2012 PERFORMANCE OF THE LHC BEAM VACUUM SYSTEM DURING PROTON RUNS

G. Lanza, V. Baglin, G. Bregliozzi, J. M. Jimenez

CERN - TE

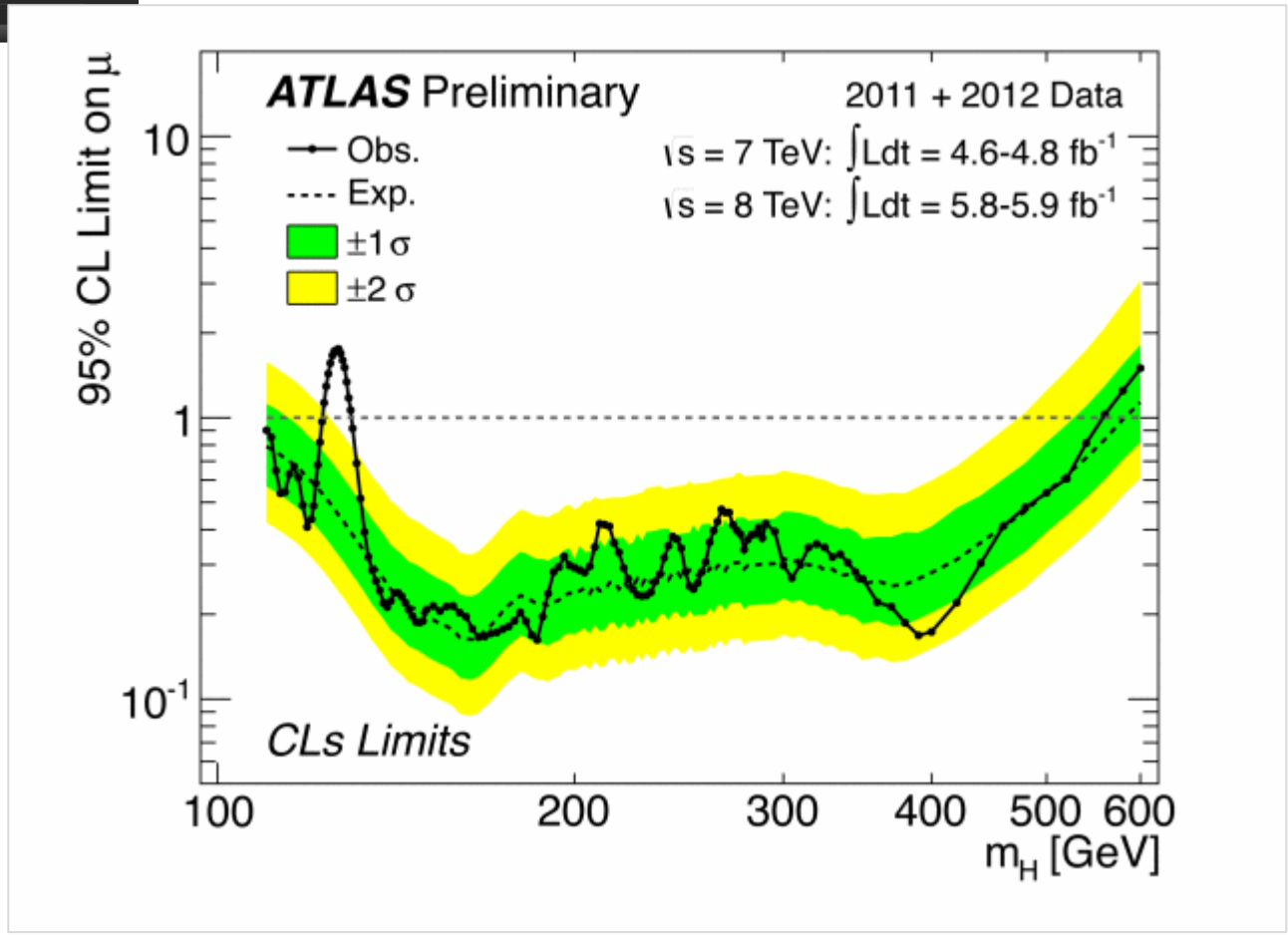
Vacuum, Surfaces and Coatings

LHC

2012

Boson discovery

ATLAS and CMS observed a new particle in the mass region around 125-126 GeV



LHC

Luminosity

$$L = \frac{N^2 k_b f}{4\pi\sigma_x^*\sigma_y^*} F = \frac{N^2 k_b f \gamma}{4\pi\varepsilon_n \beta^*} F$$

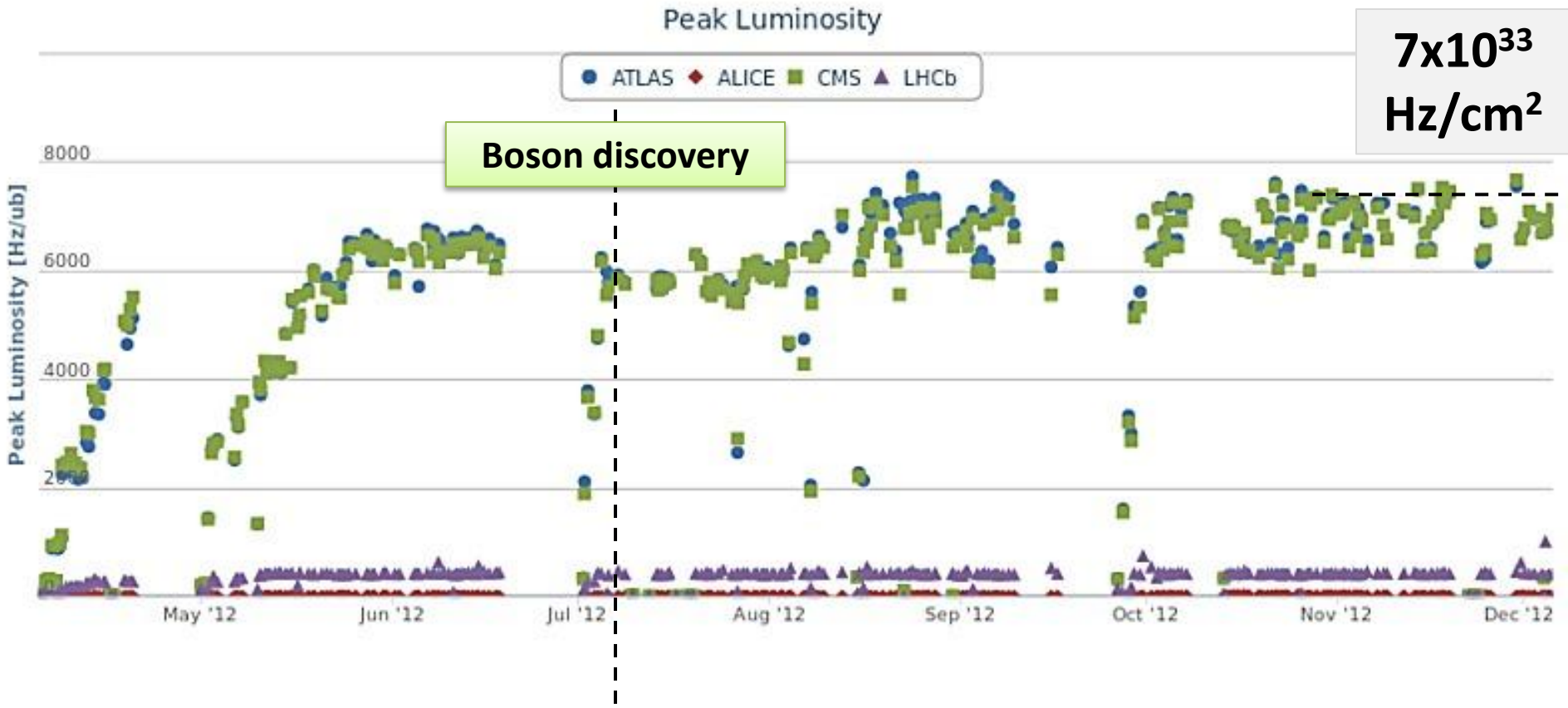
N	**Number of particles per bunch**
K_b	**Number of bunches**
f	Revolution frequency
σ_y	**Beam size at interaction point**
F	Reduction factor due to crossing angle
ε	Emittance
ε_n	**Normalized emittance**
β^*	**Beta function at IP**

Aim: maximize peak luminosity

LHC

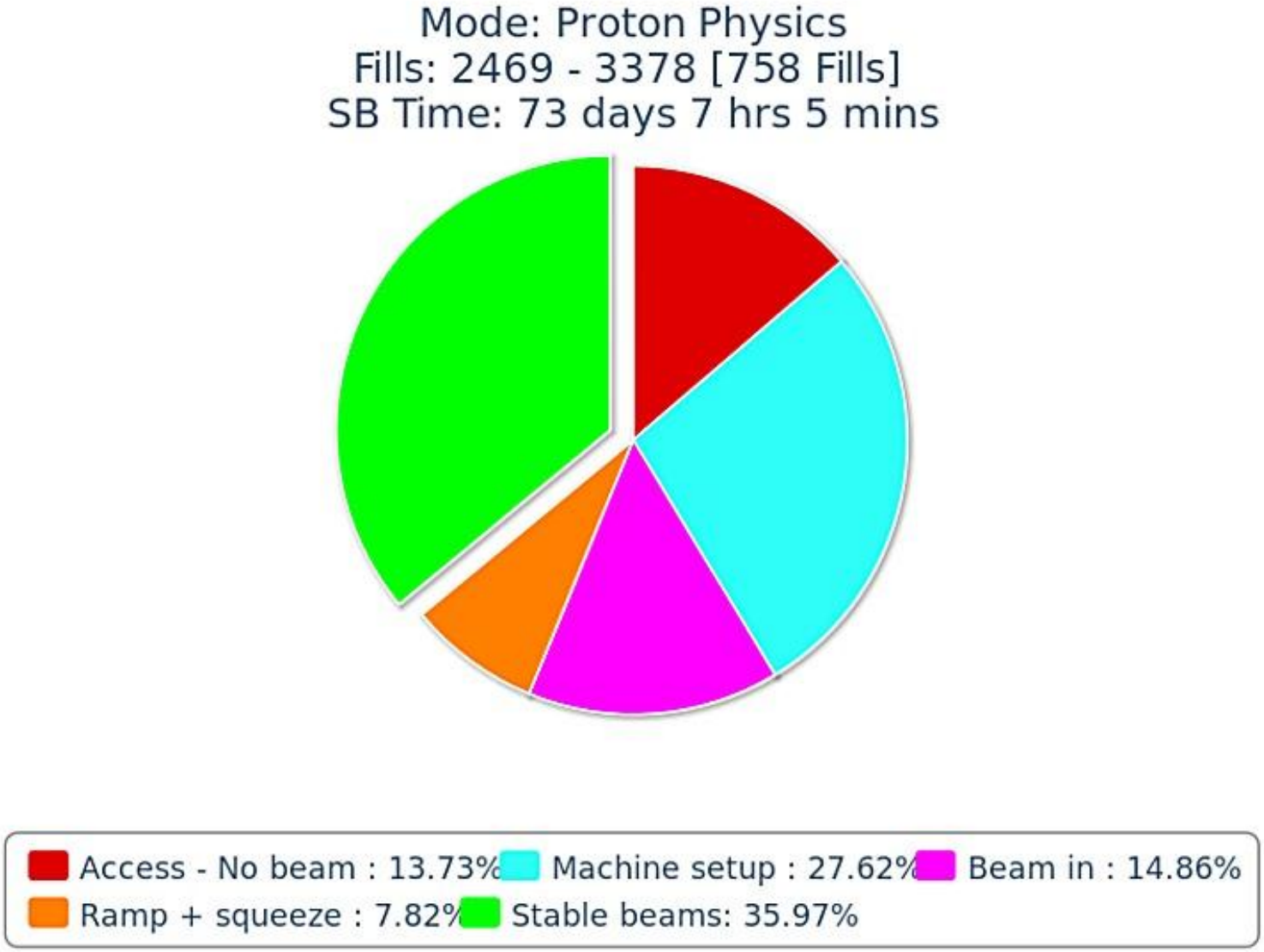
2012

4TeV

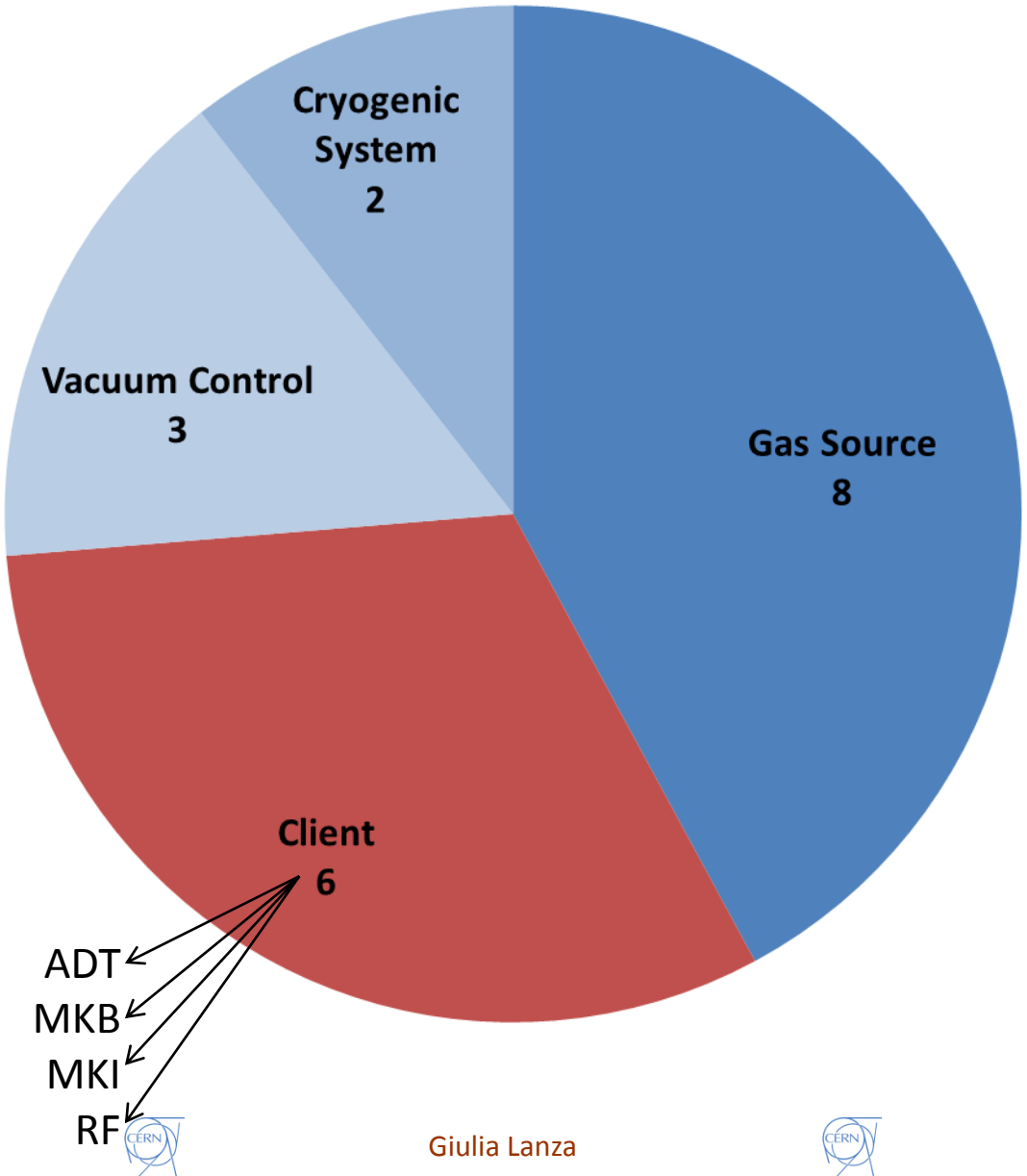


LHC OPERATION 2012

LHC Efficiency and Availability



Beam dumps 2012 related to vacuum



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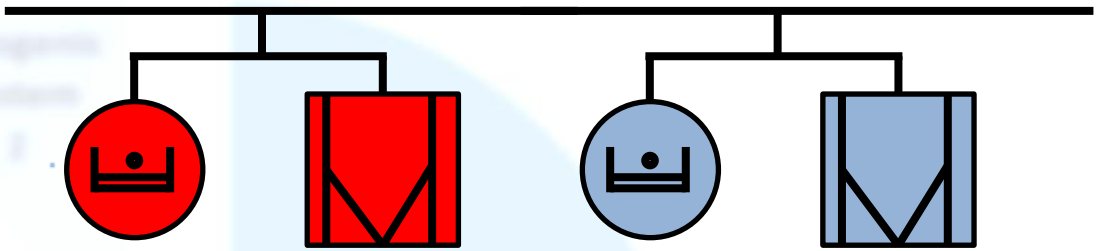
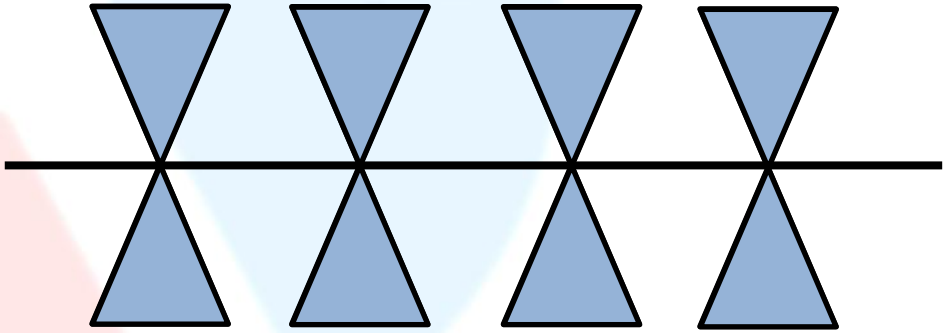


Vacuum gauges switch off or in undefined status



Vacuum valves in undefined position

PLC switch lost connection

Beam dumps 2012 related to vacuum

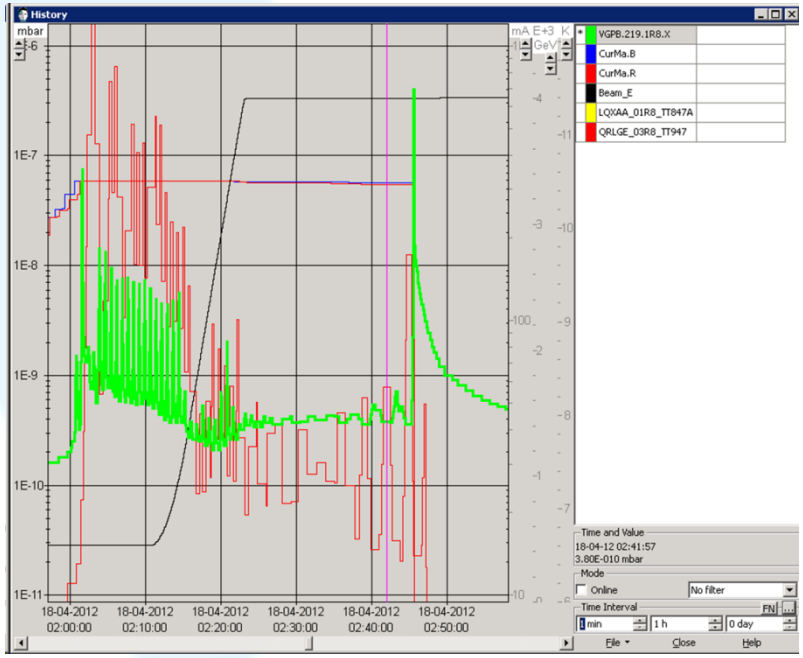
Equilibrium surface coverage of the beam screen for a given set of beam parameter and BS temperature.

Cryogenic System 2

If the surface coverage exceeds its equilibrium value, pressure excursion or transient due to cryogenics appears when the beam is injected

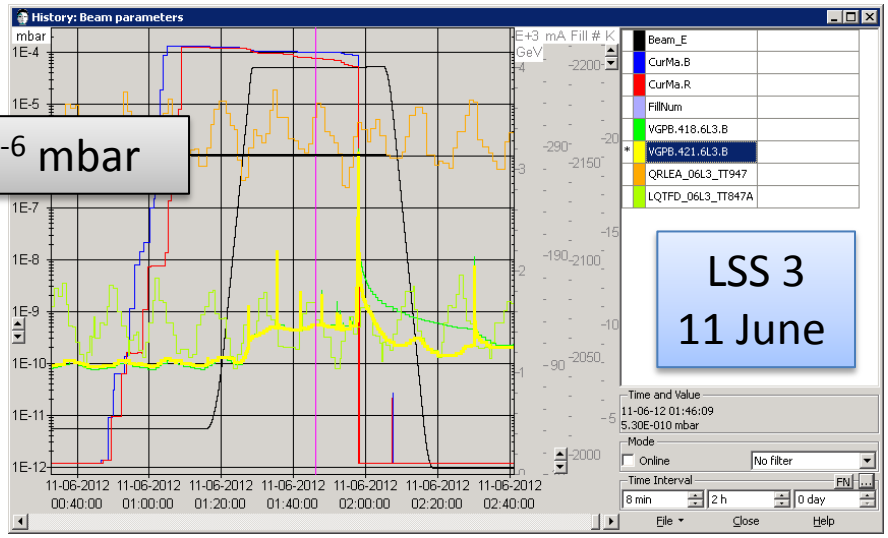
The equilibrium surface coverage depends on:

- Beam screen temperature
- Beam current



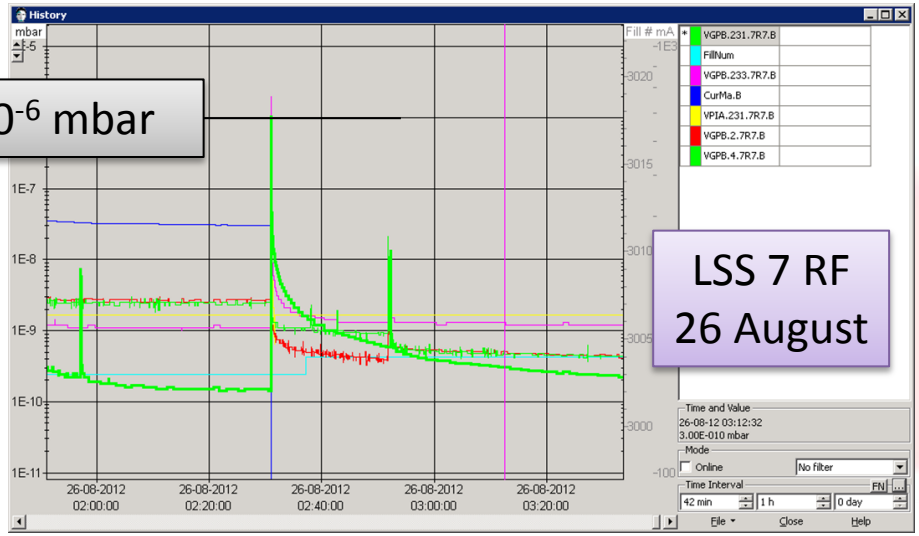
V. Baglin, LHC Project Workshop – Chamonix XIII
G. Bregliozzi, LBOC presentation, 31.05.2011

Beam dumps 2012 related to vacuum



1x10^{-6} mbar

LSS 3
11 June

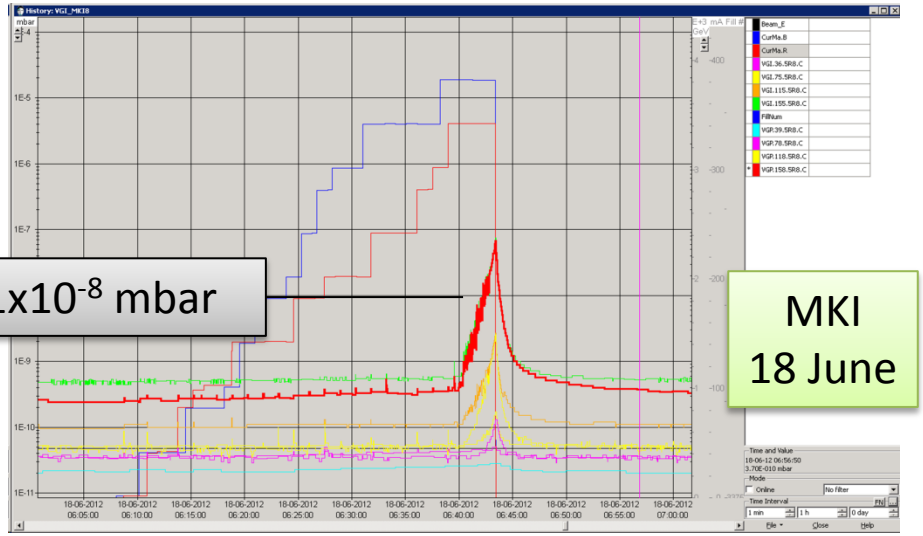


1x10^{-6} mbar

LSS 7 RF
26 August

Gas Source
8

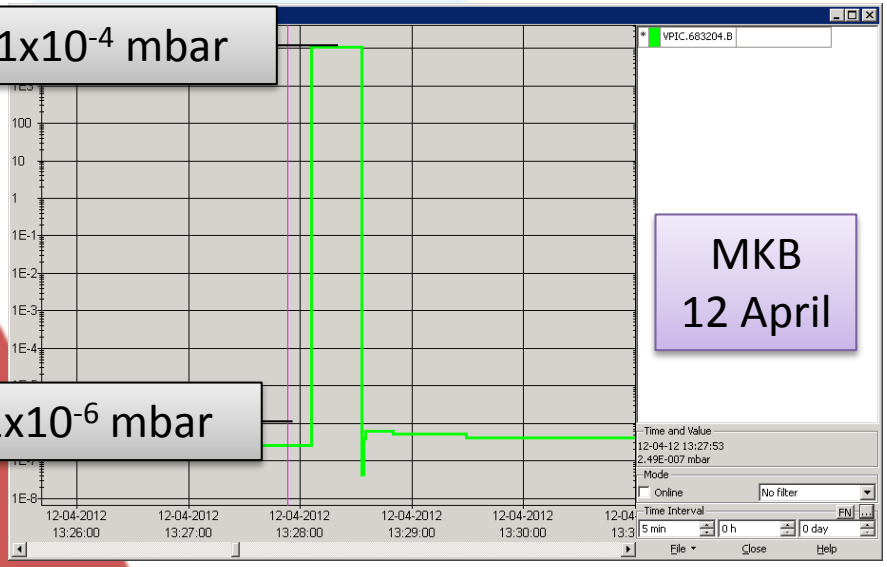
Beam dumps 2012 related to vacuum



$1x10^{-8}$ mbar

MKI
18 June

$1x10^{-4}$ mbar



MKB
12 April

$1x10^{-6}$ mbar

Client
6

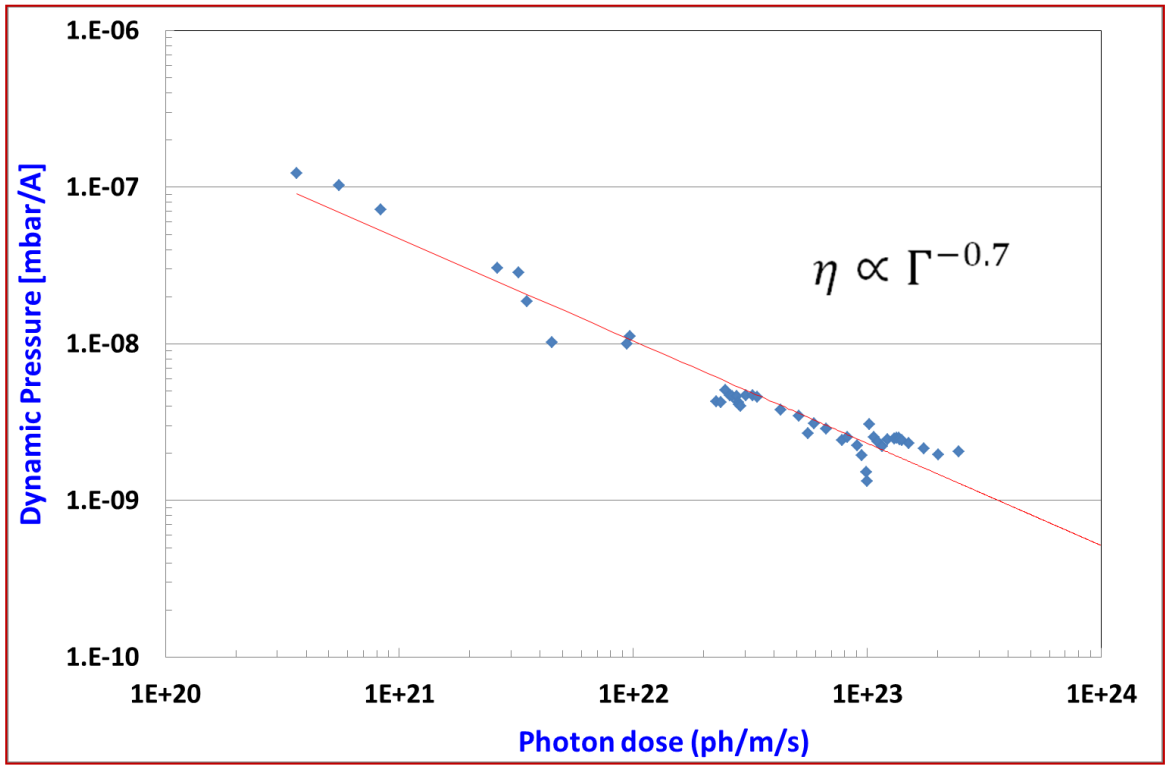
Synchrotron Radiation and Electron Cloud

Synchrotron Radiation

Pressure increases due to synchrotron light irradiation

$$P_{ph} = \frac{\eta_{ph,g} \cdot \dot{\Gamma}_{ph}}{S}$$

Vacuum cleaning
(photon desorption yield decreasing)
of the vacuum system



Synchrotron Radiation

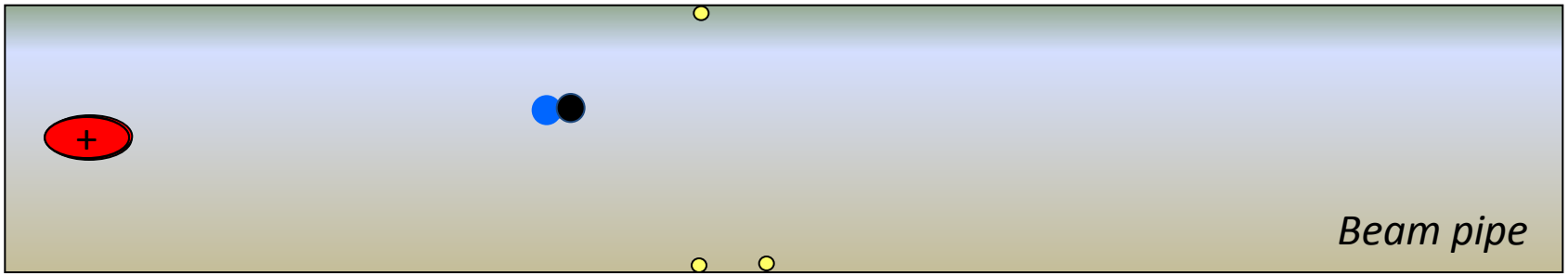
After LS1 the proton energy will increase to

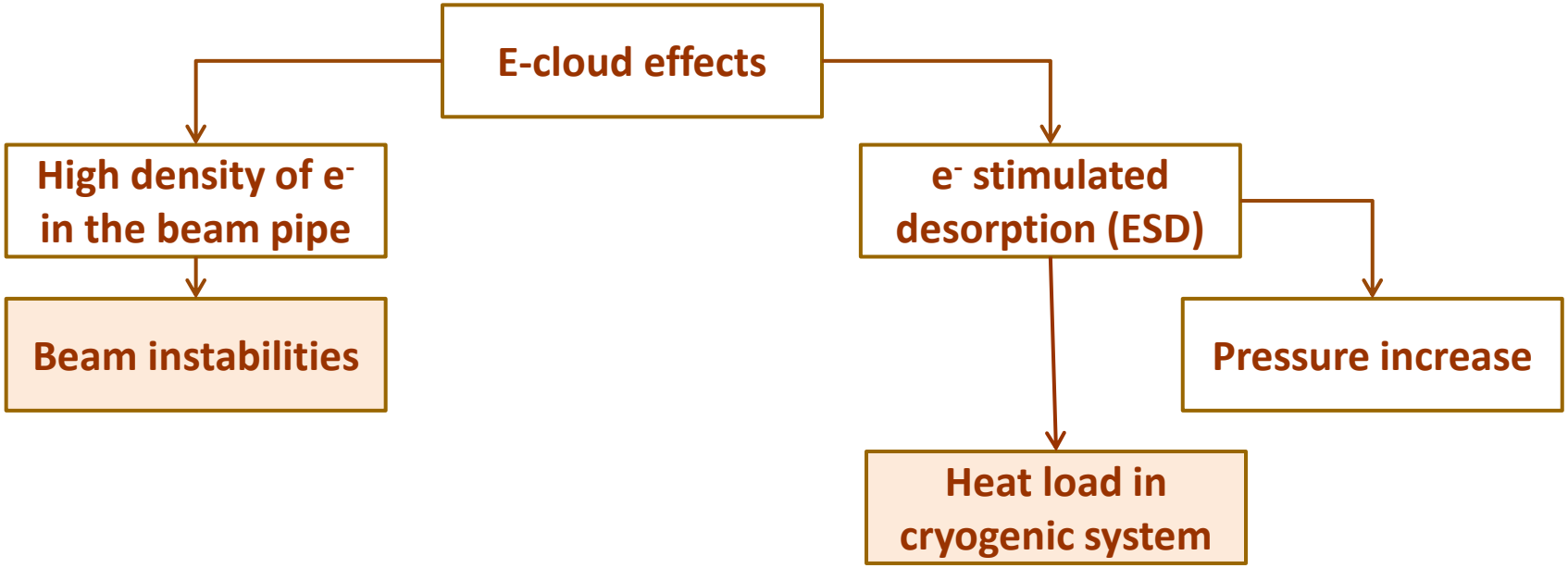
7 TeV

The photon flux will increase of one order of magnitude

Electron Cloud

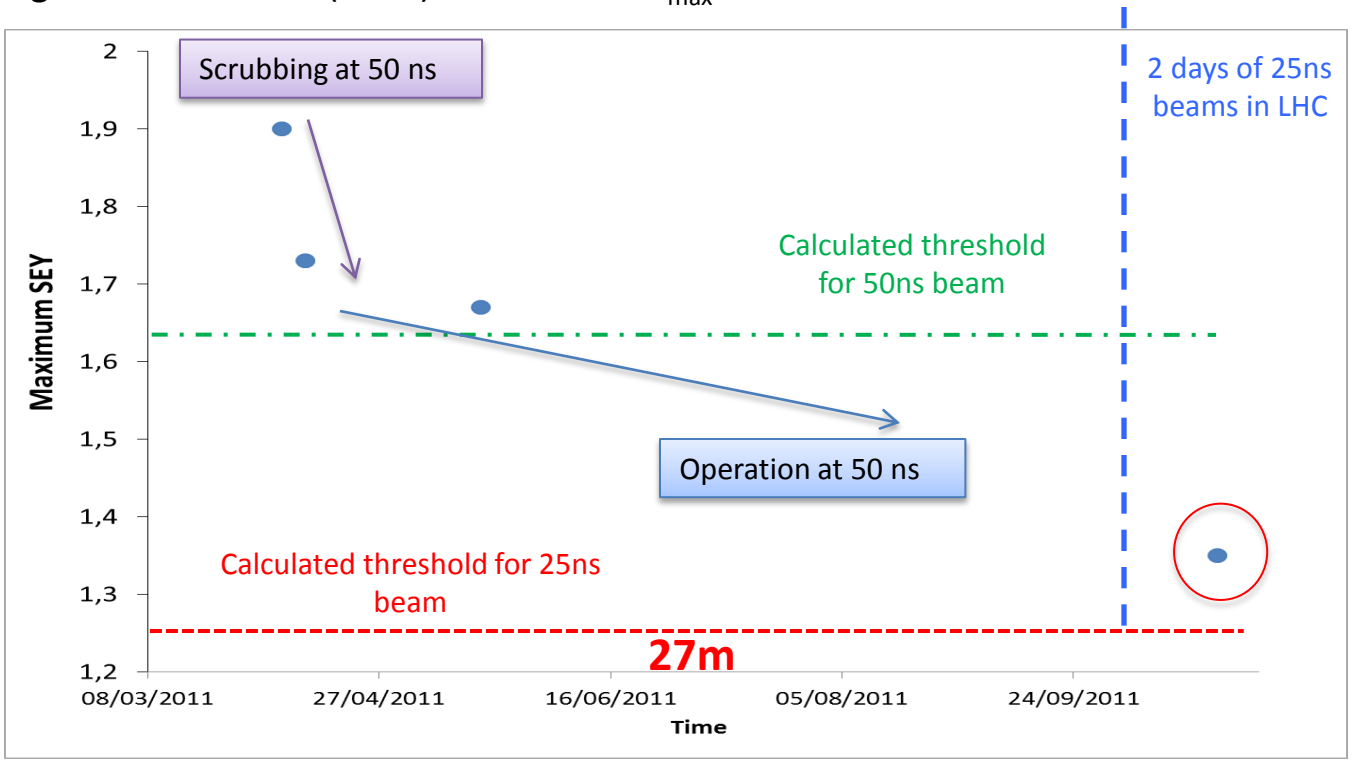
Electron clouds in beampipes are generated by **electron multipacting** on the wall of the vacuum chamber. The electrons are accelerated by the electric field of the bunches.





Secondary Electro Yield

- Scrubbing at 50 ns Scrubbing has lowered δ_{max} to 1.7.
- During the 2011 operation with 50 ns the δ_{max} further decrease.
- Scrubbing with 25ns beam (~40h) has lowered δ_{max} to 1.35 !

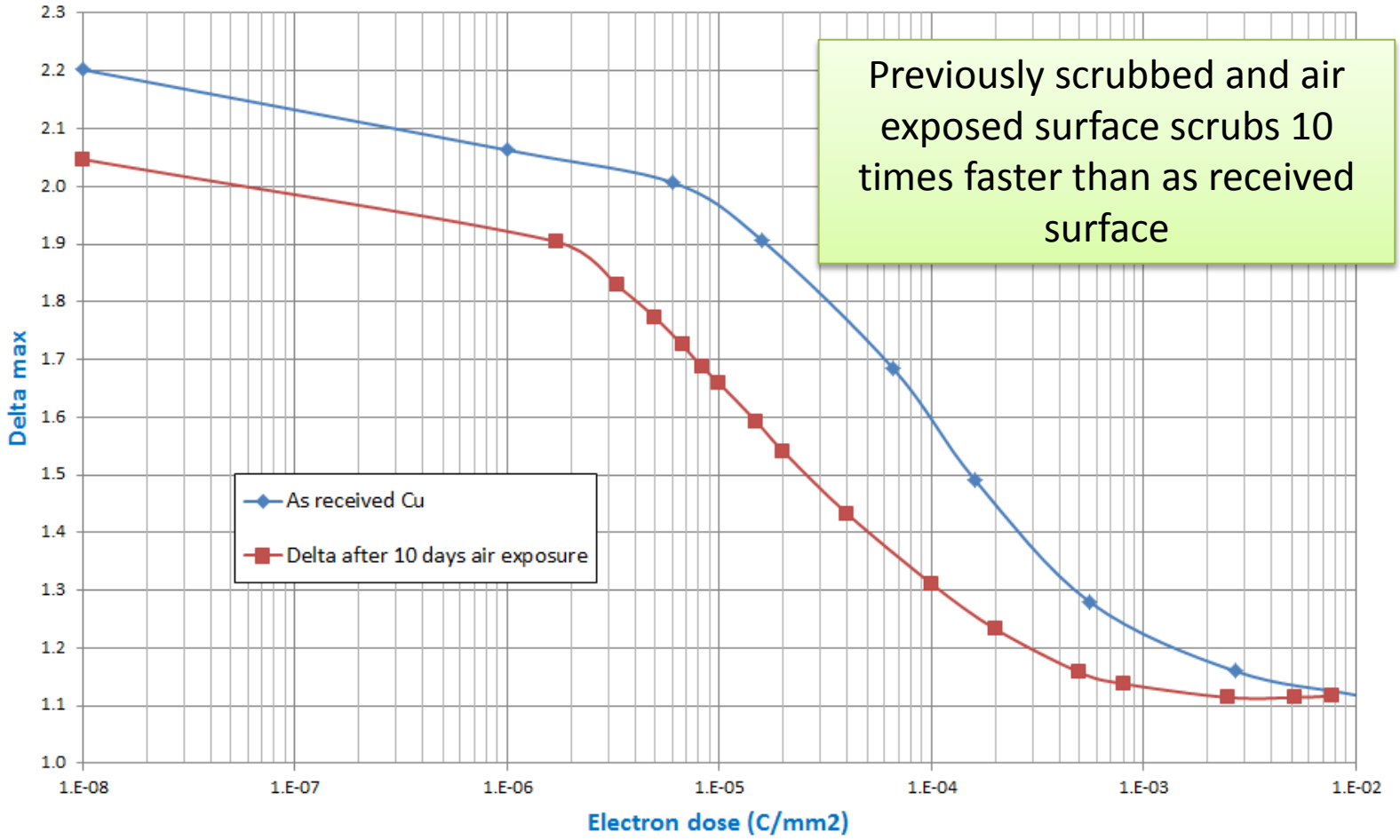


1) No more electron cloud at 50 ns (up to 1.45 10^{11} ppb at least)
2) Requires further scrubbing to operate with 25 ns

From G.Rumolo, EVIAN 2011

Vacuum Scrubbing

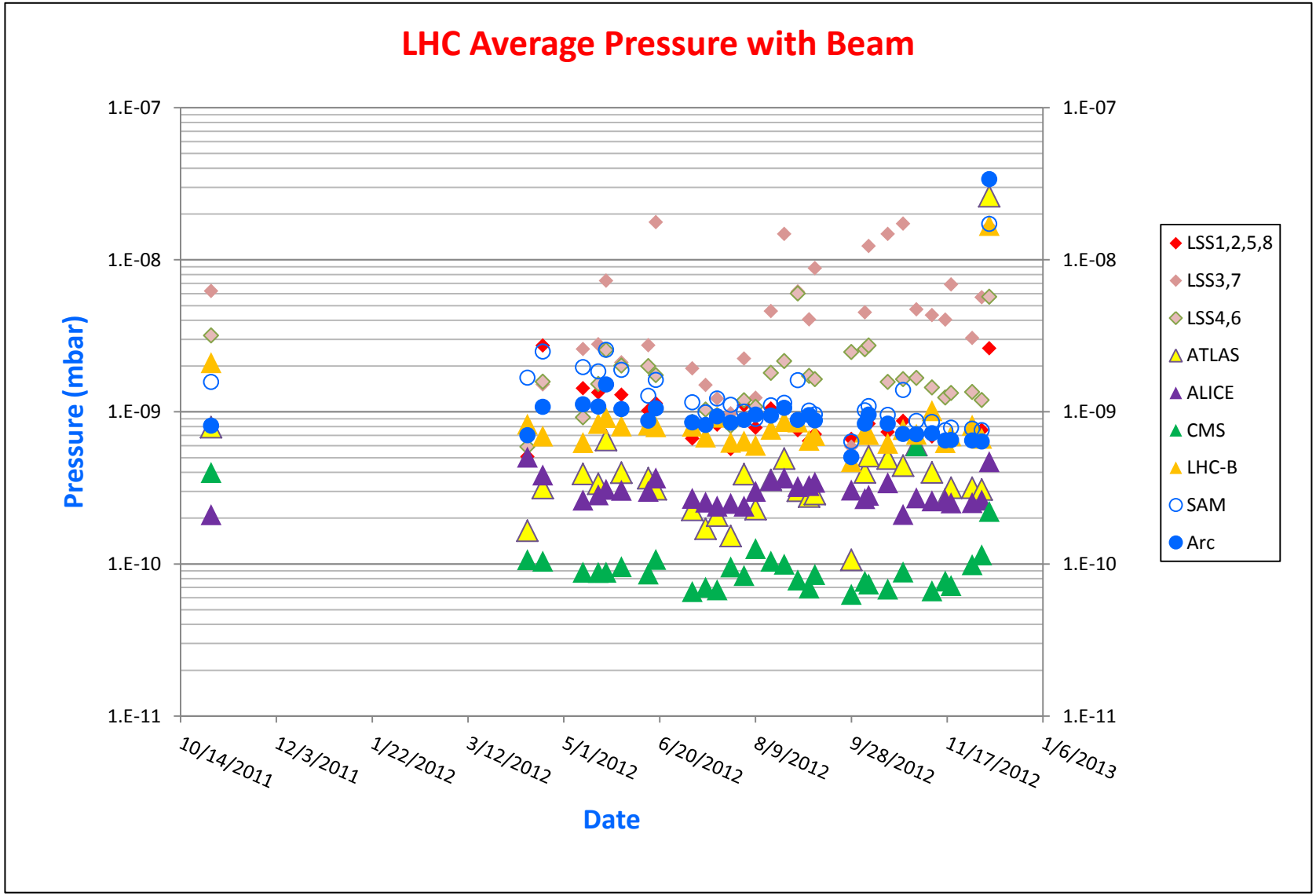
- For as received Cu, ~ 0.5 mC/mm2 is required to reach 1.3
- Pre-scrubbed material and exposed to air need 0.1 mC/mm2 to reach 1.3



Previously scrubbed and air exposed surface scrubs 10 times faster than as received surface

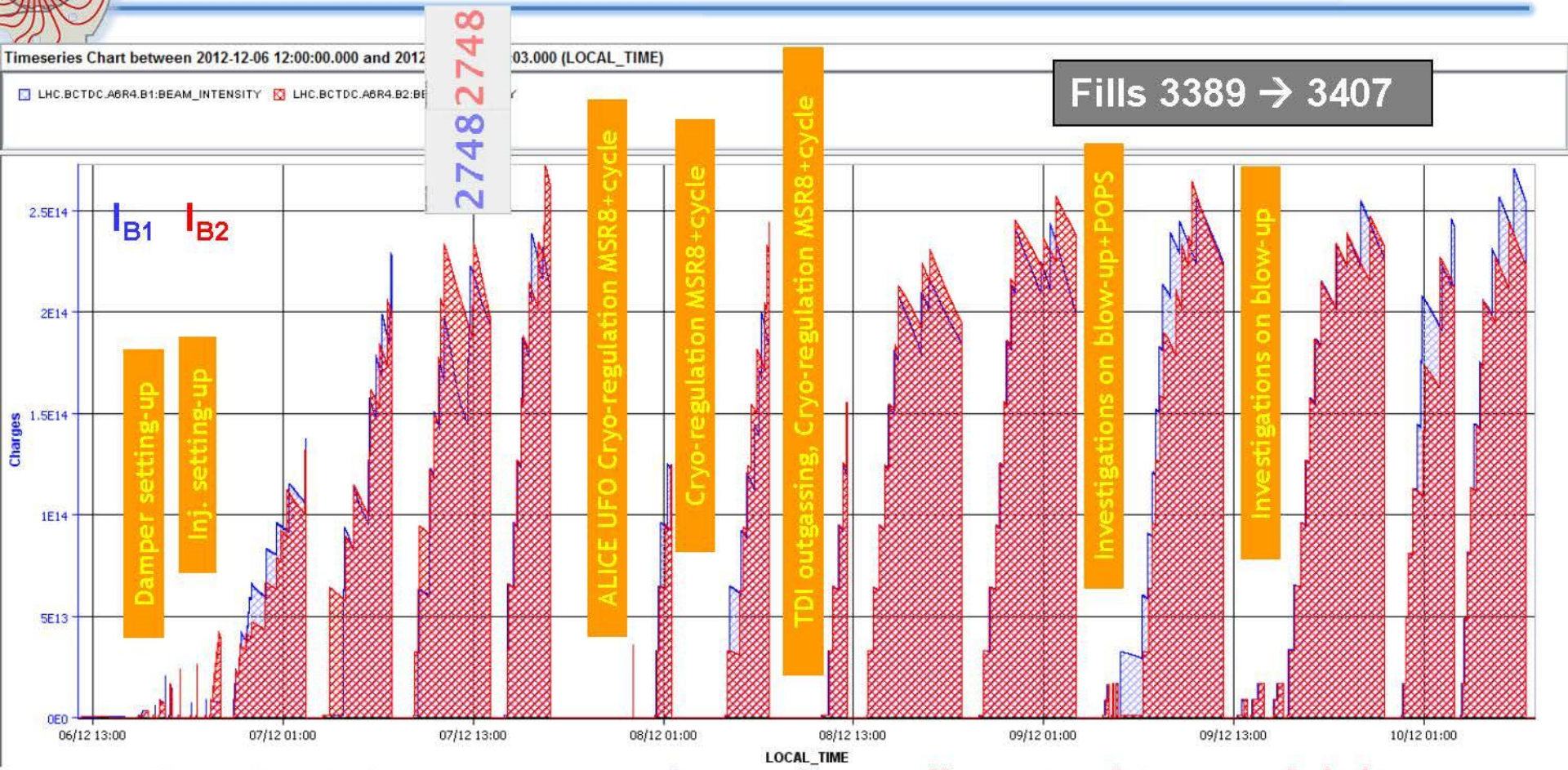
J.M. Jimenez *et al*, LHC PR 632, 2003

Vacuum Scrubbing



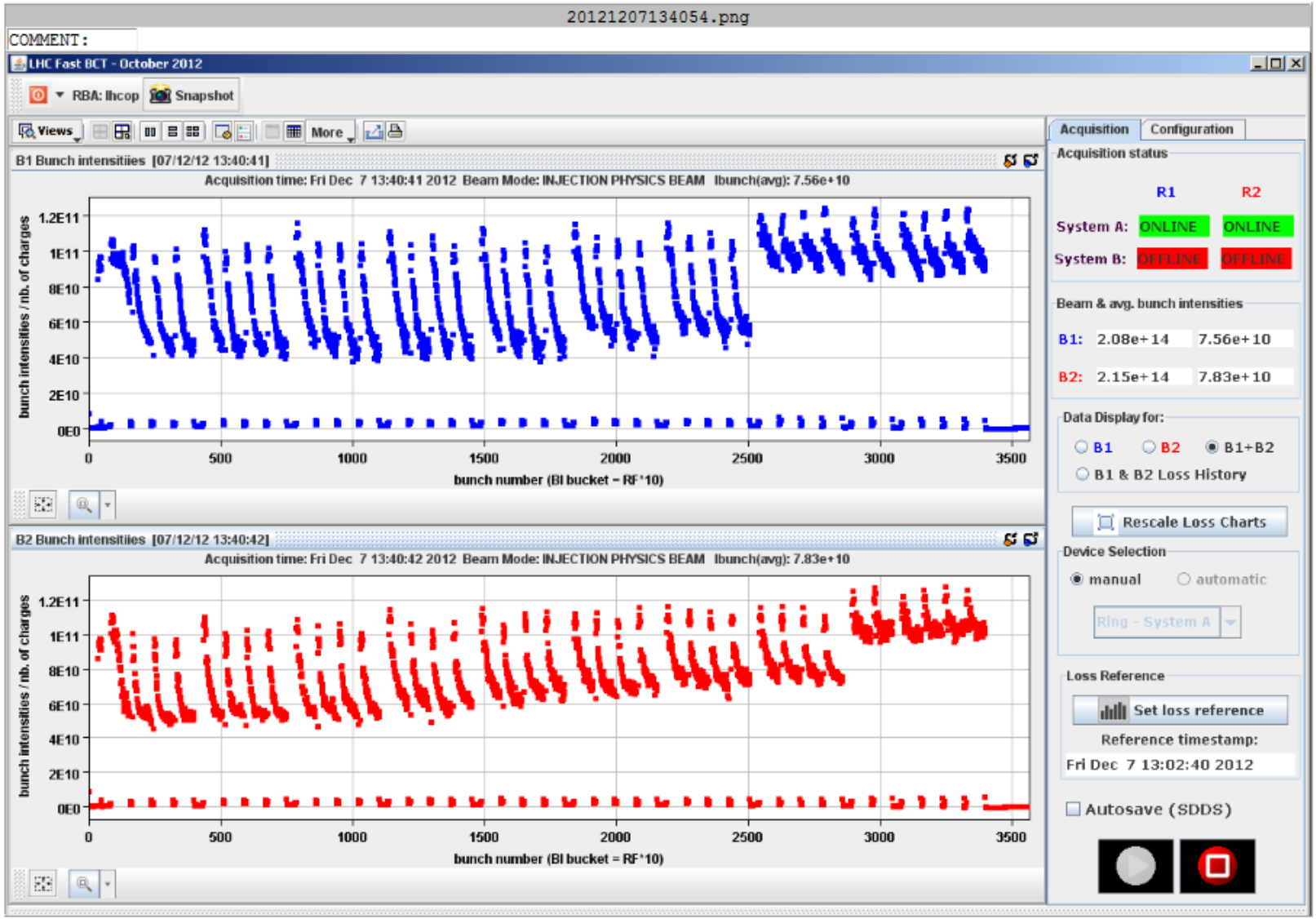
Scrubbing Run 25 ns

Scrubbing Overview



- Fast intensity ramp-up and overall excellent machine availability
- Beam under control (damper, chromaticity, octupoles) in spite of the record intensities (up to 2.7×10^{14} p, 2748 bunches per beam)

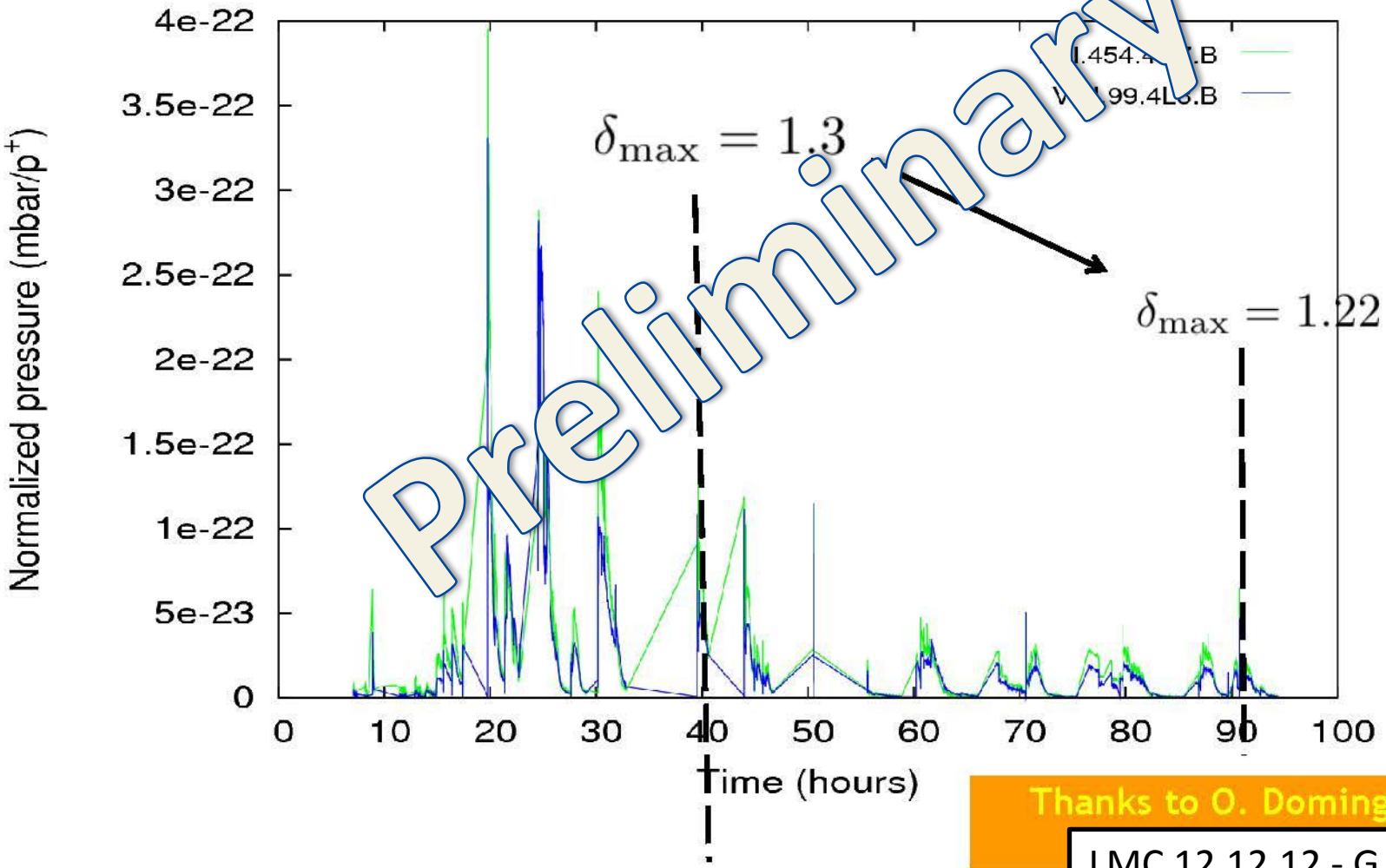
Scrubbing Run 25 ns



Scrubbing Run 25 ns

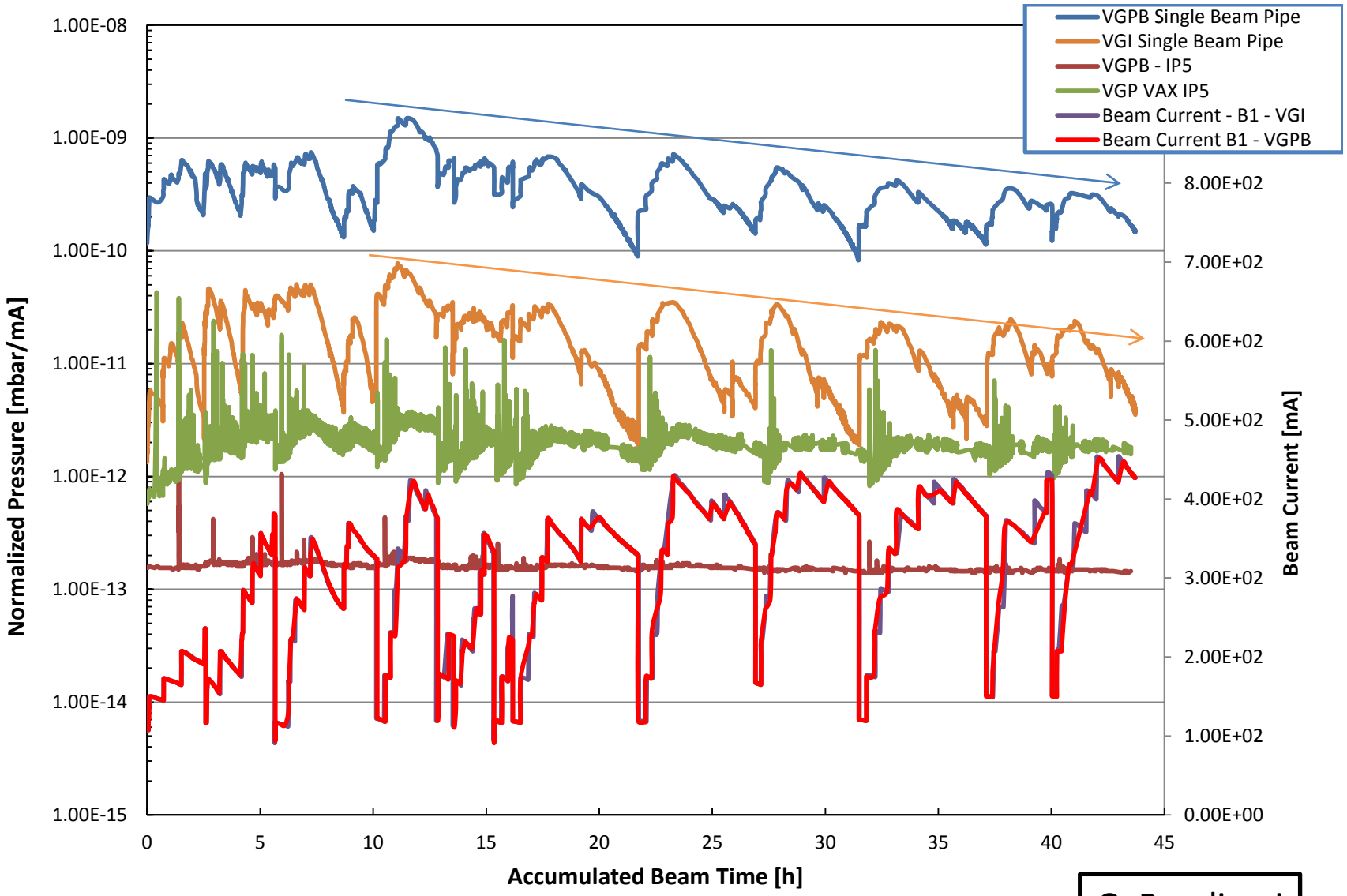
Vacuum evolution (II)

- **Clearer trend in terms of normalized pressure**(pressure gauges used for the SEY analysis in the LSS).



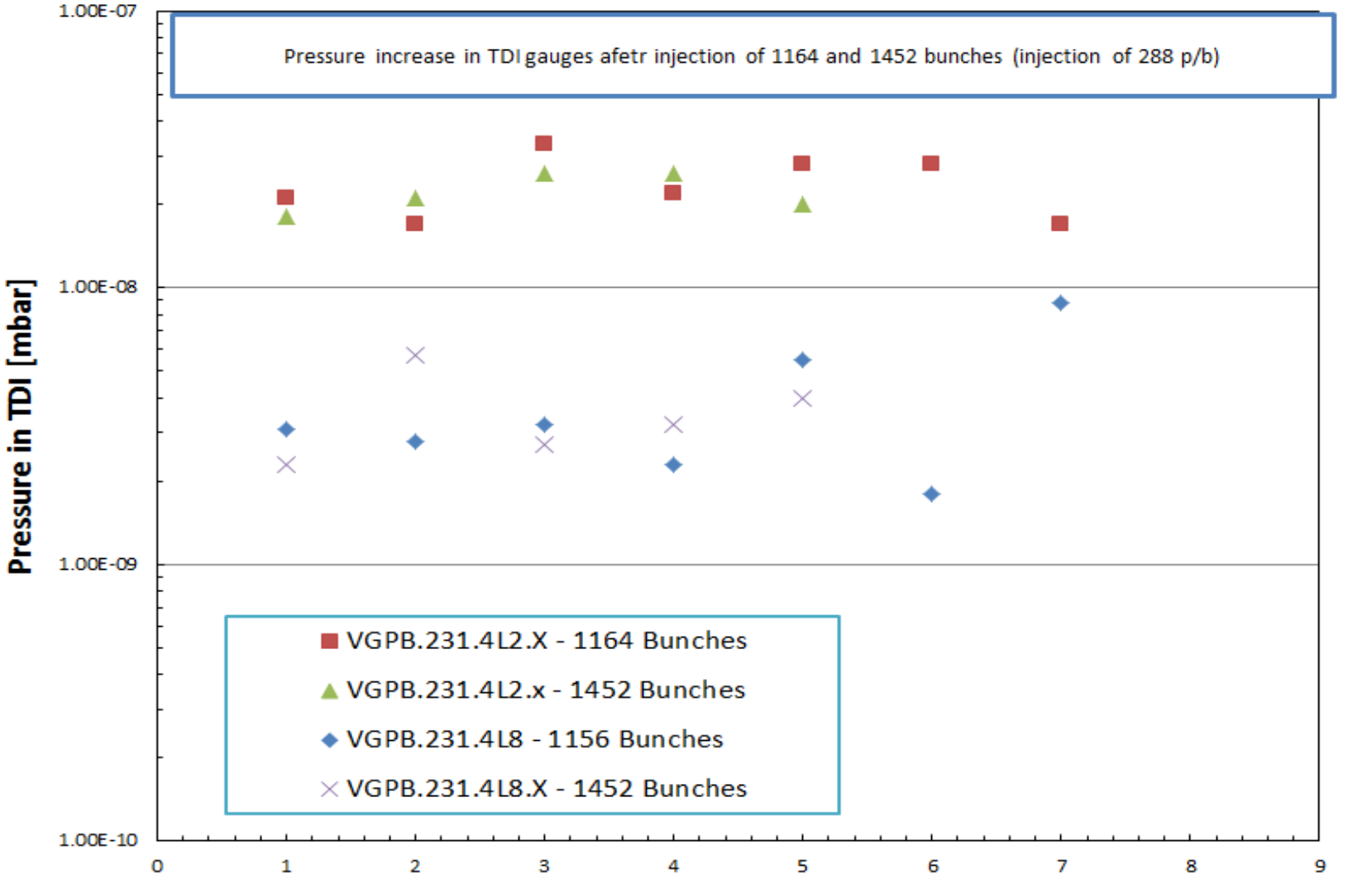
Thanks to O. Dominguez,

Scrubbing Run 25 ns



G. Bregliozzi

Scrubbing Run 25 ns



G. Bregliozzi

LHC LOCAL INTERVENTIONS

2012 Vacuum Intervention

Christmas Break 2011

- BSRT
- BGI left
- CMS
- Upgrade ZDC (VMTS repair) Pt2-8

TS n.3

- MKI
- BSRT left (Ne)
- BSRT right (BO)

TS n.4

- Wire scanner
- BSRT left (Ne)
- BSRT right (Ne)

1. BSRT
2. Wire scanner leak

2012 Vacuum Intervention

N2 Venting and Bake out

Typical of Christmas Breaks or Long Shutdown

Neon venting

Typical of Technical Stops and Urgent intervention

- No bake out of the sector
- Partial bake out

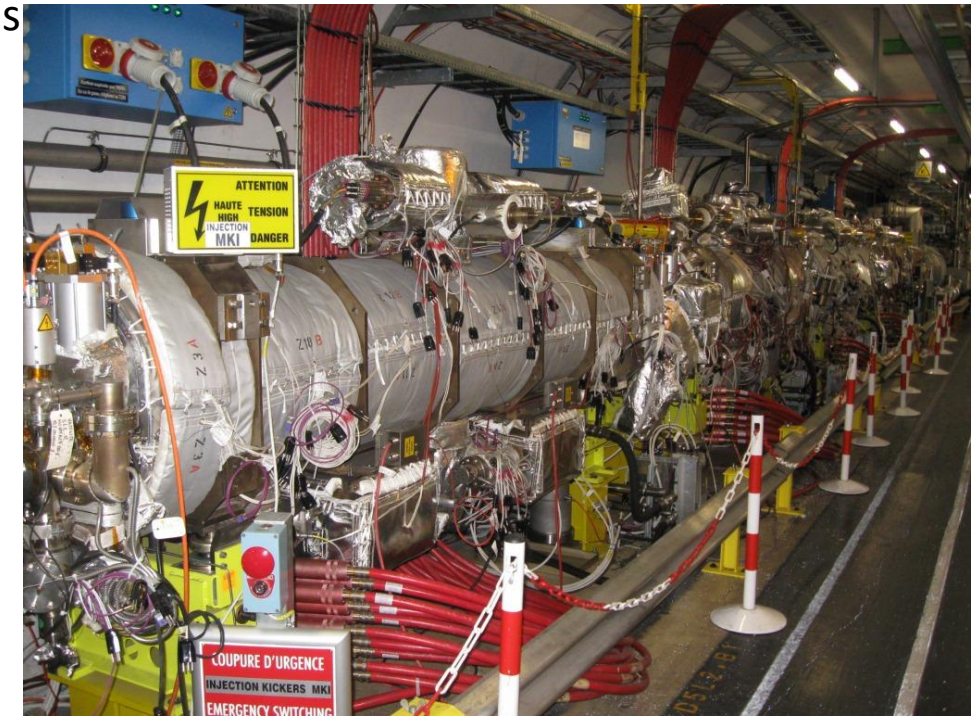
2012 MKI Exchange

Venting & Bake out

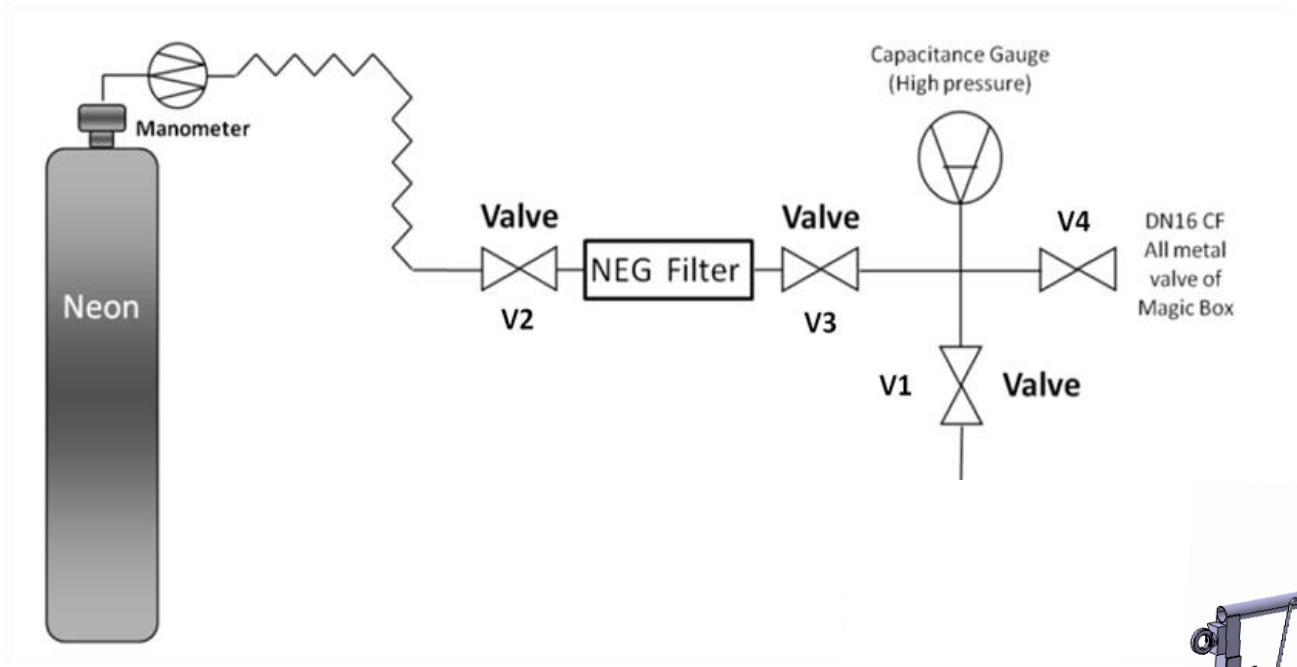
- 5 days of Technical Stop with shifts days and nights
- The MKI arrived in the tunnel already baked and validated.
- Bakeout of the interconnection modules
- The conditioning of the new MKI

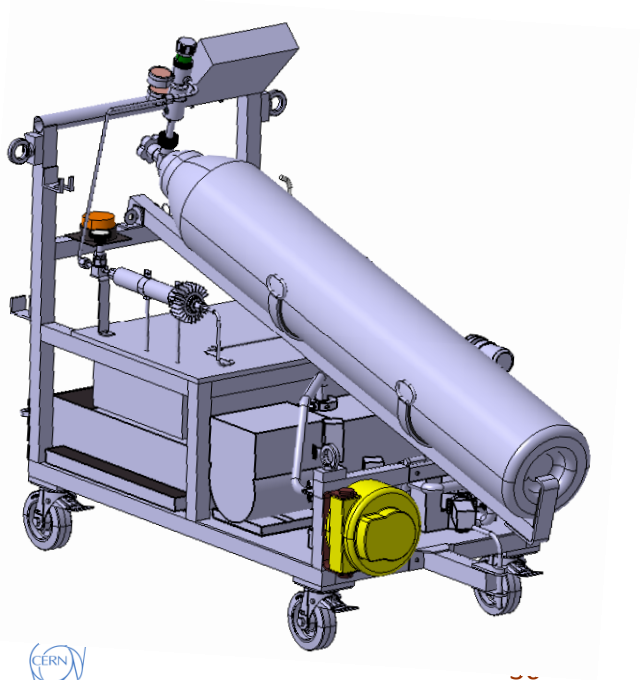
  “slowed down” the machine for ca. 1

  week



Neon venting





G. Bregliozzi - PAC 2009

2012 Vacuum Interventions

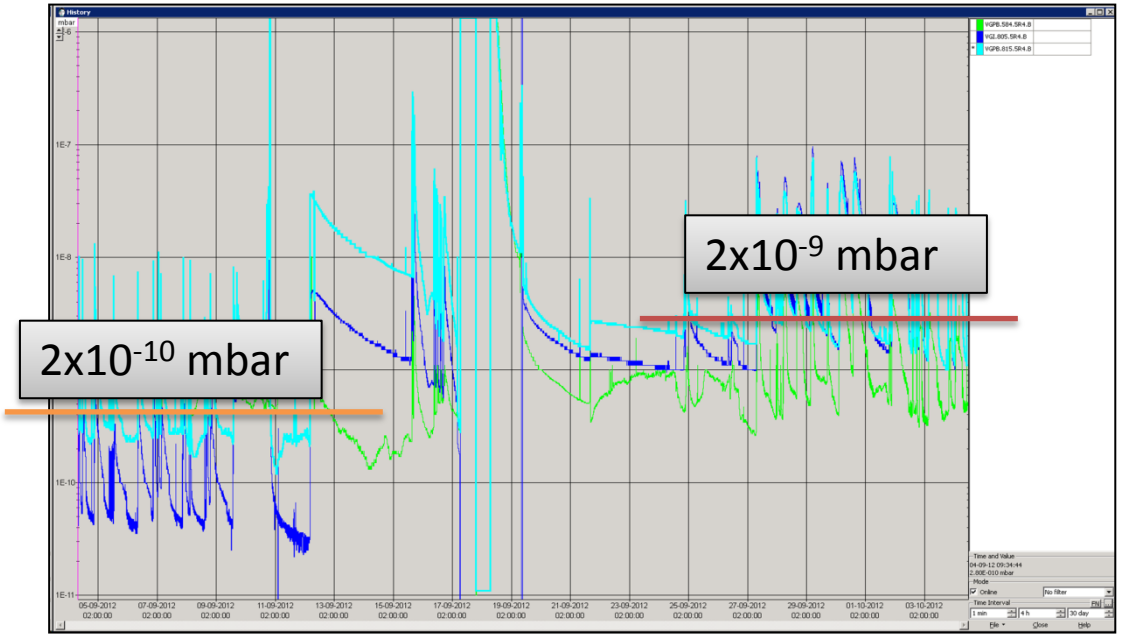
BSRT right (sector D5R4.B)

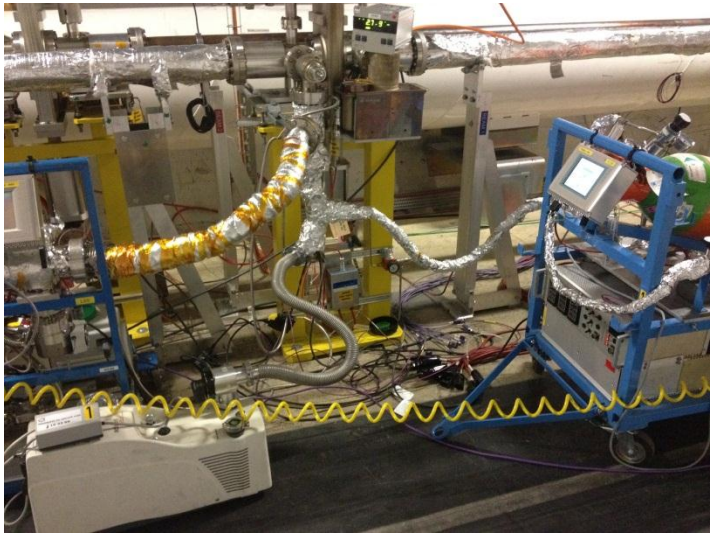
Neon venting

Gauge	P before	P after	P 1week after
Left	1.7x10-10	1.8x10-9	1.0x10-9
Right	1.1x10-10	5.2x10-9	2.1x10-9
Ion Gauge	5.5x10-11	3.6x10-9	1.0x10-9

Neon trolley Bake Out

3 days intervention





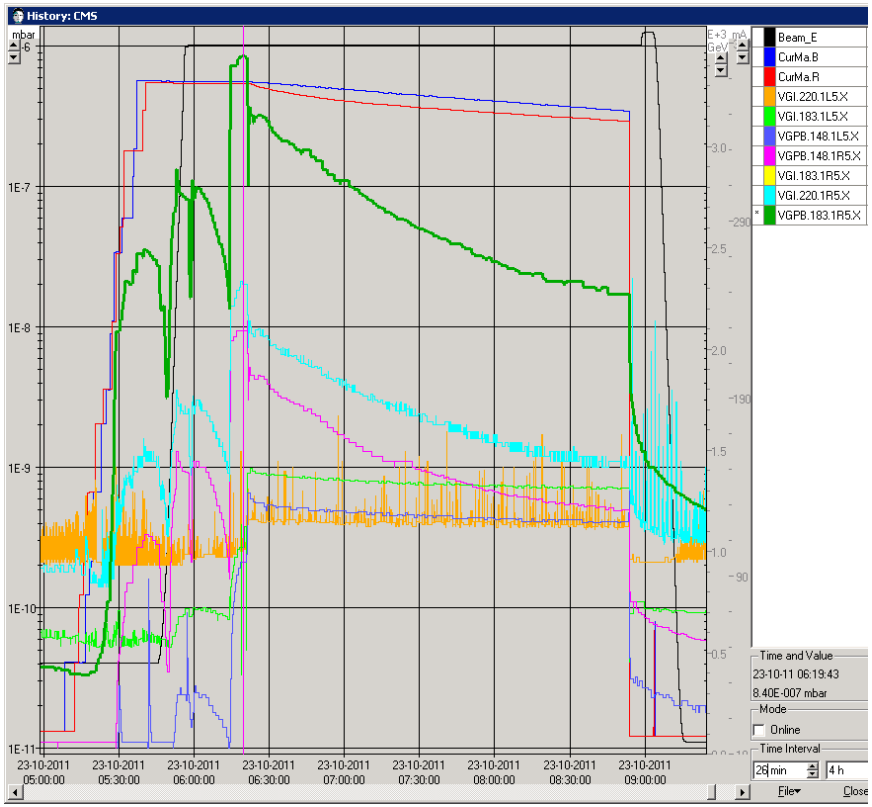
Neon venting

Bake Out

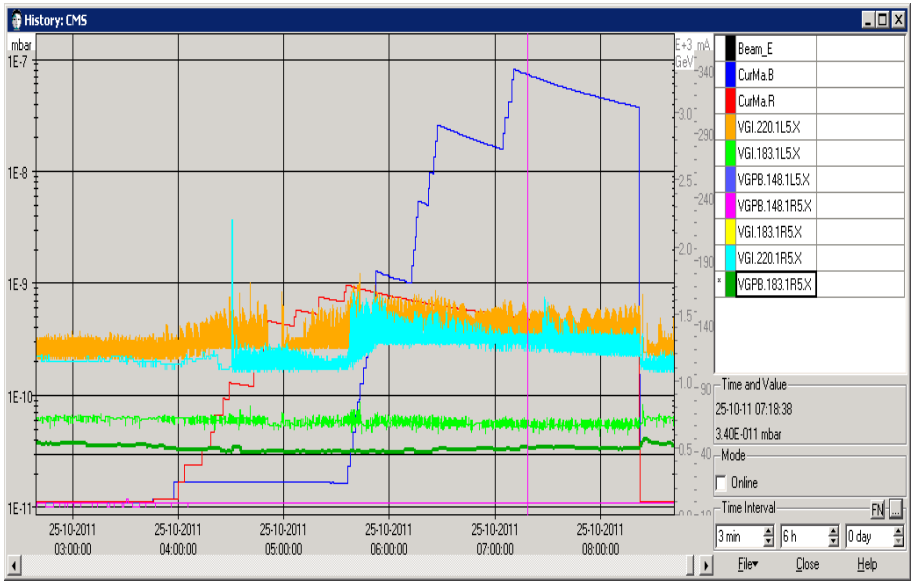
CMS pressure spikes

- CMS background suffered from pressure rise localized around 18 m from the IP
- The CMS magnetic field ensure the multipacting suppression, it was not ecloud!

Fill 2241 at **50 ns** bunch spacing



Fill 2251 at **25 ns** bunch spacing, small pressure rise were detected

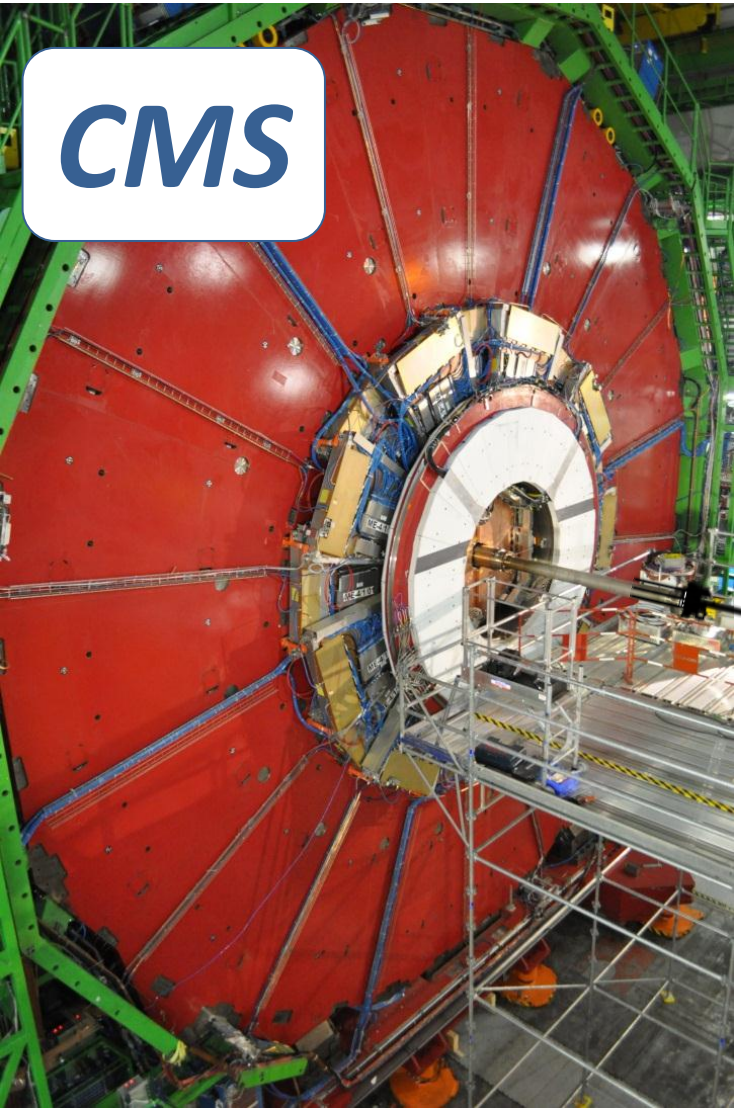


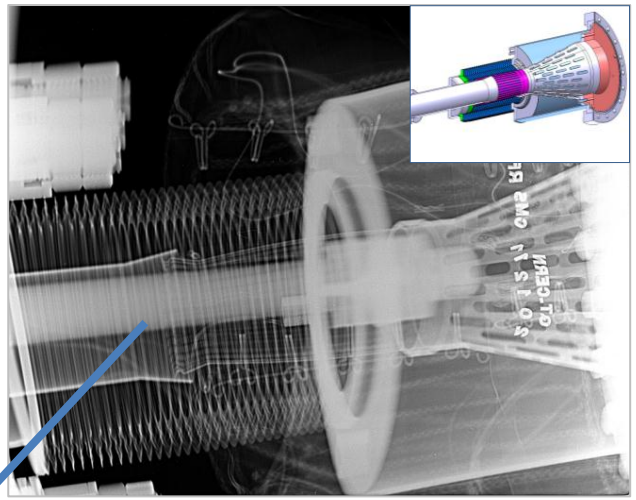
Winter Technical Stop 2011-12 : X-Ray

CMS

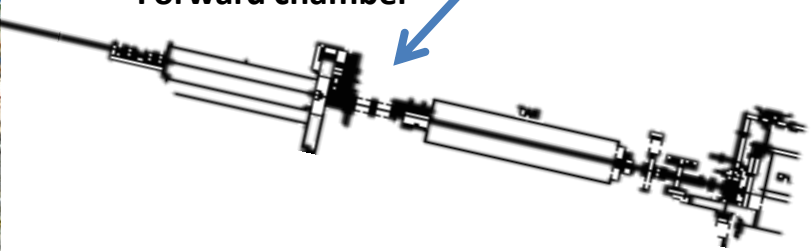
Neon venting

Bake Out





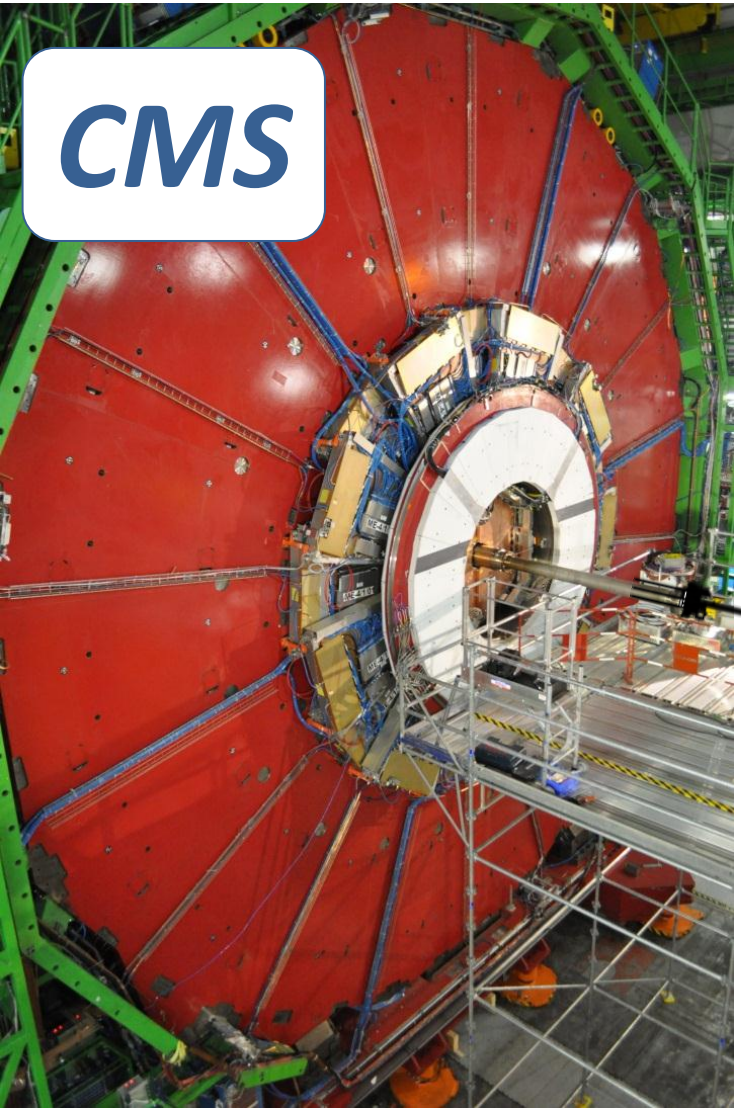
Forward chamber



CMS

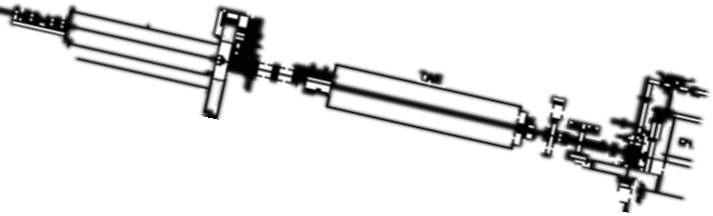
Neon venting

Bake Out



16 m & 18 m flanges were opened while Ne flushing

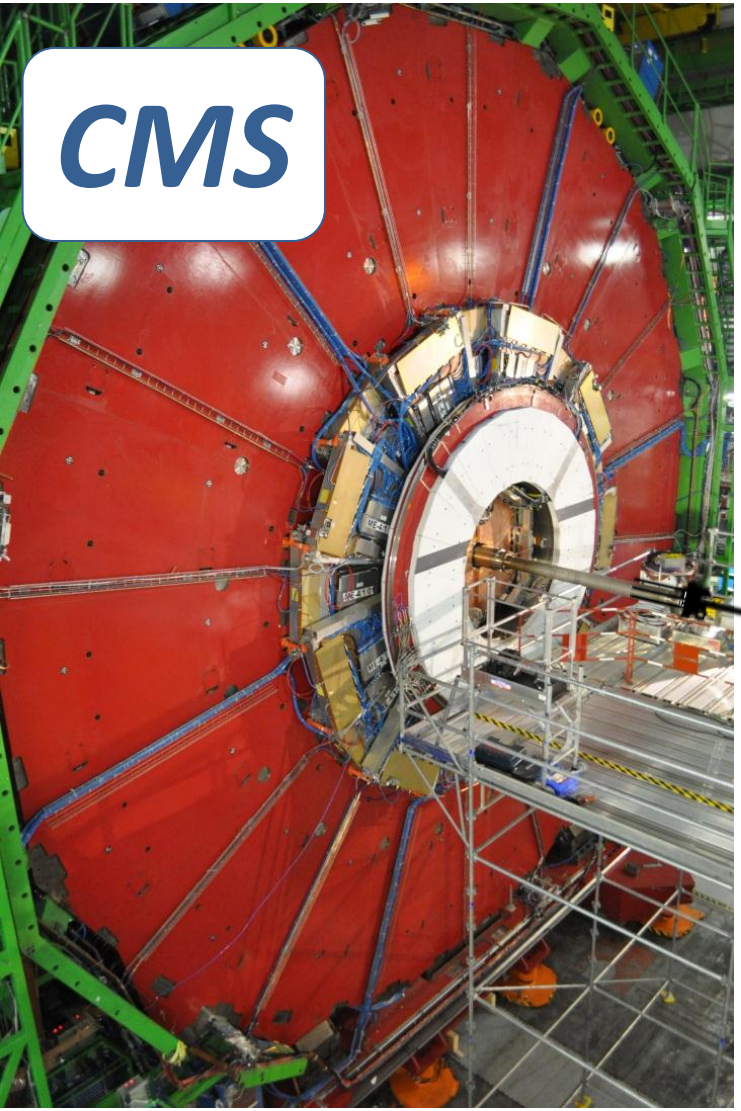
Forward chamber



CMS

Neon venting

Bake Out



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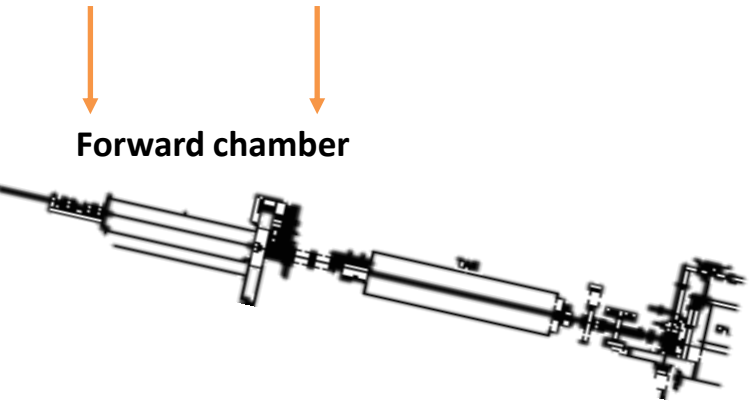
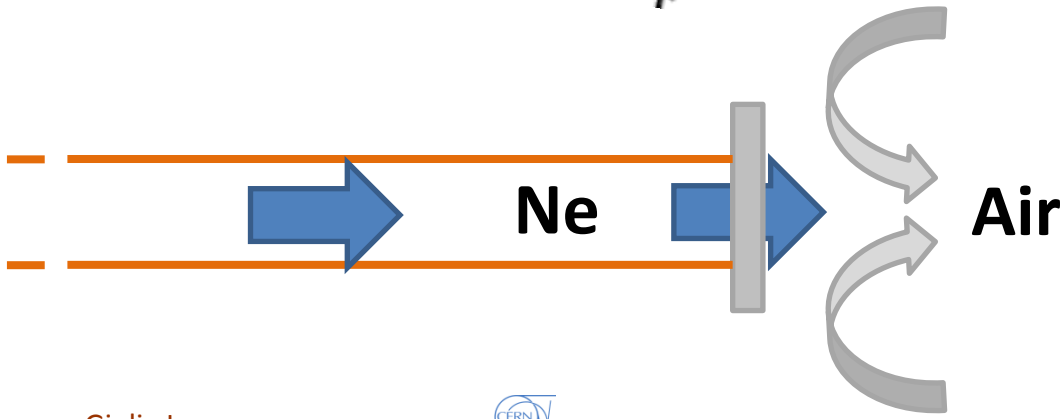
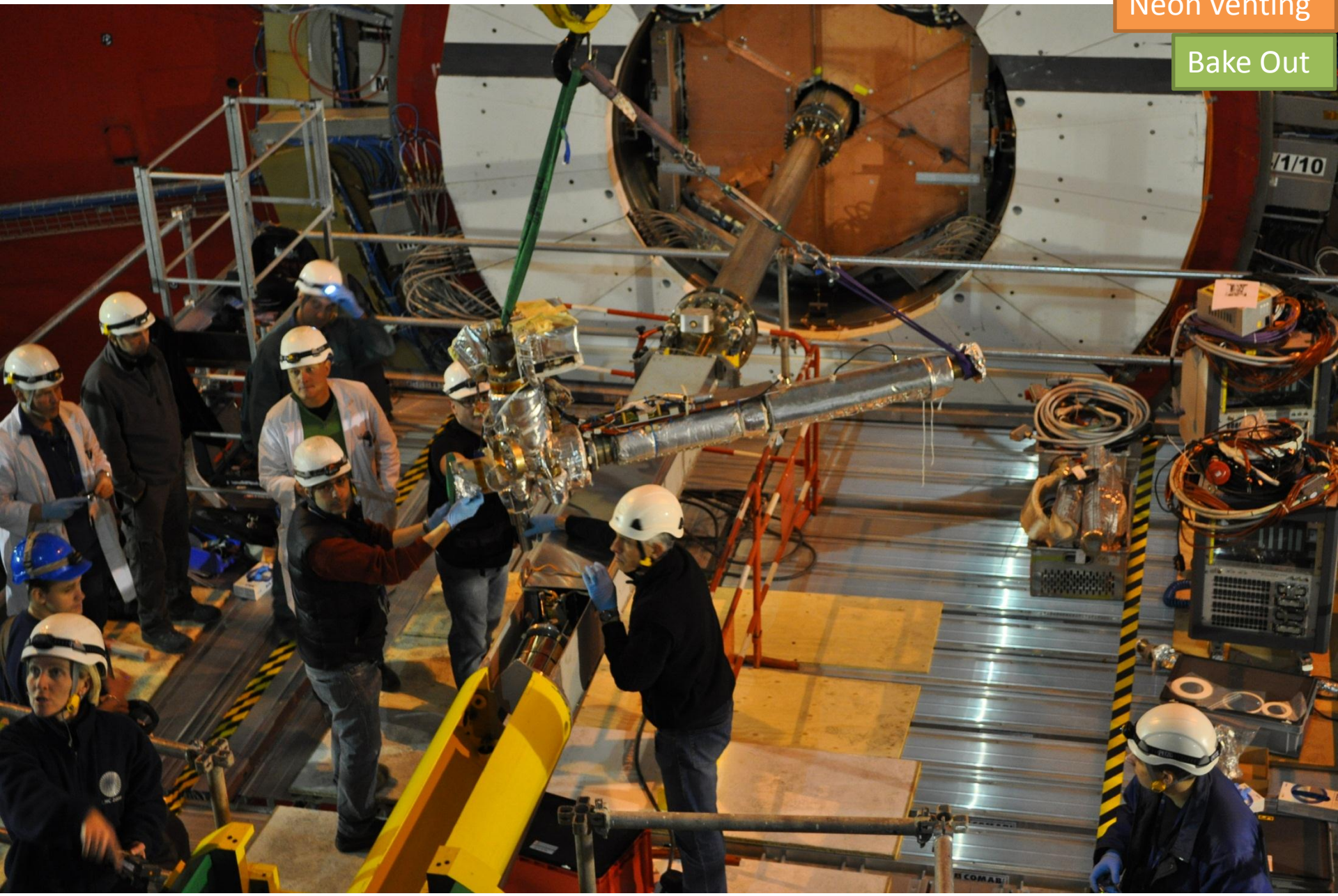




Neon venting

Bake Out



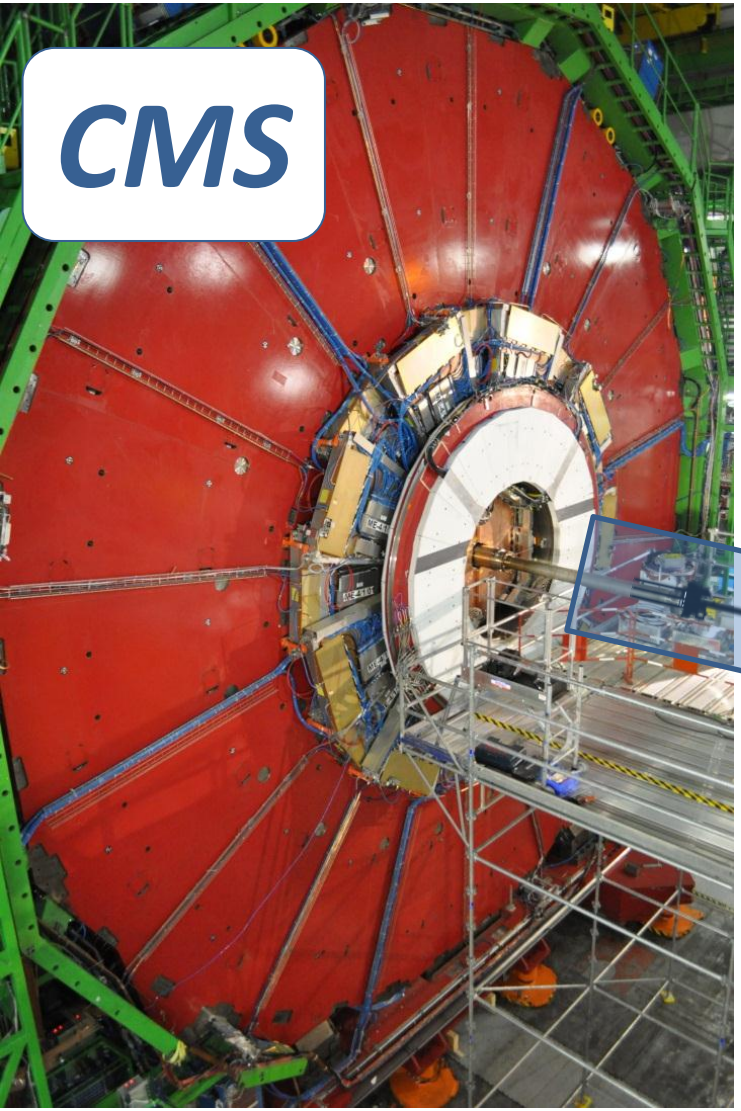
Neon venting

Bake Out

CMS

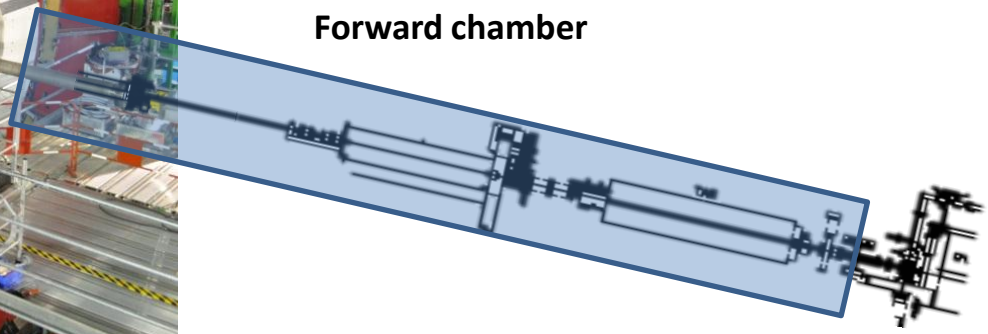
Neon venting

Bake Out



Partial NEG chambers saturation

Forward chamber

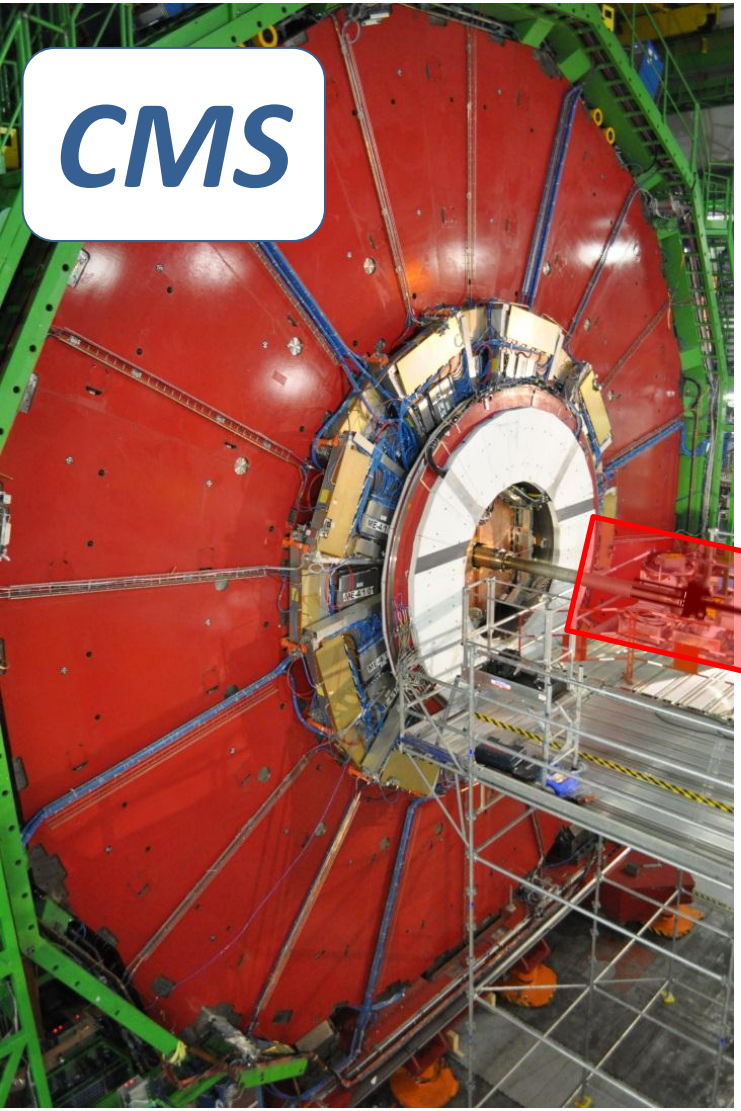


G. Bregliozzi, T. Porcelli - IPAC 2012

CMS

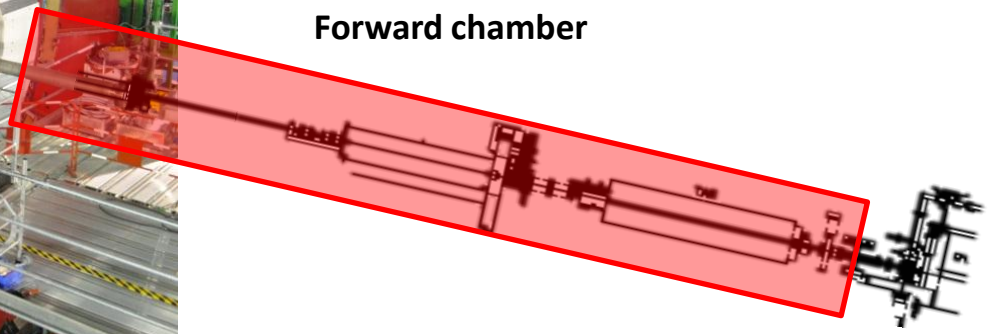
Neon venting

Bake Out



Partial bake out

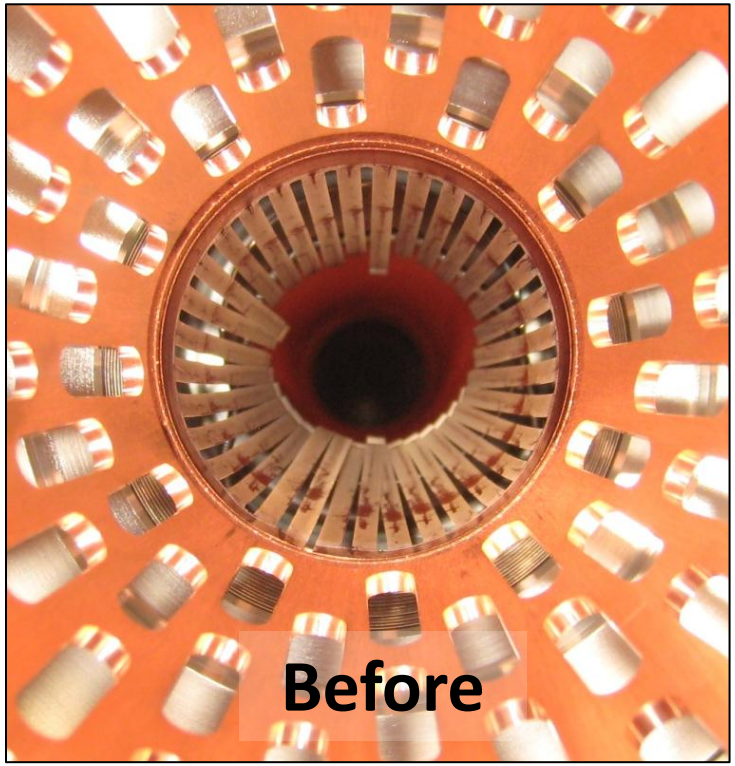
Forward chamber

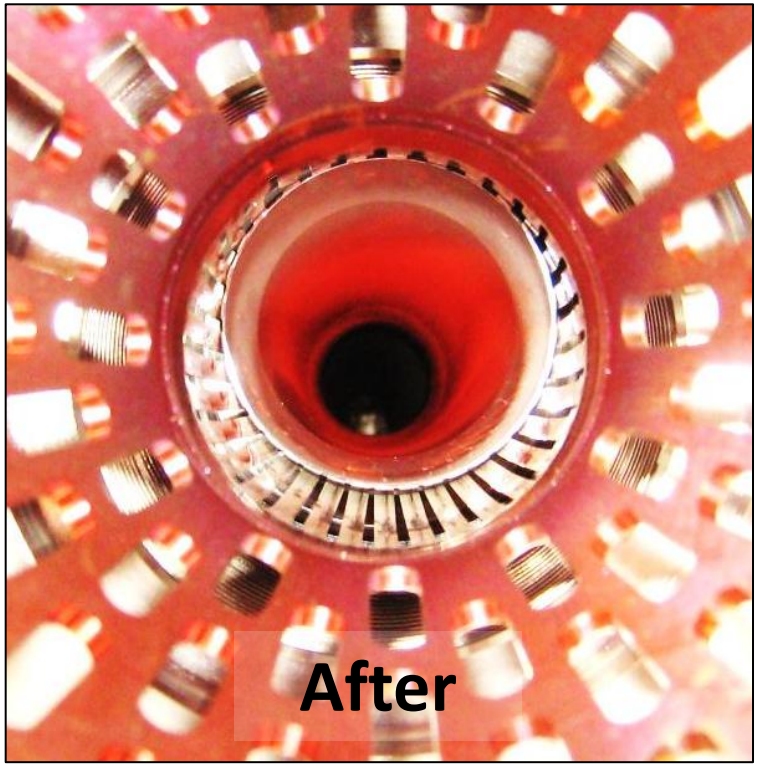


RF insert and CMS

Neon venting

Bake Out



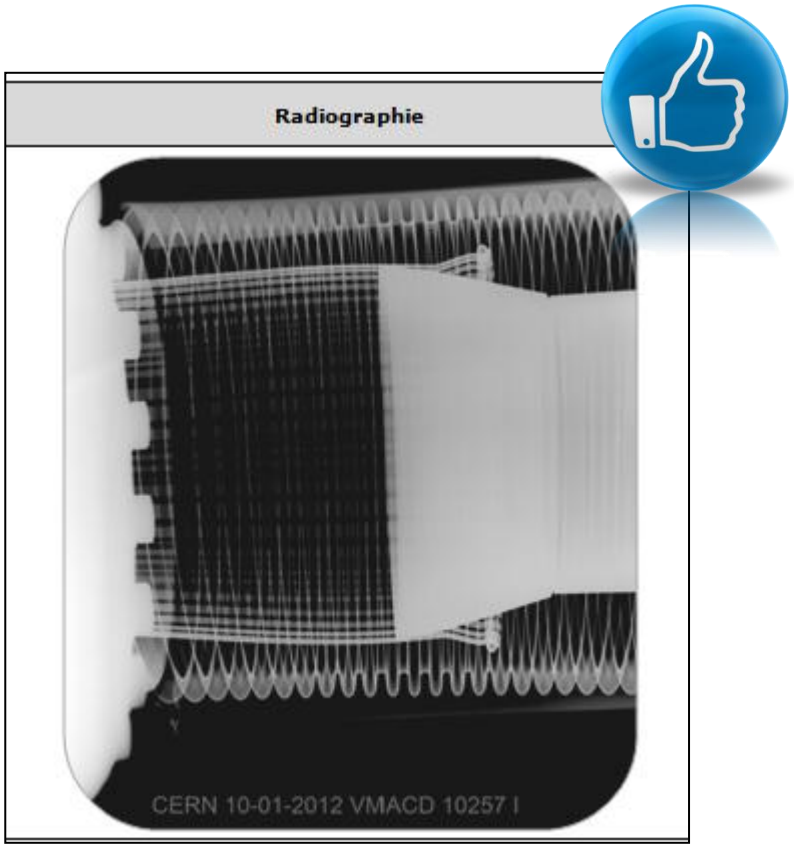


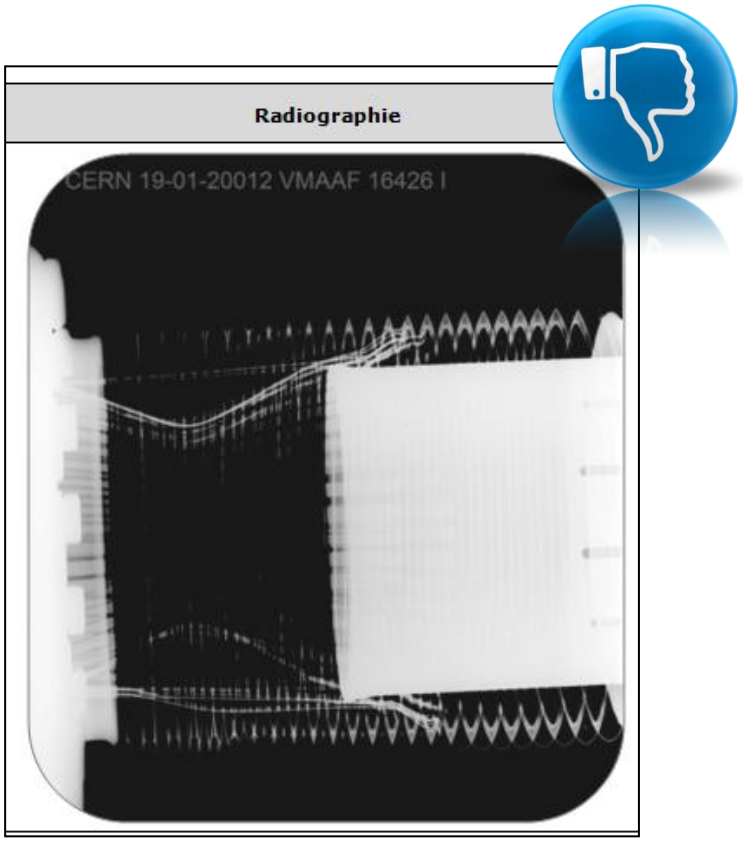
The neon injection and flushing helped preserving the NEG properties and avoided the need of a full bake of the CMS beam pipe.`

X-ray campaign

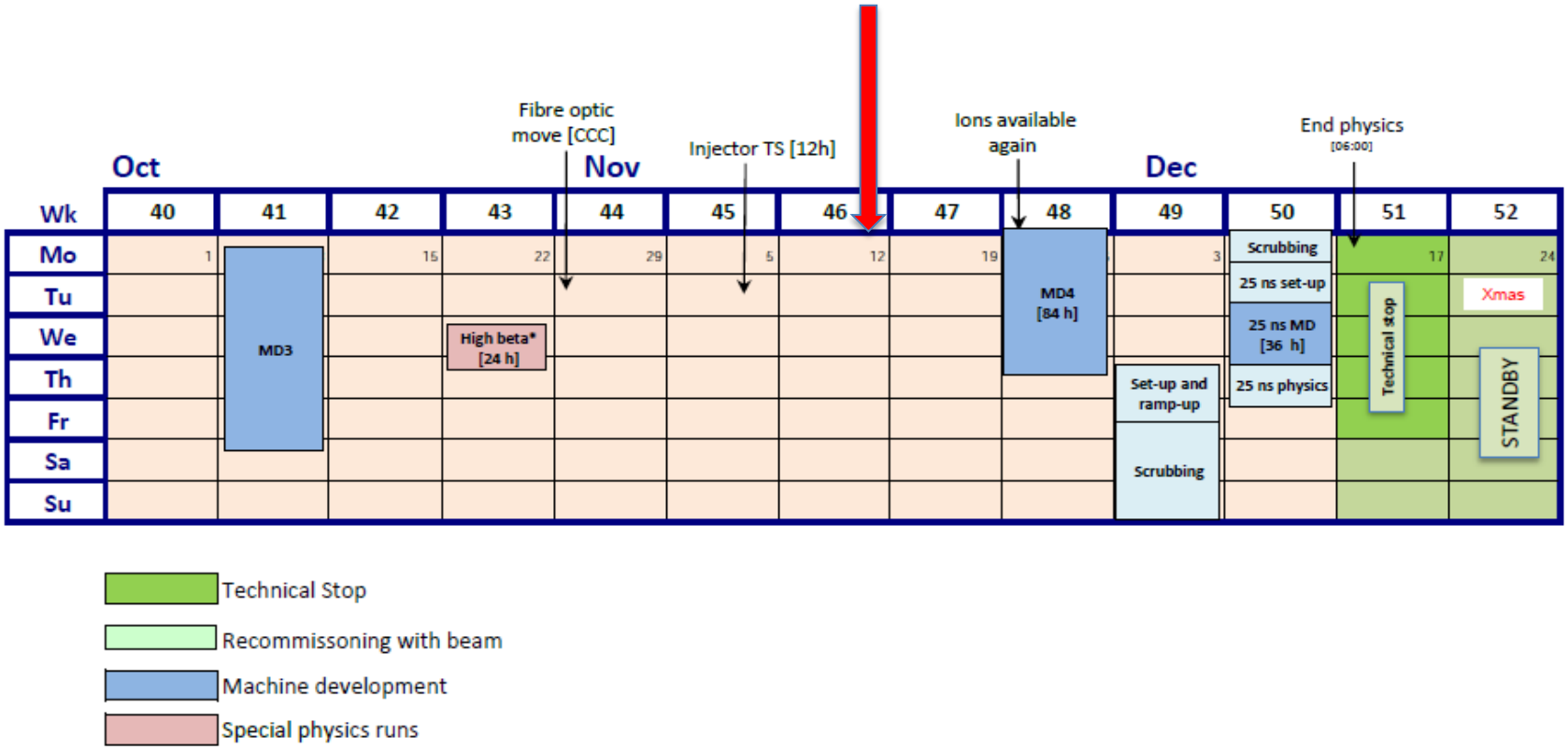
Started in January 2011

- 1800 X-rays
- 95 non conformities (~ 5 %)
- 58 vacuum sector concerned out of 190 at room temperature (88 sectors at cryogenic temperature)





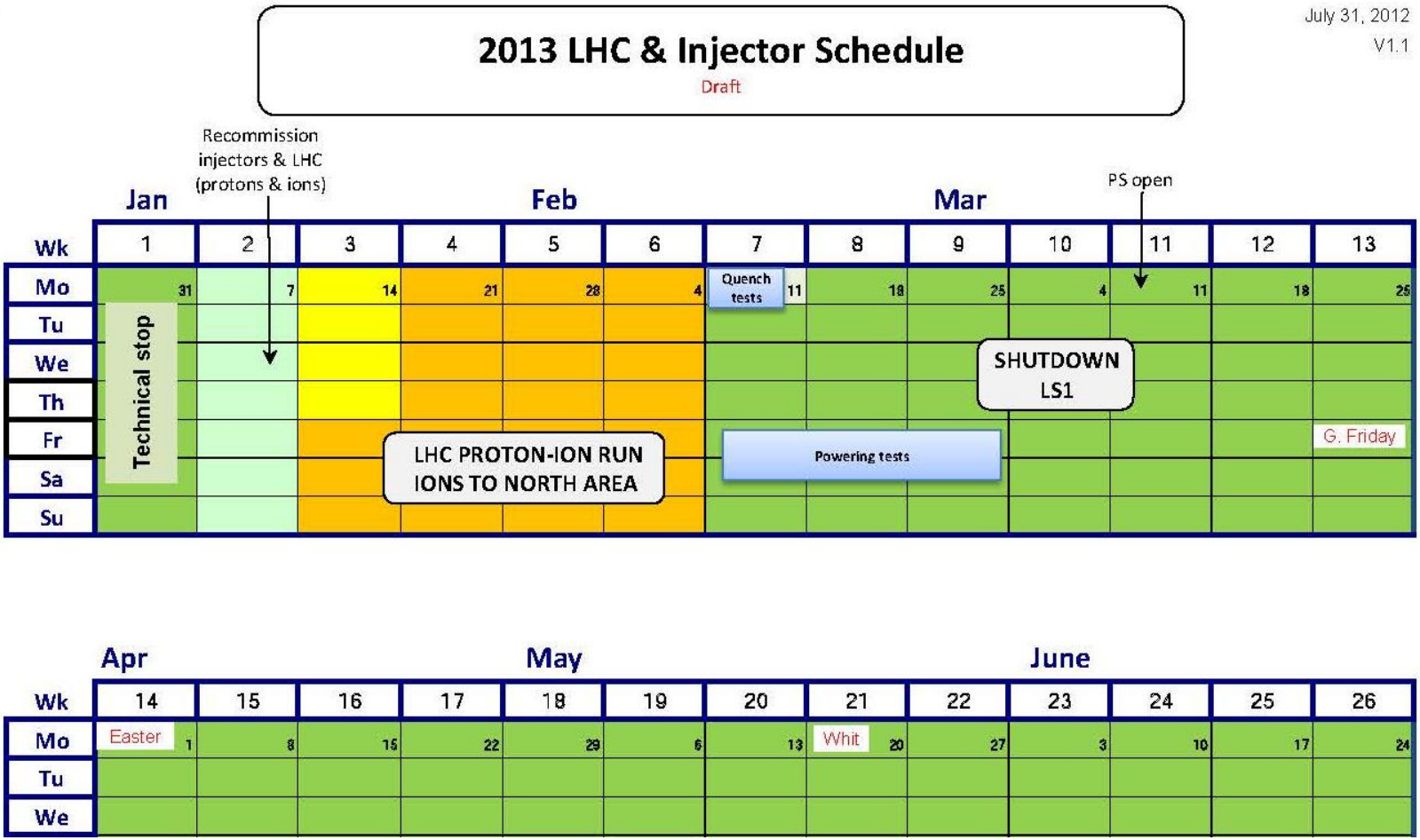
LHC: end of 2012 physics period



LHC machine - Schedules and Coordination: https://espace.cern.ch/en-dep-mef-lpc/default.aspx

LHC: 2013 proton-ion period and LS1

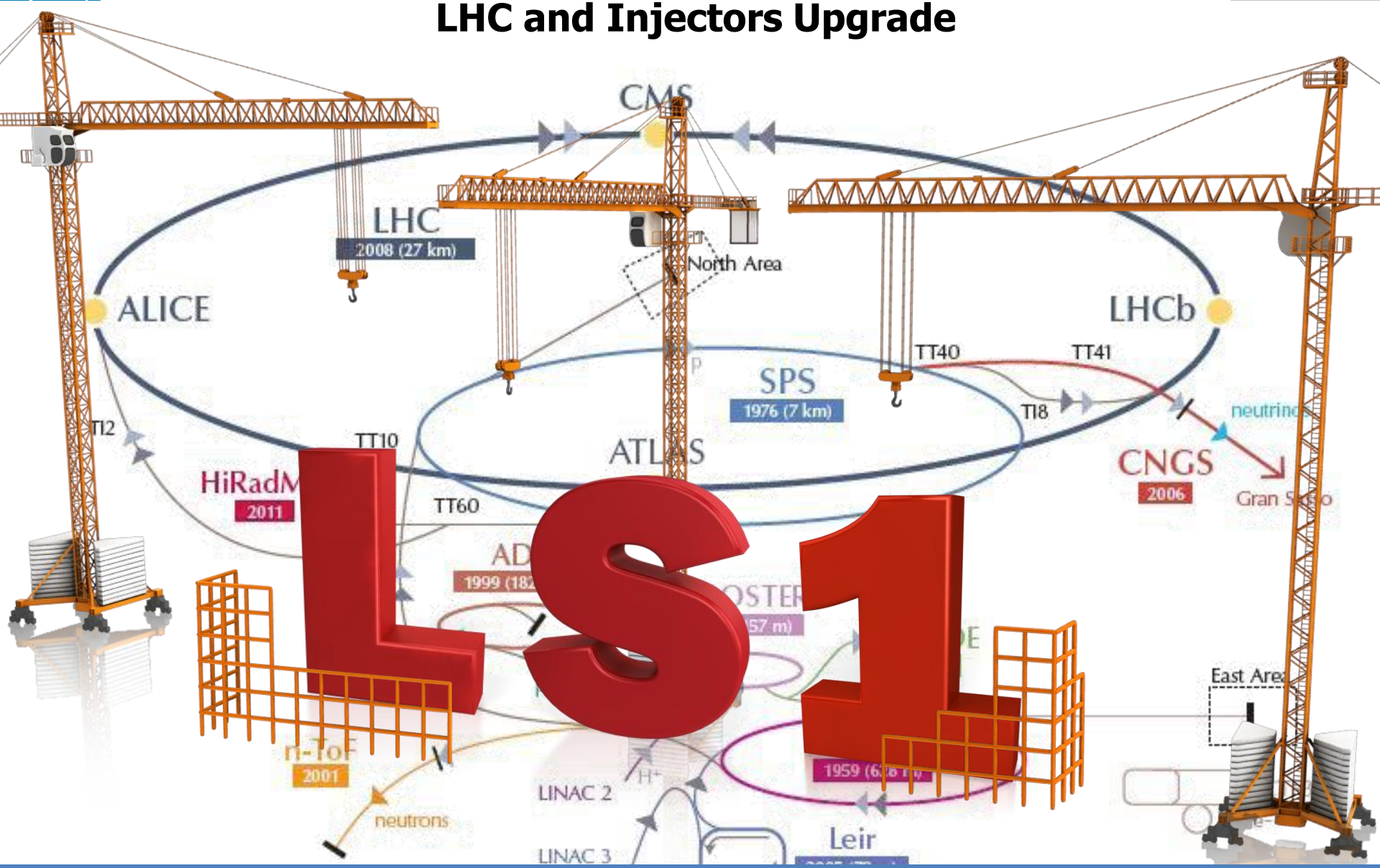
LS1 starts on February 12th, 2013



LHC machine - Schedules and Coordination: https://espace.cern.ch/en-dep-mef-lpc/default.aspx

2013-2014

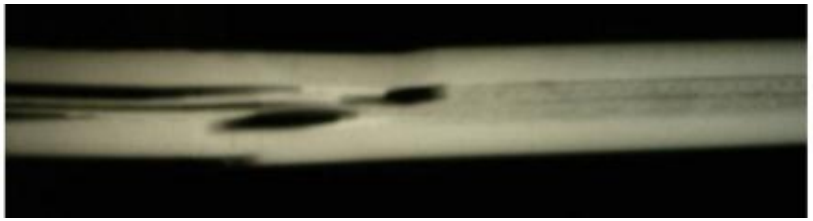
LHC and Injectors Upgrade

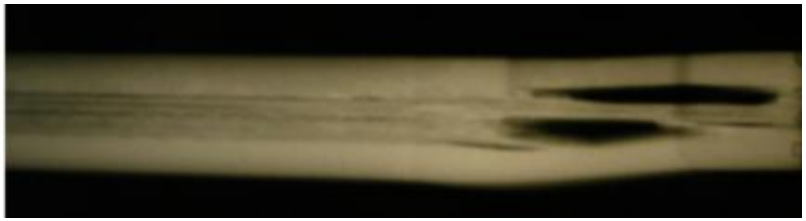


Long Shutdown 1: the Magnets splices consolidation

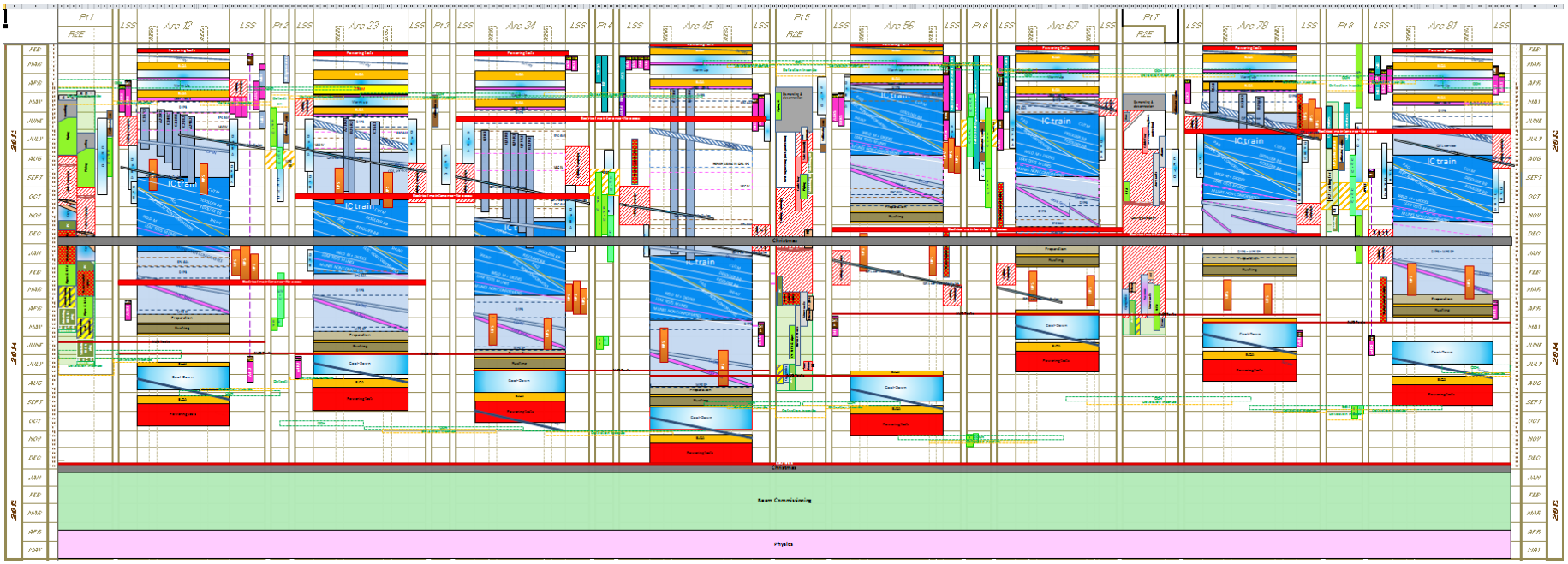
Despite correct splice resistance between SC cables, in case of bad bonding between the SC cable and the copper bus, a 13 kA joint can burn-out **when a quench occurs.**

Resistance measurements and γ-ray pictures have shown the presence of many of such defective joints with discontinuity in the copper stabilizer in the machine, limiting the safe operating current





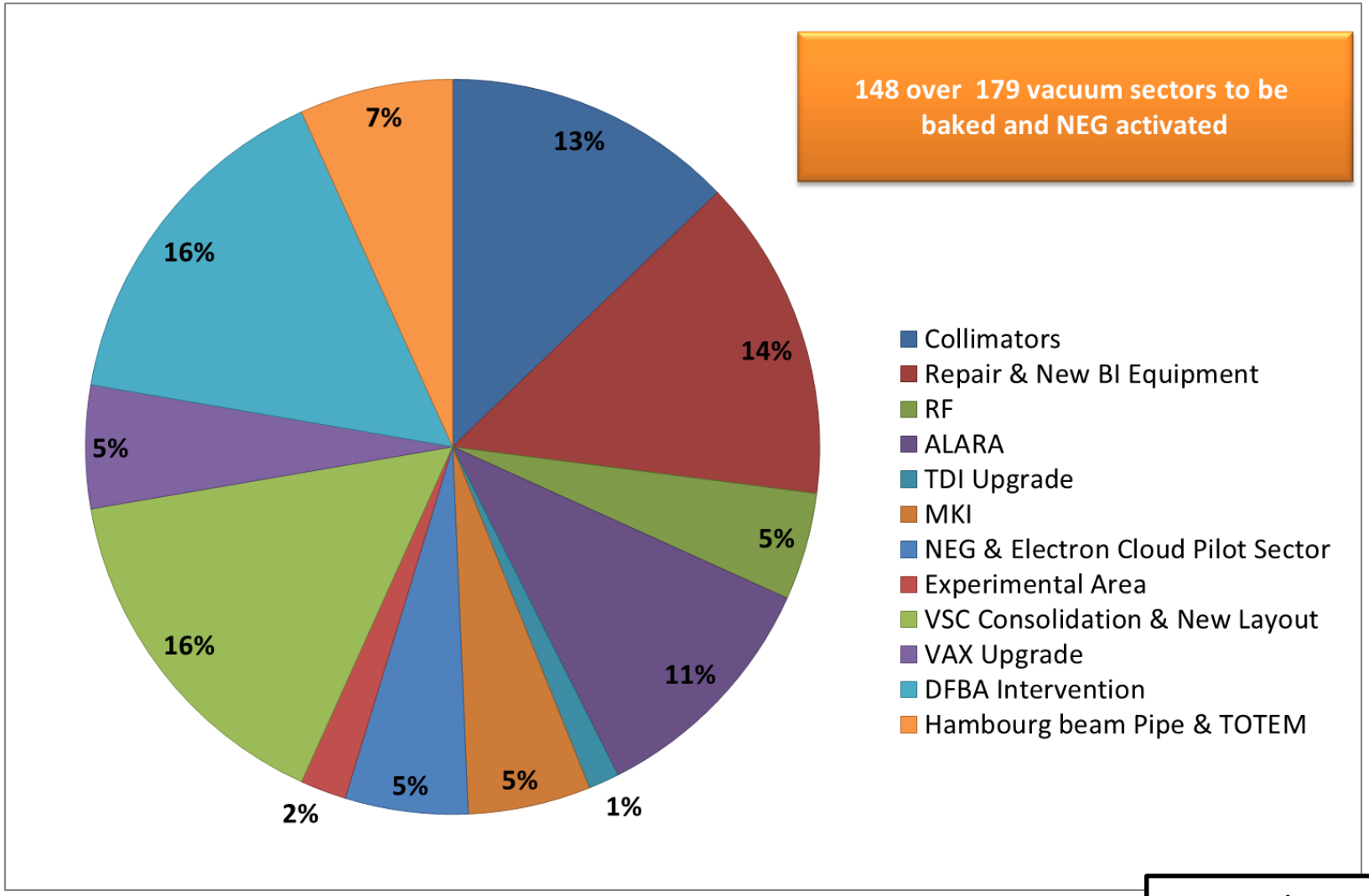
Long Shutdown 1



22 months of shutdown

Warm up of all the cryogenic sectors

Long Shutdown 1



G. Bregliozzi

Long Shutdown 1: beam vacuum activities

- NEG coating inserts in experimental areas
  - Increase the pumping speed
  - Suppress the e-cloud
  - Reduce background pressure level for the Experiments

- NEG cartridge Installation
  - Increase the pumping speed
  - Presence of a fast, easy to re-activate pump to ensure a minimum pumping speed in highly saturated areas

- Long Straight Section opening
  - RF insert exchange
  - Bake out and activation of the opened sectors

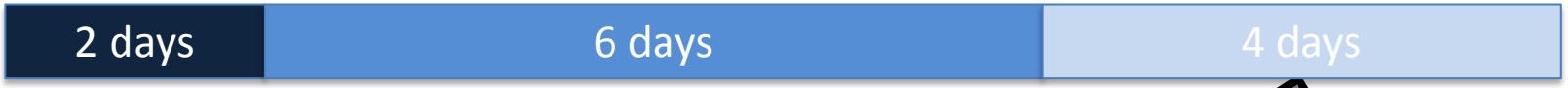
Long Shutdown 1: main beam vacuum activities

- Installation of fast valve in Point 4
- MKI consolidation
- TDI sectorisation
- Electron cloud pilot sector installation
- NEG pilot sector installation
- Experimental area vacuum upgrade (coating of the RF insert)

Long Shutdown 1: Machine upgrade

- Collimators exchange
- Upgrade of the TCDQ
- Repair BI equipment (BTV, BSRT, BGI, …)
- Installation of new BI equipment
- TDI exchange
- DFBA consolidation
- New experimental beam pipe

After the Long Shutdown 1



⇒ Rough time estimate for **first scrubbing run after LS1** (20

- ~50h = **2 days** machine time, as was needed i… β^*_{max} from 2.1 to 1.55
- An additional 20h net beam time wi… to get to 1.45
- At least **4 days** machine time f… urther scrubbing at 7 TeV with increasing number of bu…
- Total of **12 days** wit… ine availability and no contingency

⇒ Scrubbing sc… foresee a staged approach

- Firs… ng with 25ns beams (few trains @injection) to allow a peri… on cloud free operation with 50ns and intensity ramp up. Then, … crubbing for 25ns operation

To be yet validated with the analysis of the ongoing scrubbing run + MDs with ramp to 4TeV

Courtesy G. Rumolo

Conclusions

Synchrotron Radiation and e-cloud effect challenged the machine as expected.

Beam scrubbing remains the solution for vacuum cleaning and beam pipe conditioning

Conclusions

The **Machine Development at 25ns** bunch spacing has been run before the long shutdown of 2013-2014 and the following data analysis will give indication on how to run the LHC in 2015

The next shutdown is not a stop, it's an ADVANCEMENT towards new challenging limits of the LHC.

Enjoy your holiday and get ready to be part of this ADVANCEMENT of the LHC

Thanks all the LBV section for the great work of this year

Thanks to V.Baglin and G.Bregliozzi for their analysis, slides and patience

…THANK YOU FOR YOUR ATTENTION.