Transverse impedance of crystal goniometer

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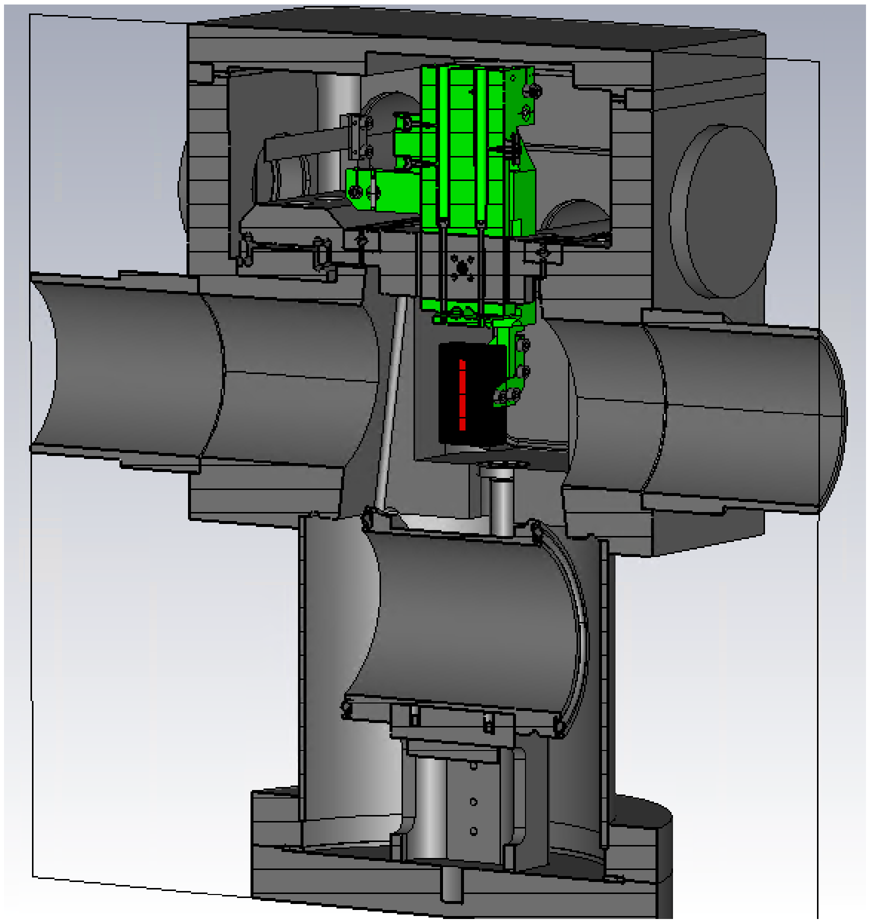
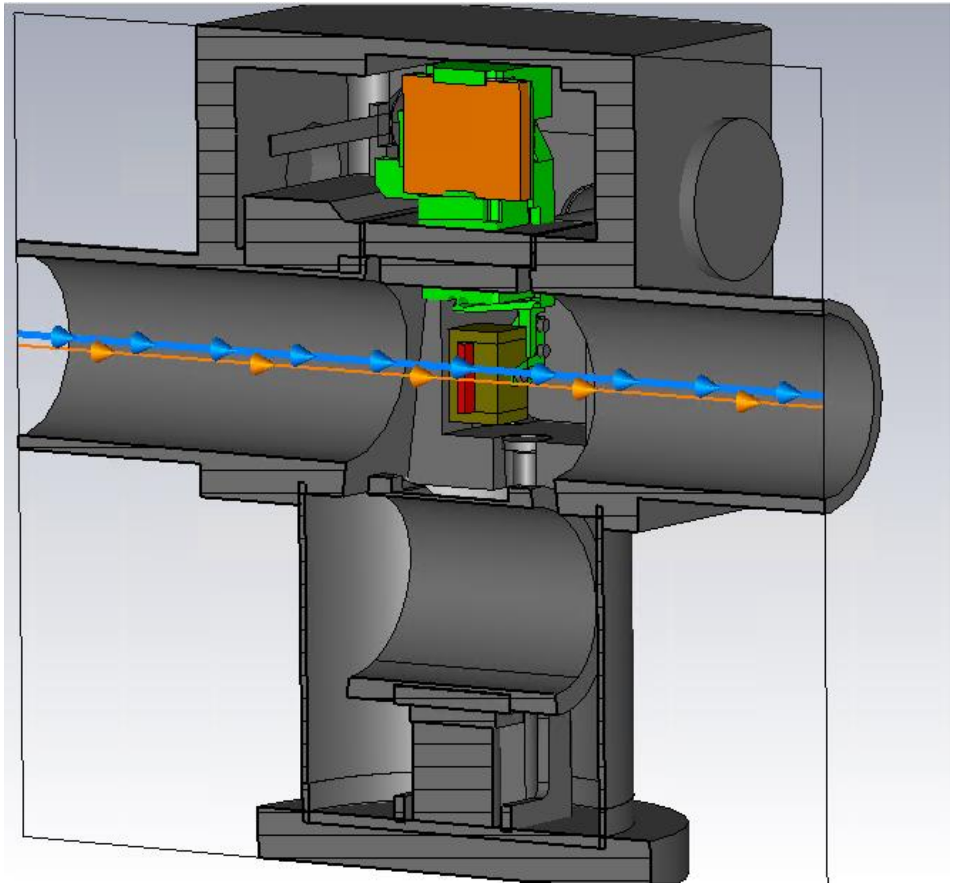
Status end of 2020



→ Collaboration with University of Sapienza (Rome)
→ Understand and improve the discrepancies between simulations and measurements
→ Danilo performed simulations of longitudinal impedance
→ With the issues of 11T dipoles, crystals are now the baseline of HL-LHC with ions
→ Need a fast approval of the system for Run 3, based on version 2

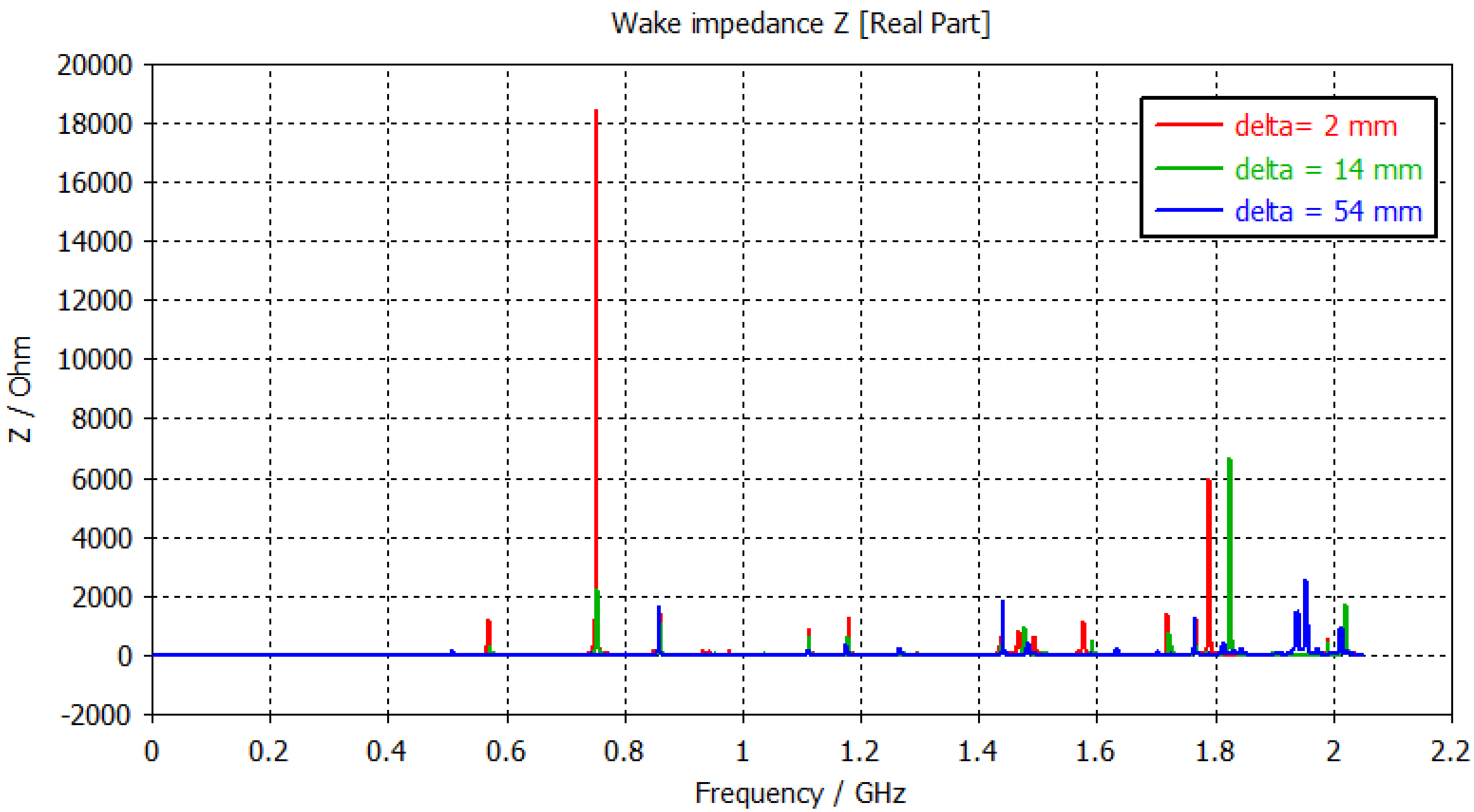
→ Need transverse impedance for ions, and we decided to do it ourselves with high priority

Need to remodel

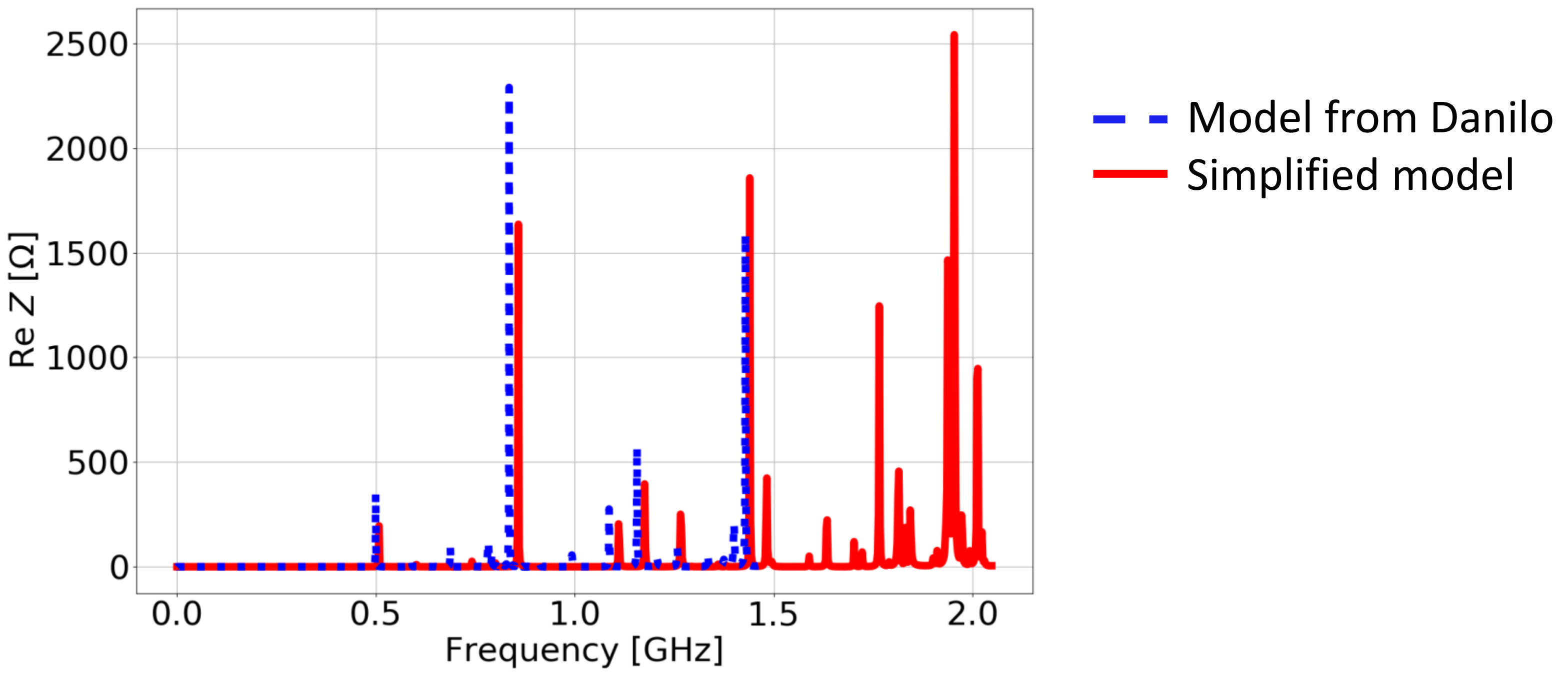


- The model could not be digested correctly by CST
- Required remodeling to remove many unnecessary details and model issues

Longitudinal impedance

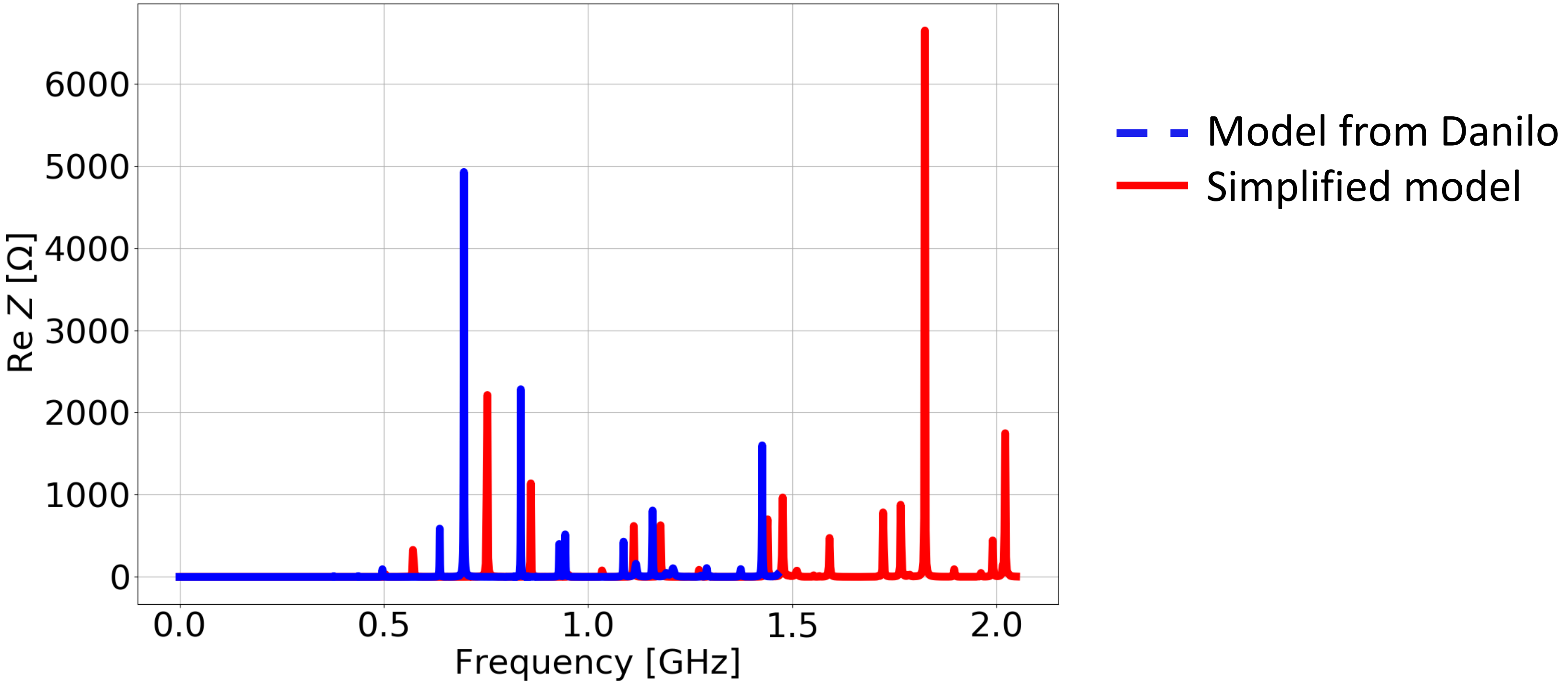


longitudinal impedance (crystal in parking position – 54 mm)



→ Similar impedance spectrum

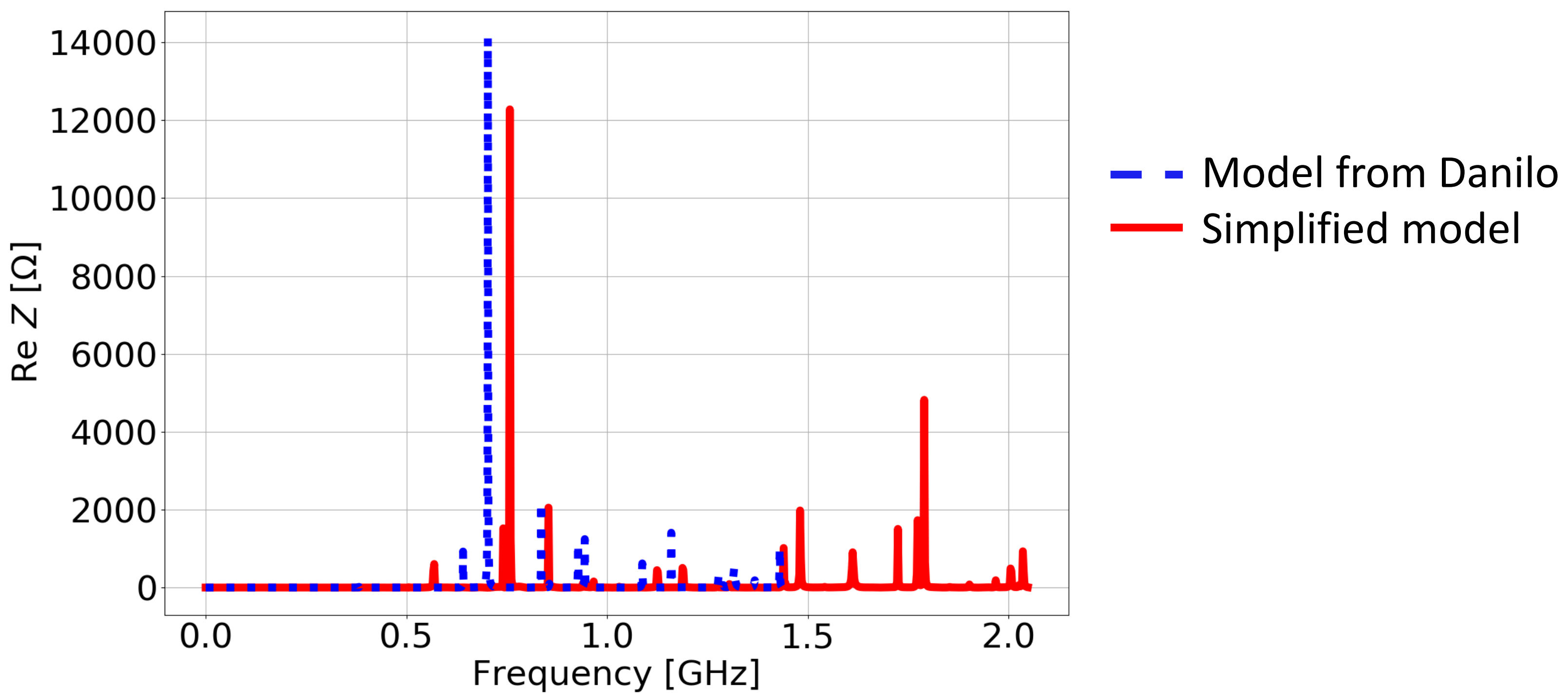
longitudinal impedance (crystal at 14 mm)



→ Impedance spectrum is quite different

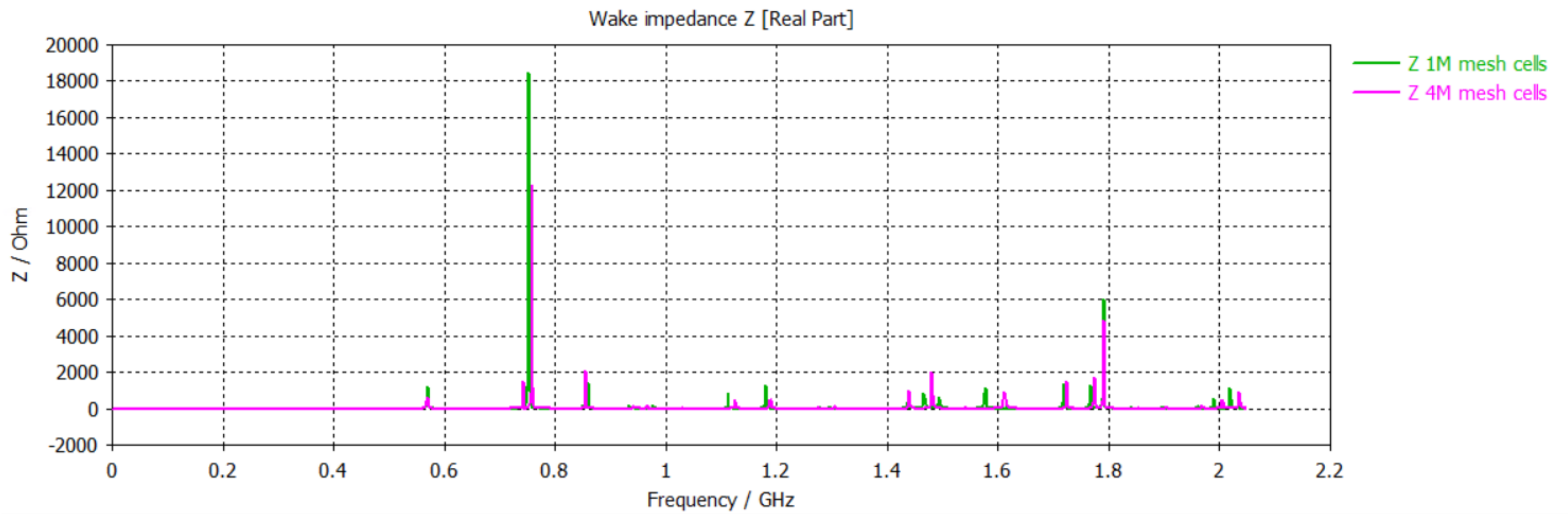
→ Same order of magnitude for frequency range and shunt impedance

longitudinal impedance (crystal at 2 mm)



→ Impedance spectrum is quite different
→ Same order of magnitude for frequency range and shunt impedance

Increasing mesh cells around the beam



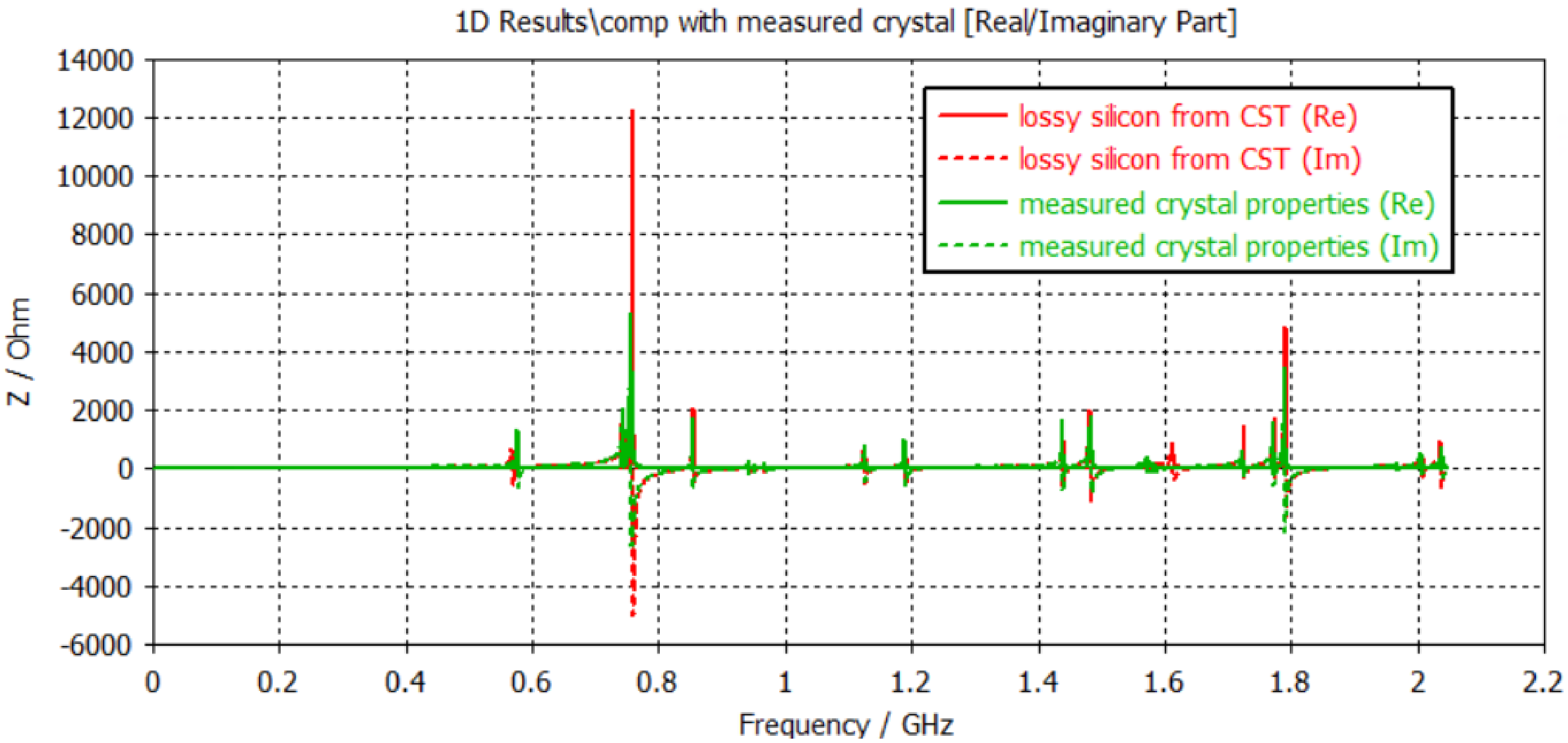
Im(Z/n)~1 mOhm (i.e. ~1% of the total LHC low frequency until 500 MHz) for 1 crystal

→ 1 crystal per plane per beam
→ 2% of total LHC impedance when all crystals fully inserted

Using the crystal properties measured by Danilo and Mauro

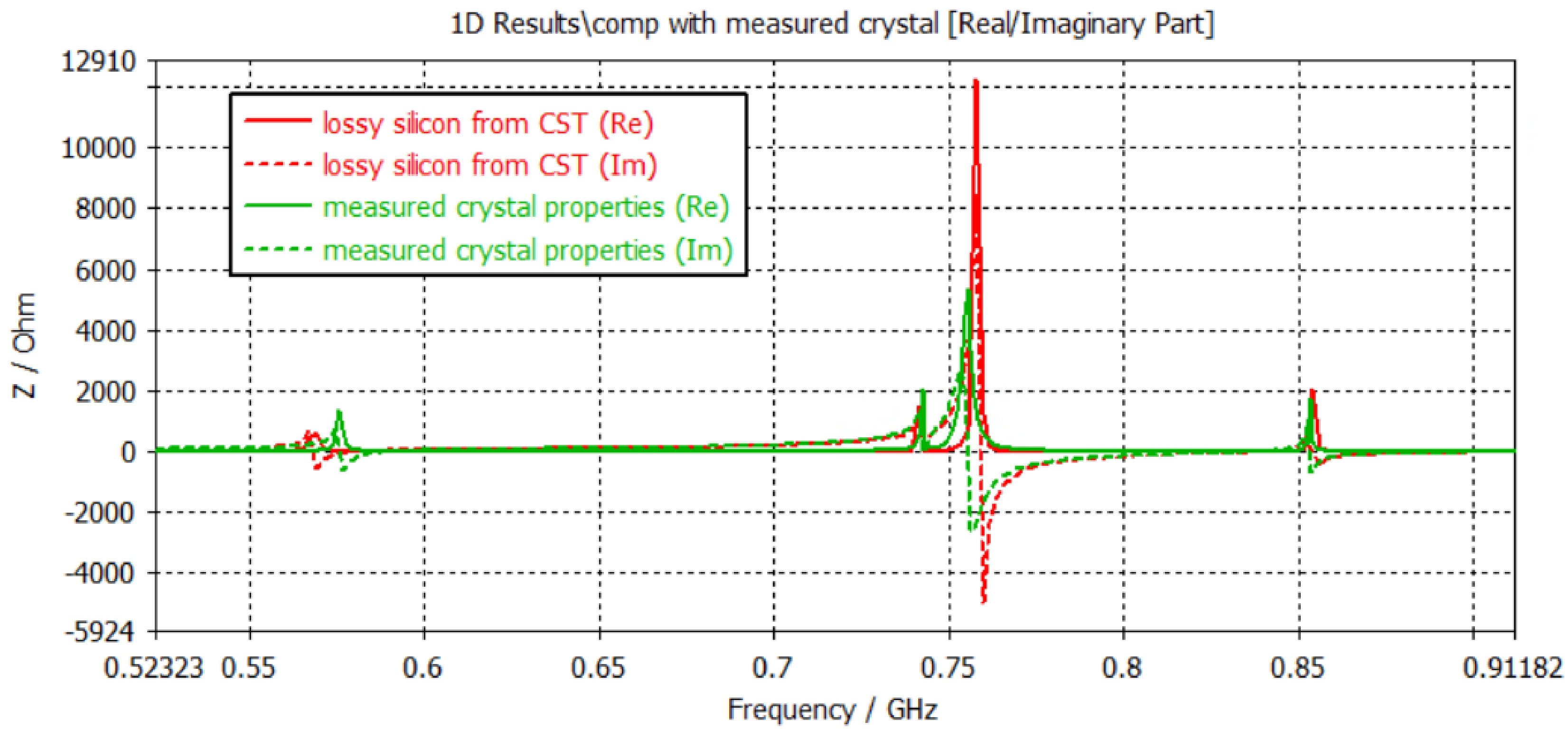
- Measured by cavity perturbation measurements between 2 and 4 GHz
- Significant difference between placing the crystal in one direction or another

Longitudinal imaginary impedance



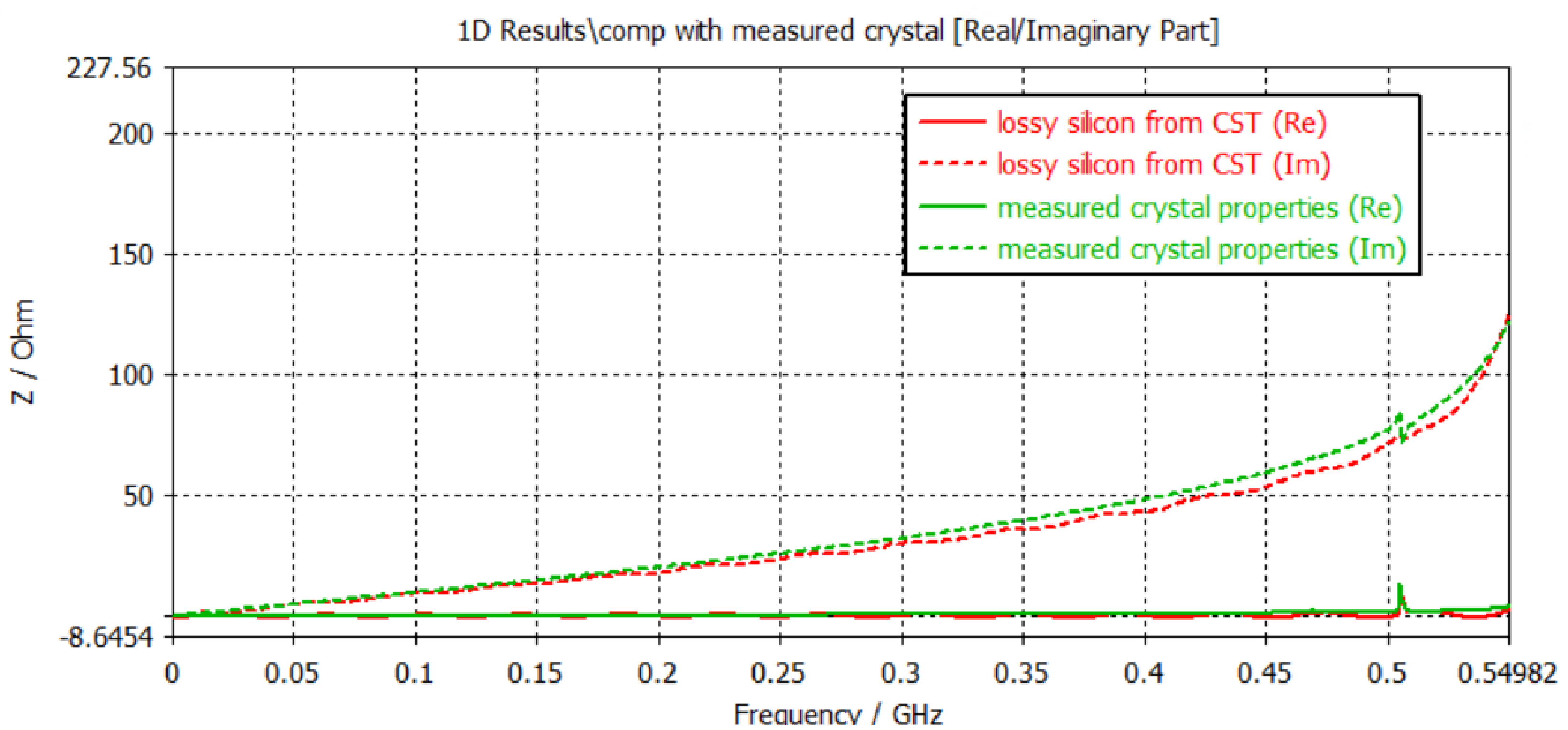
→ More losses on the main crystal mode

Longitudinal imaginary impedance



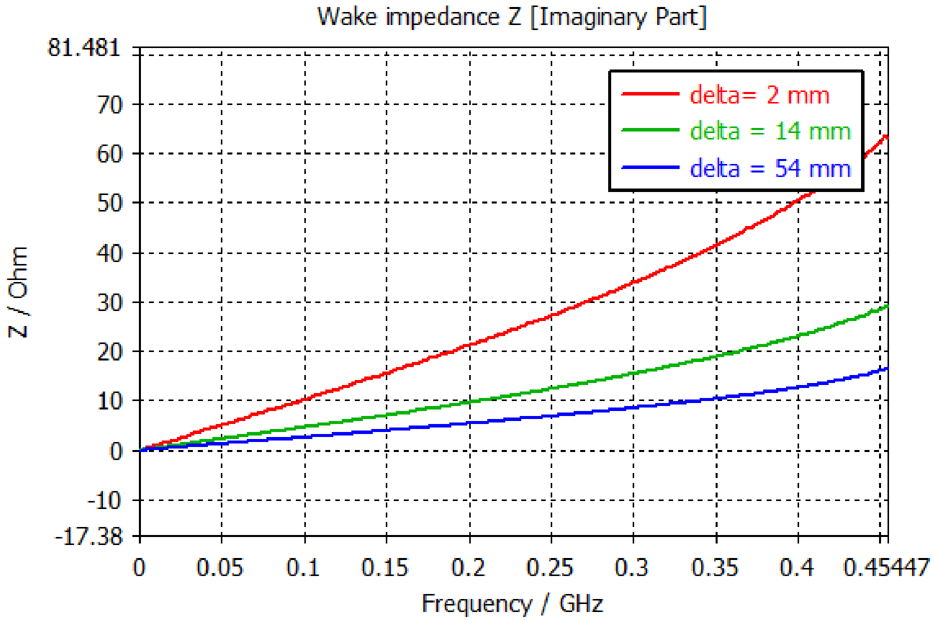
→ Frequency shift of 2.5 MHz and reduction of the crystal mode by a factor 2.4

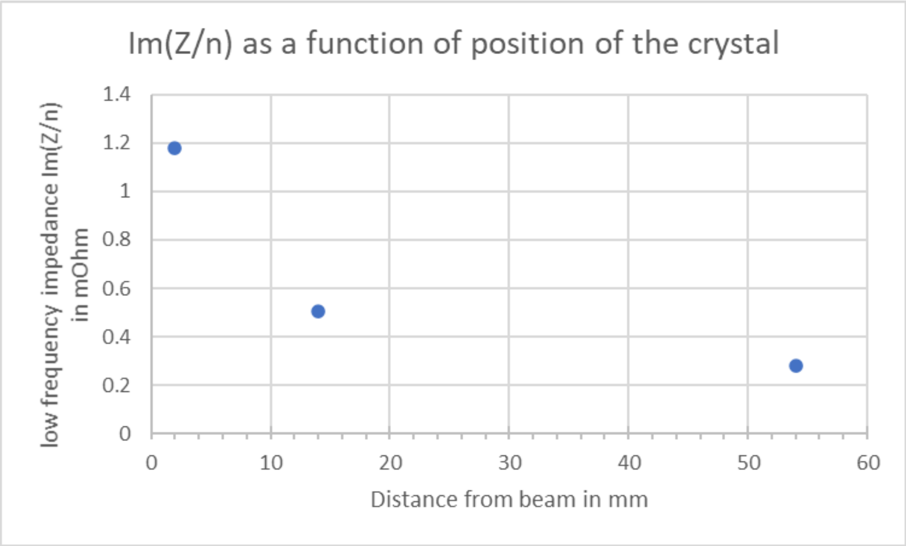
Longitudinal imaginary low frequency impedance



→ No significant change with crystal properties

Longitudinal imaginary low frequency impedance

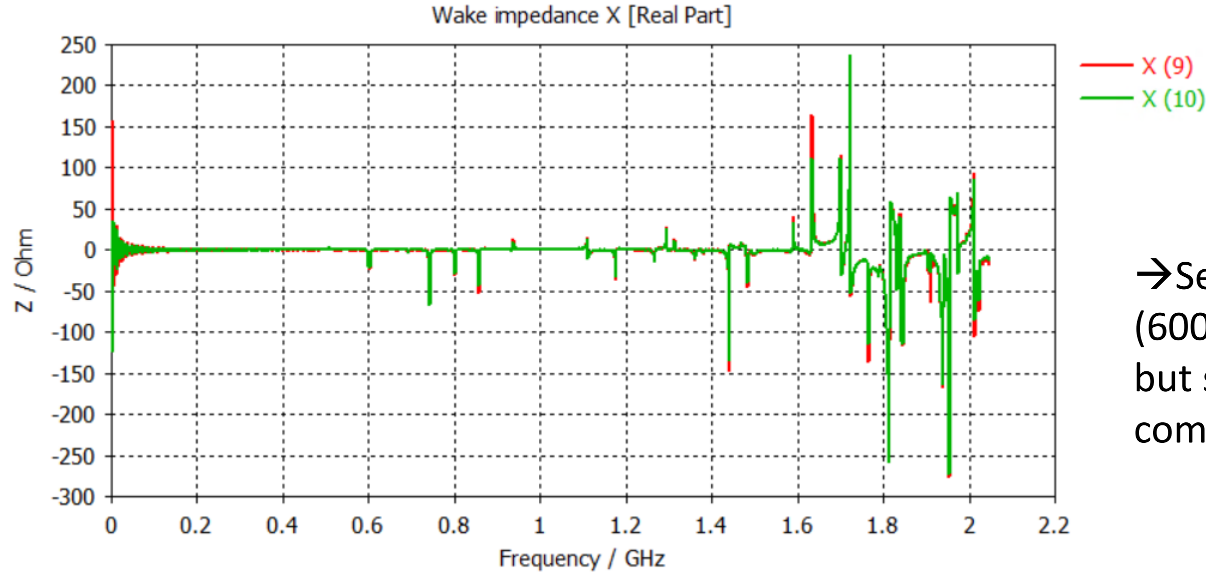




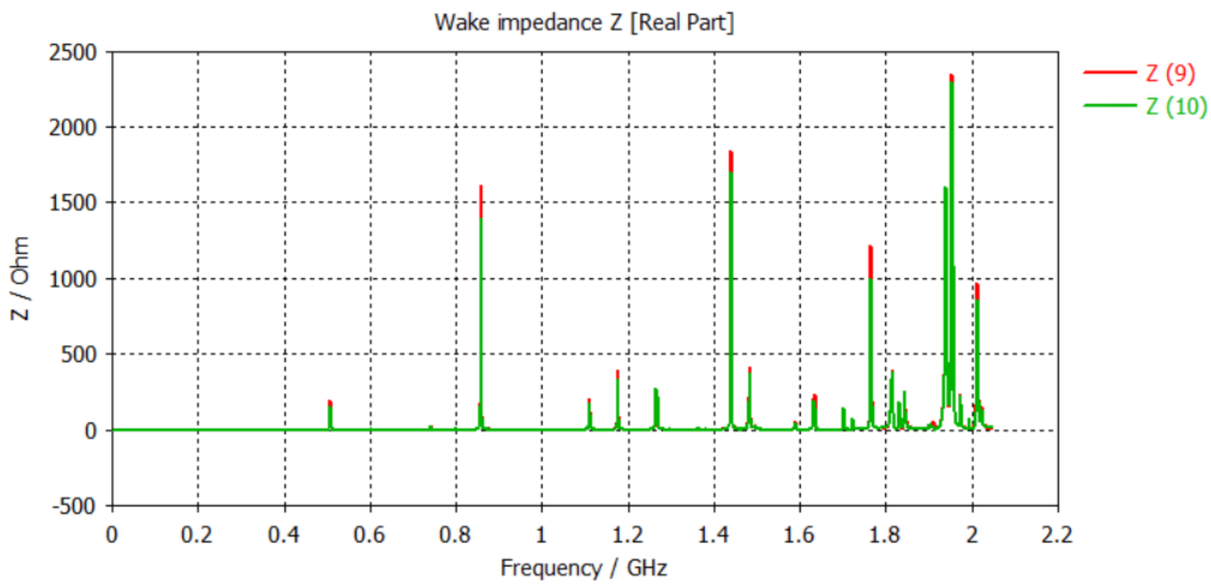
→ Significant contribution of the goniometer to the longitudinal impedance of LHC
→ Contribution divided by 5 when crystal in parking position

Transverse impedance

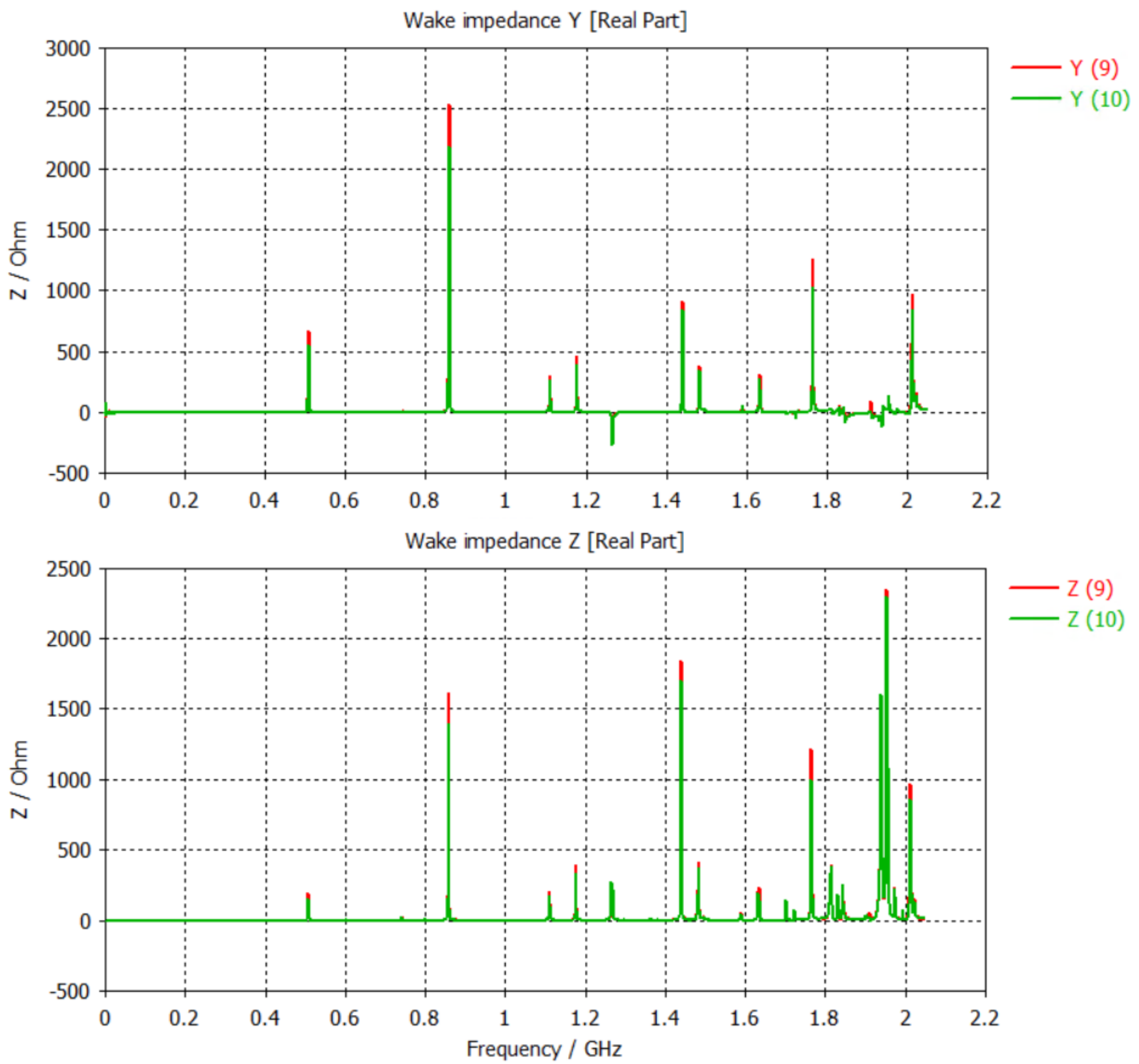
54 mm (parking position): are there transverse modes?



→Several transverse modes below 1 GHz (600 MHz, 800 MHz, 940 MHz), but shunt impedance small compared to large constant term.



Transverse modes?



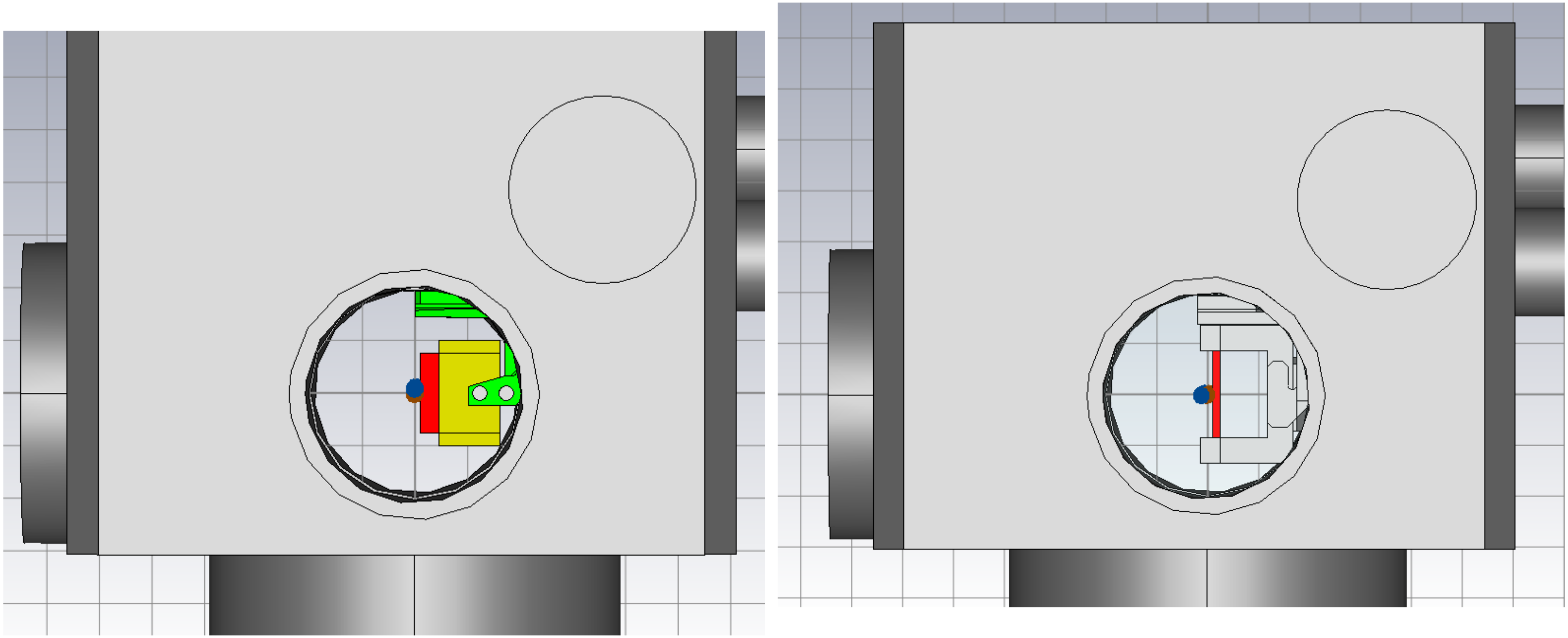
→ All major vertical modes are already longitudinal modes

Transverse impedance (very noisy, requires convergence)

- 2 mm
  - → Zx= 15 Ohm/mm = 15 kOhm/m
  - → Zy= 13 Ohm/mm = 13 kOhm/m
- 14 mm
  - → Zx =11 Ohm/5mm= 2 kOhm/m
  - →Zy = 5 Ohm/5mm = 1 kOhm/m
- 54 mm
  - → Zx=5 Ohm/5mm=1 kOhm/mm
  - → Zy= 5 Ohm/5mm=1 kOhm/mm

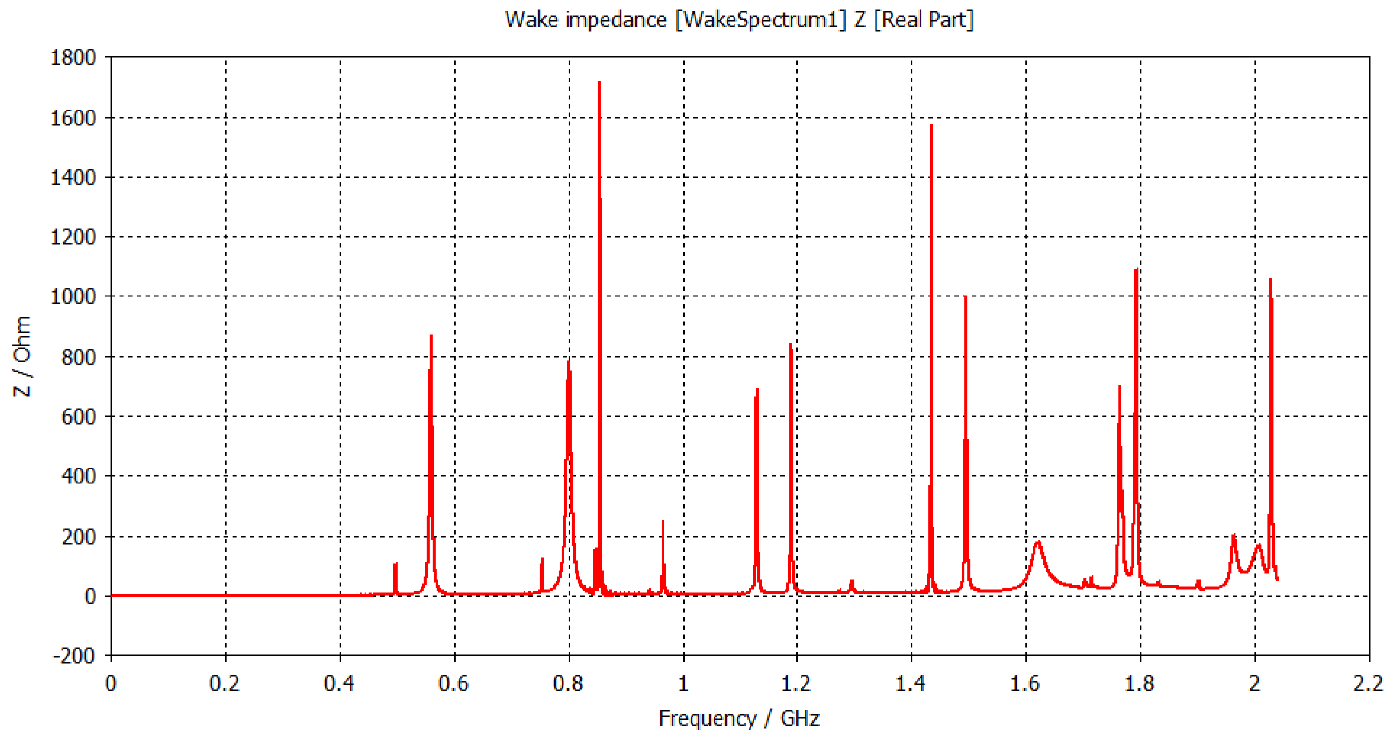
→ These are small contributions
(< 0.1% of the transverse impedance assuming standard beta functions)

Results with version 3

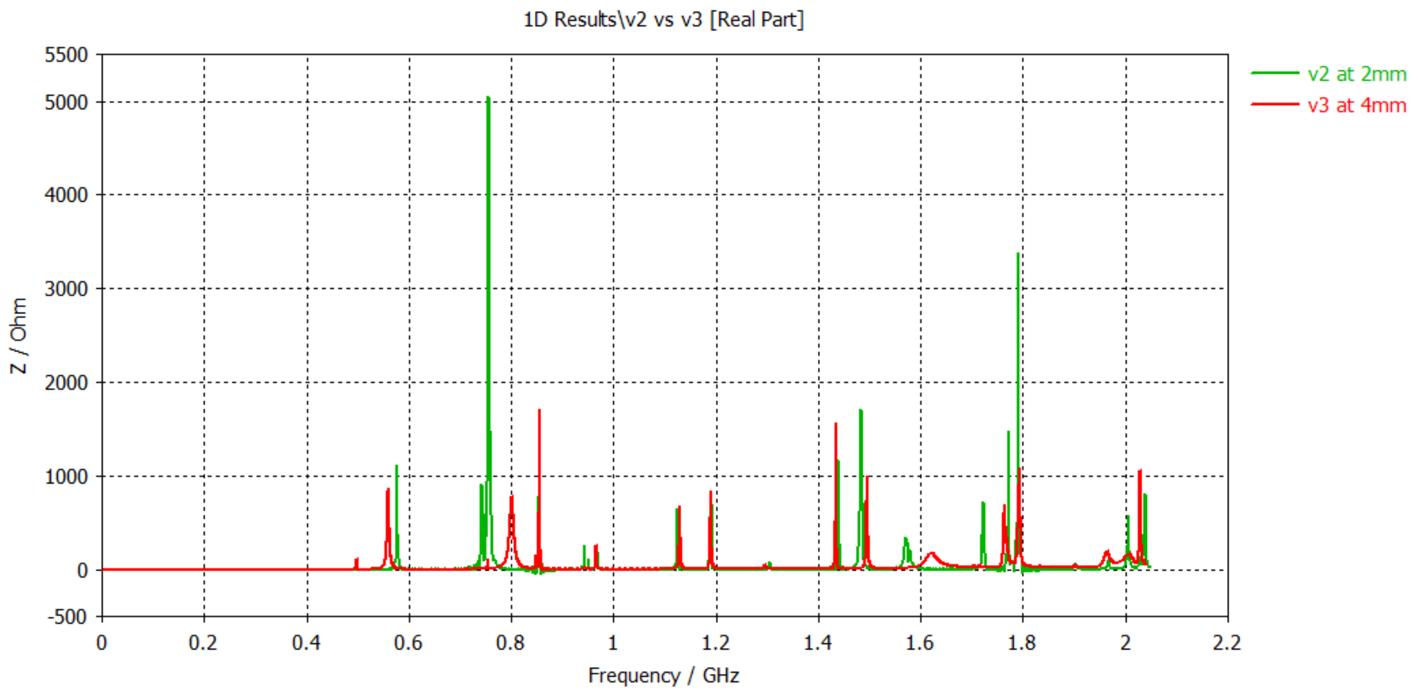


→ Reused version 2 and added the crystal holder from version 3

Crystal version 3 at 4 mm



Crystal version 3 @4 mm vs crystal version 2 @ 2mm



→ Similar longitudinal impedance contributions, need to compare with version 3 at 2 mm (simulations ongoing)

→ Conclusions similar to version 2 for the transverse impedance

Power loss for v3 at 4 mm (from Francesco Giordano)

- Protons:

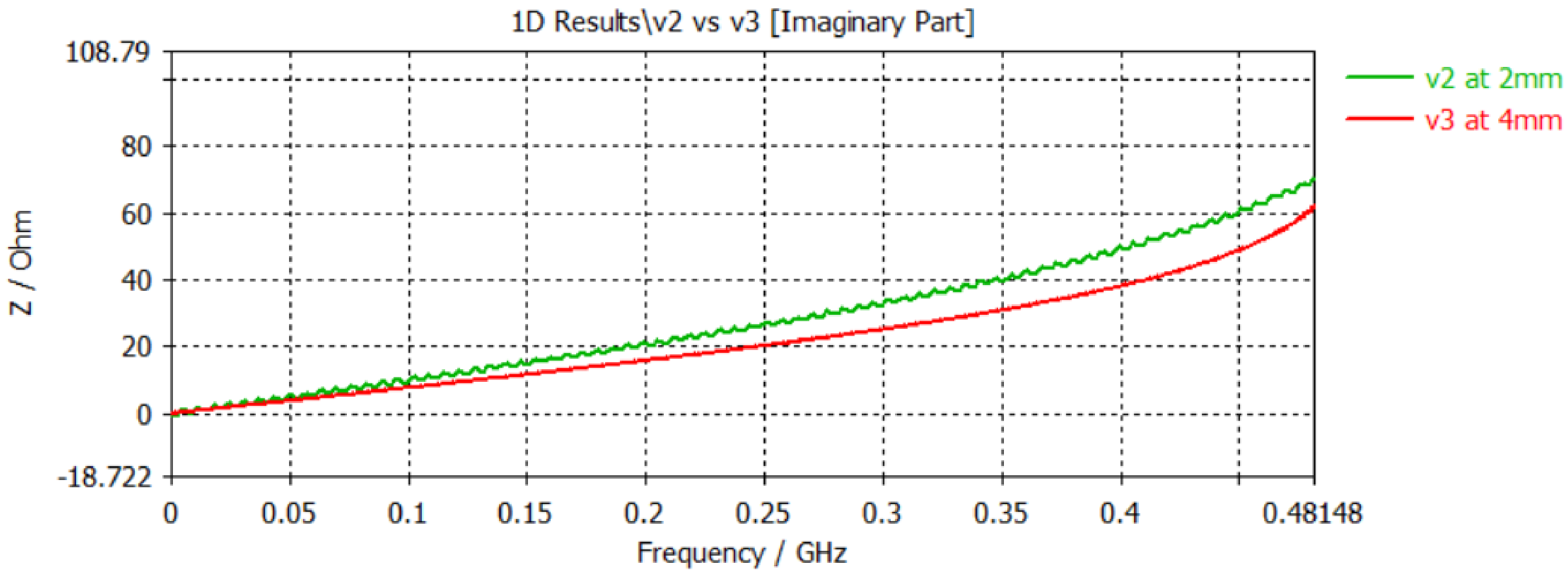
- Fill5979 max power loss: 545.97 W, average power loss: 183.18 W
- HL2760b max power loss: 2150.43 W, average power loss: 710.47 W
- 8b4eHL max power loss: 1209.78 W, average power loss: 482.96 W

- Ions

- HL: max power loss: 1.89 W, average power loss: 1.10 W

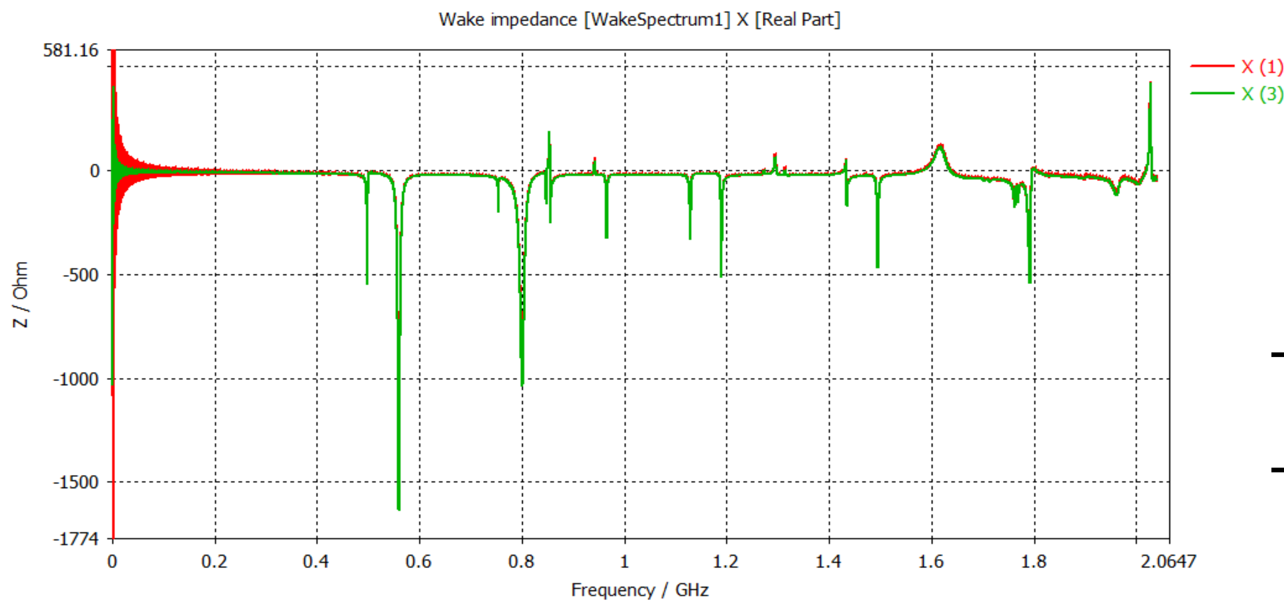
To be confirmed for crystals at 2 mm

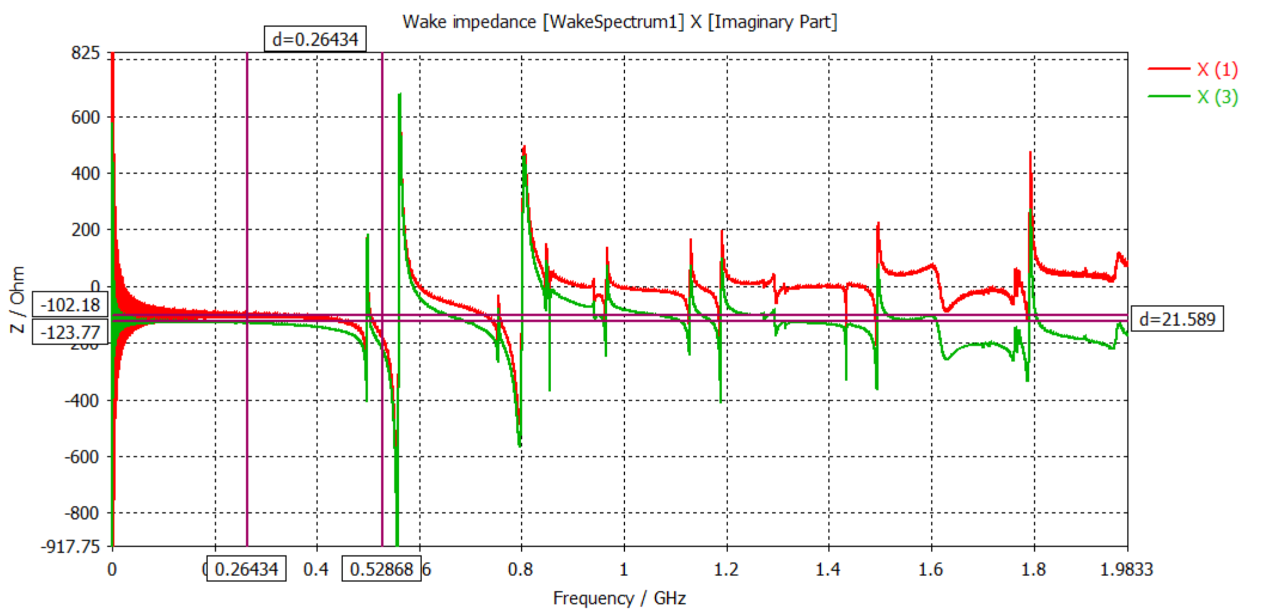
Imaginary longitudinal impedance
crystal version 3 @4 mm vs crystal version 2 @ 2mm



→ Same order of magnitude for v2 and v3, to be confirmed with ongoing simulations with v3 at 2 mm
→ crystals cost ~1 mOhm per device

Horizontal driving impedance (4 mm from crystal with displacement of 2 mm)

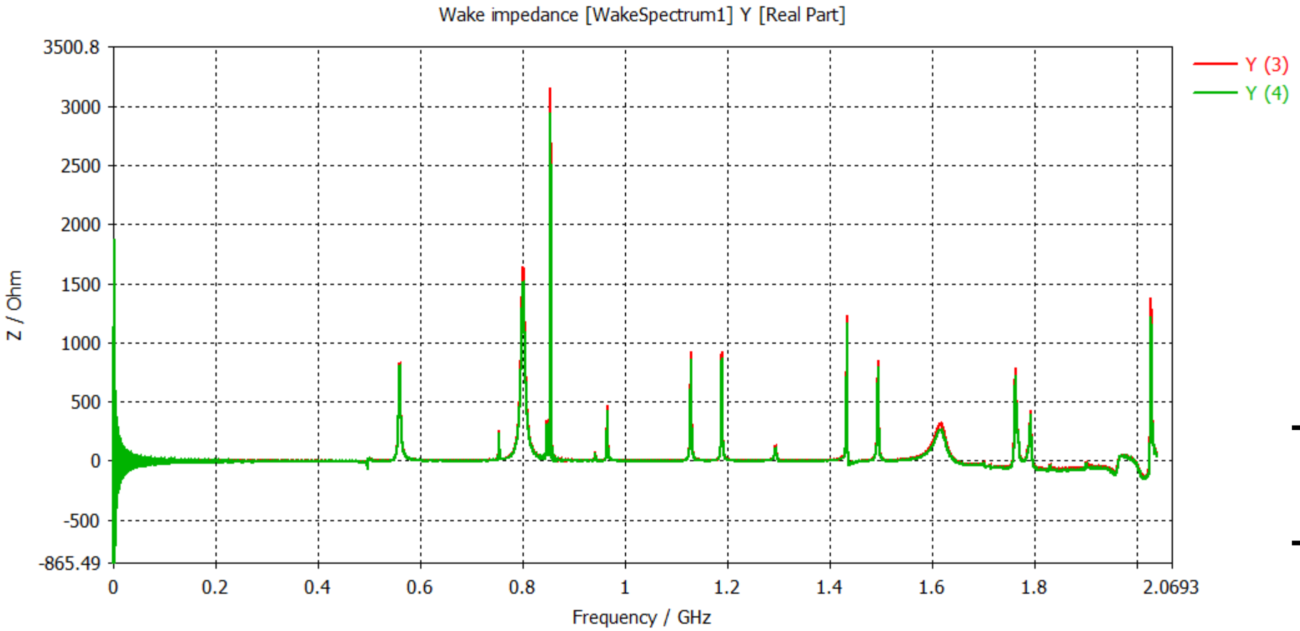


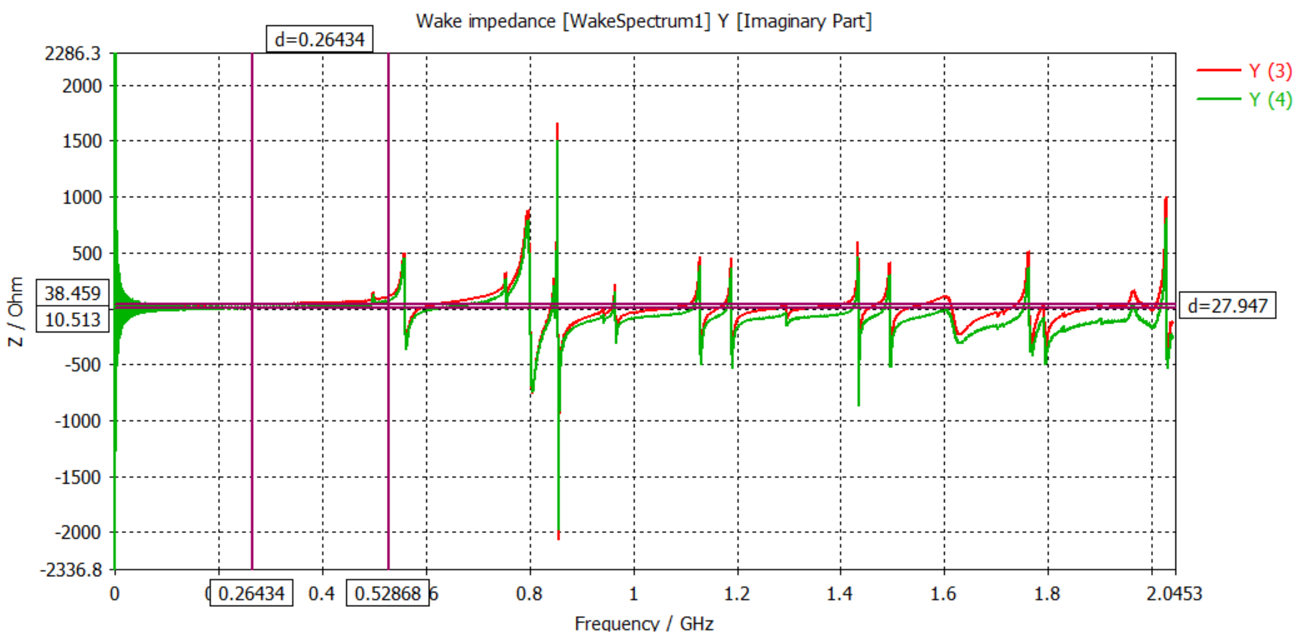


→ No identified major transverse mode

→ At low frequency Im(Zx)~ 11 kOhm/m

Vertical driving impedance (4 mm from crystal with displacement of 2 mm)





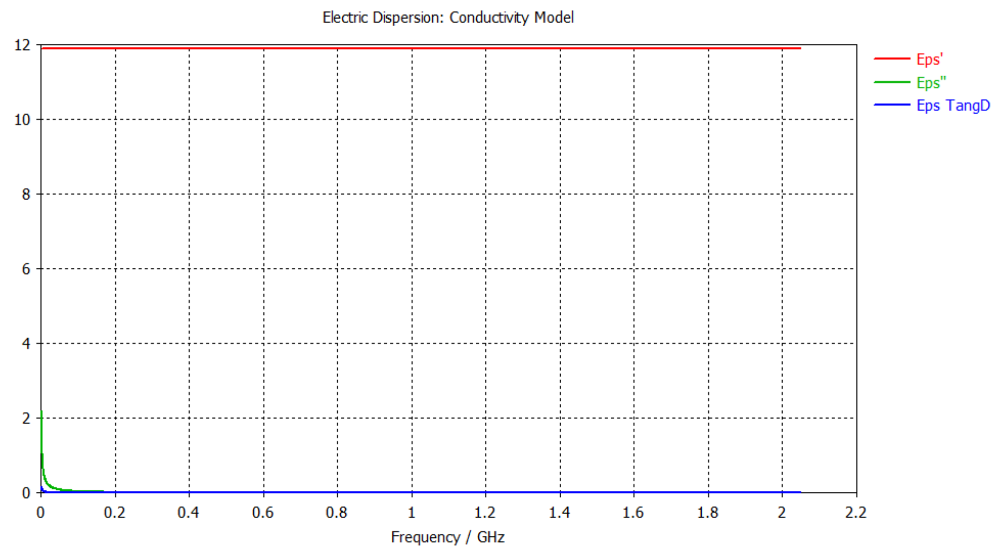
→ No identified major transverse mode

→ At low frequency Im(Zy)~ 14 kOhm/m

Outlook

- Longitudinal impedance contribution is significant compared to LHC impedance model (1 mOhm/goniometer)
- Transverse contribution appears less significant for beta functions of IR7, to be confirmed with more simulations
- Could we get an assessment of the crystal parameters closer to the frequency range of interest?

Silicon lossy
(CST default model)



Silicon fit from measured data