HL- LHC High-Luminosity LHC

The LHC upgrade ¶

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Portuguese Industry @ CERN, September 2019
The HL-LHC Project

What, when, where, by whom?
LHC; the largest scientific instrument

- 27 km, p-p at 7+7 TeV (6.5+6.5 in 2018)
- 1232 x 15 m Twin Dipoles SC Magnets
- Operational field 8.3 T @11.85 kA (7.7 T in 2018)
- HEII cooling, 1.9 K with 3 km circuits (130 tonnes He inventory).
- Other 500 SC magnets (quads) and nearly 8000 SC corrector magnets.
- 400 MHz Standing wave RF
- Cryo : 8 x 18 kW@4.5K
- And so much more
LHC is at 93% of the design energy (now planned for 2021-23)
LHC is 20% above planned luminosity (number of collisions)
Goal of High Luminosity LHC (HL-LHC) as fixed in November 2010

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 $250 \text{fb}^{-1}$ 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.

**Ultimate** performance established 2015-2016: with same hardware and same beam parameters: use of engineering margins:

$L_{\text{peak ult}} \approx 7.5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$ and **Ultimate Integrated** $L_{\text{int ult}} \approx 4000 \text{fb}^{-1}$

LHC should not be the limit, would Physics require more...
More luminosity $\Rightarrow$ higher the collision rate

Higgs: the needle in the haystack

Picture repeated 40 millions times each second

$Z \rightarrow \mu\mu$ event from 2012 data with 25 reconstructed vertices
The largest HEP accelerator in construction

Dispersio

ns Supp

essor (DS) in P7

Matching Section (MS)

Interaction Region (ITR)

Modifications
1. In IP2: new DS collim. in C.Cryost.
2. In IP7 new DS collimation with 11 T

Cryogenics, Protection, Interface, Vacuum, Diagnostics, Inj/Extr… extension of infrastr.

Change/new lay-out
1. TAXN
2. D2
3. CC
4. Q4
5. Correctors
6. Q5
7. Q5@1.9K in P6
8. New collimators

Complete change and new lay-out
1. TAXS
2. Q1-Q2a-Q2b-Q3
3. D1
4. All Correctors Magnets
5. Heavy shielding (W)

> 1.2 km of LHC !!
Surface infrastructures
Underground infrastructures
Project structure

WP17 subWPs:
- Civil Works
- Electrical Engineering
- Cooling & Ventilation
- Access & Alarms
- Tech Monitoring
- Transport
- Logistics & Storage
- Operational Safety
High Luminosity: a luminous future for LHC!

LHC / HL-LHC Plan

Today: Half way through

- **Run 1**
  - 2011: LS1
  - 2012: splice consolidation button collimators R2E project
  - 2013: experiment beam pipes
  - 2014: 75% nominal luminosity

- **Run 2**
  - 2019: 13 TeV
  - 2020: EYETS
  - 2021: 2022: 2023: 2 x nominal luminosity

- **Run 3**
  - 2024: 2025: 2026: 2027: 2.5 x nominal luminosity

- **Run 4-5**
  - 2028: 14 TeV
  - 2029: 2030: 2031: 2032: 5 to 7 x nominal luminosity

- **FP7 Hi-Lumi**
  - DESIGN STUDY

- **PDR PREPARATION**

- **ASSESS & TDR**

- **MAIN ACCELERATOR COMPONENTS**
  - CONSTRUCTION AND TEST
  - INSTALLATION

- **MAJOR CIVIL WORKS**

- **TECHNICAL INFRASTRUCTURE**

- **PHYSICS**

- **30 fb⁻¹**

- **150 fb⁻¹**

- **300 fb⁻¹**

- **3000 fb⁻¹**

- **11**
Global collaboration
Technology

Landmarks
Technology landmarks

CIVIL ENGINEERING
2 new caverns and two new 300-metre service galleries, two new large shafts; 10 new technical buildings on surface in P1 and P5 (ATLAS and CMS)

CRYOGENICS
2 new large 1.9 K helium refrigerators for HL-LHC near ATLAS and CMS

“CRAB” CAVITIES
9 superconducting “crab” cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.

FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.

BENDING MAGNETS
2 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.

COLLIMATORS
16 to 26 new collimators and 60 replacement collimators to reinforce machine protection.

SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service galleries to the LHC tunnel.
New Magnet Technology in Nb$_3$Sn: an 11 T dipole replacing an 8.3 T LHC dipole in 2020

**11T Nb$_3$Sn**

LBH\_A (11T)  
By-pass cryostat with collimator

LBH\_B (11T)
IT quadrupole. Increase in field but also in size wrt LHC. Very relevant also for FCC magnets.
New generation of Magnets (~130)

**IT Quads**

- **D1**
- **D2**

**MCB XF**

- **Skew quad**
- **Octupole**
- **Decapole**
- **Dodecapole**

**D2 orbit corrector**
Crab Cavity

CERN DQW prototype for SPS test Collaboration with UNILANC & STFC - C.I. Daresbury (UK)
The DQW CC in cryomodule for the SPS test
Collimators low-Z : special MoGR Mo-coated upgrade partly in 2020 and then in 2025

Samples of MoGr (Molybdenum-Graphite) from producer (CERN EN/MME/STI)

Cold-Warm-Cold bypass to host Collimators in the DS region

New injection protection absorber

In total some 40 new absorber and collimators devices in LS2 (2020) and LS3 (2025)
SC Links inside flexible cryostat: first 60 m long prototype 20 kA cable tested at CERN

First long length of 20 kA MgB₂ cable (IT Quad circuit)

Demo 1
No current degradation; thermal contraction and thermal loss management successful!
Industry

Procurement for HL-LHC
COST: 950 MCHF for materials slightly less than 2000 Staff-year
How we are doing? (Plan versus Actual)

[Graph showing the comparison between Plan (PV), PV Trend (Baseline 2.7.0), Actual (AC), and Estimated (EV) with time from Jan-2015 to Jan-2027. The graph plots kCHF on the y-axis and time on the x-axis.]
On track for all WPs
The HL-LHC Project
Main components, technical services and infrastructure
Tendering on-going or already open and checking

- MS-4514: Design and Manufacture of high precision 18kA and 14kA (class 0) DC Current Transformers
- MS-4513: Design and Manufacture of high precision 2kA (class 2) DC Current Transformers
- MS-4512: MLI for cryomagnets
- MS-4500: IPOC Digitizers
- Manufacture of Pumping Slot Shields for beam screen (high-precision thin walled beryllium-cooper components)
Still to come as components

- Bladders for the Quadrupoles series production
- Cold-warm Transitions
- Expansion Bellows
- Studs to maintain the absorbers on the beam screens
- Semi-rigid, radio frequency cables
- Laser to be used in the FSI (Frequency Scanning Interferometry)
- Hydrostatic Levelling Sensors and Wire Positioning Sensors
- Manufacturing of the Thermal Shields in Al. for cryomagnets
- VAX Supports – Metallic structures
- Mechanical Switches for Energy Extraction Systems
- Electronics for beam instrumentation
- Overhead cranes for P1 and P5 (25t and 20t capacity)
- D2 magnet components (wedges, end spacers, Al ring)
- Service modules for magnets cryostats
- 1 Vacuum vessel for RFD prototype
- Faraday Cage for RF services
- …and of course we will always need raw materials, tooling and small hardware…
Still to come as service contracts or material/installation….

- Service contract for Q2 magnet production
- Service contract for cryostating and cold mass production
- Cryogenic Plants for P1 and P5 Cooling and ventilation material + installation
- Electrical distribution material + installation
- Access systems material + installation
- Power converters
Industry

Tools to communicate and to get informed
Information must be **dynamic** ...

https://project-hl-lhc-industry.web.cern.ch/
Information must be dynamic ...

- Get in touch with your ILO – He is the key contact between CERN and the Industry of each country
  https://ilo.infn.it/index.php

- HL-LHC ILOs Portal (ILOs only)
  HL-LHC Procurement Plan provided since 2015.
  What’s coming the next (next 18 months. Next revision soon!!!

- CERN Procurement Website
  All MSs & ITs are announced
  (Not only HL)
  https://found.cern.ch/java-ext/found/CFTSearch.do
Our objective

- The High Luminosity project seeks industrial suppliers and collaborations for the current construction phase and make the High Luminosity upgrade.
- CERN aims at fostering R&D collaborations and knowledge exchange also with SMEs, a perfect opportunity to match their capacity with the requirements of HiLumi.
- Understanding our needs is the first step to tender successfully.
- Understanding your capabilities and the know how that could come from industry is the best way to specify equipment that can be built by industry.
- Industrial events are always profitable for both parties.
Ready for the challenge?

Become a CERN supplier to built future accelerators

Visit us on

https://project-hl-lhc-industry.web.cern.ch
Thank you for your attention

Special Thanks to all HL-LHC WP Leaders