

# Dummy septum impedance studies

Serena Persichelli

Dummy septum meeting

02-05-2013

Acknowledgements

Jan Borburg, Michael Hourican,  
Simone Gilardoni, Massimo Giovannozzi,  
Elias Metral, Mauro Migliorati, Chiara Pasquino, Benoit Salvant

# Aim of the study

- ❑ Establish the impact of the dummy septum on the total impedance of the PS and the effects on the stability of the beam
- ❑ Verify the presence of trapped modes that can be excited by the beam in the septum, evaluating frequencies and configurations with frequency domain simulations (CST MWS) and time domain simulations (CST PS)
- ❑ Give an estimation of the coupled bunch instability rise time for the low frequency modes
- ❑ Consider the possibility of using ferrites in order to damp impedance sources (trapped modes) and reduce coupled bunch instability growth rate
- ❑ Consider the insertion of sliding contact between the screen and the displacement system

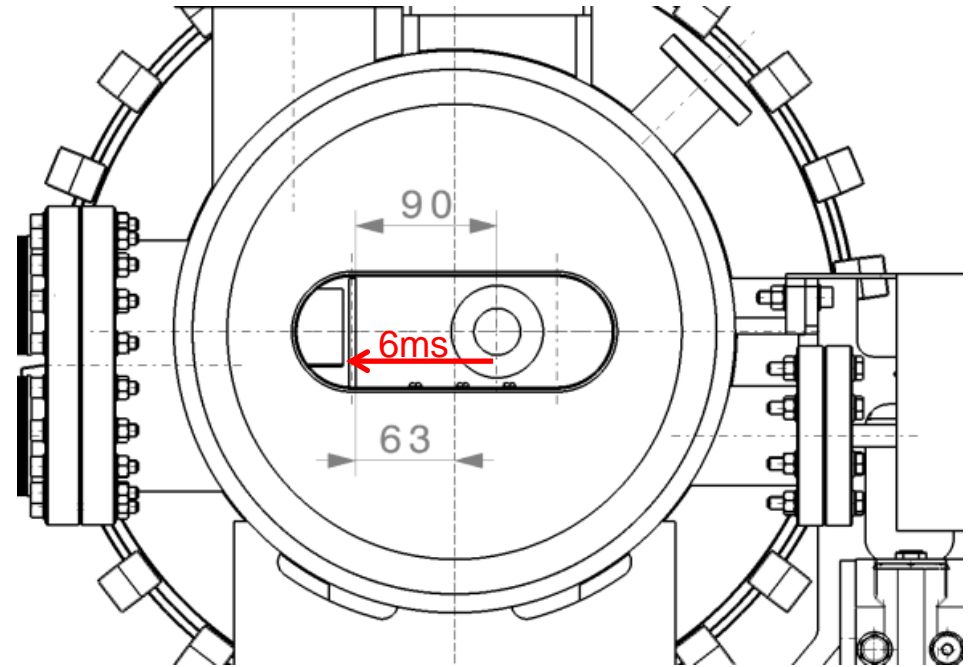
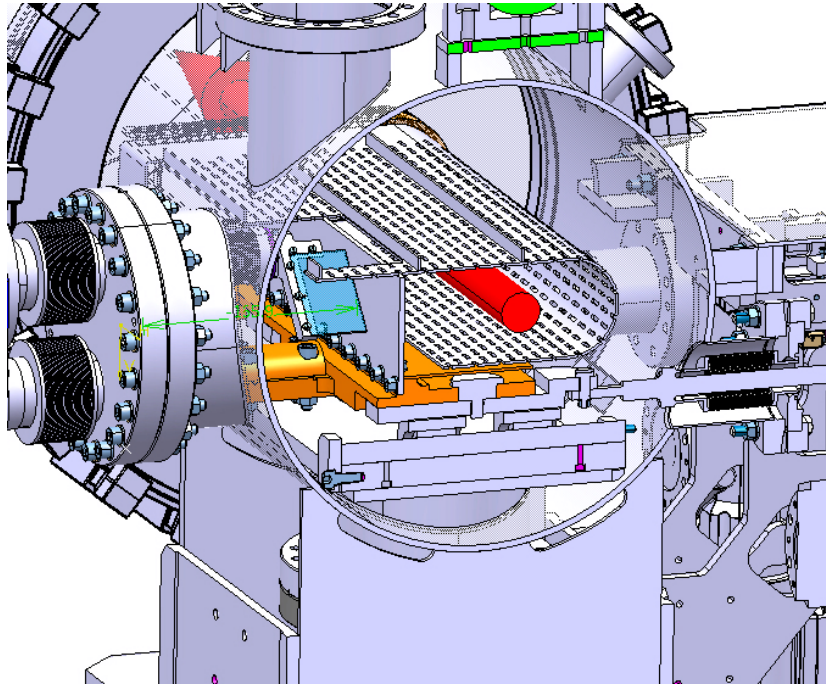
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- ❑ Dummy Septum proposal
  - *Beam/blade position before extraction*
  - *Old design vs. new design*
  - *Model for CST simulations*
  
- ❑ Longitudinal impedance
  - *Beam in orbiting position*
  - *Beam before extraction*
  
- ❑ Eigenmodes
  - *CST MWS analysis*
  
- ❑ Contribution to PS impedance budget
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- ❑ Conclusions and recommendations

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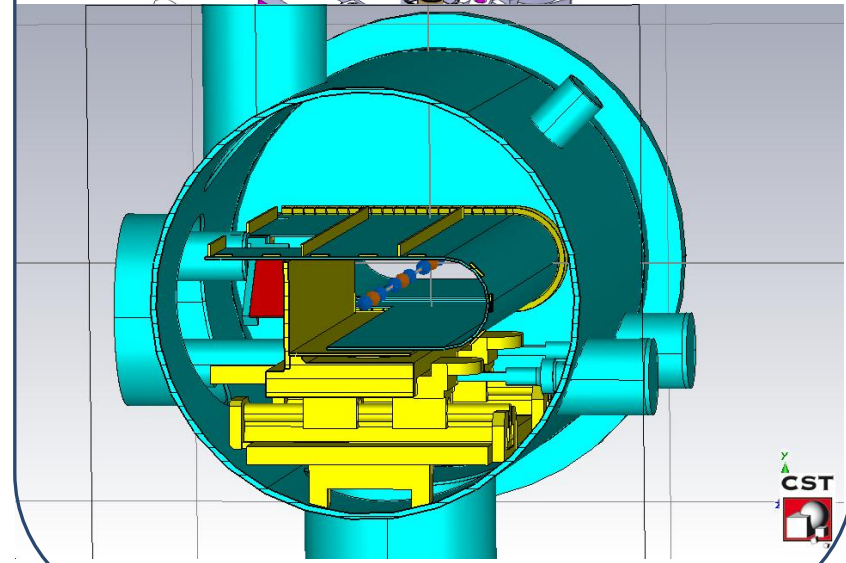
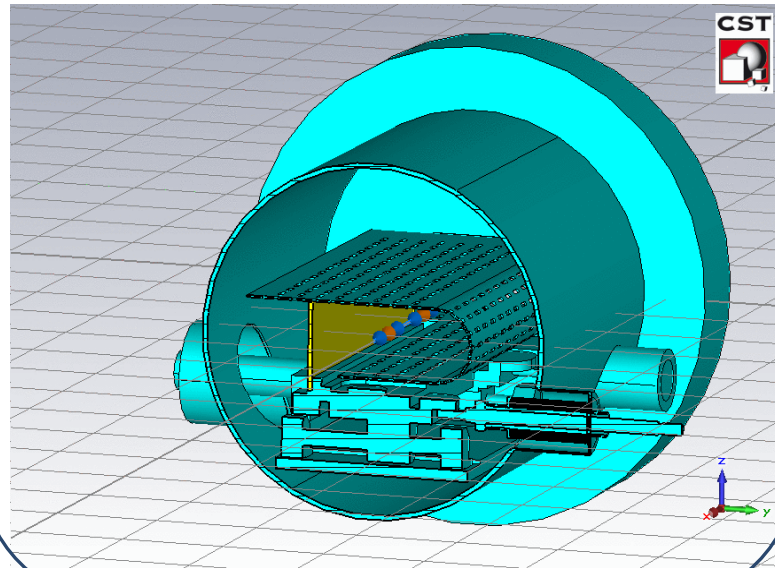
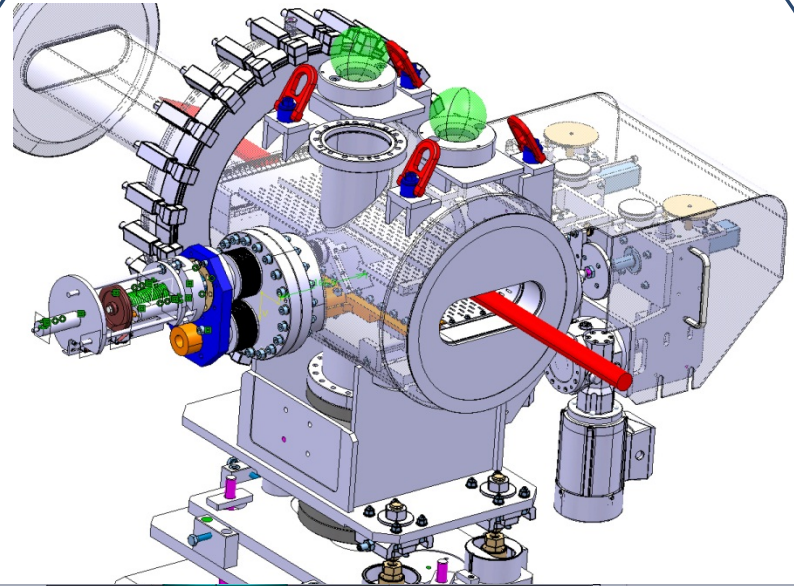
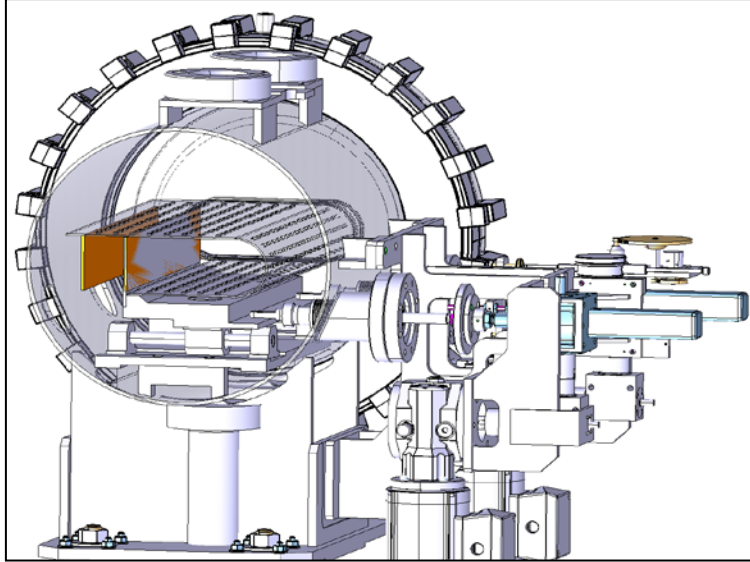
# Dummy septum during PS MT extraction



Courtesy of Mike Hourican

- **The beam circulates in a position displaced of 27 mm from the geometrical centre of the septum;**
- During extraction the beam takes **6 ms** to move from the orbiting position to few mms from the blade;
- The beam is going to stay very close to the blade only for few turns, then it is extracted;
- **The nominal position of the blade is between 80 and 100 mm from the orbiting position;**
- For simulation has been considered only the position of the blade shown in figure.

# Old design vs. final design

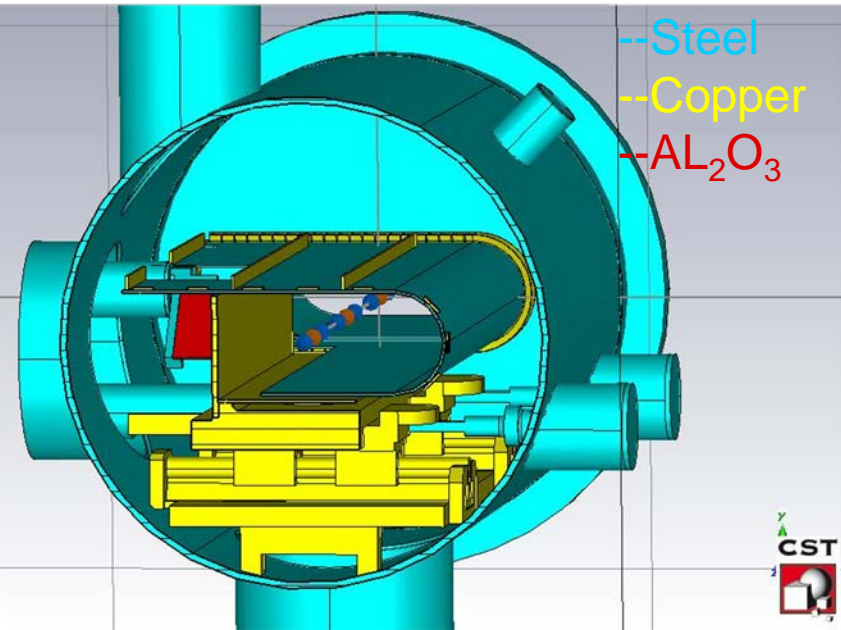
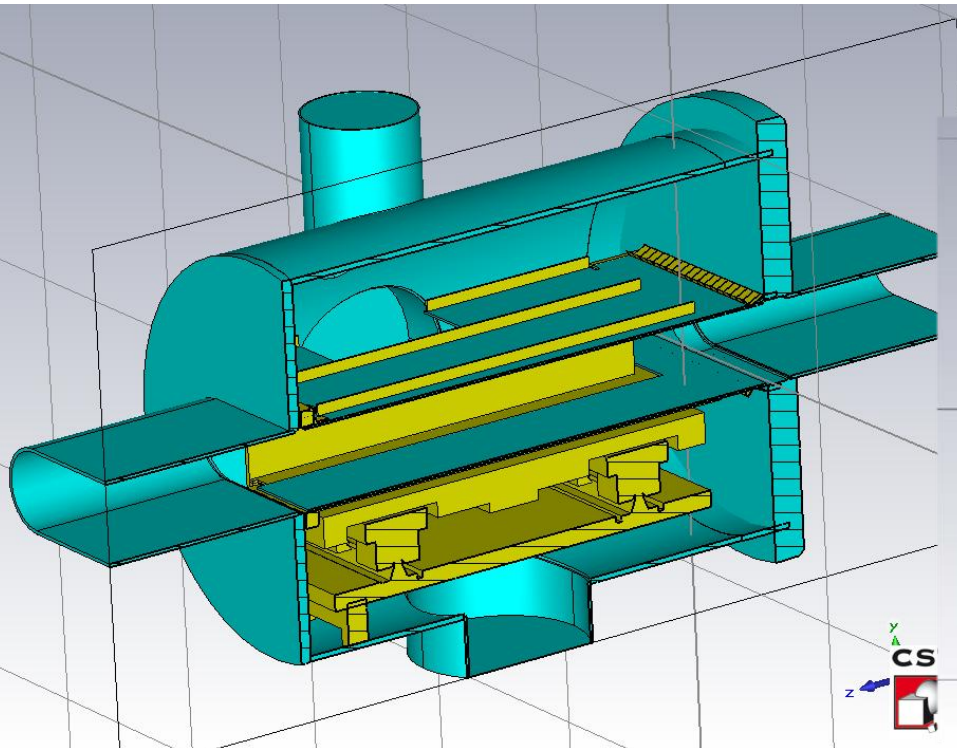




# Design for impedance simulations

From the mechanical drawing imported  
from CATIA

- The RF screen can not be processed correctly by ACIS because of the holes: a screen without holes has been considered for simulations;
- Elliptical beam pipes have to be extended to avoid negative impedance effects;
- RF fingers to allow continuity between the screen and the tank has been considered in simulations;
- Bellows for the displacement of the blade and cooling, and the support of the Alumina screen can be not considered in simulations since the impact on the impedance is negligible.



# Agenda

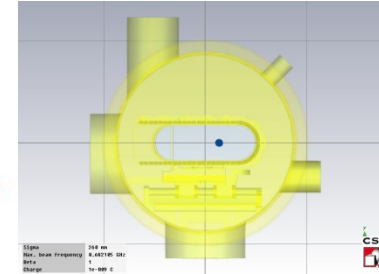
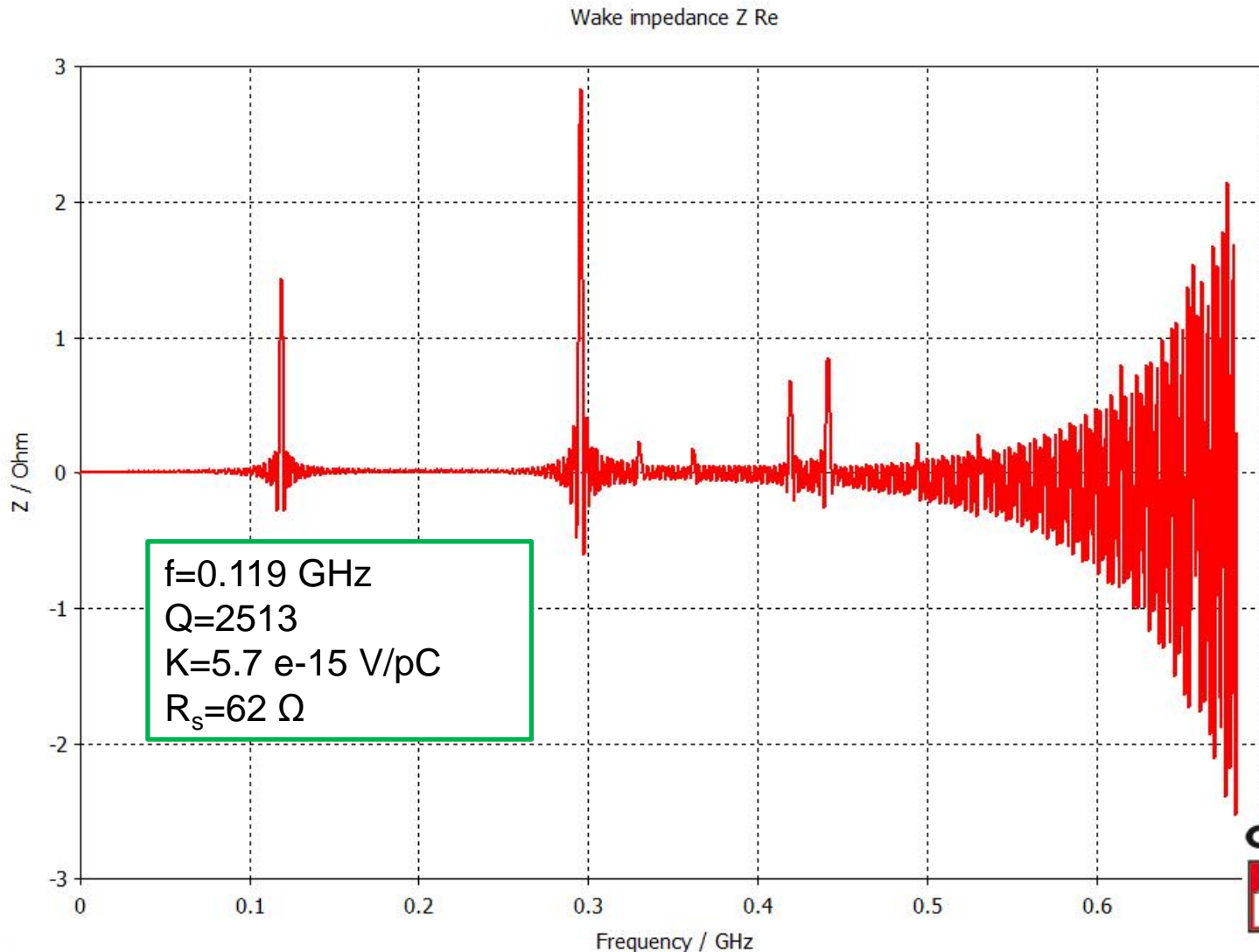
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# Longitudinal impedance (time domain)

Beam in orbiting position

Modes excited by bunch of 26 cm length circulating at 27 mm from the centre



$\sigma=26 \text{ cm}$   
 $f_{\text{MAX}}=0.7 \text{ GHz}$   
Wavelength=100 m  
Method: Direct

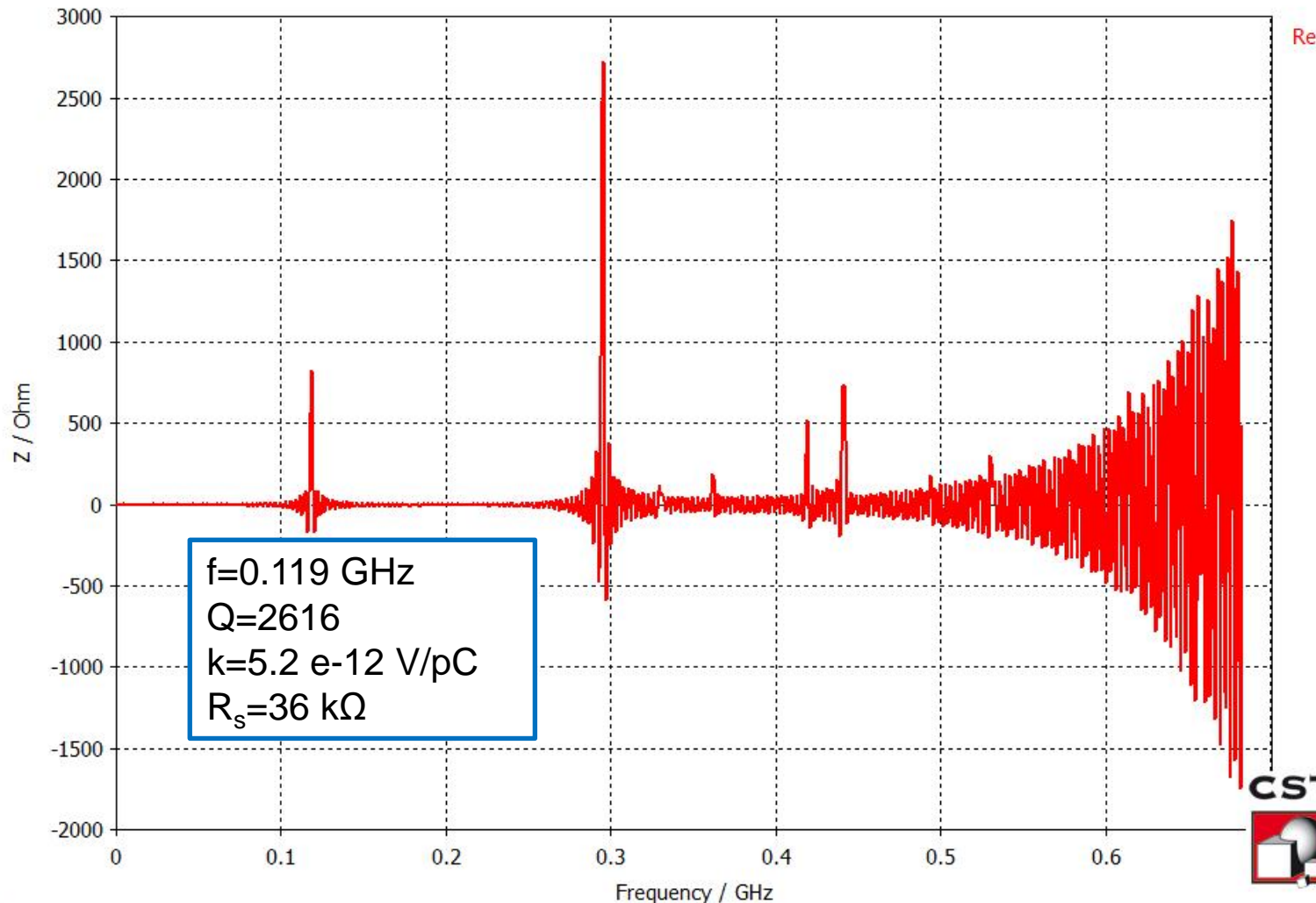


# Longitudinal impedance (time domain)

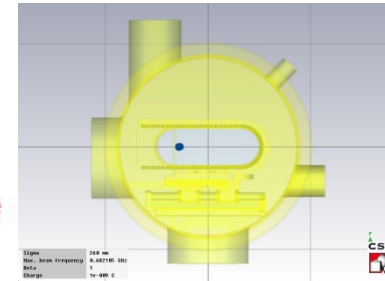
Before extraction

Modes excited by bunch of 26 cm length circulating at 5 mm from the blade

Wake impedance Z Re



Re



$\sigma=26 \text{ cm}$   
 $f_{\text{MAX}}=0.7 \text{ GHz}$   
Wavelength=100 m  
Method: Direct

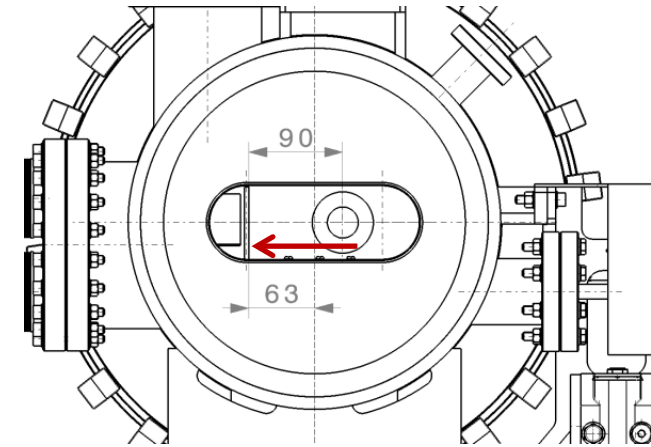
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# Eigenmodes (frequency domain)

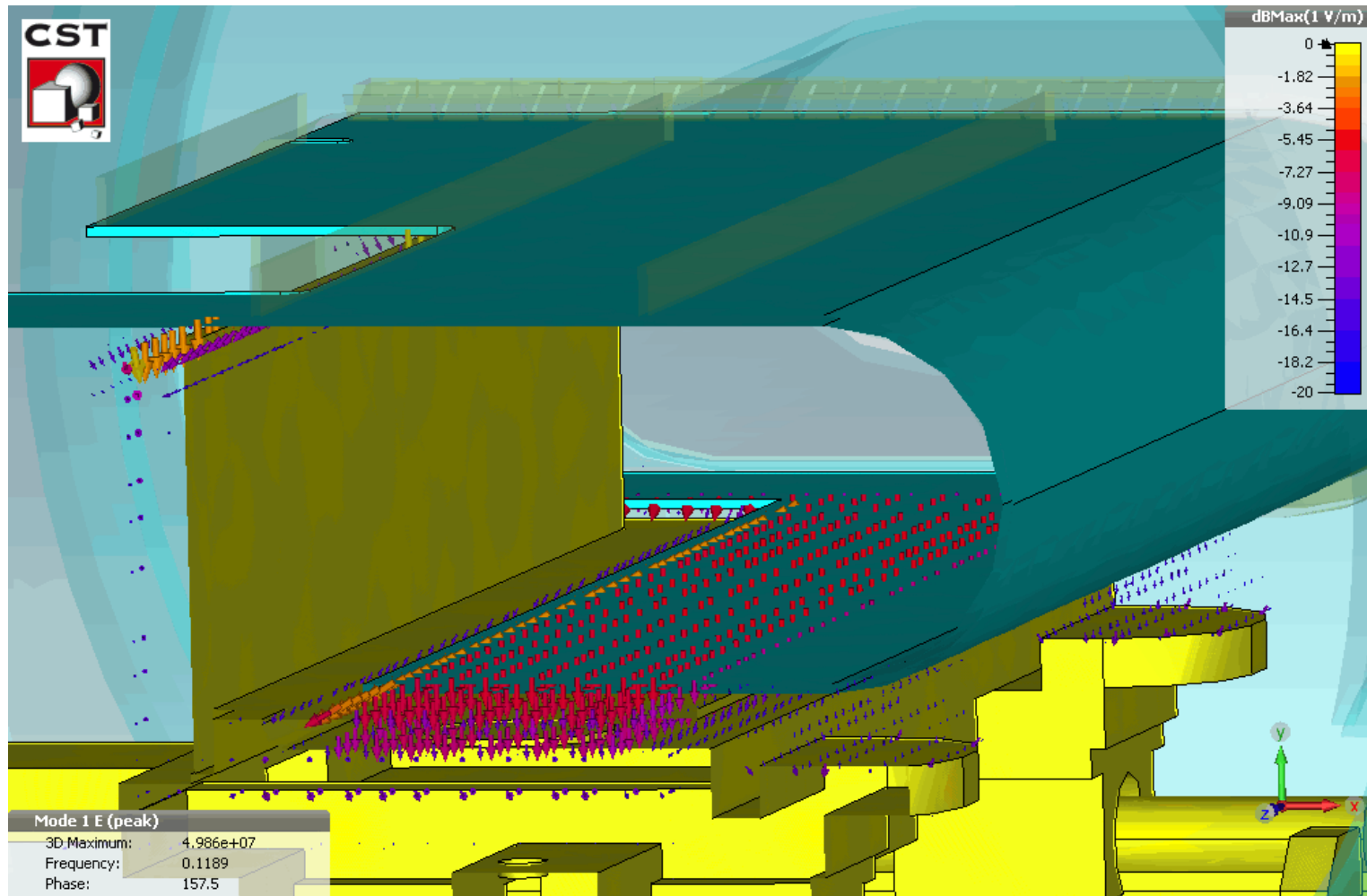
Evaluation of the shunt impedance with beam in different positions

	Freq [MHz]	Q	$R_s$ [ $\Omega$ ] @27	$R_s$ [ $\Omega$ ] @0	$R_s$ [ $\Omega$ ] @-55
1	119	2655	62	640	36176
2	295	3975	76	794	74899
3	331	3947	7	76	5153
4	362	4727	2	25	2909
5	420	4987	13	132	10109
6	441	4885	22	226	18914
7	495	5777	3	33	2097
8	533	7597	9	94	8852
9	616	3585	3	33	2145
10	656	5805	18	184	13988



# Eigenmodes (frequency domain)

Trapped mode at 119 MHz



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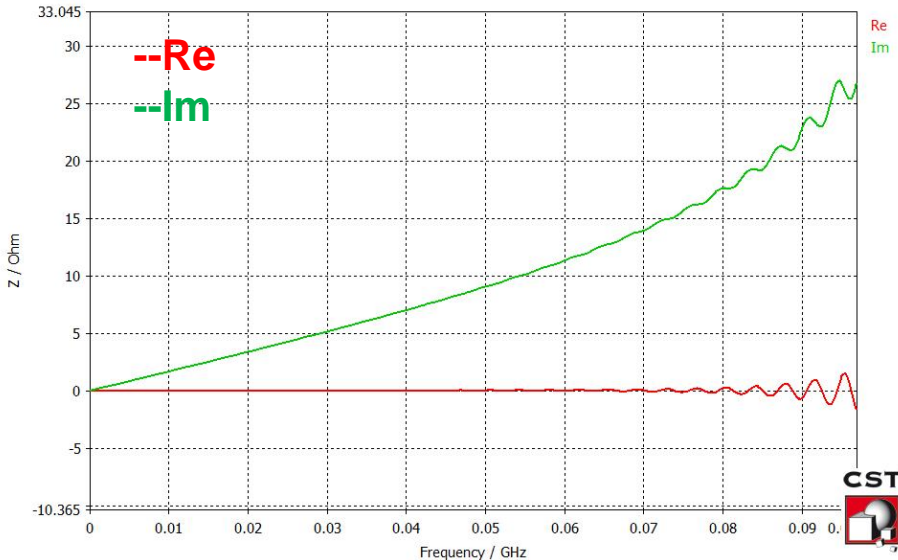


# Effective imaginary impedance (time domain)

Contribution to the impedance budget

## Longitudinal impedance before extraction

1D Results\Particle Beams\ParticleBeam1\Wake impedance Z

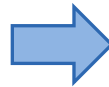


A bunch circulating in the PS before the extraction excites an imaginary part of the longitudinal impedance that is purely inductive:

$$\frac{Z(p)}{p} = 0.12 \Omega$$

Estimated total longitudinal impedance in the PS:

$$\frac{Z(p)}{p} = (18.4 \pm 2.2 \Omega)$$



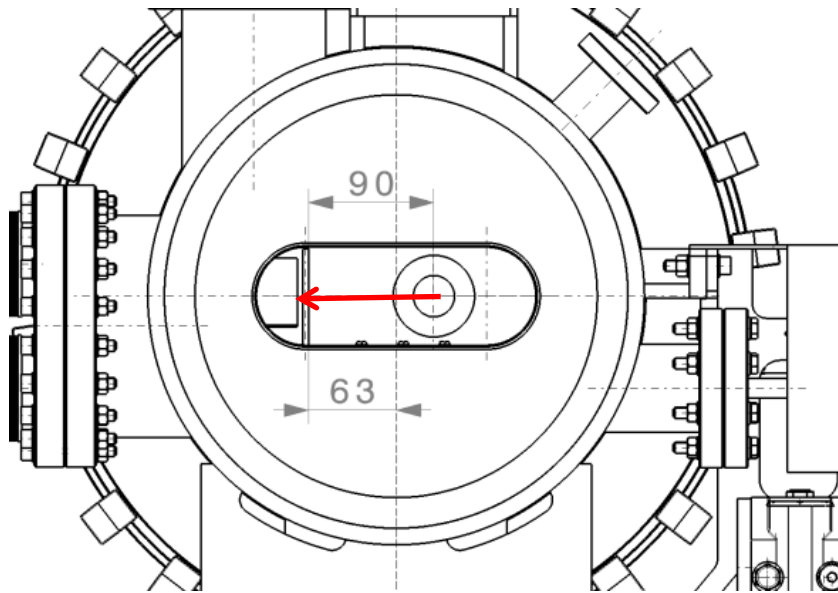
The contribution of the dummy septum to the total imaginary part of longitudinal impedance of the PS is predicted to be less than 1%

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# Coupled bunch instability growth rate evaluation

LIU parameters hav to be considered for the growth rate estimation



PS parameters (25 ns)

	13 GeV	26 GeV
$V_{RF}$ [kV]	165	100
h	21	84
# of bunches	18	72
charge	1.28 e-07	3.2 e-08
Slippage factor	0.0163	0.0215

Growth rate :

$$\alpha = \frac{c^2 \eta_c Q N_b}{2 L^2 E_0 \omega_s} \omega_r \text{Re}\{Z(\omega_r)\} \left[ \frac{1}{s} \right]$$

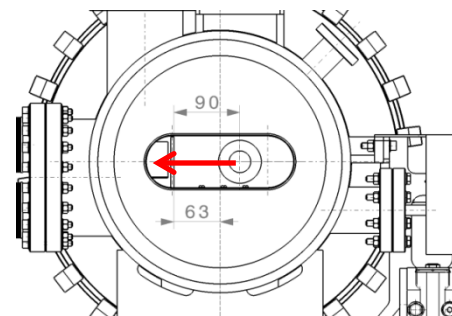
NB: mode full coupled with the multibunch spectrum

# Coupled bunch instability growth rate

Compute the instability growth rate considering PS parameters

**Growth rate:**  $\alpha = \frac{c^2 \eta_c Q N_b}{2 L^2 E_0 \omega_s} \omega_r \text{Re}\{Z(\omega_r)\} \left[ \frac{1}{s} \right]$

**Gaussian shape of the bunch:**  $R'_s = R_s e^{-(\omega\sigma)^2} \quad \sigma = 3 \text{ ns}$



PS parameters (25 ns)

	13 GeV	26 GeV
$V_{RF}$ [kV]	165	100
h	21	84
# of bunches	18	72
charge	1.28 e-07	3.2 e-08
Slippage factor	0.0163	0.0215

Displacement [mm]	$R_s$ [ $\Omega$ ]	$R'_s$ [ $\Omega$ ]	$\alpha$ [1/s] @13 GeV	$\alpha$ [1/s] @26 GeV
0	640	10	0.15	0.08
10	1484	23	0.35	0.18
20	3385	53	0.82	0.43
30	7301	114	1.77	0.95
40	14762	231	3.59	1.87
50	27397	428	6.65	3.47
60	49215	770	11.97	6.25

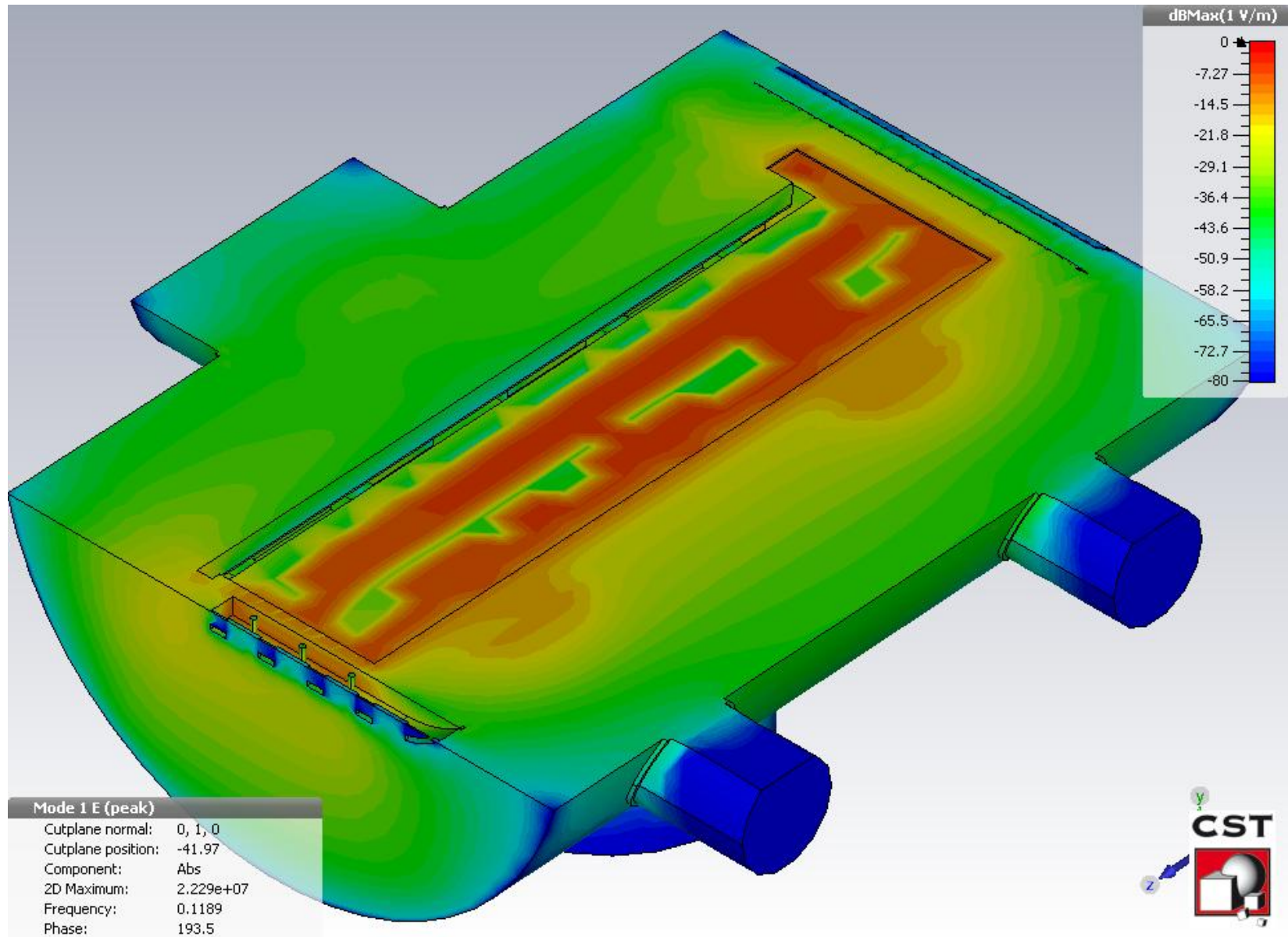
**NB:** the beam is extracted in 6 ms (few synchrotron periods) so in any case the coupled bunch instability has no time to rise and develop!

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# Ferrite proposal for trapped modes damping

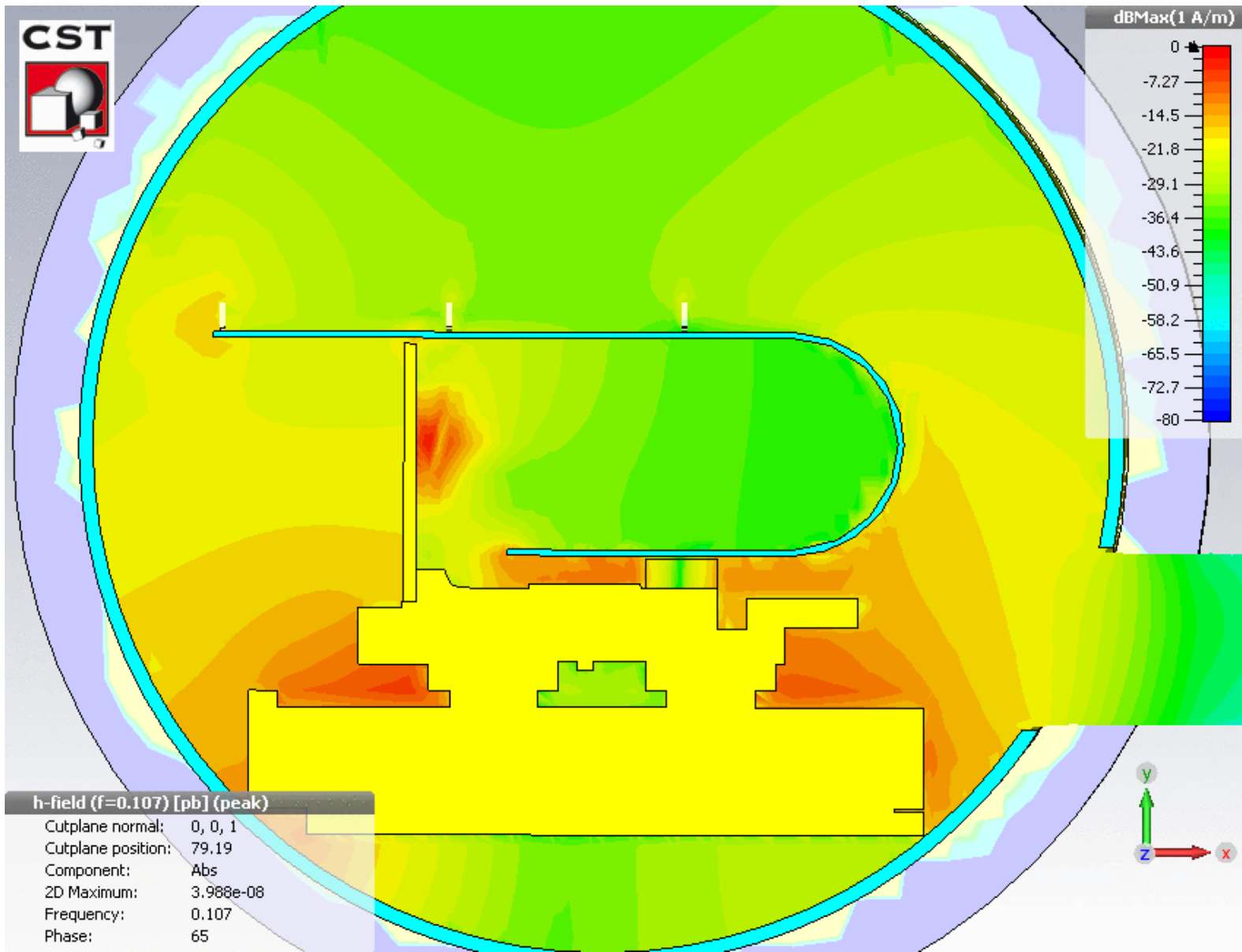
119 MHz mode electric field





# Ferrite proposal for trapped modes damping

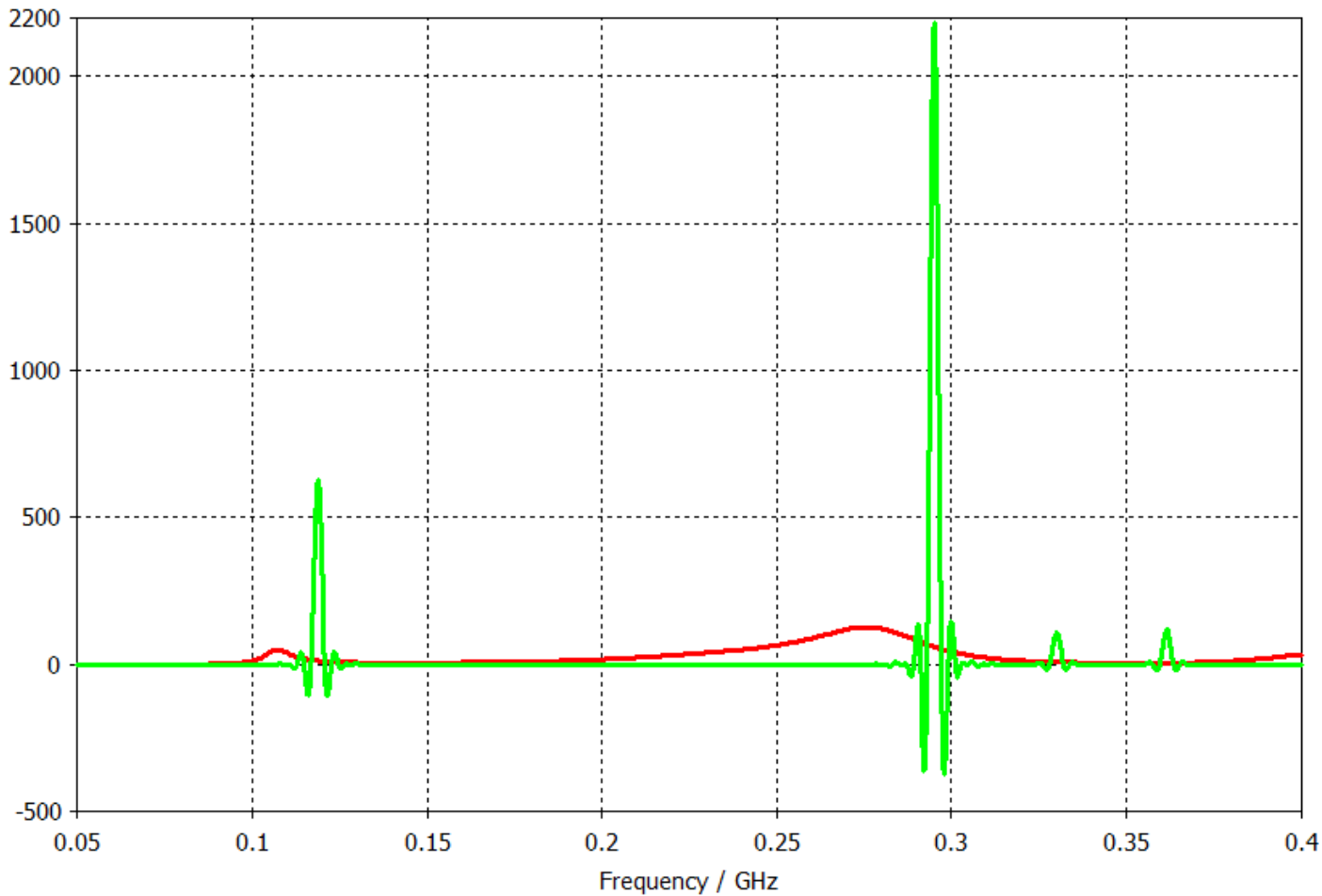
119 MHz mode magnetic field



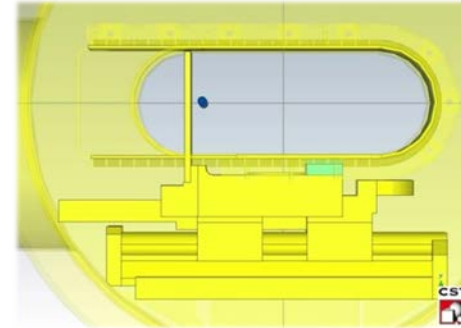
# Ferrite proposal for trapped modes damping

*Damping effect on longitudinal impedance*

1D Results\Particle Beams\ParticleBeam1\Wake impedance Z\New Folder



— Ferrite TT211R  
— No Ferrite



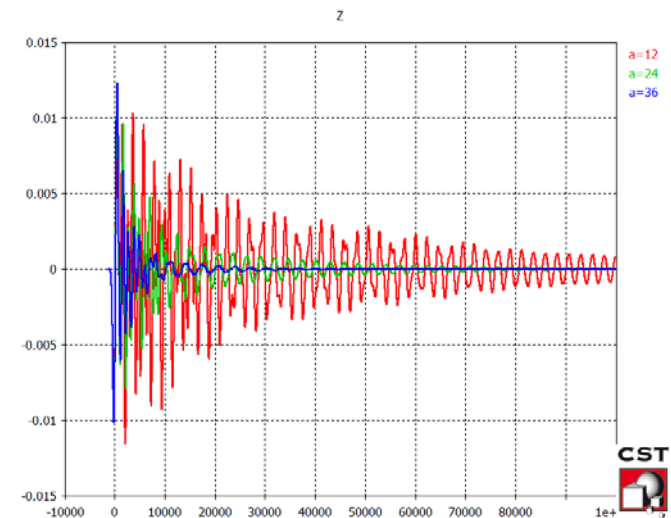
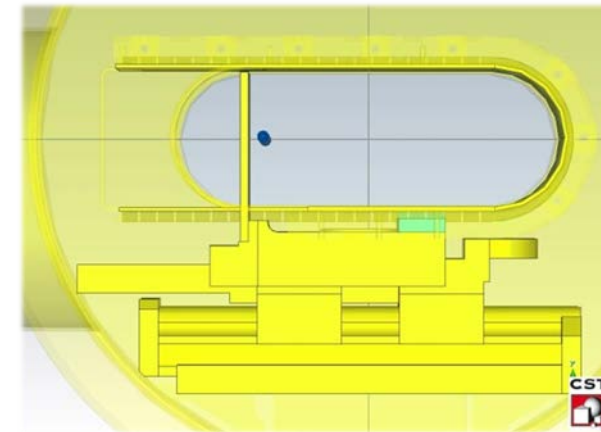
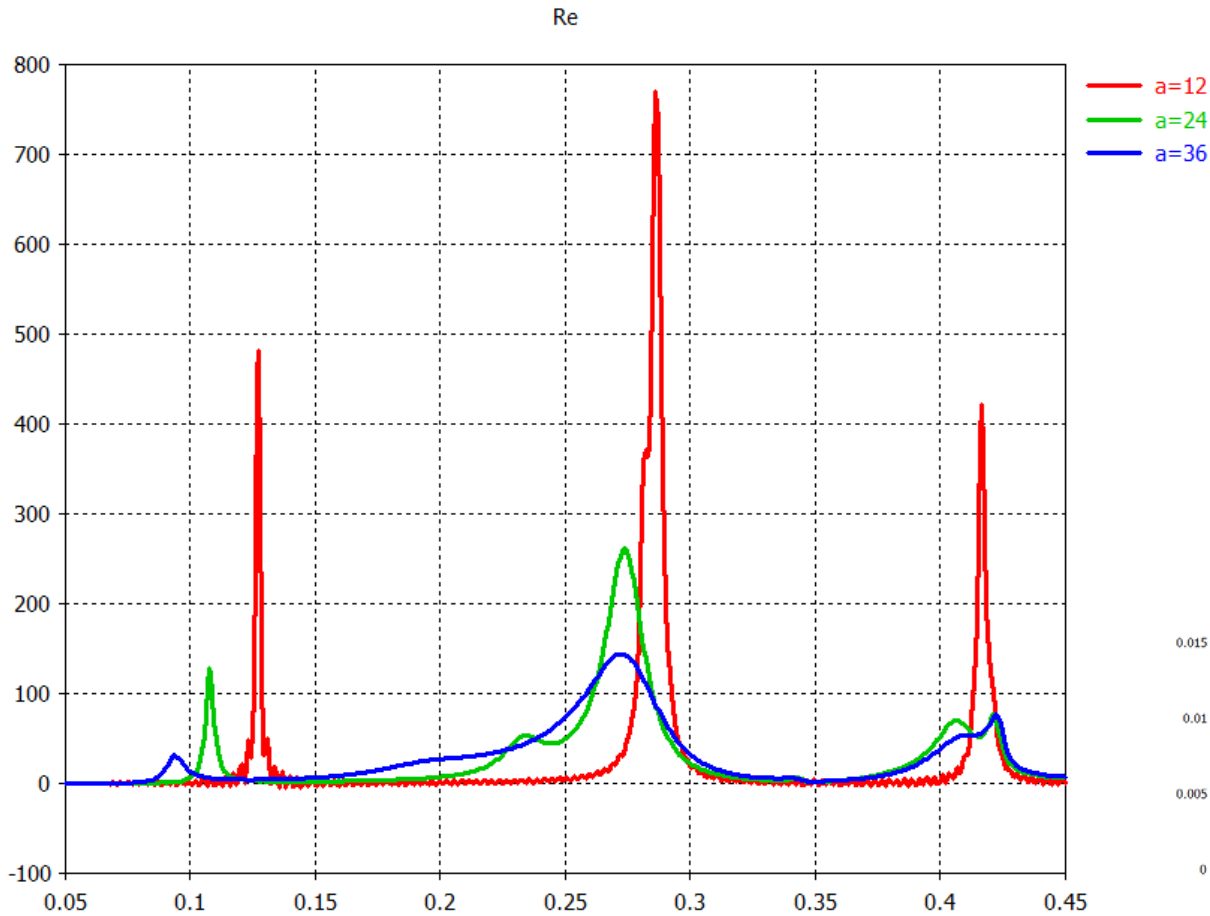
TT2-11R Ferrite  
24x7x395 mm



# Ferrite proposal for trapped modes damping

*Damping effect with different ferrite thickness*

TT2-11R Ferrite  
24x7x395 mm



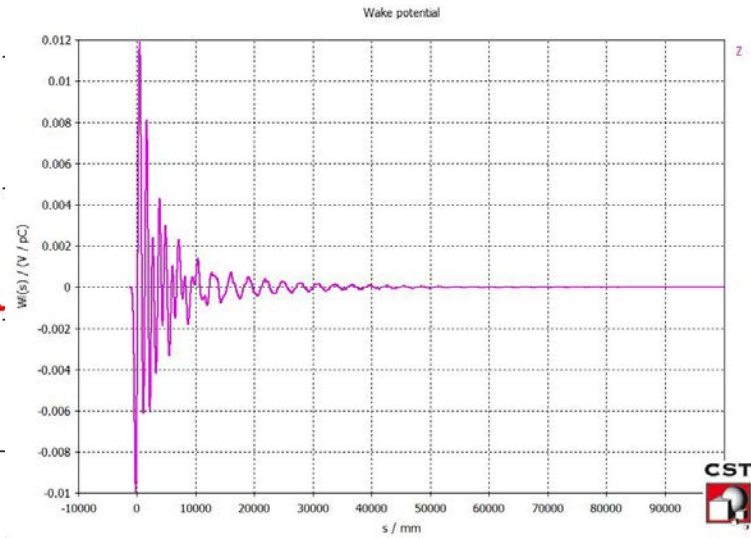
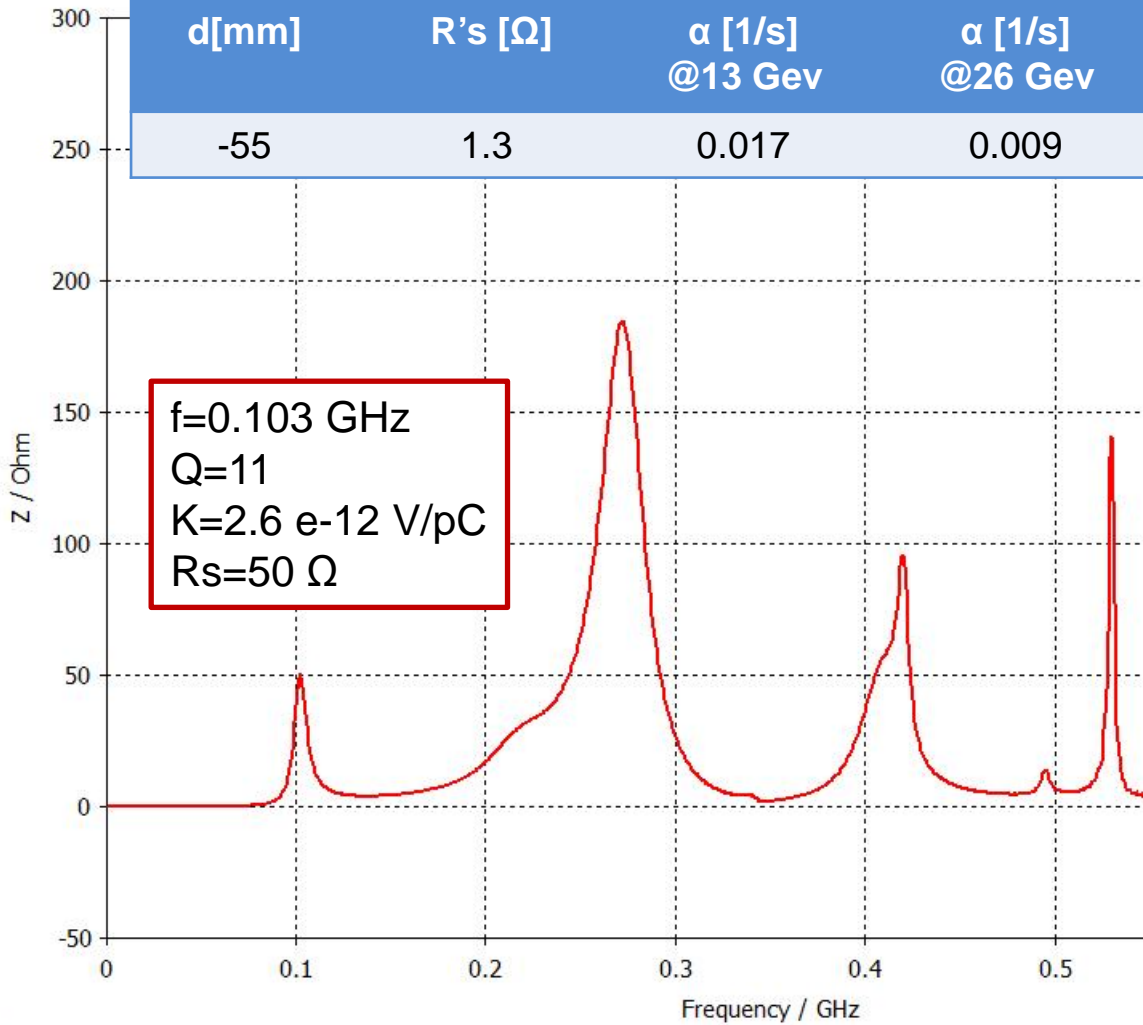
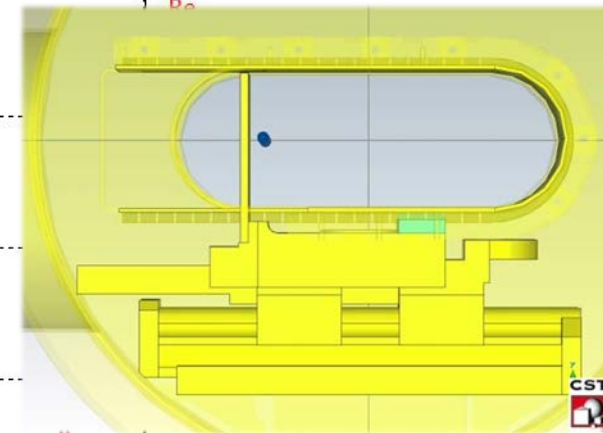
# Ferrite proposal for trapped modes damping

*Effects of the insertion of ferrite on the growth rate*

TT2-11R Ferrite  
24x7x395 mm

Wake impedance  $Z_{Re}$

d[mm]	R's [ $\Omega$ ]	$\alpha$ [1/s] @13 GeV	$\alpha$ [1/s] @26 GeV
-55	1.3	0.017	0.009



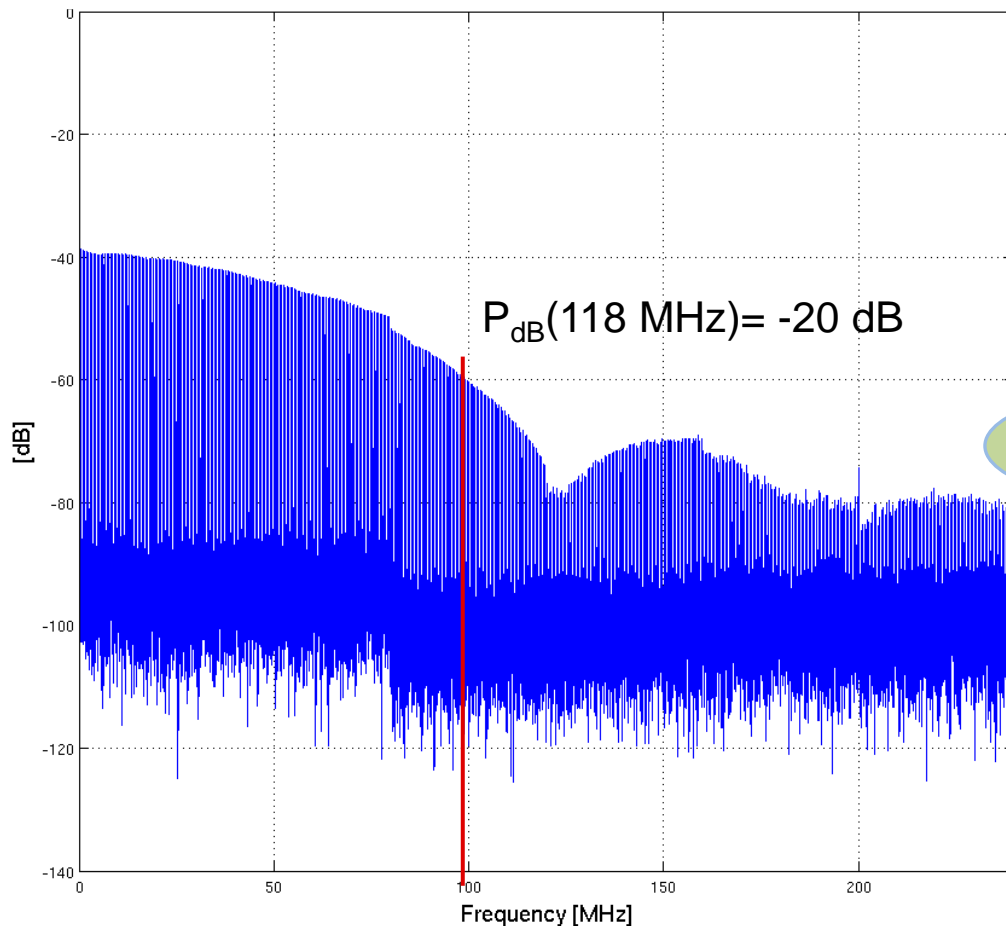
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# Heating and power loss

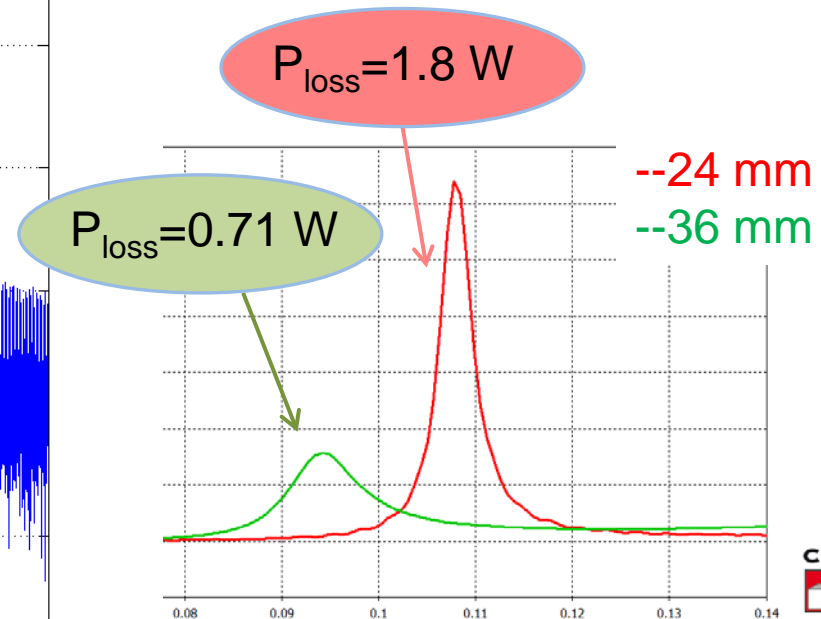
Estimation of the power loss considering the heating from ferrite

At extraction energy the first mode is inside the beam spectrum and the power at 100 MHz is about -20 dB



Power loss formula for a resonance:

$$P_{loss} = 2(MI_b)^2 R_s 10^{\frac{P_{dB}(f)}{10}}$$

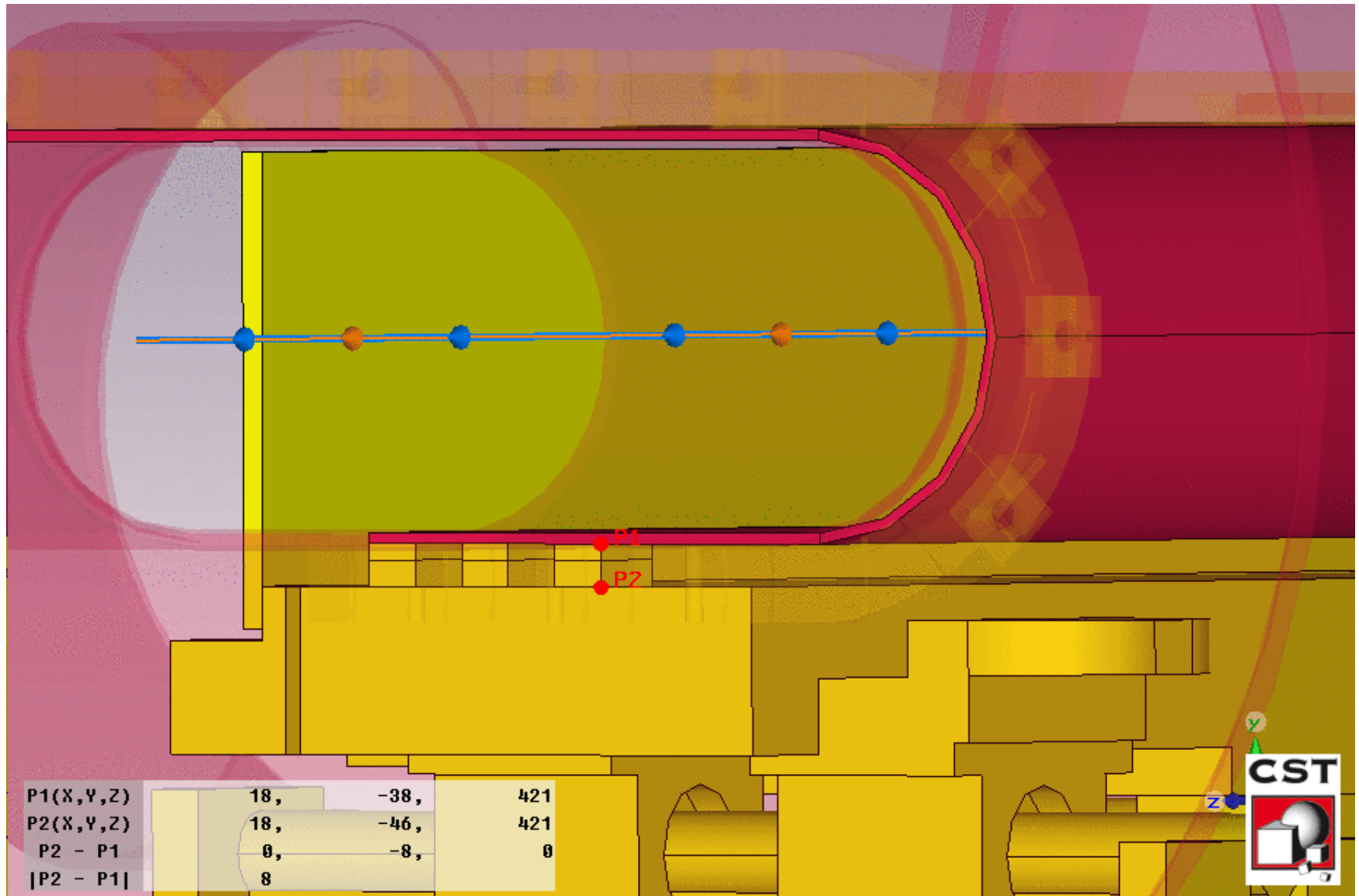




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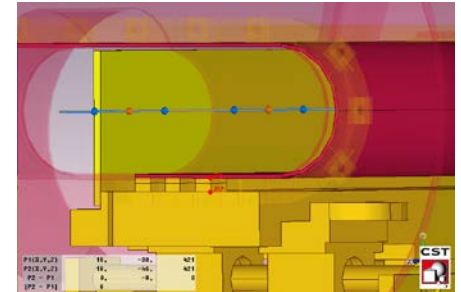
# Sliding contacts proposal



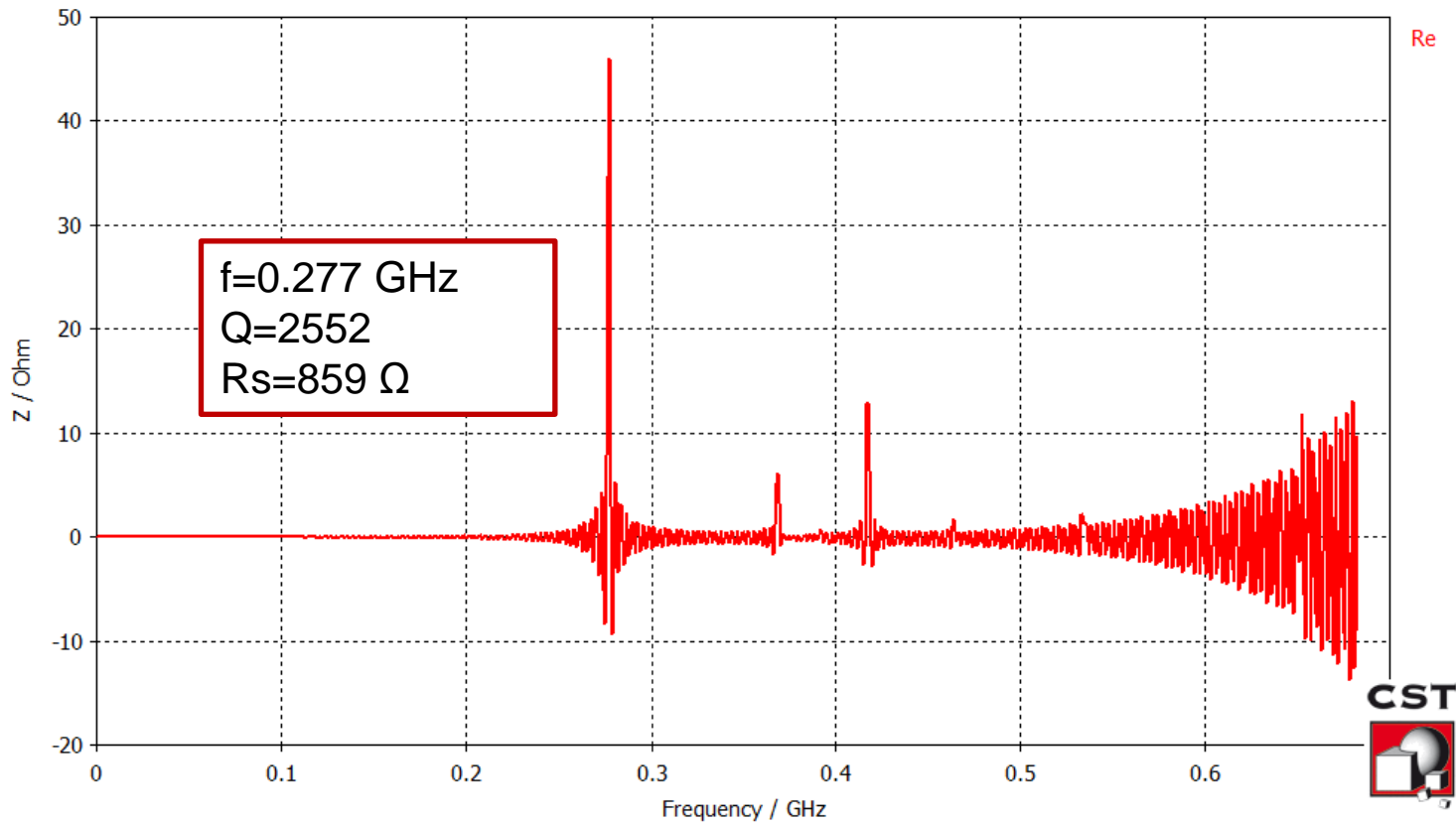
# Sliding contacts proposal

*Trapped mode cancelling and effect on the growth rate*

d[mm]	R's [ $\Omega$ ]	$\alpha$ [1/s] @13 Gev	$\alpha$ [1/s] @26 Gev
-55	9.6 e-08	3.5e-09	-



Wake impedance Z Re



# Sliding contacts proposal

277 MHz mode electric field

$f=0.277$  GHz  
 $Q=2552$   
 $R_s=859 \Omega$

$d[\text{mm}]$	$R_s [\Omega]$	$\alpha [1/\text{s}]$ @13 GeV	$\alpha [1/\text{s}]$ @26 GeV
-55	$9.6 \text{ e-}08$	$3.5\text{e-}09$	-



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# Conclusions

## ➤ Impedance and instabilities

Longitudinal and transverse impedance show several modes with a resonance frequency that falls in the PS bunch spectrum; in particular the mode at 118 MHz has been studied deeply to understand its impact on coupled bunch instability and heating.

- For the broadband impedance, the effective longitudinal impedance is predicted to be negligible compared to the imaginary part of the total impedance measured for the PS
- For the trapped modes, a resonance around 100 MHz can be source of heating and instabilities:

- *Heating* : the first mode is inside the beam spectrum and the power at 118 MHz is -20 dB at extraction. Thanks to the cooling system it is not predicted to be an issue even with the insertion of a block of ferrite.

- *Longitudinal instabilities*: when the beam is in the orbiting position, the shunt impedance of the first mode is  $60 \Omega$ , and the impact is limited. When the beam is few mm far from the blade the shunt impedance is  $50 \text{ k}\Omega$ , but anyway the beam is going to approach the blade only for a limited time.

The growth rate evaluated in the orbiting position is very small compared to growth rates measured in the PS. The growth rate becomes not negligible when the beam approaches the blade (rise time of 170 ms), but since the beam is extracted in 6 ms (3 synchrotron periods) the instability has not the time to rise and develop. For these reasons the coupled bunch instabilities should not be enhanced by this mode.

# Recommendations

## ➤ Recommendations from the impedance team

- Impedance bench measurements should be performed before installation to confirm the results from simulations.
- Even if the mode at 119 MHz is not predicted to be an issue for the coupled bunch instability, two proposals have been made in order to decrease further the impact:
  - Sliding contact (mode 119 MHz cancelling): should be inserted between the screen and the displacement system in order to avoid the generation of trapped modes below 300 MHz. Since sliding contacts have been inserted also in other septa we believe that this solution will be reliable and sufficient to cancel the 119 MHz mode.
  - Supports for a block of ferrite TT2-11R (modes damping): should be assembled between the displacement system and the screen to allow the insertion of a brick with the dimension that have been suggested. The need of the ferrite will be understood only after impedance bench measurement or in case that the sliding contact wouldn't work properly on mode cancelling.