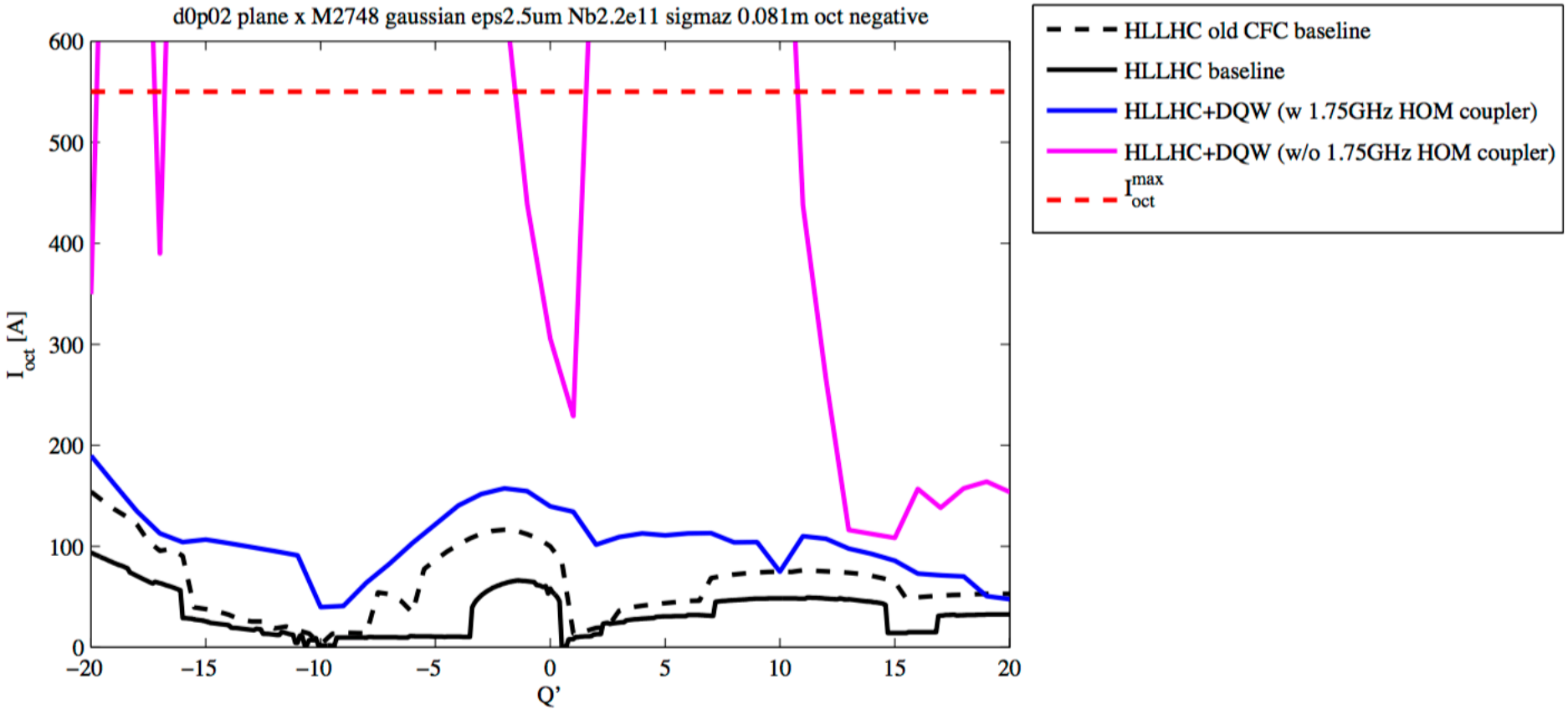
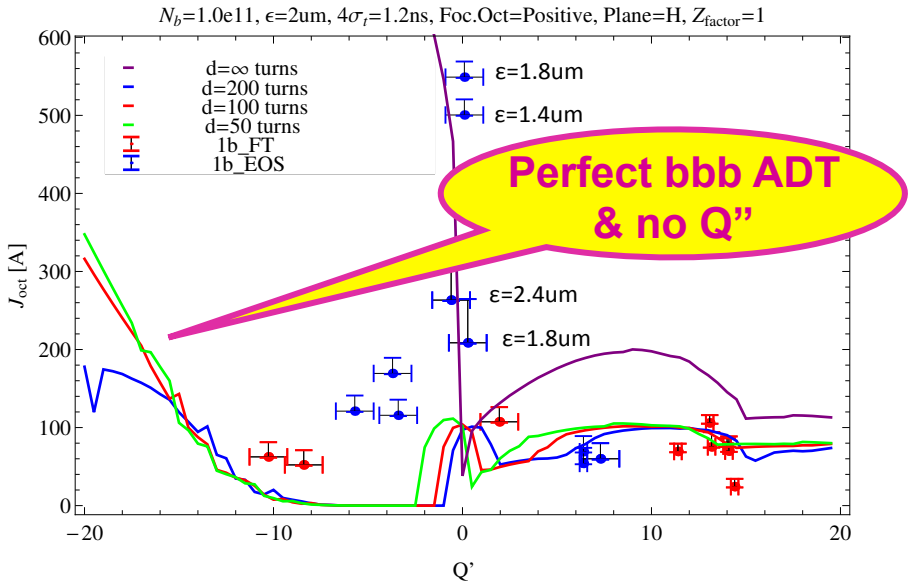
MD RESULTS: IMPEDANCE

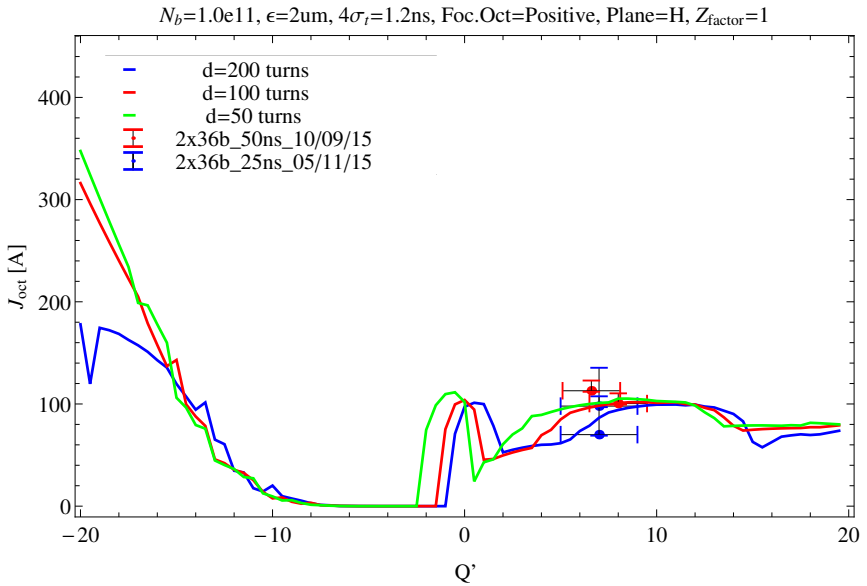
E. Métral, B. Salvant, N. Biancacci, L. Carver et al.

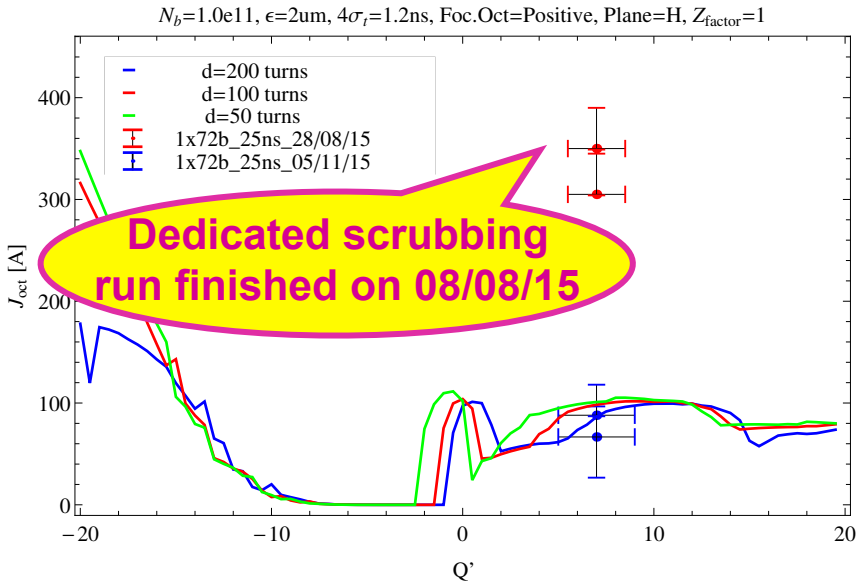
Context: Prediction for HL-LHC at β* = 15 cm (NicoloB et al.)

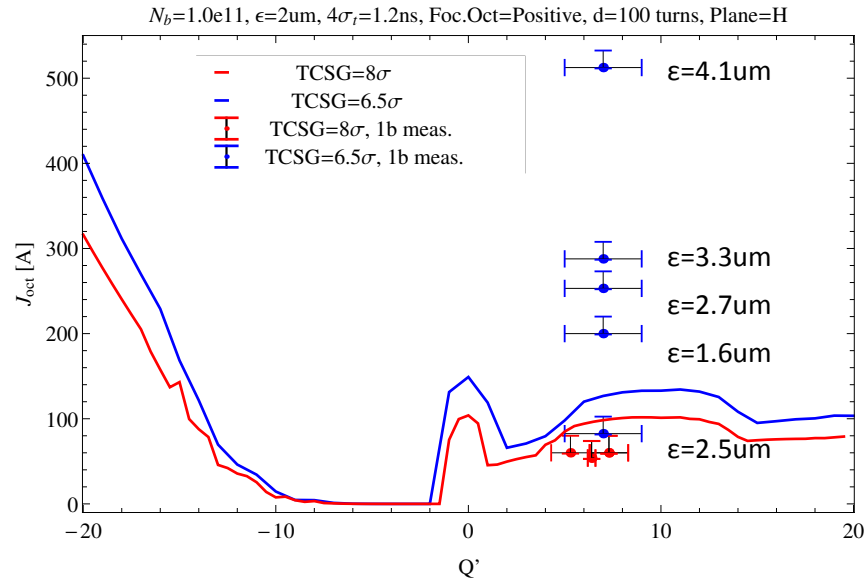


OVERVIEW PLOTS OF LHC STABILITY STUDIES AT 6.5 TEV (LeeC & NicoloB et al.)





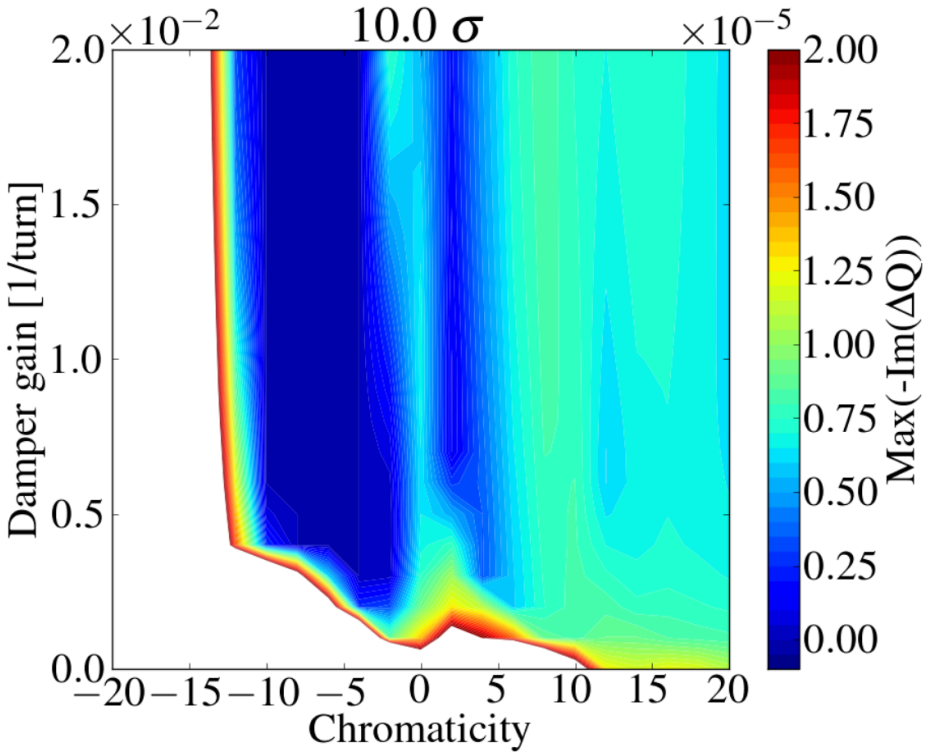




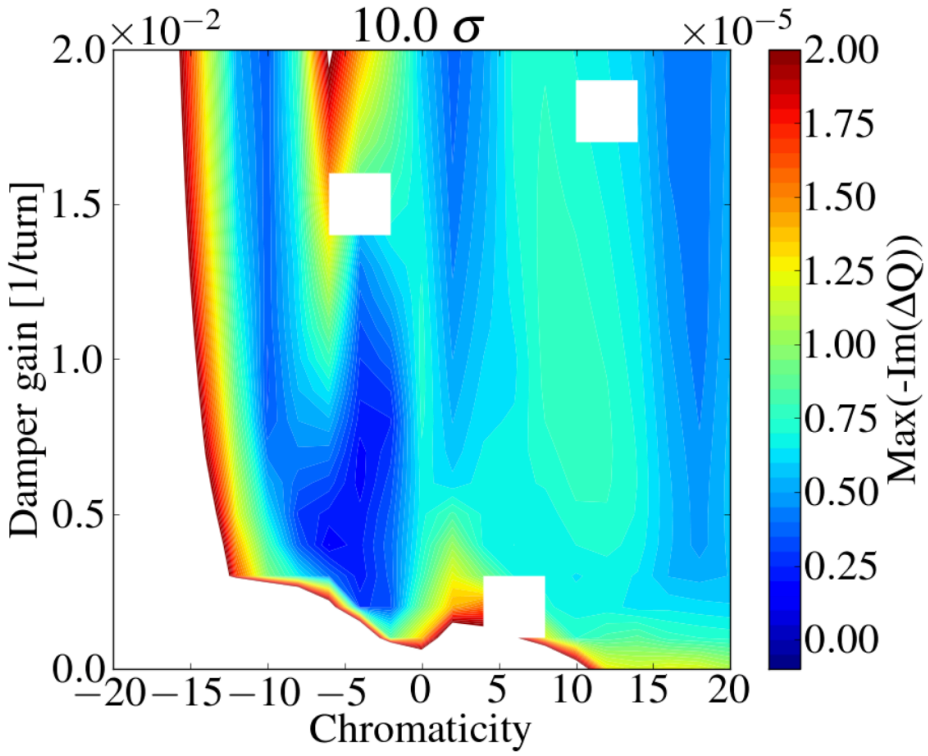
PAST (2012) WORK ON DAMPER (XavierB et al.)

More "realistic" cases studied (finite resolution > ~ 1 μm; effect of modulation of measured BPM signal around the main RF frequency, used to enhance the sensitivity => measured position slightly differs from average position in presence of head-tail motion)

Perfect Damper



"Imperfect" Damper



=> Would like to scan the ADT gain in the future

PAST (2012) WORK ON Q" (1/4) (NicolasM et al.)

- Formula for the 2nd order chromaticity (Eq. (158) of LHC Project Report 501 by StephaneF and OliverB: http://cdsweb.cern.ch/record/522049/files/lhc-project-report-501.pdf)

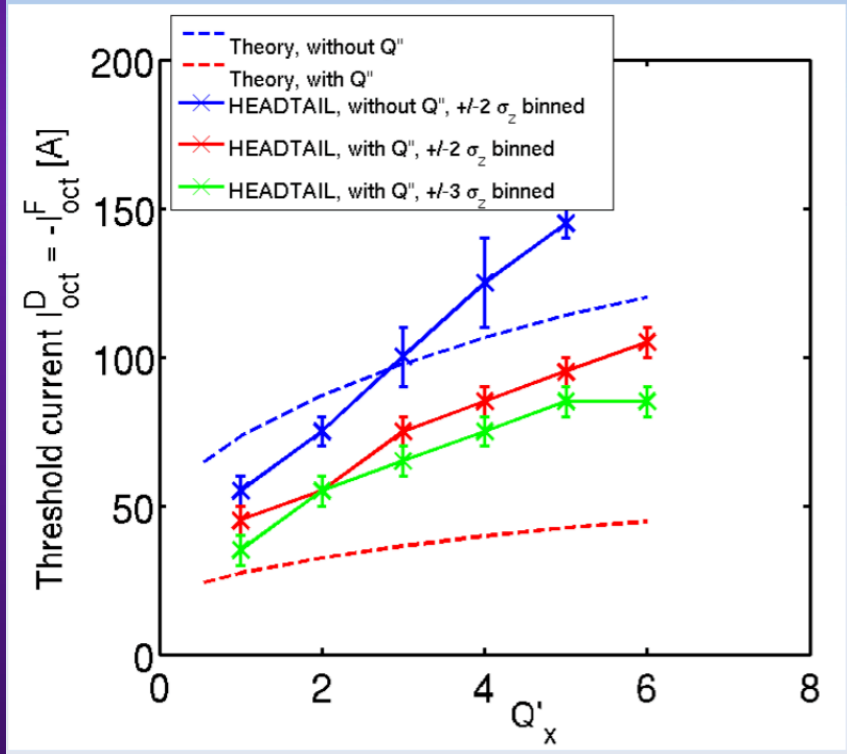
$$Q''_{x,y} = \pm \frac{1}{4\pi} \int ds\, \beta_{x,y}\, D_x^2\, K_3^+$$

  - Q_x'' = - 36000 for 450 A in the (D) octupoles at 4 TeV
  - Q_y'' = + 15000 for 450 A in the (D) octupoles at 4 TeV

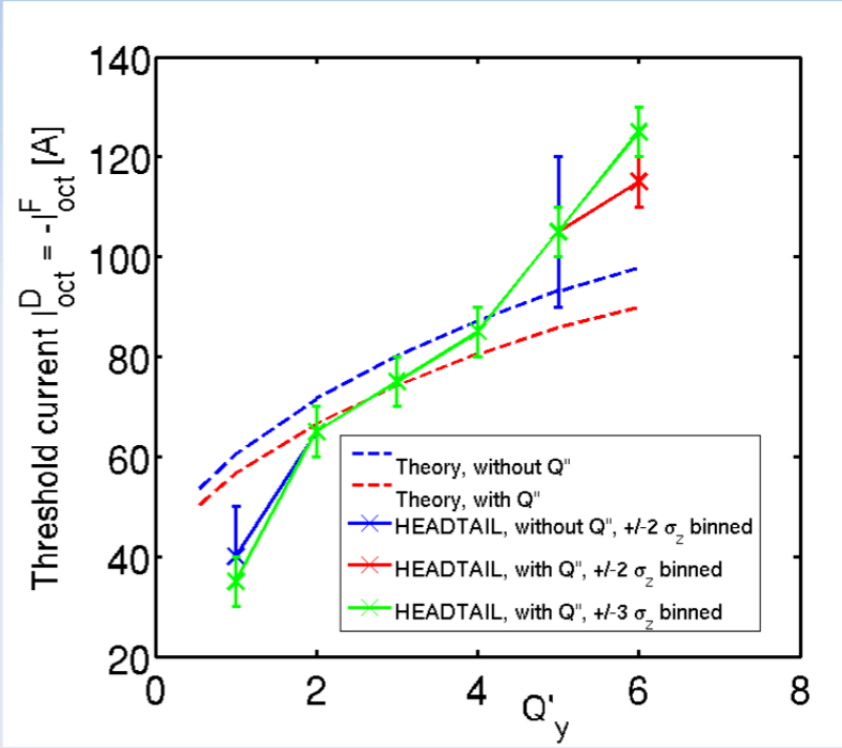
PAST (2012) WORK ON Q'' (2/4) (NicolasM et al.)

- **HEADTAIL simulations for a single-bunch at 4 TeV/c, with tight collimator settings, rms bunch length of 9 cm, dipolar impedances only, linear bucket, ultimate intensity 1.7e11 p/bunch, transverse emittances (rms. norm.) of 2 microm**

- Landau damping threshold for positive chromaticity (headtail mode *m=1*):



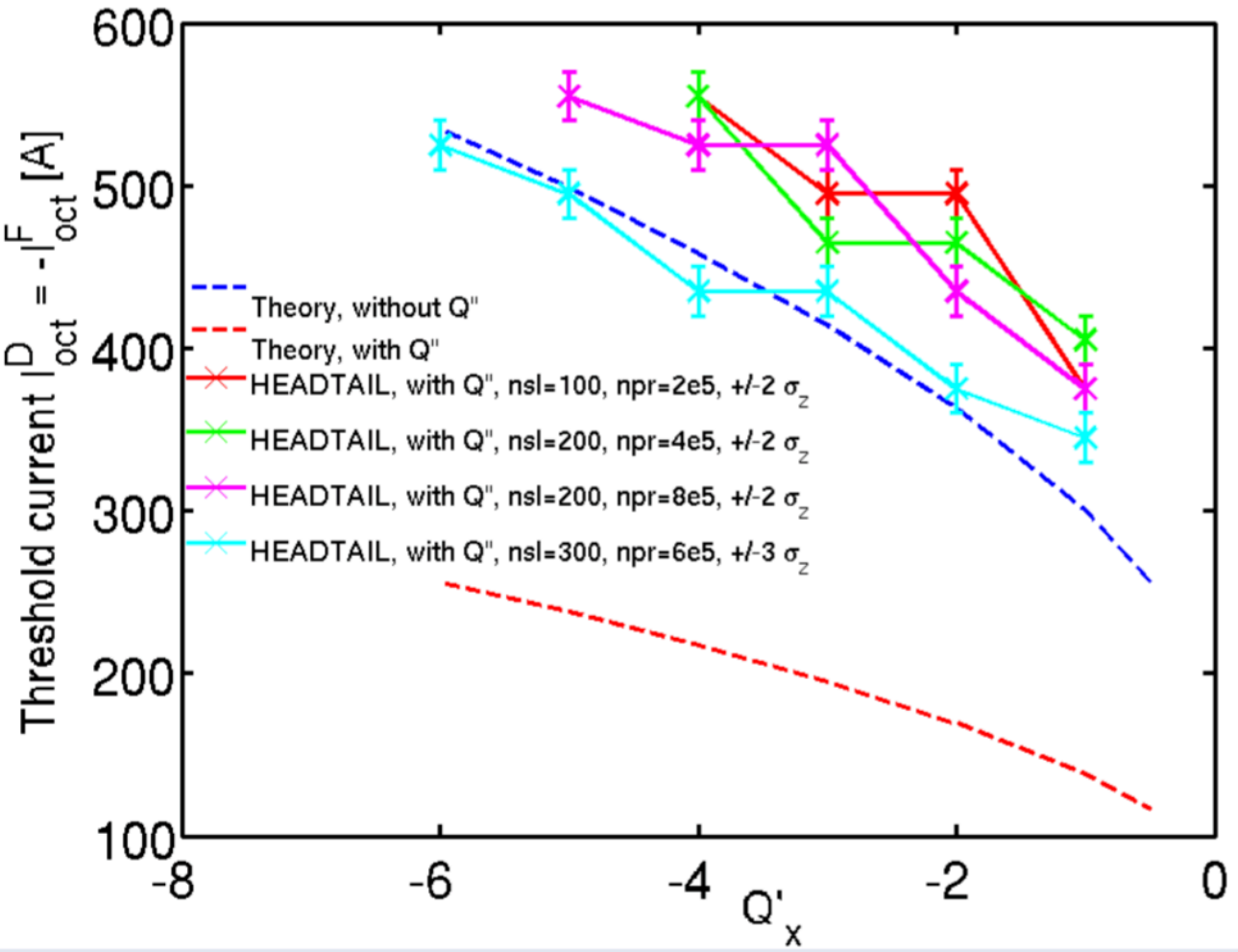
Horizontal plane (*Q''<0*)



Vertical plane (*Q''>0*)

PAST (2012) WORK ON Q'' (3/4) (NicolasM et al.)

- Landau damping threshold for $Q'_x<0$, in horizontal (headtail mode $m=0$):



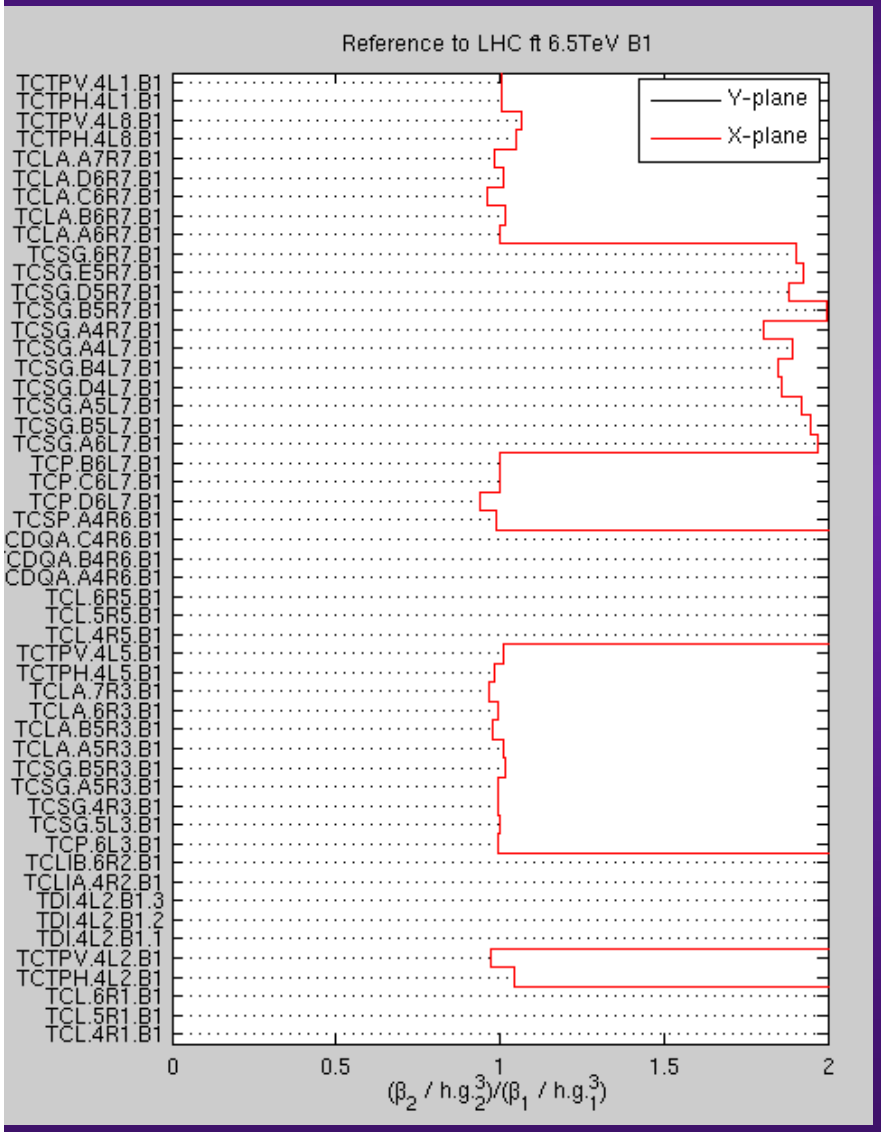
→ Higher discrepancy for $Q'_x<0$ with m=0, than for $Q'_x>0$ with $m=1$.

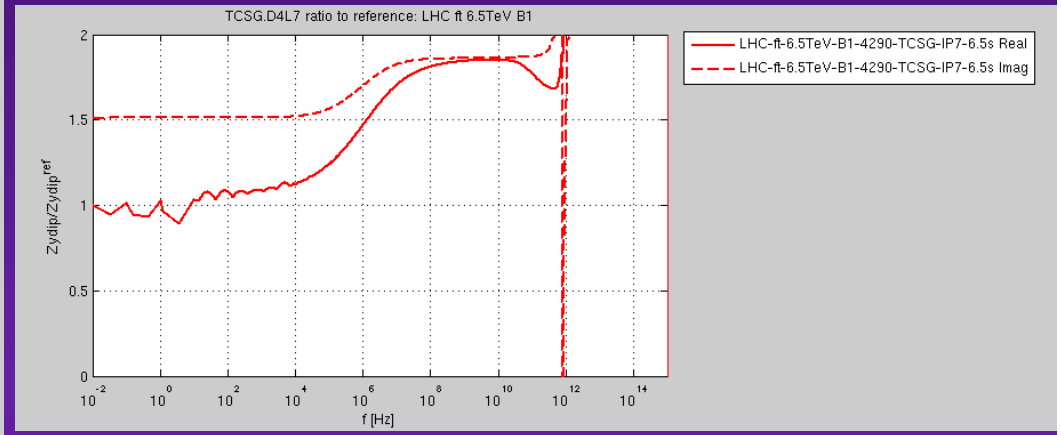
→ Number of slices and macroparticles has a rather small impact, but number of σ_z binned slightly more significant.

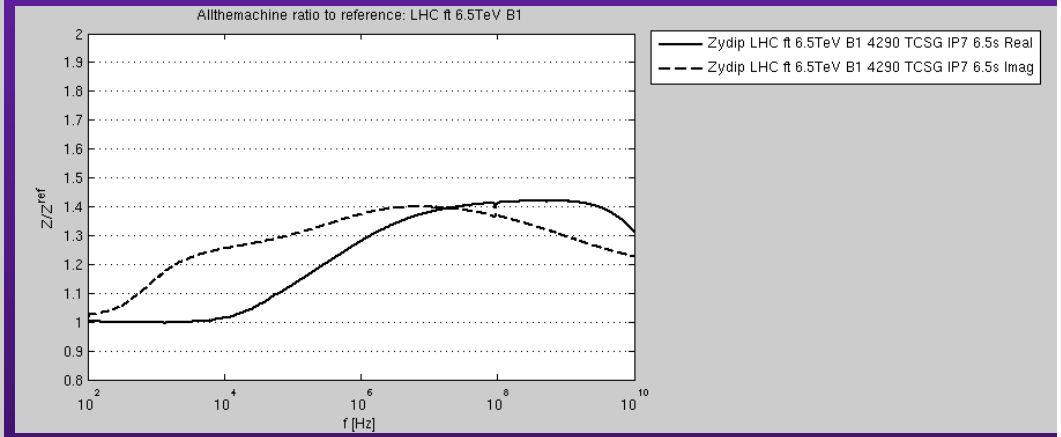
PAST (2012) WORK ON Q” (4/4)
(NicolasM et al.)

- Due to these first results, we continued to compare to the (simpler) case without Q” but this should be re-studied => Ongoing

IMPEDANCE MODEL WITH TCSGs at 8 and 6.5 σ







PAST (2012) RESULTS (1/2)

- **Operational results from 2012 (4 TeV)**
  - **~ 1.6E11 p/b within ~ 2.2 μm reached with Q' ~ 15, ~ max. (550 A) octupoles and ~ max. ADT gain (50-turn damping time)**

  => Why large loct (~ 5 times more than predicted)? And high Q'?

- **MD results with 1 (B2) full (1380 bunches) 50 ns beam**

Fill, date and time	inst. rank	energy and $\beta^*_{IP1,5}$	beam and plane	n_b	Q_x	Q_y	$4\sigma_t$ [ns]	RF volt. [MV]	Q'_x	Q'_y	Int. [10^{11} p^+/b]	ε_x [μm .rad]	ε_y [μm .rad]	τ^d_x [tr.]	τ^d_y [tr.]	foc. oct. cur. [A]	coll. settings
2744 19/06/12 23:48	1st	4TeV/c 11m	B2V	1380	64.28 ±0.001	59.31 ±0.001	1.21 ±3%	12	8.7 ±2	3.3 ±2	1.5 ±0.2	2.35 ±0.45	2.35 ±0.45	100	200	−110	physics except TCL
2771 23/06/12 19:06	1st	4TeV/c 0.6m	B2V	1380	64.31 ±0.003	59.32 ±0.003	1.24 ±5%	12	9.3 ±2	1.9 ±2	1.43 ±0.21	2.3 ±0.5	2.3 ±0.5	50	100	−19	physics except TCL
2771 23/06/12 20:21	2nd	4TeV/c 0.6m	B2V	1380	64.31 ±0.003	59.32 ±0.003	1.26 ±5%	12	−3 ±2	−7 ±2	1.4 ±0.2	2.3 ±0.5	2.3 ±0.5	50	100	−235	physics except TCL
2771 23/06/12 20:49	3rd	4TeV/c 0.6m	B2H	1380	64.31 ±0.003	59.32 ±0.003	1.26 ±5%	12	5.9 ±2	−0.9 ±2	1.4 ±0.2	2.3 ±0.5	2.3 ±0.5	50	100	−58	physics except TCL
2771 23/06/12 21:55	4th	4TeV/c 0.6m	B2V	1380	64.31 ±0.003	59.32 ±0.003	1.26 ±5%	12	2.3 ±2	0.8 ±2	1.37 ±0.2	2.3 ±0.5	2.3 ±0.5	Inf	Inf	−402	physics except TCL

PAST (2012) RESULTS (2/2)

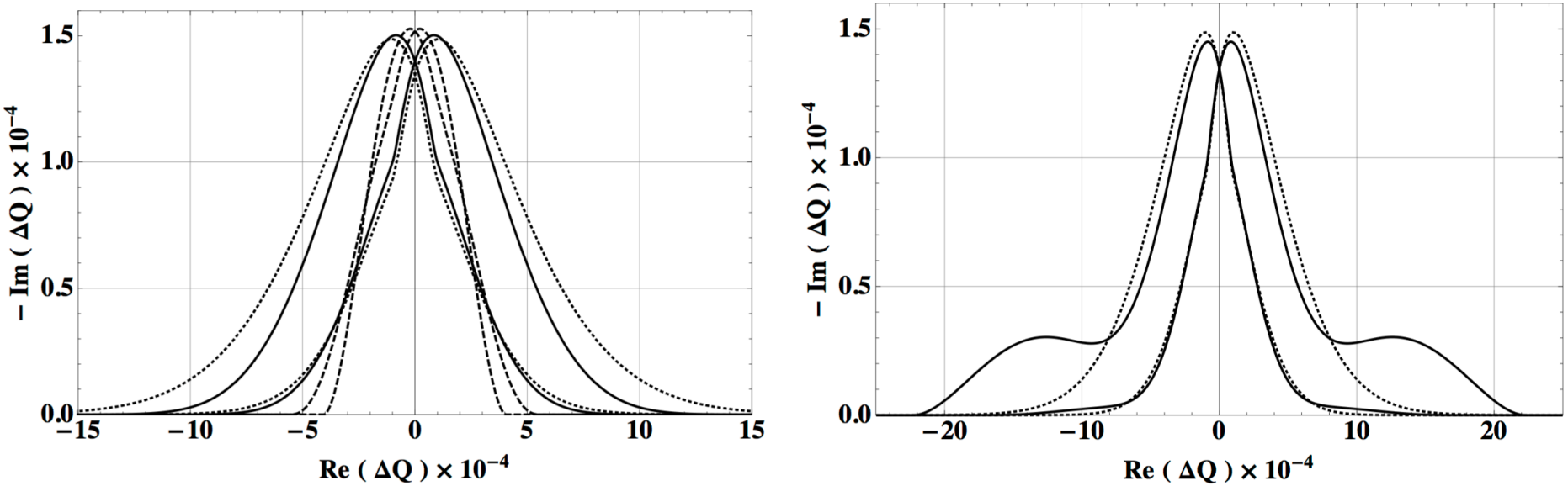


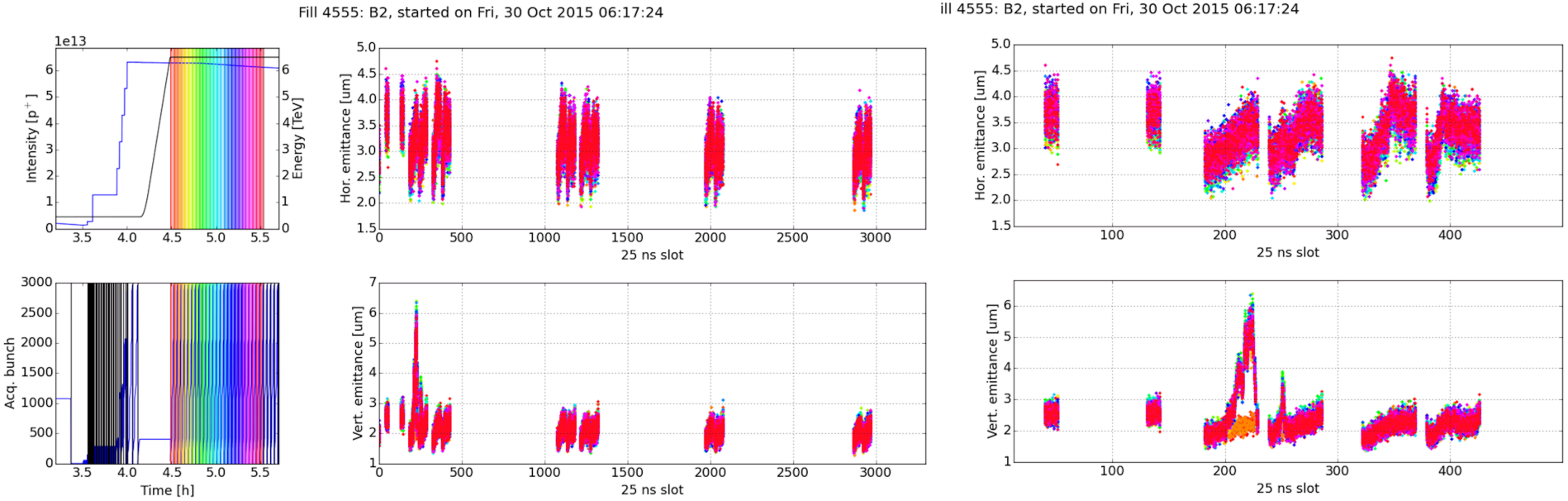
Fig. 4.8. Stability diagrams (for both positive and negative detunings a_0) for the LHC at top energy (7 TeV) with maximum available octupole strength: (Left) for the 2nd order (dashed curves), the 15th order (full curves), and the Gaussian (dotted curves) distribution; (Right) for the Gaussian distribution (dotted curve) and a distribution with more populated tails than the Gaussian (full curve).

OPERATIONAL RESULTS FROM 2015

- **6.5 TeV**
  - By the end of the 2015 run, we were operating with 2244b, Q' ~ 15 / 15, Joct ~ 550 A and ADT damping time ~ 100 turns
  - Stable beams could be reached without instabilities for intensities of ~ 1.15E11 within ~ 3.5 µm
- **Injection**
  - Scrubbing runs (until 08/08/15) => Settings at injection
  - In addition, we recommended to lower the vertical tune on 19/08/15 (LMC#231) => Optimization made + nice simulations revealed beneficial effect. More space for Q' increase, etc.
  - Some issues observed with ADT (witness bunches blow-up,...)
  - Some observations of larger coupling strength (C^-) or closer tune distance when instability issues at injection… To be followed up

TEST WITH BCMS BEAM

- **Before the test:** stable 2244 b beam
- **After the test:** stable 2244 b beam
- **BCMS test (with same parameters as for operational beam with 2244 b) on Fill #4555 (on 30/10/15) with ~ 600 b, ~ 1.1E11 within ~ 1.5 – 2 µm:** Instabilities seen in B1H at beginning of ramp, B2V during squeeze and B2H during stable beams



PREDICTIONS before 2015… with partial past knowledge...

- For LOF > 0 (would be better for LOF < 0)
- ~ maximum ADT gain (50 turns) + high chromaticity (~ + 15 units)
- For constant collimators setting in mm