



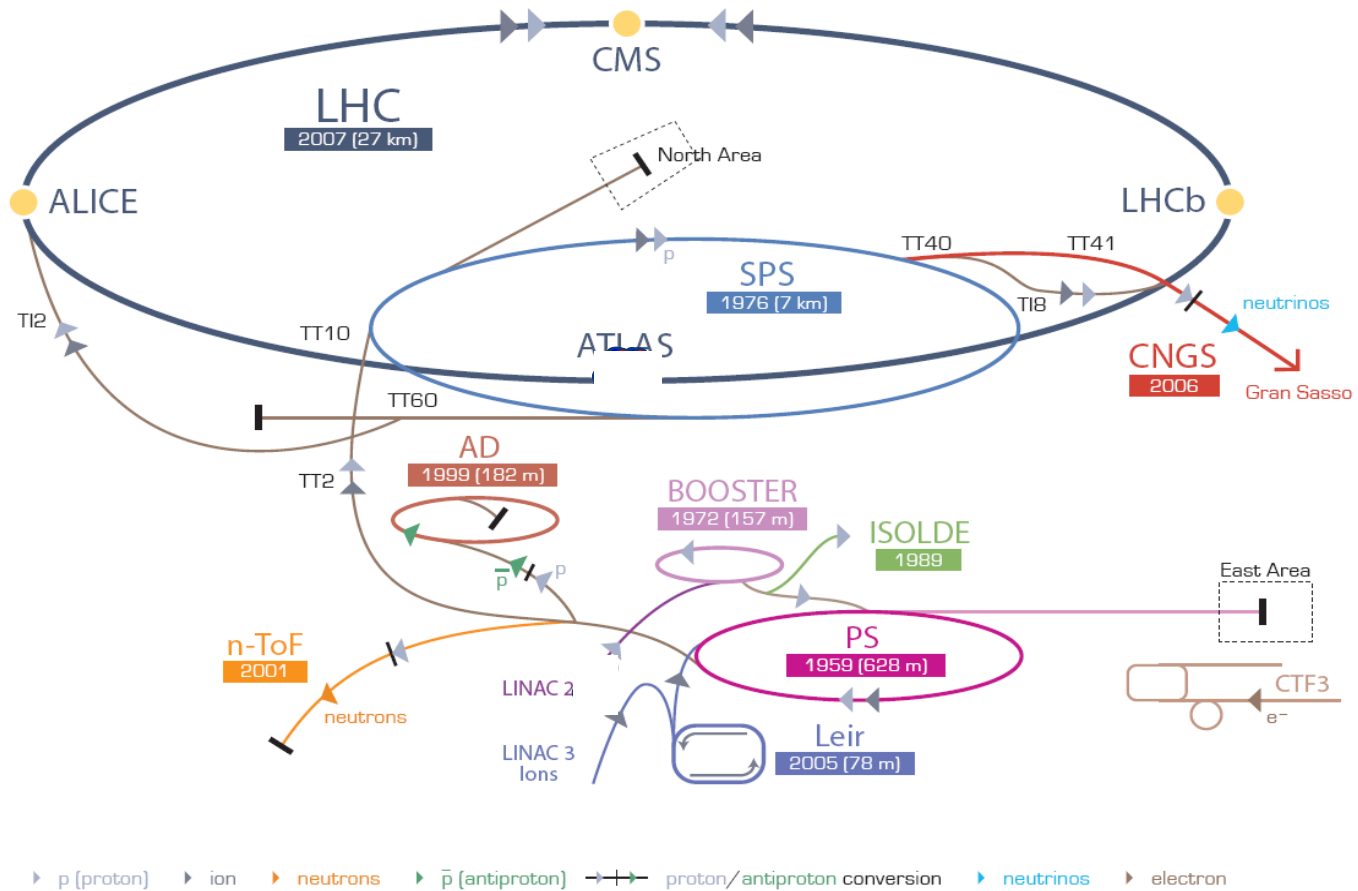
[www.cern.ch](http://www.cern.ch)

## LS1 activities

J.M. Jimenez

4<sup>th</sup> December'13

# CERN Accelerator Complex



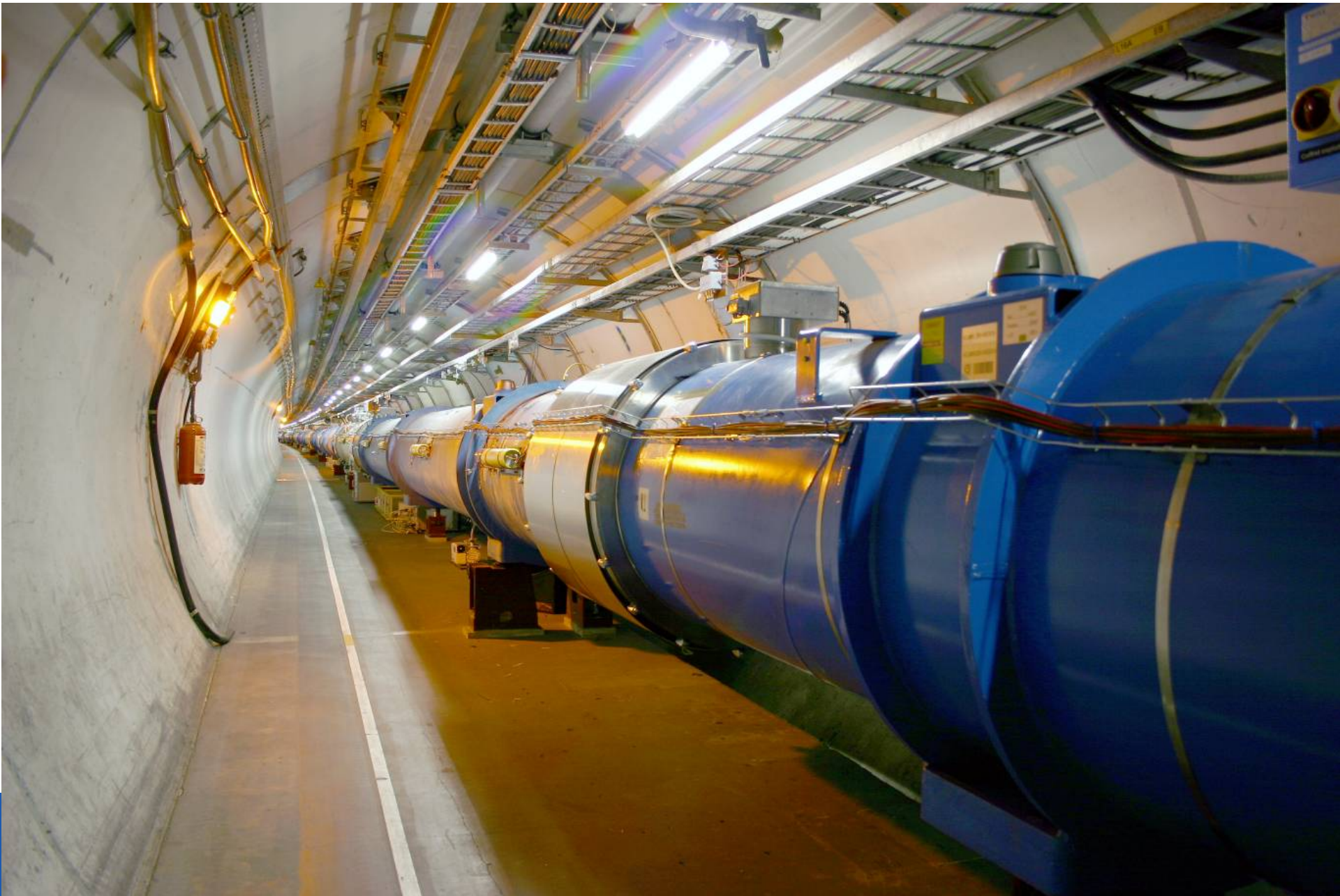
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

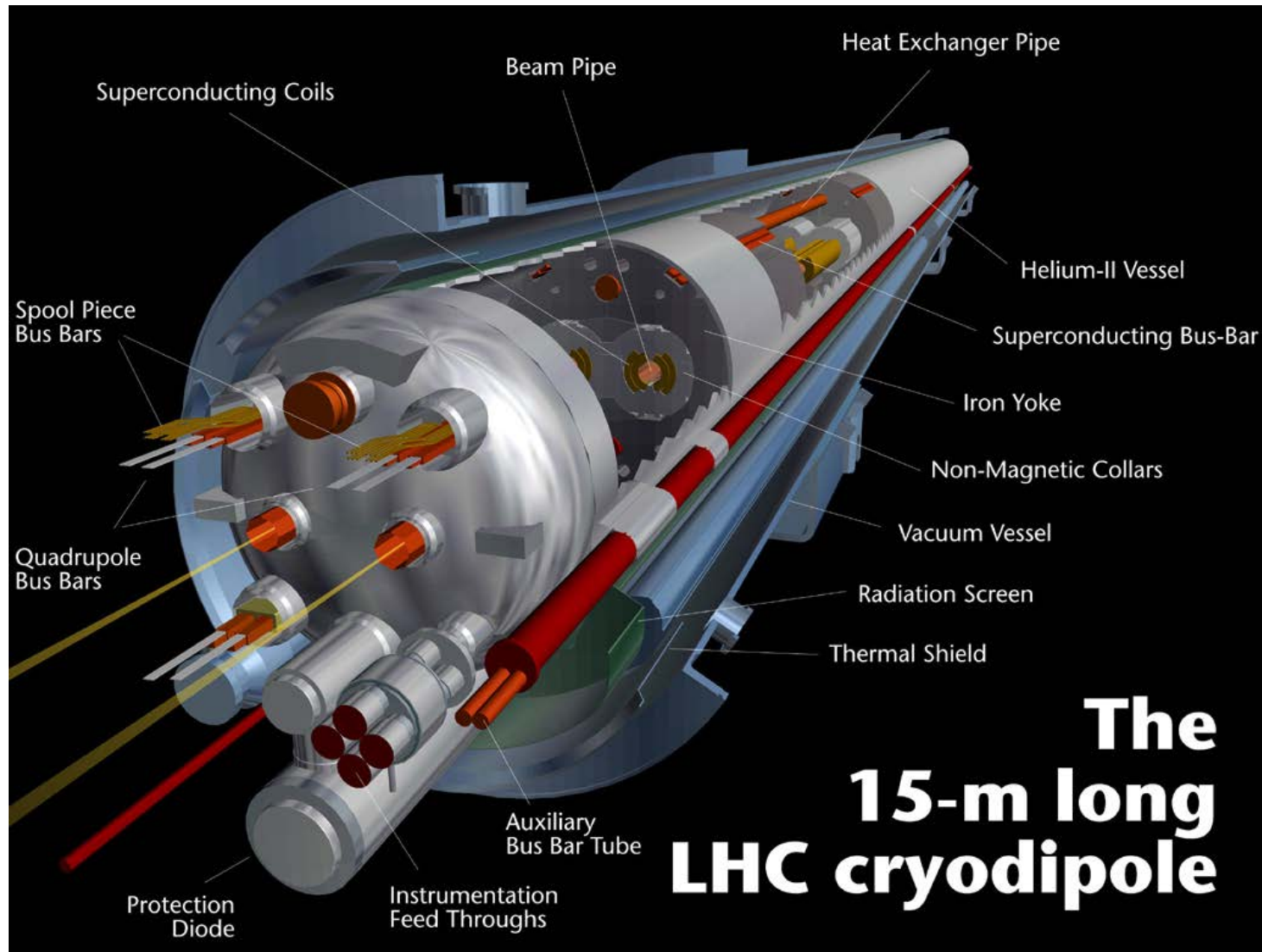
# LHC: A Marvel of Technology

## *The LHC tunnel with dipole magnets*



# LHC: A Marvel of Technology

*Dipole Magnets: 1232 of them operating at 1.9K*



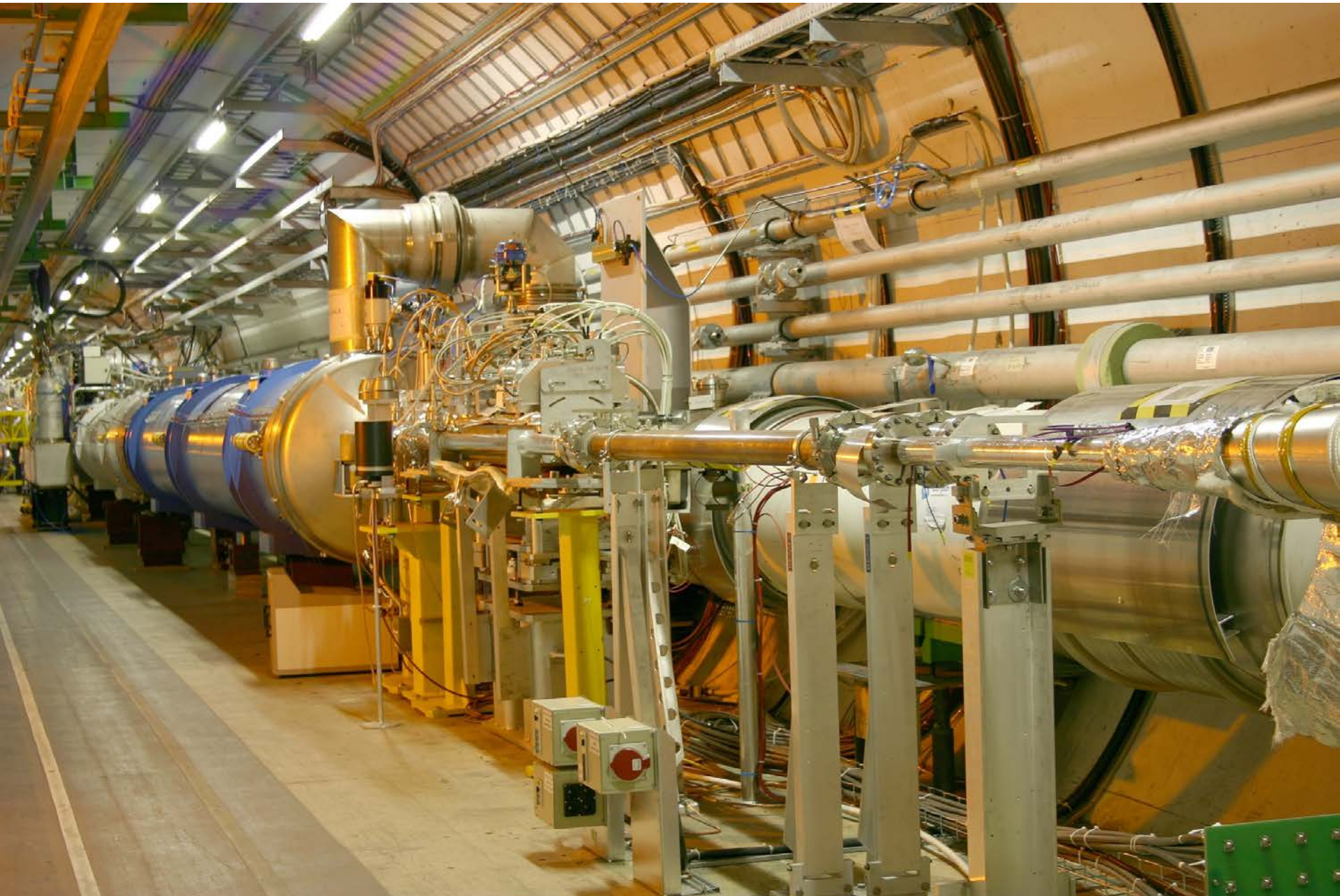
**7 TeV**  
**8.33 T**  
**11850 A**  
**7MJ**

Contracts by  
4.7cm during  
cool-down



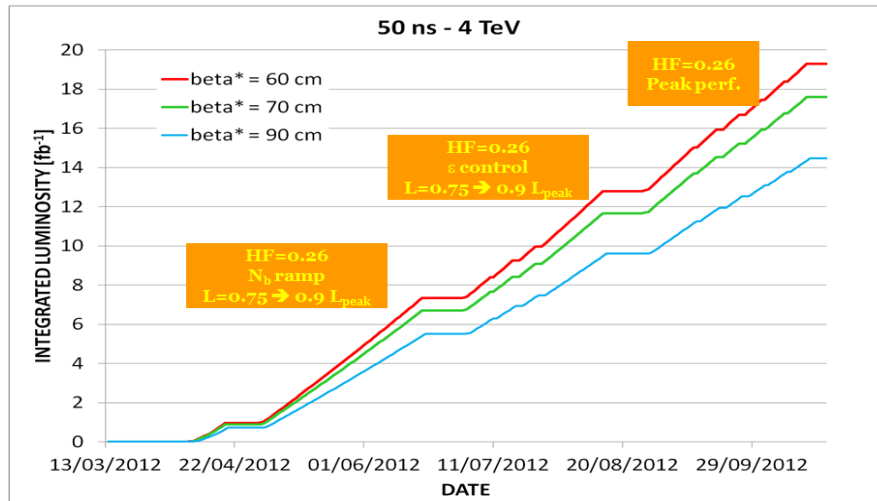
# LHC: A Marvel of Technology

## *The LHC long straight sections*

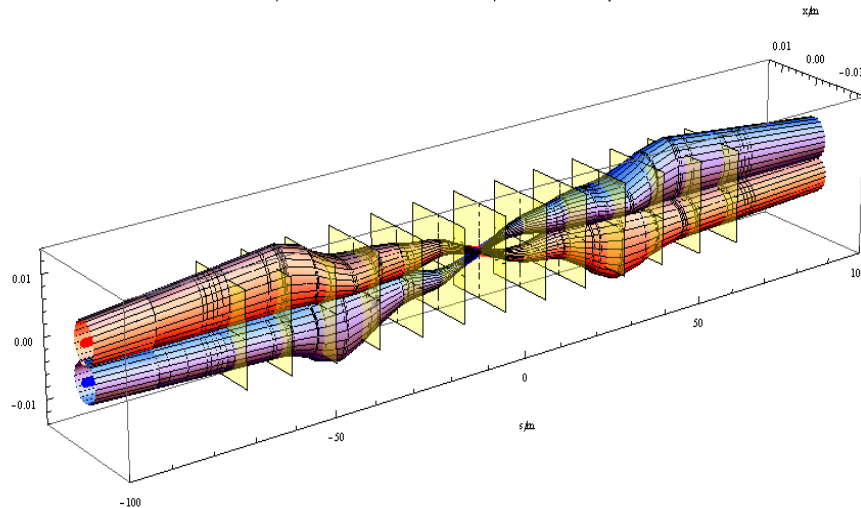


# LHC: A Marvel of Technology

## Challenges for 2012: increasing luminosity...

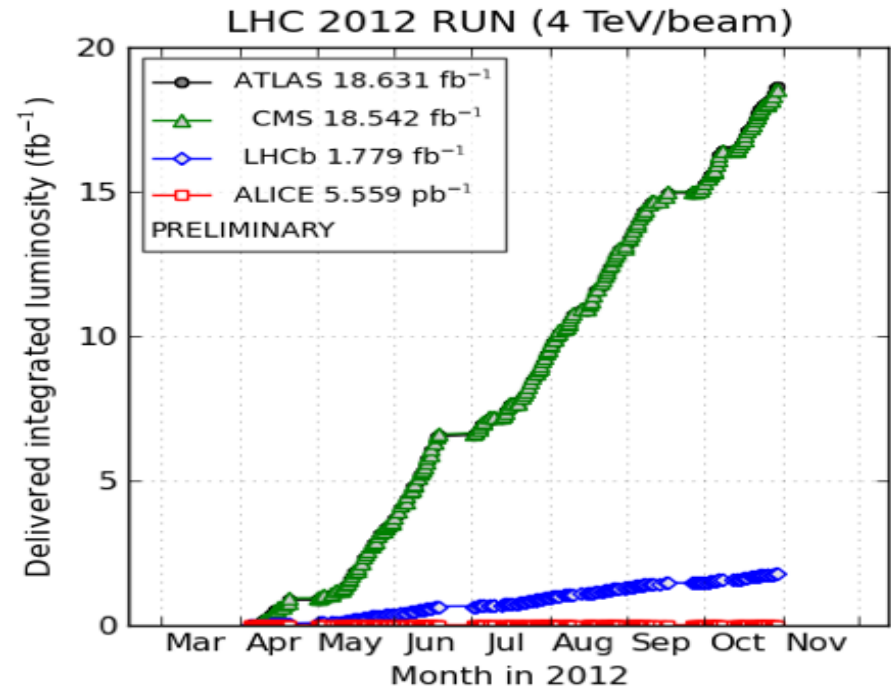


( $\sigma_x, \sigma_y, \sigma_z$ ) envelope for  $\epsilon_x = 1.00529 \times 10^{-9}$  m,  $\epsilon_y = 1.00529 \times 10^{-9}$  m,  $\sigma_z = 0.000306$



Objectives being achieved...!

Even if running at 50 ns but with an optimised crossing angle



(generated 2012-10-30 08:23 including fill 3238)

# LHC: A Marvel of Technology

## *Some technological challenges for next years...*

Circumference (km)	26.7	100-150m underground
Number of Dipoles	1232	Cable Nb-Ti, cold mass 37million kg
Length of Dipole (m)	14.3	
Dipole Field Strength (Tesla)	8.4	Results from the high beam energy needed
Operating Temperature (K)	1.9	Superconducting magnets needed for the high magnetic field Super-fluid helium
<b>Current in dipole sc coils (A)</b>	<b>13000</b>	Results from the high magnetic field 1ppm resolution
Beam Intensity (A)	0.5	$2.2 \cdot 10^{-6}$ loss causes quench
<b>Beam Stored Energy (MJoules)</b>	<b>362</b>	Results from high beam energy and high beam current 1MJ melts 2kg Cu
<b>Magnet Stored Energy (MJoules)/octant</b>	<b>1100</b>	Results from the high magnetic field
Sector Powering Circuit	8	1612 different electrical circuits



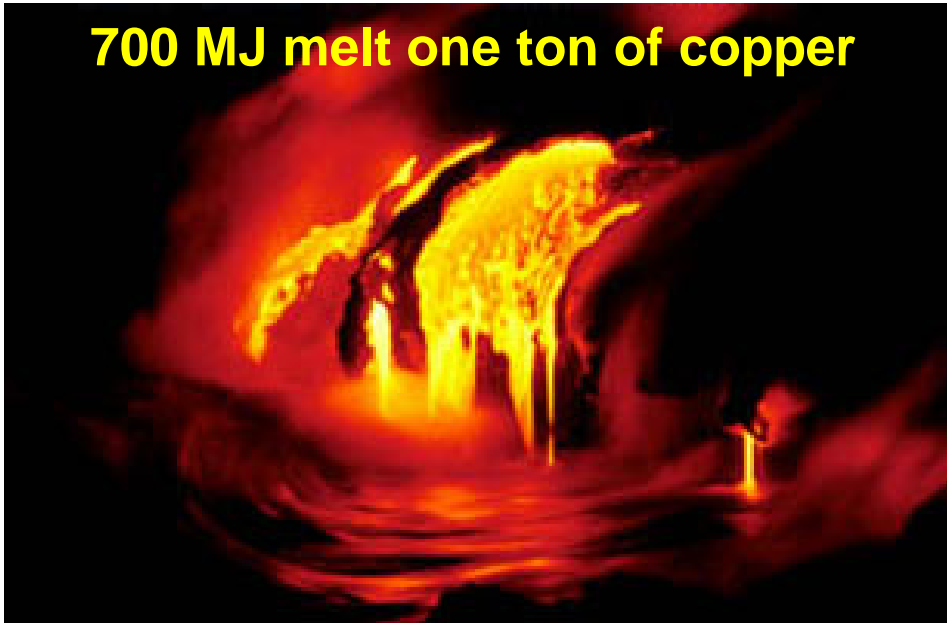
# LHC: A Marvel of Technology

## *LHC beam stored energy*

Momentum at collision	7 TeV (1 eV = $1,6 \times 10^{-19}$ Joule)
Number of bunches	2808
Protons per bunch	$1.15 \cdot 10^{11}$
Total number of protons	$6.5 \times 10^{14}$ (1 ng of H <sup>+</sup> ) (for 2 beams)

**Energy stored in the two beams: 724 MJoule**  
**Energy to heat and melt one ton of copper: 700 MJoule**

**700 MJ melt one ton of copper**



700 MJoule dissipated in 88  $\mu$ s

$$700 \cdot 10^6 / 88 \cdot 10^6 \cong 8 \text{ TW}$$

**World Electrical Installed Capacity  $\cong 3.8$  TW**

**90 kg of TNT  
per beam**





# LHC: A Marvel of Technology

## LHC cryomagnets stored energy

$$1232 * 108 \text{ mH} = 133 \text{ H} ; \frac{1}{2} L \cdot I^2 \sim 10 \text{ GJ}$$

- Energy stored in the magnet system: 10 GJoule
- Energy stored in one (of 8) dipole circuit: 1.3 GJoule

10 GJoule  $\cong$  flying 700 km/h



**Magnetic energy must be discharged in around 40 seconds!**



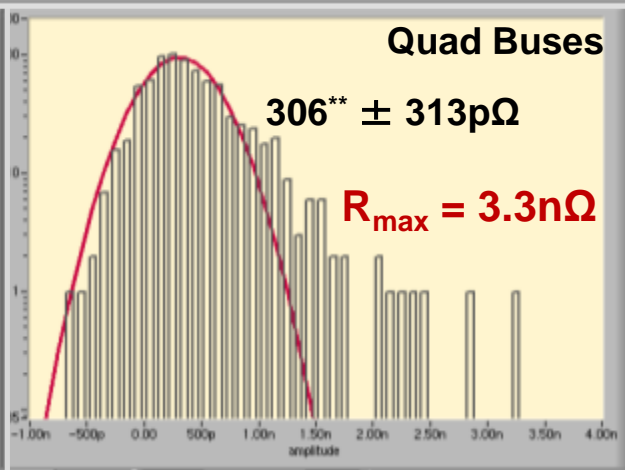
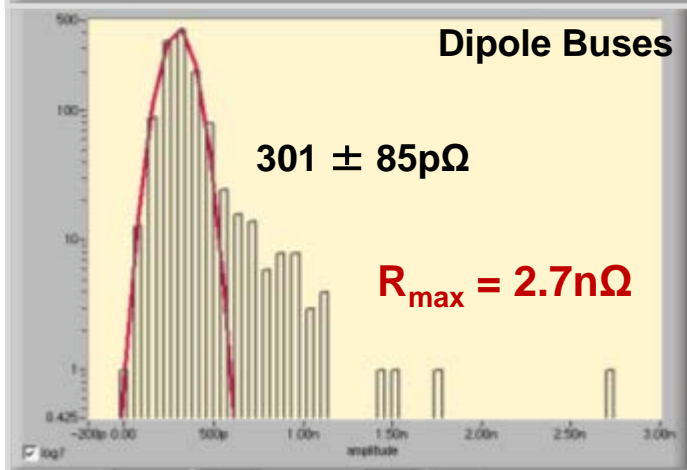
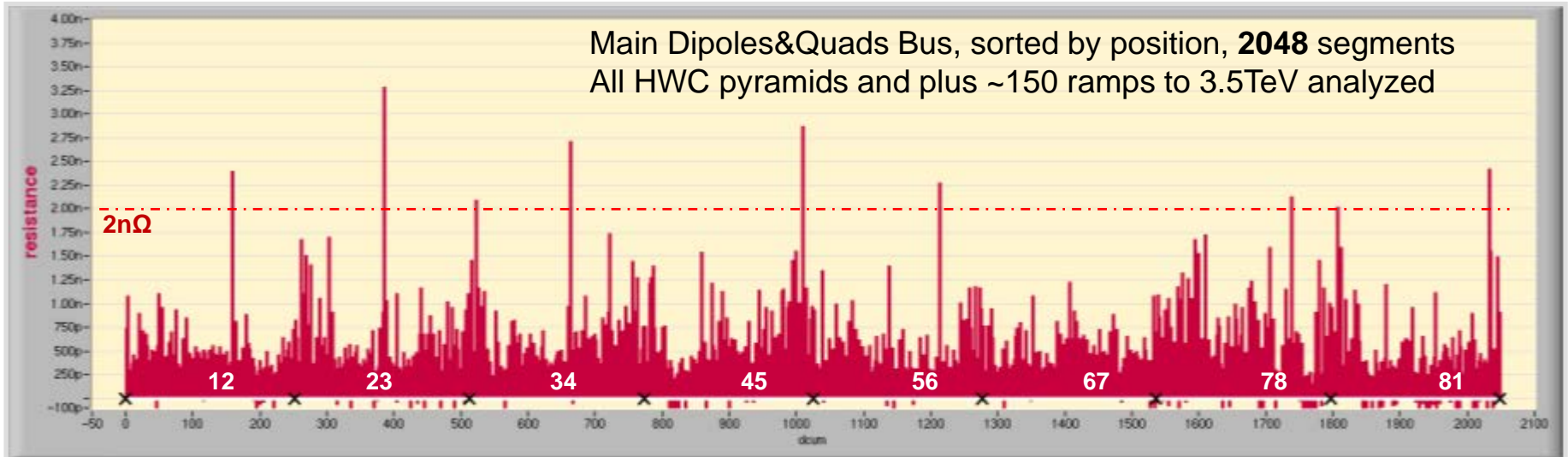
10 GJ  $\cong$  55 km/h

The energy stored in the LHC magnets corresponds approximately to 8 such trains running at 300 km/h



# LS1 activities

## LHC Main Splices: Busbars SC



### Top 10 Splice Resistances

MQ.A23	MQ.33L3.B2	<->	MQ.33R2.B2	3.28E-09
MQ.A45	MQ.12L5.B2	<->	MQ.11L5.B1	2.87E-09
MB.A34	MB.A31L4	<->	MB.C31L4	2.71E-09
MQ.A81	MQ.12L1.B2	<->	MQ.11L1.B1	2.42E-09
MQ.A12	MQ.27L2.B2	<->	MQ.25L2.B2	2.40E-09
MQ.A56	MQ.21L6.B2	<->	MQ.19L6.B2	2.27E-09
MQ.A78	MQ.20L8.B1	<->	MQ.22L8.B1	2.13E-09
MQ.A34	MQ.9R3.B2	<->	MQ.11R3.B2	2.09E-09
MQ.A81	MQ.11R8.B2	<->	DFLAS.7R8.4	<b>2.02E-09</b>
MB.A34	MB.C19L4	<->	MB.B20L4	1.74E-09

(\*\*) number of splices in the quads segments corrected, 1.3 added

# LS1 – magnet replacement

	Dipoles (15)			SSS (4)		
	Done	To Do	Remarks	Done	To Do	Remarks
Cryostat	15	0		4	0	
BS removal	15	0		4	0	
Stripping	15	0		2	2	In progress
SU1 (Fidu)	15	0		1	3	
Polarity	15	0		1	3	
Cleaning	15	0		0	4	
BS Installation	15	0		0	4	
Leak&Press test	14	1		0	4	
SU2 (cartography)	14	1		0	4	
Storage	14	1		0	4	
Extremities WP08b	9	6	Not a critical issue	0	4	
Endosc+RF	0	15	VSC	0	4	VSC
Diode	0	15	Planned as soon as available	1	3	



Q5 and Q7, built  
for the first time  
at CERN



Cryo-BLM  
mounted on Q7R3



Finished SSS 233, with vacuum barrier: a **long story** of leaks and repairs (bulk material leak). Successful final pressure test !

All dipoles ready, awaiting diode installation

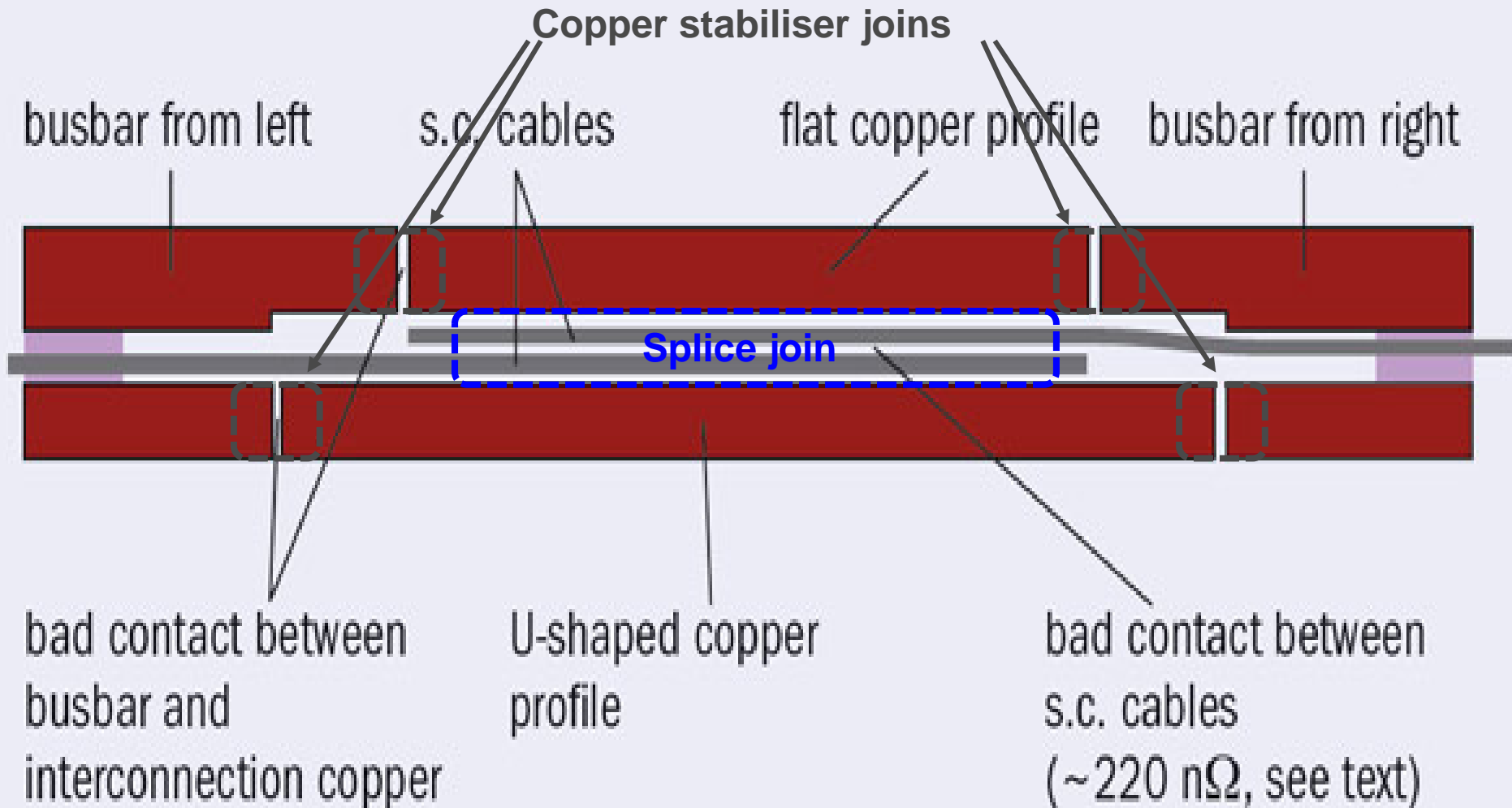
Preparing for higher intensities

Only 1 more magnet to test (Q7R3) before the 2012 year end and cryo-shutdown in SM-18

# LS1 activities

## Splices & Copper stabilizers

### Splices





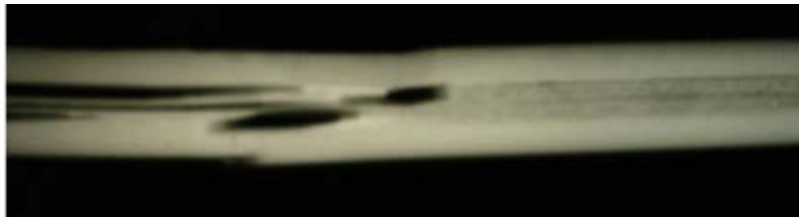
# LS1 activities

## *Splices & Copper stabilizers*

- Despite correct splice resistance between SC cables, a 13 kA joint can burn-out **in case of a quench**, if there would be a bad bonding between the SC cable and the copper bus, coinciding with a discontinuity in the copper stabilizer

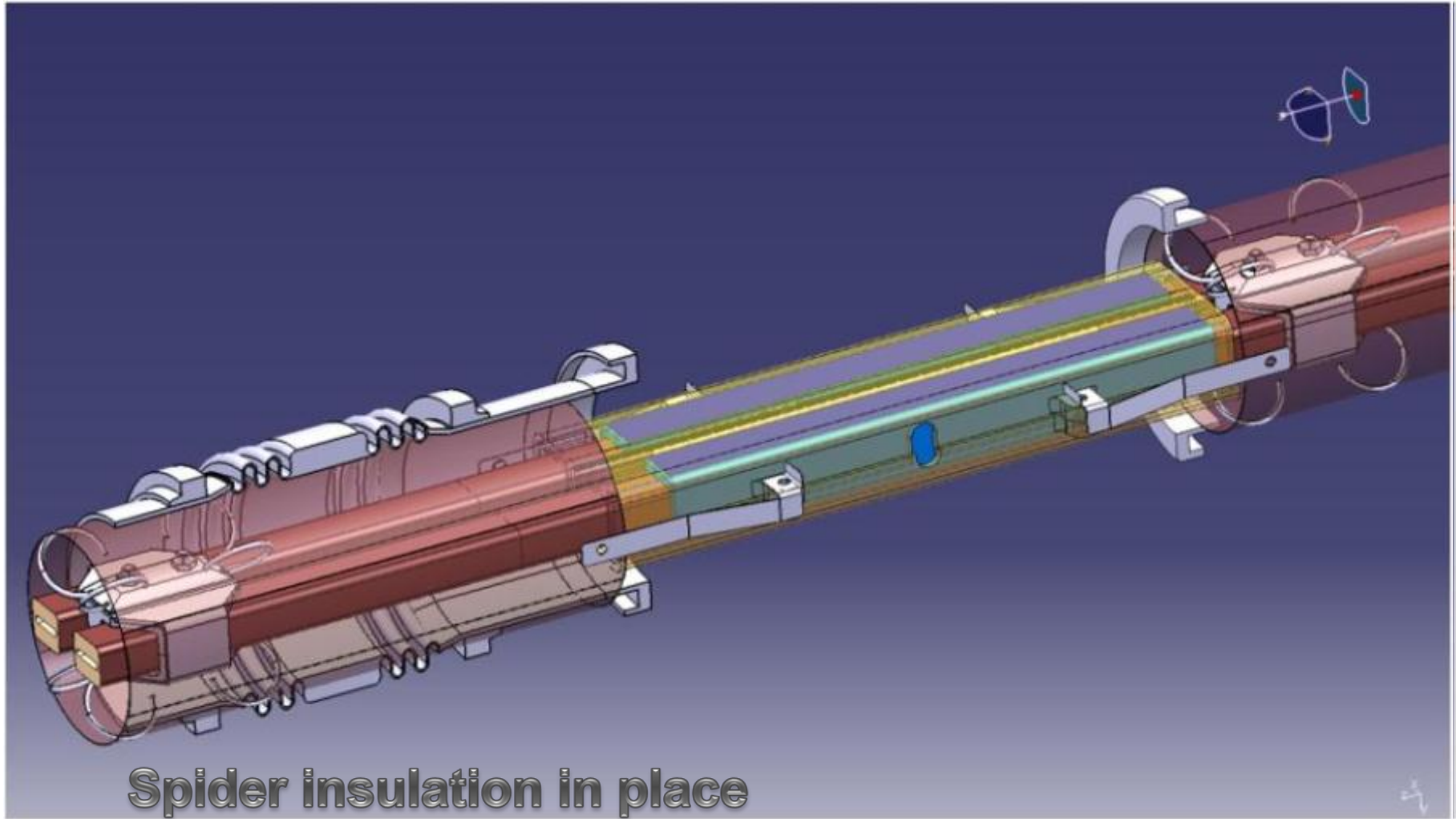


- Resistance measurements and  $\gamma$ -ray pictures have shown the presence of many of such defective joints in the machine, limiting the safe operating current



# LS1 activities

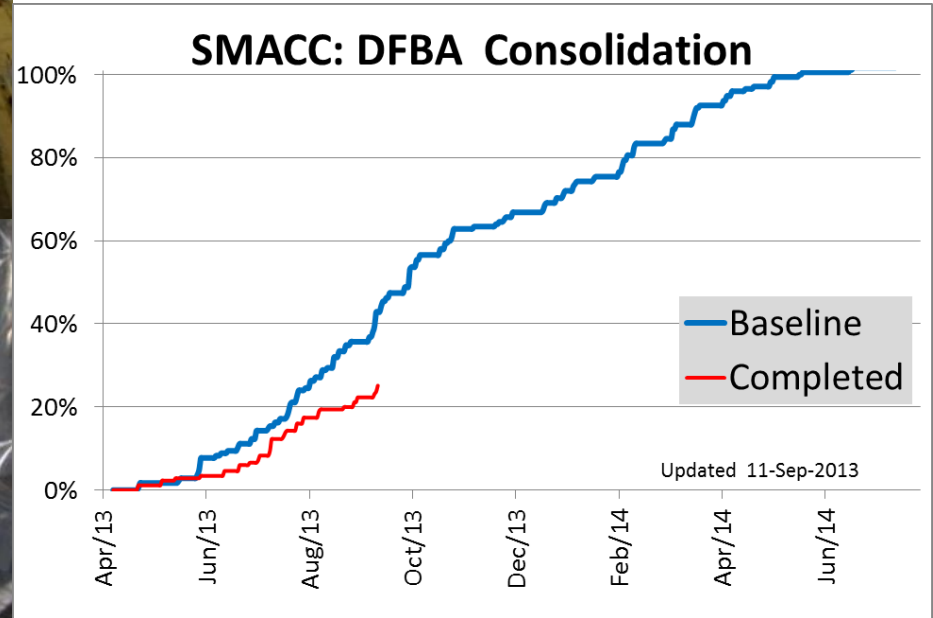
## *13kA splices consolidation*





# LS1 activities

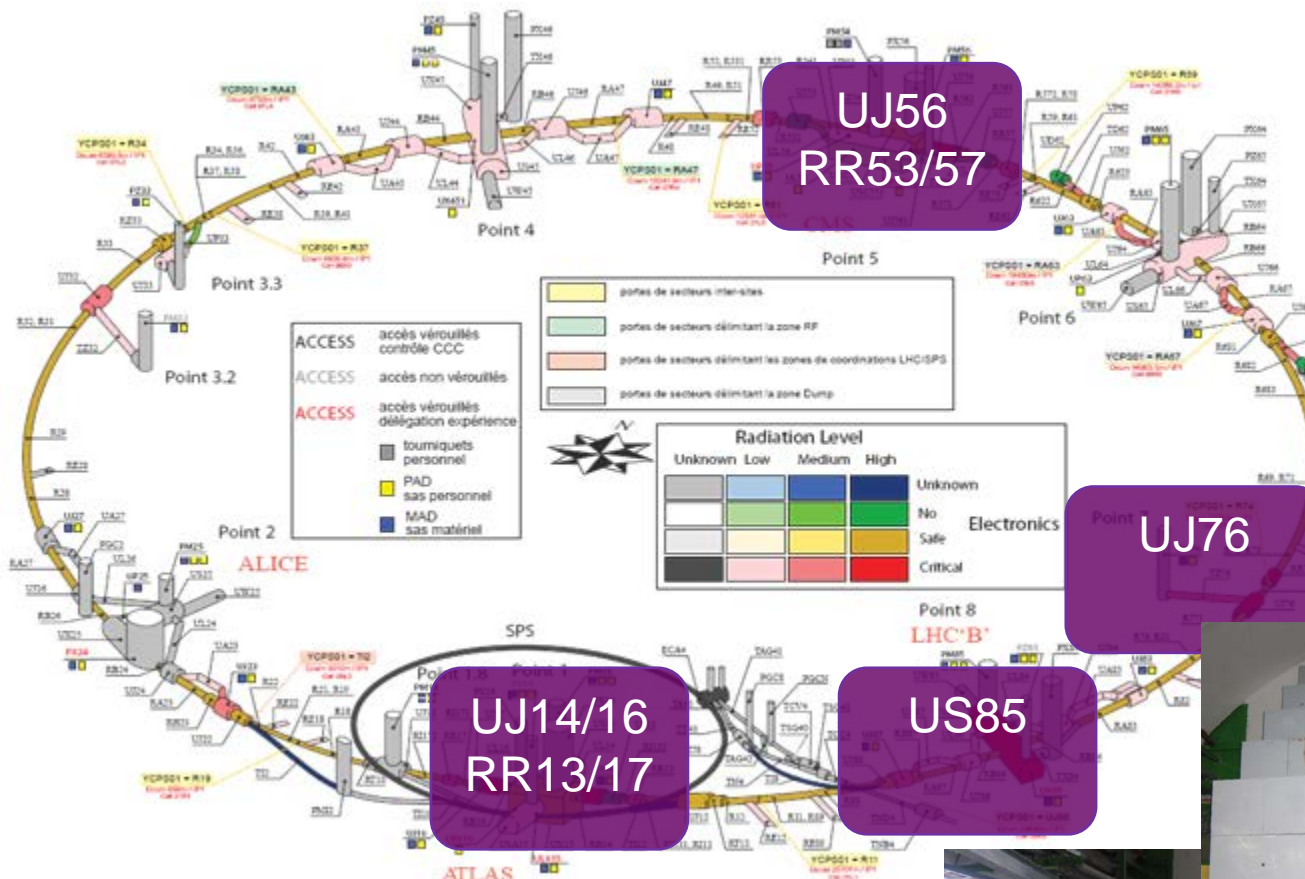
## Cryo-feedbox consolidation





# LS1 activities

## Radiation to Electronic in LHC tunnel: a concern...

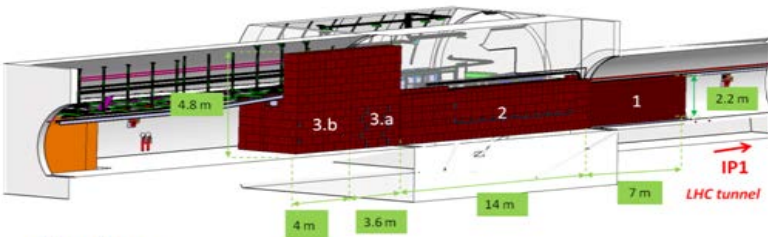


UJ56  
RR53/57

UJ76

UJ14/16  
RR13/17

US85

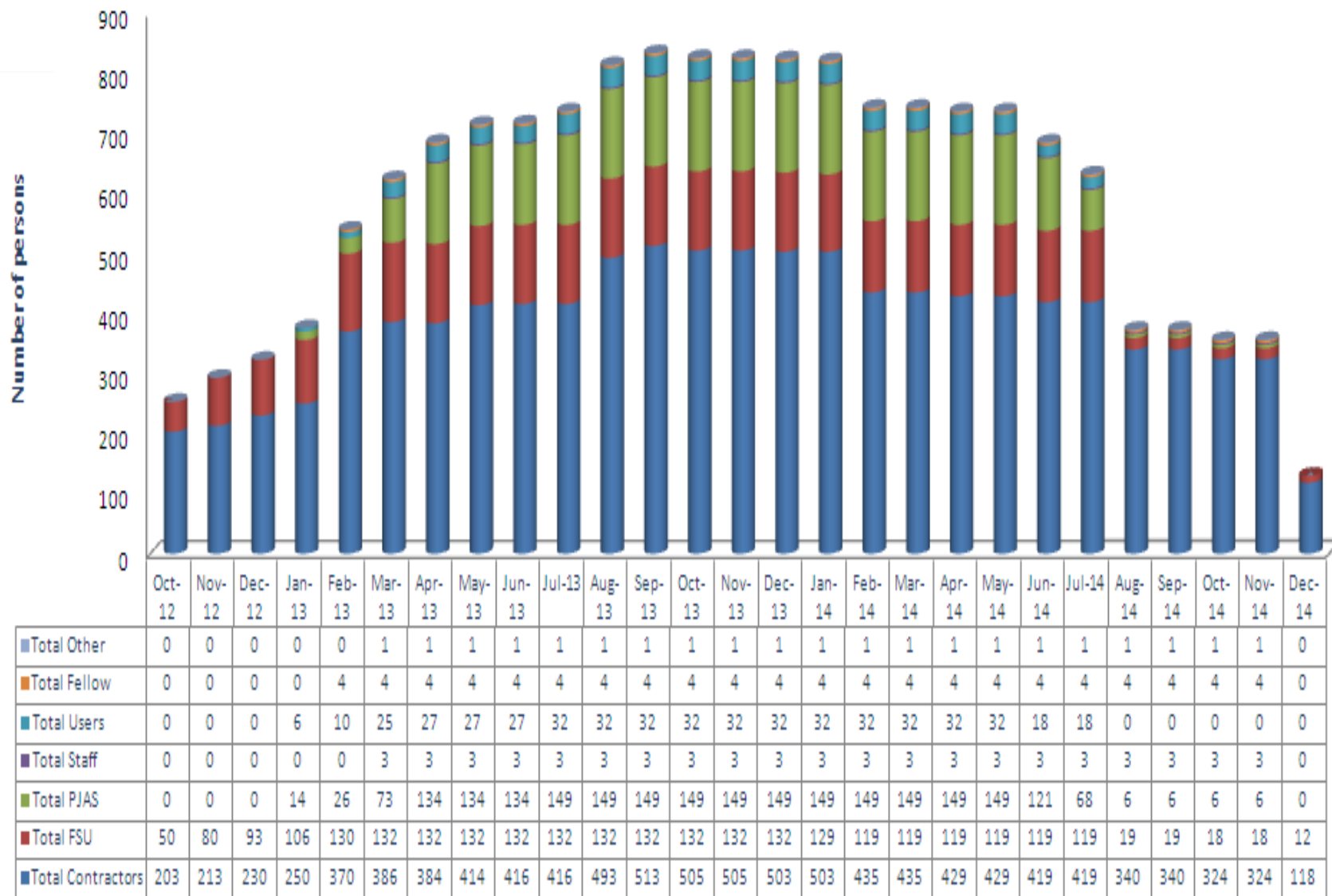


~ 600 tons cast iron & concrete

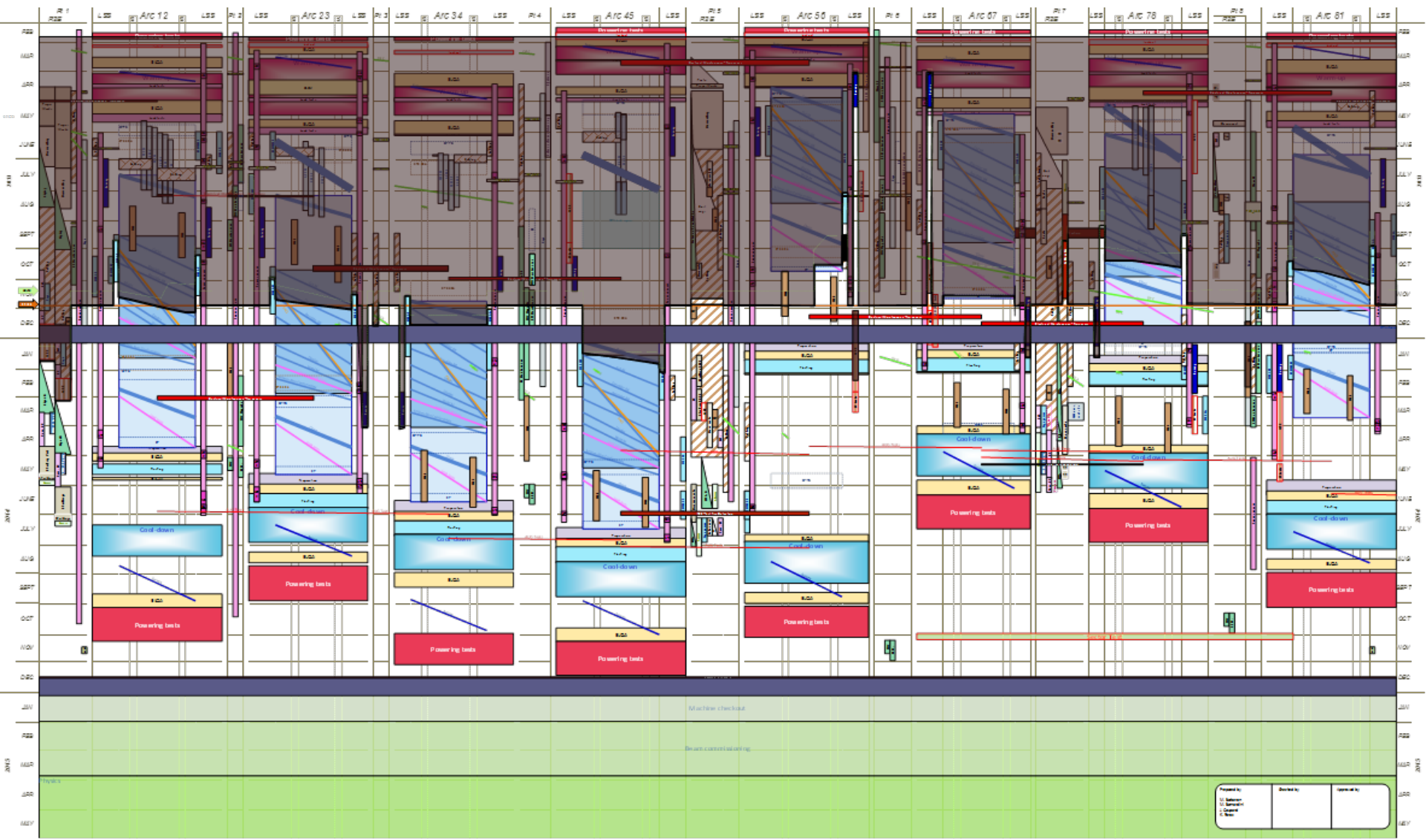
Courtesy M. Lazzaroni



# Overall additional number of persons at CERN during LS1 per status



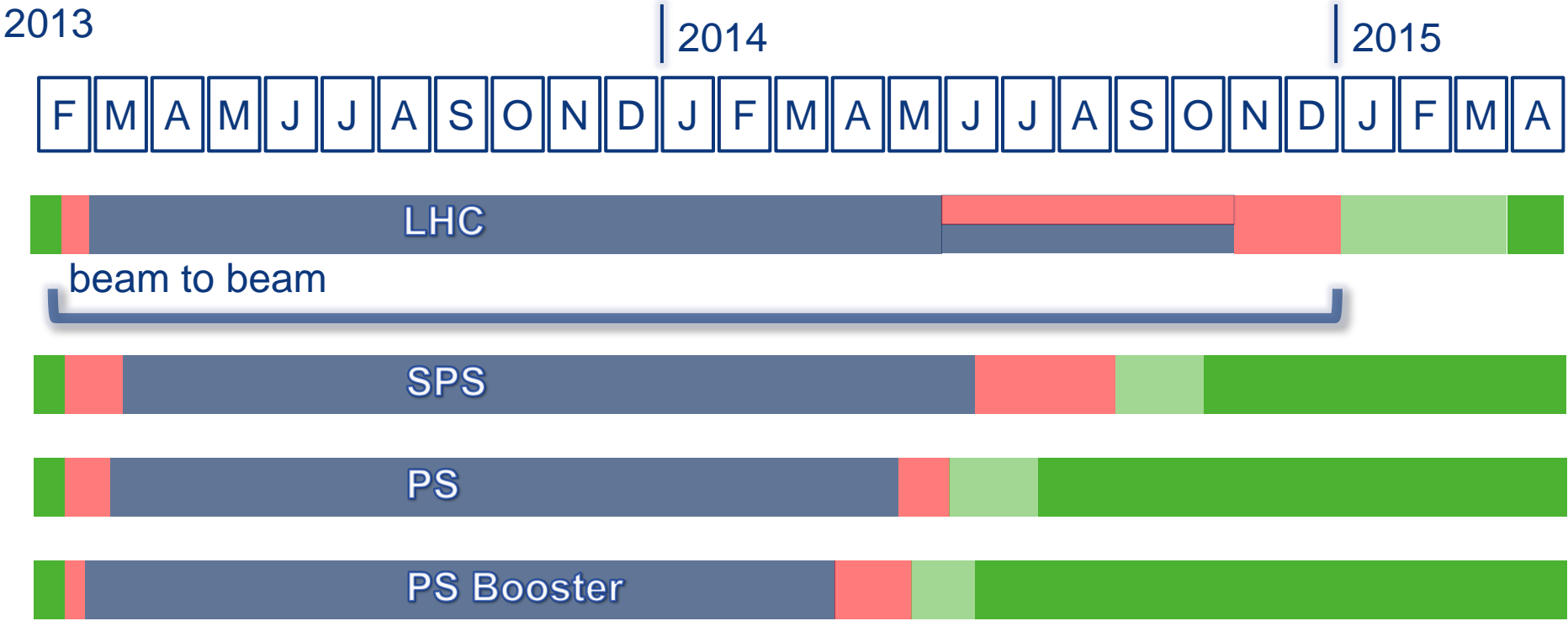
# LS1 activities Dashboard...



# Resuming Operation

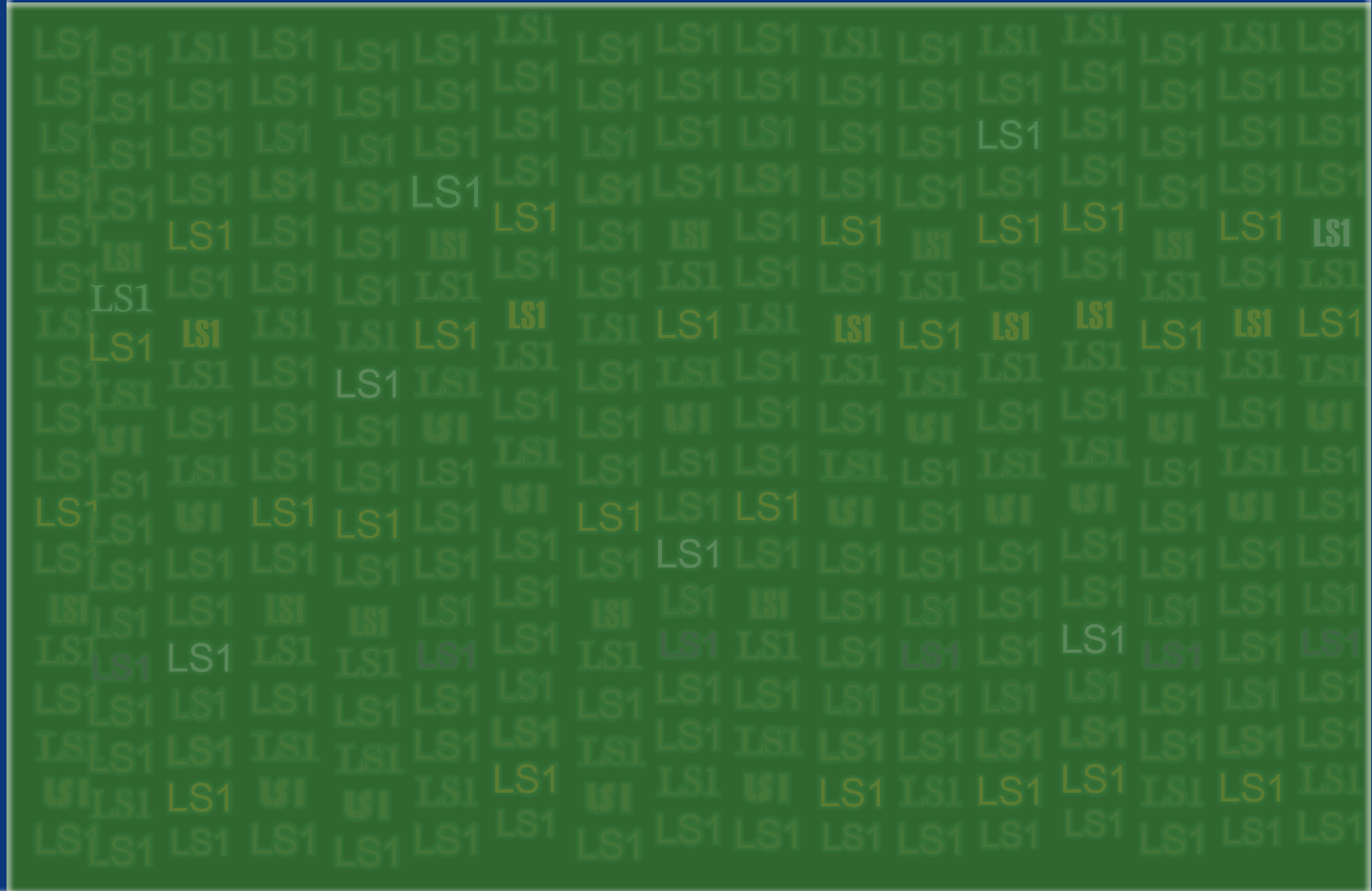
- Physics
- Beam commissioning
- Shutdown
- Tests

from mid February 2013 to end December 2014



# Long Shutdown 1

(13th Feb. 2013 to Dec. 2014) – Beam Commissioning Jan.-Apr. 2015)



**A very busy period – *Safety, Quality, Schedule***





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