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# Annual Progress Report **2016**

## of the Organization for the sixty-second financial year

| Action to be taken | | Voting Procedure |
|---|---|---|
| For discussion | **SCIENTIFIC POLICY COMMITTEE**<br>304th Meeting<br>12-13 June 2017 | – |
| For recommendation | **FINANCE COMMITTEE**<br>360th Meeting<br>13-14 June 2017 | Simple majority of Member States represented and voting and at least 51% of the contributions of all Member States |
| For approval | **COUNCIL**<br>185th Session<br>15-16 June 2017 | Simple majority of Member States represented and voting |

## Annual Progress Report
## GENEVA, June 2017

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# I. EXECUTIVE SUMMARY

# Introduction

2016 was an excellent year for CERN, with unprecedented performance of the accelerator complexand many other accomplishments over the full spectrum of the Organization's activities. It was also a year of changes. The new CERN management began its mandate, and a new organisational structure was introduced: some modifications were implemented to the existing three sectors (for Research and Computing, Accelerators and Technology, and Finance and Human Resources), and a fourth one, for International Relations, was added. The new sector gathers together the activities relating to relations with the Member States, the ongoing geographical enlargement of CERN through the addition of new Member and Associate Member States, and Education, Communications and Outreach. The five-yearly review of the financial and social conditions of the members of the personnel had been completed at the end of 2015, and its implementation got under way in 2016.

This Annual Progress Report follows the revised layout adopted last year, and introduces for the first time a section on Key Performance Indicators (KPI), as recommended by the External Auditors. Their number and scope will be expanded in the future.

## Main scientific achievements

The scientific programme of the Laboratory is based on three pillars: (1) full exploitation of the LHC, the highest-energy collider in the world, including operation of the LHC with nominal parameters, as well as construction and installation of LHC upgrades; (2) a scientific diversity programme at lower energies, serving a broad community, profiting from the versatility of the injector chain and ranging from radioisotope studies to antiproton and fixed-target physics; also included is participation in accelerator-based neutrino projects outside Europe, mainly through R&D on neutrino detectors and construction of cryogenic components; (3) preparing for the future, with a vibrant accelerator R&D programme and design studies towards colliders at the energy frontier that might follow the LHC, as well as exploration of future opportunities for scientific diversity. These are now discussed in turn.

### LHC

The accelerator performed remarkably well throughout the year, despite a number of set-backs such as a power cut caused by an inquisitive stone marten, and beam intensity limitations due to vacuum problems in the SPS internal beam-dump. The latter issue limited the number of bunches that could be injected, and a replacement has been prepared that will be installed for 2017. Nevertheless, the LHC surpassed its design luminosity of $10^{34}$ cm$^{-2}$s$^{-1}$ during the year, with a peak of ~$1.5 \times 10^{34}$ cm$^{-2}$s$^{-1}$ reached at the ATLAS and CMS interaction regions. The machine availability was also excellent, with a strong increase of the beam availability to an average of 50% of the scheduled time for physics over the year. As a result, the integrated luminosity delivered to ATLAS and CMS was ~40 fb$^{-1}$ in proton-proton collisions, over 50% more than the initial target and greater than for all the previous years combined. The pp run was followed by a month of running for heavy ion physics, with p-Pb collisions in a number of different configurations: at 5 and 8 TeV, and with the Pb ions circulating in either direction (particularly interesting for the experiments with asymmetric acceptance, ALICE and LHCb). At the end of the year a test was made with two sectors of the machine increasing the current of the dipole magnets towards that required for the nominal energy of 14 TeV. Although this target was not achieved, useful data were taken concerning the training quenches that are required to reach nominal energy.

The LHC experiments took data efficiently throughout the year, with more than 90% of the delivered luminosity used in physics analyses. ATLAS and CMS demonstrated that they could operate at a pile-up level of about 24 concurrent interactions per beam crossing, with tails of up to about 40 (the detectors were designed for about 23 pile-up events per crossing). Several precision measurements were made with the Run 1 data, including few-percent measurements of inclusive cross-sections that challenge the precision of predictions from theory, with next-to-next-to-leading order (NNLO) calculations needed in many cases. Theory has kept up, with a huge growth of such NNLO calculations over the past months. Another example was the first measurement of the W boson mass at the LHC (by ATLAS), which matches the precision of earlier measurements at other colliders. The large data set of Run 2 will allow such precision studies to progress further, as well as providing a rich resource for searches for physics beyond the Standard Model. No conclusive signs of such new physics have been observed by ATLAS and CMS so far, with the excess of events in the di-photon spectrum at 750 GeV that was seen in 2015 not being confirmed with the new data. The Higgs boson, discovered in Run 1, has been seen in the 13 TeV data at the rate expected for the Standard Model particle, with a significance approaching 10$\sigma$ per experiment. As the only fundamental scalar, the Higgs boson is profoundly different from the other known elementary particles, and the precise measurement of its properties, including couplings and rare decays, is one of the main goals of Run 2.

The instantaneous luminosity in LHCb was levelled to $4\text{x}10^{32}$ $\text{cm}^{-2}\text{s}^{-1}$, giving a total of around 1.9 $\text{fb}^{-1}$ for the year. With the increased cross-section for beauty and charm hadron production that comes with the higher energy, this data sample contains a larger number of decays than collected in Run 1. LHCb made excellent progress in 2016 in the study of flavour physics. An example was the first observation of the ultra-rare $B^0 \rightarrow K^+K^-$ decay, with a branching ratio of $8 \times 10^{-8}$, the rarest purely hadronic beauty decay ever observed. ALICE continued the study of heavy ion collisions, probing the quark-gluon plasma that is formed when nuclear matter is produced in conditions of high temperatures and high density. For example, the ALICE collaboration has discovered that the production of J/psi mesons in central Pb-Pb collisions is less suppressed by nearly a factor of four at LHC energy than at RHIC energy. The study of the p-Pb data taken in 2016 will be crucial for a deeper understanding of the underlying physics. Large local distortions due to ion backflow were seen in the Time Projection Chamber (TPC) detector but were mitigated with the implementation of a dynamic correction scheme originally developed for the upgrade. All four experiments now take part in the heavy ion running, giving breadth to the physics programme, from the observation of gamma-gamma scattering in ATLAS to results from LHCb using its SMOG gas-injection system to study ion collisions in fixed-target mode. In total there were over 300 scientific publications from the LHC experiments during the year and about 2,500 PhD students, broken down as shown in the KPI tables in Section III.

Computing for the LHC broke a number of records, due to the larger than expected data set and pile-up. Almost 50 PB of data were recorded, and the global transfer rate reached peaks of 55 GB/s (a factor 2.5 higher than in Run 1). The worldwide LHC Computing Grid now comprises 170 sites over 42 countries, providing about 700 PB of storage and running up to 2 million jobs per day. The experiments made big strides in reducing their demand for computing resources by minimising the number of copies, delaying processing and optimising the software. Nevertheless, concern has arisen for the coming years due to the excellent LHC performance and consequent increase in demand that is expected to exceed the pledged resources (which are based on a flat budget model). Looking further ahead to the HL-LHC era, there will need to be an increase in storage of about a factor of 10 and an increase in CPU power of about a factor of 60, so that mere technology evolution will probably not be enough. The HEP software foundation has been set up to explore possible improvements in the software, making best use of features of modern processors such as parallelism, while other initiatives are exploring new models for the hardware infrastructure (e.g. virtual data clouds and associated services, high-performance computing, etc.).

Full exploitation of the LHC is the highest priority of the European Strategy for Particle Physics (ESPP). In 2016, the Council formally approved the high-luminosity upgrade, HL-LHC, and its Cost-to-Completion, as well as a European Investment Bank credit facility that will allow the project to be financed within a constant CERN Budget. HL-LHC involves a major upgrade, in particular, of the regions around ATLAS and CMS, to enable an increase in instantaneous luminosity to at least five times the design value. The aim of the LHC injectors upgrade (LIU) is to increase the injectors' reliability, lifetime and beam intensity for the HL-LHC era. Good progress was made, with the new Linac4 achieving its nominal energy of 160 MeV. In the R&D for HL-LHC, the 2 m-long model of an 11 T dipole, using superconducting $Nb_3Sn$, reached a magnetic field of 12.5 T, and a test of the first full cross-section triplet quadrupole reached a similar peak field, which is beyond the design value. The second cost and schedule review of the LIU and HL-LHC projects was successfully completed in October. The major Phase I upgrades of the ALICE and LHCb experiments are proceeding according to plan, ready for installation in the next long shutdown (LS2). For ATLAS and CMS, both the Phase I upgrades, as well as Phase II upgrades to allow the experiments to benefit fully from the HL-LHC, have made good progress, and the first Phase II Technical Design Report has been submitted.

## Scientific diversity

CERN's scientific diversity programme exploits the unique capabilities of the accelerator complex, with the PS booster, PS and SPS providing beams to a variety of facilities and experiments, in parallel to their roles as injectors to the LHC. During the year the availability of the injector chain was very good, ranging from 97% for Linac2 to 90% for the PS. A capacitor failure involving the PS power supply occurred in May; it was repaired, and replacements have been ordered for 2017. Despite the problem with the SPS internal beam dump mentioned earlier, over 80% of the expected protons were delivered to the experiments and test beams in the North Area.

The Antiproton Decelerator is a unique facility in the world, providing low-energy antiprotons for precise spectroscopy and gravitational measurements, in particular via the production of antihydrogen atoms. There are five experiments running (AEgIS, ALPHA, ASACUSA, ATRAP and BASE) and one in preparation (GBAR). In 2016 ALPHA provided the first measurement of the spectral lines of antihydrogen, thus opening the door to precision spectroscopy and new tests of CPT symmetry. The ASACUSA experiment carried out the most precise measurement of the antiproton-to-electron mass ratio to date. 2016 saw the start of commissioning of the new ELENA ring, which will reduce the antiproton energy to 100 keV, increasing the trapping efficiency of the experiments by one to two orders of magnitude.

At the SPS, the COMPASS experiment switched in 2016 to measurement of exclusive processes for generalised parton distribution studies, using a muon beam and a 2.5 m-long liquid hydrogen target. Following the repair of its vertex magnet, NA61 continued its study of heavy ion collisions in fixed-target mode, as well as measuring particle production in targets used for the JPARC and Fermilab neutrino projects. NA62, which is devoted to the study of very rare kaon decays as a window on new physics, completed the transition from commissioning to physics data taking and recorded a data set corresponding to almost 10% of the total required sample, with detector performance in line with expectations. A new experiment, NA64, made first searches for dark sector particles, providing the interesting exclusion of possible dark-matter candidates with its first data. The UA9 experiment made major progress in demonstrating crystal collimation as a promising way to remove the beam halo in the LHC proton beams.

CAST started a new three-year programme in 2016, searching for solar chameleons (postulated candidates for dark energy) and dark matter axions using three new sub-detectors, which have undergone commissioning and are ready for data taking in 2017. CLOUD, the East Area experiment studying cloud formation using a proton beam from the PS, focused on two topics: pure biogenic nucleation and growth under realistic environmental conditions, and anthropogenic organics nucleation and growth under polluted urban conditions.

ISOLDE, CERN's radioactive ion beam facility, carried out 46 successful experiments in 2016, with beam time spread between nuclear structure physics, nuclear astrophysics, materials science and biophysics studies. A highlight was the study of the charge exchange reaction $^{7}$Be(n,p), designed to shed light on the cosmological lithium problem. This was the first joint ISOLDE-n_TOF experiment and constitutes the first direct measurement of this reaction in the range of interest of Big Bang nucleosynthesis. The main breakthrough of the year was the completion of the installation of the first phase (two cryomodules) of HIE-ISOLDE, allowing a large variety of beams to be accelerated to 5.5 MeV per nucleon. Due to limited resources, hard choices had to be made, and the proposal to move the TSR storage ring to ISOLDE will not go ahead.

The Neutrino Platform was set up at CERN a few years ago to act as a focal point for the European neutrino community involved in accelerator-based projects in the US and Japan. Activities include R&D on detector technologies, construction of the first cryostat for the DUNE detector at the Long-Baseline Neutrino Facility (LBNF) in the US, and provision of a test-beam facility. Concerning the latter, major progress was made last year with the completion of the EHN1 hall extension in the North Area. Construction of the cryostats for the two liquid-argon detector prototypes (single- and double-phase) for the DUNE experiment made significant progress. The refurbishment of the two ICARUS modules is nearing completion, and the detector will be shipped to Fermilab in spring 2017 to participate in the short-baseline neutrino programme there. Other activities include the construction of the Baby-MIND spectrometer for the WAGASCI neutrino experiment in Japan. To support these efforts, and complement them with physics studies, a neutrino group was set up in the EP department, and a task force for neutrino studies was established in the TH department.

## Preparing for the future

The studies towards future colliders at the energy frontier and those of future opportunities for scientific diversity are focused on providing input for the next update of the European Strategy for Particle Physics. The ESPP will get under way towards the end of 2018, with a completion date now set for spring 2020. At the energy frontier, activities include the design studies for the CLIC (linear) and FCC (circular) colliders and R&D towards high energy accelerators, mainly through the development of high-field superconducting magnets and the AWAKE project.

The parameters for a staged implementation of CLIC, starting at 380 GeV for Higgs and top physics and upgradeable to 3 TeV in further stages, have been refined, based on an overall power and cost optimisation exercise for the initial stage. The CTF3 programme was brought to a successful conclusion, proving the CLIC two-beam acceleration concept. The CTF3 80-220 MeV linac will be available as a new stand-alone user facility, known as CLEAR (CERN Linear Electron Accelerator for Research), from 2017. The Linear Collider Detector (LCD) project teams performed physics and detector studies for CLIC, in close cooperation with the teams working on the corresponding ILC activities. R&D was actively pursued on pixel modules for the vertex detector and the main tracker. 2016 marked a gradual change in the LCD activities to explore synergy with high-priority projects such as detector upgrades for HL-LHC.

The FCC collaboration has developed an optimised baseline for the overall layout of a hadron collider with a 97.75 km circumference and has established full-ring closed optics solutions for both hadron (FCC-hh) and lepton (FCC-ee) colliders. A working group has been put in place to focus on the High-Energy LHC option, a ~ 28 TeV proton-proton collider using the FCC-hh magnet technology in the current LHC tunnel. The design and the comparative analysis of options for 16 T magnets has further advanced within the H2020 EuroCirCol project, and a world-wide effort to develop $Nb_3Sn$ wire to FCC specifications has been launched. In a combined effort with CLIC and external partners, developments toward higher-efficiency klystrons are progressing well. For FCC-hh, a new reference detector scenario based on unshielded solenoids has been developed, allowing a significant reduction of shaft and cavern dimensions. For FCC-ee, a baseline physics operation scenario with target luminosities for energies between 88 and 370 GeV has been defined.

The AWAKE experiment studies proton-driven plasma wakefield acceleration with target accelerating gradients of the order of few GeV/m, which could lead to very compact designs for future accelerators. A major milestone was reached during the first physics run at the end of the year, with the observation of self-modulated instabilities of the SPS proton bunches in a 10 m-long plasma cell. Preparation for the next phase, the acceleration of an injected electron beam, is ongoing.

A “Physics Beyond Colliders” study group was established in 2016, to investigate future opportunities at CERN for the scientific diversity programme. Its mandate is to explore the unique opportunities offered by CERN’s rich accelerator complex to address outstanding questions in particle physics through projects that are complementary to high-energy colliders and other efforts worldwide. Ideas presented at the kick-off meeting in September 2016 included a beam-dump facility at the SPS, at which the proposed SHiP experiment (or others) would study hidden particles, proton electric-dipole moment measurements using a small storage ring, searches for axions, and ultra-rare decays of known particles. The study should conclude with a report by the end of 2018, in time for the update of the ESPP.

### Theory

At the beginning of the year, theoretical physics activities at CERN were organised within a separate department, TH, in the Research and Computing sector. Research in TH has thrived throughout the year in string theory, quantum field theory, physics of the Standard Model and beyond the Standard Model, QCD, collider physics, physics of heavy flavours, lattice field theory, high-temperature quantum field theory, heavy ions, cosmology and astroparticle physics, leading to 262 original publications issued as TH preprints. The TH department continues to serve as a vibrant reference centre where scientists can discuss and exchange ideas, and as a meeting place for the international community, hosting 770 scientists in 2016 (including associates, paid and unpaid visitors), as well as offering an intense programme of seminars, institutes and workshops. Theorists made a fundamental contribution to working groups on LHC physics, led the investigation of the physics opportunities at a 100 TeV hadron collider in the context of the FCC study, and played a leading role in launching new physics research initiatives in the context of the Neutrino Platform and Physics Beyond Colliders studies.

## Other Activities

Significant progress was made in 2016 in areas other than the core scientific programme. A few highlights are described below.

### Geographical enlargement

A three-pronged strategy for geographical enlargement was presented to the Council in March 2016 by the new Management. In the course of the year, Romania became CERN’s 22nd Member State, Cyprus joined as an Associate Member State in the pre-stage to Membership, and Ukraine became an Associate Member State. Agreements were signed with Slovenia for Associate Membership in the pre-stage to Membership and with India for Associate Membership. Lithuania’s application for Associate Membership reached the final stages of the process. International Cooperation Agreements were signed with Latvia and Qatar.

### Education, communications and outreach

CERN hosted 142 protocol visits and events in 2016 (representing a 13% increase on 2015), including visits by five heads of state or government. A design study for a CERN alumni programme was completed, with the formal launch expected in 2017. Outreach was significantly strengthened, with a record 120,000 participants (a 12% increase on 2015) in a total of 5,048 organised visits, as well as an estimated 70,000 visitors to the on-site exhibitions. The travelling exhibitions in Austria, the Czech Republic, France, Georgia, Italy, Lithuania and Portugal attracted some 100,000 visitors. 35 teacher programmes were attended by 953 participants, bringing to more than 10,000 the number of high school teachers having taken part in the programmes since they began in 1998. S'Cool LAB welcomed 5,877 visitors. In 2016, CERN featured in 145,000 press cuttings worldwide and received 628 journalists on site. There were 4 million unique visitors to the core websites, and a strong presence was maintained on social media, with 1.7 million mentions of CERN and the LHC.

## Knowledge transfer

Knowledge transfer activities continued to be pursued energetically, with seminars on various topics and the distribution of communication material. The KT fund received a record number of 13 applications in 2016, and the network of BIC (Business Incubator Centres) was joined by a new one in Italy, bringing the total to nine. The incubators have hosted 16 companies using CERN technologies so far. A new organisational structure for medical applications activities was implemented at the beginning of 2016.

## Safety, health and the environment

Protecting people, the environment and CERN's infrastructure is a top priority for the Management. In the new organisational structure, the medical service and fire brigade joined HSE (the occupational Health and Safety and Environmental protection unit). A tripartite agreement for mutual assistance in emergency rescue operations was signed with France and Switzerland. Resources were secured within the MTP to upgrade the SPS fire protection system to the best standards during LS2. Radioactive waste management has been progressing at full speed, with 1,200 $m^3$ of low-level-radioactivity waste eliminated during the year, four times more than was produced. With the goal of making the Laboratory a model for an environmentally-aware scientific research infrastructure, a CERN Environmental Protection Steering (CEPS) board has been established, which will define objectives and implementation priorities for 11 specific topics.

Details on the number of occupational accidents are given in Chapter III and Appendix 7.

## Infrastructure consolidation and civil engineering work

The consolidation of the Globe of Science and Innovation was completed as planned, slightly below budget. The North Area extension for Neutrino Platform activities was also completed. Civil engineering consultancy contracts for the HL-LHC work were placed, and the construction tendering process was launched. The annual site consolidation programme was carried out as planned.

## Human Resources

Following the approval of the measures proposed in the framework of the five-yearly review of the financial and social conditions of members of the personnel by the Council at the end of 2015, 2016 saw their implementation in two stages. In a first stage, on 1 January, the diversity-related measures, which included extended recognition of registered partnerships, improved conditions for parental leave, support for dual-career couples, enhancement of the Saved Leave Scheme and extension of the teleworking scheme, were implemented. The second stage of implementation, on 1 September, concerned a new career structure, including a new salary grid and a new performance appraisal and career evolution programme based on a less onerous system called MERIT (Merit Evaluation and Recognition Integrated Toolkit). As for learning and development (L&D), integration of the learning needs inventory as a core process and further streamlining and modernisation of the training offer, have enhanced the overall quality of L&D.

Some 1,600 young people were trained in 2016, including around 750 fellows, 278 summer students from 87 countries, and about 200 technical students. A grand total of 5,800 participants were registered for all L&D courses. Over 130 new staff members were selected. Several outreach events were organised to ensure that CERN is visible in the Member States and is identified as an employer of choice for students, graduates and professionals alike.

## Budget Position of the Organization

In the course of the annual planning exercise, the new Management reviewed the spending profile for 2016 thoroughly. Consequently, a Revised Budget was presented as part of the Medium Term Plan in June 2016. For this reason, the financial tables and figures in this Annual Progress Report show not only the Final Budget published at the end of 2015, but also the Revised Budget, and the Budget Out-Turn is compared to the revised figures.

The Revised Budget reprofiled about 30 MCHF of the Final Budget to take into account a more realistic execution versus time of projects and other activities. The 2016 Budget Out-Turn balance is 55.4 MCHF higher than forecast in the Revised Budget, mainly due to 50 MCHF lower expenses. This reduction in expenses is mainly attributable to the Management’s continuous efforts to optimise resources and reduce the budget deficit, as well as to the favourable impact of the CHF-EUR exchange rate and to a small amount of re-profiling in the spending for certain consolidation and non-LHC activities. Significantly less postponement of expenses to future years has been done than in previous years, thereby mitigating concerns about the timely execution of the scientific programme. In particular, the resources allocated to LHC operation and to the LHC upgrades in 2016 were spent as anticipated.

The Organization’s financial position at the end of 2016 shows a significant improvement compared to expectations, with a cumulative budget deficit of -118.4 MCHF, about 93 MCHF lower than anticipated in the Final Budget, and comparable with the cumulative balance at the end of 2015 (-118.1 MCHF).

An overview of revenues and expenses is given in section II, while the details of the various activities and budget headings are reported in section IV.

# II. SUMMARY OF REVENUES AND EXPENSES

# 1. SUMMARY OF REVENUES AND EXPENSES BY ACTIVITY

**Figure 1: Summary of Revenues and Expenses by Activity**

| (in MCHF, rounded off) | **Final 2016 Budget** **CERN/FC/5955**[2] (2016 prices) | **Revised 2016 Budget** **CERN/FC/6011** (2016 prices) | **2016 Out-Turn** **CERN/FC/6096/Rev.** (2016 prices) | **Variation of 2016 Out-Turn with respect to Revised 2016 Budget** **MCHF** | **%** |
|---|---|---|---|---|---|
| | | (a) | (b) | (c)=(b)-(a) | (c)/(a) |
| **REVENUES** | **1 227.5** | **1 233.1** | **1 238.0** | **5.0** | **0.4%** |
| Member States' contributions | 1 119.7 | 1 119.0 | 1 119.0 | 0.0 | 0.0% |
| Associate Member States' contributions | 7.6 | 8.2 | 8.4 | 0.3 | 3.4% |
| Contributions anticipated from new Associate Member States | 3.5 | | | | |
| EU contributions | 14.4 | 19.7 | 17.6 | -2.1 | -10.6% |
| Other revenues | 82.4 | 86.2 | 93.0 | 6.8 | 7.9% |
| **EXPENSES** | **1 236.0** | **1 203.6** | **1 153.2** | **-50.4** | **-4.2%** |
| Scientific programmes | 506.7 | 489.0 | 459.7 | -29.3 | -6.0% |
| Infrastructure and services | 280.6 | 301.8 | 278.6 | -23.2 | -7.7% |
| Centralised expenses | 193.1 | 181.3 | 185.0 | 3.6 | 2.0% |
| Projects and studies | 255.7 | 231.5 | 229.9 | -1.5 | -0.7% |
| **BALANCE** | | | | | |
| Annual balance | -8.5 | 29.5 | 84.8 | 55.4 | |
| Capital repayment allocated to the budget (Fortis, FIPOI 1, 2 and 3) | -25.1 | -25.1 | -25.1 | 0.0 | |
| Recapitalisation Pension Fund | -60.0 | -60.0 | -60.0 | 0.0 | |
| Annual balance allocated to budget deficit | -93.6 | -55.6 | -0.3 | 55.4 | |
| **-Cumulative balance[1]- - 118.1** | **-211.7** | **-173.7** | **-118.4** | **55.4** | |

[1] The cumulative balance of -118.1 MCHF is the accumulated budget deficit at the end of 2015 as stated in the Financial Statements for 2015 (CERN/FC/6001, page 19).

[2] The breakdown of expenses by activity follows the structure introduced in the MTP 2016 (CERN/FC/6011).

## 2. OVERVIEW OF REVENUES

### Figure 2: Total Revenues

| (in MCHF, rounded off) | **Final 2016 Budget**<br>**CERN/FC/5955**<br>(2016 prices) | **Revised 2016 Budget**<br>**CERN/FC/6011**<br>(2016 prices) | **2016 Out-Turn**<br>**CERN/FC/6096/Rev.**<br>(2016 prices) | **Variation of 2016 Out-Turn with respect to Revised 2016 Budget** | |
|---|---|---|---|---|---|
| | | | | **MCHF** | **%** |
| | | (a) | (b) | (c)=(b)-(a) | (c)/(a) |
| **REVENUES** | **1,227.5** | **1,233.1** | **1,238.0** | **5.0** | **0.4%** |
| Member States' contributions | 1,119.7 | 1,119.0 | 1,119.0 | 0.0 | 0.0% |
| Associate Member States' contributions | 7.6 | 8.2 | 8.4 | 0.3 | 3.4% |
| Contributions anticipated from new Associate Member States | 3.5 | | | | |
| EU contributions | 14.4 | 19.7 | 17.6 | -2.1 | -10.6% |
| Additional contributions | 14.6 | 16.8 | 13.6 | -3.1 | -18.7% |
| *for LINAC4, HIE-ISOLDE, ELENA, AWAKE, CLIC, IdeaSquare, FAIR, CESSAMag* | *14.6* | *16.8* | *13.6* | *-3.1* | *-18.7%* |
| Personnel paid from team accounts | 11.7 | 12.9 | 11.8 | -1.2 | -8.9% |
| Personnel on detachment | 0.9 | 1.0 | 0.9 | 0.0 | -5.1% |
| Internal taxation | 28.5 | 30.0 | 31.5 | 1.4 | 4.7% |
| Knowledge transfer | 1.1 | 1.7 | 1.9 | 0.3 | 14.8% |
| Other revenues | 25.5 | 23.8 | 33.2 | 9.5 | 39.9% |
| *Sales and miscellaneous* | *5.7* | *6.7* | *11.5* | *4.8* | *71.5%* |
| *SCOAP3 revenues* | *4.3* | *4.3* | *4.9* | *0.6* | *13.9%* |
| *OpenLab revenues* | *2.7* | *2.7* | *2.3* | *-0.4* | *-14.3%* |
| *Financial revenues* | *2.0* | *2.0* | *6.7* | *4.7* | *233.9%* |
| *In-kind*[1] | *4.9* | *2.0* | *1.9* | *-0.2* | *-8.9%* |
| *Housing fund* | *6.0* | *6.0* | *6.0* | *0.0* | *-0.7%* |

[1] Theoretical interest on the FIPOI loan.

**Comments on Figure 2:**

Outstanding Member State' contributions for 2016 are not taken into account in the revenues in Figure 2, but are shown in the KPI section.

Romania became a Member State on 17 July 2016 and paid 75% of its theoretical Member State contribution (2 MCHF) for the first quarter of 2016 and 100% of its actual Member State contribution (8.2 MCHF) for the remaining part of the year, in accordance with Council Resolution CERN/3189/RA.

Cyprus and Ukraine became Associate Member States in 2016 and paid 10% of their theoretical Member State contributions for 2016.

The revenues for EU projects are higher than in the Final 2016 Budget due to new proposals submitted and accepted in the framework of Horizon 2020. For more details on EU projects, please refer to Chapter IV.5.

The “Financial revenues” heading includes gains and losses resulting from currency exchange-rate fluctuations.

The in-kind revenue resulting from the 0% interest on the FIPOI loan reflects the advantage at the current market interest rate, offset by the corresponding expense.

## 3. OVERVIEW OF EXPENSES

### Figure 3: Total Expenses by Activity and Balance

| (in MCHF, rounded off) | Final 2016 Budget CERN/FC/5955[3] (2016 prices) | Revised 2016 Budget CERN/FC/6011 (2016 prices) | 2016 Out-Turn CERN/FC/6096/Rev. (2016 prices) | Variation of 2016 Out-Turn with respect to Revised 2016 Budget | |
|---|---|---|---|---|---|
| | | | | MCHF | % |
| | | (a) | (b) | (c)=(b)-(a) | (c)/(a) |
| **EXPENSES** | **1 236.0** | **1 203.6** | **1 153.2** | **-50.4** | **-4.2%** |
| **Running of scientific programmes and support** | **980.4** | **972.1** | **923.2** | **-48.9** | **-5.0%** |
| **Scientific programmes** | **506.7** | **489.0** | **459.7** | **-29.3** | **-6.0%** |
| *LHC (machine, detectors and computing, including spares and consolidation)* | *282.8* | *260.8* | *259.9* | *-0.9* | *-0.3%* |
| *Non-LHC physics and scientific support* | *83.4* | *83.3* | *68.2* | *-15.1* | *-18.1%* |
| *Accelerators and areas (including consolidation)* | *140.4* | *144.9* | *131.5* | *-13.4* | *-9.2%* |
| **Infrastructure and services** | **280.6** | **301.8** | **278.6** | **-23.2** | **-7.7%** |
| *General Infrastructure, services and centralised expenses (incl. admin, international relations, safety)* | *249.5* | *262.2* | *246.3* | *-16.0* | *-6.1%* |
| *Infrastructure consolidation, buildings and renovation* | *31.1* | *39.5* | *32.3* | *-7.2* | *-18.3%* |
| **Centralised expenses** | **193.1** | **181.3** | **185.0** | **3.6** | **2.0%** |
| *Centralised personnel expenses* | *35.7* | *36.3* | *36.1* | *-0.3* | *-0.7%* |
| *Internal taxation* | *28.5* | *30.0* | *31.5* | *1.4* | *4.7%* |
| *Internal mobility, personnel on detachment, personnel paid from team accounts* | *13.4* | *14.4* | *15.1* | *0.7* | *4.9%* |
| *Budget amortisation of staff benefit accruals* | *17.3* | *17.3* | *17.3* | *0.0* | *0.0%* |
| *Energy and water, insurance and postal charges, miscellaneous* | *82.3* | *70.2* | *65.4* | *-4.8* | *-6.8%* |
| *Interest, bank and financial expenses, in-kind* [1] | *15.8* | *13.0* | *19.6* | *6.6* | *50.7%* |
| **Projects and studies** | **255.7** | **231.5** | **229.9** | **-1.5** | **-0.7%** |
| **LHC upgrades** | **141.6** | **112.4** | **122.7** | **10.3** | **9.1%** |
| *LINAC4* | *4.9* | *5.6* | *5.3* | *-0.3* | *-4.8%* |
| *LHC injectors upgrade* | *45.5* | *36.4* | *37.1* | *0.6* | *1.8%* |
| *HL-LHC construction* | *62.9* | *47.3* | *56.1* | *8.8* | *18.6%* |
| *LHC detectors upgrade (Phase 1) and consolidation* | *19.7* | *15.7* | *17.2* | *1.5* | *9.2%* |
| *HL-LHC detectors, including R&D (Phase 2)* | *8.7* | *7.4* | *7.0* | *-0.4* | *-5.2%* |
| **Energy frontier** | **36.6** | **34.6** | **33.4** | **-1.2** | **-3.4%** |
| *Linear collider studies (CLIC, ILC, detector R&D)* | *27.9* | *25.1* | *22.2* | *-2.9* | *-11.7%* |
| *Future Circular Collider study* | *8.8* | *9.4* | *11.2* | *1.8* | *18.7%* |
| **Scientific diversity activities** | **77.4** | **84.5** | **73.9** | **-10.6** | **-12.5%** |
| *ELENA* | *13.5* | *11.8* | *10.1* | *-1.6* | *-13.9%* |
| *HIE-ISOLDE* | *10.0* | *9.3* | *7.2* | *-2.1* | *-22.8%* |
| *CERN Neutrino Platform* | *16.8* | *17.2* | *22.8* | *5.6* | *32.4%* |
| *R&D (incl. EU support) for accelerators, medical applications* | *37.1* | *46.2* | *33.8* | *-12.4* | *-26.9%* |
| BALANCE | | | | | |
| Annual balance | -8.5 | 29.5 | 84.8 | 55.4 | |
| Capital repayment allocated to the budget (Fortis, FIPOI 1, 2 and 3) | -25.1 | -25.1 | -25.1 | 0.0 | |
| Recapitalisation Pension Fund | -60.0 | -60.0 | -60.0 | 0.0 | |
| Annual balance allocated to budget deficit | -93.6 | -55.6 | -0.3 | 55.4 | |
| **-Cumulative balance[2]- - 118.1** | **-211.7** | **-173.7** | **-118.4** | **55.4** | |

[1] Including theoretical interest on the FIPOI loan (compensated by a corresponding heading in the revenues).

[2] The cumulative balance of -118.1 MCHF is the accumulated budget deficit as stated in the Financial Statements for 2015 (CERN/FC/6001, page 19).

[3] The breakdown of expenses by activity follows the structure introduced in the MTP 2016 (CERN/FC/6011).

**Comments on Figure 3:**

This improvement in the budget position compared with the Revised Budget amounts to 55.4 MCHF.

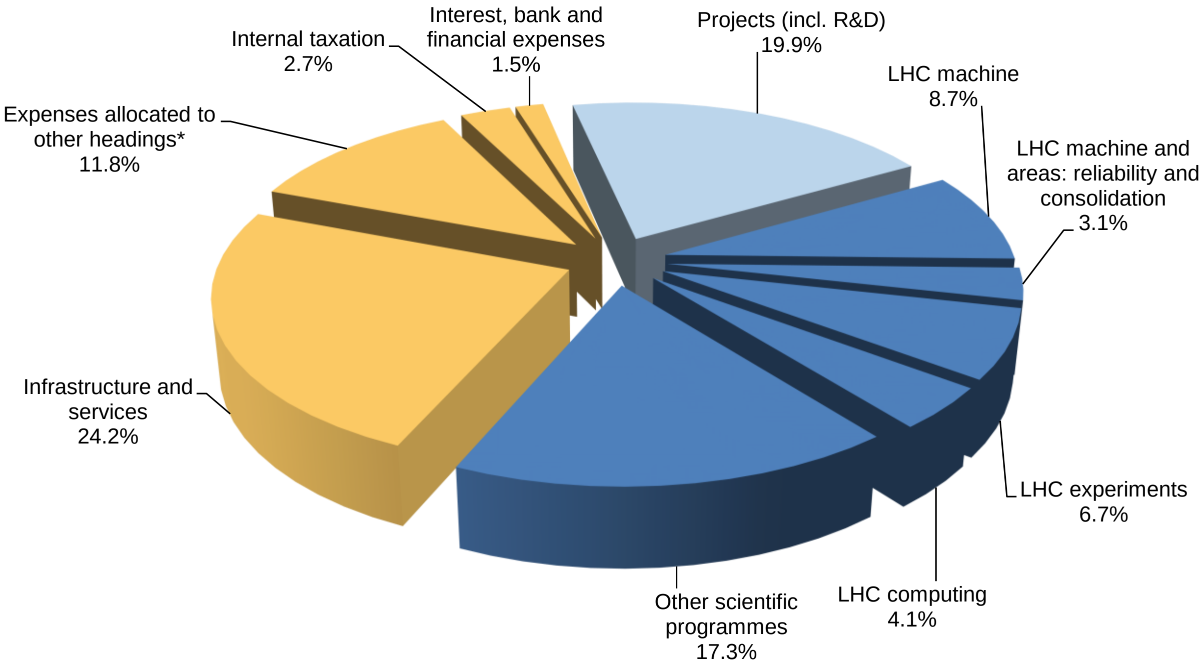
Around 52 MCHF of the difference in expenses were already anticipated and explained as the outcome of the probable revenues and expenses exercise for 2016 and were presented as part of the Final 2017 Budget (CERN/FC/6060).

The main reasons for the variation in expenses are explained below, while a detailed analysis is provided in each factsheet in Section IV.1:

- The appreciation of the CHF-EUR exchange rate contributed to the decrease in expenses of around 13 MCHF, including energy; this amount was already anticipated in the Revised 2016 Budget (CERN/FC/6011);
- The priority given to the LHC upgrades resulted in a slightly higher level of expenses than planned for the LHC Injectors Upgrade, the LHC luminosity upgrade (HL-LHC) and the Phase-1 LHC detectors upgrades;
- The focus on the LHC upgrades resulted in a shortage of personnel that generated some underspending in accelerator maintenance and consolidation and in other areas. For instance, fewer resources than planned have been spent on R&D projects such as the superconducting magnets (other than those for HL-LHC and FCC), the superconducting RF programme and the upgrade of the SM18 hall;
- Some of the expenses for non-LHC projects, such as CLIC, ELENA, HIE-ISOLDE, AWAKE, MEDICIS and FAIR, were reprofiled;
- Some of the personnel allocated to scientific support were re-redeployed to the LHC experiments, the FCC project and the LHC detectors upgrade headings;
- The expenses for certain building projects, such as the construction of Building 311 (magnetic measurement laboratory) and consolidation of the polymer laboratory, were reprofiled, taking into account contract adjudications and contractual deliverables;
- The administration budget allocated to the Directorate was reduced, mainly thanks to savings resulting from the new organisational structure.

## 4. EXPENSES BY SCIENTIFIC AND NON-SCIENTIFIC PROGRAMMES

**Figure 4: Expenses breakdown by activity**



* Including: Centralised personnel expenses, internal mobility, personnel on detachment, paid but not available (3.5%),
Personnel paid from team accounts (1%),
Budget amortisation of staff benefit accruals (1.5%),
Energy and water (5.2%),
Insurance, postal charges, miscellaneous (0.4%),
In-kind (theoretical interest on the FIPOI loan) (0.2%)

# III. SUMMARY OF FACTS AND KEY PERFORMANCE INDICATORS (KPIs)

| | Value | *Note* |
|---|---|---|
| **ACCELERATORS** | | |
| **LHC pp run** | | |
| Peak luminosity | ~ 1.5 x $10^{34}$ cm$^{-2}$ s$^{-1}$ | |
| Fraction of time in stable beams | 49% | |
| Integrated luminosity | | |
| ATLAS | 39 fb$^{-1}$ | |
| CMS | 40 fb$^{-1}$ | |
| LHCb | 2 fb$^{-1}$ | |
| ALICE | 13 pb$^{-1}$ | |
| **Injectors: Percentage of time with stable beams** | | |
| Linac2 | 97% | |
| PS Booster | 95% | |
| PS Machine | 90% | |
| N_TOF | 89% | |
| SPS Fixed Target | 92% | |
| EAST Area North Branch | 88% | |
| EAST IRRAD-CHARM | 89% | |
| AD (Antiproton Decelerator) | 89% | |
| 25 ns beam for LHC (standard & BCMS) | ~ 91% | |
| LHC Ions | ~ 95% | |
| SPS Machine | | *1* |
| **EXPERIMENTS and THEORY** | | *2* |
| **Publications** | | *2.1* |
| ATLAS | 106 | |
| CMS | 110 | |
| ALICE | 24 | |
| LHCb | 68 | |
| Theory papers with at least one CERN author | 262 | |
| **PhD students in LHC experiments** | | *2.2* |
| ATLAS | 1 133 | *2.3* |
| CMS | 819 | |
| ALICE | 254 | |
| LHCb | 276 | |
| **LHC COMPUTING** | | |
| Detector data recorded | 49 PB | |
| Global data transfer rates | 35 GB/s | |
| Number of jobs per day | 2 million | |

1 A careful operation strategy was put in place to deliver at least 80% of the protons to all experiments and test beam in the North Area despite the occurrence of several issues

2 Numbers of publications and PhD students are given here for the four main LHC experiments only. They will be expanded in the future to reflect the full richness of CERN's

2.1 Physics publications for which preprint date is within 2016

2.2 Number of PhD students in January 2017, unless specified

2.3 Number of PhD students at 31 December 2016

| | Value | *Note* |
|---|---|---|
| **SAFETY, HEALTH AND ENVIRONMENT PROTECTION** | | |
| **Occupational accidents** | | *3* |
| Employed members of Personnel | 103 | |
| Accidents at work | 67 | |
| Commuting accidents | 36 | |
| Associated members of Personnel | 53 | |
| Accidents at work | 34 | |
| Commuting accidents | 19 | |
| CERN Contractors | 78 | |
| Accidents at work | 75 | |
| Commuting accidents | 3 | |
| **Radioactive waste** | | |
| Received | 316 | *4.1* |
| Eliminated | 1 200 | *4.2* |
| Stored | 8 613 | *4.3* |
| **OUTREACH** | | |
| **Protocol visits** | 142 | |
| **Visitors at CERN** | | *5.1* |
| Visits | 5 048 | |
| Participants | | |
| Requested | ~300 000 | |
| Received | ~120 000 | |
| **S'Cool LAB visitors** | 5 877 | *5.2* |
| **CERN Teacher Programme** | | *5.3* |
| Number of programmes | 35 | |
| Number of participants | 953 | |
| **Travelling exhibitions** | | |
| Number of visitors | ~100 000 | |
| Number of countries visited | 7 | |
| **visitors to on-site exhibitions** | ~70 000 | *5.4* |
| **Press cuttings** | ~145 000 | |
| **Mentions on social media** | ~1.7 million | |
| **Number of website hits** | ~ 4 million | |

3 Further details on frequency and severity rates can be found in Appendix 7

4.1 Volume of waste received from Accelerators & Experiments (before treatment) in m$^3$

4.2 Volume of eliminated waste (equivalent before treatment) in m$^3$

4.3 Volume of stored waste (before treatment and including waste candidate for clearance from regulatory control) in m$^3$

5.1 CERN visitors are those who book a guided tour of CERN through the Visits Service

5.2 Not included in the number of visitors at CERN

5.3 CERN welcomed the 10,000th teacher to take part in the programmes since their launch in 1998

5.4 Some of these visitors are included in the total number of visitors, since visitors taking part in the guided tours of CERN often also visit the exhibitions

| | Value | Note |
|---|---|---|
| **REVENUES** | | |
| **Percentage of outstanding contributions** | | *6* |
| Member States | 1.6 | |
| Associate Member States | 4.2 | |
| Associate Member States in the pre-stage to Membership | 15.3 | |
| **Percentage of contributions received on time** | | |
| Member States | 86.2 | |
| Associate Member States | 74.6 | |
| Associate Member States in the pre-stage to Membership | 0.0 | |
| **PROCUREMENT & KNOWLEDGE TRANSFER** | | |
| **Orders** | | |
| Invitations to tender (>200 kCHF) | 93 | |
| Number of orders | | |
| >= 200 kCHF | 120 | |
| between 1 and 200 kCHF | 12 693 | |
| < 1 kCHF | 12 495 | |
| Total adjudications in kCHF | 291 273 | |
| **Industrial return** | | |
| Balanced countries for supplies | 5 | |
| Balanced countries for industrial services | 6 | |
| Very poorly balanced countries for supplies | 8 | |
| Poorly balanced countries for industrial services | 21 | |
| **Knowledge transfer** | | |
| New technology disclosures | 91 | |
| KT contracts signed | 42 | |

| | Value | Note |
|---|---|---|
| **HUMAN RESOURCES** | | |
| **Resources** | | *7* |
| FTE paid from CERN budget | 2491 | |
| Fellows | 750 | |
| Associates for the purpose of training | | |
| Administrative students | 35 | |
| Apprentices | 20 | |
| Doctoral students | 190 | |
| Summer students | 278 | *7.1* |
| Technical students | 193 | |
| Trainees | 114 | |
| Scientific Associates | 43 | |
| Project Associates | 188 | |
| Users | 11 821 | |
| Visiting scientists and other associated personnel | 954 | |
| **Staff recruitment** | | |
| Vacancies published | 147 | |
| Applications received | 12 193 | *8.1* |
| Fraction of LD contracts | 31% | *8.2* |
| **Training** | | *9* |
| Courses | 251 | |
| Sessions | 508 | |
| Days of training | 13 700 | |
| Participants | 5 800 | |

6 Outstanding contributions from past years are not included

7 Figures are at 31.12.2016 unless otherwise specified
7.1 Headcount during 2016

8.1 Details by nationality and by gender are available in the HR Annual Personnel Statistics
8.2 Number of LD staff divided by total number of staff on December 31

9 Figures do not include safety training, academic lectures and training courses not organised by CERN

# IV. APPENDICES

## 1. DETAILS OF ACTIVITIES AND PROJECTS (FACT SHEETS)

# LHC programme

### 1. LHC machine, reliability and consolidation

| | | |
|---|---|---|
| **Goal** | **LHC machine and experimental areas** | Proton run: The total integrated luminosity target is set at 100-120 $fb^{-1}$ to be delivered to the high luminosity experiments during LHC Run 2. This target will be confirmed by a model, to be produced by the beginning of 2016, which will give reliable forecasts for the total achievable integrated luminosity.<br>Special physics runs (high Beta optics) will be carried out upon approval by physics committees and depending on the production of total integrated luminosity.<br>Lead ions: The 2016 target is to provide lead ion collisions for a month at the end of the year, eventually reaching an integrated luminosity of 10 $nb^{-1}$ to the four major experiments by LS3. |
| | **Consolidation and spares** | Continuation of construction of RF spare module and purchase of RF klystrons for the LHC.<br>The principal objectives for 2016 are the continuation of activities which do not require direct access to the LHC tunnel. These include the replacement of HVAC units, cranes and other infrastructure systems. They also include the complete separation of the normal and the secure networks for the Meyrin site with the creation of a new substation, ME91, and the replacement of the Meyrin emergency diesel generator sets.<br>Start of the programme to replace the LHC lifts. |
| **Achievements** | | 2016 was the first production year of Run 2.<br>An excellent performance was achieved in the proton run, with instantaneous luminosity exceeding the nominal values by 40% (1.4 x $10^{34}$ $cm^{-2}s^{-1}$) and total integrated luminosity reaching about 40 $fb^{-1}$, against a 2016 goal of 25 $fb^{-1}$.<br>A key ingredient in this achievement was the very high level of availability of the LHC machine, with 50% of the scheduled time spent in stable physics operation, compared to 30% in previous years.<br>With the present performance of the machine, the proton-proton Run 2 goal of 100-120 $fb^{-1}$ integrated luminosity is achievable.<br>Periods of machine development studies were carried out and a set of parameters (13 TeV-25ns, 40cm Beta*, 2,200 bunches at 1.1e11 protons per bunch) was defined to reach the performance target. The latter was achieved despite the occurrence of several technical issues, such as pressure rises in one kicker magnet in the presence of high intensity beams and the 66 kV transformer fault at LHC point 8.<br>During the year, several special physics runs took place, including a very high Beta (2.5 km) run for Totem and special runs for LHCf.<br>At the end of the year, a month of operation was dedicated to highly successful proton-lead ion collisions, with data-taking at two different levels of energy and special runs for LHCf and LHCb. In all operating conditions (3 different machine configurations in 4 weeks), the luminosity delivered to the experiments exceeded the original request. |

## 1. LHC machine, reliability and consolidation (cont.)

| | |
|---|---|
| **Achievements** | Before the Extended Year-End Technical Stop (EYETS), a magnet training campaign was carried out in two LHC sectors (S34 and S45) in order to assess the limitations and the time needed before operating the machine at 14 TeV. Amongst other topics, this assessment will be first discussed during the LHC performance workshop in January 2017, and recommendations will be provided by the CERN Machine Advisory Committee (CMAC).<br>The EYETS is now in full swing, with lots of activities ongoing in the accelerator complex.<br>Spares and Consolidation<br>The RF spare module has been fully qualified in 2016, in case it needs to be exchanged with a unit of the machine. In the meantime, the construction of additional spare parts is under way, with the first cavities delivered and undergoing testing.<br>A strategy for the exchange and refurbishment of the RF klystrons has been elaborated with the industrial supplier.<br>Five LHC dipoles were also repaired during 2016, thus reconstituting the LHC spare magnets inventory. The repair of dipoles following the sector 3-4 incident is now complete. All magnets but one have been reconditioned or reconstructed.<br>Only a few radiation-induced failures were observed during 2016, thanks to the implementation of previously reported successful mitigation measures, as well as to lower radiation levels (per unit of luminosity). The latter are due to reduced beta-star and crossing angle and further improved vacuum conditions. Concerning the remaining mitigation measures, the FGClite (power converter controller) production has been successfully qualified, with a first deployment in the ARC during the EYETS. The Radiation-to-Electronics (R2E) project is now focussed on equipment lifetime constraints and ongoing/future equipment developments in order to ensure reliable operation up to LS2 as well as during HL-LHC operation.<br>Technical infrastructure consolidation requires continuous effort. The programme for the renewal of the LHC HVAC units (located in surface buildings) has been performed on schedule and within budget. The commissioning phase will take place in 2017. During the present EYETS, the lift replacement activities have started. Finally, contracts have been signed for the new 400/66 kV substation in Bois-Tollot and the new Meyrin emergency diesel generator sets.<br>Regarding consolidation of an environmental nature, studies were done on the removal of obsolete oil-transformers (new transformers will arrive in 2017), and the replacement of TCR coils for noise reduction in St-Genis will be finalised in 2017. |

| | |
|---|---|
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Regarding consolidation of an environmental nature, studies were done on the removal of obsolete oil-transformers (new transformers will arrive in 2017), and the replacement of TCR coils for noise reduction in St-Genis will be finalised in 2017.

| **Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices)** | | **Final 2016 Budget (a)** | **2016 Revised Bud. (b)** | **2016 Out-Turn (c)** | **Budget usage in % (c)/(a)** | **Budget variation (c)-(a)** | **Revised Bud. usage in % (c)/(b)** | **Revised Bud. Variation (c)-(b)** | **2016 Open Commitment** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|---|
| **LHC machine and experimental areas** | **Personnel (FTE)** | **339.2** | **327.9** | **341.5** | **101%** | **2.4** | **104%** | **13.7** | | |
| | Personnel (kCHF) | 59,055 | 56,610 | 57,864 | 98% | -1,191 | 102% | 1,254 | | |
| | Materials (kCHF) | 44,035 | 42,940 | 36,976 | 84% | -7,059 | 86% | -5,964 | 3,894 | |
| | **Total (kCHF)** | **103,090** | **99,550** | **94,840** | **92%** | **-8,250** | **95%** | **-4,710** | **3,894** | |
| **Spares** | **Personnel (FTE)** | | | **3.7** | | **3.7** | | **3.7** | | |
| | Personnel (kCHF) | | | 669 | | 669 | | 669 | | |
| | Materials (kCHF) | 7,390 | 6,650 | 4,792 | 65% | -2,598 | 72% | -1,858 | 626 | |
| | **Total (kCHF)** | **7,390** | **6,650** | **5,461** | **74%** | **-1,929** | **82%** | **-1,189** | **626** | |
| **Consolidation** | **Personnel (FTE)** | **65.9** | **74.3** | **82.9** | **126%** | **17.0** | **112%** | **8.6** | | |
| | Personnel (kCHF) | 11,030 | 12,400 | 13,119 | 119% | 2,089 | 106% | 719 | | |
| | Materials (kCHF) | 37,515 | 21,500 | 22,683 | 60% | -14,832 | 106% | 1,183 | 4,674 | |
| | **Total (kCHF)** | **48,545** | **33,900** | **35,803** | **74%** | **-12,742** | **106%** | **1,903** | **4,674** | |

# LHC experiments

## 2. ATLAS detector

| | |
|---|---|
| **Goals** | Fully exploit the improved physics potential of LHC Run 2, taking advantage of the higher LHC collision energy (13-14 TeV) at nominal luminosity, and the better performance of the ATLAS detector owing to its 4th pixel layer (IBL) and improved trigger capabilities (increased selectivity in the presence of pile-up, and rates increased to 100 kHz at level 1 and 1 kHz at HLT). Continue construction of Phase-1 upgrade projects, as well as R&D towards TDRs for Phase-2 upgrades. |
| **Achievements** | Thanks to the excellent LHC performance in 2016, ATLAS has successfully collected 36 fb-1 of pp data, more than in all the previous years combined. The high-rate and high-efficiency LHC operations in 2016 have required adjustments of the ATLAS level 1 trigger to maintain rates within the readout capabilities of the detector electronics. With the LHC bunch configuration and pile-up levels during 2016, ATLAS has been able to run at a 100 kHz level 1 trigger rate. Thanks to continuous optimisation of the high-level trigger algorithms to cope with the high pile-up, the trigger DAQ has averaged a 1 kHz average rate of output to the CERN Tier-0 computing system. The Tier-0 has struggled to keep up with processing the large data volumes despite significant improvements in 2016 and continued strong support from CERN/IT. Due to Tier-0 backlogs, several runs were processed at Tier-1 computing centres, allowing data taken two weeks before a conference to be included in the results presented. The high data rates in 2016 also challenged the offline Grid computing capacity, with large data transfers and the need for increased Monte Carlo simulation production. With the increased luminosity in 2016, the operating conditions of the 4th pixel detector layer (IBL) were carefully optimised to ensure that the average LV current stayed within safe limits. Critical reference data were obtained in lab measurements with a new X-ray irradiator. The main change and major decision was to operate the IBL warm in 2016, with a reduced digital supply voltage, and the detector has thus been operating well with relatively stable conditions. In 2017 the operating temperature can be safely reduced back to the nominal value of -20°C.<br>ATLAS submitted many results to the ICHEP conference based on up to 15 fb-1 of √s=13 TeV pp collisions from 2016 and 2015, and further results were released thereafter. Measurements of many different Standard Model processes demonstrated the detailed understanding of the 2016 data. The Higgs boson, discovered in Run 1, was again observed in the two “discovery channels” H→γγ and H→4l at the rates expected in the Standard Model. Many new particle searches were also conducted, but no significant excesses of physics beyond the Standard Model have persisted in any channel. By the end of 2016, ATLAS had submitted or published over 600 papers in peer-reviewed journals, including 50 using Run 2 data. Other achievements during 2016 include the successful data collection during the heavy ion running period. The Phase-I upgrade projects, such as the New Small Wheel muon detector, the calorimeters and the Trigger/DAQ system, have now entered the production phase, and substantial progress has been made on the detailed plans and R&D for the Phase-II Upgrades, e.g. for the Trigger/DAQ system and the new Inner Tracker. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **78.7** | **80.4** | **92.8** | **118%** | **14.1** | **115%** | **12.4** | | |
| Personnel (kCHF) | 15,375 | 15,555 | 16,515 | 107% | 1,140 | 106% | 960 | | |
| Materials (kCHF) | 3,335 | 3,335 | 3,527 | 106% | 192 | 106% | 192 | 103 | |
| **Total (kCHF)** | **18,710** | **18,890** | **20,042** | **107%** | **1,332** | **106%** | **1,152** | **103** | |

## 3. CMS detector

| | |
|---|---|
| **Goals** | Fully exploit the improved physics potential of LHC Run 2, taking advantage of the higher LHC collision energy (13-14 TeV) at nominal luminosity, using the upgraded trigger system: this could be "The Discovery Year". |
| **Achievements** | CMS was ready at the start of the run with the fully upgraded trigger system. The flexibility provided by the new trigger set-up allowed the optimal exploitation of the exceptional performance of the LHC, which exceeded all the forecasts for instantaneous luminosity. CMS eventually logged 37.8 $fb^{-1}$, more than 92% of the luminosity delivered by the LHC. Efficient processing allowed CMS to submit more than 70 new results for the ICHEP conference in August, based on the first 13 $fb^{-1}$ delivered from the LHC. While these early results confirmed the extended discovery reach, no significant sign of new physics has been detected with this early data. The full 2016 data set will be used to present new results at the winter conferences in 2017. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **107.6** | **107.8** | **120.0** | **112%** | **12.4** | **111%** | **12.2** | | |
| Personnel (kCHF) | 20,365 | 20,365 | 22,352 | 110% | 1,987 | 110% | 1,987 | | |
| Materials (kCHF) | 3,895 | 3,850 | 3,595 | 92% | -300 | 93% | -255 | 145 | |
| **Total (kCHF)** | **24,260** | **24,215** | **25,947** | **107%** | **1,687** | **107%** | **1,732** | **145** | |

## 4. ALICE detector

| | |
|---|---|
| **Goals** | In 2016, as in 2015, ALICE will collect data with proton and Pb ion beams. With protons, the main objective is a run with a luminosity of around $10^{30}$ $cm^{-2}s^{-1}$ to collect about 10 $pb^{-1}$ for rare triggers, i.e. one quarter of the total luminosity of 40 $pb^{-1}$ that we plan to integrate during the four years of Run 2. This will provide the same integrated parton luminosity for the pp reference data as for the 1 $nb^{-1}$ Pb-Pb sample that we plan to integrate during the same period (thereby ensuring that the pp measurement does not dominate the uncertainties). For the run with Pb beams in the autumn, a decision will have to be taken on whether to dedicate it to completing the collection of the sample of Pb-Pb collisions or to collecting p-Pb data. Analysis of the pp and PbPb data from 2015. |
| **Achievements** | In 2016 ALICE integrated 9.7 $pb^{-1}$ of reference pp data, approaching one half of the total goal for integrated luminosity in pp for Run 2. The heavy ion run was dedicated to the collection of p-Pb data. A sample of 760 M events (about one order of magnitude larger than that collected in 2013) was recorded at the reference energy of 5.02 TeV, and about 20 $nb^{-1}$ of rare triggers were collected at the maximum energy of 8.16 TeV. Issues due to the presence of large localised distortions in the 2015 TPC data have successfully been dealt with by implementing a distortion correction scheme that was originally planned for the LS2 upgrades. The 2015 Pb-Pb sample has been successfully reprocessed with the new scheme. The data analysis has proceeded, with the submission of 25 new papers and two series of new preliminary results released for two of the most important heavy-ion conferences (SQM 2016 in June and Hard Probes 2016 in September). |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **50.9** | **50.3** | **57.3** | **113%** | **6.5** | **114%** | **7.1** | | |
| Personnel (kCHF) | 9,740 | 9,610 | 10,894 | 112% | 1,154 | 113% | 1,284 | | |
| Materials (kCHF) | 1,770 | 1,680 | 1,826 | 103% | 56 | 109% | 146 | 0 | |
| **Total (kCHF)** | **11,510** | **11,290** | **12,720** | **111%** | **1,210** | **113%** | **1,430** | **0** | |

## 5. LHCb detector

| | |
|---|---|
| **Goals** | Continue efficient data-taking at 4 x $10^{32}$ $cm^{-2}s^{-1}$ and 25 ns bunch crossings. Continue detector construction for LHCb upgrade and further define objectives and methods for the HL-LHC Phase. |
| **Achievements** | The LHCb detector started data-taking in excellent shape, and the experiment managed to acquire data at 13 TeV and 25 ns bunch spacing consistently over the whole year. Thanks to exceptional efficiency from the LHC and the reliability of LHCb, we have recorded in excess of 1.7 $fb^{-1}$ integrated luminosity in pp collisions and ~30 $nb^{-1}$ in p-Pb and Pb-p. The new concept and improved trigger and farm strategy, better adapted to the new running conditions with increased energy and 25 ns bunch crossing, with online data stream analysis up to HLT1, allows precise and “real time” event reconstruction. The processing farm has been upgraded to cope with this exceptional physics input.<br>The preparations for the upgrade in LS2 are progressing well, with progress being scrutinised by the LHCC and UCG. Several Engineering Design Reviews and Production Readiness Reviews have taken place, signalling the natural progress from R&D to final prototyping and production. For the HL-LHC era, LHCb is further defining its objectives, and an expression of interest for Phase-II is being finalised.<br>Physics exploitation has continued at an intense rate. During the calendar year 64 papers were published or submitted to a journal, bringing the total scientific output of the collaboration to 356 publications. Important topics include the study of time-dependent B→hh states and $B_s \to D_sK$ from Run-1 and early Run-2 data, with extensive spectroscopy studies and the first observation of the $B^0 \to K^+K^-$ decay (a strongly suppressed decay with BR of only $8\times10^{-8}$). |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **49.2** | **49.2** | **48.3** | **98%** | **-0.9** | **98%** | **-0.9** | | |
| Personnel (kCHF) | 10,180 | 10,180 | 9,222 | 91% | -958 | 91% | -958 | | |
| Materials (kCHF) | 1,495 | 1,420 | 2,117 | 142% | 622 | 149% | 697 | 16 | |
| **Total (kCHF)** | **11,675** | **11,600** | **11,338** | **97%** | **-337** | **98%** | **-262** | **16** | |

# 6. Common items, other experiments

## 6a. Totem detector

| | |
|---|---|
| **Goals** | Pursue data-taking with large $\beta^*$ (90 m and ≥ 1km) and with standard optics, both standalone and in common with CMS. Complete the upgrade operations by installing a complete timing reference system and TOF detectors in Roman Pots. Data analysis of the new data sets for elastic scattering, total cross-section and diffraction. |
| **Achievements** | Data-taking with large $\beta^*$ (2.5 km) and standard optics was performed in standalone mode and in common with CMS. The DAQ was fully integrated in CMS, and data of 15.3 $\text{fb}^{-1}$ were collected with standard optics together with CMS (CT-PPS, CMS-TOTEM common project). The timing reference system was installed in the LHC tunnel. The diamond detectors (TOF and tracking) were installed in the cylindrical (horizontal) Roman Pots during a technical stop, and 2.5 $\text{fb}^{-1}$ of data were collected in common with CMS with standard LHC optics. The total cross-section measurement at 2.7 TeV is close to being published, and the analysis of the 2.5 km $\beta^*$ data taken in 2016 is steadily progressing. The analysis of the CT-PPS data has started together with CMS in particular QED channels (boson-boson and muon-muon final states). |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **5.6** | **5.6** | **4.8** | **85%** | **-0.8** | **85%** | **-0.8** | | |
| Personnel (kCHF) | 1,185 | 1,185 | 1,012 | 85% | -173 | 85% | -173 | | |
| Materials (kCHF) | 295 | 280 | 287 | 97% | -8 | 102% | 7 | 3 | |
| **Total (kCHF)** | **1,480** | **1,465** | **1,299** | **88%** | **-181** | **89%** | **-166** | **3** | |

## 6b. LHCf detector

| | |
|---|---|
| **Goals** | Analysis of the data taken in 2015 and before, including joint analyses with ATLAS. Feasibility study to join p-Pb collisions. |
| **Achievements** | Analyses of neutral pion production using the Run 1 data were completed and the results were published. Analysis of the photon spectra using the 13TeV data was completed and the results will be published in early 2017. Data-taking in the p-Pb collisions using the Arm2 detector was successfully performed in November. A Monte Carlo study for the joint analyses with ATLAS was published. Discussions for data analysis are in progress. |

## 6c. MoEDAL

| | |
|---|---|
| **Goals** | To analyse the data taken in 2015, and also to redeploy sensitive MoEDAL volume for data taking in 2017. |
| **Achievements** | Since April 2015 the MoEDAL collaboration has produced two papers (JHEP 1608 (2016) 067 and one to be published in PRL) giving the world's best limits for multiply magnetically-charged monopole production. At the LHCC closed session in September 2016 we proposed to submit a letter of intent for a new MoEDAL sub-detector, for the detection of penetrating of mini-charged particles and very long-lived neutral particles. In addition, the collaboration grew to include groups from Russia (Moscow), the US (Alabama) and the UK (QMC). |

## 6d. Support for LHC detectors

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **37.9** | **37.9** | **27.8** | **73%** | **-10.1** | **73%** | **-10.1** | | |
| Personnel (kCHF) | 5,920 | 5,910 | 4,602 | 78% | -1,318 | 78% | -1,308 | | |
| Materials (kCHF) | 2,395 | 2,375 | 833 | 35% | -1,562 | 35% | -1,542 | 230 | |
| **Total (kCHF)** | **8,315** | **8,285** | **5,435** | **65%** | **-2,880** | **66%** | **-2,850** | **230** | |

# 7. LHC detector consolidation (ended)

## 8. LHC computing

| | |
|---|---|
| **Goals** | Support full worldwide workloads of the LHC experiments at nominal luminosity and data rates, including:<br>• Data archiving volumes of up to 50 PB per year, data ingest rates of close to 10 GB/s into the Tier 0.<br>• Distribution of full raw data volumes to 13 Tier-1 centres.<br>• Full reconstruction, simulation, and analysis workflows of all experiments fully supported.<br>• Full use of Wigner centre as an integral part of the Tier 0. |
| **Achievements** | Successfully supported the 2016 data taking and full global workflows, including responding to the significantly increased needs of computing generated by the exceptional performance of the LHC and experiments. The LHC delivered some 50% more integrated luminosity than initially anticipated, leading to significantly more demands on the computing and storage services, and new peak performance indicators in all aspects of computing:<br>• 49.4 PB of new LHC data was collected, with rates achieved of more than 500 TB per day of new data, a peak in July of 11 PB archived; the full data ingest rates from all 4 LHC experiments were supported without problems;<br>• All raw data was distributed to all 13 Tier-1 centres. In May and June record data transfer rates triggered a need to add additional hardware to the core transfer service to manage the new peak rates, which were greater than 6 GB/s out of CERN; also moved several Tier 1 sites to upgrade the LHCOPN dedicated bandwidths. Additional resources were also added to the LHCONE core backbone. The global data transfers achieved constant rates of around 100 PB/month for most of the running period;<br>• The full experiment workflows were continually optimised and supported, allowing data to be prepared for the ICHEP conference within 2 weeks;<br>• The Tier 0 was fully functional, with both sites (Meyrin and Wigner) fully active. Resources were added to the Tier 0 to ensure sufficient capacity for the prompt feedback loops of the experiments during data-taking, in response to the increased needs.<br>Resources globally in WLCG are fully occupied at all times, and opportunistic resources allow the experiments to use significantly more capacity than that formally pledged. Concern for 2017 and 2018 has arisen, however, due to the LHC performance and the consequent increased needs of the experiments unlikely to be (formally) fulfilled by the funding agencies. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **109.5** | **111.0** | **117.2** | **107%** | **7.7** | **106%** | **6.2** | | |
| Personnel (kCHF) | 22,800 | 22,905 | 23,894 | 105% | 1,094 | 104% | 989 | | |
| Materials (kCHF) | 25,065 | 22,035 | 23,154 | 92% | -1,911 | 105% | 1,119 | 753 | |
| **Total (kCHF)** | **47,865** | **44,940** | **47,048** | **98%** | **-817** | **105%** | **2,108** | **753** | |

# Other programmes

## 9. Non-LHC physics (experimental programme)

| | |
|---|---|
| **Goals** | Reach goals defined in the experiment proposals and approved by scientific committees and Research Board. Data taking in standard running mode once the accelerator chain is fully operational after the shutdown. Analysis of data taken in previous years. |
| **Achievements** | **NA62** is devoted to the study of very rare kaon decays which offer a window of opportunity to look for new physics. Kaons are particularly interesting because their decays are very well calculable in the Standard Model, so a discrepancy between the measured and predicted rate may have profound consequences. In 2016 NA62 completed the transition from commissioning to data-taking and analysis. The hardware improvements identified the previous year were implemented, and a major improvement of the TDAQ performance was achieved. In particular, the full portfolio of hardware and software triggers was deployed, and a very large data set, corresponding to almost 10% of the total required statistics, was written to tape. Initial analysis of the data taken indicates detector performance in line with expectations. Data-taking will continue until LS2.<br>**COMPASS** switched in 2016 to measurements of exclusive processes for generalised parton distributions using a muon beam and a 2.5 m-long liquid hydrogen target surrounded by a large recoil detector. The new equipment (DC5, RICH and DAQ) was commissioned successfully. Despite the intensity limitations of the SPS, the 2016 run almost reached the originally projected luminosity. The analysis of the 2015 polarised Drell-Yan data is proceeding well, and publication is targeted for spring 2017. Results from earlier data were published in seven papers, including the final results for the longitudinal structure function $g_1$ of the proton and the deuteron, fragmentation functions, multi-dimensional results for the Sivers function, and a first measurement of the gluon Sivers function. A highlight is a long paper on the three-pion final state in $\pi^- p$ collisions with unprecedented precision and depth of analysis.<br>**AD**: in 2016, the ALPHA experiment reached a goal that the antimatter community had been systematically working towards for many years, the first optical spectroscopy of antihydrogen, thus opening the door to precision spectroscopy of antihydrogen and new tests of CPT symmetry. In parallel, the ASACUSA experiment carried out the most precise measurement of the antiproton-to-electron mass ratio to date. Combined with measurements from ATRAP, BASE and ALPHA, this pushes limits on mass and charge differences between protons (electrons) and antiprotons (positrons) to the sub-ppb level. Preparations for tests of the Weak Equivalence Principle are equally advancing: AEGIS commissioned the steps needed for a pulsed beam of antihydrogen, and GBAR started to be installed in a new zone; GBAR will be the first experiment to benefit from the new ELENA decelerator, whose commissioning has started.<br>**CAST** started its new 3-year programme in 2016 by searching for (a) solar chameleons, candidates for the dark energy sector, with the pixellised Ingrid detector (Primakoff effect with chameleons) and the KWISP force sensor (via chameleon matter coupling), and (b) dark matter axions (axion Primakoff effect inside a resonance cavity). All three sub-detectors have undergone a commissioning phase associated with an upgrade of several detector components. |

## 9. Non-LHC physics (experimental programme) (cont.)

| | |
|---|---|
| **Achievements** | For example, a new 300 nm-thin entrance window made Ingrid sensitive to converted soft X-rays (~100 eV). We are confident that 2017 will be a data-taking period for all three sub-detectors.<br>**CLOUD**: The CLOUD11 run in the East Hall T11 beamline from 26 September to 25 November focused on two topics: (a) pure biogenic nucleation and growth under realistic environmental conditions, and (b) anthropogenic organics nucleation and growth under polluted urban conditions. In addition, experiments from the 2015 CLOUD10 run to simulate daytime Hyytiälä boreal forest conditions were completed using the new UV sabre 3. Numerous upgrades of the CLOUD facility were made, of which the major items were an enlarged upper platform for safer access, and construction and operation of the new 400 W optical power UV sabre 3 (385 nm) to simulate daytime atmospheric NOx chemistry. Five CLOUD papers were published in high-impact scientific journals (Nature, PNAS and Science).<br>**ISOLDE**, CERN's exotic beam facility, carried out 46 successful experiments in 2016, with a balanced distribution of beam time spread between nuclear structure studies done by nuclear ground state properties (23%), decay studies (20%) and Coulomb excitation/scattering studies (23%). Nuclear astrophysics studies (7%), materials science (11%) and biophysics and medicine (7%) accounted for most of the remaining share. The year started with the production of a $^{7}$Be sample for n_TOF(EAR-2) in order to study the charge exchange reaction $^{7}$Be(n,p), shedding light on the cosmological lithium problem. This was the first joint ISOLDE-n_TOF experiment and constitutes the first direct measurement of this reaction in the range of interest of Big Bang nucleosynthesis. A new method of Phase Imaging Ion Cyclotron Resonance (PI-ICR) has been successfully implemented at ISOLTRAP with the aim of improving the resolving power of mass measurement by an order of magnitude and reaching exotic species with half-lives that are a factor of ten shorter. Six successful experiments were carried out at the ISOLDE decay station, IDS, from He to Hg, inaugurating the new ISOLDE-built neutron time of flight spectrometer. The electromagnetic properties of the nuclei are determined by measuring the hyperfine spectrum, either detecting photons in COLLAPS or ions in CRIS. The former published the evolution of the Ca (A=40-52) isotopes radii in Nature Physics. The large and unexpected increase in the size of the neutron-rich calcium isotopes beyond N = 28 challenges the doubly-magic nature of $^{52}$Ca and opens new intriguing questions about the evolution of nuclear sizes away from stability, which are of importance for our understanding of neutron-rich atomic nuclei. In materials science, important results concerning the nature of doping in nitride semiconductors were obtained, as were data on the surface wetting of graphene. The new Gandalph spectrometer observed the first photo-detachment of radioactive ions, and a successful examination of the prototype target for the new ESS facility was performed. The main breakthrough of the year was the accomplishment of HIE-ISOLDE Phase 1, so that the large variety of ISOLDE beams can be accelerated to 5.5 MeV per nucleon (MeV/u) for mass over charge of 4.5. The 2016 campaign with post-accelerated beams started on 9 September, accelerating a beam of the semi-magic (Z=50) $^{110}$Sn to 495 MeV (4.5 MeV/u). Six experiments were done with beams, from $^{9}$Li addressing the structure of the unbound nucleus, to collective octupole degrees of freedom in the heaviest accelerated beam $^{142}$Xe. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **23.7** | **25.9** | **29.4** | **124%** | **5.7** | **114%** | **3.5** | | |
| Personnel (kCHF) | 4,390 | 4,800 | 5,011 | 114% | 621 | 104% | 211 | | |
| Materials (kCHF) | 2,165 | 1,800 | 1,811 | 84% | -354 | 101% | 11 | 103 | |
| **Total (kCHF)** | **6,555** | **6,600** | **6,822** | **104%** | **267** | **103%** | **222** | **103** | |

## 10. Theory

| | |
|---|---|
| **Goals** | World-leading research in theoretical particle physics and related fields. Support experiments and the TH community. Provide training in theory and resources for a wide visitor programme. |
| **Achievements** | In 2016 the CERN Theoretical Physics department (CERN-TH) successfully achieved important goals in the context of its three main missions: producing cutting-edge research in theoretical particle physics, serving the international theoretical physics community, and supporting the activities of the Laboratory.<br>Research at CERN-TH has been thriving in string theory, quantum field theory, physics of the Standard Model and beyond the Standard Model, QCD, collider physics, physics of heavy flavours, lattice field theory, high-temperature quantum field theory, heavy ions, cosmology, and astroparticle physics. This led to 262 original publications issued as CERN-TH preprints. Here are some notable examples, out of the many influential results obtained in 2016. The most precise theoretical prediction (arXiv:1602.00695) for the Higgs boson production cross-section, which is a crucial theoretical input for the physics programme of the LHC. A systematic treatment (arXiv:1605.02149) of the leading non-linear effects in the baryon acoustic oscillations, which is a key observable in cosmology to test dark energy and neutrino masses. A breakthrough (arXiv:1606.05495) in the important mathematical problem of determining the modular properties of lattice sums of indefinite signature, by exploiting insights gained in the study of instanton corrections in string theory. A precise determination (arXiv:1607.04266) of how much light accompanies fast-moving protons, solving a decades-old problem and eliminating the largest uncertainty on many of the theory predictions needed for Higgs studies and new physics searches at the LHC. The exploration (arXiv:1610.07962) of clockwork theories, which offer a mechanism for generating light particles with exponentially suppressed interactions.<br>CERN-TH has continued to serve as a vibrant reference centre where scientists can discuss and exchange ideas, and as a meeting place for the international community. In 2016, CERN-TH hosted 770 scientists - 505 associate members of the personnel (473 visiting scientists, 10 scientific associates, 3 guest professors, 19 cooperation associates) and 265 unpaid scientific visitors. It offered an intense programme of seminars (about 5-8 per week), and hosted 5 TH Institutes (“Recent Developments in M-theory”, “Emergent Properties of Space-time”, “Charting the Unknown”, “The Big Bang and the Little Bangs”, “From Quarks to Gravitational Waves”), 8 Workshops and Meetings (including the TeV Particle Astrophysics 2016 Conference). CERN-TH also pursued its role in post-graduate education, hosting 44 fellows, who will form tomorrow’s generation of physics professors.<br>CERN-TH is committed to contributing to the scientific life of the Laboratory. Its role in supporting the experimental programme is essential. Theorists made a fundamental contribution to all working groups on LHC physics and to their publications. They led the investigations on the physics opportunities of a 100 TeV hadron collider in the context of CERN’s study for a Future Circular Collider facility; this work was documented in the 5-volume report on “Physics at 100 TeV”. CERN-TH played a leading role in launching new physics research initiatives in the context of the Neutrino Platform (with a newly formed group dedicated to neutrino theoretical physics) and Physics Beyond Colliders (co-organising a kick-off meeting at CERN). Members of CERN-TH are the driving force behind the organisation of educational programmes (CERN School of High-Energy Physics, Latin-American School, Asia-Europe-Pacific School, CERN-Fermilab Hadron Collider Physics School, Summer Student Program, High-School Teacher Program, Academic Training, CERN Colloquia) and various outreach activities. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **65.8** | **65.1** | **62.0** | **94%** | **-3.8** | **95%** | **-3.0** | | |
| Personnel (kCHF) | 10,250 | 10,305 | 9,635 | 94% | -615 | 93% | -670 | | |
| Materials (kCHF) | 1,470 | 1,645 | 1,548 | 105% | 78 | 94% | -97 | 31 | |
| **Total (kCHF)** | **11,720** | **11,950** | **11,183** | **95%** | **-537** | **94%** | **-767** | **31** | |

## 11. Knowledge transfer

| | |
|---|---|
| **Goals** | • Organise the ICTR-PHE 2016 conference and the associated Medical Applications Office brainstorming meeting.<br>• Contribute to the activities of the CERN Medical Applications office.<br>• Run the ENLIGHT network (meeting, submitting hadron therapy projects, lobbyign for funding, running COST proposal if successful).<br>• Assist Member States which express interest in medical applications (hadron therapy in particular).<br>• Research suitable funding opportunities, in particular for medical applications, draft/submit projects.<br>• Communication/dissemination activities (KT annual report, medical applications-related communication, ENLIGHT Highlights, medical applications seminars).<br>• Technology and Innovation Monitor: production version deployed at EC-JRC.<br>• Foster applications of new projects for the KT Fund and follow up the existing funded projects.<br>• Continue to develop the network of incubators concept.<br>• Actively scout for more projects aimed at demonstrating the impact that CERN has on society through the dissemination of its know-how and technologies.<br>• Aerospace applications: define a strategy aimed at maximising the impact of the Organization's activities on the aerospace field. |
| **Achievements** | The ICTR-PHE 2016 conference was successfully organised (440 participants, 165 oral presentations and many scientific papers generated). For the first time, it included a start-up corner in the industrial exhibition, which helped promote entrepreneurship and its link with research.<br>A new structure for medical applications was implemented at the beginning of 2016, including a steering group chaired by the Director of Accelerators and Technology and the Medical Application Project Forum (MAPF), Chaired by the Section Leader of the Medical Applications Section of the KT Group.<br>The KT Forum met twice in 2016. The second meeting was partially dedicated to presenting the strategy for medical applications. Specifically for hadron therapy, a new partnership agreement has been signed with MedAustron, covering the ongoing and future support activities.<br>A series of KT seminars on various topics (entrepreneurship, medical applications, aerospace applications) was launched. Over the year, 45 news items and communication products (e.g. printed material) were published in a coordinated manner through various communication channels online (Bulletin, Courier, social media, CERN Website, KT website and external channels) and offline. The KT group has strengthened links with the ECO group and contributed to drafting the key messages related to knowledge transfer in the CERN Communication Strategy document.<br>CERN's Technology Innovation Monitor has been integrated by the JRC in its suite of tools for innovation monitoring.<br>The CERN Knowledge Transfer Fund received a record number of applications in 2016 (13). A report on the impact of the CERN Knowledge Transfer fund from its creation to date was compiled and distributed to the Management.<br>One additional incubator (Italy) joined the network of incubators, bringing the total number to nine. 16 companies using CERN technologies are/have been hosted in the incubators.<br>The scouting for technologies continued in 2016, in particular with the organisation of a KT Innovation Day with the Experimental Physics department. 2016 saw a high number of technology disclosures and contracts signed (more than 90 and 40, respectively).<br>A strategy for maximising the impact of CERN's know-how in the field of aerospace was prepared and its implementation began in 2016. |

## 11. Knowledge transfer (cont.)

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **18.1** | **19.2** | **18.0** | **100%** | **0.0** | **94%** | **-1.2** | | |
| Personnel (kCHF) | 3,470 | 3,385 | 2,816 | 81% | -654 | 83% | -569 | | |
| Materials (kCHF) | 3,520 | 4,455 | 3,128 | 89% | -392 | 70% | -1,327 | 111 | |
| **Total (kCHF)** | **6,990** | **7,840** | **5,944** | **85%** | **-1,046** | **76%** | **-1,896** | **111** | |

## 12. Scientific support (associates, computing, R&D detectors and technical support)

| | |
|---|---|
| **Goals** | **Scientific support:**<br>**ESE:** Involvement in the LHC experiments to be maintained for the Phase 1 upgrades and their commissioning, and the developments for Phase 2. RD53 is a common ATLAS/CMS/LCD project for developing a pixel readout chip in 65 nm CMOS in 2016. Involvement in NA62 should reduce following its successful start-up. Technological support for common developments will be maintained, and new IP blocks to be bought/supported. Production of the GBT chipset and of the Versatile Links to be done. High speed links, LowPowerGBT and VL+ development, additional effort and resources in silicon photonics highly desirable. A more radiation hard version of DC-DC converter needed, and adaptation to special needs, as well as bulk radiation-tolerant power supplies (collaboration with industry to maintain current availability). TTC PON to be finalised before LS2 if LHCb will use it.<br>**DT:** Provide a centralised engineering and design office, as well as specialised workshops and facilities to design, manufacture and test prototype detector components with special attention to LHC upgrade project needs. Define the direct contribution to detector construction projects where the complexity, production time and cost in industry would be too high, or the technology does not yet have a sufficient industrial base.<br>**SFT:** Assist experiments to resolve any issues that may surface in the stability and performance of their data processing software through the preparation of new LCG software releases. User workshops and surveys will be organised to collect feedback on the performance of Geant4 and ROOT during Run 2. Code reviews will be conducted to identify specific code needing improvements, including changes to new technologies. The CernVM program of work will expand to cover potential new applications, such as data preservation as a service, new HEP clients, such as AMS, as well as non-HEP projects, such as BlueBrain and Euclid. Effort on R&D will increase in order to evaluate new technologies and to re-engineer LHC software for improving performance on new CPU architectures. Efforts will be made to establish the HEP Software Foundation, with a view to expanding collaboration with software units in other HEP laboratories.<br>**R&D detectors:**<br>Seed funding and support for generic R&D activities on gas, solid state, silicon, fibre and crystal detectors. Operation of R&D facilities. General development of detector components. |
| **Achievements** | **ESE**: The design of the ALICE ALPIDE chip for the ITS upgrade has been finalised. The design of the ATLAS muon to central trigger interface, to be installed during LS2, has been done and a prototype will be produced in 2017. For CMS, the TCDS (trigger, control and distribution system) has been finalised and the opto-electrical devices for the pixel upgrade delivered. The NA62 straw detector and calorimeter readout electronics have been running smoothly and all the needed GTK stations delivered. The production of the GBT chipset and of the versatile link components has reached the expected pace and deliveries to experiments have been made. Similarly, about 30,000 rad-hard DC-DC converters have been delivered and a new more rad-hard version has been designed for prototyping. The specifications of the lpGBT and VL+ have been finalised and a first prototype is expected in 2017. RD53 has made substantial progress on the design of a common ATLAS/CMS/LCD chip, but the submission will now be made in Spring 2017. The necessary detailed studies of the radiation hardness of the selected 65 nm CMOS technology made great progress and showed some issues after 0.5 GGy. The TTC-PON specifications have been finalised and the development is starting, in view of its use in ALICE after LS2.<br>**DT**: Production of Phase 1 detector upgrades were launched with CERN teams in the LHC experiments. Production of large-size GEM foils for CMS GE1/1 and the ALICE TPC have been launched, complemented by a strong industrialisation effort in view of future projects. Varied technical support has been provided to Small and Medium sized experiments. The DT carbon-composite laboratory has produced prototype local support structures for CLIC, CMS, LHCb, and ATLAS detector R&D efforts. In terms of infrastructure for the experiments, |

## 12. Scientific support (associates, computing, R&D detectors and technical support) (cont.)

| | |
|---|---|
| **Achievements** | the modernisation of magnet safety systems for the LHC experiments and other experimental magnets at CERN has continued, and consolidated the operational efficiency of numerous gas systems. A leading role has been taken in the design of the ProtoDUNE-SP DAQ system and Detector Control systems for the Neutrino Platform. DT has also pursued R&D on detector technologies for the interest of the overall HEP community: developing radiation-tolerant silicon sensors for the vertex and tracking detectors for the luminosity upgrade of the LHC, novel R&D on precise timing with micromegas, GEM optical readout, ageing of GEM detectors, neutron detectors, and CLIC/ILD detector concepts, micro-engineering and applications such as micro-fluidics cooling and development of MGy dosimetry for the FCC.<br>**SFT**: New production releases were made of all the software products developed and maintained by the group for use in LHC data processing applications in 2017. The ROOT software toolkit now supports parallelism at various levels and allows physicists to speed up the analysis of their data sets. A big effort has been made to extend the tools offered for multivariate analysis, including a new deep-learning library that exploits the use of GPUs. A new production service has been introduced, in collaboration with IT, that supports web-based analysis (SWAN) and this is already well used in LHC analyses and in the preparation of tutorials. The performance of algorithms used in Geant4 to model geometry have been improved and models that simulate physics processes continue to be refined, extended and tuned. After more than three years of R&D, the project has produced a prototype capable of transporting particles in complex geometries whilst exploiting micro-parallelism, SIMD and multithreading. An assessment of progress made has been made in a community meeting organised by the HSF and this has provided essential guidance for future work aimed at delivering adequate performance in the HL-LHC era. The scale of deployment of the two main products of the CernVM ecosystem, the CernVM File System and CernVM Appliance, is such that about 350 million files – belonging to about 50 experiments – are distributed worldwide by CernVM-FS, and more than 10,000 new VMs instantiated every month to serve the needs of the LHC experiments. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| **Scientific support** | **Personnel (FTE)** | **176.6** | **182.1** | **137.9** | **78%** | **-38.7** | **76%** | **-44.2** | | |
| | Personnel (kCHF) | 32,120 | 32,860 | 24,393 | 76% | -7,727 | 74% | -8,467 | | |
| | Materials (kCHF) | 14,190 | 11,485 | 7,850 | 55% | -6,340 | 68% | -3,635 | 2,439 | |
| | **Total (kCHF)** | **46,310** | **44,345** | **32,242** | **70%** | **-14,068** | **73%** | **-12,103** | **2,439** | |
| **LHC physics centre at CERN (LPCC)** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | | | | | | | | | |
| | Materials (kCHF) | 170 | 155 | 106 | 63% | -64 | 69% | -49 | | |
| | **Total (kCHF)** | **170** | **155** | **106** | **63%** | **-64** | **69%** | **-49** | | |
| **Detectors R&D** | **Personnel (FTE)** | **6.7** | **7.3** | **7.9** | **118%** | **1.2** | **107%** | **0.5** | | |
| | Personnel (kCHF) | 1,540 | 1,635 | 1,825 | 119% | 285 | 112% | 190 | | |
| | Materials (kCHF) | 485 | 1,200 | 671 | 138% | 186 | 56% | -529 | 192 | |
| | **Total (kCHF)** | **2,025** | **2,835** | **2,497** | **123%** | **472** | **88%** | **-338** | **192** | |
| **Scientific exchanges (students and associates)** | **Personnel (FTE)** | **1.3** | **1.8** | **2.3** | **176%** | **1.0** | **127%** | **0.5** | | |
| | Personnel (kCHF) | 705 | 735 | 381 | 54% | -324 | 52% | -354 | | |
| | Materials (kCHF) | 8,935 | 8,850 | 9,053 | 101% | 118 | 102% | 203 | 0 | |
| | **Total (kCHF)** | **9,640** | **9,585** | **9,434** | **98%** | **-206** | **98%** | **-151** | **0** | |

## 13. Low- and medium-energy accelerators / PS and SPS complexes / Accelerator maintenance and consolidation / Experimental areas consolidation

| | |
|---|---|
| **Goals** | The complex will run a full range of physics in the fixed-target experimental areas in 2016. In particular, new physics will be delivered with the full HIE-ISOLDE phase 1 operation at 5.5 Mev per nucleon.<br>This programme will be carried out in parallel with operation for LHC injection. Optimisation of the operational cycles of the machines is a continuous process to ensure the delivery of the maximum beam time to all users.<br>Preparations for the AD target consolidation in LS2 continue.<br>The consolidation of East Hall and North Area will continue for the most urgent items.<br>A number of activities thatdo not require access to the accelerator tunnels are continuing. These include the studies for the replacement of the RF amplifier tubes of the SPS, the project to replace the current n_TOF target, work on the PS and SPS surface buildings, the development of new power converters for the PS main RF system, the replacement of the power converters for the TT2 transfer line magnets, the renovation of the existing SPS compensator BEQ1 to serve as a real spare and the consolidation of electrical substations in the Meyrin West Area, SPS (points 2 and 4). |
| **Achievements** | The injector complex ran well in 2016, including HIE-ISOLDE operation at 5.5 MeV per nucleon (more details in factsheet No.30). The availability of the injectors reached the following levels: 97% for Linac2, 95% for the PS-Booster and 90% for the PS. A capacitor failure occurred in the PS Power Supply (POPS) in May 2016. It was repaired and an order was placed for new condensators to be delivered in 2017.<br>For the SPS, a careful operation strategy was put in place to deliver at least 80% of the protons to all experiments and test beam in the North Area despite the occurrence of several issues. The main issue was the vacuum degradation of the SPS internal beam dump (TIDVG), which limited the intensity that could be delivered to the North Area and the LHC. Construction of a new beam dump is under way, and the faulty TIDVG will be replaced by a new one during 2017.<br>The programme to consolidate the RF amplifier tubes (used in the PS and the SPS) has started in order to guarantee safe operation until LS2. New high-voltage power supplies for the PS RF were delivered. Contracts were placed for the procurement of main electrical components for the new converter for TT2. Orbit corrector power supplies for the PS (150 units) will be installed during the EYETS.<br>Regarding infrastructure systems, the consolidation of electrical substations in the Meyrin West Area has been completed, and consolidation activities have progressed in some of the SPS electrical substations (points 3, 4, 5 and 7). The consolidation of the SPS compensator for BEQ1 (static VAR compensator) was re-scheduled for LS2. Work to consolidate the cooling and ventilation infrastructure,, including HVAC for the SPS surface buildings, SPS raising-pump systems, and consolidation of cooling and ventilation control systems, has also been carried out successfully.<br>The AD target consolidation programme (ring magnets, RF, etc.) progressed as expected, with an emphasis on the preparation of the activities to be carried out during LS2, in particular the installation of the ELENA machine transfer lines. Conclusive tests were done in HIRADMAT for the choice of the target material.<br>The East Area renovation project has now been defined, with a complete refurbishment during LS2 of both the building and the beam lines (magnet and power converter replacement). During 2016, the project structure was set up, the layout was essentially frozen and a first Cost and Schedule Review was completed at the end of the year. The most urgent work, however, namely the replacement of the beam monitors and vacuum pumps, had already been carried out. |

## 13. Low- and medium-energy accelerators / PS and SPS complexes / Accelerator maintenance and consolidation / Experimental areas consolidation (cont.)

| | |
|---|---|
| **Achievements** | The CLOUD zone has been equipped with an additional platform giving access to the top of the reaction chamber. During the shutdown the first quadrupole in the T9 beam was replaced.<br>In general very stable conditions were achieved during North Area operation with proton beams. Initial problems of spikes and 25/30 Hz noise in the focusing quadrupoles chain (QF) disappeared thanks to detailed analysis and repair work (intermittent earth fault). This significantly improved the situation for the users and allowed NA62 reaching nominal beam intensity towards the end of the run.<br>A consolidation project for the North Area, similar to what is currently done for East Area, will be developed for implementation during LS3. The most urgent consolidation works were however carried out in the North Area: realignment of two beam lines (H2 and H4), the renovation of one crane in the EHN1 experimental hall, the replacement of parts of the chilled water network and electrical infrastructure, also in view of connecting to the EHN1 extension, and the repair of several mobile dumps. The renovation of the power converter for COMPASS (5 kA, 600 V) has started in December 2016.<br>The new CHARM and IRRAD facilities have been operating routinely (3800h beam time) and with a new record number of users (30 users in total).<br>The n_TOF target replacement study is progressing: three target designs have been pre-selected. The decision for the final design will be taken in 2017 for installation during LS2. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| **Low- and medium-energy accelerators** | **Personnel (FTE)** | **36.7** | **37.2** | **39.1** | **107%** | **2.4** | **105%** | **1.8** | | |
| | Personnel (kCHF) | 6,835 | 6,945 | 7,330 | 107% | 495 | 106% | 385 | | |
| | Materials (kCHF) | 2,540 | 3,160 | 2,875 | 113% | 335 | 91% | -285 | 339 | |
| | **Total (kCHF)** | **9,375** | **10,105** | **10,205** | **109%** | **830** | **101%** | **100** | **339** | |
| **PS and SPS complexes** | **Personnel (FTE)** | **199.4** | **196.3** | **190.7** | **96%** | **-8.6** | **97%** | **-5.6** | | |
| | Personnel (kCHF) | 34,120 | 33,555 | 33,220 | 97% | -900 | 99% | -335 | | |
| | Materials (kCHF) | 19,890 | 20,450 | 18,450 | 93% | -1,440 | 90% | -2,000 | 2,064 | |
| | **Total (kCHF)** | **54,010** | **54,005** | **51,670** | **96%** | **-2,340** | **96%** | **-2,335** | **2,064** | |
| **Accelerator maintenance and consolidation** | **Personnel (FTE)** | **173.4** | **180.1** | **185.7** | **107%** | **12.3** | **103%** | **5.5** | | |
| | Personnel (kCHF) | 34,400 | 35,515 | 36,856 | 107% | 2,456 | 104% | 1,341 | | |
| | Materials (kCHF) | 33,355 | 39,700 | 28,140 | 84% | -5,215 | 71% | -11,560 | 7,485 | |
| | **Total (kCHF)** | **67,755** | **75,215** | **64,996** | **96%** | **-2,759** | **86%** | **-10,219** | **7,485** | |
| **Consolidation of experimental areas** | **Personnel (FTE)** | **8.0** | **7.7** | **6.5** | **82%** | **-1.4** | **85%** | **-1.2** | | |
| | Personnel (kCHF) | 1,220 | 1,205 | 1,202 | 98% | -18 | 100% | -3 | | |
| | Materials (kCHF) | 8,045 | 4,375 | 3,438 | 43% | -4,607 | 79% | -937 | 778 | |
| | **Total (kCHF)** | **9,265** | **5,580** | **4,639** | **50%** | **-4,626** | **83%** | **-941** | **778** | |

# Infrastructure, services and centralised expenses

## 14. Manufacturing facilities (workshops, etc.)

| | |
|---|---|
| **Goals** | **Projects**:<br>• Support for the design and construction of prototypes for HL-LHC. Focus on 11 T magnets, SC link, collimators, RF crab cavities, hollow electron lenses.<br>• LHC, injectors and experiments consolidation, engineering support for the preparation of LS2.<br>• HIE-Isolde, support for the fabrication of cryomodules and assembly tools.<br>• ELENA, complete the design and the fabrication of the main components. Support for the construction of vacuum chambers, alignment and support elements, electron cooler and other machine components. Design and construction of vacuum chambers and supports for the transfer lines.<br>• Studies and support for the AWAKE collaboration.<br>**Organisation:**<br>• Consolidate workshop equipment and conformity to current standards.<br>• Support the CERN-wide safety conformity of machine tools.<br>• Consolidation of group quality policies and procedures.<br>• Continue the program of selective investment in modern fabrication technologies (ex. additive manufacturing). |
| **Achievements** | **Projects:**<br>The Mechanical & Materials Engineering group (EN-MME) has contributed to several projects for the HL-LHC. In particular the design office supported the engineering computation and design of the 11 T magnets and the work shop delivered dipole and quadrupole components and assembly tools. The support work on the collimation design and material characterisation continued during the year. The crab cavity forming process were simulated and studied and several prototypes were fabricated. A complete pre design of the Hollow Electron Lenses was carried out.<br>LS2 preparation has been one of the main priorities of the design office and work shop, specifically support to equipment groups for the EYETS 2016-2017.<br>Two complete SRF cavities were fabricated for HIE-Isolde, and a fully machined version subcontracted for fabrication in collaboration with industry.<br>The design and construction of components for ELENA was successfully completed during the year.<br>The first aluminium cryostat to be used for the LArTPC (liquid argon time projection chambers) modules of ICARUS was assembled and delivered to the neutrino platform team. The second cryostat is almost finished. Steel structures needed for protoDUNE (large-size prototype of a single phase LArTPC detector) were subcontracted to industry and delivered.<br>**Organization:**<br>In preparation of EYETS 2016-17, the responsibility of stakeholders from the design to the fabrication phase was clarified, which streamlined the coordination and transfer of jobs. The design office quality manual was updated. |

## 14. Manufacturing facilities (workshops, etc.) (cont.)

| **Achievements** | The metal additive manufacturing (a.k.a. 3D metal printing) equipment has been commissioned and an R&D program for copper and niobium was launched in collaboration with the KT Fund and FCC studies. |
|---|---|

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **54.9** | **56.2** | **59.9** | **109%** | **5.1** | **107%** | **3.7** | | |
| Personnel (kCHF) | 9,185 | 9,300 | 9,420 | 103% | 235 | 101% | 120 | | |
| Materials (kCHF) | 3,880 | 2,385 | 2,716 | 70% | -1,164 | 114% | 331 | -6,559 | |
| **Total (kCHF)** | **13,065** | **11,685** | **12,137** | **93%** | **-928** | **104%** | **452** | **-6,559** | |

## 15. General facilities & logistics (site maintenance, transport)

| | |
|---|---|
| **Goals** | Ensure a similar level of service to the CERN community as in 2015.<br>Operate and maintain the infrastructure systems, i.e. the electrical distribution network and cooling and ventilation systems, to ensure maximum availability of the accelerator complex and the associated experiments. With this in mind, interventions and maintenance will be scheduled, as much as possible, so as not to perturb the accelerator schedule.<br>The general services department will perform capacity planning to adapt site services to the evolution of the requirements and available resources. In light of this, it will also:<br>• Continue the site consolidation based on a risk analysis approach with the highest priority to the safety related actions and the indications of the CERN Masterplan.<br>• Improve access to CERN sites. Develop a CERN security policy proposal, with priority to the video surveillance and the access control policies.<br>• Pursue the efforts on the Service Management and Support, take actions to conduct the maturity service analysis optimising the services by the consideration of dashboards and KPI. |
| **Achievements** | In 2016, the overall maintenance work for infrastructure systems has been completed according to the time allowed for intervention without impacting the accelerator schedule, with the global aim to ensure the highest availability of the complex.<br>Cranes, lifts and trucks consolidation programmes were performed as expected. On a more operational side, a total of 16,050 transport and handling operations for a total mass of 113,000 tons were carried out. Out of the total number of heavy transports, about 1,300 concerned radioactive equipment and 679 were used for the transport of dangerous goods.<br>Globally for cooling and ventilation systems, corrective maintenance needs have decreased by about 8% and preventive maintenance by 20% (this is also due to the postponing of some work to the forthcoming EYETS); the exception concerns chillers for which an increase of preventive and corrective maintenance work has taken place because of the higher number of machines of this type installed in recent years and the ageing conditions of old ones. The number of major events and accelerators downtime are similar to 2015.<br>Concerning the electrical transmission and distribution network, more than 740 operations and 2,700 maintenance orders have been carried out to ensure the maximum availability of the accelerator complex and associated experiments.<br>On the side of Site Management and Buildings, the work program was dynamically adapted along 2016, reassigning resources and priorities, by introducing a trimester review of the department budget execution. This practice has been instrumental in the goals achievements. |

## 15. General facilities & logistics (site maintenance, transport) (cont.)

| Achievements | |
|---|---|
| **Achievements** | • The Site consolidation plan has been executed on its full 2016 scope according to the resources available.<br>• The CERN access has been improved by the automatisation of entrance A, the addition of pedestrians turnstiles and plate readers at entrance B. Video surveillance has been reinforced and a deployment plan approved to be executed along 2017.<br>• Maturity services analysis have been conducted on the Hostel, cleaning and mobility services introducing KPIs and dashboards. Daily and weekly monitoring of logistics services have been put in place to react quickly to any unexpected high load. Resources have been re-distributed during seasonal peaks to avoid the creation of a backlog which could potentially perturb the accelerator schedule. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site facility management** | **Personnel (FTE)** | **58.7** | **59.9** | **50.6** | **86%** | **-8.1** | **84%** | **-9.3** | | |
| | Personnel (kCHF) | 10,940 | 10,670 | 8,431 | 77% | -2,509 | 79% | -2,239 | | |
| | Materials (kCHF) | 20,145 | 20,005 | 17,448 | 87% | -2,697 | 87% | -2,557 | 1,904 | |
| | **Total (kCHF)** | **31,085** | **30,675** | **25,879** | **83%** | **-5,206** | **84%** | **-4,796** | **1,904** | |
| **Technical infrastructure** | **Personnel (FTE)** | **130.0** | **132.3** | **139.0** | **107%** | **9.0** | **105%** | **6.8** | | |
| | Personnel (kCHF) | 22,660 | 22,935 | 23,952 | 106% | 1,292 | 104% | 1,017 | | |
| | Materials (kCHF) | 13,520 | 14,905 | 17,931 | 133% | 4,411 | 120% | 3,026 | -1,226 | |
| | **Total (kCHF)** | **36,180** | **37,840** | **41,883** | **116%** | **5,703** | **111%** | **4,043** | **-1,226** | |
| **Logistics** | **Personnel (FTE)** | **15.3** | **13.5** | **13.6** | **89%** | **-1.7** | **101%** | **0.1** | | |
| | Personnel (kCHF) | 2,480 | 2,245 | 2,207 | 89% | -273 | 98% | -38 | | |
| | Materials (kCHF) | 720 | 1,155 | 1,018 | 141% | 298 | 88% | -137 | 612 | |
| | **Total (kCHF)** | **3,200** | **3,400** | **3,225** | **101%** | **25** | **95%** | **-175** | **612** | |
| **Stores activity** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | | | | | | | | | |
| | Materials (kCHF) | 375 | 375 | 394 | 105% | 19 | 105% | 19 | 255 | |
| | **Total (kCHF)** | **375** | **375** | **394** | **105%** | **19** | **105%** | **19** | **255** | |
| **Housing fund** | **Personnel (FTE)** | **1.5** | **1.0** | **1.2** | **79%** | **-0.3** | **118%** | **0.2** | | |
| | Personnel (kCHF) | 220 | 210 | 344 | 156% | 124 | 164% | 134 | | |
| | Materials (kCHF) | 4,100 | 3,940 | 2,610 | 64% | -1,490 | 66% | -1,330 | 255 | |
| | **Total (kCHF)** | **4,320** | **4,150** | **2,955** | **68%** | **-1,365** | **71%** | **-1,195** | **255** | |

## 16. Informatics

| | |
|---|---|
| **Goals** | • Ensure adequate level of availability of the Informatics services including data loss protection (backups) against accidental errors or human mistakes for its user base, as well as perform capacity planning to anticipate the needs. Ensure prompt corrective actions in case of service failures. Protect and educate against the risks of computer security vulnerabilities.<br>• Continue the design & implementation of a second networking hub aiming at improving business continuity.<br>• Start preparing the 20-year-old CERN structured cabling replacement.<br>• Conclude the tendering process of the SCOAP3 next cycle starting in 2016. Enlarge the membership of the consortium.<br>• Implementation of the Learning Management System (LMS).<br>• Pursue the introduction of the digital records management system. |
| **Achievements** | • The services were generally delivered to users' satisfaction, capacity increased as requested and backup performed.<br>• Computer Security awareness campaigns have been organised, in particular raising the attention to risks at the highest levels of the organisation. Additional effort was started in the framework of the new Computer Security hardening project. Two serious cases of software licence violations have been contained without damage to the organisation.<br>• The 2nd networking hub project has made good progress and is scheduled to be completed in 2017.<br>• The Wi-Fi deployment project has started to rejuvenate the CERN wireless infrastructure and should reduce the scope of the renewal of the structured cabling infrastructure in the coming years.<br>• SCOAP3: The SCOAP3 collaboration grew to about 3,000 partners from 47 countries, as well as two Intergovernmental Organizations (JINR, IAEA). The first three-year phase of its operation was concluded in 2016. Through this phase, 13,600 high-energy physics articles have been published open access over 10 high-quality journals from learned societies and commercial publishers. About 20’000 authors in 100 countries benefited from this infrastructure at no direct cost. CERN ensured an efficient and effective operations including management of incoming and outgoing funds, informatics infrastructures, relations with participating publishers, support to the international governance of SCOAP3. Following a consensus across the participating countries, and successful negotiations with publishers, the initiative was extended for three more years: 2017 to 2019. During 2016, MoUs across partners, and contracts with publishers, were correspondingly amended.<br>• Implementation of the Learning Management System (LMS).<br>• Implementation of the Learning Management System for Technical, Language, Management and Communications training is well underway. Restructuring within the main stakeholders in HR department introduced some delay in the project. Initially Safety was expected to be included within the development of the LMS, however HSE department needed more time to define their internal processes.<br>• Implementation of the Safety training will take place in 2017 (within the same tool as the other training programs).<br>• Pursue the introduction of the digital records management system. |

## 16. Informatics (cont.)

| | |
|---|---|
| **Achievements** | • The introduction of the digital records management system is well underway. Front line services such as Records Office, Registration Service, User Office, Personnel Accounting, and Teams and Collaboration all now rely on the new digital records management system. Over 200,000 documents have been digitised and added to the system. All new personnel have a fully digital personnel file. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **180.7** | **193.2** | **195.3** | **108%** | **14.6** | **101%** | **2.1** | | |
| Personnel (kCHF) | 32,100 | 33,220 | 34,568 | 108% | 2,468 | 104% | 1,348 | | |
| Materials (kCHF) | 25,110 | 24,655 | 22,741 | 91% | -2,369 | 92% | -1,914 | 3,677 | |
| **Total (kCHF)** | **57,210** | **57,875** | **57,309** | **100%** | **99** | **99%** | **-566** | **3,677** | |

## 17. Safety, health and environment

| | |
|---|---|
| **Goals** | **Occupational Health and Safety:**<br>• Limit number of incidents (improved awareness/training/prevention, implement lessons learned from LS1 in view of LS2).<br>• Improve hazard control (work procedures, choice of work methods, technological choice).<br>• Participation in CERN (existing & future) projects at all levels for integration of Safety as early as possible.<br>• Safety Training: new editions of major courses (updates, improved didactic), training centre operation and extension/consolidation for LS2.<br>**Occupational Medicine & Emergency preparedness:**<br>• Develop the partnership with the Geneva health system (HUG) enhancing the CERN emergency services (formation and coordination procedures).<br>• Efficiency optimisation of the safety and security call/control centres. Study integration at CCC (Cern Control Centre).<br>**Radiation protection:**<br>• Keep doses to persons As Low As Reasonably Achievable (ALARA) using consequent work planning and prediction software.<br>• Radioactive Waste Treatment Centre: ramp-up waste treatment capacity, and elimination, in view of LS2.<br>• Further extension of RAMSES coverage along with CERN consolidation work of injector chain.<br>• Research and development for the next generation of radiation monitoring equipment.<br>**Environmental Protection and Environmental Panorama:**<br>• Environmental impact studies for upgrade of facilities and new projects.<br>• Further extension of monitoring installations, including hydrocarbon detection for water releases.<br>• Extension of environmental laboratory allowing for physical separation of ‘conventional’ and radioactive samples. |
| **Achievements** | **Occupational Health and Safety:**<br>• The DSOC has established a working group to set-up a better framework for accident and near-miss reporting.<br>• Important improvement mechanical safety of machine-tools, 2,170 inspections carried out, 900 machine-tool are conform out of the 1,200 recorded in the database (none of the non-conform ones are at high risk and therefore can be used with compensatory measures)<br>• 31 projects had been completed, 27 new CERN projects added for a total of ~120 projects provided with tailored Safety prescriptions and best Safety practices. Among major achievements: Safety clearances for NA61 and AWAKE; start of the SHiP (Physics Beyond colliders) and SPS Fire consolidation projects; important contribution for the underground layout of HL-LHC.<br>• Safety training is now part of the HSE/DI group, under the direct responsivity of the new Deputy HSE Department Head. A revision of the courses and the facilities needed for LS2 is in progress.<br>**Occupational Medicine & Emergency preparedness:**<br>• The partnership is well implemented between HUG and CERN with more than 200 medical emergencies/year and SMUR intervention in 31 % of cases. The CERN ambulance team is also benefiting from the joint training program which has been implemented with the HUG<br>• The integration of the SCR into the CCC (Cern Control Centre). has been studied and the decision was that this is not the highest priority for the CERN emergency services at the moment. However, a joint working group has been established for the joint handling of calls related to medical emergencies with HUG. |

## 17. Safety, health and environment (cont.)

**Achievements**

- A tripartite collaboration agreement for emergency interventions on the CERN sites has been signed between the CERN and the Host State Fire Brigades. This agreement paves the way for a closer collaboration between the 3 services in the face of serious incidents affecting CERN

**Radiation protection:**

- The individual doses to CERN's radiation workers continued to be low. The majority of the about 9,000 monitored workers received an individual dose of less than 1 mSv in the period between 1 January 2016 and 30 November 2016. Seven workers received an individual dose exceeding 1 mSv, the highest individual dose being 1.9 mSv (status 30 November 2016). The collective dose to all CERN's radiation workers had been 208 mSv.
- The ramping up of the Radioactive Waste Treatment Centre had been finished in 2016. About 1200 m3 of low level radioactive waste had been eliminated, the major part being sent to the final repository in France, the rest cleared from regulatory control and sent to Switzerland. For the first time in decades CERN disposed of considerably more waste than it produced.
- CERN's radiation monitoring system had been further consolidated by installing the RAMSES radiation monitoring system at the PS (East Area) and SPS (BA80, AWAKE). RAMSES had been installed for the new projects MEDICIS, LIGHT, Test Gun, AD Gbar. The installation of the GROAC system, developed to guarantee the reliability of radiation monitoring still covered by ARCON will be completed during EYETS 2016/17.
- The project to develop the future RAMSES monitor "CROME" met all milestones with ten prototypes produced for testing. The next generation electronics for ultra-low current measurements had been designed in collaboration with EPFL. The studies for a detector system able to measure radioactivity below the new Swiss exemption limits have identified very promising technical solutions.

**Environmental Protection and Environmental Panorama:**

- In addition to the consolidation of the CERN environmental monitoring network (3 additional monitoring stations), water release points in surrounding rivers of Prévessin, Meyrin and LHC sites have been equipped with hydrocarbon detectors (13 in total). Early detection of hydrocarbon pollutions and quick intervention of the Fire and Rescue service are ensured.
- The establishment of the CERN Environmental Protection Steering board was agreed at the end of 2016. This board will be set-up in 2017 to oversee all aspects of CERN's environmental protection strategy.

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **154.7** | **169.3** | **168.1** | **109%** | **13.4** | **99%** | **-1.2** | | |
| Personnel (kCHF) | 23,865 | 26,380 | 27,552 | 115% | 3,687 | 104% | 1,172 | | |
| Materials (kCHF) | 16,085 | 17,030 | 12,491 | 78% | -3,594 | 73% | -4,539 | 1,935 | |
| **Total (kCHF)** | **39,950** | **43,410** | **40,043** | **100%** | **93** | **92%** | **-3,367** | **1,935** | |

## 18. Administration

| | |
|---|---|
| **Goals** | **Finances & Accounting:**<br>• Continue to actively manage the treasury at CERN to limit the use of short term loans and avoid being charged negative interest.<br>• Finalise the revised accounting policies concerning Property, Plant and Equipment and Intangible Assets (recommendations from External Auditors) for the 2015 Financial Statements.<br>• Continue to adapt processes and activities according to best practices.<br>• Maintain a focus on continuous improvement of automation of accounting processes.<br>• Quarterly close of the books.<br>• Pursue the automatisation of the accounts payable process.<br>• Continue to work with HR on the project aiming to suppress multiple filing in the area of Payroll.<br>• Assure the T-account structure for the upgrades of the different LHC experiments.<br>• Strengthen AML (Anti Money Laundering) / CDD (Customer Due Diligence) compliance of Visiting Research Team Accounts.<br>**Procurement:**<br>• Further improve the industrial return coefficient of poorly balanced Member States.<br>• Streamline and automate processes to optimise end-to-end supply chain based on:<br>○ Definition, follow-up and update of the procurement policy, strategy and process resulting from experience gained,<br>○ Best practice procurement principles and legal developments,<br>○ Monitoring of key performance indicators,<br>○ Benchmarking of procurement processes with similar organisations (e.g. EIROforum members),<br>○ Development and implementation of e-learning modules for internal and external stakeholders providing training and information about the procurement service and the relevant procedures.<br>**Human Resources:**<br>Fostering a professional environment that confirms CERN as a top-ranking employer, able to adapt its HR strategies and processes to changing needs, while attracting, retaining, motivating and developing a competent and diverse workforce, by:<br>• Reviewing the Organization’s Staff Contract Policy.<br>• Conducting the Five-Yearly Review of financial and social conditions, with specific emphasis on the CERN career structure and diversity-related matters.<br>• Developing CERN-wide Benchmark Jobs.<br>• Rolling out the Diversity and Learning & Development Policies.<br>• Conducting projects related to Leadership Culture and Capacity Planning.<br>• Furthering the sourcing, recruitment and development of technical fellows via the Technicians Training Experience (TTE) programme.<br>• Pursuing the transformation from a traditional HR Department into a service and delivery partnership.<br>• Continuing to implement process simplification and effectiveness gains, for example by implementing a repository on the E. Personnel file aiming to suppress the flow of paper documents. |

## 18. Administration (cont.)

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|---|---|
| **Goals** | **Directorate:**<br>• Continue working on the enlargement process to obtain additional Associate Members and agreements with non-Member States aiming for additional revenues (in collaboration with the IR- Sector).<br>• Implementation of the medium- and long-term strategy and financial plan including scrutinising the various activities. |
| **Achievements** | **Finance and Accounting:**<br>• Credit facility to finance HL-LHC (up to 250 MCHF).<br>• PPE (Property, Plant and Equipment) and Intangible Assets in production +1.1 BCHF in balance sheet.<br>• Business computing:<br>○ New Payroll Software, data warehouse & start-up of sector wide reporting.<br>○ New dashboards, e.g. monthly financial indicators for project follow-up.<br>• Clean opinion for ALL audits (CERN and third party funding - EU projects).<br>• Review of insurance portfolio and financial harmonisation of CERN's foundations.<br>• Concluding the ongoing Five-Yearly Review of financial and social conditions (with support from HR Department and sector representatives).<br>• Streamlining the planning and controlling processes.<br>**Procurement:**<br>• Further efforts to improve the industrial return to the Member States were made and during 2016 an internal working group was set up to review the Procurement Rules with the aim to:<br>○ Improve the distribution of industrial return to the CERN Member States;<br>○ Introduce objective and transparent procedures enabling CERN to reject bids that are found to be "abnormally low".<br>• Several initiatives and actions were implemented to increase efficiency in the overall end-to-end supply chain, such as:<br>○ A complete revision of the procurement codes;<br>○ The e-procurement project is on-going and will be finalised in 2017;<br>○ The benchmarking activities of the EIROforum Working Group on Procurement continued. A meeting was held at ESTEC in June 2016, allowing the various organizations to learn best practices in common areas of interest.<br>• As a result of the above and previous process improvements, the Procurement service was awarded the 2016 EIPM, Peter Kraljic award for Innovation and Process Excellence;<br>• The Tendering for two EU-financed Pre-Commercial Procurement projects was successfully completed and the contracts for phase 1 have been placed;<br>• A record number of market surveys and invitations to tenders was successfully issued.<br>**Human Resources:**<br>• Implementation of the Five-Yearly Review in 2 stages:<br>○ 1 Jan: modernised diversity-related conditions: extended recognition of registered partnerships, improved conditions offered during parental leave, support to dual-career couples, enhancement of the Saved Leave Scheme and Extension of the teleworking scheme.<br>○ 1 Sept: concerned a rationalised career structure, including a new salary grid and the delivery of the new performance appraisal. |

## 18. Administration (cont.)

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|---|---|
| **Achievements** | • Called MERIT (Merit Evaluation and Recognition Integrated Toolkit); mapping of all staff members to the completed design of Benchmark Jobs.<br>• Approval of new CHIS rules.<br>• Management proposal to Council for additional LD positions as optimisation of the P&M balance without increase of budget or peak deficit. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **206.8** | **199.6** | **212.6** | **103%** | **5.8** | **107%** | **13.1** | | |
| Personnel (kCHF) | 38,755 | 37,625 | 36,363 | 94% | -2,392 | 97% | -1,262 | | |
| Materials (kCHF) | 14,660 | 17,500 | 8,998 | 61% | -5,662 | 51% | -8,502 | 354 | |
| **Total (kCHF)** | **53,415** | **55,125** | **45,362** | **85%** | **-8,053** | **82%** | **-9,763** | **354** | |

## 19. International relations

| | |
|---|---|
| **Goals** | A stakeholder relations office (SRO) was constituted in 2013, bringing together the leaders of CERN's activity in communication, education, international relations, and relations with international organisations. This contributes to coordinating and streamlining CERN's relations with all major stakeholder groups. The SRO works as follows.<br>To increase awareness of and foster support for CERN and its missions, and to promote the interaction of science with society in Europe.<br>To promote the public understanding of particle physics, cosmology, and related technologies through activities such as:<br>• Teacher Programmes: to update the knowledge and to enthuse school teachers (about 1,000 teachers a year) so that they become ambassadors for CERN by motivating their students to continue their scientific studies at secondary level.<br>• School students: to perform experiments on modern physics and CERN technologies in a newly created S'Cool LAB. The S'Cool LAB has been inaugurated in summer 2014.<br>• Visits and exhibitions: to inform the outside world about the science that is done at CERN by providing the opportunity to visit the Laboratory, meet scientists, and visit experimental facilities, for more than 100,000 visitors per year. The permanent exhibition in the Globe of Science and Innovation receiving 65,000 visitors per year, is one of the focal points of CERN visits. Four new visit points (SM18, the LHC Control Centre, Computing Centre and the refurbished Synchrocyclotron) have been completed and have been inaugurated in 2014 as state-of-the-art exhibition venues. The travelling exhibitions continue to tour Europe (2014: Poland, Greece, Spain) to inform citizens in these countries about CERN research and reinforce their interest in participating in CERN. A new "interactive LHC tunnel" exhibit has been shown in 8 different venues in France, Germany, Greece, Belgium and Switzerland.<br>• In the framework of the 60th anniversary celebrations of CERN, three new traveling exhibitions and three compact versions of the "LHC interactive tunnel" have travelled to locations in more than 10 Member States.<br>• Events around the announcements of important physics results, including press conference, media visits, video and photo coverage, and participation at major physics conferences.<br>To foster the engagement of CERN with society and key target audiences through a range of activities and using a variety of tools. The target audiences include Member States representatives, decision-makers, the general public, the media, the scientific community and more specific audiences such as the local communities and the cultural and artistic community.<br>The CERN Communication Group deploys a strategy to generate and secure sustained political, financial and popular support for CERN's scientific and societal missions from all its stakeholder groups. To support this strategy a new structure for the communications group was put in place with three sections: Content (including writing, photo, video, graphic design), Audience engagement (including internal, scientific community, local communities.) and the press office specifically dealing with all media-related activities. In capitalising on its current visibility, CERN will build on the communications foundation to engage with many aspects of society and thereby contribute to embedding science firmly in mainstream culture.<br>Working with the organisers of major conferences such as ICHEP, EPS-HEP and Lepton-Photon to use these as a platform for greater engagement with media and communities local to the conference venue.<br>Participating in major public-facing science conferences such as ESOF and AAAS to generate popular and media engagement.<br>This heading also includes the scientific exchanges programme funding, including the summer students, technical and doctoral students as well as scientific associates for the LHC experiments and the Theory Group.<br>As part of the new management structure, activities under Fact Sheet 19 were in 2016 integrated in the International Relations Sector.<br>The dialogue with Member States was reinforced through the establishment of a network of Management Liaisons, and the consolidation as well as creation of Thematic Forums (ILO, KT, Teacher and Students, Scientific Computing) to bring together CERN and |

## 19. International relations (cont.)

| | |
|---|---|
| **Achievements** | Member State representatives.<br>A four-pronged strategy for geographical enlargement was presented to the CERN Council (March 2016). Romania became the 22nd Member State (July 2016), Cyprus joined as an Associate Member State in the pre-stage to Membership (April 2016), and Ukraine became an Associate Member State (October 2016). Agreements were signed with Slovenia for Associate Membership in the pre-stage to Membership (December 2016) and with India for Associate Membership (November 2016). Lithuania submitted an application for Associate Membership (March 2016). International Cooperation Agreements (ICAs) with Latvia, Qatar and Sri Lanka were approved, and certain existing ICAs were broadened in scope. CERN's collaboration with other international organisations was further developed with a new Cooperation Agreement with the Inter-Parliamentary Union (IPU).<br>Relations with the Host States were enhanced, notably with the Agreement between CERN, France and Switzerland relating to Mutual Assistance between their Services for Emergency Rescue Operations, in particular on the CERN site.<br>CERN hosted 142 Protocol Visits and Events (12.7% increase on 2015), including visits by five Heads of State or Government.<br>In order to expand the networks of support, a design study for a CERN Alumni Programme was completed, with formal launch expected in June 2017.<br>Outreach was significantly strengthened, with a record 119,997 participants in organised visits (12% increase on 2015), distributed over 5,048 visits with 4,219 groups, as well as an estimated 70,000 visitors to the open exhibitions. 65 events were organised at the Globe of Science and Innovation (re-opened May 2016 after refurbishment), with some 7,500 participants. Several CERN exhibitions were enhanced significantly, and the new Microcosm Exhibition was opened. The travelling exhibitions reached some 100,000 visitors in Czech Republic, Lithuania, Portugal, Georgia, France, Austria and Italy.<br>35 teacher programmes brought together 953 participants, and CERN welcomed high school teacher no. 10,000 since the start of the programmes (1998), S'Cool LAB accommodated 5,877 visitors. The CERN Summer Student Programme welcomed 278 students from 87 countries, including 137 students from 62 Non-Member States.<br>Throughout 2016, CERN featured in 145,000 press cuttings worldwide, and organised 242 media visits, bringing 628 journalists on site. During 2016, CERN attracted 4 million unique visitors to the core websites, and maintained a strong presence on social media, with 1.8 million followers on Twitter (among other platforms) and 1.7 million social media mentions of CERN and the LHC.<br>The Bulletin for the CERN Community was redesigned and integrated into the core website, and through "In Theory" and "In Practice" feature articles, editorial content showcased the people behind the science.<br>131 video clips were published, and 330 photo sessions organised, among other efforts to integrate the audio-visual dimension more closely in the broader communications efforts.<br>CERN had an active presence at ESOF, AAAS and ICHEP, and contributed to key communications networks, including the EPPCN and Interactions.<br>The 4th edition of TEDxCERN reached a large global audience, including through 75 viewing parties worldwide.<br>Fundraising activities for the CERN&Society Foundation enabled the engagement in STEM projects of over 1,500 high school students, training of 60 teachers, training of 30 librarians and IT specialists, support for 14 summer students, over 100 hours of Open Software development by software engineers, and residency for four artists at CERN under the increasingly successful and respected Arts at CERN Programme. |

## 19. International relations (cont.)

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **46.0** | **63.2** | **63.8** | **139%** | **17.8** | **101%** | **0.7** | | |
| Personnel (kCHF) | 7,825 | 11,085 | 11,731 | 150% | 3,906 | 106% | 646 | | |
| Materials (kCHF) | 2,910 | 6,625 | 5,374 | 185% | 2,464 | 81% | -1,251 | 560 | |
| **Total (kCHF)** | **10,735** | **17,710** | **17,105** | **159%** | **6,370** | **97%** | **-605** | **560** | |

## 20. Infrastructure consolidation, buildings and renovation

| | |
|---|---|
| **Goals** | Execution of the annual consolidation plan covering primarily safety, façade, roof, toilet block, HVAC, Electricity interventions and technical galleries. Execution of the civil engineering works on Building 107. Execution of building 311 for the magnetic measurements. Execution of building 771 for the polymer lab. Globe overall consolidation. |
| **Achievements** | The annual consolidation programme was carried out to its full extent. The civil engineering work in the Building 107 progressed according to plan within the new organisation. All work packages have been launched. For the building 311, the engineering work and the tendering process have been completed, the works have started and they are proceeding according to the schedule. For the building 711, the civil engineering works were completed and the HVAC works were delayed due to an issue with the supplier. A new schedule has been setup to complete the building in 2017. For the globe consolidation, the works were organised and completed as planned and within the budget. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **18.7** | **16.8** | **20.3** | **109%** | **1.7** | **121%** | **3.6** | | |
| Personnel (kCHF) | 2,930 | 2,585 | 3,084 | 105% | 154 | 119% | 499 | | |
| Materials (kCHF) | 28,120 | 36,950 | 29,227 | 104% | 1,107 | 79% | -7,723 | 9,673 | |
| **Total (kCHF)** | **31,050** | **39,535** | **32,311** | **104%** | **1,261** | **82%** | **-7,224** | **9,673** | |

## 21. Centralised expenses

| | |
|---|---|
| **Centralised personnel expenses** | This heading is dominated by the CERN share of the health insurance scheme for the pensioners, the costs for personnel arrivals and departures and unemployment benefits. These costs can be estimated but there is no specific goal associated. The amount paid for unemployment benefits has decreased due to a decreasing number of LD departures since 2015 (new staff policy), but is expected to increase again as from 2018 (end of 8 years LD contracts). |
| **Internal taxation** | The internal taxation appears in centralised expenses and offsets the equivalent heading in revenues. The personnel costs in all other headings are thus without internal taxation. |
| **Personnel internal mobility** | This heading aims to enhance internal mobility between departments by helping to pay salary differences between an experienced staff member and a new recruit. |
| **Personnel on detachment** | CERN personnel that is on a detachment for collaboration or other institute. The full personnel cost of the detachment is covered by the third party and is accounted as revenues for CERN. |
| **Personnel paid but not available** | The amount of staff members exercising their saved leave or compensation leave usually at the end of their career. The heading is funded by the provision for “amortisation of staff benefits accruals”. The FTEs under this heading (20.7) are moved from other activities to this heading during the year, when the staff concerned is exercising their right to this leave (which is not known in advance and therefore still under the original activity). |
| **Personnel paid from team accounts** | This heading concerns staff and fellows working funded by third parties as shown also under revenues. The difference between budgeted FTEs and the FTEs in the Out-Turn, is due to additional team-funded fellows (offset by revenues). |
| **Budget amortisation of staff benefits accruals** | Corresponds to the funding over 10 years of saved leave and shift work compensation of employed members of personnel as recognised for the first time in the balance sheet when implementing IPSAS (should end in 2018). |
| **Energy and water** | This heading is dominated by the electricity supply. It further includes heating gas and water costs. The savings with respect to Revised 2016 Budget result mainly from a lower electricity consumption in SPS and a relatively warm winter with the reduced use of heating oil and gas. |
| **Insurances, postal charges, miscellaneous** | Personnel and goods insurances as well as the postal charges.<br>An in-depth review and several improvements have been implemented in 2016. The objective was to reach an optimal coverage of our risks with the most competitive premiums. |
| **Interest, bank and financial expenses** | This heading includes the interest on the BNP Paribas Fortis loan, bank charges and financial expenses (i.e. exchange loss). CERN has no short-term loans outstanding as of 31 December 2016.<br>Difference in other financial expenses is due to an exchange loss of 7.6 MCHF. It was partially offset by foreign exchange and fair value gains of 5.6 MCHF. The net loss recorded in 2016 amounts to 2.0 MCHF. This was not planned in the budget. |
| **In-kind** | Relating to the fair value of CERN’s right having been granted some interest free loans (also under revenues). |

## 21. Centralised expenses (cont.)

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| **Centralised personnel expenses** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | 35,705 | 36,335 | 36,079 | 101% | 374 | 99% | -256 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | **35,705** | **36,335** | **36,079** | **101%** | **374** | **99%** | **-256** | | |
| **Internal taxation** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | 28,545 | 30,045 | 31,451 | 110% | 2,906 | 105% | 1,406 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | **28,545** | **30,045** | **31,451** | **110%** | **2,906** | **105%** | **1,406** | | |
| **Internal mobility** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | 820 | 500 | | | -820 | | -500 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | **820** | **500** | | | **-820** | | **-500** | | |
| **Personnel on detachment** | **Personnel (FTE)** | **3.3** | **3.5** | **3.1** | **95%** | **-0.2** | **88%** | **-0.4** | | |
| | Personnel (kCHF) | 925 | 970 | 801 | 87% | -124 | 83% | -169 | | |
| | Materials (kCHF) | | | 53 | | 53 | | 53 | | |
| | **Total (kCHF)** | **925** | **970** | **855** | **92%** | **-70** | **88%** | **-115** | | |
| **Personnel paid but not available** | **Personnel (FTE)** | | | **20.7** | | **20.7** | | **20.7** | | |
| | Personnel (kCHF) | | | 2,482 | | 2,482 | | 2,482 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | | | **2,482** | | **2,482** | | **2,482** | | |
| **Personnel paid from team accounts** | **Personnel (FTE)** | **81.2** | **91.7** | **84.1** | **104%** | **2.9** | **92%** | **-7.6** | | |
| | Personnel (kCHF) | 11,695 | 12,940 | 11,783 | 101% | 88 | 91% | -1,157 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | **11,695** | **12,940** | **11,783** | **101%** | **88** | **91%** | **-1,157** | | |
| **Budget amortisation of staff benefits accruals** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | 17,330 | 17,330 | 17,328 | 100% | -2 | 100% | -2 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | **17,330** | **17,330** | **17,328** | **100%** | **-2** | **100%** | **-2** | | |
| **Energy and water** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | | | | | | | | | |
| | Materials (kCHF) | 76,040 | 63,985 | 60,405 | 79% | -15,635 | 94% | -3,580 | 24 | |
| | **Total (kCHF)** | **76,040** | **63,985** | **60,405** | **79%** | **-15,635** | **94%** | **-3,580** | **24** | |
| **Insurance, postal charges, miscellaneous** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | | | | | | | | | |
| | Materials (kCHF) | 6,240 | 6,240 | 5,028 | 81% | -1,212 | 81% | -1,212 | 0 | |
| | **Total (kCHF)** | **6,240** | **6,240** | **5,028** | **81%** | **-1,212** | **81%** | **-1,212** | **0** | |
| **Interest, bank and financial expenses** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | | | | | | | | | |
| | Materials (kCHF) | 10,940 | 10,940 | 17,700 | 162% | 6,760 | 162% | 6,760 | 0 | |
| | **Total (kCHF)** | **10,940** | **10,940** | **17,700** | **162%** | **6,760** | **162%** | **6,760** | **0** | |
| **In-kind** | **Personnel (FTE)** | | | | | | | | | |
| | Personnel (kCHF) | | | | | | | | | |
| | Materials (kCHF) | 4,900 | 2,045 | 1,863 | 38% | -3,037 | 91% | -182 | | |
| | **Total (kCHF)** | **4,900** | **2,045** | **1,863** | **38%** | **-3,037** | **91%** | **-182** | | |

# Projects

## LHC upgrades

### 22. LINAC4

| | |
|---|---|
| **Goals** | Complete commissioning with beam up to the final energy of 160 MeV, start a run to improve reliability, and test at 160 MeV the PS Booster H- injection equipment. |
| **Achievements** | After completing installation, the accelerator has been commissioned with beam in two steps, up to 107 MeV energy in July and up to the final 160 MeV in October. In the last part of the year, Linac4 was delivering beam to the PS Booster H- injection equipment under test in the Linac4 area. Preparation for a long run to improve reliability has started; the year-long reliability run will take place in 2017.<br>The Linac4 facility was handed over to operation at the end of 2016. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **17.0** | **18.3** | **19.6** | **115%** | **2.6** | **107%** | **1.2** | | |
| Personnel (kCHF) | 3,095 | 3,315 | 3,145 | 102% | 50 | 95% | -170 | | |
| Materials (kCHF) | 1,770 | 2,270 | 2,172 | 123% | 402 | 96% | -98 | 201 | |
| **Total (kCHF)** | **4,865** | **5,585** | **5,318** | **109%** | **453** | **95%** | **-267** | **201** | |

## 23. LHC injectors upgrade

| | |
|---|---|
| **Goals** | Progress on equipment design, procurement and construction towards the goal of completing all LIU installations during LS2 (e.g. elements for Linac3 10 Hz operation, new LEIR external dump, new POPS-B main building, PS-Booster injection equipment and instrumentation, new PS injection elements, new SPS ion injection elements, SPS-LHC transfer line collimators, BAF3 infrastructure).<br>Complete set up and execution of the Half Sector Test (HST) with the main goal to test the new H- injection into the PS-Booster and the relative instrumentation, and thereby mitigate the risks of a direct connection.<br>Carry on beam studies and optimisation using the additional means implemented during LS1 and successive YETS (Year End Technical Stop) (e.g. PS Ionisation Profile Monitor, slotline kicker for SPS High Bandwidth Feedback System) and gain further experience on running the injectors with higher intensity LHC-type proton and ion beams in all their variants. |
| **Achievements** | The design, procurement and construction of equipment for the upgraded machines continued throughout 2016. Typical examples are: all equipment needed for the Linac4-PSB 160 MeV connection, beam instrumentation, as well as the PS and LEIR dumps. The PSB main power convertor building was completed and the PSB decabling campaign, to be carried out during the Extended Year End Technical Stop (EYETS), was prepared.<br>The Half Sector Test (HST) set-up and the Stripping Foil Test Stand were installed during summer 2016 in the Linac4 transfer line and their operation successfully began in October 2016. The first 160 MeV $H^-$ beam was sent to the HST on 26th of October 2016. The HST is serving the purpose to reduce technical and planning risks for installation and commissioning of the future PSB injection chicane during LS2.<br>2016 beam studies (simulations and measurements) have been instrumental to define future beam parameters:<br>• Proton beams: Extensive Machine Development studies were devoted to the PSB-PS and the PS-SPS beam transfers combined with the SPS losses at injection energy. Some performance risks were identified in the achievable PS intensity, as well as in the control of the losses at SPS injection. A prototype of high bandwidth transverse feedback system was installed and operated in the SPS; the feasibility and advantages of such system were demonstrated.<br>• Ion beams: The ion beam parameter table was assessed at the beginning of 2016 and the LIU Technical Design Report (TDR), Volume 2: Ions (CERN-ACC-2016-0041) was released in April 2016. The ion chain restarted early in 2016, which gave more time to conduct machine studies. Linac3 could profit from the enlarged aperture at the entrance of the solenoid and source improvements, providing beam currents to LEIR up to 50% higher than in previous years. A large number of machine studies were carried out in LEIR leading to its unprecedented performance. All the efforts made along the ion injection chain were rewarded in 2016 with a peak luminosity up to 7 times larger than anticipated.<br>The second Cost and Schedule Review of both LIU and HL-LHC projects took place in October 2016. The baseline of both projects, which includes the scope description, the schedule and the cost, was closely scrutinised. Important recommendations of the review for the LIU project were, among others:<br>• Increase the follow up on EVM to closely monitor the cost and schedule variances;<br>• Develop a strategy to mitigate the remaining performance risks in reaching the LIU beam parameters in the PS and SPS. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **112.4** | **114.9** | **118.2** | **105%** | **5.8** | **103%** | **3.2** | | |
| Personnel (kCHF) | 18,380 | 18,480 | 19,240 | 105% | 860 | 104% | 760 | | |
| Materials (kCHF) | 27,115 | 17,940 | 17,819 | 66% | -9,296 | 99% | -121 | 8,120 | |
| **Total (kCHF)** | **45,495** | **36,420** | **37,059** | **81%** | **-8,436** | **102%** | **639** | **8,120** | |

## 24. HL-LHC construction

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|---|---|
| **Goals** | • Manufacture and qualification of the superconducting cable for the first full length prototype.<br>• Construction of the first prototype $Nb_3Sn$ coil (7.5 m long) by CERN and of the first full cold mass by the USA (4.5 m long).<br>• Assembly of the first type of cryo-module of Crab Cavity and design of the second type.<br>• Beam test of the first low impedance collimator in MoGr.<br>• Test of first complete cold powering system.<br>• Validation of the new beam screen design.<br>• Start manufacturing of the prototype of Long Range Beam-Beam compensating wire. |
| **Achievements** | The manufacture and qualification of the $Nb_3Sn$ superconducting cable for the first long prototype of Inner Triplet (IT) Quadrupole has started: 2 unit length have been manufactured and the remaining unit length (2 plus spares) will be finished in March 2017. A 3 months delay in the production of the strand occurred, with no impact on the schedule of the magnet manufacturing. The Nb3Sn superconducting cable for the 11 T long prototype has been entirely manufactured and fully qualified (5 unit length) well in advance with respect to the needs for winding:<br>• The first 7.5 m long coil for the Q2A/B IT quadrupole has been manufactured at CERN using a dummy Rutherford cable. The whole coil fabrication process was successfully validated. The first full length ‘single coil’ (4.5 m) for Q1/Q3 IT quadrupole has been assembled in Lawrence Berkeley National Laboratory (LBNL-USA) by LARP collaboration. Various mechanical checks and electrical tests are under way. Another achievement in 2016 is the construction by Fermi National Accelerator Laboratory (FNAL-USA) of a long coil, which was successfully tested at BNL. A 2m long model of IT quadrupole was also assembled in 2016;<br>• The two first Crab Cavities have been built: one RF Dipole type (RFD type) was done in USA and one Double Quarter Wave type (DQW type) was completed at CERN. The DQW type was not initially foreseen to be built by CERN; this decision was taken to mitigate a shortfall of one US-LARP producer. This event implies a six months delay in the assembly of the cryo-module, which will be finished by summer 2017. The design of the second type of cryo-module will proceed accordingly with the same delay of six months. Any impact of this situation has been integrated into the schedule for SPS crab cavity test. Since then, the schedule has not suffered further delays;<br>• The test of the first full length, double jaw collimator in Molybdenum Graphite (MoGr) has been completed in the HiRadMat facility (CERN), as well as in BNL facilities. The low impedance material (MoGr) has been successfully validated in 2016 for the fluence and impact energy density foreseen in the HL-LHC era;<br>• All sub-elements of the cold powering system have been tested and validated. The complete system test is foreseen in April 2017 with about four month delays. The test will however be conducted directly with current (100 kA) corresponding to the needs of the IT quadrupoles, contrary to what was originally foreseen in the testing plans (testing in two phases, with lower current). This situation does not affect the final delivery date of the cold powering system;<br>• The first short prototype (1m long) of beam screen, shielded with heavy tungsten, has been manufactured and validated. Relevant measurements of the aperture and mechanical tolerances were carried out. The evaluation of the sensitivity to quench, which emerged from some risk assessment done in 2016, will be carried out in 2017; |

## 24. HL-LHC construction (cont.)

**Achievements**

- The first two long-range beam-beam compensating wire systems (a wire embedded in a functional collimator) have been completed in 2016 and installed during the Extended Year End Technical stop (EYETS 2016-17). The remaining two systems are under assembly, with some advance with respect to the initial planning.

The second Cost and Schedule Review of both LIU and HL-LHC projects took place in October 2016. The baseline of both projects, which includes the scope description, the schedule and the cost, was closely scrutinised. In particular for HL-LHC, the increase in cost estimate of the civil engineering works led the project management team to carry out a re-baselining exercise during summer 2016. The impact in terms of cost and schedule for each HL-LHC work package was debated, the Earned Value Management system was presented and the “Clean Bill of Health” delivered at the 1st C&S review has been confirmed.

The review pointed out, as one of the first priorities for the project, the need for timely preparation and execution of the tender for Infrastructure contracts and regular oversight by the LIU/HL-LHC Executive Committee. The need for an “event risk” to the cost uncertainty calculation was also identified until the commitment of external contributors is solidified.

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **144.3** | **145.4** | **164.5** | **114%** | **20.2** | **113%** | **19.1** | | |
| Personnel (kCHF) | 25,015 | 25,045 | 27,690 | 111% | 2,675 | 111% | 2,645 | | |
| Materials (kCHF) | 37,855 | 22,250 | 28,421 | 75% | -9,434 | 128% | 6,171 | 13,066 | |
| **Total (kCHF)** | **62,870** | **47,295** | **56,111** | **89%** | **-6,759** | **119%** | **8,816** | **13,066** | |

## 25. LHC detectors upgrade (Phase 1) and consolidation / HL-LHC detectors, including R&D (Phase 2)

| | |
|---|---|
| **Goals** | **ATLAS:** Progress with the Phase 1 upgrade programme: completion of MM module-0, purchase of PCB modules for MM production, purchase of LAr fibers, development of muCTPI prototypes.<br>**CMS:** Prepare for the insertion of the Pixel Phase 1 during YETS 2016/2017. Finalise the GEM Phase 2 demonstrator and install during YETS 2016/2017. Consolidate services for these sub-detectors.<br>**ALICE:** The main objectives for the ITS upgrade in 2016 are the completion of all R&D activities and start of production. In particular the pixel chip production will start mid-2016 and the module production in the last trimester of 2016. The O2 project will continue its R&D activities that will be completed in 2017. In parallel to the involvement in ALICE operation, the TC team will work on the preparations for the LS2 upgrade, including surface areas like cleanrooms and assembly areas, as well as the preparations for changes of the infrastructure, specifically for housing the future O2 computing farm.<br>**LHCb:** Continue R&D and in some cases start procurements and construction of components which will be installed during LS2 planned around 2018, following the TDRs that have all now been endorsed by the LHCC and subsequently approved.<br>**TOTEM:** development of time detector sensors; installation of precision clock distribution in combination with the time detectors in vertical and horizontal Roman Pots; integration of detector packages with cooling systems in Roman Pots. Continue R&D for the large upgrades expected during LS3 planned around 2022, in particular in the fields of electronics, photonics, pixels and silicon sensors, large micro-pattern gas detectors, detector cooling and parallelisation of software. |
| **Achievements** | **ALICE**: The Production Readiness Reviews for the ITS pixel chip (ALPIDE), the detector barrel mechanics and the cooling plant were successfully passed and the items have proceeded to production. The PRR for the ITS staves will take place in March 2017. The O2 project has successfully developed prototypes of the following components: the detector read-out, the data quality control and the computing farm monitoring system. The call for tender for a container solution at Point 2 has been successfully concluded, and the next steps will depend on the decision concerning the Prevessin computing centre. Offers for the optical fibre infrastructure have been gathered and the final fibre cable trays and test patch-cords from two providers are being installed in the end-of-year technical stop. The installation of a cleanroom for ITS assembly and integration tests as well as a cleanroom for the TPC upgrade are ongoing.<br>**ATLAS**: The Phase-I projects have made substantial progress during 2016. The first Phase-II Technical Design Report (TDR) for the Strip detector of the new Inner Tracker (ITk) was submitted to the LHCC in December. For the New Small Wheel muon detector (NSW), a Module-0 has been completed at CERN and the Final Design Review for the Micromegas detectors (MM) has been passed. For the MM of the NSW, despite facing serious challenges due to delays in industry, significant progress has been made, and the first PCB modules for the MMs have been produced. The mechanical support structure of the entire NSW has been designed, tested and has passed the Final Design Review. The LAr Phase-I upgrade project is making very good progress. A back-up solution has been developed for a custom serialiser ASIC, which the manufacturer has failed to produce reliably so far. Concerning the MUCTPI, the specification and design of the prototype has been completed, and the hardware has been ordered. An assembled prototype module is expected in the first quarter of 2017. A successful integration test between a MUCTPI demonstrator system and a TGC Sector-Logic prototype was performed in November 2016. For the Phase-II projects, the decision process for the TDAQ trigger architecture has been completed. The layout of the new ATLAS Inner Tracker is nearly complete and a decision is prepared for early 2017.<br>**CMS**: The Pixel Phase-I upgrade is being installed as foreseen. The detector parts have been produced in various laboratory around the world and are delivered to CERN where the final integration in the CMS detector is taking place. Ten GEM chambers have been produced and are now installed in the endcap of CMS to fully demonstrate the mechanical installation procedures, the services and eventually the performance of these devices, which are meant eventually to withstand the HL-LHC conditions. |

## 25. LHC detectors upgrade (Phase 1) and consolidation / HL-LHC detectors, including R&D (Phase 2) (cont.)

**Achievements**

**LHCb**: the upgrade, scheduled for installation in LS2 has made further significant progress. Due to a delayed start of LS2 and Run 3 (beginning of 2021), schedules and milestones have been redefined. Progress on subsystem and common projects is steady, along with the exciting start of Run 2. Several Engineering Design Reviews and PRRs have been achieved: components are going through procurement process, together with test-beam activity dedicated to subsystem qualification. Studies and R&D dedicated to LS3 and successive runs have begun, with a goal of bringing the detector to accept a maximum luminosity of $10^{34}$ $cm^{-2}s^{-1}$, and a staged strategy is being developed.

**DT** in collaboration with the ATLAS team has completed the Micromegas Module-0, technology and tools have been transferred to the assembly sites. Contributed to the design and preparation for production of the ALICE ITS. For CMS, DT gave engineering advisory support to the studies and mock- up work done for the Phase-I Pixel detector installation. R&D for Phase-II detectors focused on the proposal of a layout for the ATLAS ITK pixel, and the development of novel modules for the CMS Tracker Phase-II upgrade, design of the mechanics and cooling for the upgrade tracker, the latter being a long-term R&D activity carried out in common for ATLAS and CMS. Efforts to improve the performance and greenhouse environmental footprint of gas systems for future detectors have been launched.

**ESE** has finalised the design of the ALICE ITS chip (ALPIDE) and actively participate in the system design and in the implementation of the assembly process. The first prototype of the VELOPIX ASIC for the LHCb VELO upgrade has been delivered and is being validated. The optical links for the CMS pixel upgrade have been delivered. The design of the ASICs and front-end hybrids for the CMS ITK upgrade has been well advanced and the procurement process for the hybrids worked out. The group also provided a significant work for the system design of the CMS High Granularity Calorimeter. The design of the upgrade of the ATLAS central trigger logic for phase 1 made significant progress (ready to build a prototype of the new muon to central trigger processor interface). The specification of the readout ASICs for the ATLAS ITK upgrade has been almost finalised and the ASICs designs started. The common pixel detectors readout ASIC (RD53) is ready for submission in 2017. Last but not least ESE provided all the electronics coordinators of the LHC experiments.

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| **LHC detectors upgrade (Phase 1) and consolidation** | **Personnel (FTE)** | **45.2** | **45.2** | **49.3** | **109%** | **4.1** | **109%** | **4.1** | | |
| | Personnel (kCHF) | 10,270 | 10,270 | 11,743 | 114% | 1,473 | 114% | 1,473 | | |
| | Materials (kCHF) | 9,380 | 5,430 | 5,409 | 58% | -3,971 | 100% | -21 | 944 | |
| | **Total (kCHF)** | **19,650** | **15,700** | **17,152** | **87%** | **-2,498** | **109%** | **1,452** | **944** | |
| **HL-LHC detectors, including R&D (Phase 2)** | **Personnel (FTE)** | **26.3** | **25.3** | **16.9** | **64%** | **-9.4** | **67%** | **-8.4** | | |
| | Personnel (kCHF) | 4,235 | 4,110 | 3,176 | 75% | -1,059 | 77% | -934 | | |
| | Materials (kCHF) | 4,500 | 3,305 | 3,226 | 72% | -1,274 | 98% | -79 | 557 | |
| | **Total (kCHF)** | **8,735** | **7,415** | **6,403** | **73%** | **-2,332** | **86%** | **-1,012** | **557** | |
| **CERN contribution to HL-LHC detectors (Phase 2)** | **Personnel (FTE)** | | | 2.3 | | 2.3 | | 2.3 | | |
| | Personnel (kCHF) | | | 626 | | 626 | | 626 | | |
| | Materials (kCHF) | | | | | | | | | |
| | **Total (kCHF)** | | | **626** | | **626** | | **626** | | |

# Energy frontier

## 26. Linear collider studies (CLIC, ILC)

| | |
|---|---|
| **Goals** | Follow up and document new baseline parameters including new power estimates for an optimised staged implementation.<br>Compile options for electron beam tests at CERN beyond the CTF3 programme.<br>Execute the CTF3 programme measurements for the X-band structure breakdown rate with beam, phase stability and module performance studies.<br>Obtain first results from the drive beam gun and sub-harmonic buncher.<br>Define with the ATF team the CLIC specific programme for the period 2016-2019.<br>Pursue the experimental program for CLIC damping ring technologies with collaborators.<br>Get all X-band test-stands into full operation, and define optimised/new structures for 3000GeV/380GeV, followed by preparation for industrial production of disks and full structures.<br>Follow up XFEL collaboration plans and integrate in common studies with CLIC where possible.<br>The 2nd generation module plans to be firmed up and defined as a work-package for 2016-2019.<br>Summarise the beam based alignment studies, progress and tools.<br>Follow and participate in ILC preparation activities in collaboration with European laboratories and universities and facilitate the European preparatory studies in selected technical domains. |
| **Achievements** | The CLIC initial stage has been defined at 380 GeV. In 2016 the parameters for a staged implementation starting at 380 GeV for Higgs and top physics, upgradeable to 3 TeV in two further stages, were further refined, based on an overall power and cost optimisation for the initial stage. The resulting project plans were published as a CERN yellow report including updates of the physics reach for such a facility.<br>The studies of electron beam facilities at CERN after CTF3 were concluded. A new stand-alone user facility – CLEAR (CERN Linear Electron Accelerator for Research) – will be available for users from 2017 onwards. This new open electron beam facility is an adaptation of the CALIFES electron linac located in the experimental area of the CLIC Test Facility 3 (CTF3) at CERN. It capabilities and initial programme have been defined and documented, including its important role for future LC studies at CERN and for European researchers.<br>The CTF3 programme was brought to successful conclusion by the end of 2016, proving the CLIC two beam concept and gradient performance, measuring the X-band structure breakdown rate with beam, benchmarking the drive-beam phase stability, verifying instrumentation prototypes and carrying out detailed module performance studies.<br>The ATF2 final focus studies continued with promising results on the beam size and its dependence on intensity, and installation of two CERN produced octupoles at KEK in November. These octupoles are foreseen for low beta studies in ATF2 during the coming year.<br>The drivebeam front end and damping ring studies progressed at CERN and in test-programs in lightsources, respectively. The major hardware components for these studies are completed in industry and being delivered, in particular high efficiency klystrons were further designs and simulation studies are ongoing in order to establish new baseline parameters for the CLIC powering systems by the end of 2018.<br>The X-band stations at CERN have all been installed, tripling the X-band test capacity at CERN for accelerating structure and RF component tests during the period 2016-2019. Optimised new structures for 3000GeV/380GeV were defined. The new CLIC 3TeV accelerating structure baseline design has improved features in order to easy machining and reduce surface heating. |

## 26. Linear collider studies (CLIC, ILC) (cont.)

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|---|---|
| **Achievements** | To promote X-band use in larger facilities and support collaborators interested in using the technology in compact FELs a European design study for X-band FEL implementations with ~25 collaborators is being prepared for submission at the end of March 2017.<br>The CLIC module measurements in the laboratory and CTF3 beam are being completed and evaluated, together with results from the Marie Curie studies of alignment, stability and system integration in the PACMAN project, in order to update the CLIC standard module design and the construction/installation and operation schemes.<br>The beam based alignment studies for CLIC have been summarised and published.<br>The collaboration with ILC is continuing related to beamdynamics studies, SCRF, civil engineering and cryogenics, as well as common studies in ATF2 at KEK. The EJADE Marie Curie exchange programme is operational to support participation of European researchers in LC activities in Japan. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **51.8** | **48.9** | **47.2** | **91%** | **-4.6** | **96%** | **-1.7** | | |
| Personnel (kCHF) | 9,355 | 8,410 | 8,013 | 86% | -1,342 | 95% | -397 | | |
| Materials (kCHF) | 14,190 | 12,290 | 10,064 | 71% | -4,126 | 82% | -2,226 | 2,866 | |
| **Total (kCHF)** | **23,545** | **20,700** | **18,077** | **77%** | **-5,468** | **87%** | **-2,623** | **2,866** | |

## 27. Linear collider detector R&D

| | |
|---|---|
| **Goals** | Physics studies with electron-positron collisions at the energy frontier, including common reference studies with FCC, where possible. CLIC detector optimisation studies and accompanying simulation and reconstruction software developments as well as engineering and integration studies. Prototyping of a low-mass pixel detector with fast timing and small pixels and with power-pulsed read-out electronics (based on silicon/ASIC or HV-CMOS/ASIC). Definition of a hardware concept for a low-mass all-silicon tracker to linear collider specifications with manageable occupancies. Participation in the RD53 collaboration with ATLAS and CMS for the ASIC development. Participation in CALICE fine-grained calorimetry R&D (with either scintillator-SiPM or silicon readout) with the aim of reaching detailed understanding of responses, calibration and manufacturability for future collider applications. Overall progress in other key R&D items, e.g. super-conductors for a high-field detector solenoid, assessment of engineering and integration challenges. |
| **Achievements** | The primary activity of the Linear Collider Detector (LCD) project is to perform physics and detector studies for CLIC, in close cooperation with the corresponding ILC activities. A new optimised CLIC detector has been defined. It goes together with the completion of an improved software suite that features silicon-based track reconstruction. Following detailed benchmarking of Higgs physics and top quark physics, a new CLIC staging baseline has been defined. It proposes a first stage at 380 GeV centre-of-mass energy followed by upgrades to 1.5 TeV and 3 TeV. The physics motivation and corresponding optimised accelerator design were published in a CERN report. A publication presenting an overview of Higgs physics at the three CLIC energy stages was completed. A significant part of the LCD resources is invested in R&D towards a silicon tracking system for CLIC. Performance optimisation studies, together with engineering studies, led to the definition of the main tracker layout in the new CLIC detector model. R&D was actively pursued on pixel modules for the vertex detector and the main tracker. To this aim silicon/ASIC, HV-CMOS/ASIC and fully integrated CMOS technologies were developed and tested at a CERN SPS test beam. The results provide an improved understanding and a narrowing down of the technology options to be explored in the coming year.<br>The year 2016 marked a gradual change in the Linear Collider Detector R&D project in the sense that a fraction of the LCD resources is invested in other CERN priority projects such as FCC-hh, FCC-ee and detector upgrades for HL-LHC. LCD is engaged in the optimisation of a vertex detector for FCC-hh, making use of optimisation tools initially developed for Linear Collider studies. Similarly, LCD is engaging in detector optimisation studies for FCC-ee with the aim of proposing a CLIC-like detector adapted to the FCC-ee experimental conditions. LCD also participates in the CMS endcap calorimeter upgrade (CMS HGCal). The future CMS endcaps will feature fine-grained calorimetry with active silicon and scintillator planes. Similar technologies were initially studied by the CALICE collaboration for Linear Collider applications. They are currently also the preferred options for CLIC. LCD is building a facility for full-wafer silicon sensor testing and has contributed to the HGCal beam tests in 2016. |

| **Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices)** | **Final 2016 Budget (a)** | **2016 Revised Bud. (b)** | **2016 Out-Turn (c)** | **Budget usage in % (c)/(a)** | **Budget variation (c)-(a)** | **Revised Bud. usage in % (c)/(b)** | **Revised Bud. Variation (c)-(b)** | **2016 Open Commitment** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **20.1** | **20.6** | **21.3** | **106%** | **1.2** | **103%** | **0.7** | | |
| Personnel (kCHF) | 3,660 | 3,750 | 3,488 | 95% | -172 | 93% | -262 | | |
| Materials (kCHF) | 650 | 670 | 607 | 93% | -43 | 91% | -63 | 25 | |
| **Total (kCHF)** | **4,310** | **4,420** | **4,096** | **95%** | **-214** | **93%** | **-324** | **25** | |

## 28. Future Circular Collider study

| | |
|---|---|
| **Goals** | Continuation of conceptual study of baseline and remaining options with iterations between all technical areas during 2016 aiming at draft description of baseline with first cost model, identification of critical areas, cost drivers and performance limitations.<br>A review of the status of the study and the corresponding baseline and options will be carried out in April 2016 at the FCC week to be held in Rome. |
| **Achievements** | Throughout 2016 the FCC collaboration continued to grow steadily and by the end of the year 98 institutes from 30 countries were active in FCC studies. In addition, 20 companies are already involved in the FCC study. The annual collaboration meeting held in Rome in April was attended by 470 participants from 168 institutes worldwide, confirming the support and wide-spread interest of the community.<br>Following the FCC week in Rome, an optimised baseline for the overall layout of the FCC hadron collider with 97.75 km circumference was developed. Subsequently closed full-ring optics solutions for both hadron (FCC-hh) and lepton (FCC-ee) colliders have been established for the new layout. The principle compatibility of the present designs with FCC physics goals was confirmed by beam dynamics and machine performance studies.<br>Existing collaborations with PSI and EPFL have been enlarged in the important areas of beam dynamics and 16 T magnet development for FCC-hh. For FCC-ee dedicated working groups, involving international experts, are now active in the critical areas of machine-detector-interface and energy calibration & polarisation.<br>A working group focusing on the High-Energy LHC option, based on FCC-hh technology, has been established. First studies were focusing on requirements and compatibility of FCC-hh technology with LHC infrastructure, machine layout and integration aspects.<br>Civil Engineering (CE) studies have progressed well with further optimisation of the tunnel location in the Geneva basin and the definition of layouts and dimensions for tunnels, shafts, caverns and surface buildings, based on integration studies on machines and detectors. Two consultant contracts have been placed to develop CE cost and schedule models as input for further optimisation work. On the technical infrastructure side baseline concepts for cooling & ventilation and cryogenics have been defined.<br>The design and comparative analysis of options for 16 T magnets has further advanced within the H2020 EuroCirCol project and together with the new PSI effort all relevant coil geometries are now covered. Fabrication of mechanical parts for the construction of 16 T racetrack model magnets at CERN has started. A world-wide effort to develop Nb3Sn wire with FCC specifications has been launched. This involves purchasing state-of-the-art wire and R&D collaborations with European, Japanese, Korean, Russian and US institutes and industry. A cost model for Nb3Sn conductor and 16 T magnets has been developed and will be used to define targets for material and production cost.<br>Also supported by the H2020 EuroCirCol project, the design of the beam screen vacuum system for FCC-hh has been optimised. Several prototypes have been built and are now ready for testing at the ANKA light source in Karlsruhe where the experimental set-up has been already installed.<br>Three collaborations are active in the area of 400 and 800 MHz cavity prototyping, in view of new production methods, coating technology and efficiency, relevant for both FCC-hh and FCC-ee. In a combined effort with CLIC and external partners development work, prototyping and tests towards higher efficiency klystrons are progressing well, encouraged by excellent experimental results.<br>On the physics and experiments side a reference report on “Physics at 100 TeV”, summarising physics opportunities in the areas of Standard Model, Higgs, Beyond Standard Model, Heavy Ions, and FCC injectors has been published.<br>For FCC-hh a new reference detector scenario, based on unshielded solenoids, has been defined, allowing for significant reduction of shaft and cavern dimensions, more towards LHC values. Detailed calorimeter studies ECAL, HCAL (High Granularity Calorimetry) complement the work. |

## 28. Future Circular Collider study (cont.)

| | |
|---|---|
| **Achievements** | For FCC-ee a baseline physic operation scenario with target luminosities from 88-370 GeV was defined. Detector studies are ongoing, exploiting synergies with linear collider detector activities.<br>A common software framework for detector studies has been developed and is now being used for physics simulations based on benchmark processes.<br>A socio-economic impact assessment study for HL-LHC and FCC has been launched. |

| **Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices)** | **Final 2016 Budget (a)** | **2016 Revised Bud. (b)** | **2016 Out-Turn (c)** | **Budget usage in % (c)/(a)** | **Budget variation (c)-(a)** | **Revised Bud. usage in % (c)/(b)** | **Revised Bud. Variation (c)-(b)** | **2016 Open Commitment** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **30.1** | **39.4** | **43.6** | **145%** | **13.5** | **111%** | **4.3** | | |
| Personnel (kCHF) | 4,880 | 6,345 | 7,765 | 159% | 2,885 | 122% | 1,420 | | |
| Materials (kCHF) | 3,880 | 3,095 | 3,443 | 89% | -437 | 111% | 348 | 672 | |
| **Total (kCHF)** | **8,760** | **9,440** | **11,208** | **128%** | **2,448** | **119%** | **1,768** | **672** | |

# Scientific diversity activities

## 29. ELENA

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|---|---|
| **Goals** | Completion of the installation of the ELENA ring together with the lines required for commissioning (but not yet the transfer lines to the existing experiments) followed by commissioning of the ELENA ring. Most of the commissioning will be done with the help of an ion source providing 100 keV H- or protons in parallel to normal AD operation that provides antiprotons to the experiments; Towards completion of ELENA commissioning, some AD antiproton bunches will be used by ELENA for tests of setting-up of the nominal machine cycle. Depending on the availability of the electron cooler and progress of manufacture and installation of other components, two commissioning periods with and without cooler may take place. The target of ELENA commissioning is to gain a good understanding of the machine and confidence that the machine will run properly with antiprotons by the end of the 2016 run; such that the decision on the installation of the electrostatic transfer lines from ELENA to the existing experiments, can be taken. |
| **Achievements** | The ELENA ring, except the electron cooler temporarily replaced by a simple chamber, has been installed by autumn. The installation suffered a delay due to several reasons such as the unavailability of vacuum chambers due to issues with the surface quality and Non-Evaporable Getter (NEG) coatings, an internal leak of the injection kicker tank and delays with the construction of profile monitors for the transfer lines.<br>The elements under vacuum have been baked to reach the very low pressures required with the low beam energy followed by hardware tests of installed components. ELENA ring commissioning with H- beam from a dedicated ion source has started in November in parallel to AD operation for the experiments. Main achievements after the very successful first two weeks of commissioning with beam were:<br>• The beam from the external source was transported successfully to the ring and observed on a monitor between the injection septum and kicker. This milestone was difficult to achieve, as two profile monitors foreseen in this line were not available yet and could therefore not be used when steering the beam.<br>• A small intensity has been observed circulating for at least several tens of turns. This milestone has been reached by careful adjustments of the injection steering, without powering orbit corrector magnets.<br>After two weeks, commissioning with beam had to be interrupted due to a technical problem with the source (broken isolation transformer).<br>Together with the experiments and the CERN management, the decision has been taken to postpone to LS2 the installation of the transfer lines from ELENA to the existing experimental area. Most of the transfer line to the GBAR experiment was installed in 2016. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **22.1** | **23.1** | **25.9** | **117%** | **3.8** | **112%** | **2.8** | | |
| Personnel (kCHF) | 3,835 | 3,895 | 4,148 | 108% | 313 | 106% | 253 | | |
| Materials (kCHF) | 9,655 | 7,870 | 5,978 | 62% | -3,677 | 76% | -1,892 | 1,940 | |
| **Total (kCHF)** | **13,490** | **11,765** | **10,125** | **75%** | **-3,365** | **86%** | **-1,640** | **1,940** | |

## 30. HIE-ISOLDE

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|---|---|
| **Goals** | Installation and hardware commissioning of the second high-beta cryomodules (CM2) following delays in assembly of CM1 as announced in April 2014.<br>Procurement, assembly and test of the remaining two high-beta cryomodules (CM3 and CM4).<br>Physics with Radioactive Ion Beams @ 5.5 MeV/u. |
| **Achievements** | In preparation for the 2016 physics run, the first cryomodule (CM1) was removed, vented and equipped with new radio-frequency (RF) input lines/couplers. It was installed back in the beam line along with the second cryomodule (CM2) in May 2016. The cool down of the two cryomodules was longer than expected, and highlighted limitations in the management of transients from the cryogenics plant;<br>RF measurements at cold highlighted a degraded performance of two cavities (out of five) in CM1. All other cavities reached the nominal field of 6 MV/m. After the physics run, the RF performance of both underperforming CM1 cavities could be recovered up to 5.5 MV/m after conditioning with Helium processing;<br>Beam commissioning activities at the REX normal conducting injector were performed simultaneously with hardware commissioning at HIE-linac. A mixture of helium, carbon, oxygen, neon and argon beams and with A/q = 4 was used for the set-up beam. The beam was transmitted through the cryomodules into the HEBT (High Energy Beam Transfer) lines with REX energy and was used to commission the diagnostic boxes. The superconducting cavities were phased, a process which also verified that the calibration of the gradients was accurate. The beam energy was measured using the first dipole of the first HEBT line, silicon detectors and a Time Of Flight (TOF) system.<br>At the beginning of September, the first exotic beam marked the start of operations of HIE-ISOLDE Phase 1. Besides demonstrating the experimental capabilities of the facility, this successful first run validated the technical choices of the HIE-ISOLDE project. 6 radioactive ion beams and 3 stable beams were delivered to the two experimental beam lines between 4.3 and 6.8 MeV/u for a total of 837 hours of beam time (compared to 90 hours in 2015).<br>All components for the remaining two high-beta cryomodules have been procured. The third cryomodule (CM3) has been assembled and tested and is ready for installation beginning of 2017. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **23.2** | **23.8** | **26.3** | **113%** | **3.1** | **111%** | **2.5** | | |
| Personnel (kCHF) | 4,230 | 4,345 | 4,200 | 99% | -30 | 97% | -145 | | |
| Materials (kCHF) | 5,800 | 4,960 | 2,985 | 51% | -2,815 | 60% | -1,975 | 513 | |
| **Total (kCHF)** | **10,030** | **9,305** | **7,185** | **72%** | **-2,845** | **77%** | **-2,120** | **513** | |

## 31. CERN Neutrino Platform

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|---|---|
| **Goals** | Finish the civil engineering construction of the EHN1 Nord area test beam extension. Continue the overhauling of the WA104 detector and make it ready for transport to the FNAL Short Baseline facility. Assist the WA105 Collaboration in the construction and operation of a first 3 m3 demonstrator of the two phases technology. Start the preparation of two large LAr TPC demonstrators for the Dune project in EHN1. Integrate the neutrino platform effort in the overall plans of the community for long and short baseline facilities in the USA. Provide CERN expertise in various domains in order to setup these international projects correctly. Prepare the in-kind contributions of CERN in these programs. |
| **Achievements** | EHN1 building completed and given to Physics. Installation of services infrastructure started (electricity, ventilation, network, metallic structures,…). Construction of the NP02 and NP04 LNG type cryostats has started and is well advanced. Several key detector R&D studies done successfully and translated to detector components for the various detector prototypes under construction. NP02-WA105 detector demonstrator assembled and installed inside its new cryostat. Cryogenics installed and first operations started in view of cool down in early 2017. ICARUS detectors and cryostats in the final phase of construction. First vessel ready for the transport to FNAL. Second vessel will be ready in early 2017. All engineering and safety aspects of these large activities done and documented. MIND detector and new magnet 90% assembled and ready for test beams in late spring 2017. Continue to provide CERN expertise in various domains in order to correctly setups these international projects. Prepare the in-kind contributions of CERN in these programs. In particular the second version of the engineering of the large LBNF cryostats has started. It will be completed in 2017, before production can start. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **13.5** | **13.3** | **12.6** | **93%** | **-0.9** | **95%** | **-0.7** | | |
| Personnel (kCHF) | 2,235 | 2,150 | 1,988 | 89% | -247 | 92% | -162 | | |
| Materials (kCHF) | 14,570 | 15,095 | 20,847 | 143% | 6,277 | 138% | 5,752 | 2,150 | |
| **Total (kCHF)** | **16,805** | **17,245** | **22,835** | **136%** | **6,030** | **132%** | **5,590** | **2,150** | |

## 32. Proton driven plasma wakefield acceleration

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|---|---|
| **Goals** | Installation of the AWAKE experiment, hardware and beam commissioning of the facility, first proton beam to the plasma cell. Start physics run for self-modulation instability studies.<br>Design, modification and component preparation of the electron source and electron beam-line. |
| **Achievements** | The installation of the AWAKE experiment for the self-modulation instability (phase 1) has been completed on schedule. The commissioning with SPS beam of the following elements was carried out successfully: the proton beam line, the laser and laser beam line, the proton and laser beam synchronisation system, the experimental diagnostics as well as the infrastructure services. The prototype rubidium vapour cell has been commissioned on surface and the entire 10 m long plasma cell system was installed and commissioned in the AWAKE facility. The safety clearance was released for the AWAKE experiment phase 1. The year 2016 ended with the first physics run and a major milestone was reached: the self-modulation of the SPS proton bunch in the plasma cell has been observed.<br>Preparation activities for the next phase are ongoing: the integration of the electron source and beam line has been finalised, beam line equipment has been ordered, the PHIN electron source has been prepared for transport to AWAKE, the electron spectrometer system has been designed and its construction has started.<br>Simulation studies related to AWAKE Run 2 (after Long Shutdown 2) have been performed to define the experimental setup. First studies on the long-term prospect of proton-driven plasma wakefield acceleration have started. |

| **Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices)** | **Final 2016 Budget (a)** | **2016 Revised Bud. (b)** | **2016 Out-Turn (c)** | **Budget usage in % (c)/(a)** | **Budget variation (c)-(a)** | **Revised Bud. usage in % (c)/(b)** | **Revised Bud. Variation (c)-(b)** | **2016 Open Commitment** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **16.5** | **18.2** | **15.5** | **94%** | **-1.0** | **85%** | **-2.7** | | |
| Personnel (kCHF) | 2,545 | 2,715 | 2,439 | 96% | -106 | 90% | -276 | | |
| Materials (kCHF) | 6,345 | 8,935 | 7,617 | 120% | 1,272 | 85% | -1,318 | 538 | |
| **Total (kCHF)** | **8,890** | **11,650** | **10,056** | **113%** | **1,166** | **86%** | **-1,594** | **538** | |

## 33. Superconducting RF studies

| | |
|---|---|
| **Goals** | Cryolab cold-tests: test of existing 1.3 GHz cavities for surface treatment and diagnostics development.<br>R&D on cavity fabrication and surface treatment of other cavities (BCP, EP, HiPIMS…) at 400 MHz, 704 MHz and 802 MHz.<br>Development of cold and warm diagnostics tooling (T-Map, OST, Optical inspection, field measurement).<br>Upgrade of production and treatment facilities in building 252 (RF lab air condition, tuning bench, clean preparation, field flatness measurement).<br>Upgrade of vertical and horizontal test cryostats in SM18 (including M7 cryogenic feed-box, clean preparation facility).<br>Completion of string assembly of four 704 MHz 5-cell cavities with helium tanks and power couplers.<br>Start of assembly of a 704 MHz 4-cavity cryomodule.<br>Completion of 5 further 704 MHz cavities, using traditional construction techniques at CERN and using electro-hydraulic forming in collaboration with industry.<br>In collaboration with JLAB, development and fabrication of an 802 MHz prototype cavity and cryomodule.<br>R&D on “high-Q” technologies such as “N2 doping” or Nb3Sn coating on bulk Nb cavities.<br>Study on optimised cool-down schemes.<br>High-power tests of 3rd generation 704 MHz power couplers.<br>Test of MW-class IOTs at CERN in collaboration with ESS. |
| **Achievements** | Thirteen 1.3 GHz monocell cavities were coated with different techniques (HiPIMS and DCMS). The best 6 of these were successfully tested in the Cryolab. Ten more cavities were received, which still must be equipped with cut-off pipes (on order).<br>Half-cells both at 400 MHz and at 704 MHz were formed successfully with electro-hydroforming, a promising new technology. Seamless cavities at 100 MHz (for HIE-ISOLDE) were fabricated with industry, at 400 MHz and at 800 MHz in collaboration with INFN/LNL (Legnaro).<br>The vertical EP (electro-polishing) was developed and optimized for 704 MHz; several tests (about 6) were performed with varying parameters to further optimise the HiPIMS (High Power Impuse Magnetron Sputtering) method. One Nb cavity was coated with Nb at CERN and shipped to FNAL for complementary tests there.<br>The development of contactless temperature sensors (T-sensors) was started and made good progress towards reliable T-mapping. OST (Oscillating Superleak Transducer) sensors have been successfully applied for both 704 MHz and 400 MHz cavities in the upgraded V3 cryostat.<br>The clean-room facilities in SM18, required initially for the HL-LHC crab cavities, were upgraded and modernized as priority, the upgrade of the facilities in building 252 has started but had to face major problems (unstable floor, asbestos, HVAC …) which will be addressed in 2017.<br>The test facilities in SM18 (4 vertical cryostats and 2 bunkers) were upgraded by new inserts for test of 704 MHz 5-cell cavities and 400 MHz cavities (both crab cavities and accelerating cavities). A new cryogenic valve box was specified and ordered for installation in 2017.<br>The string assembly of four 704-MHz cavities was postponed; the cryomodule (CM) vacuum vessel was received and qualified, the magnetic shielding was redesigned correcting a design flaw. Due to other priorities (HL-LHC, HIE-ISOLDE and LHC spare cavities), the CM assembly is presently planned for 2018. A 3rd 704 MHz cavity (out of 4) was electropolished in an optimised vertical EP set-up. |

## 33. Superconducting RF studies (cont.)

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|---|---|
| **Achievements** | Production of 802 MHz single cell plus five cell cavity is started at JLAB; the definition of the cut-off tube configuration is progressing.<br>The collaboration with FNAL on high-Q techniques was strengthened and formalised, one bulk Nb cavity was Nb-coated at CERN and sent to FNAL for complementary tests. About 100 samples for A15 $Nb_3Sn$ and $V_3Sn$ (crystalline structure common to a family of high-temperature superconductors) were prepared in about 30 coating runs, the 16 best samples were tested at UNIGE to confirm their performance (successfully).<br>The influence of cool-down speed and temperature gradient during cool-down were studied complementing the work at our partner labs – it was found that the optimum is different for bulk Nb cavities and Nb-coated cavities.<br>Three power couplers are fully completed, a fourth awaits electron-beam welding. Two further 3rd generation FPCs (Fundamental Power Coupler) are under construction. Preparing for the high-power FPC tests, a 704 MHz resonant ring study has been launched and a special WR2300 10-dB coupler has been design and constructed. A first attempt has shown matching difficulties, and configuration of the resonant ring will have to be modified; this activity is now on hold due to other priorities.<br>A test bench dedicated to the ESS IOTs has been designed and its construction completed; commissioning is ongoing. Two different industrial tubes are expected to be delivered by spring 2017. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **8.4** | **8.7** | **8.8** | **105%** | **0.4** | **101%** | **0.1** | | |
| Personnel (kCHF) | 1,300 | 1,315 | 1,258 | 97% | -42 | 96% | -57 | | |
| Materials (kCHF) | 3,170 | 4,915 | 2,233 | 70% | -937 | 45% | -2,682 | 888 | |
| **Total (kCHF)** | **4,470** | **6,230** | **3,492** | **78%** | **-978** | **56%** | **-2,738** | **888** | |

## 34. Superconducting magnet R&D (SCM)

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|---|---|
| **Goals** | Upgrade critical current test facility for superconducting strands up to 18 T.<br>Set-up test facility for very high current ‘HFM’ (30 kA).<br>Model coils for improved training/reduced margin. |
| **Achievements** | The infrastructure reorganisation of the superconductors’ testing laboratory has started according to the upgrade scenario: the control room was relocated to make space for a sample preparation area for the existing FRESCA (Facility for the REception of Superconducting CAbles, now used for research and development – 10T ultimate field) and the future FRESCA2 (15T target field) test stations and additional heat treatment ovens were installed and are ready for operation. In preparation of the upgrade to ultra-high fields (test bed at 18 T or higher) high field solenoids were ordered to fit the present test stations (two 15 T 70 mm bore, two 16 T 70 mm bore, two 15 T 100 mm large bore), and are now in production at an industrial manufacturer. These solenoids, which should be operational in 2017, will increase the test capacity and test volume for high field superconductors.<br>In the SM-18, a new 30 kA power converter was successfully powered (in short circuit mode), to be fully commissioned in 2017 for operation in Cluster D. The HFM (High Field Magnet) test station of SM-18 was commissioned for operation at 20 kA and 1.9 K. An inner triplet HL-LHC quadrupole model was tested while commissioning the test station, as a validation. This new test station is foreseen to host FRESCA2 and future high field magnets.<br>The FRESCA2 magnet was assembled in 2016 and is ready for test (training) in 2017. This magnet has been built with coils delivered by CEA (Commissariat à l’Energie Atomique), which includes spares for long term operation as a test station. The coil design has large margin and the target operational field should be reached with limited training.<br>Canted-cosinus theta magnet designs were explored, and in particular as an option of easier manufacturing, and possibly lower cost for the orbit corrector dipoles to be used for HL-LHC.<br>An HTS (High Temperature Superconductor) variable temperature test bed was installed in an existing test cryostat ("diode" vertical cryostat in SM-18) to perform characterisation tests on a small-size HTS insert. This proof-of-principle experiment allowed early testing of the first CERN-built HTS magnet demonstrator, in advance and support of the EuCARD2 model dipole construction. The results achieved confirm the soundness of the cable and magnet design and construction: Ic (critical current) was reached down to 20 K with no training quench. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | | **2.0** | **3.0** | | **3.0** | **151%** | **1.0** | | |
| Personnel (kCHF) | | 405 | 622 | | 622 | 154% | 217 | | |
| Materials (kCHF) | 1,475 | 4,805 | 2,566 | 174% | 1,091 | 53% | -2,239 | 319 | |
| **Total (kCHF)** | **1,475** | **5,210** | **3,188** | **216%** | **1,713** | **61%** | **-2,022** | **319** | |

## 35. R&D for medical applications

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|---|---|
| **Goals** | • To obtain funding for OpenMED (bio-LEIR) and start construction.<br>• Assuming that the funding is allocated for the D3LVE project (EC proposal), to manage this project and produce the deliverables.<br>• To complete the MEDICIS project and prepare for the first production of radio-isotopes in 2017.<br>• To continue the R&D for improved medical imaging and diagnostic techniques, including dosimetry and medical simulations.<br>• With the new governance of medical applications agreed by the CERN Council, to complete the creation of the “collaboration board”.<br>• To continue the search for additional funding of the other projects under the CERN Medical Applications responsibility. |
| **Achievements** | In 2016, the CERN Management re-organised the decision-taking structure for Medical Applications.<br>Concerning OpenMED, it was decided to complete a pre-CDR (Conceptual Design Report) before seeking external funds and setting up a collaboration; this will be ready for distribution in March 2017.<br>The D3LVE (Distributed Data for Decision support and Learning as a Virtual Environment) project was not funded, a resubmission in the near future is planned.<br>On the side of the MEDICIS project, the remote handling systems, the target Front-End and the separator magnet have been completed, and the other elements of the laboratory and beam line are either procured or specified.<br>R&D activities on scintillating crystals, Monte Carlo simulations, compact accelerators, Medipix, computing and software tools continued, aimed at applications in medical imaging, dosimetry, medical simulations, accelerators for cancer therapy.<br>In particular, studies about the possible advantages of radioactive beams (11-C, 15-O) for hadrontherapy were carried out. These studies include: data taking in Japan, the development of integrated tools for the automatic generation of patient geometry, material descriptions, including reading and implementing treatment plan specifications into Fluka for quality verification.<br>There were improvements in the nuclear interaction models for light ions at energies of relevance for hadrontherapy, with particular attention to Helium beams. Assistance was given to external collaborators at CNAO and HIT, in particular for the new features essential for the therapeutic exploitation of Helium beams.<br>In the framework of the search for additional funding, following the CERN-EC annual meeting in Brussels in October 2016, CERN sent its input to the Commission in terms of topics of interest for EU-funded projects and calls. A CERN & Society project to support ENLIGHT was submitted.<br>The ICTR-PHE conference http://cerncourier.com/cws/article/cern/64366 brought together over 450 participants from 33 countries, and featured 165 presentation and over 100 posters. For the first time, the industrial exhibition featured an innovation corner dedicated to start-up companies. The conference was followed by a brainstorming in Divonne, in the presence of the Medical Applications International Strategy Committee (ISC), on the needs of the medical field, with around 80 participants (mostly external experts). The conclusions were presented to the CMASC (CERN Medical Applications Steering Committee).<br>The annual ENLIGHT meeting took place in Utrecht http://cerncourier.com/cws/article/cern/66573. For the first time, the meeting included a one-day training event for young scientists. The first ENLIGHT Advisory Committee was also selected.<br>A workshop on Design Characteristics of a Novel Linear Accelerator for Challenging Environments was held at CERN, with over 70 participants. |

| **Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices)** | **Final 2016 Budget (a)** | **2016 Revised Bud. (b)** | **2016 Out-Turn (c)** | **Budget usage in % (c)/(a)** | **Budget variation (c)-(a)** | **Revised Bud. usage in % (c)/(b)** | **Revised Bud. Variation (c)-(b)** | **2016 Open Commitment** | **Comments** |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **10.9** | **12.7** | **16.1** | **148%** | **5.2** | **127%** | **3.4** | | |
| Personnel (kCHF) | 1,795 | 1,955 | 2,557 | 142% | 762 | 131% | 602 | | |
| Materials (kCHF) | 4,100 | 3,030 | 2,031 | 50% | -2,069 | 67% | -999 | 357 | |
| **Total (kCHF)** | **5,895** | **4,985** | **4,588** | **78%** | **-1,307** | **92%** | **-397** | **357** | |

## 36. Other R&D

This heading combines all other R&D activities like some limited funding for technology R&D and anticipated continued support from EU projects in the future. Existing EU projects are reported under the various activities concerned and below. This heading also includes some funding for the study of the technical feasibility of a beam dump facility at CERN, in the framework of the “Physics Beyond Colliders” Study Group. Furthermore, CERN’s support to other organisations such as FAIR, ITER, ESS, etc., for which some partial external funding exists are grouped under this heading. Personnel detached to and working on this external support compromises the available workforce for CERN’s core activities.

### 36a. EU supported computing R&D

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|---|---|
| **Goals** | Expect to participate in several H2020 proposals, notably concerning the pre-procurement of commercial cloud services that, if successful, will start in 2015. |
| **Achievements** | • During 2016 CERN has participated as a partner in the submission of multiple H2020 proposals. From these proposals, 2 were funded and will start in 2017:<br>○ Up to University - Bridging the gap between schools and universities through informal education (starts January 2017),<br>○ AARC2 – Authentication and Authorisation For Research and Collaboration - a continuation of the AARC project (starts May 2017).<br>• Coordinator for the following FP7 projects:<br>ICE-DIP: Intel – CERN Industrial Doctorate Programme. This project is funded under the Marie Curie programme and provides an example of how public-private partnerships can contribute to training the next generation of highly qualified ICT specialists to take on leading roles in European research and industry.<br>• Coordinator for the following H2020 projects:<br>○ PICSE - Procurement Innovation for Cloud Services in Europe (successfully completed in April 2016),<br>○ HNSciCloud – Pre Commercial Procurement pilot for the introduction of commercial IaaS cloud services in the public research sector.<br>• Partner in the following H2020 projects:<br>○ OpenAIRE2020,<br>○ EGI-ENGAGE,<br>○ EUDAT2020,<br>○ INDIGO-DataCloud,<br>○ AARC.<br>• Active contribution to the EC-cofunded Research Data Alliance (RDA) including co-chairs of interest groups and representation of EIROforum as IT Working Group as Organizational Member and participation in the RDA EU Synchronisation Assembly. Together with the RDA Interest Group on Active Data Management plans, an international and inter-disciplinary workshop was held at CERN in June.<br>• As input for the pilot European Open Science Cloud, a project funded under call INFRADEV-4-2016 CERN has published a document “The European Open Science Cloud Pilot Phase”, https://doi.org/10.5281/zenodo.50072.<br>• CERN responded to the Consultation on Cloud Computing Research Innovation Challenges for WP 2018-2020 by publishing an input paper: https://doi.org/10.5281/zenodo.160709.<br>• EC nominated reviewer for GreenDataNet project.<br>• Member of the e-infrastructures external advisory board for the CORBEL project. |

## 36a. EU supported computing R&D (cont.)

| | |
|---|---|
| **Achievements** | • CERN-IT personnel have participated at the following events organised by the EC:<br>○ Make presentation at the 3rd annual concertation meeting of on-going PCP projects (Brussels, 10 March 2016),<br>○ Make presentation at the conference on open science organised by Dutch presidency of the EU (Amsterdam, 5 April 2016),<br>○ Make presentation at the JRC science lecture (Brussels, 26 May 2016),<br>○ Participate in the ICT Proposers Day 2016 (Bratislava, 26 September 2016),Make presentation at the Post Consultation workshop on Cloud Computing Research Innovation Challenges for WP 2018-2020 (Brussels, 7 November 2016),<br>○ Make presentation at the EC open science policy platform meeting (Brussels, 9 December 2016). |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **6.6** | **10.8** | **7.4** | **114%** | **0.9** | **69%** | **-3.4** | | |
| Personnel (kCHF) | 1,175 | 1,875 | 998 | 85% | -177 | 53% | -877 | | |
| Materials (kCHF) | 85 | 2,560 | 182 | 215% | 97 | 7% | -2,378 | | |
| **Total (kCHF)** | **1,260** | **4,435** | **1,181** | **94%** | **-79** | **27%** | **-3,254** | | |

## 36b. Support to FAIR, ITER, ESS (with corresponding revenues)

| | |
|---|---|
| **Goals** | NA. |
| **Achievements** | **FAIR:**<br>The test station in B180 for the SuperFRS magnets for FAIR is reaching its completion. All main equipment for the cryogenics (compressor, cold box, cryo valves, dewar, distribution system) was delivered and commissioned, including a full renovation of the compressor building (Civil engineering, oil containment, piping, controls, ventilation, safety). The magnet test platforms are partly installed, the towers remain to be installed in 2017. Cabling was done, and power converters, energy extraction systems, demineralised water distribution were installed and commissioned. The test station will be ready for handover to GSI in June 2017.<br>**ITER:**<br>In 2016 activities for ITER mainly included Consultancy for materials for various work items & Destructive & Non-Destructive Tests (agreement 14), as well as Design, development & manufacturing of the HTS (High Temperature Superconductor) current leads for the ITER magnet systems (Agreement 16).<br>**ESS:**<br>Elements reporting the advancement of collaboration with ESS, in particular the test of MW-IOTs at CERN, are provided in fact sheet n.33. |

| Comparison Final 2016 Budget and 2016 Out-Turn (2016 prices) | Final 2016 Budget (a) | 2016 Revised Bud. (b) | 2016 Out-Turn (c) | Budget usage in % (c)/(a) | Budget variation (c)-(a) | Revised Bud. usage in % (c)/(b) | Revised Bud. Variation (c)-(b) | 2016 Open Commitment | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Personnel (FTE)** | **20.8** | **22.7** | **24.8** | **119%** | **4.0** | **109%** | **2.1** | | |
| Personnel (kCHF) | 3,565 | 3,925 | 3,718 | 104% | 153 | 95% | -207 | | |
| Materials (kCHF) | 11,545 | 9,740 | 7,533 | 65% | -4,012 | 77% | -2,207 | 699 | |
| **Total (kCHF)** | **15,110** | **13,665** | **11,251** | **74%** | **-3,859** | **82%** | **-2,414** | **699** | |

# 2. FINANCIAL FIGURES

## 2.1. EXPERIMENTS (CERN'S CONTRIBUTION TO THE COLLABORATIONS AND EXPERIMENTS ON SITE) AND ACCELERATORS

### Figure 5: Scientific Programme

| Final 2016 Budget - CERN/FC/5955 (2016 prices) | | | | Revised 2016 Budget - CERN/FC/6011 (2016 prices) (a) | | | | | Activity | 2016 Out-Turn - CERN/FC/6096/Rev. (2016 prices) (b) | | | | Revised 2016 Budget usage in % (b)/(a) | | | | 2016 Out-Turn Open Commitment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FTE | kCHF | | | FTE | kCHF | | | Fact sheet | | FTE | kCHF | | | FTE | kCHF | | | kCHF |
| Personnel | Personnel | Materials | Total | Personnel | Personnel | Materials | Total | | | Personnel | Personnel | Materials | Total | Personnel | Personnel | Materials | Total | Materials |
| 844.4 | 155 650 | 127 190 | 282 840 | 844.3 | 154 720 | 106 065 | 260 785 | | LHC programme | 896.4 | 160 144 | 99 790 | 259 933 | 106% | 104% | 94% | 100% | 10 444 |
| 339.2 | 59 055 | 51 425 | 110 480 | 327.9 | 56 610 | 49 590 | 106 200 | 1 | LHC machine | 345.3 | 58 533 | 41 768 | 100 301 | 105% | 103% | 84% | 94% | 4 520 |
| 339.2 | 59 055 | 44 035 | 103 090 | 327.9 | 56 610 | 42 940 | 99 550 | | LHC machine and experimental areas | 341.5 | 57 864 | 36 976 | 94 840 | 104% | 102% | 86% | 95% | 3 894 |
| | | 7 390 | 7 390 | | | 6 650 | 6 650 | | Spares | 3.7 | 669 | 4 792 | 5 461 | | | 72% | 82% | 626 |
| 65.9 | 11 030 | 37 515 | 48 545 | 74.3 | 12 400 | 21 500 | 33 900 | 1 | LHC machine and areas: reliability and consolidation | 82.9 | 13 119 | 22 683 | 35 803 | 112% | 106% | 106% | 106% | 4 674 |
| 329.9 | 62 765 | 13 185 | 75 950 | 331.1 | 62 805 | 12 940 | 75 745 | | LHC experiments | 351.0 | 64 597 | 12 184 | 76 781 | 106% | 103% | 94% | 101% | 498 |
| 78.7 | 15 375 | 3 335 | 18 710 | 80.4 | 15 555 | 3 335 | 18 890 | 2 | ATLAS detector | 92.8 | 16 515 | 3 527 | 20 042 | 115% | 106% | 106% | 106% | 103 |
| 107.6 | 20 365 | 3 895 | 24 260 | 107.8 | 20 365 | 3 850 | 24 215 | 3 | CMS detector | 120.0 | 22 352 | 3 595 | 25 947 | 111% | 110% | 93% | 107% | 145 |
| 50.9 | 9 740 | 1 770 | 11 510 | 50.3 | 9 610 | 1 680 | 11 290 | 4 | ALICE detector | 57.3 | 10 894 | 1 826 | 12 720 | 114% | 113% | 109% | 113% | 0 |
| 49.2 | 10 180 | 1 495 | 11 675 | 49.2 | 10 180 | 1 420 | 11 600 | 5 | LHCb detector | 48.3 | 9 222 | 2 117 | 11 338 | 98% | 91% | 149% | 98% | 16 |
| 43.5 | 7 105 | 2 690 | 9 795 | 43.4 | 7 095 | 2 655 | 9 750 | 6 | Common items, other experiments* | 32.6 | 5 615 | 1 120 | 6 734 | 75% | 79% | 42% | 69% | 233 |
| 109.5 | 22 800 | 25 065 | 47 865 | 111.0 | 22 905 | 22 035 | 44 940 | 8 | LHC computing | 117.2 | 23 894 | 23 154 | 47 048 | 106% | 104% | 105% | 105% | 753 |
| 709.6 | 129 050 | 94 765 | 223 815 | 723 | 130 940 | 97 275 | 228 215 | | Other programmes | 680 | 122 669 | 77 069 | 199 738 | 94% | 94% | 79% | 88% | 13 541 |
| 23.7 | 4 390 | 2 165 | 6 555 | 25.9 | 4 800 | 1 800 | 6 600 | 9 | Non-LHC physics (experimental programme) | 29.4 | 5 011 | 1 811 | 6 822 | 114% | 104% | 101% | 103% | 103 |
| 65.8 | 10 250 | 1 470 | 11 720 | 65.1 | 10 305 | 1 645 | 11 950 | 10 | Theory | 62.0 | 9 635 | 1 548 | 11 183 | 95% | 93% | 94% | 94% | 31 |
| 18.1 | 3 470 | 3 520 | 6 990 | 19.2 | 3 385 | 4 455 | 7 840 | 11 | Knowledge transfer | 18.0 | 2 816 | 3 128 | 5 944 | 94% | 83% | 70% | 76% | 111 |
| 184.6 | 34 365 | 23 780 | 58 145 | 191.2 | 35 230 | 21 690 | 56 920 | 12 | Scientific support** | 148.1 | 26 599 | 17 680 | 44 279 | 77% | 76% | 82% | 78% | 2 631 |
| 36.7 | 6 835 | 2 540 | 9 375 | 37.2 | 6 945 | 3 160 | 10 105 | 13 | Low- and medium-energy accelerators | 39.1 | 7 330 | 2 875 | 10 205 | 105% | 106% | 91% | 101% | 339 |
| 199.4 | 34 120 | 19 890 | 54 010 | 196.3 | 33 555 | 20 450 | 54 005 | 13 | PS and SPS complexes | 190.7 | 33 220 | 18 450 | 51 670 | 97% | 99% | 90% | 96% | 2 064 |
| 173.4 | 34 400 | 33 355 | 67 755 | 180.1 | 35 515 | 39 700 | 75 215 | 13 | Accelerator maintenance and consolidation | 185.7 | 36 856 | 28 140 | 64 996 | 103% | 104% | 71% | 86% | 7 485 |
| 8.0 | 1 220 | 8 045 | 9 265 | 7.7 | 1 205 | 4 375 | 5 580 | 13 | Consolidation of experimental areas | 6.5 | 1 202 | 3 438 | 4 639 | 85% | 100% | 79% | 83% | 778 |
| 1 554.0 | 284 700 | 221 955 | 506 655 | 1 567 | 285 660 | 203 340 | 489 000 | | Grand Total | 1 576 | 282 813 | 176 858 | 459 671 | 101% | 99% | 87% | 94% | 23 985 |
| | 23.19% | 18.08% | 41.27% | | 23.17% | 16.49% | 39.66% | | % of total revenues | | 22.84% | 14.29% | 37.13% | | | | | |

* Including: Totem, LHCf, MoEDAL

** Including: associates, computing, R&D detectors, technical support

## 2.2. NON-SCIENTIFIC PROGRAMME (INFRASTRUCTURE AND SUPPORT SERVICES)

### Figure 6: Infrastructure, services and centralised expenses

| **Final 2016 Budget - CERN/FC/5955** (2016 prices) | | | | **Revised 2016 Budget - CERN/FC/6011** (2016 prices) (a) | | | | **Activity** | | **2016 Out-Turn - CERN/FC/6096/Rev.** (2016 prices) (b) | | | | **Revised 2016 Budget usage in %** (b)/(a) | | | | **2016 Out-Turn Open Commitment** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FTE** | **kCHF** | | | **FTE** | **kCHF** | | | **Fact sheet** | | **FTE** | **kCHF** | | | **FTE** | **kCHF** | | | **kCHF** |
| **Personnel** | **Personnel** | **Materials** | **Total** | **Personnel** | **Personnel** | **Materials** | **Total** | | | **Personnel** | **Personnel** | **Materials** | **Total** | **Personnel** | **Personnel** | **Materials** | **Total** | **Materials** |
| **951.7** | **245 980** | **227 745** | **473 725** | **1 000** | **254 375** | **228 735** | **483 110** | | **Infrastructure, services and centralised expenses** | **1 032** | **257 577** | **205 998** | **463 575** | **103%** | **101%** | **90%** | **96%** | **11 468** |
| **54.9** | **9 185** | **3 880** | **13 065** | **56.2** | **9 300** | **2 385** | **11 685** | **14** | **Manufacturing facilities (workshops, etc.)** | **59.9** | **9 420** | **2 716** | **12 137** | **107%** | **101%** | **114%** | **104%** | **-6 559** |
| **205.5** | **36 300** | **38 860** | **75 160** | **206.6** | **36 060** | **40 380** | **76 440** | **15** | **General facilities & logistics (site maintenance, transport)** | **204.3** | **34 934** | **39 401** | **74 335** | **99%** | **97%** | **98%** | **97%** | **1 800** |
| **180.7** | **32 100** | **25 110** | **57 210** | **193.2** | **33 220** | **24 655** | **57 875** | **16** | **Informatics** | **195.3** | **34 568** | **22 741** | **57 309** | **101%** | **104%** | **92%** | **99%** | **3 677** |
| **154.7** | **23 865** | **16 085** | **39 950** | **169.3** | **26 380** | **17 030** | **43 410** | **17** | **Safety, health and environment** | **168.1** | **27 552** | **12 491** | **40 043** | **99%** | **104%** | **73%** | **92%** | **1 935** |
| **206.8** | **38 755** | **14 660** | **53 415** | **199.6** | **37 625** | **17 500** | **55 125** | **18** | **Administration*** | **212.6** | **36 363** | **8 998** | **45 362** | **107%** | **97%** | **51%** | **82%** | **354** |
| **46.0** | **7 825** | **2 910** | **10 735** | **63.2** | **11 085** | **6 625** | **17 710** | **19** | **International relations** | **63.8** | **11 731** | **5 374** | **17 105** | **101%** | **106%** | **81%** | **97%** | **560** |
| **18.7** | **2 930** | **28 120** | **31 050** | **16.8** | **2 585** | **36 950** | **39 535** | **20** | **Infrastructure consolidation, buildings and renovation** | **20.3** | **3 084** | **29 227** | **32 311** | **121%** | **119%** | **79%** | **82%** | **9 673** |
| **84.4** | **95 020** | **98 120** | **193 140** | **95.2** | **98 120** | **83 210** | **181 330** | **21** | **Centralised expenses** | **107.9** | **99 924** | **85 050** | **184 974** | **113%** | **102%** | **102%** | **102%** | **28** |
| | 35 705 | | 35 705 | | 36 335 | | 36 335 | | Centralised personnel expenses | | 36 079 | | 36 079 | | 99% | | 99% | 3 |
| | 28 545 | | 28 545 | | 30 045 | | 30 045 | | Internal taxation | | 31 451 | | 31 451 | | 105% | | 105% | |
| 3.3 | 1 745 | | 1 745 | 3.5 | 1 470 | | 1 470 | | Internal mobility and personnel on detachment | 3.1 | 801 | 53 | 855 | 88% | 55% | | 58% | |
| | | | | | | | | | Personnel paid but not available | 20.7 | 2 482 | | 2 482 | | | | | |
| 81.2 | 11 695 | | 11 695 | 91.7 | 12 940 | | 12 940 | | Personnel paid from team accounts | 84.1 | 11 783 | | 11 783 | 92% | 91% | | 91% | |
| | 17 330 | | 17 330 | | 17 330 | | 17 330 | | Budget amortisation of staff benefit accruals | | 17 328 | | 17 328 | | 100% | | 100% | |
| | | 76 040 | 76 040 | | | 63 985 | 63 985 | | Energy and water | | | 60 405 | 60 405 | | | 94% | 94% | 24 |
| | | 6 240 | 6 240 | | | 6 240 | 6 240 | | Insurance, postal charges, miscellaneous | | | 5 028 | 5 028 | | | 81% | 81% | 0 |
| | | 10 940 | 10 940 | | | 10 940 | 10 940 | | Interest, bank and financial expenses | | | 17 700 | 17 700 | | | 162% | 162% | 0 |
| | | 4 900 | 4 900 | | | 2 045 | 2 045 | | In-kind | | | 1 863 | 1 863 | | | 91% | 91% | |
| | 20.04% | 18.55% | 38.59% | | 20.63% | 18.55% | 39.18% | | % of total revenues | | 20.81% | 16.64% | 37.44% | | | | | |

* The Out-Turn number includes the apprentices (19 FTEs) that are not budgeted for (as of August 2016 all new appointed apprentices are classed as associate members of the personnel in the Materials expenses).

## 2.3. PROJECTS (CONSTRUCTION, R&D)

### Figure 7: Projects

| Final 2016 Budget - CERN/FC/5955 (2016 prices) | | | | Revised 2016 Budget - CERN/FC/6011 (2016 prices) (a) | | | | | Activity | 2016 Out-Turn - CERN/FC/6096/Rev. (2016 prices) (b) | | | | Revised 2016 Budget usage in % (b)/(a) | | | | 2016 Out-Turn Open Commitment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FTE | kCHF | | | FTE | kCHF | | | Fact sheet | | FTE | kCHF | | | FTE | kCHF | | | kCHF |
| Personnel | Personnel | Materials | Total | Personnel | Personnel | Materials | Total | | | Personnel | Personnel | Materials | Total | Personnel | Personnel | Materials | Total | Materials |
| **569.1** | **99 570** | **156 085** | **255 655** | **593.4** | **102 305** | **129 160** | **231 465** | | **Projects** | **623.3** | **106 817** | **123 133** | **229 950** | **105%** | **104%** | **95%** | **99%** | **33 856** |
| **345.3** | **60 995** | **80 620** | **141 615** | **349.2** | **61 220** | **51 195** | **112 415** | | **LHC upgrades** | **370.8** | **65 621** | **57 047** | **122 669** | **106%** | **107%** | **111%** | **109%** | **22 889** |
| 17.0 | 3 095 | 1 770 | 4 865 | 18.3 | 3 315 | 2 270 | 5 585 | **22** | LINAC4 | 19.6 | 3 145 | 2 172 | 5 318 | 107% | 95% | 96% | 95% | 201 |
| 112.4 | 18 380 | 27 115 | 45 495 | 114.9 | 18 480 | 17 940 | 36 420 | **23** | LHC injectors upgrade | 118.2 | 19 240 | 17 819 | 37 059 | 103% | 104% | 99% | 102% | 8 120 |
| 144.3 | 25 015 | 37 855 | 62 870 | 145.4 | 25 045 | 22 250 | 47 295 | **24** | HL-LHC construction | 164.5 | 27 690 | 28 421 | 56 111 | 113% | 111% | 128% | 119% | 13 066 |
| 45.2 | 10 270 | 9 380 | 19 650 | 45.2 | 10 270 | 5 430 | 15 700 | **25** | LHC detectors upgrade (phase 1) and consolidation | 49.3 | 11 743 | 5 409 | 17 152 | 109% | 114% | 100% | 109% | 944 |
| 26.3 | 4 235 | 4 500 | 8 735 | 25.3 | 4 110 | 3 305 | 7 415 | **25** | HL-LHC detectors, including R&D (phase 2) | 19.3 | 3 802 | 3 226 | 7 029 | 76% | 93% | 98% | 95% | 557 |
| **101.9** | **17 895** | **18 720** | **36 615** | **108.9** | **18 505** | **16 055** | **34 560** | | **Energy frontier** | **112.1** | **19 266** | **14 115** | **33 381** | **103%** | **104%** | **88%** | **97%** | **3 563** |
| 71.8 | 13 015 | 14 840 | 27 855 | 69.5 | 12 160 | 12 960 | 25 120 | **26,27** | Linear collider studies (CLIC, ILC, detector R&D) | 68.5 | 11 501 | 10 672 | 22 173 | 99% | 95% | 82% | 88% | 2 890 |
| 30.1 | 4 880 | 3 880 | 8 760 | 39.4 | 6 345 | 3 095 | 9 440 | **28** | Future Circular Collider study | 43.6 | 7 765 | 3 443 | 11 208 | 111% | 122% | 111% | 119% | 672 |
| **121.9** | **20 680** | **56 745** | **77 425** | **135.3** | **22 580** | **61 910** | **84 490** | | **Scientific diversity activities** | **140.4** | **21 930** | **51 971** | **73 901** | **104%** | **97%** | **84%** | **87%** | **7 404** |
| 22.1 | 3 835 | 9 655 | 13 490 | 23.1 | 3 895 | 7 870 | 11 765 | **29** | ELENA | 25.9 | 4 148 | 5 978 | 10 125 | 112% | 106% | 76% | 86% | 1 940 |
| 23.2 | 4 230 | 5 800 | 10 030 | 23.8 | 4 345 | 4 960 | 9 305 | **30** | HIE-ISOLDE | 26.3 | 4 200 | 2 985 | 7 185 | 111% | 97% | 60% | 77% | 513 |
| 13.5 | 2 235 | 14 570 | 16 805 | 13.3 | 2 150 | 15 095 | 17 245 | **31** | CERN Neutrino Platform | 12.6 | 1 988 | 20 847 | 22 835 | 95% | 92% | 138% | 132% | 2 150 |
| 16.5 | 2 545 | 6 345 | 8 890 | 18.2 | 2 715 | 8 935 | 11 650 | **32** | Proton-driven plasma wakefield acceleration | 15.5 | 2 439 | 7 617 | 10 056 | 85% | 90% | 85% | 86% | 538 |
| 8.4 | 1 300 | 3 170 | 4 470 | 8.7 | 1 315 | 4 915 | 6 230 | **33** | Superconducting RF studies | 8.8 | 1 258 | 2 233 | 3 492 | 101% | 96% | 45% | 56% | 888 |
| | | 1 475 | 1 475 | 2.0 | 405 | 4 805 | 5 210 | **34** | Superconducting magnet R&D (SCM) | 3.0 | 622 | 2 566 | 3 188 | 151% | 154% | 53% | 61% | 319 |
| 10.9 | 1 795 | 4 100 | 5 895 | 12.7 | 1 955 | 3 030 | 4 985 | **35** | R&D for medical applications | 16.1 | 2 557 | 2 031 | 4 588 | 127% | 131% | 67% | 92% | 357 |
| 27.3 | 4 740 | 11 630 | 16 370 | 33.5 | 5 800 | 12 300 | 18 100 | **36** | Other R&D (FAIR, ITER, ESS, EU, etc.) | 32.2 | 4 717 | 7 715 | 12 432 | 96% | 81% | 63% | 69% | 699 |
| | 8.11% | 12.72% | 20.83% | | 8.30% | 10.47% | 18.77% | | % of total revenues | | 8.63% | 9.95% | 18.57% | | | | | |

## 2.4. MULTI-ANNUAL PROJECTS

### Figure 8 (1/3): Expenses – Details of projects included in the activity headings

(in kCHF, rounded off)

| Final 2016 Budget CERN/FC/5955 (2016 prices) | | | Revised 2016 Budget CERN/FC/6011 (2016 prices) (a) | | | Programme | Project | 2016 Out-Turn CERN/FC/6096/Rev. (2016 prices) (b) | | | Revised 2016 Budget usage in % (b)/(a) | | | Variation of 2016 Out-Turn with respect to Revised 2016 Budget (c) = (b)-(a) | (d) = (c)/(a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Personnel | Materials | Total | Personnel | Materials | Total | | | Personnel | Materials | Total | Personnel | Materials | Total | kCHF | % |
| **15 660** | **66 040** | **81 700** | **17 395** | **46 860** | **64 255** | | **LHC programme** | **19 370** | **46 625** | **65 995** | **111%** | **99%** | **103%** | **1 740** | **3%** |
| | **6 280** | **6 280** | | 5 790 | **5 790** | **LHC programme**<br>Included in Figure 5 | **LHC machine and experimental areas** | **670** | **3 720** | **4 390** | | **64%** | **76%** | **-1 400** | **-24%** |
| | 5 275 | 5 275 | | 4 705 | 4 705 | | LHC spares | 670 | 2 845 | 3 515 | | 60% | 75% | -1 190 | -25% |
| | 1 005 | 1 005 | | 995 | 995 | | LHC magnet repair | | 855 | 855 | | 86% | 86% | -140 | -14% |
| | | | | 90 | 90 | | Electrical Circuit Change for ALFA | | 20 | 20 | | 22% | 22% | -70 | -78% |
| **11 030** | **37 650** | **48 680** | **12 370** | **21 485** | **33 855** | | **LHC machine and areas reliability and consolidation** | **13 055** | **22 690** | **35 745** | **106%** | **106%** | **106%** | **1 890** | **6%** |
| 170 | 2 180 | 2 350 | 960 | 855 | 1 815 | | Collimation system enhancements | 1 145 | 925 | 2 070 | 119% | 108% | 114% | 255 | 14% |
| 505 | 5 760 | 6 265 | 365 | 1 205 | 1 570 | | Electrical network 2025 | 860 | 1 005 | 1 865 | 236% | 83% | 119% | 295 | 19% |
| 380 | 840 | 1 220 | 380 | 740 | 1 120 | | Experimental areas consolidation | 345 | 325 | 670 | 91% | 44% | 60% | -450 | -40% |
| 7 320 | 19 385 | 26 705 | 7 990 | 11 085 | 19 075 | | LHC consolidation | 7 480 | 13 800 | 21 280 | 94% | 124% | 112% | 2 205 | 12% |
| 2 655 | 9 225 | 11 880 | 2 675 | 6 520 | 9 195 | | Radiation to electronics (R2E) | 3 225 | 5 180 | 8 405 | 121% | 79% | 91% | -790 | -9% |
| | | | | | | | POPS repair, spare and consolidation | | 1 065 | 1 065 | | | | 1 065 | |
| | | | | 815 | 815 | | Spare and consolidation in the framework of HL-LHC | | 65 | 65 | | 8% | 8% | -750 | -92% |
| | 260 | 260 | | 265 | 265 | | CERN control centre consolidation | | 325 | 325 | | 123% | 123% | 60 | 23% |
| | **-5** | **-5** | | **20** | **20** | | **LHC detectors** | | **65** | **65** | | 325% | 325% | 45 | 225% |
| **50** | **135** | **185** | | | | | **LHC injectors** | | | | | | | | |
| **1 715** | **20 830** | **22 545** | **1 820** | **18 195** | **20 015** | | **LHC Computing Grid** | **2 115** | **19 345** | **21 460** | **116%** | **106%** | **107%** | **1 445** | **7%** |
| **2 865** | **1 150** | **4 015** | **3 205** | **1 370** | **4 575** | | **EU projects** | **3 530** | **795** | **4 325** | **110%** | **58%** | **95%** | **-250** | **-5%** |
| | | | | | | | **TT projects** | | **10** | **10** | | | | **10** | |
| **18 005** | **33 980** | **51 985** | **18 865** | **39 115** | **57 980** | | **Other programmes** | **17 945** | **24 285** | **42 230** | **95%** | **62%** | **73%** | **-15 750** | **-27%** |
| **350** | **135** | **485** | **350** | **245** | **595** | **Other programmes**<br>Included in Figure 5 | **AEGIS** | **375** | **230** | **605** | **107%** | **94%** | **102%** | **10** | **2%** |
| **1 075** | **570** | **1 645** | **1 105** | **170** | **1 275** | | **NA62** | **1 085** | **60** | **1 145** | **98%** | **35%** | **90%** | **-130** | **-10%** |
| | **535** | **535** | | **905** | **905** | | **PCB Workshop Machine** | | **5** | **5** | | **1%** | **1%** | **-900** | **-99%** |
| **50** | **15** | **65** | **50** | **15** | **65** | | **ISOLDE robots** | **70** | **15** | **85** | **140%** | **100%** | **131%** | **20** | **31%** |
| **50** | **445** | **495** | **50** | **380** | **430** | | **Magnet Infrastructure Upgrade** | **-5** | **105** | **100** | **-10%** | **28%** | **23%** | **-330** | **-77%** |
| **1 990** | **2 070** | **4 060** | **1 985** | **4 585** | **6 570** | | **SM18 infrastructure Upgrade** | **1 800** | **3 770** | **5 570** | **91%** | **82%** | **85%** | **-1 000** | **-15%** |
| **135** | **1 345** | **1 480** | **135** | **2 355** | **2 490** | | **TE Infrastructure Consolidation** | **220** | **2 305** | **2 525** | **163%** | **98%** | **101%** | **35** | **1%** |
| | **830** | **830** | | **830** | **830** | | **EP Safety and Consolidation** | | **-340** | **-340** | | **-41%** | **-41%** | **-1 170** | **-141%** |
| | | | **50** | **170** | **220** | | **LHC injectors** | **100** | | **100** | **200%** | | **45%** | **-120** | **-55%** |
| **185** | **445** | **630** | **105** | **475** | **580** | | **Timing development** | **180** | **165** | **345** | **171%** | **35%** | **59%** | **-235** | **-41%** |
| **385** | **3 700** | **4 085** | **475** | **1 855** | **2 330** | | **AD consolidation** | **470** | **1 635** | **2 105** | **99%** | **88%** | **90%** | **-225** | **-10%** |
| **35** | **780** | **815** | **35** | **280** | **315** | | **East area consolidation** | **25** | **205** | **230** | **71%** | **73%** | **73%** | **-85** | **-27%** |
| **805** | **3 565** | **4 370** | **700** | **2 245** | **2 945** | | **North area consolidation** | **705** | **1 525** | **2 230** | **101%** | **68%** | **76%** | **-715** | **-24%** |
| **70** | **1 485** | **1 555** | **70** | **350** | **420** | | **66/18 kV loop PS consolidation** | **-20** | **600** | **580** | **-29%** | **171%** | **138%** | **160** | **38%** |
| **670** | **1 365** | **2 035** | **720** | **1 525** | **2 245** | | **18 kV loop + substations SPS consolidation** | **750** | **865** | **1 615** | **104%** | **57%** | **72%** | **-630** | **-28%** |
| **7 900** | **14 970** | **22 870** | **7 985** | **16 410** | **24 395** | | **Accelerator consolidation** | **7 815** | **9 615** | **17 430** | **98%** | **59%** | **71%** | **-6 965** | **-29%** |
| **245** | **915** | **1 160** | **245** | **1 565** | **1 810** | | **PS and SPS spares** | **240** | **600** | **840** | **98%** | **38%** | **46%** | **-970** | **-54%** |
| | | | | | | | **Computer Security Hardening** | **15** | **145** | **160** | | | | **160** | |
| **4 060** | **810** | **4 870** | **4 685** | **1 435** | **6 120** | | **EU projects** | **3 795** | **660** | **4 455** | **81%** | **46%** | **73%** | **-1 665** | **-27%** |
| | | | **120** | **3 320** | **3 440** | | **TT projects** | **325** | **2 120** | **2 445** | **271%** | **64%** | **71%** | **-995** | **-29%** |

# Figure 8 (2/3): Expenses – Details of projects included in the activity headings

(in kCHF, rounded off)

| **Final 2016 Budget CERN/FC/5955** (2016 prices) | | | **Revised 2016 Budget CERN/FC/6011** (2016 prices) (a) | | | **Programme** | **Project** | **2016 Out-Turn CERN/FC/6096/Rev.** (2016 prices) (b) | | | **Revised 2016 Budget usage in %** (b)/(a) | | | **Variation of 2016 Out-Turn with respect to Revised 2016 Budget** (c) = (b)-(a) | (d) = (c)/(a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Personnel** | **Materials** | **Total** | **Personnel** | **Materials** | **Total** | | | **Personnel** | **Materials** | **Total** | **Personnel** | **Materials** | **Total** | **kCHF** | **%** |
| **8,495** | **55,285** | **63,780** | **8,965** | **63,315** | **72,280** | | **Infrastructure, services and centralised expenses** | **9,805** | **47,815** | **57,620** | **109%** | **76%** | **80%** | **-14,660** | **-20%** |
| | **1,295** | **1,295** | | **1,415** | **1,415** | **Infrastructure, services and centralised expenses** Included in Figure 6 | **Manufacturing facilities** | | **1,280** | **1,280** | | **90%** | **90%** | **-135** | **-10%** |
| | 1,295 | 1,295 | | 1,415 | 1,415 | | Investment in new mechanical technologies | | 1,280 | 1,280 | | 90% | 90% | -135 | **-10%** |
| | **2,740** | **2,740** | | **1,465** | **1,465** | | **General facilities & logistics (site maintenance, transport)** | **15** | **85** | **100** | | **6%** | **7%** | **-1,365** | **-93%** |
| | 1,560 | 1,560 | | 300 | 300 | | Globe car park and "Esplanade des Particules" | 15 | 15 | 30 | | 5% | 10% | -270 | -90% |
| | 1,180 | 1,180 | | 1,165 | 1,165 | | Building 38 (hotel renovation) | | 70 | 70 | | 6% | 6% | -1,095 | -94% |
| **2,215** | **10,750** | **12,965** | **2,370** | **10,930** | **13,300** | | **Informatics** | **2,350** | **8,645** | **10,995** | **99%** | **79%** | **83%** | **-2,305** | **-17%** |
| | 3,355 | 3,355 | | 2,420 | 2,420 | | Computing network consolidation | | 1,705 | 1,705 | | 70% | 70% | -715 | -30% |
| | 485 | 485 | | 1,065 | 1,065 | | 2nd Network Hub | | 550 | 550 | | 52% | 52% | -515 | -48% |
| | 5,880 | 5,880 | | 6,755 | 6,755 | | SCOAP3 | | 5,420 | 5,420 | | 80% | 80% | -1,335 | -20% |
| 2,215 | 465 | 2,680 | 2,190 | 495 | 2,685 | | OpenLab | 2,165 | 855 | 3,020 | 99% | 173% | 112% | 335 | 12% |
| | 565 | 565 | 180 | 195 | 375 | | AIS re-engineering | 185 | 115 | 300 | 103% | 59% | 80% | -75 | -20% |
| **605** | **-30** | **575** | **110** | **590** | **700** | | **Administration** | **120** | **255** | **375** | **109%** | **43%** | **54%** | **-325** | **-46%** |
| | -5 | -5 | | 140 | 140 | | HR projects | 5 | 25 | 30 | | 18% | 21% | -110 | -79% |
| 605 | -20 | 585 | 110 | 360 | 470 | | FAP projects | 115 | 150 | 265 | 105% | 42% | 56% | -205 | -44% |
| | -5 | -5 | | 90 | 90 | | Risk management | | 80 | 80 | | 89% | 89% | -10 | -11% |
| **1,500** | **9,515** | **11,015** | **2,685** | **10,120** | **12,805** | | **Safety, health and environment** | **2,840** | **5,930** | **8,770** | **106%** | **59%** | **68%** | **-4,035** | **-32%** |
| | 555 | 555 | | 585 | 585 | | Radio infrastructure upgrade for firefighters | 50 | 35 | 85 | | 6% | 15% | -500 | -85% |
| | | | | 30 | 30 | | Consolidation of calibration hall | | 30 | 30 | | 100% | 100% | | |
| 390 | 3,305 | 3,695 | 1,120 | 2,405 | 3,525 | | Ramses II light | 1,375 | 645 | 2,020 | 123% | 27% | 57% | -1,505 | -43% |
| | 480 | 480 | | 895 | 895 | | Emergency | | 650 | 650 | | 73% | 73% | -245 | -27% |
| 1,085 | 4,890 | 5,975 | 1,540 | 5,910 | 7,450 | | Radioactive waste management | 1,390 | 4,525 | 5,915 | 90% | 77% | 79% | -1,535 | -21% |
| | | | | | | | SPS fire safety | | 5 | 5 | | | | 5 | |
| 25 | 285 | 310 | 25 | 295 | 320 | | HLD Instrumentation upgrade | 25 | 40 | 65 | 100% | 14% | 20% | -255 | -80% |
| **95** | **60** | **155** | **95** | **640** | **735** | | **International relations** | **140** | **555** | **695** | **147%** | **87%** | **95%** | **-40** | **-5%** |
| | | | | 115 | 115 | | New microcosm exhibition | | 100 | 100 | | 87% | 87% | -15 | -13% |
| | 60 | 60 | | 190 | 190 | | IdeaSquare building | 10 | 325 | 335 | | 171% | 176% | 145 | 76% |
| | | | | 170 | 170 | | Visitpoint | | | | | | | -170 | -100% |
| | | | | | | | Alumni | | 10 | 10 | | | | 10 | |
| 95 | | 95 | 95 | 165 | 260 | | Other outreach projects | 130 | 120 | 250 | 137% | 73% | 96% | -10 | -4% |
| **2,930** | **28,130** | **31,060** | **2,585** | **37,015** | **39,600** | | **Infrastructure consolidation, buildings and renovation** | **3,085** | **30,460** | **33,545** | **119%** | **82%** | **85%** | **-6,055** | **-15%** |
| | 50 | 50 | | 5 | 5 | | AD control rooms | | 5 | 5 | | 100% | 100% | | |
| 115 | 5,780 | 5,895 | 120 | 6,355 | 6,475 | | Building 107 (surface treatment) | 305 | 5,945 | 6,250 | 254% | 94% | 97% | -225 | -3% |
| 365 | 4,360 | 4,725 | 420 | 4,665 | 5,085 | | Building 311 (magnetic measurements) | 595 | 2,135 | 2,730 | 142% | 46% | 54% | -2,355 | -46% |
| | | | | 1,115 | 1,115 | | Building 774 (Prévessin main building) | | 865 | 865 | | 78% | 78% | -250 | -22% |
| | | | | 500 | 500 | | Building 90 (new main building) | 55 | 80 | 135 | | 16% | 27% | -365 | -73% |
| | 395 | 395 | | 545 | 545 | | Building 156 (extension) | | 350 | 350 | | 64% | 64% | -195 | -36% |
| | 520 | 520 | | 550 | 550 | | Library reading room | | | | | | | -550 | -100% |
| | 1,500 | 1,500 | | | | | CMS site consolidation | | | | | | | | |
| | 1,105 | 1,105 | | 3,530 | 3,530 | | Renovation Globe of Science and Innovation | -5 | 2,220 | 2,215 | | 63% | 63% | -1,315 | -37% |
| | -115 | -115 | 75 | 30 | 105 | | LHCb building | 75 | 70 | 145 | 100% | 233% | 138% | 40 | 38% |
| | 1,245 | 1,245 | | 1,085 | 1,085 | | Workshop and assembly hall in LHC point 8 | | 1,235 | 1,235 | | 114% | 114% | 150 | 14% |
| | 1,170 | 1,170 | 40 | 2,775 | 2,815 | | Polymer laboratory consolidation | 40 | 1,175 | 1,215 | 100% | 42% | 43% | -1,600 | -57% |
| | 465 | 465 | | 500 | 500 | | Replacement of Water-Cooled Cables | | -5 | -5 | | -1% | -1% | -505 | -101% |
| | 10 | 10 | | | | | ISOLDE robots | | 5 | 5 | | | | 5 | |
| 2,450 | 11,645 | 14,095 | 1,930 | 15,360 | 17,290 | | Surface and technical infrastructure consolidation (roofs, facades, heating, etc.) | 2,020 | 16,215 | 18,235 | 105% | 106% | 105% | 945 | 5% |
| | | | | | | | Cooling tower Point 18 | | 10 | 10 | | | | 10 | |
| | | | | | | | Flexible storage building Prevessin | | 155 | 155 | | | | 155 | |
| **1,045** | **1,220** | **2,265** | **1,120** | **1,140** | **2,260** | | **EU projects** | **1,255** | **595** | **1,850** | **112%** | **52%** | **82%** | **-410** | **-18%** |
| **105** | **1,605** | **1,710** | | | | | **TT projects** | | **10** | **10** | | | | **10** | |

# Figure 8 (3/3): Expenses – Details of projects included in the activity headings

(in kCHF, rounded off)

| **Final 2016 Budget CERN/FC/5955** (2016 prices) | | | **Revised 2016 Budget CERN/FC/6011** (2016 prices) (a) | | | **Programme** | **Project** | **2016 Out-Turn CERN/FC/6096/Rev.** (2016 prices) (b) | | | **Revised 2016 Budget usage in %** (b)/(a) | | | **Variation of 2016 Out-Turn with respect to Revised 2016 Budget** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | (c) = (b)-(a) | (d) = (c)/(a) |
| **Personnel** | **Materials** | **Total** | **Personnel** | **Materials** | **Total** | | | **Personnel** | **Materials** | **Total** | **Personnel** | **Materials** | **Total** | **kCHF** | **%** |
| **94,630** | **151,095** | **245,725** | **97,080** | **124,505** | **221,585** | | **Projects** | **100,690** | **119,025** | **219,715** | **104%** | **96%** | **99%** | **-1,870** | **-1%** |
| **8,975** | **13,900** | **22,875** | **7,975** | **11,905** | **19,880** | **Projects**<br>Included in Figure 7 | **CLIC** | **7,595** | **10,010** | **17,605** | **95%** | **84%** | **89%** | **-2,275** | **-11%** |
| **2,920** | **440** | **3,360** | **2,920** | **445** | **3,365** | | **Linear collider detector R&D** | **3,130** | **400** | **3,530** | **107%** | **90%** | **105%** | **165** | **5%** |
| **4,230** | **5,805** | **10,035** | **4,345** | **4,965** | **9,310** | | **HIE-ISOLDE** | **4,200** | **2,970** | **7,170** | **97%** | **60%** | **77%** | **-2,140** | **-23%** |
| **3,765** | **9,655** | **13,420** | **3,825** | **7,870** | **11,695** | | **ELENA** | **4,080** | **5,980** | **10,060** | **107%** | **76%** | **86%** | **-1,635** | **-14%** |
| **2,465** | **6,340** | **8,805** | **2,645** | **8,840** | **11,485** | | **Proton Plasma wakefield acceleration (AWAKE)** | **2,355** | **7,535** | **9,890** | **89%** | **85%** | **86%** | **-1,595** | **-14%** |
| | | | | **15** | **15** | | **High radiation material test facility** | | **15** | **15** | | **100%** | **100%** | | |
| **135** | **2,915** | **3,050** | **135** | **1,970** | **2,105** | | **MEDICIS** | **170** | **1,325** | **1,495** | **126%** | **67%** | **71%** | **-610** | **-29%** |
| **2,240** | **14,570** | **16,810** | **2,155** | **15,095** | **17,250** | | **CERN Neutrino Platform** | **1,775** | **20,820** | **22,595** | **82%** | **138%** | **131%** | **5,345** | **31%** |
| **3,095** | **2,125** | **5,220** | **3,315** | **2,660** | **5,975** | | **LINAC4** | **3,145** | **2,385** | **5,530** | **95%** | **90%** | **93%** | **-445** | **-7%** |
| **18,340** | **27,115** | **45,455** | **18,430** | **17,955** | **36,385** | | **LHC Injectors Upgrade** | **19,190** | **17,820** | **37,010** | **104%** | **99%** | **102%** | **625** | **2%** |
| **24,310** | **35,300** | **59,610** | **24,640** | **22,100** | **46,740** | | **LHC luminosity upgrade project (HL-LHC)** | **26,885** | **28,300** | **55,185** | **109%** | **128%** | **118%** | **8,445** | **18%** |
| **10,270** | **9,075** | **19,345** | **10,270** | **5,100** | **15,370** | | **LHC detectors upgrade** | **12,370** | **5,740** | **18,110** | **120%** | **113%** | **118%** | **2,740** | **18%** |
| **4,805** | **3,880** | **8,685** | **6,225** | **3,095** | **9,320** | | **Future Circular Collider study** | **7,625** | **3,445** | **11,070** | **122%** | **111%** | **119%** | **1,750** | **19%** |
| **30** | **3,700** | **3,730** | **30** | **4,410** | **4,440** | | **Superconducting magnets R&D** | **345** | **2,165** | **2,510** | **1150%** | **49%** | **57%** | **-1,930** | **-43%** |
| | | | | **2,200** | **2,200** | | **SM18 extension for superconducting RF** | | **15** | **15** | | **1%** | **1%** | **-2,185** | **-99%** |
| **1,560** | **9,185** | **10,745** | **1,560** | **6,870** | **8,430** | | **Upgrade Building 180 test facility (FAIR)** | **1,115** | **5,740** | **6,855** | **71%** | **84%** | **81%** | **-1,575** | **-19%** |
| **4,235** | **4,485** | **8,720** | **4,110** | **3,300** | **7,410** | | **R&D for HL-LHC detectors** | **3,175** | **3,240** | **6,415** | | **98%** | **87%** | **-995** | **-13%** |
| **3,255** | **2,470** | **5,725** | **4,500** | **5,565** | **10,065** | | **EU projects** | **3,535** | **955** | **4,490** | **79%** | **17%** | **45%** | **-5,575** | **-55%** |
| | **135** | **135** | | **145** | **145** | | **TT projects** | | **165** | **165** | | **114%** | **114%** | **20** | **14%** |
| **136,790** | **306,400** | **443,190** | **142,305** | **273,795** | **416,100** | | **Grand Total** | **147,810** | **237,750** | **385,560** | **104%** | **87%** | **93%** | **-30,540** | **-7%** |

## 3. SUMMARY OF EXPENSES BY NATURE

### Figure 9: Materials expenses by nature

(in kCHF, rounded off)

| Nature | Final 2016 Budget CERN/FC/5955 (2016 prices) | Revised 2016 Budget CERN/FC/6011 (2016 prices) | 2016 Out-Turn CERN/FC/6096/Rev. (2016 prices) | Revised 2016 Budget usage in % | Variation of 2016 Out-Turn with respect to Revised 2016 Budget kCHF | % |
|---|---|---|---|---|---|---|
| | | (a) | (b) | (b)/(a) | (c)=(b)-(a) | (c)/(a) |
| **Materials expenses** | **592 900** | **548 350** | **486 535** | **88.7%** | **-61 815** | **-11.3%** |
| Goods, consumables and supplies | 323 315 | 270 275 | 213 487 | 79.0% | -56 788 | -21.0% |
| Electricity, heating gas and water | 76 040 | 63 985 | 59 523 | 93.0% | -4 462 | -7.0% |
| Industrial services | 106 230 | 117 460 | 122 925 | 104.7% | 5 465 | 4.7% |
| *Service contracts* | *72 840* | *81 540* | *85 957* | *105.4%* | *4 417* | *5.4%* |
| *Repair and maintenance* | *29 455* | *31 520* | *31 274* | *99.2%* | *-246* | *-0.8%* |
| *Temporary labour* | *3 935* | *4 400* | *5 693* | *129.4%* | *1 293* | *29.4%* |
| Associated Members of the Personnel | 39 625 | 40 665 | 41 087 | 101.0% | 422 | 1.0% |
| Other overheads | 47 690 | 55 965 | 49 513 | 88.5% | -6 452 | -11.5% |
| *Consultancy* | *9 310* | *7 510* | *9 004* | *119.9%* | *1 494* | *19.9%* |
| *Contributions to Collaborations* | *7 030* | *6 825* | *7 495* | *109.8%* | *670* | *9.8%* |
| *Miscellaneous* [1] | *31 350* | *41 630* | *33 015* | *79.3%* | *-8 615* | *-20.7%* |
| **Interest and financial costs** | **12 885** | **12 885** | **19 454** | **151.0%** | **6 569** | **51.0%** |
| Fortis bank | 9 875 | 9 875 | 9 873 | 100.0% | -2 | 0.0% |
| In-kind (FIPOI interest 0%)[2] | 2 045 | 2 045 | 1 863 | 91.1% | -182 | -8.9% |
| Short-term interest | | | 15 | | 15 | |
| Other financial expenses | 965 | 965 | 7 703 | 798.3% | 6 738 | 698.3% |
| **TOTAL MATERIALS** | **605 785** | **561 235** | **505 989** | **90.2%** | **-55 246** | **-9.8%** |

[1] Including insurance and postal charges, handling and transport, bank charges, depreciation of current assets.

[2] Theoretical interest at market rate for FIPOI 1, 2 and 3 loans at 0%. This heading is compensated by the corresponding revenue line "Other revenues / In-kind".

### Comments on Figure 9:

The "Other financial expenses" heading includes losses resulting from currency exchange-rate fluctuations that are not planned in the budget. Most of the loss of 7.7 MCHF in financial expenses recorded in 2016 was offset by gains from currency exchange rate fluctuations of 5.6 MCHF under revenues.

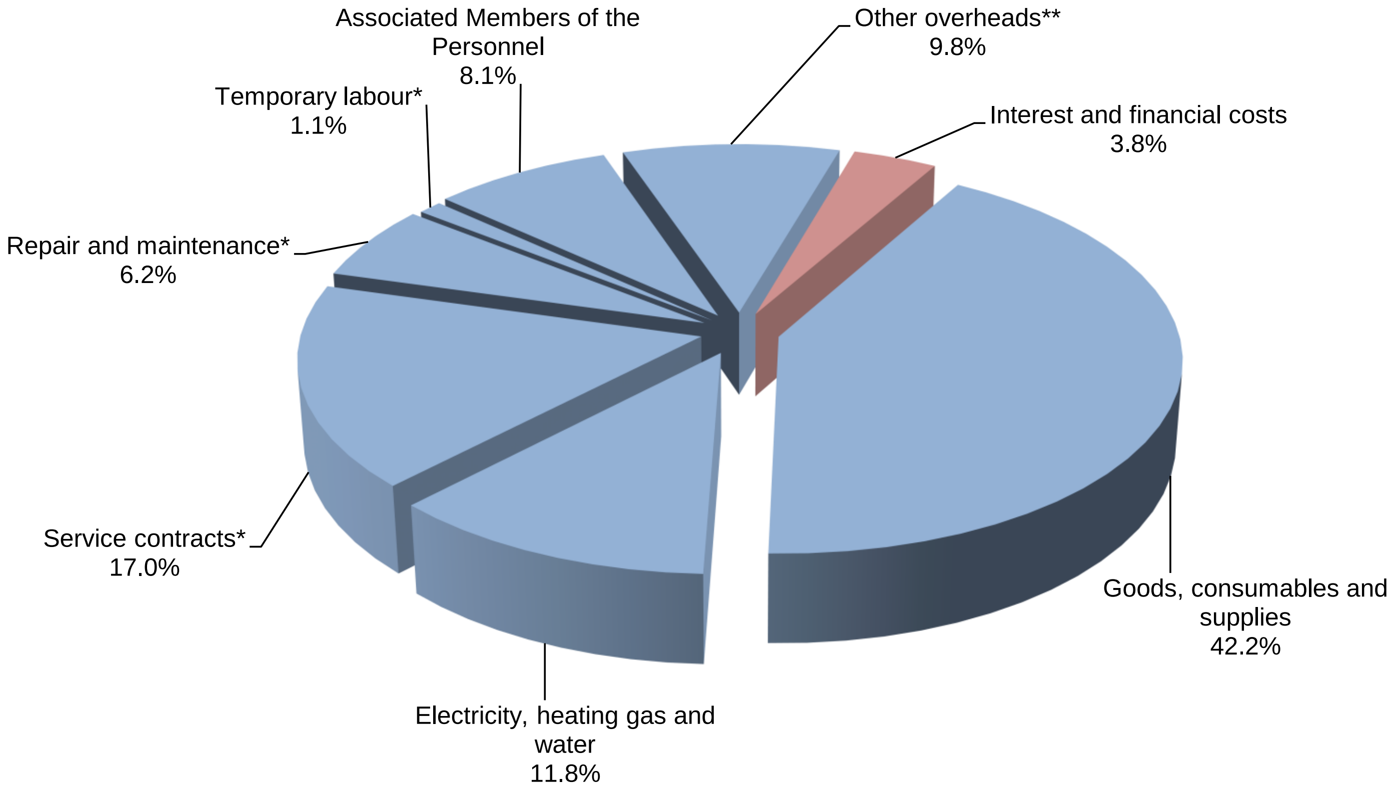
## Figure 10: Materials expenses by nature (chart)

Materials expenses: 96.2%

Interest and financial costs: 3.8%

* Total for industrial services: 17% + 6.2% + 1.1% = 24.3%.

** Including insurance and postal charges, consultancy, CERN contributions to collaborations, handling and transport, bank charges, depreciation of current assets.



## Figure 11: Personnel expenses by nature

(in kCHF, rounded off)

| Nature | Final 2016 Budget CERN/FC/5955 (2016 prices) | Revised 2016 Budget CERN/FC/6011 (2016 prices) | 2016 Out-Turn CERN/FC/6096/Rev. (2016 prices) | Revised 2016 Budget usage in % | Variation of 2016 Out-Turn with respect to Revised 2016 Budget | |
|---|---|---|---|---|---|---|
| | | | | | **kCHF** | **%** |
| | | (a) | (b) | (b)/(a) | (c)=(b)-(a) | (c)/(a) |
| **Staff members** [1] | **484,495** | **488,035** | **488,725** | **100.1%** | **690** | **0.1%** |
| ***Basic salaries (incl. saved leave)*** | ***307,240*** | ***312,225*** | ***312,047*** | ***99.9%*** | ***-178*** | ***-0.1%*** |
| Basic salaries | 312,980 | 317,210 | 317,191 | 100.0% | -19 | 0.0% |
| Contribution to saved leave schemes | -5,740 | -4,985 | -5,144 | 103.2% | -159 | 3.2% |
| ***Annual variation - paid leave*** | | | ***-319*** | | ***-319*** | |
| ***Allowances*** | ***67,015*** | ***64,585*** | ***66,046*** | ***102.3%*** | ***1,461*** | ***2.3%*** |
| Non-resident allowances / international indemnities | 20,265 | 19,690 | 19,696 | 100.0% | 6 | 0.0% |
| Family and child allowances | 24,615 | 24,865 | 24,727 | 99.4% | -138 | -0.6% |
| Special allowances | 2,560 | 2,160 | 2,791 | 129.2% | 631 | 29.2% |
| Overtime | 2,600 | 2,755 | 2,654 | 96.3% | -101 | -3.7% |
| Various allowances | 16,975 | 15,115 | 16,177 | 107.0% | 1,062 | 7.0% |
| ***Social contributions*** | ***110,240*** | ***111,225*** | ***110,951*** | ***99.8%*** | ***-274*** | ***-0.2%*** |
| Pension Fund | 85,505 | 86,060 | 85,826 | 99.7% | -234 | -0.3% |
| Health insurance | 24,735 | 25,165 | 25,125 | 99.8% | -40 | -0.2% |
| **Fellows** [2] | **63,750** | **70,200** | **73,184** | **104.3%** | **2,984** | **4.3%** |
| **Apprentices** | **425** | **400** | **422** | **105.5%** | **22** | **5.5%** |
| **Centralised personnel budget** [3] | **64,250** | **66,380** | **67,547** | **101.8%** | **1,167** | **1.8%** |
| ***Centralised personnel expenses*** | ***35,705*** | ***36,335*** | ***36,096*** | ***99.3%*** | ***-239*** | ***-0.7%*** |
| Installation, recruitment and termination of contracts | 5,800 | 6,750 | 6,258 | 92.7% | -492 | -7.3% |
| *Installation and removal costs* | *1,100* | *1,225* | *1,228* | *100.2%* | *3* | *0.2%* |
| *Termination allowances* | *4,700* | *5,525* | *5,030* | *91.0%* | *-495* | *-9.0%* |
| Additional periods of membership of the Pension Fund for shift work [4] | 145 | -240 | 19 | -7.9% | 259 | -107.9% |
| Contribution to health insurance for pensioners incl. long-term care | 29,760 | 29,825 | 29,820 | 100.0% | -5 | 0.0% |
| *Contribution to health insurance for pensioners* | *26,860* | *27,020* | *27,016* | *100.0%* | *-4* | *0.0%* |
| *Contribution to long-term care for pensioners* | *2,900* | *2,805* | *2,803* | *99.9%* | *-2* | *-0.1%* |
| ***Internal taxation*** | ***28,545*** | ***30,045*** | ***31,451*** | ***104.7%*** | ***1,406*** | ***4.7%*** |
| **TOTAL PERSONNEL** | **612,920** | **625,015** | **629,879** | **100.8%** | **4,864** | **0.8%** |
| Budget Amortisation of staff benefit accruals | 17,330 | 17,330 | 17,328 | 100.0% | -2 | 0.0% |
| **TOTAL PERSONNEL incl. bud. amort. of staff benefit accruals** | **630,250** | **642,345** | **647,207** | | **4,862** | |

[1] Including staff paid from team accounts (9.1 MCHF).

[2] Including fellows paid from team accounts (2.6 MCHF).

[3] Including centralised expenses for staff and fellows paid from team accounts (0.06 MCHF).

[4] This is a variation on the provision for personnel on shiftwork in line with Administrative Circular 22A.

**Comments on Figure 11:**

The total CERN staff member strength in 2016 was 2,513.4 FTEs, of which 53.3 FTEs were charged to team accounts and 2,460.1 FTEs were charged to CERN accounts (2,439.1 FTEs under CERN core budget, 9.6 FTEs under EU funding, 5.9 under OpenLab, and 5.6 under other external revenues). Personnel “paid but not available” accounted for 20.7 FTEs, and 3 FTE were on detachment, resulting in a staff strength of 2,415.3 active FTEs charged to CERN’s core budget.

With respect to the Final Budget, the overall expenses for staff members were 0.9% higher, which is explained by the corresponding increase in the number of FTEs due to updated departures and recruitments.

The reduction in the amounts paid for allowances is mainly explained by a decrease of the non-resident allowances / international indemnities and of allowances under the heading “Various allowances”. The number of staff who receive non-resident allowance is decreasing; furthermore, the international indemnity is suppressed for staff recruited after the 2005 Five-Yearly Review once they are awarded an indefinite contract. The heading “Various allowances” consists of expenses linked to education, home leave and termination indemnities. The amount of expenses for education is similar to the 2015 amount. Although higher than in 2015, payment of termination indemnities are lower than expected due to the new staff contract policy (possibility to extend an LD contract to up to 8 years).

The special responsibility allowances shown under the special allowances heading increased.

With respect to the Final Budget, the social contributions expenses for staff members are higher, due to a corresponding increase in the number of FTEs.

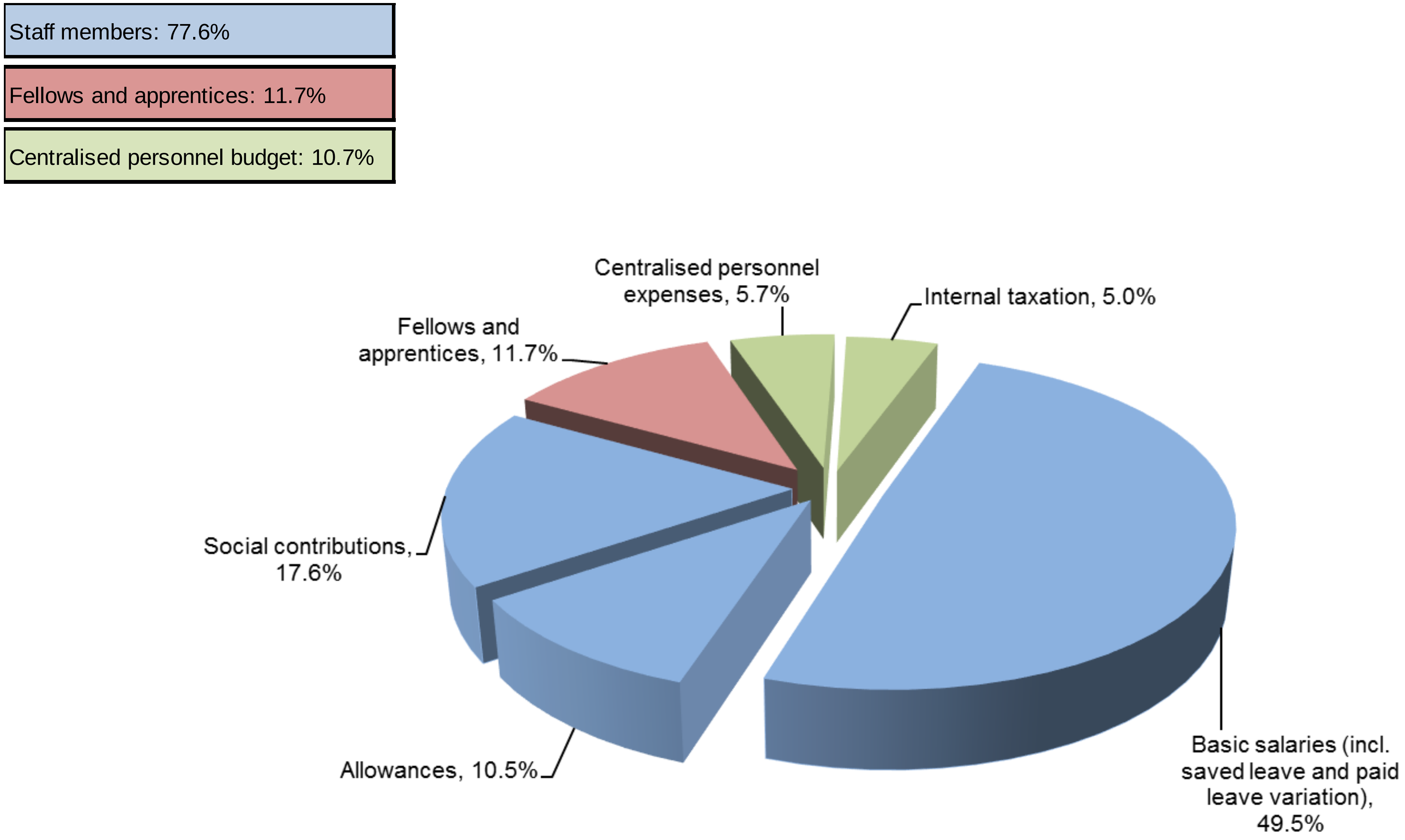
The new Management increased the budget for the fellowship programme by 10%.

The apprentices recruited since September 2016 are no longer accounted within the personnel budget.

The termination allowances under the centralised personnel expenses mainly consist of reinstallation indemnities and unemployment benefits. The unemployment benefits decreased by 35% with respect to 2015, due to a decrease of beneficiaries (94 in 2015 and 56 in 2016). The amount for reinstallation allowances is difficult to predict, as the reinstallation payments can be made at any time during the 2.5 years following the end of the contract.

The amount of internal taxation depends on the applicable taxation rates, which are based on the salary positions of the staff and is offset by an equivalent revenue heading, thus having no impact on the budget balance.

**Figure 12: Personnel expenses by nature (chart)**



## Figure 13: Expenses - Energy and water

(in MCHF, rounded off)

| **Nature** | **Final 2016 Budget CERN/FC/5955** (2016 prices) | **Revised 2016 Budget CERN/FC/6011** (2016 prices) | **2016 Out-Turn CERN/FC/6096/Rev.** (2016 prices) | **Revised 2016 Budget usage in %** | **Variation of 2016 Out-Turn with respect to Revised 2016 Budget** MCHF | **%** |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (c)/(b) | (d)=(c)-(b) | (d)/(b) |
| **Energy and water (baseload)** | **15.2** | **14.3** | **13.1** | **92.0%** | **-1.1** | **-8.0%** |
| Electricity | 6.8 | 6.3 | 6.3 | 99.5% | 0.0 | -0.5% |
| Heating oil and gas | 4.8 | 4.4 | 3.7 | 84.8% | -0.7 | -15.2% |
| Water and waste water | 3.6 | 3.6 | 3.2 | 87.5% | -0.5 | -12.5% |
| **Energy for basic programmes** | **60.8** | **49.5** | **47.3** | **95.4%** | **-2.3** | **-4.6%** |
| Experimental areas[1] | 14.2 | 13.0 | 13.0 | 100.0% | 0.0 | 0.0% |
| Data handling | 1.7 | 1.6 | 1.3 | 83.7% | -0.3 | -16.3% |
| Accelerators: | 21.5 | 13.9 | 12.5 | 89.4% | -1.5 | -10.6% |
| *AD* | 0.6 | 0.5 | *0.6* | 110.4% | *0.1* | 10.4% |
| *PS* | 3.6 | 3.0 | *3.0* | 100.3% | *0.0* | 0.3% |
| *SPS*[2] | 17.2 | 10.4 | *8.9* | 85.2% | *-1.5* | -14.8% |
| LHC | 23.4 | 21.0 | 20.4 | 97.4% | -0.5 | -2.6% |
| **TOTAL ENERGY** | **76.0** | **63.8** | **60.4** | **94.6%** | **-3.4** | **-5.4%** |

[1] This includes particle physics (PS and SPS fixed targets), ISOLDE, LHC experiments and LHC test beam to the East, West and North Areas.

[2] The reduction in electricity consumption for the SPS is due to lower intensity of the fixed target experimental programme following a problem with the SPS internal beam dump as well as CERN energy savings campaign.

## 4. CARRY-FORWARD

**Figure 14: Carry-forward**

| (in kCHF, rounded off) | Re-profiling included in 2016 Probable Expenses CERN/FC/6060 | Comparison between 2016 Probable Expenses and 2016 Out-Turn[1] | Carry-forward to 2017[2] |
|---|---|---|---|
| **Operation** | **13,885** | **10,963** | **7,327** |
| LHC programme | 5,295 | 744 | -161 |
| Other programmes | 985 | 4,402 | 2,803 |
| Infrastructure and services | 7,745 | 5,100 | 4,025 |
| R&D studies and projects | -140 | 718 | 660 |
| **Project** | **39,285** | **-3,291** | **-3,291** |
| LHC programme | 4,395 | -4,158 | -4,158 |
| Other programmes | 13,660 | 1,160 | 1,160 |
| Infrastructure and services | 10,690 | 4,799 | 4,799 |
| R&D studies and projects | 10,540 | -5,091 | -5,091 |
| **Total** | **53,170** | **7,673** | **4,037** |

[1] Excluding the exchange gain and losses as compensated by the corresponding revenue.
[2] Calculated versus 2016 Probable Expenses

**Comments on Figure 14:**

The 53.2 MCHF of materials carry forward to 2017 and re-profiling to future years was already included in the 2016 Probable Revenues and Expenses (CERN/FC/6060).

The final comparison between the 2016 Probable Expenses and 2016 Out-Turn results in a further total positive balance for Materials of 7.7 MCHF (+11.0 MCHF for operation and –3.3 MCHF for projects).

On the basis of Article 9 of the CERN Financial Rules "*The budget amounts shall be compared with the amounts of the final budget Out-Turn. The positive balance of that part of the budget which is allocated to multi-annual projects shall be carried-forward to the following year within the Cost-to-Completion. The unused part of the budget allocated to operation shall be carried-forward to the following financial year, provided that it relates to commitments open when the accounts for the financial year concerned are closed. Any excess budget expenses shall be carried forward to the next financial year*", the final calculated carry-forward totals 7.3 MCHF for operation and –3.3 MCHF for projects.

# 5. EU-SUPPORTED PROJECTS

## Figure 15: EU Projects

| Project name | Framework Programme | Project title | Start date | End Date | Total EC contribution kEUR | EC contribution to CERN kEUR | 2016 Out-Turn kCHF | 2016 EU resources kCHF | 2016 additional resources (1) kCHF |
|---|---|---|---|---|---|---|---|---|---|
| EUCard2 | FP7 | Enhanced European Coordination For Accelerator Research And Development | 01-May-13 | 30-Apr-17 | 8,000 | 1,910 | 1,385 | 374 | 1,011 |
| TICAL | FP7 | 4D total absorption imaging calorimeter | 01-Feb-14 | 31-Jan-18 | 2,258 | 2,258 | 530 | 530 | |
| HICCUP | FP7 | High Impact Cross-section Calculations for Unprecedented Precision | 01-Apr-14 | 30-Mar-19 | 1,515 | 1,273 | 325 | 325 | - |
| Best Paths | FP7 | Beyond State-of-the-art technologies for power AC corridors and multi-terminal HVDC systems | 01-Oct-14 | 30-Sep-18 | 35,500 | 804 | 190 | 190 | - |
| Cessamag | FP7 | CERN-EC Support for SESAME Magnets | 01-Nov-12 | 31-Oct-16 | 5,000 | 5,000 | 121 | 121 | - |
| LHCTheory | FP7 | Theoretical predictions and analyses of LHC physics: advancing the precision frontier | 01-Apr-12 | 31-Mar-17 | 2,050 | 1,718 | 104 | 104 | - |
| EuroC | FP7 | European Robotics Challenges | 01-Jan-14 | 31-Dec-17 | 16,500 | 24 | 59 | 59 | - |
| TeraUniverse | FP7 | Exploring The Terauniverse With The Lhc, Astrophysics And Cosmology | 01-Apr-11 | 31-Mar-16 | 1,929 | 433 | 17 | 17 | - |
| Chanda | FP7 | solving CHAllenges in Nuclear Data | 01-Dec-13 | 30-Nov-17 | 5,400 | 117 | 13 | - | 13 |
| GO-Lab | FP7 | Global Online Science Labs for Inquiry Learning at School | 01-Nov-12 | 31-Oct-16 | 9,697 | 168 | 11 | 12 | - 1 |
| HotLHC | FP7 | Hot and dense QCD in the LHC era | 01-Jan-12 | 31-Dec-16 | 1,379 | 151 | 8 | 8 | - |
| EUHit | FP7 | European High-Performance Infrastructures in Turbulence | 01-Apr-13 | 31-Mar-17 | 7,000 | 173 | 2 | 2 | - |
| Citymobil2 | FP7 | Cities Demonstrating Cybernetic Mobility | 01-Sep-12 | 31-Aug-16 | 9,500 | 27 | - | - | - |
| Torch | FP7 | A Large-Aera Detector For Precision Time-of-Flight Measurements | 01-Jun-12 | 31-May-17 | 2,696 | 1,395 | - 330 | - 330 | - |
| | | | | | | | | | |
| AIDA-2020 | H2020 | Advanced European Infrastructures for Detectors at Accelerators | 01-May-15 | 30-Apr-19 | 10,000 | 2,356 | 1,185 | 383 | 802 |
| HNSciCloud | H2020 | Helix Nebula the SCIence Cloud | 01-Jan-16 | 30-Jun-18 | 6,230 | 1,759 | 392 | 297 | 95 |
| QUACO | H2020 | QUAdrupoleCOrrector | 01-Mar-16 | 28-Feb-20 | 4,653 | 3,961 | 350 | 75 | 275 |
| BetaDropMNR | H2020 | Ultra-sensitive NMR in liquids | 01-Oct-15 | 30-Sep-20 | 1,500 | 1,500 | 413 | 305 | 108 |
| THOR | H2020 | Technical and Human Infrastructure for Open | 01-Jun-15 | 30-Nov-17 | 3,456 | 854 | 288 | 288 | - |
| Neonat | H2020 | Understanding the mass scales in nature | 01-Dec-15 | 30-Nov-20 | 1,876 | 1,463 | 216 | 216 | - |
| EUDAT2020 | H2020 | European DATa 2020 | 01-Mar-15 | 28-Feb-18 | 19,200 | 669 | 207 | 207 | - |
| BrightnESS | H2020 | Building a research infrastructure and synergies for highest scientific impact on ESS | 01-Sep-15 | 31-Aug-18 | 19,942 | 715 | 188 | 188 | - |
| ENSAR2 | H2020 | European Nuclear Science and Application Research 2 | 01-Mar-16 | 29-Feb-20 | 10,000 | 983 | 172 | 124 | 48 |
| Indigo-DataClouds | H2020 | INtegrating Distributed data Infrastructures for Global ExplOitation | 01-Apr-15 | 30-Sep-17 | 11,000 | 306 | 115 | 115 | - |
| AARC | H2020 | Authentication and Authorisation for Research and Collaboration | 01-May-15 | 30-Apr-17 | 2,941 | 193 | 113 | 113 | - |
| FAST | H2020 | Fast advanced Scintillator Timing | 01-Jan-15 | 30-Apr-16 | 200 | 200 | 99 | 99 | - |
| OpenAIRE2020 | H2020 | Open Access Infrastructure for Research in Europe | 01-Jan-15 | 30-Jun-18 | 13,000 | 465 | 85 | 85 | - |
| TURBO-PET | H2020 | New high-resolution, high-sensitivity dedicated breast positron emission tomography scanner | 01-Nov-14 | 31-Oct-17 | 2,200 | 95 | 75 | 31 | 44 |
| CREMLIN | H2020 | Connecting Russian and European Measures for Large-scale Research Infrastructures | 01-Sep-15 | 30-Aug-18 | 1,696 | 76 | 74 | 15 | 58 |
| Egi Engage | H2020 | European Grid Infrastructure Engage | 01-Mar-15 | 30-Jul-17 | 8,000 | 138 | 57 | 57 | - |
| ULTIMA | H2020 | ULTrafast Imaging sensor for Medical Applications | 01-Sep-15 | 28-Feb-17 | 150 | 150 | 55 | 55 | - |
| CREATIONS | H2020 | CREATIONS - Developing an Engaging Science Classroom | 01-Oct-15 | 30-Sep-18 | 1,798 | 170 | 44 | 44 | - |
| Eurocircol | H2020 | European Circular Energy-Frontier Collider Study | 01-Jun-15 | 31-May-19 | 2,999 | 138 | 42 | 42 | - |
| MathAM | H2020 | Mathematical Structures in Scattering Amplitudes | 01-Sep-15 | 31-Aug-20 | 1,365 | 943 | 31 | 31 | - |
| Picse | H2020 | Procurement Innovation for Cloud Services in Europe | 01-Oct-14 | 31-Mar-16 | 500 | 187 | 29 | 29 | - |
| Myrte | H2020 | MYRRHA Research and Transmutation Endeavour | 01-Apr-15 | 31-Mar-19 | 8,996 | 106 | 3 | 3 | - |
| ASCIMAT | H2020 | Advanced Scintillation Materials of the Institute of Physics from the Czech Academy of Sciences | 01-Jan-16 | 31-Dec-18 | 999 | 144 | 9 | 9 | |
| | | | | | | Other (2) | 226 | 213 | 13 |
| | | | | | | **TOTAL** | **6,902** | **4,436** | **2,466** |

(1) Costs incurred by CERN and declared to the European Commission as additional contribution: does not take into consideration other direct support and central administrative costs

(2) EU projects administrative support ; costs for obtaining audit certificates

**Comments on Figure 15:**[1]

Figure 15 shows all EU projects, other than Marie Curie projects, still active in 2016. The 2016 figures are split into EU-funded expenses and additional expenses funded by CERN's core budget in line with the specific contracts signed separately for each project. Most of the EU-supported projects concern R&D for accelerators and detectors (CESSAMag, EuCARD-2, Aida2020). The EU resources for projects other than Marie Curie projects have decreased by 38.0%. This decrease is due to the end of major FP7 projects (AIDA, HILUMI, COFUND-2), and to a correction for the TORCH project in the 2015 accounts.

Eleven new EU projects were selected for funding in 2016, with a start date in 2017, in the framework of a total European Commission (EC) contribution of 4.57 MEUR (over a period of 4 years).

The newly selected projects are funded under the following programmes:

- Marie Curie: 5 projects (EC funding for CERN of 1.6 MEUR),
- Excellent Science: 5 projects (EC funding for CERN of 2.6 MEUR),
- Other: 1 project (EC funding for CERN of 0.38 MEUR).

Out of these 11 projects, two are coordinated by CERN and three are mono-site projects (CERN is the only beneficiary of the grant). Of a total number of 155 EU projects funded since 2007, 44 are or have been coordinated by CERN and 36 are or have been mono-site projects.

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[1] This document presents the actual spending of EU projects during the year that will be covered by an EU contribution. The Financial Statements show the same values and in addition the accounting entries (typically the balance when we close a project).

## Figure 16: Marie Curie Projects

| Project name | Framework Programme | Project title | Start date | End Date | Total EC contribution kEUR | EC contribution to CERN kEUR | 2016 Out-Turn kCHF | 2016 EU resources kCHF | 2016 additional resources (1) kCHF |
|---|---|---|---|---|---|---|---|---|---|
| COFUND-4 | FP7 | Cofunding Of The Cern Fellowship Programme 4 | 01-Oct-13 | 30-Sep-18 | 8,000 | 8,000 | 2,288 | 2,288 | - |
| COFUND-3 | FP7 | Cofunding Of The Cern Fellowship Programme 3 | 01-Oct-12 | 30-Sep-17 | 10,000 | 10,000 | 1,673 | 1,673 | - |
| PacMan | FP7 | A Study on Particle Accelerator Components' Metrology and Alignment to the Nanometre scale | 01-Sep-13 | 31-Aug-17 | 2,671 | 2,671 | 983 | 983 | - |
| Ice-Dip | FP7 | Intel-Cern European Doctorate Industrial Program | 01-Feb-13 | 31-Jan-17 | 1,249 | 1,249 | 338 | 338 | - |
| Mcnet-ITN | FP7 | Training Network for Monte Carlo Event Generators for LHC Physics | 01-Jan-13 | 31-Dec-16 | 3,947 | 497 | 202 | 202 | - |
| EFTstrong | FP7 | Effective Theories for Strong Interactions: precison Tools to Meet Experiment | 01-Sep-15 | 31-Aug-17 | 269 | 269 | 146 | 146 | - |
| EPLANET | FP7 | European Particle Physics Latin American Network | 01-Feb-11 | 31-Jan-16 | 3,245 | 2,298 | 124 | 19 | 104 |
| EDUSAFE | FP7 | Education in Advance VR/AR Safety Systems for Maintenance in Extreme Environments | 01-Sep-12 | 31-Aug-16 | 3,121 | 500 | 110 | 110 | - |
| FTK | FP7 | Fast Tracker for Hadron Collider Experiments | 01-Feb-13 | 31-Jan-17 | 1,595 | 187 | 100 | 100 | - |
| HiggsSelfCoupling | FP7 | Precision Higgs Boson Self-Coupling Measurements | 01-Nov-14 | 31-Oct-16 | 199 | 199 | 84 | 84 | - |
| BSMafterLHC8 | FP7 | Directions for BSM Physics after the First Run of the LHC | 01-Oct-14 | 30-Sep-16 | 208 | 208 | 83 | 83 | - |
| Bootstrap | FP7 | Conformal Bootstrap Methods and their applications | 01-Sep-14 | 31-Aug-16 | 208 | 208 | 65 | 65 | - |
| Cloud-TRAIN | FP7 | Cloud Initial Training Network 2 | 01-Oct-12 | 30-Sep-16 | 3,772 | 689 | 53 | 53 | - |
| Ardent | FP7 | Advanced Radiation Dosimetry European Network Training initiative | 01-Feb-12 | 31-Jan-16 | 3,988 | 1,115 | 5 | 5 | - |
| | | | | | | | | | |
| COFUND-5 | H2020 | COFUNDing of the CERN Fellowship Programme 2014 | 01-Oct-15 | 30-Sep-20 | 6,372 | 6,372 | 693 | 693 | - |
| Medicis-Promed | H2020 | MEDICIS-produced radioisotope beams for medicine | 01-Apr-15 | 31-Mar-19 | 2,829 | 796 | 312 | 247 | 66 |
| STREAM | H2020 | Smart Sensor Technologies and Training for Radiation Enhanced Applications and Measurements | 01-Jan-16 | 31-Dec-19 | 3,873 | 707 | 169 | 153 | 16 |
| NP4theLHC14 | H2020 | New Physics for the Large Hadron Collider: new minimal models of composite Higgs — NP4theLHC14 | 01-Oct-15 | 30-Sep-17 | 187 | 187 | 132 | 95 | 37 |
| ResolvedJetsHIC | H2020 | Probing the Strongly-Coupled Quark-Gluon Plasma with Jets — ResolvedJetsHIC | 01-Nov-15 | 31-Oct-17 | 175 | 175 | 138 | 77 | 61 |
| AMVA4NewPhysics | H2020 | Advanced Multi-Variate Analysis for New Physics Searches at the LHC | 01-Sep-15 | 31-Aug-19 | 2,402 | 350 | 77 | 63 | 14 |
| E-jade | H2020 | Europe-Japan Accelerator Development Exchange Programme | 01-Jan-15 | 31-Dec-18 | 1,651 | 628 | 54 | 54 | - |
| Intelum | H2020 | International and intersectoral mobility to develop advanced scintillating fibres and Cerenkov fibres for new hadron and jet calorimeters for future colliders | 01-Mar-15 | 28-Feb-19 | 922 | 102 | 39 | 39 | - |
| PrecisionTools4LHC | H2020 | High precision predictions and tools for LHC Physics | 01-Oct-16 | 30-Sep-18 | 175 | 175 | 34 | 23 | 12 |
| Invisibles Plus | H2020 | invisibles neutinos, dark matter & dark energy physics | 01-Feb-16 | 31-Jan-20 | 2,070 | 130 | 13 | 13 | - |
| OMA | H2020 | Optimization of Medical Accelerators | 01-Feb-16 | 31-Jan-20 | 3,872 | 265 | 13 | 13 | - |
| Mixmax | H2020 | Development and Implementation of new generation of Pseudo Random Number Generators based on Kolmogorov-Anosov K-systems | 01-Jan-15 | 31-Dec-18 | 252 | 18 | 2 | 2 | - |
| | | | | | | Other (2) | 290 | 290 | - |
| | | | | | | **TOTAL** | **8,220** | **7,911** | **310** |

(1) Costs incurred by CERN as additional support to the projects: does not take into consideration other direct support and central administrative costs

(2) HR-TA andFAP-EF expenses for Marie Curie projects administration and financial management

### Comments on Figure 16:

Figure 16 shows all EU Marie Curie projects at CERN still active in 2016. The 2016 figures are split into EU-funded expenses and additional expenses funded by CERN's core budget in line with the specific contract signed separately for each project.

In 2016, Marie Curie projects represented 64% of CERN's total EU funding. This is mostly due to the four-year Initial Training Networks and COFUND projects, which co-fund the CERN fellowship programme.

The EU funding for Marie Curie projects decreased by 22% in 2016, due to the end of 16 projects since 2015, including one COFUND project, and the long implementation of the new ones, such as the RISE projects.

**Figure 17: EU Projects financial status – Projects completed in 2016**

| Project | Framework Programme | Start date | End Date | EU contribution for CERN - kEUR | % completion (time) | % contribution used |
|---|---|---|---|---|---|---|
| Ardent | FP7 | 01-Feb-12 | 31-Jan-16 | 1,115 | 100.00% | 100.00% |
| EPLANET | FP7 | 01-Feb-11 | 31-Jan-16 | 2,298 | 100.00% | 83.38% |
| TeraUniverse | FP7 | 01-Apr-11 | 31-Mar-16 | 433 | 100.00% | 91.55% |
| Bootstrap | FP7 | 01-Sep-14 | 31-Aug-16 | 208 | 100.00% | 100.00% |
| Citymobil2 | FP7 | 01-Sep-12 | 31-Aug-16 | 27 | 100.00% | 86.08% |
| EDUSAFE | FP7 | 01-Sep-12 | 31-Aug-16 | 500 | 100.00% | 96.24% |
| BSMafterLHC8 | FP7 | 01-Oct-14 | 30-Sep-16 | 208 | 100.00% | 100.00% |
| Cloud-TRAIN | FP7 | 01-Oct-12 | 30-Sep-16 | 689 | 100.00% | 100.00% |
| Cessamag | FP7 | 01-Nov-12 | 31-Oct-16 | 5,000 | 100.00% | 100.00% |
| GO-Lab | FP7 | 01-Nov-12 | 31-Oct-16 | 168 | 100.00% | 96.40% |
| HiggsSelfCoupling | FP7 | 01-Nov-14 | 31-Oct-16 | 199 | 100.00% | 100.00% |
| Mcnet-ITN | FP7 | 01-Jan-13 | 31-Dec-16 | 497 | 100.00% | 93.30% |
| | | | | | | |
| Picse | H2020 | 01-Oct-14 | 31-Mar-16 | 187 | 100.00% | 100.00% |
| | | | | | **Average** | **96%** |

**Comments on Figure 17:**

Figure 17 shows the use of EU contributions at CERN for the whole duration of finished projects with a financial activity in 2016.

The utilisation rate of the EU financial contribution amounted to 96% on average. Lower use of contributions can be due either to the difference between flat rates used by the EC to compute the financial contribution and the real costs incurred by the Organization (Marie Curie projects) or to the over-estimation of the overall effort in the initial budget.

# Figure 18: EU Projects financial status – On-going projects

**FP7 - On-going projects**

| Project | Framework Programme | Start date | End Date | Max. contribution (Total) - kEUR | EU contribution for CERN - kEUR | % completion (time) | % contribution used |
|---|---|---|---|---|---|---|---|
| Ardent | FP7 | 01-Feb-12 | 31-Jan-16 | 3,988 | 1,115 | 100.00% | 100.00% |
| Best Paths | FP7 | 01-Oct-14 | 30-Sep-18 | 35,500 | 804 | 56.30% | 32.29% |
| Bootstrap | FP7 | 01-Sep-14 | 31-Aug-16 | 208 | 208 | 100.00% | 100.00% |
| BSMafterLHC8 | FP7 | 01-Oct-14 | 30-Sep-16 | 208 | 208 | 100.00% | 100.00% |
| Cessamag | FP7 | 01-Nov-12 | 31-Oct-16 | 5,000 | 5,000 | 100.00% | 100.00% |
| Chanda | FP7 | 01-Dec-13 | 30-Nov-17 | 5,400 | 117 | 77.12% | 100.00% |
| Citymobil2 | FP7 | 01-Sep-12 | 31-Aug-16 | 9,500 | 27 | 100.00% | 86.08% |
| Cloud-TRAIN | FP7 | 01-Oct-12 | 30-Sep-16 | 3,772 | 689 | 100.00% | 100.00% |
| COFUND-3 | FP7 | 01-Oct-12 | 30-Sep-17 | 10,000 | 10,000 | 85.04% | 67.21% |
| COFUND-4 | FP7 | 01-Oct-13 | 30-Sep-18 | 8,000 | 8,000 | 65.04% | 49.88% |
| EDUSAFE | FP7 | 01-Sep-12 | 31-Aug-16 | 3,121 | 500 | 100.00% | 96.24% |
| EFTstrong | FP7 | 01-Sep-15 | 31-Aug-17 | 269 | 269 | 66.71% | 66.43% |
| EPLANET | FP7 | 01-Feb-11 | 31-Jan-16 | 3,245 | 2,298 | 100.00% | 83.38% |
| EUCard2 | FP7 | 01-May-13 | 30-Apr-17 | 8,000 | 1,910 | 91.78% | 70.52% |
| EUHit | FP7 | 01-Apr-13 | 31-Mar-17 | 7,000 | 173 | 93.84% | 40.46% |
| EuroC | FP7 | 01-Jan-14 | 31-Dec-17 | 16,500 | 24 | 75.00% | 100.00% |
| FTK | FP7 | 01-Feb-13 | 31-Jan-17 | 1,595 | 187 | 97.88% | 99.80% |
| GO-Lab | FP7 | 01-Nov-12 | 31-Oct-16 | 9,697 | 168 | 100.00% | 96.40% |
| HICCUP | FP7 | 01-Apr-14 | 30-Mar-19 | 1,515 | 1,273 | 55.10% | 30.53% |
| HiggsSelfCoupling | FP7 | 01-Nov-14 | 31-Oct-16 | 199 | 199 | 100.00% | 100.00% |
| HotLHC | FP7 | 01-Jan-12 | 31-Dec-16 | 1,379 | 151 | 100.00% | 63.29% |
| Ice-Dip | FP7 | 01-Feb-13 | 31-Jan-17 | 1,249 | 1,249 | 97.88% | 100.00% |
| LHCTheory | FP7 | 01-Apr-12 | 31-Mar-17 | 2,050 | 1,718 | 95.07% | 89.20% |
| Mcnet-ITN | FP7 | 01-Jan-13 | 31-Dec-16 | 3,947 | 497 | 100.00% | 93.30% |
| PacMan | FP7 | 01-Sep-13 | 31-Aug-17 | 2,671 | 2,671 | 83.36% | 99.00% |
| TeraUniverse | FP7 | 01-Apr-11 | 31-Mar-16 | 1,929 | 433 | 100.00% | 91.55% |
| TICAL | FP7 | 01-Feb-14 | 31-Jan-18 | 2,258 | 2,258 | 72.88% | 63.47% |
| Torch | FP7 | 01-Jun-12 | 31-May-17 | 2,696 | 1,395 | 91.73% | 51.94% |
|  |  |  |  |  | **Average** | **89%** | **81%** |

**H2020 - On-going projects**

| Project | Framework Programme | Start date | End Date | Max. contribution (Total) - kEUR | EU contribution for CERN - kEUR | % completion (time) | % contribution used |
|---|---|---|---|---|---|---|---|
| AARC | H2020 | 01-May-15 | 30-Apr-17 | 2,941 | 193 | 83.56% | 72.72% |
| AIDA-2020 | H2020 | 01-May-15 | 30-Apr-19 | 10,000 | 2,356 | 41.78% | 26.18% |
| AMVA4NewPhysics | H2020 | 01-Sep-15 | 31-Aug-19 | 2,402 | 700 | 33.36% | 8.20% |
| ASCIMAT | H2020 | 01-Jan-16 | 31-Dec-18 | 999 | 144 | 33.33% | 5.88% |
| BetaDropMNR | H2020 | 01-Oct-15 | 30-Sep-20 | 1,500 | 1,500 | 25.03% | 23.24% |
| BrightnESS | H2020 | 01-Sep-15 | 31-Aug-18 | 19,942 | 715 | 44.47% | 24.21% |
| COFUND-5 | H2020 | 01-Oct-15 | 30-Sep-20 | 6,372 | 6,372 | 25.03% | 9.98% |
| Creations | H2020 | 01-Oct-15 | 30-Sep-18 | 1,798 | 170 | 41.74% | 24.00% |
| Cremlin | H2020 | 01-Sep-15 | 30-Aug-18 | 1,696 | 76 | 44.52% | 18.37% |
| Egi Engage | H2020 | 01-Mar-15 | 30-Jul-17 | 8,000 | 81 | 76.08% | 100.00% |
| E-jade | H2020 | 01-Jan-15 | 31-Dec-18 | 581 | 628 | 50.00% | 9.18% |
| ENSAR2 | H2020 | 01-Mar-16 | 29-Feb-20 | 10,000 | 983 | 20.89% | 11.55% |
| EUDAT2020 | H2020 | 01-Mar-15 | 28-Feb-18 | 19,200 | 669 | 61.28% | 44.08% |
| Eurocircol | H2020 | 01-Jun-15 | 31-May-19 | 2,999 | 138 | 39.66% | 27.83% |
| FAST | H2020 | 20-Nov-14 | 20-Nov-18 | 200 | 200 | 52.84% | 68.52% |
| HNSciCloud | H2020 | 01-Jan-16 | 30-Jun-18 | 6,230 | 1,759 | 40.07% | 15.48% |
| Indigo-DataClouds | H2020 | 01-Apr-15 | 30-Sep-17 | 11,000 | 306 | 70.10% | 60.55% |
| Intelum | H2020 | 01-Mar-15 | 28-Feb-19 | 922 | 102 | 45.96% | 53.51% |
| Invisibles Plus | H2020 | 01-Feb-16 | 31-Jan-20 | 2,070 | 130 | 22.88% | 9.50% |
| MathAM | H2020 | 01-Sep-15 | 31-Aug-20 | 1,365 | 943 | 26.67% | 3.01% |
| Medicis-Promed | H2020 | 01-Apr-15 | 31-Mar-19 | 2,829 | 796 | 43.84% | 30.88% |
| Mixmax | H2020 | 01-Jan-15 | 31-Dec-18 | 252 | 18 | 50.00% | 8.97% |
| Myrte | H2020 | 01-Apr-15 | 31-Mar-19 | 8,996 | 106 | 43.84% | 3.10% |
| Neonat | H2020 | 01-Dec-15 | 30-Nov-20 | 1,876 | 1,463 | 21.69% | 13.56% |
| NP4theLHC14 | H2020 | 01-Oct-15 | 30-Sep-17 | 187 | 187 | 62.60% | 58.84% |
| OMA | H2020 | 01-Feb-16 | 31-Jan-20 | 3,872 | 265 | 22.88% | 4.35% |
| OpenAIRE2020 | H2020 | 01-Jan-15 | 30-Jun-18 | 13,000 | 465 | 57.21% | 51.77% |
| Picse | H2020 | 01-Oct-14 | 31-Mar-16 | 500 | 187 | 100.00% | 97.08% |
| PrecisionTools4LHC | H2020 | 01-Oct-16 | 30-Sep-18 | 175 | 175 | 12.48% | 11.89% |
| QUACO | H2020 | 01-Mar-16 | 28-Feb-20 | 4,653 | 3,961 | 20.90% | 1.73% |
| ResolvedJetsHIC | H2020 | 01-Nov-15 | 31-Oct-17 | 175 | 175 | 58.36% | 51.25% |
| STREAM | H2020 | 01-Jan-16 | 31-Dec-19 | 3,873 | 707 | 25.00% | 19.86% |
| THOR | H2020 | 01-Jun-15 | 30-Nov-17 | 3,456 | 854 | 63.42% | 44.67% |
| TURBO-PET | H2020 | 01-Nov-14 | 31-Oct-17 | 2,200 | 95 | 72.24% | 31.85% |
| ULTIMA | H2020 | 01-Sep-15 | 28-Feb-17 | 150 | 150 | 89.19% | 34.65% |
|  |  |  |  |  | **Average** | **46%** | **31%** |

**Comments on Figure 18:**

Figure 18 shows the amount of time spent on each EU project compared to the overall completion time and the percentage of the EU contribution used as at 31 December 2016. The discrepancy in H2020 projects between the completion time and the amount of the contribution used is explained by:

- the 2 PCP projects (Quaco and HNSciCloud), for which the costs for the PCP are foreseen in Year 2;
- the difficulties in implementing the secondment of 3 RISE projects;
- the slow implementation of COFUND-5, for which only 18 ESR of the 60 planned started in 2016;
- the late recruitment of personnel on ITN and ERC projects;

The expenses for the projects shown as underspending in figure 18 will be balanced in the coming years.

## AIDA 2020

In spring 2017, the AIDA-2020 project (coordinated by CERN) will be approaching completion of the first two years of activities. Since the beginning of the project, the 15 work packages (of which 6 are coordinated by CERN staff together with a second coordinator from another institute) have been the subject over 80 meetings. The First Annual Meeting took place at DESY in Hamburg with 135 participants. Members of the project have produced more than 30 publications, including journal papers and conference proceedings. About 40 communication and dissemination activities, including posters, talks and press articles have been registered.

CERN teams are actively involved in most of the work packages and have significantly contributed to the advances made in AIDA-2020 during the year. A few examples are given below:

After an early launch of the project web-side and the newsletter "On Track", activities in **WP2 (Innovation and Outreach)** turned to producing informative videos to illustrate the capacities of the nine facilities provided under the AIDA-2020 Transnational Access programme. Moreover, a technology landscape report was delivered, giving insight into the domains of detector technology where dissemination from research to industry is highest. In summer 2016, AIDA-2020, through WP2, had opened a call for proposals for its Proof-of-Concept innovation fund. It received 11 good applications, and three successful applicants have since been selected for funding.

In **WP3 (Advanced Software)**, the six milestones met during 2016 included enhancements to the geometry package DD4Hep, design documents for a new Event Data Model and a running prototype for a Geant4-based simulation toolkit using USolids with realistic LHC geometries.

Major CERN contributions to **WP7 (Advanced Hybrid Pixel Detectors)** were made in the areas of dedicated simulations (TCAD) of silicon sensors and through the validation of pixel detector prototypes in several test-beam campaigns. The combined results of tests and simulations led to an optimised layout ("active-edge") for future sensor productions.

Prototypes of standard micro-fabrication technologies for silicon cooling devices were produced as part of WP9 (New Support Structures and Micro-Channel Cooling). Important progress has also been made in the field of miniaturised high-pressure hydraulic connectors.

The Transnational Access to CERN PS and SPS test beams (the CERN part of **WP10**) supported more than 200 users. Close to 10% of the access units was granted to user groups from non-EU or associated countries. The Transnational Access to the GIF++ Gamma Irradiation Facility and the IRRAD Proton Irradiation Facility (**WP11**) allowed more than 50 users to either benefit from financial support in performing their irradiation experiments at CERN or to gain access to irradiation tests performed by the irradiation facilities' operation teams.

In **WP 14 (Infrastructure for Advanced Calorimeters)** significant progress was made on irradiated silicon sensor systems for highly granular calorimeters at the LHC. Moreover, work on the improvement of a light-attenuation bench to characterize long scintillating fibres with several excitation wavelengths resulted in a system which allows the transport of light from a large range of scintillator materials.

For **WP15 (Upgrade of Beam and Irradiation Test Infrastructure),** important milestones have been achieved such as the specifications for an online user and sample management system for the IRRAD proton facility and the design of an upgraded cosmic tracker for the Gamma Irradiation Facility (GIF++) at CERN. The delivery and commissioning of a new particle beam pixel telescope was completed ahead of schedule, and the telescope is now operational at the CERN PS.

## EuCARD-2

The EuCARD-2 project promotes a coordinated R&D effort to develop the next generation of particle accelerators. It brings together more than 300 participants from 40 universities, research laboratories and industries working on 12 advanced Work packages covering key accelerator technologies and provides access to three test facilities. The project started in May 2013 and will be completed in April 2017. During 2016, the project has finalised some key milestones and deliverables, in preparation for the final reporting that will take place in early 2017.

The 16 deliverable reports produced in 2016 marked the progress made in many different fields. Two reports have assessed the industrial potential of proton acceleration of low and intermediate energies for domains as varied as material testing, boron neutron capture therapy, heating of fusion plasmas, special isotope production, nuclear imaging and diagnostics (Positron Emission Tomography, PET, and Single Photon Emission Computed Tomography, SPECT), and production of radioisotopes as therapeutic agents for cancer treatments. Four detailed reports have analysed the future development strategies for the advanced European accelerator infrastructure: particle colliders, high-performance hadron rings, high-power high-current superconducting linacs, and polarised beam accelerators. Simulation of new collimator materials, and energy storage and virtual power plant approaches for large accelerator facilities, were other subjects analysed during the past year. Considerable progress was made as well in the field of novel plasma wakefield accelerator techniques, where the new design study for a pilot plasma-based user facility promoted by EuCARD-2 (EuPRAXIA) gained considerable momentum, involving a wide scientific community.

In 2016 the project organised or co-organised 21 workshops on advanced subjects related to future accelerator technologies. Some of these workshops were devoted to applications of accelerators for medicine, industry and the environment, the focus of the year in this respect being an event on low-energy electron beams for industrial and environmental applications that attracted wide industrial participation. Other subjects included the global efficiency of proton driver accelerators, coordination of European superconducting magnet test stands, technological challenges shared by lowemittance rings, and upgrading strategies for high-power proton linacs. Finally, an end-of-year workshop in Scharbeutz (Germany) gathered together 25 accelerator experts from around the world with experience in different accelerator technologies with the goal of figuring out how the particle accelerator landscape will look at the end of this century. Are we moving towards larger global accelerators or smaller distributed facilities? Are accelerators going to be widely installed in industries and hospitals, or will they remain specialised instruments reserved for scientific institutions? Are we going to see miniaturised accelerators on electronic chips or attached to lasers? Not surprisingly, the expert panel agreed in identifying some common trends and in predicting a bright future for particle accelerator technologies.

### CESSAMag

The acceptance tests on the last batches of SESAME magnets were successfully passed in early 2016, and the batches were shipped to SESAME. By the end of March 2016, all magnets had been delivered to SESAME on time. The powering scheme followed suit, arriving in SESAME in February 2016. Unfortunately, some limited mechanical damage and pollution of electronic cards by salted water was observed in some racks. After rinsing the electronics and replacing the damaged parts, the system was fully operational in August 2016, with no impact on quality or schedule.

The bulk of the CESSAMag activity in 2016 was directed towards supporting installation and commissioning. In the early part of the year, the survey network was established, connected to the network of the injectors and extended to the experimental areas. The same network was checked after the end of installation in November, to verify the impact of the removal and reinstallation of the concrete ceiling of the machine tunnel, and was properly corrected. The girders were aligned after installation, and a first machine cell was installed and aligned in the second quarter of 2016. This was used to refine and formalize the installation strategy to be followed by the SESAME team for the 15 other cells. In November 2016, in collaboration with the SESAME team, the hardware commissioning of the CESSAMag equipment was carried out: for the magnets, this consisted of tests of interconnections, tests of polarities, adjustment of thresholds for interlock circuits, and thermal checks of interconnections at full power; some high voltage tests could not be carried out, due to the insufficient insulating properties of the cooling water, which was due to be improved. For the powering scheme, all connections were checked, as were polarities, communication with the control system, and interlocks. Some minor errors were corrected. Finally, and for the first time, the dipole chain was powered to its nominal excitation, corresponding to 2.5 GeV, for 6 hours; the stability and noise were monitored and found to be within specifications. The CESSAMag activities are coming to an end with the closure of the books and the production of a large number of deliverable reports, the activity reports for the second period and the final report. A concluding communication on science for peace (the final deliverable) was produced, co-signed by CERN, the European Commission and SESAME.

In January 2017, we were informed of the first beam in the storage ring, and the opening ceremony is scheduled for May 2017, to be attended by a CERN delegation including the Director-General.

## 6. NEW COLLABORATION AGREEMENTS

| Country / Organization | Agreement Reference | Title |
|---|---|---|
| Brazil | P132 | Protocol to the Co-operation Agreement dated 13 September 2006 between the European Organization for Nuclear Research (CERN) and O Conselho Nacionalde Desenvolvimento Cientifico e Tecnologicodo Brasil (CNPq) concerning Scientific and Technical Co-operation in High-Energy Physics |
| Estonia | P133 | Protocol to the 2010 Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Republic of Estonia concerning participation of Universities and Scientific Institutions from the Republic of Estonia in CERN's scientific programme |
| Georgia | P119/A2 | Addendum N. 2 to Protocol P119 to the 2008 Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Government of Georgia concerning collaboration in integration work aimed at comparing engineering models and as-built LHC Long Straight Sectionelements for the High Luminosity LHC Project at CERN |
| India | P074/LHC/LINAC4/W2 | Addendum N. LINAC4/W2 to the Protocol dated 15 February 2006 to the 1991 Co-operation Agreement, as extended in 2001 and in 2011 between CERN and the Department of Atomic Energy (DAE) of the Government of India concerning joint participation in LINAC4 under the Novel Accelerator Technologies project (NAT). This Addendum defines the collaboration between<br>CERN and the Department of Atomic Energy (DAE) of the Government of India for the construction of waveguide couplers for the LINAC4 Project at CERN |
| Japan | P090/CTF/8 | Implementation Contract between KEK and CERN concerning mutual CERN-KEK Offices for the Promotion of Collaborative Projects concerning Accelerator Science |
| Japan | P090/CTF/9 | Collaborative Research Contract between CERN and KEK concerning collaboration on High Gradient Accelerator Technology Centred at Fabrication and Tests of X-Band Accelerating Structures (KEK) |
| Latvia | ICA-LV-0137 | Cooperation Agreement between the European Organization for Nuclear Research (CERN) and the Government of the Republic of Latvia concerning Scientific and Technical Cooperation in High-Energy Physics |
| Malta | P121/A3 | Addendum N. 3 to Protocol P121 to the 2008 Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Government of the Republic of Malta concerning collaboration in magnetic field modeling and measurement techniques for the control of particle accelerators |
| Malta | P121/A4 | Addendum N. 4 to Protocol P121 to the 2008 Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Government of the Republic of Malta concerning collaboration in the development of control software for the LHC collimation system of the Large Hadron Collider (LHC) at CERN |
| Qatar | ICA-QA-0136 | Cooperation Agreement between the European Organization for Nuclear Research (CERN) and the Qatar Foundation for Education, Science |

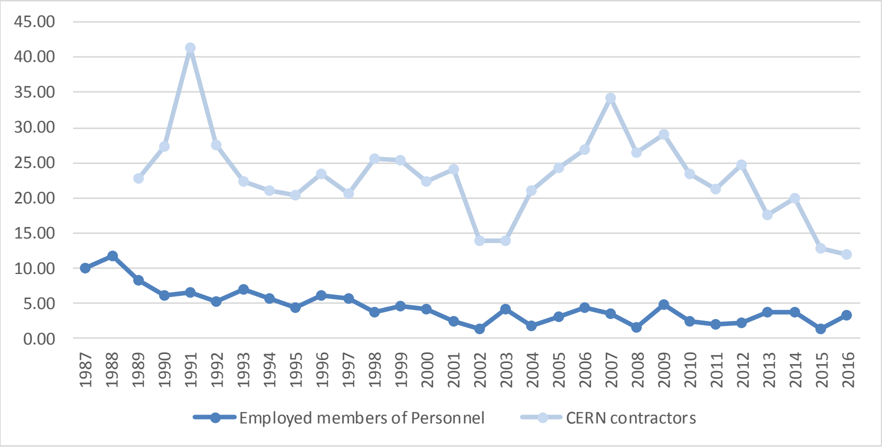
| | | |
|---|---|---|
| | | and Community Development concerning Scientific and Technical Cooperation in High-Energy Physics |
| JINR | P115/A2 | Addendum P115/A.2 to Protocol P115 to the 2010 Co-operation Agreement concerning scientific and technical co-operation between the European Organization for Nuclear Research (CERN)and the Joint Institute for Nuclear Research(JINR) concerning collaboration in software development for administrative applications |
| JINR | P123/A1 | Addendum N. 1 to the 2015 Protocol P123 to the 2010 Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Joint Institute for Nuclear Research (JINR) concerning collaboration in the design, manufacture and assembly of Precision Laser Inclinometer to monitor ground angular oscillations during the LHC operations with the aim of studying their effects on the luminosity for the High Luminosity LHC beam delivered to the ATLAS Experiment |
| JINR | P124/A2 | Addendum Nº 2 to Protocol P124 to the 2010 Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Joint Institute for Nuclear Research (JINR) concerning work concerning various steel structures in concerning the NP01, NP02, NP03, NP04 and NP05 projects in the Neutrino Platform |
| Russia | P068/LHC/A3 | Addendum A3 to Protocol P068/LHC concerning participation in the experimental programme at the Large Hadron Collider (LHC). Protocol concerning contributions of the Russian Teams to the LHC experiments covering Maintenance and Operation expenditures at CERN in 2016 |
| Russia | P109/A12 | Addendum N. P109/A12 to the 2013 Protocol concerning scientific collaboration between the European Organization for Nuclear Research (CERN) and the National Research Centre Kurchatov Institute (NRC KI) to the 1993 Co-operation Agreement between the Government of the Russian Federation and CERN concerning participation of the State Research Center of the Russian Federation- Institute for High Energy Physics (IHEP)in the 2017 campaign of upgrade of the Beam Loss Monitor (BLM) system of the CERN accelerator chain during Extended Year-End Technical Stop (EYETS) |
| Russia | P109/A13 | Addendum Nº P109/A13 to the 2013 Protocol concerning scientific collaboration between the European Organisation for Nuclear Research (CERN) and the National Research Centre Kurchatov Institute (NRC-KI) to the 1993 Co-operation Agreement between the Government of the Russian Federation and CERN concerning additional work for the production of Ionization Chambers of the Beam Loss Monitoring system at CERN |
| Russia | P110/A3 | Addendum N. P110/A3 to the 2013 Protocol concerning scientific collaboration between the European Organization for Nuclear Research (CERN) and the Budker Institute of Nuclear Physics (BINP) |

## 7. OCCUPATIONAL ACCIDENTS

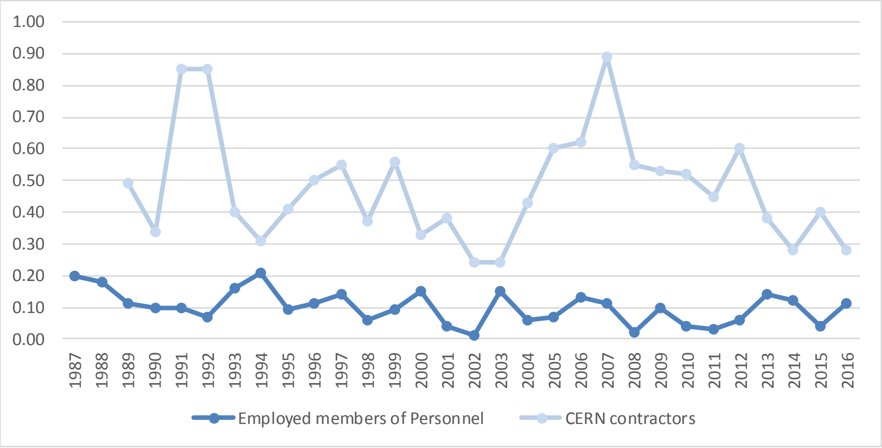
### Figure 19a: Frequency and Severity rates over the last 30 years

| Year | Employed members of the personnel | | CERN Contractors | |
|---|---|---|---|---|
| | Frequency rate | Severity rate | Frequency rate | Severity rate |
| 1987 | 10.00 | 0.20 | | |
| 1988 | 11.70 | 0.18 | | |
| 1989 | 8.30 | 0.11 | 22.78 | 0.49 |
| 1990 | 6.20 | 0.10 | 27.33 | 0.34 |
| 1991 | 6.60 | 0.10 | 41.45 | 0.85 |
| 1992 | 5.20 | 0.07 | 27.43 | 0.85 |
| 1993 | 7.03 | 0.16 | 22.30 | 0.40 |
| 1994 | 5.70 | 0.21 | 20.94 | 0.31 |
| 1995 | 4.33 | 0.09 | 20.30 | 0.41 |
| 1996 | 6.17 | 0.11 | 23.48 | 0.50 |
| 1997 | 5.81 | 0.14 | 20.70 | 0.55 |
| 1998 | 3.82 | 0.06 | 25.52 | 0.37 |
| 1999 | 4.66 | 0.09 | 25.39 | 0.56 |
| 2000 | 4.14 | 0.15 | 22.40 | 0.33 |
| 2001 | 2.50 | 0.04 | 24.12 | 0.38 |
| 2002 | 1.37 | 0.01 | 13.83 | 0.24 |
| 2003 | 4.15 | 0.15 | 13.83 | 0.24 |
| 2004 | 1.74 | 0.06 | 21.00 | 0.43 |
| 2005 | 3.02 | 0.07 | 24.20 | 0.60 |
| 2006 | 4.33 | 0.13 | 26.91 | 0.62 |
| 2007 | 3.63 | 0.11 | 34.31 | 0.89 |
| 2008 | 1.62 | 0.02 | 26.54 | 0.55 |
| 2009 | 4.77 | 0.10 | 29.00 | 0.53 |
| 2010 | 2.39 | 0.04 | 23.33 | 0.52 |
| 2011 | 1.97 | 0.03 | 21.33 | 0.45 |
| 2012 | 2.27 | 0.06 | 24.62 | 0.60 |
| 2013 | 3.80 | 0.14 | 17.67 | 0.38 |
| 2014 | 3.75 | 0.12 | 19.98 | 0.28 |
| 2015 | 1.36 | 0.04 | 12.82 | 0.40 |
| 2016 | 3.40 | 0.11 | 11.92 | 0.28 |

### Figure 19b: Frequency rate over the last 30 years



### Figure 19c: Severity rate over the last 30 years



**Comments on Figure 19a:**

| **2016** | Number of accidents | Number of accidents leading to absence | Number of days of absence |
|---|---|---|---|
| Employed members of the personnel | 103 | 32 | 1 059.1 |
| Associated members of the personnel | 53 | na | na |
| CERN Contractors | 78 | 31 | 716.5 |

The frequency and severity rates are calculated as followed:

$$\text{Frequency Rate} = \frac{\text{Number of accidents with days off}}{\text{Number of hours worked per year}} \times 1{,}000{,}000$$

$$\text{Severity Rate} = \frac{\text{Number of days off}}{\text{Number of hours worked per year}} \times 1{,}000$$

For associated members of the personnel, CERN has no knowledge of the number of working hours, nor of the number of days off following an occupational accident. Therefore, CERN cannot calculate the evolution of the frequency and severity rates for this category of personnel.

## 8. LIST OF ACRONYMS

| | Acronym | Meaning | Complementary information |
|---|---|---|---|
| **A** | AAAS | American Association for the Advancement of Science | |
| | AARC | Authentication and Authorisation for Research and Collaboration | |
| | ACT | ALICE Configuration Tool | |
| | AD | Antiproton Decelerator | Decelerator in use since 2000, decelerating the antiproton beam from the Momentum of 3.57 GeV/c to 100 MeV/c. |
| | AF | Architects Forum | Coordination of common application – part of the LHC Grid organisation |
| | ALARA | As Low As Reasonably Achievable | Concept or philosophy that assumes that there is no “safe” dose of radiation. Under this assumption, the probability for harmful biological effects increases with increased radiation dose, no matter how small. Therefore, it is important to keep radiation doses to affected populations (for example, radiation workers, minors, visitors, students, members of the general public, etc.) as low as is reasonably achievable. |
| | ALICE | A Large Ion Collider Experiment | Experiment at the LHC |
| | ATF | Accelerator Test Facility | |
| | ATLAS | A Toroidal LHC ApparatuS | Experiment at the LHC |
| | ATS | Accelerator and Technology sector | |
| | AWAKE | Advanced WAKefield Experiment | The AWAKE project has been proposed as an approach to accelerate an electron beam to the TeV energy regime in a single plasma section. |
| **B** | BASE | Baryon Antibaryon Symmetry Experiment | |
| | β∗ | Beam size at the interaction point | |

| Acronym | Meaning | Complementary information |
|---|---|---|
| BE | Beams department | |
| BE-RF | BE Radio-Frequency group | |
| BRIL | CMS Beam Radiation Instrumentation and Luminosity | |

**C**

| | | |
|---|---|---|
| CAD | Computer-Aided Design | |
| CAE | Computer-Aided Engineering | |
| CALICE | CAlorimeter for LInear Collider Experiment | Collaboration to develop new, high performance detectors for high energy positron-electron experiments at future International Linear Collider |
| CAST | CERN Axion Solar Telescope | A solar axion search using a decommissioned LHC test magnet. |
| CB | Collaboration Board | |
| CBD | Cumulative Budget Deficit | |
| CDR | Conceptual Design Report | |
| CERN | Conseil Européen pour la Recherche Nucléaire | European Organization for Particle physics. |
| CESSAMag | CERN-EC Support for SESAME Magnets | |
| CLIC | Compact Linear Collider | |
| CLICdp | CLIC Detector and Physics study | |
| CLOUD | PS 215 experiment or CLOUD (Cosmics Leaving Outdoor Droplets) | A study of the link between cosmic rays and clouds with a cloud chamber at the CERN PS. |
| CMASC | CERN Medical Applications Steering Committee | |

| **Acronym** | **Meaning** | **Complementary information** |
|---|---|---|
| CMOS | Complementary Metal-Oxide Semiconductor | |
| CMS | Compact Muon Solenoid | Experiment at the LHC. |
| CNGS | CERN Neutrino to Gran Sasso | Experiment aimed at investigating the neutrino oscillations. |
| COMPASS | Common Muon and Proton Apparatus for Structure and Spectroscopy (NA58 experiment) | High-energy physics experiment at the Super Proton Synchrotron (SPS). |
| CP | Charge and Parity | |
| CPU | Central Processing Unit | |
| C-RRB | (LHC) Computing Resources Review Board | |
| C-RSG | Computing Resources Scrutiny Group | |
| CtC | Cost-to-Completion | |
| CTF3 | CLIC Test Facility | |
| CVI | Cost Variation Index | |

**D**

| | | |
|---|---|---|
| DAQ | Data Acquisition System | |
| DCAL | ALICE Di-jet Calorimeter | |
| DCS | Detector Control System | |
| DG | Director-General | |
| DG CNECT | Directorate-General for Communications Networks, Content and Technology (EU) | |

| Acronym | Meaning | Complementary information |
|---|---|---|
| DG RTD | Directorate-General for Research and Innovation (EU) | |
| DOE | Department of Energy (USA) | |
| DQW | Double-Quarter Wave | |
| DUNE | Deep Underground Neutrino Experiment | |
| **E** EA | East Area | |
| EAR-2 | Experimental Area 2 | New experimental area for n_TOF. |
| EC | European Commission | |
| ECAL | Electromagnetic CALorimeter | Calorimeter part of CMS. |
| ECS | Experiment Control System | |
| EDMS | Engineering Data Management Service | |
| EGI-ENGAGE | Engaging the Research Community towards an Open Science Commons | |
| EHN1 | | The Experimental Hall located on the Prevessin site, the largest surface hall at CERN |
| ELENA | Extra Low Energy Antiprotons | ELENA is a compact ring for cooling and further deceleration of 5.3 MeV antiprotons delivered by the CERN Antiproton Decelerator (AD). |
| EN | Engineering department | |
| EN-MME | EN Mechanical & Materials Engineering group | |
| EP | Experimental Physics Department | |

| Acronym | Meaning | Complementary information |
|---|---|---|
| EP-DT | EP Detector Technologies group | |
| EP-ESE | EP Electronic Systems to Experiments group | |
| EP-SFT | EP SoFTware Development for Experiments group | |
| ERP | Enterprise Resource Planning | |
| ESOF | EuroScience Open Forum | |
| ESPP | European Strategy for Particle Physics | |
| ESS | European Spallation Source | Project to realise a research centre in Lund (Sweden) for the study of materials using beams of slow neutrons. |
| EU | European Union | EU is used in this document as short form for EU commission supported project. |
| EUDAT2020 | | Horizon 2020 project EUDAT: the collaborative Pan-European infrastructure providing research data services, training and consultancy for researches, research communities and research infrastructures and data centers |
| EVM | Earned Value Management | |
| EYETS | Extended Year End Technical Stop | Technical stop end of 2016-april 2017 |
| FAP | Finance and Administrative Processes Department | |
| fb-1 | Inverse Femtobarn | A measure of the integrated luminosity. |
| FCC | Future Circular Collider | |
| FELs | Free Electron Lasers | |
| FIPOI | Fondation des Immeubles Pour les Organisations Internationales | Non-profit organization in Geneva to help International Organizations with office space via financing solutions, renting and consulting. |

**F**

| | Acronym | Meaning | Complementary information |
|---|---|---|---|
| | FNAL | Fermi National Accelerator Laboratory (Fermilab) | |
| | FP7 | Framework Program 7 | |
| | FSU | Field Support Unit | |
| | FTA | Active Full Time Equivalent | This includes everybody who is not unavailable due to leave entitlements built up in the past. |
| | FTE | Full Time Equivalent | |
| **G** | GBAR | Gravitational Behavior of Antihydrogen at Rest | Research program with the Antiproton Decelerator (AD) allowing to prepare a measurement of the effect of gravity on antihydrogen atoms. |
| | GDB | Grid Deployment Board | Dedicated board for the Worldwide LHC Computing Grid. |
| | GDPR | General Data Protection Regulation | |
| | GEM | Gas Electron Multiplier | |
| | GeV | Giga electron Volt | |
| | GLIMOS | Group Leader In Matters Of Safety | |
| **H** | HCAL | Hadron Calorimeter | |
| | HELIOS | HELIcal Orbit Spectrometer | New experiment at HIE-ISOLDE |
| | HEP | High-Energy Physics | ICHEP (International Conference on HEP), EPS-HEP (Europhysics conference on HEP),IHEP (Institute for High Energy Physics). |
| | HE-LHC | Higher-Energy LHC | Higher-energy proton collider. |
| | HIE-ISOLDE | High Intensity and Energy ISOLDE | |
| | HFM | High Field Magnets | |

| Acronym | Meaning | Complementary information |
|---|---|---|
| HiPIMS | High Power Impulse Magnetron Sputtering | |
| HL-LHC | High Luminosity LHC | |
| HLT | High Level Trigger | High-Level Trigger combines and processes the full information from all major detectors of ALICE in a large computer cluster. |
| HMPID | High Momentum Particle Identification Detector | Part of the ALICE detector. |
| HNSciCloud | Helix Nebula Science Cloud | |
| HPC | High Performance Computing Center | |
| HP-SPL | High-Power Superconducting Proton Linac | |
| HR | Human Resources department | |
| HSE | Occupational Health and Safety and Environmental Protection Unit | |
| HTS | High Temperature Superconductor | |
| HUG | Hopitaux Universitaires de Genève | |
| HVAC | Heating Ventilation Airconditioning Cooling | |
| I<br>ICARUS | Imaging Cosmic And Rare Underground Signals | |
| ICE-DIP | Intel-CERN European Doctorate Industrial Program | European Industrial Doctorate scheme hosted by CERN and Intel Labs Europe |
| ICT | Information Communication Technology | |
| ILC | International Linear Collider | |

| **Acronym** | **Meaning** | **Complementary information** |
|---|---|---|
| ILO | Industrial Liaison Officer | |
| INSPIRE | | A new scientific information system for HEP (High-Energy Physics), successor of SPIRE (Spectral and Photometric Imaging Receiver). |
| INTC | ISOLDE and Neutron Time-of-flight experiments Committee | |
| IP | Intellectual Property | |
| IP1, IP2, IP5, IP8 | Collision points | IP1: at ATLAS, IP2: at ALICE, IP5: at CMS, IP8: at LHCb. |
| IPT | Industry, Procurement & Knowledge Transfer | |
| IR | Interaction Regions | |
| IR | International Relations sector | |
| IR-ECO | Education & Communications Group | |
| ISGTW | International Science Grid This Week | |
| ISOLDE | On-Line Isotope Mass Separator | Facility dedicated to the production of a large variety of radioactive ion beams for many different experiments in the fields of nuclear and atomic physics, solid-state physics, materials science and life sciences. The facility is located at the PS Booster (PSB). |
| ISR | Intersecting Storage Rings | |
| IT | Information Technology department | |
| ITER | International Thermonuclear Experimental Reactor | |
| ITK | Inner Tracker | |

| | Acronym | Meaning | Complementary information |
|---|---|---|---|
| | ITS | Inner Tracking System | |
| **J** | J-PARC | Japan Proton Accelerator Research Complex | |
| **K** | KPI | Key Performance Indicator | . |
| | KT | Knowledge Transfer | |
| **L** | LBNF | Long-Baseline Neutrino Facility | |
| | LC | Linear Collider | |
| | LCD | Linear Collider Detector | |
| | LCG | LHC Computing Grid | Global collaboration linking grid infrastructures and computer centres worldwide. |
| | LEIR | Low Energy Ion Ring | LEIR turns low-intensity ion pulses injected from CERN’s LINAC3 into high-density bunches which are accelerated from 4.2 MeV/u to 72 MeV/u. |
| | LEP | Large Electron Positron (LEP) collider | |
| | LHC | Large Hadron Collider | http://public.web.cern.ch/public/en/LHC/LHC-en.html |
| | LHCb | Large Hadron Collider beauty experiment | Experiment at the LHC. |
| | LHCC | Large Hadron Collider Committee | |
| | LHCf | Large Hadron Collider forward experiment | Verification of interaction model for very high energy cosmic ray at 1017 eV. The LHCf experiment uses forward particles created inside the LHC as a source to simulate cosmic rays in laboratory conditions. |
| | LINAC2 | LINear Accelerator 2 | 50 MeV linear accelerator for protons in use since September 1978. |
| | LINAC3 | LINear Accelerator 3 | 4.2 MeV/u Heavy Ion Linac in use since 1994. |

| Acronym | Meaning | Complementary information |
|---|---|---|
| LINAC4 | LINear Accelerator 4 | 160 MeV linear accelerator that is built to replace LINAC2 as injector to the PS Booster (PSB). |
| LIU | LHC Injectors Upgrade project | |
| LMS | Learning Management System | |
| LS1 | Long Shutdown 1 | Shutdown of the accelerator complex in 2013-2014. |
| LS2 | Long Shutdown 2 | Shutdown of the accelerator complex in 2019-2020. |
| LS3 | Long Shutdown 3 | Shutdown of the accelerator complex in 2023-2025. |
| MCHF | Million Swiss Franc | |
| M&O | Maintenance and Operation | |
| MB | Management Board | |
| MEDICIS | Medical isotopes collected from ISOLDE | Recuperation of the dumped CERN protons for the production of medical isotopes in the ISOLDE class A work sector. |
| MIND | Magnetised Iron Neutrino Detector | |
| MMT | Magnetic Monopole Trapper | |
| MoEDAL | Monopole and Exotics Detector At the LHC | Detector of the LHC that searches for the massive stable (or pseudo-stable) particles, such as magnetic monopoles or dyons, produced at the LHC. |
| MQXC | 2 m long quadrupole of NbTi | |
| MTP | Medium-Term Plan | |
| MW | MegaWatt | |
| mSv | milli Sievert | Measure of the health effect of low levels of ionizing radiation on the human body. |

| | Acronym | Meaning | Complementary information |
|---|---|---|---|
| **N** | NA58 | North Area 58 experiment or COMPASS | Common Muon and Proton Apparatus for Structure and Spectroscopy. |
| | NA61 | North Area 61 experiment or SHINE | Study of Hadron Production in Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS. |
| | NA62 | North Area 62 experiment | Experiment to measure the very rare kaon decay K+-> π+ nu nubar. |
| | NA63 | | Continued investigation of scattering of high energy particles in crystalline structures |
| | Nb3Sn | Niobium-Tin | |
| | NDT | Nuclear Track Detector system (MoEDAL) | |
| | n_TOF | neutron Time-Of-Flight facility | n_TOF is a pulsed neutron source coupled to a 200 m flight path designed to study neutron-nucleus interactions for neutron kinetic energies ranging from a few meV to several GeV. |
| **O** | OB | Overview Board | Dedicated board for LHC computing. |
| | openAIRE2020 | Open Access Infrastructure Research Information | Horizon 2020 project |
| | OSQAR | Optical Search of QED vacuum magnetic birefringence, Axion and photon Regeneration | |
| **P** | pA collisions | Proton-nucleus collisions | Collisions between one parton from the proton and the color fields of the nucleus. |
| | P+M | Personnel and Materials | An expression to describe total expenses, i.e. combined expenses in personnel and materials costs. |
| | $Pb^{82}$ | Lead ion | |
| | PCB | Printed Circuit Board | |
| | PHOS | PHOton Spectrometer | Part of the ALICE detector. |

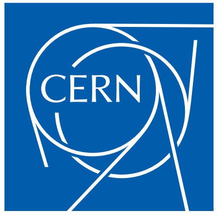
| | Acronym | Meaning | Complementary information |
|---|---|---|---|
| | PICSE | Procurement Innovation for Cloud Services in Europe | |
| | PIMMS-2 | Proton Ions Medical Machine Study | |
| | PIP-II | Proton Improvement Plan-II | Project at Fermilab |
| | PLM | Product Lifecycle Management | |
| | pp | proton-proton | |
| | PS | Proton Synchrotron | |
| | PSB | Proton Synchrotron Booster | |
| **Q** | QA | Quality Assurance | |
| | QCD | Quantum ChromoDynamics | |
| **R** | R2E | Radiation to Electronics | The goal of the R2E Project is to study and propose mitigation actions (e.g. relocation or redesign of equipment, shielding, etc.) with the aim of increasing the mean time between failures of the LHC machine to one week for failures of controls electronics caused by radiation at ultimate beam conditions. |
| | RCS | Research and Computing sector | |
| | R&D | Research and Development | |
| | RAMSES | RAdiation Monitoring System for the Environment and Safety | Radiation Monitoring system developed for LHC based on current industry standards and in use since 2007. |
| | REX(-ISOLDE) | Radioactive Beam Experiment | REX-ISOLDE is a post-accelerator for radioactive ions produced by ISOLDE to accelerate the 60 keV ions from ISOLDE up to 0.8 - 2.2 MeV/u. |
| | RF | Radio Frequency | |

| | **Acronym** | **Meaning** | **Complementary information** |
|---|---|---|---|
| | RFQ | Radio Frequency Quadrupole | |
| | RICH | Ring Imaging CHerenkov detector | |
| | RP | Radiation Protection | |
| | RRB | Resources Review Board | |
| **S** | SBN | Short Baseline Neutrino | |
| | SC | Super Conducting | |
| | SCM | Super Conducting Magnet R&D | |
| | SEU | Single Event Upset | |
| | SHINE | North Area 61 experiment or SHINE | Study of Hadron Production in Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS. |
| | SHiP | Search for Hidden Particles | |
| | SMB | Site Management and Buildings | |
| | SPC | Scientific Policy Committee | |
| | SPS | Super Proton Synchrotron | |
| | SPSC | Super Proton Synchrotron Committee | |
| | SRO | Stakeholder relations office | |
| | STFC | Science & Technology Facilities Council | |
| | SURF | Sanford Underground Research Facility | Underground laboratory near Lead, South Dakota, which houses multiple physics experiments in areas such as dark matter and neutrino research |

**T**

| Acronym | Meaning | Complementary information |
|---|---|---|
| T2K | | Neutrino experiment in Japan designed to investigate how neutrinos change from one flavour to another as they travel. http://t2k-experiment.org/ |
| TDAQ | Trigger and DAQ | |
| TDR | Technical Design Report | |
| TE | TEchnology department | |
| TE-CRG | Cryogenics Group | |
| TE-VSC | Vacuum, Surfaces and Coatings Group | |
| TeV | Tera electron Volt | |
| TH | Theoretical Physics (Department) | |
| Tier-0 | First layer of the computing grid | The first layer is the CERN Computing Centre |
| Tier-1 | Second layer of the computing grid | These are large computer centres with sufficient storage capacity and with round-the-clock support for the Grid. There are currently 11 of these centres. |
| Tier-2 | Third layer of the computing grid | The Tier 2s are typically universities and other scientific institutes, which can store sufficient data and provide adequate computing power for specific analysis tasks. There are currently 129 Tier 2 centres globally. |
| TIM | Technology and Innovation Monitor | |
| TMVA | multivariate analysis tools | |
| TOF | Time of Flight | |
| TOTEM | TOTal cross section, Elastic scattering and diffraction dissociation Measurement at the LHC | Experiment at the LHC. |

| | Acronym | Meaning | Complementary information |
|---|---|---|---|
| | TPC | Time Projection Chamber | |
| | TRD | Transition Radiation Detector | |
| | TSR | Test Storage Ring | |
| **U** | UNESCO | United Nations Educational Scientific and Cultural Organization | |
| **V** | VAR | Volt Ampere Reactive | |
| | VELO | VErtex LOcator detector | Part of the LHCb detector. |
| | V3Si | Vanadium-Silicon | |
| **W** | WLCG | Worldwide LHC Computing Grid | |
| **X** | xTCA | | Flexible and scalable infrastructure for designing complex control and data acquisition systems |
| **Y** | YETS | Year End Technical Stop | |



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