Study of the single-bunch instabilities in the LHC

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Overview

- Motivation
- Data analysis of an instability on 02/04/2012
- Threshold octupole current
- Conclusions

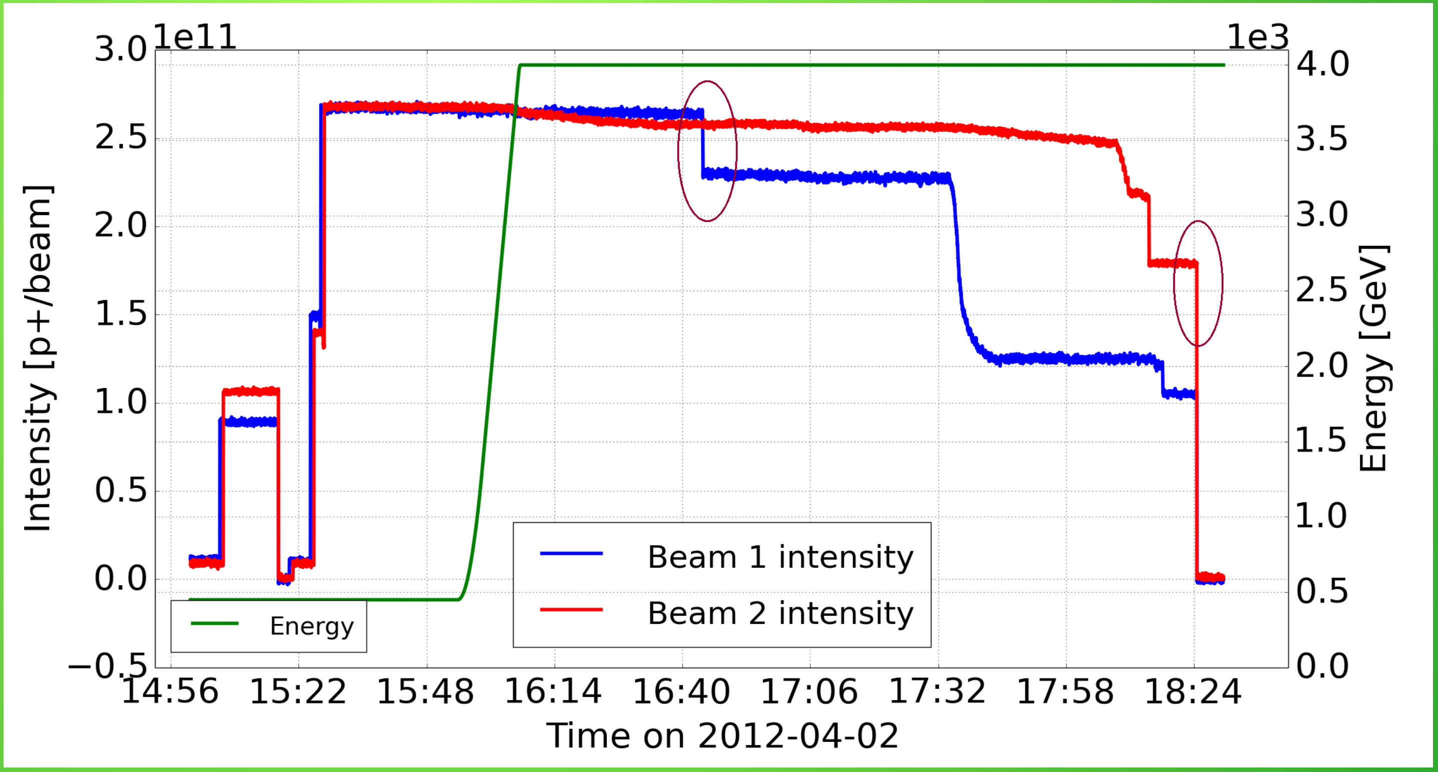
Motivation

Transverse collective instabilities are one of the most important limitations to achieve the highest luminosities in the LHC and have been regularly observed during the LHC Run I.

For instance, in 2012 there were observed some single-bunch instabilities during normal operation, which can be studied with HEADTAIL and NHTVS simulations.

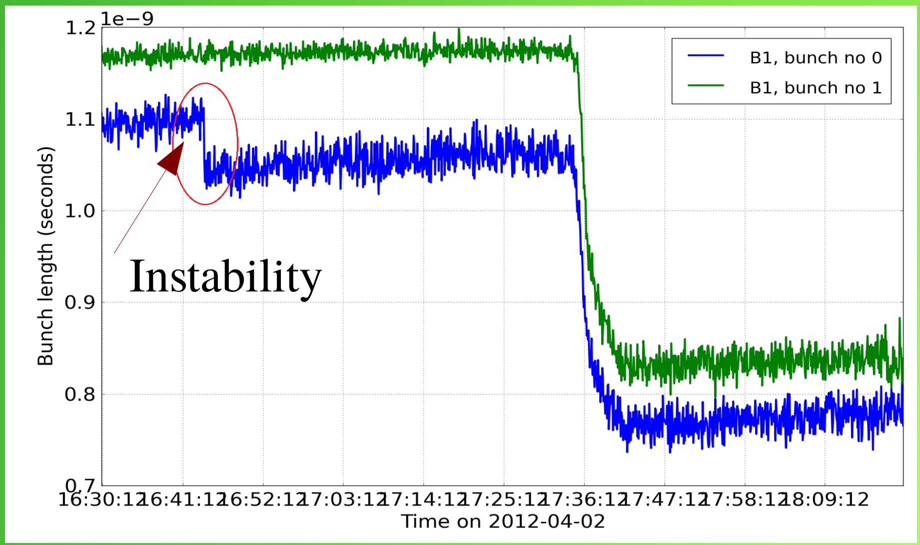
Instability analysis in Fill#2447

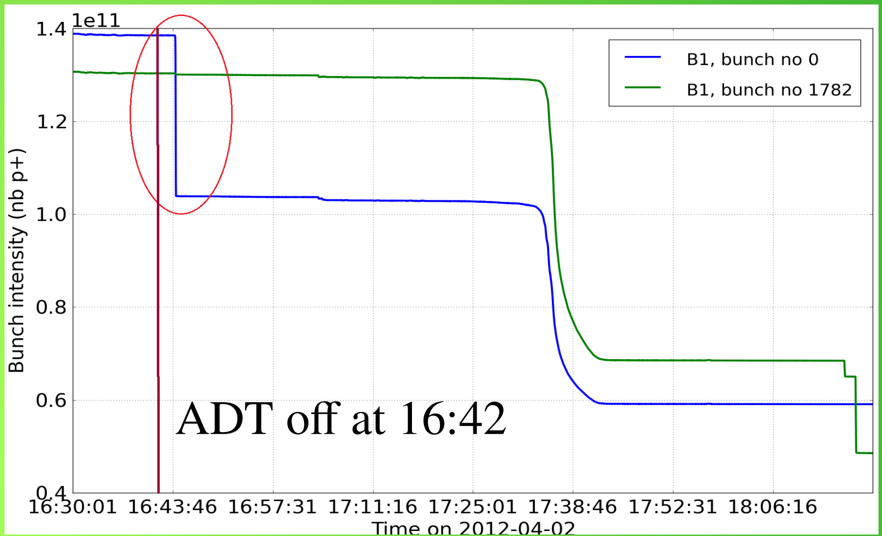
- On the 02/04/2012 were observed some instabilities during the collimator's "loss maps"
- Nominal bunches
- ADT were switched off
- After the end of the squeeze
- Focusing octupole current I_{oct}= -406 A



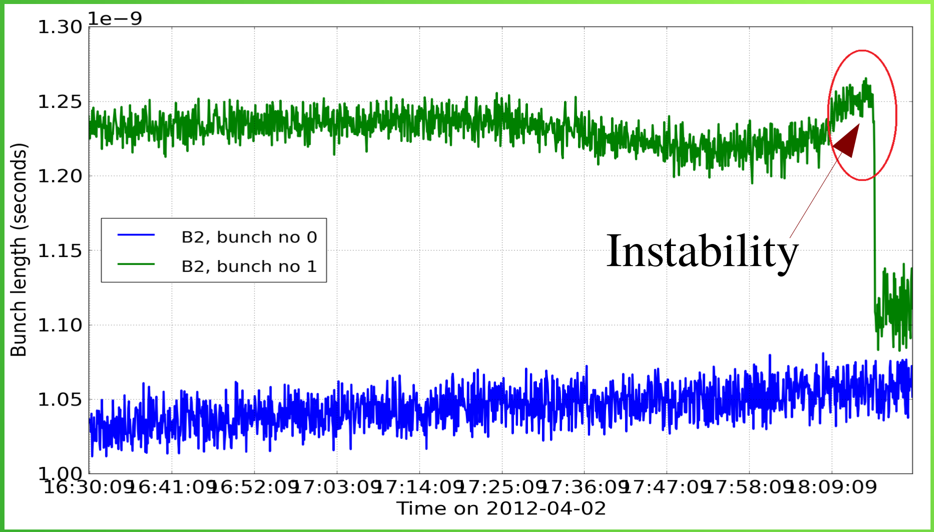
Data analysis

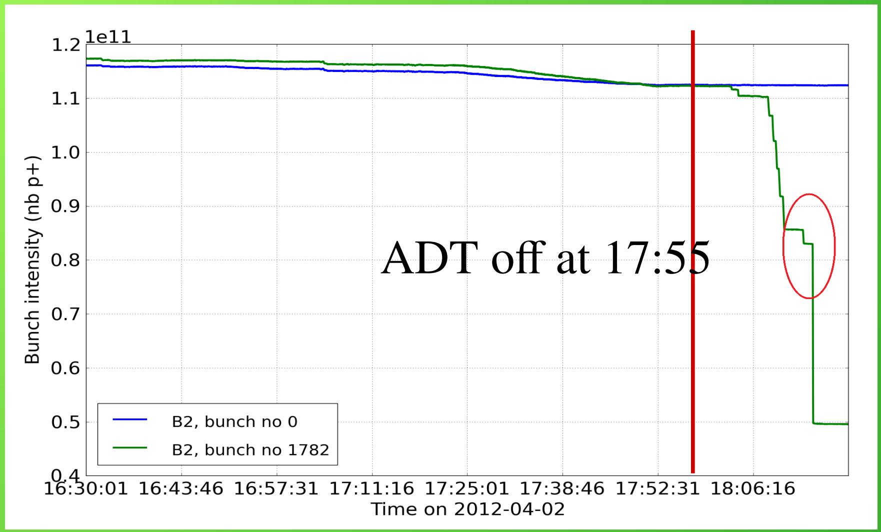
The instability in the beam 1 was ~ at 16:43 in the bunch 1, in the horizontal plane



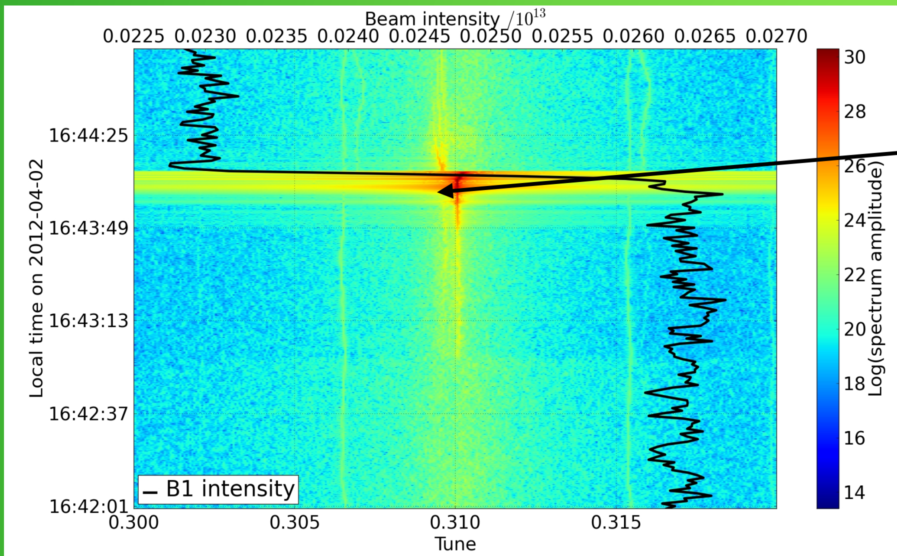


The 1st instability in the beam 2 was ~ at 17:55 in the bunch 2, in the vertical plane

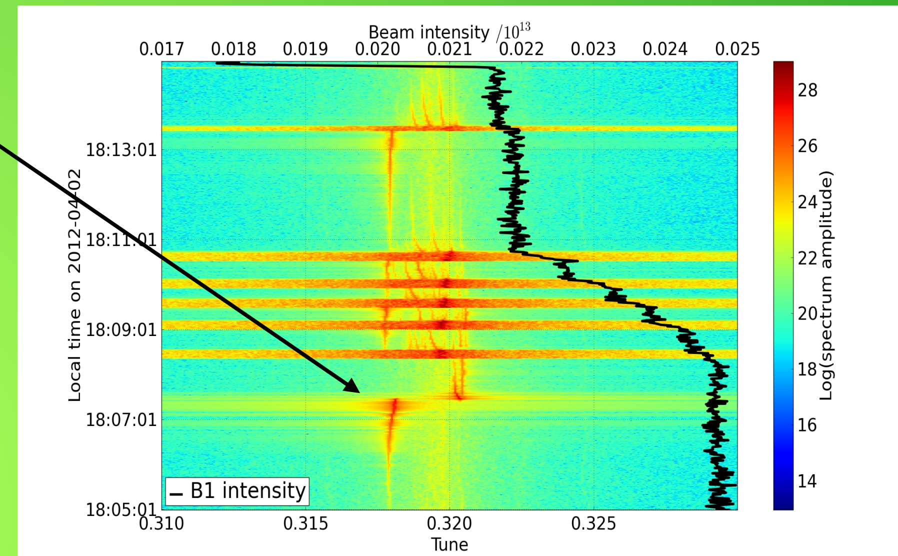




Data analysis

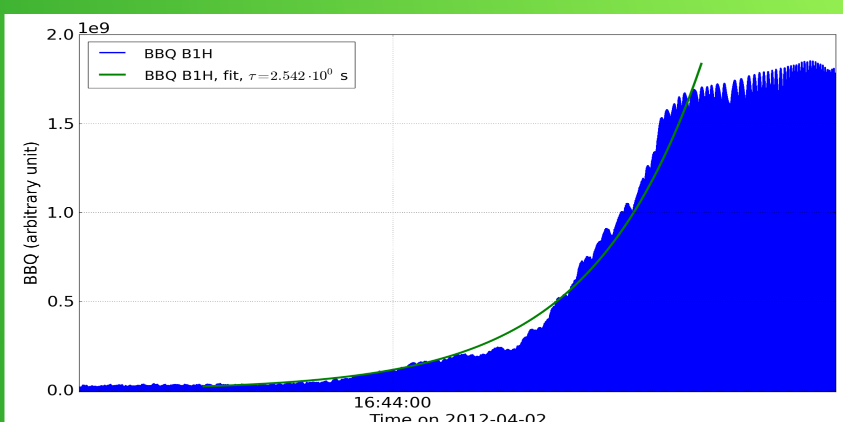


Growing coherent Signal → instability

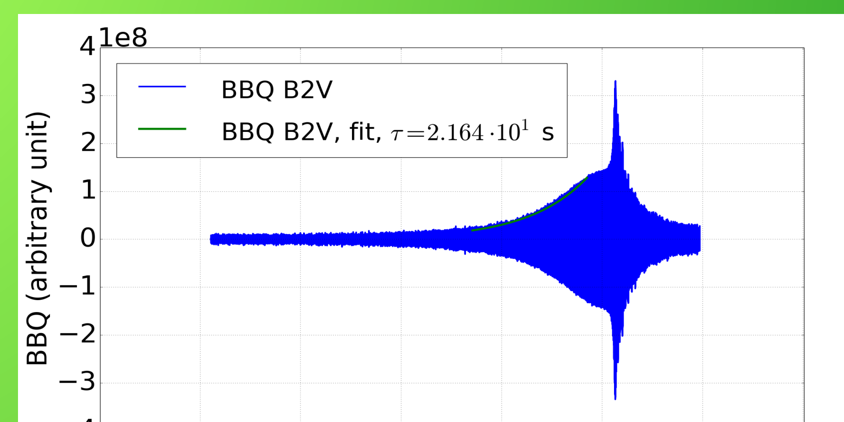


Tune spectrum: instability in the horizontal plane

Tune spectrum: instability in the vertical plane



Rise time $\tau_H = 2.542$s from “raw” BBQ data



Rise time $\tau_V = 21.6$s from “raw” BBQ data

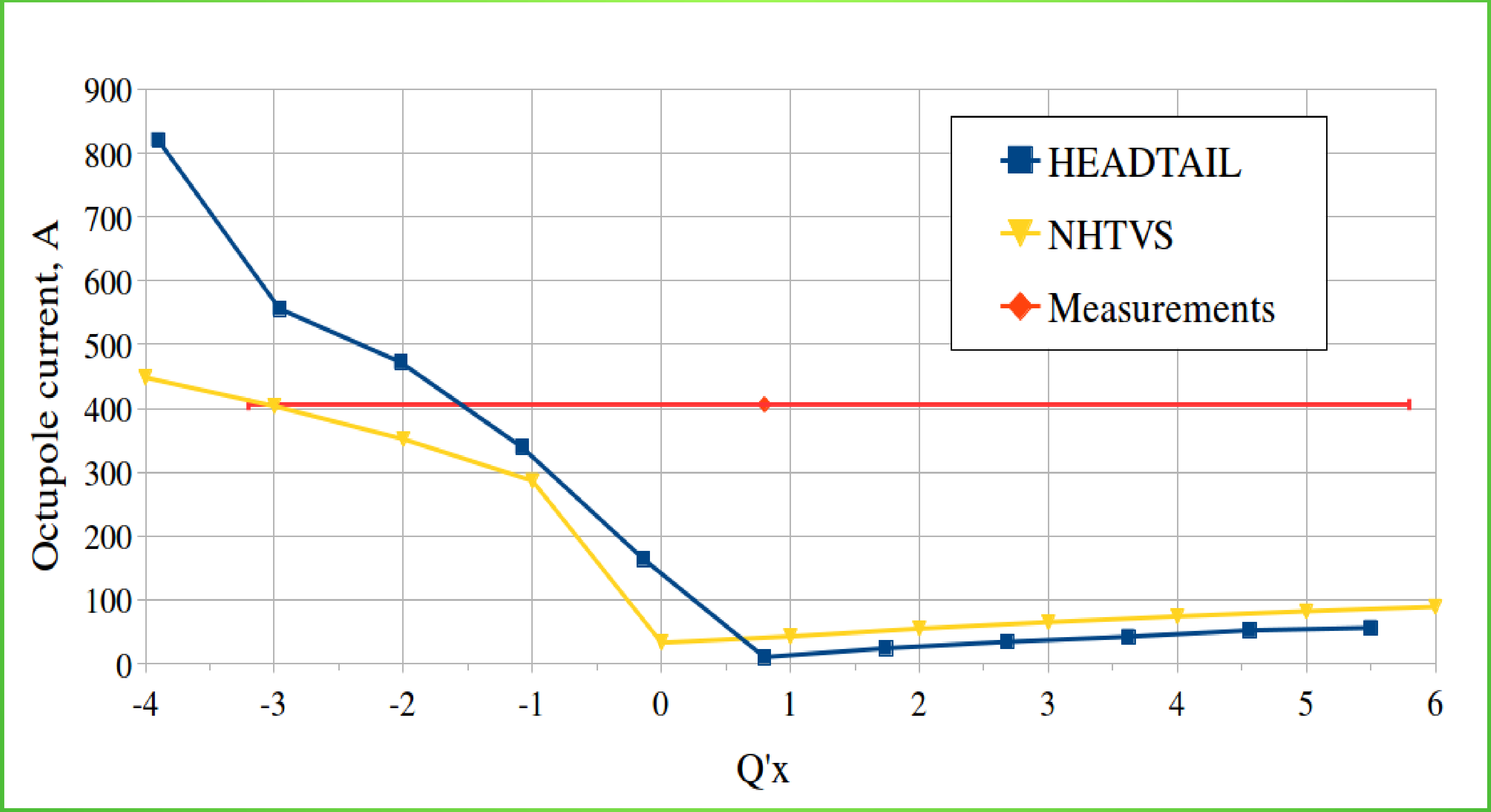
Simulations

One of the way to check the accuracy of the LHC impedance model, which has been chosen, is to compare the octupole current threshold from simulations and the octupole current in measurements.

Threshold octupole current. Beam 1H

Comparison between the octupole current during the measurements and the octupole current threshold from HEADTAIL.

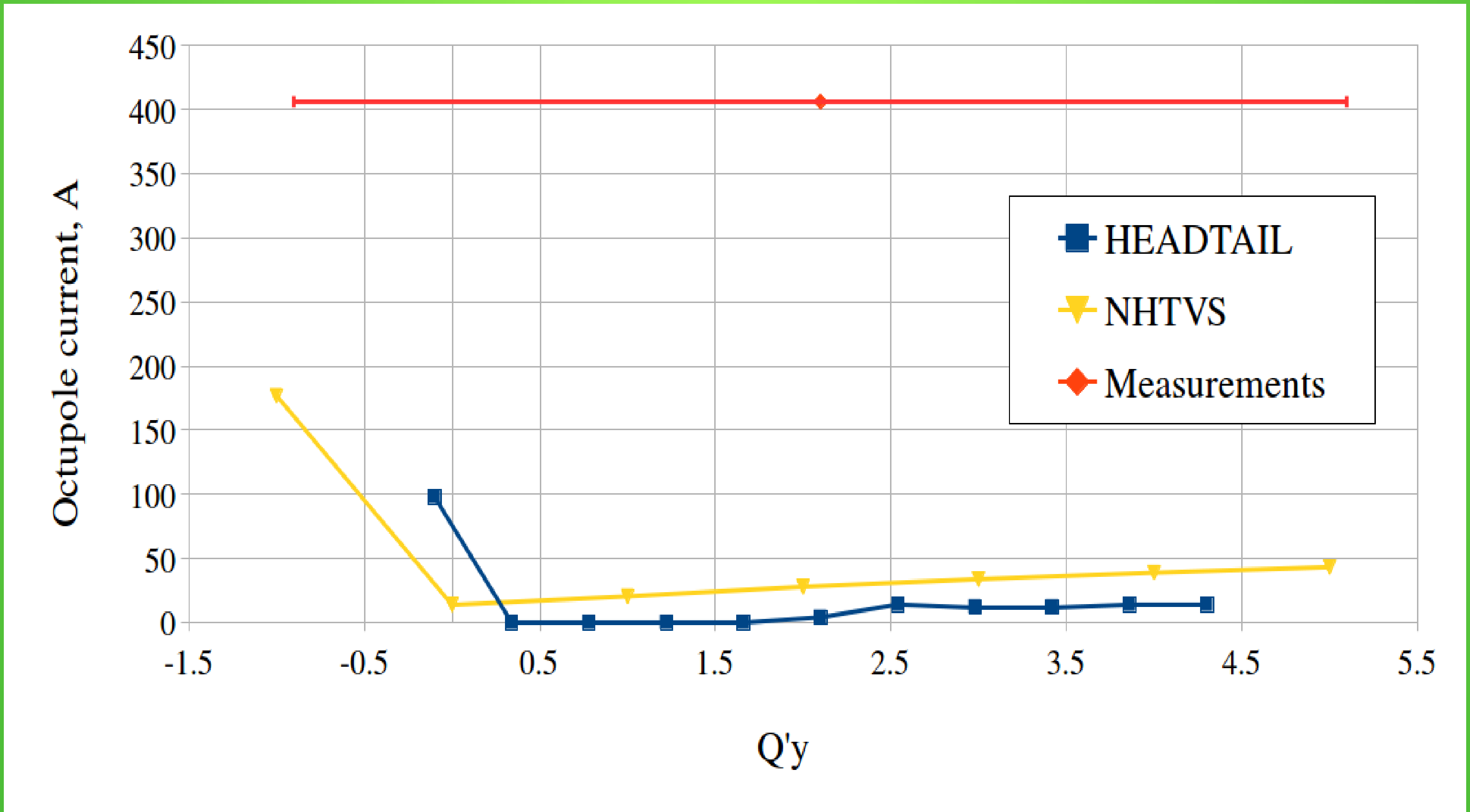
I_{oct} = 406 A in measurements.



Threshold octupole current. Beam 2V

Comparison between the octupole current during the measurements and the octupole current threshold from HEADTAIL.

I_{oct} = 406 A in measurements.



Conclusions

For the observed single-bunch instabilities :

– the discrepancy factor 2-4 between simulations and measurements in the rise time gives a good agreement.

– from HEADTAIL simulations the stabilizing octupole current seems to be rather high for negative chromaticities and close to 0 A for positive chromaticities.

– results from NHTVS simulations show the same profile of the stabilizing octupole current as with HEADTAIL.

– however, from NHTVS results the octupole current for negative chromaticities is lower and for positive chromaticities is less than 50 A.

– furthermore, having the chromaticity -2 in the measurements in beam 1 in the horizontal plane, the current LHC impedance model could explain the rise time observation.

Thank you for your attention!

Backup slide 1. Instability data 02-04-2012

	Time	Bunch intensity (e11)	Energy (GeV)	Squeezed/Not	Bunch length (ns)	Focusing octupole current (A)	ADT (on/off)	Rise time (s)	Azimuthal mode
B1H_bunch1 (unstable)	16:43	1.38	4000	yes (~60 cm)	1.1	-406	off	3.078	0
B1H_bunch2		1.3			1.16				
B2V_bunch1	18:07	1.22	4000	yes (~60 cm)	1.05	-406	off	22	-1
B2V_bunch2 (unstable)		1.1			1.23				

Backup slide 2. Input parameters for the simulations 02-04-2012 (B1H/B2V)

Number_of_particles_per_bunch:	1.38e+11 / 1.1e+11
Bunch_length_(rms_value)_[m]:	0.0847 / 0.0852
Normalized_horizontal_emittance_(rms_value)_[um]:	2.76 (average value for B1)
Normalized_vertical_emittance_(rms_value)_[um]:	2.76 (average value for B1)
Longitudinal_momentum_spread:	0.00013308
Synchrotron_tune:	0.00234243
Relativistic_gamma:	4263.156
Number_of_turns:	300000
Horizontal_chromaticity_[Q'x]:	-3.9 … 5.5, h=0.94 (Q'_y = 0) – B1H
Vertical_chromaticity_[Q'y]:	-0.1 … 4.3, h = 0.44 (Q'_x = 0) – B2V
Number_of_macroparticles_per_bunch:	5e5
Number_of_slices_in_each_bunch:	100
Number_of_turns_for_the_wake:	10
Second_order_horizontal_chromaticity (x/y):	depends on the octupole current
Main_rf_voltage_[V]:	12e+6
LHC_defocusing_octupoles_current_[A]:	0...900 with a step = 2 A (I_oct MD = -406 A)
Switch_for_wake_table	4 (without coupling terms)
Damper_gain	0