Hollow Electron Lens Impedance Simulations

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Acknowlegments:
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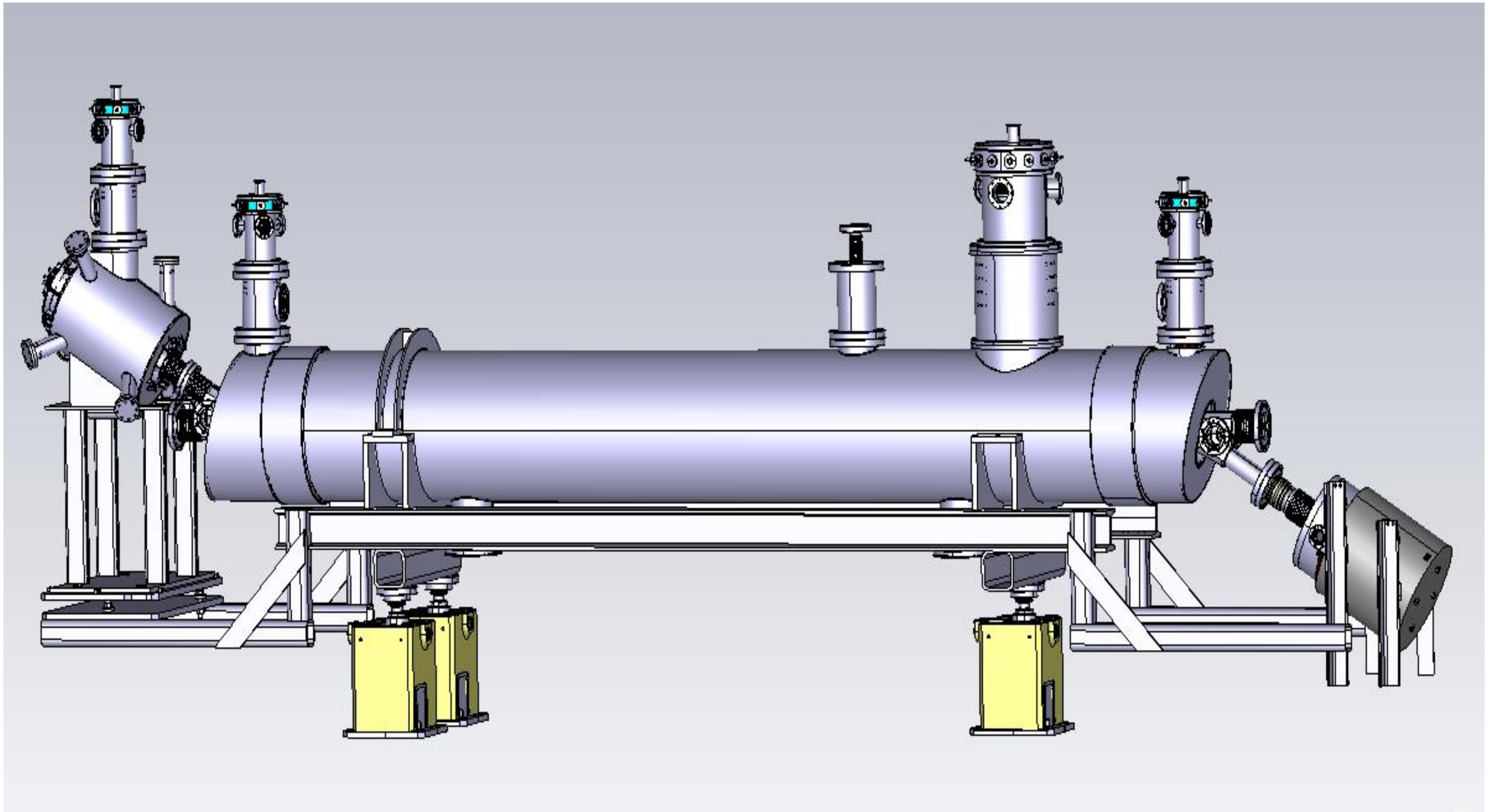
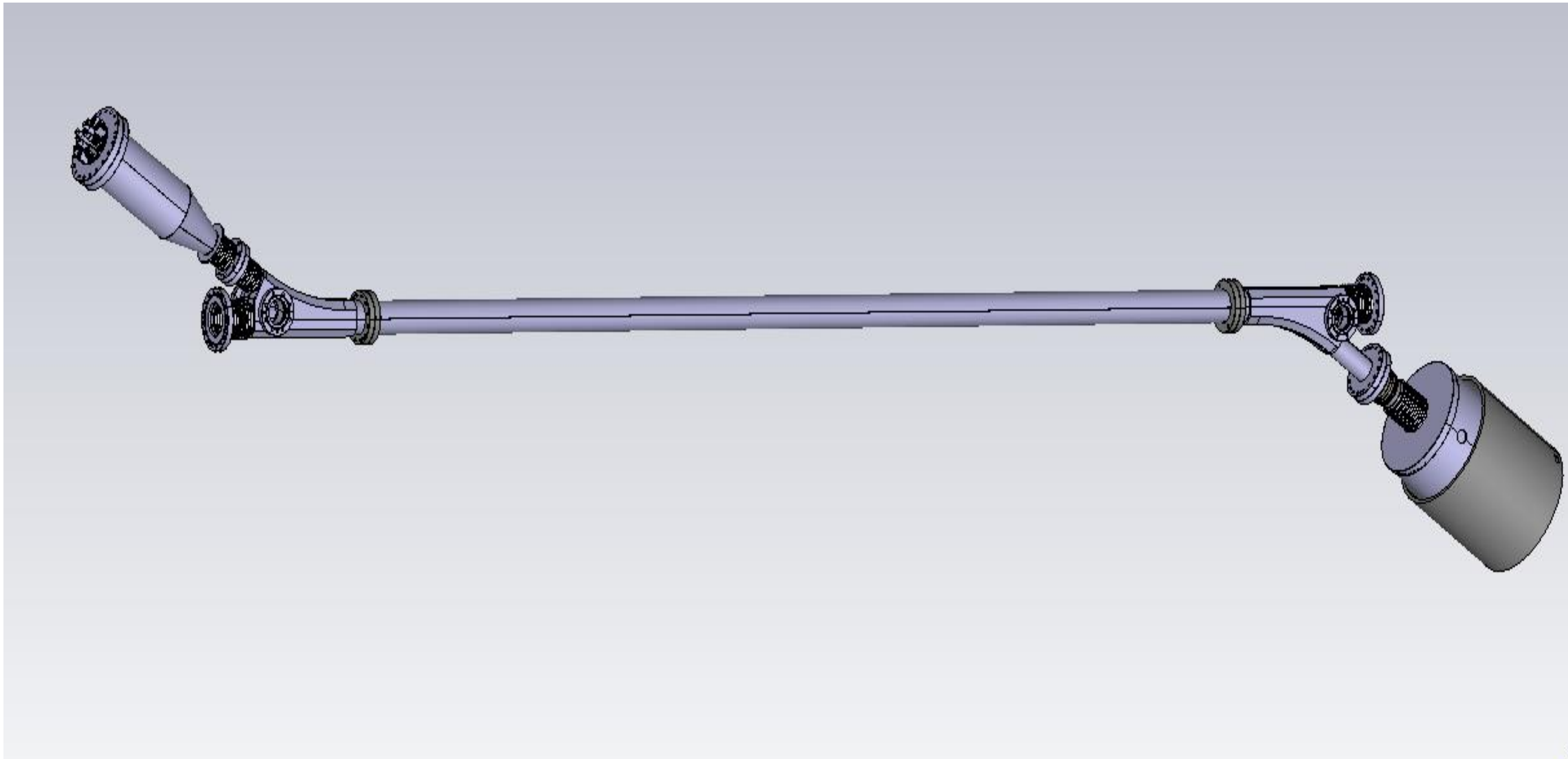
ELECTRON LENS MODEL

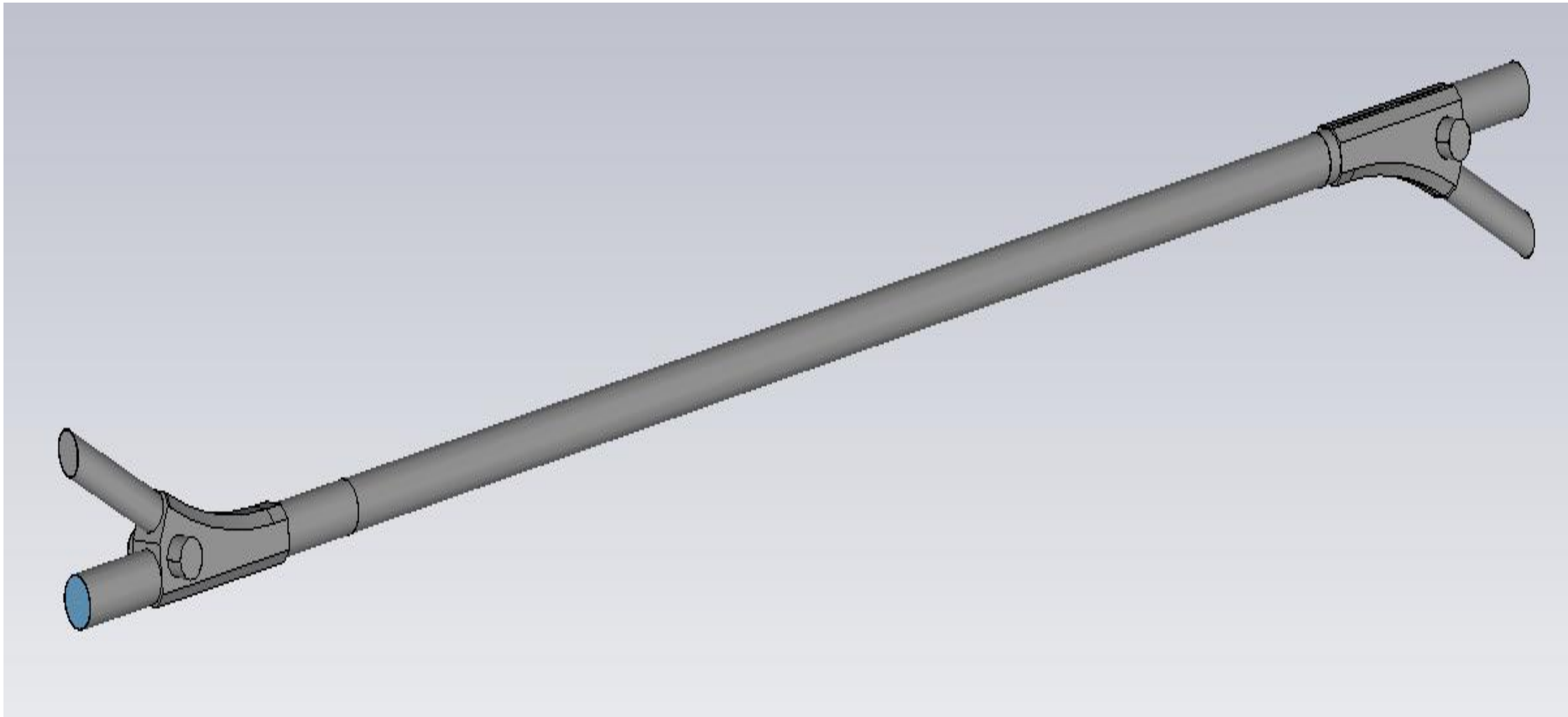


- This new structure is planned for HL-LHC, it will be assembled and mounted in the next years (LS1 or LS2)
- It is capable to interact with the beam for different purposes (acting on the emittance, bunch by bunch compensation, halo scraping etc.)



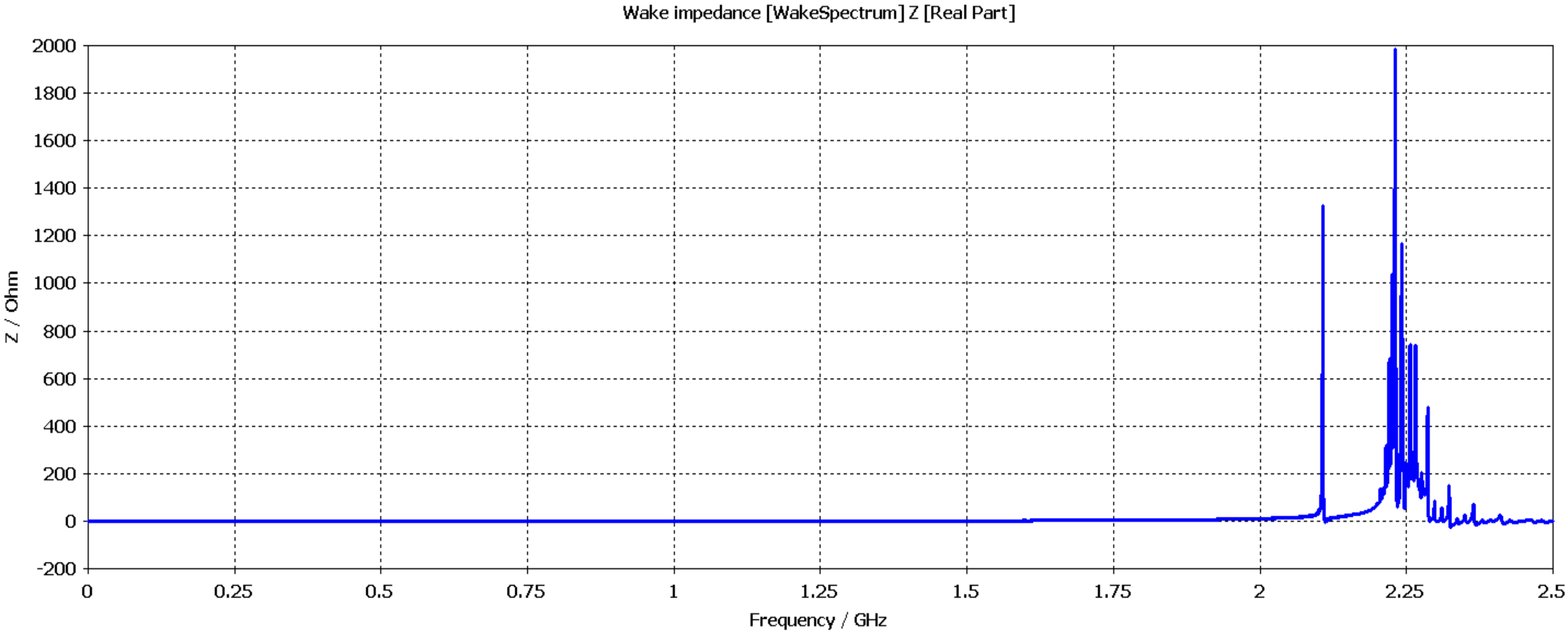
→ The Pipe was extracted in order to be characterized from the electromagnetic point of view

(this work was already presented at : Impedance Meeting, 17/03/2017)



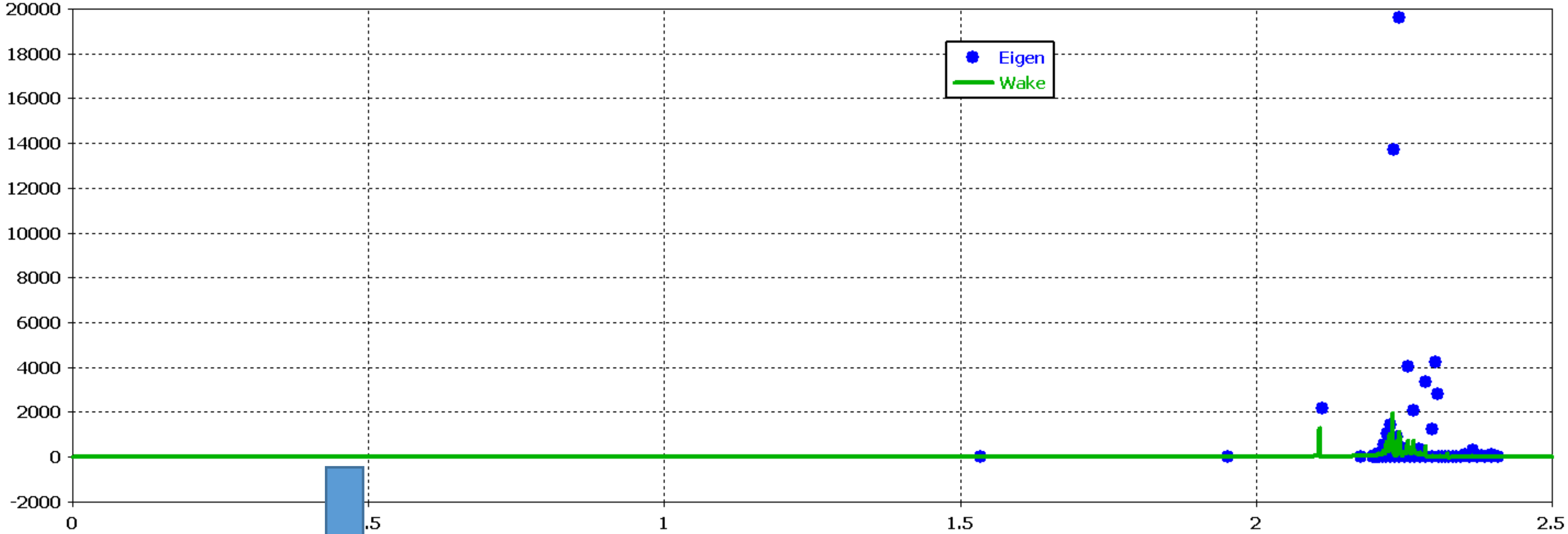
→ The structure was simplified in order to perform CST simulations, all the original dimensions and materials were preserved

Longitudinal Impedance, Real part

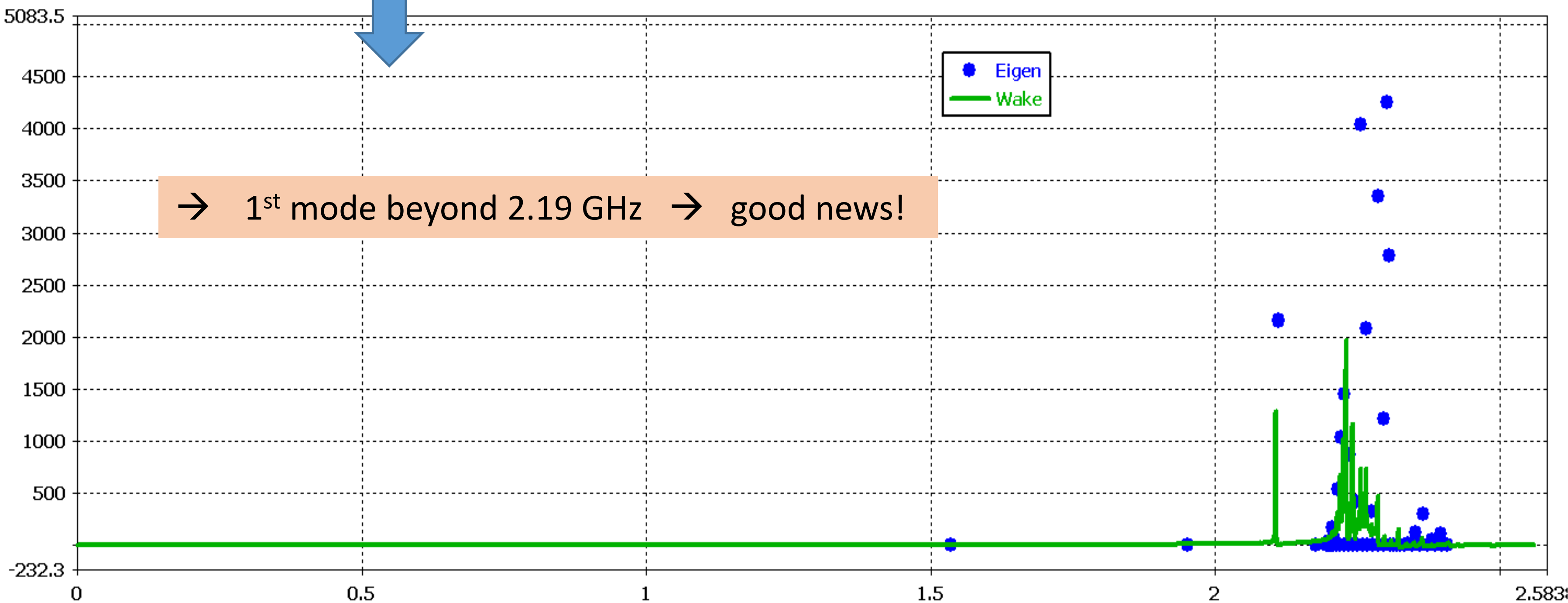


→ 1st mode beyond 2.19 GHz → good news!

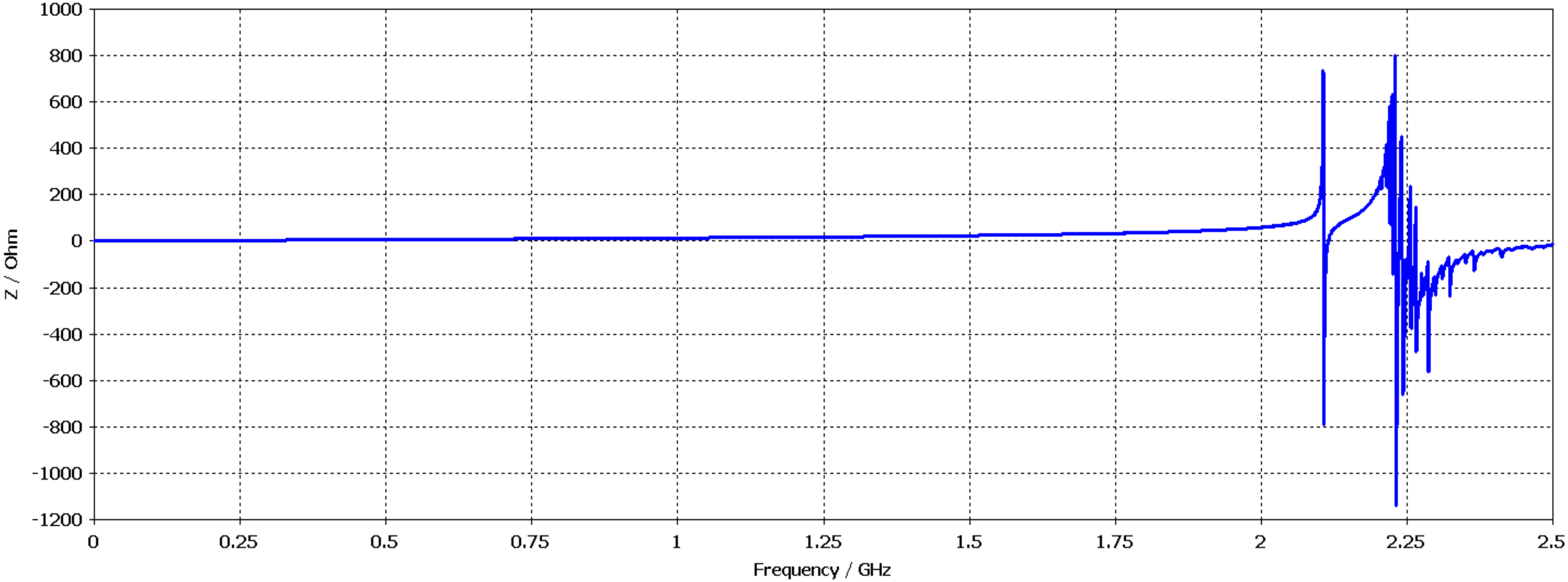
Longitudinal Impedance, Wake vs Eigen



ZOOM IN

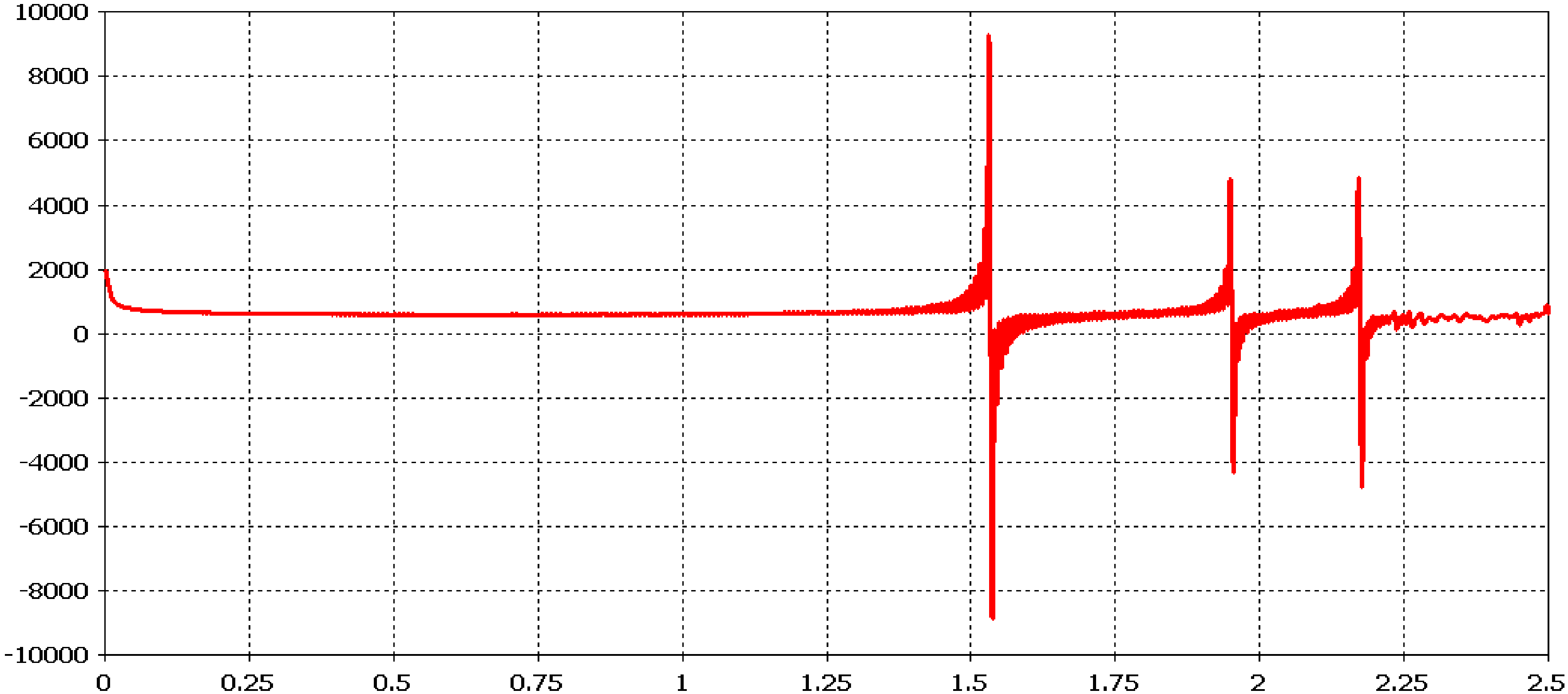


Longitudinal Impedance, Imaginary Part



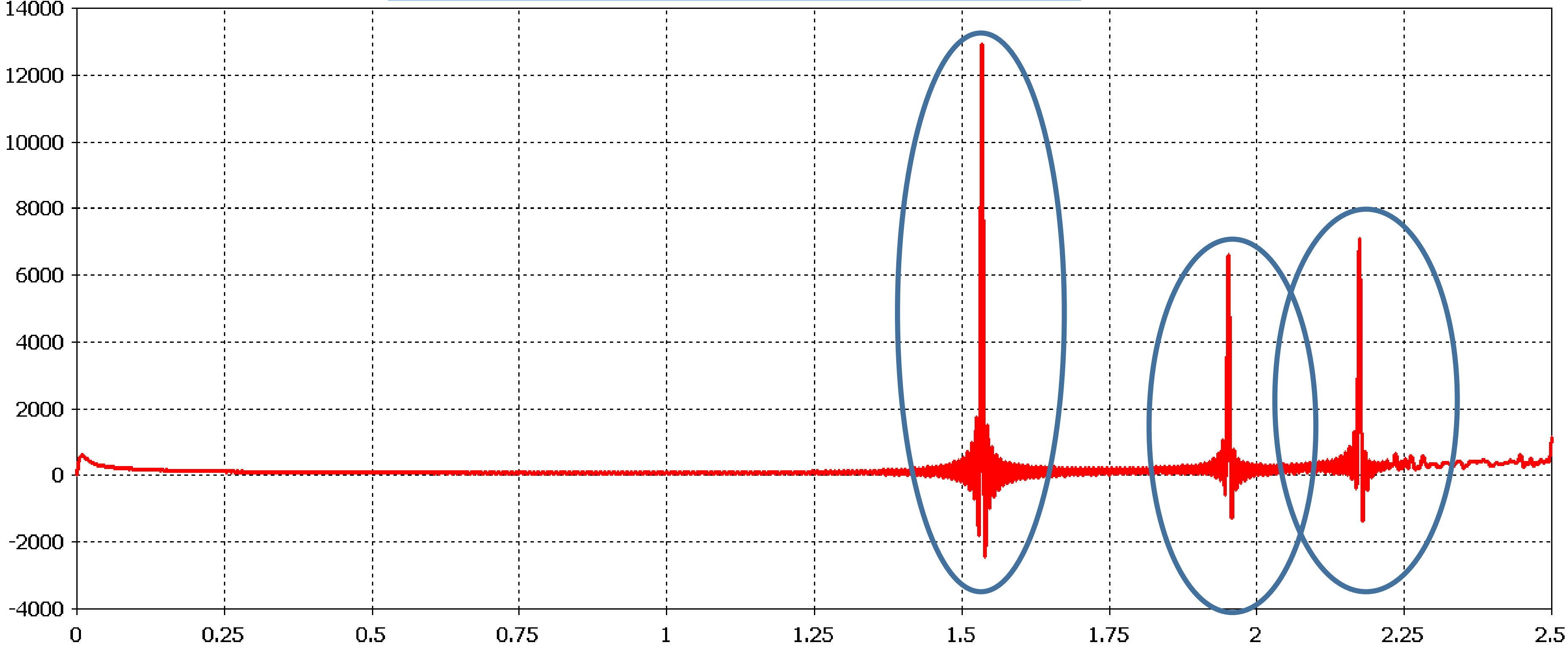
Electron Lens	Total LHC Impedance
$\frac{Z(f)}{n(f)} = 0.021\ \mathrm{m}\Omega$	$\frac{Z(f)}{n(f)} = 90\ \mathrm{m}\Omega$

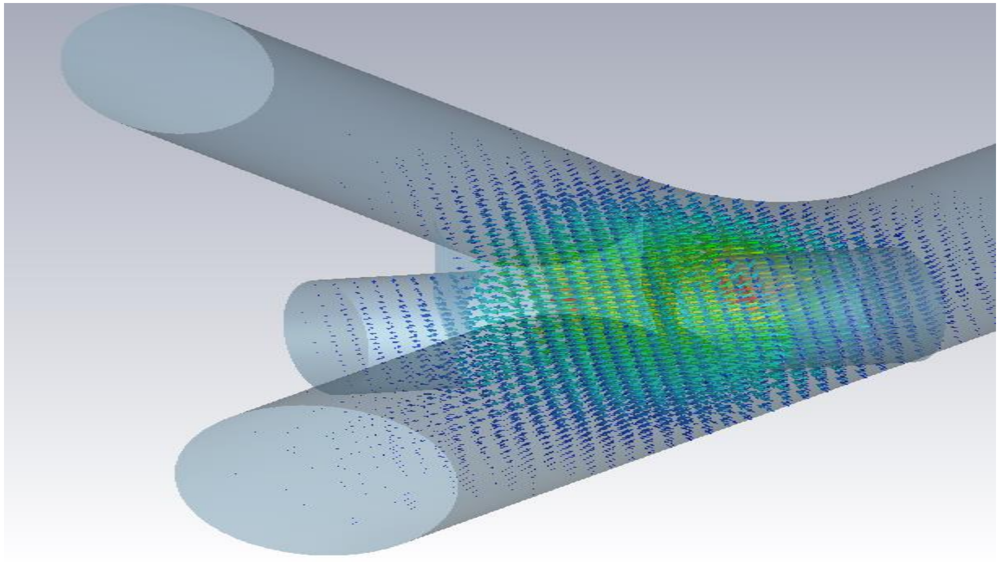
Dipolar X Impedance, Imaginary



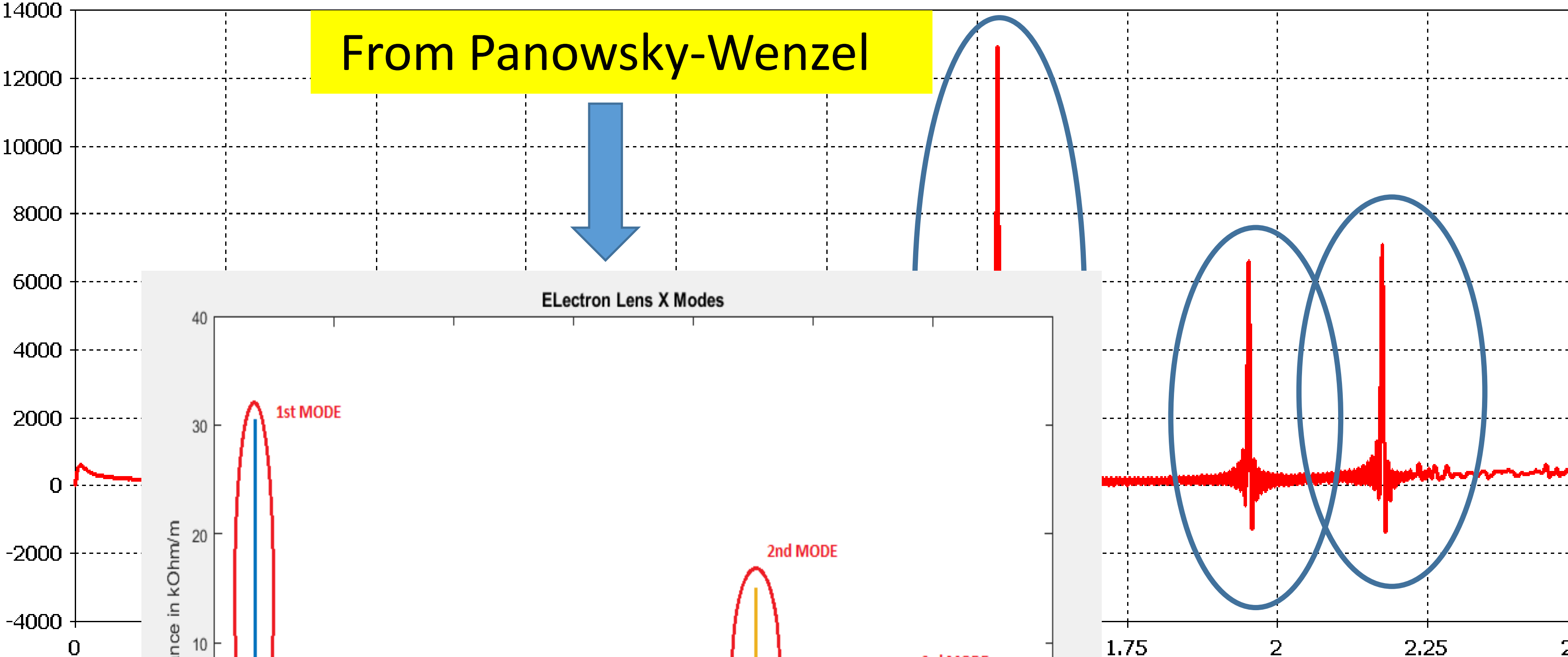
Electron Lens	Total LHC Impedance
$Z_{trans} = 600\ \Omega/m * \frac{\beta_x}{70}$	$Z_{trans} = 2\ \mathrm{M}\Omega/m$

Dipolar X Impedance, Real

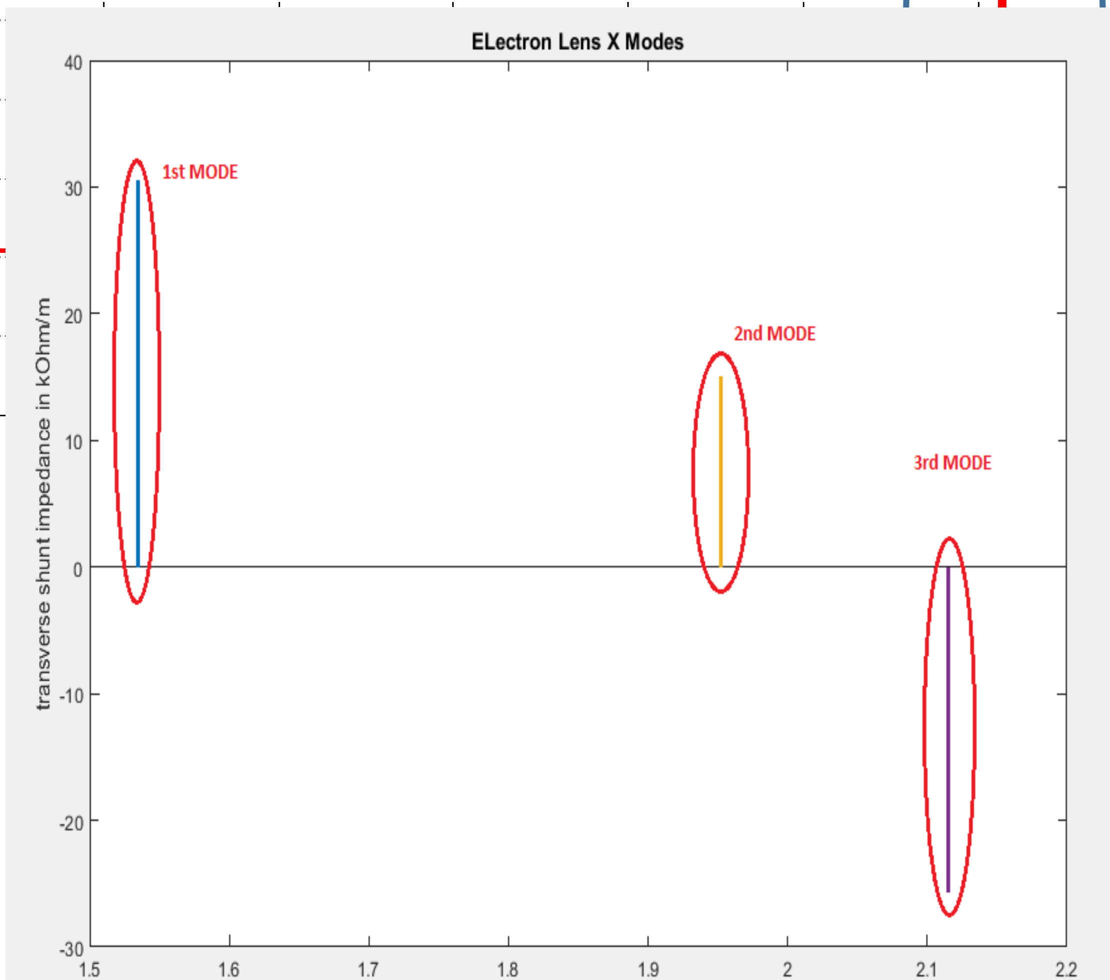




Dipolar X Impedance, Real



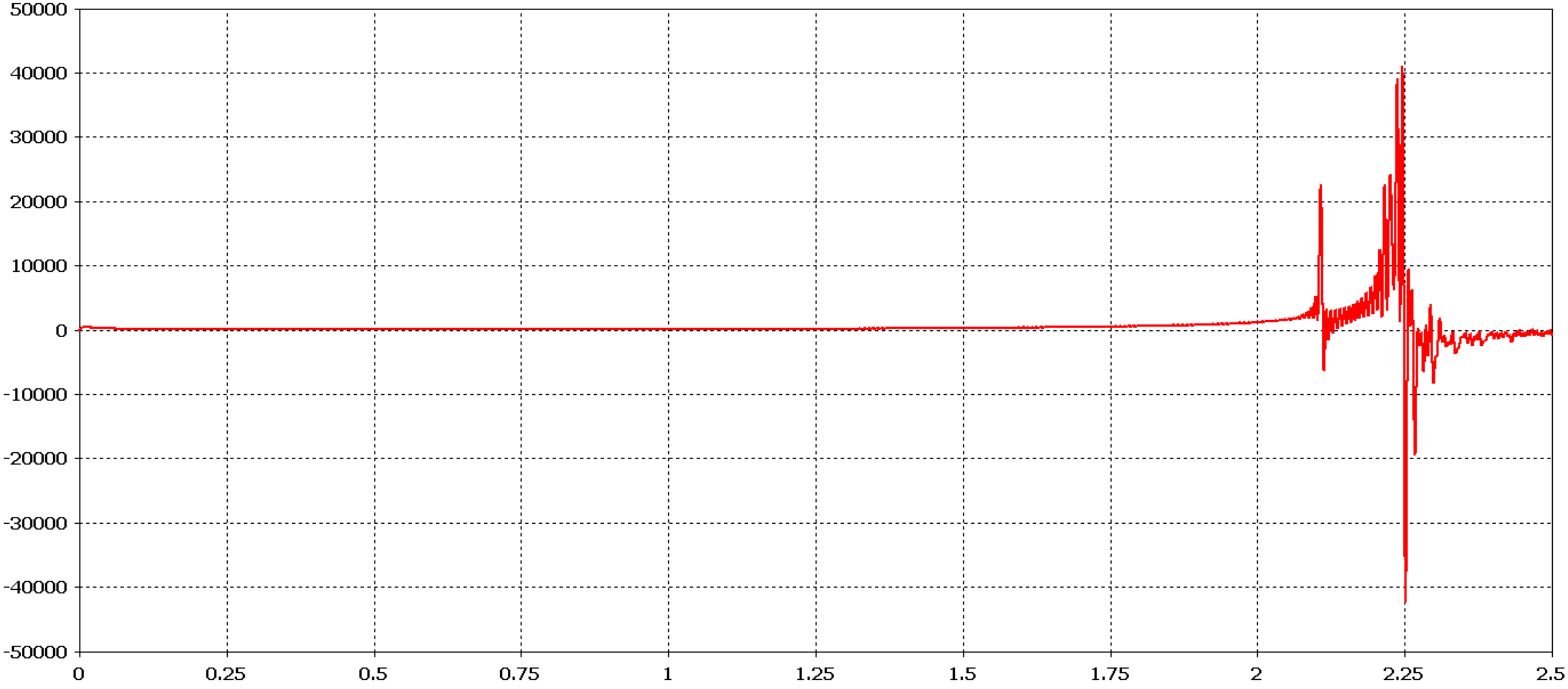
From Panowsky-Wenzel



$Z_{\perp x\ mode1}$ = 34 kΩ/m
$Z_{\perp x\ mode2}$ = 15 kΩ/m
$Z_{\perp x\ mode3}$ = 23 kΩ/m

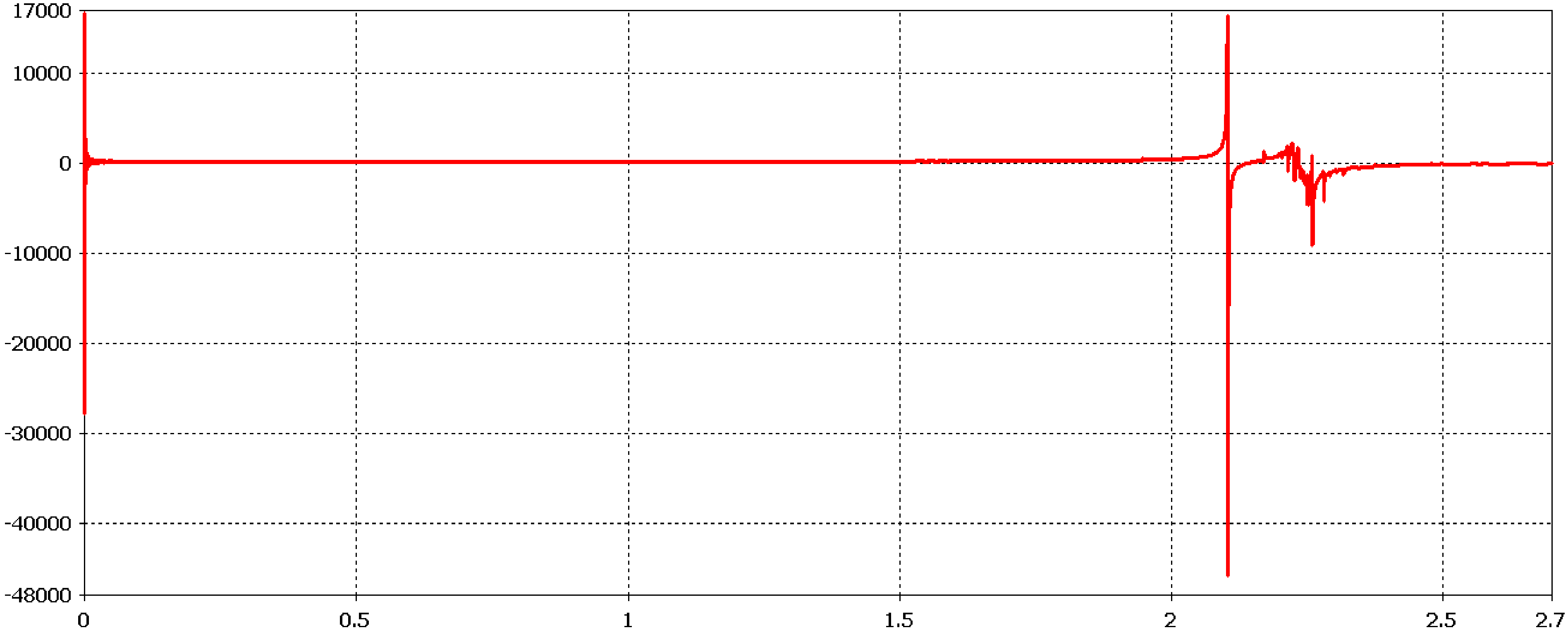
To be multiplied by $\frac{\beta_x}{70}$

Dipolar Y Impedance, Imaginary



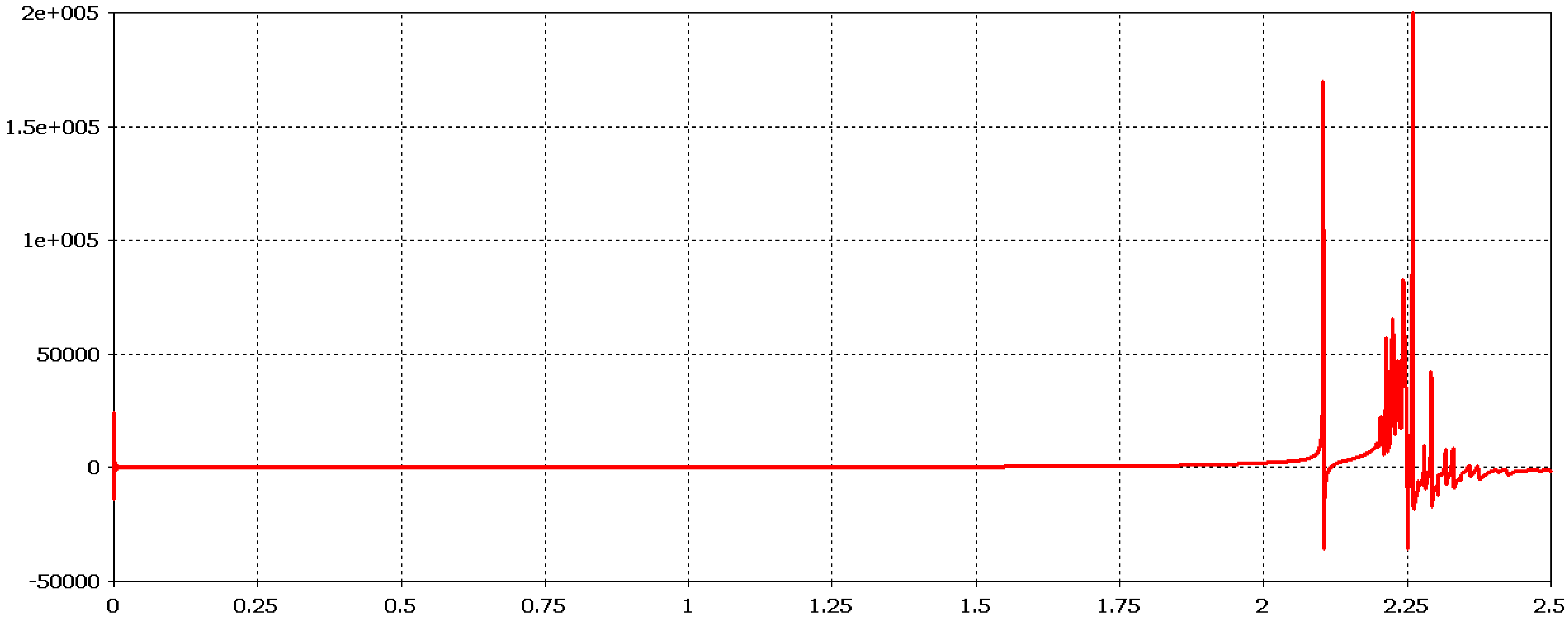
Electron Lens	Total LHC Impedance
$Z_{trans} = 700\ \Omega/m * \frac{\beta_y}{70}$	$Z_{trans} = 2\ \mathrm{M}\Omega/m$

Quadrupolar X Impedance, Imaginary



Electron Lens	Total LHC Impedance
$Z_{trans} = 140\ \Omega/m * \frac{\beta_x}{70}$	$Z_{trans} = 2\ \mathrm{M}\Omega/m$

Quadrupolar Y Impedance, Imaginary



Electron Lens	Total LHC Impedance
$Z_{trans} = 150\ \Omega/m * \frac{\beta_y}{70}$	$Z_{trans} = 2\ \mathrm{M}\Omega/m$

CONCLUSIONS

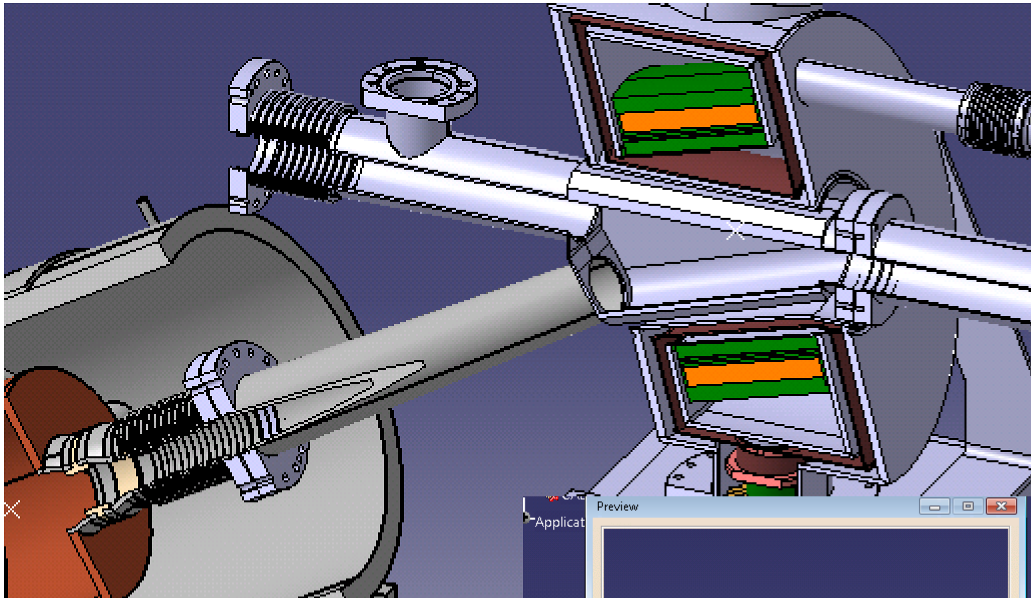
→ The device has shown good performance from the impedance point of view

→ All the values obtained are significantly below the LHC budget

For more info:

[G.Mazzacano, Hollow Electron Lens Impedance Simulations] https://indico.cern.ch/event/623679/

Thank you for your time



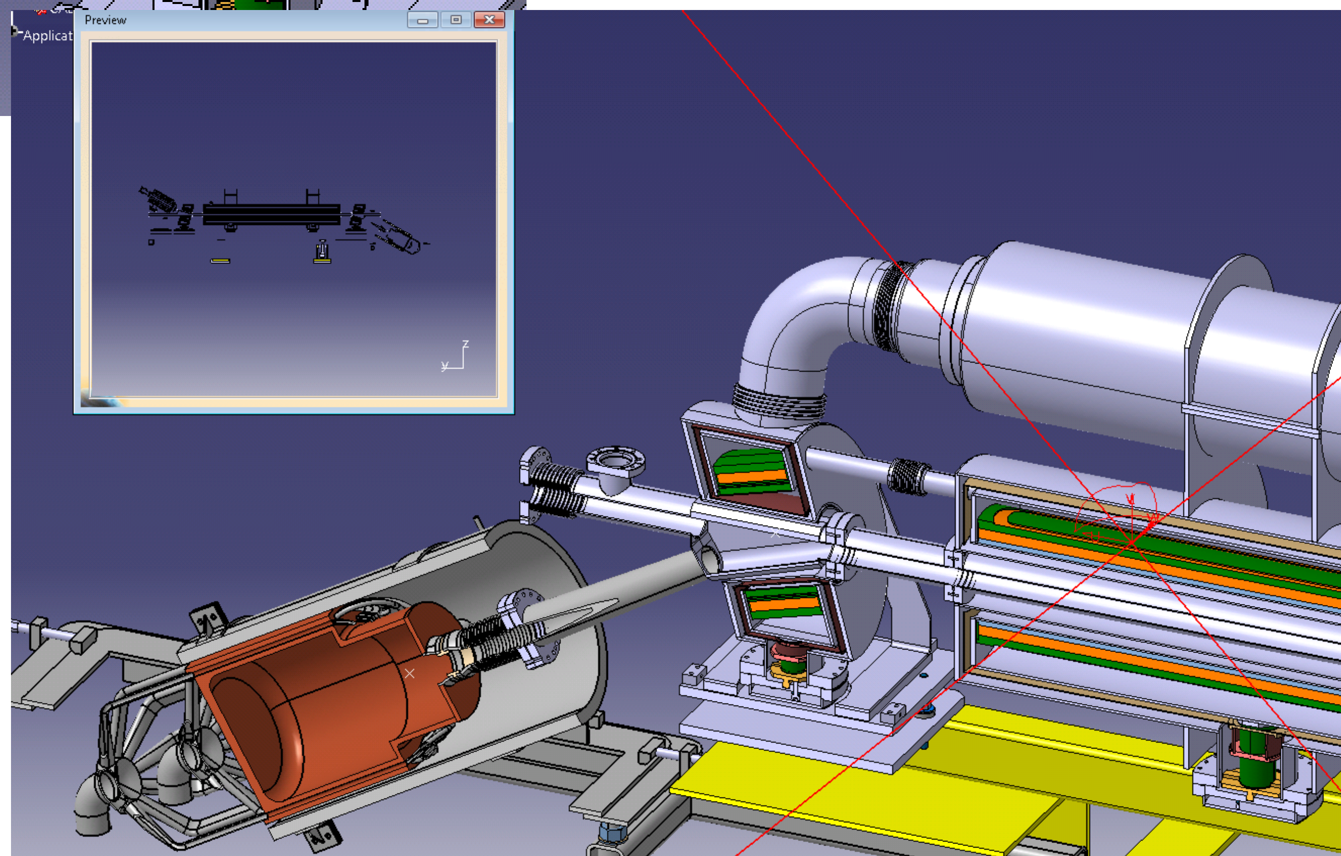
Updated design
(last change on Oct 13 on SMARTEAM)

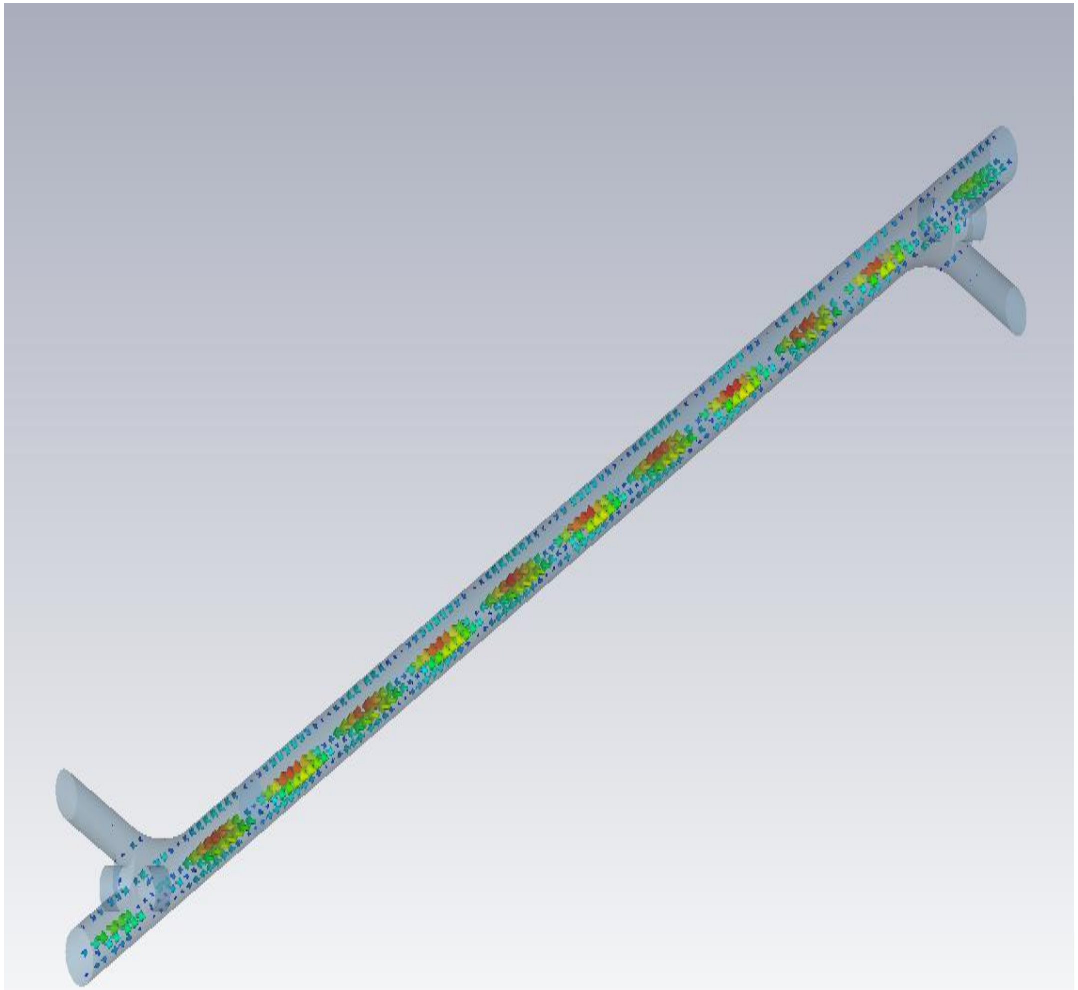
Main points:

- The ports on top and bottom of Y chamber disappeared

- The smoothing of the chamber was removed

- We will redo detailed simulations.





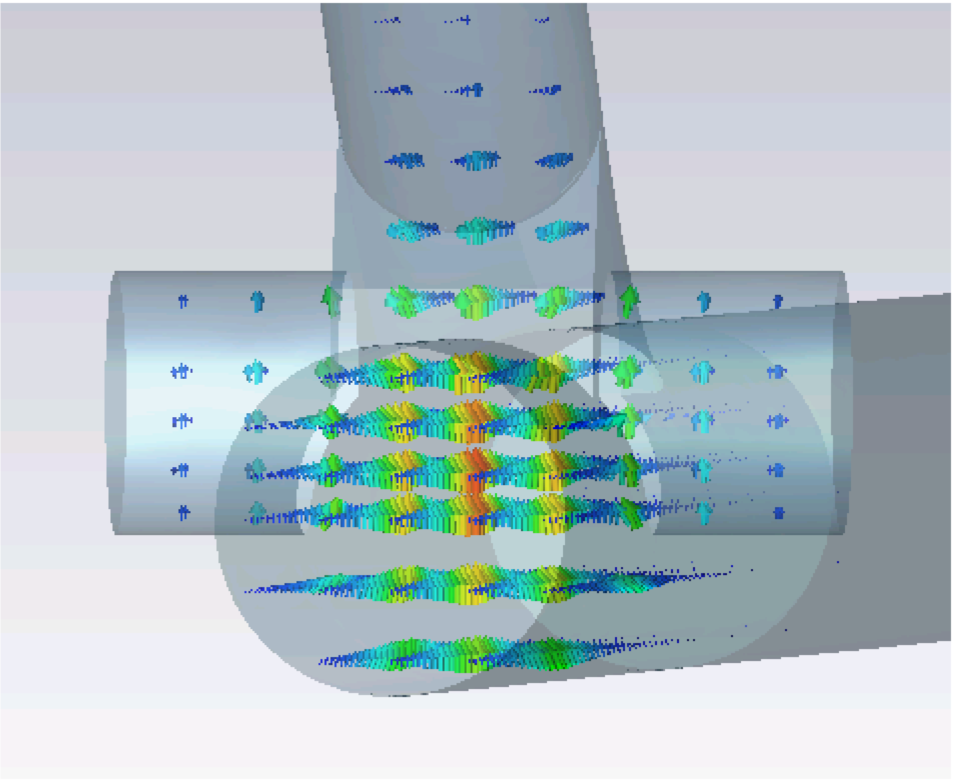
- The family of modes between 2.19 GHz and 2.35 GHz gives the biggest longitudinal impedance contribution. The values are not critical (out of LHC beam spectrum frequencies) and apparently from Eigenmode simulations they seem to be fake modes due to the main pipe…. But they are not:

→ They don't shift in frequency if the length of the structure is changed

→ TE modes present a Ez component

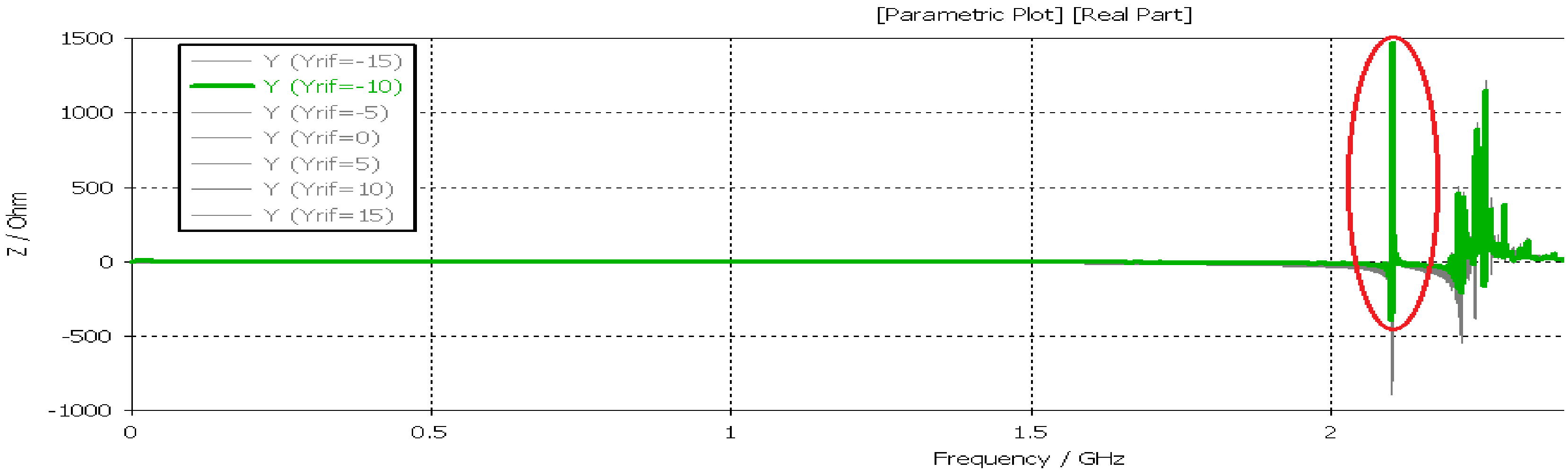
→ In Wakefield simulations (open boundaries) they are still inside the structure

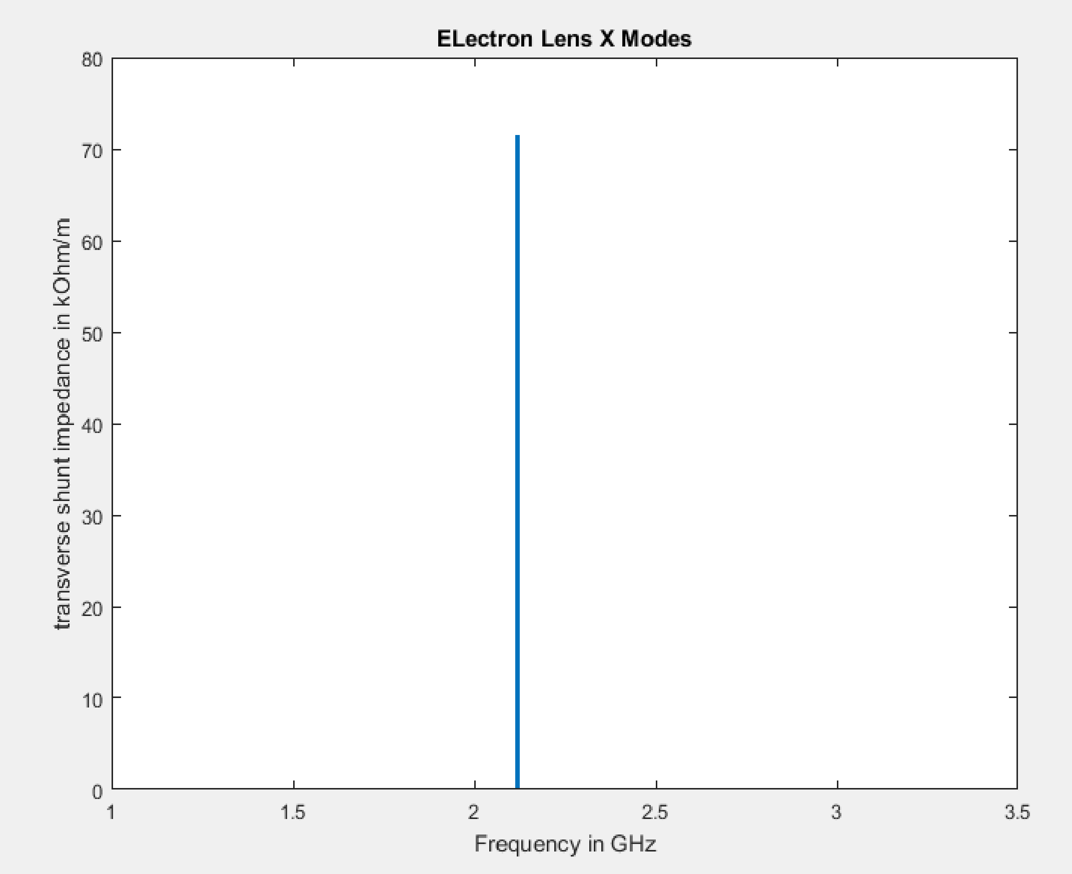
Frequency	Q factor	Shunt Imp.	R/Q
2.24 GHz	3040	1.80 Ohm	0.0005 Ohm



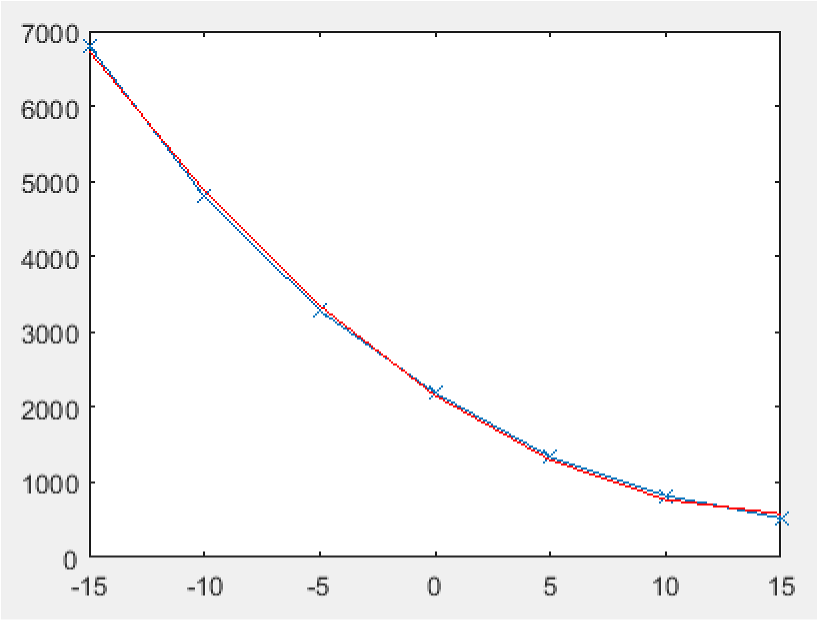
- First significant trapped mode along Y below cutoff
- It is due to a vertical aperture of the structure
- Not clear what type of mode it is, to be checked.

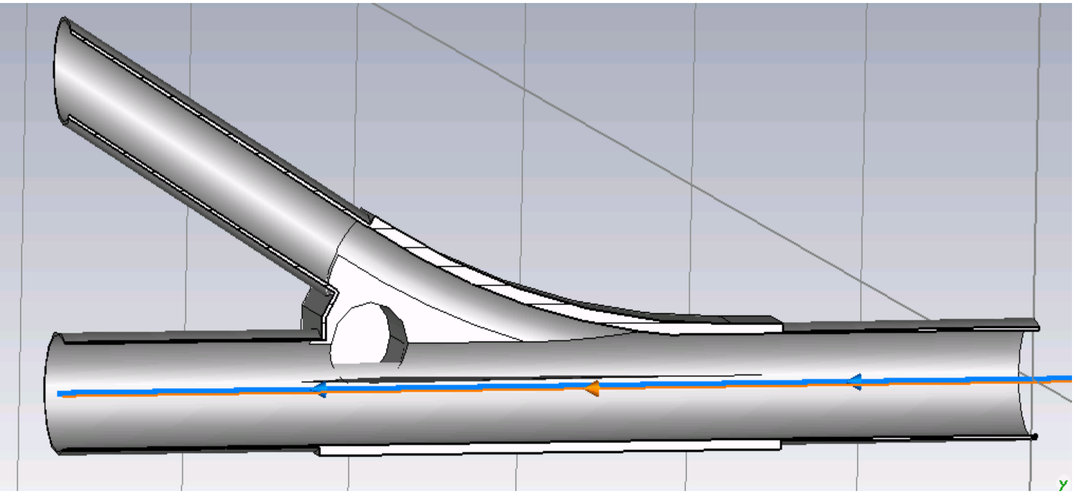
Frequency	Q factor	Shunt Imp.	R/Q
2.114 GHz	3325	850 Ohm	0.255





Shunt impedances for different Y displacements



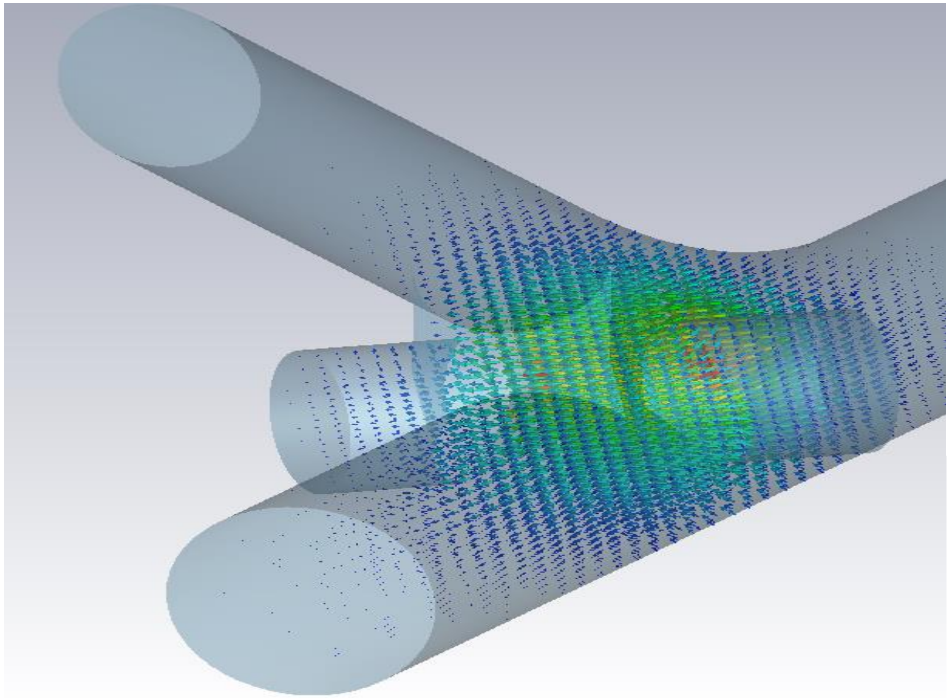


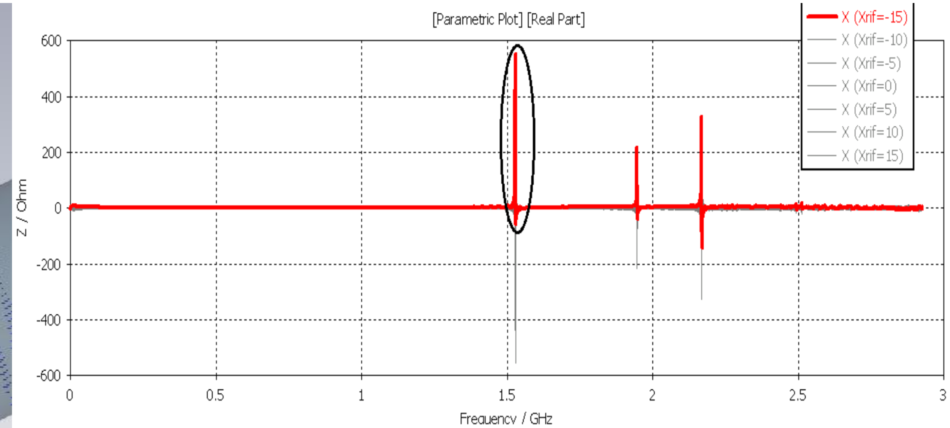
- The below cutoff mode seems to be an asymmetric transverse mode. The roughly obtained values give back:

  $Z_{\perp y\ mode}$ = 67.5 kΩ/m

- The pattern's asymmetry could be there due to an upwards opening of the structure towards the beginning of it. No symmetry plane in zero for this mode.

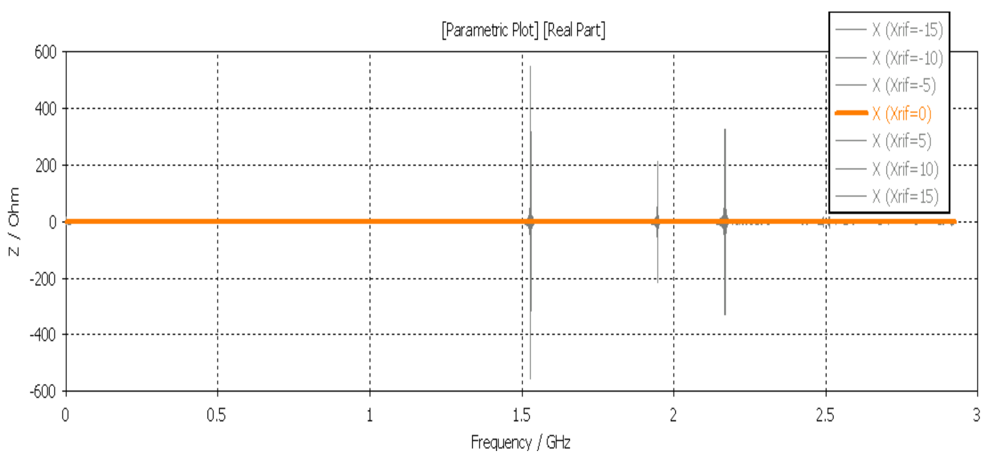
- To be further investigated in quadrupolar analysis, see end of slides.





- This below cutoff TM mode is due to the cylindrical transverse cavity present in the structure. It causes resonance along X especially with Xdisp = -15mm.
- Be careful, $Z_{\perp x\ mode}$ = 32 kΩ/m ! Not negligible value!
- From the plot can be noted the presence of a "twin mode" with opposite phase in the opposite part of the structure

Frequency	Q factor	Shunt Imp.	R/Q
1.53 GHz	3168	1650 Ohm	1.92 Ohm



- No contribution to impedance for Xposition = 0, all the modes are pure transverse dipolar ones, they totally depend on the Xdisplacement. This agrees with theory, the structure is totally symmetric along X axis as a matter of fact.

COMPARING DIPOLAR AND QUADRUPOLAR IMPEDANCE

$Z_{\perp x,dip} slope = 500\ \Omega/m$

$Z_{\perp x,quad} slope = 200\ \Omega/m$

$Z_{\perp y,dip}\ slope = \ 800\ \Omega/m$

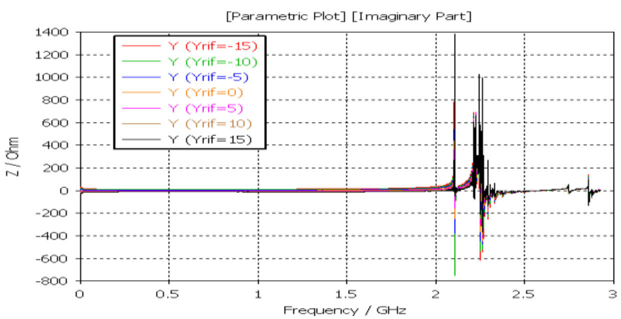
$Z_{\perp y,quad}\ slope = 180\ \Omega/m$

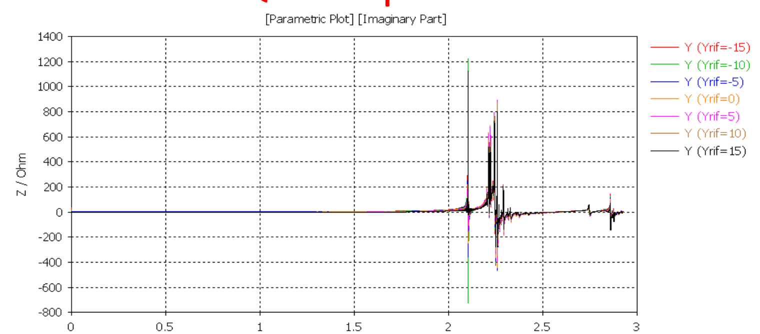
- The quadrupolar part of the transverse impedance gives a smaller broadband contribution than the dipolar one
- No transverse X modes below cutoff.
- Quadrupolar Y impedance is similar.

Dipolar

Quadrupolar

Y





X