SOURCES OF INSTABILITIES

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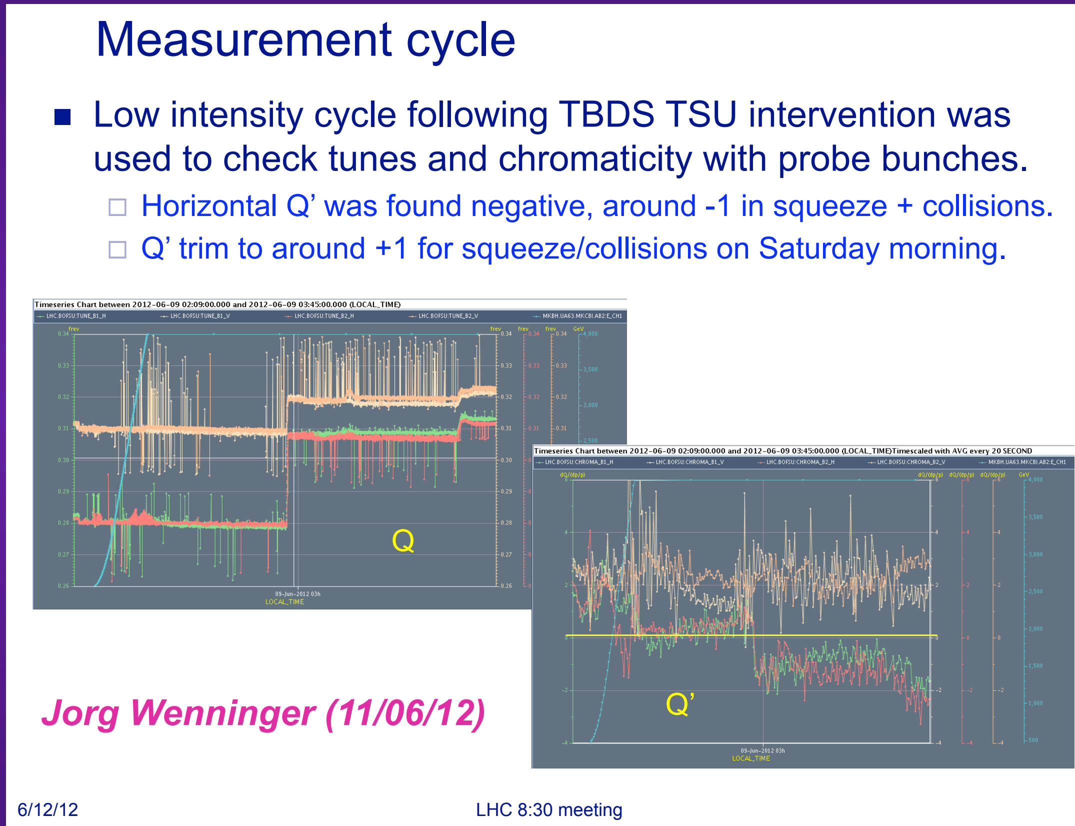
- Executive summary
  - Instabilities and recent chromaticities' measurements
  - Sign of the octupoles?
- Reminder of the problem(s)
- "Clear" (MD) studies made in the past
- 2 types of instabilities recently observed (always in H plane):
  - Squeeze
  - Collision
- 2 end-of-fill studies with reduced ADT gain
- Appendix

EXECUTIVE SUMMARY (1/7)

- **Negative H chromas during squeeze and collisions might give a hint to (only H) instabilities observed these days => Ongoing…**

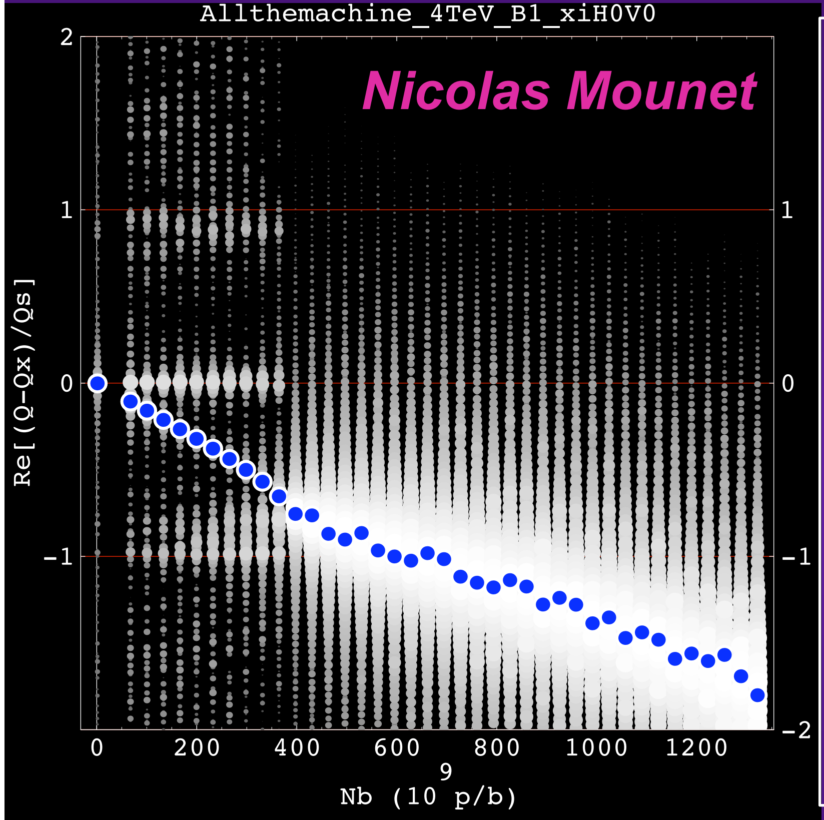


- **But we need dedicated MDs and instrumentation to be able to disentangle between HT modes (standing waves) 0 or -1 (1) or TMCI (travelling wave)…**

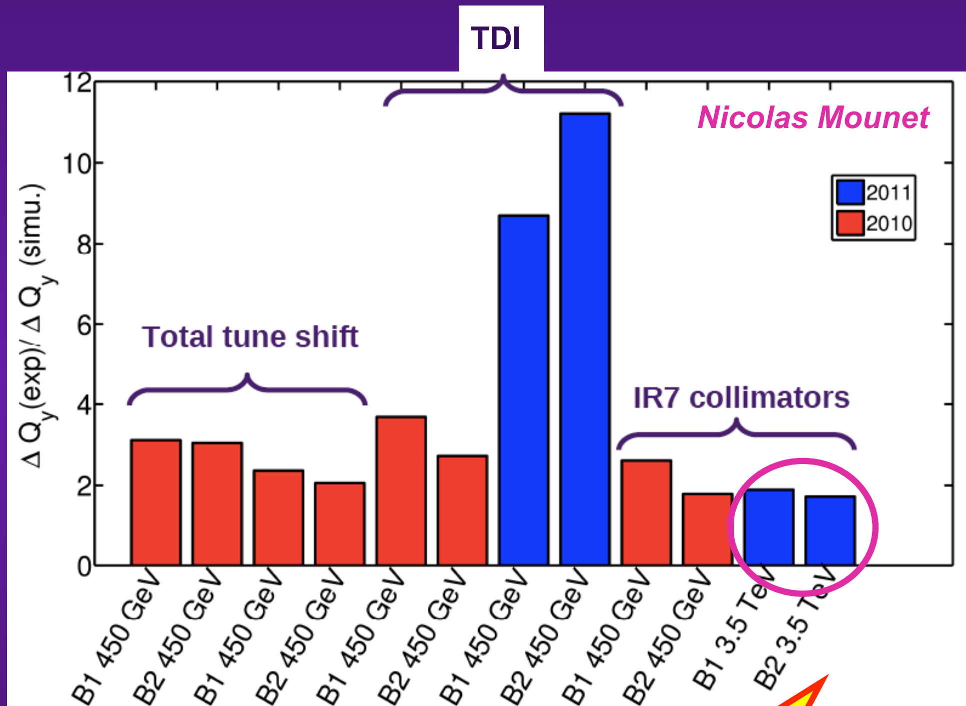
EXECUTIVE SUMMARY (2/7)

- **What could/would happen if the impedance a 4 TeV (from the collimators), and in particular the imaginary part (leading to a real tune shift), is larger than predicted?**
  - Can lead to a loss of transverse Landau damping (if still below TMCI) for HT mode – 1 => Increase Landau octupoles' current => Could explain why we need more octupoles' current than predicted (but we need a factor ~ 5-10!). Ongoing as we are close (~ 500 A) to the limit (550 A) => Important MD!
  - Can lead to TMCI (see next slide). Current threshold: ~ 3.8 10^{11} p/b for SB TMCI (and ~ 3 10^{11} p/b for CB TMCI) => In case of impedance larger by a factor ~ 2, we could be close to the limit (with ~ 1.5 10^{11} p/b)… => SOLUTION: increase chromaticity (positive), octupoles' effect to be re-studied (some improvements seen in the past), impedance reduction (open collimators, phase 2 collimators), high-bandwidth FB…

EXECUTIVE SUMMARY (3/7)



- Transverse (real) coherent tune shift measurements



To be re-measured at 4 TeV with tight collimators' settings (MD!)

EXECUTIVE SUMMARY (4/7)

- For the 2 kind of instabilities observed these days (but it can also apply to the previous), our current interpretation is the following
  - During / at the end of the squeeze => We have negative chromas and the use of ADT with negative chromas must be studied (MD request with a single bunch first) => Ongoing analyses by AlexeyB, NicolasM and ADT experts (WolfgangH and DanielV) => SOLUTION: optimization (if needed) of the ADT gain for negative chromaticities (MD needed) or go (as usual) to positive chromaticities (MD planned to study effect of octupoles with only 1 beam). 2nd possibility: TMCI (discussed before)…
  - In collision => Instability happens on selected bunches with insufficient tune spread (and thus Landau damping) due to no HO collisions (or offsets) as mentioned by WernerH in his LMC talk (https://espace.cern.ch/lhc-machine-committee/Presentations/1/lmc_134/lmc_134c.pdf) => SOLUTION: avoid this situation of some bunches with very small tune spread!

EXECUTIVE SUMMARY (5/7)

- **PAST RECOMMENDATIONS FROM ICE TEAM**

> - (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)
>
> Elias Métral, LBOC, 30/08/2011 22/22

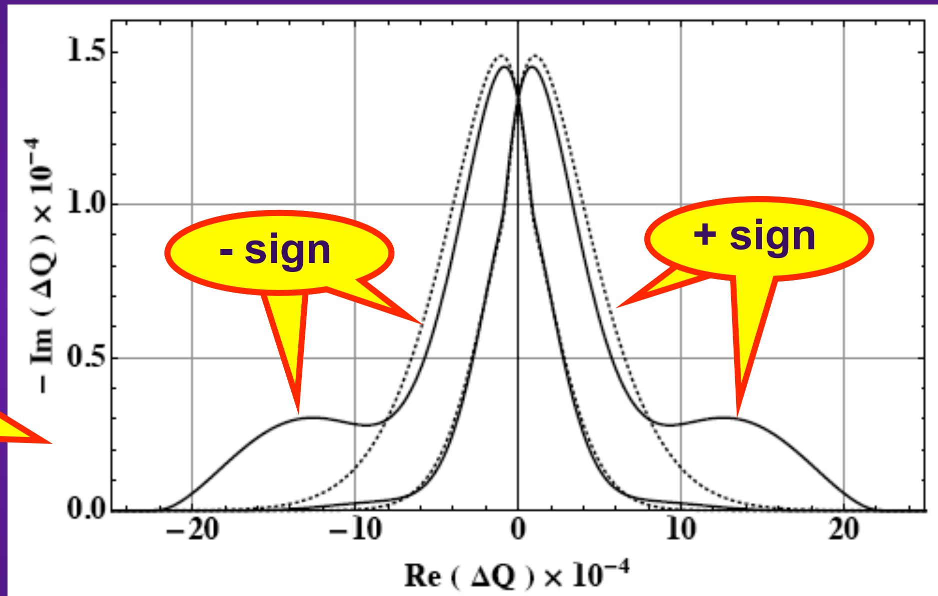
Why very low (positive) chromas? => Because (assuming still in the HT regime), it minimizes the required octupole current, which is important if we are close to the limit in octupole current…

- **In order to make some progress we need to know the tunes and chromaticities with a sufficiently good precision => NEW RECOMMENDATIONS FROM ICE TEAM: knowledge of the tunes and chromaticities for all the fills!**

EXECUTIVE SUMMARY (6/7)

- Concerning the sign of the octupoles (- sign for the moment for the amplitude detuning) => Several mechanisms to be taken into account
  - Shape of the stability diagram for Landau damping of HT modes => - sign better

Gaussian distribution (dotted) and distribution with more populated tails. The real part of the complex tune shift is negative



=> Biggest open question (why very high octupole current needed?) => MD!

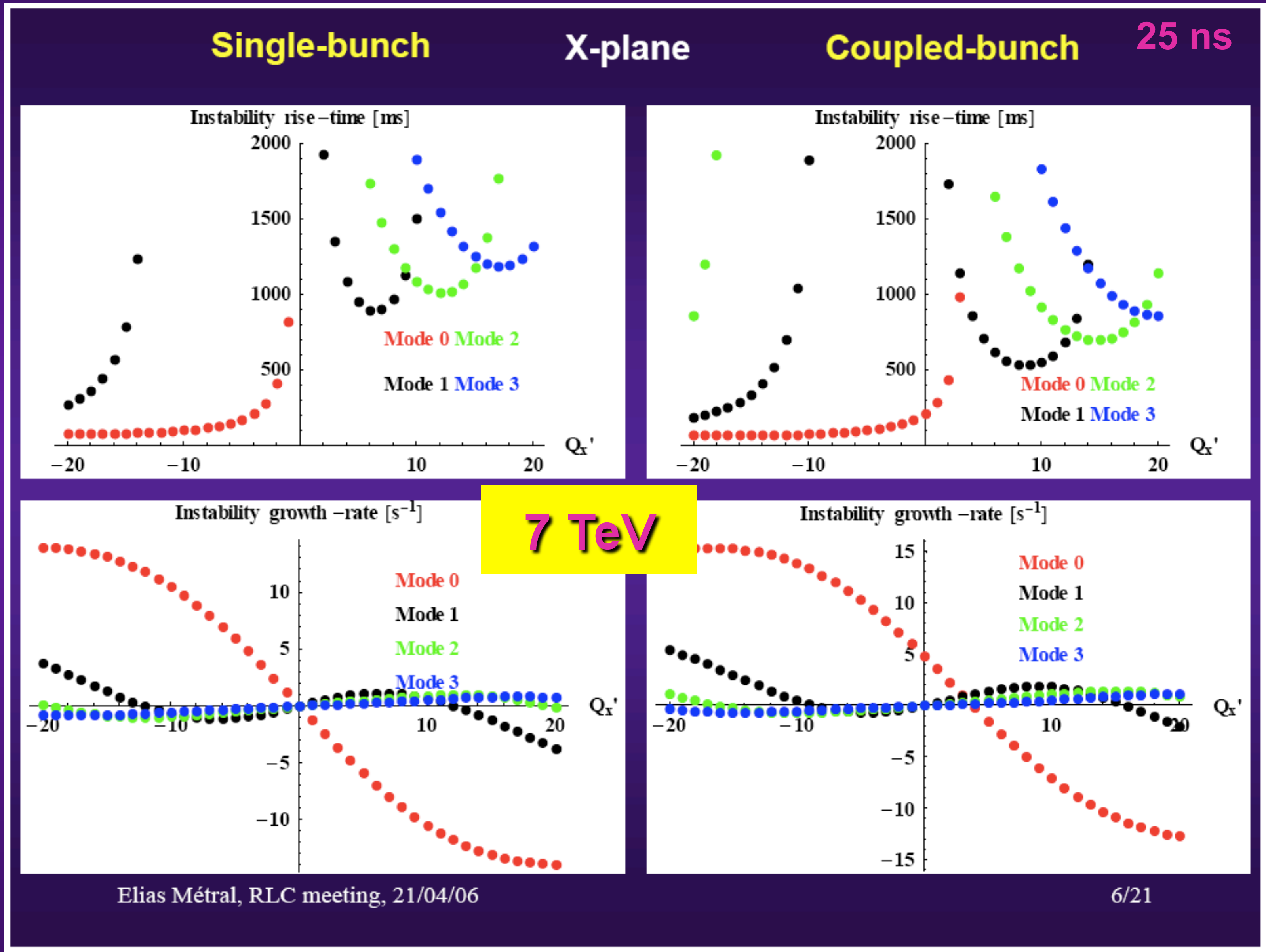
  - Proximity of the 0.33 resonance => - sign better but working point can be shifted down by a few 10^{-3}

EXECUTIVE SUMMARY (7/7)

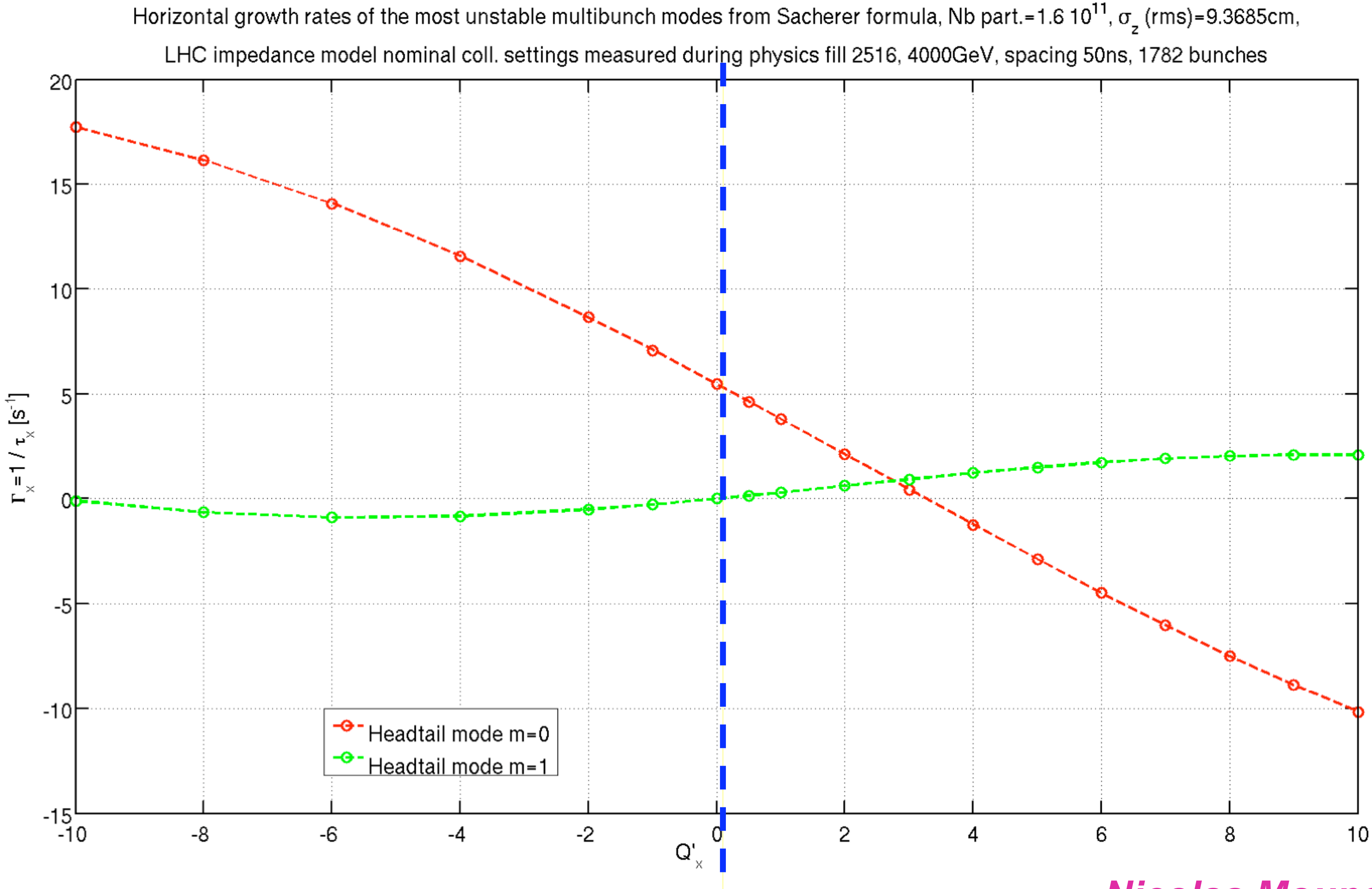
- Interplay with beam-beam (still ongoing discussions):
  - + sign better for private IP8 bunch (and - sign can explain why we can lose these bunches and also after few hours => recent discussions Stephane-Elias…)
  - + sign increases tune spread for nominal bunches (all consequences to be investigated)

=> PROPOSITION: Keep the sign as it is (-) for the moment as we need first to know why we need the very high octupoles' current. If the octupoles' current can be reduced and if we cannot find filling schemes without some bunches with very small tune spreads, then we could envisage to change the sign (ideally we would like to remove octupoles - and ADT - during SB!)

REMINDER OF THE PROBLEM(S) (1/4)

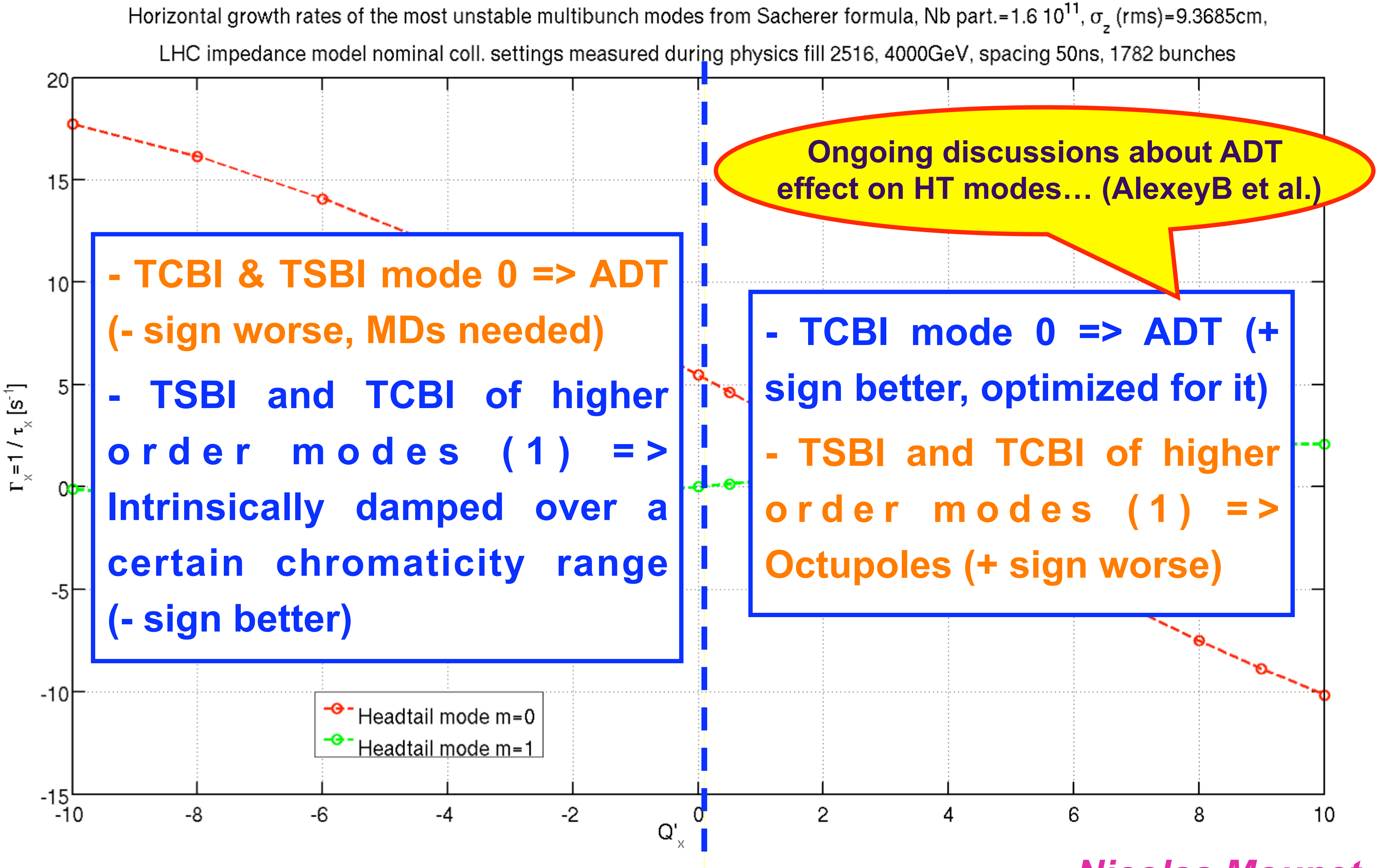


REMINDER OF THE PROBLEM(S) (2/4)



Nicolas Mounet

REMINDER OF THE PROBLEM(S) (3/4)



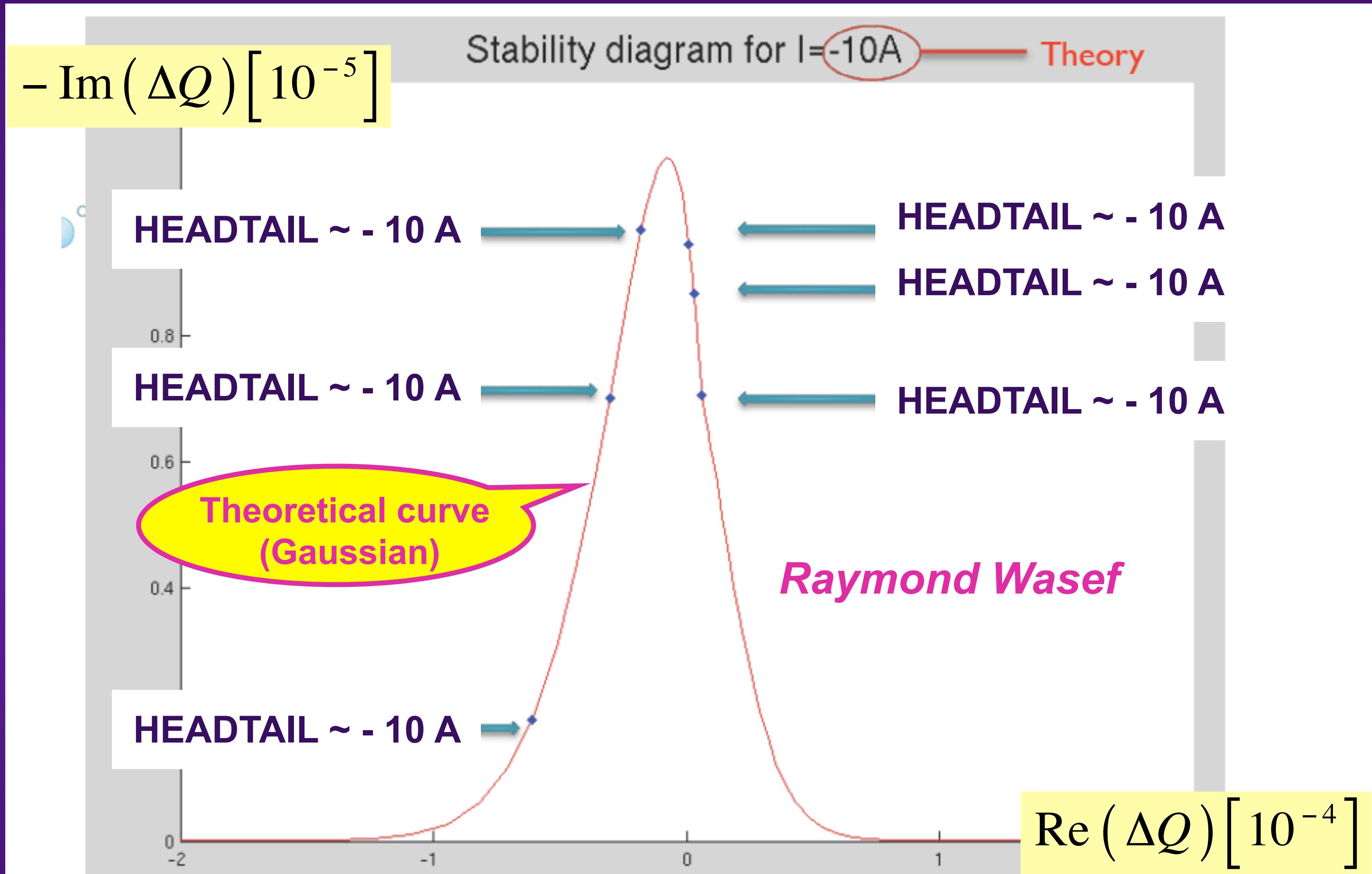
Ongoing discussions about ADT effect on HT modes… (AlexeyB et al.)

- TCBI & TSBI mode 0 => ADT (- sign worse, MDs needed)
- TSBI and TCBI of higher order modes (1) => Intrinsically damped over a certain chromaticity range (- sign better)

- TCBI mode 0 => ADT (+ sign better, optimized for it)
- TSBI and TCBI of higher order modes (1) => Octupoles (+ sign worse)

Nicolas Mounet

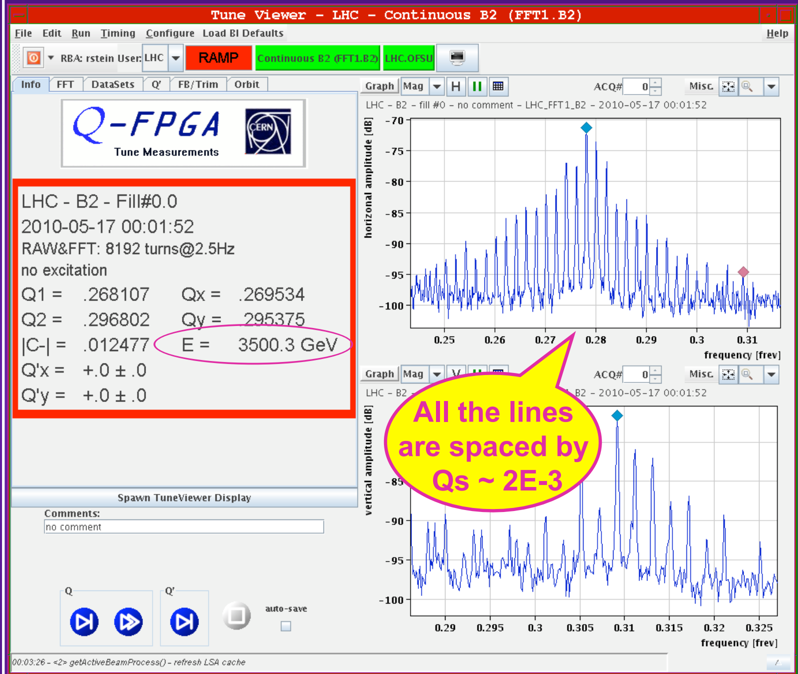
REMINDER OF THE PROBLEM(S) (4/4)

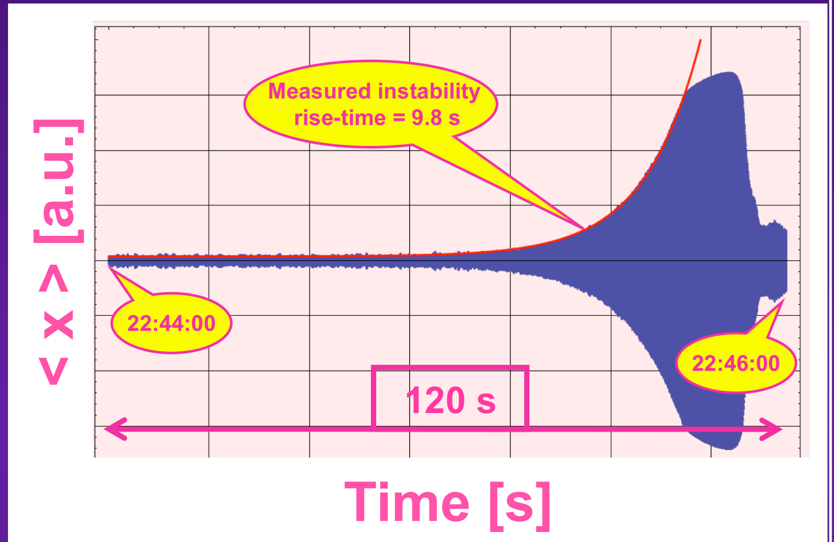


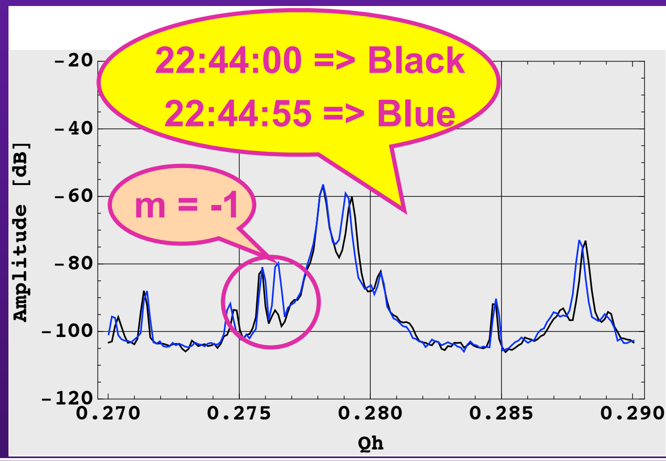
Benchmark between HEADTAIL and theoretical stability diagram (Berg-Ruggiero1996)

"CLEAR" (MD) STUDIES MADE IN THE PAST (1/2)

- **Single-bunch head-tail instability m = - 1 without Landau octupoles (for Q' ~ 6) on LHC flat-top**



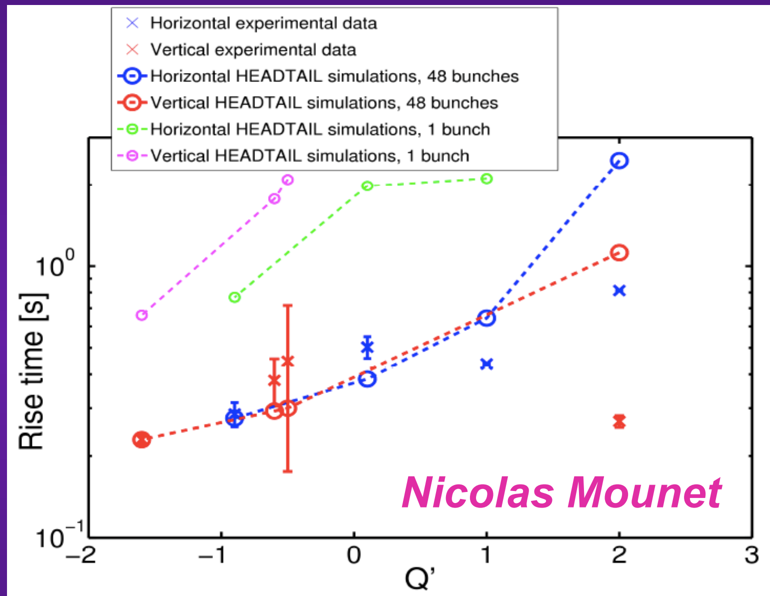




- Rise-time and Landau octupoles' current for stability (between 10 and 20 A) within factor ~ 2 with predictions

"CLEAR" (MD) STUDIES MADE IN THE PAST (2/2)

- **TCBI rise-time studies (for mode 0) with 48 bunches (12 + 36)**
  - **Good agreement at 450 GeV**

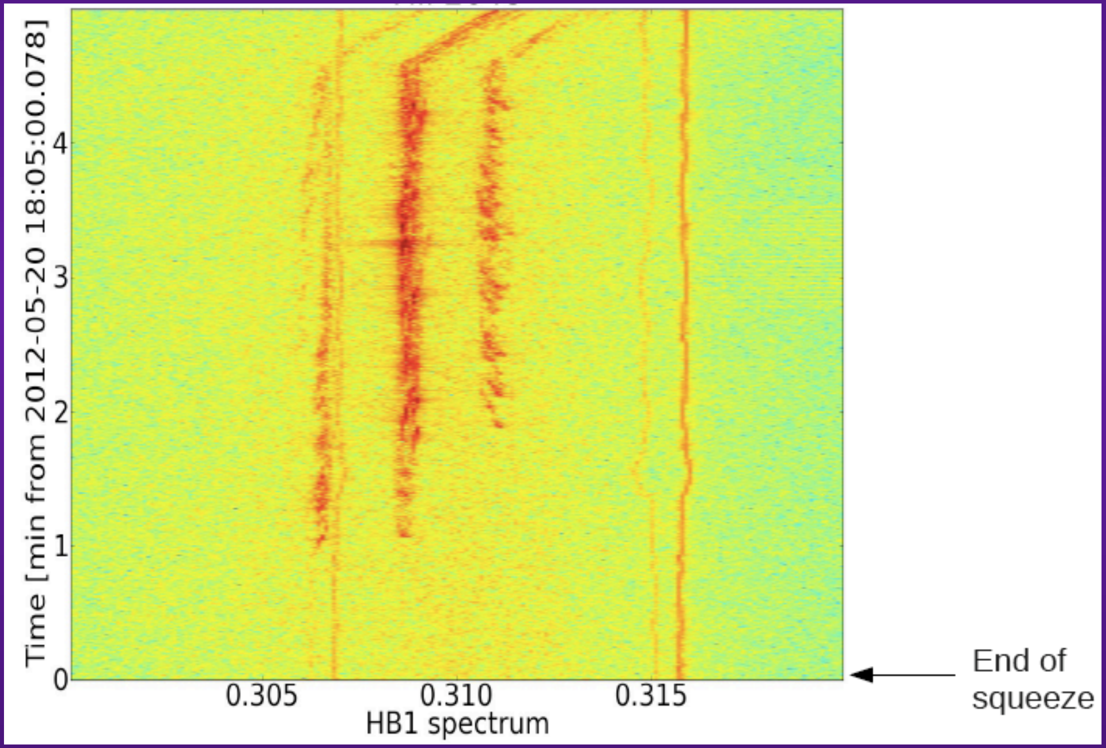


  - **~ 2-3 faster rise-times observed at 3.5 TeV (but uncertainty on chromaticities)**
  - **Landau octupoles' current for stability at 3.5 TeV within factor ~ 2 with predictions (less than predicted => Studies with Q" ongoing)**

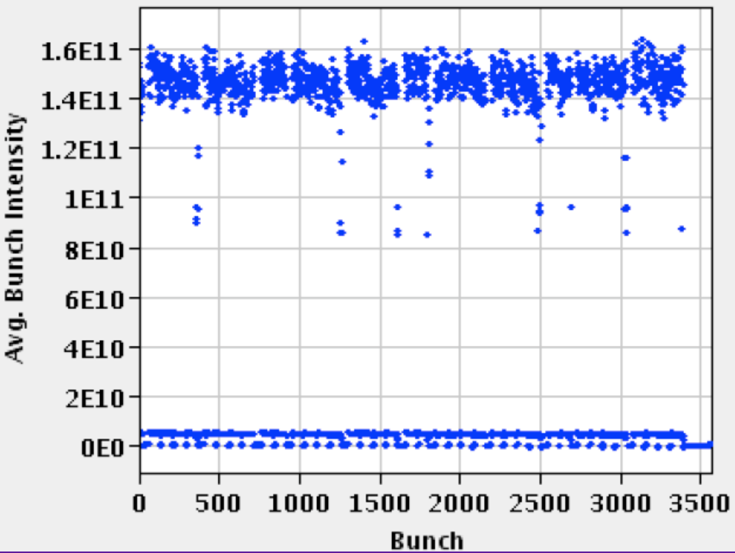
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (1/6)

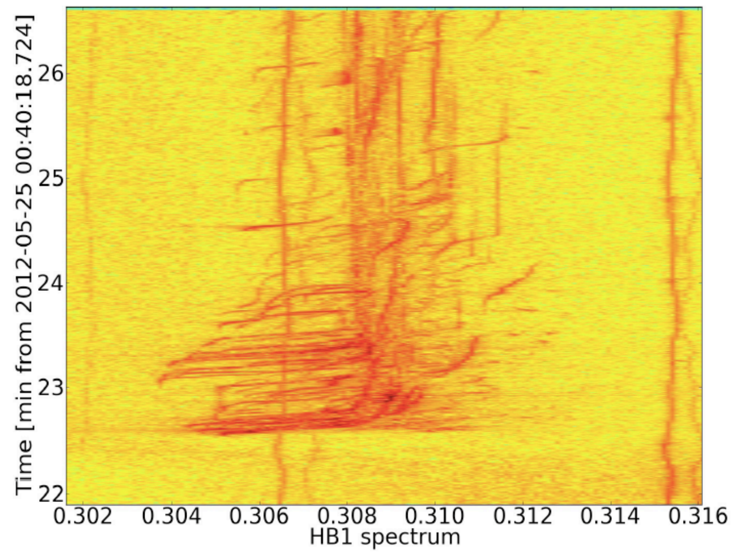
- During / at the end of the squeeze

Xavier Buffat



- In collision => "Snowflakes"



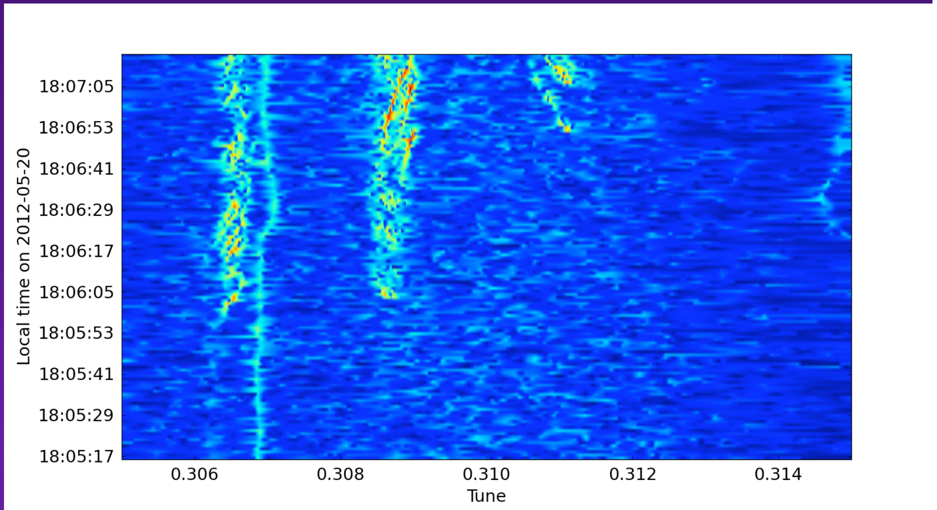


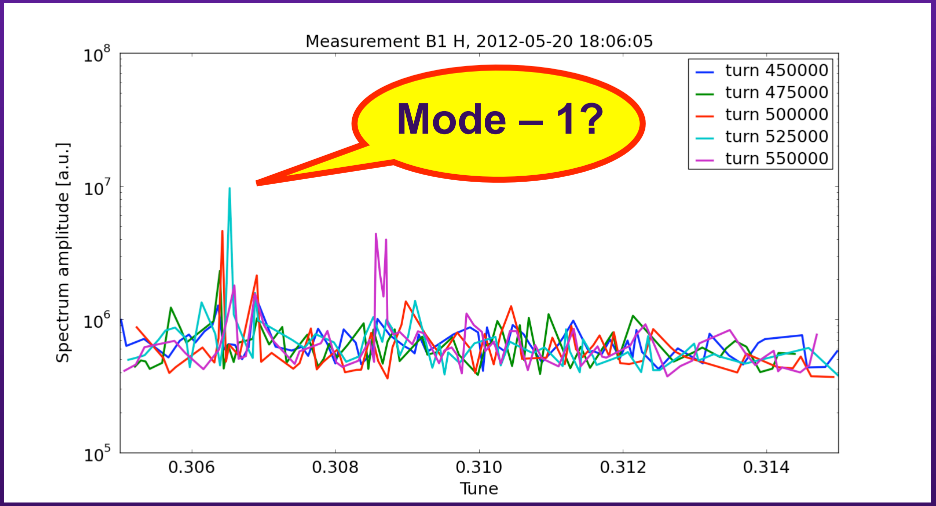
=> Always in H only (both beams) for both cases!

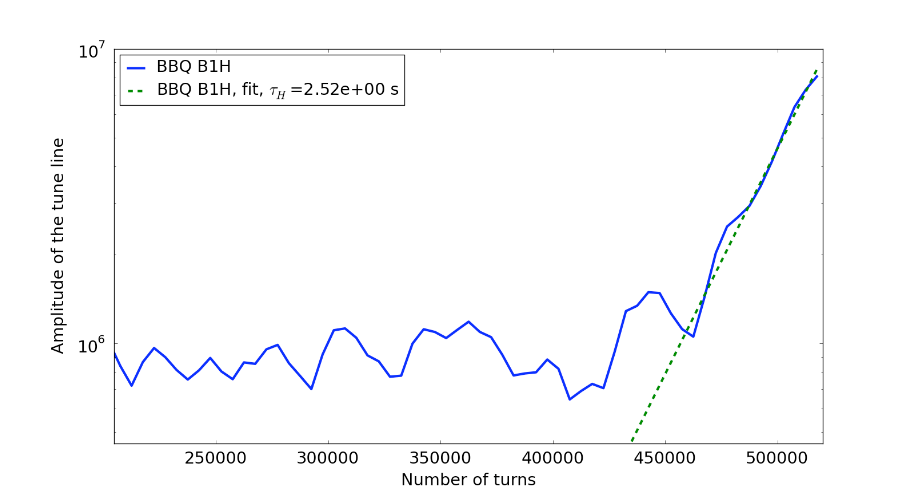
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (2/6)

Nicolas Mounet

- **During / at the end of the squeeze**
  - In some cases we can go in collision, and when we go in collision then the coherent lines disappear meaning that we restore Landau damping
  - On many fills: 2634, 2635, 2648, 2657, 2668, 2676, 2716…







2 TYPES OF INSTABILITIES RECENTLY OBSERVED (3/6)

Xavier Buffat

- **In collision => "Snowflakes"**
  - In stable beams
  - Can happen anytime
  - Concerned initially only IP8 private bunches => Explains why filling scheme was changed
  - End of trains are getting unstable
  - Always 1 bunch which starts to oscillate and then propagation through beam-beam (colliding pairs)
  - On many fills:
    - 1st one: 2488 (during leveling test)
    - But also 2505, 2605, 2634, 2635, 2644, 2646, 2662, 2691, 2692, 2710, 2716…

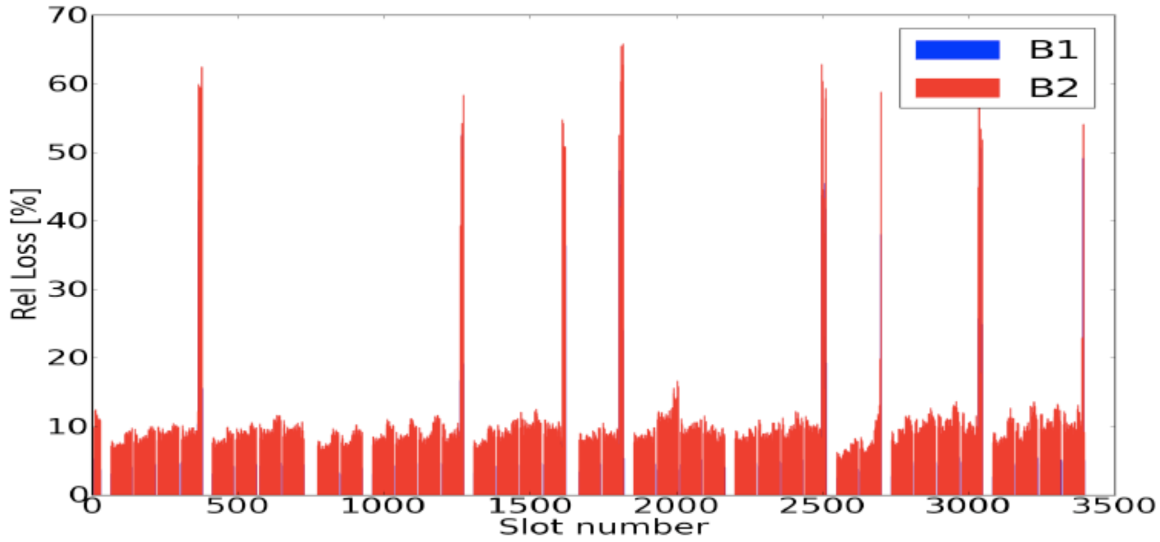
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (4/6)

Snowflake

Fill 2662,2691

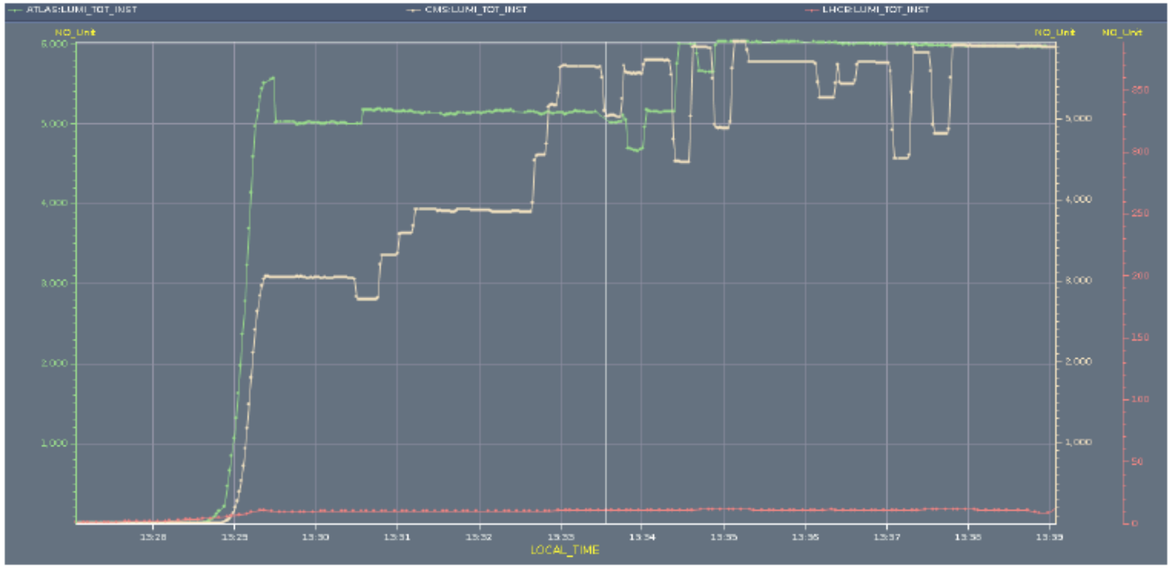
End of trains are getting unstable

Fill 2691



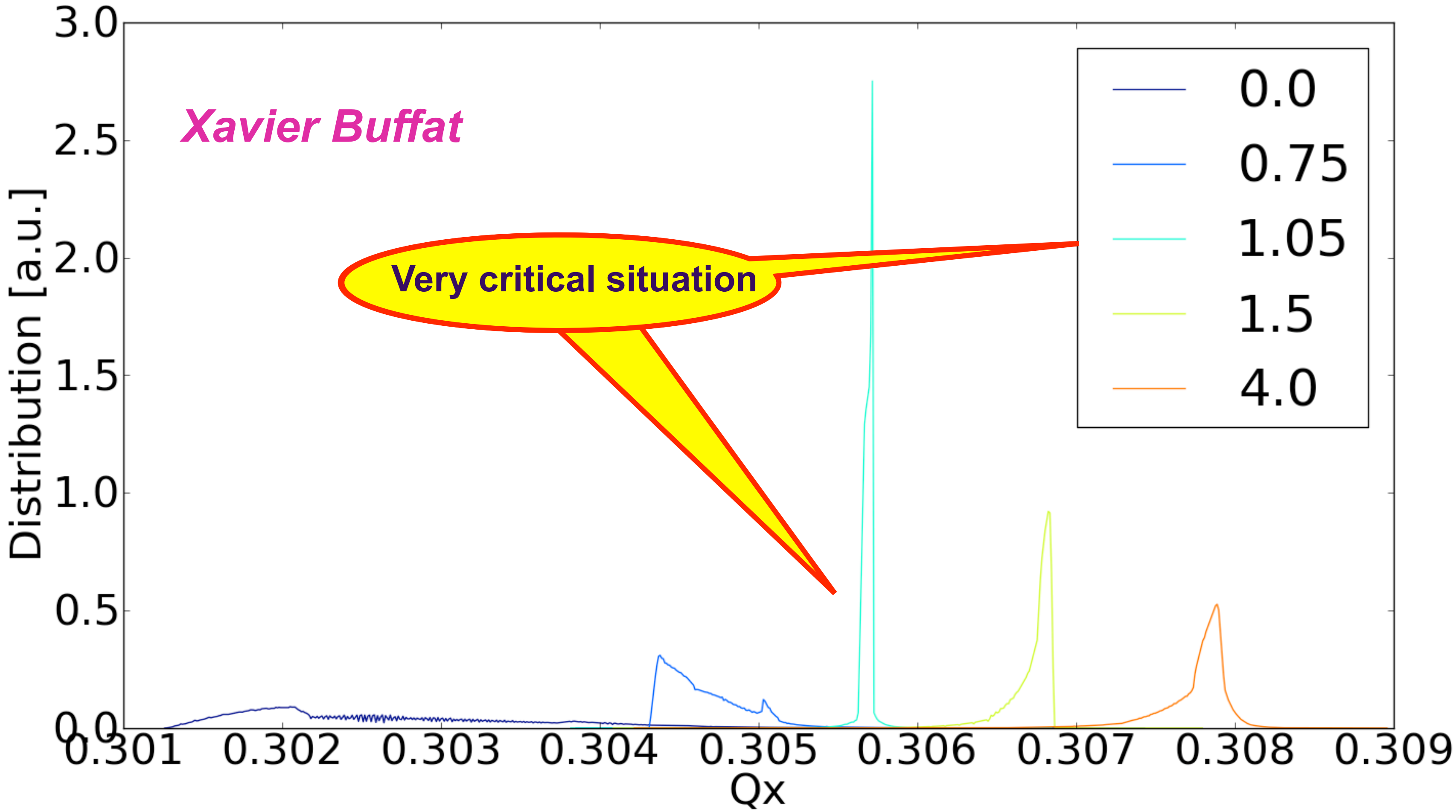
Xavier Buffat

Lumi indicates an offset → tune spread similar to IP8 private bunches



2 TYPES OF INSTABILITIES RECENTLY OBSERVED (5/6)

- **Horizontal tune distribution for an IP8 private bunch, with current octupoles**



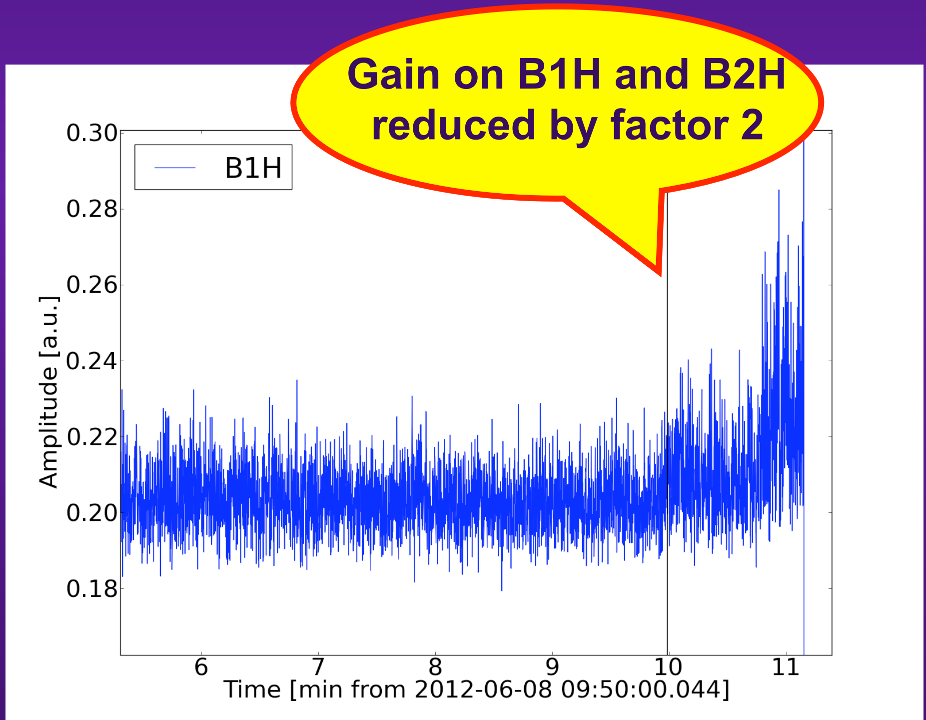
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (6/6)

- **Another instability mentioned by GianluigiA in stable beams**
  - **We were in collision with 1 beam with no ADT and 1 beam with all gain and the beam with no ADT was more stable**

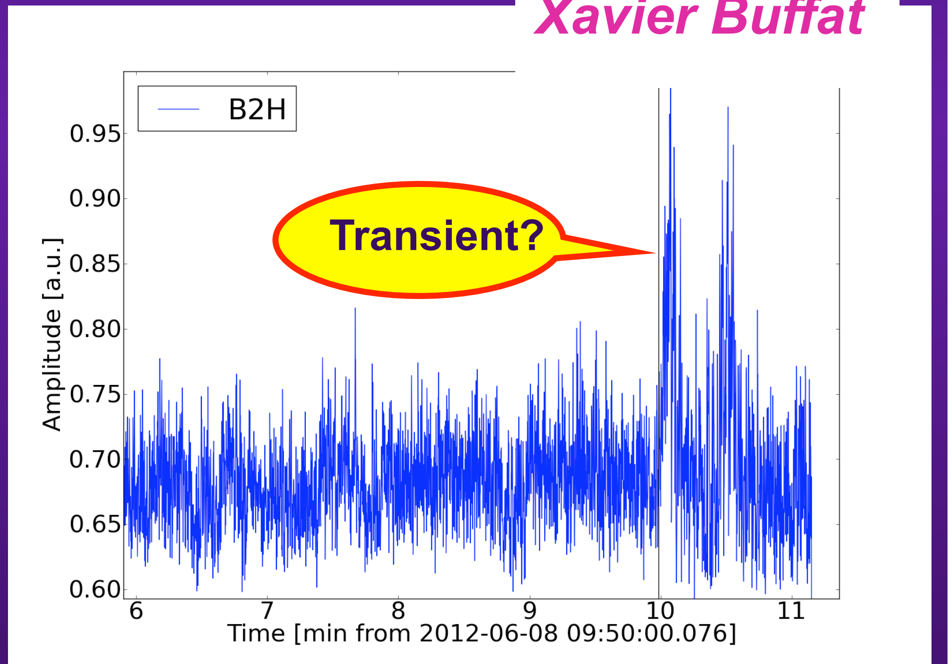
=> Could point either to a problem with the ADT (which we do not believe) or due to the fact that the chromaticities were negative and for this the ADT needs to be studied (MD requested with a single bunch first => MD block 3?)

2 EOF studies with reduced ADT gain

- **2 times dumped by something else! => Not conclusive and therefore we would like to redo it**
  - **Some activity seen but no beam loss observed when ADT gain reduced by factor 2**
  - **Beam losses seen when beams were separated**

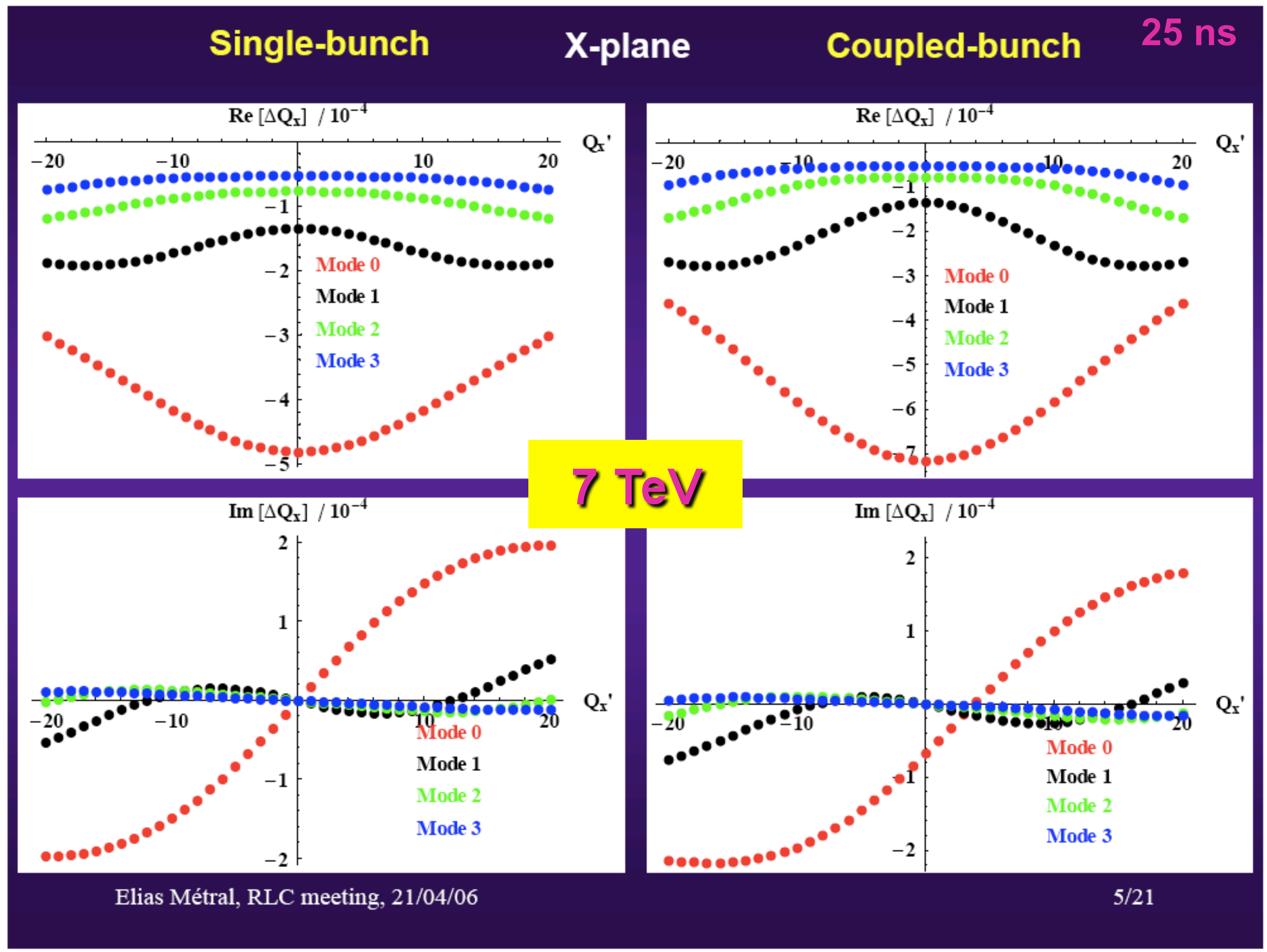


Xavier Buffat

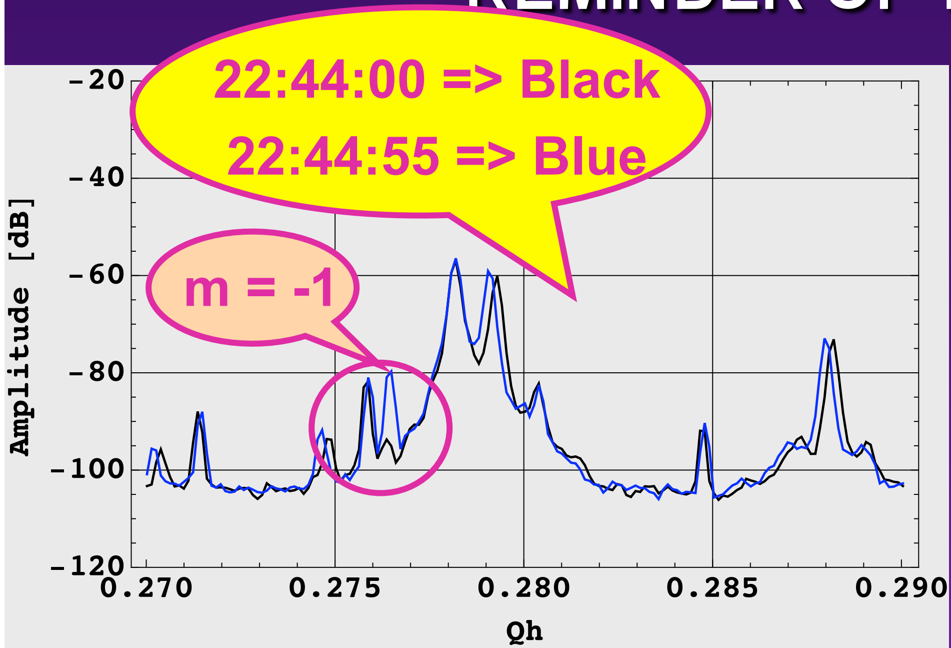


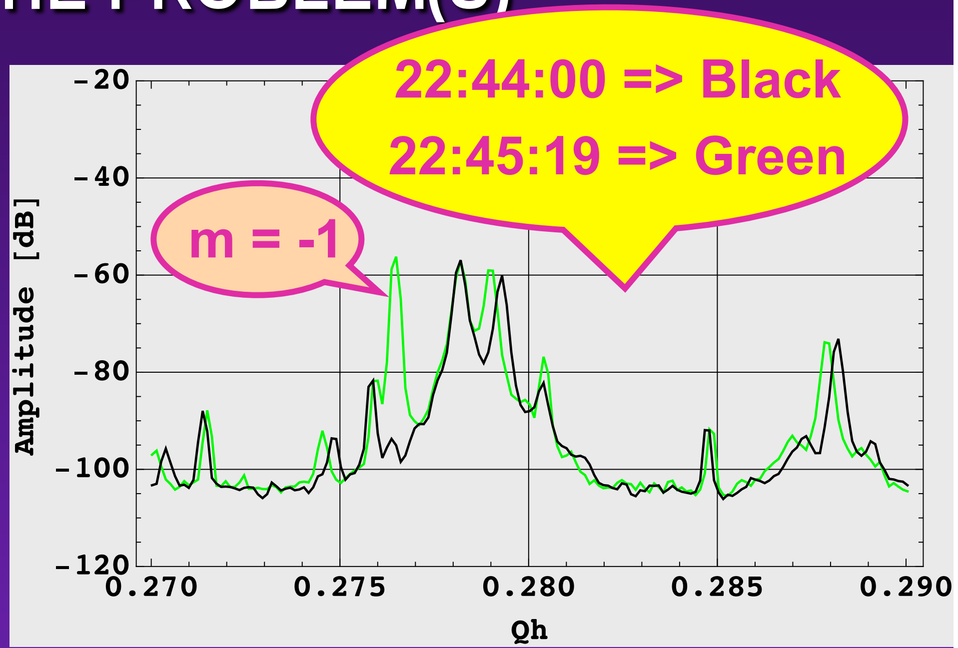
APPENDIX

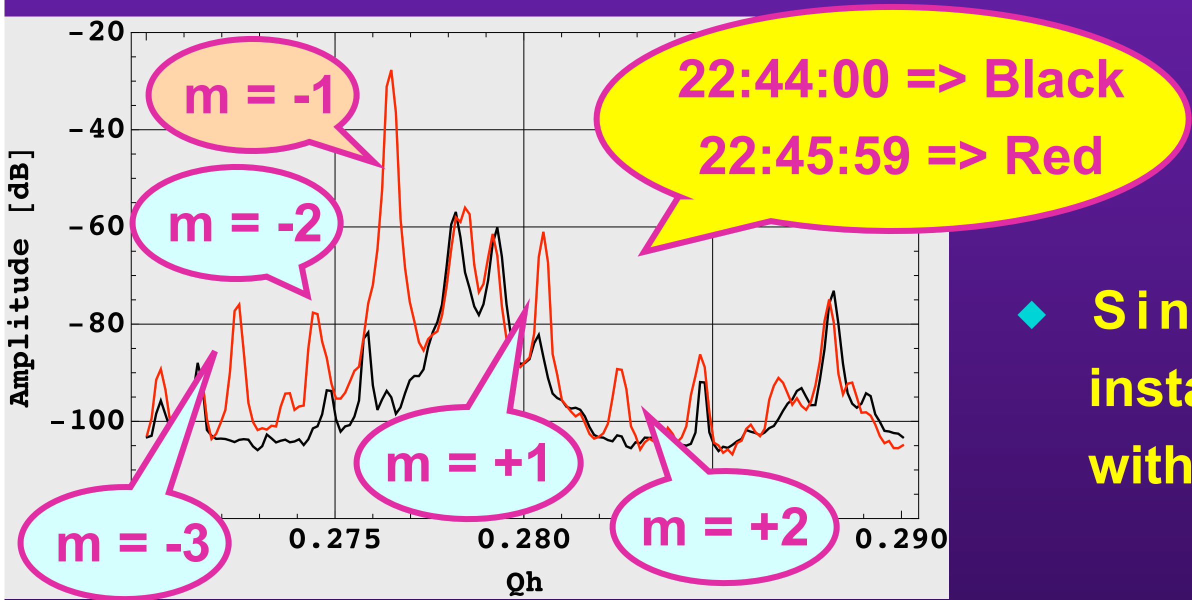
REMINDER OF THE PROBLEM(S)



REMINDER OF THE PROBLEM(S)







- **Single-bunch head-tail instability m = - 1 at 3.5 TeV without Landau octupoles**

REMINDER OF THE PROBLEM(S)

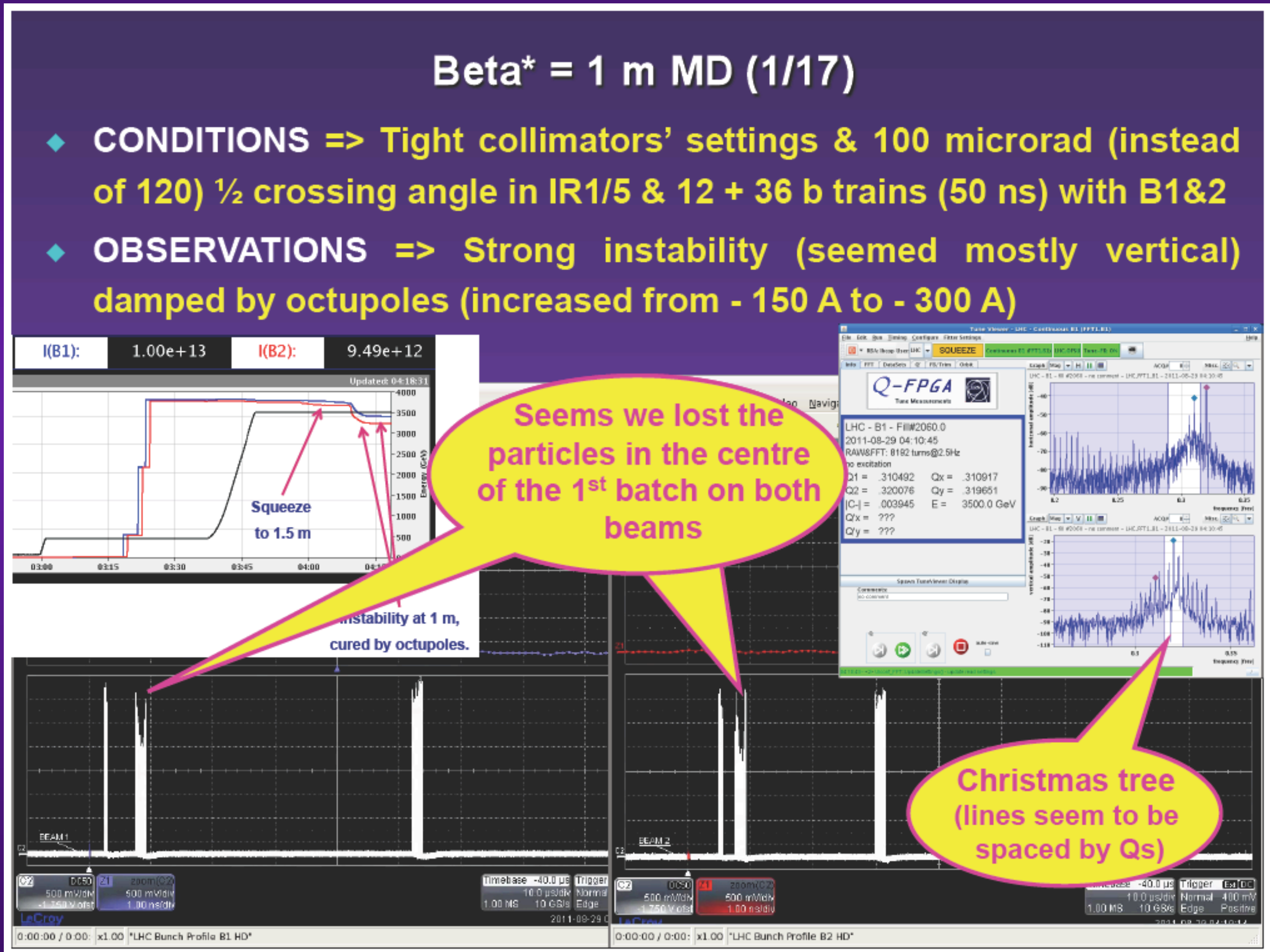
- **TCBI rise-time studies (for mode 0) with 48 bunches (12 + 36)**
  - **Landau octupoles used at 3.5 TeV to stabilize the beam**

Landau octupole current [A]	Beam 1	Beam 2
HEADTAIL predictions (Gaussian bunch)	120	100
Measurements	60	70

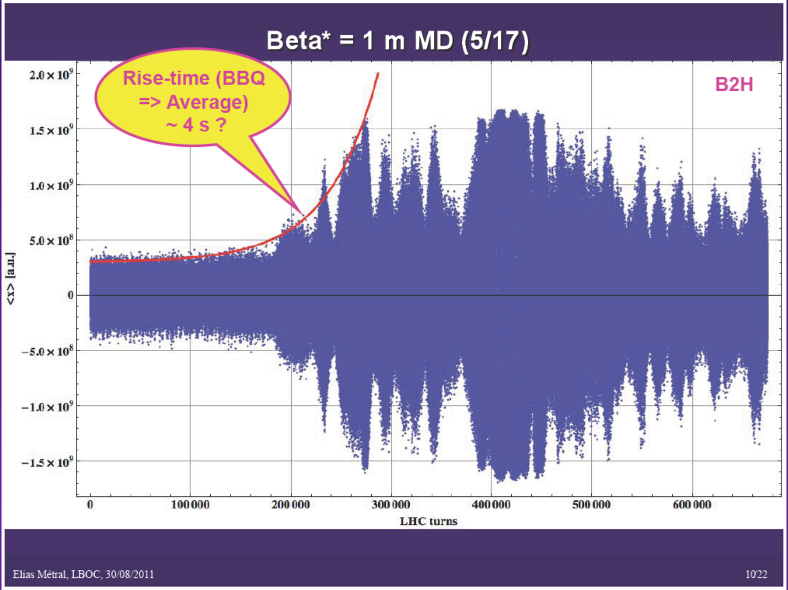
- **Simulations are more critical (but uncertainty on chromaticities)**
- **Remaining difference could maybe be explained by the Q" effect introduced by the octupoles (ongoing analyses)**

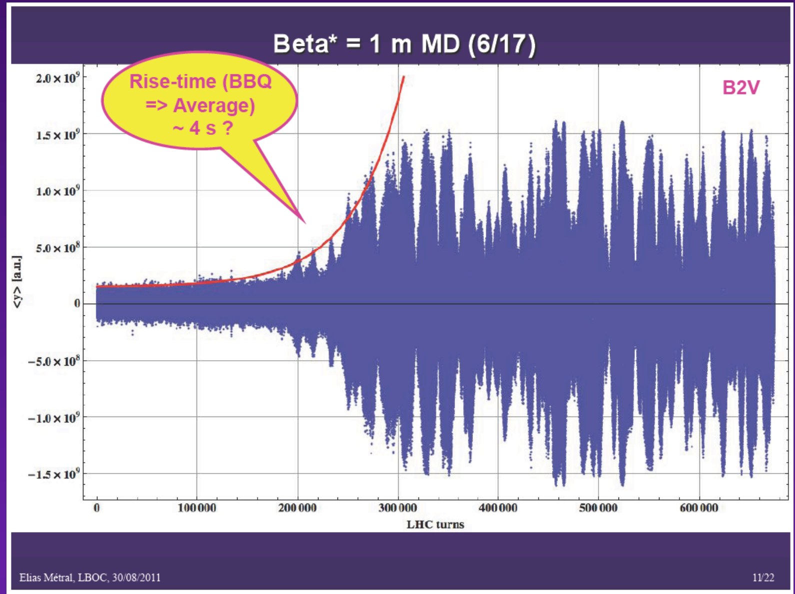
INSTABILITIES ALREADY OBSERVED IN 2011

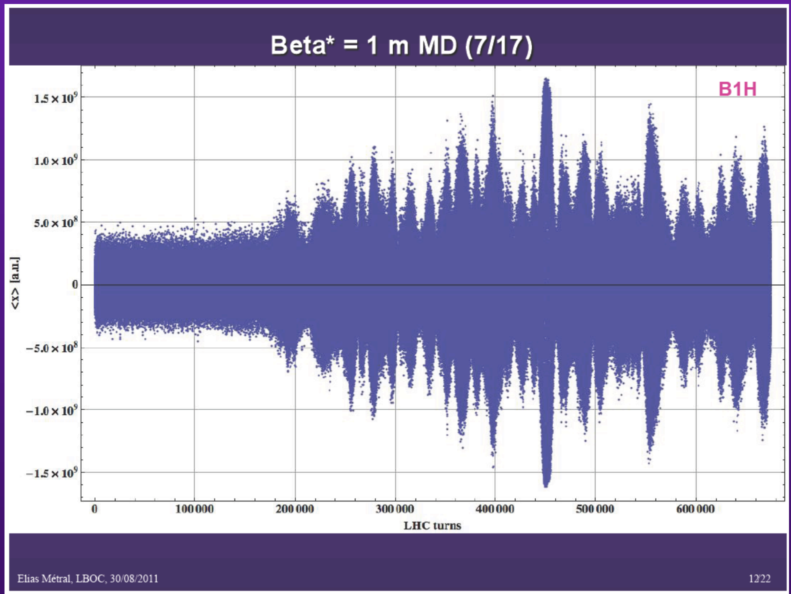
- On 29/08/11 during beta* = 1 m MD with batches of 36 b (50 ns)

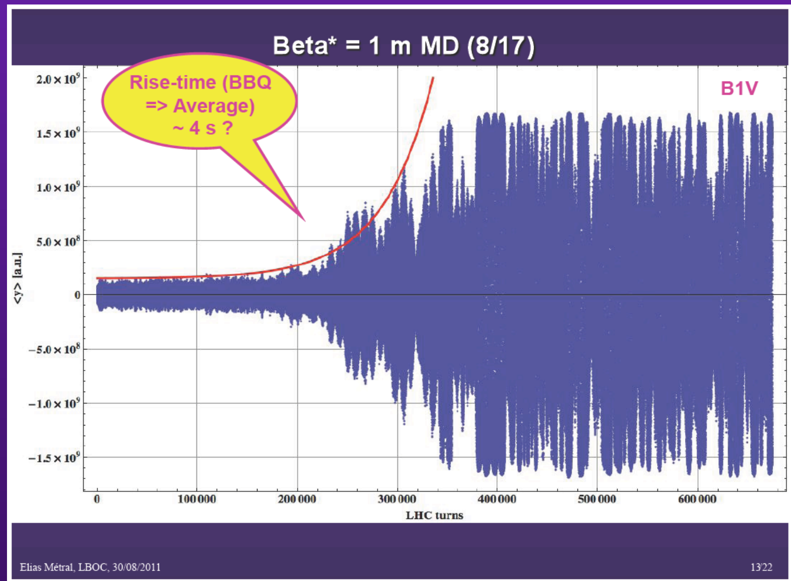


INSTABILITIES ALREADY OBSERVED IN 2011



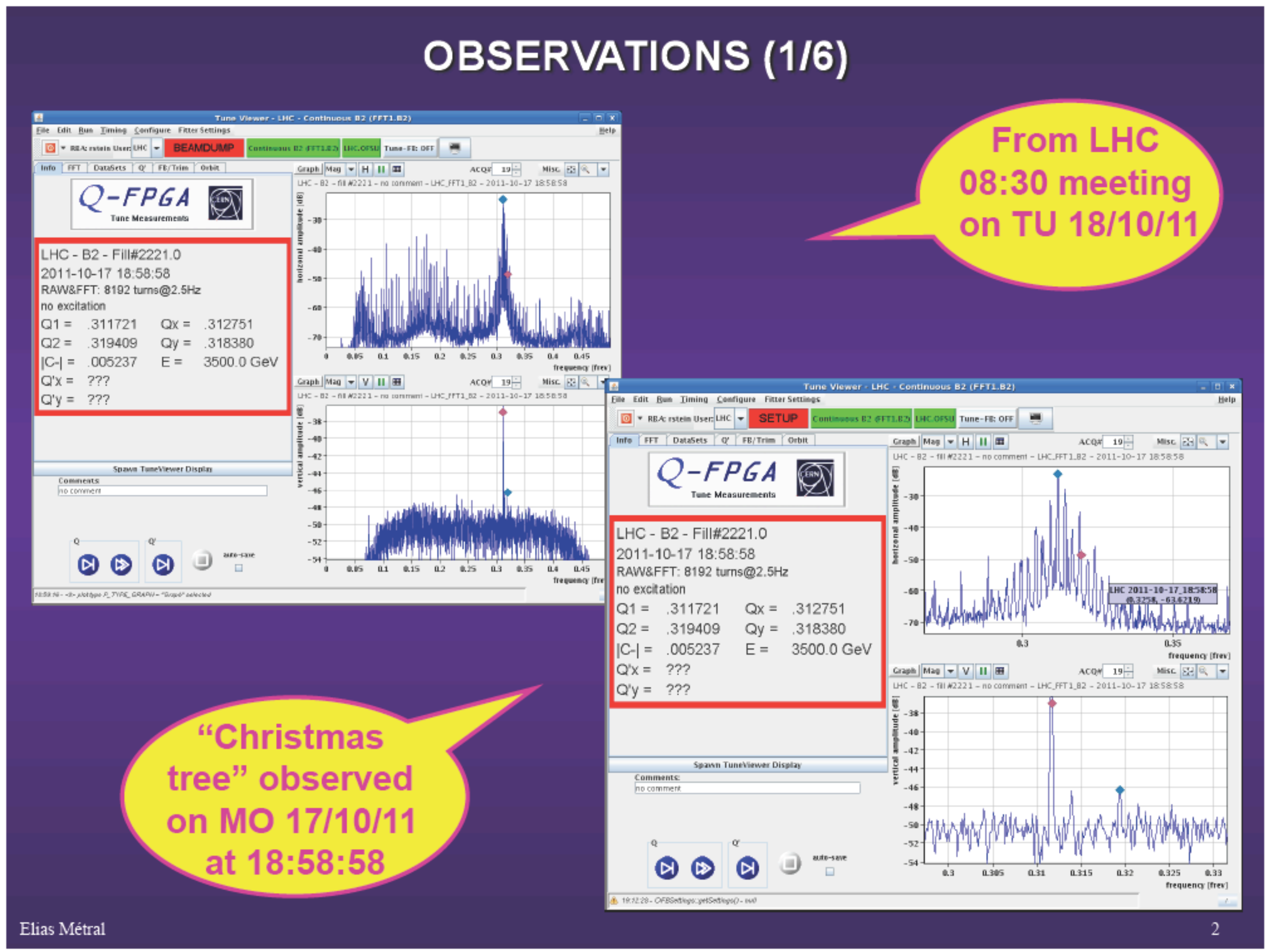






INSTABILITIES ALREADY OBSERVED IN 2011

- On 17/10/11 => "Christmas tree" at the end of the squeeze with ~ 1.45E11 p/b (i.e. higher intensity than before but not with the tight collimators' settings)



INSTABILITIES ALREADY OBSERVED AT THE BEGINNING OF 2012

- **See NicolasM's LBOC talk on 03/04/12**

	24/03/2012	30/03/2012	31/03/2012
General conditions	Single bunch, flat top (4 TeV/c)	Two bunches, β*=0.6m (4 TeV/c)	Two bunches, β*=0.6 m (4 TeV/c)
B1 intensity	1.05 10^{11} p+/bunch	1.1 10^{11} p+/bunch	0.8 10^{11} p+/bunch
B2 intensity	0.8 10^{11} p+/bunch	10^{11} p+/bunch	0.9 10^{11} p+/bunch
Bunch length	1.1 ns	1.1 ns	1.15 ns
B1 norm. ε_x / ε_y	2.8 / 2.7 µm.rad	2.1 / 1.8 µm.rad	1.8 / 0.9 µm.rad
B2 norm. ε_x / ε_y	1.5 / 1.6 µm.rad	2.2 / 2.4 µm.rad	1.3 / 1.5 µm.rad
B1 Q'_x / Q'_y	0 → 5 (?)	(-4 → 4) ? / 3	2 / 2
B2 Q'_x / Q'_y	0 → 5 (?)	3 / 3	2 / 2
Octupoles (foc.)	-232 A	-232 A	-232 A
RF voltage	12 MV	12 MV	12 MV
Q_x / Q_y	0.28 / 0.31	0.31 / 0.32	0.31 / 0.32
Coll. settings	Closer than tight settings	Tight settings	Tight settings except one TCP in IR3 for B1 (closer)
Observations	B2 H unstable (23:07)	B2 H/V unstable (16:35)	B1 H (V ?) unstable (19:21 → 19:34) B2 H/V unstable (18:10)