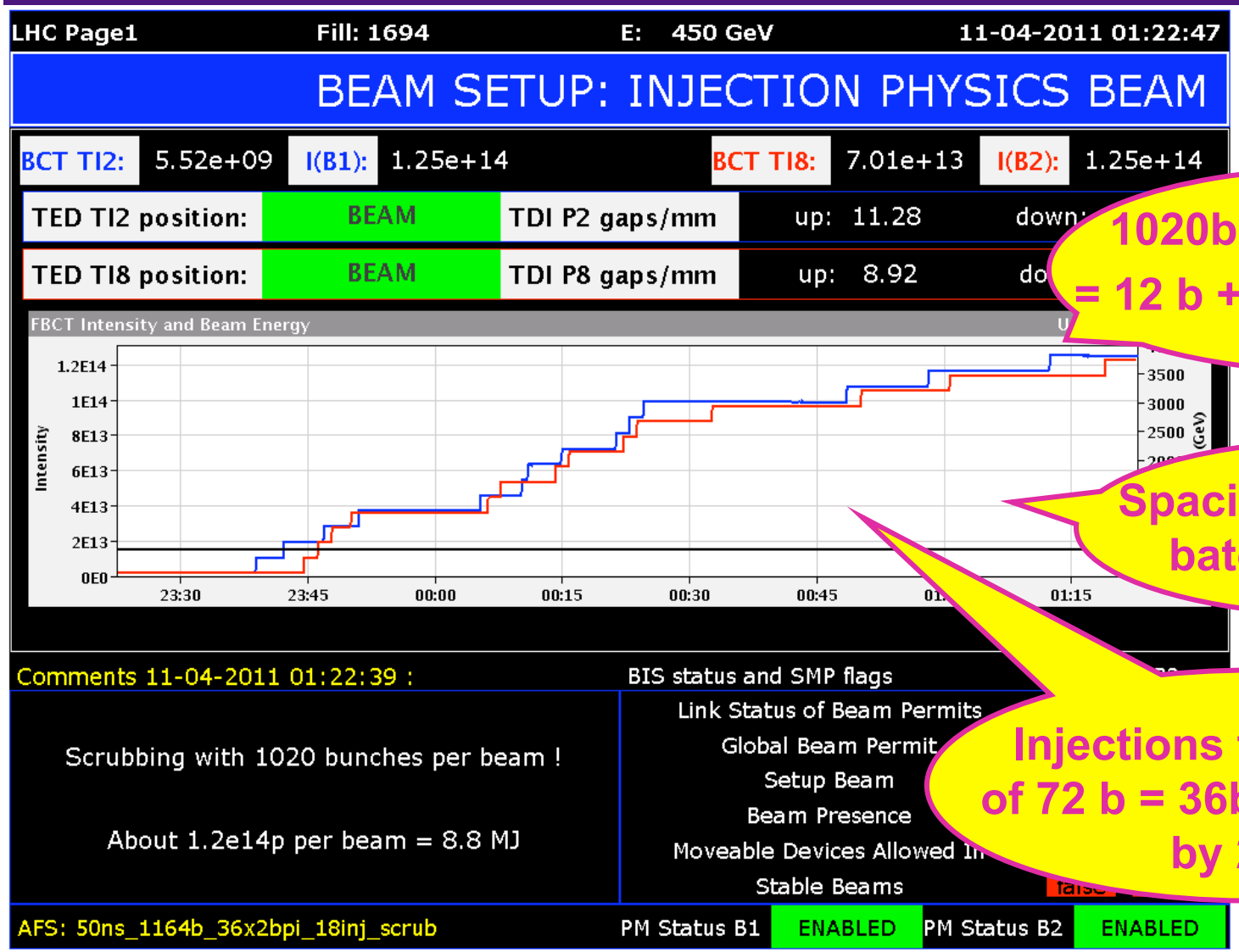
SOME BEAM OBSERVATIONS DURING THE LHC 2011 SCRUBBING RUN

Elias Métral (for many people from ABP, OP, BI, RF etc. MANY THANKS!)

- **Introduction => Goal of the scrubbing run (see GA's talk at LBOC 29/03/11)**
- **Many people in "shifts" to take data during the scrubbing run**
  - **BSRT => Transverse (bu by bu) emittance along the batches**
  - **Schottky => Transverse (bu by bu) tunes along the batches**
  - **ADT PU, LHC BPM => Coherent motion along the bacthes**
  - **HEADTAIL monitor => CB and SB motions**
  - **Bunch length evolution**
  - **BBQ, BCT, FBCT etc.**
- **Next: check of the scrubbing effects:**
  - **Change of the radial position by change of the RF frequency => Ongoing**
  - **Acceleration, squeeze, collision => Still to be done**

GOAL OF THE SCRUBBING => SCRUB and reach a "stable" situation with at least ~ 1000 bunches with 50 ns (1/5)

=> ~ Done on Monday 11/04/11 at ~ 01:20

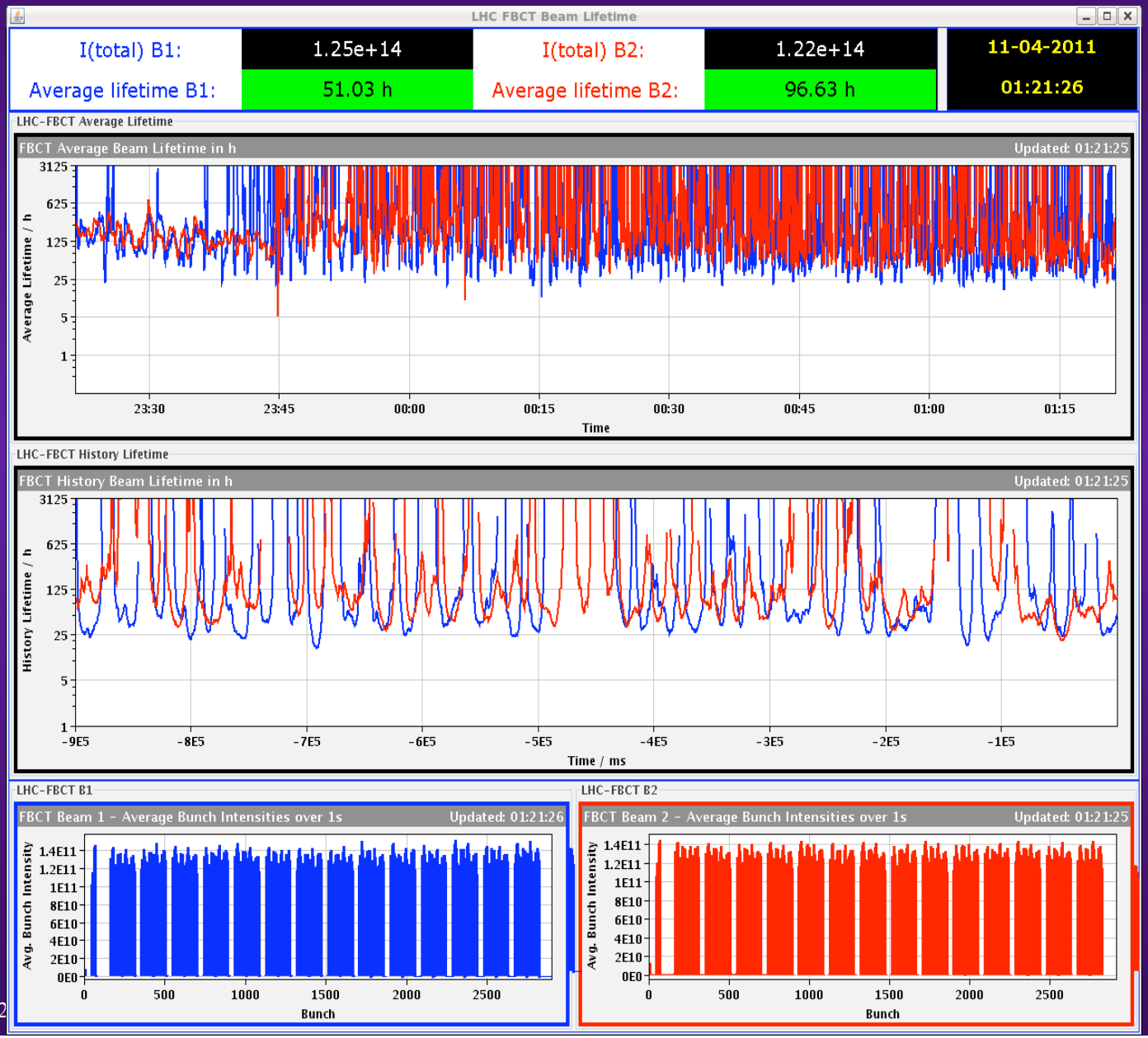


1020b = 12b + 1008b
= 12 b + 14 × (36b + 36b)

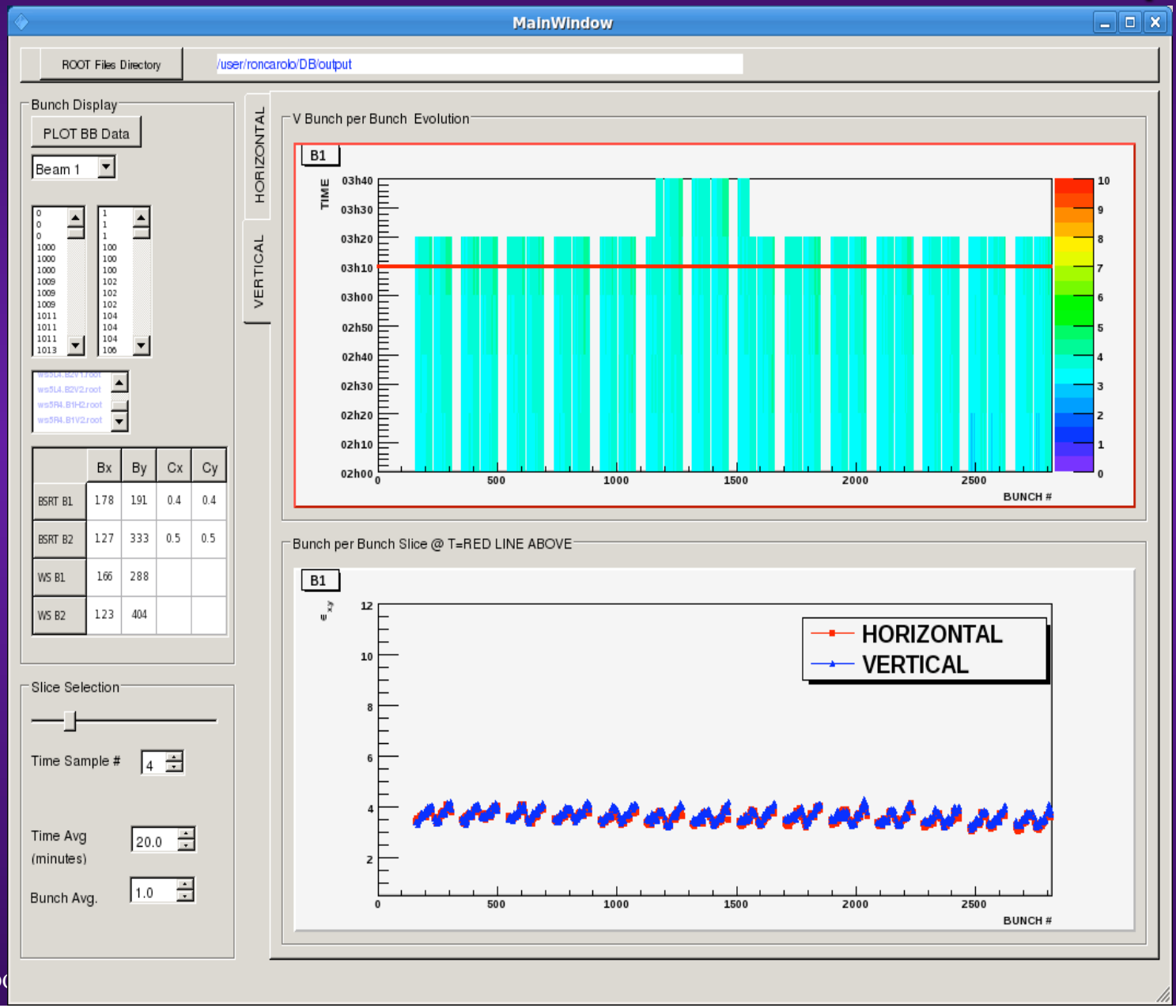
Spacing between LHC batches = 1100 ns

Injections from the SPS of 72 b = 36b + 36b spaced by 225 ns

GOAL OF THE SCRUBBING => SCRUB and reach a “stable” situation with at least ~ 1000 bunches with 50 ns (2/5)

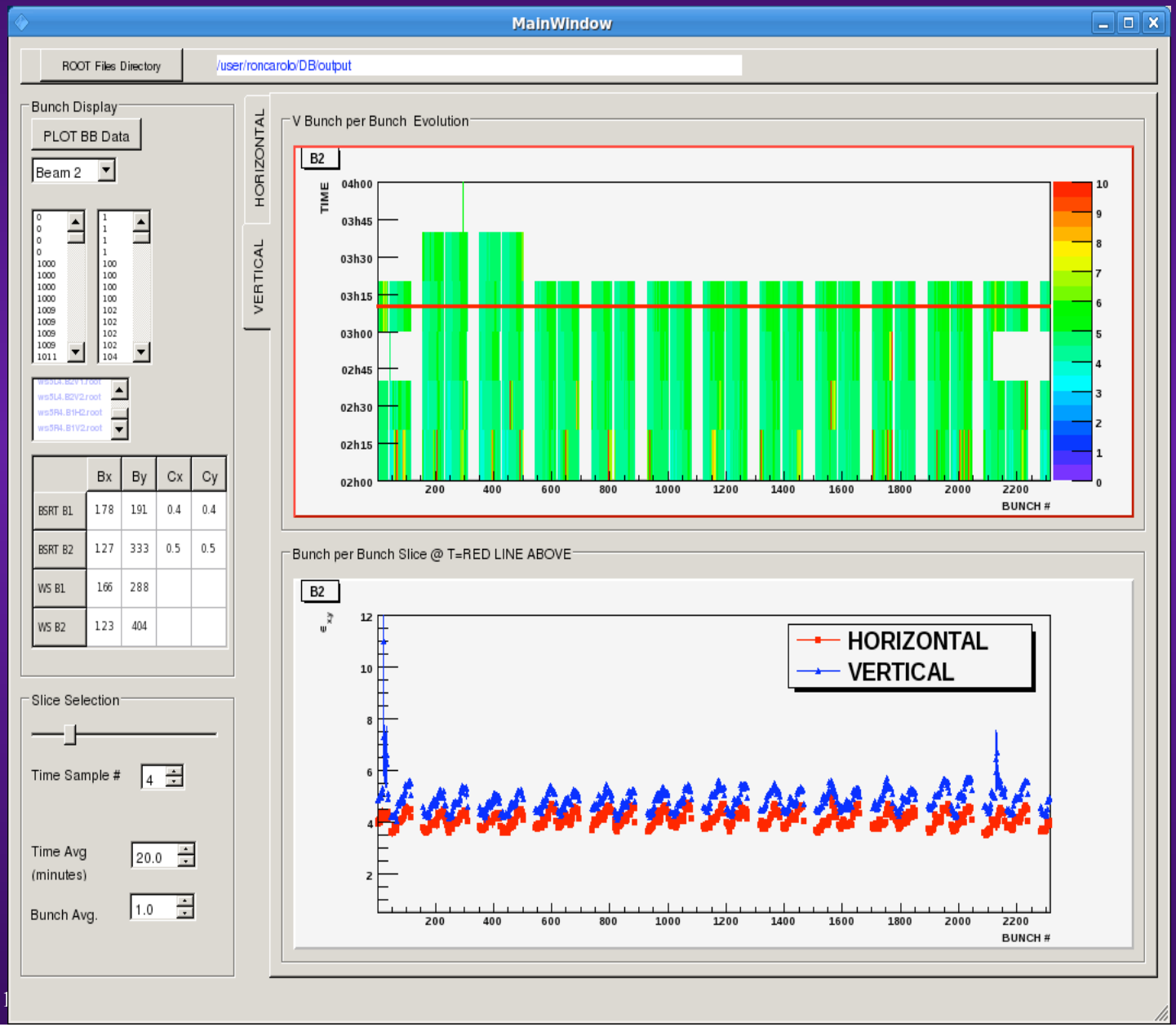


GOAL OF THE SCRUBBING => SCRUB and reach a “stable” situation with at least ~ 1000 bunches with 50 ns (3/5)



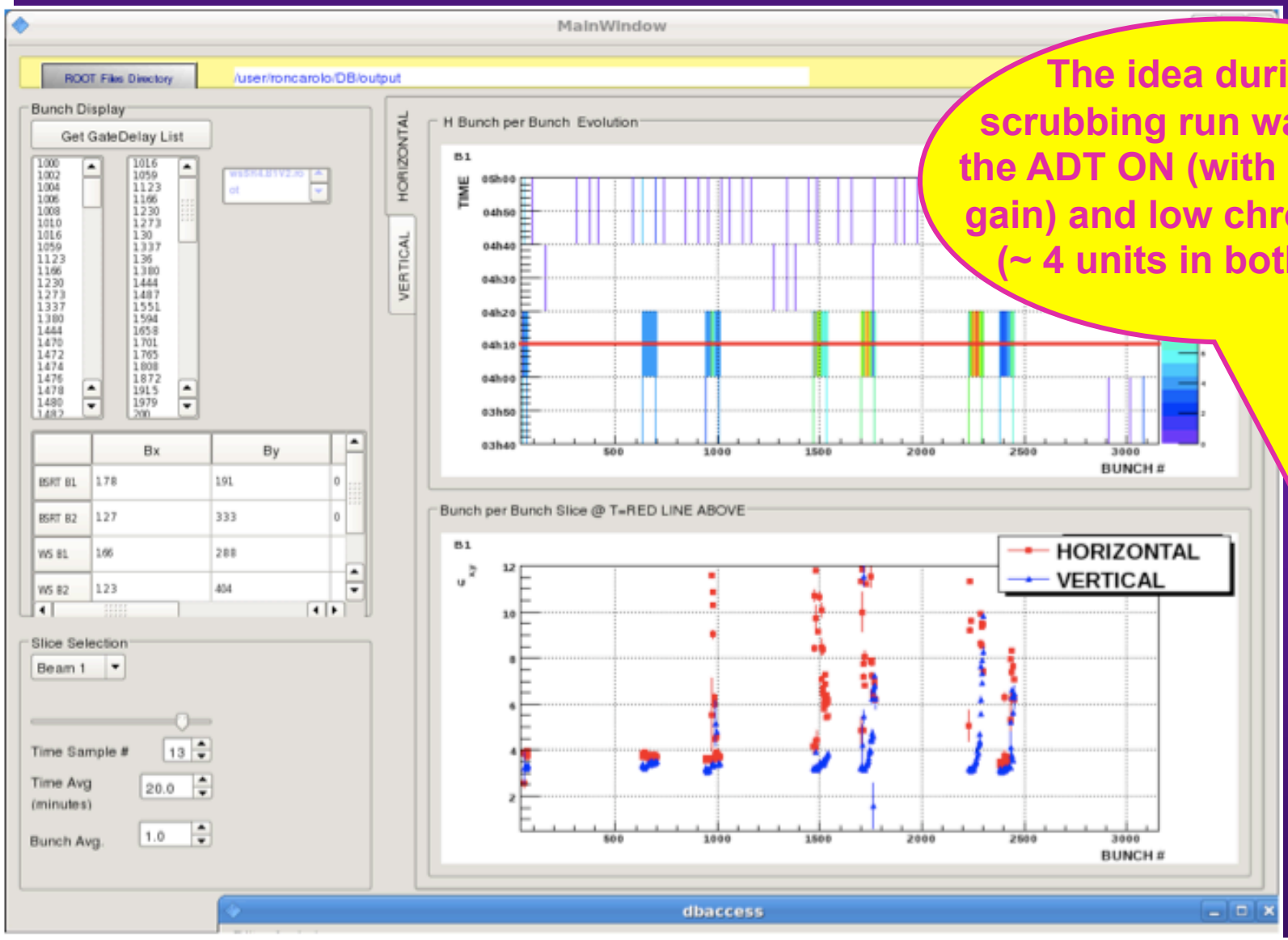
	Bx	By	Cx	Cy
BSRT B1	178	191	0.4	0.4
BSRT B2	127	333	0.5	0.5
WS B1	166	288		
WS B2	123	404		

GOAL OF THE SCRUBBING => SCRUB and reach a “stable” situation with at least ~ 1000 bunches with 50 ns (4/5)



GOAL OF THE SCRUBBING => SCRUB and reach a “stable” situation with at least ~ 1000 bunches with 50 ns (5/5)

Reminder: BSRT on Tuesday 06/04/11



The idea during the scrubbing run was to keep the ADT ON (with reasonable gain) and low chromaticities (~ 4 units in both planes)

ECLOUD COHERENT TUNE SHIFT ALONG THE BATCH (1/3)

- **The magnitude of the electron density can be inferred from the induced coherent tune shift as it is proportional to it:**
  - **Prediction from FrankZ in the LHC Design Report: For full saturation of the electron density (~ 1.2E13 m^{-3}) the expected tune shift amounts to + 0.05**

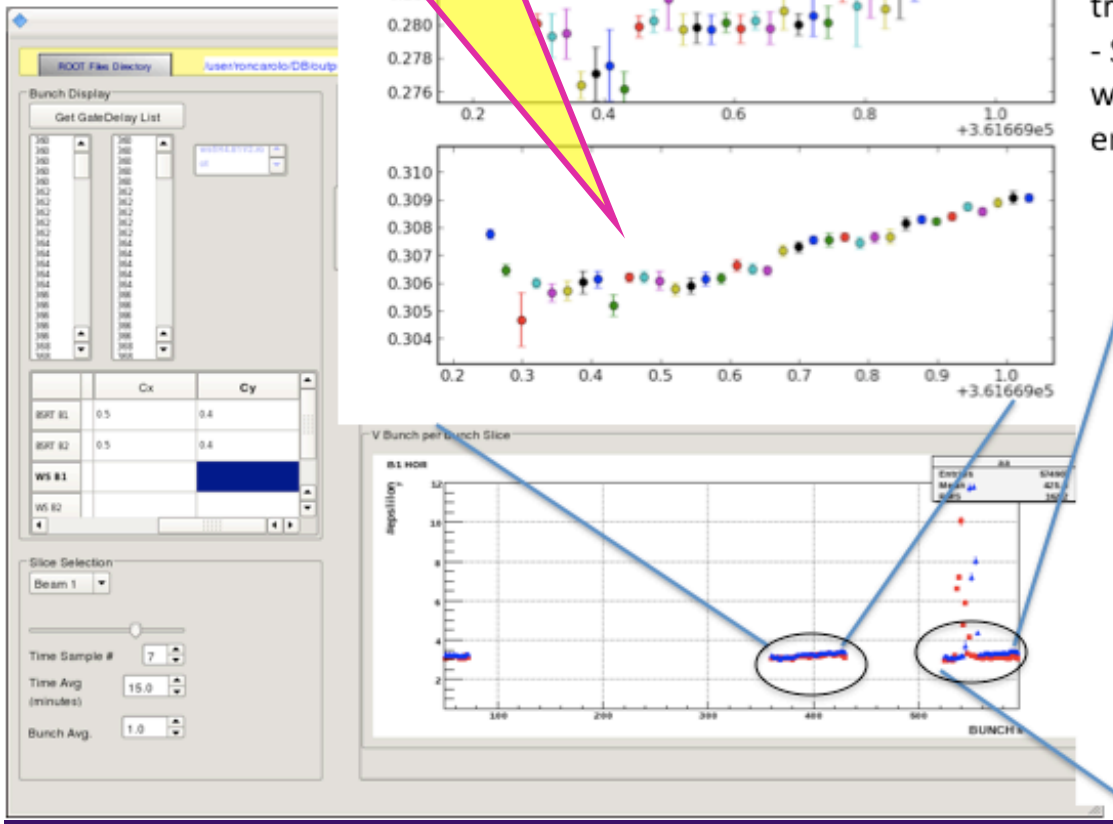
  => For an electron could density of ~ 5E11 m^{-3}, it should lead to a tune shift of ~ + 0.002
  - **Reminder: Measured tune shifts in the SPS in the past of the order of 0.01**

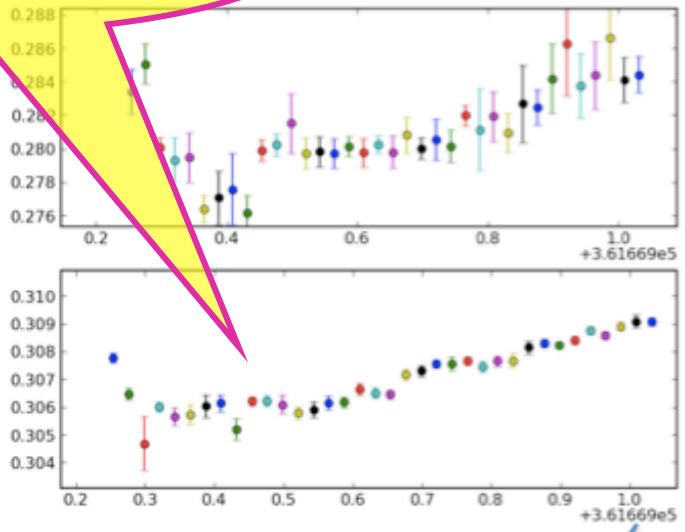
ECLOUD COHERENT TUNE SHIFT ALONG THE BATCH (2/3)

- **Pictures from Schottky monitor => Still under analyses…**

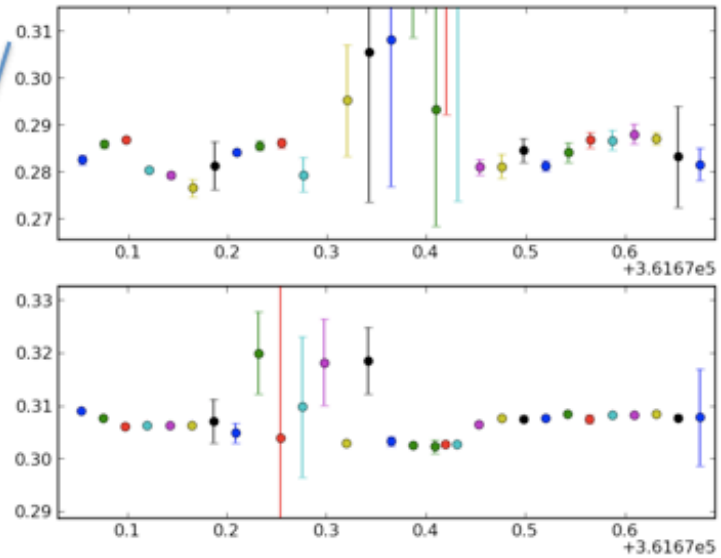
Tune shift ~ + 0.003? => Ecloud density ~ 7E11 m^{-3}?

Fill1674 time 14-17 5th April





Beam 1
-first train shows trend in tune along the train to be compared to intensity trend
- Second train follows trend as measured with BSRT coherent oscillations or emittance growth?

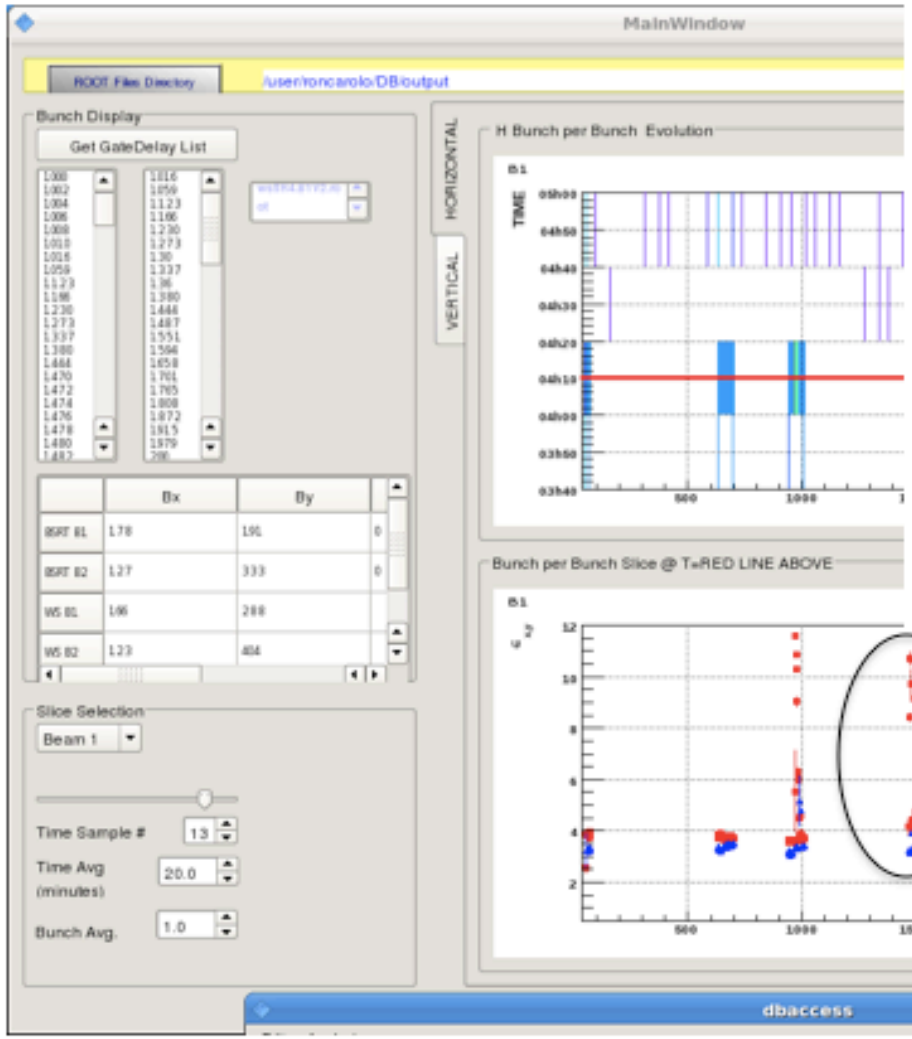


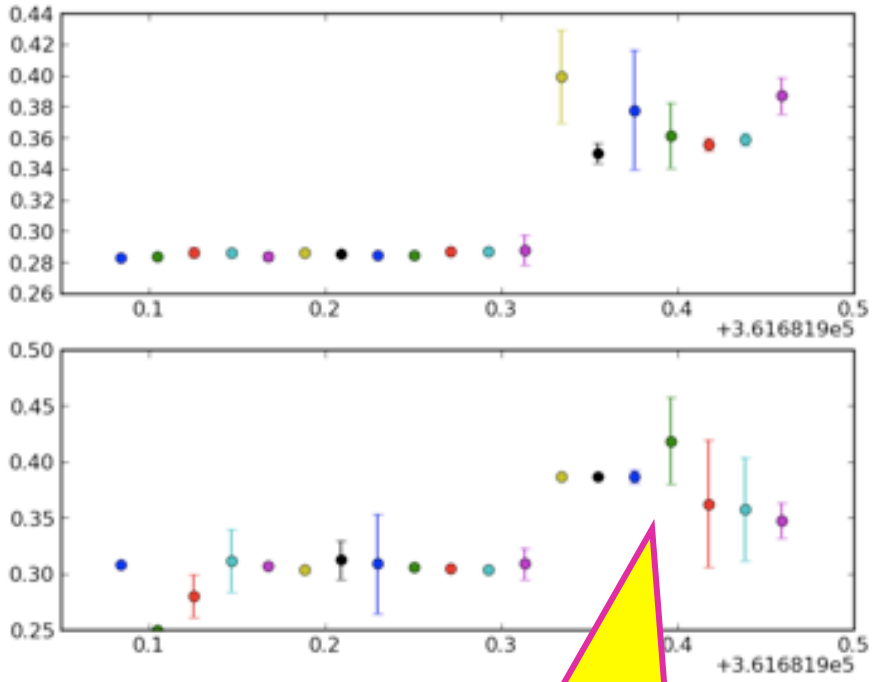
ECLOUD COHERENT TUNE SHIFT ALONG THE BATCH (3/3)

Fill1674 around 12-4 am 6th April

Beam 1

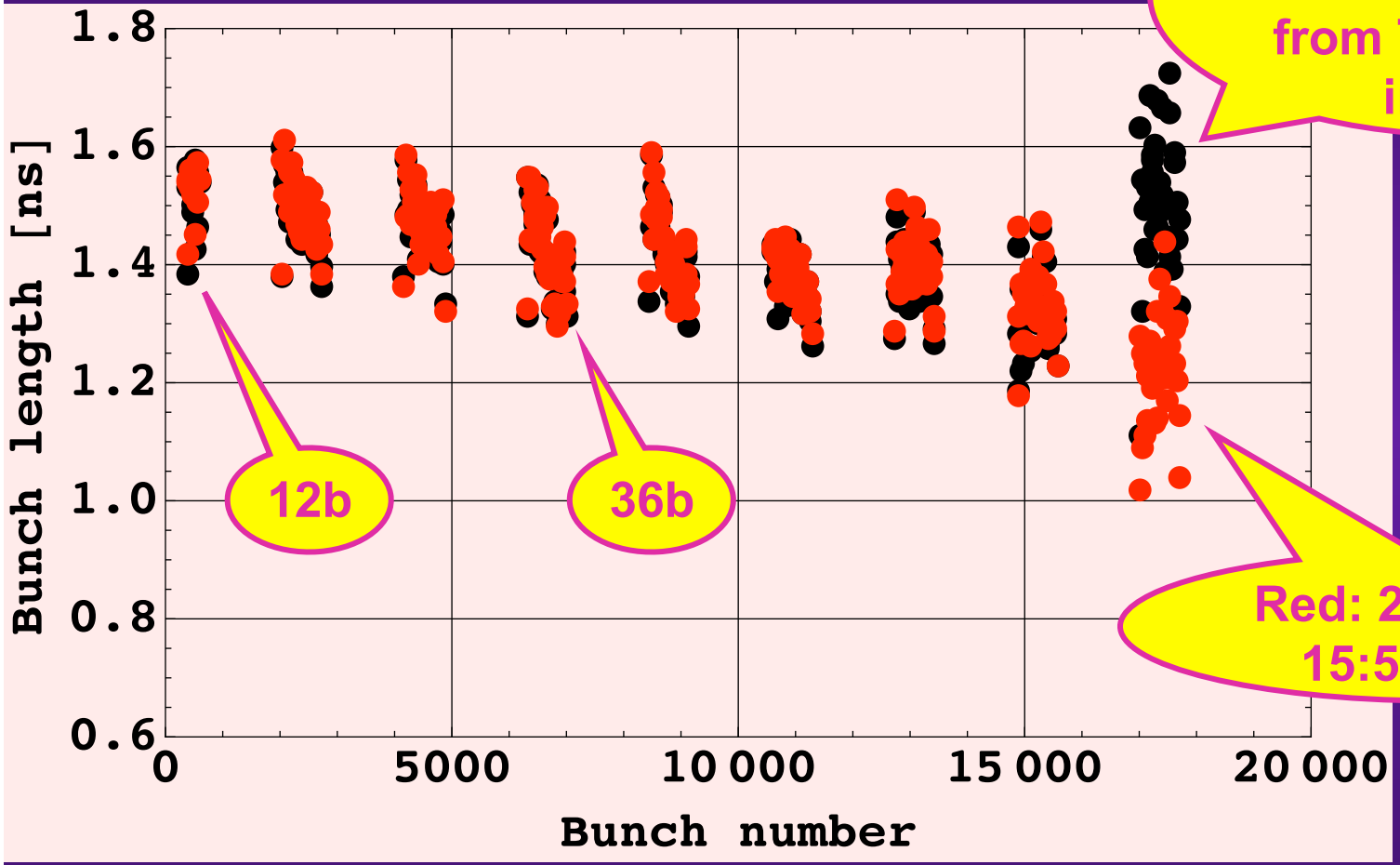
-3rd train 36 bunches shows maybe some saturation effect but values too high





Tune shift ~ + 0.1? => Ecloud density ~ 2.5E13 m^{-3}?

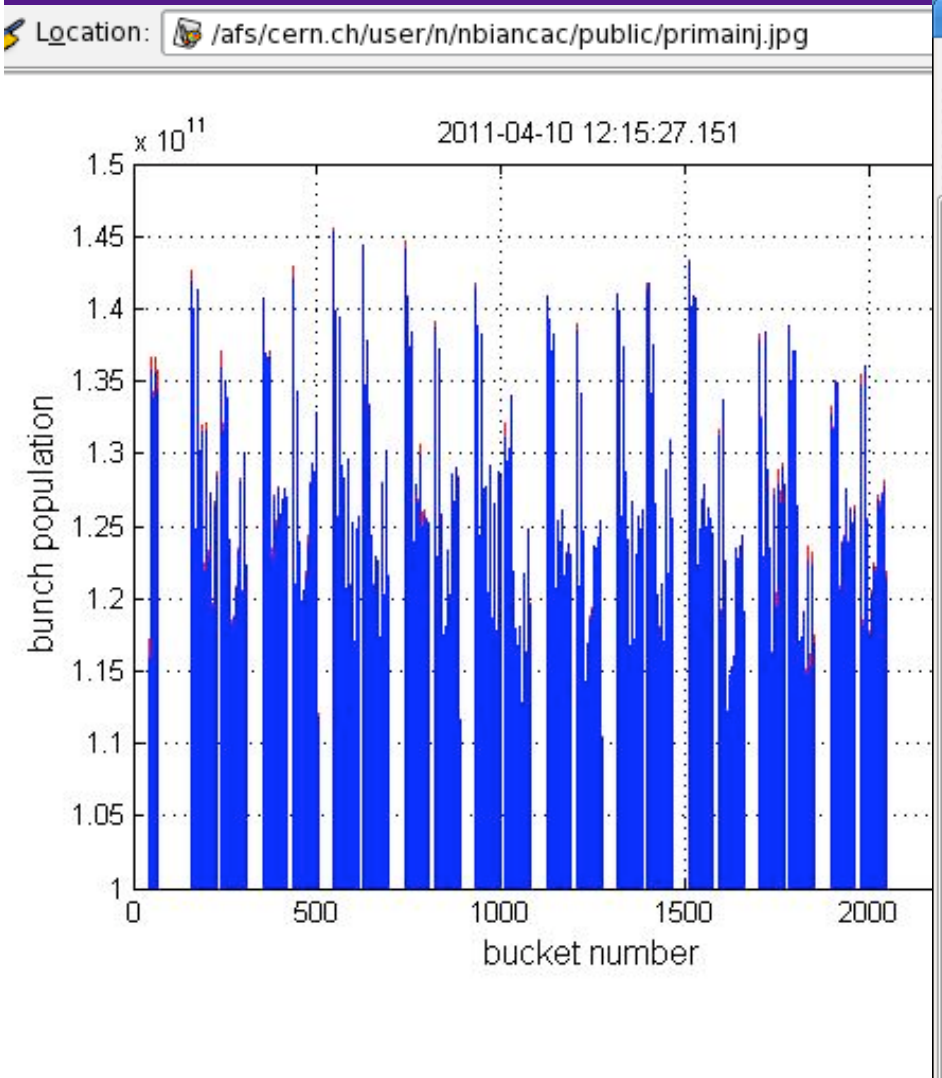
BUNCH LENGTH EVOLUTION

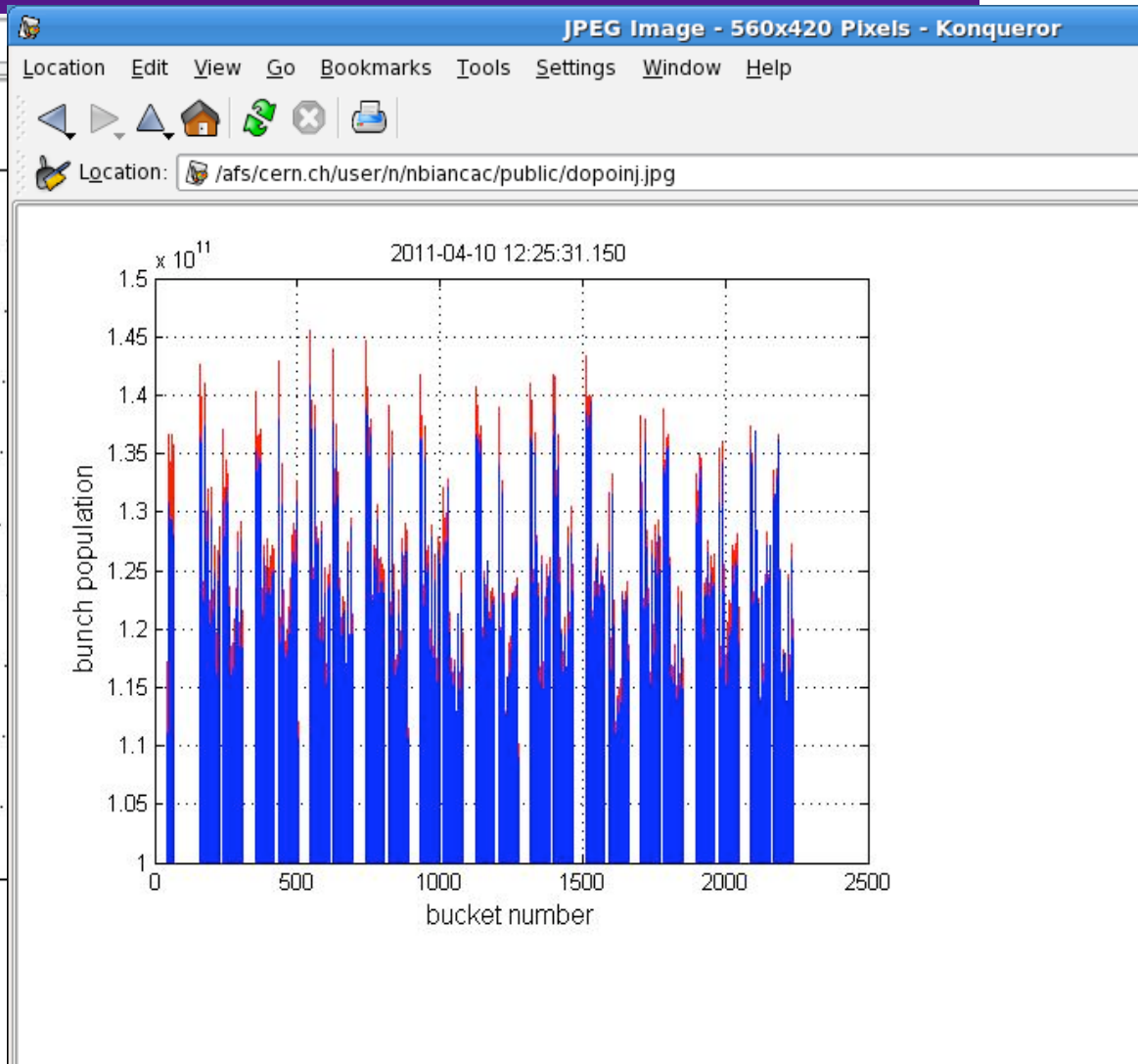


=> Was looked at as some bunch shortening effects were measured in the past with ecloud (also with space charge)

Some FBCT meas. (1/4)

- **Sunday 10/04/11 at 12:21 => Global losses: last injection (11th batch) provokes losses over all the batches**





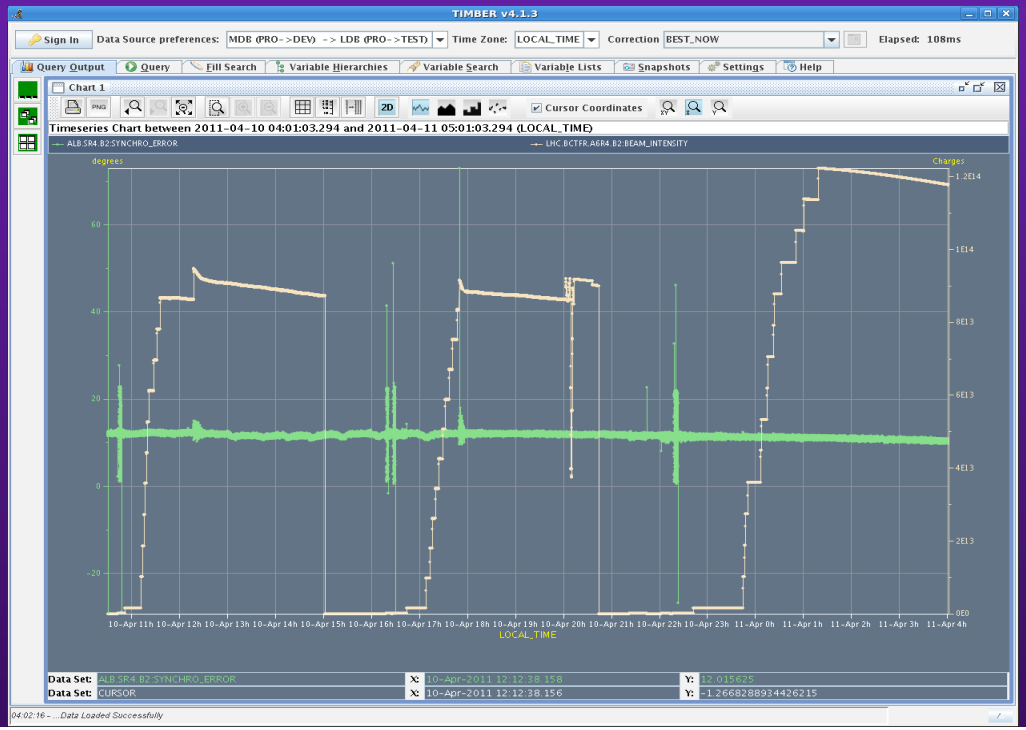
Some FBCT meas. (2/4)

- Similar things already observed sometimes in the previous days
- See next picture: We see the BCT for B1 and B2 during the last 2 fills and we see that the losses observed on B2 after the last batch injected are correlated with some beam in the abort gap (in both cases). It is also correlated (in both cases) with some activity on the synchro loop

Some FBCT meas. (3/4)

Some FBCT meas. (4/4)

- Understood (Daniel et al.) => It was a problem in the beam phase module: it was not correctly initialized and a DC offset was too high and it happened to be just below the threshold (threshold at 200, DC offset 190). This DC offset was slightly increasing at every injection, and for the 11th injection it went above threshold. At that point, the background was too high and the phase reading was rather random
- Solved => No such thing happened with the 1020 bunches on Monday morning

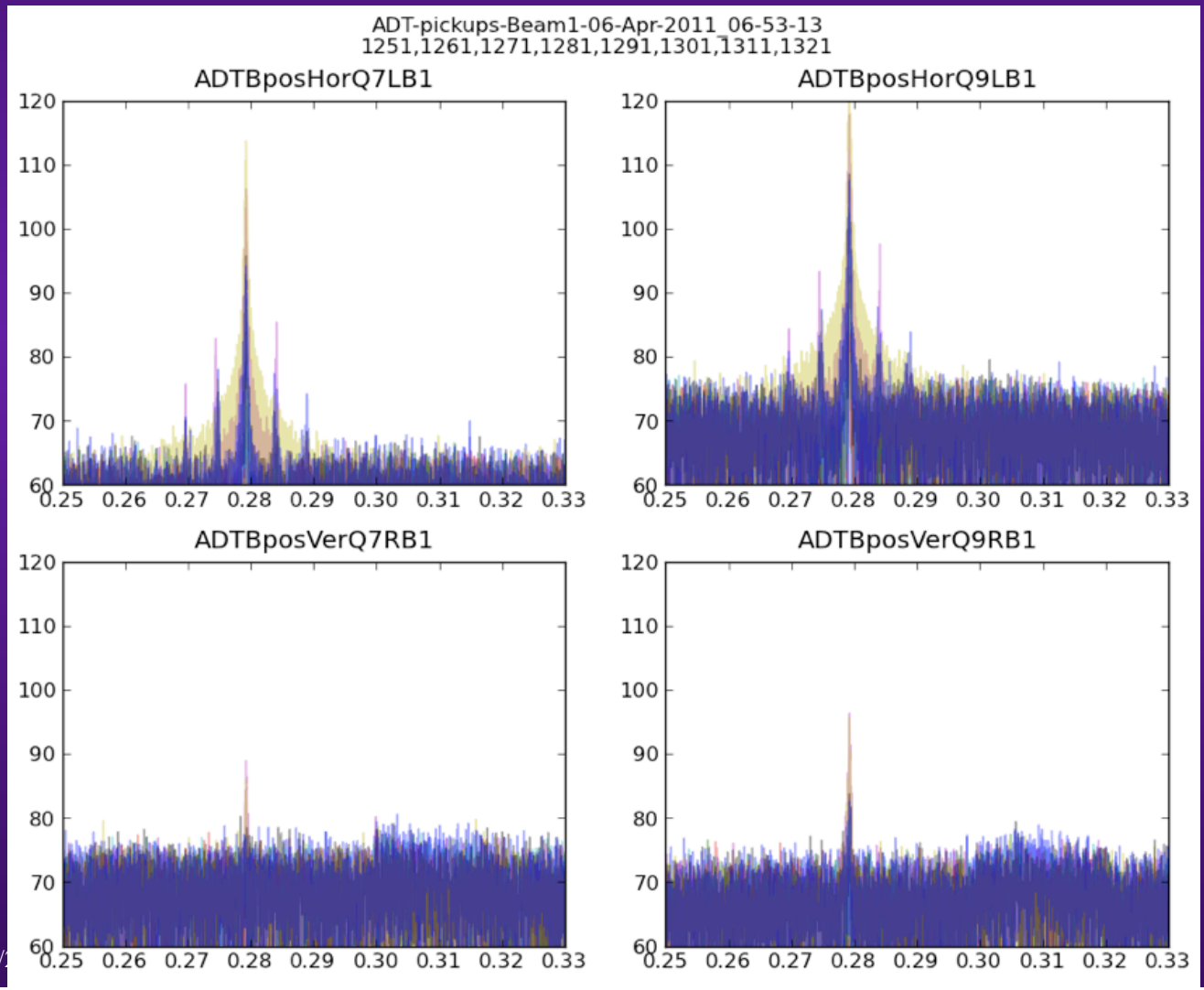


Some ADT meas. (1/2)

- **In some cases, the gain of the transverse damper was too high and drove beam instabilities => On Saturday 09/04/11, we increased the gain of the ADT from 0.18 to 0.26 (at 08:50) and to the maximum 0.3 (at 09:50). It seems the damper damped the oscillations at the middle and end of the batch but not at the beginning => The electronics of the damper pick-ups was saturating on the first bunches with larger intensity. This COULD explain the reason for a longer damping time at the beginning of the 72 bunch trains taking into account that at the edges the gain of the feedback is lower (WolfgangH). GianluigiA asked to reduce the intensity of these bunches at the beginning (indeed of the whole 12 bunches of the first PSB ring, i.e. ring 3)**

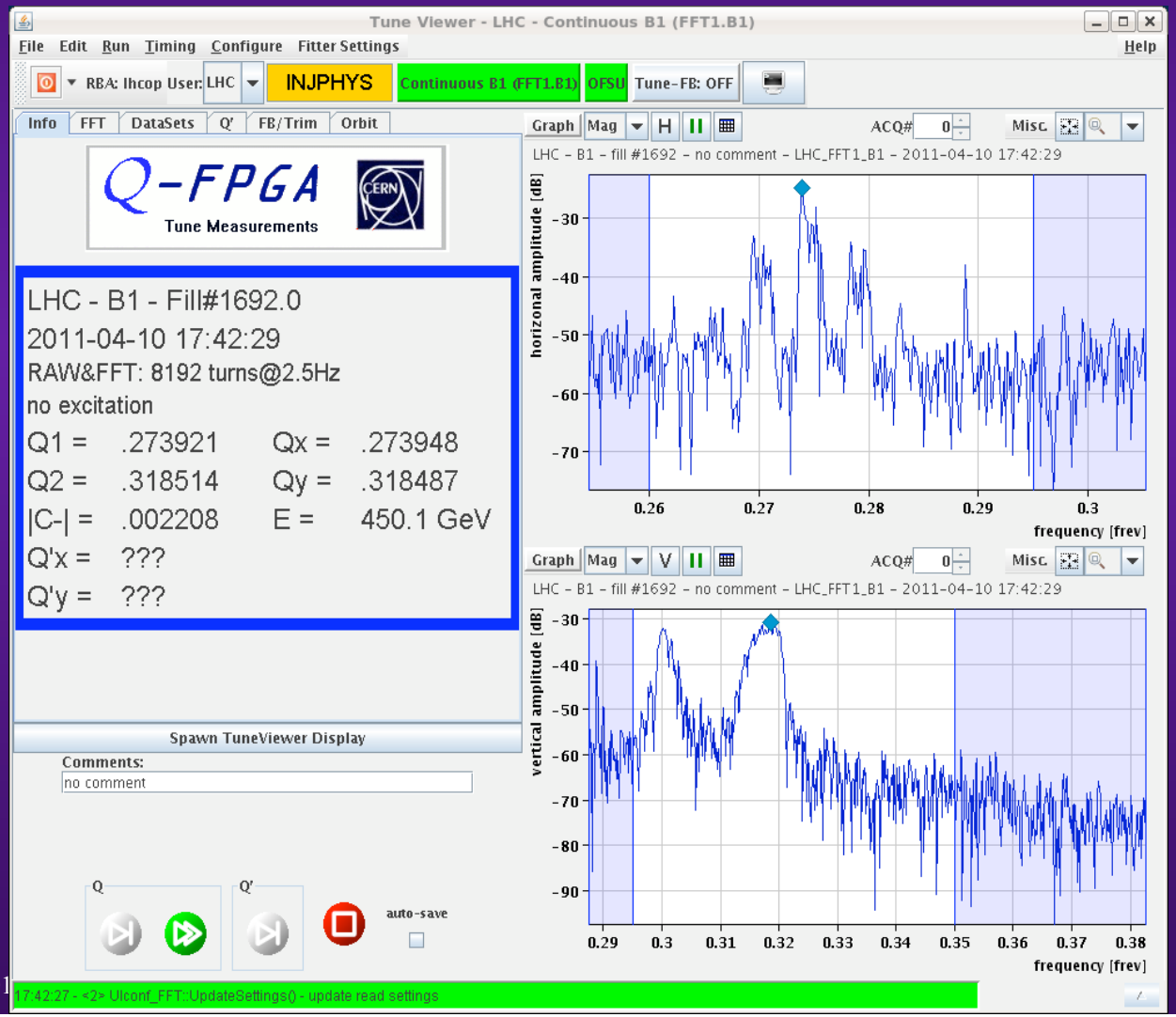
Some ADT meas. (2/2)

- Many data taken and under analyses => Example of some “Christmas” tree



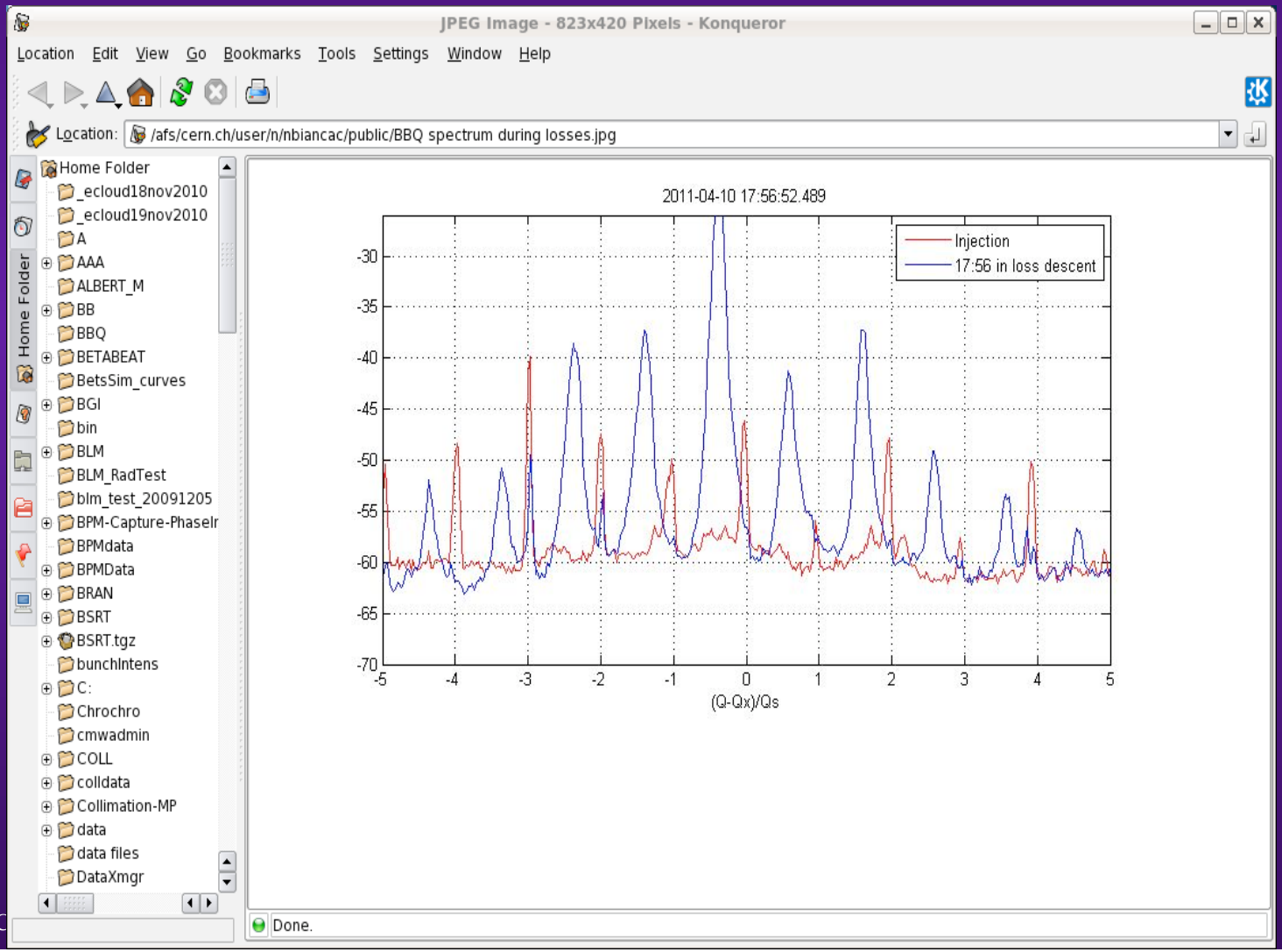
Some BBQ meas. (1/3)

- **Sunday 10/04/11 at 17:42 => 660 bunches. Lifetime dip for B1. "Xmas tree" on tune. Nothing special seen on B2**



Some BBQ meas. (2/3)

- **Sunday 10/04/11 at 17:56 => B2 BBQ signal. "strange" pattern appears during losses 5' after injection of 11th batch in B2**



Some BBQ meas. (3/3)

- In some cases, we see some sidebands on the BBQ for few minutes after the injection of a batch (without growing oscillations) and then they disappear => It seems to be correlated (to be checked in detail) with longitudinal oscillations, which also can take sometimes (with many batches) few minutes to filament => Longitudinal damper?

- For these Christmas trees, we should try and see if there is 1 line growing first or not? Is it really growing etc.

- Reminder: Last year we also observed sometimes Christmas trees due to a single-bunch instability but IT WAS A CONSEQUENCE of beam losses but NOT THE CAUSE. Is it also a CONSEQUENCE of beam losses?

BEAM LOSSES OBSERVED WITH Δf_{RF} = + 10 H_Z (1/5)

$$\frac{dB}{B} = 0 = \gamma^2 \frac{df}{f} + \left(\gamma^2 - \gamma_{tr}^2\right)\frac{dR}{R}$$

=> $$\Delta R = R\,\frac{\Delta f}{f}\,\frac{\gamma^2}{\gamma_{tr}^2 - \gamma^2} \approx -107\ \mu\text{m}$$

$$R = 4242.893\ \text{m}$$

$$\frac{\Delta f}{f} = \frac{10}{400.789\times 10^6} \approx 2.5\times 10^{-8}$$

$$\frac{\gamma^2}{\gamma_{tr}^2 - \gamma^2} = \frac{479.6^2}{55.68^2 - 479.6^2} \approx -1.01$$

BEAM LOSSES OBSERVED WITH Δf_{RF} = + 10 H_Z (2/5)

Beam instability observed on B2 H (on MO 11/04/2011 at 12:34) with 1020b + 1020b => Rise time of a few hundreds ms

BEAM LOSSES OBSERVED WITH Δf_{RF} = + 10 H_Z (3/5)

- Beam losses also observed on B2 today (on TU 12/04/2011) redoing the test with 444b + 444b:
  - Loss occurring ~ 5 minutes after the frequency trim
  - The losses affect initially B2 then B1 again and finally B2
  - The first loss is affecting all bunches while the second only some of the bunches of the tail of the trains
  - No sign of instability is observed: neither in the BBQ nor from the damper pick-ups

BEAM LOSSES OBSERVED WITH Δf_{RF} = + 10 H_Z (4/5)

- Info on the ELogBook (10:43 this morning): A trim by +/- 20 Hz of fRF was already made during the week end (Saturday 09/04/11 at 14:24) with at least 600 bunches in the machine. At that time the trim was done first by -22 and then +22 Hz and no losses were detected. At that time the horizontal damper gain was higher (0.3 instead of 0.25) and no offset in the horizontal tune was introduced to compensate for the coherent Laslett tune shift with intensity. All other parameters were the same

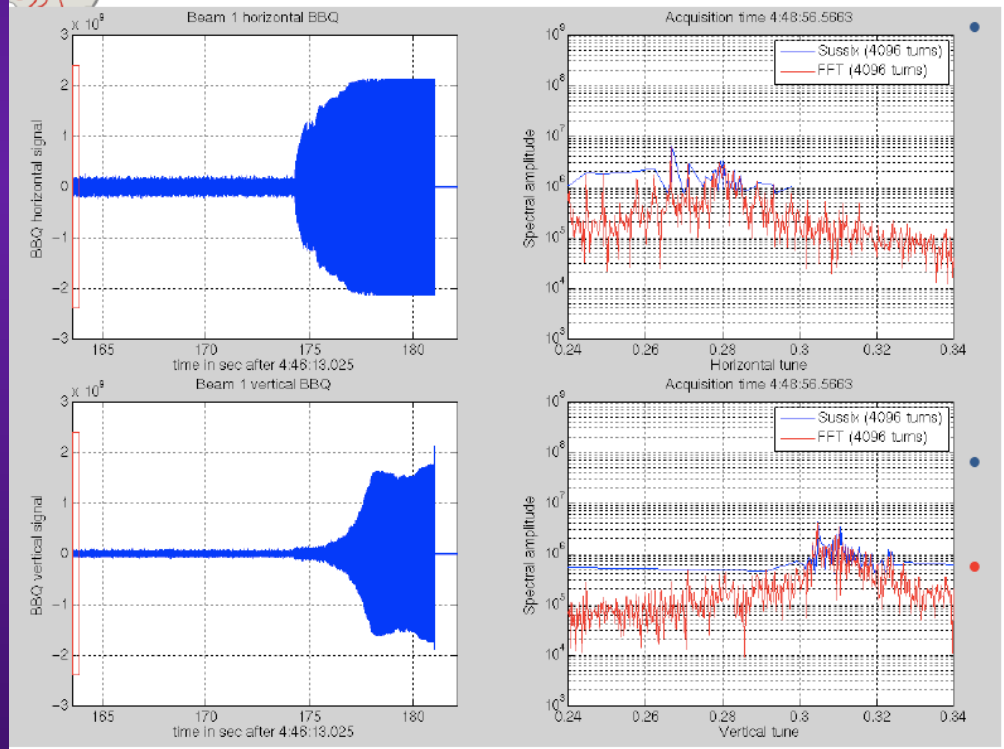
=> I could not find that in the ELogBook on Saturday 09/04/11 at 14:24 but I could found:

  - On Saturday 09/04/11 at 15:41 => Corrected the RF frequency by 15 Hz

BEAM LOSSES OBSERVED WITH Δf_{RF} = + 10 H_Z (5/5)

Shape of H instability is not exponential and seems similar to one of the instabilities observed last year when the ADT was switched OFF

Beam stability at 3.5 TeV (50 ns)



- Observed instabilities (H faster) with 1x12+4x24 bunches at flat-top when the damper is switched OFF. Not observed for 9x12 bunches for the same machine settings.
- Rise-time: few tenth of s (H), 1-2 s (V)
- Can be cured by the transverse feedback

H. Bartosik, B. Salvant

PRELIMINARY CONCLUSIONS

- 1020b + 1020b with 50 ns bunch spacing done on Monday 11/04/11 at ~ 01:20
- Scrubbing effect clearly observed from beam-based measurements => BSRT
- No clear sign of coherent instabilities (with Q' at ~ 4 units in both planes and ADT ON with reasonable gain, i.e. not saturating) => Try and keep the chromaticities as low as possible
- In some cases bunches with intensity of ~ 1.7E11 p/b were circulating in the LHC (with chromaticities of ~ 2 units in both planes and ADT gain max in H, i.e. ~ 0.3) => Seemed to be ~ OK…
- 3 important observations:
  - Some losses observed on all the bunches after the injection of a batch in some fills => Understood by RF people and solved for the fill with 1020b
  - Sidebands observed on BBQ after some injections (the are damped after few minutes, without growing oscillations) => Might be linked to undamped longitudinal dipolar oscillations, which also could last for few minutes
  - Issues with satelitte bunches in the LHC for close injections
- Next steps: Check of the effect of the orbit change & Acc./Squeeze/collision...