LHC BEAM PARAMETERS: PUSHING THE ENVELOPE?

**Elias Métral (for the collective effects team.
Many thanks to ABP, OP, BI, RF etc.)**
(15 min, 15 slides)

- Introduction
- Executive summary
- Some impedance and coherent instability results:
  - Transverse and longitudinal impedance
  - Christmas tree in May!
  - Transverse coherent instability induced by beam-beam?
  - TCBI with 75 ns beam at 450 GeV/c
  - Recommendation

INTRODUCTION

- L_{int} goal for 2011 = 1 fb^{-1}
- L_{peak} goal for 2011 = 1E33 $cm^{-2}s^{-1}$ (~ 2.07E32 $cm^{-2}s^{-1}$ in 2010)
- Many collective effects observed in 2010:
  - 1st in Spring: Increasing the intensity / bunch

  => SBI from impedance: Solved by octupoles
  - 2nd in Summer: Increasing # of bunches and changing Xing angle

  => Beam-beam (see WernerH's talk): HO alone OK but LR?

  => CBI from impedance: Solved by TF (with small chroma, few units)
  - 3rd in Autumn: Reducing the batch spacing (150, 75 and 50 ns)

  => Ecloud (see GianluigiA's talk): 50 ns is the most critical
- Which parameters can be realistically used in 2011 to increase the luminosity and reach the goals?

EXECUTIVE SUMMARY (1/6)

- 1 fb^{-1} can be reached with the following parameters, which should be fine according to latest MDs

75 ns BUNCH SPACING

824 b already injected with 75 ns!

- N_b = 0.8E11 p/b
- M = 936 b
- E = 4 TeV
- β^* = 2 m
- ε_n = 3.435 μm
- Xing angle = 285 μrad
- σ_z = 7.55 cm
- Run time = 180 days
- Run factor = 0.2

=> L = 3.215E32 cm^{-2}s^{-1}

See Roderik's talk

$$F_1\left[\times 10^{30}\right] = \frac{N_b^2 M}{\varepsilon_n} \approx 1.75$$

Same result obtained with the same F_1

=> Example with 50 ns:

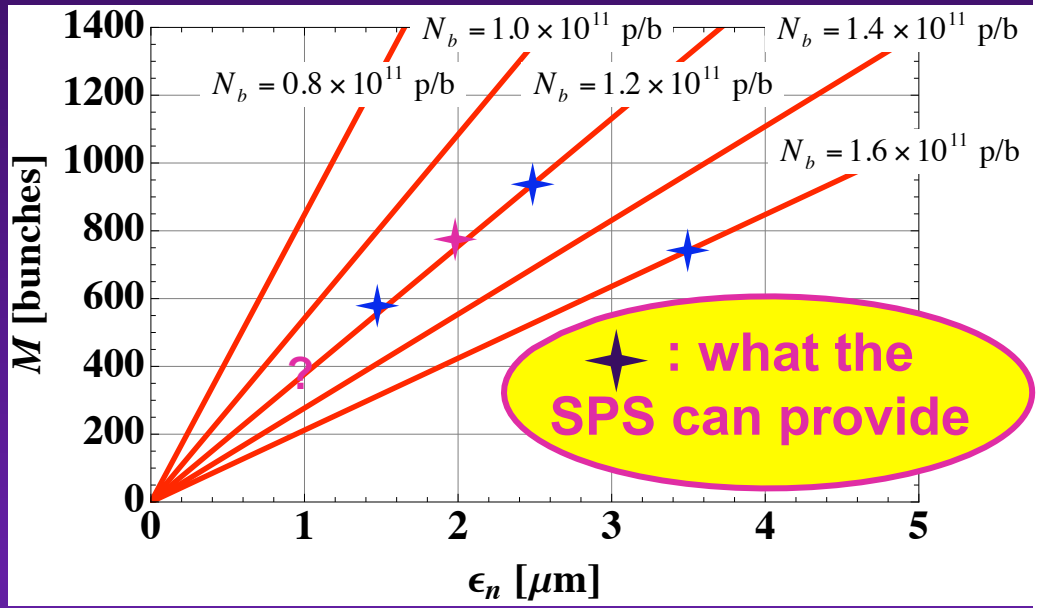
- N_b = 0.6E11 p/b
- M = 1404 b
- ε_n = 2.88 μm

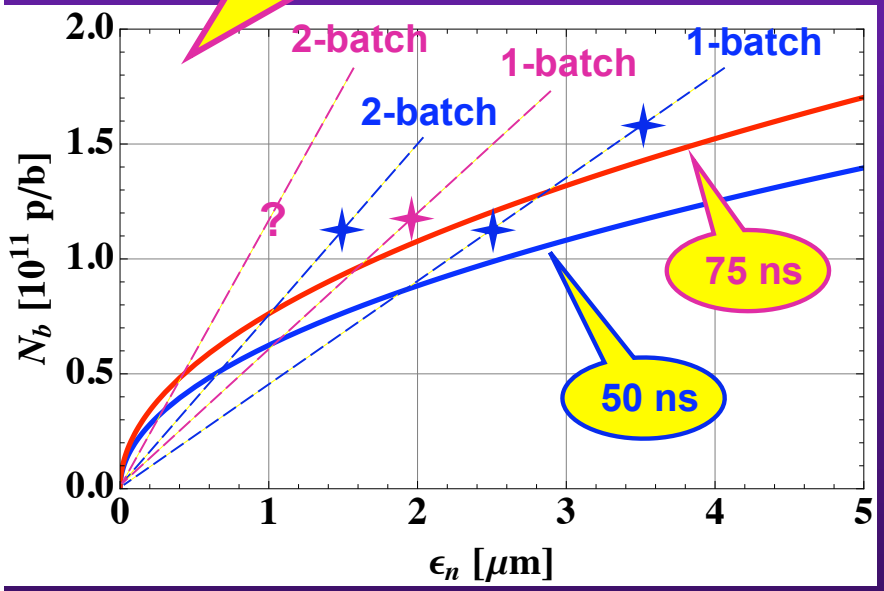
EXECUTIVE SUMMARY (2/6)

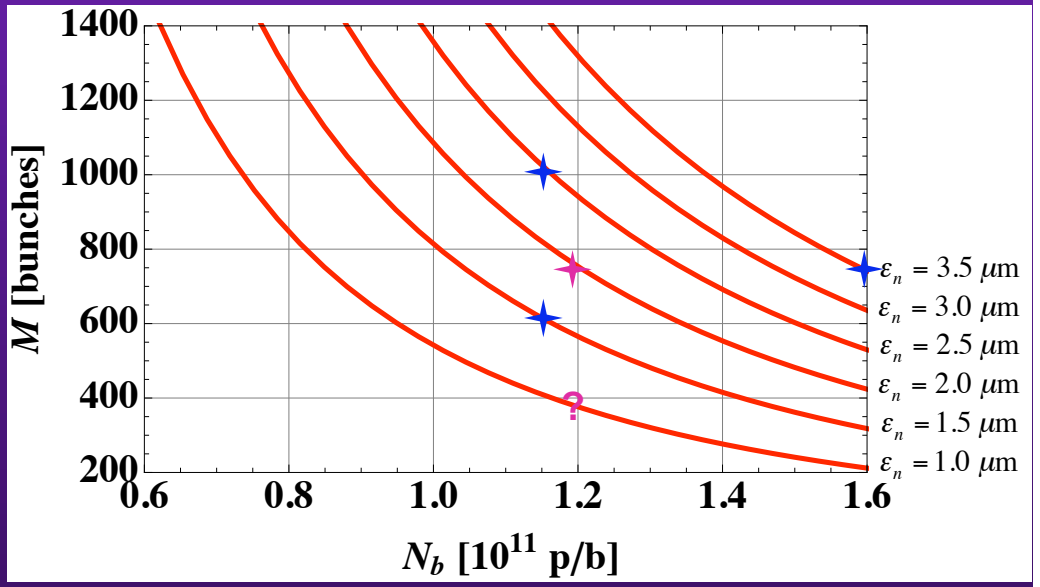
- **(N_b, M, ε_n) to reach 1E33 cm^{-2}s^{-1}, assuming β^* = cst = 2 m, nominal Xing angle and bunch length**

$$F_1 \approx 5.42$$

Assuming 936 b for 75 ns and 1404 b for 50 ns







EXECUTIVE SUMMARY (3/6)

- **Potential from the injectors (SPS)**

75 ns	N_b [10^{11} p/b]	ε_n [μm]	F_1 [10^{30}]	L [10^{33} cm^{-2} s^{-1}] = F_1 / 5.42
1-batch	1.2	2	6.7	1.2
2-batch (to be studied)	1.2?	1?	13.4?	2.3?

Current limit in the PS (CBI on FT => Heiko)

50 ns	N_b [10^{11} p/b]	ε_n [μm]	F_1 [10^{30}]	L [10^{33} cm^{-2} s^{-1}] = F_1 / 5.42
1-batch	1.15	2.5	7.4	1.4
1-batch	1.6	3.5	10.3	1.9
2-batch	1.15	1.5	12.4	2.2

EXECUTIVE SUMMARY (4/6)

- **Current constraints from the LHC**
  - **Impedance: Should be OK with Octupoles (TSBI) + TF (TCBI) with small chroma (few units)**
  - **Beam-beam (see WernerH's talk):**
    - **Margin for H0 => N_b / ε_n can be increased**
    - **More flexibility with 50 ns than 75 ns**
    - **Better small ε_n for LR (aperture and Xing angle)**
  - **Ecloud (see GianluigiA's talk):**
    - **75 ns safer for production mode**
    - **Scrubbing should be done with 50 ns as no scrubbing was observed in the arcs with 75 ns and ~ nominal N_b (and margin needed for acceleration etc.)**
    - **Ecloud build-up ~ independent of ε_n (recent conf. by Octavio)**
    - **Better large ε_n for beam stability (at least at the beginning)**

EXECUTIVE SUMMARY (5/6)

- **Proposed scenario to reach 1E33 $cm^{-2}s^{-1}$**
  - **SCRUBBING RUN (1-2? weeks):**
    - **50 ns, N_b ~ 1.4E11 p/b, ε_n ~ 4 μm (CBU from injectors)**
    - **Increase # of b looking at vacuum pressure**
  - ***PHYSICS (production mode with 50 ns): PLAN A (challenging)***
    - **50 ns, N_b ~ 1.15E11 p/b, ε_n ~ 4 μm (CBU from injectors)**
    - **Increase # of b up to ~ 1000 b => L = 6.1E32 $cm^{-2}s^{-1}$**
    - **Better than 75 ns for the L flexibility between experiments + LR can be studied**
    - **Decrease ε_n (reducing the CBU from injectors) to increase L (LR will disappear and HO increase but there is margin) => 1E33 $cm^{-2}s^{-1}$ reached when ε_n ~ 2.4 μm (SPS should be able to send ~ 2.5 μm in 1 batch and ~ 1.5 μm in 2 batches)**
    - **Increase # of b as much as we can… Increase N_b…**

Use max. which is OK with injection losses

EXECUTIVE SUMMARY (6/6)

- **PHYSICS (production mode with 75 ns): PLAN B (more realistic)**
  - **75 ns, N_b ~ 1.2E11 p/b, ε_n ~ 4 μm (CBU from injectors)**
  - **Increase # of b (936 b => L = 6.2E32 $cm^{-2}s^{-1}$)**
  - **LR can be studied**
  - **Decrease ε_n (reducing the CBU from injectors) to increase L (LR will disappear and HO increase but there is margin) => 1E33 $cm^{-2}s^{-1}$ reached when ε_n ~ 2.45 μm (SPS should be able to send ~ 2 μm in 1 batch and ~ 1? μm in 2 batches)**

TRANSVERSE AND LONGITUDINAL IMPEDANCE

- Transverse impedance
  - From tune shift meas. vs. intensity + collimators' gap (moving all IR7 collimators) => Within < 40% with theoretical predictions
  - Instability rise-time (see Christmas tree) => Within less than factor 2
- Transverse impedance from (TDI + 2 TCLIs) seems to be ~ 2.5 times larger than expected => From (clean) meas. by StefanoR
- Longitudinal impedance => Deduced from Loss of Landau damping leading to undamped bunch oscillations at beginning of the run with small long. emittance (ElenaS)

$$\mathrm{Im}\left(\frac{Z_l}{n}\right)^{m=2}_{eff\ ,MEAS} \approx 0.09\ \Omega$$

Our predictions

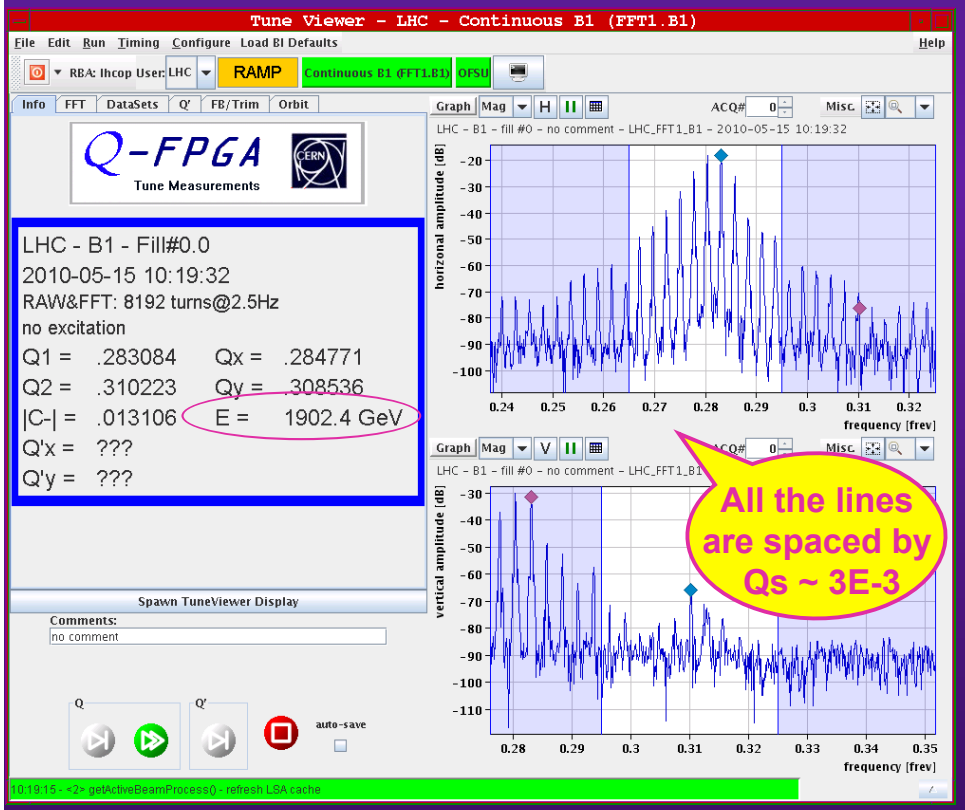
$$\mathrm{Im}\left(\frac{Z_l}{n}\right)^{m=2}_{eff\ ,THEORY} \approx 0.086\ \Omega$$

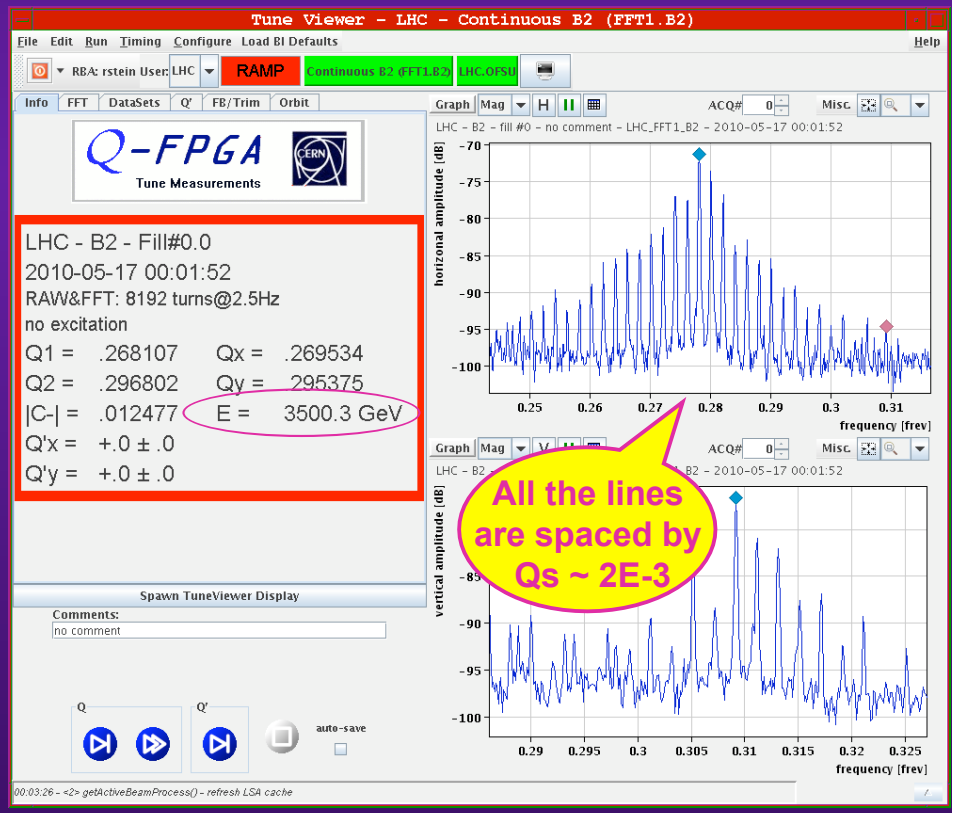
CHRISTMAS TREE IN MAY! (1/2)

- A 1st ramp was tried with a single-bunch of ~ 1E11 p/b (on both B1 and B2) on SA 15/05/2010

=> Bunch unstable at ~ 1.8 TeV/c for B1 and ~ 2.1 TeV/c for B2

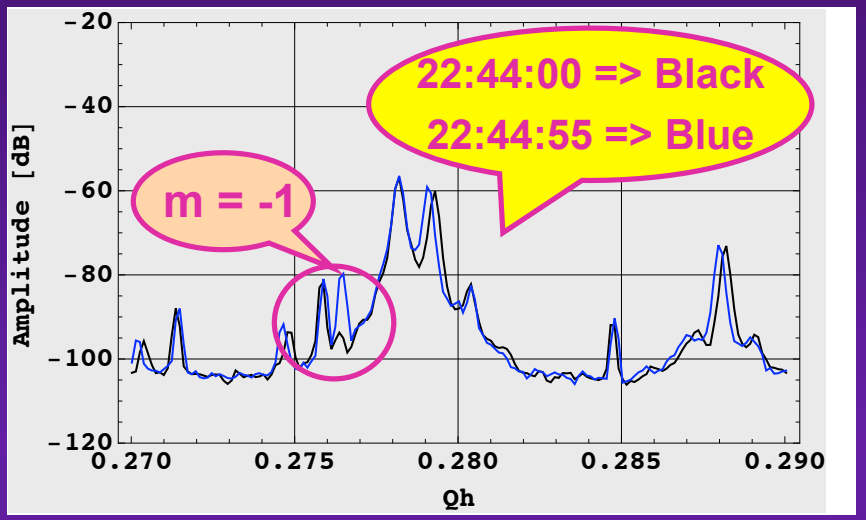
=> Famous Christmas tree => Reproduced by simulations (with loss)

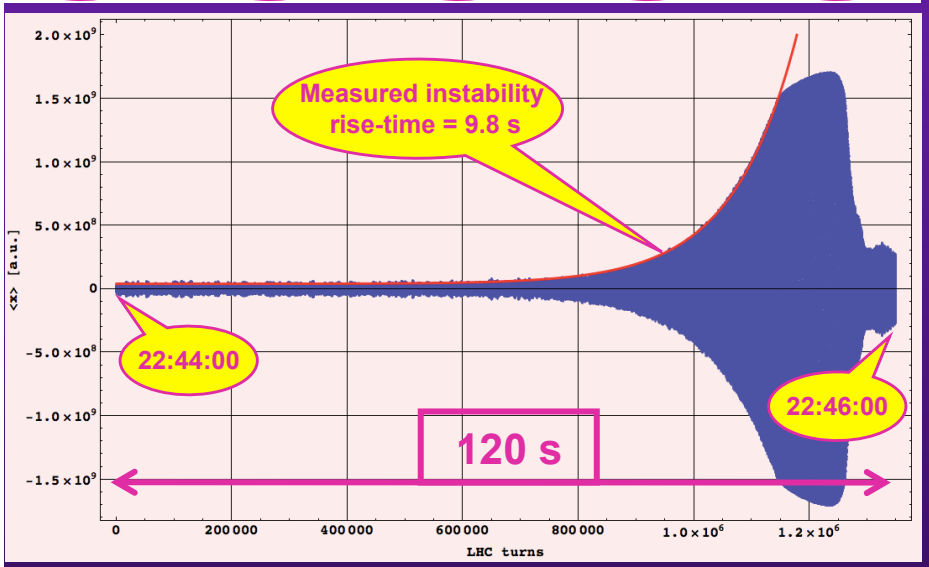


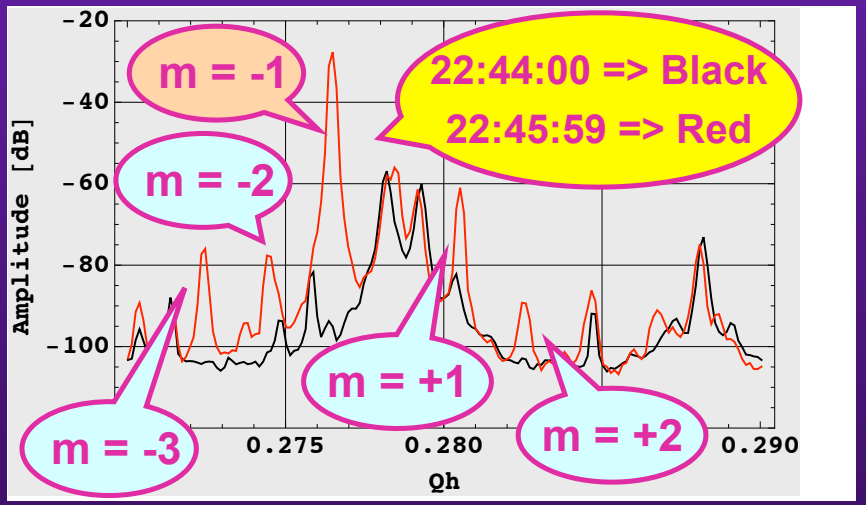


CHRISTMAS TREE IN MAY! (2/2)

=> TSBI of HT mode m = -1 from machine impedance predicted with a rise-time ~ 5 s without octupoles and intrinsic nonlinearities

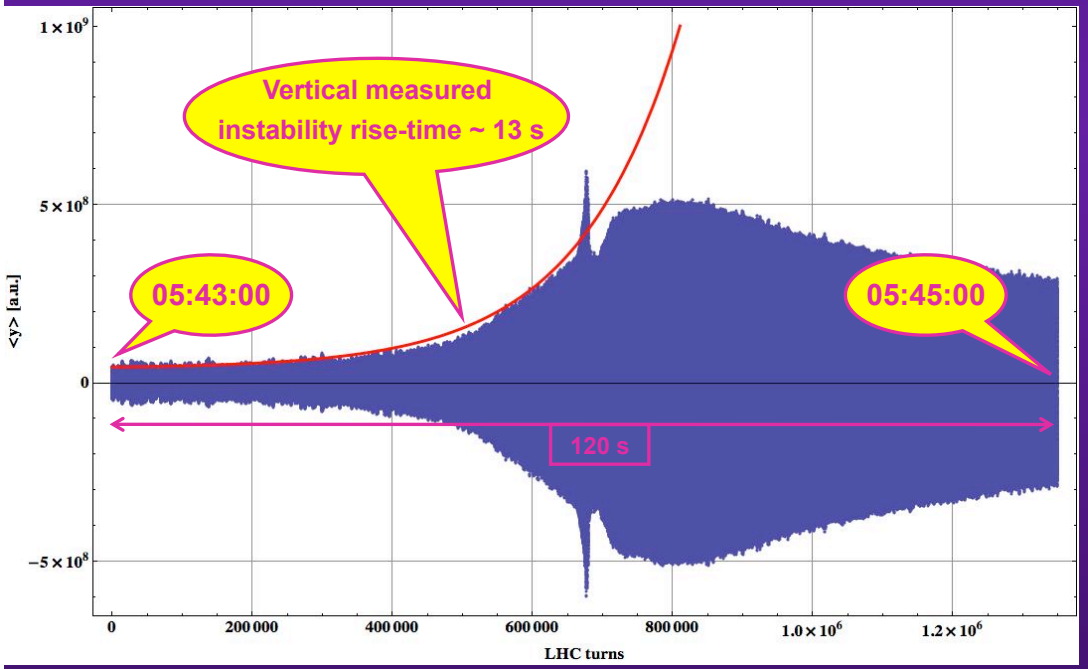


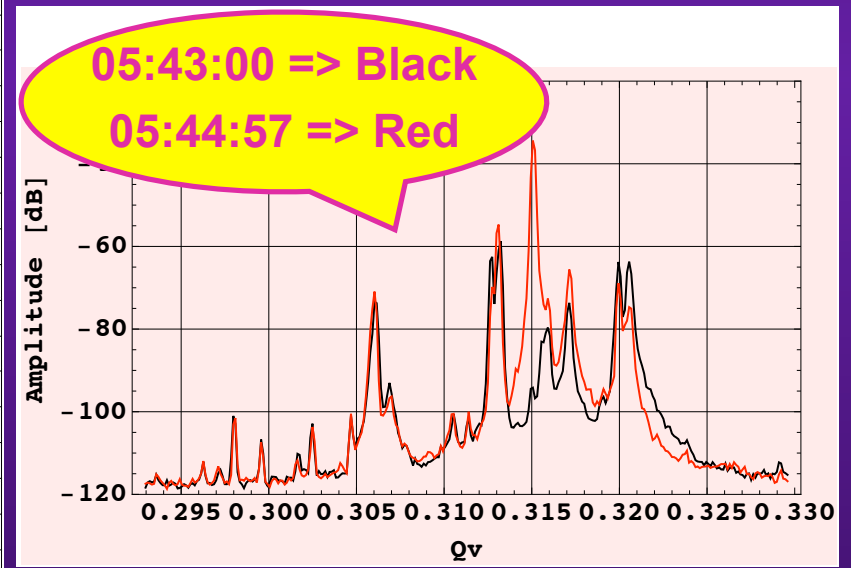




TRANSVERSE COHERENT INSTABILITY INDUCED BY BEAM-BEAM?

- Vertical instability observed at 3.5 TeV/c in stable beams => Could be a loss of Landau damping? (followed up by WernerH and TatianaP)

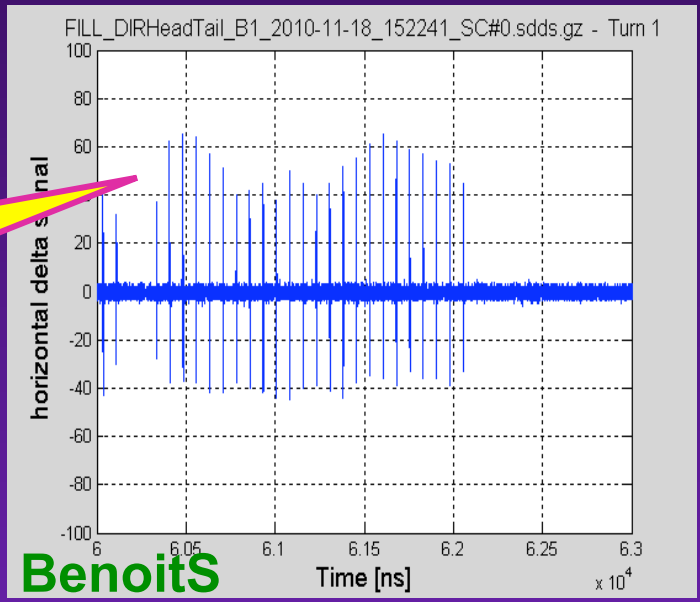




TCBI WITH 75 ns BEAM AT 450 GeV/c (1/2)

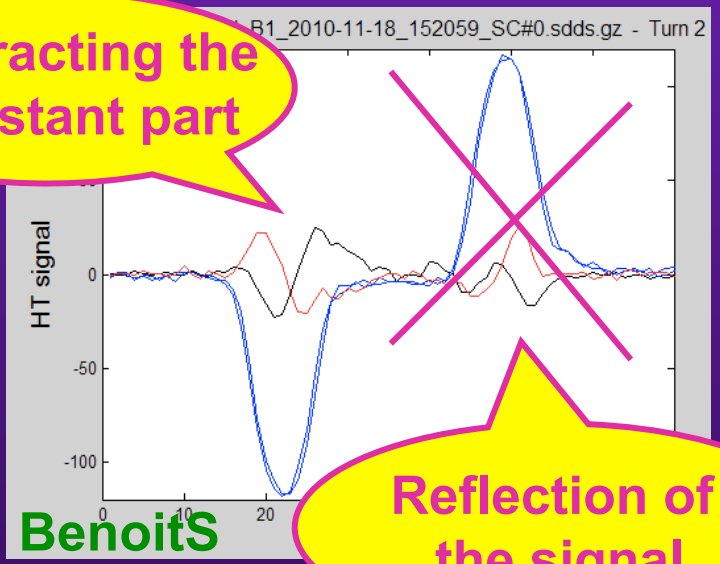
- 11 batches of 2 * 24 b spaced by 225 ns (batch spacing 1.85 μs) => Only B1 and both H & V!
- Q' ~ 10 in H&V
- No growing oscill. but losses
- Stabilized with Q' ~ 20 and no losses anymore

Coupled-bunch pattern



MEASUREMENT

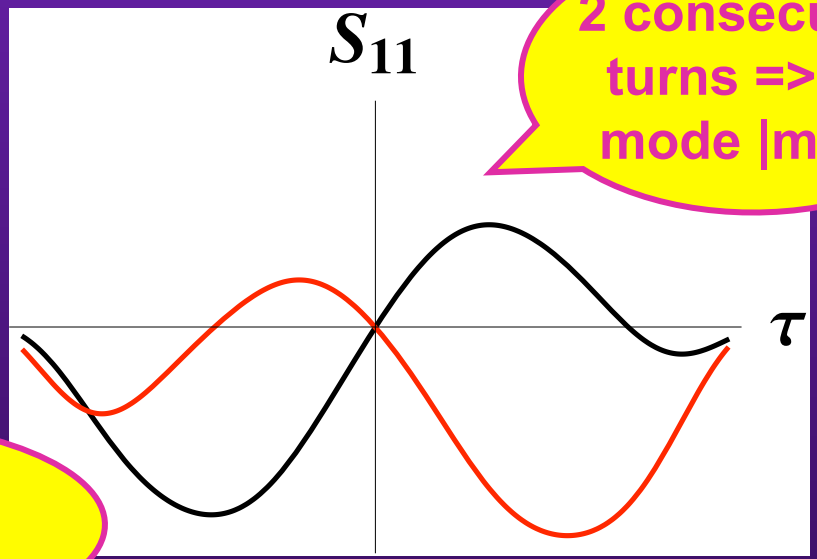
Subtracting the constant part



Reflection of the signal

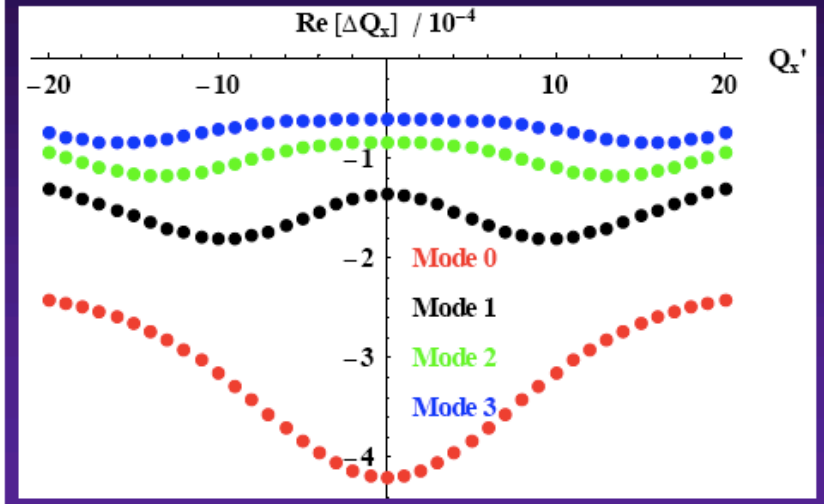
THEORY

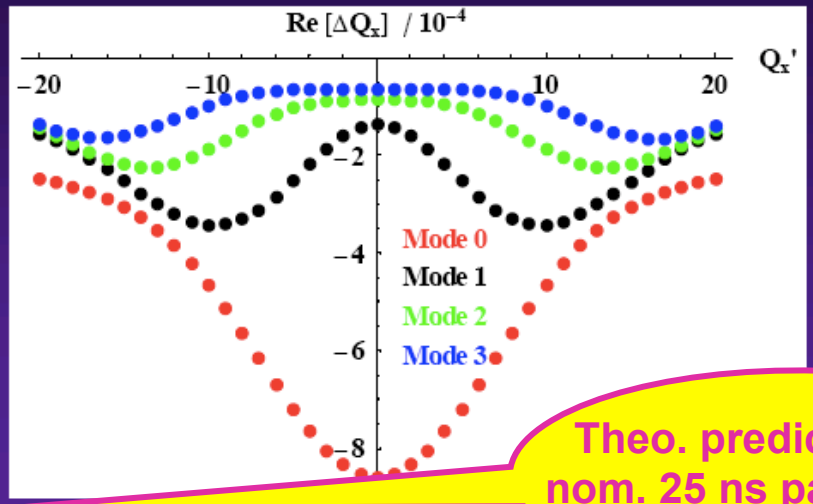
2 consecutive turns => HT mode |m| = 1

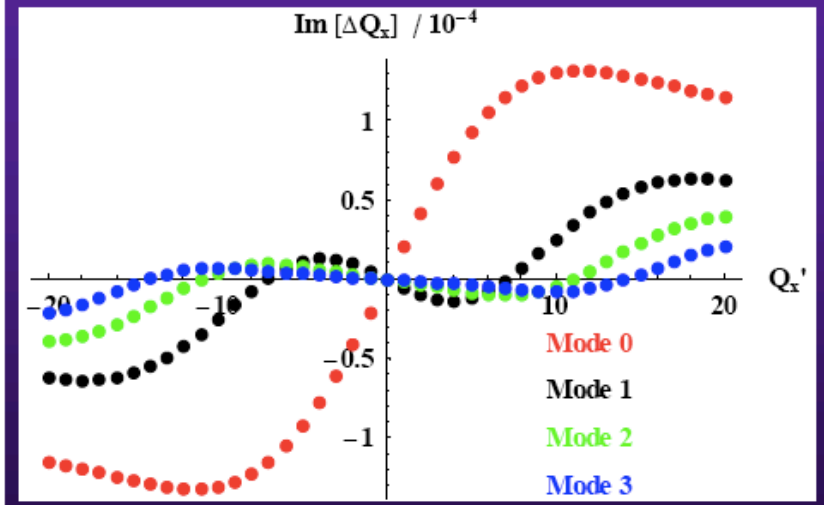


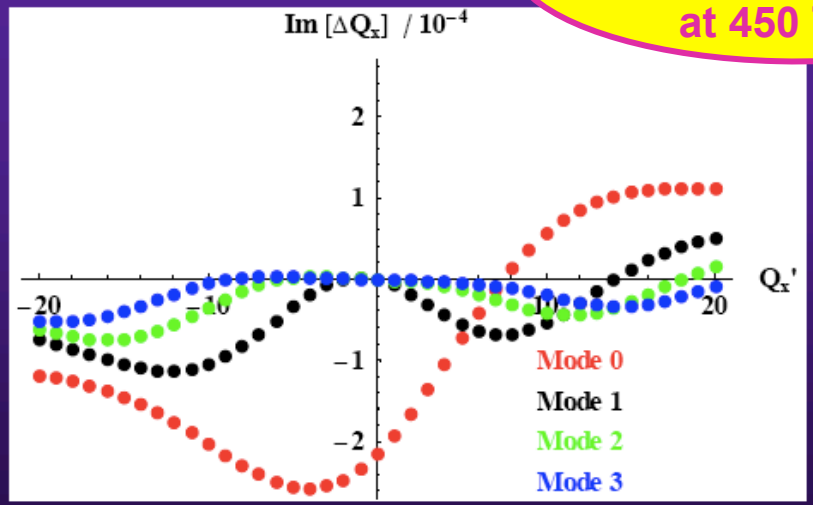
TCBI WITH 75 ns BEAM AT 450 GeV/c (2/2)

Single-bunch **X-plane** **Coupled-bunch**









Theo. predictions with nom. 25 ns parameters at 450 TeV/c

Elias Métral, RLC meeting, 21/04/06 15/21

RECOMMENDATION

- In case of TCBI from (machine impedance and/or ecloud) => Should be damped by the TF => Better to have the smallest chromaticity
- One should not have TMCI from the machine impedance => No reason to increase the chromaticity for TMCI
- The only reason to increase the chromaticity could come from the ecloud-induced vertical single-bunch "TMCI-like" instability, which was most probably observed during the 1st MD with 50 ns beam on 02/11/10 … => Possible issue: TCBI from machine impedance with HT mode |m| = 1 could develop, which cannot be damped by TF => Increase the chromaticity even more (see previous slide)…

ACK: Many thanks to all people who worked on impedances in the past (F. Ruggiero, L. Vos, F. Caspers, VAC etc.)

HAPPY CHRISTMAS!