# Collimator impedance

N. Mounet, E. Métral, B. Salvant

R. Bruce, S. Redaelli, B. Salvachua, G. Valentino

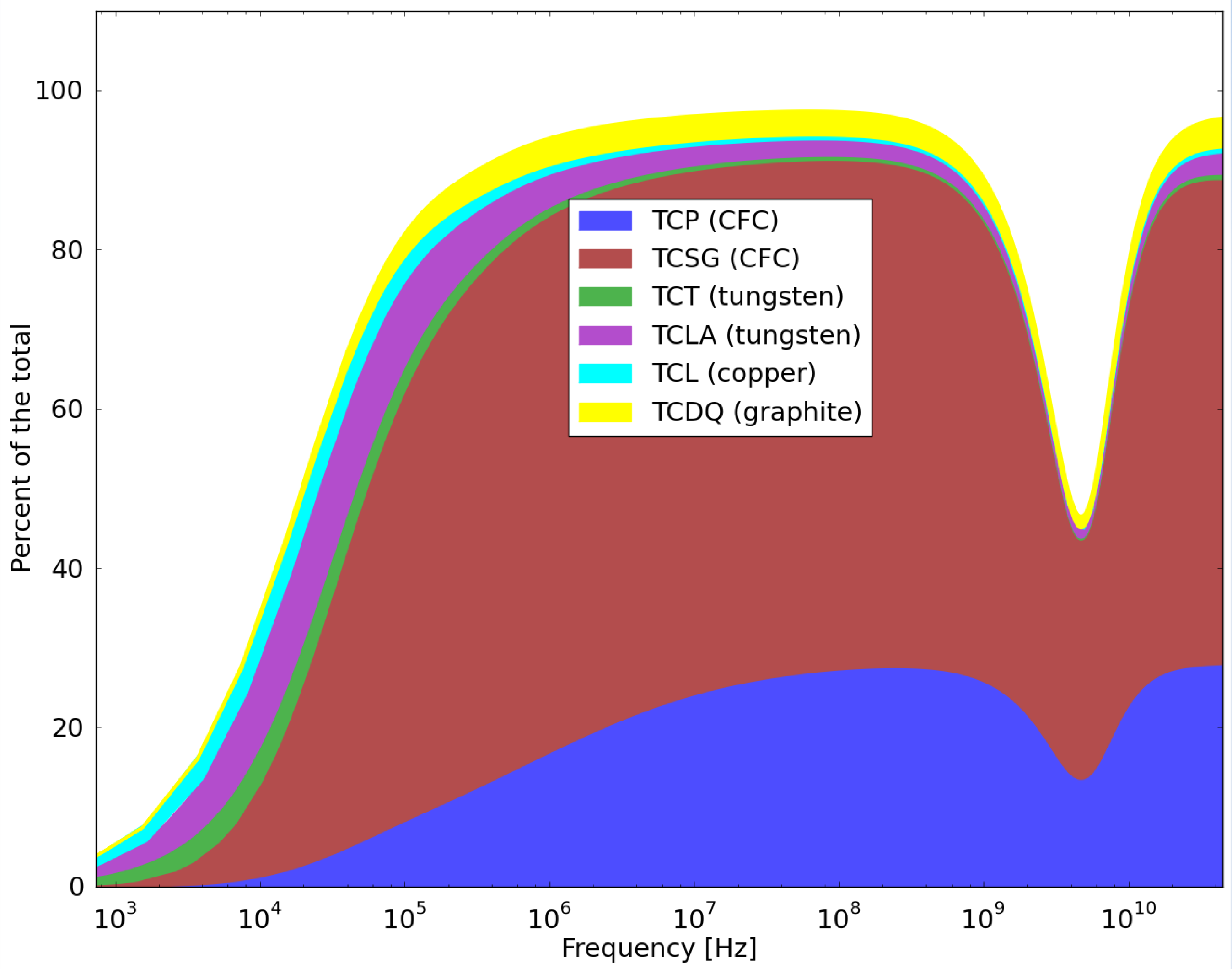
Acknowledgements: G. Arduini, A. Bertarelli, X. Buffat, K. Li, T. Pieloni, G. Rumolo, S. White, M. Zobov, collimation team, LHC operation, BI.

# Collimator impedance

- Review of collimator impedance & single-beam limits in 2012
- Post-LS1 resistive-wall impedance for several collimator scenarios and impact on beam stability
- Possible improvements with molybdenum coating
- Resistive-wall contribution of the dispersion suppressor collimators
- Impact of TCTP mode at 100 MHz
- Conclusions

# Introduction: contribution of various collimator families to total ”2012 - 4TeV” impedance (1/2)

- Real part of the impedance: relative contribution of collimator families to total impedance model (vertical dipolar, 4 TeV, 2012 settings):

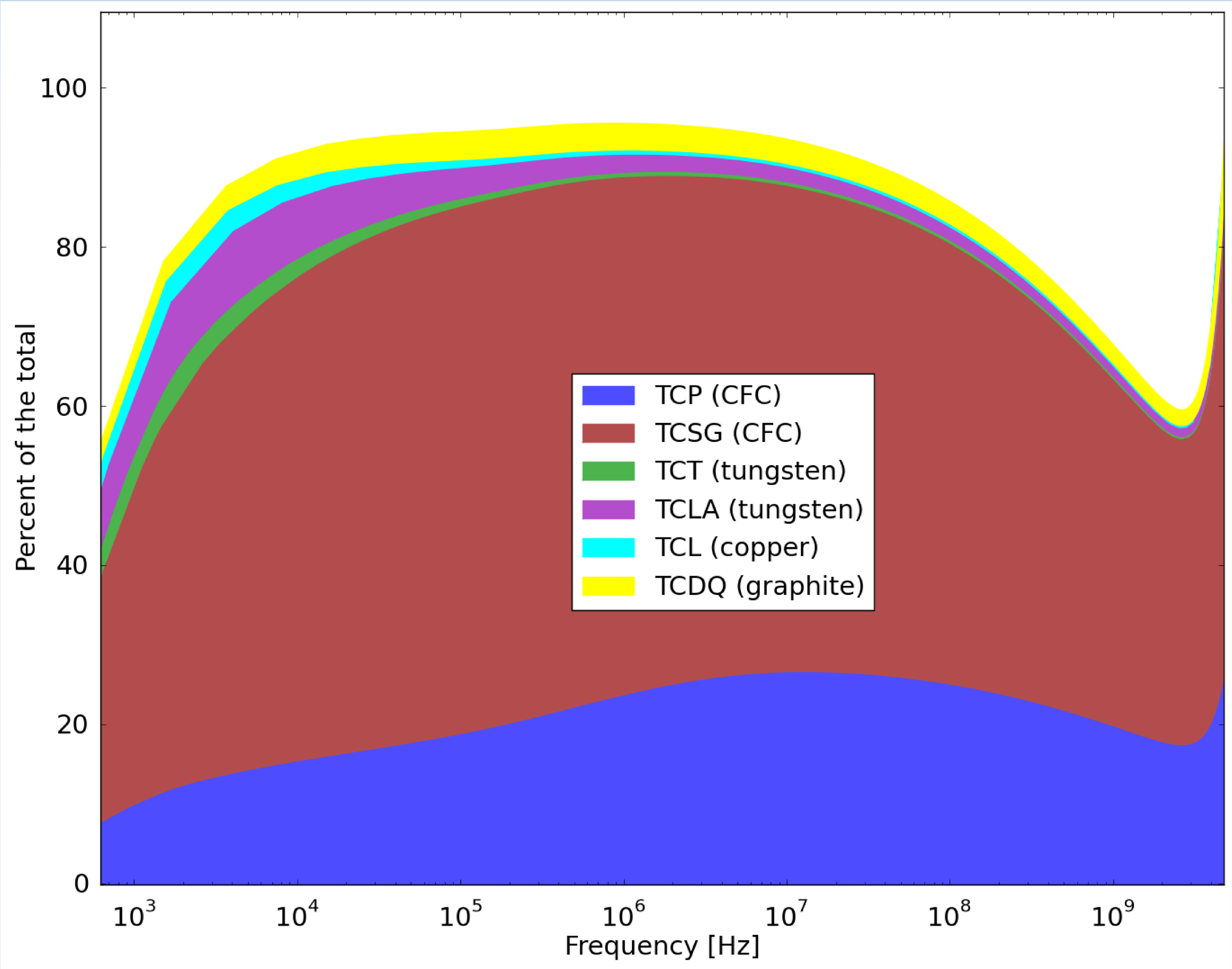



⇒ TCSG and TCP are largely dominant.

Note: this is similar in horizontal.

# Introduction: contribution of various collimator families to total "2012 - 4TeV" impedance (2/2)

- Imag. part of the impedance: relative contribution of collimator families to total impedance model (vertical dipolar, 4 TeV, 2012 settings):

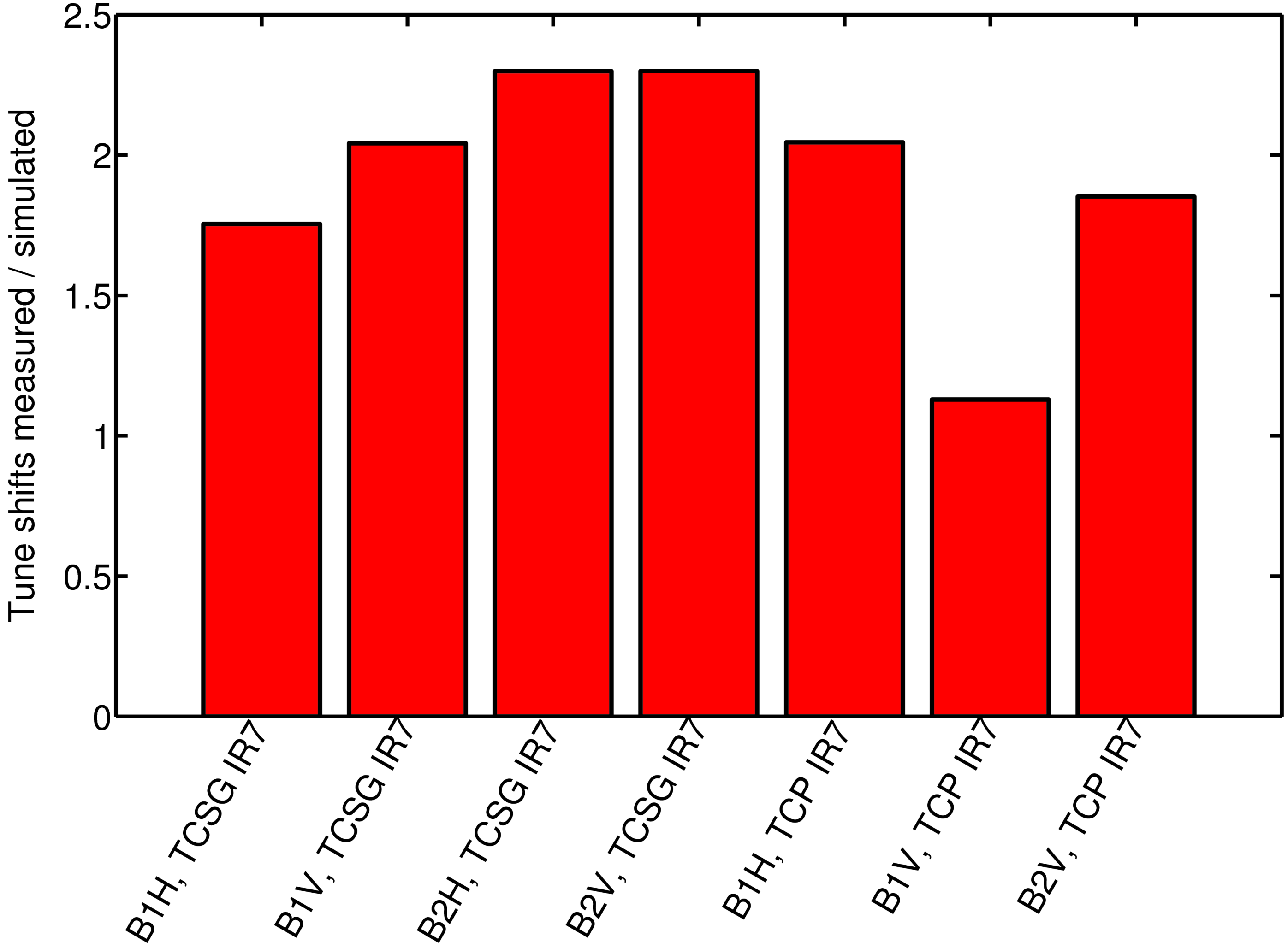



⇒ TCSG and TCP are largely dominant.

Note: this is similar in horizontal.

# Evaluation of the LHC impedance model w.r.t beam-based measurements

- Tune shifts measurements when moving collimator families at 4TeV (*Q' ~ 1-5*)
  → compare tune slope w.r.t. intensity between simulations & measurements:

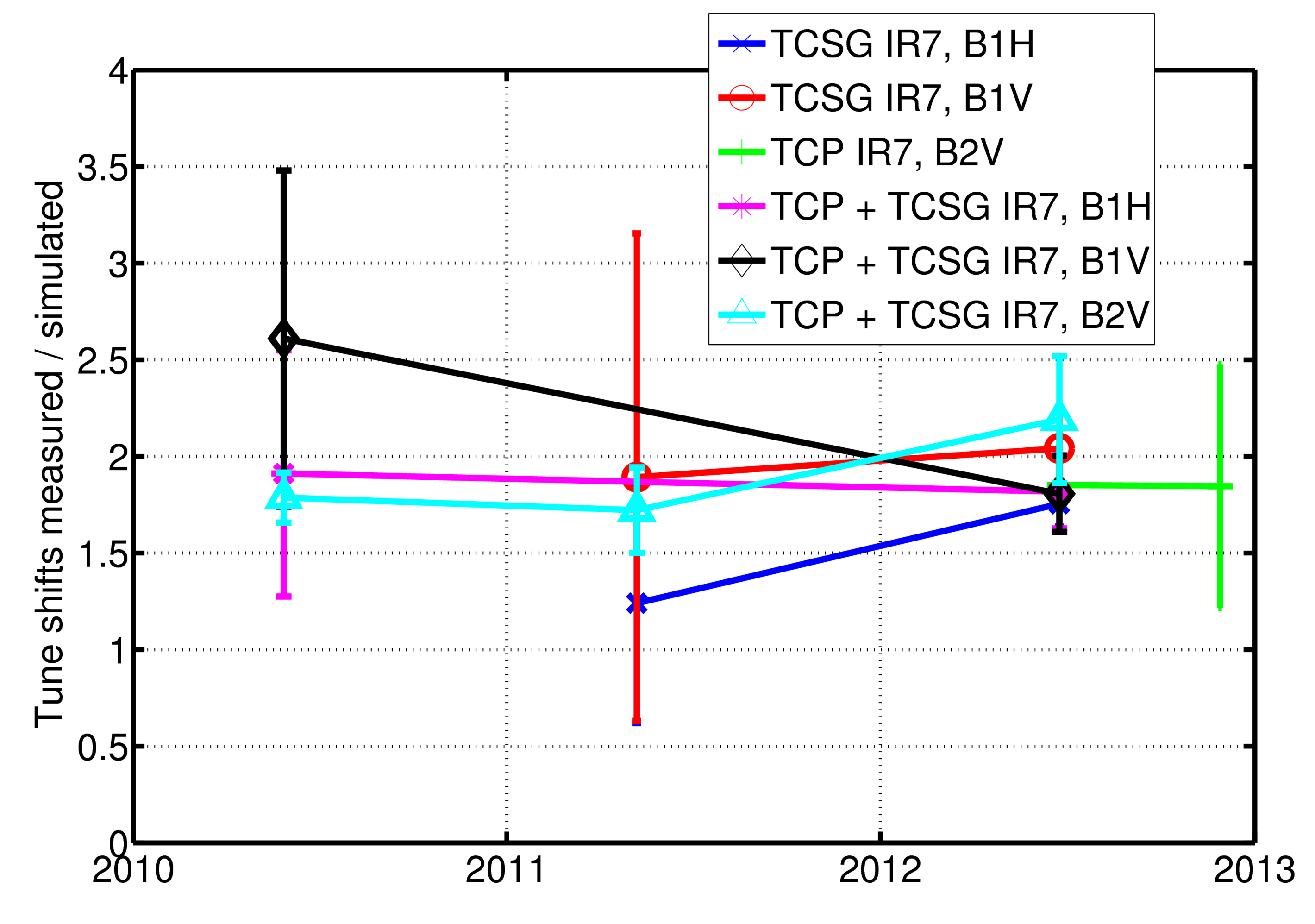



IPAC 2013, TUPWA047

→ Discrepancy factor around 2. Possible explanations:

- resistivity increased, e.g. from irradiation damage ?
- geometric impedance much higher than expected ?

# Evolution of the discrepancy between model & measurements since 2010



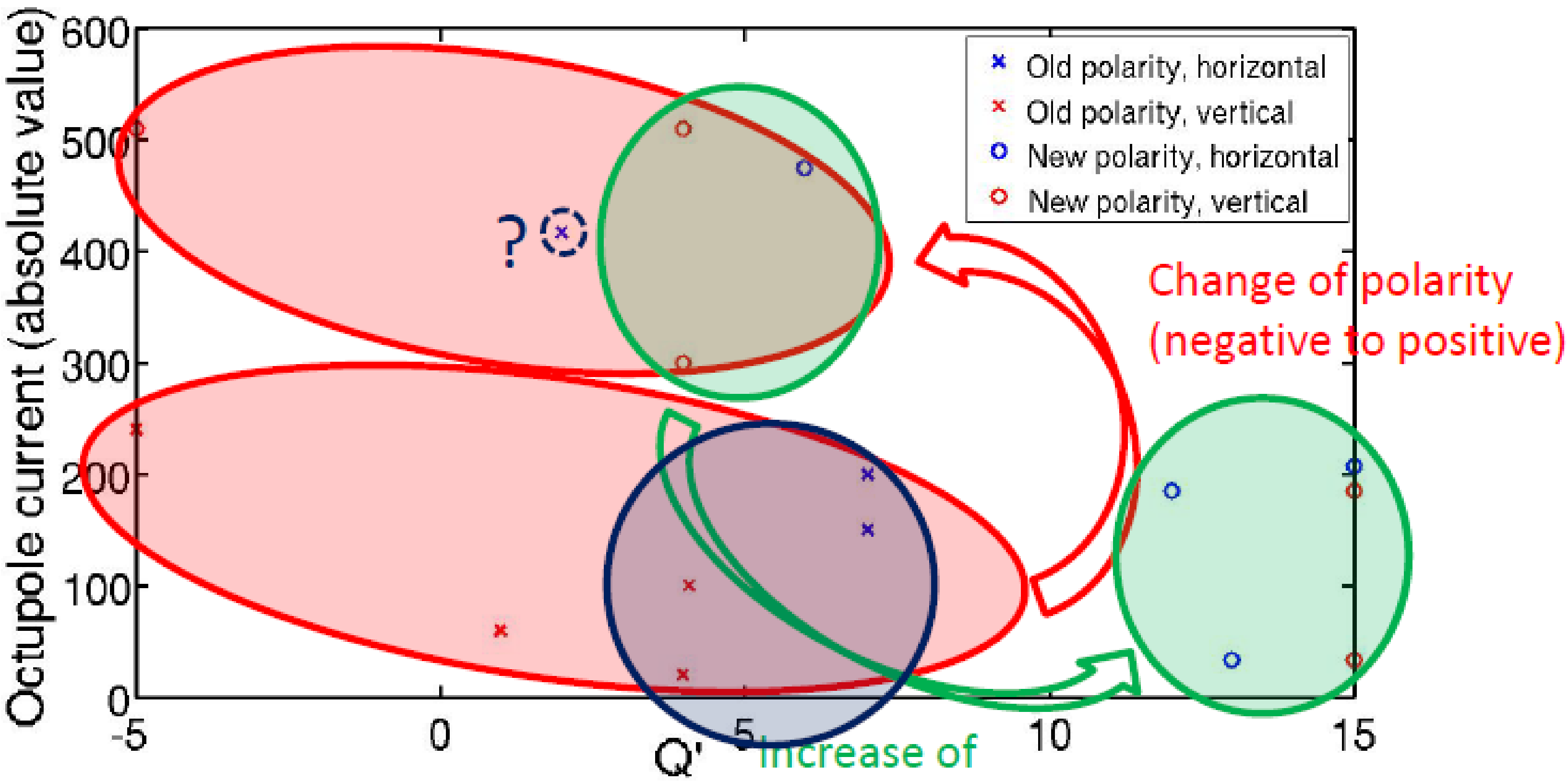

IPAC 2013, TUPWA047

→ No significant evolution of the discrepancy, i.e carbon materials conductivity seems to have remained unchanged,

→ studies ongoing on geometric impedance (M. Zobov & O. Frasciello, INFN).

# Single beam stability limit in 2012

Single-beam and flat top instabilities observed this year (not the problematic end-of-squeeze ones – cf. E. Métral & T. Pieloni's talks)




Increase of chromaticity with new positive polarity

Should decrease with higher chromaticity

Note: beam and machine parameters are sometimes slightly different between these measurements.

(From Evian 2012)

→ At high chroma / high damper gain, +/-250 A were needed in the octupoles.

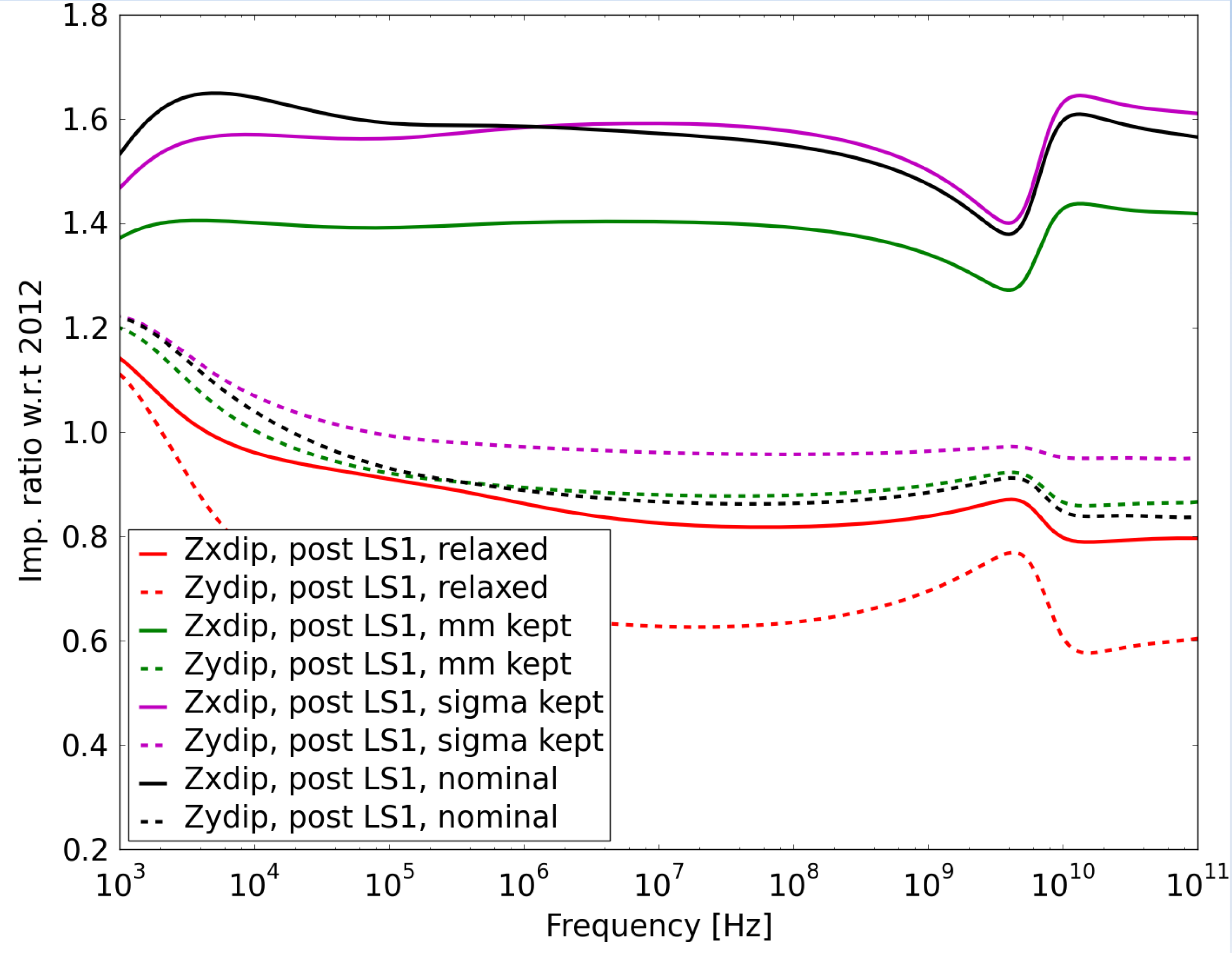
# Post-LS1 impedance scenarios

4 cases studied:

- “**nominal**”: most critical
  at high frequency (>1MHz): **+60 % impedance**.
- “**tight settings in sigma**”: tighter than 4TeV 2012 settings
  at high frequency (>1MHz): **+60 % impedance**.
- “**tight settings in mm**”: closer to 4TeV 2012 settings
  at high frequency (>1MHz): **+40 % impedance**.
- “**relaxed**”: most relaxed collimators settings, close to 2011 settings
  at high frequency (>1MHz): **-15 % impedance**.

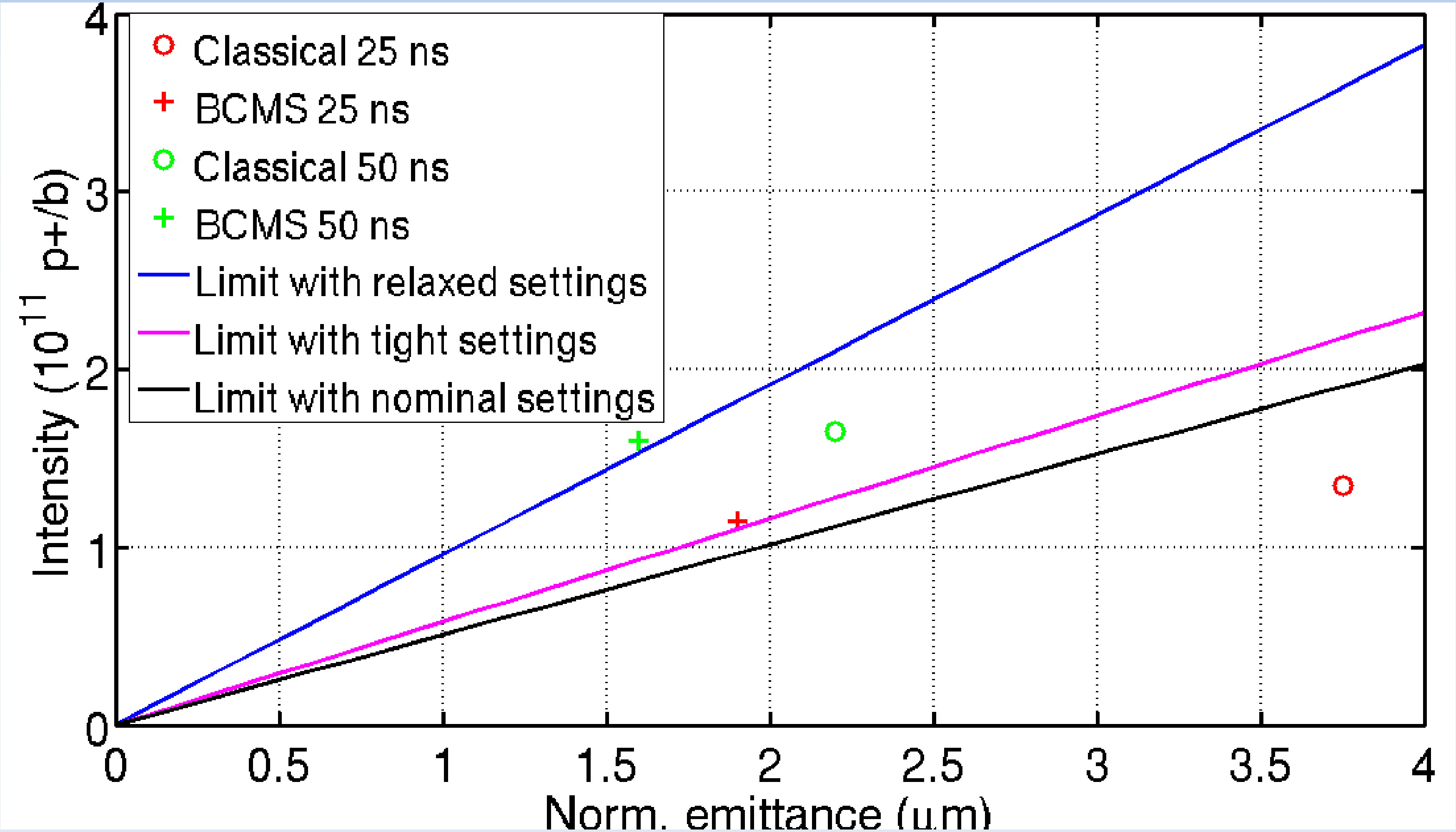
# Post-LS1 impedance scenarios

- Ratio of the post-LS1 impedances w.r.t. 2012 impedance:



# Post-LS1 impedance scenarios: intensity limit vs. emittance

- Assuming linear intensity dependence of instability growth rate:

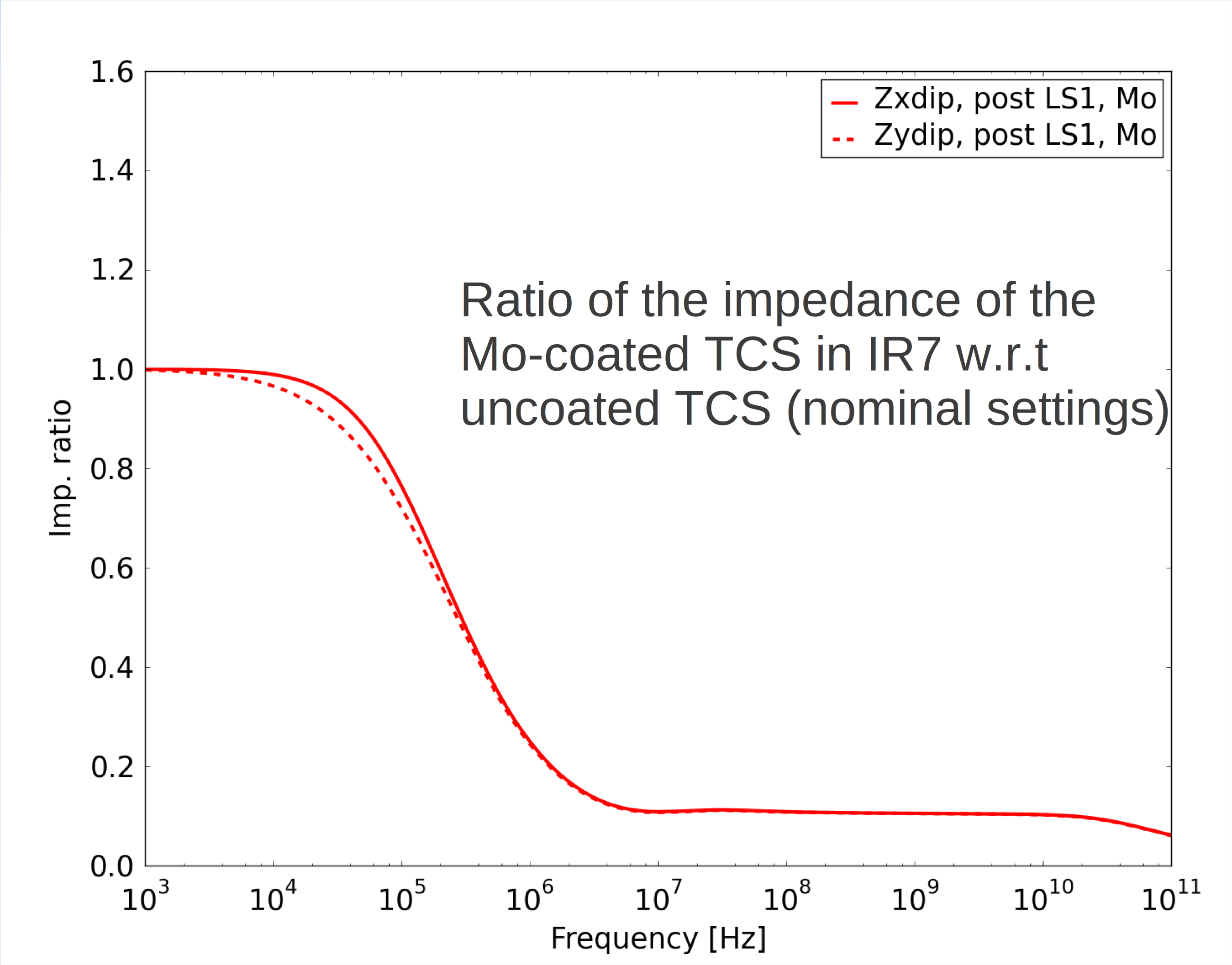


# Ways to achieve single-beam stability

- Use a classical 25 ns beam → OK even with nominal settings.
- Use relaxed settings until head-on collision → then all beams except 50 ns BCMS should be stable.
- Use the ”old” (negative) octupole polarity with high Q' (>15). Has not been tested but can potentially improve the situation.
- Use additional octupoles present in the machine (see. R. Tomas et al, Evian 2012).
- Decrease the impedance ?

# Possible improvement with Molybdenum coating

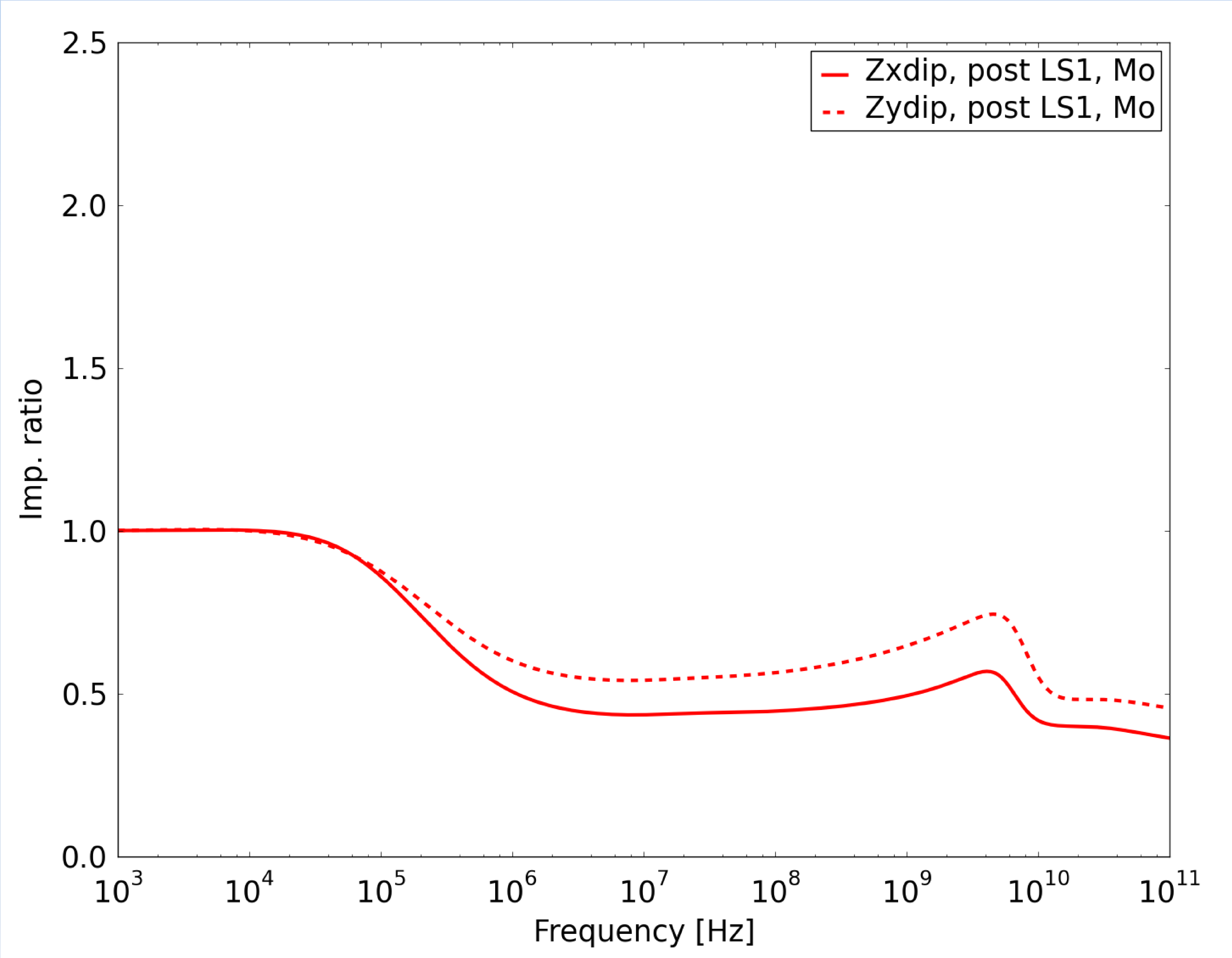
- Idea: coat all TCS in IR7 by molybdenum on top of the CFC jaw (50µm, $\rho_{CFC}$ = 5 µΩ.m, $\rho_{Mo}$ = 5.35 µΩ.cm – cf. A. Bertarelli et al).




⇒ Impedance of these collimators decreased by a factor 10.

# Possible improvement with Molybdenum coating

- Ratio on total impedances (nominal settings):




⇒ One can gain significantly with Mo coating.

# Impact of the dispersion suppresor collimators

- 2 TCLD in IR7 (one in IR2 but open for proton run).

- Half-gap can be small (~mm) but tungsten material & beta functions not too high

  → comparable to some of the current TCLA or TCT,

  → small resistive-wall contribution.

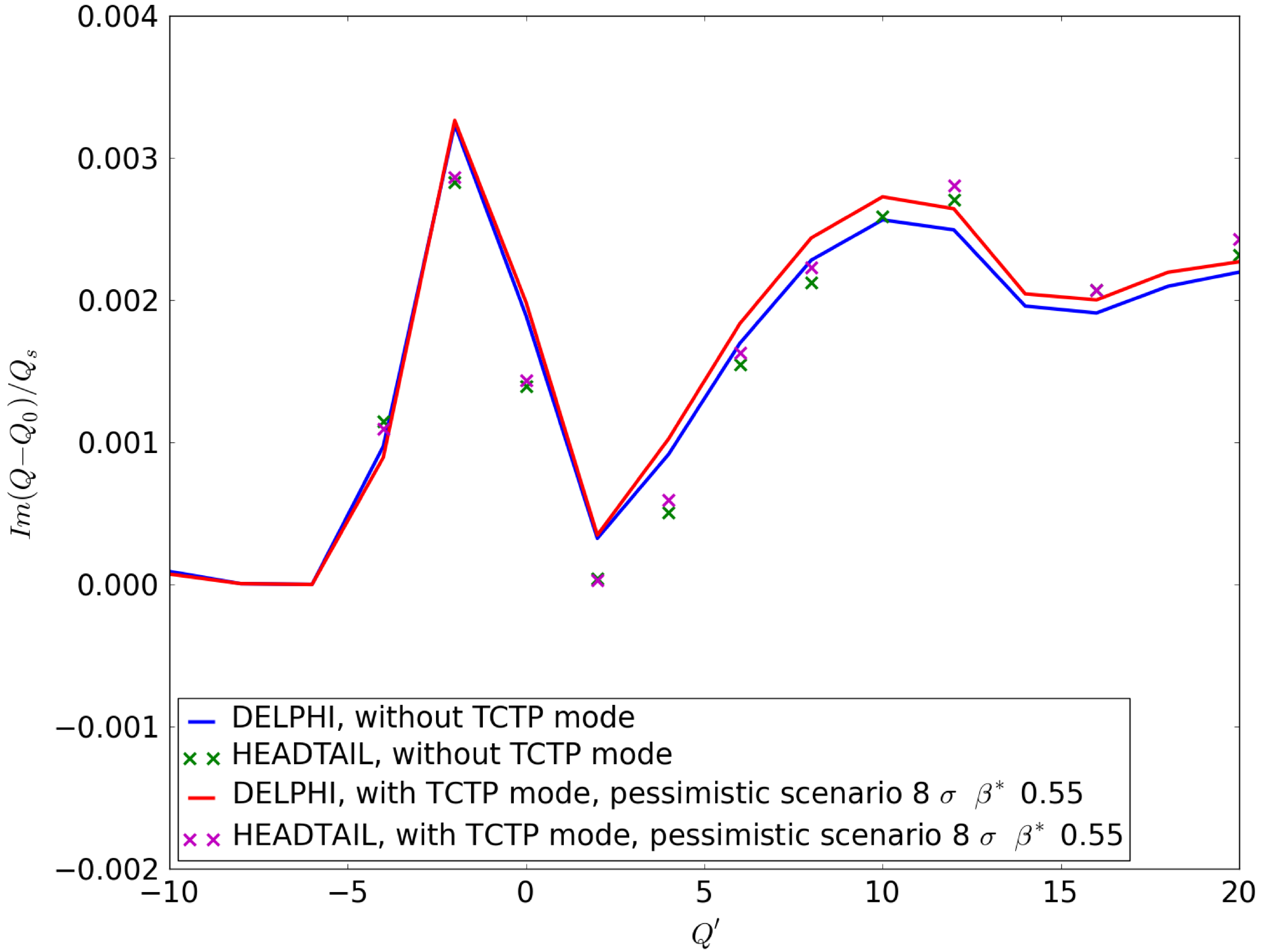
- Geometric impedance to be evaluated with design.

# Impact of newly found resonant mode on TCTP

- From CST time domain simulations: strong trapped mode in the transverse impedance of the new (post-LS1) TCTP tertiary collimators (geometry also used for post-LS1 TCSG in IR6)
- Can be considered as a additional resonator impedance.
- In the most pessimistic case, taking into account post-LS1 half-gaps and beta functions (cf. R. Bruce), mode corresponds to a resonator with:
  - Shunt impedance ~20 MOhm/m,
  - Frequency ~100 MHz,
  - Quality factor ~18.
- There are also a few harmonics (weaker).
- What is the impact fo this mode on the beam dynamics ?

# Impact of TCTP mode

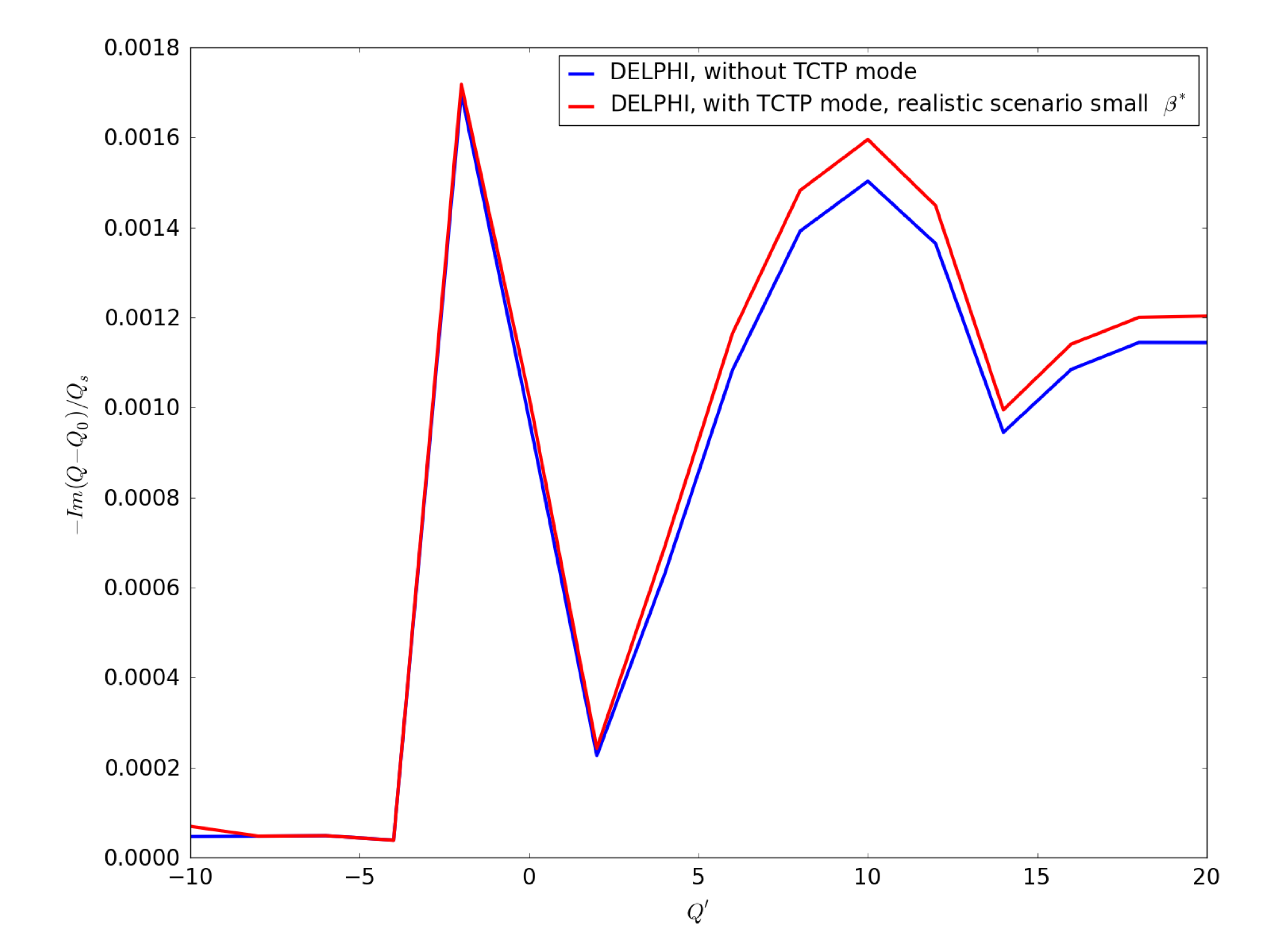
- Taking into account the mode harmonics, we get in the most pessimistic TCT scenario (8 sigmas) with nominal (6.5 TeV) settings




⇒ Mode does not have any significant impact (according to both HEADTAIL and DELPHI codes), with damper on. Even less impact with damper off.

# Impact of TCTP mode

- Impact becomes larger with generally more relaxed settings (here tight settings), even with realisitic TCT settings.




→ if we are marginally stable, we might want to worry...

# Conclusions

- Collimator impedance is a critical factor for beam stability.
- Investigated experimentally through tune shifts measurements, which are around a factor 2 above predictions from the impedance model. Discrepancy has remained constant since 2010 and is under study.
- Collimator and beam scenarios for post-LS1 operation can lead to single-beam instabilities. Several strategies are currently under study to tackle this.
- Coating the TCS in IR7 with a metallic layer of Mo could significantly reduce the impedance.
- The new dispersion suppressor collimator should have very little impact (depending on the design).
- The TCTP resonant mode exhibited recently can have a marginal impact on beam stability, depending on the settings.
- NOTE: the (problematic) end-of-squeeze instabilities observed in 2012 are not yet understood, in particular the role of impedance is not clear yet. We might have much tighter constraints on the impedance !