A bright future for LHC : the High Luminosity collider

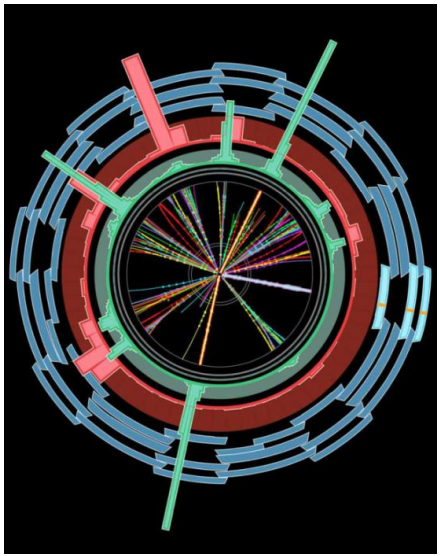
Lucio Rossi – HL-LHC Project Leader

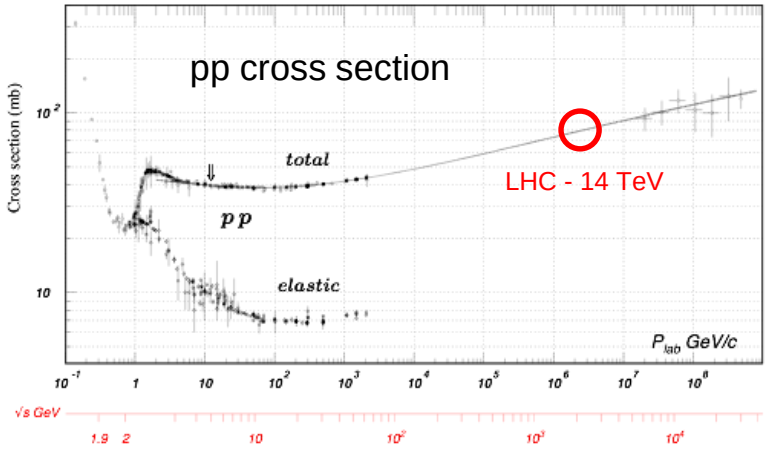
Talks fo the CERN guides – Globe – 26 February 2019

After energy, luminosity is the most important parameter of a collider

$$\frac{dN_{event}}{dt} = L\sigma_{event}$$

We can say : more luminosity → more collisions…





Particle accelerators like generator of very fine light they use the «light», of quantum mechanics

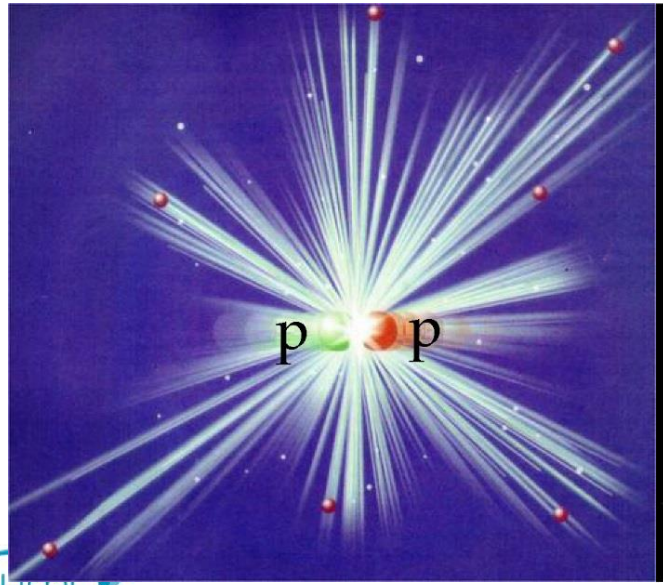
Accelerators | Microscopes | Binoculars | Optical, radio télescopes

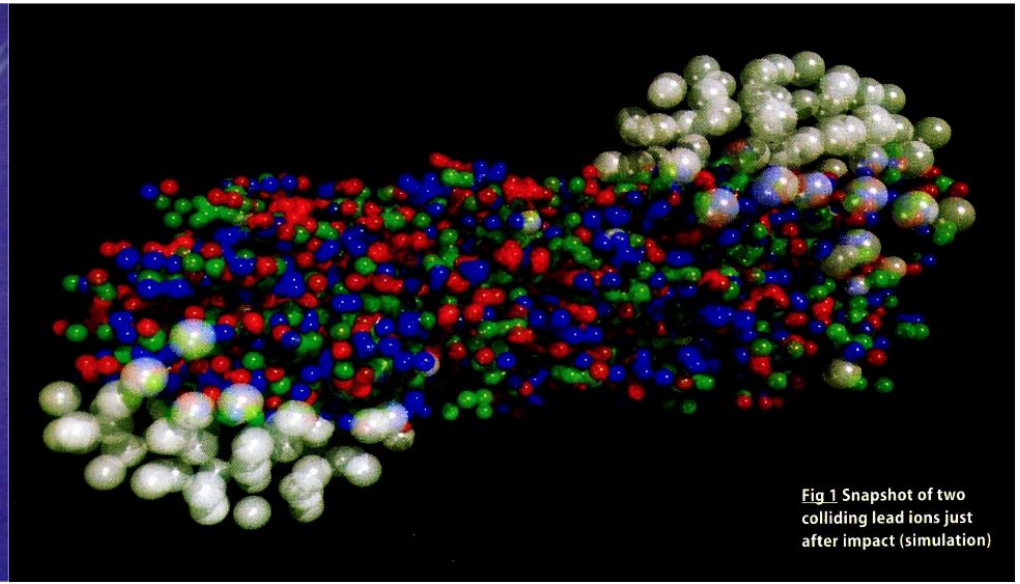
Particle physics looks at matter in its smallest dimensions and accelerators are very fine microscopes or, better, ***atto-scopes!***

$\lambda = h/p$; @LHC: $T = 1\ TeV \Rightarrow \lambda \cong 10^{-18}\ m$

Accelerators also a wonderful «time macchines»

- Trip back toward the Big Bang: $t_{\mu s} \cong 1/E^2_{Gev}$
- t ≅ 1 ps for single particle creation
- t ≅ 1 μs for collective phenomena QGS (Quark-Gluon Soup)

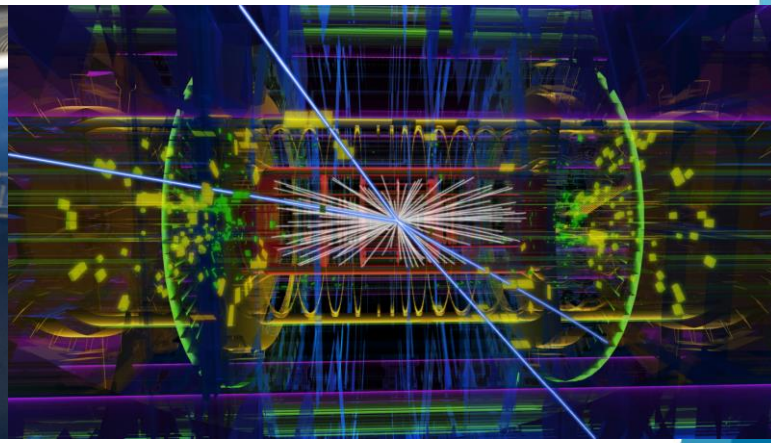




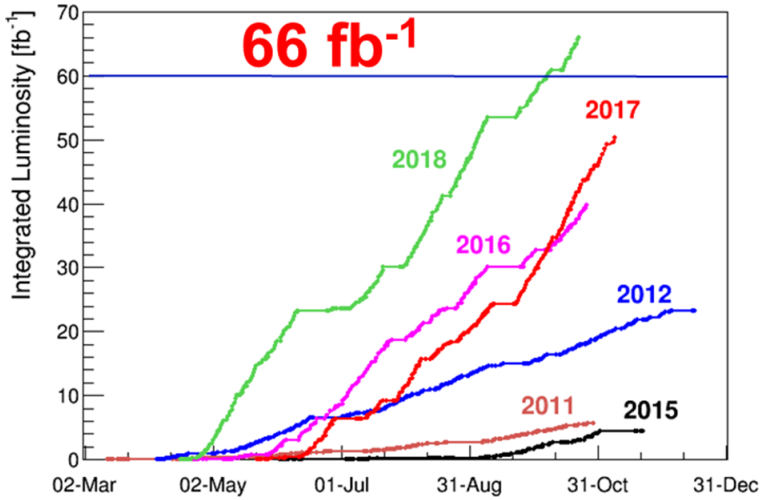
How well works the LHC today?

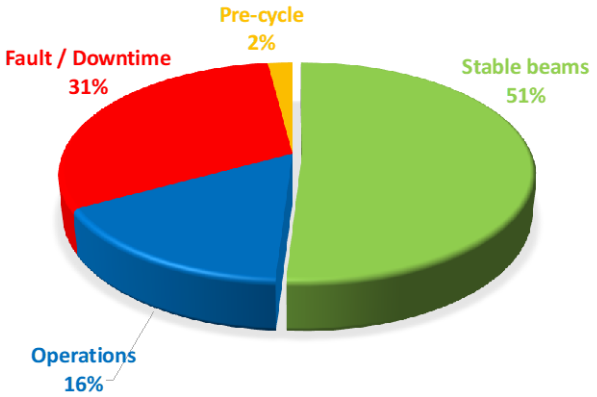
LHC works very well.

We arrived at 93% of the collision energy for what LHC has been designed for.
(Maybe we will reach 100% in 2021, see a few slides after this one)
And luminosity at peak is almost double than the design of the LHC (of course there were margins); while in integrated luminosity we are about 20% above our objectives.



LHC today



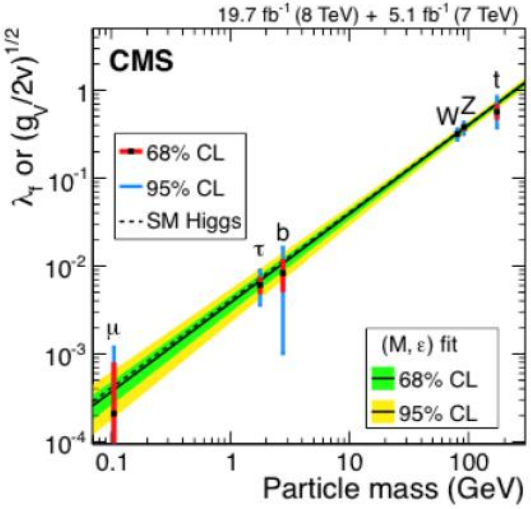


Period	Int. Luminosity [fb-1]
Run 1	29.2
Run 2: 2015	4.2
Run 2: 2016	39.7
Run 2: 2017	50.2
Run 2: 2018	66.0
Total Run1 + Run 2	189.3

Goal of Run1+Run2 was 150 fb-1!

Wvoléution of energy and luminosity in LHC.

Energy stays constant



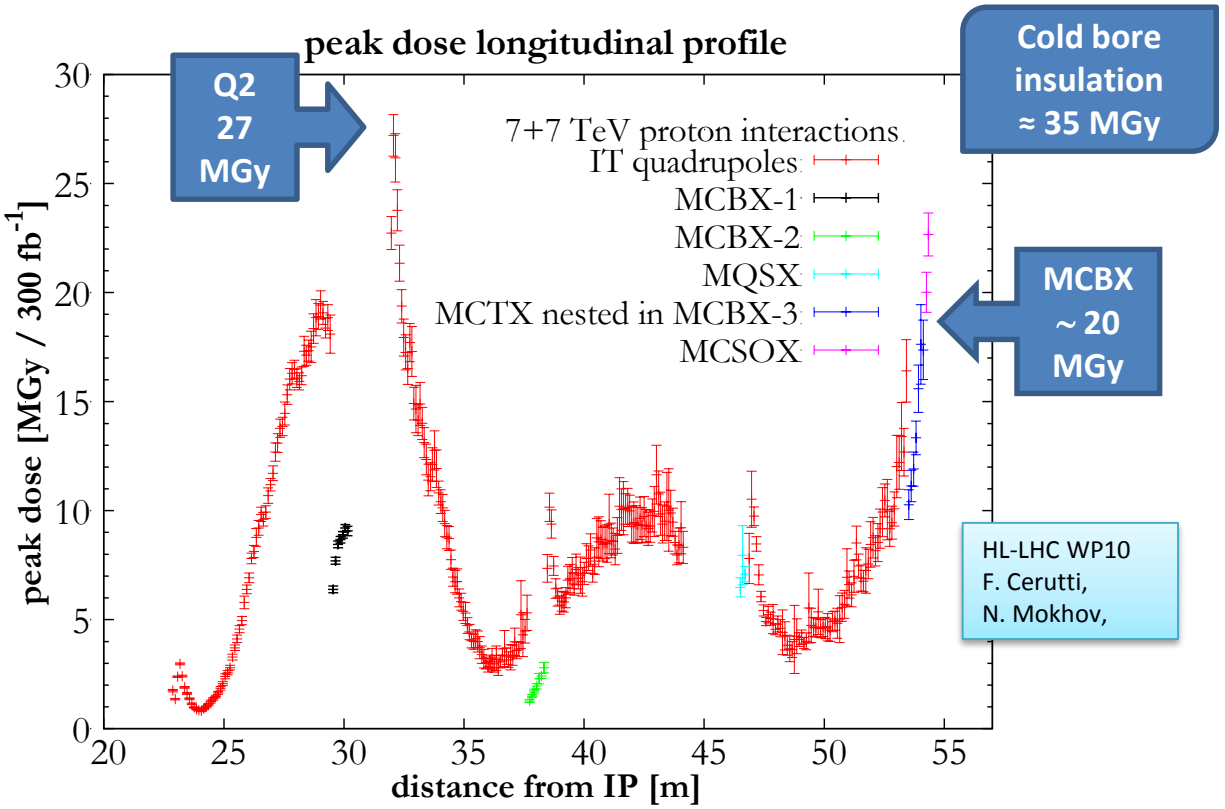
Augmentation de l'énergie et de la luminosité

At about 2024 we will reach a few limitations (that we knew since the design time of the LHC).

- Radiation damage limit in the magnets near the experiments and inside the experiemnts (Inner Tracker especially)
- Cryogenic limit of the magnets near experiment, (IT quadrupoles), so we need to make different design to increase.
- Change triplets (and experiment IT) needs a very Long Studown → we «profit» to substantially increase **luminosity**

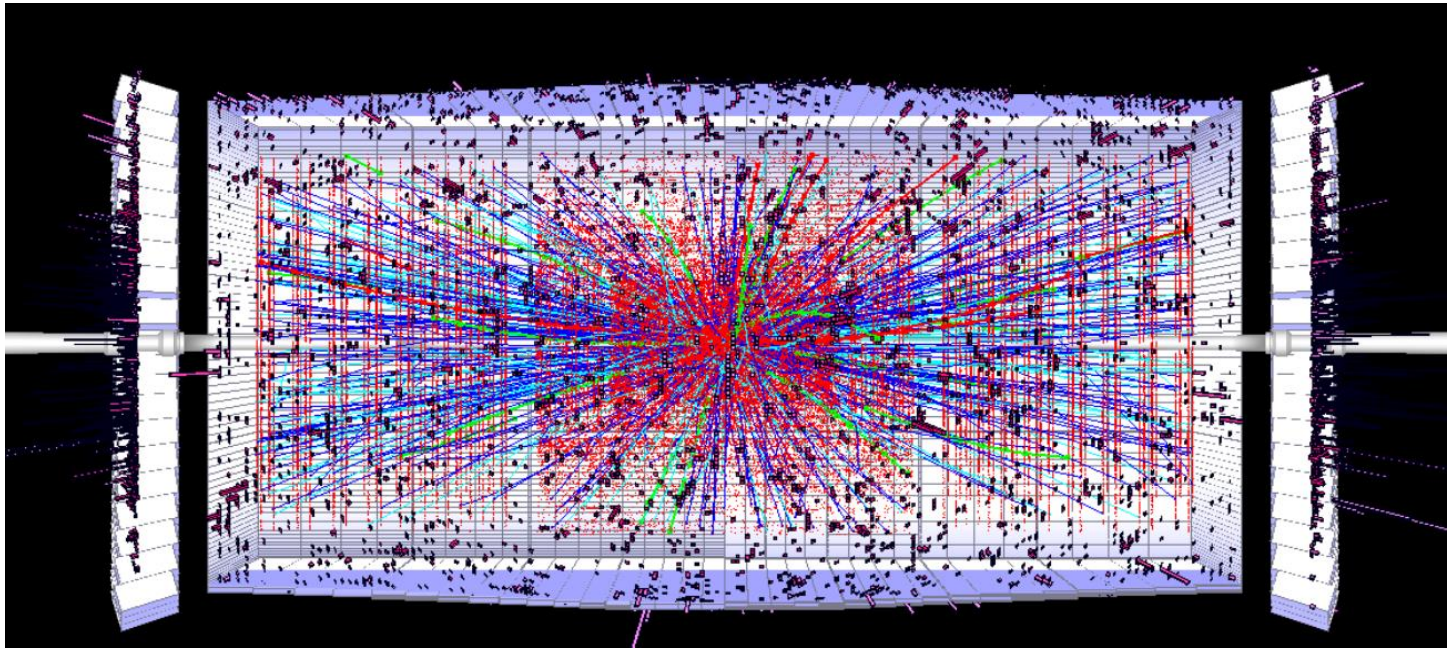
The technical trigger of the upgrade: Radiation damage in low-beta triplet region

Warning dose :
> 30 MGy
Critical dose: ~
> 50 MGy



HL-LHC WP10
F. Cerutti,
N. Mokhov,

High Luminosity: a bright future for the LHC
Generate more light → machine upgrade
Better eyes to profit of higher luminosity → detector upgrade



Luminosity the main ingredients

$$\dot{N}_{evt} = L \times \sigma_{evt}; N_{evt} = \int L dt \times \sigma_{evt}$$

L_{int}

Beam current

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

energy

Beam size

Beam current and emittance: involve injection chain and whole ring
β* involves «only» 2 IRs, 2x600 m

$$L_0 = 1 \cdot 10^{34}\ cm^{-2} s^{-1}$$

LHC has been designed for L_0 with margin
All systems have ~ designed to withstand $2L_0$ (to be achieved by increasing N_b x 1.5)

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$$\dot{N}_{evt} = L \times \sigma_{evt}; N_{evt} = \int L dt \times \sigma_{evt}$$

L_{int}

Beam current

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

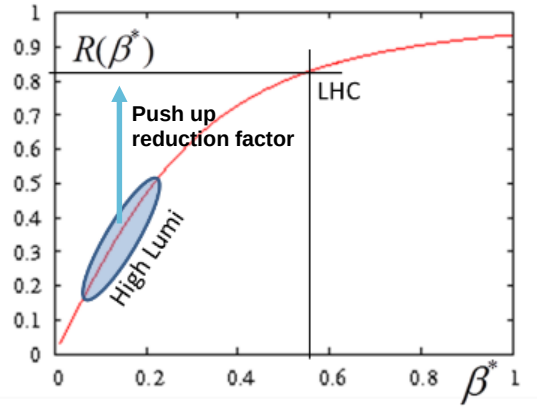
energy

Beam size

$$R = \frac{1}{\sqrt{1 + (\frac{\theta_c \sigma_s}{2\varepsilon_n \beta^*}\gamma)^2}}$$

Beam current and emittance: involve injection chain and whole ring

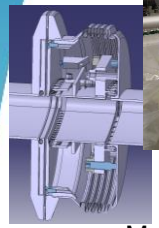
β* involves «only» 2 IRs, 2x600 m



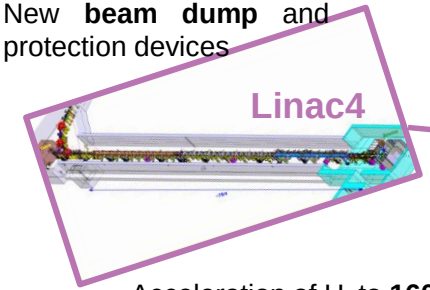
$$L_0 = 1 \cdot 10^{34}\ cm^{-2}s^{-1}$$

Unit of lumi through the talk
LHC has been designed for L_0 with margin
All systems have ~ designed to withstand $2L_0$ (to be achieved by increasing N_b x 1.5)

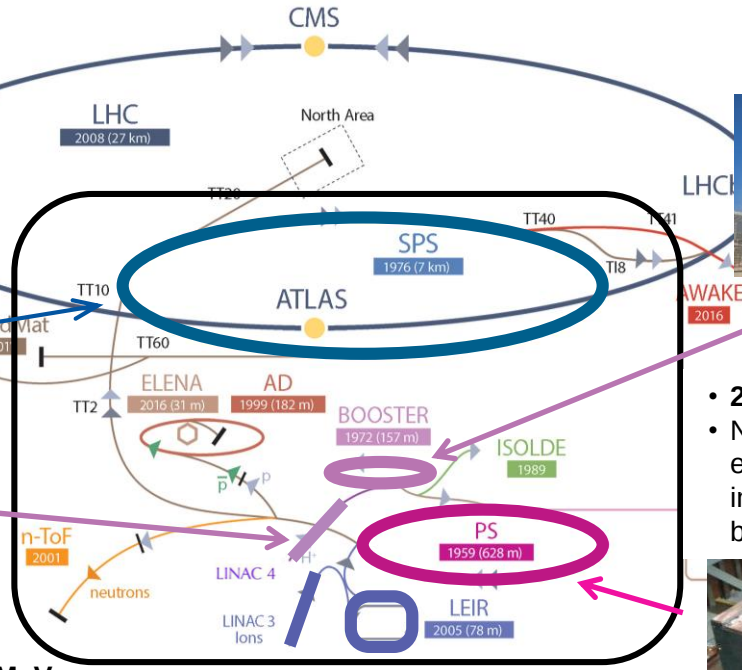
Goals of the LHC Injectors Upgrade project
Doubling protons & high brightness

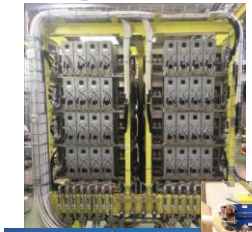


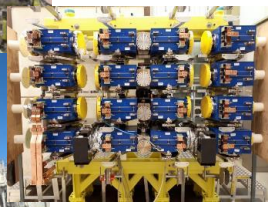
- Main **RF** system (200 MHz) upgrade
- Longitudinal **impedance** reduction & partial a-C coating
- New **beam dump** and protection devices



- Acceleration of H^- to **160 MeV**
- Nominal 40 mA within 0.4 μm, Run 3 target 25 mA within 0.3 μm



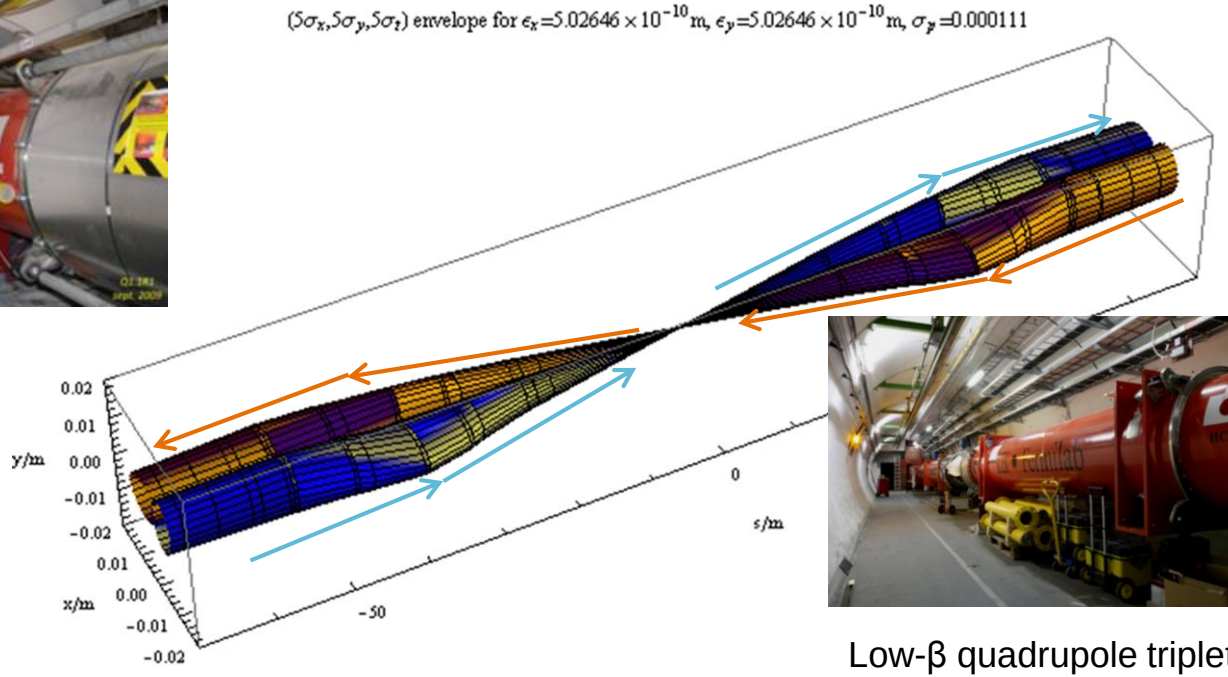




- **160 MeV** H^- charge exchange injection
- Acceleration to **2 GeV** with new main

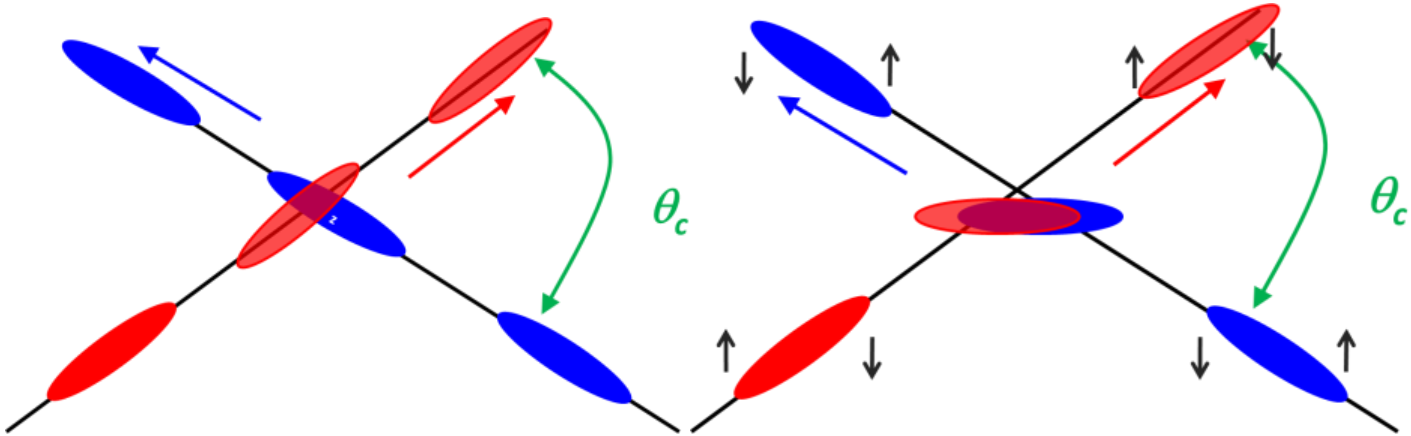
- **2 GeV** injection
- New **RF** equipment including broad-band feedback

Beam envelope scales as 1/√β* at IPs
HL → Reduce β* by a factor four



Low-β quadrupole triplet

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**
- ***Crab cavity maximizes the lumi and can be used also for luminosity levelling: if the lumi is too high, initially you don't use it, so lumi is reduced by the geometrical factor. Then they are slowly turned on to compensate the proton burning***

EC-FP7 funded *HiLumi* design study 2011-15
5 ME from EU; 15 ME from CERN, 30 ME total

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

Short Name	Country	Logo
CERN	Geneva Switzerland	
CEA	Saclay France	
DESY	Hamburg Germany	
INFN	Frascati Italy	
CSIC	Madrid Spain	
EPFL	Lausanne Switzerland	
SOTON	Southampton United Kingdom	
RHUL	London United Kingdom	

Short Name	Country	Logo
STFC*	Daresbury United Kingdom	
ULANC*	Lancaster United Kingdom	
UNILIV*	Liverpool United Kingdom	
UNIMAN*	Manchester United Kingdom	
HUD	Huddersfield United Kingdom	
KEK	Tsukuba Japan	
BINP	Novosibirsk Russia	

*Members of Cockcroft Institute

Goal of HL-LHC as fixed in 2010

From FP7 HiLumi LHC Design Study application

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_{peak} = **5×10^{34} cm^{-2}s^{-1} with levelling**, allowing:

An integrated luminosity of **250 fb^{-1} per year**, enabling the goal of

L_{int} = 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.

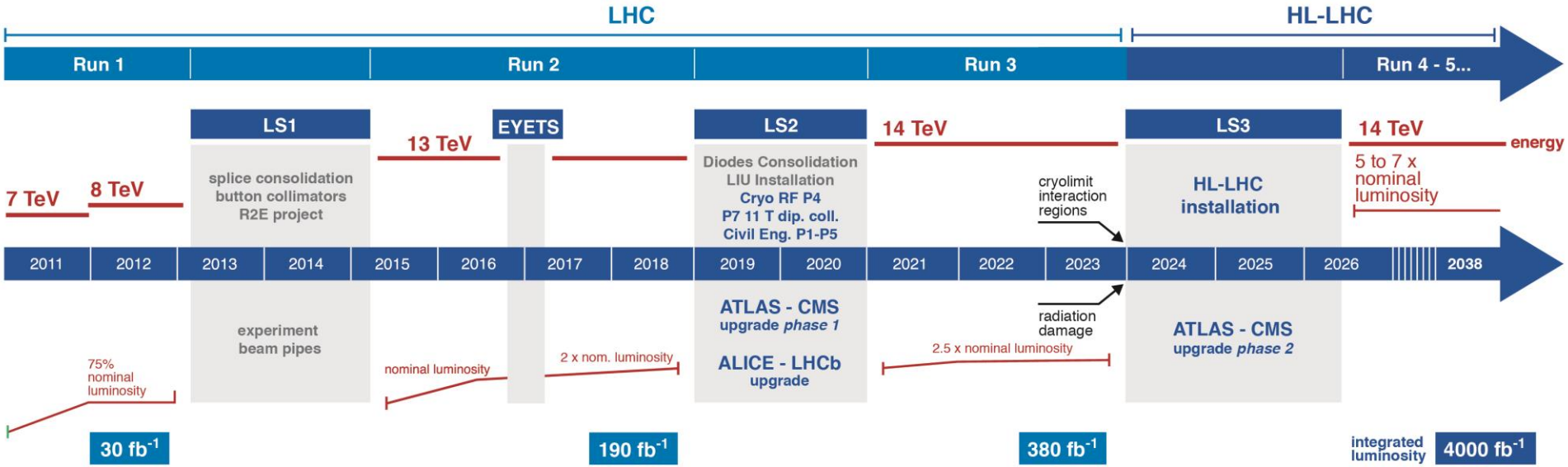
Ultimate performance established 2015-2016: with same hardware and same beam parameters: use of **engineering margins:**

$L_{peak\ ult} \cong 7.5\ 10^{34}$ cm^{-2}s^{-1} and **Ultimate Integrated $L_{int\ ult} \sim 4000$ fb^{-1}**

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

Project approved by CERN Council in June 2016

LHC / HL-LHC Plan



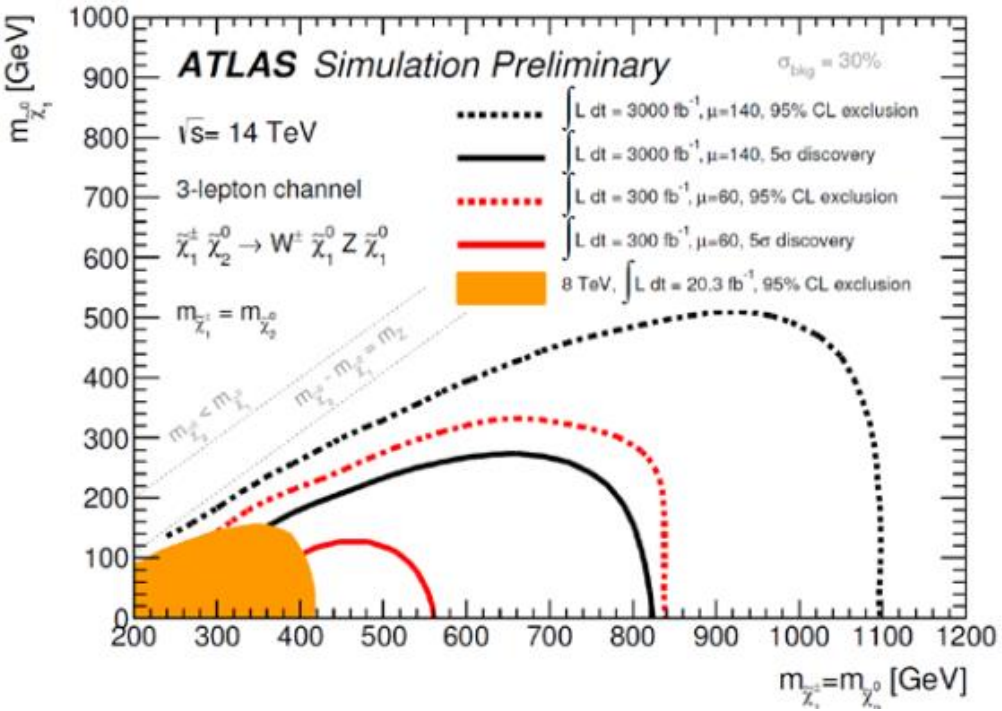
HL-LHC TECHNICAL EQUIPMENT:

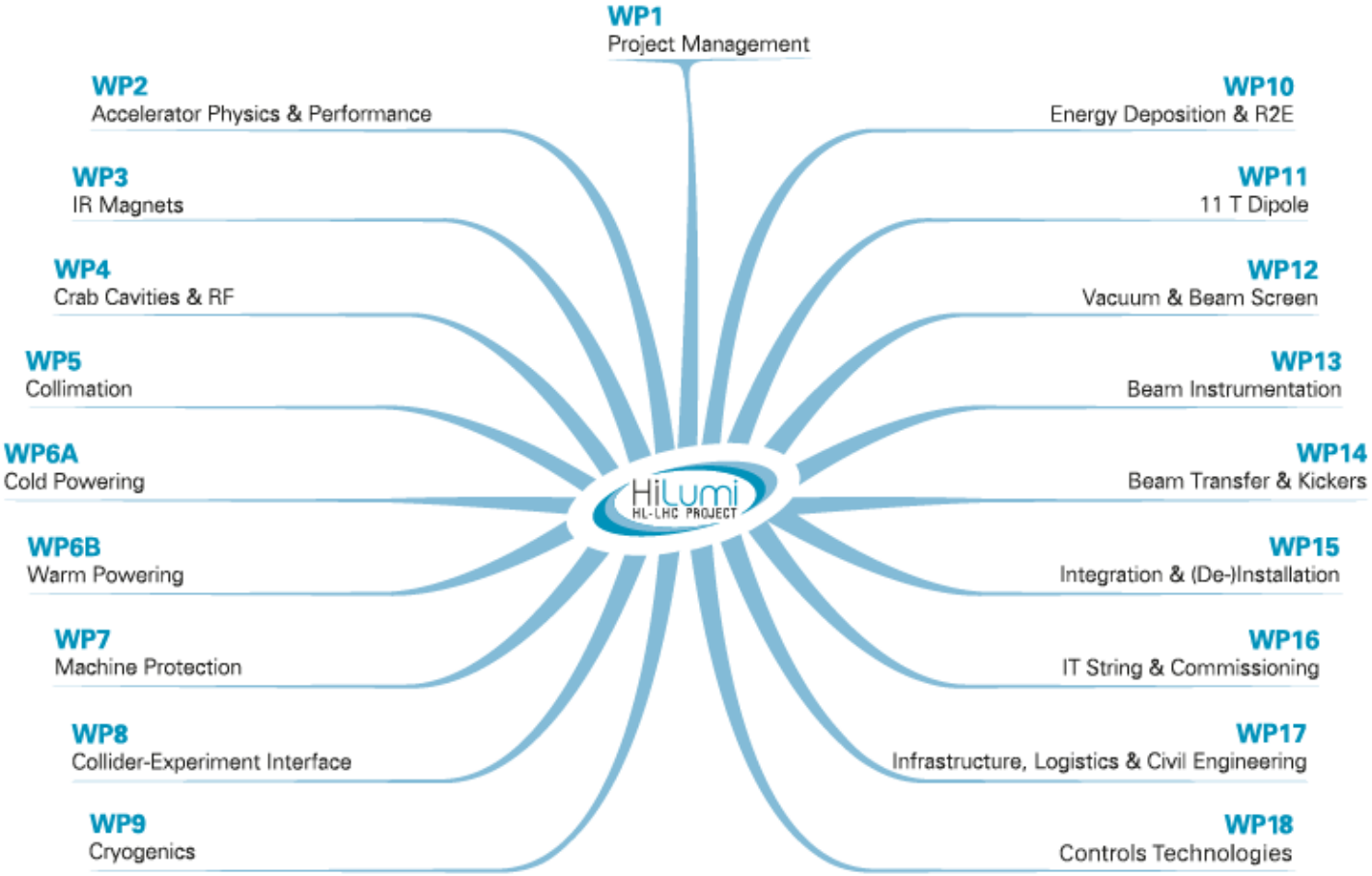
DESIGN STUDY	PROTOTYPES	CONSTRUCTION	INSTALLATION & COMM.	PHYSICS

HL-LHC CIVIL ENGINEER:

DEFINITION	EXCAVATION / BUILDINGS

Example of Physics reach in HL-LHC : direct production of chargino-neutralino pairs




WP1
Project Management
WP2
Accelerator Physics & Performance
WP3
IR Magnets
WP4
Crab Cavities & RF
WP5
Collimation
WP6A
Cold Powering
WP6B
Warm Powering
WP7
Machine Protection
WP8
Collider-Experiment Interface
WP9
Cryogenics
WP10
Energy Deposition & R2E
WP11
11 T Dipole
WP12
Vacuum & Beam Screen
WP13
Beam Instrumentation
WP14
Beam Transfer & Kickers
WP15
Integration & (De-)Installation
WP16
IT String & Commissioning
WP17
Infrastructure, Logistics & Civil Engineering
WP18
Controls Technologies
HiLumi
HL-LHC PROJECT

High Luminosity LHC Project

[1] In kind contributions
[2] INFN Directorate
[3] INFN Milano LASA
[4] INFN Genova

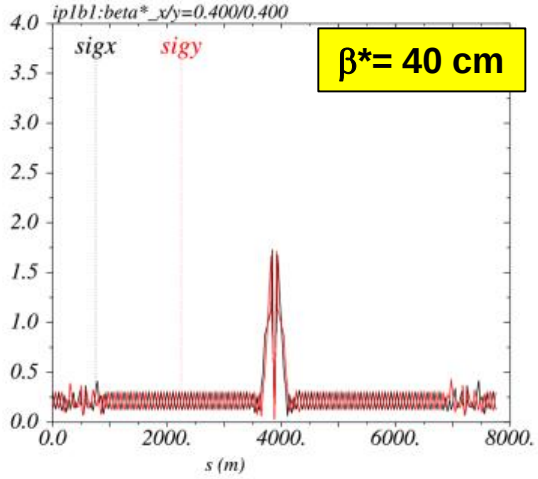
[5] University of Manchester/Cockcroft Institute
[6] Lancaster University/Cockcroft Institute
[7] Royal Holloway/John Adams Institute
[8] University of Southampton
[9] US HL-LHC Accelerator Upgrade Project

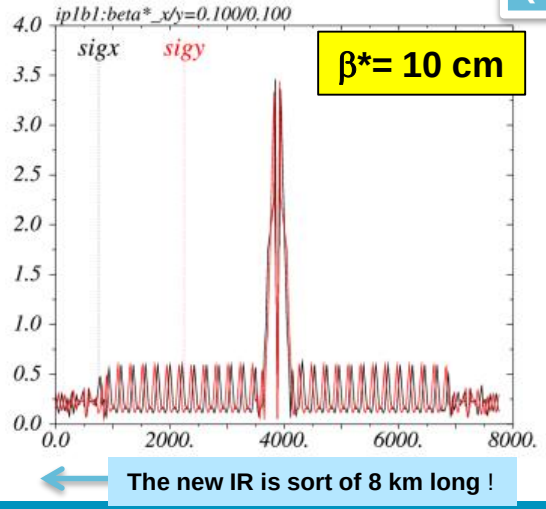
LHC is already much optimized: many accelerator physics challenge: The Achromatic Telescopic Squeezing (ATS) scheme

Small β* is limited by aperture but not only: optics matching & flexibility (round and flat optics), chromatic effects…

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)

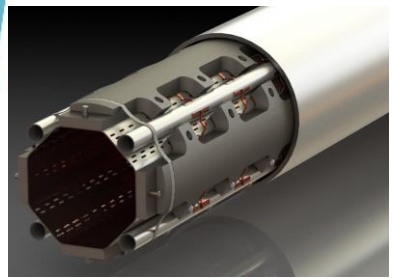




The new IR is sort of 8 km long !

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

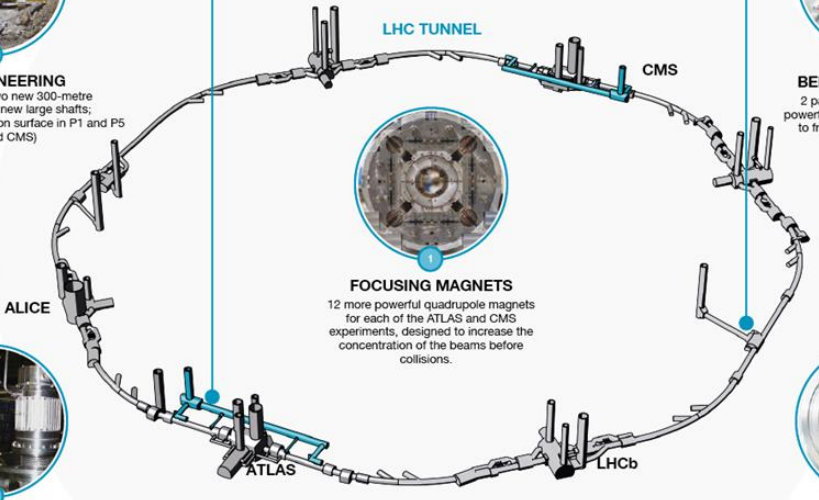
Technology landmarks



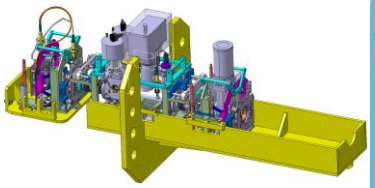
"CRAB" CAVITIES
8 superconducting "crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.

CIVIL ENGINEERING
2 new caverns and two new 300-metre service galleries, two new large shafts; 10 new technical buildings on surface in P1 and P5 (ATLAS and CMS)

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



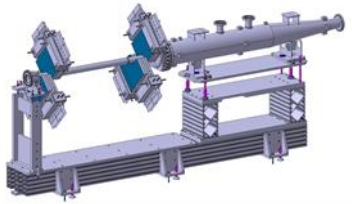
FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.

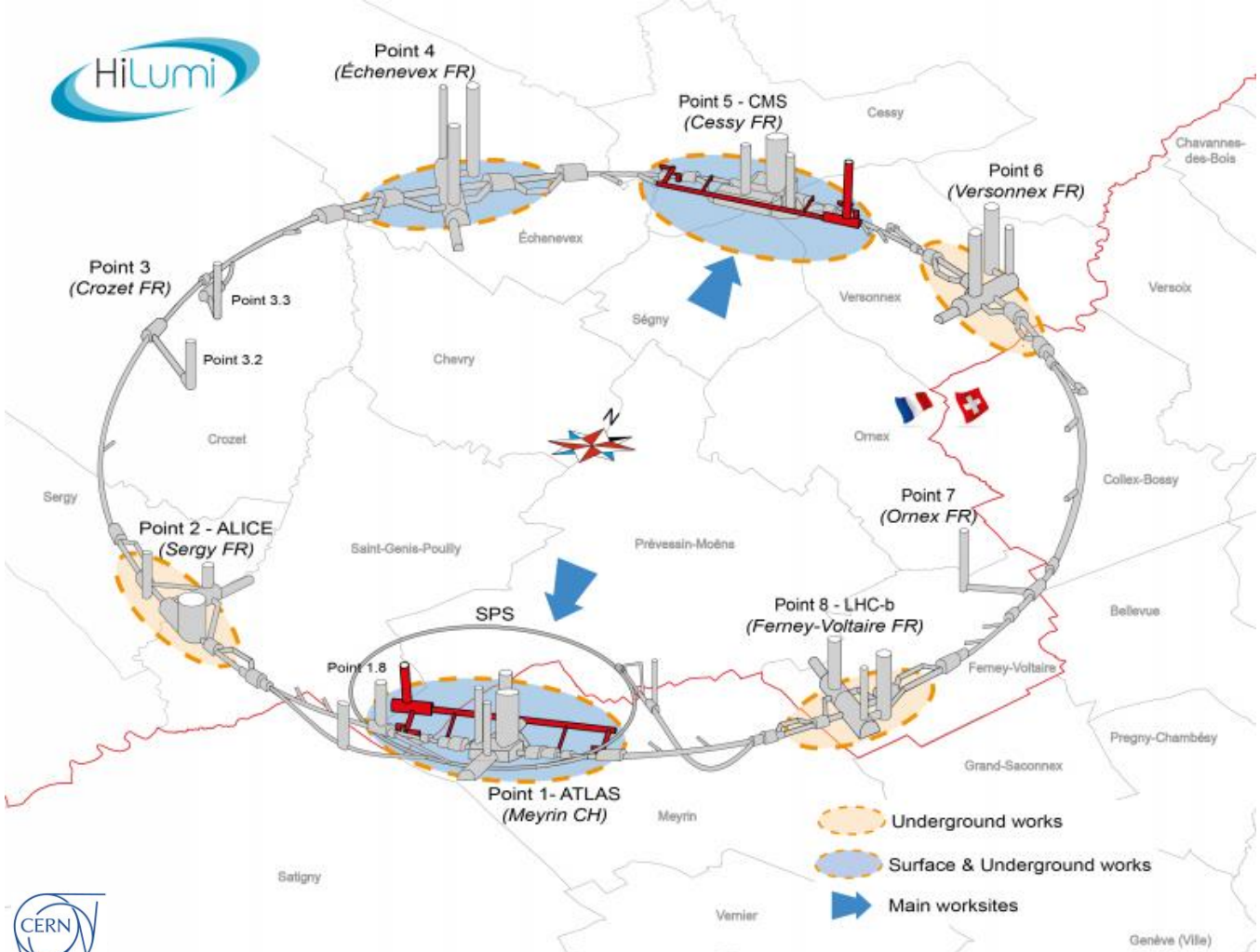


CRYOGENICS
2 new large 1.9 K helium refrigerators for HL-LHC near ATLAS and CMS

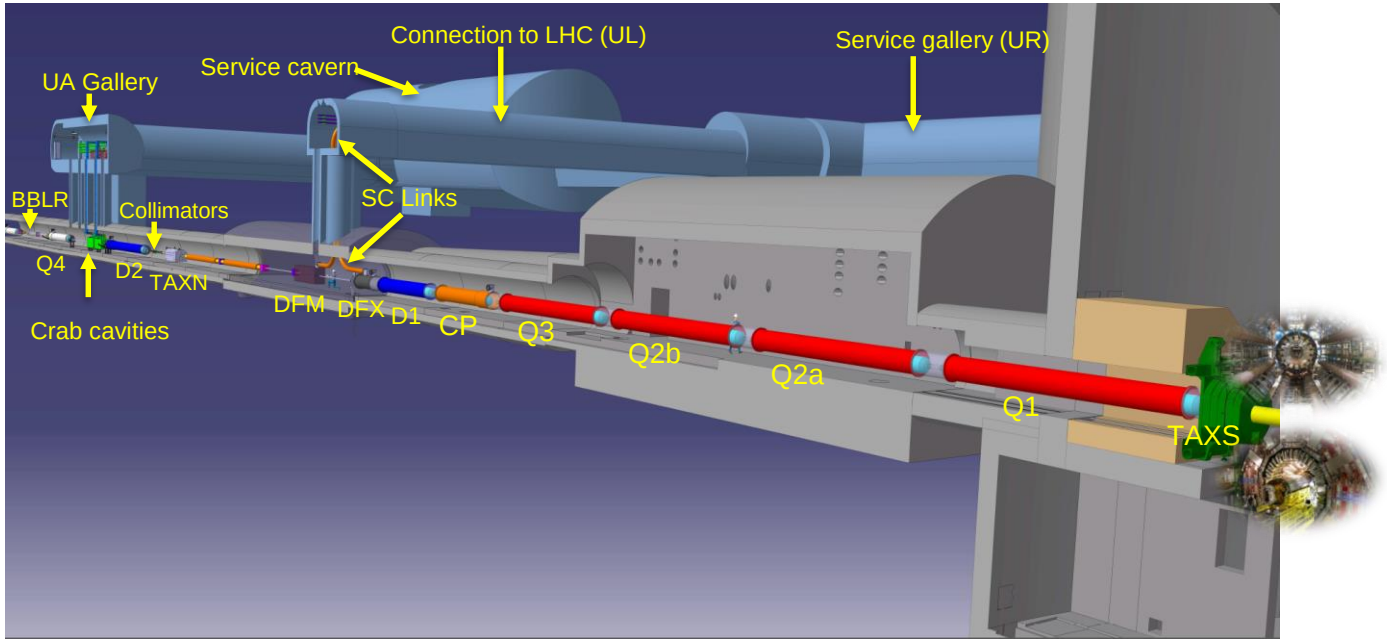
COLLIMATORS
15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.

SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service galleries to the LHC tunnel.



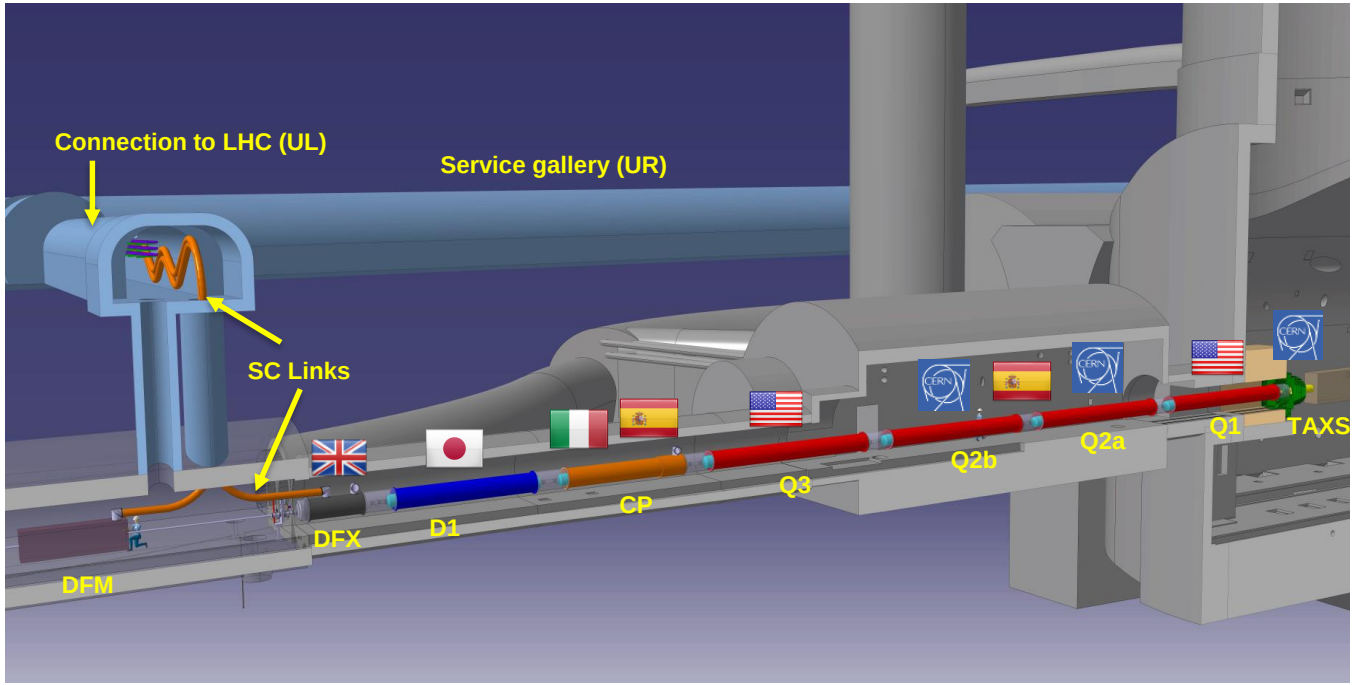

Point 4
(Échenevex FR)
Point 5 - CMS
(Cessy FR)
Point 6
(Versonnex FR)
Point 3
(Crozet FR)
Point 3.3
Point 3.2
Point 2 - ALICE
(Sergy FR)
Point 7
(Ornex FR)
Point 8 - LHC-b
(Ferney-Voltaire FR)
SPS
Point 1.8
Point 1- ATLAS
(Meyrin CH)
Cessy
Chavannes-des-Bois
Échenevex
Versonnex
Versoix
Ségny
Chevry
Crozet
Ornex
Collex-Bossy
Sergy
Saint-Genis-Poully
Prévessin-Moëns
Bellevue
Ferney-Voltaire
Pregny-Chambésy
Grand-Saconnex
Meyrin
Satigny
Vernier
Genève (Ville)
Underground works
Surface & Underground works
Main worksites

The Insertion Region (till Q4)

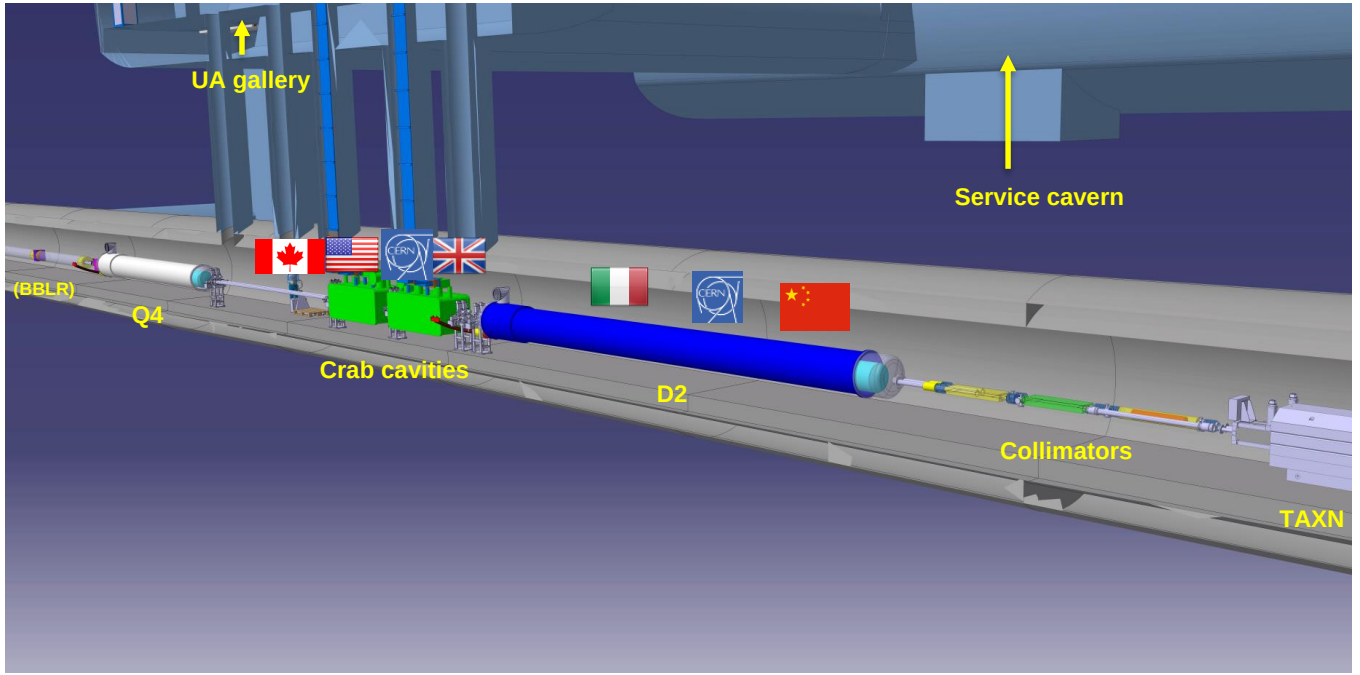


In total about 1.2 km of the LHC will be replaced by new technologies!
Biggest HEP project of this decade, but it has a reasonable size (25-30% of the LHC) to be a test-bed for new technologies…

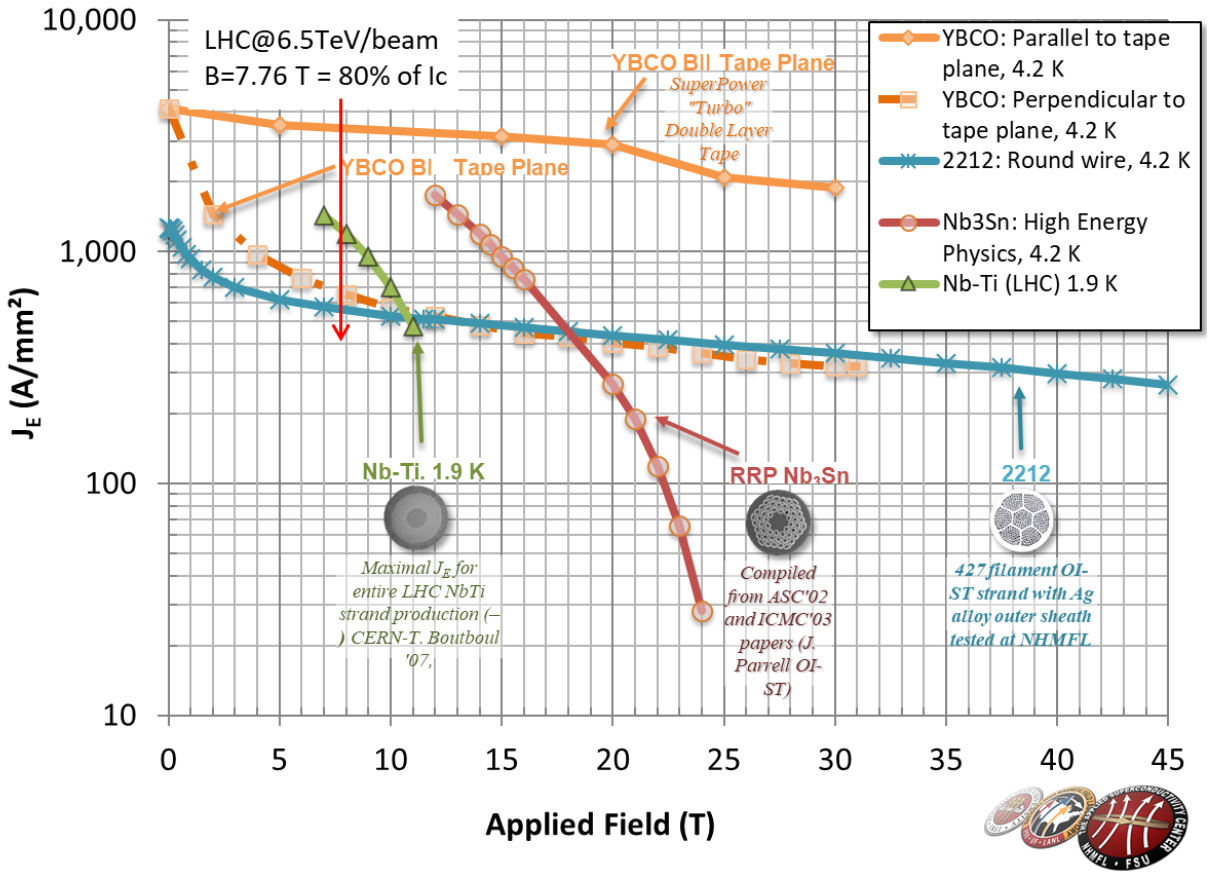
The Inner Triplet region with in-kinds



The MS (matching section) region with in-kinds

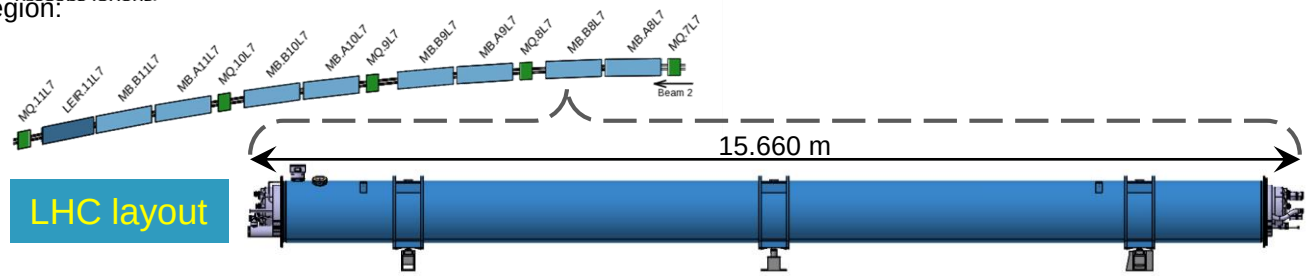


Superconductor space

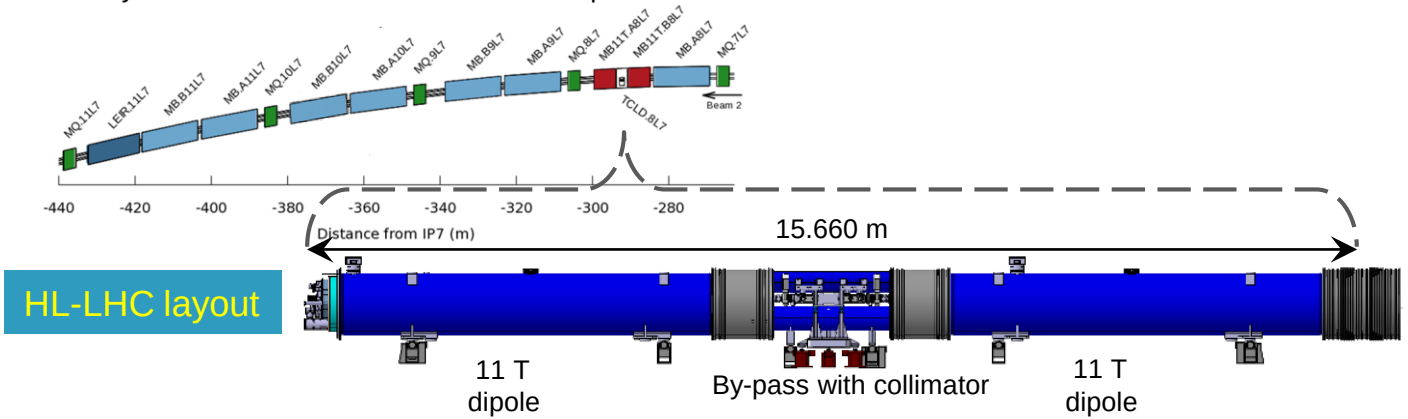


High Luminosity LHC 11 T dipole in the DS7 (Dispersion Suppressor of LHC P7)

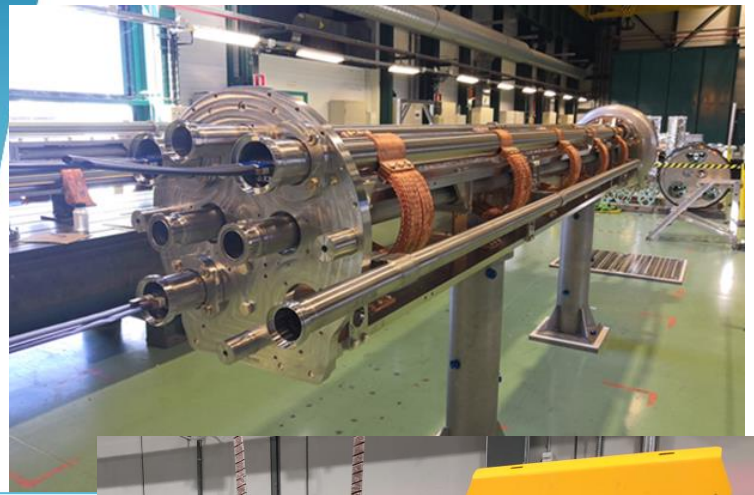
Present layout of the DS region:



New layout with one collimator and two 11T dipoles:

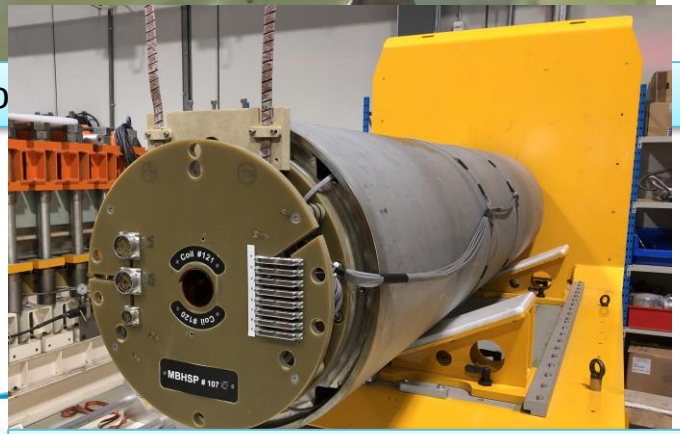


11 T dipole (and new connection cryostat)

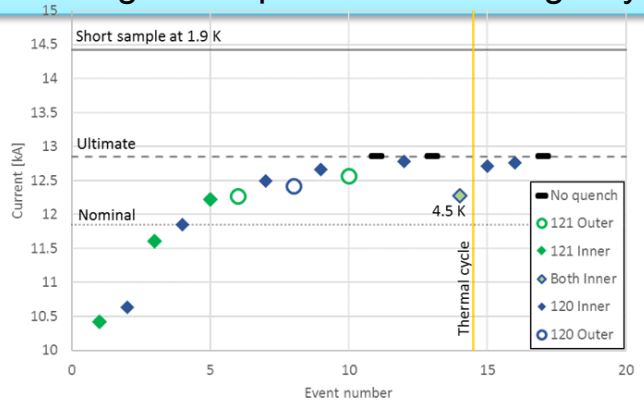


First co

1st 5.5 m long 11 T dipole before testing July ‘18

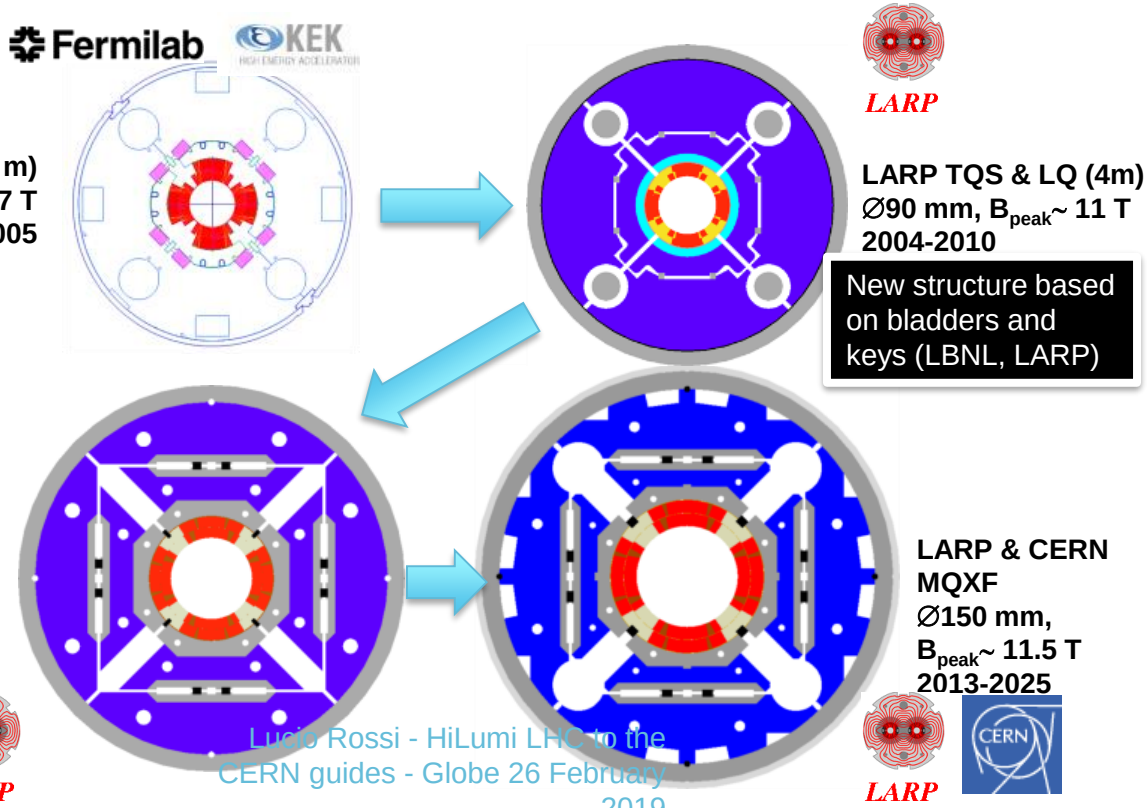


Model SP107 (new layout – taskforce)

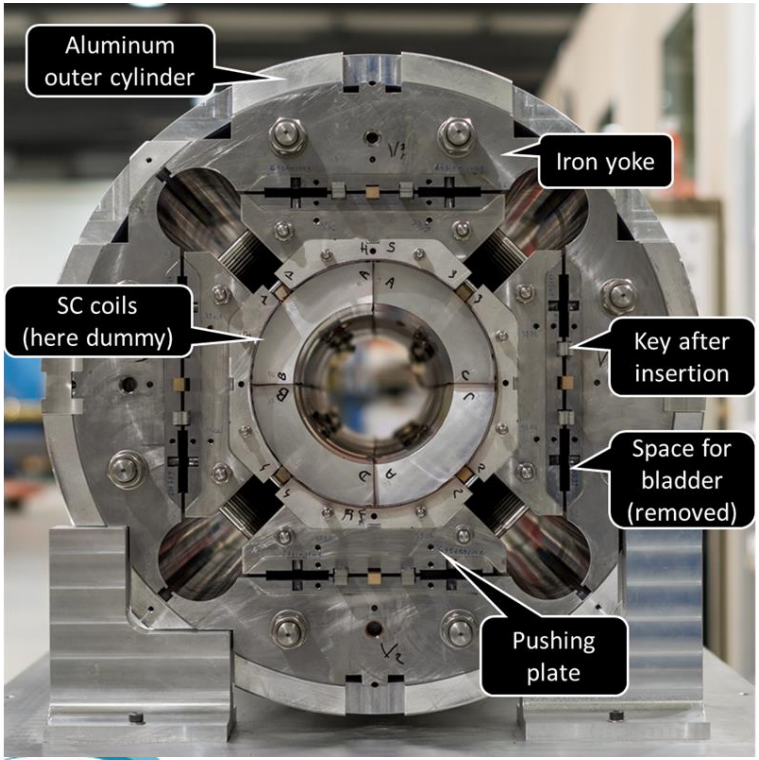


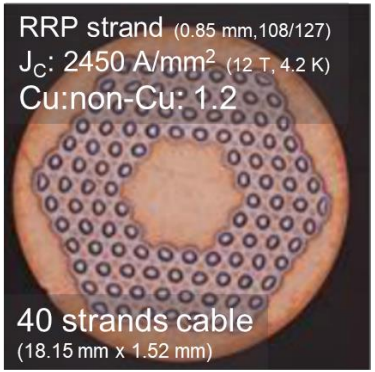
11T production in B.180

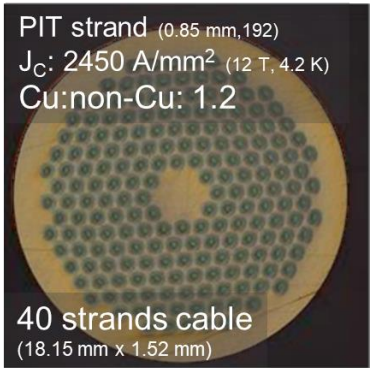
LHC low-β quads: steps in magnet technology from LHC toward HL-LHC

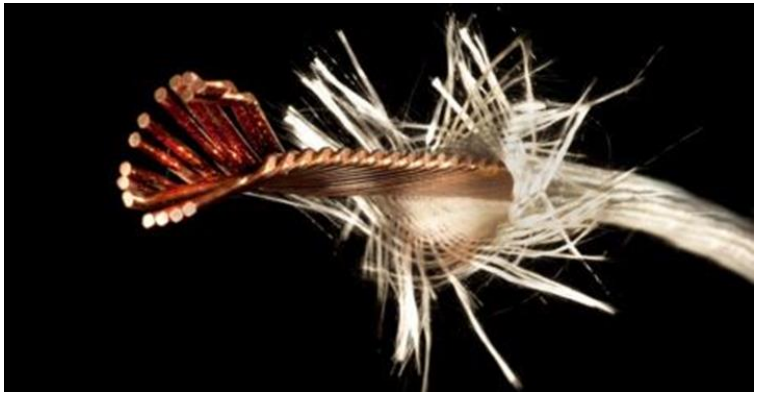


New structure to accomodate brittleness of the Nb_3Sn superconductor

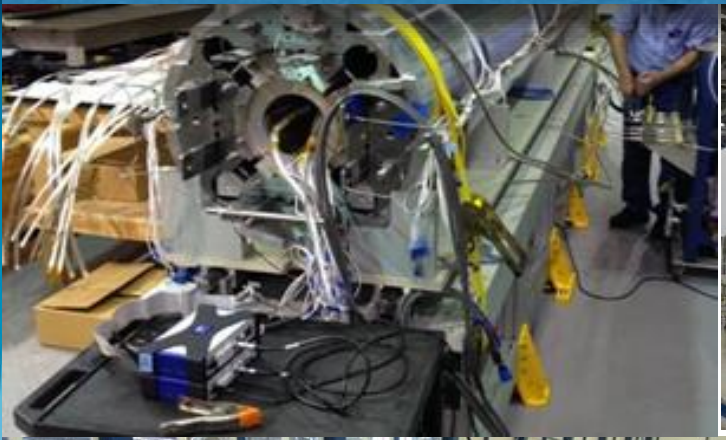




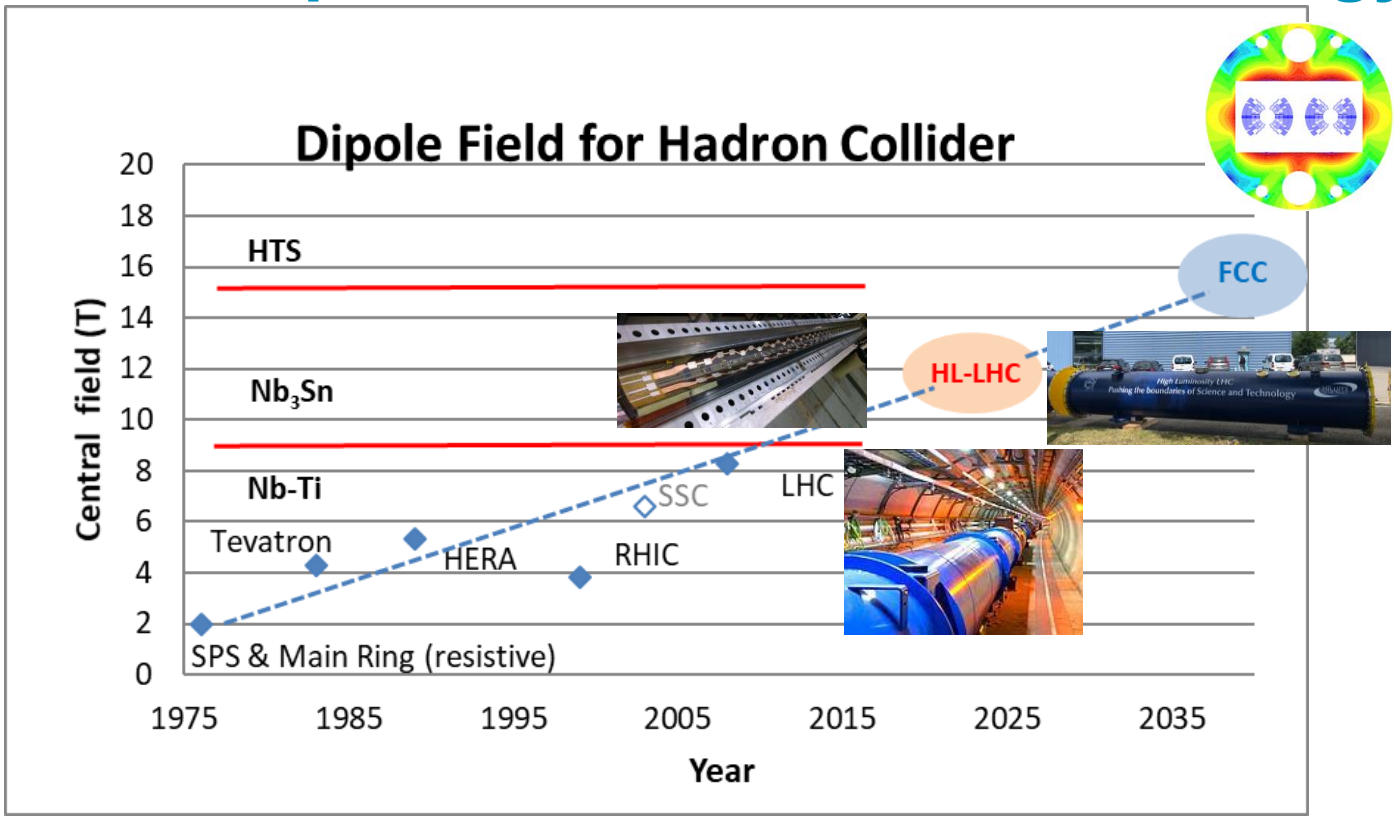




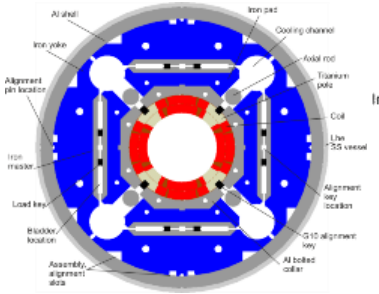
HiLumi: 15 years of R&D to go beyond the technological limit of LHC Nb-Ti



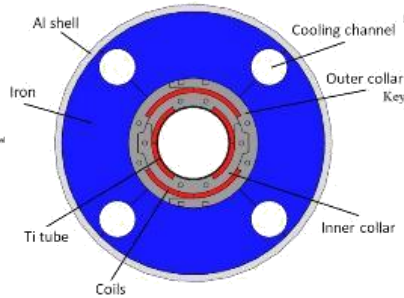
With HiLumi we prepare the technology for a future leap in hadron collider technology…



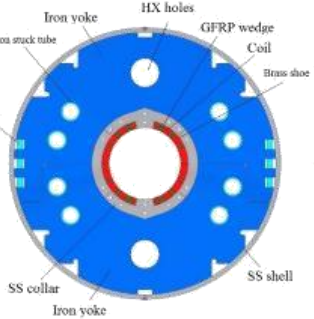
HL-LHC magnet “zoo”



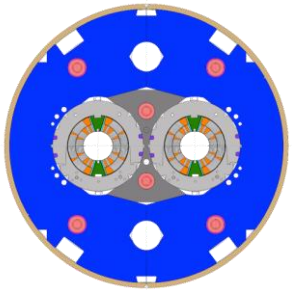
Triplet QXF (LARP and CERN)



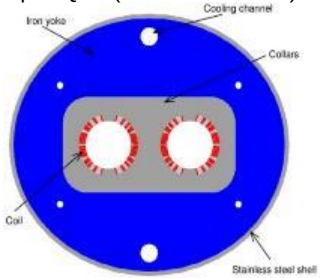
Orbit corrector (CIEMAT)



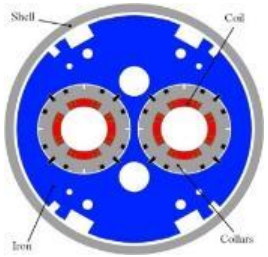
Separation dipole D1 (KEK)



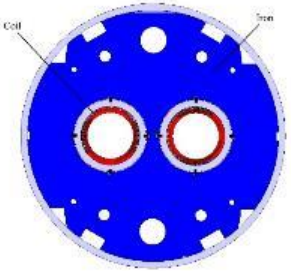
11 T dipole (CERN)



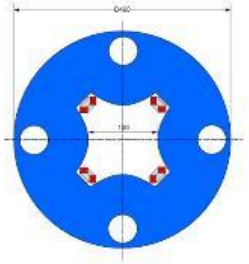
Recombination dipole D2 (INFN)



Q4 (CEA)

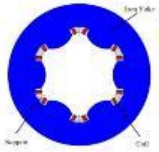


D2/Q4 orbit corrector (CERN)

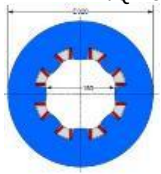


Skew quadrupole (INFN)

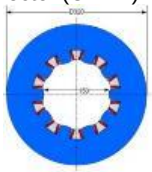
Approximately 150 single magnets and 50 cold masses for HL-LHC



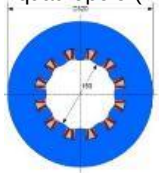
Sextupole (INFN)



Octupole (INFN)



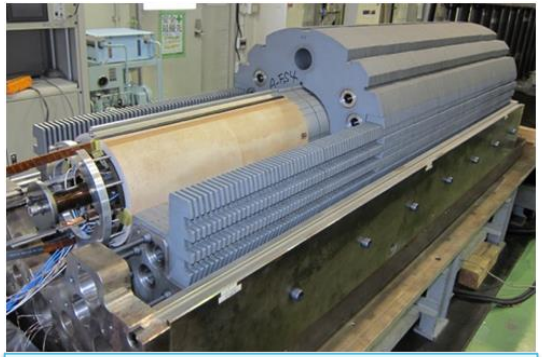
Decapole (INFN)



Dodecapole (INFN)

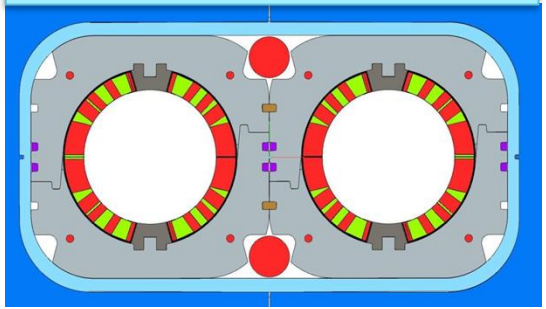
Many magnets designed and manufactured via collaboration

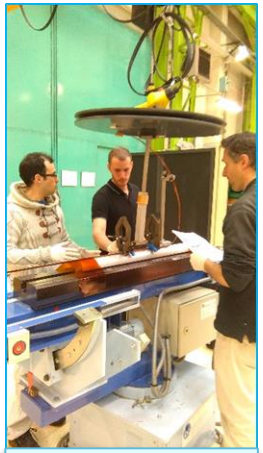
HL-LHC WP3



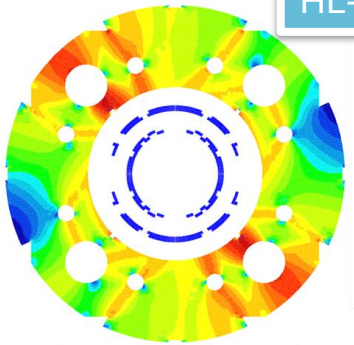
D1 – KEK
Recent test beyond nominal

D2 – INFN Genova (model & full proto)





Q4 MQYY – CEA Saclay (QUACO)

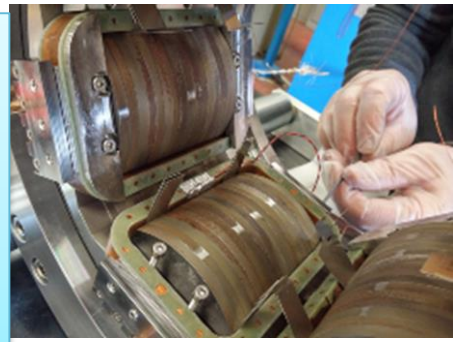


Iron field map when both dipoles are simultaneously powered

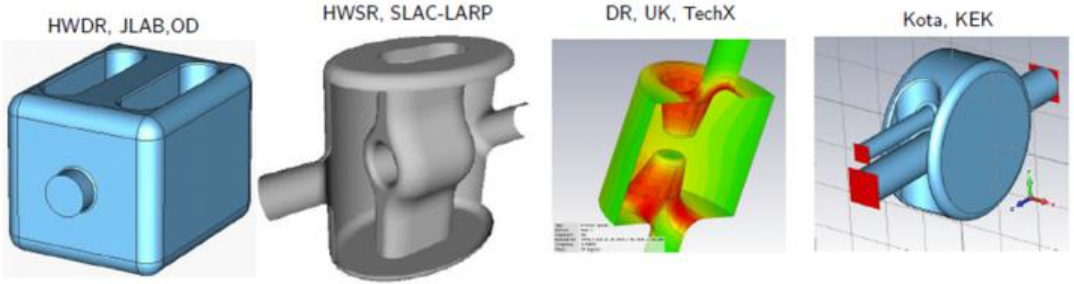
Nested orbit correctors – CIEMAT Madrid

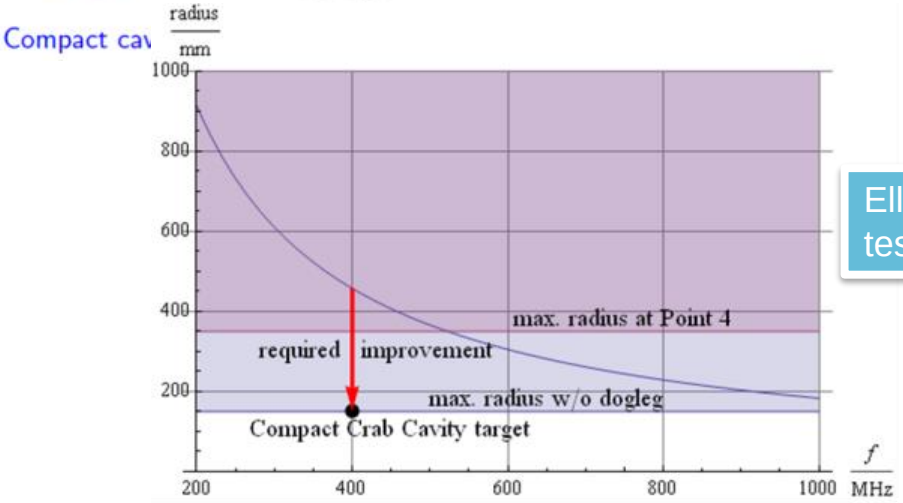
rric
HO Correctors
INFN-Milano LASA

Test @ 2.17 K (1h @134.4 A i.e. 108% nominal current)
No-training
3 «natural» quenches @241 A, i.e. 97% of short sample limit 4.2 K



Crab Cavity, for p-beam rotation at 10 fs level!





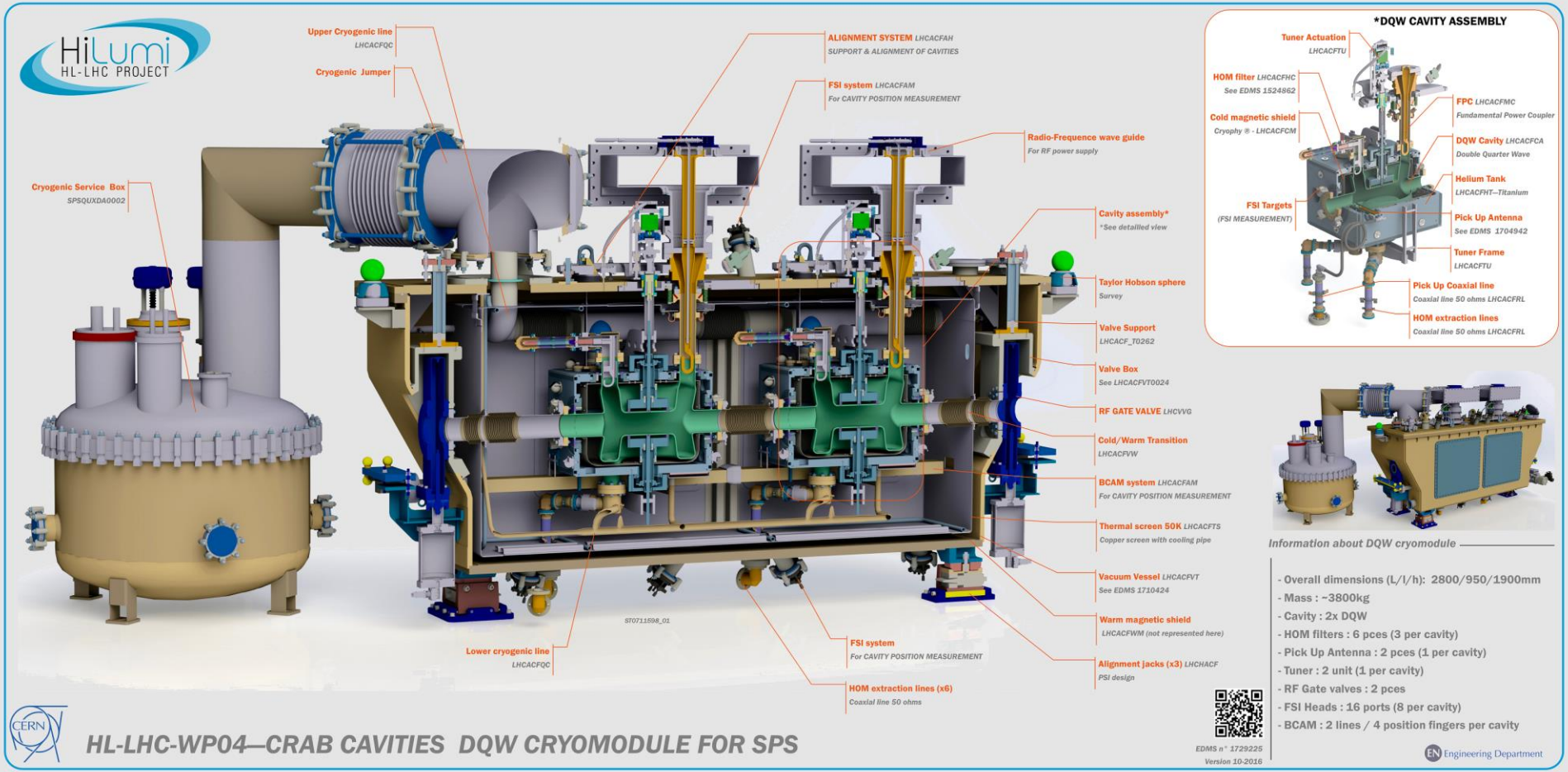
Elliptical type CC has been tested first in KEK 2008

Crab Cavity consruction for SPS test at CERN (DQW type)

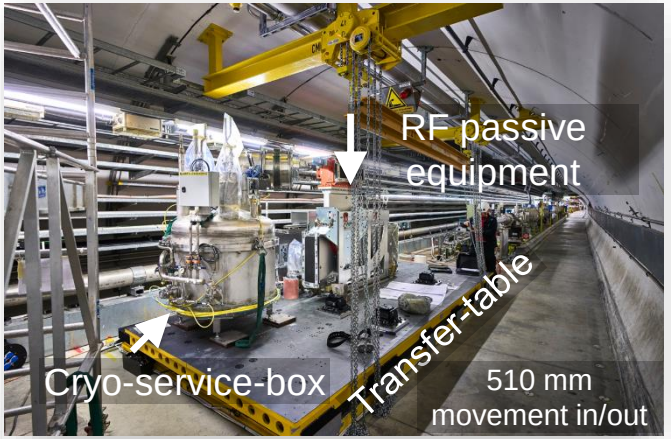
FPC on in Conditioning
Test box & installation of DT

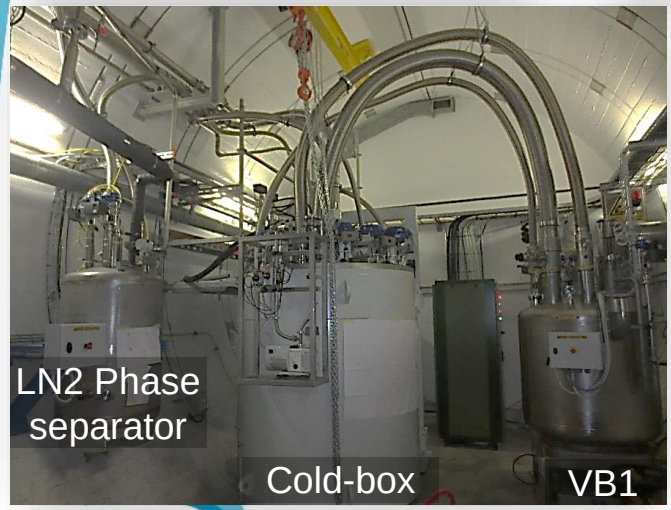
FPC installation onto cavity

String assembly completed
Aug 18, 2017

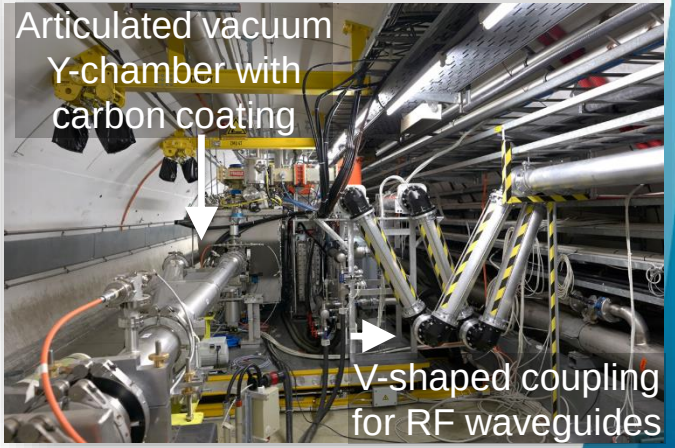

Upper Cryogenic line
LHCACFQC
Cryogenic Jumper
Cryogenic Service Box
SPSQUXDA0002
ALIGNMENT SYSTEM LHCACFAN
SUPPORT & ALIGNMENT OF CAVITIES
FSI system LHCACFAM
For CAVITY POSITION MEASUREMENT
Radio-Frequence wave guide
For RF power supply
Cavity assembly*
*See detailled view
Taylor Hobson sphere
Survey
Valve Support
LHCACF_T0262
Valve Box
See LHCACFVT0024
RF GATE VALVE LHCVVG
Cold/Warm Transition
LHCACFVW
BCAM system LHCACFAM
For CAVITY POSITION MEASUREMENT
Thermal screen 50K LHCACFTS
Copper screen with cooling pipe
Vacuum Vessel LHCACFVT
See EDMS 1710424
Warm magnetic shield
LHCACFWM (not represented here)
Alignment jacks (x3) LHCHACF
PSI design
Lower cryogenic line
LHCACFQC
FSI system
For CAVITY POSITION MEASUREMENT
HOM extraction lines (x6)
Coaxial line 50 ohms
ST0711598_01
*DQW CAVITY ASSEMBLY
Tuner Actuation
LHCACFTU
HOM filter LHCACFHC
See EDMS 1524862
Cold magnetic shield
Cryophy ® - LHCACFCM
FSI Targets
(FSI MEASUREMENT)
FPC LHCACFMC
Fundamental Power Coupler
DQW Cavity LHCACFCA
Double Quarter Wave
Helium Tank
LHCACFHT—Titanium
Pick Up Antenna
See EDMS 1704942
Tuner Frame
LHCACFTU
Pick Up Coaxial line
Coaxial line 50 ohms LHCACFRL
HOM extraction lines
Coaxial line 50 ohms LHCACFRL
Information about DQW cryomodule
- Overall dimensions (L/l/h): 2800/950/1900mm
- Mass : ~3800kg
- Cavity : 2x DQW
- HOM filters : 6 pces (3 per cavity)
- Pick Up Antenna : 2 pces (1 per cavity)
- Tuner : 2 unit (1 per cavity)
- RF Gate valves : 2 pces
- FSI Heads : 16 ports (8 per cavity)
- BCAM : 2 lines / 4 position fingers per cavity
HL-LHC-WP04—CRAB CAVITIES DQW CRYOMODULE FOR SPS
EDMS n° 1729225
Version 10-2016
Engineering Department

HL-LHC SPS Test stand for crab-cavities

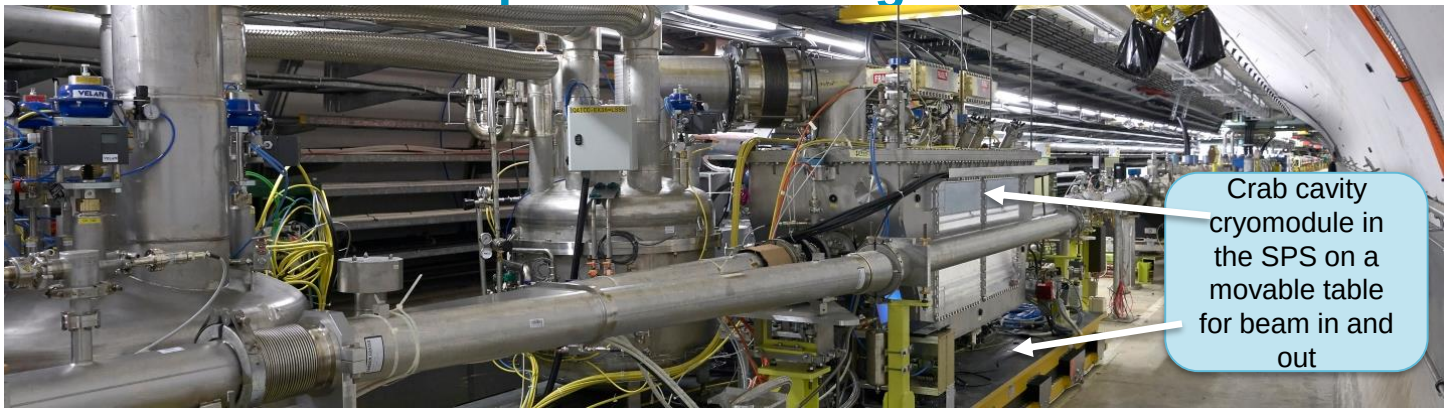


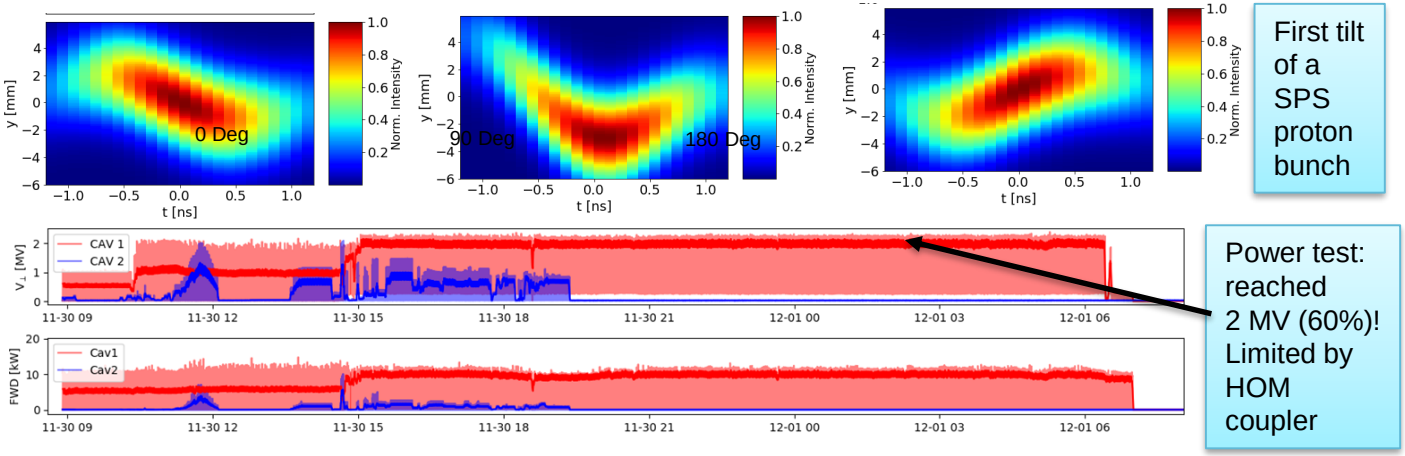


DQW crab-cavity cryomodule



2018 HiLumi LHC CC in the SPS: First proton crabbing ever!

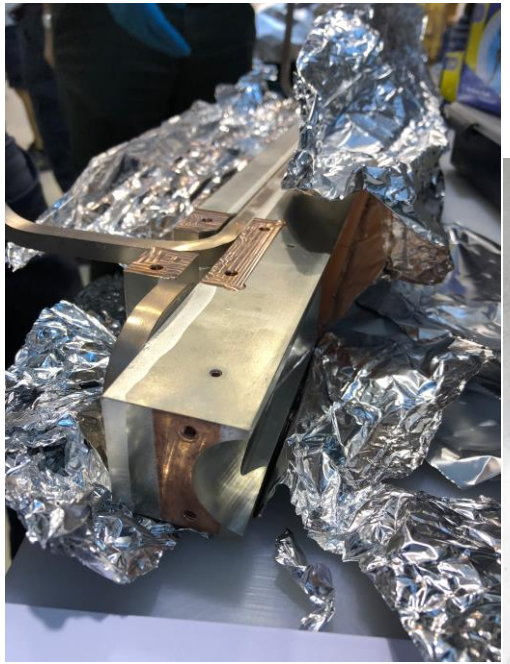




Collimators

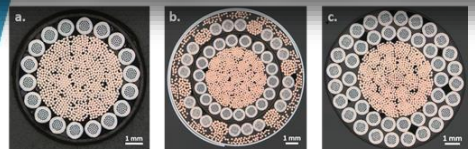
TCLD for ions (IP2) ready to be installed in the bypass

First TCLD jaw prototype in Industry (courtesy of EN/STI)

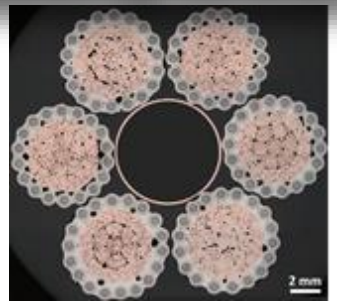


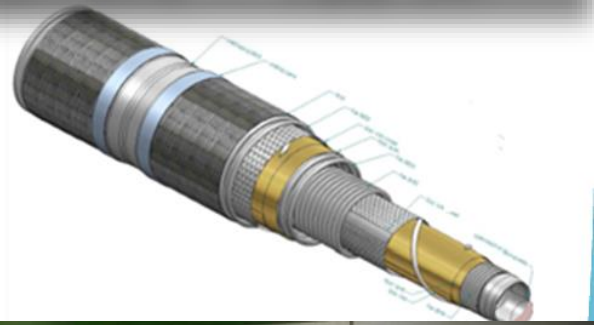
Samples of MoGr (Molybdenum-Graphite) from producer (courtesy of EN/MME)

New superconducting links for 100 kA current – 130 m



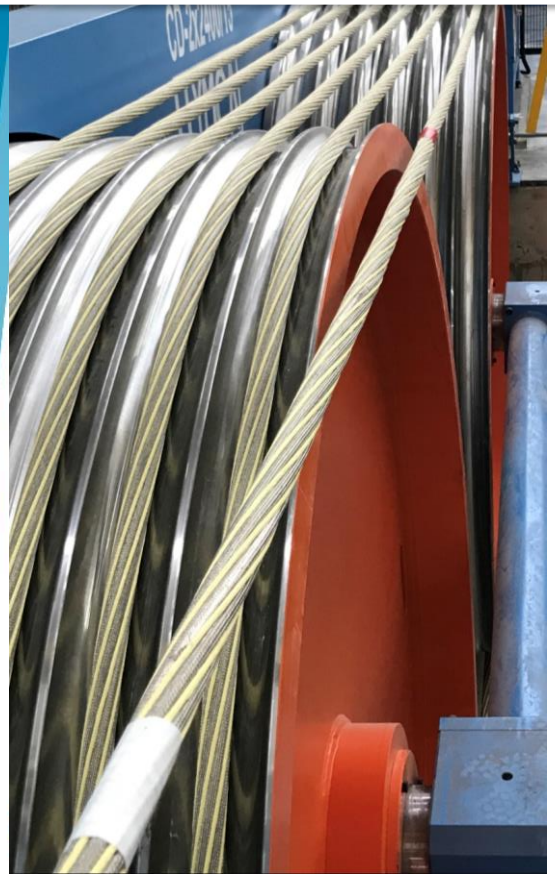
MgB_2 superconductor

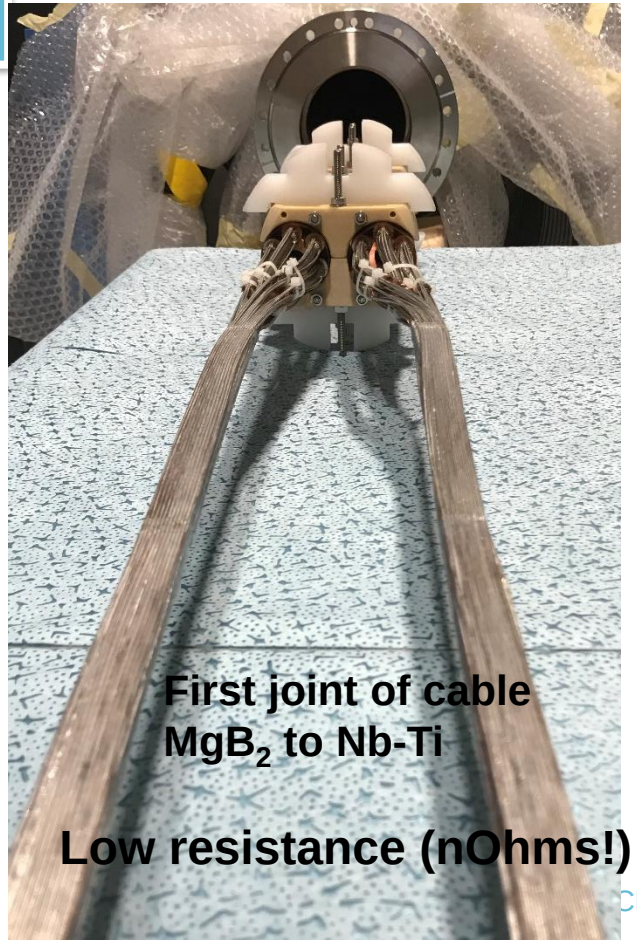




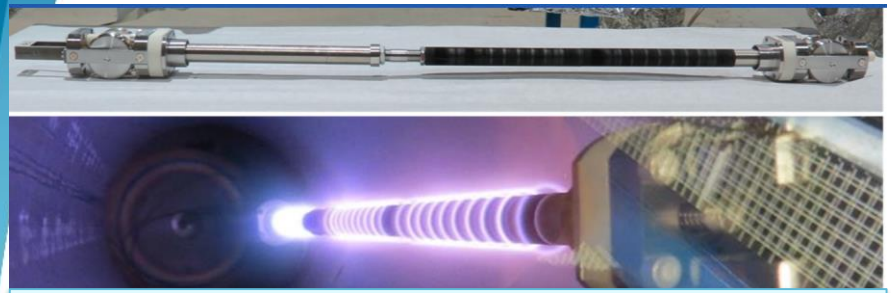
SC Links inside flexible cryostat: first 60 m long prototype 20 kA cable tested at CERN

First long length of 20 kA MgB_2 cable (IT Quad circuit)

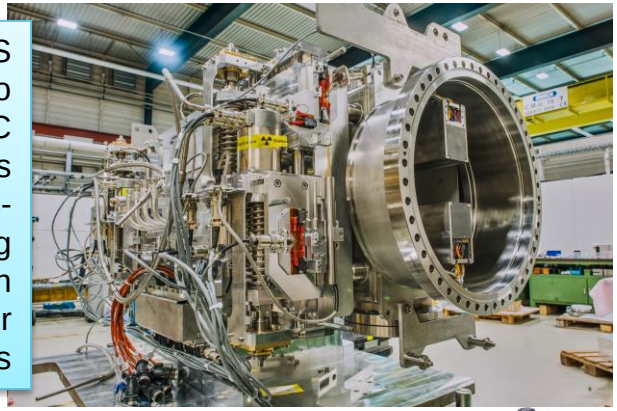




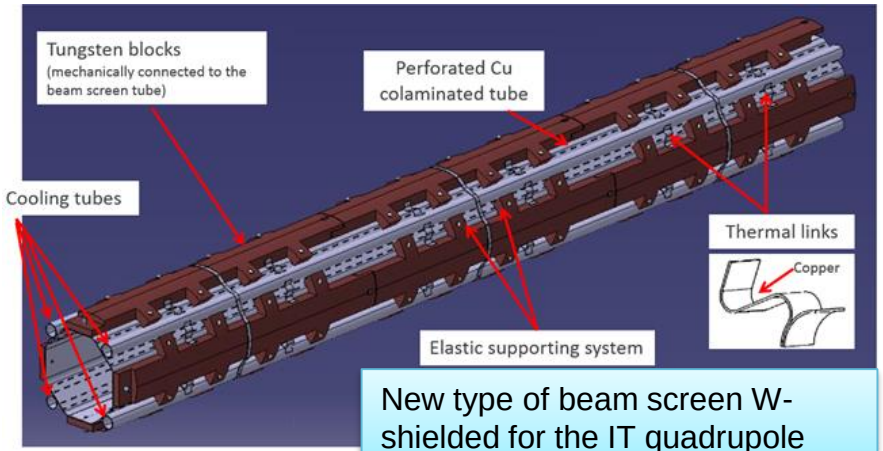
And many other important novelties



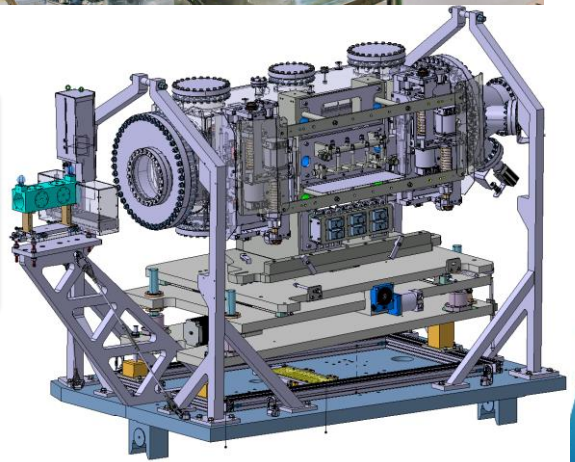
A-Carbon coating of magnet beam screen to fight e-cloud



New TDIS absorber to protect SC magnets from mis-firing injection kicker magnets

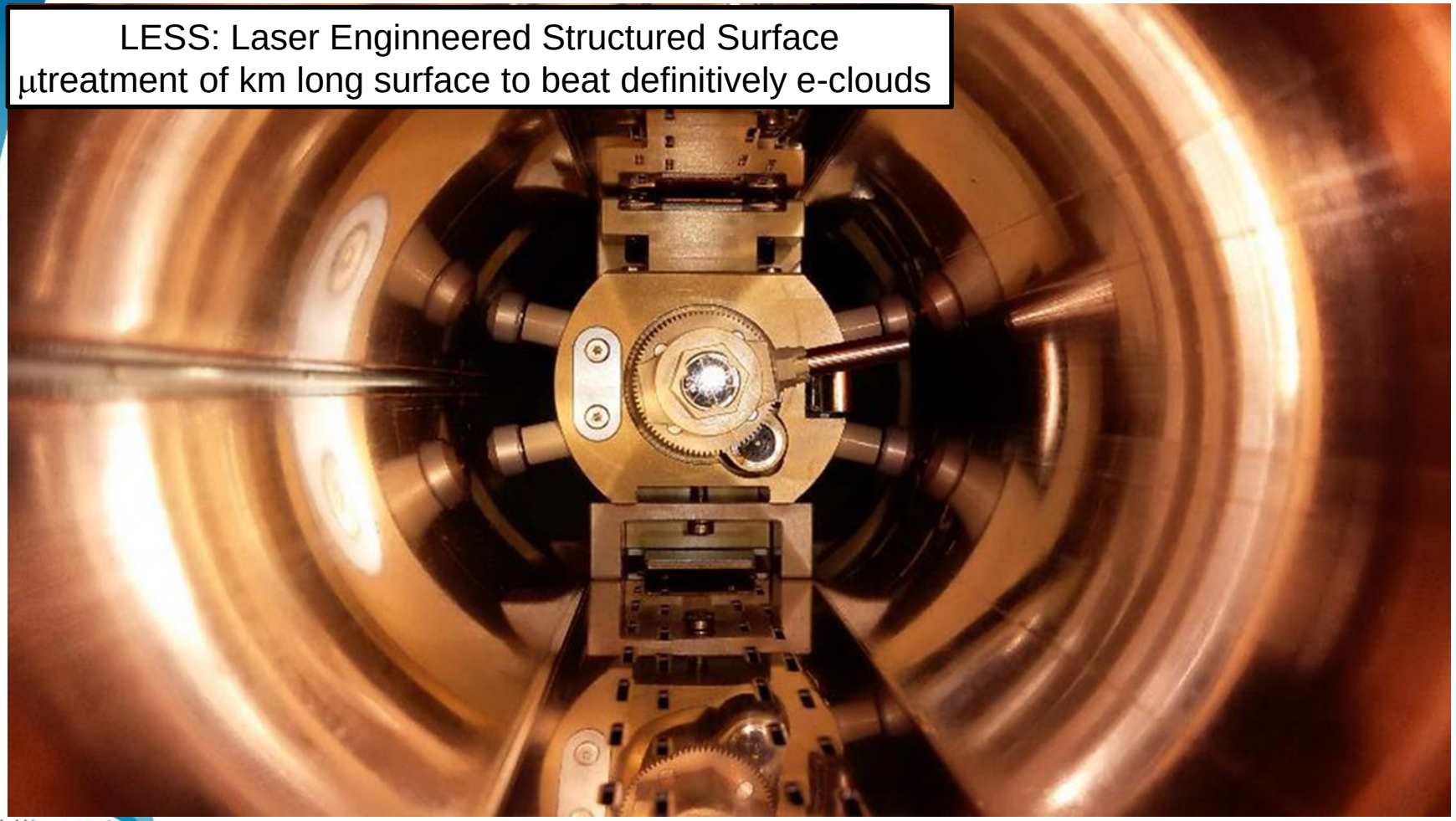


New type of beam screen W-shielded for the IT quadrupole

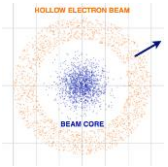


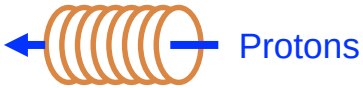
Improving beam diagnostics: BGV detector

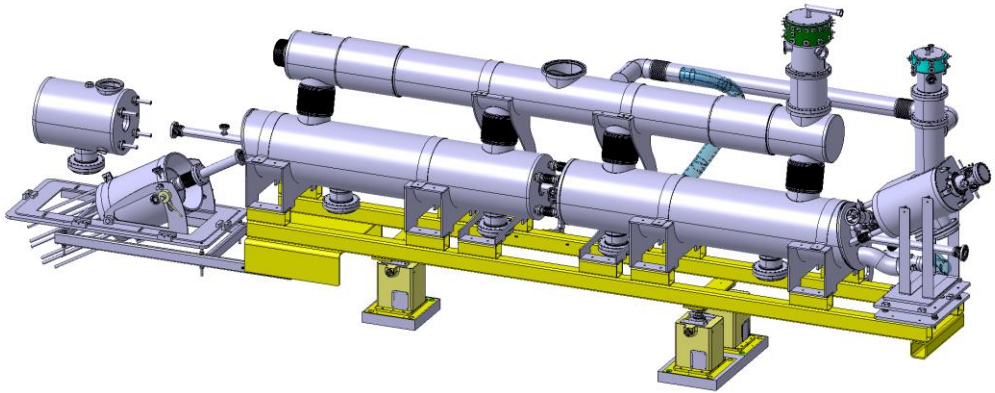
LESS: Laser Enginneered Structured Surface
μtreatment of km long surface to beat definitively e-clouds



A few options on the table to improve beam handling and cleaning

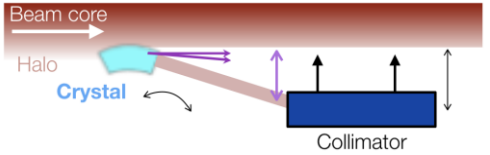




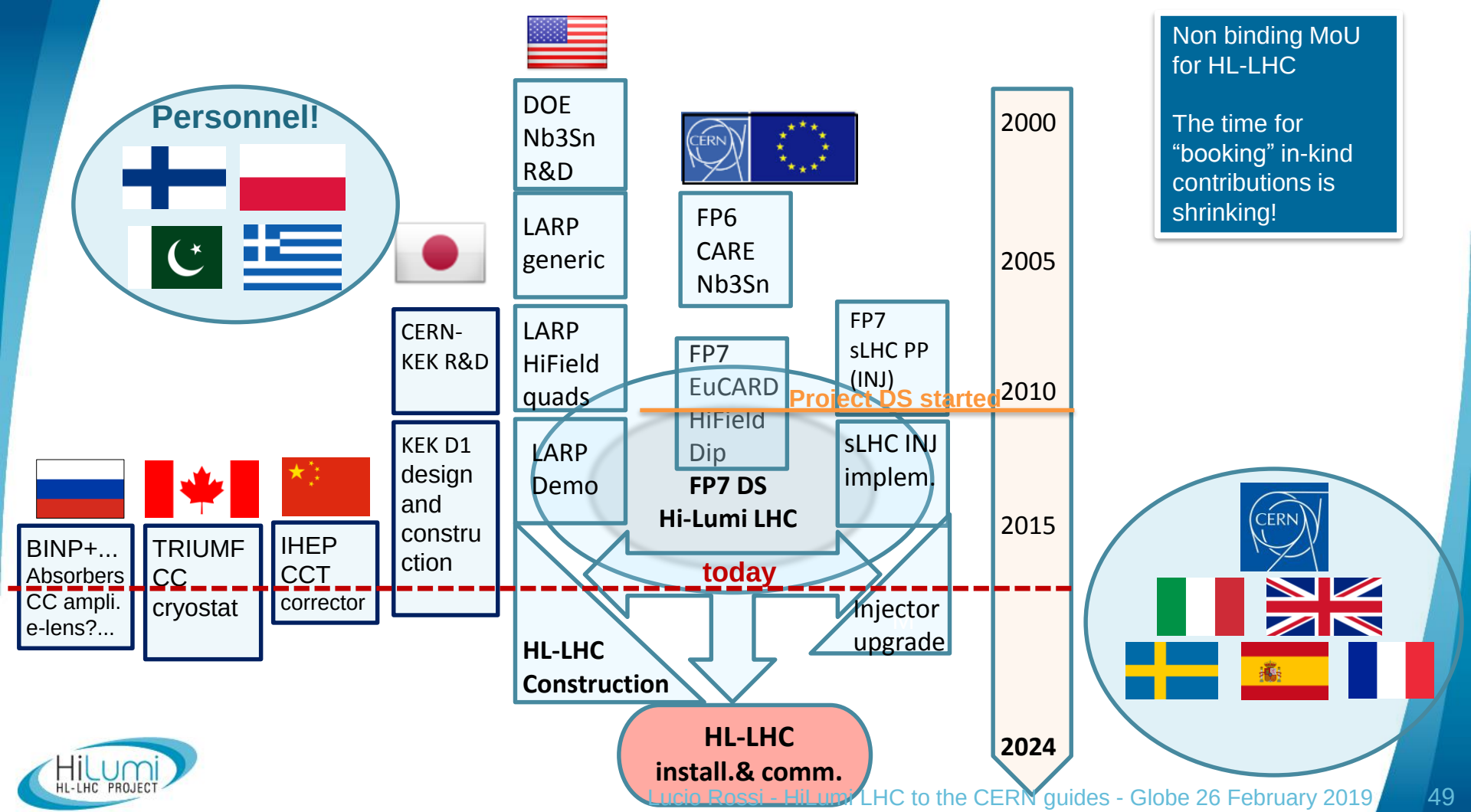


Hollow electron lens

Courtesy UA9/PNPI



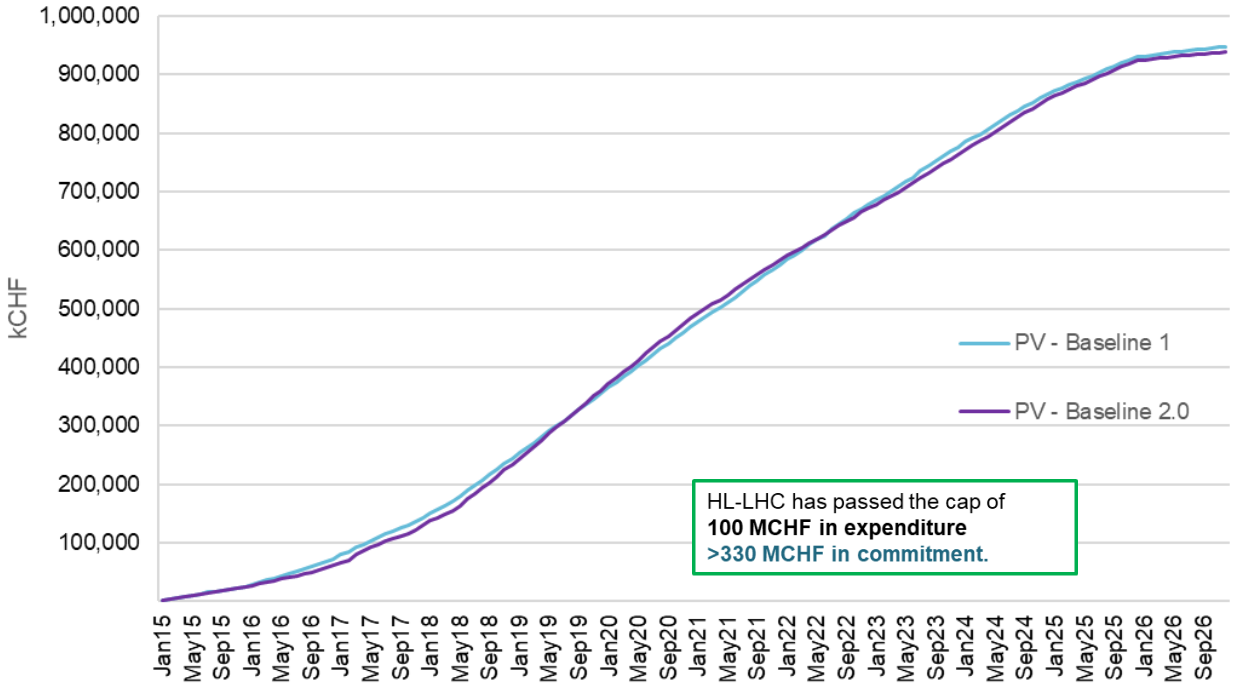
Crystal collimation


Personnel!
DOE Nb3Sn R&D
LARP generic
LARP HiField quads
LARP Demo
FP6 CARE Nb3Sn
FP7 EuCARD HiField Dip
FP7 DS Hi-Lumi LHC
FP7 sLHC PP (INJ)
sLHC INJ implem.
CERN-KEK R&D
KEK D1 design and construction
BINP+... Absorbers CC ampli. e-lens?...
TRIUMF CC cryostat
IHEP CCT corrector
Project DS started
today
HL-LHC Construction
Injector upgrade
HL-LHC install.& comm.
2000
2005
2010
2015
2024
Non binding MoU for HL-LHC
The time for "booking" in-kind contributions is shrinking!

Recent signed collaborations and in-kinds

HiLumi HL-LHC PROJECT

950 MCHFof material cost and about 2000 Person-years (200 FTE for 10 years)



No additional budget form Member States. (Excpet the additional exceptional contribution).

Extra-need of people, beyond the 200 people of staff, fullifileld with personnel from MS and NMS project associates (or collaborating associates)

A great effort … but also an investment

HL-LHC Industry

Industry Relations and Procurement Website for the HL-LHC project

Search this site | Search

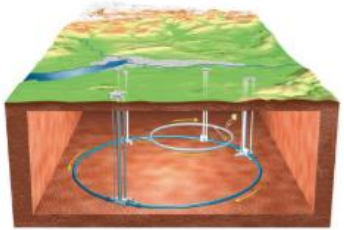
Home | General Info | Procurement Overview | Tendering | Acquisition Timeline | Events | Contact

Building the HL-LHC with the Industry

The HL-LHC Industry Website has been specially designed for all those firms that wish to participate in this ambitious project. We want to share all the relevant information related to the procurement that will be required to accomplish this major upgrade of the LHC.

The industry will have a crucial role and will be heavily involved within the HL-LHC Project since it will be the main source to provide the technologies and equipment that are required to successfully achieve the goals of this upgrade of the LHC.

The HL-LHC will collaborate with many types of industries and businesses to pursue its goals. Knowledge and technology to be developed during the HL-LHC project will make a lasting impact on society.



ILOS

ILOs Portal

HIGHLIGHTS

12 June 2017

BIG SCIENCE BUSINESS FORUM

Big Science Business Forum 2018

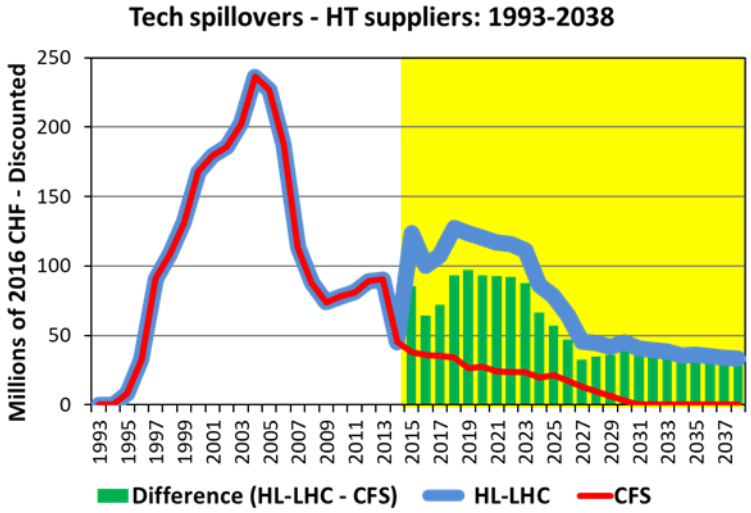
Big Science Business Forum 2018 will be the first one-stop-shop for European companies and other stakeholders to learn about Europe's Big Science organisations' future investments and procurements. CERN event will at thie major event that will be held at Copenhagen on 27 and 28 February 2018.

Read more

Avec un clair retour pour la société

A recent study of the University of Mialn Economy Dept, has estimated that for each CHF invested in the HL-LHC there is a net gain for HiTech companies of about 1.7 CHF

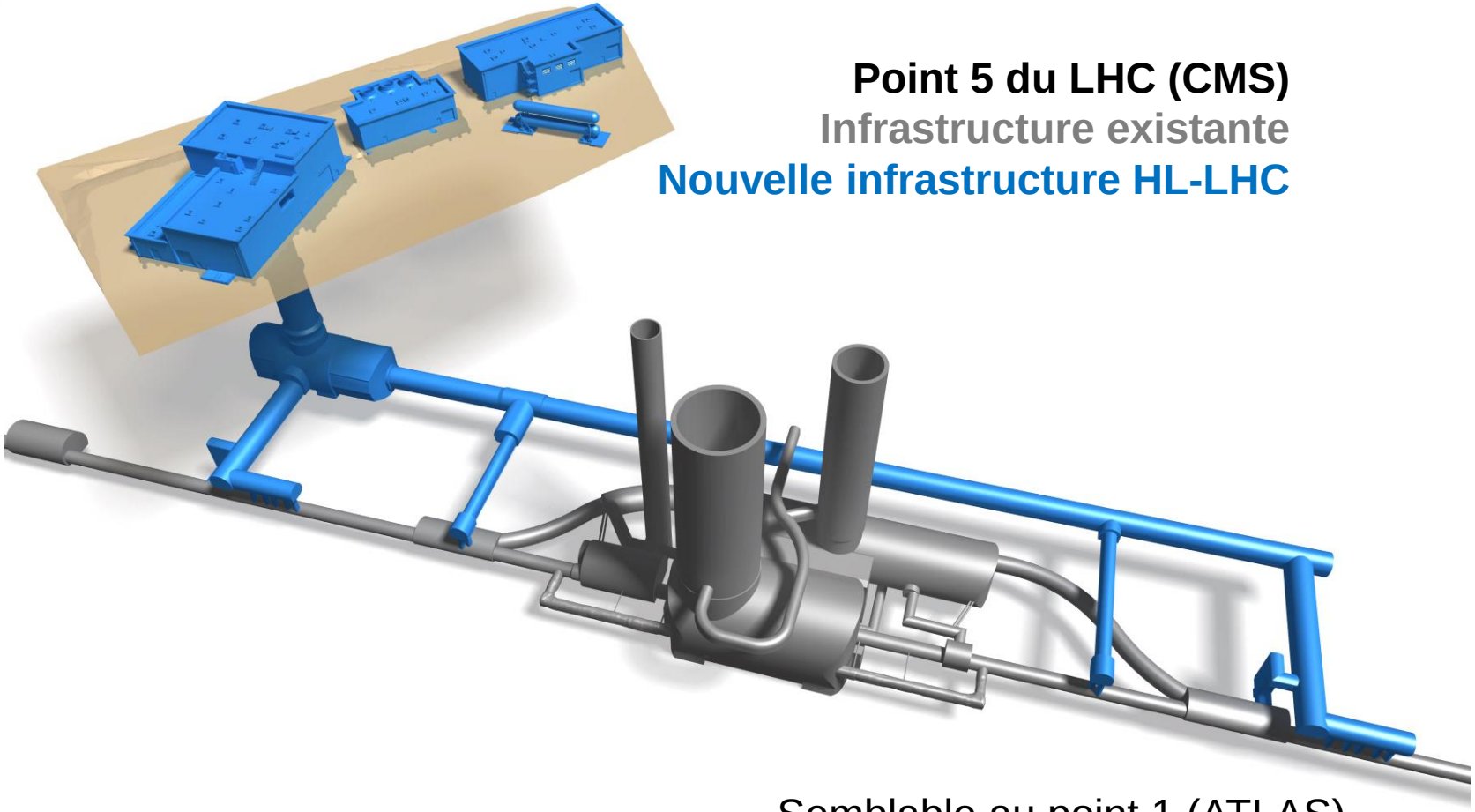
- Technology return to industry
- Training
- Public cultural effect
- Publications of scientific articles



Point 5 du LHC (CMS)

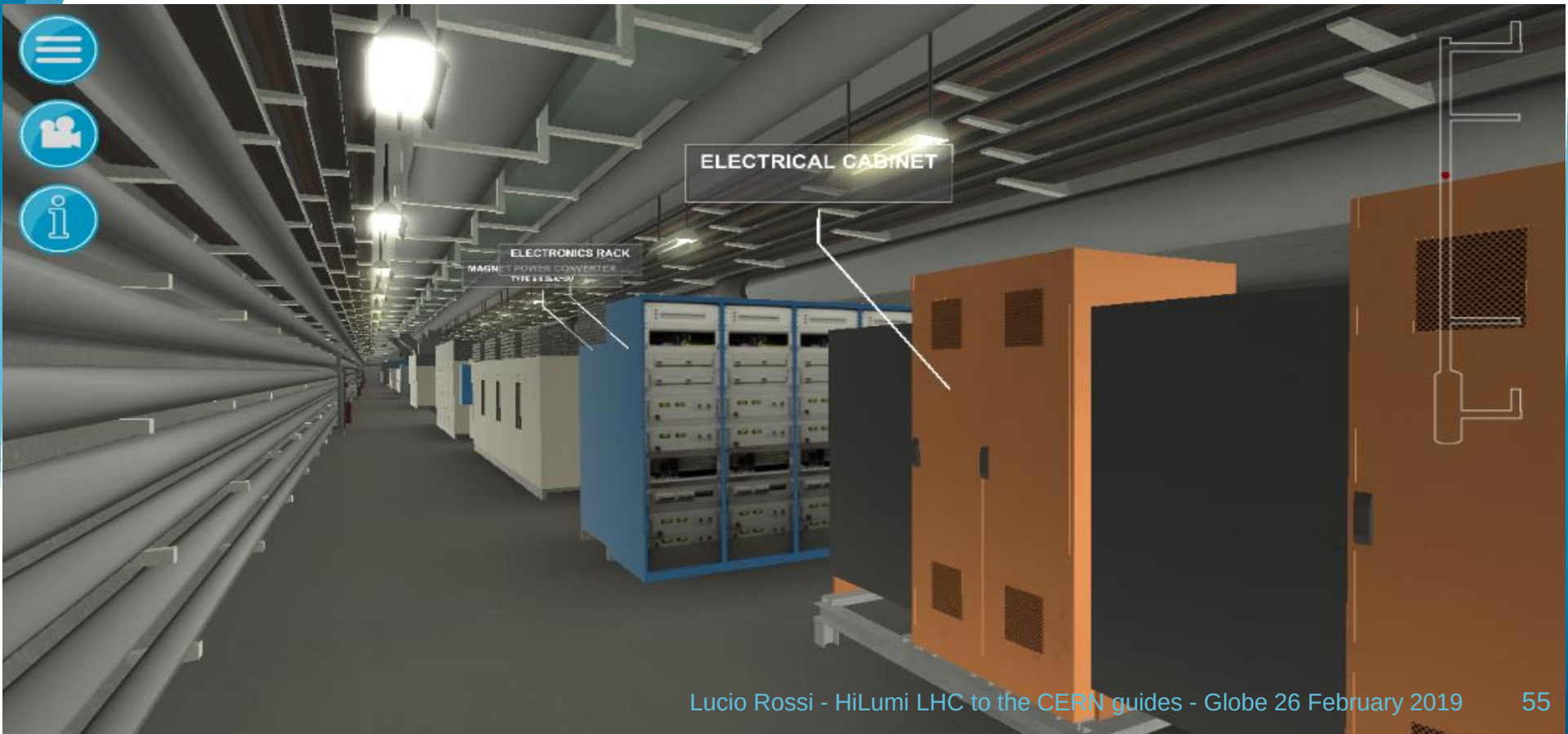
Infrastructure existante

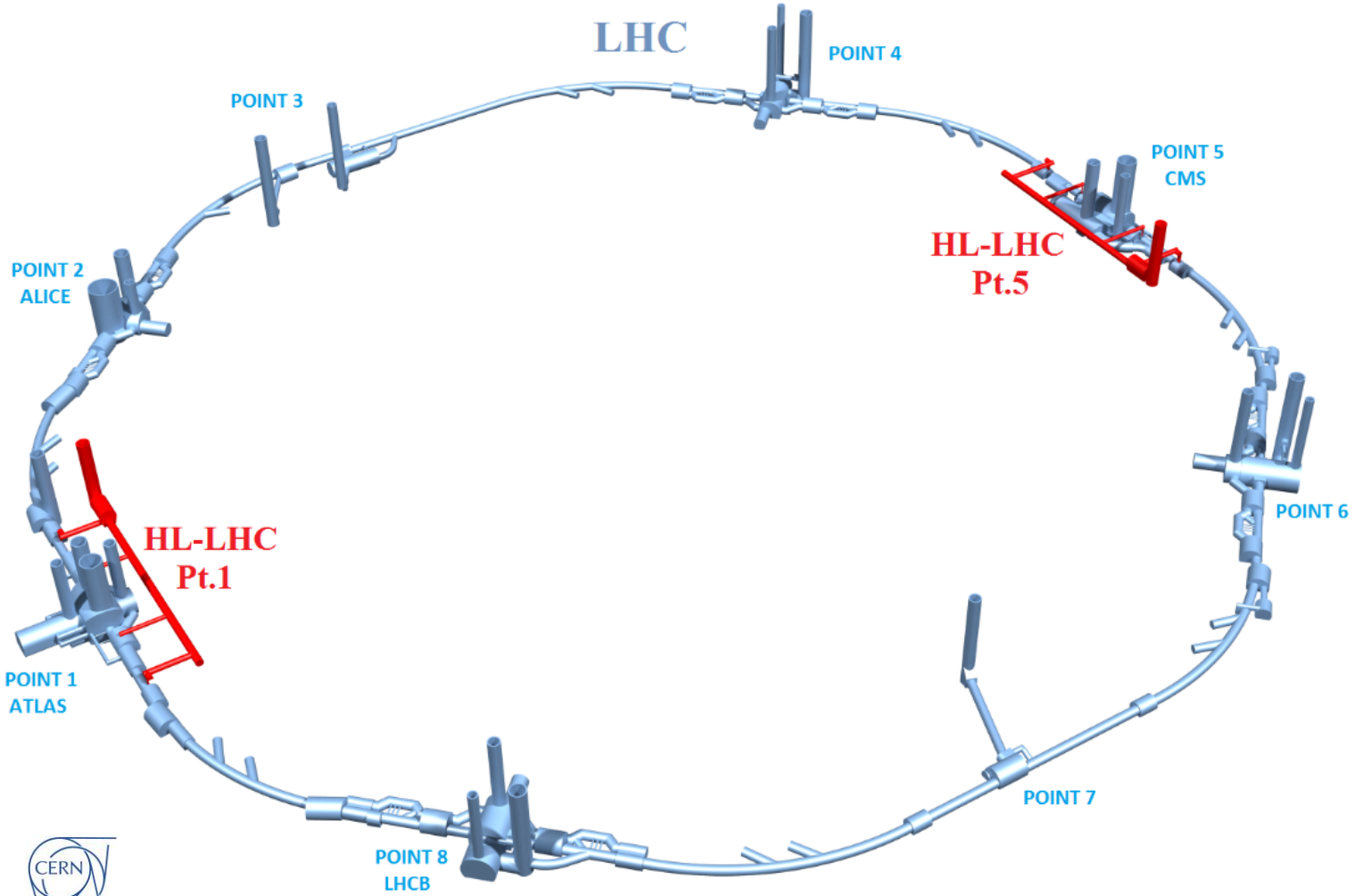
Nouvelle infrastructure HL-LHC



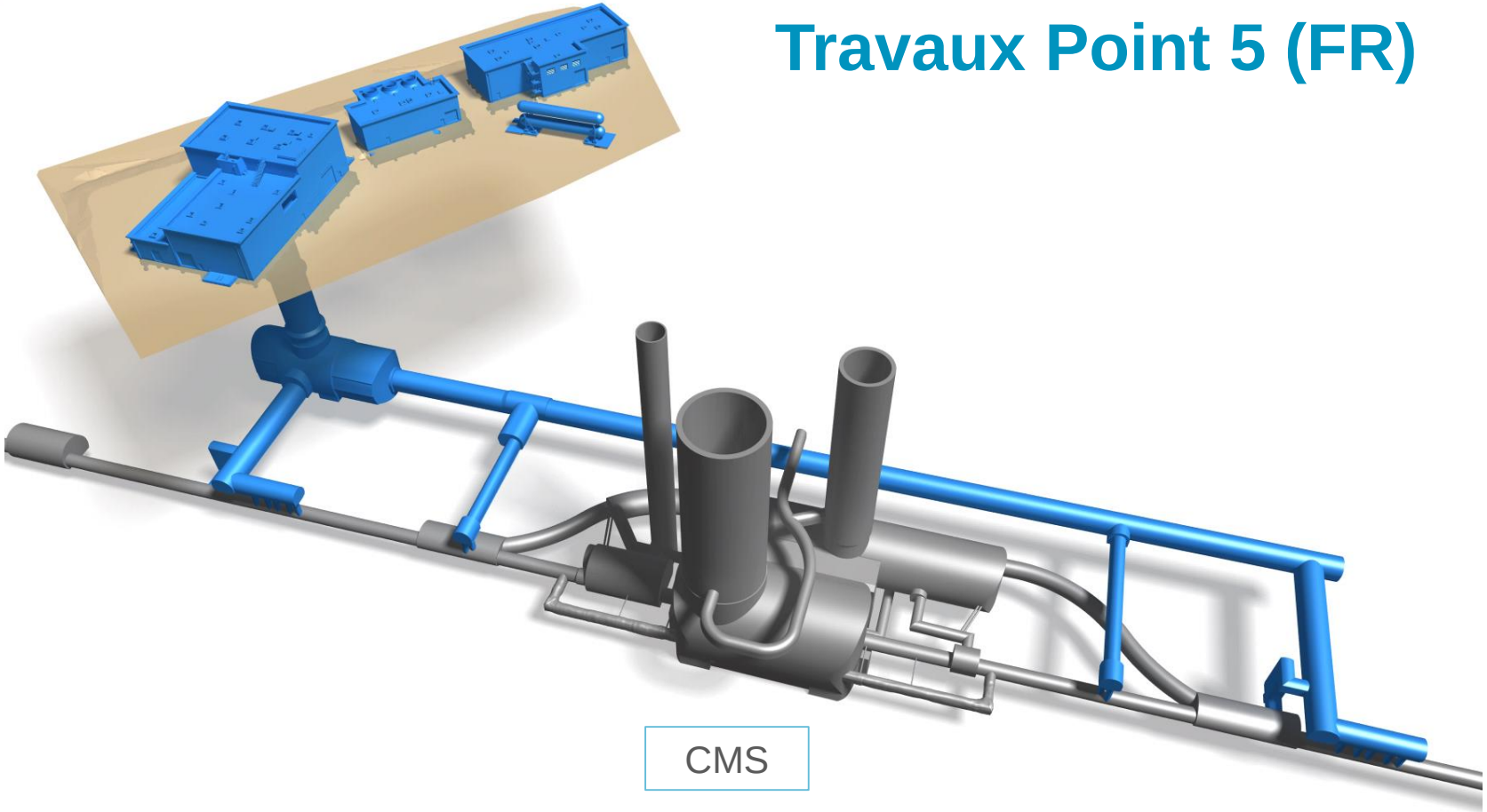
Semblable au point 1 (ATLAS)

2021–2025: Préparation de l’infrastructure



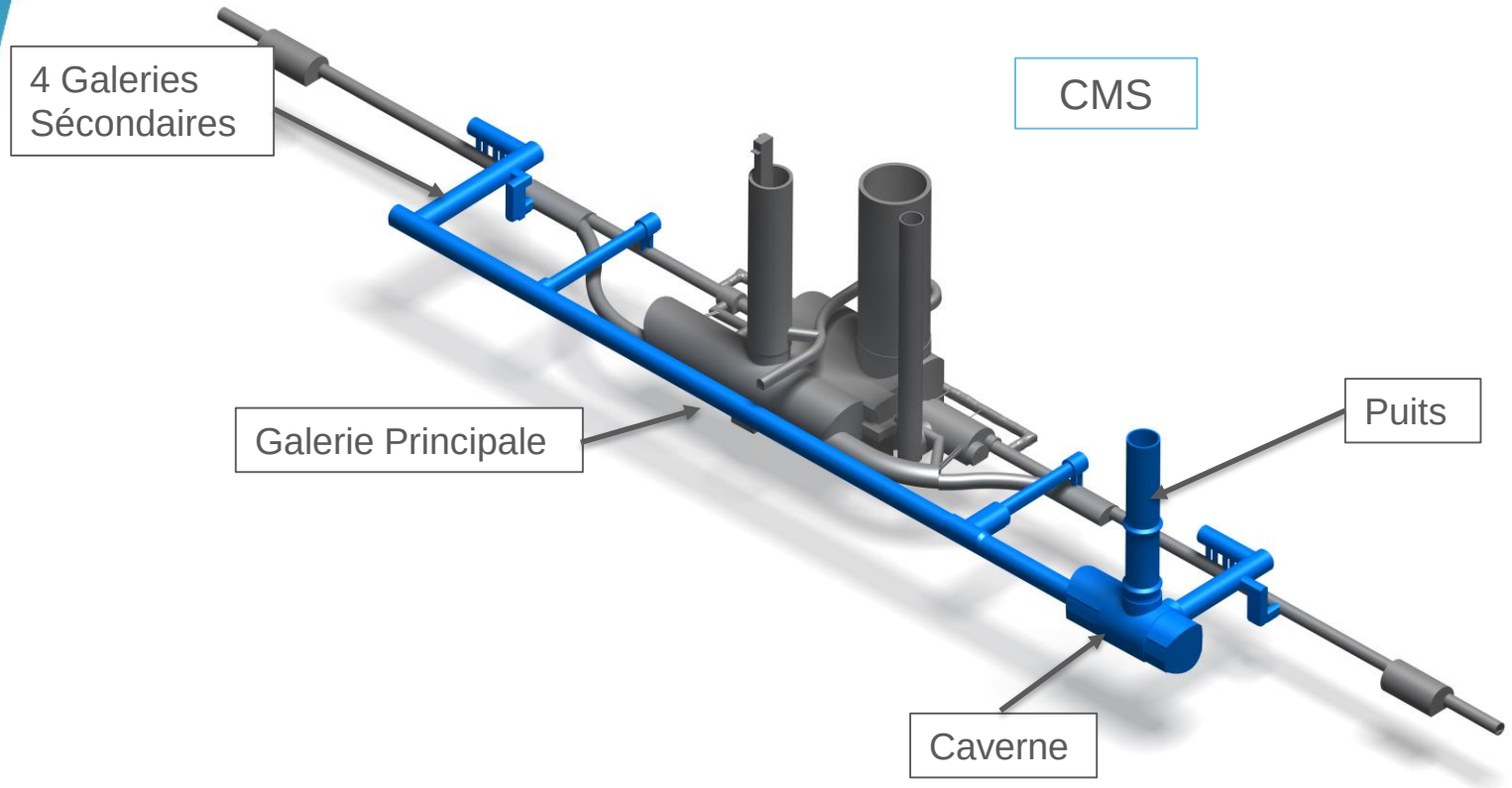

LHC
POINT 4
POINT 3
POINT 5
CMS
HL-LHC
Pt.5
POINT 2
ALICE
HL-LHC
Pt.1
POINT 6
POINT 1
ATLAS
POINT 7
POINT 8
LHCB

Travaux Point 5 (FR)

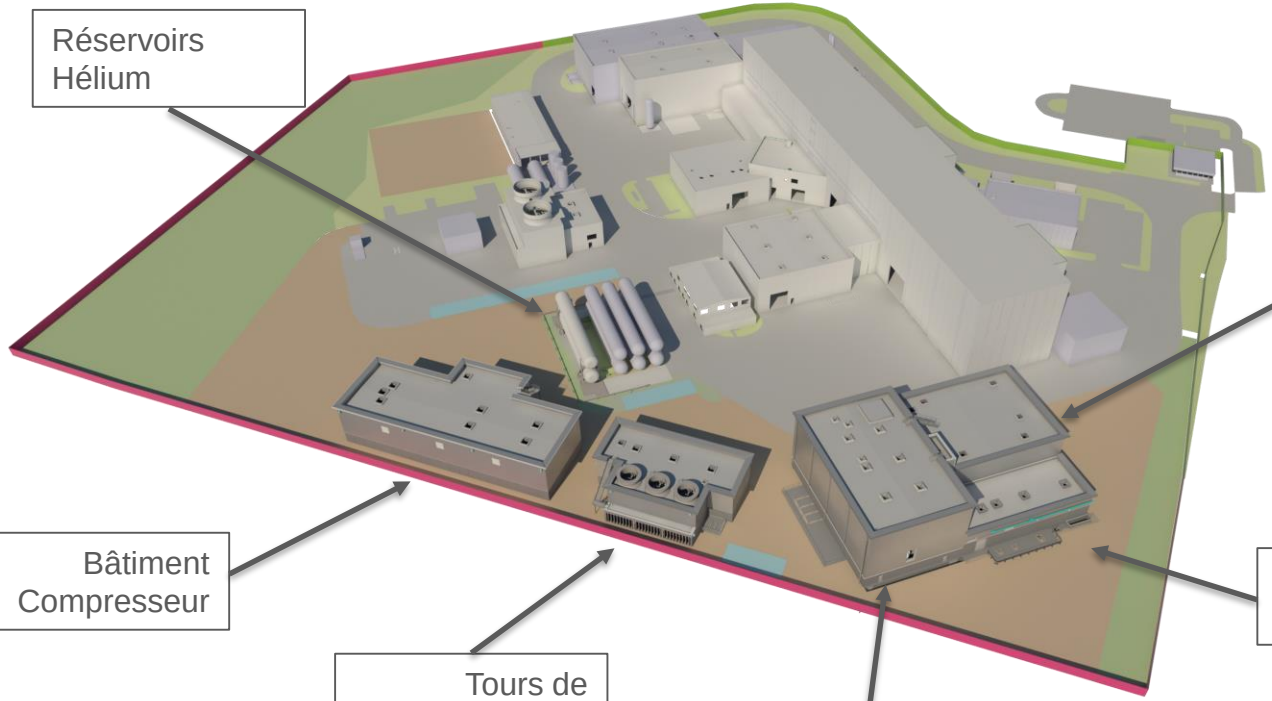


CMS

Travaux Souterrains



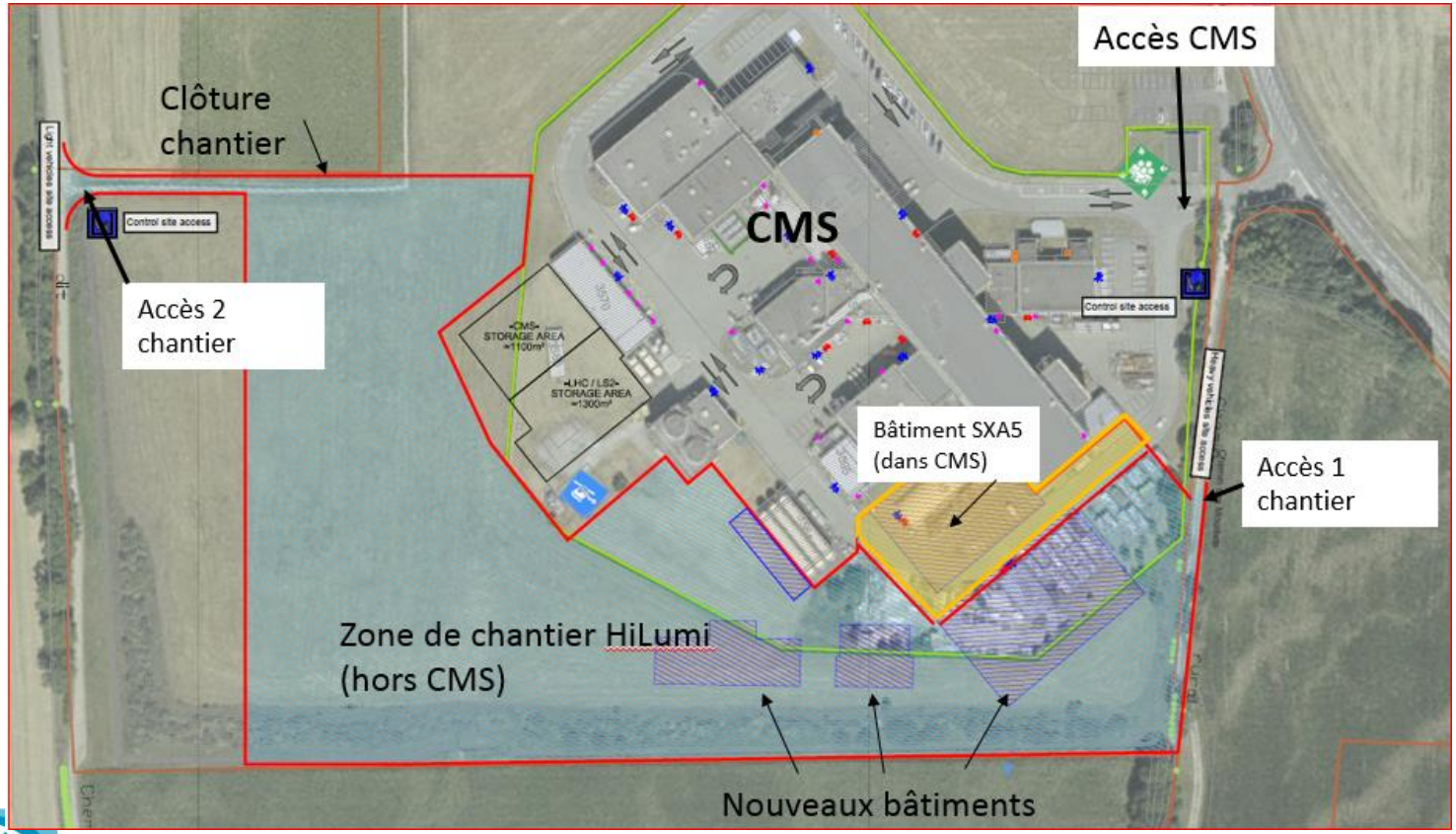
Travaux Surface



Informations sur Travaux

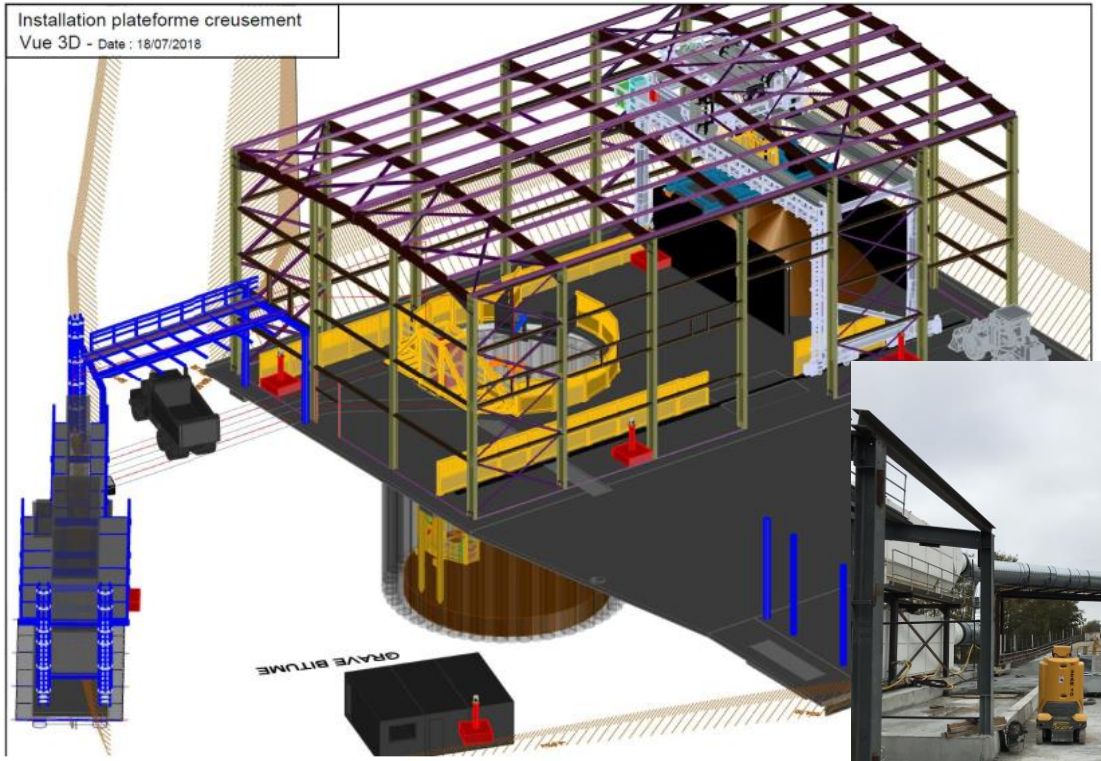
- Entreprise: CIB Consortium Implenia Baresel
  - Origine France, Allemagne, Suisse;
- Valeur du contrat: 58 millions EUR
- Durée des travaux: 2018-2022 (54 mois)
  - Souterrain: mi-2018 jusqu'à fin-2021;
  - Surface: début -2020 jusqu'à mi-2022;

Chantier Point 5 (Installations de chantier 1/3)

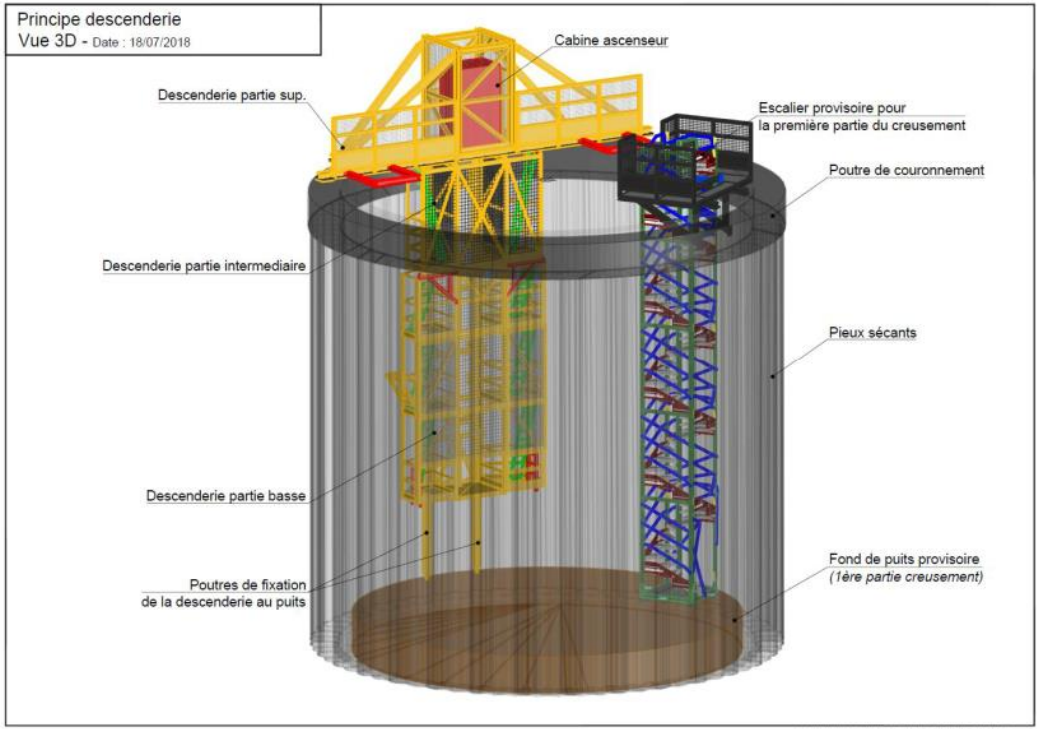


Chantier Point 5 (Installations de chantier 2/3)

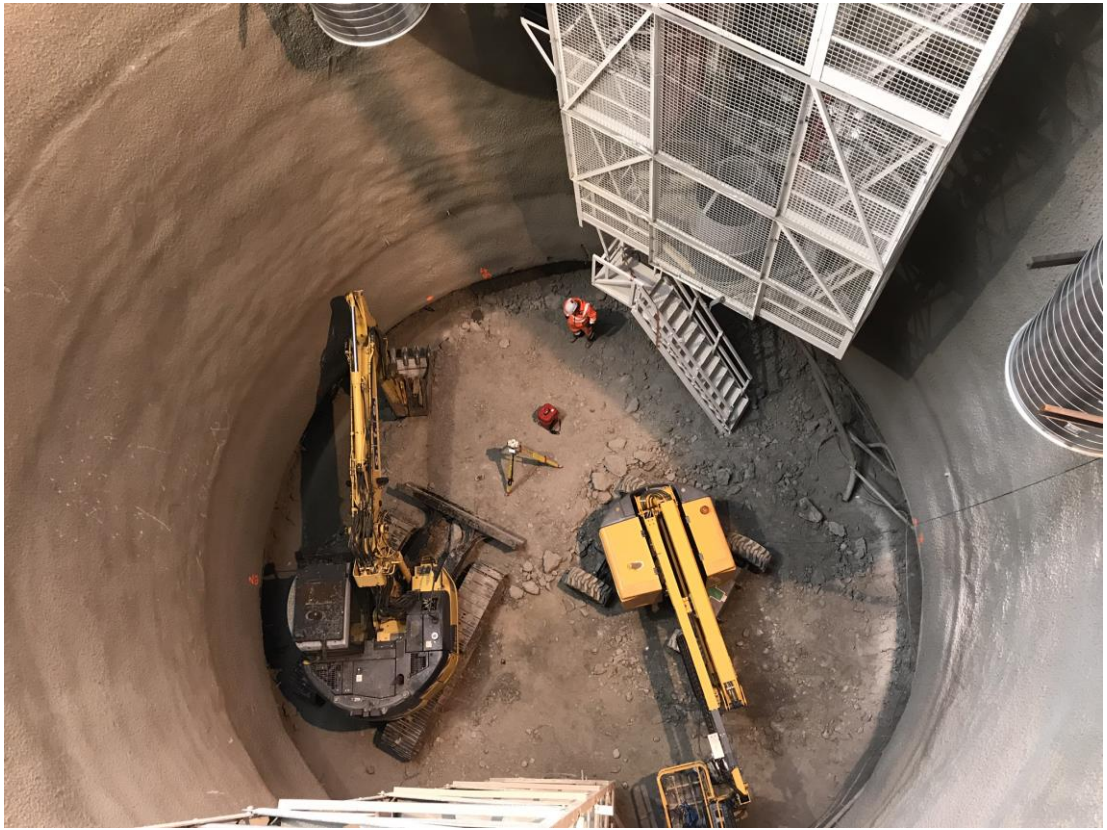
Chantier Point 5 (Installations de chantier 3/3)



Chantier Point 5 (Puits 1/3)

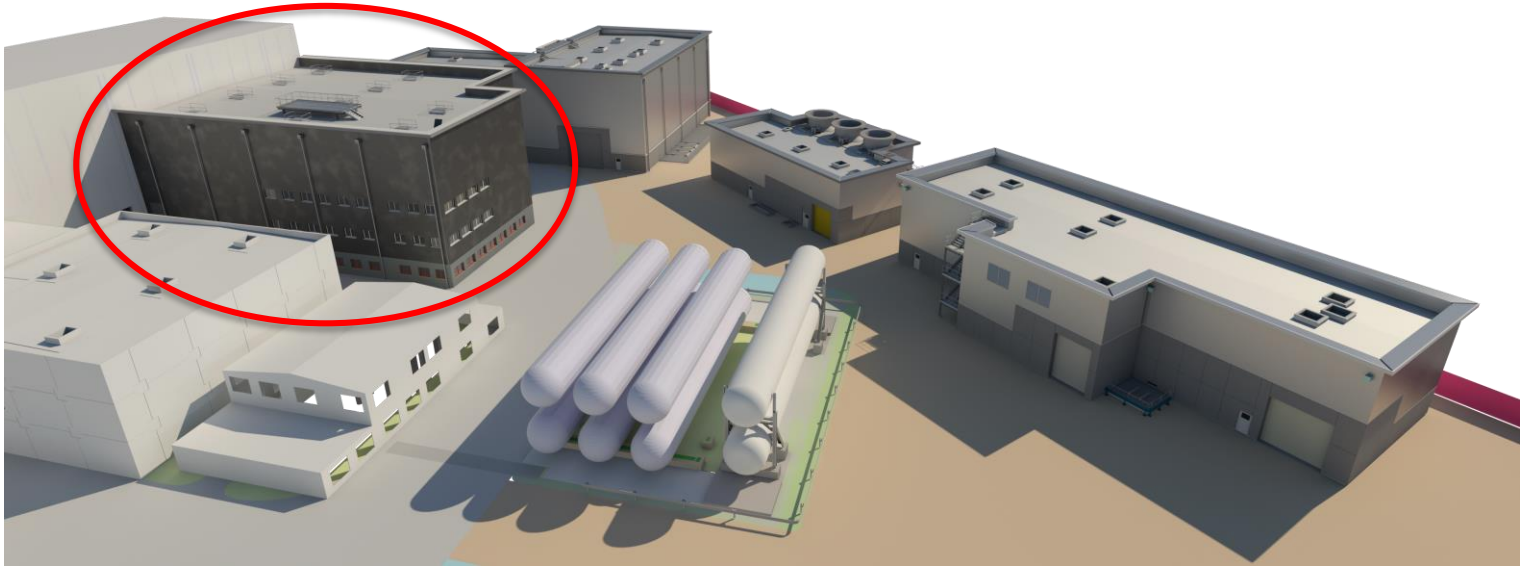


Chantier Point 5 (Puits 2/3)

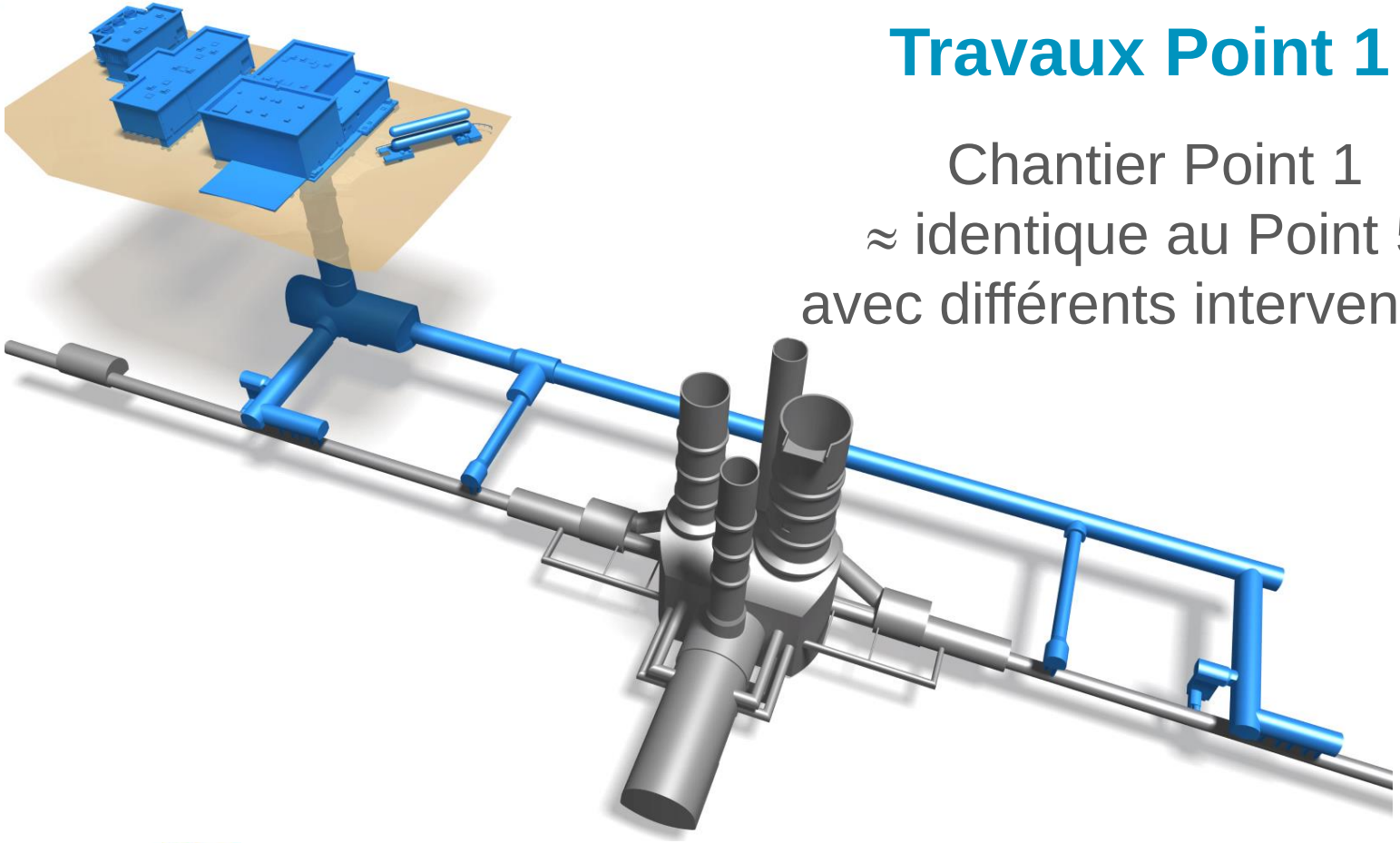


Chantier Point 5 (Puits 3/3)

Chantier SXA5



Travaux Point 1

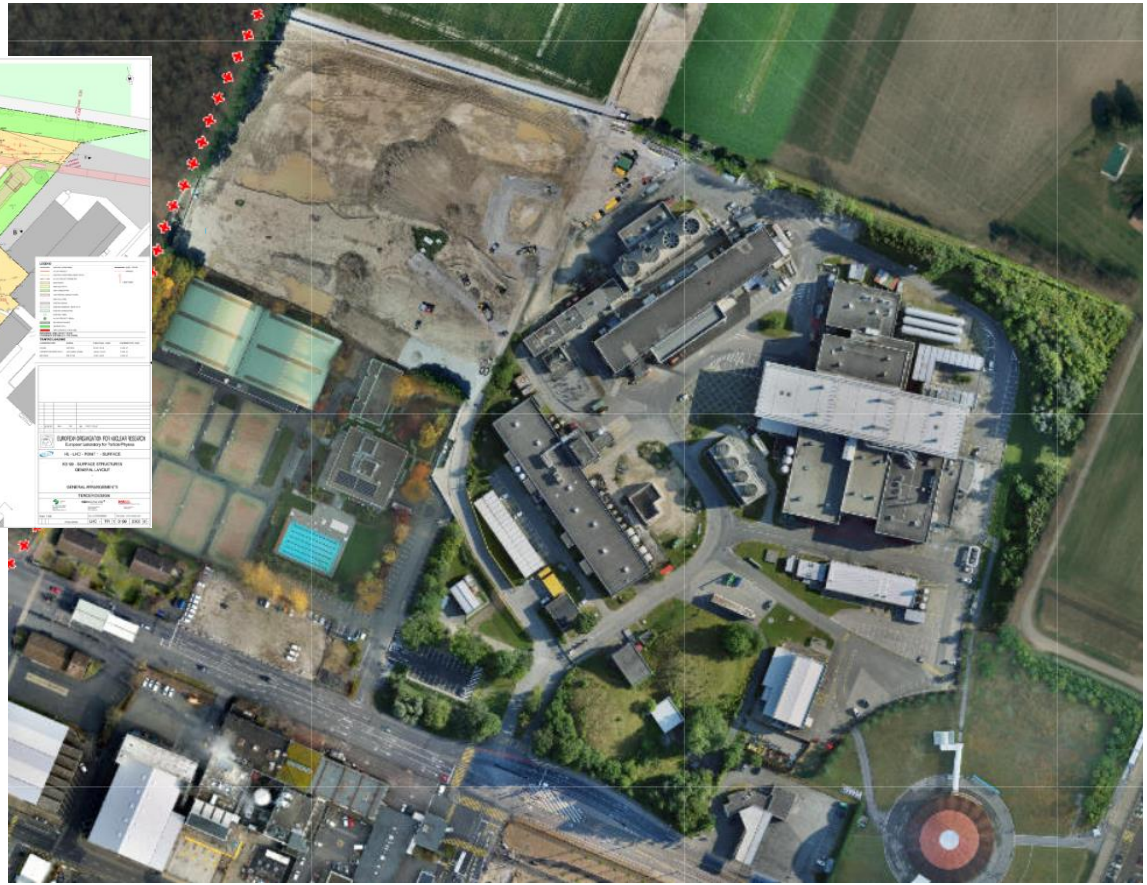


Chantier Point 1
≈ identique au Point 5,
avec différents intervenants

Informations sur Point 1 (CH)

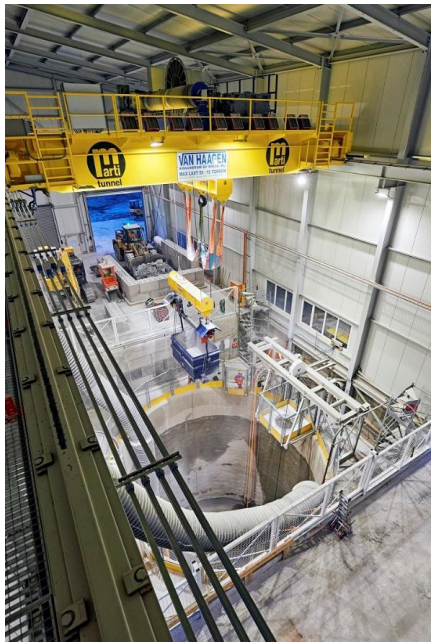
- Entreprise: groupement Marti
  - Origine Suisse, Allemagne, Autriche;
  - Pilote Souterrain: Marti Tunnel AG de Berne;
  - Pilote Surface: Marti Construction SA de Meyrin;
- Valeur du contrat: 67 million CHF
- Durée des travaux: 2018-2022 (53 mois)
  - Souterrain: mi-2018 jusqu'à mi-2021;
  - Surface: fin-2019 jusqu'à mi-2022;

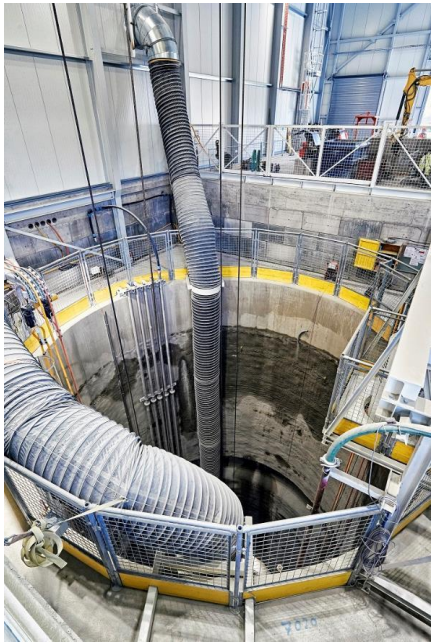
Chantier Point 1

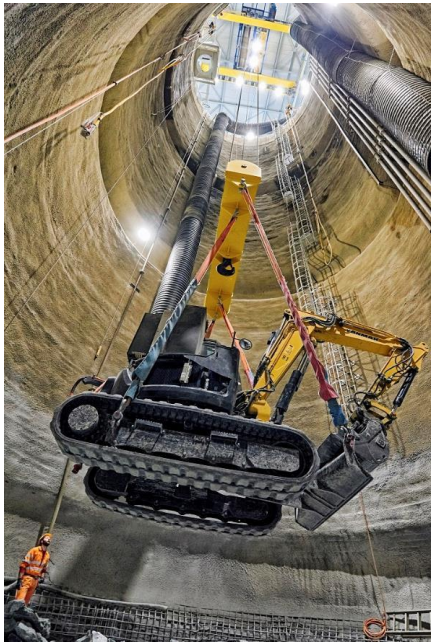


Contract T117 – JVMM – LHC P1 (ATLAS)

Contract T117 – JVMM – LHC P1 (ATLAS)







Contract T117 – JVMM – LHC P1 (ATLAS)

Material on the HiLumi project (accelerators)

Isabel Bejar Alonso
Communication & outreach for HL-LHC

- http://hilumilhc.web.cern.ch/

- EDMS document(s): 2061550 v.1 "HL-LHC Video Trailer" by Polar Media in status: Released
  Trailer of the Documentary film on the High Luminosity LHC project co produced with Polar Media (...
  Link: https://edms.cern.ch/document/2061550/1/approvalAndComments
- EDMS document(s): 2061569 v.1 "HL-LHC Videos animations" by Isabel BEJAR ALONSO in status: Released
  Civil Enginnering, Crab cavities, ,Works on points, 11T Simulation with Frederic…
  Link: https://edms.cern.ch/document/2061569/1/approvalAndComments
- EDMS document(s): 1852260 v.1.1 "Posters HiLumi - October 2017" by Isabel BEJAR ALONSO, Hector GARCIA GAVELA in status: Released
  Link: https://edms.cern.ch/document/1852260/1.1/approvalAndComments

Thanks!
Questions?