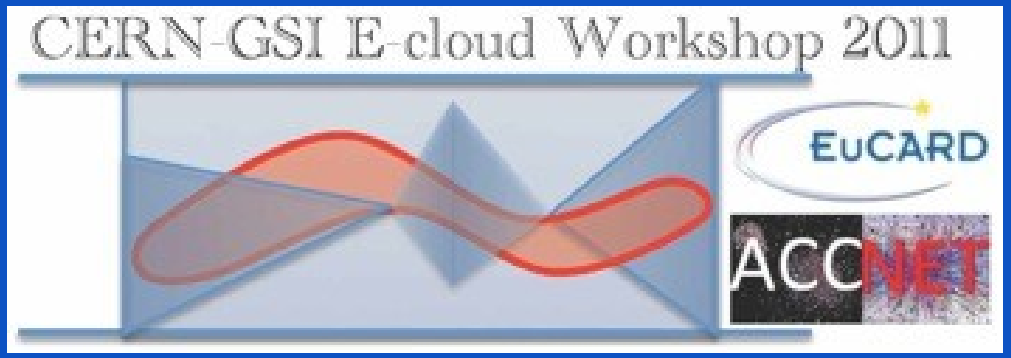


E-CLOUD VACUUM OBSERVATIONS AND FORECAST IN THE LHC

G. Bregliozzi

On behalf of VSC Group

with the contributions of G. Arduini, V. Baglin, J.M. Jimenez and G. Lanza

Outline

1. Introduction
2. Pressure rises with:
    a. 150 ns and 75ns bunch spacing;
    b. E-Cloud driving parameters @ 50ns bunch spacing.
3. Parameters for the LHC
    a. Pressure rise function of different positions
4. Scrubbing and Forecast for 2011
5. Summary & Conclusions

Introduction

- The electron cloud build-up:
  - Is a threshold phenomenon ↗ bunch population
    ↘ number of bunches in the train → Linear build-up
  - Depends highly on the Secondary Electron Yield (SEY) δ
    - Is enhanced by the low energy electrons surviving the gaps between bunch trains (reflectivity of low-energy electrons)
  - Is attenuated by the spacing between bunches and bunch trains
  - Is affected by many other parameters like:
    - Size of the beam vacuum pipe
    - Magnetic field
    - Temperature of the beam pipe walls

Electron cloud: Vacuum pressure rise parameters

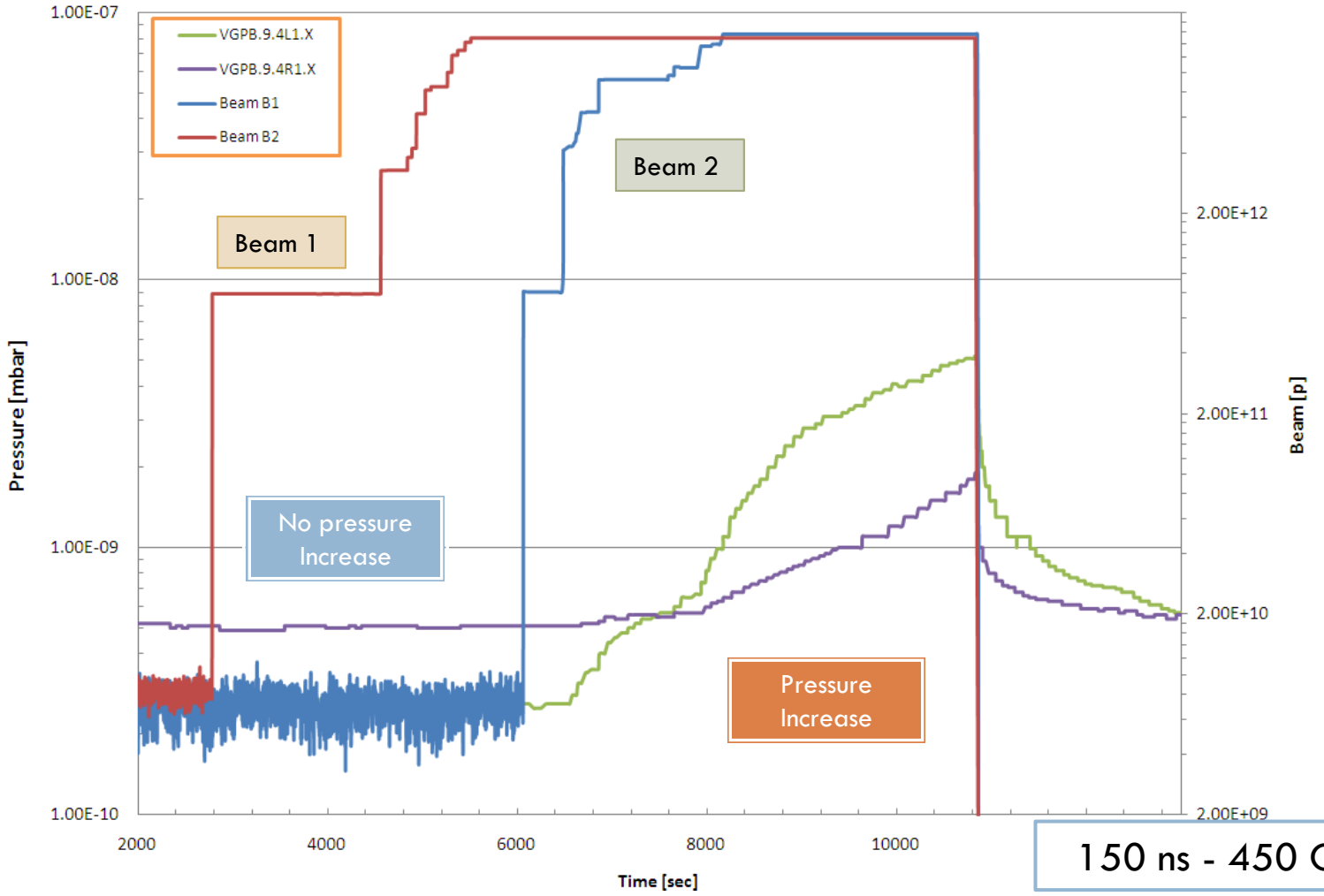
- Vacuum pressure rise
  - Electron stimulated desorption (ESD)
  - Multipacting length
  - Effective pumping speed

$$P_{Tot} \approx \sum \frac{\eta_{gas} \cdot \dot{\Gamma}_{Electrons}}{S_{gas}}$$

$$P_{Tot} \approx \sum P_{gas}$$

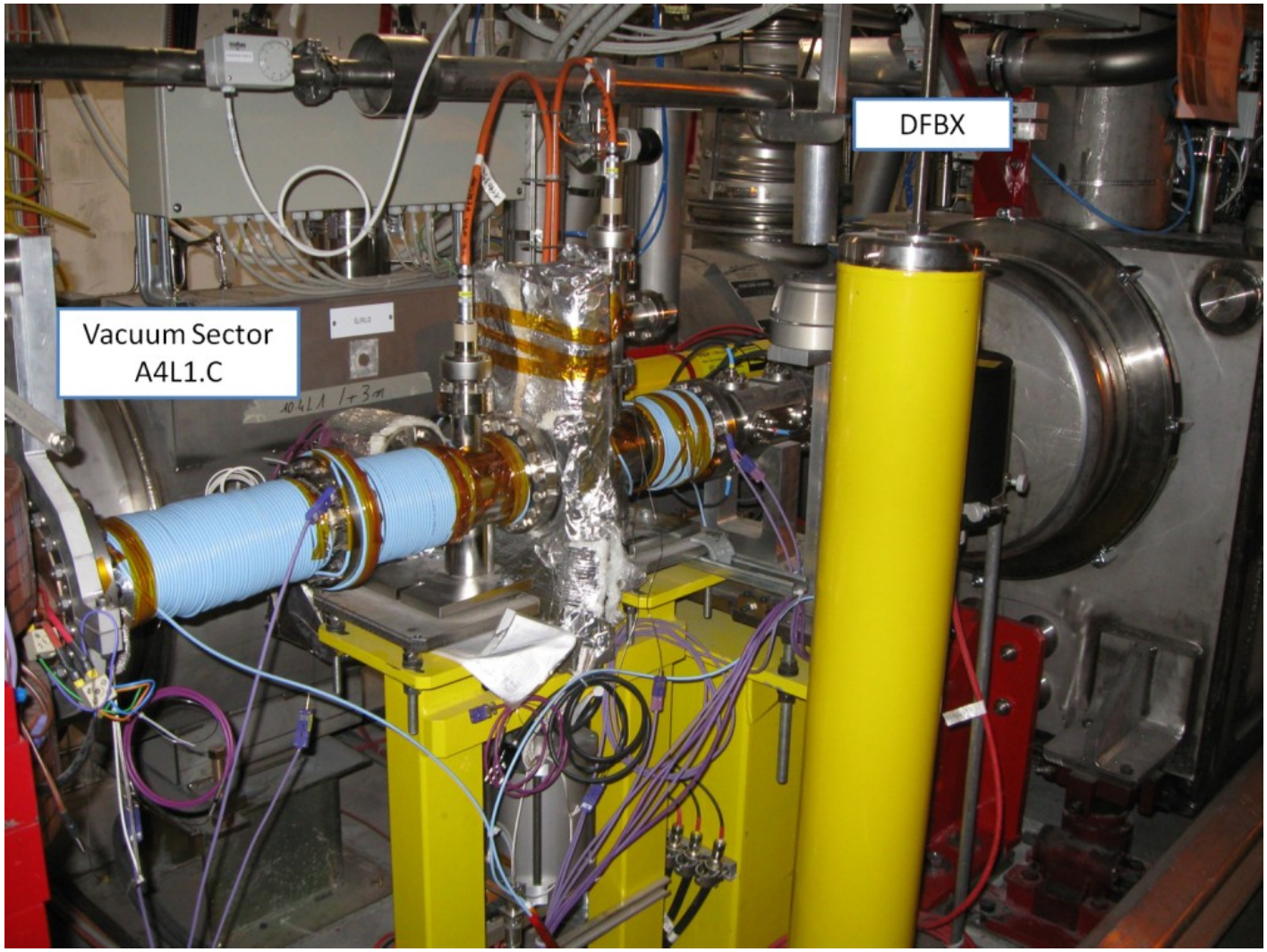
150 ns bunch spacing: Merged vacuum

E-cloud effect detectable in merged vacuum: interaction of the two beams

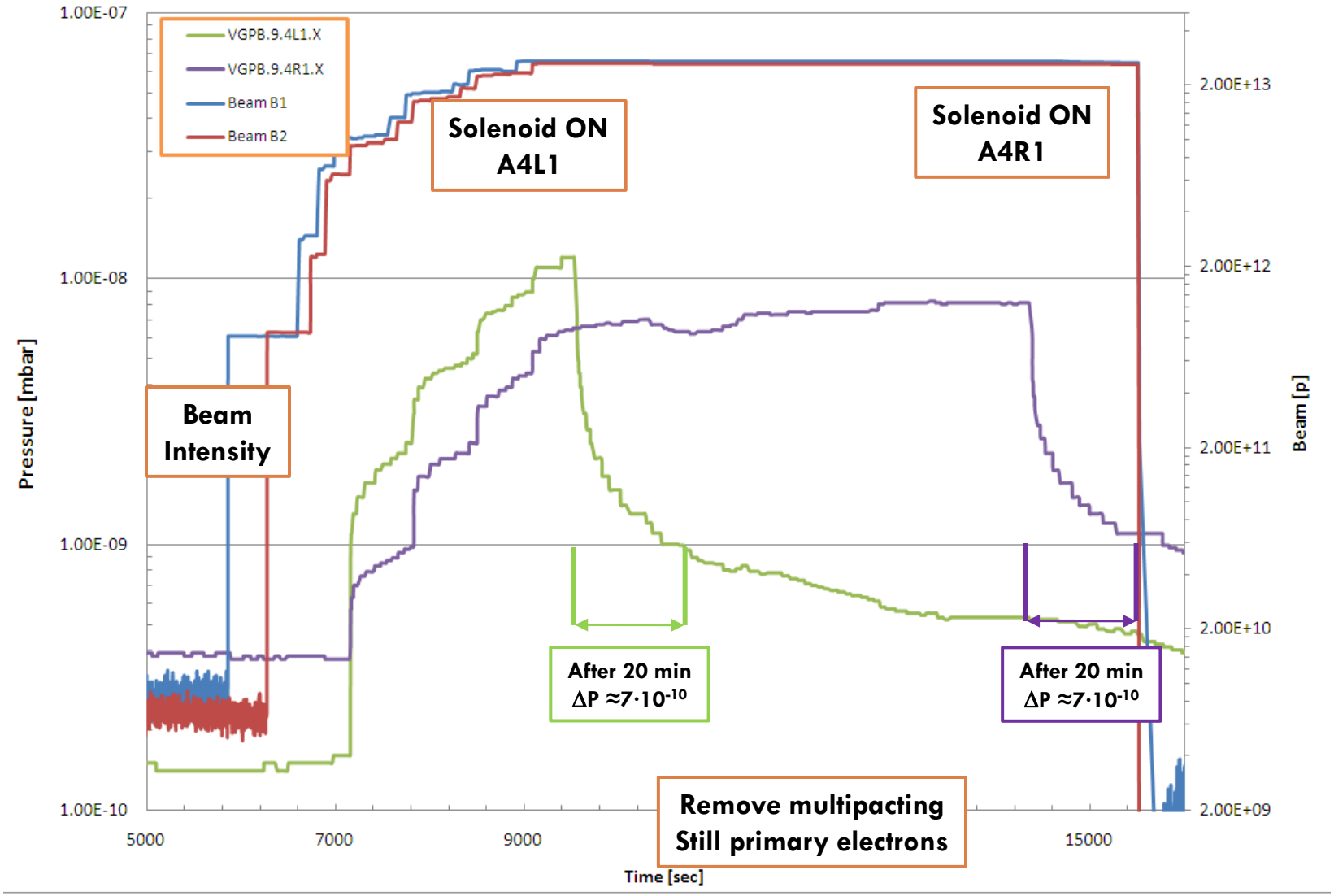


150 ns - 450 GeV

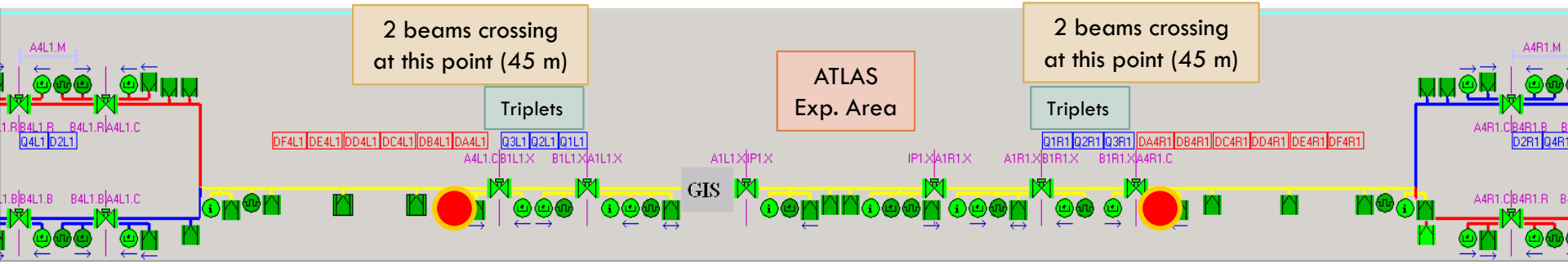
Installation of Solenoids



Solenoid Effect



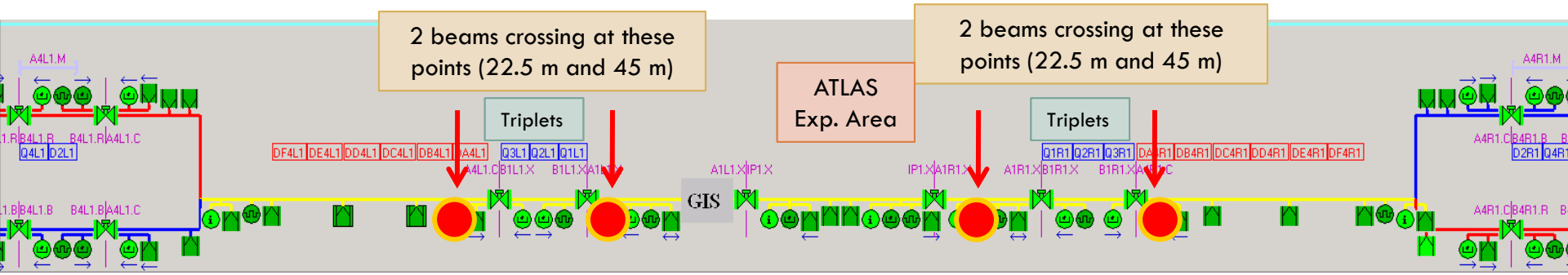
Summary: Operation with 150 ns bunch spacing



Summary with 150 ns at 3.5 TeV:

- In the LSS
  - Pressure rises in the pipes **with 2 circulating beams**:
    - Electron stimulated desorption: bigger effects observed in the Cold/Warm transition of the Inner triplets on Q3/DFBX side for ATLAS, ALICE and LHCb where the two beams cross at this position.
    - No pressure increase in CMS due to leak magnetic field from the solenoid variable from 10 up to 150 Gauss.
- In the arcs: Nothing observed

Summary: Operation with 75 ns bunch spacing

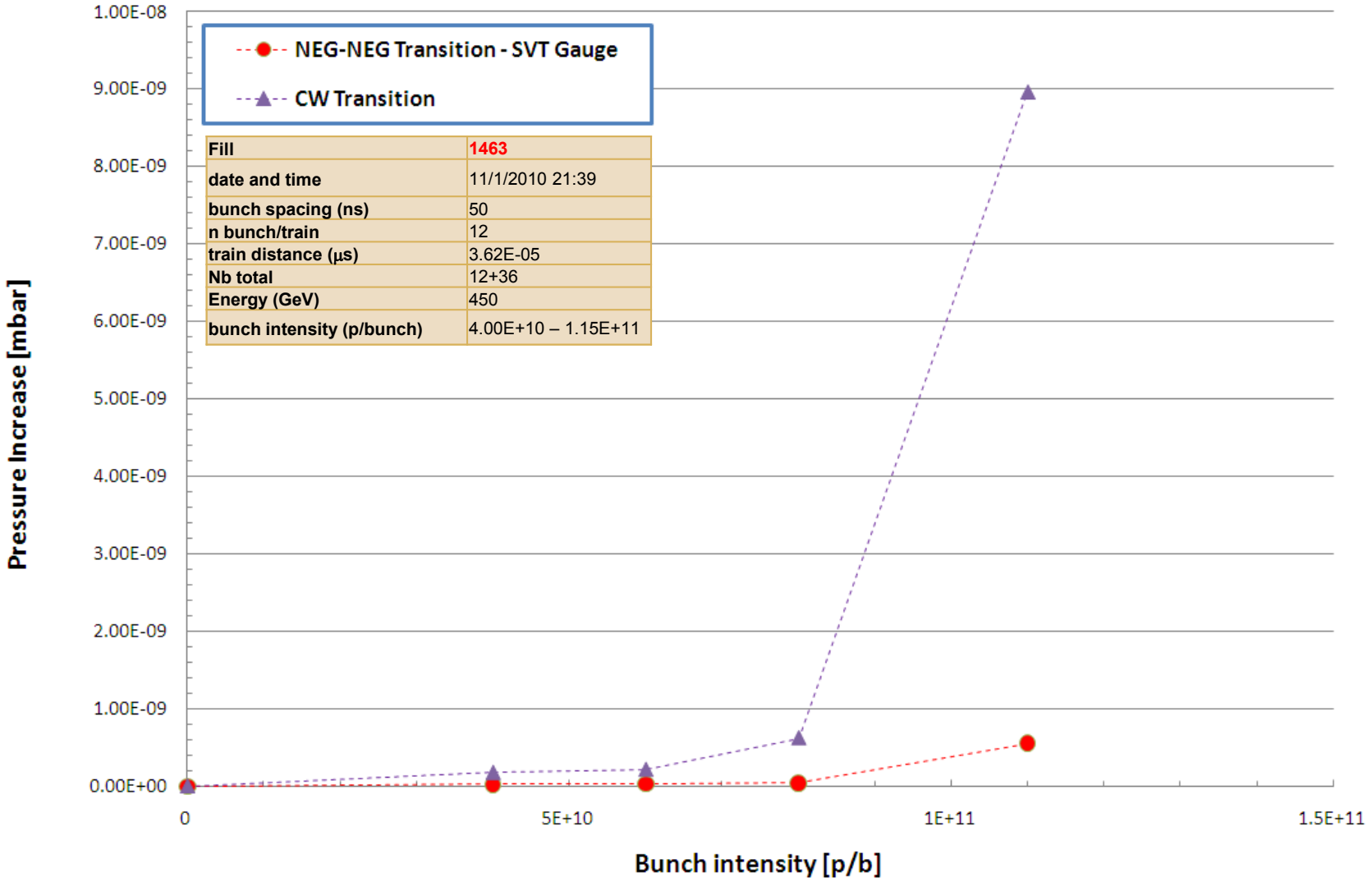


Summary with 75 ns at 450 GeV:

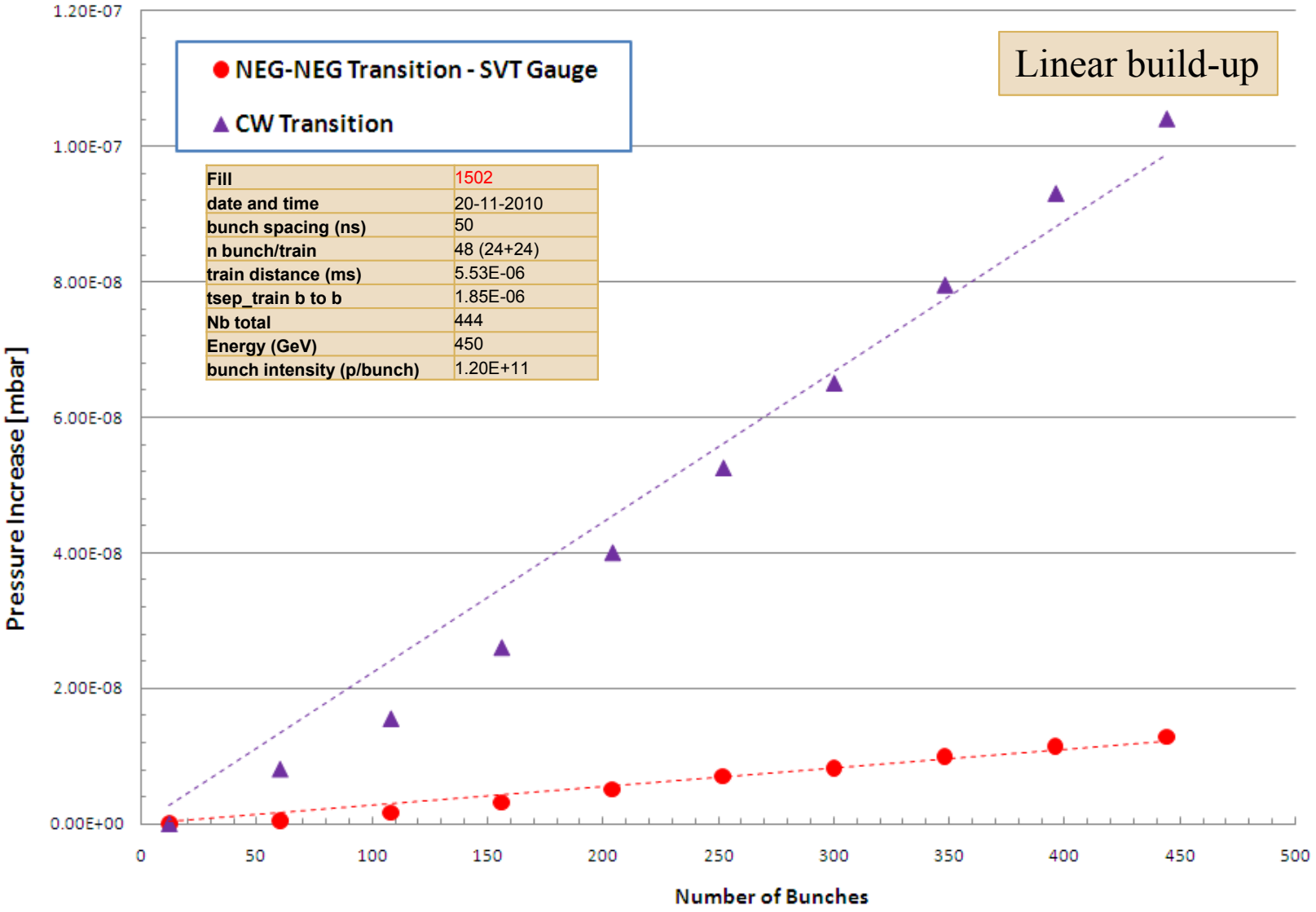
- In the LSS
  - Pressure rises in the pipes **with 1 circulating beam** results from the multipacting length *vs* pumping speed configurations.
  - Pressure rises in the pipes **with 2 circulating beams** is enhanced in particular in the Cold/Warm transition of the Inner triplets on Q3/DFBX side for ATLAS, ALICE and LHCb where the two beams cross at this position.
- In the arcs: Nothing observed

MD Study at 50 ns

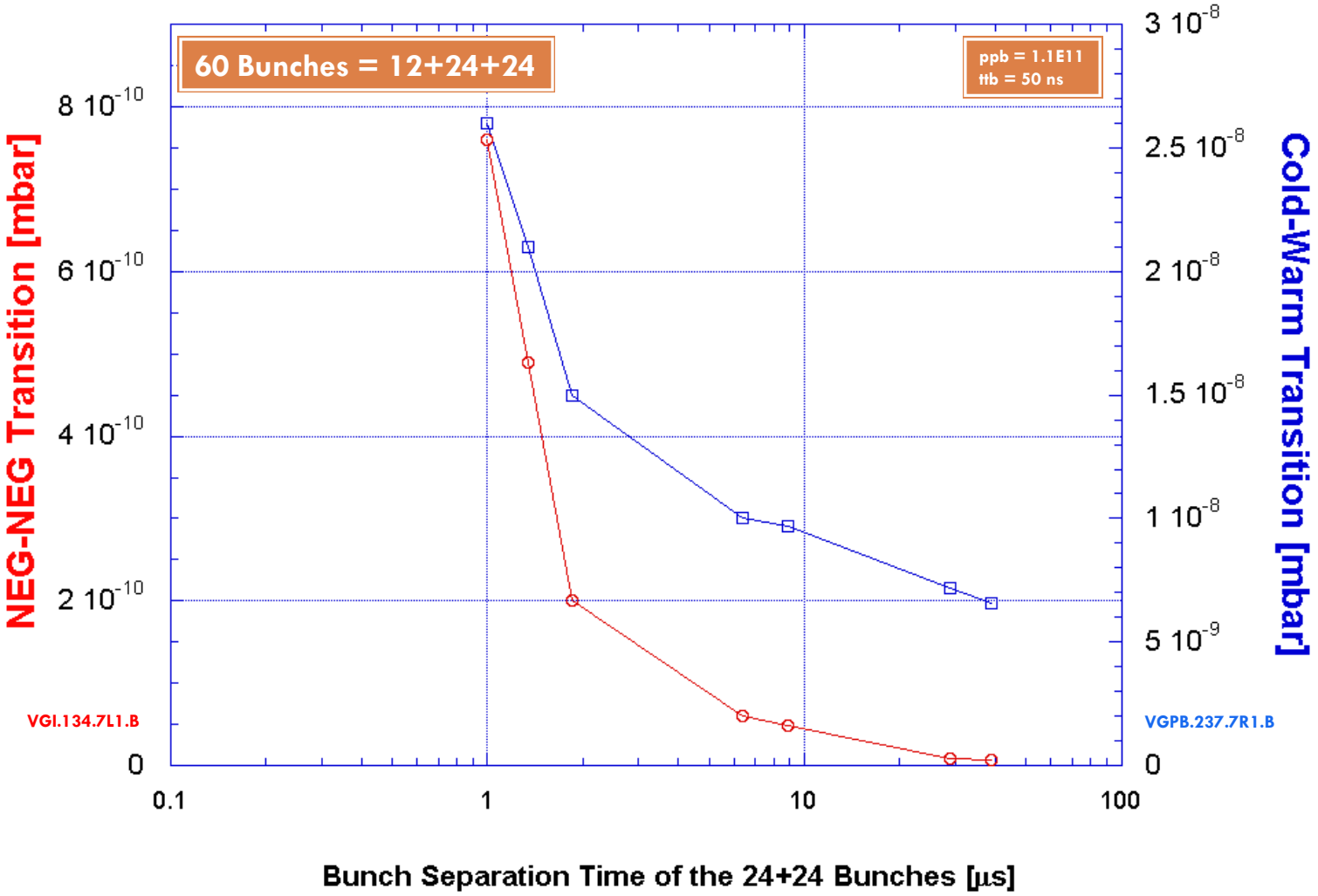
E-Cloud Driving Parameters: Bunch Intensity



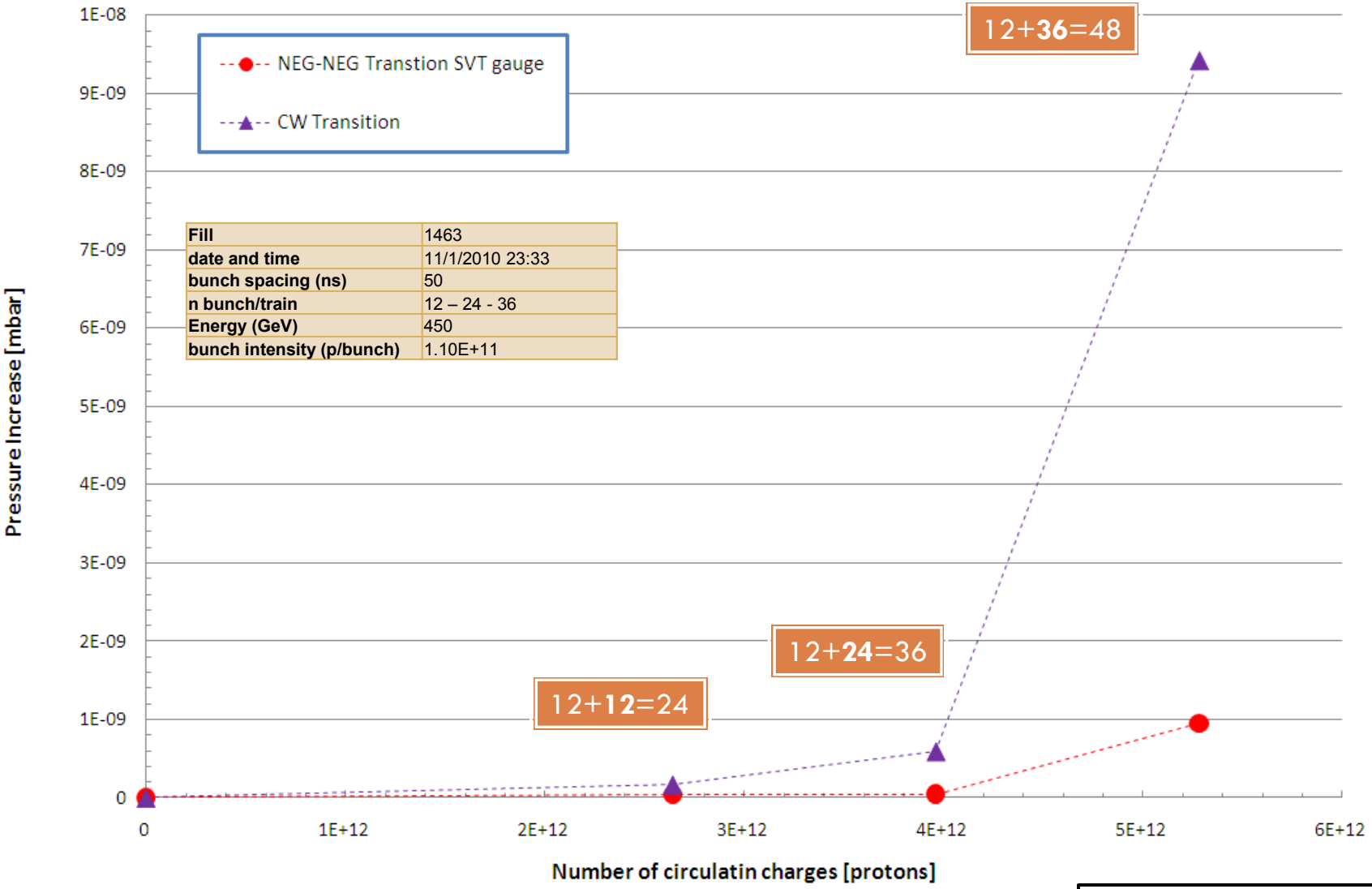
Pressure Increase vs. Beam Current



E-Cloud Driving Parameters: Train Spacing



E-Cloud Driving Parameters: Batch Population

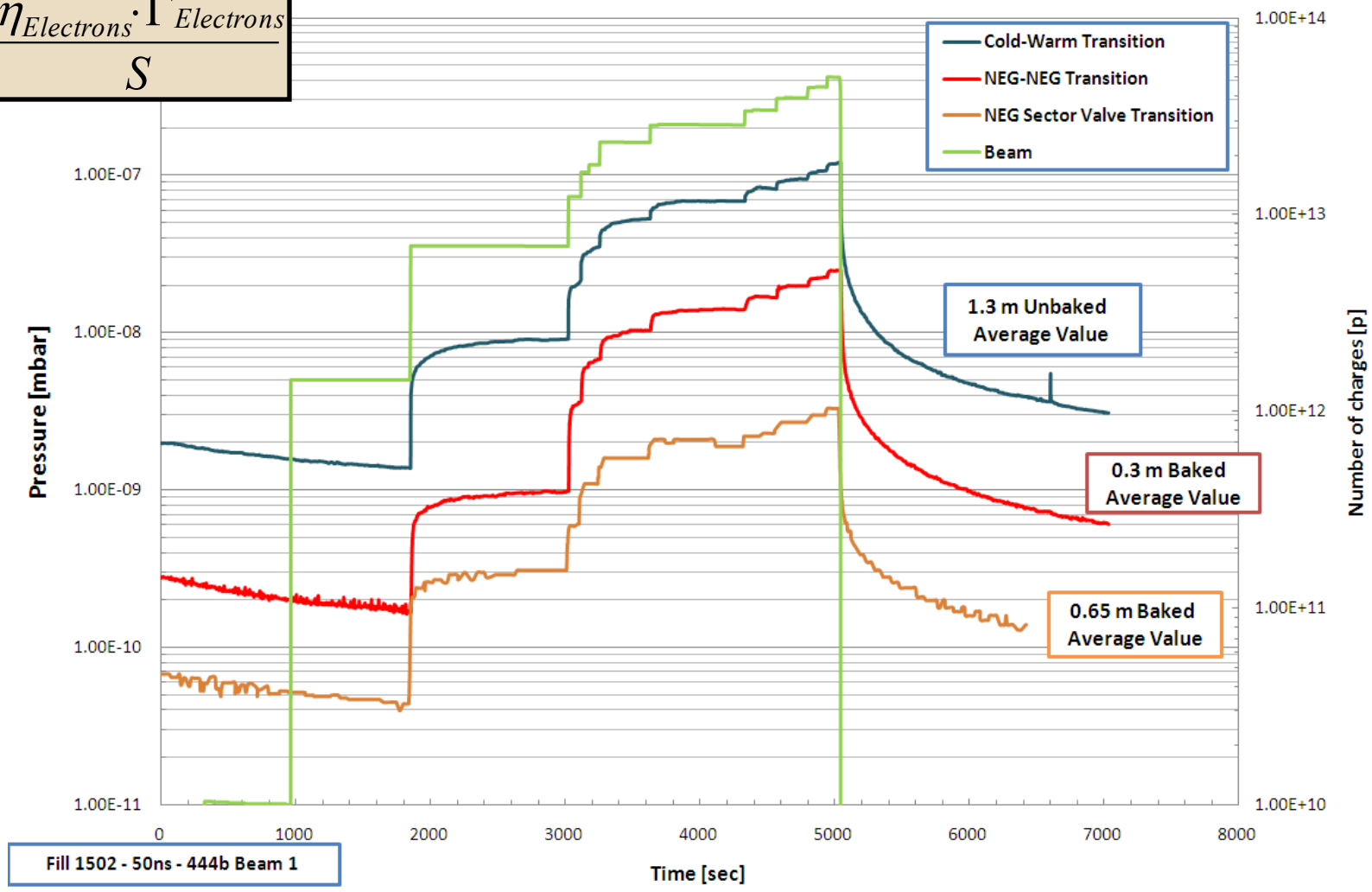


First 12 bunch have no effects on the pressure

Link between observed **pressure increase** and **LHC** machine **configuration**

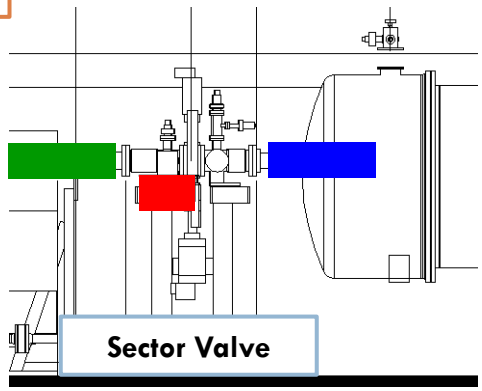
Pressure rise @ different locations: 50 ns

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

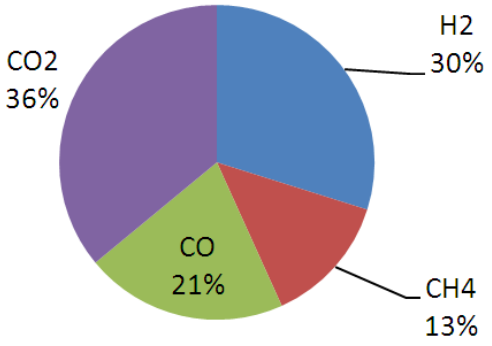


Pressure rise @ different locations: Gas composition

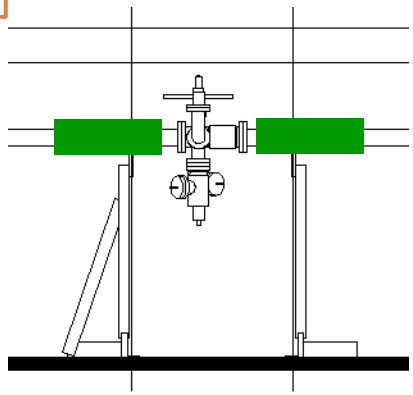
A Cold-Warm transitions



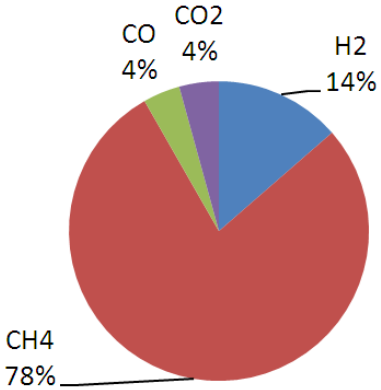
- Unbaked: SEY ~2.3.
- Length 1.3 m
- Pumping speed from NEG, Cryo and Ion pumps



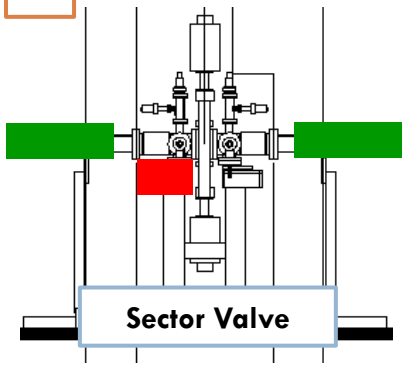
B Warm/warm transition



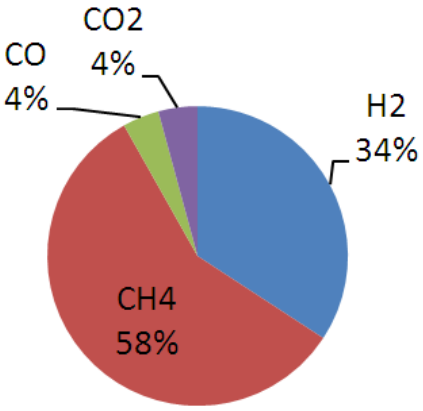
- Baked but uncoated: SEY ~1.6-1.9.
- Length 0.3 m
- Pumping speed from NEG and maximum for $CH_4 \approx 10$ L/s



C Warm/warm transition



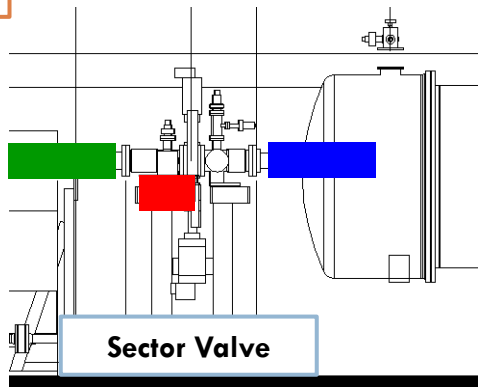
- Baked but uncoated: SEY ~1.6-1.9.
- Length 0.6 m
- Pumping speed from NEG and ion pumps



Cold
NEG
Ion Pump

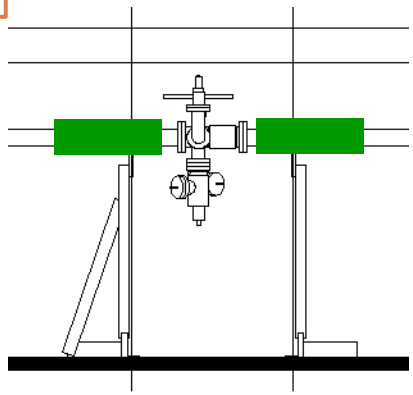
Pressure rise @ different locations: Gas composition

A **Cold-Warm transitions**



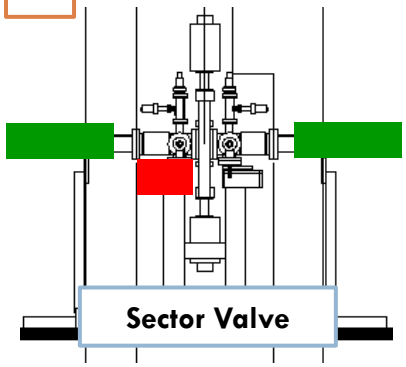
- Unbaked by design: SEY ~2.3.

B **Warm/warm transition**



- Baked but uncoated by design : SEY ~1.6-1.9.

C **Warm/warm transition**



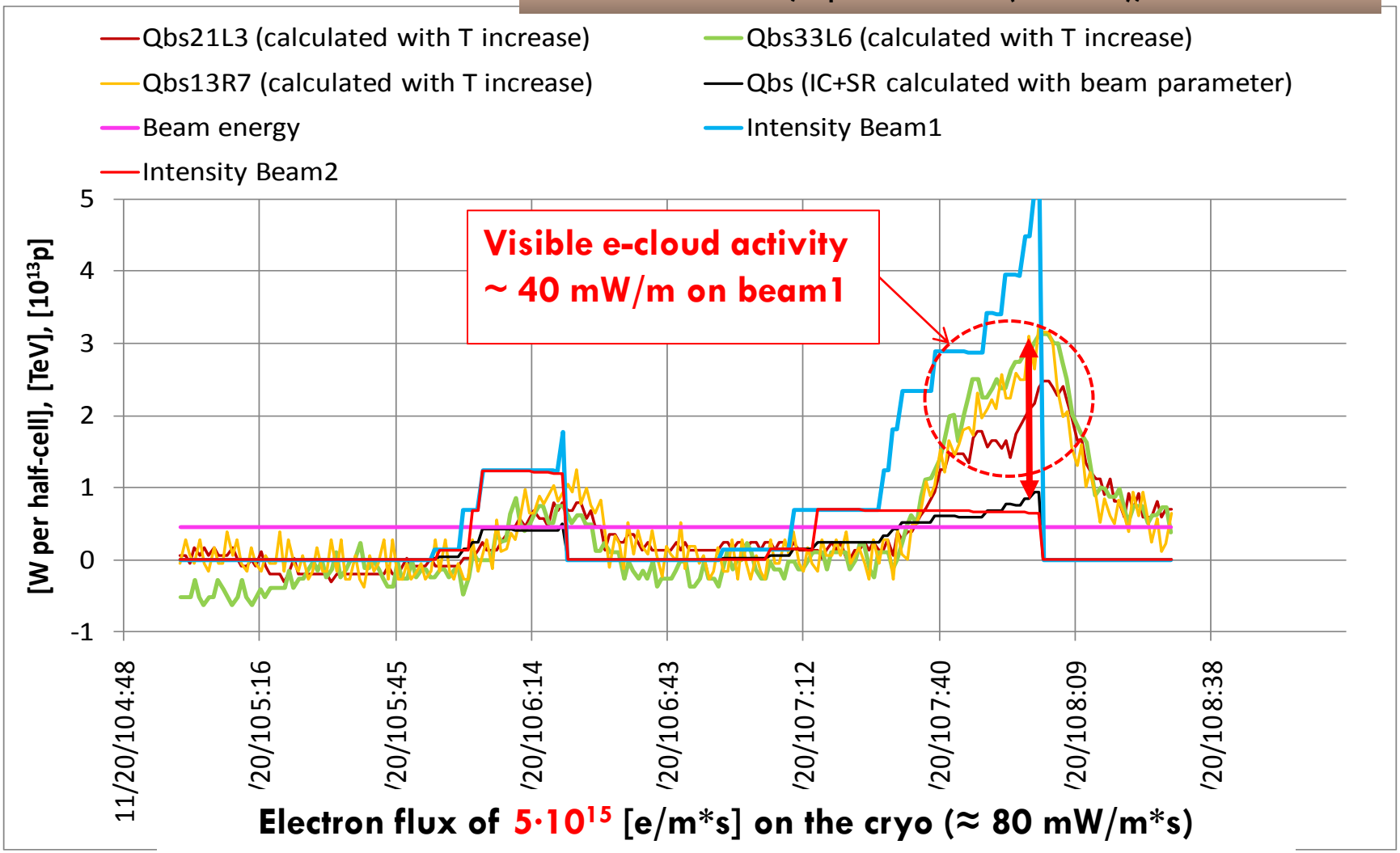
- Baked but uncoated by design: SEY ~1.6-1.9.

	% Dominant Gas	Max Pressure [mbar]	η [molecules/e-]	Length [m]	Γ́ [e/s/m]
A	30 % H_2 35 % CO_2	$1.0 \cdot 10^{-8}$	$\approx 10^{-1}$	1	
B	80 % CH_4	$3.5 \cdot 10^{-10}$	$\approx 10^{-3}$	0.3	$\approx 5 \cdot 10^{+15}$
C	60 % CH_4 35 % H_2	$2 \cdot 10^{-10}$	$\approx 10^{-2}$	0.65	$\approx 4 \cdot 10^{+15}$

Cold
NEG
Ion Pump

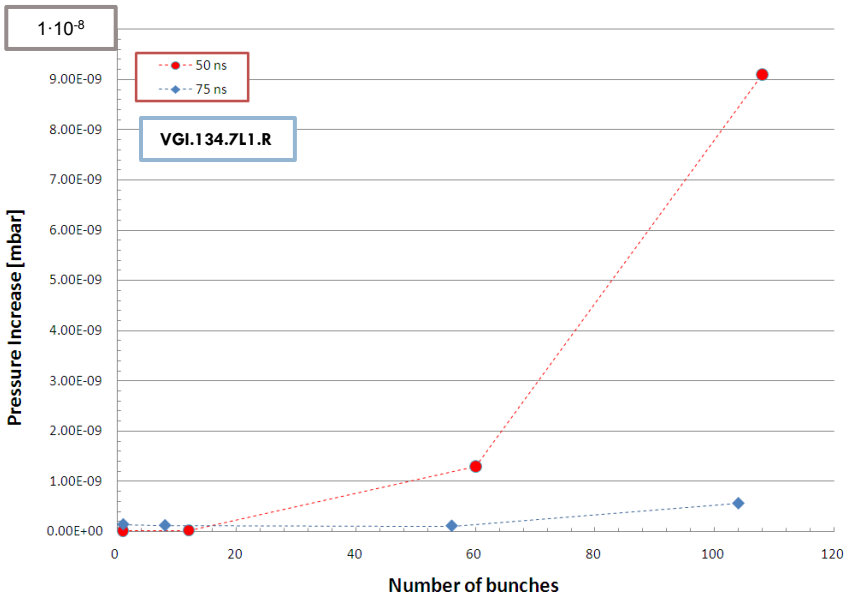
Cryogenic observations @ 50 ns

Fill 1502 - 50 ns, up to 444 b (Beam1), 450 GeV



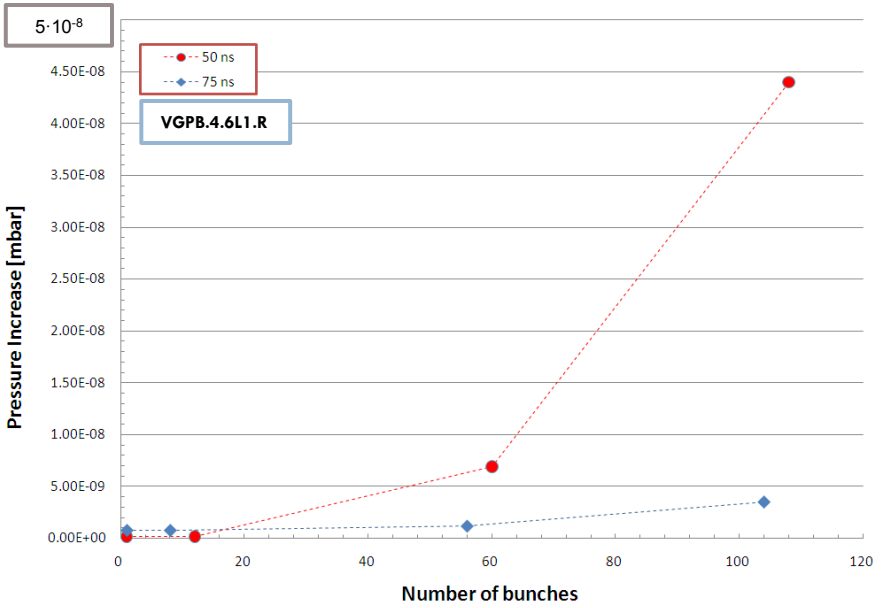
Pressure increase: 75 ns vs. 50 ns

NEG-NEG transition – SVT Gauge



Factor ≈16 between the slope for 50 ns than 75 ns

CW Transition



Factor ≈ 13 between the slope for 50 ns than 75 ns

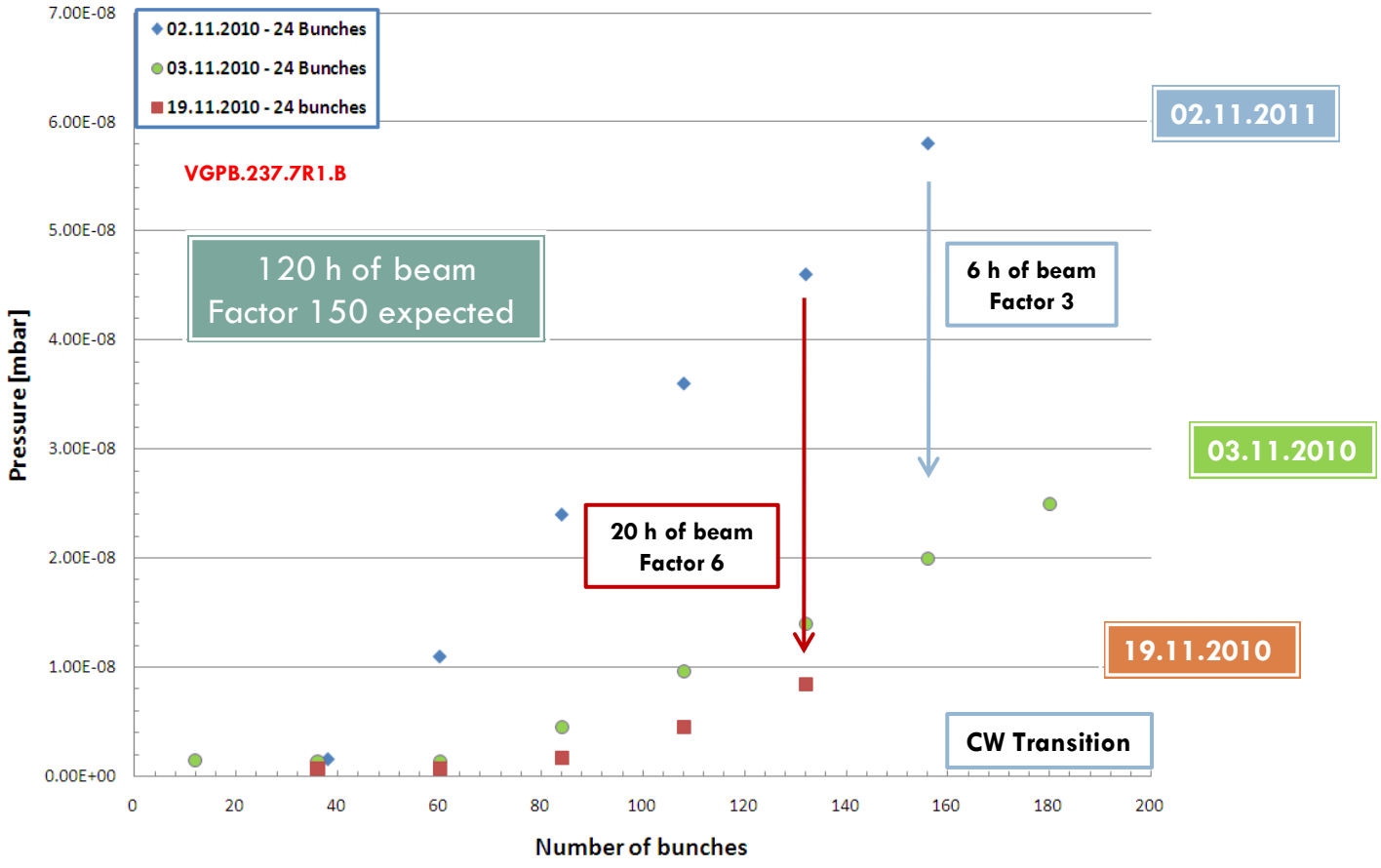
Fill	1498	1502
date and time	18-11-2010	20-11-2010
bunch spacing (ns)	75	50
n bunch/train	48	
train distance (ms)	5.53E-06	
tsep_train b to b	1.85E-06	
Nb total B2	200	108
Energy (GeV)	450	
bunch intensity (p/bunch)	1.3E+11	1.20E+11

After 2 hours of conditioning between injection at 75 and 50 ns

Not constant electron activity

Beam conditioning

- In wk 46, we had **less activity** with 24 b and 1.85 μs compared to wk 44.
- **A factor 6** in the slopes between 2nd and 19th of November was **gained (≈20h of conditioning*).**



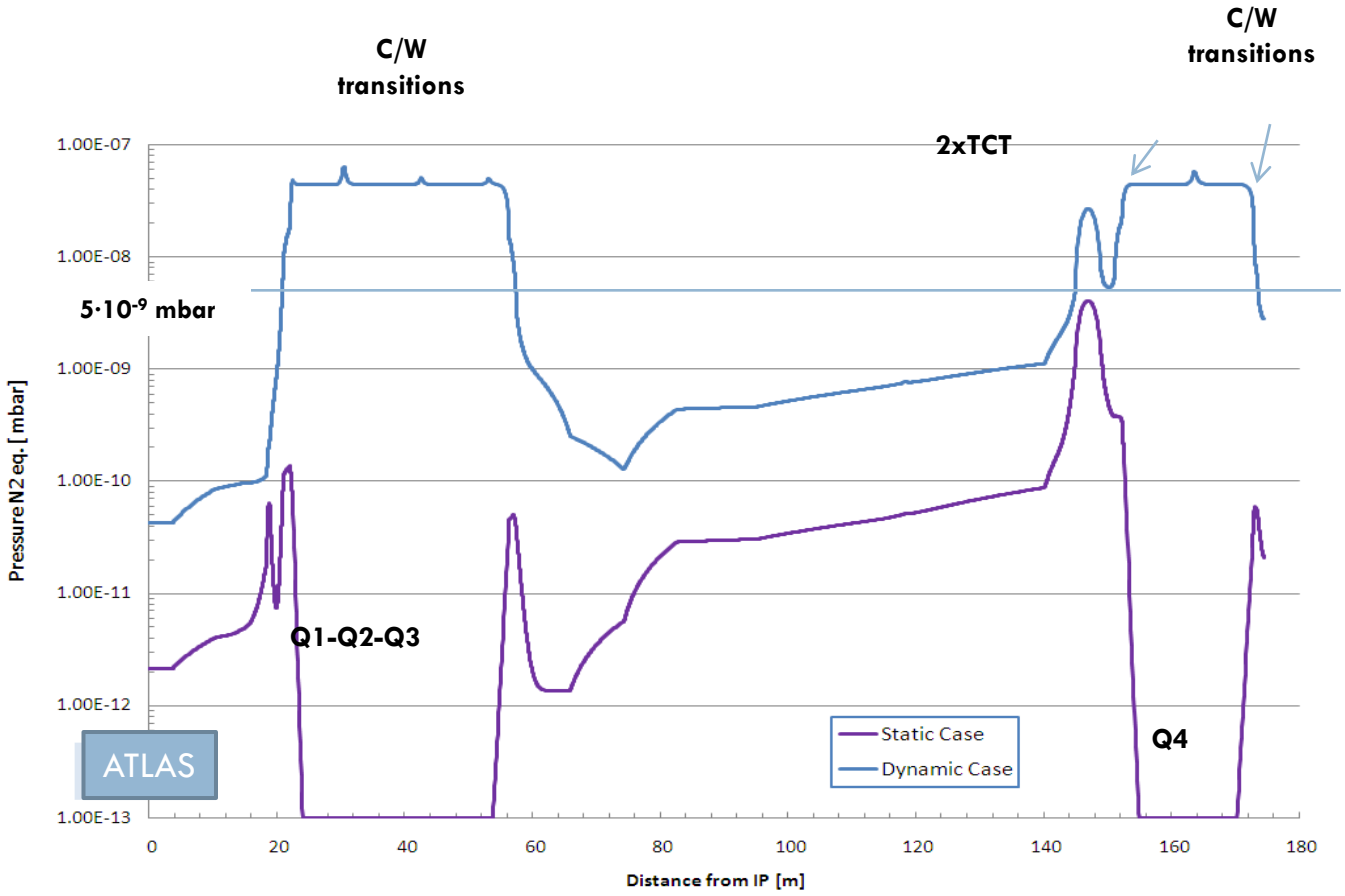
*24 h of beam scrubbing with not constant electron activity

During scrubbing run 2011: Pressure forecast

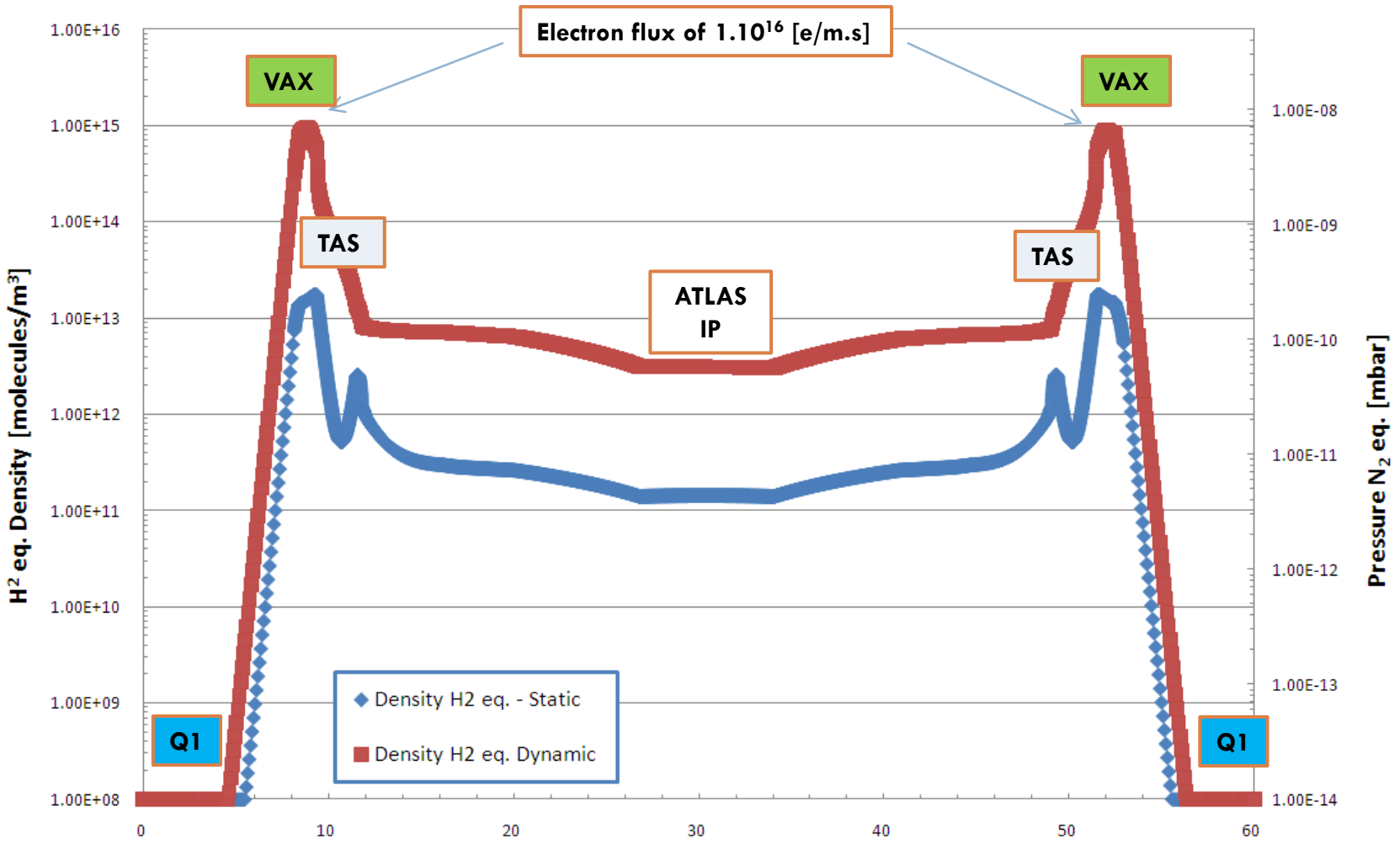
Huge electron cloud activity in Cold, C/W and RT non-NEG coated parts

RT & Cold: electron flux of 1.10^{16} [e/m.s]

About 25% of the LSS at pressure higher than $5 \cdot 10^{-9}$ mbar



Forecast: Pressure distribution



VASCO Simulation

Summary

➢ **150 ns and 75 ns**

- Pressure increase due to E-cloud on the merged vacuum beam pipes where interaction of the two beams is present: Faster vacuum cleaning expected.

➢ **50 ns**

- More electron cloud activity is seen at 50 ns compared to 75 ns (≈ factor 15).
- Analysis of Electron cloud build-up driving parameters.
- Beam conditioning is demonstrated at 450GeV between wk44 and wk 46 at Cold and RT in the LHC.

➢ **Defined a link between observed pressure increase and machine configuration.**

- Multipacting length
- Effective pumping speed for specific gas
- Electron stimulated desorption (ESD)

Conclusions

➢EXPECTATIONS FROM THE SCRUBBING WEEK

- At least 2 order of magnitude of vacuum cleaning are expected in the RT and CW transition after a week
- 1 week of scrubbing should be enough to run with 50 ns beams

IF WE CAN KEEP THE BEAM STABLE WITH CONSTANT ELECTRON ACTIVITY IN THE BEAM-PIPES

Thank you for your attentions