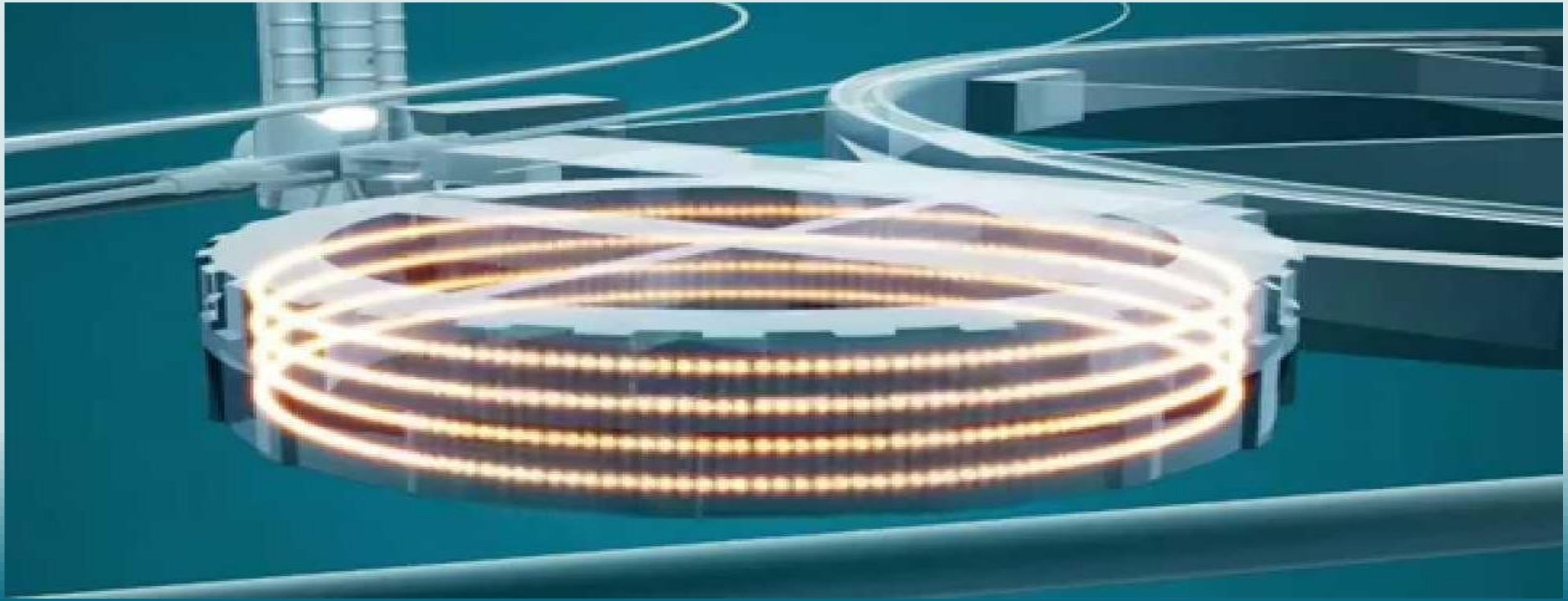
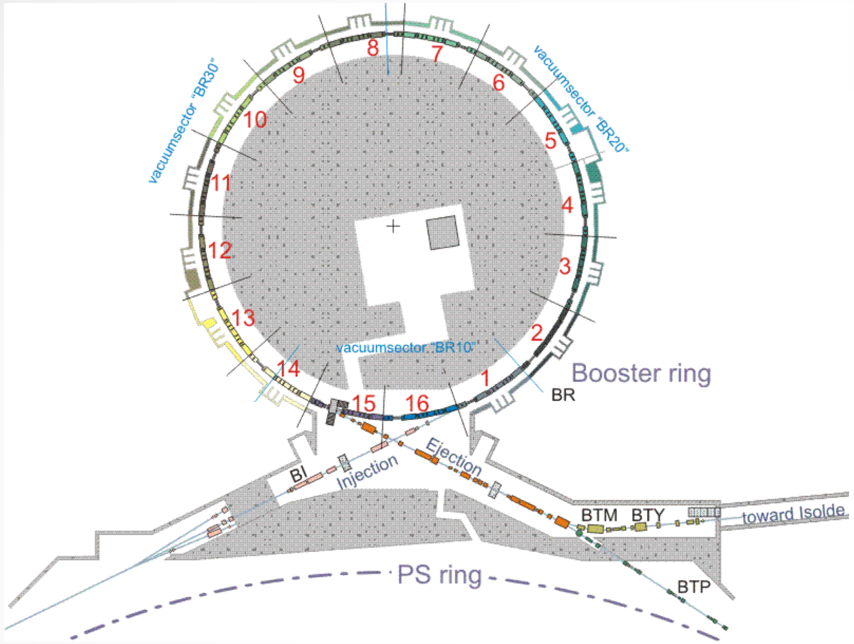
The PSBooster impedance model

15/12/2017 Tatiana Rijoff

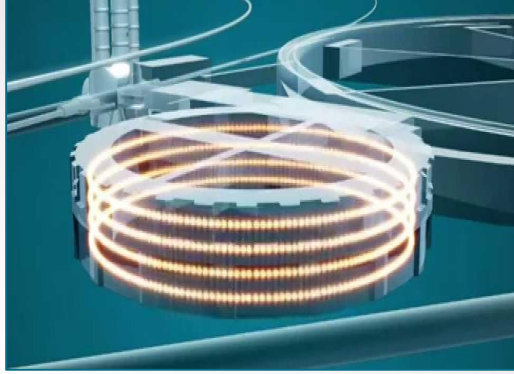


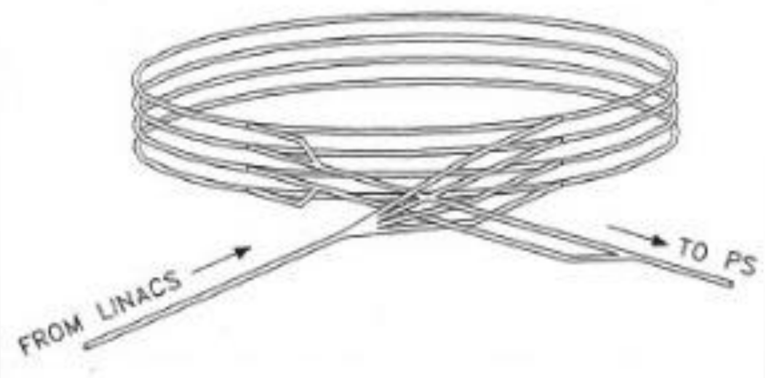
The proton syncrotron booster



Considered energies:
E_{kin} = 160 MeV
E_{kin} = 1 GeV
E_{kin} = 1.4 GeV

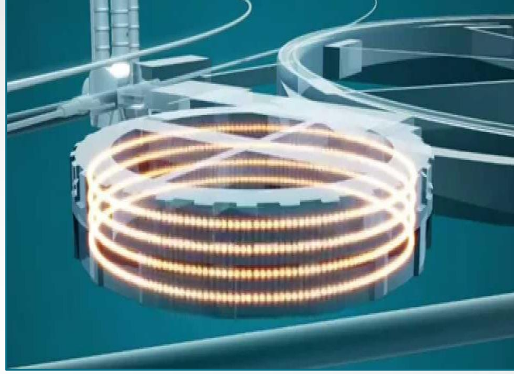
f = [0.5 - 40] MHz





end 5	end 5	end 5	end 5
BR1.ONO6L1	BR2.ONO6L1	BR3.ONO6L1	BR4.ONO6L1
BR1.OSK6L1	BR2.OSK6L1	BR3.OSK6L1	BR4.OSK6L1
BR1.XNO6L1	BR2.XNO6L1	BR3.XNO6L1	BR4.XNO6L1
BR1.XSK6L1	BR2.XSK6L1	BR3.XSK6L1	BR4.XSK6L1
			BR4.ACWF6L1.1
			BR4.ACWF6L1.2
BR.BHZ61	BR.BHZ61	BR.BHZ61	BR.BHZ61
BR.STSCRAP61	BR.STSCRAP61	BR.STSCRAP61	BR.STSCRAP61
BR.QFO61	BR.QFO61	BR.QFO61	BR.QFO61
BR1.BPM6L3	BR2.BPM6L3	BR3.BPM6L3	BR4.BPM6L3
BR1.ONOH0.6L3	BR2.ONOH0.6L3	BR3.ONOH0.6L3	BR4.ONOH0.6L3
BR1.QSK6L3	BR2.QSK6L3	BR3.QSK6L3	BR4.QSK6L3
BR1.XNOH0.6L3	BR2.XNOH0.6L3	BR3.XNOH0.6L3	BR4.XNOH0.6L3
BR.QDE6	BR.QDE6	BR.QDE6	BR.QDE6
BR1.DHZ6L4	BR2.DHZ6L4	BR3.DHZ6L4	BR4.DHZ6L4
BR1.DVT6L4	BR2.DVT6L4	BR3.DVT6L4	BR4.DVT6L4
BR1.OSK6L4	BR2.OSK6L4	BR3.OSK6L4	BR4.OSK6L4
BR1.XSK6L4	BR2.XSK6L4	BR3.XSK6L4	BR4.XSK6L4
BR.QFO62	BR.QFO62	BR.QFO62	BR.QFO62
BR.STSCRAP62	BR.STSCRAP62	BR.STSCRAP62	BR.STSCRAP62
BR.BHZ62	BR.BHZ62	BR.BHZ62	BR.BHZ62
end 6	end 6	end 6	end 6

Frequency range



f = [0.5 - 40] MHz

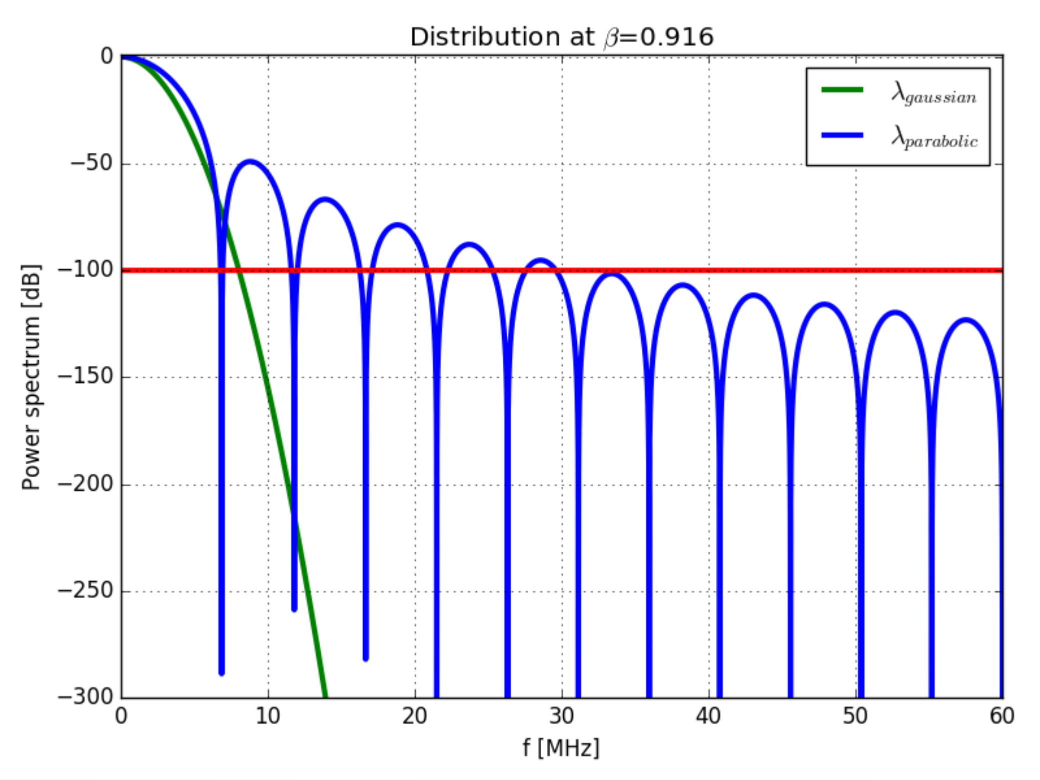
$$f_{\min} = \left(1 - Q_u\right) f_{rev} \qquad u = x, y$$

Energy (MeV)	f_{rev} [MHz]	$f_{min}x$ [MHz]	$f_{min}y$ [MHz]
160	0.99	0.77	0.62
1000	1.67	1.30	1.05
1400	1.75	1.36	1.10

Frequency range

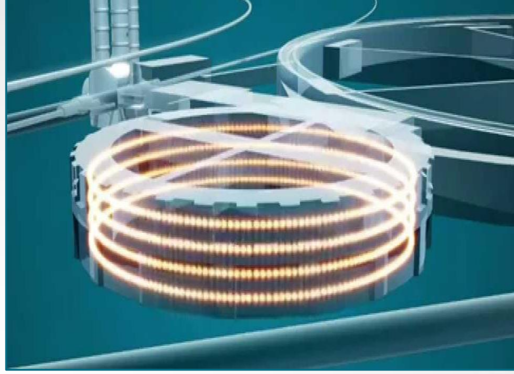
f = [0.5 - 40] MHz

f_{max} = Maximum frequency excited by the beam

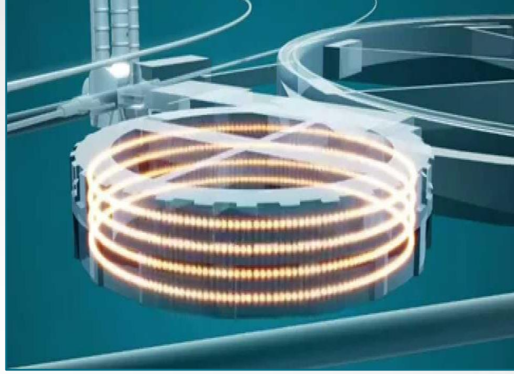


worst case at extraction (smallest bunch length)

worst case with a parabolic bunch profile



The aim of the study



$$Z_{\perp}^{PSB}(f) = \sum_{i=1}^{N} \frac{\beta_{\perp}^{i}}{\langle \beta_{\perp} \rangle} Z_{\perp}^{i}(f)$$

$$Z_{\parallel}^{PSB}(f) = \sum_{i=1}^{N} Z_{\parallel}^{i}(f)$$

Identify the relevant impedance sources in the ring and construct the impedance model

ω_0 = revolution angular frequency
ω_s = synchrotron frequency
ω_β = betatron angular frequency
ω_ξ = chromaticity frequency shift

$$h_l(\omega) = \left(\frac{\omega \sigma_z}{\beta c}\right)^{2l} e^{-\frac{\omega^2 \sigma_z{}^2}{\beta^2 c^2}}$$

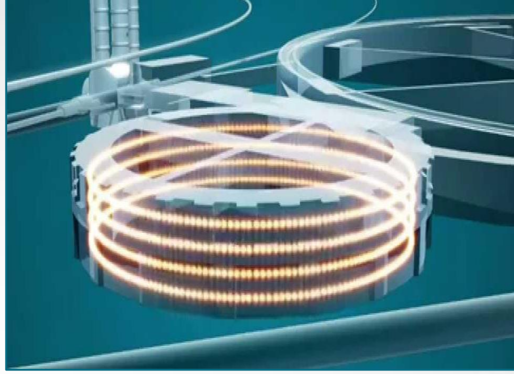
$$\omega' = p\,\omega_0 + l\,\omega_s$$

$$\left(\frac{Z_\parallel}{\omega}\right)_{eff} = \frac{\sum_{p=-\infty}^{\infty} \frac{Z_\parallel(\omega')}{\omega'} h_l(\omega')}{\sum_{p=-\infty}^{\infty} h_l(\omega')}$$

$$(Z_\perp)_{eff} = \frac{\sum_{p=-\infty}^{\infty} Z_\perp(\omega' + \omega_\beta) h_l(\omega' + \omega_\beta - \omega_\xi)}{\sum_{p=-\infty}^{\infty} h_l(\omega' + \omega_\beta - \omega_\xi))}$$

$$\xi_1 = -\frac{\Gamma\left(l + \frac{1}{2}\right)}{2^l\, l!} \frac{N r_0 c^2}{4\pi \omega_\beta \gamma T_0 \sigma} i\, Z_{\perp\ eff}$$

The aim of the study

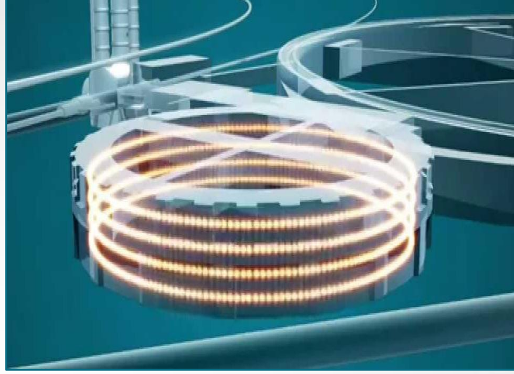


ξ_1 ➔ complex mode frequency shift

$$\Im(\xi_1) \Rightarrow \tau^{-1}$$

$$\Re(\xi_1) \Rightarrow \Delta Q$$

The impedance model



Simulation code
CST particle studio

- Resistive Wall
- Indirect space charge
- Transitions
- KSW
- Extraction kicker

- Finemet
- Tune pickup
- Wire scanner

- Scraper

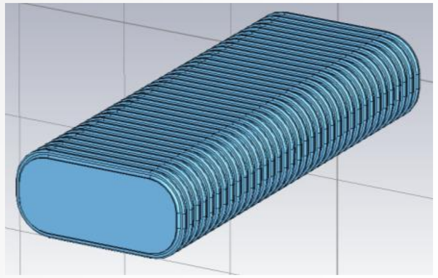
- ...

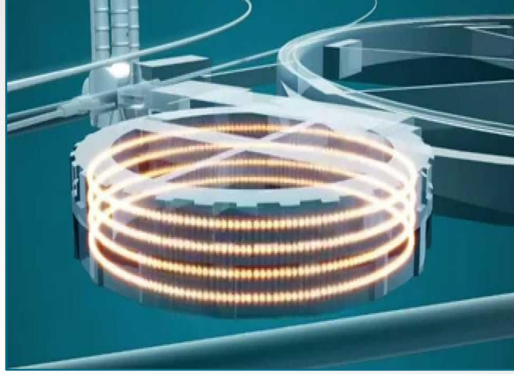
Impedance budget

Growth rate
Tune shift

Analytical codes
ReWall
TLWall
scripts (mathematical/ matlab/ python)

Resistive wall

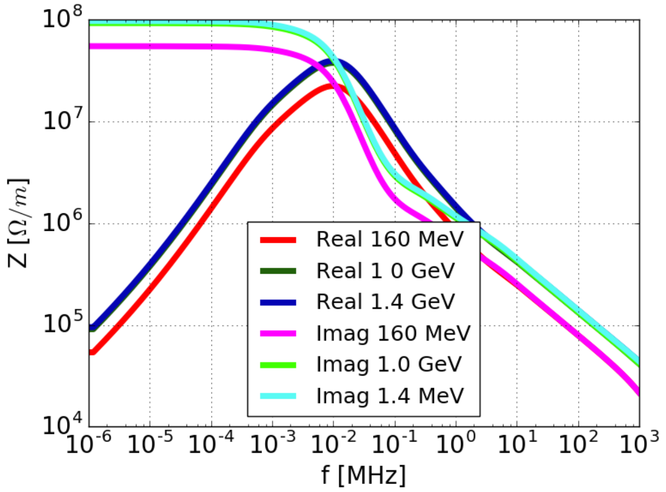


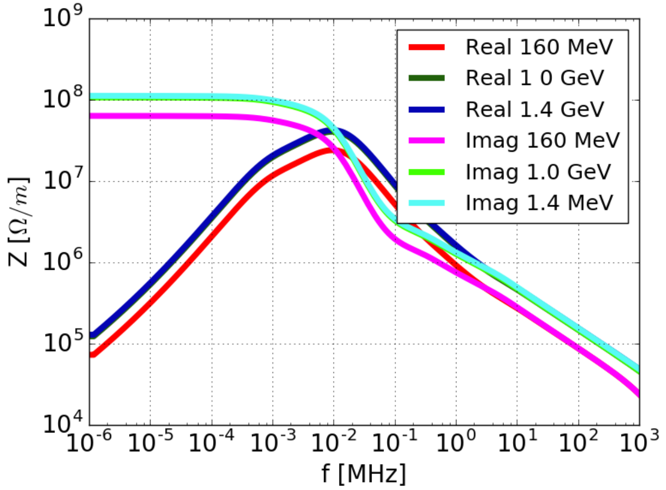


Horizontal transverse impedance

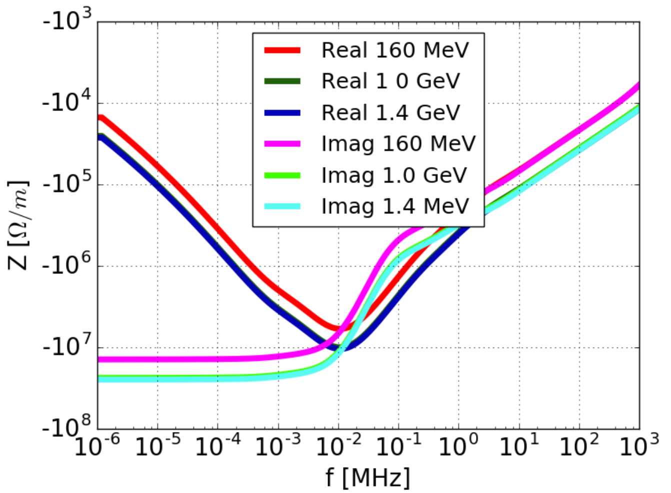
Vertical transverse impedance

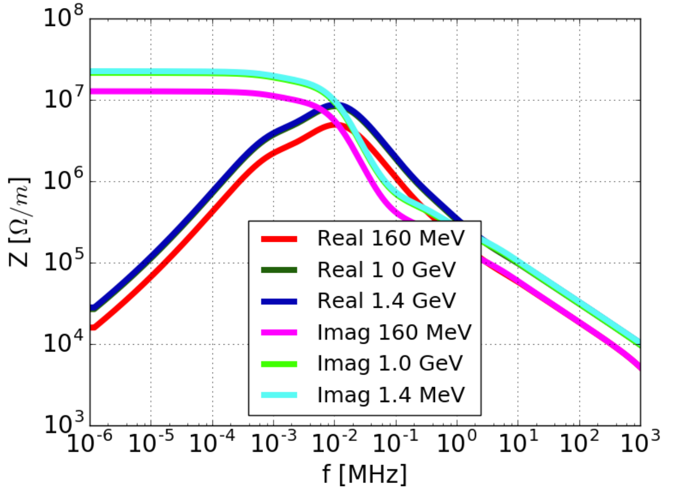
driving



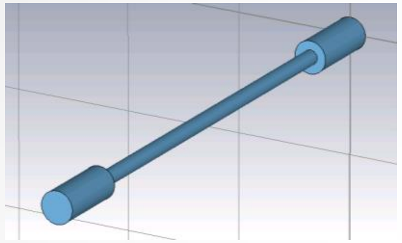


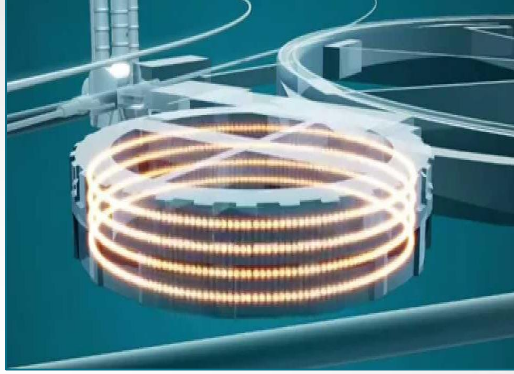
detuning





Step transition

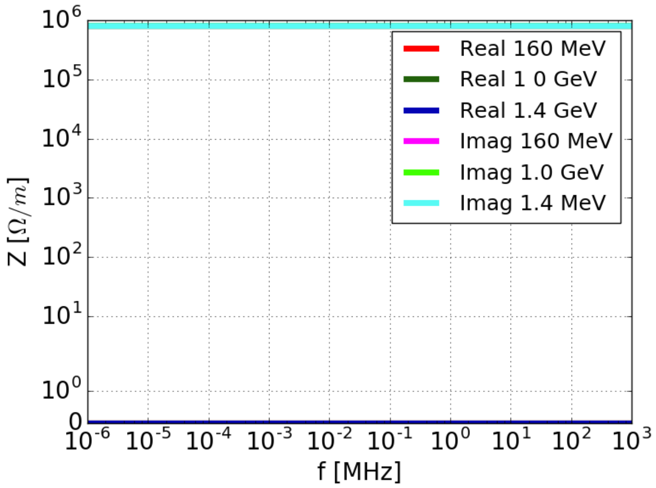


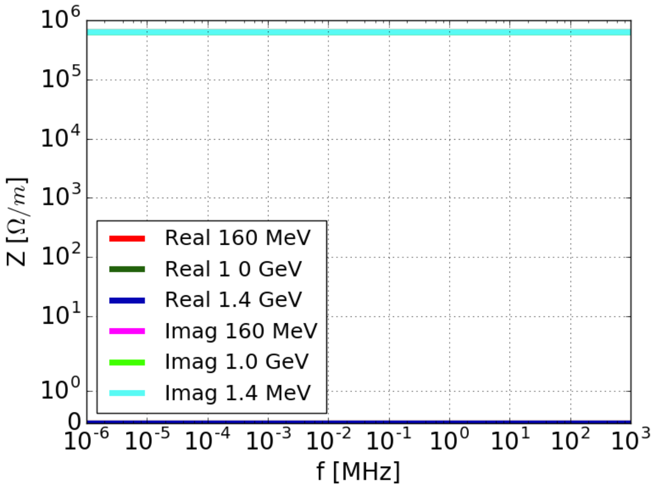


Horizontal transverse impedance

Vertical transverse impedance

driving

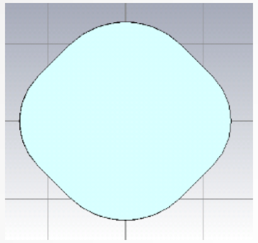


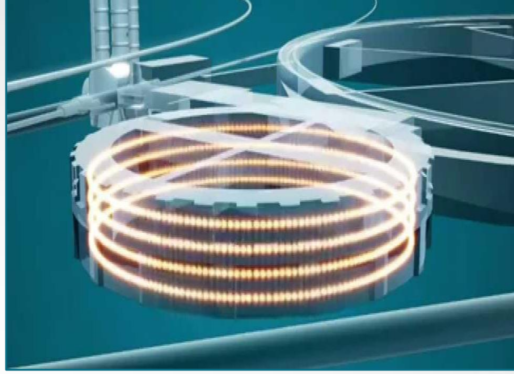


detuning

quadrupolar term is null

Indirect space charge



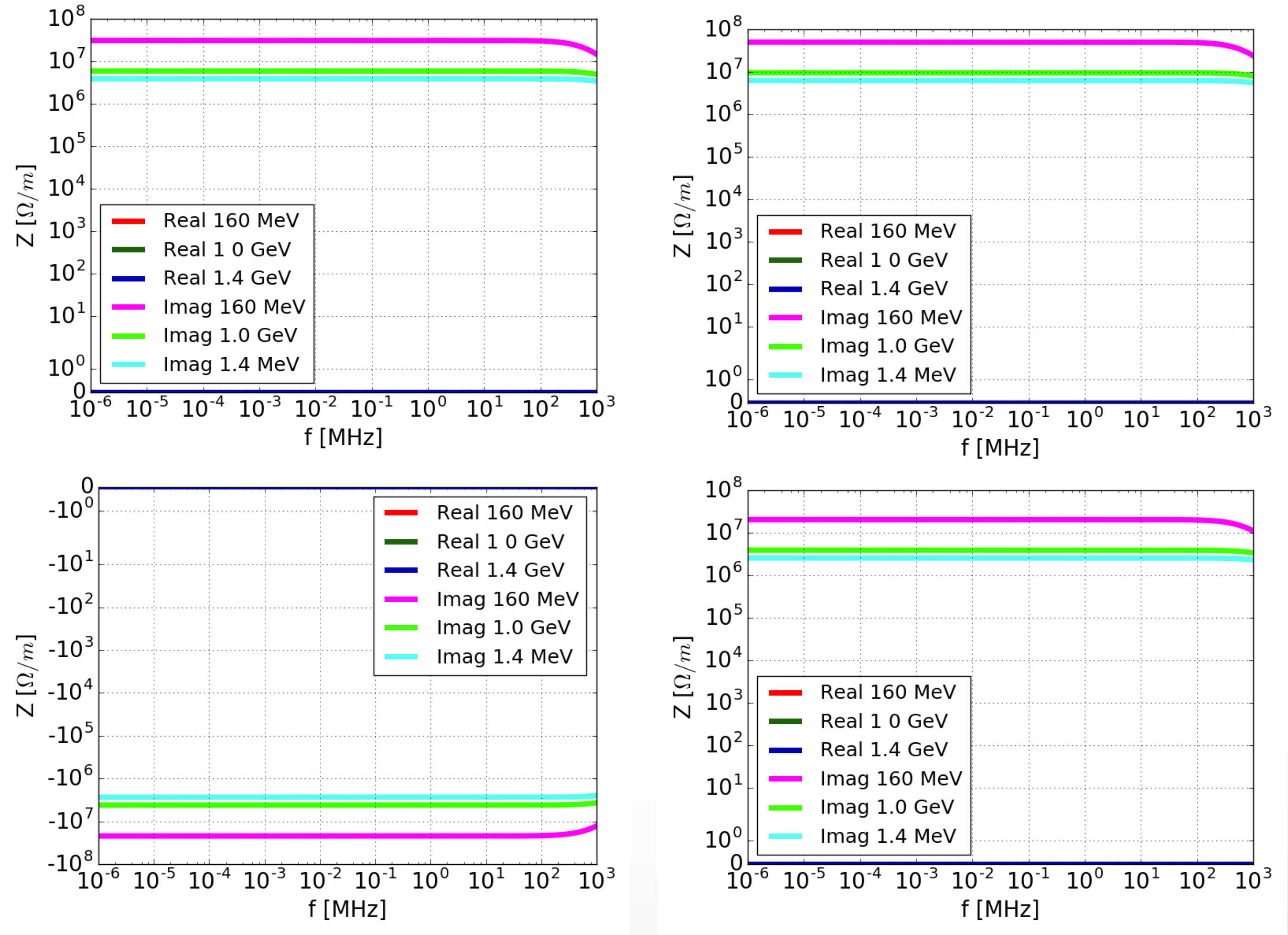


Horizontal transverse impedance

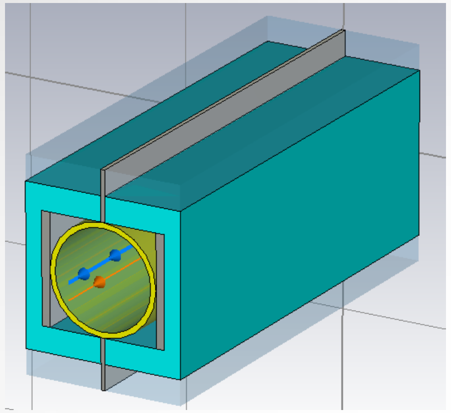
Vertical transverse impedance

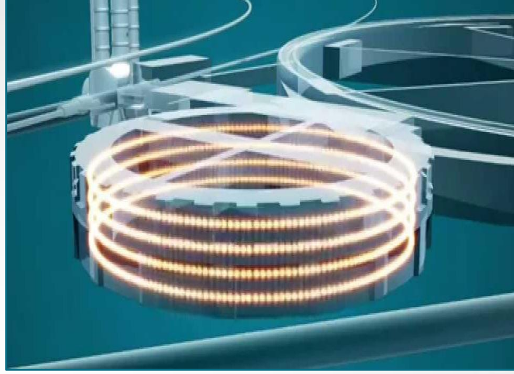
driving

detuning



Injection kicker



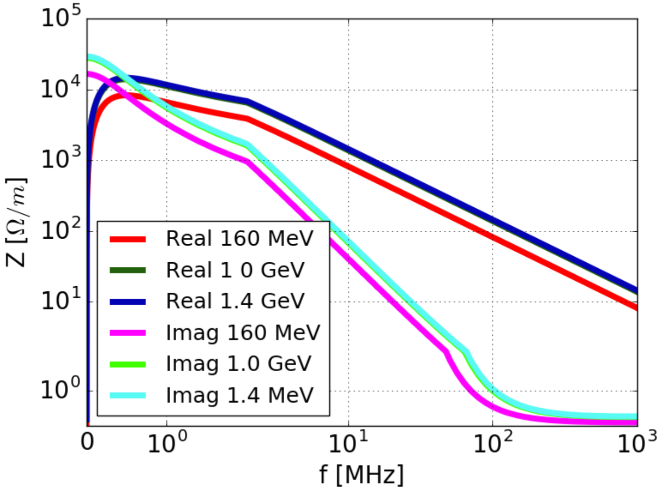


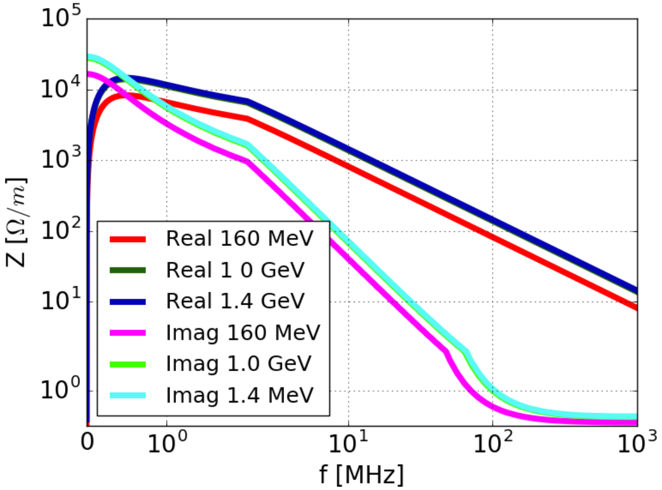
considered a titanium coating with R = 0.3 Ω

Horizontal transverse impedance

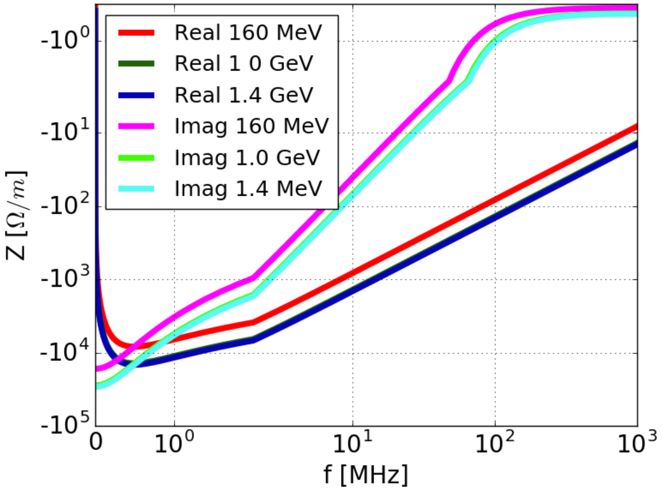
Vertical transverse impedance

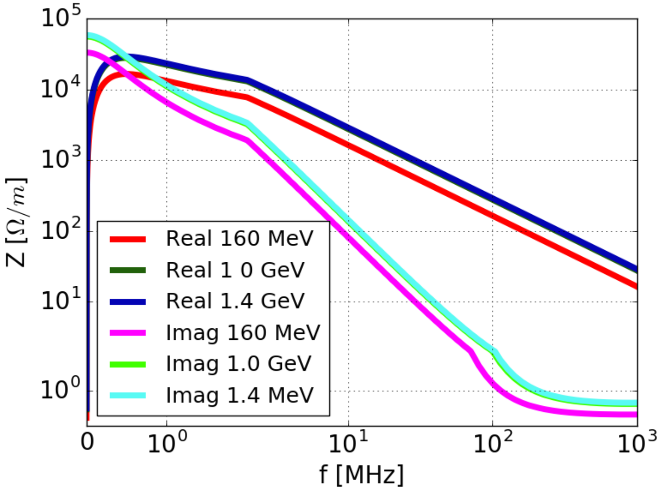
driving



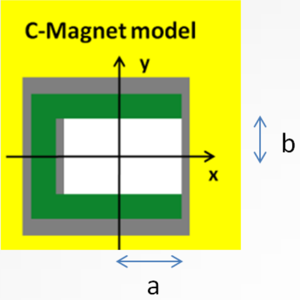


detuning





Extraction kicker



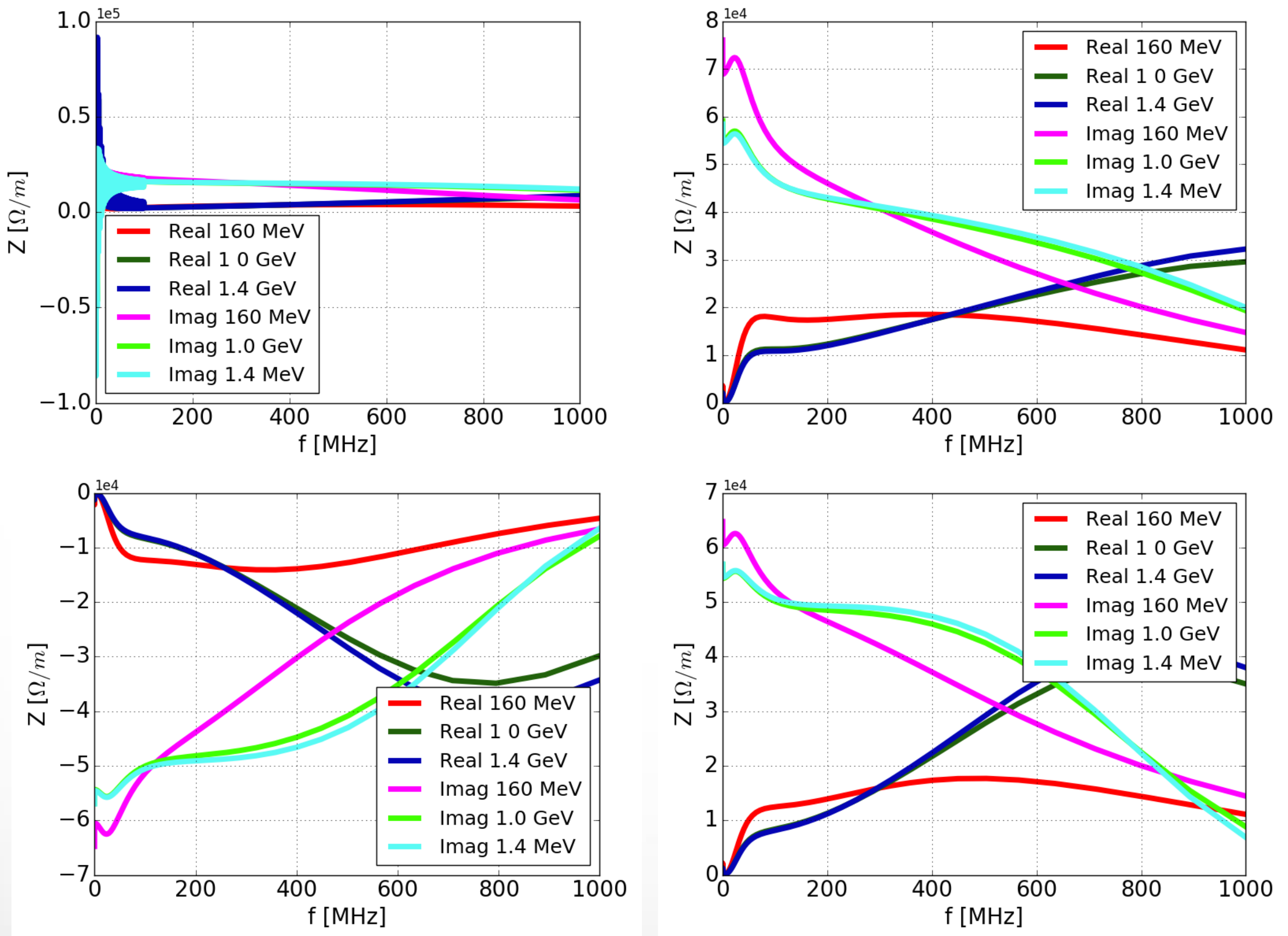
- ferrite kicker
- coupling with external circuits

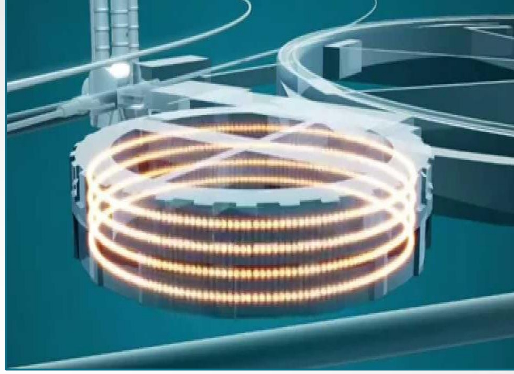
Horizontal transverse impedance

Vertical transverse impedance

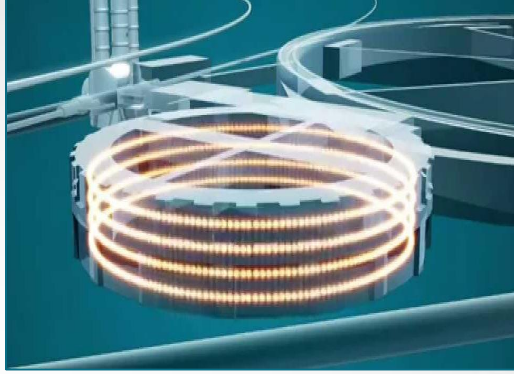
driving

detuning

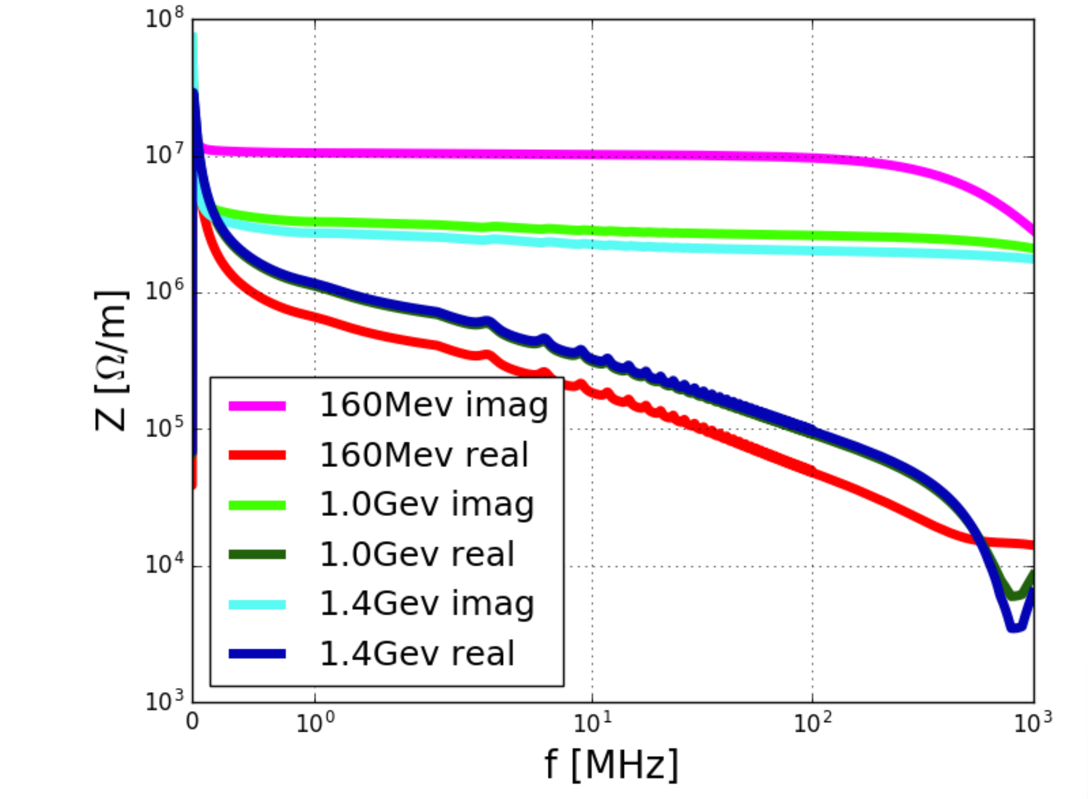




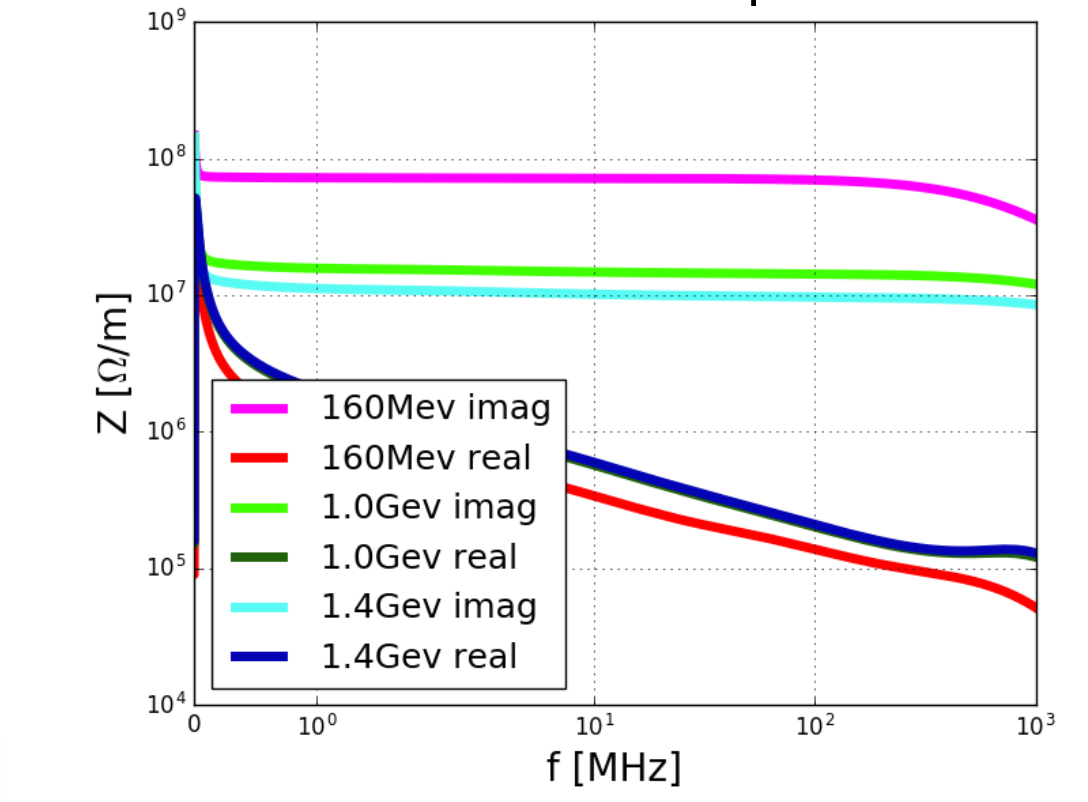
Total impedance



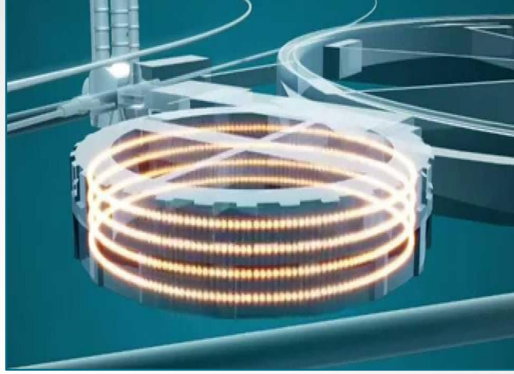
Horizontal transverse impedance

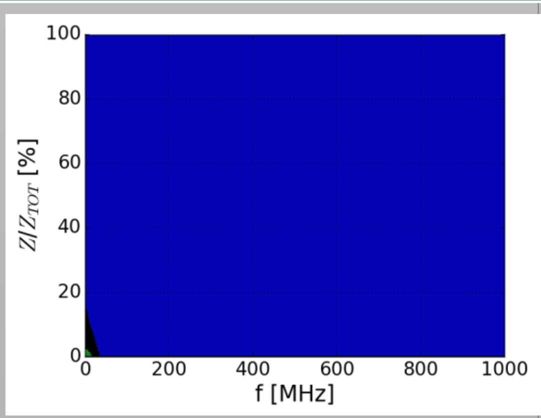
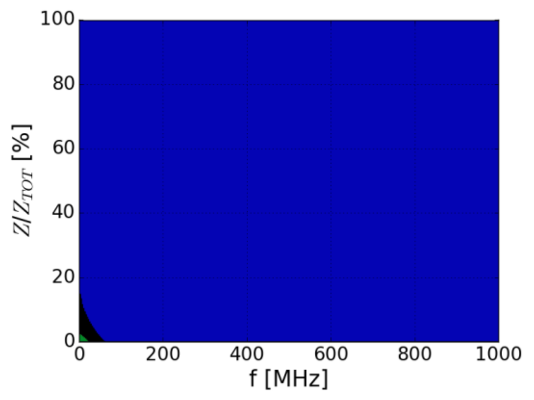
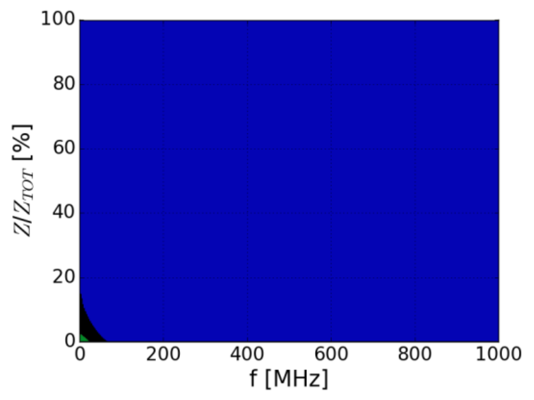
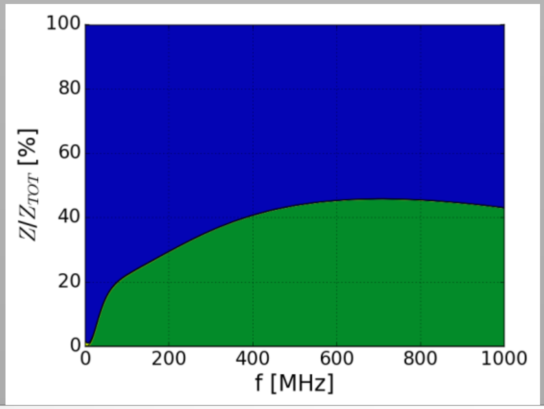
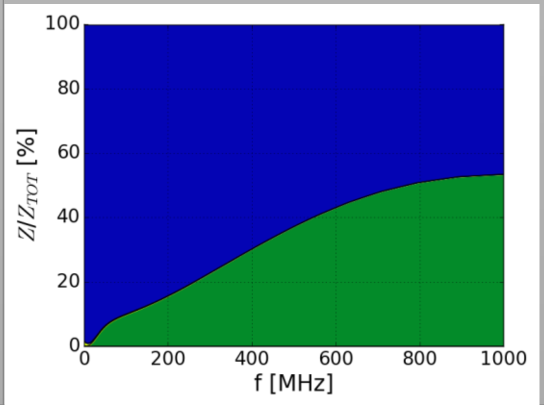
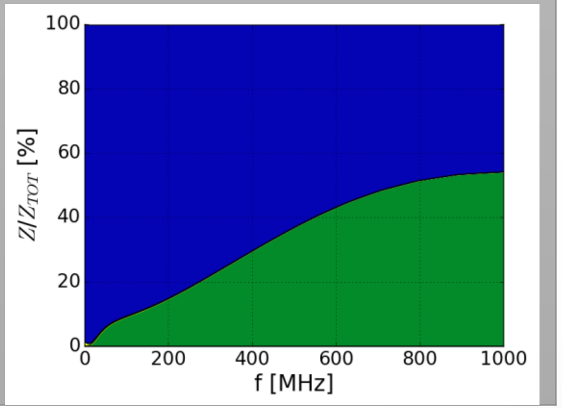


Vertical transverse impedance



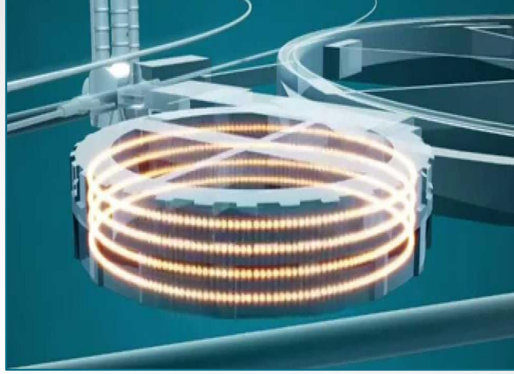
Analysis of the different contribution- real

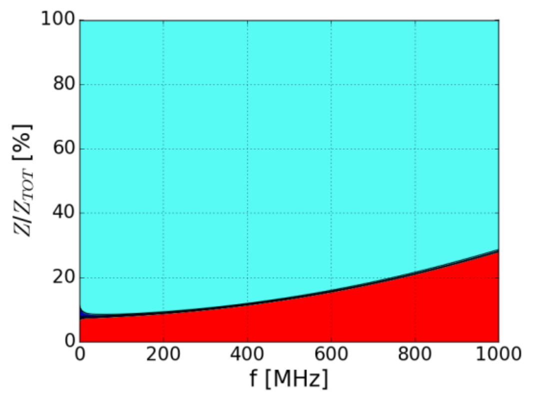
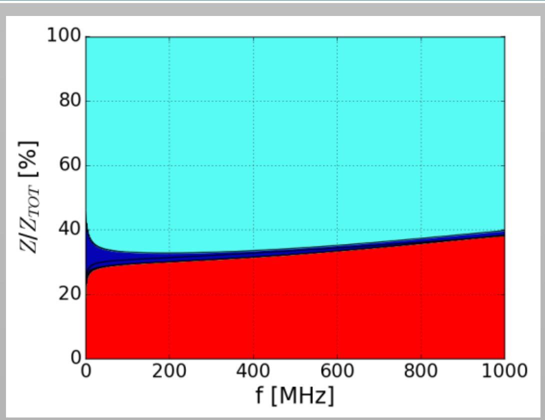
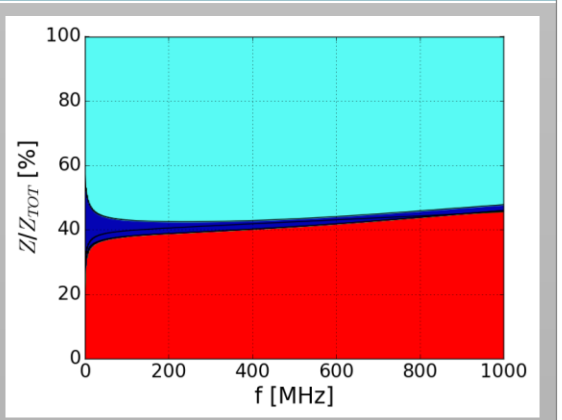
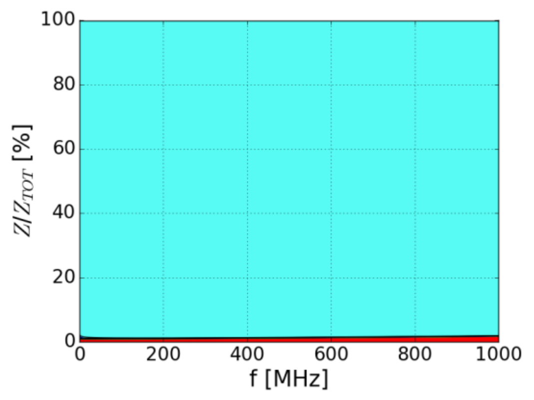
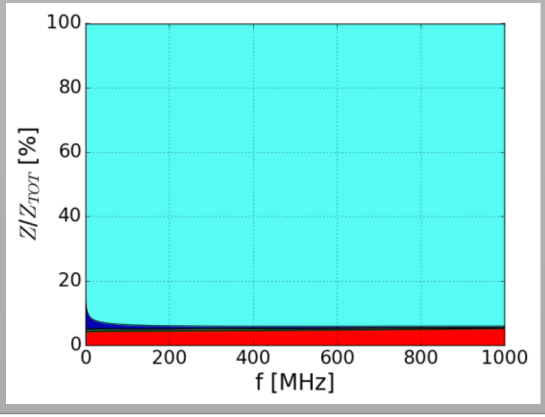
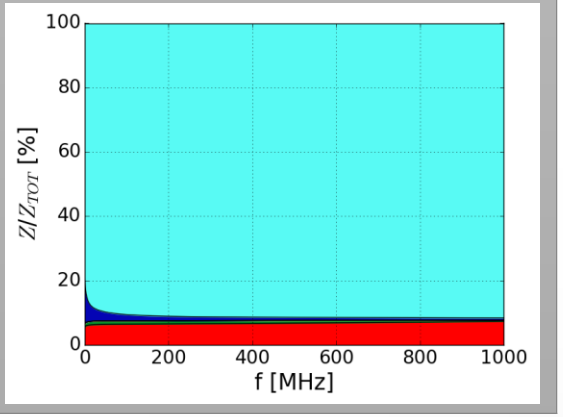


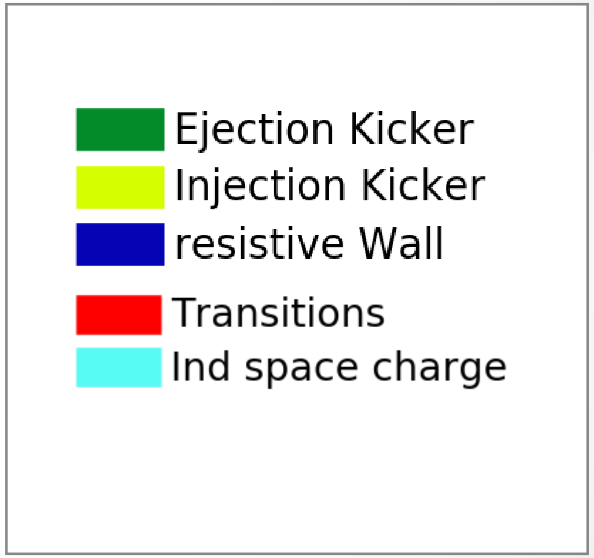
	160 MeV	1.0 GeV	1.4 GeV
x			
y			

Ejection Kicker
Injection Kicker
resistive Wall
Transitions
Ind space charge

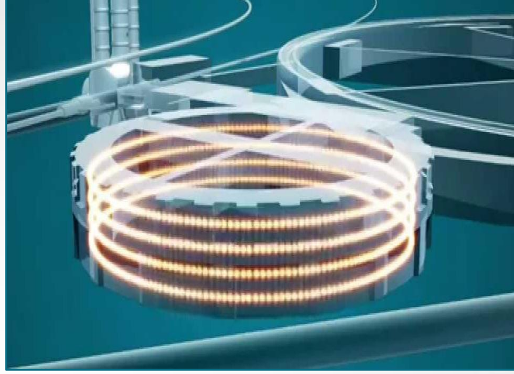
Analysis of the different contribution- imaginary



	160 MeV	1.0 GeV	1.4 GeV
x			
y			

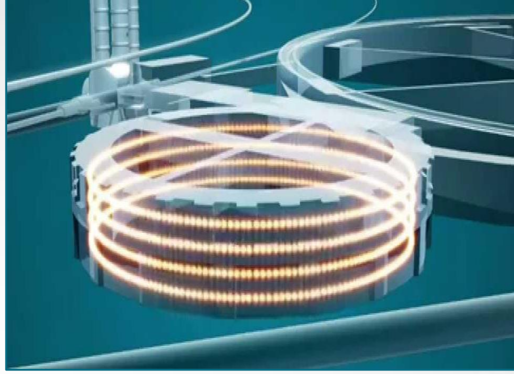


Effective Impedance in PSBooster

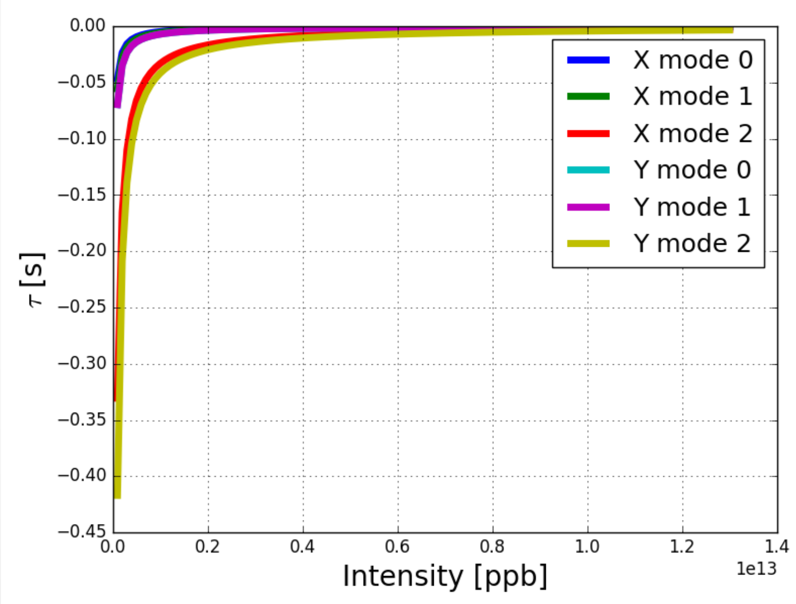


Z_{eff_x}[MΩ/m]	E_{kin}=160 MeV	E_{kin}=1.0 GeV	E_{kin}=1.4 GeV
X	2.484 + j 5.994	2.309 + j 1.685	1.416 + j 1.160
Y	4.006 + j 14.192	1.802 + j 3.274	1.114 + j 2.457
X dip	3.313 + j 11.093	3.200 + j 2.766	1.970 + j 1.834
Y dip	3.307 + j 10.609	1.476 + j 2.557	0.910 + j 1.960

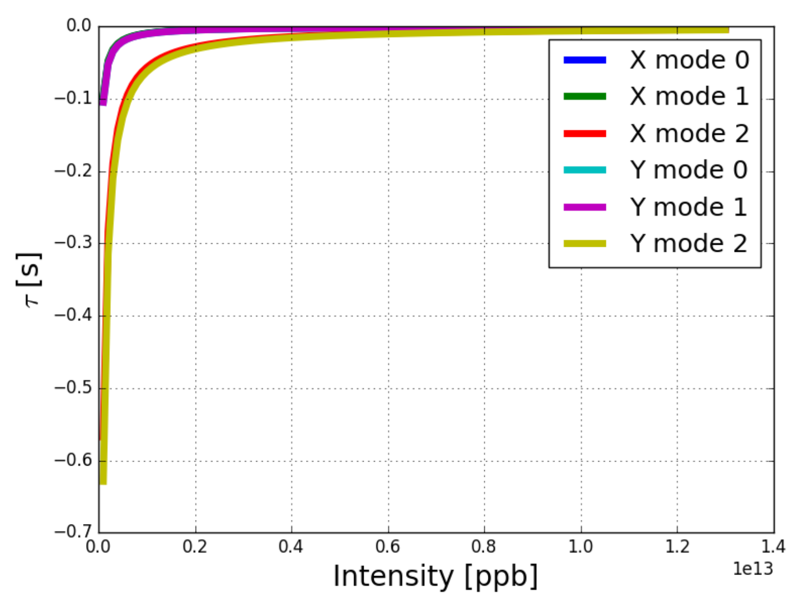
Growth rate



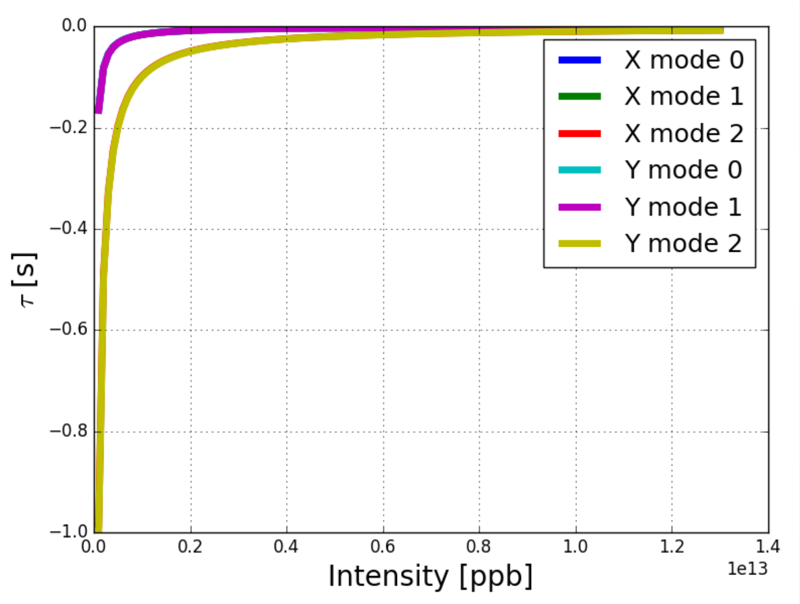
160 MeV



1.0 GeV



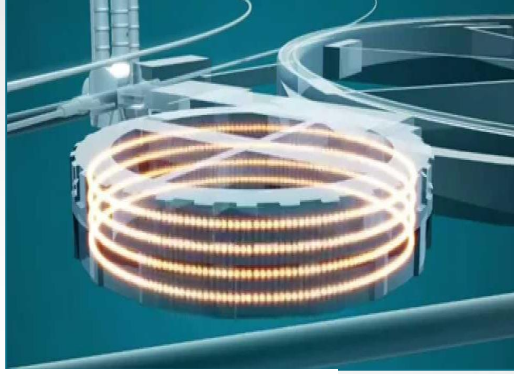
1.4 GeV

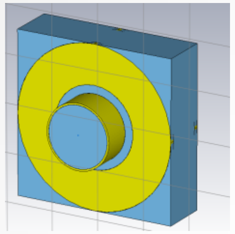


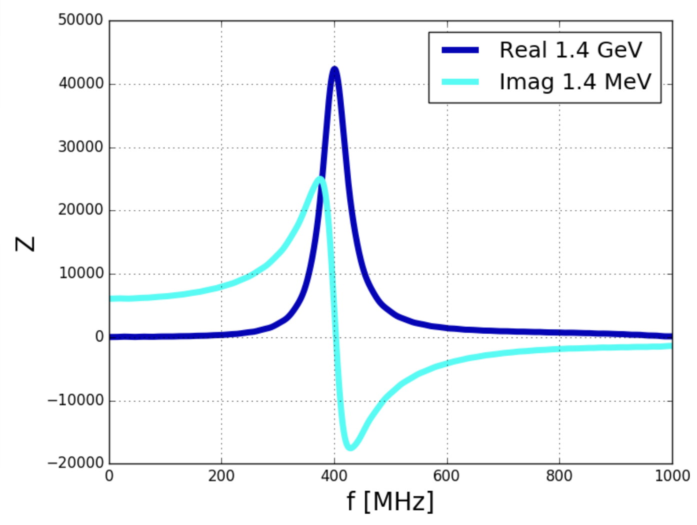
cromax= - 0.95
cromay= - 2.1

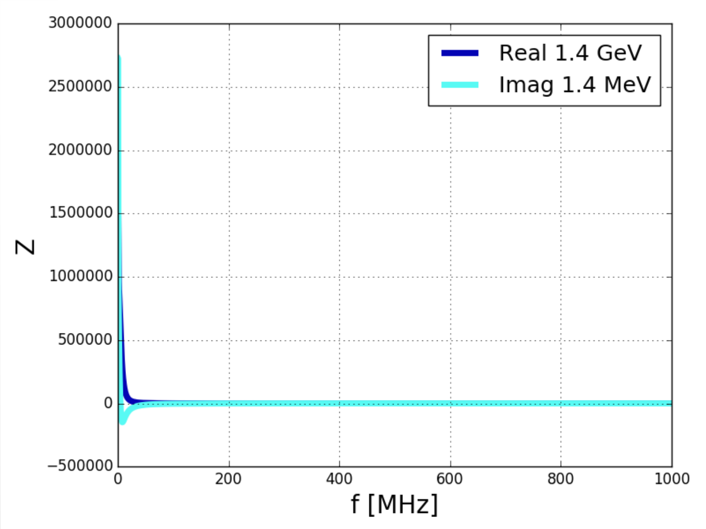
beam is stable

Update model with Finemet cavity (ring 4)



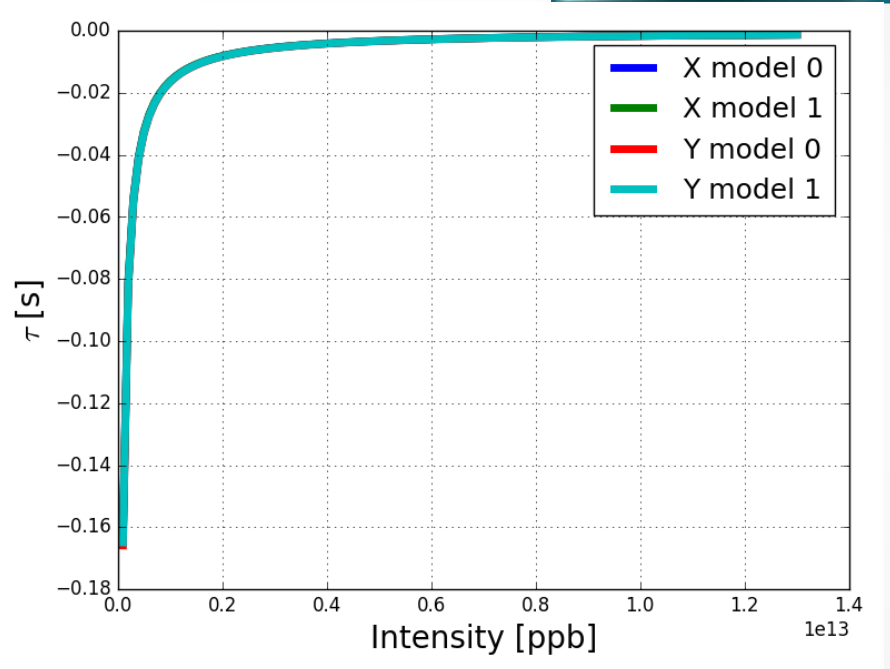






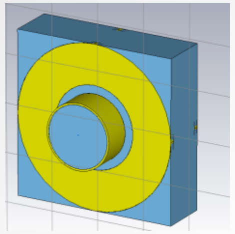
E = 1.4 GeV

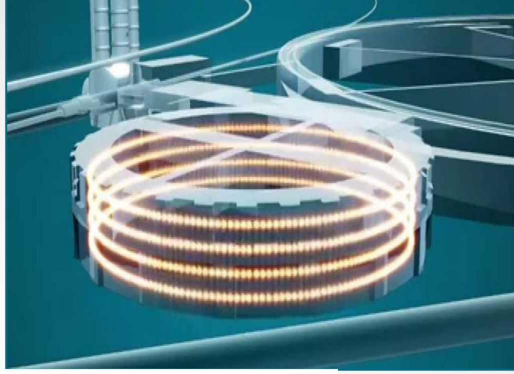
cromax= - 0.95
cromay= - 2.1

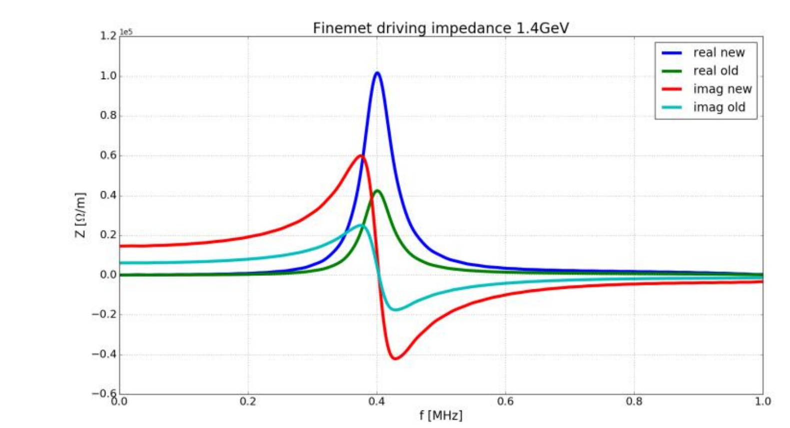


Z_{eff_x}[M Ω/m]	model 0	model 1
x	1.416 + j 1.160	1.417 + j 1.160
y	1.114 + j 2.457	1.114 + j 2.462

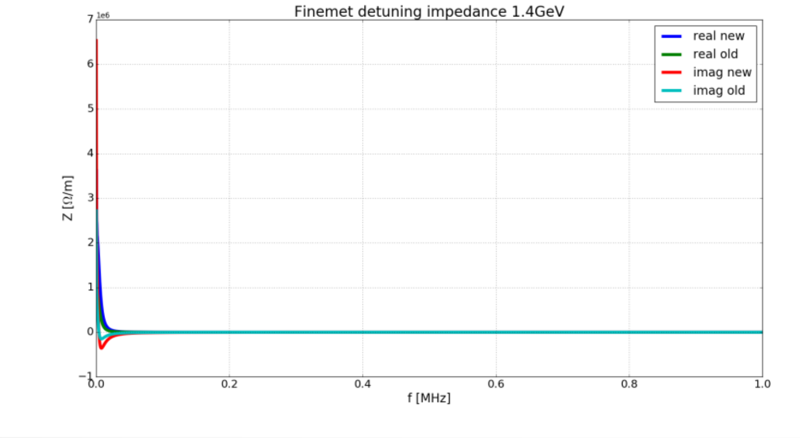
Update model with Finemet cavity (future)





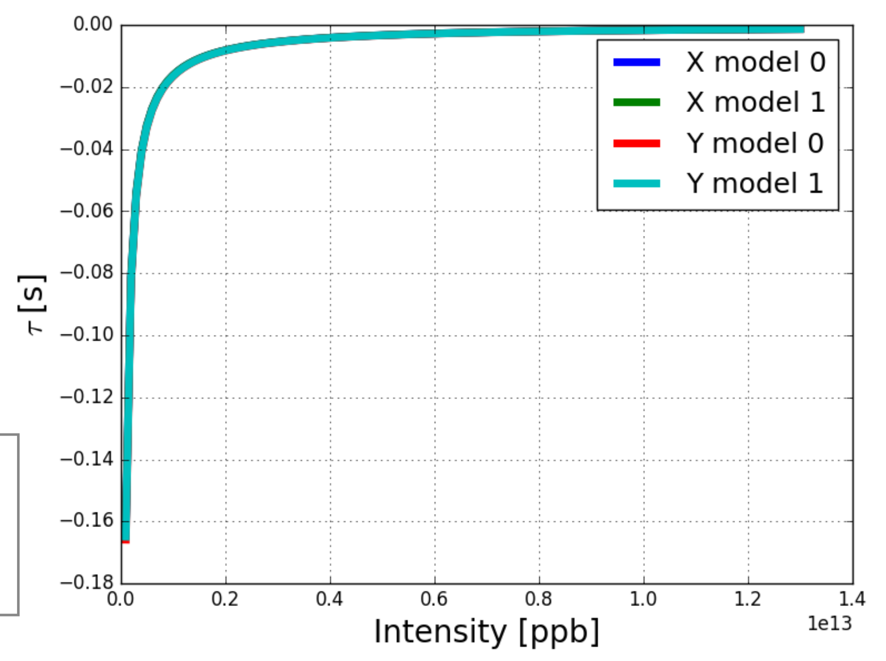


all the RF cavities replaced with finemet



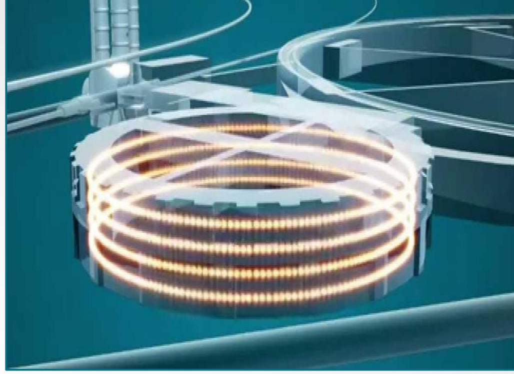
E = 1.4 GeV

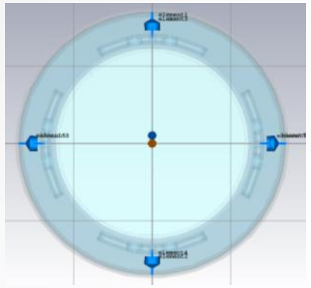
cromax= - 0.95
cromay= - 2.1

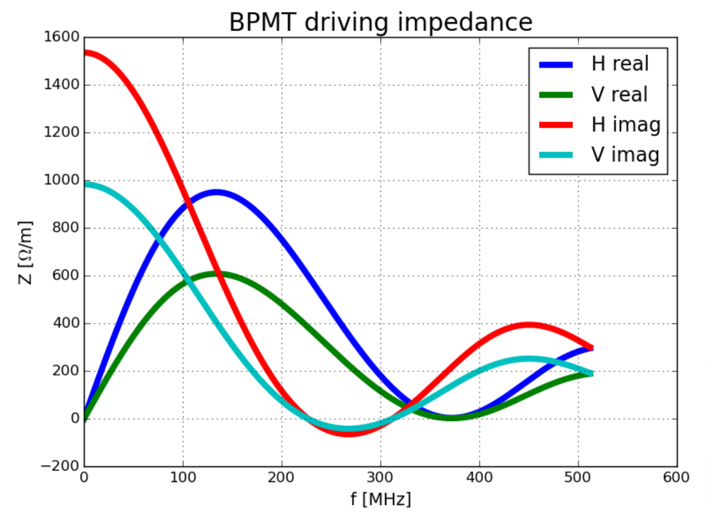


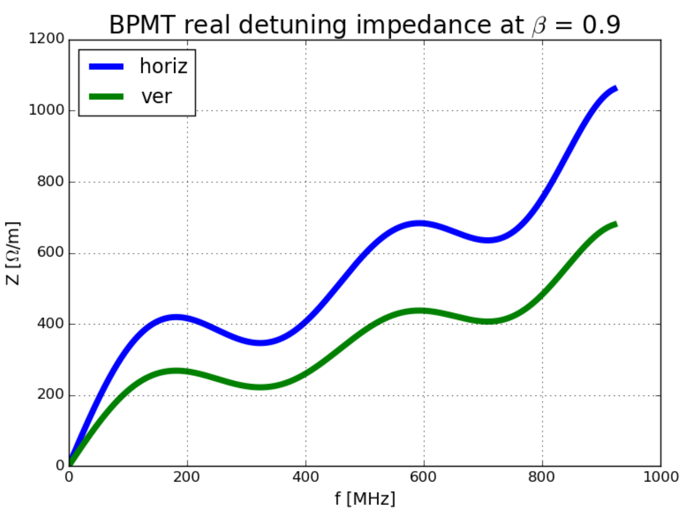
Z_{eff_x}[MΩ/m]	model 0	model 1
x	1.416 + j 1.160	1.419 + j 1.161
y	1.114 + j 2.457	1.115 + j 2.471

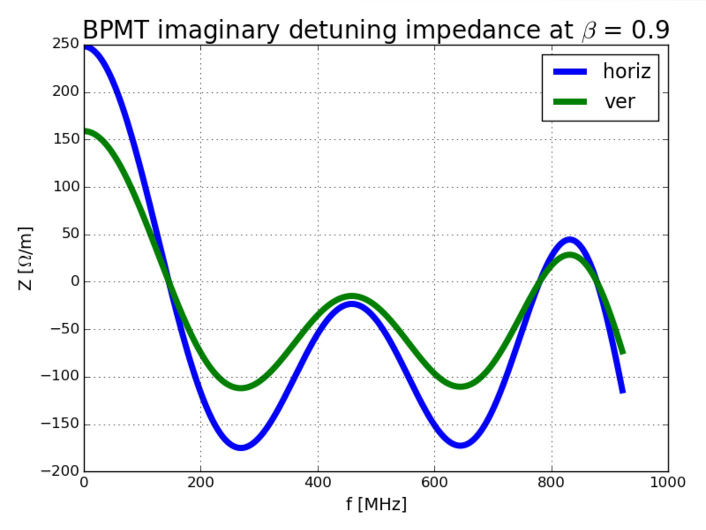
Update model with Tune Pickup



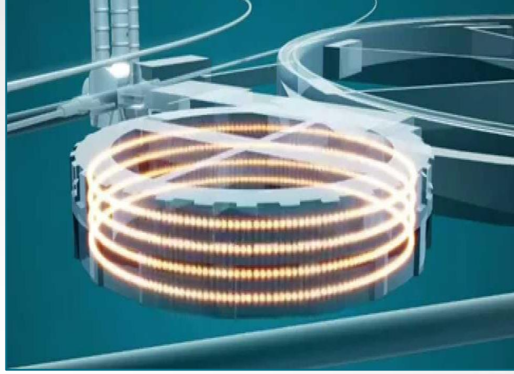


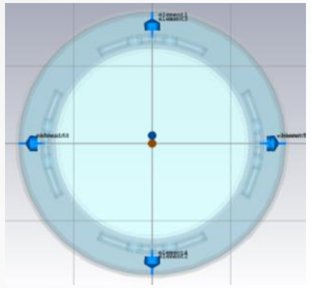




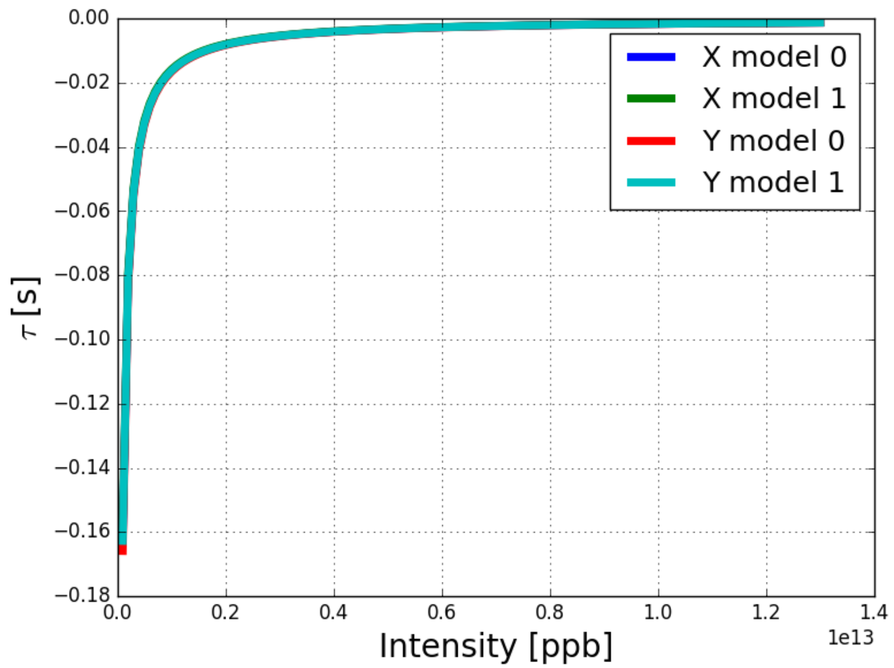


Update model with Tune Pickup





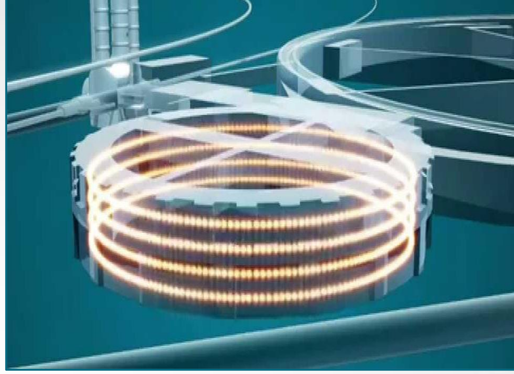
E = 1.4 GeV

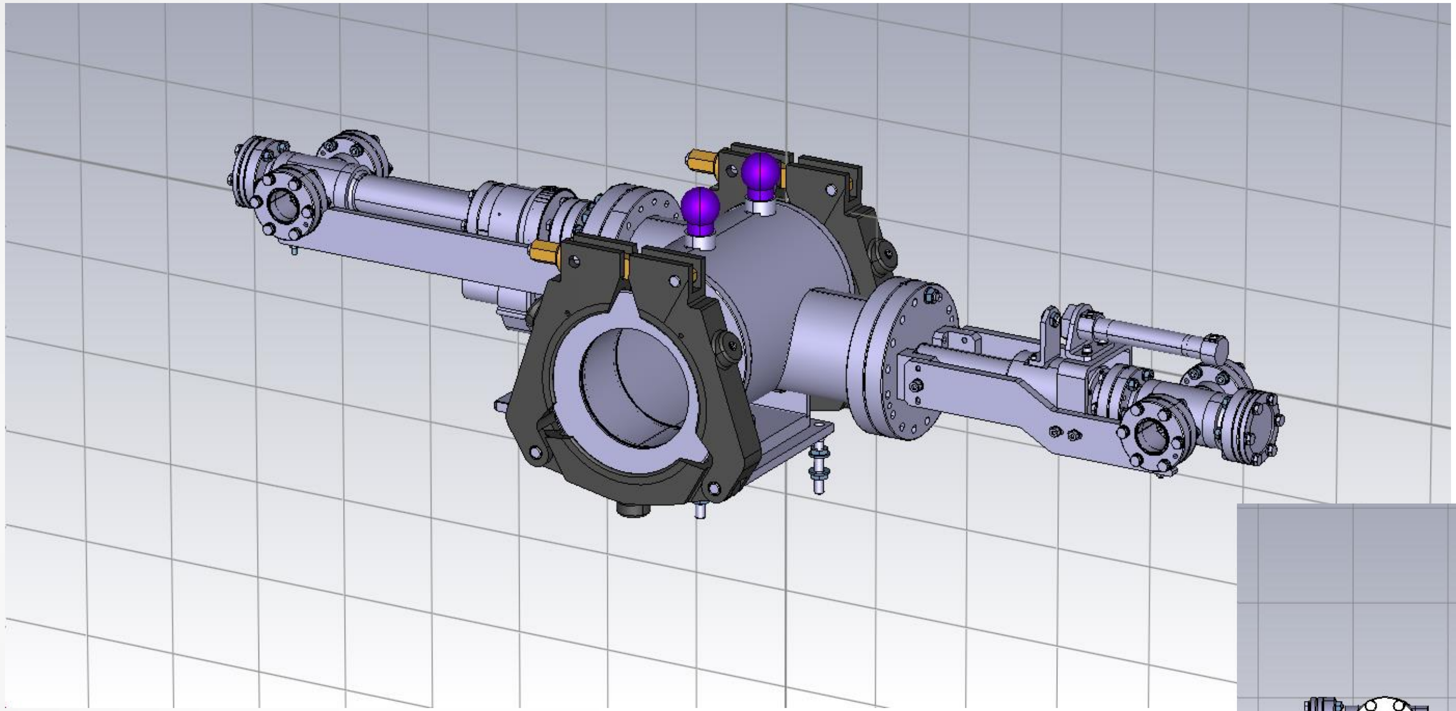


cromax= - 0.95
cromay= - 2.1

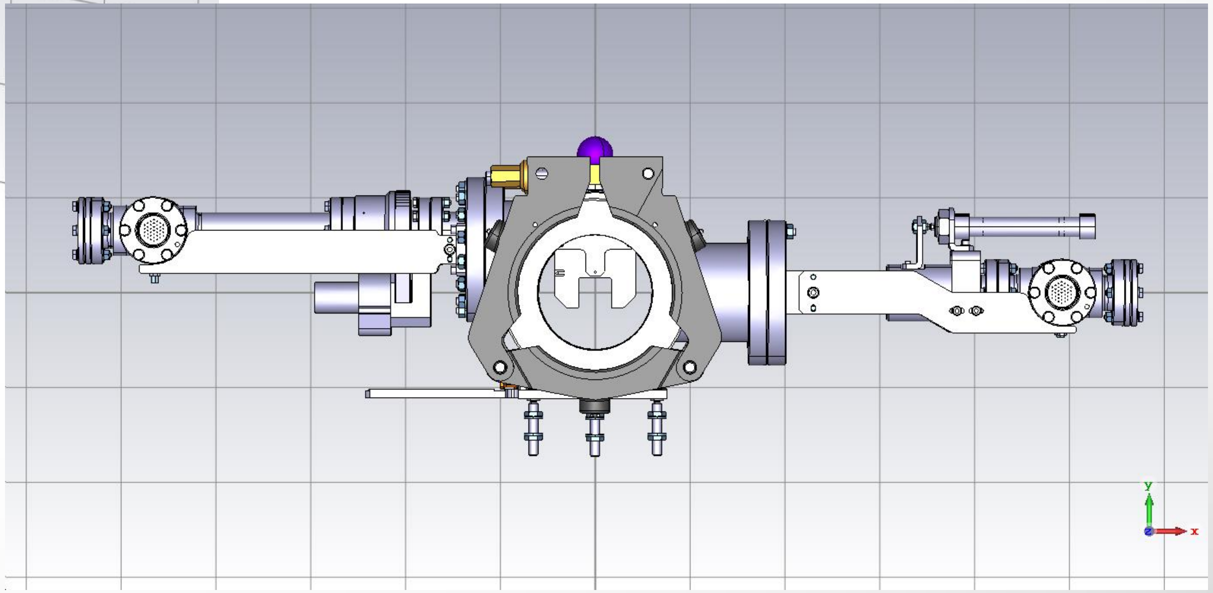
Z_{eff_x} [M Ω/m]	model 0	model 1
x	1.416 + j 1.160	1.417 + j 1.161
y	1.114 + j 2.457	1.114 + j 2.457

Studying on PSB Wire Grid Detector

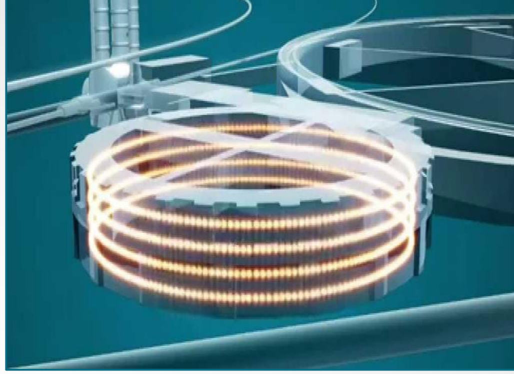


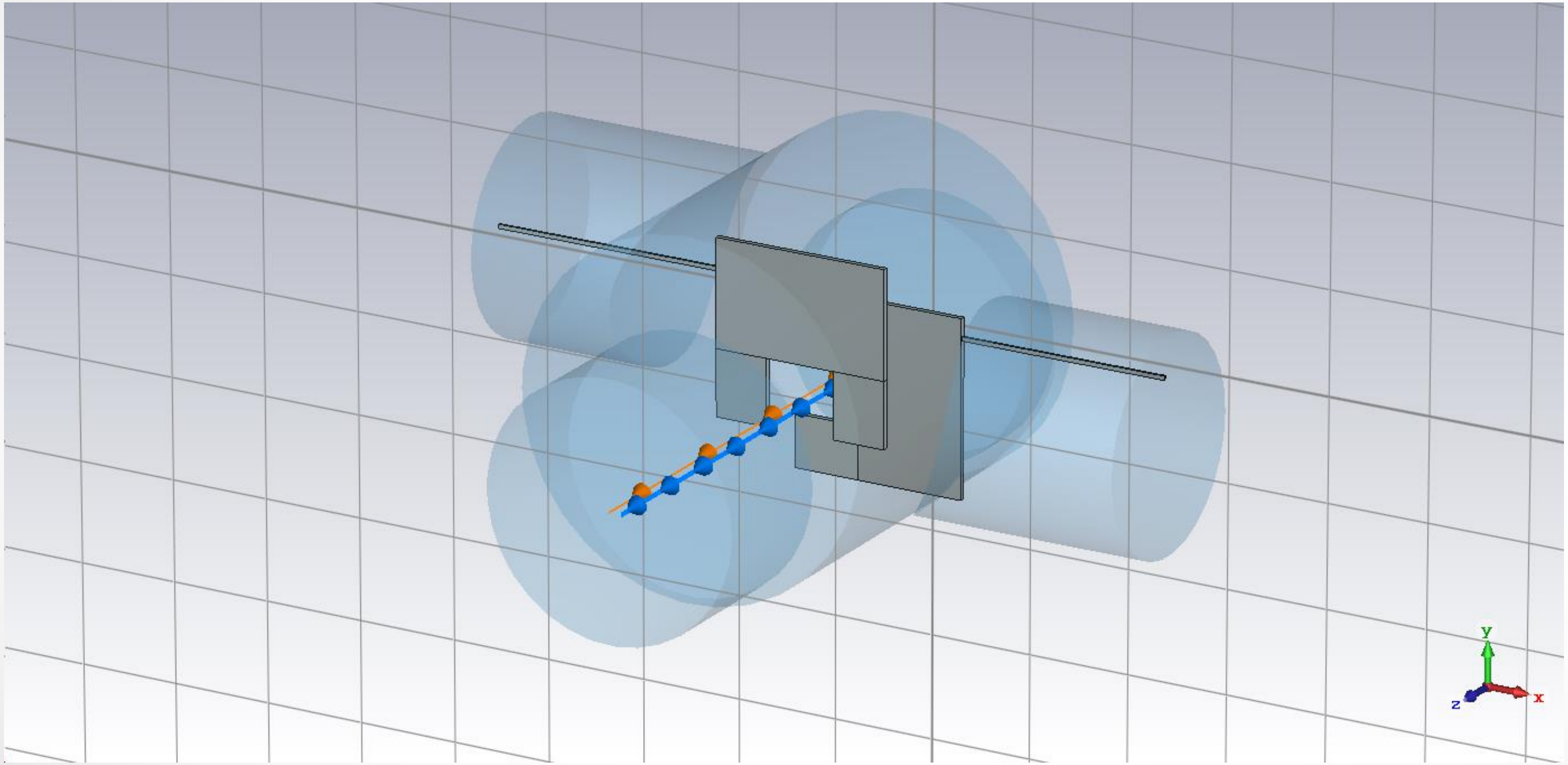


thanks L. Teofili for the Catia model

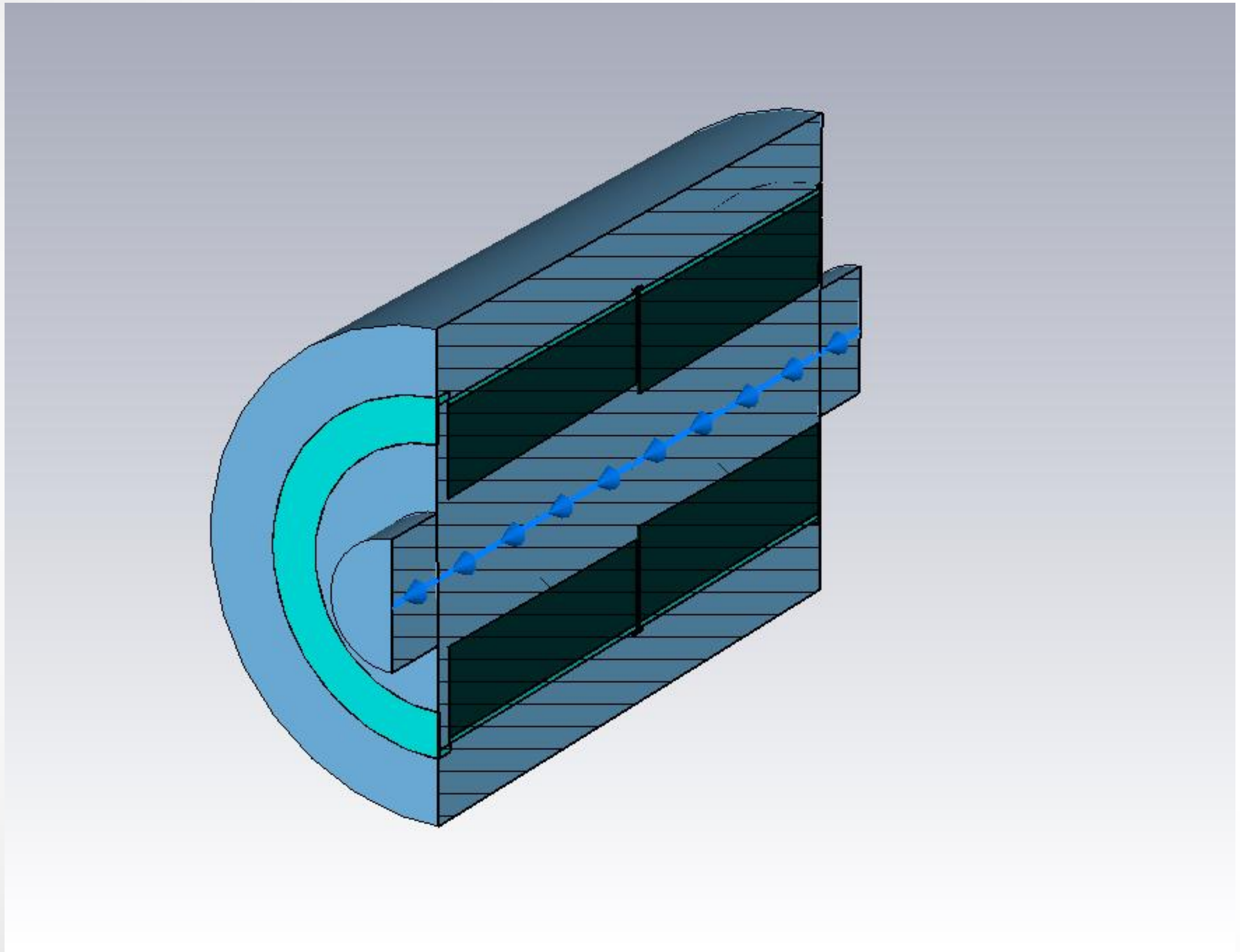


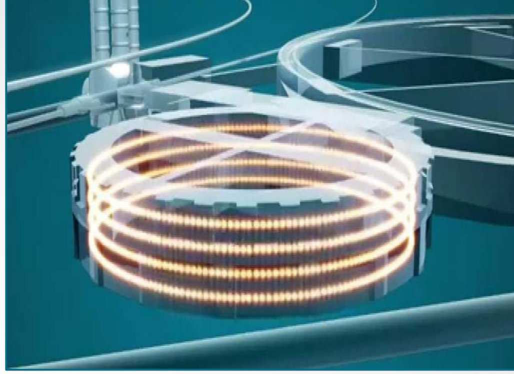
Studying on PSB Wire Grid Detector



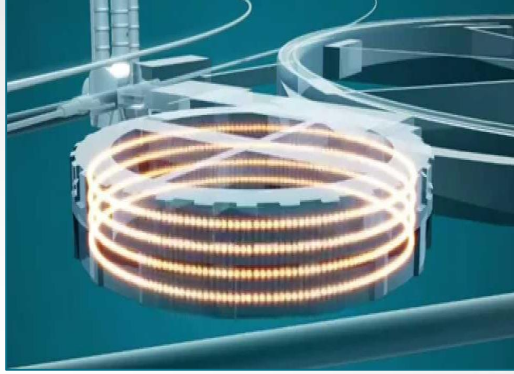


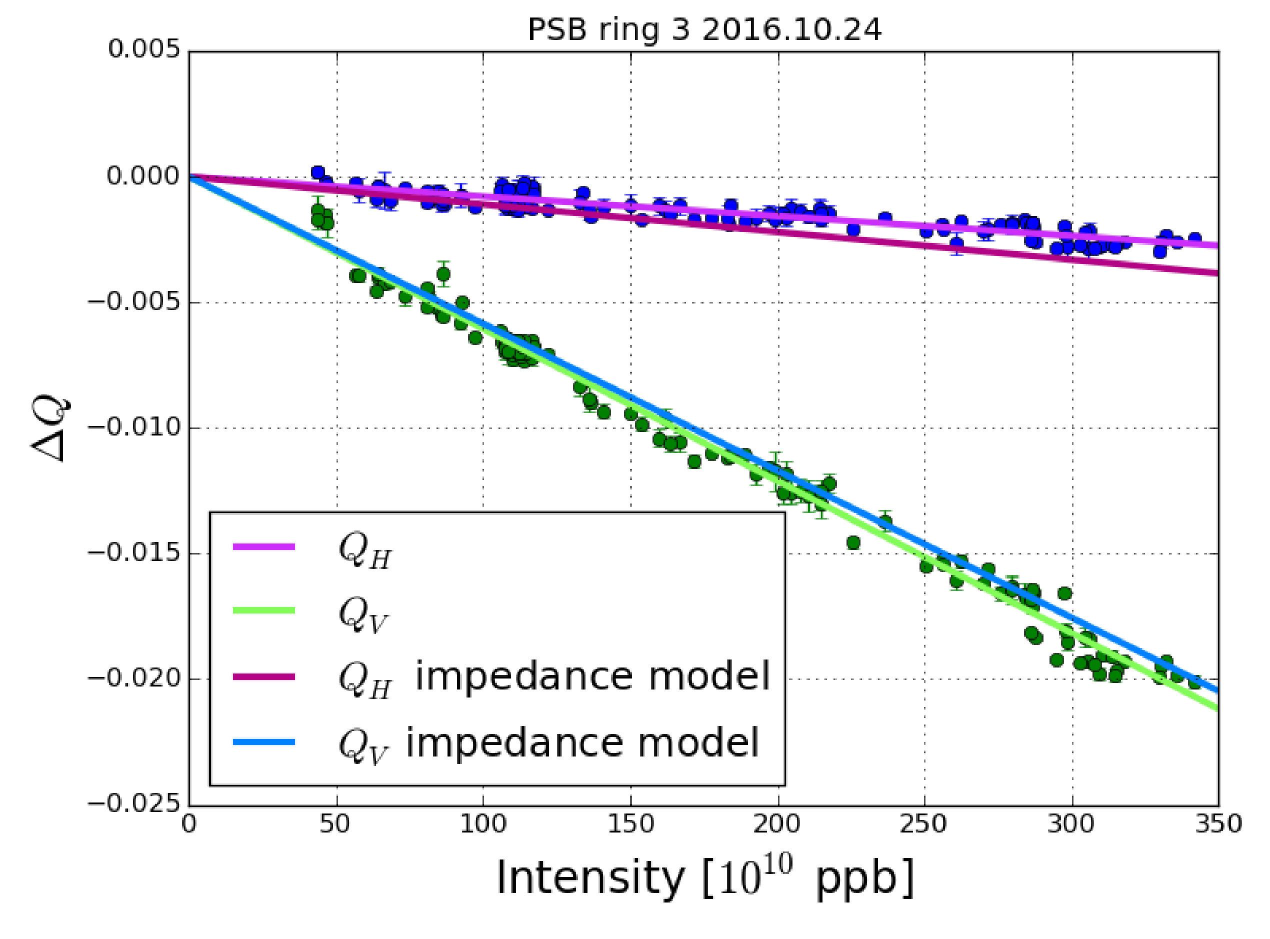
Studying on PSB Scraper (with L. Teofili)





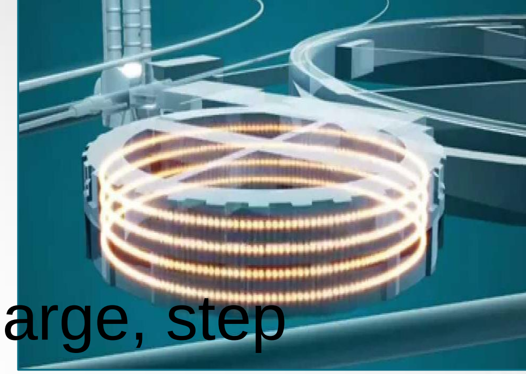
Comparison with experimental data





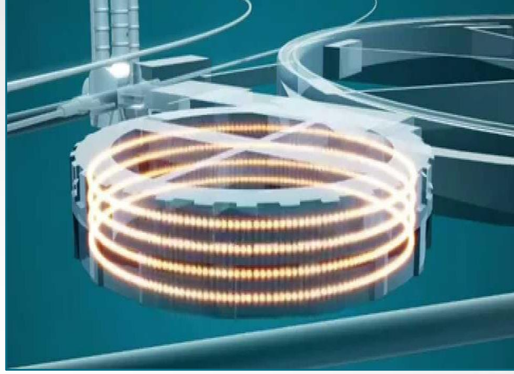
good agreement

Conclusions



- The PSB model take care about resistive wall, indirect space charge, step transition, injection and extraction kickers.
  - the most important contribution to the total impedance is given by resistive wall and extraction kicker (for real impedance), indirect space charge and step transition(for imaginary impedance)
- The impedance model with Finemet cavities, tune pickup have been developed.
- The update of the model with the new scraper and wire grid detector are under studies.
- From the MDs we found a good agreement between theoretical model and experimental results.

Conclusions (future talk)



- It would be interesting for me to do a talk about the MD stability studies that I am doing on PSBooster

Thank you for your attention