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Exploitation et défis futurs du LHC

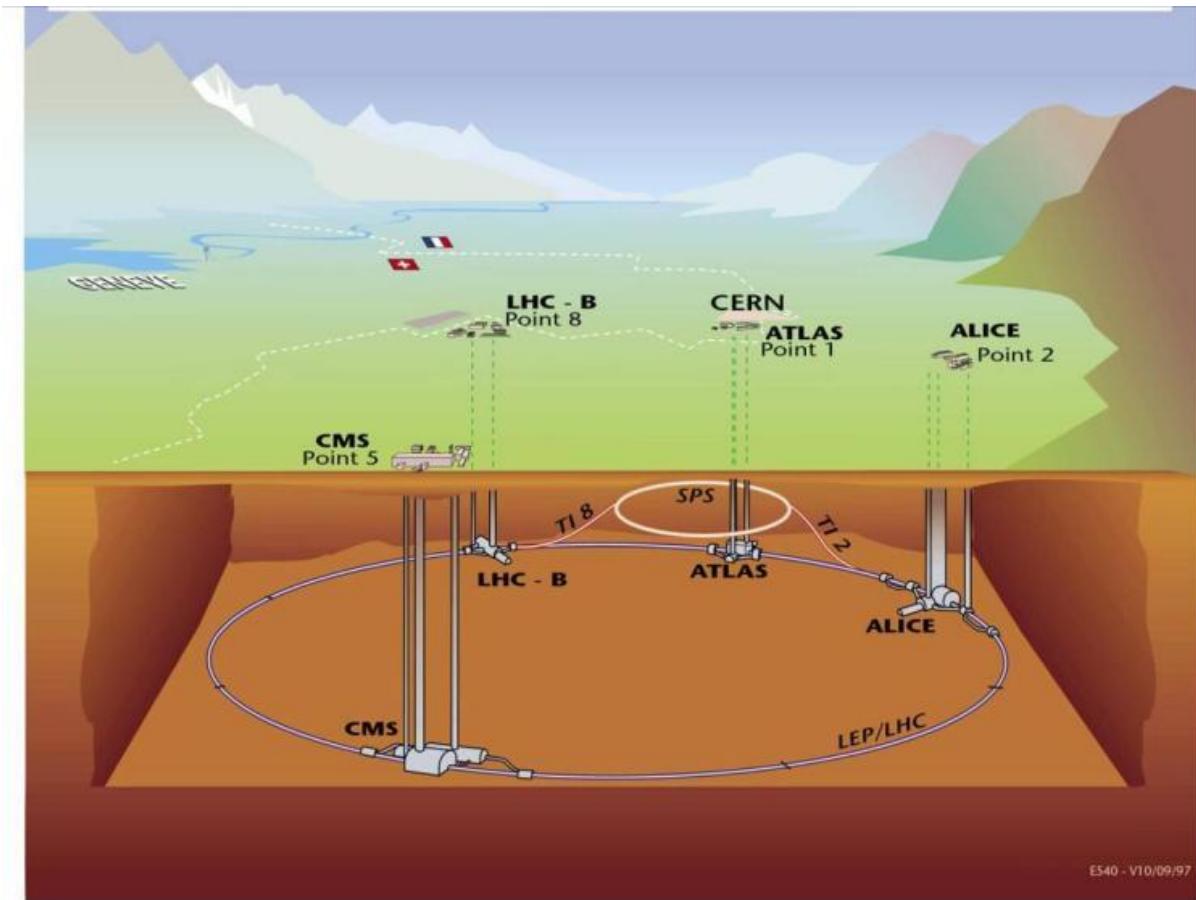
Frédéric BORDRY

6 juin 2013

Le LHC (Large Hadron Collider)

Un accélérateur-collisionneur:
proton-proton
7 TeV – 7 TeV

Egalement des collisions plomb-plomb (énergie de collision de 1150 TeV) et plumb-proton

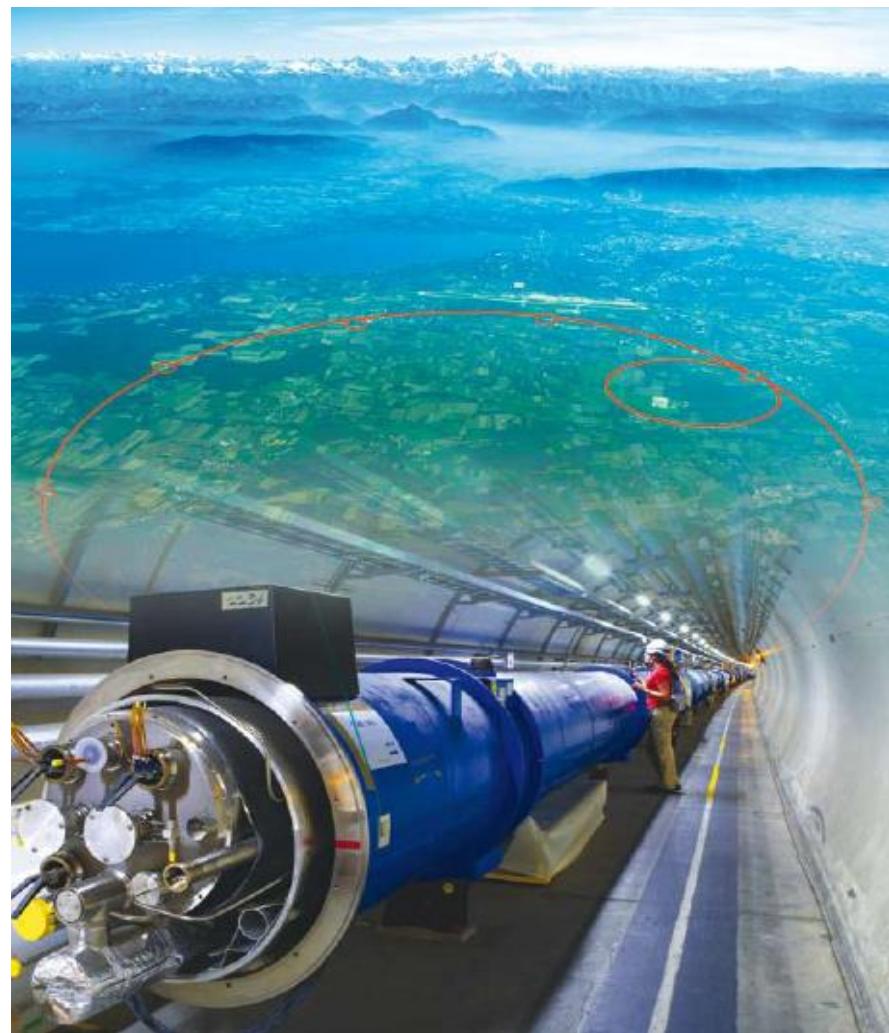


Un accélérateur de 27 km de circonférence...

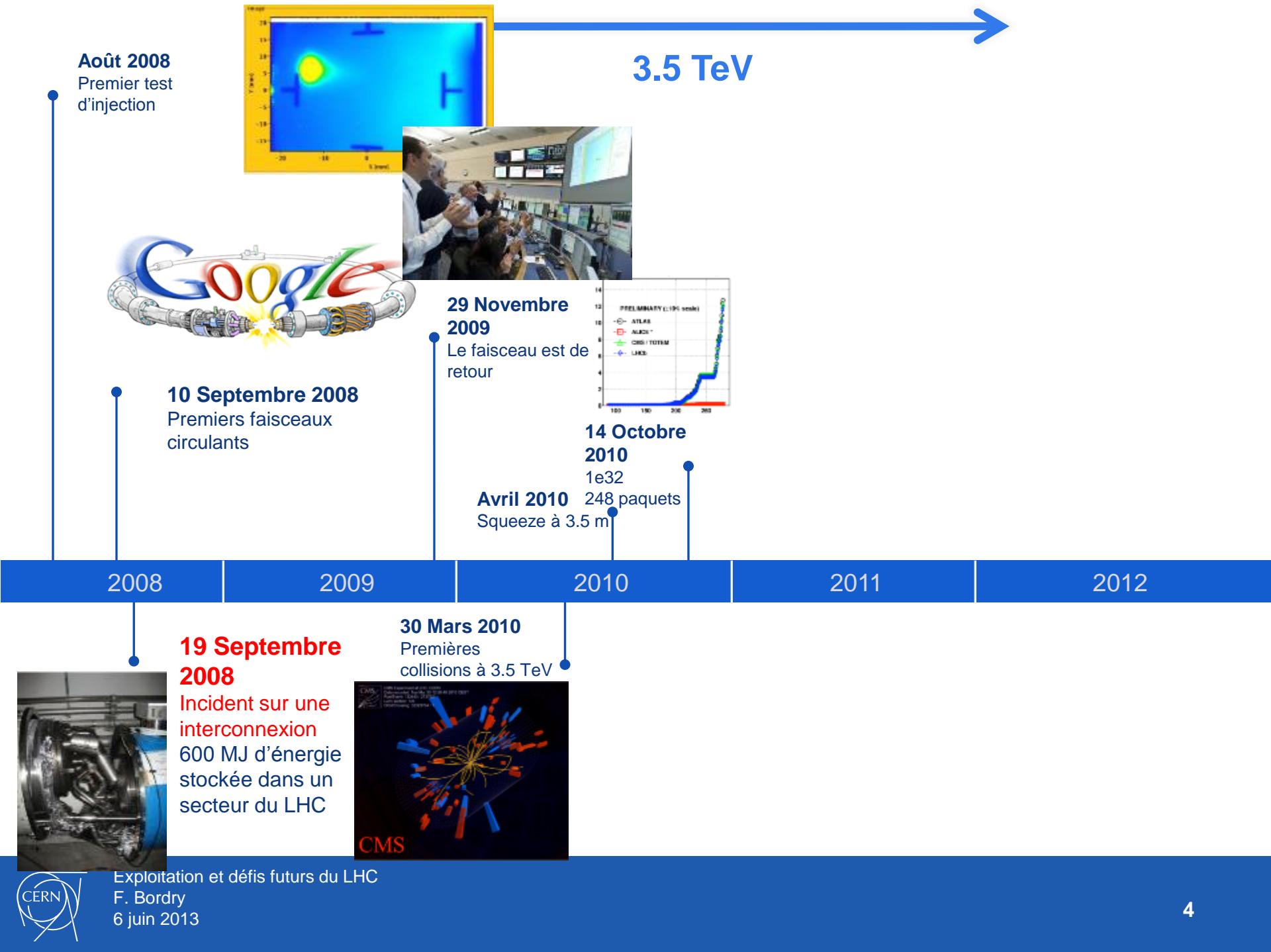
Le LHC (Large Hadron Collider)

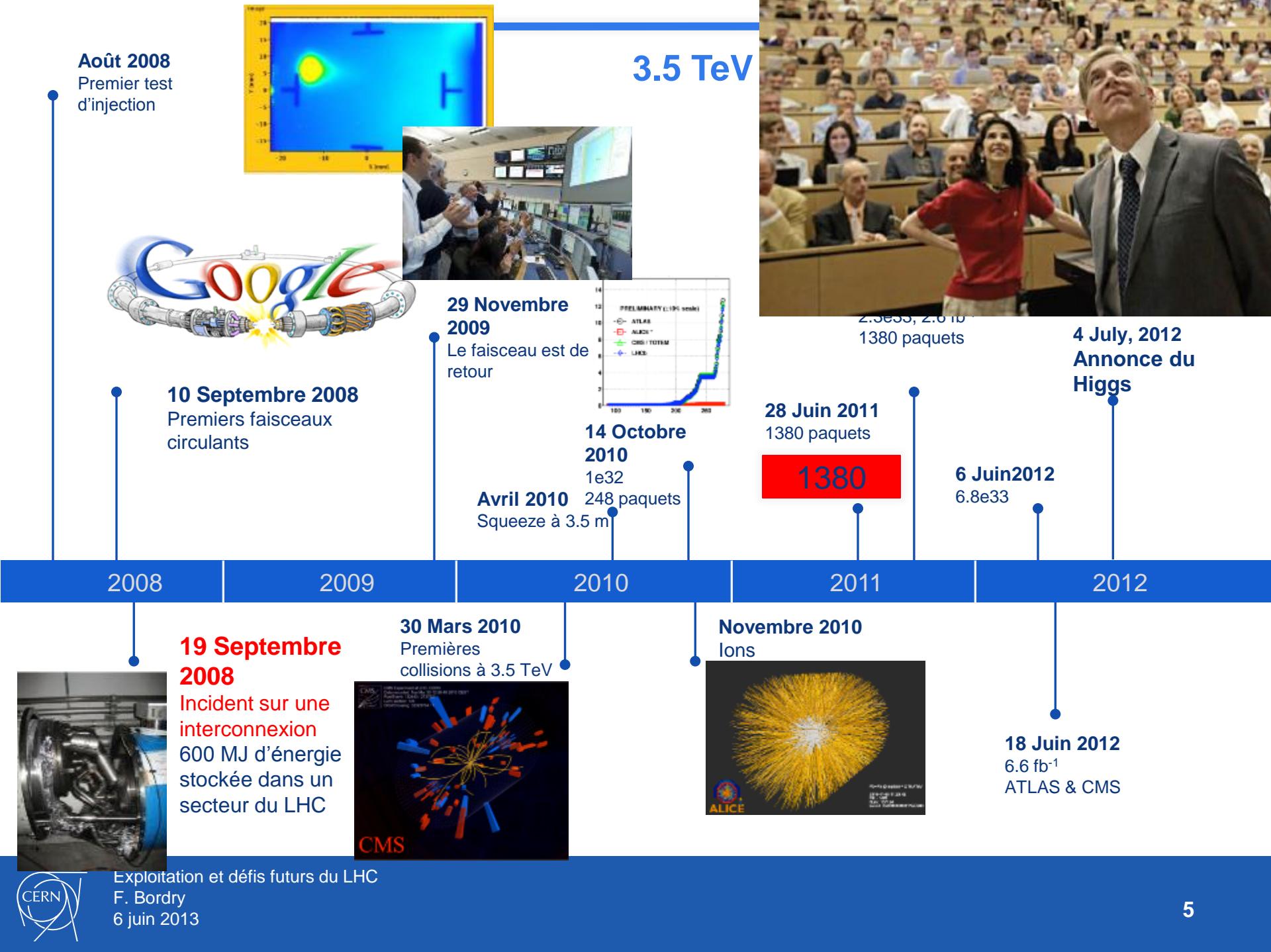
Un accélérateur- collisionneur: proton-proton **7 TeV – 7 TeV**

- 1983 : Etudes conceptuelles préliminaires
- 1988 : Premiers modèles d'aimants (faisabilité)
- 1994 : Approbation par le Conseil du CERN
(sous la présidence d'Hubert Curien)
- 1996-1999 : Industrialisation des productions de série
- 1998 : DUP & début du génie civil
- 1998-2000 : Passation des principaux marchés
- 2004 : Début de l'installation dans le tunnel
- 2005-2007 : Installation des aimants dans le tunnel
- 2007 : Test fonctionnel du premier secteur
- 2008-2009 : Fin de la mise en service et réparation
- 2009-2030 : Exploitation pour la physique



Un accélérateur de 27 km de circonférence...

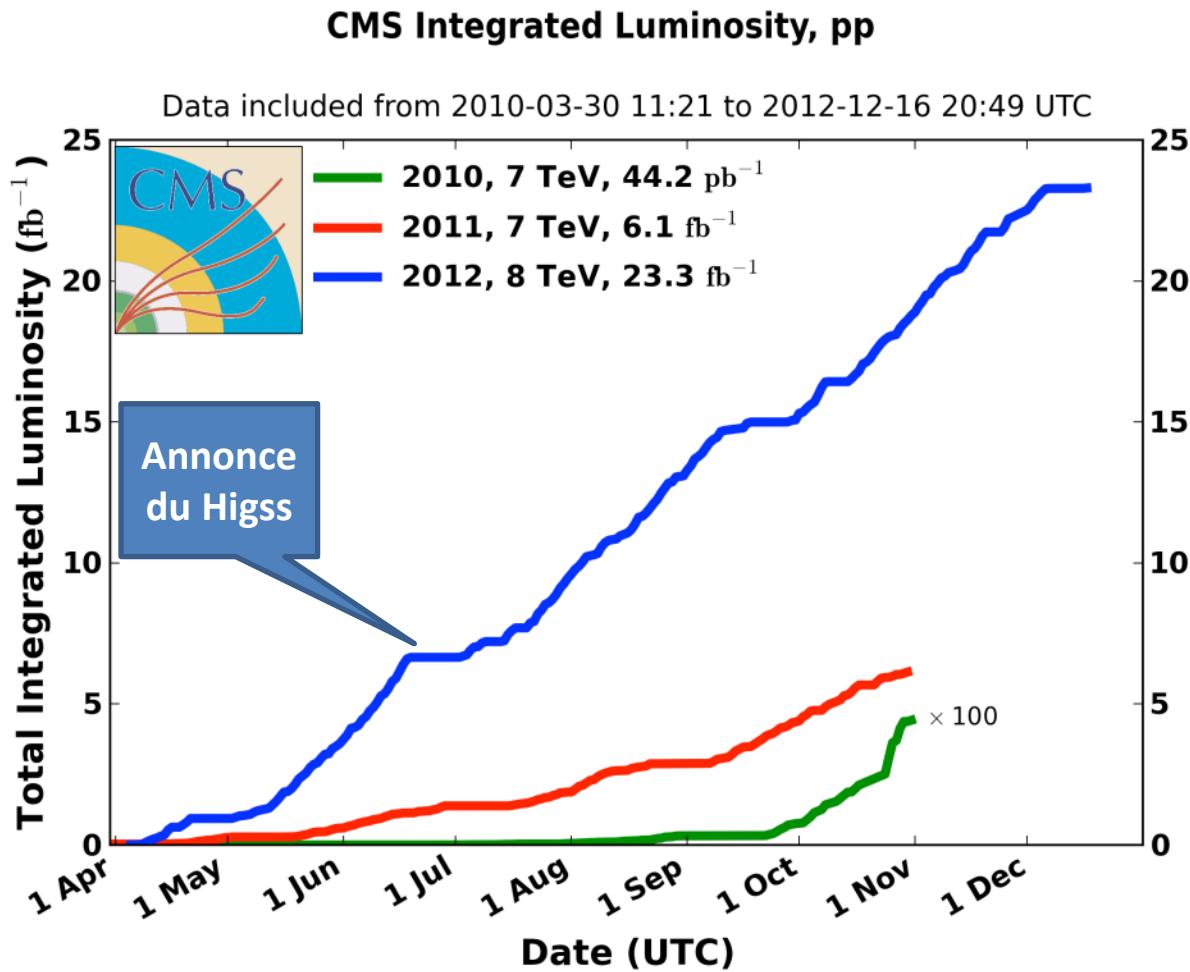




Peak performance through the years

	2010	2011	2012	Nominal
Bunch spacing [ns]	150	50	50	25
No. of bunches	368	1380	1380	2808
beta* [m] ATLAS and CMS	3.5	1.0	0.6	0.55
Max bunch intensity [protons/bunch]	1.2×10^{11}	1.45×10^{11}	1.7×10^{11}	1.15×10^{11}
Normalized emittance [mm.mrad]	~2.0	~2.4	~2.5	3.75
Peak luminosity [cm $^{-2}$ s $^{-1}$]	2.1×10^{32}	3.7×10^{33}	7.7×10^{33}	1.0×10^{34}

2010-2012: une belle moisson de collisions



2010: **0.04 fb^{-1}**
7 TeV CdM
Mise en service

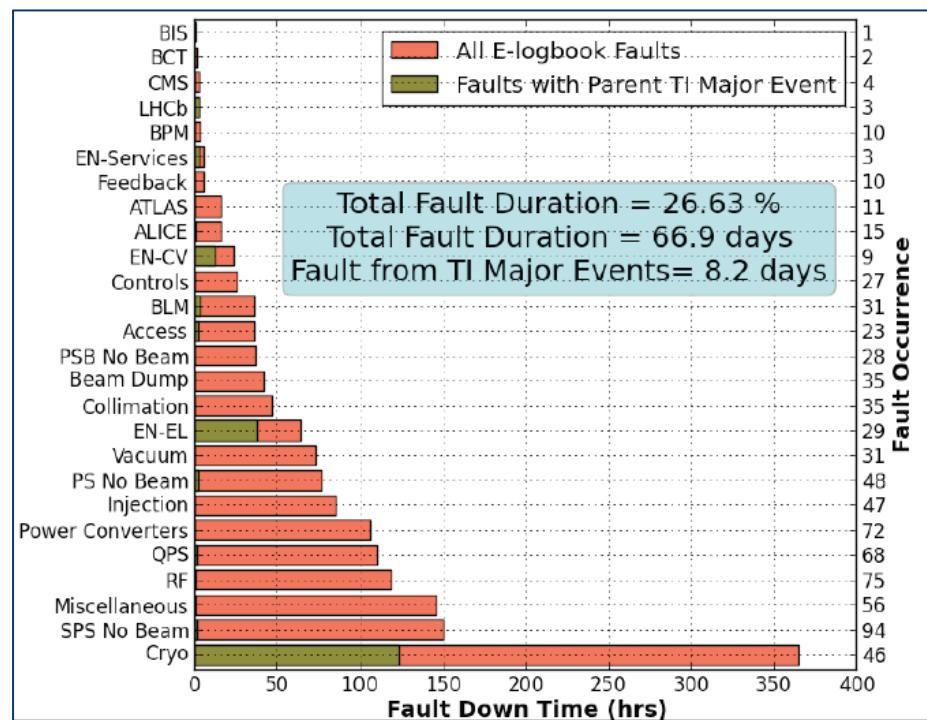
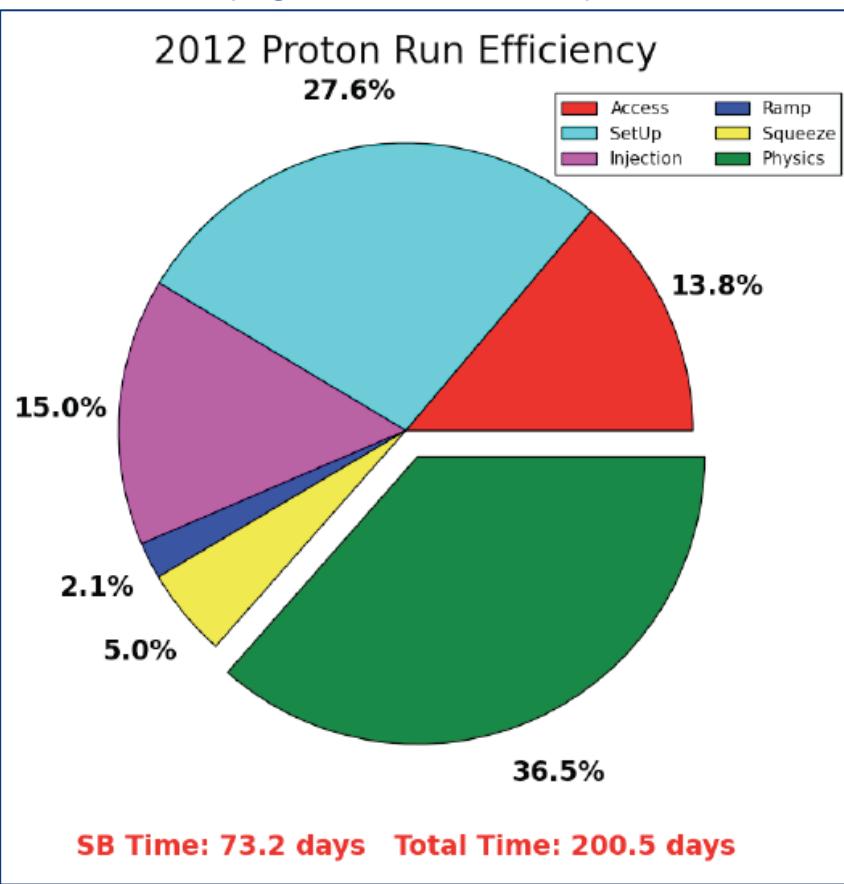
2011: **6.1 fb^{-1}**
7 TeV CdM
... exploration des limites

2012: **23.3 fb^{-1}**
8 TeV CdM
... production

3.5 TeV puis 4 TeV
Jusqu'à 1380 paquets
de $1.5 \cdot 10^{11}$ protons

Availability

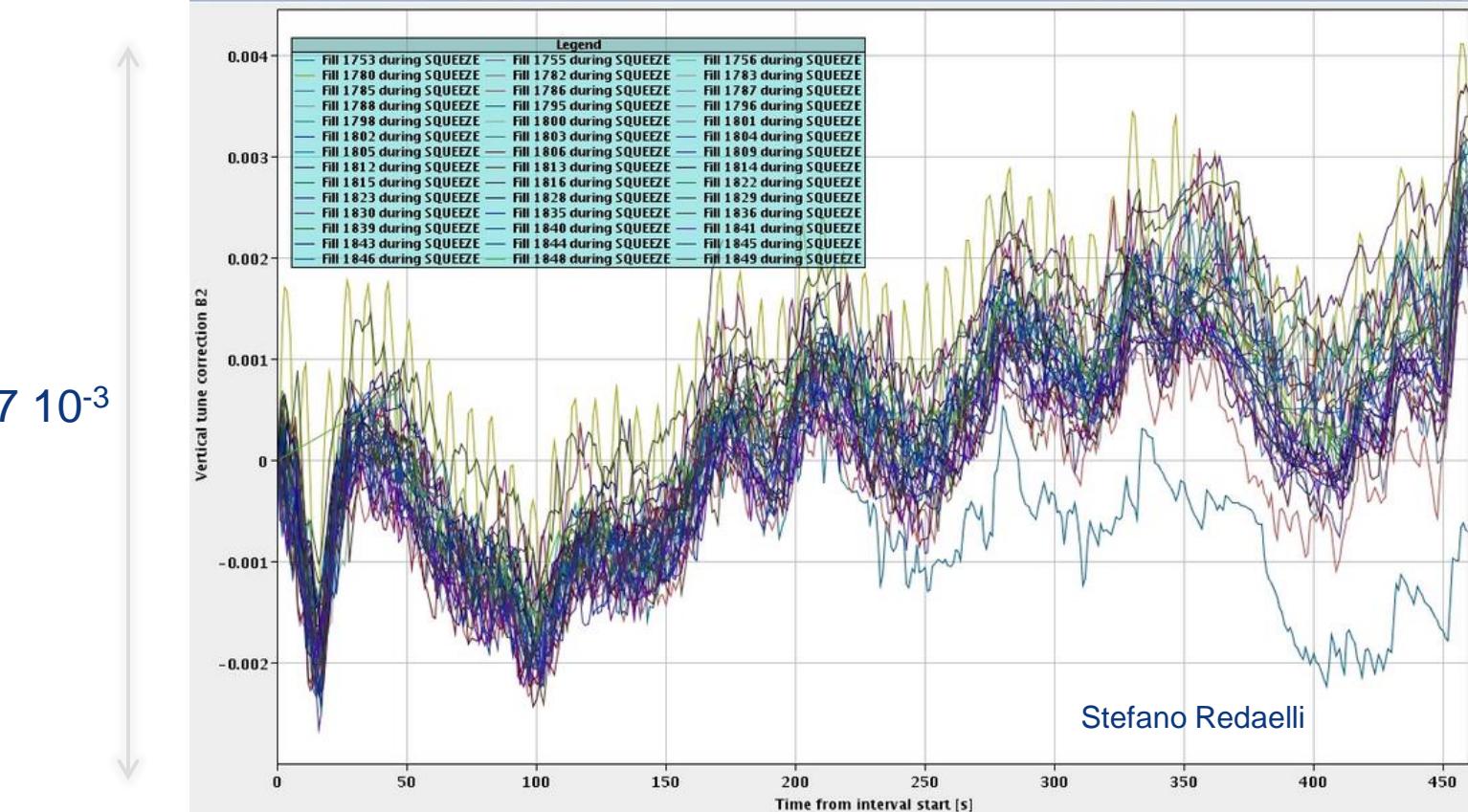
- There are a lot of things that can go wrong – **it's always a battle**
- Pretty good availability considering the complexity and principles of operation



Cryogenics availability in 2012: 94.7%

Reproducibility

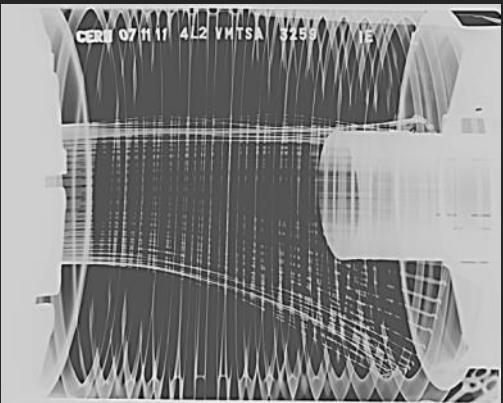
LHC magnetically reproducible with rigorous pre-cycling:
optics, orbit, collimator set-up, tune, chromaticity...



Some issues...

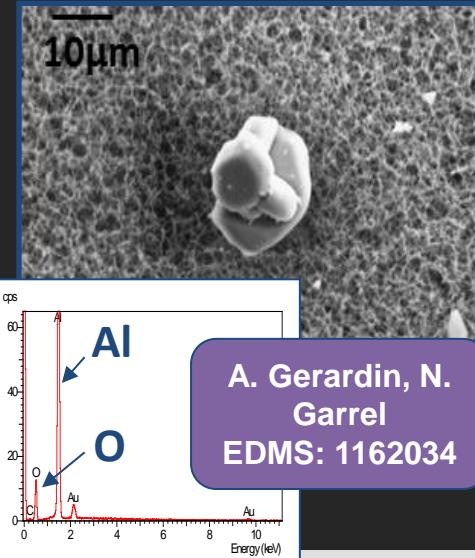
Beam induced heating

- Local non-conformities (design, installation)
 - Injection protection devices
 - Sync. Light mirrors
 - Vacuum assemblies



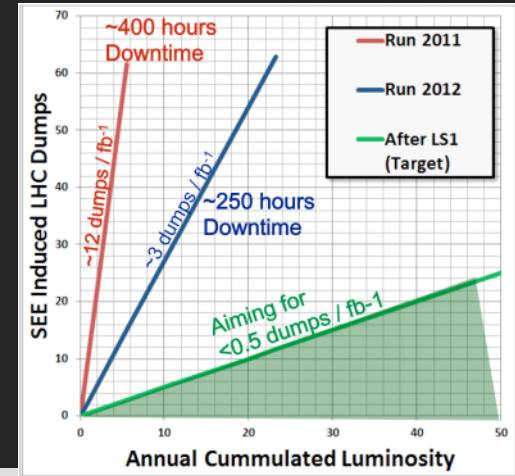
UFOs

- 20 dumps in 2012
- Timescale 50-200 μ s
- Conditioning observed
- Worry about 6.5 TeV



Radiation to electronics

- Concerted program of mitigation measures (shielding, relocation...)
- Premature dump rate down from 12/fb⁻¹ in 2011 to 3/fb⁻¹ in 2012



Courtesy of Mike Lamont

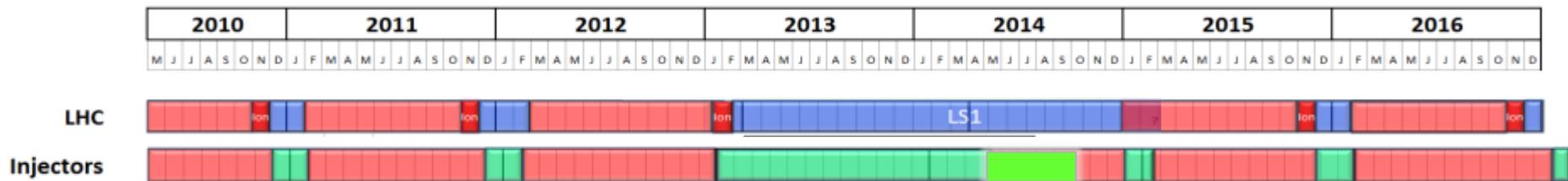
Long Shutdown 1 (LS 1: Fév. 2013- Déc. 2014)

LS1 a été conçu comme un long arrêt technique pour la consolidation des interconnexions entre les aimants principaux afin d'atteindre le courant nominal dans les circuits quadrupôles et dipôles du LHC.

Il est devenu maintenant un arrêt qui comprend, en outre, la maintenance, la consolidation, la modernisation de l'ensemble du complexe des accélérateurs du CERN et des installations expérimentales associées, après 3 années pleines d'opération des installations.

LS 1 (16th Feb. 2013 to Dec. 2014)

- Numerous projects and activities:
 - SMACC (Superconducting Magnets And Circuits Consolidation)
 - R2E (Radiation to Electronics)
 - Massive shutdown maintenance after more than 3 years of operation
 - Several major consolidations PSB, PS, SPS , LHC and electricity network
 - A lot of projects (Linac 4, HIE-Isolde, Elena, nTof EAR 2, **High Luminosity LHC**,)
- Compared to previous shutdowns, an exceptional number of ...
 - Simultaneous activities (co-activities) – **Planning and safety**
 - Non-CERN workers (FSU, collaborations, contracts,...)- **Logistics: Registration, training, transport, parking, access, dosimeter, PPE, catering, accommodation,...**

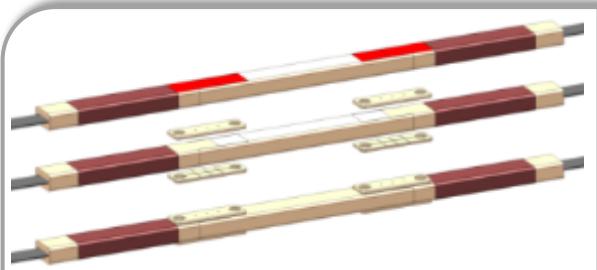


Main activities in LHC

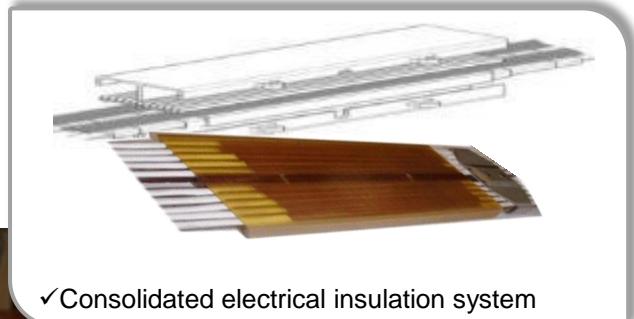
- The main key drivers are:

Superconducting Magnets And Circuits Consolidation (SMACC)

- Interconnections consolidation
 - Total magnet to magnet interconnects in the LHC: 1 695 (**10'170 high current splices**)
 - Number of splices to be redone: ~1'000 - 1'500 (~ 10-15%)
 - Number of shunts to be applied: > 27 000 (**100% of interconnections**)



✓ Consolidated dipole magnets bus splice



✓ Consolidated electrical insulation system

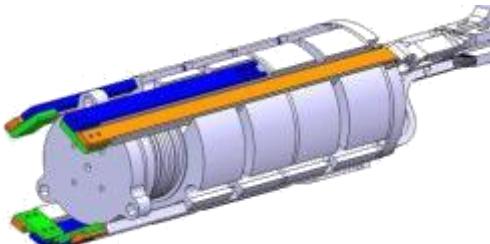


Main activities in LHC

- The main key drivers are:

Superconducting Magnets And Circuits Consolidation (SMACC)

- Interconnections consolidation
- Magnets to exchange: 18 (15 dipoles and 3 quadrupoles)
- Cryogenic feedbox consolidation
- DN200
-
- Quadrupole diodes



Magnet installation



DN200



Principaux travaux de consolidation pour le LHC en 2013-2014

Ouvrir et refermer définitivement 1 695 interconnexions

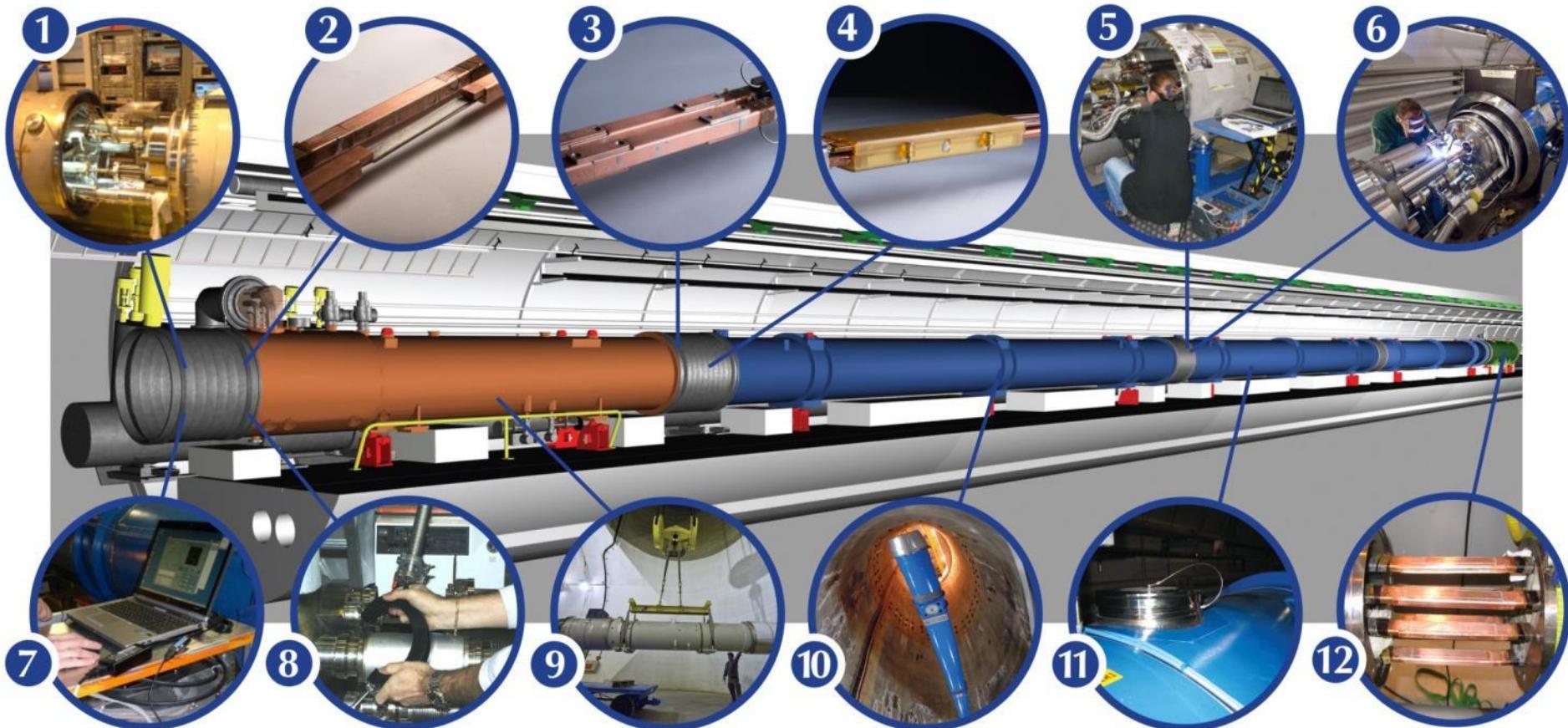
Refaire entièrement 1 500 de ces interconnexions

Consolider les 10 170 interconnexions de 13 kA: installer 27 000 dérivation

Installer 5 000 systèmes d'isolation électrique consolidés

Réaliser 300 000 mesures de la résistance électrique

Réaliser 10 170 soudures orbitales de lignes en acier inoxydable



Réaliser 18 000 tests d'assurance qualité électrique

Réaliser 10 170 tests d'étanchéité

Remplacer 4 quadripôles

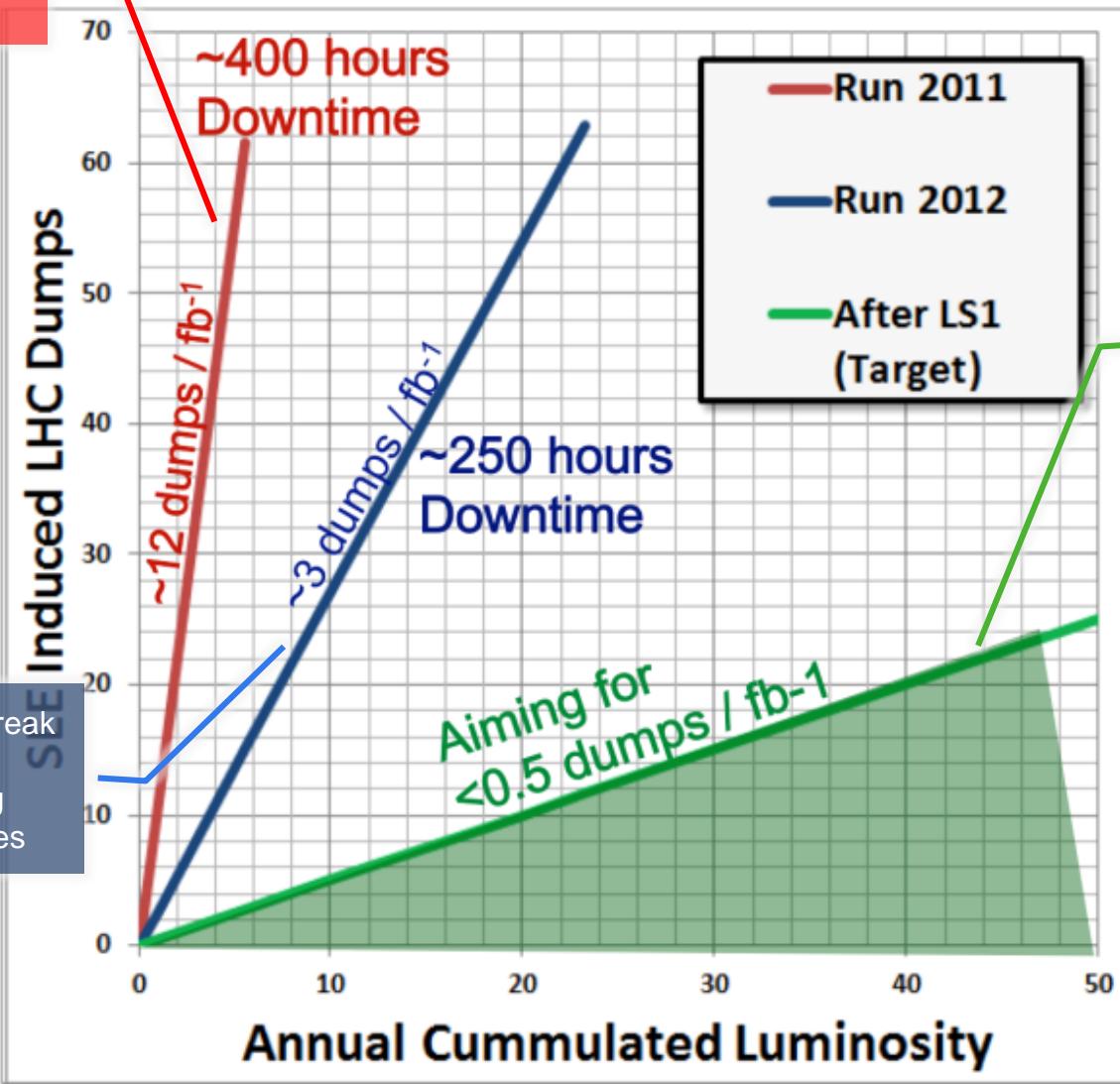
Remplacer 15 dipôles

Installer 612 nouvelles soupapes, ce qui porte leur nombre total à 1344

Consolider les circuits de 13 kA dans les 16 boîtiers principaux d'alimentation électrique

Radiation to Electronics

Several shielding
campaigns prior 2011
+ Relocations 'on the fly'
+ Equipment Upgrades



2011/12 Christmas Break
'Early' Relocation
+ Additional Shielding
+ Equipment Upgrades

R2E Project to reach
nominal and ultimate
luminosity

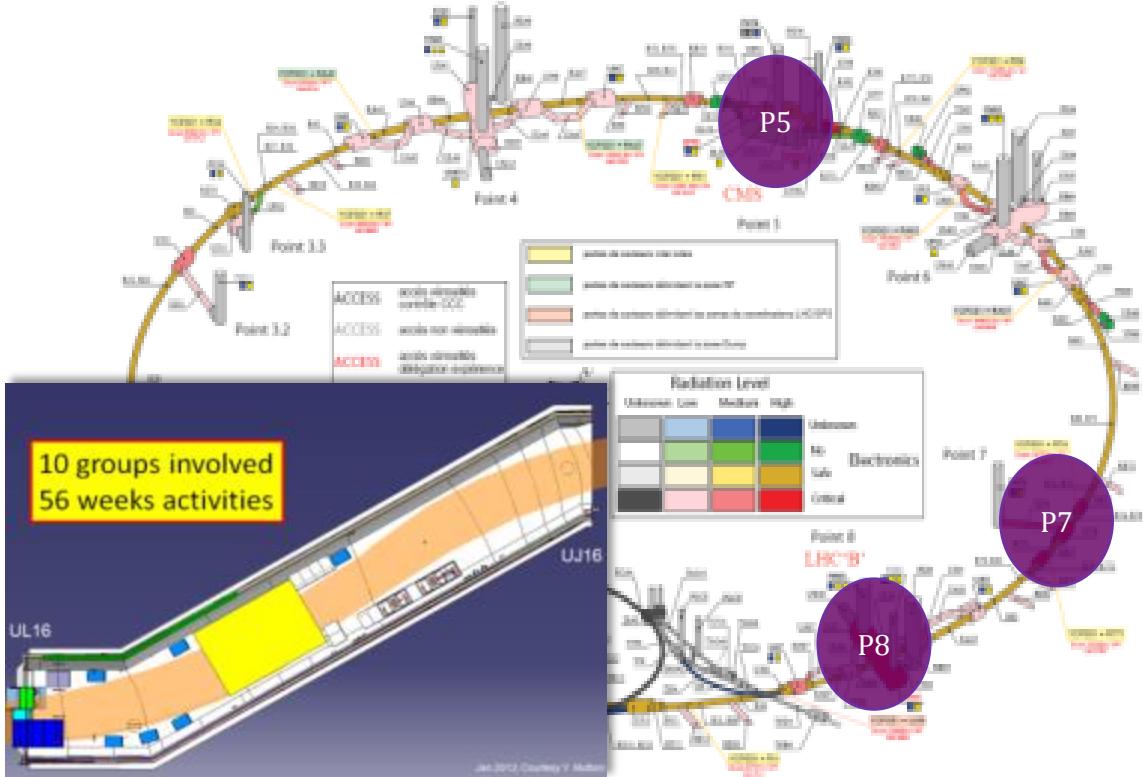
Courtesy Markus Brugger



Main activities in LHC

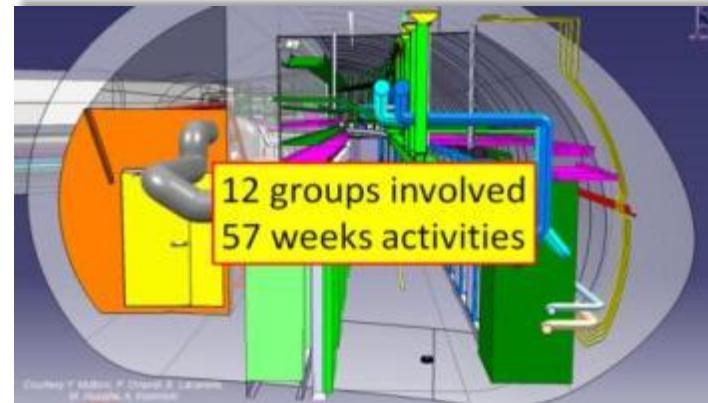
The main key drivers are:

- Superconducting Magnets And Circuits Consolidation
- **Radiation To Electronics – R2E**

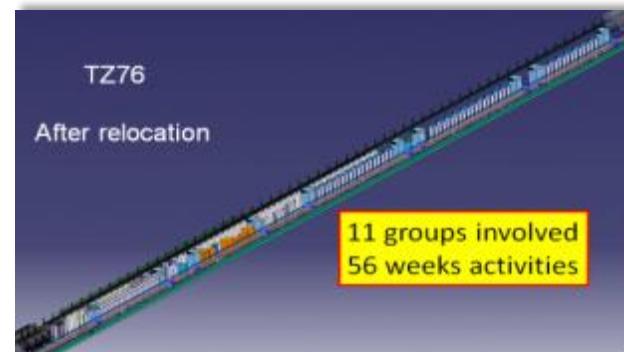


Point 1 – ULs, Ujs, RRs

In total 70 weeks and a combined effort of about 150 persons



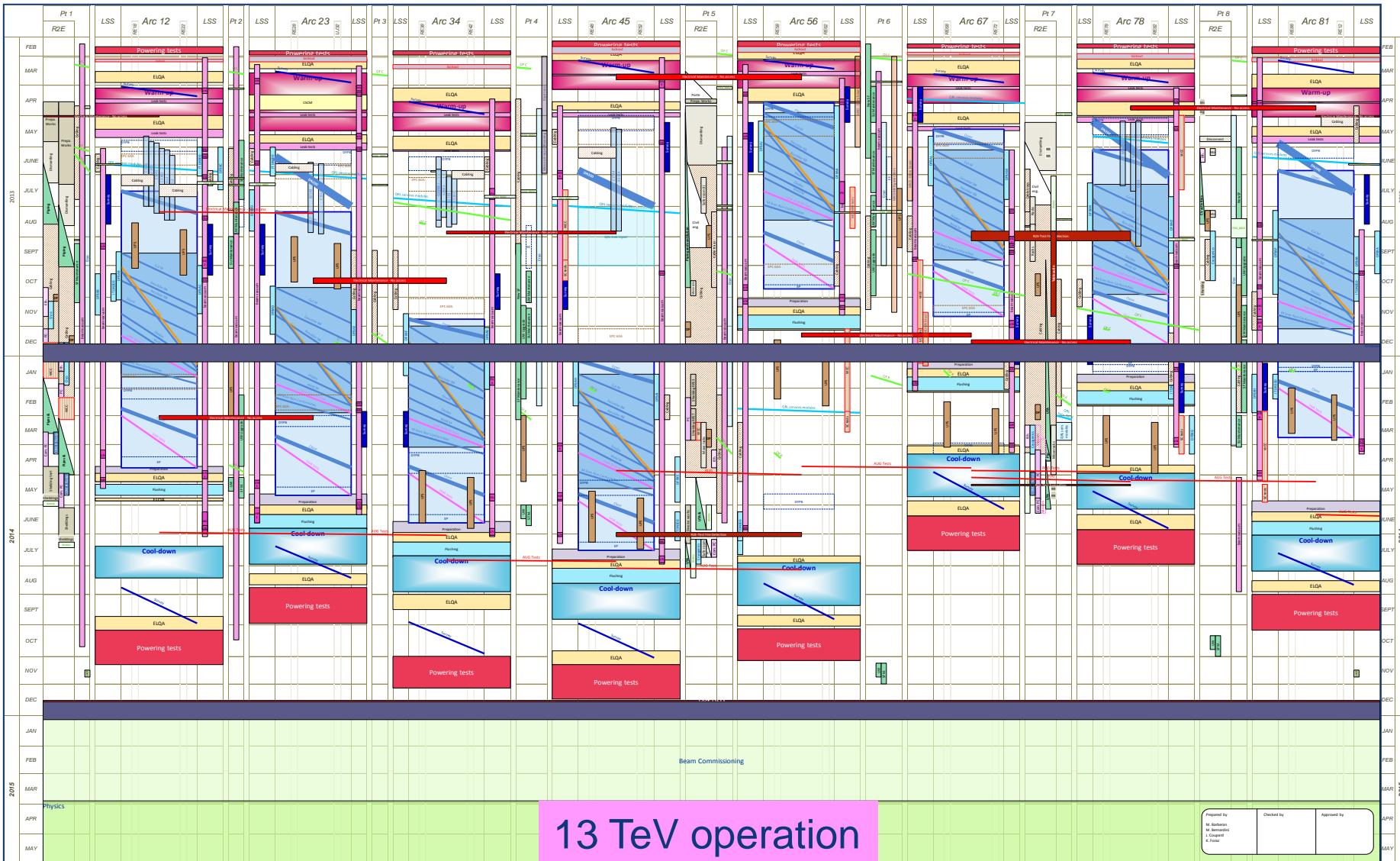
Point 5 – UJ56, UL55, RRs



Point 7 – UJ, TZ



LS1: LHC planning



SMACC: Opening of interconnections



First IC opening in S56
8th of April 2013

Collaborations with NTUA (Athens),
WUT (Wroclaw) and support of
JINR-DUBNA

SMACC: 7th May: the last interconnection in sector 5-6 was opened



> 2 sectors equivalent have been opened around the LHC.

SMACC: Opening of busbar lines

Opening of M lines started on 18.04.2013

- measurement of > 1000 splices so about 80% of S56
- Rate according to plan after 1 week of learning = 10.6 IC/day



TEMPORAL EVOLUTION STATS

Sector 5-6 Open M Activity Evolution
Click and drag in the plot area to zoom in



SMACC: Installation of shunts

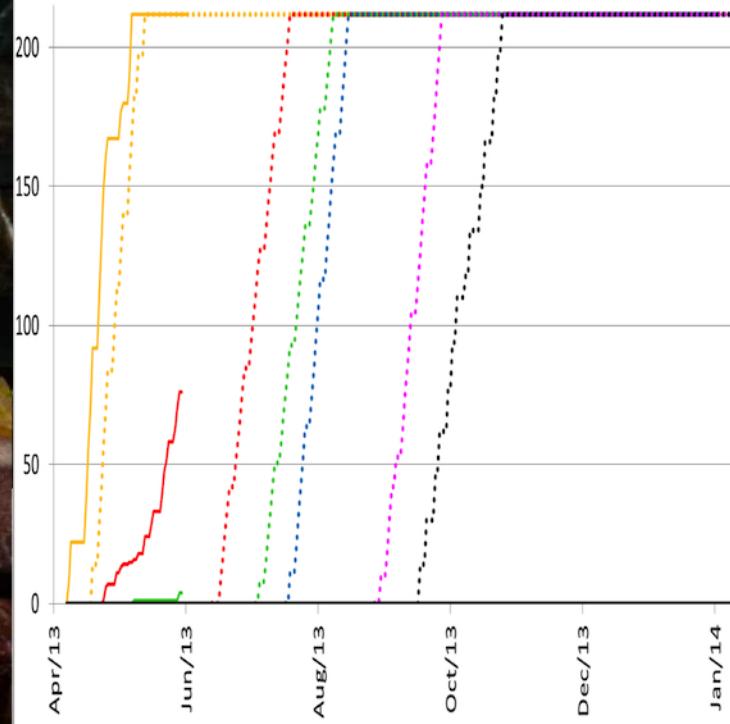
First shunt soldered on 24.04.2013

- in >80 IC in sector 56 (> 1/3 of one sector)
- Started ahead of schedule, learning for critical activity

24.04.2013 : First shunts soldered (QBBI.11R5)

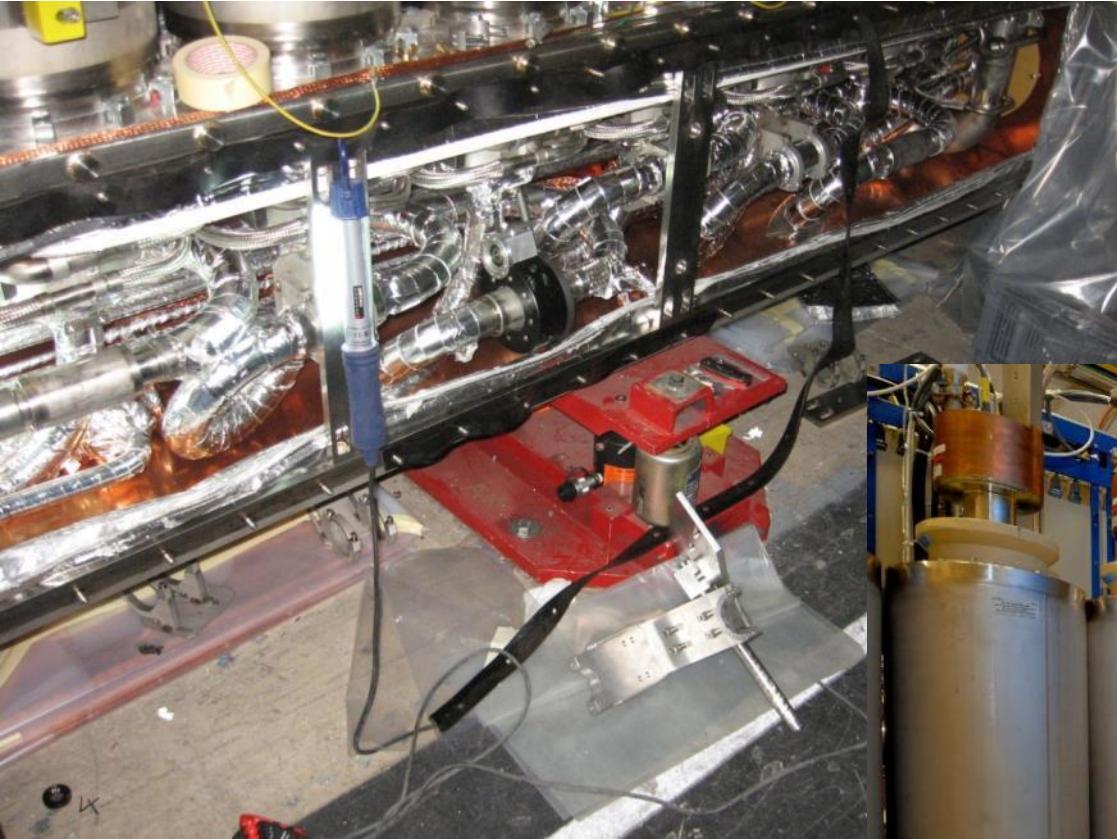


Sector 56

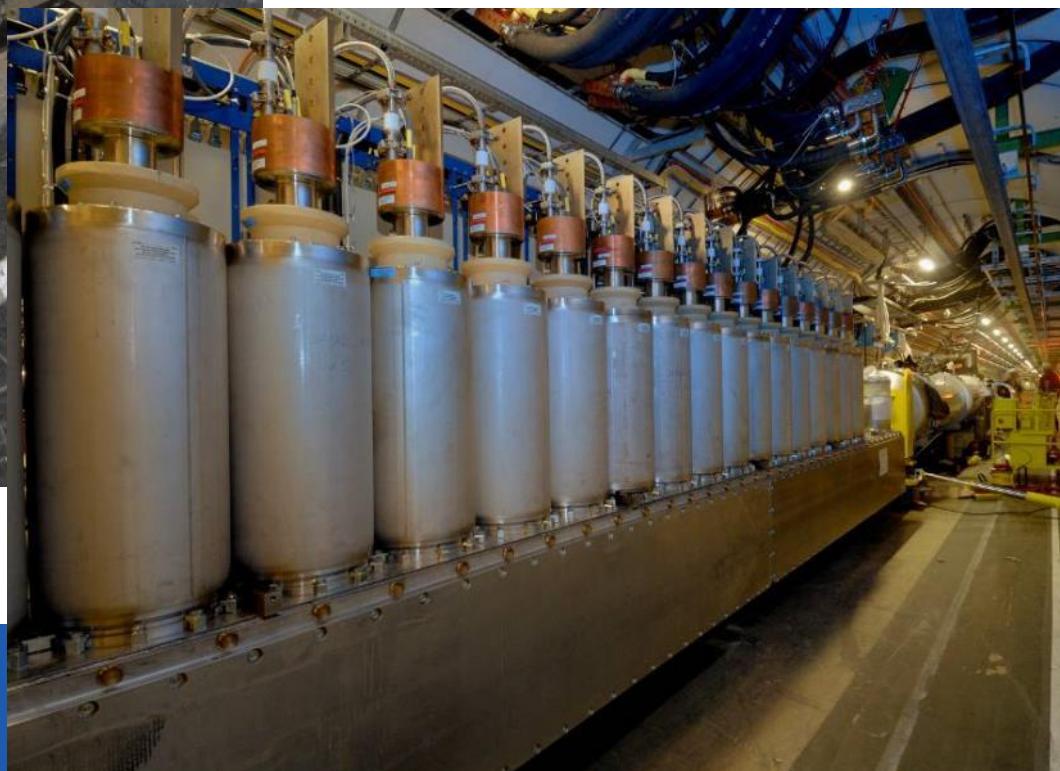


SMACC: Cryo-feedbox (DFBA) consolidation

Started



First sleeves cut
in the DFBAK HCM

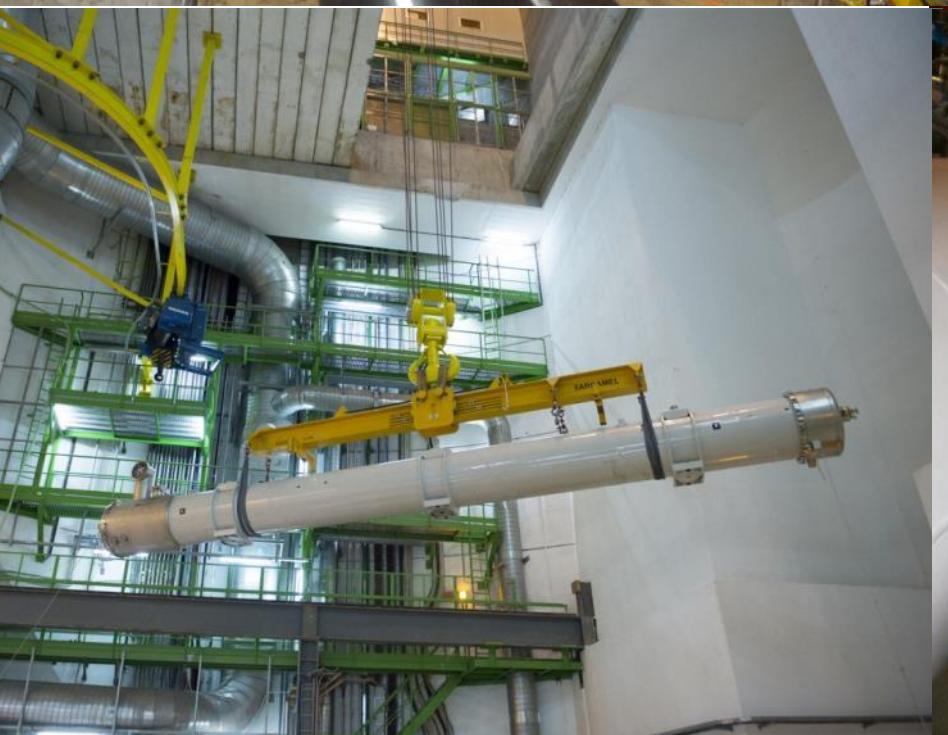


30.05.2013 :

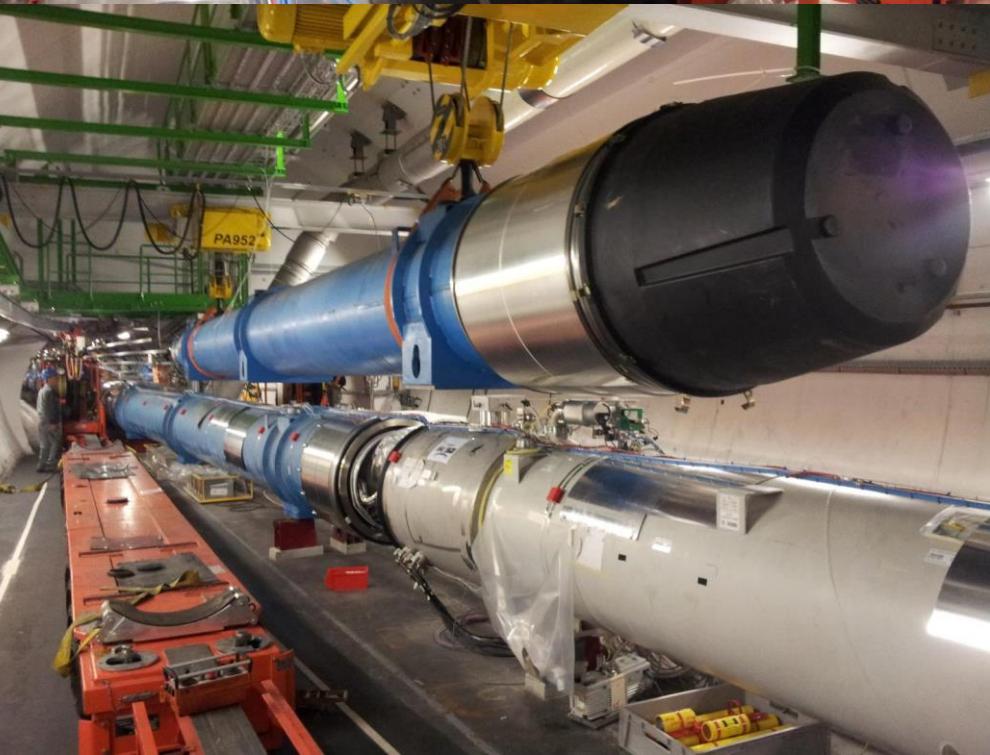
First magnet ready to be removed (Q5L8)

SIT (Special Intervention team)

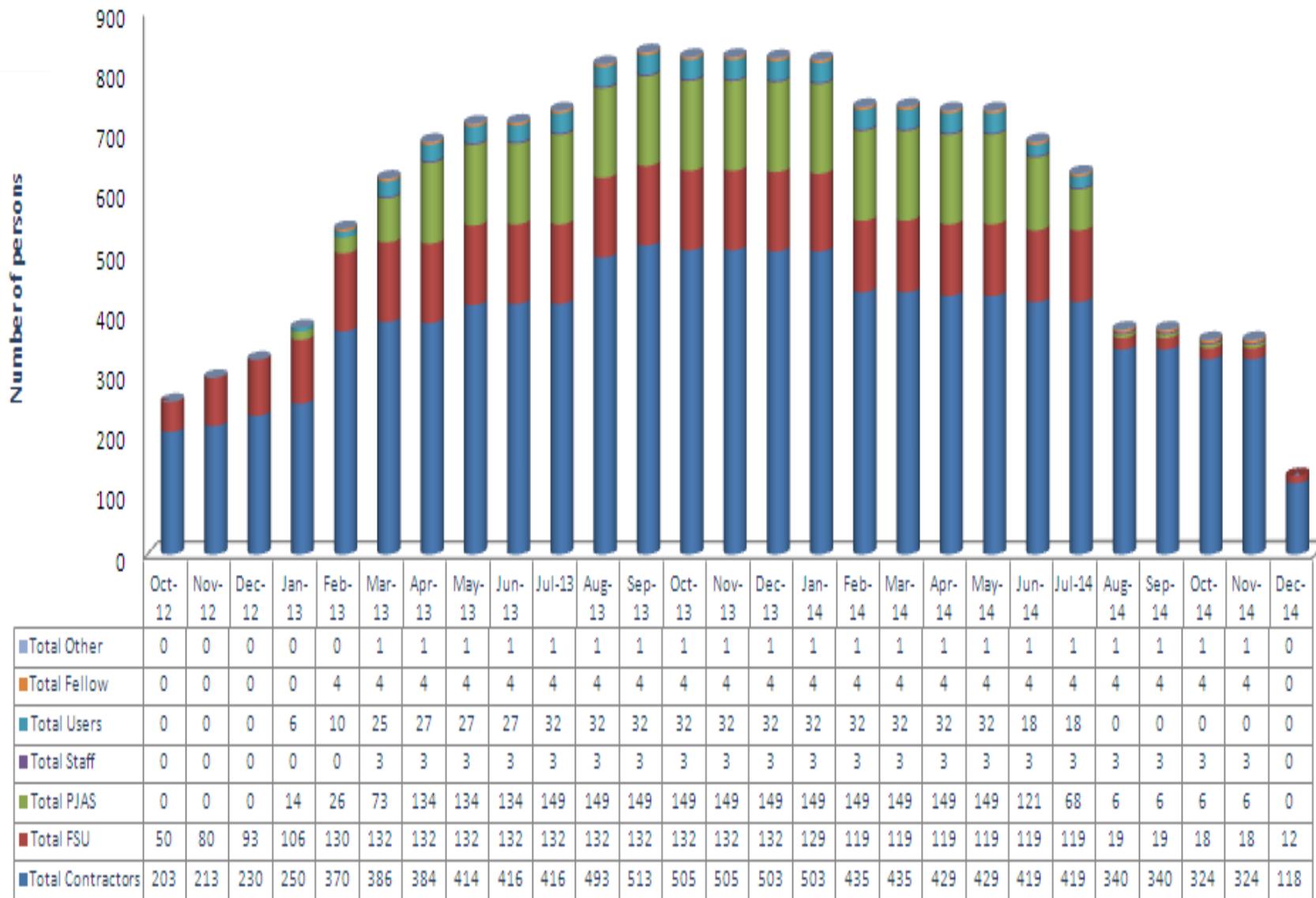
With contributions from TE-CRG, VSC, MPE, EN-HE,...



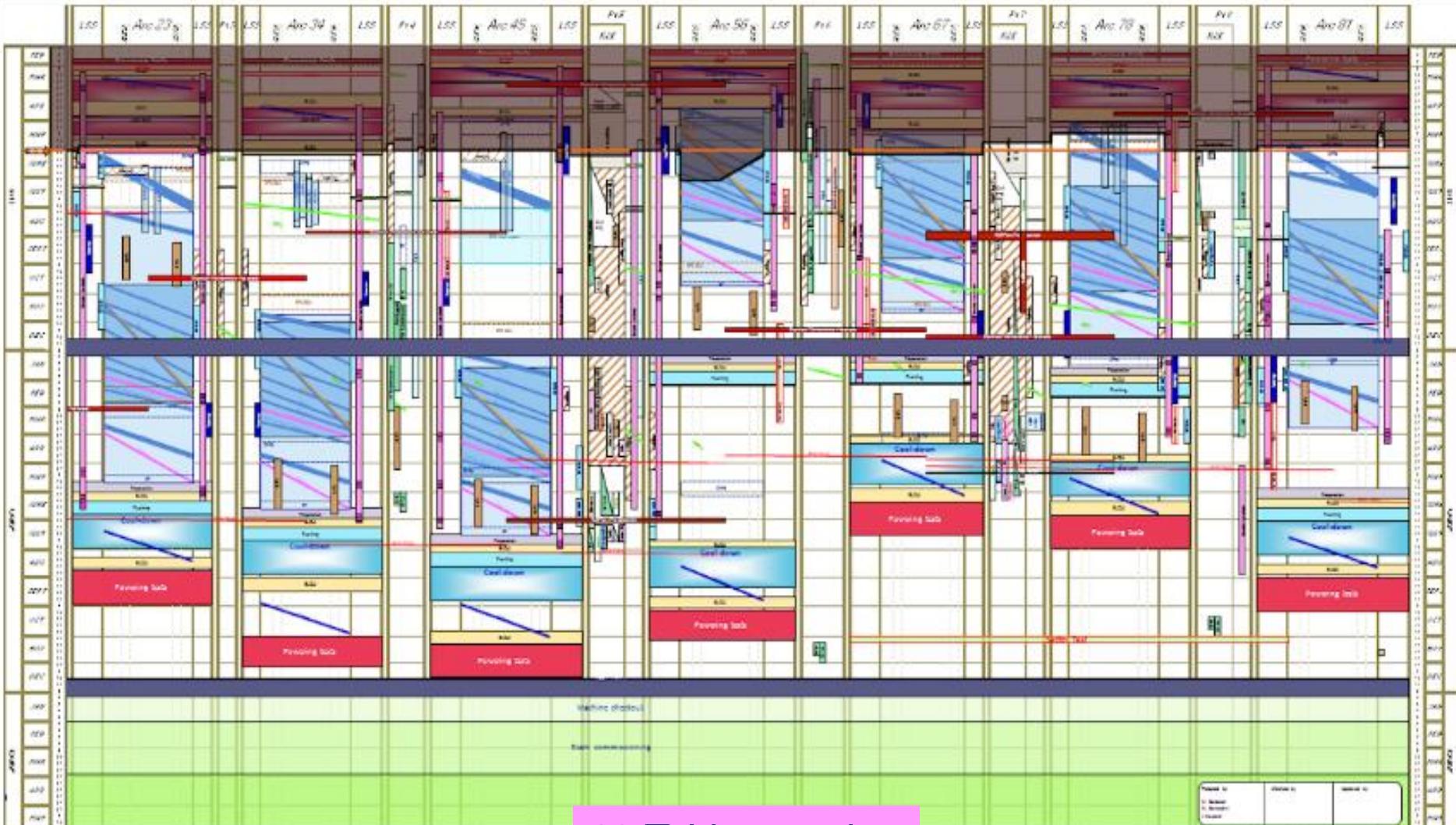
2013/05/31



Overall additional number of persons at CERN during LS1 per status



LS1: LHC planning



- █ Physics
- █ Beam commissioning
- █ Shutdown
- █ Tests

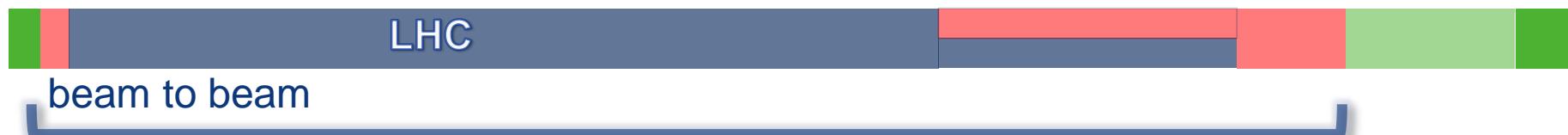
LS1

de mi-février 2013 à fin décembre 2014

2013

2014

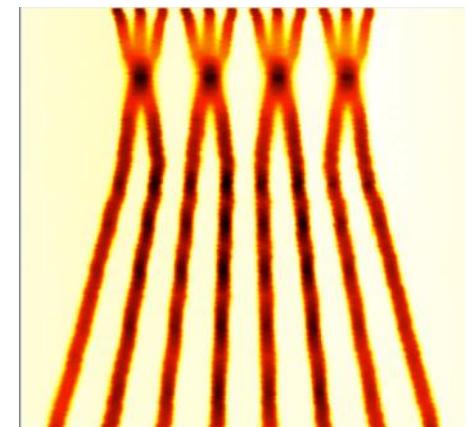
2015



2015 – post LS1

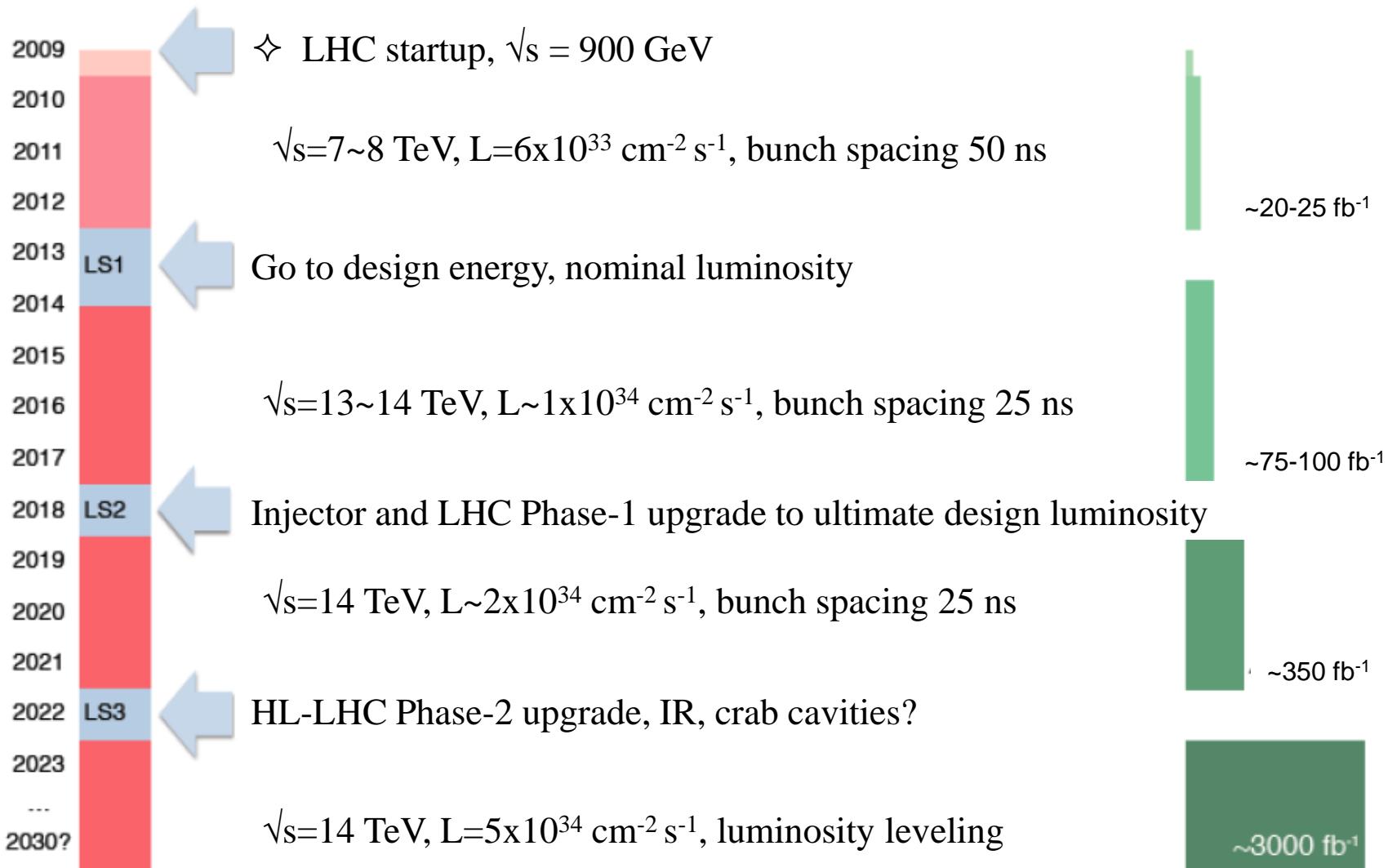
- Energy: **6.5 TeV**
- Bunch spacing: **25 ns**
 - pile-up considerations
- Injectors potentially able to offer nominal intensity with even lower emittance

BCMS = Batch
Compression and Merging
and Splitting



	Number of bunches	I _b LHC FT[1e11]	Emit LHC [um]	Peak Lumi [cm ⁻² s ⁻¹]	~Pile-up	Int. Lumi per year [fb ⁻¹]
25 ns low emit	2520	1.15	1.9	1.7e34	52	~45

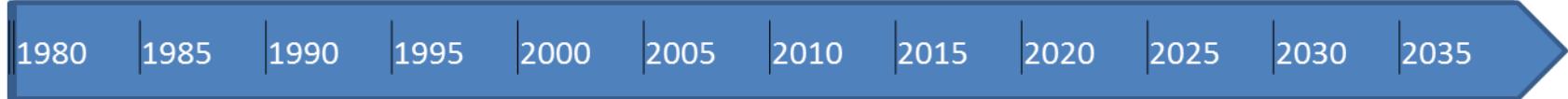
"Pleine Exploitation du potentiel du LHC"



"Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030."

*“CERN should undertake design studies for accelerator projects in a global context, with emphasis on **proton-proton** and electron- positron **high-energy frontier machines**.”*

(Update of the European Strategy for Particle Physics)



LEP

Construct. Physics Upgr

today

LHC

Design, R&D Proto Construct. Physics

HL-LHC

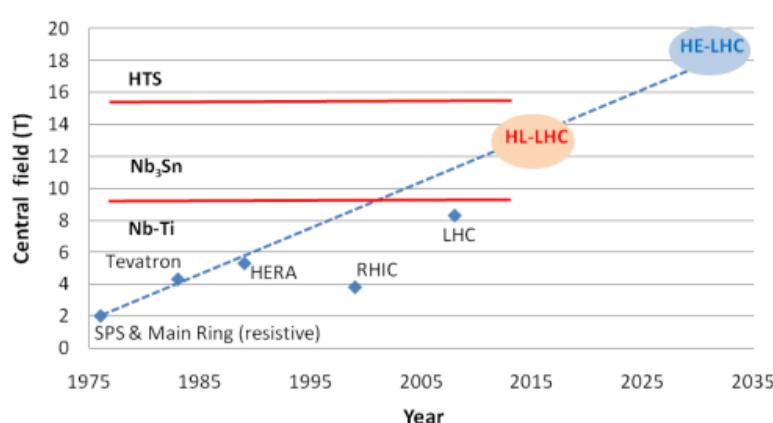
Design, R&D Construct. Physics

Projet

HE-LHC

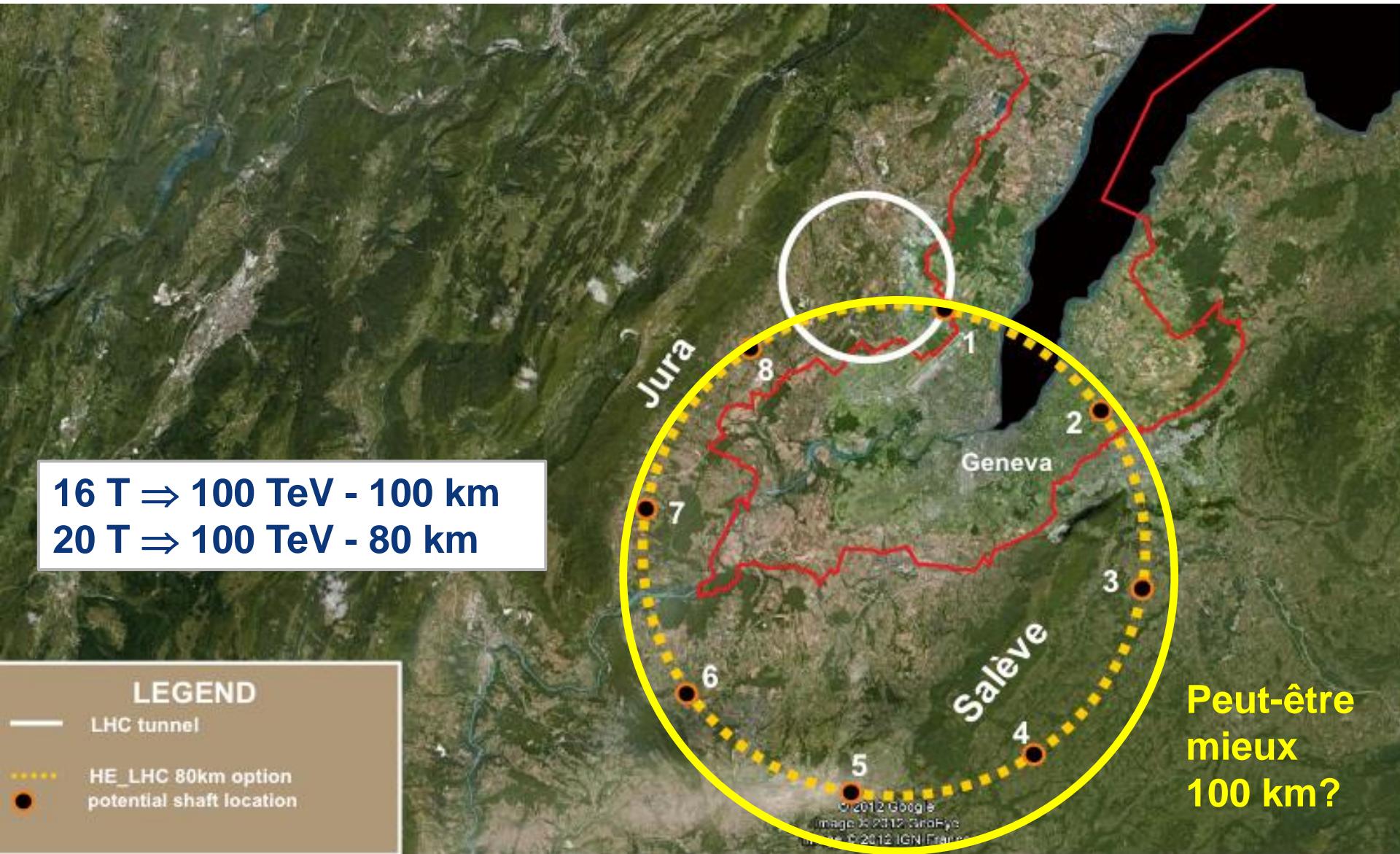
Design, R&D Proto Construct. Physics

Dipole Field for Hadron Collider



**2000 aimants de 16-20 T
27 à 33 TeV dans le cdm**

Un tunnel de 80-100 km dans la région genevoise (VHE-LHC) avec la possibilité de collisions e⁺- e⁻ (TLEP) and p-e (LHeC)

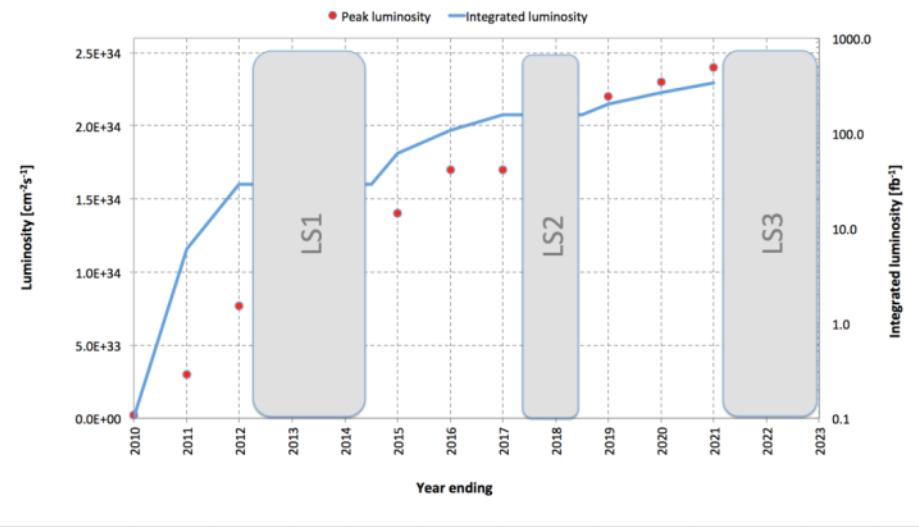


Accélérateurs :

LS1 ≡ Energie

LS2 ≡ Intensité

LS3 ≡ Luminosité



LS5 ≡ Energie ?

- La Stratégie européenne ouvre de très riches perspectives (*HL-LHC et R&D*)
- Les technologies du LHC nécessitent un engagement soutenu et à long terme.
- Toutes les études et réalisations entamées doivent être poursuivies et de nouvelles études pour les futurs accélérateurs du CERN doivent être engager



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