



**High  
Luminosity  
LHC**

**Project presentation to  
*European Particle  
Physics Communicators  
Network***

**Lucio Rossi**

**Project Leader**

**CERN, 5 November 2015**



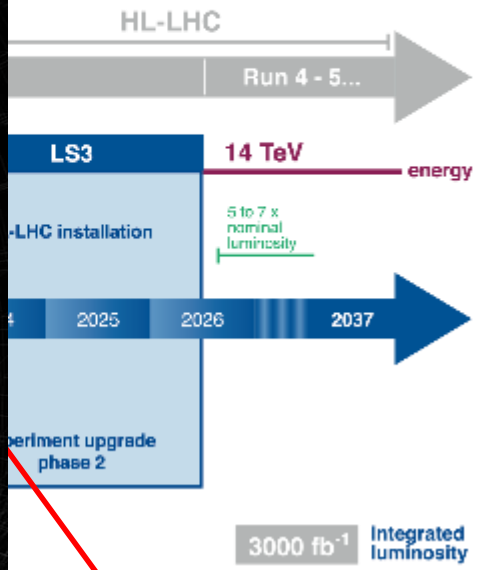
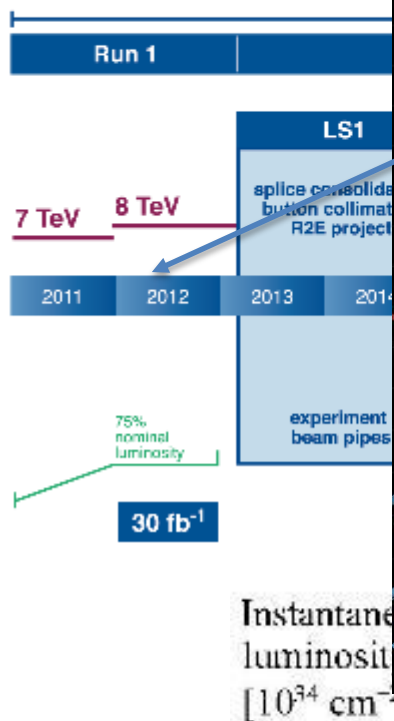
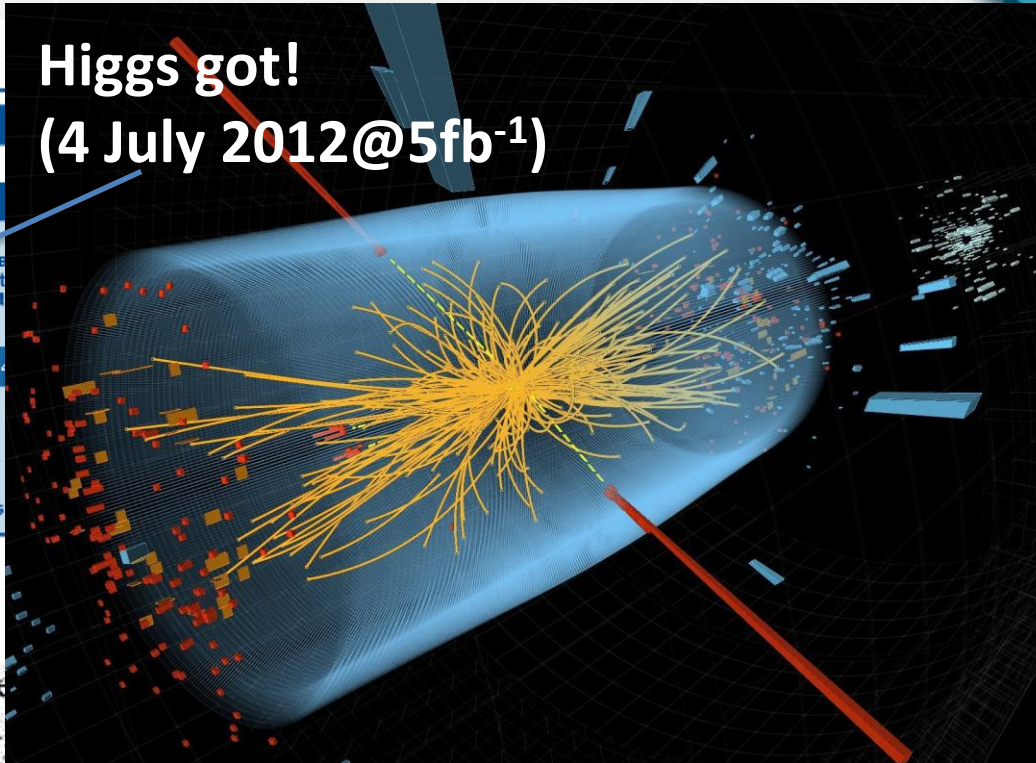
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.



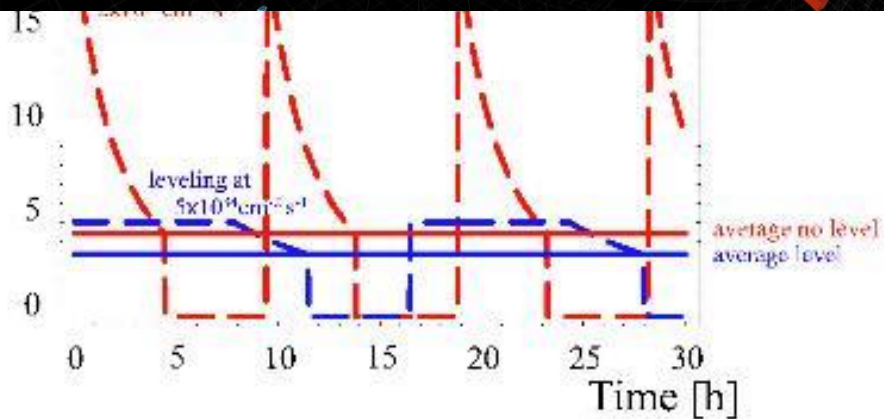
# LHC / HL-LHC Plan



**Higgs got!**  
(4 July 2012@5fb<sup>-1</sup>)



Instantaneous luminosity [10<sup>34</sup> cm<sup>-2</sup> s<sup>-1</sup>]



Levelling!

**Technical limits to lumi increase (Machine & Experiments)**



# 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  **$5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  with levelling**, allowing:

An integrated luminosity of  **$250 \text{ fb}^{-1}$  per year**, enabling the goal of  **$3000 \text{ fb}^{-1}$** .

This luminosity is more than ten times the luminosity reach of the first 10 years of the LHC lifetime.

Concept of ultimate performance (Oct.2013, ECFA & RLIUP) under study:

$$L_{\text{peak}} \cong 7.5 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1} \text{ and } \text{Int. L} \sim 4000 \text{ fb}^{-1}$$

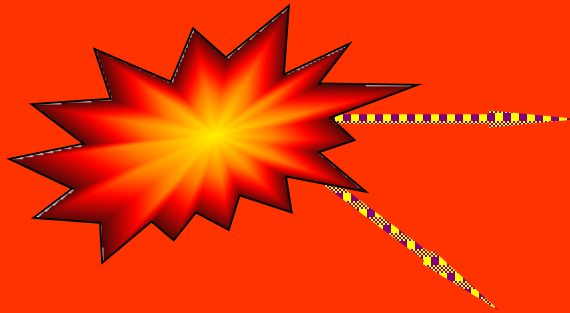
LHC should not be the limit, would Physics require more...

# Energy and luminosity: the two discovery parameters

2 routes to new knowledge about the  
fundamental structure of the matter

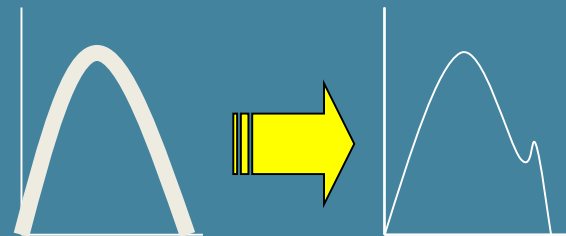
## High Energy Frontier

New phenomena  
(new particles)  
created when the  
“usable” energy  $> mc^2$  [ $\times 2$ ]

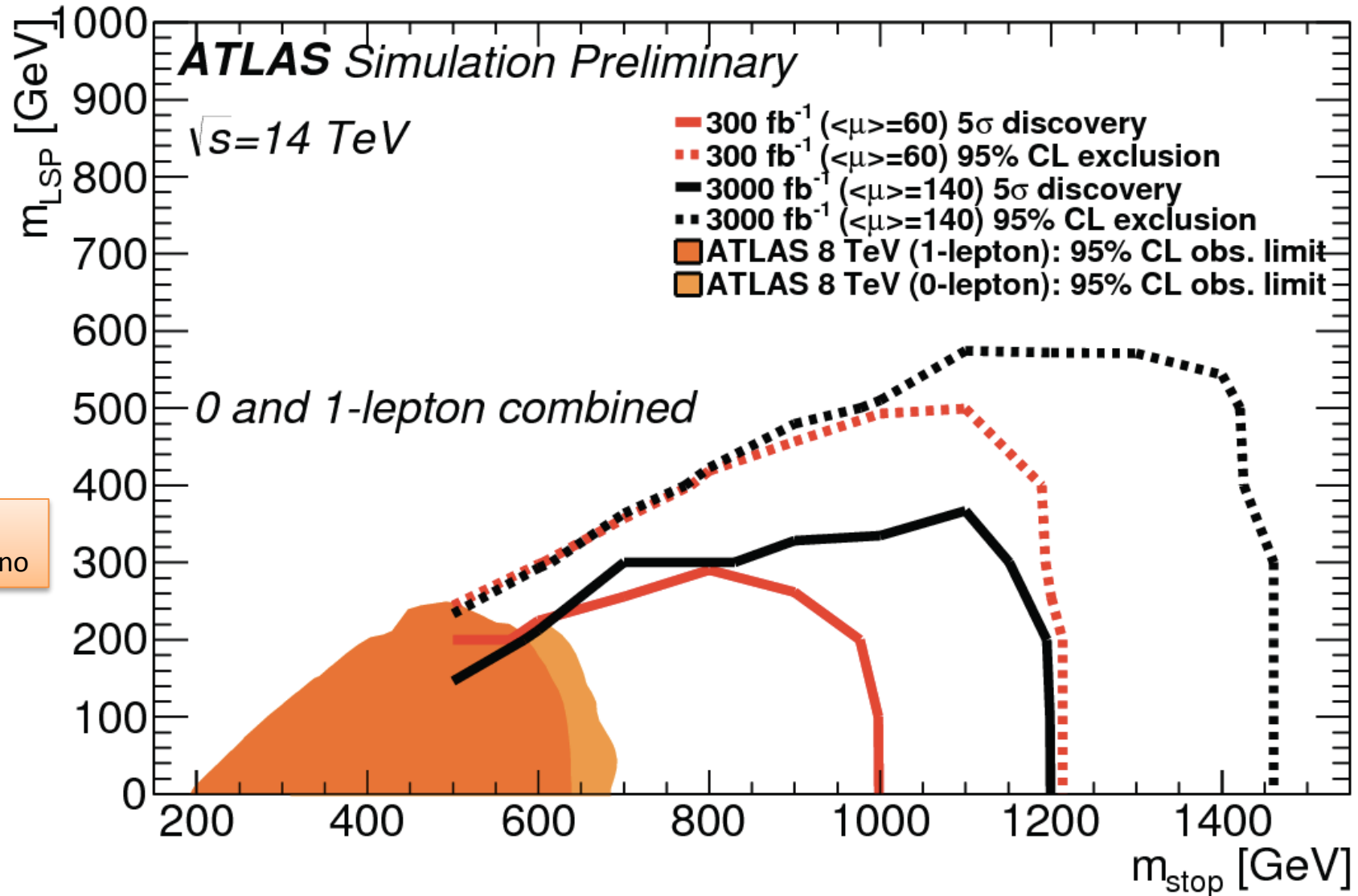


## High Precision Frontier

Known phenomena studied  
with high precision *may* show  
inconsistencies with theory



# HiLumi: more precision... and also new heavier particles (if they exists...)



Courtesy  
M. Mangano







2

**CIVIL ENGINEERING**

2 new 300-metre service tunnels and 2 shafts near to ATLAS and CMS.



3

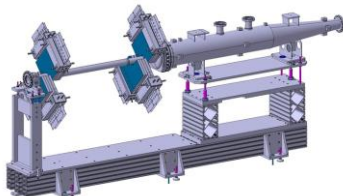
**"CRAB" CAVITIES**

16 superconducting „crab“ cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.

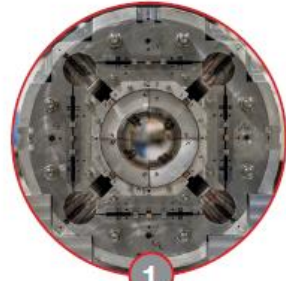
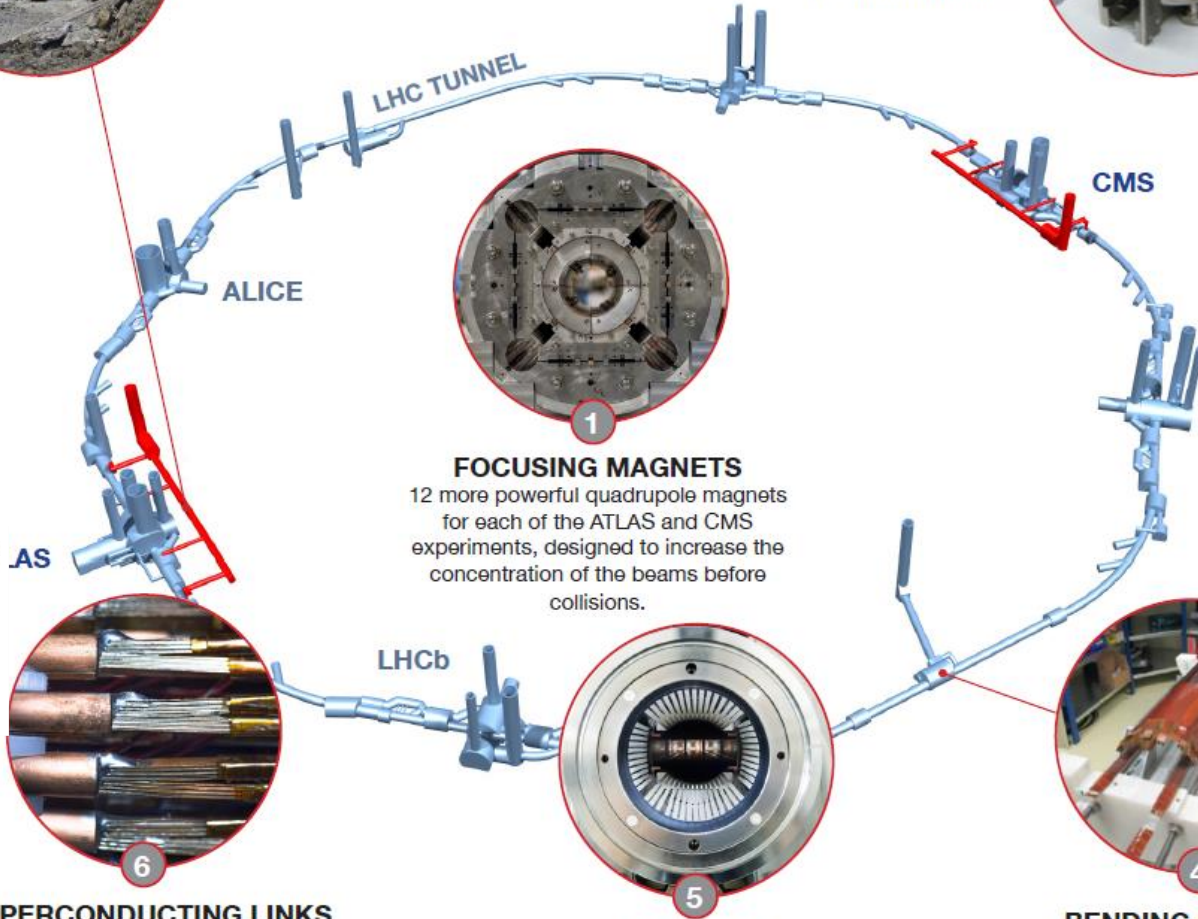
Cryo@P1-P5



Cryo@P4



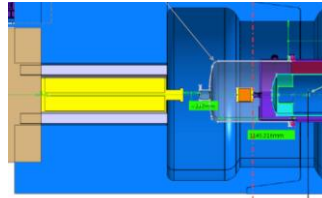
Beam diagnostics  
BGV



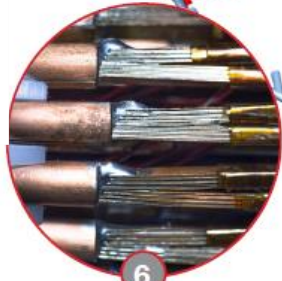
1

**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.



New TAS and VAX



6

**SUPERCONDUCTING LINKS**

Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service tunnels near ATLAS and CMS.



5

**COLLIMATORS**

15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.



4

**BENDING MAGNETS**

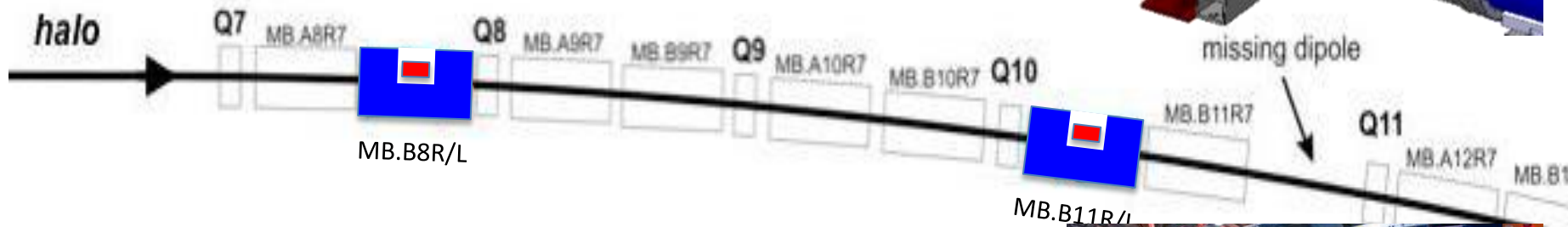
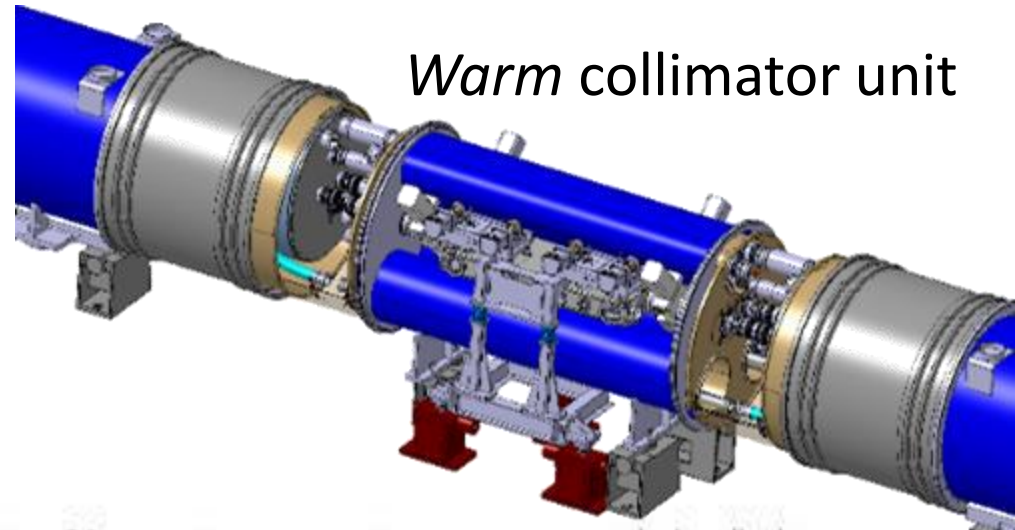
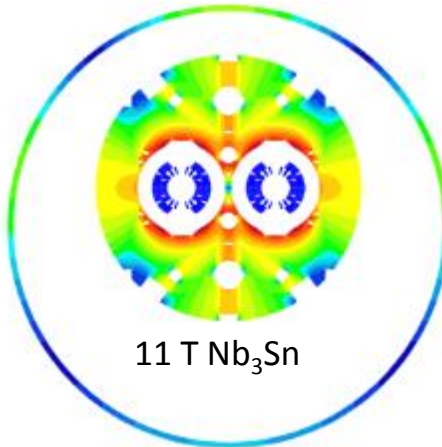
4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.

CERN Novembre 2015



# 11 T dipole with collimation in cold arc

11 T dipole  
twin  
aperture  
magnet



$\int B dL = 119.2 \text{ Tm} @ I_{\text{nom}} = 11.85 \text{ kA}$   
in series with MB with 20 % margin

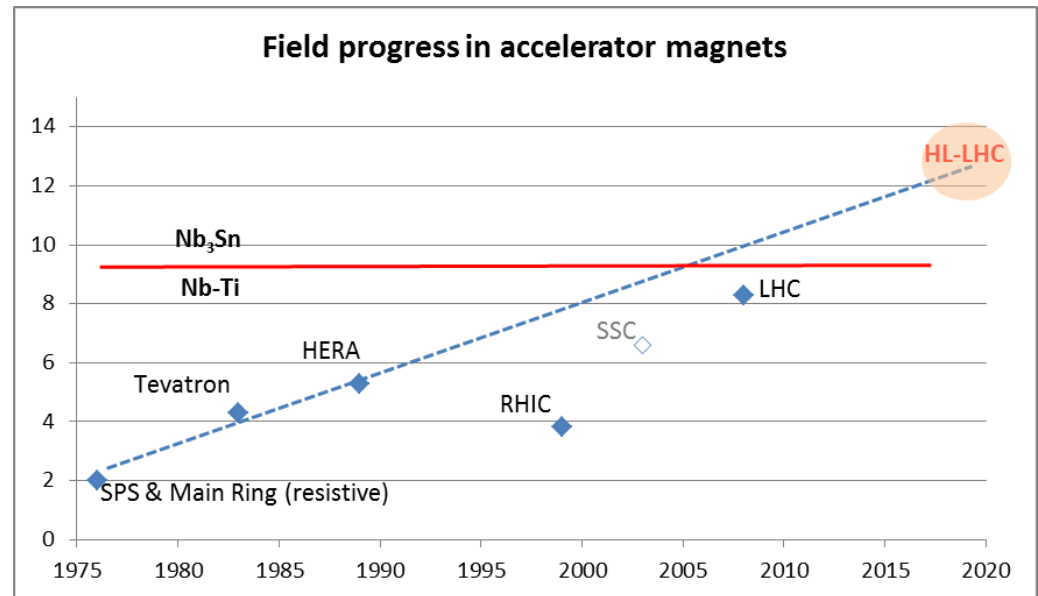
Courtesy of M. Karppinen, F. Savary, D. Duarte





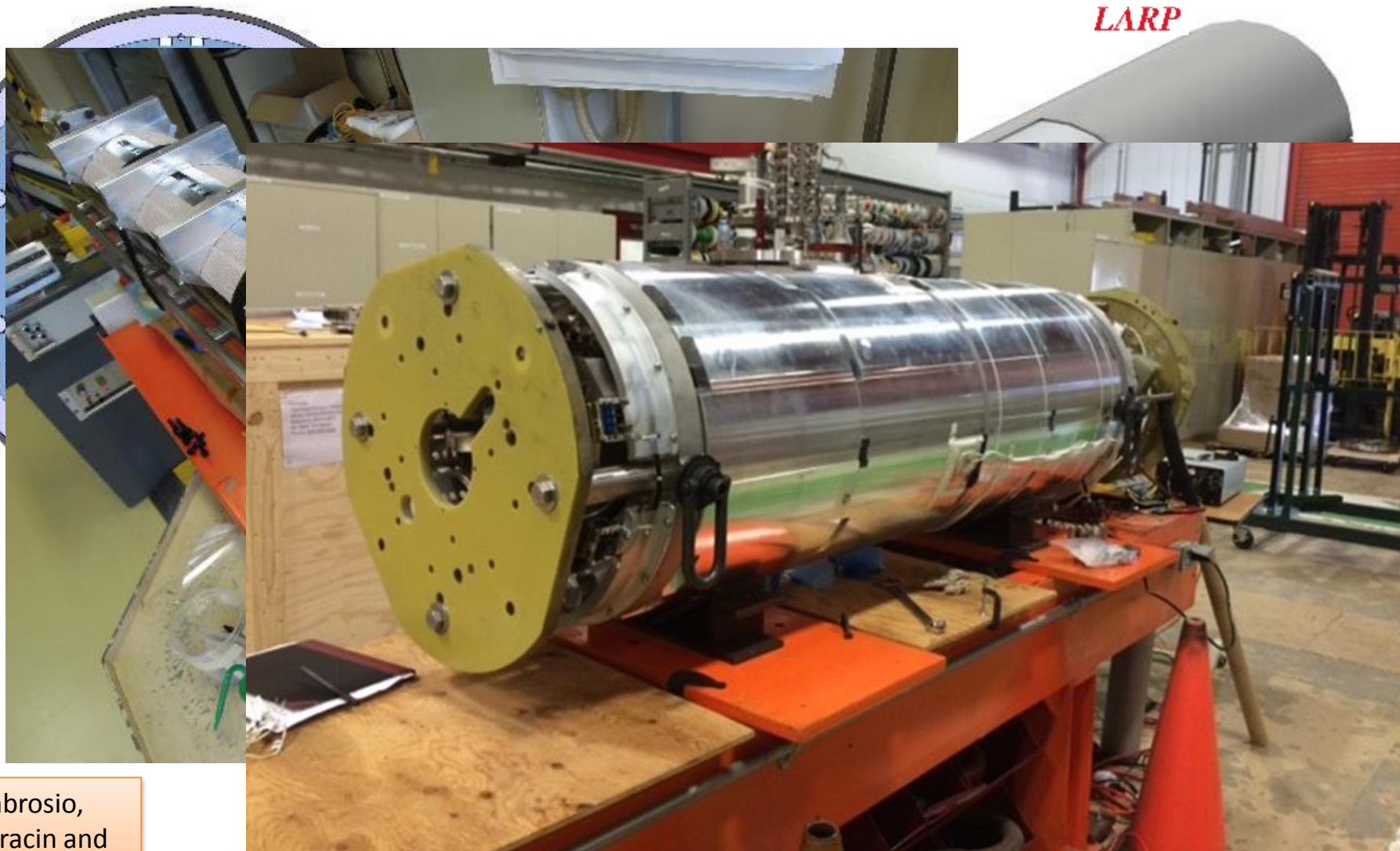
# The Hilumi backbone: IT Quads

- 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 ; use of Nb<sub>3</sub>Sn**
  - 11 T dipole (designed for 12.3 T peak field, 60 mm)
  - New IT Quads features 140 T/m in 150 mm, B~12 T operational field, **designed for 13.5 T**.



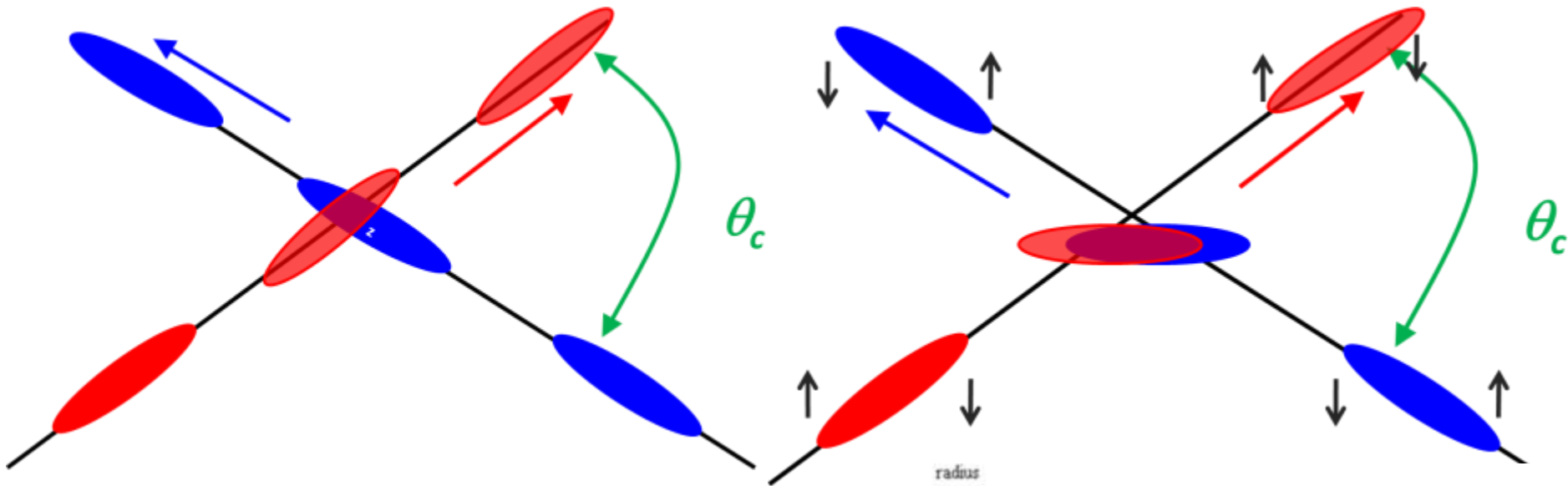


# New IT Quadrupole first short prototype is coming! Strong US-LARP involvement!



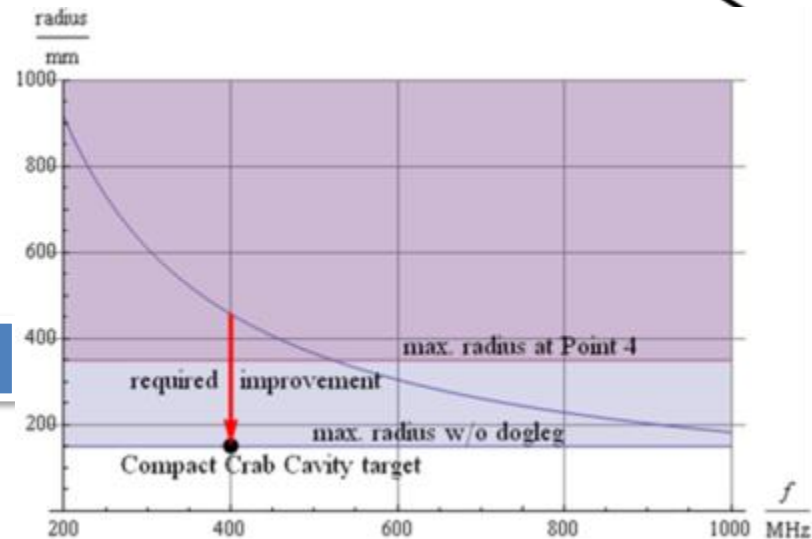
G. Ambrosio,  
P. Ferracin and  
E. Todesco

# Effect of the Crab Cavities



- RF crab cavity deflects head and tail in opposite direction so that collision is almost “head on” and luminosity is maximized.
- COMPACT design! New concepts.

New concept  $\Rightarrow$  a lot of different interesting designs

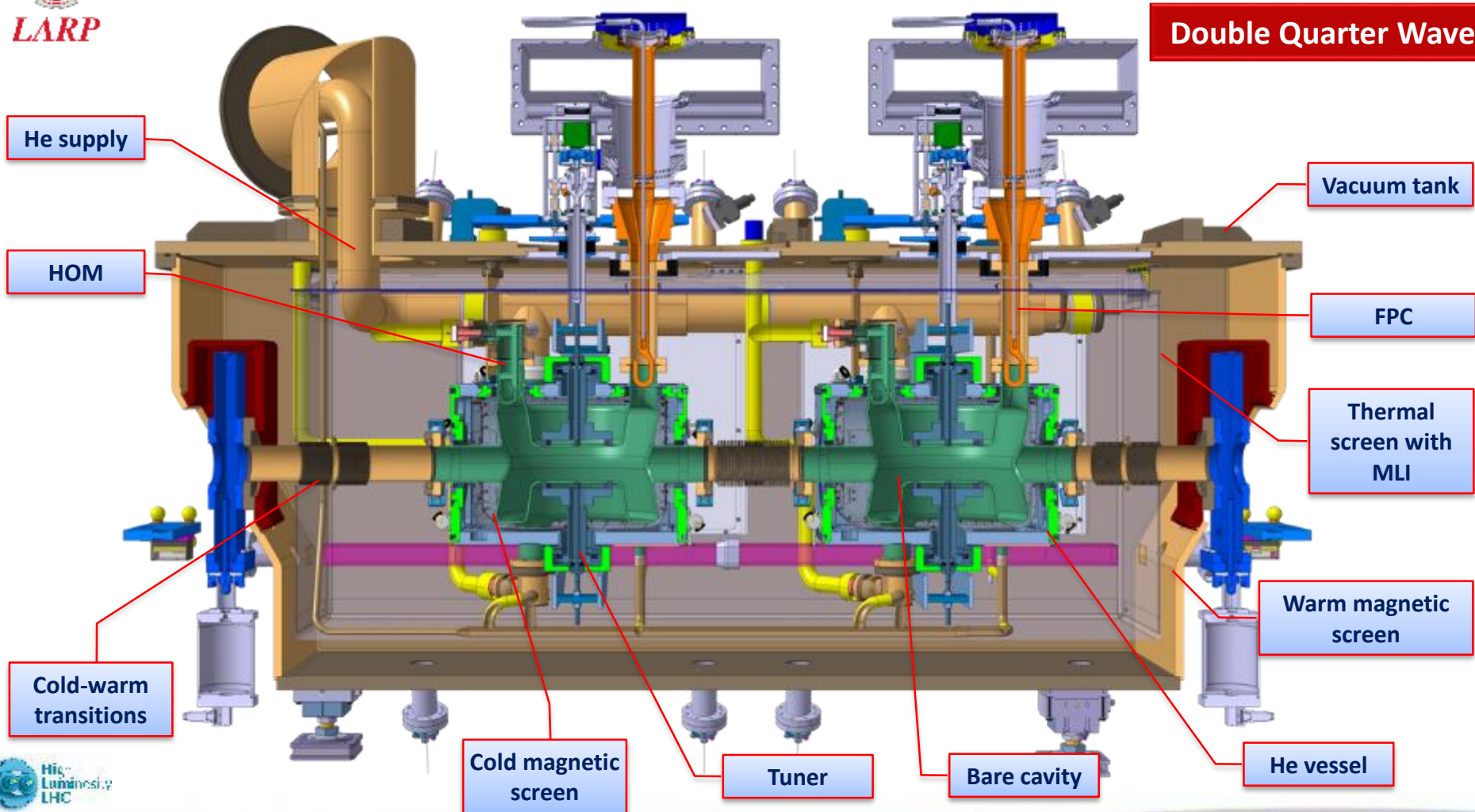


# SCRF Crab Cavity complexity!

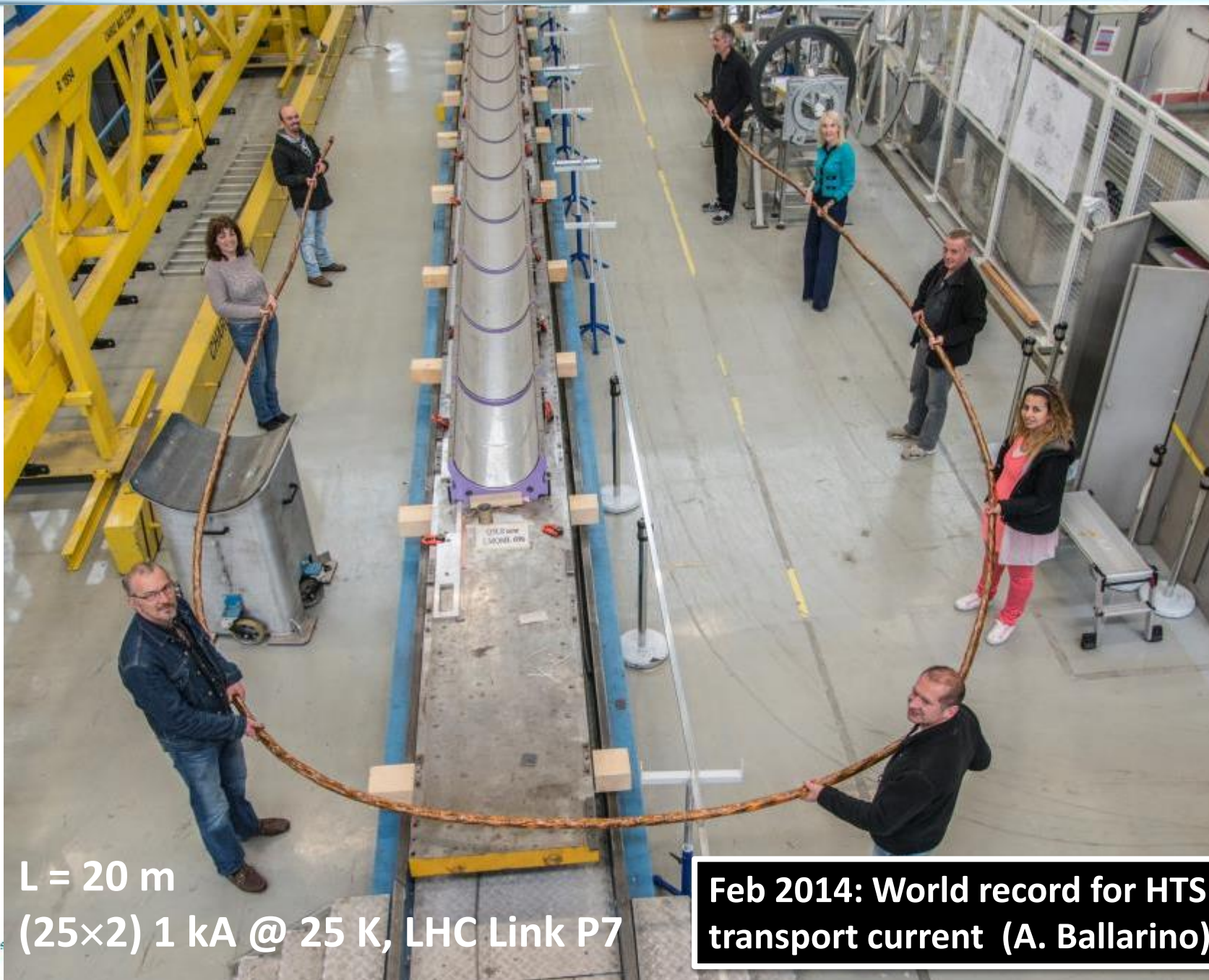
- We will make a test in SPS before LS2.



R. Calaga and O. Capatina







L = 20 m  
(25×2) 1 kA @ 25 K, LHC Link P7

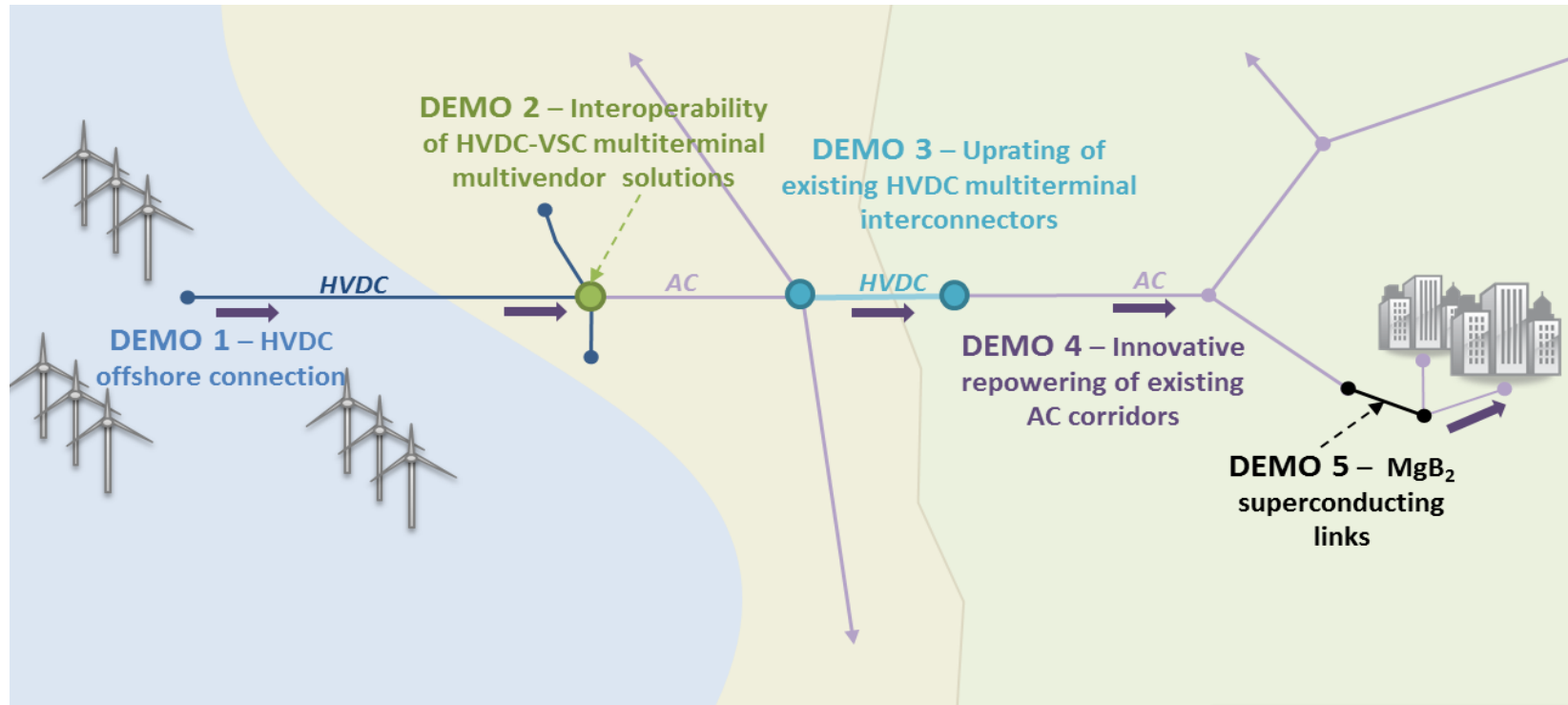
Feb 2014: World record for HTS  
transport current (A. Ballarino)





# Spin off of HiLumi: BestPaths Project

Five top technology demonstrations including a HVDC MgB<sub>2</sub> superconducting link

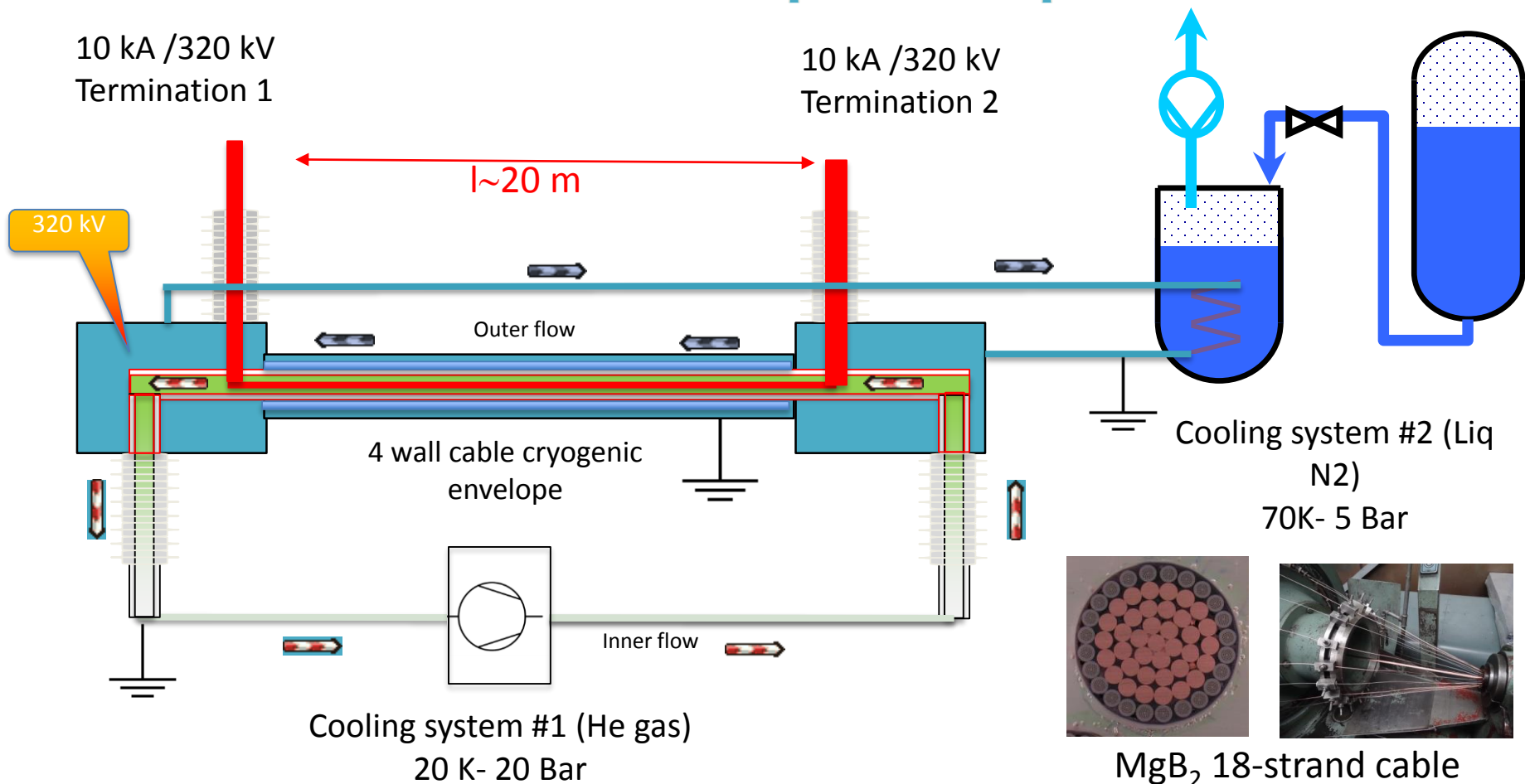


Courtesy A. Ballarino

10 kA, 320 kV DC MgB<sub>2</sub> line, 20 K operation

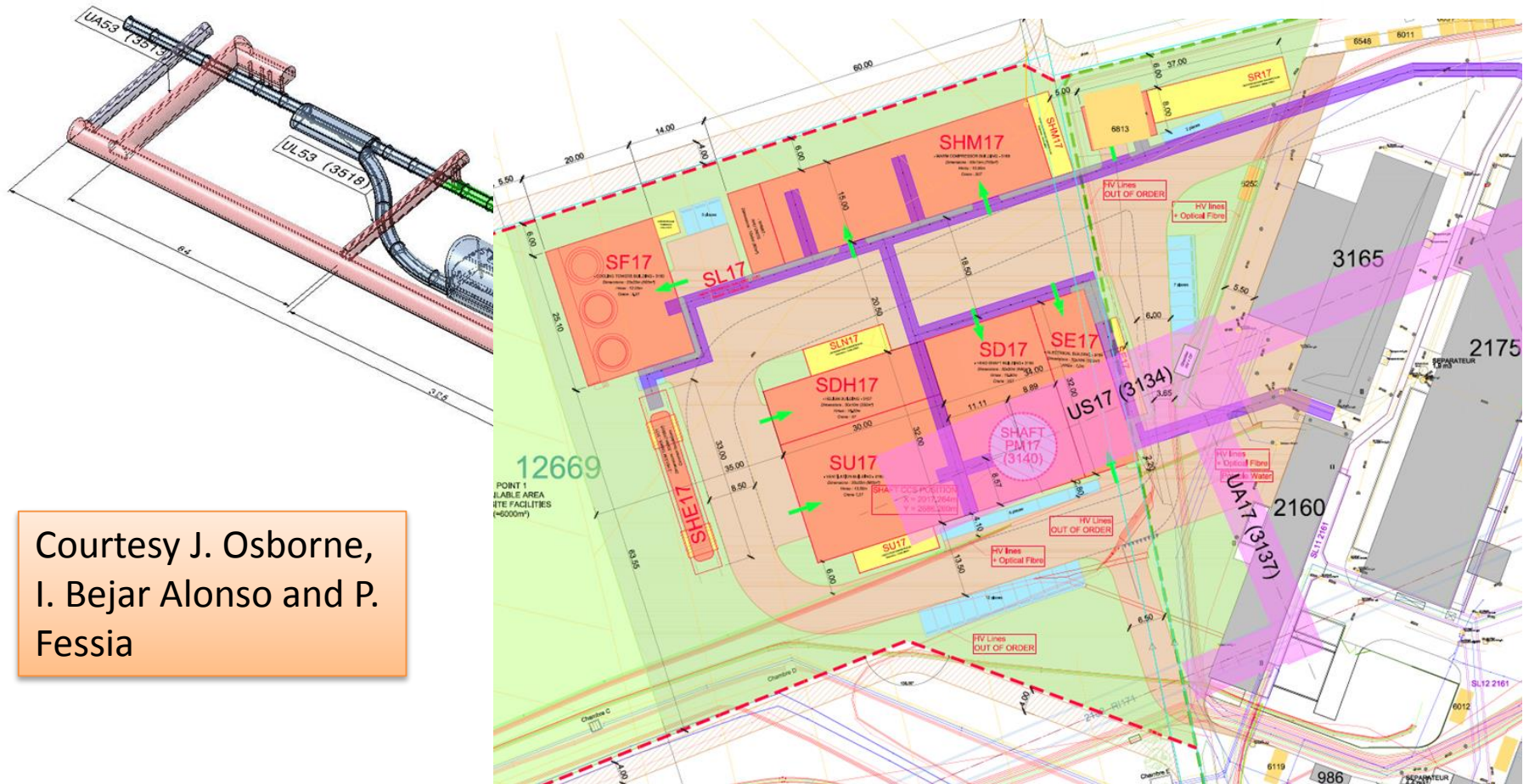
# BestPaths Project

Courtesy A. Ballarino



Presented by Nexans at EUCAS 2015 Conference

May 2013: HiLumi as 1st priority in EU strategy  
Sept 2015: budget CERN Council (950 MCHF+1600 FTE-y)  
NOW: launching C.E. consultancy contracts



Courtesy J. Osborne,  
I. Bejar Alonso and P.  
Fessia

# A few milestones...

## HL-LHC Plan



FP7  
Hi-Lumi  
**DESIGN STUDY**

PDR PREPARATION

ASSESS & TDR

CONSTRUCTION AND TEST

INSTALLATION

PHYSICS

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040

Launch CE contracts

IP1 & IP5 excavation starts

TEST first IT QUAD and first Twin 11 T

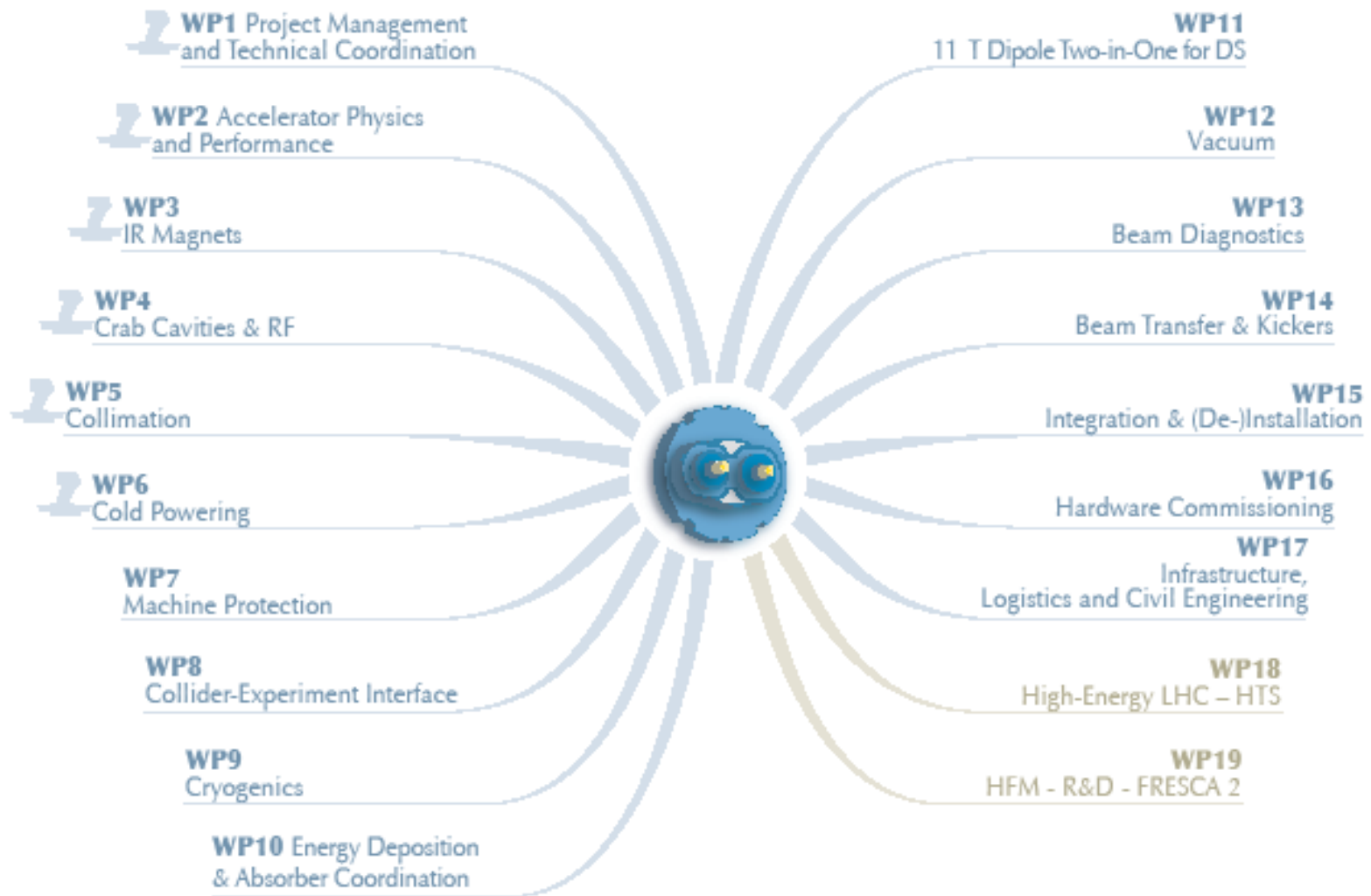
TEST LONG 11 T and IT Quad

TEST first final Crab cavity

TEST Crab Cavity in SPS







# High Luminosity LHC Participants



Science & Technology  
Facilities Council



UNIVERSITY OF  
LIVERPOOL

LANCASTER  
UNIVERSITY

MANCHESTER  
1824



UNIVERSITY OF  
Southampton



EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

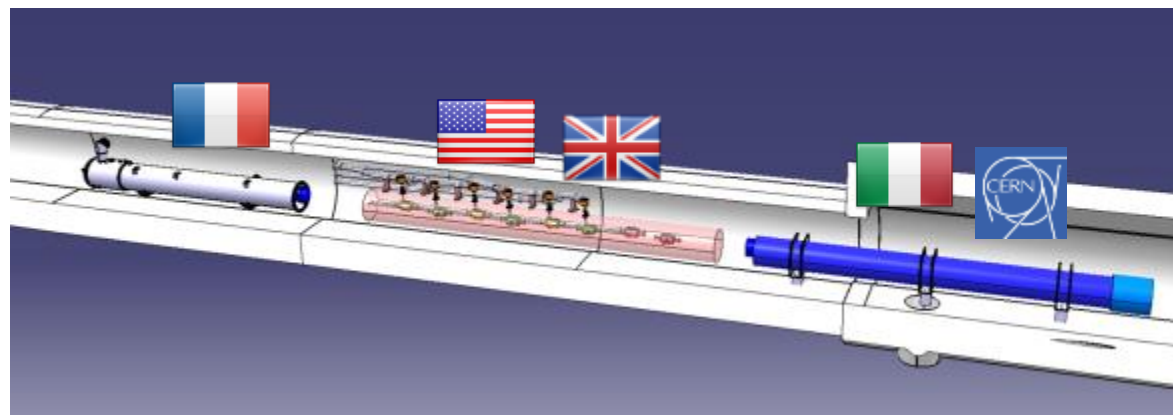
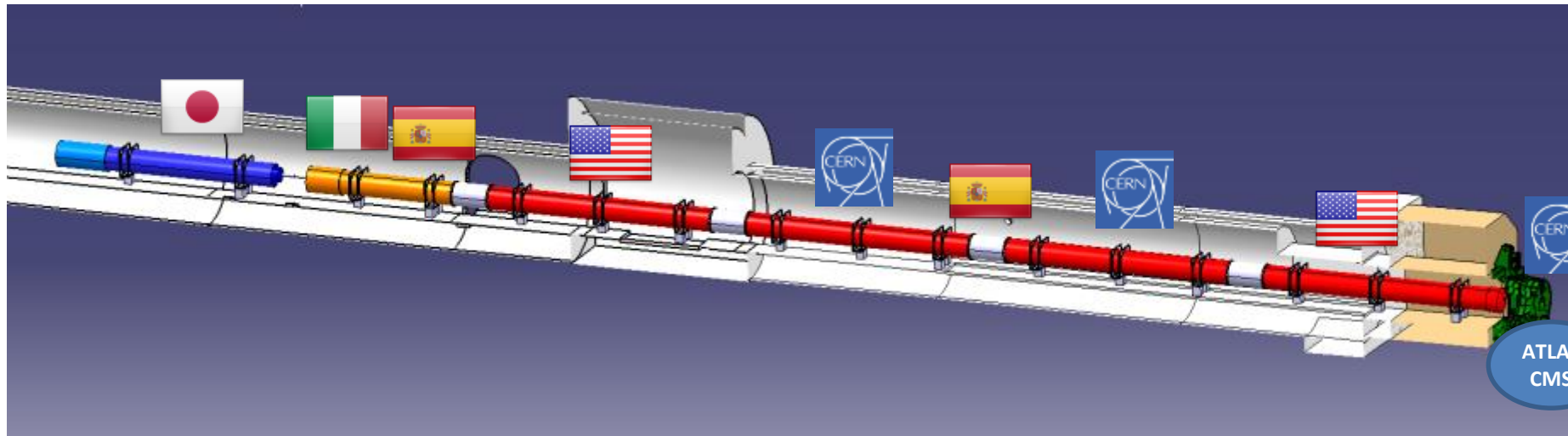
CSIC  
Consejo Superior de Investigaciones Científicas

Ciemat  
Centro de Investigaciones  
Energéticas, Medicinables  
y Tecnológicas

INFN  
Istituto Nazionale  
di Fisica Nucleare



# 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**

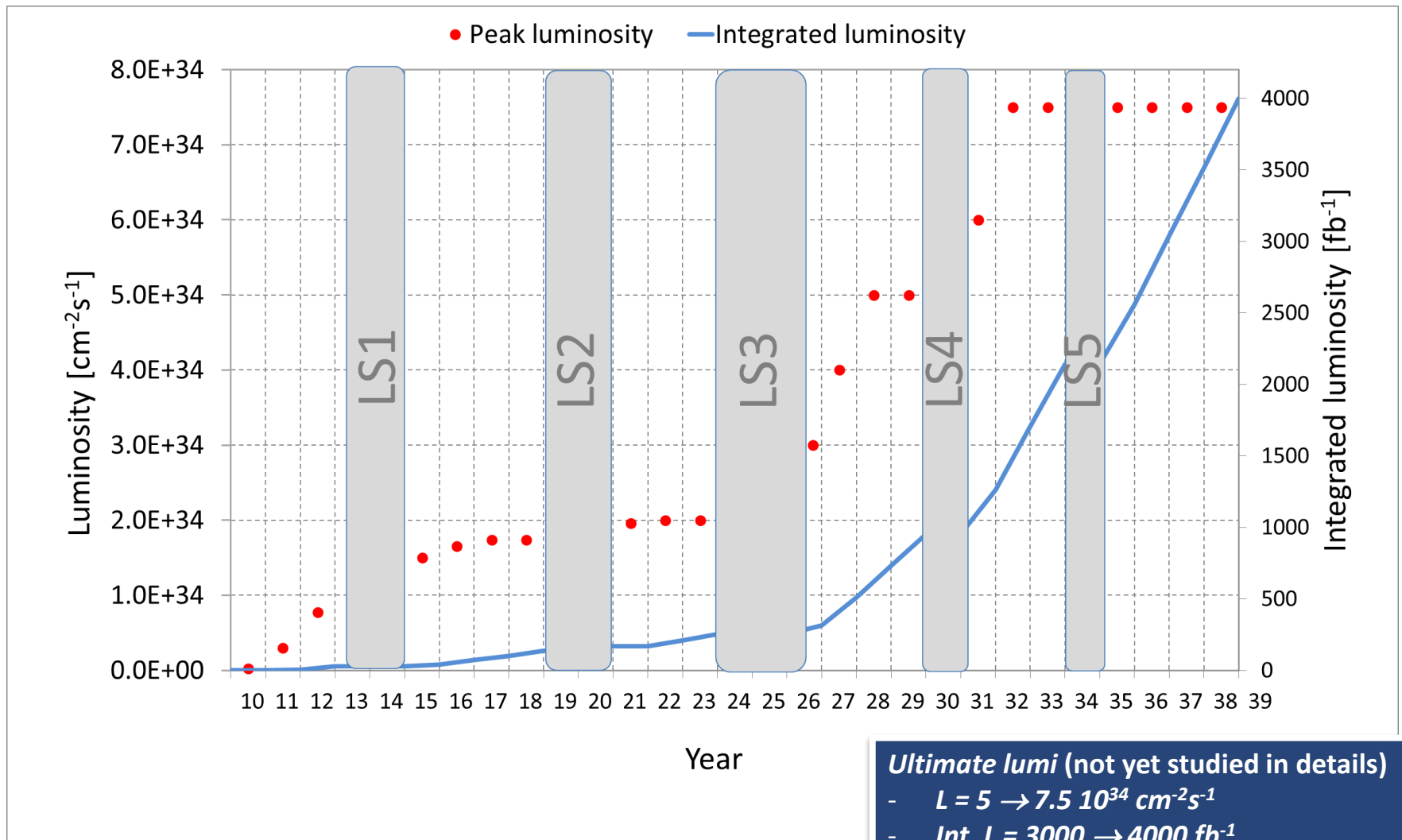
HO Correctors: Design and Prototypes **IT**

Q4 : Design and Prototype **FR**

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

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

# HL-LHC *ultimate performance*



**Ultimate lumi (not yet studied in details)**

- $L = 5 \rightarrow 7.5 \cdot 10^{34} \text{ cm}^2\text{s}^{-1}$
- $\text{Int. } L = 3000 \rightarrow 4000 \text{ fb}^{-1}$
- $\text{Pile up } \mu \sim 200$





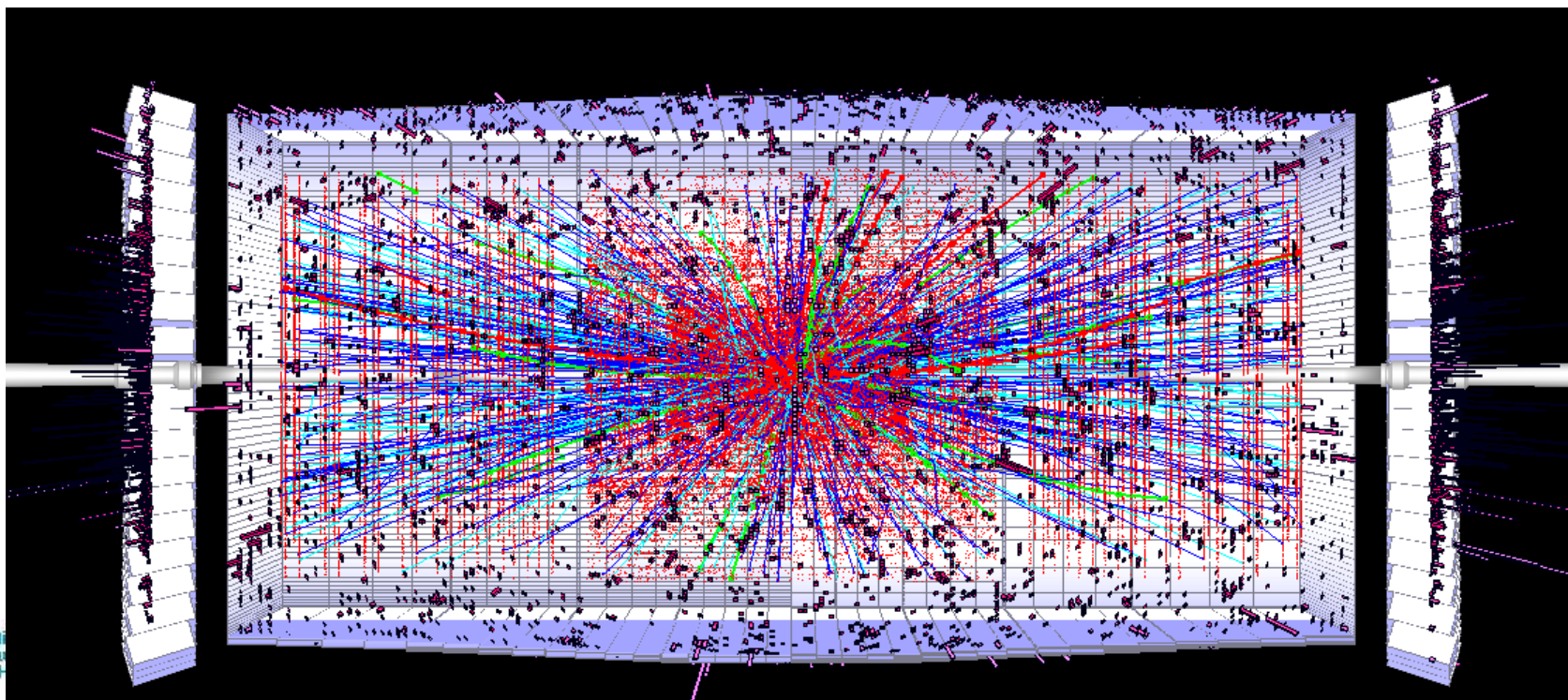


# High Luminosity LHC

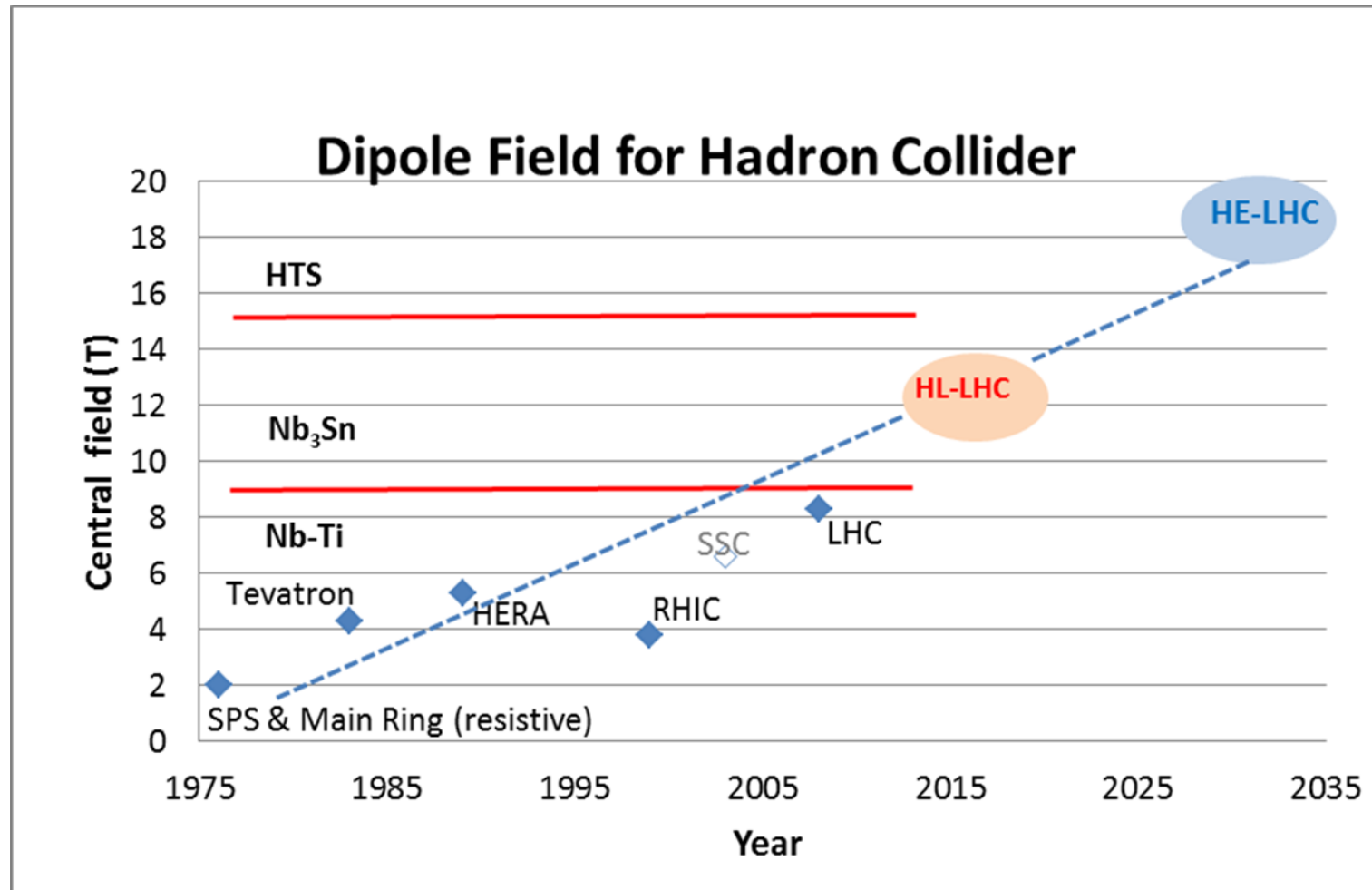
HL-LHC will generate a powerful light... that experiments has to manage (pile up...)



The HiLumi LHC Design Study (a sub-system of HL-LHC) is cofunded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404



# HiLumi LHC is for physics discovery... and to prepare the next leap forward





# Beyond the LHC: the FCC's

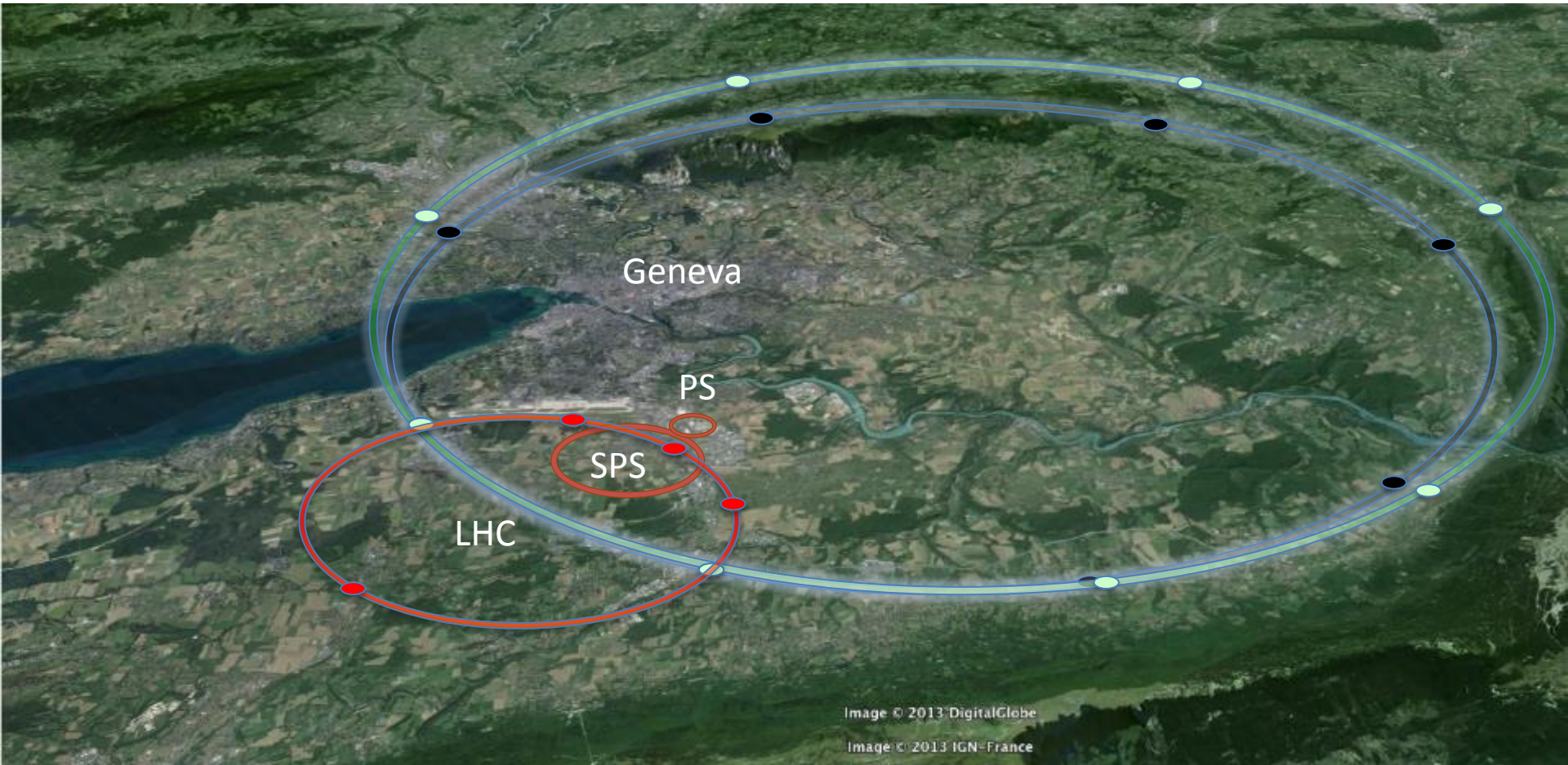


Image © 2013 DigitalGlobe  
Image © 2013 IGN-France

## LHC

27 km, 8.33 T  
14 TeV (c.o.m.)  
1300 tons NbTi  
0.2 tons HTS

## HE-LHC

27 km, **20 T**  
**33 TeV (c.o.m.)**  
3000 tons LTS  
700 tons HTS

## FCC-hh

80 km, **20 T**  
100 TeV (c.o.m.)  
9000 tons LTS  
2000 tons HTS

## FCC-hh

100 km, **16 T**  
100 TeV (c.o.m.)  
6000 tons Nb<sub>3</sub>Sn  
3000 tons Nb-Ti





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