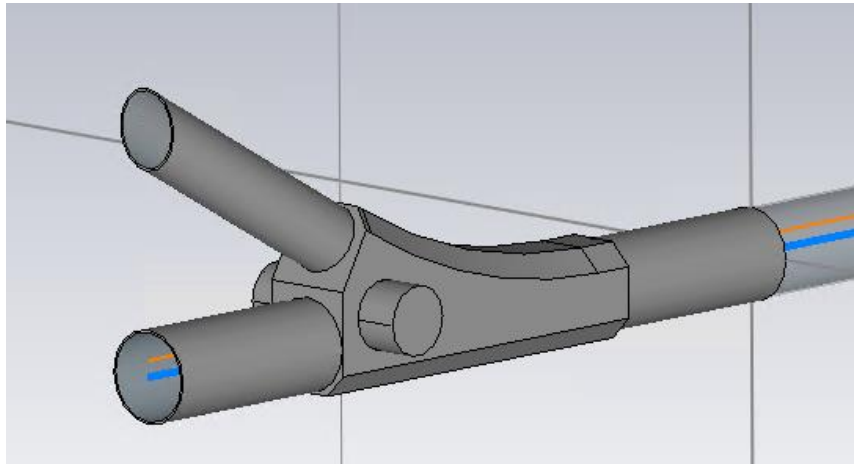
Update on electron lens impedance studies (without electrons)

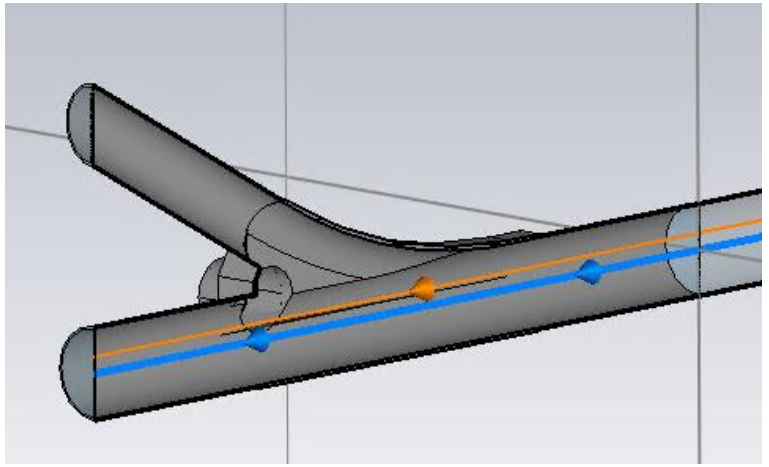
B. Salvant, C. Zannini

Thanks to Antti Kolehmainen, Diego Perini (EN-MME) and Riccardo de Maria (BE-ABP)

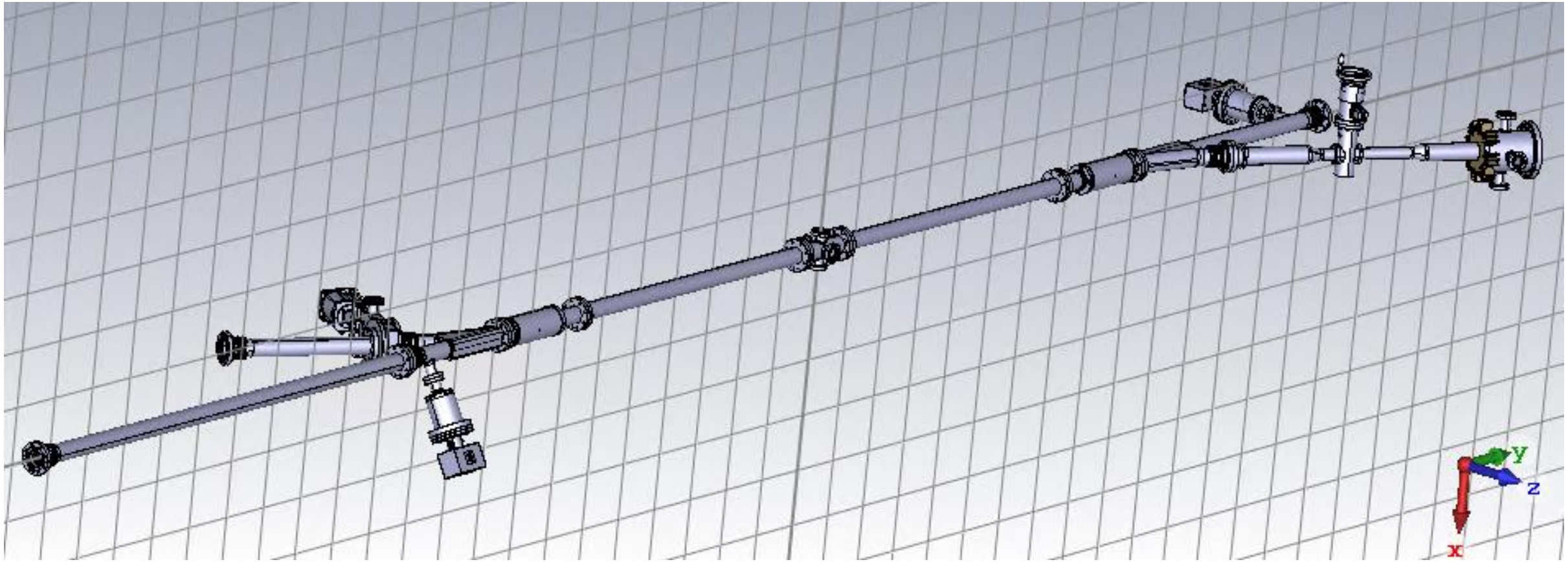
Context

- Hollow electron lens for halo control for HL-LHC
- Design discussed since a long time with EN-MME
- Work in particular in 2017 by a 2-week HSSIP stagiaire Chloe Rakotoalivony in 2017





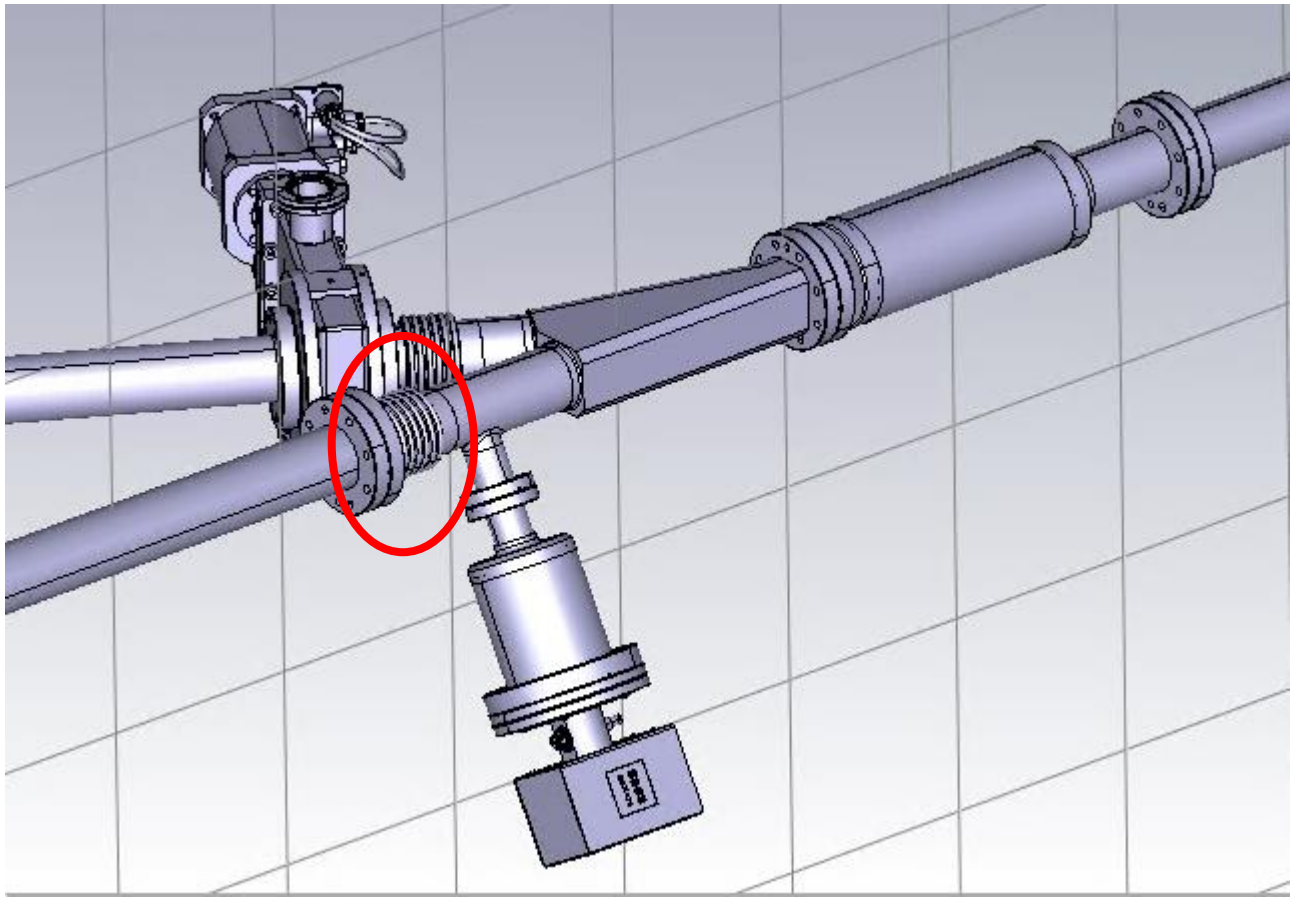
New design (August 2020)



Provided by Antti from EN-MME

Comments

- Bellow should be shielded



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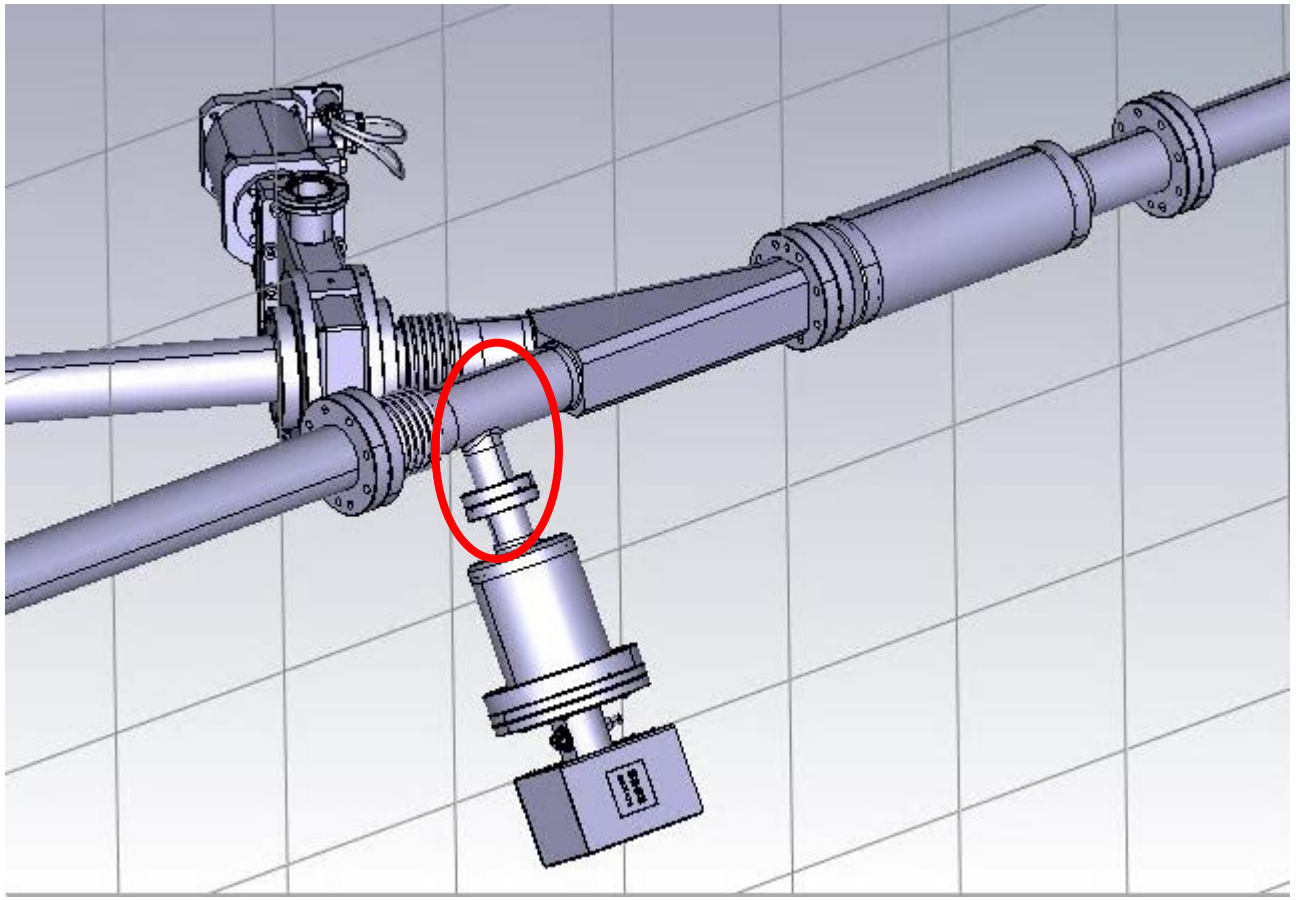

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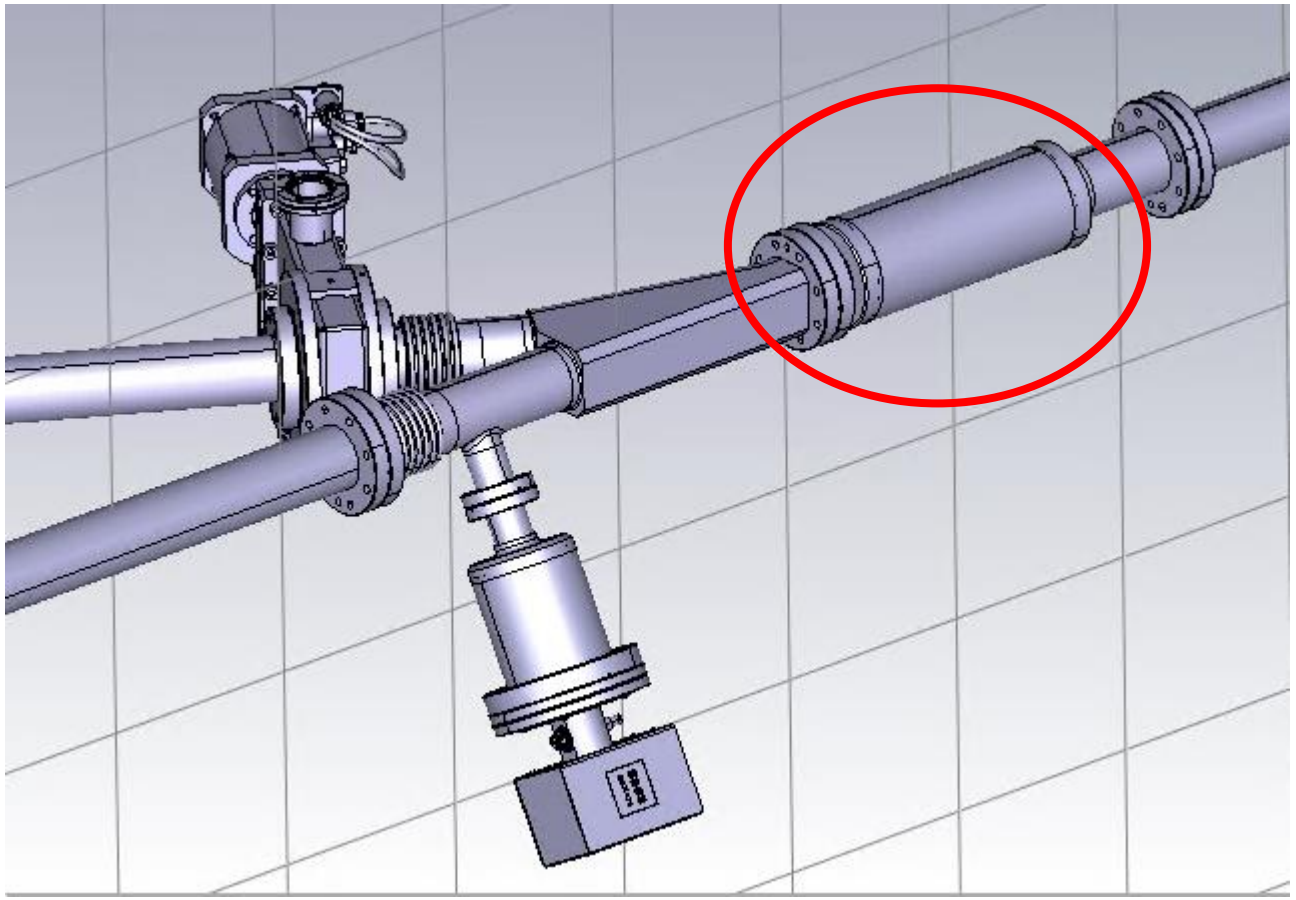
- Pump should be shielded
- Non-standard BPM (studied)



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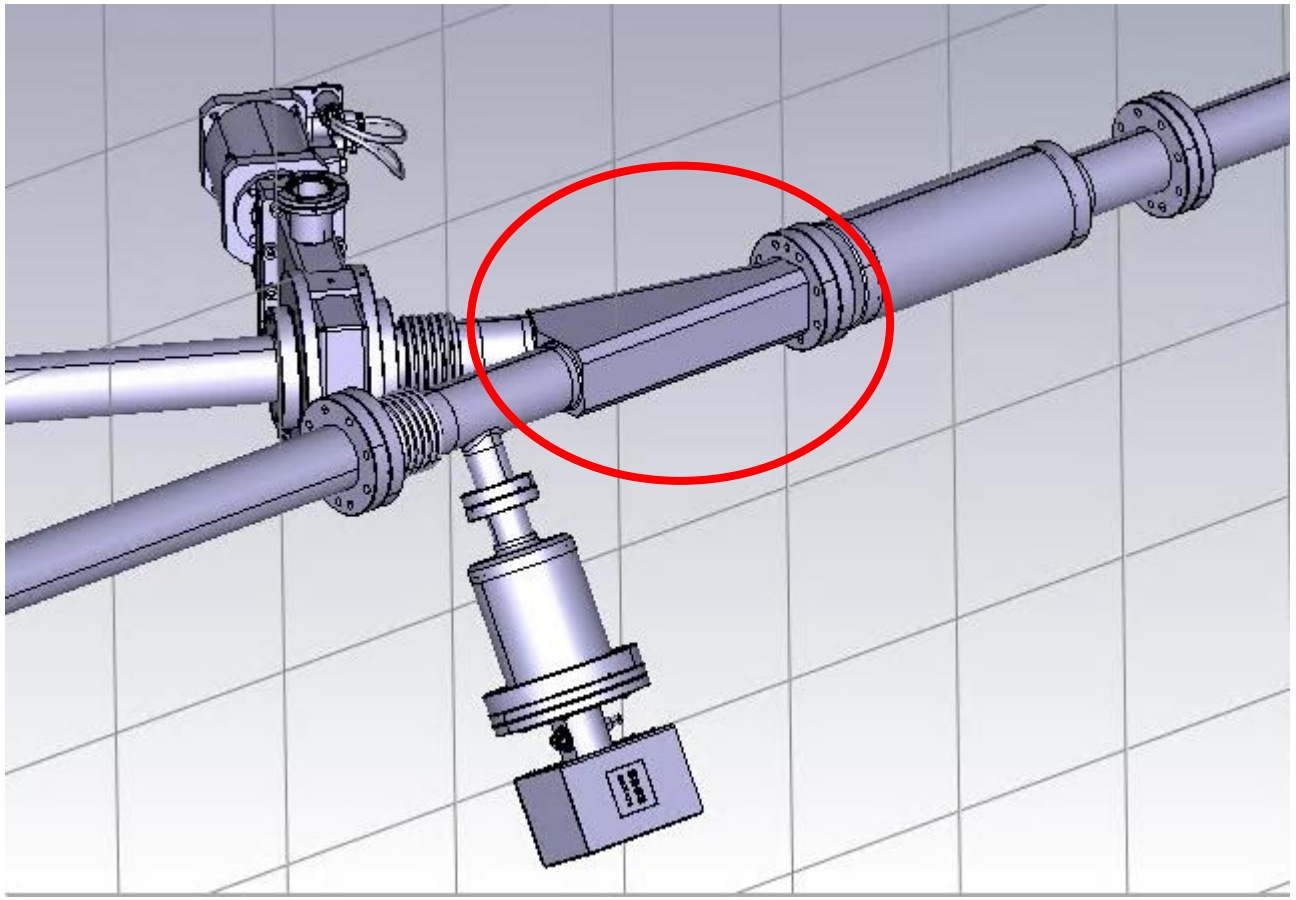
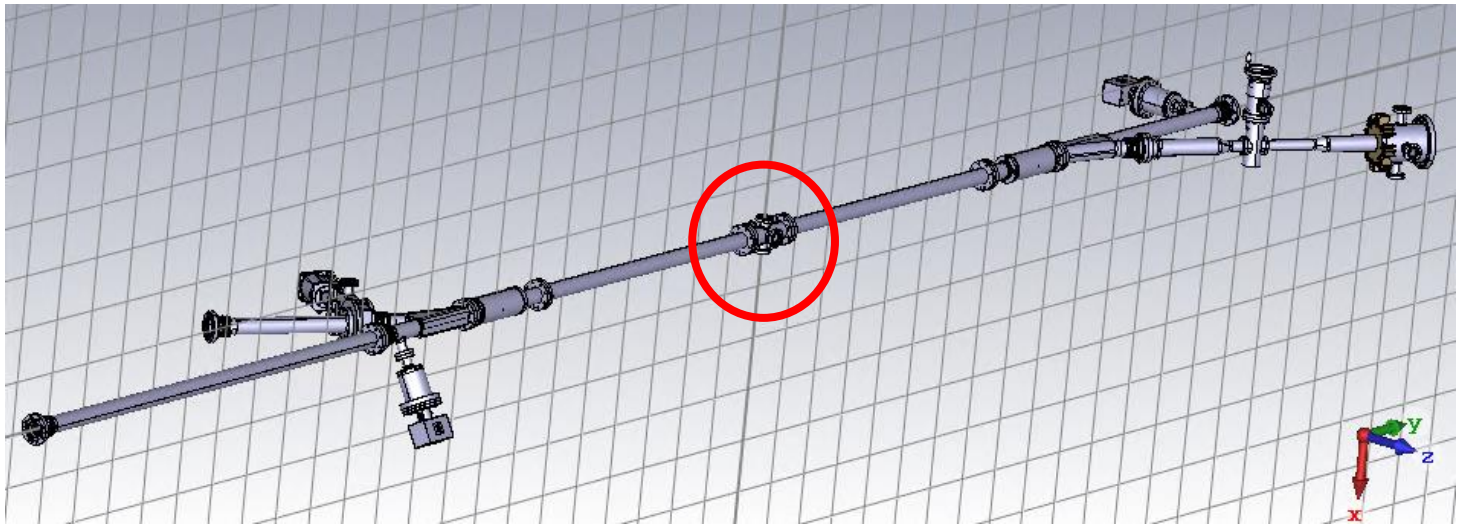
- Non-standard BPM (studied)
- Y chamber volume could be reduced



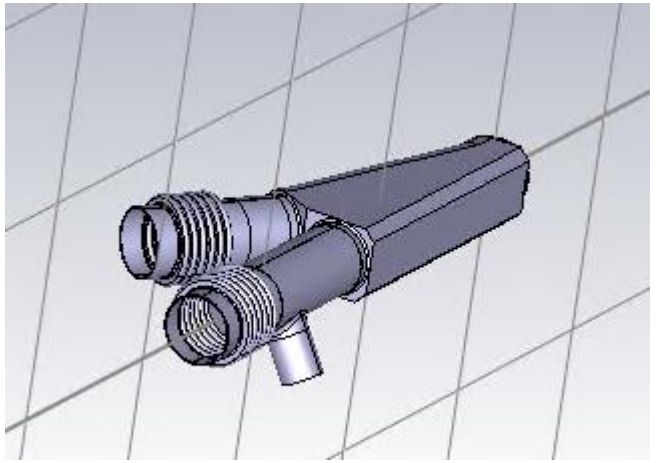
Comments

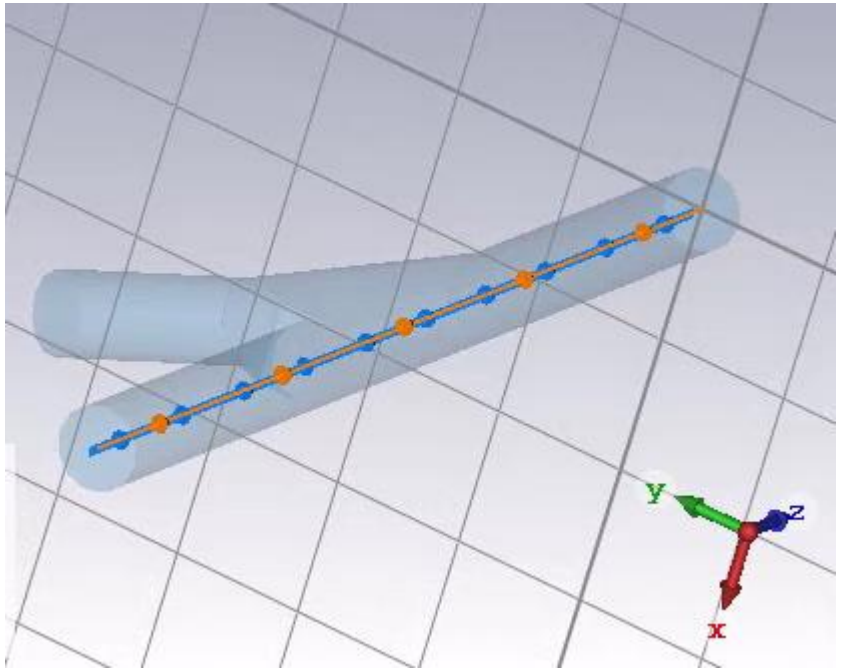
- Bellow should be shielded
- Pump should be shielded
- Non-standard BPM (studied)
- Y chamber volume could be reduced
- BGC design ongoing and not available
- Coatings? ID60 should impose copper coating in plain tubes.
- New request to have 2 bellows around the BGC



→ Under discussion with EN-MME

Y chamber

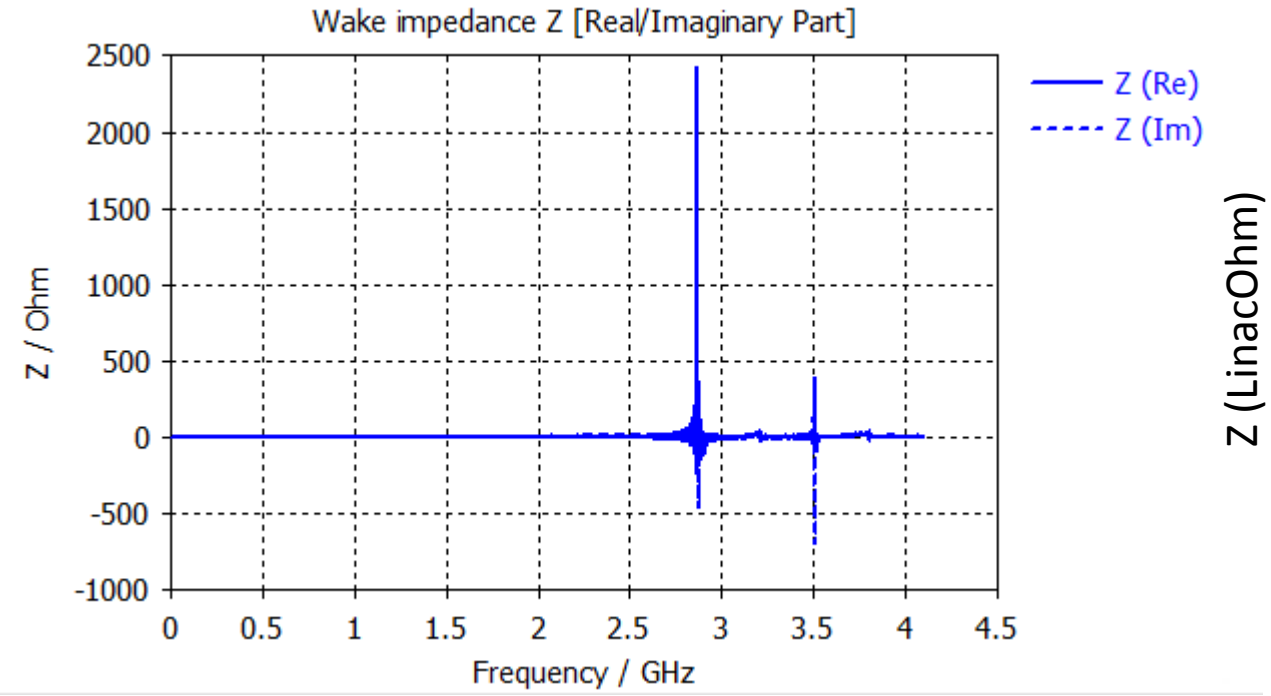




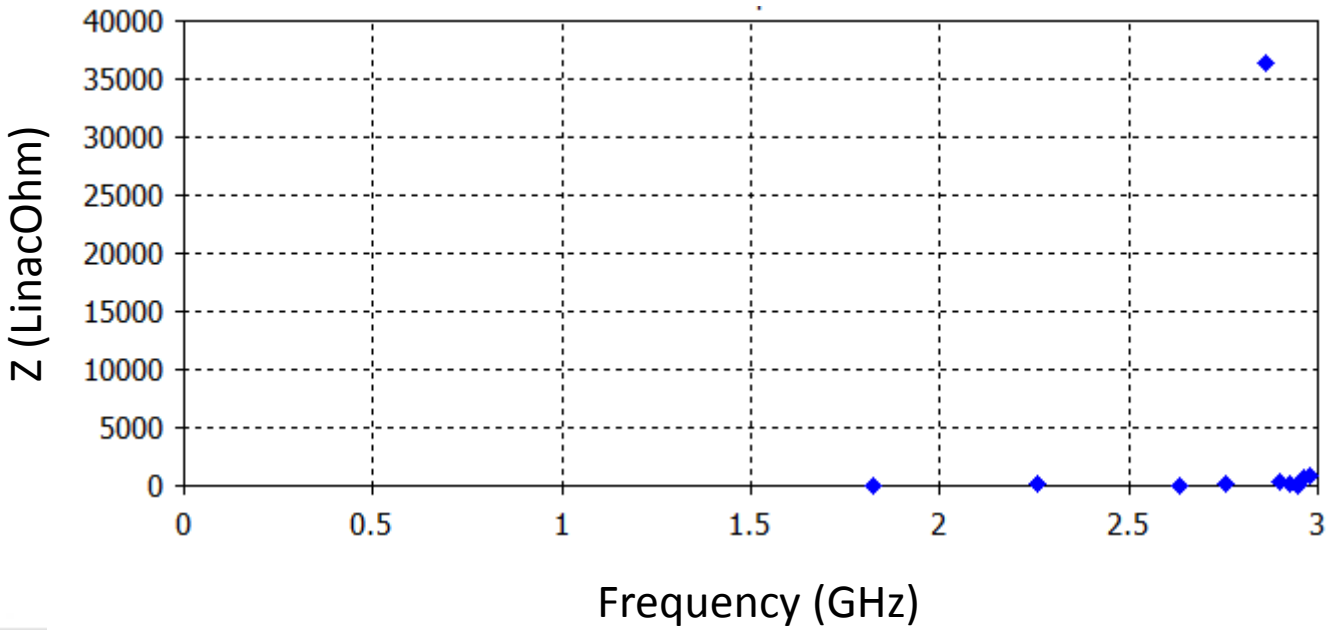
→ EN-MME followed the guideline we provided to minimize the volume around the incoming pipes
→ We could theoretically do a bit better, by adding a blade as in the other LHC Y chambers.
→ Nevetherless, contrary to the other Y chambers, not a simple symmetric merge of two pipes

Longitudinal impedance

CST Wakefield solver

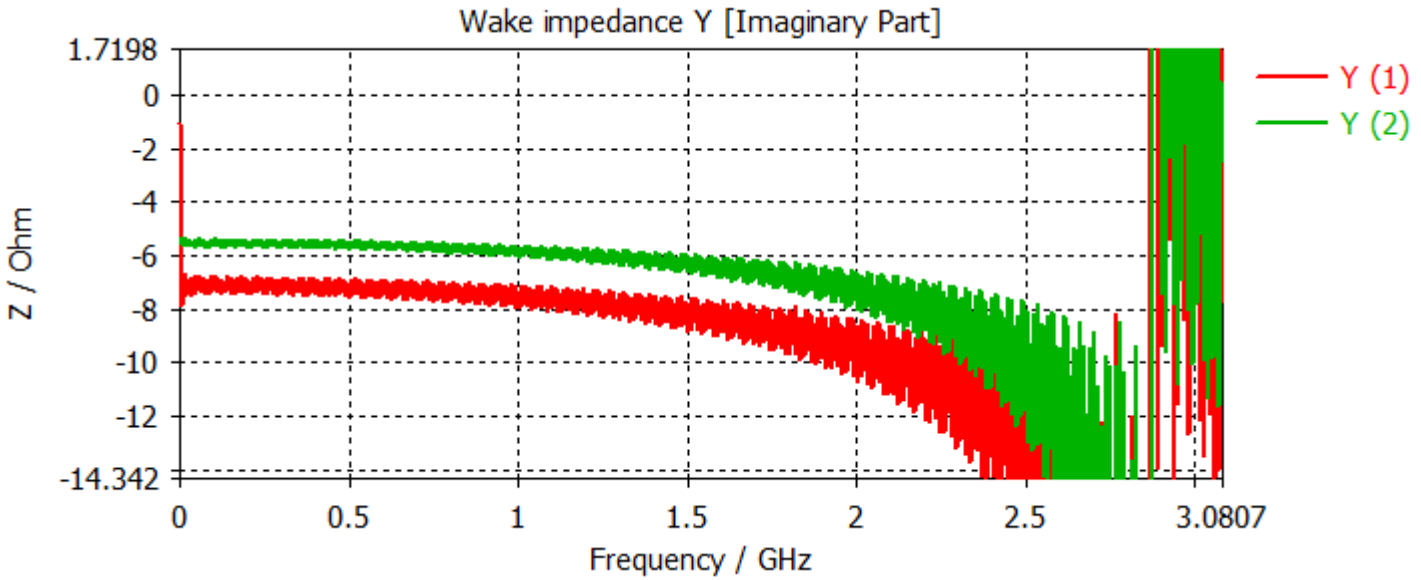


CST Eigenmode solver



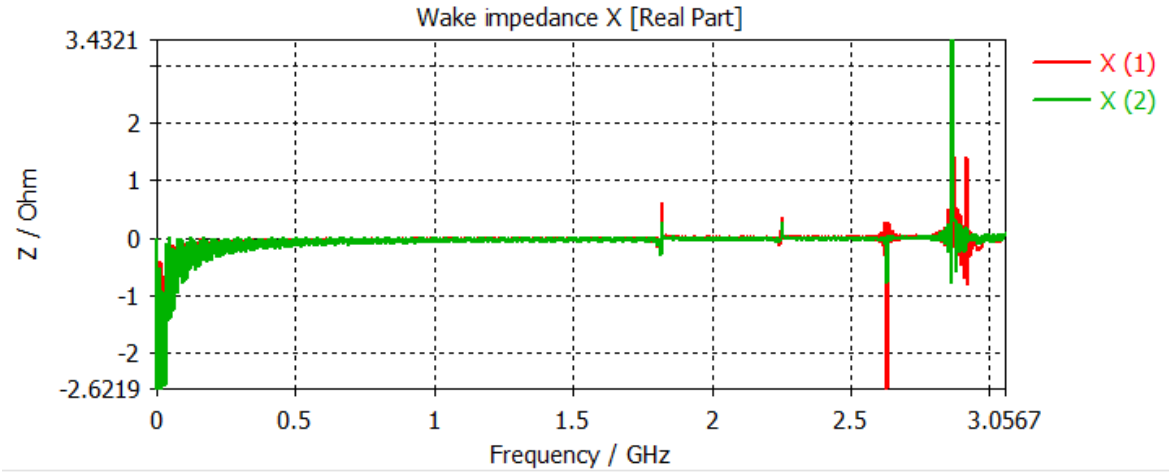
- First mode at 2.86 GHz (18 kOhm and Q=18,000 if copper coated, 2 kOhm and Q= 2800 if not)
- $\mathrm{Im}(Z/n)^{\mathrm{eff}} \sim 0.02$ mOhm for 1 Y chamber (to be compared to 90 mOhm for full LHC)

Transverse impedance (y → horizontal)

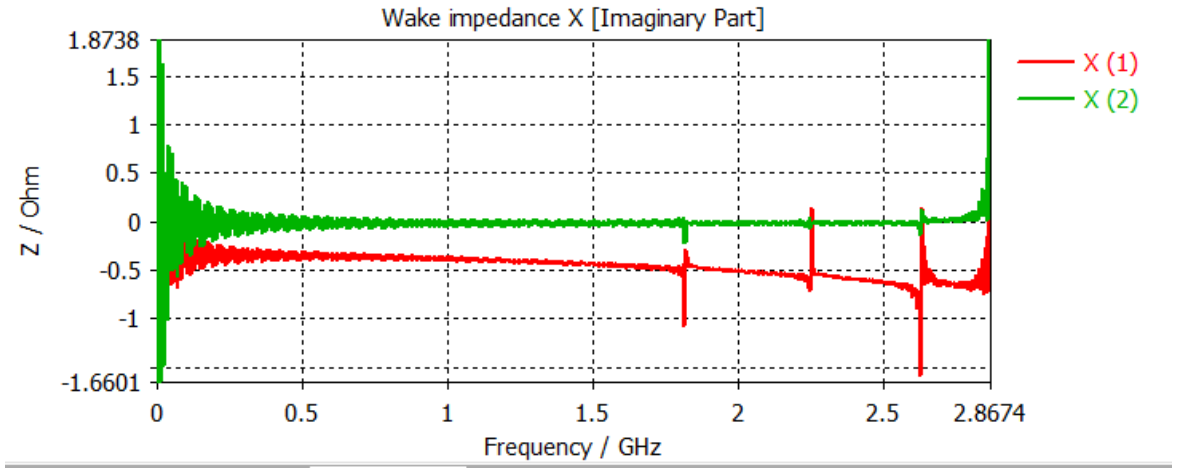


→ Beta ~280 m (from Riccardo)
→ Im(Zx)= 1.5 Ohm per 5 mm = 300 Ohm/m for 1 Y chamber

Transverse impedance (x→ vertical)

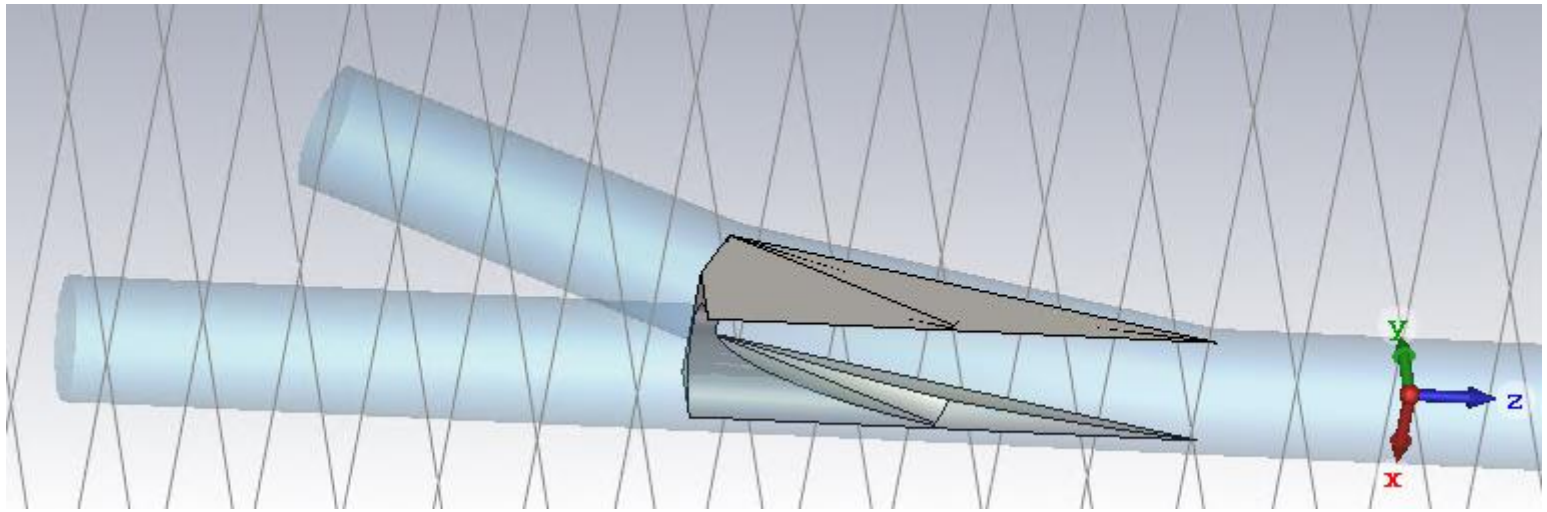


→ Beta ~280 m (from Riccardo)
→ Im (Zy)= 0.5 Ohm per 5 mm = 100 Ohm/m for 1 Y chamber



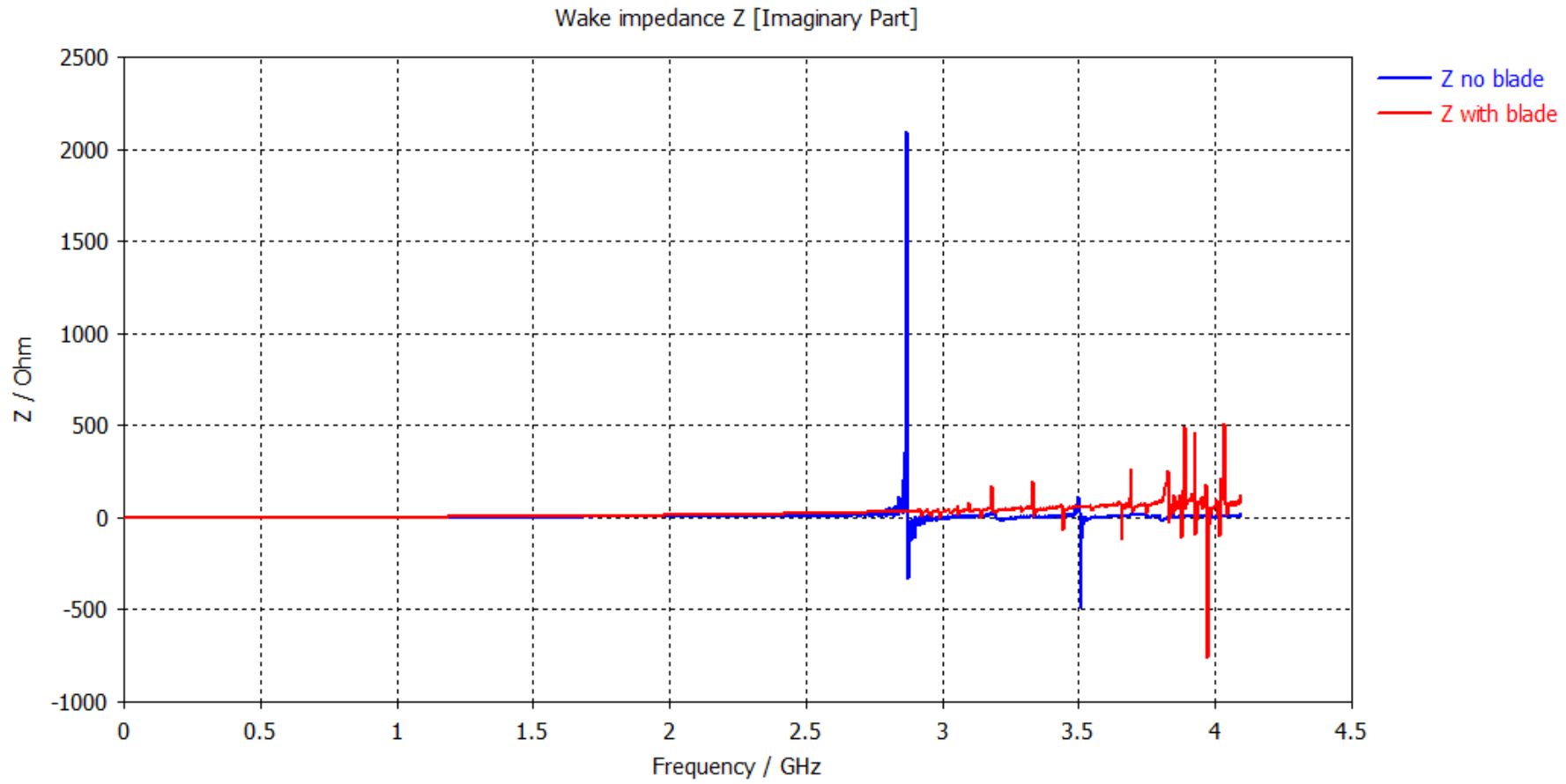
→ First mode at 1.82 GHz
→ 4 kOhm/m and Q=19,000 for copper from eignemode

Adding a shielding blade



→ Not a trivial geometry to manufacture

Impact of shielding blade



→ Mode at 2.86 GHz disappears
→ No significant beneficial impact on Im(Z/n)
→ Vertical mode gets worse (30 kOhm/m instead of 4 kOhm/m)

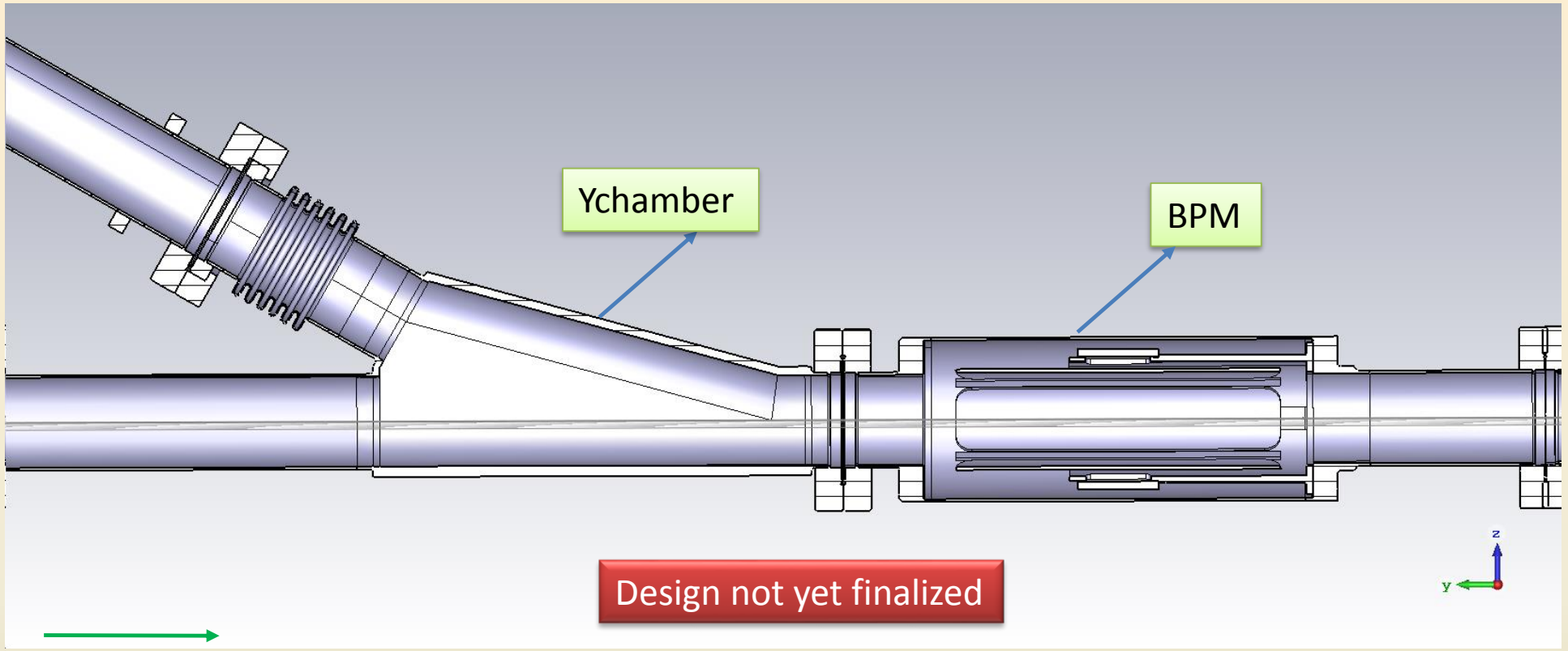
Conclusions for Y chamber

- Current model leads to very moderate impedance contribution.
- One could reduce longitudinal impedance if it is an issue by adding a blade, but

  (1) It is not clear that the shape is feasible

  (2) The first vertical mode at 1.85 GHz increases from 4 to 30 kOhm/m in simulations.
- The additional request of adding two bellows around the BGC needs to be studied.

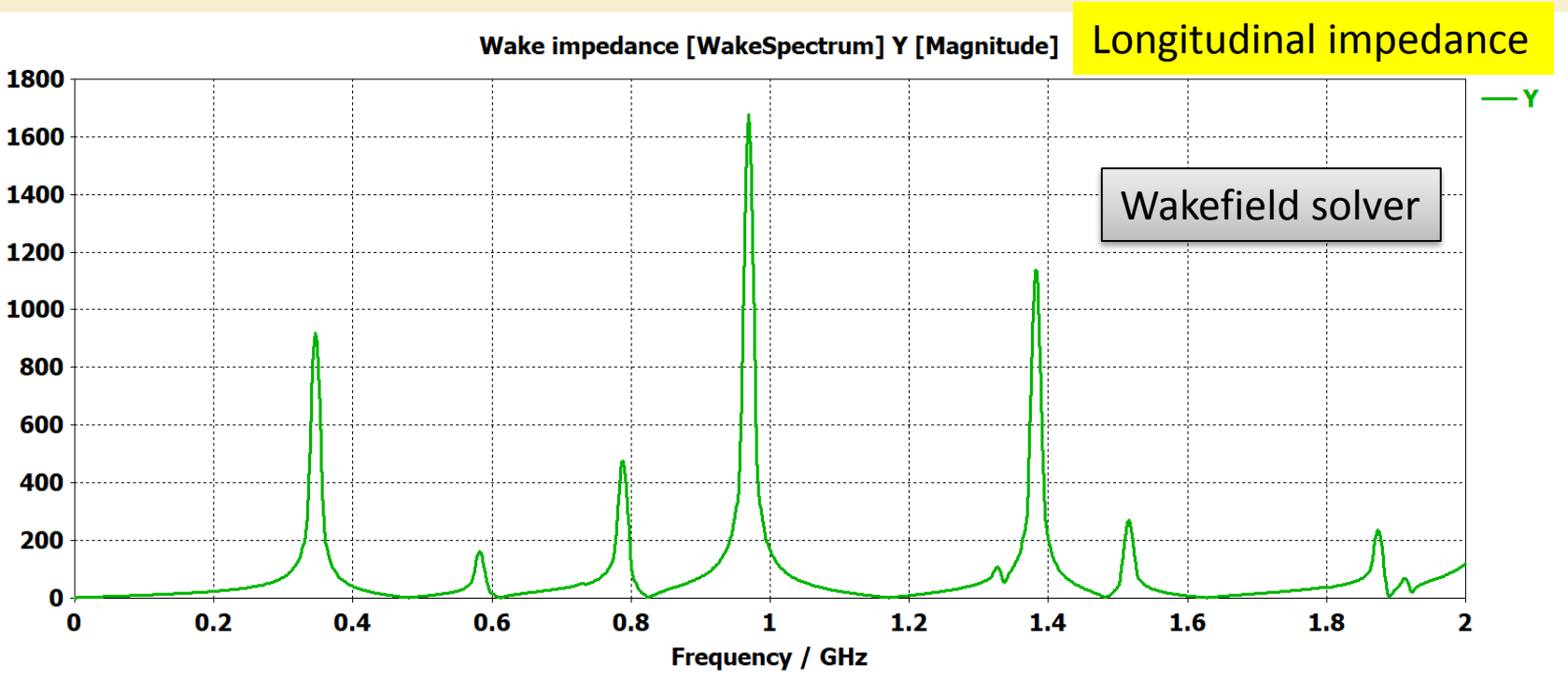
Simulation model



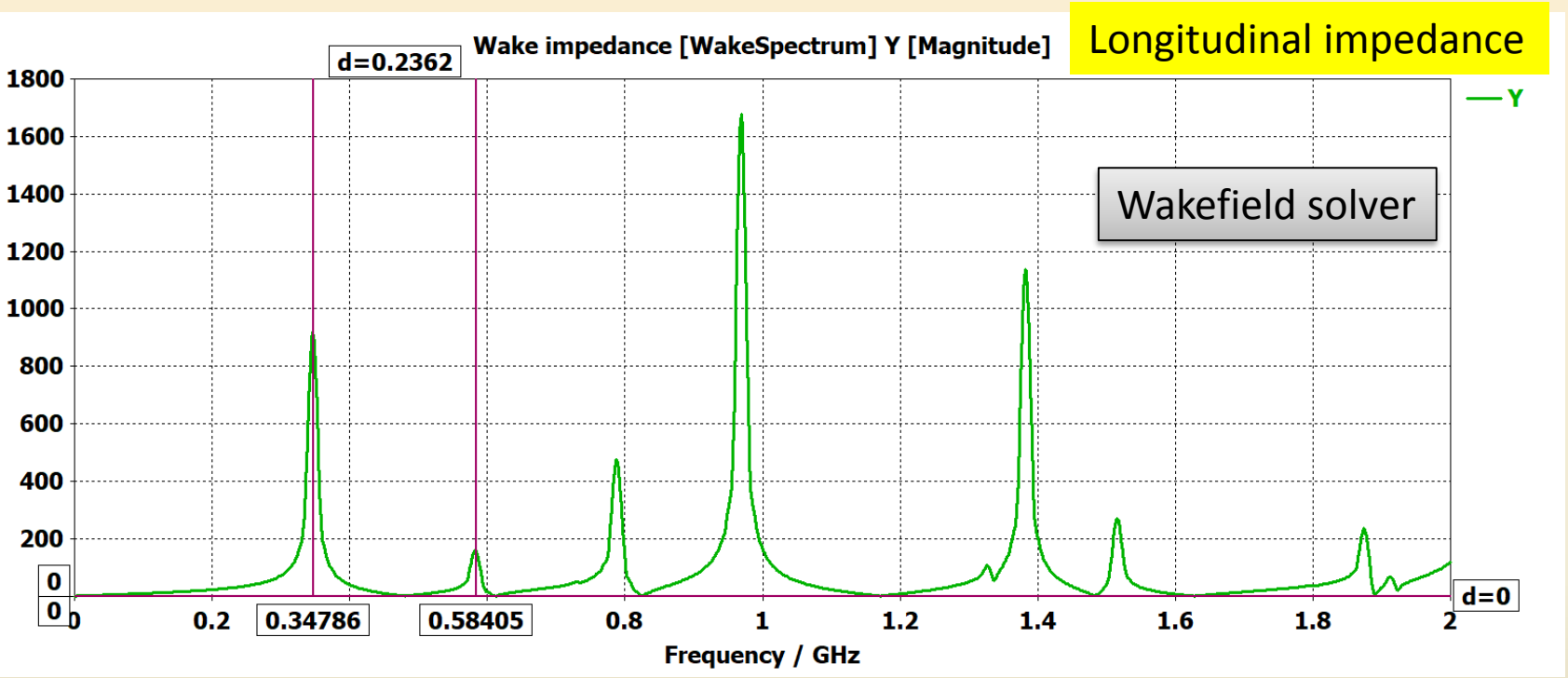
Geometric impedance of the hollow electron lens

$Z_{G\text{-}elens} \approx$ 2*Ychamber + 2*BPM + CBGC

Beam position monitor impedance simulations



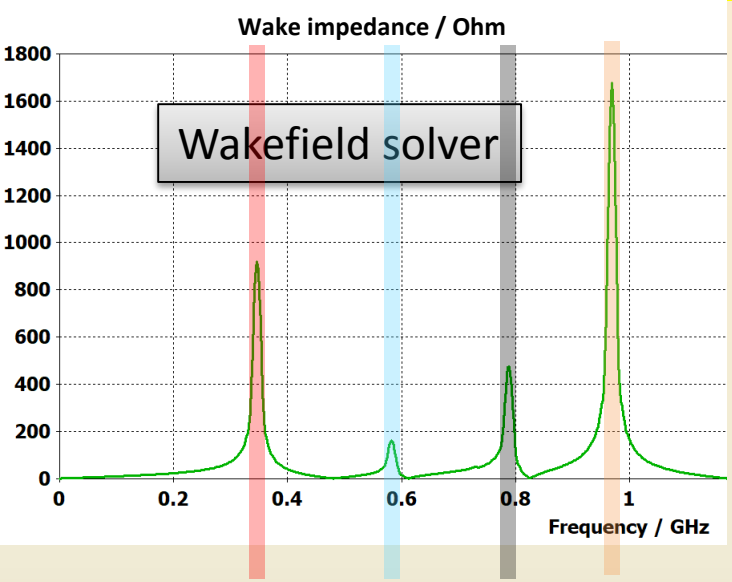
Beam position monitor impedance simulations

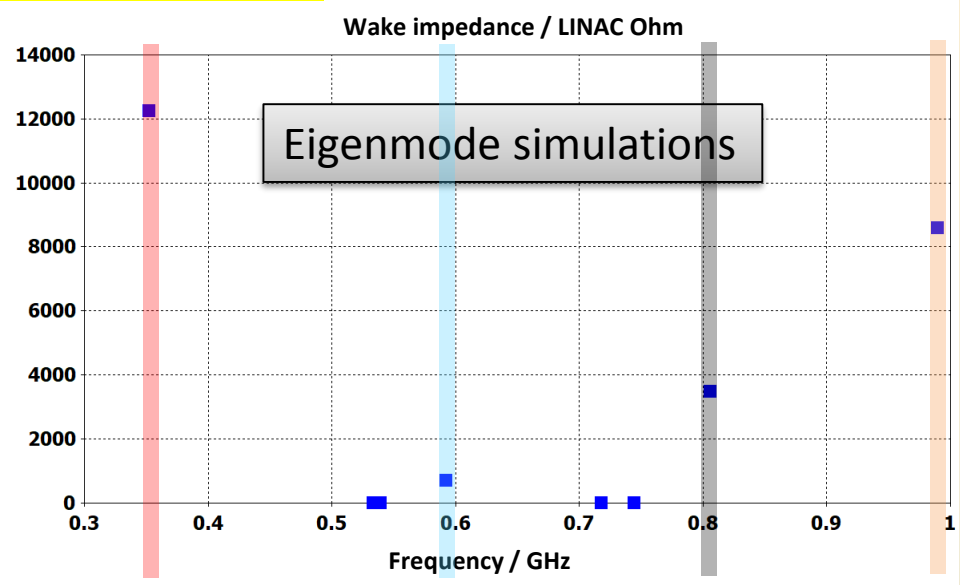


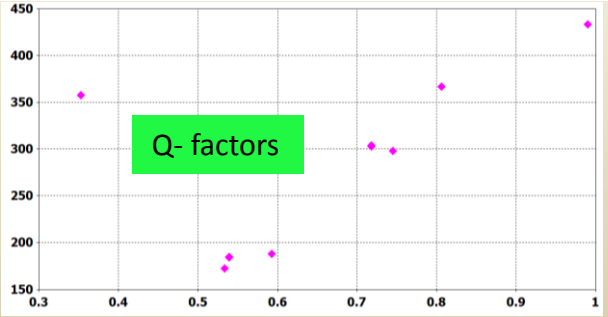
Wake is not decayed. Impedance spectrum gives information about the frequency of the impedance resonances. First resonance expected at about 350 MHz. Four significant impedance resonances are expected below 1 GHz

Beam position monitor impedance simulations

Longitudinal impedance magnitude







Very good agreement between eigenmode and wakefield solver for the frequencies of the impedance resonances

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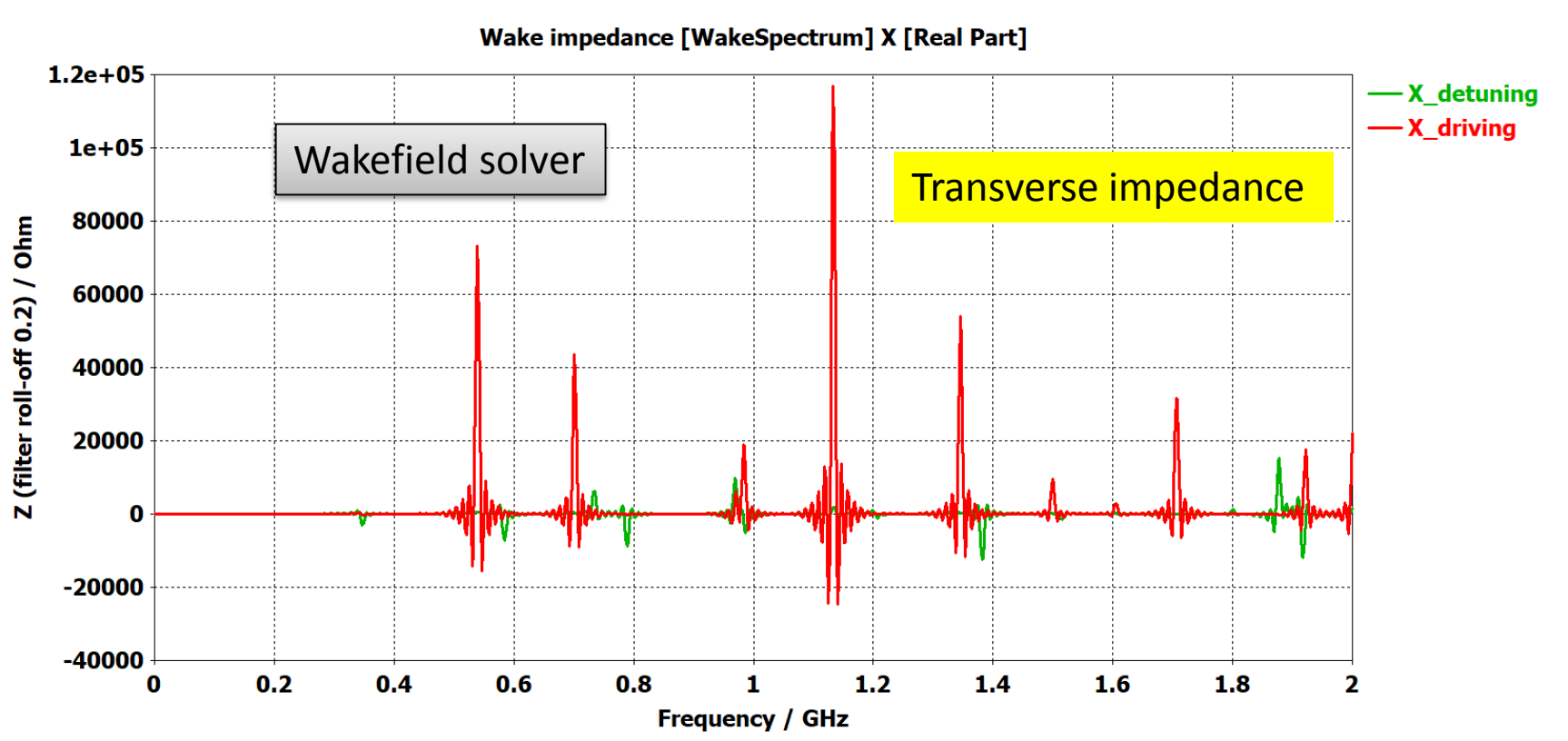
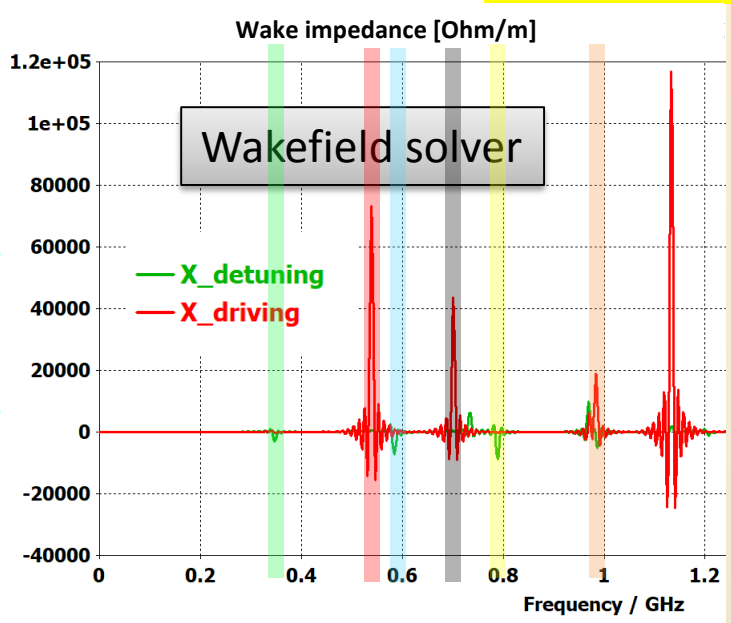
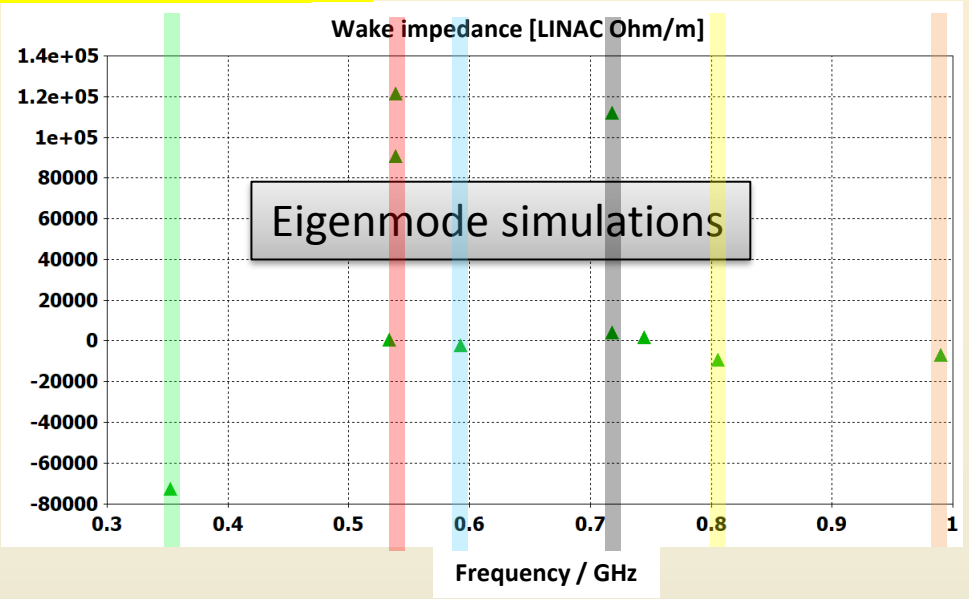


Wake is not decayed. Impedance spectrum gives information about the frequency of the impedance resonances. First detuning resonance expected at about 350 MHz. First driving resonance expected at about 540 MHz.

Beam position monitor impedance simulations

Horizontal impedance magnitude





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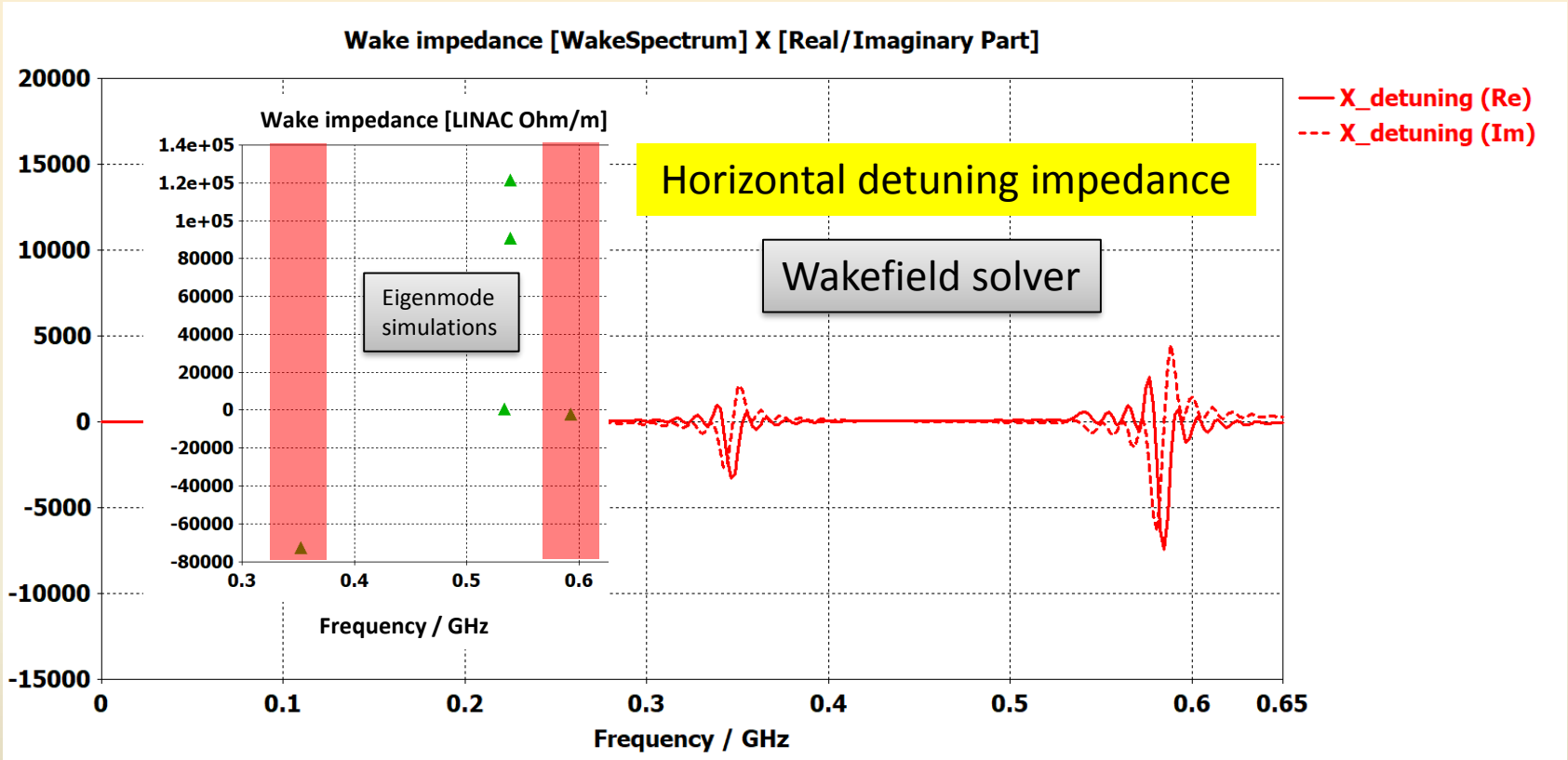

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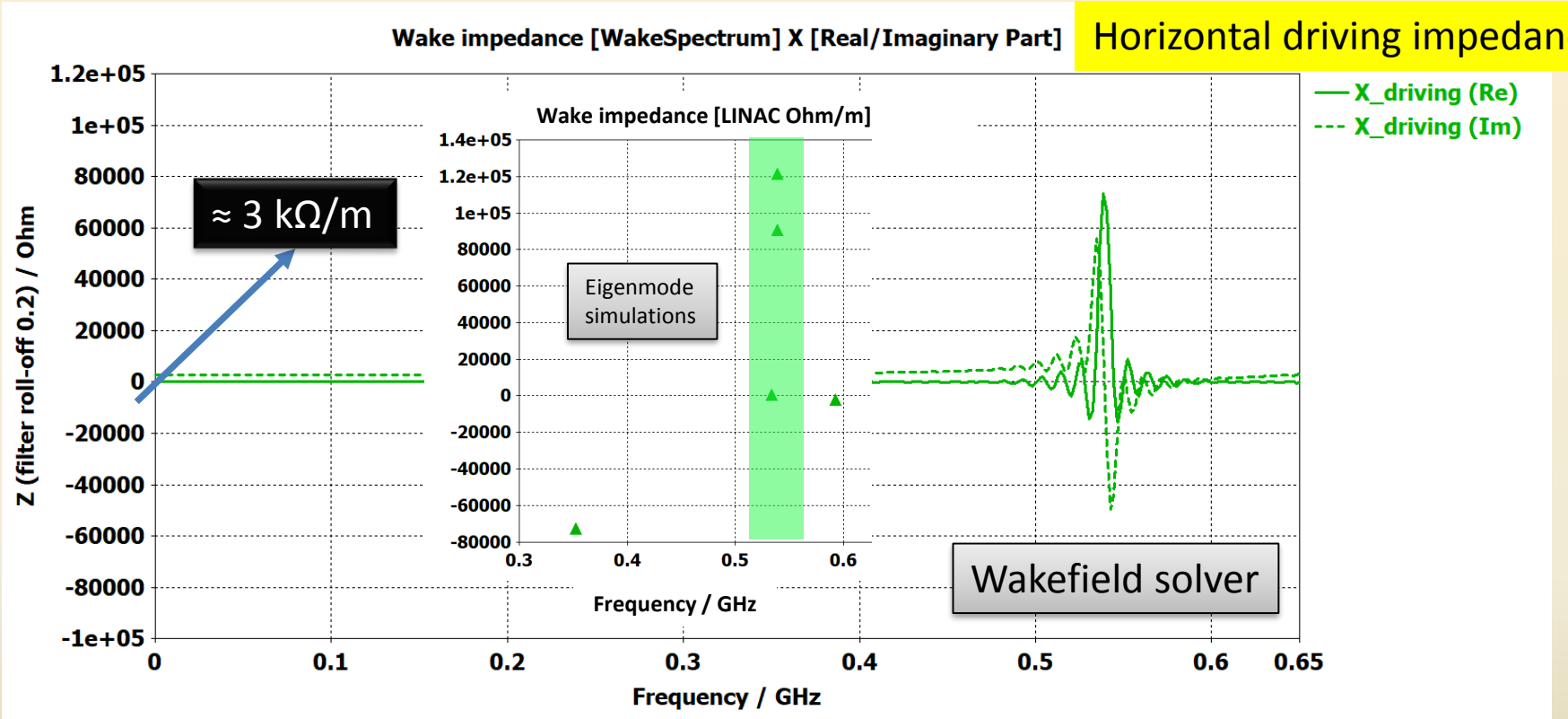

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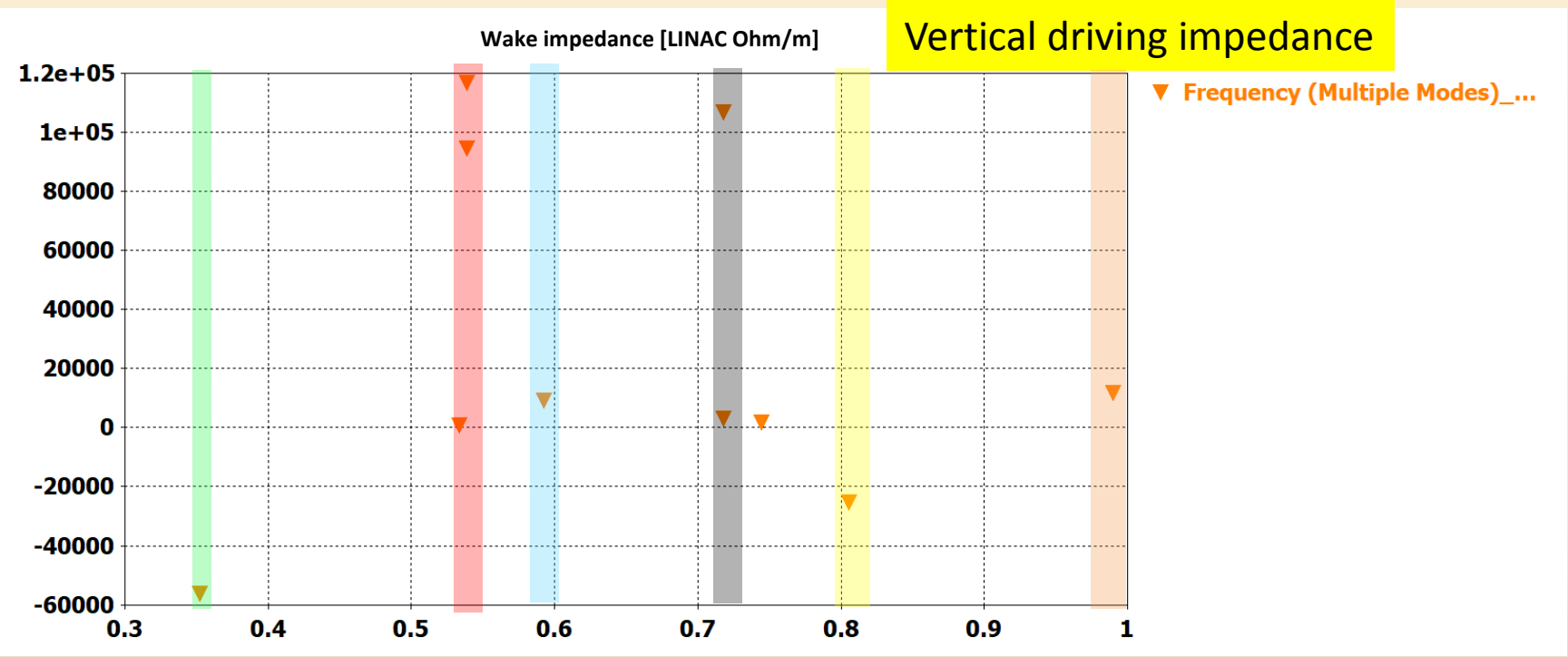

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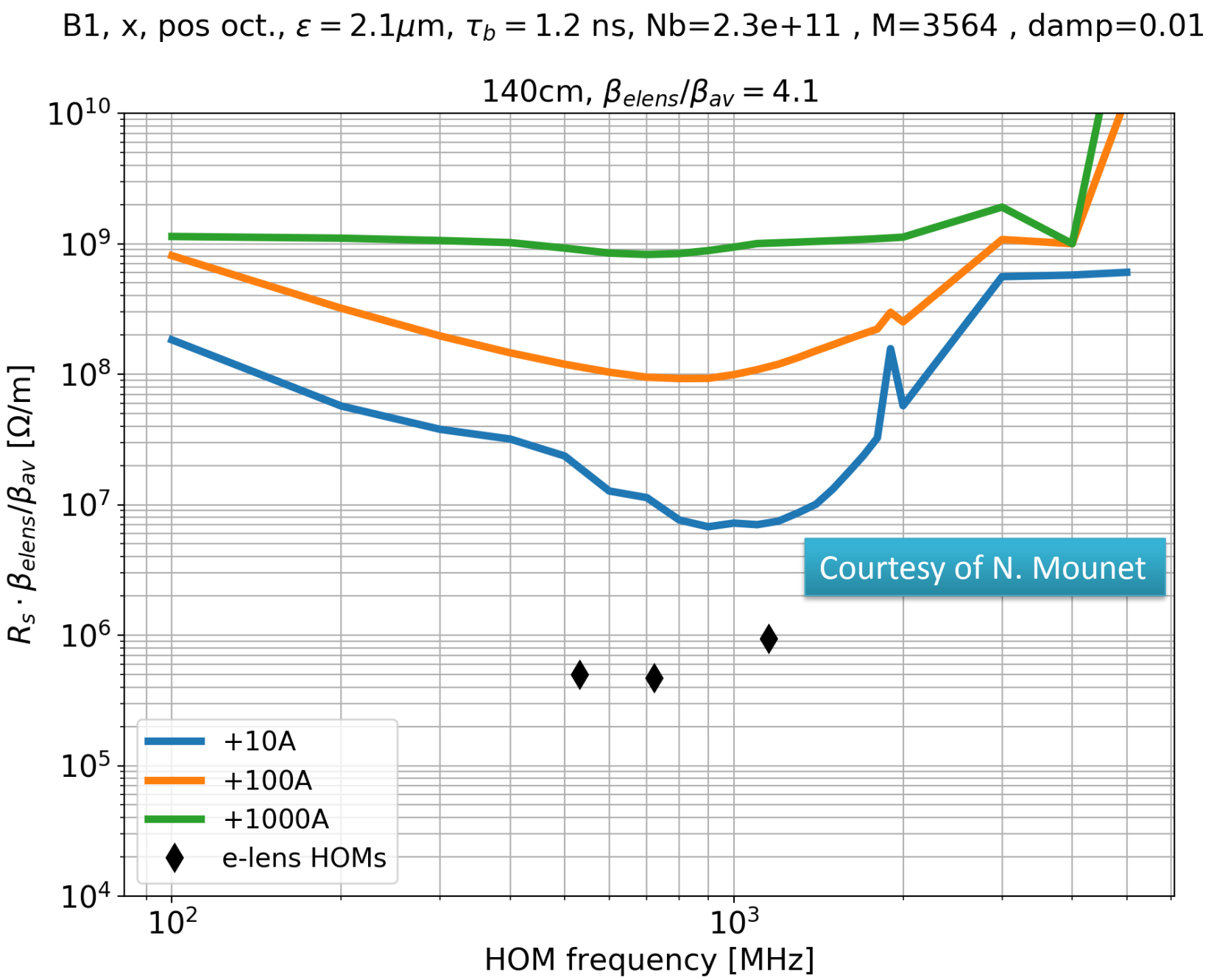
Large margin on the shunt impedance of the three main HOMs

Effect on HL-LHC stability



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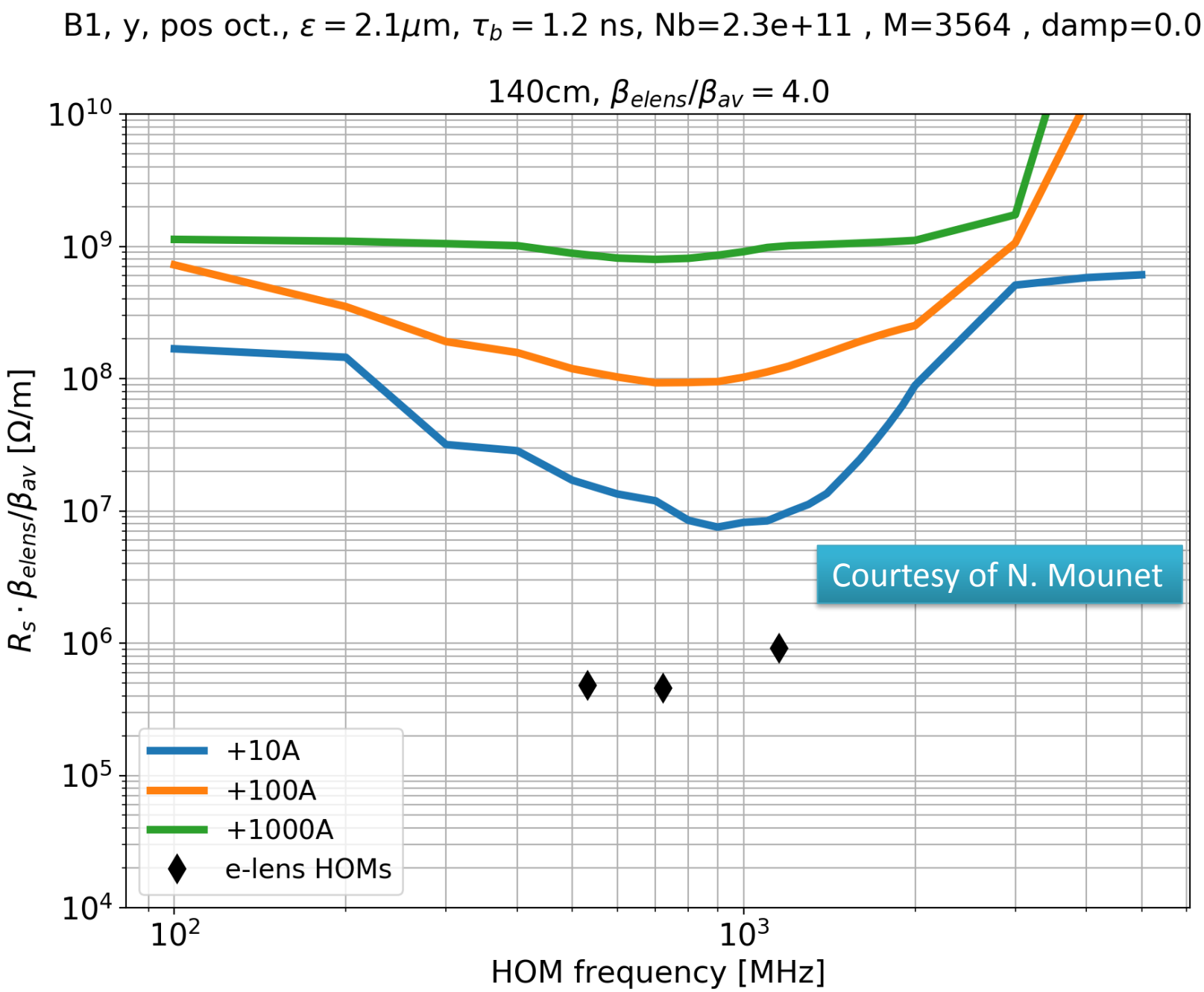


Summary

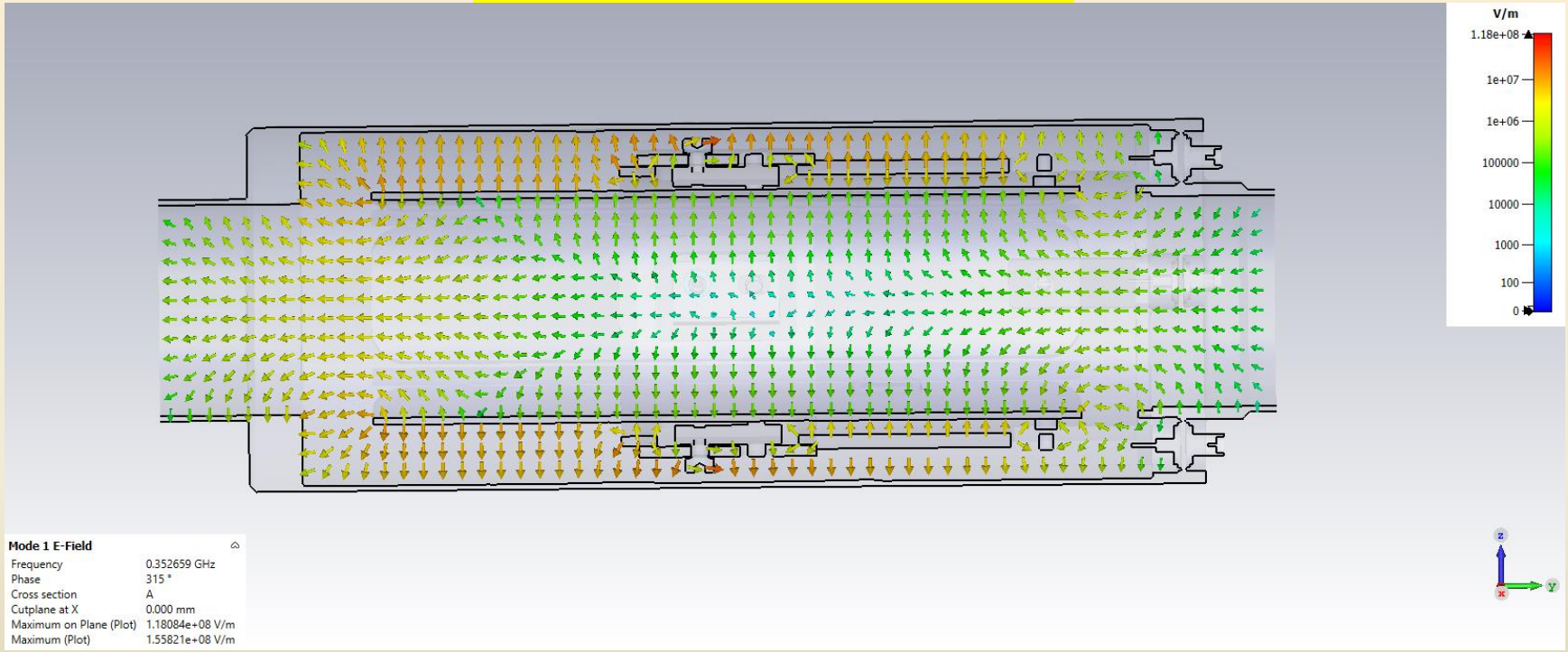
- A preliminary beam coupling impedance model of the electron lens including the effect of BPM and Y chamber has been built

- The results are not final
  - Design not yet finalized:
    - BGC not integrated in the CATIA model
    - BPM terminations not integrated in the CATIA model

Appendix

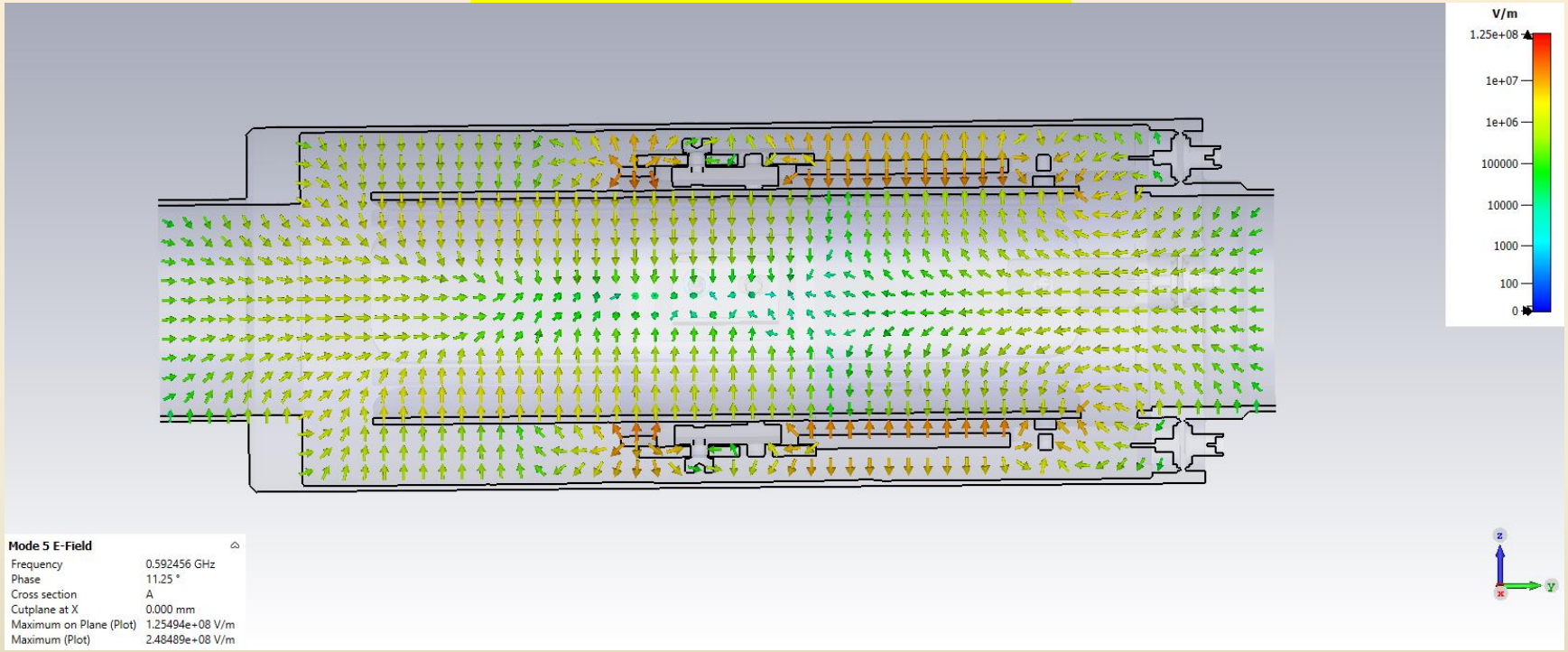
Beam position monitor impedance simulations

First detuning mode



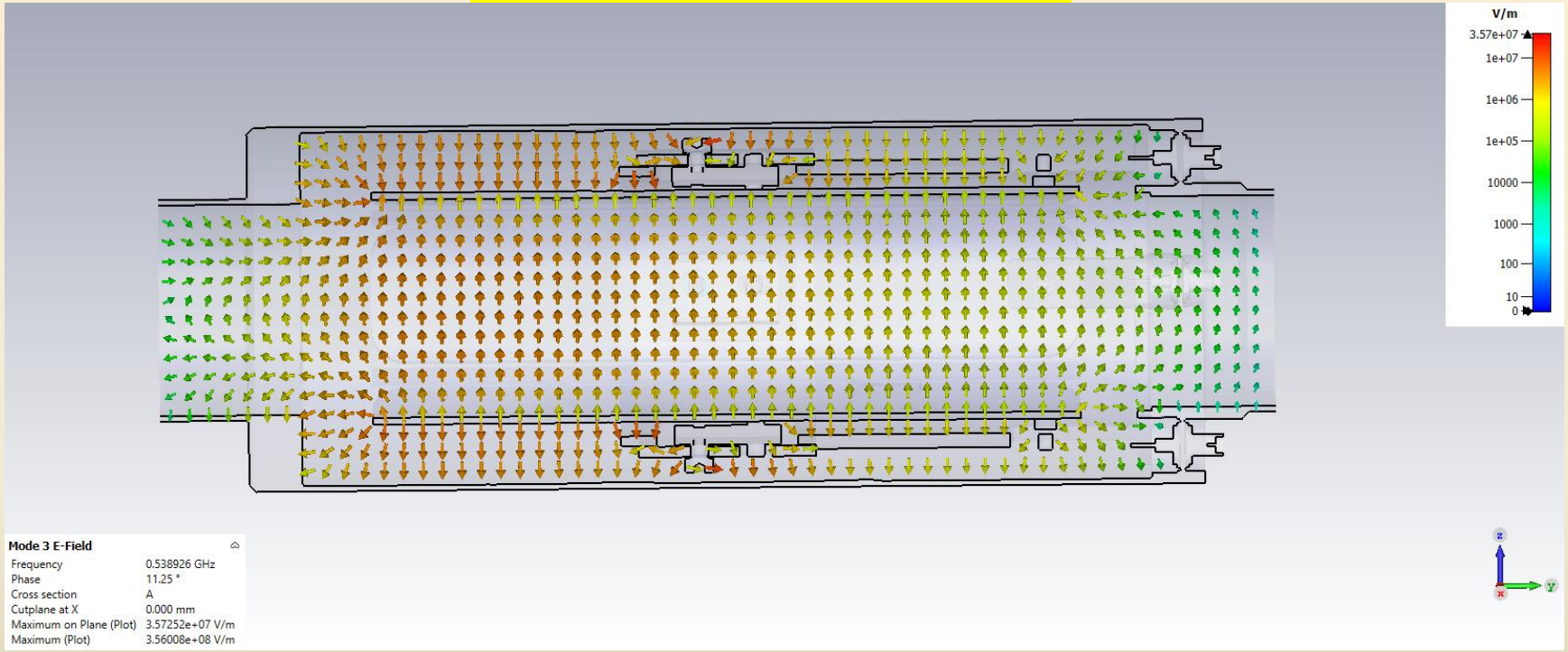
Beam position monitor impedance simulations

Second detuning mode

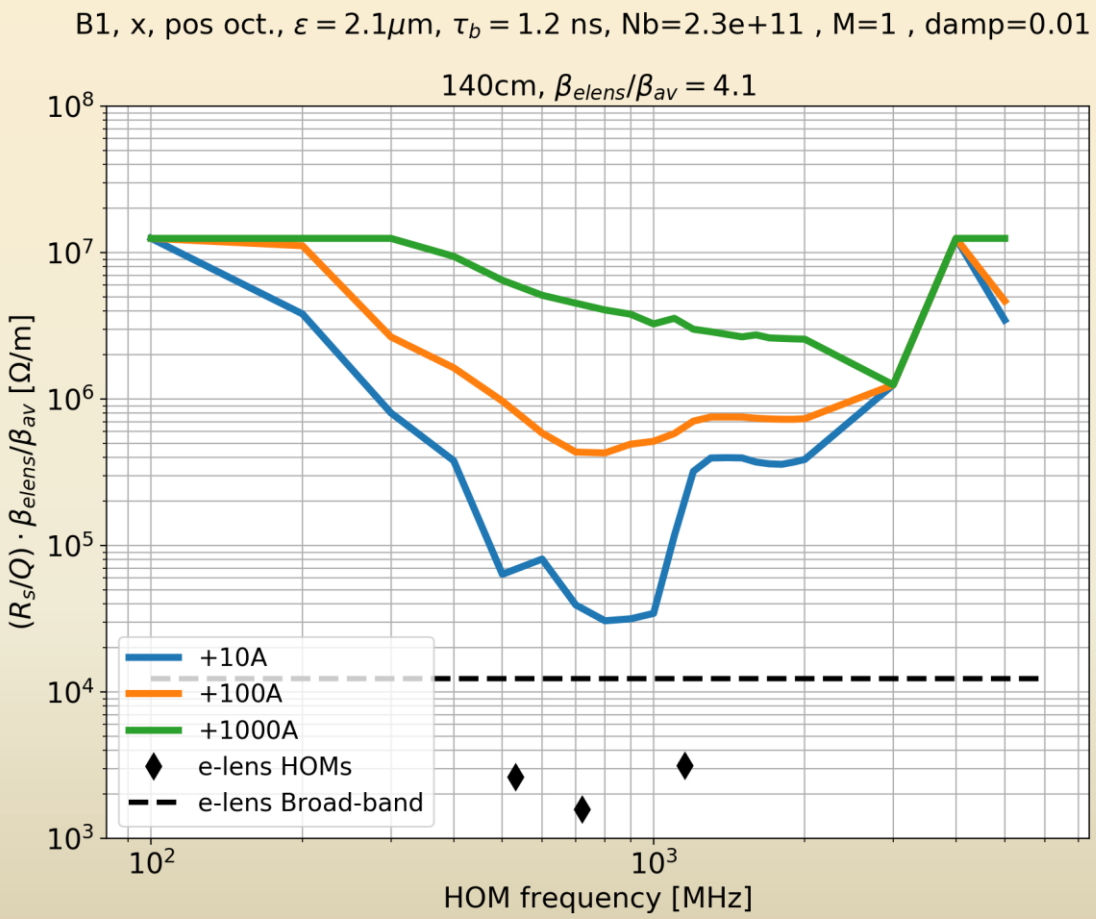


Beam position monitor impedance simulations

First driving mode



Single bunch stability



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