# COMBINATION OF COLLABORATIVE PROJECT AND COORDINATION AND SUPPORT ACTION

## Construction of new infrastructures - preparatory phase

FP7-INFRASTRUCTURES-2007-1

# Preparatory Phase of the Large Hadron Collider Upgrade

**SLHC-PP**

**Date of preparation**: **2 May 2007**

**Project starting date:** **1 April 2008**
**Duration:** **36 months**

| Participant no. | Participant organisation name | Part. 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 |
| 6 | Czech Technical University | CTU | Czech Republic |
| 7 | Deutsches Elektronen-Synchrotron | DESY | Germany |
| 8 | Eidgenössische Technische Hochschule Zürich | ETHZ | Switzerland |
| 9 | Stichting voor Fundamenteel Onderzoek der Materie | FOM-NIKHEF | The Netherlands |
| 10 | Gesellschaft für Schwerionenforschung | GSI | Germany |
| 11 | Imperial College London | Imperial | United Kingdom |
| 12 | Istituto Nazionale di Fisica Nucleare | INFN | Italy |
| 13 | Paul Scherrer Institut | PSI | Switzerland |
| 14 | Science and Technology Facilities Council | STFC | United Kingdom |
| 15 | Rheinische Friedrich-Wilhelms-Universität Bonn | UBONN | Germany |
| 16 | Université de Genève | UNIGE | Switzerland |
| 17 | University of Sheffield | USFD | United Kingdom |

**Work programme topics addressed** *INFRA-2007-2.2.1.33*

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**Proposal Abstract**

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 luminosity of the LHC. 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. These will be global endeavors, involving 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 will comprise coordinating activities for the organisation of the new accelerator and detector upgrades collaborations, negotiations and agreements with new partners and putting in place the new structure of the SLHC experiments. Support activities will 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 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. 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.

**Key-words:** LHC, SLHC, particle accelerators, particle detectors, particle physics, world-class infrastructure, global project, major upgrade

## Table of Contents

## i) Summary Tables

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| 16 | Université de Genève | UNIGE | Switzerland |
| 17 | University of Sheffield | USFD | United Kingdom |

*Table 1b - List of **other organisations** involved in the Preparatory Phase*

| Organisation name | Organisation short name | Country | Specific role or contribution to the preparatory phase |
|---|---|---|---|
| Budker Institute of Nuclear Physics | BINP | Russia | Negotiation for participation to the construction of the new injectors |
| Institute for High Energy Physics | IHEP | Russia | Negotiation for participation to the construction of the new injectors, S-ATLAS project office participation and construction of Nb-TI quadrupole |
| Institute for Nuclear Research | INR | Russia | Negotiation for participation to the construction of the new injectors |
| The Russian Federal Nuclear Center | VNIIEF | Russia | Negotiation for participation to the construction of the new injectors |
| All-Russian Scientific Research Institute Of Technical Physics | VNIITF | Russia | Negotiation for participation to the construction of the new injectors |
| Raja Ramanna Centre for Advanced Technology | CAT | India | Negotiation for participation to the construction of the new injectors |
| Bhabha Atomic Research Centre | BARC | India | Negotiation for participation to the construction of the new injectors |
| Institute of High Energy Physics | IHEP | China | Negotiation for participation to the construction of the new injectors |
| Fermi National Accelerator Laboratory | FNAL | USA | Negotiation for participation to the construction of the NbTi quadrupole |

| | | | |
|---|---|---|---|
| Brookhaven National Laboratory | BNL | USA | Negotiation for participation to the construction of the NbTi quadrupole and S-ATLAS project office participation<br>S-ATLAS R&D projects<br>and the project coordination |
| TRI-University Meson Facility | TRIUMF | Canada | Negotiation for participation to the construction of the NbTi quadrupole |
| Lawrence Berkeley National Laboratory | LBNL | USA | Development of switched capacitor DC-DC converters for tracking detector power distribution and construction of Nb-Ti quadrupole<br>S-ATLAS R&D projects |
| High Energy Accelerator Research Organization | KEK | Japan | Development of advanced superconductor for superconducting quadrupole design |
| Stanford Linear Accelerator Center | SLAC | USA | Advanced collimator design |
| University of Tsukuba | U. of Tsukuba | Japan | S-ATLAS R&D projects |
| The University of Liverpool | U. of Liverpool | United Kingdom | S-ATLAS R&D projects |
| Lancaster University | Lancaster U. | United Kingdom | S-ATLAS R&D projects |
| University of Glasgow | U. of Glasgow | United Kingdom | S-ATLAS R&D projects |
| University of Cambridge | U. of Cambridge | United Kingdom | S-ATLAS R&D projects |
| Queen Mary University of London | QM London | United Kingdom | S-ATLAS R&D projects |
| Albert-Ludwigs-Universität Freiburg | U. of Freiburg | Germany | S-ATLAS R&D projects |
| Max-Planck-Institut für Physik | MPI | Germany | S-ATLAS R&D projects |
| University of Ljubljana | U. of Ljubljana | Slovenia | S-ATLAS R&D projects |
| Charles University in Prague | CU | Czech Republic | S-ATLAS R&D projects |
| Jagiellonian University of Krakow | JU | Poland | S-ATLAS R&D projects |
| Oxford University | U. of Oxford | United Kingdom | S-ATLAS R&D projects |
| Hampton University | HU | USA | S-ATLAS R&D projects |
| New York University | NYU | USA | S-ATLAS R&D projects |
| Universitat de Barcelona | UB | Spain | S-ATLAS R&D projects |
| Università degli Studi di Milano | U. of Milano | Italy | S-ATLAS R&D projects |
| Universitat de València | U. de València | Spain | S-ATLAS R&D projects |
| University of California Santa Cruz | UCSC | USA | S-ATLAS R&D projects |
| Department of Energy | DOE | USA | CMS2 R&D Activities |
| Alikhanov Institute for Theoretical and Experimental Physics | ITEP | Russia | CMS2 R&D Activities |
| National Science Foundation | NSF | USA | CMS2 R&D Activities |
| Science and Technology Facilities Council | STFC | United Kingdom | S-ATLAS R&D projects and CMS2 R&D Activities |

### ii) 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, and to fully exploit its physics potential towards new discoveries. Thus Europe will maintain its leading position in the field in the foreseeable future.

SLHC is expected to have significant impact on the research in Particle Physics. Once the physics programme of the nominal LHC will have been accomplished, and in particular, the Higgs boson and Super-symmetry will have been found (provided they are in the expected mass ranges), SLHC will be an excellent tool for deepening this research. The tenfold luminosity opens the way to increase the accuracy in the determination of key physics parameters of the Standard Model and of new physics, extending the possible discovery of new elementary particles and increasing the sensitivity to rare processes.

If the existing accelerators are capable of meeting the needs of the nominal LHC, they will not deliver beam with the ultimate 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 (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. During the second phase (implementation), the new injectors will be built and the SPS and LHC will be upgraded. In addition, the high luminosity associated with these upgraded characteristics requires to rearrange the interaction regions and to use quadrupole magnets with high field and large aperture. Higher beam intensity and collision rate also impose to enhance the capability and performance of the particle physics experiments. At present the two largest LHC experiments, ATLAS and CMS, are multipurpose detectors, each of them serving about 2000 scientists from some 130 to 160 institutes. These experiments need major changes in the forward region layout, the central tracking detectors, the read-electronics and the data acquisition systems. These changes will cost around 130 M€ in materials each and the upgraded detectors (S-ATLAS and CMS2) will be constructed and operated by formally new scientific collaborations.

The first phase of this upgrading is planned from 2008 to 2011 and the full upgrade, aiming at a ten-fold increase of the integrated luminosity per year, is planned to be completed in 2016. Both are fully supported by the CERN Council, who recognized the needs of resources and activities to the proposed level. 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 of the LHC. These will be global endeavors, involving 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 issues to be addressed. 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. In the last years and in particular within the CARE project partly funded through FP6, options for achieving the first objective have been analysed, while limited R&D work took place concerning the second. Clear priorities have emerged which now have to be elaborated by further studies and prototype work. In view of the implementation phase, these specialized activities will continue with the same partners and many new ones.

# 1 Objectives and description of the activities foreseen

## 1.1 Objectives of the Preparatory Phase

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. In particular, one of the first priorities is to set up a Project management structure using modern tools, including Earned Value Management for tracking project progress and expenditure, budget follow-up and planning.

The upgrade of the high luminosity insertions will require the development of prototype superconducting quadrupole magnets of advanced design to replace the existing ones. This will require setting up collaborations between partners in order to coordinate the design of these magnets and their ancillary corrector packages. The resulting design will require validation by building at least one short model before proceeding to a full-length prototype.

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.

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 development, construction and installation of the ATLAS and CMS detector upgrades, indicated in Section 0, 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. Management structures, financial rules and decision processes have to be well defined, and detailed financial plans, implementation plan and schedules to be produced at the early project stages. They will help new partners to join under clear conditions and avoid duplication of work.

The present LHC experiments have revealed severe difficulties in providing power to the complex inner tracking detectors. At SLHC, the tracking detectors will comprise >300 million particle detection elements, designed in state-of-the art solid-state sensor technologies coupled to deep-submicron radiation-hard electronics. They are mostly inaccessible, in strong magnetic fields and in a highly radioactive environment; therefore high reliability criteria apply. In this context new high-tech developments are needed in the domain of detector powering. They will build on the experience gained with LHC and will aim at reducing considerably the total electrical current to be fed into the tracking detectors. For this development work a new collaboration will be set up, that will perform the R&D work in common for S-ATLAS and CMS2.

## 1.2 Work plan

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 which concern the setting-up of the coordination framework 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 organization structures needed. And of the elaboration of new formal conditions allowing setting up extended collaborations including not only the partners listed but also as many new partners as possible.

There is one support work package, 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 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.

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.

The tabular description of the work packages and the estimated budget are shown in Table 2a.

The interconnections between the different components of the Preparatory Phase Project are shown in Fig. 1.1, and the duration of the tasks, as well as the corresponding deliverables and milestones are displayed in Fig 1.2.

The Work Packages of the SLHC Preparatory Phase *not directly supported by the EC* are presented in Table 2b.

*Table 2a - List of Preparatory Phase* ***Work Packages foreseen under this proposal***

| **Work Package No** | **Descriptive Title** | **Short description and specific task objectives** | **Leading Participant** (+ co-participants) | **Total direct costs (k€)** | **Requested EC contribution to the direct costs (k€)** |
|---|---|---|---|---|---|
| WP1 | **SLHC-PP project management** | Management and coordination of all Work Packages, progress monitoring, budget follow-up, reporting and dissemination | **CERN**<br>STFC-RAL (UK) | **645** | **400** |
| WP2 | Coordination activities: **Coordination for the SLHC accelerator implementation** | Establish the formal structures for the SLHC accelerator upgrade<br>2.1 Project management preparation<br>2.2 Networking and communication | **CERN**<br>CEA (FR), STFC-RAL (UK), CIEMAT (ES) | **600** | **600** |
| WP3 | Coordination activities:<br>**Coordination for S-ATLAS experiment implementation** | Upgrade coordination and organization of S-ATLAS<br>3.1 Coordination and project structures<br>3.2 Project Office | **CERN**<br>FOM-NIKHEF (NL), STFC-RAL (UK), UNIGE (CH) | **901** | **501** |
| WP4 | Coordination activities:<br>**Coordination for CMS2 experiment implementation** | Upgrade coordination and organization of CMS2<br>4.1 CMS2 organisational structure<br>4.2 CMS2 Technical Coordination Unit. | **CERN**<br>DESY (DE), ETHZ (CH), Imperial(UK) | **900** | **500** |
| WP5 | Support activities: **Radiation protection and safety issues** | Optimisation of design options for luminosity increase with respect to radiological impact.<br>5.1 Detector Activation:<br>5.2 Accelerator Activation<br>5.3 Impact Study<br>5.4 Radioactive Waste<br>5.5 Maintenance planning | **CERN**<br>GSI (DE), PSI (CH), CTU (CZ), USFD (UK) | **1,500** | **700** |

| | | | | | |
|---|---|---|---|---|---|
| WP6 | Technical Work Package 1: **Development of Nb-Ti quadruple magnet prototype** | Development of high field Nb-Ti quadrupole magnet prototypes with very large aperture<br>6.1 Design of the complete quadrupole magnet and ancillary equipments<br>6.2 Construction and test of 1-m long model<br>6.3 Construction and test of full-scale prototype quadrupole | **CERN**<br>CEA (FR), STFC-RAL (UK), CIEMAT (ES), CNRS-IN2P3 (FR) | **2,400** | **800** |
| WP7 | Technical Work Package 2: **Critical components for the injectors** | Development of injector chain components.<br>7.1 RTD towards an H- ion source meeting the required duty factor for the future injection accelerators of the LHC.<br>7.2 Field stabilization in pulsed superconducting low beta (v/c) accelerating structures | **CERN**<br>CEA (FR), DESY (DE), INFN (IT), STFC-DL (UK) | **2,397** | **799** |
| WP8 | Technical Work Package 3: **Tracking detector power distribution** | Development of radiation-hard and magnetic-field tolerant microelectronic components for tracking detector power distribution systems<br>8.1 Linear voltage regulation<br>8.2 DC-DC conversion<br>8.3 Serial powering | **STFC-RAL (UK)**<br>CERN, AGH-UST (PL), PSI (CH), UBONN (DE) | **1,985** | **600** |
| Totals: | | | | **11,328** | **4,900** |

<u>Note:</u> The **indirect costs** are not included in this table.

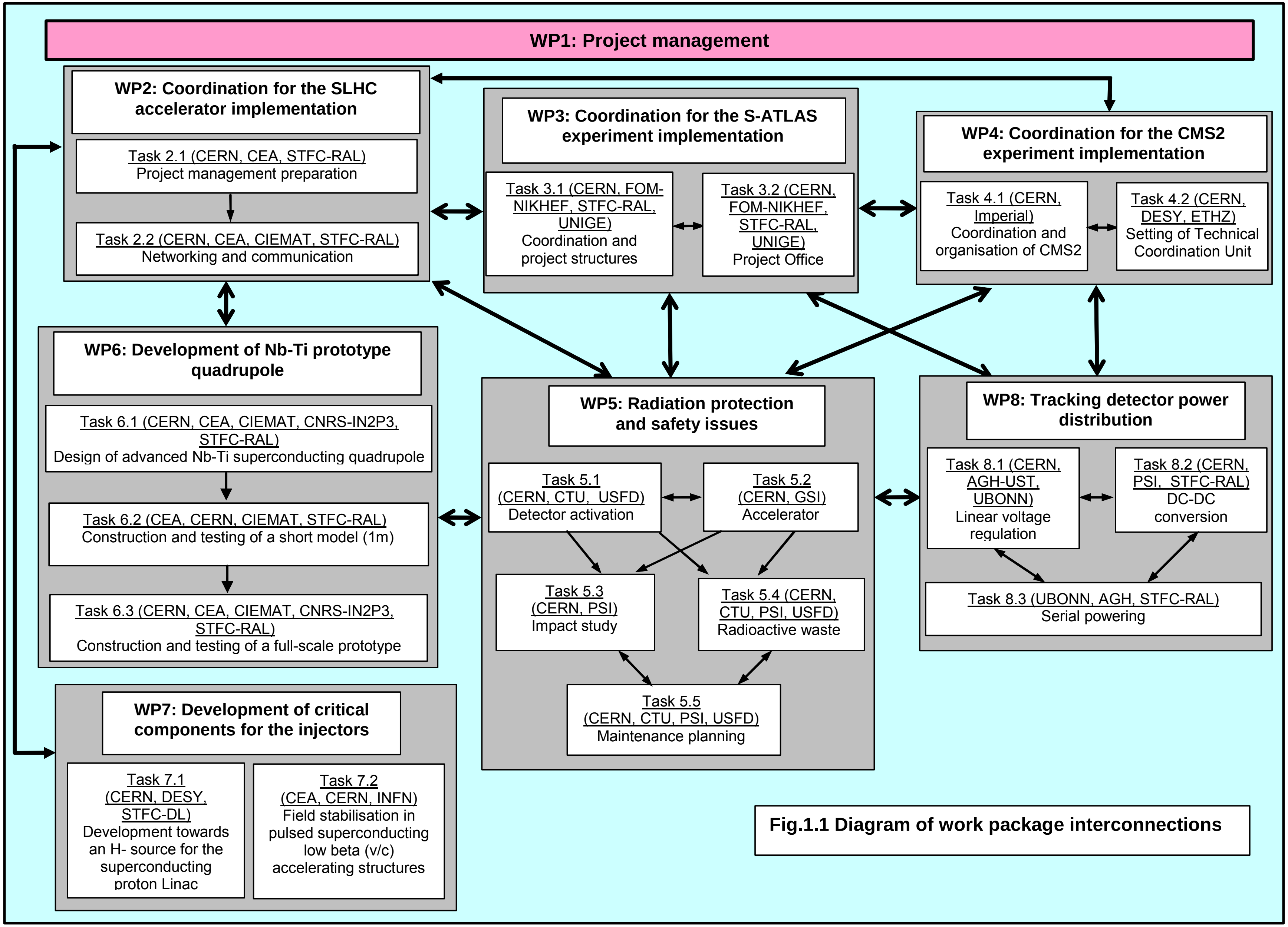


**Fig.1.1 Diagram of work package interconnections**

| 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 SHLC project management preparation | | | | | | ! | | !D | | D | | D |
| Task 2.2 Networking and communication | | | | D | | | | | | | | |
| **WP3. Coordination for the 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 organisational structure of CMS2 | | | | D | | ! | | | | | | D |
| Task 4.2 Setting of Technical Coordination Unit | | | | D | | !D | | | | | | D |
| **WP5. Radiation protection and safety issues** | | | | | | | | | | | | |
| Task 5.1 Detector activation | | | | ! | | D | | | | | | |
| Task 5.2 Accelerator activation | | | | | | !D | | | | | | |
| Task 5.3 Impact study | | | | | | | | !D | | | | |
| Task 5.4 Radioactive waste | | | | | | | | | | | | D |
| Task 5.4 Maintenance planning | | | | | | | | | | ! | | D |
| **WP6. Development of Nb-Ti prototype quadrupole** | | | | | | | | | | | | |
| Task 6.1 Design of advanced Nb-Ti superconducting quadrupole | | | | ! D | | ! | | ! | | | | D |
| Task 6.2 Construction and testing of 1-m short model | | | ! | | | D | | ! D | | | | |
| Task 6.3 Construction and testing of 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 | | | | | | | | | | | | |
| 7.1.1 Finite element thermal study of Linac 4 RF source | | | | D | ! | | | | | | | |
| 7.1.2 Design of a plasma generator for 3.6% duty factor | | | | | | D | | | | | | |
| 7.1.3 Construction of plasma generator and sub systems | | | | | | | | | | D | | |
| 7.1.4 System testing and plasma generation | | | | | | | | | | | | D |
| Task 7.2 Field stabilization in superconducting accelerating structures | | | | | | | | | | | | |
| 7.2.1 Characterization of tuners | | | | D | | | | | | | | |
| 7.2.2 Design and specification of RF system architecture | | | | | | !D | | | | | | |
| 7.2.3 Production of system and definition of demonstration | | | | | | | | | | D | | |
| 7.2.4 Test and validation of RF system | | | | | | | | | | | | D |
| **WP8. Tracking detector power distribution** | | | | | | | | | | | | |
| Task 8.1 Linear voltage regulation | | D | | | | | | !D | | | | D |
| Task 8.2 DC-DC convertion | | | | D | | | | !D | | | | D |
| Task 8.3 Serial powering | | | | D | D | | | !D | | | | D |

**Figure 1.2 SLHC Work Package Task-chart**

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

*Table 2b - List of **other** Preparatory Phase **Work Packages not directly supported by the EC***

| **Work Package No** | **Descriptive Title** | **Short description and specific objectives of the task** | **Organisations involved** | **Approximate budget** |
|---|---|---|---|---|
| WP9 | Improved injection complex | Study of a replacement of the PS, with a final energy of about 50 GeV, and of a new superconducting proton linac, capable of about 5 GeV and large current. | CERN, CEA, IN2P3, INFN, GSI | 7 M€ |
| WP10 | Front end of the improved injection complex | Replacing the old proton linac 2 with a new one, Linac 4, delivering $H^-$ ions at 160 MeV | CEA, IN2P3, INFN, BINP, ITEP, IHEP, VNIIEF, VNIITF (Russia), BARC, CAT (India), IHEP (China) | 66 M€ |
| WP11 | High-field SC magnets, based on $Nb_3Sn$ | Development of magnets with about 15T max. field, to be used for the ultimate upgrade of the interaction regions for very high luminosity This work includes advanced collimator design | CERN, CEA, CIEMAT, INFN, STFC, Twente Univ. Wroclaw Univ, LBNL, KEK, FNAL, BNL, SLAC | 20 M€ |
| WP12 | SC pulsed field magnet | Development of pulsed SC magnets for a possible SC version of the PS and possibly of the SPS | CERN, GSI, BNL, INFN KEK, JINR, Dubna | 10 M€ |
| WP13 | Cryogenic upgrade | Study of the possible cryogenics improvement for the cooling of the Interaction region new magnets. | CRN, CEA , CERN, CEA, CNRS, Wroclaw Univ, Valadolid Univ. | 2 M€ |
| WP14 | Common R&D for S-ATLAS and CMS2 | Common development work in electronics, detectors, triggering, data acquisition, data analysis, simulation and computing | CERN | 12 M€ |
| WP15 | S-ATLAS R&D projects | Development and testing of electronics, sensors and modules for an upgraded Inner Detector for ATLAS | KEK, U. of Tsukuba, U. of Liverpool, CERN, Lancaster U., U. of Glasgow, USFD, U. of Cambridge , QM London, U. of Freiburg, MPI, CU, JU, U. of Ljubljana, U. of Oxford, STFC, HU, LBNL, NYU, UB, U. of Milano, FOM-NIKHEF, U. de Valencia, UCSC, BNL. | 7 M€ |

| | | | | |
|---|---|---|---|---|
| WP16 | CMS2 R&D Activities | R&D on technical issues related to the CMS2 inner tracking detector (solid state pixel detector), outer tracking detector, Level 1 Trigger and data acquisition, Calorimeters, and Muon systems. | DESY, DOE, DUBNA, ETHZ, IHEP, INFN, IN2P3, ITEP, NSF, PSI , STFC | 12 M€ |
| Total | | | | 136 M€ |

### 1.3 Deliverables, milestones and staff effort

*Table 3a - **Deliverables** List*

| Del. no. | Deliverable name | WP no. | Nature | Dissemi-nation level | Delivery date |
|---|---|---|---|---|---|
| 1.1.1 | SHLC-PP web-site operational | 1 | O | PU | M3 |
| 3.1.1 | Establish review office | 3 | R | PU | M6 |
| 8.1.1 | Specifications of the components to be developed within the partnership | 8 | R | PU | M6 |
| 1.1.2 | Periodic Report | 1 | R | PU | M12 |
| 2.2.1 | Functioning collaboration communication structure | 2 | 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 | O | PU | M12 |
| 4.1.1 | Project Structures for construction of systems and sub-systems | 4 | R | PU | M12 |
| 4.2.1 | Core of upgrade Technical Coordination unit established | 4 | R | PU | M12 |
| 6.1.1 | Basic design of the triplet | 6 | R | PU | M12 |
| 7.1.1 | Finite element thermal study of the Linac 4 design source at the final duty factor. | 7 | 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 | R | PU | M12 |
| 8.2.1 | Evaluation report on DC-DC conversion technologies | 8 | R | PU | M12 |
| 8.3.1 | Evaluation report on generic serial powering studies | 8 | R | PU | M12 |
| 8.3.2 | Specification of serial powering components | 8 | | PU | M15 |
| 4.2.2 | Schedule and reporting mechanism defined. | 4 | R | PU | M18 |
| 5.1.1 | Estimation of activation and radiation levels for accelerators, detectors and interaction regions | 5 | R | PU | M18 |
| 6.2.1 | Construction of the model | 6 | D | PU | M18 |
| 7.1.2 | Design of the plasma generator to operate at 3.6% duty cycle. | 7 | R | PU | M18 |

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|---|---|---|---|---|---|
| 7.2.2 | Design of RF system architecture including modelling of RF components, simulation of the RF system and simulation of beam dynamics of full LINAC. RF system and high power modulator specifications. | 7 | R | PU | M18 |
| 1.1.3 | Periodic Report | 1 | R | PU | M24 |
| 2.1 1 | Memoranda of understanding for the implementation phase. | 2 | R | PU | M24 |
| 2.1.2 | Cost plan and time planning for the implementation phase | 2 | R | PU | M24 |
| 3.2.1 | Document detailed technical scope of upgrade | 3 | R | PU | M24 |
| 3.2.2 | Schedule for the Upgraded Detector parts and for the S-ATLAS installation | 3 | R | PU | M24 |
| 5.3.1 | Environmental Impact Study | 5 | R | PU | M24 |
| 6.2.2 | Assessment of the design | 6 | R | PU | M24 |
| 8.1.2 | Performance report on the prototypes | 8 | P, R | PU | M24 |
| 8.2.2 | Prototypes and viability report | 8 | P, R | PU | M24 |
| 8.3.3 | Custom serial powering circuitry and evaluation of generic high-current serial powering chip | 8 | P, R | PU | M24 |
| 6.3.1 | Construction Corrector magnet package | 6 | P | PU | M26 |
| 2.1.3 | Common fund, Financial Management System (software) and user requirements and user guide document | 2 | O | PU | M30 |
| 2.1.4 | Quality Assurance plan for the implementation phase | 2 | R | PU | M30 |
| 7.1.3 | Construction of plasma generator and sub-systems | 7 | 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 | P | PU | M30 |
| 6.3.2 | Prototype quadrupole magnet | 6 | P | PU | M32 |
| 6.3.3 | Test of complete quadrupole prototype | 6 | R | PU | M34 |
| 1.1.4 | Periodic Report | 1 | R | PU | M36 |
| 1.1.5 | Final Report | 1 | R | PU | M36 |
| 2.1.5 | Earned Value management system (software) with user requirements and user guide document | 2 | O | PU | M36 |
| 3.1.2 | Establish initial Memorandum of Understanding for the upgrade, agreed with major partners. | 3 | R | PU | M36 |
| 3.1.3 | Develop detailed cost books for the upgrade including the installation phase | 3 | R | PU | M36 |
| 3.2.3 | Technical documentation, drawing and CAD information for the existing experiment and upgraded elements | 3 | R | PU | M36 |
| 3.2.4 | WEB interface tools and configuration databases for the Upgrade detector project | 3 | R | PU | M36 |
| 4.1.2 | Cost book and MoU for the upgrade and installation phase | 4 | R | PU | M36 |
| 4.2.3 | Pilot design(s) and schedule(s) for the upgrade project published. | 4 | R | PU | M36 |

| | | | | | |
|---|---|---|---|---|---|
| 5.0.1 | Documentation of results for the assessment of compliance with relevant regulation (concerning all tasks) | 5 | R | PU | M36 |
| 5.4.1 | Radioactive waste study incl. waste characterization and disposal pathways | 5 | R | PU | M36 |
| 6.1.2 | Complete IR design | 6 | R | PU | M36 |
| 6.3.4 | Assessment of the design | 6 | R | PU | M36 |
| 7.1.4 | Plasma generation and testing during working hours over a total period of 1 month. | 7 | R | PU | M36 |
| 7.2.4 | Full test and validation of RF system. Final report. | 7 | D | PU | M36 |
| 8.1.3 | Fully characterized regulators ready for series production | 8 | D | PU | M36 |
| 8.2.3 | Integration in full-scale detector modules | 8 | D | PU | M36 |
| 8.3.4 | Full-scale supermodule with custom serial powering circuitry | 8 | D | PU | M36 |

*Table 3b - List of* ***milestones***

| Milestone number | Milestone name | Work package(s) involved | Expected date | Means of verification |
|---|---|---|---|---|
| 1.1 | Consortium Agreement | 1 | M3 | Sending copy to the EC |
| 1.2 | Kick-off meeting | 1 | M3 | EC Project Office invited |
| 3.1 | Project structure for R&D phase | 3 | M6 | Documented as WEB structure |
| 6.1 | Qualification of magnet components | 6 | M8 | Qualification document published |
| 3.2 | Schedule for R&D phase and initial implementation schedule | 3 | M9 | Schedule document |
| 6.2 | Basic Magnet design | 6 | M10 | Magnet design report |
| 1.3 | First Annual SLHC-PP Meeting | 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 | M12 | Meeting with stakeholders in accelerator and experiments, to define an agreement on design parameters. |
| 7.1 | List of required improvements for the design of the high duty factor plasma generator to function at 3.6% duty factor | 7 | M14 | Report approved by partners |
| 2.1 | Task distribution and description for each participant for the implementation phase | 1, 2 | M18 | Document published |
| 2.2 | Draft cost and time planning | 2 | M18 | Document on web |

| | | | | |
|---|---|---|---|---|
| 2.3 | Financial management system (beta version) | 2 | M18 | Beta version released |
| 3.3 | Initial cost estimate for upgrade | 3 | M18 | Report |
| 3.4 | Initial installation plan | 3 | M18 | Report |
| 4.1 | Project Scope Defined | 4 | M18 | Report publication |
| 4.2 | Key structural requirements in place (information repository, tools, coordination framework, safety and quality systems, integration office) | 4 | M18 | Publication of report describing the features |
| 5.2 | Activation levels in the SLHC accelerator and its injectors | 5 | M18 | Results of study published in Report |
| 6.3 | Complete cold mass design | 6 | 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 | M18 | Report approved by partners |
| 6.4 | Complete cryomagnet design | 6 | M22 | Design Report published |
| 6.5 | Cryogenic and power test of the model | 6 | M22 | Test report published |
| 1.4 | Second Annual Review meeting | 1 | M24 | Presentations on SLHC-PP web site |
| 2.4 | EVM software (beta version) | 2 | M24 | Beta version released |
| 3.5 | Upgrade project structures for construction of all deliverables | 3 | M24 | Documented as WEB structure |
| 5.3 | Environmental impact of radioactive releases from SLHC and its injectors | 5 | M24 | Results of study published in Report |
| 8.1 | Linear voltage regulator prototypes | 8 | M24 | Prototype linear voltage regulator fully tested and working according to specifications, detailed in deliverable report 8.1.2 |
| 8.2 | DC-DC conversion prototype | 8 | M24 | Prototypes fully tested. The actual milestone is the technology decision taken as a result of the viability study, as reported in deliverable 8.2.2 |
| 8.3 | Serial powering prototype | 8 | M24 | Prototype serial powering circuit blocks fully tested and working according to specifications, as detailed in deliverable report 8.3.3. Design decision on generic high-current device is taken. |
| 6.6 | Electrical test of collared coil | 6 | M28 | Test report published |
| 6.7 | Cold test corrector magnets | 6 | M28 | Test report published |

| | | | | |
|---|---|---|---|---|
| 5.4 | Definition of strategies for operation and maintenance of high-intensity accelerators and associated experiments (meeting of stakeholders). | 5 | M30 | Meeting with stakeholders in accelerator and experiments. Minutes of the meeting, fixing the selected options for the final report. |
| 3.6 | First complete set of technical drawings and documents for the major upgrade parts | 3 | M32 | Reviewed and documented by review report |
| 1.5 | Final Project Review | 1 | M36 | Final Report to be delivered |

*Table 3c – Summary of **staff effort***

| **Participant no. / short name** | **WP1** | **WP2** | **WP3** | **WP4** | **WP5** | **WP6** | **WP7** | **WP8** | **Total person months** |
|---|---|---|---|---|---|---|---|---|---|
| 1. CERN | **54** | **45** | **52** | **36** | **94** | **72** | **161** | 90 | 604 |
| 2. AGH-UST | | | | | | | | 36 | 36 |
| 3. CEA-Saclay | | 6 | | | | 42 | 20 | | 68 |
| 4. CIEMAT | | 6 | | | | 24 | | | 30 |
| 5. CTU | | | | | 8 | | | | 8 |
| 6. DESY | | | | 12 | | | 2 | | 14 |
| 7. ETHZ | | | | 12 | | | | | 12 |
| 8. GSI | | | | | 24 | | | | 24 |
| 9. Imperial | | | | 12 | | | | | 12 |
| 10. INFN | | | | | | | 7 | | 7 |
| 11. CNRS-IN2P3 | | | | | | 18 | | | 18 |
| 12. FOM-NIKHEF | | | 20 | | | | | | 20 |
| 13. PSI | | | | | 24 | | | 16 | 40 |
| 14. STFC-RAL | 3 | 6 | 20 | | | 24 | 1 | **58** | 112 |
| 15. Uni Bonn | | | | | | | | 60 | 60 |
| 16. UNIGE | | | 10 | | | | | | 10 |
| 17. USFD | | | | | 8 | | | | 8 |
| **TOTAL** | **57** | **63** | **102** | **72** | **158** | **180** | **191** | **260** | **1083** |

Note: the person-months of the lead participant are shown in bold.

## 1.4 Work packages to be supported by the EC

### 1.4.1 WP1 – SLHC-PP project management

*Table 4.1 – **Work package 1** description*

| **Work package number** | 1 | **Start date or starting event:** | | | | Month 1 | |
|---|---|---|---|---|---|---|---|
| **Work package title** | SLHC-PP project management | | | | | | |
| **Activity Type** | MGT | | | | | | |
| **Participant** | CERN | STFC-RAL | | | | | |
| **Person-months per participant:** | 54 | 3 | | | | | |

**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** *(possibly broken down into tasks), and role of participants*

<u>Task 1.1 Coordination, progress monitoring, reporting and dissemination of information</u>

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.

The Work package leaders play a key reporting and monitoring role in the framework of WP1.

The management and coordination tasks of the project will be carried out mainly by CERN.
STFC-RAL will be the WP8 Leader.

| Deliverables | Description | Nature | Delivery date |
|---|---|---|---|
| 1.1.1 | SHLC-PP web-site operational (intranet + public pages) | O | M3 |
| 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 | M3 |
| 1.2 | Kick-off meeting | R | M3 |
| 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 |

### 1.4.2 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.

*Table 4.2 – **Work package2** description*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **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 | STFC-RAL | CIEMAT | | | |
| **Person-months per participant:** | 45 | 6 | 6 | 6 | | | |

**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 define the project management structure, all the collaborators' tasks and work packages for the implementation phase and to set up the project and collaboration management tools. Responsibilities have to be attributed to the partners. 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 a formal collaboration framework. The partners for the implementation phase have to be found and agreement with the partners has to be reached on the tasks and responsibilities. The financial contributions of the non-member-state partners have to be agreed upon. The Memoranda of Understanding (MoU) have to be written to define the tasks and responsibilities of the partners in the implementation phase (CERN, CEA and STFC-RAL).

2.1.b Make a cost plan and a time planning for the implementation phase (CERN). The two are very much related and provide essentially the boundary conditions in which all technical work will be done.

2.1.c 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.d 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.e 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 facilities exist already, some software facilities will have to be written and conduct codes to be agreed upon. (CERN, CEA, 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 and component description. 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 | Memoranda of understanding for the implementation phase. | R | M24 |
| 2.1.2 | Cost plan and time planning for the implementation phase | R | M24 |
| 2.1.3 | Common fund, Financial Management System (software) and user requirements and user guide document | O | M30 |
| 2.1.4 | Quality Assurance plan for the implementation phase | R | M30 |
| 2.1.5 | 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 | Task distribution and description for each participant for the implementation phase | R | M18 |
| 2.2 | Draft cost and time planning | R | M18 |
| 2.3 | Financial management system (beta version) | O | M18 |
| 2.4 | EVM software (beta version) | O | M24 |

### 1.4.3 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

*Table 4.3 - **Work package 3** description*

| **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:<br>• 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.<br>• 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 | M6 |
| 3.1.2 | Establish the initial Memorandum of Understanding for the upgrade, agreed with major partners. | R | M36 |
| 3.1.3 | Develop detailed cost books for the upgrade including the installation phase | R | M36 |

| Deliverables task 3.2 | Description | Nature | Expected 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 | M6 |
| 3.2 | Schedule for R&D phase and initial implementation schedule | R | M9 |
| 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 |

### 1.4.4 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 CSM2 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.

*Table 4.4 - **Work package 4** description*

| **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 | ETHZ | Imperial | | | |
| **Person-months per participant:** | 36 | 12 | 12 | 12 | | | |

**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 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 College)

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, ETHZ)

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

| Deliverables task 4.2 | Description | Nature | Expected date |
|---|---|---|---|
| 4.2.1 | Core of upgrade Technical Coordination unit established | R | M12 |
| 4.2.2 | Schedule and reporting mechanism defined. | 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 |

### 1.4.5 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 experiments with the aim of maximising luminosity while reducing radiation damage to 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.

The assessment of the consequences of intensity- and luminosity increases - for accelerator/detector design and operation with regard to radiation protection necessitates a close collaboration between accelerator experts, detector designers and radiation protection experts from the early planning phase on. 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 iterative process of optimizing accelerator and experiment design and future operation in view of radiation protection and safety constraints will bring together experts from all relevant fields and 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 all safety aspects including radiation protection and environmental issues are taken into account as early as possible. The results and conclusions of this optimization process concerning safety and radiation protection will be documented in reports which will be used to evaluate the conformity of the proposed design with safety and radiation protection regulations.

The achievement of the objectives described below is important for the design of the SLHC in order to identify critical issues – and to find adequate solutions- in the often conflicting requirements of machine and experiment performance on the one side, and safety and radiation protection regulation on the other.

The results to be obtained will also be indispensable when assessing the needs for the safety approval procedure and the impact of safety issues on the final costs. Therefore reports on safety and radiation protection will be prepared facilitating the assessment of compliance with relevant regulations.

*Table 4.5 - **Work package 5** description*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Work package number** | WP5 | **Start date or starting event:** | | | Month 1 | | |
| **Work package title** | Radiation protection and safety issues for accelerators and experiments | | | | | | |
| **Activity Type** | SUPP | | | | | | |
| **Participant** | CERN | PSI | GSI | USFD | CTU | | |
| **Person-months per participant:** | 94 | 24 | 24 | 8 | 8 | | |

**Objectives**

- Assessment of radiological impact on personnel and environment for various design options for the integration of focusing and experiment assemblies with a view to minimize activation and radiation exposure.
- Assessment of radiological impact on personnel and environment for the entire accelerator chain as a function of beam intensity increase.
- Optimization of shielding designs and 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 and geometries in order to minimize future radioactive waste and to facilitate waste characterization for future elimination.

**Description of work**

<u>Task 5.1 Detector Activation:</u> Simulation calculations for activation and radiation in the detectors and adjacent regions, in particular for the beam pipe close to the interaction regions, studies of consequences for different accelerator focusing options, design of protection measures such as shielding, and of design options aiming at minimizing the radiation exposures during maintenance and repair intervention. (GSI, USFD, CTU)

<u>Task 5.2 Accelerator Activation:</u> Simulation calculations for activation and radiation in other regions of the accelerators; 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)

<u>Task 5.3 Impact Study:</u> Assessment of dose rates in areas of the SLHC accessible during operation, as well as the exposure due to effluents (air, water) of the public and the environment. Assessment of dose rates to personnel from activated equipment in the accelerators during access in the tunnels, with provisions for safe maintenance and repair intervention. (CERN, PSI).

<u>Task 5.4 Radioactive Waste:</u> Systematic study on activation of structural material of accelerator and experiments, and the consequences in terms of future radioactive waste (amounts, waste characterization, disposal pathways, and costs). Study of possibilities to minimize waste (CERN, PSI, USFD, CTU)

<u>Task 5.5 Maintenance planning:</u> Safety planning for maintenance and repair of highly activated components of experiments and accelerators in a complex underground environment, in compliance with relevant regulation (CERN, PSI, USFD, CTU).

| Deliverables | Description | Nature | Delivery date |
|---|---|---|---|
| 5.1.1 | Estimation of activation and radiation levels for accelerators, detectors and interaction regions | R | M18 |
| 5.3.1 | Environmental Impact Study | R | M24 |
| 5.4.1 | Radioactive waste study incl. waste characterization and disposal pathways | R | M36 |
| 5.0.1 | Documentation of results for the assessment of compliance with relevant regulation (concerning all tasks) | 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 design constraints | R | M12 |
| 5.2 | Activation levels in the SLHC accelerator and its injectors | R | M18 |
| 5.3 | Environmental impact of radioactive releases from SLHC and its injectors | R | M24 |
| 5.4 | Definition of strategies for operation and maintenance of high-intensity accelerators and associated experiments (meeting of stakeholders). | R | M30 |

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

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 β* at the collision point. However, while the beam current depends on the whole ring and the chain of injectors, the β* depends mainly on the optical properties of the interaction region. So, acting on the low- β 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.

*Table 4.6 - **Work package 6** description*

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

**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 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 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, 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, 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 |

### 1.4.7 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 improvements. 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.

*Table 4.7 - **Work package 7** description*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **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 | DESY | INFN | STFC-DL | | |
| **Person-months per participant:** | 161 | 20 | 2 | 7 | 1 | | |

**Objectives**

- To experimentally demonstrate that the required duty factor for the plasma generator of an $H^-$ ion source of the SPL can be achieved and 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

The goal will be to build a plasma generator and confinement system with a configuration as similar as possible to the DESY 2MHz RF negative hydrogen ion source, but capable of supporting 0.71ms pulses at 50Hz operation (3.6% duty factor), at a power level to be defined after tests with the low duty factor RF H- ion source of Linac 4. This would be the basis of the design for a future H- ion source for the SPL.

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 3.6% duty cycle.
- Construction of the plasma generator and sub-systems (e.g. RF generator, hydrogen gas injection and pumping).
- Infrastructure preparation and system installation
- Plasma generation.

CERN will be the leading institute and will co-ordinate the other efforts. STFC-DL 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 stabilization 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 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 the plasma generator to operate at 3.6% duty cycle. | 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 testing during working hours over a total period of 1 month. | 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 3.6% 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 |

### 1.4.8 WP8 – Tracking Detector Power Distribution

The main physics aims of the SLHC project require very significant changes, improvements and upgrades of the two large multipurpose detector systems at LHC. These changes are needed to be able to handle a factor 10 more luminosity and also 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 of >300 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.

Since inner trackers are quasi inaccessible, very stringent reliability criteria are applied to the design and construction of these trackers. The highly segmented parallel powering presently adopted brings very high currents to the tracker volume. This caused severe integration difficulties in the present LHC and is highly incompatible with the requirement of low mass for particle detectors in general. Therefore, for the future SLHC detectors, new high-tech developments are needed in the domain of detector powering. 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 options will need on-detector radiation-hard linear ***voltage regulators***. The radiation hardness criterion is not fulfilled by commercially available components and forms the principal reason for dedicated development. At present no collaboration framework exists for the detector powering studies. The CNI SLHC preparatory phase project forms a crystallization centre around which a large new collaboration is expected to grow.

*Table 4.8 - **Work package 8** description*

| **Work package number** | WP8 | **Start date or starting event:** | | | Month 1 | |
|---|---|---|---|---|---|---|
| **Work package title** | Tracking Detector Power Distribution | | | | | |
| **Activity Type** | RTD | | | | | |
| **Participant** | STFC-RAL | AGH-UST | CERN | PSI | UBONN | |
| **Person-months per participant:** | 58[1] | 36 | 90 | 16 | 60 | |

| **Objectives** |
|---|
| The objective of work package 8 is to explore various *linear voltage regulation* and *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. |

[1] The STFC-RAL resources for power distribution R&D have not yet been awarded officially, but this is expected imminently.

**Description of work**

Task 8.1 Linear voltage regulation

On-detector linear voltage regulators provide noise filtering and protect the delicate front-end circuitry from over-voltage, over-current and over-temperature events. Two families of linear regulators will be developed:

1. "Stand-alone components" for low current (100-300mA) applications.
2. Characterized design macros, "IP blocks", to be embedded in the front-end read-out ASICs

Both families will be needed independently of the power distribution scheme chosen. The development program will be structured as follows:

*"Evaluation phase"*

The aim of the evaluation phase is to define the component specifications and establish contacts with industrial partners for possible collaboration in the development.

*"First prototype phase"*

Development of prototype regulators of both families, one stand-alone and one IP block for a selected current level. Full evaluation of the prototype performance.

*"Final prototype phase"*

Development of final prototype regulators of both families, the current level of the IP blocks being defined by the LHC experiments. A final evaluation report will be produced on the program comprising fully characterized and documented IP blocks ready for integration on-chip as well as fully characterized stand-alone regulator ready for series production.

CERN will be responsible for the development of the "stand-alone" component. AGH-UST and UBONN will develop the IP block.

Task 8. 2 DC-DC conversion

The development aims for radiation-hard components operating in magnetic fields up to 4 Tesla. The magnetic field compatibility excludes commercial components based on ferromagnetic materials. The following alternative solutions will be explored: buck converters based on air core inductors, transformers based on the use of piezoelectric materials, 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 the first-generation 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 step-down transformer using piezoelectric materials being more innovative, the first prototype will be built with discrete components. The on-chip DC-DC converter, integrated in modern CMOS technologies, will also be prototyped to assess the feasibility of this solution. A report will detail the performance of the prototypes, with conclusions on the final viability of each conversion approach.

*"Integration phase"*

Integration of the converters in full-scale detector modules. Prototypes developed in phase 2 will be used at first, but in parallel a new generation will be developed. A report on the full DC-DC R&D results together with a feasibility evaluation of DC-DC technologies for the SLHC tracking detectors will be compiled.

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

Task 3: 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"*

Specification 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 the custom electronics in tracking detector super-modules. A super-module will consist of large number (~20) of detector modules powered in series. The super-module performance will be fully characterized.

AGH, RAL and University of Bonn 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 | Specifications of the components to be developed within the partnership | R | M6 |
| 8.1.2 | Performance report on the prototypes | P,R | M24 |
| 8.1.3 | Fully characterized regulators ready for series production | D | M36 |

| **Deliverables task 8.2** | **Description** | **Nature** | **Delivery date** |
|---|---|---|---|
| 8.2.1 | Evaluation report on DC-DC conversion technologies | R | M12 |
| 8.2.2 | Prototypes and viability report | P, R | M24 |
| 8.2.3 | Integration in full-scale detector modules | D | M36 |

| Deliverables task 8. 3 | Description | Nature | Delivery date |
|---|---|---|---|
| 8.3.1 | Evaluation report on generic serial powering studies | R | M12 |
| 8.3.2 | Specification of serial powering components | R | M15 |
| 8.3.3 | Custom serial powering circuitry and evaluation of generic high-current serial powering chip | P,R | M24 |
| 8.3.4 | Full-scale super-module with custom serial powering circuitry | D | M36 |

| Milestones | Description | Nature | Expected date |
|---|---|---|---|
| 8.1 | Linear voltage regulator prototypes | P | M24 |
| 8.2 | DC-DC conversion prototype | P | M24 |
| 8.3 | Serial powering prototype | P | M24 |

## 1.5 Work packages not directly supported by the EC

### WP9 Study of a new injector complex

The Proton Synchrotron (PS) is at the heart of the CERN accelerator complex, serving as the pre-injector for the LHC as well as feeding protons to the Super Proton Synchrotron (SPS) for the fixed-target physics program. By the time the LHC becomes operational it will be almost 50 years old. It is showing severe signs of fatigue and reliability is becoming a real issue. In addition, it is a bottleneck in increasing the intensity of the beam for the LHC. A study is in progress of a new synchrotron of modern design and higher energy (around 50 GeV) to replace the PS. This machine will give improved reliability and will allow the beam intensity for LHC to be increased considerably. This new machine would require a higher injection energy to be provided by a new superconducting proton linear accelerator (SPL) capable of 5 GeV.

### WP10 Replacing the existing Linac

In the present complex, the proton beam is accelerated to 50 MeV by a linear accelerator (Linac2) and injected into the PS Booster where it is further accelerated to 1.4 GeV before being injected into the PS. There are two main limitations to this system.

Firstly, the rather low injection energy into the Booster produces large space charge effects that limit the beam intensity. Secondly, the multi-turn injection of protons produces a large dilution of transverse emittance and therefore beam brightness in the LHC. The situation can be considerably improved if the linac energy is increased to about 160 MeV and if negative hydrogen ions (H-) are accelerated instead of protons. These ions can be injected with much less phase space dilution by converting them to protons on a “stripper” foil at the entrance to the Booster. This would immediately improve the luminosity in the LHC.

In a first instance, the new linac (Linac4) would feed the existing accelerator complex and would eventually serve as the front end of the SPL. This is considered to be the most urgent improvement of the LHC injector chain and will become operational in 2012 at the same time as the inner triplet first phase upgrade.

**WP11 Development of very high field magnets**

The first stage of the upgrade of the intersection regions relies on existing technology, but requires advanced design. The second phase, to become operational in 2016, depends on the development of advanced superconductor technology ($Nb_3Sn$). The magnets need to achieve very high fields under a permanent heat load created by the products of the particle interactions. This development starts now and needs several years. WP11 also includes high field magnets for a beta-beam machine for neutrino physics.

**WP12 Development of pulsed superconducting magnets**

The CERN accelerator injector complex will have to be upgraded in beam intensity and beam energy at the end of the chain. One of the options for the construction of a new proton synchrotron (WP9) is to make it superconducting, in order to maximize the performance and economize on power consumption. Such a machine must be able to cycle much more rapidly than the LHC and therefore requires the development of superconducting magnets (in particular the superconducting wire) allowing pulsed operation. This work allows the appropriate choice of the technology to be used for the PS upgrade.

**WP13 Cryogenics upgrade**

Increasing the luminosity of the LHC by an order of magnitude means that the heat load on the inner triplets due to debris from the collision point is also increased by an order of magnitude. This requires an improvement in the cooling capacity of the existing cryogenic system.

**WP14 Common R&D for S-ATLAS and CMS2**

WP14 is targeted to common R&D efforts for the experiments in a variety of domains. These domains cover Microelectronics, Optoelectronics, Tracking detectors, Calorimetry, Triggering, Data Acquisition, Controls, Data Analysis, Simulation and Computing. CERN will use its central role in the particle physics community to stimulate collaboration frameworks for common development work across SLHC experiments. Setting up such coordination frameworks at an early stage will allow using resources from the collaborating partners in the most effective way and will avoid duplication.
For the SLHC front-end read-out systems, the work will include the application of radiation-hard design techniques to new CMOS technology standards, making extensive use of the lessons learnt from LHC. High-speed radiation-hard optoelectronics applications, compatible with SLHC data rates, are also part of this work package. Developments for tracking detectors will mostly concentrate on solid state detector technologies aiming for radiation-hard sensor technologies, low-mass detectors and reliable interconnect technologies. The work on Triggering, Data Acquisition and Controls concentrates on a coordinated effort to set up specifications and to track new relevant industrial technologies as they become available. These will include networking technologies, processor technologies and expert systems. The work on data simulation, data analysis and computing aims at optimising the performance and use of data analysis and simulation tools in view of the needs of the users and of industrial evolutions in processor architectures. In particular it will develop on parallel data analysis techniques to make effective use of multiple processing cores. In addition it will develop improved software application portability across different platforms. The virtualization techniques foreseen will reduce cost in developing, packaging and deploying Grid applications while enhancing security. Several of the developments mentioned above are vital to face the huge SLHC data rates and data volumes. The work done in WP14 will intensively use the requirements generated by the R&D work of WP15 and WP16. It will be part of CERN’s participation in these work packages.

### WP15 S-ATLAS R&D projects

WP15 covers the R&D needed to develop the most critical elements of a new ATLAS Inner Detector. The most central elements are new radiation hard readout ASICs in deep sub micron technology, new silicon detectors that can withstand a factor 10 higher radiation and handle a factor 10 higher rate, and improved or new packaging technologies for silicon sensor modules as bump-bonding or more novel methods. Engineering issues related to light and stable radiation resistant materials and efficient powering and cooling are also covered with high priority. The work involves numerous university groups and key industrial partners, and progresses through iterations of prototypes that are irradiated and carefully evaluated by the project partners in beams and test setups. Simulations and performance studies of larger systems will be done in parallel.

### WP16 CMS2 R&D Activities

WP16 covers the R&D required to replace elements of the CMS detector which will not be able to cope with the environment of the SLHC. The major work will concern the tracking detectors. A new tracker will contain a much larger surface of pixel detectors in order to cope with the high density of particles, and may also contain electronics for local track segment finding. The key areas of research involve; development of radiation hard sensors for the innermost tracking layers, studies of techniques required in the industrialization of pixel detector bonding, new readout electronics for higher rates and triggering on tracking information. The outer volume of a new tracker will most likely consist of long pixels and or shorter length strips than the current tracker resulting in a much higher channel count. In order to keep the physics potential of the detector at a maximum, it will be essential to understand how to reduce the material and power requirements of the new tracker whilst increasing the channel count. These efforts will require close coordination with the activities in WP8. Work here will include sensor and electronics development, extensive simulation and some prototype development.

The current Level-1 Trigger relies on the muon and calorimeter systems of CMS, which may not have the needed resolution to perform adequately at SLHC. The solution for this is to involve information from the tracking detectors, and this requires extensive redevelopment of both the tracking system, and the Level-1 Trigger. The order of magnitude increase in the data volume which is expected with the SLHC will require a significant increase in the capacity of the data acquisition system

The forward regions of the CMS Muon and Calorimeter systems may be subject to backgrounds at the SLHC which will require replacing the readout electronics of some of the detectors. In addition the local track segment finding electronics may not be able to perform adequately in the high rate environment of the SLHC. R&D will involve analysis of the observed backgrounds at LHC, modelling and extrapolation to SLHC backgrounds, and development of new electronics to cope with higher occupancies and rates in the detectors. In addition, the very forward calorimeter may be occluded by proposed magnetic elements for final focusing of the SLHC beams. R&D will be required on alternative technologies for the most forward regions of the calorimeter, as well as simulation on the effects on physics performance of potential machine optics solutions.

## 1.6 Focus on needs of users

The upgraded LHC will serve a particle physics community of some 4000 scientific users from a few hundred participating Institutes from countries world-wide, who will come each year to CERN to participate in international experiments.

Upgrading the LHC by increasing its luminosity is clearly a way to efficiently use the potential of the world's largest infrastructure in high-energy physics, for it aims to improve and exploit to its best a complex which is unique in the world and will keep Europe at the frontier of the research in this field. Increasing the beam intensity and the luminosity to the limits of the LHC possibilities is a way of making of this unique infrastructure an even better instrument for the physics, as fundamental science.

The expected impact on the research in Particle Physics of setting up the LHC upgrade is significant. Once the physics programme of the nominal LHC will have been accomplished, and in particular, the Higgs boson and Super-symmetry will have been found, provided they are in the expected mass ranges, the upgraded LHC will indeed be an excellent tool in response to the needs of deepening this research. Running the LHC upgrade at ten times the luminosity opens the way to increase the accuracy in the determination of key-physics parameters of the Standard Model and of new physics, to extend the possible discovery of new elementary particles and to increase the sensitivity to rare processes.

The project reinforces the European capacity of producing not only high-energy and high-intensity proton beams in the years to come but it is also part of Europe's long-term goal to create intense neutrino and muon beams. In the shorter term, the upgrades of the injector chains will provide an increased flux of protons for fixed target experiments and nuclear physics, strongly requested already by the corresponding user communities.

### 1.7 Coordinating effect of Preparatory Phase

CERN is prepared to financially commit the Organisation in order to support the preparatory phase of the LHC upgrade with planned additional resources over the period 2008 to 2011 for priority programs which include preparatory work towards the implementation of the SLHC. This is based on the recommendation done by the CERN Council Strategy Group, unanimously approved at an extraordinary session of the CERN Council in July 2006, which states:

*"The LHC will be the energy frontier machine for the foreseeable future, maintaining leadership in the field; the highest priority is to fully exploit the physics potential of the LHC, resources for completion of the initial programme have to be secured such that machine and experiments can operate optimally at their design performance. A subsequent major luminosity upgrade (SLHC), motivated by physics results and operation experience will be enabled by focused R&D; to this end R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015."*

The first step for the LHC upgrade foreseen by CERN aims at addressing the above recommendation of vigorous R&D and is planned to cover the period 2008-2011 with activities on the injectors, the machine itself and the detectors. *The CNI preparatory phase project proposed within the EC Research Infrastructures programme is a necessary and timely complement to these activities, running in parallel with them over the same period of time and providing the necessary coordination of the upgrade work on the accelerators and the experiments as well as the answers to critical technical issues which have to be addressed in addition to the R&D CERN-plan.*

The present CNI-PP proposal, which is complementary to the CERN first-step upgrade efforts and ends at approximately the same time (beginning of 2011), combines well with a larger bulk of activities related to SLHC. The proposed project will indeed allow the participants to be prepared for the setting up of collaboration consortia, Memoranda of Understanding, cost books and construction plans at the time the R&D activities planned at CERN and supported by the CERN Council will be completed. At this point, reached at the beginning of 2011, the first phase of the LHC upgrade, with a possible consequent luminosity increase by a factor ~2, (as a result of the work foreseen in WP6 and WP7) will be achieved such that the implementation of the full upgrade, aiming at a luminosity 10 times above the nominal, can begin immediately afterwards in view of its completion in 2016.

# 2 Implementation

## 2.1 Management Structure

The project management and coordination activities will be implemented through the management structure, shown in Figure 2.1, which is similar to the management structure of successful FP6 Research Infrastructure projects, such as CARE and EUROTeV. Modern project management tools, which have proved their efficiency in the LHC project, will also be used for the SLHC PP.

**Project Management (WP1)**

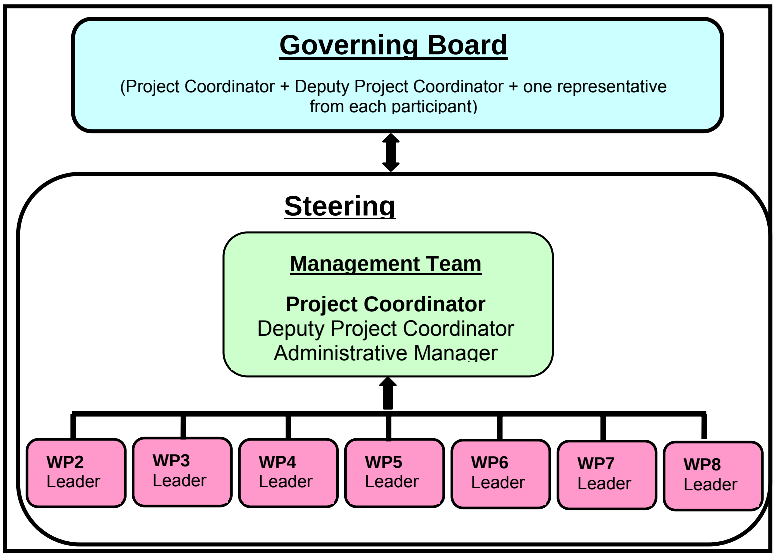


Figure 2.1. Management structure

- **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. At that first meeting the nomination of the Deputy Project Coordinator, the Work Package Leaders, and the Administrative Manager will be confirmed, the preparation of the Consortium Agreement will be discussed an the work plan and budget formally accepted. 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. The PC will be the SLHC-PP contact person with the European Commission.

***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 DPC will be also in charge of organising the dissemination of information.

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. 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 be supported in their daily activities by an administrative office situated on the premises of the coordinating institution, CERN.

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.

### 2.1.1 Monitoring and reporting progress

The list of the deliverables with their delivery date is reported in Table 3a. The project milestones list is reported in Table 3b. The latter represent important control points in the project for monitoring the major results of the programme, and may serve as stages to take strategic decisions.

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.

### 2.1.2 Communication and dissemination of information

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

Distribution of written SLHC-PP documentation

Other than the formal reporting vis-à-vis the European Commission, specified in the contract, 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.

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 PP project.

Scientific exchange

The scientific results of the projects 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.

## 2.2 Relevant Parties

2.2.1 Relevant experience of the Consortium partners

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 at the end of 2007. 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 Coordinating partner 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 2.1 below.

**Table 2.1 Involvement and relevant experience of the participants in the project**

| Participant | From | Key tasks in the project | Relevant expertise and experience |
|---|---|---|---|
| AGH-UST | PL | - development of linear voltage regulators and 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 conceptual improvements of the higher duty factor design | - broad experience with the design, construction and technical coordination of large particle physics experiments<br>- modeling and FEM thermal analysis<br>- development of RF sources |
| ETHZ | 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 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 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 |

2.2.2 Complementarity and collaborations between the partners

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. All partners in WP6 have previously collaborated with CERN.

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).

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, ETHZ, 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, CERN, PSI, STFC and UBONN as well as by the non-member state LBNL laboratory.

2.2.3 Key stakeholders for the SLHC Preparatory Phase

CERN has 20 Member States, of which 18 are Members of the European Union - Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Poland, Portugal, the Slovak Republic, Spain, Sweden, and the United Kingdom; The other two CERN Member States are Switzerland and Norway. CERN has 8 observer states – India, Israel, Japan, Russia, USA, Turkey, the European Commission and UNESCO, providing major contributions to the CERN program and to this project.

The CERN Council is the body, which assembles the 20 Member States of CERN and includes senior representatives of their national research ministries and governmental agencies. The Council takes all important decisions on the scientific programme of the Organisation and the associated funding. The participation of CERN in the LHC-upgrade project is supported by its Council, and the LHC-upgrade scientific programme has been approved. For this reason CERN is the key stakeholder in the Preparatory Phase of the LHC-upgrade, combining the support and commitment of its Member States to this project.

In addition, the following participants in the SLHC-PP project are either funding agencies at national level, or are part of larger national research structures:

- CEA (France)
- CIEMAT (Spain)
- CNRS-IN2P3 (France)
- DESY (Germany)
- FOM-NIKHEF (Netherlands)
- GSI (Germany)
- INFN (Italy)
- STFC (UK)

2.2.4 Provisions for entry of new partners

The possibility to include new partners during the course of the SLHC-PP project within the initial budget has been envisaged (not an exhaustive list):

- Some of the large US accelerator laboratories (BNL, FNAL, LBNL, SLAC) through their already established LHC Accelerator Research Program (LARP), for contribution to the design, manufacturing and testing of the inner triplet quadrupoles
- The Japanese national accelerator laboratory (KEK) contributing to the development of advanced superconductor for superconducting quadrupole magnet design
- The Canadian TRIUMF laboratory, expressing interest to work on the design efforts of the NbTi quadrupole
- Romania, a new EU Member State and Non-Member State of CERN, which participates in the LHC Experiments, and has expressed interest in contribution to the LHC upgrade.
- China, Russia and/or India, with which CERN is currently negotiating a contribution to the construction of the SLHC new injector complex.

In case the Consortium (through its Governing Board) approves the entry of new participant(s), part of the EU allocation of the Coordinator (CERN) will be used as EU contribution to the budget of the new participant(s).

## 2.3 Resources

Overview of the SLHC-PP budget

Table 3.1 gives the budget breakdown of the SLHC-PP direct costs (in €) per Work Package.

| | WP1 | WP2 | WP3 | WP4 | WP5 | WP6 | WP7 | WP8 | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Activity type | MGT | COORD | COORD | COORD | SUPP | RTD | RTD | RTD | |
| Man-months | 57 | 63 | 102 | 72 | 158 | 180 | 191 | 260 | **1083** |
| Personnel costs | 565,000 | 525,000 | 816,000 | 720,000 | 1,224,000 | 1,500,000 | 1,538,000 | 1,455,000 | **8,343,000** |
| Material and equipment | 10,000 | 0 | 11,000 | 50,000 | 76,000 | 762,000 | 826,000 | 440,000 | **2,175,000** |
| Travel costs | 70,000 | 75,000 | 54,000 | 100,000 | 160,000 | 138,000 | 33,000 | 90,000 | **720,000** |
| Other direct costs | 0 | 0 | 20,000 | 30,000 | 40,000 | 0 | 0 | 0 | **90,000** |
| Sub-contracting | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| **Total direct costs** | **645,000** | **600,000** | **901,000** | **900,000** | **1,500,000** | **2,400,000** | **2,397,000** | **1,985,000** | **11,328,000** |
| **Requested EU contribution** | **400,000** | **600,000** | **501,000** | **500,000** | **700,000** | **800,000** | **799,000** | **600,000** | **4,900,000** |

Table 3.1. Breakdown of the SLHC-PP direct costs (€) budget per Work Package

The **indirect costs** are not included in this table. The indirect costs depend on the activity type and the accounting principles of each participant, and are indicated on the A3 Forms.

For WP1 (SLHC-PP project management), a total of 57 person-months are estimated - 7 x 3 = 21 p·m for the WP2-WP8 Leaders, 12 p·m for the Coordinator, 6 p.m. for the Deputy Project Coordinator, 12 p·m. for the Administrative Manager and 6 p.m. for personal assistant to the Management Team. The material and consumables needed will be 10 k€, and 70 k€ are reserved for travel expenses of the Management Team and the Steering Committee.

For WP2 (Coordination for the accelerator upgrade implementation) a total 63 p·m are estimated for total personnel costs of 525 k€. For setting up the collaboration framework 20 p·m. are estimated for CERN, CEA and STFC-RAL (12 +4 +4 p·m ). A cost and time planning will need 4 p·m from CERN. The project monitoring structures will take and estimated 8 p·m. to set-up at CERN. The Finance management system will take 7 p·m at CERN. Setting up the Quality assurance plane will need from CERN 5 p·m 15 p·m are needed to set up the collaboration communication structures shared between CERN, CEA, STFC-RAL and CIEMAT (7+2+2+4). The information storage and dissemination will be set up by CERN using 4 p·m. 75 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, meeting between participant 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 24.p·m (12 for Imperial College and 12 for CERN) for the overall coordination of the CMS2 upgrade. The creation of the Technical Coordination Unit for the upgrade will require 48 p·m., 12 p·m, each from ETHZ and DESY as well as 24 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) Tasks 5.1, 5.3 and 5.5, shared partly between the CERN ATLAS and CMS-collaborations on the one hand and the USFD and CTU on the other hand require 31 p·m each for estimating the activation of the detector parts, to elaborate maintenance strategies for them and to estimate the volume and activity of radioactive waste. For this purpose, they also request 100 k€ for travel, 36 k€ for material expenses and 40 k€ for other expenses. The CERN radiation protection group and its partners GSI and PSI will spend an effort of 96 p·m for estimating the additional activation of the accelerator areas (task 5.2) the impact on the environment of releases (task 3), the production of radioactive accelerator waste (task 5.4) and maintenance and repair options for accelerator components (task 5.5). Material expenses, mainly for computers for numerical calculations, amount to 40 k€, and travel funds to 50 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 20 p.m for the thermal modelling and design of the plasma generator, with contributions from CERN, DESY and STFC-DL. 58 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 150 k€ for the RF system, 100 k€ for the vacuum assembly, 100 k€ for infrastructure modifications and 250k€ for the Plasma generator assembly. 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 107 p·m: 80 p·m for CERN, 20 p·m for CEA and 7 p·m for INFN. The total cost for man-power in task 2 of this work-package will be 838 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 (Detector powering systems) will need 260 person months for development in radiation hard microelectronics design, system integration and testing for total personnel budget of 1,455 k€. 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 material resources required for this task 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 4.9 M€, the matching funding of 6.4 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 2008-2011 will be 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).

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.

# 3 Impact

## 3.1 Critical Questions

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 four hundred institutions with five 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 the proposed Preparatory 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.

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 consequences on the machine protection system have to 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 (Safety Code F). In the preparatory phase it must be shown that solutions to the 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 program 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, bringing low currents inside the tracker volume, complemented by development of radiation-hard voltage regulators are key technical issues, 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 full-scale prototype H- ion source with high performance, complemented by the study of the field stabilization in pulsed superconducting Radio Frequency cavities.

- Development of novel technology for detector powering limiting the current in the tracker volume, complemented by the study of radiation-hard voltage regulators

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, and that is why they are included in the SLHC-PP proposal. 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.

### 3.2 Attractiveness of ERA

The LHC upgrade will have a significant impact on the research in High Energy Physics at world-wide level. At ten-fold the nominal luminosity of the LHC, it will allow Europe to maintain the leadership in this field 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 are found in LHC;

The SLHC will be a unique infrastructure 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 countries, contributing to the SHLC Implementation Phase will also participate in the forthcoming scientific experiments. The SLHC will serve a large community of physicists (approximately 4000) from all over the globe in order to deepen the frontier research in fundamental physics, and this is a true example of the implementation of the European Research Area, which should include "*world-class research infrastructures, integrated, networked and accessible to research teams form across Europe and the world*", as stated in the recently published Green Paper on the ERA[2].

The SHLC 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

[2] The European Research Area : New Perspectives, COM(2007) 161, 4 April 2007.

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 a 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.

### 3.3 Catalytic effect of EC contribution

The upgraded LHC will allow significant progress in the understanding of particle physics and of the fundamental interactions, at a moderate extra cost relative to the overall initial LHC investment, given that the tunnel, the accelerator and the detectors would be reused to a large extent. In addition, such a major upgrade of the collision performance and of the injector complex has been demonstrated to be compatible with the established accelerator-design criteria and basic limitations of the hardware systems. The major upgrade is therefore an efficient way to optimize and enhance the performance of the existing infrastructure (LHC), and - importantly – to make a tremendous cost reduction compared to the construction of a new infrastructure of the same scale.

The Community contribution to the Preparatory phase of the LHC upgrade is vital for the following reasons:

(i) With all its resources allocated to the commissioning and the start of the LHC late in 2007, and additional resources previewed *only* for the technical programme of the SLHC in the period 2008-2011, CERN does not have the possibility to finance non-technical activities at present.

(ii) The SLHC project is not a CERN project only. It is a global project, which will involve most of the European countries, but also many countries from other parts of the world (e.g. USA, Japan, India, China, Russia, Canada, Israel). Many of these countries have expressed strong interest in contributing to the SLHC project, but a lot of coordination and organisational work needs to be done before the Implementation Phase can begin.

Therefore, the EC support is timely and necessary in order to significantly progress on the coordination tasks, support to the accelerator and experiment organisational activities and the establishment of implementation cost books and schedules, in parallel with the technical activities covered outside this CNI-PP project. The EC support will contribute to defining a consistent work-plan for the upgrade of the accelerator and the experiments, and will serve to firmly establish and test technical designs before they can be adopted for the final construction. While starting to run the LHC at nominal energy in 2008, it is essential to start working in parallel on the elements quoted above, in order to be ready on the time scale for the completion of the LHC upgrade in 2016, as proposed by CERN and supported by the CERN Council and the 20 CERN Member States.

Through the EC support for the Preparatory Phase, the interactions between CERN and its partners established during the construction of the LHC will be maintained and reinforced, and new partners will be attracted into the large-scale collaborations on the LHC upgrade. In addition, the aim is to establish from the starting point solid interactions between the accelerator designers (the machine) and the particle physicists (the experiments) communities.

The EC funding will help assemble the efforts of different European and non-European teams on a common and well-defined scientific goal, and will lead to fostering of intellectual and cultural exchanges. This should accelerate understanding and developing solutions for the challenging technical issues for the LHC upgrade, as it has been always the case for the previous large projects lead by CERN in the last 50 years.

The proposal is laying the foundation of the infrastructure of the LHC upgrade and it is in the interest of Europe to participate in the setting of the project in view of optimizing the multilateral efforts and the effectiveness of the large-scale SLHC collaborations, which will extend well beyond the CERN Member States.

## 4 Ethical Issues

The SLHC-PP project dos not involve any ethical issues that relate to:

- Informed consent
- Data protection issues
- Use of animals
- Human embryonic stem cells
- Dual use

**ETHICAL ISSUES TABLE**

| | YES | PAGE |
|---|---|---|
| **Informed Consent** | - | |
| • Does the proposal involve children? | - | |
| • Does the proposal involve patients or persons not able to give consent? | - | |
| • Does the proposal involve adult healthy volunteers? | - | |
| • Does the proposal involve Human Genetic Material? | - | |
| • Does the proposal involve Human biological samples? | - | |
| • Does the proposal involve Human data collection? | - | |
| **Research on Human embryo/foetus** | | |
| • Does the proposal involve Human Embryos? | - | |
| • Does the proposal involve Human Foetal Tissue / Cells? | - | |
| • Does the proposal involve Human Embryonic Stem Cells? | - | |
| **Privacy** | | |
| • Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction) | - | |
| • Does the proposal involve tracking the location or observation of people? | - | |
| **Research on Animals** | | |
| • Does the proposal involve research on animals? | - | |
| • Are those animals transgenic small laboratory animals? | - | |
| • Are those animals transgenic farm animals? | - | |
| • Are those animals cloning farm animals? | - | |
| • Are those animals non-human primates? | - | |
| **Research Involving Developing Countries** | | |
| • Use of local resources (genetic, animal, plant etc) | - | |
| • Benefit to local community (capacity building ie access to healthcare, education etc) | - | |
| **Dual Use** | | |
| • Research having potential military / terrorist application | - | |
| **I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL** | **YES** | |

# 5 Consideration of 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.