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.
LS 1 from 16th Feb. 2013 to Dec. 2014

- LHC
- SPS
- PS
- PS Booster

Beam to beam available for works:
- Physics
- Beam commissioning

- Shutdown
- Powering tests

2013
- F
- M
- A
- M
- J
- J
- A
- S
- O
- N
- D
- J
- F
- M
- A

2014
- J
- J
- A
- S
- O
- N
- D
- J
- F
- M
- A

2015
- F
- M
- A
- M
- J
- J
- A
- S
- O
- N
- D
- J
- F
- M
- A

17th Nov.

The main 2013-14 LHC consolidations

1. 1695 Openings and final reclosures of the interconnections
2. Complete reconstruction of 3000 of these splices
3. Consolidation of the 10170 13kA splices, installing 27000 shunts
4. Installation of 5000 consolidated electrical insulation systems
5. 300 000 electrical resistance measurements
6. 10170 orbital welding of stainless steel lines
7. 18 000 electrical Quality Assurance tests
8. 10170 leak tightness tests
9. 3 quadrupole magnets to be replaced
10. 15 dipole magnets to be replaced
11. Installation of 612 pressure relief devices to bring the total to 1344
12. Consolidation of the 13 kA circuits in the 16 main electrical feedboxes
Closure Nb1695
the last one!
18th June 2014

NTUA (GR), HNINP, WUT (PL), JINR (Dubna)
Cool-down of LHC sectors

Arc-magnet average temperature [K]

Time

Sector 12
Sector 23
Sector 34
Sector 45
Sector 56
Sector 67
Sector 78
Sector 81

Slow-down during weekends

CSCM

ITR8 intervention
**LHC schedule V4.1**

Safety First, Quality Second, Schedule Third

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st beam (March 2015)</td>
<td>Check-out, Beam Commissioning, Physics</td>
</tr>
<tr>
<td>Jan</td>
<td></td>
</tr>
</tbody>
</table>
Maximum beam energy : 13 TeV c.m. in 2015

Decision to run at a **maximum** energy of 6.5 TeV per beam during the powering tests and during 2015.
(10 to 15 training quenches per sector are expected to be needed to reach that energy).

“We accept the risk that results from late quench tests could force to run at lower energy”

*Emilio Meschi – LHC physics coordinator*

**NO change of beam energy in 2015.**

A decision regarding the possibility of increasing the energy will be taken later in 2015, based on the experience gained in all eight sectors at 6.5 TeV per beam during powering tests and operation with beams.
LHC goal for 2015 and for Run 2 and 3

Priorities for the 2015 run:
- Establish proton-proton collision at 13 TeV with 25ns and low $\beta^*$ to prepare production run in 2016.
  Optimisation of physics-to-physics duration
- Later in 2015: decision on special runs “when and duration” (90m optics):
  not in the 1st part of the year. Waiting LHCC recommendation
- Pb-Pb run: one month at the end of 2015

The goal for Run 2 luminosity is $1.3 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ and operation with 25 ns bunch spacing (2800 bunches), giving an estimated pile-up of 40 events per bunch crossing.

“A maximum pileup of $\sim50$ is considered to be acceptable for ATLAS and CMS”
LHC / HL-LHC Plan

Plan approved by CERN management upon preparation in HL-LHC Coord Group and RLIUP

See deliverable D1.7 Common LHC time plan

Lumi saturation & Technical bottlenecks:

50 ns bunch pile up ~40

0.75 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

50 \Rightarrow 25 \text{ ns}

1.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7-2.2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7-2.2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

25 \text{ ns bunch pile up} ~45

25 \text{ ns bunch pile up} ~60

50 \Rightarrow 25 \text{ ns}

75\% nominal luminosity

30 fb^{-1}

150 fb^{-1}

300 fb^{-1}

3000 fb^{-1} luminosity

7 TeV

8 TeV

10^{34} \text{ cm}^{-2}\text{s}^{-1}

Run I

Run II

Run III

75\% nominal luminosity

0.75 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

50 \Rightarrow 25 \text{ ns}

1.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7-2.2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7-2.2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

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1.7-2.2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}

1.7-2.2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}
Two important International Reviews

• (May 2013 : Collimation Review)

• International Review of the Crab Cavity (BNL, 5-6 May 2014): Downselect & Prioritization.

• International Review of the MQXF SC Cable (CERN 5-6 November 2014): more margin, finalize optimization & need more Industrialization especially with EU NbSn.

LRossi-LHC Up@9th CERN-KEK committe@KEK
## HL-LHC Baseline Parameters

WP2 charge – PLC webpage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal LHC (design report)</th>
<th>HL-LHC 25ns (standard)</th>
<th>HL-LHC 25 ns (BCMS)</th>
<th>HL-LHC 50ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy in collision [TeV]</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>$N_b$</td>
<td>1.15E+11</td>
<td>2.2E+11</td>
<td>2.2E11</td>
<td>3.5E+11</td>
</tr>
<tr>
<td>$n_b$</td>
<td>2808</td>
<td>2748</td>
<td>2604</td>
<td>1404</td>
</tr>
<tr>
<td>Number of collisions at IP1 and IP5</td>
<td>2808</td>
<td>2736</td>
<td>2592</td>
<td>1404</td>
</tr>
<tr>
<td>$N_{tot}$</td>
<td>3.2E+14</td>
<td>6.0E+14</td>
<td>5.7E+14</td>
<td>4.9E+14</td>
</tr>
<tr>
<td>beam current [A]</td>
<td>0.58</td>
<td>1.09</td>
<td>1.03</td>
<td>0.89</td>
</tr>
<tr>
<td>x-ing angle [μrad]</td>
<td>285</td>
<td>590</td>
<td>590</td>
<td>590</td>
</tr>
<tr>
<td>beam separation [σ]</td>
<td>9.4</td>
<td>12.5</td>
<td>12.5</td>
<td>11.4</td>
</tr>
<tr>
<td>$β^*$ [m]</td>
<td>0.55</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>$ε_n$ [μm]</td>
<td>3.75</td>
<td>2.50</td>
<td>2.50</td>
<td>3</td>
</tr>
<tr>
<td>$ε_L$ [eVs]</td>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r.m.s. bunch length [m]</td>
<td>7.75E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piwinski angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geometric loss factor R0 without crab cavity</td>
<td>0.305</td>
<td></td>
<td>0.305</td>
<td>0.331</td>
</tr>
<tr>
<td>Geometric loss factor R1 with crab cavity</td>
<td>0.829</td>
<td></td>
<td>0.829</td>
<td>0.838</td>
</tr>
<tr>
<td>beam-beam / IP without Crab-cavity</td>
<td>3.1E-03</td>
<td>3.3E-03</td>
<td>3.3E-03</td>
<td>4.7E-03</td>
</tr>
<tr>
<td>beam-beam / IP with Crab-cavity</td>
<td>3.8E-03</td>
<td>1.1E-02</td>
<td>1.1E-02</td>
<td>1.4E-02</td>
</tr>
<tr>
<td>Peak Luminosity without crab-cavity</td>
<td>1.00E+34</td>
<td>7.18E+34</td>
<td>6.80E+34</td>
<td>8.44E+34</td>
</tr>
<tr>
<td>Virtual Luminosity with crab-cavity: $L_{peak}^R1$ [cm$^{-2}$ s$^{-1}$]</td>
<td>(1.18E+34)</td>
<td>19.54E+34</td>
<td>18.52E+34</td>
<td>21.38E+34</td>
</tr>
<tr>
<td>Events / crossing without levelling w/o crab-cavity</td>
<td>27</td>
<td>198</td>
<td>198</td>
<td>454</td>
</tr>
<tr>
<td>Levelled Luminosity [cm$^{-2}$ s$^{-1}$]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Events / crossing (with levelling and crab-cavities)</td>
<td>5.00E+34</td>
<td>138</td>
<td>146</td>
<td>135</td>
</tr>
<tr>
<td>Peak line density of pile up event [evt/mm]</td>
<td>0.21</td>
<td>1.25</td>
<td>1.31</td>
<td>1.20</td>
</tr>
<tr>
<td>Levelling required</td>
<td>8.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency requires long fill times (ca. 11h)!</td>
<td>L.Rossi-LHC Up@9th CERN-KEK committe@KEK</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Collision values

*This makes 250 fb$^{-1}$/y a solid goal*
In-kind contribution and Collaboration for HW design and prototypes

Q1-Q3 : R&D, Design, Prototypes and in-kind USA
D1 : R&D, Design, Prototypes and in-kind JP
MCBX : Design and Prototype ES
HO Correctors: Design and Prototypes IT
Q4 : Design and Prototype FR
Only with $350 \text{ fb}^{-1}/\text{y}$ ($L_{\text{lev}}=7.5 \times 10^{34}$ and some optimism) the goal is reachable.

$L_{\text{lev}}=7.5 \times 10^{34}$
(or lower if $T_{\text{proton}}^{160} \rightarrow 200 \text{ days/y}$)
Int. $L \sim 4000 \text{ fb-1}$
Collaborations

• In addition to the FP7-HiLumi LHC (CERN contracts):
  • CEA (FR) for Q4 Design & proto (also completion Fresca2 technological demo)
  • INFN-Milano (IT): HO Corrector magnets Design and Prototypes
  • INFN-Genova (IT): D2 Design
  • CIEMAT (ES): IT Orbit corrector magnet (nested) desing and prototype
  • UniMan (UK) for collimators
  • UniGE (CH), Uni. Bratislava (SK), Twente Univ. (NL) for Nb3Sn
  • South Hampton U. (UK) under way for SC links

LRossi-LHC Up@9th CERN-KEK
committe@KEK
We need more collaborations

• Russia
• China (proposal made but ...)
• India (proposal starting: TAXS/TAXN?)
• Brazil? Mexico?
• Georgia? (R. Veness)
• More initiative welcome also from Member States Institutions:

• frame: 50%-50% subdivision of the cost.
Status of approval and Budget

- (May 2013 Brussel : approval by Council as EU)
- (June 2013: first construction money for HL-LHC in the CERN MTP)
- In 2014 HiLumi LHC established as 1st US priority by P5, process under way
- June 2014: approval of MTP 2014-2018 with HL-LHC as main CERN project for the next decade.
- **Council has approved MTP 2015-2019 including Design and initial Construction cost and took note favorably of the total CtC to 2025** (with a cut proposed by CERN management of about 10%). This include approximately 740 MCHF.
- We are missing **about 20% (only!)** for the total project wrt to the budgetary evaluation of 2011 (which did not included WP14 and SM18 infrastructure)
- This is a challenge, not a nuisance!
HiLumi Book: a collection of papers in scientific style 20 papers, 300 pages (sorry for the 10 months delay!)
Preliminary Design Report
PDR

V0 end Nov. For EU
V1 January ’15 after CERN ED approval
V2 March 2015 as CERN yellow report
WP3 the magent zoo in the IR

- Triplet QXF (LARP and CERN)
- Orbit corrector (CIEMAT)
- Separation dipole D1 (KEK)
- Skew corrector (INFN)
- Recombination dipole D2 (INFN design)
- Q4 (CEA)
- Corrector sextupole (INFN)
- Corrector octupole (INFN)
- Corrector decapole (INFN)
- Cross-sections in scale LRos
TRIPLET AND DIPOLES

• Triplet
  • First dummy and Nb$_3$Sn coils manufactured in US and at CERN
  • Cable review done, design in December 2014
  • First quadrupole test in 2015

• Separation dipole D1
  • First Nb-Ti coils being manufactured
  • First test in 2015

• Recombination dipole D2
  • Cross-section defined
  • Mechanical structure in progress

QXF coil wound in US
[G.Ambrosio et al., ASC 2014]

D2 collaring [P. Fabbricatore, S. Farinon]

D1 winding at KEK [T. Nakamoto, et al., ASC 2014]
Dressed cavity designs are almost complete. This includes the cavity, tuner, couplers, magnetic shielding and the LHe vessel.
CC SPS tests

On schedule for install the first cryomodule at the end of 2016 and test in in SPS in 2017 and 2018.
Record in MgB$_2$ SC Line

Demonstration of possibility of transferring high-current in MgB$_2$ cables from round wire
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.

L = 20 m
(25×2) 1 kA @ 25 K, LHC Link P7
Performance of a-C coated Beam Screen

• Photon stimulated desorption at RT of a-C coating at KEK Photon Factory \( (E_c = 4 \text{ keV}) \)

• COLDEX equipped with a-C coated beam screen held at 50 K

~2.2 m, ID 67 beam screen
Internally coated with amorphous carbon

• Tests with LHC type beams in SPS (3-9/11/2014):
  • Heat load < 1 W/m
  • Pressure rise < 10^{-8} \text{ mbar} (mainly H}_2\text{)

• 2015: continue characterisation at cryogenic temperature of a-C coating in the laboratory and with COLDEX
Cost & Schedule Review - Scope

- HL-LHC and LIU projects
- taking into consideration how these are linked to the consolidation project and the operation of the CERN accelerator complex
- Assess the status of the project development taking into account the technical developments that are still ongoing
- Assess the project baseline (not technical – RLIUP), i.e.
  - Project Scope
  - Schedule
  - Cost
  And
  - Project Management Methods
  - Risks
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