HL-LHC (High Luminosity LHC)

General Overview

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HL-LHC Configuration, Quality & Resources Officer
On behalf of the HL-LHC Project team

TOBB İkiz Kuleler, ANKARA, 14th April 2016
The HL-LHC Project

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

A peak luminosity of $L_{\text{peak}} = 5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with levelling, allowing:

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

Concept of ultimate performance recently defined:
$L_{\text{ult}} \approx 7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ and **Ultimate Integrated** $L_{\text{int ult}} \sim 4000 \text{ fb}^{-1}$

LHC should not be the limit, would Physics require more…
Nominal parameters would be reached in 2037
HL-LHC Project Governance

C-MAC
Experiments
HL-LHC Collaboration Board
US-LARP KEK

CERN Directorate and Accelerator & Technology Sector
ATSMB & EATSMB

HL-LHC & LIU Executive Committee

HL-LHC Project Office
LIU Project

HL-LHC Coordination Group
HL-LHC TCC

HL-LHC Work Packages

IEFC
LMC
A&TS DH GLs

I. Bejar Alonso - Configuration, Quality and Resource Officer
HL-LHC Workpackages

HL-LHC Project Management
Project Leader: Lucio Rossi, CERN
Deputy Project Leader: Oliver Brüning, CERN
Project Office Manager: Laurent Tavian, CERN
Configuration, QA, Resource Manager: Isabel Bejar Alonso, CERN
Integration: Paolo Fessia, CERN
Collaborations & Consolidation: Beniamino Di Girolamo, CERN
Budget Officer: Benoit Delillo, CERN
Safety Officer: Thomas Otto, CERN
Secretariat: Cécile Noels & Julia Cachet, CERN

WP15 Integration & (De-)Installation
Paolo Fessia

WP16 IT String & Commissioning
Marta Bajko – Mirko Pojer

WP17 Infrastructure & Logistics
Laurent Tavian
Beniamino Di Girolamo

WP1 Energy Deposition & R2E
Markus Brugger – Francesco Cerutti

WP6A Cold Powering
Amalia Ballarino
Vittorio Parma

WP6B Warm Powering
Jean-Paul Burnet
Michele Martino

WP7 Machine Protection
Daniel Wollman
Reiner Denz

WP8 Collider-Experiment Interface
Helmut Burkhardt – Francisco Sanchez
Galan

WP9 Cryogenics
Serge Claudet
Rob Van Weeldeh

WP10 Energy Deposition & R2E
Markus Brugger – Francesco Cerutti

WP11 11T Dipole
Frédéric Savary
Hervé Prin

WP12 Vacuum
Vincent Baglin
Roberto Reisevan

WP13 Beam Instrumentation
Rhodri Jones
Hermann Schmickler

WP14 Beam Transfer
Chiara Bracco
Brennan Goddard

WP17 Infrastructure & Logistics
Laurent Tavian
Beniamino Di Girolamo

I. Bejar Alonso - Configuration, Quality and Resource Officer
The HL-LHC Project
Main components, technical services and infrastructure
Many points around the ring
The largest HEP accelerator in construction

Complete change and new lay-out
1. TAXS
2. Q1-Q2-Q3
3. D1
4. All correctors
5. Heavy shielding (W)

> 1.2 km of LHC
New Insertion Region lay out

- Longer Quads; Shorter D1 (thanks to SC)
- Interaction region length is unchanged

Thick boxes are magnetic lengths -- Thin boxes are cryostats
Why changing the inner triplets

- Triggered by radiation damage on existing equipment due to leap in performance
- Dose of 30 MGy expected @ 300 fb\(^{-1}\) with impact on electrical insulation integrity

LHC has better aperture than anticipated and all margin can now be used. However seems very difficult to have \(\beta^* < 35-40\) cm (55 cm being the nominal)
Working on the Inner triplet magnets
Test at FNAL in progress. The magnet tested at Fermilab consists of two coils manufactured at CERN and two others manufactured by the LARP (LHC Accelerator Research Program) consortium.
HiLumi LHC magnet zoo

Overall, about 150 magnets are needed
Superconducting crab cavities – Why?

- Deflecting (or crab) cavities will be needed for compensation of the effective geometric crossing angle ($\theta_C$) at the Interaction Points (IP) to recover the luminosity loss due to increased crossing angle.

- The cavities generate a transverse electric field that rotates each bunch by $\theta_C/2$. The time dependent transverse kick from an RF deflecting cavity is used to perform a bunch rotation, in the $x$-$z$ plane or $y$-$z$ plane depending on the crossing angle orientation, about the barycentre of the bunch.

- The kick is transformed to a relative displacement of the head and the tail of the bunch at the IP to impose a head-on collision while maintaining the required beam separation to minimize parasitic collisions.
Crab cavities

Mostly standardized interfaces and common platform

Main differences
- Cavity symmetry & length
- HOM couplers

Double Quarter Wave, Vertical Deflection

RF Dipole
Horizontal Deflection
SPS Cryomodule:
Include 2 identical cavities
Why upgrading the Collimation system

- Because of a high stored energy, above 700 MJ, the beams in LHC are highly destructive. **Even a local beam loss of a tiny fraction of the full beam in a superconducting magnet could cause a quench**, and large beam losses could cause damage to accelerator components.
- In the LHC, a multistage **collimation system** has been installed to safely dispose of beam losses.
- The **HiLumi LHC** imposes increased challenges to the collimation system. The **factor ~2 increase in total stored beam energy** requires a corresponding improvement of cleaning performance to achieve the same losses in the superconducting magnets.
Collimation system evolving with the Run

IR1+IR5, per beam:
4 tertiary collimators
3 physics debris collimators
fixed masks
Completely new layouts
Novel materials.

Cleaning: DS coll. + 11T dipoles, 2 units per beam

Final decision on installation to be taken based on Run 2 experience

Ion physics debris:
DS coll. + 11T dipoles

Low-impedance, high robustness secondary collimators
TCSPM Overview

- Longer jaws, tapering and vacuum tank
- Shorter RF fingers, upstream and downstream flange collars
- Same flange-to-flange length
- BPM vertical buttons upstream, on top of the horizontal BPMs for jaw positioning
Increasing availability

Baseline: removal to Double Decker Underground

- 2×150 kA
- 4 pairs 150(+/- 75) kA for MS–LS3
- 4 pairs 100(+/-50) kA for ITR – LS3
- All lines in MgB$_2$ (or HTS)
- tens of 6-18 kA CLs pairs in HTS
Superconducting link concept

New “DFB”: joint box

MgB$_2$

HTS

No LHe
Eliminating Technical bottlenecks

8 x 18 kW @ 4.5 K
1'800 SC magnets
24 km and 20 kW @ 1.9 K
36'000 tons @ 1.9 K
96 tons of He

Cryogenic plant
The 11T Dipole Two-in-One for DS

Create space in the dispersion suppressor regions of LHC, i.e. a room temperature beam vacuum sector, to install additional collimators (TCLD)

Replace a standard Main Bending dipole by a pair of 11T dipoles (the 11T dipole is also called MBH)

\[ \int B dL = 119.2 \text{Tm} \quad @ \quad I_{\text{nom}} = 11.85 \text{kA} \]
in series with MB with 20% margin
Beam diagnostic improvement

- Cryogenic BLMs & Radiation Hard Electronics
  - Cryogenic BLMs
  - Radiation hard electronics
- Fast WireScanners
- Insertion Region BPMs
  - Cold directional couplers
  - Tungsten shielded cold directional couplers
  - Warm directional couplers
  - High precision electronics for insertion region BPMs
- Luminosity Monitors
- Diagnostics for Crab Cavities
- Upgrade to Synchrotron Light Monitors
  - Upgrade to existing monitor
  - New light source
  - Halo diagnostics
- Beam Gas Vertex Detector
  - Final Implementation
- Long-Range Beam-Beam Compensator
  - Prototype
  - Final Implementation
And many other improvements

- **Machine protection**: improved robustness to mis-injected beams, to kickers sparks will be required. The kicker system, collimation and TDI, is the main shield against severe beam induced damage.

- **Quench Protection System** of SC magnets to remake a 20 years old design.

- **Remote manipulation**: the level of activation around 2020 requires development of special equipment to allow replacing/servicing collimators, magnets, vacuum components etc., according to ALARA principle. Remote manipulation, enhanced reality and supervision is the key to minimizing the radiation doses sustained during interventions.

- **Vacuum**
Installation Overview for LS2 (2019-2020)

- New transp. refrigerator
- New Q5
- TCSPM
- Cryo-bypass+TCLD
- In-situ a-C coating
- Mask for D2
- TAXN
- High bandwidth pick-ups
- Fast wire scanners
- BGV
- Prep. works halo diagnostic systems
- TDIS
- TCDD Mask for D1
Point 1 Civil Engineering underground
### Surface buildings

<table>
<thead>
<tr>
<th>Description</th>
<th>Sigle</th>
<th>H</th>
<th>L</th>
<th>W</th>
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<tr>
<td>Plateforme réservoirs hélium</td>
<td>SHE</td>
<td>5</td>
<td>33</td>
<td>5</td>
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<td>Bâtiment ventilation</td>
<td>SU</td>
<td>9</td>
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<td>Bâtiment électrique</td>
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<td>Bâtiment tête de puits</td>
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<td>Bâtiment compresseurs</td>
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<td>15</td>
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<td>Rectifier Building 3175</td>
<td>SR</td>
<td>7</td>
<td>12</td>
<td>8</td>
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<td>Tour de refroidissement</td>
<td>SF</td>
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<td>Bâtiment déchargement hélium</td>
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<td>14.4</td>
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- ≈ 3’400 m² new buildings
- Present surface ≈ 75’200 m²
- New surface ≈ 91’200 m²
- Present surface ≈ 42’300 m²
- New surface ≈ 55’300 m²
Typical view of the infrastructure needs
Space needed for cable trays

UR:

Size of cable trays (AC and signal):
600/60 mm. Distance between: 250mm
Constraints: Cable trays must be accessible for additional cables.

UA:
General view
Thank you for your attention

Special Thanks to all HL-LHC WP Leaders for their contribution
### Main HiLumi-LHC Magnet Features

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Field/Gradient (T) / (T/m)</th>
<th>Aperture (mm)</th>
<th>Origin Design</th>
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<tbody>
<tr>
<td>Q1, Q3 Q2a, Q2b</td>
<td>Single aperture</td>
<td>Nb$_3$Sn</td>
<td>132.6 T/m</td>
<td>150</td>
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<tr>
<td>D1</td>
<td>Single aperture</td>
<td>Nb-Ti</td>
<td>6.5 T</td>
<td>150</td>
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<tr>
<td>D2</td>
<td>Twin aperture</td>
<td>Nb-Ti</td>
<td>4.5 T</td>
<td>105</td>
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<td>Q4</td>
<td>Two-in-one aperture</td>
<td>Nb-Ti</td>
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<td>DS 11T</td>
<td>Two-in-one aperture</td>
<td>Nb$_3$Sn</td>
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<td>60</td>
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