HL-LHC Progress

Lucio Rossi – CERN Accelerator & Technology Sector
HL-LHC Project Leader

CERN-KEK committee, KEK, 18 November 2019
KEK for CERN LHC Project

現地（CERN）での写真
ATLAS検出部
強収束4極マグネット

強収束4極マグネット
Signatures for HiLumi LHC – 5 July 2018
Half way passed
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 $L_{\text{int ult}} \sim 4000 \text{ fb}^{-1}$

LHC should not be the limit, would Physics require more...

Experiment are designing for this goal. We need to be compatible with it!

Project approved by CERN Council in June 2016
HL-LHC performance (ultimate $L_{\text{lev}}$ from 2032)

Design goal

O. Bruning, M. Lamont, L. Rossi
HiLumi: a global project since the start

B. Di Girolamo talk on collaboration with in-kind.
Luminosity: collision rate per unit cross section which parameters count for LHC?

\[ L = \gamma \frac{f_{rev} n_b N_b^2}{4\pi \epsilon_n \beta^*} \]

\[ R = \frac{1}{\sqrt{1 + \left(\frac{\theta_c \sigma_s}{2\epsilon_n \beta^* \gamma}\right)^2}} \]
Integration much advanced and detailed (DFBH/Disconnectors last piece of the puzzle)

All SMRs (change of C.E. layouts) treated to 90% - only a few buildings TBD. Very moderate extra-cost (consider the 2015 decision of advancing C.E.!)
Collaborations “Tunnel view” the IT zone

Connection to LHC (UL)
Service gallery (UR)
SC Links
Surface Works at Point 1

- SD17 Head Shaft Building
- SHM17 Compressor Building
- SF17 Cooling Towers
- Earth Platform (excavation spoils)
- SHE17 Helium Tank Platform
- SHE17 Helium Tank Platform
- SE17 Electrical Building
- SU17 Ventilation Building
- Harmonic Filter Slab
- Spoil Platform
Overall excavation ≈ 76%

Excavation Progress:
UR15: ≈ 276m of 300m
UA17: ≈ 70m of 70m
UPR17: ≈ 17m of 29m
UL17: ≈ 28m of 50m

Precast Invert Progress:
UR15 invert: ≈ 50m of 300m
No accelerator project has so many absolute novelties and in such a broad technology spectrum.
And HiLumi HF magnets magnets follows!

\[ B_p \approx 13 \text{ T no quench!} \]

**11T dipole full length**

**IT QUAD 1 m long**
Real Nb3Sn magnets are coming... first time in an accelerator... and not the smallest one!

11 T dipole

IT QUAD Q2a/Q2b

IT QUAD Q1/Q3
And more technology novelties...

- Canted Cosine Theta – CCT
  For D2 (Dual) orbit correctors
  CERN-IHEP Beijing

- D1 large aperture – KEK

- D2 INFN-Genova
  Asymmetric coils

- Super Ferric magnets for single large aperture HO Correctors
  INFN-LASA-Milan

- NESTED (H-V) large aperture orbit corrector – CIEMAT - Madrid
First system test in March 2019
MgB$_2$ 60m-2×18kA @ 25 K
2×18kA REBCO Cable @ 50 K
Crab Cavity: another “Prima”, full steam ahead

First use in proton (colliders!)
10 fs accuracy on control (crab + perfect anticrab 400 m away)
First use of SSPA in colliders (pp!)
First time compact crab cavity (40% smaller than elliptical of elliptical)

Modification of SPS-type cold magnetic shields to HL-LHC completed by UK
Many other CM design are jointly being finalized

HL-LHC cryomodule conceptual design completed, important changes from SPS beam test experience
## Crab Cavity Series (CERN, Canada, Russia, UK, US-AUP)

<table>
<thead>
<tr>
<th>DQW cryomodules (5)</th>
<th>RFD cryomodules (5)</th>
<th>Solid State RF Systems (20)</th>
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</thead>
<tbody>
<tr>
<td>- Cavities + processing + helium vessels by Research Instruments (DE) under CERN</td>
<td>- Bare cavities by Zanon (IT) under US-AUP</td>
<td>- High power solid state amplifiers by BINP-Russia</td>
</tr>
<tr>
<td>- Cold magnetic shields by UK</td>
<td>- Processing + cold magnetic shield + helium vessel + HOM couplers + antennas + cold tests by US-AUP</td>
<td>- First step, one amplifier prototype for qualification of SSPA technology</td>
</tr>
<tr>
<td>- HOM couplers + antennas by MEPHI-Russia &amp; CERN</td>
<td>- 4 CM by UK (STFC) &amp; 1 CM at CERN with some components by CERN</td>
<td>- 5 CM by TRIUMF-Canada with some components by CERN</td>
</tr>
<tr>
<td>- 4 CM by UK (STFC) &amp; 1 CM at CERN with some components by CERN</td>
<td>- All cavities &amp; CM cold validation tests at CERN (and a few at Uppsala-Sweden)</td>
<td>- CM cold validation tests at CERN</td>
</tr>
</tbody>
</table>
Collimator and Injection devices
First time low impedance collimators!
Progress and optimization across all project-1

WP9: First 3-D integrated model IT cryoline
Increased "H" to provide cold quench buffer for triplets
Reduced "B" as not impacting pressure drop
Verifying jumper/piping interfaces with all users while progressing now in service galleries

WP8: TAN: first HL-LHC equipment in LHC

WP10: optimizing TAXN length and improving shielding

WP12: Beam Screen quench test, BS inspection mole

2kA Energy Extraction Systems preseries WP7

WP7 Final CLIQ unit

Lucio

HiLumi LHC Progress - CERN - KEK ST.COM., KEK 18 Nov 2019
First use of Frequency Scanning Interferometry (FSI): sub-µm accuracy of COLD MASS

A leap forward for alignment of all cold machines
Budget HL-LHC at 4th Cost & Schedule Review

Baseline 2.10:
+ 19 MCHF, as balance between change of scope and (projected) extra-cost. (see B. Delille and ALSO see WPs presentations).

3 new equipment: Baseline 3.0
Approved by ED but exposed here for your C&SR assessment (60% in-kind from Russia): + 20 MCHF

HL-LHC; nearly 300 MCHF spent; > 500 MCHF (>HALF) committed.

Residual cost risk is about 50 MCHF

Cost-to-Completion
950 MCHF C&SR1
950 MCHF C&SR2
950 MCHF C&SR3
969 MCHF C&SR4 baseline 2.10
989 MCHF C&SR4 baseline 3.0
(136 MCHF in-kind, 20% of equip.)
100 MCHF HL-CONS,
~ 2000 FTE-y of CERN staff

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Critical path

We accumulated small delays, well within margin; we have still > 1 year margin.

However a first analysis, shows that 2.5 year is difficult goal, probably 3 year LS3 is more realistic.

For LS2: the critical is 11 T dipole (but in case we install half of them)

Not surprising are IT Quad in Nb₃Sn! And then CC.
Thanks