Impedance studies of FCC-ee vacuum chamber including bellows

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FCCIS WP2 Workshop 2021

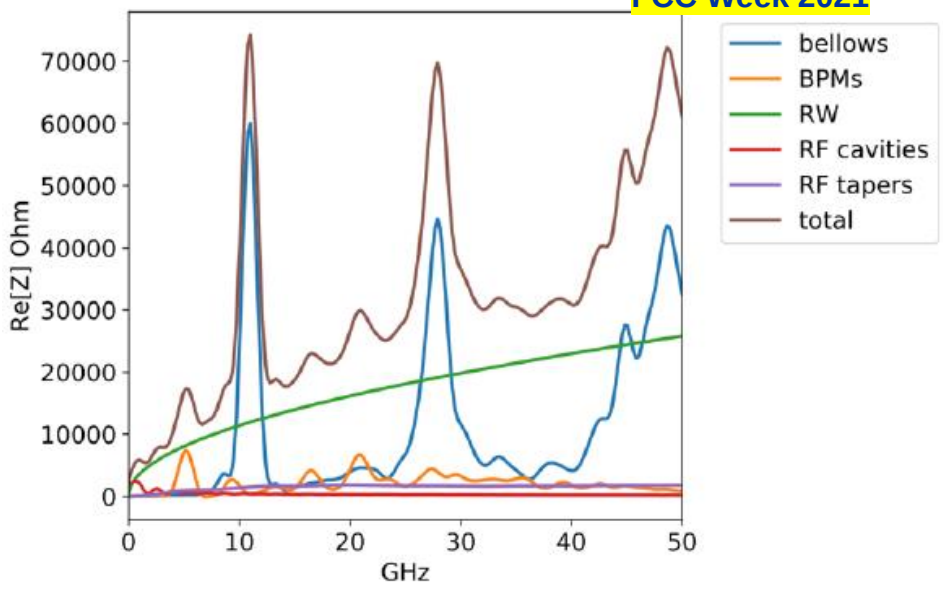
Thanks to : M. Migliorati, C. Zannini, S. James Rorison, R. Kersevan

Motivations

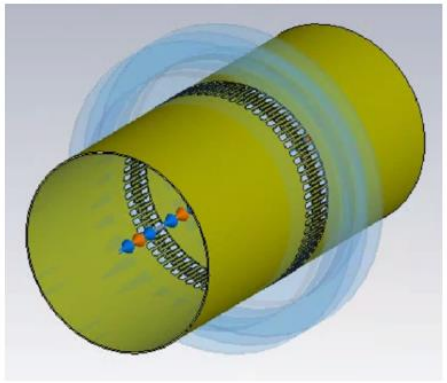
➢**The FCC-ee total machine impedance is constantly being updated while studying new devices**

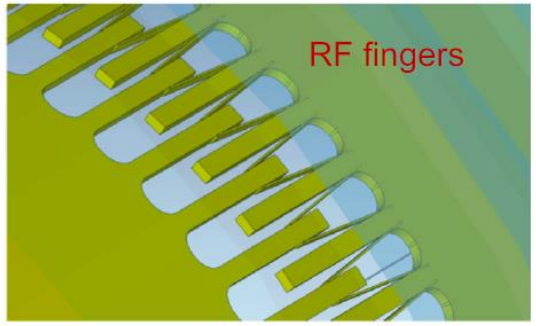
➢**The impedance evaluated so far already already poses concern and demonstrates how the machine can become critical due to collective effects**

Slide from M.Migliorati, FCC Week 2021



Y. Suetsugu, Japan-Italy Collaboration Meeting "Crab Factories" 2008 (INFN-LNF)





A comment on the number of bellows:

- 2900 dipole arcs 24 m long. We consider bellows every 8 m → 2900*3=8700
- 2900 quads/sextupoles arcs

total of 11600 bellows plus:

- RF, injection system, collimators, …

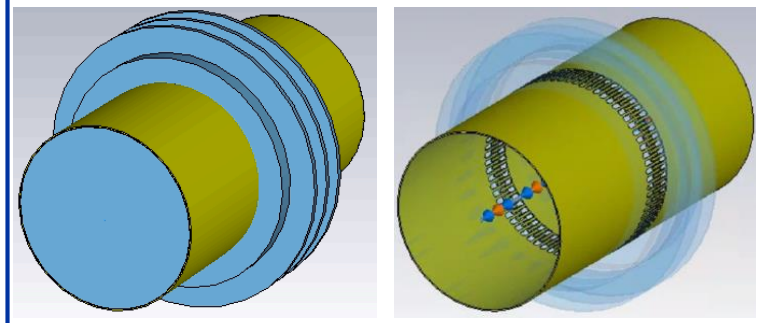
As a pessimistic estimation we have considered 20000 bellows

➢**Bellows are one of the major impedance sources among the accelerator machine : an accurate evaluation is needed**

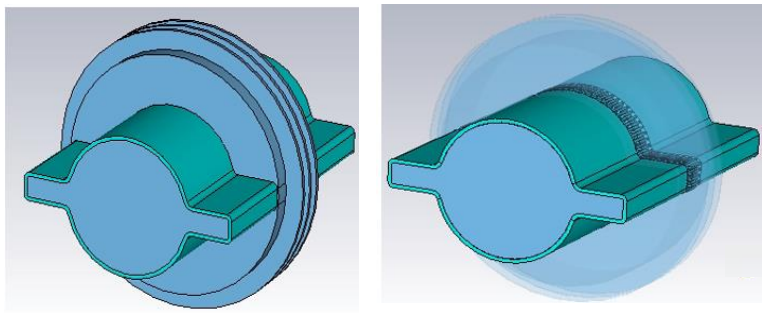
Strategy

Step by step approach

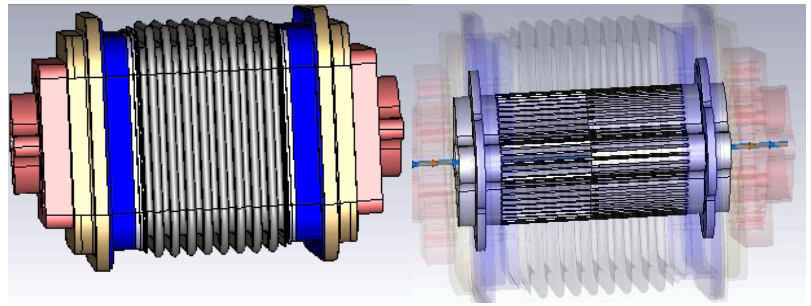
Round model



Winglets model



Realistic model



All models : RF shielding with comb-type fingers

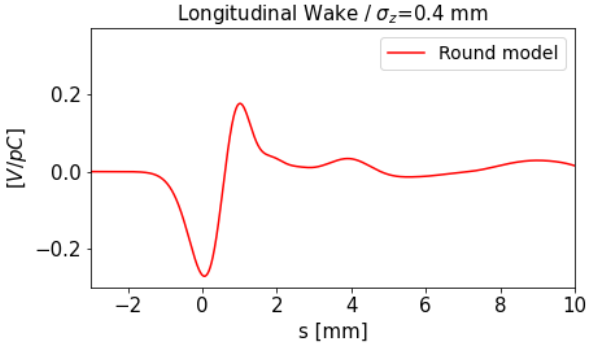
Contents and studies

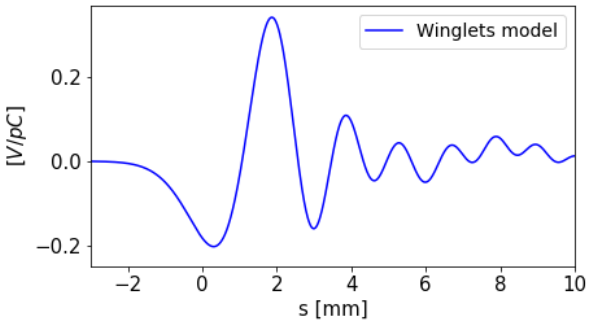
- **Simulated wake potential and impedance results**
- **Understanding of impedance behaviour with simplified model**

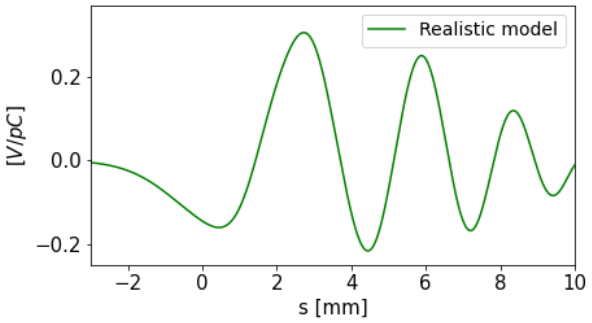
➢ **The impedance simulations results are used by Prof. Migliorati and colleagues to perform beam dynamic studies**

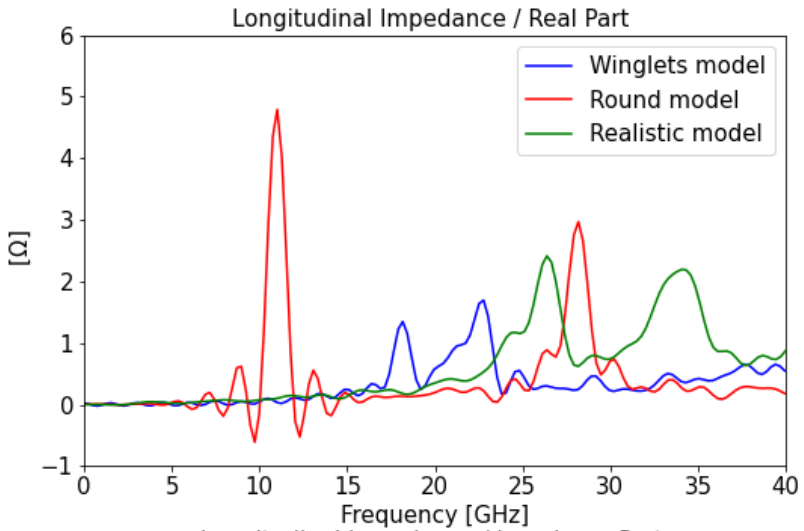
Longitudinal studies

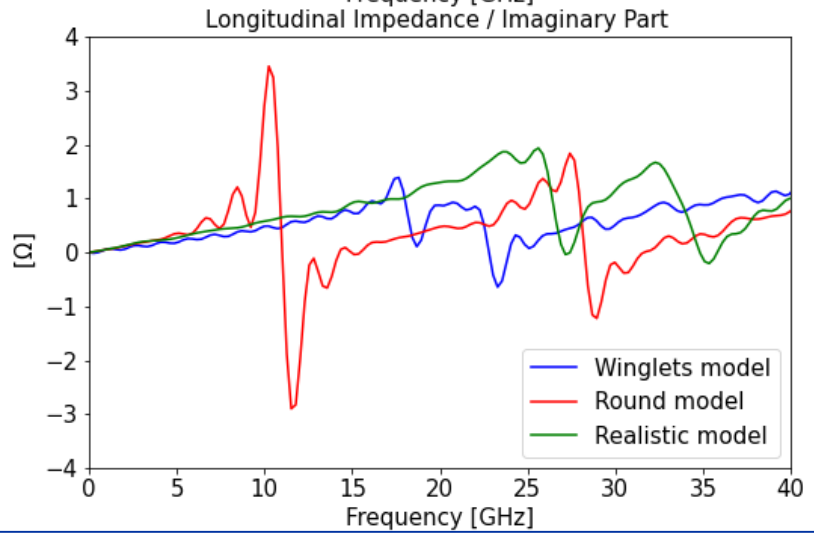
- It is considered a **bunch length of 0.4mm** to meet the dynamic studies, where 0.4 mm is used as a Green function, that convoluted with the nominal real bunch gives the correct wake.





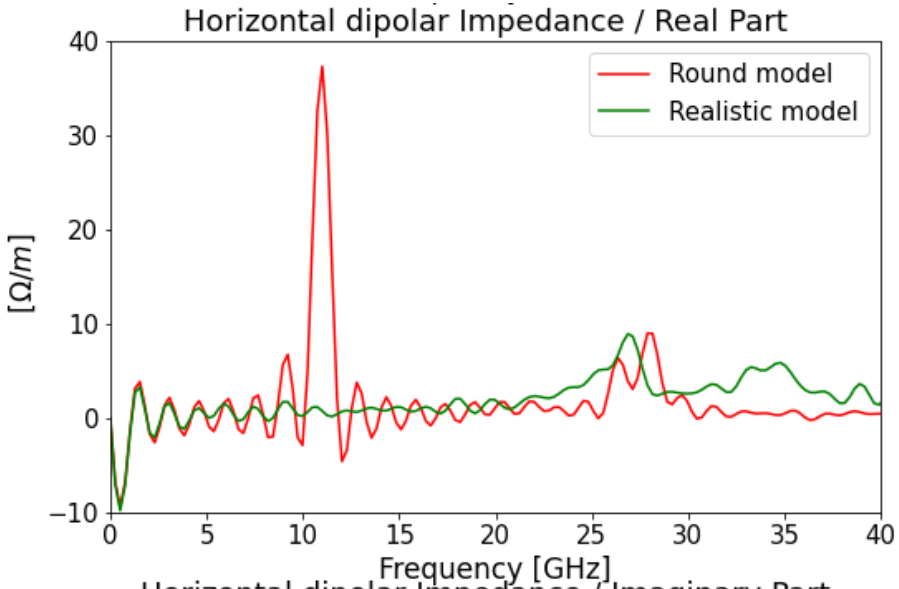


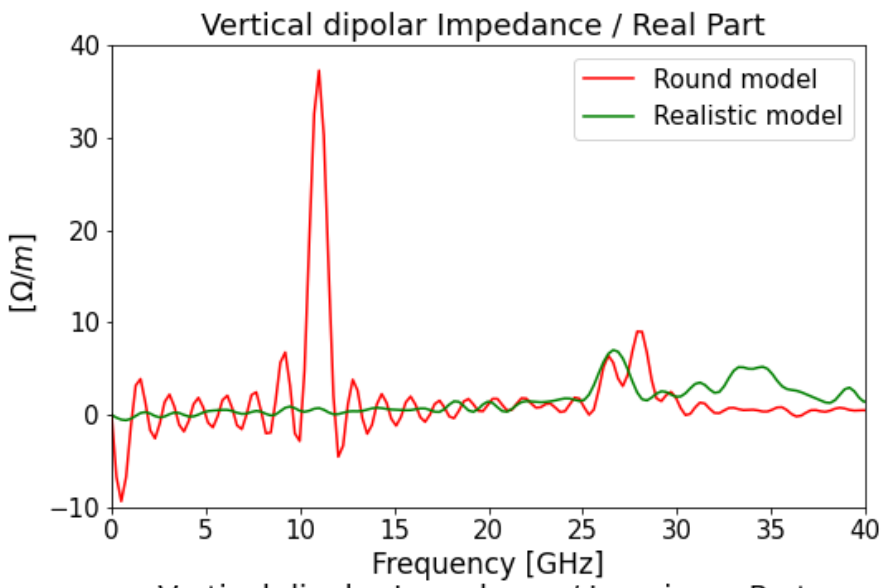


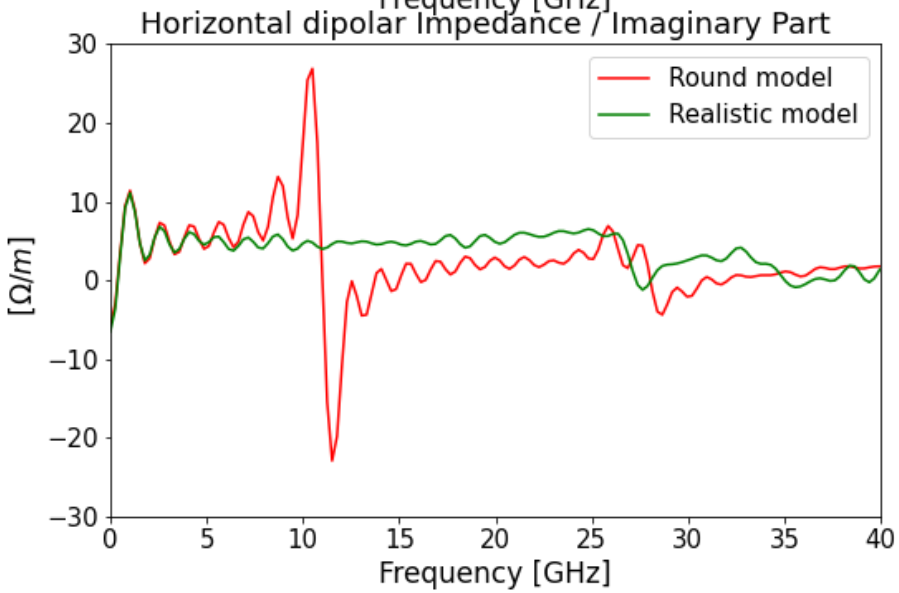


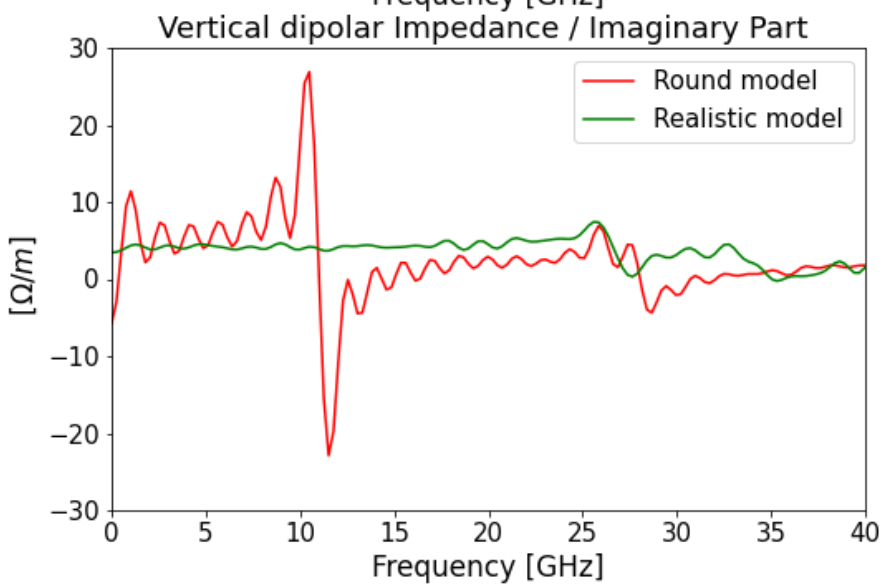
- The resonance around 11 GHz is almost deleted in the cases of realistic vacuum chamber
  - ✓ The first resonance appears above 15 and 20 GHz
  - ✓ At low frequencies the impedance contribution is negligible.
- At higher frequencies are present resonant frequency and magnitude shifts between the three models.

Transverse studies









Dipolar term:

- First resonance above 25 GHz for the realistic model

Quadrupolar term (not shown)

- First resonance above 20 GHz for the realistic model
- For the model with circular chamber the contribution is zero

No major transverse resonances

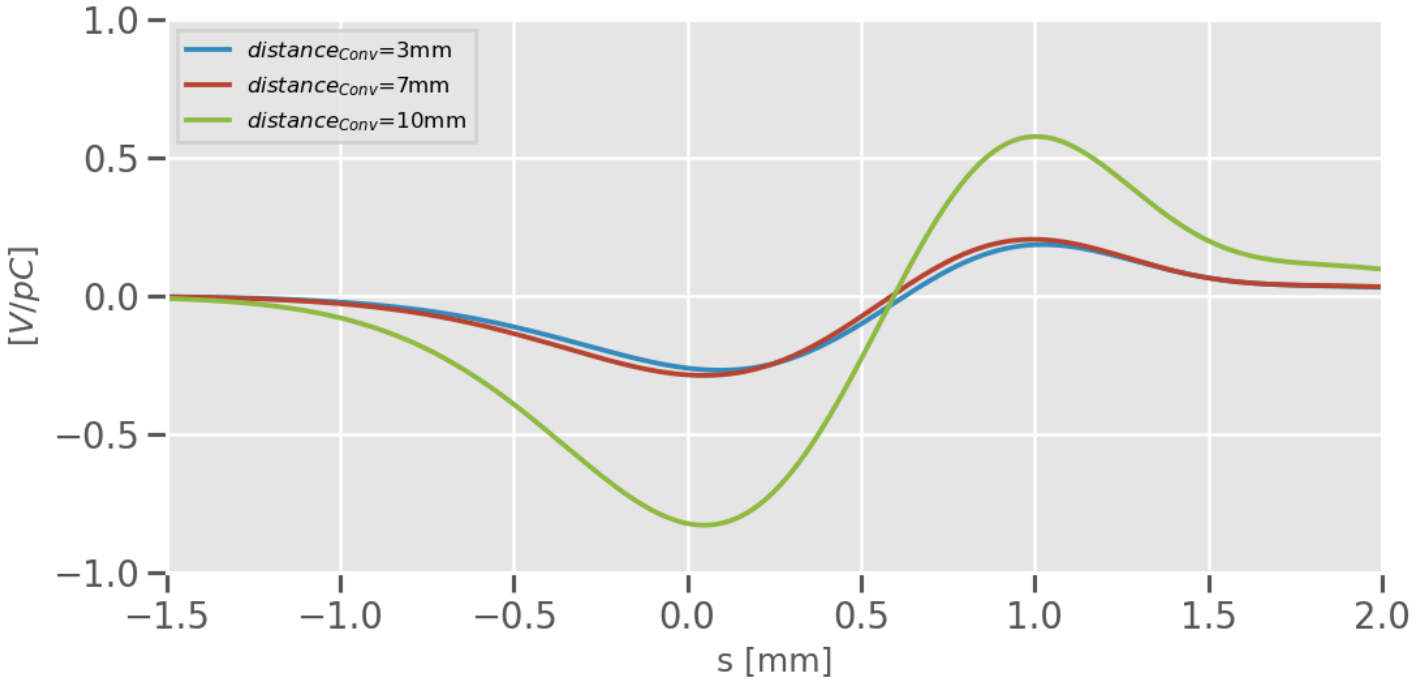
Understanding of the wake and impedance behaviour

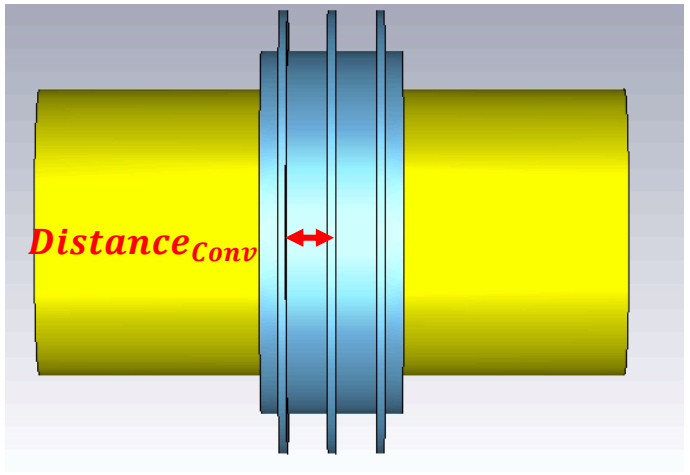
- Study of the effect of the geometric parameters of the bellow model on wake and impedance

- Study of the source of the impedance resonances

Effect of the geometric parameters of the bellow model

- Some tests have been carried out varying the main geometric parameters of the bellows

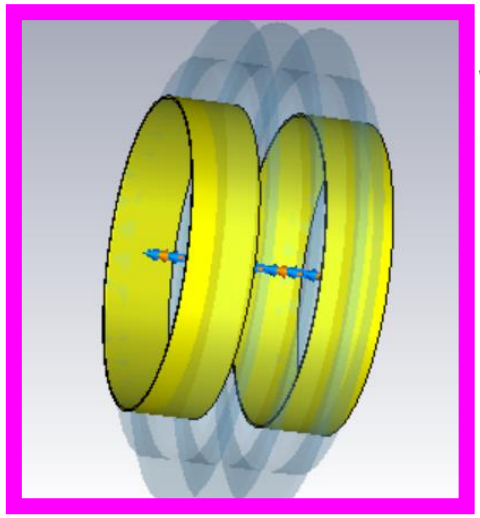




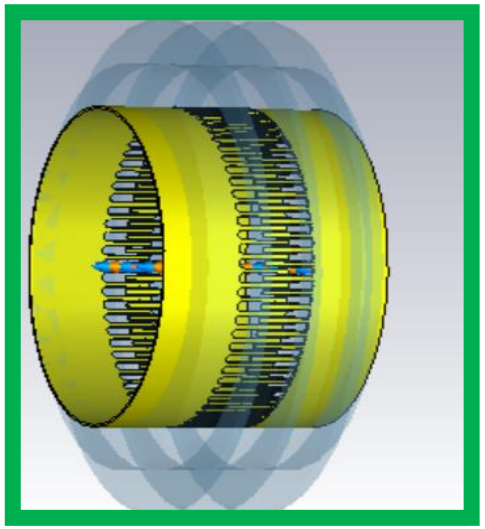
- The most significant impact on the short range wake potential is produced by varying the space between the convolutions as well as the height of the bellow

- For instance, when the height is 80 % greater than a fixed value the wake is higher more than a factor 2

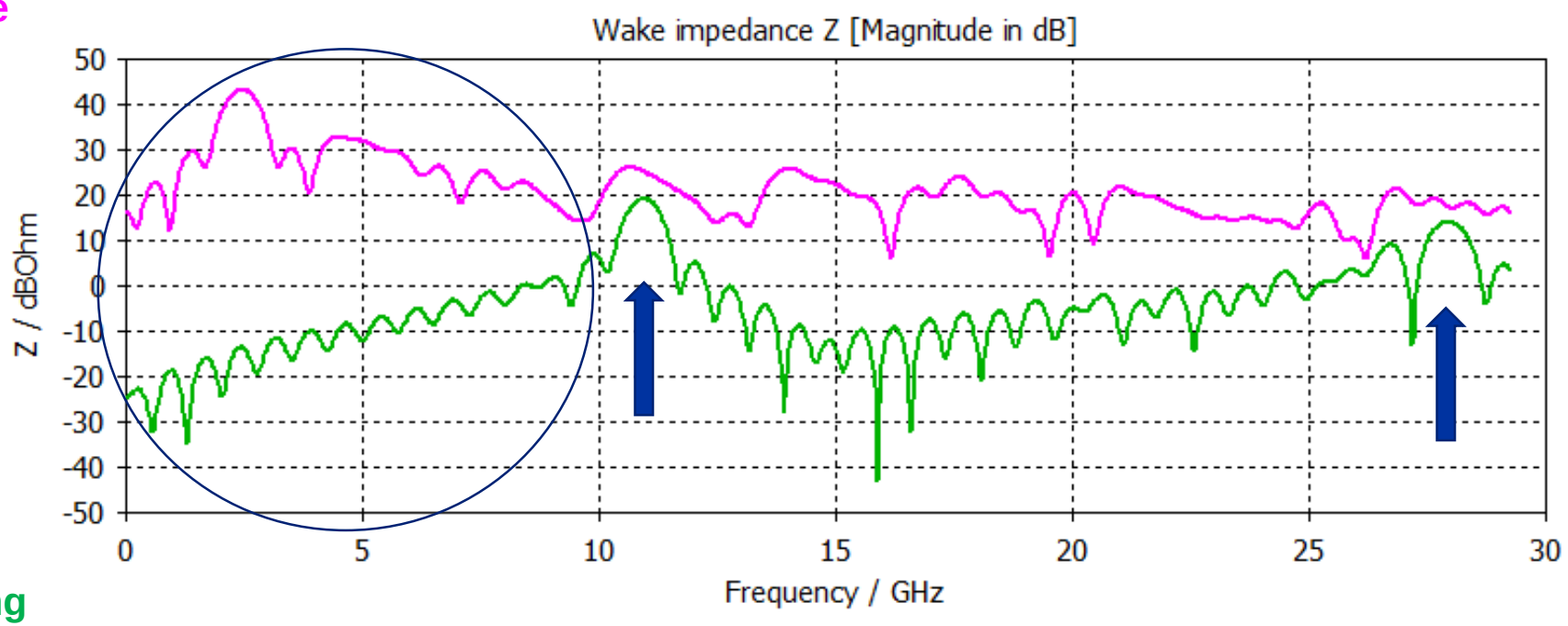
Source of the resonances and effect of the shielding



Model with aperture

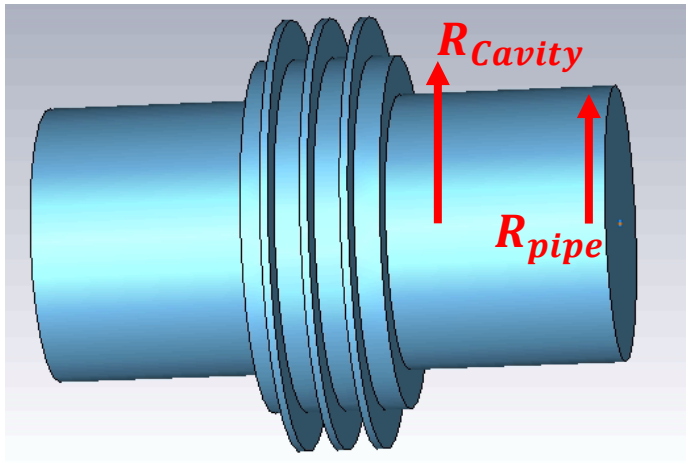


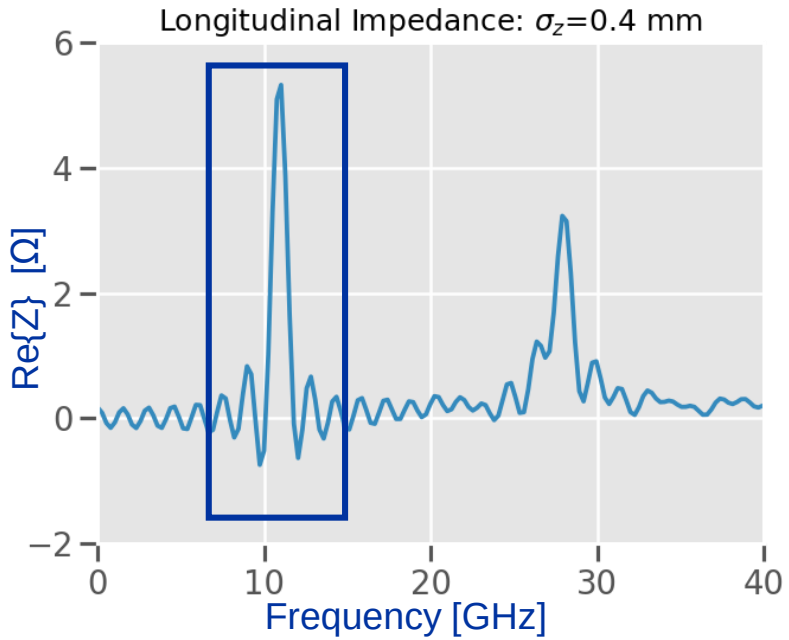
Model with shielding



- The low frequency resonances due to the bellows are suppressed by the shielding
- The resonances around 11 and 27 GHz are attenuated by the shielding

Source of the resonances



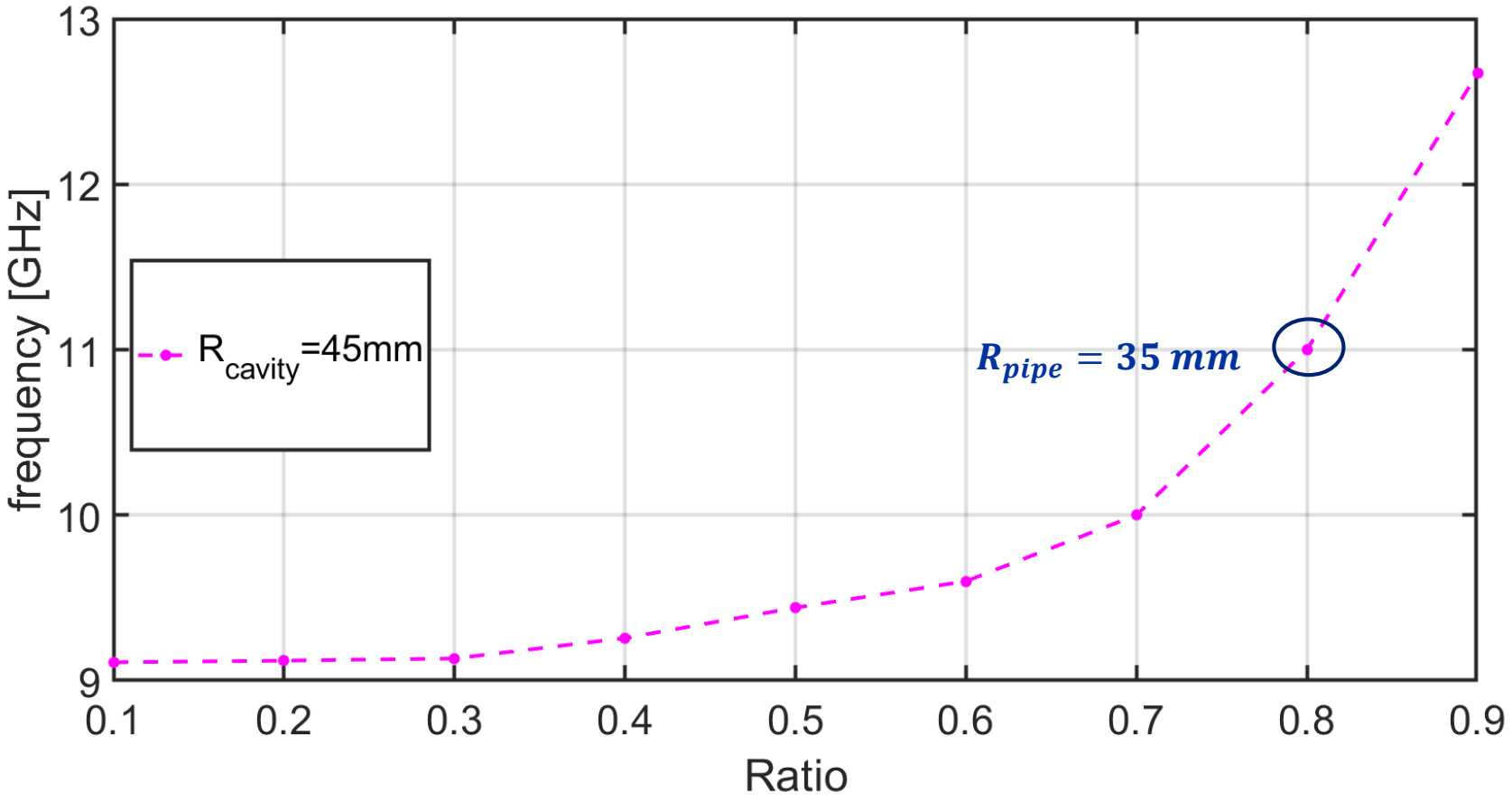


- Several tests have been carried out on the main geometric parameters of a simplified model to understand the correlation with the impedance resonances

- The most significant shift in frequency of the resonances occurs when the $Ratio = \frac{R_{pipe}}{R_{Cavity}}$ varies.

Now we focus the attention on the first resonance…

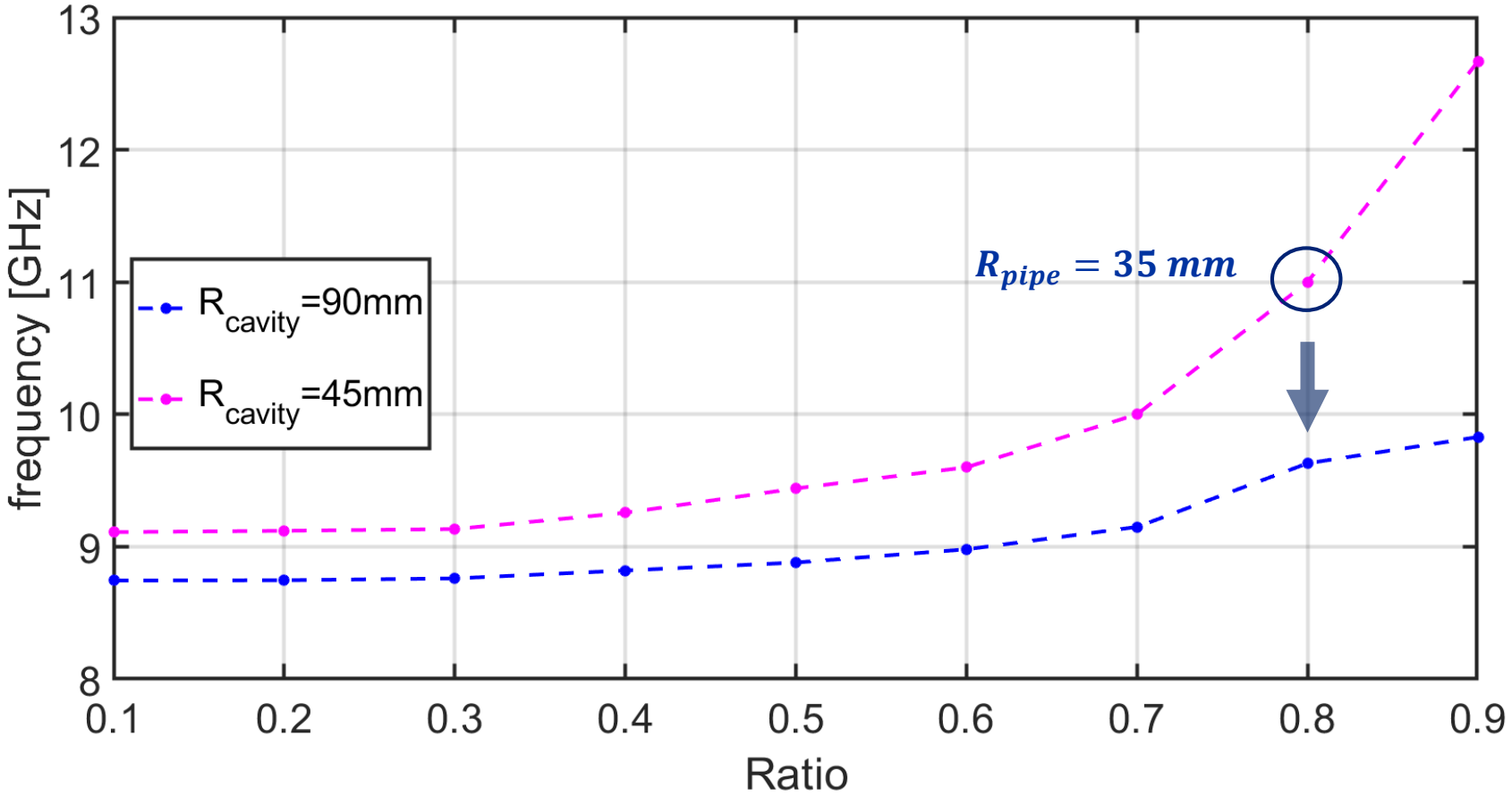
Frequency Shift of the first resonance as a function of ratio



$$Ratio = \frac{R_{pipe}}{R_{Cavity}}$$

- Up to a certain value of the Ratio (around 0.3) the frequency shift of the resonance is almost zero:
  - ↑ the coupling between pipe and cavity (↑ Ratio) -> Mode is propagating more and more ->frequency shift

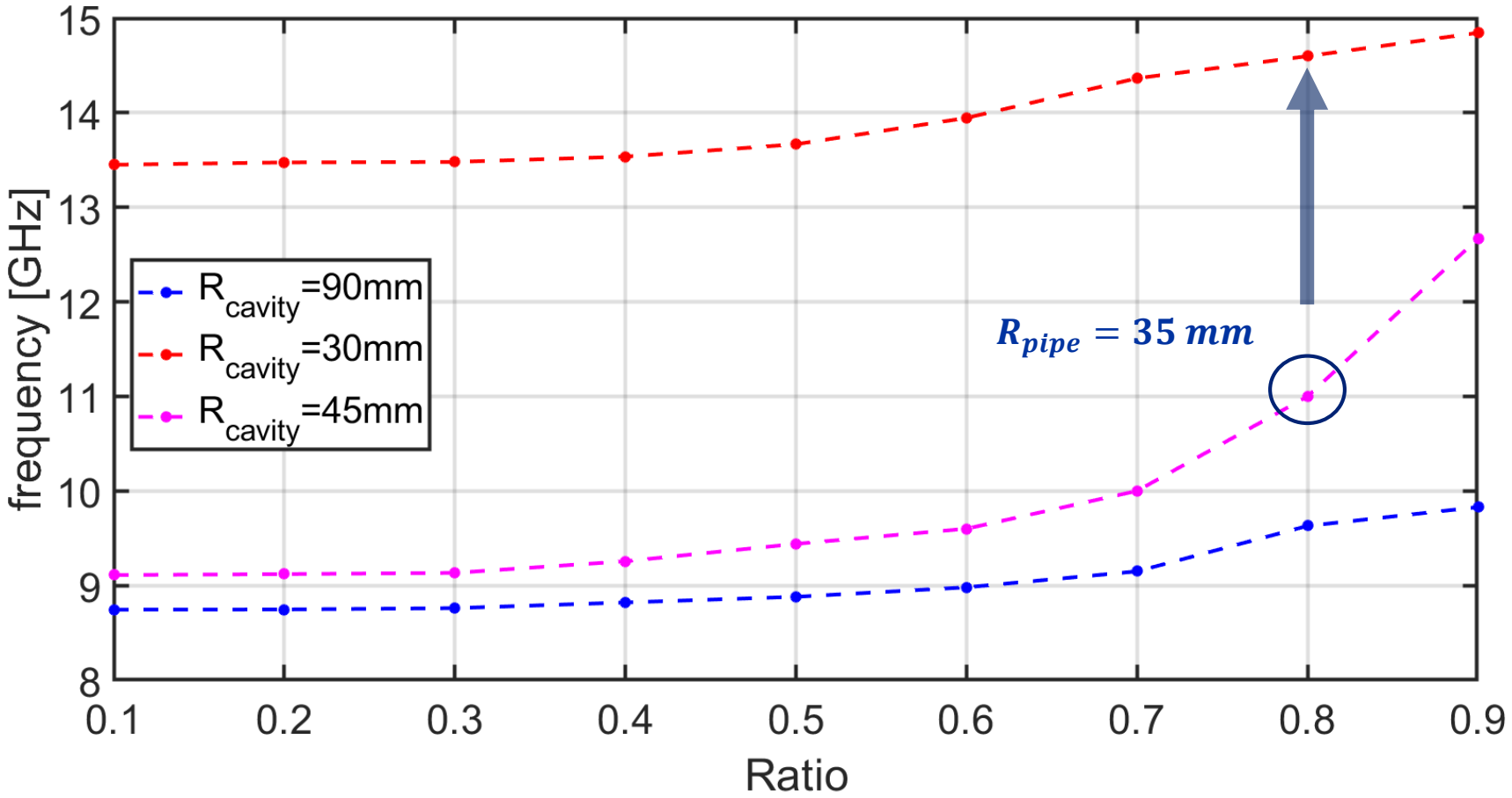
Frequency Shift of the first resonance as a function of ratio



$$Ratio = \frac{R_{pipe}}{R_{Cavity}}$$

- **Up to a certain value of the Ratio (around 0.3) the frequency shift of the resonance is almost zero:**
  - **↑ the coupling between pipe and cavity (↑ Ratio) -> Mode is propagating more and more ->frequency shift**
- **Increasing R_{Cavity} the frequency decreases**

Frequency Shift of the first resonance as a function of ratio

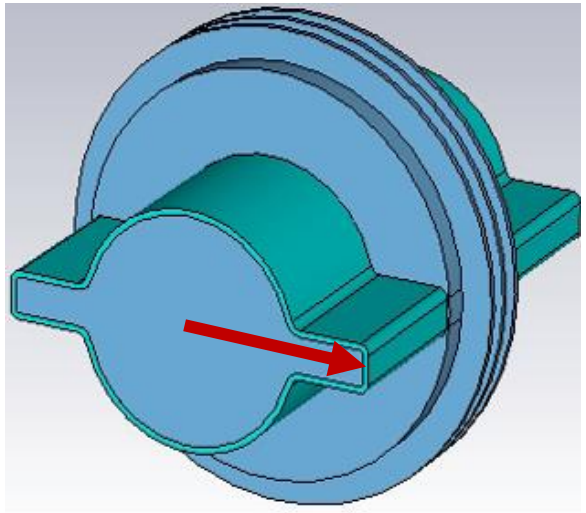


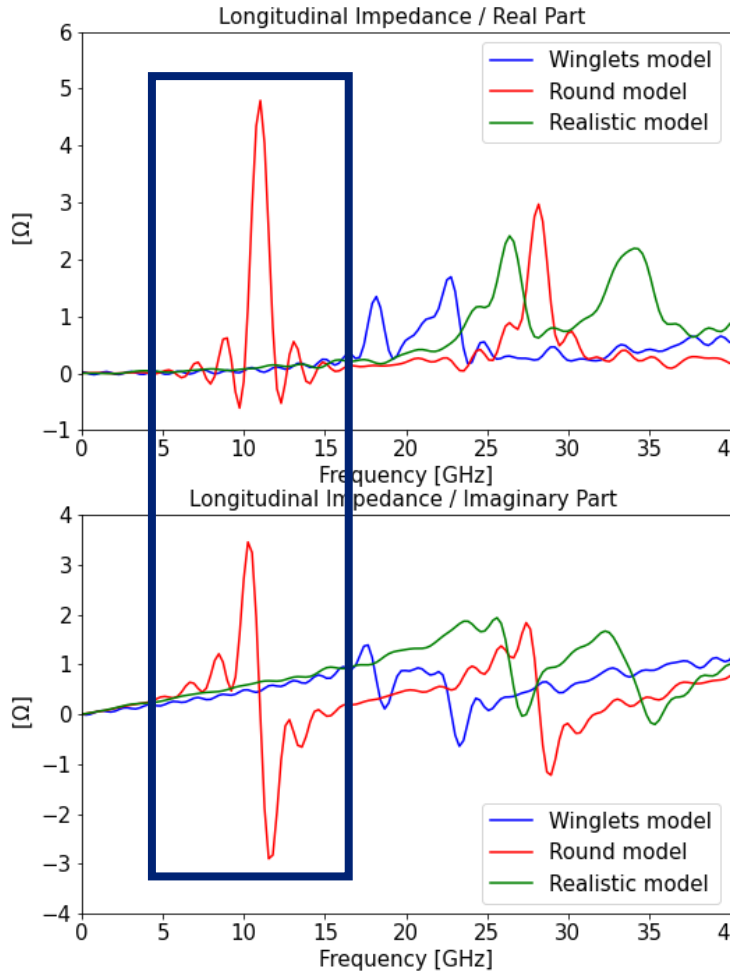
$$Ratio = \frac{R_{pipe}}{R_{Cavity}}$$

- **Up to a certain value of the Ratio (around 0.3) the frequency shift of the resonance is almost zero:**
  - **↑ the coupling between pipe and cavity (↑ Ratio) -> Mode is propagating more and more ->frequency shift**
- **Decreasing R_{Cavity} the frequency increases**

Source of the resonances

- The first resonance is related to the coupling between the pipe and the cavity of the bellows
- When the radius of the pipe approaches the radius of the cavity the resonance tends to vanish





- It is not surprising that the resonance around 11 GHz is now almost deleted
- The horizontal aperture of the pipe is changed and approaches the radius of the cavity

Summary

- The numerical convergence of the results has been preliminary studied.
- The simulations required important computational resources and are time consuming.
  - To properly discretize fingers is difficult.
- The longitudinal and transverse Wake Potential and Impedance have been computed and compared.
- The study has been performed on three models, starting from a simplified version and ending with the realistic one.
- The realistic model shows negligible impedance contribution in the low frequency range:
  - The first resonance appears above 20 GHz both for longitudinal and transverse impedance.

Outlooks

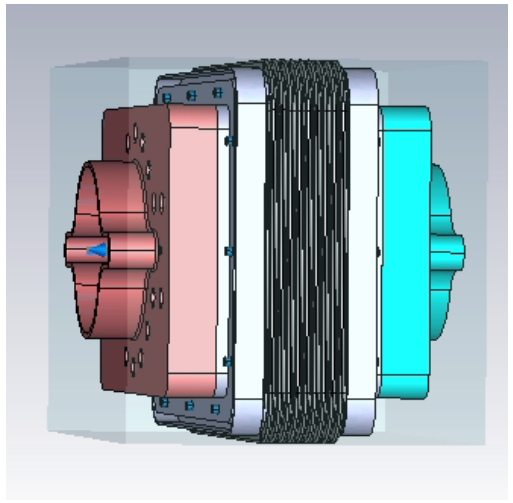
- The beam induced power loss estimation is a necessary task.
- The inclusion of the vacuum flanges will be studied later since there is not an ultimate model so far.

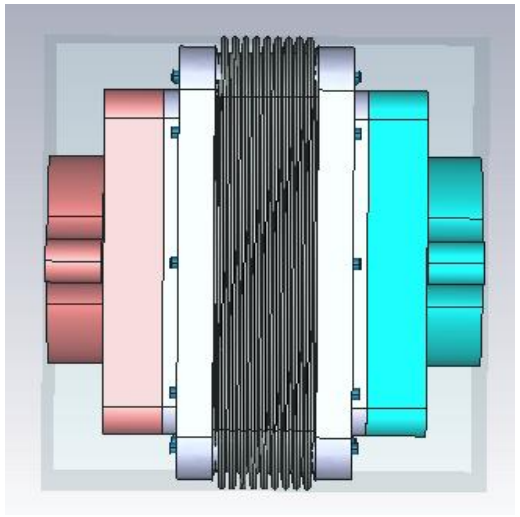
Thank you!

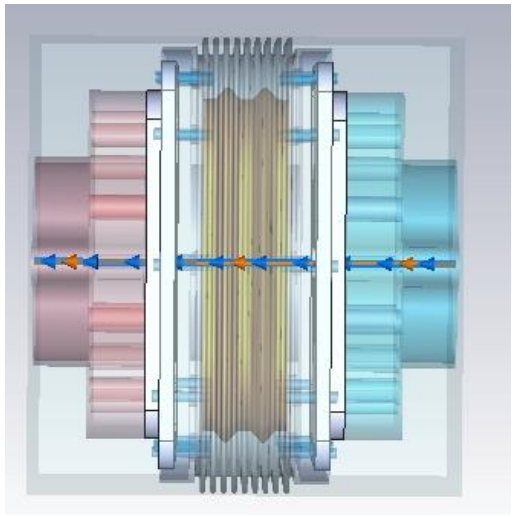
Collaboration with Vacuum group

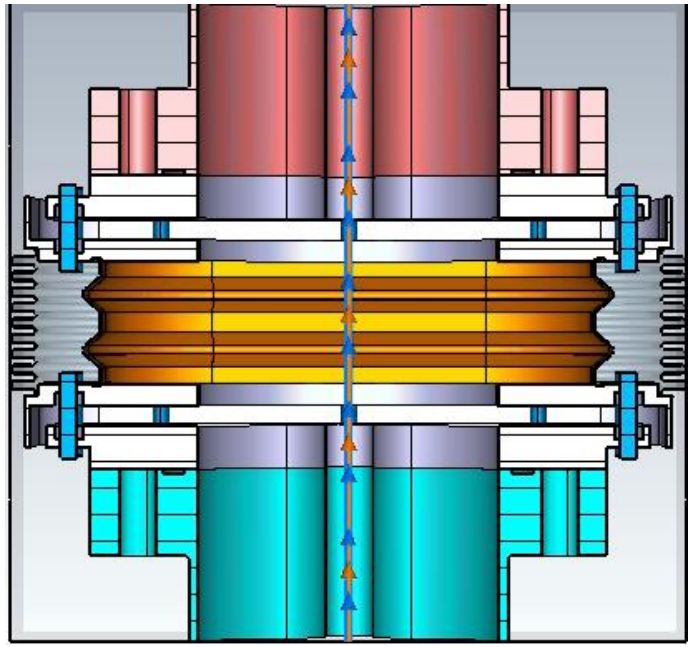
•Collaboration with the vacuum group to manage to obtain as much as possible a realistic model for bellows and flanges for FCC-ee.

• They send me some models of bellows in order to perform impedance studies



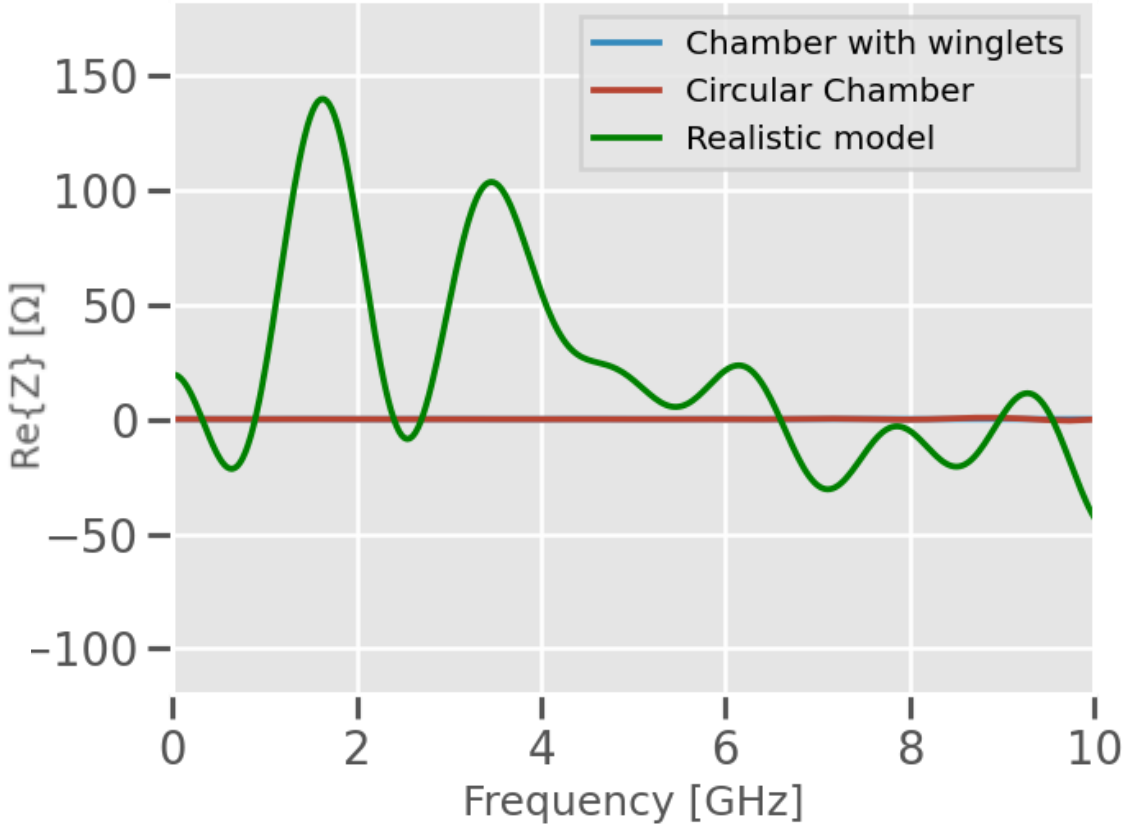




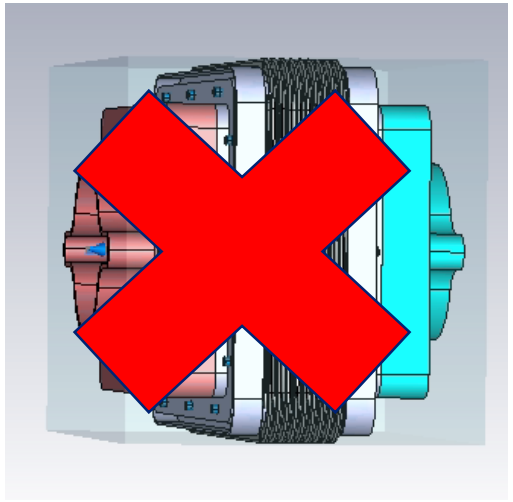


• It is the model for LHC and they wanted to confirm the non feasibility to employ this for FCC-ee from impedance point of view.

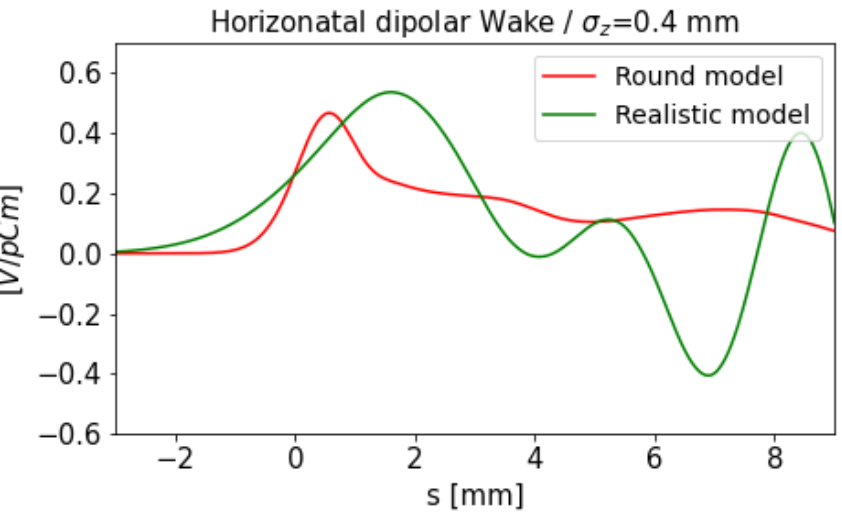
Longitudinal Impedance

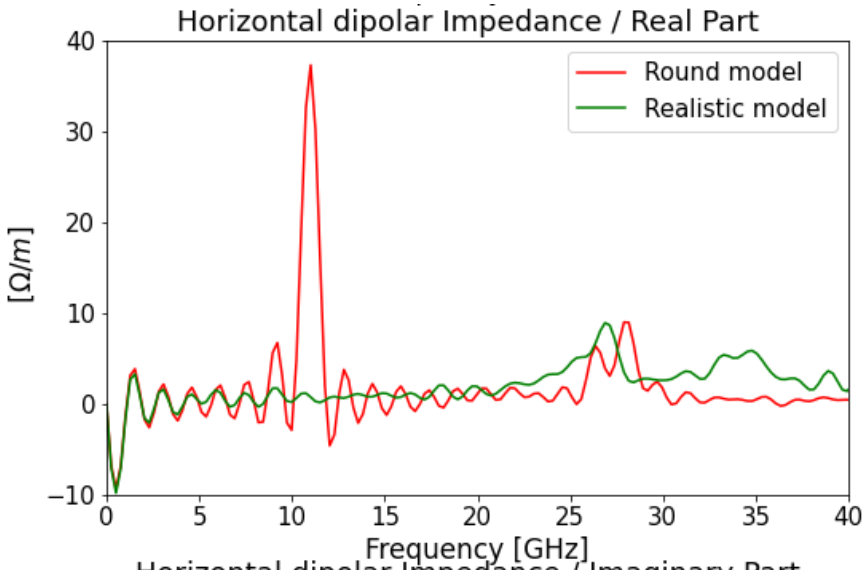


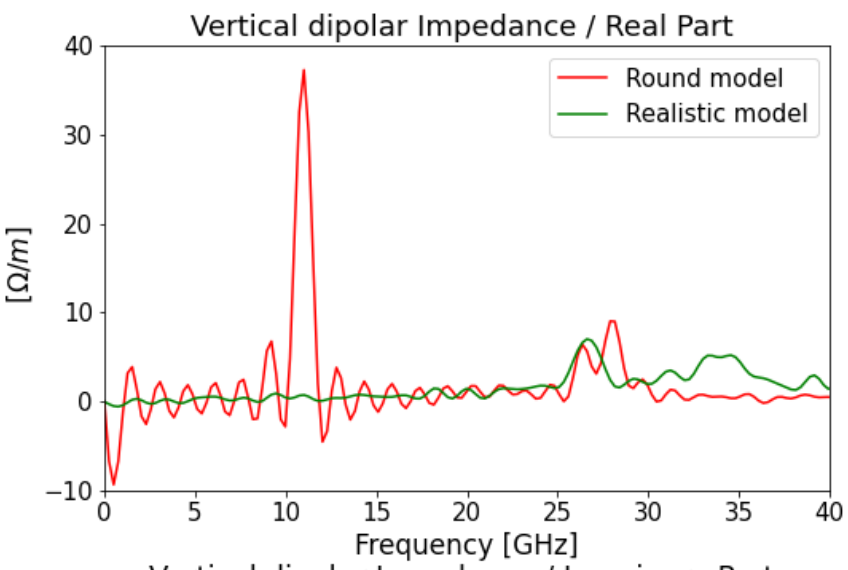
- **At low frequency the impedance contribution is huge for the new model compared to the previous where it was almost zero**
- **The model could not be employed for FCC-ee.**

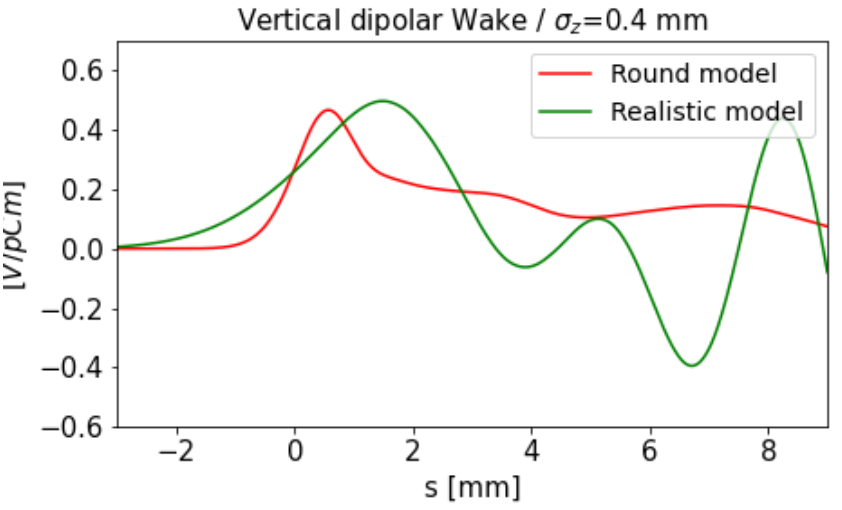


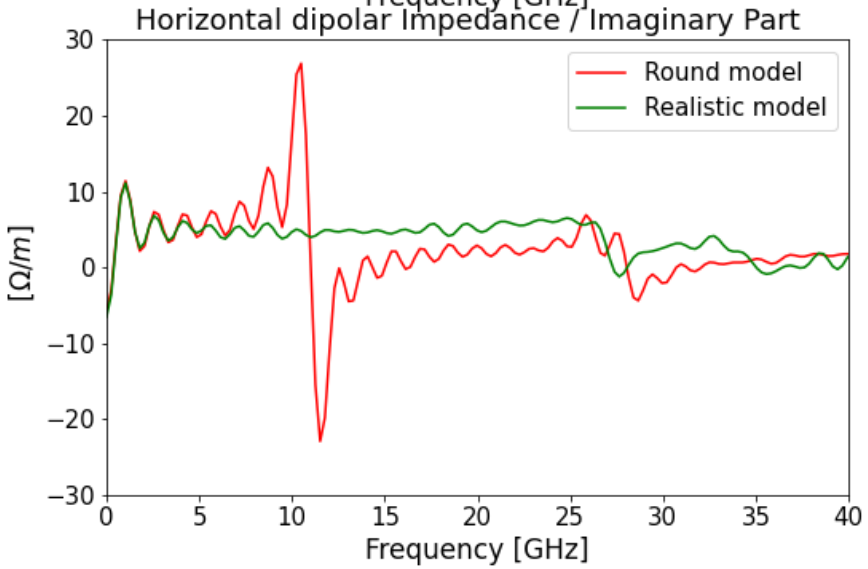
Transverse studies: dipolar impedance

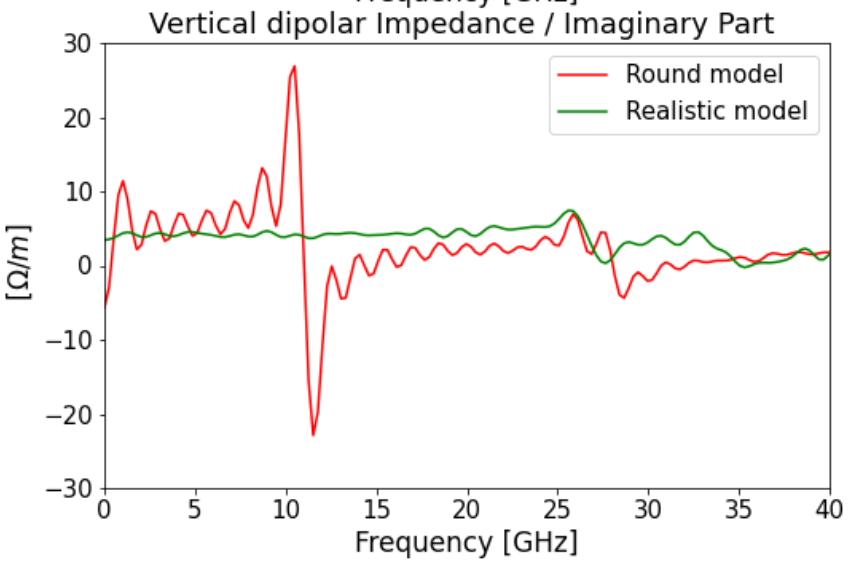




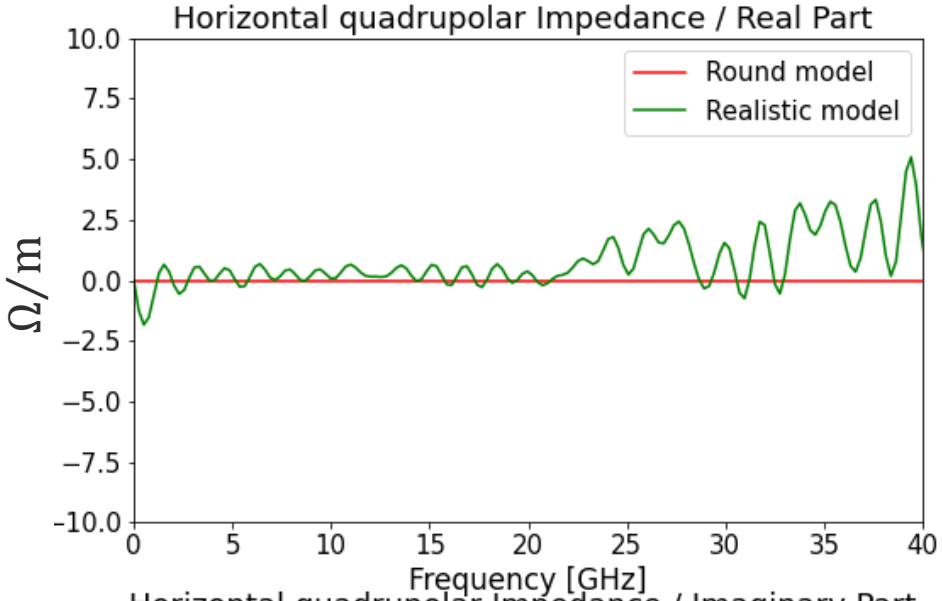


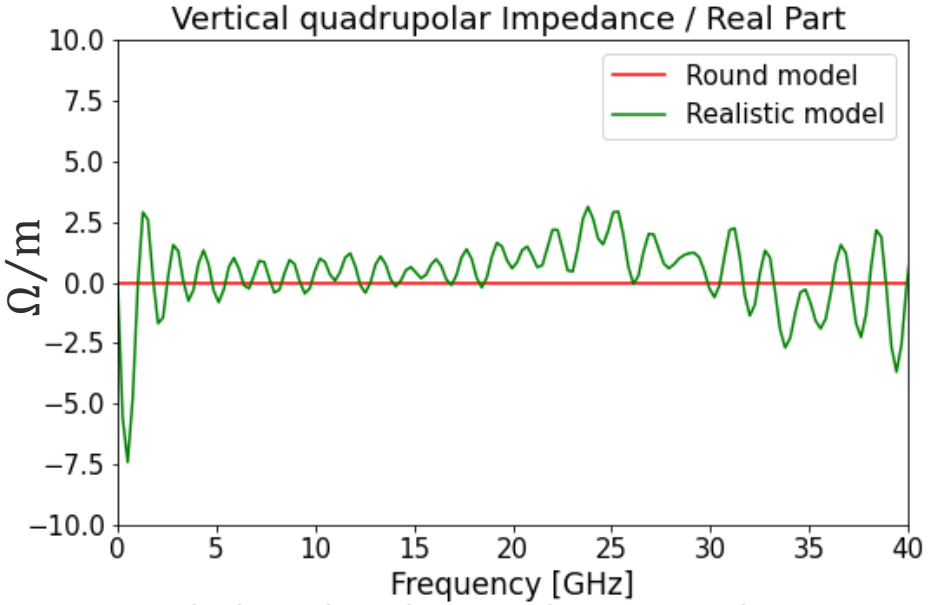


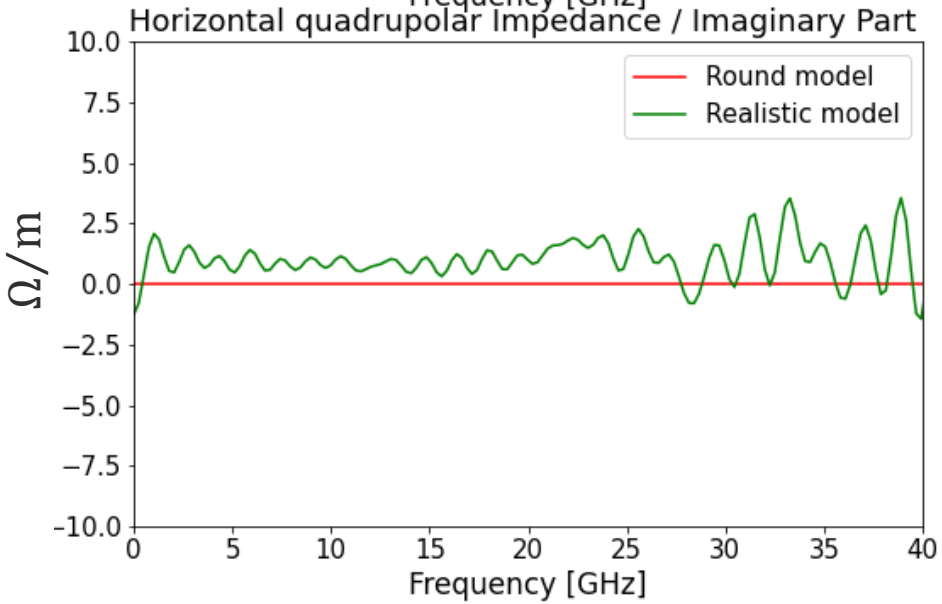


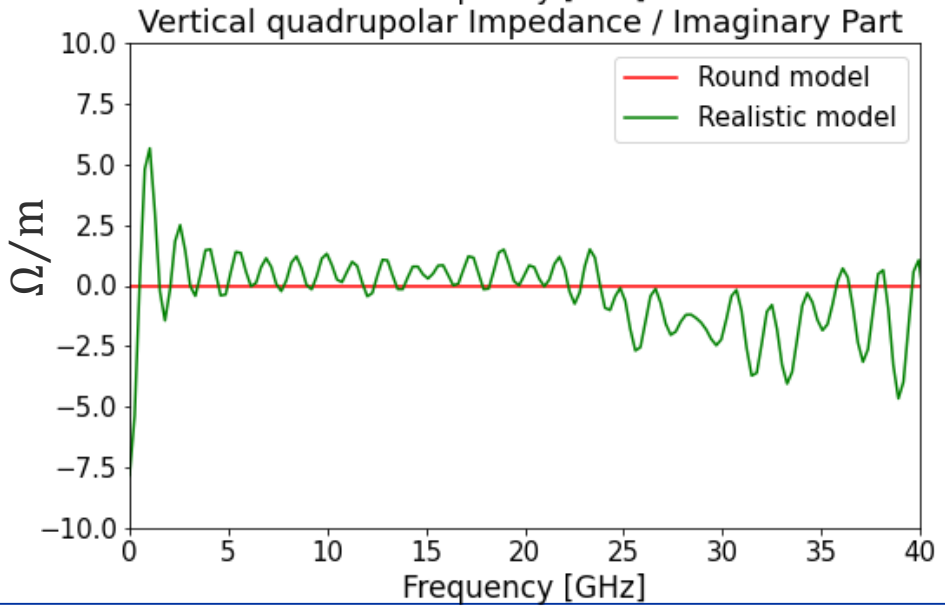


Transverse studies: quadrupolar impedance









Transverse studies: dipolar impedance

Winglets model