KEK-JAPAN

High Luminosity LHC

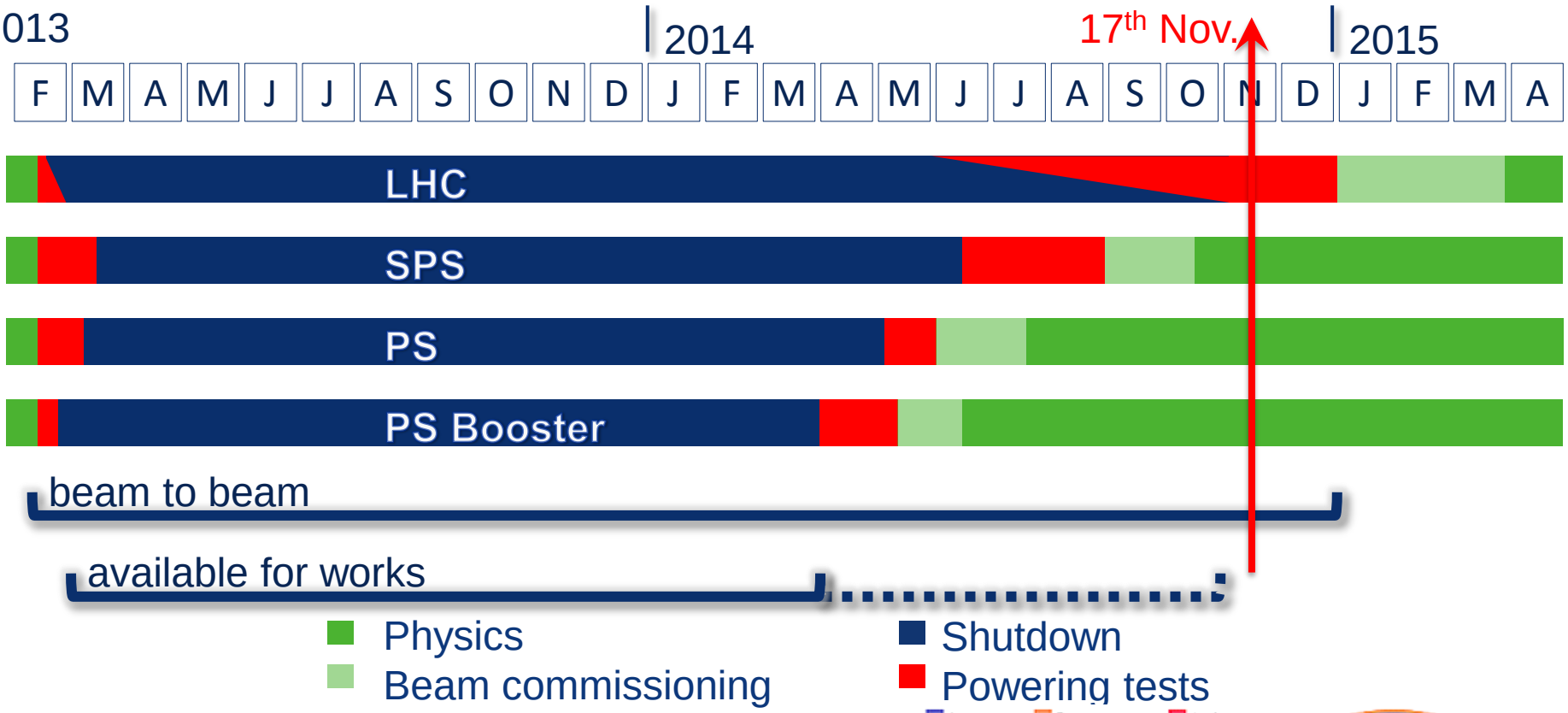
LHC Upgrade

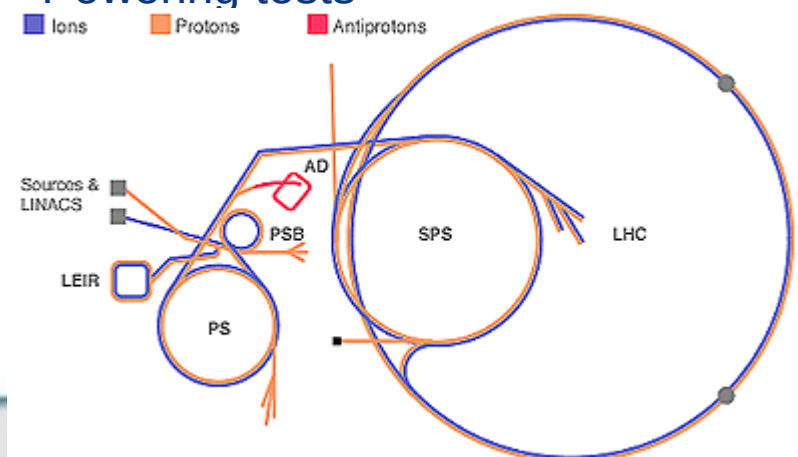
Lucio Rossi – CERN
HL-LHC project leader

talk to 9th CERN-KEK committee
21 November 2014 @ KEK

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





High Luminosity LHC

The main 2013-14 LHC consolidations

1695 Openings and final reclosures of the interconnections

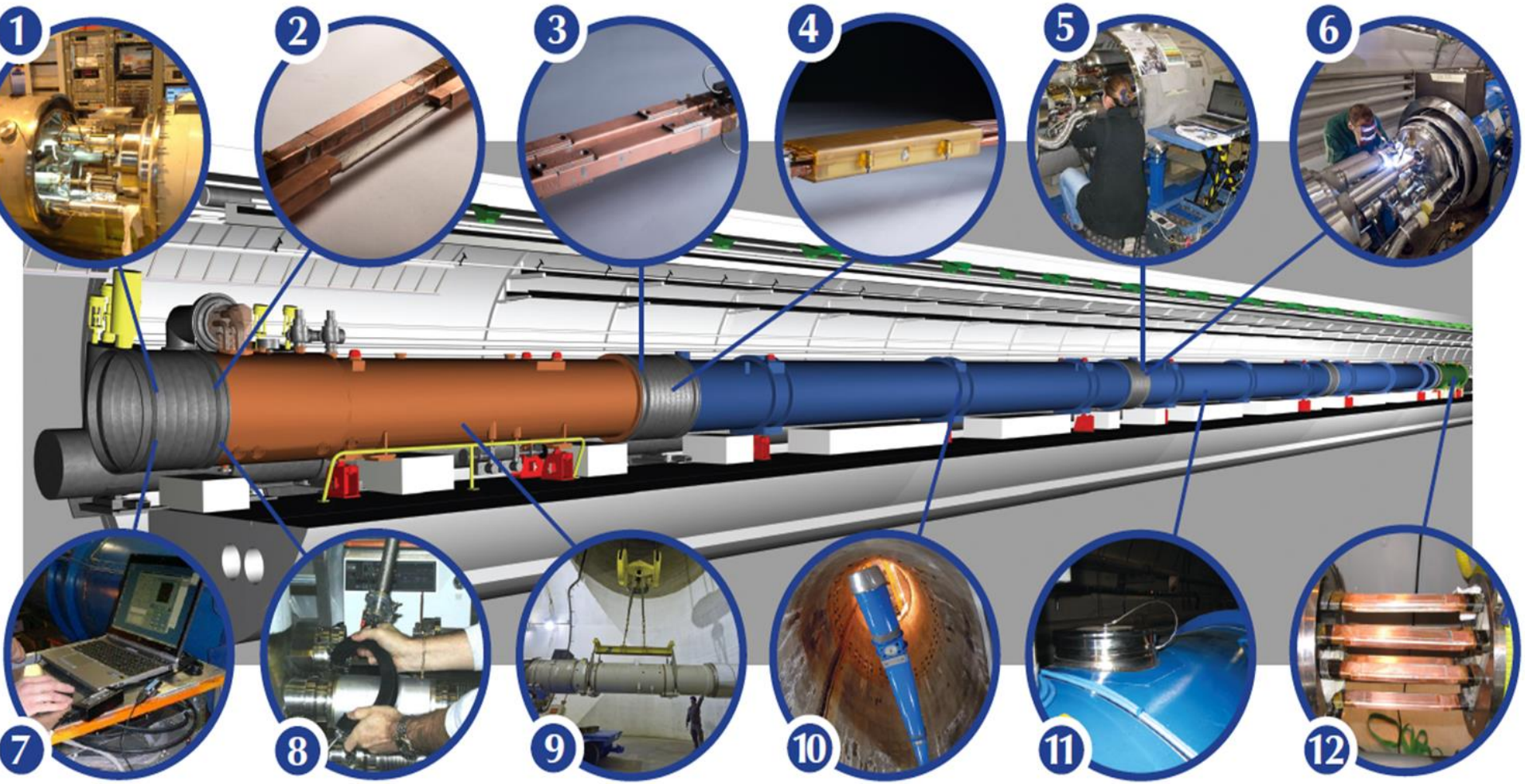
Complete reconstruction of 3000 of these splices

Consolidation of the 10170 13kA splices, installing 27 000 shunts

Installation of 5000 consolidated electrical insulation systems

300 000 electrical resistance measurements

10170 orbital welding of stainless steel lines



18 000 electrical Quality Assurance tests

10170 leak tightness tests

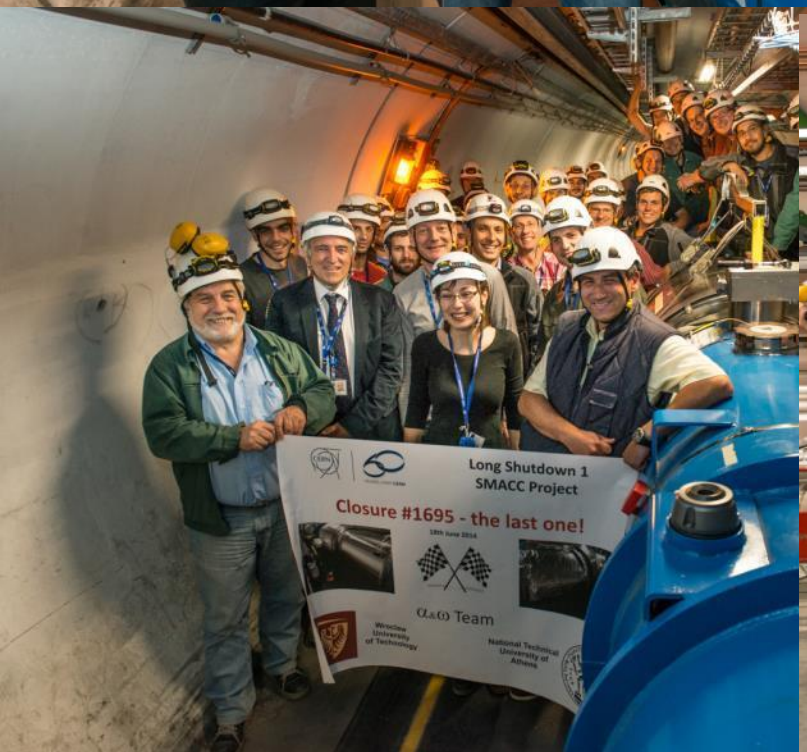
3 quadrupole magnets to be replaced

15 dipole magnets to be replaced

Installation of 612 pressure relief devices to bring the total to 1344

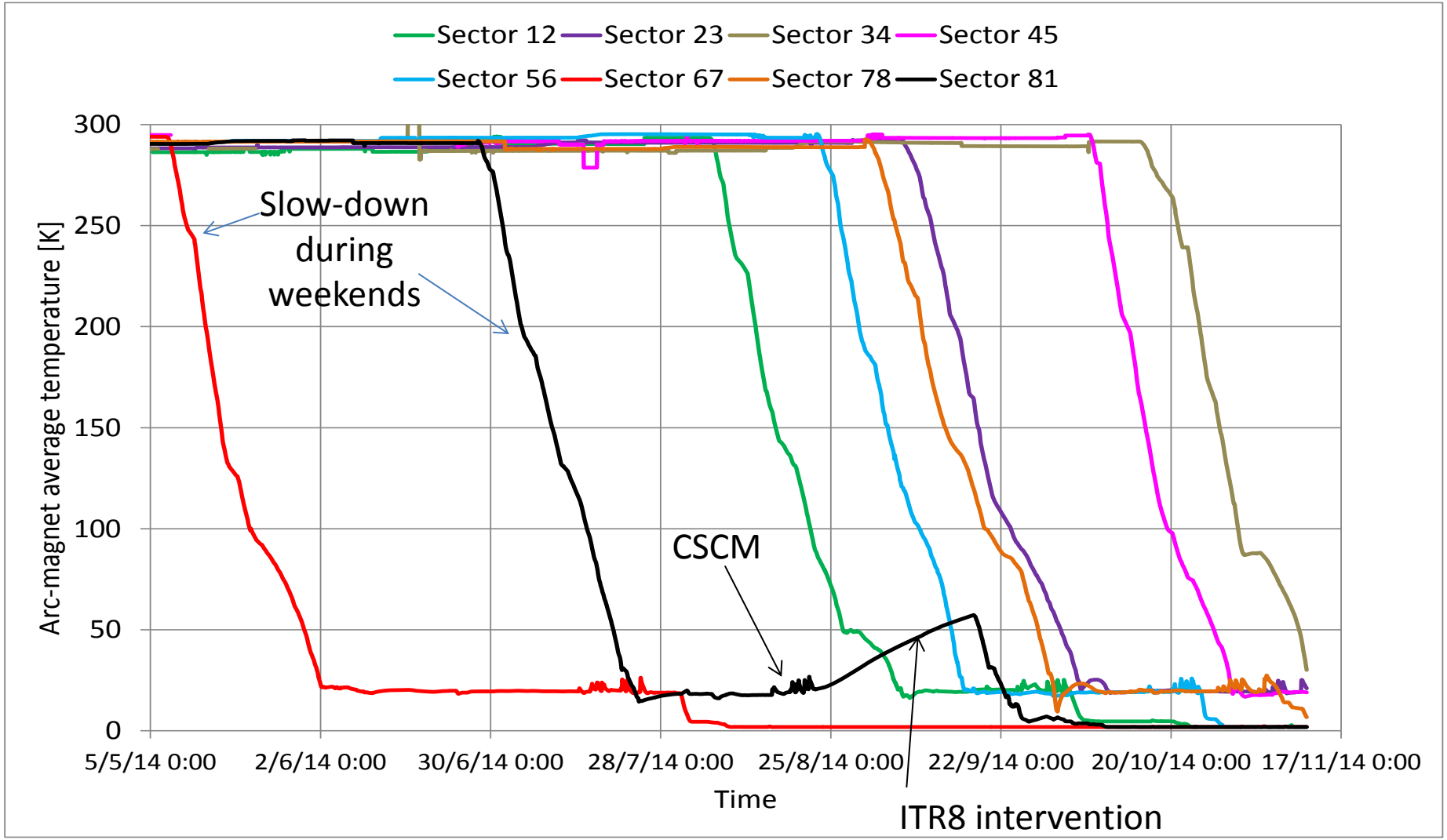
Consolidation of the 13 kA circuits in the 16 main electrical feed-boxes

Closure Nb1695 the last one! 18th June 2014



NTUA (GR), HNINP, WUT (PL), JINR (Dubna)

Cool-down of LHC sectors

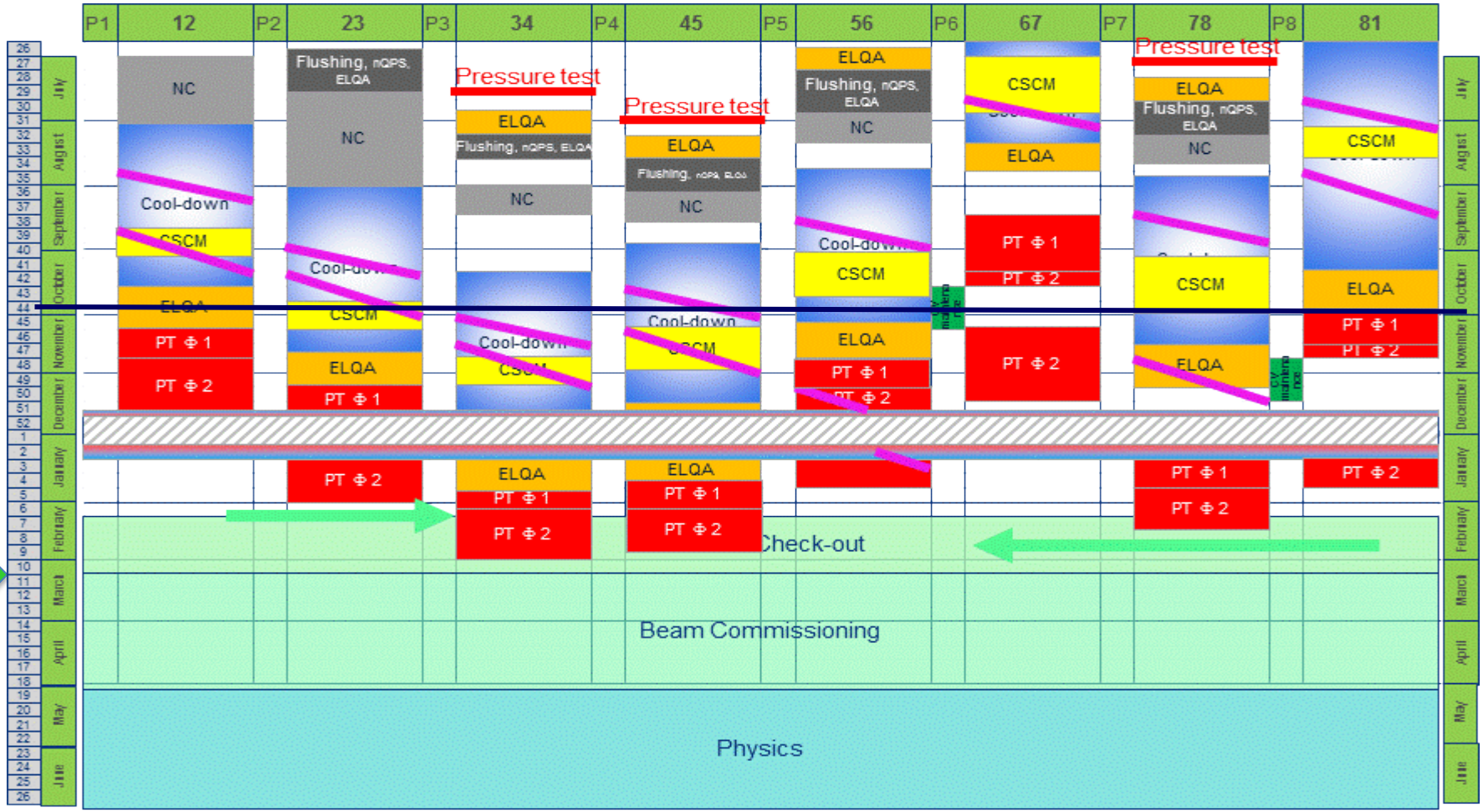


High Luminosity LHC

Courtesy of Laurent Tavian

LHC schedule V4.1

Safety First,
Quality Second,
Schedule Third



1st beam (March 2015)

High Luminosity LHC

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.

High Luminosity LHC

LHC goal for **2015 and for Run 2 and 3**

Priorities for the 2015 run :

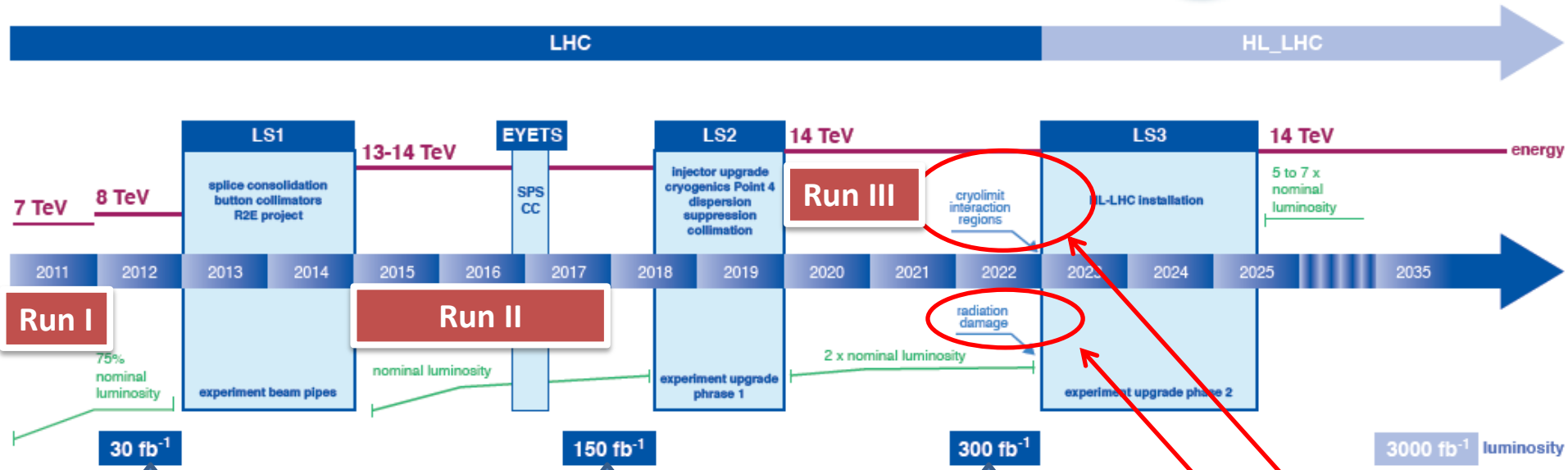
- **Establish proton-proton collision at 13 TeV with 25ns and *low* β^* to prepare production run in 2016.**
  Optimisation of physics-to-physics duration
- **Later in 2015: decision on special runs "when and duration" (90m optics): not in the 1st part of the year. Waiting LHCC recommendation**
- **Pb-Pb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

The goal for Run 2 luminosity is 1.3 x 10^{34} cm^{-2} 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 ~50 is considered to be acceptable for ATLAS and CMS"

High Luminosity LHC

LHC / HL-LHC Plan



0.75 10^{34} $cm^{-2}s^{-1}$
50 ns bunch
high pile up ~40

1.7 10^{34} $cm^{-2}s^{-1}$
25 ns bunch
pile up ~45

1.7-2.2 10^{34} $cm^{-2}s^{-1}$
25 ns bunch
pile up ~60

50 ⇒ 25 ns

Lumi saturation & Technical bottlenecks:

Plan approved by CERN management upon preparation in HL-LHC Coord Group and RLIUP
See deliverable D1.7 Common LHC time plan

Two important International Reviews

- (May 2013 : Collimation Re
- International Review of the
  5-6 May 2014): Downselect
  SPS TEST!
- International Review of the
  (CERN 5-6 November 2014
  finalize optimization & nee
  Industrialization especially

HL-LHC Baseline Parameters
WP2 charge – PLC webpage

$$L = \gamma \frac{f_{rev}\, n_b\, N_b^{\,2}}{4\pi \varepsilon_n \beta^*} R$$

Parameter	Nominal LHC (design report)	HL-LHC 25ns (standard)	HL-LHC 25 ns (BCMS)	HL-LHC 50ns
Beam energy in collision [TeV]	7	**7**	7	7
N_b	1.15E+11	**2.2E+11**	2.2E11	3.5E+11
n_b	2808	**2748**[1]	2604	1404
Number of collisions at IP1 and IP5	2808	**2736**	2592	1404
N_{tot}	3.2E+14	**6.0E+14**	5.7E+14	4.9E+14
beam current [A]	0.58	**1.09**	1.03	0.89
x-ing angle [μrad]	285	**590**	590	590
beam separation [σ]	9.4	**12.5**	12.5	11.4
β^* [m]	0.55	**0.15**	0.15	0.15
ε_n [μm]	3.75	**2.50**		3
ε_L [eVs]	2.50			2.50
r.m.s. bunch length [m]	[illegible]		[illegible]	7.55E-02
Piwinski angle			3.14	2.87
Geometric loss factor R0 without crab	[illegible]	**0.305**	0.305	0.331
Geometric loss factor R1 with cr[illegible]	[illegible]0.981)	**0.829**	**0.829**	**0.838**
beam-beam / IP without [illegible]	3.1E-03	**3.3E-03**	3.3E-03	4.7E-03
beam-beam / IP with Cra[illegible]	3.8E-03	**1.1E-02**	1.1E-02	1.4E-02
Peak Luminosity without [illegible] cavity [$cm^{-2}\,s^{-1}$]	1.00E+34	**7.18E+34**	6.80E+34	8.44E+34
Virtual Luminosity with crab-cavity: Lpeak*R1/R0 [$cm^{-2}\,s^{-1}$]	(1.18E+34)	**19.54E+34**	18.52E+34	21.38E+34
Events / crossing without levelling w/o crab-cavity	27	**198**	198	454
Levelled Luminosity [$cm^{-2}\,s^{-1}$]		**5.00E+34**	5.00E34	2.50E+34
Events / crossing (with levelling and crab-cavities f[illegible]		**138**	146	135
Peak line d[illegible]		**1.25**	1.31	1.20
Levelling ti[illegible]		**8.3**	7.6	18.0

Collision values

LIU required

Impedance, efficiency etc.

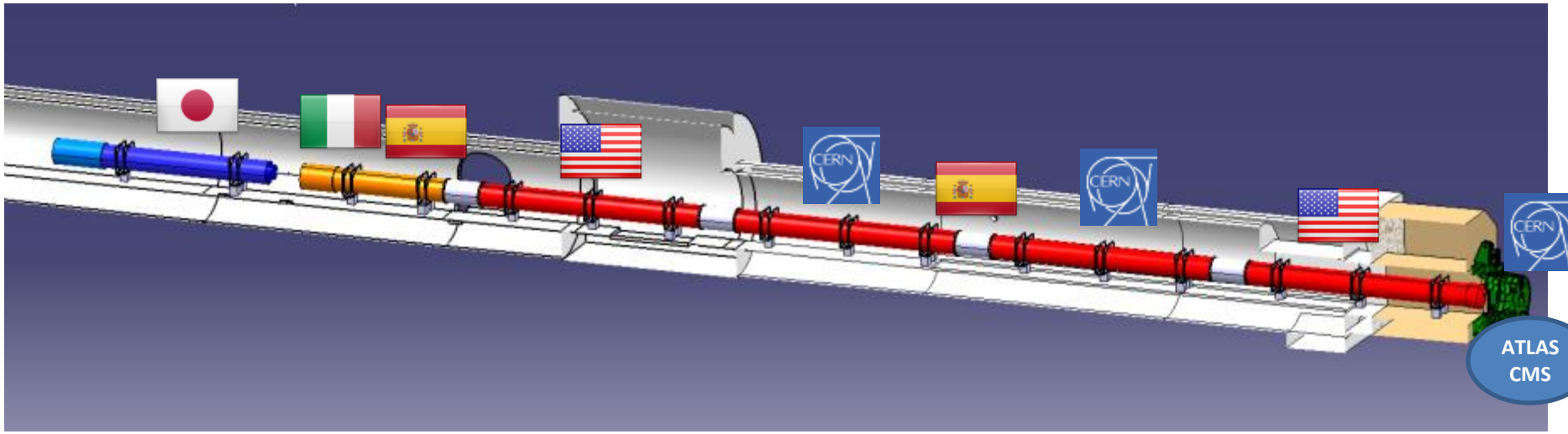
New IT Quads & ATS

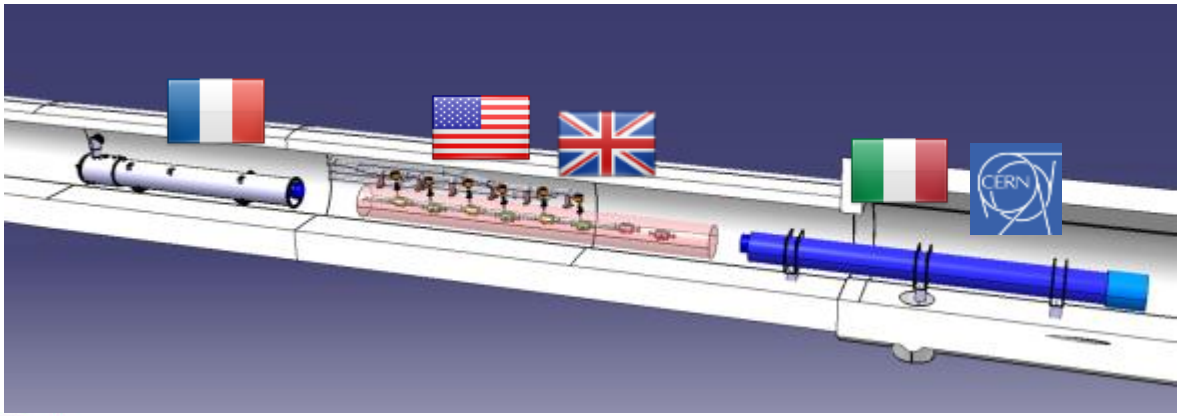
Levelling required

Efficiency requires long fill times (ca. 10h)!

This makes 250 fb^{-1}/y a solid goal

In-kind contribution and Collaboration for HW design and prototypes



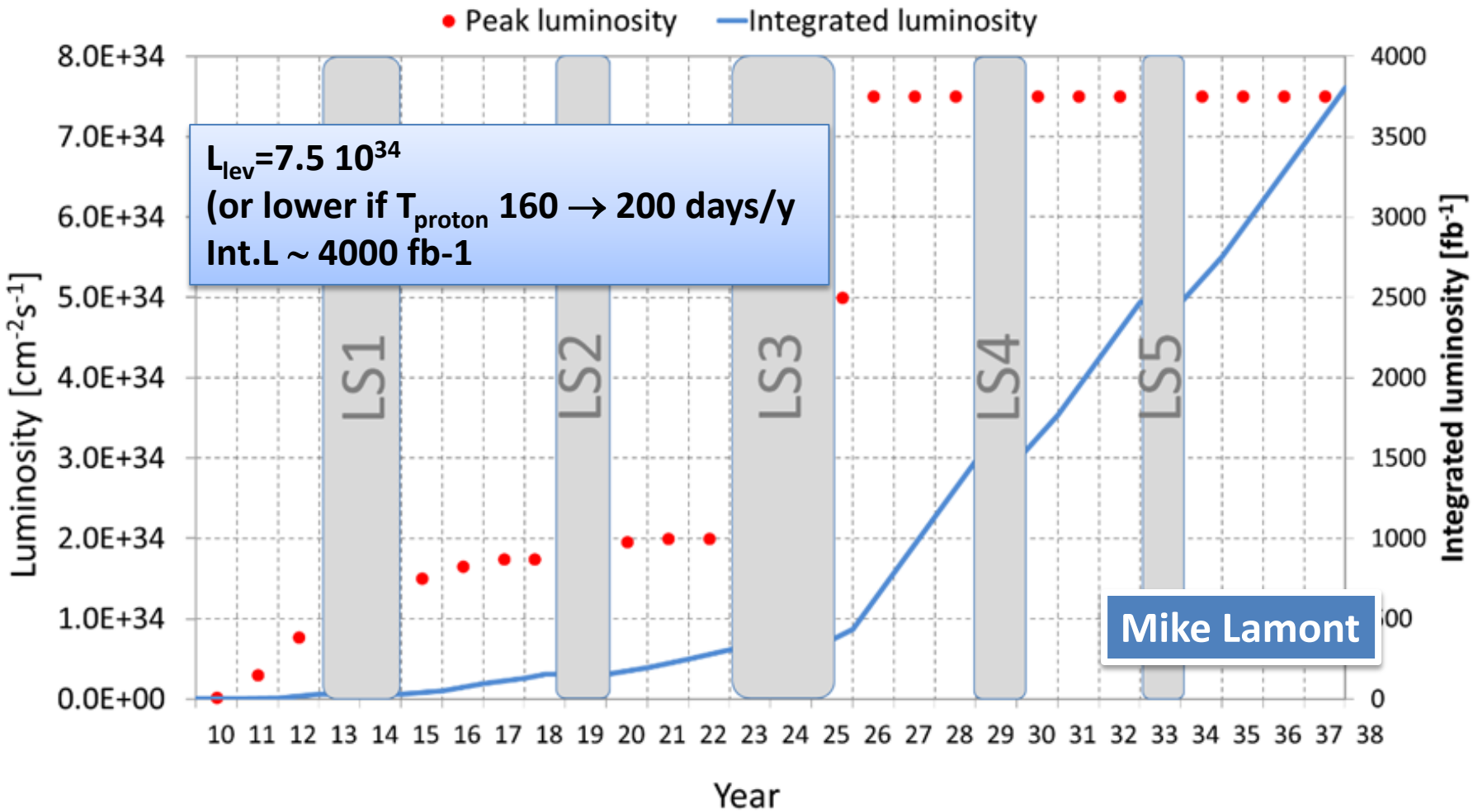


CC : R&D, Design and in-kind **USA**

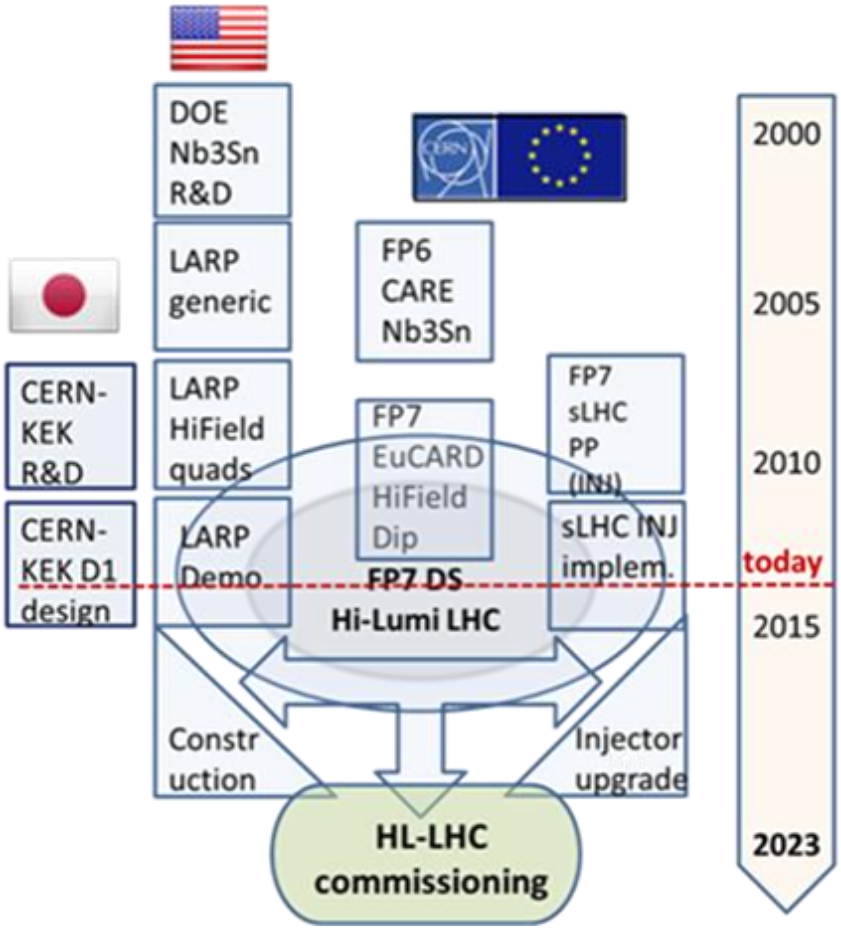
CC : R&D and Design **UK**

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 fb^{-1}/y (L_{lev}=7.5 10^{34} and some optimism) the goal is reachable



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

We need more collaborations

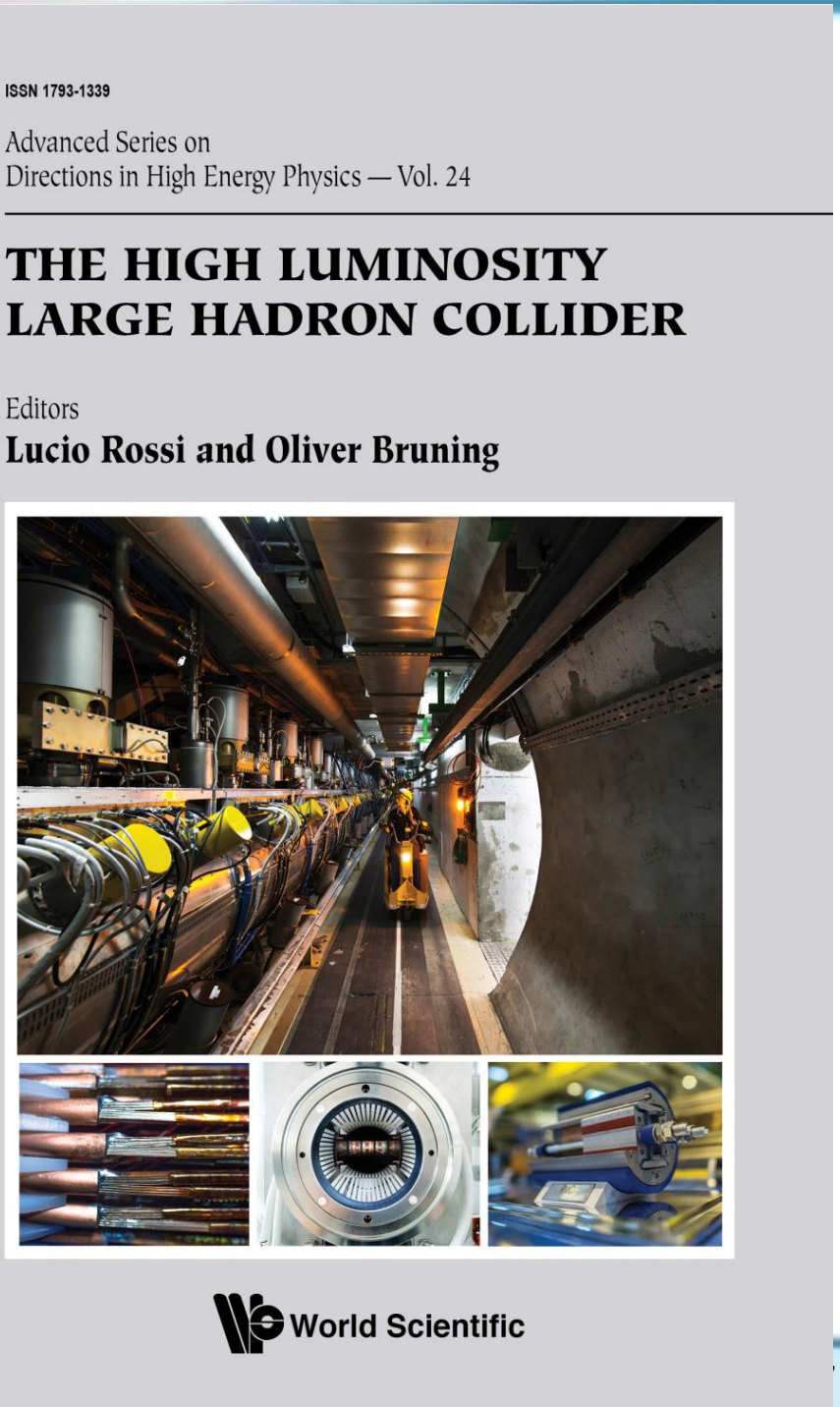
- Russia
- China (proposal made but …)
- India (proposal starting: TAXS/TAXN?)
- Brazil? Mexico?
- G[illegible]ness)
- More initiative welcome also from Member States Institutions:
- frame: 50%-50% subdivision of the cost.

Time to think beyond FP7 Hilumi governance.

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 inclede approc^xiamtely 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

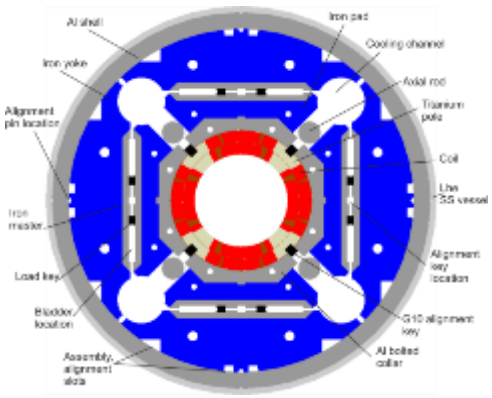
V0 end Nov. For EU
V1 January ’15 after CERN ED approval
V2 March 2015 as CERN yellow report

HL–LHC PRELIMINARY DESIGN REPORT

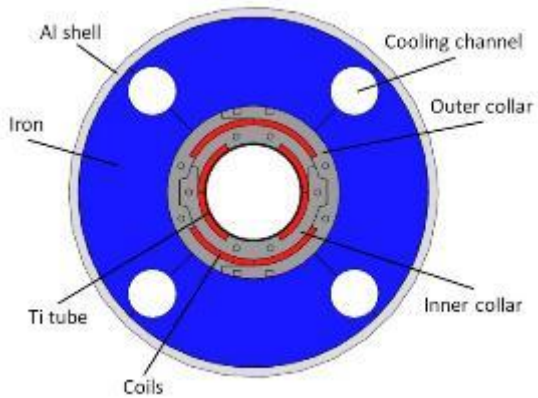
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

WP3 the magent zoo in the IR

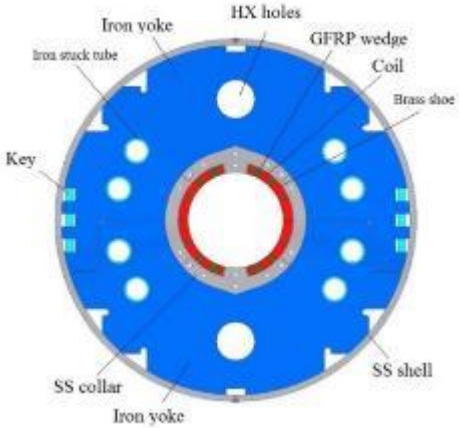
Ezio Todesco



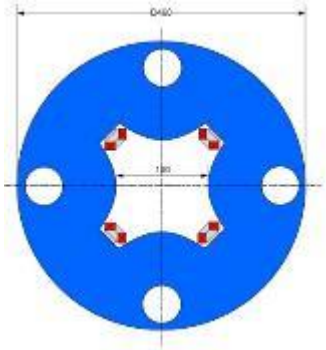
Triplet QXF (LARP and CERN)



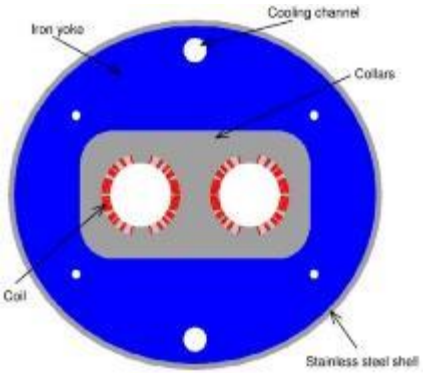
Orbit corrector (CIEMAT)



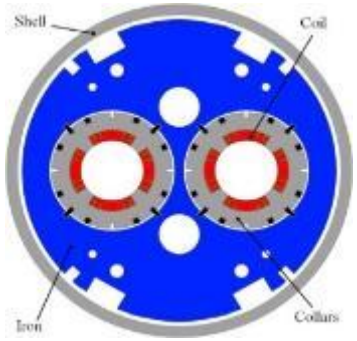
Separation dipole D1 (KEK)



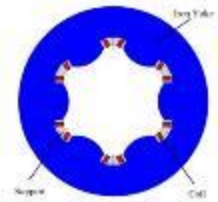
Skew corrector (INFN)



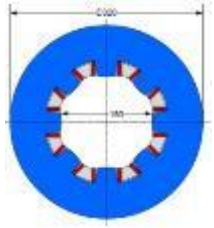
Recombination dipole D2
(INFN design)



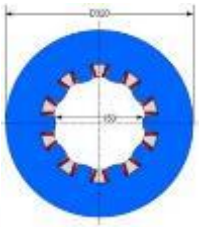
Q4 (CEA)



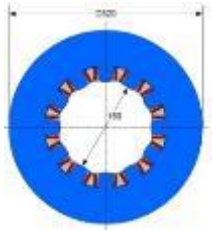
Corrector sextupole (INFN)



Corrector octupole (INFN)



Corrector decapole (INFN)



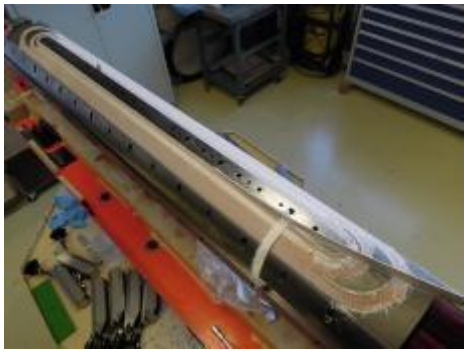
Corrector dodecapole (INFN)

Cross-sections in scale

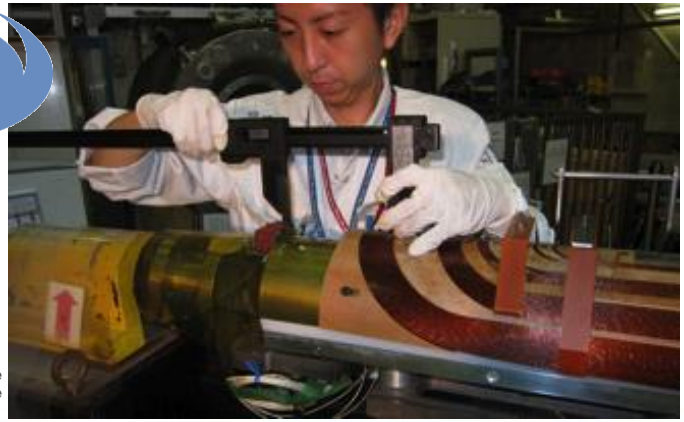
LRos

TRIPLET AND DIPOLES

- Triplet
  - First dummy and Nb_3Sn 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



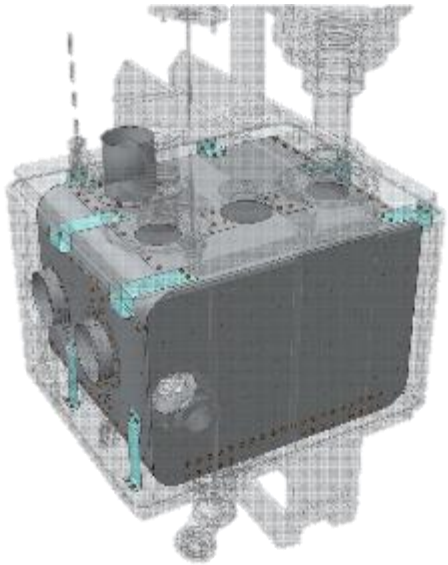
QXF coil wound in US
[G.Ambrosio et al., ASC 2014]

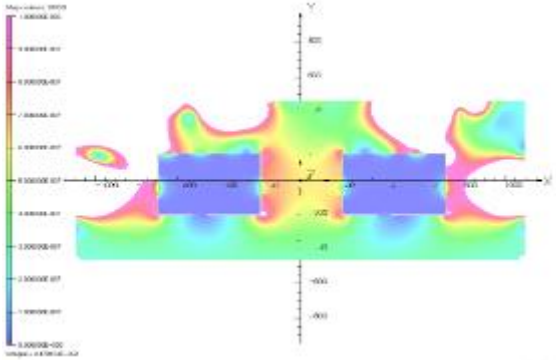


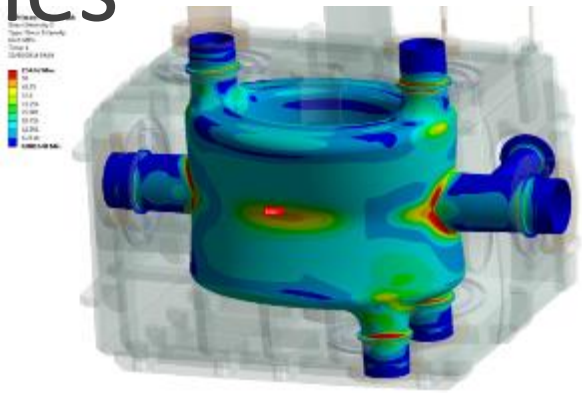
D1 winding at KEK [T. Nakamoto, et al., ASC 2014]

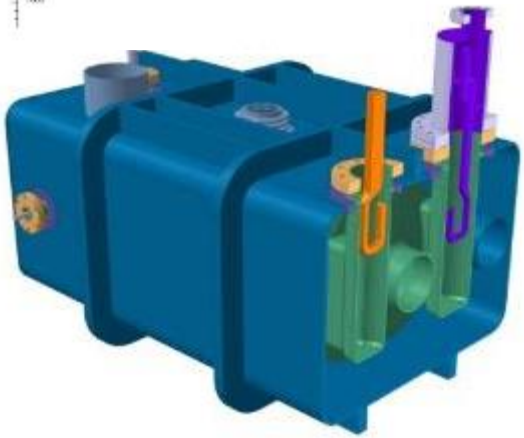
D2 collaring [P. Fabbricatore, S: Farinon]

WP 4 : Dressed Crab Cavities

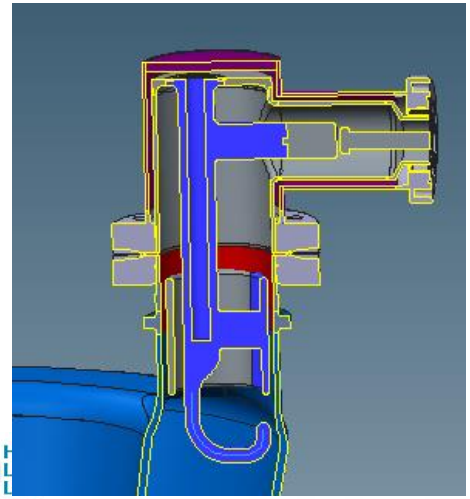


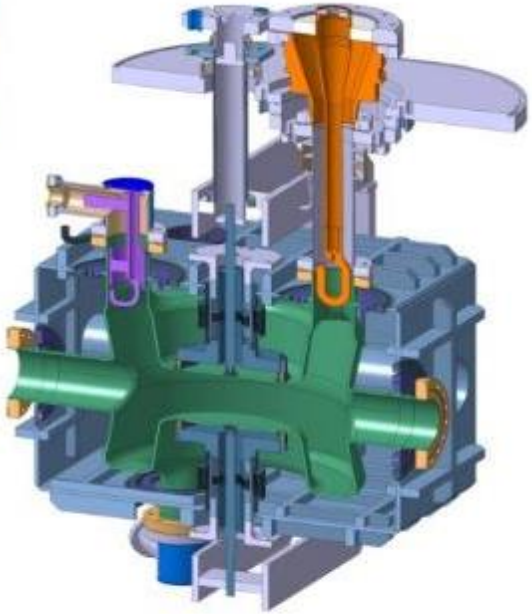






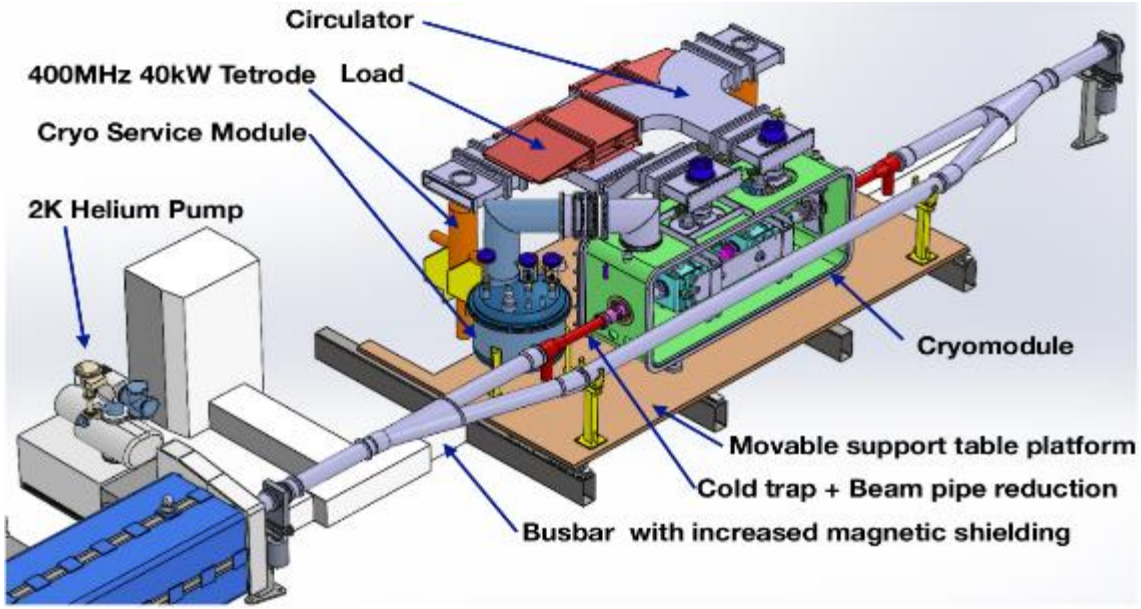
R. Calaga



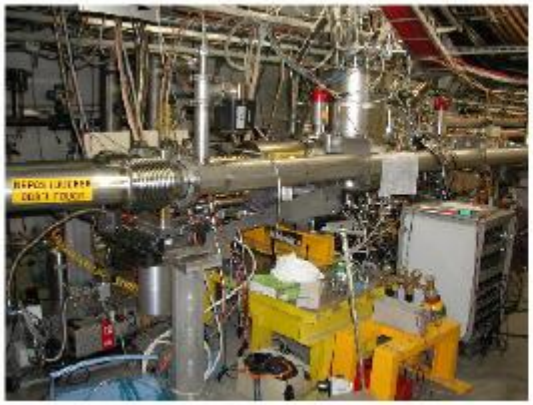


Dressed cavity designs are almost complete.
This includes the cavity, tuner, couplers, magnetic shielding and the LHe vessel.

CC SPS tests

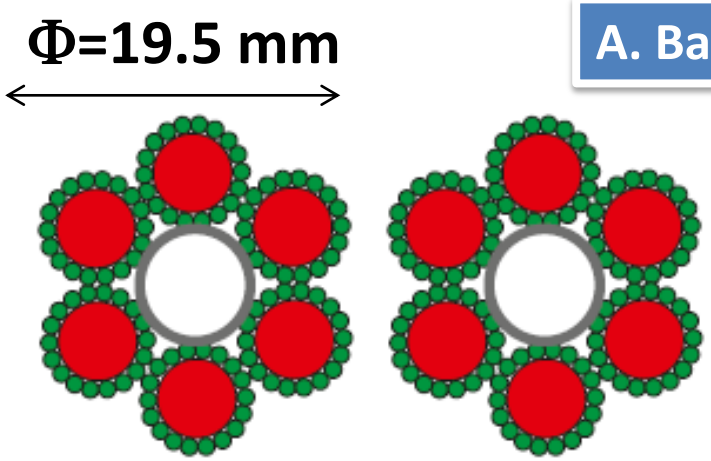


On schedule for install the first cryomodule at the end of 2016 and test in in SPS in 2017 and 2018.



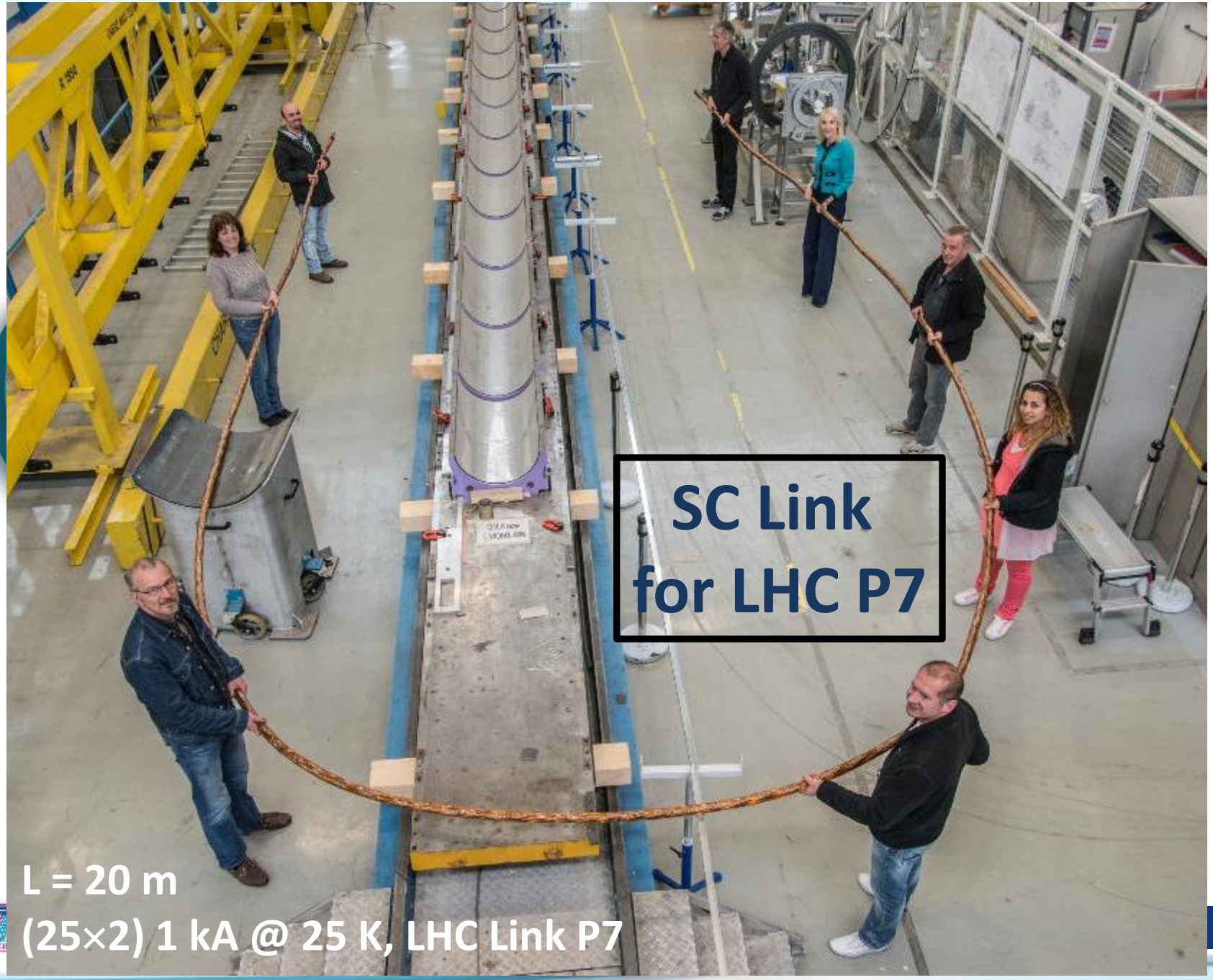
Record in MgB_2 SC Line

A. Ballarino



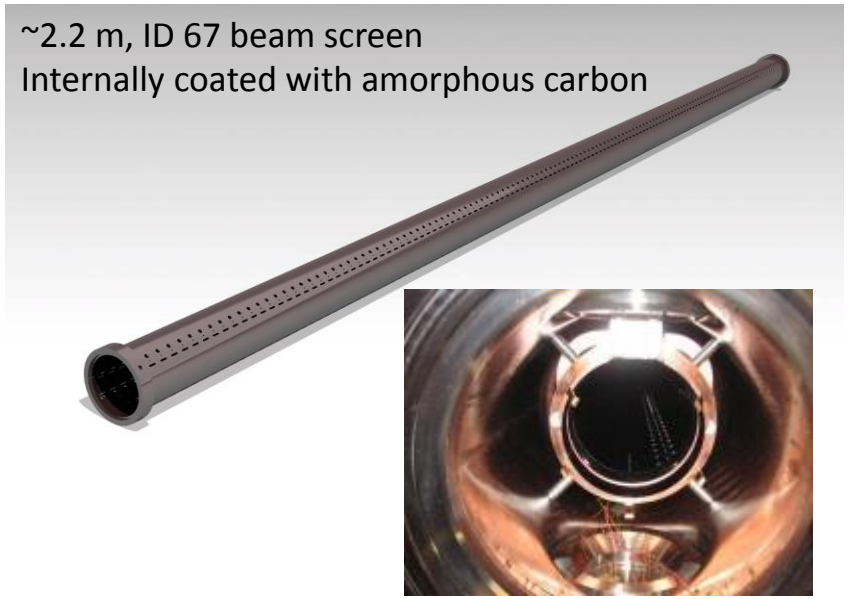
Ltot=2×20 m
I= 20 kA @ 24 K
Bp=1 T
Forced flow of He gas

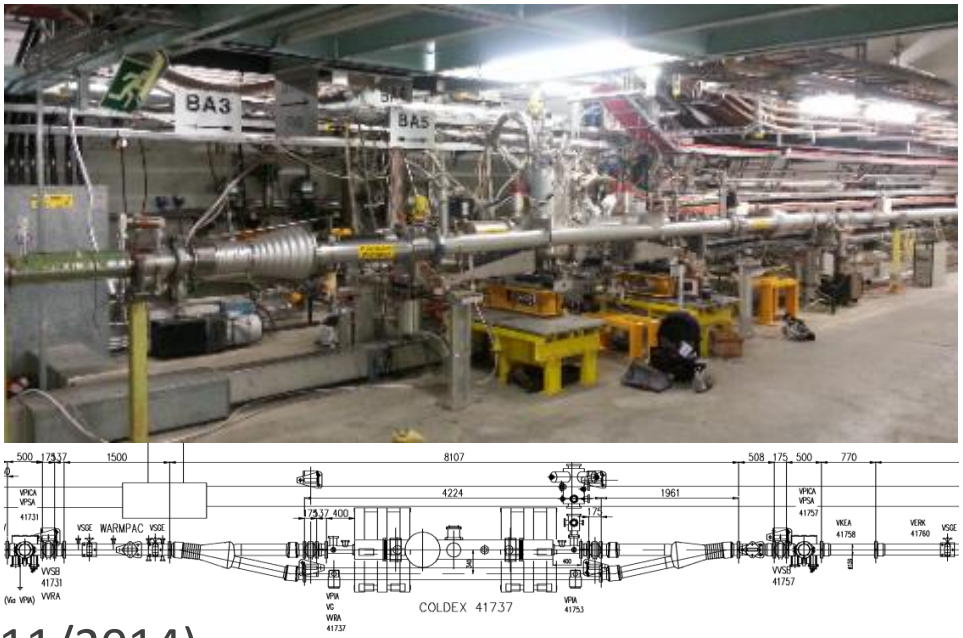
Demonstration of possibility of transferring high-current in MgB2 cables from round wire


SC Link
for LHC P7
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 keV)
- COLDEX equipped with a-C coated beam screen held at 50 K





- Tests with LHC type beams in SPS (3-9/11/2014):
  - Heat load < 1 W/m
  - Pressure rise < 10^{-8} mbar (mainly H_2)
- 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

High Luminosity LHC

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.