FP7 High Luminosity Large Hadron Collider Design Study

HiLumi LHC

Collaborative Project

Capacities – Research Infrastructures

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Proposal Abstract

The Large Hadron Collider (LHC) is the largest scientific instrument ever built. It has been exploring the new energy frontier since 2009, gathering a global user community of 7,000 scientists. It will remain the most powerful accelerator in the world for at least two decades, and its full exploitation is the highest priority in the European Strategy for Particle Physics, adopted by the CERN Council and integrated into the ESFRI Roadmap. To extend its discovery potential, the LHC will need a major upgrade around 2020 to increase its luminosity (rate of collisions) by a factor of 10 beyond its design value. As a highly complex and optimized machine, such an upgrade of the LHC must be carefully studied and requires about 10 years to implement. The novel machine configuration, called High Luminosity LHC (HL-LHC), will rely on a number of key innovative technologies, representing exceptional technological challenges, such as cutting-edge 13 tesla superconducting magnets, very compact and ultra-precise superconducting cavities for beam rotation, and 300-metre-long high-power superconducting links with zero energy dissipation.

This FP7 Design Study proposal (HiLumi LHC) is part of an overall project that will federate efforts and R&D of a large community towards the ambitious HL-LHC objectives. HiLumi LHC involves participants from outside the European Research Area (ERA), in particular leading US and Japanese laboratories, which will facilitate the implementation of the construction phase as a global project. The proposed governance model is tailored accordingly and may pave the way for the organization of other global research infrastructures.

HiLumi LHC will help to foster opportunities for the European industry to bid for contracts worth 300 M€ in innovative fields during the second half of this decade, and will establish the ERA as a focal point of a global research cooperation and a leader in frontier knowledge and technologies.

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1. Scientific and/or technical quality, relevant to the topics addressed by the call

1.1. Concept and objectives

1.1.1. Context

The Large Hadron Collider (LHC), run by CERN at the Franco-Swiss border near Geneva, is the largest instrument ever designed and built for scientific research. It has been successfully commissioned and since March 2010 has been producing proton-proton collisions with a 7 TeV centre-of-mass energy, a factor of 3.5 greater than the previous record (held by Tevatron at the Fermi National Laboratory, USA). The LHC will push the limits of human knowledge, enabling physicists to go beyond the Standard Model: the enigmatic Higgs boson, mysterious dark matter and the world of supersymmetry are just three of the long-awaited mysteries that the LHC will unveil. Thanks to the LHC, Europe is decisively regaining world leadership in High Energy Physics, a key sector of knowledge and technology. The LHC can act as catalyst for a global effort unrivalled by other branches of science: out of the 10,000 CERN users, more than 7,000 are scientists and engineers using the LHC, half of which are from countries outside the EU.

The LHC baseline programme has the goal of producing first results in the 2010-11 run aimed at an integrated luminosity[1] of at least 1 fb^{-1} by the end of 2011. Today progress towards this goal is advancing well, meeting all intermediate milestones. After attaining the **maximum energy of 14 TeV centre-of-mass energy** at the end of 2013, it is expected that the LHC's will reach the **design luminosity[2] of 10^{34} cm^{-2} s^{-1}** in 2015, see Fig. 1.1, left. This peak value will give a total luminosity integrated over a one year run of about 40 fb^{-1}.

After 2019 the statistical gain in running the accelerator without a considerable luminosity increase beyond its design value will become marginal. The running time necessary to half the statistical error in the measurements will be more than ten years at the end of 2019, see Fig. 1.1, right. **Therefore to maintain scientific progress and to explore its full capacity, the LHC will need to have a decisive increase of its luminosity. That is why, when the CERN Council adopted the European Strategy for Particle Physics[3] in 2006, its first priority was agreed to be "*to fully exploit the physics potential of the LHC. A subsequent major luminosity upgrade, motivated by physics results and operation experience, will be enabled by focused R&D*"**. The European Strategy for Particle Physics has been integrated into the ESFRI[4] Roadmap of 2006 and its update of 2008, and the priority to fully exploit the potential of the LHC has been reaffirmed at the most recent CERN Council session in September 2010.

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[1] **Integrated luminosity** is a quantity proportional to the number of recorded collisions, measured in inverse femtobarns, fb^{-1}

[2] **Luminosity** is the number of collision per square centimetre and per second, cm^{-2} s^{-1}

[3] **European Strategy for Particle Physics**, http://cern.ch/council/en/EuropeanStrategy/ESParticlePhysics.html, adopted by the CERN Council at a special session at ministerial level in Lisbon in 2006.

[4] **European Strategy Forum for Research Infrastructures**, ESFRI, http://ec.europa.eu/research/esfri

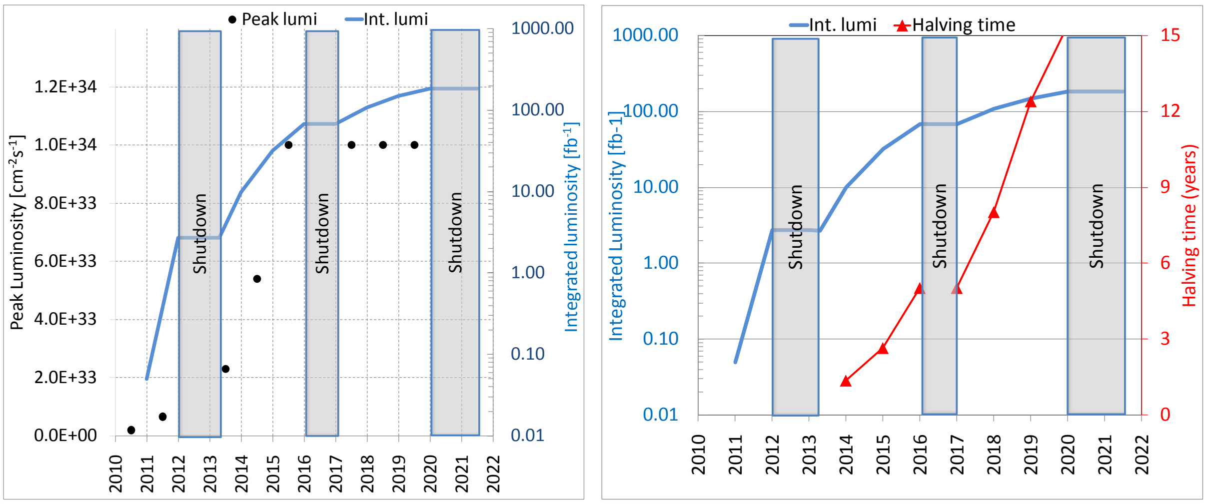

Figure 1.1: Left: peak luminosity and integrated luminosity vs. time. Right: integrated luminosity (log plot) and time to half the statistical error as a function of year of LHC running.

The status of R&D (in particular of superconducting magnets capable of going beyond the present Nb-Ti LHC technology) and of various studies carried out from 2001 to 2007 led to planning based on a two-phase luminosity upgrade. The first phase, called sLHC, was defined with the goal of increasing the peak luminosity, 10^{34} $cm^{-2}s^{-1}$, by at least a factor of two. The sLHC Preparatory Phase[1] was focussed i) on improving the LHC injector chain, to increase the beam intensity and its quality; ii) on developing an improved version of the triplet quadrupole magnets (so called low-β triplet) to allow fast replacement of the present triplet with a larger aperture one built with existing Nb-Ti LHC technology; iii) on launching the upgrade of the two general purpose LHC detectors: ATLAS and CMS. **The FP7 sLHC-PP project is associated with this initial upgrade phase, sometimes called upgrade Phase I, allowing a collaborative approach at a European level.** sLHC-PP is now approaching its end, enabling the LHC to reach design luminosity and beyond.

After 2017, a very ambitious upgrade of the LHC luminosity (sometimes previously called upgrade Phase II) was deemed necessary to fully exploit the physics potential of the LHC up to about 2030. The change in schedule entailed by delays of the LHC commissioning and especially by the incident of September 2008[2], just after the LHC start-up, has significantly modified the scenario for the replacement of the triplet magnets. To minimize the machine stops and maximize the productive use of the LHC for physics, the replacement of the triplet magnets and of all hardware changes needed to enable the ambitious luminosity upgrade will now take place in one stop, at around 2020. **This new phase of the LHC life has been recently named as High Luminosity LHC (HL-LHC), and has the scope of enabling to attain the astonishing threshold of 3000 fb^{-1} in 10-12 years.** All the hadron colliders in the world have so far produced a total integrated luminosity of about 10 fb^{-1}, while the LHC will deliver about 200-300 fb^{-1} at best in its first 10-12 years of life.

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[1] FP7 sLHC-PP project: public website http://cern.ch/SLHCPP/, project website http://cern.ch/info-slhc-pp/

[2] CERN Press Release 16 October 2008: "CERN releases analysis of LHC incident" http://public.web.cern.ch/press/pressreleases/Releases2008/PR14.08E.html

The High Luminosity upgrade of the LHC is a major, extremely challenging upgrade. For its successful realization a number of **key novel technologies** have to be developed, validated and integrated, which is the main scope of this FP7 Design Study proposal, named **HiLumi LHC**.

This FP7 Design Study will be instrumental in initiating a **new global collaboration** for the LHC luminosity upgrade that matches the spirit of the worldwide user community of the LHC experiments.

1.1.2. Physics reasons for a luminosity upgrade of the LHC

As mentioned in the European Strategy of Particle Physics, the LHC upgrade depends critically on the physics motivations. The first year of LHC physics is now coming to an end with a clear message: the experiments perform beyond the most optimistic expectations and are ready to fully exploit the data that the LHC will provide. This gives a great indication that the projections for the physics-performance capabilities of the experiments, developed over years of computer-simulation work, provide a correct assessment of their discovery potential, and strengthen the reliability of the extrapolations to the forthcoming, larger, data samples foreseen by HL-LHC.

In particular, operation at higher luminosity as foreseen by **HL-LHC has three main purposes**:

1) **Perform more accurate measurements** on the new particles discovered in the LHC.
2) **Observe rare processes**, whether predicted by the Standard Model (SM) or by the new physics scenarios unveiled by the LHC, which have rates below the sensitivity of the current phase.
3) Extend the **exploration of the energy frontier, therefore extending the discovery reach**, by probing the very rare events where most of the proton momentum is concentrated in a single quark or gluon.

The history of the Tevatron experiments at Fermilab, USA, provides good examples for all three points. For instance, the oscillations of B_s mesons, arguably the most significant discovery of Tevatron Run2[1] so far, were only measured more than 20 years after the start of the Tevatron. Lastly, it is widely recognized that a further increase to the Tevatron integrated luminosity could lead to the detection of the Higgs boson, crowning 25 years of operations with a last-minute revolutionary discovery.

How the three main purposes can be met by HL-LHC

The primary goal of the LHC is to pin down the mechanism responsible for the breaking of the symmetry between electromagnetic and weak interactions. Such “electroweak symmetry breaking” (EWSB) is the phenomenon at the source of **the masses of elementary particles, and the simplest candidate for it is the so-called Higgs mechanism: a single elementary particle, called the Higgs boson**, plays the double role of triggering the EWSB and, through its interaction with the other elementary particles, giving them mass. The precise value of the Higgs boson’s mass is a free parameter of the model, but it is fully within the reach of the LHC experiments. Assuming the **Standard Model (SM)** realization of the Higgs mechanism,

[1] Run2 being the high luminosity upgrade of Tevatron

5-10 fb^{-1} of integrated luminosity is sufficient for the discovery of the Higgs boson through the allowed mass range, as shown in Fig. 1.2, left.

However, a complete characterization of its properties requires more statistics, since this calls for the detection of several decay channels. In several theories beyond the SM, furthermore, the Higgs boson is not alone, but is accompanied by a richer particle structure. For example, **the so-called supersymmetric theories predict the existence of 3 additional Higgs particles. Their detection may require larger data samples, such as the one provided by HL-LHC**. The discovery reach for the CP-odd[1] state increases by almost 100 GeV when going from 300 to 3000 fb^{-1}, see Fig. 1.2, right for details.

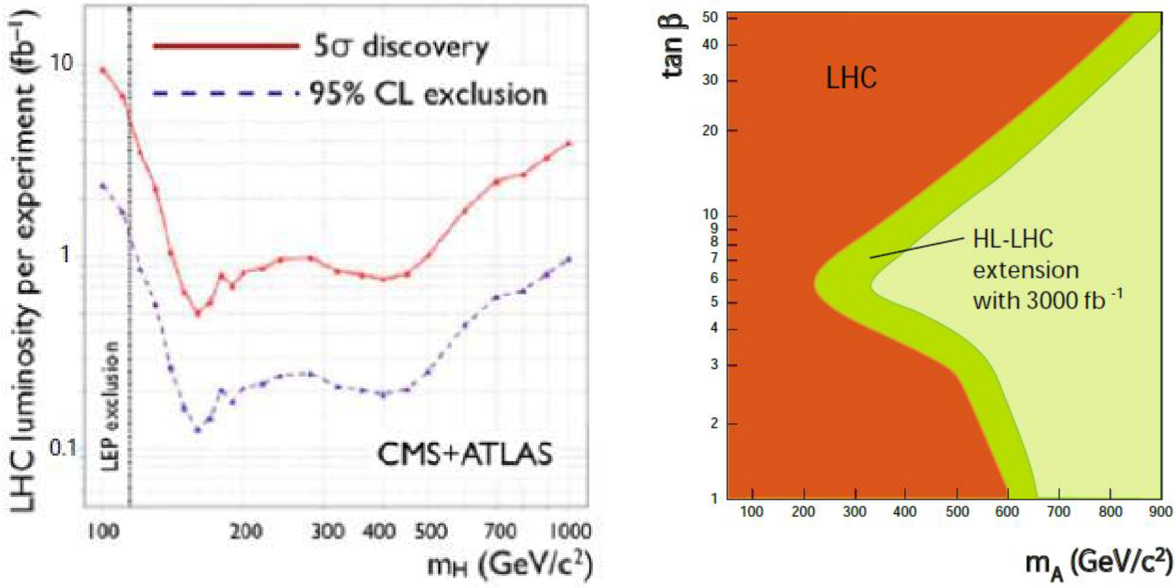

Figure 1.2: Left: integrated luminosity at 14 TeV centre-of-mass energy needed for the discovery of the Standard Model Higgs boson as a function of its mass. Right: domains where one or more of the four supersymmetric Higgs bosons are visible at the LHC (with 300 fb^{-1}) and extension of the discovery zone made possible by HL-LHC (tanβ is the ratio of the two Higgs expectation values, and m_A is the mass of the CP-odd Higgs) In the right-most triangular-shaped domain, only the lightest Higgs is seen: this zone is pushed by the HL-LHC to larger values of the m_A parameter by almost 100 GeV.

Another example is given by the possible observation of new forces, in the form of a heavier partner of the Z boson, the Z′. The discovery of a Z′ requires only a handful of events, and 300 fb^{-1} is sufficient to extend the reach up to masses of about 5.5 TeV, as shown in Fig. 1.3. Precise measurements of the Z′ properties demand however thousands of events, which is only possible if the mass is smaller than about 2.5 TeV. Beyond that, **more statistics – provided by HL-LHC – are required.** Furthermore, a possible variant of the existence of a new Z′ would make the high luminosity LHC a most urgent upgrade: the co-existence of a Z′ with a new set of particles below the Z′ decay threshold. This could happen in scenarios predicted by supersymmetric theories, where the new partners of leptons and of weak gauge bosons are expected to have a mass in the range of few hundred GeV. **The HL-LHC would become something of a Z′ factory, allowing precise measurements of this new particle, with many of the advantages of a lepton collider**.

[1] CP = Charge Parity

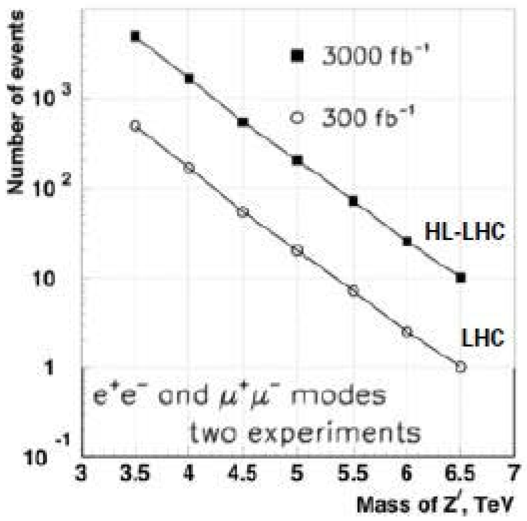

Figure 1.3: Discovery reach for **Z′** gauge bosons by LHC and by HL-LHC.

From the Z′ example, we also learn that additional statistics can push the energy reach of the LHC. Fig. 1.3 shows in fact that a factor of 10 increase in integrated luminosity will increase by about 1 TeV the discovery potential for Z′ bosons. Similar results hold for many other searches of very massive objects, such as the squarks and gluinos of supersymmetric theories, where the discovery reach is extended by about 500 GeV (since they are always produced in pairs). A factor of 10 increase in integrated luminosity will, for the same reasons, **extend by 50% the territory for searching for a possible substructure of quarks**, by testing at much shorter distances the point-like behaviour of their scattering distributions, in analogy to Rutherford's experiment.

Whatever new physics will be discovered during the current phase of the LHC, answering some of the presently outstanding questions of particle physics such as the origin of EWSB, new questions will unavoidably arise. The existence of new forces and symmetries associated to Z′ bosons, or of supersymmetry, will call for an explanation of why and how such symmetries are broken. **The observation of stable and weakly interacting particles, suggestive of the particles that form the dark matter measured in the Universe, will impose further tests for which HL-LHC is a key tool.** The Tevatron examples listed earlier highlight the potential longevity characteristic of a hadron collider, with new results constantly emerging even after more than 20 years of operation. **HL-LHC will then constitute, with no rival in sight, the great leap forward of HEP in the decade 2020-2030.**

1.1.3. LHC Baseline programme and objectives of the HiLumi LHC proposal for the collider upgrades

The main objective of HiLumi LHC Design Study is to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

1) A peak luminosity of $\mathbf{5\times10^{34}\ cm^{-2}s^{-1}}$ **with levelling**, allowing:

2) An integrated luminosity of $\mathbf{250\ fb^{-1}}$ per year, enabling the goal of $\mathbf{3000\ fb^{-1}}$ twelve years after the upgrade. This luminosity is more than ten times the luminosity reach of the first 10 years of the LHC lifetime.

The LHC is designed for a 14 TeV collision energy, i.e. 7 TeV per proton beam, and a peak luminosity for each of the two general purpose experiments (ATLAS and CMS) of 10^{34} $cm^{-2}s^{-1}$.

Luminosity is, after collision energy, the most important parameter of a collider, because it is proportional to the number of useful events. For physics purposes, luminosity integrated over time is the relevant parameter: however integrated luminosity does not depend on collider performance only, but also on many external parameters (injector performance, availability and quality of technical services, stops or breaks required by maintenances, etc.). The expectations in term of integrated luminosity of Fig. 1.1 are based on LHC capability and physics laws (peak luminosity, burning rate of protons, duration of a run, etc.) and on the running experience at CERN, which includes the external factors previously mentioned. As a rule of thumb LHC running at peak design luminosity will produce about 40 fb^{-1} of integrated luminosity per year for each of the two experiments.

As mentioned above, LHC is at present providing collisions at 7 TeV with a beam energy of 3.5 TeV. A technical stop of about 16 months, planned for 2012-13 (see Figs. 1.1 and 1.4), will be required to consolidate the splice at the magnet interconnect (the cause of the incident of September 2008). This intervention will allow **operating the magnets at the design value of 8.3 tesla (T)**, therefore enabling attainment of the **design collision energy of 14 TeV**. However, in the 2012-2013 shutdown many interventions will be carried out in addition to the splice consolidation, the main one being the consolidation of the collimation system by installing collimators in a cold region (DS, Dispersion Suppressor region) – a feature never foreseen in the original LHC design. This collimation consolidation is necessary to allow the **design beam current**, **0.58 A,** given the observed minimum beam lifetimes during the first year of operation. Without this consolidation, the beam currents inside the LHC would be limited to 20-40% of their design values, limiting the peak luminosity of the LHC to $L = 0.1\text{-}0.2\times10^{34}$ $cm^{-2}s^{-1}$ (0.1 being more realistic because of inevitable machine imperfections). Once the intensity limit is removed, and design luminosity will be hopefully attained in 2015, then in the years 2017-2020 LHC can run steadily “producing” luminosity, see Fig. 1.1, right. LHC will then attempt to go beyond design luminosity and most probably the limit will be found between the design value and a value called “ultimate” (at most twice the design luminosity). This ultimate luminosity performance requires an increase in beam current from 0.58 A to 0.86 A, which can only be obtained by increasing the single bunch population from 1.15 to 1.7×10^{11} protons.

There are various expected limitations, either in beam characteristics (injector chain, beam impedance and beam-beam interactions in the LHC) or in technical systems (see section 1.1.4), such as cryogenic power limitation in the triplets and hardware degradation by radiation. The mitigation of potential performance limitations arising from the LHC injector complex will be addressed in a separate upgrade project at CERN, the LHC Injector Upgrade Project (LIU). Any potential limitations coming from the LHC injector complex and LHC collimation system put aside, it is expected that the LHC will reach a performance limitation from the beam-beam interactions inside the experimental regions with the designed operation mode at the ultimate bunch intensity of 1.7×10^{11} protons (the so called ‘beam-beam’ limit). Any further performance increase of the LHC will require significant hardware and beam parameter modifications with respect to the designed LHC configurations, which are at the heart of this design study proposal. In Fig. 1.4 the LHC baseline programme in terms of energy and luminosity is schematically illustrated.

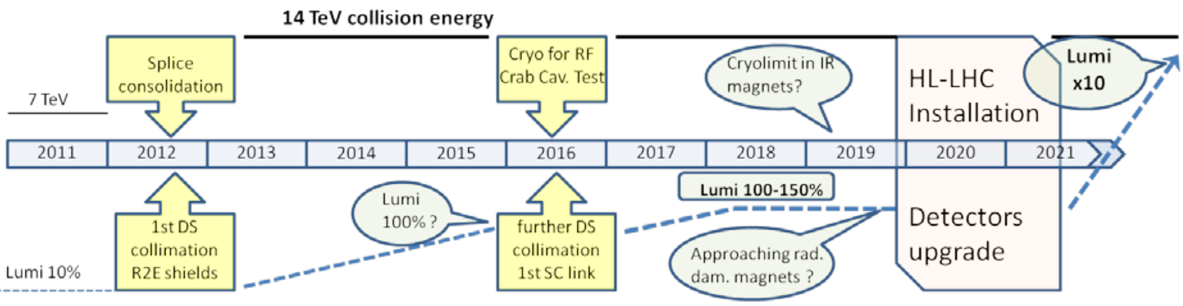

Figure 1.4 Baseline programme of LHC in terms of energy of the collisions (continuous upper line) and of luminosity (dashed lower line). The first long shutdown 2012-13 is to allow design parameters of beam energy and luminosity. The second one, 2016, is for secure luminosity and reliability (Linac4[1] injector will also be connected).

Based on the scenario of Fig 1.1, **the LHC is expected to reach some 200 fb^{-1} of integrated luminosity by 2020. With some optimism, this could be around 300 fb^{-1} at best.** In any case, at this point it will be mandatory to significantly decrease the statistical errors to enhance the discovery potential (see section 1.1.2). A significant increase of the average luminosity by a factor of five shall allow reaching an integrated luminosity of around 200-250 fb^{-1} per year, approaching total integrated luminosity of 3000 fb^{-1} in a reasonable time.

One new feature is that the HL-LHC operation will have to rely on luminosity levelling. As shown in Fig.1.5, left, the luminosity profile quickly decreases from the initial peak value, because of “proton burning” (protons lost in collision): by a real-time control of collider parameters, it becomes possible to suppress at least for hours the luminosity decay i.e. “levelling” its value, offering ideally constant conditions for data taking. The simplest levelling concept only slightly decreases the average luminosity, see Fig 1.5, right. A preferred novel and complex concept, by circumventing the beam-beam limit, may offer even higher average luminosity. Levelling helps avoid an excessive pile-up (multiplicity of events for each proton-proton collision) in the experimental detectors that may partially blind them. Indeed pile-up and degraded performance by intense radiation are serious limitations in the high luminosity regime: coping with peak luminosity higher than 5×10^{34} cm^{-2} s^{-1} may become impossible and levelling has become a key ingredient of the HL-LHC baseline.

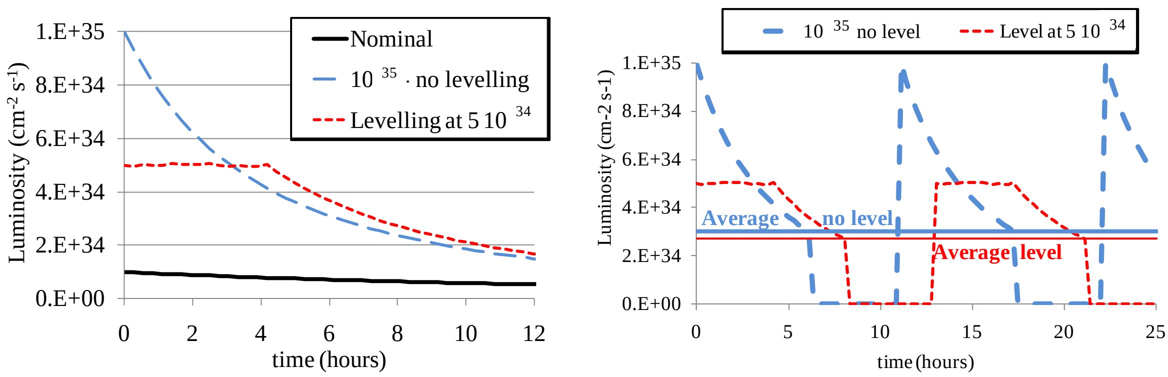

Figure 1.5: Left: luminosity profile for a single long run starting at design peak luminosity (solid line), with upgrade (dashed line) with levelling (dotted line). Right: luminosity profile with optimized run time, without and with levelling (dashed and dotted lines), and average luminosity in both cases.

[1] Linac4 is the new short linear accelerator (replacing the present Linac2) at the beginning of the LHC injector chain http://cern.ch/linac4/

1.1.4. Main hardware challenges and technical reasons for the upgrade

1.1.4.1. Luminosity limitation

The strength of the beam-beam interaction can be parameterized by the beam-beam parameter $\xi_{\text{beam-beam}}$:

$$\zeta_{beam-beam} = \frac{r_p}{4\pi} \cdot \frac{N_b}{\varepsilon_n}$$

Equation 1.1: The beam-beam parameter

where N_b is the number of protons per bunch, r_p the classical proton radius $r_p = e^2/(4\pi\varepsilon_0 m_p c^2)$ and ε_n the normalized transverse beam emittance. For hadron colliders it is assumed that the beam-beam interaction cannot exceed a so-called beam-beam limit, which is defined either by a sharp decrease of the beam lifetime or a sharp increase of the background in the experiments. For the LHC it is expected that the beam-beam limit is attained when the LHC will run at its design configuration with ultimate bunch intensities. The luminosity can be expressed in this case by:

$$L \propto \eta_{form}\, \Delta\zeta_{bb}\ \frac{1}{\beta^*} \left(N_b \times n_b\right)$$

Equation 1.2: Luminosity at the beam-beam limit

where: η_{form} is the beam geometrical form factor, $\Delta\xi_{bb}$ is the head-on beam-beam tune shift, β^* is the beam focal length at the collision point and n_b is the number of bunches in each beam. Note that ($N_b \times n_b$) is the beam current I_b and that the beam-beam tune shift parameter corresponding to the beam-beam limit depends on N_b and n_b. An increase in the LHC peak luminosity requires an improvement of any of the above terms. Preliminary studies have shown the potential of improving the first two terms, by the use of crab cavities[1] that tilt the LHC bunches longitudinally at the interaction points (IPs) affecting both the geometrical form factor and the beam-beam tune shift parameter, and by compensation schemes for the beam-beam interactions in the experimental insertions (compensation of long-range beam-beam interactions in the common vacuum chambers of the insertion, by the installation of wires with DC or pulsed currents, and the use of electron lenses to compensate the tune shift arising from head-on beam-beam collisions). A reduction of the β^* values at the IP is limited by the triplet magnet aperture and by the correct ability of the corresponding chromatic aberrations.

Improving the beam current beyond design intensities will be difficult and will already require a few modifications to the LHC hardware, for example in the RF system. Going beyond the ultimate current of 0.86 A will be intensively investigated, but is not something for which solutions and scenarios exist at this stage. Increasing the beam current beyond ultimate intensities will require not only a major upgrade of the main RF system in the LHC, but may simply not be possible for various reasons such as limitations in the collimation efficiency, electron cloud effects, beam instability or intensity limitations coming from the LHC injector complex, and other technical limitations such as radiation effects, heat deposition and heat removal at 1.9 K.

[1] Crab cavities are special radio frequency (RF) resonators operating in transverse gradient mode.

1.1.4.2. Removal of luminosity limitations

A classical path to luminosity upgrade is to reduce β^* by means of stronger and larger aperture focusing quadrupole magnets, placed directly next to the collision points (the so-called low-β triplet quadrupoles). A smaller β^* value implies different optics: the beta-functions inside the triplet quadrupoles increase inversely to β^*, implying larger beam sizes and requiring larger aperture triplet magnets, the matching section must change parameters and may need to be modified too, and the stronger chromatic aberrations coming from the larger beta-functions inside the triplet magnets need to be corrected, and might require upgrades of the LHC correction circuits. Schemes are being studied to compensate or minimize these effects. Following an upgrade path based on a reduction of β^* requires quadrupole magnets with higher performance in terms of peak magnetic field B_p. The increased B_p can then be transformed into higher quadrupole gradient G and/or larger quadrupole bore diameter Ø since $B_p \sim G \cdot Ø$. Increasing the attainable magnetic field is challenging but is always highly rewarding.

The present triplet is manufactured with Nb-Ti superconductor, cooled at 1.9 K like the LHC main dipole magnets; its B_{peak} is about 8 T (similar to the LHC dipoles, 8.5 T, while LHC arc quadrupole are around 7 T). **The goal for the HL-LHC is to reach B_{peak} of 13 T, with a jump of more than 50% beyond LHC. This requires a completely new hardware, i.e. accelerator magnets based on advanced Nb_3Sn superconductor, a technology never applied to accelerators so far.** Nb_3Sn technology is just emerging from basic R&D phase and, thanks mainly to a decennial programme led by DOE in the US, is becoming a reality. These new magnets will be designed to have a factor of three, at least, better shielding against particle debris from collisions, thus limiting the heat deposition at low temperature. Furthermore, other bottlenecks will be removed thanks to a new design of the proximity cryogenics and new cryoplants (see section 1.1.4.3). **All together the gain in radiation tolerance will be a factor of ten.** Both Point 1 (P1) and Point 5 (P5) of the LHC will be equipped with a new triplet, see Fig. 1.6.

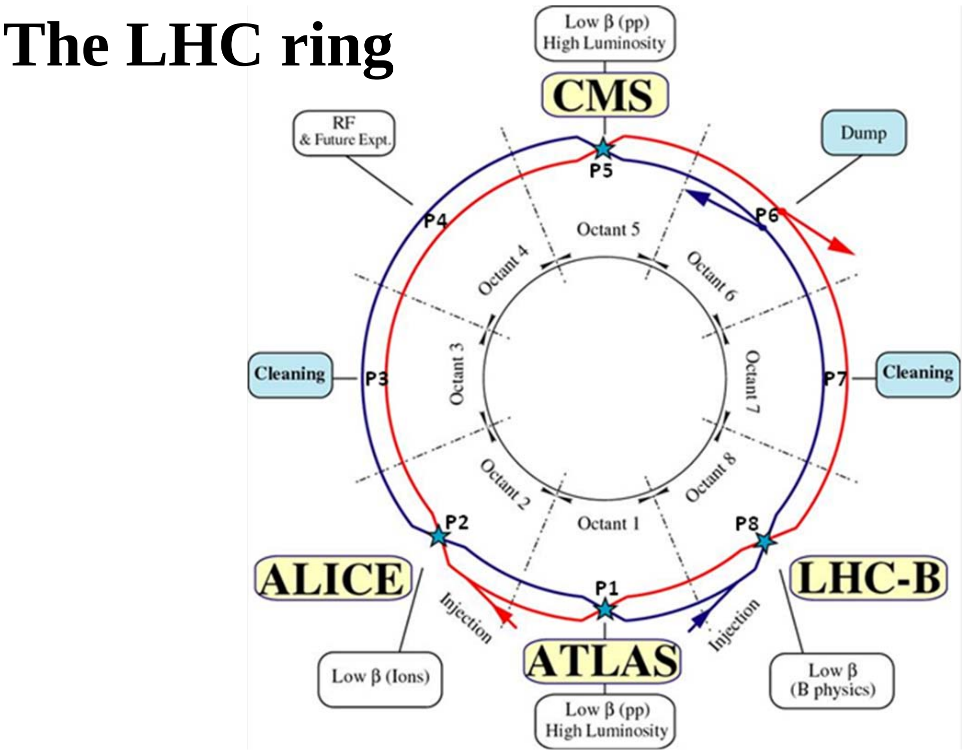

Figure 1.6: Schematic of the LHC, indicating the points of beam collision or beam services (P1 to P8).

Equation 1.2 hides the fact that decreasing β^* inevitably reduces the beam geometric factor and therefore also implies a reduction in the peak luminosity. The optimal choice for β^* therefore depends on the balance between the luminosity gain due to smaller β^* and the luminosity loss via the beam geometric form factor. Different schemes have been proposed to counteract the reduction of the beam geometric form factor for smaller β^* values. A very attractive solution is the use of special RF cavities, called Crab Cavities, which by mean of a suitable transverse kick to the beam rotate the bunches in a way that allows a better overlap with bunches of the oncoming beam. In this way equation 1.2 holds and luminosity really increases with $1/\beta^*$. **Crab cavities have been tested recently in an electron ring but have never been investigated, not to mention tried, in a hadron collider where their use is much more challenging. The effect of crab cavities on the beam can be varied very quickly and precisely: so they constitute the ideal tool for luminosity levelling, a key feature in the project** (see section 1.1.3). Both points P1 and P5 will be equipped with crab cavities.

HL-LHC will push the beam current to its limit aiming at a peak luminosity of more than five times the design value. Protecting the whole ring and especially the triplet magnets (also against the malfunction of the crab cavities) will be another challenge that must be addressed separately. New techniques must be employed for collimators, in order to be robust without generating too large an impedance, and the positioning control of the collimator jaws needs to be better than 10 µm (on movable elements in ultra-high vacuum).

1.1.4.3. Removal of technical bottlenecks

Not surprisingly, the radiation level may become a limiting factor in itself. Radiation damage to electronics implies removing sensible equipment such as the Magnet Power Converter (MPC) from the tunnel. Problems of integration and shielding make the preferred solution a removal of the MPC to the surface. **This will requires a completely new scheme of the cold powering with a superconducting link carrying some 150 kA for 300 m with a vertical jump of 100 m, which is a great challenge for SC cables and cryogenics.**

Radiation wear or damage will already be a limiting factor in the present LHC. Indeed at 300-400 fb^{-1} of the total integrated luminosity many elements of the present low-β triplet will be degraded (for example the epoxy impregnated corrector coils and the end parts of the main coils) and a substitution of the triplet magnets (an operation that will require at least a one-year stop) will be required at this stage anyway. The best option for the replacement of the triplet installation is therefore to plan for the triplet upgrade installation at the time when the existing triplet elements require a replacement due to radiation damage anyway, thus minimizing the overall operational stop time of the LHC, a consideration that has been critical in the decision of merging the previous phase I and phase II of the upgrade into the one being presented in this HiLumi LHC proposal.

Radiation sensitivity of electronics will also hit other parts of the machine. Indeed the study and R&D on the superconducting link carried out for the upgrade may also be employed for the removal of power supplies from zones with high radiation levels (e.g. the experimental insertion regions). This action might already be essential to achieve higher than design beam currents and could be carried out in a shutdown before the one of 2020 for the upgrade.

Cryogenics power is limited for various reasons in Point 5 Left (left of CMS experiment, see Fig. 1.6). Preparing for the upgrade, it will be necessary to equip Point 4 with a new refrigeration plant, to serve the LHC SC RF cavities independently of the arc between Point 4 and Point 5 and of the triplet at Point 5 Left. This additional refrigeration plant not only removes cryogenic load from the triplet at Point 5 left, it also allows to test the first set of

Crab Cavities in Point 4 in around 2016, for a full validation of their equipment and beam manipulation in the machine.

As mentioned in section 1.1.4.2, a new cryoplant will be needed in Point 1 and Point 5, for the new inner triplet magnets and for crab cavities. These new plants will also allow to cool-down and warm-up the IR[1] independently of the main body of the LHC machine, with a great gain in flexibility and operational ease, something that will be certainly needed when all parameters are pushed.

1.1.5. Link to LIU and Detector Upgrades

This study needs to be strongly coordinated with the study carried out under the project: LHC Injector Upgrade (LIU). The relations with Injectors are as follows:

1) Coordination of any stop of the injector for upgrade to minimize the total down time;
2) Determination of the actual optimal beam to be injected into the LHC with understanding of the bottlenecks. Today the bottleneck is believed to be in the SPS[2] capability of providing bunch populations beyond design values with good emittance.
3) Optimization of the Injection sequence and parameters to minimize to LHC down time, affecting as little as possible the other physics experiments relying on the LHC injector chain.

Strong ties must also be kept with the detector upgrade programme. A luminosity increase must comply with many limits or boundary conditions on the detector side: pile up, radiation damage in the detector, acceptable background, etc. In addition, hardware boundaries required either by detectors (beam pipe) or collider (interface at the triplet) may need to be changed. Last but not least, it is necessary to carefully tune the intervention of the detector and the machine, which is not always so straightforward.

1.2. Progress beyond the state-of-the-art

All HiLumi LHC WPs demands to go beyond the established state-of-the-art hardware solutions, and a striking advance is demanded in the domain of superconductivity technologies, namely for high field accelerator magnets, compact crab cavities and long vertical GW range DC links. In addition to these new hardware developments, the HiLumi LHC goals require novel optics design concepts, such as novel correction schemes for the correction of chromatic aberrations that become a limiting factor for very small β^* values, and operation modes, such as the operation with flat beams and dynamic optic adjustments during physics operation, that go beyond the established solutions used in previous superconducting storage rings.

> While the LHC has been the summit of 30 years of hadron colliders, its high luminosity upgrade will open the gate for new technologies and new concepts that will likely mark the next generation of colliders, either for hadrons or for leptons.

[1] **Insertion Region** (IR): the zone of the accelerator around the beam collision and beam service points.

[2] **Super Proton Synchrotron** (SPS). Rated for 450 GeV it is the largest accelerator of the LHC Injector chain and is just before the LHC http://cern.ch/public/en/research/SPS-en.html.

1.2.1. Superconducting magnets

The present LHC constitutes the summit of 30 years of development in the domain of superconducting technologies: Nb-Ti based magnets are pushed to their limits: very compact two-in-one magnets provide 8.3 T operating field (magnets are designed, and many have been tested up to 9 T) by using superfluid helium cooling. The plot in Fig. 1.7 illustrates the progress over the years from the resistive magnet era (SPS at CERN and Main Ring at Fermilab) into the superconductivity era: from Tevatron[1] (Fermilab) to LHC, passing through HERA[2] (at DESY, in Hamburg) and RHIC[3] (at Brookhaven National Laboratory, USA). The upgrade heavily relies on the success of the advanced Nb_3Sn technology, since Nb-Ti superconductor cannot go beyond 9 T. Nb_3Sn has been under development for more than ten years and has now reached a maturity that allows designs of real equipment based on it. Nb_3Sn has been used in solenoids for NMR spectroscopy for more than15 years. However its brittleness and its magnetization properties (much worse than Nb-Ti) make it very difficult to use in accelerator magnets. ITER[4] is now using Nb_3Sn on a very large scale, 400 tonnes (similar to LHC scales: 1200 tonnes of high grade Nb-Ti) making a step closer to enabling this technology. However for accelerators we need a current density between 2.5 and 3 times that used in ITER’s toroidal coil. A 12-year-long programme led by DOE in the US and two EU programmes (FP6 CARE-NED[5] and the current FP7-EuCARD[6]) have shown the feasibility of Nb_3Sn accelerator magnets with the proper qualities. In particular the US LARP[7] (LHC Accelerator Research Program) has successfully tested a quadrupole that is already a step beyond the present LHC triplet quadrupole. The results of this research are already entering industrial NMR. Indeed the superior quality of superconductors for accelerators is an asset for all types of applications (very much like the Nb-Ti development for the Tevatron in the US enabled the NMR technology and later whole body MRI). For the LHC upgrades we will need some 20 tonnes of high grade Nb_3Sn (with J_c = 2500-3000 A/mm^2 at 12 T, 4.2 K), about sixteen 5- to 8-m-long magnets for the IRs and about ten 5-m-long dipoles for the Dispersion suppressors. **The development of the accelerator magnets pursued for HiLumi LHC paves the way for a possible future large project: the High Energy LHC (HE-LHC). Increasing the magnetic field by 50%, from 8 to 13 T, is the best way to prepare the jump to 16-20 T.** Adapting these magnets to HL-LHC needs will constitute a unique chance to experiment with this new technology in a real situation and will give the necessary insight for large scale application required for the HE-LHC.

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[1] **Tevatron** at Fermilab, USA http://www-bdnew.fnal.gov/tevatron/
[2] **HERA** at DESY, Hamburg, Germany http://adweb.desy.de/mpy/hera/
[3] **RHIC** – the Relativistic heavy Ion Collider – at Brookhaven, USA http://www.bnl.gov/rhic/
[4] **ITER**, France http://www.iter.org/
[5] **The FP6 CARE project** ran from January 2004 to December 2008 and was coordinated by CEA http://esgard.lal.in2p3.fr/Project/Activities/Current/
[6] **The FP7 EuCARD project** began April 2009 and will run until March 2013, it is coordinated by CERN http://cern.ch/EuCARD/
[7] **The US LARP program** http://www.uslarp.org/

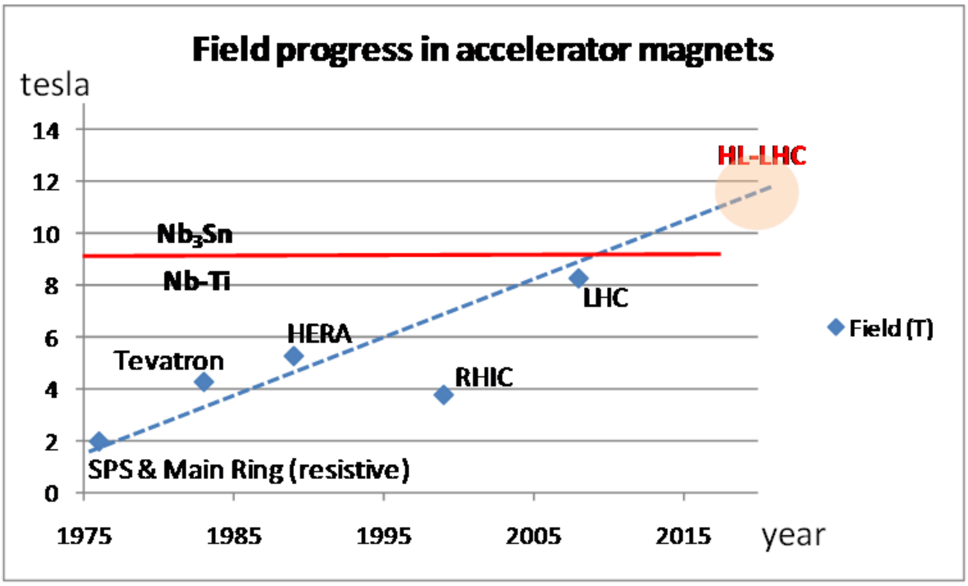

Figure 1.7: Progress of accelerator magnets: from 2 to 9 tesla is the realm of Nb-Ti, however to go beyond 9 tesla Nb_3Sn is needed.

1.2.2. RF cavities

Superconducting (SC) RF cavities of large sizes (400 MHz) are already employed in the LHC and constitute the summit of the Nb coated Cu technology developed for LEP. **The Crab Cavities for LHC will go beyond the state-of-the art for at least two reasons:** the first is that the transverse cavity dimensions are limited by the proximity of the second beam closer than λ/4 from the first (194 mm), which practically excludes the well-known geometry of an elliptical cavity and **calls for an unconventional, compact design;** the second is the demand for very exact control of the phase of the RF (to better than 0.001°), since the slightest phase error would not only offset the bunch head and tail as required for head-on collisions with a non-zero crossing angle, but also the centre of the bunches, which for the very small transverse size of the bunches would lead to an offset of the entire bunch and thus to a significant luminosity loss. For the accelerating cavities, a special region around Point 4 was created, see Fig. 1.6, in which the beam separation is increased by the use of doglegs to 400 mm in order to allow the installation of the elliptical 400 MHz accelerating cavities. Compact Crab Cavities could be installed on either side of each high luminosity Points 1 and 5, without additional doglegs, but their design would definitely be beyond the present state-of-the-art. Fig. 1.8 shows by how much smaller than a conventional TM_{110} cavity the Compact Crab Cavity has to be in order to fit between the LHC beam separation. **The challenging requirement to the precise phase control is equally beyond the state-of-the-art,** but similar requirements are found in modern XFEL light sources and in next generation linear colliders. **The fact that in the LHC this very demanding beam gymnastics is tried on a very intense hadron beam makes it even more challenging.** Of large concern are the failure modes of the Crab Cavities, which must be studied in detail in order to allow safe operation of the machine.

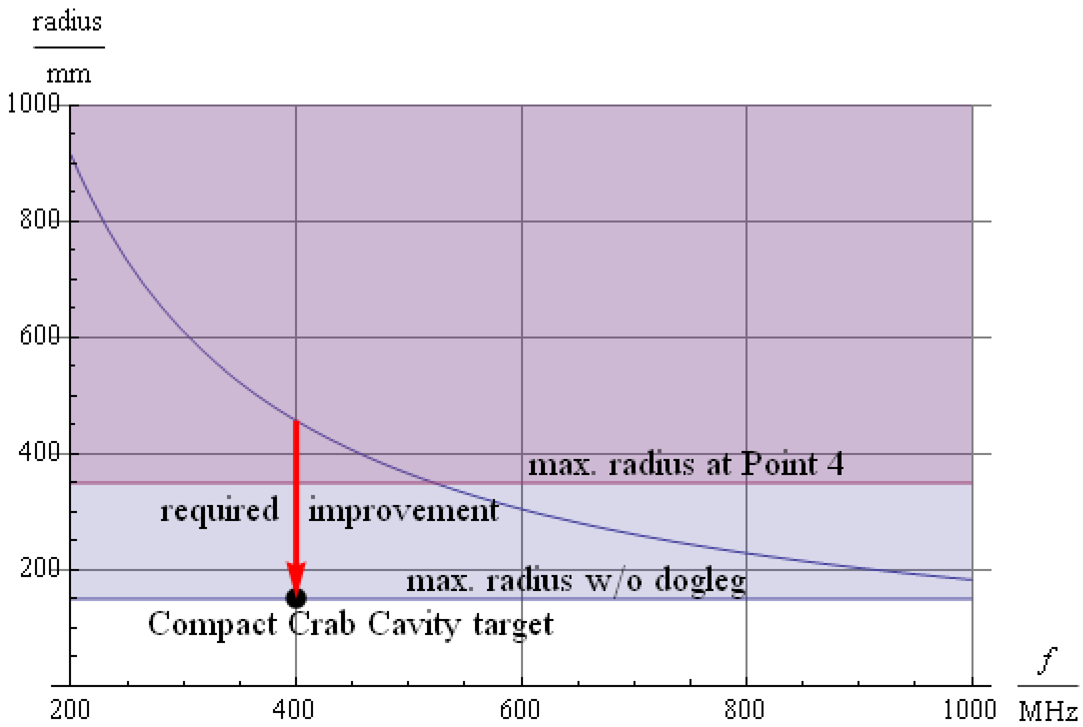

Figure 1.8: Size of a typical TM_{110} cavity vs its resonance frequency, indicating the requirements of a Compact Crab Cavity to fit between the LHC beam pipes without a dogleg.

1.2.3. Superconducting link

The SC link is testing a new technique: displacing magnet power converters hundreds of metres away will require a completely new design. Not only will we need to design superconducting lines capable of 200 kA-5 kV DC (1 GW, with no dissipation) but the cryogenics will need to cope with a height difference of 100 m. This poses new challenges that will require advances in superconductors: we plan to employ novel MgB_2 wires or High Temperature Superconductors (HTS) like Bi-2223 or YBCO coated tapes. **Such power and especially such a large current have never been tried and will constitute a novelty in the technological panorama.** Also cryostats and cryogenics will need to go beyond present limits: use of return cryogen to cool the thermal shield of the cryoline will be extensively used, in conjunction with long, flexible cryostats that will favour an easy installation. Indeed such a type of line has not yet been conceived.

1.2.4. Beam Collimation

Safely handling a beam of 0.86 A or more, with beta function at collision beyond the design value will also constitute a progression into new territory. For beam collimation, 75 collimators need to be precisely aligned in a dynamic mode with a precision of ~ 10 µm, in order to assure the protection of the triplet against a beam that will have an energy of half GJ, something that is more than fifty times the present limit. The protection of the triplet must be accomplished during the large change of the collision beam parameter (β^* passing from 10 m to 10-25 cm), which will be one of the most critical phases of HL-LHC operation; just the beam halo itself could be well beyond the damage limit.

1.3. S/T methodology and associated work plan

1.3.1. Overall strategy of the work plan

The Project is subdivided into closely interlinking Work Packages (WPs), see fig. 1.9. The definition of clear goals for each WP is the task of the project management, which has to assure the necessary coherence of parameters and goals. Project Management and Technical Coordination (WP1) has to provide guidelines, tools and a strict follow up of the project to assure that the quality of the components and the risks associated are consistent and balanced over the project. Furthermore, the Quality Assurance (QA) plan and integration studies must guarantee that the components are suitable for the LHC, i.e. equal or better than present LHC quality standards. It is well known that upgrades in peak performance may result in a degraded integrated performance because of technical stops or less flexible optics and operation. WP1 will strongly monitor this point.

Apart from WP2, which being accelerator physics is at the heart of the design study and will be closely related to all WPs, the WPs are organized around the main equipments upon which the performance of the upgrades relies on. The first scope is reducing the beta functions at collision, β^*, so IR magnets (WP3) accomplishing this functions are the first hardware we need to consider. Crab Cavities (WP4) then make the decreased β^* really effective, by eliminating the reduction due to the geometrical factors, and provide levelling of the luminosity. Collimators (WP5) are necessary to protect the magnets from the 500 MJ stored energy beam (a technical stop to change a magnet takes 2-3 months). Superconducting (SC) links (WP6) are there to avoid radiation damage to electronics and to ease installation and integration in a very crowded zone of the tunnel.

In addition, the High Luminosity LHC project contains other WPs not included in the FP7 Design Study. They are essential components of the project but they refer to accelerator functions or process of exquisite pertinence of CERN: machine protection (WP7), interface between collider and experiment (WP8), cryogenics (WP9), energy deposition and equipment damage (WP10), integration, installation (WP12), etc. The only exception is the 11 T dipole (WP11), which is an equipment with similar technology as the triplet magnet but with the need of a short time scale (2016/17). Other non-FP7 WPs plan to be added at a later stage (Hardware commissioning, for example) when the project is more mature.

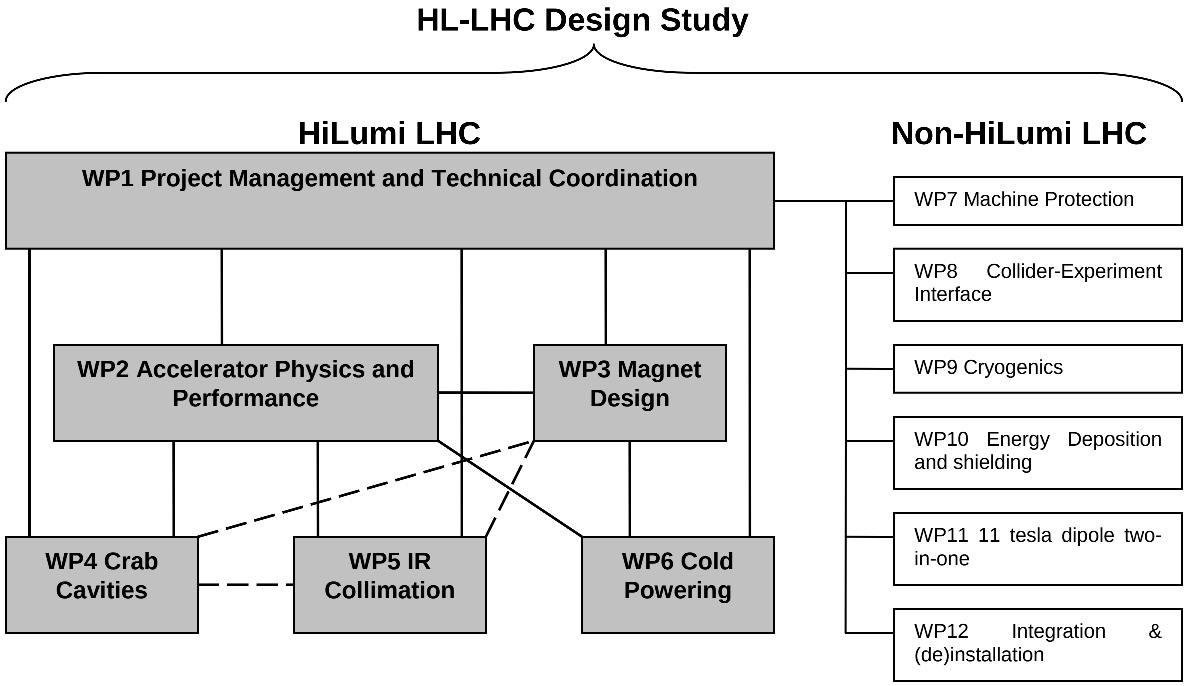

Figure 1.9: Relations between the different Work Packages (WP1-6) of HiLumi LHC, solid connecting lines indicate strong connections; dashed lines indicate synergies. The many links between WP1-6 and the WPs that are not part of the FP7 Design Study HiLumi LHC (WP7-12) have been excluded from this diagram for clarity.

Technically all WPs can proceed with reasonable autonomy, provided that there are formal points of exchange of critical information. It is foreseen to have a project advancement meeting every three months, and every year an annual meeting of the collaboration. The continuous information exchange will be assured by the steering committee (see section 2.1) that will meet at least four times a year, and as often as felt necessary with formal minutes that will be circulated among all collaborators.

The basic plan of the whole HL-LHC project is illustrated in Fig. 1.10, where the place of HiLumi LHC is evident: the aim is to have a relatively short period to examine all possible solutions, giving value to the large amount of studies done in the FP6 CARE project and the FP7 sLHC PP and EuCARD projects, as well as the US-LARP programmes. Then resources will be concentrated on the most promising solutions, taking into account that less promising solutions may be also pursued to have necessary fall-back options. All the work must converge towards a **Preliminary Design Report (PDR)** delivered about 2.5 years after the beginning of HiLumi LHC. The PDR will contain all elements enabling the Collaboration and the CERN management to make a choice among the most promising paths to the upgrade. For that time LHC will be working near its limit and this will be fed into the PDR. Once a path is chosen, the study will concentrate on a detailed design of the chosen solution and the study should arrive to a reasonably complete, including P+M cost evaluation, **Technical Design Report (TDR)** delivered at the end of the design study, i.e. at the end of the fourth year. **The TDR is the main deliverable of HiLumi LHC and, once endorsed by the collaboration and CERN management will enable the collaboration to start the constructive project toward HL-LHC.** This path must fit of course with the LHC injector upgrade path and the LHC Detector upgrade path. For this reason managing the boundary conditions with clear input-output and optimization loop, will be one of the main tasks of the HiLumi LHC project management.

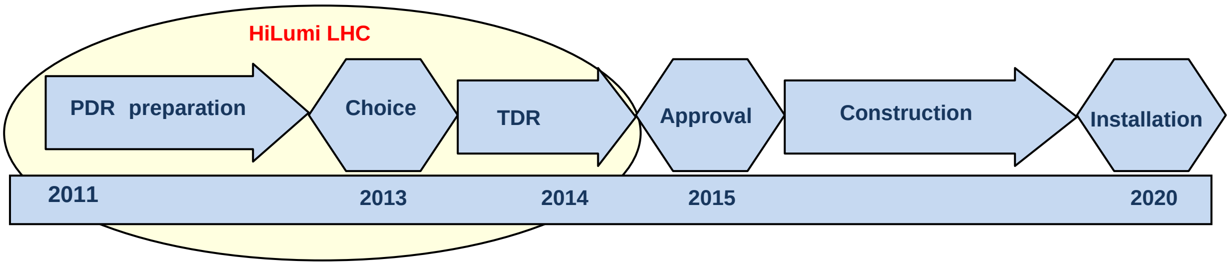

Figure 1.10: Timeline of the HL-LHC project, with the two main decision points: end of 2013 and 2015, enabling installation in 2020.

1.3.2. Work Package List

Table 1.3 a: HiLumi LHC Work Packages

WP No	Work package title	Type of activity[1]	Lead particip ant No	Lead participant short name	Person-months[2]	Start month	End month
1	Project Management and Technical Coordination	MGT	1	CERN	126	M1	M48
2	Accelerator Physics and Performance	RTD	1 & 13	CERN & UNILIV	591.44	M1	M48
3	Magnet Design	RTD	1 & 18	CERN & LBNL	332	M1	M48
4	Crab Cavities	RTD	1 & 12	CERN & ULANC	477.8	M1	M48
5	IR Collimation	RTD	1 & 9	CERN & RHUL	283.6	M1	M48
6	Cold Powering	RTD	1 & 5	CERN & INFN	151	M1	M48
				TOTAL	1961.84		

[1] One per WP: RTD = Research & technological development; MGT = Management of consortium.

[2] The total number of person-months allocated to each work package.

Table 1.3 b: HL-LHC Design Study Work Packages not within HiLumi LHC

WP No	Work package title	Type of activity[1]	Lead participant No	Lead participant short name
7	Machine Protection	RTD	1	CERN
8	Collider-Experiments Interface	RTD	1	CERN
9	Cryogenics	RTD	1	CERN
10	Energy deposition	RTD	1	CERN
11	11 T dipole two-in-one	RTD	1	CERN
12	Integration and (de-)installation	RTD	1	CERN

1.3.3. Timing of the Work Packages and their components

In the Gantt charts below, D=Deliverable and M=Milestone.

Apart from tasks 6.2-6.4, all tasks begin at the start of the project, month 1. Regardless of the specific deadlines of task milestones and deliverables, all tasks continue until month 48 to **provide input to the WP1 task 1.1 deliverable D1.10 HL-LHC Technical Design Report, which is the main deliverable of HiLumi LHC.**

In cases where multiple tasks in a work package contribute to a milestone or deliverable, this output is assigned to task 1 of the respective work package, in these cases details of the tasks involved can be found in the work package descriptions of table 1.3d.

[1] One per WP: RTD = Research & technological development

HiLumi LHC		1st YEAR												2nd YEAR											
Task	**Description**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	**Project Management and Technical Coordination**																								
1.1	Management	M					M						M								D				M
1.2	Parameter and Lay-out Committee						M			D									M						
1.3	Quality assurance plan						M						M						M						
1.4	Radiological impact												M												
1.5	Liaison with Detector and Injector Upgrades									M									M						D
1.6	Dissemination of Information and Industry outreach			M			M						M												
2	**Accelerator Physics and Performance**																								
2.1	Coordination and Communication																								
2.2	Optics and Layout												M						D						
2.3	Particle Simulations																								MM
2.4	Intensity Limitations																								M
2.5	Beam-Beam Effects																								
2.6	Beam Parameter and Luminosity Optimization																								
3	**Magnet Design**																								
3.1	Coordination and Communication																								
3.2	Nb_3Sn quadrupoles for the inner triplet												M												M
3.3	Separation dipoles												M												M
3.4	Cooling																								
3.5	Special Magnet Studies																		M						M
4	**Crab Cavities**																								
4.1	Coordination and Communication																								
4.2	Support studies						M						M						D						D
4.3	Compact Crab Cavity Design						M																		
4.4	Elliptical Crab Cavity Technical Design																								
4.5	Compact Crab Cavity Validation Prototyping																								
5	**IR Collimation**																								
5.1	Coordination and Communication												M												
5.2	Simulations of Beam Loss in the Experimental IR's												D						DM						
5.3	Simulations of Energy Deposition in the Experimental IR's												D												DM
5.4	Design of Collimation in the Experimental IR's																								
6	**Cold Powering**																								
6.1	Coordination and Communication																		D						M
6.2	LHC Cryogenics: Cooling and Operation																		M						
6.3	Electrical transfer and cryostats: thermo-electrical and mechanical models																								D
6.4	Energy deposition and material studies																								M

D=Deliverable and M=Milestone

HiLumi LHC		3rd YEAR												4th YEAR												
Task	**Description**	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	50
1	**Project Management and Technical Coordination**																									
1.1	Management	M							D				M		D										DDM	DD
1.2	Parameter and Lay-out Committee						M								M											
1.3	Quality assurance plan						D						M								D					
1.4	Radiological impact												D													
1.5	Liaison with Detector and Injector Upgrades						M						D													
1.6	Dissemination of Information and Industry outreach						M						M								M				D	
2	**Accelerator Physics and Performance**																									
2.1	Coordination and Communication																									
2.2	Optics and Layout																									
2.3	Particle Simulations												DD													
2.4	Intensity Limitations						M						D													
2.5	Beam-Beam Effects						M						D													
2.6	Beam Parameter and Luminosity Optimization															M									D	
3	**Magnet Design**																									
3.1	Coordination and Communication																									
3.2	Nb_3Sn quadrupoles for the inner triplet												M												D	
3.3	Separation dipoles												M												D	
3.4	Cooling												MM												D	
3.5	Special Magnet Studies												DM													
4	**Crab Cavities**																									
4.1	Coordination and Communication						D																		D	
4.2	Support studies																									
4.3	Compact Crab Cavity Design				M																					
4.4	Elliptical Crab Cavity Technical Design																									
4.5	Compact Crab Cavity Validation Prototyping																									
5	**IR Collimation**																									
5.1	Coordination and Communication																		DM						DM	
5.2	Simulations of Beam Loss in the Experimental IR's																									
5.3	Simulations of Energy Deposition in the Experimental IR's																									
5.4	Design of Collimation in the Experimental IR's												DM													
6	**Cold Powering**																									
6.1	Coordination and Communication						M						D													
6.2	LHC Cryogenics: Cooling and Operation																									
6.3	Electrical transfer and cryostats: thermo-electrical and mechanical models																M		DM			D	D			
6.4	Energy deposition and material studies						D												DM		M					

D=Deliverable and M=Milestone

1.3.4. Deliverables list

Table 1.3 b: Deliverables List

Del. no. [1]	Deliverable name	WP no.	Nature [2]	Dissemination level[3]	Delivery date[4]
D1.1	First release of lay-out data-base	1 (Task 1.2)	O	PU	M9
D5.1	Simulation models for beam loss	5 (Task 5.2)	O	RE	M12
D5.2	Simulation models for energy deposition	5 (Task 5.3)	O	RE	M12
D2.1	Optics and lattice files	2 (Task 2.2)	O	PU	M18
D4.1	Operational Scenarios	4 (Task 4.2)	R	PU	M18
D5.3	Beam halo simulations	5 (Task 5.2)	R	PU	M18
D6.1	Preliminary report on cooling options for the cold powering system	6 (Task 6.1)	R	PU	M18
D1.2	1st Periodic Report	1 (Task 1.1)	R	PP	M20
D1.3	Beam INJ parameter	1 (Task 1.5)	R	PP	M24
D4.2	RF System Conceptual Design	4 (Task 4.2)	R	PP	M24
D5.4	Energy deposition simulations	5 (Task 5.3)	R	PU	M24
D6.2	Preliminary report on results of thermo-electrical studies	6 (Task 6.3)	R	PP	M24
D1.4	Component standards	1 (Task 1.3)	R	PP	M30
D4.3	Elliptical Crab Cavity Technical Design	4 (Task 4.1)	R	PU	M30
D6.3	Preliminary report on energy deposition calculations	6 (Task 6.4)	R	PU	M30
D1.5	HiLumi LHC Preliminary Design Report	1 (Task 1.1)	R	PU	M32
D1.6	First estimate of radiological impact of available design options	1 (Task 1.4)	R	PP	M36
D1.7	Common LHC Time Plan	1 (Task 1.5)	R	PP	M36
D2.2	Magnet field quality specifications	2 (Task 2.3)	R	PU	M36
D2.3	Corrector magnets specifications	2 (Task 2.3)	R	PU	M36
D2.4	Beam Intensity Limitations	2 (Task 2.4)	R	PU	M36
D2.5	Beam-beam effects	2 (Task 2.5)	R	PU	M36
D3.1	Issues in special magnet studies	3 (Task 3.5)	R	PU	M36

[1] Deliverable numbers in order of delivery dates.
[2] R = Report, P = Prototype, D = Demonstrator, O = Other
[3] **PU** = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).
[4] Measured in months from the project start date (month 1).

D5.5	Conceptual design IR collimation	5 (Task 5.4)	O	RE	M36
D6.4	Cryogenic scenarios and flow scheme for the cold powering system	6 (Task 6.1)	R	PP	M36
D1.8	2nd Periodic Report	1 (Task 1.1)	R	RE	M38
D5.6	Technical design IR collimation	5 (Task 5.1)	O	PU	M42
D6.5	Thermo-electrical studies	6 (Task 6.3)	R	PP	M42
D6.6	Energy deposition studies	6 (Task 6.4)	R	PU	M42
D1.9	Final QA management plan	1 (Task 1.3)	R	PP	M44
D6.7	Cryostat drawings and report	6 (Task 6.3)	O	PP	M45
D6.8	Final design report	6 (Task 6.3)	R	PP	M46
D1.10	HiLumi LHC Technical Design Report	1 (Task 1.1)	R	PU	M48
D1.11	Collaboration model for the HL-LHC construction phase	1 (Task 1.1)	R	PU	M48
D1.12	Final plan for use and dissemination of foreground	1 (Task 1.6)	R	PU	M48
D2.6	Specification of machine and beam parameters	2 (Task 2.6)	R	PU	M48
D3.2	Design study of the Nb_3Sn inner triplet	3 (Task 3.2)	R	PU	M48
D3.3	Design study of the separation dipoles	3 (Task 3.3)	R	PU	M48
D3.4	Design study of the cooling	3 (Task 3.4)	R	PU	M48
D4.4	Compact Crab Cavity Conceptual Design Report	4 (Task 4.1)	R	PU	M48
D5.7	Design report and functional specification	5 (Task 5.1)	R	PU	M48
D1.13	3rd Periodic Report	1 (Task 1.1)	R	PP	M50
D1.14	Final Project Report	1 (Task 1.1)	R	PP	M50

1.3.5. List of milestones

Table 1.3 c: List of milestones

Milestone number	Milestone name	Work package(s) involved	Expected date [1]	Means of verification
MS1	Kick-off meeting	1 (Task 1.1)	M1	Minutes
MS2	Website for the whole project and for the DS follow-up	1 (Task 1.6)	M3	Release of web address
MS3	Forming all official bodies requested by the governance	1 (Task 1.1)	M6	Activity Report
MS4	Installation of PLC and 1st meeting	1 (Task 1.2)	M6	Minutes of 1st meeting
MS5	Formation of the working group on QA management	1 (Task 1.3)	M6	First meeting minutes
MS6	Rules of publication	1 (Task 1.6)	M6	Published on web
MS7	Machine protection concerns satisfied	4 (Task 4.2)	M6	Report
MS8	Common specifications for the alternative proposals of Compact Crab Cavity geometries	4 (Task 4.3)	M6	Performance specification document
MS9	Definition of the body to link HL with LIU and detector upgrade	1 (Task 1.5)	M9	Minutes first meeting
MS10	Organization of the 1st Annual Collaboration Meeting	1 (Task 1.1)	M12	Activity Report
MS11	Acquisition of main standards and adaptation to HL-LHC	1 (Task 1.3)	M12	List of the standards
MS12	Definition of regulatory framework, design limits and dose objectives	1 (Task 1.4)	M12	Report
MS13	Establish permanent collaboration with ITLO and TIARA	1 (Task 1.6)	M12	Activity Report
MS14	Distribution of Preliminary Optics and Lattice files to all work packages	2 (Task 2.2)	M12	Publication on web
MS15	Requirements for Nb_3Sn inner triplet and comparison with present status of the art	3 (Task 3.2)	M12	Report
MS16	Requirements for separation dipoles	3 (Task 3.3)	M12	Report
MS17	Operational scenario during LHC ramping specified	4 (Task 4.2)	M12	Report
MS18	Set up of models and implementation of upgrade optics	5 (Task 5.1)	M12	Publication on web

[1] Measured in months from the project start date (month 1).

MS19	Agreed criteria to evaluate figure of merit of variants	1 (Task 1.2)	M18	Publication on web and presented to 2nd annual meeting
MS20	Preliminary QA management plan	1 (Task 1.3)	M18	Report
MS21	Agreement on most probable injector scenario	1 (Task 1.5)	M18	Report on various inj. Scenario
MS22	Review of the Nb-Ti option for inner triplet for new peak and integrated luminosity targets	3 (Task 3.5)	M18	Report
MS23	Assessment of beam halo losses in various upgrade scenarios	5 (Task 5.2)	M18	Publication on web
MS24	Cryogenic scenarios	6 (Task 6.2)	M18	Preliminary Report
MS25	Organization of the 2nd Annual Collaboration Meeting	1 (Task 1.1)	M24	Activity Report
MS26	Initial estimates of dynamic aperture and field quality specifications	2 (Task 2.3)	M24	Report
MS27	Initial models of correction systems	2 (Task 2.3)	M24	Report
MS28	Initial estimate of machine impedance	2 (Task 2.4)	M24	Report
MS29	Study of magnetic shimming in HQ	3 (Task 3.2)	M24	Report
MS30	Conceptual design of Nb_3Al and Nb-Ti separation dipoles	3 (Task 3.3)	M24	Report
MS31	Analysis of possible options for quadrupoles in cleaning insertions	3 (Task 3.5)	M24	Report
MS32	Assessment of energy deposition	5 (Task 5.3	M24	Publication on web
MS33	Thermo-electrical models	6 (Task 6.1)	M24	Preliminary report
MS34	Energy deposition	6 (Task 6.4)	M24	Preliminary Report
MS35	Mid-term Review	1 (Task 1.1)	M25	Review Panel report
MS36	Initial Compact Crab Cavity down-selection, leaving at least two CC options for technical design and prototyping	4 (Task 4.3)	M28	Report indicating the remaining contenders
MS37	Data-base of baseline scenario and variants	1 (Task 1.2)	M30	To be fed into the Preliminary Design Report
MS38	Interface machine-experiments definition and time plan	1 (Task 1.5)	M30	Activity Report
MS39	Presentation for schools and educated public of the scopes of the HL-LHC and technology spin offs	1 (Task 1.6)	M30	Activity Report
MS40	Initial estimates of intensity limitations	2 (Task 2.4)	M30	Report
MS41	Preliminary estimates of beam-beam effects.	2 (Task 2.5)	M30	Report
MS42	Cryogenic scenarios	6 (Task 6.1)	M30	Report

MS43	Organization of the 3rd Annual Collaboration Meeting	1 (Task 1.1)	M36	Activity Report
MS44	Draft of the final structure to be presented at the 3rd Annual meeting	1 (Task 1.3)	M36	Draft Report
MS45	Industry Forum on the HL-LHC opportunities	1 (Task 1.6)	M36	Activity Report
MS46	Study of minimal distance between two coils in a cold mass	3 (Task 3.2)	M36	Report
MS47	Conceptual design of a crab cavity dogleg	3 (Task 3.3)	M36	Report
MS48	Study of the supercritical He cooling	3 (Task 3.4)	M36	Report
MS49	Study of the superfluid He cooling	3 (Task 3.4)	M36	Report
MS50	Study of two-in-one quadrupoles for outer triplet	3 (Task 3.5)	M36	Report
MS51	Definition of new IR collimation solution	5 (Task 5.4)	M36	Publication in form of project report
MS52	Final evaluation of the baseline and most probable alternative	1 (Task 1.2)	M38	Activity Report
MS53	Collation of data for parameter optimization.	2 (Task 2.6)	M39	Report
MS54	Cryostat for current leads	6 (Task 6.3)	M40	Report and drawings
MS55	Verification of new IR collimation solution in simulations. Possible iteration in design	5 (Task 5.1)	M42	Publication in form of project report
MS56	Thermo-electrical models and cryostat conceptual design	6 (Task 6.3)	M42	Report and Codes
MS57	Energy deposition studies	6 (Task 6.4)	M42	Report
MS58	Chart for Industry participation to the HL-LHC construction	1 (Task 1.6)	M44	Activity Report
MS59	Material studies	6 (Task 6.4)	M44	Report
MS60	Organization of the final Annual Collaboration Meeting	1 (Task 1.1)	M48	Activity Report
MS61	Final report	5 (Task 5.1)	M48	Publication on web

1.3.6. Work Package Descriptions

Table 1.3 d: Work package description

Work package number	1		Start date or starting event:		M1
Work package title	Project Management and Technical Coordination				
Activity Type	MGT				
Participant number	1	17	18	20		
Participant short name	CERN	FNAL	LBNL	SLAC		
Person-months per participant:	114	4	4	4		

Objectives

Task 1.1. Management

- Effective management and coordination of all Work Packages inside the DS and of the WPs not included in this application, following up budget and plan.

Task 1.2. Parameter and Lay-out Committee

- Install a HL-LHC Parameter and Lay-out Committee (PLC) to serve as a common reference for the vast community and canalise and make effective the various efforts.

Task 1.3. Quality assurance plan

- Install and endorse a strict QA plan for the project

Task 1.4. Radiological impact

- Assure that safety, and environmental responsibility, is built-in in the design phase at each level, with particular care of radiological effects and long-term operation and dismantling issues.

Task 1.5. Liaison with Detector and Injector Upgrades

- Assure the coherence of the project with strong ties with LHC Physics Centre, LHC detector upgrades plans, LHC injector upgrades plans.

Task 1.6. Dissemination of Information and Industry outreach

- Dissemination of information and innovation inside and outside the member of the consortium and in particular to Industry.

Description of work

Task 1.1. Management

The activities of this task are for the work package coordinator [CERN] to oversee and co-ordinate the work of the whole project as well as of all other work package tasks, to ensure the consistency of the work according to the project plan and the financial follow up.

Critical activities will be installing the Collaboration Board (CB), the Steering Committee (SC) and all the official bodies foreseen for the governance of the project. A further specific activity will be to coordinate the WP technical and scientific tasks with tasks carried out by the other work packages when relevant, to avoid doubling and voids in the interfaces. The coordination duties also include the organization of WP internal steering meetings, the setting up of proper reviewing, the reporting to internal and external management bodies (Collaboration Board, CERN council, etc.) and the distribution of the information within the WP and to the whole project.

This task is also responsible for the main deliverables of the project: the Technical Design Report and the model for sustainable worldwide collaboration during the HL-LHC construction phase.

In collaboration with LBNL, the task also covers the organization of and support to the annual meetings of the entire collaboration, and possible workshops or specialized working sessions, implying the attendance of invited participants from inside and outside the consortium.

Task 1.2. Parameter and Lay-out Committee

A Parameters and Lay-out Committee (PLC) is a key instruments to maintain a consistent set of parameters that enable the various group all over the world to work with up-to-date values. Indeed the complexity of LHC and of all possible variants of the upgrades may generate too many options of how to proceed. Attractive ideas may not be compatible with the actual operation of LHC or with other parameters of HL-LHC. The PLC has the scope of streamline the workflow, maximize resources and avoid technical conflicts. SLAC and LBNL will help to have a strong link between this committee and US studies (LARP and others).

Upon mandate of the Project coordinator, the Committee will generate a data-base, public and easily accessible, and will define the process to scrutinize change requests, evaluating all performance consequences and keep track of the technical implications of accepted changes. However the definition of the financial implication of a change will remain with the project coordinator. The PLC will maintain an HL-LHC baseline lay-out and accepted variants. The PLC, in consultation with the PC and the SC, will propose the criteria for evaluating the variants and to give quantitative figure of merits. This exercise will eventually lead to a classification of the various variants, which is one of the main objectives of the PDR.

Task 1.3. Quality assurance plan

The quality assurance plan will define the standards of design, construction and integration of the various components, as well as the compatibility with existing LHC hardware and infrastructure. It will specify the norms to be followed, and their equivalence, which is a very important task for a project whose hardware is coming from many different regions and laboratories, each one following their national standard. Installation, integration and hardware commissioning will be part of the definition of the QA: very likely a team will commission components designed by another Institute and manufactured by a third one. LBNL and SLAC will assure the participation of the US labs and will provide the information of standards and best practices used for the US contributions.

This task will provide also a methodology of work based on a cascade of independent review, aimed to intercept and correct mistakes, non-conformities and short of performance at the early stage.

The main tool for this will be a working group that will integrate the experience of LHC and of the LHC detector collaborations, as well as the experience of other large projects with similar characteristics (SNS[1], for example).

Task 1.4. Radiological impact

All equipment to be installed and operated on the CERN site must comply with the CERN HSE (Health & Safety and Environmental) regulatory framework. The main objectives of this task are:

- Provision of advise to all Work Packages on Radiation Protection (RP) aspects and conventional HSE aspects, including hazard identification, risk assessment methods and tools, risk reduction and mitigation options, choice of material, and regulatory requirements.
- Estimation of radiological quantities, including shielding, activation, job doses, and environmental releases
- Coordination of all RP risk assessment activities
- Documentation of results on RP risk assessments, contribution of related chapters to project reports.

[1] **Spallation Neutron Source** (SNS), hosted by Oak Ridge National Laboratory, http://neutrons.ornl.gov/facilities/SNS/

The work to be executed in the framework of this task consists of the advising and coordination of all RP- and conventional HSE-related activities. It establishes and provides a unique contact for all Work Packages on design and material choices, as well as information and advice on the impact of different options on radiological quantities and RP as well as conventional HSE risks.

The radiation protection work includes optimization of the design according to the ALARA[1] principle for handling of components during installation, maintenance and removal of components and for activation and releases of cooling liquids and air. Furthermore, the task defines the applicable regulatory framework and monitors its implementation in all parts of the project. The work also includes assessments and studies on shielding, activation and doses to workers and environment as soon as details on design options become available.

This task will interact with all WPs and given the international nature of the project, equivalence among EU, USA and Japanese standards and rules must be defined.

Task 1.5. Liaison with Detector and Injector Upgrades

The final effective performance of HL-LHC will be strongly affected by the performance of the injectors. Actually the needs of the HL-LHC may require substantial upgrades of the injector themselves. Conversely the possibility and performance of the injectors may orient the LHC upgrades toward certain scenario rather than other. The impact of the HL-LHC baseline lay-out and main variants has to be carefully evaluated (with WP2) and request to injectors will be an important chunk of the figure of merits of the variants (see task 1.2).

Strong ties exist also between the performance of HL-LHC and detectors. Hardware boundary may change either for request of detectors (example: beam pipe diameters or materials) or for request of the machine (example: distance of first quadrupole from interaction point). Each possibility must be evaluated and also in this case there is a feed back in the figure of merit of task 1.2. FNAL will provide its very similar experience of the Tevatron upgrade and interference with its detector upgrade. SLAC will bring the experience of the linear collider and of PEPII accelerator - BaBar interaction.

To assure the strong connection a formal channel of communication and fast information will be created, also to coordinate the work of various actors (in WP1, WP2, and WP8 outside of this FP7 design study). The formal channel of information exchange will likely be special sessions of the Steering Committee (see section 2.1), where all WP coordinators are present, enlarged to include a representative of the LIU project and technical coordinators of the concerned experiments.

Task 1.6. Dissemination of Information and Industry outreach

This task will concentrate the effort of communication and spreading information in an effective way. Different mailing lists for the different groups will be formed and maintained to limit information pollution and increase the effectiveness of the messages sent. Information will also be available on the project website. Here particular care will be taken by the project coordinator to add disclaimers, to authenticate/assess information to ensure its usefulness and maintain coherence in the project. Dissemination will aim to make the parameters and lay-outs uniform, something not obvious when various tens of physicists are at work in different places. Rules will be issued for accepting publications as official HL-LHC project notes or project reports; a scientific editorial board will be formed and put into function. Finally a system of archiving and retrieval of the papers and technical notes will be set up. The system will have to work across different laboratories of the various continents. Particular attention will be devoted to open access publication, with a sum of 25 k€ allocated explicitly to endorse it.

[1] As Low As Reasonably Achievable (ALARA) is a key principle in design of equipment and process requiring exposition of people to ionizing radiation.

Dissemination will also target the general public about the scientific scopes of the HL-LHC project, its significance and the impact of the novel technologies and possible spin-offs. A strong liaison with Industry is also foreseen involving collaboration and outreach (see section 3.2 for more details). To this end an Industry and Technology Board (ITB) will be formed, in close liaison with existing structures such as the CERN External Technology Transfer Network (ETTN), comprising industrial liaisons and TT officers from institutes of its Member States, and with other EU projects, namely FP7-TIARA[1]. The ITB may coincide or share tooling and work with the ITLO and TIARA and will have the goal of effective communication with Industry, preparing the participation of European Industry in the HL-LHC construction, which may require industrial contracts for up to 300 M€. It will also give advice to the project coordinator of how to improve and disseminate information among Industry concerning spin offs that can be generated by advancements within this Design Study.

Deliverables

D1.1) First release of lay-out data-base: First release of the data-base of most likely lay-outs and definition of modification process. (Task 1.2) [month 9]

D1.2) 1st Periodic Report: This deliverable describes the work progress, the achievements of the project objectives, and the resources used within the first period (months 1-18). A public version of the report will be made available online. (Task 1.1) [month 20]

D1.3) Beam INJ parameter: List of parameter agreed with LHC Inj. Upgrade project on minimal beam characteristics at LHC entrance, to reach the scope of HL-LHC. (Task 1.5) [month 24]

D1.4) Component standards: List of applicable standards and equivalence of norms for component design and construction. (Task 1.3) [month 30]

D1.5) HiLumi LHC Preliminary Design Report: the PDR will serve to the CB to recommend to the CERN council the most promising lay-out for the upgrade. (Task 1.1) [month 32]

D1.6) First estimate of radiological impact of available design options: First risk assessments and radiological studies for design options and operational parameters of HL-LHC (Task 1.4) [Month 36]

D1.7) Common LHC Time Plan: definition of a relatively detailed plan of the various stop and installation to be carried out in the main ring, in the experimental areas and injectors (including beam transfer lines) to reach the scope around d 2020-22. The plan should include also the intervention on technical infrastructure. (Task 1.5) [month 36]

D1.8) 2nd Periodic Report: This deliverable describes the work progress, the achievements of the project objectives, and the resources used within the second period (months 19-36). A public version of the report will be made available online. (Task 1.1) [month 38]

D1.9) Final QA management plan: Final structure of QA management and QA construction plan. (Task 1.3) [month 44]

D1.10) HiLumi LHC Technical Design Report: The main deliverable of the project, intended to be the description of how the LHC upgrade will be actuated and will sign the starting of the main hardware construction. (Task 1.1) [month 48]

D1.11) Collaboration model for the HL-LHC construction phase: A model of sustainable collaboration will be proposed to assure the proper integration of the worldwide effort for the HL-LHC project construction phase. (Task 1.1) [month 48]

[1] The **FP7 TIARA** (Test Infrastructure and Accelerator Research Area) project http://www.eu-tiara.eu/

D1.12) Final plan for use and dissemination of foreground: This deliverable describes the foreground generated by the project and how the project intends for this foreground to be used and communicated beyond the lifetime of the project. (Task 1.6) [month 48]

D1.13) 3rd Periodic Report: This deliverable describes the work progress, the achievements of the project objectives, and the resources used within the third period (months 37-48). A public version of the report will be made available online. (Task 1.1) [month 50 – two months after the end of the project]

D1.14) Final Project Report: This deliverable gives an overview of the work and achievements during the entire project. A public version of the report will be made available online. (Task 1.1) [month 50 – two months after the end of the project]

Milestones

Milestone name	Work package(s) involved	Expected date	Means of verification
Kick-off meeting	1 (Task 1.1)	M1	Minutes
Website for the whole project and for the DS follow-up	1 (Task 1.6)	M3	Release of web address
Forming all official bodies requested by the governance	1 (Task 1.1)	M6	Activity Report
Installation of PLC and 1st meeting	1 (Task 1.2)	M6	Minutes of 1st meeting
Formation of the working group on QA management	1 (Task 1.3)	M6	First meeting minutes
Rules of publication	1 (Task 1.6)	M6	Published on web
Definition of the body to link HL with LIU and detector upgrade	1 (Task 1.5)	M9	Minutes first meeting
Organization of the 1st Annual Collaboration Meeting	1 (Task 1.1)	M12	Activity Report
Acquisition of main standards and adaptation to HL-LHC	1 (Task 1.3)	M12	List of the standards
Definition of regulatory framework, design limits and dose objectives	1 (Task 1.4)	M12	Report
Establish permanent collaboration with ITLO and TIARA	1 (Task 1.6)	M12	Activity Report
Agreed criteria to evaluate figure of merit of variants	1 (Task 1.2)	M18	Publication on the web and presented to 2nd annual meeting
Preliminary QA management plan	1 (Task 1.3)	M18	Report
Agreement on most probable injector scenario	1 (Task 1.5)	M18	Report on various inj. scenario
Organization of the 2nd Annual Collaboration Meeting	1 (Task 1.1)	M24	Activity Report

Mid-term Review	1 (Task 1.1)	M25	Review Panel report
Data-base of baseline scenario and variants	1 (Task 1.2)	M30	To be fed into the Preliminary Design Report
Interface machine-experiments definition and time plan	1 (Task 1.5)	M30	Activity Report
Presentation for schools and educated public of the scopes of the HL-LHC and technology spin offs	1 (Task 1.6)	M30	Activity Report
Organization of the 3rd Annual Collaboration Meeting	1 (Task 1.1)	M36	Activity Report
Draft of the final structure to be presented at the 3rd Annual meeting	1 (Task 1.3)	M36	Draft Report
Industry Forum on the HL-LHC opportunities	1 (Task 1.6)	M36	Activity Report
Final evaluation of the baseline and most probable alternative	1 (Task 1.2)	M38	Activity Report
Chart for Industry participation to the HL-LHC construction	1 (Task 1.6)	M44	Activity Report
Organization of the final Annual Collaboration Meeting	1 (Task 1.1)	M48	Activity Report

Work package number	2	**Start date or starting event:**				M1
Work package title	Accelerator Physics and Performance					
Activity Type	RTD					
Participant number	1	2	4	5	6	7
Participant short name	CERN	CEA	DESY	INFN	BINP	CSIC
Person-months per participant:	101	24	12	67.2	65	24
Participant number	8	11	13	14	15	16
Participant short name	EPFL	STFC	UNILIV	UNIMAN	KEK	BNL
Person-months per participant:	48	28	34.8	34.8	19.2	14.4
Participant number	17	18	20			
Participant short name	FNAL	LBNL	SLAC			
Person-months per participant:	56.64	48	14.4			

Objectives

Task 2.1. Coordination and Communication

- Coordinate and schedule work package tasks
- Monitor work progress and inform the project management and work package participants
- Manage the WP budget and use of resources
- Prepare internal and deliverable reports

Task 2.2. Optics and Layout

- Identify layout options for the Interaction Region (IR) upgrades.
- Identify optics solutions for the LHC upgrade.

Task 2.3. Particle Simulations

- Determine field quality tolerances for new magnetic elements for the LHC upgrade.
- Specify tolerances of the correction circuit settings.
- Evaluate the dynamic aperture.

Task 2.4. Intensity Limitations

- Specify limits for maximum acceptable impedance of new components, and evaluate intensity limitations due to the machine impedance.
- Estimate impact of electron cloud effects.
- Estimate emittance growth rates from intrabeam scattering.

Task 2.5. Beam-Beam Effects

- Evaluate beam-beam effects for the LHC upgrade and identify minimum requirements for the beam separations in the Interaction Regions.
- Evaluate the limitations imposed by beam-beam interactions.

Task 2.6. Beam Parameter and Luminosity Optimization

- Identify relevant experience from LHC commissioning and operation.
- Determine optimum sets of machine and beam parameters based on the outcomes of Tasks 2.2, 2.3, 2.4 and 2.5, and the operational experience of the LHC.

Description of work

Task 2.1. Coordination and Communication.

The activities of this task are for the work package coordinators [CERN, UNILIV] to oversee and co-ordinate the work of all other work package tasks, to ensure the consistency of the work according to the project plan and to coordinate the WP technical and scientific tasks with tasks carried out by the other work packages when relevant. The coordination duties also include the organization of WP internal steering meetings, the setting up of proper reviewing, the reporting to the project management and the distribution of the information within the WP as well as to the other work packages running in parallel.

The task also covers the organization of and support to the annual meetings dedicated to the WP activity review and possible activity workshops or specialized working sessions, implying the attendance of invited participants from inside and outside the consortium.

Task 2.2. Optics and Layout

The goal of this task is to prepare reference lattice and optics files for various configurations that can be used for further beam dynamic studies (e.g. particle loss and heat deposition studies in the IRs and preparation of new configurations for the LHC cleaning insertions), to explore the performance limitations in terms of the optics design (e.g. chromatic aberrations, number of long-range beam-beam encounters, required minimum collimator apertures) and to generate critical magnet parameters (magnet length, gradient, and aperture) for the various scenarios for all linear magnet systems including the orbit correctors for generating the crossing angle generation and the skew quadrupole correction system. The generation of optics files implies the preparation of complete injection and collision optics files that feature continues transitions of the magnet gradients (squeeze). The optics studies should also provide estimates for the maximum acceptable linear optic errors, specify alignment and orbit tolerances for the machine and discuss correction strategies for these effects during operation.

This task is linked to task 2.3 and to WP5, in addition the lattice and optics files generated by task 2.2 for the different configurations under consideration for HL-LHC will be made available to all partner laboratories and collaborators in a central project database. Task 2.2 therefore provides direct input into WP1 of the HiLumi LHC project.

The task will involve the following:

- **IR4 optics design** with room for a global Crab cavity installation. CERN and INFN will generate lattice and optics files for the full LHC machine using the new IR4 solution and the design configurations in the remaining insertions.
- **Study options for correcting chromatic aberrations** from the optics focal system near the experiments. This will be carried out by CERN and EPFL.
- **Generate optics and lattice files for different magnet solutions:** Optics and Layout Design for Nb-Ti and Nb_3Sn solutions with and without local crab cavities, $\beta^* < 0.5$m and optics design for round and flat beams featuring single bore triplet magnets and lattice and optics files for the full LHC machine (CERN, CEA, BINP, CSIC, UNILIV, UNIMAN). The flat beam option should include estimates of the maximum acceptable coupling and strategies for its correction. These are built to a large extent on the existing Phase 1 upgrade study. The solutions under investigation are as follows:
    - a single bore Nb-Ti magnet solution with $\beta^* < 0.5$m (CERN, CSIC)
    - as above but with local Crab Cavities (CERN, UNILIV and UNIMAN)
    - a 2-in-1 Nb-Ti magnet solution with $\beta^* < 0.5$m (CERN, BINP)
    - a single bore Nb_3Sn magnet solution with $\beta^* < 0.5$m (CERN)
    - as above but with local Crab Cavities (CERN, UNILIV and UNIMAN)

- o 2-in-1 Nb_3Sn magnet solution with $\beta^* < 0.5$m (CERN, BINP)

Task 2.3 Particle Simulations

This task aims at studying the dependence of the Dynamic Aperture of the machine on the field quality of the magnetic focusing system and the separation-recombination dipole magnets next to the experiments for a selection of optics configuration from Task 1.

Studies of other Work Packages of the HiLumi LHC project, such as WP3 'Magnet design' and WP5 'Collimation and cleaning efficiency studies' require detailed information on the likely working configuration of the LHC. The work of Task 2.3 consist in the generation of magnet field quality specifications, specification of required correction circuits and proposals for potential working points for operation. All information will be made available to all partner laboratories and collaborators in a central project database. Task 2.3 therefore provides direct input into all work packages of the HiLumi LHC project.

This task involves the following:

- **Monte Carlo tracking studies:** CERN, INFN, CSIC, UNIMAN, BNL and SLAC will perform single particle Monte Carlo (different realizations for machine imperfections) tracking studies for selected configurations of Task 2.2 with the aim of defining the required field quality of the magnets and designing magnetic correction systems.
- **Preparation of simulation tools:** CERN and KEK will prepare simulation tools for studying the effect of beam-beam interactions and non-linear fields on the single particle dynamics for operation with large crossing angles, flat beams and variation of the longitudinal bunch orientation along the machine with Crab cavities. The currently used programmes for particle simulation studies such as MADX and Sixtrack do not yet offer all required tools and modules for the study of beam-beam interactions with large crossing angles, hour-glass effect and Crab cavity implementations.
- **Specification of required correction circuits:** CERN, UNILIV and UNIMAN will specify the required non-linear correction systems for the new insertions
- **Study of optimum working points (tunes) for the upgrade:** CERN will evaluate synchro-betatron resonances and perform single particle tracking with the aim of identifying the optimum working point (tune values) for the two LHC beams.
- **Radiation and heat deposition studies:** FNAL and BINP will quantify the expected radiation and heat deposition values for selected elements (e.g. triplet magnets, TAS and TAN (radiation absorbers placed in the triplet region), magnets in the collimation regions etc).

Task 2.4 Intensity Limitations

This task will look after performance limitations arising from the interaction of the beam with itself and its surrounding. The goal of this task is to define key parameters such as maximum acceptable impedance values and to identify optimum beam configurations (e.g. required chromaticity control and landau damping octupole settings) for the different scenarios of Task 2.2.

This task will provide critical input for estimates the potential performance reach of the upgraded LHC and therefore feed directly into WP1 and other tasks of WP2 of the HiLumi LHC project. It will involve the following:

- DESY and INFN will estimate the impedance of new components of the upgrade options.
- SLAC will estimate the required corrector circuit settings (chromaticity and Landau damping octupoles).
- STFC and INFN will provide estimates for the Intra Beam Scattering (IBS) growth rates for different beam parameters.

- DESY will evaluate electron cloud effects.

Task 2.5 Beam-Beam Effects

This task will evaluate performance limitations arising from the interaction between the two beams. The goal of this task is to define key parameters such as minimum required beam separation and maximum acceptable beam brightness values and to identify optimum beam configurations (e.g. flat beam versus round beam IR design) for the different scenarios of Task 2.2.

This task will provide critical input for estimates of the potential performance reach of the upgraded LHC and will therefore feed directly into WP1 and other tasks of WP2 of the HiLumi LHC project. It will consist of:

- Calculations by CERN, INFN and BNL of bunch-by-bunch orbit variations due to self-consistent treatment of the beam-beam interactions.
- Evaluations by CERN, LBNL and FNAL of compensation schemes for the long-range beam-beam interactions (e.g. DC and pulsed wire installations).
- Evaluations by CERN, EPFL and BINP of compensation schemes for the head-on beam-beam interactions (correction of the linear and non-linear effect) (e.g. electron lens installation).
- Studies by CERN, KEK and STFC of crab cavity beam-beam compensation scheme.

Task 2.6 Beam Parameter and Luminosity Optimization

This task will evaluate the experience from the first years of LHC operation and determine the optimum choice for the beam parameters (e.g. minimum achievable emittances, optimum bunch length and minimum acceptable bunch spacing).

This task will provide optimized beam parameters and optics configurations for various scenarios of Task 2.1 based on the operational experience from the first years of LHC operation. It feeds directly into WP1, WP5, WP6 and other tasks of WP2 of the HiLumi LHC project. It consists of:

- Evaluation by STFC of the geometric luminosity reduction factor for various configurations of Task 2.2 and look into options for luminosity levelling (e.g. via Crab cavities or crossing angle variations or dynamic optic changes).
- Evaluation by LBNL of options for optimizing the luminosity production by variation of beam parameters during a fill (e.g. tune, beam separation, emittance [radiation damping] etc.).
- Determination of STFC of the optimum beam parameter values (e.g. initial emittance, beam brightness, bunch length and bunch separation) for different scenarios of Task 2.2.

Deliverables

D2.1) Optics and lattice files: Optics (injection, collision and squeeze transition with crossing angle configurations) and lattice files in MADX format with specification of the required magnet parameters (strength and aperture) for each sub-task. (Task 2.2) [month 18]

D2.2) Magnet field quality specifications: Specification of field quality requirements, based on Monte-Carlo tracking studies for selected optics and lattice configurations defined by Task 2.2. (Task 2.3) [month 36]

D2.3) Corrector magnet specifications: Specification of required magnetic correction circuits for selected configurations of Task 2.2. (Task 2.3) [month 36]

D2.4) Beam intensity limitations: Estimates of intensity limitations set by impedance, electron cloud effects, and intrabeam scattering (Task 2.4) [month 36]

D2.5) Beam-beam effects: Estimates of impact of beam-beam effects, including head-on and crab configurations, and long-range effects. Evaluation of compensation schemes. (Task 2.5) [month 36]

D2.6) Specification of machine and beam parameters: Optimized machine and beam parameter sets for maximum performance reach in selected configurations of Task 2.2, taking account of collective effects, and beam-beam effects. Evaluation of options for luminosity levelling. (Task 2.6) [month 48]

Milestones

Milestone name	Work package(s) involved	Expected date	Means of verification
Distribution of Preliminary Optics and Lattice files to all work packages	2 (Task 2.2)	M12	Publication on web
Initial estimates of dynamic aperture and field quality specifications	2 (Task 2.3)	M24	Project report
Initial models of correction systems	2 (Task 2.3)	M24	Project report
Initial estimate of machine impedance	2 (Task 2.4)	M24	Project report
Initial estimates of intensity limitations	2 (Task 2.4)	M30	Project report
Preliminary estimates of beam-beam effects.	2 (Task 2.5)	M30	Project report
Collation of data for parameter optimization.	2 (Task 2.6)	M39	Project report

Work package number	3	**Start date or starting event:**			M1
Work package title	Magnet Design					
Activity Type	RTD					
Participant number	1	2	5	15	16	17
Participant short name	CERN	CEA	INFN	KEK	BNL	FNAL
Person-months per participant:	90	48	44	72	42	18
Participant number	18					
Participant short name	LBNL					
Person-months per participant:	18					

Objectives

Task 3.1. Coordination and Communication

- To coordinate and schedule work package tasks
- To monitor work progress and inform the project management and work package participants
- To follow up the WP budget and use of resources
- To prepare internal and deliverable reports

Task 3.2. Nb_3Sn quadrupoles for the inner triplet

- Analyze the performance of existing Nb_3Sn models, in particular LARP HQ quadrupoles
- Conceptual design studies of a very large aperture option (150 mm)
- Finalize the requirements for the HL-LHC inner triplet Nb_3Sn quadrupole

Task 3.3: Separation dipoles

- Conceptual design of separation dipoles according to the specifications given by WP2 using either Nb_3Al or Nb-Ti. If a model is built, specify and follow-up the tests needed for assessing the design.
- Explore the possibility of using separation dipoles to create doglegs to increase the beam separation, thus allowing the installation of non-compact crab cavities.

Task 3.4: Cooling

- Choose the operational temperature of the inner triplet quadrupoles and of the separation dipoles. Consider and compare both the superfuid and supercritical He options.

Task 3.5: Special Magnet Studies

- Design a two-in-one quadrupole for the outer triplet (Q4-Q6) with nominal beam separation (192 mm) and aperture as large as possible (80-100 mm), satisfying the electromagnetic and mechanical requirements. Design of a two-in-one quadrupole for the inner triplet in the case of a dipole first option.
- Review the Nb-Ti option for the inner triplet considering the new targets in luminosity, and follow-up the tests of the short model built within the SLHC-PP project.
- Analysis of the expected lifetime of resistive quadrupoles in IR3 and IR7. Study of possible solutions, both resistive and superconductive, for the time scale of 2030 with a total integrated luminosity of 3000 fb^{-1}.

Description of work

Task 3.1. Coordination and Communication.

The activities of this task are for the work package coordinators [CERN and LBNL] to oversee and co-ordinate the work of all other work package tasks, to ensure the consistency of the work according to the project plan and to coordinate the WP technical and scientific tasks with tasks carried out by the other work packages when relevant. The coordination duties also include the organization of WP internal steering meetings, the setting up of proper reviewing, the reporting to the project management and the distribution of the information within the WP as well as to the other work packages running in parallel.

The task also covers the organization of and support to the annual meetings dedicated to the WP activity review and possible activity workshops or specialized working sessions, implying the attendance of invited participants from inside and outside the consortium.

Task 3.2. Nb_3Sn quadrupoles for the inner triplet

This task is intended to give a final assessment of the possibility of using Nb_3Sn quadrupoles for the LHC inner triplet and the performance parameters that can be achieved. A tentative layout with a 120 mm aperture quadrupole is given from WP2, and the necessary full list of requirements (field quality, radiation resistance, integration in the machine) should be worked out. A comparison with the present performance of the 120 mm aperture short model (HQ) magnets of LARP should be done, and iterations on the design if needed should be carried out. In particular we plan to analyze the following issues: (i) radiation resistance of all components (ii) magnet field quality and the possibility to apply corrections using magnetic shims (iii) option of splitting the magnet into two coils, with a related estimate of the loss in performance, possibly complemented by a hardware test, (iv) design of a helium containment vessel compatible with a magnet structure based on aluminum shrinking cylinder (v) magnet protection).

This task will be mainly driven by LARP collaboration (BNL, FNAL and LBNL). INFN will lead the quench protection study. CERN will participate in the studies and coordinate the efforts.

Task 3.3: Separation dipoles

The input necessary from WP2 is the needed integrated strength, a tentative lay-out, and an aperture requirement for the separation dipoles D1 and D2 used in the ATLAS and CMS interaction regions. Then, the first step is the conceptual designs of a separation dipole considering Nb_3Al or Nb-Ti conductor. Main issues as (i) field quality, (ii) peak stresses at operational field, (iii) integration in the machine, (iv) radiation resistance (v) magnet protection will be analysed. If both options are viable, the second step would be the proposal of a short model to assess the Nb_3Al technology. The third step would then be the follow-up the construction of the model, contributing to the test definition and to the analysis of the test results.

A similar type of technology would allow to further separate the LHC beams from the nominal distance of 194 mm to a wider one (400 to 500 mm). This “dogleg” is the plan B if the option of compact crab cavities is not viable. The inputs from the WP4 (crab cavities) and WP2 (beam dynamics) are the integrated field and the aperture. The task outcome is the conceptual design of a dogleg, and should strongly rely on the results of the D1-D2 programme.

This task is lead by KEK for the Nb_3Al part and by BNL for the Nb-Ti option. INFN will steer the studies on protection. CERN will participate in the studies and coordinate the efforts.

Task 3.4: Cooling

The cooling system of the Nb_3Sn inner triplet can operate either in superfluid (i.e., below 2.17 K) or in supercritical helium (i.e., above 2.17 K). Contrary to Nb-Ti magnets, Nb_3Sn can operate in supercritical helium at around 4.5 K with a limited loss in field gradient w.r.t. the superfluid option (about 10%). This would also solve the Nb_3Sn conductor instability issues that have been found by the US colleagues during the last decade.

As the heat loads envisaged today are more than one and a half order of magnitude above what is prevalent in the previous accelerators magnets designed for operation at supercritical helium (RHIC, HERA, Tevatron), it is mandatory to address the problem of cooling from the very beginning of the design of future quadrupoles.

Both the supercritical and the superfluid options should be analysed and compared. The programme can be divided into different phases: (i) analysis of heat loads and status of the different cooling scenarios (ii) principle of heat removal system, thermohydraulic simulations and first experiments (iii) validation of the system.

A similar study should be carried out for the separation dipoles.

This task is steered by CERN for the superfluid part and by CEA-Grenoble for the supercritical part.

Task 3.5: Special Magnet Studies

This task includes three different studies:

- The conceptual design of a large aperture two-in-one quadrupole for the outer triplet. The present baseline of the LHC involves 70 mm aperture magnets (MQY) whose aperture could be a bottleneck. One should explore the possibility of having two-in-one quadrupoles with apertures in the range 80-100 mm, with the same constraint of the 194 mm beam separation. Electromagnetic and mechanical aspects should be analysed. This design also applies to the option of a two-in-one inner triplet in the option of a dipole first option. This subtask is steered by CEA-Saclay.
- The analysis of the expected lifetime of the resistive quadrupoles used in the cleaning insertion (MQWA and MQWB). The first step is to have an estimate of the radiation load, together with the lifetime of the present hardware. Then solutions to extend the lifetime of present hardware up to 2030 or options to replace them will be analysed. This subtask is steered by CERN.
- The Nb-Ti option for the inner triplet is the plan B in case that experience shows that the Nb_3Sn technology is not suitable. A considerable work has been done in the SLHC-PP framework, i.e. the so-called phase I, which aimed at a peak luminosity of 2.3×10^{34} cm^{-2} s^{-1}. A short model is being built. One has to check that the Phase I scenario and lay-out is compatible with the new targets of the HL-LHC. This subtask is steered by CERN.

Deliverables

D3.1) Issues in special magnet studies: this would cover the design of the two-in-one outer triplet, solutions for the replacement of the resistive quadrupoles, and the follow-up of the Nb-Ti option for the inner triplet. (Task 3.5) [month 36]

D3.2) Design study of the Nb_3Sn inner triplet: analysis of the main issues in the magnet design, with a conceptual design of single aperture separation dipoles in Nb_3Sn. (Task 3.2) [month 48]

D3.3) Design study of the separation dipoles: analysis of the main issues in the magnet design, with a conceptual design of single aperture separation dipoles in Nb_3Al. Moreover, both single and double aperture dipoles in Nb-Ti (Task 3.3) [month 48]

D3.4) Design study of the cooling: the comparison between superfluid and supercritical options with pro and cons. (Task 3.4) [month 48]

Milestones

Milestone name	Work package(s) involved	Expected date	Means of verification
Requirements for Nb_3Sn inner triplet and	3 (Task 3.2)	M12	Report

comparison with present status of the art			
Requirements for separation dipoles	3 (Task 3.3)	M12	Report
Review of the Nb-Ti option for inner triplet for new peak and integrated luminosity targets	3 (Task 3.5)	M18	Report
Study of magnetic shimming in HQ	3 (Task 3.2)	M24	Report
Conceptual design of Nb_3Al and Nb-Ti separation dipoles	3 (Task 3.3)	M24	Report
Analysis of possible options for quadrupoles in cleaning insertions	3 (Task 3.5)	M24	Report
Study of minimal distance between two coils in a cold mass	3 (Task 3.2)	M36	Report
Conceptual design of a crab cavity dogleg	3 (Task 3.3)	M36	Report
Study of the supercritical He cooling	3 (Task 3.4)	M36	Report
Study of the superfluid He cooling	3 (Task 3.4)	M36	Report
Study of two-in-one quadrupoles for outer triplet	3 (Task 3.5)	M36	Report

Work package number	4	**Start date or starting event:**			M1	
Work package title	Crab Cavities					
Activity Type	RTD					
Participant number	1	2	3	11	12	15
Participant short name	CERN	CEA	CNRS	STFC	ULANC	KEK
Person-months per participant:	107	6	40.8	31	70.5	68.5
Participant number	16	17	18	19	20	
Participant short name	BNL	FNAL	LBNL	ODU	SLAC	
Person-months per participant:	60	12	18	48	16	

Objectives

Task 4.1. Coordination and Communication.
- Coordination and scheduling of the WP tasks
- Monitoring the work, informing the project management and participants within the JRA
- Follow up the WP budget and use of resources

Task 4.2. Support studies
- Tunnel preparation SPS and LHC
- Local IR layout and spatial integration
- Effect of phase noise, LLRF system conceptual design
- RF power system specification
- Operational aspects (how to commission/make invisible)
- Interlocks and fast Feedback

Task 4.3. Compact Crab Cavity Design
- Complete cavity and cryomodule specifications
- Design optimisation for novel schemes
- Conceptual design of SOM, HOM and LOM couplers
- Conceptual design of helium tank and cryostat
- Multipacting simulations on cavity & couplers
- FEM simulations: mechanical & thermal aspects
- Initial down-selection of the CC options
- Completion of a full technical design on the initial down-selected options, with mechanical drawings and specification.
- Design of tooling, dies and cavity fabrication equipment

Task 4.4. Elliptical Crab Cavity Technical Design
- Coupler development and testing
- Tuner design and mock up on copper models
- Study of mechanical effects: resonances, microphonics.
- Cavity performance with couplers and horizontal cryostat
- Performance difference between 2 K & 4 K
- Cryostat and He Tank Design
- Complete the full technical design

Task 4.5. Compact Crab Cavity Validation Prototyping
- Procurement / fabrication of tooling, dies and equipment
- Construction of models (in copper initially) to refine manufacturing techniques and tooling.

- Fabrication of prototype niobium cavity
- Cleaning and electro-polishing on the bare niobium cavity. (i.e. no couplers, antennas or other accessories), including cavity surface inspection
- Development and procurement of all test equipment and instrumentation
- Low power tests and measurements on the bare cavity in a test cryostat to test for compliance with design gradient and other cavity performance specs.
- Make the final CC design down-selection

Description of work

WP4 is part of a larger "Crab Cavity Project", which aims at obtaining a significant luminosity increase by installing local Crab Cavities in IR5 and IR1 as part of the luminosity upgrade planned for around 2021. To fully exploit the inner triplet upgrade, these crab cavities are needed. They are the instrument of choice both for compensation of the crossing angle and for luminosity levelling, allowing for optimum integrated luminosity during the collision run without the need of excessive peak intensities.

This project will require four superconducting Compact Cavities for each high luminosity IR, two per beam on either side of IP. At present, there are a number of proposals of possible concepts of Compact Crab Cavities; their detailed study will be part of WP4. To mitigate the risk of the not yet established technology of the Compact Crab Cavities, more conventional Elliptical Crab Cavities are another important element of the project.

The primary objective of Work Package 4 is to prepare for the construction phase of Compact Crab Cavities which should start around 2015. WP4 equally includes the Technical Design of Elliptical Crab Cavities. Prototyping and tests have been included in this design study only to the absolute minimum necessary to validate design choices.

Task 4.1. Coordination and Communication.

The activities of this task are to oversee and co-ordinate the work of all the other tasks of the work package concerned, to ensure the consistency of the WP work according to the project plan and to coordinate the WP technical and scientific tasks with the tasks carried out by the other WPs when it is relevant. The task will be executed jointly by CERN, ULANC and STFC. The coordination duties also include the organization of WP internal steering meetings, the setting up of proper reviewing, the reporting to the project management and the distribution of the information within the WP as well as to the other work packages running in parallel.

The task also covers the organization of and support to the annual meetings dedicated to the WP activity review and possible activity workshops or specialized working sessions, implying the attendance of invited participants from inside and outside the consortium.

WP4 requires coordination with other WPs on the following subjects:

- With WP2 (Accelerator Physics and Performance) on:
    - Impedance and growth rate estimates for specific HOM's to specify exact damping needs and feedback measures,
    - Effect of non-zero dispersion and stable working points,
    - Crab consistent optics,
    - Local doglegs & feedback to control beam transverse position at the location of the Crab Cavity,
    - Beam-beam simulations to investigate instabilities, noise issues and DA.
- With WP3 (Magnet Design) on:
    - The possible need of doglegs if Compact Crab Cavities are impossible (see task 3.3).
- With WP5 (IR Collimation) on:
    - Tracking simulations for loss maps for fast failure modes.

Task 4.2. Support studies

The studies will look at integration of the Crab Cavities in the accelerator tunnels, at the study of the preparation of the tunnels of both SPS (for tests) and LHC (BNL, CERN). In addition, RF studies common to Elliptic and Compact Crab Cavities will be carried out (KEK, LBNL and SLAC). This includes the study of the influence of phase noise and its reduction, along with the conceptual design of the low-level RF system. Another item is the study of the high power RF system. The conceptual study of typical necessary operational scenarios (CERN, CNRS, and ULANC) such as: how can the Crab Cavity RF system be commissioned? How can the Crab Cavity system be made "invisible" to the beam if it is not needed? How can cavity or amplifier trips be dealt with, what are the necessary interlocks and feedbacks?

Task 4.3. Compact Crab Cavity Design

For each of the proposed compact cavity topologies, the conceptual design including the power coupler as well as the wrong-order-mode couplers will be performed (STFC, ULANC, BNL, FNAL, KEK, ODU, SLAC). Coordinated by CERN, the design study will include multipacting simulations as well as mechanical and thermal stress analyses that will allow detailed definition of the structure of the cavity. Common performance specifications will keep the alternative designs directly comparable. The goal of the design study is to determine performance limitations of the various options; comparison will allow an initial down-selection, leaving at least two CC options. Complete full engineering designs follow, including drawings and specifications of the selected contenders, along with the design of necessary tooling and dies in preparation for next stage, the compact cavity prototyping (Task 4.5). A conceptual design of the helium tank and the cryostat will equally be performed (CNRS, CEA, KEK). This study will feed into task 3.3 to determine whether a dogleg (magnetic chicane) is needed or not.

Task 4.4. Elliptical Crab Cavity Technical Design

A conceptual design of an Elliptical Crab Cavity exists. Building on this, the development and testing of power couplers, design of the tuner and mock up on copper models are subject of Task 4.4 (BNL, CEA, CNRS, KEK). Also mechanical effects (resonances, microphonics) will be studied. A comparison of the performance at 2 K and 4.4 K cooling will be studied qualitatively and quantitatively in order to allow the optimum choice of the cryogenic system (CERN). The technical design of cryostat and He tank at the optimum operation temperature shall subsequently be done (CERN, CNRS). The given constraints of the LHC IR4 have to be taken into consideration (studied in Task 4.2).

Task 4.5. Compact Crab Cavity Validation Prototyping

Actual prototyping and tests of prototypes are not included in HiLumi LHC; some initial prototyping as necessary for validation of design choices is however included (CERN, KEK and ODU). This includes procurement/development of tooling, dies and other equipment needed for cavity manufacturing. If necessary, Cu models may have to be built before fabricating in niobium. Initial measurements on the cavity models and checks against the simulations and design specifications. Evaluation of measurement results will be done jointly with ULANC and STFC. Preparation of RF tests in cryogenic conditions ("Vertical Tests") to test for compliance with design gradient and other cavity performance specifications; the actual tests will not be part of the design study.

Deliverables

D4.1) Operational Scenarios: Design report detailing operational scenarios with crab cavities, weighing up the performance increase against a possibly increased LHC downtime and including trip mitigation techniques and possible commissioning strategies. (Task 4.2) [month 18]

D4.2) RF System Conceptual Design: Conceptual Design of High Power and Low Level RF systems. (Task 4.2) [month 24]

D4.3) Elliptical Crab Cavity Technical Design: Technical Design Report for an Elliptical Crab Cavity compatible with a global scheme and integration near point 4. (Task 4.1 using inputs from 4.2 and 4.4) [month 30]

D4.4) Compact Crab Cavity: Conceptual Design Report of possible Compact Crab Cavities compatible with a local scheme around the high luminosity interaction points of LHC, including the cavity geometry, sufficient suppression of wrong-order modes, the power coupler, the cryostat and the integration in the LHC. (Task 4.1 using inputs from 4.2, 4.3 & 4.5) [month 48]

Milestones

Milestone name	Work package(s) involved	Expected date	Means of verification
Machine protection concerns satisfied	4 (Task 4.2)	M6	Report
Common specifications for the alternative proposals of Compact Crab Cavity geometries	4 (Task 4.3)	M6	Performance specification document
Operational scenario during LHC ramping specified	4 (Task 4.2)	M12	Report
Initial Compact Crab Cavity down-selection, leaving at least two CC options for technical design and prototyping	4 (Task 4.3)	M28	Report indicating the remaining contenders

Work package number	5	**Start date or starting event:**		M1	
Work package title	IR Collimation				
Activity Type	RTD				
Participant number	1	7	9	14		
Participant short name	CERN	CSIC	RHUL	UNIMAN		
Person-months per participant:	123.6	38	64	58		

Objectives

Task 5.1: Coordination & Communication

- To coordinate and schedule work package tasks
- To monitor work progress and inform the project management and work package participants
- To follow up the WP budget and use of resources
- To prepare internal and deliverable reports

Task 5.2: Simulations of Beam Loss in the Experimental IRs

- Assess locations and magnitudes of beam loss in the experimental IRs for various upgrade scenarios.
- Study impact of imperfections on beam loss.
- Explore interplay of IR beam losses with machine parameters (beta*, crossing angle).
- Specify operational tolerances related to collimation and the IR upgrade.
- Define beam impact scenarios for energy depositions studies and collimator design.
- Prepare input for energy deposition studies.

Task 5.3: Simulations of Energy Deposition in the Experimental IRs

- Assess locations and magnitude of energy deposition in the IRs for various upgrade scenarios including imperfections.
- Investigate any possibly required shielding requirements.
- Provide input to collimator design.
- Prepare input for background simulations.

Task 5.4: Design of Collimation in the Experimental IRs

- Study required collimation to keep losses at the same level or below before the IR upgrade.
- Specification of collimator requirements.
- Integration of collimators, new layout and optics.
- Feed forward to simulation WPs.

Description of work

Task 5.1: Coordination & Communication

The activities of this task are for the work package coordinators [CERN, RHUL] to oversee and co-ordinate the work of all other work package tasks, to ensure the consistency of the work according to the project plan and to coordinate the WP technical and scientific tasks with tasks carried out by the other work packages when relevant. The coordination duties also include the organization of WP internal steering meetings, the setting up of proper reviewing, the reporting to the project management and the distribution of the information within the WP as well as to the other work packages running in parallel. The task also covers the organization of and support to the annual meetings dedicated to the WP activity review and possible activity workshops or specialized working sessions, implying the attendance of invited participants from inside and outside the consortium.

Task 5.2: Simulations of Beam Loss in the Experimental IRs

The upgrade of the LHC insertions for a low beta optics will change both the beam size and the available aperture in the experimental IRs. Beam loss simulations will be set up for a limited set of upgrade scenarios for evaluating proton losses after the upgrade of the LHC. Realistic imperfections will be specified and included into the studies. Various computer programmes will be used and the results compared. Some programmes include simulation of impedance effects. CERN and CSIC will use the Sixtrack/Collimation code, RHUL a GEANT-based code and UNIMAN the Merlin code. The interplay of IR beam losses with machine parameters (beta*, crossing angle) will be evaluated and operational tolerances related to collimation and the IR upgrade will be studied. This WP will also define beam impact scenarios for energy depositions studies and collimator design. The numerical computer programmes will be used to prepare input for energy deposition studies.

Task 5.3: Simulations of Energy Deposition in the Experimental IRs

Each IR upgrade scenario must be qualified in terms of energy deposition and power load on various accelerator components and infrastructure items. Detailed models will be set up for the modified IRs. Including the input from WP 5.2 energy deposition will be calculated including the impact of imperfections. Any need and effects from shielding will be studied. The energy deposition results will be used to define required input to collimator design. Particle fluxes will be recorded at well-defined interface planes to the experiments and will be provided for simulations of background in the particle physics experiments. At CERN and UNIMAN the FLUKA code and at RHUL the GEANT based code will be used. The partners will agree on the focus of work and split of the IRs to be studied. For example, a partner might be asked to study in detail IR1, while another partner focuses on IR5 and CERN is cross-checking results and consistency.

Task 5.4: Design of Collimation in the Experimental IRs

The results on beam loss and energy deposition will be used to evaluate the need for improved collimation in the experimental IRs. This WP will define the locations, materials and dimensions of collimators and absorbers in the IRs. The partners involved – CERN and CSIC – will concentrate on different IR’s, which have different space constraints. Functional collimator specifications will be provided. For existing collimators it will be decided whether they can remain in their original position of need to moved or removed. The integration of the modified collimation scheme will be addressed and any possible integration constraints will be fed back to simulation studies and the proposed solutions.

Deliverables

D5.1) Simulation models for beam loss: Set up of simulation models for beam loss halo that correctly describe the halo, the optics and the available LHC aperture after an upgrade. Some of the simulations must allow high statistics of primary beam halo (5-20M protons). (Task 5.2) [M12]

D5.2) Simulation models for energy deposition: Set up energy deposition models that correctly describe the IR1 and IR5 geometries after the upgrade. Define appropriate interfaces to experiments. (Task 5.3) [M12]

D5.3) Beam halo simulations: Simulate and compare beam loss in IR1 and IR5 for various scenarios of halo and upgrade changes. Verify that an upgrade scenario has acceptable beam loss characteristics. For the verified scenarios provide input to energy deposition and other studies (Task 5.2) [M18]

D5.4) Energy deposition simulations: Simulate and compare the local energy deposition for both upgraded IRs. If more than one qualified scenario exists, compare the different scenarios. Generate input to background studies for the experiments. (Task 5.3) [M24]

D5.5) Conceptual design IR collimation: Given the simulated halo loss and energy deposition, work out conceptual designs for upgraded IR collimation systems in IR1 and IR5. (Task 5.4) [M36]

D5.6) Technical design IR collimation: Study and simulate the conceptual solution of IR collimation for IR1 and IR5. Verify the solution versus various engineering constraints and develop it into a technical design. Iterate if needed. (Task 5.1 using inputs from 5.2, 5.3 and 5.4) [M42]

D5.7) Design report and functional specification: Provide a design report for the upgraded collimation systems in IR1 and IR5. Provide functional specifications for any additional collimators and absorbers that are required in the upgraded systems (Task 5.1 using inputs from 5.2, 5.3 and 5.4) [M48]

Milestones

Milestone name	Work package(s) involved	Expected date	Means of verification
Set up of models and implementation of upgrade optics	5 (Task 5.1 using inputs from 5.2, 5.3)	M12	Publication on web
Assessment of beam halo losses in various upgrade scenarios	5 (Task 5.2)	M18	Publication on web
Assessment of energy deposition	5 (Task 5.3	M24	Publication on web
Definition of new IR collimation solution	5 (Task 5.4)	M36	Publication in form of project report
Verification of new IR collimation solution in simulations. Possible iteration in design	5 (Task 5.1 using inputs from 5.2, 5.3, 5.4)	M42	Publication in form of project report
Final report	5 (Task 5.1 using inputs from 5.2, 5.3, 5.4)	M48	Publication on web

Work package number	6	**Start date or starting event:**		M1		
Work package title	Cold Powering					
Activity Type	RTD					
Participant number	1	5	10			
Participant short name	CERN	INFN	SOTON			
Person-months per participant:	58	22	71			

Objectives

Task 6.1. Coordination and Communication

- To define the global system taking inputs from different work-package (WP) tasks
- To coordinate and schedule WP tasks, to monitor work progress and inform the project management and WP participants
- To follow up the WP budget and use of resources
- To prepare internal and deliverable reports

Task 6.2. LHC Cryogenics: Cooling and Operation

- To study different cooling options within the LHC cryogenic system
- To define cryogenic interfaces with the other system components
- To elaborate the optimized flow-scheme
- To define cryogenic requirements and components for operation and protection

Task 6.3. Electrical transfer and cryostats: thermo-electrical and mechanical models

- To study the thermal and electrical performance of the superconducting components in steady state and in transient conditions
- To study and define requirements for quench protection of superconducting components
- To design a cryostat for the operation of the current leads

Task 6.4. Energy deposition and material studies

- To calculate maps of energy deposition from collision debris and beam losses
- To calculate the induced radiation on the cold powering components
- To study the potential effect of radiation on advanced superconducting materials

Description of work

Task 6.1. Coordination and Communication.

The activities of this task are for the WP coordinators [CERN, INFN] to oversee and co-ordinate the work of all the other tasks in the WP7, to ensure the consistency of the work according to the project plan and to coordinate the WP technical and scientific tasks with other tasks carried out within other work packages when relevant. The coordination duties also include the organization of WP internal steering meetings, the setting up of proper reviewing, the reporting to the project management and the distribution of the information within the WP as well as to the other work packages running in parallel.

The task includes the coordination of the global cold powering system taking into account inputs from the different work packages and from parallel activities on the cold powering strictly related to LHC machine and carried over within separate working groups.

The task also covers the organization of and support to the meetings dedicated to the WP activity review and possible activity workshops or specialized working sessions, implying the attendance of invited participants from inside and outside the consortium.

Task 6.2. LHC Cryogenics: Cooling and Operation

The activities of this task are concentrated on the study of the cryogenic cooling to be adopted for the different electrical components of the cold powering system. The task covers a study on the availability and on the supply of the helium cryogen at appropriate temperature and pressure levels, and the definition of the requirements for control and operation. A study on space requirements and components integration in the LHC is also performed in collaboration with Task 6.1 and task 6.3.

CERN will lead this activity, which is strongly related to the LHC cryogenic system, and SOTON will participate in the work.

Task 6.3. Electrical transfer and cryostats: thermo-electrical and mechanical models

The task covers the study of the thermal and electrical performance of the multi-circuit superconducting long transfer line, cooled by supercritical helium, both in steady state and in transient conditions. Different types of advanced conductors are analyzed - MgB_2, BSCCO 2223 and YBCO - as well as different types of coolants – liquid helium, supercritical helium in a variable temperature range and liquid nitrogen. The study of heat transfer in supercritical helium will be supported by experimental tests. The effect of the electrical insulation around the cables on the heat transfer is analyzed. Quench propagation in superconducting cable systems cooled by supercritical helium is studied with the final goal of identifying the requirements for the protection of long multi-circuit high-current cables. The aim is to propose quench protection and detection strategies to avoid any degradation. The study of the behaviour during restive transition includes the analysis of potential thermal and/or electrical interference between cables belonging to different circuits and incorporated in the same cryogenic envelope. Experimental work will be needed for the validation of the theoretical modelling. Modelling codes will be elaborated for the analysis of the thermo-electrical performance.

The task includes the conceptual design of a cryostat optimized for the operation of the current leads feeding via the superconducting transfer line the magnet system. SOTON will lead this activity, with contributions from CERN.

Task 6.4. Energy deposition and material studies

This task is focused on the study of the energy deposition on cryogenic components. The activity aims at the calculation of the maps of energy deposition from particle debris at the positions where the components of the cold powering system will be located. The goal is to study the potential impact on the superconducting components and the consequent requirements in terms of maximum operating temperature. The task also covers aspects of induced radiation to be taken into account for repair and/or maintenance interventions. Calculations of fluencies and energies of particles are also needed to study the potential effects on superconducting materials.

The effect of radiation on superconducting materials potentially used in the cold powering system (MgB_2, YBCO and BSCCO 2223) is also studied.

The task is coordinated by INFN Institute of Milano, with contributions from CERN.

Deliverables

D6.1) Preliminary report on cooling options for the cold powering system: list of cooling options with advantages and disadvantages of different solutions. (Task 6.1) [month 18]

D6.2) Preliminary report on results of thermo-electrical studies: first analysis of performance of cables operating in transient mode and cooled with different coolants. (Task 6.3) [month 24]

D6.3) Preliminary report on energy deposition calculations: first results of energy deposition studies on different components of the cold-powering system (Task 6.4) [month 30]

D6.4) Cryogenic scenarios and flow scheme for the cold powering system: the cryogenic cooling options and the flow diagram are described in a document (Task 6.1) [month 36]

D6.5) Thermo-electrical studies: detailed study of thermo electrical performance is described in a document and modelling codes are made available (Task 6.3) [month 42]

D6.6) Energy deposition studies: the results of the energy deposition studies are summarized in a report together with the studies performed on the radiation properties of superconducting materials (Task 6.4) [month 42]

D6.7) Cryostat drawings and report: Conceptual drawings of cryostat and report on cryostat thermal and electrical functionalities (Task 6.3) [month 45]

D6.8) Final design report: final design report with design of the cryostat incorporating the current leads and report on thermal performance (Task 6.3) [month 46]

Milestones

Milestone name	Work package(s) involved	Expected date	Means of verification
Cryogenic scenarios	6 (Task 6.2)	M18	Preliminary Report
Thermo-electrical models	6 (Task 6.1 using input from 6.3)	M24	Preliminary Report
Energy deposition	6 (Task 6.4)	M24	Preliminary Report
Cryogenic scenarios	6 (Task 6.1 using input from 6.2 and 6.3)	M30	Report
Cryostat for current leads	6 (Task 6.3)	M40	Report
Thermo-electrical models and cryostat conceptual design	6 (Task 6.3)	M42	Report and Codes
Energy deposition studies	6 (Task 6.4)	M42	Report
Material studies	6 (Task 6.4)	M44	Report

1.3.7. Work Packages not directly supported by the EC

The following Work Packages are part of the High Luminosity Large Hadron Collider (HL-LHC) project, but are not part of the FP7 design study (HiLumi LHC).

WP7 Machine Protection

The LHC must be protected in all phases of operation from injection to collisions, which requires a large and highly redundant machine protection system (MPS). For HL-LHC, a number of its components must be improved or renewed.

The impact of new magnets/electrical circuits must be evaluated in terms of reaction time for beam loss monitor response and orbit changes. The criticality of electrical circuits with respect to machine protection depends on circuit time constants (L/R), power converter ramp rates (dI/dt) and on the local optical functions. The local beam optics also has an influence, and the large betatron function of HL-LHC in the region of the triplets enhances the criticality of certain circuits. Collaboration with WP5 will evaluate the aperture limits to ensure their proper protection, in particular for super-conducting elements. The phase space coverage of the collimators must be verified. Coherence of collimation and absorber settings (injection, dump) must be ensured. The failure modes of crab cavities must be studied in detail (time constants, beam excursions etc). Specifications for the speed of interlocks must be given both for internal interlocking of crab cavities and for beam parameter monitoring. The need for upgrades of the LHC beam dumping system must be evaluated, especially if beam intensity will reach the so-called ultimate value or beyond.To protect the LHC against failures occurring over a single turn (injection, extraction) a number of passive protection are installed in the LHC. The need for upgrades of those devices and for additional protection devices must be studied and evaluated. The total intensity and bunch structure changes may require additional diagnostics or interlocks to protect the HL-LHC or to enhance the redundancy of interlocks, in particular in view of the possible installation of fast crab cavities. HL-LHC may require modifications to the safe parameters and flags used for interlocking and may also require modifications of the interlocking logic within one of the protection systems of the LHC.

WP8 Collider-Experiments Interface

This work package will evaluate the inherent constraints on beampipe design for various options for the high luminosity insertions at HL-LHC. It will take into account physics requirements at the interaction point and in the forward region along with LHC machine constraints. Mechanical, electromagnetic and vacuum calculations will be performed to verify the viability of various design options. It will also evaluate via simulations the fluence, dose rate, integrated dose and activation to be expected in various regions of the experimental cavern, for the principal HL-LHC design options being considered and for various shielding configurations. The backgrounds and particle fluences induced in triggering, monitoring and physics detectors for various modes of HL-LHC operation will be evaluated, taking into account both routine operations and various pathological conditions.

For the luminosities expected at HL-LHC, the effect of beam-induced radiation upon the detectors and materials which may be deployed in the experimental areas will be determined to inform the choice of detector technologies, and the design of shielding. Magnetic fields and forces affecting various parts of the experiment structure, detectors and ancillary systems, will be calculated based on various designs of the HL-LHC experimental insertion and on various compatible mechanical and shielding structures for the experiments. Practical shielding configurations will be designed and analysed based upon radiation calculations, and taking into account the radiation tolerance of equipment and the calculated magnetic fields and forces. Instrumentation suitable for monitoring beam conditions in experiments at HL-LHC, including instantaneous backgrounds, fluences, dose-rates and luminosity, along with integrated doses and integrated luminosity will be designed and prototyped.

WP9 Cryogenics

In order achieve the HL-LHC goal of running at an average luminosity 5×10^{34} $cm^{-2}s^{-1}$, the cryogenic infrastructure for the magnet cooling will have to be adapted along several lines.

Generic Underground Cryogenic Distribution: Changes in the accelerator optics layout will impact strongly on the individual magnets installed in the matching sections (MS), requiring as well adaptation of the cryo-line (QRL) and of the remote magnet powering via superconducting links.

Specific cryogenic cooling capacity upgrades: The radio frequency particle accelerating cavities (RF-cavities) function presently at saturated helium temperatures (4.5 K), and draw their cooling from the same refrigerator source as the whole 3.3 km long magnet sector they belong to. When going to high luminosities this sharing of cooling resources can no longer be maintained and a dedicated Cryo-plant for RF in Point 4 (see Fig. 1.6) of about 5-7 kW @ 4.5 K needs to be installed. The challenge will be to reach an extremely stable vapour pressure by installing a cold-box as close as possible near the RF-cavities in a confined underground space. Additionally studies need to be done for possibly using the same refrigerator for cooling so-called “crab-cavities” which rotate the high energy particle bunches for optimal luminosity.

The high luminosities will increase thermal load on the magnets near the interaction points (IPs). At present these magnets share the cooling resources with the 3.3 km long magnet sector they belong to, a situation which cannot be maintained. Therefore new Cryo-plants in the collision points P1 and P5 (Fig. 1.6) of about 2-4 kW per IP need to be installed. Besides the obvious benefit of increased cryogenic power, this will allow complete separation of the cryo-infrastructures of the arc and of the triplet magnets, with big operational advantages (e.g. completely independent cool-down and warm-up).

WP10 Energy deposition and shielding

The HL-LHC luminosity goals pose various challenges that come from the increased radiation environment. Many magnets and equipments in the vicinity of the beam collision or beam service points, see Fig. 1.6, will suffer from this increased radiation level, part from the debris and part from the primary beam: the energy deposition and the power must be carefully evaluated for proper functionality of the magnets (induced quench) and the damage/destruction limit must also be properly predicted. In addition, the cryogenic system capacity has to suit the total power absorbed by the cold masses, which scales proportionally to the peak luminosity as well. Moreover, dedicated protection devices (like the TAS and the TAN) and local shielding must sustain the induced thermomechanical stress. On the other hand, the 3000 fb^{-1} goal of integrated luminosity represents a quite demanding requirement in terms of lifetime of several components (superconducting cables, insulators, instrumentation, electronics, ...), defined by the dose and the radiation fluence to which materials are exposed.

In order to face such challenges, contributing to the machine design optimization and preventing critical showstoppers, radiation-matter interaction simulations, as accurate as possible, are essential, and imply the detailed modelling of the whole areas of interest as well as the proper characterization of the relevant source terms, including beam losses in addition to beam-beam collisions. The energy deposition studies will feed into almost all working packages: WP1 (for safety: use of the same modelling and type of calculation), WP2 (for optics and positioning of various elements), WP3 (for magnets stability and protection), WP5 (the energy deposition by beam losses are part of the design of the collimators themselves, see task 5.3), WP6 (Stability and protection of the sc link, part of task 6.3 given the important implication on its design), WP11 (11 T dipole for dispersion suppressor); WP12 (Integration).

WP11 11 T dipole two-in-one

The present collimation system will probably not be sufficient to handle the beam intensity beyond 40% of design value, thus limiting the LHC luminosity to 20% of the design value. For this reason new 4-m long collimators need to be inserted in the continuous cryostat (Dispersion Suppression region, DS). The first implementation (in the two DS around P3, see Fig. 1.6) will happen in 2013, see Fig. 1.4, and the only solution to fit them inside the cryostat is to displace some 32 cold equipments: among them 24 heavy superconducting magnets, all needing to be removed from the tunnel and then re-installed.

However, for future implementation, which will most probably be necessary for luminosity levels above the design value, another possibility will be exploited: replacing two 8 T 15-m long dipoles with two 11 T, 11-m long new dipoles, avoiding the magnet displacement. This requires Nb_3Sn technology, very similar to that of the quadrupole triplet. The design of these magnets will be done in parallel with, and will largely profit from, the design of magnets within WP3. Would the design and R&D phase be successful, four or eight of these magnets will be installed in the shutdown of 2016 (see again Fig. 1.4). The magnets must be very similar to the LHC ones since they must fit in the continuous cryostat and must be powered in series with the LHC dipole line. Use of cryo-collimators (working at 50-70 K) would allow the interface to be minimized and would eliminate the cold-warm transition in a critical zone (the solution for IP3 features warm collimators and needs such transitions). Most probably the 11 T will be first Nb_3Sn magnet to be installed in the LHC and will constitute an ideal preparatory test for the even more challenging triplet quadrupole magnets. This WP features a strong partnership between CERN and FNAL, who will also lead the construction of the first single bore model in its laboratory.

WP12 Integration and (de-)installation

HL-LHC naturally inherits procedures and tools developed for the LHC, include an efficient Change Control procedure that provides a smooth and coherent evolution of the “Parameters and Layout” and of the “Hardware Baseline”, which together form the unique and non-ambiguous reference description of the LHC at a given time.

Integrated System Engineering and systematic Technical Reviews, both internal and external, will be enforced whenever strategic decisions must be taken. Both require a complete view of the impact of installing new equipment, important due to the unprecedented complexity of the system and the restricted tunnel space. The integration process proved to be an essential milestone to decide changes in the LHC layout, it provides the necessary inputs for sound scheduling and costing of these changes. HL-LHC benefits from well accepted integration procedures and tools extensively used during LHC preparation, installation and commissioning phases. The process starts with digital models for every component that needs installing in a given area. Storage and change control of all the underlying information and drawings are done with the CERN Engineering & Equipment Data Management System (EDMS) that is systematically used to trace the project baseline evolutions, to follow the procurement and installation of the machine elements (via the Manufacturing and Test Folder – MTF) and to resolve the eventual non-conformities. In addition, to check that the model provides a proper representation of the installed machine, point-clouds from real measurements obtained with a laser scanner can be superimposed onto 3D integration models. These features are important assets when dealing with large system evolution such as the HL-LHC upgrades: a precise knowledge of the environment is essential during the design phase to minimize conflicts between equipment during installation; it allows optimizing the intervention in the field, with a precise identification of the parts that need to be de-installed or modified. Such optimizations are mandatory in activated areas where it must be proven that doses received during any intervention are under control and have been minimized according to the ALARA principle.

1.3.8. Summary effort table

Table 1.3 e: Summary of staff effort

The table below shows the person months over the whole duration of the project (4 years). The person months of the work package coordinators are highlighted in bold.

Participant no./short name		WP 1	WP 2	WP 3	WP 4	WP 5	WP 6	Total person months
1	CERN	**114**	**101**	**90**	**107**	**123.6**	**58**	593.6
2	CEA	0	24	48	6	0	0	78
3	CNRS	0	0	0	40.8	0	0	40.8
4	DESY	0	12	0	0	0	0	12
5	INFN	0	67.2	44	0	0	**22**	133.2
6	BINP	0	65	0	0	0	0	65
7	CSIC	0	24	0	0	38	0	62
8	EPFL	0	48	0	0	0	0	48
9	RHUL	0	0	0	0	**64**	0	64
10	SOTON	0	0	0	0	0	71	71
11	STFC	0	28	0	31	0	0	59
12	ULANC	0	0	0	**70.5**	0	0	70.5
13	UNILIV	0	**34.8**	0	0	0	0	34.8
14	UNIMAN	0	34.8	0	0	58	0	92.8
15	KEK	0	19.2	72	68.5	0	0	159.7
16	BNL	0	14.4	42	60	0	0	116.4
17	FNAL	4	56.64	18	12	0	0	90.64
18	LBNL	4	48	**18**	18	0	0	88
19	ODU	0	0	0	48	0	0	48
20	SLAC	4	14.4	0	16	0	0	34.4
	Total	126	591.44	332	477.8	283.6	151	1961.84

1.3.9. Risks and contingency plans

HL-LHC has a very high-level goal. Many processes or new equipment proposed for the Design Study are at risk: innovative technologies have an intrinsic element of risk. Designing for 3000 fb^{-1} , which is almost a factor of a thousand higher than the integrated luminosity provided by all hadron colliders built so far, and a factor 5-10 higher than the LHC original design, is risk in itself. The beam quality required for HL-LHC has never been reached or designed in synchrotron light-less accelerators. Nobody has ever used Nb_3Sn in an accelerator. Crab cavities have never been proposed for proton colliders. Collimators sets (around 50, about 1 m long) with dynamic precision with beam at ten µm level are also a step beyond. Cryogenic DC power lines operating at 0.15 GW (designed at up to 1 GW transient) 3-600 m long and with a 100 m height jump were not seriously considered until recently.

The strategy to assure reaching the goal is basically to have an alternative solution, perhaps less effective but still acceptable, for each of the main hardware and processes. The difficulty will be producing a set of coherent parameters for each of the cases of missing performance, still maintaining the goal of 5×10^{32} cm^{-2} s^{-1} with levelling and 3000 fb^{-1}. For example if crab cavities will fail there are two schemes (each one with its drawbacks) to compensate this. If Nb_3Sn is not suitable for accelerators as demanding as the LHC, a lesser solution based on Nb-Ti will be adopted, with compensatory measures to regain performance.

A table of key risks per work package is given below.

Work Package	**Key risk**	**Likelihood**	**Impact**	**Mitigation strategy**
WP1	Change of management team personnel during the project	Medium	Low	Many competent project members allow for replacements to management to be found within consortium if necessary
	Unilateral withdraw of key partner(s).	Low	Medium	Other partners will take over responsibility and, ultimately, CERN management, endorsed by CERN council, will find the necessary resources to compensate. The net effect will be some delay.
WP2	Divergence of optics and layout solutions.	Low	Medium	Review options early in the design study and implement a review board for the continuous monitoring of the optics and layout options.
	Incompatibility of required performance levels with technical feasible upgrade options (e.g. desired minimum beta functions at the Interaction Points versus acceptable chromatic aberration values and the required mechanical triplet aperture and long range beam-beam interactions).	Medium	Medium	Review the potential performance reach of the various design options of the design study early on and implement a review board for the continuous evaluation and monitoring of the performance reaches of each upgrade option and the consistency of their proposed machine parameters.
WP3	Non feasibility of separation dipoles with Nb_3Al coils	High	Low	A plan B option with Nb-Ti is studied as well.
	Non feasibility of inner triplet quadrupoles with Nb_3Sn coils, due to: (i) lack of field quality (ii) lack of radiation resistance (iii) lack of magnet performance	Medium	(i) Low (ii) Medium (iii) High	(i) An approach based on magnetic shimming is studied (ii) Radiation resistance requirements have to be established at the beginning of the study and checked on available models as soon as possible. (iii) The plan B option with Nb-Ti done

				within SLHC-PP is followed up.
WP4	Technical problems in realizing novel Compact Cavity (CC) designs in SCRF technology that can operate reliably at the required gradient	Medium	High	1) Taking several CC designs (two at least) to the bare cavity prototype test stage. 2) Maintain a conventional elliptical cavities back-up solution that can be reverted to if none of the compact designs reach spec.
	Unforeseen fundamental LHC machine operation issues that would delay, degrade or prevent operation with beam	Low	High	Full test of crab cavity in SPS before installing CCs in the LHC
WP5	Different results from various computer programmes used in partner institutes	Medium	Low	Additional work will then be invested in analysis and improvement of the physics models in the computer programmes. The number of simulated upgrade scenarios must then be reduced.
	Much higher simulated losses in the experimental IR's after an upgrade.	Medium	High	Much higher losses will impose either in change in upgrade concept or a major change in IR collimation. Work effort will then be diverted on finding a conceptual solution, probably reducing the manpower available for energy deposition studies.
WP6	Delay in design study, which would imply a delay in the following prototyping activity	Medium	Medium	Close monitoring of progress so that corrective actions can be taken if necessary
	Identification of critical aspects of the system design leading to major complications requiring changes in the design concept	Medium	High	Regular evaluation of progress with adaptation in the approach to reach the final goal

2. Implementation

2.1. Management structure and procedures

2.1.1. Rationale

The proposed FP7 Design Study (HiLumi LHC) concerns an ambitious luminosity upgrade of CERN's flagship machine, the LHC. Today, CERN is truly a world laboratory in terms of the participation in its scientific programme. Half the number of the particle physicists involved in the LHC experiments and using the LHC itself come from Non-Member States worldwide. The CERN Council wishes therefore to see this global makeup reflected in the way that the LHC upgrade is organized.

The management structure (see Fig. 2.1) and procedures defined below establish clear responsibilities, decision-making and reporting. They are the fruit of CERN's extensive experience in successfully organizing and managing very large and complex projects, such as the LHC. Inspiration has been provided by the management principles of the LHC experiments ATLAS and CMS, organized as separate joined ventures, each involving some 160 participating institutes and over 2,000 scientific staff, with recognized success. Te management structure and procedures will also integrate the experience gained by CERN in coordinating other FP7 projects, such as SLHC-PP and EuCARD.

The cost of HiLumi LHC (including the parts that will be funded by the US and Japanese partners) represents about 50% of the costs of the HL-LHC Design Study as a whole, and close to 100% of its collaborative content. It is understood that the remaining 50% of the HL-LHC Design Study are tasks to be carried out mainly by CERN, as the owner and operator of the LHC machine. They largely concern the upgrade of existing CERN service infrastructures and other activities specific to CERN as a host laboratory.

The proposed HiLumi LHC management structure and procedures set out below therefore cover the entire HL-LHC Design Study. The proposed architecture may also serve as a model for organizing future accelerator projects.

2.1.2. Management structure and responsibilities

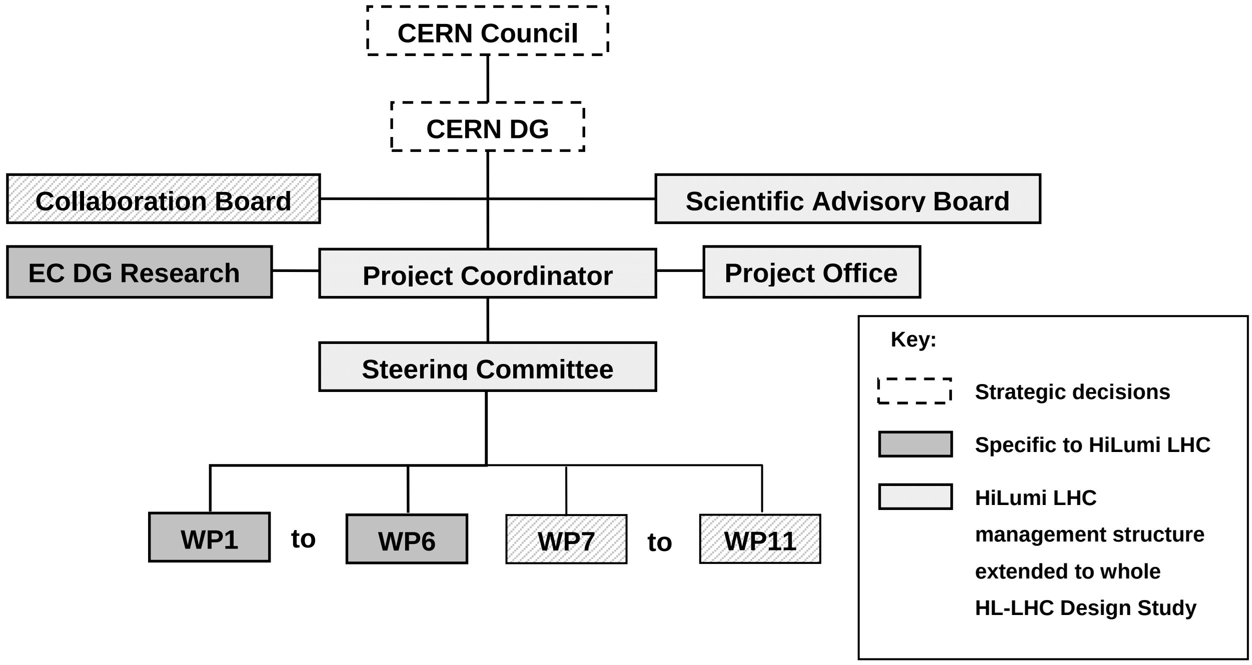

Figure 2.1: Management structure of HiLumi LHC and its extension to the HL-LHC Design Study as a whole

WP#	Title	HL-LHC Design Study
1	Project management and Technical Coordination	HiLumi LHC
2	Accelerator Physics and Performance	
3	Magnet Design	
4	Crab cavities	
5	IR Collimation	
6	Cold Powering	
7	Machine Protection	Not within HiLumi LHC
8	Collider-Experiment Interface	
9	Cryogenics	
10	Energy deposition and shielding	
11	11 T dipole two-in-one	
12	Integration and (de-)installation	

Key components of the management structure and responsibilities:

- Single governance model for the HL-LHC Design Study, rooted in HiLumi LHC, making use of successful collaborative models already implemented at CERN, ATLAS and CMS;
- Participation by all partners, including non-European partners, in the management and decision-making;
- Optimized communication between all the WPs, inside as well as outside HiLumi LHC;
- Open architecture: new WPs may be integrated without requiring modification of HiLumi LHC;

- CERN Council retains responsibility for the overall scientific strategy and the scientific programme of CERN;
- The CERN Director-General, as the Organization's executive, is responsible for ensuring consistency of the HL-LHC Design Study, including HiLumi LHC, with the overall scientific strategy and scientific programme approved by the CERN Council;
- Maximization of individual and collective competence, and continuous rejuvenation through rotating appointments.

CERN Council

The Council is the supreme decision making body of CERN. The CERN Council is responsible for defining the overall scientific strategy and the scientific programme of the Organization, including the luminosity upgrade of the LHC. In this capacity, the Council shall regularly review and update the HL-LHC Design Study. Through the Director-General of CERN, who is also a member of the Collaboration Board, there will be an ongoing dialogue between the HL-LHC Design Study partners and the Council, in this process.

CERN Director-General

As mentioned, the Director-General is CERN's executive and therefore prepares and executes decisions by the Council. As far as the HL-LHC Design Study is concerned, he/she will ensure that it complies with the Council decisions and, at the same time, that there is an ongoing dialogue between the HL-LHC Design Study partners and the Council and that respective concerns are addressed in a timely manner. The Director General will report and make recommendations for implementation to the Council, on the basis of the results of the HL-LHC Design Study. He/she appoints the Project Coordinator and may call for external reviews.

Collaboration Board (CB)

The CB is the top-level decision-making and arbitration body of the HL-LHC Design Study. It shall meet at least once a year and more often upon request by its chair, the Director-General of CERN, the SC, the Project Coordinator or any of the WP Coordinators.

All partners shall be represented in the CB, with voting rights. CERN shall be represented by its Director-General. The CB shall elect its chair from among its members for a two-year term, renewable once. The Project Coordinator and his/her deputy(ies) shall be ex officio members of the CB, without voting rights.

A limited number of representatives of the LHC user community (including in particular of the ATLAS experiment and the CMS experiment) and the chair of the Scientific Advisory Committee (SAC) shall also be represented in the CB, without voting rights.

The voting rules will depend on the type of decision concerned, and shall be set out in the Consortium Agreement. Consensus shall be sought whenever possible and appropriate. For voting specifically related to HiLumi LHC, only the parties to the HiLumi LHC grant agreement shall be entitled to vote.

The CB shall review work progress, including deliverables, and shall decide on modifications to the work programme or the allocation of the EC funding, on the accession and withdrawal of partners as well as on default and termination. It shall arbitrate on issues that are not resolved at lower level.

Where CERN considers that a decision by the CB regarding the HL-LHC Design Study concerns a matter that falls within the mandate of the CERN Council, such matter shall take the form of a recommendation to the CERN Council. The CERN Director General shall inform the CB of decisions taken by the CERN Council following such recommendations.

The CB shall make a proposal to the Director-General for a candidate for the position of Project Coordinator (as from the completion of his/her first two year term). It appoints the WP coordinators, on the proposal by the Project Coordinator. The CB shall appoint the members of the SAC and calls for SAC meetings. It may call for external reviews.

Upon completion of the HL-LHC Design Study, the CB shall prepare recommendations to the CERN Council on the implementation of its results.

Scientific Advisory Committee (SAC)

The SAC is an advisory body to the CB.

The SAC members shall be recognized experts that do not participate in the HL-LHC Design Study. They shall be appointed by the CB for a two-year term, renewable. The head of the LHC Physics Centre shall be an ex-officio member.

The SAC shall advise the CB on a regular basis on all scientific matters related to the LHC luminosity upgrade. The SAC shall elect its chair for a two-year term. He/she shall attend CB and SC meetings as an advisor only.

Steering Committee (SC)

The SC is the executive body of the HL-LHC Design Study and as such will be responsible for the coordination and management of the WPs. It shall meet at least four times a year, and as often as felt necessary.

The SC shall be composed of the Project Coordinator and his/her deputy(ies), the Administrative Manager as well as the WP coordinators and their deputies.

The SC's responsibilities shall include monitoring and reviewing work progress, deciding on technical and administrative matters and consolidation of reports received from the WP coordinators. The SC, together with the Project Coordinator, shall manage the quality assurance programme of the FP7 DS. The SC may, via the Project Coordinator, make proposals to the CB concerning modifications to the work programme or to allocation of EC funding, on the accession and withdrawal of partners as well as on default and termination.

The voting rules will depend on the type of decision concerned, and shall be set out in the Consortium Agreement. For voting specifically related to HiLumi LHC, only the coordinators of the WPs that form a part of the HiLumi LHC grant agreement shall be entitled to vote.

The SC may call for internal or external reviews.

Project Coordinator

The Project Coordinator (PC) is appointed by the Director General of CERN for two years, renewable. He/she is responsible for the management and coordination of the HL-LHC Design Study and, in this capacity, he/she will follow up on milestones and deliverables, and monitor the use of resources. The PC will chair and organize the SC meetings.

The PC shall be responsible for the preparation of periodic reports as well as the final report to the EC. He/she shall report on work progress to the CB and to the Director General of CERN.

He/she will appoint the task leaders, on the proposal by the WP coordinators and on approval of the SC.

Together with the SC, the PC will manage the quality assurance programme of HiLumi LHC.

He/she shall organize internal and external reviews upon request of the CB or the SC or at his/her own initiative. As the coordinator of WP1, the PC will have the duties described in the WP1 work programme, notably dissemination and links to industry.

The PC shall be assisted by one or several deputies and an Administrative Manager, all appointed by him/her, and by a Coordination Office:

- The Deputy Project Coordinator(s) shall assist the PC in the daily execution of his/her tasks.
- The Administrative Manager (AM) shall be responsible for the distribution of the EC funding and the collection of certificates on financial statements, periodic reports and justifications of costs. He/she will monitor the application of gender equality practices in conformity with the European Charter and Code of Recruitment of Researchers.
- The Coordination Office shall provide support regarding planning, budget, administration and legal aspects, including the associated software tools. Professional support shall also be provided by the following CERN services: Resources Planning and Control, Finance and Accounting, Knowledge and Technology Transfer and the Legal Service.

Work Package (WP) Coordinators

Each WP shall have two coordinators, one from CERN and one from another partner (with the exception of WP1). They shall be appointed by the CB, on the proposal by the PC, for a term of two years, renewable.

The WP coordinators shall coordinate WP activities. They shall ensure the effective cooperation between the participants in their WP, monitor the progress of the work in their WP and review milestones and deliverables. They shall contribute to the preparation of all periodic and final reports concerning their WP.

Task Leaders

The task leaders are appointed by the PC, on the proposal by the WP coordinators and on approval of the SC, for a term of two years, renewable.

They shall lead and coordinate the technical activities related to their task. They shall ensure the effective cooperation between the participants in their task, monitor the progress of the work and review milestones and deliverables. They shall contribute to the preparation of all periodic and final reports regarding their tasks.

2.1.3. Decision-making principles

- A plenary annual meeting of all participants in the HL-LHC Design Study will be held each year. This will be a major event for dissemination, information on technical achievements, critical reviews, as well as an opportunity to collectively address outstanding organizational issues. This meeting shall include special sessions for the CB and SC meetings. It will be hosted by a different partner each year.
- Responsibilities and procedures for decision-making have been described in section 2.1.1 above. The detailed voting rules will depend on the type of decision concerned and shall be set out in the Consortium Agreement. Key elements regarding decision-making are:
    - Through the Director General of CERN, who is a member of the CB, there will be an ongoing dialogue between the partners of the HL-LHC Design Study and the CERN Council;
    - The SC shall prepare decisions by the CB through appropriate proposals.
    - Where a decision regarding the HL-LHC Design Study falls within the mandate of the CERN Council, the decision of the CB shall take the form of a recommendation to the CERN Council;
    - Thorough high-level external reviews shall efficiently prepare the decision-making in a transparent and objective manner;

  - Technical decisions may be made by the SC;
  - Day-to-day management decisions may be taken by Project Coordinator, WP coordinators or the task leaders.
- Management procedures of the partners, including of the US and Japanese partners, shall be taken into due account in the administrative management of HiLumi LHC.

Internal reporting procedures

Reporting procedures concerning the use of resources and scientific/technical progress, from the partners and work package coordinators to the project coordinator and collaboration board, will be specified in the Consortium Agreement.

2.2. Individual participants

Full name of participant: European Organization for Nuclear Research	**1**
Short name of participant: CERN	
Description of participant: CERN is the world's largest particle physics centre and operates the world's largest complex of particle accelerators. The 55-year history of CERN is marked with impressive achievements in the construction and operation of powerful linear and circular accelerators. At the end of 2009, CERN brought into operation the Large Hadron Collider (LHC). 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. CERN has experience in managing the largest world accelerator infrastructures and by its very nature of International Organization the expertise in leading large-scale collaborations involving a large number of institutes from all over the world. CERN has a long and solid experience in the EU Framework Programmes and the CERN administrative, legal and financial services are competent to process all issues the consortium may have to face, including at the highest political level if required. Over several decades, CERN has developed and maintained leading expertise in various fields, in particular accelerator physics, radio frequency cavities, magnet design, beam collimation and superconducting technologies. CERN will actively participate in all Work Packages and will be the coordinating laboratory of the HL-LHC project.	
Tasks in HiLumi LHC • **WP1**: Project management (tasks 1.1 and 1.6) and technical coordination (tasks 1.2, 1.3, 1.4, 1.5) of HiLumi LHC project. • **WP2**: Coordinate (task 2.1), contribute to optics and lattice files (task 2.2), particle simulations (task 2.3) and beam-beam effects (task 2.5). • **WP3**: Coordinate (task 3.1), contribute to all studies (tasks 3.2, 3.3, 3.4, 3.5). • **WP4**: Coordinate (task 4.1), contribute to all studies (tasks 4.2, 4.3, 4.4, 4.5). • **WP5:** Coordinate (task 5.1), contribute to all studies (tasks 5.2, 5.3, 5.4). • **WP6:** Coordinate (task 6.1), contribute to all studies (tasks 6.2, 6.3, 6.4).	
Short CV for the key persons: • **Prof Lucio Rossi:** Magnets, Cryostats and Superconductors Group Leader and Deputy Head of CERN Technology Dept. At University of Milan until 2001, responsible for first LHC	

superconducting dipole prototype, superconductor and magnet development for ATLAS LHC experiment. Leader of LHC main superconducting magnets construction (~1 B€). Broad expertise in magnet design, technologies and applied superconductivity. 2007 IEEE-Council of Superconductivity Award for sustained and significant contribution to Applied Superconductivity field. Project coordinator and WP1 coordinator.

- **Dr. Oliver Bruning:** Studied Physics at University Hamburg in Germany and University of Berkeley in Ca, USA. Joined CERN in 1995 and contributed to LHC conceptual design studies, quality assurance during installation and commissioning preparation. Head of CERN Accelerator and Beam Physics group since 2005. CERN link person for Accelerator Studies to USLARP programme. Deputy project coordinator and WP2 coordinator.
- **Ezio Todesco:** From 1989 to 1997 worked on LHC single particle beam dynamics. Joined Main Magnet and Superconductors Group in 1998 to follow up field quality in main LHC dipoles and quadrupoles. Started work on LHC upgrade in 2005. Since 2008 in charge of LHC magnetic model and closely follows behaviour of magnets during first phases of beam commissioning. WP3 coordinator.
- **Dr. Erk Jensen:** PhD from TU Hamburg-Harburg in 91. Expert in power RF systems and currently Deputy Group Leader of CERN RF group and Section leader for Synchrotrons RF and CLIC RF structures. Interests include High Power, High Efficiency RF systems, advanced acceleration techniques and computational methods for field simulations. Leads EuCARD WP “NCLinac”. WP4 coordinator.
- **Dr. Ralph Assmann:** PhD from Ludwigs-Maximilian-University Munich, supported by Max-Planck-Institute for Physics, Werner-Heisenberg-Institute scholarship. Post-doc and staff at SLAC in US from 1994 to 1998. At CERN since 1998, currently Senior Physicist, LHC collimation Project Leader, LHC Machine Coordinator and Deputy EuCARD coordinator. WP5 coordinator**.**
- **Dr. Amalia Ballarino:** Responsible for development, design and procurement of more than 1,000 CERN LHC High Temperature Superconducting current leads, received award “Superconductor Industry Person of The Year 2006”. Developing novel bus system incorporating high-current High Temperature Superconducting (HTS) cables. EuCARD High Tc link (task 7.5) coordinator. WP6 coordinator.

Full name of participant: Commissariat à l'Énergie Atomique et aux énergies alternatives — **2**

Short name of participant: CEA

Description of participant:

CEA is the leading French organisation for research, development, and innovation in the fields of energy, defence, information technologies, communication and health. The IRFU institute of CEA, based at Saclay, performs research on the fundamental laws of the Universe, including Particle Physics, Nuclear Physics and Astrophysics.

DSM is the ‘Directorat’ (about 1,700 permanent staff) of CEA, involved in various kinds of physics and associated technologies. Within CEA-DSM, IRFU (Institut de Recherche sur les lois Fondamentales de l'Univers) with about 120 permanent staff, will be the main contributor to HiLumi LHC, with the contribution of SIS (Structure engineering and instrumentation department).

Tasks in HiLumi LHC

- **WP2**: Contribute to the optics design (task 2.2).
- **WP3**: Analyse cooling system with supercritical helium (task 3.4) and study conceptual design of large aperture two-in-one quadrupole (task 3.5).

- **WP4**: Participation in the conceptual design of a helium tank and cryostat (task 4.3), follow-up of development and testing of power couplers and tuners (task 4.4).

Short CV for the key persons:

- **Antoine Dael:** Graduated Diplôme d'Ingénieur de l'Ecole Supérieure d'Electricité (Paris) in 1970. Currently Head of CEA Saclay accelerator, cryogenics and magnetism division (130 people). Previous experience includes leader of ATLAS barrel toroid from 1994 to 2001, Project leader of the SMC experiment, high homogeneity solenoid magnet and dipole magnet for the polarized target from 1989 to 1993.
- **Florence Ardellier:** Graduated with Mechanical Engineer diploma from UTC (Université de Technlogie de Compiègne) in 1994. Since 2008 Head of IRFU Engineering Division (SIS). From 2004 to 2008 Technical coordinator of reactor Neutrino experiment (Double Chooz). From 1999 to 2004 Responsible of Optical Modules development for ANTARES telescope deployed in sea at 2500 m depth.
- **Jean-Michel Rifflet**: Graduated with Engineer diploma of ENSAM (Ecole Nationale Supérieure des Arts et Métiers) in 1980. Since 2002 Head of IRFU/SACM/LEAS (superconducting magnets laboratory). From 1989 to 2002 responsible of study, prototyping and industrialization of cold masses of main LHC quadrupoles. Responsible for CEA/Saclay part of French LHC contribution.
- **Jacques Payet:** Engineer, specialist in charged particle beam dynamics at CEA – Saclay DSM/IRFU/SACM. Activities include design of particle accelerators, beam transfer lines and particle beam analysis equipments for fundamental physics (ESRF, SOLEIL, S3 etc). Involved in scientific projects in international frame (ELFE@CERN, EURISOL/Beta-beam, EuroNu).
- **Stéphane Chel:** PhD in Accelerator Physics and Technology, 20 years at CEA-Saclay. Superconducting RF cavities expert, participated in design and qualification of accelerator systems (e.g. MACSE, SOLEIL, SUPER-3HC). Head of accelerating structures and RF systems group (SACM/LESAR). Led team delivering cryomodule TDR and qualified QWR prototype in SPIRAL2 project. CARE WP leader, EuCARD task leader, ILC-Higrade rep.

Full name of participant: Centre National de la Recherche Scientifique	**3**

Short name of participant: CNRS

The Centre National de la Recherche Scientifique (National Centre for Scientific Research) is a government-funded research organization, under the administrative authority of the French Ministry of Research. CNRS' annual budget represents a quarter of French public spending on civilian research. As the largest fundamental research organization in Europe, CNRS carries out research in all fields of knowledge, through its ten research institutes.

IN2P3 is the CNRS National Institute of Nuclear Physics and Particle Physics. IN2P3 devotes itself to research in the physics of the infinitely small, from the atomic nucleus down to the elementary particles, and in the physics of the infinitely large, to study the composition and evolution of the Universe. The objectives are to determine matter's most elementary constituents and understand their interactions, and to understand the structure and properties of nuclei. It participates to the development and test of radiofrequency cavities ("crab cavities") required for the LHC luminosity increase, by improving the factor of merit at the collision point.

The laboratory mainly involved in HiLumi LHC is the Laboratoire de Physique Subatomique et de Cosmologie (LPSC – UMR5821) jointly held by CNRS/IN2P3 and Université Joseph Fourier Grenoble 1 (UJF). This laboratory contributes to the IN2P3 Physics programme (nuclear physics, hadron physics, cosmology, astroparticle and particle physics). Its "particle accelerator" group is involved in the EUROTRANS project (GENEPI1&2 and GUINEVERE machines), the SPIRAL2 project (radiofrequency couplers) and the French contribution to LHC. It has been involved in medical accelerator projects like ETOILE and CNAO (Italy) and high power linear accelerators (IPHI). It has been involved in the FP6 CARE/HIPPI programme (work package coordination on normal conducting structures).

CNRS will represent the Université Joseph Fourier Grenoble 1 (UJF) via the special clause 10 which shows the participation of the latter in the project as member of the above-mentioned JRU.

Tasks in HiLumi LHC

- **WP4**: Leading role in the conceptual design of a helium tank and cryostat (task 4.3), participation in the study of operational scenarios with crab cavities (task 4.2), and in the development and testing of power couplers (task 4.4).

Short CV for the key persons:

- **Jean-Marie De Conto**: Accelerator Physicist at LPSC in Grenoble and University Professor at UJF Grenoble. Graduated from the Ecole Supérieure d'Electricité and "HDR" (Habilitation à Diriger des Recherches) from the UJF. Joined CNRS in 1989 and UJF in 2005. Expert on accelerator design and beam dynamics. Member of the Comité National de la Recherche Scientifique. Received the "Cristal du CNRS" award in 2004.

Full name of participant: Deutsches Elektronen-Synchrotron	**4**

Short name of participant: DESY

Description of participant:

DESY is a German research centre for High Energy physics, synchrotron light and FEL physics. DESY has a long lasting experience in accelerator design and operation such as HERA, PETRA, DORIS and FLASH. Superconducting magnets and cavities were developed for the storage ring HERA, FLASH and XFEL. FLASH is the most advanced SASE FEL infrastructure and serves also as unique test bed for superconducting RF technology. The approved XFEL project with its 800 superconducting 1.3 GHz cavities will be the largest superconducting RF accelerator for the near future. PETRA III is one of the most brilliant storage ring-based sources of X-ray radiation in the world. As the most powerful light source of its kind, it offers scientists outstanding experimental opportunities with X-rays of an exceptionally high brilliance.

The development, construction and operation of accelerator facilities of particle accelerators involve special challenges for both humans and machines. Over 50 years DESY has accumulated vast experience of accelerator development, construction and operation, and is one of the world's leading authorities in this field. Large high-energy accelerators for particle physics research were in operation at DESY until 2007, the last one being the unique super electron microscope HERA. Wide-ranging international cooperation has a long tradition at DESY. Today, physicists at DESY contribute their expertise to a range of large international facilities, in particular to the experiments at the world's most powerful accelerator, the Large Hadron Collider LHC in Geneva, and to the development work for the planned International Linear Collider ILC.

Tasks in HiLumi LHC

- **WP2**: Impedance calculations and evaluation of electron cloud effects (task 2.4).

Short CV for the key persons:

- **Rainer Wanzenberg**: Graduated with Ph.D. in Physics in 1990 from the University of Hamburg. Since 1992 has been an Accelerator Physicist at DESY. Main research interest is wakefields and collective effects, has been recently mainly working for PETRA III.
- **Olga Zagorodnova**: Graduated with a Diploma in Applied Mathematics in 1993 from

Moscow State University. Since 2005 has been a Research Associate at DESY, working for Impedance models of PETRA III and the XFEL.

Full name of participant: Istituto Nazionale di Fisica Nucleare	**5**
Short name of participant: INFN	

Description of participant:

The INFN - the National Institute of Nuclear Physics - is the major Italian research organization dedicated to the study of the fundamental constituents of matter, and conducts theoretical and experimental research in the fields of subnuclear, nuclear, and astroparticle physics. Fundamental research in these areas requires the use of cutting-edge technologies and instrumentation, which the INFN develops both in its own laboratories and in collaboration with the world of industry. These activities are conducted in close collaboration with the academic world. The INFN workforce includes about 2,000 of its own employees, almost 2,000 university employees involved in research conducted by the Institute, and 1,300 young researchers, including undergraduate and graduate students and research fellows. Researchers are grouped in 19 units and 4 National Labs, providing a significant and relevant contribution since 1951 to the advances in Nuclear and Sub-nuclear physics, all over the world.

The involved units and National Labs are as follows:

INFN-LNF: Laboratori Nazionali di Frascati

Frascati National Laboratories is the biggest INFN research structure dedicated to nuclear and subnuclear physics studies with charged particle accelerators. LNF has a long tradition in design, construction and operation of electron-positron accelerators and colliders. The main LNF infrastructure is the DAΦNE accelerator complex consisting of a linear accelerator, an intermediate damping/accumulator ring and two intersecting main rings. DAΦNE is the electron-positron collider that works at the energy of Φ-resonance at 1.02 GeV c.m. ("Φ-factory"). Since 2000 it has been delivering luminosity for several physics experiments: KLOE, FINUDA, DEAR and SIDDHARTA. A wide spectrum of experiments is also being carried out at the DAΦNE beam test facility (BTF), a dedicated beam line providing electron and positron beams in the energy range 25-725 MeV with intensities varying from a single electron to 100 mA in short pulses from 1 to 10 nsec. 3 separate beam lines are used in DAΦNE for synchrotron radiation studies extracting photons from wiggler and dipole magnets. Recently SPARC linear accelerator has been successfully commissioned at Frascati. This 150 MeV electron accelerator with a photo injector provides high brightness beams to drive several FEL experiments as well as tests of new acceleration techniques. The LNF Accelerator Division participates in numerous international accelerator projects and collaborations such as ILC, CLIC, CTF3, SuperB, CNAO etc. Scientific activities of LNF cover many fields of research: high energy physics, nuclear physics, astrophysics, theoretical physics, technological research, synchrotron radiation. Frascati physicists participate in experiments at CERN, SLAC, FNAL, DESY, TJNAF, LNGS, VIRGO and other Italian and international laboratories.

INFN-MI: Milano Research Unit, LASA *(Laboratorio Acceleratori e Superconduttività Applicata).*

LASA was established in the 80's to accomplish the design, realization and test of the K800 Superconducting Cyclotron, now in operation at LNS (INFN premises near Catania, Italy).

Since then, LASA has conducted mainly technological research aimed to the application of superconductivity to subnuclear and nuclear physics, giving major contributions to the development and construction of superconducting magnets for accelerators (LHC) and detectors (ATLAS toroidal magnet), and superconducting cavities for particle accelerators (TESLA and

XFEL).
Tasks in HiLumi LHC • **WP2**: INFN-LNF: IR4 optics design (task 2.2), Monte Carlo tracking studies (task 2.3), estimate impedance of new components of upgrade options and IBS growth rates for different beam parameters (task 2.4), calculate bunch-by-bunch orbit variations (task 2.5). • **WP3**: INFN-MI: Lead quench protection study (task 3.2) and studies on separation dipole protection (task 3.3). • **WP6**: INFN-MI: Coordinator (task 6.1), leading energy deposition and material studies (task 6.4).
Short CV for the key persons: • **Mikhail Zobov** (INFN-LNF)**:** Graduated from Moscow Engineering Physics Institute in 1983 and defended his Ph.D. thesis on beam dynamics in high intensity ion linacs in 1989. Since 1991 working in Accelerator Division of LNF INFN (Frascati, Italy) participating in design, commissioning and operation phases of e+e- Φ-factory DAΦNE. Responsible for beam dynamics studies at DAΦNE for many years. • **Giovanni Volpini** (INFN-MI): PhD in Physics from University of Milan in 1993; since then worked on development of first long prototypes of LHC dipoles, built within a collaboration between CERN and INFN, to the realization of the ATLAS toroidal magnet at CERN. Now completing development of the first model of the pulsed dipole for the SIS300 synchrotron at FAIR GSI. Has led the Superconducting Magnet Group at LASA since 2002. • **Francesco Broggi** (INFN-MI): At INFN since 1987. Worked on current leads system for a superconducting cyclotron, on superconducting magnets (SM) diagnostics (ATLAS Barrel Toroids and prototypes), on SM characterization and instrumentation, energy deposition in low-β LHC inner triplet in actual and possible future layouts. Involved in CERN Superconducting Irradiation Test project to evaluate degradation of Nb_3Sn under radiation. WP6 coordinator.

Full name of participant: Budker Institute of Nuclear Physics	**6**
Short name of participant: BINP	
Description of participant: BINP (Novosibirsk) was established in 1958 with the main research directions included HEP, accelerator physics (e+e- colliders mainly), thermonuclear physics, SR generation and utilization, etc. Nowadays the following facilities are in operation at BINP: e+e- colliders VEPP-4M (energy up to 6 GeV) and VEPP-2000 (round beams, energy 1 GeV), FEL with the world record power in the THz radiation region, SR source VEPP-3, two open traps for plasma researches. The total staff of BINP now is around 3,000 including 1000 workers and engineers in a workshop equipped by modern technologies to manufacture wide range of accelerator equipment.	
Tasks in HiLumi LHC • **WP2:** Generate optics and lattice files for 2-in-1 Nb-Ti and Nb_3Sn magnet solutions (task 2.2), radiation and heat deposition studies (task 2.3), and evaluation of compensation schemes for head-on beam-beam interactions (task 2.5).	
Short CV for the key persons: • **Eugene Levichev:** BINP Deputy Director responsible for the accelerator research direction. Expert in the field of accelerator development and operation, beam optics and dynamics	

study.

Full name of participant: Consejo Superior de Investigaciones Cientificas	**7**
Short name of participant: CSIC	
Description of participant: The CSIC is a Spanish laboratory having a long-standing reputation in theoretical and experimental physics. From the experimental point of view, it has expertise in the design and construction of detectors and beam instrumentation for nuclear, medical and particle physics. CSIC is the largest public multidisciplinary research organization in Spain. It has 116 institutes or centres distributed throughout Spain. There is also a delegation in Brussels. IFIC is a Nuclear and Particle Physics institute where ongoing research activities include experimental and theoretical work with application in near-term and far-future projects. The institute has been participating in leading particle physics experiments since 1950 when it was founded. It has a long tradition on detector development and computing for HEP. The group participating in the project has been involved in collider experiments (DELPHI, ATLAS) and neutrino experiments (NOMAD, HARP, K2K and T2K)	
Tasks in HiLumi LHC • **WP2**: Generate optics and lattice files for single bore Nb-Ti magnet solutions (task 2.2), Monte Carlo tracking studies (task 2.3). • **WP5**: Simulations of Beam Loss in experimental IRs using Sixtrack/collimation code (task 5.2), design of collimation in the experimental IRs (task 5.4).	
Short CV for the key persons: • **Angeles Faus-Golfe:** Research Scientist at IFIC-CSIC since 2007, currently in charge of the Accelerator Physics group at IFIC. Main expertise includes design optics for experimental insertions and beam dynamic non-linear studies; non linear collimation system for circular and linear colliders; beam instrumentation design and construction.	

Full name of participant: Ecole Polytechnique Fédérale de Lausanne	**8**
Short name of participant: EPFL	
Description of participant: Swiss Federal Institute of Technology in Lausanne (EPFL) is one of the leading institutions of higher learning worldwide. Particle Accelerator Physics Laboratory (LPAP) research projects are carried out at major accelerator facilities. At the Paul Scherrer Institute (PSI) the laboratory is engaged in development of novel bright synchrotron light sources, including the future X-Ray Free Electron Laser SwissFEL. High intensity proton beams are used to produce powerful sources for neutron scattering and bright muon beams. Developments of accelerator applications for life sciences include hadron therapy of tumors and coherent X-ray sources for phase-contrast imaging. Projects at CERN include work on future upgrades of LHC and associated accelerators, as well as research and development towards the future high energy frontier electron-positron linear collider.	
Tasks in HiLumi LHC	

- **WP2**: Study options for correcting chromatic aberrations (task 2.2), evaluate compensation schemes for head-on beam-beam interactions (task 2.5).

Short CV for the key persons:

- **Leonid Rivkin:** Professor of Accelerator Physics at EPFL and Head of Large Research Facilities Department at Paul Scherrer Institute. Graduated with BA in Physics from Harvard University in 1978 and PhD in Physics from California Institute of Technology in 1985. Ten years at Stanford Linear Accelerator Center on various accelerator projects including PEP and SLC, followed by twenty years at PSI, including B-factory projects and Swiss Light Source.

Full name of participant: Royal Holloway, University of London	**9**

Short name of participant: RHUL

Description of participant:

RHUL is a research-led multi-faculty higher education institute within the federal University of London; its performance in the latest UK wide Research Assessment Exercise placed it 9th nationally, with its physics department scoring a grade 5 for research. RHUL is part of the John Adams Institute for Accelerator Science (JAI), which was established in 2005 as a partnership between RHUL, Oxford University and the UK Science and Technology Facilities Council.

The key strategic aim of the JAI is to develop a Centre of Excellence in the UK for advanced and novel accelerator technology providing expertise, research, development and training in accelerator techniques, and promoting advanced accelerator applications in science and society. RHUL are leaders in advanced beam diagnostics, including laser-based systems and cavity BPMs; they are also leaders in advanced simulation techniques and radiative processes with a growing new programme of RF simulation and accelerator cavity tests.

Tasks in HiLumi LHC

- **WP5**: Coordinator (task 5.1), LHC Collimation simulation and optimization (tasks 5.2 and 5.3).

Short CV for the key persons:

- **Grahame Blair:** Professor of Particle Physics and leader of Centre of Particle Physics at RHUL. Principal Investigator of the UK LC-ABD accelerator programme in the UK. Work package leader of the Beam Diagnostics work package in EUROTeV and the NCLINAC work package within EuCARD. Member of the Steering Committee of the DITANET Marie Curie ITN and local project manager at RHUL. WP5 coordinator.

Full name of participant: University of Southampton	**10**

Short name of participant: SOTON

Description of participant:

The University of Southampton is one of the top 15 research universities in the UK and has achieved consistently high scores for its teaching and learning activities. It combines academic excellence with an innovative and entrepreneurial approach to research, supporting a culture that engages and challenges students and staff in their pursuit of learning.

The Institute of Cryogenics at University of Southampton has been for more than 15 years an active player in HTS applications with a cumulated funding of more than 5 M€ from governments and industry.

It has worked closely with CERN on the successful HTS current leads project for LHC, involving in the design/manufacture of prototypes and the full cryogenic tests for all of the 600 A assemblies.

Tasks in HiLumi LHC

- **WP6**: participate in study of cryogenic cooling (task 6.2) and lead study of thermal and electrical performance of multi-circuit superconducting long transfer line (task 6.3).

Short CV for the key persons:

- **Professor Yifeng Yang:** Director of Institute of Cryogenics at SOTON, working on applied superconductivity and cryogenic for more than 20 years. Led UK research councils (EPSRC/TSB) and FP7 projects on HTS superconducting generators, HTS AC losses, HTS current leads prototypes and tests for CERN, 20T+ superconducting magnet system with HTS high field inserts. Developed close collaboration with industry e.g. Rolls Royce, Edison, Columbus Superconductor, and Oxford Instruments.

Full name of participant: Science & Technology Facilities Council	**11**

Short name of participant: STFC

Description of participant:

The Science and Technology Facilities Council is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide.

The Council operates world-class, large scale research facilities and provides strategic advice to the UK government on their development. It also manages international research projects in support of a broad cross-section of the UK research community.

The Council also directs, coordinates and funds research, education and training.

Tasks in HiLumi LHC

- **WP2:** Provide estimates for Intra beam Scattering (task 2.4), study crab cavity beam-beam compensation scheme (task 2.5), evaluate beam parameter values and luminosity optimization (task 2.6).
- **WP4:** Contribute to coordination (task 4.1), participate in compact crab cavity design (task 4.3), and validation prototyping (task 4.5).

Short CV for the key persons:

- **Deepa Angal-Kalinin**: Accelerator Physics group leader in ASTeC Department at STFC. Experience in lattice and optics design and beam dynamics in a variety of accelerators, including microtron, storage rings for light sources, straight and re-circulating linac for next generation light sources and beam delivery system for future lepton colliders. Has worked at Daresbury Laboratory since 2002.
- **Peter McIntosh**: RF and Diagnostics group leader in ASTeC Department at STFC. Experience in both normal conducting and superconducting RF system design for a variety of particle accelerators, which have included; SRS, 4GLS, NLS, ALICE, EMMA, ILC, CLIC, PEP-II and SPEAR3. Worked at Daresbury Laboratory since 1987, while also working at SLAC from 2001 – 2005.
- **Bruno Muratori**: Senior accelerator physicist in the Accelerator Physics group in ASTeC department at STFC. Experience in lattice and optics design in a variety of accelerators including novel non scaling FFAG. Expertise in beam-beam effects and luminosity in

colliders. Fellow at CERN before joining Daresbury Laboratory in 2003.

- **Philippe Goudket**: RF Scientist in the RF and Diagnostics group in ASTeC Department at STFC. Experience of RF structure design and characterisation, receiving Ph.D from Lancaster University in 2004 working on multipactor breakdown processes in the Cornell SRF accelerating cavities. Worked at Daresbury Laboratory since 2000 contributing to ILC crab cavity, NLS cavity and cryomodule and EMMA RF cavity developments.

Full name of participant: University of Lancaster	**12**

Short name of participant: ULANC

Description of participant:

Lancaster University is approaching its 50th anniversary with a world-class reputation as a centre for excellence in teaching, scholarship and research. Currently ranked as a top 10 UK university and in the top 125 universities in the world, Lancaster continues to sustain its reputation for teaching and research excellence both nationally and internationally.

The High Power Microwave group in the Engineering Department is one of the only particle accelerator engineering groups in the UK. The group is a member of the Cockcroft Institute for Accelerator Science and Technology.

The High Power Microwave Group and the Cockcroft Institute both have strong collaborative links with other universities and research organisations around the world.

Tasks in HiLumi LHC

- **WP4**: Coordinator (task 4.1) and participant in studies (tasks 4.2, 4.3, 4.5).

Short CV for the key persons:

- **Graeme Burt:** Lecturer in RF Engineering in the Engineering department at Lancaster University. Joined the Cockcroft Institute in 2004 to study the crab cavity for the International Linear Collider. Experience in RF cavity design and specialises in crab cavities. Designed crab cavities for the International Linear Collider and the Compact Linear Collider (CLIC) and has led the initial UK cavity design work for LHC. WP4 coordinator.
- **Amos Dexter:** Senior Lecturer in RF Engineering in the Engineering department at Lancaster University. Experience in RF Engineering and designed the low level RF systems for the crab cavities for both the ILC and CLIC. Experience developing codes for electromagnetic computation. Worked for Lancaster University and Capenhurst.
- **Christopher Lingwood:** Research Associate in RF Engineering in the Engineering department at Lancaster University. Completed a PhD in Klystron design for CLIC at Lancaster University. In the last 12 months working on crab cavity design and multipactor simulations and has contributed to the initial design work on the LHC crab cavity.

Full name of participant: University of Liverpool	**13**

Short name of participant: UNILIV

Description of participant:

The University of Liverpool is one of the UK’s top 20 research-led universities. It has 21,000 students pursuing over 400 programmes in 54 subject areas. The Particle Physics Group in the Department of Physics is one of the largest such groups in the UK, with over 50 staff members.

The group has access to exceptional facilities including the Liverpool Semiconductor Detector Centre, large scale, high performance computing, and the Cockcroft Institute for Accelerator

Science and Technology.

The Particle Physics Group and the Cockcroft Institute both have strong collaborative links with other universities and research organisations around the world.

Tasks in HiLumi LHC

- **WP2**: Coordinator (task 2.1) and participant in studies (tasks 2.2 and 2.3)

Short CV for the key persons:

- **Andrzej Wolski:** Reader in Accelerator Science in the Department of Physics at UNILIV. Experience in lattice and optics design and beam dynamics in a variety of accelerators, including storage rings for light sources and colliders, and had a leading role in the R&D programme for damping rings for International Linear Collider. Worked at Daresbury Laboratory in UK, and at Lawrence Berkeley National Laboratory in US. WP2 coordinator.
- **Kai Hock:** Lecturer in Accelerator Science in the Department of Physics at the University of Liverpool. Joined the Cockcroft Institute in 2006 to study collective effects in the International Linear Collider damping ring. Currently works on beam tomography for EMMA accelerator at Daresbury. Experience developing codes for electromagnetic computation.
- **Maxim Korostelev:** Research Associate in Department of Physics at UNILIV. Received PhD in 2006 from École Polytechnique Fédéral de Lausanne, working at CERN on optics design and performance of an ultra-low emittance damping ring for CLIC. Since 2006, has worked at Cockcroft Institute, developing skills in modelling accelerator impedance and beam instabilities, contributing to the optics design for the Large Hadron-electron Collider (LHeC).

Full name of participant: University of Manchester	**14**

Short name of participant: UNIMAN

Description of participant:

The University of Manchester is the largest research-led university in UK, a member of the Russell Group of universities, with strong established programmes in particle physics, astrophysics, cosmology, accelerator physics and nuclear engineering through the Cockcroft Institute and the Dalton Institutes.

It has broad physics and technology base in high power microwave structures, RF structures and cavities, fixed-field alternate gradient synchrotrons, accelerator-driven sub-critical reactors, and particle beams for cancer therapy.

In Univ. of Manchester-CI, there are four academics, five post-doctoral fellows and many PhD students.

Tasks in HiLumi LHC

- **WP2:** Generate optics and lattice files for single bore Nb-Ti and Nb_3Sn magnets with local crab cavities (task 2.2), specify the required corrective circuits (task 2.3).
- **WP5:** Simulations of Beam Loss in experimental IRs using Merlin code (task 5.2), simulations of energy deposition using FLUKA code (task 5.3).

Short CV for the key persons:

- **Robert Appleby:** Beam physicist and lecturer at University of Manchester, and a staff member of the Cockcroft Institute. Experience of hadron and electron machine optics and beam dynamics, particle shower + background formation and computational physics.

Full name of participant: High Energy Accelerator Research Organization	**15**
Short name of participant: KEK	
Description of participant: Established in 1997, KEK, the High Energy Accelerator Research Organization, is one of the world's leading accelerator science research laboratories, using high-energy particle beams and synchrotron light sources to probe the fundamental properties of matter. With state-of-the-art infrastructure, KEK is advancing our understanding of the universe that surrounds us, its mechanisms and their control. Over 600 scientists, engineers, students and staff perform research activities on the Tsukuba and Tokai campuses. KEK have the largest experience in the domain of crab cavities. They have already tested elliptical cavities with crab function on a 4 GeV electron-positron collider. In the field of magnet design, KEK is currently exploring the potential of a novel Nb_3Al superconductor (a less developed variant within the same family as Nb_3Sn), which can be extremely useful for recombination dipoles near collisions.	
Tasks in HiLumi LHC • **WP2**: Accelerator beam dynamics: Theory, simulation, and code development for various beam dynamics (tasks 2.3, 2.5). • **WP3**: Superconducting magnet technology: Cryogenics Science Center is willing to be involved in design work of high field superconducting magnets under high mechanical stress and high radiation environment (task 3.3). • **WP4**: Superconducting crab-cavity technology: R&D of compact crab cavities and related components for HiLumi LHC, including tests using KEKB crab cavities if necessary (tasks 4.2, 4.3, 4.4, 4.5).	
Short CV for the key persons: • **Katsunobu Oide**: Graduated with Ph.D. in Physics from Tokyo University in 1980. Joined KEK in 1981, becoming Associate Professor in 1989 and Professor within the Accelerator Division in 1997. In 2001 became Head of Division II (KEKB), and in 2009 Director of KEK Accelerator Laboratory. Involved in KEK-PS, TRISTAN, JLC/NLC, FFTB, KEK-ATF, KEKB, ILC projects. Expert in Beam dynamics, accelerator design & development. • **Katsuo Tokushuku**: Graduated in 1988 with a Ph.D. in Nuclear Physics from Tokyo University. Joined KEK in 1998. Currently Professor at KEK and ATLAS-Japan co-leader. Research activities include ZEUS experiment mainly on trigger and QCD analysis, ATLAS experiment on trigger. CERN LHCC member from 2000 to 2003, and CERN Science Policy Committee (SPC) member since 2009. • **Akira Yamamoto**: Began at KEK in 1977, working on superconducting magnets for particle accelerators and detectors. In 1983, receive Doctor of Science Degree (Univ. of Tokyo); Scientific associate at CERN from 1987 to 1988, working for the LHC accelerator magnets. Became Professor of KEK Cryogenics Centre in 1996, and in 2003 Head of KEK Cryogenics Science Centre.	

Full name of participant: Brookhaven National Laboratory	**16**
Short name of participant: BNL	
Description of participant:	

Established in 1947 on Long Island, Upton, New York, Brookhaven is a multi-program national laboratory operated by Brookhaven Science Associates for the U.S. Department of Energy (DOE). Seven Nobel Prizes have been awarded for discoveries made at the Lab.

Brookhaven has a staff of approximately 3,000 scientists, engineers, technicians and support staff and over 4,000 guest researchers annually.

Brookhaven National Laboratory's role for the DOE is to produce excellent science and advanced technology with the cooperation, support, and appropriate involvement of the scientific and local communities.

This multidisciplinary laboratory has expertise in all accelerator-related disciplines.

Tasks in HiLumi LHC

- **WP2:** Monte Carlo tracking studies (task 2.3), calculations of bunch-by-bunch orbit variations (task 2.5).
- **WP3:** Work within LARP to demonstrate Nb_3Sn technology for IR Upgrade magnets and, if demonstration is successful, to produce IR quadrupoles with Nb_3Sn conductor (tasks 3.2 and 3.3).
- **WP4:** Coordinate the crab cavity R&D within LARP and play a significant role in the development and construction of compact crab cavities for LHC luminosity upgrade (tasks 4.2, 4.3 and 4.4).

Short CV for the key persons:

- **Peter Wanderer:** Graduated with Ph.D. in Elementary Particle Physics (experimental) from Yale University in 1970. Staff scientist at Brookhaven, working on superconducting magnets since 1978. Became head of Magnet Test Group in 1983. Co-chair (with Steve Peggs) of RHIC Magnet Acceptance Committee during 1990s. Head of Superconducting Magnet Division since 2006. LARP Magnet Leader 2007-9. Currently APUL Project Manager.
- **Rama Calaga:** Graduated in 2006 with Ph.D. in Accelerator Physics (experimental) from Stony Brook University. LARP-TooHigh fellow 2006-08, associate accelerator physicist at BNL. Started work on superconducting RF technology and beam dynamics for RHIC collider. LARP long term CERN visitor for LHC commissioning in beam physics and crab cavity upgrade studies. LARP liaison for accelerator systems and task leader for crab cavity R&D.

Full name of participant: Fermi National Accelerator Laboratory (Fermilab)	**17**

Short name of participant: FNAL

Description of participant:

Fermilab is funded by the US Department of Energy (DOE) and is the premier high energy physics lab in the country. The lab began operation in 1972 with a fixed target programme utilizing protons from the 400 GeV Main Ring. The Fermilab Tevatron, which first saw proton-antiproton collisions in 1985, was the world's first superconducting collider. It remained the highest energy collider until the 2009 start of the LHC, and the collider experiments remain the centrepiece of the physics programme, which is complemented by an extensive neutrino programme.

In addition to the local physics programmes, Fermilab has been a very active participant in the LHC from the beginning. The lab has played a major role in the CMS experiment, and together with KEK, designed and built the final focusing quadrupoles for the accelerator. As a member of the LARP collaboration, Fermilab has made numerous other contributions to the LHC accelerator, and is a key collaborator in Nb_3Sn R&D for future upgrades.

Tasks in HiLumi LHC

- **WP1**: Contribute to HiLumi LHC management through the LARP programme (task 1.5).
- **WP2**: Beam-beam, coherent effects, and crab cavity simulations, as well as contributing to optical design (tasks 2.3 and 2.5).
- **WP3**: Through LARP, design and test large aperture, Nb_3Sn magnets (task 3.2).
- **WP4**: Compact crab cavity design (task 4.3).

Short CV for the key persons:

- **Eric Prebys** (USLARP)**:** Graduated in 1990 with a PhD from the University of Rochester. CERN Fellow on the Opal Experiment from 1990-92. From 1992 to 2001: RA and assistant professor at Princeton University, SSC, Belle Experiment and studies of high field QED at SLAC. Joined Fermilab in 2001, former head of Proton Source, current head of LARP. Collaborator on Belle and Mu2e experiments.
- **Vladimir Shiltsev:** Graduated with a PhD in Accelerator Physics in 1994 from BINP. Joined Fermilab in 1996, Tevatron Department Head from 2001 to 2005. Since 2007, founding Director of Fermilab's Accelerator Physics Center. 2004 European Accelerator Prize winner from European Physical Society; American Physical Society Fellow. Research interests in accelerator physics and technology, experimental and theoretical beam dynamics in highest energy accelerators (circular and linear). Author of more than 200 papers.

Full name of participant: Lawrence Berkeley National Laboratory	**18**

Short name of participant: LBNL

Description of participant:

Lawrence Berkeley National Laboratory was the first national laboratory and is operated for the US Department of Energy under contract by the Regents of the University of California. The Lawrence Berkeley National Laboratory was founded by Ernest Orlando Lawrence on the Berkeley Campus of the University of California in 1931. It provides national scientific leadership and technological innovation to support the DOE's objectives. The Laboratory's employee population is approximately 3600.

Berkeley Lab's mission includes the following: to perform leading multidisciplinary research in the energy sciences, general sciences and bio-sciences; to develop and operate unique national experimental facilities (including the Advanced Light Source Center, the National Energy Research Supercomputing Center, the National Center for Electron Microscopy, and the 88-Inch Cyclotron) that are available to qualified scientific investigators; to educate and train future generations of scientists and engineers; and to transfer knowledge and technical innovations between LBNL research programmes, universities and industry to promote national economic competitiveness.

Tasks in HiLumi LHC

- **WP1:** Contribute to HiLumi LHC management through the LARP programme (tasks 1.1, 1.2 and 1.3).
- **WP2:** Evaluations of compensation schemes for long-range beam-beam interactions (task 2.5) and beam parameter and luminosity optimization (task 2.6).
- **WP3:** Coordinator (task 3.1), Nb_3Sn quadropoles for the inner triplet (task 3.2).
- **WP4:** Crab cavity RF studies (task 4.2).

Short CV for the key persons:

- **Steve Gourlay:** Graduated with HEP Ph.D. from University of California, Davis in 1985. Joined Fermilab Advanced Magnet R&D Group in 1988. Head of Fermilab Superconducting Magnet Group in 1995, working on development of high gradient LHC quadrupoles. CERN Scientific Associate 1996-7 then joined LBNL. Head of Superconducting Magnet R&D

Group 2001-5 working on high field Nb_3Sn dipoles; head of LARP magnet activities 2003-6. Since 2006 Director of LBNL Accelerator and Fusion Research Division.

- **GianLuca Sabbi**, Graduated with Doctoral Degree in 1995, with thesis on CERN's LEP beam instabilities. Associate Scientist at Fermilab Head from 1996 to 2000, contributing to development of MQXB IR LHC quadrupoles. Joined LBNL in 2000 to participate in high field accelerator magnet development using advanced superconductors such as Nb_3Sn and HTS. Currently head of LBNL Superconducting Magnet Program and leads LARP magnet R&D component**.** WP3 coordinator.
- **John Corlett:** Head of AFRD Center for Beam Physics.

Full name of participant: Old Dominion University, Center for Accelerator Science	**19**
Short name of participant: ODU	
Description of participant:	
The Center for Accelerator Science at Old Dominion University is a joint initiative and partnership between ODU and Jefferson lab to advance the state of the art in accelerator science and technology, in particular in the area of superconducting cavities and accelerators, and educate the next generation of accelerator scientists. To this end ODU CAS works in close collaboration with Jefferson lab and has access to its resources, both in terms of personnel and facilities. Jefferson Lab is a world-leading nuclear physics research laboratory funded by the US Department of Energy and is a world leader in SRF technology. ODU CAS also has strong links to and is involved in collaborations with industry for the design and development of superconducting cavities and accelerators.	
Tasks in HiLumi LHC • **WP4**: Design, development, prototyping, fabrication, and testing of superconducting compact crab cavities and cryomodules (tasks 4.3 and 4.5).	
Short CV for the key persons: • **Jean Delayen:** American Physical Society Fellow. Graduated with Ph.D. from California Institute of Technology (CIT) in 1978. Scientist and Senior Scientist at CIT until 1986. Project Manager for SRF, Argonne National Laboratory until 1995. Currently Jefferson Lab Principal Scientist and since 2009, director of Center for Accelerator Science, ODU. Involved in SRF technology since 1970, invented half-wave, spoke, and parallel-bar deflecting / crabbing cavity.	

Full name of participant: SLAC National Accelerator Laboratory	**20**
Short name of participant: SLAC	
Description of participant: SLAC National Accelerator Laboratory is home to the longest linear accelerator in the world. Originally a particle physics research centre, SLAC is now a multipurpose laboratory for astrophysics, photon science, accelerator and particle physics research. SLAC is funded by the US Department of Energy and operated by Stanford University. It is located in Menlo Park, California and was founded in 1962. Six scientists have been awarded the Nobel Prize for work carried out at SLAC.	

SLAC programs explore the ultimate structure and dynamics of matter and the properties of energy, space and time – at the smallest and largest scales, in the fastest processes and at the highest energies – through robust scientific programs, excellent accelerator based user facilities and valuable partnerships.

Tasks in HiLumi LHC

- **WP1:** Contribute to HiLumi LHC management through the LARP programme (tasks 1.2, 1.3 and 1.5).
- **WP2:** Monte Carlo tracking studies (task 2.3), estimate required corrector circuit settings (task 2.4).
- **WP4:** Crab cavity RF studies (task 4.2) and compact crab cavity design (task 4.3).

Short CV for the key persons:

- **Uli Wienands:** Joined SLAC in 1994. Run coordinator for PEP-II B Factory, organized transition of Linac Coherent Light Source to operations and participated in SuperB and PEP X design studies. Currently head of Sector 0-20 and Facility for Advanced Accelerator Experimental Tests Dept and represents LARP PS2/PSB accelerator physics task. After Ph.D 9 years at TRIUMF on high-intensity proton synchrotron designs for KAON Factory proposal and led Low Energy Booster design and construction at US Superconducting Super Collider Laboratory near Dallas, Texas.
- **Thomas Markiewicz:** Joined SLAC in 1987, worked with SLD experiment at SLAC Linear Collider, on wire tracking chamber design and construction, Next Linear Collider and ILC programmes, on machine detector interface issues, and with LARP, on collimation design and construction. LARP deputy director, in charge of Accelerator Physics portfolio. Graduated with Ph.D. from UC Berkeley in 1981, participated in CERN's SPS UA1 experiment 1981-7.

2.3. Consortium as a whole

The consortium is composed of 20 internationally leading universities, research institutes, and laboratories from 6 European countries, Russia, USA and Japan. The partners have both complementary and overlapping expertise.

Overview of the consortium

The consortium includes partners that have contributed to the design and construction of the LHC components: CEA (FR), CNRS (FR) and INFN (IT) from Europe, BINP from Russia, BNL, FNAL and LBNL from the US and KEK from Japan. The presence of all these important LHC partners in the HiLumi LHC design study is a solid guarantee for the success, showing their long term commitment. For the luminosity upgrade, members are called to collaborate at the very beginning of the project.

All these large laboratories or institutes are references in the field of highest technology accelerators. In addition to very good design capabilities (they all have accelerator teams and technology groups at the highest level) the partners also have – like CERN – important laboratory infrastructures: this is an important asset if for any reason the design study should be complemented with R&D or prototyping activities beyond the possibilities of the CERN site. The new participation of STFC (UK) and SLAC (US) also goes along the same lines.

The presence of large laboratories has been complemented with a strong participation of universities, such as EPFL (CH), the three British universities that federate under the Cockcroft Institute along with STFC (Lancaster, Liverpool and Manchester), Royal Holloway and the University of Southampton: their participation is well focussed to the particular domain where they are at the cutting edge and their contribution is extremely valuable. The participation of DESY (DE) and CSIC (ES) is relatively small, however it is important as it allows access to accelerator specialists and keeps ties with the community in Germany and Spain. At this stage no direct participation of Industry is envisaged, however direct contacts with Industry have been formed in all WPs, and these are very strong for the WPs with important hardware design.

Key areas of expertise of the consortium

Accelerator Physics

Many members of the consortium contributed to design studies for the LHC (e.g. CEA, CSIC, EPFL, INFN, UNILIV, STFC, BNL, LBNL, FNAL SLAC and KEK), which assures an intimate knowledge of key design concepts from the present LHC machine within all work packages and therefore provides a sound foundation for further design upgrades. The HiLumi LHC consortium benefits from and further develops efforts that are already ongoing in various other R&D programmes. The previous FP6-CARE-HHH network, the US-LARP programme, the present FP7-EuCARD project all feature excellent studies: however they are done in parallel, without proper coordination and synchronization. The HiLumi LHC consortium is regrouping specialized theoretical teams (e.g. BINP, CEA, INFN) with teams involved in the operation of superconducting storage rings or who have participated in the LHC commissioning effort (DESY, FNAL, SLAC, LBNL and BNL), so that new ideas and operational experience can merge and provide solutions that are innovative and viable at the same time. Furthermore, the HiLumi LHC consortium is building synergies with other design studies with similar design challenges (for example the RHIC upgrade plans at BNL, USA and the LHeC[1] related design studies [e.g. EPFL, UNILIV, UNIMAN, SLAC]) and existing expertise in laboratories outside CERN (e.g. BINP, INFN, FNAL, SLAC, LBNL and BNL).

Magnets

European laboratories bring the experience of the construction, installation and operation of the largest superconducting system in the world. The US laboratories however bring the innovation developed over the last ten years while Europe was busy building the LHC. In 2003, the US effort of R&D was formalised by the DOE (US Department of Energy) funding the LHC Accelerator Research Program, LARP. Today LARP is the most advanced programme for magnet research, so the presence of the US laboratories in HiLumi LHC is a key feature. The fact that CERN has a unique large facility for testing magnets in superfluid helium at 1.9K, and has the associated know how, is essential to support the LARP programme. In addition the recent development via FP6-CARE-NED and FP7-EuCARD of a European Nb_3Sn conductor with nearly the quality of the US magnets using different technology is also a necessary complement to the US research. The Japanese KEK laboratory complements these US and European approaches and competence by exploring the practical potential of its novel Nb_3Al superconductor (a less developed variant within the same family as Nb_3Sn), which can be extremely useful for some special magnets. The European presence in these critical technologies is reinforced in the areas of enhanced Nb-Ti magnets and special cooling (CEA) and in the domain of design and protection of high field magnets (INFN).

Crab Cavities

The largest experience in this domain is at KEK, where elliptical crab cavities were already tested on a 4 GeV electron-positron collider. European researchers (Lancaster University) and US laboratories, through LARP, have joined the research with innovative solutions for compact crab cavities of the type that could be installed in the LHC. Already US scientists have worked together with EU partners at CERN, and the R&D effort is coordinated through EuCARD. At present, CERN has little experience and resources in this field, so the collaboration of KEK and US laboratories is fundamental to carry out the design study. The presence of CEA and CNRS, with their well recognized experience in cryostats for cavities, is also a necessary complement. CERN

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[1] The LHeC: Deep Inelastic Electron-Nucleon Scattering at the LHC http://www.ep.ph.bham.ac.uk/exp/LHeC//

will lead the integration in a cryomagnetic line and guide the design to accommodate the necessary requirements that will be raised by machine protection, a key issue for this technology. Furthermore, CERN will provide the necessary know-how for the design of the test of KEK elliptical cavity in the CERN SPS accelerator and in the LHC Point 4.

Collimators

The main partners of CERN in this work package are university groups. The necessity of complex and detailed simulations of beam losses and energy depositions is a dominant factor. Given the uncertainties, it has been decided that different codes and approaches must be integrated to reach the goal with a good degree of certainty. All teams are strongly and successfully committed within the EuCARD project: therefore the challenge, and the additional motivation, to be a member of this consortium is to step from R&D to focussed design.

Cold Power

CERN is the most advanced user of High Temperature Superconductors (HTS) for cold power, with 3 MA of current fed from room temperature into the cold LHC. However the experience of CERN is limited to the use of liquid helium temperature and current leads. Southampton University will add its experience in modelling and construction of cryostats at variable temperatures, a key asset for long cables, as well as the experience in testing HTS. The long experience in energy deposition calculations on superconductors, specific to INFN-Milano in Europe, will complement and reinforce the energy deposition team of CERN, giving value to the respective Fluka teams.

Balance of the consortium

All together the consortium is an appropriate mix of university laboratories and large research laboratories, and this helps to provide a good balance between accelerator physics and engineering design. This is important since the success of the project depends on a correct balance between requirements from beam physics and the actual possibilities of hardware realization. Would the first part be too large, with predominance of academic spirit over practical engineering, the design would be jeopardized, but vice versa would also be a disadvantage because innovation comes from demanding requests.

The consortium of 20 partners is worldwide and quite large, showing the wide interest of the HL-LHC project. However, most of the participants have already worked together for LHC or other projects, allowing HiLumi LHC to build on strong and established links. Many members are part of the FP7 EuCARD project: for them the participation to this design study is triggered by the will of applying the R&D results and innovation in a design that will give the practical application and, by providing the necessary focus and concrete boundary conditions, will indicate the road for further R&D and innovation.

The presence of the non-EU laboratories is an important feature of real added value, since for critical technologies such as superconducting magnets for IPs and crab cavities, as mentioned above, they have studied and built the best demonstrations to date. While HiLumi LHC will provide the necessary focus to their R&D programmes, CERN, the other EU members, and European accelerator science as a whole, will largely benefit from sharing these advanced technologies with the non-EU partners.

At the end of HiLumi LHC Design Study, the integration of the different laboratories in the three worldwide research areas (EU, JP, US) will be much stronger and this is the best preparation for even larger future efforts (such as CLIC or HE-LHC). In addition the integration between big laboratories and universities in the EU research area will be strengthened by this programme: indeed in a design study the participants need to integrate their effort in a much tighter way than, for example, an R&D programme, and need to proceed with much more coordination.

This FP7 Design Study with its four-years of close cooperation, paves the way to a sustainable international collaboration in view of the HL-LHC construction phase.

Subcontracting

No sub-contracting is foreseen in this proposal.

Other countries

Several key partners are from the US and Japan, however they are not requesting EU funding.

Additional partners

During the implementation of HiLumi LHC, new partners could be expected to join the design study, without requesting an increase of the EC funding to the project. This process will be defined in the Consortium Agreement, and will involve discussions in the Steering Committee and approval of the Collaboration Board. The main criteria for admission will be linked to the objectives, deliverables and milestones of HiLumi LHC. Joining of additional participants is common in large collaborative efforts in Particle Physics, which have a good record of being inclusive and at the same time improving the capabilities of the collaborations.

2.4. Resources to be committed

Budget overview

To carry out the proposed FP7 Design Study, the resources committed by the consortium members amount to about 27.3 M€ in total costs, of which 20.7 M€ are direct costs and 6.6 M€ are indirect costs (overheads). Given the nature of the Design Study most resources, 18.3 M€ are in the form of personnel costs of the scientists and engineers that will carry out the work. About 2 M€ are allocated to consumables, prototyping and testing. This amount for equipment and consumables is relatively small, since the Design Study relies on R&D carried in other ongoing projects (FP7-EuCARD, FP7-SLHC-PP, US-LARP) in order to profit from synergies and avoid duplication of efforts and funding. In many areas the hiring of young researchers is foreseen, including at PhD and post-doc level, while senior staff will provide the necessary supervision and leadership. The amount allocated for travel is about 336 k€. This figure is modest, about 170 € per person-month, when considering the worldwide collaboration, and is necessary to assure close contacts among consortium members, both for the technical work and for common governance of the integrated teams to meet the ambitious goals of the projects.

Budget distribution

Of the 27.3 M€ total costs, 10.3 M€ are committed by CERN (38%), 7.3 M€ will be provided by the other European partners (27%) and 9.7 M€ by the American and Japanese partners[1] (35%), see Fig. 2.2a. The main commitment comes from CERN, which is natural as owner and operator of the LHC on behalf of its 20 Member States. The significant contribution of European partner institutes demonstrates the attractiveness of a common venture beyond the state-of-the art and the expected return in excellence and new technologies for their centres of competence. The contribution of the USA and Japan, about 35% of the total costs, is a premiere in large accelerator projects of this kind, and a very promising step towards efficient and time-effective organization of global projects. Their presence is necessary to meet all objectives of the Design Study both for the resources that they make available and for the know-how that they provide. The chart in Fig. 2.2b shows the distribution of the total costs among the 20 partners of the consortium.

The total cost of the European partners, including CERN, amount to about 17.6 M€ (Fig. 2.2c). The US and Japanese costs will be covered entirely by their own funding agencies, respectively the

[1] The way American and US laboratories calculate indirect costs (overheads) is different from the way this is done for EU projects.

Department of Energy (DOE) for the American laboratories, and MEXT (Minister for Education, Culture, Sports, Science and Technology) for the KEK laboratory in Japan.

For the American partners, in contrast to their domestic practices, the four-year budget contribution to the HiLumi LHC Design Study will be committed from the beginning to ensure a continuous collaborative effort in the Design Study.

The distribution of total costs among European partners shows a reasonably good balance, taking into account the existing projects in which the different institutes are already involved and committed. The partners from Italy and France have a budget of just over 1 M€ for each country. The relative small participation of Germany is due to the fact that the German accelerator community is already heavily engaged in two of the largest accelerator constructions in the world (a synchrotron light source XFEL at DESY and an accelerator for Nuclear Physics FAIR at GSI). The same reason explains the modest participation of Spain. The strong participation of UK laboratories and universities (at a level of about 3.5 M€) confirms the renewed interest of the scientific community of that country for a common European project in the field of HEP accelerators, already noticed in FP7 EuCARD.

The partners in this proposal have demonstrated their commitments to collaborative projects in past or ongoing bilateral collaborations with CERN, in other EU projects like FP6-CARE and FP7-EuCARD, or though informal partnerships. As a matter of good practice, commitments to the budget and deliverables have been requested and received prior to the submission of the proposal from all partners, including the US and Japanese participants.

Strategy for the requested EU funding

A significant difference between the ratios in the charts for the total costs of European partners (Fig. 2.2c) and for the requested EU funding (Fig. 2.2d) arises from the CERN policy for EU funding in this project:

- CERN shall not request any EU funding as a contribution for the RTD Work Packages. The reason is that the technical work in this Design Study is part of the core activity of CERN, as laid down in its Medium Term Plan for 2011-2015.
- CERN requests 85% reimbursement of the costs incurred for general project management and communication activities (tasks 1.1 and 1.6 of WP1), and 50% of the costs for the technical coordination tasks: tasks 1.2 to 1.5 in WP1 and tasks 2.1, 3.1, 4.1, 5.1 and 6.1 in Work Packages 2-6, which correspond to the estimated workload of each work package coordinator from CERN. The request of 85% reimbursement for management and communication is consistent with the fact that CERN asks for EU contribution only for the extra cost associated with the size and complexity of the collaboration within the FP7 Design Study; the costs for the coordination of the Work Packages outside this FP7 Design Study (about 15% of the total management costs) are not requested for reimbursement from the EU.
- All other European partners ask for a reimbursement of 50% of their total costs, the other 50% being provided from their own matching funds or from national funding agencies.
- The US and Japanese participants do not ask for any EU contribution to their costs.

This strategy leads to request for EU funding at the level of 4.98 M€, i.e. effectively 28% of the total costs incurred by the European partners, and 18% of the total project cost of 27.3 M€. The requested EU contribution for CERN, which is only for management and coordination activities, is 778 k€, i.e. 12.8% of CERN’s total costs or 2.8% of the total budget of HiLumi LHC.

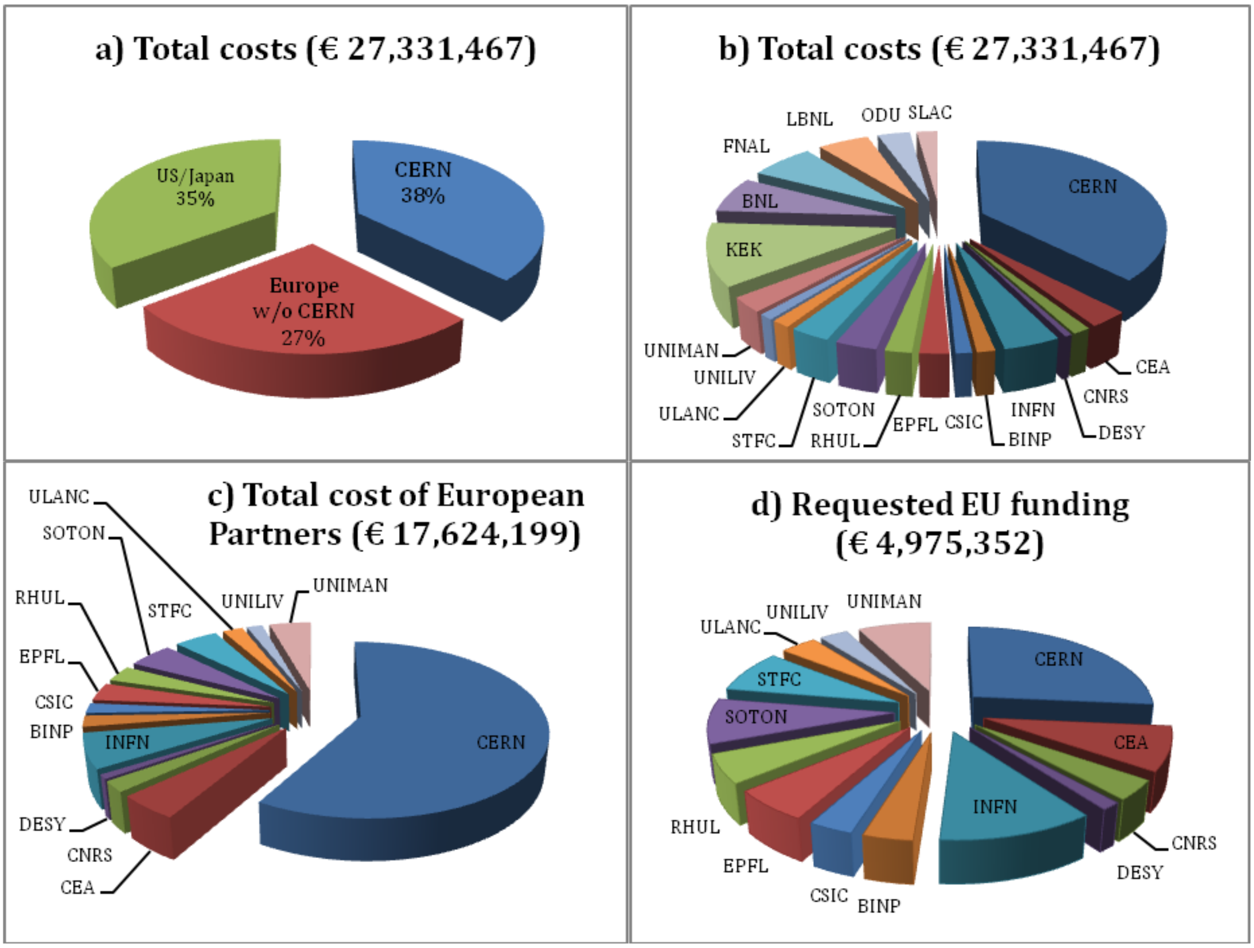

Figure 2.2: a) distribution of total cost by main groupings; b) distribution of toal cost per Consortium member; c) distribution of total costs of European partners d) distribution of EU funding per European partner.

The budget figures are summarized in the following tables:

Work package	Type	Person Months (PM)	Personnel cost (Euro)	Subcontracting (Euro)	Consumables and prototypes (Euro)	Travel (Euro)	Indirect costs (Euro)	Total budget (Euro)	Total eligible budget (Euro)	Requested EC contribution (Euro)
WP1	MGT	126	1,466,703	-	100,000	35,500	796,481	2,398,684	2,123,950	778,910
WP2	RTD	591.44	5,054,492	-	105,000	141,300	1,652,895	6,953,687	4,471,794	1,659,993
WP3	RTD	332	4,138,027	-	58,000	45,000	929,802	5,170,829	2,463,993	567,937
WP4	RTD	477.8	4,615,238	-	1,587,400	45,550	1,293,543	7,541,731	3,329,926	642,696
WP5	RTD	283.6	1,956,728	-	39,000	52,000	1,218,708	3,266,436	3,254,436	692,819
WP6	RTD	151	1,080,859	-	169,267	16,500	713,474	1,980,100	1,980,100	632,997
Total		**1961.84**	**18,312,047**	**-**	**2,058,667**	**335,850**	**6,604,903**	**27,311,467**	**17,624,199**	**4,975,352**

Table 2.2: Overview of resources per work package for the full duration of the project. A breakdown of the cost into personnel cost, materials and consumables and travel costs is given.

Parti-cipant number	Short name	Person Months	RTD (Euro)	Management (Euro)	Total (Euro)	Requested EU contribution (Euro)
1	CERN	593.6	8,182,088	2,123,950	10,306,038	1,316,272
2	CEA	78	811,729	-	811,729	405,864
3	CNRS	40.8	364,015	-	364,015	182,007
4	DESY	12	146,461	-	146,461	73,230
5	INFN	133.2	1,134,688	-	1,134,688	567,344
6	BINP	65	364,068	-	364,068	182,034
7	CSIC	62	325,145	-	325,145	162,573
8	EPFL	48	587,104	-	587,104	293,552
9	RHUL	64	530,835	-	530,835	265,418
10	SOTON	71	829,225	-	829,225	414,613
11	STFC	59	797,959	-	797,959	398,979
12	ULANC	70.5	375,773	-	375,773	187,886
13	UNILIV	34.8	292,370	-	292,370	146,185
14	UNIMAN	92.8	758,790	-	758,790	379,395
15	KEK	159.7	3,117,081	-	3,117,081	-
16	BNL	116.4	1,809,822	-	1,809,822	-
17	FNAL	90.64	1,710,983	97,026	1,808,009	-
18	LBNL	88	1,358,473	84,768	1,443,241	-
19	ODU	48	918,214	-	918,214	-
20	SLAC	34.4	497,960	92,940	590,900	-
	TOTAL	**1961.84**	**24,912,783**	**2,398,684**	**27,331,467**	**4,975,352**

Table 2.3 Overview of participant resources for full project duration: total cost (including indirect cost).

The costs of the studies to be carried out in the framework of Work Packages 7 to 12 (mostly CERN-specific), not included in the FP7 Design Study but associated to it, can be estimated at some 15 M€, including an important contribution from Fermilab to WP11.

The total cost of the HL-LHC project (design, R&D, industrialization, construction and commissioning) is evaluated to be about 500 M€, of which 300 M€ in manufacturing and assembly of industrial components.

3. Impact

In coherence with and building upon promising R&D activities from EuCARD within FP7 and LARP in the US, **the HiLumi LHC Design Study will produce the Technical Design Report of the LHC High Luminosity upgrade as the main deliverable**. This report will be analyzed by the CERN Directorate and its conclusions and recommendations will be submitted to the CERN Council, the highest European authority for Particle Physics, which decides on the priorities for Particle Physics in Europe and provides input to the ESFRI Roadmap as regards the projects in this field. A positive decision would commit the CERN member states and the European and world-wide particle physics community to years of dedicated work towards the High Luminosity LHC upgrade, confirming the leading position of Europe on the high-energy frontier in particle physics. The upgrade of the LHC, a world-class research infrastructure, will not only significantly strengthen the European Research Area (ERA), but will also create new links and partnerships between Europe, Russia, USA and Japan at an unprecedented level in the field of particle accelerators. HiLumi LHC will contribute to the development of technological capacity, enhancing the scientific performance, and increasing the attractiveness of the ERA, and more generally, to the implementation of global research cooperation.

Synergies with other programmes and European projects

HiLumi LHC will constitute the focal point of a number of past or ongoing coordinated collaborative efforts.

- **US program LARP** (LHC Accelerator Research Programme) federates the US Department of Energy funded studies and R&D in support of the LHC. LARP members are the four main National Laboratories active in HEP: Fermilab (leader), BNL, LBNL, SLAC, and a number of university groups in the US. It mainly concerns the development of High Field Superconductors and Superconducting Magnets, beyond LHC technology, many accelerator studies, special rotatable collimator and more recently Crab Cavities. The program started in 2004 (however seed money for High Field superconductors and magnets was awarded starting from 1999). LARP has passed through different phases and is now advancing to full magnet demonstrators.
- **FP6-CARE**. Through its Joint Research Activity NED (Next European Dipole) and its network HHH (High-energy High-intensity Hadron colliders), this program started to federate European laboratories around the main studies and technology development needed for the LHC upgrades, from 2004 to 2008. In this project the first R&D on high field Nb_3Sn magnets for accelerators was initiated.
- **FP7-sLHC-PP**, running from 2008 to 2011, is preparing the LHC complex (LHC Injectors, LHC machine proper and LHC detectors) for the initial phase of the upgrade by grouping a numbers of coordination activities and technical Work Packages, targeting mainly Linac4 and the improvement of the SPS that will be implemented during the machine shutdown planned for 2016.
- **FP7-EuCARD**, running from 2009 to 2013, includes a network and R&D activities on enabling technologies for several potential LHC upgrades to expand whenever possible, the technology limits. Therefore the spectrum of EuCARD activities is wide with a large number of collaborating institutes. Among the main activities linked to the LHC upgrade are the EuroLumi network and the high field dipole magnets, crab cavities, collimation and SC link teams. Selected project deliverables will serve as inputs to HiLumi LHC.

- **The LHC upgrade KEK program** in Japan, oriented towards developing a new superconductor, called Nb_3Al, which may alleviate some of the difficulties associated to the use of the brittle Nb_3Sn material.

HiLumi LHC will not only constitute the converging point of all these collaborative efforts, but will also give them the necessary focus to pass from R&D to the stage of industrial prototypes. This phase will take full advantage of the completed or ongoing R&D work and, thanks to the input and demands from industry, will provide feed back to the R&D activities in order to give them new motivations and directions for the next steps. The dynamic of this long path toward the High Luminosity LHC as a major and very challenging upgrade of the machine is illustrated in Fig. 3.1.

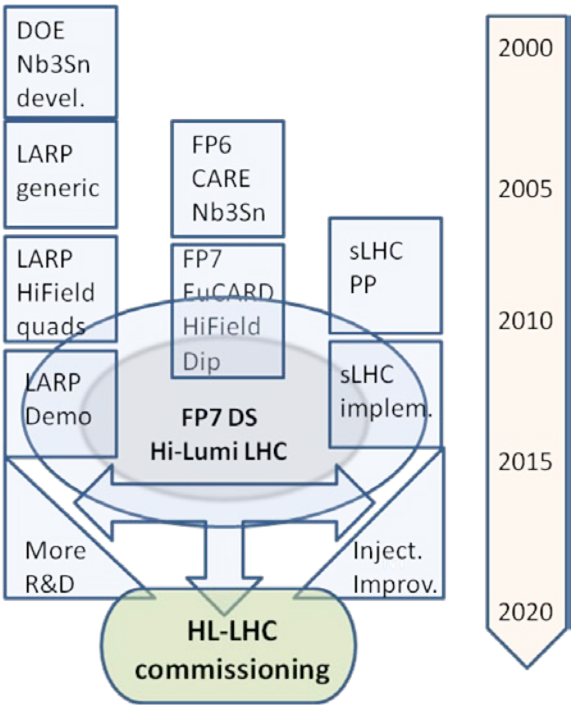

Figure 3.1: US (left branch) and EU programmes (centre and right branch) involving activities linked to the LHC upgrades.

3.1. Expected impacts listed in the work programme

3.1.1. Impact on technological development capacity of the ERA

HiLumi LHC is expected to have a number of important technological impacts, concerning the development of High Energy Physics (HEP) research infrastructures, medical and industrial applications of accelerators, and certain technologies not directly related to accelerators. The potential impact is exemplified in four major areas:

- Superconducting material and cables
- High field magnets
- High-intensity particle beams
- Cold powering

Industrialization of superconducting cables of higher quality

Today 15- 18 T (and exceptionally up to 20-23 T) superconducting magnets are built in the from of solenoids, but their superconductors have characteristics and quality far from what is needed for particle accelerators (current density, field precision, persistent current and dynamic effects). The impact of HiLumi LHC will be based on three main steps: the first will be to finalize a high quality superconducting Nb_3Sn cable, whose studies were initiated by FP6-CARE-NED. The second step will be to make it suitable for large current compact cables, improving the technical properties. Eventually, the third and decisive step will be to trigger its industrialization with the goal of bringing its cost down: today Nb_3Sn is 8 to 10 times more expensive than the classical Nb-Ti; the scope of the R&D in this project is to reduce it by a factor of 2. The 20 tonnes that will be employed for the HL-LHC magnets are the minimum quantity to make the high grade Nb_3Sn appealing to industry.

Paving the way to a future increase of LHC energy

The LHC upgrade critically depends on the success of high field accelerator magnet technology, beyond 10 teslas. The success of this technology will be a milestone in accelerator technology and it will pave the way to new applications. Large accelerators can be made more compact with considerable savings in infrastructure and land occupation: the most striking impact is enabling the possibility of another major upgrade of the LHC energy (rather than luminosity that is the subject of this design study). A High Energy LHC, based on magnets with field in excess of 16 T, would open new possibilities for HEP, especially for the search of physics beyond the Standard Model. However, before embarking on the replacement of thousands of LHC magnets by magnets of higher field, the technology must be assessed in a real accelerator environment, exposed to beam losses, etc. The thirty 11-13 T superconducting magnets for the HL-LHC will provide a unique opportunity to assess the possibility of a later energy upgrade, to be considered for the decade after 2020.

More compact accelerators for medical and industrial applications

A common requirement for medical and industrial applications is to reduce the volume and weight of accelerators, together with their cost. For example small powerful medical accelerators that could rotate around the patient would avoid the need of the very complex, bulky and expensive gantries currently in existence. Indeed, hadron and carbon accelerator-based therapy centres for cancer treatment are rapidly gaining momentum [PSI in Switzerland, Heidelberg in Germany, CNAO in Italy, Medaustron in Austria, Etoile in France and others]. High field, and therefore more compact, accelerators and gantries could be a real breakthrough making hadron therapy centres smaller and hence more accessible to city hospitals[1]. This will also drive the cost of such facilities (70-100 M€ at present) and make them more affordable for less wealthy countries and regions in Europe. Besides therapy, the availability of 13 T accelerator magnets will certainly strongly impact on Magnetic Resonance Imaging (MRI) systems. Accelerator and MRI have followed parallel development, usually MRI profiting from accelerator technology[2]. In the same way that the LHC has reached the limit of Nb-Ti technology with its 9 T field magnets, MRI is designing to reach it with the 11.7 T of the solenoid of ISEULT[3]. The size and storage energy in high field MRI are similar to accelerator magnets and many other features are similar (large multi-kilo-amperes cable, compact design, protection through large cold diodes, etc). The

[1] "Nb3Sn development for High Energy Physics of the DOE program, made the building of compact cyclotrons for hadron therapy possible and on demand at point of use short live PET isotopes medical applications," Timothy Antaya, leader of accelerator for medical application of PFC, MIT.

[2] "The large quantities of superconducting wires and quality required for the Tevatron, and supplied by Intermagnetics, significantly benefited and accelerated the commercialization of MRI superconducting wire and magnets," Carl Rosner, CEO of ITER magnetics, the first to commercialize MRI wire and magnets.

[3] ISEULT is the largest MRI magnet ever designed. It is part of the Franco-German platform Neurospin, see http://irfu.cea.fr/en/Phocea/Vie_des_labos/Ast/ast_visu.php?id_ast=2421

consortium believes that HiLumi LHC will be a key player in opening the route of MRI magnets above 10 T with normal 4.2 K cryogenics or cryogen-free lay-out.

Recently the use of very high field accelerators is being considered by security agencies and institutions for quick inspection and safety check of baggage and containers; an ultra-compact accelerator can generate penetrating beam to screen the contents of ship containers or allow fast checking of baggage[1], substituting intruding techniques.

Beam manipulations with Crab cavities

The success of the crab cavities programme, and especially a design that integrates in a safe way into the machine, will enable a new design for deflecting cavities for beam recombination, which is one of the favourite scheme for the Compact Linear Collider - CLIC (CLIC beam recombination scheme) and for the International Linear Collide (ILC), both being considered for implementation of the next collider project. Crab cavities can be seen as ultra-fast radio frequency kickers, with reaction times from femto- to nano-seconds. The impact in the new generation light sources could be very important, for example to single out femto-seconds long beams from a longer primary beam, allowing for very short light pulses. In general the new shape devised in the crab cavities (allowing 400 MHz to be more compact than the classical 800 MHz) will impact on superconducting radio frequency (SCRF) design in a major way, in particular the cryo-modules (which today make up 2/3 of a SCRF device) will be highly simplified and cheaper.

More efficient transport of electrical energy

The Cold Powering WP, dealing with superconducting links, may have a strong impact on the energy transport system. Many other accelerators in the world will profit from this technology, since it allows relocating power converters and warm-to-cold interfaces far from the radiation zone of the accelerator. This reinforces the ALARA[2] good practice and makes many interventions much simpler. Other equipment such as power-supply-driven MRI, which are usually in zones where space is a real asset, will benefit from displacing the power supply far away in less precious infrastructure zones. The use of High Temperature Superconductors or Magnesium Di-boride (MgB_2) may render the cryogenics very simple allowing to work in closed circuit for years, in the same way as modern NMR magnets. While AC superconducting cables are penetrating very slowly into the power industry, these DC superconducting links are pioneering. The HiLumi LHC 100-200 kA line will be a real system test for future possible 0.1-1 GW power lines. This technology offers almost zero power consumption (1-2 % for cryopower compared to 10-15% for classical links), underground cables liberate land and minimize electromagnetic radiation, and high voltage DC transmission suppresses AC losses and synchronization issues.

Besides these specific anticipated impacts, a key added value of the HiLumi LHC Design Study is that all these technologies, developed in R&D programmes such as EuCARD, LARP, etc, will be examined and evaluated as part of a global system: integration, installation, commissioning, reliability, influence in a complex system, and feedback from operation. This systematic approach will orient the on-going R&D and will introduce in each component development a functional vision that is indispensable for their practical application. The integration of the technologies into a complex and advanced system such as

[1] "Nb_3Sn development for High Energy Physics of the DOE program, also enables portable accelerators for the detection of concealed strategic nuclear materials in containers and baggage"
Timothy Antaya, leader of accelerator medical application of PFC, MIT.

[2] **ALARA –** As Low As Reasonably Achievable – is the driving principle of radio protection.

the LHC – with its 1,700 large superconducting magnets and 4 SCRF cryomodules, with its 3 MA current of cold powering and with 130 tonnes of cryogenic helium, all working together around the clock – will be a real challenge as system demonstrators for all the new accelerator-related technologies.

3.1.2. Impact on international cooperation

The HL-LHC project will set new working methods in the area of large particle accelerators. Indeed, while the large experimental physics detectors have since long been international ventures, large accelerators have been developed largely on a national basis or at CERN, which is in itself a European collaboration. Given the uniqueness of infrastructures such as the LHC, where the number of users outside Europe is becoming very large[1], a new approach is necessary for major upgrades, going beyond limited, but otherwise useful, in-kind external contributions.

HiLumi LHC, with its 20 partners that span Europe, America and Asia will set the foundations for a new global collaboration, coordinated by a leading Particle Physics laboratory. The American and Japanese contributions will be significant. A new governance model has been devised to allow a global participation on an equal footing, while preserving the role of the CERN Council's European strategy and decision making principles (see section 2.1).

The use of an FP7 design study framework has been well received by the non-European partners. The establishment of this worldwide collaboration and the commitments of the partners have been achieved within months, where other approaches often take years. **The four-year concrete collaboration within this Design Study will open the possibility of discussions among partners as to their implication in the construction phase and the choice of a sustainable collaboration model based on a concrete four years of experience.** If successful, this model for international research cooperation may pave the way to global Research Infrastructures in other fields of science.

3.1.3. Impact on European industry

HiLumi LHC will have to prepare European industry in an optimal way to bid for industrial contracts, including in high-technology fields, with an estimated value of 300 M€ for the construction phase of the HL-LHC upgrade.

Through task 1.6 (Dissemination of Information and Industry Outreach), HiLumi LHC aims to involve Industry at an early stage to the needed development, in order to have industrial feedback about the Best Engineering Practice to be applied, to maximize the chance of technical success of the construction phase.

Through industrial liaison initiatives, the project also wants to make European Industry aware of the opportunities to become an equipment or service provider of this project. To this end, Industry must be exposed to the theme of the design phase and informed about technology progress. Suitable routes for technology transfer will also be devised and explored.

3.1.4. Impact on European science and society

Through outreach planned within WP1, HiLumi LHC seeks to demonstrate the dynamism of fundamental sciences to the young generation. Via the project's university partners, HiLumi LHC will also involve a number of PhD students and postdocs in high-tech research and

[1] The number of LHC users from CERN Non-Member States is currently more than 3,000 from all over the world

implementation. By means of regular working visits and workshops with partners from the USA, Japan, Russia and other countries, the project will emphasise the importance of transnational exchanges of ideas and the mobility of researchers, portraying the excitement and potential of European research for the scientists of tomorrow and will favour exchange between areas[1].

The societal impacts of the HiLumi LHC technologies, as emphasised in section 3.1.2, include medical applications such as improvements to hadron therapy for cancer patients, very compact PET cyclotrons and enhancements to magnetic resonance imaging (MRI) scans. The project can also foresee aiding the development of more compact accelerators, which save on cost, space and consumption. In addition the links with industry give the potential for more societal benefits, as spin-offs are discovered and exploited.

3.2. Dissemination and exploitation of project results, and management of intellectual property

3.2.1. Dissemination and exploitation of project results

Internal communication and dissemination

Internally the project has a solid communication plan, with a dedicated task in WP1 (task 1.6) and a coordination and communication task within each of the technical work packages 2-6. Using these tasks, the project will form a liaison team to ensure a steady two-way flow of information within the project. Excellent, rapid and efficient dissemination and communication is especially important in such a global project and a key of scientific success. Appropriate tools will be provided by the Project Coordination Office to this end.

The project intranet will make best use of web-based collaborative workspaces allowing the sharing of information and documents, with discussion facilities, mailing lists managed to maximize the usefulness of information, calendars, and instructions for successful audio and video-conferences. These instruments will complement the more traditional but effective dissemination via the Annual and Final Meetings and the publications and project reports. In addition to dissemination, the annual meetings play a special role by enhancing the flow of information and the interactions, strengthening the consensus and the support of the community for the HL-LHC upgrade.

The scientific publications will be stored and accessible via the well establish CERN CDS (CERN Document Server) library tool, that, in addition to the usual access per title, author, date etc allows access per project, work package and task. Access to CDS is public and open to any interested reader from all over the world. The official project reports, such as deliverable reports, periodic reports, the technical documents, such as drawings, milestone reports and all other reports considered by the partners as strategic for the project and specified in the Consortium Agreement will be stored in the CERN EDMS (Electronic Data Management System), with version control. Access to EDMS will be granted to all HiLumi LHC project participants. Over the lifetime of the FP7 EuCARD project, HiLumi LHC will take advantage of the EuCARD network on accelerator performance[2] where several of the concepts of the LHC upgrade have their source and first evaluations. This has the additional advantage of reaching a larger scientific community, including that of other Design Studies or

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[1] For example through the prestigious Toohigh Fellow of the US LARP Programme (2 years of a highly competitive grant, with part of the time spent in Europe).

[2] AccNet, the EuCARD accelerator network http://accnet.lal.in2p3.fr/

Preparatory Phase EU projects, such as SLHC-PP, and of enhancing the exchange between R&D and design for an optimal coherence. Likewise, HiLumi LHC will take advantage of the US LARP meetings in the USA to better reach the US community as should be expected in a global project.

Global dissemination to the scientific accelerator community

Within the scientific accelerator community, links already exist between the HiLumi LHC partners themselves and researchers beyond the project. The project will capitalise on these links and use them to disseminate project results to the community, including related FP7 projects such as SLHC-PP, EuCARD, TIARA, enabling two-way exchange of information and mutual referencing.

Scientific publications are the main means of dissemination of project results to the scientific community. Rules will be issued for accepting publications as official HL-LHC project notes or project reports; a scientific editorial board will be formed and put into function. The Particle Physics community widely supports the principle of Open Access to all results that are generated through publicly funded research, in line with the efforts of the European Commission to ensure widest possible dissemination of FP7 results. Project members will be encouraged to submit publications of scientific and technical results in peer-reviewed journals, with an emphasis on journals that offer Open Access. In WP1, task 1.6 concerning dissemination, a 25 k€ budget is foreseen for partial financial support for authors choosing Open Access. The CDS publication database set-up for internal dissemination, as described above, will be publically accessible. In this way, Internet users will have free and unrestricted access to project publications. Project results will be advertised on the web site and presented at major international conferences such as IPAC (International Particle Accelerator Conference), PAC (US Particle Accelerator Conference), MT (Magnet Technology Conference), ASC (Applied Superconductivty Conference in North America), EUCAS (European Conference on Applied Superconductivity). These are large conferences with 700 to 1,500 participants. Many other meetings and workshops (such as the annual SC RF workshops, the annual crab cavity workshop, the biannual workshop on advanced superconductors and magnet design and optimization, the biannual workshop on instrumentation and magnetic measurements, etc.) will be used to disseminate information and give the floor to students and young scientists to exercise their communication skills, form networks etc. In addition, the annual HiLumi LHC meetings may also be extended where appropriate to interested members of the accelerator science community from outside of the consortium, whose active feedback is sought. An events calendar on the public website will list the relevant conferences and workshops to the HiLumi LHC project.

Students and young researchers that will work within HiLumi LHC will be encouraged to present their findings at the annual meetings and also to participate in outreach events to act as inspiring role models for a future generation of scientists. Within task 1.6, the project foresees to present to schools and the educated public the scopes of HL-LHC and the technology spin-offs.

Dissemination to scientific policy making bodies

The main goal of this Design Study is to prepare the necessary grounds to make decisions on the project implementation. To this end, there will be targeted dissemination to the relevant decision-making bodies. A report of the advancement of HiLumi LHC will be made yearly at the European Strategy Session of the CERN Council, which in turn will provide input to the updates of the ESFRI Roadmap. For the USA and Japan, similar reports will be organized by the US and Japanese HiLumi LHC members. For partners not directly depending on HEP policies, or depending on national funding, such as Universities and National Institutes, presentations of HiLumi LHC results and prospects for constructions will be organized by the HiLumi LHC members of these institutes to the relevant authorities and funding agencies. A short monograph is foreseen, summarizing the Technical Design Report for the purpose of transparent and synthetic information for the decision makers.

Dissemination to the world wide public and media

The HiLumi LHC project acknowledges the important of a sound communication strategy to maximize the impact of the project and the public support to investments in fundamental sciences. Given that this design study will be coordinated by CERN and involve the Large Hadron Collider, the project is already able to capitalise on the worldwide attention that CERN has received during the LHC startup and the first year of results in 2010. Journalists show an ever-increasing interest in CERN and the LHC, in media that range from video news to major documentaries, from books to blogs. As mentioned in the latest CERN annual report, in the last two months of 2009 alone, the name of the laboratory appeared more than 5,500 times in worldwide publications. By linking closely with the CERN communication team and utilizing the existing dissemination channels, project dissemination to the media and therefore the general public can be effective and wide-reaching from the beginning.

In addition, with 20 worldwide partners in the design study, many of which are large, internationally renowned laboratories with dedicated communication teams, HiLumi LHC can exploit the different communication means already available to reach local, national, continental and worldwide audiences. With partners from 7 European countries as well as America and Asia, project members are encouraged to disseminate locally, with the possibility of translating key dissemination material into different languages to reach appropriate audiences. In this way, the project is assured to disseminate not only within Europe, but to a worldwide public.

Dissemination to Industry

A dedicated task within WP1 – Task 1.6 Dissemination of Information and Industry Outreach will ensure that relations to Industry, particularly on a European level, are established and exploited as appropriate. By making use of the existing industrial relations of the partners and related projects e.g. the CERN External Technology Transfer Network, comprising industrial liaison and TT officers from institutions of its Member States, HiLumi LHC will form an Industry and Technology Board (ITB) to communicate to industry, preparing the participation of Industry in the HL-LHC construction. It will also advise the project coordinator of how to improve and disseminate information among Industry concerning spin offs that could be generated by advancements within this Design Study.

Public HL-LHC website

The project website will act as the central hub of knowledge dissemination to the scientific community, industry, and the general public. Here particular care will be taken by the project coordinator to add disclaimers, to authenticate/assess information to ensure its usefulness and maintain coherence in the project. The website will consist of an overview section for non-experts, appropriate information about the goals and status of the different activities of HiLumi LHC, a section for industry as well as a section about project results. Technical Deliverables of HiLumi LHC are to be made available on the public website, and thus at the disposal of any interested parties.

3.2.2. Management of intellectual property

The principles for dissemination, access and use of knowledge generated through the HiLumi LHC (Foreground) will fully comply with the *Rules for participation in FP7 and for dissemination of research results*, adopted by the European Council and Parliament in December 2006.

Access to Foreground and Background and ownership of Foreground will follow the principles set out in Annex II to the EC Grant Agreement. The implementation of these principles will be detailed in the Consortium Agreement.

Given the goal of the HL-LHC Design Study, including HiLumi LHC, Access rights to Background or to Foreground needed for use of Foreground within CERN's scientific programme, in particular the HL-LHC, shall be granted royalty free and shall include have-made rights. The latter are essential to allow industry to bid on the high tech work that is connected with the luminosity upgrade.

As outlined in the previous section, the partners will endeavour to publish the results of the HiLumi LHC as swiftly as possible in conference proceedings and scientific journals where appropriate. The Consortium Agreement will define in detail the procedures for publication. The publication procedures will take into account the potential for commercial exploitation and/or the need for protection of intellectual property rights of the results concerned.

4. Ethics Issues

The HiLumi LHC project does not involve any ethical issues that relate to:

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

ETHICS ISSUES TABLE

	Research on Human Embryo/ Foetus	YES	Page
*	Does the proposed research involve human Embryos?	No	
*	Does the proposed research involve human Foetal Tissues/Cells?	No	
*	Does the proposed research involve human Embryonic Stem Cells (hESCs)?	No	
*	Does the proposed research on human Embryonic Stem Cells involve cells in culture?	No	
*	Does the proposed research on Human Embryonic Stem Cells involve the derivation of cells from Embryos?	No	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**Yes**	

	Research on Humans	YES	Page
*	Does the proposed research involve children?	No	
*	Does the proposed research involve patients?	No	
*	Does the proposed research involve persons not able to give consent?	No	
*	Does the proposed research involve adult healthy volunteers?	No	
	Does the proposed research involve Human genetic material?	No	
	Does the proposed research involve Human biological samples?	No	
	Does the proposed research involve Human data collection?	No	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**Yes**	

	Privacy	YES	Page
	Does the proposed research involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	No	
	Does the proposed research involve tracking the location or observation of people?	No	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**Yes**	

	Research on Animals	YES	Page
	Does the proposed research involve research on animals?	No	
	Are those animals transgenic small laboratory animals?	No	
	Are those animals transgenic farm animals?	No	
*	Are those animals non-human primates?	No	
	Are those animals cloned farm animals?	No	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**Yes**	

	Research Involving ICP Countries	YES	Page
	Is the proposed research (or parts of it) going to take place in one or more of the ICP Countries?	Yes[1]	
	Is any material used in the research (e.g. personal data, animal and/or human tissue samples, genetic material, live animals, etc): a) Collected in any of the ICP countries? b) Exported to any other country (including ICPC and EU Member States)?	 No No	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**Yes**	

	Dual Use	YES	Page
	Research having direct military use	No	
	Research having the potential for terrorist abuse	No	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**Yes**	

[1] FP7-HL-LHC-DS partner number 6 Budker Institute of Nuclear Physics (BINP) is from Russia, an “International Cooperation Partner Country (ICPC) within the list of countries in annex 1 of the work programme. This is the only ICPC partner in the project. There are no ethical issues related to the research that will be carried out by this partner.

5. Consideration of gender aspects

The European Commission document "She Figures 2009: Statistics and Indicators on Gender Equality in Science"[1] states that women in scientific research remain a minority, accounting for just 30% of EU researchers according to a study made in 2006. Despite the rise in female student numbers in the past years, more senior positions in science and research are still heavily dominated by men. Particle Physics is one of these fields. In an attempt to offset this trend, gender balance, or in more general terms, equal opportunities have moved into the focus of the human resource policy of many research organizations participating in the HiLumi LHC proposal. Most of the HiLumi LHC participants have established policy of equal gender opportunities, and support the principles and the guidelines contained in the European Charter for Researchers and Code of Conduct for Recruitment of Researchers[2], developed by the European Commission in 2005.

The project management of HiLumi LHC will strive to ensure equal opportunity and will recommend to all participants to respect the European Charter and Code for Recruitment of Researchers when hiring new staff to work on the project. At the time the proposal is submitted already several key members of the Coordination Group are women, including the CERN coordinator of Work Package 6 Cold Powering and the leader of the Spanish participating institute CSIC.

In seminars, workshops and conferences, organized by HiLumi LHC, particular attention will be paid to select, whenever possible, female researchers as speakers and conveners in order to provide positive role models to young female scientists.

To ensure positive action in all job categories and at all levels, the gender distribution will be monitored throughout the HiLumi LHC project. Apart from striving for a better gender balance the HiLumi LHC community is committed to a fair treatment in recruitment and career development regardless of sex, ethnic origin, physical handicaps, religious orientation, nationality, etc. Equally important are respect and dignity in the work-place and appropriate support for those parents who are taking care of young children.

[1] http://ec.europa.eu/research/science-society/document_library/pdf_06/she_figures_2009_en.pdf

[2] http://ec.europa.eu/euraxess/pdf/brochure_rights/am509774CEE_EN_E4.pdf