RECOMMENDATIONS FOR THE CHROMATICITIES, OCTUPOLES' CURRENTS AND BUNCH LENGTH TO BE USED DURING THE 2012 RUN

Elias Métral and Benoit Salvant, Hugo Day, Nicolas Mounet

- **Recommended values vs. the ones of 2011**
- **MKI and ALFA**
- **Proposed scenario to decide on and change the bunch length**
- **2 questions were also raised by Stephane Fartoukh and answered:**
  - **Effect of the phase advance between localized impedance sources**
  - **Effect of Q" on the beam stability**
- **Summary and next steps**

RECOMMENDED VALUES VS. ONES OF 2011

	Used at the end of 2011	Proposed value for 2012
Chromaticities	~ + 2	~ + 1 (≥ 0, as low as possible)
Octupoles's current [A]: IoctD = - IoctF	200	~ 450
Rms bunch length [cm] (4-sigma bunch length [ns])	9 (1.2)	~ 10 (~ 1.35)

Minimizes the amount of octupoles needed and better for beam lifetime

As the complex tune shift with the tight collimators' settings will be ~ 2.3 times higher

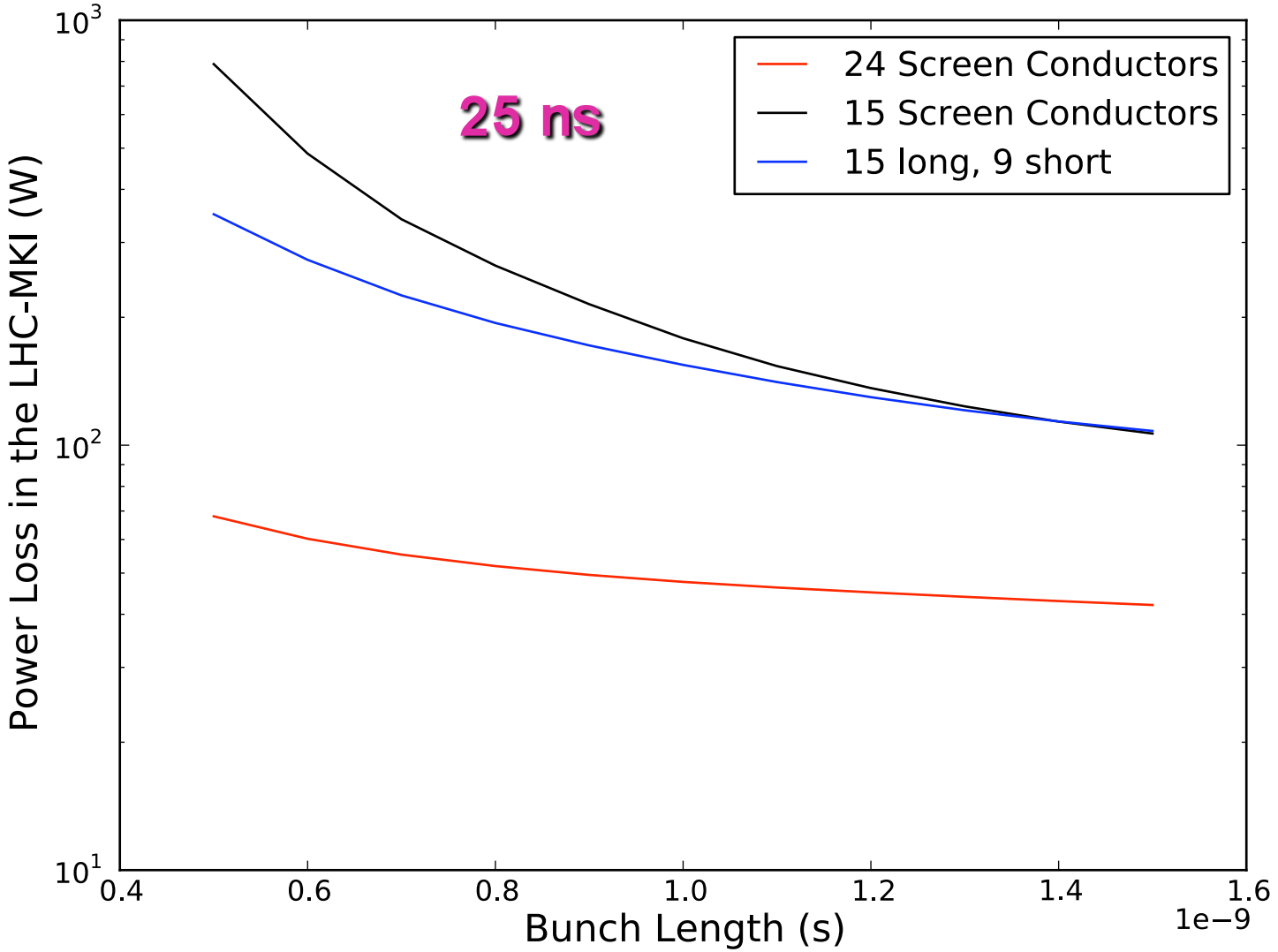
After we reached the same performance as last year with the same bunch length (for RF heating reason with MKI mainly)

MKI (1/3)

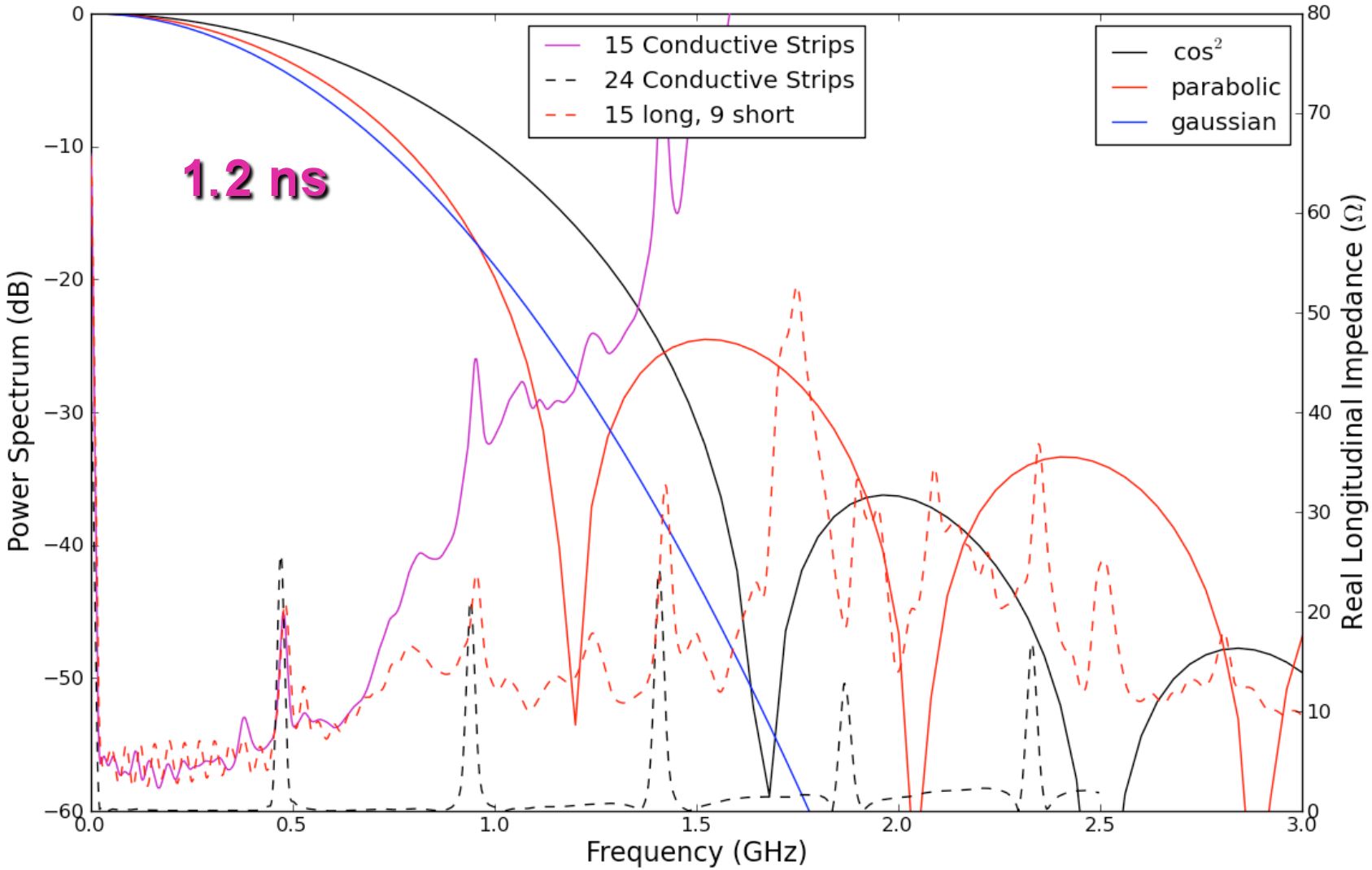
- **Effect of bunch length on power loss (for parabolic distribution):**
  - **1.15E11 p/b => Power scales with the square => It would be 1.7 times higher for 1.5E11 p/b**
  - **=> Small effect of bunch length but goes in the good direction (see also next slide) => The longer the bunch the better**

	25ns		50ns	
	1.1ns (W)	1.2ns (W)	1.1ns (W)	1.2ns (W)
24 Screen Conductors	44	43	17	16
15 Screen Conductors	150	133	78	68
No Screen Conductors	4817	3703	3067	2663
15 long, 9 short	138	127	69	62
No Metalisation	47660	40637	30187	27841
No Damping Ferrites	28	27	15	14
No Screen	4904	4314	3120	2745
Alt Screen 1	75	74	33	33

MKI (2/3)


25 ns
24 Screen Conductors
15 Screen Conductors
15 long, 9 short
Power Loss in the LHC-MKI (W)
10^3
10^2
10^1
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1e−9
Bunch Length (s)

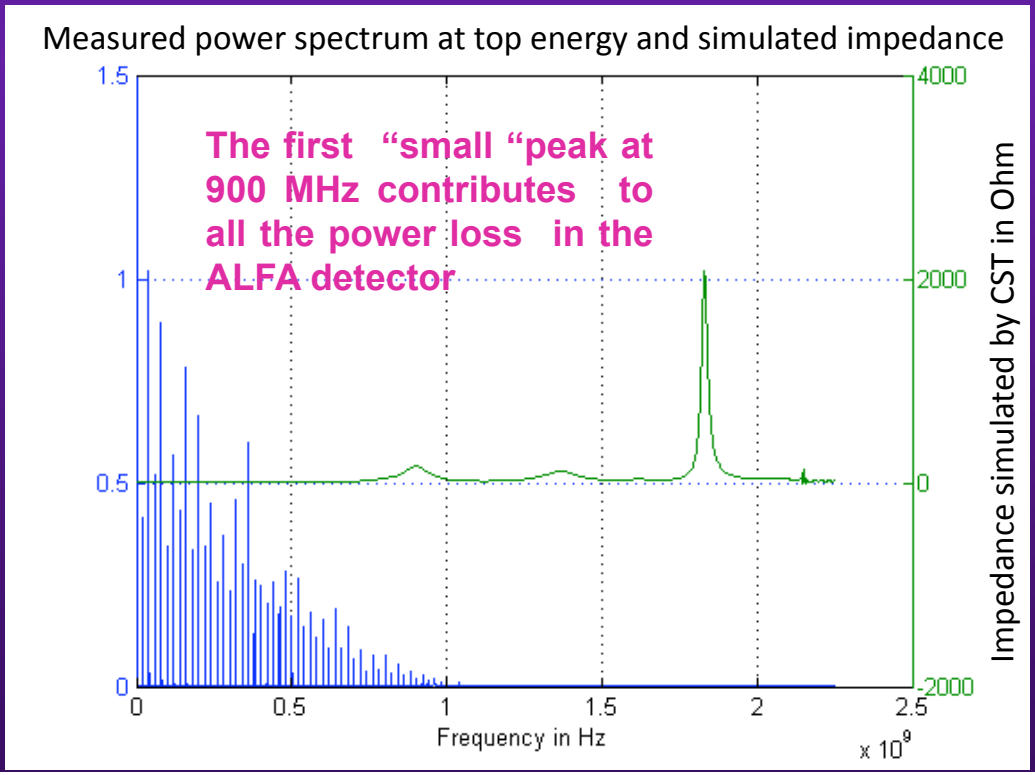
MKI (3/3)


15 Conductive Strips
24 Conductive Strips
15 long, 9 short
cos^2
parabolic
gaussian
1.2 ns
Power Spectrum (dB)
Real Longitudinal Impedance (Ω)
Frequency (GHz)
0
−10
−20
−30
−40
−50
−60
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0

ALFA (1/2)

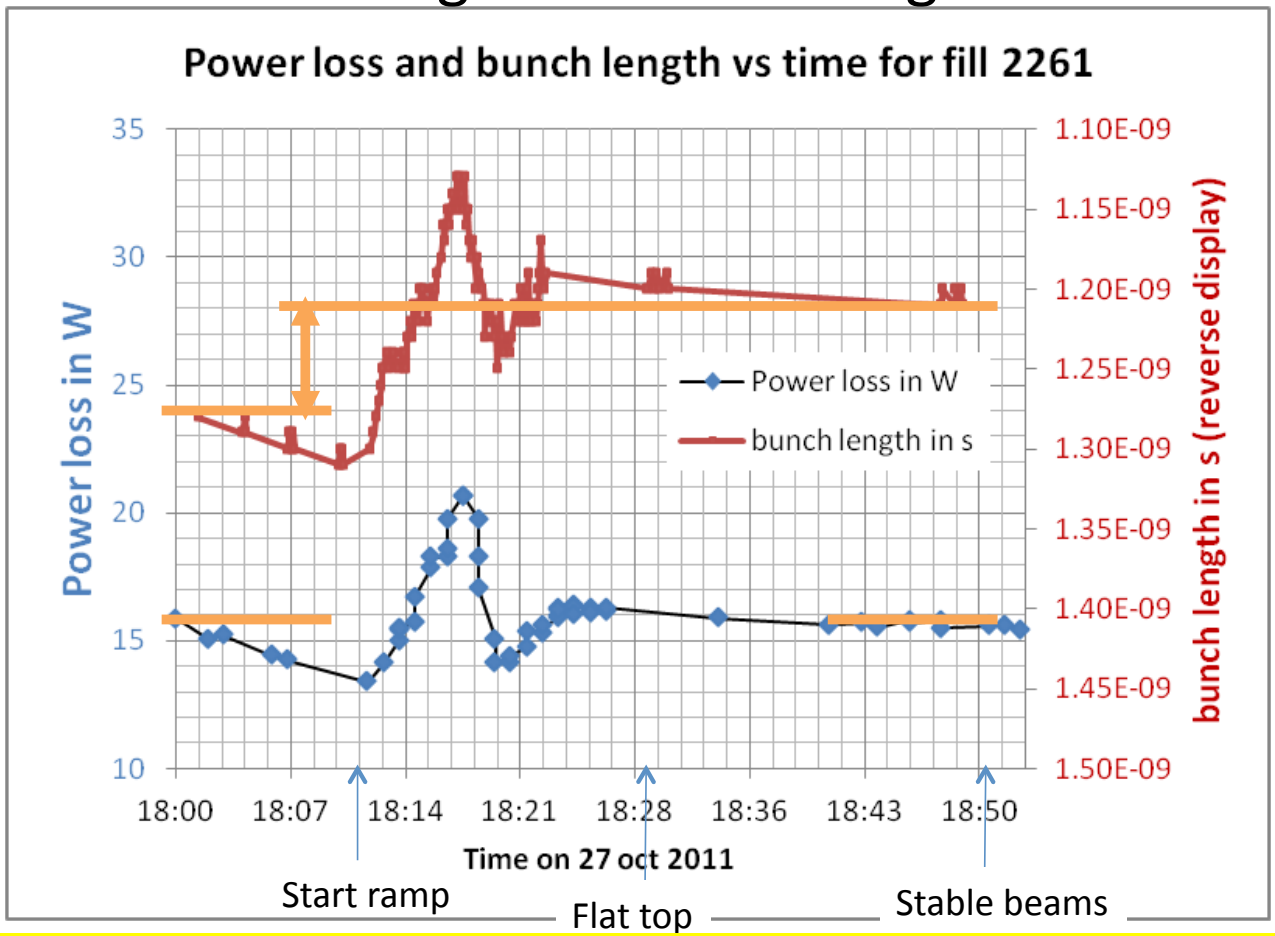
- **See last talk by BenoitS: https://impedance.web.cern.ch/impedance/documents/Bsalvant%20-%20Update%20of%20the%20heating%20of%20ALFA%20detector%20v4-Feb2012.pptx:**

  => Bunch length increase could help (10 to 30% heat load decrease are expected with coarse extrapolation), but it will also strongly depend on the longitudinal bunch distribution



ALFA (2/2)

Scaling with bunch length?



Comparing before and after the ramp → 0.05 ns decrease in bunch length seems have no impact on power loss → Not only the bunch length matters but also the distribution (blow up…).

=> We could try and decrease the power spectrum near ~ 900 MHz…

PROPOSED SCENARIO TO DECIDE ON AND CHANGE THE BUNCH LENGTH

- **PhilippeB's email to MikeL on 19/02 (I also agree):**
  - **We start with 2011 settings and ramp intensity back to "best achieved 2011" (of course if heating limits the intensity increase we re-consider longer bunches immediately)**
  - **When conditions are stable, at end 2011 intensity, we try a few fills with longer (1.35-1.4 ns) and shorter (1.1-1.15 ns) bunches to evaluate the consequences in term of luminosity and machine heating**
  - **We settle to a bunch length figure for the rest of the run**

Can we also try, for the same bunch length, to modify the longitudinal distribution?

EFFECT OF THE PHASE ADVANCE BETWEEN LOCALIZED IMPEDANCE SOURCES

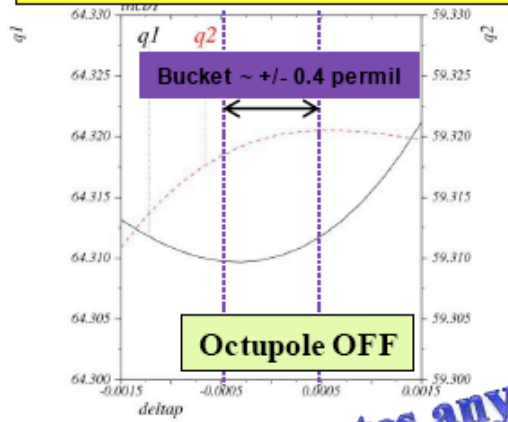
- There is none, as done in the past (see http://indico.cern.ch/getFile.py/access?resId=0&materialId=minutes&confId=178918) => This was checked by reviewing the theory (in particular from Alexey Burov) and performing HEADTAIL simulations by Nicolo Biancacci et al.

- The physical picture should be that when moving from one interaction point to the next one, both source and witness particles accumulate the same phase advance, making the overall mutual effect between them independent of it

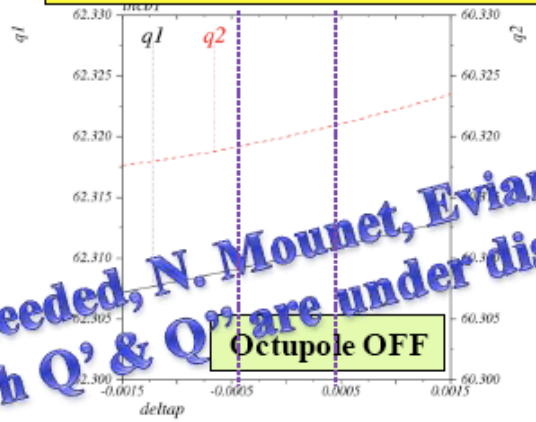
EFFECT OF Q'' ON THE BEAM STABILITY (1/6)

Other concerns: **Tune vs. δ_p** possibly impacting on **collective effects, sensitivity to RF trims, resonances,…**

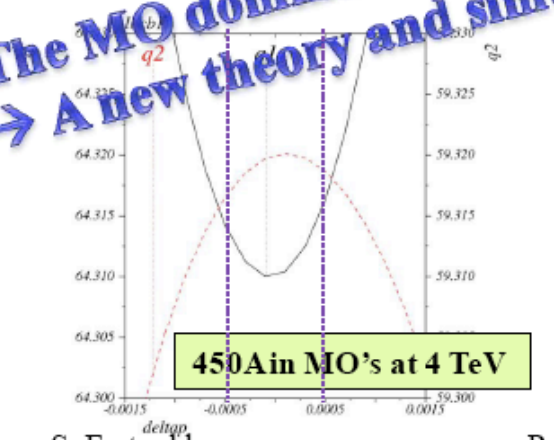
Nominal optics @ β*=60 cm

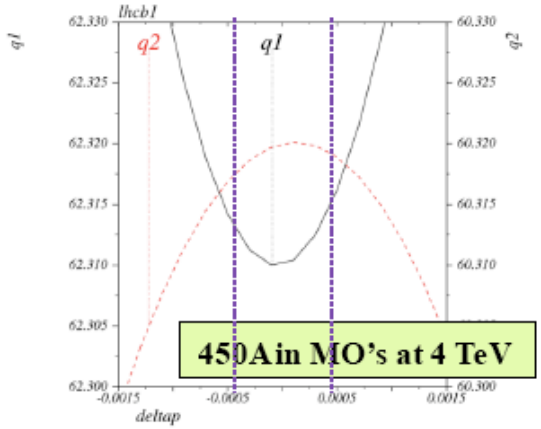


ATS (pre-squeeze) @ β*=60 cm



The MO dominates anyway (450 A needed, N. Mounet, Evian 2011)
→ A new theory and simulations with Q' & Q'' are under discussion





S. Fartoukh Perf. Workshop, Chamonix2012

EFFECT OF Q" ON THE BEAM STABILITY (2/6)

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

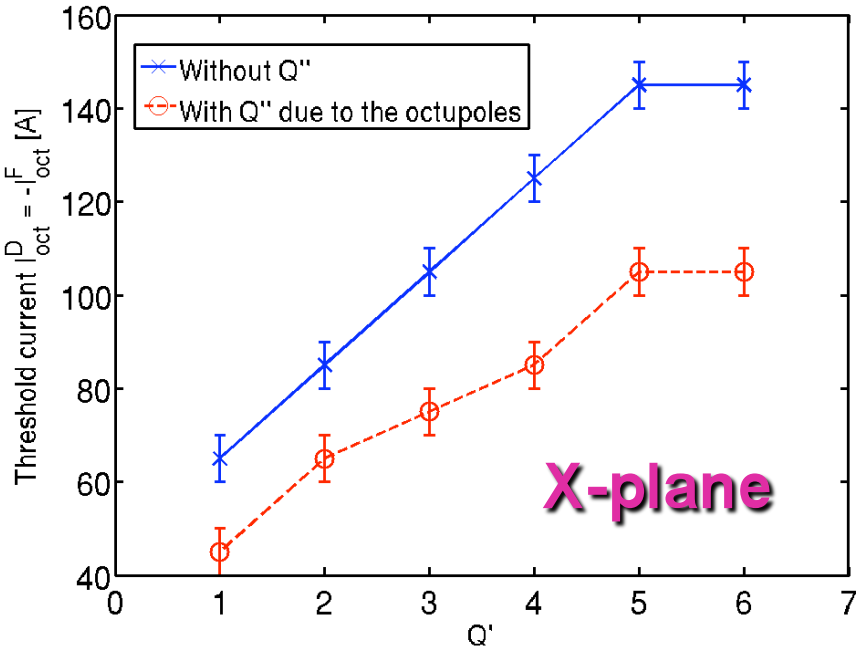
$$Q''_{x,y} = \pm \frac{1}{4\pi} \int ds\, \beta_{x,y}\, D_x^2\, K_3^+$$

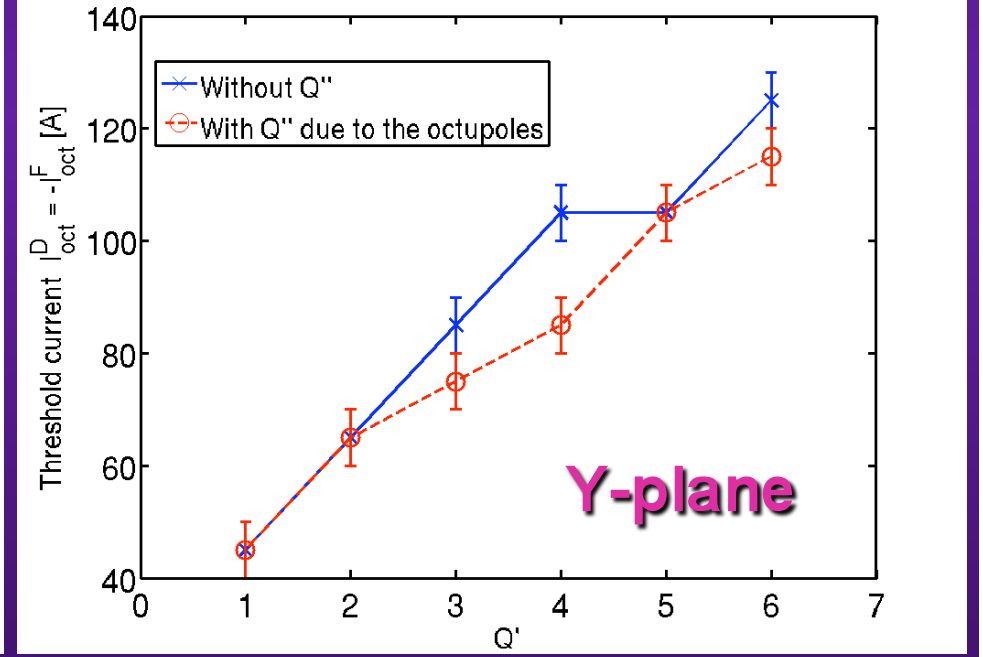
  - Q_x" = - 36000 for 450 A in the (D) octupoles at 4 TeV
  - Q_y" = + 15000 for 450 A in the (D) octupoles at 4 TeV

- Note that some tests have already been performed last year with high octupole currents (without noticeable detrimental effects => Still to be checked…):
  - 300 A, 48 bunches, 1.2E11 p/bunch (08/05/2012),
  - 350 A, 2 bunches, 1e11 p/bunch (07/05/2012).

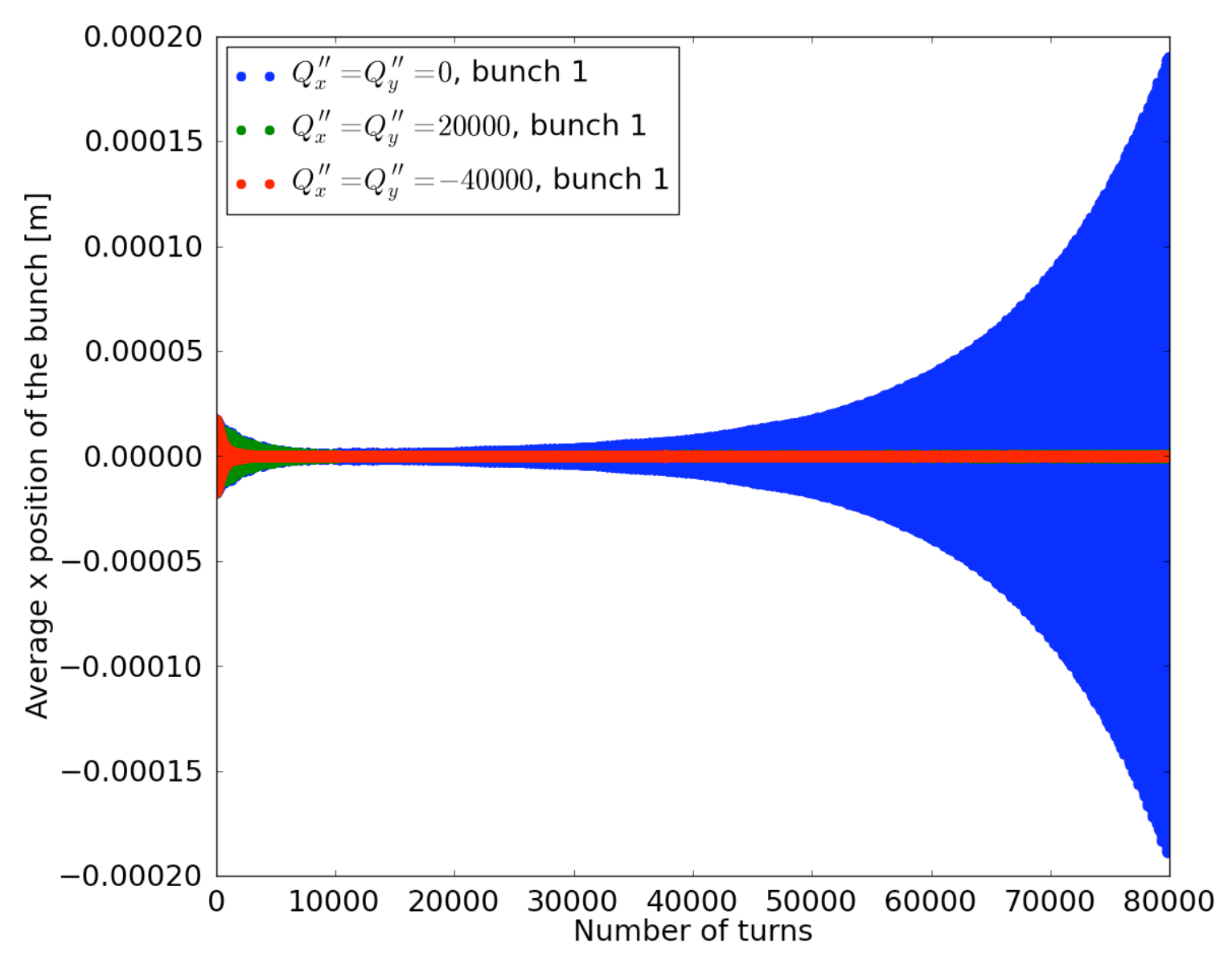
EFFECT OF Q" ON THE BEAM STABILITY (3/6)

- **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 => Nicolas Mounet**

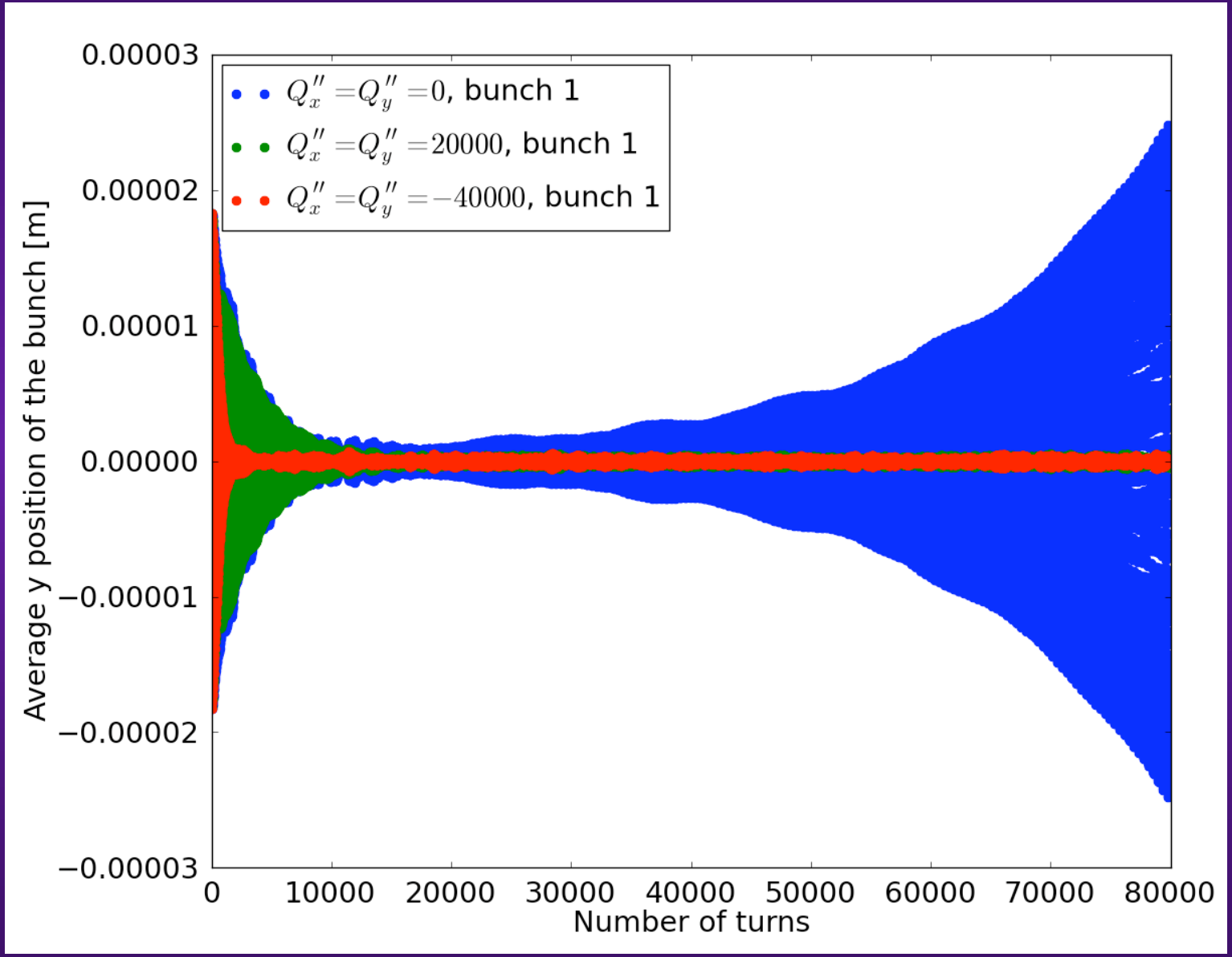




EFFECT OF Q" ON THE BEAM STABILITY (4/6)



EFFECT OF Q" ON THE BEAM STABILITY (5/6)



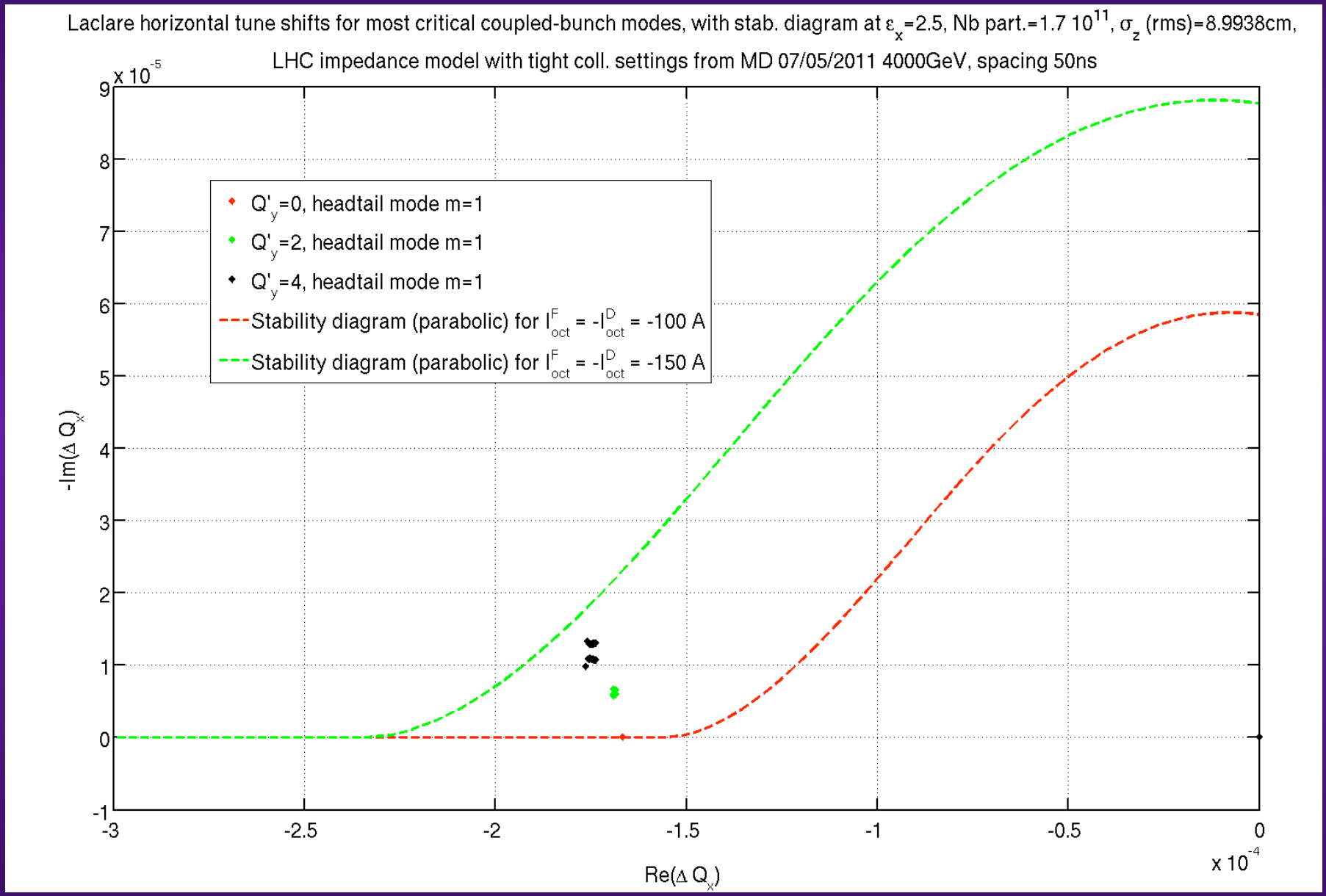
EFFECT OF Q" ON THE BEAM STABILITY (6/6)

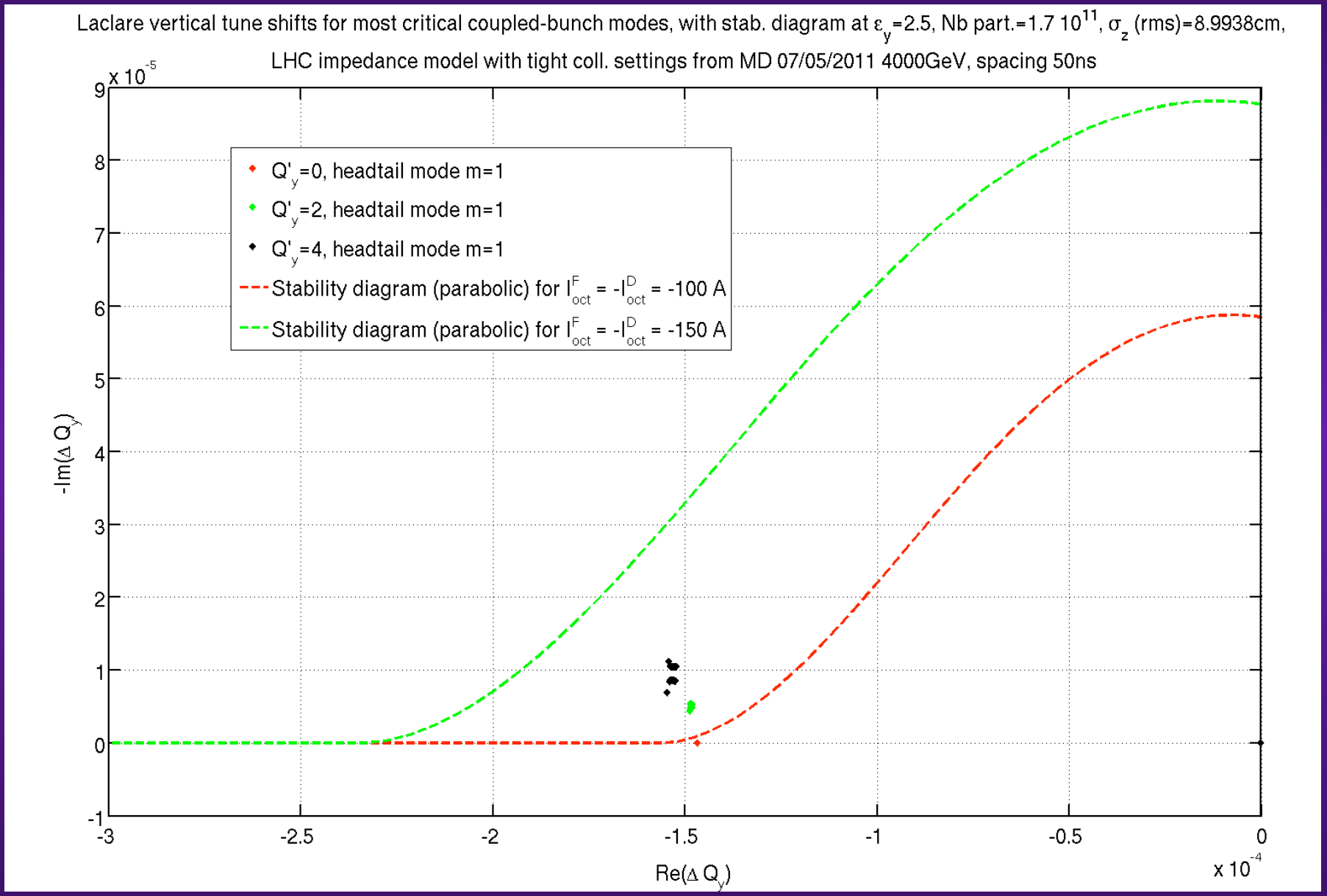
- **Conclusions**
  - **Only a beneficial effect is observed (as was expected with the simple picture of an increase of the Landau damping through the nonlinearities but was good to check… can depend on the mode, the sign etc…)**
  - **Next step: detailed comparison with theory (dispersion relation including the effect of Q"…) => Nicolas Mounet and Alexey Burov**

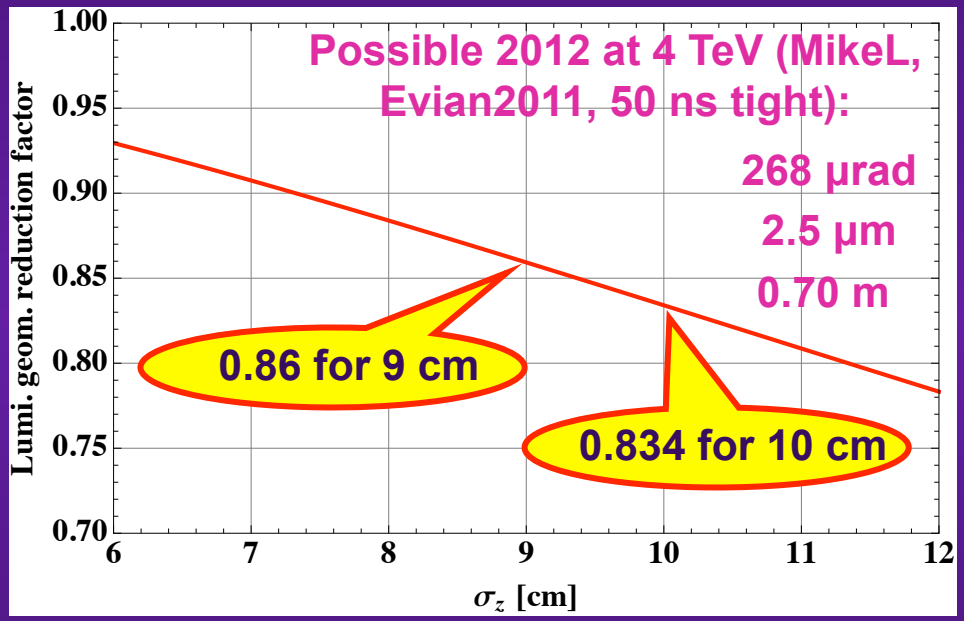
SUMMARY AND NEXT STEPS

- Follow-up during the year, in particular when the tight collimators' settings will be commissioned and the bunch current increased (heating)
- Try and understand which octupole current is really needed at top energy in stable condition but without beam-beam as we predict a much smaller value (with new model etc.) => Higher impedance than expected (transverse trapped modes?)? More critical transverse profiles at some point(s)? Transient effects on Q' or other parameters? Etc.
- Try and understand better the effect of space charge (in particular at injection) and beam-beam (in stable beams) on the beam stability
- Continue our studies on the sign of Q' and effect of Q" on the beam stability
- Etc.

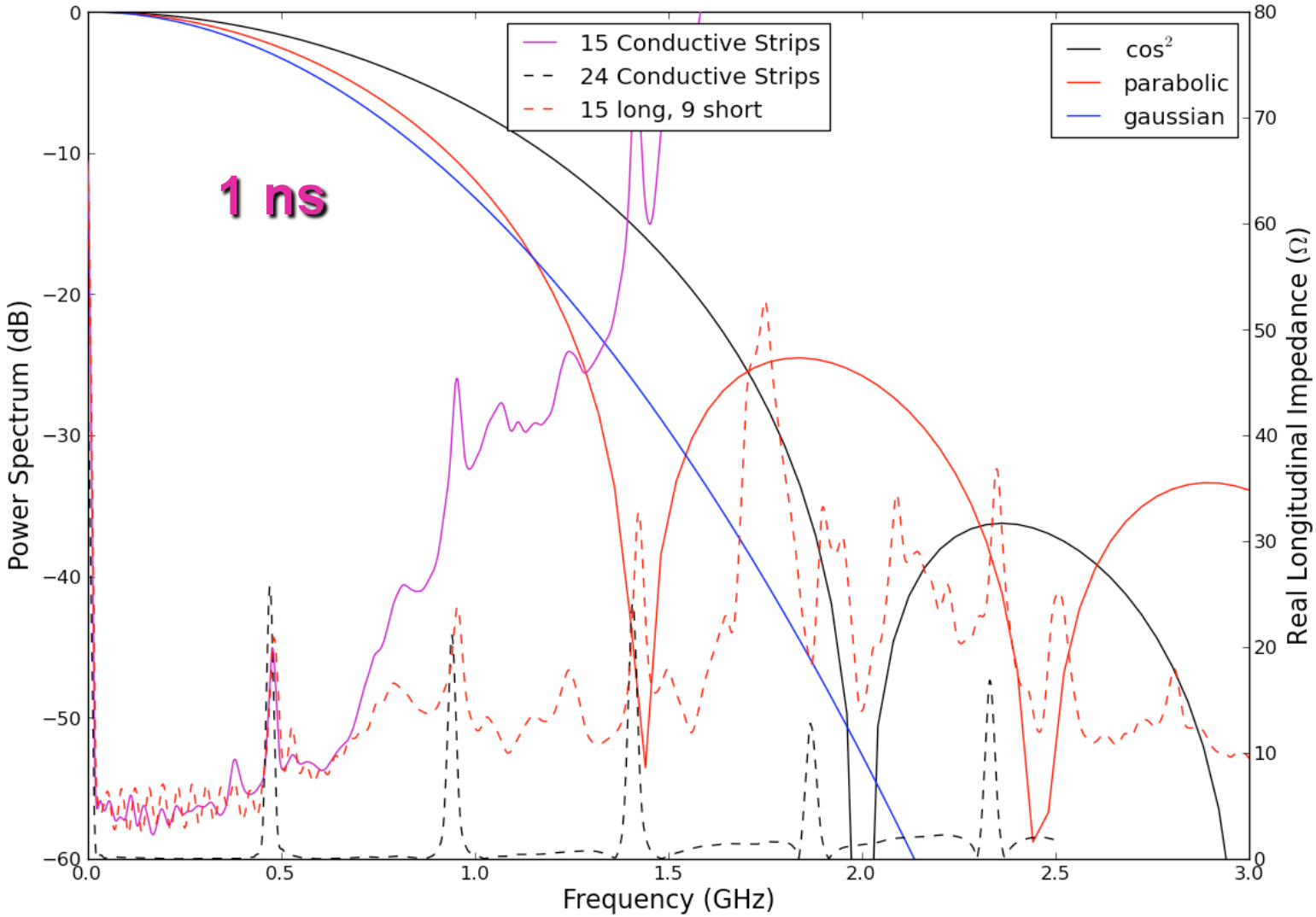
APPENDIX

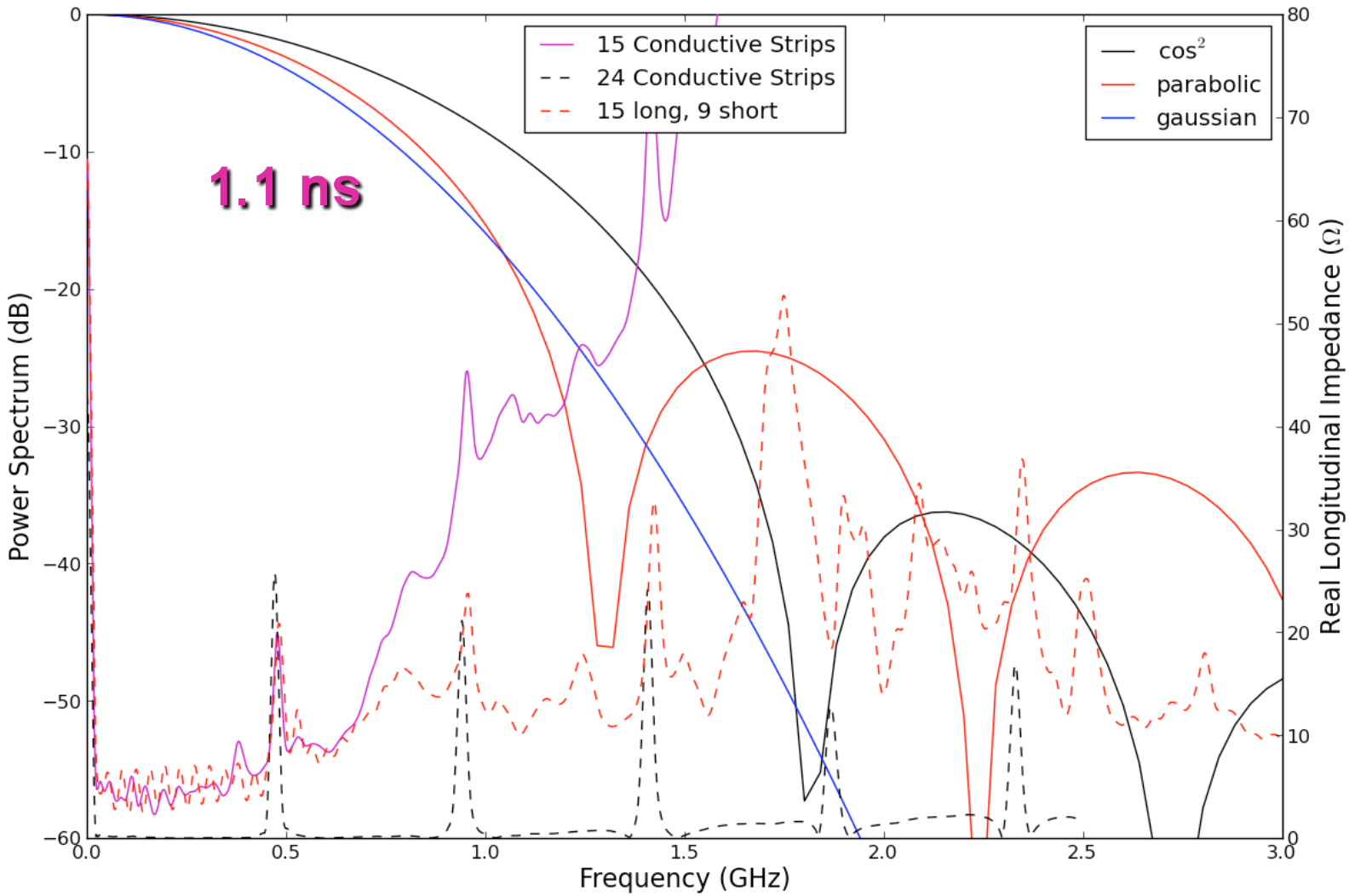

Laclare horizontal tune shifts for most critical coupled-bunch modes, with stab. diagram at ε_x=2.5, Nb part.=1.7 10^{11}, σ_z (rms)=8.9938cm,
LHC impedance model with tight coll. settings from MD 07/05/2011 4000GeV, spacing 50ns
x 10^{-5}
Q'_y=0, headtail mode m=1
Q'_y=2, headtail mode m=1
Q'_y=4, headtail mode m=1
Stability diagram (parabolic) for I^F_{oct} = -I^D_{oct} = -100 A
Stability diagram (parabolic) for I^F_{oct} = -I^D_{oct} = -150 A
-Im(Δ Q_x)
Re(Δ Q_x)
x 10^{-4}
9
8
7
6
5
4
3
2
1
0
-1
-3
-2.5
-2
-1.5
-1
-0.5
0

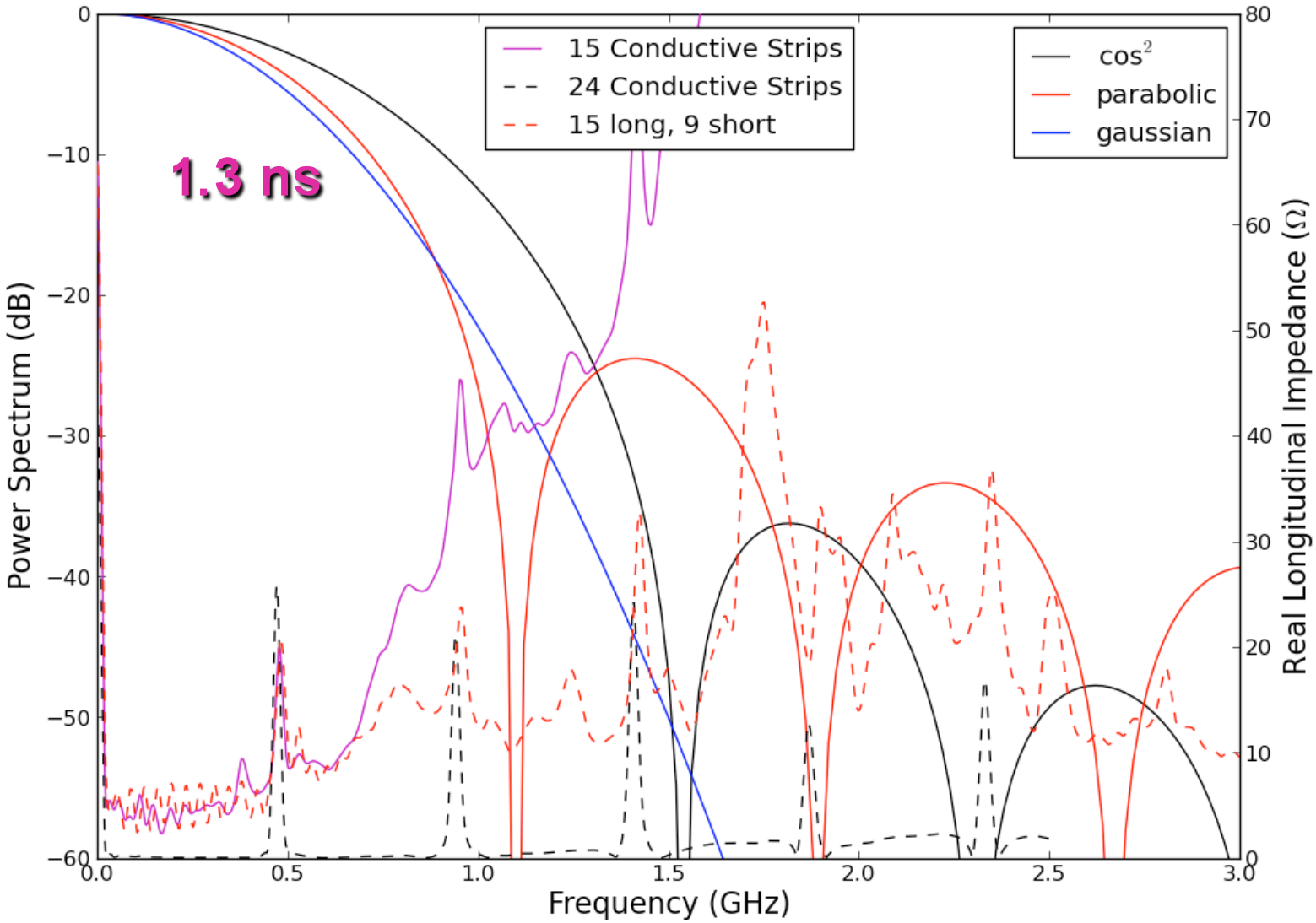

Laclare vertical tune shifts for most critical coupled-bunch modes, with stab. diagram at ε_y=2.5, Nb part.=1.7 10^11, σ_z (rms)=8.9938cm,
LHC impedance model with tight coll. settings from MD 07/05/2011 4000GeV, spacing 50ns
x 10^-5
9
8
7
6
5
4
3
2
1
0
-1
-Im(Δ Q_y)
Q'_y=0, headtail mode m=1
Q'_y=2, headtail mode m=1
Q'_y=4, headtail mode m=1
Stability diagram (parabolic) for I^F_oct = -I^D_oct = -100 A
Stability diagram (parabolic) for I^F_oct = -I^D_oct = -150 A
-3
-2.5
-2
-1.5
-1
-0.5
0
Re(Δ Q_y)
x 10^-4

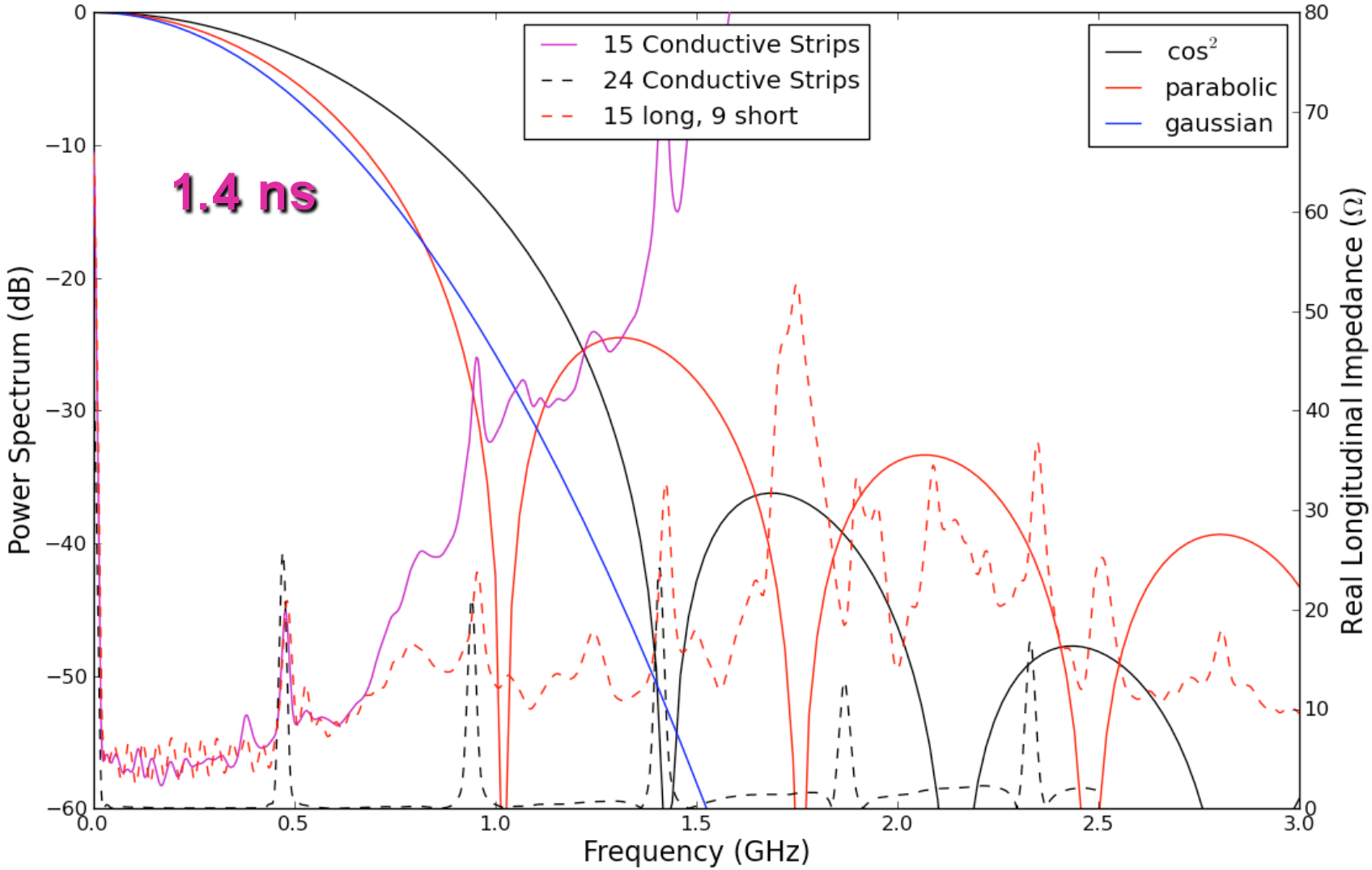


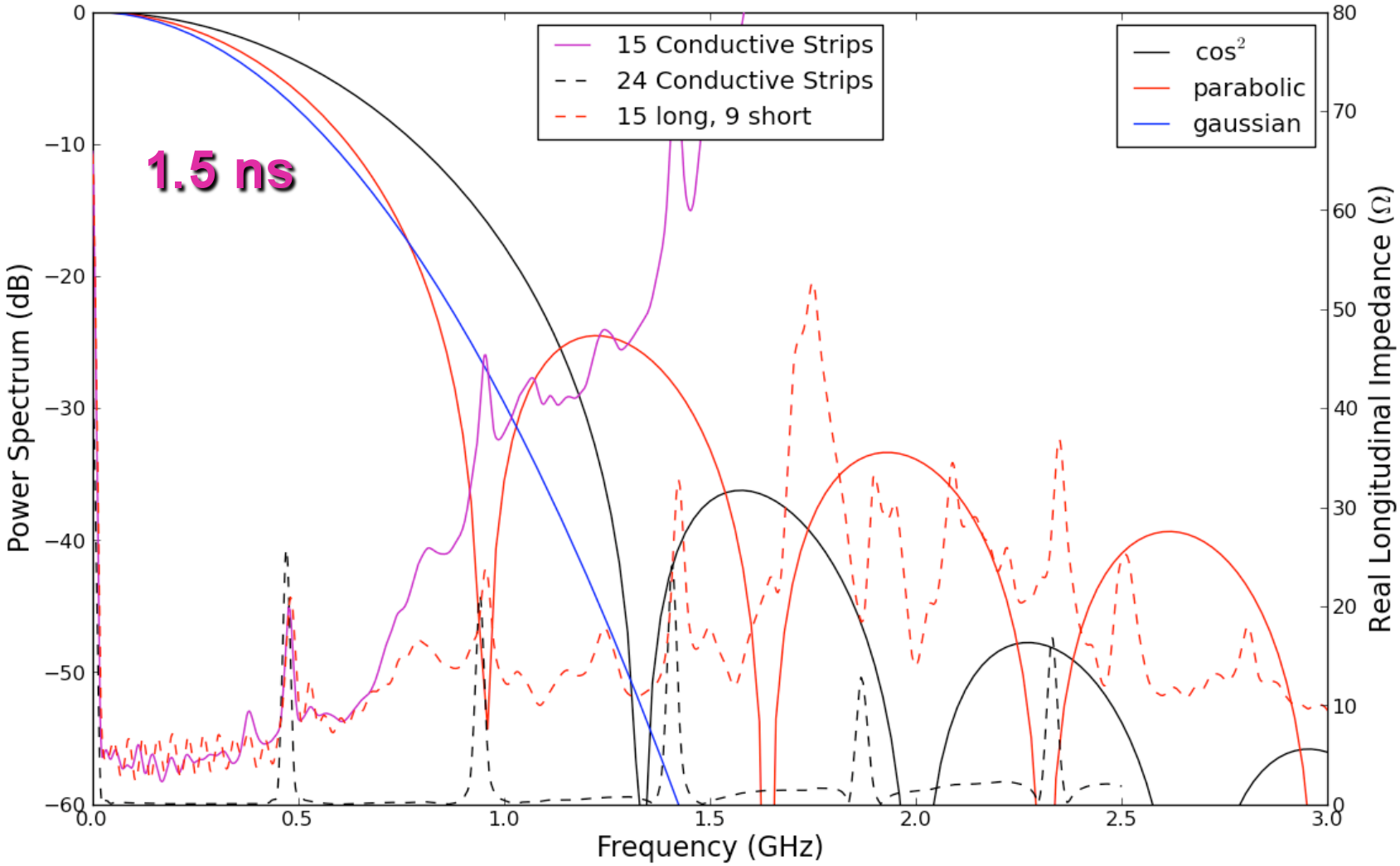
$$F = 1/\sqrt{1+\left(\frac{\theta_c \sigma_z}{2\sigma^*}\right)^2}$$


15 Conductive Strips
24 Conductive Strips
15 long, 9 short
cos^2
parabolic
gaussian
1 ns
Power Spectrum (dB)
Real Longitudinal Impedance (Ω)
Frequency (GHz)
0
−10
−20
−30
−40
−50
−60
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0


15 Conductive Strips
24 Conductive Strips
15 long, 9 short
cos^2
parabolic
gaussian
1.1 ns
Power Spectrum (dB)
Real Longitudinal Impedance (Ω)
Frequency (GHz)
0
−10
−20
−30
−40
−50
−60
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0


15 Conductive Strips
24 Conductive Strips
15 long, 9 short
cos^2
parabolic
gaussian
1.3 ns
Power Spectrum (dB)
Real Longitudinal Impedance (Ω)
Frequency (GHz)
0
−10
−20
−30
−40
−50
−60
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0


15 Conductive Strips
24 Conductive Strips
15 long, 9 short
cos^2
parabolic
gaussian
1.4 ns
Power Spectrum (dB)
Real Longitudinal Impedance (Ω)
Frequency (GHz)
0
−10
−20
−30
−40
−50
−60
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0


15 Conductive Strips
24 Conductive Strips
15 long, 9 short
cos^2
parabolic
gaussian
1.5 ns
Power Spectrum (dB)
Real Longitudinal Impedance (Ω)
Frequency (GHz)
0
−10
−20
−30
−40
−50
−60
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0