*Draft, released 11/9/2007, in preparation of negotiation meeting of 14/9/2007*

# SEVENTH FRAMEWORK PROGRAMME

## Capacities - Research Infrastructures
## FP7-INFRASTRUCTURES-2007-1

## *Preparatory Phase of the Large Hadron Collider Upgrade*

## Grant agreement for: CP-CSA-Infra Combination of Collaborative Project and Coordination and Support Action

# *Annex I - "Description of Work"*

Project acronym: SLHC-PP
Project full title: Preparatory Phase of the Large Hadron Collider Upgrade
Grant agreement no.: 212114

Date of preparation of Annex I (latest version): September 11th 2007
Date of approval of Annex I by Commission:

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# List of Beneficiaries

| Beneficiary Number | Beneficiary name | Beneficiary short name | Country | Date enter project | Date exit project |
|---|---|---|---|---|---|
| 1(coordinator) | European Organization for Nuclear Research | CERN | Switzerland | M1 | M36 |
| 2 | AGH University of Science and Technology | AGH-UST | Poland | M1 | M36 |
| 3 | Commissariat à l'Energie Atomique | CEA-Saclay | France | M1 | M36 |
| 4 | Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas | CIEMAT | Spain | M1 | M36 |
| 5 | Centre National de Recherche Scientifique | CNRS-IN2P3 | France | M1 | M36 |
| 6 | Czech Technical University | CTU | Czech Republic | M1 | M36 |
| 7 | Deutsches Elektronen-Synchrotron | DESY | Germany | M1 | M36 |
| 8 | Eidgenössische Technische Hochschule Zürich | ETH Zürich | Switzerland | M1 | M36 |
| 9 | Stichting voor Fundamenteel Onderzoek der Materie | FOM-NIKHEF | the Netherlands | M1 | M36 |
| 10 | Gesellschaft für Schwerionenforschung | GSI | Germany | M1 | M36 |
| 11 | Imperial College London | Imperial | United Kingdom | M1 | M36 |
| 12 | Istituto Nazionale di Fisica Nucleare | INFN | Italy | M1 | M36 |
| 13 | Paul Scherrer Institut | PSI | Switzerland | M1 | M36 |
| 14 | Science and Technology Facilities Council | STFC | United Kingdom | M1 | M36 |
| 15 | Rheinische Friedrich-Wilhelms-Universität Bonn | UBONN | Germany | M1 | M36 |
| 16 | Université de Genève | UNIGE | Switzerland | M1 | M36 |
| 17 | University of Sheffield | USFD | United Kingdom | M1 | M36 |

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# PART A

## A1. Budget breakdown and project summary

## A.1. Overall budget breakdown for the project

The following table summarises the budget breakdown including indirect costs for each of the 17 participants (in €)

| Participant short name | RTD (A) | Coordination (B) | Support © | Management (D) | Other (E) | Total A+B+C+D+E | Total receipts | Requested EU contribution |
|---|---|---|---|---|---|---|---|---|
| CERN | 5684640 | 1755200 | 886400 | 720000 | 0 | 9046240 | 0 | 3021162 |
| AGH-UST | 256000 | 0 | 0 | 0 | 0 | 256000 | 0 | 104000 |
| CEA-Saclay | 1276200 | 68400 | 0 | 0 | 0 | 1344600 | 0 | 465460 |
| CIEMAT | 531000 | 68400 | 0 | 0 | 0 | 599400 | 0 | 218860 |
| CNRS-IN2P3 | 320000 | 0 | 0 | 0 | 0 | 320000 | 0 | 105600 |
| CTU | 0 | 0 | 126400 | 0 | 0 | 126400 | 0 | 44940 |
| DESY | 32000 | 240000 | 0 | 0 | 0 | 272000 | 0 | 99726 |
| ETH Zurich | 0 | 240000 | 0 | 0 | 0 | 240000 | 0 | 89166 |
| FOM-NIKHEF | 0 | 278400 | 0 | 0 | 0 | 278400 | 0 | 64200 |
| GSI | 0 | 0 | 240000 | 0 | 0 | 240000 | 0 | 72225 |
| Imperial | 0 | 240000 | 0 | 0 | 0 | 240000 | 0 | 89166 |
| INFN | 120000 | 0 | 0 | 0 | 0 | 120000 | 0 | 40000 |
| PSI | 144000 | 0 | 180000 | 0 | 0 | 324000 | 0 | 108225 |
| STFC | 1222825 | 434600 | 0 | 0 | 0 | 1657425 | 0 | 489850 |
| UBONN | 480000 | 0 | 0 | 0 | 0 | 480000 | 0 | 120000 |
| UNIGE | 0 | 147200 | 0 | 0 | 0 | 147200 | 0 | 35310 |
| USFD | 0 | 0 | 107200 | 0 | 0 | 107200 | 0 | 32100 |
| TOTAL | 10066665 | 3472200 | 1540000 | 720000 | 0 | 15798865 | 0 | 5199991 |

## A.2. Project summary form

| | | | |
|---|---|---|---|
| Project Number | 212114 | Project Acronym | SLHC-PP |

**One Form per Project**

| | | | |
|---|---|---|---|
| **General Information** | | | |
| *Project Title* | *Preparatory Phase of the Large Hadron Collider Upgrade* | | |
| *Starting date* | *1 April 2008* | | |
| *Duration in months* | *36* | *Call (part) identifier* | *FP7-INFRASTRUCTURES-2007-1* |
| *Activity code(s) most relevant to your topic* | | *Infra-2007-2.2.1.33* | |
| *Free keywords* | LHC, SLHC, particle accelerators, particle detectors, particle physics, world-class infrastructure, global project, major upgrade | | |
| *Abstract (max. 2000 char.)* | | | |

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The Large Hadron Collider upgrade (SLHC) is the project with highest priority in the European Strategy Roadmap in Particle Physics, unanimously approved by the CERN Council in July 2006. The SLHC, with expected 1 B€ budget, includes a major upgrade of the accelerator cascade, a new injector complex, and will result in a tenfold increase of the LHC luminosity. Thus the SLHC will remain the most powerful particle accelerator in the world in the next two decades, and the potential of this unique world-class infrastructure for new discoveries will be fully exploited.

The Preparatory Phase of the LHC-upgrade (SLHC-PP), co-funded by the EC, will have an important catalytic effect for the implementation of the major accelerator and detector upgrades, planned for the period 2011-2016. This global endeavor will involve not only the 20 CERN Member States, but also many other countries from all over the world, among which Russia, USA, Japan, India, and China.

The SLHC-PP project comprises coordinating activities for the organisation of the new accelerator- and detector-upgrade collaborations, negotiations and agreements with new partners and putting in place the new structure of the SLHC experiments. Support activities address upfront priority safety issues, including radiation protection and radioactive waste disposal. Finally, key prototypes of Nb-Ti high-field magnets with large aperture, the prototype of a new H- ion source, field stabilization in SC accelerating structures, and novel tracking detector powering systems will be developed in the technical work packages. The success of these activities relies on the recognized abilities of the major laboratories in these fields as well as on the highly specialized expertise of specific institutes and universities.

The SLHC-PP project will run in parallel with an extensive R&D programme towards the SLHC Implementation Phase, which will be funded by CERN together with important contributions from many CERN non-member states. This programme is supported by the CERN Council, who recognized the needs of resources and activities to the proposed level and voted a special contribution for the period 2008-2011. In this way Europe will continue to serve as a focal point for the world's best particle physicists and will maintain its leading position in the foreseeable future.

## A.3. List of beneficiaries

| Beneficiary Number * | Beneficiary name | Beneficiary short name | Country |
|---|---|---|---|
| 1 (coordinator) | European Organization for Nuclear Research | CERN | Switzerland |
| 2 | AGH University of Science and Technology | AGH-UST | Poland |
| 3 | Commissariat à l'Energie Atomique | CEA-Saclay | France |
| 4 | Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas | CIEMAT | Spain |
| 5 | Centre National de Recherche Scientifique | CNRS-IN2P3 | France |
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| 13 | Paul Scherrer Institut | PSI | Switzerland |
| 14 | Science and Technology Facilities Council | STFC | United Kingdom |
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| 16 | Université de Genève | UNIGE | Switzerland |
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# PART B

## B1. Concept and objectives, progress beyond state-of-the-art, S/T methodology and work plan

### B 1.1 Concept and project objective(s)

Brief description of the major upgrade of the LHC

The upgrade of the Large Hadron Collider (LHC) is called Super-LHC (SLHC). It is the project with highest priority in the document for the European Strategy in Particle Physics, unanimously approved by the CERN Council in July 2006. This project includes a major upgrade of the cascade of accelerators needed to inject a beam into the LHC and will result in an increase of the luminosity of the LHC by one order of magnitude. This will allow the LHC to remain the most powerful particle accelerator in the world in the next two, possibly three decades, with a significant impact on the research in Particle Physics and to fully exploit its physics potential towards new discoveries. Thus Europe will maintain its leading position in the field in the foreseeable future.

If the existing accelerators are capable of meeting the needs of the nominal LHC, they will not deliver beam with the ultimate SLHC characteristics envisaged and they suffer from age-related reliability problems. It is therefore necessary to renew and upgrade them, taking into account the needs of SLHC. This will be implemented in consecutive phases during the next decade, with progressive replacement of the low energy accelerators.

In the first phase (2008-2011, preparation), a new 160 MeV $H^-$ linac (Linac4) will be built and the next two accelerators, replacing the present PSB and PS, will be designed and their cost estimated. In parallel, the necessary upgrades of the SPS and LHC will be defined and development of magnets with high-field and large aperture will be carried out. During the second phase (implementation, to be completed in 2016), the new injectors will be built, the SPS and LHC upgraded and the high-luminosity interaction regions rearranged. Higher luminosity also imposes to enhance the capability and performance of the particle physics experiments, ATLAS and CMS. This implies major changes in the forward detection region layout, the central tracking detectors, the read-electronics and the data acquisition systems.

The full upgrade aims at a ten-fold increase of the integrated luminosity per year. It is fully supported by the CERN Council, who recognized the needs of resources and activities to the proposed level and voted a special contribution for the period 2008-2011. The total investment, including machine and detectors, will exceed 1 B€ and the total budget planned for the first phase is about 135 M€.

The CNI Preparatory Phase of the LHC-upgrade, which fits well in the plan described above, will have an important catalytic effect for organising the new collaborations for implementing the accelerator and the detector upgrades. This global endeavor, will involve not only the 20 CERN Member States, but also many other countries from Europe and all over the world, among which Canada, China, India, Israel, Japan, Russia and the USA. European industries will also be involved to contribute to the technology development and prototyping work.

Coordinating the accelerator and experiments activities with the aim of attracting partners, organizing exchange of information and creating collaboration frameworks in vital domains, such as SC quadrupoles for collision areas and power distribution for future detectors, are among the key elements of the SLHC-PP project. The main objectives are clearly defined, in agreement with the European roadmap: the upgrade of the luminosity of the LHC, including the improvement of the LHC injectors and particle detectors. Clear priorities have progressively emerged which now have to be elaborated by further studies and prototype work.

Objectives and description of the activities foreseen

For the LHC machine, the main objective of the preparatory phase is to set up the conditions that will allow a progressive upgrade of the two high luminosity insertions in the years 2012-2016. It is also necessary to prepare for the implementation of the upgrade of the LHC injector chain and for the commissioning of a new high brightness H- linear accelerator to replace the existing one as the first element in this chain.

It will be necessary to set up links with collaborating institutes and to firmly establish common project management tools and procedures amongst all partners. One of the first priorities is to set up a Project management structure using modern tools, including Earned Value Management (EVM) for tracking project progress and expenditure, budget follow-up and planning. The communication between the participants has to be streamlined in workshops and meetings and the general information dissemination has to be set up. The main objectives, detailed in WP2, are to provide within the 3 years of the project, a web-site linked to the technical databases, a Financial Management System, and an EVM system. The progress on the last two topics will be monitored half-through the project approximately.

Increasing the luminosity of the LHC will mean that the radiation levels in both the machine and detectors will increase substantially. This will require effort in the field of radiation impact studies. It will also address the problems of material activation, production of radioactive waste, the control of the dose to personnel and safe disposal of the waste. These issues are addressed in WP5. Main deliverables are the estimation of activation and radiation levels for the accelerator and the S-ATLAS and CMS2 experiments at month 24, and a completed impact study at month 36.

The upgrade of the high luminosity insertions will require the development of prototype superconducting quadrupole magnets of advanced design to replace the existing ones and overcome the present performance limitation. This will require setting up collaborations between partners in order to coordinate the design of these magnets and their ancillary corrector packages. The tasks planned include the design of advanced Nb-Ti superconducting quadrupole, the construction and testing of a short model, and the construction and testing of a full-scale prototype. Their achievements are the main deliverables of WP6, planned to be delivered towards the end of the project. Milestones concern the design of the magnet, cold-mass and full cryo-magnet, and will be provided between the 10th and the 22nd month. Various tests (cryogenic, power, electrical, collared coil), foreseen between month 22 and month 28, will allow to measure and verify the progress towards the objectives.

The H- superconducting linear accelerator envisaged sets difficult technical challenges resulting from the CERN operating environment. One concerns the ion source, which has to provide a very bright beam with a high duty cycle and a life-time compatible with the physics run duration. Another one concerns the beam energy stability, which has to allow for the required density of particles in the synchrotron that will accumulate the linac beam and give it the time structure necessary for LHC. Both issues are crucial to the project and require detailed investigations based on the preliminary work done during the sixth Framework Programme.

The objectives for the first issue is to study the thermal load of an RF driven plasma source with high duty cycle, to design and construct such a plasma generator and sub-systems, to prepare the infrastructure and to install the system. The achievement of these objectives (thermal study, design, construction and plasma generation to check thermal conditions) are the deliverables (see WP7, task 1) staggered between the 12th month and the 36th month. As a milestone before working on the design and construction, a list of required improvements is due on the 14th month.

The objectives for the second issue is to elaborate the architecture of an RF system for the stabilization of the accelerating field and to specify the system components, to validate the system in a test stand using a prototype electronics, and to produce a report describing the architecture retained and specifying the complete Linac RF system. This report is the main deliverable of these activities, due at the end of the project (see WP7, task 2). Other deliverables are due in months 12, 18 and 30, on tuner and cavity characterization, design and modelling of the RF system and on the production of the prototype electronics, respectively. The description and specification of the RF system to be tested in the test stand is a milestone planned in the midst of the project.

The development, construction and installation of the ATLAS and CMS detector upgrades will typically involve half the institutes and staff involved in the current systems. In addition, many new institutes are expected to join. Once developed and approved, the new parts will take approximately 5 years to be constructed and installed. Since the existing detectors are highly integrated and complex, the technical challenges of replacing central parts of the existing systems require careful technical planning and a large co-ordination effort.

The SLHC detector upgrade S-ATLAS and CMS2 will be well defined technical and financial projects with a clear interface to the existing collaborations ATLAS and CMS. This is mandatory to allow significant numbers of new members to join for the SLHC phase. This will also permit some existing members to take on precise technical tasks related to the SLHC detector construction beyond their current responsibilities in the present LHC experiments. Following ATLAS and CMS experience, a sound management framework and centralised technical coordination during the preparatory phase are needed for a successful implementation. They will help new partners to join under clear conditions and avoid duplication of work.

Work package 3 is dedicated to the S-ATLAS experiment upgrade and comprises two tasks. The first task concentrates on the collaboration management structures, participation rules, review procedures and all financial aspects. Following a set of clear milestones throughout the first two years, its ultimate deliveries comprise the detailed upgrade cost book and the initial Memorandum of Understanding (MoU) at the end of the PP phase (month 36). The second task comprises the organisation of a technical project office coordinating and documenting all technical issues linked to the upgrade. These comprise technical WEB interfaces, databases, drawing and CAD documentation, configuration control, as well as installation scenarios and scheduling. Its main deliverables are the documentation of the technical scope of the upgrade and the schedule for the construction of the upgraded detector parts and installation at month 24, and the full technical documentation and configuration databases at month 36.

Work package 4 is comparable to WP3, but fully adapted to the CMS2 Collaboration structure and the CMS2 technical infrastructures. Within the first task the management, reviewing and participation rules of the future Collaboration will be established, the project structure will be defined as well as the handling financial issues. Its deliverables comprise the operational Project structure for the construction of systems and subsystems at month 12, and a full cost book and MoU at month 36. The second task comprises the organisation of the Technical Coordination Unit. Its main deliverables are the reporting and scheduling mechanisms defined at month 18 and the publication of the pilot design and schedule for the upgrade at month 36.

The present LHC experiments have revealed severe difficulties in providing power to the complex inner tracking detectors. At SLHC these difficulties will be much enhanced and the current technical solutions are known to fail. The SLHC tracking detectors will comprise several hundreds of million particle detection elements, designed in state-of-the art solid-state sensor technologies. Each sensor is coupled to custom-designed deep-submicron radiation-hard electronics. The tracking detectors are located near the beam pipe in a highly radioactive environment and in strong magnetic fields of 2 to 4 T. After installation the tracking detectors become inaccessible and have to operate without failure for many years, therefore high reliability criteria apply. In this context new high-tech developments are needed in the domain of on-detector powering, principally involving microelectronics developments and strongly affecting the overall design of the future trackers. The developments will ultimately lead to a considerable reduction in input current and cable volumes. Most notably, power efficiency will be increased by large factors as well.

For this development work, described in WP 8, a new collaboration is being set up, that will perform the R&D work in common for S-ATLAS and CMS2. DC-DC conversion and serial powering techniques will be pursued. The main deliverables are evaluation reports of the two techniques at month 12, followed by design of custom circuits and implementation in early detector prototypes, finally leading to the evaluation of full-scale detector modules in which the techniques are implemented at month 36.

## B 1.2 Progress beyond the state of the art

The coordination activities of the work-packages 2, 3 and 4 concern the upgrade of the accelerator and of the S-ATLAS and CMS2 experiments, respectively, and deal with the creation of the necessary project structures. However, as described in the initial SLHC-PP proposal, the whole preparatory phase of the LHC upgrade includes many more activities than those included in this project, activities which are supported by CERN and its partners. Consequently, the WPs 2 to 4 also include the coordination of these activities specific to the work packages not supported directly by the EC to as described in Table 2b of the SLHC-PP Proposal and covering important developments beyond the present state of the art. For the accelerator they concern for instance high-field SC magnets based on $Nb_3Sn$, pulsed SC magnets, Low-beta insertion design, collimation development and design of a new injector accelerator PS2. For the experiments, the higher particle rates at SLHC result in significantly increased radiation levels and call for increased detector granularities as well as high-rate detection, electronics and data transmission applications. More specifically, developments will include: thin beryllium or aluminium beam vacuum tubes, radiation-hard silicon sensors, silicon pixel detectors, interconnect technologies, fast radiation-hard gas detector technologies, various microelectronics application developments, optoelectronics developments for high speed data links, trigger developments as well as Grid application developments.

The present project will allow progress beyond the state-of-the-art in specific technical areas. This concerns the work-packages 6, 7 and 8 and the following paragraphs briefly summarize (in this order) the starting point of these activities and what advance is expected to result from the work planned.

The LHC upgrade requires new triplets of quadrupoles for the interaction regions, in order to reach higher luminosity. The present triplet includes quadrupoles of 70 mm aperture diameter, with two different cross sections and different operating currents. The new triplet to be developed will be composed of 4 quadrupoles of the same cross-section, a larger inner bore diameter of 130 mm (to relax collimation aperture) and identical operating current, allowing to power the quadrupoles in series. As the stored energy and electro-magnetic forces strongly increase in the new design, the performance limits of NbTi quadrupoles have to be explored. Mechanics, force containment and thermal aspects will be reviewed and the insulation upgraded with respect to the one used in LHC. The cold mass will be designed to include the corrector magnets and optimized for working at 1.9 K.
The NbTi superconductor will be qualified both as cable and as coil package. A 1 m long model magnet will be constructed and tested in cryogenic conditions, in order to qualify the coil manufacturing procedure, the mechanical assembly procedure, the coil stability and the field quality. The final effective proof of the advance made with respect to the existing design and of the success of the proposed system with large aperture will be the construction of a long prototype (5 to 10 m) and its successful tests (incl. quadrupole, correctors, and the thermal and mechanical behaviour of the cryostat). Final tests aim at assessing the suitability of the quadrupole magnet for the new LHC interaction region in terms of field quality, quench behaviour and safety. The developed components will open the way towards significantly better LHC performance and a reduction of physical bottle-necks in other critical parts of the collider.

Another element that determines the LHC performance is the quality of the proton beam generated in the injectors. To meet the needs of the SLHC and to prevent age-related reliability problems, it is therefore needed to renew and upgrade the existing injection accelerators. This includes a new 160 MeV $H^-$ linac and later a Superconducting Proton Linac (SPL). The latter will have to satisfy demanding requirements in terms of beam characteristics and reliability. Two technical subjects are particularly critical in this respect, the $H^-$ ion source and the energy stability at the end of the linac.

The beam emittance from the $H^-$ source must be small and stable, with reliability in excess of 99% for a lifetime of 2000 hours. With the SPL, cycling up to 50 Hz with a duty factor of 4%, a solution has to be found and demonstrated. One possibility is an RF driven plasma source. The ion source developed at DESY for the production of H- ions with a low duty factor needs to be upgraded for increased duty factors which result in larger thermal load and require cooling, while the hydrogen gas flow into the plasma region has to be increased. Thermal study of the Linac 4 design source will open the way to the design and construction of a plasma generator operating at 4% duty cycle. Analysis of the thermal and vacuum conditions will allow to qualify the plasma generation method.

The energy stability depends on the stability and reproducibility of the field in the SC cavities. The latter are sensitive to mechanical vibrations and subject to Lorentz forces resulting from pulsed operation. Work was done on this issue within CARE and will serve as a basis for elaborating an RF system achieving the specified field stabilization. The 700 MHz test facility set in CEA Saclay will be intensely used to characterize the cavities and their tuners, and to validate a system solution using prototype electronics. In parallel to this, the various RF components will be modelled before starting to work on the design of the complete RF system. The quality of the system will then be checked through simulations of the beam behaviour over the full linac.

Once all components are assembled in the test stand and the prototype electronics as well as the interfaces are built, validation tests of the RF system design will be carried out and the performance analysed. Re-optimization of the architecture might occur at this stage.

The upgrades of the inner detectors are the principal focus of the experiments upgrade programs. The present LHC inner silicon pixel and strip sensor detectors are designed to cope with the already very significant LHC particle rates and radiation levels. For the increased SLHC irradiation levels, new sensor materials and operating conditions are presently being tested. The readout of the ~60 million LHC inner detector elements is closely integrated onto the sensor material. For this purpose radiation-hard microelectronics applications have been developed in 0.25 µm CMOS technology. Once constructed and installed, inner detectors are highly inaccessible. Therefore ultimate reliability is a must. In view of the reliability criterion, highly parallelized powering schemes are presently used in the LHC inner detectors. However, this leads to large volumes of very bulky cables passing through the outer regions of the experiment and entering the inner region, dissipating significant amounts of heat along their track and inside the inner detector volume. The inner detector cooling has been adapted. However, together with the cables themselves this has largely increased the presence of material in the vicinity of the detectors. Yet, precision and efficiency in particle detection call for low-mass detectors. The power distribution scheme impacts directly on the on-detector microelectronics design. Therefore, it is crucial to address power distribution technologies in an early phase of the design. In this context WP8 addresses on-detector radiation-hard magnetic field tolerant DC-DC converter technologies and serial powering schemes. The work principally involves microelectronics developments or low-noise on-detector electronics integration. It integrates well into the sensor development work and deep sub-micron electronics development work carried out in parallel (cf. WP14, WP15 and WP16, see Table 2b of the original SLHC-PP proposal). The work on the power distribution starts nearly from scratch. During the 3-year period of the project, the potential technologies will be assessed, design work carried out, prototypes built and finally the selected technologies will be integrated and tested in full-size detector prototypes.

## B 1.3 S/T Methodology and associated work plan

### B 1.3.1 Overall strategy and general description

The SLHC-PP project is divided into 8 Work Packages, which address the three types of activities directly supported by the EC.

There are three coordination work packages (WP2, WP3 and WP4) which concern the setting-up of the coordination frameworks necessary at the start of the SLHC implementation phase. They address this question for the LHC accelerator complex as well as for the two largest experiment upgrades, S-ATLAS and CMS2. They treat of the preparation of the coordination and organisation structures needed for the SLHC project as a whole, comprising many more partners than the present SLHC-PP project supported by the European Commission. Within the coordinating Work Packages new formal conditions will be elaborated to allow setting up extended collaborations.

There is one support work package (WP5), which addresses the upfront priority safety issues for the accelerator and the detector upgrades. It includes the critical questions of radioprotection radioactive waste disposal and of complying with safety rules fitting into the existing legal framework, taking into account the status of CERN as an international organization.

There are in addition three work packages (WP6, WP7 and WP8) on crucial technical issues which have to be addressed before the implementation can start. They deal with specific topics, which require RTD work as well as the construction of models and final prototypes. One concerns the accelerator itself, called at times the “machine”, one concerns two critical components of the injector complex and the last one the very important question of power distribution in the tracking detectors of the experiments.

All these work packages require highly specialised expertise on particular topics, which often can only be found in specific institutes and universities. This explains why, besides the major laboratories, there are several organisations of modest size, in particular for what concerns the experiments.

Finally, one work package (WP1) is devoted to the global management of the SHL-PP project. For this purpose an appropriate management structure is set up, as described in section B 2.1. The management work package also includes the dissemination of information within the consortium and also outside the consortium, for the SLHC project a whole.

In order to track the progress of the project, realistic deliverables and milestones have been defined. The definition of the deliverables is based on the wide scope of competencies and experience among the SLHC-PP partners. CERN, as a coordinator, has over 5 decades of experience in collaborating with universities and laboratories within Europe and well beyond Europe for the construction of ever larger projects. For this purpose specialised in-house management and tracking tools have been set up and are continuously improved upon. These tools will find their use and further optimisation within the SLHC project. In particular, the main tool for monitoring technical and financial progress will be the Earned Value Management (EVM) system, successfully used for the LHC project. The EVM tool is further described in section B 2.1. Mitigation of risk is principally based on proven methodologies, the involvement of partners with the relevant expertise and the setting of realistic goals. In addition, in some areas more than one technical option is explored for the most critical innovative issues to be addressed.

The progress of the project will be followed up on a regular basis by the Work Packages Leaders and by the Steering Committee (see section B 2.1). Progress will be reported upon through regular reporting, including presentations at the Annual Meeting. The ultimate reviewing body is the Governing Board, comprising representatives of all beneficiaries. The Consortium Agreement sets out the managerial structure and the correcting actions foreseen in case one of the partners cannot fulfil its commitments.

In the subsections below, the 8 Work Packages and their respective Personnel effort, Timing, Deliverables and Milestones are described in detail.

## B 1.3.2 Timing of work packages and their components

| SLHC Preparatory Phase | 1st YEAR | | | | | | | | | | | | 2nd YEAR | | | | | | | | | | | | 3rd YEAR | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WORK PACKAGE DESCRIPTIONS** | Q1 | | | Q2 | | | Q3 | | | Q4 | | | Q5 | | | Q6 | | | Q7 | | | Q8 | | | Q9 | | | Q10 | | | Q11 | | | Q12 | | |
| | | | 3 | | | 6 | | | 9 | | | 12 | | | 15 | | | 18 | | | 21 | | | 24 | | | 27 | | | 30 | | | 33 | | | 36 |
| **WP1. SLHC-PP project management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 1.1 Coordination, progress monitoring, reporting and dissemination of information | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D |
| **WP2. Coordination for the SHLC accelerator implementation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 2.1 Project management preparation | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| Task 2.2 Networking and communication | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP3. Coordination for S-ATLAS experiment implementation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 3.1 Coordination and project structures | ▨ | ▨ | ▨ | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| Task 3.2 Project Office | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | D |
| **WP4. Coordination for the CMS2 experiment implementation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 4.1 Coordination and organisation of CMS2 | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| Task 4.2 CMS2 Technical Coordination Unit | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| **WP5. Radiation protection and safety issues for accelerator and experiments** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 5.1 Detector Radiation & Activation | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D | | | | | | | | | | | | |
| Task 5.2 Accelerator Radiation & Activation | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D | | | | | | | | | | | | |
| Task 5.3 Impact Study | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D |
| **WP6. Development of Nb-Ti quadrupole magnet prototype** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 6.1 Design of advanced Nb-Ti superconducting quadrupole | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| Task 6.2 Construction and testing of a short model | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ! | ▨ | D | | | | | | | | | | | | |
| Task 6.3 Construction and testing of a full-scale prototype | | | | | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ | D | ▨ | ! | ▨ | ▨ | ▨ | D | ▨ | D | ▨ | D |
| **WP7. Development of critical components for the injectors** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 7.1 Development toward an H- source for the SPL | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ! | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| Task 7.2 Field stabilisation in pulsed superconducting low beta (v/c) accelerating structures | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| **WP8. Tracking detector power distribution** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 8.1 DC-DC conversion | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ! | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | D |
| Task 8.2 Serial powering | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | !D | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | D |

**! = MILESTONE**
**D = DELIVERABLE**

*Draft, released 11/9/2007, in preparation of negotiation meeting of 14/9/2007*

### B 1.3.3 Work package list / overview

| Work Package No | Work Package Title | Type of Activity | Leading beneficiary No | Person-months | Start month | End month |
|---|---|---|---|---|---|---|
| WP1 | SLHC-PP project management | MGT | 1 | 42 | M1 | M36 |
| WP2 | Coordination for the SLHC accelerator implementation | COORD | 1 | 46 | M1 | M36 |
| WP3 | Coordination for S-ATLAS experiment implementation | COORD | 1 | 102 | M1 | M36 |
| WP4 | Coordination for CMS2 experiment implementation | COORD | 1 | 90 | M1 | M36 |
| WP5 | Radiation protection and safety issues for accelerator and experiments | SUPP | 1 | 116 | M1 | M36 |
| WP6 | Development of Nb-Ti quadrupole magnet prototype | RTD | 1 | 180 | M1 | M36 |
| WP7 | Development of critical components for the injectors | RTD | 1 | 179 | M1 | M36 |
| WP8 | Tracking detector power distribution | RTD | 14 | 183 | M1 | M36 |
|  | TOTAL |  |  | 938 |  |  |

## B 1.3.4 Deliverables list

Project deliverables in order of delivery date

First year of the project:

| Deliverable number | Deliverable title | WP number | Lead beneficiary number | Estimated person-months | Nature | Dissemination level | Delivery date |
|---|---|---|---|---|---|---|---|
| 1.1.1 | SHLC-PP web-site operational (intranet + public pages) | 1 | 1 | 2 | O | PU | M03 |
| 3.1.1 | Establish a review office | 3 | 1 | 3 | R | PU | M06 |
| 1.1.2 | Periodic Report (progress of work + use of resources + financial statement) | 1 | 1 | 10 | R | PU | M12 |
| 2.2.1 | Functioning collaboration communication structure | 2 | 1 | 15 | O | PU | M12 |
| 2.2.2 | Project web site linked to the technical databases: Machine layout database, hardware baseline database, project notes and reports | 2 | 1 | 4 | O | PU | M12 |
| 4.1.1 | Project Structures for construction of systems and sub-systems | 4 | 1 | 6 | R, O | PU | M12 |
| 4.2.1 | Personnel and working practices of the Technical Coordination unit in place | 4 | 1 | 12 | R, O | PU | M12 |
| 6.1.1 | Basic design of the triplet | 6 | 1 | 10 | R | PU | M12 |
| 7.1.1 | Finite element thermal study of the Linac 4 design source at the final duty factor. | 7 | 1 | 14 | R | PU | M12 |
| 7.2.1 | In depth characterisation of the two tuners plus cavities developed in the frame of the “HIPPI” JRA , FP6 (tuner/cavity characteristics) | 7 | 1 | 11 | R | PU | M12 |
| 8.1.1 | Evaluation report on DC-DC conversion technologies | 8 | 14 | 30 | R | PU | M12 |
| 8.2.1 | Evaluation report on generic serial powering studies and specification of serial powering components | 8 | 14 | 32 | R | PU | M12 |

Second year of the project:

| Deliverable number | Deliverable title | WP number | Lead beneficiary number | Estimated person-months | Nature | Dissemination level | Delivery date |
|---|---|---|---|---|---|---|---|
| 4.2.2 | Schedule and reporting mechanism implemented | 4 | 1 | 16 | R | PU | M18 |
| 6.2.1 | Construction of the model | 6 | 1 | 25 | D | PU | M18 |
| 7.1.2 | Design of a high duty factor plasma generator | 7 | 1 | 11 | R | PU | M18 |
| 7.2.2 | Design of RF system architecture including modelling of RF components, simulation of the RF system and simulation of beam dynamics of the full LINAC. RF system and high power modulator specifications. | 7 | 1 | 37 | R | PU | M18 |
| 1.1.3 | Periodic Report (progress of work + use of resources + financial statement) | 1 | 1 | 10 | R | PU | M24 |
| 3.2.1 | Document the detailed technical scope of the upgrade | 3 | 1 | 18 | R | PU | M24 |
| 3.2.2 | Schedule for the Upgraded Detector parts and for the S-ATLAS installation | 3 | 1 | 18 | R | PU | M24 |
| 5.1.1 | Validation of simulation tools with measurements at LHC | 5 | 1 | 24 | R | PU | M24 |
| 5.1.2 | Estimation of activation and radiation levels for critical areas of the experiments at SLHC | 5 | 1 | 30 | R | PU | M24 |
| 5.2.1 | Estimation of activation and radiation levels for critical areas of SLHC and its injectors | 5 | 1 | 30 | R | PU | M24 |
| 6.2.2 | Assessment of the design | 6 | 1 | 5 | R | PU | M24 |
| 8.2.2 | Custom serial powering circuitry and evaluation of generic high-current serial powering chip | 8 | 14 | 32 | P,R | PU | M24 |

Third year of the project:

| Deliverable number | Deliverable title | WP number | Lead beneficiary number | Estimated person-months | Nature | Dissemination level | Delivery date |
|---|---|---|---|---|---|---|---|
| 6.3.1 | Construction Corrector magnet package | 6 | 1 | 20 | P | PU | M26 |
| 2.1 1 | Common fund, Financial Management System (software) and user requirements and user guide document | 2 | 1 | 11 | O | PU | M30 |
| 2.1.2 | Quality Assurance plan for the implementation phase | 2 | 1 | 8 | R | PU | M30 |
| 7.1.3 | Construction of the plasma generator and sub-systems (e.g. 2Hz RF generator, hydrogen gas injection and pumping). | 7 | 1 | 41 | D | PU | M30 |
| 7.2.3 | Production of a prototype electronic system and other elements for a full system demonstration. Definition of demonstration procedure. | 7 | 1 | 46 | P | PU | M30 |
| 8.1.2 | Prototypes and viability report | 8 | 14 | 42 | P, R | PU | M30 |
| 6.3.2 | Prototype quadrupole magnet | 6 | 1 | 85 | P | PU | M32 |
| 6.3.3 | Test of complete quadrupole prototype | 6 | 1 | 10 | R | PU | M34 |
| 1.1.4 | Periodic Report (progress of work + use of resources + financial statement) | 1 | 1 | 10 | R | PU | M36 |
| 1.1.5 | Final report | 1 | 1 | 10 | R | PU | M36 |
| 2.1.3 | Earned Value management system (software) with user requirements and user guide document | 2 | 1 | 8 | O | PU | M36 |
| 3.1.2 | Establish the initial Memorandum of Understanding for the upgrade. | 3 | 1 | 18 | R | PU | M36 |
| 3.1.3 | Develop detailed cost books for the upgrade including the installation phase | 3 | 1 | 18 | R | PU | M36 |
| 3.2.3 | Technical documentation, drawing and CAD information for the existing experiment and upgraded elements | 3 | 1 | 18 | R | PU | M36 |
| 3.2.4 | WEB interface tools and configuration databases for the Upgrade detector project | 3 | 1 | 9 | R | PU | M36 |
| 4.1.2 | Cost book and MoU for the upgrade and installation phase | 4 | 1 | 24 | R | PU | M36 |
| 4.2.3 | Pilot design and schedule for the upgrade project published. | 4 | 1 | 32 | R | PU | M36 |
| 5.3.1 | Impact Study (dose rates, environmental impact and waste production from activated material) for SLHC | 5 | 1 | 32 | R | PU | M36 |
| 6.1.2 | Complete IR design | 6 | 1 | 20 | R | PU | M36 |
| 6.3.4 | Assessment of the design | 6 | 1 | 5 | R | PU | M36 |
| 7.1.4 | Plasma generation and study of the thermal and vacuum conditions. | 7 | 1 | 11 | R | PU | M36 |
| 7.2.4 | Full test and validation of RF system. Final report. | 7 | 1 | 8 | D | PU | M36 |
| 8.1.3 | Integration in full-scale detector modules | 8 | 14 | 15 | D | PU | M36 |
| 8.2.3 | Full-scale super-module with custom serial powering circuitry | 8 | 14 | 32 | D | PU | M36 |

## B 1.3.5 Work package descriptions

### WP1 – SLHC-PP project management

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | 1 | **Start date or starting event:** | | | | Month 1 | |
| **Work package title** | SLHC-PP project management | | | | | | |
| **Activity Type** | MGT | | | | | | |
| **Participant** | CERN | | | | | | |
| **Person-months per participant:** | 42 | | | | | | |

**Objectives**: (i) effective management and coordination of all Work Packages and of the whole project, (ii) progress monitoring and reporting, (iii) contractual and financial follow-up of the project, (iv) dissemination of information inside and outside the consortium

**Description of work**

Task 1.1 Coordination, progress monitoring, reporting and dissemination of information

This task comprises a number of coordinating and communication activities under the responsibility of the Project Coordinator and Deputy Project Coordinator. These include the overall co-ordination and continuous monitoring of the progress in each Work Package, the organisation of the Project Steering Committee meetings and of the Annual SLHC-PP meetings as well as the regular communication with the EU Commission. The coordination of activities encompassing simultaneously several work packages is also included in this task. The dissemination of information forms an important element for this task. The main tool for dissemination of information related to the project will be a dedicated SLHC-PP web-site. The activities and results of the SLHC-PP project will be made available to the scientific community inside and outside the consortium and to the general public. A series of technical and scientific reports and working notes linked to the project will be created. The dissemination of information includes the participation and reporting at workshops and conferences. The communication on the SLHC-PP project will be well integrated into the information tools related to activities carried out outside the consortium. The normal status reports presented to the CERN Council will include SLHC and will inform the CERN member states and the observer states about the progress of the project.

The task includes the administrative and contractual follow-up, which will be carried out under the responsibility of the Administrative Manager. The latter includes the preparation of all required contracts, periodic activity reports, as well as the foreseen Deliverable and Milestone Reports and the Final Activity Reports. The financial follow-up encompasses the distribution and payments of EU funding, the budget control, the cost reporting and the collection of Audit reports.

| Deliverables | Description | Nature | Delivery date |
|---|---|---|---|
| 1.1.1 | SHLC-PP web-site operational (intranet + public pages) | O | M03 |
| 1.1.2 | Periodic Report (progress of work + use of resources + financial statement) | R | M12 |
| 1.1.3 | Periodic Report (progress of work + use of resources + financial statement) | R | M24 |
| 1.1.4 | Periodic Report (progress of work + use of resources + financial statement) | R | M36 |
| 1.1.5 | Final report | R | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 1.1 | Consortium Agreement | R | M03 |
| 1.2 | Kick-off meeting | R | M03 |
| 1.3 | First Annual SLHC-PP Meeting | R | M12 |
| 1.4 | Second Annual SLHC-PP Meeting | R | M24 |
| 1.5 | Final Project Review | R | M36 |

## WP2 – Coordination for the SLHC accelerator implementation

The SLHC accelerator upgrade program is to be executed in collaboration between CERN and a set of institutes. While for preceding accelerator projects, like the building of the LHC, the collaborations were between CERN and one institute at a time for each issue, this time a more complete partnership is required. For this purpose, the framework of the collaboration has to be created. This comprises the agreements on the collaboration contracts and the establishment of the project management infrastructure and tools.

A project of this size needs modern management and coordination tools. The experience from the project management of the LHC machine construction and the LHC experimental collaboration management can be used to construct collaboration structures and project follow up tools, which will allow a globally distributed project to function and come to results.

To define the SLHC project, extensive networking will be needed. The collaborators have to communicate inside regular meeting circuits, working groups, committees and topical workshops while they are geographically distributed over several continents. Physical meetings and workshops have to be organized and electronically supported; remote meetings at regular time intervals have to be set-up. The last implies dissemination via the web of the meeting related documentation in a structured way. The data storage and dissemination are very important in such a global project and have to be taken care of from the very beginning.

International collaborations, which produce hardware and software objects, will have to agree upon the standards to follow and the definition of quality related entities. Therefore a quality assurance plan has to be made for the SLHC project. The plan has to define quality standards on different levels, e.g. construction and tests standards, document standards, computing standards and approval trees for deliverables.

For the injectors, the preparatory phase will also concern the negotiation of contributions from institutes in countries that are not members of CERN, like e.g. Russia, India and China. The precise nature of these contributions will have to be defined, as well as the financial rules, the control structure and the internal scientific reviewing- and approval- procedures.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | WP2 | **Start date or starting event:** | | Month 1 | | | |
| **Work package title** | Coordination for the SLHC accelerator implementation | | | | | | |
| **Activity Type** | COORD | | | | | | |
| **Participant** | CERN | CEA-Saclay | STFC-RAL | CIEMAT | | | |
| **Person-months per participant:** | 34 | 4 | 4 | 4 | | | |

**Objectives**

SLHC is the luminosity upgraded LHC accelerator. Upgrading such a large facility requires a well-organized and solidly defined project management. As the project will be done in a collaboration between many partners, the management of the collaboration is a part of the project management. For the SLHC accelerator, the collaboration management will be more advanced than for the original LHC construction. The objective of this work package is to set up the project and collaboration management tools. Furthermore, the communication between the participants has to be streamlined in workshops and meetings and the general information dissemination has to be set up.

**Description of work**

Task 2.1 Project Management preparation

2.1.a Set up the project monitoring structures. The Earned Value Management system, which was successfully used for the LHC, will be the basis for this. With respect to the LHC version, the system has to be extended to cope with the new collaboration structure (CERN). This task includes upgrading the EVM software, putting the project framework in the database and providing documentation and training to the users of the system.

2.1.b Set up a finance management system for the implementation. Up to now, for the CERN accelerators, each institute had its own system and there was no system for the collaboration entity. A common fund has to be established (CERN). This includes getting support software, putting the project framework in the database and providing documentation and training to the users of the system.

2.1.c Set up a quality assurance plan for the implementation phase. Quality standards and approval trees have to be defined. The components and installations delivered by the various partners and industry have to be on a common high quality standard and according to their specification; a QA plan will be created for this (CERN).

Task 2.2 Networking and communication

2.2.a Set up collaboration communication structures. In preceding projects all technical, scientific and organisational issues were discussed and decided upon in CERN based working groups and committees. These entities were able to meet on a weekly or bi-weekly basis. For the SLHC international collaboration such a structure is also needed, but distances (Europe and intercontinental) need to be overcome. In the experiments this problem has already been addressed by organising bi-monthly full weeks of meetings and workshop-type events. Video conferencing facilities are widely used. For the SLHC a system will be set up where the requisite bodies can function with monthly or bimonthly physical meetings and electronically supported remote contacts on a frequent basis (e.g. every week telephone conferences, video conferences, web casts, etc). It is essential that a small team keeps track of these activities, provides minutes, follows up and takes care of documenting these on the web. Although many tools already exist, some software facilities will have to be written and conduct codes to be agreed upon. (CERN, CEA-Saclay, STFC-RAL and CIEMAT)

2.2.b Set up the storage and dissemination of the technical information and knowledge. This includes making the databases, web-sites and making the scientific/technical publications concerning the upgrade of the machine available on web based systems. The SLHC database structure will cover: basic machine description and beam parameters, machine layout, component description and traceability. All reporting will be stored on the database. The databases will feature regulated input-output access via the internet as an extension of the existing CERN facilities. (CERN)

| **Deliverables Task 2.1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 2.1 1 | Common fund, Financial Management System (software) and user requirements and user guide document | O | M30 |
| 2.1.2 | Quality Assurance plan for the implementation phase | R | M30 |
| 2.1.3 | Earned Value management system (software) with user requirements and user guide document | O | M36 |

| **Deliverables task 2.2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 2.2.1 | Functioning collaboration communication structure | O | M12 |
| 2.2.2 | Project web site linked to the technical databases: Machine layout database, hardware baseline database, project notes and reports | O | M12 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 2.1 | Financial management system (beta version) | O | M18 |
| 2.2 | EVM software (beta version) | O | M24 |

## WP3 – Coordination for S-ATLAS experiment implementation

The implementation phase of the present ATLAS LHC detector, as carried out by the Collaborating Institutes, was based on:

- Letter of Intent (LoI) followed later by Technical Design Reports
- Cost Books for the proposed construction, assembly and installation work, based on an agreed overall schedule
- Memorandum of Understanding (MoU) for the experiment, through which the specific work and deliverables for each FA were defined
- Payment in a Common Fund allowing the construction of major experimental infrastructures, which were beyond the funding capabilities of single institutes.

The process of getting these documents and commitments agreed was cumbersome as the collaboration rules where being defined in parallel. This WP main aim is to set up a structure to address these issues in a co-ordinated way for the ATLAS upgrade, S-ATLAS. The major coordination issues at the preparatory stage for S-ATLAS are:

A. the preparation of the management/organization/scientific structures needed to plan, cost and implement the detector upgrades; including the preparation of agreements defining the sharing of responsibilities among the participating institutes and funding agencies (FA)
B. the technical planning and coordination tools needed to allow the changes to be efficiently and safely implemented in large complicated existing experimental facilities

The first task includes the organization of scientific exchange and dissemination of information to the potential participants in R&D activities targeted towards future SLHC implementation; this includes exchange of information between the experiments and the accelerator experts.

The ATLAS detector-system serves some 2000 users from 160 institutes. The experiment will need major changes in the forward region layout, the central tracking detectors, the read-electronics and the data acquisition systems for SLHC. These changes will cost around 130 M€ in materials and could include up to half the number of institutes and personnel that were involved in developing the current systems. Once approved, the timescales for constructing the new parts and installing them are estimated to be approximately 5 years.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | WP3 | **Start date or starting event:** | | Month 1 | | | |
| **Work package title** | Coordination for S-ATLAS experiment implementation | | | | | | |
| **Activity Type** | COORD | | | | | | |
| **Participant** | CERN | FOM-NIKHEF | STFC-RAL | UNIGE | | | |
| **Person-months per participant:** | 52 | 20 | 20 | 10 | | | |

**Objectives**

During the FP7 project period of three years the major preparatory goals are:

- Establish the formal structures needed for the ATLAS upgrade construction project, and through Technical Documentation, Cost and Schedule planning, establish an initial MoU with the major FAs taking responsibilities for the Upgrade Construction.
- Establish a Project Office to address the critical technical integration and coordination issues of the new detectors, and the technical and managerial tools needed for the project planning and follow up.

**Description of work**

Task 3.1 Coordination and project structures

Establish a managerial structure (called Upgrade Management Board - UMB) taking responsibility for setting up the formal framework for the detector construction consortium, including the preparatory phase. This structure will take responsibility for the preparation of Cost Books, Reviewing Processes, and Collaboration Agreements. The upgrade management structure shall have a mandate that includes the definition and implementation of:

- hierarchical structures
- participation rules
- financial rules
- formal interface to the global SLHC organization
- sub-project structures
- setting-up of Cost Books for the implementation phase
- internal scientific reviewing and approval procedures
- Scientific exchange and dissemination of information (WEB information, workshops, etc)

The UMB interacts with the Upgrade Collaboration Board, a body that will involve all major stakeholders in the detector upgrade project. The Upgrade Management Board, supported by the Project Office described in task 2, will play a major role in moving from the R&D phase, to formulation of Construction projects and establishing the sharing of responsibilities for detector construction among FAs and institutes. CERN has an overall responsibility for this task but NIKHEF, STFC-RAL, and UNIGE will take important roles within the Upgrade Management Board, including the Reviewing process and Cost book preparation.

Task 3.2 Project Office

The Project Office ensures a consistent information structure related to the technical infrastructures and tools of the upgrade experiment. It is central in the definition of installation scenarios and scheduling.

While individual laboratories or groups of laboratories perform R&D activities on individual detectors and components, the Project Office checks the compatibility of the R&D projects with the global technical framework.

One of the principal tasks of the Project Office is to ensure in a wide sense that there is a consistent information structure for the upgrade projects, taking into account the present technical infrastructure. This information structure covers technical WEB interfaces, databases, drawing and CAD documentation, technical documentation and configuration control, with the aim of making controlled, well documented, safe and consistent changes to the detectors. Installation scenarios and scheduling are also included in its tasks. Such general technical issues need to be resolved convincingly in the preparatory phase to be able to launch realistic plans for constructing the final detector elements, and to allow the participating institutes and FAs to make meaningful contributions to individual parts of the complete detector assembly.

CERN carries the majority of the responsibility for this task, while NIKHEF, STFC-RAL and UNIGE take main responsibilities related to R&D project coordination, documentation and setting up adequate management tools for the projects.

| **Deliverables task 3.1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 3.1.1 | Establish a review office | R | M06 |
| 3.1.2 | Establish the initial Memorandum of Understanding for the upgrade. | R | M36 |
| 3.1.3 | Develop detailed cost books for the upgrade including the installation phase | R | M36 |

| **Deliverables task 3.2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 3.2.1 | Document the detailed technical scope of the upgrade | R | M24 |
| 3.2.2 | Schedule for the Upgraded Detector parts and for the S-ATLAS installation | R | M24 |
| 3.2.3 | Technical documentation, drawing and CAD information for the existing experiment and upgraded elements | R | M36 |
| 3.2.4 | WEB interface tools and configuration databases for the Upgrade detector project | R | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 3.1 | Project structure for R&D phase | R | M06 |
| 3.2 | Schedule for R&D phase and initial implementation schedule | R | M09 |
| 3.3 | Initial cost estimate for upgrade | R | M18 |
| 3.4 | Initial installation plan | R | M18 |
| 3.5 | Upgrade project structures for construction of all deliverables | R | M24 |
| 3.6 | First complete set of technical drawings and documents for the major upgrade parts | R | M32 |

## WP4 – Coordination for the CMS2 experiment implementation

Substantial changes to the CMS experiment will be necessary to upgrade the apparatus for exploitation of the physics opportunities at SLHC. The improved apparatus (CMS2) will be able to handle a factor 10 more luminosity and will incorporate experience from several years of operation at LHC. Changes are needed to most of the detector systems and it may be necessary to radically re-design the forward regions, depending on the choice of the final focusing scheme to achieve high luminosity at SLHC. Large parts of the central tracking system and its services will need to be replaced to cope with higher luminosity and the resulting radiation dose. In addition, readout and trigger electronics and the data acquisition system will need to be modified or replaced to deal with higher collision rates and different bunch spacing in the accelerator. Since CMS is a highly complex, compact apparatus, designed for rapid maintenance and implemented by a large number of institutes worldwide, the technical challenges of replacing major parts requires very careful technical planning and a sophisticated co-ordination effort.

The current CMS experiment is a collaboration of over 2000 scientists and engineers involving 130 institutes worldwide, and represents a material investment of 350 M€. The changes needed to accomplish the CMS2 apparatus, compatible with the SLHC physics program, have been estimated to cost around 130 M€ in materials, and could include up to half the institutes and personnel involved in developing the current systems. Once approved, the timescales for constructing the new parts and installing them are estimated to be approximately 5 years.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | WP4 | **Start date or starting event:** | | Month 1 | | | |
| **Work package title** | Coordination for the CMS2 experiment implementation | | | | | | |
| **Activity Type** | COORD | | | | | | |
| **Participant** | CERN | DESY | ETH Zürich | Imperial | | | |
| **Person-months per participant:** | 42 | 18 | 15 | 15 | | | |

**Objectives**

i) the organization of scientific exchange and dissemination of information to the potential participants in R&D activities targeted to future SLHC implementation, ii) the preparation of the management/organization/scientific structures needed to plan, cost and implement the detector upgrades; including the preparation of agreements defining the sharing of responsibilities among the participating institutes and funding agencies (FA), iii) the technical planning and coordination studies needed to allow the changes to be efficiently and safely implemented in large complicated existing experimental facilities.

**Description of work**

Task 4.1 Coordination and organisation of CMS2

Overall coordination task for managing the upgrade of the experiment for SLHC. Identification of participating institutes and their contribution, including activities related to seeking and integrating new partners. Definition of the organisational project structure needed to manage the consortium of institutes participating in the construction and modification work. Negotiation with institutes and funding agencies to establish collaboration agreements, cost books and reporting methods. Exchange and dissemination of scientific and technical information. (CERN, Imperial)

Task 4.2 CMS2 Technical Coordination Unit

Creation of an CMS2 Technical Coordination Unit, responsible for providing the framework necessary for proper coordination of all aspects of the upgrade and modification work. The structure will incorporate experience from the Engineering Integration Centre and Electronics Steering Group successfully used for mechanical and electronics integration of the existing CMS experiment. Key structural requirements are: accurate and continually updated central information repositories with change control procedures, encompassing the as-built structure and evolving upgrade design and the inventory of existing equipment; agreed tools for design of modifications; frameworks for coordinating and reviewing conceptual and subsequent detailed design; a quality management system; provision for safety oversight; an office charged with ensuring coherent integration, resolving integration conflicts and studying installation scenarios and tooling requirements. The unit will also define a scheduling and reporting mechanism, including milestone definition, progress reporting, transparent connection to the CMS run operations structure in order to fully incorporate experience with the existing experiment and to minimise the impact of upgrade work on the physics programme. (CERN, DESY, ETH Zürich)

| **Deliverables task 4.1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 4.1.1 | Project Structures for construction of systems and sub-systems | R, O | M12 |
| 4.1.2 | Cost book and MoU for the upgrade and installation phase | R | M36 |

| **Deliverables task 4.2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 4.2.1 | Personnel and working practices of the Technical Coordination unit in place | R, O | M12 |
| 4.2.2 | Schedule and reporting mechanism implemented | R | M18 |
| 4.2.3 | Pilot design and schedule for the upgrade project published. | R | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 4.1 | Project Scope Defined | R | M18 |
| 4.2 | Key structural requirements in place (information repository, tools, coordination framework, safety and quality systems, integration office) | R | M18 |

### WP5 – Radiation protection and safety issues for accelerator and experiments

The SLHC project entails a tenfold increase of luminosity (and therefore collision rate) of the particle beams in the interaction points. In the SLHC experiments, scattered radiation is proportional to the collision rate. An increase in activation levels of the detector and its surroundings comparable to the luminosity increase has to be anticipated. This has technical repercussions calling for a tight integration of the accelerator and the S-ATLAS and CMS2 experiments with the aim of maximising luminosity while keeping radiation damage at a minimum.

The luminosity increase required for the SLHC will be obtained by two complementary ways: a better focusing of the beam in the interaction points and an increase of the beam intensity. The latter will lead to higher beam losses in the accelerators of the injector chain and the SLHC, with higher activation of structural material, of ventilated air and cooling water and related potential radiological impact on personnel and the environment.

In view of the high luminosity, it will be crucial for the design of the SLHC to identify all critical issues and design constraints – and to find, if possible, adequate solutions- in the often conflicting requirements of machine and experiment performance on the one side, and component safety and radiation protection regulation on the other.

The results to be obtained will be indispensable when assessing the feasibility of design and construction for both, the accelerator and the experiments in terms of radiation protection constraints and identifying the needs for safety approval procedures as well as the impact of safety issues on the final costs.

Collaborative efforts must be established in order to reach an optimum between the design of accelerator and experiments and the tight regulatory requirements for radiation protection to be applied during their entire lifecycle including operation, maintenance and repair work of SLHC with its injector chain and of the experiments, eventual dismantling of the facilities, and the management of future radioactive waste.

This goal necessitates an iterative process of optimizing accelerator and experiment design and future operation in view of radiation protection and safety constraints. It will bring together experts from all relevant fields and different laboratories and will require effective coordination and exchange of information and data, in particular with other Work Packages. The involvement of all stakeholders from the start will ensure that essential safety aspects concerning radiation protection and environmental issues are taken into account as early as possible. The results and conclusions of this optimization process concerning radiation protection will be documented in reports which will be used to evaluate the compatibility of the proposed design with safety standards and radiation protection regulation.

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|---|---|---|---|---|---|---|
| **Work package number** | WP5 | **Start date or starting event:** | | Month 1 | | |
| **Work package title** | Radiation protection and safety issues for accelerator and experiments | | | | | |
| **Activity Type** | SUPP | | | | | |
| **Participant** | CERN | CTU | GSI | PSI | USFD | | |
| **Person-months per participant:** | 58 | 18 | 16 | 16 | 8 | | |

**Objectives**

- Identification of crucial radiation protection issues in the accelerator and the experiments. Identification of critical areas (in terms of ambient dose equivalent rate) for operation and maintenance of the accelerators and experiments.
- Assessment of radiological impact on personnel and environment for the entire accelerator chain as a function of beam intensity increase and for different design options for the integration of focusing and experiment assemblies.
- Investigation of operative procedures for interventions in high intensity accelerator/ high luminosity regions for maintenance and repair with a view to minimize the radiological impact.
- Investigation of activation of different structural and detector materials in order to estimate future radioactive waste and the cost of its future characterisation and elimination.

**Description of work**

Task 5.1 Detector Radiation & Activation: Simulation calculations for activation and radiation in the detectors and adjacent regions. Validation of the simulations with measurements at LHC. Studies of consequences for different accelerator focusing options, investigation of protection measures such as shielding, and of design options aiming at reducing radiation exposures during maintenance and repair intervention. (CERN, GSI, USFD, CTU)

Task 5.2 Accelerator Radiation & Activation: Simulation calculations for activation and radiation in critical regions of the SLHC and its injectors; evaluation of doses to materials and equipment with provisions to minimize the consequences for equipment lifetime and reliability of beam operation, thereby also minimizing the frequency of maintenance and other interventions. (CERN, GSI)

Task 5.3 Impact Study: Based on the activation studies, assessment of dose rates in areas of the SLHC accessible during operation, as well as of the exposure of the public and the environment due to effluents (air, water). Estimation of dose rates to personnel from activated equipment in the accelerators during access for maintenance and repair intervention. Estimation of amounts of radioactive waste and cost of conditioning and disposal. Study of possibilities to minimize waste(CERN, PSI, USFD, CTU).

| **Deliverables task 5.1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 5.1.1 | Validation of simulation tools with measurements at LHC | R | M24 |
| 5.1.2 | Estimation of activation and radiation levels for critical areas of the experiments at SLHC | R | M24 |

| **Deliverables task 5.2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 5.2.1 | Estimation of activation and radiation levels for critical areas of SLHC and its injectors | R | M24 |

| **Deliverables task 5.3** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 5.3.1 | Impact Study (dose rates, environmental impact and waste production from activated material) for SLHC | R | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 5.1 | Compilation and evaluation of design parameters and details relevant for the assessment of radiological impact. Identification of critical parameters and potential design constraints | R | M12 |
| 5.2 | Dose rate and activation levels in critical areas of the SLHC accelerator, its injectors and in critical areas of the detectors | R | M24 |
| 5.3 | Environmental impact of radioactive releases from SLHC and its injectors | R | M36 |

## WP6 - Development of Nb-Ti quadrupole magnet prototype

The inner triplets in the high luminosity regions are critical components for controlling the luminosity of the collider, the most important performance index for a collider after the collision energy. The luminosity depends critically on the beam current and on the so-called $\beta^*$ at the collision point. However, while the beam current depends on the whole ring and the chain of injectors, the $\beta^*$ depends mainly on the optical properties of the interaction region. So, acting on the low-$\beta$ quadrupoles is the most effective way to increase the luminosity in a fast and relatively inexpensive way in a circular collider. Furthermore, a triplet with a sufficiently large aperture can help a lot in attaining or passing the design beam current in the LHC which is today limited, among other things, by a severe problem of collimator aperture.

The inner triplets in the high luminosity regions consist of a set of 16 high-gradient quadrupoles which focus the beams at the experimental collision points. Each of the four triplets is composed of a string of 4 quadrupoles equipped with magnet corrector packages and other important equipment (like absorbers, cryogenic distribution feed boxes, etc.) As the luminosity increases in the first years of the LHC operation, these quadrupoles will become the main bottleneck to the machine performance. It is expected that about 5 years will be needed to achieve this. Further increase in luminosity will require the replacement of these quadrupoles by a more advanced design with a larger aperture.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Work package number** | WP6 | **Start date or starting event:** | | Month 1 | | |
| **Work package title** | Development of Nb-Ti quadrupole magnet prototype | | | | | |
| **Activity Type** | RTD | | | | | |
| **Participant** | CERN | CEA-Saclay | CIEMAT | CNRS-IN2P3 | STFC-RAL | |
| **Person-months per participant:** | 72 | 42 | 24 | 18 | 24 | |

**Objectives**

The objective is the design, the development, the manufacture and test of the NbTi quadrupole for the interaction regions of the LHC upgrade for higher luminosity.

A new inner triplet layout has been recently proposed [LHC Project report 1000], which serves as a basis of this proposal. In this proposal, each triplet is composed of four quadrupoles all of the same cross section with an inner bore of 130 mm and with two different magnet lengths: (8 and 9 m). For comparison, the present layout features quadrupoles of 70 mm wide aperture, with two different lengths, two different cross sections and different operating currents. In the new design the operating current will be the same, allowing the triplet to be powered in series. This design allows room for reducing physical bottle-necks occurring in other critical component of the machine (e.g. the collimation aperture).

While the peak field remains essentially unchanged, it is limited by the intrinsic properties of the NbTi, i.e. less than 10 T of peak field, the energy and the forces considerably increase with respect to the present design and reach limits so far unexplored for NbTi quadrupoles. These reasons, as well as the necessity to qualify the procedures and the actual field quality, all demand that at least one short model (one-meter-long), be manufactured and cold tested before proceeding to the construction and test of a full scale prototype. This will be a complete magnet with cryostat and all necessary equipment like corrector magnets and it will be the base for preparing the manufacture of the 16 quadrupoles needed for the 2 high luminosity interaction regions (ATLAS and CMS).

**Description of work**

Task 6.1 Design of advanced Nb-Ti superconducting quadrupole: The 130 mm aperture poses considerable problems of mechanics and force containment, with forces and energy even larger than in the LHC main dipoles. The design package will review all these aspects: magnetic, mechanical, coil positioning and stability, protection and thermal behaviour. The thermal design will be reviewed and the insulation scheme will be possibly upgraded with respect to the one used for the LHC. The superconductor, fine filament high quality NbTi, high RRR copper stabilized, will be fully qualified both as cable and as coil package for thermal and mechanical properties (like elastic modulus, ultimate strength, insulation creep limit, etc.).

The design of the complete cold mass will be carried out, including the corrector magnet package. The principle choices on corrector magnet technology will be done following the freezing of the optics lay-out. The cryostat, interface and interconnections will be carefully studied and optimized for a working temperature of 1.9 K.

All these issues will also be studied in view of the higher radiation level and heat deposition that the increased luminosity will generate in the triplet equipment.

CERN is the leading institute and will coordinate the effort. CEA-Saclay and CERN will be in charge of the magnet design with contributions from CIEMAT and STFC-RAL. CIEMAT and STFC-RAL will be in charge of the corrector design and CERN and CNRS-IN2P3 will be in charge of cryostat design.

Task 6.2 Construction and testing of a short model: This task concerns the construction and test in cryogenic conditions of a 1 meter long model magnet. This will allow qualifying the coil manufacturing procedure, the mechanical assembly procedure, the coil stability as well as the field quality in real operation conditions. The task is composed of the design and construction of the necessary tooling, as well as its installation and qualification. After that, the coil winding and curing with a new insulation scheme will be tested and applied to the coils (1 or 2 spare coils are foreseen). The mechanical assembly will be carried out, either in a vertical assembly, according to the classic technique in CEA-Saclay style, or in a horizontal assembly.

Once assembled and fully instrumented, the bare magnet will be cold tested and measured from low field up to full power.

The coil manufacturing will be led by CEA-Saclay, in collaboration with CERN, while CERN will take care of the cold mass assembly and of the cold test at its own premises. CIEMAT and STFC-RAL will do the corresponding tests on corrector magnet short models.

Task 6.3 Construction and testing of a full-scale prototype: This task has the objective to manufacture and full test a complete prototype quadrupole. The final, effective proof of the system proposed for this new interaction region triplet will be the construction of a prototype (the length is still to be defined: in the range from 5 to 10 m, input from task 1) and its successful test of all aspects: quadrupole magnet, correctors and the thermal and mechanical behaviour of the cryostat. The content of this task starts with the design and construction of the tooling according to the magnet and the cryostat design decided in task 1 followed by the test of the long magnet winding procedure and the curing and collaring stages. Once the coils have been collared, the selected procedure for the cold mass assembly, already tested in the task 2, will be applied on the long prototype, with specific tooling suitably designed and installed. The cryostat with improved features will then be manufactured and the cold mass assembled into it. Finally the magnet will be tested in the unique cold test facility of CERN, where complete tests will be done to assess the suitability of the magnet for the new interaction region of LHC in terms of field quality, quench behaviour and safety.

CERN will provide the necessary guidance and coordination for the global effort. CERN will manufacture the long prototype magnet, with contributions from CEA-Saclay, STFC-RAL and CIEMAT. The correctors will be manufactured by CIEMAT and STFC-RAL. CNRS-IN2P3 will assist CERN in manufacturing the cryostat and the tooling for the assembly of the magnet into the cryostat.

| **Deliverables Task 6. 1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 6.1.1 | Basic design of the triplet | R | M12 |
| 6.1.2 | Complete IR design | R | M36 |

| **Deliverables Task 6. 2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 6.2.1 | Construction of the model | D | M18 |
| 6.2.2 | Assessment of the design | R | M24 |

| **Deliverables Task 6. 3** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 6.3.1 | Construction Corrector magnet package | P | M26 |
| 6.3.2 | Prototype quadrupole magnet | P | M32 |
| 6.3.3 | Test of complete quadrupole prototype | R | M34 |
| 6.3.4 | Assessment of the design | R | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 6.1 | Qualification of magnet components | O | M8 |
| 6.2 | Basic Magnet design | O | M10 |
| 6.3 | Complete cold mass design | O | M18 |
| 6.4 | Complete cryomagnet design | O | M22 |
| 6.5 | Cryogenic and power test of the model | O | M22 |
| 6.6 | Electrical test of collared coil | O | M28 |
| 6.7 | Cold test corrector magnets | O | M28 |

### WP7 - Development of critical components for the injectors

The quality of the proton beam circulating in the LHC which determines its performance, is established in the lowest energy accelerators and can, at best, be preserved in the higher energy accelerators. It is true in particular for the superconducting linac (SPL), which must meet demanding requirements in terms of beam characteristics and reliability. Two technical subjects are especially critical for reliably reaching the required density of particles in all planes, the $H^-$ ion source and the stability of the energy from the linac.

The emittances of the beam from the $H^-$ ion source must be small and stable, the reliability has to exceed 99% and the lifetime 2000 hours. In the case of Linac4, which cycles at 2 Hz, existing solutions are expected to be applicable with only limited research and development. This is not the case with the SPL which cycles at up to 50 Hz with a duty factor of 4%, and an adequate solution remains to be found and demonstrated. Development and tests are critically needed to demonstrate that the characteristics required for the SPL can potentially be achieved and to guide the design of the operational source.

The stability and reproducibility of the field in the accelerating structures determines the stability in energy and phase of the beam delivered by the linac. Superconducting cavities are very efficient accelerating devices because of their very high gradient capability and because of the excellent power efficiency. However, they are very sensitive to mechanical vibrations, and the Lorentz forces resulting from pulsed operation at high gradient are an unavoidable source of excitation. The work done in the JRA “HIPPI” (part of the “CARE” I3 in the FP6) is already starting to address these issues by supporting the study of low beta superconducting cavities operating in pulsed mode, the development of a fast tuner and the realization of a high power 700 MHz test place in the CEA-Saclay. From that basis, there is the need to elaborate the architecture of an RF system that will achieve an adequate stabilization of the accelerating field and to specify its components. This “real” system has to use a single klystron to drive a large number of cavities, each cavity being fed through a high power amplitude/phase modulator. The complete linac beam dynamics has to be simulated to correctly analyse the consequences for the beam. The 700 MHz test place will be repeatedly used during this task to refine the characterization of the cavities and their tuner, to test corrective actions and finally to validate a system solution using prototype electronics.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | WP7 | **Start date or starting event:** | | Month 1 | | | |
| **Work package title** | Development of critical components for the injectors | | | | | | |
| **Activity Type** | RTD | | | | | | |
| **Participant** | CERN | CEA-Saclay | DESY | INFN | STFC-DL | | |
| **Person-months per participant:** | 148 | 20 | 3 | 7 | 1 | | |

**Objectives**

- To develop a test bed for a high duty factor for the plasma generator of an H- RF ion source, to guide the design of the operational source.
- To elaborate the architecture, to specify the components and to demonstrate the performance of an RF system that will properly stabilize the accelerating field in the SPL and achieve the characteristics required for LHC in the following synchrotron ("PS2").

**Description of work**

Task 7.1 Development towards an H- source for the SPL

Development is required towards a negative hydrogen ion source that can fulfil the duty factor, intensity, emittance and reliability requirements of the SPL. One candidate for the plasma production method is the RF (2 MHz) driven plasma source. DESY has developed an ion source design where the RF antenna is separated from the vacuum system by a ceramic plasma chamber, which has allowed DESY to demonstrate a very high reliability source for low duty factors for the production of negative hydrogen ions with high intensities.

Increasing the duty factor of the source will result in increased thermal load on the elements of the plasma generation region, which will require cooling. The initial challenge is to manage the thermal load into the source.

The thermal distribution will be calculated with finite element modelling of the heat loads into the plasma generation system. Such modelling has already been shown to be fruitful for the Penning Ion Source design at ISIS.

Furthermore, the increased duty cycle will require increased hydrogen gas flow into the plasma region. Simulations will be performed to improve the geometry of the vacuum pumping system in order to reduce the pressure downstream of the plasma generation system (to avoid discharges in the high electric field region of the ion extraction region).

Construction of a plasma generation system and its sub systems (100kW 2MHz RF generator for up to 4% duty cycle, vacuum system and hydrogen delivery) will allow comparison with the thermal model, and with the efficiency of the vacuum pumping.

The resulting plasma generation system (and in particular its sub systems) will be available to serve for future testing, and as the basis of a future RF ion source for high duty factor operation.

The steps to design and build this generator are:
- Finite element thermal study of the Linac 4 design source at the final duty factor.
- Design of the plasma generator to operate at 4% duty cycle.
- Construction of plasma generator and sub-systems (e.g. RF generator, hydrogen gas injection and pumping).
- Infrastructure preparation and system installation
- Plasma generation and study of the thermal conditions.

CERN will be the leading institute and will co-ordinate the other efforts. RAL will be involved in the ion source thermal modelling, and DESY will contribute to the modelling and design of the plasma generator.

Task 7. 2: Field stabilisation in pulsed superconducting low beta (v/c) accelerating structures

The goal is to elaborate the architecture of an RF system that will achieve an adequate stabilization of the accelerating field and to specify its components. First a detailed characterisation of the tuner/SC-cavity ensemble will be necessary to compare the two existing RF cavity/tuner ensembles and provide accurate data for the RF system design, using the test stand and high power RF source in CEA-Saclay and the results from the "HIPPI" JRA. In parallel the modelling of the different RF components, the cavity/tuner, the power amplifier, etc. will be done. As the component models are completed, the design architecture of the complete RF system will start. This architecture will address the complication introduced by the powering of several cavities from one RF source. Simulations to predict, understand and optimise the behaviour of the system will be combined with a simulation of the beam dynamics of the full Linac to ensure the beam quality at the exit of the accelerator. When optimized, the RF system will be fully specified, including items such as the high power modulator, the Low Level RF system and the algorithms controlling them.

Subsequently the preparation of the demonstration to validate the design can start. Prototype electronics and other necessary interfaces will be built. All components will be assembled in the test stand. The system validation tests will follow. It is expected that re-optimisation of the architecture will occur.
Finally a report will be produced summarising the results and describing the architecture and specifications of the complete Linac RF system.
The CEA-Saclay team will provide, operate and manage the test stand for superconducting cavities, with its 700 MHz high power RF system and one cavity/tuner ensemble. They will also contribute to the simulation of the RF system and of the Linac beam dynamics.
The INFN team will provide the other cavity/tuner ensemble and will participate in the in-depth testing of these components and the preparation of the data for the RF system design.
CERN will provide overall co-ordination and will participate in the design of the system architecture, the beam dynamics simulations and the preparation of the demonstration.
All participants will be present at and participate in the tests and will also contribute to the final report, though CERN will have the main responsibility for it.

| **Deliverables task 7.1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 7.1.1 | Finite element thermal study of the Linac 4 design source at the final duty factor. | R | M12 |
| 7.1.2 | Design of a high duty factor plasma generator | R | M18 |
| 7.1.3 | Construction of the plasma generator and sub-systems (e.g. 2Hz RF generator, hydrogen gas injection and pumping). | D | M30 |
| 7.1.4 | Plasma generation and study of the thermal and vacuum conditions. | R | M36 |

| **Deliverables task 7.2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 7.2.1 | In depth characterisation of the two tuners plus cavities developed in the frame of the “HIPPI” JRA , FP6 (tuner/cavity characteristics) | R | M12 |
| 7.2.2 | Design of RF system architecture including modelling of RF components, simulation of the RF system and simulation of beam dynamics of the full LINAC. RF system and high power modulator specifications. | R | M18 |
| 7.2.3 | Production of a prototype electronic system and other elements for a full system demonstration. Definition of demonstration procedure. | P | M30 |
| 7.2.4 | Full test and validation of RF system. Final report. | D | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 7.1 | List of required improvements for the design of the high duty factor plasma generator to function at a high duty factor. | R | M14 |
| 7.2 | Describe the RF system and give specifications of the system to be tested in the high power test stand. | R | M18 |

### WP8 – Tracking detector power distribution

Full exploitation of the physics potential of the SLHC project requires very significant changes, improvements and upgrades of the two large multipurpose detector systems at LHC. This is needed to be able to handle a factor 10 more luminosity and because the lifetime of the current systems is limited due to radiation damage. The changes involve all parts of the detector systems, but mostly affect the replacement of the large central tracking systems, comprising several hundreds of million particle detection elements, designed in state-of-the-art solid-state sensor technologies coupled to deep-submicron radiation-hard electronics. Sensitive elements (pixels and strips) will be as small as 80*80 $\mu m^2$ in the inner regions, going up to 3 $mm^2$ in the outer regions. Each individual sensitive element is coupled directly on the detector to its own electronics amplifier and address logic. The S-ATLAS and CMS2 central trackers will be subject to high radiation levels and will be housed in strong magnetic fields of up to 4 Tesla. They will represent materials investments above 60 M€ each. Once designed and financially approved, they will take approximately 5 years to be constructed.

The distribution of power to the readout electronics of the SLHC trackers poses a huge technical challenge, which strongly affects the overall design of the tracker. The highly segmented independent powering presently adopted for the LHC trackers becomes impractical at the SLHC for a number of reasons including: 1) there is no space for large increase in the number of power cables (which would correspond to the much increased number of electronic channels); 2) power losses in the power cables lead to a poor power efficiency and causes heat dissipation; 3) the material represented by the power cables and additional cooling leads to increased multiple-scattering and limits the resolution of the tracking detectors. Therefore, novel solutions to the power distribution challenge must be identified and developed to maturity.

Two main approaches shall be investigated. One consists in exploring ***DC-DC conversion*** to bring higher voltages and lower currents inside the tracker volume, and the other in exploring ***serial powering schemes***. Both approaches address their implementation directly into the on-detector electronics, and therefore mainly involve microelectronics developments. The radiation hardness criterion is not fulfilled by commercially available components and forms the principal reason for dedicated development. For the DC-DC conversion, the incompatibility with commercial products is enhanced by the presence of a large magnetic field inside the detectors, which renders the conventionally used magnetic components (inductors with ferromagnetic core) unsuitable. At present no collaboration framework exists for the detector powering studies. The SLHC-PP project forms a crystallisation centre around which a large new collaboration is expected to grow.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | WP8 | **Start date or starting event:** | | Month 1 | | | |
| **Work package title** | Tracking detector power distribution | | | | | | |
| **Activity Type** | RTD | | | | | | |
| **Participant** | STFC-RAL | CERN | AGH-UST | PSI | UBONN | | |
| **Person-months per participant:** | 35 | 48 | 36 | 16 | 48 | | |

**Objectives**

The objective of work package 8 is to explore various *DC-DC conversion* options as well as *serial powering schemes,* to select the most suitable schemes for integration into dedicated ASICs and to test the scheme in full-scale S-ATLAS and CMS2 detector module prototypes. At the end of the preparatory phase, a fully qualified technical solution, ready for use in the implementation phase will be available.

**Description of work**

Task 8. 1 DC-DC conversion

The development aims for radiation-hard components operating in magnetic fields up to 4 Tesla. The following alternative solutions will be explored: buck converters based on air core inductors and on-chip conversion for small current applications.

The R&D program shall be structured as follows:

*"Evaluation phase"*

An evaluation of different conversion approaches will be made, singling out the critical difficulties and developing conceptual solutions to overcome them. Exploration of partnerships with industry.

*"Prototype phase"*

Development of prototype converters for the alternative solutions. Although this generation of prototypes are intended to be demonstrators only, the air-core inductor converter will have the same level of integration as the final product. All active components will be embedded in ASICs and the number of passive components shall be minimized to be compatible with the real application. The on-chip DC-DC converter, integrated in modern CMOS technologies, will also be prototyped to assess the feasibility of this solution. Prototypes will be integrated in detector modules and tested at the system level. A report will detail the performance of the prototypes, with conclusions on the final viability of each conversion approach and recommendation for LHC upgrades.

CERN will play the major role in the inductor-based converter, with contribution from STFC-RAL in the system-level testing. PSI will be in charge of the evaluation and first prototyping of the on-chip DC-DC conversion.

Task 2: Serial Powering

Serial powering is a novel and highly promising concept for power distribution in silicon particle detectors. It involves a constant current source feeding a chain of silicon strip or pixel modules combined with shunt and linear voltage regulators on the module. This reduces the number of cables, minimizes the total current brought into the detector volume and therefore the power losses in the cables.

In serial powering schemes, each module sits at a different potential; thus control, clock and data signals must be AC-coupled or use optical signal transmission. Apart from the challenges of designing radiation-hard power electronics, serial powering systems require the development of over-current protection and redundancy schemes and exploration of grounding and shielding techniques.

The serial powering R&D programme consists of three phases:

*" Generic studies"*

*S*pecification and development of AC-coupling or opto-decoupling elements; investigation of grounding and shielding techniques for serial powering schemes; system evaluation of serial powering systems based on commercial shunt regulators.

*"Development of custom radiation-hard power electronics"*

Design, submission and characterization of custom radiation-hard shunt regulators, power devices and AC–coupling circuitry. Several design iterations in different technologies are foreseen. The concept of a generic high-current serial powering chip, with various protection and slow-control features, capable of powering S-ATLAS and CMS2 pixel and strip detectors, will be evaluated.

*"System design and characterization of super-modules"*

Implementation of custom electronics in tracking detector super-modules. A super-module will consist of a significant number of detector modules powered in series. The super-module performance will be fully

characterized.
AGH-UST, RAL and UBONN will be responsible for this task. AGH-UST will contribute predominantly to the design of the radiation-hard electronics. STFC-RAL and UBONN work on all sub-tasks.

| **Deliverables task 8.1** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 8.1.1 | Evaluation report on DC-DC conversion technologies | R | M12 |
| 8.1.2 | Prototypes and viability report | P, R | M30 |
| 8.1.3 | Integration in full-scale detector modules | D | M36 |

| **Deliverables task 8. 2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 8.2.1 | Evaluation report on generic serial powering studies and specification of serial powering components | R | M12 |
| 8.2.2 | Custom serial powering circuitry and evaluation of generic high-current serial powering chip | P,R | M24 |
| 8.2.3 | Full-scale super-module with custom serial powering circuitry | D | M36 |

| **Milestones** | **Description** | **Nature** | **Expected date** |
|---|---|---|---|
| 8.1 | DC-DC conversion prototype | P | M24 |
| 8.2 | Serial powering prototype | P | M24 |

## B 1.3.6 Efforts for the full duration of the project

### Indicative efforts (person-month) per beneficiary per WP

| Participant short name | Participant number | WP1 | WP2 | WP3 | WP4 | WP5 | WP6 | WP7 | WP8 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| CERN | 1 | 42 | 34 | 52 | 42 | 58 | 72 | 148 | 48 | 496 |
| AGH-UST | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 36 |
| CEA-Saclay | 3 | 0 | 4 | 0 | 0 | 0 | 42 | 20 | 0 | 66 |
| CIEMAT | 4 | 0 | 4 | 0 | 0 | 0 | 24 | 0 | 0 | 28 |
| CNRS-IN2P3 | 5 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 18 |
| CTU | 6 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 18 |
| DESY | 7 | 0 | 0 | 0 | 18 | 0 | 0 | 3 | 0 | 21 |
| ETH Zurich | 8 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 15 |
| FOM-NIKHEF | 9 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 20 |
| GSI | 10 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 16 |
| Imperial | 11 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 15 |
| INFN | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 7 |
| PSI | 13 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 16 | 32 |
| STFC | 14 | 0 | 4 | 20 | 0 | 0 | 24 | 1 | 35 | 84 |
| UBONN | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 48 |
| UNIGE | 16 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 |
| USFD | 17 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 8 |
|  | TOTAL | 42 | 46 | 102 | 90 | 116 | 180 | 179 | 183 | 938 |

## Indicative efforts (person-months) per activity type per beneficiary

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| | CERN | AGH-UST | CEA-Saclay | CIEMAT | CNRS-IN2P3 | CTU | DESY | ETH Zurich | FOM-NIKHEF |
| Work packages for RTD activities | | | | | | | | | |
| WP6 | 72 | 0 | 42 | 24 | 18 | 0 | 0 | 0 | 0 |
| WP7 | 148 | 0 | 20 | 0 | 0 | 0 | 3 | 0 | 0 |
| WP8 | 48 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL RTD | 268 | 36 | 62 | 24 | 18 | 0 | 3 | 0 | 0 |
| Work packages for Coordination activities | | | | | | | | | |
| WP2 | 34 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| WP3 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| WP4 | 42 | 0 | 0 | 0 | 0 | 0 | 18 | 15 | 0 |
| TOTAL Coord. | 128 | 0 | 4 | 4 | 0 | 0 | 18 | 15 | 20 |
| Work packages for Support activities | | | | | | | | | |
| WP5 | 58 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 |
| TOTAL Coord. | 58 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 |
| Work packages for Management activities | | | | | | | | | |
| WP1 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL manag.. | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | |
|---|---|---|---|---|---|---|---|---|---|
| | GSI | Imperial | INFN | PSI | STFC | UBONN | UNIGE | USFD | TOTAL |
| Work packages for RTD activities | | | | | | | | | |
| WP6 | 0 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 180 |
| WP7 | 0 | 0 | 7 | 0 | 1 | 0 | 0 | 0 | 179 |
| WP8 | 0 | 0 | 0 | 16 | 35 | 48 | 0 | 0 | 183 |
| TOTAL RTD | 0 | 0 | 7 | 16 | 60 | 48 | 0 | 0 | 542 |
| Work packages for Coordination activities | | | | | | | | | |
| WP2 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 46 |
| WP3 | 0 | 0 | 0 | 0 | 20 | 0 | 10 | 0 | 102 |
| WP4 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 90 |
| TOTAL Coord. | 0 | 15 | 0 | 0 | 24 | 0 | 10 | 0 | 238 |
| Work packages for Support activities | | | | | | | | | |
| WP5 | 16 | 0 | 0 | 16 | 0 | 0 | 0 | 8 | 116 |
| TOTAL Coord. | 16 | 0 | 0 | 16 | 0 | 0 | 0 | 8 | 116 |
| Work packages for Management activities | | | | | | | | | |
| WP1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 |
| TOTAL manag.. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 |

## B 1.3.7 List of milestones and planning reviews

### List of milestones

First year of the project:

| Milestone number | Milestone name | WP number | Lead beneficiary number | Delivery date | Comments |
|---|---|---|---|---|---|
| 1.1 | Consortium Agreement | 1 | 1 | M03 | Sending copy to the EC |
| 1.2 | Kick-off meeting | 1 | 1 | M03 | EC Project Office invited |
| 3.1 | Project structure for R&D phase | 3 | 1 | M06 | Documented as WEB structure |
| 6.1 | Qualification of magnet components | 6 | 1 | M08 | Qualification document published |
| 3.2 | Schedule for R&D phase and initial implementation schedule | 3 | 1 | M09 | Schedule document |
| 6.2 | Basic Magnet design | 6 | 1 | M10 | Magnet design report |
| 1.3 | First Annual SLHC-PP Meeting | 1 | 1 | M12 | Presentations on SLHC-PP web site |
| 5.1 | Compilation and evaluation of design parameters and details relevant for the assessment of radiological impact. Identification of critical parameters and design constraints | 5 | 1 | M12 | Meeting with stakeholders in accelerator and experiments, to define an agreement on design parameters. |

Second year of the project:

| Milestone number | Milestone name | WP number | Lead beneficiary number | Delivery date | Comments |
|---|---|---|---|---|---|
| 7.1 | List of required improvements for the design of the high duty factor plasma generator to function at a high duty factor | 7 | 1 | M14 | Report approved by partners |
| 2.1 | Financial management system (beta version) | 2 | 1 | M18 | Beta version released |
| 3.3 | Initial cost estimate for upgrade | 3 | 1 | M18 | Report |
| 3.4 | Initial installation plan | 3 | 1 | M18 | Report |
| 4.1 | Project Scope Defined | 4 | 1 | M18 | Report publication |
| 4.2 | Key structural requirements in place (information repository, tools, coordination framework, safety and quality systems, integration office) | 4 | 1 | M18 | Publication of report describing the features |
| 6.3 | Complete cold mass design | 6 | 1 | M18 | Design Report published |
| 7.2 | Describe the RF system and give specifications of the system to be tested in the high power test stand | 7 | 1 | M18 | Report approved by partners |
| 6.4 | Complete cryomagnet design | 6 | 1 | M22 | Design Report published |
| 6.5 | Cryogenic and power test of the model | 6 | 1 | M22 | Test report published |
| 5.2 | Dose rate and activation levels in critical areas of the SLHC accelerator, its injectors and in critical areas of the detectors | 5 | 1 | M24 | Results of study published in Report |
| 1.4 | Second Annual Review meeting | 1 | 1 | M24 | Presentations on SLHC-PP web site |
| 2.2 | EVM software (beta version) | 2 | 1 | M24 | Beta version released |
| 3.5 | Upgrade project structures for construction of all deliverables | 3 | 1 | M24 | Documented as WEB structure |
| 8.1 | DC-DC conversion prototype | 8 | 14 | M24 | Prototypes fully tested. The actual milestone is the technology decision taken as a result of the viability study, as reported in deliverable 8.1.2 |
| 8.2 | Serial powering prototype | 8 | 14 | M24 | Technology decision, following evaluation report on the generic serial powering chip (deliverable 8.2.2) |

Third year of the project:

| Milestone number | Milestone name | WP number | Lead beneficiary number | Delivery date | Comments |
|---|---|---|---|---|---|
| 6.6 | Electrical test of collared coil | 6 | 1 | M28 | Test report published |
| 6.7 | Cold test corrector magnets | 6 | 1 | M28 | Test report published |
| 3.6 | First complete set of technical drawings and documents for the major upgrade parts | 3 | 1 | M32 | Reviewed and documented by review report |
| 5.3 | Environmental impact of radioactive releases from SLHC and its injectors | 5 | 1 | M36 | Results of study published in Report |
| 1.5 | Final Project Review | 1 | 1 | M36 | Final Report to be delivered |

## List of planning reviews

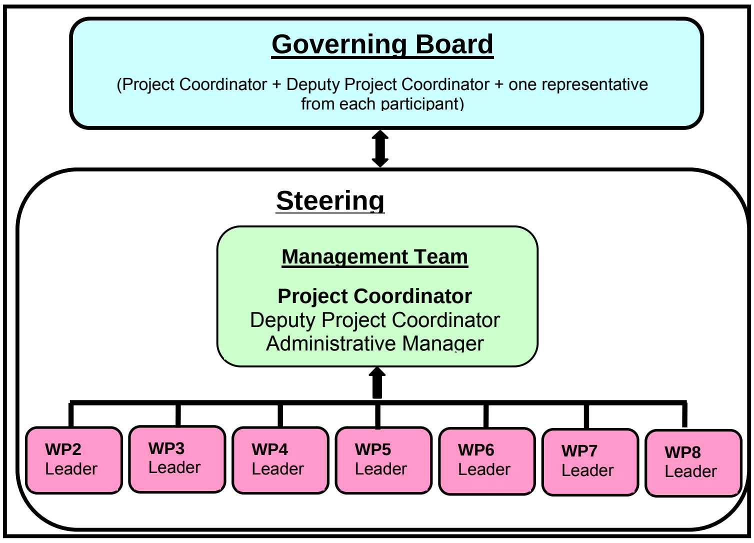
| Tentative schedule of project reviews | | | |
|---|---|---|---|
| **Review No** | **Tentative timing, i.e. after month X = end of a reporting period** | *Planned venue of review* | *Comments, if any* |
| 1 | M12 | CERN | Venue will be decided by Governing Board |
| 2 | M24 | CERN | Venue will be decided by Governing Board |
| 3 | M36 | CERN | Venue will be decided by Governing Board |

## B2. Implementation

### B 2.1 Management structure and procedures

The project management and coordination activities will be implemented through the management structure, shown in the Figurebelow, which is similar to the management structure of successful FP6 Research Infrastructure projects, such as CARE and EUROTeV.

**Project Management (WP1)**



- Governing Board (GB)

The SHLC-PP Consortium is composed of 17 legal entities. The Governing Board (GB) is the top-level decision making and arbitration body. It has one representative from each participant in the project and includes the Project Coordinator and Deputy Project Coordinator. Each member has one vote and decisions will be taken by simple majority. The GB will have the power to decide, upon Steering Committee proposals, on strategic issues, such as modifications of the project programme (if necessary), admission of new participants during the Preparatory Phase. The GB will be convened for the first time one month before the start of the contract. The Governing Board will review the progress of the project at the annual SLHC-PP meetings, and, where necessary, decides on changes in the work plan and budget allocation for the next reporting period. During the Preparatory Phase project, the GB will meet once a year with intermediate phone meetings, if required. The chair of the GB will be elected by its members.

- Steering Committee (SC)

The SC is composed of 10 members: the Project Coordinator and Deputy Project Coordinator, the Administrative Manager, and the seven Work Package Leaders of WP2 to WP8. It is the executive body of the Consortium in charge of the coordination and management of all activities in the project. It shall monitor and review the work progress and will take executive decisions on scientific and administrative issues that may arise during the implementation of the project. The SC will have regular meetings typically four times a year.
The Project Coordinator (PC) will be responsible for the daily scientific management of the SLHC-PP project, including the overall supervision and regular follow-up of the progress in all Work Packages. The PC will chair

and organize the Steering Committee meetings, and will be in charge of the preparation of the Periodic Reports and the Final Report.

*Lyn Evans (CERN)* will be SLHC-PP Project Coordinator.

Lyn Evans is the LHC Project Leader. He has more than 30 years experience in building particle accelerators. He started his career at CERN in 1969 and has contributed to all major CERN projects thereafter. In 1990, Evans was appointed Head of the SPS Division, and eventually ran the Large Electron Positron Collider, which occupied the tunnel now taken up by the LHC. He was appointed LHC Project Leader in 1993 and since then has been in charge of the largest and most complex scientific project ever undertaken.

The Deputy Project Coordinator (DPC) will assist the Coordinator in the daily scientific management tasks, will replace the Coordinator in case of absence, and will have the responsibility for the coordination of the Work Packages related to the SLHC Experiments (WP3, WP4, WP8 and part of WP5).

The Administrative Manager (AM) will be responsible for the administrative and contractual follow-up of the project, including budget control and cost reporting. The AM will monitor the contractual deadlines for deliverables and milestones, and will assist in organising the Annual Review and Final Review meetings. The AM will be in charge of financial issues, such as payments and distribution of EU funding received, collection of audit reports, of management reports and justification of costs, as well as of legal issues, such as the implementation of the Consortium Agreement and Intellectual Property Rights agreed by the participants. The AM will be in charge of the implementation of the dissemination of information. In addition, the AM will oversee the gender equality and safety practices.

The Project Coordinator, Deputy Project Coordinator, and Administrative Manager will form the Management Team. The Management Team will profit from administrative assistance for their various activities.

The WP Leaders will manage the RTD, coordination and/or support activities in the framework of their own WP. They have the responsibility for ensuring the effective cooperation between the participants in each WP, for monitoring the task progress, including the milestones, and for producing the deliverable reports in their WPs. They will contribute to the preparation of all other reports regarding the activities of their WPs, which are requested by the Management Team.

Modern project management tools, which have proved their efficiency in the LHC project, will also be used for SLHC PP. An efficient IT tool has been developed at CERN for Progress Project Tracking, and a special version is available for management of EU projects. This tool is in use in major CERN/EU co-funded projects, such as EGEE and Ethics. A customization for the SLHC-PP project is now being evaluated.

The progress of the project will be assessed by the Governing Board at the Annual SLHC-PP Meetings. The continuous monitoring of the progress in all Work Packages will be done by the Management Team. Each WP Leader will periodically inform the management upon the status of the work package activities.

The main tool for monitoring technical and financial progress will be the Earned Value Management system, successfully used for the LHC project. In this system, each Work Package is broken down into tasks and sub-tasks, according to the work breakdown structure, and the progress of each task (or sub-task) is regularly monitored. In this way, deviation from the budget or task schedule can be detected early and preventive measures can be taken accordingly. The EVM system has been used for the first time in the LHC project and has proved its management value in this extremely complex project with a budget of some 2 billion euros.

No extension in the number of beneficiaries of this action is envisaged at this point. However many scientific partners contribute already to the preparatory phase for SLHC project, in work packages not supported directly by the EC, as described in Table 2b of the SLHC-PP Proposal. Other scientific partners are expected to join the SLHC scientific activities in the course of the project.

## B 2.2 Beneficiaries

The project Consortium consists of 17 partners, who have solid experience and largely sufficient combined expertise to successfully achieve all project objectives.

CERN is the world's largest particle physics centre and operates the world's largest complex of particle accelerators. The 50-year history of CERN is marked with impressive achievements in the construction and operation of powerful linear and circular accelerators, such as the Intersecting Storage Rings in the 70s, the Super Proton Synchrotron in the 80s, and the Large Electron Positron Collider in the 90s. CERN is currently installing and soon commissioning the Large Hadron Collider, scheduled to switch on in 2008. With proton-proton collisions at 14 TeV, the LHC will be the most powerful accelerator in the world awaited so eagerly by the particle physics communities on all continents. Throughout its history CERN has coordinated ever-larger particle physics experiments and has made fundamental contributions to the development of the technologies involved (particle detection, data acquisition, simulation and analysis techniques).

In the SLHC-PP project, CERN is the Coordinator and will actively participate in all Work Packages. Other than playing the leading role, like in all previous large-scale accelerator projects, mentioned above, CERN has a solid experience in the EU Framework Programmes. In FP6 only, CERN has participated in some 30 EU co-funded projects and successfully coordinated several of those. The Office of EU Relations, the Finance EU unit, the Legal Service, and the Technology Transfer unit at CERN have profound experience and expertise in the handling and administration of EU projects.

CERN has a long-standing experience and a broad expertise in the development, design, manufacturing, commissioning, testing and operating of particle-accelerators and detectors, as well as in radiation protection and safety.

An overview of the involvement of the other participants in the project and their relevant experience is presented in Table below.

**Involvement and relevant experience of the participants in the project**

| Participant | From | Key tasks in the project | Relevant expertise and experience |
|---|---|---|---|
| AGH-UST | PL | - electronics design for serial powering | - design of IP blocks, development and testing of radiation hard ASICs for readout of silicon strip detectors |
| CEA-Saclay | FR | - design of the LLRF system architecture<br>- beam dynamics simulation of the LINAC<br>- testing of RF in the high-power test stand<br>- design of the superconducting quadrupole<br>- construction of the coils in the 1 m-long model | - development of superconducting RF technology<br>- study and simulation of particle beam dynamics for proton injectors<br>- design and manufacturing of supercond. magnets for accelerators |
| CIEMAT | ES | - corrector package design and fabrication for Nb-Ti magnet prototype | - design, fabrication and testing of super-conducting magnets for particle accelerators |
| CNRS-IN2P3 | FR | - design and manufacturing of the cryostat for the quadrupole | - experience in design and construction of cryogenic equipment for accelerators |
| CTU | CZ | - simulation, estimation and measurements of radiation and activation levels in the detector areas | - radiation and activation calculations and simulations for LHC experimental areas<br>- developing radiation monitoring devices |
| DESY | DE | - participation in the CMS2 Technical Coordination Unit<br>- thermal analysis of the H- source and | - broad experience with the design, construction and technical coordination of large particle physics experiments |

**Involvement and relevant experience of the participants in the project**

| **Participant** | **From** | **Key tasks in the project** | **Relevant expertise and experience** |
|---|---|---|---|
| | | conceptual improvements of the higher duty factor design | - modeling and FEM thermal analysis<br>- development of RF sources |
| ETH Zürich | CH | - participation in the CMS2 Technical Coordination Unit | - leadership of the CMS Engineering Integration Centre |
| FOM-NIKHEF | NL | - organisation and planning of the ATLAS upgrade | - involved in R&D for the ATLAS upgrade<br>- leading organisational role in the preparations for the ATLAS Upgrade Planning |
| GSI | DE | - estimation of accelerator and detector activation with Monte-Carlo radiation transport codes | - experience in use of coders from design and planned facilities |
| Imperial | UK | - organisation and planning of the CMS upgrade | - extensive experience in the coordination of large particle physics projects, in particular the CMS electronics coordination |
| INFN | IT | - RF testing and characterization of the system in the CEA-Saclay RF facility | - design, construction, testing of RF systems and SC cavities for accelerators |
| PSI | CH | - tracking detector powering, in particular on-chip DC-DC conversion for small current applications<br>- maintenance planning of activated accelerator components in high-radiation areas | - extensive experience in the design and construction of silicon pixel detector systems, in particular the CMS barrel pixel detectors<br>- extensive operational radiation protection experience from the 1 MW sector cyclotron and associated targets |
| STFC | UK | WP2: Applied Science Division (ASD); contribute to the definition of management structures, communication channels and management of WP implementation;<br>WP3: Particle Physics Department (PPD) will lead the review office;<br>WP6: ASD; involvement in design and development of prototype corrector magnet packages;<br>WP7: Accelerator Science and Technology Centre (ASTeC); involvement in thermal modelling of ion source.<br>WP8: PPD will provide the leadership and contribute to development of serial-powering systems and characterization of serial powering and DC-DC circuitry. | - manages international research projects for the UK research community.<br>- directs, coordinates and funds research, education and training.<br>- strong history in design, construction of tracking detectors.<br>- collaborators in ATLAS and CMS experiment, led construction of ATLAS semiconductor Tracker.<br>- strong involvement in R&D for ATLAS Tracker Upgrade, coordinates power distribution R&D.<br>- established reputation in development of superconduction magnet systems, End Cap Toroids ATL:AS experiment.<br>- contributions to Diamond, and R&D for 4GLS, neutrino factory, and ESS. |
| UBONN | DE | - development of serially powered pixel module chains suitable for the SLHC environment | - design of front-end readout chip and flex circuits<br>- module construction, testing and repair for ATLAS pixel detectors |
| UNIGE | CH | - preparation of cost-books and Project Office tasks related to upgrading the inner detector of ATLAS | - experience with project planning; inner-detector planning and engineering |
| USFD | UK | simulation, estimation, measurements of radiation & activation levels in detector areas | - radiation and activation calculations and simulations for LHC experimental areas |

## B 2.3 Consortium as a whole

The beneficiaries of this proposal form a consortium well suited to address the objectives of the proposal. CERN is the Coordinator and has organisational structures, covering technical studies, administration and contract services, that have supported development and construction of accelerator and detector systems for LHC. This consortium is based on the LHC experience and all the partners have worked with CERN in various earlier projects. They are therefore carefully selected and their roles defined together with CERN to be able to address the objectives of the proposal in the best possible way. The overall coherence of the consortium is ensured by the Coordinator in WP1. A Consortium Agreement, laying down complementary details of the internal relationships and responsibilities between beneficiaries, is under preparation and it is expected to be agreed upon and signed before starting the project.

WP 2, 6 and 7 cover organisational tasks, and two specific technical studies and developments for the accelerator upgrade of LHC. The beneficiaries are carefully selected to cover the objectives of these WPs, and include the key personnel needed to carry them out. CERN has had a long history of collaborative links with STFC in the fields of Beta Beams for a Neutrino Facility; the Muon Ionisation Cooling Experiment; Laser for the CLIC photo-injector and targetry for the Neutron-time-of-flight facility. DESY and CERN currently collaborate on the negative hydrogen ion source for Linac4, and within the ILC global design effort. STFC, CERN and DESY have previously participated in the FP5 project High Power Negative Ion Sources (HP-NIS). For the quadrupole development, all partners have previous experience in superconducting magnet design and construction. CEA-Saclay designed the main LHC quadrupoles and did the industrial follow-up of series production. Both CIEMAT and STFC have been involved in the design and construction of corrector packages for the LHC and CNRS-IN2P3 has a considerable experience in cryostat design and tooling construction for devices cooled at superfluid liquid helium.

WP 3, 4 and 8 address the main organisational tasks needed for the detectors for SLHC. CERN has a broad experience in the management and technical coordination of large particle physics experiments. As the experiments became ever larger, the coordinating tasks have been shared with a selective number of partners. In this context DESY, ETH Zürich, FOM-NIKHEF, STFC. UNIGE as well as non-member state laboratories BNL and Protvino have provided significant and very diversified contributions to the ATLAS and CMS projects in the domains of mechanical integration, electronics coordination, reviewing, dissemination of information, databases, costing and planning. The tracking detector powering project is a new collaboration. Pioneering work was started to explore the diverse technical options by AGH-UST, CERN, PSI, STFC and UBONN as well as by the non-member state LBNL laboratory.

WP 5 addresses on of the most crucial issues of the SLHC project, safety and irradiation, for both accelerator and experiment. The partners in the work package, PSI, GSI, USFD, CTU, are institutes with very specific expertise in this subject, and with experience from similar studies carried out for LHC. The two first mainly on the machine side, the two latter mainly on the machine/detector interface side. CERN has experience in all issues related to this work package, but relies on these partners to take on specific studies and provide additional expertise.

Sub-contracting is not foreseen in the proposal. However some of the work-packages require industrial contracts that will be rewarded based on the standard purchasing procedures of CERN or the other contract partners. Typically these are based on competitive tendering among qualified vendors following standard EU rules. There are no third parties foreseen to carry out the work described in the proposal.

## B 2.4 Resources to be committed

Overview of the SLHC-PP budget

| | Estimated eligible costs (whole duration of the project) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Participant short name | Effort (PM) | Personnel cost | Sub-contracting | Other direct cost | Indirect cost OR lump sum, flat rate or scale of unit | TOTAL costs | Total receipts | Requested EC contribution |
| CERN | 496 | 3997500 | 0 | 1656400 | 3392340 | 9046240 | 0 | 3021162 |
| AGH-UST | 36 | 120000 | 0 | 40000 | 96000 | 256000 | 0 | 104000 |
| CEA-Saclay | 66 | 515000 | 0 | 232000 | 597600 | 1344600 | 0 | 465460 |
| CIEMAT | 28 | 234000 | 0 | 99000 | 266400 | 599400 | 0 | 218860 |
| CNRS-IN2P3 | 18 | 150000 | 0 | 50000 | 120000 | 320000 | 0 | 105600 |
| CTU | 18 | 54000 | 0 | 25000 | 47400 | 126400 | 0 | 44940 |
| DESY | 21 | 137000 | 0 | 33000 | 102000 | 272000 | 0 | 99726 |
| ETH Zurich | 15 | 120000 | 0 | 30000 | 90000 | 240000 | 0 | 89166 |
| FOM-NIKHEF | 20 | 160000 | 0 | 14000 | 104400 | 278400 | 0 | 64200 |
| GSI | 16 | 130000 | 0 | 20000 | 90000 | 240000 | 0 | 72225 |
| Imperial | 15 | 120000 | 0 | 30000 | 90000 | 240000 | 0 | 89166 |
| INFN | 7 | 42000 | 0 | 33000 | 45000 | 120000 | 0 | 40000 |
| PSI | 32 | 225000 | 0 | 45000 | 54000 | 324000 | 0 | 108225 |
| STFC | 84 | 612500 | 0 | 196000 | 848925 | 1657425 | 0 | 489850 |
| UBONN | 48 | 240000 | 0 | 60000 | 180000 | 480000 | 0 | 120000 |
| UNIGE | 10 | 80000 | 0 | 12000 | 55200 | 147200 | 0 | 35310 |
| USFD | 8 | 48000 | 0 | 19000 | 40200 | 107200 | 0 | 32100 |
| TOTAL | 938 | 6985000 | 0 | 2594400 | 6219465 | 15798865 | 0 | 5199991 |

For WP1 (SLHC-PP project management) a total of 42 person-months are estimated. 12 p·m for the Coordinator, 6 p.m. for the Deputy Project Coordinator, 12 p·m. for the Administrative Manager and 12 p.m. for administrative assistance to the Management Team. The material and consumables needed will be 21 k€, and 72 k€ are reserved for travel expenses of the Management Team and the Steering Committee.

For WP2 (Coordination for the accelerator upgrade implementation) a total 46 p·m are estimated for total personnel costs of 284 k€. The project monitoring structures will take an estimated 8 p·m. to set-up at CERN. The Finance management system will take 11 p·m at CERN. Setting up the Quality assurance plan will take 8 p·m and be shared by CERN, CEA-Saclay and STFC-RAL (4+2+2). 15 p·m are needed to set up the collaboration communication structures shared between CERN, CEA-Saclay, STFC-RAL and CIEMAT (7+2+2+4). The information storage and dissemination will be set up by CERN using 4 p·m. 16 k€ is the travel budget, which will cover attendance of meetings and short term visits between the partners.

WP3 (Coordination for the S-ATLAS experiment implementation) requires 102 p·m for preparatory coordination efforts such as organisational planning, setting up WEB and Database tools, running a review office, preparing cost books and documentation of the planned upgrade for ATLAS. The workload sharing between the partners is linked to estimates of work needed for the specific tasks, and the percentages needed by identified personnel at CERN, STFC-RAL, FOM-NIKHEF and UNIGE. The material costs are minor (11 k€) and linked to personal computing equipment and licences. The travel costs (54 k€) are related to Upgrade Management Body meetings, meetings between participants and travels to workshops. 20 k€ are reserved for the organisation of workshops and topical meetings, including invitations to external experts.

WP4 (Coordination for the CMS2 experiment implementation) will require 30.p·m (15 for Imperial College and 15 for CERN) for the overall coordination of the CMS2 upgrade. The creation of the Technical Coordination Unit for the upgrade will require 18 p·m from DESY, 15 p·m from ETH Zürich as well as 27 p·m from CERN. Travel resources of 100 k€ are requested for short term collaboration visits and information dissemination. 50

k€ are requested for material and equipment budget, including 30 k€ for engineering tools. 30 k€ are reserved for the organisation of disseminations events, such as workshops and topical meetings, including invitations to external experts.

WP5 (Radiation protection and safety issues for accelerator and experiments) Within Tasks 5.1 and 5.3, and through the participation of CERN, CTU, GSI and USFD the S-ATLAS and CMS2-collaborations require a total of 52 p·m for measuring and simulating the activation of the SLHC detector parts in the critical regions, and to elaborate shielding and maintenance strategies. For this purpose they also require 60 k€ for material expenses and 52 k€ for travel. Within Tasks 5.2 and 5.3 the CERN radiation protection group and its partners GSI and PSI will spend an effort of 64 p·m for estimating the additional activation of the accelerator areas, the impact on the environment of releases, the production of radioactive accelerator waste and maintenance and repair options for accelerator components. Material expenses, mainly for computers for numerical calculations, amount to 32 k€, and travel funds to 46 k€.

WP6 (Nb-Ti quadrupole prototype) In task 6.1, 48 p·m are needed, as well as 35 k€ of materials and 60 k€ of travelling for the design and thorough evaluation of the materials and of the system limits in operating conditions. They include FEM modelling efforts. In task 2 the construction of the tooling, and the magnet model as well as the test require 78 p·m. The material cost is estimated at 250 k€ while the travelling will require 30 k€. In task 3 the construction of the prototype, with cryostat and ancillary equipment and the associated test will require 54 p·m. as well as 477 k€ for materials. For travelling 48 k€ are needed to ensure the necessary information exchange, participation to the test.

WP7 (Development of critical injector components). In task 1, the development towards an H- source will require 22 p.m for the thermal modelling and design of the plasma generator, with contributions from CERN, DESY and STFC-DL. 49 p·m will be required for the production and installation of the generator and its sub-systems and the remaining 6 p·m. are for task management and coordination. The hardware components will comprise of approximately 135 k€ for the RF system, 100 k€ for the vacuum assembly, 30 k€ for infrastructure modifications and 150k€ for the Plasma generator assembly. The remaining costs are for installation, travel, software and consumables. In task 2 of WP7 the work to design and model the architecture of the LLRF system for the low beta accelerating structures and then to test and validate this system will need 102 p·m: 75 p·m for CERN, 20 p·m for CEA-Saclay and 7 p·m for INFN. The total cost for man-power in task 2 of this work-package will be 782 k€. The material cost will be 120 k€ in total and will cover 20 k€ for the test electronics, 70 k€ for the operation of the high-power test stand and 30 k€ for the tuning-systems. 12 k€ will be used for travelling for the collaboration visits and for presence at the test-stand.

WP8 (Tracking detector power distribution) will need 183 person months for development in radiation hard microelectronics design, system integration and testing for total personnel budget of 1,035 k€ direct cost. The sharing of the resources between the 5 partners (AGH, CERN, PSI, STFC-RAL and UBONN) has been driven by the needs of the project and the different specialization domains of each task. It takes into account that radiation-hard microelectronics design is rather time consuming. The required material resources include chip submission, test equipment, hybridisation, electronics production and assembly. They amount to 440 k€.

Resources for the SHLC Preparatory Phase. The Scientific Programme of the LHC upgrade has been approved by the CERN Council. For the SHLC-PP activities, directly supported by the EC with 5.2 M€, the matching funding of 10.6 M€ will be secured from the annual budget of CERN and from the research budgets of the other participants. For the SHLC-PP programme, not directly supported by the EC, a special additional contribution of the CERN Member States for the period 2008-2011has been voted by the CERN Council in June 2007.
Active contribution of all collaborating institutions via national funding agencies from CERN Member and Non-Member States is also expected for the Work Packages, not directly supported by the EC (see Table 2b of the original Proposal).

Long-term sustainability of the SLHC. The Large Hadron Collider is expected to operate for a period of 10 years, which will be extended by another decade or two by means of subsequent upgrades. During this life-cycle, the maintenance and operation costs of the machine will be covered by the annual CERN budget, whereas the maintenance and the operation of the detectors will be covered by the Experiment Collaborations. Typically CERN contributes to less than 20% of the Experiments' budget.
Active contribution to the whole SLHC Programme is expected also from many CERN Observer and Non-Member States, such as the USA, Canada, Japan, Russia, China, India, Israel, and many others, which have already contributed significantly with resources, material, and production of components for the LHC.

## B3. Impact

### B 3.1 Strategic impact

The LHC upgrade will be a highly complex project with expected budget exceeding 1 billion euros, to which not only the 20 CERN Member States, but also many other countries are expected to contribute, in view of using this unique infrastructure. The SLHC is likely to involve more than three hundred institutions with four thousand collaborators from all over the world, who will be working on the accelerator and detector upgrades. For such a large-scale project, the SLHC Implementation Phase needs a number of critical organisational, financial, coordination, technical, and legal issues to be resolved before construction. These issues will be addressed during thePreparatory Phase project.

Coordination and organisational aspects
The organizational, coordination and financial issues concern the new structures to be put in place, for the accelerator itself on the one side, and for the future experiments on the other side, in order to fix the interrelations between all relevant parties involved:
- Research Institutes, Universities and Funding Agencies that will participate in the LHC accelerator upgrade;
- Experiment Collaborations and Coordinating structures of the Experiments;
- CERN governing bodies such as the CERN Council, the CERN Management and the Scientific Policy Committee.

For the experiments, the SLHC Preparatory Phase will address the questions of setting up the participation and financial rules, the internal scientific reviewing and approval procedures, and the hierarchical and sub-project structures. In addition, the Project Office and the Technical Coordination Unit created for each of the two large experiments will manage and prepare the relevant documentation and databases for issues related to the technical integration of the upgrade options, such as mechanical engineering, drawings, layout, services, electronics, installation, shielding, safety, etc.
For the accelerator, the structure existing for the LHC may have to be amended and completed by means of new Memoranda of Understanding in areas where new partners are presently solicited for contributing to the development and delivery of specific components. The preparation of these agreements, many of which will be with countries outside the EU, will benefit directly from the Community support in the Preparatory Phase. The experience from the project management of the LHC machine will be used to construct collaboration structures and project follow-up tools to allow a globally distributed collaboration to function.
All these coordination and organisational efforts aim to involve the key stakeholders necessary to drive the LHC upgrade project forward, to take decisions and to make financial commitment before the SLHC Implementation Phase can start.

Radiation protection and legal safety aspects
The question of the machine-detector interface is a critical point to be dealt with in the Preparatory Phase. Solutions satisfying the machine specialists and the experimental physicists must be found which, at the same

time respect stringent regulatory requirements in matters of safety and radiation protection. The accelerator upgrade options have direct consequences for the SLHC Accelerator and Experiments. Increased particle fluxes and layout modifications will raise the radiation and background levels in the experimental and accelerator areas. Safe operation of the future detectors requires mitigation of radiation effects through new shielding and design optimization. The changes in beam characteristics also imply risks of beam losses and activation in the accelerator itself. The most critical areas will be studied and their consequences on the machine protection system will be revisited.

In both cases, complying with safety rules is an essential part of the Preparatory Phase aiming at defining scenarios which fit into the legal framework of safety regulations, taking into account the status of CERN as an international organisation. Special attention must be paid to the optimization process in radiation protection, which is a fundamental requirement for designs according to CERN's Radiation Protection Code. In the preparatory phase it must be shown that solutions to the critical problems arising from luminosity- and intensity increases can be found which satisfy all stakeholders in the project as well as the regulatory boundary conditions.

Technical aspects

The baseline of the LHC upgrade program focuses on the increase of luminosity and major upgrades of the injectors, including the construction of a new linear accelerator. Critical aspects of this programme are the needs for high-field and large-aperture quadrupole triplets in the interaction regions, for a reduction of the injector limitations and for a good detector performance at high luminosity. For the SLHC detectors, lowering the electrical power currents fed into the tracker volume, is a key technical issue, without which the future trackers are not feasible. Therefore, the following topics will be addressed early in the preparation for the LHC:

- Development of high-field Nb-Ti quadrupole magnet prototypes with large aperture
- Development of a test bed for the study of a high duty factor H- ion source, complemented by the study of the field stabilization in pulsed superconducting Radio Frequency cavities.
- Development of novel technologies in on-detector DC-DC conversion and serial powering, and the integration of these technologies into the on-detector microelectronics circuitry.

These elements are technical corner stones for the LHC upgrade, which may have important impact to the full cost of the LHC accelerator and detector upgrades. They will profit from the R&D and design studies already carried out and which partly took place in the CARE project within the 6th Framework Programme of the European Community. The deliverables of these tasks together with the results of the work-packages not directly supported by EC will make the basis on which the SLHC can then be built with confidence.

The LHC upgrade will have a significant impact on the research in High Energy Physics at world-wide level. At ten-times the nominal luminosity of the LHC, it will allow Europe to maintain the leadership in particle physics by providing solid ground for fundamental advances in the following areas:

- accuracy improvement in the determination of the Standard Model parameters and of the parameters of New Physics, resulting from possible discoveries in LHC;
- extension of the discovery reach in the high mass region and of the sensitivity to rare processes;
- statistics measurements of Super-Symmetry particles, possibly seen in the first LHC phase;
- search for heavy neutral bosons;
- charged boson scattering and jet tagging observations, in case no Higgs particles are found at LHC;

The SLHC will provide an infrastructure which will be unique in the world, which no single country can possibly afford to build. Therefore, global collaborations for the SLHC Implementation Phase will be required, involving almost all European countries and many countries from other continents.

The SLHC project will reinforce the European capacity of producing not only high-energy and high-intensity proton beams in the years to come, but also in a more distant future intense neutrino and muon beams. As a consequence, the scientific excellence of Europe will also be reinforced with the potential increase of the flux of neutrinos and the flux of protons for fixed target experiments in both particle physics and nuclear physics.

The technical work proposed aims at mastering technologies with significant impact on other European or global infrastructures using similar components. In particular, mastering the technique of building novel high-field, large-aperture magnets is useful to the whole accelerator community and has applications in other existing or future projects, such as FAIR (Facility for Antiproton and Ion Research), listed among the projects recommended by ESFRI, and ILC (International Linear Collider). In a similar way, many proton accelerator facilities are interested in the progress in the design of $H^-$ ion sources and in improving the field stability, and consequently of the beam energy, in the environment of superconducting Radiofrequency Cavities subject to mechanical vibrations. The development of a source capable to meet the requirements of the Superconducting Proton Linac will immediately be useful for the design of modern neutron spallation sources such as the SNS (USA) or the ESS (European Spallation Source), which also is one of the projects on the ESFRI Roadmap. The development of dense, efficient and low-mass and power distribution systems, functioning in high radiation and strong magnetic field environments, will have a major impact on future high energy physics experiments at SLHC, ILC and CLIC, because the present level of technology has clearly been identified as a major limitation. Space applications have already shown significant interest in the development of high efficiency, low-mass radiation tolerant power supply systems. For example, the first generation radiation tolerant linear power regulators developed in collaboration between CERN and European microelectronics industry have found significant use within Space applications.

## B 3.2 Plan for the use and dissemination of foreground

The dissemination activities at general project level have the following main components:

- Web-based dissemination
  A dedicated web-site, hosted on a CERN server and managed by the management team, will be the main dissemination tool of the SHLC-PP project. It will serve to inform the scientific community at large, as well as any other interested parties, of the activities and results of the preparatory phase project.
- Scientific exchange
  The scientific results of the project will be disseminated through publications in journals, as well as by attendance of various conferences and workshops in the field of accelerator and detector technologies for particle physics. The main dissemination event will be the Annual SLHC-PP Meeting, which will be open to external participants. Active discussions on the SLHC Implementation Phase will also take place during these Annual Meetings, both within the accelerator and detector communities, which account for several thousand engineers and physicists world-wide. Topical workshops on specific particle accelerator or detector issues will be organised during the project.
- Distribution of written SLHC-PP documentation
  Other than Web-based dissemination of information and the formal reporting to the European Commission, summary reports on the SLHC-PP project will be submitted to the ministries and government agencies of the CERN Member and Observer states through the normal status reports to the CERN Council. The reports to the CERN Council will be prepared under the responsibility of the Project Coordinator.

## B4. Ethical issues

Not applicable.

## B5. Gender aspects

Recent surveys of the European research and education system have shown that female students and scientists are underrepresented in many engineering and scientific fields. Particle Physics is one of these fields. Therefore, all institutes and laboratories involved in the Project have introduced equal opportunities programs over the past years. These programs promote and monitor gender balance at the recruitment and career level and promote the awareness of gender issues at the work place. Work-life balance and childcare issues also get proper attention. Launched generally a decade ago, these programs are progressively showing their impact with increased female representation in professional research. However, due to the lack of female influx in engineering and science fields at the educational level, progress is slow.

Within the SHLC-PP project the promotion of gender balance in particle physics will be addressed through several lines of actions, such as:

- Encouraging applications from female individuals at all levels, including post-graduate, post-doctoral and management positions, available within the consortium.
- Inviting renowned female experts in particle accelerators and detectors to deliver talks at the annual workshops and topical meetings, organized by the consortium.

Remaining informed of the work of the European Parliament's Committee on Women's Rights and Equal Opportunities and promoting adherence to selective actions proposed.