RECENT OBSERVATIONS OF BEAM INSTABILITIES IN THE LHC

E. Métral

- 2 observations
  - On Friday 26/08/11 evening during the 25 ns injection MD with a train of 48 bunches
  - On Monday 29/08/11 (early) morning during the beta* = 1 m MD with batches of 36 bunches (50 ns)
- What were the predictions? Conclusions

25 ns Injection MD (1/4)

- OBSERVATIONS: B2 injection of 48b batch with 25 ns tried twice => Beam dumped immediately after injection each time:
  - 1st time ADT on, beam dumped after ~ 1000 turns (i.e. ~ 100 ms) on IR6 BPM
  - 2nd time ADT off, beam dumped after ~ 500 turns (i.e. ~ 50 ms) on P7 beam losses
- PM BLM data: fast (~ 150 turn) increase in BLM signals, TCPV in P7
- Orbit BPM PM data: nothing seen at first look
- No vacuum activity aside small pressure rise in MKIP8 with 2x12b & 1x24b 25 ns circulating

25 ns Injection MD (2/4)

- **Fast vertical beam loss**

25 ns Injection MD (3/4)

- **PAST PREDICTIONS**

E. Benedetto, Ph.D. Thesis, Politecnico di Torino, 2006

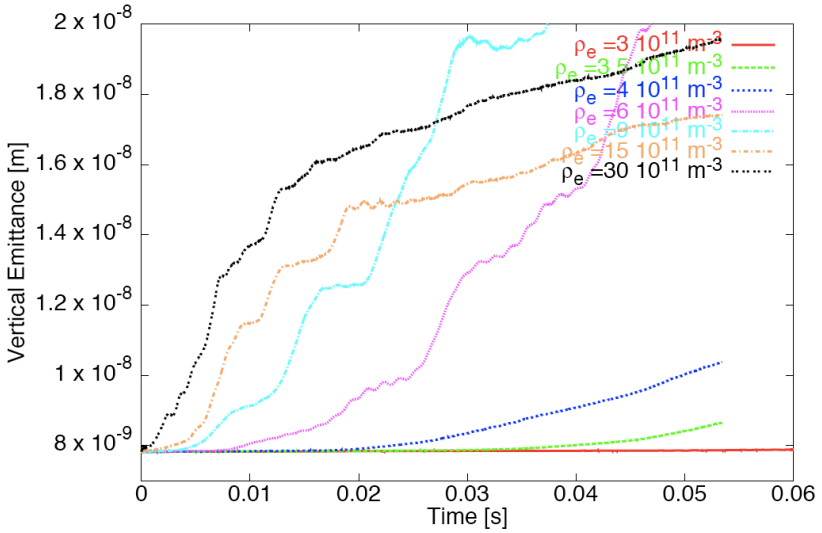


Figure 7.8. Vertical emittance as a function of time for different values of electron cloud density, and $Q' = 2$ (for LHC at injection).

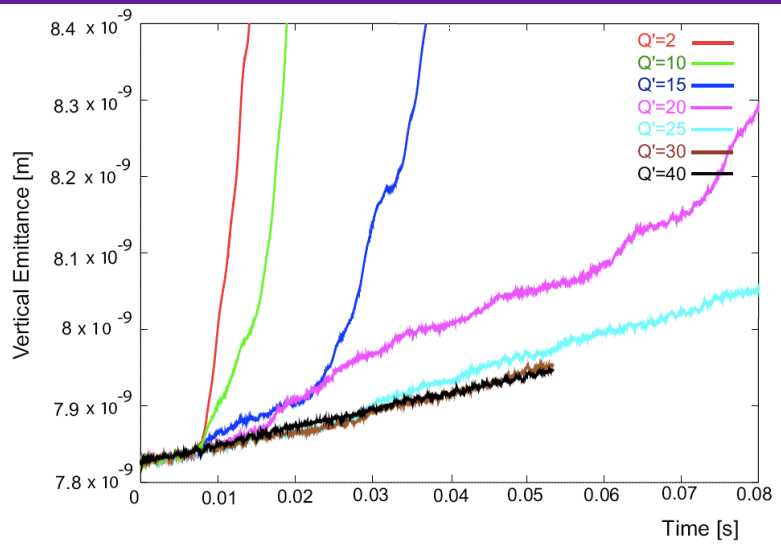


Figure 7.11. Vertical emittance growth for different chromaticities, for LHC at injection, $\rho_e = 6 \times 10^{11}$ m^{-3}

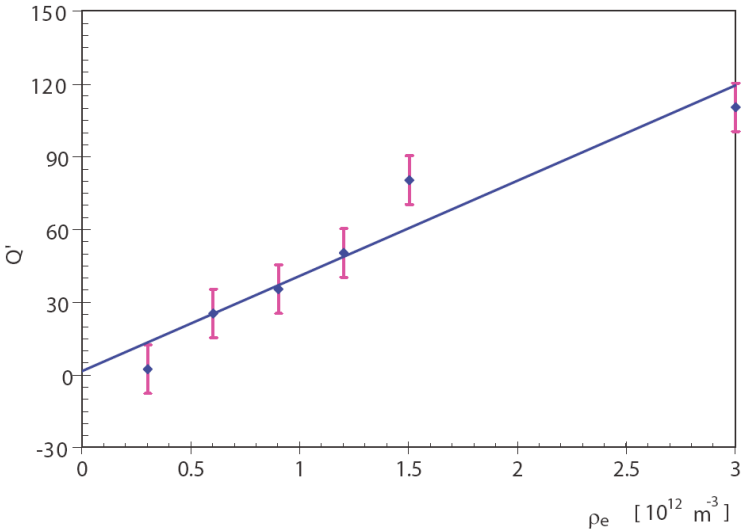


Figure 7.13. Chromaticity as a function of the electron-cloud density level at which the transition between the two regimes occurs in the simulation.

25 ns Injection MD (4/4)

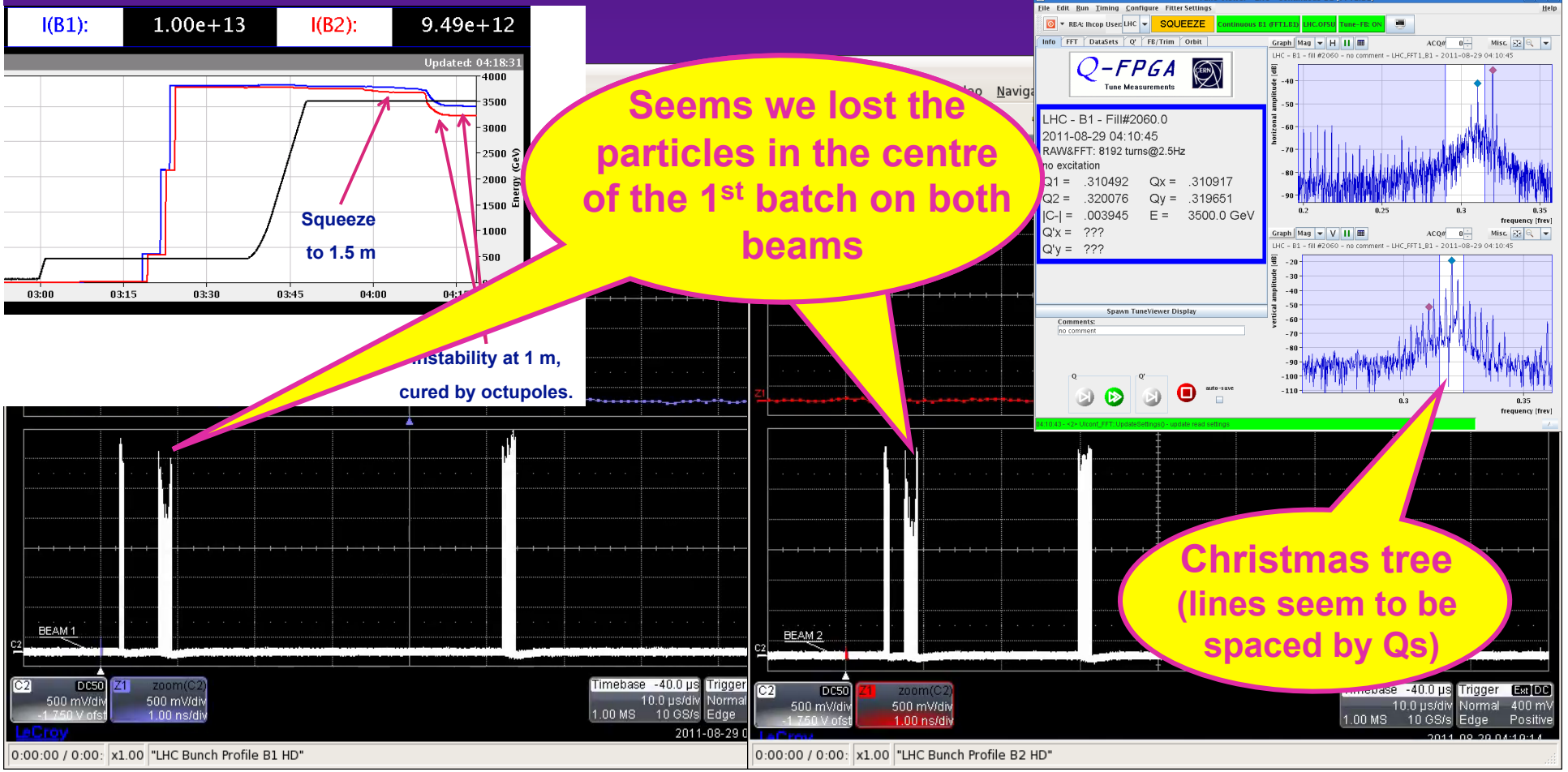
- **PREDICTIONS just before the MD (by FrankZ):**
  - Based on the SEY we deduced from the previous runs, when do we expect to see saturation of the ecloud? => After ~20 bunches
  - Which value of ecloud density? => ~ 1E12 m^{-3}
  - A fast instability is predicted
  - Chromaticity (>15) would be needed to stabilize the beam

- **CONCLUSION:**
  - Fast ecloud instability most probably observed as predicted
  - Plan for future MD: higher Q' (~ 20 in both planes) to be able to keep the beam in the machine (even if slow losses)!

Because it is a TMCI-like instability and not a (slow) head-tail instability!…

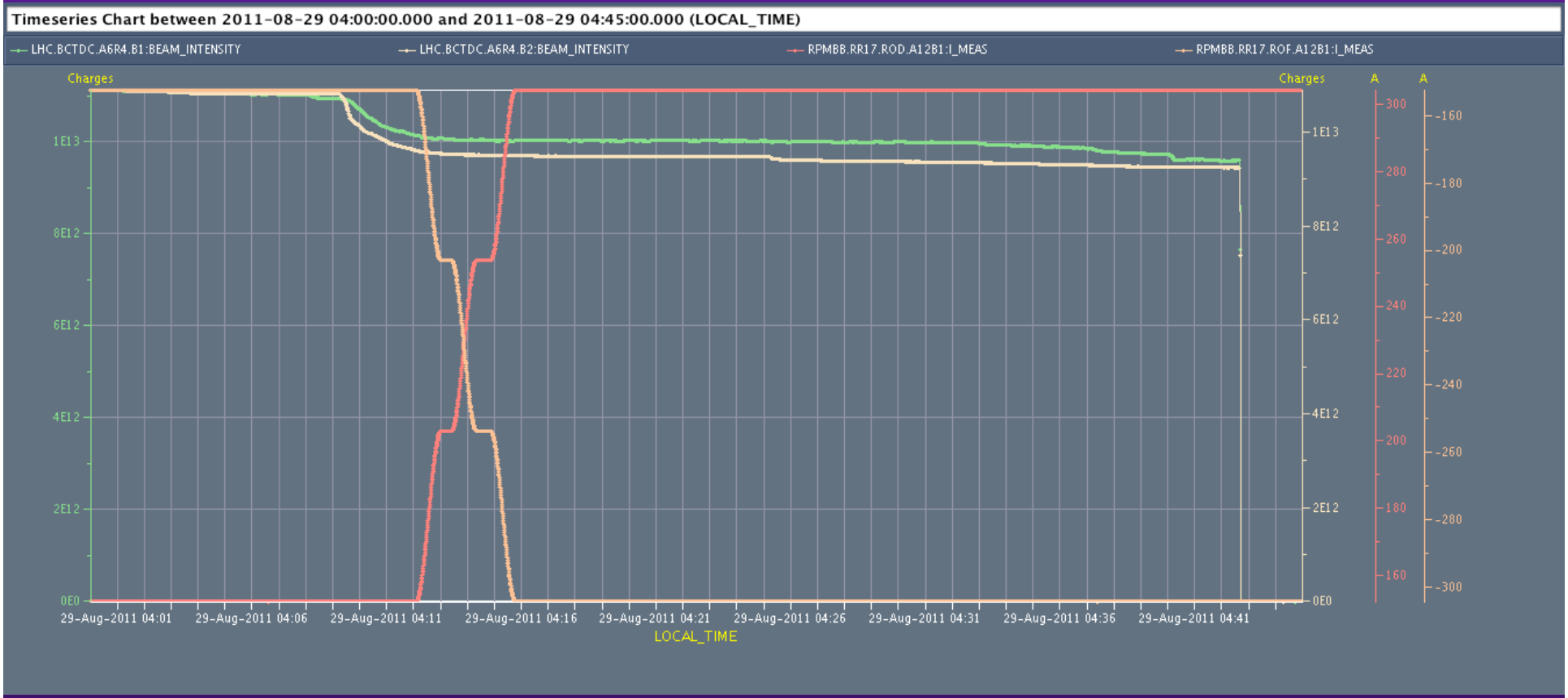
Beta* = 1 m MD (1/17)

- CONDITIONS => Tight collimators' settings & 100 microrad (instead of 120) ½ crossing angle in IR1/5 & 12 + 36 b trains (50 ns) with B1&2
- OBSERVATIONS => Strong instability (seemed mostly vertical) damped by octupoles (increased from - 150 A to - 300 A)



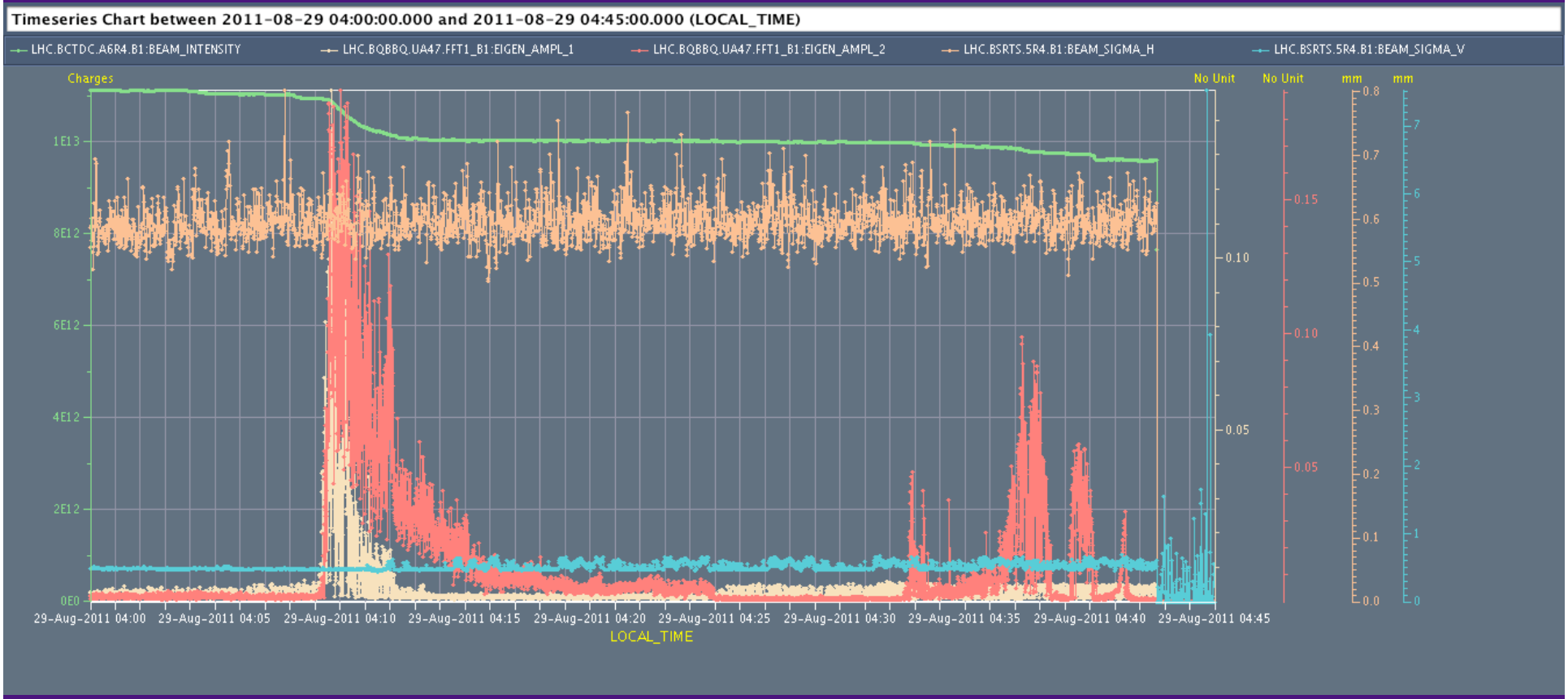
Beta* = 1 m MD (2/17)

- Chromaticities ~ 4-6 according to Jorg (as it was increased by 2-3 units compared to the initial values of ~ 2-3 units, tbc)
- Octupoles' current: Initial (before instability => -150 A as usual) and final (after instability => -300 A)



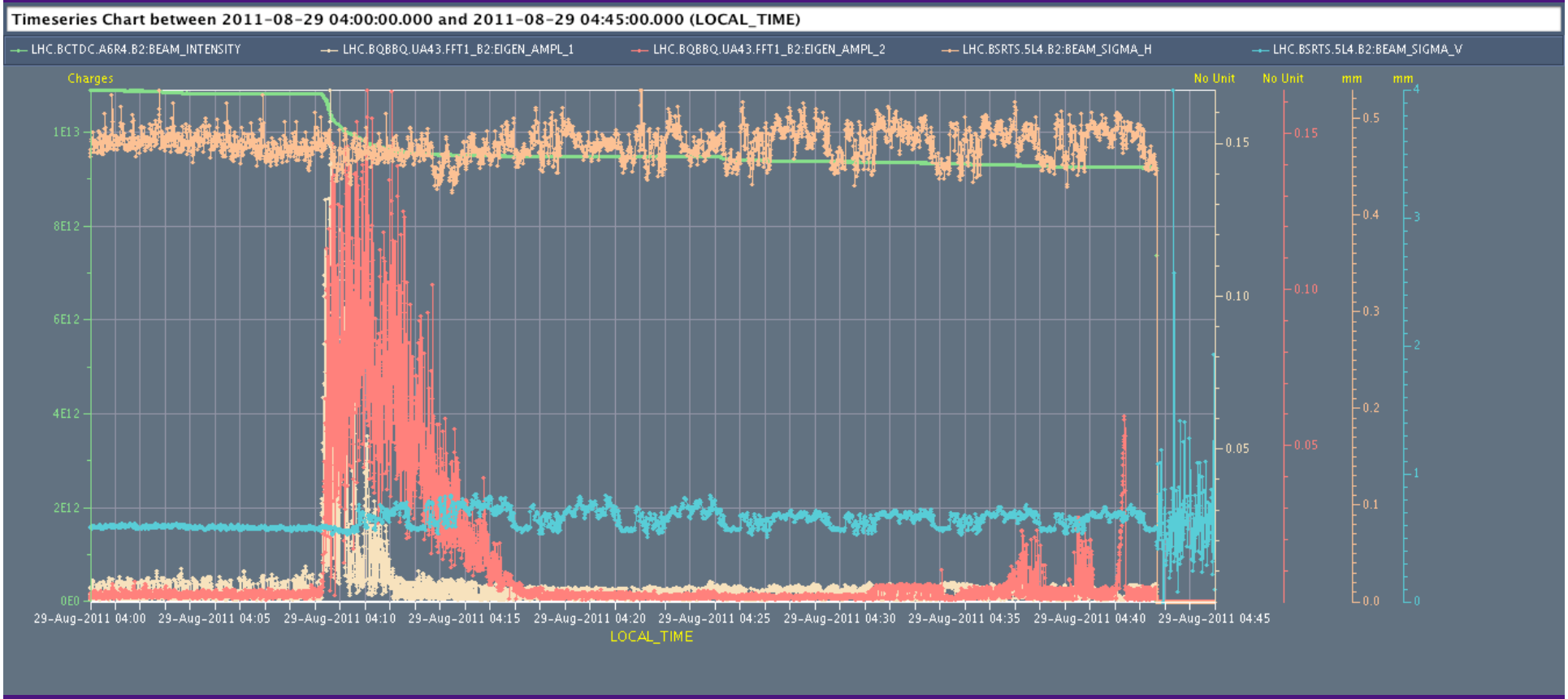
Beta* = 1 m MD (3/17)

B1

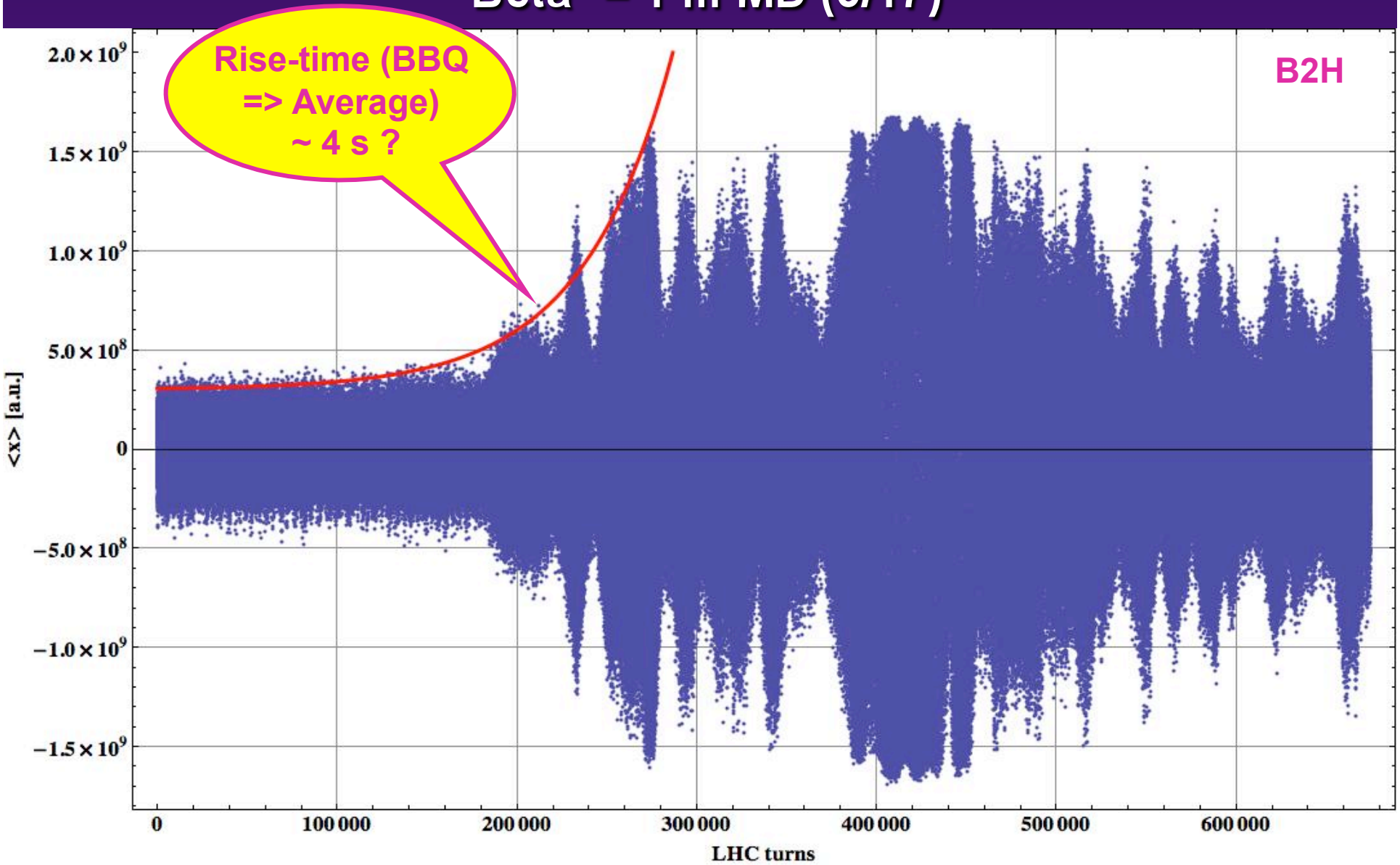


Beta* = 1 m MD (4/17)

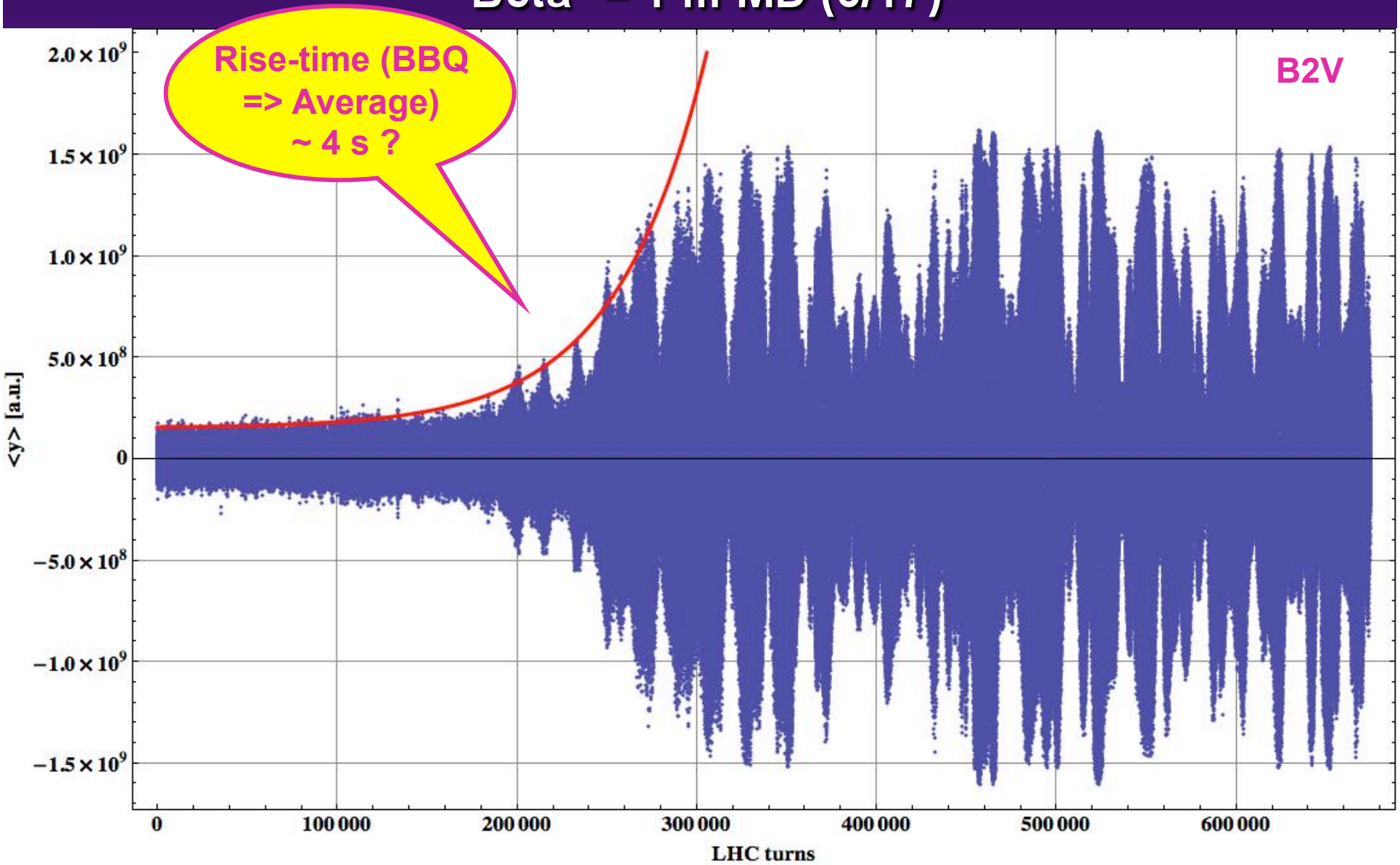
B2



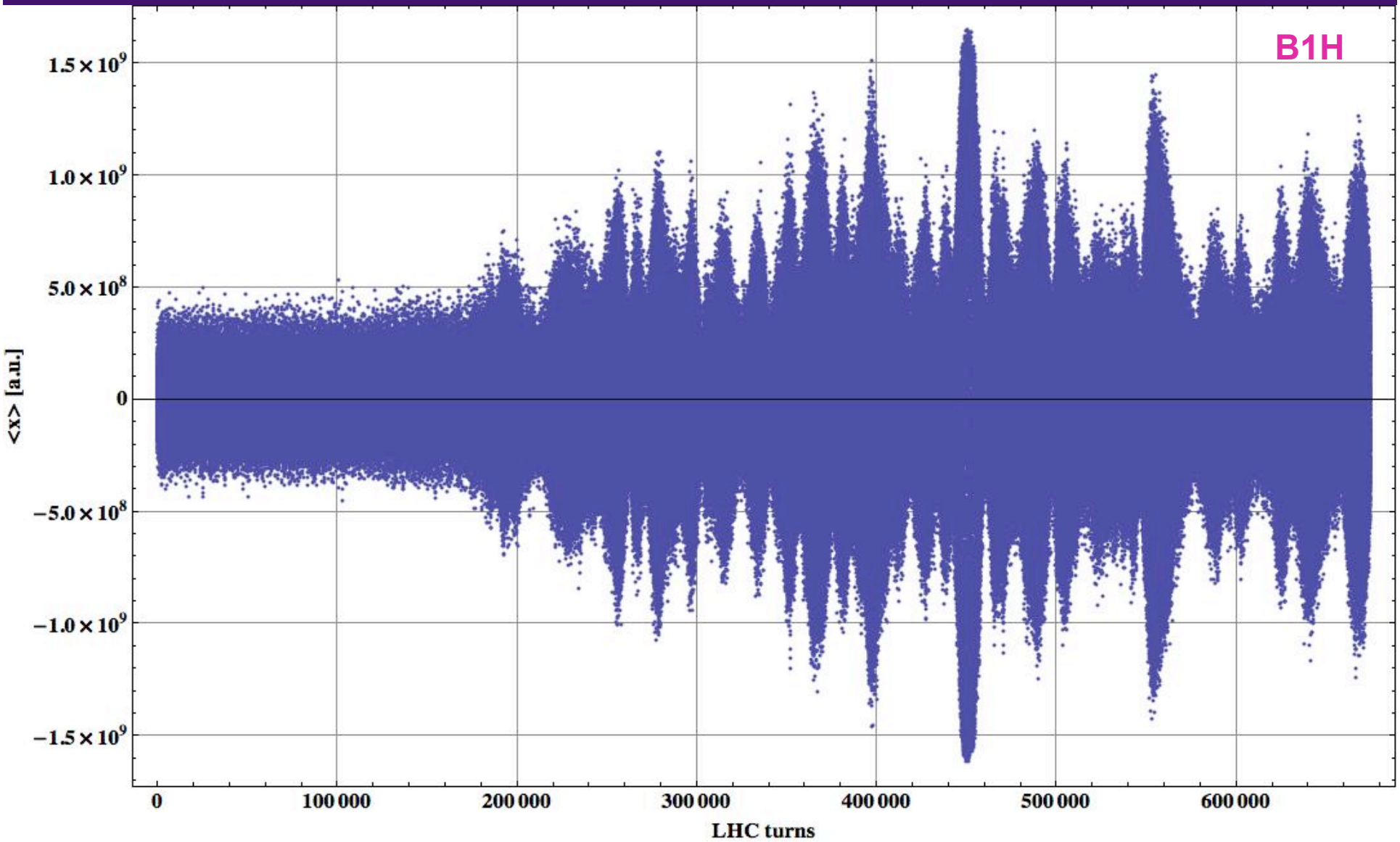
Beta* = 1 m MD (5/17)



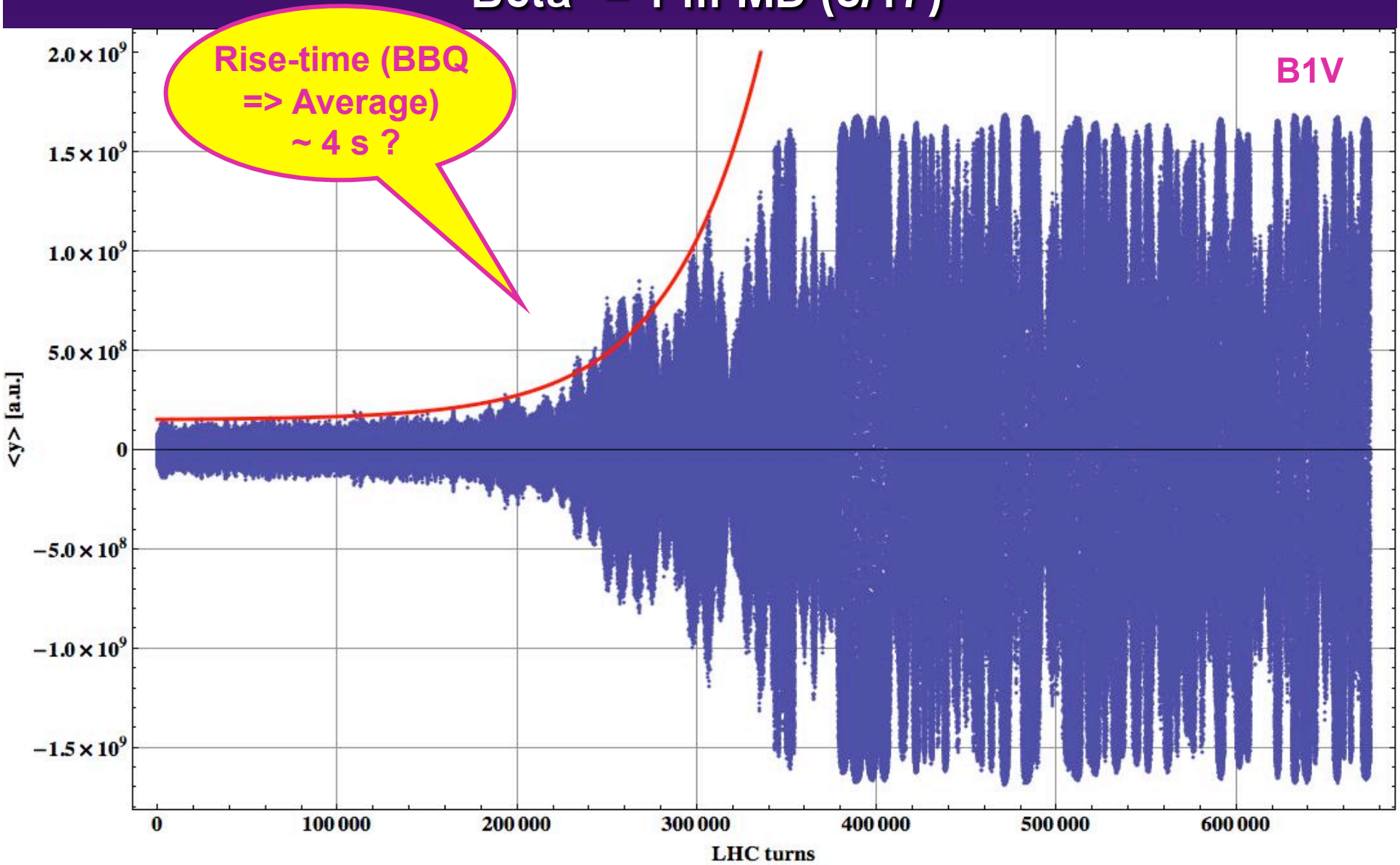
Beta* = 1 m MD (6/17)



Beta* = 1 m MD (7/17)

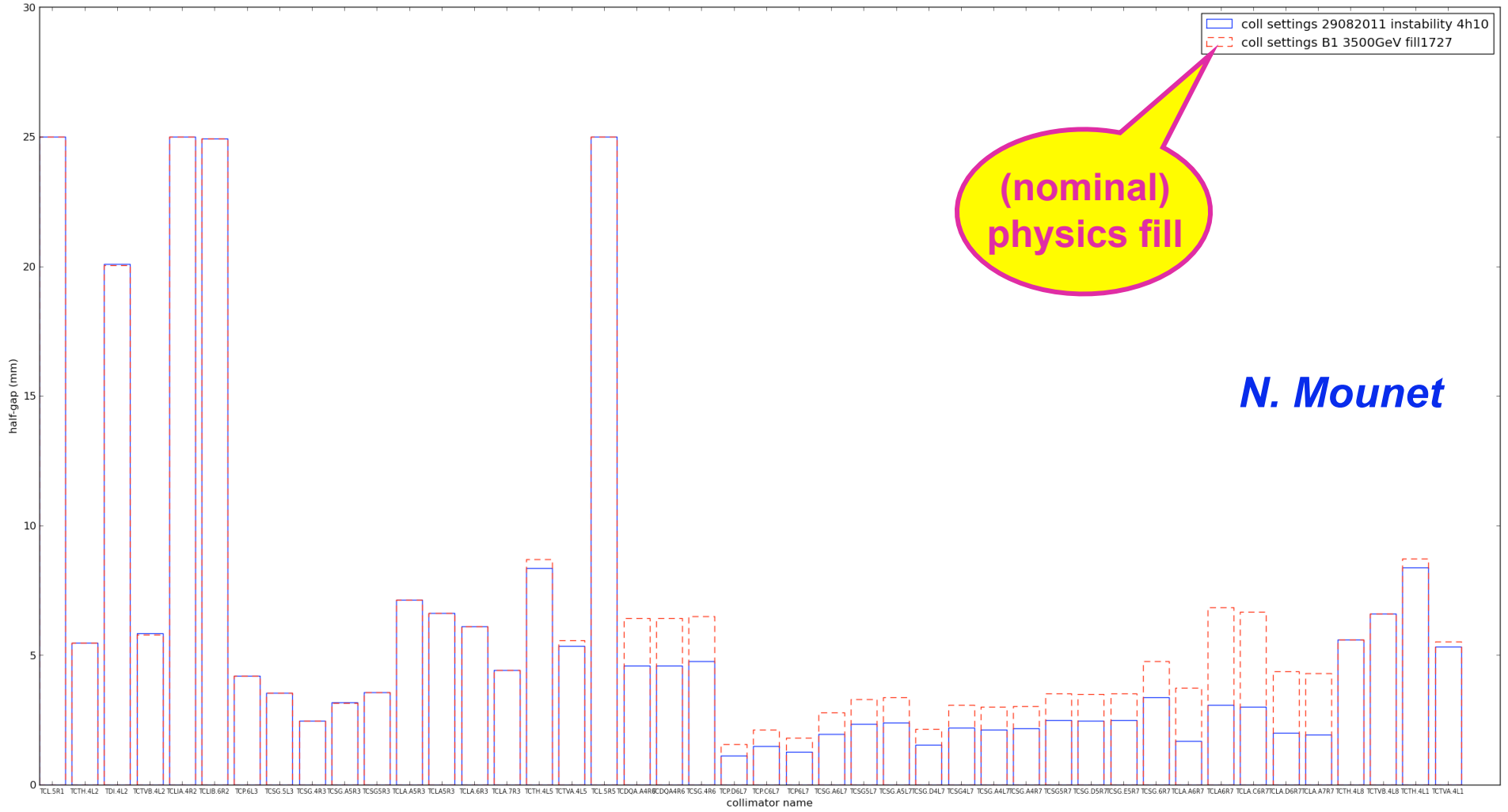


Beta* = 1 m MD (8/17)

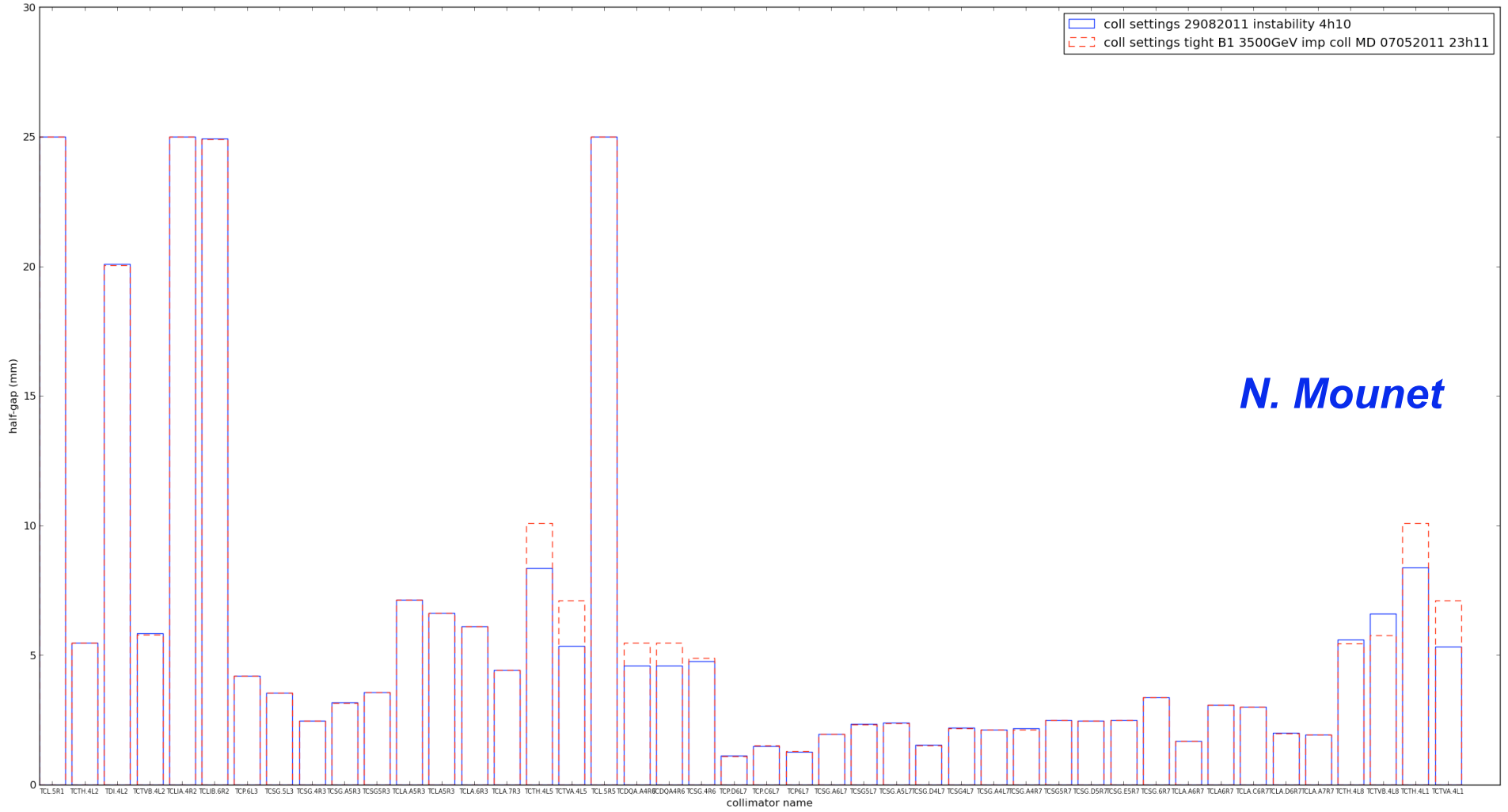


Beta* = 1 m MD (9/17)

- **Collimators' settings**



Beta* = 1 m MD (10/17)

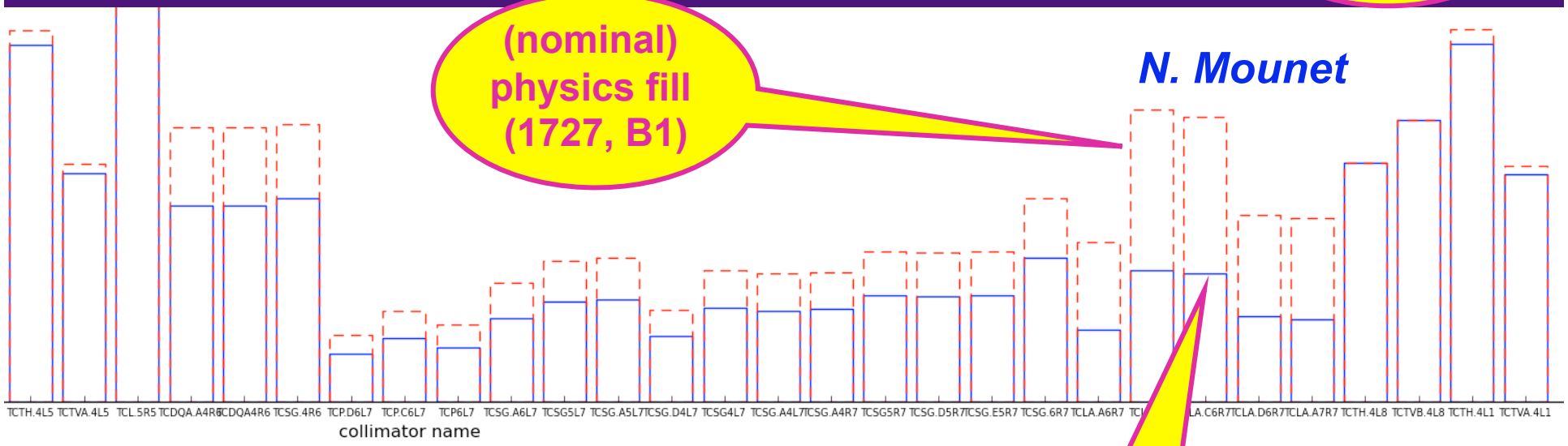


Beta* = 1 m MD (11/17)

Zoom of the collimators which moved

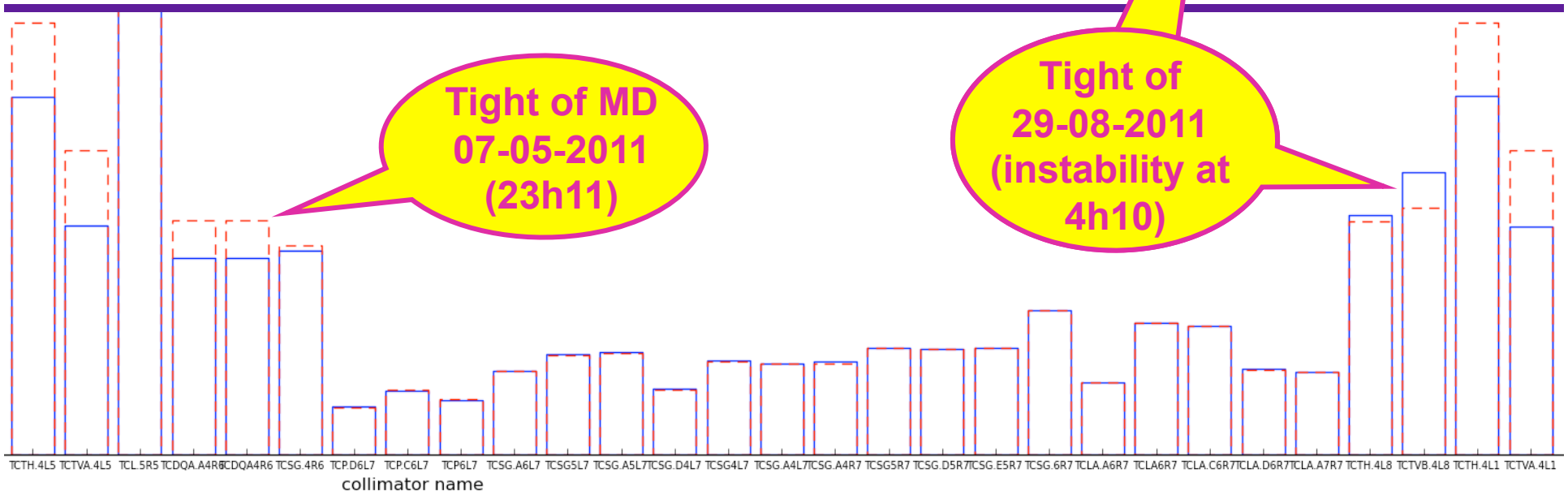
(nominal) physics fill (1727, B1)

N. Mounet

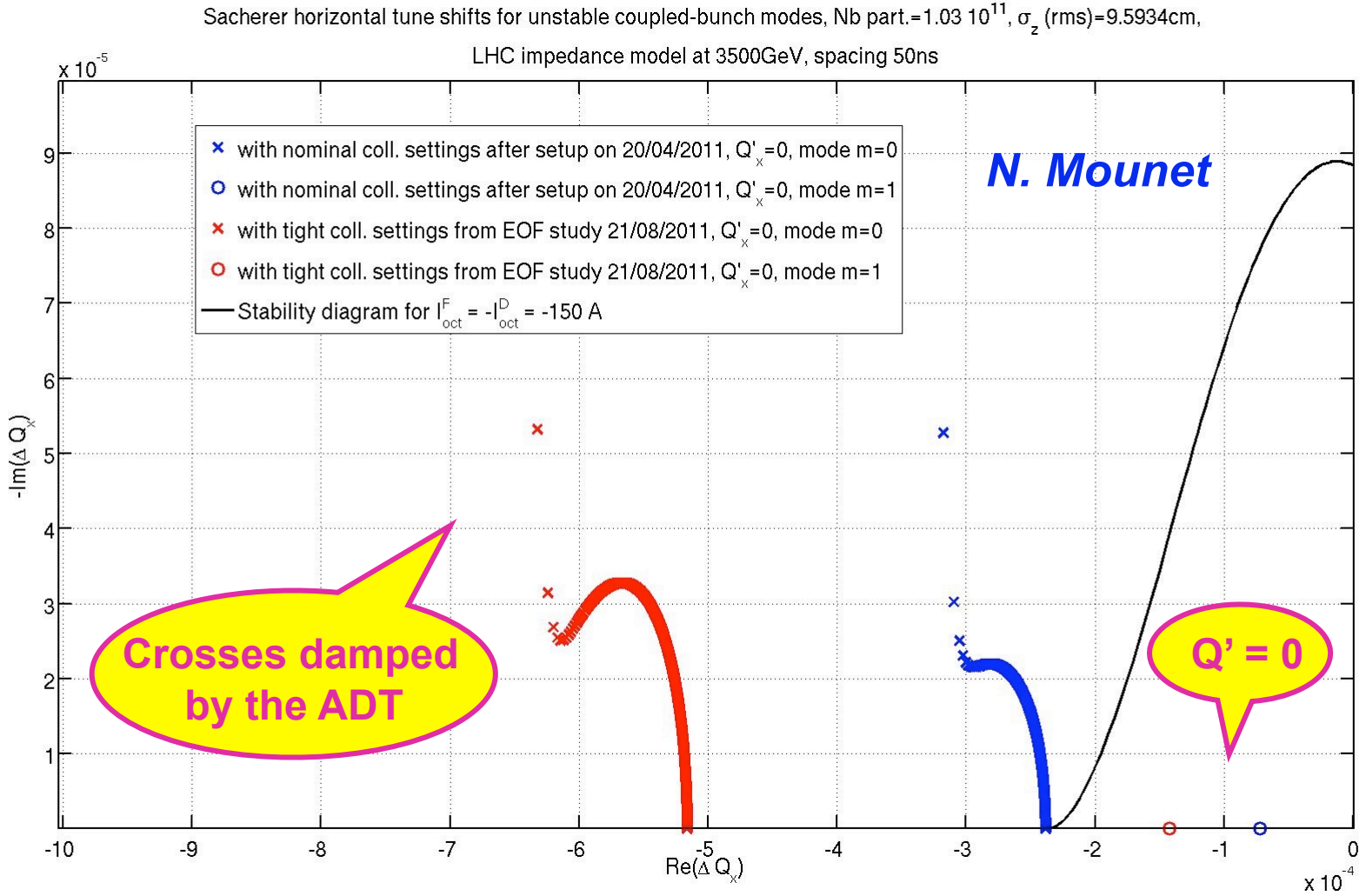


Tight of MD 07-05-2011 (23h11)

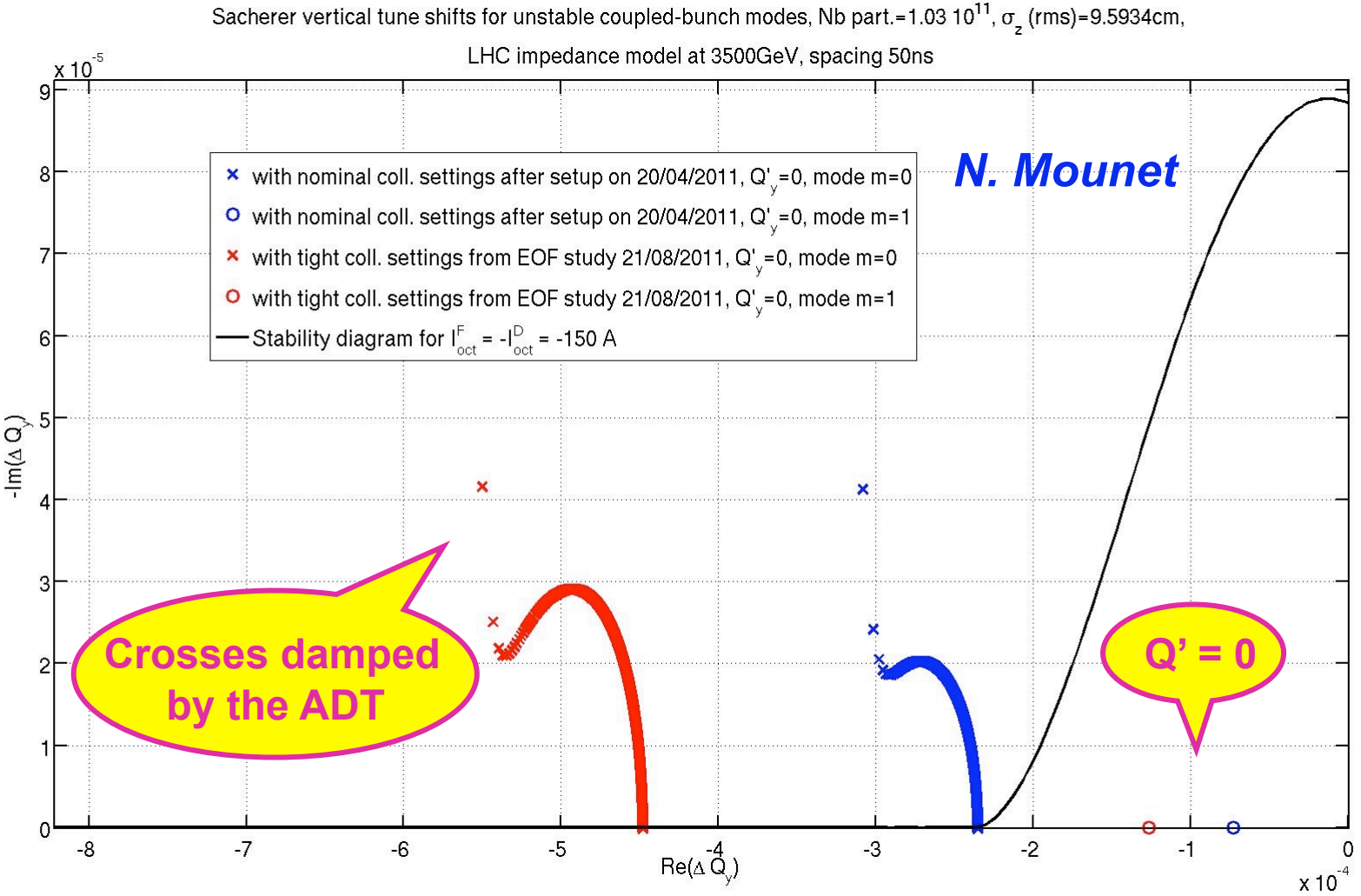
Tight of 29-08-2011 (instability at 4h10)



Beta* = 1 m MD (12/17)



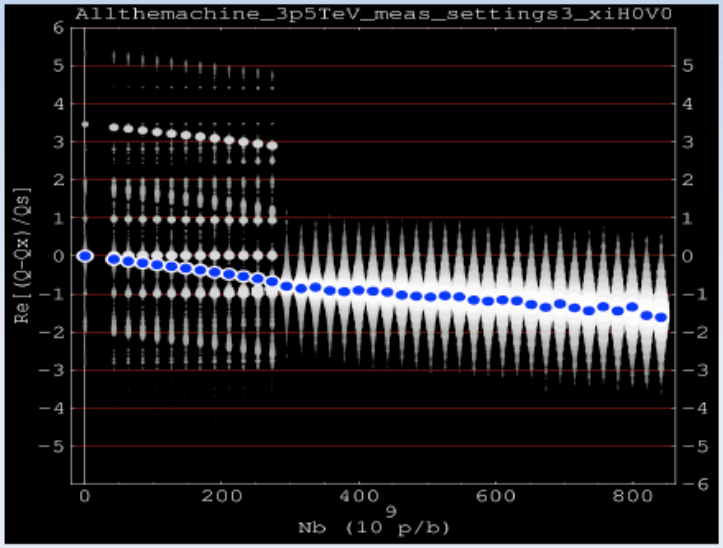
Beta* = 1 m MD (13/17)



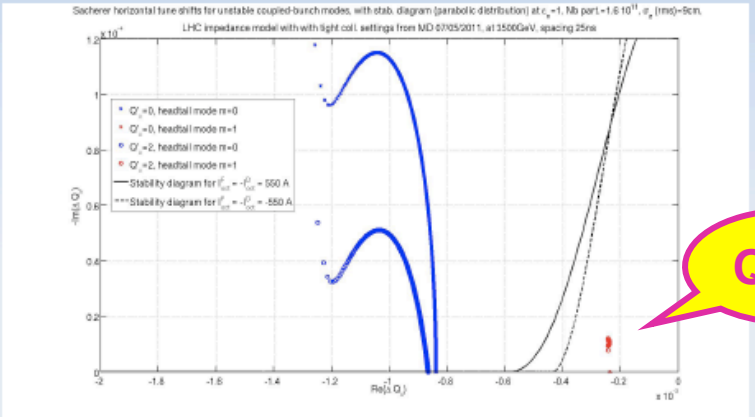
Beta* = 1 m MD (14/17)

First case: tight settings at 3.5 TeV

- TMC threshold: ~3.10^{11} p/bunch

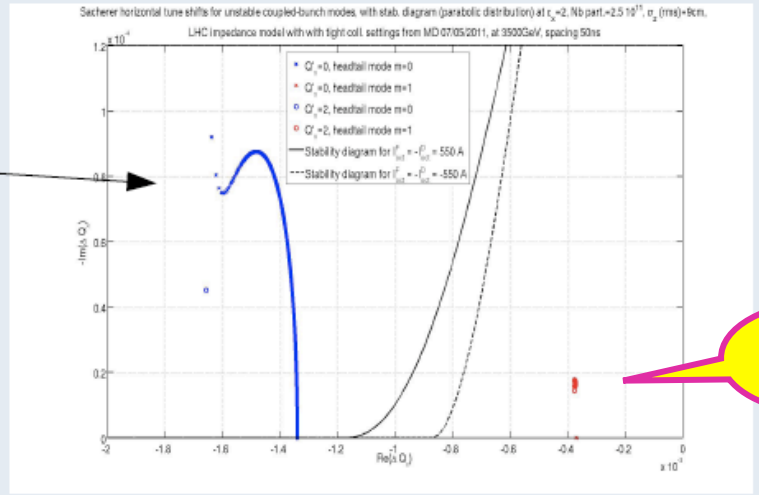


- Coupled-bunch modes (each point = one possible coupled-bunch mode along the train, unstable if above the octupoles stability diagram)



25ns
1.6 10^{11} p/b
ε=1

Q' = 2



50ns
2.5 10^{11} p/b
ε=2

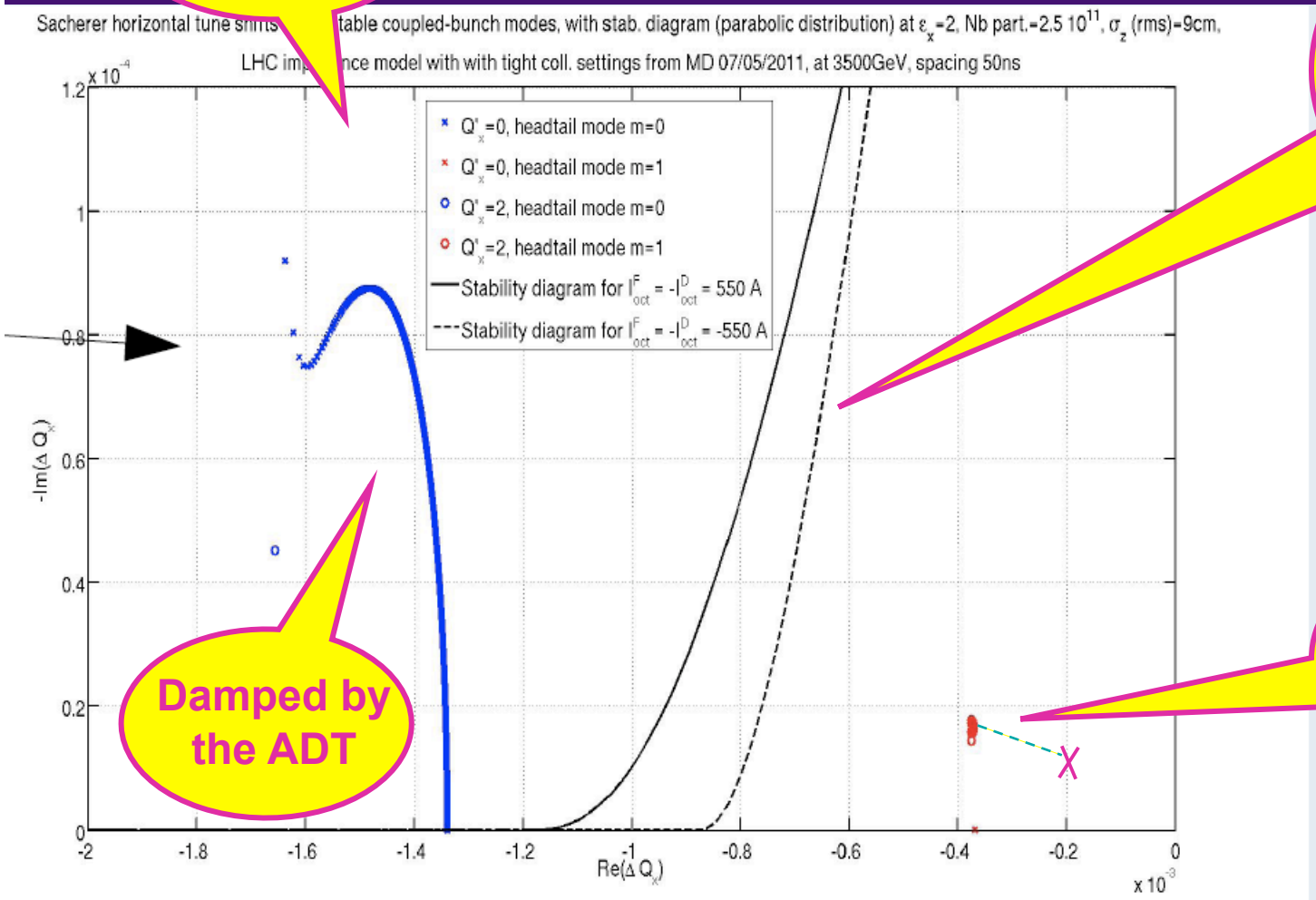
Q' = 2

Points in blue are "rigid-bunch" modes → can be damped by feedback.

This case a priori OK, but TMC quite low → need to check for coupled-bunch TMC.

Beta* = 1 m MD (15/17)

Zoom for 50 ns case



Damped by the ADT

For - 150 A it should be 550/150 ~ 3.7 times smaller (homothetic)

50ns
2.5 10^{11} p/b
ε=2

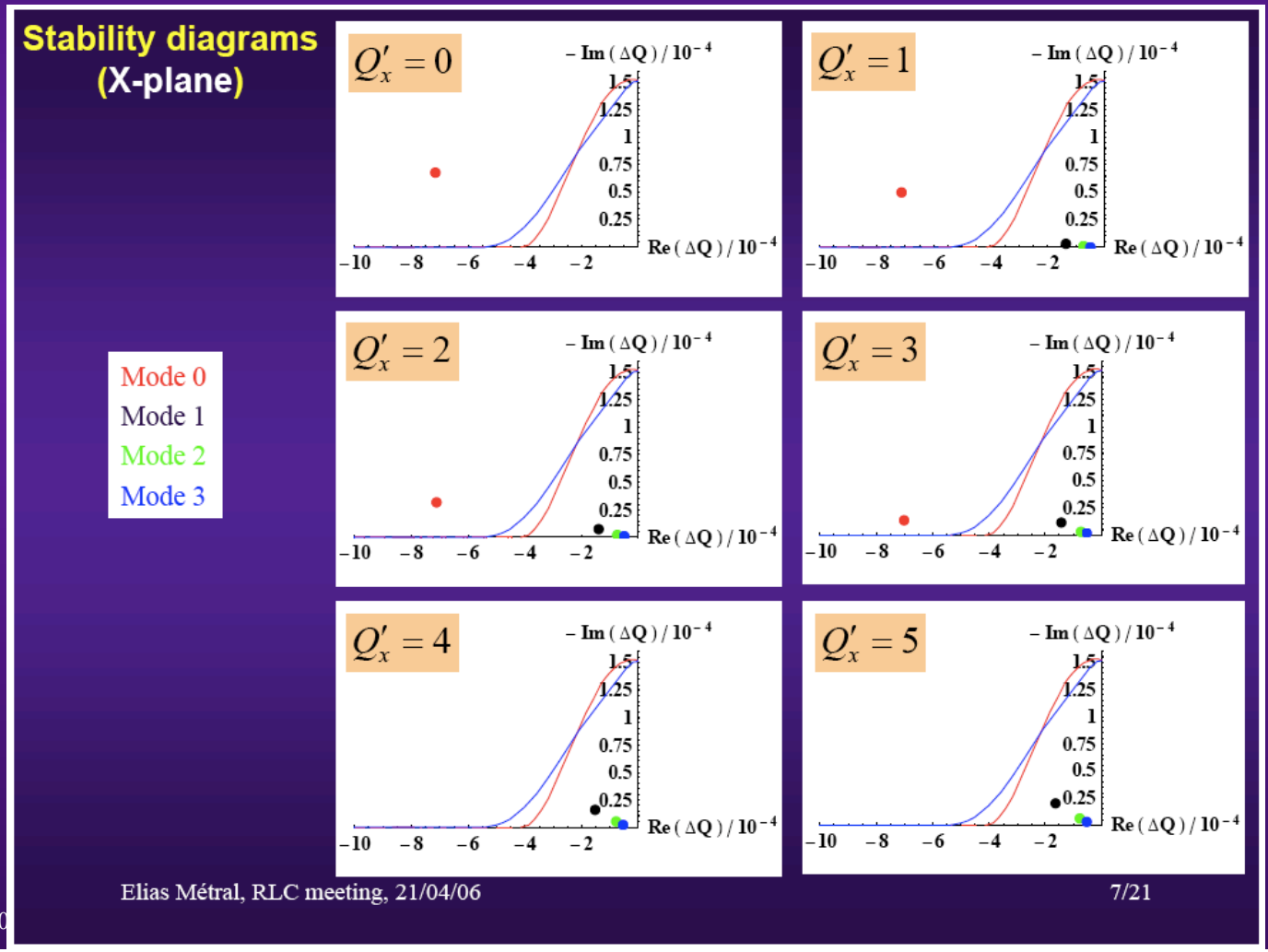
For ~ 1.2E11 p/b it should be ~ 2 times smaller

N. Mounet

=> We can imagine that we lost Landau damping for the mode |m| = 1 because the chromaticity was too high (~ 4-6)

Beta* = 1 m MD (16/17)

- Reminder => Qualitatively on past predictions for the 25 ns beam at 7 TeV, for 550 A in the octupoles, just to see how mode |m| = 1 grows with chromaticity



Beta* = 1 m MD (17/17)

CONCLUSION:

- **Expected (real) tune shifts when moving from the nominal collimators' settings and the tight settings:**
  - **Single-bunch (HEADTAIL): ~ -2E-4 in both planes**
  - **Coupled-bunch (1782 bunches, Sacherer): ~ - 3E-4 in both planes**
- **Instabilities with rise-times of few seconds are what could be expected for TCBI with |m| = 1 and few units of chromaticities (above ~ 4-6) if Landau damping is lost**
- **Landau damping could have been lost with the parameters used (depending on transverse emittance, distribution tails etc. => See also last LBOC on TCBI predictions)**

=> The observed instabilities "could be" TCBI of mode |m| = 1 (would also explain the Chrismas tree as observed with SBI |m| = 1)

- **(Usual) recommendation: Try and control better the chromaticities, reducing their values to 1-2 units if possible, and/or increase the octupole current (still some margin as the maximum current is 550 A)**