

# HiLumi LHC

FP7 High Luminosity Large Hadron Collider Design Study

## Deliverable Report

# 1st Periodic HiLumi LHC Report

The HiLumi LHC Collaboration

28 June 2013



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This work is part of HiLumi LHC Work Package 1: **Project Management & Technical Coordination.**

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Grant Agreement No: 284404

# HiLumi LHC

FP7 High Luminosity Large Hadron Collider Design Study  
Seventh Framework Programme, Capacities Specific Programme, Research Infrastructures,  
Collaborative Project

## PROJECT PERIODIC REPORT

# 1<sup>ST</sup> PERIODIC HILUMI LHC REPORT

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### Abstract

An internal report of the work performed during the 1<sup>st</sup> year, between 1 November 2011 (M1) to 30 April 2013 (M18) including the work progress and the use of resources.

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The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404. HiLumi LHC began in November 2011 and will run for 4 years.

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### Delivery Slip

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# PROJECT PERIODIC REPORT

**Grant Agreement number:** 284404

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## Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):
  - has fully achieved its objectives and technical goals for the period;
  - has achieved most of its objectives and technical goals for the period with relatively minor deviations;
  - has failed to achieve critical objectives and/or is not at all on schedule.
- The public website, if applicable
  - is up to date
  - is not up to date
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: .....Lucio Rossi.....



Date: ...28.../ ...06...../ ...2013.....

The signature of this declaration is done directly via the IT reporting tool SESAM.

## EXECUTIVE SUMMARY

As part of the HL-LHC programme, the HiLumi LHC Design Study is federating efforts and R&D of a large international community towards a successful LHC upgrade. The project consortium has 15 partners, including institutes from outside the European Research Area, such as Russia, Japan and 5 collaborating laboratories from the US, which enables the implementation of the construction phase as a global project.

The HiLumi LHC Design Study is progressing well with the completion 7 out of 7 deliverables scheduled and the achievement of 24 out of 24 milestones in the first period.

The main efforts of the Project Coordination Office (**WP1**) were to set up a suitable and complete project structure. Besides the Project Coordination, the Steering Committee and the Collaboration Board, the Scientific Advisory Committee has also started through the CERN - Machine Advisory Committee. In addition, the Technical Coordination team has been created. Another important step is the installation of the Coordination Group, the forum where the HL-LHC project, the LHC Injector Upgrade project, the LHC Detector Upgrade project and the CERN management discuss the common issues and synergy of these different projects related to the LHC. Another success is the development of close links with LARP, the R&D programme on hadron accelerators in the US. The LARP and HiLumi annual meetings are organized together and their efforts have been truly unified. LARP is preparing an estimated 200 M\$ in-kind contribution to HL-LHC.

In these first 18 months, **WP2** has defined a number of parameter sets and machine optics that would allow HL-LHC to reach the very ambitious performance target for an integrated luminosity of  $250 \text{ fb}^{-1}$  per year. The second key objective was achieved in close collaboration with WP3, resulting in a complete layout and optics for HL-LHC with 140 mm aperture in the inner triplet (IT) quadrupoles. The decision was then taken to increase the aperture in the IT to 150 mm, to ensure full compatibility with the baseline  $\beta^*$  of 15 cm. The aperture requirements for all other new magnets have also been specified. Reaching the third objective is also progressing well; field quality specifications for the new IT are nearly finalised, and first specifications for the non-linear corrector coils have been produced.

During this period **WP3** has reached the main goals of fixing the aperture of the quadrupole triplet and setting the first baseline for the layout from Q1 to D1 (the first dipole from the interaction region), with the suitable technological choice, the maximum aperture and the proper cable. A very important goal has been the first estimate of the needed shielding and radiation dose on the magnets for the life span of the HL-LHC ( $3000 \text{ fb}^{-1}$ ).

**WP4** has set up the Crab Cavity Technical Coordination Working Group to prepare, organize and run Crab Cavities beam tests in SPS, to provide relevant specifications for the crab cavity project and to assess operational and machine safety risks associated with operation. The design and test of three different types of compact crab cavities (CCCs) made excellent technical progress. Studies of the operating scenarios are directly linked to the RF system design and to the machine protection issues. An important result obtained during the reporting period is the clear concept of the operational scenario.

For the Collimation upgrade (**WP5**), models to simulate the multi-turn halo cleaning were successfully setup and the first complete loss maps of the LHC could be achieved for the optics layouts. Due to the various new or updated simulation packages, which also included multi-turn tracking of the collision, both beam halo and beam losses could be calculated and energy deposition will be calculated.

**WP6** is progressing remarkably well and well ahead of schedule. However, the WP was supposed to start in Year 2. The options for the cryogenic cooling of the Cold Powering System has been studied and a test station for the measurement of Superconducting Cables as required for application to the Superconducting Links has been conceived, manufactured and commissioned. It serves to finalize the development of a novel Superconducting MgB2 round wire and verify its suitability for use in high-current cables. Various layouts for the cold powering of the magnets have been proposed and choices are under way.

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## 1. PUBLISHABLE SUMMARY



### FP7 HIGH LUMINOSITY LARGE HADRON COLLIDER DESIGN STUDY

The Large Hadron Collider (LHC) at CERN has been exploring the new high-energy frontier since 2010, attracting a global user-community of more than 7,000 scientists. It will need a major upgrade after 2020 to maintain scientific progress and exploit its full capacity. The novel machine configuration, called High Luminosity LHC (HL-LHC), will rely on a number of key innovative technologies, representing exceptional technological challenges.

As part of the HL-LHC programme, the HiLumi LHC Design Study is federating the efforts and R&D of a large international community towards a successful LHC upgrade. The list of participants within the HiLumi LHC also includes institutes from outside the European Research Area, such as Russia, Japan and the US, which enables the implementation of the construction phase as a global project.

The HiLumi LHC Design Study in its first period is progressing well with the completion of 7 out of 7 deliverables scheduled and the achievement of 24 out of 24 milestones for this period.

#### WP1 Project management and Technical Coordination

The main achievements of the work package were the formation of the Collaboration Board, Steering Committee, CERN-Machine Advisory Committee (CERN-MAC) as Scientific Advisory Committee, Technical Coordination, Parameter and Lay-out Committee, and the nomination of the Project Safety Officer. Another important body installed by the HiLumi LHC management (and not foreseen at the beginning of the project) is the HL-LHC Coordination Group, where the HL-LHC project, the LIU (LHC Injector Upgrade) Project, the LHC Detector Upgrade Projects and the CERN management sit together, chaired by the HiLumi LHC coordinator, to discuss common issues and determine high

level politics and synergy. Significant efforts were focused on the preparation of two reports for the Open Symposium for the renewal of the European Strategy for High Energy Physics. Due to the work of FP7 HiLumi LHC DS, a remarkably complete report was submitted to the Study Group for the update of the European Strategy for High Energy Physics. As results, the HiLumi LHC is now the priority project of the European Scientific Policy of High Energy Physics, adopted at the special CERN Council session held in Brussels at the headquarters of the European Commission on 30 May 2013.

Furthermore, the management team also focused on the organization of the kick-off and 1<sup>st</sup> Annual Meetings, held in November 2011 and November 2012 respectively, as well as its collaboration with LARP to organise the Joint LARP/HiLumi collaboration meetings in May 2012 and April 2013.

**WP2 Accelerator Physics and Performance** had three key objectives during the first eighteen months of the project. The first goal was to define a number of parameter sets and machine optics that would allow HL-LHC to reach the very ambitious performance target for an integrated luminosity of  $250 \text{ fb}^{-1}$  per year. This goal was met [1] in close collaboration with the LHC Injector Upgrade project and the LHC operations group. A main part of the goal was to develop optics to reduce the beam sizes ( $\beta^*=15 \text{ cm}$ ) at IP1 (ATLAS) and IP5 (CMS). To



Figure 1: HiLumi LHC website

achieve this, a novel technique is proposed, the Achromatic Telescopic Squeeze (ATS) [2]. This scheme was successfully tested in 2012 at low beam intensity because of the present aperture constraints. To allow operation with the ATS at high intensity, a number of magnets and other components will need to be replaced to increase the aperture. The second key objective of WP2 was to develop a baseline layout including initial specifications for the new equipment. This objective was achieved in close collaboration with WP3, resulting in a complete layout and optics for HL-LHC with 140 mm aperture in the inner triplet (IT) quadrupoles [3, 4]. The decision was then taken to increase the aperture in the IT to 150 mm, to ensure full compatibility with the baseline  $\beta^*$  of 15 cm. Important progress has also been made with the transition optics from injection to collision [7], and in alternative layouts to reduce the demands on the crab cavities [8]. The third key objective of WP2 was to start the analysis of the new optics in terms of long-term beam stability and to produce first specifications for the field quality of the new magnets. This work is progressing well [9] in close collaboration with WP3; field quality specifications for the new IT are nearly finalised [10], and first specifications for the non-linear corrector coils have been produced [11]. The experience gained with LHC high intensity/high brightness operation in 2012 has proved extremely valuable for understanding performance limitations and benchmarking simulation codes. An international workshop on "Beam-Beam Effects in Hadron Colliders"<sup>1</sup> was organized at CERN in March 2013, partly sponsored by HiLumi LHC and with significant contributions from WP2. The luminosity production scenario has also been reviewed to take into account the longitudinal pile-up density: this has important implications for the luminosity levelling schemes, indicating a preference for levelling by control of  $\beta^*$  during the fill. In this scenario, large beam-beam tune spreads are expected, and a study of a higher harmonic RF system to mitigate these effects has begun, in collaboration with WP4.

During the first 18 months of activity, Task 3.2 of **WP3-Magnet design** has focused on the selection of the aperture of the triplet. A preliminary exploration of the option with 140 mm aperture showed that (i) a large shielding is necessary to bring the dose from 200 MGy down to 40 MGy and that (ii) there are no design obstacles to go to larger apertures, provided that the cable width is scaled accordingly. This led to the choice, in July 2012, of a triplet aperture of 150 mm with Nb<sub>3</sub>Sn technology; this choice allowed the target of a maximum performance with a 6-mm-thick tungsten shielding to be kept. Based on the LARP experience, the design of the 150 mm aperture quadrupole QXF started in August 2012. With respect to the 120 mm aperture quadrupole HQ, the strand diameter has been increased from 0.8 mm to 0.85 mm and the number of strands from 35 to 40 to have more superconductor, lower stress and more margin for protection. Based on the results of the HQ and 11 T programmes, a superconducting Rutherford cable with a core (which a stainless steel ribbon placed in between opposite faces of the cable) has been chosen to minimize the ramp rate effects. Filament size has been fixed to be lower than 50  $\mu$ m, corresponding to the number of elements of the order of 150. Working in the hypothesis of 20% margin on the load-line, an operational gradient of 140 T/m has been set for the inner triplet quadrupoles. In Task 3.3 a first baseline with 160 mm aperture for the D1

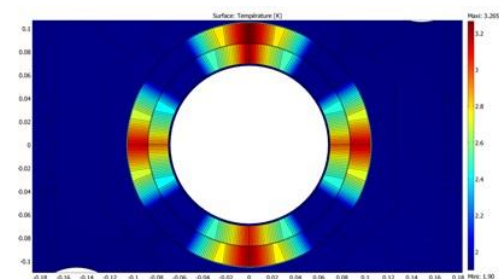


Figure 2: Temperature map in the Inner Triplet quadrupole coil, 140 mm aperture case

<sup>1</sup> <http://indico.cern.ch/conferenceDisplay.py?confId=189544>

magnet design was considered. The stray field has been identified as a potential problem, thus suggesting reducing the number of layers from two to one to have less flux and more iron to provide shielding. Mechanical analysis has shown that stresses are within 100 MPa. This magnet will work in a novel and extreme regime of saturation, with a reduction of the transfer function from low current to nominal of about 10%. In Task 3.4 the results from FLUKA simulations enabled the definition of the cooling options. The chosen baseline is having the triplet cooled with two heat exchangers of 80 mm diameter at 45° from coil midplane, and the separation dipole with the corrector package cooled with one heat exchanger at 90° from coil midplane. This allows removing the 600 W total load on the cold mass from Q1 to D1. An additional load of 500 W is on the beam screen, which is removed at higher temperature (20-40 K) and independently cooled. Simulations of the heat transfer from the bath to the coils have fixed the need of openings in the coil pole, between the laminations, and the thickness of the helium ring between the coils and the cold bore. For Task 3.5 (Special Magnet Design) CEA-Saclay has made a wide parametric study, with apertures ranging from 85 to 120 mm and three types of coil, namely one or two layers of MQM cable or one layer of MQ cable. Both magnetic and mechanical design have been considered, studies showing that all cases are fairly similar. The final choice will be taken based on other aspects such as integration and protection. The aperture has been fixed to 90 mm, with the preferred choice of 1 layer MQ cable, a nominal gradient of 120 T/m with 20% margin on the loadline. The Nb-Ti version of the quadrupole (MQXC) has been assembled and tested (AP0) reaching design field after a few quenches, and with one quench after thermal cycle; a second aperture has been assembled and tested with similar performance. Field quality still needs to be assessed.



Figure 3: Nb prototype of 4-rod cavity

**WP4 Crab Cavities** are essential for high luminosity operation, since they compensate for luminosity loss resulting from non-zero crossing angle with small  $\beta^*$ . The narrow distance of the LHC beam pipes makes an unconventional and compact design necessary. During the first period of the HiLumi LHC Design Study, considerable progress could be achieved: The conceptual and the technical design of three compact cavities (“4-rod”, “RF dipole” and “double quarter-wave”) were finished successfully, prototype Nb cavities were

fabricated and successfully tested for all of them. Important questions concerning the Machine Protection have been addressed and are now treated in the LHC Machine Protection Working Group. The preparation for the integration of crab cavities in the LHC and initially in the SPS is addressed by the CCTC (Crab Cavity Technical Co-ordination Working Group, chaired by Alick Macpherson (CERN). It confirmed BA4 (COLDEX) as the location for this test and detailed preparation work and planning has advanced well; a dedicated crab cavity engineering meeting has converged towards a cryostat design for the SPS test. An existing 400 MHz, 50 kW, tetrode amplifier with solid state drivers will be used; initial tests of the amplifiers are foreseen in 2013 if the human resources can be found. The more conventional, elliptical crab cavities are not compatible with the narrow distance of LHC beam pipes; they were planned as fall-back solution in case the initially risky compact design would fail. They could only be installed in LHC IR4 with significant negative impact on possible performance. With the excellent progress on the compact crab cavity designs, the studies on elliptical cavities became lower priority and were thus put on hold. A conceptual design was however finished and is

ready to be reconsidered would the initial SPS beam tests of the compact prototypes not be successful.

**WP5 IR Collimation** team has started activities towards the design of the new collimation system for the HL-LHC era. The progress of this work package benefits from strong collaborations with WP2 and WP10 within HL-LHC, as well as with other teams at CERN, US-LARP and EuCARD. At CERN, models to simulate the multi-turn halo cleaning were successfully setup and the first complete loss maps could be achieved for the optics layouts. Simulation packages also included multi-turn tracking of the collision. Debris losses in IR2 during ion operation were also established. Simulation results for protons are being benchmarked against LHC beam measurements at 4 TeV. Manchester and Huddersfield universities have continued their development of the Merlin tracking code for collimation studies. Merlin now has a complete model of the LHC optics and collimators, which is consistent with the state-of-the-art tools developed at CERN. The code has been extended with improved scattering in collimators, with elastic and single diffractive cross sections fitted to recent experimental data. The code is being benchmarked against SixTrack simulations and LHC loss map measurements and it is now essentially ready to be used for simulations of various relevant HL cases. Preliminary results for HL optics are available. The work benefitted from extended visits to CERN by collaborators from Manchester and Huddersfield. Valencia has been working on setting up simulation tools based on SixTrack to understand the beam loads on the collimators in case of fast beam failures at the LHC. Energy deposition simulations could also be performed thanks to the synergy with WP10 that made important advancements in the modelling of the FLUKA geometry of IR1 and IR5. This work already has implications for the Long Shutdown (LS1) layout changes and represents an important step toward the IR collimation layout for HL-LHC.

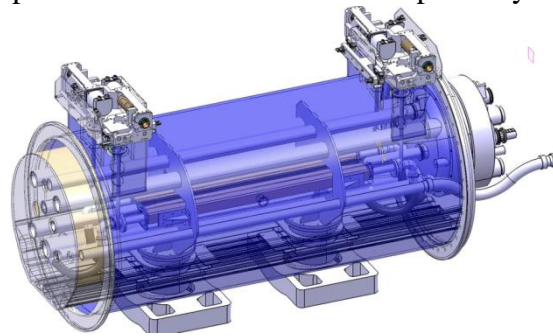


Figure 4: 3D model of the cold collimator assembly

The WP5 activities benefitted from beam studies that were carried out at the LHC to understand the system limitations and possible running scenarios in the HL-LHC era. Studies included scans of physics debris absorbers in IR1/5, loss maps and hierarchy limit measurements for future collimator settings, quench tests with proton, IR collimators losses for fast failure scenarios, aperture measurements for  $\beta^*$  reach estimates.

The activity of **WP6 Cold Powering** started in November 2012. However, significant preparation work, involving all Tasks of WP6, was performed in 2012.

Three global meetings of WP6 took place at CERN: during the joint Hi-Lumi LHC-LARP annual meeting in November 2011, in June 2012 and in October 2012. A fourth meeting took place during the joint Hi-Lumi LHC – LARP meeting in Frascati, in November 2012.

The preparatory work made possible the setting up of the test station for a 20 kA cable in November 2012. The cable itself has already been designed and manufactured, and is ready to be tested. The preparatory works also made it possible to readily start the integration in November 2012.

In addition to the progress on the SC link proper, the main advancement was in the analysis and definition of the cryogenic and powering scenarios of the inner triplet circuits and of the Matching Sections superconducting circuits.

**Coordinator:** CERN

**Partners:** see <http://hilumilhc.web.cern.ch/HiLumiLHC/about/participants/>

**Website:** <http://www.cern.ch/HiLumiLHC>

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## 2. CORE OF THE REPORT FOR THE PERIOD: PROJECT OBJECTIVES, WORK PROGRESS AND ACHIEVEMENTS, PROJECT MANAGEMENT

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### 2.1. PROJECT OBJECTIVES FOR THE PERIOD

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The HiLumi LHC Design Study is progressing well with 7 deliverables scheduled and completed for this period and the achievement of 24 milestones.

**WP1** had four objectives for the first eighteen months period.

- a) To start the collaboration in a very effective way, making sure that proper meetings are in place, that WPs works in synergy and that the necessary managing/control bodies are formed and duly active.
- b) To make the collaboration with the non-European partners effective, and in particular with the US laboratory of LARP, whose participation is necessary to reach the objectives of the project despite the fact that they are “associated” and not a beneficiary of the project.
- c) To integrate the project in the mainstream CERN research by participating in the High Energy Physics EU strategy update, establishing a close connection with the twin project LHC detector upgrade, and by negotiating the suitable beam parameters set with the project LHC injector upgrade (LIU).
- d) To prepare the necessary frame of central services, including the website, documentation, QA concepts and safety regulation frame.

**WP2** had three key objectives during the first eighteen months of the project. The first goal was to define a number of parameter sets and machine optics that would allow HL-LHC to reach the very ambitious performance target for an integrated luminosity of  $250 \text{ fb}^{-1}$  per year. The second key objective was to develop a baseline layout including initial specifications for the new equipment. The third key objective of WP2 was to start the analysis of the new optics in terms of long term beam stability and to produce first specifications for the field quality of the new magnets.

Fixing the aperture of the inner triplet quadrupoles (called also low- $\beta$  triplet) has been a key objective of **WP3** as the aperture of the triplet is a cornerstone of all upgrades. Based on this, a second objective was to have a first baseline for the layout from Q1 to D1, with a technological choice (between different types of superconductors and magnet structures), effective aperture for the beam, and the type of cable used for the superconducting coils. A further objective was to have a first estimate of the needed shielding and radiation dose collected in the coils and cold mass of various magnets in all span life till the  $3000 \text{ fb}^{-1}$  goal.

The goals of **WP4** were to organize and schedule the design work for crab cavities, address machine protection issues, start preparing the SPS tests and the necessary infrastructure for both the SPS and the LHC. Further objectives were to complete the initial design of the Compact Crab Cavities and start the conceptual design for the cryomodule, the HOM- LOM- and SOM-dampers and the power couplers.

In the first 18 months, **WP5** had the objective to simulate and compare beam losses in IR1 and IR5 for various scenarios of halo and upgrade changes. Activities also focused on verifying that an upgrade scenario has acceptable loss characteristics. Another goal was to provide inputs to energy deposition and other studies for the verified scenarios.

The goals of **WP6** have been multiple, tackling challenges both of technology development and of system integration. The main efforts and advances have been:

- a) To study various options for the cryogenic cooling of the Cold Powering System.
- b) To conceive and construct a test station for the measurement of Superconducting Cables as required for application to the Superconducting Links.
- c) To finalize the development of a novel Superconducting MgB2 round wire and verify its suitability for use in high-current cables.
- d) To elaborate options for the powering of the Hi-Luminosity magnets and propose an optimized powering layout. To perform preliminary studies on the Distribution Feed Box. To launch integration studies in the LHC.

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## 2.2. WORK PROGRESS AND ACHIEVEMENTS DURING THE PERIOD

### 2.2.1. WP1: Project management and Technical Coordination

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This WP manages the project, monitors progress and communicates information within and outside the consortium. It includes 6 tasks:

- Task 1.1: Management
- Task 1.2: Parameter and Lay-out Committee
- Task 1.3: Quality assurance plan
- Task 1.4: Radiological impact
- Task 1.5: Liaison with Detector and Injector Upgrades
- Task 1.6: Dissemination of Information and Industry outreach

For details of Task 1.1 and Task 1.6 please refer to section “Project management during the period”.

#### 2.2.1.1. Task 1.2: Parameter and Lay-out Committee

##### Progress towards objectives and significant results

The first Parameter and Layout Committee (PLC) meeting took place in July 2012 and was triggered by two key events in the project development:

- The identification of a coherent set of beam parameters for the LIU and HL-LHC projects. First discussions of a coherent set of beam parameters for the LIU and HL-LHC projects started with a first common workshop in 2011 and continued in 2012 during the annual LHC performance workshop at Chamonix. The initial discussions were followed by a second common workshop between the LIU and HL-LHC projects in March 2012 that led to a set of common target beam parameters that are endorsed by both projects.
- A decision on the inner coil diameter of the Nb<sub>3</sub>Sn triplet magnets in July 2012 (see the reports of WP2 and WP3).

Both decisions naturally affect the future work of all HL-LHC work packages. All main hardware groups of the CERN accelerator sector, as well as the main WPs of the HL-LHC project, are represented at the PLC. The mandate of the PLC is to establish and maintain a coherent and dynamic list of parameters and associated hardware layouts for the HL-LHC. The PLC looks after a list of key beam parameters, new accelerator components including the ones interfacing with the experimental detectors and nominal performance estimates and operation scenarios. The PLC will monitor and recommend changes in parameters or the machine layout based on interim reports from the work package leaders or any other relevant bodies. When applicable, the PLC will request dedicated studies to solve or mitigate any possible inconsistencies and will prepare the decision making process at the Steering Committee (SC). For the later task, the PLC will work closely together with a dedicated technical committee, the HL-LHC Technical Committee (HL-LHC TC), which provides a forum for detailed and in-depth discussions of technical implementations before they are brought to the PLC. For example, first topics for the HL-LHC TC are the technical options for electrical wires for a compensation of the long-range beam-beam encounters at the LHC interaction regions (IR) and methods for removing halo beam particles before the beams are brought into collision in order to minimize loss spikes at the beginning of a new physics fill.



The first PLC meeting aimed at documenting the above decisions in a central place that is accessible to all collaborators and to agree with all HL-LHC work package leaders on the format and regularity of the PLC meetings. For the beginning it is planned to have the PLC meetings approximately once every two to three months. The first PLC meeting took place in July 2012. The second meeting took place two month later in September 2012 and started to look at the implications of the triplet inner coil diameter for other equipment. The second PLC meeting addressed the magnet inner coil diameter, the resulting IR magnet layout and optics and the resulting vacuum chamber and beam screen designs. The third PLC meeting was held on 18 January 2013 and was dedicated mainly to discuss the cryogenic lay-out of the interaction regions and the matching sections; the need for new diagnostics in the HL-LHC run was also discussed together with the preliminary design of the Crab cavities. The 4<sup>th</sup> PLC took place on 26 March 2013: the repository and documentation system, based on CERN EDMS, was presented and discussed. In the same PLC the complete magnetic lay-out of the interaction region from TAS to D1, including triplets, was approved and the matching section lay-out was discussed together with possible schemes for the cold powering, whose choice has a strong influence on magnets, cryogenics and SC links work packages.

The deliverable D1.1, ‘First release of layout database’ was finalized in April and approved in the SC committee of June. Originally, it was foreseen for July 2012. However, all relevant information on the layout and optics files was already available to all HL-LHC collaborators since July 2012 in the form of presentations and minutes of various meetings, and no delay has been generated on the Milestone or other Deliverables. The magnet layout and optics files are accessible to all collaborators via a common repository:

‘[afs/cern.ch/eng/lhc/optics/HLLHCV1.0](https://afs.cern.ch/eng/lhc/optics/HLLHCV1.0)’

The PLC meetings are documented on a dedicated Internet page that is linked from the general HiLumiLHC Intranet page (<https://espace.cern.ch/HiLumi/PLC/default.aspx>). The central publication of the HL-LHC parameter table and the creation of a common Glossary for the whole HL-LHC project represents a major step towards the project objectives. The agreed list of common target parameters for the LIU and HL-LHC projects corresponds to one explicit deliverable of the WP1. A full list of future PLC topics is maintained under the PLC Intranet page.

### **Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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#### **2.2.1.2. Task 1.3: Quality assurance plan**

The quality assurance plan (QAP) task defines 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. This is very important since HiLumi is an International collaboration and in-kind contributions of hardware are foreseen in a significant quantity from non-EU Nations: USA, Japan, and others.

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

## Progress towards objectives and significant results

The task was reassigned to a new task leader, Ms Isabel Bejar Alonso, in July 2012. While the dates for the deliverables have not changed order, and milestones have been readapted taking into consideration the new start date and the priorities of the project. The main activities since July 2012 were:

- Study of the LHC QAP and identification of the documents to be updated.
- Comparison of the LHC QAP with the QAP for other research infrastructures today under study/construction on the CERN site.
- Comparison of the LHC QAP with the quality assurance guide for project management of the DOE (DOE G 413.3-2) and other DOE guides for the design and construction of research facilities.
- Study of the ISO 9000 series, the ISO 12207 and ISO 15288 that were used as a basis for the LHC QAP. Identification of the differences between the version used for the LHC and the present version (2008).
- Drafting of a project chart as a basis for discussion on the relations between the different committees and entities for the resource management, procurement management, communication management, process options and deviations management, quality objectives and control activities management, risk management, project schedule management, project cost management, and finally project effort management.
- Drafting of a Quality Manual based on the ISO 9001 to establish the framework for the required Quality procedures, instructions and checklists.
- Prioritization of the LHC Quality procedures to be updated.
- Drafting of a documentation structure in EDMS (Electronic Data Management System) that takes into consideration that the scientific publications will be stored and accessible via CERN CDS and that official project reports will be stored in the CERN EDMS.
- Drafting of the initial requirements for access control and version control on CERN EDMS.

The milestone *MS5 Formation of the working group on Quality Assurance (QA) management* has been delayed to after the 2nd Joint HiLumi LHC-LARP Annual Meeting due to the change of task leader. Ms Isabel Bejar Alonso has been in place since July 2012, and since then the delay has been progressively recovered. MS5 has been effectively fulfilled on M17 with only a minor impact on MS9. There was no impact on any other MS deliverables because informal meetings among Quality Assurance people were held whenever necessary to support the advancement of the design study.

The MS9 Acquisition of main standards and an adaptation to HL-LHC has been postponed by 6 months, taking into consideration the new prioritization of the LHC Quality procedures to be updated, and the new date has actually been met.

The MS13 foreseen on M18 has been successfully fulfilled, providing a global QA management for the whole project (QA applies of course not only to the six FP7 HiLumi Design Study WPs, rather is the mandatory framework for the full set of 16 WPs in which the

entire High Luminosity LHC is structured). Of course the future work is to make this effective in the design works carried out by various technical WPs and to keep it updated according to evolution of the needs.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**2.2.1.3. Task 1.4: Radiological impact**

**Progress towards objectives and significant results**

This task started with some delay with respect to what was foreseen in the Description of Work (DoW). The reason being that the Long Shut-down 1 (LS1) of LHC, which was foreseen in 2012-13 when the DoW was prepared, was then shifted to 2013-14. The task 1.4 leader, being strongly involved to support LS1 radiobiological safety, has started to reduce the activity of this task. However he followed various workshops where his support was needed: for example the workshop of WP8 (Collider-Experiment Interface, a WP not included in the FP7 but of course very important for the project) that was held on 30<sup>th</sup> November 2012 (<https://indico.cern.ch/categoryDisplay.py?categId=4417>). He participated in the two Annual Meetings at CERN and Frascati in 2011 and 2012 and the Remote Handling workshop held on 30<sup>th</sup> May 2013. MS10, which is a critical report to fix the regulatory framework for radiobiological safety, could be completed with a minor delay and is now used throughout the whole project and also applied by the LHC experiment upgrade.

The impact of this document is more on the equipment engineering rather than the general layout phase of the interaction regions.

The activity of task 1.4 to check the engineering design, the use of material, the concept to disconnect and reconnect the magnets in a radioactive environment, and similar items, will mainly take place in the years 3 and 4 of the Design Study.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**2.2.1.4. Task 1.5: Liaison with Detector and Injector Upgrades**

**Progress towards objectives and significant results**

A permanent forum to discuss the liaison with the LHC Detector Upgrade was formed: the HL-LHC Coordination Group. The mandate and composition of this group were agreed at the highest level (CERN Research Director and CERN Accelerator Director). The HL-LHC Coordination Group provides coordination not only with the Detector Upgrade but also with the LIU (LHC Injector Upgrade) and the CERN management: the CERN Director for Research and Computing and the CERN Director of Accelerators and Technology have an essential role in endorsing the choices made by the HL-LHC and Detector Upgrade in terms of scientific goals and of resources and logistics (shutdown scheduling). The Coordination Group, chaired by the HL-LHC PC, has already met four times. The plan of each upgrade project (ATLAS, CMS, LHCb and Alice) has been examined and actions are under way to harmonize the request among the various experiments and between detectors and LHC Collider/LHC Injectors needs. The need for strict and rigorous coordination is of particular importance and urgency as the experiment plans to put detectors inside the machine in the LSS (long straight sections). Scientifically, the most important concept that has emerged in the meetings has been the new idea of luminosity density, i.e., the importance of the number of events per crossing (pile up) per unit length rather than the absolute number of pile up. This novel concept may have long-

term implications for the upgrade configuration both for the LHC collider and LHC detectors. Indeed the recent idea of separating events in space, but also in time to be able to distinguish them (time stamping), is a truly novel concept in collider performance design.

The future work of the HL-LHC Coordination Group will continue by preparing a strong participation of HL-LHC in the next LHC Detector Upgrade workshop under ECFA (European Committee for Future Accelerators) to be held in October 1-3 2013, and then to harmonize the request of the various experiments of HL and of LIU in terms of shutdown and their duration. This is of utmost importance because the Detector Upgrade is applying for funds from the National Funding Agency and a solid timetable is necessary for the credibility of the whole project.

The liaison with the LIU project is progressing very well and is even ahead of schedule. Two full day meetings were held on 24<sup>th</sup> June 2011 (before FP7 HiLumi LHC DS formal start) and on 30<sup>th</sup> March 2012, with few preparation meetings<sup>2</sup>. A list of agreed parameters has been published and maintained on the site of HL-LHC (PLC workplace: <https://espace.cern.ch/HiLumi/PLC/layouts/xlviewer.aspx?id=/HiLumi/PLC/SiteAssets/Parameter%20Table.xlsx&Source=https%3A%2F%2Fespace%2Ecern%2Ech%2FHiLumi%2FPLC%2FSiteAssets%2FForms%2FAllItems%2Easpx&DefaultItemOpen=1>) and of the LIU project. The Deliverable D1.3 foreseen form M24 is virtually ready six months in advance of the planned schedule.

Future plan: the work continues with a close collaboration to progress the optimization of the LIU beam parameters for HL-LHC and in preparing a common review: RLIUP (Review of the LHC and Injector Upgrade) to be held in October 2013.

#### **Planning, deviations and corrective actions**

Task on schedule		Ahead of schedule	√	Minor delay		Significant delay	
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<sup>2</sup> <https://indico.cern.ch/categoryDisplay.py?categId=3064>

## 2.2.2. WP2: Accelerator Physics and Performance

### 2.2.2.1. Task 2.1: Coordination and Communication

#### Progress towards objectives and significant results

Main activities of the last period were:

- Participate in the organization of the First and Second HiLumi Annual Meeting (Nov 2011 and Nov 2012) and the Joint LARP CM20/HiLumi Meeting (April 2013).
- Organize Task leader meetings (see details below) in order to discuss and whenever needed redefine the resource allocation versus tasks and laboratories, agree on the priorities for 2012/13 and streamline the activities (e.g., focusing on the development and analysis of only one triplet layout, with very precise scaling laws established in order to rapidly study other variants).
- Re-organize Task 2.5 (Beam-beam effects) with the nomination of A. Valishev (FNAL) as Task leader and T. Pieloni (CERN) as liaison person with EU laboratories, in particular EPFL. In this new structure, EPFL will focus its activity on the study of beam-beam effects, including in particular weak-strong beam-beam simulations (initially hosted in Task 2.3), instead of optics where CERN becomes the lead beneficiary.
- Tighten the link and maintain a constant communication with the other work packages, in particular with WP3 which heavily relies on the inputs given by WP2 and more recently with WP4 for the impact of the implementation of crab cavities on beam dynamics.
- Report on the progress of WP2 at the 2<sup>nd</sup> and 3<sup>rd</sup> extended Steering Committee (5/04/2102 and 23/07/2012).
- Report on the progress of WP2 at the 2<sup>nd</sup> restricted Steering Committee meeting (14/02/2013).

#### Work Package and Task Leader meetings

<i>Dates</i>	<i>Type of meeting</i>	<i>Venue</i>	<i>Attendance</i>	<i>Indico link</i>
11/11/2011	WP2 meeting (introduction and preparatory meeting to the 1 <sup>st</sup> HiLumi workshop)	CERN (EVO meeting)	25	<a href="https://espace.cern.ch/HiLumi/WP2/Shared%20Documents/">https://espace.cern.ch/HiLumi/WP2/Shared%20Documents/</a>
02/03/2012	Task leader meeting	CERN	5	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=180058">https://indico.cern.ch/conferenceDisplay.py?confId=180058</a>
16/03/2012	Task leader meeting	CERN	5	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=182291">https://indico.cern.ch/conferenceDisplay.py?confId=182291</a>

29/03/2012	Task leader meeting	CERN	5	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=183488">https://indico.cern.ch/conferenceDisplay.py?confId=183488</a>
20/04/2012	Task leader meeting	CERN	6	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=187068">https://indico.cern.ch/conferenceDisplay.py?confId=187068</a>
28/06/2012	Task leader meeting	CERN	7	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=195765">https://indico.cern.ch/conferenceDisplay.py?confId=195765</a>
2/7/2012	Joint WP2-WP3 meeting	CERN	10	<a href="https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx">https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx</a>
26/7/2012	Joint WP2-WP3 meeting	CERN	10	<a href="https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx">https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx</a>
19-20/09/2012	HL-LHC Task 2.2 workshop	CERN	20	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=208496">https://indico.cern.ch/conferenceDisplay.py?confId=208496</a>
10/12/2012	Joint WP2-WP3 meeting	CERN	10	<a href="https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx">https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx</a>
28/01/2013	Joint WP2-WP3 meeting	CERN	10	<a href="https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx">https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx</a>
25/04/2013	Task leader meeting	CERN	9	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=247616">https://indico.cern.ch/conferenceDisplay.py?confId=247616</a>

### Contractual milestones and deliverables

The Work Package had one deliverable, D2.1 and one milestone, MS26 in this period. All were achieved.

### Planning, deviations and corrective actions

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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### Use of resources

Please refer to Section **Error! Reference source not found.**

#### 2.2.2.2. Task 2.2: Optics and Layout

#### Progress towards objectives and significant results

The goals for Task 2.2 were defined in a brain-storming meeting held with all team members during the HL-LHC kick-off meeting in November 2011 where the topics to be studied by the team were identified and the different responsibilities were defined. Summarising briefly here, the main tasks were and still are:

- Set the baseline for the ATS [2] optics in IR1 and IR5 for different magnet technologies (NbTi and Nb<sub>3</sub>Sn superconductors).
- Establish optics solutions for 120 mm and 140 mm triplet apertures, focusing more on larger aperture triplets which offer smaller  $\beta^*$  and therefore higher performance.
- Study the optics transitions between the injection and collision optics (so-called “squeeze”).
- Study the robustness and the flexibility of the optics with respect to magnet tolerances (quadrupole field errors and misalignment) and fringe fields of the large aperture HL-LHC magnets.
- Study and improve the optics “squeeze-ability” of the other two LHC experimental insertions, Alice (IR2) and LHCb (IR8), in various scenarios (proton and ion), i.e.,

with the high-luminosity insertions IR1 and IR5 operating in ATS or non-ATS mode.

- Finally keep open the option for flat beam optics in IR1 and IR5, as well as short bunches as design alternatives to the crab cavity option.

In several meetings and tutorials the scripts and subroutines were explained to the team members to get them familiar with the tools to be used and the special boundary conditions of the ATS scheme. Having thus prepared the grounds, as a first step the work concentrated on finalizing and updating baseline beam optics and layout, and possible variants. As a first result the possible parameter space within which converging beam optics are obtained could be created. An example of a typical ATS optics is presented in Figure 5. It shows the beam optics in the complete LHC and the arc  $\beta$ -beating waves that reflect the ATS scheme are nicely visible. In collaboration with the representatives of WP3 (Magnet design and development) a first set of parameters for the new triplet magnets had been established.

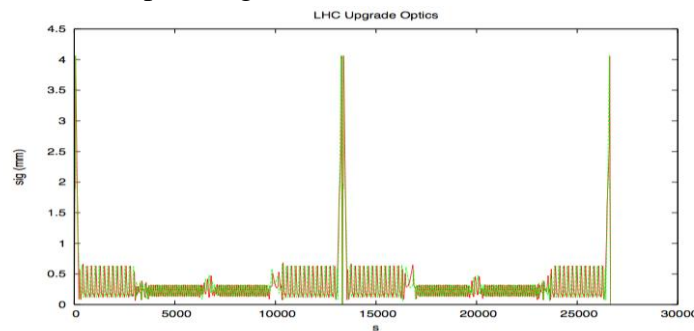


Figure 5: Horizontal and vertical Beam sizes in mm along the 27 km circumference of the LHC ring, assuming the nominal emittance of the LHC beam , for a typical ATS collision optics with IR1 and IR5 squeezed down to  $\beta^*=10$  cm

Following the beam optics calculations for the ATS scheme in IR1 and IR5, the main challenge was to establish optimal phase advances for IR2 and IR8, where the ALICE and LHCb detectors are located, that are compatible with ATS squeeze as well as low-beta optics for ion operations and injections. An example that illustrates the complexity is given for IR8 in Fig.7. The optics has to be matched on the left side to the standard periodic FODO structure of the LHC arc, whereas, on the other side, the matching section and dispersion suppressor of this low-luminosity IR is used to create the  $\beta$ -beating wave which is needed for the ATS scheme to squeeze down the beam sizes at the interaction point of the ATLAS experiment (IR1). Still at the same time the IR8 optics corresponds to a moderately low- $\beta$  insertion for the beam collisions in IP8.

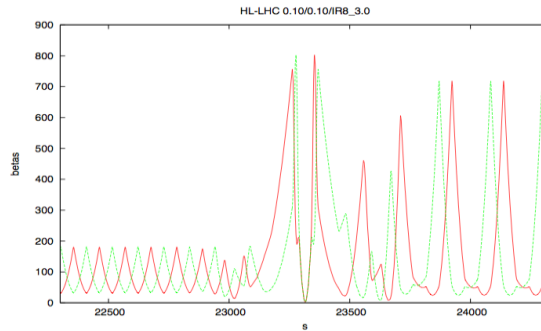


Figure 6: IR8 optics: the IR quadrupole settings are defined to fulfil the optics matching conditions for standard FODO optics on the left, and the ATS scheme conditions on the right side, and at the same time the luminosity requirements of the LHCb experiment. In red is the vertical  $\beta$ -function and in green the horizontal one.

In order to reach this goal in the large range of possible optics solutions, optimal phase advances have been identified for IR2 and IR8 (see Fig. 3) that are compatible at the same time with the injection optics, and the various operation modes (proton and ion) and subsequent  $\beta^*$  requirements in the four LHC experimental experiments ATLAS, ALICE, CMS and LHCb.

The results achieved so far, the successful upgrade optics and layout, and the corresponding parameter space of the HL-LHC were published at the IPAC2012 conference [3, 12]. The next natural step was to concentrate the effort of the team on the study of the optics and magnet tolerances, especially in the region of the ultra-high beta functions, namely the inner triplets of IR1 and IR5. In parallel the transition between the meanwhile well-established HL-LHC-injection optics and the collision optics were studied. A number of constraints concerning the phase advance, the tolerable beta beat and the boundary conditions from the magnet technology have to be met. At any moment a smooth transition is required for the quadrupole strengths. Step-like change in the normalized gradients, zero crossings of the gradients or situations that lead to intolerable hysteresis and saturation have to be avoided. A successful scenario has been developed fulfilling all these requirements [7].

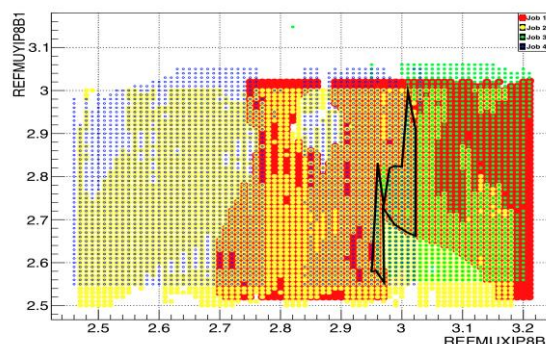


Figure 7: A large variety of optics of IR8 (injection, collision with  $\beta^*=10$  m or 3 m, while IR8 is also used for the ATS scheme deployed for IR1) with different horizontal and vertical phase advances (in units of  $2\pi$ ) has been calculated in order to find a common solution for all required beam optics in IR2/8

From the second half of 2012 the development of the optics variant including some magnet layout modifications, notably the split of the Q1 and Q3 triplet magnets and an optimization of the phase advance in IR2 and IR8 has taken place, and a new optics taking into account all the above points has been released (HLLHCV1.0) providing a baseline for all the studies [6].



In September 2012, the effort and results of the Task 2.2 team were presented in a workshop held at CERN, defining the present status, discussing the results and setting the new goals for the forthcoming period. The workshop contributions, representing the progress of Task 2.2 during the year are available via the following Indico link:

<https://indico.cern.ch/categoryDisplay.py?categId=4096>.

This work has been summarized in the 2nd Joint HiLumi LHC-LARP Annual Meeting: <https://indico.cern.ch/conferenceTimeTable.py?confId=183635#20121114>

**Contractual milestones and deliverables**

The milestone MS26 (“Distribution of Preliminary Optics and Lattice files to all work packages”) was reached ahead of schedule in month M5 via the publication on the official CERN optics database of a complete optics and layout version of the HL-LHC, with crab-cavities and 140 mm-150 T/m Nb3Sn inner triplets equipping the new high-luminosity insertions ATLAS and CMS [4] (see also second Task leader meeting held on March 16<sup>th</sup> 2012 <https://indico.cern.ch/conferenceDisplay.py?confId=182291>). Anticipating already a further increase of the triplet aperture up to 150 mm, the aperture of all other equipment (TAS and TAN absorbers, separation dipoles D1/D2 and matching quadrupoles Q4/Q5) was then derived and communicated in May to all WP3 participants (including US labs) in the framework of the LARP/HiLumi LHC collaboration meeting [5].

The first WP2 deliverable D2.1 (“optics and lattice files”) was on schedule (M18) incorporating in particular the baseline triplet parameters (150 mm-140 T/m) and the above mentioned more recent layout modifications together with the IR2 and IR8 phase advance optimization. This provides baseline optics. In parallel, an optimization of the layout of the matching section (and the re-calculation of the corresponding optics) which might be needed in order to reduce the demand on the deflecting voltage of the crab-cavities is well advanced [8].

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**Use of resources**

Please refer to Section **Error! Reference source not found.**

**2.2.2.3. Task 2.3: Particle Simulations**

**Progress towards objectives and significant results**

The first activities focused on the definition of the work packages and the distribution among the various collaborators and collaborating institutes. This included re-evaluating the actual level of resources and even re-defining the boundaries between Task 2.3 and Task 2.5. Indeed, the weak-strong beam-beam simulations activities, originally included in the objectives of Task 2.3, were moved to Task 2.5 for the sake of providing a more self-contained scope to Task 2.5. Furthermore, the overall organisation of Task 2.3 has been critically reviewed. Originally, the activities had a parallel structure with the various institutes contributing to the in-depth analysis of the four optics layouts. Given rather precise scaling laws which have been derived to pass from one layout to the other [13], and the convergence towards only a couple of layouts, it has been decided to assign the first one to the SLAC team, which was already well-advanced with the numerical simulations of the field quality, while the second layout has been assigned to several other institutes, each looking after the field quality of certain magnet families.

The first results achieved, were the preliminary estimate of the field quality specifications for the new triplets. The SLAC team, in collaboration with the CERN team, carried out a detailed

tracking campaign, whose results have been published in an article at the IPAC2012 conference [9]. These have been recently updated in the presentations at the 2nd Joint HiLumi LHC-LARP Annual Meeting: <https://indico.cern.ch/conferenceTimeTable.py?confId=183635#20121114> and they have been summarized in a paper submitted to the IPAC13 conference [10]. This study has been pushed towards the analysis of the impact on beam dynamics of a more realistic error table. This piece of information has been obtained by WP3, with which there is an on-going fruitful collaboration, and it has been used as starting point for the determination of a new specification table for the field quality of the triplets. In Figure 4 an example of the minimum dynamic aperture computed as a function of the phase space angles is shown. The error table used in the simulations is shown in Table 1, where the multipole components of the inner triplet are expressed in relative terms with respect to the expected triplet field imperfections provided by WP3. In this scenario, the non-linear corrector package of the triplet was equipped with ( $a_3$ ,  $b_3$ ,  $a_4$ ,  $b_4$ ,  $b_6$ ) correction coils (as in the nominal LHC). In view of the obvious criticality of the multipoles ( $a_5$ ,  $b_5$ ,  $a_6$ ), the corresponding triplet corrector magnets will be needed and they have been implemented in the latest layout version of the HL-LHC. The specification of the triplet correctors system, including detailed simulations of dynamic aperture have been performed [11] by the CERN team together with the study of the DA dependence on beta\* for round and flat optics [14].

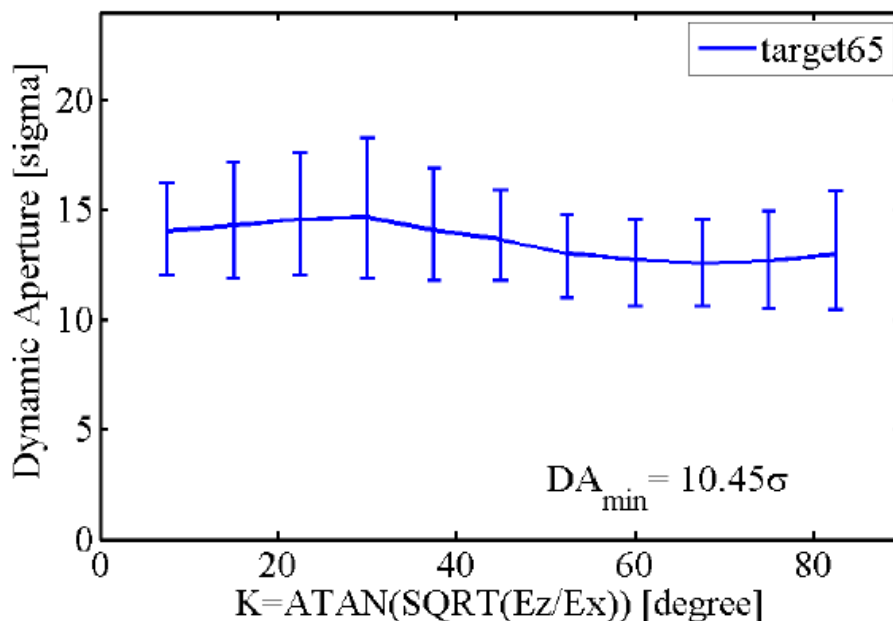


Figure 8: Minimum dynamic aperture as a function of phase space angle for the error table presented below (Table 1).

A preliminary analysis of the insertion magnets' field quality and impact on DA has been conducted by the SLAC team in collaboration with the CERN team [15] and a specification of the field quality has been provided by the CERN team for the IT and insertion magnets at injection [16].

Table 1: Latest error tables used in the tracking simulations. The multipoles are expressed as relative values [%] with respect to the reference table provided by WP3. In this scenario, the triplet corrector package contained ( $a_3$ ,

*b3, a4, b4, b6) correction coil. No corrector coils were assumed for a5, b5, and this explains the low values for the corresponding errors and justifies the requirements for the corresponding correctors in the present layout.*

skew	uncertainty	r.m.s.	normal	uncertainty	r.m.s.
<b>a3</b>	100	100	<b>b3</b>	100	100
<b>a4</b>	100	100	<b>b4</b>	100	100
<b>a5</b>	20	20	<b>b5</b>	20	20
<b>a6</b>	50	20	<b>b6</b>	50	50
<b>a7</b>	80	50	<b>b7</b>	50	50
<b>a8</b>	80	50	<b>b8</b>	50	50
<b>a9</b>	80	50	<b>b9</b>	50	50
<b>a10</b>	100	80	<b>b10</b>	50	50
<b>a11</b>	100	80	<b>b11</b>	80	80
<b>a12</b>	100	100	<b>b12</b>	80	80
<b>a13</b>	100	100	<b>b13</b>	80	80
<b>a14</b>	100	100	<b>b14</b>	50	50

In parallel, the analysis of the impact on the fringe field of the large aperture magnets, namely new triplets and D1 separation dipole, has been performed, using analytical estimates [17]. This has shown that the fringe fields might indeed have a non-negligible impact on the beam dynamics and therefore, efforts to implement new features in the SixTrack code are ongoing in order to complement the analytical analysis with long-term numerical simulations.

Effort has been put on further improving the analysis and simulation tools and in particular SixTrack [18][19][20]. As an example models needed to simulate the protons' beam dynamics in the presence of the crab cavities have been implemented. Special multipoles, so-called RF multipoles, have been implemented in the SixTrack code. The debugging phase has been successfully completed and preliminary numerical simulations of the impact of field quality imperfections in the crab cavities are in progress [21]. The aim is to compute a complete error table based on tracking studies (dynamic aperture) and analytical calculations of a few observables such as tune, chromaticity, coupling and amplitude detuning.

Two general meetings to review the status of Task 2.3 activities have been organised and the material can be found at the following links.

<http://indico.cern.ch/conferenceDisplay.py?confId=196176>

<http://indico.cern.ch/conferenceDisplay.py?confId=211515>

### **Contractual milestones and deliverables**

The initial dynamic aperture evaluation both at injection and collision energies, and for different optical configurations has been performed and the field quality requirements for the magnets is very well advanced with a first error table produced for the inner triplets (MS27 for M24). The specification of the triplets' correction system is ready, ahead of schedule (MS28 for M24). The field quality targets of the new HL-LHC magnets (D2.2) and the layout specification of the triplet corrector package (D2.3) are therefore expected to be delivered on time for month M36.

### **Planning, deviations and corrective actions**

Task on schedule		Ahead of schedule	√	Minor delay		Significant delay	
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## Use of resources

Please refer to Section **Error! Reference source not found.**

### 2.2.2.4. Task 2.4: Intensity Limitations

#### Progress towards objectives and significant results

During the reporting period, the task focused on seven main activities:

- 1) Definition of the work packages and distribution among the various collaborators and institutes.
- 2) Follow-up of the LHC performance and participation in the LHC Machine Developments (MDs) via beam experiments in order to improve the understanding of collective effects in the present machine and assess our predictive power for the HL-LHC in terms of intensity limitations.
- 3) Intra-Beam Scattering (IBS) studies for the current LHC, nominal LHC and HL-LHC, and setting-up of a benchmarking case with all the IBS contributors.
- 4) Evaluation of the impedance budget for the crab cavities to be installed in the HL-LHC, and dedicated impedance studies for other equipment.
- 5) Development of new ideas to push the machine performance.
- 6) Electron cloud (heat load) studies.
- 7) Identification of possible scenarios with a high harmonic RF system.

**Item 1):** All the information related to the Task 2.4 (objectives, description of the work, sub-tasks, milestones, deliverables, person-months from the collaboration, work breakdown structure, Gantt chart, mailing list of 29 people, meetings, publications, inputs needed, questions raised, etc.) can be found at the following link:

<https://espace.cern.ch/HiLumi/WP2/task4/SitePages/Home.aspx>.

This web page is maintained by the Task leader and three Task 2.4 meetings took place until now. The detailed study plan for 2013 was discussed and approved by the team at the beginning of the year and the main goal is to have an initial estimate of the machine impedance by

01/11/2013

([https://espace.cern.ch/HiLumi/WP2/task4/SiteAssets/SitePages/Home/ImpedanceStudiesPlan\\_HL-LHC\\_v2.pdf](https://espace.cern.ch/HiLumi/WP2/task4/SiteAssets/SitePages/Home/ImpedanceStudiesPlan_HL-LHC_v2.pdf)).

**Item 2):** The LHC luminosity in 2012 has reached a record peak value of  $7.7 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$  at 4 TeV (i.e. 77% of the 7 TeV design luminosity of  $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ ). The present LHC filling scheme contains 1374 colliding bunches, spaced by 50 ns, with  $1.6 \times 10^{11}$  p/b, and within transverse r.m.s. normalized emittances of about 2.2  $\mu\text{m}$ . A review of the collective effects in the LHC (and its injector complex) was presented at the IPAC2012 conference [22].

Three types of instabilities perturbed the intensity ramp-up: i) in collision (during the levelling process with parallel separation in LHCb, but for some specific bunches only), ii) during the collapsing process (putting the beams into collision) and iii) during or at the end of the squeeze process [23]. Concerning the first two types of instabilities mentioned above, a possible explanation lies in the fact that the tune spread induced by the LHC Landau octupoles and the long-range beam-beam interactions compensated each other [24] with the polarity of the octupoles initially chosen to achieve a negative amplitude detuning in both planes, which generally improves the damping efficiency of coherent modes induced by resistive impedances. For this reason the polarity of the Landau octupoles was changed to positive in August.

Furthermore, the gain of the transverse damper was increased to achieve a minimum damping time (50 turns) and the chromaticity (initially kept to a few units) was adjusted to 15-20 units. Since then the beam dumps linked to the instabilities disappeared and the intensity could be increased, but then instabilities at the very the end of the squeeze reappeared, although with limited beam losses. The new values of the transverse damper gain and chromaticity were suggested following a new analytical approach for the study of the single-bunch and coupled-bunch transverse coherent instabilities, including the head-tail azimuthal and radial modes, the coupled-bunch modes, the variability with chromaticity, the Landau octupoles and the transverse damper (see Figure 9) [25].

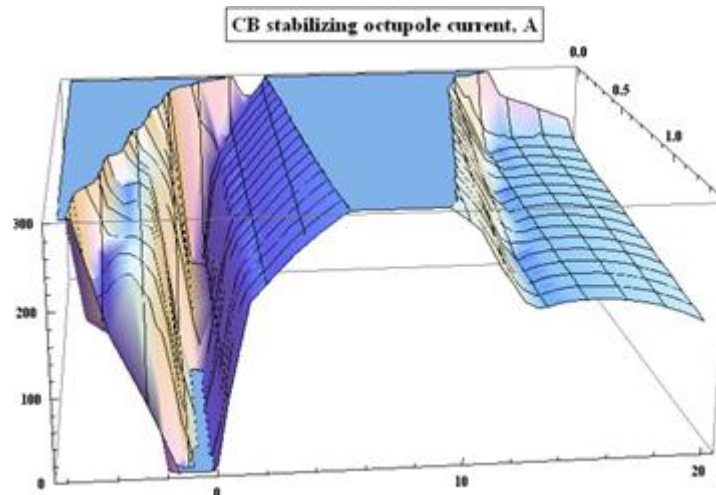


Figure 9: Stability curve for the transverse coupled-bunch instability with Landau octupoles only (i.e. without beam-beam), using the current LHC beam parameters, for positive octupoles current in A (vertical axis), vs. chromaticity (horizontal axis) and transverse damper gain (in units of synchrotron tunes)[25]. The maximum gain of 1.4 corresponds to a damping time of 50 turns.

The instabilities still occurring at the end of the squeeze are however not yet fully understood, noting in addition that more Landau octupoles' current is needed during the physics fills (i.e. with 2 beams) than in dedicated MDs with only one beam. In particular, the octupole current used in operation is close to its maximum value of 550 A, although the energy is limited to 4 TeV. This is therefore a major concern for the HL-LHC because the scaling to 7 TeV would imply exceeding the maximum current of the octupole circuit. The RF heating of some equipment is also worrisome and it is closely followed up [26]. Some successful impedance reduction actions have however been already implemented, as for instance on one of injection kicker modules [27], but further modifications will be required for the HL-LHC era.

Tests with bunches spaced by 25 ns provided important input for the understanding of the effectiveness of beam conditioning (“scrubbing”) [28]. In parallel, the operating experience with electron cloud clearing electrodes at DAFNE has been reviewed [29][30], revealing a very beneficial impact of clearing electrodes.

**Item 3):** IBS studies have been finalized and presented at the occasion of a Task 2.4 meeting [31], revealing no major issues with the current HL-LHC parameter set. All the results have been published in [32].

**Item 4):** Some guidance for the impedance budget of the crab cavities was already given in 2011 [33] and the different so-called compact crab cavity prototypes have been designed and built following these recommendations. The first impedance model for HL-LHC including new collimators (several scenarios are being considered, depending on the materials and positions) and crab cavities were presented at the HiLumi workshop in Frascati, 14-16/11/2012, with a

review of all the other equipment which will be installed or modified, in particular the new experimental beam pipes. The new design for the vacuum chamber of the CMS experiment has already been studied and the results have been published in [34].

Furthermore, following the 2011 LHC run with issues clearly identified for some machine components equipped with RF fingers, a dedicated task force was set up in 2012 in order to review all these equipment. The information related to this task force can be found at <http://emetral.web.cern.ch/emetral/LRFF/LRFF.htm> and recommendations have been made at the end of 2012 (both for the LHC and HL-LHC). A paper has been submitted at the IPAC2013 conference [35] and the final report should be published before the end of the year.

**Item 5):** The use of circular modes and flat emittance beams has been proposed as an alternative plan, which seems promising and deserves to be studied in more details [36]. This is now followed up in the Task 2.5.

**Item 6):** Detailed studies have been performed on the heat load generated by an electron cloud in the cold arcs, as it is a concern for operation (near and) beyond nominal beam current. All the results have been published in Ref. [37].

**Item 7):** A first meeting has been organised in collaboration with WP4 (<https://indico.cern.ch/conferenceDisplay.py?confId=231528>) to discuss the possible needs of a higher harmonic RF system to flatten the bunch longitudinal profile and therefore reduce the beam-beam tune spread, pile-up peak density, beam induced RF heating and increase beam stability.

**Contractual milestones and deliverables**

Even if there were neither deliverables nor milestones foreseen for this reference period, the overall progress of the various activities is satisfactory. The two milestones MS29 and MS30 are for month 24 (01/11/2013) and month 30 (01/05/2014), with initial estimates of the machine impedance and intensity limitations, respectively. The deliverable D2.4 attached to Task 2.4 is a report expected for month 36 (01/11/2014) on “Beam intensity limitations”.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**Use of resources**

Please refer to Section **Error! Reference source not found.**

**2.2.2.5. Task 2.5: Beam-Beam Effects**

**Progress towards objectives and significant results**

During the reporting period, the task was concentrating on the evaluation of the HL-LHC scenarios with respect to beam-beam effects along three major directions: a) using a well-tested-approach – the so-called weak-strong simulations; b) developing self-consistent strong-strong simulations; c) participating in LHC Machine Development (MD) beam experiments with the goal to improve the understanding of beam-beam effects in the present machine and for simulation benchmarking.

The progress on item **a** includes: significant development of the tools and methods in the Lifetrac code, which now enables detailed simulations of beam-beam effects with machine imperfections, crab-cavities, etc. [38], evaluation of the baseline HL-LHC scenario using the SixTrack and Lifetrac codes in the case of machine containing no field errors [39], initial evaluation of the HL-LHC scenario including three head-on collision points (IR1, IR5 and IR8) and full compensation of the crossing angle by crab cavities. The simulations established that the baseline scenario with  $\beta^*=15$  cm and a full crossing angle of 590  $\mu$ rad (corresponding to a

minimum long range encounter separation of  $12.5 \sigma$ ) provides the necessary dynamic aperture (DA). The agreement between the SixTrack and Lifetrac codes is good (Figure 10). The initial evaluation of the HL-LHC scenario with full crab-on crossing and luminosity levelling with  $\beta^*$  suggests that the minimum DA requirements could be met [40].

Concerning the detrimental effects of the long-range beam-beam interactions in the LHC (and a fortiori HL-LHC) in case of insufficiently large crossing-angle, and the option to mitigate them by the use of dedicated DC current wires which would be positioned in the two high-luminosity insertions, first simulation results showed the potential of such a scheme, enabling a possible reduction of the crossing angle by a few  $\sigma$ 's [41].

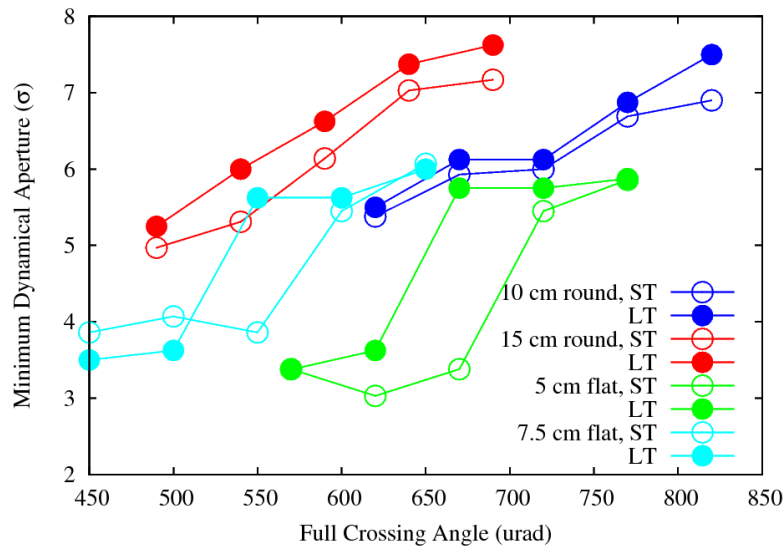


Figure 10: Minimum DA for various collision schemes vs. crossing angle simulated with SixTrack (ST) and Lifetrac (LT) codes.

Along the objective **b**, significant progress was achieved in code development: machine impedance and feedback models were implemented in the BeamBeam3D [42] and in the COMBI codes. The combined action of beam-beam effect and machine impedance (Figure 11) indicates a possible source of coherent instability, which has motivated a dedicated experiment in the LHC [43] for benchmarking. In parallel a full code-to-code benchmark has been performed showing a good quantitative agreement between the two models. The study is now extended to multi-bunch beams.

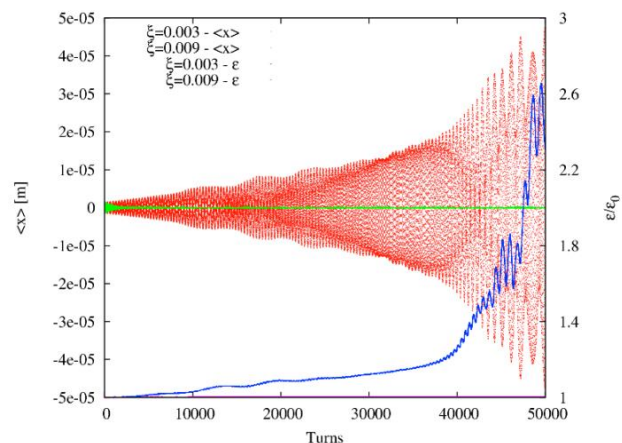
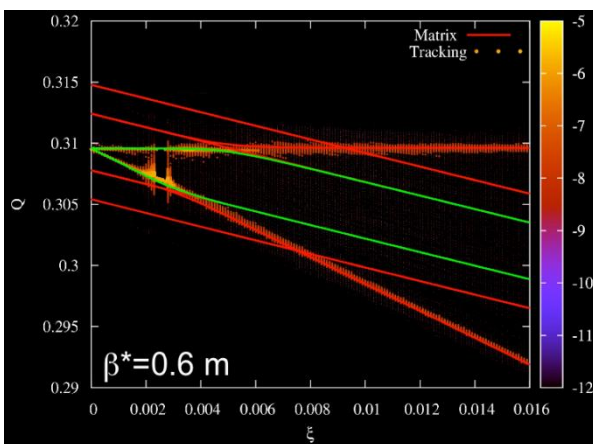


Figure 11: Dependence of coherent synchro-betatron beam-beam mode tunes on beam intensity (left), dipolar oscillation of the beam (in red) and emittance evolution (in blue) as a function of turn in unstable regime (right)

From objective **c**, three main results will contribute strongly to the task studies: the leveling techniques, in particular via  $\beta^*$ , the means to cure transverse coherent instabilities and the elaboration of possible DA scaling laws for long range beam-beam effects.

Leveling with transverse offset was regularly used in operation in 2012 in order to deliver an appropriate constant luminosity to the LHCb experiment. No detrimental effect on beam emittance growth is observed when offsets are controlled and kept such that a minimum Landau damping is provided, i.e., from a head-on collision in other interaction points.

The feasibility of luminosity leveling by the use of  $\beta^*$  [44][45][46] has been proven technically in three dedicated experiments in 2012. In Fig. 8 the luminosity increase as a function of  $\beta^*$  at CMS and ATLAS is compared to the theoretical value. Collisions from 3 m  $\beta^*$  can be maintained with no major problems.

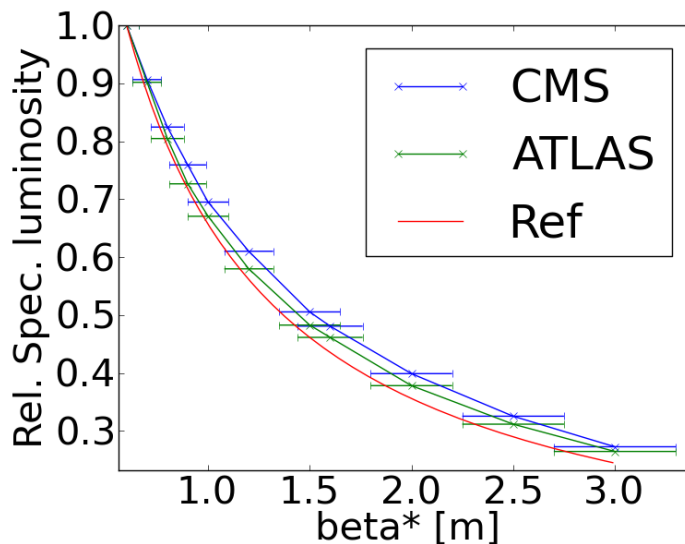


Figure 12: measured CMS (blue line), ATLAS (green line) and theoretically expected (red line) specific luminosities as a function of  $\beta^*$ . Error bars assume a 20% beta-beating error.

Landau damping resulting from the large head-on beam-beam tune spread has also proven to be an effective stabilizing mechanism against beam instabilities [47].

The long-range beam-beam experiments conducted in the LHC [48] have confirmed the possibility of deriving scaling laws for the dynamic aperture with such parameters as energy, intensities, crossing angles,  $\beta^*$  and number of collisions without the use of massive tracking campaigns [49]. Although the method does not allow evaluating the absolute value of the dynamic aperture, it makes the study of possible scenarios for the HL-LHC faster and more flexible.

Four joint Task meetings were held to coordinate the group activities, and a number of teleconference meetings in sub-groups to discuss individual progress. An e-mail list was created for information exchange.

Many of the results of the experimental and simulation studies performed in the frame of the HL-LHC projects have been presented at a workshop on "Beam-Beam Effects in Hadron Colliders" held at CERN in March 2013: <http://indico.cern.ch/conferenceDisplay.py?confId=189544>. This workshop was motivated by



the successful start of the LHC and the emergence of a vast amount of beam-beam observations. Its purpose was to review the present knowledge and compare with the observations, and to discuss and plan future research work, with special emphasis on the performance of the LHC after the first long shutdown as well as on studies needed for the planned LHC upgrade projects such as HL-LHC. The workshop has been partly sponsored by HiLumi LHC and the International Organizing Committee included several collaborators of Tasks 2.4 and 2.5.

### **Contractual milestones and deliverables**

The task is on schedule for reaching the MS31 milestone in M30, with the deliverable D2.5 (Beam-beam effects) expected 6 months later.

### **Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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### **Use of resources**

Please refer to Section **Error! Reference source not found.**

#### **2.2.2.6. Task 2.6: Beam Parameters and Luminosity Optimization**

### **Progress towards objectives and significant results**

The main activities over the last period were concentrated around observations and lessons learned from the LHC operation at 4 TeV in 2012, and on the progress that could be achieved in the injector complex during dedicated Machine Development (MD) studies.

The progress of the machine understanding was discussed together between the HL-LHC and the LHC Injector Upgrade (LIU) projects during the first and second HL-LHC/LIU joint workshops [50], with as ultimate goal an agreement on a common set of upgrade parameters. In the same spirit, possible HL-LHC beam parameters and operation scenarios were also presented at the 2012 annual LHC performance workshop [51] in order to discuss these figures with the LHC operation team, and put them into perspective with respect to recent machine studies or achievements of the LHC and of its injector chain:

- Achievement of higher than nominal beam brightness for the operation with 50ns bunch spacing during routine LHC operation. Dedicated and parasitic studies of the emittance growth in the LHC indicate that the emittance growth can be kept within 20% to 30% from the injected beam emittance to the beam emittance at the beginning of a physics fill. Furthermore, the observed emittance growth does not occur equally in both beams and both planes indicating that there is still room for further improvements on the emittance dilution. A fraction of the emittance growth during injection comes from the Intra Beam Scattering (IBS) process, requiring a strict control of the bunch length and setting limits for the maximum attainable bunch densities at injection.
- Achievement of higher than ultimate head-on beam-beam parameters for operation with 50ns bunch spacing.
- Studies related to the minimum required beam separation for the parasitic beam encounters left and right from the IPs.
- Production of higher than ultimate beam brightness in the LHC during nominal operation with 50ns bunch spacing.

- Production of bunch population beyond  $3.5 \cdot 10^{11}$  ppb with nominal beam emittance in the LHC injector complex for single bunch operation indicating that such population are not out of reach for the LHC injector complex after its upgrade.

A first version of the HL-LHC beam parameters was published in [52], containing two possible parameter sets, the first one assuming a bunch spacing of 25 ns, and the second one established with for a bunch spacing of 50 ns. This version was then reviewed after detailed discussions which took place during four dedicated HL-LHC Coordination meetings and which aimed at a common set of parameters and goals and planning for the LHC upgrade between the four machine experiments, the HL-LHC project and the CERN management.

The main outstanding issues revolve around the performance estimates for the LHC upgrade with 25ns bunch spacing, with potential limitations due to the electron-cloud effect in the injector complex and the LHC proper, and an understanding of the limitations for the experiments due to too high a number of events per bunch crossing. Recent discussions with the experiments have revealed the need to limit not only the maximum pile-up but also the longitudinal pile-up density. This has important implications for the preferred levelling scenario now based on a full compensation of the crossing angle by crab-cavities during the whole fill and the progressive reduction of the  $\beta^*$  at the interaction point to level the luminosity. This scenario entails large beam-beam tune spreads (up to 0.034 for three experiments in IR1, 5 and 8) and the study of a higher harmonic RF system to flatten the bunch profiles and reduce the beam-beam tune spread has been launched in collaboration with WP4. The latest HL-LHC beam and optics parameter table can be found in [1].

### Contractual milestones and deliverables

The present version of the HL-LHC beam parameters have been approved at the first HL-LHC Parameter and Layout Committee meeting and is documented on the PLC website: <https://espace.cern.ch/HiLumi/PLC/default.aspx>. The publication of the final beam parameters and operational procedures (D2.6) is foreseen for month 36.

### Planning, deviations and corrective actions

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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### Use of resources

Please refer to Section **Error! Reference source not found.**

## 2.2.3. WP3: Magnet design

### 2.2.3.1. Task 3.1: Coordination and Communication

#### Progress towards objectives and significant results

In these first 18 months, 25 meetings of the WP3 were organized, sometimes jointly with other WPs (optics, powering, heat deposition). The web site has been built, containing the list of meetings and links to presentations, and a series of tables and plots document the advancement of the project. The baseline lay out has also been published on the web site. Input files of the models of the different magnets have been made available. A special set of tables summarizes the different options and allows an easy comparison between them. The web site of WP3 was also used to exchange information with the other WPs (as for instance the field maps used by the energy deposition team).

**Work package meetings**

<i>Dates</i>	<i>Type of meeting</i>	<i>Venue</i>	<i>Attendance</i>	<i>Indico link</i>
17/11/11	LARP/HI LUMI	CERN	50	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=150474">https://indico.cern.ch/conferenceDisplay.py?confId=150474</a>
12/11/11	WP3: 140 mm Nb3Sn design	CERN LARP	20	<a href="https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx">https://espace.cern.ch/HiLumi/WP3/SitePages/Minutes%20and%20Presentations.aspx</a>
12/12/11	Conceptual design of Nb3Sn	CERN		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216862">https://indico.cern.ch/conferenceDisplay.py?confId=216862</a>
10/2/12	Chamonix	Chamonix	100	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216864">https://indico.cern.ch/conferenceDisplay.py?confId=216864</a>
14/2/12	WP3: layouts	CERN LARP	20	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216866">https://indico.cern.ch/conferenceDisplay.py?confId=216866</a>
22/3/12	WP3: cooling aspects	CERN LARP	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216867">https://indico.cern.ch/conferenceDisplay.py?confId=216867</a>
8/5/12	LARP/HI LUMI	FNAL	50	<a href="https://indico.fnal.gov/conferenceDisplay.py?confId=5072">https://indico.fnal.gov/conferenceDisplay.py?confId=5072</a>
7/6/12	WP3 and energy deposition	CERN LARP KEK CEA	30	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216869">https://indico.cern.ch/conferenceDisplay.py?confId=216869</a>
26/06/2012	WP3 Insulation	CERN		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216870">https://indico.cern.ch/conferenceDisplay.py?confId=216870</a>
2/7/12	Aperture selection	CERN LARP KEK CEA	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216871">https://indico.cern.ch/conferenceDisplay.py?confId=216871</a>
26/7/12	WP3: shielding and heat loads	CERN LARP KEK CEA	30	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216872">https://indico.cern.ch/conferenceDisplay.py?confId=216872</a>
2/8/12	WP3: HQ test	CERN LARP KEK CEA	35	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216876">https://indico.cern.ch/conferenceDisplay.py?confId=216876</a>
28/8/12	WP3: QXF cross-section	CERN LARP KEK CEA	30	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216877">https://indico.cern.ch/conferenceDisplay.py?confId=216877</a>
30/8/12	WP3: D1 and Q4 updates	CERN KEK CEA	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216878">https://indico.cern.ch/conferenceDisplay.py?confId=216878</a>

3/9/12	Resistive magnets IR3+7 (hosted by collimation WG)	CERN	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216873">https://indico.cern.ch/conferenceDisplay.py?confId=216873</a>
4/9/12	WP3: heat load and shielding	CERN LARP KEK CEA	25	<a href="http://indico.cern.ch/conferenceDisplay.py?confId=216859">http://indico.cern.ch/conferenceDisplay.py?confId=216859</a>
5/11/12	WP3: Q4 design	CERN CEA	20	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216874">https://indico.cern.ch/conferenceDisplay.py?confId=216874</a>
14-16/11/12	WP meeting at Annual Meeting	Frascati	50	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=183635">https://indico.cern.ch/conferenceDisplay.py?confId=183635</a>
28/11/12	D1 design, cooling	CERN KEK	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254547">https://indico.cern.ch/conferenceDisplay.py?confId=254547</a>
10/12/12	Triplet operation	CERN, LARP	30	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254553">https://indico.cern.ch/conferenceDisplay.py?confId=254553</a>
28/1/12	Correctors	CERN CIEMAT	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254554">https://indico.cern.ch/conferenceDisplay.py?confId=254554</a>
15/2/12	HQ	CERN, LARP	25	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254556">https://indico.cern.ch/conferenceDisplay.py?confId=254556</a>
7/3/12	Layout, Correctors	CERN, LARP, CEA, KEK	35	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254557">https://indico.cern.ch/conferenceDisplay.py?confId=254557</a>
26/3/13	Cooling	CERN, LARP	30	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254559">https://indico.cern.ch/conferenceDisplay.py?confId=254559</a>
8-10/4/13	Napa valley	CERN, LARP, KEK	50	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=254561">https://indico.cern.ch/conferenceDisplay.py?confId=254561</a>

### Contractual milestones and deliverables

The Work Package had one deliverable, D3.1 and 3 milestones, MS33, MS34, MS35 in the period, all achieved.

### Planning, deviations and corrective actions

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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### 2.2.3.2. Task 3.2: Nb<sub>3</sub>Sn quadrupoles for the inner triplet

#### Progress towards objectives and significant results

The 140 mm case of a Nb<sub>3</sub>Sn triplet has been fully studied. This includes feedback from energy deposition on heat loads and radiation damage. A tentative shielding has been proposed,

aiming at peak heat load of  $4 \text{ mW/cm}^3$  and peak radiation damage of 40 MGy. This shielding takes more than 20 mm of the aperture (see Fig. 1 left). On the other hand, the conceptual design of the 140 mm gave no showstoppers provided that the coil width is increased (more strands per cable and larger strand). These results, achieved in June 2012, suggested going to a 150 mm aperture to have the maximum performance. The choice of the aperture is a milestone for the project.

In the second part of 2012, the study of the conceptual design of a 150 mm aperture  $\text{Nb}_3\text{Sn}$  quadrupole MQXF was carried out, with a choice for the strand (0.85 mm diameter) and for the cable (40 strands, with core), see Figure 1 right. The analysis of the mechanical and magnetic design has been carried out. Aspects related to protections showed that this design has a larger margin with respect to the smaller aperture magnets. The test of the LARP magnet HQ at CERN has been particularly important to focus on the aspects that still need further study and analysis. The cable dimensions are now being finalized, and first winding trials are on-going.

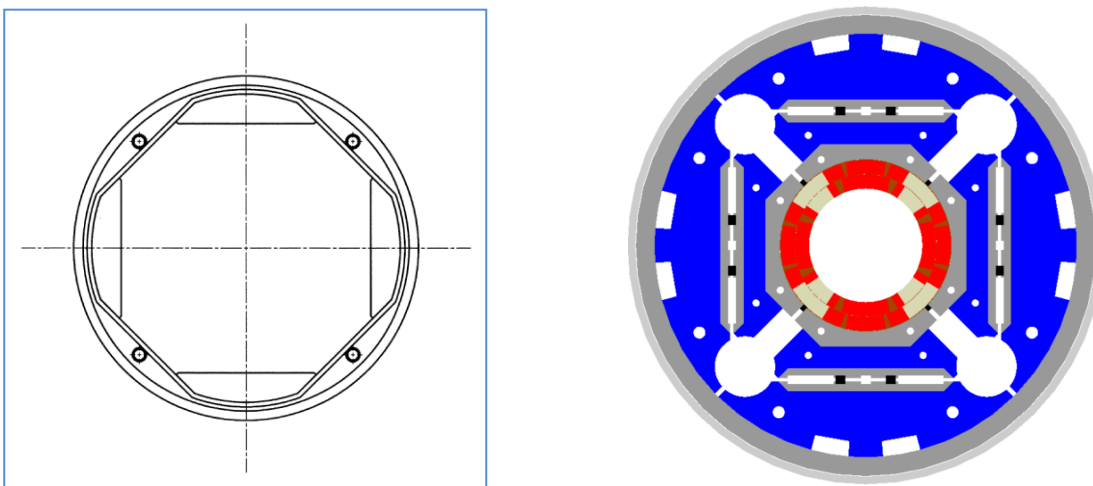


Figure 13: Proposal for shielding inside the cold bore (left) and cross-section of the MQXF

### Contractual milestones and deliverables

M12: Requirements for  $\text{Nb}_3\text{Sn}$  inner triplet and comparison with present status of the art (report)

### Planning, deviations and corrective actions

Task on schedule	√	Ahead of schedule	Minor delay	Significant delay	
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#### 2.2.3.3. Task 3.3: Separation dipoles

##### Progress towards objectives and significant results

For the separation dipole the Nb-Ti technology has been selected. A first analysis of two different options (130 and 150 mm aperture) and two layers coil gave an operational field of  $\sim 6.5 \text{ T}$ , and lengths of  $\sim 5.5 \text{ m}$ . A large loadline margin of 30% has been taken, in the hypothesis of a significant heat load. The analysis showed that both saturation and the large stray fields can be an issue for this magnet. The large saturation requires a careful study and design of the iron to minimize these effects. On the other hand, notwithstanding the large aperture, the level of coil stress is manageable (within 100 MPa). For the mechanical structure the design option based on an iron yoke giving a relevant contribution to the force containment, as in MQXA, has been selected. After discussion with WP2 colleagues, it has been suggested

that the coil width be reduced by a factor two, i.e., going to one layer to have less flux and more iron to absorb it. This reduces the field to  $\sim 5.2$  T, with a modest increase in magnet length to  $\sim 7$  m. The advantage is to strongly reduce the stray field and the iron saturation.

This new case is under analysis in the second half of 2013, after the selection of the triplet aperture, with a D1 aperture of 160 mm. For this layout, the mechanical model has been built, giving no showstoppers, and the magnetic analysis has been done. Multipole optimization has been carried out and an estimate of the random components has been provided to WP2. First results of heat deposition on this baseline have shown that the aperture could be reduced to 150 mm. This option will be considered in the second half of 2013.

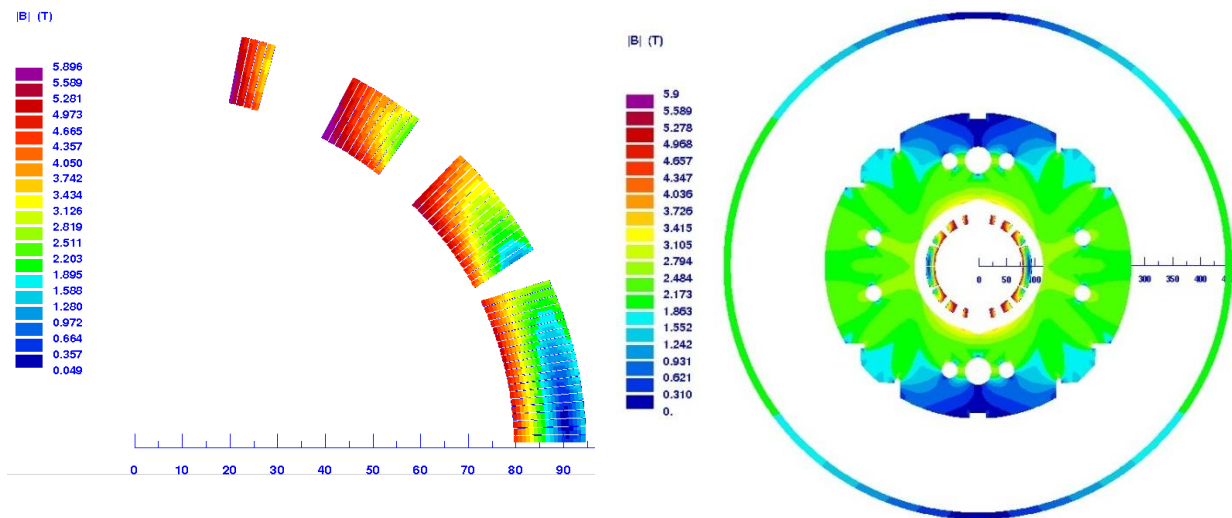


Figure 14: Proposal for D1 coil cross-section with operational field in the coil (left) showing  $\frac{1}{4}$  of the cross section and full magnet cross-section within the cryostat (right)

**Contractual milestones and deliverables**

M12: Requirements for separation dipoles

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule	Minor delay	Significant delay	
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**2.2.3.4. Task 3.4: Cooling**

**Progress towards objectives and significant results**

The thermal model of the Nb<sub>3</sub>Sn inner triplet with 140 mm aperture, considered at the beginning of the year, has been implemented. Using the heat deposition provided by the FLUKA team, the total heat load (about 1000 W) has been estimated. Given the need for a large shielding to reduce the radiation dose below 40 MGy, the design is based on the presence of an inner beam screen, which allows a thermal separation of the coil from the shielding and to remove 500 W at a higher temperature (beam screen works at 10-20 K) on the shielding before it reaches the magnet. In this way the actual heat load in the magnet is reduced by almost a factor two. The baseline is to have active cooling with heat exchanger in the triplet, and in the D1+corrector package, see Figure 15.

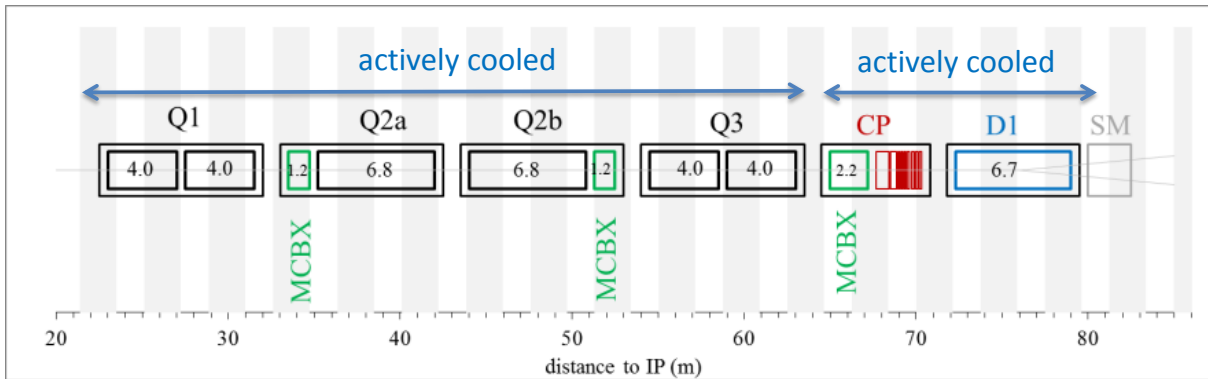


Figure 15: Baseline for cooling the magnets from Q1 to D1

The model has allowed giving (i) the thickness of the He annulus between the cold bore and the magnet; (ii) the dimension of the holes needed for the heat exchanger; (iii) the requirements on the open paths in the pole of the coil to allow heat flow from the inner part of the magnet to the heat exchanger. Under these conditions, a maximum temperature of 3.3 K in the coil under the debris shower has been estimated (operational temperature is 1.9 K, see Figure 16). The work is carried out in strong interaction with the task 3.2 of the Nb<sub>3</sub>Sn triplet.

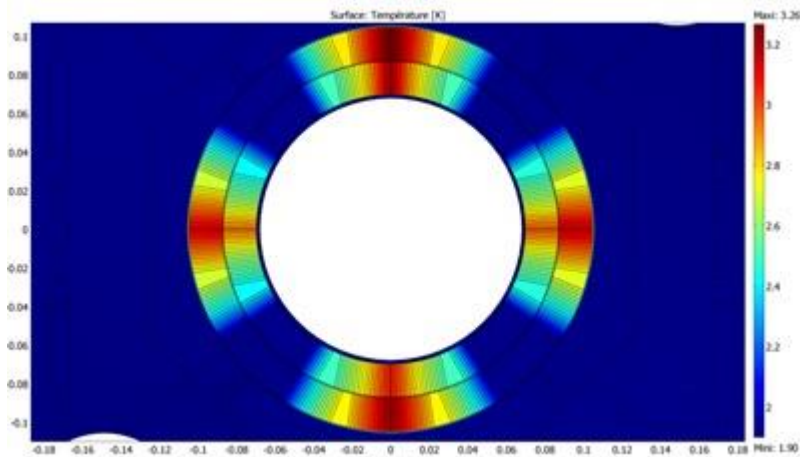


Figure 16: Temperature map in the Inner Triplet quadrupole coil due to heat load ( $mW/cm^3$ ), 140 mm aperture case, with W-shielding (cross-section plane, in meters)

**Contractual milestones and deliverables**

No such

**Planning, deviations and corrective actions**

Task on schedule	✓	Ahead of schedule	Minor delay	Significant delay
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**2.2.3.5. Task 3.5: Special Magnet Studies**

**Progress towards objectives and significant results**

The Nb-Ti technology is kept as backup for the triplet. A first magnet with such technology MQXC0, originally developed for the phase-1, has been assembled and successfully tested. It features a single 120 mm aperture and its design performance has been reached within 4

training quenches; then the magnet again reached the nominal value with one quench after thermal cycle. The second aperture MQXC1 reached nominal after 6 quenches, and in one quench after thermal cycle. Field quality has been measured at room temperature without conclusive results. A complete set of magnetic measurements will be available in Autumn 2013.

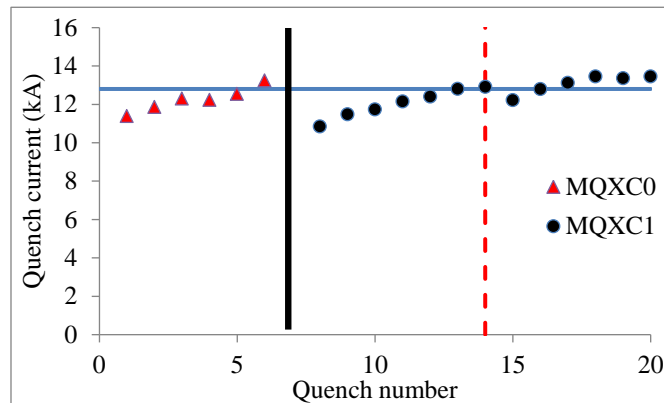


Figure 17: Training of MQXC0 and MQXC1

The conceptual design of the two-in-one large aperture quadrupole Q4 has been started in CEA-Saclay. First studies have focused on aperture ranging from 85 to 120 mm, and with three options for the coil: one or two layers with small cable (left over from LHC-MQM production), and one layer with larger LHC-MQ cable. Magnetic and mechanical analysis have been carried out and published in internal reports. Since August 2012, the analysis has been focused on the 90 mm aperture option. The three options (see Figure 18) for the cable provide operational gradient within 20%, compensated by different lengths, and similar field quality and similar stresses. The baseline of a one layer MQ cable coil has been selected, presenting the advantage of having the material (unused shorted lengths from the LHC production are available) and there is no need for quench heaters.

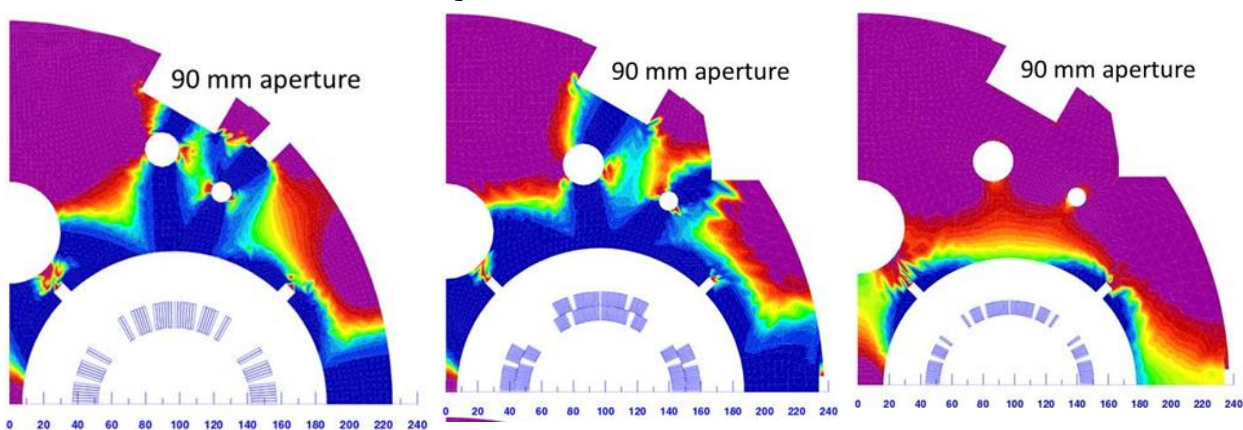


Figure 18: Proposal of cross-sections with three different cable lay-out: 1 layer MQ cable (left), 2 layer MQM cable (center), 1 layer MQM cable (right)

### Contractual milestones and deliverables

Review of the Nb-Ti options for the inner triplet for new peak and integrated luminosity targets



**Planning, deviations and corrective actions**

Task on schedule	✓	Ahead of schedule		Minor delay		Significant delay	
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**2.2.4. WP4: Crab Cavities**

**2.2.4.1. Task 4.1: Coordination and Communication**

**Progress towards objectives and significant results**

The reporting period started by putting the optimum operational and organizational structure in place; the main body here became the CCTC working group (see under Task 4.2), coordinating the work of cryogenics, HVAC, cabling, RF power, vacuum, diagnostics, machine protection, integration in view of both the initial SPS tests and the later LHC installation. This group was complemented by the Machine Protection working group and other HL-LHC working groups (Parameter, Technical Committee, e.g.); the coordination with the US-LARP partners took place inside the Hi-Lumi/LARP joint meetings, which were instrumental to the success of WP4.

The design of three different types of compact crab cavities (CCCs) made excellent technical progress – in fact for all three designs Nb prototypes were designed, fabricated and successfully tested in vertical cryostats.

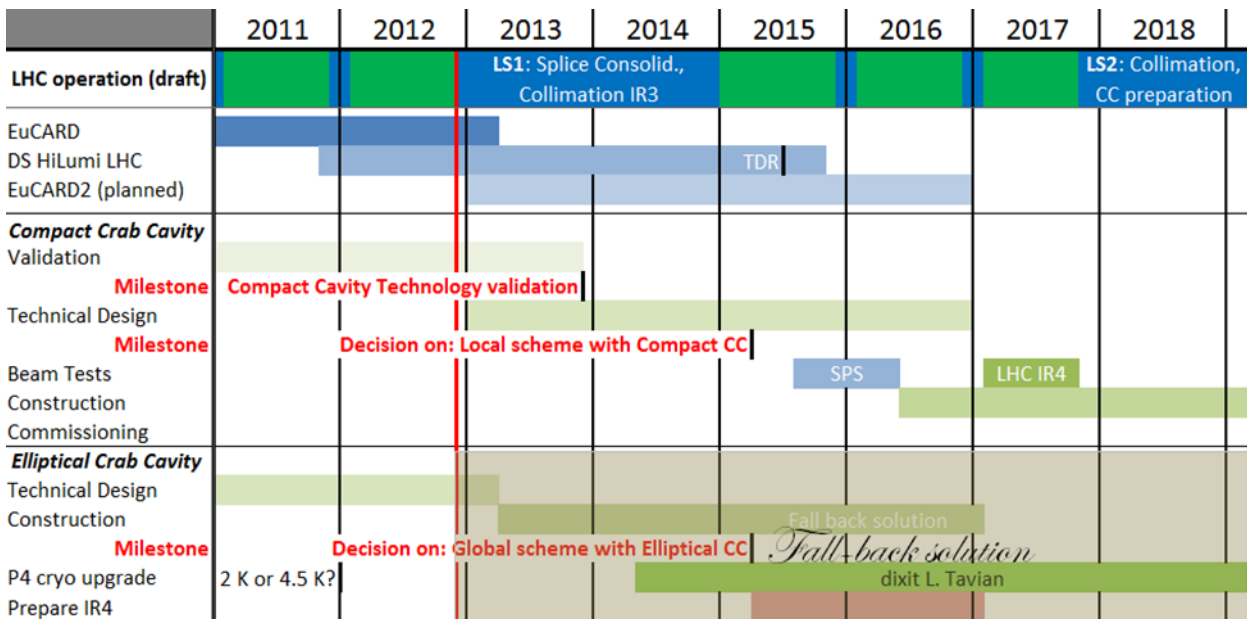


Figure 19: Excerpt of planning of LHC Crab Cavity Schedule, showing the integration with other FP7 programmes

The aforementioned good progress with the CCCs technical designs including the mitigation of HOMs and MP, the verification of the field homogeneity and the successful conceptual design of power couplers, significantly reduced the risk of their feasibility. On the other hand, studies revealed severe performance limitations of a global crabbing scheme (the only possibility when using elliptical crab cavities): betatron phase advance constraints between CC location and IPs, limitation to a single crossing plane and – most severe – a non-compatibility of the orbit distortions along the whole machine, different for heads and tails of the bunches, which does

not allow narrow collimator settings (the bunches wobble sideways on the whole turn). This together led to the decision to put the work on Elliptical Crab Cavities entirely on hold. We're presently looking at a way to formalize this change and an amendment of the contractual document is now in preparation. The freed resources will be best re-invested in strengthening the design work on the CCCs and their integration, as well as to accommodate the study for a harmonic system, see below.

Regarding required phase stability of the crab cavity voltage (for a wrong phase, also the centre of the bunch is kicked sideways) and the influence of the bunch length and longitudinal emittance on peak and average luminosity, the need of a harmonic accelerating system in the LHC was discussed on several occasions in the LHC Machine Committee (see e.g., [https://espace.cern.ch/lhc-machine-committee/Minutes/1/lmc\\_152.pdf](https://espace.cern.ch/lhc-machine-committee/Minutes/1/lmc_152.pdf)). The harmonic system will, along with the transient beam loading, in particular in the envisaged "full detuning" mode, influence individual bunch arrival times (phases) in the cavities. For this reason it was considered important to study these influences as a new Task 4.4 "Study of LHC Harmonic System", replacing the present Task 4.4 "Elliptical Crab Cavity Technical Design". The exact definition of this new task and the required resources are still being discussed, but it became clear that our US partners (LARP) are interested and competent to participate in this study. The resources are estimated to be modest.

#### Work package meetings

<i>Dates</i>	<i>Type of meeting</i>	<i>Venue</i>	<i>Attendance</i>	<i>Indico link</i>
16-17/8/2011	Workshop	CI	17	<a href="http://www.conf.dl.ac.uk/event.asp?eventID=231#">http://www.conf.dl.ac.uk/event.asp?eventID=231#</a>
14-15/11/2011	Workshop	CERN	52	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=149614">https://indico.cern.ch/conferenceDisplay.py?confId=149614</a>
11/07/2012	CCTC#1	CERN	12	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=222241">https://indico.cern.ch/conferenceDisplay.py?confId=222241</a>
26/10/2012	CCTC#2	CERN	9	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=222242">https://indico.cern.ch/conferenceDisplay.py?confId=222242</a>
14-16/11/2012	Workshop	INFN	130	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=183635">https://indico.cern.ch/conferenceDisplay.py?confId=183635</a>
29/11/2012	CCTC#3	CERN	10	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=222245">https://indico.cern.ch/conferenceDisplay.py?confId=222245</a>
13-14/12/2012	Workshop	FNAL	26	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=136807">https://indico.cern.ch/conferenceDisplay.py?confId=136807</a>
09/01/2013	Tech. Meeting	CERN	20	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=231529">https://indico.cern.ch/conferenceDisplay.py?confId=231529</a>
17/01/2013	CCTC#4	CERN	8	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=225170">https://indico.cern.ch/conferenceDisplay.py?confId=225170</a>
01/02/2013	Topical (Harm. System)	CERN	16	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=231528">https://indico.cern.ch/conferenceDisplay.py?confId=231528</a>
05/03/2013	CCTC#5	CERN	10	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=229988">https://indico.cern.ch/conferenceDisplay.py?confId=229988</a>

#### Contractual milestones and deliverables

None in this task.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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As described in the text above, the main corrective action concerns the redefinition of Task 4.4 and the re-focussing of resources on the CCCs. Also did we not yet have the active participation of two of our collaborators during the reporting period (CNRS, KEK) – but this is considered partly a teething problem and is partly explained by the changing priorities and commitments inside those participating labs, which we believe we can mitigate to a certain degree by the increased involvement of other partners (in particular the US labs).

A major concern at CERN is that the identified and requested ramp-up of manpower resources could not be implemented due to severe constraints – instead of the requested 3 fellows we could hire only one, and from the 3 requested additional posts (internally known as “flexibility posts”) only one was approved (and hired). It is thus to be expected that additional delay will be accumulated in the near future. This was now partially compensated at CERN by the extraordinary effort of a couple of supportive and committed individuals.

**2.2.4.2. Task 4.2: Support Studies**

**Progress towards objectives and significant results**

The Support Studies include the aspects of installation and integration of the crab cavities initially in the SPS and later in the LHC, design of the Low-Level RF (operational control, feedback loops and the influence of crab cavity systems on the beam), design of the overall RF system including driver and power amplifiers, and the cavity operation sequence (during fill, ramp, squeeze and collision). A key aspect in the study is the identification and mitigation of fast failure modes that may hamper machine protection (in collaboration with WP7).

Serious progress on the Support Studies was made during the reporting period. The CCTC (Crab Cavity Technical Coordination) Working Group, led by Alick Macpherson of CERN was created with its first meeting 11<sup>th</sup> July, 2012. The mandate of this working group is very much aligned with the sub-tasks of task 4.2:

- Prepare, organize, and run Crab Cavities beam tests in SPS.
- Provide relevant specifications [functional and technical] that allow the LHC crab cavity project to proceed to a Technical Design Report and beyond.
- Assess [in conjunction with WP 7 Machine Protection] operational and machine safety risks associated with crab cavity operation in LHC [and SPS].

This working group draws both physicists and engineers from a number of groups to ensure expertise coverage for the mandate. Typically high power RF, low-level RF, SCRF technology, cryostat design, vacuum, machine protection, cryogenics, beam physics, electromagnetic theory, impedances, diagnostics, integration and operation are represented at monthly CCTC meetings. Focus of the CCTC during the reporting period has been the establishment of an integration envelope, functional definition and operational implications of the SPS cryogenic system and constraints for the conceptual cryostat design (alignment tolerances, internal space constraints, superfluid helium requirements etc.). In addition, CCTC progress report meetings are held every two weeks, and have been useful in ensuring steady progress on the CCTC mandate.

Crab cavity validation in the SPS is scheduled for the 2016-2017 SPS run (assuming the necessary resources), with initial installation of the crab cavity cryomodule into the area of SPS at Pt 4 in the 2015-2016 end-of-year stop. (The installation date is dictated by the

design/production times of the cryostat and the fundamental power coupler.) The SPS run will be the first time ever that a crab cavity will interact with a proton beam, and will allow verification of possible operating scenarios as well as the system performance with and without beam. It will equally be able to demonstrate the possibility of making the crab cavity “invisible” to the beam by detuning – all essential questions before installation in the LHC can be envisaged.

The SPS installation is to consist of two cavities in a single cryostat, with each cavity individually powered. This layout permits maximum flexibility in performance evaluation of the crabbing with beam and machine protection mitigation of failure mode scenarios. As operational SPS constraints require that when not under test, the cryomodule be out of the beam line, work in this reporting period shows that this can be achieved by mechanically movable Y-chambers and a bypass line (Figure 20). Design of new Y-chambers, mechanical support structures, and the definition of cryostat integration envelopes ongoing, including full 3-D modeling using an as-installed geometry (including cable trays etc.) of the SPS location.

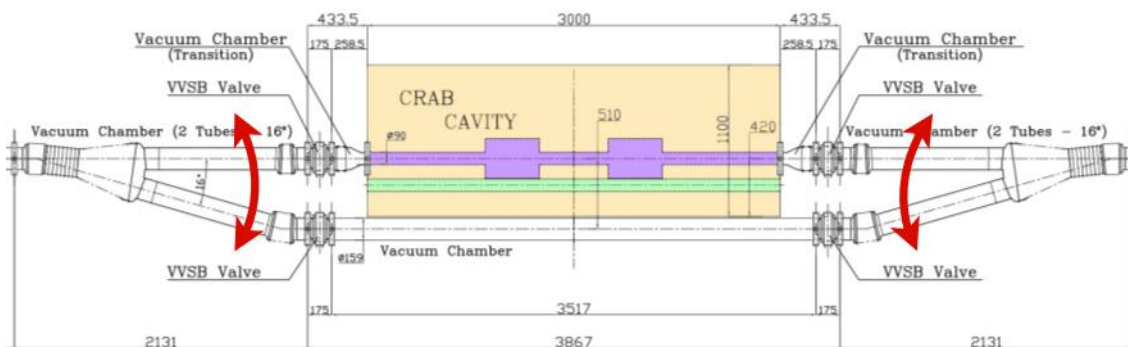


Figure 20: Sketch of the Integration envelope (top view) for the crab cavities in the SPS showing the Y-chamber, the bypass line, the crab cavities (purple), the dummy LHC beam pipe (green) and the integration envelope (yellow). Mechanical movement in/out of the beam line is indicated by red arrows.

Power requirements for the SPS run have been re-evaluated based on the up-to-date HL-LHC beam numbers, and are consistent with existing SPS Tetrode amplifiers. Existing 400 MHz, 45 kW tetrode amplifiers (1 per cavity) are to be used, and re-qualification is presently on-going. Installation of the tetrodes adjacent to the cryomodule is now foreseen, in order to ensure a feed-back loop delay time is compatible with the LHC machine protection scenarios for 1-turn failure modes (1 LHC turn = 89  $\mu$ s).

During the LHC’s Long Shutdown 1 (LS1), modification of cryogenic infrastructure (WP9, not part of FP7 Design Study) in SPS Pt 4 is on-going, with helium liquefaction capacity tests expected in September 2013. Liquefaction capacity, as well as expected static and dynamic heat load estimates is key to determining operational constraints on the SPS crab cavity run.

During Machine Developments in the SPS during the reporting period, the possibility of testing the effect of noise on the beam was prepared by measuring the beam noise. It was found that the SPS beam is (compared the LHC) relatively noisy already without crab cavities, see Figure 21, which will make this measurement difficult, if not impossible. However, ideas to excite the crab cavity system with modulation to mimic “noise” in the betatron sidebands are presently discussed that may give interesting information on how noise propagates through the system including the beam.

Studies of the operating scenarios are directly linked to the RF system design and to the machine protection issues. An important result obtained during the reporting period is the clear concept of the operational scenario. All cavities will be equipped with strong (50 dB) fast RF

feedback in order to keep the impedance presented to the beam low. During fill, ramp and squeeze, the total kick voltage is programmed to zero; this will be obtained by programming the vector sum of the voltages to neighbouring cavities to zero, whilst keeping the individual voltage at a non-zero value large enough for all control loops to lock (fast feedback and tuning loop).

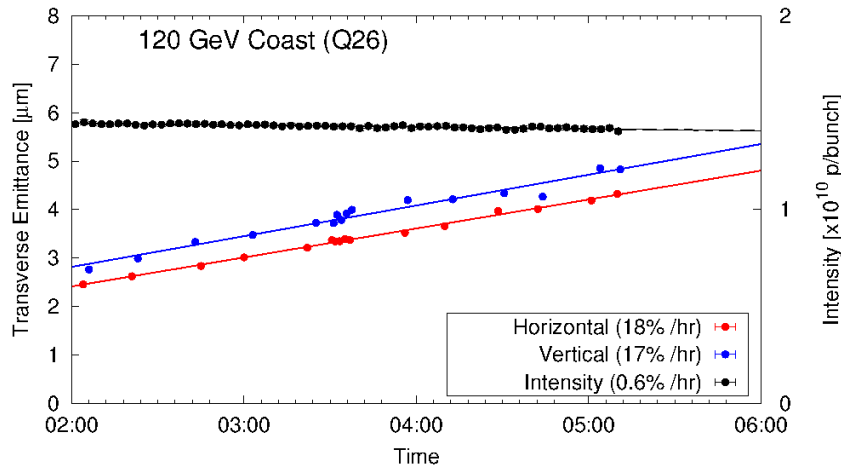


Figure 21: Emittance growth measurement results, SPS MD @ 120 GeV

**Contractual milestones and deliverables**

No deliverable was due during the reporting period.

Two Milestones (MS44 and MS46) were due during the reporting period, all achieved.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**2.2.4.3. Task 4.3: compact crab cavity design**

**Progress towards objectives and significant results**

Three novel designs compatible with the LHC constraints were proposed, designed and optimized for a nominal kick voltage of 3.34 MV per cavity at 400.79 MHz with modest surface fields. These new topologies make it possible to integrate the cryomodules in the present LHC interaction region and simultaneously be used for the alternating crossing schemes in the two IPs. As a first step of RF design validation, all three cavities were prototyped using bulk Niobium in industry (see Figure 22). Comprehensive tests at 4.5 K and 2 K are underway to determine the cavity performance and stability at the nominal gradient. Furthermore, the cavities will be tested up to their quench limits to determine the margin from the nominal voltage and study important operational aspects such as field ramping, microphonics, multipacting and evolution of the fields during a RF failure.



Figure 22: Prototypes of the three crab cavity designs fabricated in bulk Niobium (Courtesy Brookhaven National Lab, Old Dominion University, Lancaster University and Niowave Inc).

All three cavities were cold tested at 4.5 K and 2 K. The 4-Rod cavity was tested in November 2012 at CERN of up to a deflecting voltage of 1.5 MV (half the nominal) and with a quality factor lower by about a factor 10 (see Figure 23). The lower than expected quality factor is primarily due to the inadequate surface processing which will be performed in June 2013. A moderate multipacting zone was observed at this voltage which required RF processing to push beyond. However, due to foreseen cryogenic shutdown, the tests could not be continued further. A vacuum leak due to irregular features on the knife edge of the NbTi flanges was observed all through the tests which could have negatively impacted both the measured quality factor and the achieved maximum voltage. Each of the NbTi flange has undergone resurfacing and tested at room temperature to be vacuum tight. The next cold tests are scheduled for July 2013 following the surface treatment which is presently underway.

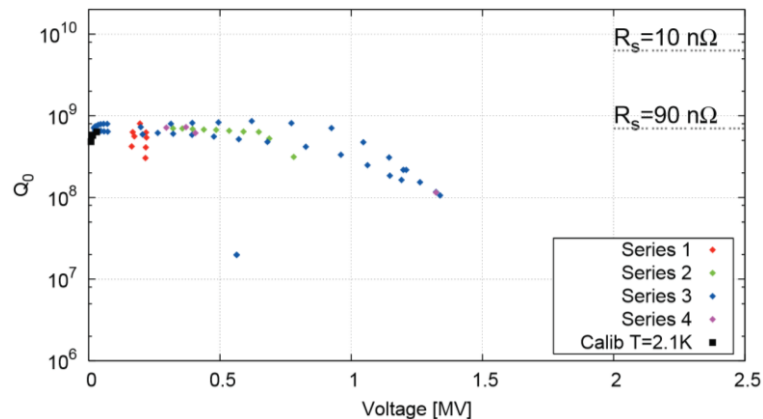


Figure 23: Vertical test results of the 4-Rod cavity performed at CERN.

The RF dipole cavity was tested in April 2013 at Jefferson Laboratory to a record maximum of 7 MV kick voltage (see Figure 24). The  $Q_0$  of the cavity at the nominal field of 3.4 MV was approximately  $3 \times 10^9$  corresponding to a surface resistance of 34 nΩ. At the quench voltage of 7 MV, the peak surface electric and magnetic fields are 75 MV/m and 131 mT which are close to or above the state of the art in the field of superconducting RF. The RF dipole also reached well beyond the nominal voltage at 4.2 K and was limited only by the available input power. The slightly elevated surface resistance is believed to be due to a contamination of the acid treatment bath. A second surface treatment with a high pressure water rinse is expected to increase the quality factor further.

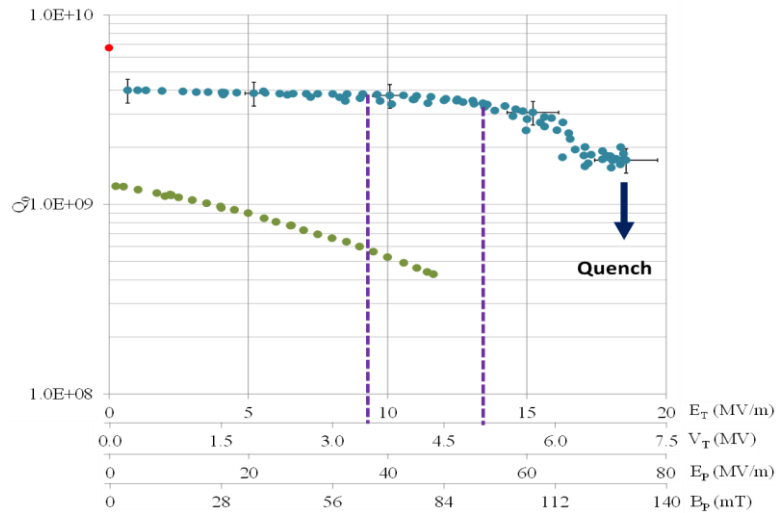


Figure 24: Vertical test results of the RF dipole (courtesy ODU).

The double quarter wave tested in June 2013 at Brookhaven National Lab. A low field multipacting was observed at approximately 0.1 MV but was quickly processed away. A low  $Q_0$  of  $3 \times 10^8$  was observed, independent of the temperature, leading to the conclusion that the residual resistance is very high (see Figure 25). It was observed that among the temperature sensors placed on the cavity flanges, the one placed on the beam pipe flange had an elevated temperature compared to the other port flanges. However, the stainless steel flanges on the beam pipe could not have accounted for the high losses. The voltage could be ramped up to 0.9 MV in CW mode which was limited by thermal losses and 1.34 MV in pulsed mode limited by available RF power. A boroscope inspection of the surface is underway to determine the quality and any inclusion of foreign material or local defects. A light chemistry and a high pressure water rinse will precede any to future tests.

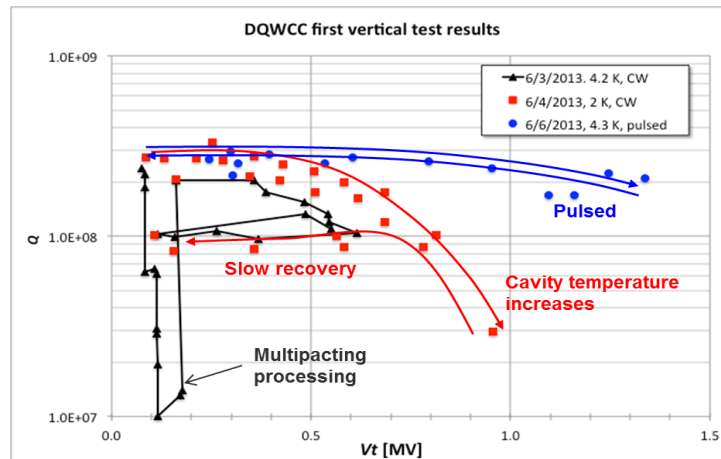


Figure 25: Vertical test results of the double quarter wave cavity (courtesy BNL).

**Contractual milestones and deliverables**

One deliverable (D4.1) was due during the reporting period and achieved.  
 One milestone (MS45) was due during the reporting period and achieved.

**Planning, deviations and corrective actions**

Task on schedule		Ahead of schedule	✓	Minor delay		Significant delay	
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**2.2.4.4. Task 4.4: Elliptical crab cavity technical design**

**Progress towards objectives and significant results**

As explained above, the Elliptical Crab Cavity Design has been put on hold.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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The delay is explained by the revised priorities and the re-focussing on the CCCs, see above.

**2.2.4.5. Task 4.5: Compact crab cavity validation prototyping**

**Progress towards objectives and significant results**

We have reported on the compact cavity prototyping work above under Task 4.3.

Task 4.5 addresses the validation prototypes for horizontal tests in the SM18 followed by beam tests in the SPS in preparation for the final cavity production, including the design of special tooling, dies and other enclosures to make up the dressed cavities. At the [Crab Cavity Engineering](#) meeting at Fermilab the first concepts of the Helium vessel enclosures and the tuning concepts were discussed for the three prototypes (see Figure 26). The double quarter wave cavity proposal uses its coaxial symmetry to adapt an integrated Helium vessel also used for tuning and stiffening purposes. A bellow structure in the coaxial enclosure attached to an external drive is used to precisely tune the cavity. The RF dipole cavity adopted a CEBAF type scissor jack mechanism to transfer the vertical drive motion to stretch or compress the cavity. The 4-Rod cavity uses a Saclay type tuner fixed to one end of the cavity to stretch or compress the cavity. The design of each Helium vessel has integrated the adjacent beam pipe of the 2<sup>nd</sup> beam into or close to the Helium vessel with the possibility of orienting them for both horizontal and vertical crossing. The integration details of these cavities into a two-cavity cryomodule for the SPS tests are underway.

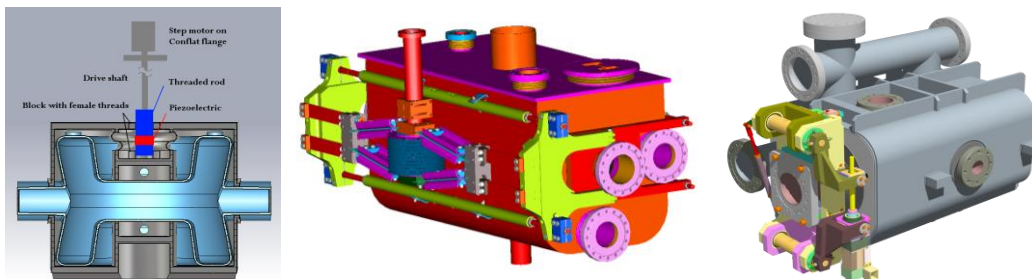


Figure 26: Helium vessel and tuning concept for the three crab cavity design (courtesy BNL, ODU, DL-LU).

A common platform for the power coupler interface is defined with appropriate dimensions for the RF antenna. This proposal is adapted to each cavity with their respective antenna shapes. The exact interface and support to the cryostat will be finalized after the initial cryomodule design is available. Tests in a horizontal cryostat of the dressed cavities with all couplers and enclosures may be needed to validate the cavity performance. Significant progress has taken place on the integration, cryogenics and infrastructure for the SPS tests which is reported under Task 4.2.

**Contractual milestones and deliverables**

None



**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**2.2.5. WP5: IR Collimation**
**2.2.5.1. Task 5.1: Coordination & Communication**
**Progress towards objectives and significant results**

A news series of meetings was started at the beginning 2012: the Collimation Upgrade Specification Meeting (CoLUSM) saw its first meeting on 20<sup>th</sup> February, 2012 (web page: <http://lhc-collimation-upgrade-spec.web.cern.ch>). More than 20 meetings have taken place so far. All the WP5 member institutes are regularly represented at these meetings, where the CERN teams working on collimation are also present to cover broadly the collimation upgrade activities, also beyond the scope of Hi-Lumi. It is important to note that the collaborators from US-LARP are also regularly attending the CoLUSM that therefore became a central forum to discuss all collimator upgrade matters beyond LS1. In particular, the works towards achieving the milestones for the first year of HiLumi have successfully been steered within the CoLUSM. Some studies relevant for the HiLumi works have also been discussed at the companion Collimation Working Group meeting (<http://lhc-collimation.web.cern.ch>), which is otherwise focused on the present LHC operation and on LS1 system upgrades.

**Work package meetings**

<i>Dates</i>	<i>Type of meeting</i>	<i>Venue</i>	<i>Attendance</i>	<i>Indico link</i>
<i>Feb. 2012- Apr. 2013</i>	<i>15 Collimation Upgrade Specification meetings</i>	<i>CERN</i>	<i>10-15</i>	<i><u><a href="#">CoLUSM web page</a></u></i>
<i>Jan. 20<sup>th</sup>, 2012</i>	<i>1<sup>st</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>12</i>	<i><u><a href="#">CoLUSM#1 Minute</a></u></i>
<i>Feb. 3<sup>rd</sup>, 2012</i>	<i>2<sup>nd</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>16</i>	<i><u><a href="#">CoLUSM#2 Minute</a></u></i>
<i>Feb. 23<sup>rd</sup>, 2012</i>	<i>3<sup>rd</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>8</i>	<i><u><a href="#">CoLUSM#3 Minute</a></u></i>
<i>Mar. 9<sup>th</sup>, 2012</i>	<i>4<sup>th</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>7</i>	<i><u><a href="#">CoLUSM#4 Minute</a></u></i>
<i>Mar. 16<sup>th</sup>, 2012</i>	<i>5<sup>th</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>9</i>	<i><u><a href="#">CoLUSM#5 Minute</a></u></i>
<i>Apr. 20<sup>th</sup>, 2012</i>	<i>6<sup>th</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>11</i>	<i><u><a href="#">CoLUSM#6 Minute</a></u></i>
<i>May 25<sup>th</sup>, 2012</i>	<i>7<sup>th</sup> Collimation Upgrade Specification Meeting</i>	<i>CERN</i>	<i>14</i>	<i><u><a href="#">CoLUSM#7 Minute</a></u></i>
<i>June</i>	<i>8<sup>th</sup> Collimation Upgrade Specification</i>	<i>CERN</i>	<i>4</i>	<i><u><a href="#">CoLUSM#8</a></u></i>

22 <sup>nd</sup> , 2012	<i>Meeting</i>			<a href="#"><u>Minute</u></a>
Jun. 29 <sup>th</sup> , 2012 Jul. 30 <sup>th</sup> , 2012	<i>Dedicated discussions relevant for HiLumi-WP5 at the collimation WG meeting</i>	CERN	15-30	<a href="#"><u>Link CWG146</u></a> <a href="#"><u>Link CWG144</u></a>
July 13 <sup>th</sup> , 2013	<i>9<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN	16	<a href="#"><u>CoIUSM#9 Minute</u></a>
July 27 <sup>th</sup> , 2012	<i>10<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN	20	<a href="#"><u>CoIUSM#10 Minute</u></a>
Sept. 7 <sup>th</sup> , 2013	<i>11<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN	14	<a href="#"><u>CoIUSM#11 Minute</u></a>
Oct. 5 <sup>th</sup> , 2013	<i>12<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN	22	<a href="#"><u>CoIUSM#12 Minute</u></a>
Oct. 19 <sup>th</sup> , 2012	<i>13<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN		<a href="#"><u>CoIUSM#13</u></a>
Nov. 2 <sup>nd</sup> , 2012	<i>14<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN		<a href="#"><u>CoIUSM#14</u></a>
Nov. 9 <sup>th</sup> , 2012	<i>Special LHC Collimation Specification Meeting on the possible usages of the Tevatron hollow e-lens at the LHC and/or SPS</i>	CERN	39	<a href="#"><u>Special CoIUSM Minute</u></a>
Dec. 7 <sup>th</sup> , 2012	<i>16<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN		<a href="#"><u>CoIUSM#16</u></a>
Jan. 25 <sup>th</sup> , 2013	<i>17<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN		<a href="#"><u>CoIUSM#17</u></a>
Feb. 15 <sup>th</sup> , 2013	<i>18<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN	12	<a href="#"><u>CoIUSM#18 Minute</u></a>
Mar. 1 <sup>st</sup> , 2013	<i>19<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN	20	<a href="#"><u>CoIUSM#19 Minute</u></a>
Mar. 22 <sup>nd</sup> , 2013	<i>20<sup>th</sup> Collimation Upgrade Specification Meeting</i>	CERN		<a href="#"><u>CoIUSM#20</u></a>
Apr. 12 <sup>th</sup> , 2013	<i>21<sup>st</sup> Collimation Upgrade Specification Meeting</i>	CERN		<a href="#"><u>CoIUSM#21</u></a>

#### **Contractual milestones and deliverables**

The Work Package had 3 deliverables, D5.1, D5.2, D5.3 and 2 milestones, MS48, MS49 all achieved in the period.

#### **Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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## Plans for next year

- Simulate the betatron cleaning performance with appropriate statistics for the latest ATS optics layouts. Extend the simulation models to include different layouts for dispersion suppressor collimation in IR7. Add progressively realistic error models to the simulations of the perfect machine.
- Continue the development of physics debris simulations with FLUKA and SixTrack and complete detailed benchmarking with LHC beam measurements. Understand in detail the LHC limitations from collimation, considering the possibility for adding dispersion suppressor collimators in the experimental regions.
- Finalize IR2 collimation layouts for the ion case (ALICE luminosity upgrade scenario), including requirements/scenarios/implications for IR1 and IR5.
- Continue the development and benchmarking of Sixtrack and Merlin, including the implementation of updated collimator scattering physics. Simulate physics cases with Merlin (Manchester/Huddersfield).
- Address beam failure cases for the ATS optics and identify possible impacts on future optics choices (Valencia). Address background issues from collimation cleaning in the HL-LHC era (CERN/RHUL).

### 2.2.5.2. Task 5.2: Simulations of Beam Loss in the Experimental IRs

#### Progress towards objectives and significant results

In order to address the beam losses in the IRs, the contributions from the multi-turn beam halo (incoming beam) and of the collision products (outgoing beam) must be evaluated. Tracking simulations based on the SixTrack version with a collimator routine are well established for the standard LHC optics solutions but the simulations setup needed to be updated for the novel optics concepts and machine configurations under investigation for the HL-LHC (e.g., ATS optics). The multi-turn tracking of physics debris had to be setup from scratch. Both implementations were performed successfully.

Simulations of realistic particle distributions after collision rely on external codes (e.g., dpmjet) to calculate the particle's coordinates at the interaction point. The simulation setup developed at CERN relies on inputs for the tracking provided by FLUKA. First results of this implementation were presented at the [11<sup>th</sup> CoIUSM](#) of 7<sup>th</sup> September, 2012. The simulation chain involving collision products, particle tracking, aperture checks and loss map generation was successfully setup. Simulations of physics cases at 4 TeV are ongoing for a detailed benchmark with beam data accumulated during the 2012 operation (including TCL collimator scans, see next section). The setup of SixTrack tracking is a crucial milestone to enable fast simulations of different collimation layouts and comparative assessment of different layout options that have then to be validated by more complete energy deposition simulations.

The complete beam halo simulation chain (tracking with collimators, aperture checks, loss map calculation) was successfully setup at CERN for the first time for the ATS optics for 15 cm  $\beta^*$  reach. This work, which is to be presented at IPAC13 (A. Marsili et al., "Simulations of collimation cleaning performance with HL-LHC optics"), profited from a strong collaboration with the optics team in WP2. An example showing the simulated loss maps for the horizontal halo case of beam 1 is given in Figure 1. A zoom around IR7 is given in Figure 2. These preliminary results show that for a perfect machine, the collimation cleaning for the ATS optics solution works in a similar way as with the standard optics solutions in protecting the present

limiting location in the dispersion suppressor (DS) in IR7. However, some additional loss locations in the arc 7-8, not present with the standard optics, were found (see Figure 1). The simulated local losses there are as high as at the IR7 DS. The particles lost at the new locations are created in scattering on collimators in IR7 and all have significant energy deviations. Therefore, the addition of new collimators in the IR7 DS, where the dispersion is rising, could also be effective in protecting the arc.

Further studies, with the addition of DS collimators, show that this is indeed the case. Figure 3 shows the simulated losses around the ring with the addition of two collimators in cells 8 and 10 set at 10 sigma. As can be seen, apart from a great improvement of the losses in the DS, the losses in the arc are completely suppressed. It should, however, be noted that these studies are still very preliminary and that the exact layout and collimator placement, as well as the integration, must be studied in more detail. Furthermore, the influence of imperfections is still to be investigated. Obviously, it should be stressed that the collimation needs depend strongly on the outcome of the LHC quench tests performed by the collimation team in February 2013, which are being analysed.

In order to perform the simulations discussed above, a baseline parameter setup for the operation scenarios after LS1 was determined. The baseline settings cases are also given as inputs to other teams, like the impedance team in WP2 (in synergy with EuCARD/EuCARD2 material studies).

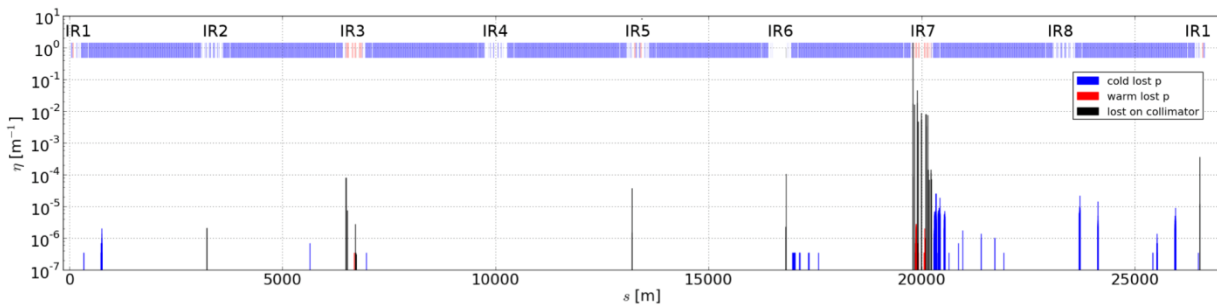


Figure 27: Loss maps around the LHC ring calculated with multi-turn tracking (15 cm ATS optics, B1, horizontal). Published at IPAC13 (A. Marsili et al., “Simulations of collimation cleaning performance with HL-LHC optics”).

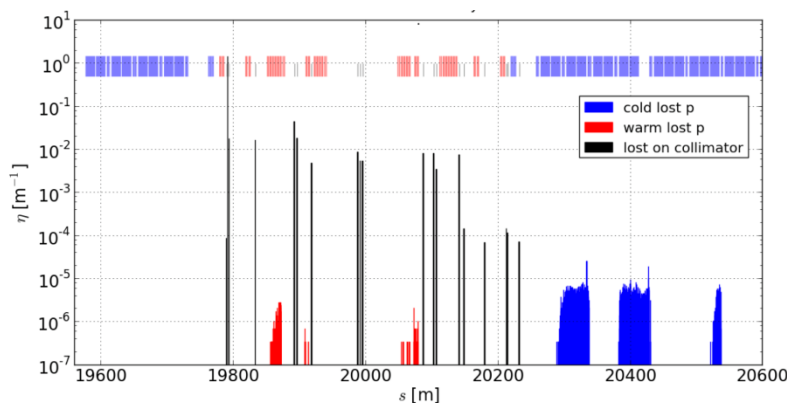


Figure 28: Zoom in IR7 of the loss maps in Figure 27. Published at IPAC13 (A. Marsili et al., “Simulations of collimation cleaning performance with HL-LHC optics”).

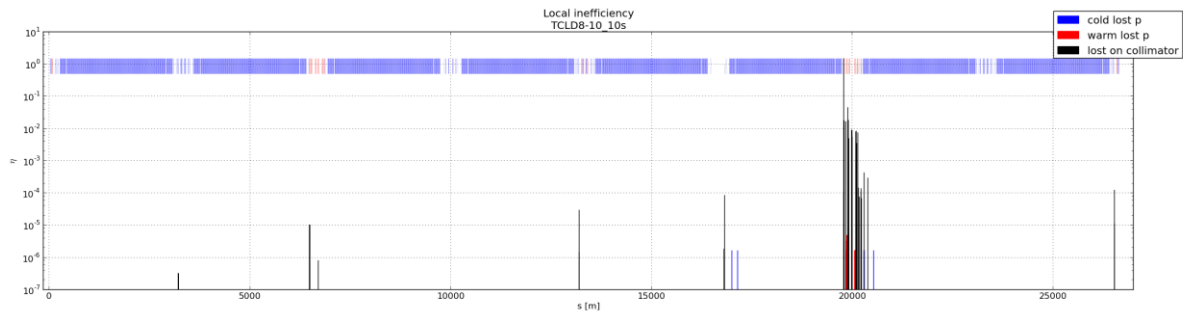


Figure 29: Preliminary loss maps around the LHC ring calculated with multi-turn tracking (15 cm ATS optics, B1, horizontal), with the addition of two collimators in the IR7 DS in cells 8 and 10.

In parallel to the simulations running at CERN, Manchester and Huddersfield universities worked actively on the setup of tracking and loss maps simulations with the Merlin code. This work was recently presented at the IPAC2012 conference (J. Molson *et al.*, “Simulating the LHC collimation system with the accelerator physics library Merlin, and loss maps results”), after being reported at the ColUSM. The code as now matured to a state that made it ready to be used for simulations or relevant cases. A comparison of the loss maps calculated for the 4 TeV case with Merlin and with SixTrack is given in Figure 31. The results are in good agreement. A detailed comparison is on-going to ensure that the input conditions and configurations used by the two codes are equivalent. This has profited significantly from visits of 5 colleagues from Manchester and Huddersfield to CERN to work in close contact with the collimation team. Improved scattering routines, with elastic and single diffractive differential cross sections fitted to measurements of the processes, and a better interface to MADX, are also under development and are expected to be ready soon.

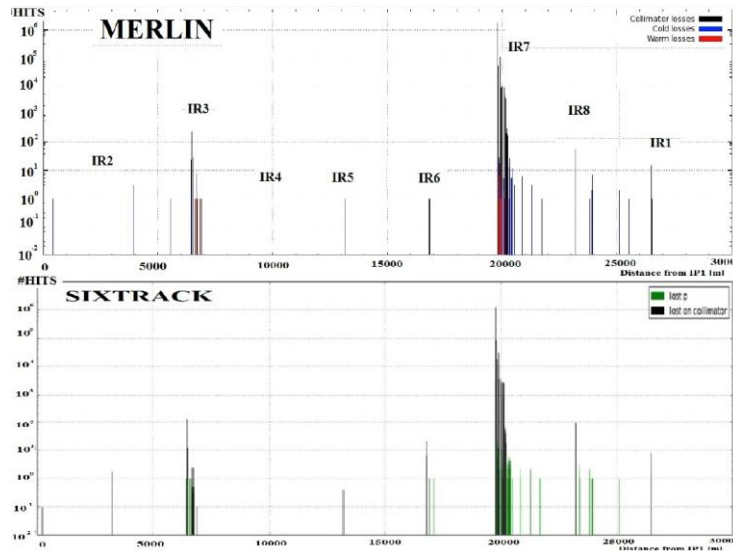


Figure 30: Comparison of loss maps calculated with SixTrack and Merlin. Published at ICAP2012 (J. Molson *et al.*, “Simulating the LHC collimation system with the accelerator physics library Merlin, and loss maps results”)

Valencia has continued the work on the setup of simulations to study the beam loads of the incoming beams on the IR collimators in case of failure scenarios. SixTrack has been modified to simulate failures of the beam dump system, where one or several extraction kickers fail and kick parts of the beam onto large oscillation amplitudes where they can potentially damage sensitive equipment. The tracking tools were setup for this case and have been benchmarked against beam measurements performed at the LHC in dedicated Machine Development (MD)

slots. The results were presented at IPAC13 (L. Lari *et al.*, “Simulation and measurements of beam losses on LHC collimators during beam abort failures”). After the successful benchmark, the simulation has been used to assess the loads on the sensitive TCTs during beam abort failures for HL-LHC, using the same optics and aperture model as the cleaning simulations. As a second step, FLUKA is used to simulate the resulting energy deposition. Preliminary results indicate a risk of damage to the tungsten jaws when large but still not unrealistic machine imperfections are considered. A more detailed study will follow. The first results of this study will also be published at IPAC13 (L. Lari *et al.*, “Studies of thermal loads on collimators for HL-LHC optics in case of fast losses”).

Valencia also continued the work on the non-linear collimation scheme as a possible option to improve the collimation system in the future. These studies, reported in two IPAC2012 papers, were carried out within the EuCARD-WP8 study and might be used as a basis for future work within Hi-Lumi-WP5.

The RHUL team is developing existing BDSIM code for HiLumi LHC, including seamless integration of particle interactions and loss (Geant4) with accelerator style tracking and tools to import LHC optics elements into the code. This work complements the MERLIN studies being performed in Manchester and Huddersfield.

The HiLumi activities have also profited from beam measurements at the LHC, during standard commissioning and dedicated MD slots. Members of the HiLumi collaboration have actively participated in works related to the collimation system commissioning, to aperture measurements relevant for  $\beta^*$  reach estimates in the future, to the analysis of 2011 quench tests, to measurements of loads on IR collimators (incoming beams) for different failure scenarios and to studies of beam losses in the matching sections of IR1 and IR5 for different TCL settings (outgoing beam).

**Contractual milestones and deliverables**

The first steps towards a complete setup of simulations for IR losses have been completed. While a detailed benchmarking with beam data is still on going, we are essentially ready to simulate the new layouts for the HL-LHC. ATS optics for  $\beta^*=15$  cm were simulated for the perfect machine. The simulation setup includes both beams. The simulations of physics debris with SixTrack include both IR1 and IR5. For proton operation, FLUKA simulations were performed for IR5 only representing the worst case for magnet head loads from physics debris. Furthermore, simulations of beam abort failures for HL-LHC have been setup and benchmarked. Tracking simulations were also performed to determine the ion beam characteristics at the location of a possible dispersion suppressor collimator in IR2 (see also next section). Clearly, the simulation tools will be developed further but overall the deliverable can be considered as fulfilled.

The WP5 HiLumi team has also actively participated to the LHC operation to understand better performance limitations from collimation relevant for the HL era.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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**2.2.5.3. Task 5.3: Simulations of Energy Deposition in the Experimental IRs**

**Progress towards objectives and significant results**

The energy deposition simulations for collimation studies in the interaction regions require a complete 3D model of the insertions to cover the machine layout up to the dispersion

suppressors. Simulations for the incoming beams rely on detailed halo simulations (loads to the tertiary collimators) and on the geometry upstream of the interaction point. Thanks to the strong collaboration with the WP10 of HL-LHC, simulations were performed to address the energy loads from the collision products for different collimation layouts. An example of FLUKA simulations of particle fluence right side of IR5 is given in Figure 31. The models of the matching sections and of the dispersion suppressors were extended and now feature a better modelling of the orbit configuration from the crossing schemes, allowing the achievement of a good agreement with what is calculated with MADX and SixTrack.

The simulations of energy deposition in IR1 and IR5 were triggered from a collimation project request for action in LS1 and this work will continue within the HiLumi scope. A baseline layout was proposed for physics debris collimators (TCL's) in IR1 and IR5 for implementation in LS1 (Collimation Working Group meeting of [30th July, 2012](#)). This study is crucial for the WP5-HiLumi simulations because it represents a first step to understand the losses in the dispersion suppressors with the present collimation layout. Figure 32 gives, for example, the preliminary estimates of energy deposition for different settings of the TCL collimators.

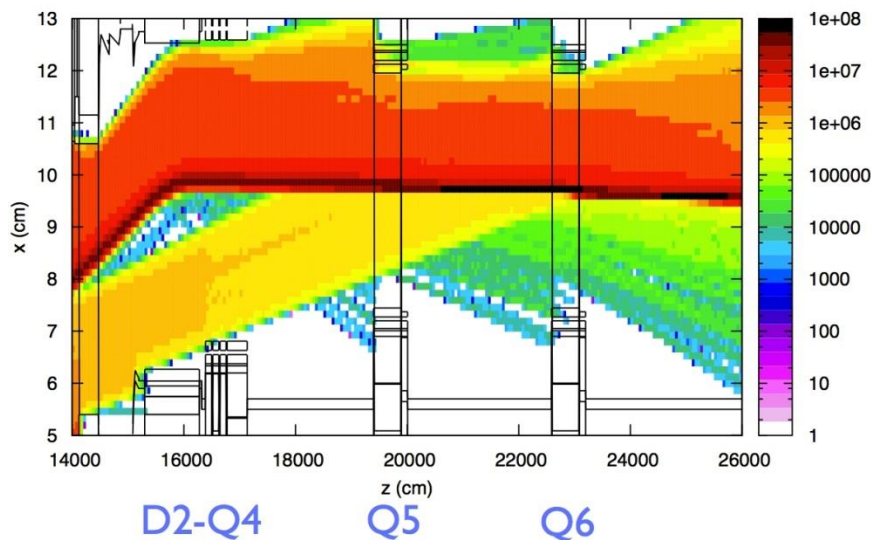


Figure 31: Beam fluence expressed in particles per  $\text{cm}^2 \text{s}^{-1}$  in the right side of IR5 calculated with FLUKA for a nominal luminosity of  $10^{34} \text{cm}^{-2} \text{s}^{-1}$  at 7 TeV. These simulations are performed with open TCL collimators. Presented at the [Collimation Working Group meeting](#) of 30<sup>th</sup> July, 2012.

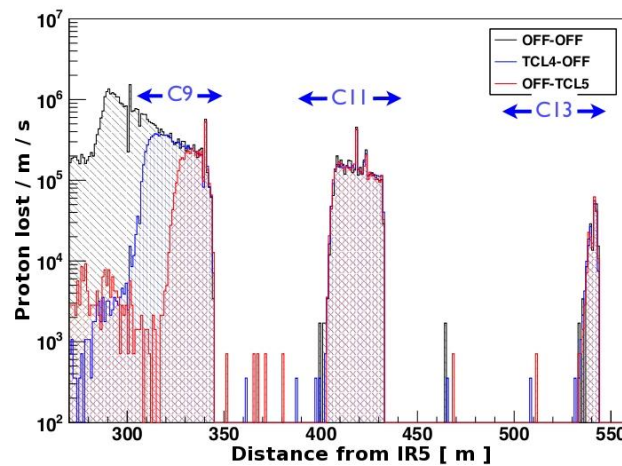


Figure 32: Results of preliminary beam loss calculations from physics debris: proton lost per m per second in the dispersion suppressor of IR5 for different configurations of the TCL collimators. Presented at the [Collimation Working Group meeting](#) of July 30<sup>th</sup>, 2012.

In order to design new IR collimation schemes, it is equally important to understand in detail the operational limitations at the LHC from beam measurements. To this end, an important participation of WP5 members from CERN and partner institutes to machine studies took place during the 2012 run. Particularly relevant for energy deposition studies was the understanding of losses in high-luminosity points for different settings of the existing collimators. For example, Figure 33 shows the losses measured in several superconducting magnets downstream of IR5 during scans of the TCL collimator in cell 5 performed during a standard physics fill at the LHC. These measurements are still on-going and will be performed for different values of peak luminosity. It is also planned to combine them with cryogenics measurements that will address the heat load on the magnets.

The simulations of energy deposition and background from the incoming beams have not yet started. The simulation tools are, however, well established and the extension to new layout that will come is essentially ready.

The WP5 team has also participated with interest in the material tests performed in 2012 at the CERN HiRadMat facility to determine new material for future collimators. This work will have an important impact on the choices of future system upgrades in the IR (in synergy with EuCARD and EuCARD-2 programmes).

As a first step towards simulation studies for dispersion suppressor collimation, a model of the two-in-one 11 T dipole was implemented in FLUKA. Following the magnet design elaborated within WP11, the FLUKA model features all geometrical characteristics essential for energy deposition studies, including an accurate representation of coils, coil wedges, poles, collars, yoke and cold mass shell (a 3D-rendering of the model is displayed in Figure 34). A realistic description of the magnetic field has been imported into the FLUKA model database to allow for an accurate particle tracking in coils, collars and yoke. With the implementation of the 11 T dipole, the FLUKA geometry layout is essentially ready for simulation studies of a dispersion suppressor layout featuring a warm collimator. The first application is the ion physics debris case in IR2 and other interaction regions (e.g., IR7 for betatron halo loads) will follow.



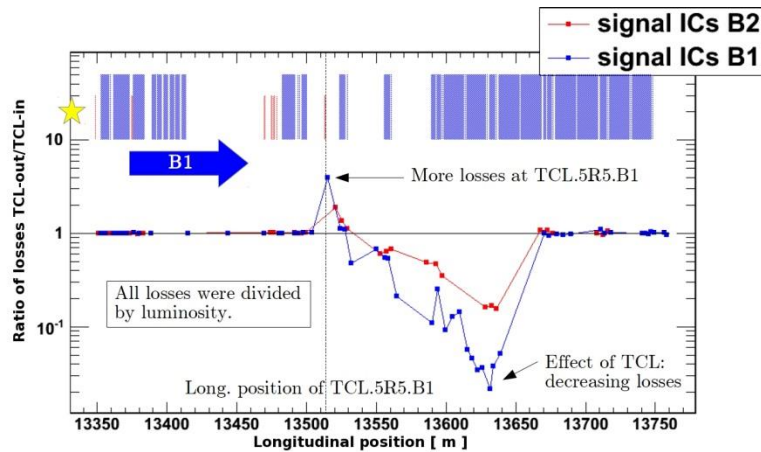


Figure 33: Losses from collision debris in the matching section on the right side of IR5: ratio of measured losses with TCL.5R5.B1 collimator IN over OUT. Data were taken at 4 TeV with initial luminosities of about  $3 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ .

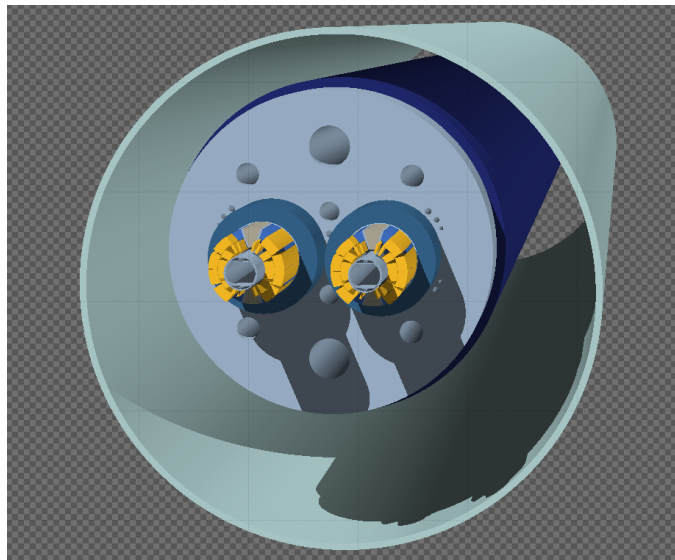


Figure 34: Losses from collision debris in the matching section on the right side of IR5: ratio of measured losses with TCL.5R5.B1 collimator IN over OUT. Data were taken at 4 TeV with initial luminosities of about  $3 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ .

**Contractual milestones and deliverables**

We are on good track to achieve the deliverables set for the next reference period. Preliminary simulations with the present collimator layout are already achieved. This study had already an impact on collimation layout change for LS1. Simulations with additional collimators in the cryogenics section of the dispersion suppressors have to be done.

The first implementation of the FLUKA geometry of the 11 T dipoles into a modified layout for dispersion suppressor collimation (based on a warm collimator and two 11 T dipoles replacing one standard 15-m long dipole) was achieved, with the immediate goal of studying the ion energy deposition in IR2.

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay		Significant delay	
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#### 2.2.5.4. Task 5.4: Design of Collimation in the Experimental IRs

##### Progress towards objectives and significant results

There are no deliverables foreseen for this task by the end of this reference period. On the other hand, detailed design work has continued in particular to compare “warm” and “cold” collimator designs in the 11 T dipole based dispersion suppressor design.

The engineering and mechanical design of the collimation devices in the experimental IRs for HL (ATS) can only start in a comprehensive way once the tracking and energy deposition studies have provided the necessary input to carry out this task. In spite of this, it was possible to make a pivotal choice for the design of collimators in the dispersion suppressor that might be installed by replacing one standard dipole with two 11 T dipoles. Following an in-depth analysis of project boundary conditions, system integration, technological challenges and technical feasibility, which was carried out in the frame of an ad-hoc working group created in late 2011 (name to be added), it was decided to opt for a warm collimator assembly to be adjoined to short 11 T dipoles (WP11) as opposed to a cold collimator to be directly integrated into a continuous cryostat (Figure 35). This decision was validated by the [17<sup>th</sup> ColUSM](#) meeting of 25<sup>th</sup> January, 2013. The warm collimator assembly is composed by a collimator module (TCLD) and cryogenic by-pass (Figure 36).

This choice is essentially based on the following reasons:

- The gain in space implied by the cold solution is marginal if not inexistent.
- The cold solution carries a number of risks, particularly as to the vacuum instability at cryogenic temperatures.
- The warm solution benefits from well-established technologies.
- A prototype of the cryogenic bypass required by the warm solution is at an advanced stage of manufacturing. Its cold tests are expected by early 2014.

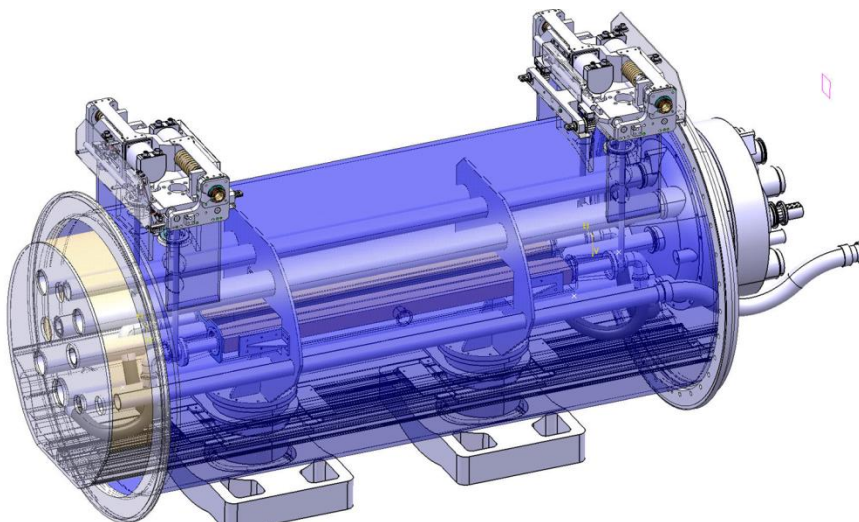


Figure 35: 3D model of the cold collimator assembly.

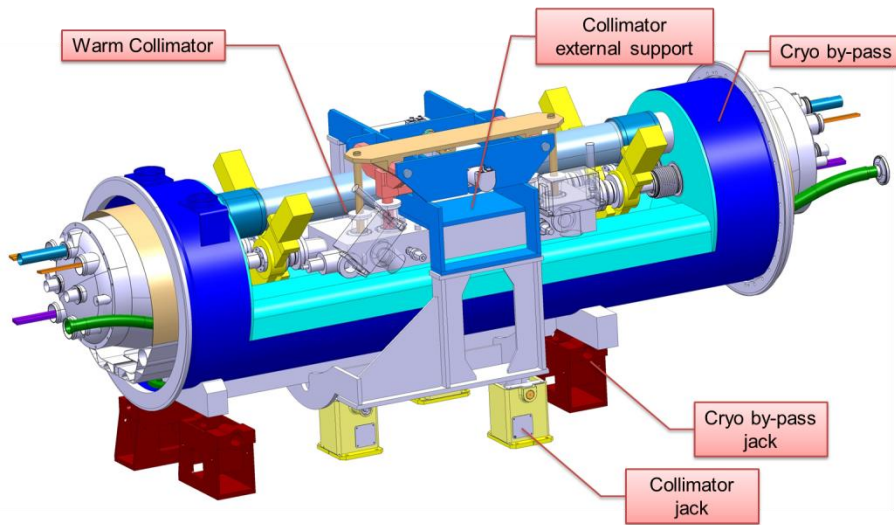


Figure 36: 3D model of the warm collimator assembly composed of a warm collimator module and a cryogenic by-pass.

**Contractual milestones and deliverables**

None

**Planning, deviations and corrective actions**

Task on schedule	√	Ahead of schedule		Minor delay	Significant delay	
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**2.2.6. WP6: Cold Powering**

**2.2.6.1. Task 6.1: Coordination and Communication**

**Progress towards objectives and significant results**

This WP was foreseen to start in year 2, on 1<sup>st</sup> November 2012. However, given the availability of the some resources and given the fact that cold powering has more influence on the design work carried out by other WPs than what was thought at the initial conception of the Project, its start has been advanced and is now already in full steam.

The cold powering for the Inner Triplet quadrupole magnets (Q1, Q2 and Q3) was conceived and discussed in a joint meeting with WP3 and, at a later stage, also with WP2; the work was finally presented in the PLC.

Three powering layouts were initially examined, all fulfilling the requirements for flexibility from the point of view of optics: 1) all quadrupole magnets in series (proposed baseline from magnet WP3), 2) Q1 in series with Q3 and equipped with a trim power supply, and Q2 with its own powering circuit and trims - this solution would ease the protection of the magnets; 3) each quadrupole is individually powered. In May 2013, option 2) was adopted as baseline (to be presented for approval to the next PLC and Annual Meeting).

A big technological progress was made with the successful test at CERN, in July 2012, of the first ex-situ MgB<sub>2</sub> round wire optimized for use in high-current transmission lines. The wire, which was produced by Columbus Superconductors (Genova, I), is the result of a development done during the last years in a close collaboration between CERN and Columbus. First MgB<sub>2</sub> cable assemblies were made at CERN and successfully tested at 4.2 K.

A novel test station, enabling the test of 20 m long cables at currents of up to 20 kA was conceived and constructed at CERN. The test station is almost unique: it incorporates novel high-temperature superconducting electrical transitions transferring the current between the liquid helium, at 4.2 K, and the helium gas at temperatures from 5 K to 70 K. The test station was commissioned at the end of 2012. The station is of key importance for the characterization, in both nominal and transient conditions, of high-current MgB<sub>2</sub> and HTS cables operated in helium gas and in a variable temperature range.

Preliminary integration studies of the cold powering system in the LHC machine have been performed.

### Work package meetings

<i>Dates</i>	<i>Type of meeting</i>	<i>Venue</i>	<i>Attendance</i>	<i>Indico link</i>
<b>June 2012</b>	<b>WP meeting #1</b>	<b>CERN</b>	<b>15</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=258878">https://indico.cern.ch/conferenceDisplay.py?confId=258878</a>
<b>October 2012</b>	<b>WP meeting #2</b>	<b>CERN</b>	<b>15</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=258876">https://indico.cern.ch/conferenceDisplay.py?confId=258876</a>
<b>November 2012</b>	<b>WP meeting #3</b>	<b>Frascati, Italy</b>	<b>15</b>	<a href="https://indico.cern.ch/sessionDisplay.py?sessionId=5&amp;confId=183635#20121114">https://indico.cern.ch/sessionDisplay.py?sessionId=5&amp;confId=183635#20121114</a>
<b>15 March 2013</b>	<b>WP meeting #4</b>	<b>CERN</b>	<b>5</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=258880">https://indico.cern.ch/conferenceDisplay.py?confId=258880</a>
<b>22 March 2013</b>	<b>Discussion on Cold Powering layout</b>	<b>CERN</b>	<b>10 (WP2, WP3, WP6)</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=258880">https://indico.cern.ch/conferenceDisplay.py?confId=258880</a>

### Contractual milestones and deliverables

The Work Package had one deliverable, D6.1, and one milestone, MS54, due in the period and both have been fulfilled successfully.

### Planning, deviations and corrective actions

Task on schedule		Ahead of schedule	√	Minor delay		Significant delay	
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#### 2.2.6.2. Task 6.2: LHC Cryogenics: Cooling and Operation

##### Progress towards objectives and significant results

A study was made in order to define the possibility that the present LHC cryogenics can offer for the cooling of the cold powering system in terms of helium temperatures, pressures and maximum mass flow-rate. The results of the study were summarized in a document that will be used as input for the definition of the cold powering system cooling scheme. A Milestone Report and a Delivery Report were produced to report and document this activity. The possibility in terms of lay-out and performance given by the availability of new refrigerators for the High Luminosity LHC baseline configuration upgrade is being examined and will be further considered and analysed.

**Contractual milestones and deliverables**

None.

**Planning, deviations and corrective actions**

Task on schedule		Ahead of schedule	√	Minor delay		Significant delay	
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**2.2.6.3. Task 6.3: Electrical transfer and cryostats: thermo-electrical and mechanical models**

**Progress towards objectives and significant results**

In the past year, SOTON has worked primarily on the conceptual design of the cryostat for the electrical current transfer from the current leads to the superconducting link. The current leads themselves and the splicing from the sub-cables of the superconducting link to the corresponding current leads, and are also integral parts of the overall design. Following several meetings with CERN, the leading partner of WP6, it was agreed that the outline design envelope would include:

1. A modular design that can be adopted for the combination of current leads and sub-cable configurations.
2. Flexibility to accommodate space constraints, which are undefined.
3. Smooth integration with the Cryoflex™ system for the superconducting lines and the current leads system with optimisation for thermal efficiency and mechanical assembly.
4. Reliable and practical design of electrical inter-connections.

The first draft of the design concept has been completed and is currently under review by the partners in the WP. All the objectives listed above have been addressed in the proposed concept.

In close collaboration with Task 6.2, work has started on defining the cooling concept for the superconducting link, current leads and the modular cryostat. A draft concept has been proposed at the end of Oct 2012 for discussion. Once agreed, the cooling option will be incorporated into the cryostat design.

Discussion on the quench protection and thermal/electrical performance of the superconducting link has been on-going between SOTON and CERN. The study tasks for the coming year have been agreed to focus on the stabilizer design and the optimisation/minimisation of contact resistance.

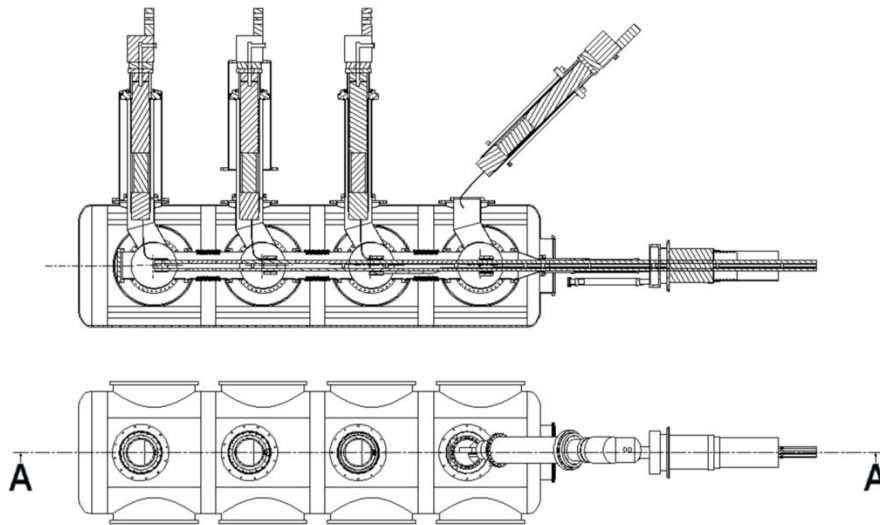


Figure 37: Schematic of cryostat with leads and connection to the link

#### Contractual milestones and deliverables

None.

#### Planning, deviations and corrective actions

Task on schedule		Ahead of schedule	√	Minor delay		Significant delay	
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#### 2.2.6.4. Task 6.4: Energy deposition and material studies

##### Progress towards objectives and significant results

The INFN activity was focused on the study of the effect of irradiation on the MgB<sub>2</sub> superconductor. After having determined the particle fluence from the 7+7 TeV p-p collision debris, Monte Carlo (by FLUKA code) simulations were performed to study the effect of the isotopic composition of Boron in the MgB<sub>2</sub> wires. The natural isotopic composition of Boron is 20% B-10 and 80% B-11, and the cross section for neutron capture of B-10 is high with respect to B-11. For thermal neutrons, the cross sections are:  
 $^{11}_5\text{B}(n, \gamma)^{12}_5\text{B} \rightarrow \sigma = 8 \times 10^{-3} b$ ,       $^{10}_5\text{B}(n, p)^{10}_4\text{Be} \rightarrow \sigma = 8 \times 10^{-2} b$ ,      and  
 $^{10}_5\text{B}(n, \alpha)^7_3\text{Li} \rightarrow \sigma = 6 \times 10^3 b$ .

Fluences similar to the ones expected in the LHC high Luminosity configuration have been investigated. The effects of the Boron composition and its modifications have been evaluated in order to estimate the “consumption” of Boron for: 1) neutron spectra as calculated on the quadrupole magnet coils, where neutrons have an energy which peaks at about 1 MeV, and 2) outside of the magnets, where the neutron energy is degraded to thermal. The decay time of the irradiated material has also been evaluated. Future calculations will also include proton and pion fluencies.

#### Contractual milestones and deliverables

None.

#### Planning, deviations and corrective actions

Task on schedule		Ahead of schedule	√	Minor delay		Significant delay	
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### 2.3. PROJECT MANAGEMENT DURING THE PERIOD

### 2.3.1. Consortium management tasks and achievements

All deliverables and all milestones due in the period have been achieved.

The progress of the management can be measured by the following results:

- a. Formation of the
  - a. Collaboration Board (CB).
  - b. Steering Committee (SC).
  - c. SAC (Scientific Advisory Committee) based on the decision approved during the year by the CB members of utilizing the CERN-Machine Advisory Committee (CERN-MAC) as Scientific Advisory Committee. This is operative from beginning of 2013. To this aim a specialist of Superconducting Magnets, a figure that was missing in the previous CERN-MAC composition, has been specifically added.
  - d. HL-LHC Coordination Group (Accelerators and Detectors) with CERN management and LIU management. See mandate<sup>3</sup>.
- b. The formation of the Technical Coordination: Herman Schmickler (CERN) has joined the project as Technical Coordinator (TC), as well as Isabel Bejar Alonso (CERN) as TC deputy, and Dorothee Duret (CERN), as budget and resource officer. The team has been completed with the nomination of Paolo Fessia as co-coordinator of the WP16, which deals with integration. Although it is besides the scope of FP7 HiLumi LHC DS, integration is in practice a function of the Management and Technical Coordination team. Mandates have been defined for each function<sup>4</sup>. The Technical Coordinator has formed the HL-LHC Technical Committee with an agreed mandate and composition that will examine all technical aspects of the project and will feed the Parameter and Lay-out Committee (see next point).
- c. The Parameter and lay-out Committee has been formed under chair of Oliver Bruning, see mandate and composition in task 1.2 annexes.
- d. The preparation of two reports for the Open Symposium for the renewal of the European Strategy for High Energy Physics. One report is directly a form of precursor of the HL-LHC preliminary Design report (<https://cdsweb.cern.ch/record/1471000?ln=en>) and the second is the first official document of the High Energy LHC, a future project that can be considered a spin-off of the study for high luminosity (<https://cdsweb.cern.ch/record/1471002?ln=en>)
- e. The Project safety officer is Thomas Otto, a senior physician as well as Technology department safety officer, which makes the coordination with the CERN structure easier, as the bulk of the hardware is supervised by the TE dept. of CERN.

The Project Office meets regularly every two weeks and minutes are registered in EDMS<sup>5</sup>. Many meetings have been held to manage interfaces between WPs and ensure good coordination, especially between WP2, WP3, WP6 and WP10 (this last WP is not included in FP7 HiLumi). The results are reported in the WP progress.

<sup>3</sup> [https://espace.cern.ch/HiLumi/HL-LHC\\_CoordinationGroup/default.aspx](https://espace.cern.ch/HiLumi/HL-LHC_CoordinationGroup/default.aspx)

<sup>4</sup> <https://indico.cern.ch/getFile.py/access?contribId=0&resId=1&materialId=0&confId=217884>

<sup>5</sup> <https://espace.cern.ch/project-hl-lhc-TB/Shared%20Documents/Forms/AllItems.aspx>

Technical Coordination has started the HL-LHC Technical Committee: a first meeting was held on 11<sup>th</sup> January 2012 on b-b long range compensation wires, a critical hardware that hardly finds its space in the various WPs, see web site:

<https://indico.cern.ch/conferenceDisplay.py?confId=217884>

A second one, in collaboration with WP5, has been dedicated to e-lens, on 8<sup>th</sup> March 2013, see:

<https://indico.cern.ch/conferenceDisplay.py?confId=236318>

Finally, a special topical Workshop dedicated to Remote Handling was organised from March 2013: it was held on 30<sup>th</sup> May 2013 and its results will be examined in the next HLTC to be held end of June.

Regarding the Annual meeting, a change with respect of the DoW, is worth underlining. In the DoW the first general meeting, due in November 2011, was called a Kick off Meeting, followed by the 1<sup>st</sup> Annual collaboration meeting in November 2012, the 2<sup>nd</sup> in November 2013 and so on. In fact, the necessity and the interest in anticipating the work on the project has suggested that a kick off meeting was worth having as early as 15<sup>th</sup> April 2011 (see: <https://indico.cern.ch/conferenceDisplay.py?confId=132315>

As such, the meeting of November 2011 was called the 1<sup>st</sup> Annual Meeting, the one of November 2012, the 2<sup>nd</sup> Annual Meeting and so on. So the numbering of Annual Meeting has increased by one. If a deliverable was due for example at the 2<sup>nd</sup> Annual Meeting in the DoW (i.e., the one in November 2013) it means that is due – with the new numbering - at the 3<sup>rd</sup> Annual Meeting, that will be in November 2013.

The HiLumi LHC Management has organized the first annual meeting at CERN, on 16<sup>th</sup>-18<sup>th</sup> November 2011 (<https://indico.cern.ch/conferenceDisplay.py?confId=150474>).

The second Annual Meeting is also being organized in the first year; to be held in Frascati on 14<sup>th</sup>-16<sup>th</sup> November 2012, co-organized by CERN and INFN - Laboratori Nazionali di Frascati (<https://indico.cern.ch/conferenceDisplay.py?confId=183635>).

The third Meeting is foreseen in Daresbury, UK, in November 2013.

Seven SCs have been held, all with video conference facilities to allow for a wider participation both inside and outside Europe (<https://indico.cern.ch/categoryDisplay.py?categId=3670>). Five SC were open to all WPs of the project HL-LHC and two were restricted to FP7 HiLumi LHC WPs. The Coordinators of WP2 and WP5 have been changed: for WP2 Stephane Fartoukh (CERN) has served as coordinator, taking over Oliver Bruning (from February 2012 to March 2013), and Gianluigi Arduini /CERN) is now in charge since April 2013, while Stefano Redaelli (CERN) was appointed WP5 coordinator by the SC since September 2012 with Robert Appleby (Univ. of Lancaster and Cockcroft Institute, UK) serving as co-coordinator from January 2013 (replacing Graham Blair).

There was particular care taken in the relationship with the USA (both with single laboratories and LARP as a whole, as well as with DOE-Office of HEP), that are collaborating without being direct beneficiaries of FP7 HiLumi LHC): various informal meetings at management level took place and at the DOE review of LARP activity, held in SLAC on 9<sup>th</sup>-10<sup>th</sup> July, two great successes were recorded:

1. The full integration into LARP of the 150 mm IR quadrupole aperture, with a change of their plan (LARP was working on a 120 mm , following the previous Phase 1 Upgrade project);



2. The first public announcement that DOE is preparing a possible contribution to the LHC upgrade of the order of 200 M\$, to be substantiated in the next years.

The most difficult managerial issue has been the path to arrive to the decision of the magnet aperture: this is an issue mainly inside WP3 and WP2 but it involves almost all WPs and involves the agreement of the US as a global partner, since the IR magnet development is so far carried out and led by US-LARP. The US laboratories (upon guidance by DOE) are expected to design and build at least a good fraction of the IR quadrupoles. A discussion was launched with LARP technical management, especially the magnet part, and then a common decision was presented in the PLC, see task 1.2 and WP3.

The HiLumi LHC has become a partner in the collaboration of the CM (Collaboration Meeting) of LARP. The last two were co-organised by LARP and HiLumi, see LARP website:  
 LARP CM18/HiLumi LHC <https://indico.fnal.gov/conferenceDisplay.py?confId=5072>  
 LARP CM20/HiLumi LHC <https://indico.fnal.gov/conferenceDisplay.py?confId=6164>

### 2.3.2. Problems and solutions

During period 1, the project has not faced significant problems that could not be essentially resolved at the partner's level.

### 2.3.3. Changes in the consortium and/or legal status of beneficiaries

At the end of the reporting period (April 2013), CNRS (beneficiary no.3) informed the Coordinator of its intention to withdraw from the project. Already at the end of the 1<sup>st</sup> year, during the 2nd Collaboration Board meeting, the non-activity of CNRS was noticed. The impact of the withdrawal of CNRS is negligible since in this project the institute was a partner with a minor contribution in WP4 only, and their absence has been largely compensated by more work by other partners. Following the notification by CNRS, the project management is currently considering options for the reallocation of its resources (EC funding and matching funds), to be approved by the Collaboration Board. A Request for Amendment to the Grant Agreement will be prepared and submitted to the EC in due course.

### 2.3.4. Project meetings

<i>Dates</i>	<i>Type of meeting</i>	<i>Venue</i>	<i>Attendace</i>	<i>Indico link</i>
<b>24/06/2011</b>	<b>Joint HL-LHC and LIU Brainstorming</b>	<b>Jiva Hill Park Hotel</b>	<b>10</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=217489">https://indico.cern.ch/conferenceDisplay.py?confId=217489</a>
<b>06/11/2011</b>	<b>WP1 Management Meeting</b>	<b>CERN</b>	<b>10</b>	<a href="http://indico.cern.ch/conferenceDisplay.py?confId=215778">http://indico.cern.ch/conferenceDisplay.py?confId=215778</a>
<b>16-18/11/2011</b>	<b>Joint HiLumi LHC/ LARP Collaboration Meeting</b>	<b>CERN</b>	<b>156</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=150474">https://indico.cern.ch/conferenceDisplay.py?confId=150474</a>
<b>17/11/2011</b>	<b>Collaboration Board meetings</b>	<b>CERN</b>	<b>25</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=160366">https://indico.cern.ch/conferenceDisplay.py?confId=160366</a>

15/12/2011	<b>1<sup>st</sup> HiLumi LHC Restricted Steering Committee Meeting</b>	<b>CERN</b>	<b>20</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=164343">https://indico.cern.ch/conferenceDisplay.py?confId=164343</a>
24/01/2012	<b>Joint HL-LHC/ LIU Preparatory Meeting</b>	<b>CERN</b>	<b>40</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=217490">https://indico.cern.ch/conferenceDisplay.py?confId=217490</a>
30/03/2012	<b>HL-LHC/LIU Joint Workshop</b>	<b>CERN</b>	<b>40</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=217493">https://indico.cern.ch/conferenceDisplay.py?confId=217493</a>
05/04/2012	<b>2nd HiLumi LHC Extended Steering Committee Meeting</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=182305">https://indico.cern.ch/conferenceDisplay.py?confId=182305</a>
19/04/2012	<b>1<sup>st</sup> HL-LHC Coordination Group Meeting</b>	<b>CERN</b>	<b>10</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=187042">https://indico.cern.ch/conferenceDisplay.py?confId=187042</a>
7-9/05/2012	<b>CM18/HiLumi Collaboration Meeting</b>	<b>FNAL</b>	<b>10</b>	<a href="https://indico.fnal.gov/conferenceDisplay.py?confId=5072">https://indico.fnal.gov/conferenceDisplay.py?confId=5072</a>
15/05/2012	<b>Powering scheme of HL-LHC magnets</b>	<b>CERN</b>	<b>20</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=187320">https://indico.cern.ch/conferenceDisplay.py?confId=187320</a>
01/06/2012	<b>New D1 absorber</b>	<b>CERN</b>	<b>20</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=187444">https://indico.cern.ch/conferenceDisplay.py?confId=187444</a>
01/06/2012	<b>2<sup>nd</sup> HL-LHC Coordination Group Meeting</b>	<b>CERN</b>	<b>10</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=192708">https://indico.cern.ch/conferenceDisplay.py?confId=192708</a>
13/06/2012	<b>Technical Committee Meeting #0</b>	<b>CERN</b>	<b>10</b>	<a href="https://espace.cern.ch/be-dep-bi-tb/Lists/Calendar/DispForm.aspx?ID=627">https://espace.cern.ch/be-dep-bi-tb/Lists/Calendar/DispForm.aspx?ID=627</a>
03/07/2012	<b>1<sup>st</sup> Parameter &amp; Lay-out Committee meeting</b>	<b>CERN</b>	<b>10</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=196571">https://indico.cern.ch/conferenceDisplay.py?confId=196571</a>
16/07/2012	<b>3<sup>rd</sup> HL-LHC Coordination Group</b>	<b>CERN</b>	<b>20</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=199700">https://indico.cern.ch/conferenceDisplay.py?confId=199700</a>

	<b>Meeting</b>			
<b>23/07/2012</b>	<b>3<sup>rd</sup> HiLumi LHC Extended Steering Committee Meeting</b>	<b>CERN</b>	<b>10</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=196457">https://indico.cern.ch/conferenceDisplay.py?confId=196457</a>
<b>25/09/2012</b>	<b>2<sup>nd</sup> Parameter &amp; Lay-out Committee meeting</b>	<b>CERN</b>	<b>10</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=201229">https://indico.cern.ch/conferenceDisplay.py?confId=201229</a>
<b>06/11/2012</b>	<b>WP1 Management Meeting</b>	<b>CERN</b>	<b>7</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=215778">https://indico.cern.ch/conferenceDisplay.py?confId=215778</a>
<b>14-16/11/2012</b>	<b>2<sup>nd</sup> Joint HiLumi/LARP Annual Meeting, Steering Committee and Collaboration Board meetings</b>	<b>Frascati, Italy</b>	<b>120</b>	<a href="https://espace.cern.ch/HiLumi/2012/SitePages/Home.aspx">https://espace.cern.ch/HiLumi/2012/SitePages/Home.aspx</a>
<b>15/11/2012</b>	<b>4<sup>th</sup> Extended Steering Committee Meeting</b>	<b>Frascati, Italy</b>	<b>20</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=217028">https://indico.cern.ch/conferenceDisplay.py?confId=217028</a>
<b>15/11/2012</b>	<b>2<sup>nd</sup> High Luminosity LHC Collaboration Board Meeting</b>	<b>Frascati, Italy</b>	<b>25</b>	<a href="https://indico.cern.ch/conferenceDisplay.py?confId=214983">https://indico.cern.ch/conferenceDisplay.py?confId=214983</a>
<b>4-5/12/2013</b>	<b>Workshop on Superconducting Technologies for the Next Generation of Accelerators</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=216711">https://indico.cern.ch/conferenceDisplay.py?confId=216711</a>
<b>11/01/2013</b>	<b>1<sup>st</sup> Technical Committee for HiLumi upgrade</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=217884">https://indico.cern.ch/conferenceDisplay.py?confId=217884</a>
<b>14/01/2013</b>	<b>4<sup>th</sup> HL-LHC Coordination Group</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=225546">https://indico.cern.ch/conferenceDisplay.py?confId=225546</a>

	<b>meeting</b>			
<b>18/01/2013</b>	<b>3<sup>rd</sup> HL-LHC PLC Meeting</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=223686">https://indico.cern.ch/conferenceDisplay.py?confId=223686</a>
<b>14/02/2013</b>	<b>1<sup>st</sup> HiLumi LHC Restricted Steering Committee Meeting</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=233342">https://indico.cern.ch/conferenceDisplay.py?confId=233342</a>
<b>21-22/02/2013</b>	<b>Joint Snowmass-EuCARD/Acc Net-HiLumi meeting</b>	<b>CERN</b>		<a href="http://indico.cern.ch/conferenceDisplay.py?confId=223094">http://indico.cern.ch/conferenceDisplay.py?confId=223094</a>
<b>8/03/2013</b>	<b>2<sup>nd</sup> Technical Committee for HiLumi upgrade</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=236318">https://indico.cern.ch/conferenceDisplay.py?confId=236318</a>
<b>26/03/2013</b>	<b>4<sup>th</sup> HL-LHC PLC Meeting</b>	<b>CERN</b>		<a href="https://indico.cern.ch/conferenceDisplay.py?confId=239311">https://indico.cern.ch/conferenceDisplay.py?confId=239311</a>
<b>8-10/04/2013</b>	<b>Joint LARP CM20/HiLumi Meeting</b>	<b>Napa Valley, US</b>		<a href="https://indico.fnal.gov/conferenceDisplay.py?confId=6164">https://indico.fnal.gov/conferenceDisplay.py?confId=6164</a>

### 2.3.5. Project planning and status

All tasks are progressing well. All milestones and deliverables were achieved. Minor delays on a few milestones and deliverables were accumulated at the beginning of the project, but they have all been recovered. The project is advancing very well and in a few cases: connection with experiments upgrade, design of the inner triplets, decision in favour of compact crab cavities and design of Sc link, works are even in advance. However now that integration issues start to appear, we know from experience that delays are likely to appear and this will compensate the present advance; therefore we are confident that the project will reach its goal in the planned time frame.

It is worth mentioning that the decision in favour of compact RF crab cavities came earlier than expected that we could save the work on elliptical RF crab cavities. In the next months a redirection for the resources toward a new initiative for a harmonic RF system will be developed and presented for approval. In the same spirit, the resources made available by the retirement of a partner, will be redirected toward these new goals.

The collaboration among different Institutes, both beneficiaries and the collaborating Institutes from the USA, is excellent, generating a creative and fertile environment that keeps the European Research Area in hadron colliders at the centre of a world effort.

The design study is now heading firmly towards the first of the two main goals: the production of the Preliminary Design Report that serves as basis for funding request to the national Agencies, both for accelerators and detectors.

Table 2: Status of progress towards deliverables of scientific and technical tasks

WP	1				2					3					4				5				6					
task	2	3	4	5	2	3	4	5	6	2	3	4	5	6	2	3	4	5	2	3	4	5	2	3	4			
ahead				√		√										√										√	√	√
On time	√	√	√		√		√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√				
Minor delay																												
late																												

### 2.3.6. Budget adjustments

There have been no budget adjustments in Period 1. Following the withdrawal of CNRS, their project share and EC contribution (182,007 €) will be allocated to other partner(s) as soon as possible.

### 2.3.7. Impact of deviations from planned milestones and deliverables

Deliverable/Milestone	Delay	Impact
D1.1 First release of layout database	9 months	All material was made available on time, not to delay the work. However, the deliverable was delayed willingly M18 to take into account new ideas and changes on the lay-out (cryogenics and cold powering of the magnets in the UIRs and Matching Sections). No impact on the project since there was a large margin on the real deadline.
MS5 Formation of the working group on QA management	6 months	The task was reassigned to a new task leader. Only MS9 (also on QA) was affected, but the delay has been recovered since then and the project has not been affected.
MS6 Rules of publication	8 months	The delay was due to the refurbishment of the publication database at CERN. The delay had no impact on other tasks or work packages.
MS9 Acquisition of main standards and adaptation to HL-LHC	5 months	The task was reassigned to a new task leader starting M9. The delay was then recovered successfully with no impact on the project since there were margins.
MS44	13 months	Draft concepts to address the milestone were presented on time, but due to the rapid evolution in both the cavity technology and RF systems, a delay in finalizing the milestone objectives was

		imperative. The delay had an impact only on the other two milestones in this WP for this period.
MS45	13 months	Draft concepts to address the milestone were presented on time, but due to the rapid evolution in both the cavity technology and RF systems, a delay in finalizing the milestone objectives was imperative. The delay had an impact only on the other two milestones in this WP for this period.
MS46	7 months	Draft concepts to address the milestone were presented on time, but due to the rapid evolution in both the cavity technology and RF systems, a delay in finalizing the milestone objectives was imperative. The delay had an impact only on the other two milestones in this WP for this period.

### 2.3.8. Communication (Task 1.6: Dissemination of Information and Industry outreach)

#### Progress towards objectives and significant results

The goal of Task 1.6 Dissemination of Information and Industry outreach is to perform effective dissemination of information and innovation inside and outside the members of the consortium and in particular to Industry.

The task has been active since the beginning of the project to promote its activities within the consortium and external stakeholders. To this end, more than 50 project-related events were held, including the Joint HiLumi LHC/ LARP Collaboration Meeting.



Figure 38: HiLumi website

**Website**

The public project website was created in October 2011. The website is not only the entry point for the HiLumi LHC Design study, but also to the larger HL-LHC project. The website has achieved already 7 out of a scale of 10 in the Google Page Ranking. (As a reference, CERN has 9).

A password-protected intranet <https://espace.cern.ch/HiLumi/> further enhances the management of the project at overall and Work Package level by using a collaborative workspace to disseminate internal information to project members.

Both websites will continue evolving during the lifetime of the project.

The graph below shows the unique visitors and total visits over the period of 18 months on the HiLumi website, with noticeable peaks around the 1<sup>st</sup> Annual meeting in November 2011, the 2<sup>nd</sup> Annual Meeting in November 2012 and the Collaboration meeting in April 2013.

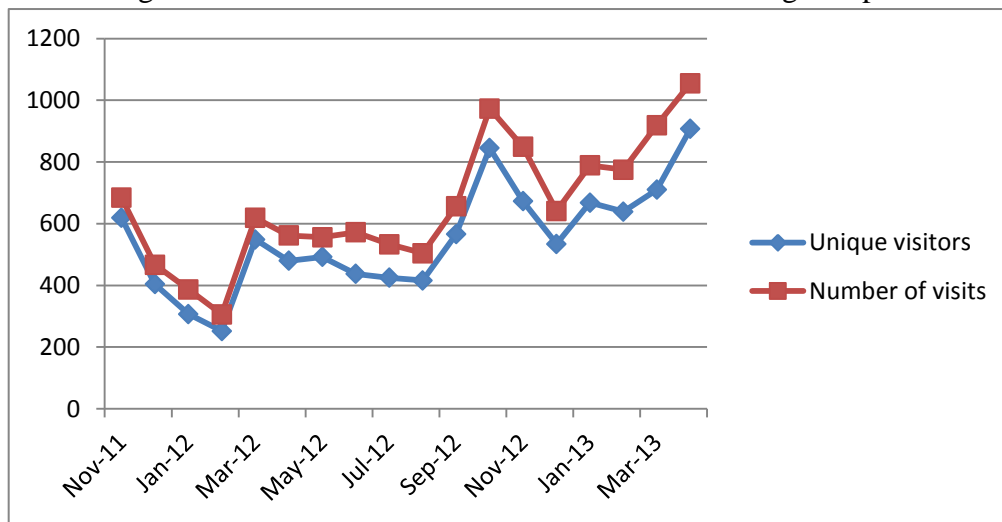


Figure 39: Year 1 website visits

The great majority of visitors arrived from Switzerland, but also the United States, France, Germany, UK, Italy and China are represented on the Top 10 list for countries of website visitors.

The following charts show the distribution of HiLumi LHC website visitors per country. With 89% the great majority were from partner countries, but a significant number of visitors connected to the website from non-partner countries, such as Canada, China and India.

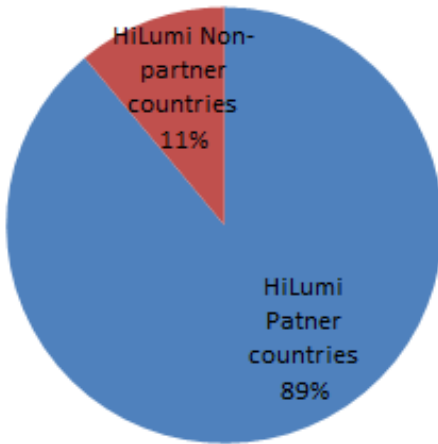


Figure 40: Distribution of visitors I.

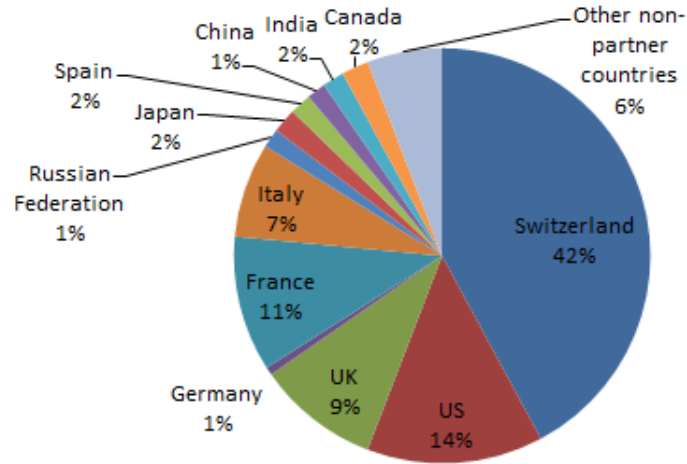


Figure 41: Distribution of visitors II.

**Publications**

The rules for accepting publications via an editorial board has been set up, as well as the system to archive and store reports and publications on CERN Document Server<sup>6</sup>. A factsheet<sup>7</sup> was created at the beginning to promote the project at various events, such as conferences, workshops and exhibitions. An additional, updated factsheet has been prepared also to promote the project to the Cordis website<sup>8</sup> visitors. Articles on HiLumi have also been written for the CERN Bulletin, CERN Courier, Reuters, Physorg.com, etc (see Annex).



Figure 42: Articles in various media

Recent news on HiLumi is regularly featured in the quarterly newsletter, Accelerating News<sup>9</sup>, which is a result of collaboration between EuCARD/EuCARD-2, TIARA, EUROnu and HiLumi LHC.

The newsletter is being distributed to more than 1055 members globally.

<sup>6</sup> <https://cds.cern.ch/collection/HiLumi%20LHC>

<sup>7</sup> [http://hilumilhc.web.cern.ch/hilumilhc/about/for\\_general\\_public/HiLumiFactsheet\\_final.pdf](http://hilumilhc.web.cern.ch/hilumilhc/about/for_general_public/HiLumiFactsheet_final.pdf)

<sup>8</sup> [http://ec.europa.eu/research/infrastructures/pdf/fp7\\_factsheet\\_hilumi\\_12AVR13.pdf](http://ec.europa.eu/research/infrastructures/pdf/fp7_factsheet_hilumi_12AVR13.pdf)

<sup>9</sup> <http://www.acceleratingnews.eu/>





Figure 43: Latest Accelerating News issue

Outreach has been enhanced with lectures and public talks, mostly by the Project Coordinator. Lucio Rossi has given about 50 outreach talks with an average audience of 270 people of different ages and different backgrounds, including science festivals, schools and universities. The list of events is available: <http://goo.gl/4REsq>. Some talks had an audience of an impressive number of 2000-4000 people. The talks are now available in CDS under Task 1.6..Industry Outreach.

A strong liaison with Industry is also foreseen involving collaboration and outreach. 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. 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 of up to 300 M€. It will also give advice to the project coordinator on how to improve and disseminate information among Industry concerning spin offs that can be generated by advancements within this Design Study.

*Communication between beneficiaries and cooperation with other projects*

A workshop “Superconducting Technologies for the Next Generation of Accelerators” will be held at the Globe of Science and Innovation (CERN) on the 4<sup>th</sup> and 5<sup>th</sup> December 2013. The workshop is being organized in close collaboration with TIARA, and will focus on future needs of mainly CERN and ESS. The aim of the workshop is to foster R&D collaborations and knowledge exchange between research infrastructures and industry, matching future accelerators’ needs with industry capabilities already present or to be developed. The possibility of applying new technologies developed within HiLumi to other applications outside HEP will also be discussed. The programme of the workshop focuses on three

technological areas: high and low field magnets, superconducting cavities, cryostats and superconducting links.

The project is closely connected to the EuCARD programme, especially with the WP on Magnets, Collimation and Crab cavity. There has been a jointly (EuCARD and HiLumi) organized workshop on 21-22 February 2013:

(<https://indico.cern.ch/categoryDisplay.py?categId=4507>) on “Frontier Capabilities for Hadron Colliders 2013.

A connection has been established with TIARA and the workshop previously cited is an example of this.

A further activity has been the dissemination toward industry with three talks organized at the CERN ILO (Industry Liaison Officers) forum, one in the workshop on precision Mechanics (Euspen<sup>10</sup>) and one for German industry.

A further event with Industry in which HiLumi LHC has contributed was held in Madrid on 27<sup>th</sup> May 2013, organized by CIEMAT, and will be reported in the next periodic report.

Many Institutes of HiLumi have contributed to the formation of the approved EuCARD2 programme. Again the Magnet collaboration for HiLumi has been instrumental in preparing EuCARD2 WP10 (Future Magnets, in view of High Energy), since HiLumi is considered a necessary step on the road toward High Energy LHC

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<sup>10</sup> <http://www.cern2012.euspen.eu/>

### 2.3.9. Status of key performance indicators

Work Package	Key Performance Indicator	Description	Method to Measure	Estimated Target	Status at end of P1
1	Quality of Deliverable Reports	The reports should be clear in the scope, in the criteria used to evaluate the resources and concise, without missing necessary information.	Acceptance rate of Deliverable Reports by EC.	To have at max one iteration with EC officials/experts on the two main Reports, the PDR (D1.5) and the TDR (D1.10).	The Deliverable and Milestone reports all fulfil their scope and are widely used in the projects and outside. They are the base for numerous presentations at the various bodies and committees. We think that the target has been attained (but only after iteration with a European Officer can this target be finally validated).
1	Quality of design activities	Scientific output of HiLumi: journal papers or articles and presentations at relevant conferences produced by design activities.	Number of journal, reports (excluding HiLumi MS or Deliverable reports), and conference publications.	More than 60.	The number of publications as deposited in the project repository amounts to 67 (including the papers published at the IPAC2013 held in Shanghai in May 2013: the work of course has been done before so it pertains to the P1. The numbers are superior to the “pro-rata target of 22 publications.
2	Quality of injected beam	A particle beam, with a given time structure, can be characterised by two main parameters: number of particles per bunch and normalized emittance. Both parameters have a critical role in luminosity.	Improvement of injected beam parameters at the end of HiLumi studies.	Bunch populations: +30% Emittance: -20%.	Studies of the emittance growth during the LHC operation showed that the emittance growth can be kept within 20% to 30%. Furthermore, the observed emittance growth does not occur equally in both beams and both planes, indicating that there is still room for further improvements on the emittance dilution for the HL-LHC operation.  Variation of the bunch populations can arise from instabilities in the injector complex, mismatch between the injector machines and the LHC and instabilities in the LHC.  The work done so far allows to estimate that the increase in bunch population of +30% and the decrease of emittance of -20% (which make a +62% in beam brightness) are achievable in the project.

2	Timely inputs from WP2 to other WPs	Accelerator Physics is a critical WP since it feeds into many other WPs: delays in certain deliverables will strongly impact on the whole programme.	Delay with respect to deadline for D2.2, D2.3 and D2.4.	Cumulative delay of the three deliverables must not exceed 3 months.	Ahead of schedule for the deliverables D2.2 and D2.3, with already a very clear picture of what the HL-LHC optics and layout shall be, and already near to final specifications established for the field quality of the triplet (and a few other magnet classes). Just on schedule for the deliverable D2.4 pending a complete understanding of the possible intensity limitations in the present LHC.
3	Effective collaboration with non-EU laboratory	The WP on Magnets strongly depends on the effectiveness of collaboration of EU and non-EU partner.	Common review between EU and non-EU partners	A review every four months in average.	The collaboration is very effective and the meetings are even more numerous than foreseen, thanks to extensive use of video conferences. Thanks to this there is actually more than one review or meeting each month. A complete synergy between the EU and USA and Japan teams has been obtained.
3	Coordination with WP not included in the HiLumi	The WP on 11 T dipole and WP on Energy deposition (part of the HL-LHC project but not included in the FP7 Hi Lumi, LHC) shares many technologies with WP3: collaboration is critical for success.	Number of formal exchange between WP3 and non-HiLumi WP.	12 documented exchanges.	7 exchanges. Non-HiLumi WP talks at WP3 meetings.
4	Effective collaboration with non-EU laboratory	The WP on Crab Cavity strongly depends on the effectiveness of collaboration of EU and non-EU partner.	Common review between EU and non-EU partners.	A review every four months in average.	The collaboration with the US-LARP Partners is very effective, with frequent exchange. A Workshop organized in Fermilab was very effective. The US partners took on a large fraction of work with the design of cryomodules.
4	Decision elliptical vs compact crab cavity	WP4 must chose, at certain point, between two alternative design: elliptical and compact. Speeding up in the decision will help the	Date of proposal of decision among elliptical and compact.	Decision proposal to SC in the third year of the programme.	As reported in the text above, the good progress with CCCs and the performance limitations of ECCs allowed to take this decision in favour of compact crab cavities quite in advance to our original plan.

		whole programme.			
5	MD (Machine Development) runs for collimation	WP5 is critically depends on the performance details of LHC. So it is expected that a good work will generate necessity of study runs (MD = Machine Development) in LHC.	Number of officially assigned MDs in LHC or injector accelerators.	One per year of running.	2 MD + 3 end-of-fills (TCL scans) Beam tests useful for HL were performed often in the shade of MD requested for LS1 works. Dedicated quench test for performance reach beyond LS1. This indicator is also more advanced than original target.
5	Coordination with Energy deposition WP	WP5 will collect and use many inputs also coming from WP on Energy Deposition (a non-HiLumi WP), to shield losses coming from collision debris (in addition to the losses from primary beam).	Number of meetings of exchange between WP5 and WP10 on energy deposition.	An exchange meeting, in whatever form, every four months.	Regular participation of WP10 to the ColUSM and CWG meeting. In practice there is more than a meeting per month between WP10 and WP5, so well beyond what is required by the Indicator.
6	Anticipated use of SC link in LHC	If studies of WP6 are timely done, there is the possibility of using these types of cable also in the consolidation programme of LHC, before the LHC upgrade for high luminosity, with big advantage for the operation, or in other accelerator/devices.	Decision of early installation of first SC link in LHC or in other accelerator (CERN or outside CERN).	A decision of use it by 2014.	The good progress of the Superconducting iLink activity and development indicates that the target can be met.
6	Test of cold powering systems using	WP6 will run in parallel with the tests of superconducting links of	Benchmarking of thermo-electrical models.	Meeting exchange for and discussion of	We are on a good track. Efforts made indicate that the target could be met.

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	superconducting links	the type needed for the LHC consolidation program. This will enable the validation of the models elaborated within Task 6.3 and it will bring direct input to the Task 6.2.		information by 2013.	
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### 3. DELIVERABLES AND MILESTONES TABLES

#### 3.1. DELIVERABLES

Table 1. Deliverables										
Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level <sup>11</sup>	Delivery date from Annex I (proj month)	Actual / Forecast delivery date	Status Not submitted/ Submitted	Contractual Yes / No	Comments
D1.1	First release of layout database	1	CERN	O	PU	M9	M18	Yes	Yes	<a href="#">Report</a> , <a href="#">Justification</a> of delay
D5.1	Simulation models for beam loss	5	CERN	O	RE	M12	M12	Yes	Yes	<a href="#">Report</a>
D5.2	Simulation models for energy deposition	5	CERN	O	RE	M12	M12	Yes	Yes	<a href="#">Report</a>
D2.1	Optics and lattice files	2	EPFL	O	PU	M18	M18	Yes	Yes	<a href="#">Report</a>
D4.1	Operational Scenarios	4	CERN	R	PU	M18	M18	Yes	Yes	<a href="#">Report</a>
D5.3	Beam halo simulations	5	CERN	O	RE	M18	M18	Yes	Yes	<a href="#">Report</a>
D6.1	Preliminary report on cooling options for the cold powering system	6	CERN	R	PU	M18	M18	Yes	Yes	<a href="#">Report</a>

<sup>11</sup> **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).

### 3.2. MILESTONES

Table 2. Milestones							
Mil. no.	Milestone name	WP no	Lead beneficiary	Delivery date from Annex I	Achieved	Actual / Forecast achievement date	Comments
MS1	Kick-off meeting	1	CERN	M1	Y	M4	Steering Committee meeting <a href="#">minutes</a> .
MS2	Website for the whole project and for the DS follow-up	1	CERN	M3	Y	M1	Release of the link of the <a href="#">HL-LHC website</a> .
MS3	Forming all official bodies requested by the governance	1	CERN	M6	Y	M2	At 1st Annual meeting. Available on the Intranet under " <a href="#">Management Bodies</a> ".
MS4	Installation of PLC and 1st meeting	1	CERN	M6	Y	M9	<a href="#">1st meeting minutes</a> . Minor delay for the first meeting.
MS5	Formation of the working group on QA management	1	CERN	M6	Y	M12	Updating of LHC Quality Plan meeting <a href="#">memo</a> . <a href="#">Justification</a> for delay.
MS6	Rules of publication	1	CERN	M6	Y	M14	Available on the Intranet under "Publications" and also under " <a href="#">Contact us</a> ". <a href="#">Justification</a> for delay.
MS44	Machine protection concerns satisfied	4	CERN	M6	Y	M19	Machine Protection Panel took over. <a href="#">Report</a> . <a href="#">Justification</a> for delay.
MS45	Common specifications for the alternative proposals of Compact Crab Cavity geometries	4	CERN	M6	Y	M19	<a href="#">Report</a> . <a href="#">Justification</a> for delay
MS7	Definition of the body to link HL with LIU and detector upgrade	1	CERN	M9	Y	M9	<a href="#">Liaison with Injector Upgrades Detector upgrade</a>
MS8	Organization of the 1st Annual Collaboration Meeting	1	CERN	M12	Y	M13	Meeting <a href="#">minutes</a>



MS9	Acquisition of main standards and adaptation to HL-LHC	1	CERN	M12	Y	M17	<a href="#">Report. Justification</a> for delay
MS10	Definition of regulatory framework, design limits and dose objectives	1	CERN	M12	Y	M24	<a href="#">Report</a>
MS11	Establish permanent collaboration with ITLO and TIARA	1	CERN	M12	Y	M14	<a href="#">Joint workshop</a> with TIARA
MS26	Distribution of Preliminary Optics and Lattice files to all work packages	2	CERN	M12	Y	M13	<a href="#">Report</a>
MS33	Requirements for Nb3Sn inner triplet and comparison with present status of the art	3	CERN	M12	Y	M14	<a href="#">Report</a>
MS34	Requirements for separation dipoles	3	CERN	M12	Y	M12	<a href="#">Report</a>
MS46	Operational scenario during LHC ramping specified	4	CERN	M12	Y	M19	<a href="#">Report. Justification</a> for delay
MS48	Set up of models and implementation of upgrade optics	5	CERN	M12	Y	M14	Available on the <a href="#">web</a>
MS12	Agreed criteria to evaluate figure of merit of variants	1	CERN	M18	Y	M19	<a href="#">Report</a>
MS13	Preliminary QA management plan	1	CERN	M18	Y	M19	<a href="#">Report</a>
MS14	Agreement on most probable injector scenario	1	CERN	M18	Y	M19	<a href="#">Report</a>
MS35	Review of the Nb-Ti options for the inner triplet for new peak and integrated luminosity targets	3	CERN	M18	Y	M19	<a href="#">Report</a>

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MS49	Assessment of beam halo losses in various upgrade scenarios	5	CERN	M18	Y	M18	Available on the <a href="#">web</a>
MS54	Cryogenic scenarios	6	CERN	M18	Y	M18	<a href="#">Report</a>

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## ANNEX: LIST OF PUBLICATIONS

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<b>WP1:</b>
Jacqui Hayes: Accelerate physics with your own computer ISGTW October 2011 <a href="http://www.isgtw.org/feature/accelerate-physics-your-own-computer">http://www.isgtw.org/feature/accelerate-physics-your-own-computer</a>
CERN Bulletin: EU supports the LHC high-luminosity study, November 2011 <a href="http://cdsweb.cern.ch/journal/CERNBulletin/2011/45/News%20Articles/1394587?ln=en">http://cdsweb.cern.ch/journal/CERNBulletin/2011/45/News%20Articles/1394587?ln=en</a>
CERN has 2020 vision for LHC upgrade, CERN Press release November 2011 <a href="http://press.web.cern.ch/press-releases/2011/11/cern-has-2020-vision-lhc-upgrade">http://press.web.cern.ch/press-releases/2011/11/cern-has-2020-vision-lhc-upgrade</a>
LHC@home is ready to support HiLumi LHC: take part! November 2011, CERN Bulletin <a href="http://cdsweb.cern.ch/journal/CERNBulletin/2011/47/News%20Articles/1398635?ln=en">http://cdsweb.cern.ch/journal/CERNBulletin/2011/47/News%20Articles/1398635?ln=en</a>
Robert Evans: 'Big Bang' Machine to Get Huge Upgrade in 2020 November 2011, Onislam <a href="http://www.onislam.net/english/health-and-science/news/454755-qbig-bangq-machine-to-get-huge-upgrade-in-2020.html">http://www.onislam.net/english/health-and-science/news/454755-qbig-bangq-machine-to-get-huge-upgrade-in-2020.html</a>
A LHC si guardi al future INFN LHC Italia, November 2011 <a href="http://www.infn.it/lhcitalia/index.php?option=com_content&amp;view=article&amp;id=328%3Aa-lhc-si-guarda-al-futuro&amp;Itemid=30">http://www.infn.it/lhcitalia/index.php?option=com_content&amp;view=article&amp;id=328%3Aa-lhc-si-guarda-al-futuro&amp;Itemid=30</a>
Robert Evans: 'Big Bang' Machine to Get Huge Upgrade in 2020 November 2011 <a href="http://www.reuters.com/article/2011/11/17/us-science-collider-idUSTRE7AF2HF20111117">http://www.reuters.com/article/2011/11/17/us-science-collider-idUSTRE7AF2HF20111117</a>
CERN has 2020 vision for LHC upgrade Phys.org, November 2011 <a href="http://phys.org/news/2011-11-cern-vision-lhc.html">http://phys.org/news/2011-11-cern-vision-lhc.html</a>
CERN has 2020 vision for LHC upgrade Interactions.org, November 2011 <a href="http://www.interactions.org/cms/?pid=1031212">http://www.interactions.org/cms/?pid=1031212</a>
HiLumi LHC begins EuCARD newsletter December 2011 <a href="http://eucard.web.cern.ch/EuCARD/news/newsletters/issue11/article5.html#news03">http://eucard.web.cern.ch/EuCARD/news/newsletters/issue11/article5.html#news03</a>
Meeting sets scene for LHC-luminosity upgrade CERN Courier, Jan 2012 <a href="http://cerncourier.com/cws/article/cern/48327">http://cerncourier.com/cws/article/cern/48327</a>
Kate Kahle, Lucio Rossi: Designs on higher luminosity, CERN Courier, February 2012 <a href="http://cerncourier.com/cws/article/cern/48620">http://cerncourier.com/cws/article/cern/48620</a>
Kate Kahle: Why do we need a High Luminosity LHC? Accelerating News, April 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue01/index.html#news4">http://acceleratingnews.web.cern.ch/acceleratingnews/issue01/index.html#news4</a>
Kate Kahle: Upgrading together, HL-LHC and LIU Accelerating News, April 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue01/index.html#news7">http://acceleratingnews.web.cern.ch/acceleratingnews/issue01/index.html#news7</a>
Katherine Chapman: Illuminating the way from Research to Industry, Accelerating News, June 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue02/index.html#news2">http://acceleratingnews.web.cern.ch/acceleratingnews/issue02/index.html#news2</a>
Kate Kahle: LARP's role in the luminosity upgrade, Accelerating News, June 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue02/index.html#news6">http://acceleratingnews.web.cern.ch/acceleratingnews/issue02/index.html#news6</a>
A new generation of magnets for accelerators, MRIs July 2012, Fermilab Today <a href="http://www.fnal.gov/pub/today/archive_2012/today12-07-11.html">http://www.fnal.gov/pub/today/archive_2012/today12-07-11.html</a>
Anais Schaeffer: Small but powerful: Fermilab develops magnets for future High Luminosity LHC, Phys.org August 2012 <a href="http://phys.org/news/2012-08-small-powerful-fermilab-magnets-future.html">http://phys.org/news/2012-08-small-powerful-fermilab-magnets-future.html</a>

Warmer amps for the LHC, August 2012, CERN Bulletin <a href="https://cdsweb.cern.ch/journal/CERNBulletin/2012/35/News%20Articles/1473659?ln=en">https://cdsweb.cern.ch/journal/CERNBulletin/2012/35/News%20Articles/1473659?ln=en</a>
O Bruning et al: High Energy LHC Document prepared for the European HEP strategy update:, Aug 2012 <a href="https://cdsweb.cern.ch/record/1471002?ln=en">https://cdsweb.cern.ch/record/1471002?ln=en</a>
L Rossi, O Bruning: High Luminosity Large Hadron Collider A description for the European Strategy Preparatory Group, Aug 2012 <a href="https://cdsweb.cern.ch/record/1471000?ln=en">https://cdsweb.cern.ch/record/1471000?ln=en</a>
Lucio Rossi: New progress for the HiLumi baseline configuration, Accelerating News, September 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue03/index.html#news4">http://acceleratingnews.web.cern.ch/acceleratingnews/issue03/index.html#news4</a>
Frank Zimmermann and Roy Aleksan: Accelerators in the European Strategy for Particle Physics meeting in Cracow, Accelerating News, September 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue03/index.html#news2">http://acceleratingnews.web.cern.ch/acceleratingnews/issue03/index.html#news2</a>
Marina Giampietro, Lucio Rossi and Agnes Szeberenyi: Superconducting Technologies for the Next Generation of Accelerators, Accelerating News, December 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue04/index.html#news3">http://acceleratingnews.web.cern.ch/acceleratingnews/issue04/index.html#news3</a>
Lucio Rossi and Agnes Szeberenyi: Recent progress of the HiLumi project, Accelerating News, December 2012 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue04/index.html#news6">http://acceleratingnews.web.cern.ch/acceleratingnews/issue04/index.html#news6</a>
L. Rossi, C. Sutton, A. Szeberenyi: Superconducting leads the way to high luminosity, CERN Courier, Vol 53, no 1. January 2013 <a href="http://cerncourier.com/cws/article/cern/52035">http://cerncourier.com/cws/article/cern/52035</a>
Peter McIntosh: Development and Testing of Crab Cavities for High Intensity Colliders, Accelerating News, March 2013 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue05/index.html#news2">http://acceleratingnews.web.cern.ch/acceleratingnews/issue05/index.html#news2</a>
Ezio Todesco and Stephane Fartouk:h: A first layout for the High Luminosity Upgrade, Accelerating News, March 2013 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue05/index.html#news3">http://acceleratingnews.web.cern.ch/acceleratingnews/issue05/index.html#news3</a>
Frank Zimmermann: Targeting the Energy Frontier for next Accelerators, Accelerating News, March 2013 <a href="http://acceleratingnews.web.cern.ch/acceleratingnews/issue05/index.html#news7">http://acceleratingnews.web.cern.ch/acceleratingnews/issue05/index.html#news7</a>
<b>WP2</b>
[1] L. Rossi and O. Brüning (2012), <i>High Luminosity Large Hadron Collider A description for the European Strategy Preparatory Group</i> , CERN-ATS-2012-236: <a href="http://cdsweb.cern.ch/record/1471000/files/CERN-ATS-2012-236.pdf">http://cdsweb.cern.ch/record/1471000/files/CERN-ATS-2012-236.pdf</a>
[2] S. Fartoukh (2011), <i>An Achromatic Telescopic Squeezing (ATS) Scheme For The LHC Upgrade</i> , CERN-ATS-2011-161, presented at the <a href="#">2nd International Particle Accelerator Conference</a> , San Sebastian, Spain, 4 - 9 Sep 2011: <a href="http://cdsweb.cern.ch/record/1382077/files/CERN-ATS-2011-161.pdf">http://cdsweb.cern.ch/record/1382077/files/CERN-ATS-2011-161.pdf</a>
[3] S. Fartoukh and R. De Maria, R. (2012), <i>Optics and Layout Solutions for HL-LHC with Large Aperture NB3SN and NB-TI Inner Triplets</i> , CERN-ATS-2012-136, presented at the <a href="#">3rd International Particle Accelerator Conference</a> , New Orleans, LA, USA, 20 - 25 May 2012:

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<p><a href="http://cdsweb.cern.ch/record/1459916/files/CERN-ATS-2012-136.pdf">http://cdsweb.cern.ch/record/1459916/files/CERN-ATS-2012-136.pdf</a></p>
<p>[4] <i>A repository for the optics and layout of the HL-LHC with a 140 mm- 150 T/m inner triplet</i>, available under /afs/cern.ch/eng/lhc/optics/SLHCV3.1b and <a href="http://hllhcoptics.web.cern.ch/hllhcoptics/SLHCV3.1b/">http://hllhcoptics.web.cern.ch/hllhcoptics/SLHCV3.1b/</a>.</p>
<p>[5] S. Fartoukh (2012), <i>HiLumi-LHC Optics</i>, Presentation given at the LARP CM18/HiLumi LHC Meeting, Fermilab, 7-9 May, 2012: <a href="https://indico.fnal.gov/conferenceOtherViews.py?view=standard&amp;confId=5072">https://indico.fnal.gov/conferenceOtherViews.py?view=standard&amp;confId=5072</a></p>
<p>[6] R. De Maria, S. Fartoukh, A. Bogomyagkov, M. Korostelev (2013), “HLLHCV1.0: HL-LHC layout and optics models for 150 mm Nb3Sn triplets and local crab-cavities”, TUPF014 in IPAC13 Proceedings.</p>
<p>[7] M. Korostelev, A. Wolski, R. De Maria, S. Fartoukh, “Optics Transition between Injection and Collision optics for the HL-LHC Upgrade Project”, TUPFI051 in IPAC13 Proceedings.</p>
<p>[8] B. Dalena et al. (2013), “High Luminosity LHC Matching Section Layout vs. Crab Cavity Voltage”, TUPFI001 in IPAC13 Proceedings.</p>
<p>[9] Y. Nosochkov, Y. Cai, Y. Jiao, M.-H. Wang, S. Fartoukh, M. Giovannozzi, R. de Maria, E. McIntosh (2012), <i>Field Tolerances for the Triplet Quadrupoles of the LHC High Luminosity Lattice</i>, SLAC-PUB-15026, presented at the <a href="#">3rd International Particle Accelerator Conference</a>, New Orleans, LA, USA, 20 - 25 May 2012: <a href="http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-15026.pdf">http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-15026.pdf</a></p>
<p>[10] Y. Nosochkov, <i>et al.</i> (2013), “Optimization of Triplet Quadrupoles Field Quality for the LHC High Luminosity Lattice at Collision Energy”, TUPFI016, in IPAC13 proceedings.</p>
<p>[11] R. De Maria, S. Fartoukh, M. Giovannozzi (2013), “Specification of a System of Correctors for the Triplets and Separation Dipoles of the LHC Upgrade”, WEPEA048 in IPAC13 proceedings (pre-press version at: <a href="http://159.226.222.133/prepress/WEPEA048.PDF">http://159.226.222.133/prepress/WEPEA048.PDF</a>)</p>
<p>[12] B. Holzer, R. De Maria, A. Chance, B. Dalena, J. Payet, A. Bogomyagkov, R. Appleby, M. Korostelev, K. Hock, A. Wolski, C. Milardi, A. Faus-Golfe, J. Resta (2012), <i>Optics and lattice optimizations for the LHC upgrade project</i>, CERN-ATS-2012-231, presented at the <a href="#">3rd International Particle Accelerator Conference</a>, New Orleans, LA, USA, 20 - 25 May 2012: <a href="http://cdsweb.cern.ch/record/1470609/files/CERN-ATS-2012-231.pdf">http://cdsweb.cern.ch/record/1470609/files/CERN-ATS-2012-231.pdf</a></p>
<p>[13] R. De Maria (2012), <i>Parametric Study of Optics Options for the HL-LHC Project</i>, CERN-ATS-2012-137, presented at the <a href="#">3rd International Particle Accelerator Conference</a>, New Orleans, LA, USA, 20 - 25 May 2012: <a href="http://cdsweb.cern.ch/record/1460108/files/CERN-ATS-2012-137.pdf">http://cdsweb.cern.ch/record/1460108/files/CERN-ATS-2012-137.pdf</a></p>
<p>[14] M. Giovannozzi, <i>et al.</i> (2013), “Dynamic Aperture Performance for Different Collision Optics Scenarios for the LHC Luminosity Upgrade”, WEPEA047 in IPAC13 Proceedings.</p>
<p>[15] Y. Nosochkov, <i>et al.</i> (2013), “Evaluation of Field Quality for Separation Dipoles and Matching Section Quadrupoles for the LHC High Luminosity Lattice at Collision Energy”, TUPFI017, in IPAC13 proceedings.</p>
<p>[16] R. De Maria, S. Fartoukh, M. Giovannozzi (2013), “Specifications of the Field Quality at Injection Energy of the New Magnets for the HL-LHC Upgrade Project”, WEPEA045, in IPAC13 proceedings.</p>
<p>[17] A. Bogomyagkov, <i>et al.</i> (2013), “Analysis of the Non-linear Fringe Effects of Large</p>

Aperture Triplets for the HL LHC Project”, WEPEA049, in IPAC13 proceedings.

[18] M. Giovannozzi, R. De Maria, F. Lang (2013), “Analysis of Possible Functional Forms of the Scaling Law for Dynamic Aperture as a Function of Time”, WEPEA050, in IPAC13 proceedings.

[19] R. De Maria *et al.* (2013), “Recent Developments and Future Plans for SixTrack”, MOPW002, in IPAC13 proceedings.

[20] R. De Maria, M. Giovannozzi, E. McIntosh (2013), “Investigation of Numerical Precision Issues of Long Term Single Particle Tracking”, MOPW0026, in IPAC13 proceedings.

[21] J. Barranco García, R. Calaga, R. De Maria, M. Giovannozzi, A. Grudiev, R. Tomás (2012), *Study of Multipolar RF Kicks from the main deflecting mode in Compact Crab Cavities for LHC*, CERN-ATS-2012-120, presented at the [3rd International Particle Accelerator Conference](#), New Orleans, LA, USA, 20 - 25 May 2012:  
<http://cdsweb.cern.ch/record/1459579/files/CERN-ATS-2012-120.pdf>

[22] E. Métral *et al.* (2012), *Collective effects in the LHC and its injector complex*, CERN-ATS-2012-183, invited talk given at the [3rd International Particle Accelerator Conference](#), New Orleans, LA, USA, 20 - 25 May 2012:  
<http://cdsweb.cern.ch/record/1464108/files/CERN-ATS-2012-183.pdf> and  
[http://emetral.web.cern.ch/emetral/THYB03\\_Talk.pdf](http://emetral.web.cern.ch/emetral/THYB03_Talk.pdf)

[23] E. Métral *et al.* (2012), *Impedances, instabilities and implications for the future*, presented at the 6<sup>th</sup> CERN Machine Advisory Committee, CERN, 16-17/08/2012:  
<http://indico.cern.ch/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=198003>

[24] S. Fartoukh (2012), *The sign of the LHC octupoles*, presented at the 141<sup>th</sup> LHC Machine Committee, 11/06/2012: [https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc\\_141/lmc\\_141h.pdf](https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc_141/lmc_141h.pdf)

[25] A. Burov (2012), *Nested HT method: impedance, damper, radial modes and coupled bunches*, presented at the 146<sup>th</sup> LHC Machine Committee, 29/08/2012:  
[https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc\\_146/lmc\\_146f.pdf](https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc_146/lmc_146f.pdf)

[26] B. Salvant (2012), *Beam induced RF heating*, presented at the 148<sup>th</sup> LHC Machine Committee, 14/09/2012:  
[https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc\\_148/lmc\\_148b.pdf](https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc_148/lmc_148b.pdf)

[27] B. Salvant *et al.* (2013), *Update on beam induced RF heating in the LHC*, IPAC13 Proceedings.

[28] G. Iadarola *et al.* (2013), *Electron cloud and scrubbing studies for the LHC*, IPAC13 Proceedings.

[29] D. Alesini, A. Drago, A. Gallo, S. Guiducci, C. Milardi, M. Zobov, S. De Santis, T. Demma, P. Raimondi (2012), *Experimental measurements clearing electrodes in the DaΦne collider*, presented at the [3rd International Particle Accelerator Conference](#), New Orleans, LA, USA, 20 - 25 May 2012:  
[https://espace.cern.ch/HiLumi/Publications/Scientific%20Reports%20and%20Notes/TUOBC03\\_IPAC2012.pdf](https://espace.cern.ch/HiLumi/Publications/Scientific%20Reports%20and%20Notes/TUOBC03_IPAC2012.pdf)

[30] D. Alesini *et al.* (2013), *DAΦNE Operation with Electron-Cloud-Clearing Electrodes*, in Physical Review Letters 110, 124801

[31] M. Schaumann (2012), *Simulations of IBS for HL-LHC protons*, presented at the 2<sup>nd</sup> Task 2.4 meeting, CERN, 05/09/2012: [http://emetral.web.cern.ch/emetral/Task2point4OfHLLHCWP2/2ndMeeting\\_13-06-12/PresentationHL-LHC-30052012.pdf](http://emetral.web.cern.ch/emetral/Task2point4OfHLLHCWP2/2ndMeeting_13-06-12/PresentationHL-LHC-30052012.pdf)

[32] M. Schaumann et al. (2012), *Intra-Beam Scattering and Luminosity Evolution for HL-LHC Proton Beams*, CERN-ATS-2012-290

[33] A. Burov (2011), *Beam stability in LHC with crab cavities*, LHC-CC11 workshop, CERN, 14-15/11/2011: <https://indico.cern.ch/getFile.py/access?contribId=27&sessionId=6&resId=0&materialId=slides&confId=149614>

[34] R. Wanzenberg and O. Zagorodnova (2013), *Calculation of Wakefields and Higher Order Modes for the New Design of the Vacuum Chamber of the CMS Experiment for the HL-LHC*, CERN-ATS-Note-2013-018 TECH

[35] E. Métral et al, (2013) *Lessons learnt and mitigation measures for the CERN LHC equipment with RF fingers*, TUPWA042 in IPAC13 proceedings.

[36] A. Burov (2012), *Circular modes and flat beams for the LHC*, presentation given at a CERN internal AP forum, 01/10/2012: [http://emetral.web.cern.ch/emetral/ICEsection/2012/2012-10-03/Circular\\_Modes\\_LHC\\_AP\\_talk.pdf](http://emetral.web.cern.ch/emetral/ICEsection/2012/2012-10-03/Circular_Modes_LHC_AP_talk.pdf)

[37] H. Maury Cuna et al. (2012), *Simulations of Electron-Cloud Heat Load for the Cold Arcs of the CERN Large Hadron Collider and Its High-Luminosity Upgrade Scenarios*, PRST-AB 15, 051001

[38] A. Valishev (2012), *Beam-beam effects: status and plans*, Presentation given at the LARP CM19/HiLumi LHC Meeting, Frascati, 14-16 November, 2012, <https://indico.cern.ch/contributionListDisplay.py?confId=183635>

[39] A. Valishev et al. (2013), *Beam-beam studies for the HL-LHC*, Presentation given at the ICFA Mini-Workshop on Beam-Beam Effects in Hadron Colliders, CERN, 18-22 March, 2013, <http://indico.cern.ch/conferenceDisplay.py?confId=189544>

[40] A. Valishev (2013), *Update on HL-LHC beam-beam simulations*, Presentation given at the LARP CM20/HiLumi LHC Meeting, Napa, 8-10 April, 2013, <https://indico.fnal.gov/conferenceDisplay.py?confId=6164>

[41] T. Rijoff, R. Steinhagen, F. Zimmermann (2012), *Simulation studies for LHC long-range beam-beam compensators*, CERN-ATS-2012-074, presented at the [3rd International Particle Accelerator Conference](#), New Orleans, LA, USA, 20 - 25 May 2012: <http://cdsweb.cern.ch/record/1450938/files/CERN-ATS-2012-074.pdf>

[42] S. M. White, *Coherent Effects with Beam-beam and Impedance*, [http://emetral.web.cern.ch/emetral/ICEsection/2012/2012-10-03/SB\\_Coherent.pdf](http://emetral.web.cern.ch/emetral/ICEsection/2012/2012-10-03/SB_Coherent.pdf)

[43] X. Buffat, W. Herr, T. Pieloni, S.M. White, *Stability of beams colliding with a transverse offset*, CERN-ATS-Note-2013-016 MD, Geneva, 2013.

[44] X. Buffat, W. Herr, M. Lamont, T. Pieloni, S. Redaelli, J. Wenninger (2012), *Results of  $\beta^*$  luminosity levelling*, CERN-ATS-Note-2012-071 MD

[45] X. Buffat, W. Herr, M. Lamont, T. Pieloni, L. Ponce, S. Redaelli, J. Wenninger (2013), *MD on squeeze with colliding beams*, CERN-ATS-Note-2013-002 MD.

[46] X. Buffat, W. Herr, M. Lamont, T. Pieloni, S. Redaelli, J. Wenninger (2013), <i>Colliding during the squeeze and <math>\beta</math> levelling in the LHC</i> , TUPFI033 in IPAC13 proceedings.
[47] T. Pieloni, <i>Levelling scenarios: present and future prospective</i> . 2 <sup>nd</sup> Joint HiLumi LHC-LARP Annual Meeting, Frascati, November 2012.
[48] W. Herr, X. Buffat, R. Calaga, R. Giachino, G. Papotti, T. Pieloni, D. Kaltchev, <i>Long Range Beam-Beam Effects in the LHC</i> , ICFA Mini-Workshop on beam-beam Effects in Hadron Colliders, Geneva, 2013.
[49] D. Kaltchev and W. Herr, <i>Analysis of long range studies in the LHC – comparison with the model</i> , ICFA Mini-Workshop on beam-beam Effects in Hadron Colliders, Geneva, 2013.
[50] First and second HL-LHC / LIU joint workshops (2011,2012), <a href="http://indico.cern.ch/conferenceDisplay.py?confId=138437">http://indico.cern.ch/conferenceDisplay.py?confId=138437</a> <a href="http://indico.cern.ch/conferenceDisplay.py?confId=175259">http://indico.cern.ch/conferenceDisplay.py?confId=175259</a>
[51] O. Brüning (2012), <i>HL-LHC operation with protons and ions</i> , presented at the Chamonix 2012 workshop on LHC performance workshop, 6-10 February 2012, Chamonix, France, CERN-ATS-2012-069, <a href="https://espace.cern.ch/acc-tec-sector/Chamonix/Chamx2012/papers/OB_8_03.pdf">https://espace.cern.ch/acc-tec-sector/Chamonix/Chamx2012/papers/OB_8_03.pdf</a>
[52] O. Brüning and F. Zimmerman (2012), <i>Parameter Space for the LHC High-Luminosity Upgrade</i> , CERN-ATS-2012-070, presented at the <a href="#">3rd International Particle Accelerator Conference</a> , New Orleans, LA, USA, 20 - 25 May 2012, <a href="http://cdsweb.cern.ch/record/1450919/files/CERN-ATS-2012-070.pdf">http://cdsweb.cern.ch/record/1450919/files/CERN-ATS-2012-070.pdf</a>
<b>WP3</b>
Todesco, E. et al. (2012) Design studies for the low beta quadrupoles for the LHC luminosity upgrade, submitted to IEEE Trans. Appl. Supercond., presented at ASC conference, Portland October 2012, also CERN ATS-2013-018.
Xu, Q. et al. (2012) Design of a large single aperture magnet for the HL- LHC upgrade, submitted to IEEE Trans. Appl. Supercond., presented at ASC conference, Portland October 2012.
Kirby, G. et al. (2012) Testing results for Nb-Ti 120-mm-aperture low-beta quadrupole models for the LHC high luminosity insertion, submitted to IEEE Trans. Appl. Supercond., presented at ASC conference, Portland October 2012.
Bajas, H. et al. (2012) Cold test results of the LARP HQ Nb <sub>3</sub> Sn quadrupoles magnet at 1.9 K, IEEE Trans. Appl. Supercond., presented at ASC conference, Portland October 2012, also CERN ATS-2013-020.
M. Segreti, J.-M. Rifflet Studies on large aperture Q4 with MQ and MQM cables – third report <a href="http://www.cern.ch/hilumi/wp3">www.cern.ch/hilumi/wp3</a>
L .Esposito, F. Cerutti, E. Todesco, Fluka energy deposition studies for the HL LHC, IPAC 2013 <a href="http://www.jacow.org">www.jacow.org</a> .
<b>WP4:</b>
R. Calaga et al.: “Crab Cavities for the LHC Upgrade”, LHC Performance <a href="https://cdsweb.cern.ch/record/1493034?ln=en">https://cdsweb.cern.ch/record/1493034?ln=en</a>
J. Barranco et al.: “Study of Multipolar RF Kicks from the main deflecting mode in Compact Crab Cavities for LHC”, IPAC2012, New Orleans



L. Ficcadenti, J. Tückmantel: “Slim elliptical cavity at 800 MHz for local crab crossing”, IPAC2012, New Orleans
R. Calaga et al.: “A quarter wave design for crab crossing in the LHC”, IPAC2012, New Orleans
T. Baer et al.: “Very fast LHC Crab cavity failures and their mitigation”, IPAC2012, New Orleans
K Ohmi et al.: “Response of colliding beam-beam system to harmonic excitation due to crab-cavity rf phase modulation”, EuCARD-PUB-2012-002, Phys. Rev. ST Accel. Beams 14 (2011) 111003
T. Baer et al.: “LHC Machine Protection Against Very Fast Crab Cavity Failures”, EuCARD-CON-2011-048, IPAC2011, San Sebastian
G. Arduini et al.: “5th LHC Crab Cavity Workshop, LHC-CC11 Workshop Summary Report”, EuCARD-PUB-2012-001
H. J. Kim, T. Sen: “CRAB Cavity in CERN SPS”, FERMILAB-CONF-10-259-APC
B. Hall et al.: “Analysis of the Four Rod Crab Cavity for HL-LHC”, IPAC2012, New Orleans
J.R. Delayen and S.U. De Silva: “Design and Development of Superconducting Parallel-bar Deflecting/Crabbing Cavities”, IPAC2012, New Orleans
P. Baudrenghien: “LHC & SPS RF Controls for Crab Cavities”, 5th LHC Crab Cavity Workshop, LHC-CC11, CERN
A. Burov, E. Shaphosnikova: “Impedance Aspects with Crab Cavities”, 5th LHC Crab Cavity Workshop, LHC-CC11, CERN
A. Grudiev et al.: “Study of Multipolar RF Kicks from the Main Deflecting Mode in Compact Crab Cavities for LHC”, IPAC2012, New Orleans
R. Calaga et al.: “Proton-Beam Emittance Growth in SPS Coasts”, IPAC2012, New Orleans
D. Gorelov et al.: “Engineering of a Superconducting 400 MHz Crabbing Cavity for the LHC HiLumi Upgrade”, IPAC2012, New Orleans
Q. Wu et al.: “HOM Damping and Multipacting Analysis of the Quarter-wave Crab Cavity”, IPAC2012, New Orleans
J.R. Delayen and S.U. De Silva: “Design of Superconducting Parallel-bar Deflecting/Crabbing Cavities with Improved Properties”, PAC11, New York, 2011
R. Calaga et al.: “First test results of the 4-Rod crab cavity”, IPAC13, Shanghai, 2013
S. Da Silva et al.: “Compact Superconducting RF-Dipole Cavity Designs for Deflecting and Crabbing Applications”, IPAC2013, Shanghai, 2013
S. Belomestnykh: “Double Quarter-wave Cavity Design and Plans”, LARP Review, FNAL, 2013
R. Calaga et al.: “Crab Cavities for the LHC Upgrade”, LHC Performance <a href="https://cdsweb.cern.ch/record/1493034?ln=en">https://cdsweb.cern.ch/record/1493034?ln=en</a>
J. Barranco et al.: “Study of Multipolar RF Kicks from the main deflecting mode in Compact Crab Cavities for LHC”, IPAC2012, New Orleans
L. Ficcadenti, J. Tückmantel: “Slim elliptical cavity at 800 MHz for local crab crossing”, IPAC2012, New Orleans

R. Calaga et al.: “A quarter wave design for crab crossing in the LHC”, IPAC2012, New Orleans
T. Baer et al.: “Very fast LHC Crab cavity failures and their mitigation”, IPAC2012, New Orleans
K Ohmi et al.: “Response of colliding beam-beam system to harmonic excitation due to crab-cavity rf phase modulation”, EuCARD-PUB-2012-002, Phys. Rev. ST Accel. Beams 14 (2011) 111003
T. Baer et al.: “LHC Machine Protection Against Very Fast Crab Cavity Failures”, EuCARD-CON-2011-048, IPAC2011, San Sebastian
G. Arduini et al.: “5th LHC Crab Cavity Workshop, LHC-CC11 Workshop Summary Report”, EuCARD-PUB-2012-001
H. J. Kim, T. Sen: “CRAB Cavity in CERN SPS”, FERMILAB-CONF-10-259-APC
B. Hall et al.: “Analysis of the Four Rod Crab Cavity for HL-LHC”, IPAC2012, New Orleans
J.R. Delayen and S.U. De Silva: “Design and Development of Superconducting Parallel-bar Deflecting/Crabbing Cavities”, IPAC2012, New Orleans
P. Baudrenghien: “LHC & SPS RF Controls for Crab Cavities”, 5th LHC Crab Cavity Workshop, LHC-CC11, CERN
A. Burov, E. Shaphosnikova: “Impedance Aspects with Crab Cavities”, 5th LHC Crab Cavity Workshop, LHC-CC11, CERN
A. Grudiev et al.: “Study of Multipolar RF Kicks from the Main Deflecting Mode in Compact Crab Cavities for LHC”, IPAC2012, New Orleans
R. Calaga et al.: “Proton-Beam Emittance Growth in SPS Coasts”, IPAC2012, New Orleans
D. Gorelov et al.: “Engineering of a Superconducting 400 MHz Crabbing Cavity for the LHC HiLumi Upgrade”, IPAC2012, New Orleans
Q. Wu et al.: “HOM Damping and Multipacting Analysis of the Quarter-wave Crab Cavity”, IPAC2012, New Orleans
J.R. Delayen and S.U. De Silva: “Design of Superconducting Parallel-bar Deflecting/Crabbing Cavities with Improved Properties”, PAC11, New York, 2011
<b>WP5:</b>
J. Molson, R.B. Appleby et al (2012), Simulating the LHC Collimation System with the Accelerator Physics Library MERLIN, and Loss Map Results”, The proceedings of IPAC12, Rostock, Germany, August 19-24 (2012)
Members of WP5 are co-authors of several LHC MD notes on the 2012 beam measurement.
<b>WP6</b>
Yang et al., Y.Y. (2013): Critical current and stability of MgB <sub>2</sub> Twisted-Pair DC cable assembly cooled by helium gas, <i>IEEE Transactions on Applied Superconductivity</i> , 23 (3)