ANALYSIS OF RECENT BEAM INSTABILITIES

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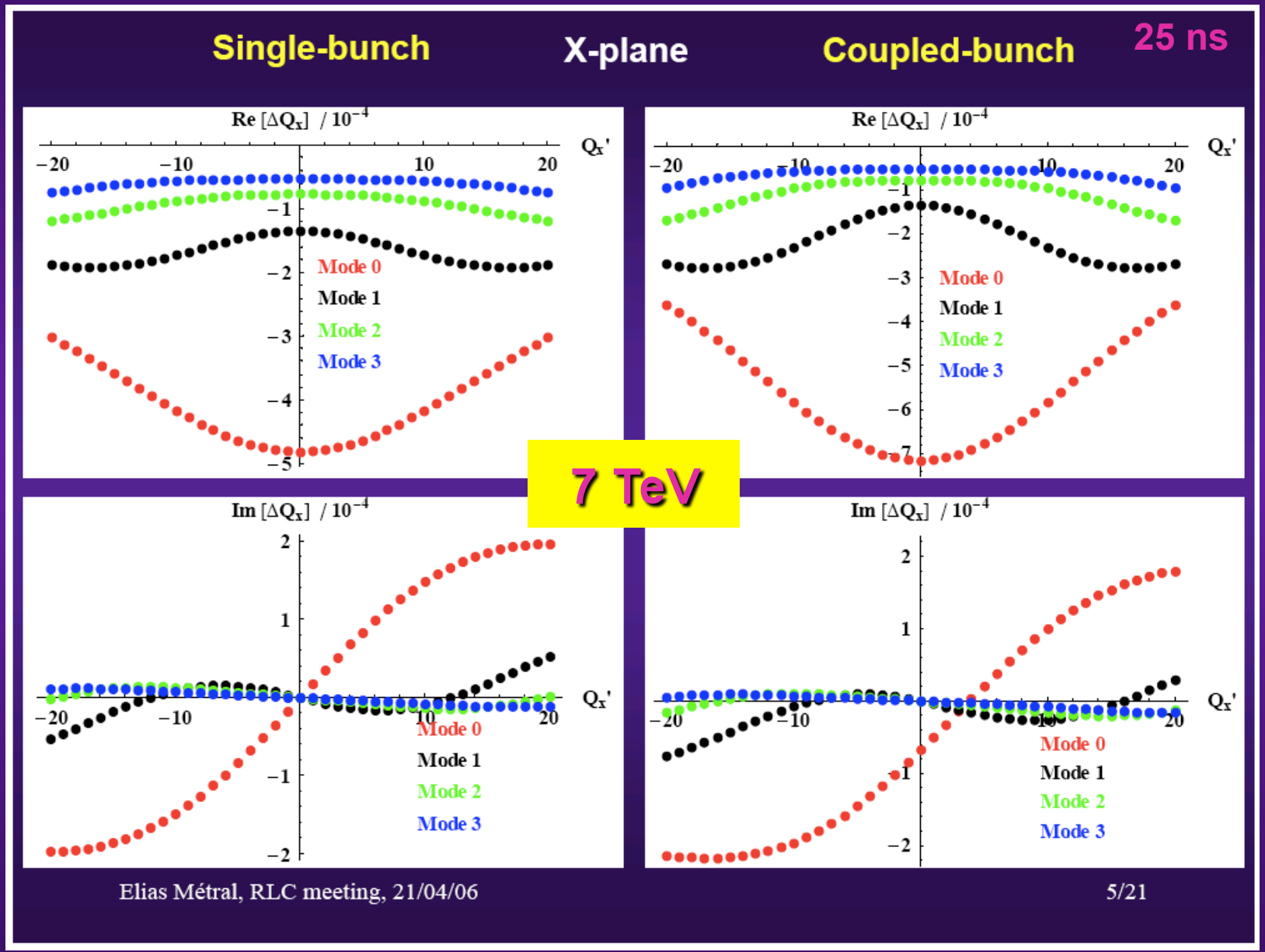
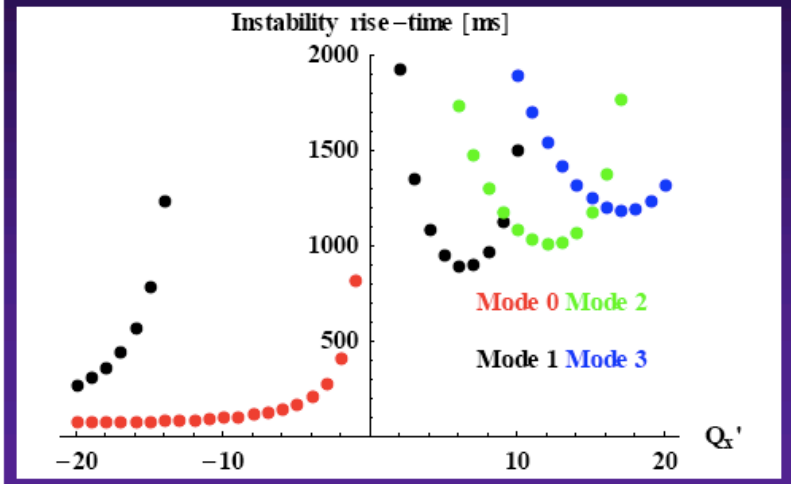
- Reminder of the problem(s)
- "Clear" (MD) studies made in the past
  - TSBI at 3.5 TeV (2010) and TCBI at 450 GeV and 3.5 TeV (2011)
- Instabilities already observed in 2011
  - On 29/08/11 during the beta* = 1 m MD (tight coll.) and on 17/10/11
- Instabilities already observed at the beginning of 2012
- 2 types of instabilities recently observed: (1) in squeeze and (2) in collision
- 2 end-of-fill studies
- Recent observations on chromaticities
- Conclusions and recommendation(s)

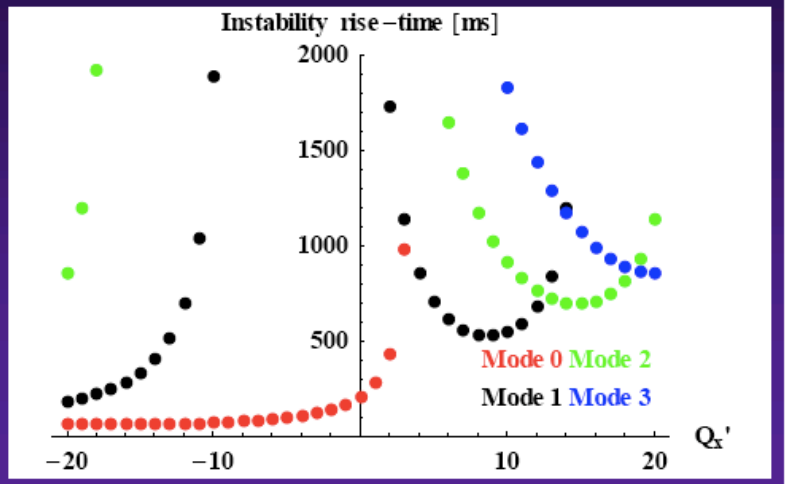
REMINDER OF THE PROBLEM(S) (1/6)



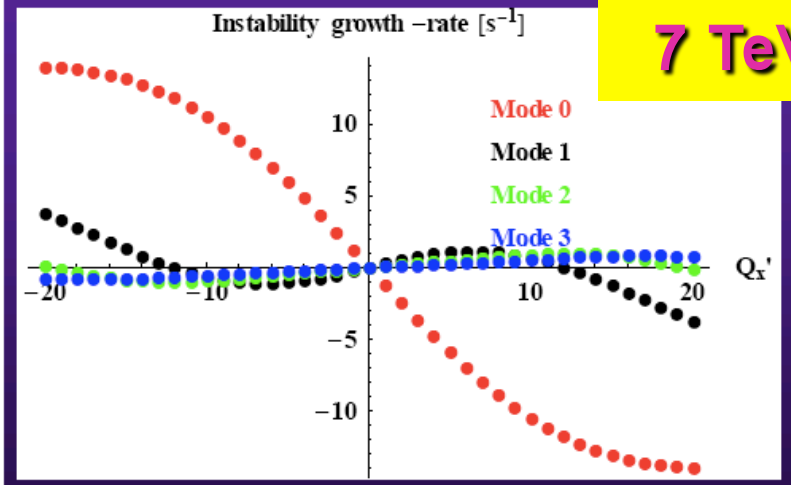
REMINDER OF THE PROBLEM(S) (2/6)

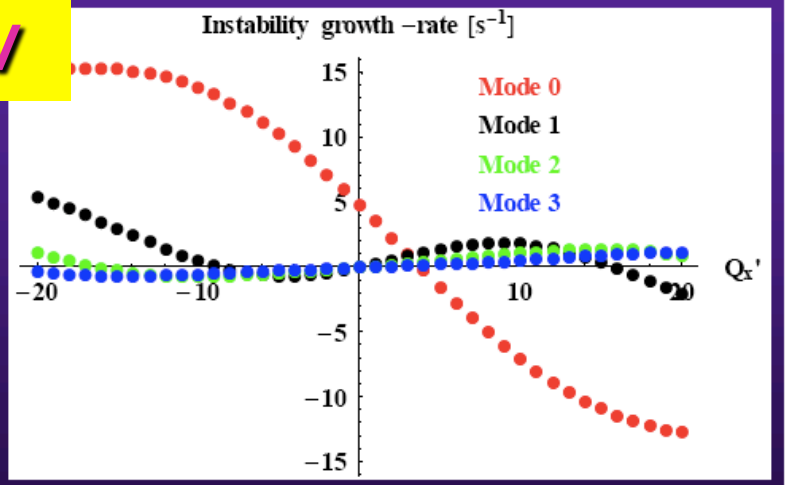
Single-bunch **X-plane** **Coupled-bunch** **25 ns**





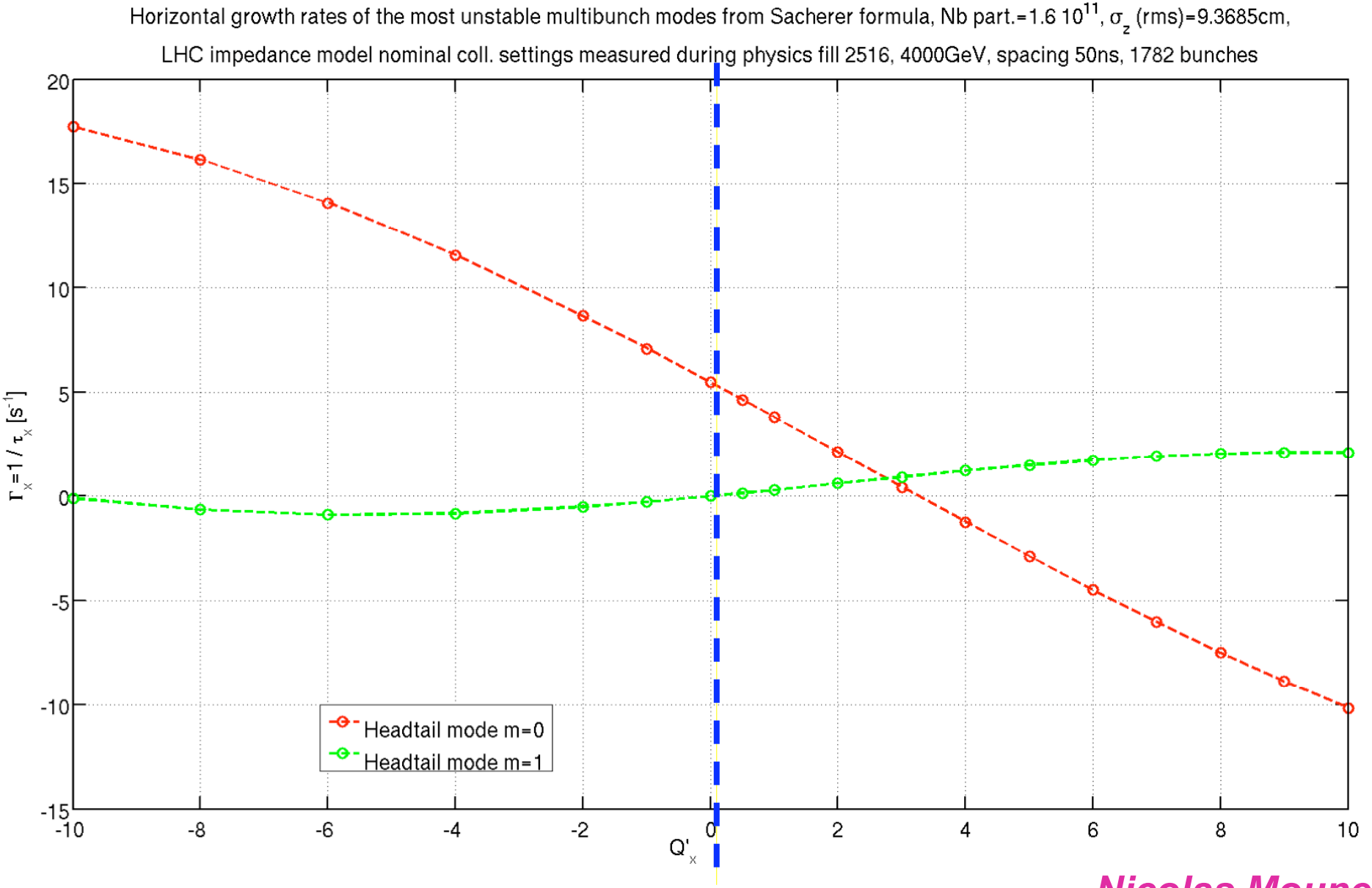
7 TeV





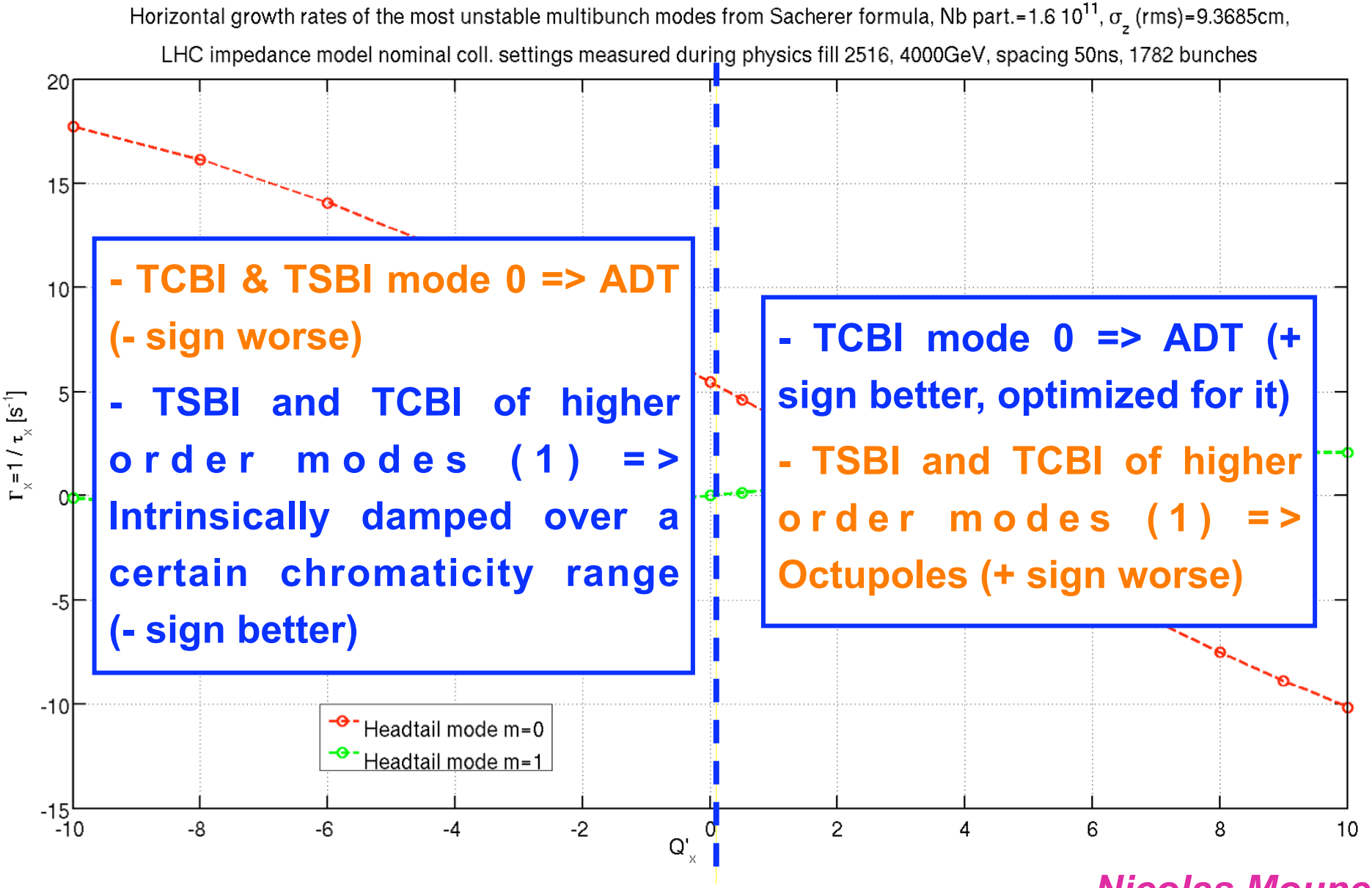
Elias Métral, RLC meeting, 21/04/06 6/21

REMINDER OF THE PROBLEM(S) (3/6)



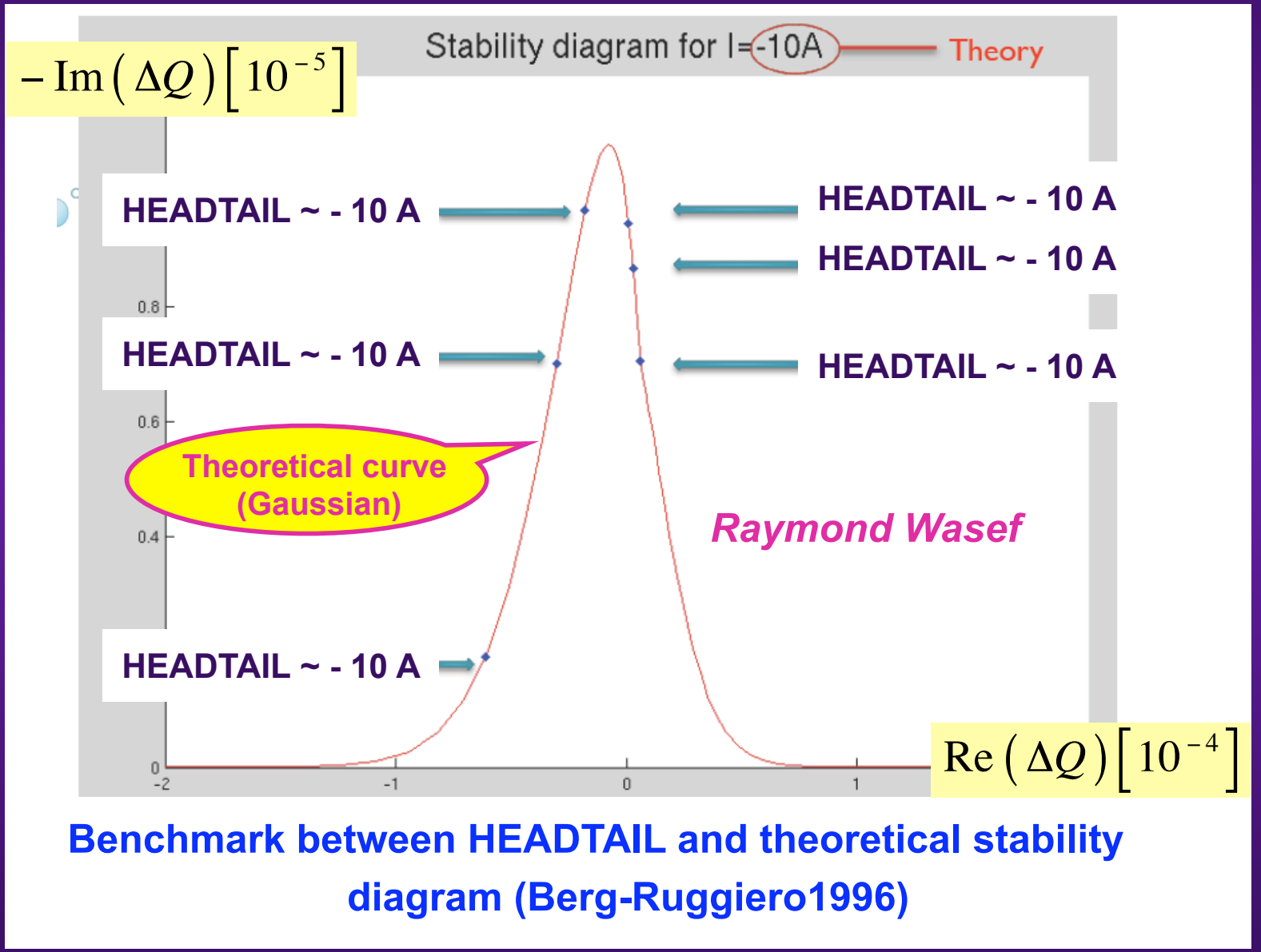
Nicolas Mounet

REMINDER OF THE PROBLEM(S) (4/6)



Nicolas Mounet

REMINDER OF THE PROBLEM(S) (5/6)



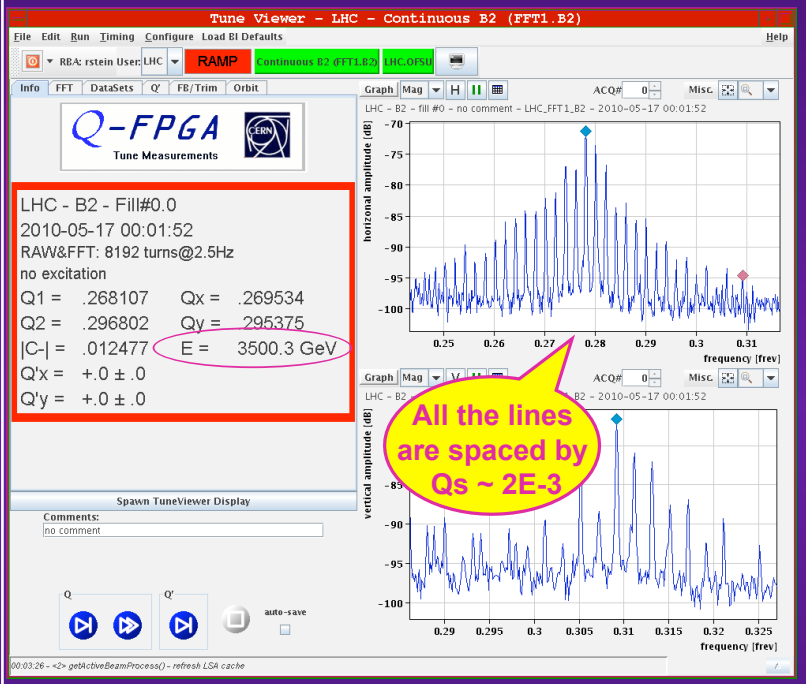
Benchmark between HEADTAIL and theoretical stability diagram (Berg-Ruggiero1996)

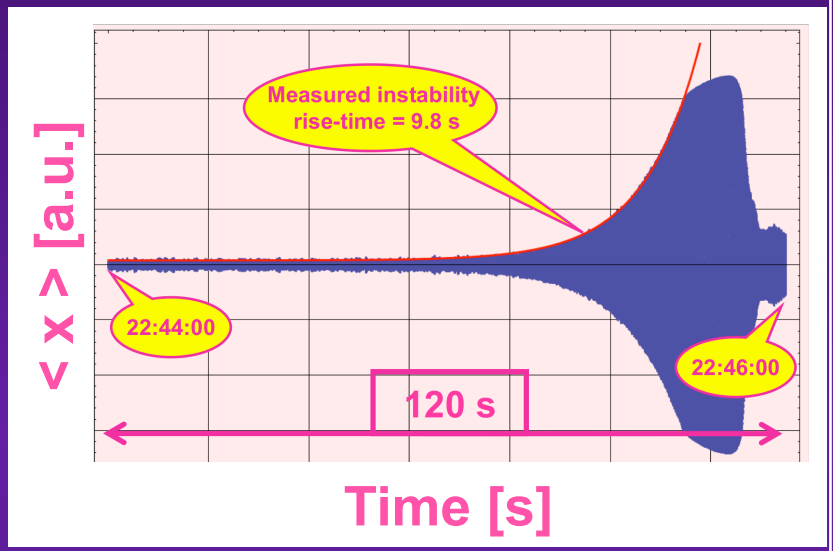
REMINDER OF THE PROBLEM(S) (6/6)

- All this is in stationary conditions, without beam-beam effects etc. and without the possible interplay between all the mechanisms
- We need first to disentangle between 1-beam effects and 2-beam effects => MD soon!
- It is very important to understand what happens in depth!
  - The octupole current used (~ 500 A) is very close to the limit (550 A) and therefore if this problem is not understood the LHC performance will be limited in the future. Reminder: ~ 5-10 less current predicted!
  - If high value confirmed in MD, going to negative chromaticities COULD be a potential solution for this issue, BUT in this case the ADT needs to be optimized => Current studies ongoing by AlexeyB and NicolasM in contact with DanielV and WolfgangH
  - If high value not confirmed => Hopefully not this pb anymore…

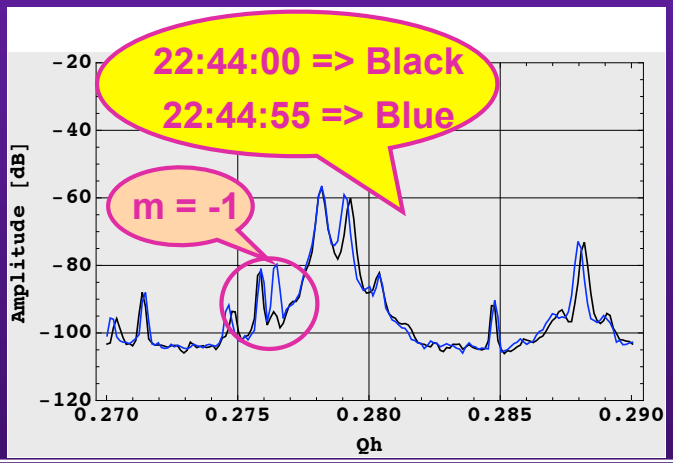
“CLEAR” (MD) STUDIES MADE IN THE PAST (1/2)

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



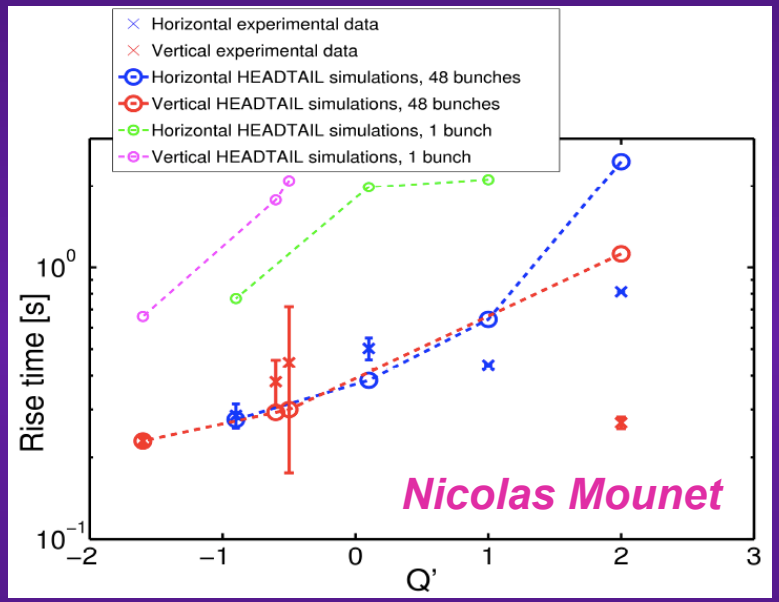


- **Rise-time and Landau octupoles’ current for stability (between 10 and 20 A) within factor ~ 2 with predictions**



“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**



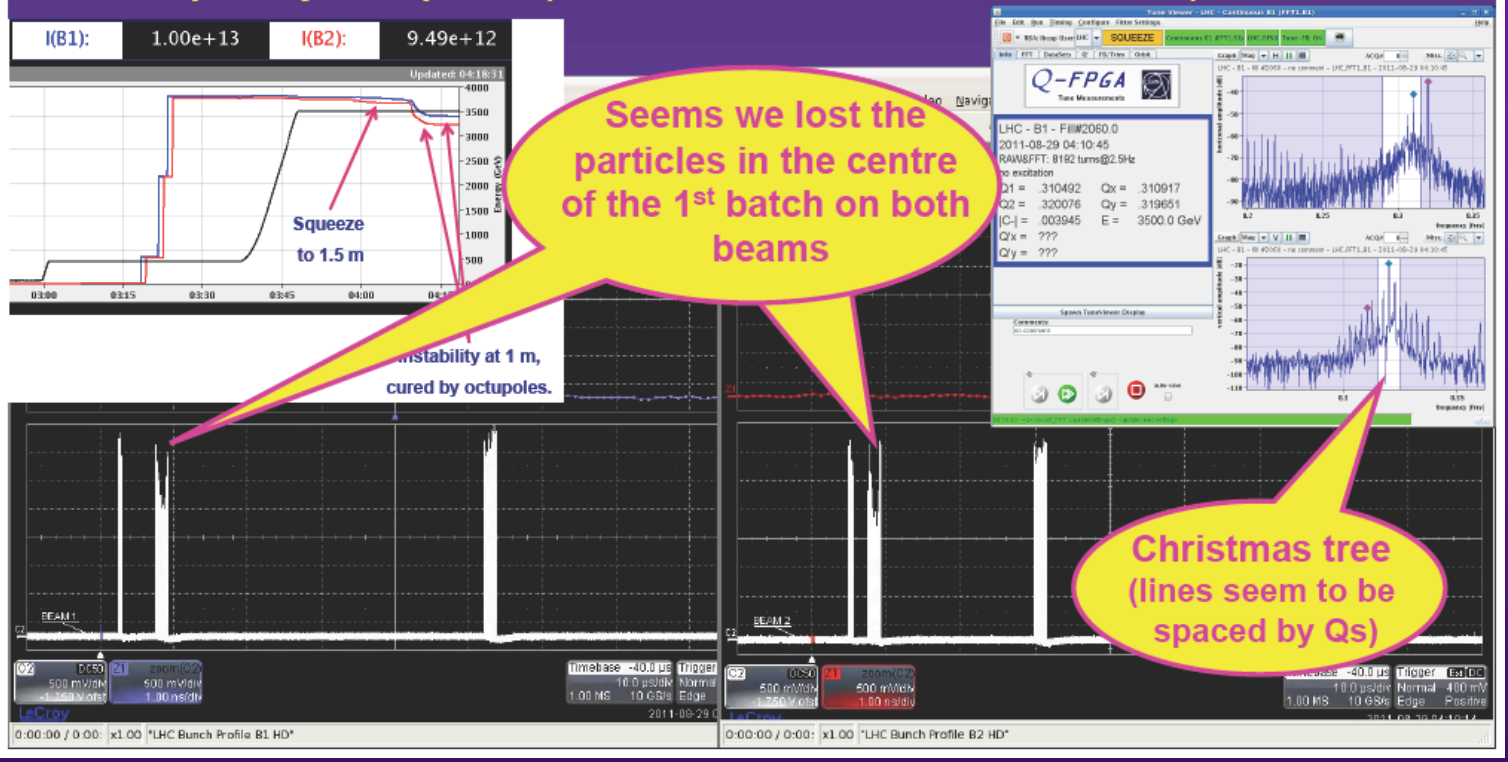
  - **~ 2-3 faster rise-times observed at 3.5 TeV (but uncertainty on chromaticities)**
  - **Landau octupoles’ current for stability at 3.5 TeV within factor ~ 2 with predictions (less than predicted => Studies with Q” ongoing)**

INSTABILITIES ALREADY OBSERVED IN 2011 (1/3)

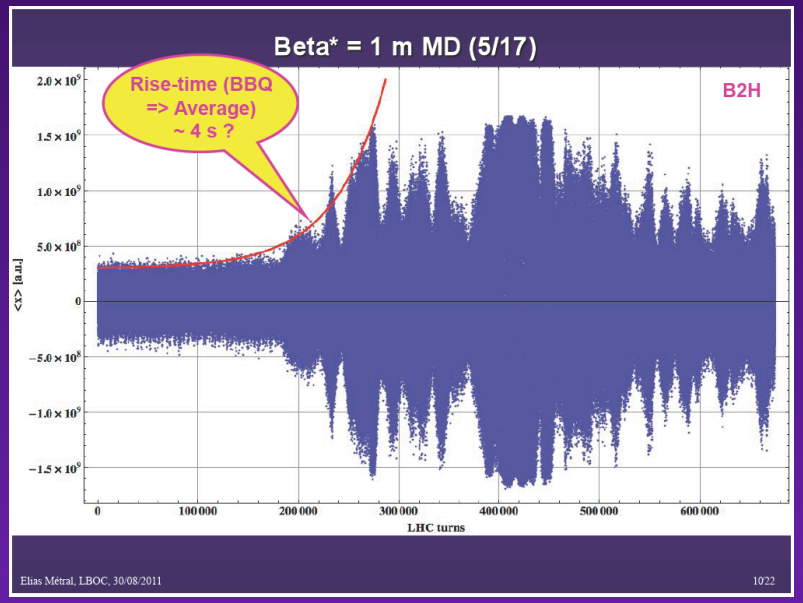
- **On 29/08/11 during beta* = 1 m MD with batches of 36 b (50 ns)**

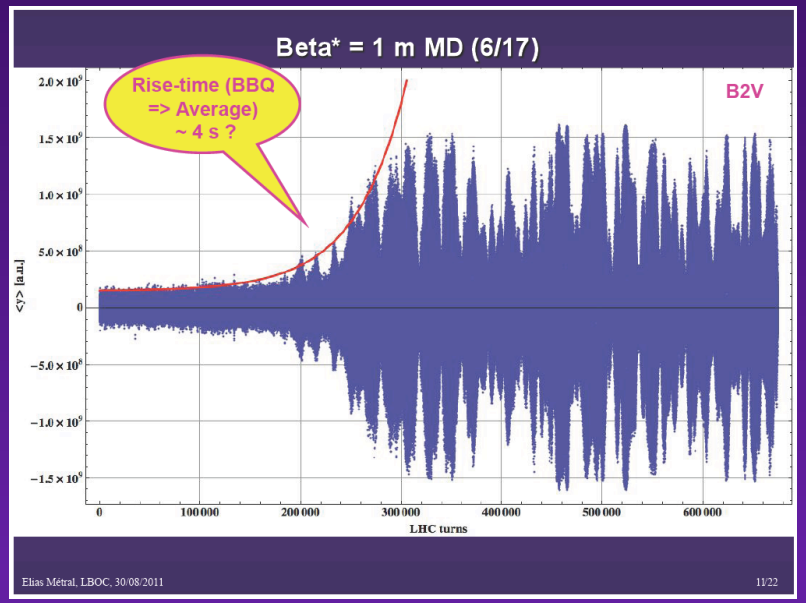
Beta* = 1 m MD (1/17)

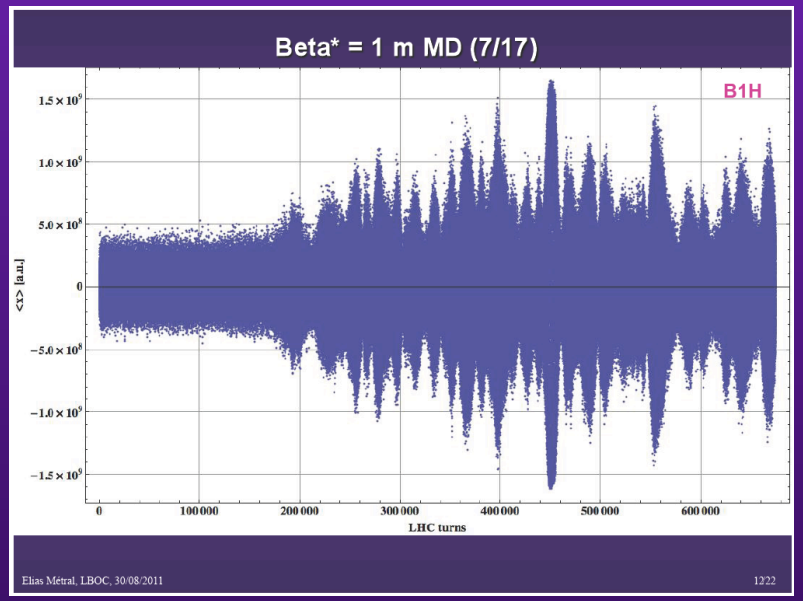
- CONDITIONS => Tight collimators' settings & 100 microrad (instead of 120) ½ crossing angle in IR1/5 & 12 + 36 b trains (50 ns) with B1&2
- OBSERVATIONS => Strong instability (seemed mostly vertical) damped by octupoles (increased from - 150 A to - 300 A)

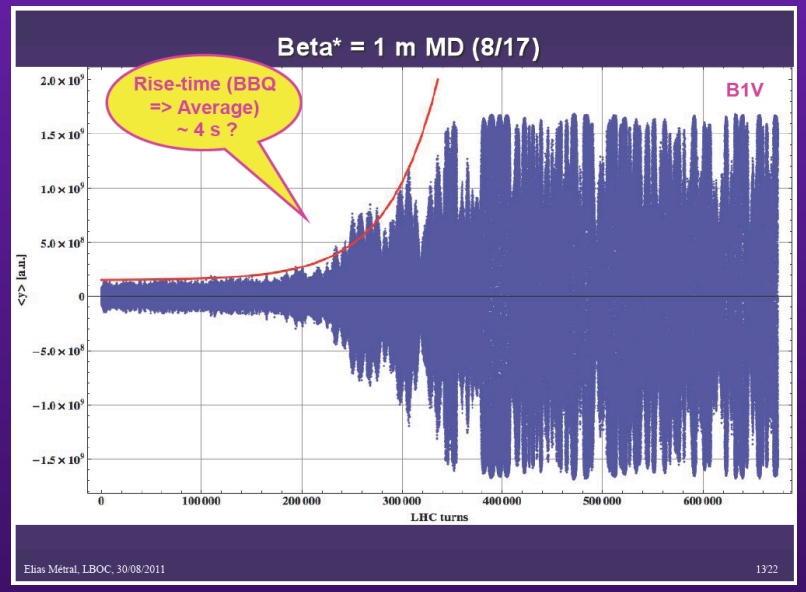


INSTABILITIES ALREADY OBSERVED IN 2011 (2/3)



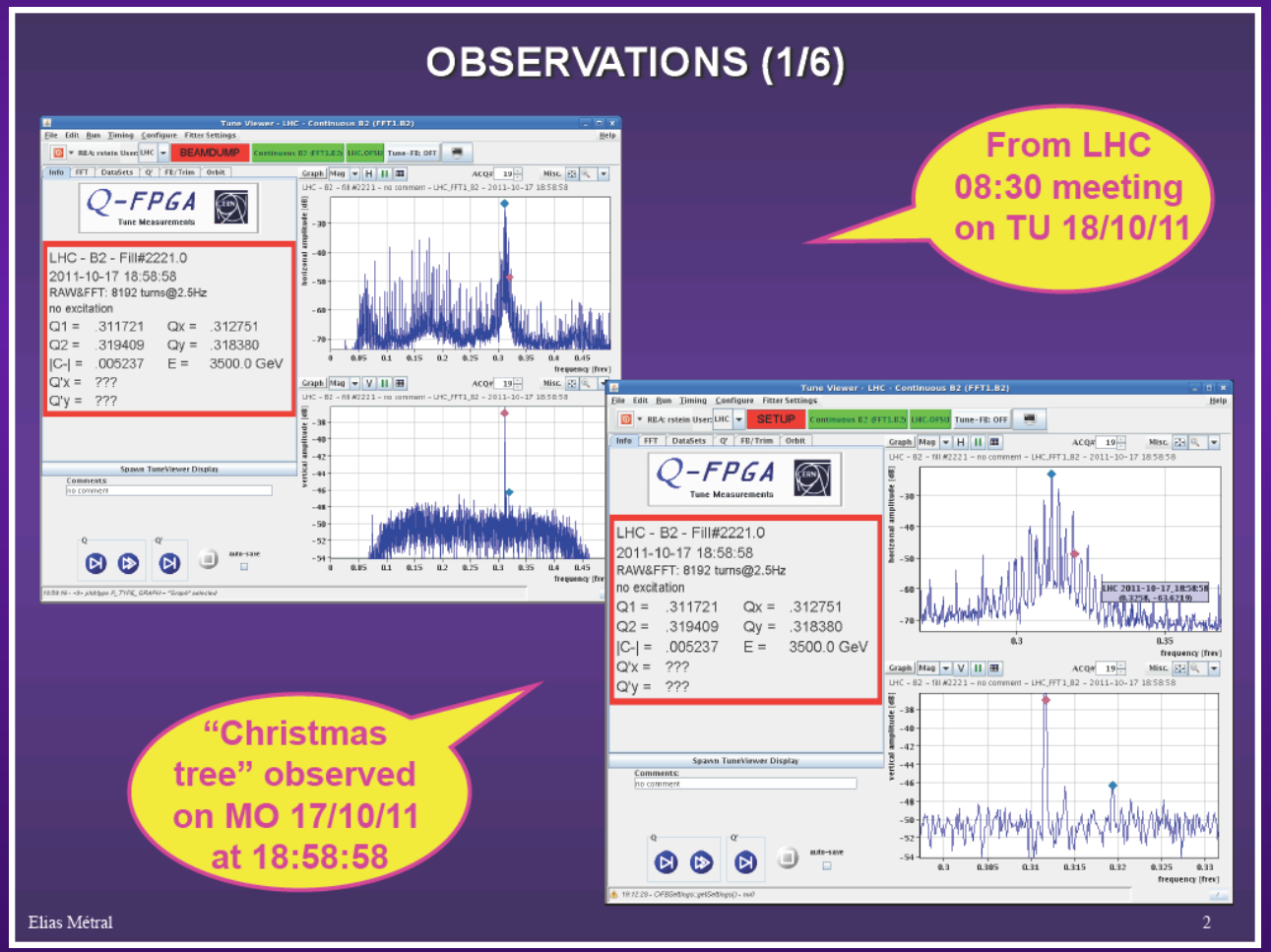






INSTABILITIES ALREADY OBSERVED IN 2011 (3/3)

- 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

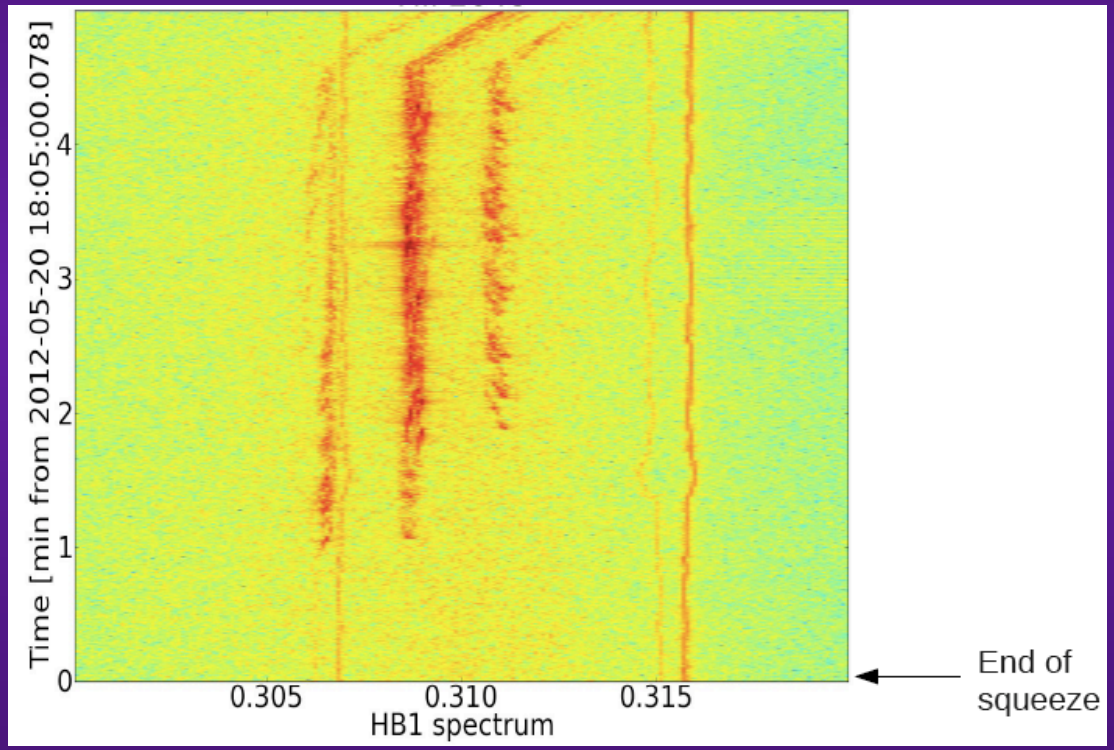
- **See NicolasM's LBOC talk on 03/04/12**

	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)

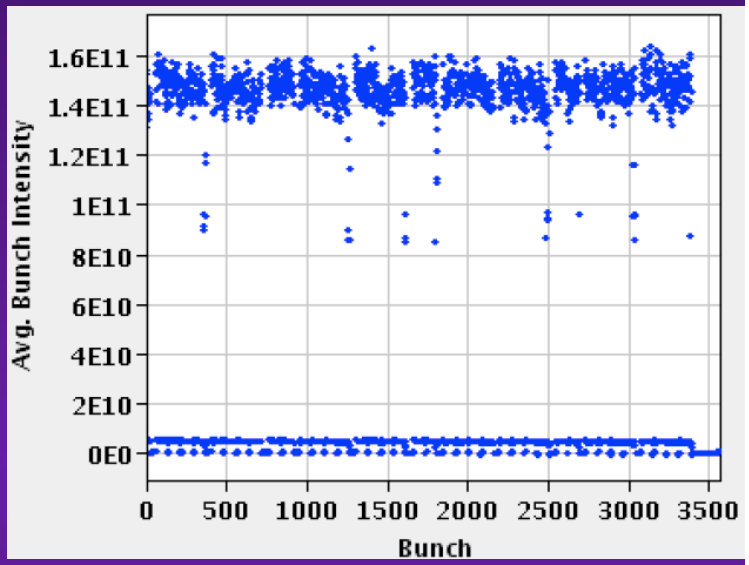
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (1/6)

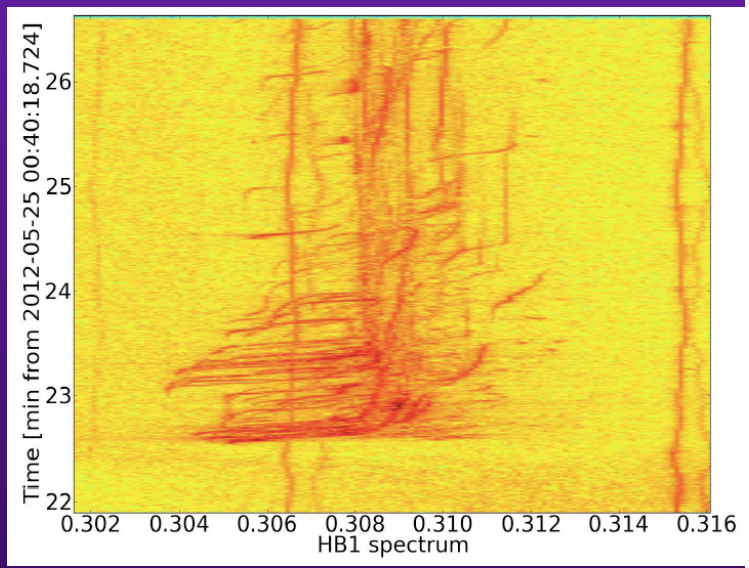
- During / at the end of the squeeze

Xavier Buffat



- In collision => "Snowflakes"



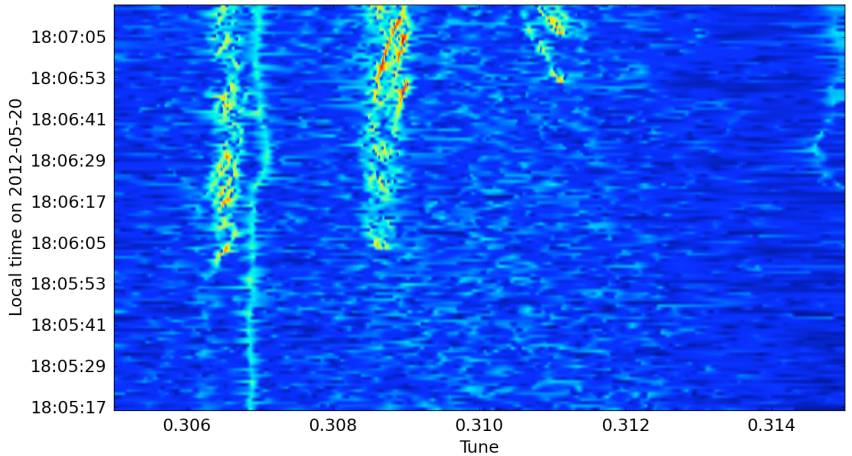


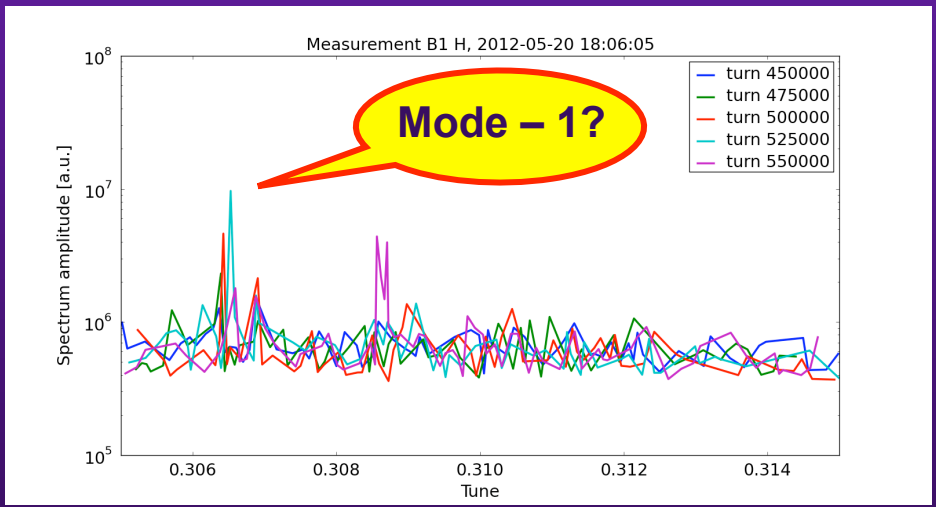
=> Always in H only (both beams) for both cases!

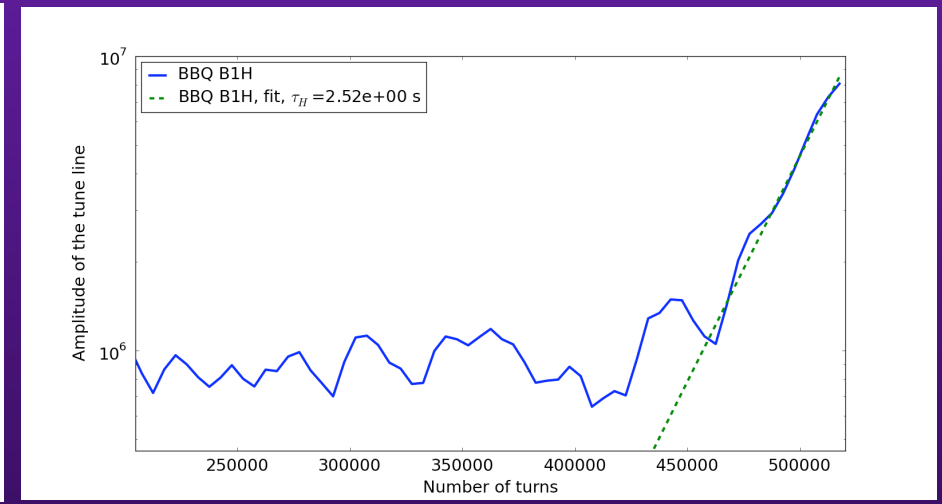
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (2/6)

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 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…

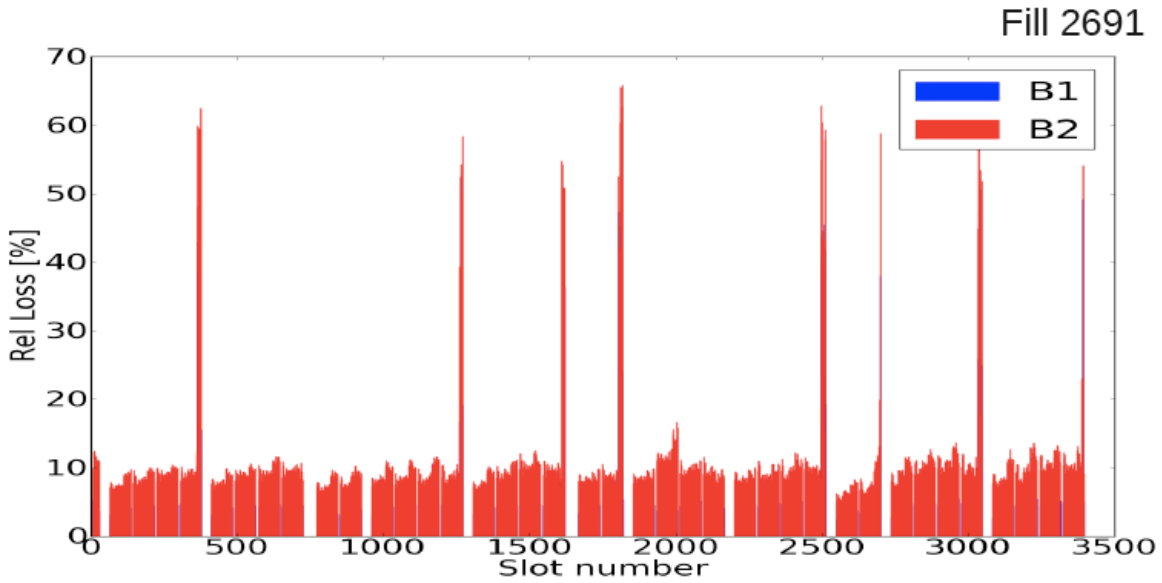
2 TYPES OF INSTABILITIES RECENTLY OBSERVED (4/6)

Snowflake

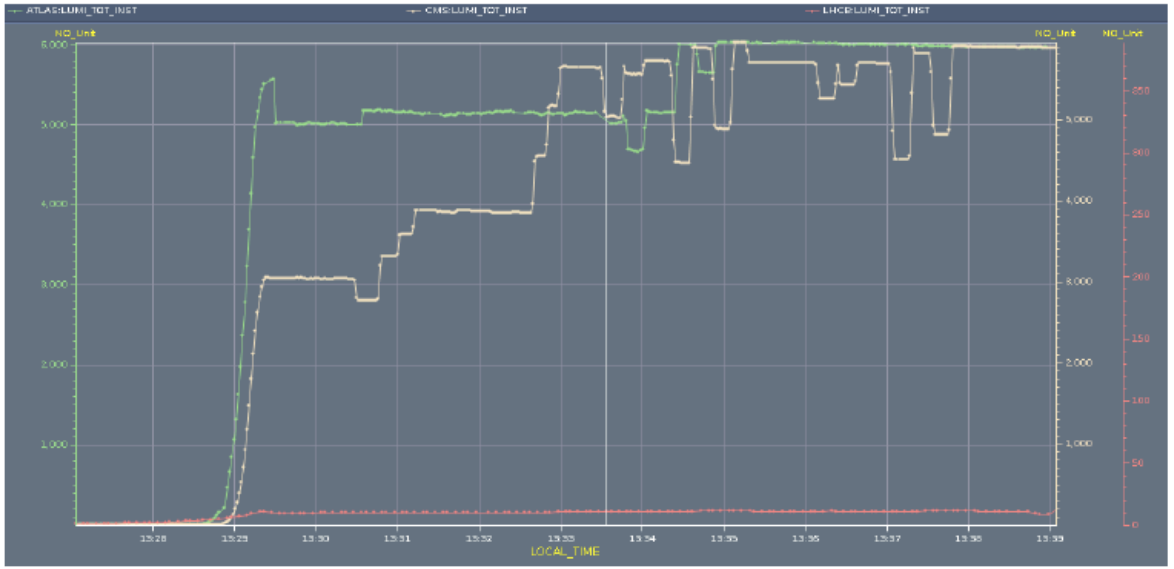
Fill 2662,2691

End of trains are getting unstable

Xavier Buffat

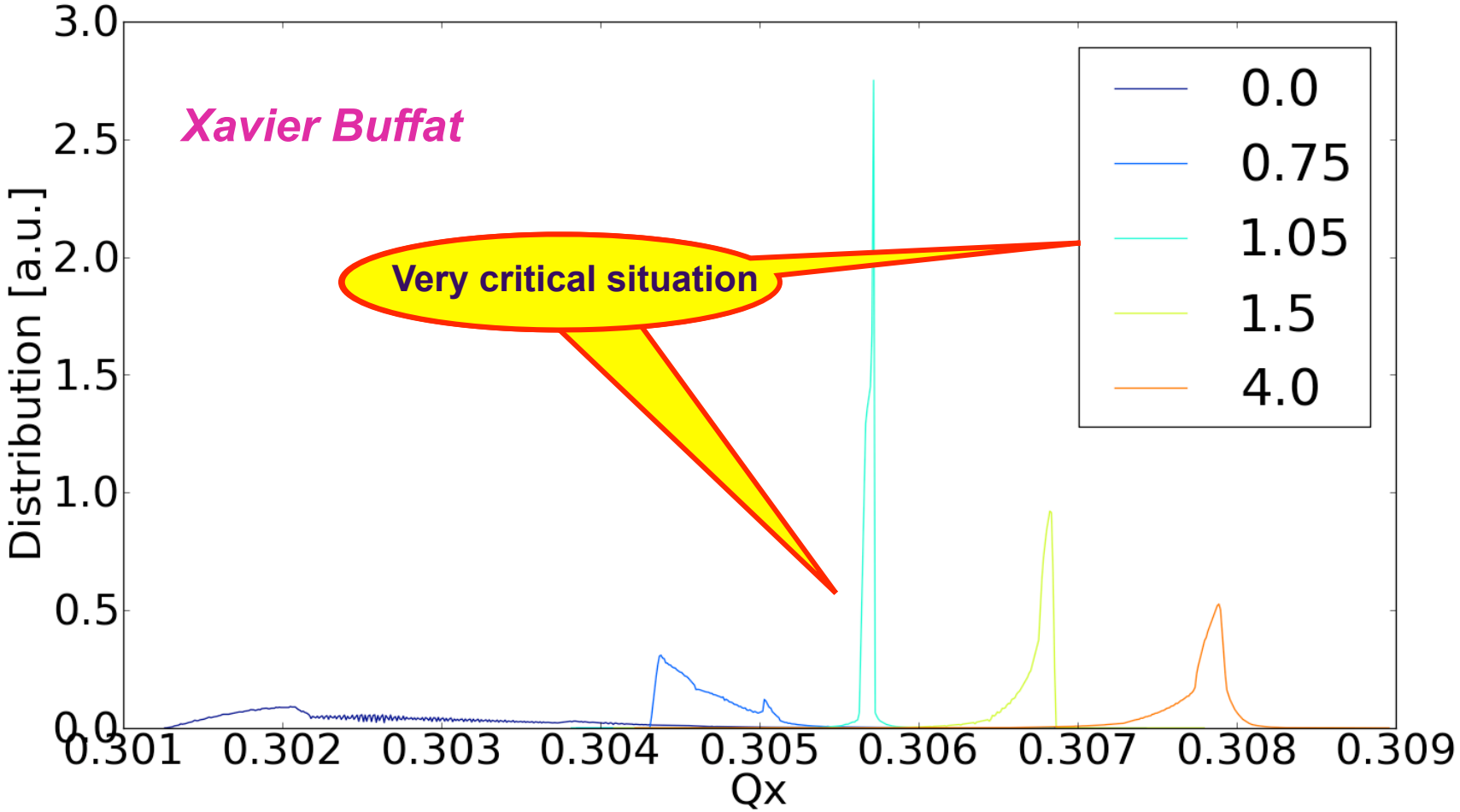


Lumi indicates an offset → tune spread similar to IP8 private bunches



2 TYPES OF INSTABILITIES RECENTLY OBSERVED (5/6)

- **Horizontal tune distribution for an IP8 private bunche, with 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**

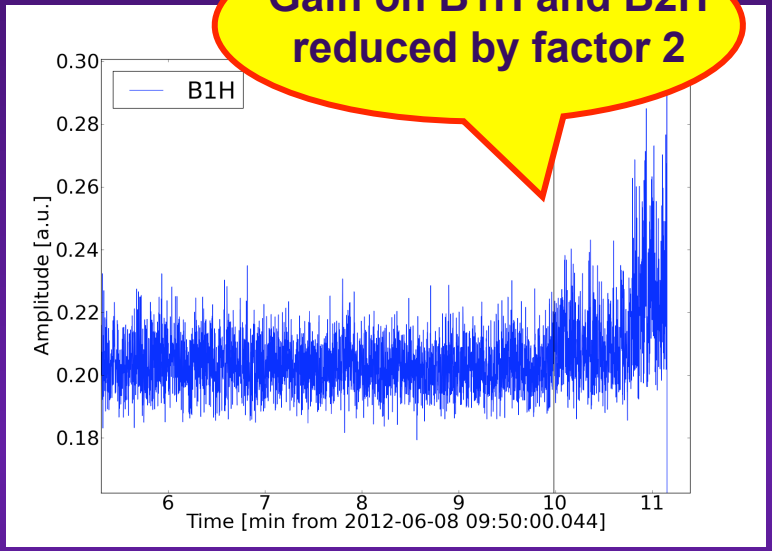
=> Could point either to a problem with the ADT (which we do not believe) or due to the fact that the chromaticities were negative and for this the ADT is maybe not optimized (ongoing studies)

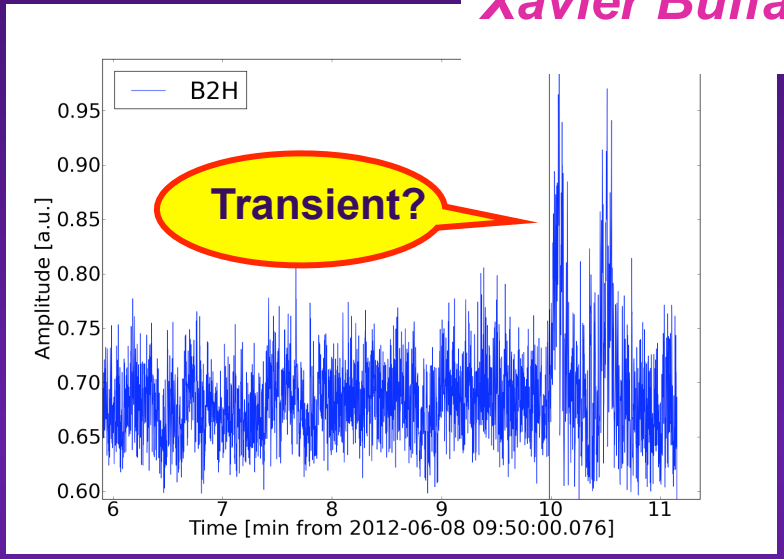
2 EOF studies

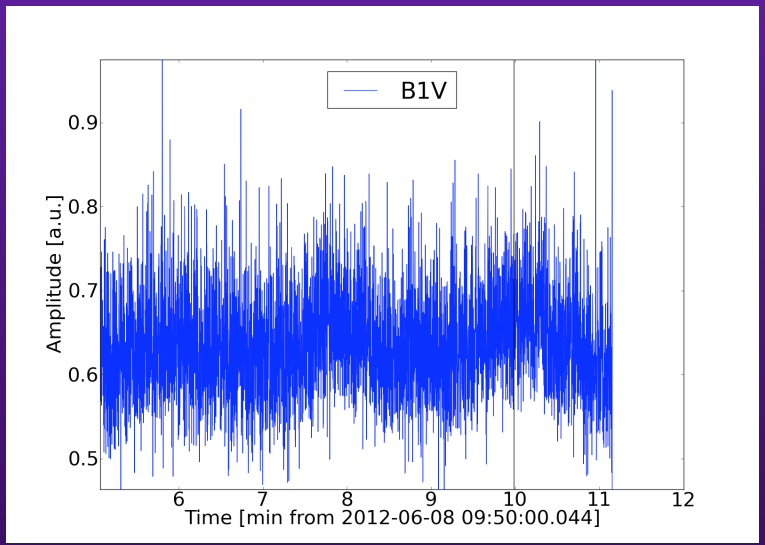
- **2 times dumped by something else! => Not conclusive and to be redone…**

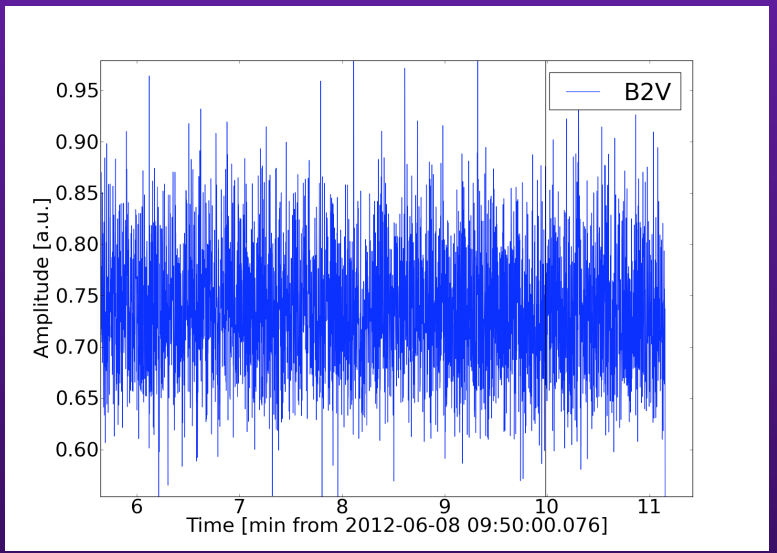
Gain on B1H and B2H reduced by factor 2

Xavier Buffat





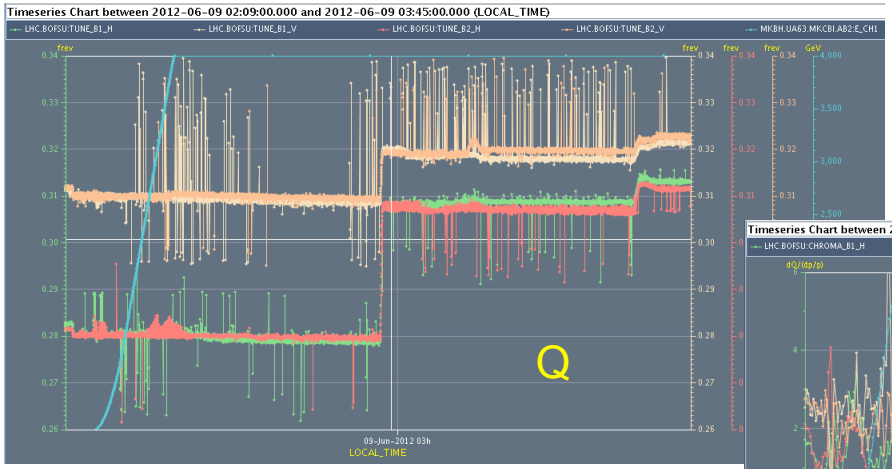


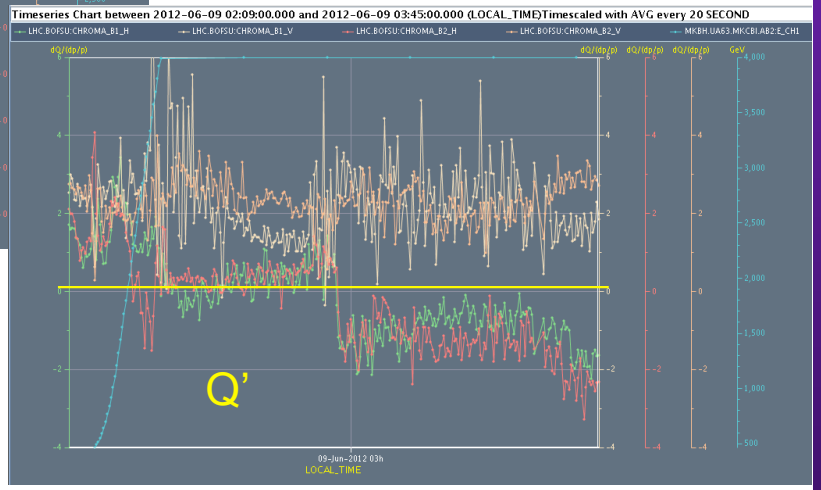


RECENT OBSERVATIONS ON CHROMATICITIES

Measurement cycle

- Low intensity cycle following TBDS TSU intervention was used to check tunes and chromaticity with probe bunches.
  - Horizontal Q' was found negative, around -1 in squeeze + collisions.
  - Q' trim to around +1 for squeeze/collisions on Saturday morning.





Jorg Wenninger (11/06/12)

CONCLUSIONS AND RECOMMENDATIONS (1/2)

- **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 chromaticities but the ADT gain is not optimized for this mode of operation (as the normal one is with positive one) => Ongoing analyses by AlexeyB, NicolasM and ADT experts (WolfgangH and DanielV) => SOLUTION: optimization of the ADT gain for negative chromaticities or go (as usual) to positive chromaticities. Negative chromas with ADT not optimized (for that) might explain why we need much more octupoles than predicted!...**
  - **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!**

CONCLUSIONS AND RECOMMENDATIONS (2/2)

- **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 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!**
- **Hope to learn more soon (during the 2nd MD block)… if we know the tunes and chromaticities…**