LHC Injectors Upgrade

CERN

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Electron cloud status @ SPS in 2012

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H. Neupert, G. Rumolo, M. Taborelli

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G. Arduini, T. Argyropoulos, T. Bohl, S. Cettour Cave, K. Cornelis, H. Damerau,
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Special thanks to all the SPS operator crew

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Studies in 2012: what we have learnt

What is the status LHC 25ns beam in the SPS?

- Nominal intensity (1.2e11 ppb)
- Ultimate intensity (1.7e11 ppb)

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No visible signature of the electron cloud is observed on the beam!

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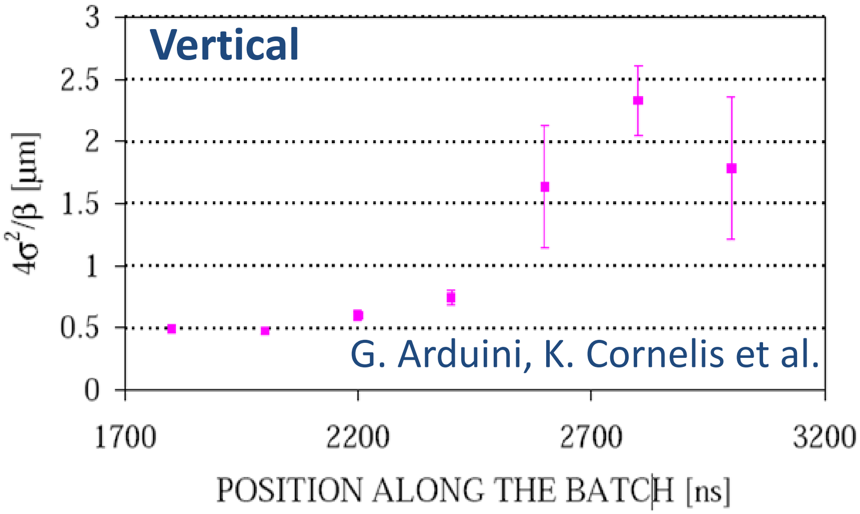
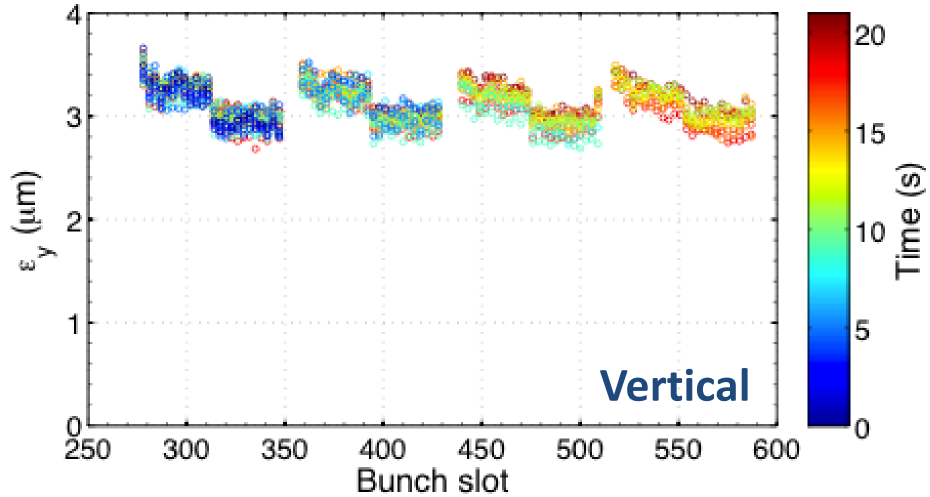
Transverse emittance

2000 (1 batch 0.8x10^{11}ppb)



2012 (4 batches 1.15x10^{11}ppb)



No emittance growth in 2012 with 4 batches

- With low chromaticity in both planes
- Identical behavior of all 4 batches
- No blow-up along bunch train

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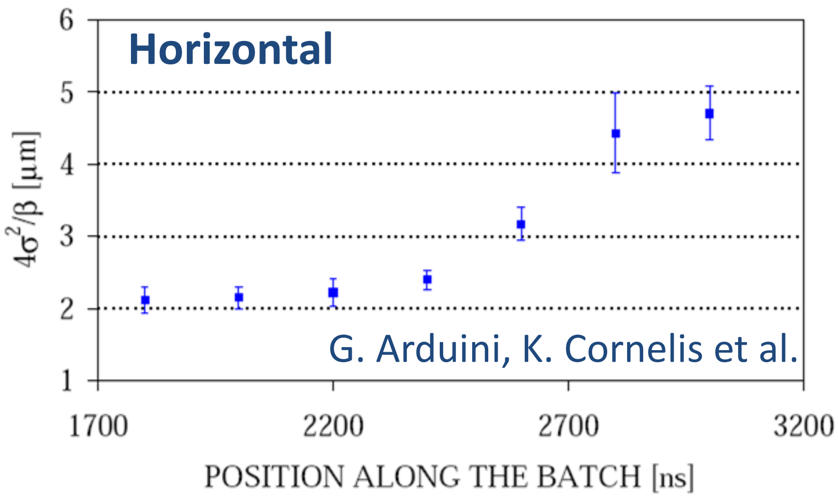

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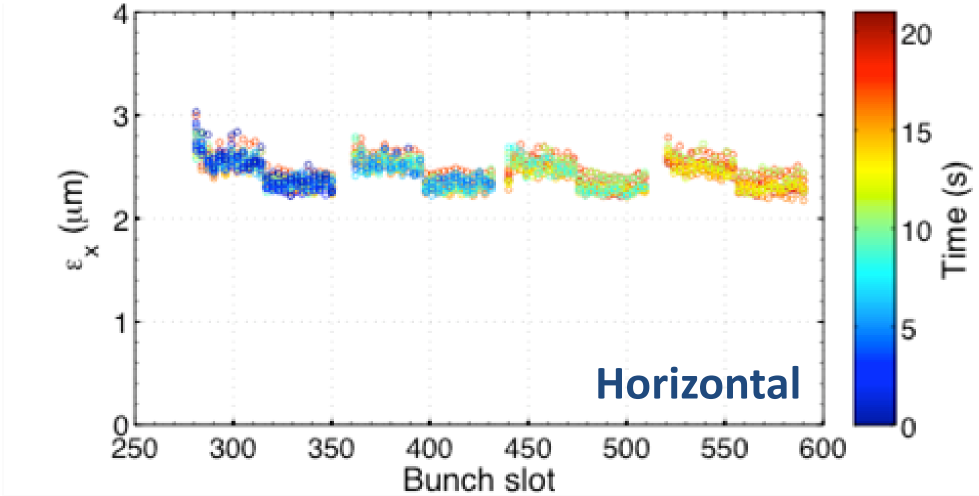

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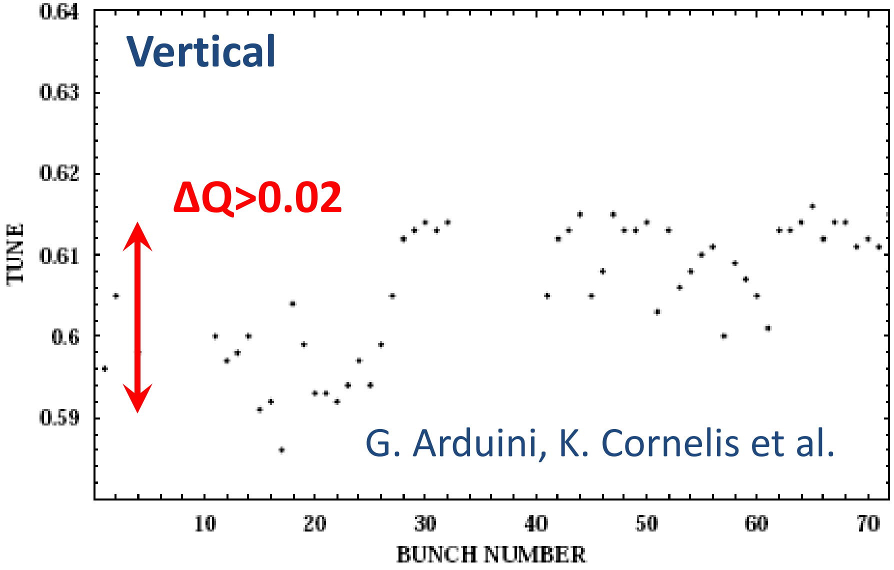
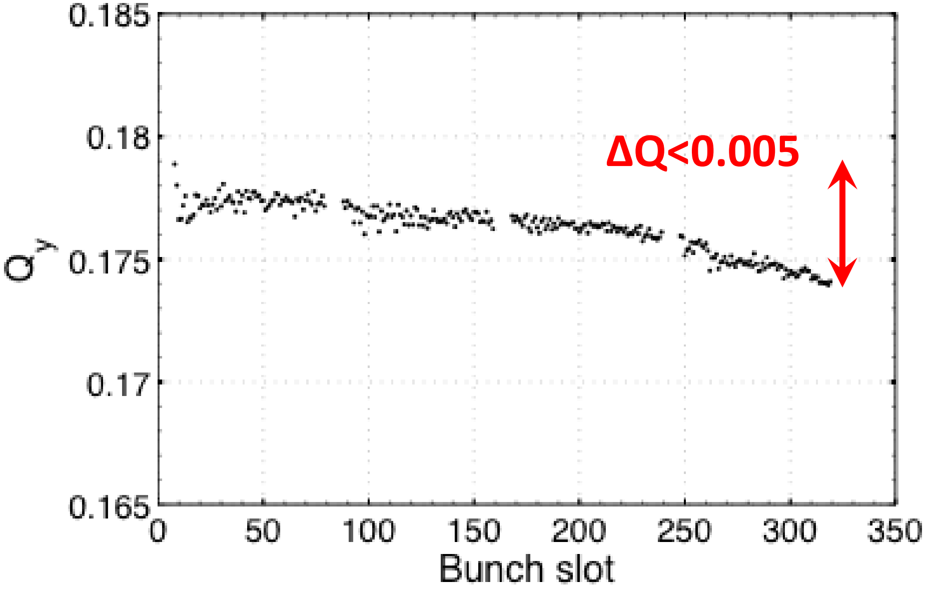
Bunch by bunch tune

2000 (one batch)



Positive tune shift!
(dominated by ecloud)

2012 (four batches)



Negative tune shift!
(dominated by resistive wall impedance?)

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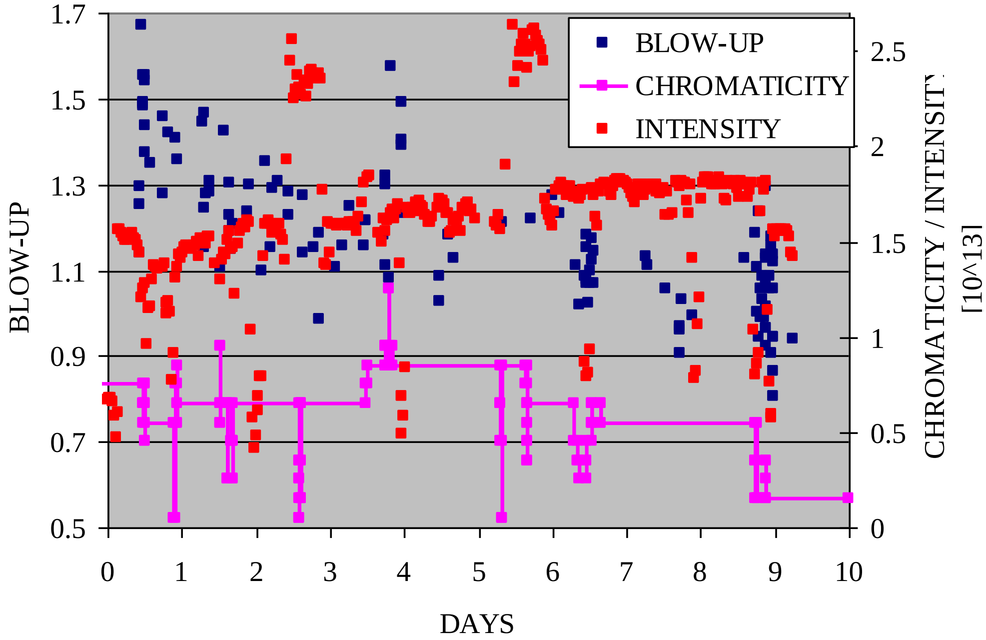
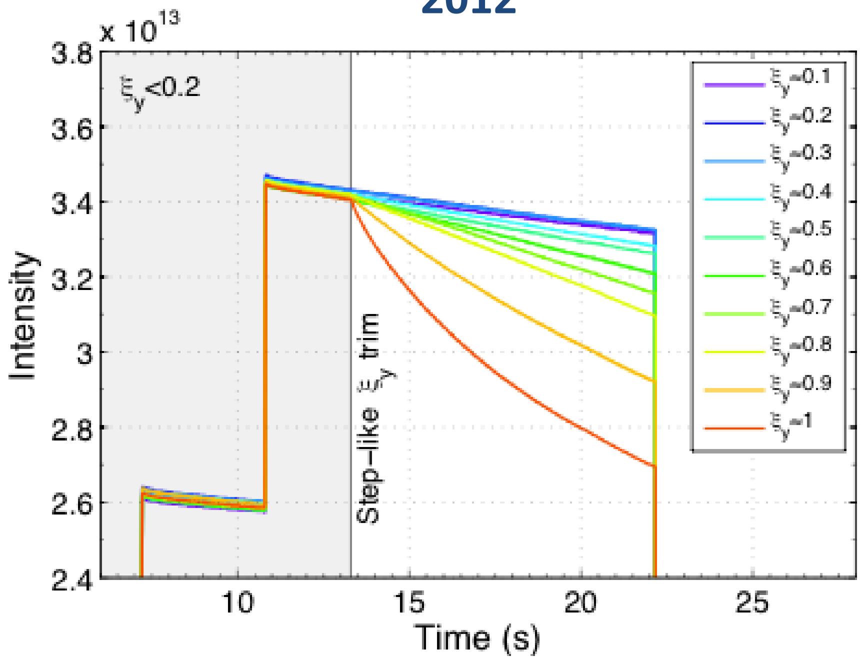
Chromaticity

2002 - G. Arduini, K. Cornelis et al.



2012



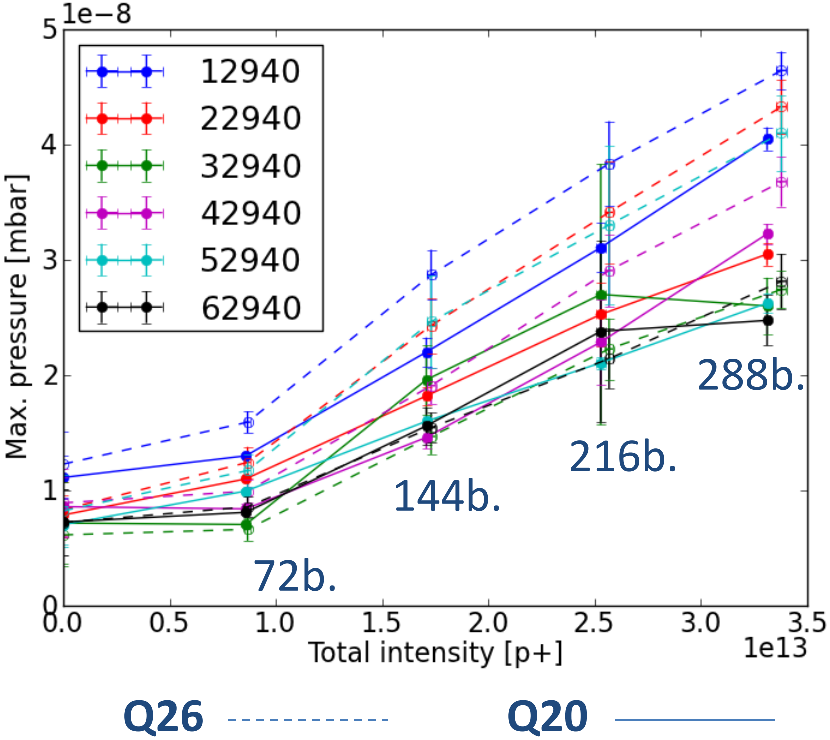
No need for large chromaticity in 2012 with 4 batches of 1.15×10^{11} p/b

- No instability or beam degradation with chromaticity around 0.1

LHC 25ns beam (nominal intensity): dynamic pressure rise

Together with effects on the beam, **the dynamic pressure rise** is **the only other observable** to qualify the present conditioning state of the SPS ring.

One gauge per arc (26 GeV, 23s cycle)



Ramarks:

- In 2012 the pressure rise is **smaller by a factor 10^4** w.r.t. beginning 2002! (>=1week scrubbing runs in 2002, 2003, 2004, 2006, 2007)
- **Not clear if still dominated by EC** (seems to be enhanced by losses)
- No particular difference between **Q20 and Q26**

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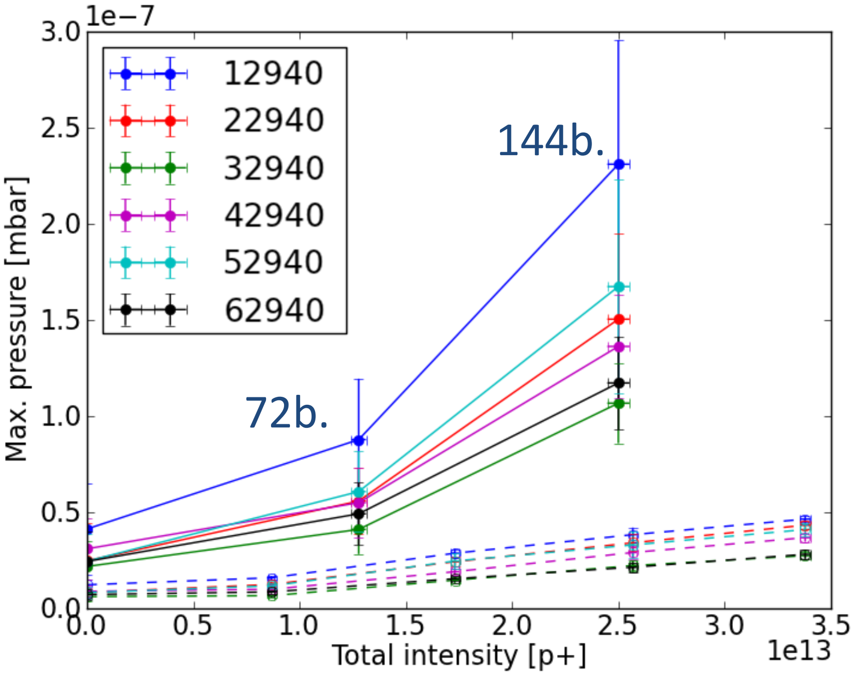


1.2e11 ppb - - - - - - - - - - **1.7e11 ppb** ———

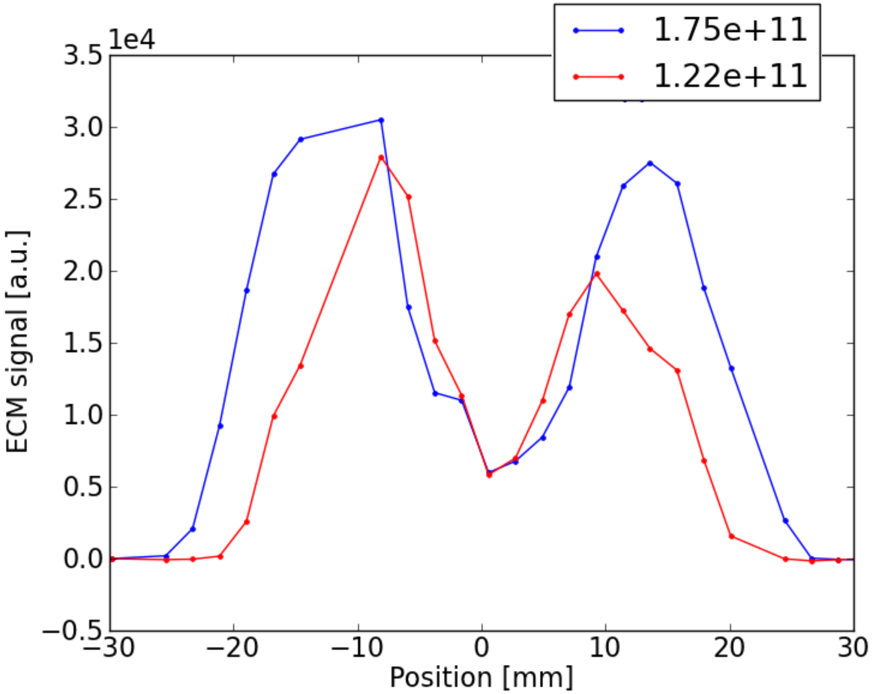
One gauge per arc (26 GeV, 23s cycle)

Ramarks:

Pressure rise in the arcs much stronger (x4 or more) than with nominal intensity.

Compatible with **e-cloud**:

LHC 25ns beam (ultimate intensity): dynamic pressure rise



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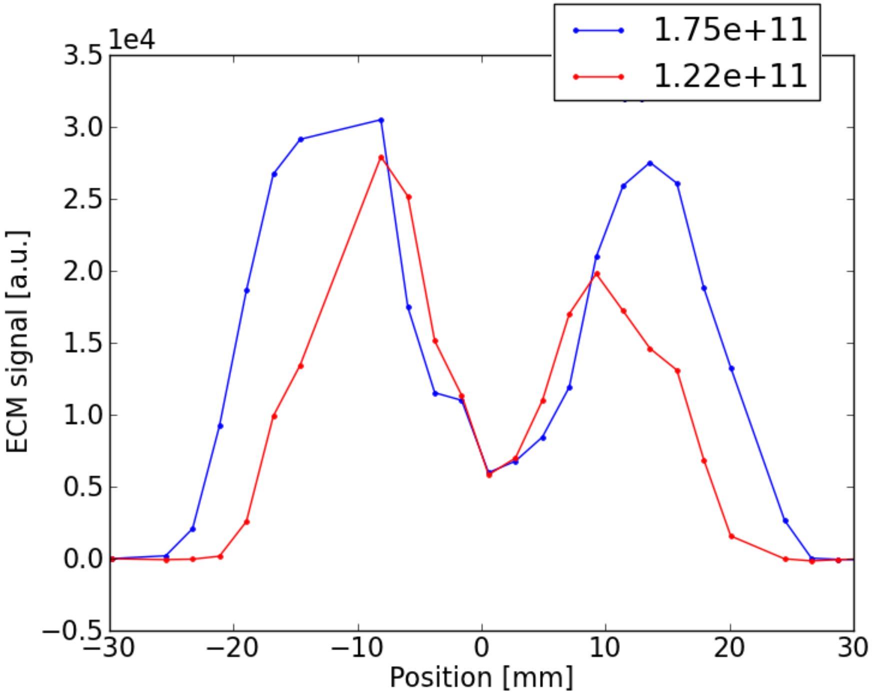

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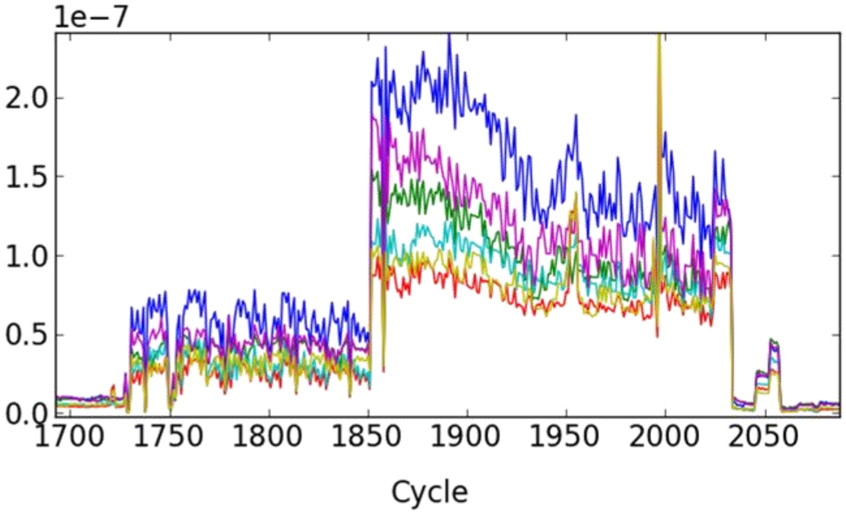

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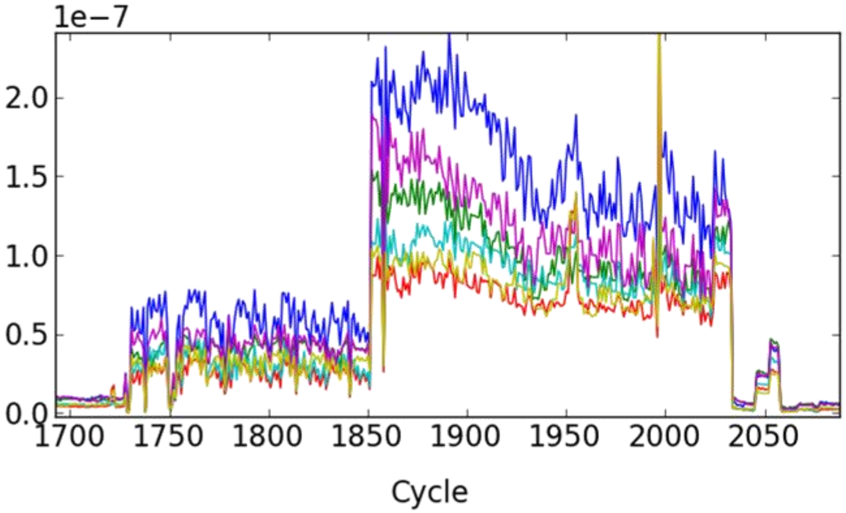

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Bunch by bunch emittance/tune measurements to be done

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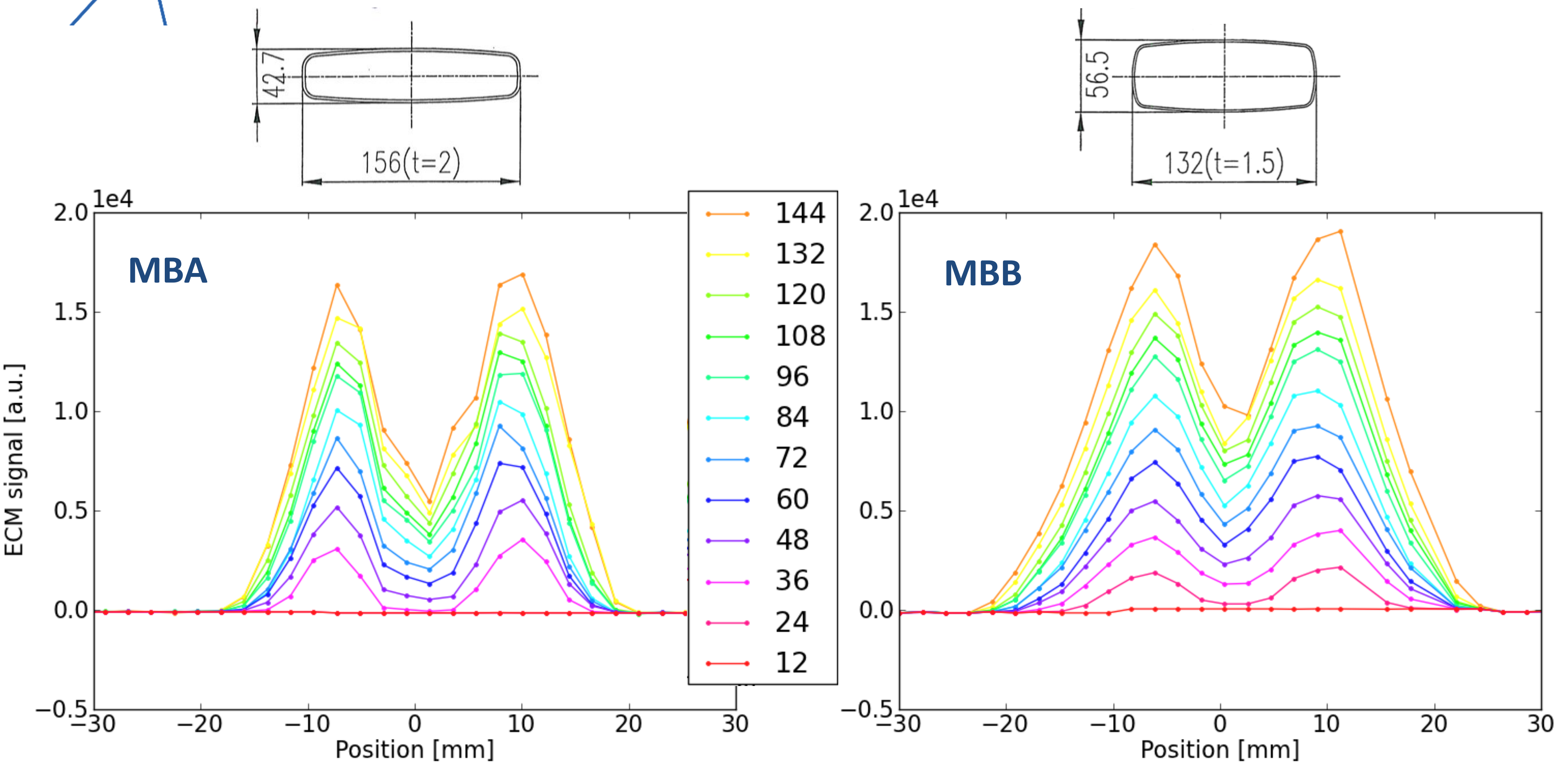
Strip detectors: MBA vs MBB

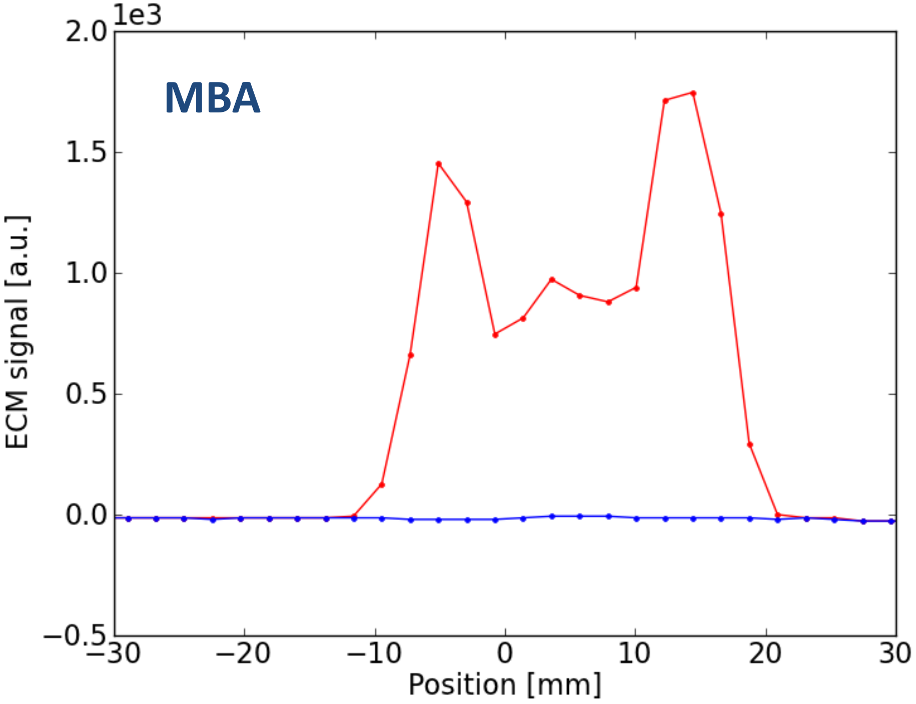


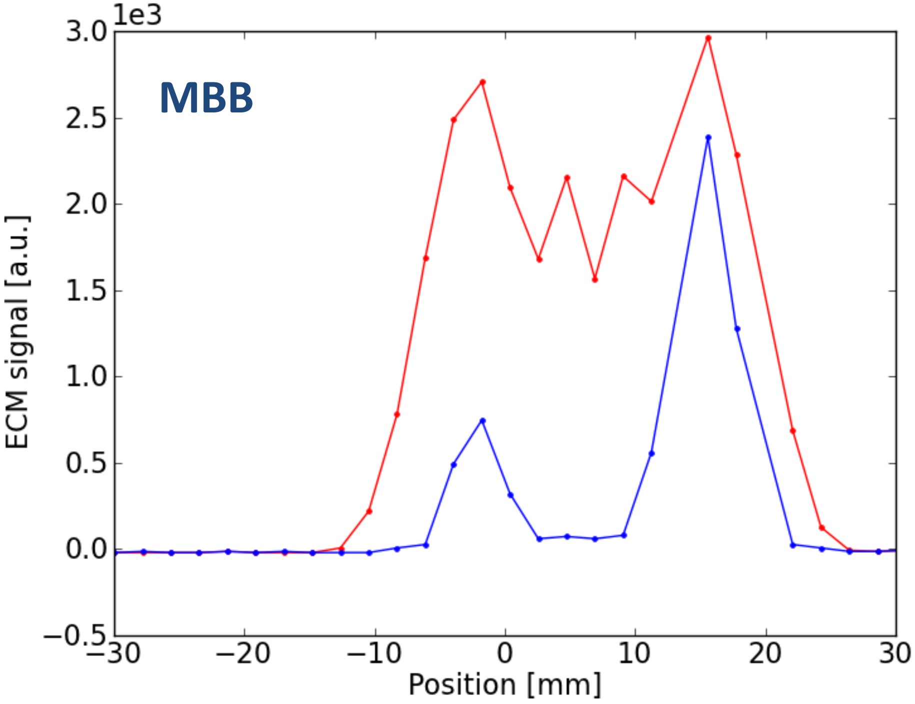
Ramarks:

- **MBA is less critical** than MBB (risetime, total flux, central density)

Measurements with 50ns beam before and after few hours of scrubbing with 25ns beam

Before scrubbing — **After scrubbing**





Ramarks:

- **Consistent with simulation** estimations (δ_{th}=2. for MBA, δ_{th}=1.6 for MBB for 50ns beam)

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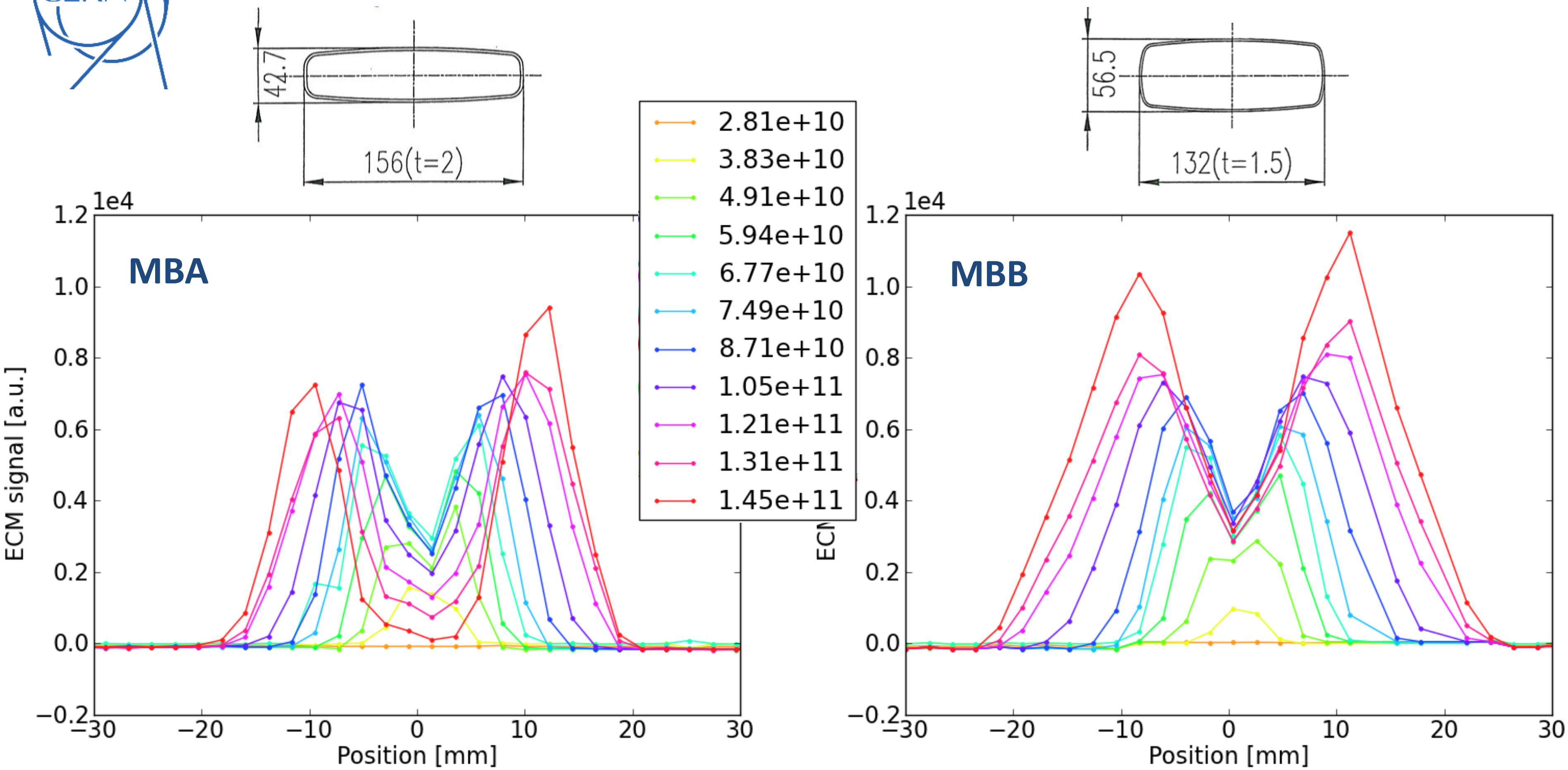
Strip detectors – dependence on bunch intensity



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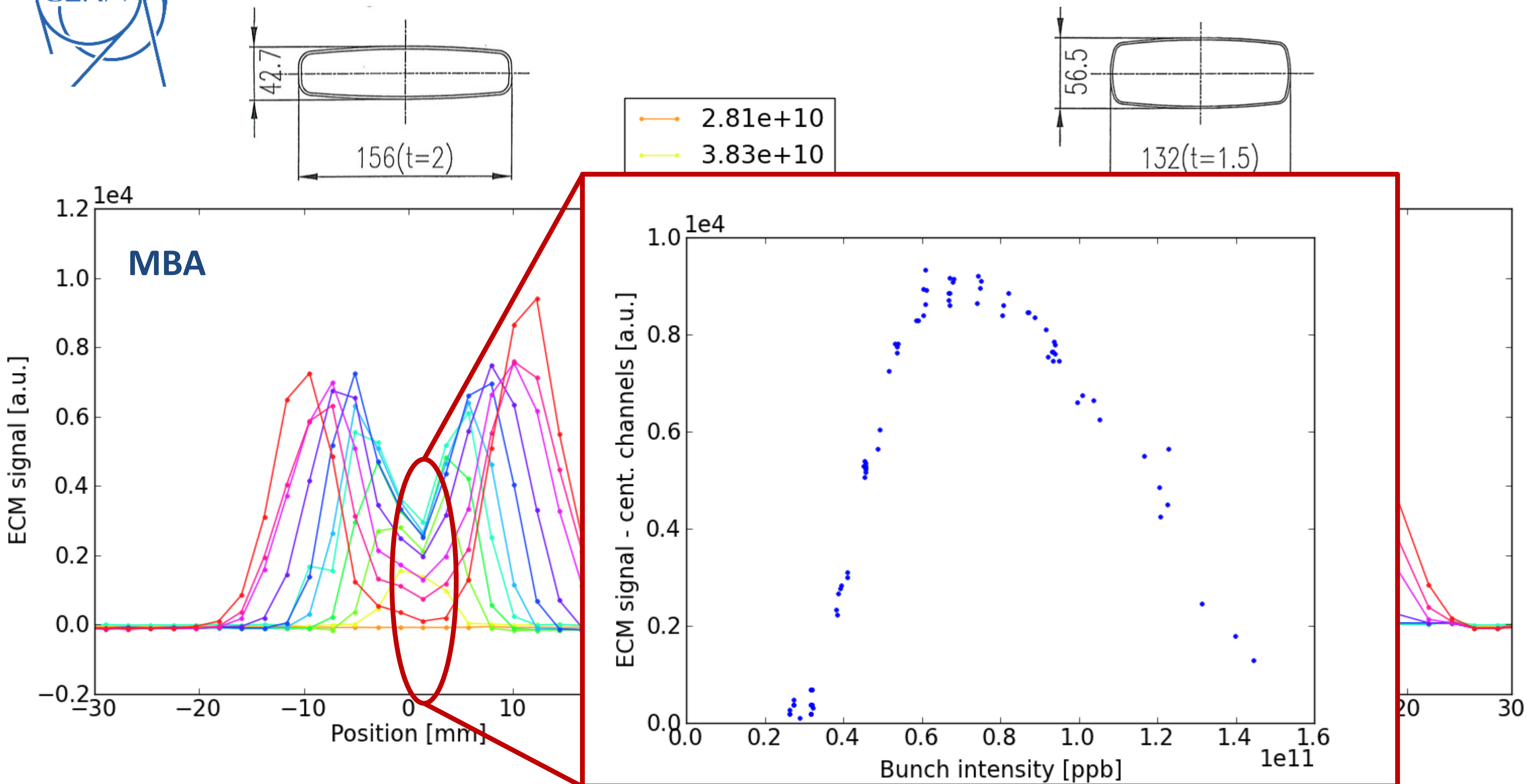
- **MBA is less critical** than MBB
- **E-cloud in the central region** (important for beam quality) is **non increasing** with bunch intensity (consistent with our EC model ☺)



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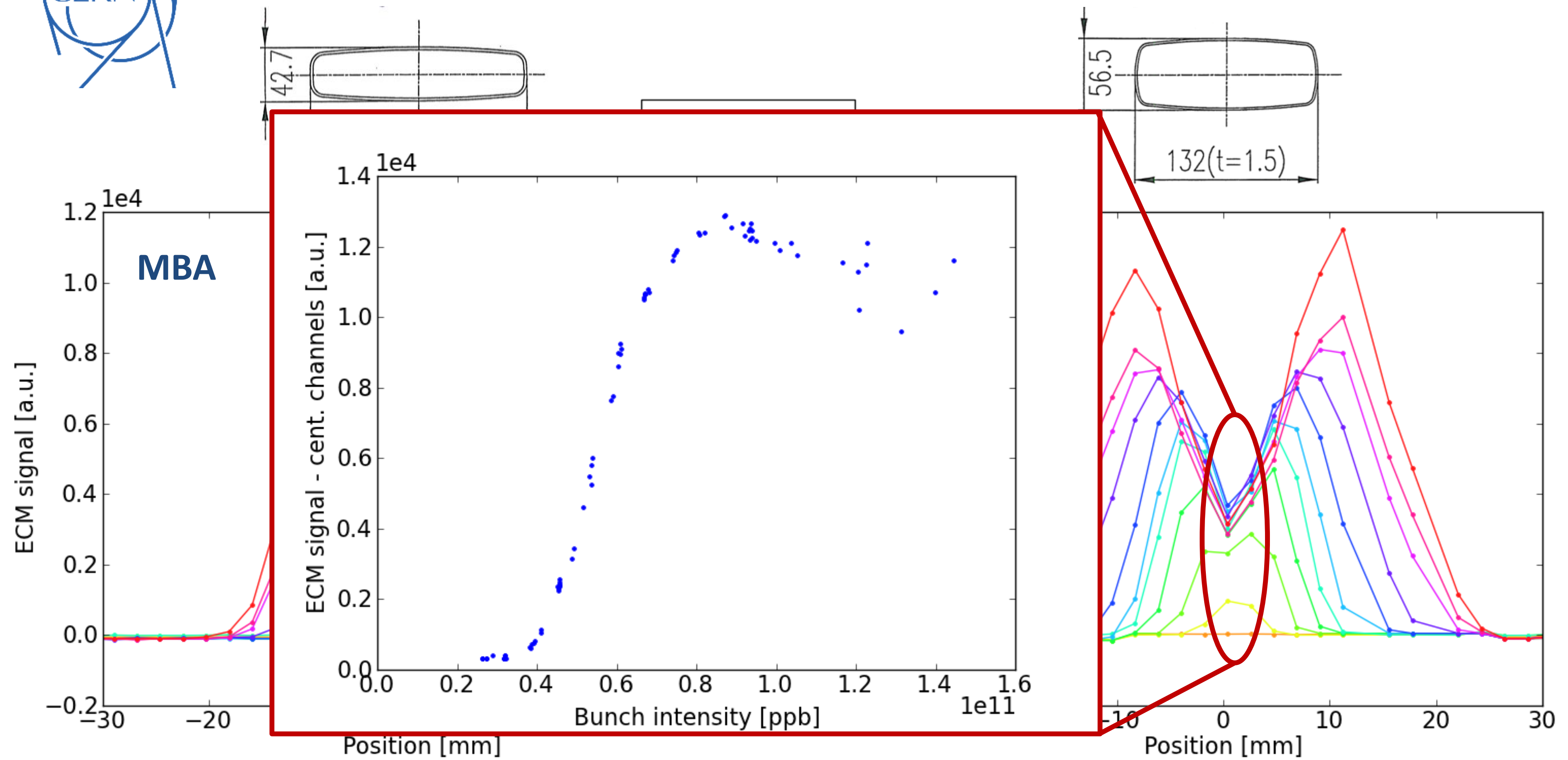

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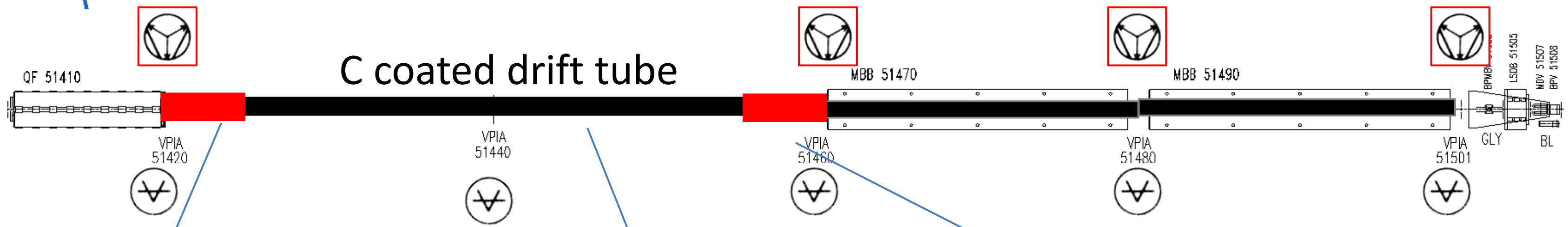
Pressure rise in aC coated chambers

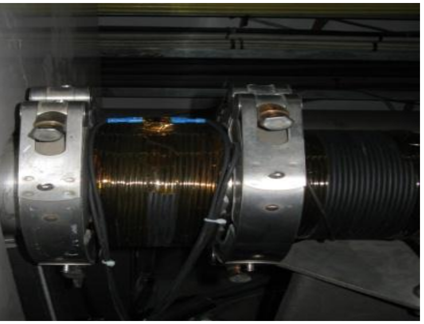


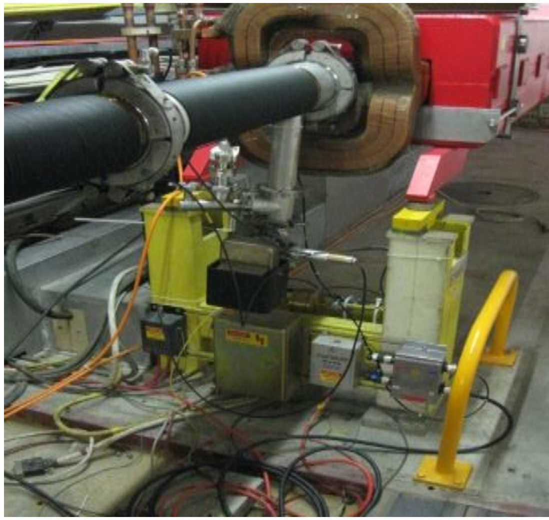
= carbon coated

External solenoid on StSt bellow (L=128 mm)

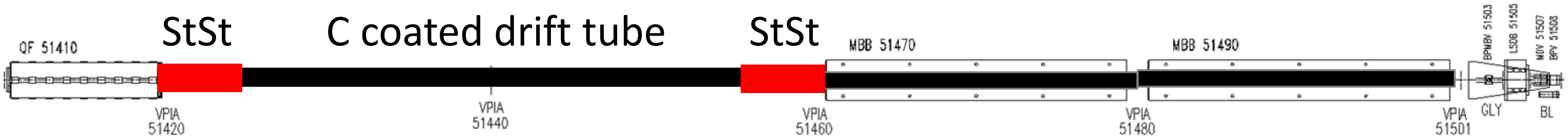
Central solenoid on carbon coated chamber (L=12324 mm)

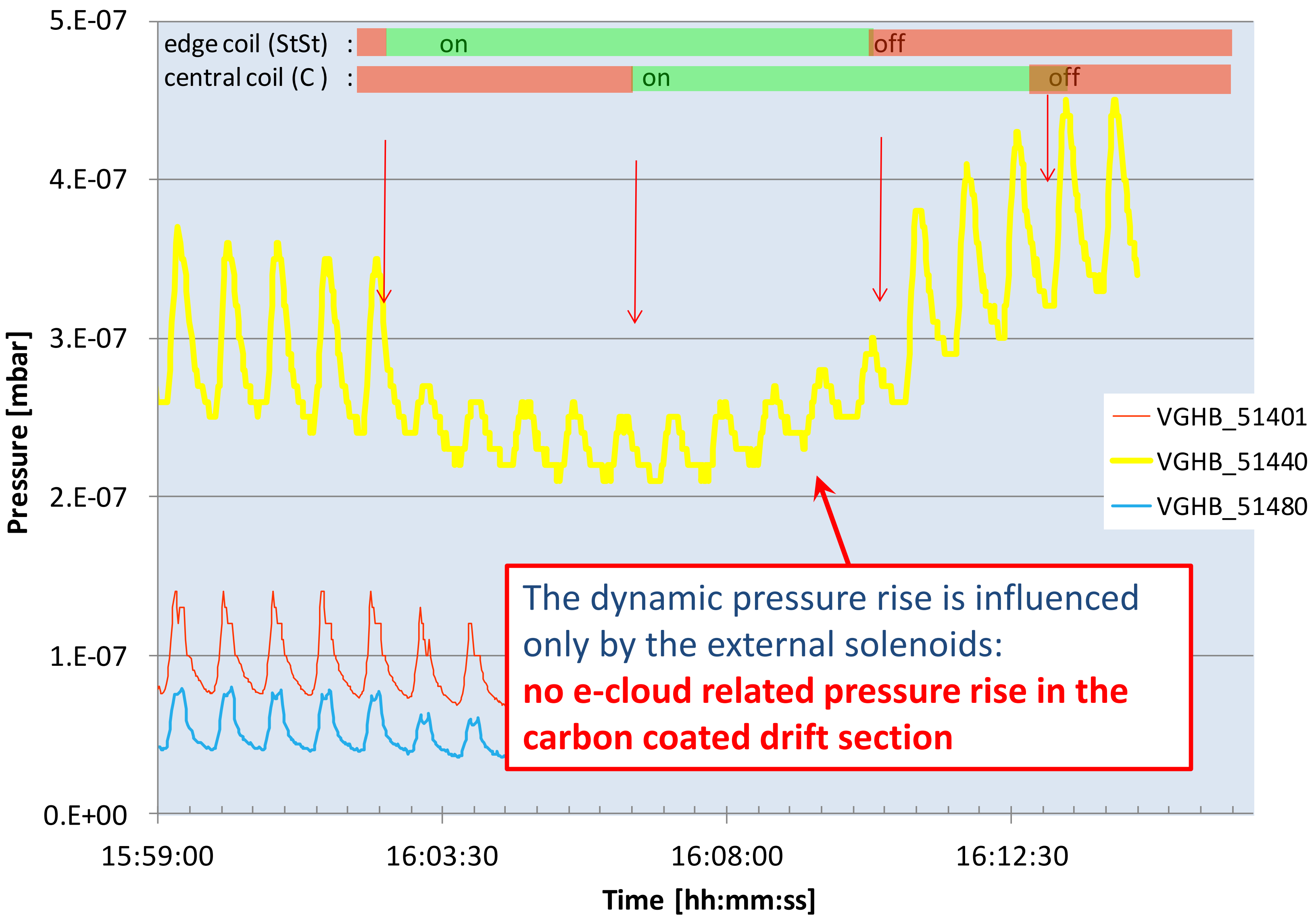
External solenoid on StSt chamber (L=850 mm)





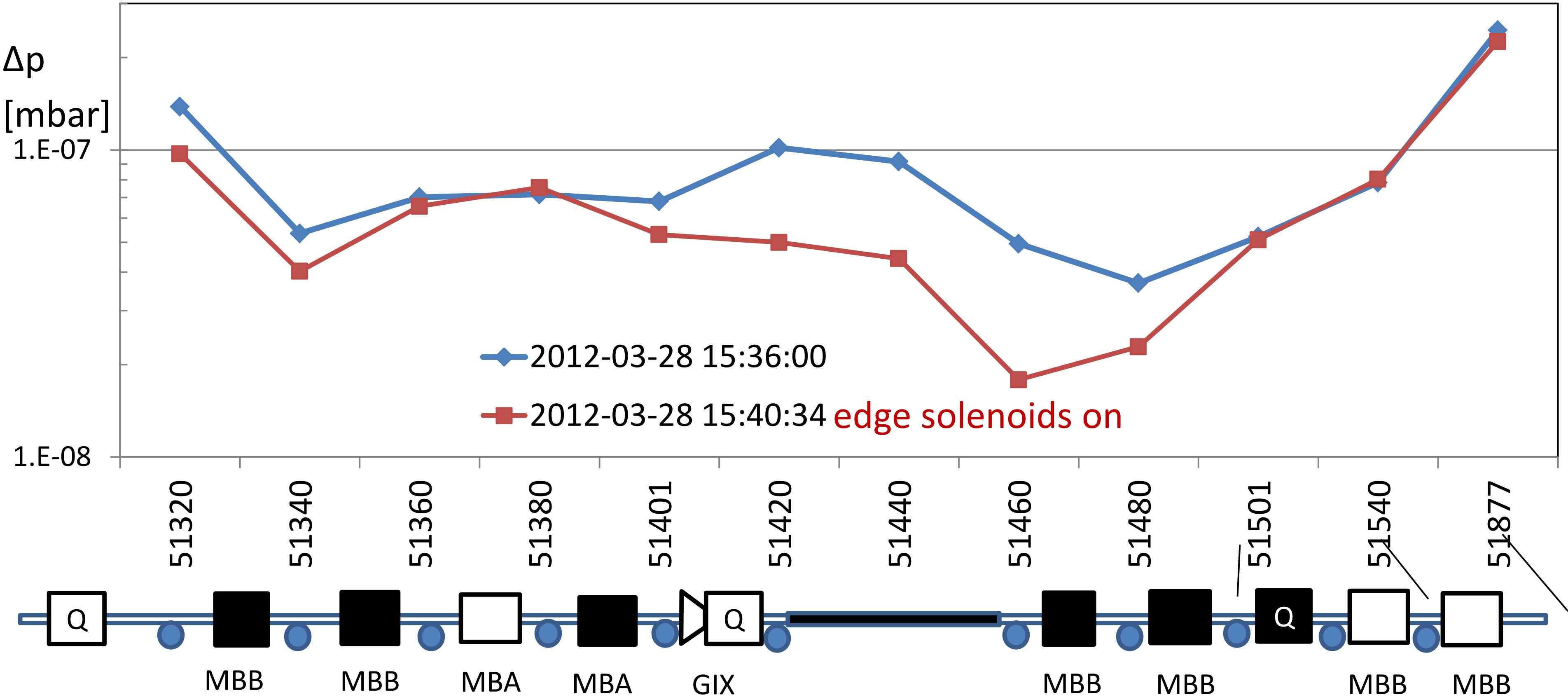
Pressure rise in aC coated chambers





The dynamic pressure rise is influenced only by the external solenoids:
no e-cloud related pressure rise in the carbon coated drift section

Pressure rise in aC coated chambers



The profile shows that the Δp to 51420, 51440 and 51460 strongly decreases and peripheral regions are not affected.

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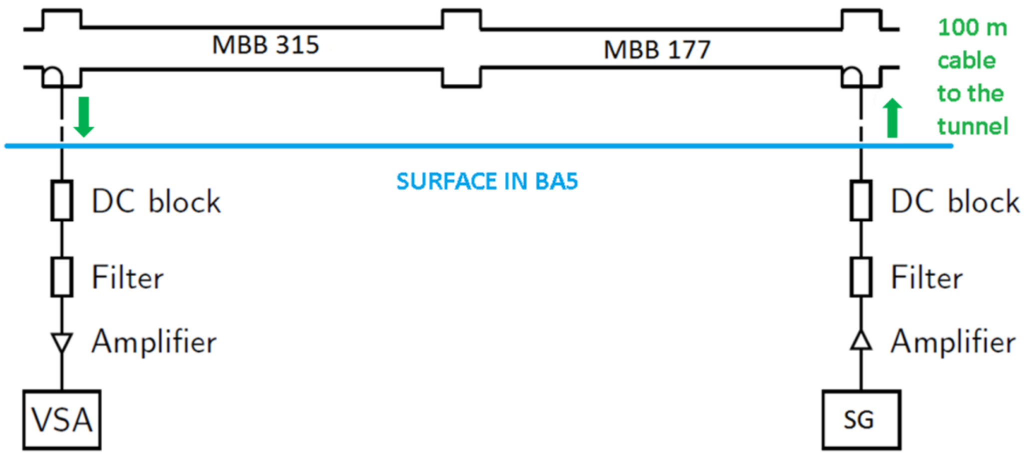
Microwave transmission setup



SG: signal generator
VSA: vector spectrum analyzer

- The setup detects the **phase modulation** introduced by the electron cloud on an EM wave traveling along the beam pipe
- In 2012 measurements have been performed over the length of **two** consecutive, uncoated SPS MBB-type dipoles

F. Caspers, S. Federmann, M. Holz

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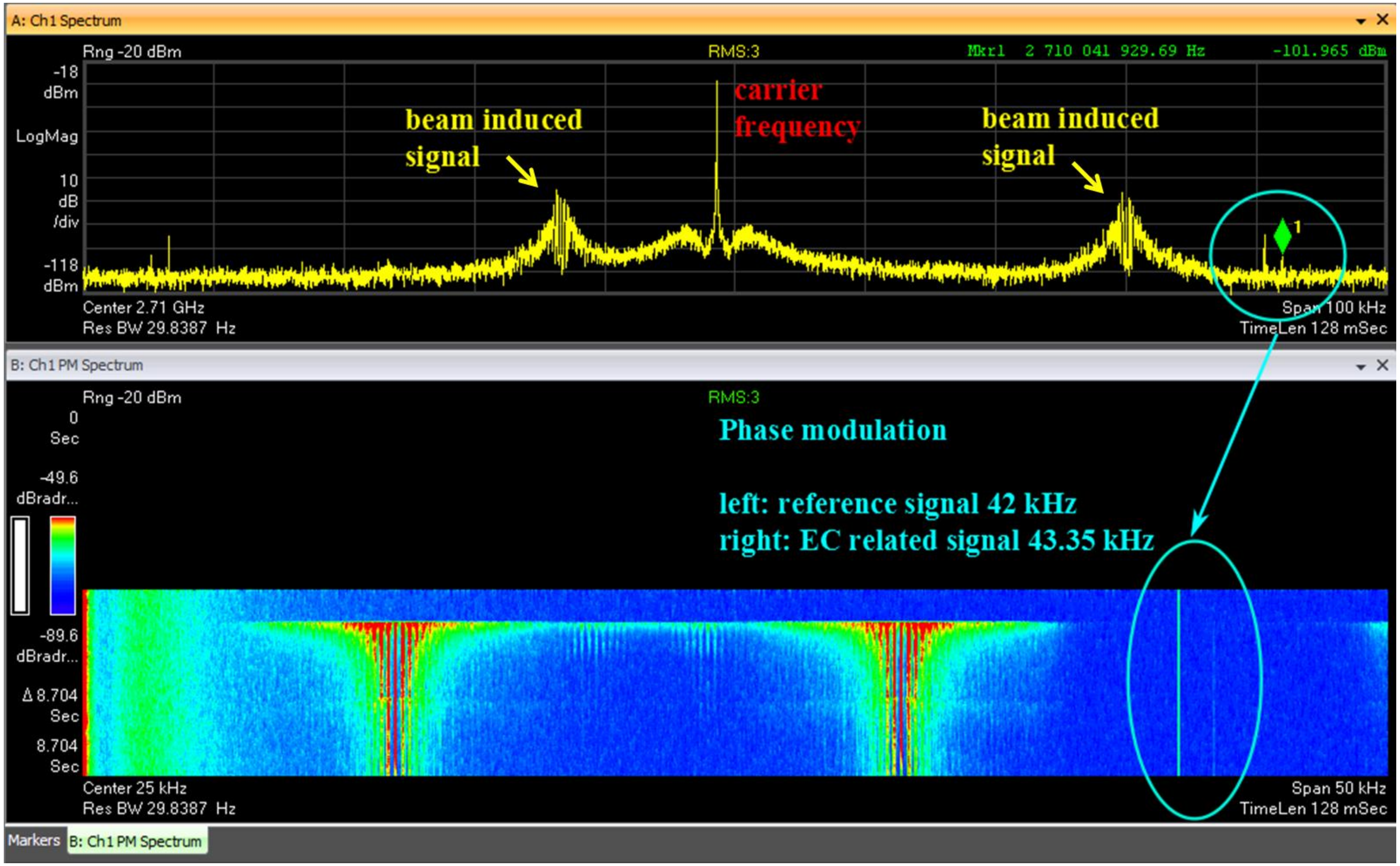


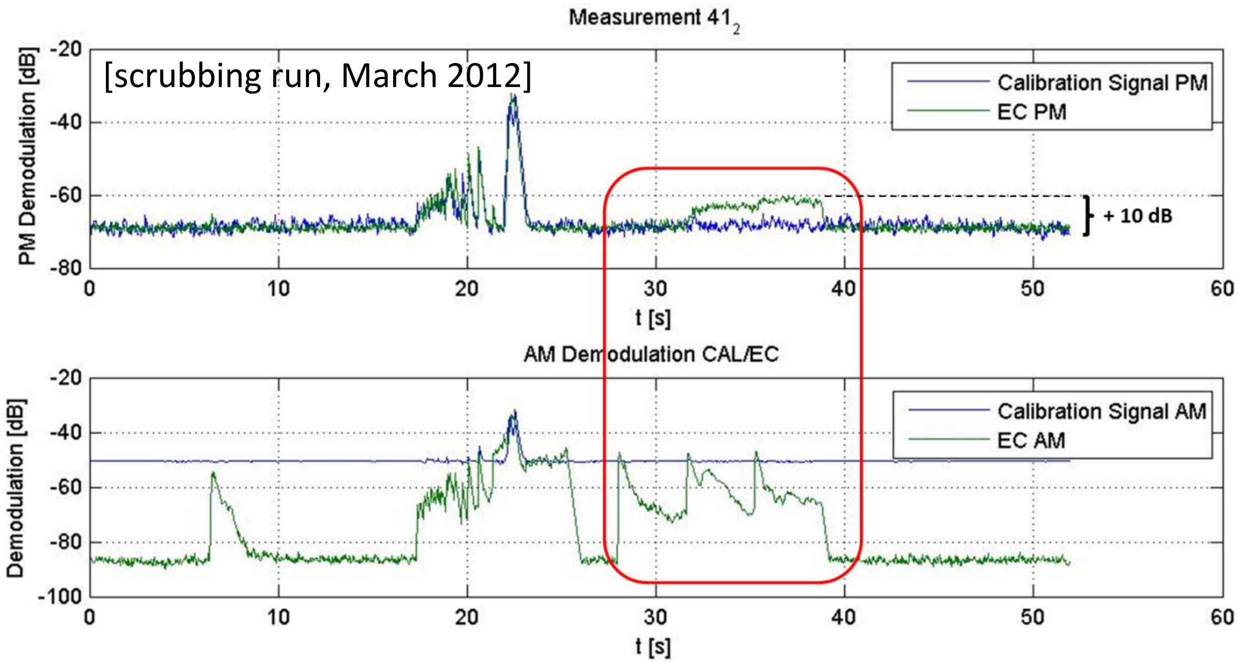
Display of the vector spectrum analyzer during a measurement with a visible phase shift due to electron cloud presence.
Strong phase-modulated **reference signal** at 42 kHz and **weak e-cloud induced phase modulation** at 43.45 kHz (SPS revolution frequency)

- T… EM w…
- I… , u…

analyzer

F. Caspers, S. Federmann, M. Holz

Microwave transmission setup



Top:
clear increase of the phase-modulated e-cloud signal from the second batch injection on.

Bottom:
Batch injection can be seen as spikes in amplitude-demodulated part.

Microwave transmission setup

Possible further improvements:

- The **new spectrum analyzer** enables us to record much more data:
  - Measuring with an **increased bandwidth** of 1 MHz (former 100 kHz) and include harmonics of the phase-modulated signal;
  - Reconstruct phase shift along the bunch train to compare with e-cloud build-up simulations
- With help of the reference signal, whose phase shift is known and pre-set, the phase shift of the EC induced signal can be quantified, providing **first quantitative estimations of the average EC density** in the measured dipoles;
- Once this measurement technique is optimized and fully developed, it could serve as **online monitoring** of the average e-cloud density (remote acquisition from the CCC to be setup)

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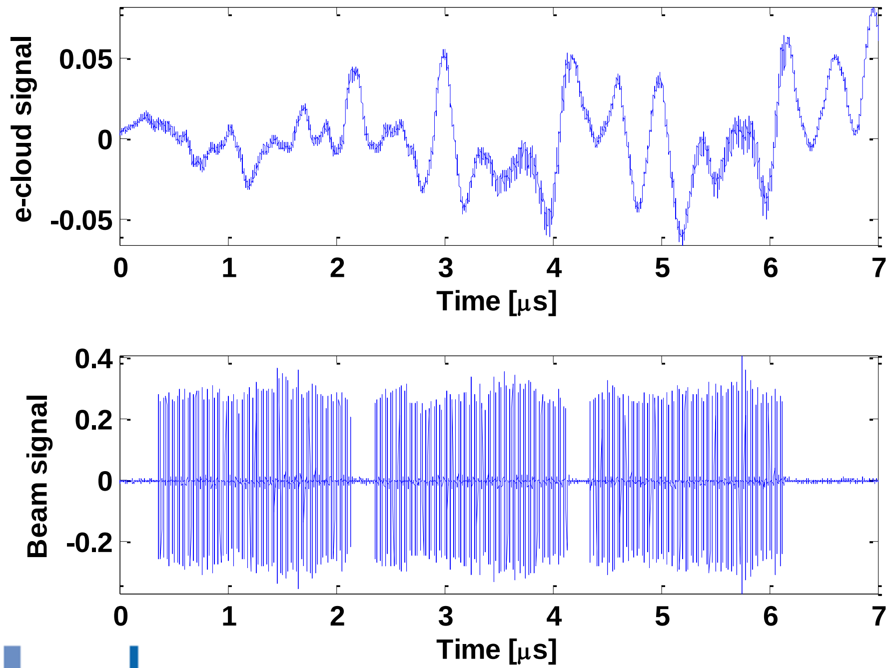
Shielded pickup measurements

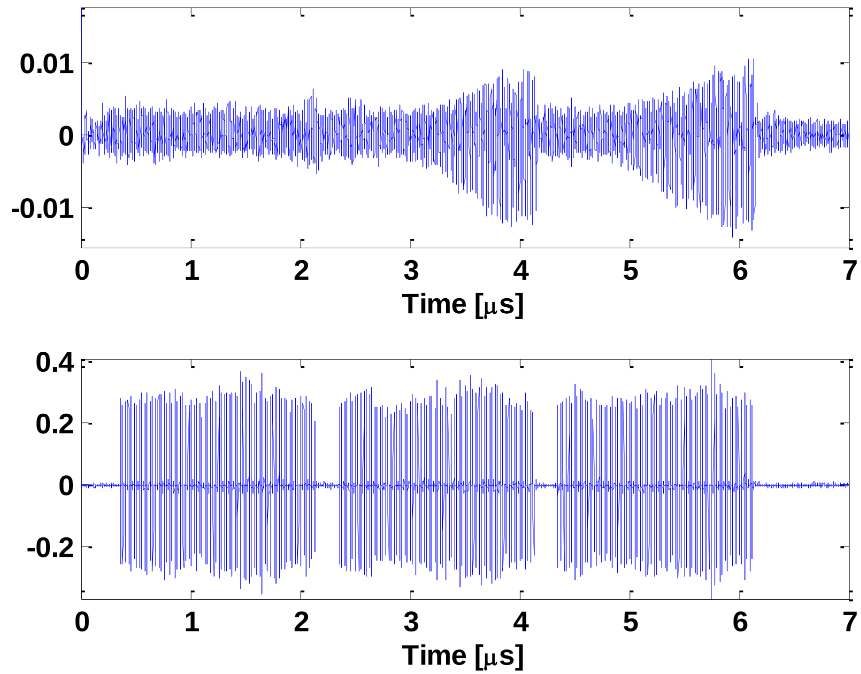
A **shielded pickup** (prepared by F. Caspers. E. Mahner and T. Kroyer in 2007) has been reinstalled in the SPS.

Remote data acquisition has been setup and a **digital filter** has been applied in order to get the ecloud related signal .

Raw data

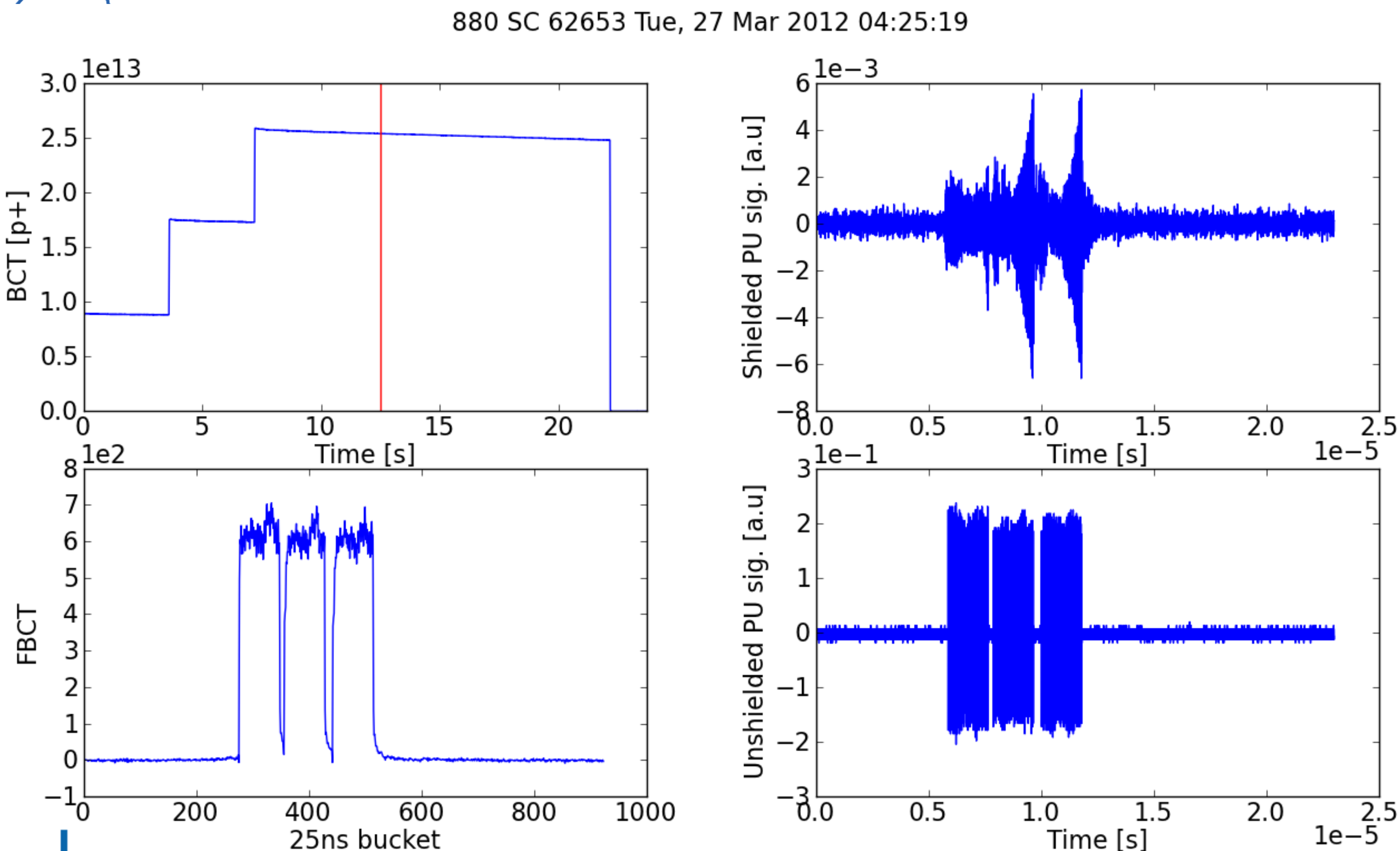


Filtered signals



Shielded pickup measurements

The **memory effect** between batches is clearly visible.



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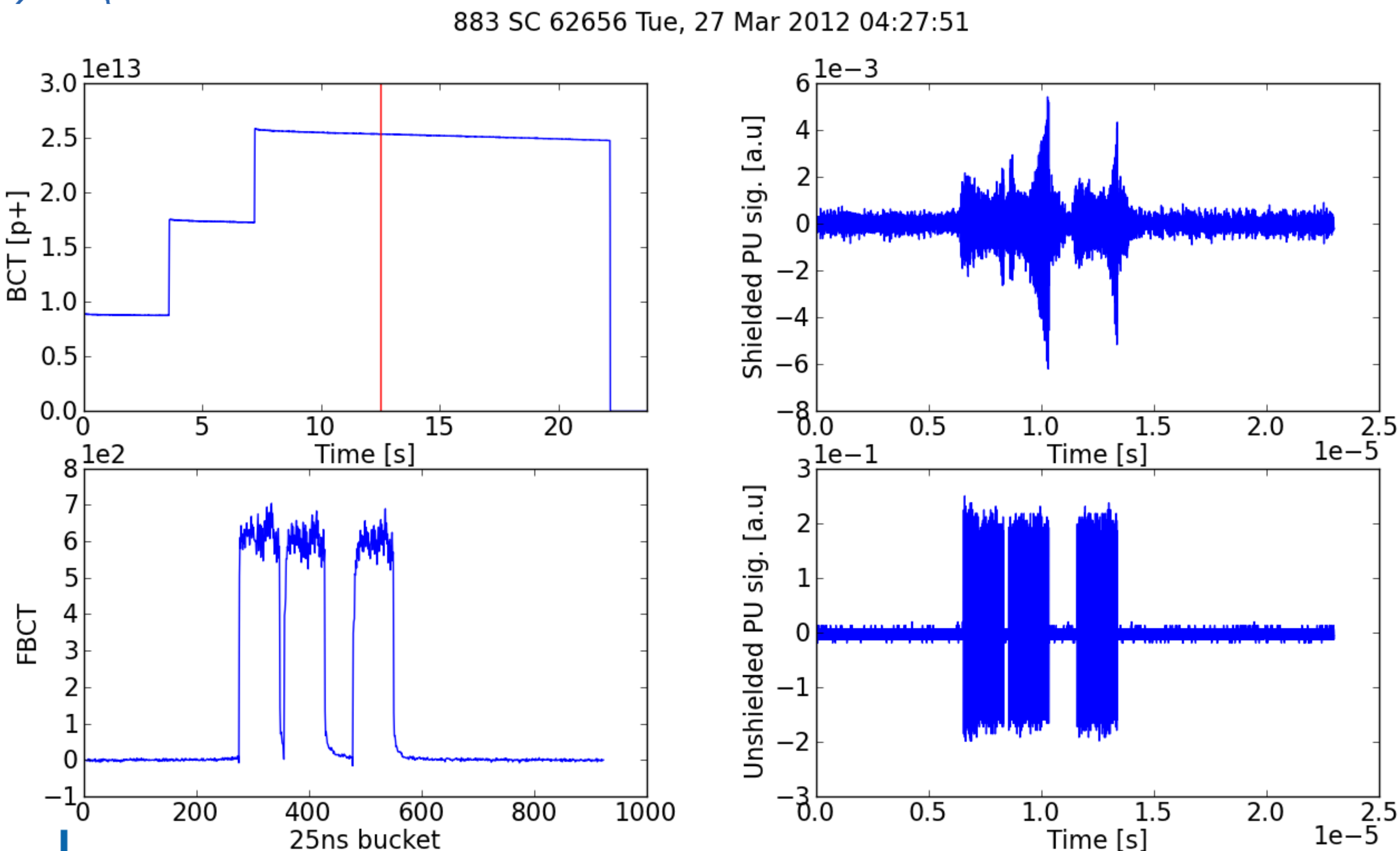

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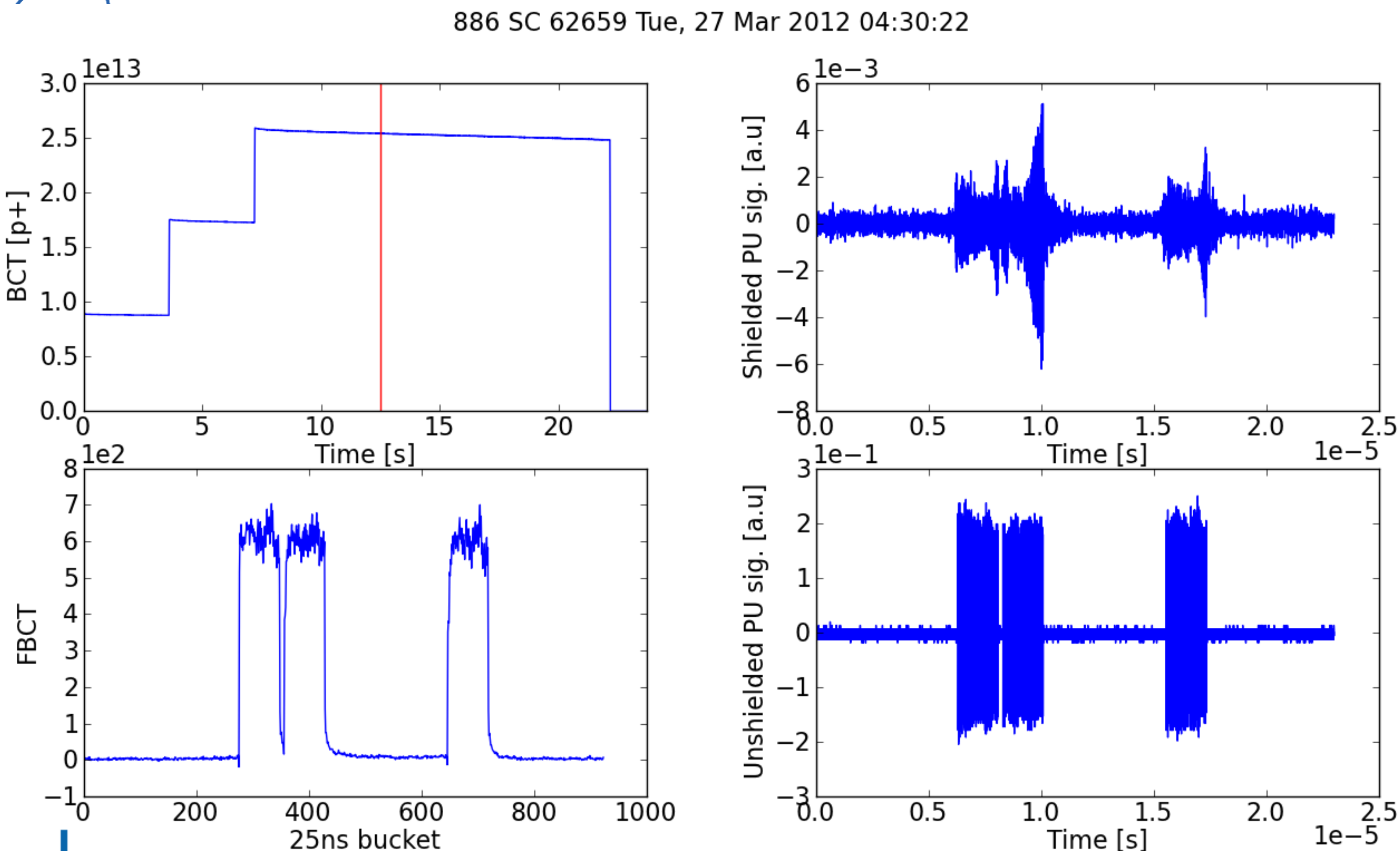

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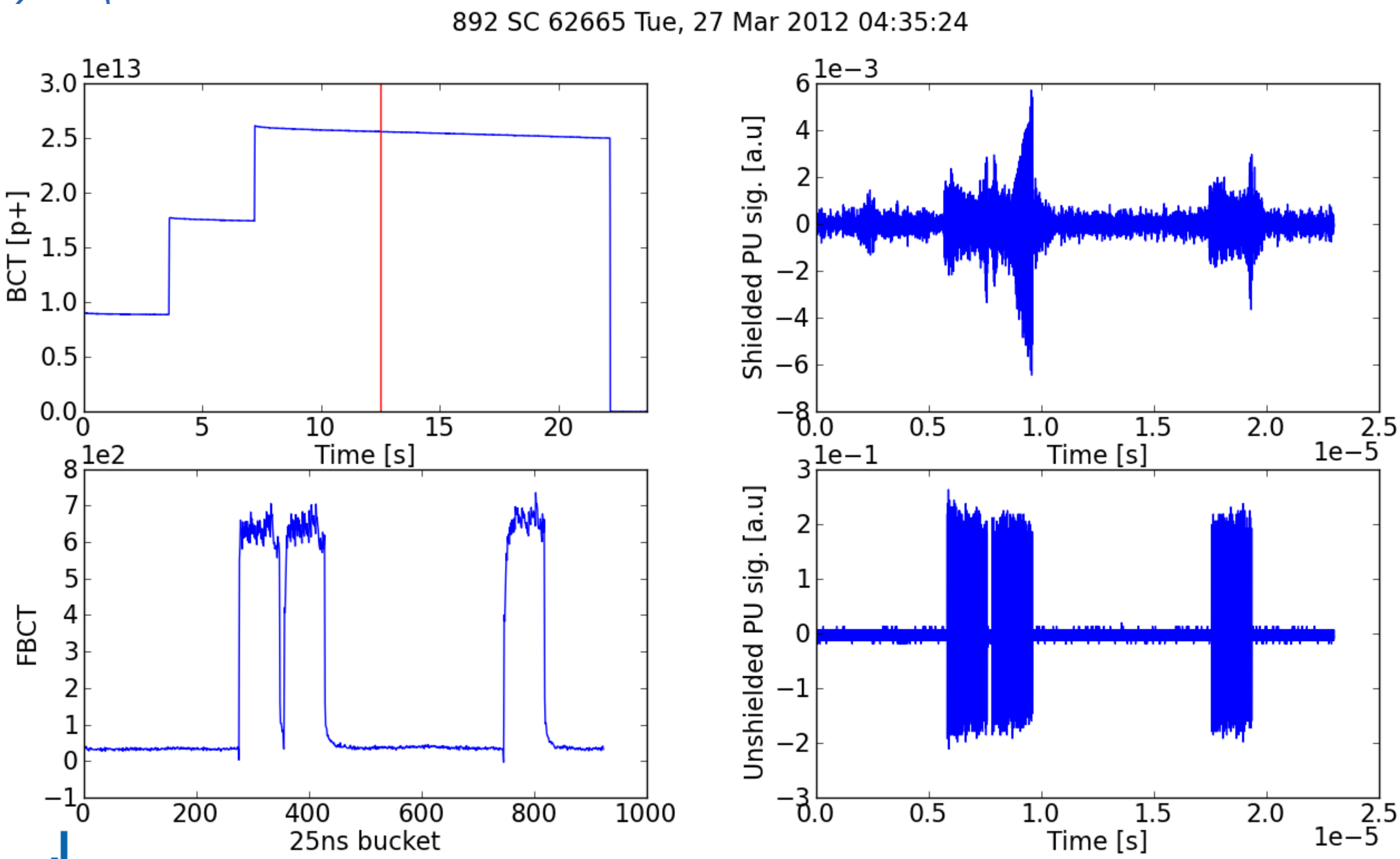

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How can we learn more about the electron cloud effect?

- Progresses in MW transmission and shielded pickup measurements

Studies in 2012: what could still be done

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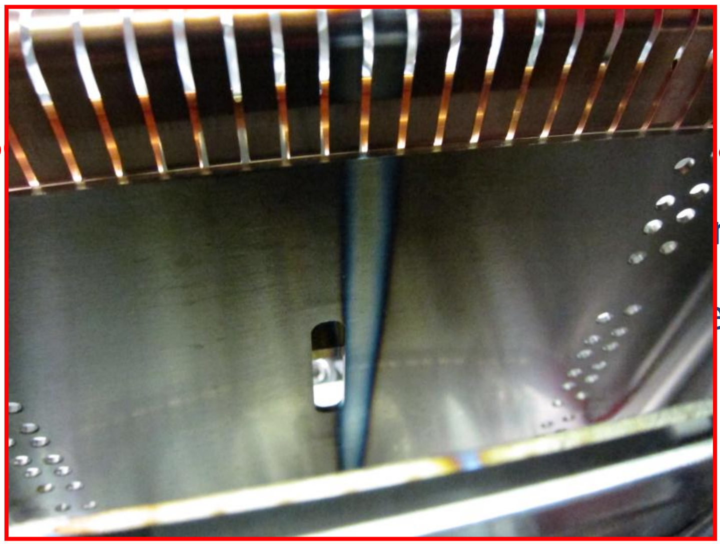

S **ab:** are w

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Understand how localized is the scrubbed region by displacing the beam (radial steering)

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Towards **high brightness:**

- After LS1, profit of **"high brightness" RF schemes available in the PS** to explore the sensitivity of these beams to the EC in the SPS

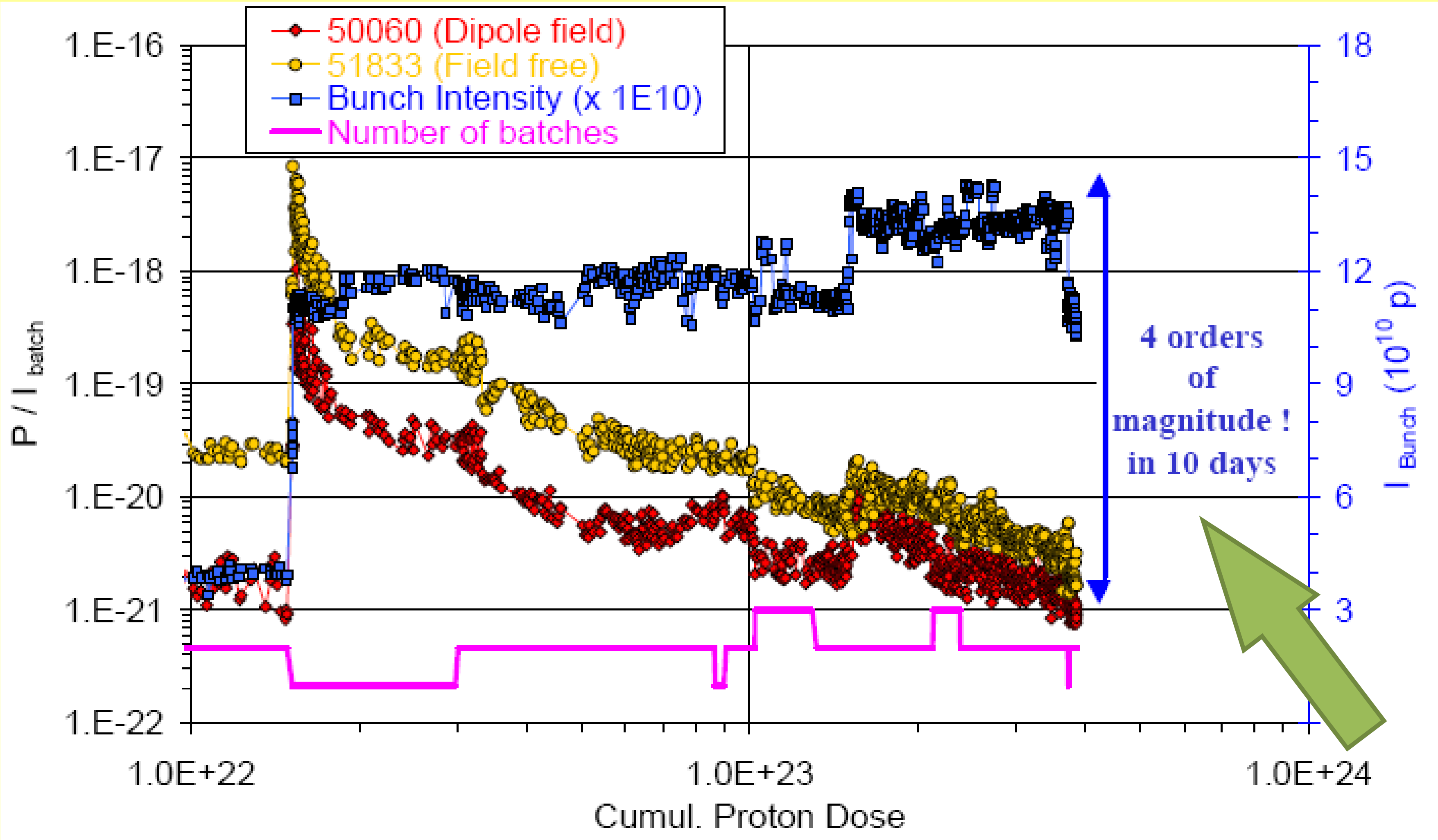
LHC Injectors Upgrade

THANK YOU FOR YOUR ATTENTION!

CERN

e⁻ Cloud Studies in the SPS

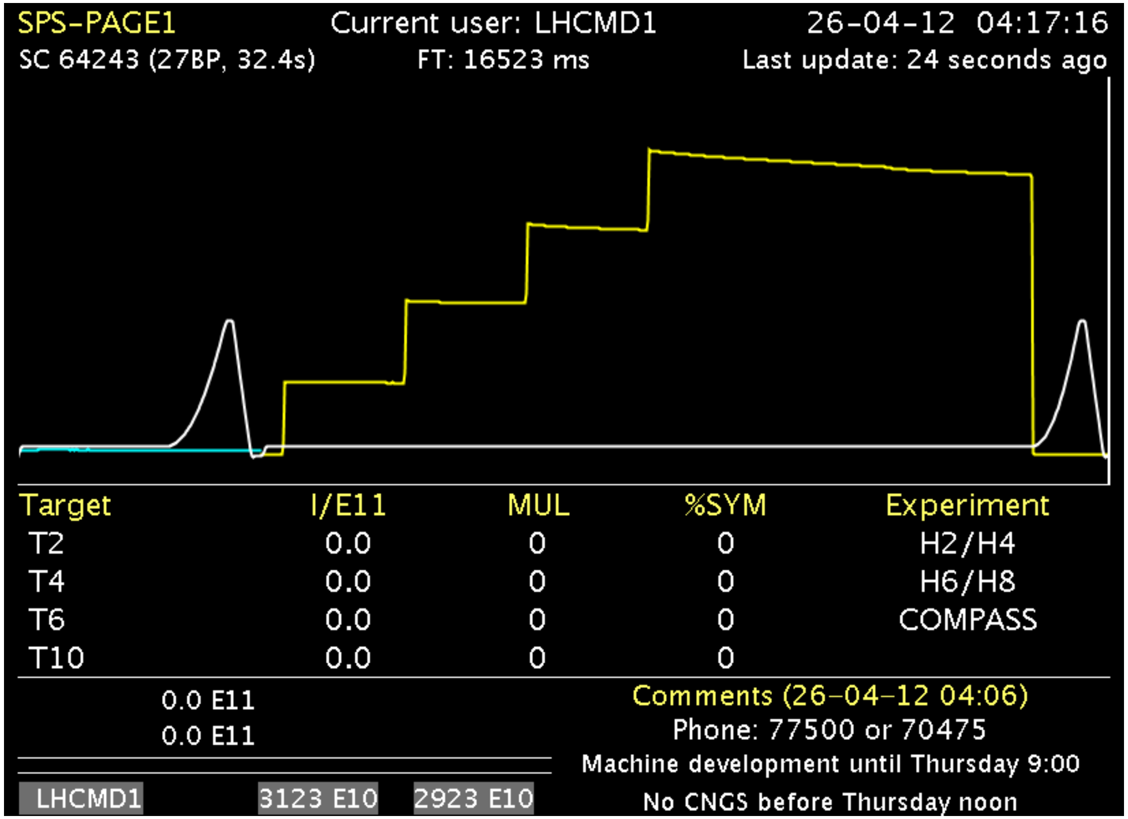
Pressure evolution with dose



G. Arduini, P. Collier, G. Ferioli, B. Henrist, N. Hilleret, L. Jensen
J.M. Jimenez, J.M. Laurent, K. Weiss, F. Zimmermann

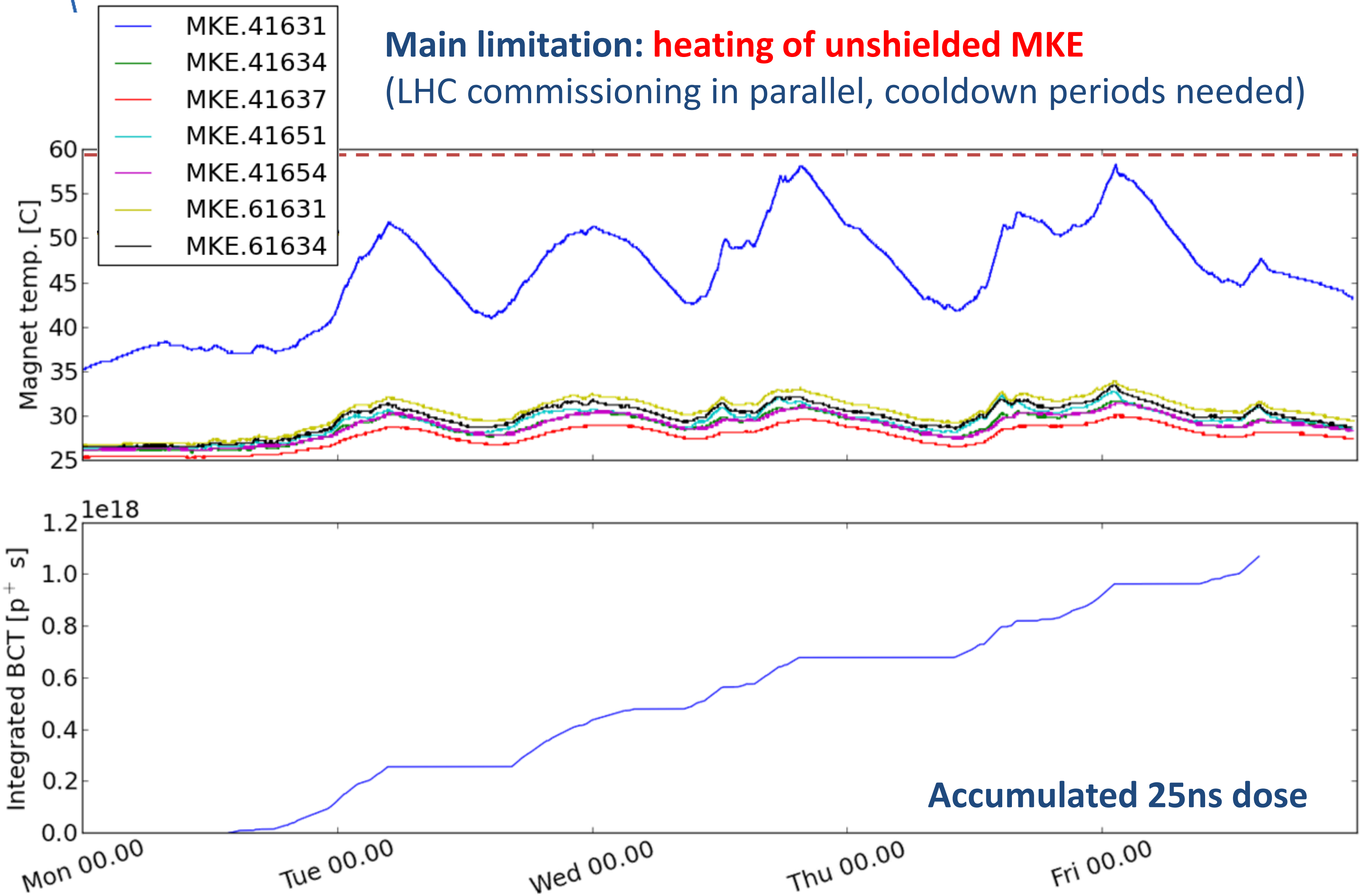
Results of **electron cloud studies (typically 25ns beam, more focus 26GeV)** from:

- 2012 **SPS Scrubbing Run** (26-30 March)
- Dedicated MD **25 April**
- Floating MD **22 May**
- Dedicated MD **25 June**

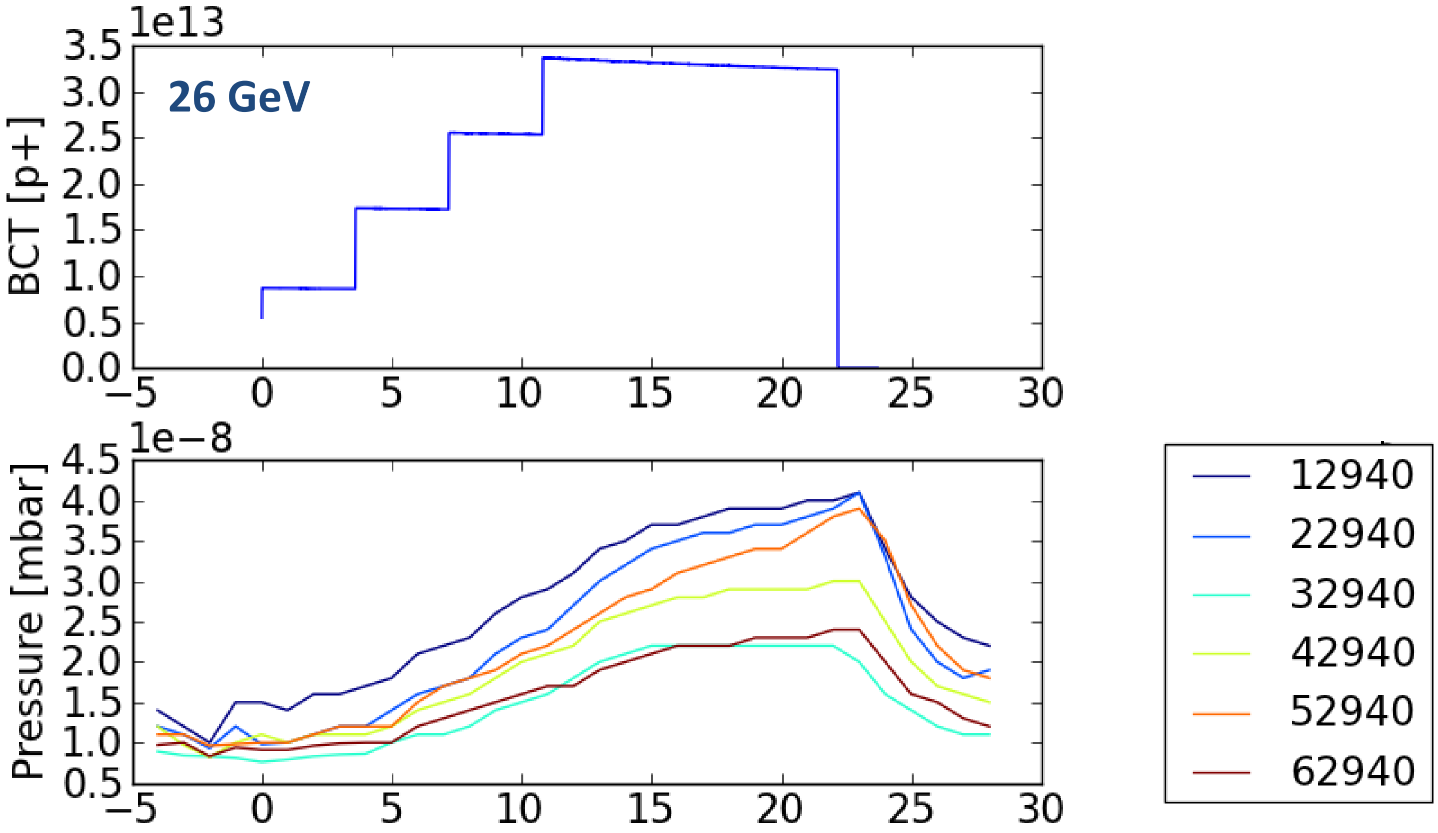


2012 SPS Scrubbing Run

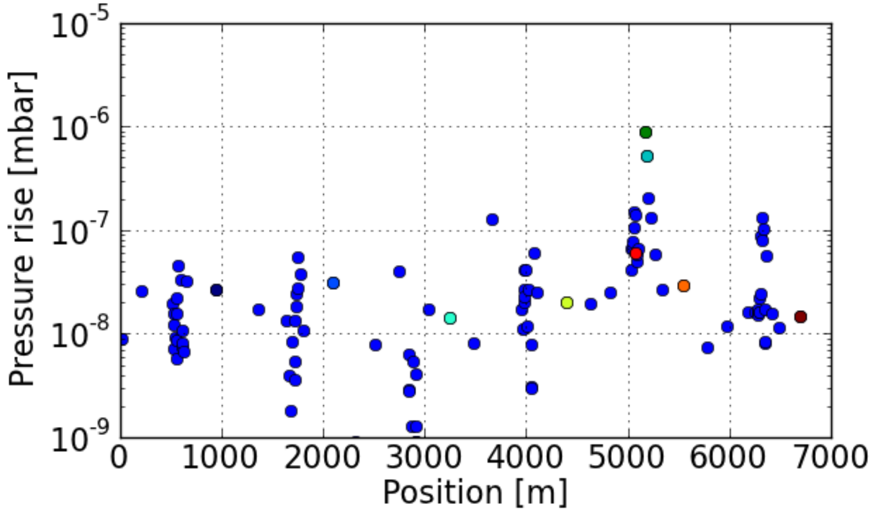
Main limitation: heating of unshielded MKE
(LHC commissioning in parallel, cooldown periods needed)



Together with effects on the beam, **the dynamic pressure rise** is **the only other observable** to qualify the present conditioning state of the SPS ring.



Typical pressure rise profile (25ns)



Dynamic pressure rise

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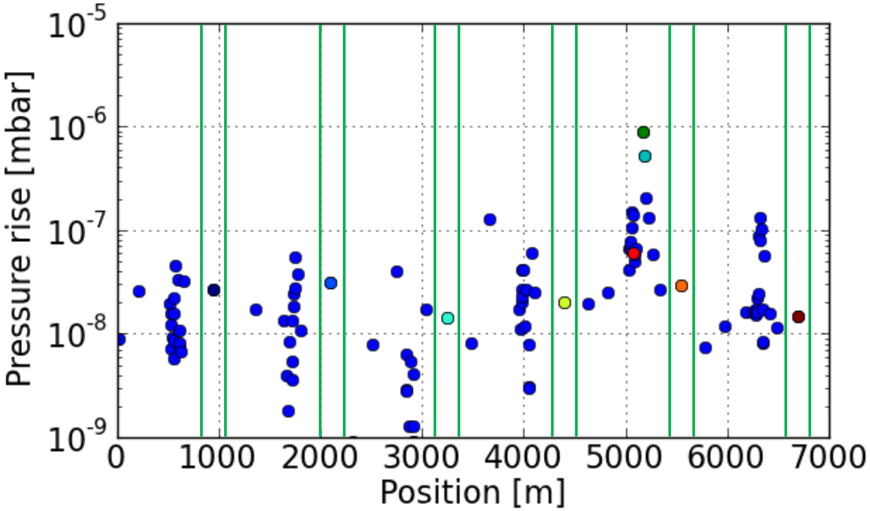

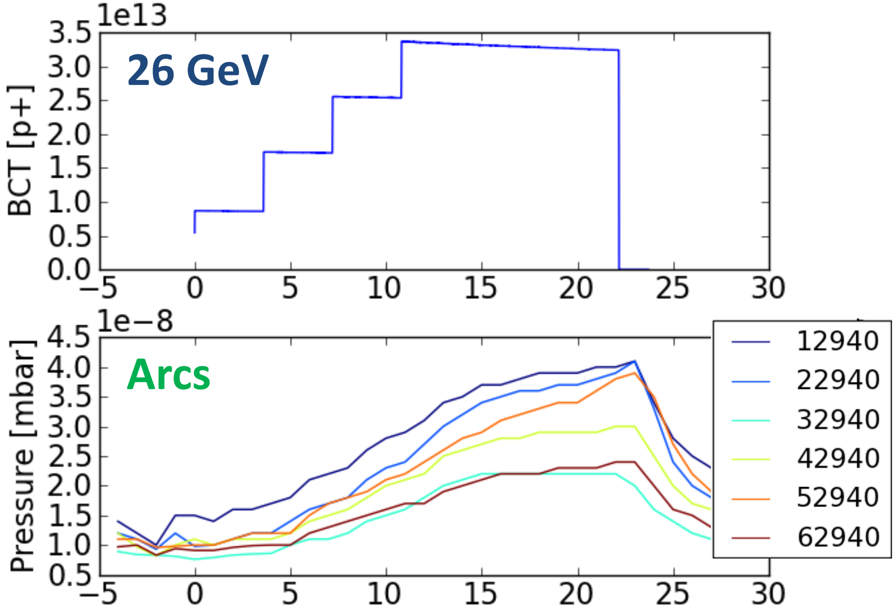

Time evolution on a **few selected gauges**:

- **One per arc** (between two MBB)

Dynamic pressure rise

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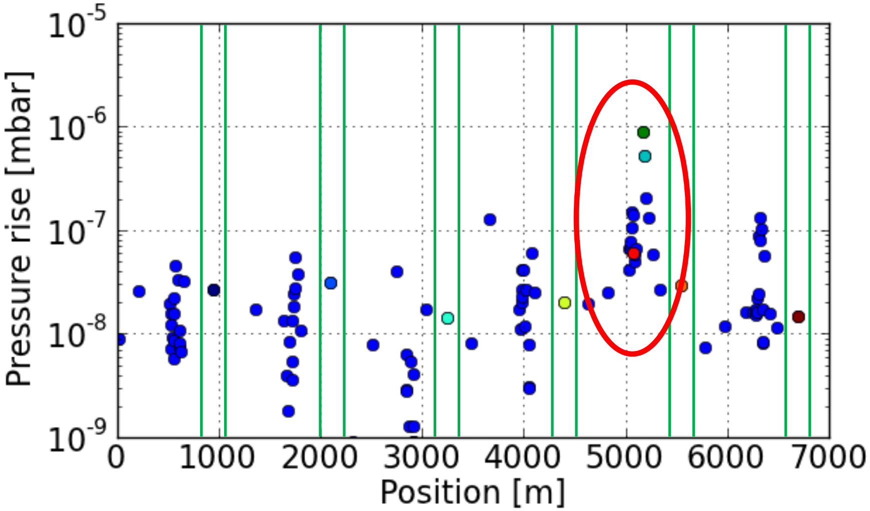
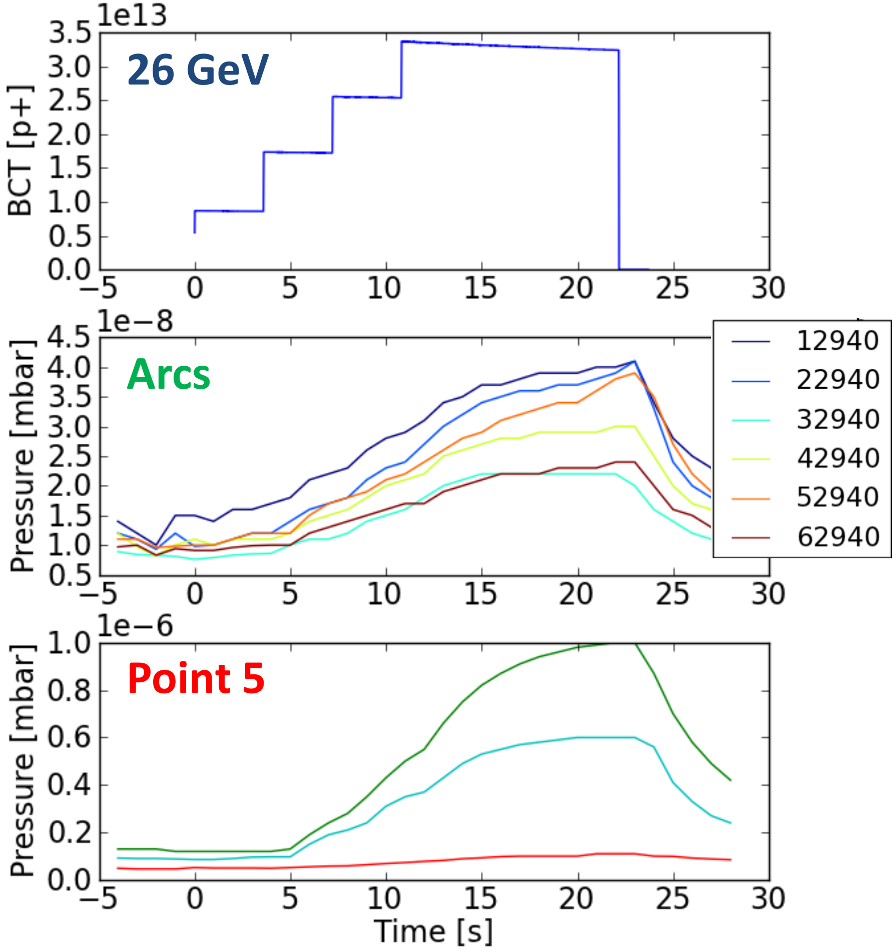


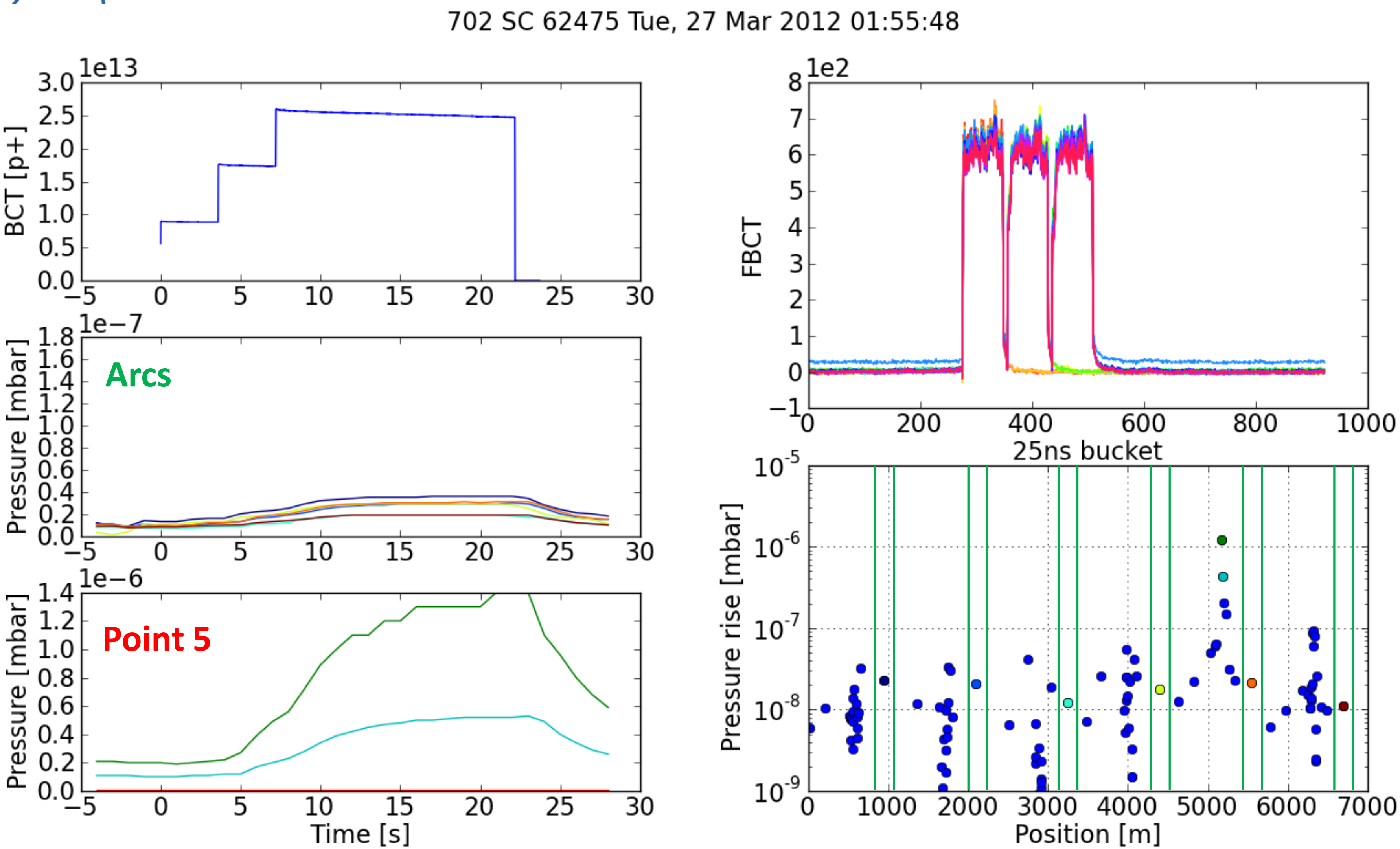


Time evolution on a **few selected gauges**:

- **One per arc** (between two MBB)
- **Three gauges around point 5** (highest press. rise observed in the ring - e-cloud equipments, UA9, BBLR)

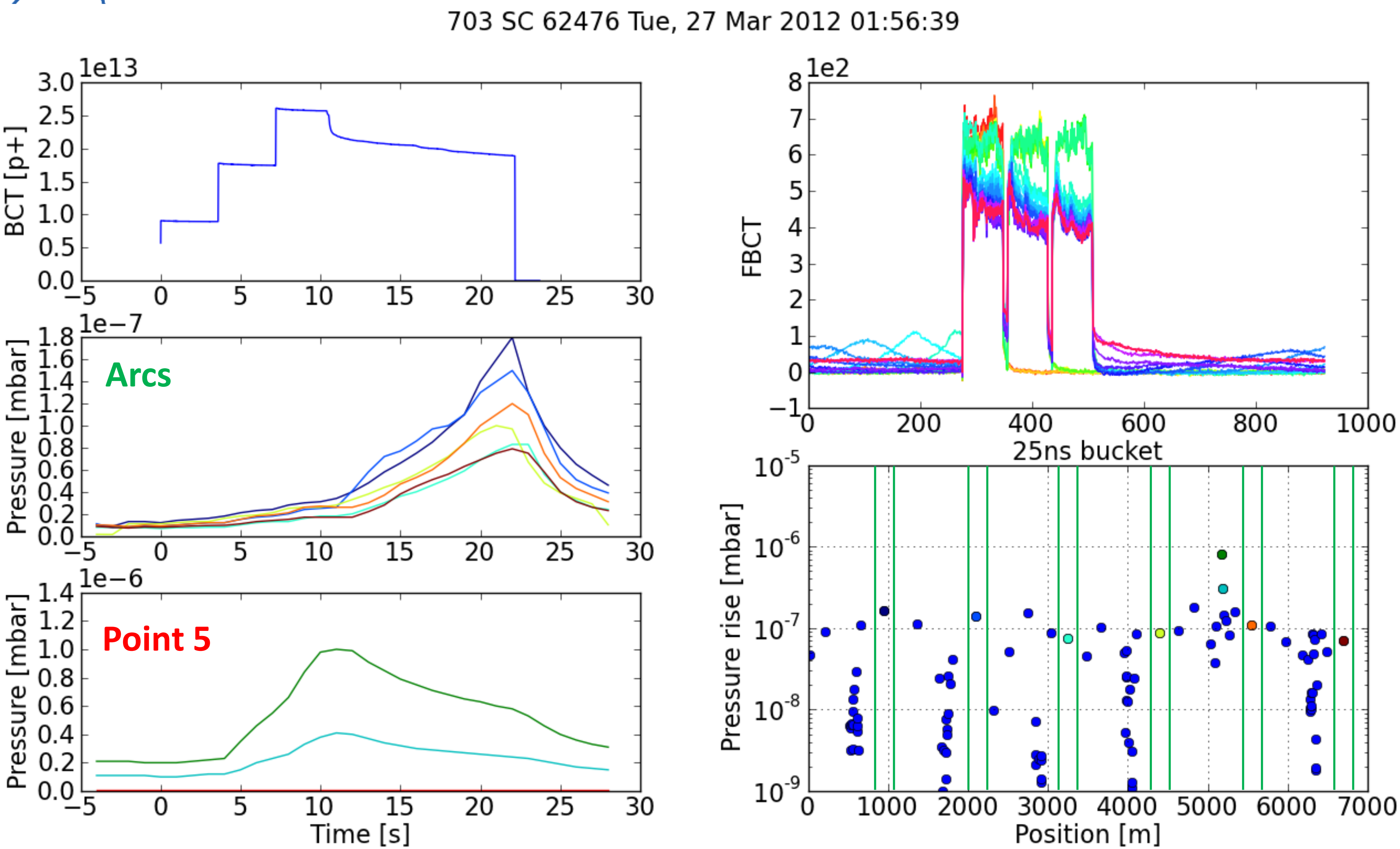
Dynamic pressure rise – effect of losses

Cycle with **nominal settings**



Dynamic pressure rise – effect of losses

Cycle with **low RF voltage**



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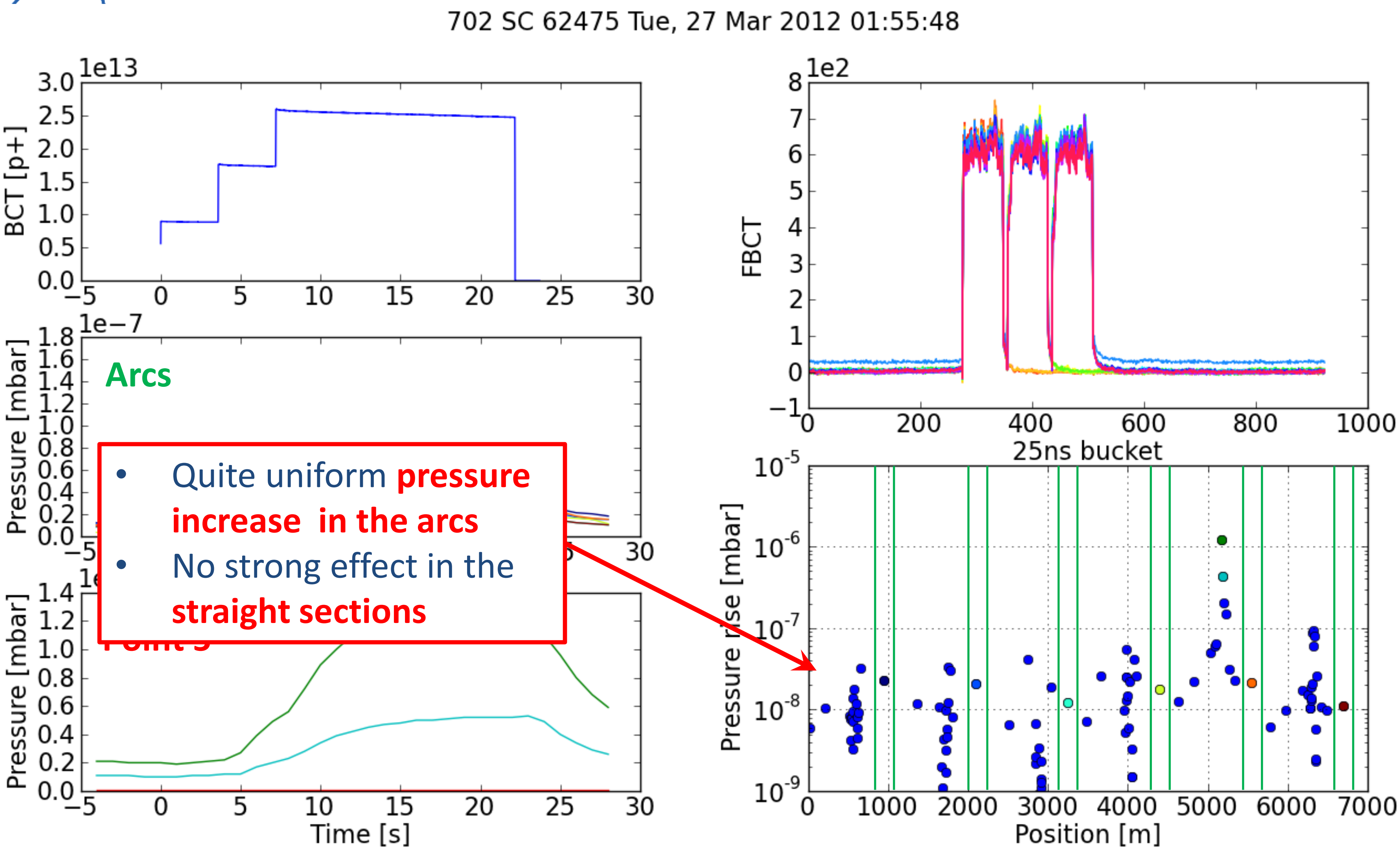

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- No strong effect in the **straight sections**

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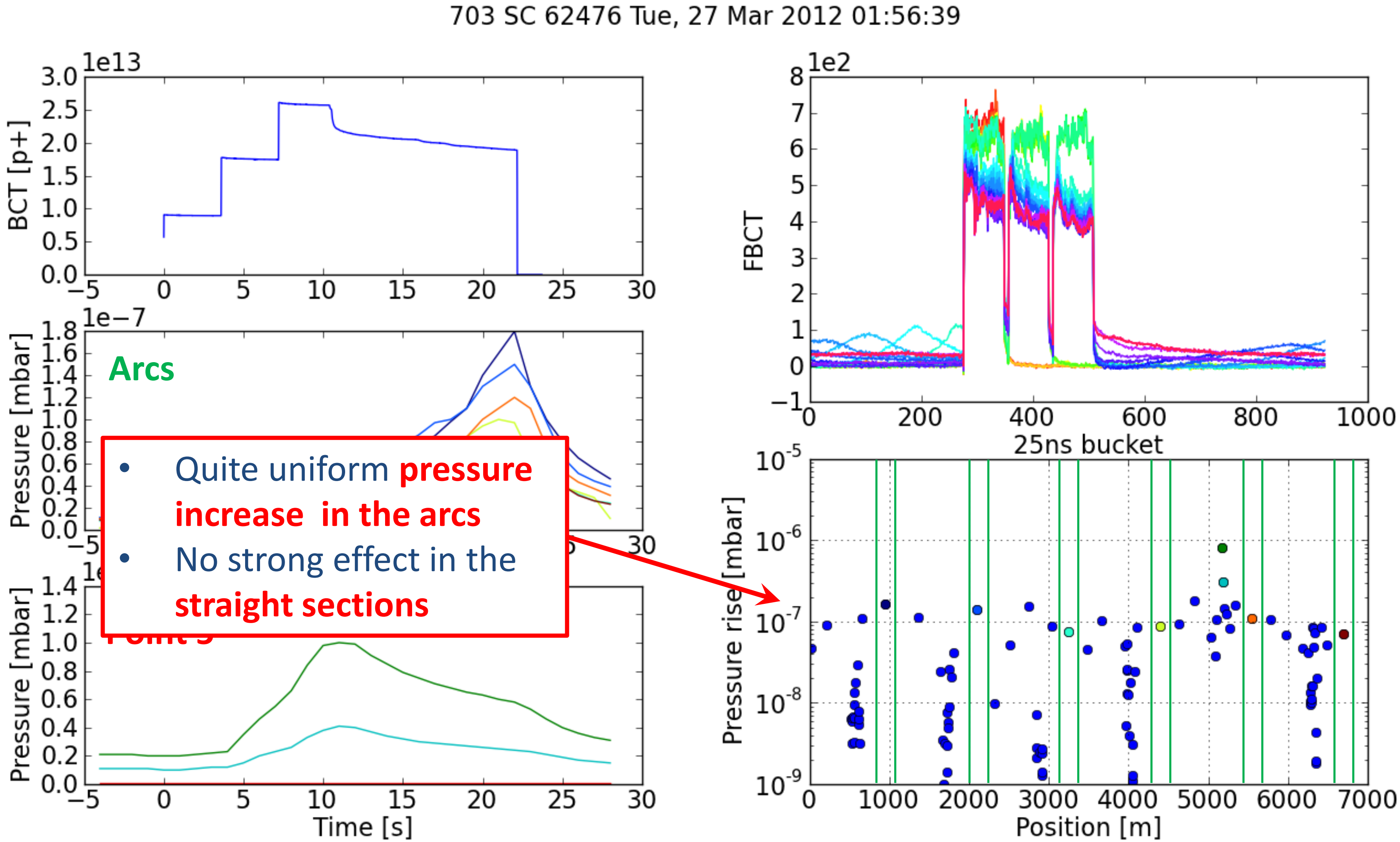

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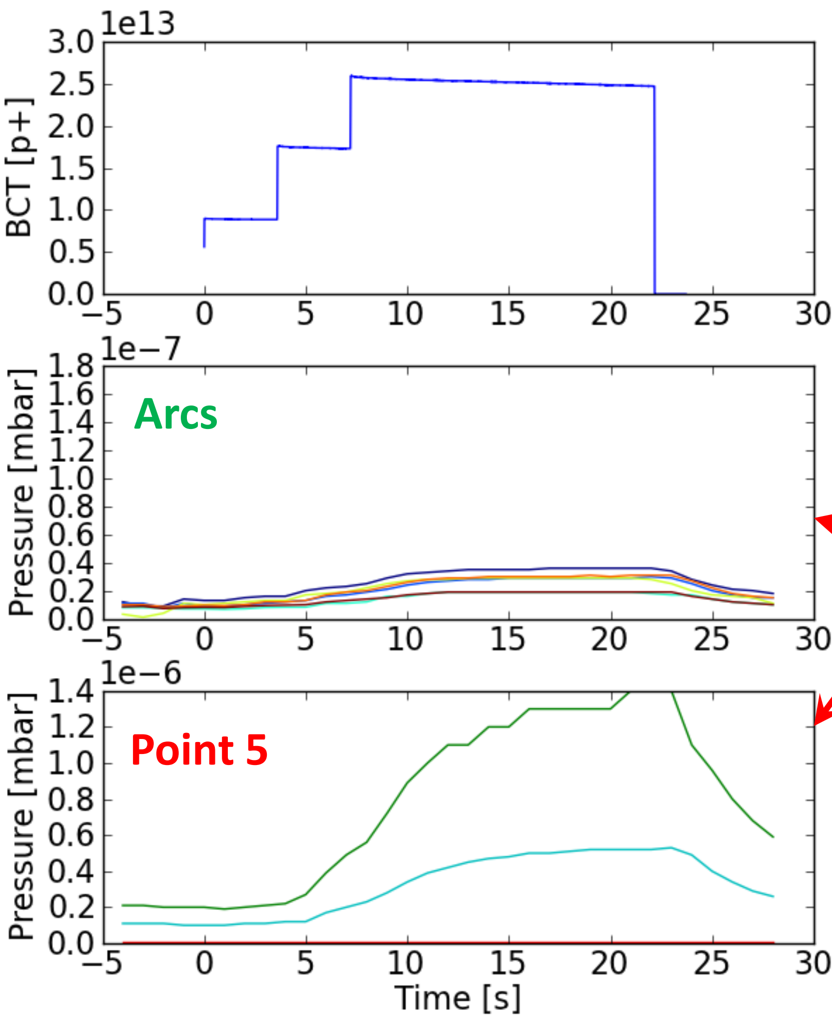
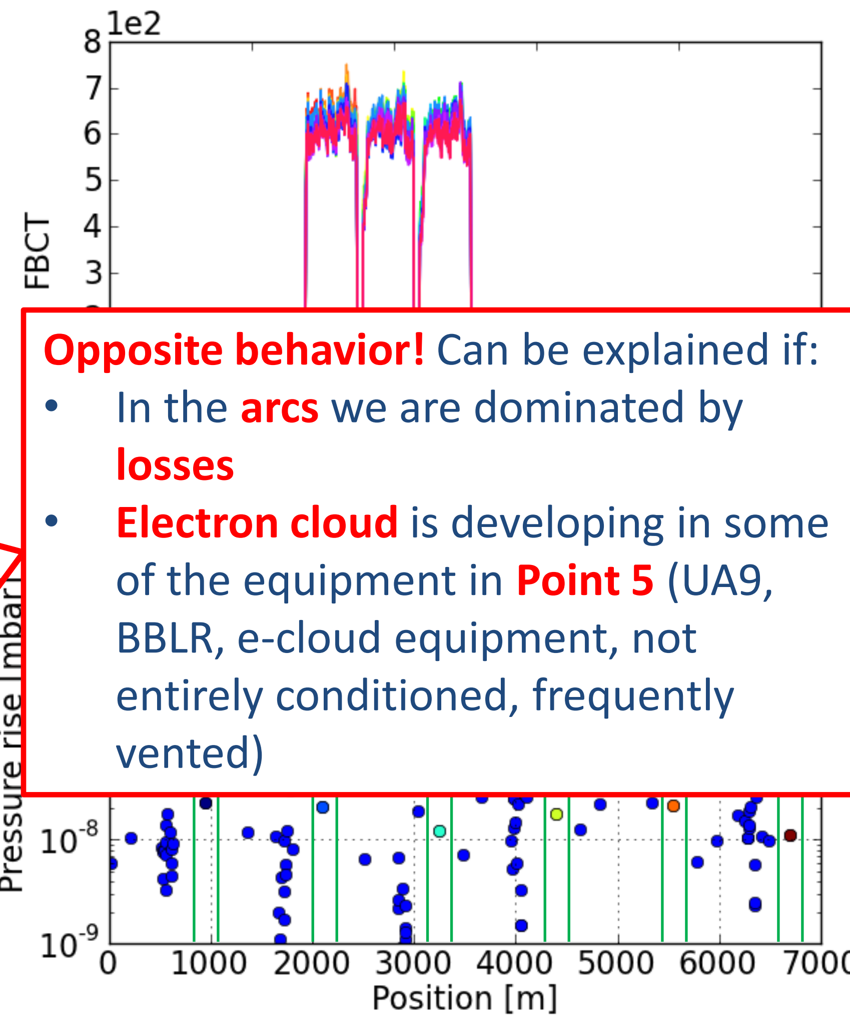
702 SC 62475 Tue, 27 Mar 2012 01:55:48





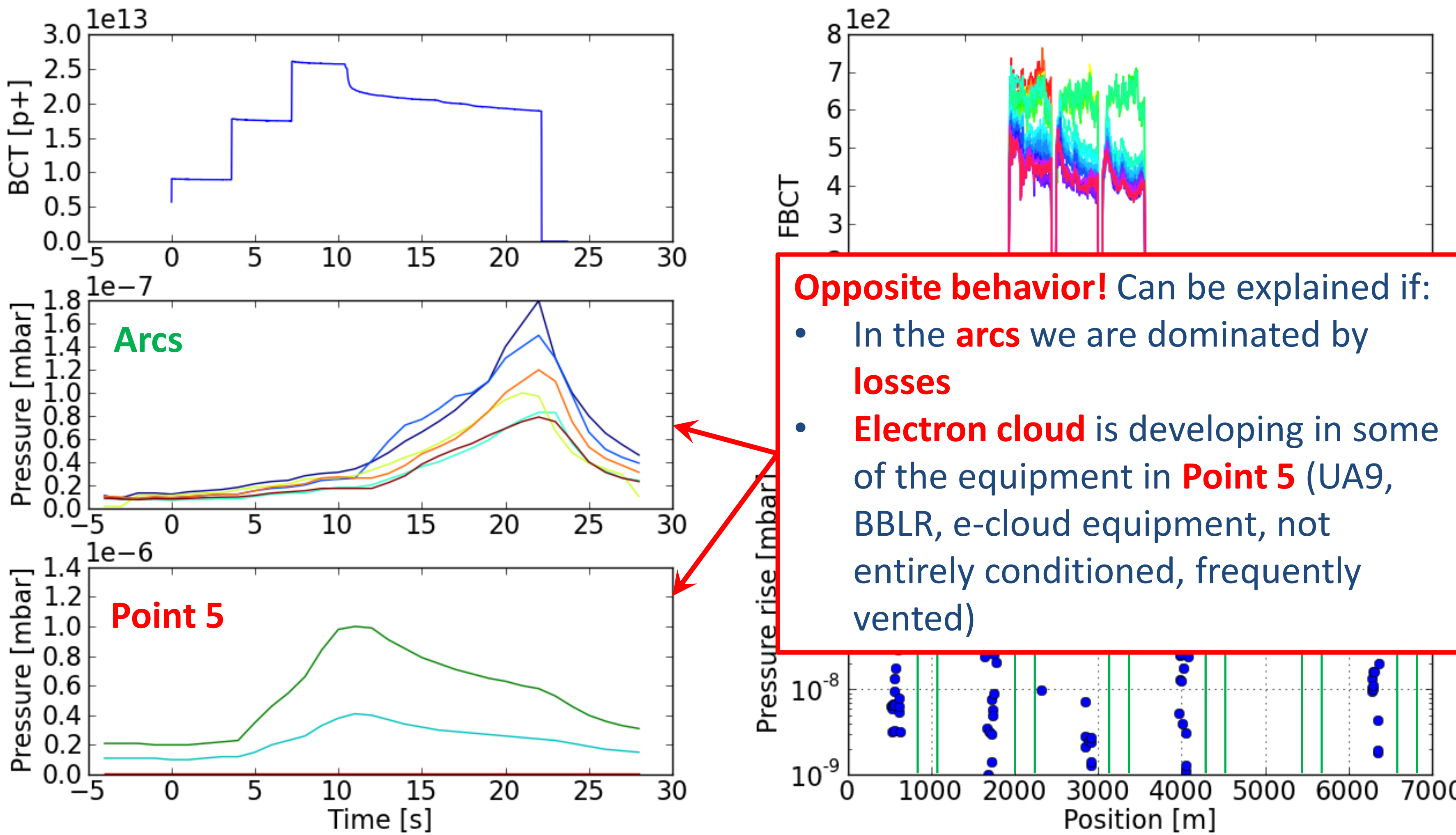
Opposite behavior! Can be explained if:

- In the **arcs** we are dominated by **losses**
- **Electron cloud** is developing in some of the equipment in **Point 5** (UA9, BBLR, e-cloud equipment, not entirely conditioned, frequently vented)

Dynamic pressure rise – effect of losses

Cycle with **low RF voltage**

703 SC 62476 Tue, 27 Mar 2012 01:56:39



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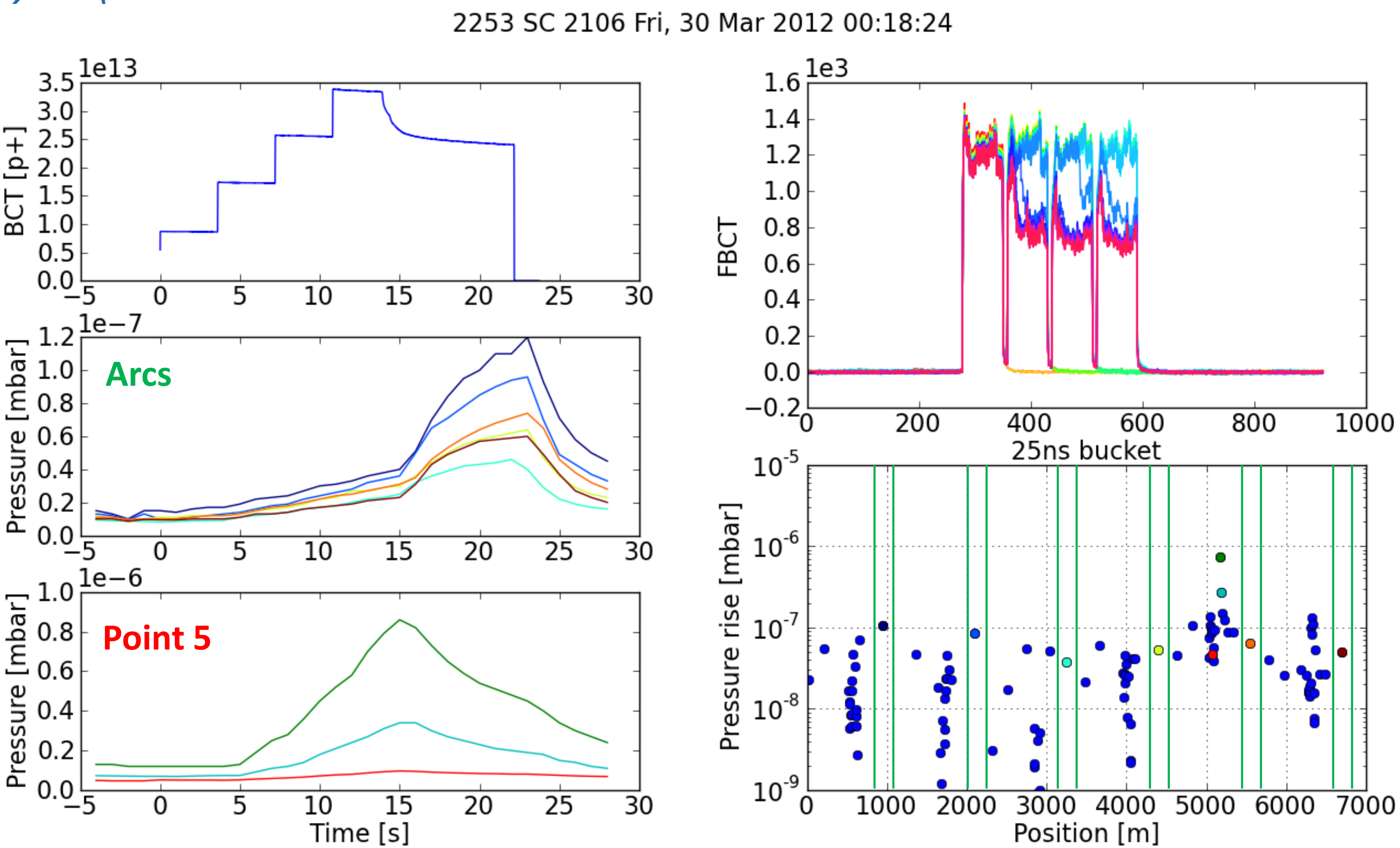
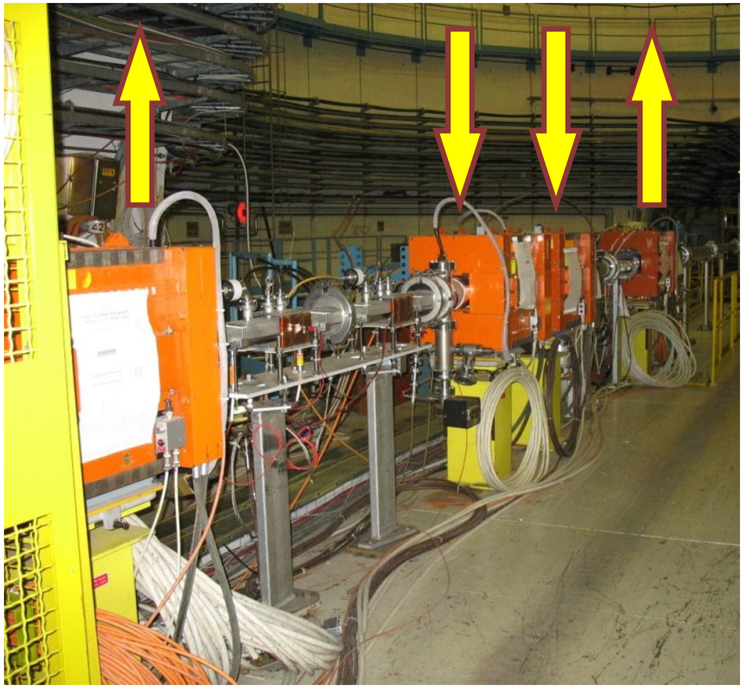
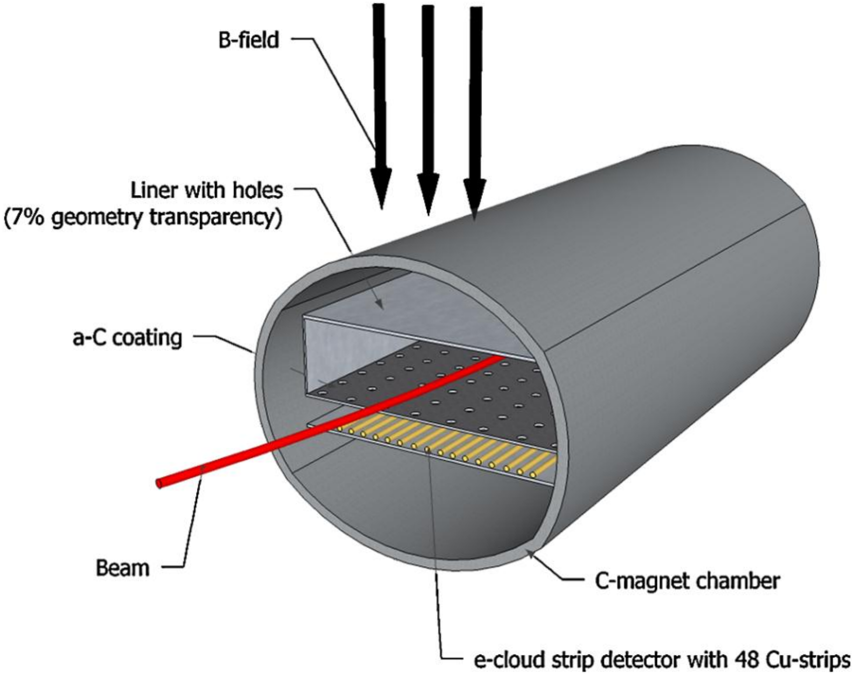
Cycle with **low vertical chromaticity (<0.05), transverse instability**



C. Y. Vallgren et al., PRSTAB

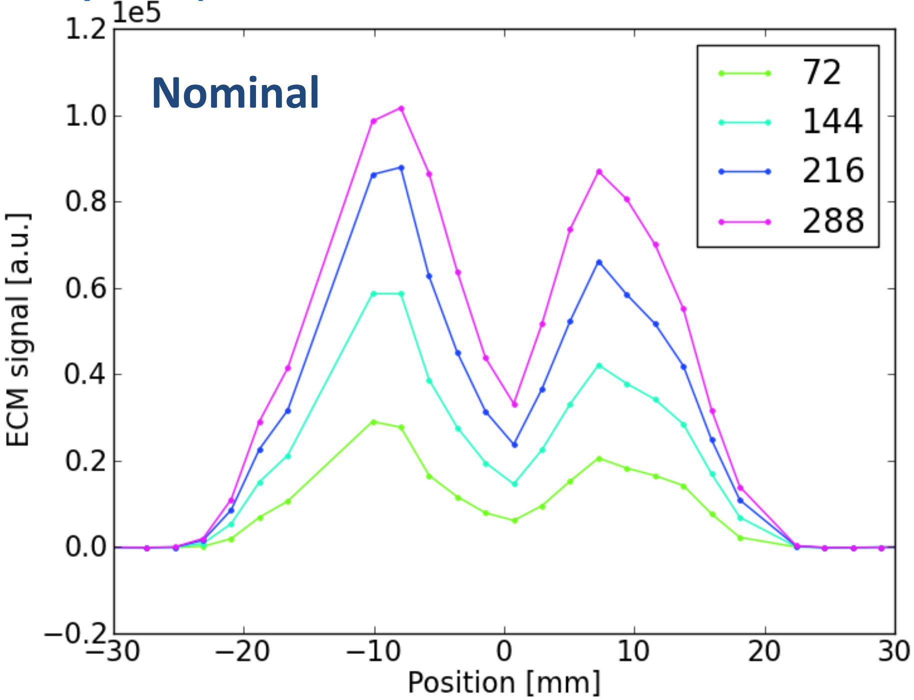


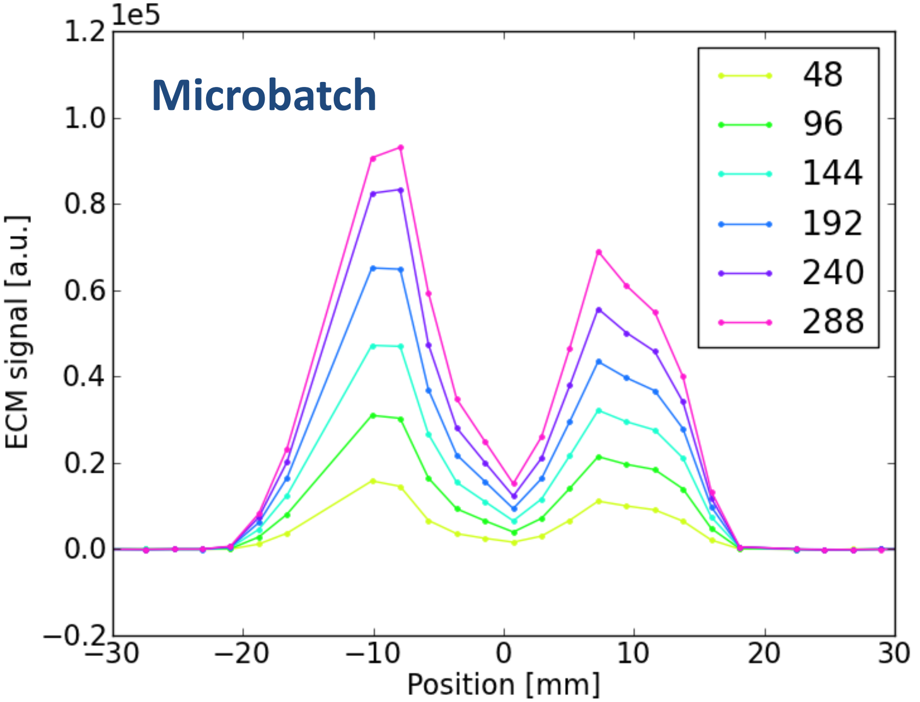


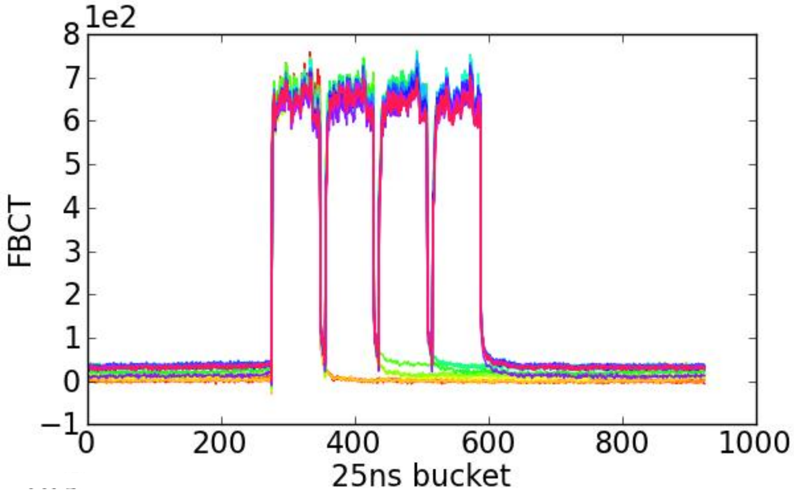
Very powerful tool since they allows to measure the **horizontal profile** of the electron flux to the wall (av. over 10 – 100 ms) , **but:**

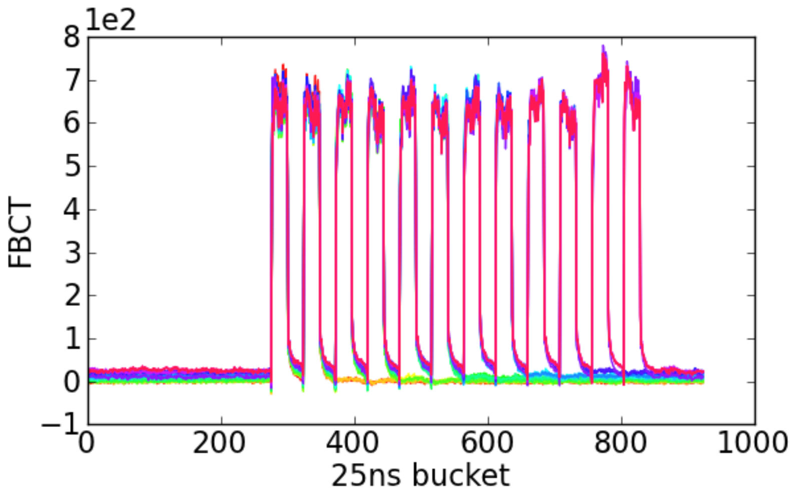
- It is **not representative of the present conditioning state** of the machine
- The **holes may significantly affect** (slow down) **the conditioning** of the chamber

Strip detectors – "microbatches"









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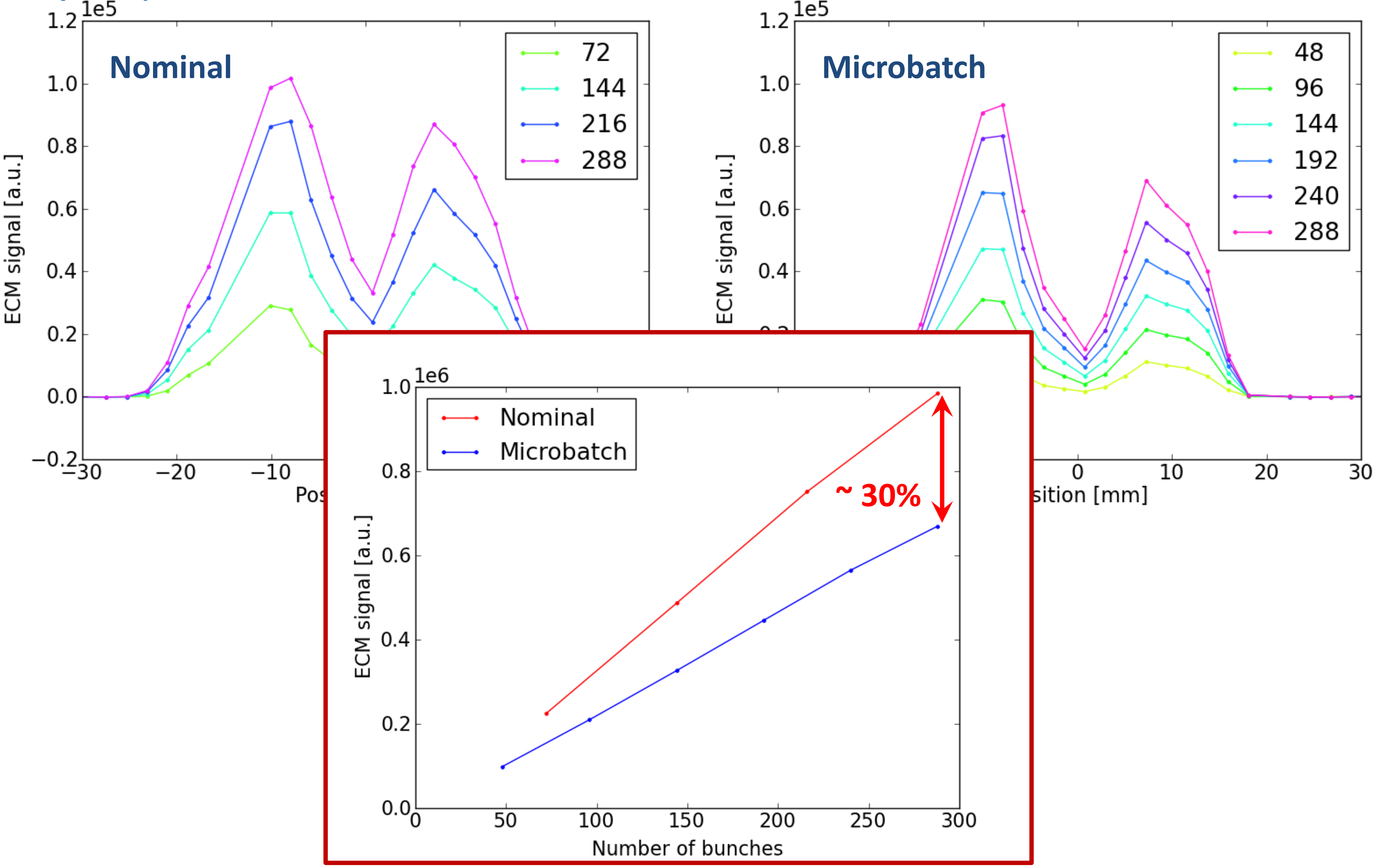

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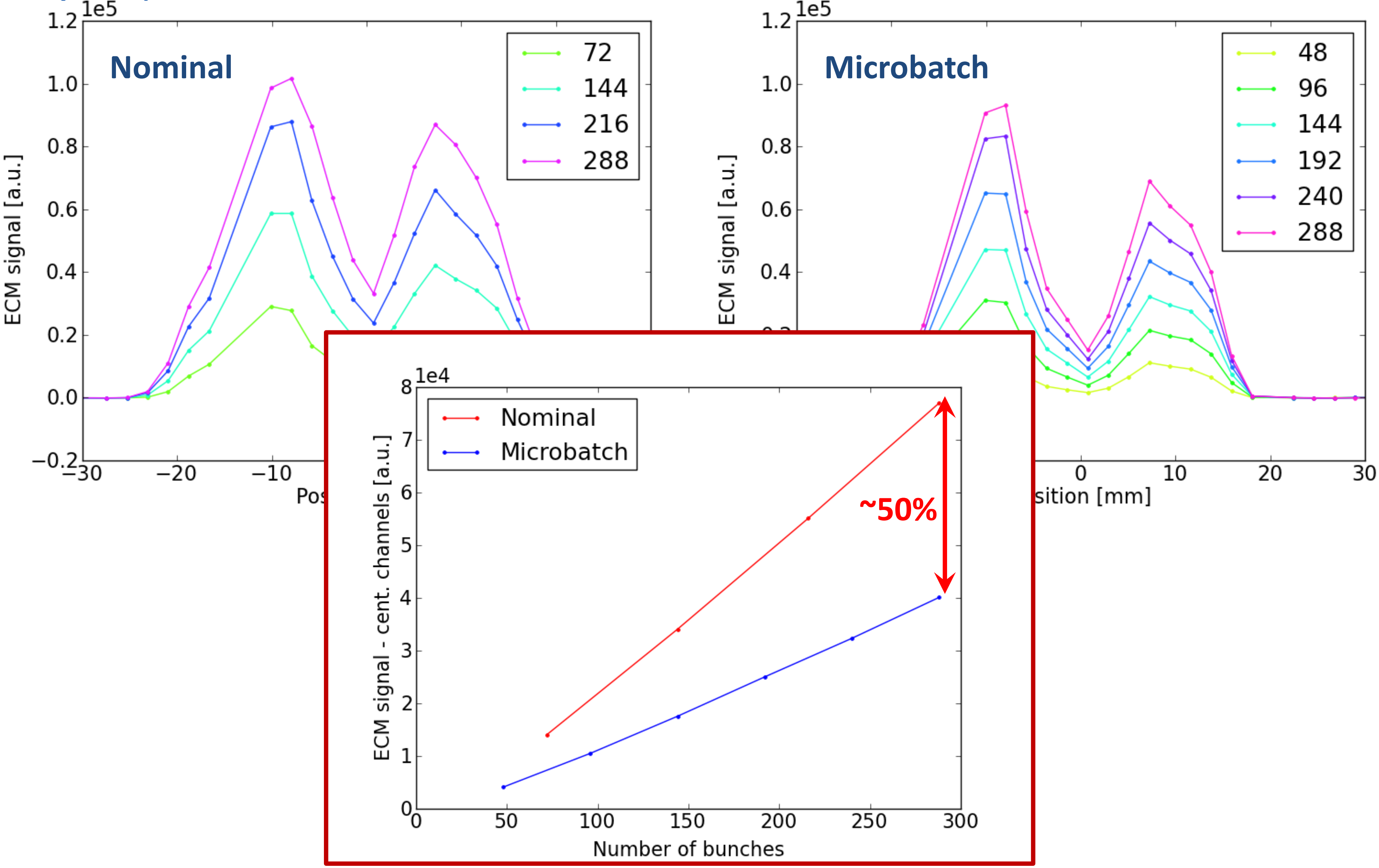
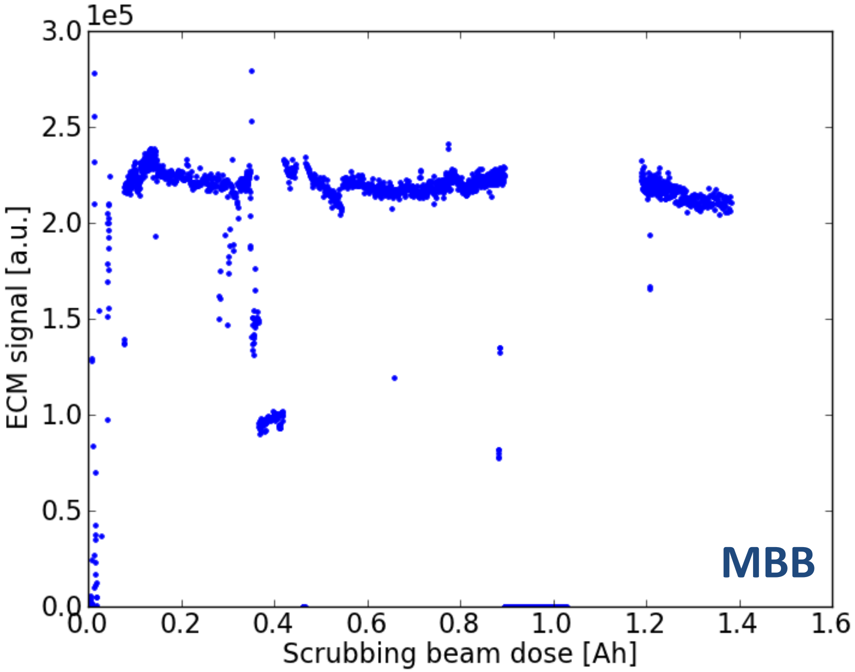


Warning: expected to be slower than in "real" bending magnets!

2012 Scrubbing run



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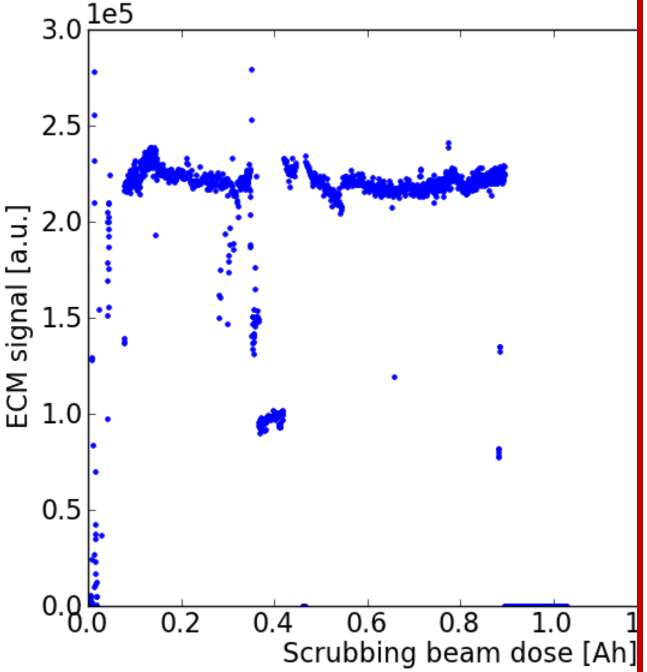
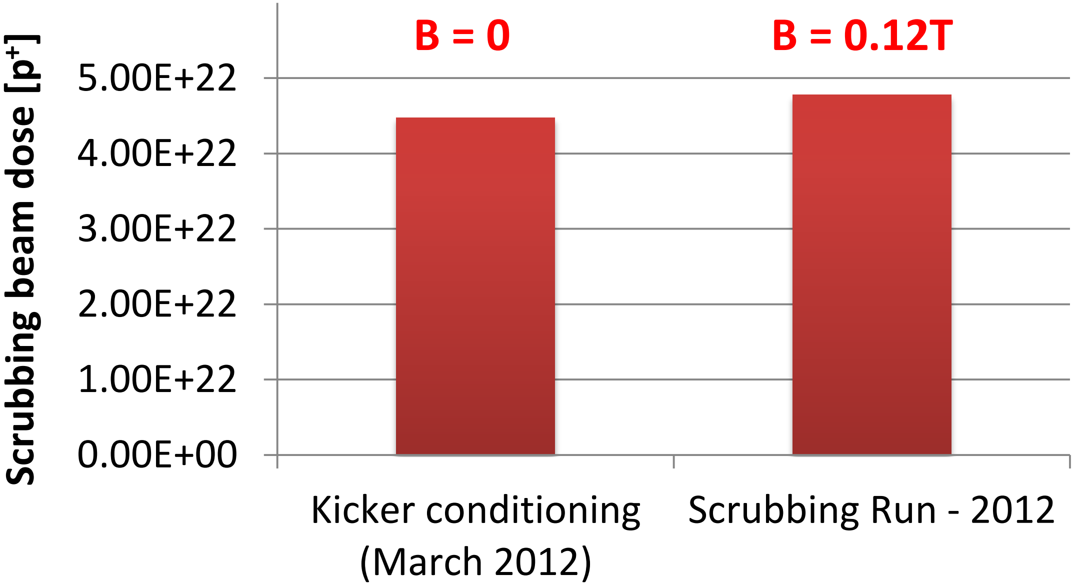


Not much conditioning observed during SR, but the liner had been **already exposed to 25ns beam**



Warning: expected to be slower than in "

MD 25/04/2012 (few h.)

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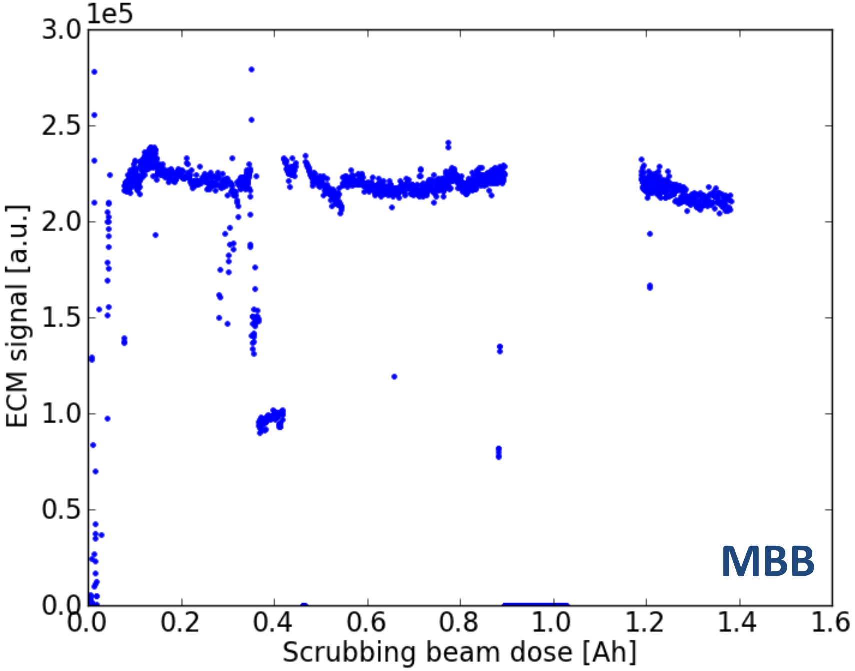
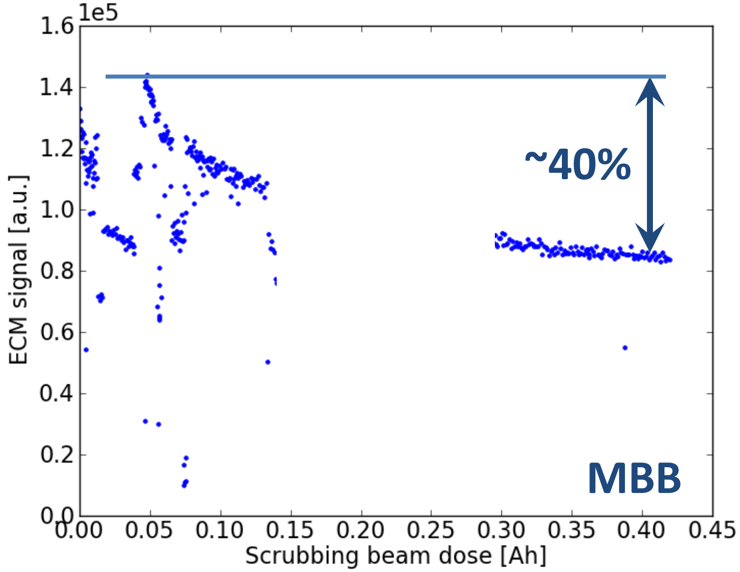
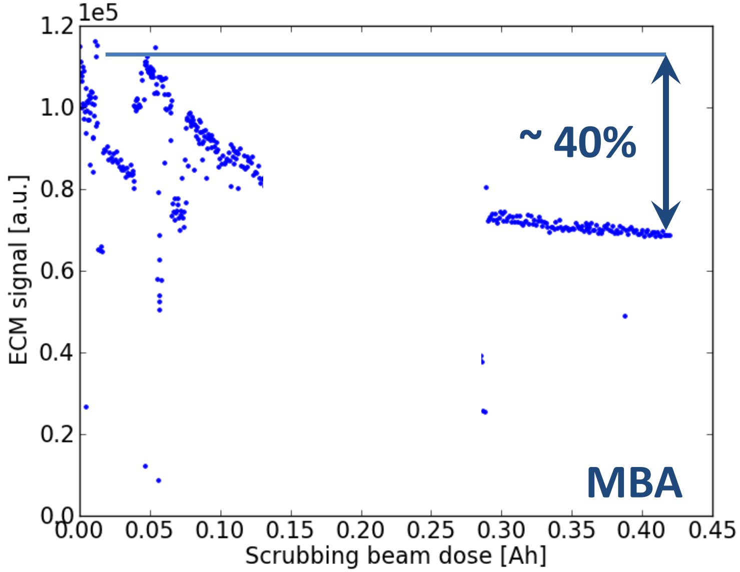
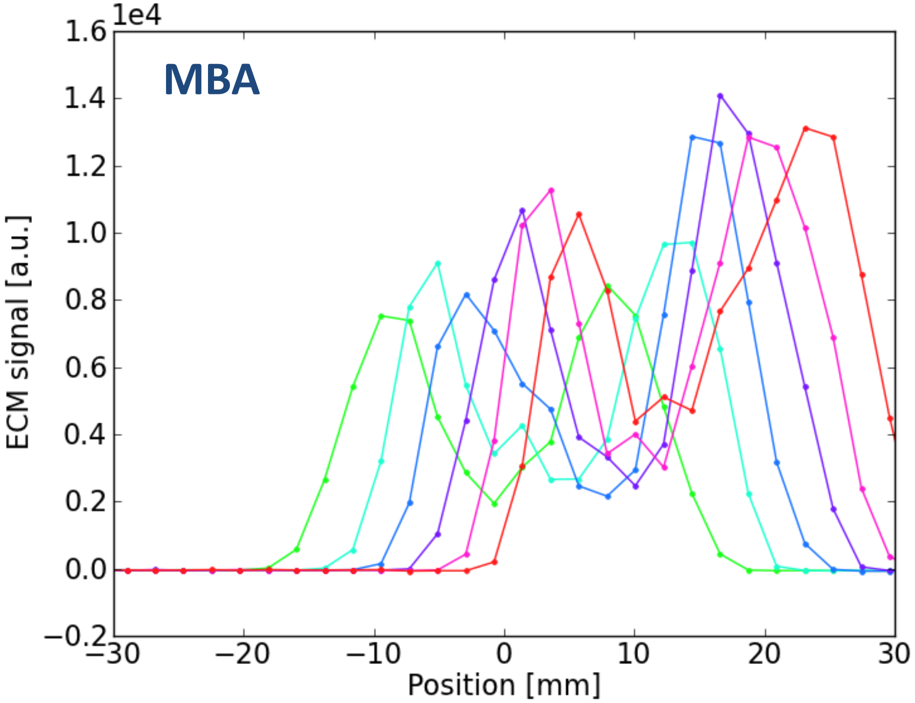


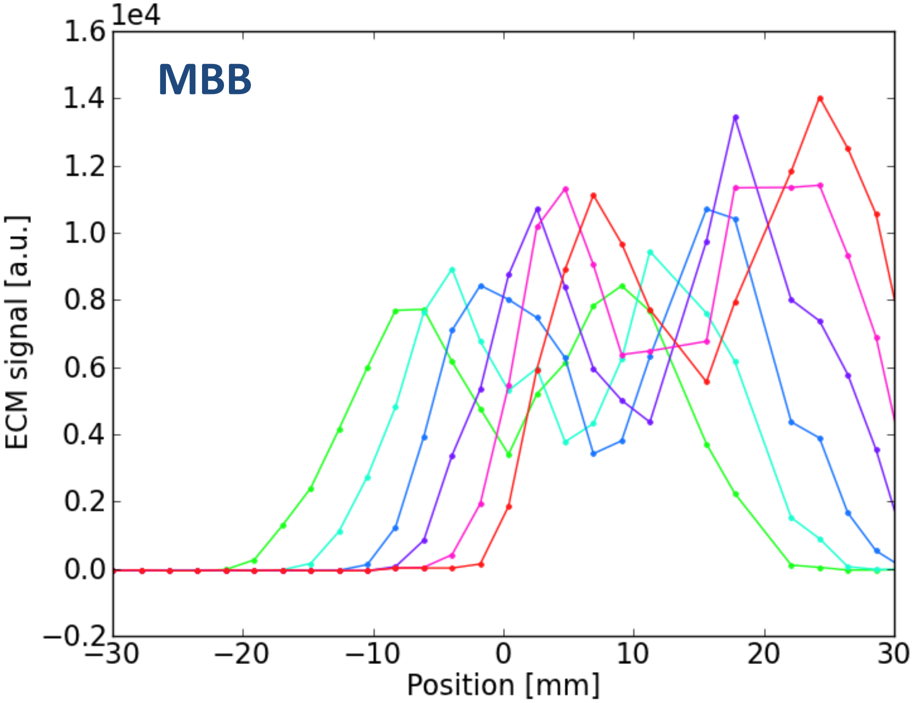




Strip detectors – conditioning

The **conditioned area** can be localized with **horizontal displacements** of beam in the ECM

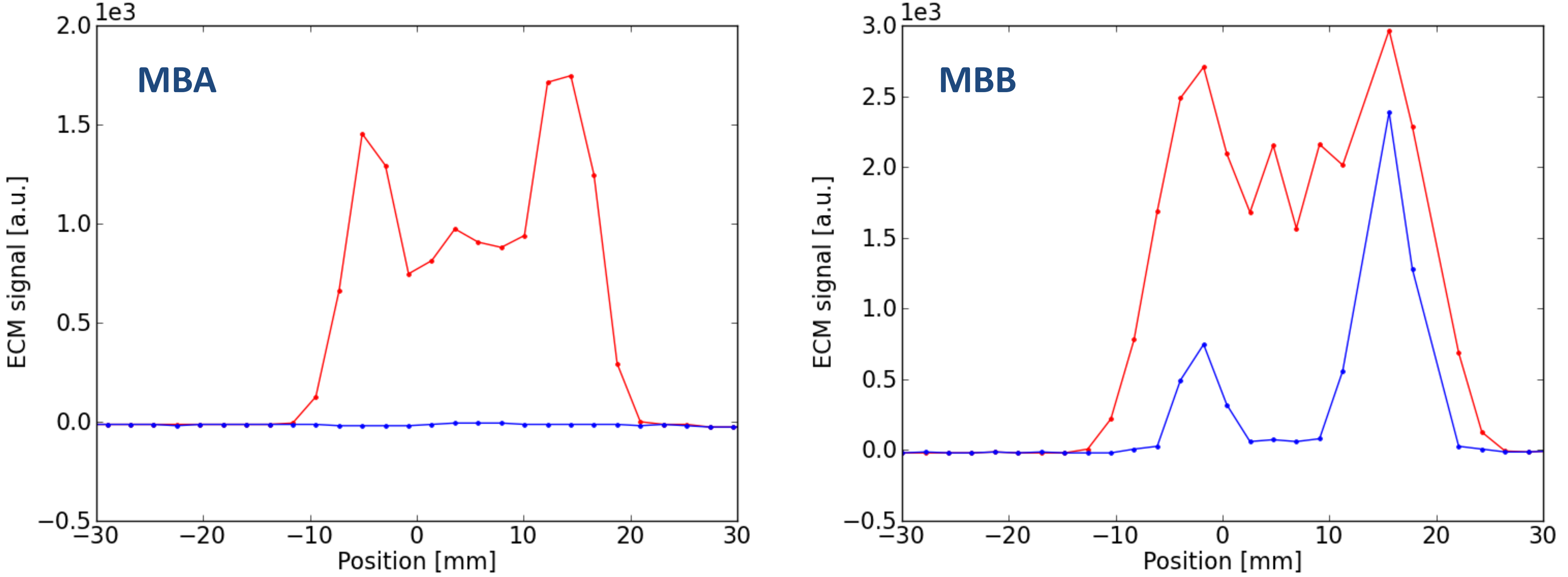




Strip detectors – conditioning

Measurements with 50ns beam before and after few hours of scrubbing

Before scrubbing ——— **After scrubbing** ———



Ramarks:

- **MBA is less critical** than MBB