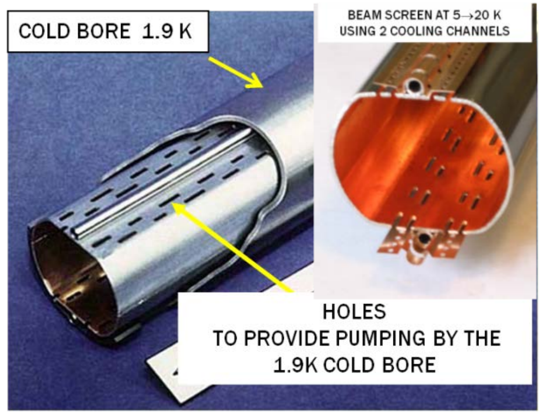
Electron cloud & vacuum pressure observations: 2011 proton run

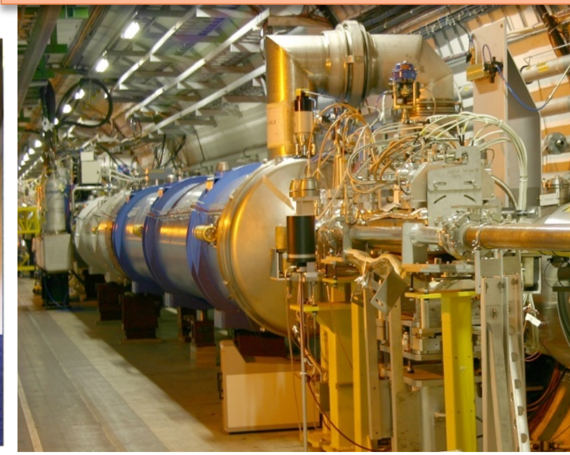
G. Bregliozzi on the behalf of the TE-VSC group

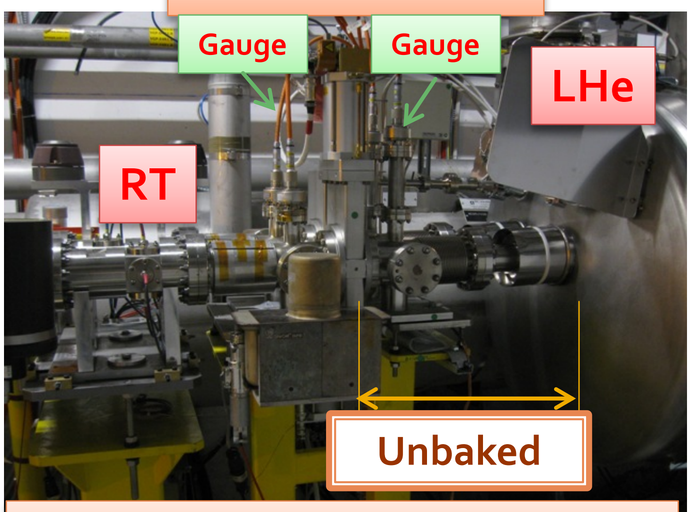
1. General layout of the LHC vacuum system
2. Electron cloud at 25 & 50 ns: Vacuum Observation
3. Pressure Spikes & Heating effects
4. Strategy and Mitigation solutions
5. Conclusion

The LHC cryogenic vacuum system

Beam Screen @ 5 – 20K



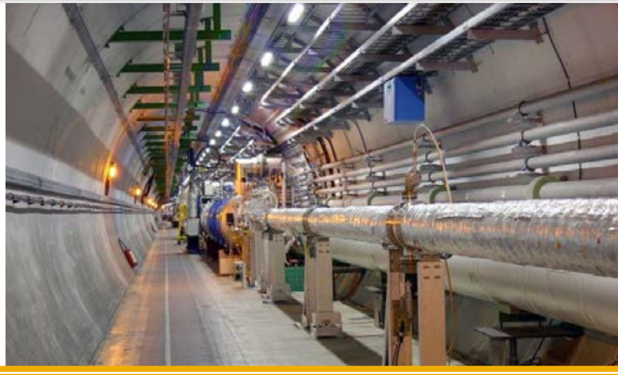




- It takes advantage of the cryogenic cooling for the superconducting magnets: the pumping is distributed onto surfaces cooled at temperature in the range 1.9 to 20 K.
- Cold beam pipes (Stand Alone Magnet) are also present in the 8 long straight sections.
- Cold-Warm transition present in each connections between room temperature and cryogenic system: unbaked due to compatibility reason with cryogenic vacuum system and vacuum sectorization.

The LHC RT vacuum system

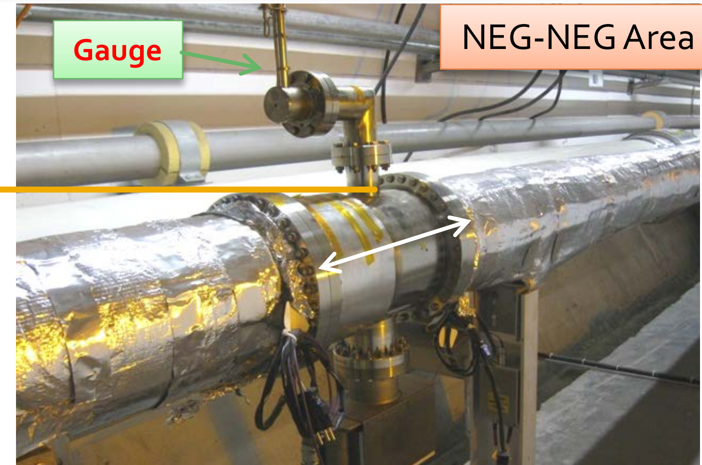
The pumping system rely mainly on TiZrV thin film coating with some localised ion pumps



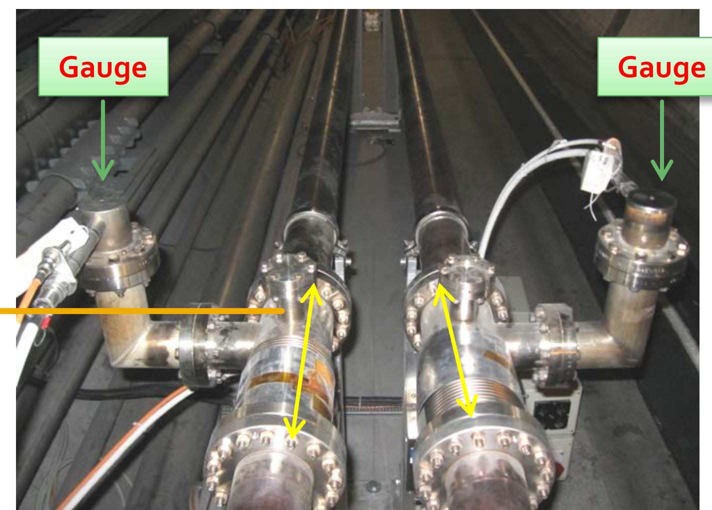
"Combined" sector both side of each experiment
Both beams circulates in the same beam pipe

"Twin" sector
Beams circulate in different beam pipes

Baked



Uncoated parts in the room temperature beam pipes

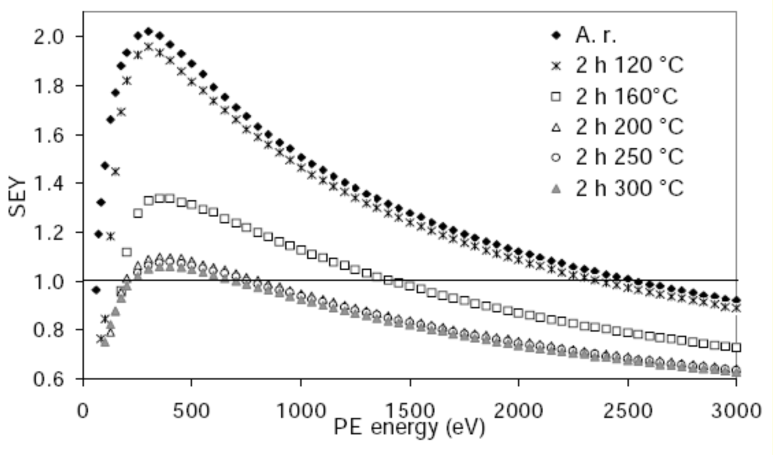


Electron Cloud at 25 & 50 ns Vacuum Observation

Vacuum System Performances

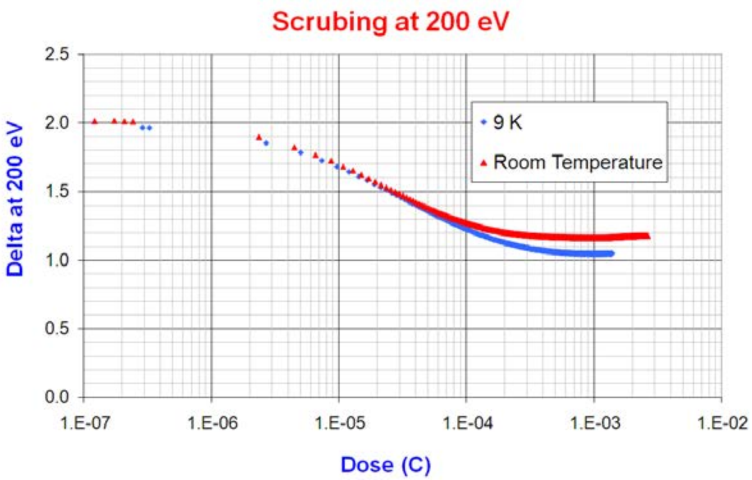
- No electron cloud in NEG areas after vacuum activation

Secondary Electron Yield: TiZrV



C. Scheuerlein *et al.* Appl.Surf.Sci 172(2001)

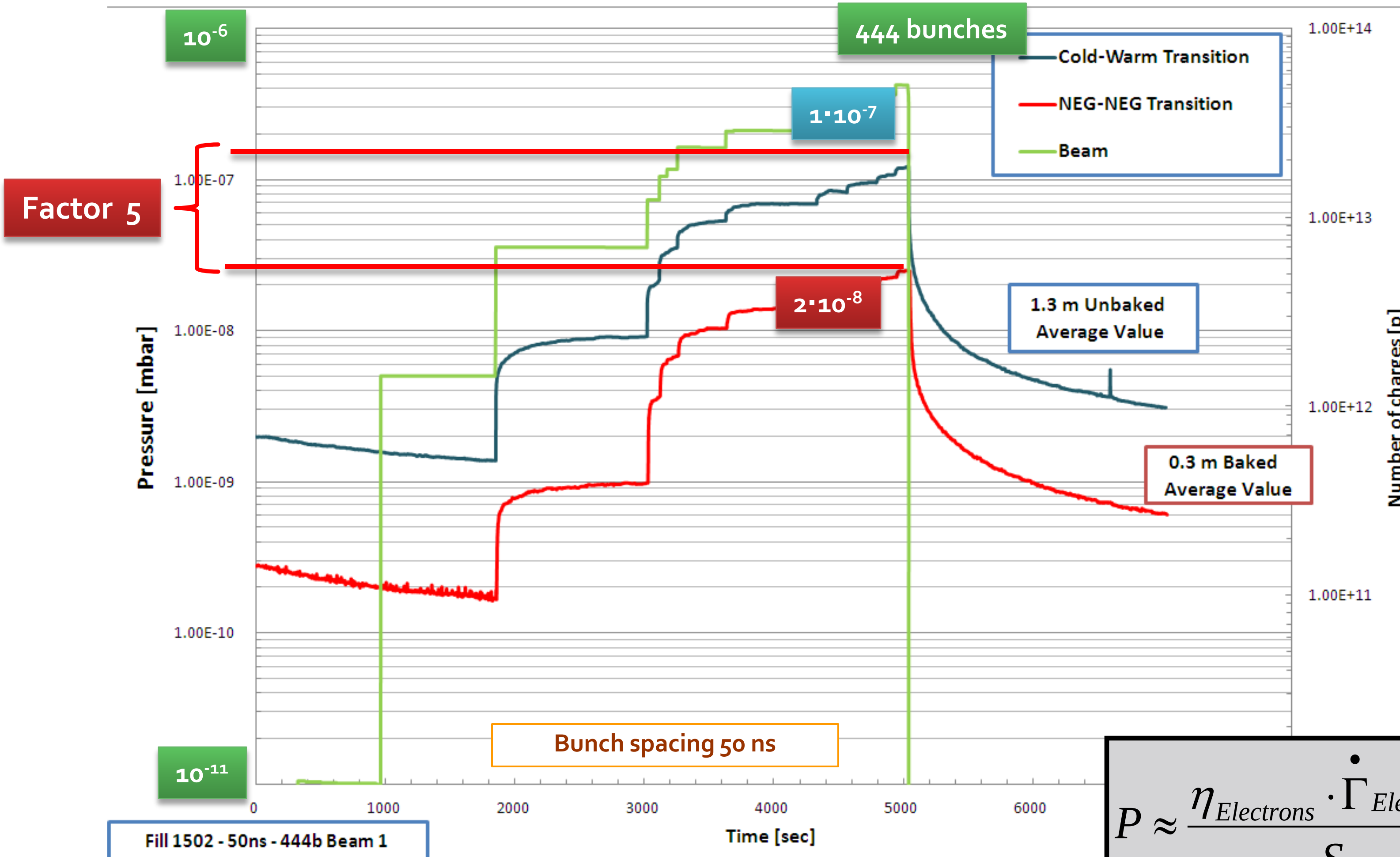
- Baked and unbaked cryogenic areas requires scrubbing



V. Baglin, R. Cimino, 2003

E-cloud Effects in LHC Vacuum at 50 ns

- Pressure increase is function of the η (Baked and Unbaked), pumping speed and length of the area .
- Two distinctive area in the LHC: Unbaked and baked.



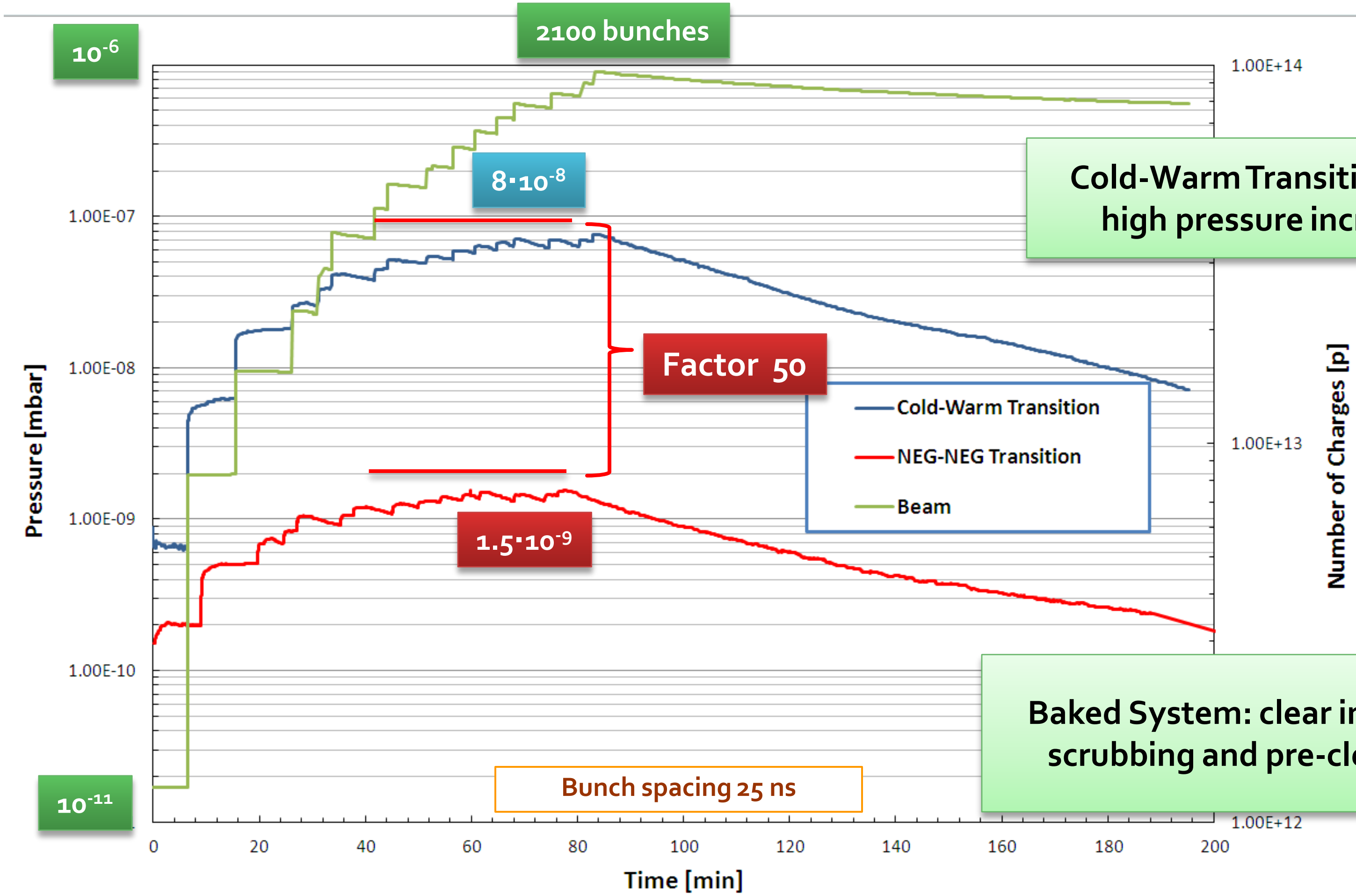
$$P \approx \frac{\eta_{Electrons} \cdot \dot{\Gamma}_{Electrons}}{S}$$

Data from 20.11.2010

No Scrubbing and Vacuum Cleaning: Almost as received surfaces

E-cloud Effects in LHC Vacuum at 25 ns

Still two distinctive area in the LHC: Unbaked and baked.

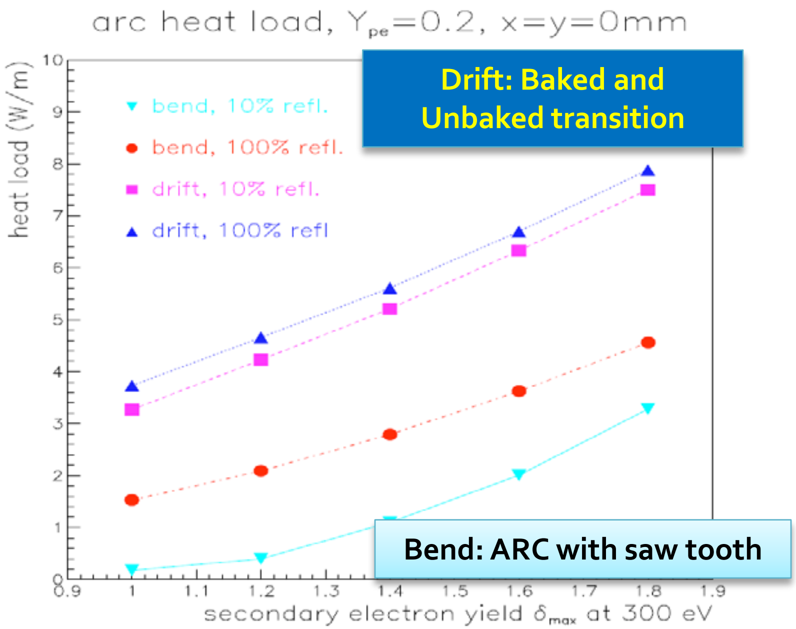


Cold-Warm Transition apparently high pressure increase……….

Baked System: clear indication of pre-scrubbing and pre-cleaning at 50 ns

Data from 14.10.2011

Heat load due to electron cloud effects: Bending magnets and drift spaces



F. Zimmermann: LHC Project Note 201

Simulated heat load due to electron cloud as a function of the maximum secondary electron yield for bending magnets and drift spaces in the LHC arcs

50 ns

- **Larger conditioning rate** in field free regions compared to ARC and stand alone magnets.

Pressure increase in baked and unbaked transitions was limiting the LHC performance.

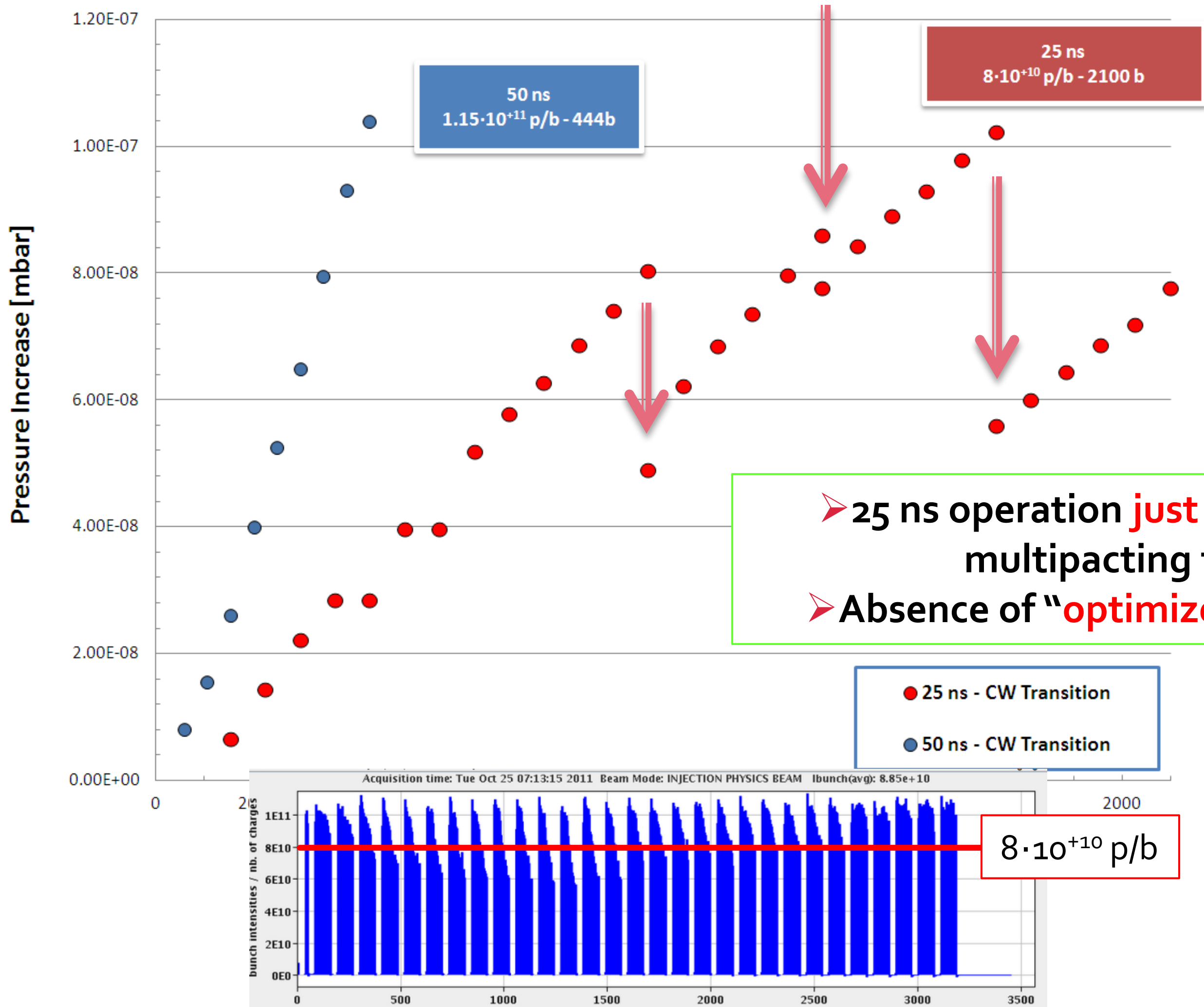
25 ns

- **Baked and Unbaked transitions:** almost fully scrubbed.
- **Pressure increase:** dominated by desorption of beam screen (~24 Km of LHC)

LHC performance limited by electron density in ARCs with high power dissipated in the beam screen.

E-cloud Effects in LHC Vacuum at 25 ns
Effectiveness of the scrubbing

Case of Cold-Warm Transition



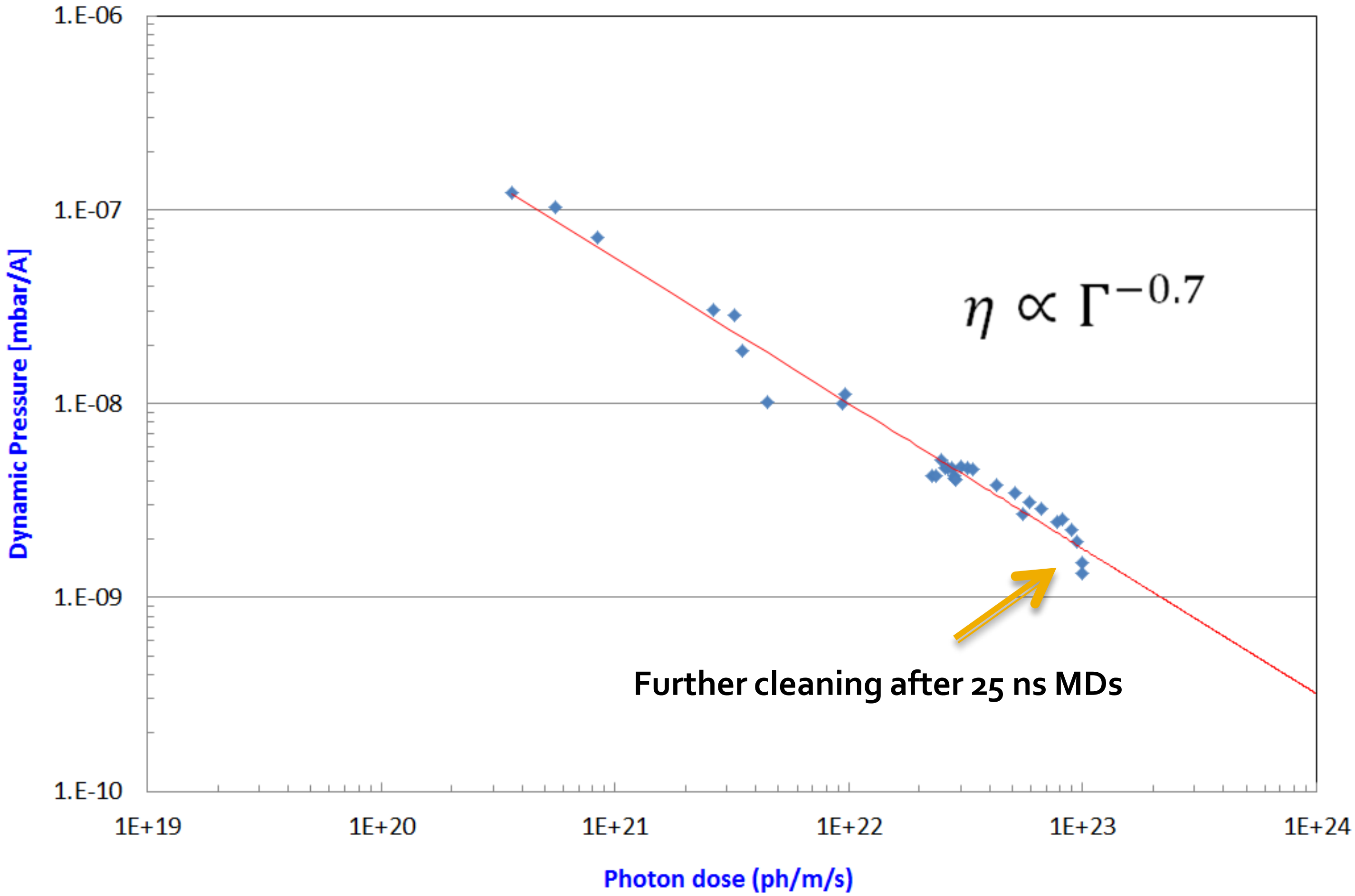
- 25 ns operation **just at the limit** of the multipacting threshold
- Absence of "**optimized**" beam cleaning

New beam time is required for further scrubbing and analysis at 25 ns

Synchrotron radiation
Effectiveness of 25 ns scrubbing run

- **Pressure reduction observed during the year while accumulating photon dose**
- **Accumulated dose so far 10^{23} ph/m**

→ Beam conditioning of the arc vacuum system



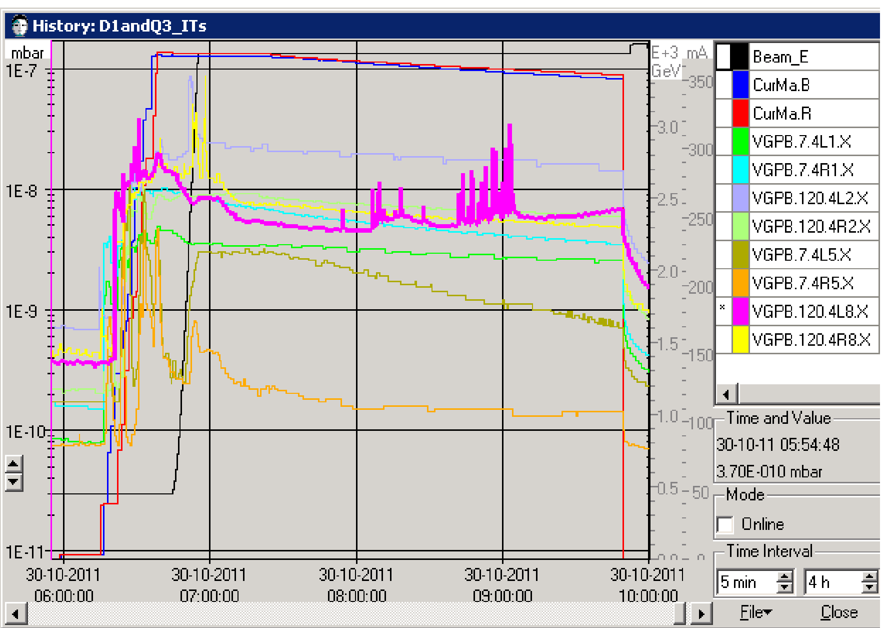
Pressure Spikes
&
Heating Effects

Pressure Spikes in LSS2 and LSS8

- Frequently, pressure spikes are observed mainly at LSS2 and LSS8
- Location of pressure spikes is in LSS2 and LSS8: TCTVB-TCLIA/TCDD areas

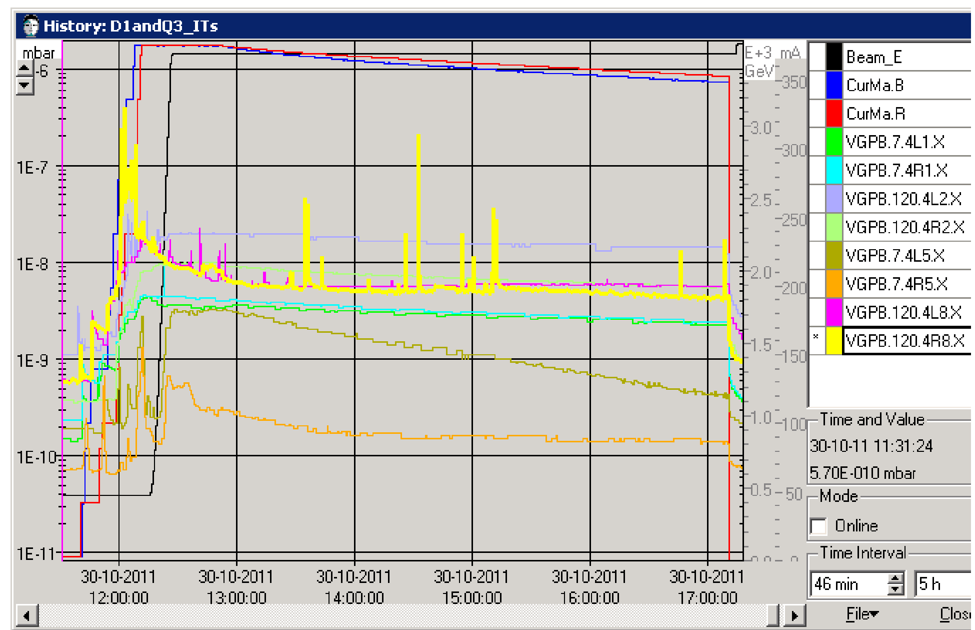
Fill 2266

- Spikes during stable beams above 10^{-8} mbar
- D1L2, D1L8, D1R8

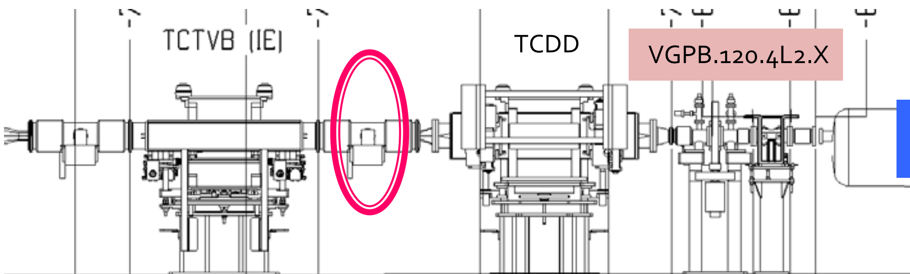


Fill 2267

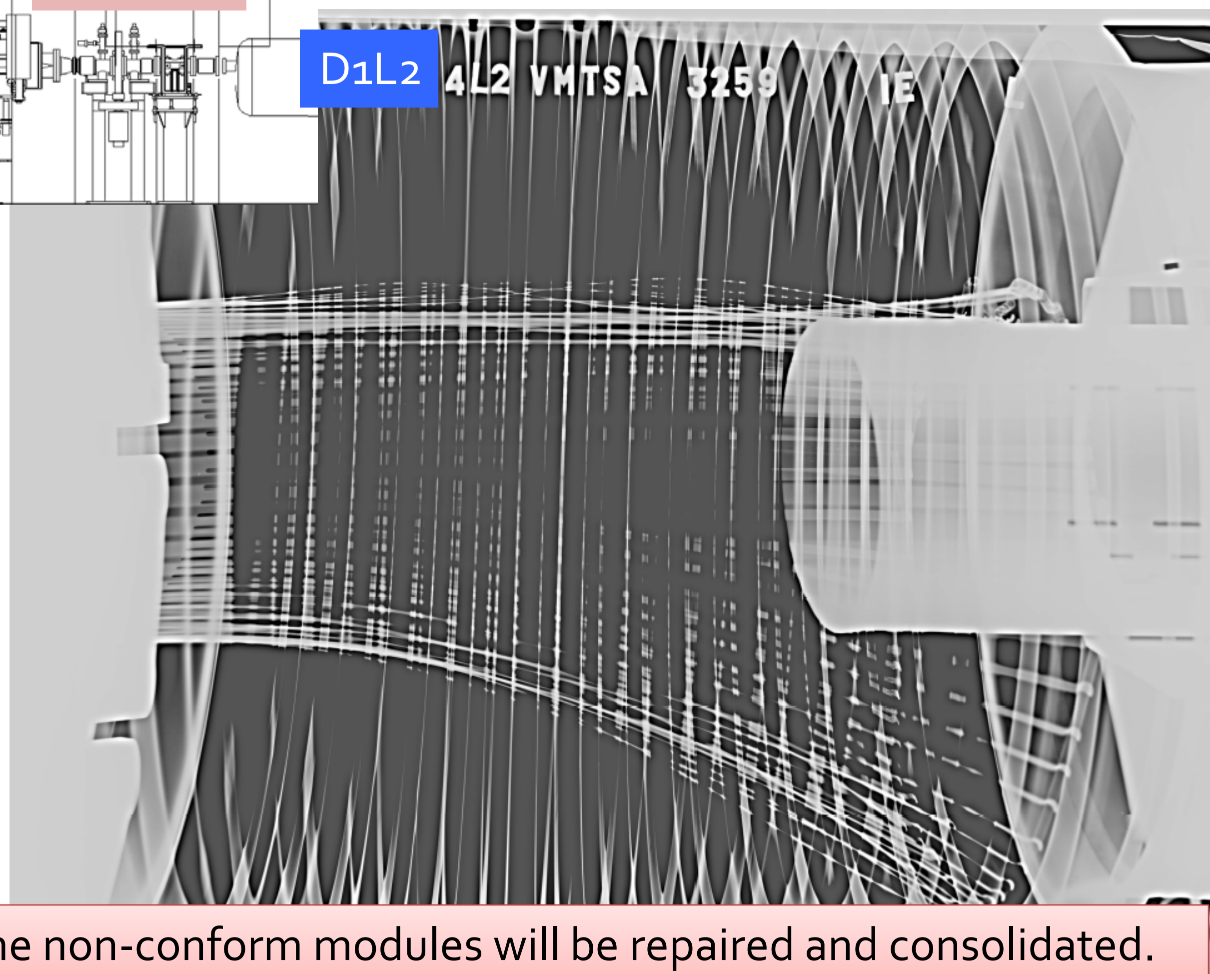
- Spikes during injection and stable beams above 10^{-7} mbar
- D1L8, D1R8



Typical default in the RF Finger



Point 2 Left side: Side view



Heating of RF fingers and spring holding the RF fingers in contact with the slots

Spring and RF fingers were deformed between May and November 2011

During beam operation possible electric arcs could induce degassing: pressure spikes

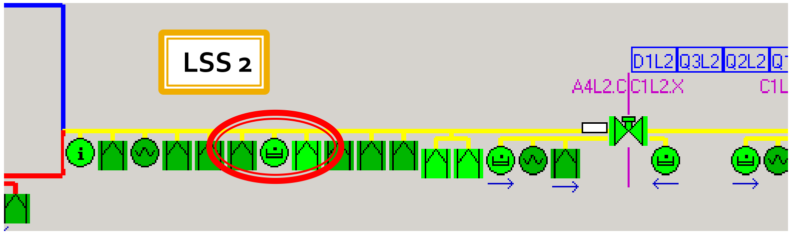
Christmas break: The non-conform modules will be repaired and consolidated. Further studies ongoing.

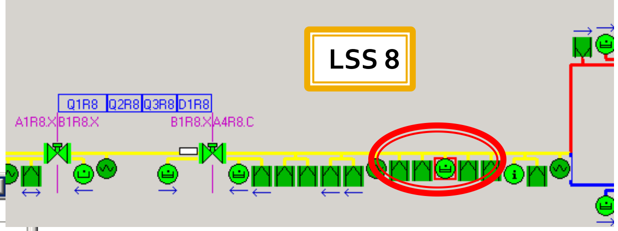
Pressure increase in TDI LSS2 and LSS8

Target Dump Injection for LHC (78 m from IP2)

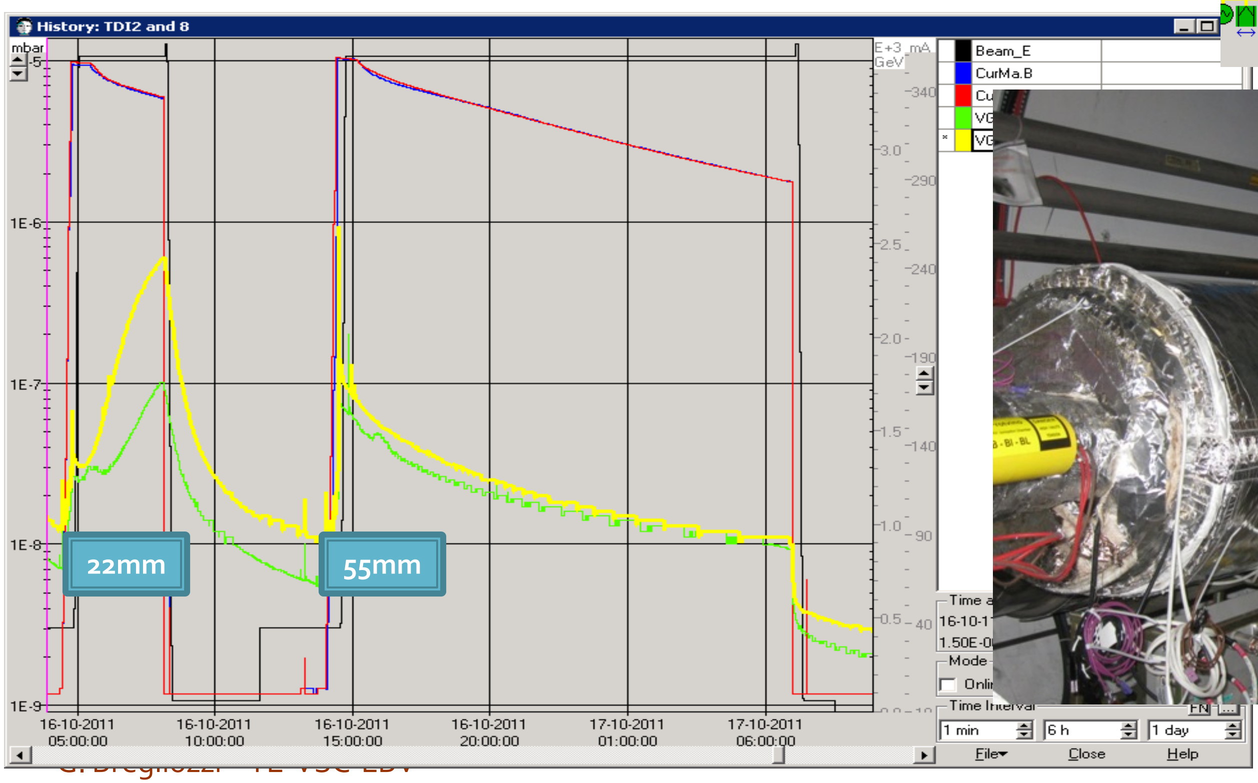
TDI Jaws Distance:

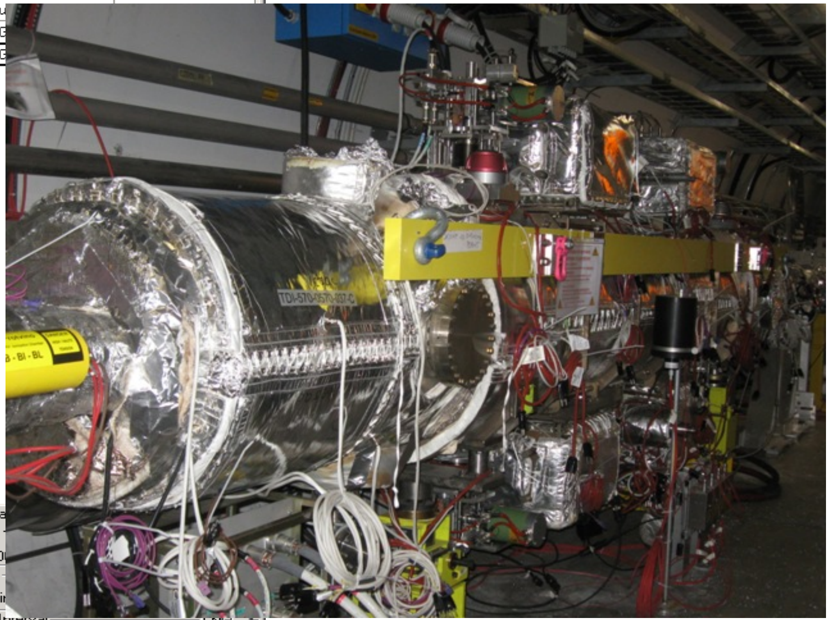
- ± 22 mm: pressure increased
- ± 55mm : pressure stays at 10^{-8} mbar





Christmas break: the pumping at TDI2L will be doubled

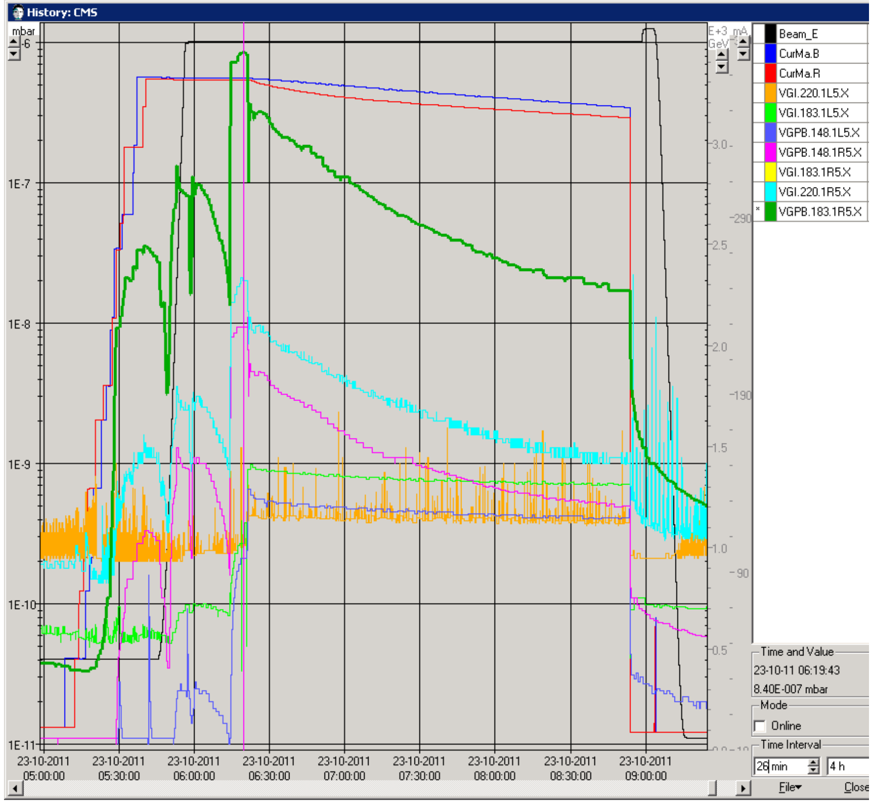




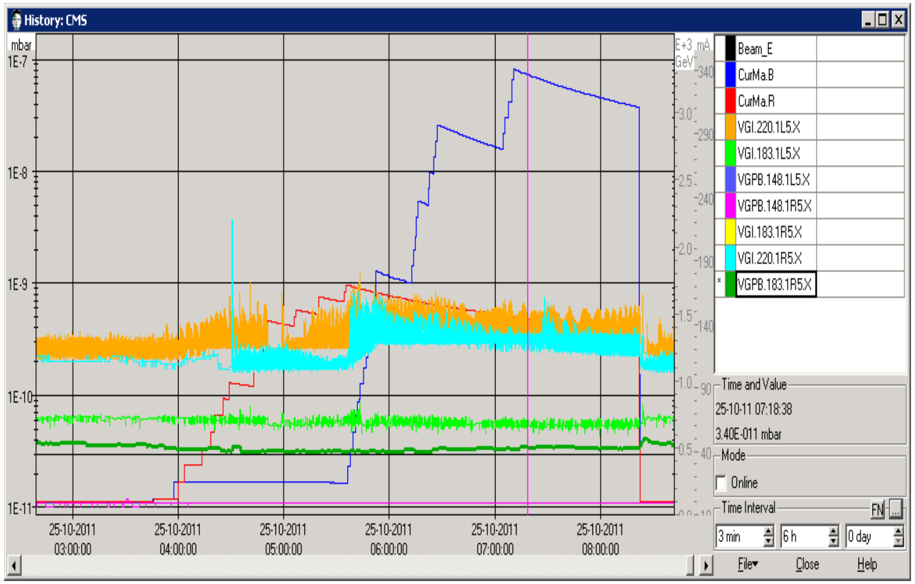
CMS Forward Area: Pressure Increase

- CMS background suffers from pressure rise localized around 18 m from the IP
- The CMS magnetic field ensure the multipacting suppression

Fill 2241 at **50 ns** bunch spacing



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



Pressure excursion at 18 m does not seems to be triggered by multipacting

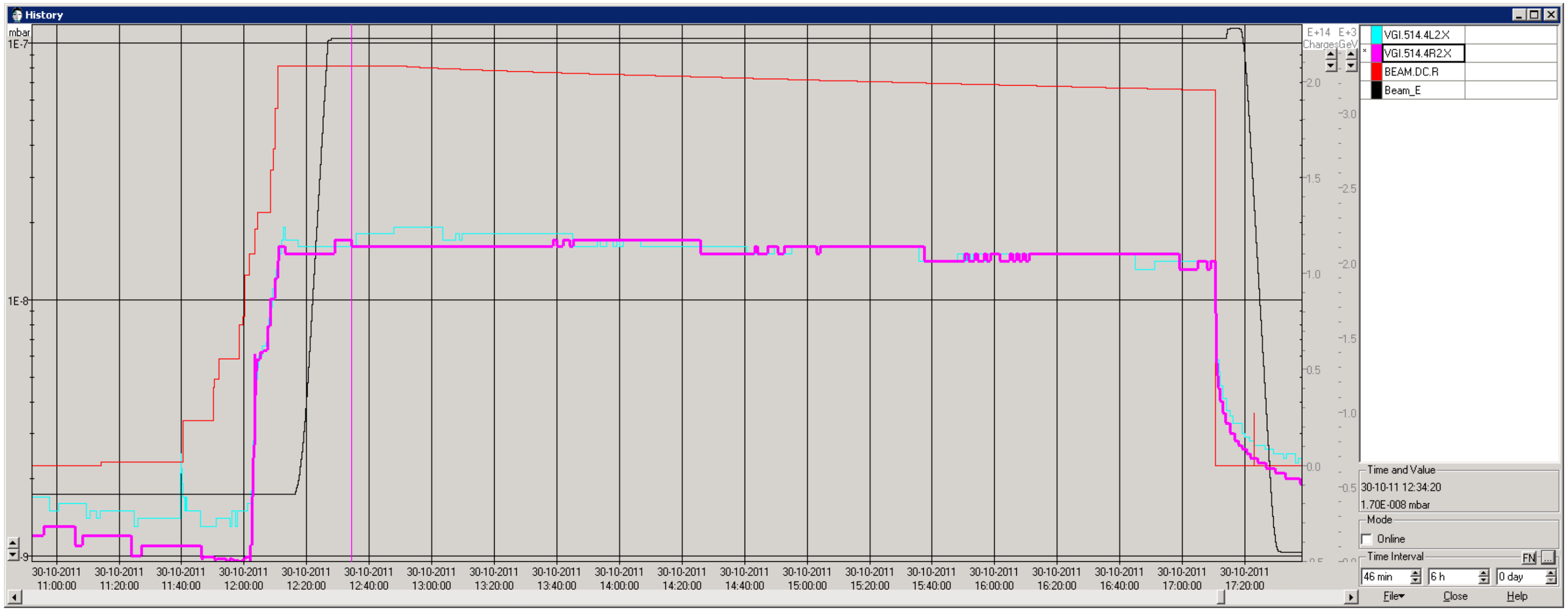
Christmas break: X-Ray and upgrade of pumping system

ALICE Background

- ALICE background is dominated by the pressure rise at 110 m from IP that must be below 10^{-8} mbar

- One layer (~1 Km) of solenoid was installed at each extremity to check potential electron cloud activity: a small reduction of the pressure was observed with solenoid ON.

Christmas break: layout will change, NEG reactivation and possible solenoid re-installation (2 layer).



Strategy
&
Mitigation Solutions

LHC Strategy for Electron cloud

The LHC Strategy is scrubbing

*"Operating the LHC with nominal parameters relies on the **surface conditioning** (scrubbing) effect, **akin to the process of an RF cavity**, by which the secondary emission yield decreases from an initial value of about 2 to about 1.4 or below, after depositing a sufficient dose of electrons on the chamber wall. During commissioning, when the yield is still high, an increased bunch spacing and/or a reduced bunch intensity will greatly reduce the heat load…." From LHC Design report (p. 116).*

- **Scrubbing and vacuum cleaning at 25 ns** → For operation at 50 ns
  - Some LSS sectors are vented during Christmas break: need a new scrubbing and cleaning of these area.

Scrubbing Run Scenario: Optimize time and efficiency.

✓ **Higher and stable beam intensity** >1.1 – $1.2 \cdot 10^{11}$ p/b

✓ Fill the machine with l**ower number of bunches while keeping stable intensity**:
- **72 trains** injection, then **144 trains** and finally **288 trains**.

✓ Determination of **scrubbing efficiency:** when the beam is dumped, injection of just 1 train with a fixed p/b intensity to check pressure increase.

✓ Could be applied **after each TS** for **24-48 h** of time or for a dedicated MD (7-10 days) : the **earlier** the better.

Mitigation solutions

Mitigation Solutions for Electron Cloud

- **Installation of solenoids in non-coated areas**:
  - In **MKI regions** to decrease pressure increase during scrubbing run **and ID800** to decrease ALICE background.
- **Increase local pumping speed by the use of NEG cartridges:**
  - Vacuum pilot sector for 2012 run: TDI, VAMTF module in LSS2 and in the cold-warm transition of ITL2 & ITR2.

Mitigation Solutions for Heating Effects

- **TDI**: It was shown that running the machine with a gap of $\pm$ 50 mm limit the increase of pressure and temperature in the TDI jaw.
- **VAMTF Modules** (Location of pressure spikes)**:**
  - Installation of different springs to withstand high temperature.
  - Add NEG cartridges to increase pumping speed.
- **ALICE ZDC in LSS2:**
  - Layout will be changed during Christmas break.
  - NEG reactivation and possible solenoid re-installation(2 layers).

Conclusions

ELECTRON CLOUD

Scrubbing period with 50 ns was very efficient to reduce the stimulated gas desorption and increase the multipacting threshold

- **During this period, pressures increased in the range 10^{-7} mbar.**
- **During the year, average pressures were in the range 10^{-9} mbar.**

25 ns beams stimulated further gas desorption from the beam screen of ARCs and stand alone magnets: pressure increased again in the range 10^{-7} mbar

- **Another period with 25 ns with <ppb> above threshold is needed for further scrubbing and analysis.**

PRESSURE SPIKES AND HEATING EFFECTS

- **Pressure increase in TDI and ALICE should be significantly reduced thanks to new layout and the increased parking distance between the TDI jaws.**
- **Consolidation of vacuum module: New spring material and additional pumping.**
- **CMS: Upgrade pumping system and X-rays as complementary diagnostic**