Update on LHC observations in LSS and simulation studies

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Thanks to
G. Iadarola, G. Rumolo and F. Zimmermann

Outline

1) Pressure rise observations with 25 and 50 ns beams

2) Bunch intensity thresholds for 50 ns

3) Behavior during pre-ramp and energy ramp

4) Interpretation using PyECLOUD simulations

5) Conclusions

1) Pressure rise observations with 25 and 50 ns beams

2) Bunch intensity thresholds for 50 ns

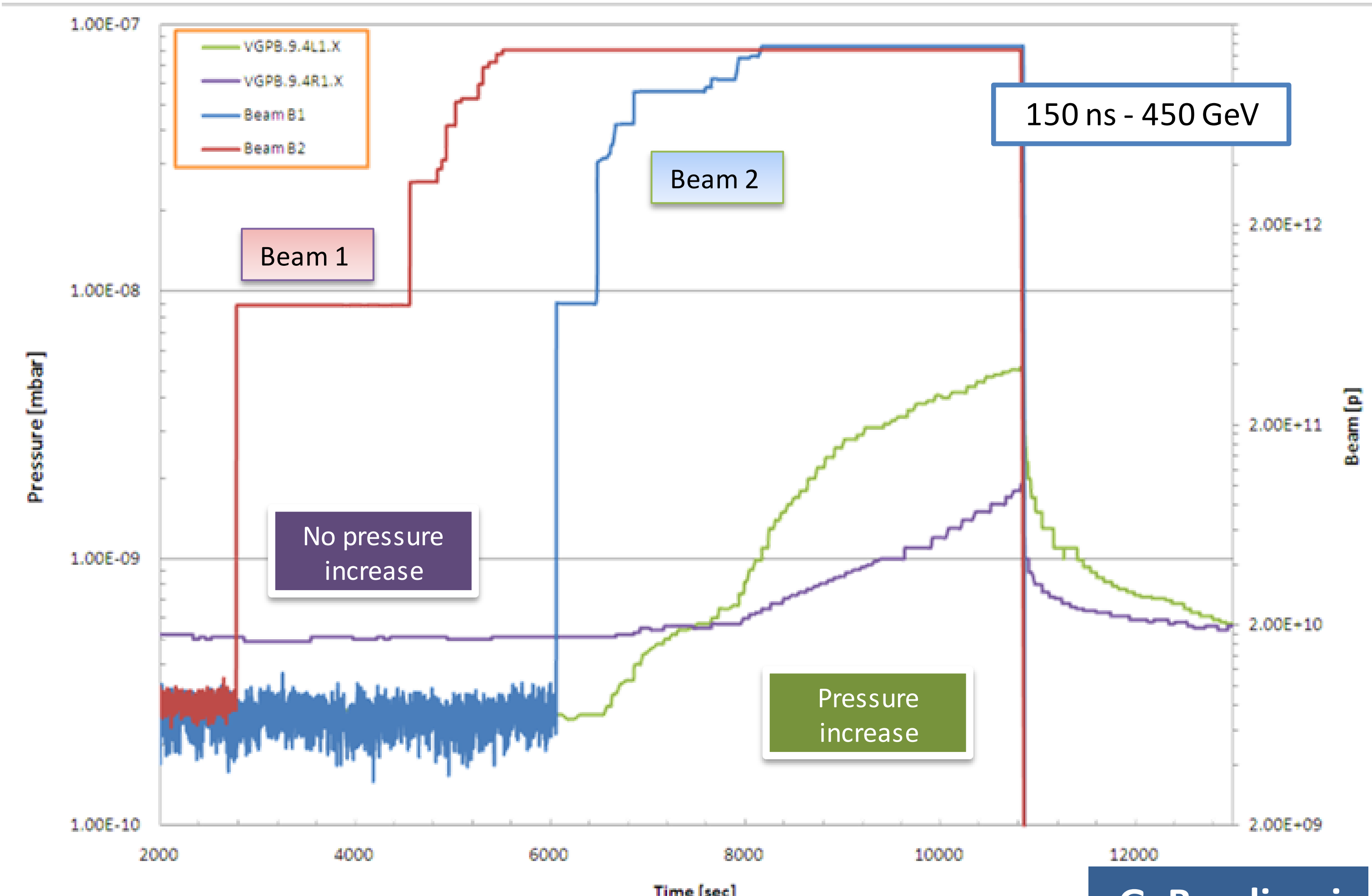
3) Behavior during pre-ramp and energy ramp

4) Interpretation using PyECLOUD simulations

5) Conclusions

ΔP with 25 and 50 ns

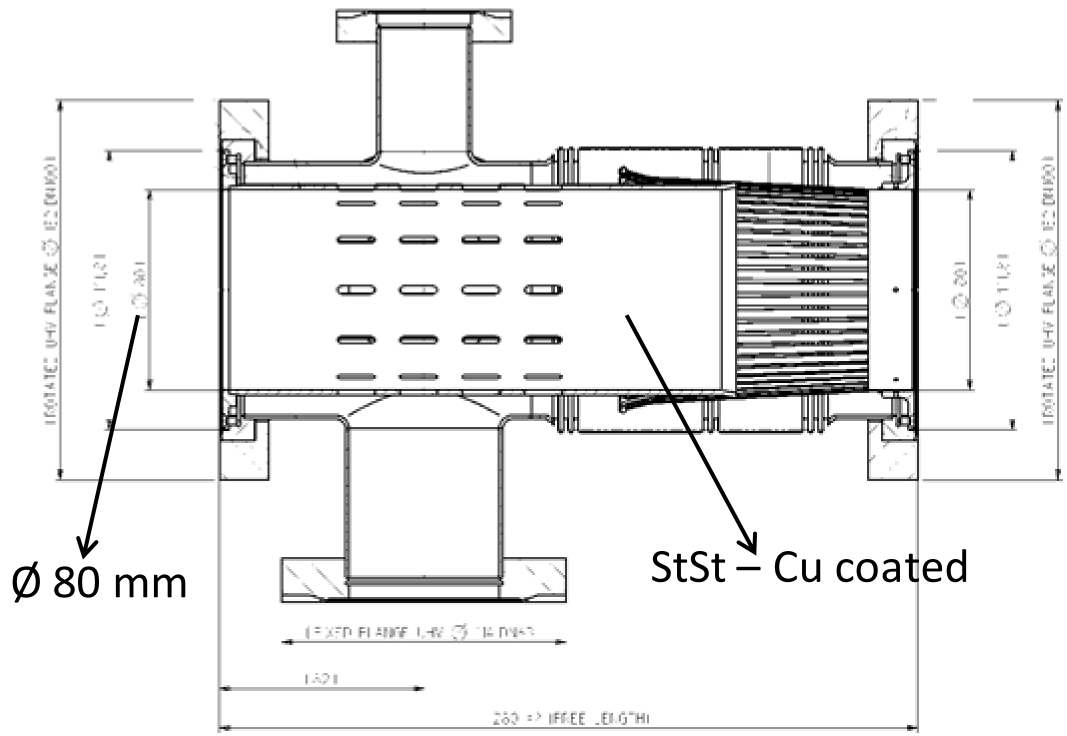
- Pressure rises were the first ECE observed in the LHC with 150 and 75 ns



G. Bregliozzi

ΔP with 25 and 50 ns

- Pressure rises were the first ECE observed in the LHC with 150 and 75 ns
- I focused on pressure gauges located in warm-warm transitions (VGI type):
  - They are more accurate than other types of gauge in the machine
  - They are all located in the same type of module (with simple geometry)

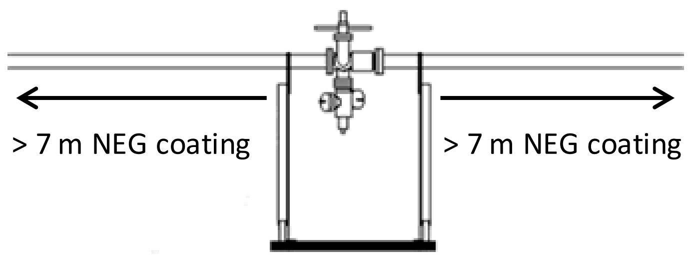


ΔP with 25 and 50 ns

- Pressure rises were the first ECE observed in the LHC with 150 and 75 ns

- I focused on pressure gauges located in warm-warm transitions (VGI type):

  - They are more accurate than other types of gauge in the machine
  - They are all located in the same type of module (with simple geometry)
  - These modules are located between two 7 m NEG-coated beam pipes



There are few exceptions where one side is shorter

  - There are 173 gauges of this type around the ring (easier comparison and extrapolation)
  - I'll focus here on beam 1 (68 guages), although conclusions are equivalent for both beams.
  - SEY estimated by the vacuum colleagues: ~ 1.6 – 1.9 [1]

ΔP with 25 and 50 ns

- I base my observations on 50 ns on 6 fills:
  - 2124: 19 September 2011 (before MDs with 25 ns)
  - 2240: 22 October 2011 (between 14 October MD and 24 October MD)
  - 2261: 27 October 2011 (after 25 ns MDs)

  $N_b \approx 1.37e11$ ppb for all three

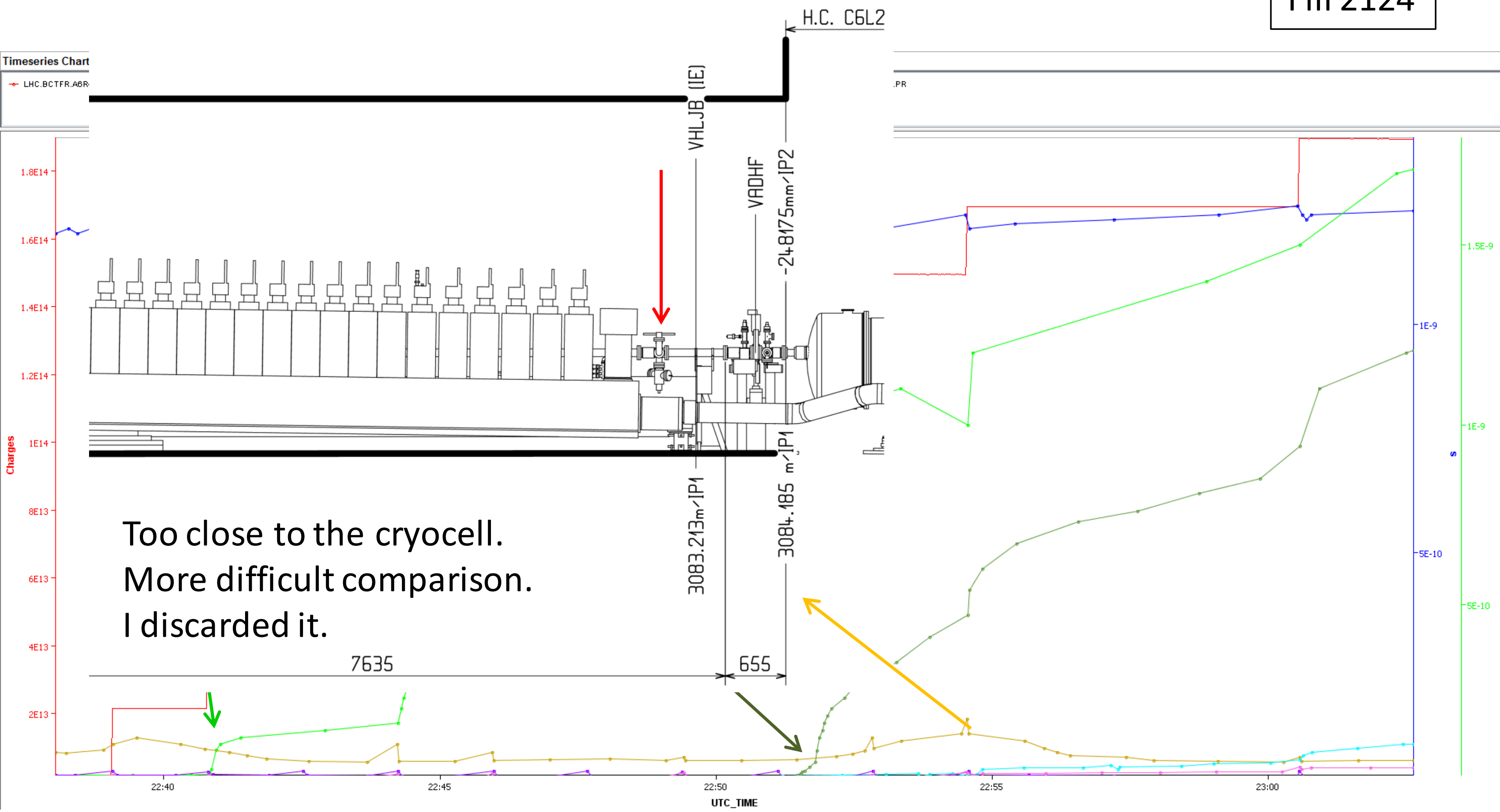
  - 2736: 16 June 2012 ($N_b \approx 1.47e11$ ppb)
  - 3000: 24 August 2012 ($N_b \approx 1.52e11$ ppb)
  - 3286: 14 November 2012 ($N_b \approx 1.65e11$ ppb)

  Three random long physics fills during 2012 operation

- I'll show some observations of 25 ns for the 24/10/11 MD

ΔP with 25 and 50 ns - Injection

Fill 2124

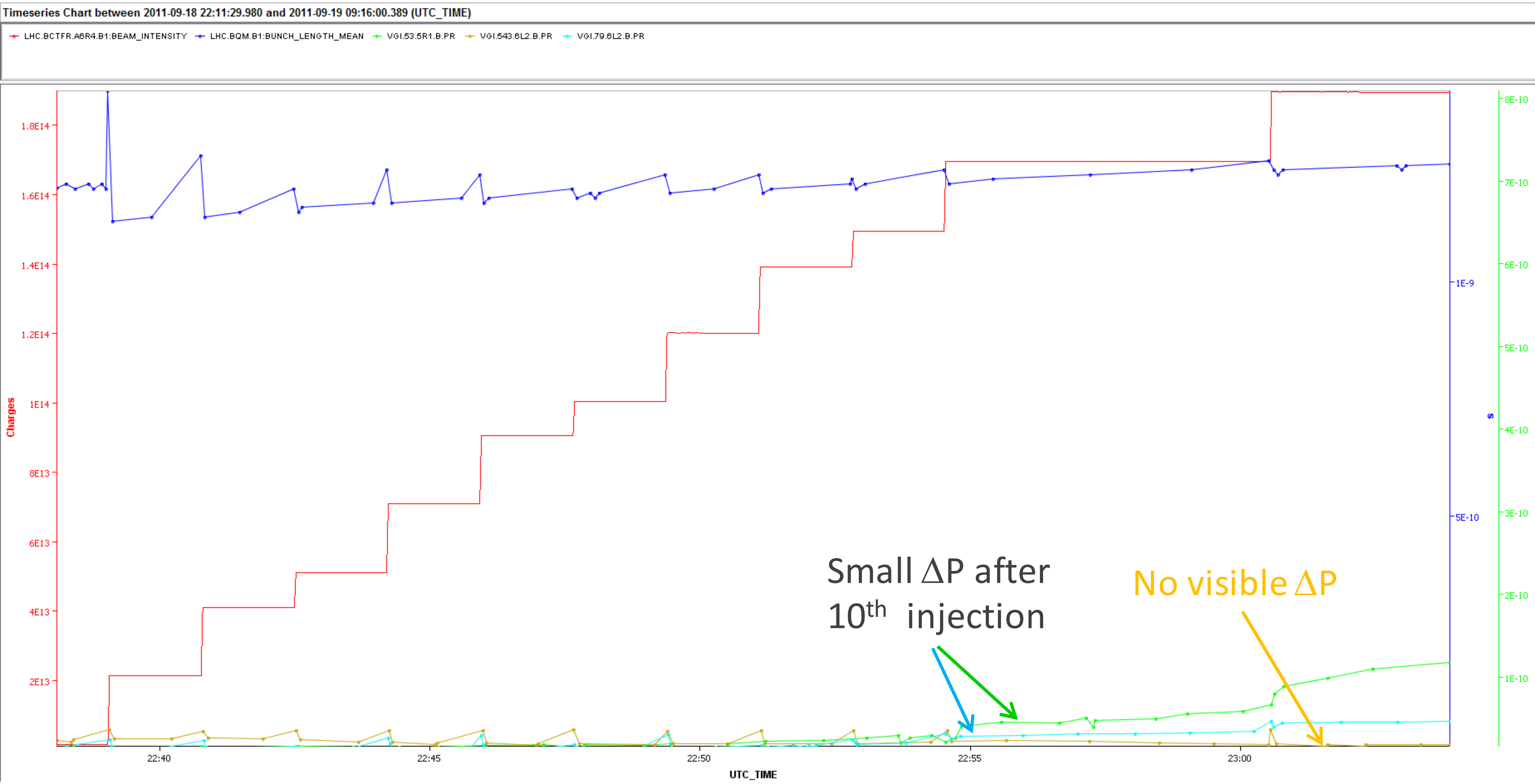


Too close to the cryocell.
More difficult comparison.
I discarded it.

ΔP with 25 and 50 ns - Injection

Sector 1-2

Fill 2124



We observe different behaviors → Different conditioning states?

ΔP with 25 and 50 ns - Injection

Sector 1-2

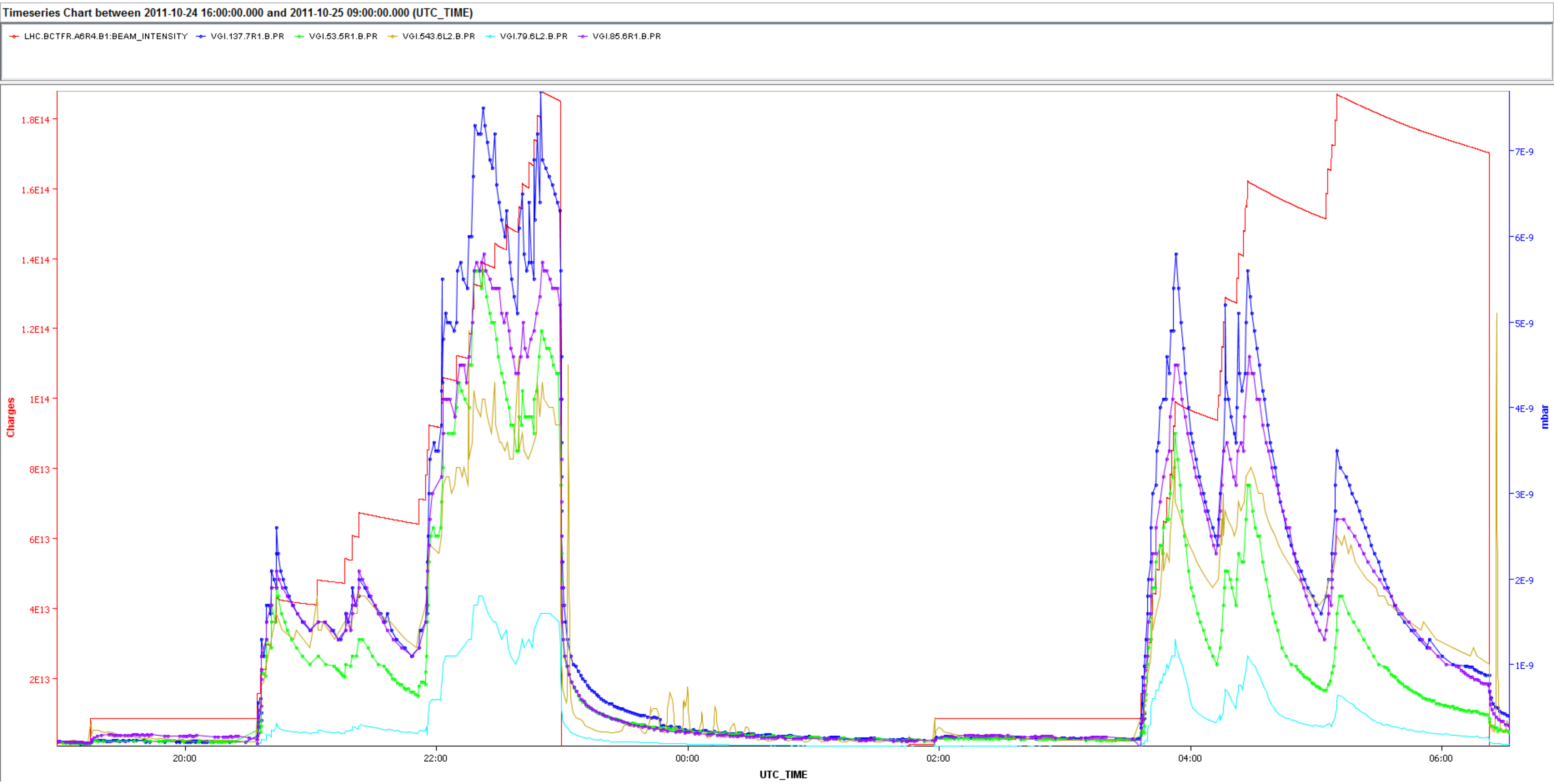
Fill 2240

There is a visible conditioning effect after the MD on 14 October with 25 ns

ΔP with 25 and 50 ns - Injection

Sector 1-2

MD 24 October 2011 – 25 ns

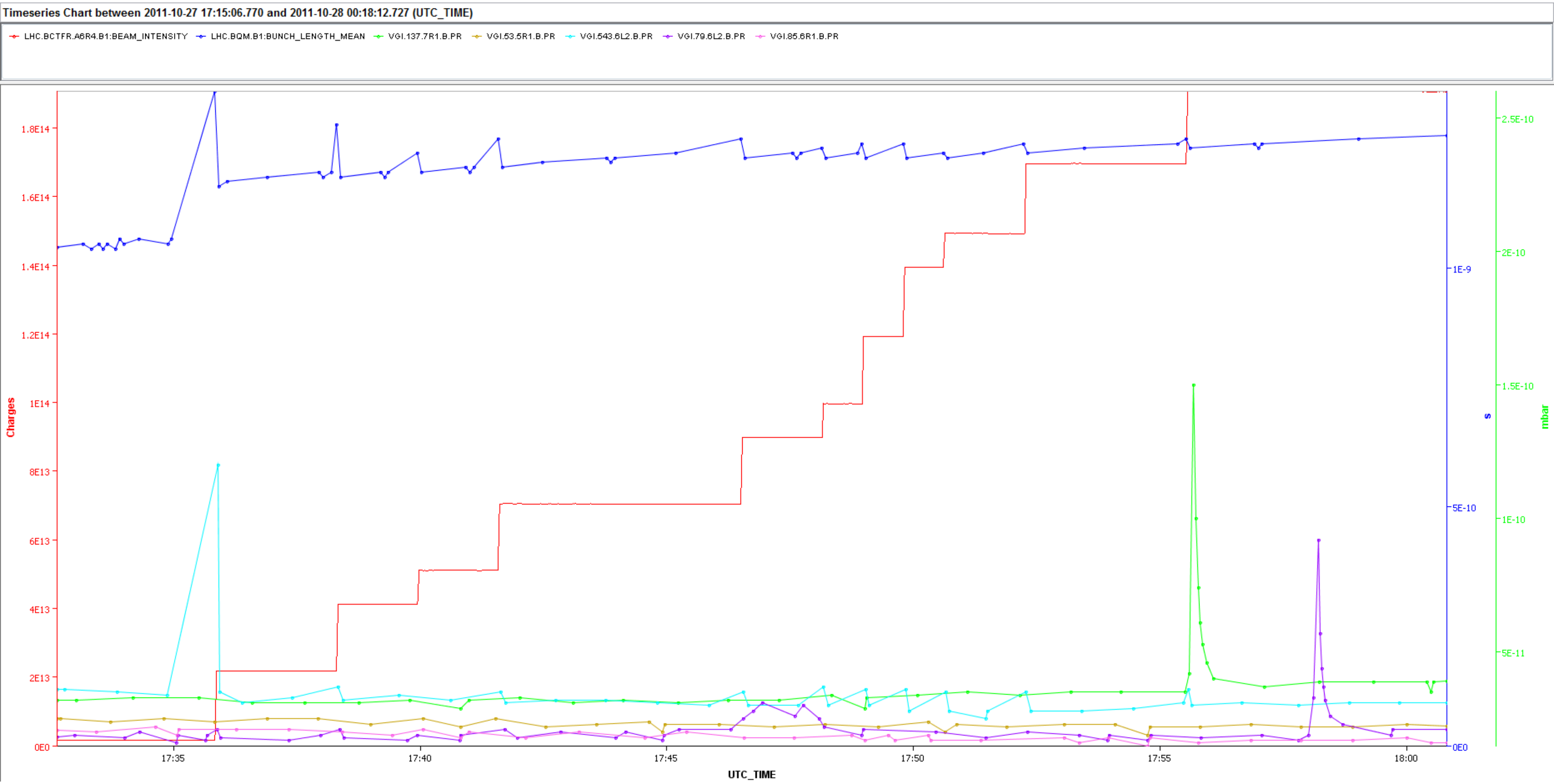


With 25 ns we observe ΔP in all the gauges

ΔP with 25 and 50 ns - Injection

Sector 1-2

Fill 2261

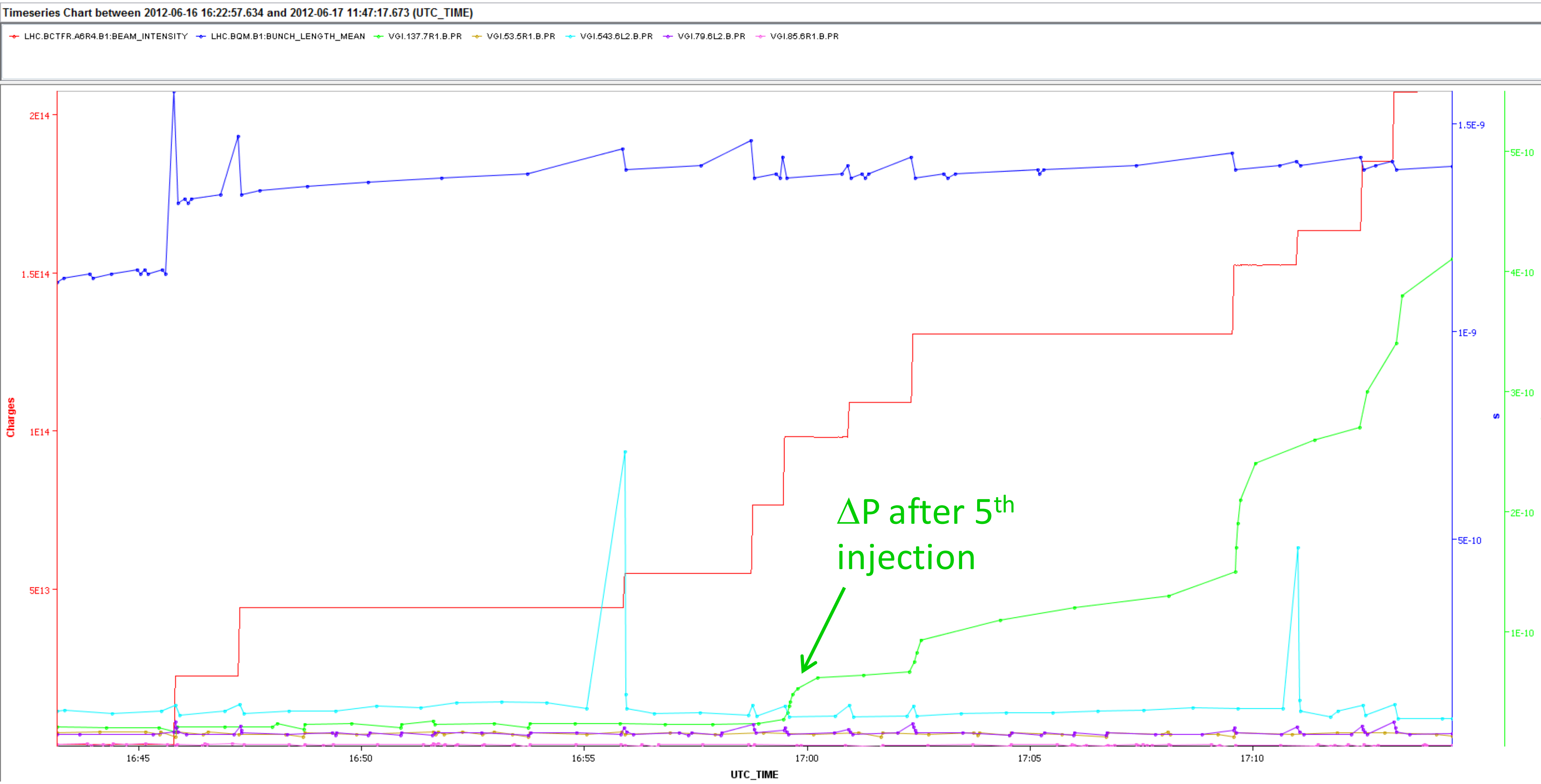


No e-cloud related ΔP observed in any of the gauges → Clear improvement after conditioning

ΔP with 25 and 50 ns - Injection

Sector 1-2

Fill 2736

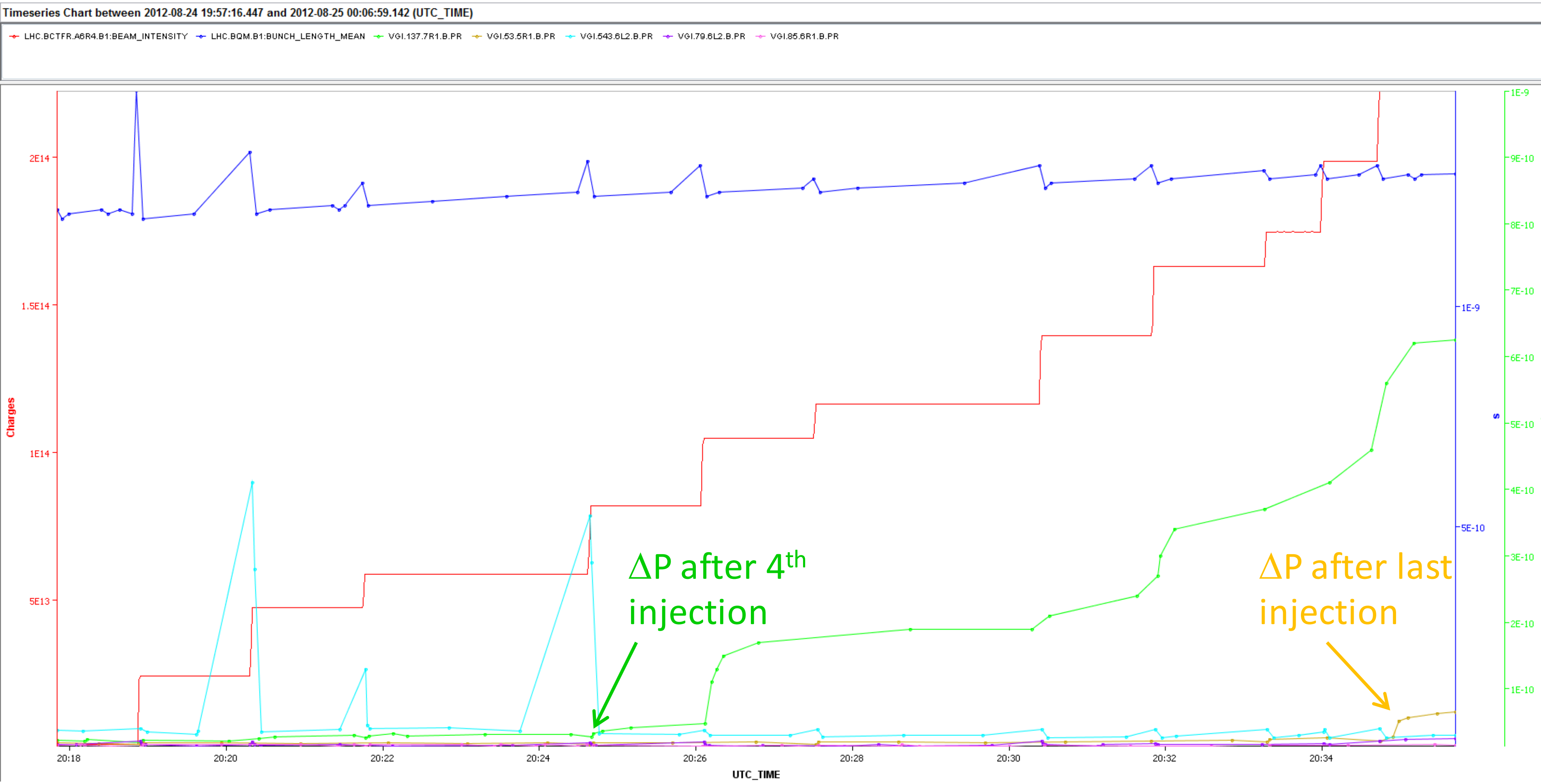


Nb≈$1.47 \cdot 10^{11}$ ppb, but looking at the thresholds it seems that some deconditioning took place in gauge VGI.137.7R1.B

ΔP with 25 and 50 ns - Injection

Sector 1-2

Fill 3000

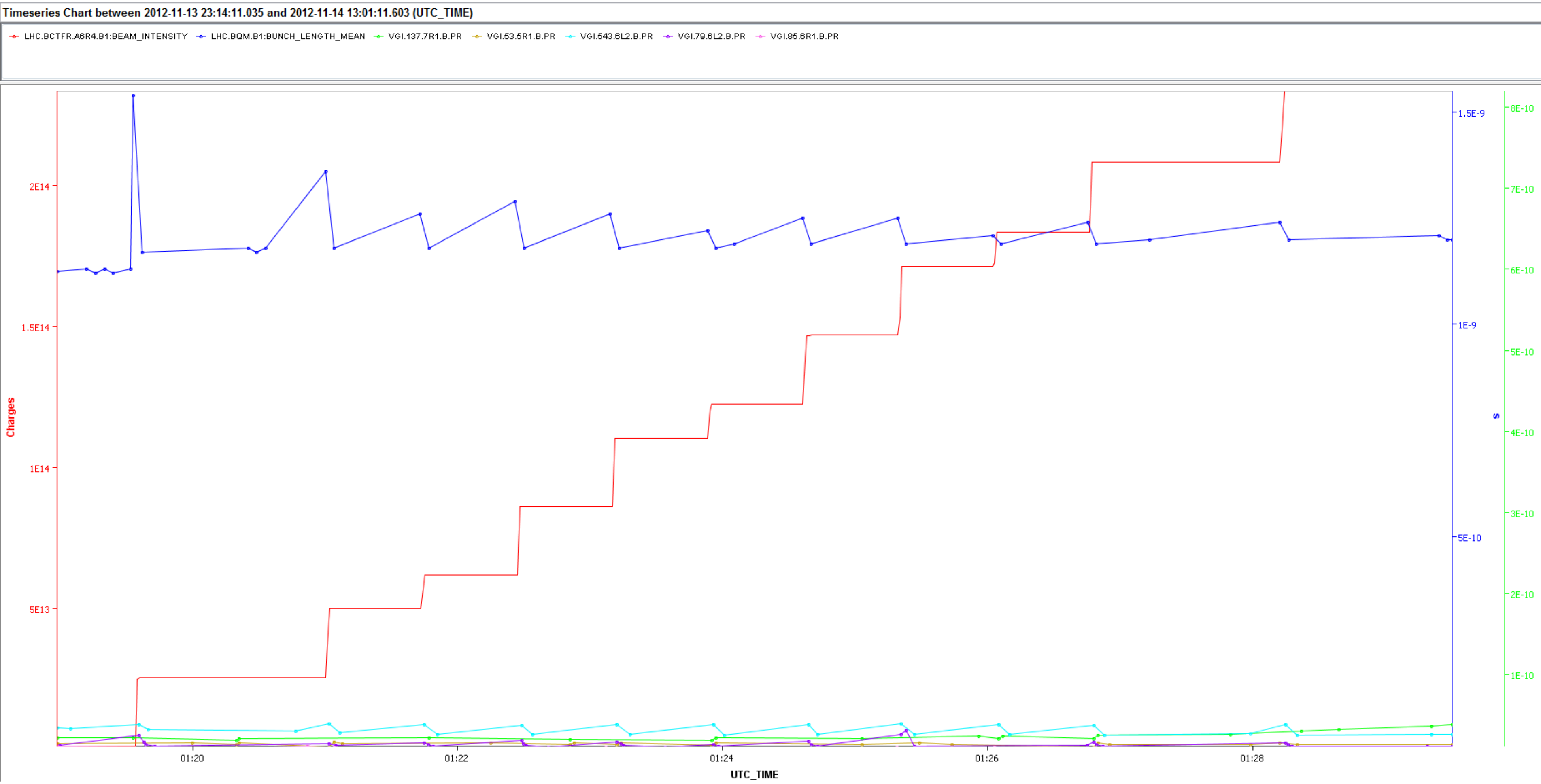


$N_b \approx 1.52 \cdot 10^{11}$ ppb, $\Delta P_{Fill3000} > \Delta P_{Fill2736}$ → some deconditioning without 25 ns beams?

ΔP with 25 and 50 ns - Injection

Sector 1-2

Fill 3286

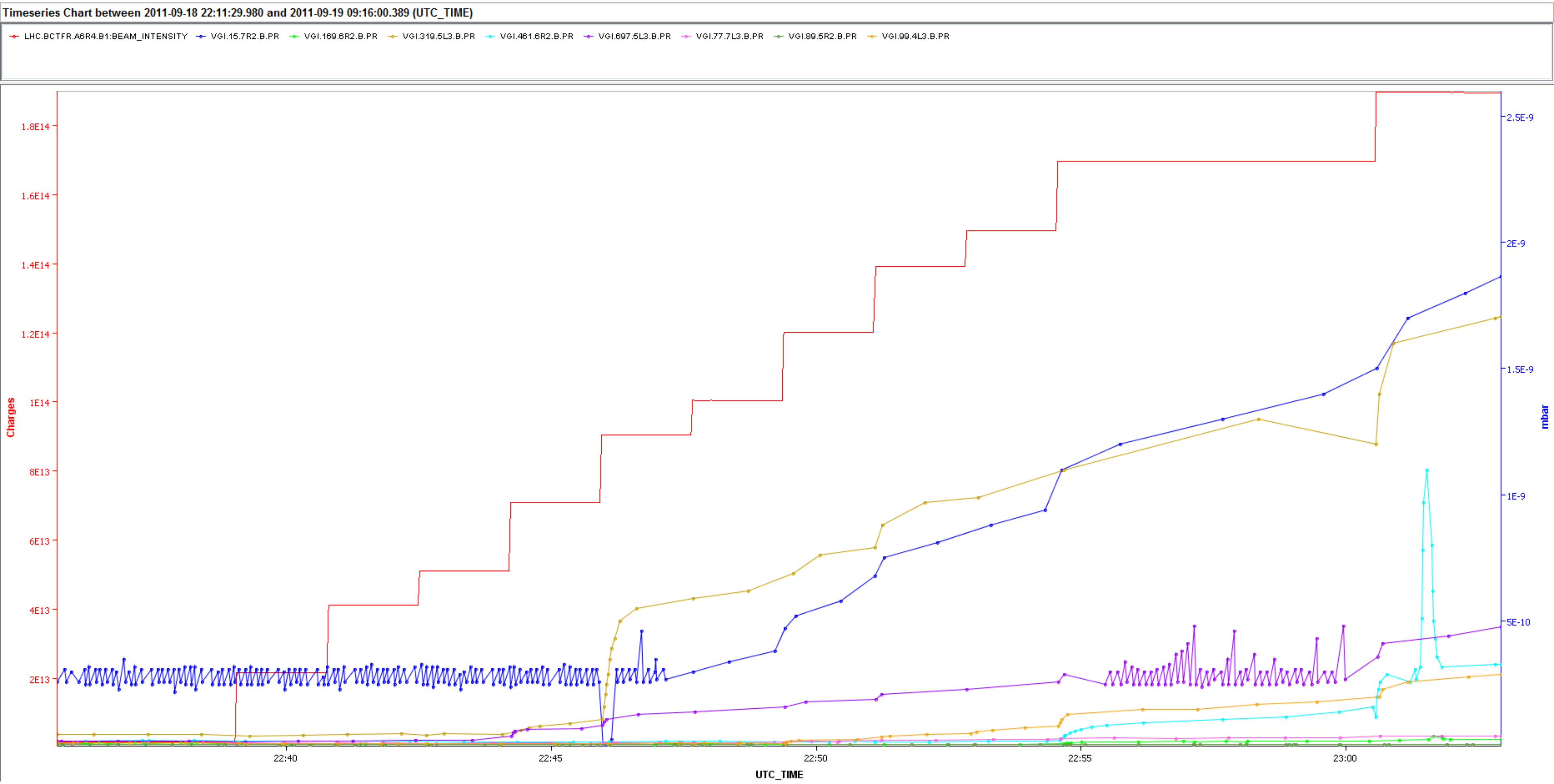


Nb≈1.65·10^{11} ppb. It has a higher threshold. All gauges must be below this threshold

ΔP with 25 and 50 ns - Injection

Sector 2-3

Fill 2124

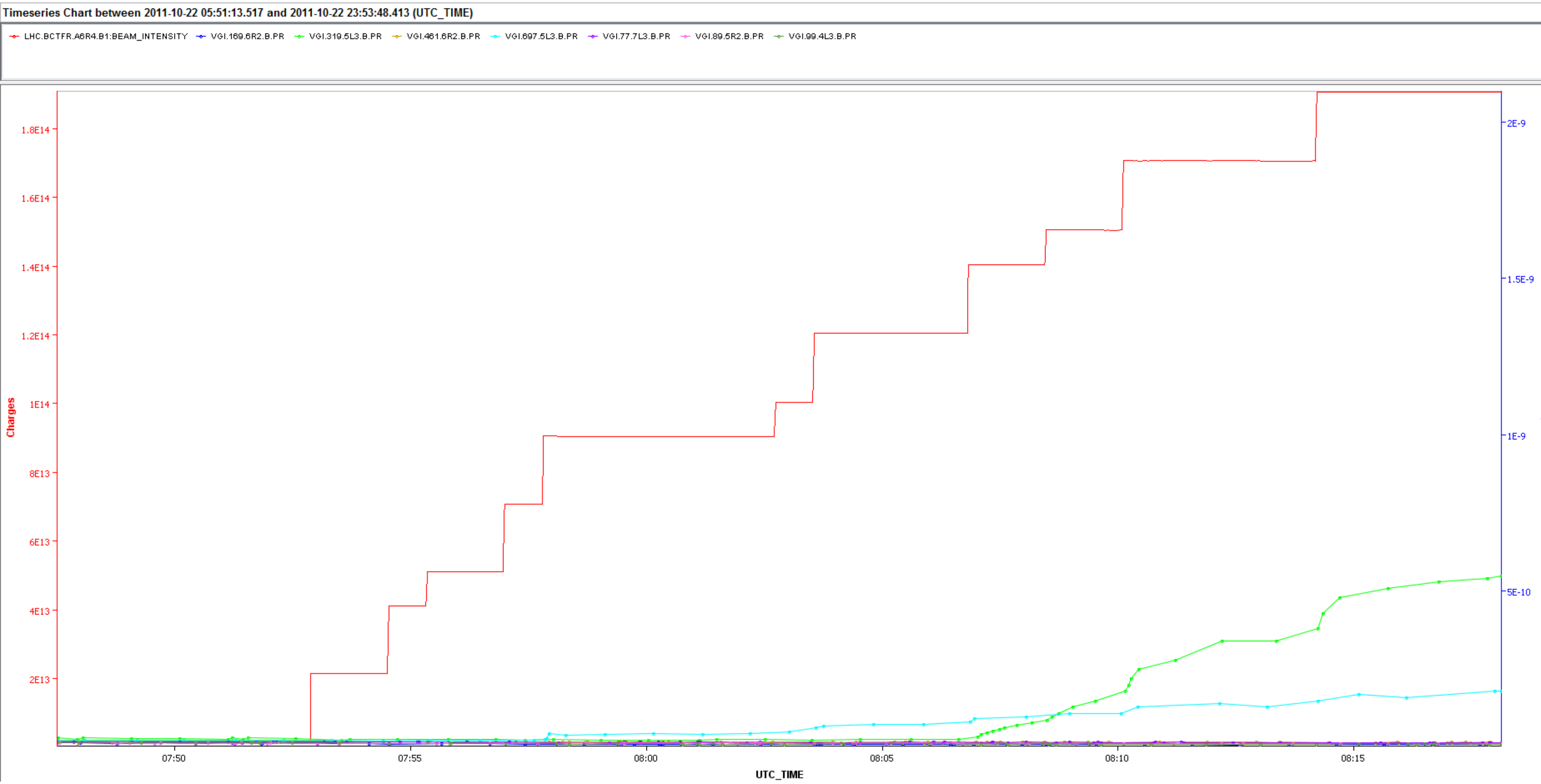


Similar behavior as in sector 1-2

ΔP with 25 and 50 ns - Injection

Sector 2-3

Fill 2240

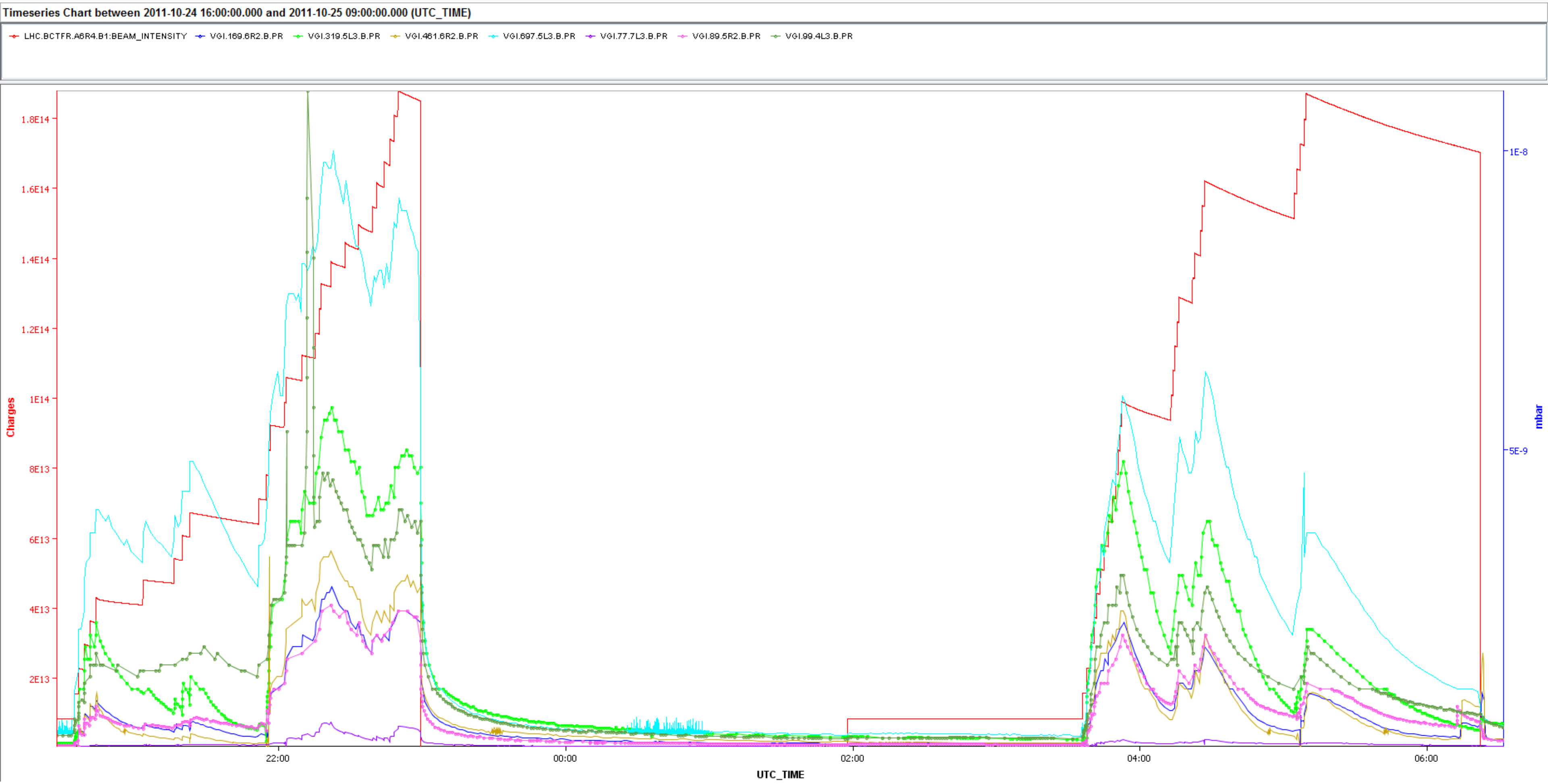


Similar behavior as in sector 1-2 (some conditioning observed after MD with 25 ns)

ΔP with 25 and 50 ns - Injection

Sector 2-3

MD 24 October 2011 – 25 ns

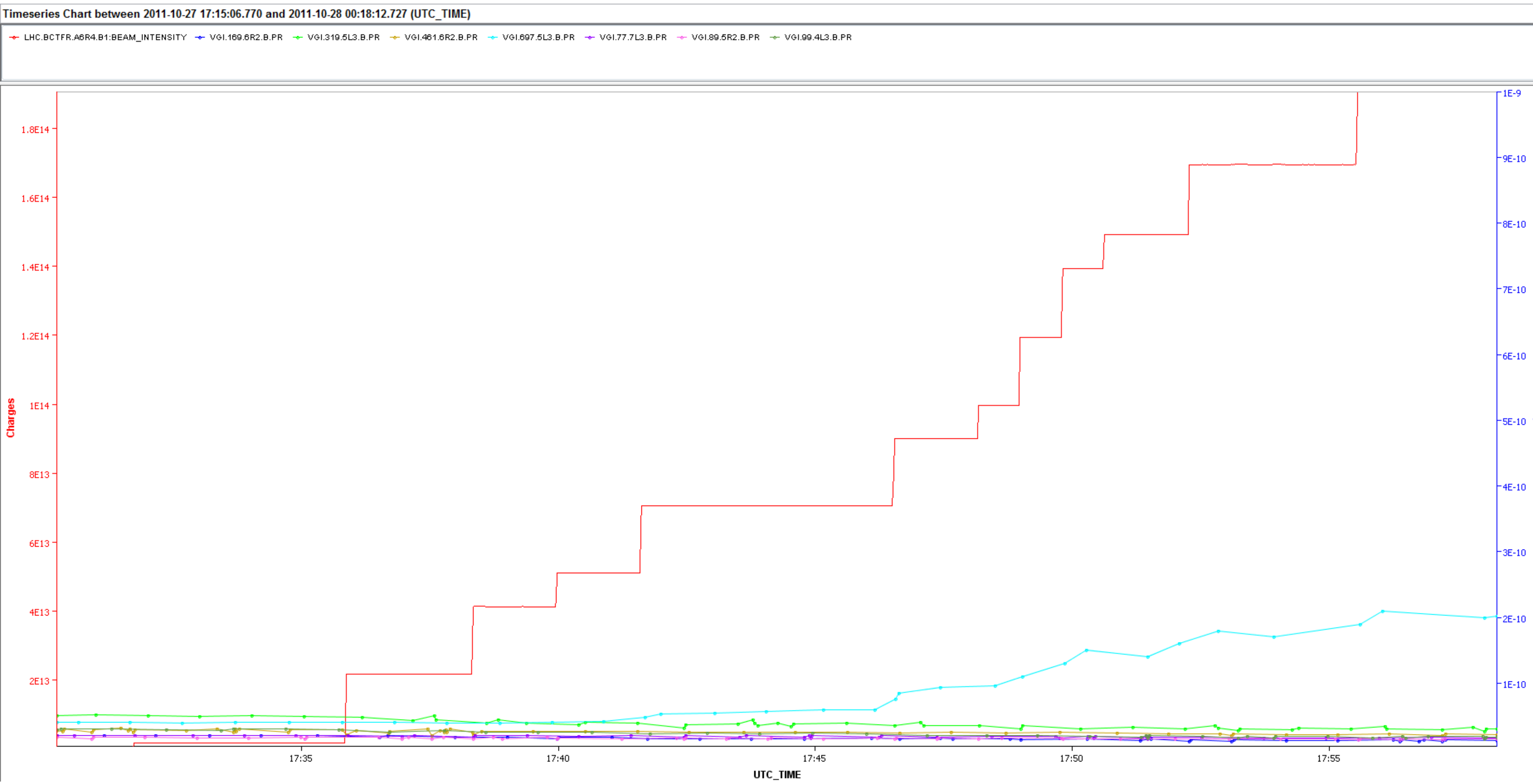


Again, with 25 ns we observe ΔP in all the gauges

ΔP with 25 and 50 ns - Injection

Sector 2-3

Fill 2261



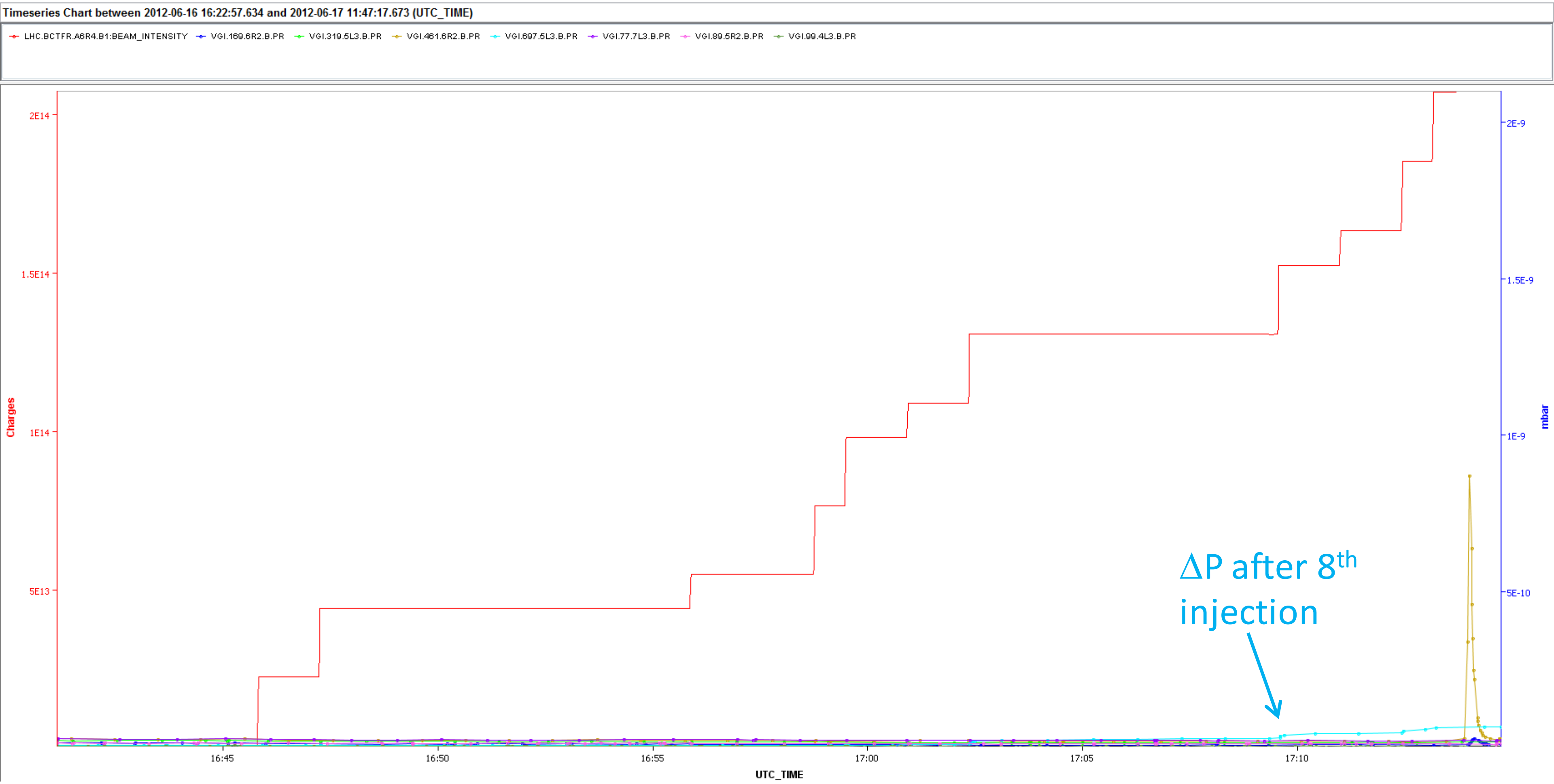
Again, conditioning observed after MDs with 25 ns.

Not enough to condition gauge VGI.697.5L3.B below the 50 ns threshold

ΔP with 25 and 50 ns - Injection

Sector 2-3

Fill 2736

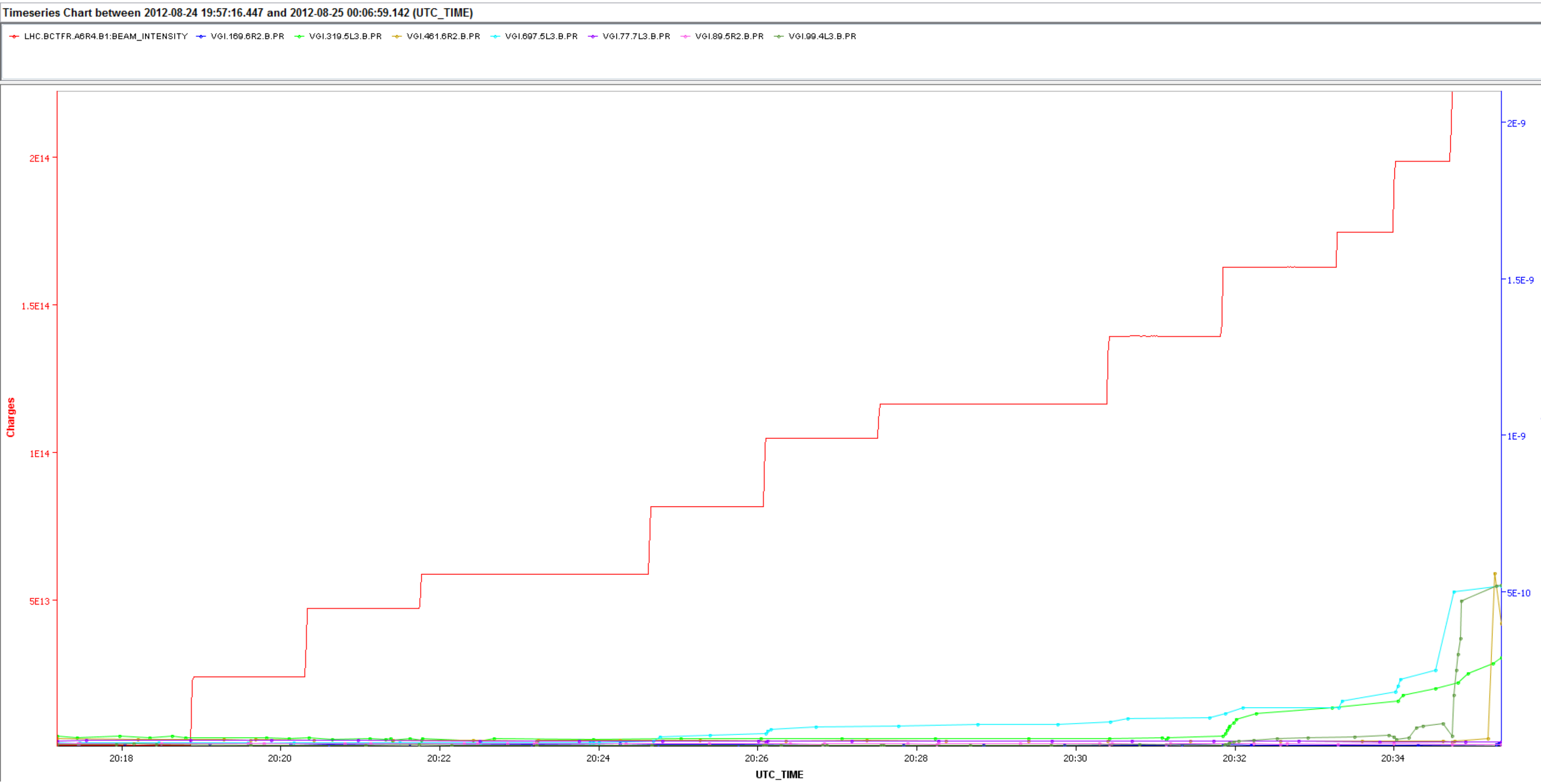


Gauge VGI.697.5L3.B looks better conditioned than before!

ΔP with 25 and 50 ns - Injection

Sector 2-3

Fill 3000

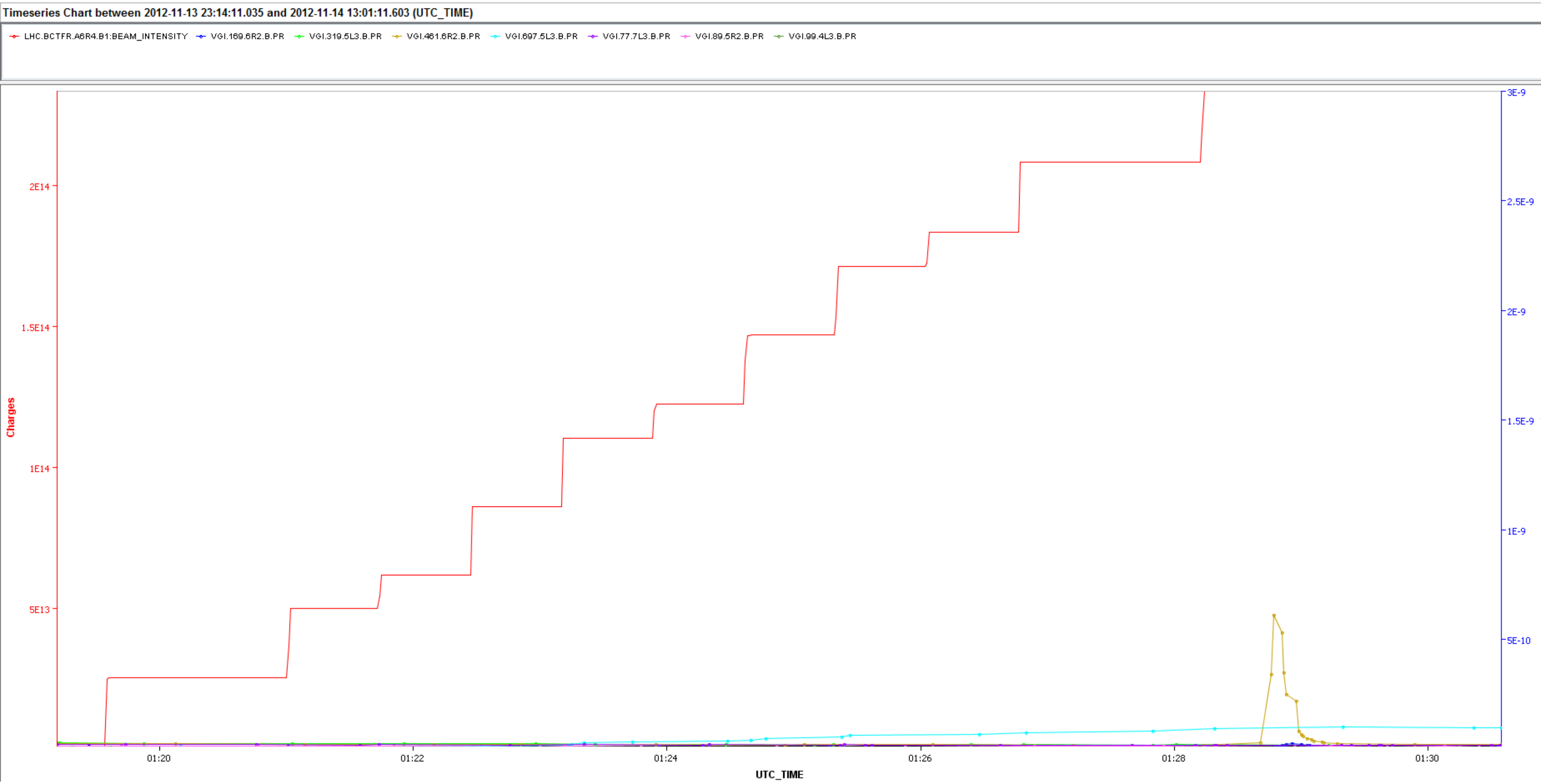


Nb≈$1.52 \cdot 10^{11}$ ppb, $\Delta P_{Fill3000} > \Delta P_{Fill2736}$ → some deconditioning without 25 ns beams?

ΔP with 25 and 50 ns - Injection

Sector 2-3

Fill 3286

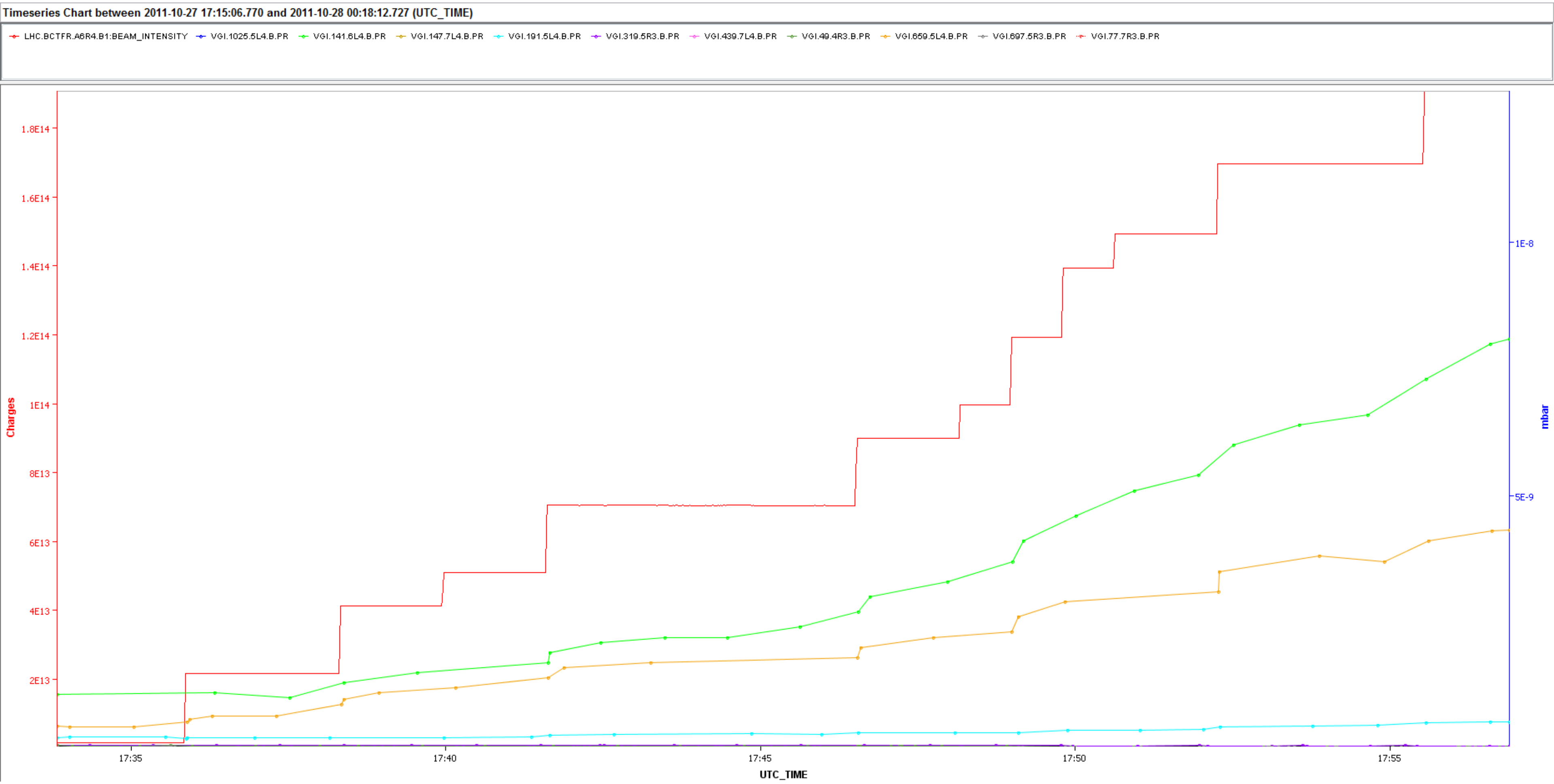


Nb≈$1.65 \cdot 10^{11}$ ppb. It has a higher threshold. Still some ΔP visible for VGI.697.5L3.B

ΔP with 25 and 50 ns - Injection

Sector 3-4

Fill 2261

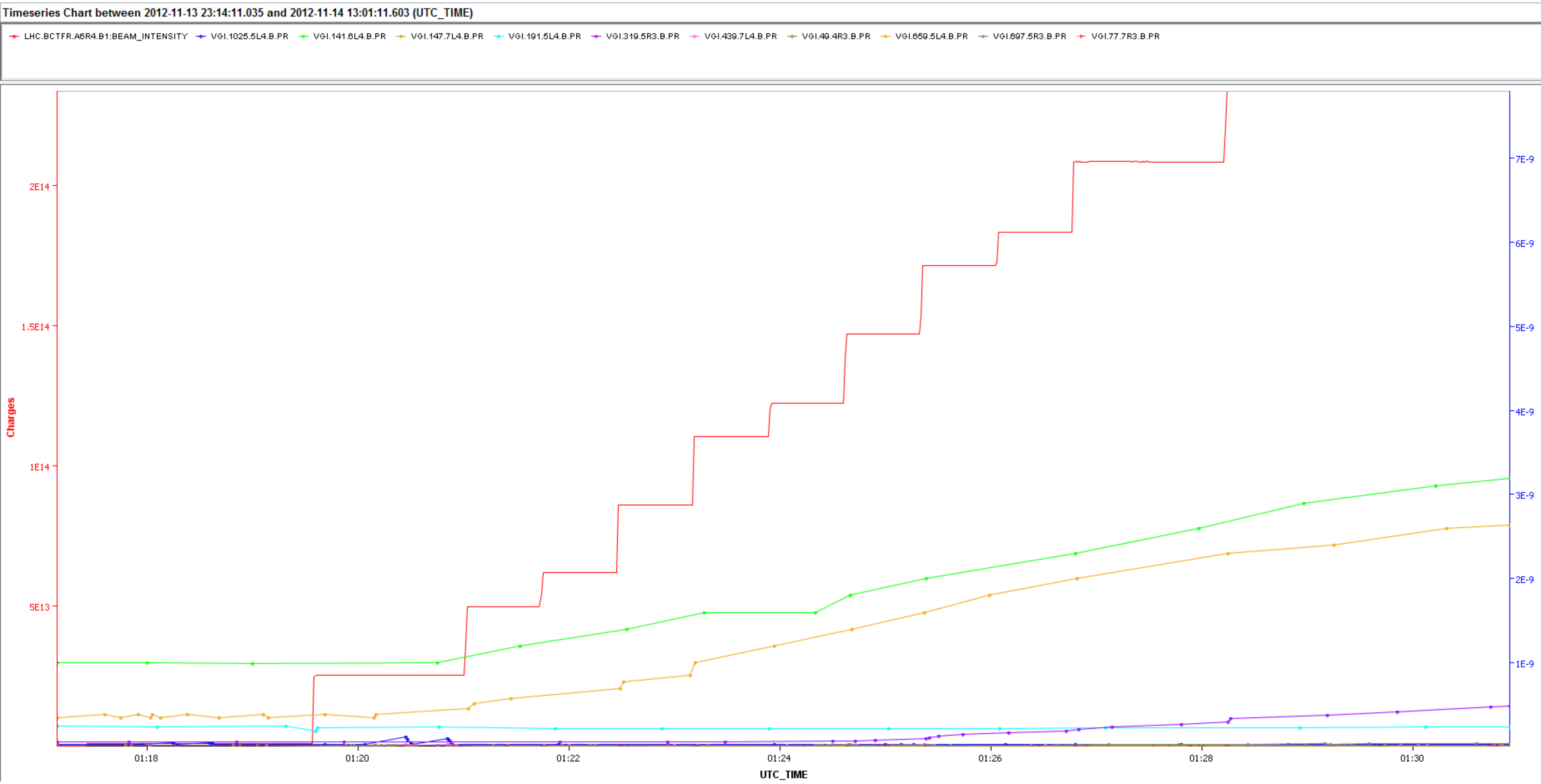


After the 25ns MDs, there are two gauges still showing large ΔP

ΔP with 25 and 50 ns - Injection

Sector 3-4

Fill 3286

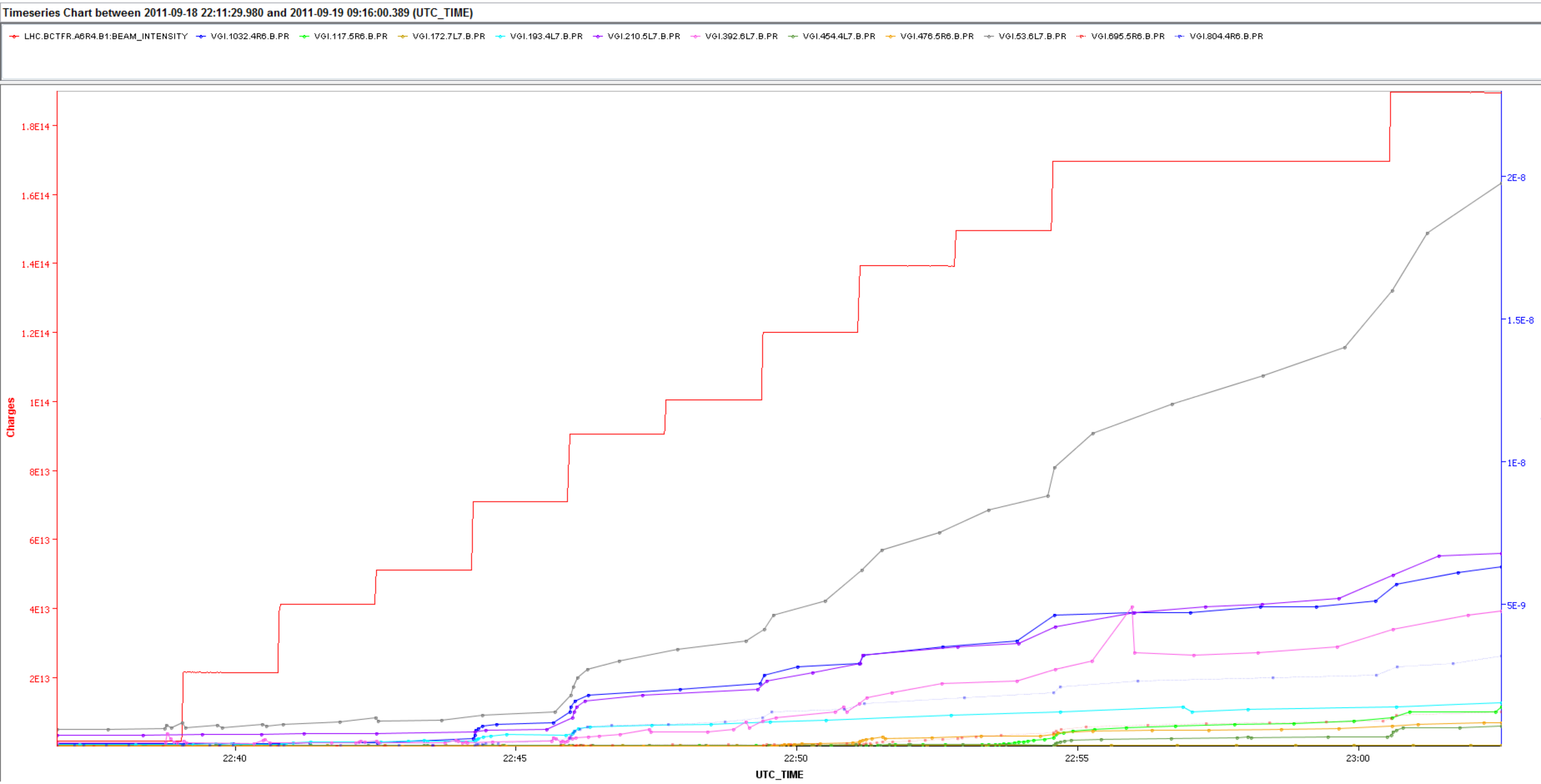


Nb≈$1.65 \cdot 10^{11}$ ppb. It has a higher threshold, but still some gauges show ΔP

ΔP with 25 and 50 ns - Injection

Sector 6-7

Fill 2124

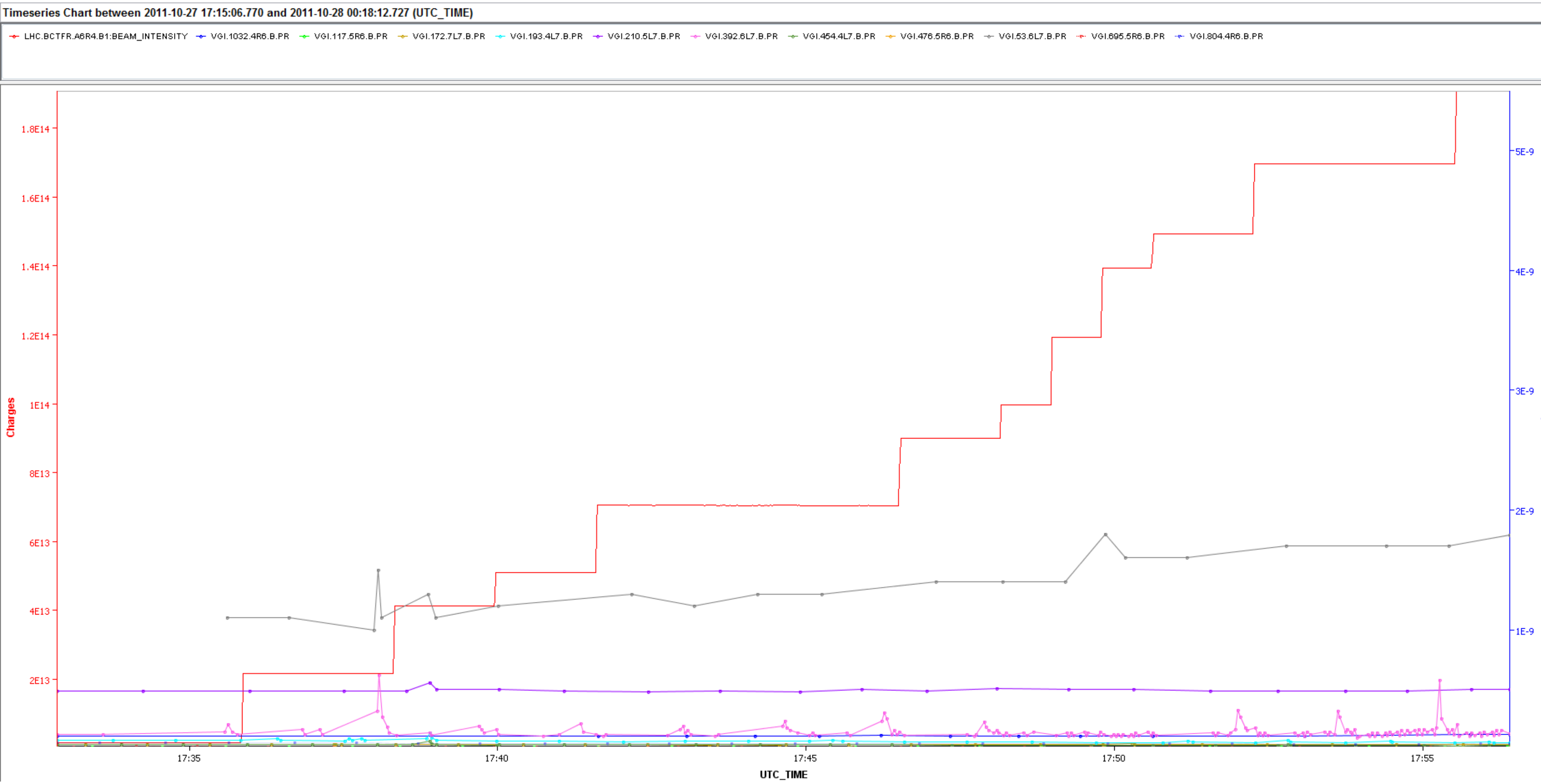


Almost all gauges show ΔP before the 25 ns MDs

ΔP with 25 and 50 ns - Injection

Sector 6-7

Fill 2261



No visible ΔP after the 25 ns MDs → Enhanced conditioning in sector 6-7?

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1) Pressure rise observations with 25 and 50 ns beams

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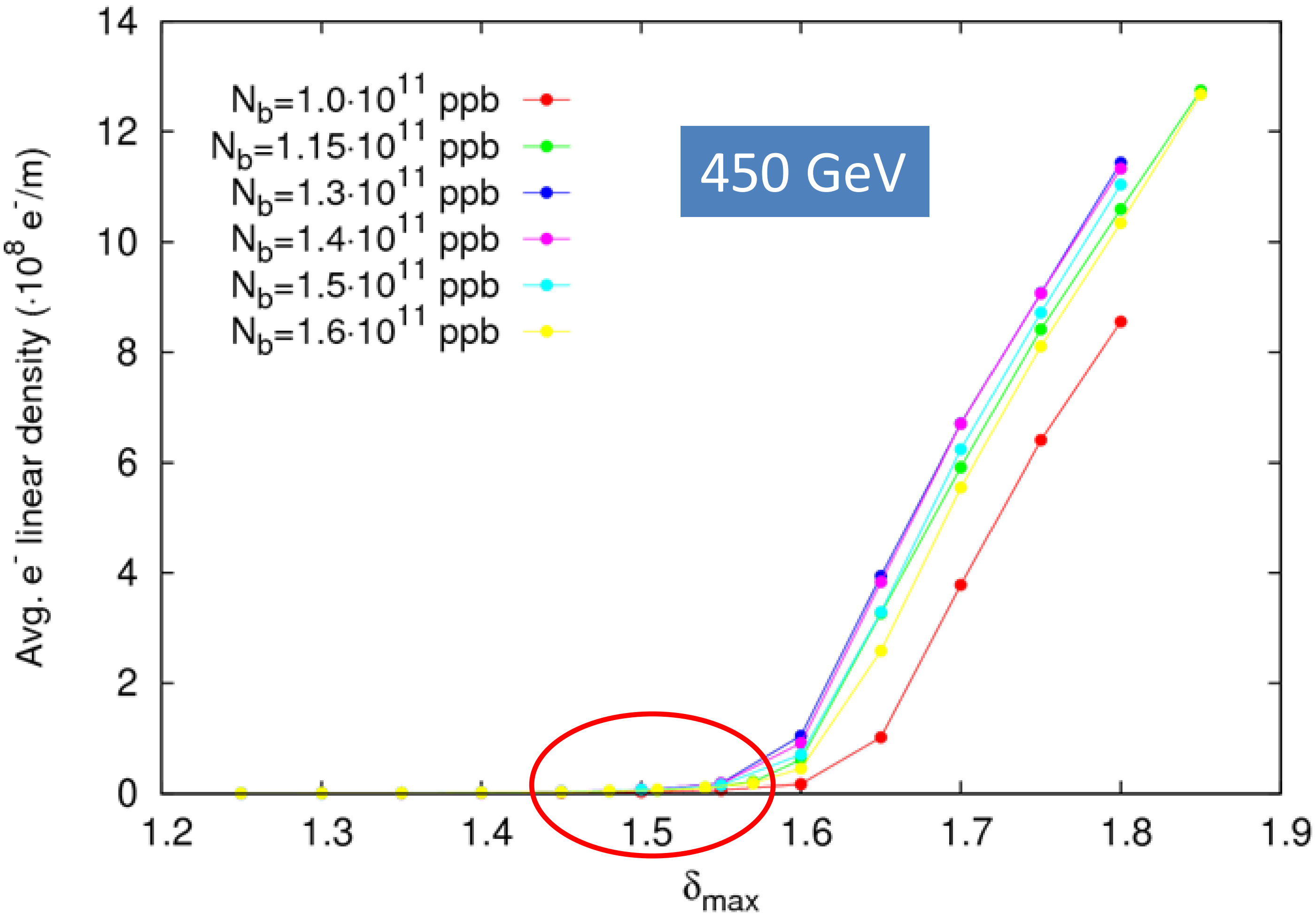
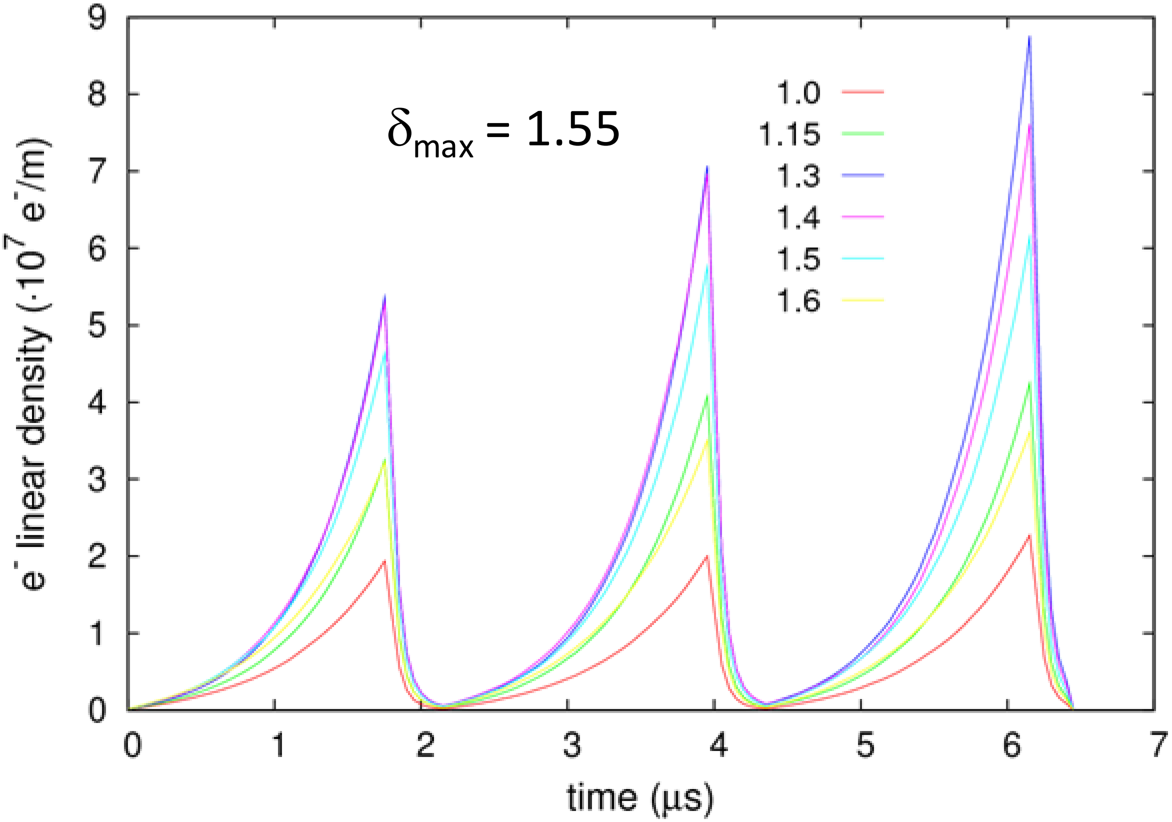
50 ns – N_b threshold



- Maximum activity for N_b=1.3-1.4
- Thresholds around $\delta_{max} \approx 1.45 - 1.55$

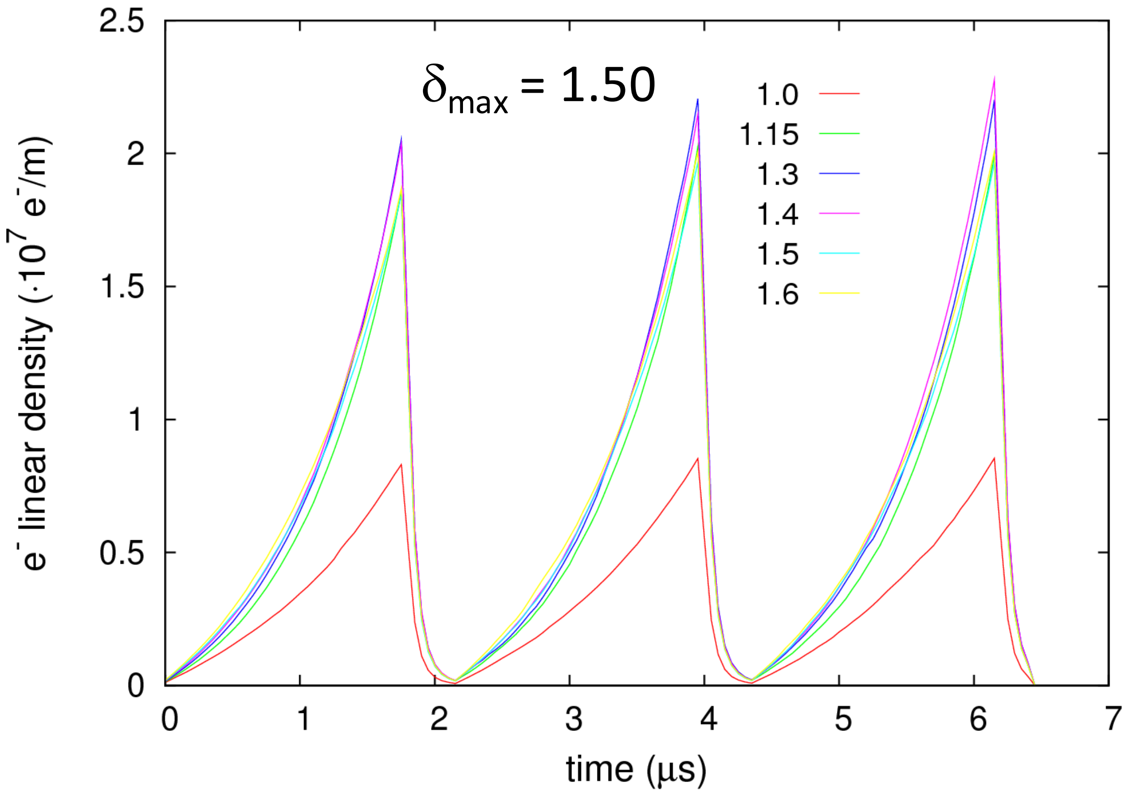
50 ns - Thresholds

450 GeV



$\delta_{max,thres} < 1.55$

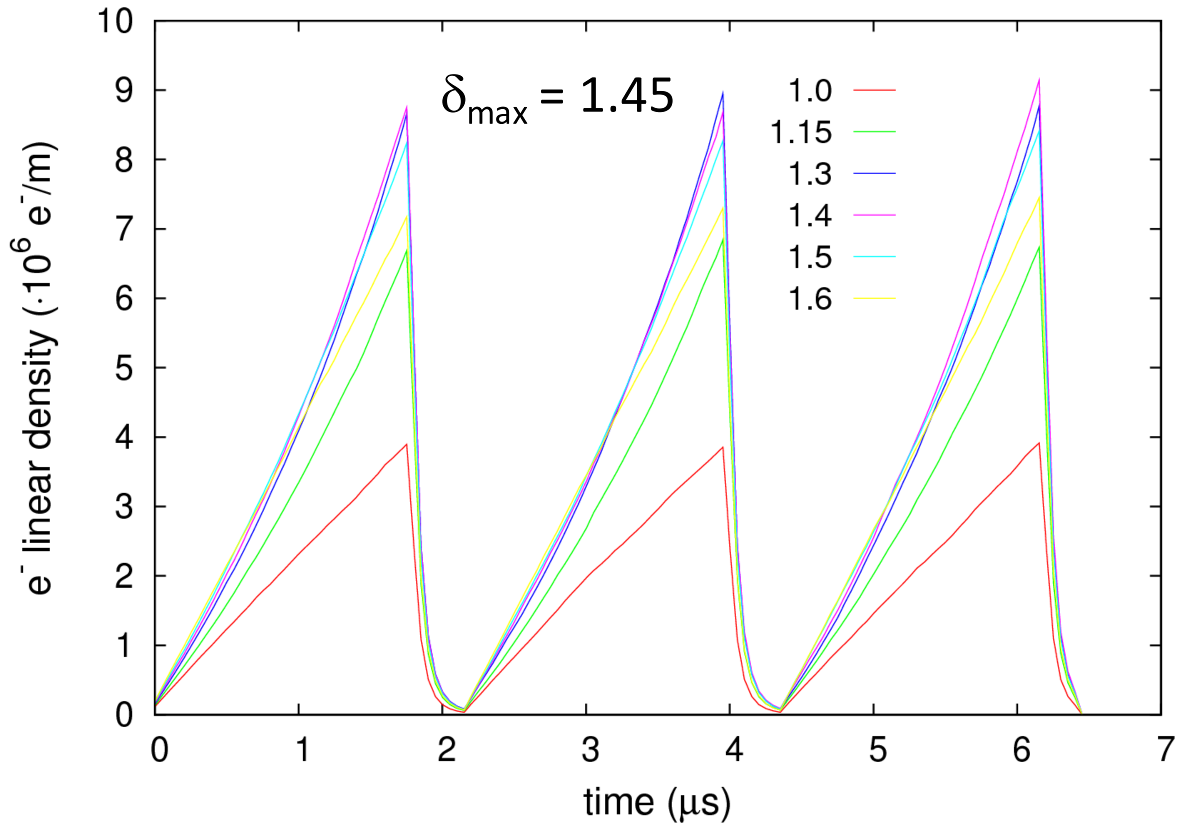
450 GeV



$\delta_{max,thres}$ < 1.50 for N_b=1.3-1.4

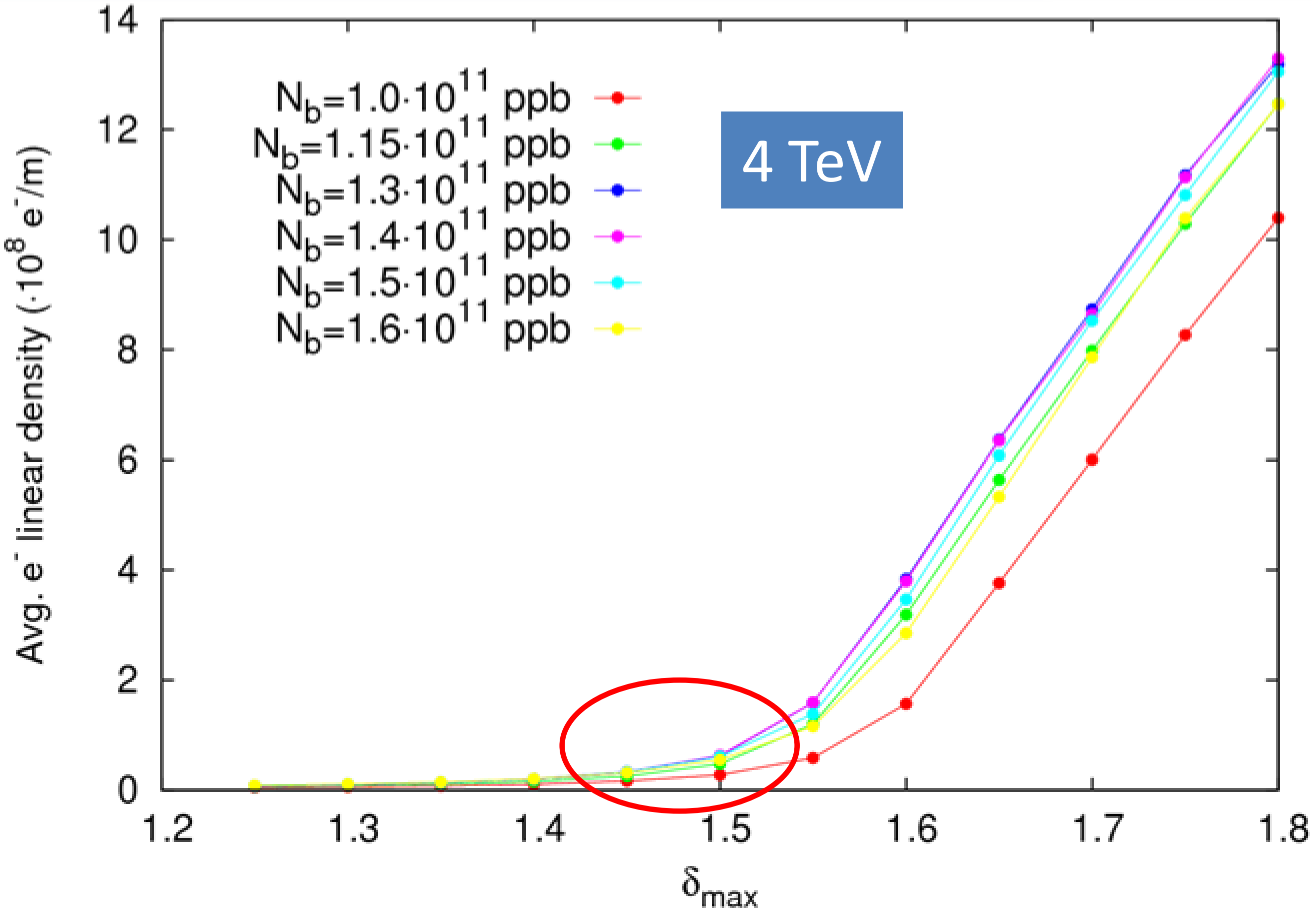
$\delta_{max,thres}$ ≈ 1.50 for N_b=1.0,1.15, 1.5 and 1.6

450 GeV



$\delta_{max,thres} \approx 1.45$ for N_b=1.3-1.4

50 ns – N_b threshold



- Maximum activity for N_b=1.3-1.4
- Thresholds around $\delta_{max} \approx 1.45 - 1.55$
- N.B: The PY* has been reduced by a factor 10 to better assess de multipactig threshold

50 ns - Thresholds

Nb ($\cdot 10^{11}$ ppb)	$\delta_{max,thres}$ (450 GeV)	$\delta_{max,thres}$ (4 TeV)
1.0	1.50	1.50
1.15	1.50	1.45
1.3	1.45	1.45
1.4	1.45	1.45
1.5	1.50	1.45
1.6	1.50	1.50

ε_{max}=230 eV

$\sigma_{z,450\ GeV}$= 10 cm

$\sigma_{z,4\ TeV}$= 9.5 cm

ε_x= 2.4 μm

ε_y= 2.9 μm

Ø = 80 mm

- The maximum e-cloud activity occurs at N_b = 1.3-1.4 $\cdot 10^{11}$ ppb.
- Why $\Delta P_{Fill3000}$> $\Delta P_{Fill2736}$ in most gauges → some deconditioning without 25 ns beams?
- Thresholds are quite similar for all bunch populations.
- Despite a stronger activity at 4 TeV (photoelectrons), threshold values are very similar at both energies

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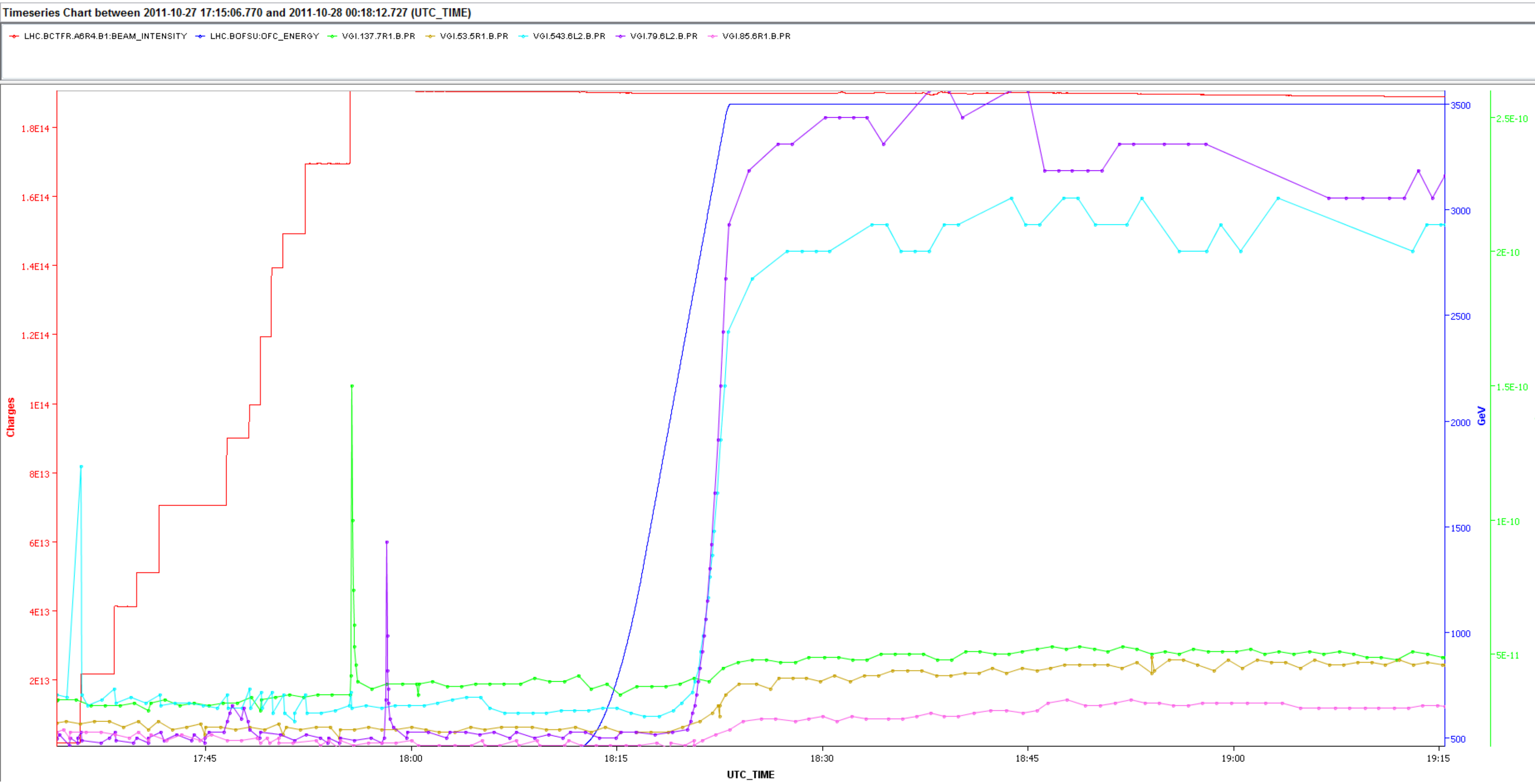
Pre-ramp and ramp

Sector 1-2

Fill 2261

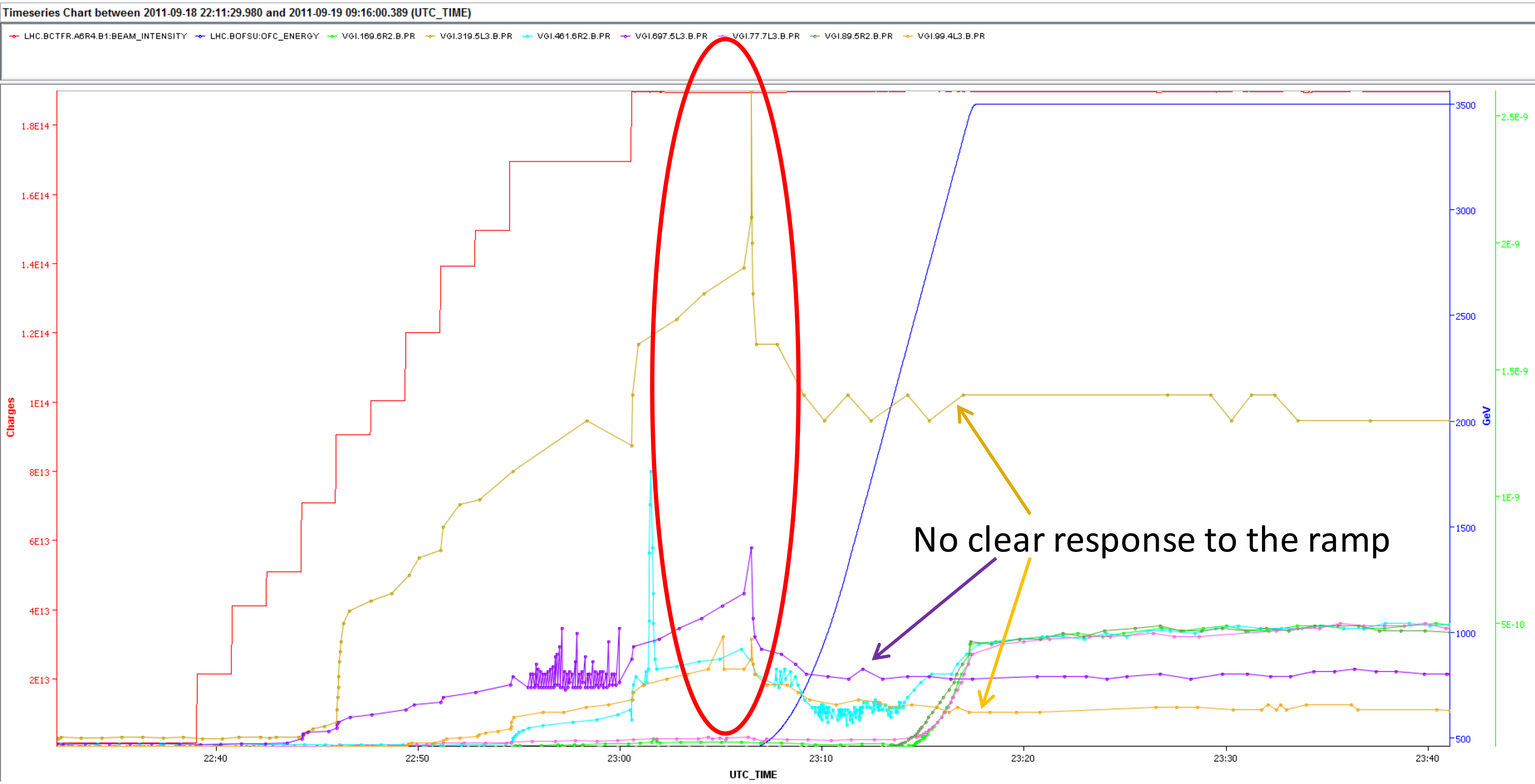


In this example, none of the gauges exhibit ΔP during injection and all detect some ΔP during the ramp (at about 2.4 TeV)

Pre-ramp and ramp

Sector 2-3

Fill 2124

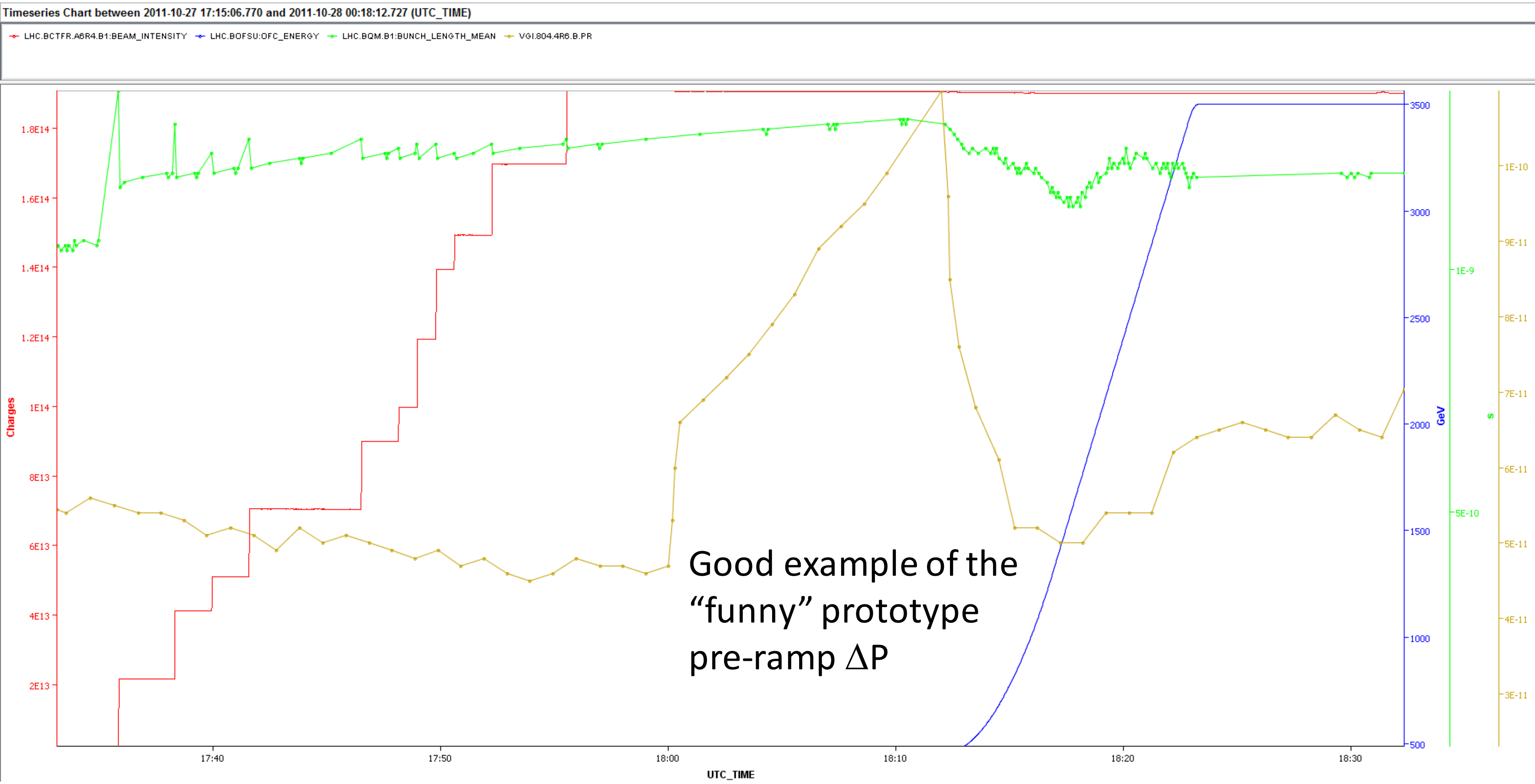


- Not all gauges show a response to the ramp (especially the most active at injection)!
- "Funny" ΔP behavior before the ramp

Pre-ramp and ramp

Gauge VGI.804.4R6.B in sector 6-7

Fill 2261



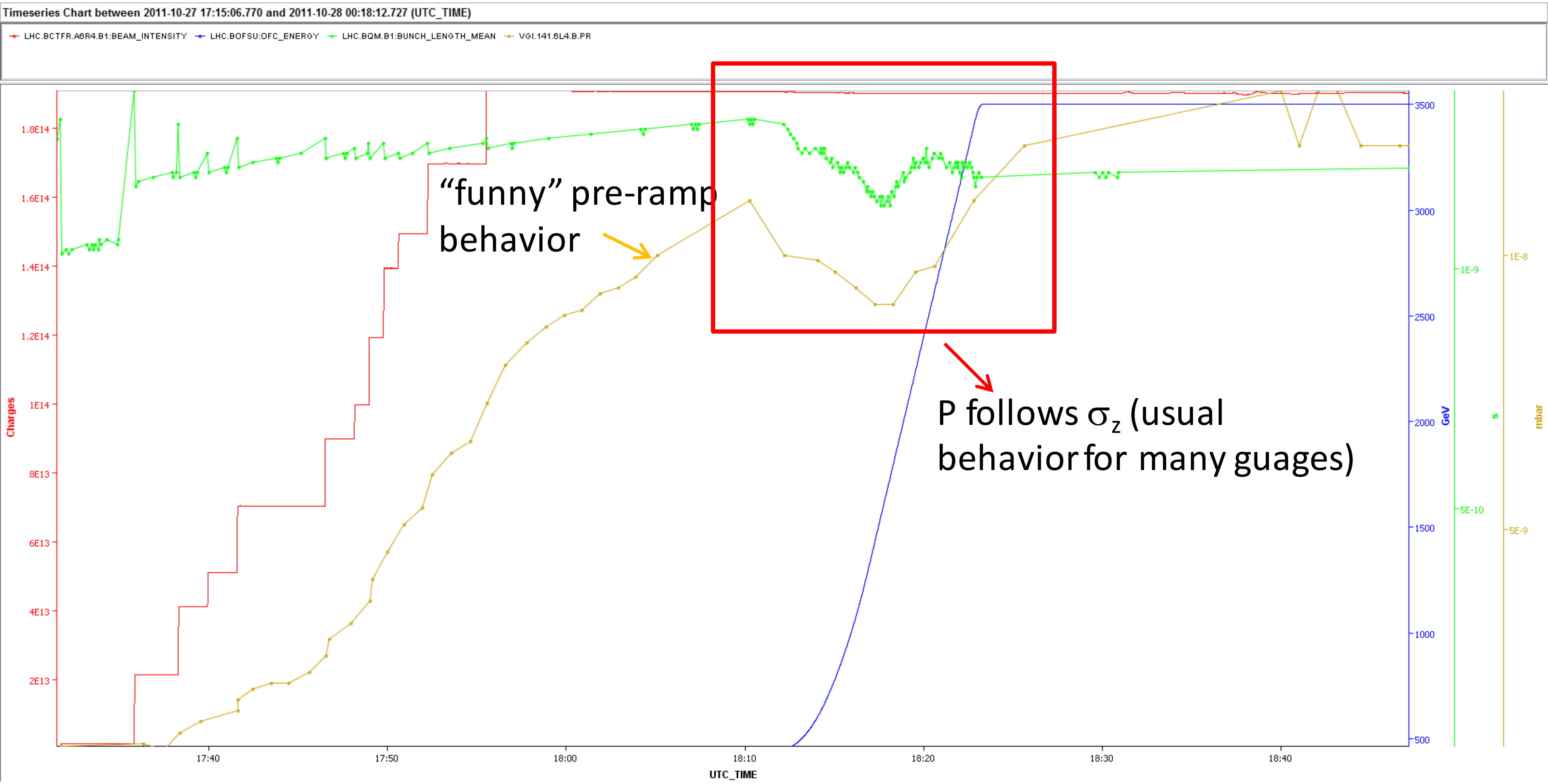
Good example of the "funny" prototype pre-ramp ΔP

No e-cloud signs during injection and suddenly, before the ramp, there is an important ΔP

Pre-ramp and ramp

Gauge VGI.141.6L4.B in sector 3-4

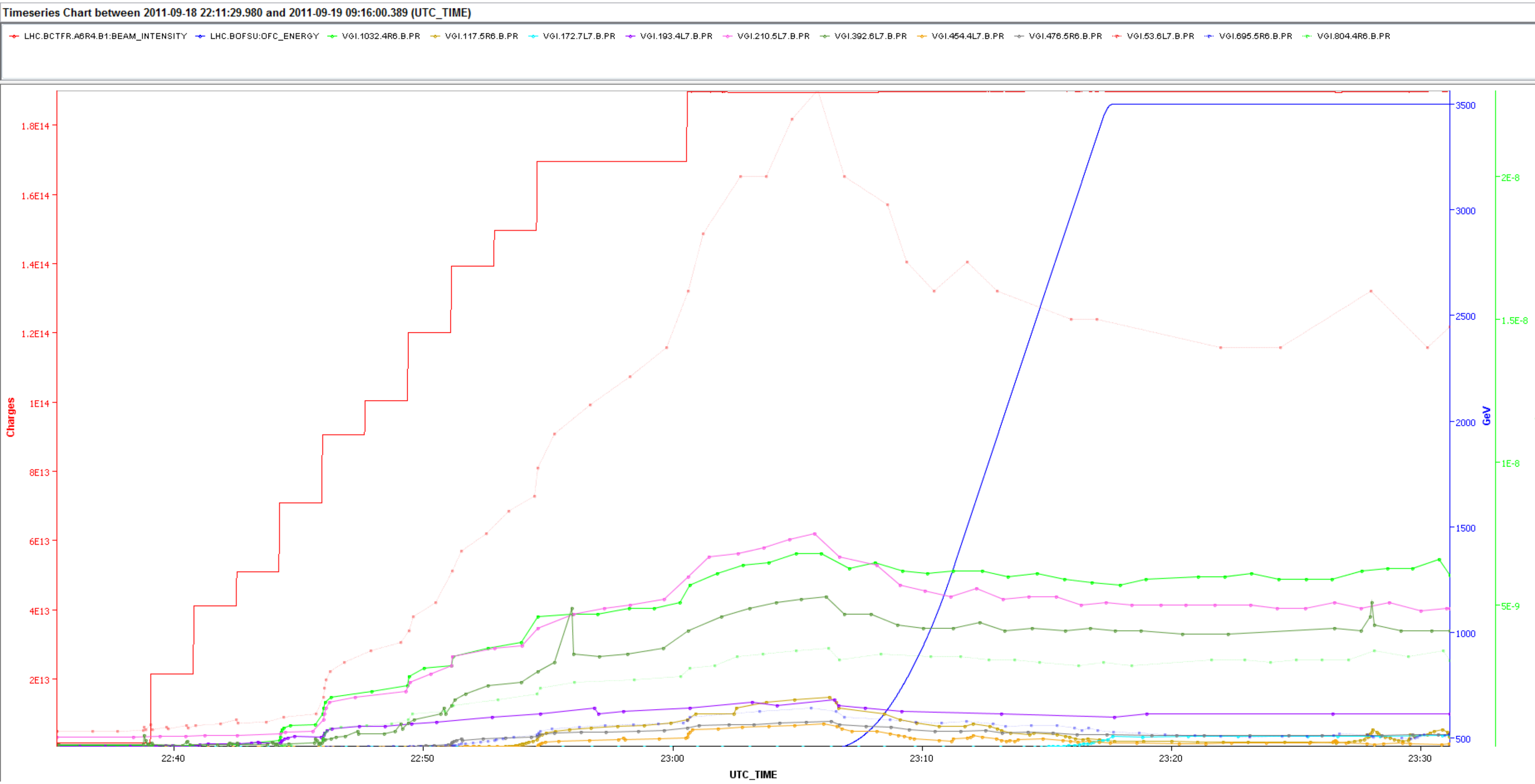
Fill 2124



Pre-ramp and ramp

Sector 6-7

Fill 2124

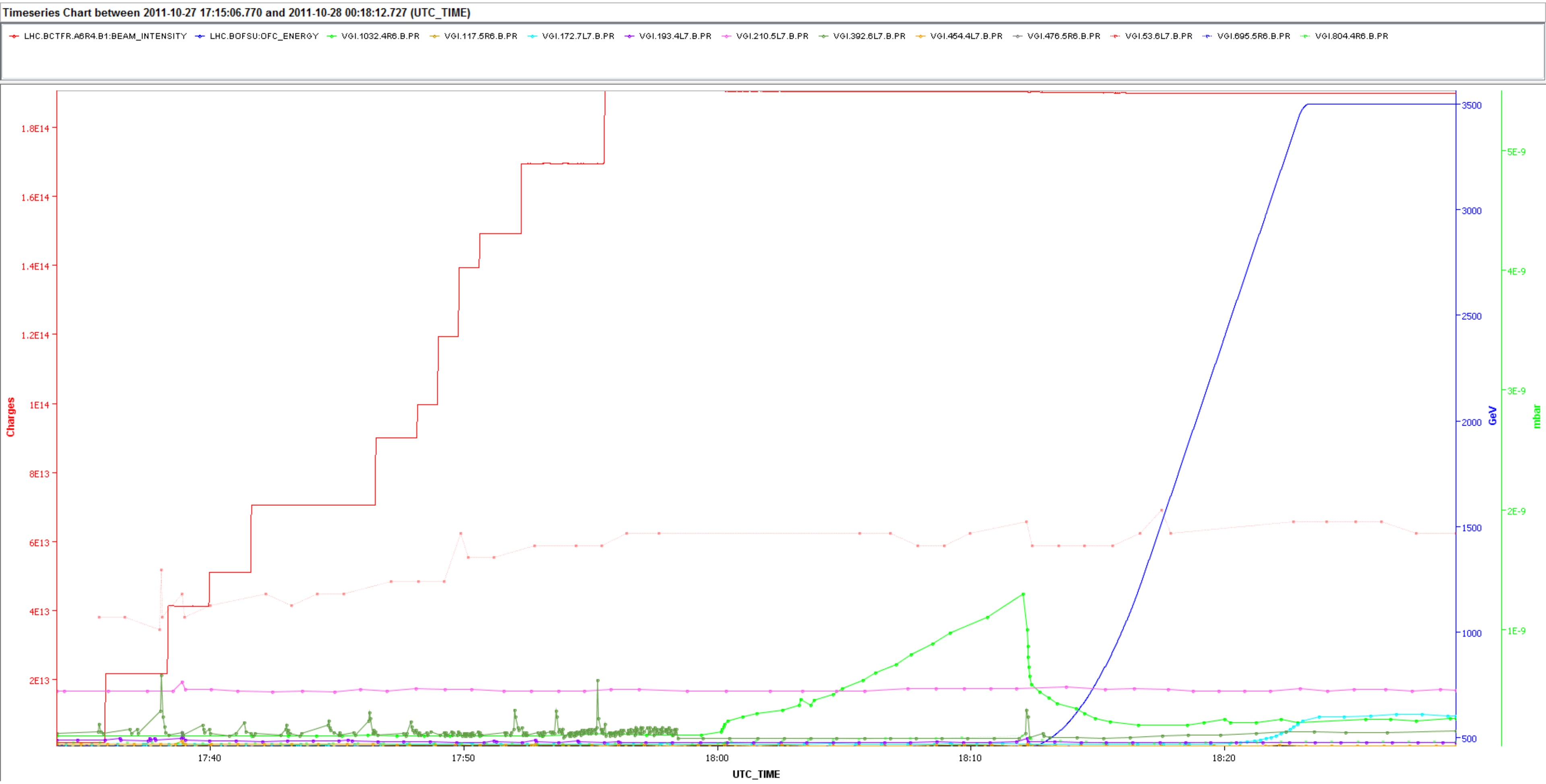


No effect during the energy ramp! (only a bit for gauge VGI.172.7L7.B)

Pre-ramp and ramp

Sector 6-7

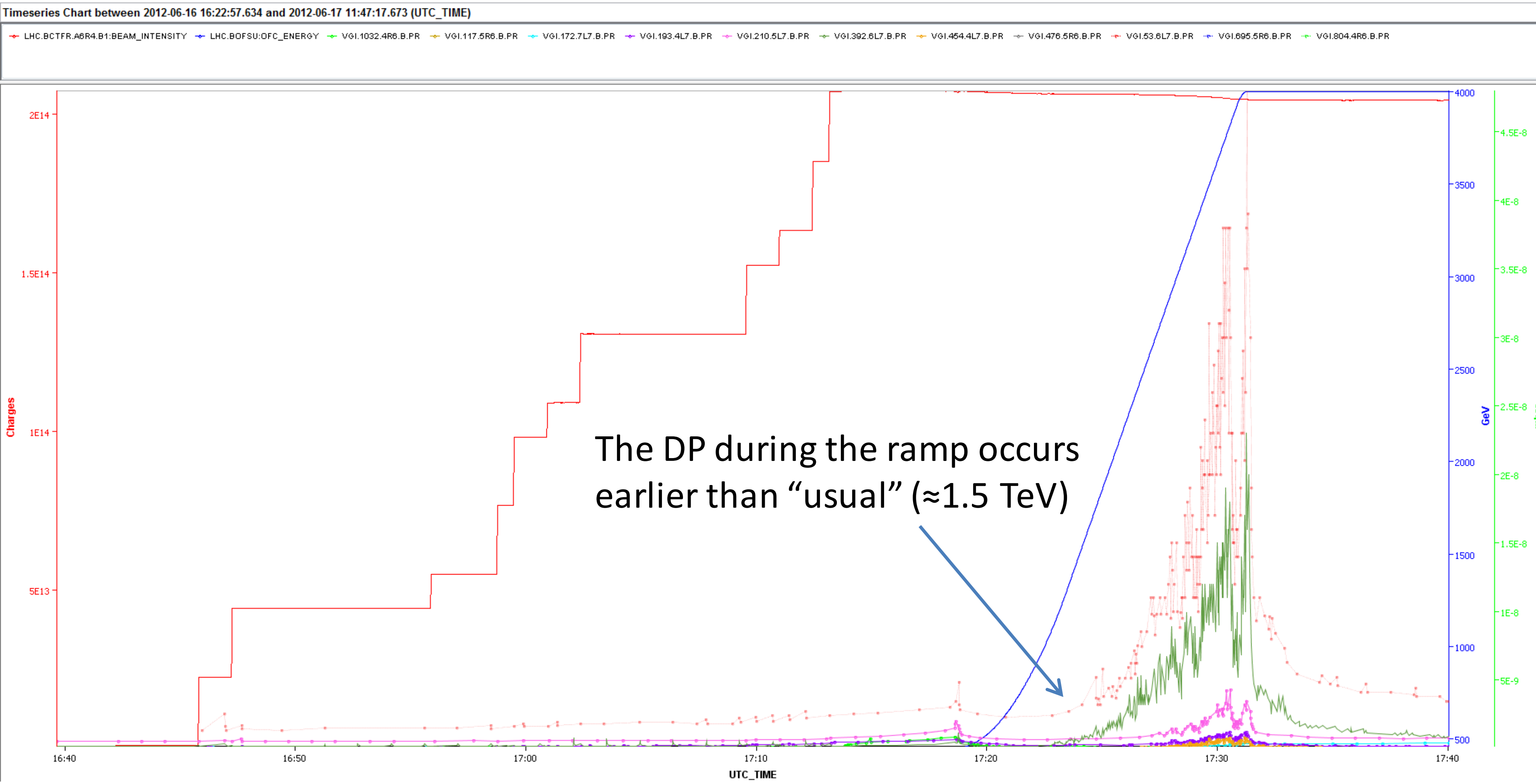
Fill 2261



Pre-ramp and ramp

Sector 6-7

Fill 2736



For this fill there is a ΔP with the ramp in gauges that never showed it

Are these effects really generated by e-cloud?

- Very different responses for different gauges
- Very different responses for different fills (same gauges)
- Different starting points (form 1.2 TeV to 2.9 TeV)
- Thresholds at 450 GeV and 4 TeV are very similar

Alternative explanations

- Photodesortion: does it present a threshold effect? Maybe:
  - The SR monitor switches at about 1.5-2 TeV from ondulator to D3 [2,3]
- Heating?
- Orbit excursions?
- Losses in collimators?

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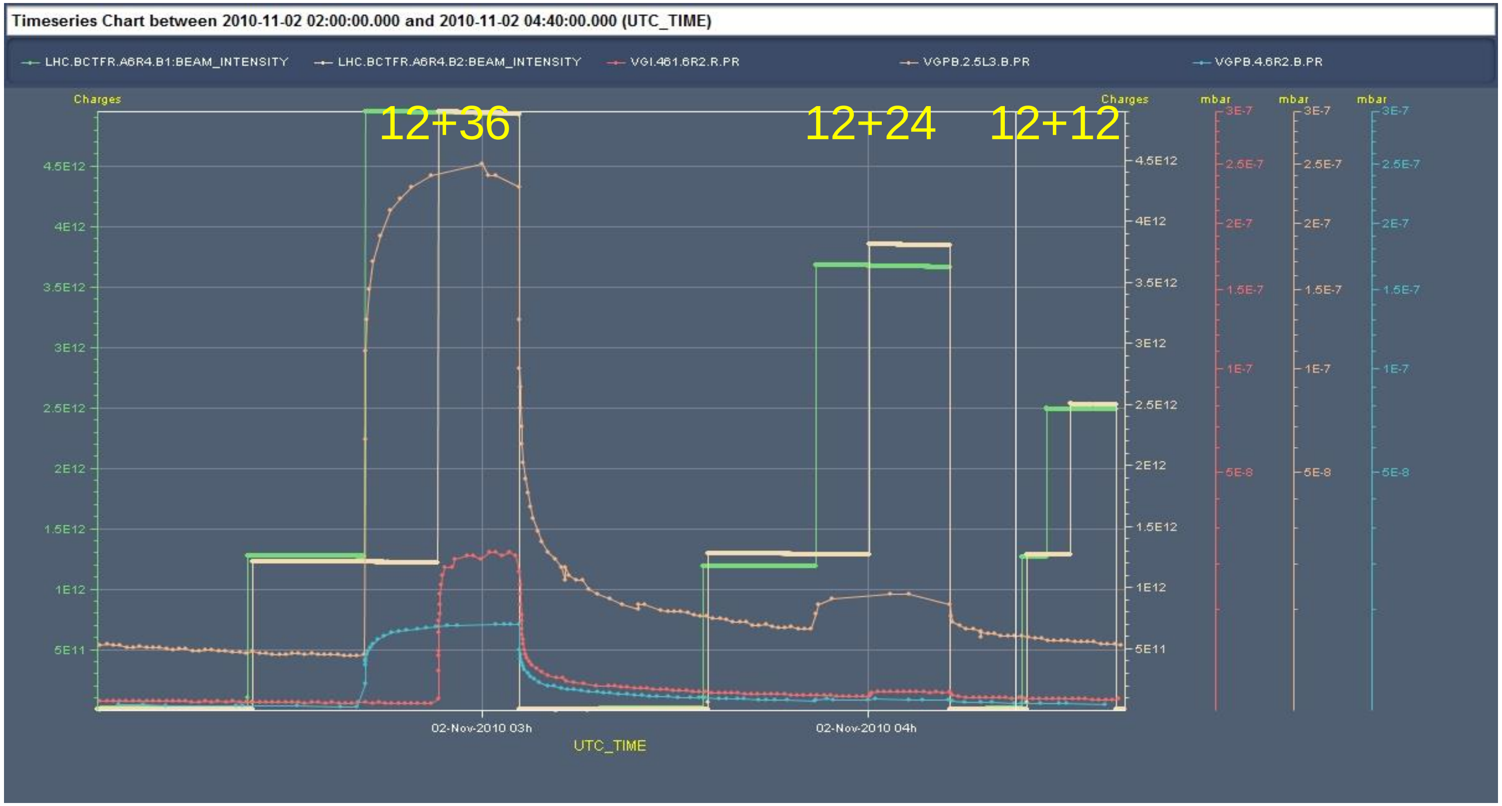
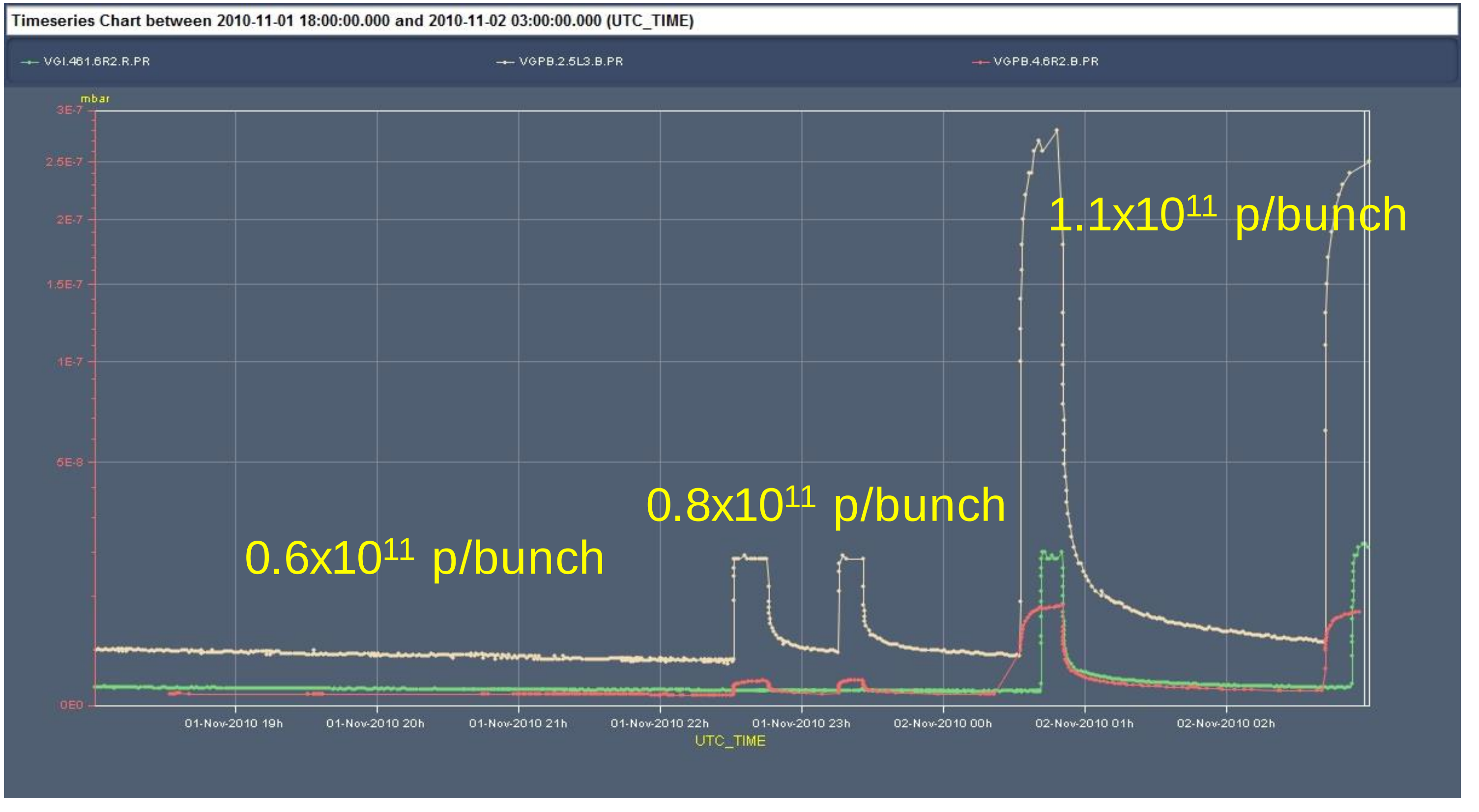
- First 50 ns MDs in November 2010:
    - ➢ Exploration of e-cloud effects with train length

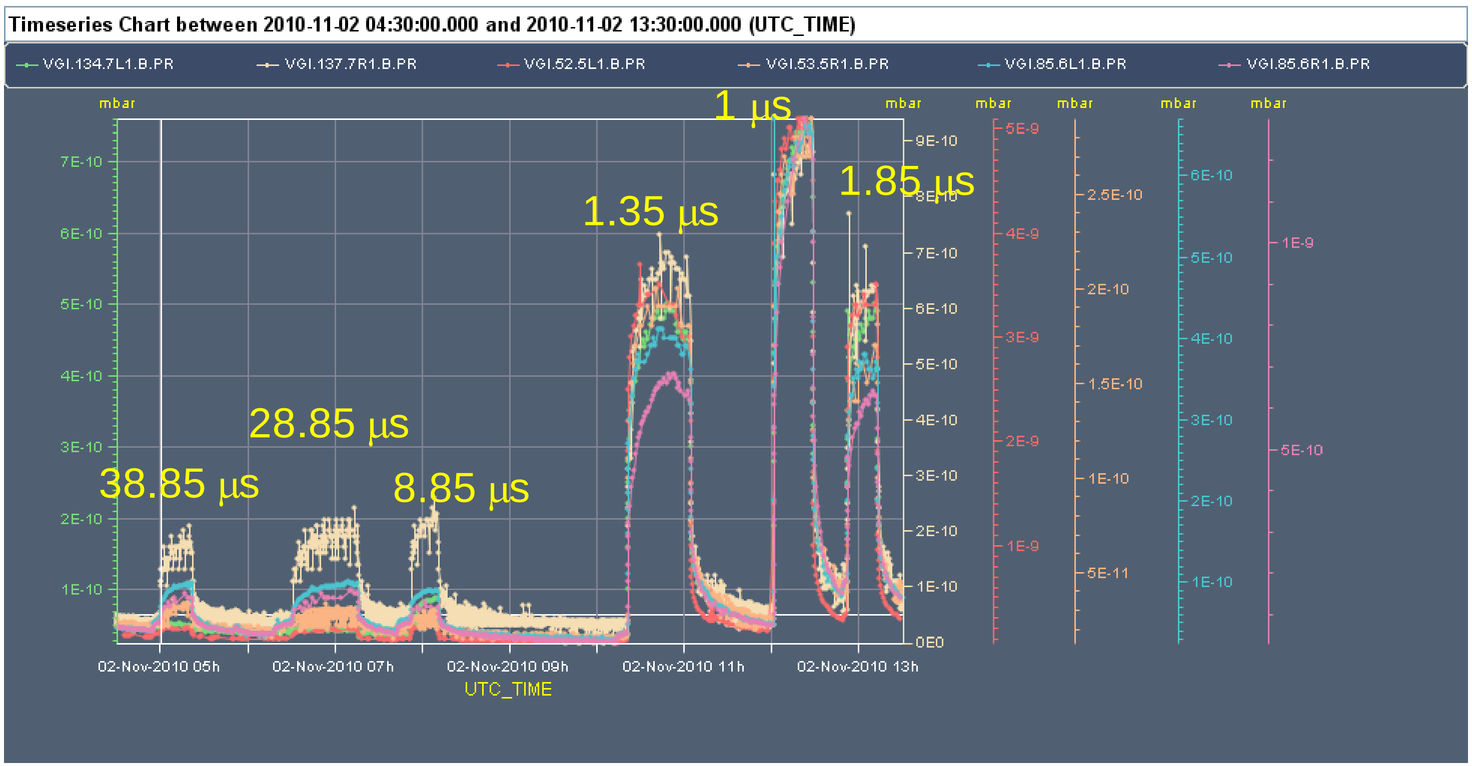


Benchmarking

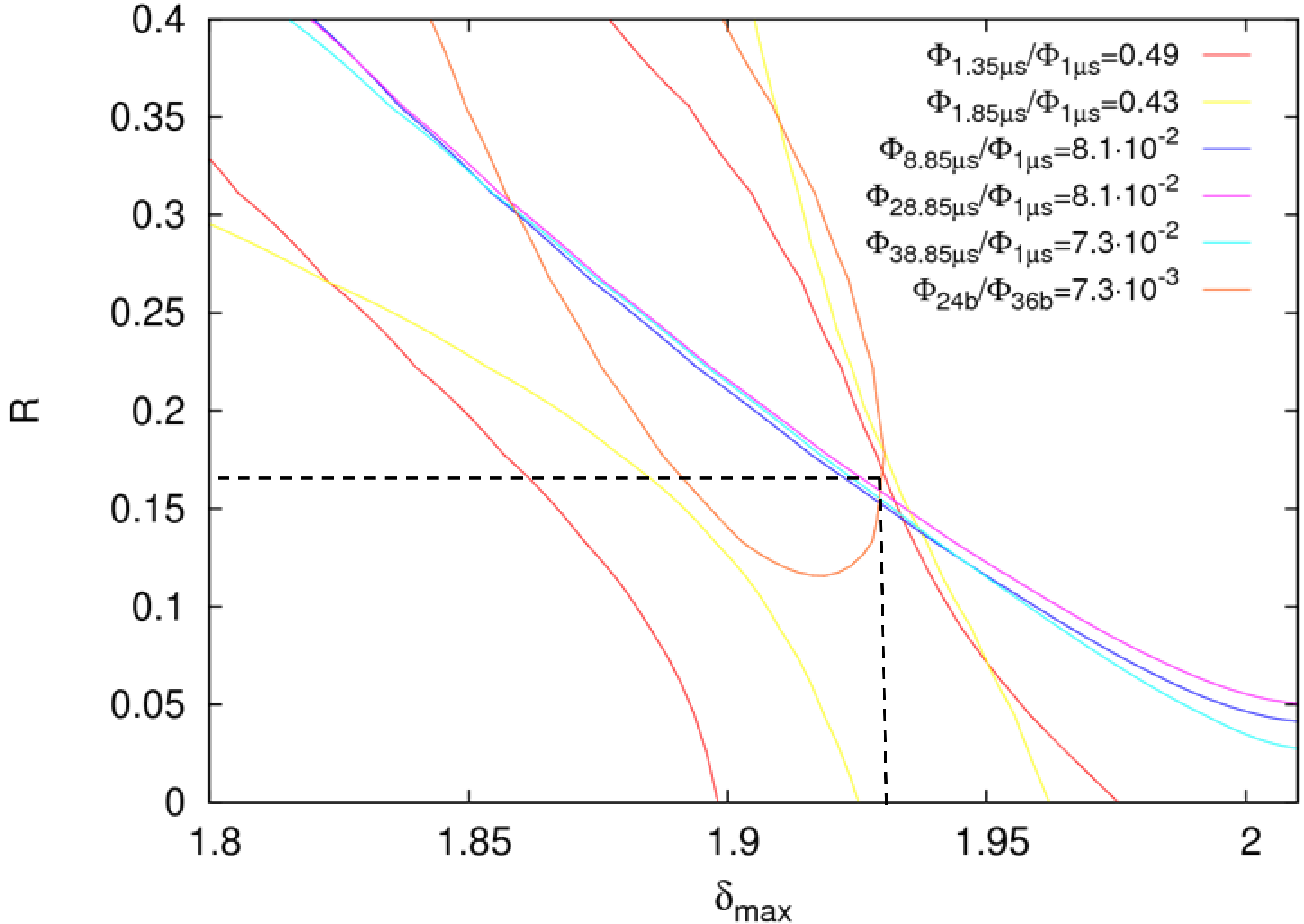
- First 50 ns MDs in November 2010:
  - ➢ Exploration of e-cloud effects with train length
  - ➢ Exploration of e-cloud effects with bunch intensity



- First 50 ns MDs in November 2010:
  - Exploration of e-cloud effects with train length
  - Exploration of e-cloud effects with bunch intensity
  - Exploration of e-cloud effects with the spacing between trains

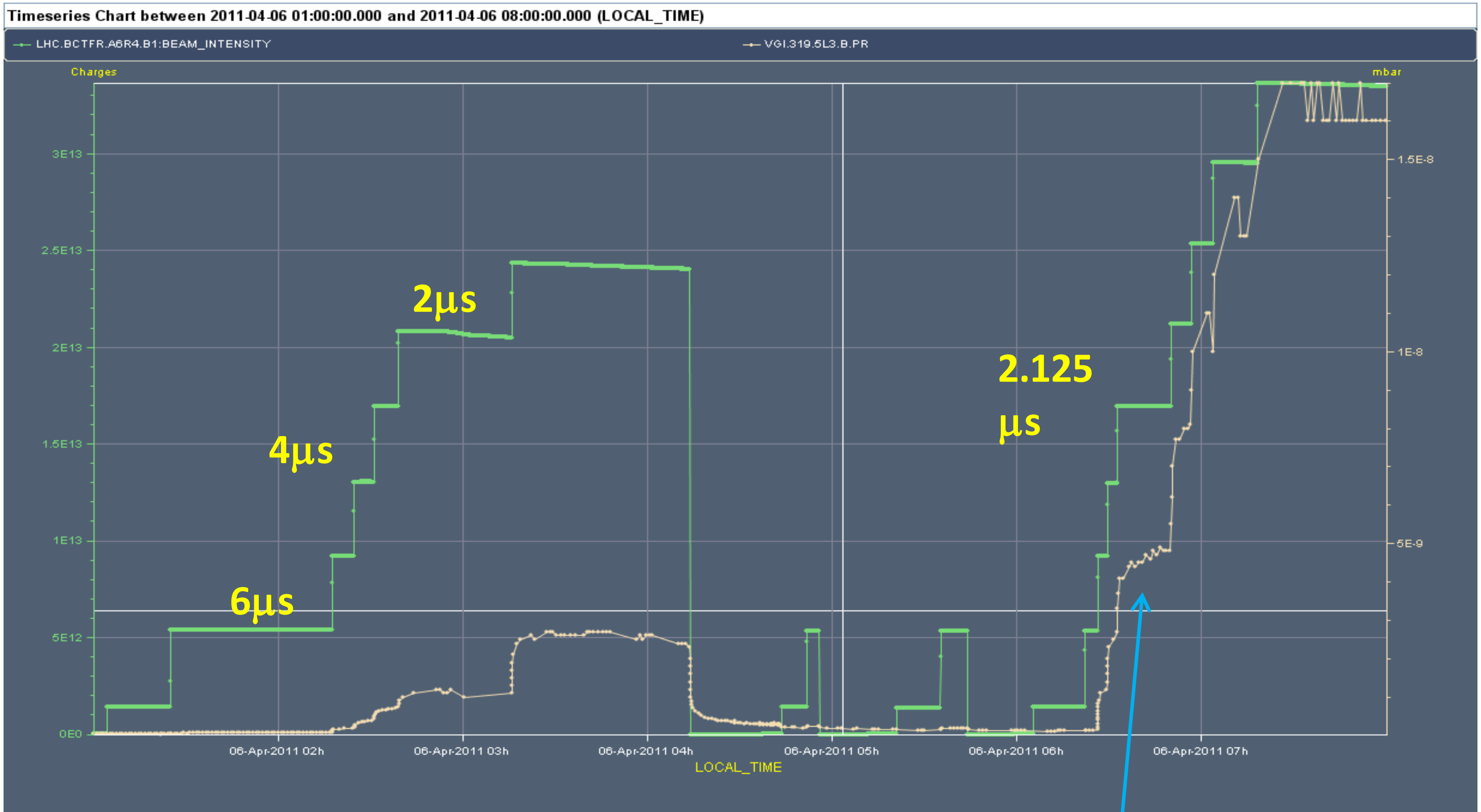


Following the methodology explained in [4], we get for gauge VGI.141.6L4.B:



Benchmarking

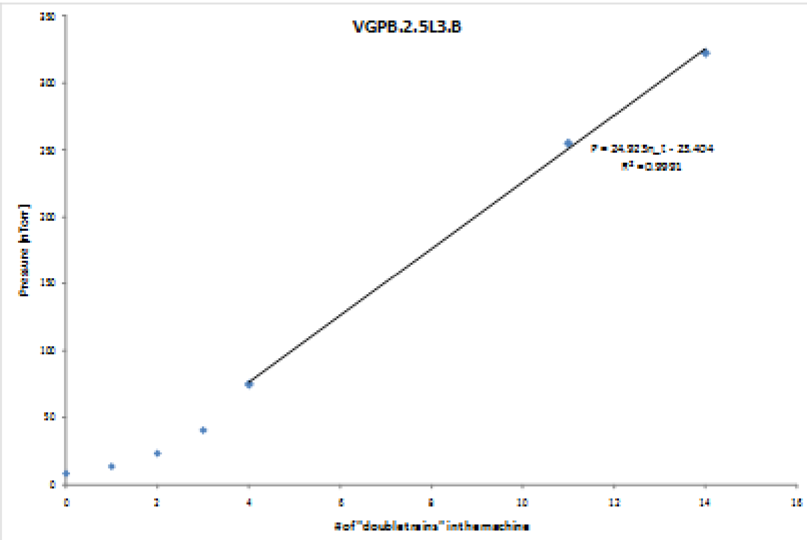
Scrubbing run in April 2011 with 50 ns



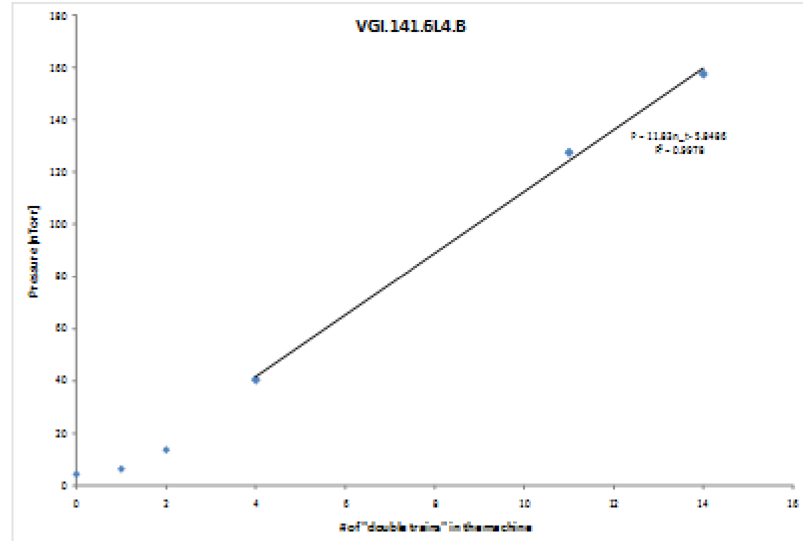
With constant spacing between trains we would expect a linear behavior

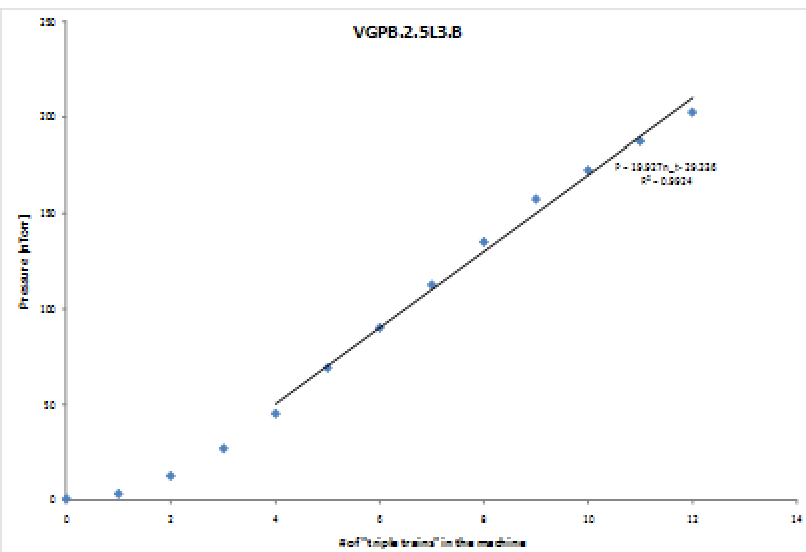
Benchmarking

- We observe a transient before the linear behavior is achieved

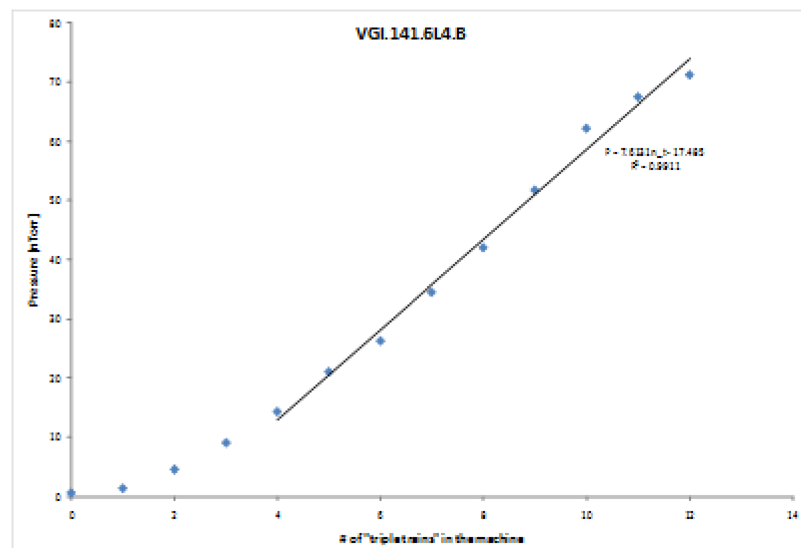


10/4/2011



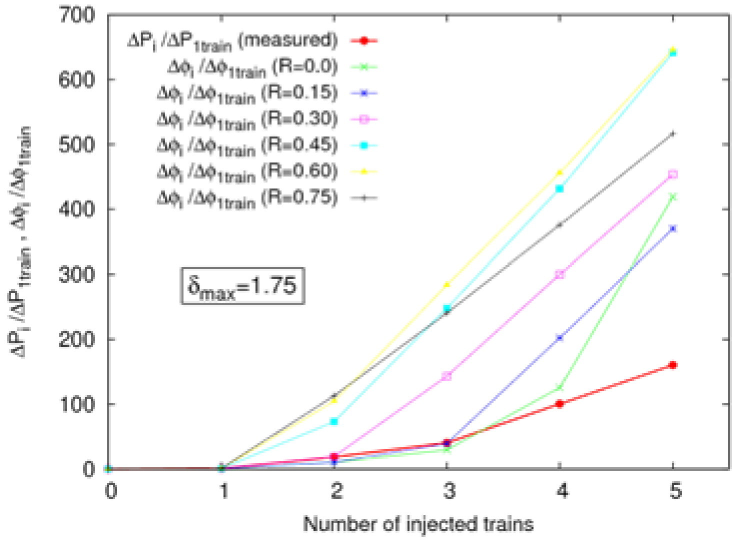


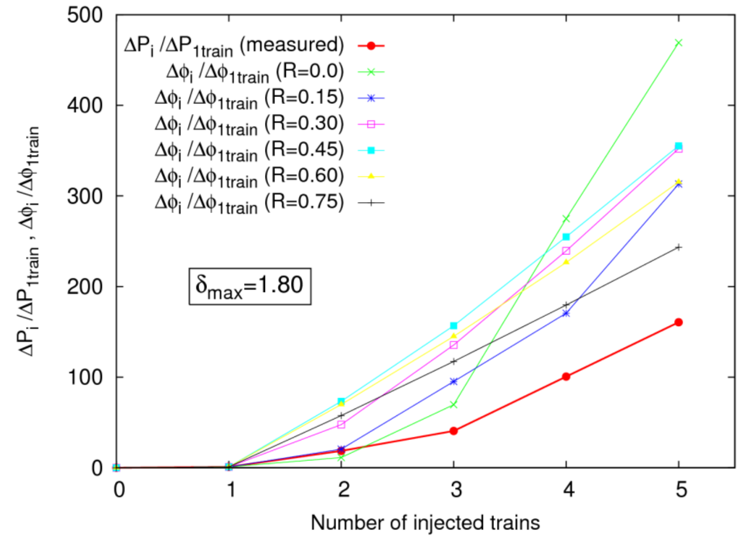
19/5/2011

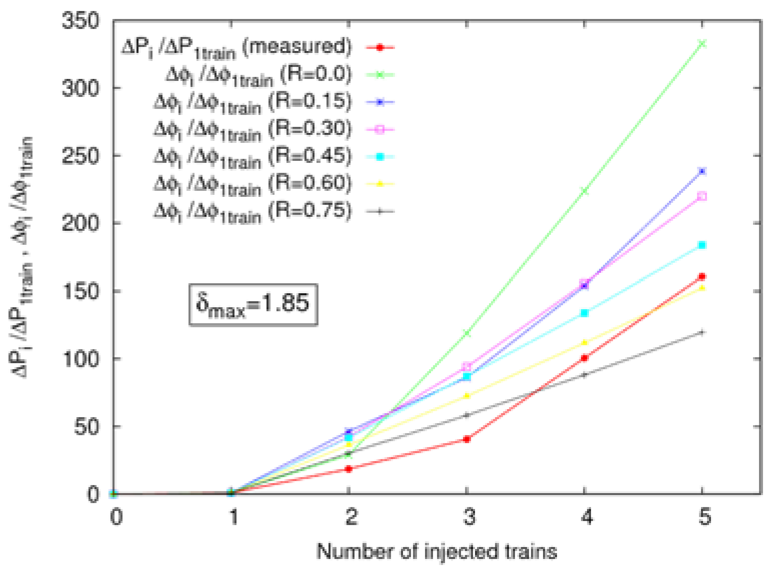


Benchmarking

- We observe a transient before the linear behavior is achieved
- This behavior cannot be fully reproduced by simulations:







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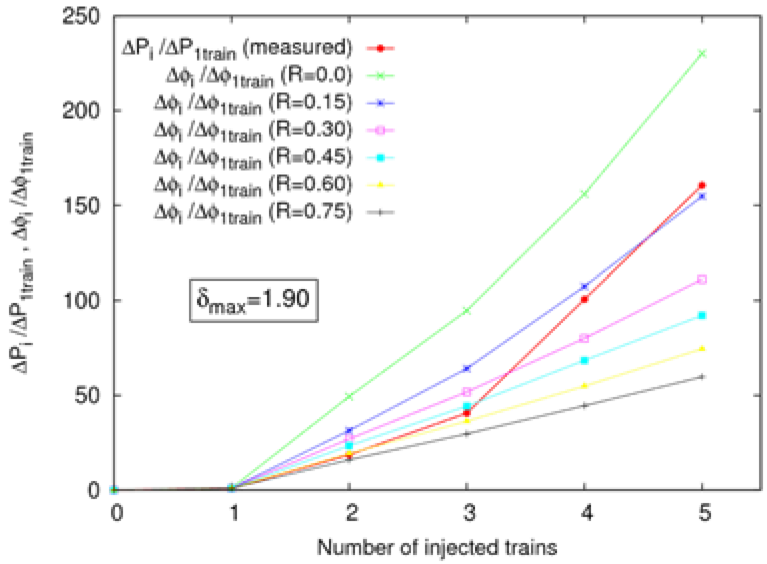
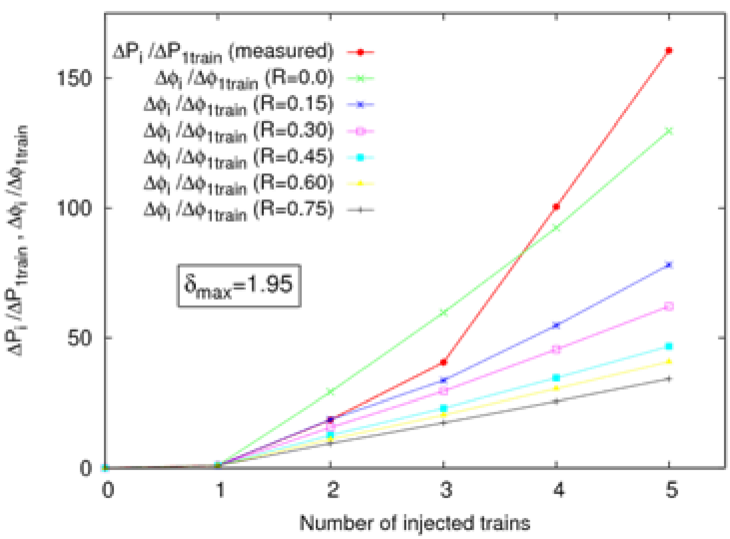
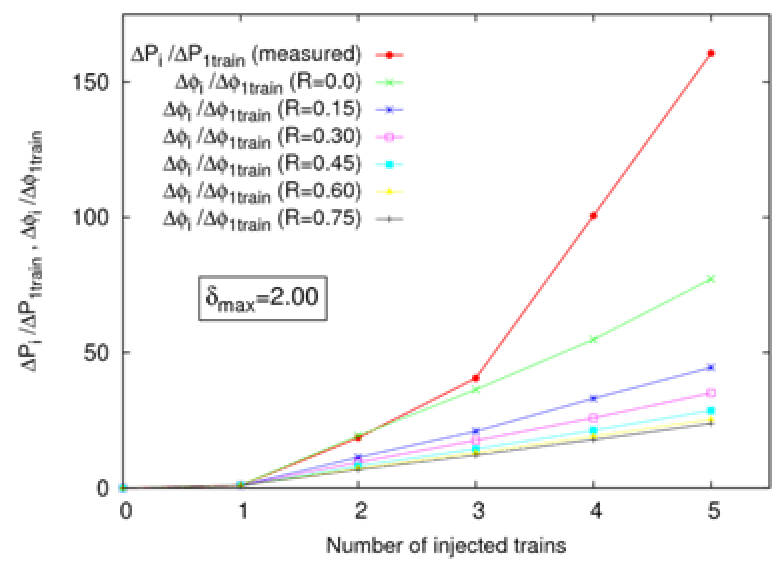






Benchmarking

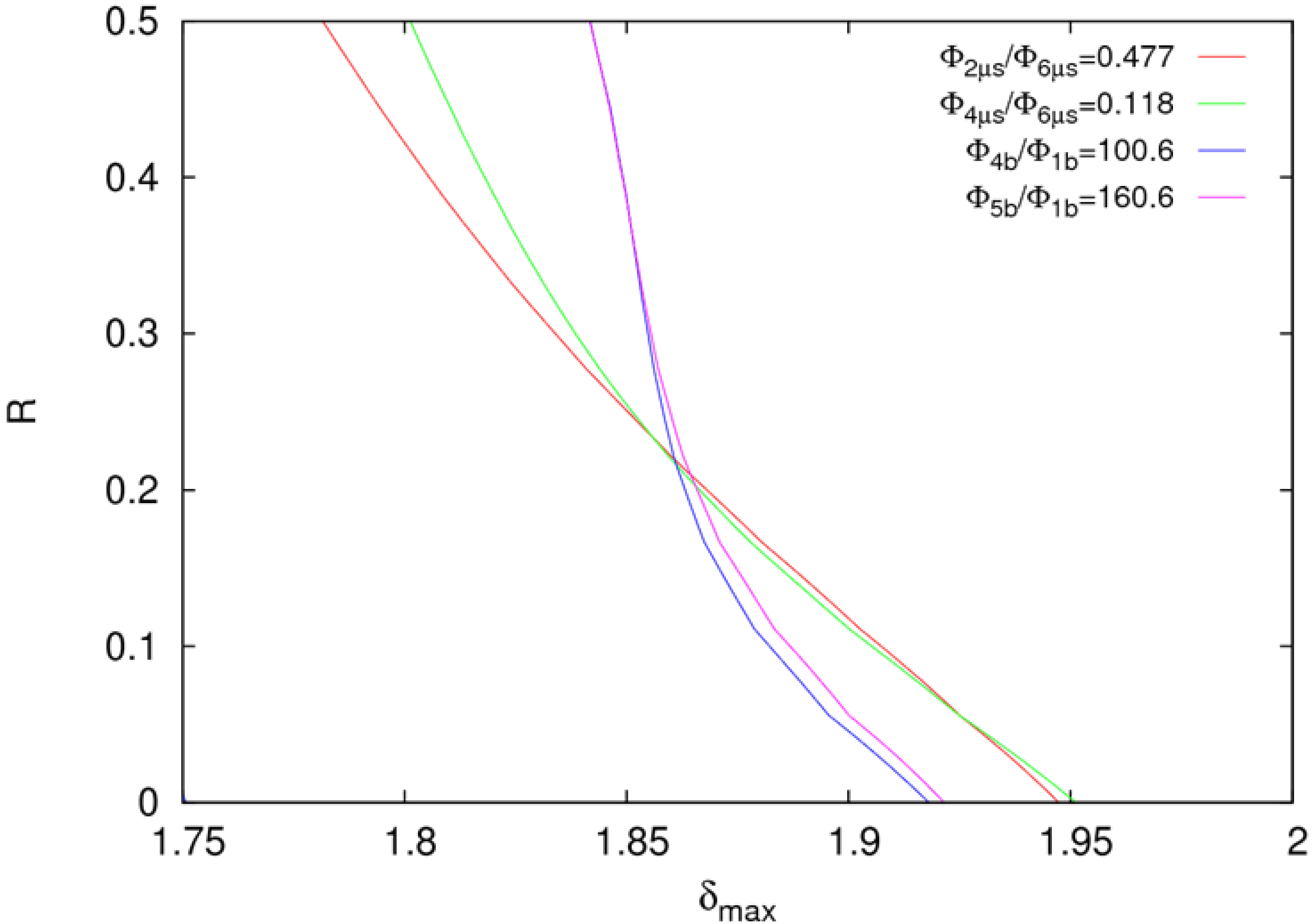
- We observe a transient before the linear behavior is achieved
- This behavior cannot be fully reproduced by simulations:

  - The exact behavior for the first trains is not well reproduced by the simulations, whereas the linear dependence after some trains disregarding the concrete δ_{max} and R values used is well reproduced.

  - Lower values of R give a better agreement for the shape presented by the first trains (change of slope). High values of R always exhibit a linear behavior from the first trains.

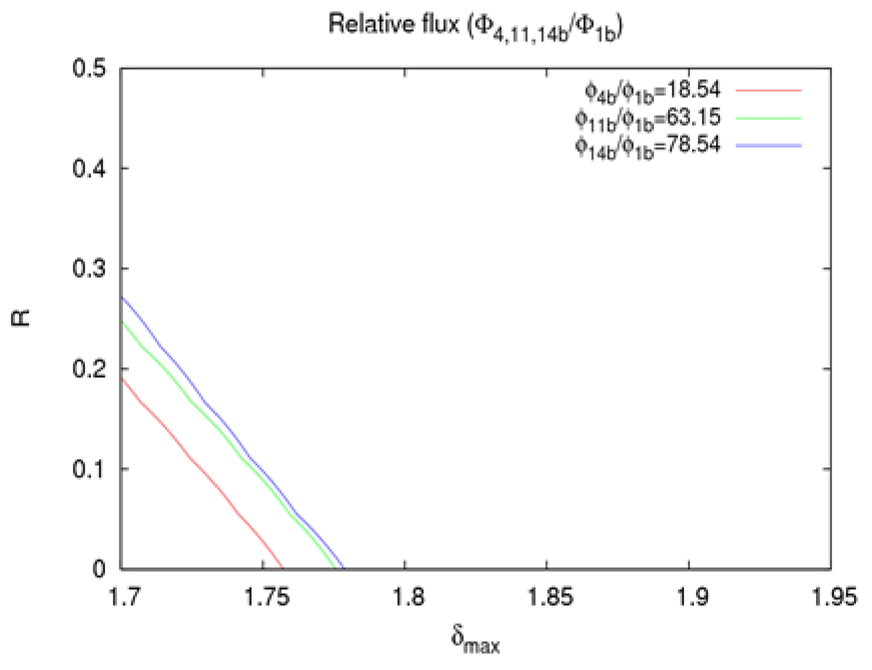
  - In the linear part, flux ratio lines for the benchmarking are expected to be ideally equal since there is not enough information to infer the reflectivity (due to a constant train spacing and the linear increases).

Following the methodology explained in [4], we get for gauge VGI.141.6L4.B:

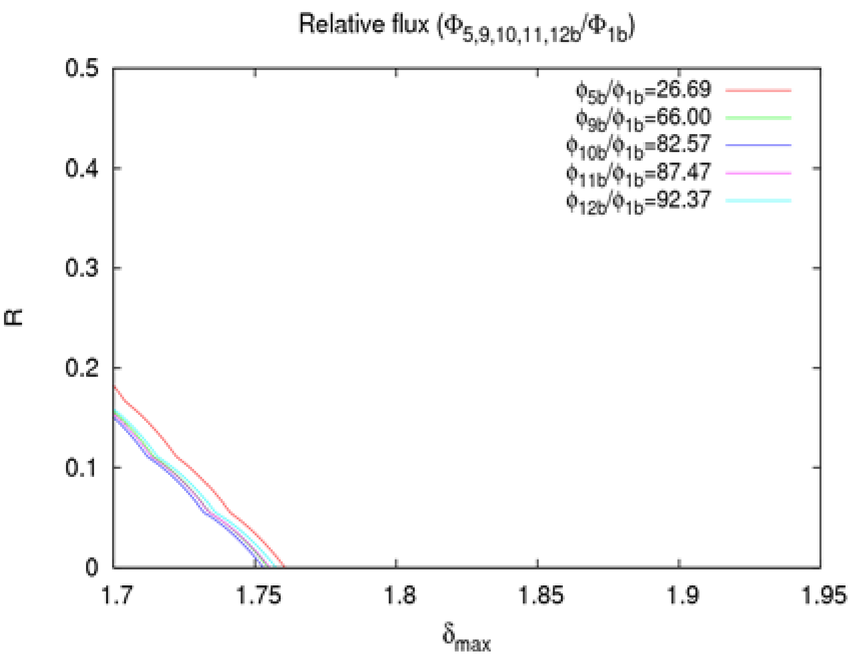


Following the methodology explained in [4], we get for gauge VGI.141.6L4.B:

10 April 2011



19 May 2011

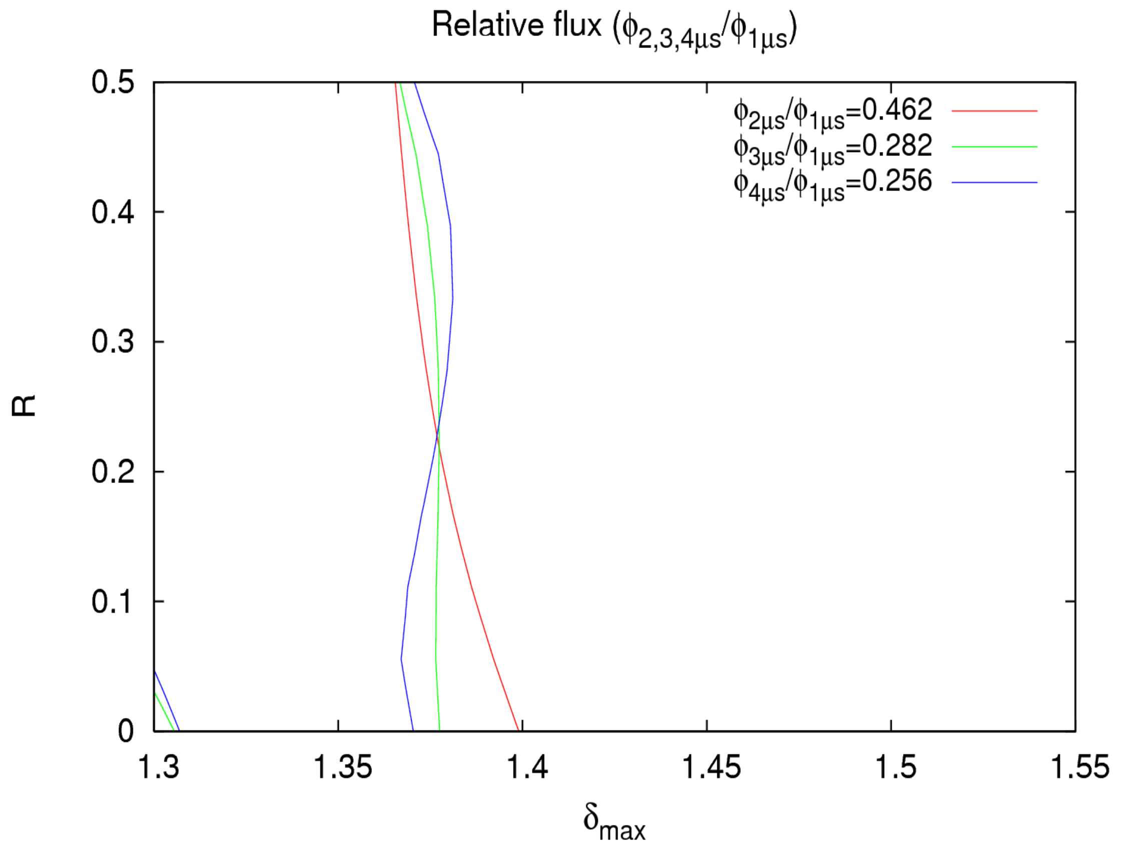


- Clear conditioning effect

(RESULTS WITH ECLOUD)

Following the methodology explained in [4], we get for gauge VGPB.2.5L3.B:

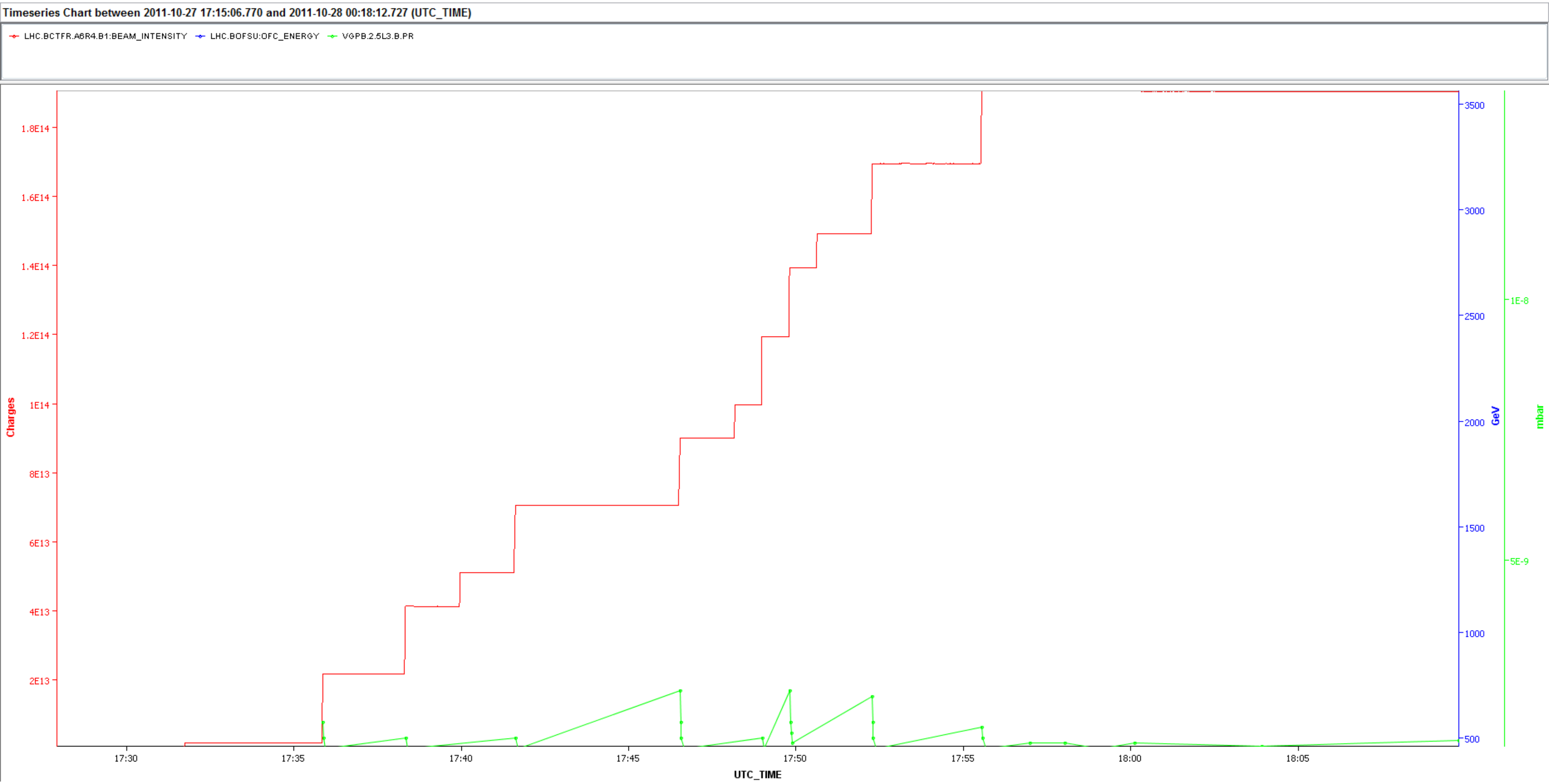
25 October 2011



(RESULTS WITH ECLOUD)

Gauge VGPB.2.5L3.B

27 October 2011 – Physics fill 2261



Outline

1) Pressure rise observations with 25 and 50 ns beams

2) Bunch intensity thresholds for 50 ns

3) Behavior during pre-ramp and energy ramp

4) Interpretation using PyECLOUD simulations

5) Conclusions

Conclusions

- Different gauges in the warm-warm straight sections show different behaviors
- Conditioning effects seem to be stronger for some gauges
- Thresholds are between 1.45 and 1.5 for N_b=1.0-1.6·10^{11} ppb
- Thresholds at 450 GeV and 4 TeV are very similar
- There are some behaviors during pre-ramp and ramp that are not explained yet and cannot be reproduce with simulations
- Benchmarking simulated flux and measured pressure can help monitoring the evolution of δ_{max} and can explain some vacuum observations due to e-cloud

THANK YOU
FOR YOUR ATTENTION

References

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[2] T. Lefevre, E. Bravin, G. Burtin, A. Guerrero, A. Jeff, A. Rabiller, F. Roncarolo and A. Fisher, "First Beam Measurements with the LHC Synchrotron Light Monitors," Conf. Proc. C **100523** , IPAC'10, Kyoto, 2010, MOPE057.

[3] O. Dominguez and F. Zimmermann, "Benchmarking electron-cloud simulations and pressure measurements at the LHC," CERN-2013-002, pp. 79-83.