SPS COLLIMATOR TESTS IN 2006: IMPEDANCE MEASUREMENT

E. Métral for the RLC team

(Many thanks to G. Rumolo who performed all the HEADTAIL simulations!)

- **(Approximate) collimator wake-field introduced in HEADTAIL**
- **HEADTAIL simulations vs. 2004 SPS tune shift measurements**
- **HEADTAIL simulations for 2006 SPS rise-time measurements**
  - **Horiz. Broad-Band (alone) from measurements ⇒ ~ 10 MΩ/m, Q=1, 1.3 GHz**
  - **LHC collimator (Thick-Wall approximation) alone**
  - **LHC collimator (with "Inductive By-pass") alone**
  - **BB + coll (TW)**
  - **BB + coll (IB)**

The purpose of the study is to disentangle the "inductive by-pass" effect

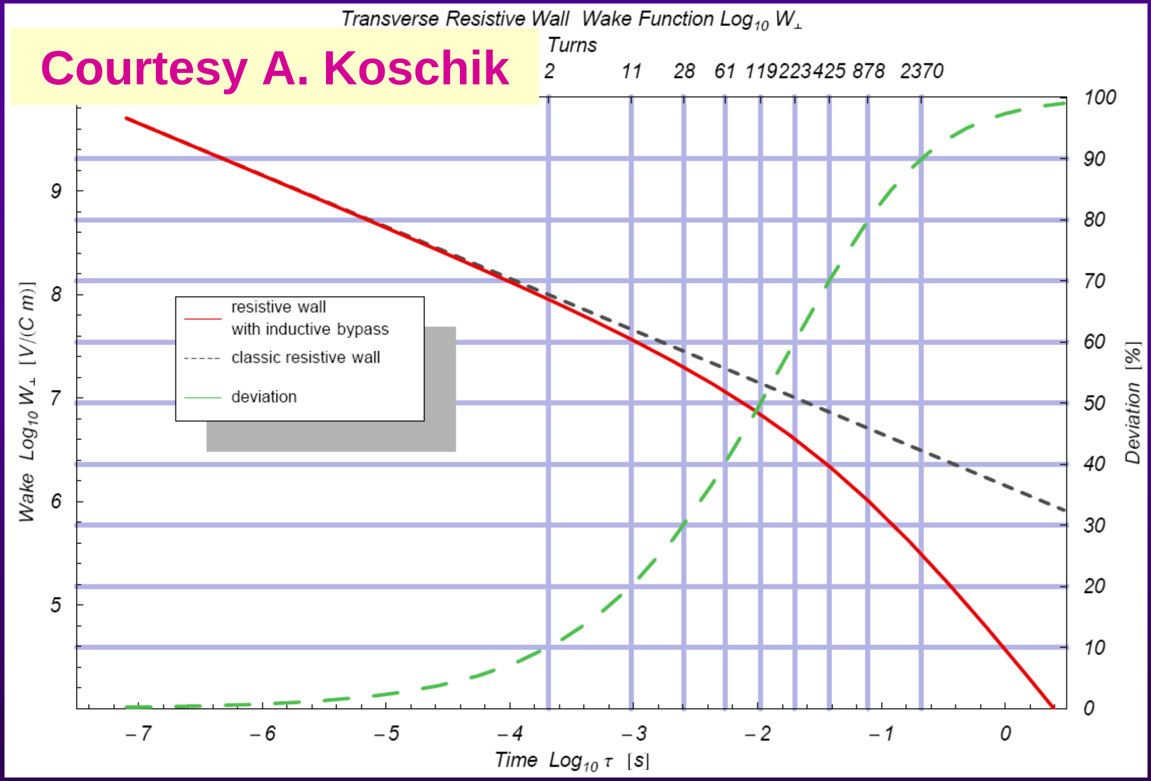
- **The "approximate" collimator wake-field derived by A. Koschik (2003) has been introduced in HEADTAIL by G. Rumolo**

From L. Vos' formula, which is an approximation of Zotter's ("exact") formula

Classical "thick-wall" formula

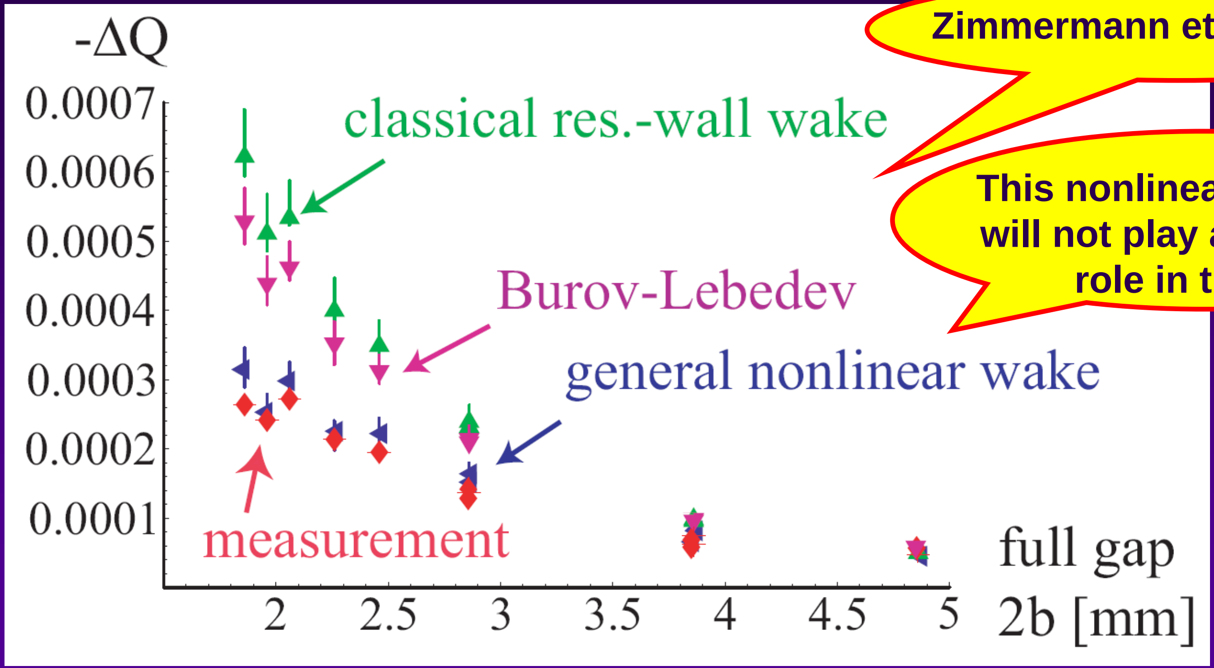
$$W^{\perp}_{m=1,\,\mathrm{ibp}}(t>0) = +\frac{cL}{\pi^{3/2}b^3}\sqrt{\frac{\mu_o\mu_r}{\sigma_c}}\cdot\frac{1}{\sqrt{|t|}} - \exp\left[\frac{4\mu_r}{b^2\sigma_c\mu_0}|t|\right]\frac{2cL\mu_r}{b^4\pi\sigma_c}\cdot\left(1-\mathrm{Erf}\sqrt{\frac{4\mu_r}{b^2\sigma_c\mu_0}|t|}\right)$$

Courtesy A. Koschik



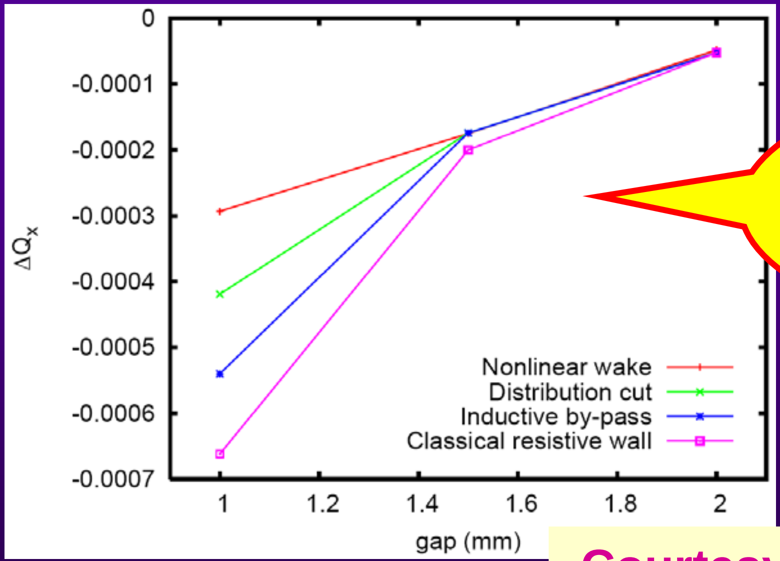
- **Nonlinear wake components have also been introduced to account for near-wall effects**

- **2004 measurements**



Zimmermann et al., EPAC06

This nonlinear wake of FZ will not play an important role in the LHC



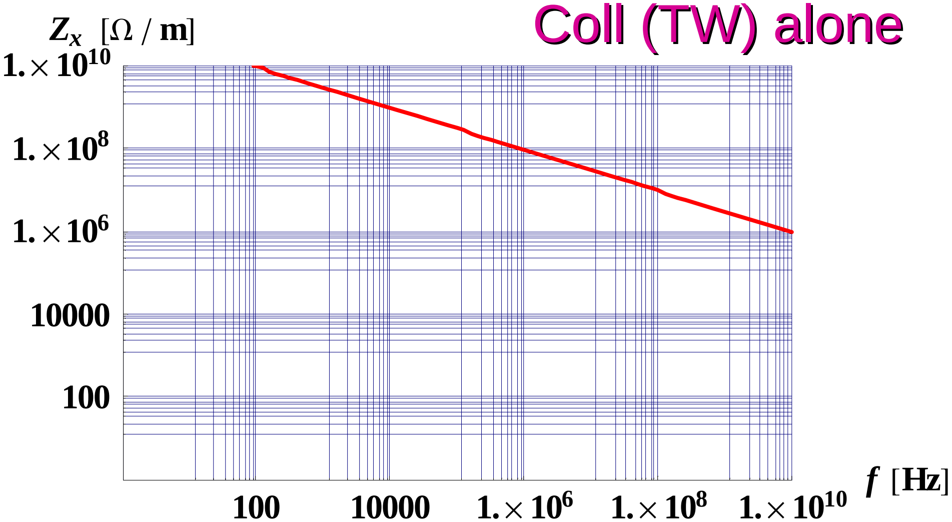
HEADTAIL simulations reproduce the SPS tune shift measurements, confirming the nonlinear theory

Courtesy G. Rumolo

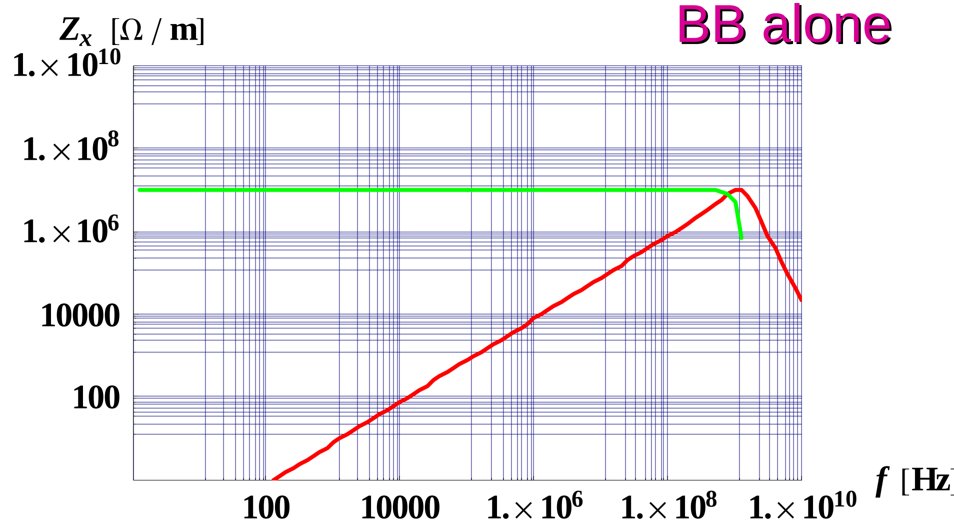
"Expected" SPS horizontal impedance

$f_\beta^1 \approx 35$ kHz

Coll (TW) alone

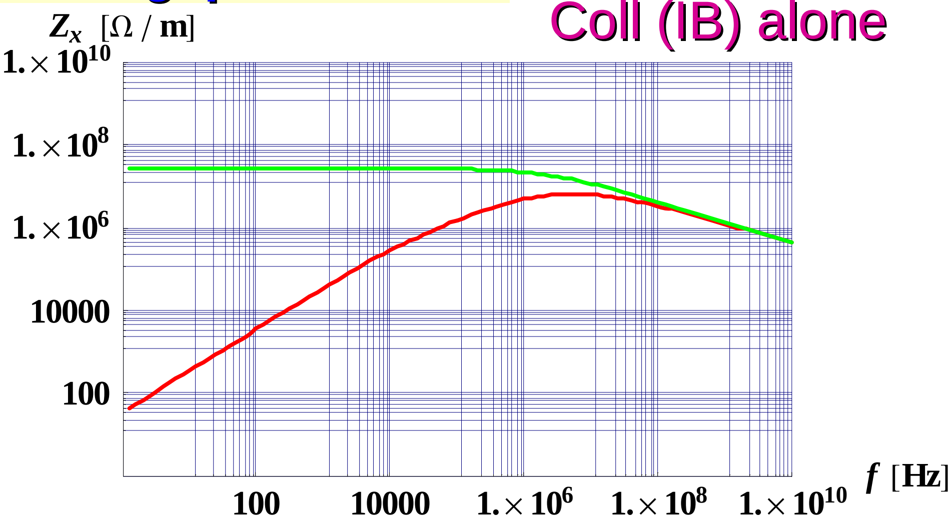


BB alone

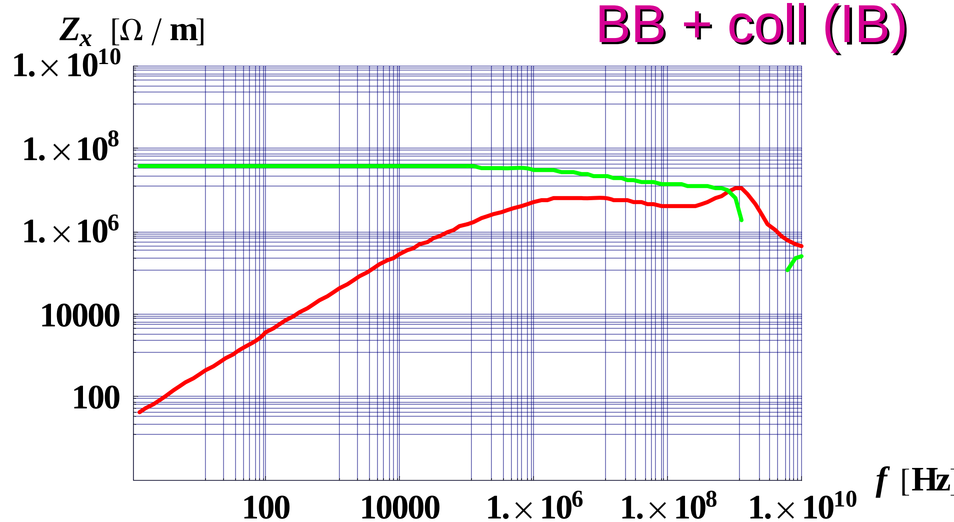


Half-gap b = 1 mm

Coll (IB) alone



BB + coll (IB)



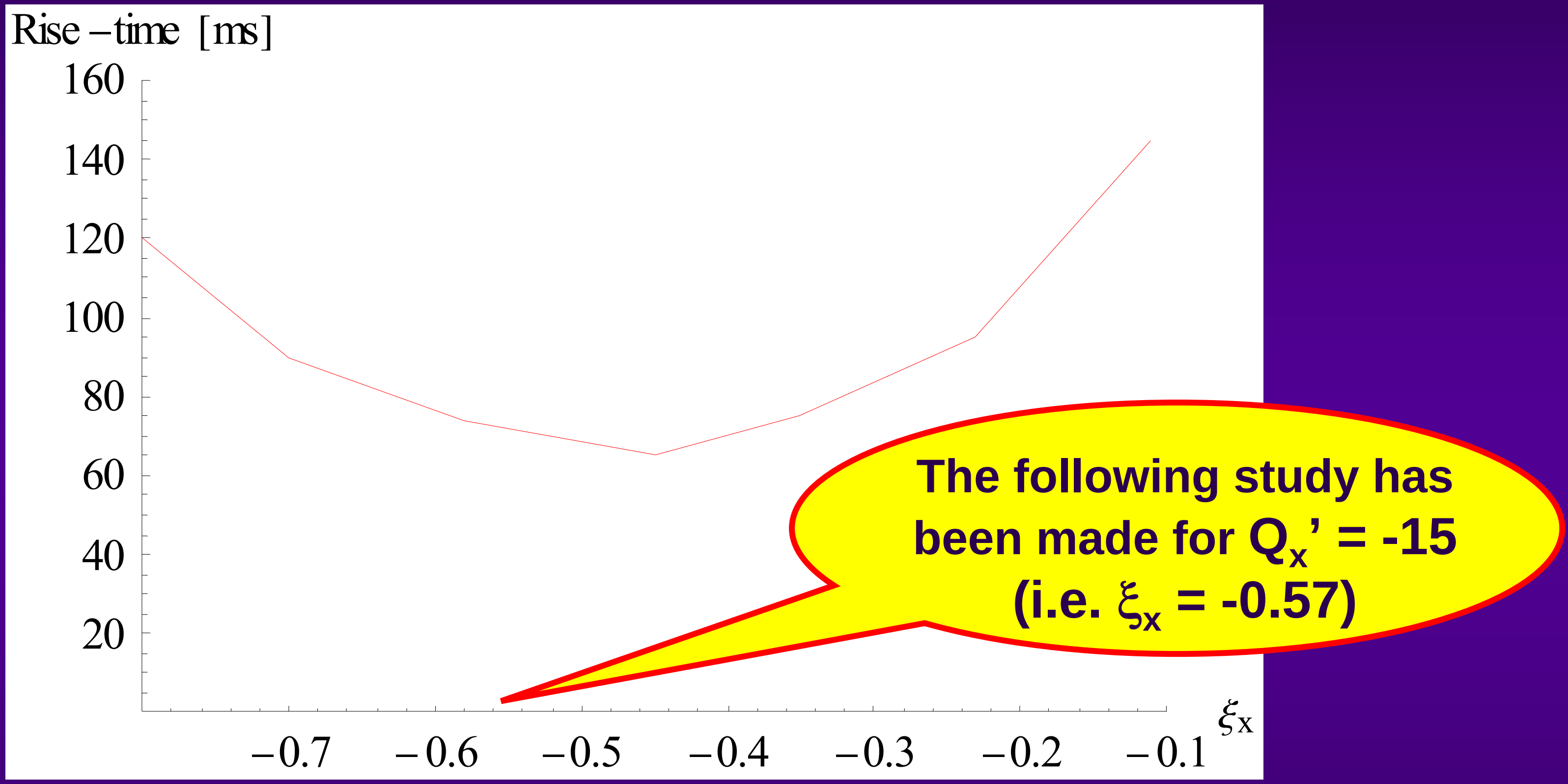
Beam and machine parameters for the HEADTAIL simulations

Beam momentum	270 GeV/c
# of bunches	1
# of protons	10^{11}
Long. emittance (2 σ)	0.35 eVs
Bunch length (1 σ)	21 cm
Mom. compaction	1.92×10^{-3}
Norm. rms transv. emittances	2.8 / 2.8 μm
Tunes	26.1397 / 26.18
Chromaticities	corrected / corrected
Collimator half gap b	1 mm (0.5 and 0.2 mm)
Horiz. beta function at coll.	20 m

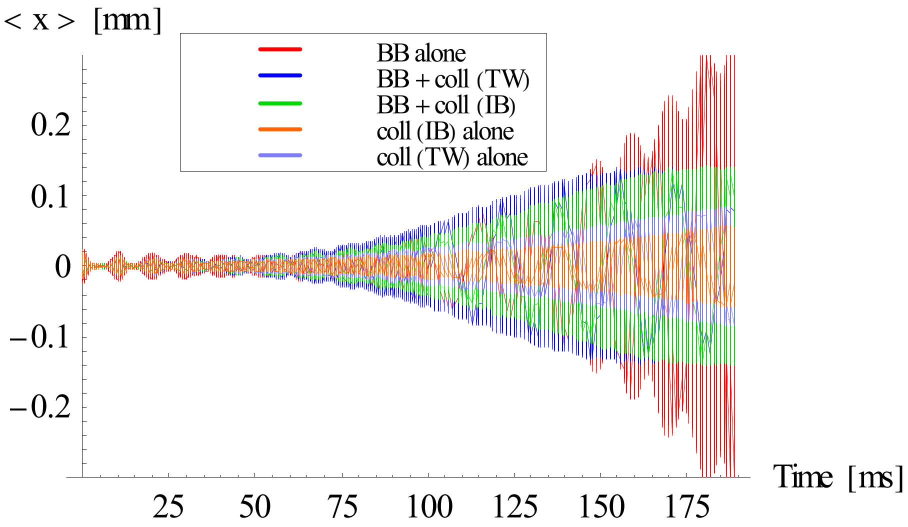
Horiz. beam size reduced to have b = 2 σ_x

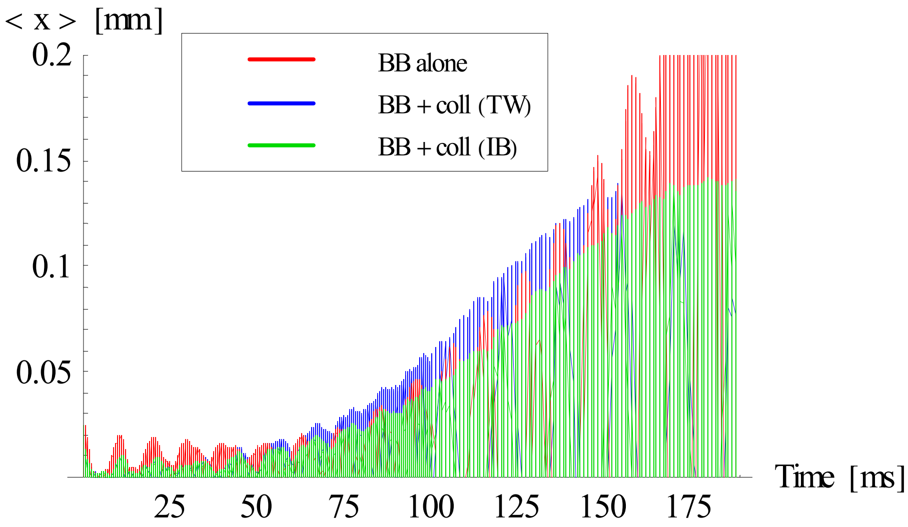
23.2 m in reality

Rise-time vs. chromaticity from HEADTAIL for the case of the LHC collimator (with inductive by-pass alone) with half gap b = 1 mm

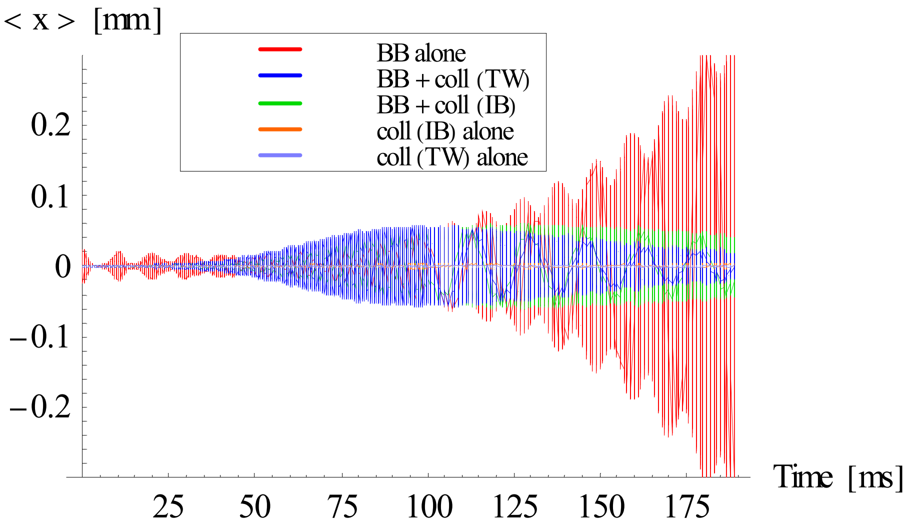


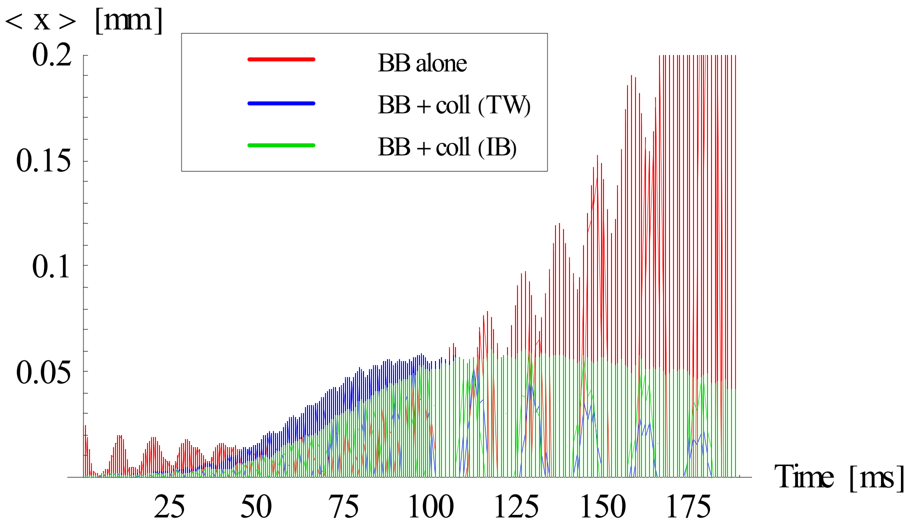
Half-gap b = 1 mm



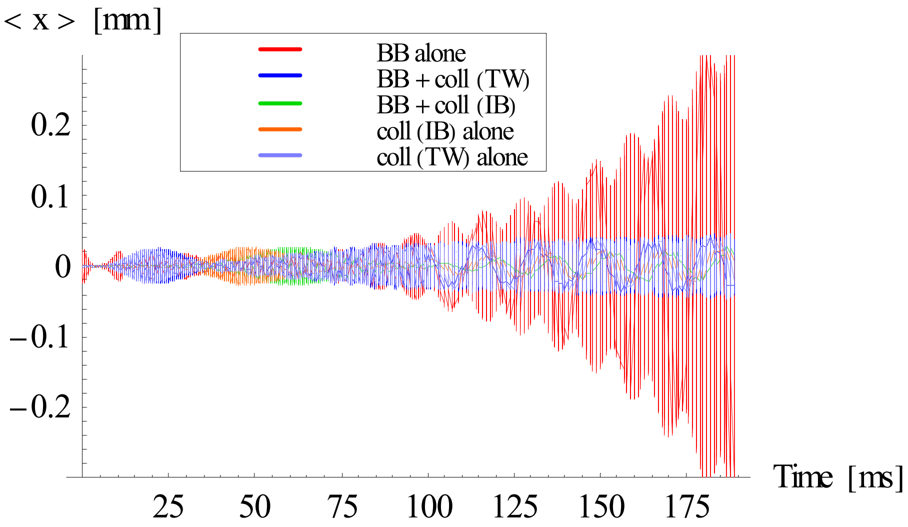


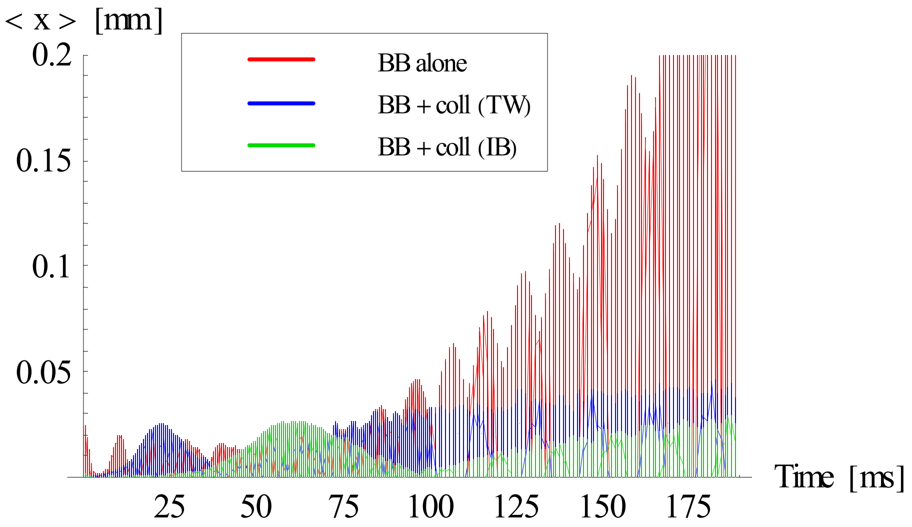
Half-gap b = 0.5 mm



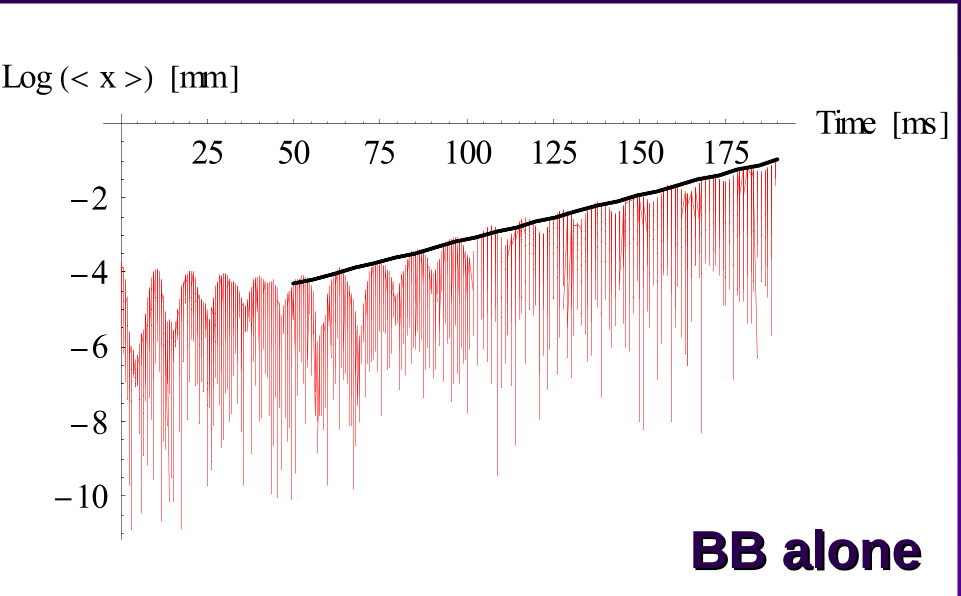


Half-gap b = 0.2 mm



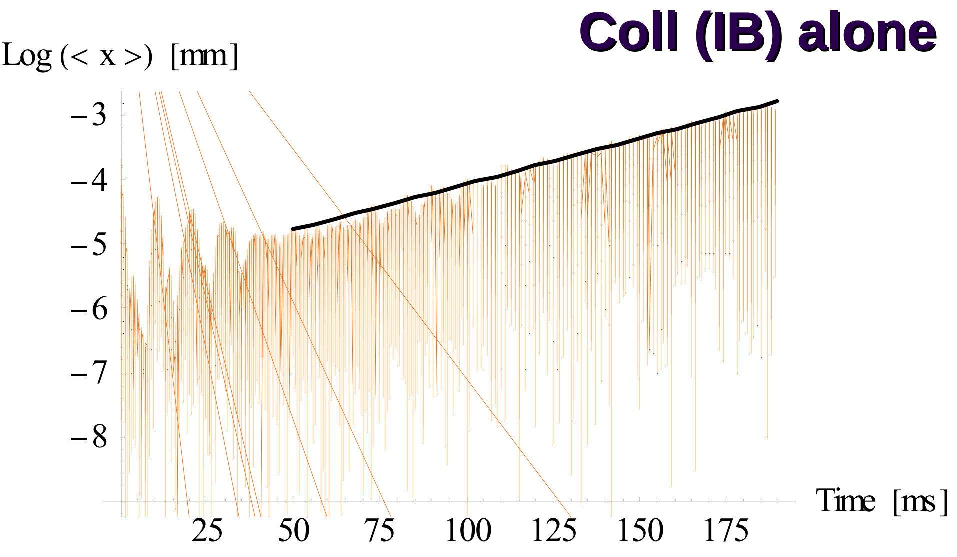


Fits (1/5)

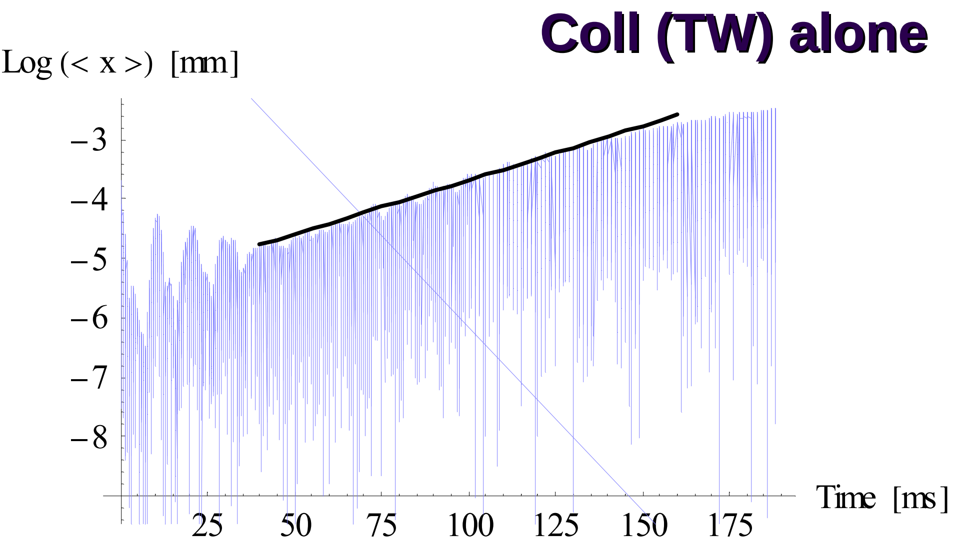


⇒ **Rise-time = 42 ms**

Fits (2/5)

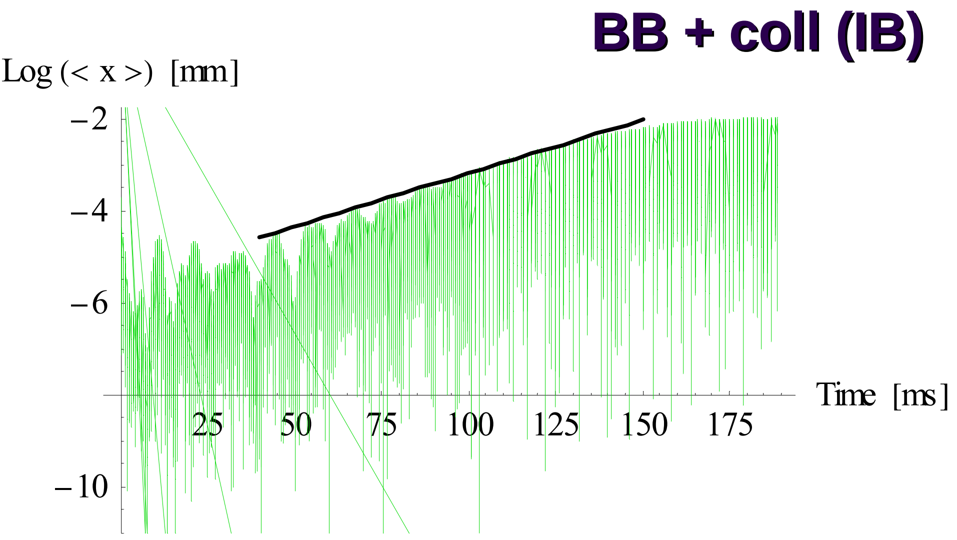


⇒ Rise-time = 70 ms

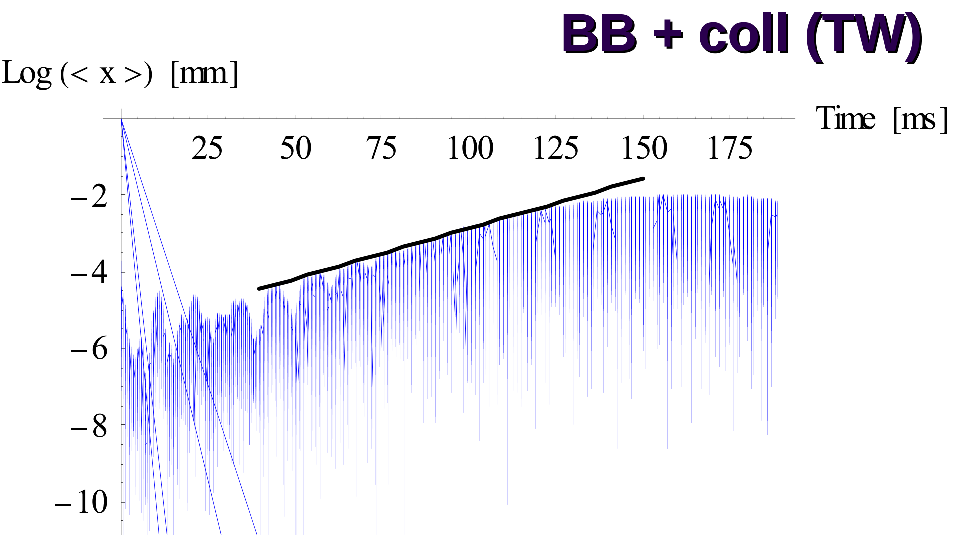


⇒ Rise-time = 55 ms

Fits (3/5)



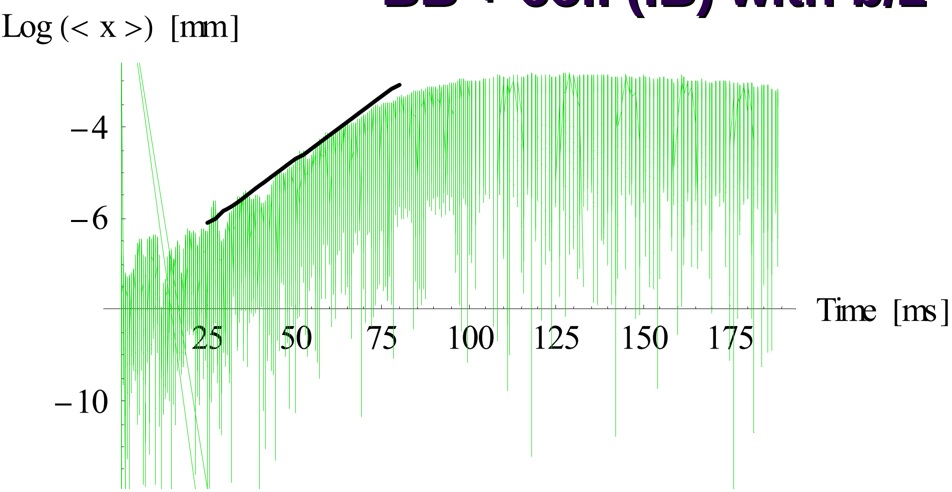
⇒ Rise-time = 43 ms



⇒ Rise-time = 38 ms

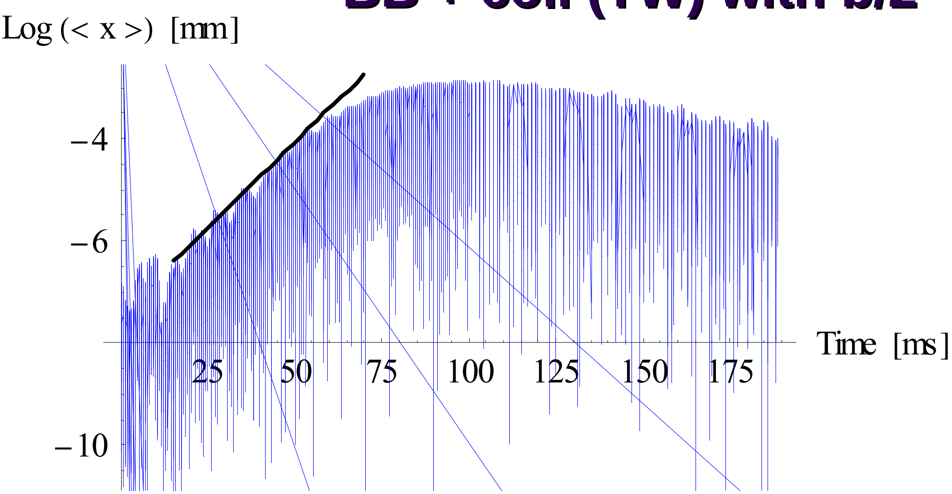
Fits (4/5)

BB + coll (IB) with b/2



⇒ **Rise-time = 18 ms**

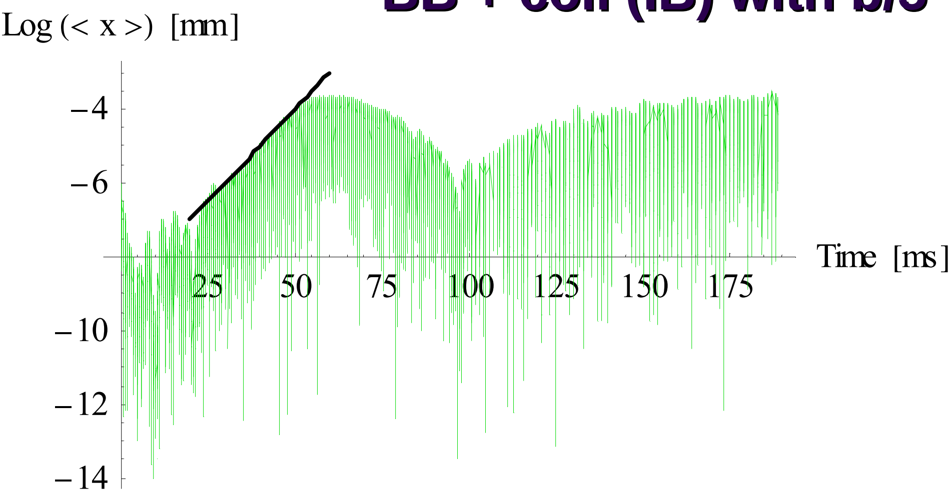
BB + coll (TW) with b/2



⇒ **Rise-time = 15 ms**

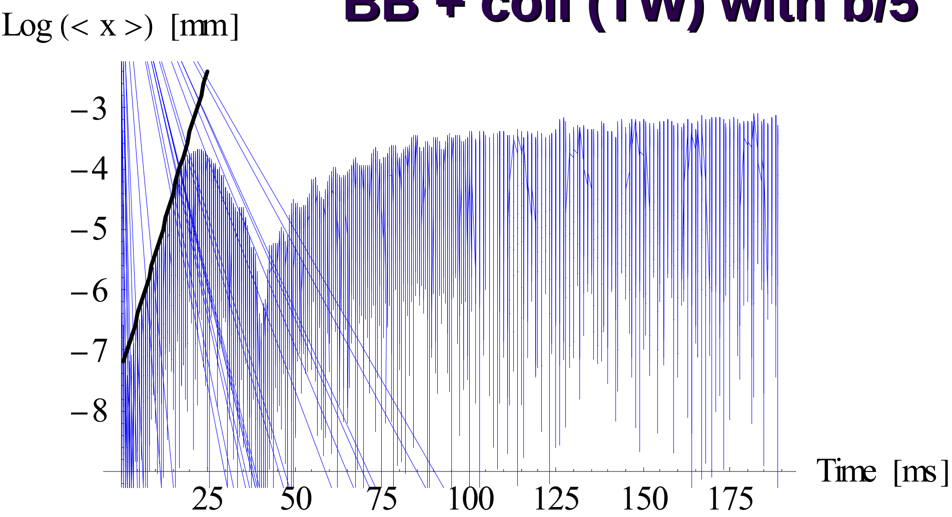
Fits (5/5)

BB + coll (IB) with b/5



⇒ **Rise-time = 10 ms**

BB + coll (TW) with b/5



⇒ **Rise-time = 5 ms**

Summary of the rise-times (in ms)

Imp. / Half gap	BB	Coll (IB)	Coll (TW)	BB + coll (IB)	BB + coll (TW)
1 mm	42	70	55	43	38
0.5 mm				18	15
0.2 mm				10	5

Reminder: Horiz. beam size reduced to have b = 2 σ_x

Conclusion & recommendation

- **Go to the highest energy, reducing the beam current and therefore the horizontal beam size, to reach the smallest values of collimator half gaps (few hundreds of μm)**

  - **It enhances the relative effect of the collimator impedance with respect to the (large) machine BB impedance**

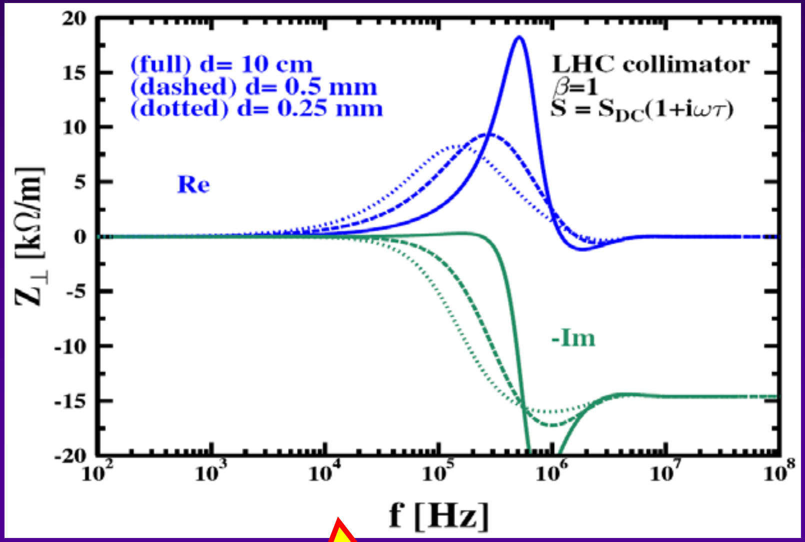
  - **It enhances the difference between the "inductive by-pass" behaviour and the "thick-wall" one**

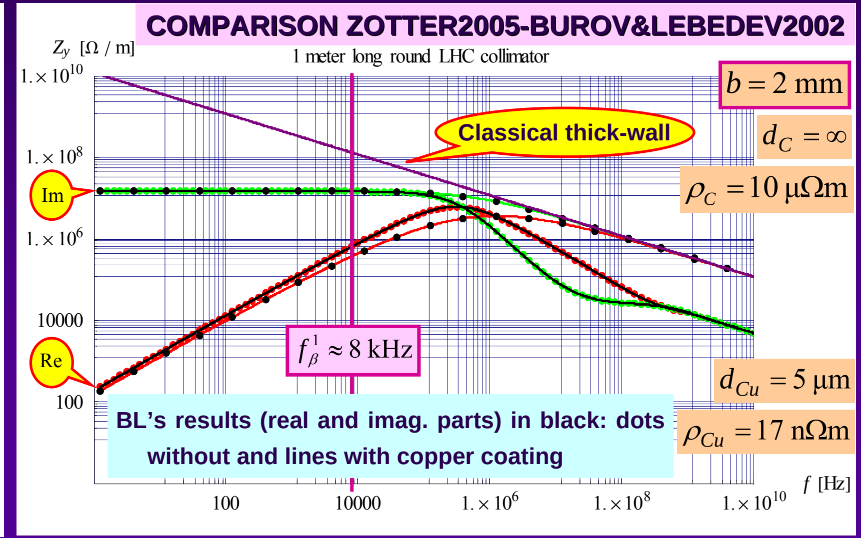
- **Is it possible to perform such measurements? Reproducibility? Precision?**

- **Instead of measuring the rise-times, one could also try to measure the damping times (with positive chromaticities) as proposed by H. Burkhardt**

Appendix: GSI results for the transverse impedance of a LHC collimator

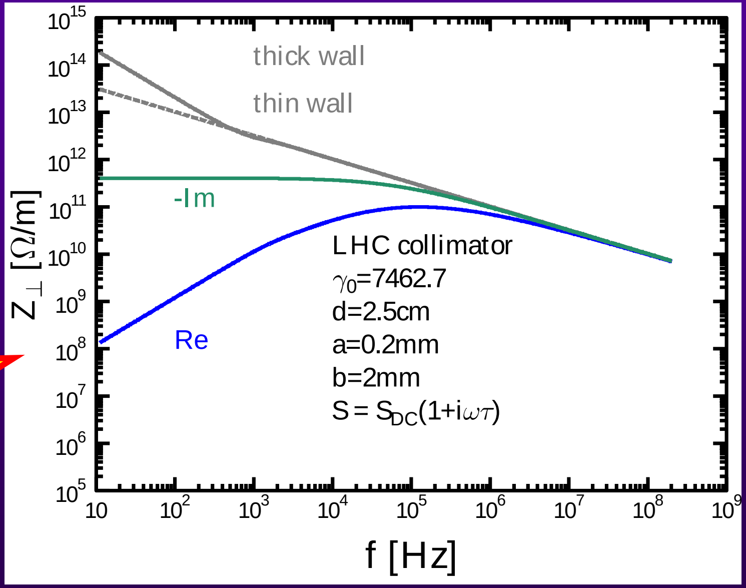
GSI RESULT (2006) **CERN RESULT (2005)**





d = 2.5 cm for the real LHC collimators

- New result from GSI sent to me on 28/09/06



~ 4 orders of magnitude higher than computed from Zotter's formalism!