Tune shifts in the LHC from collimators impedance

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LHC collimators impedance

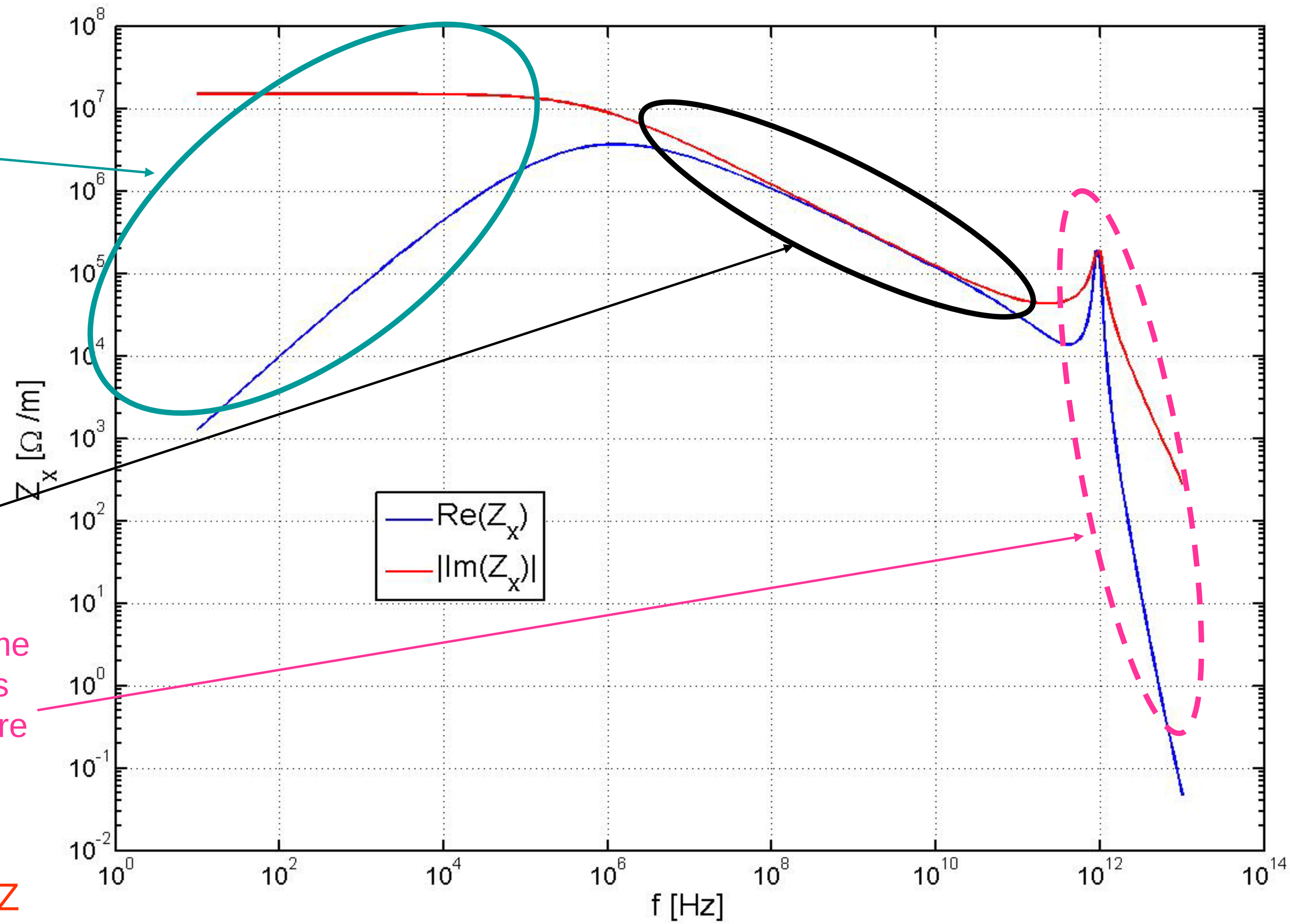
- Transverse resistive-wall impedance of an LHC graphite collimator of 1m at injection energy (log scale, 2mm half gap, Zotter's formalism without the Yokoya factors)

Low frequency or “inductive bypass” regime

“Classic thick wall” regime

High frequency regime (subject to caution as material properties are not well known)

LHC revolution frequency: ~11 khZ

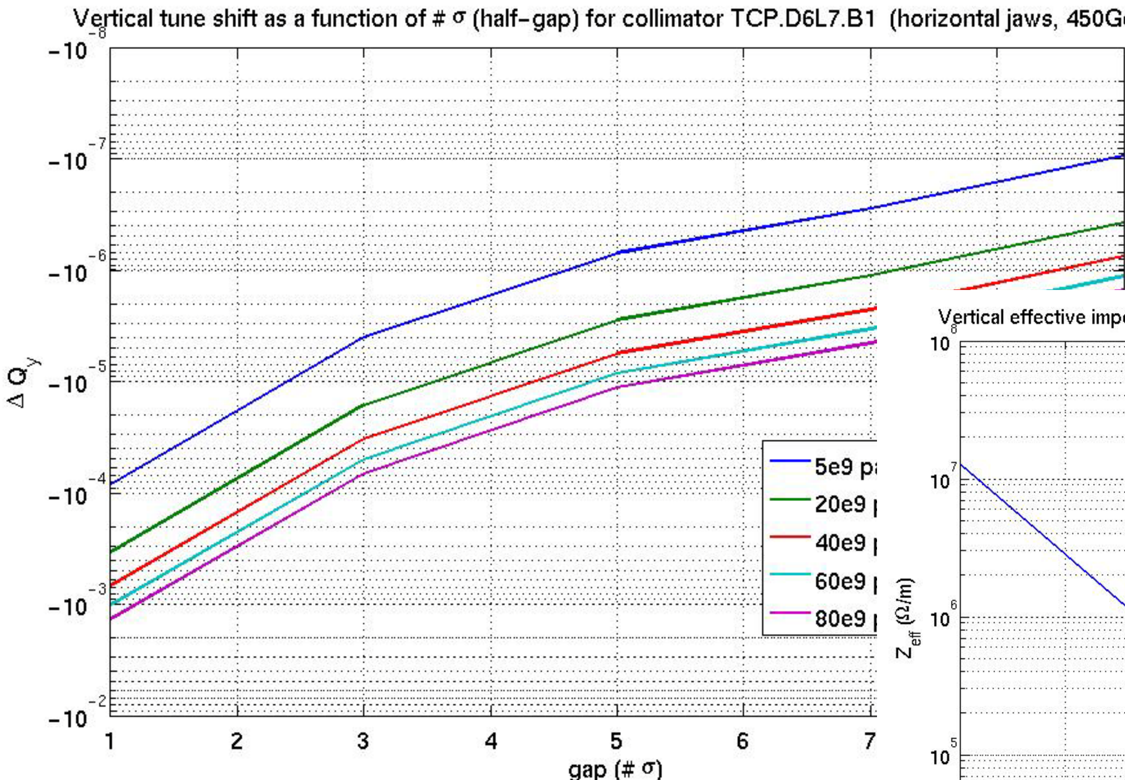


Tune shifts computation

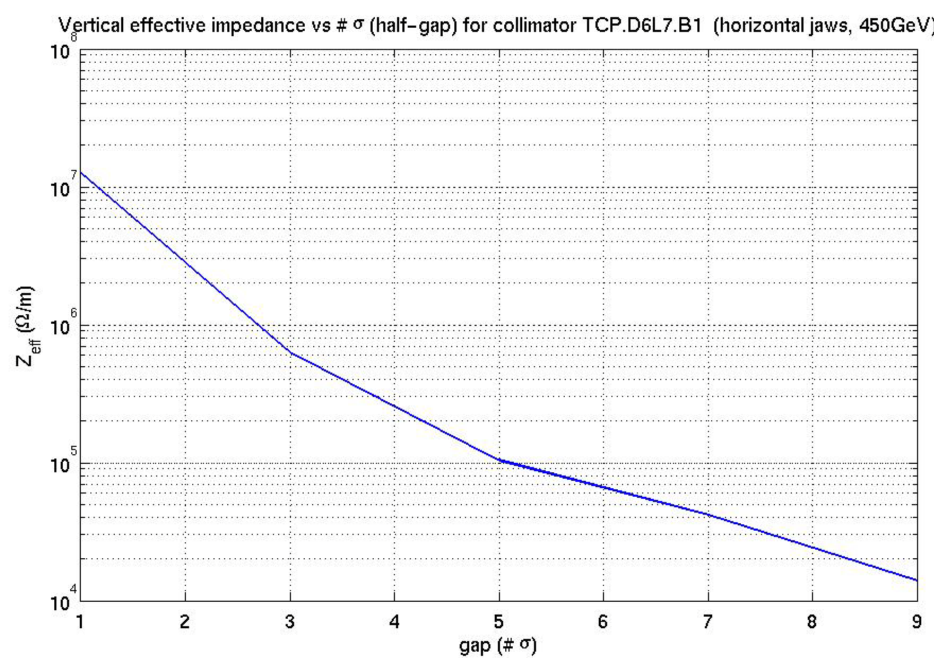
- Tune shifts predictions are needed in view of some possible measurements in the LHC with respect to collimators half gap (see minutes of discussion with the LHC Collimation Working Group https://impedance.web.cern.ch/impedance/minutes/LHCminutes_13_11_09.htm)
- 44 collimators per beam in the LHC (horizontal, vertical and skew). Settings provided by A. Rossi.
- Compute the impedance for all of them and then the wake functions (dipolar and quadrupolar), using Zotter's formalism, in the impedance database ZBASE.
- Run Headtail (in single bunch) with injection settings to get the tune shift (note: for skew collimators, coupled terms in the wakes are needed).
- Repeat the process for different gap openings of the collimator jaws and different beam intensities.
- Then the effective impedance Z_{eff} can be obtained from the slope of the curve $\Delta Q=f(I)$ using Sacherer's formula.

Tune shifts and effective impedance: one collimator

- For one horizontal collimator in IR7, at injection energy (with zero chromaticity, and neglecting for now nonlinear effects and particle losses on the jaws $\Rightarrow$ results are approximate at a half gap less than 5σ – see next slide)

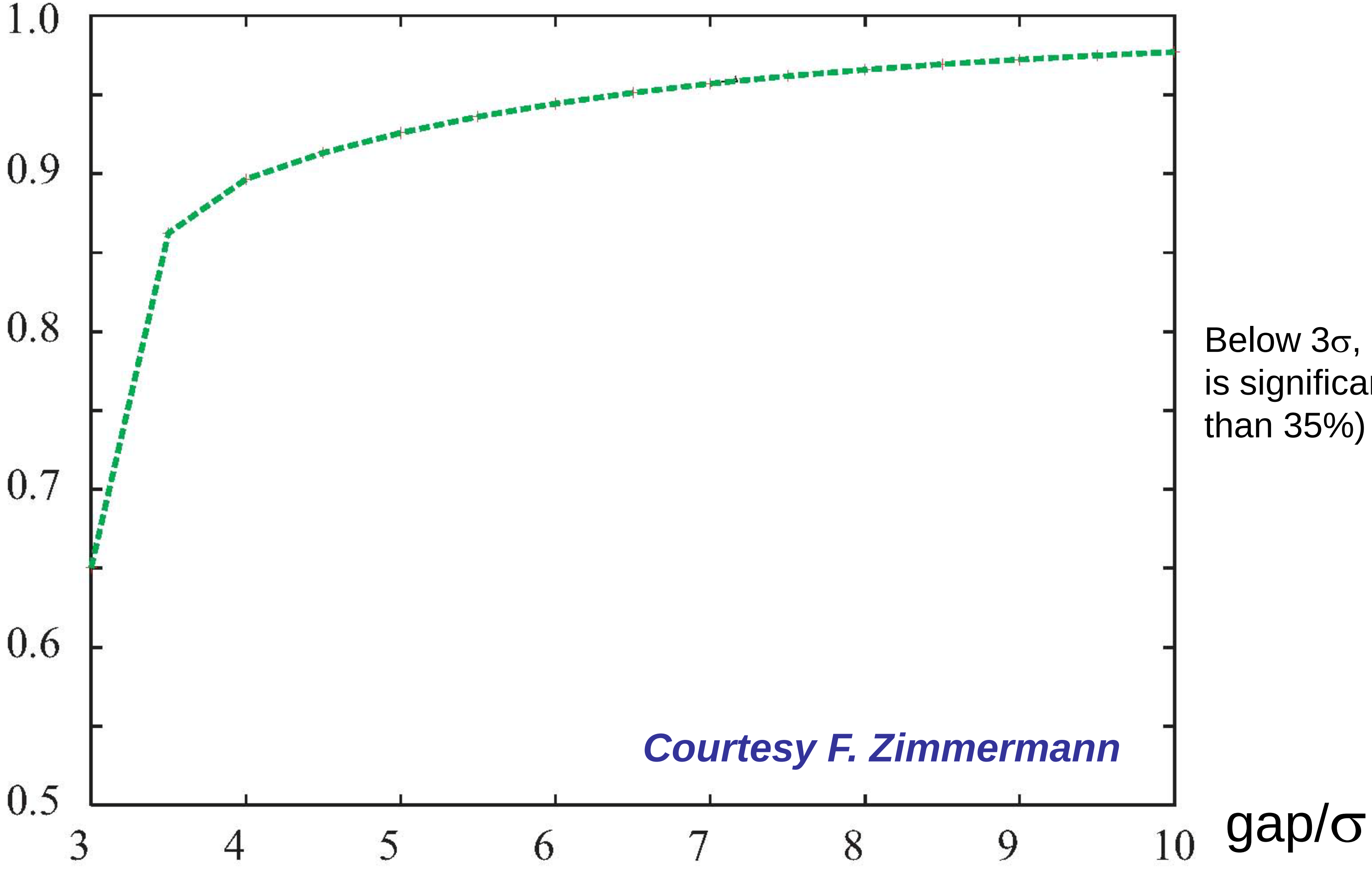


Note: here 'gap' is actually the half gap



Estimation of the nonlinear correction

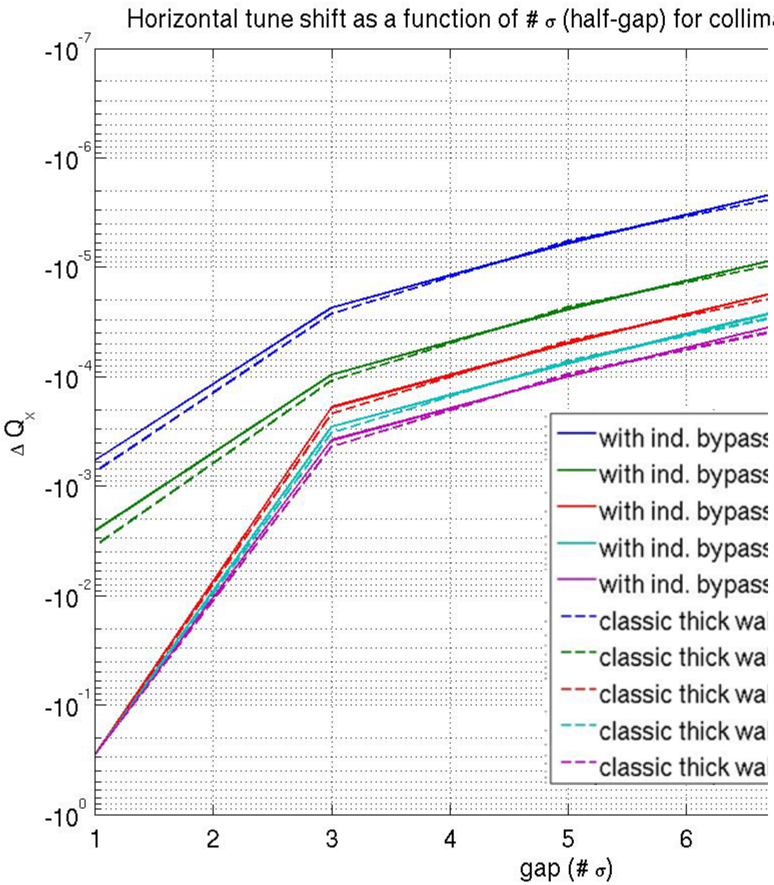
- Correction coefficient that should be applied to the tune shifts obtained, due to nonlinear effects for small number of sigmas:

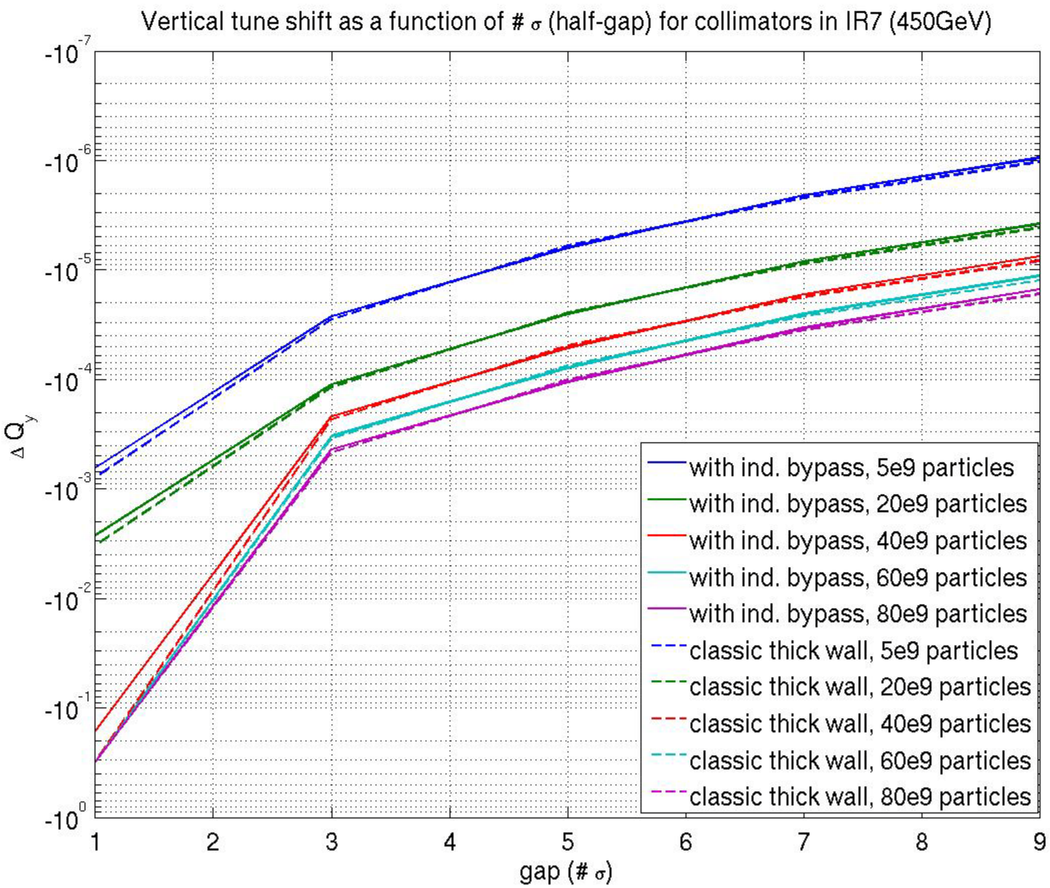


Below 3σ, correction is significant (more than 35%)

Tune shifts: all collimators in IR7

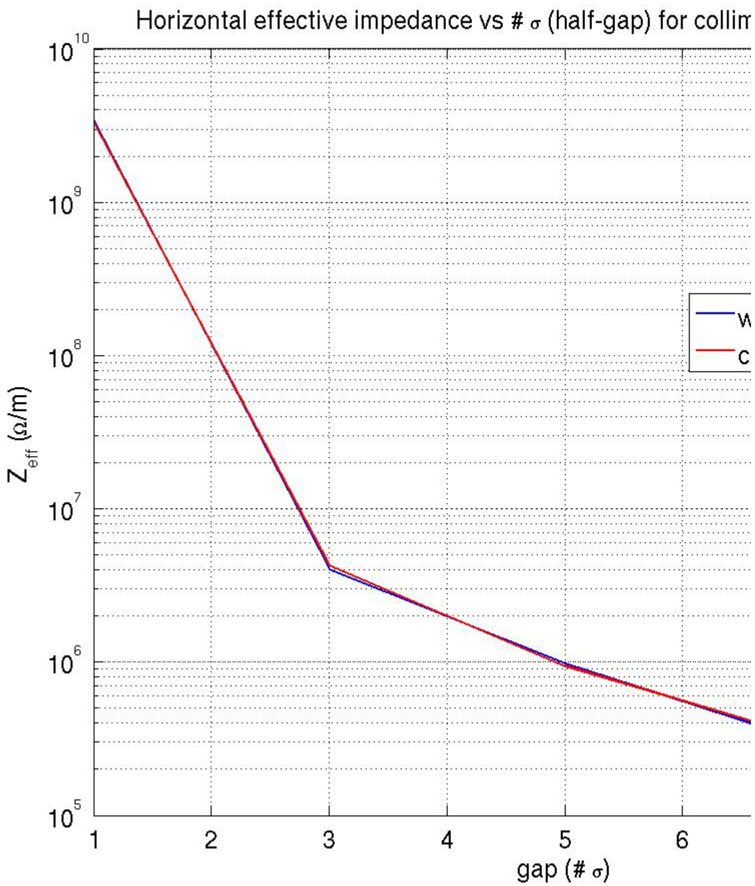
- For the 19 collimators in IR7 (when applying the same half gap to all of them), at injection energy (with the same approximations as previously), and comparing Zotter's general formalism with Yokoya factors, to the classic thick wall formula

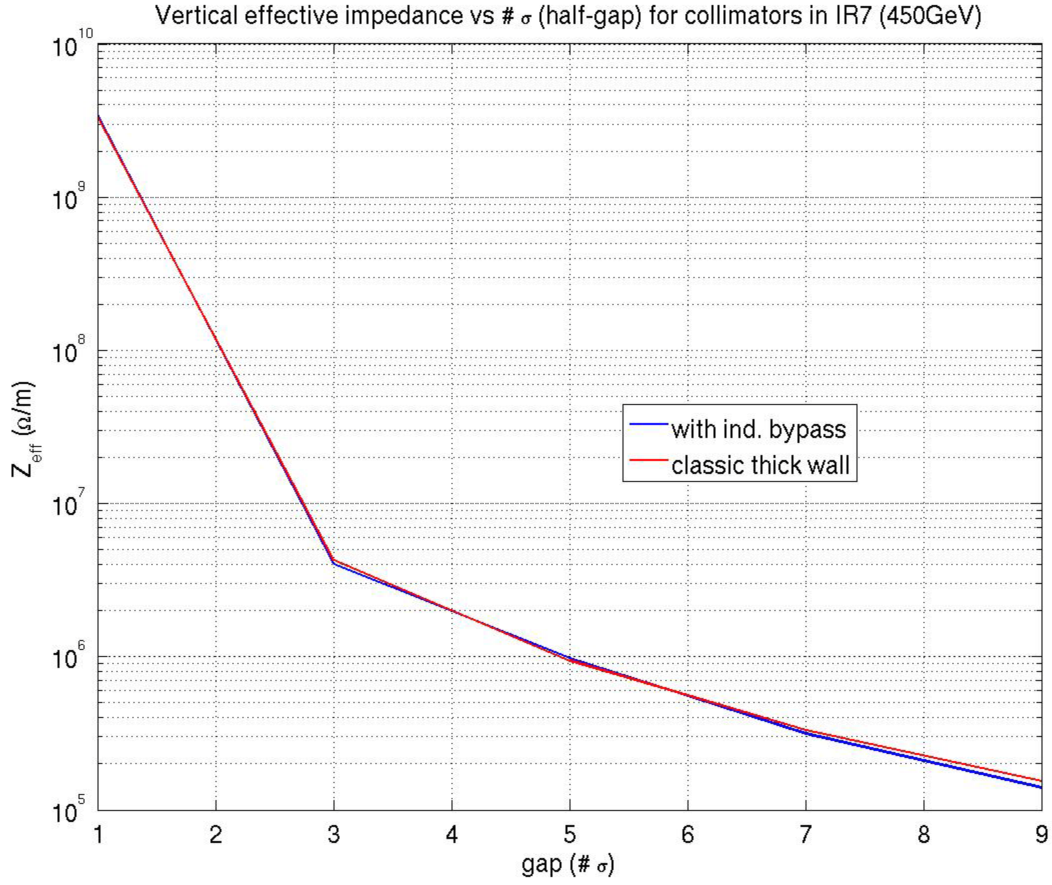




Effective impedance: all collimators in IR7

- For the 19 collimators in IR7 (when applying the same half gap to all of them), at injection energy (with the same approximations as previously), and comparing Zotter's general formalism with Yokoya factors, to the classic thick wall formula





Conclusion

- For the collimators, we have obtained single-bunch tune shifts of the same order as those obtained previously by Elias Métral (see http://ab-abp-rlc.web.cern.ch/ab-abp-rlc/Meetings/2006/2006.02.03/CBI&SBIAtLHCTopEnergy_RLC_03-02-06.pdf).

- Single bunch tune shifts when moving all the collimators in IR7 won't be visible (i.e. will be less than 10^{-4}), according to our simulations, unless we go to almost nominal intensity per bunch, and/or very narrow half gaps (at least 2.10^{10} particles per bunch at 3σ, 8.10^{10} particles per bunch at 5σ).

Perspectives

- Future work:
  - Take into account more accurately the full impedance frequency spectrum (accurate Fourier transform for the wake computation – ongoing),
  - Compute the coupled-bunch tune shifts and instability rise-times from collimators impedance,
  - Implement the rest of the machine impedance in ZBASE (at least most critical components: beam screen, warm pipe, MQW/MBW, broad band impedance, etc.) and compute the same quantities. Repeat the process at 3.5 TeV and 7 TeV,
  - Look at the single-bunch transverse mode coupling instability (TMCI) intensity threshold, for different collimators resistivities (ongoing) ⇒ Benoît Salvant,
  - Perform electromagnetic simulations of the future possible collimators (copper, ceramics, etc.) ⇒ Hugo Day, in collaboration with A. D'Allochio and A. Bertarelli.

Effective impedance: all collimators in IR7

- For the 19 collimators in IR7 (when applying the same half gap to all of them), at injection energy (with the same approximations as previously), looking at the effect of the coupled terms of the impedance (force in x but proportional to y coordinate, and vice versa):