CERN-ACC-SLIDES-2014-0097

HiLumi LHC

FP7 High Luminosity Large Hadron Collider Design Study

Presentation

HL-LHC Project -Status and Perspectives

Rossi, L (CERN)

07 July 2014

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.

This work is part of HiLumi LHC Work Package **1: Project Management & Technical Coordination**.

The electronic version of this HiLumi LHC Publication is available via the HiLumi LHC web site <http://hilumilhc.web.cern.ch> or on the CERN Document Server at the following URL: <http://cds.cern.ch/search?p=CERN-ACC-SLIDES-2014-0097>

CERN-ACC-SLIDES-2014-0097

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ICHEP 2014 VALENCIA

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High Luminosity LHC

HL-LHC Project - Status and Perspectives

Lucio Rossi – CERN

For the HL-LHC Project team

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LHC: Coming up from a 2 years shutdown - Interconnect consolidation

High Luminosity LHC

Other works : R2E

- Point 1
  - All equipment are reinstalled and reconnected
  - Commissioning in progress

- Point 5 & Point 7
  - Major cabling campaign in progress

UL16 power converters

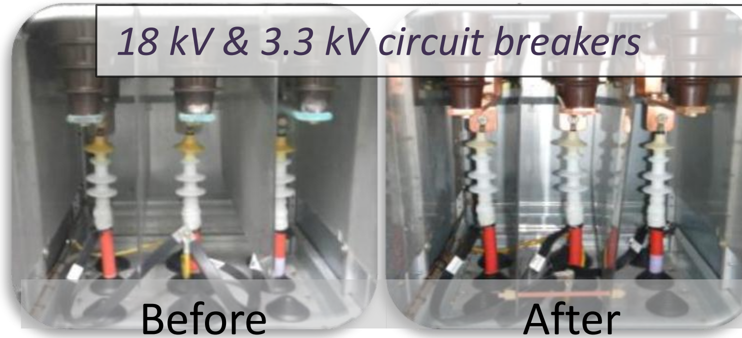
UL55 safe-room

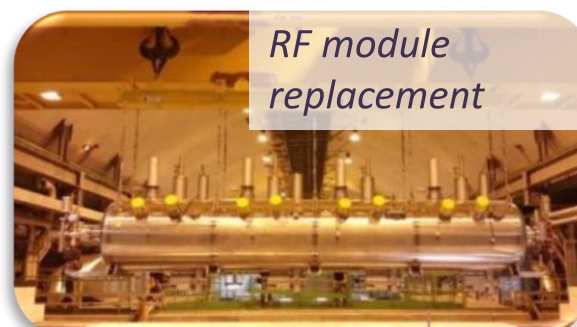
Warm Cable installation @ P5

TZ76

High Luminosity LHC

And many others



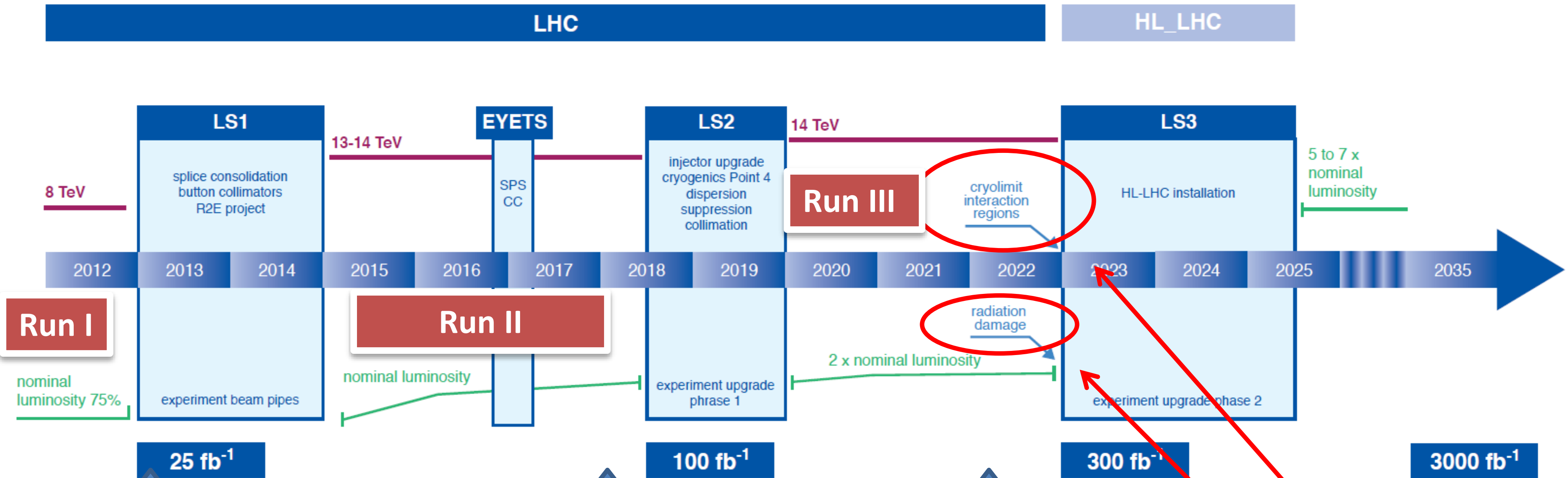


Key point

- We are on time for restarting Physics in LHC
- In April 2015, 13 TeV c.o.m.

- Chamonix Workshop on 22-25 September to define operating conditions and scenarii

New LHC / HL-LHC Plan



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

$1.5\ 10^{34}\ cm^{-2}s^{-1}$
25 ns bunch
pile up ~40

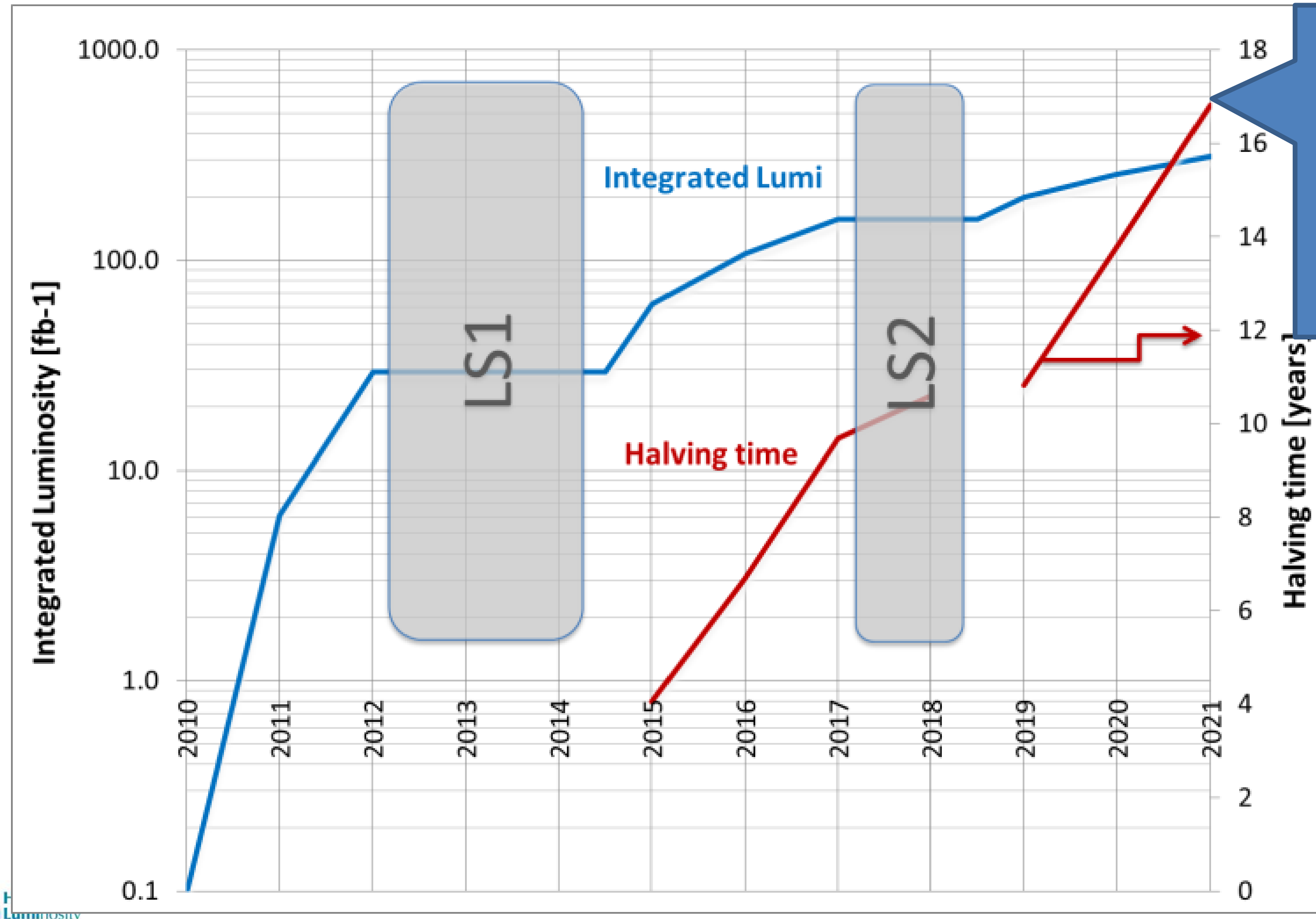
$1.7\text{-}2.2\ 10^{34}\ cm^{-2}s^{-1}$
25 ns bunch
pile up ~60

Technical limits (experiments, too) like :

50 $\Rightarrow$ 25 ns

High Luminosity LHC

Mantain and increase physics reach



Necessity of a jump in luminosity (useful luminosty ⇒ data quality)

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:

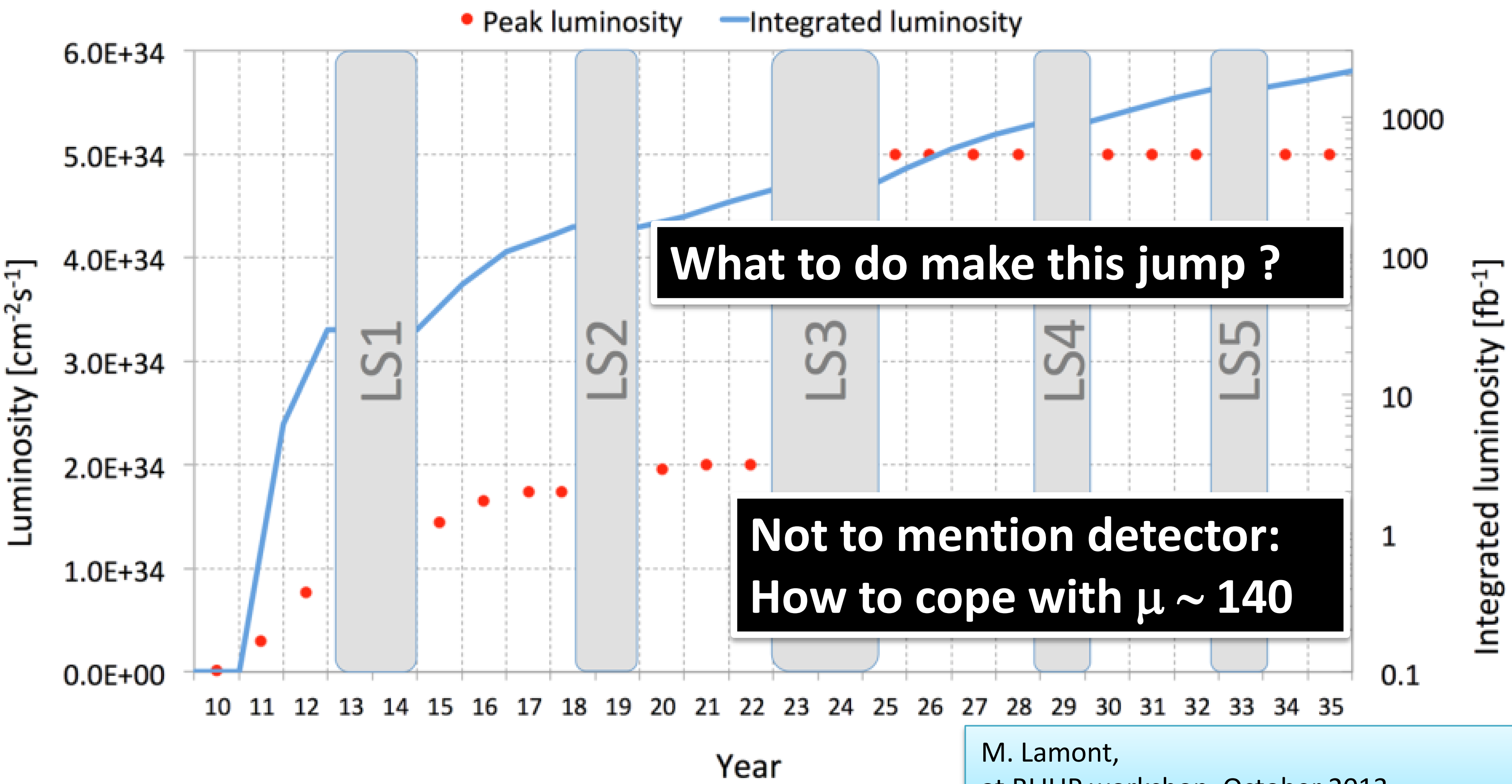
A peak luminosity of **5×10^{34} $cm^{-2}s^{-1}$ with levelling,** allowing:

An integrated luminosity of **250 fb^{-1} per year**, enabling the goal of **3000 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: under definition:
$L_{peak} \cong 7.5\ 10^{34}$ $cm^{-2}s^{-1}$ and Int. L ~ 4000 fb^{-1}

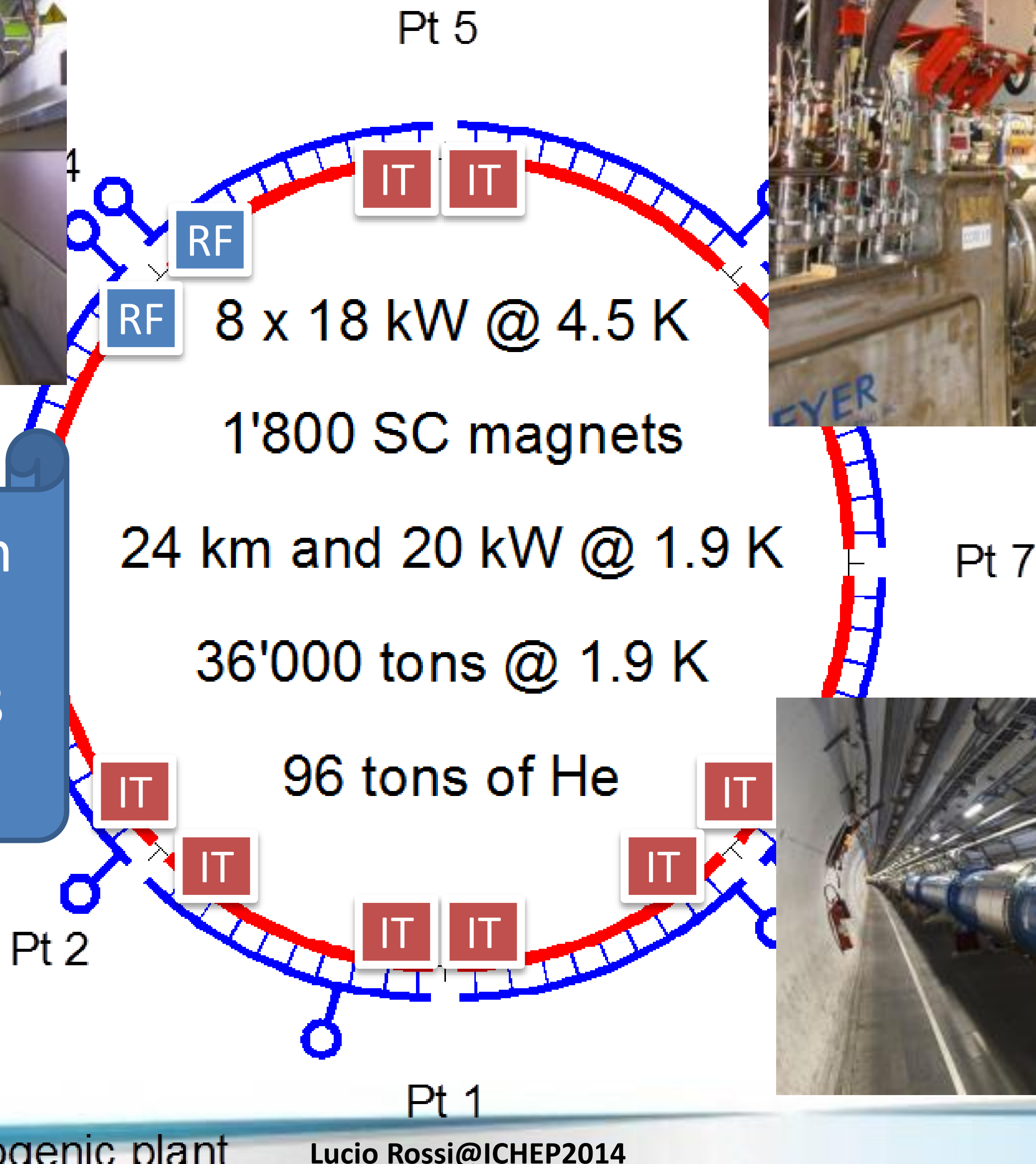
High Luminosity LHC

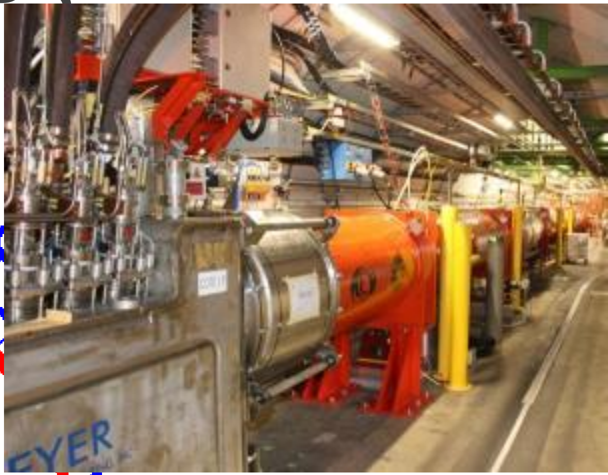
This goal would be reached in 2036



M. Lamont,
at RLIUP workshop, October 2013

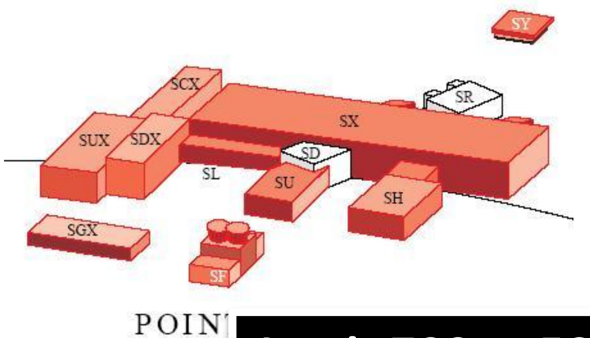
Rliminating Technical bottlenecks
Cryogenics P4- P1 –P5

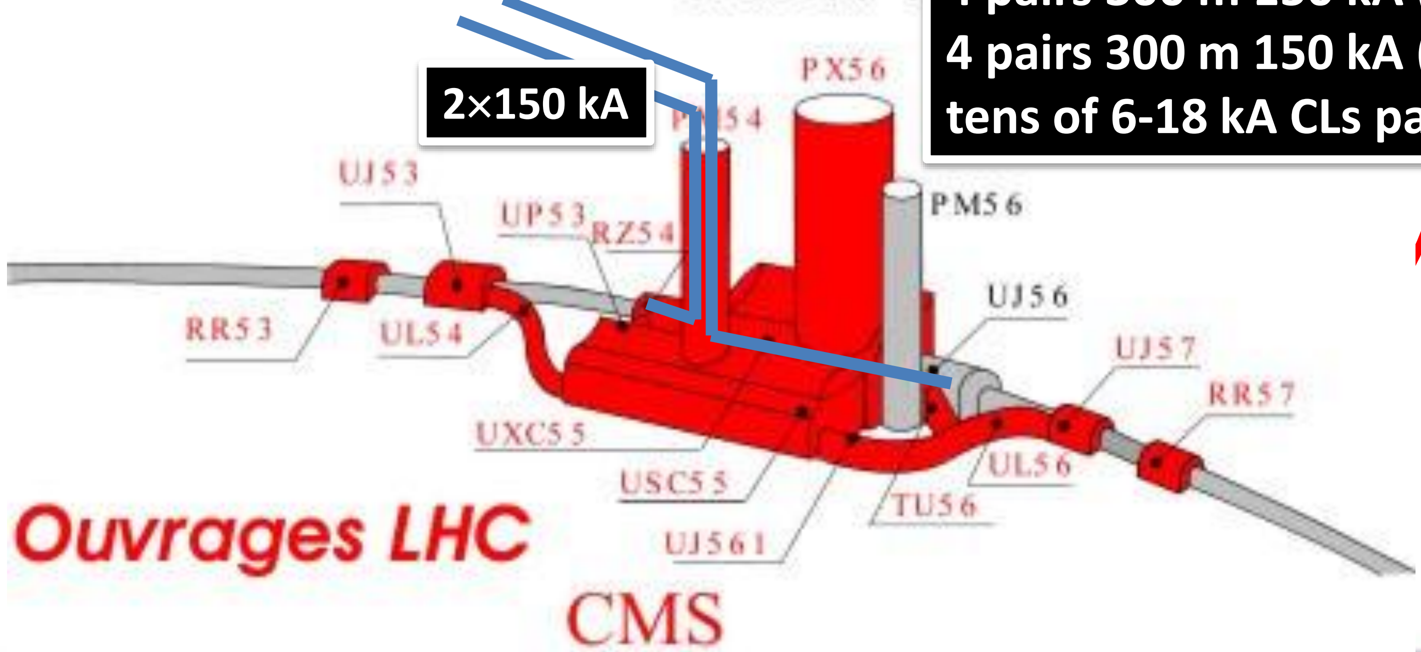




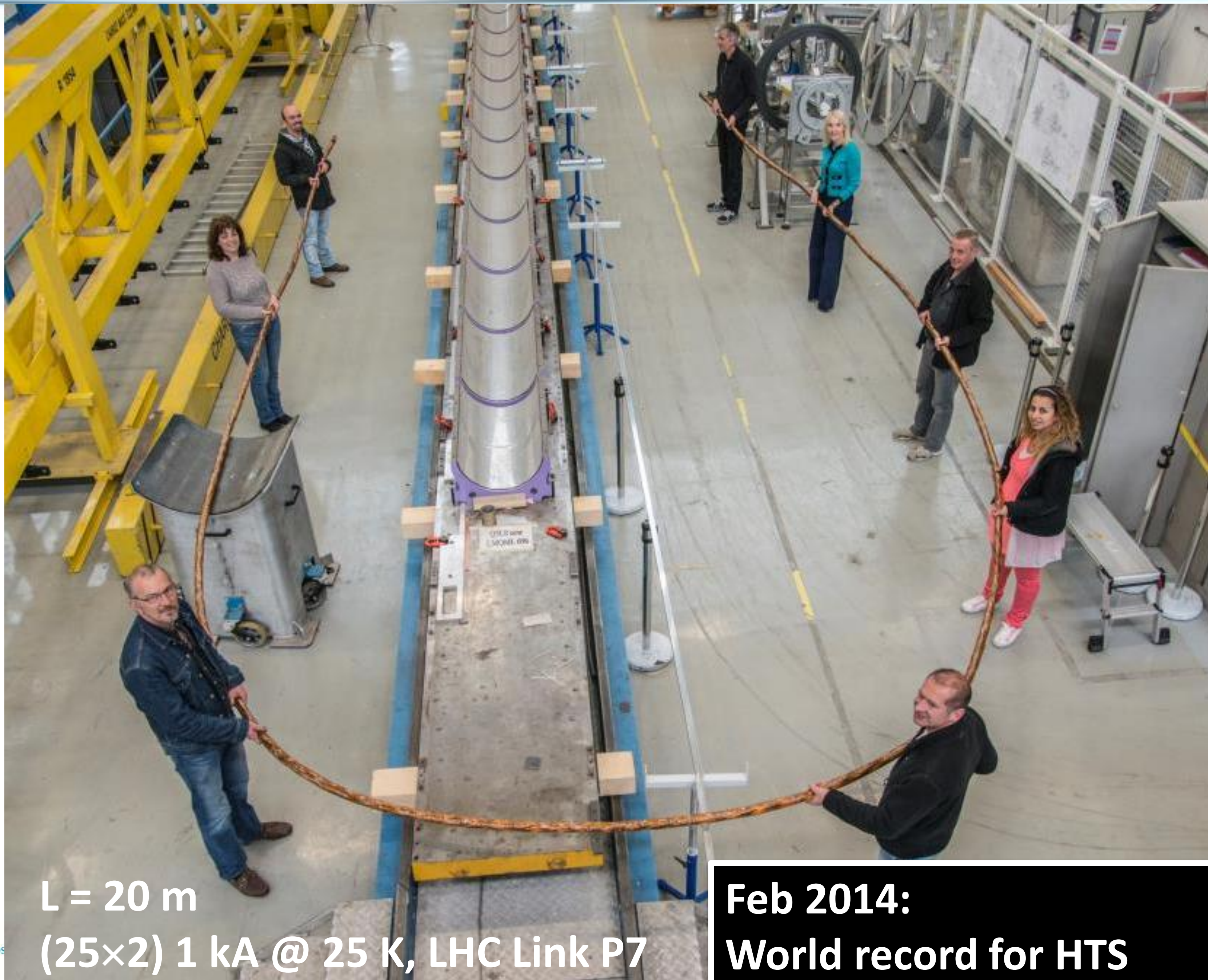
New Plant 8 kW in P4
New Plants for 18 kW in P1 and P5

Availability: SC links ⇒removal of EPCs, DFBs from tunnel to surface





1 pair 700 m 50 kA – LS2
4 pairs 300 m 150 kA (MS)– LS3
4 pairs 300 m 150 kA (IR) – LS3
tens of 6-18 kA CLs pairs in HTS



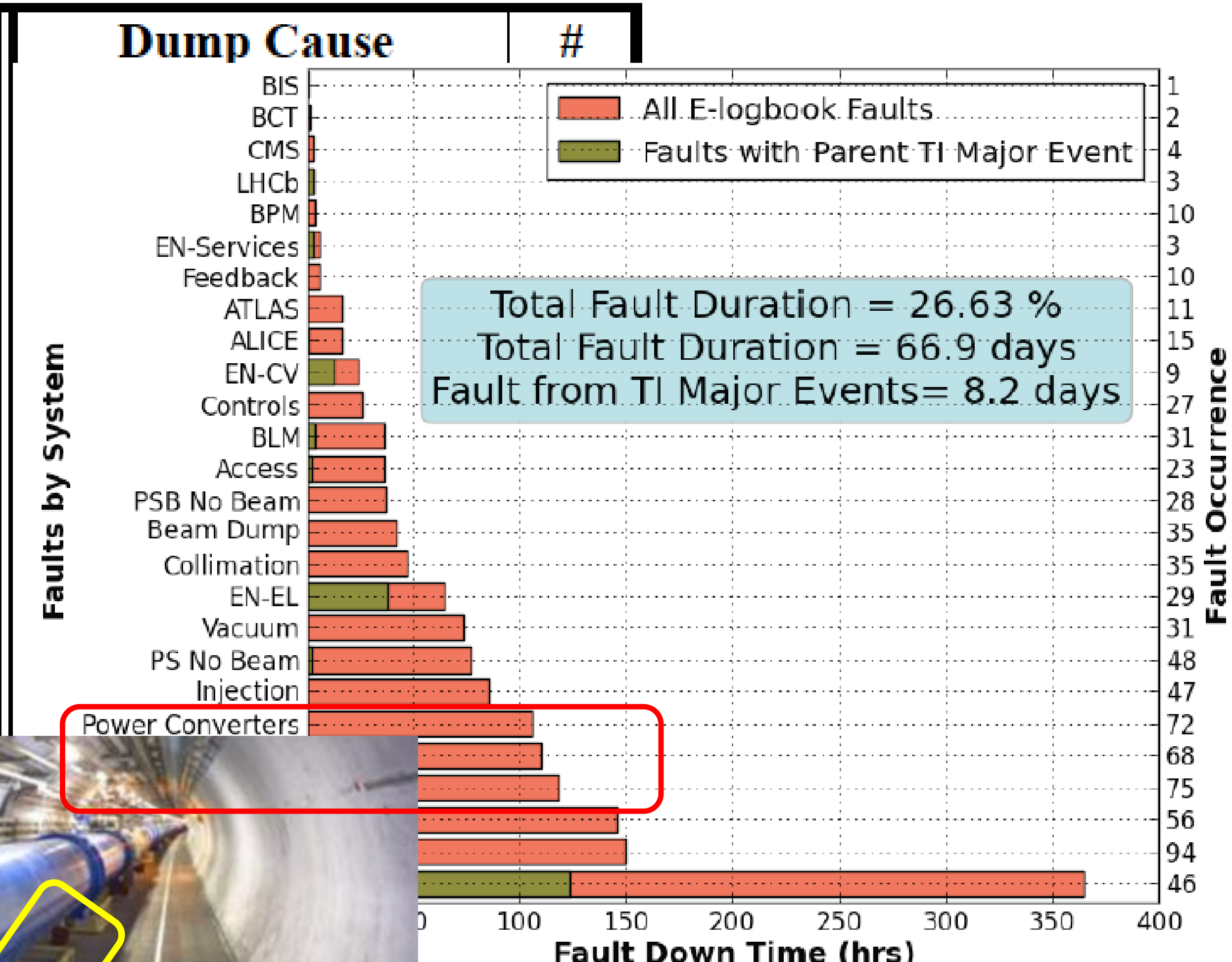
L = 20 m

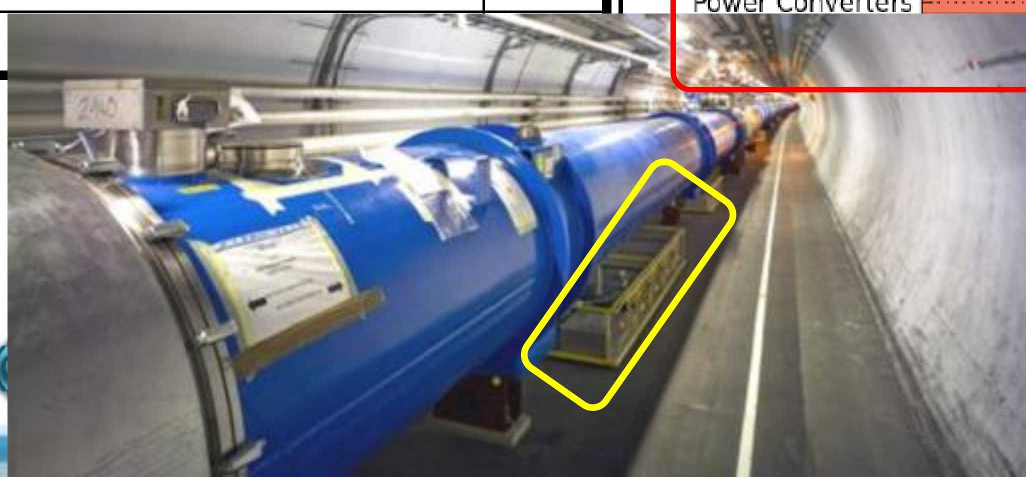
(25×2) 1 kA @ 25 K, LHC Link P7

Feb 2014:
World record for HTS

QPS boxes and intervention time

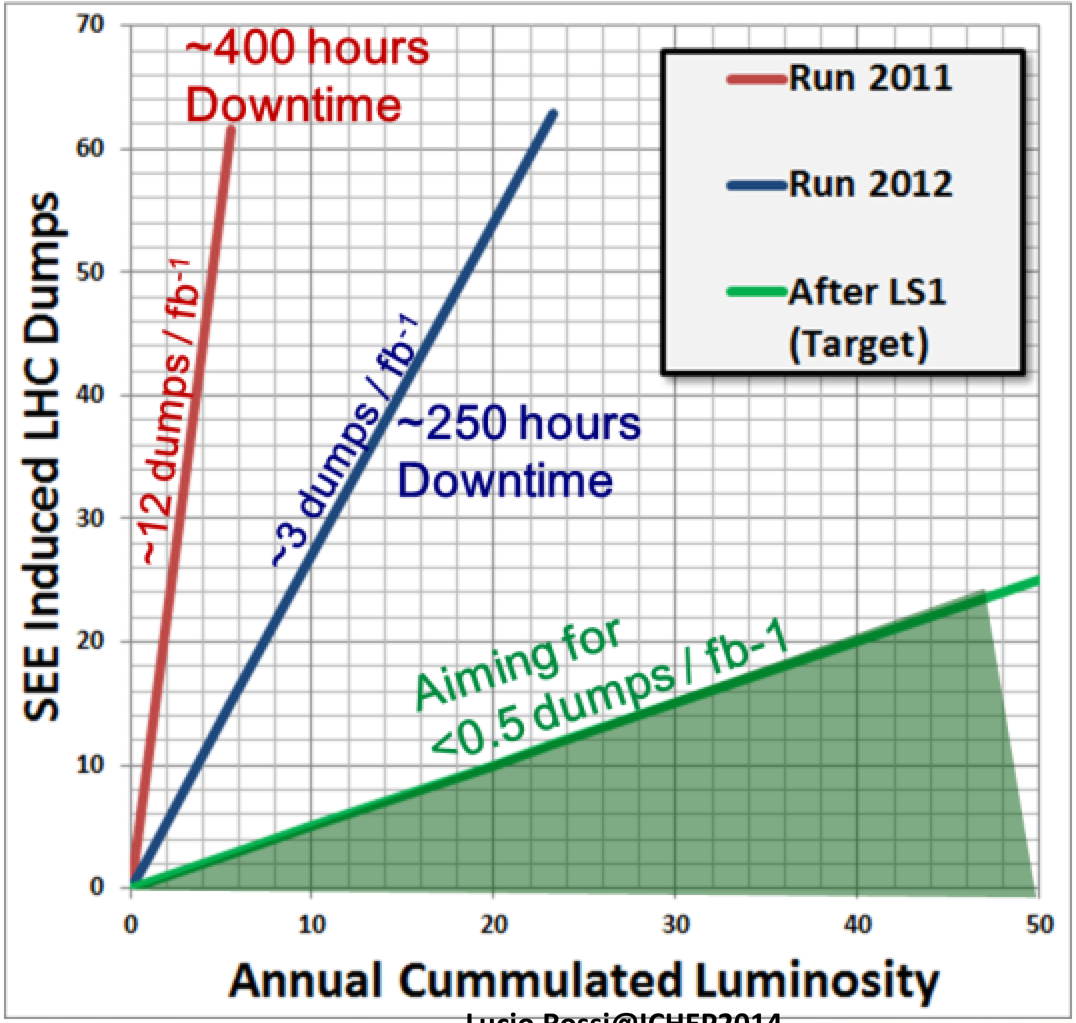
Dump Cause	#
Beam: Losses	58
Quench Protection	56
Power Converter	35
Electrical Supply	26
RF + Damper	23
Feedback	19
BLM	18
Vacuum	17
Beam: Losses (UFO)	15
Cryogenics	14
Collimation	12





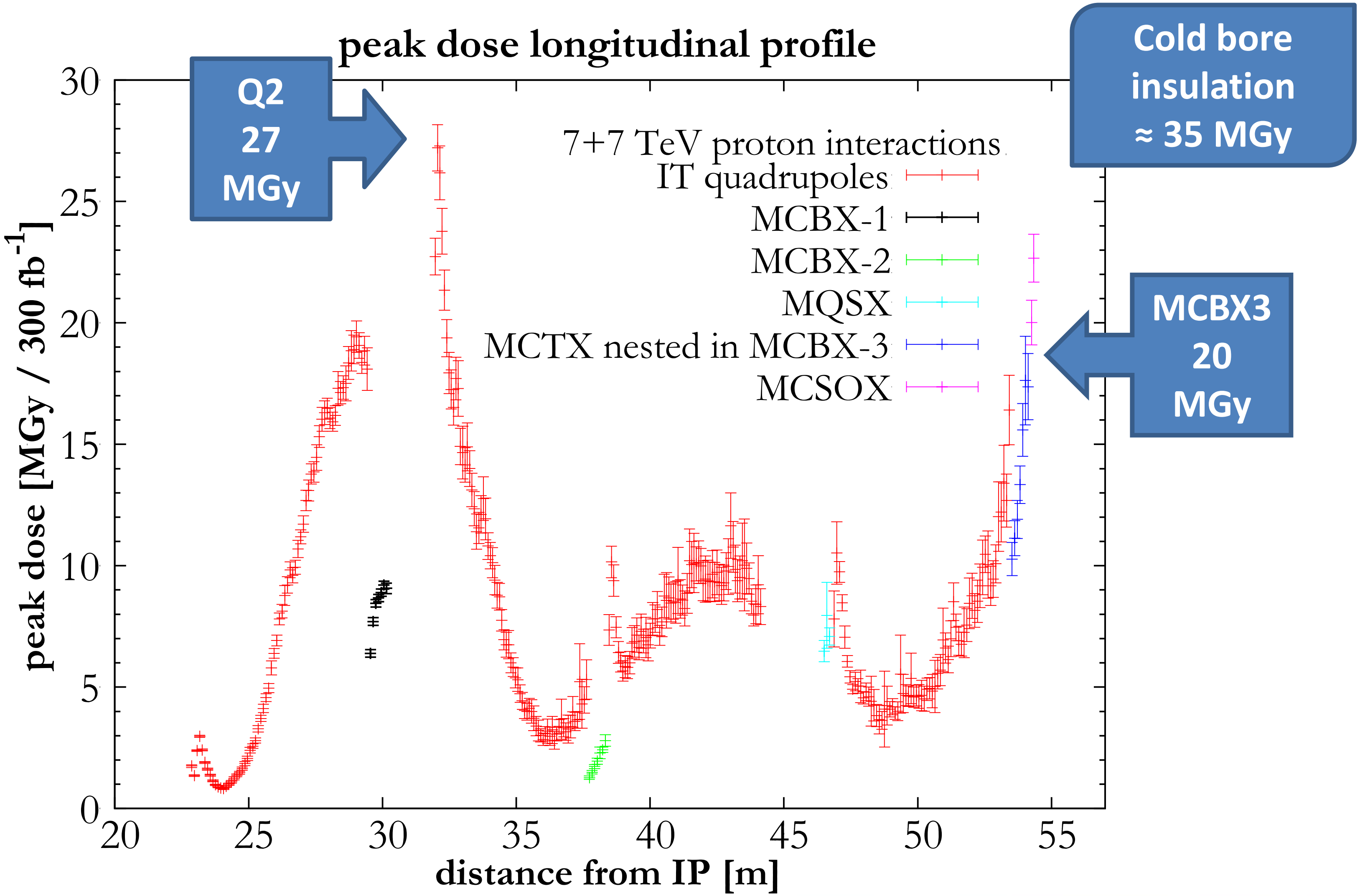
Consolidation of infrastructure !
But also new paradigma: remove from tunnel of QPS (as much as possible)

R2E improvement. Need further for 1-3 fb^{-1}/day!



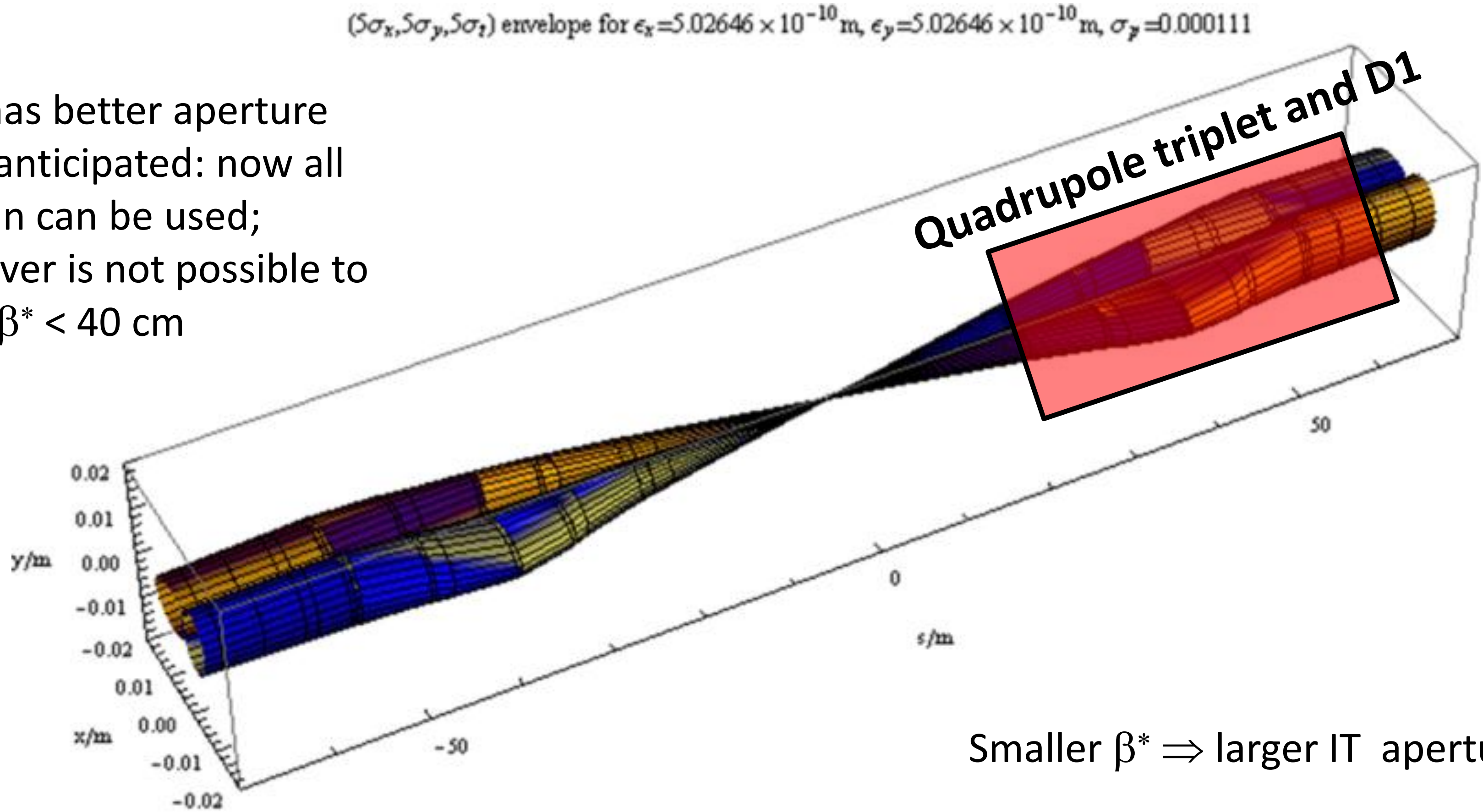
Workshop in October

The big technical bottleneck: Radiation damage to triplet



The most straight forward action: reducing beam size with a «local» action

LHC has better aperture than anticipated: now all margin can be used; however is not possible to have $\beta^* < 40$ cm



Smaller $\beta^* \Rightarrow$ larger IT aperture

Parameters (PLC web page)

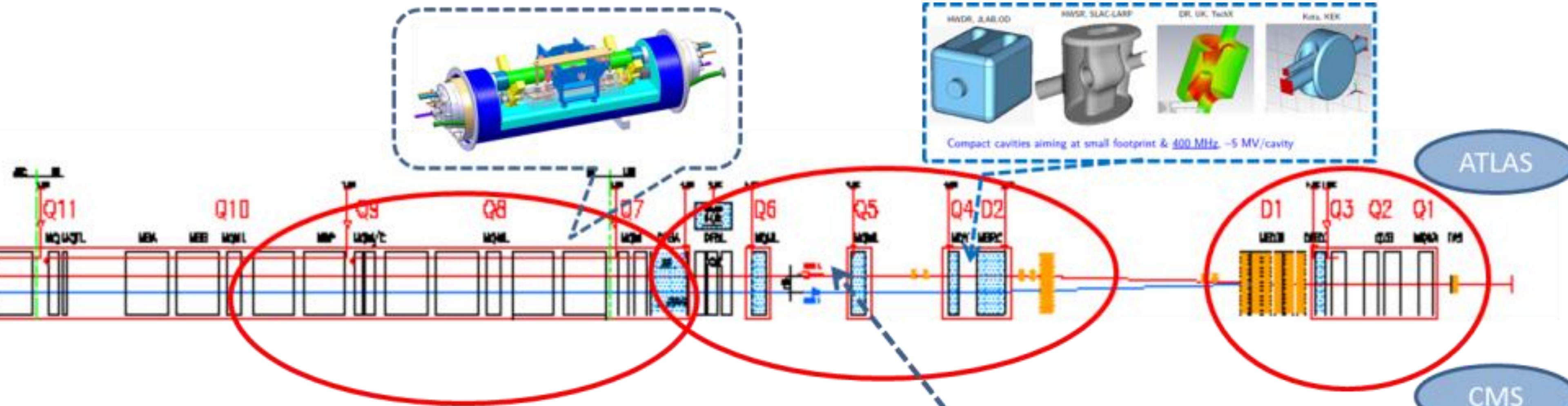
https://espace.cern.ch/HiLumi/PLC/default.aspx

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

Parameter	nominal	25ns	50ns
N_b	1.15E+11	2.2E+11	3.5E+11
n_b	2808	**2808**	1404
N_{tot}	3.2E+14	6.2E+14	4.9E+14
beam current [A]	0.58	**1.11**	0.89
x-ing angle [μrad]	300	590	590
beam separation [σ]	9.9	12.5	11.4
β^* [m]	0.55	**0.15**	0.15
ε_n [μm]	3.75	2.50	3
ε_L [eVs]	2.51	2.51	2.51
energy spread	1.20E-04	1.20E-04	1.20E-04
bunch length [m]	7.50E-02	7.50E-02	7.50E-02
IBS horizontal [h]	80 -> 106	18.5	17.2
IBS longitudinal [h]	61 -> 60	20.4	16.1
Piwinski parameter	0.68	3.12	2.85
Reduction factor 'R1*H1' at full crossing angle (no crabbing)	0.828	0.306	0.333
Reduction factor 'H0' at zero crossing angle (full crabbing)	0.991	**0.905**	0.905
beam-beam / IP without Crab Cavity	3.1E-03	3.3E-03	4.7E-03
beam-beam / IP with Crab cavity	3.8E-03	1.1E-02	1.4E-02
Peak Luminosity without levelling [$cm^{-2}\,s^{-1}$]	1.0E+34	7.4E+34	8.5E+34
Virtual Luminosity: Lpeak*H0/R1/H1 [$cm^{-2}\,s^{-1}$]	1.2E+34	**21.9E+34**	23.1E+34
Events / crossing without levelling	19 -> 28	210	475
Levelled Luminosity [$cm^{-2}\,s^{-1}$]	-	5E+34	2.50E+34
Events / crossing (with leveling for HL-LHC)	*19 -> 28	140	140
Leveling time [h] (assuming no emittance growth)	-	9.0	18.3

High Luminosity LHC

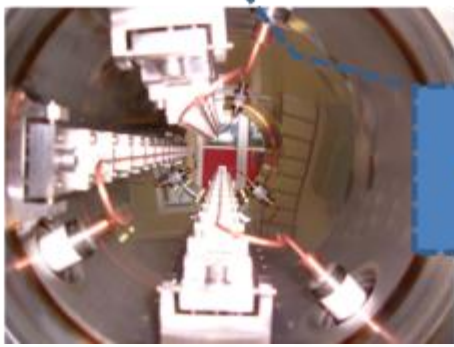
The critical zone around IP1 and IP5



1. Deep change in the IRs and interface to detectors; relocation of Power Supply

2. Deep change also matching section: Magnets, collimators and CC

3. For collimation we need to change also this part, DS in the continuous cryostat



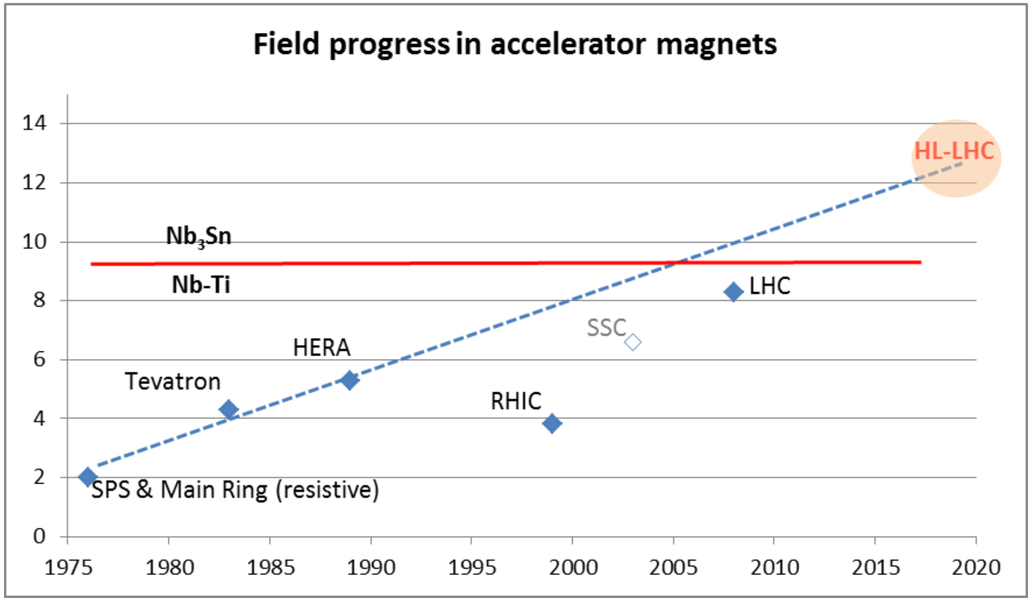
4. LR BB compensation wires

1.2 km of LHC !!

High Luminosity LHC

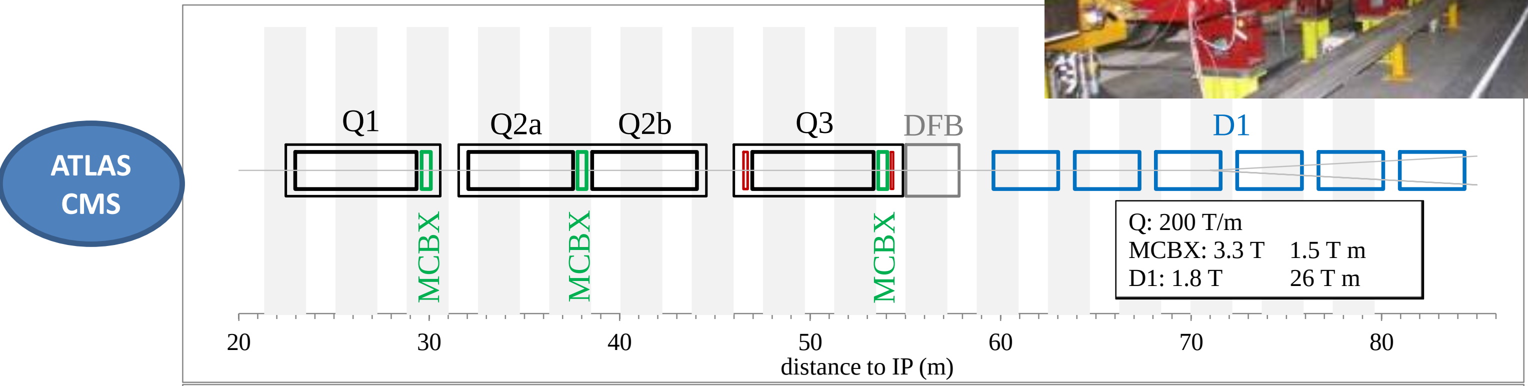
Magnet the progress

- LHC dipoles features 8.3 T in 56 mm (designed for 9.3 peak field)
- LHC IT Quads features 205 T/m in 70 mm with 8 T peak field
- HL-LHC
  - 11 T dipole (designed for 12.3 T peak field, 60 mm)
  - New IT Quads features 140 T/m in 150 mm > 12 T operational field, designed for 13.5 T).

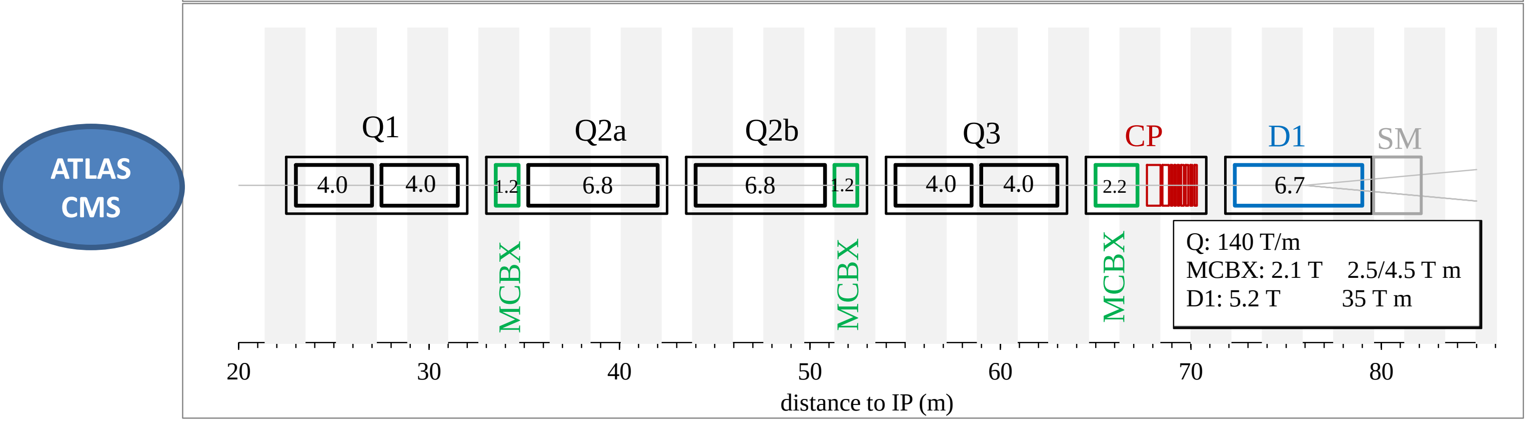


New Interaction Region lay out

Longer Quads; Shorter D1 (thanks to SC)



LHC



E. Todesco

HL LHC

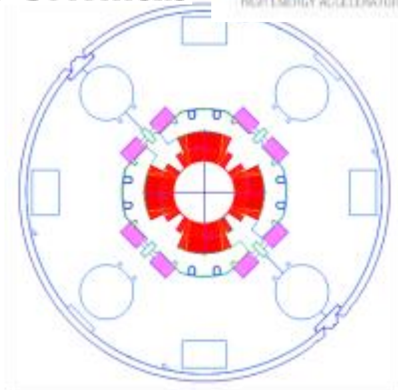
Thick boxes are magnetic lengths -- Thin boxes are cryostats

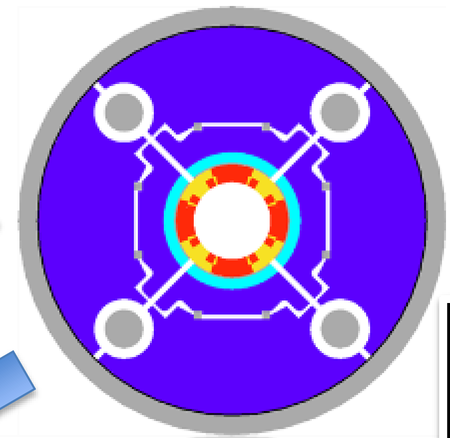
High Luminosity LHC

LHC low-β quads: steps in magnet technology from LHC toward HL-LHC

Fermilab KEK

LHC (USA & JP, 5-6 m)
∅70 mm, B_{peak}~ 8 T
1992-2005





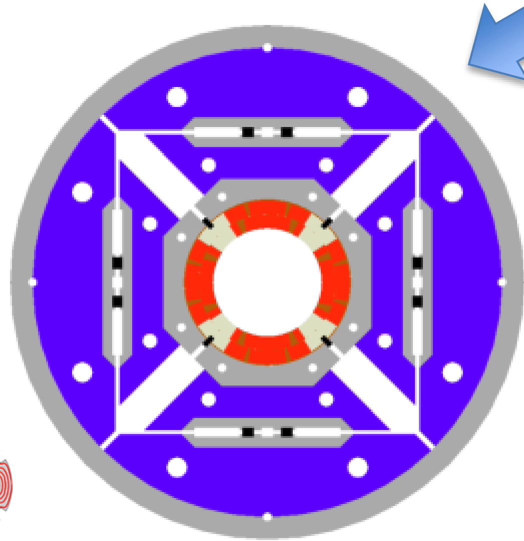
LARP

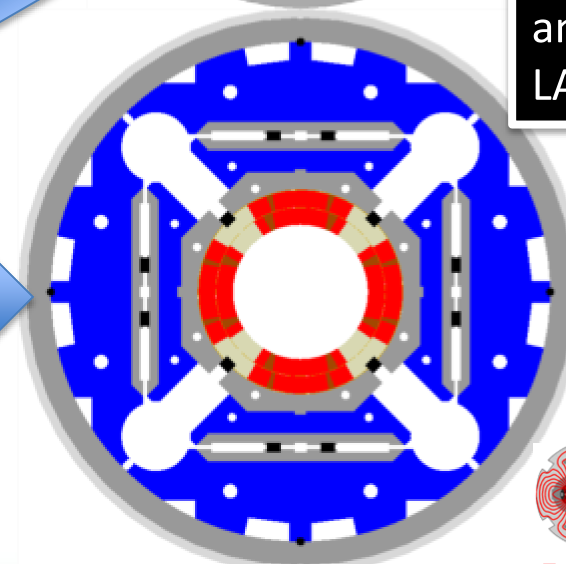
LARP TQS & LQ (4m)
∅90 mm, B_{peak}~ 11 T
2004-2010

New structure based on bladders and keys (LBNL, LARP)

LARP HQ
∅120 mm,
B_{peak}~ 12 T
2008-2014

LARP

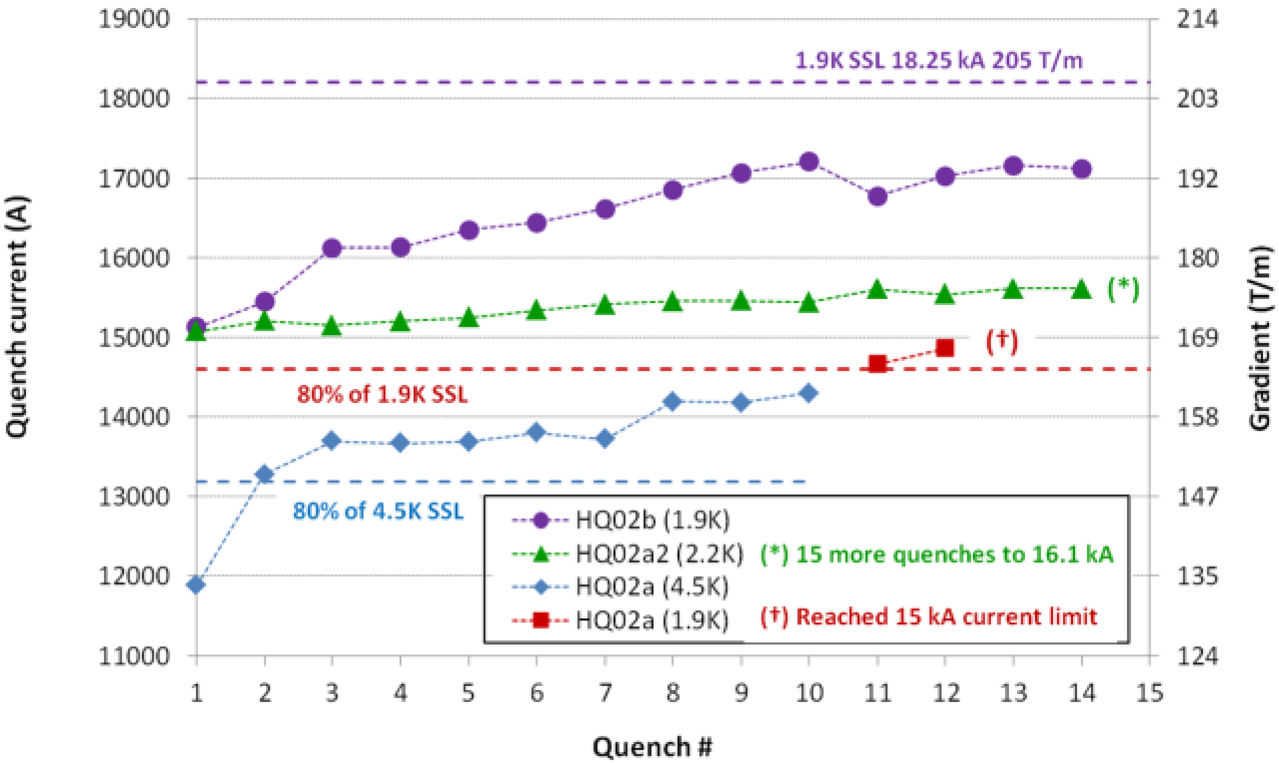




LARP & CERN MQXF
∅150 mm,
B_{peak}~ 12.1 T
2013-2020

LARP

Progress in MQXF (IT quads)



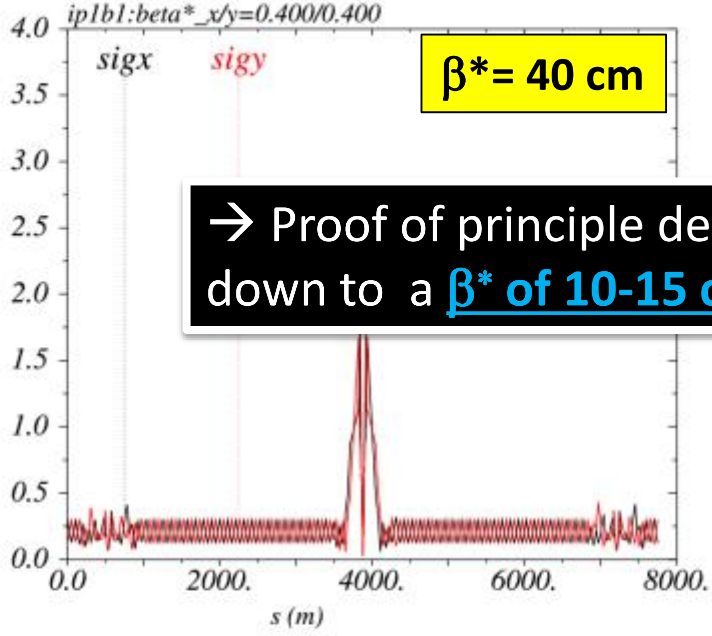
High Luminosity LHC

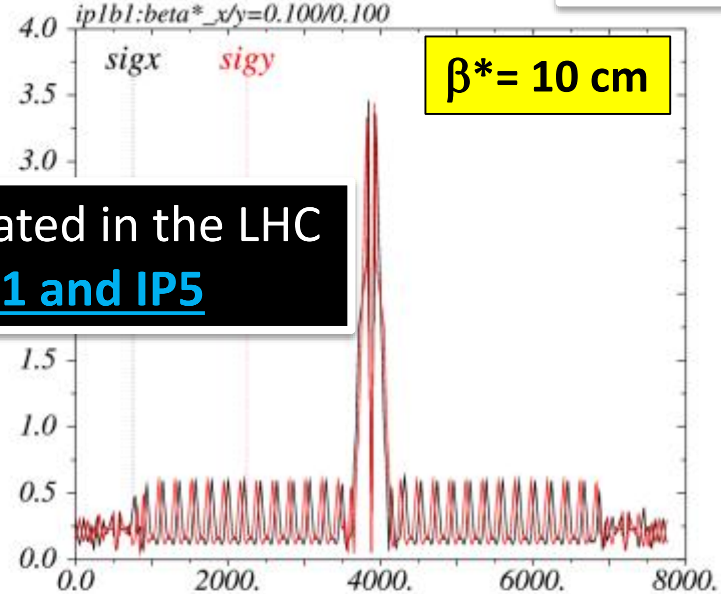
The ***Achromatic Telescopic Squeezing*** (ATS) scheme

Small β* is limited by aperture but not only: optics matching & flexibility (round and flat optics), chromatic effects (not only Q'), spurious dispersion from X-angle,..

A novel optics scheme was developed to reach un-precedent β^* w/o chromatic limit based on a kind of generalized squeeze involving 50% of the ring

(S. Fartoukh)

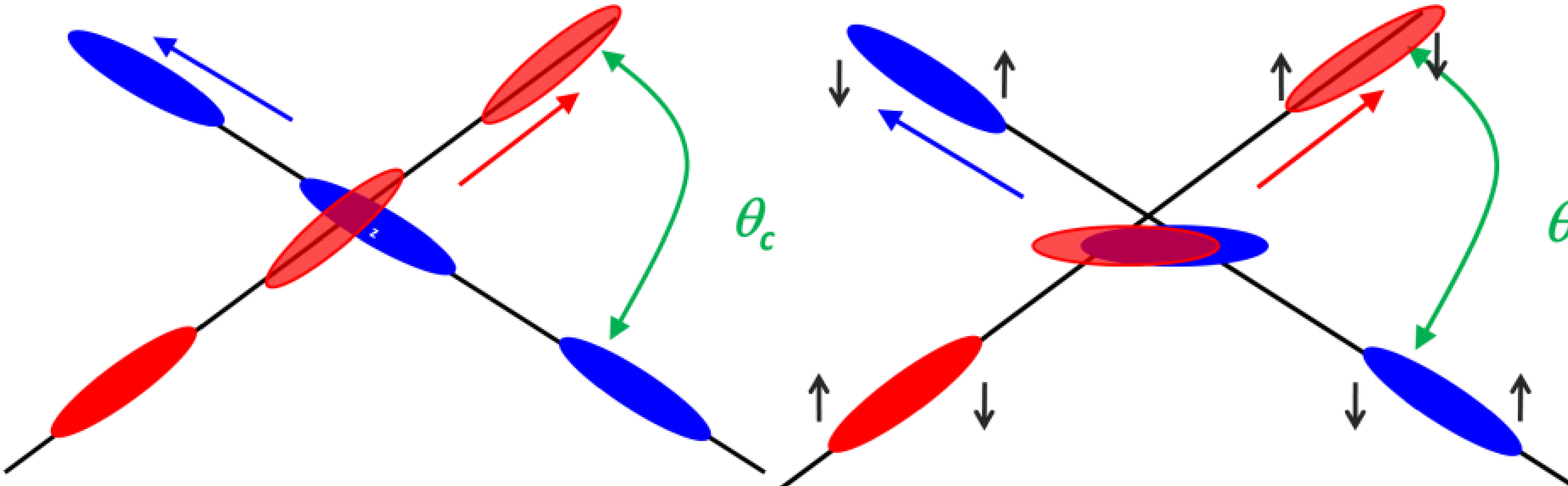




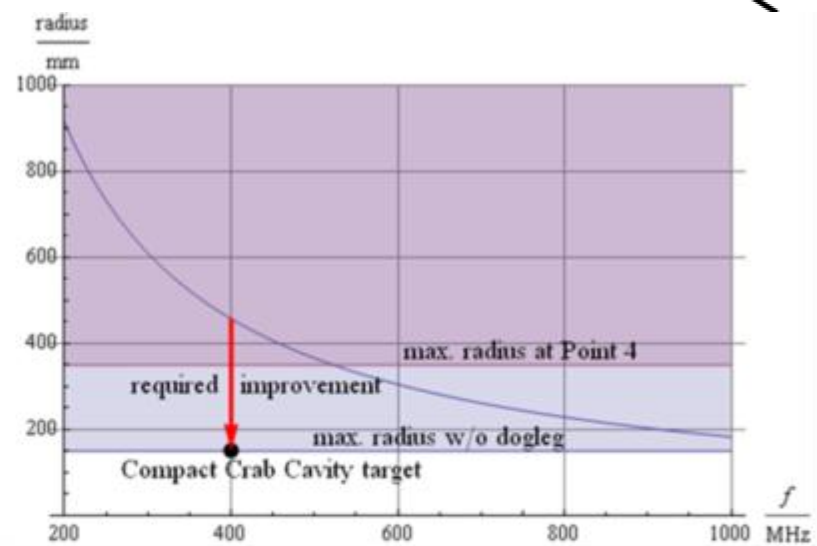
→ Proof of principle demonstrated in the LHC down to a **β* of 10-15 cm at IP1 and IP5**

Beam sizes [mm] @ 7 TeV from IR8 to IR2 for typical ATS "pre-squeezed" optics (left) and "telescopic" collision optics (right)

Effect of the crab cavities



- **RF crab cavity deflects head and tail in opposite direction so that collision is effectively "head on" and then luminosity is maximized**

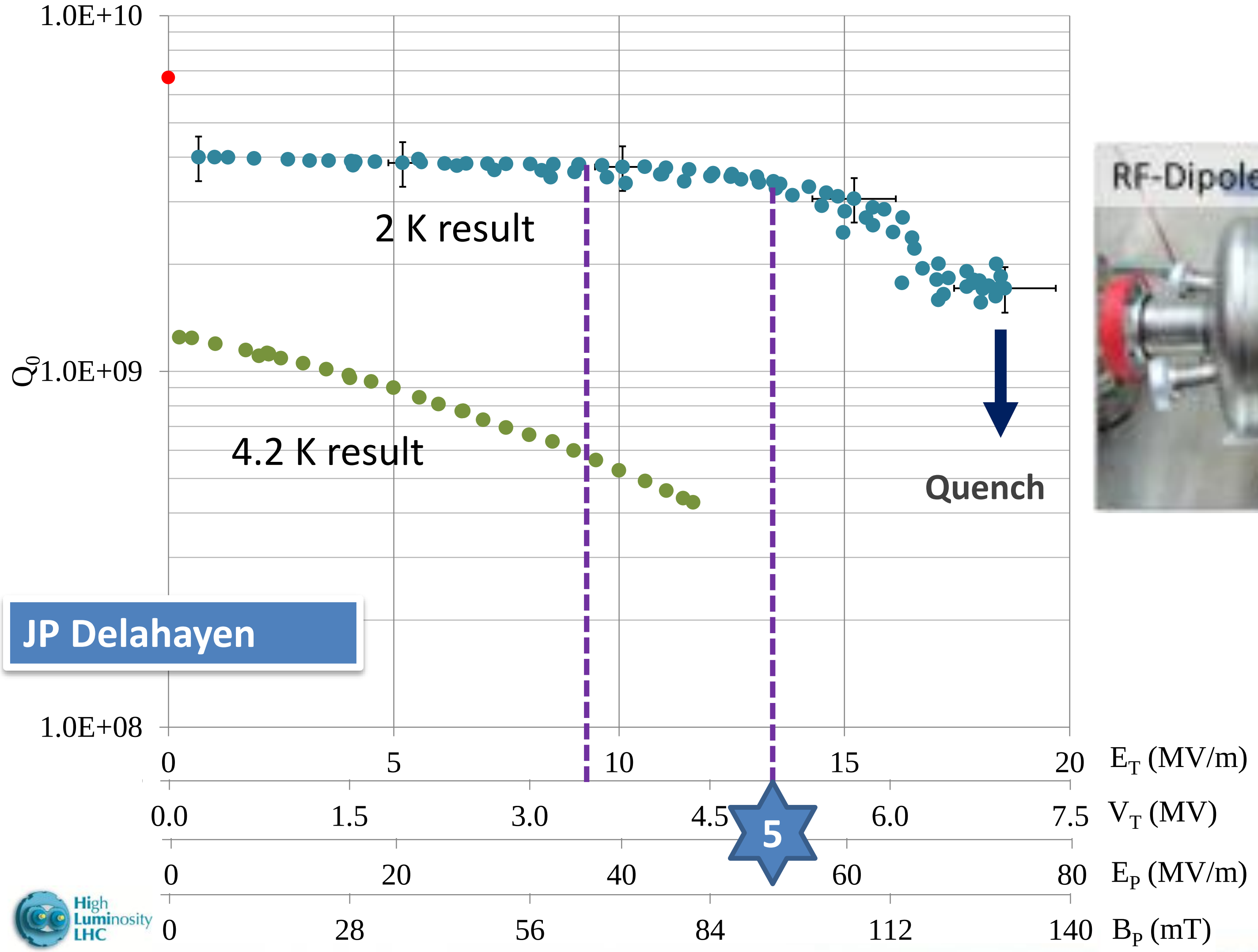


High Luminosity LHC

And excellent results: RF dipole > 5 MV

¼ w and 4-rods also tested (1.5 MV)

cleaning & vacuum issues: new test under way



JP Delahayen

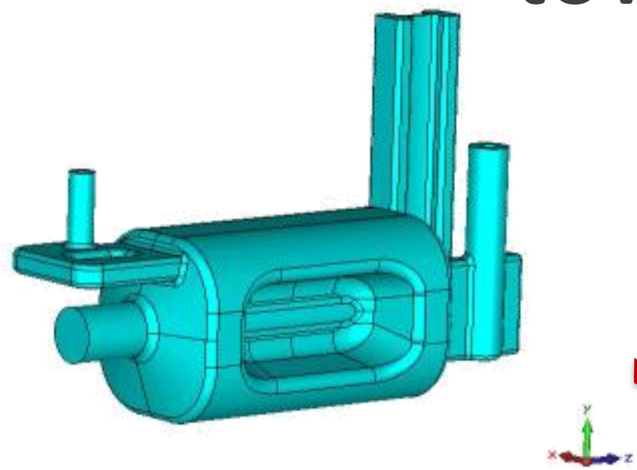
Old Dominion University

LARP

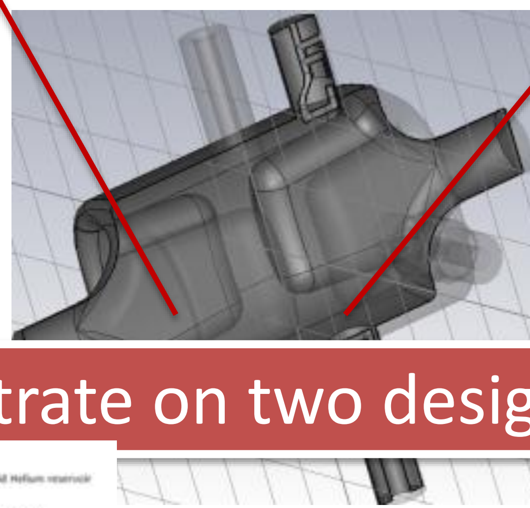
High Luminosity LHC

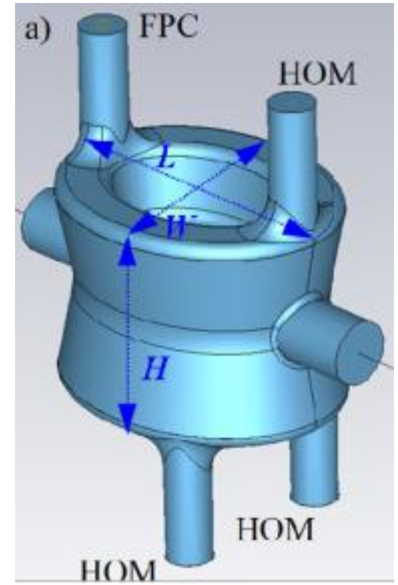
Latest cavity designs toward accelerator

Coupler concepts



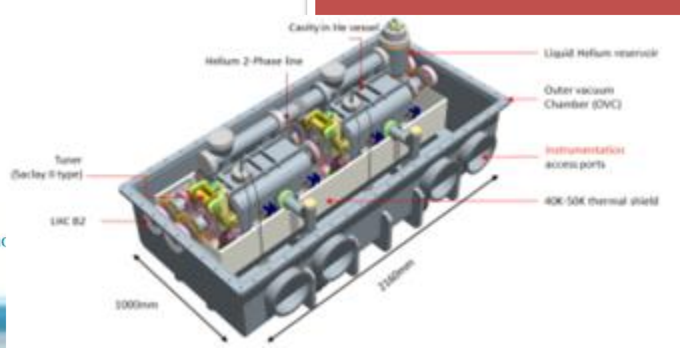
RF Dipole: Waveguide or waveguide-coax couplers





Double ¼-wave: Coaxial couplers with hook-type antenna

Concentrate on two designs

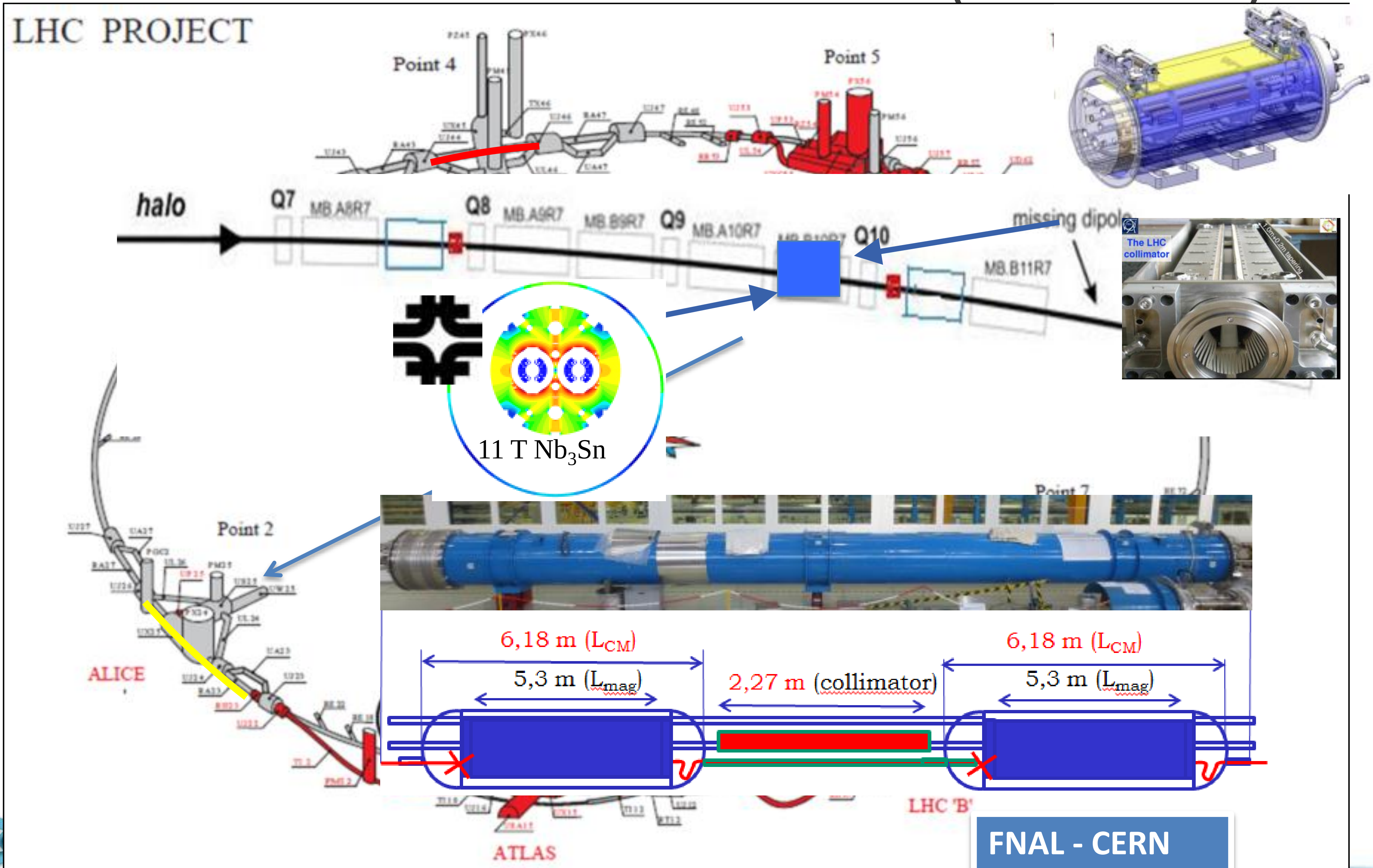


Coax

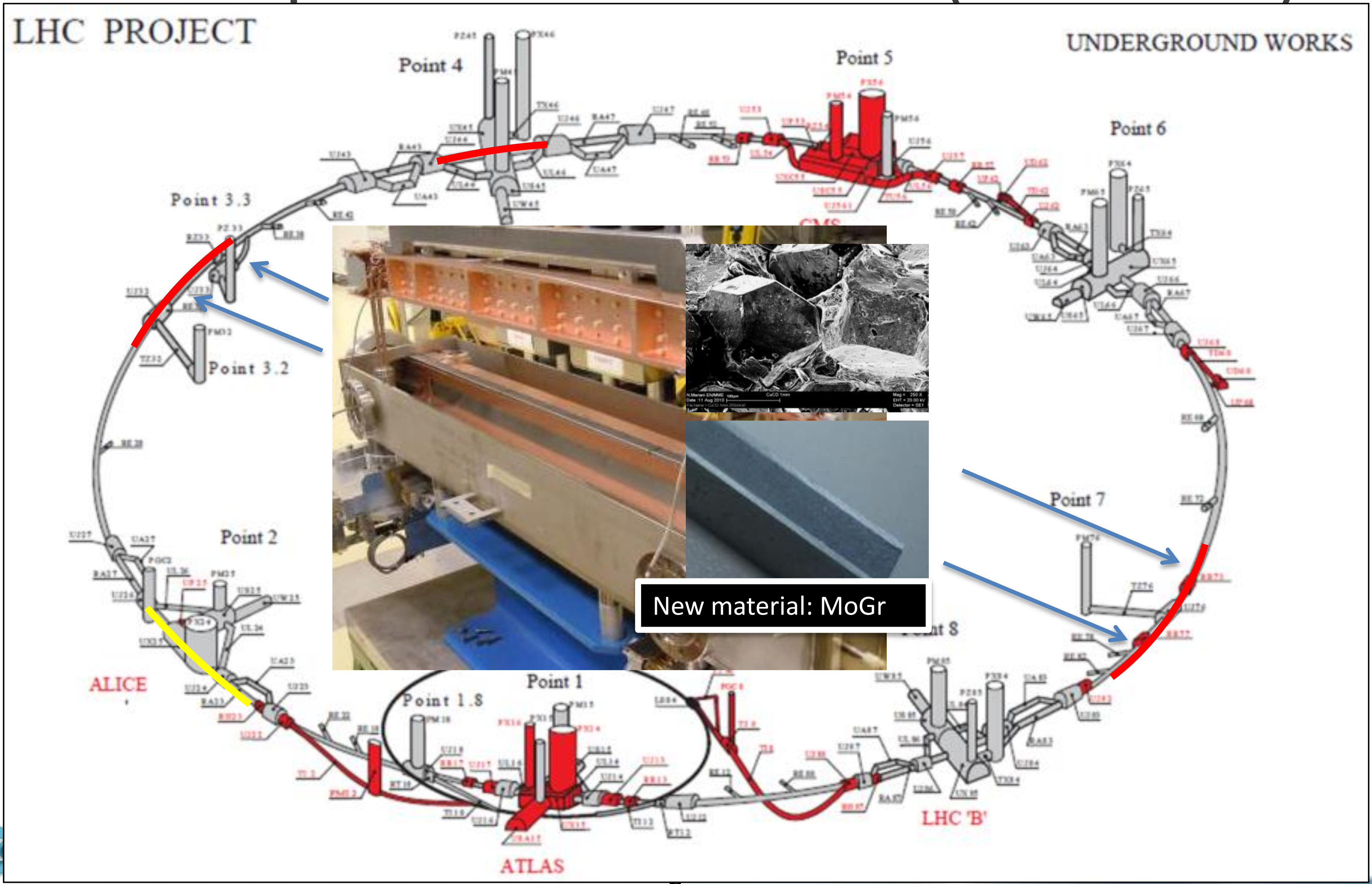
nt ar

Present baseline: 3 cavity /cyomodule
4 cavity/cryomod is under study for Crab Kissing
TEST in SPS under preparation (A. MacPherson)

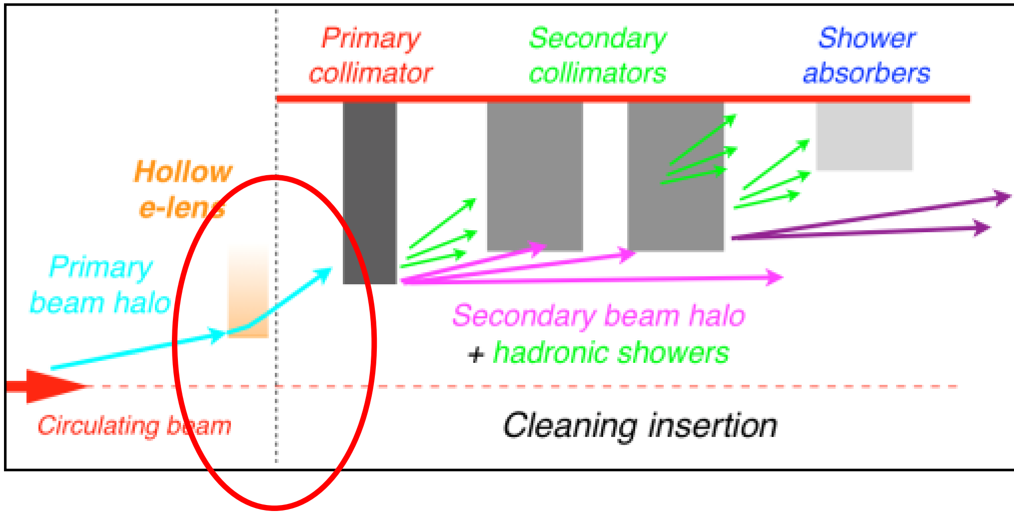
P2 - DS collimators ions – 11 T (LS2 -2018)

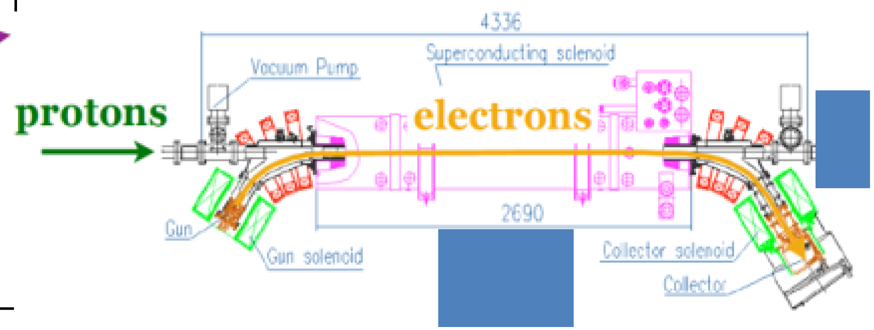


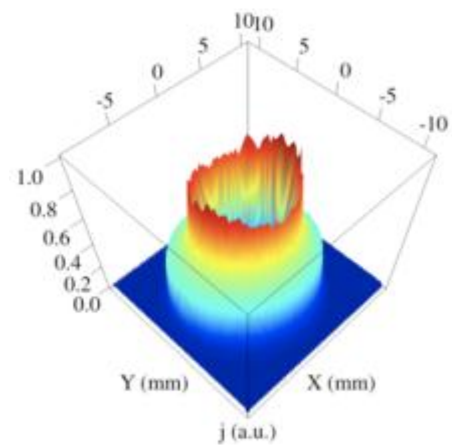
Low impedence collimators(LS2 & LS3)



Controlling diffusion rate: hollow e-lens



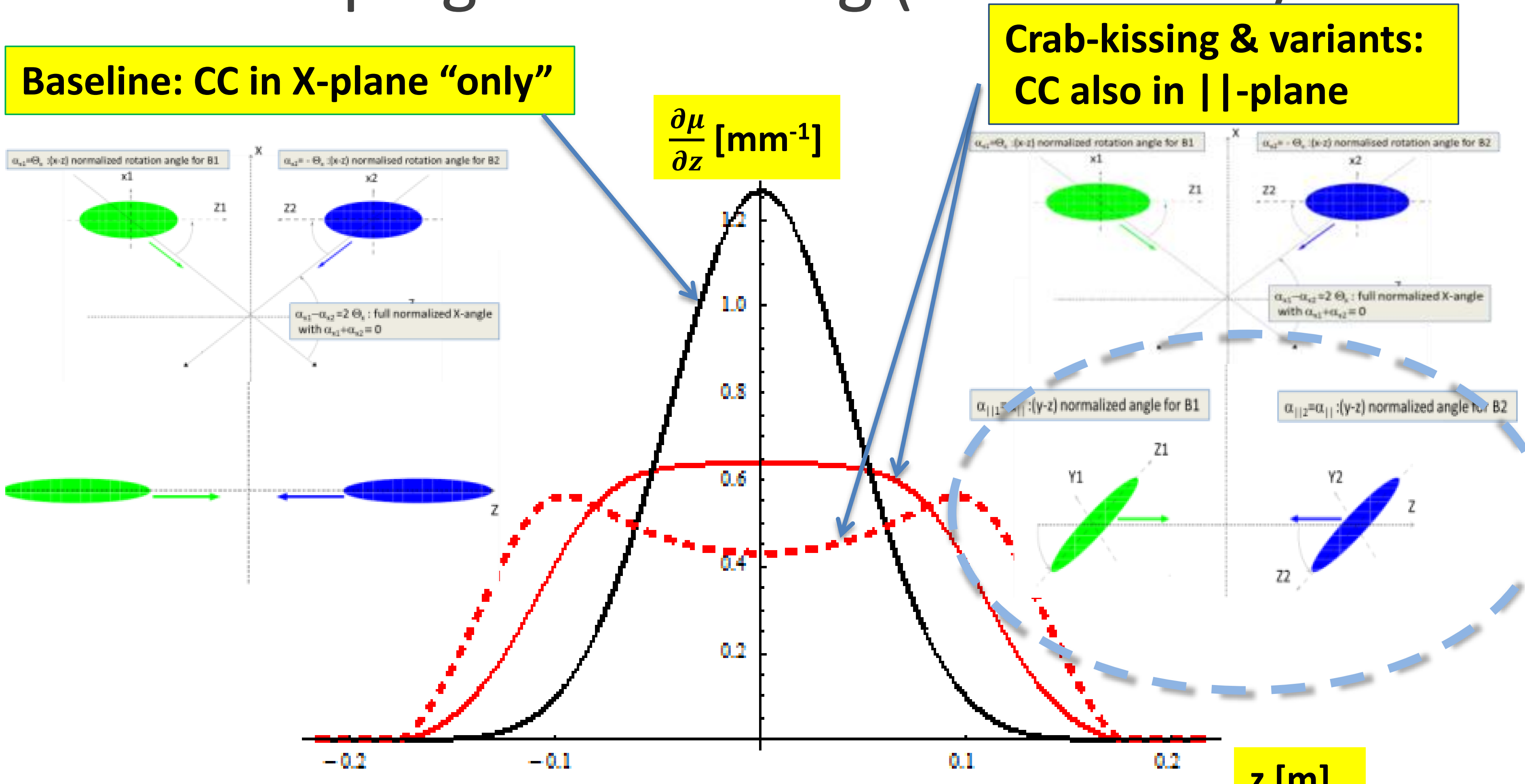




Promises of hollow e-lens:
1. Control the halo dynamics without affecting the beam core;
2. Control the time-profile of beam losses (avoid loss spikes);
3. Control the steady halo population (crucial in case of CC fast failures).

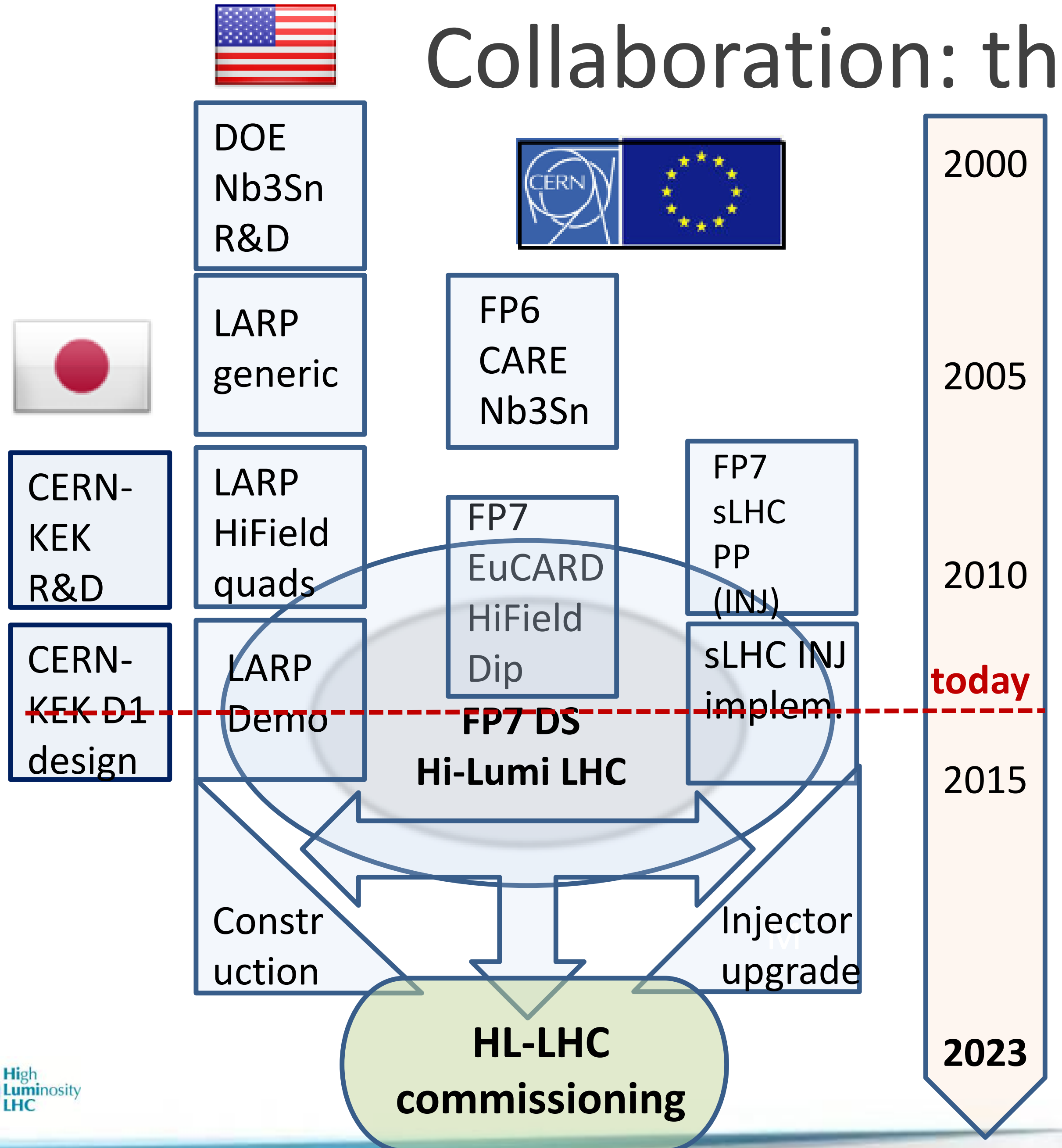
Remarks:
- very convincing experimental experience in other machines!
- full potential can be exploited if appropriate halo monitoring is available.

The **Crab-kissing** (CK) scheme for **pile-up density** shaping and leveling (S. Fartoukh)



... Work on-going together with the machine experiments (S. Fartoukh, A. Valishev, A. Ball, B. Di Girolamo, *et al*.)

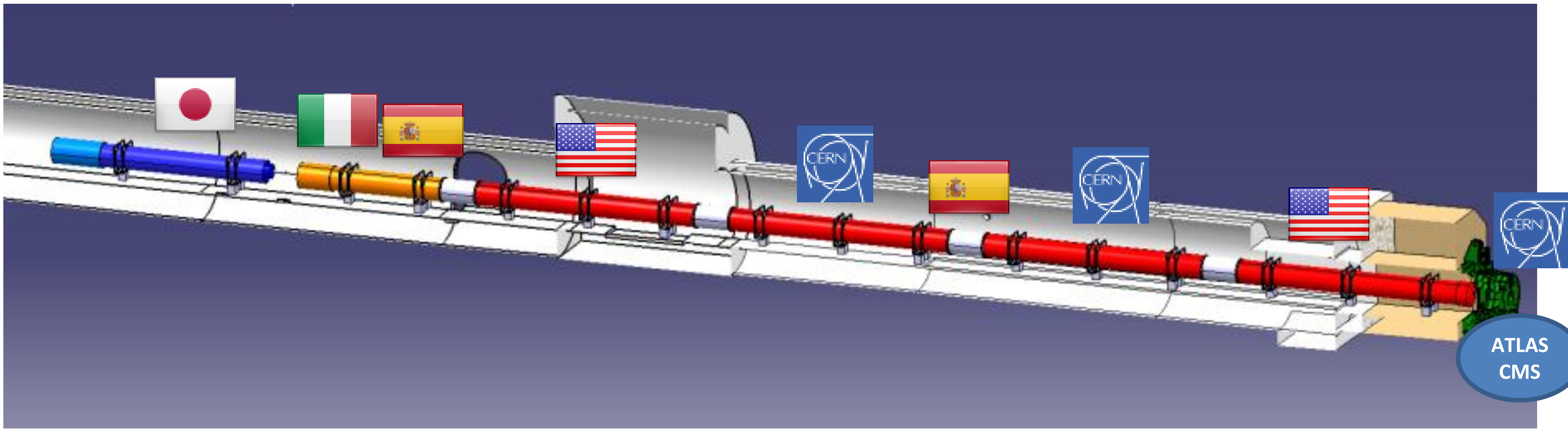
Collaboration: the long way

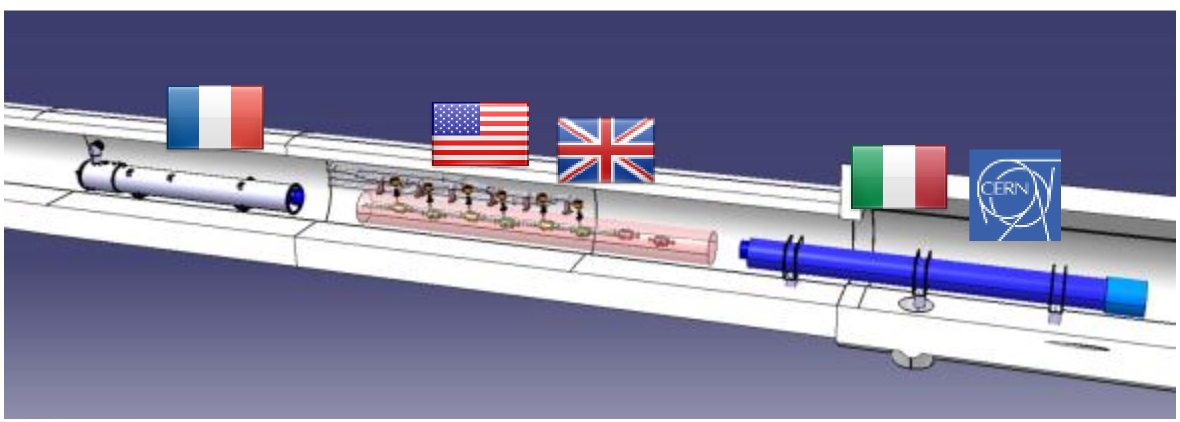


The HL-LHC project formally started in 2010; however it is the focal point of 20 years of <u>converging</u> International Collaboration

High Luminosity LHC Participants

In-kind contribution and Collaboration for HW design and prototypes



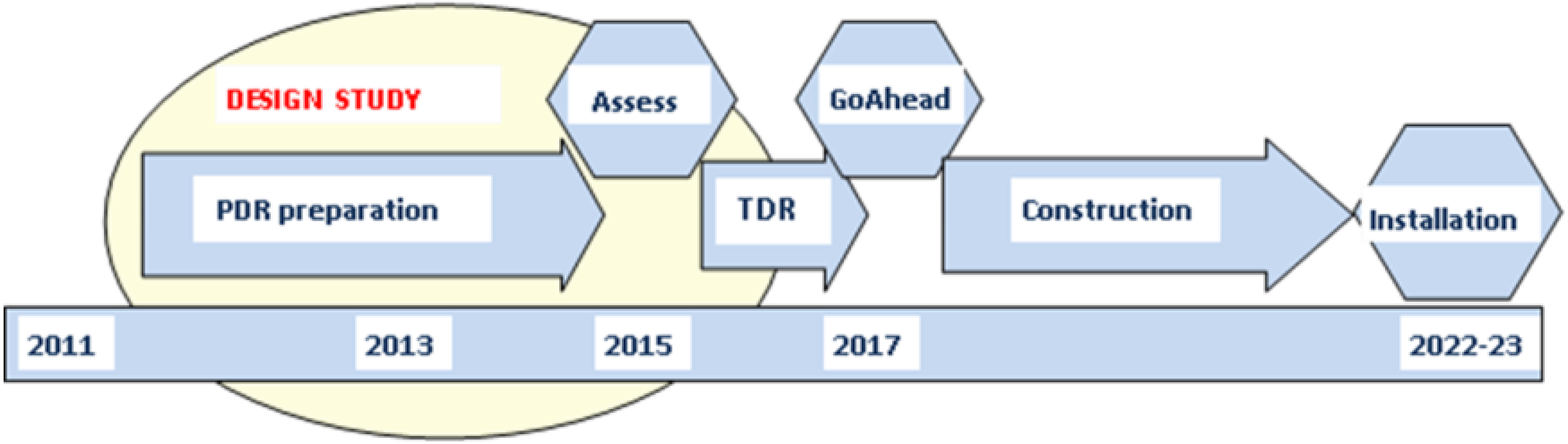


Q1-Q3 : R&D, Design, Prototypes and in-kind **USA**
D1 : R&D, Design, Prototypes and in-kind **JP**
MCBX : Design and Prototype **ES**
HO Correctors: Design and Prototypes **IT**
Q4 : Design and Prototype **FR**

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

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

Implementation plan



- All WP active, from diagnostics to Machine Protection;
- Integration started with vigour as well as QA (workshop soon)
- Cryo, SC links, Collimators, Diagnostics, etc. starts in LS2 (2018)
- Proof of main hardware by 2016; Prototypes by 2017
- Start construction 2017/18 from IT, CC, other main hardware
- IT String test (integration) in 2019-20; Main Installation 2023-24
- Though but – based on LHC experience – feasible
- Cost: 840 MCHF (Material, CERN accounting)