Preliminary Considerations on 800 MHz Cavity HOM-Free Design

M. Zobov, A. Gallo

LNF INF, Frascati, Italy

R. Bolgov, M. Gusarova, Ya. Shashkov, N. Sobenin

MEPHI, Moscow, Russia

High Luminosity LHC

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404

CAPACITIES

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Why "Preliminary"?

We do not know yet exact requirements coming from:

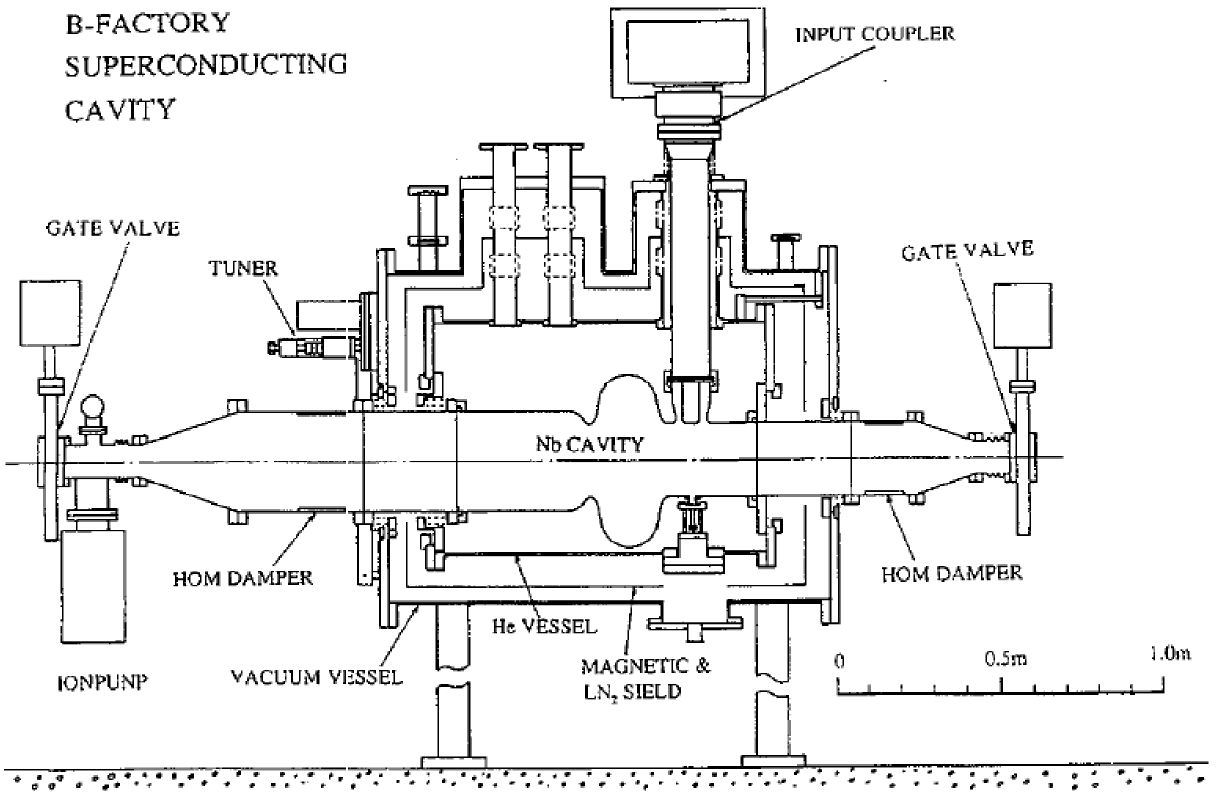
- Beam dynamics
- Geometrical constraints

What we know

- Beam coupling impedance should be as small as possible
- Not very high R/Q because of beam transients
- Required volatge of 8 MV

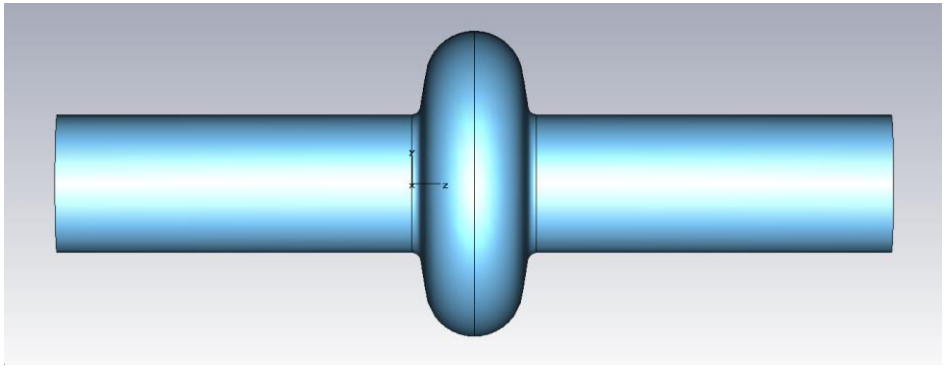
Since high R/Q is not required it is worthwhile to exploit the “single mode” cavity design:

1. Relatively Simple
2. No HOMs

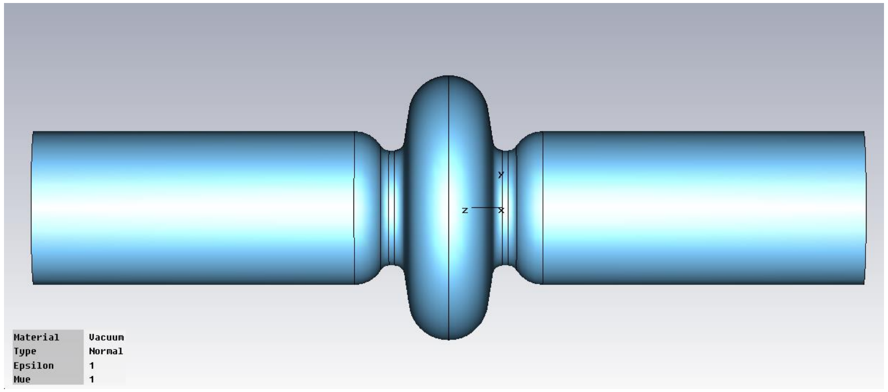


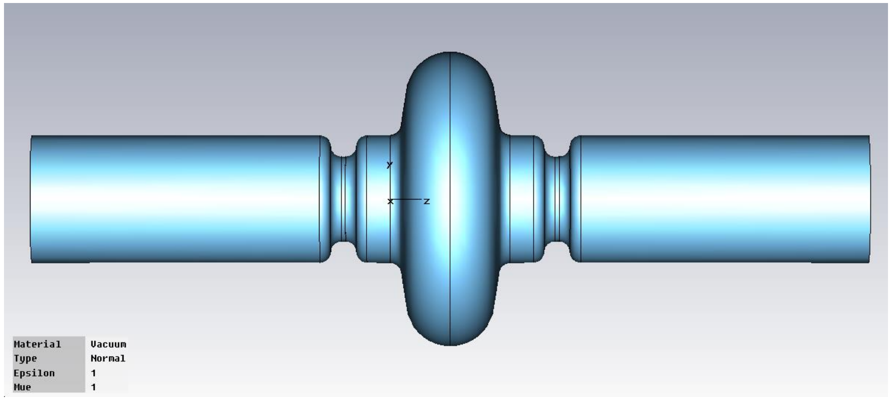
From KEKB Design Report

New proposals (1/2)



- Longer Pipe;
- Absorber at the end;
- Probably needs some pipe radius retuning;





- Longer Pipe;
- Absorber at the end;
- The bottleneck could increase the WM rejection without dangerous changes in the HOMs damping efficiency;

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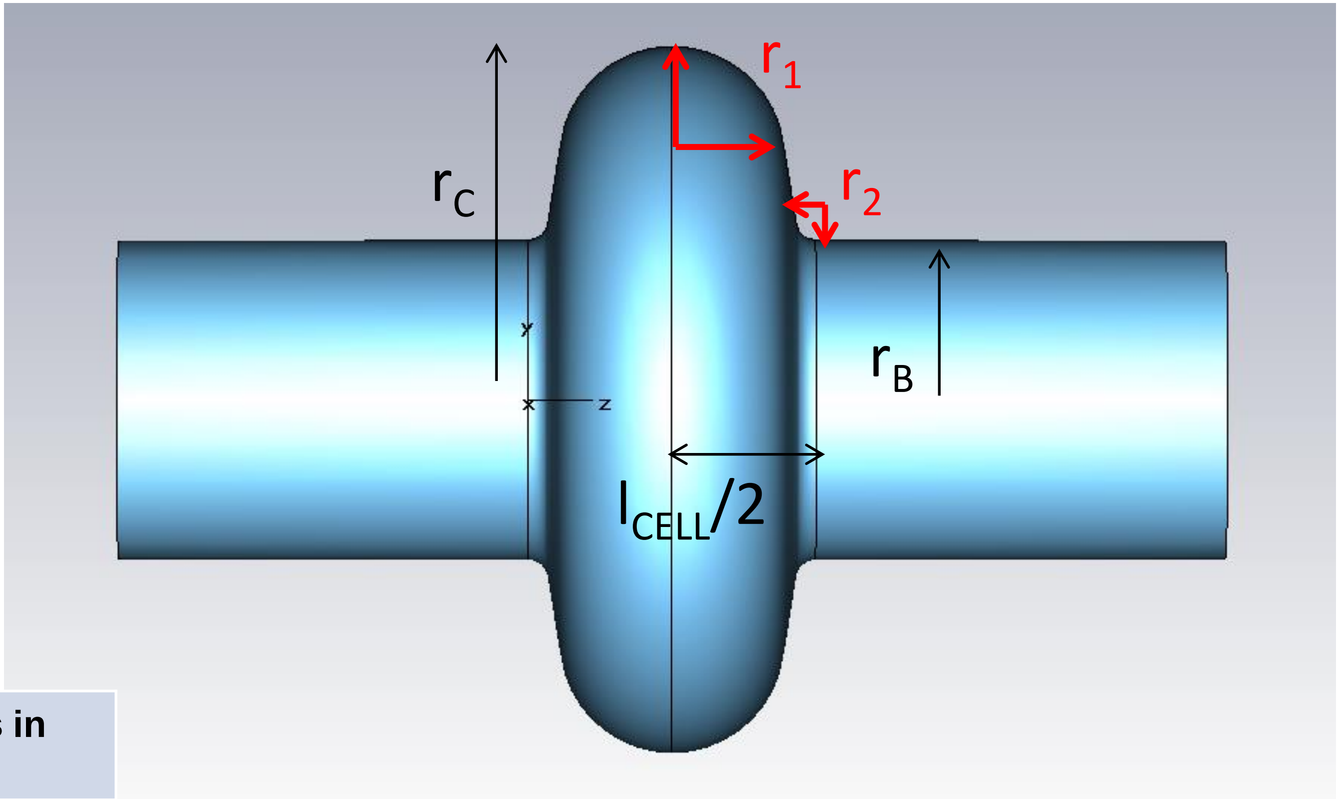
Working point chosen



Parameters in mm	
l_{CELL}	140
r_C	169.3
r_B	75
r_{1h}	52
r_{2h}	12.5
r_{PIPE}	/

Fres	800 MHz
R/Q	45.5 Ohm (circuit)
Epeak/Vacc	14.6 m^{-1}
Hpeak/Vacc	28.2 mT/MV

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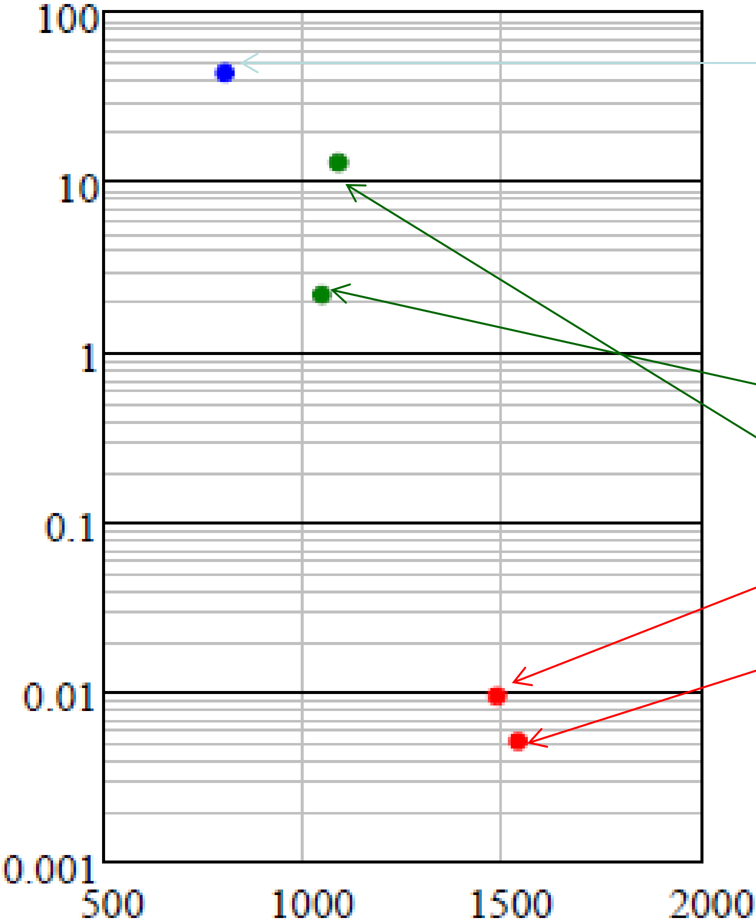
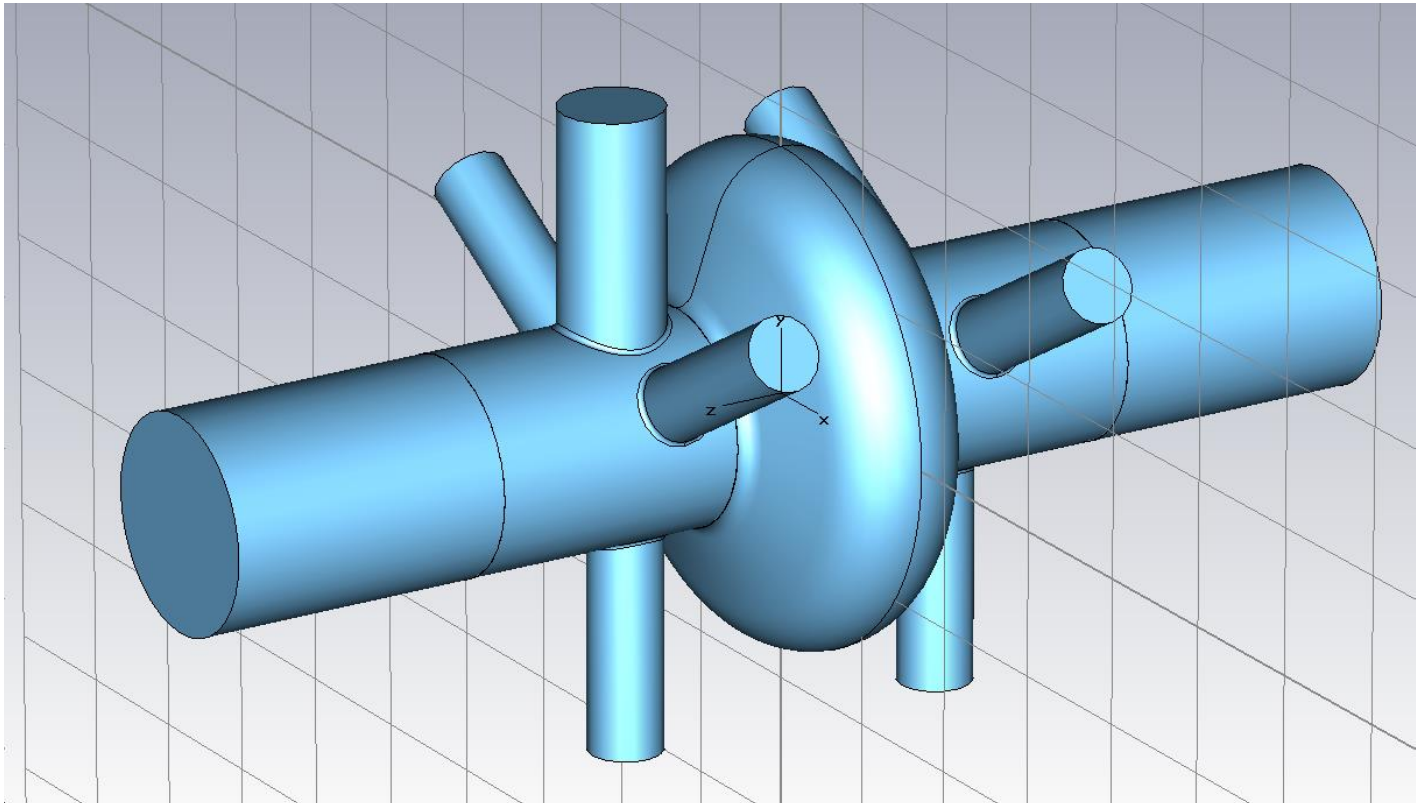
800 MHz Cavity Modes
(Baseline design)



R/Q of Cavity Modes

Mode	f, MHz	R/Q_0, Ohm	Q_0
TM_{010}	800	44.78	33421
TE_{111}	1047	2.25	28677
TM_{110}	1086	13.23	29666
TM_{210}	1486	9.60E-03	36622
TE_{211}	1539	5.30E-03	35654

Cavity with damping couplers



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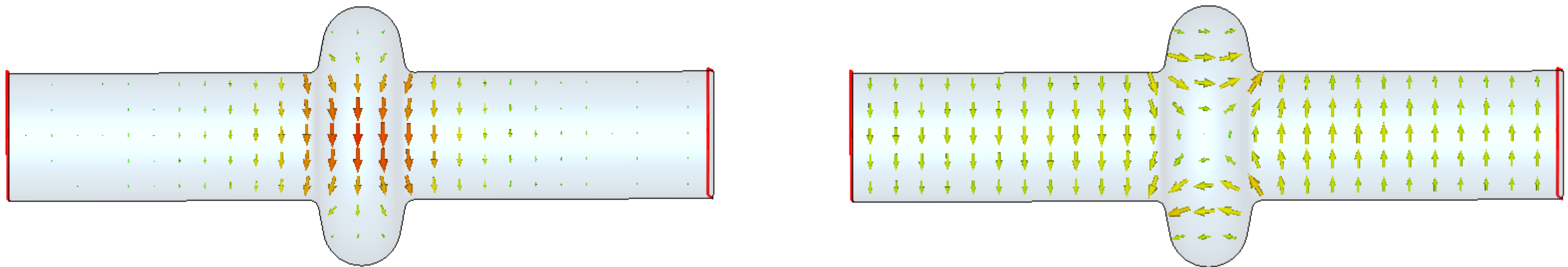
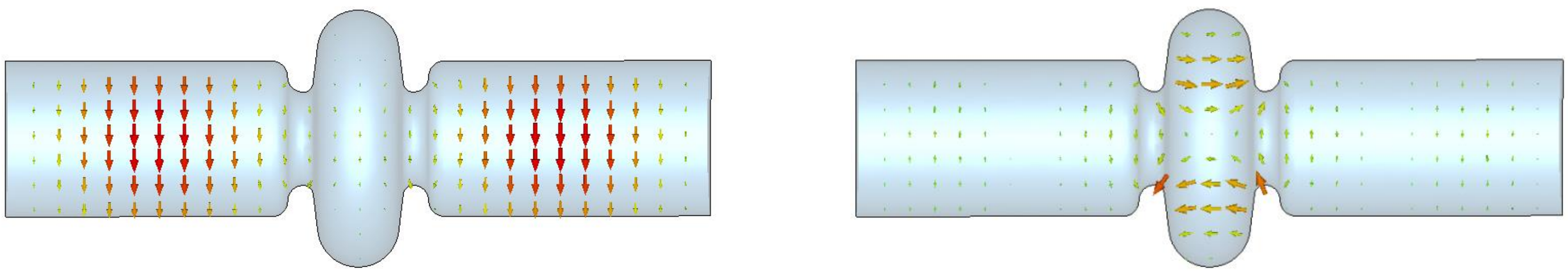
Geometry Optimization

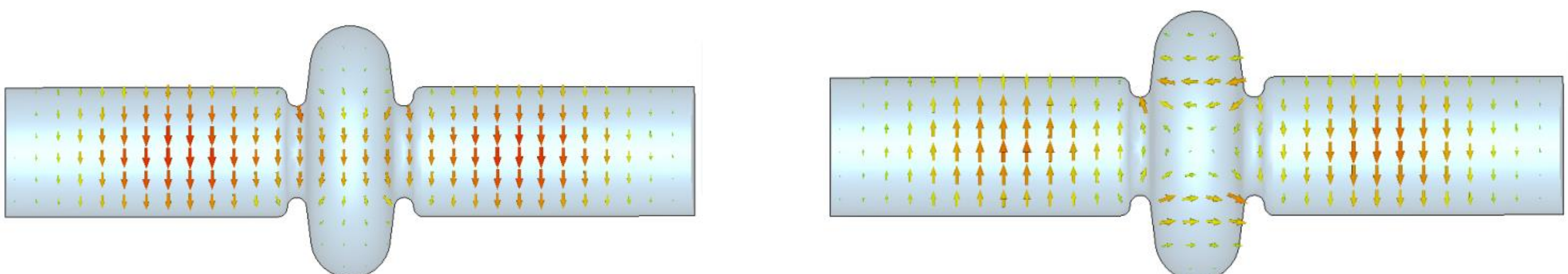
H111 (Electric Field) | E110 (Electric Field)



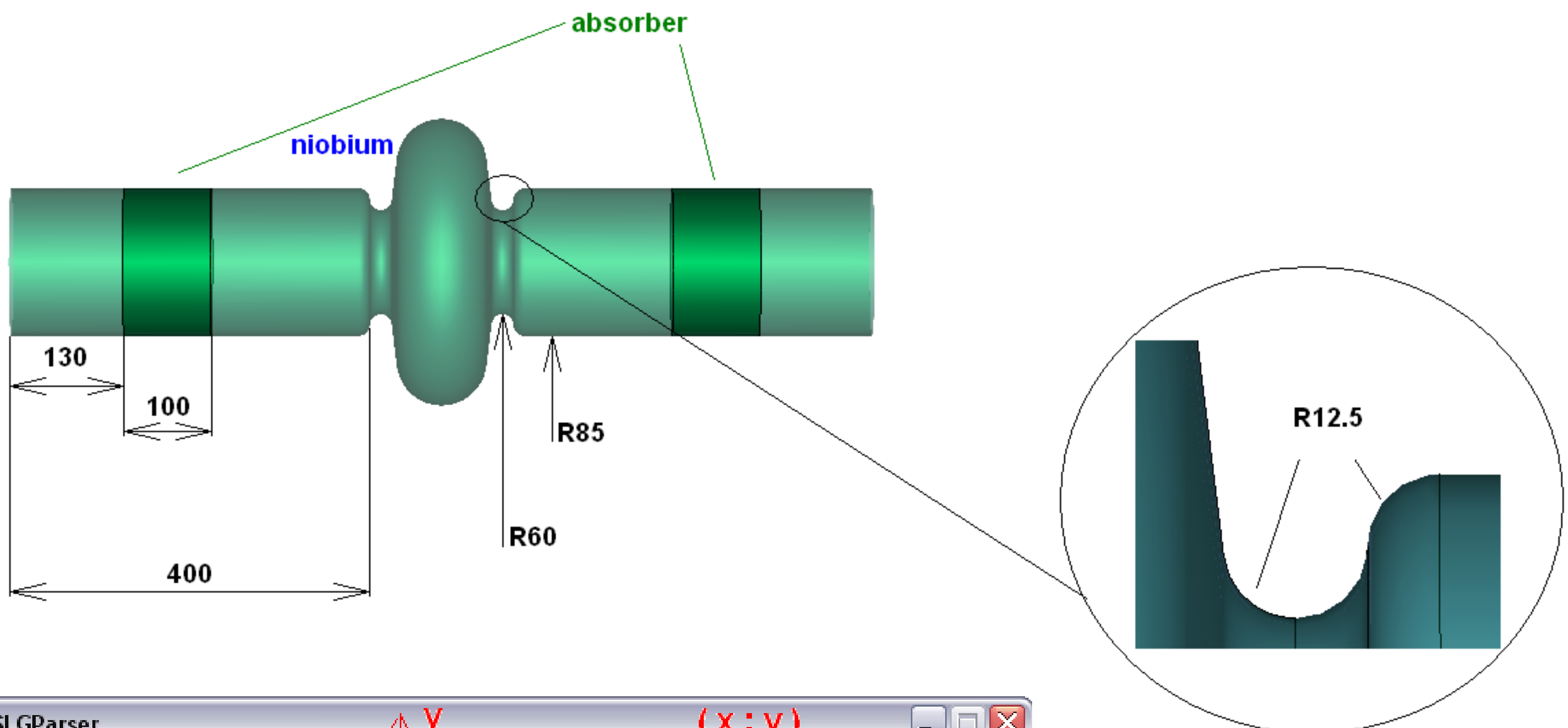
Drift Tube Radius: 85 mm

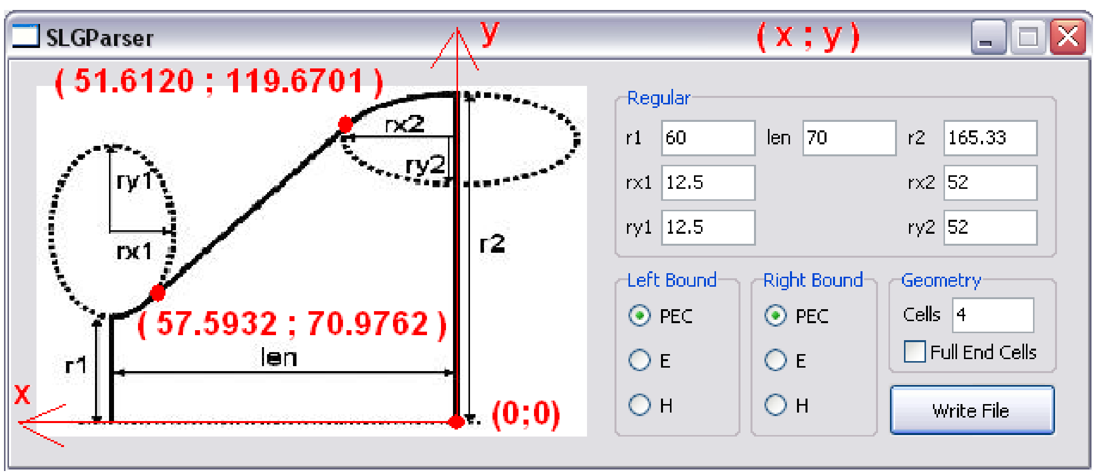


Drift Tube Radius: 100 mm

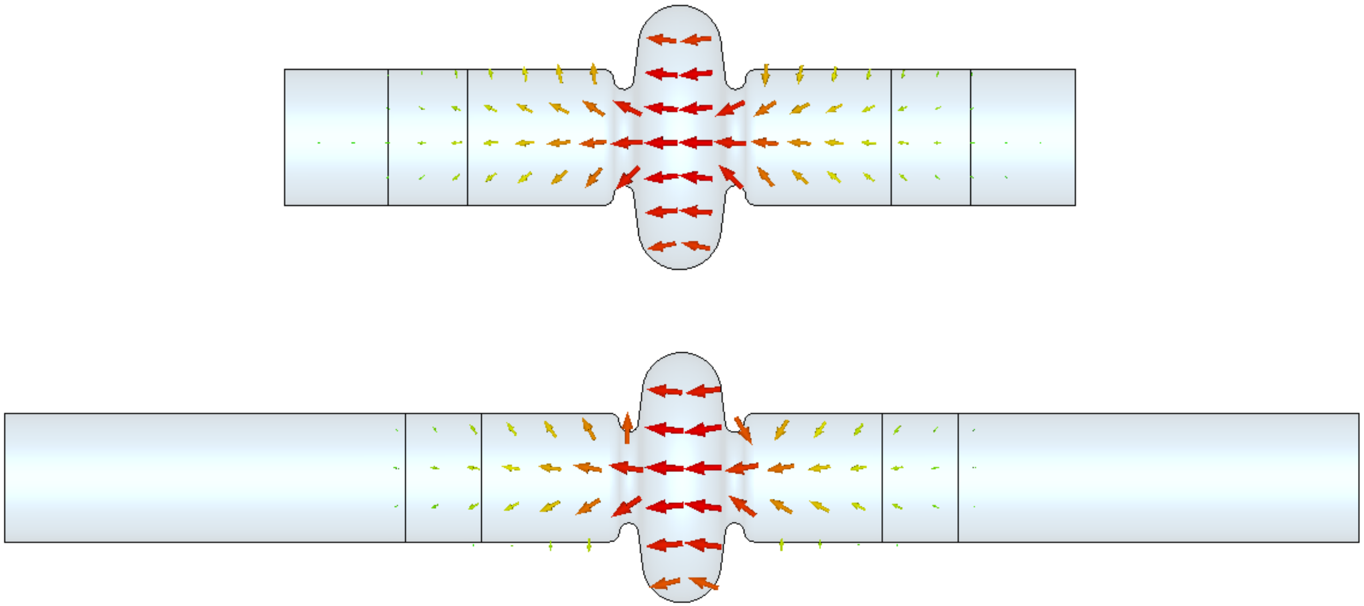


Drift Tube Radius: 85 mm

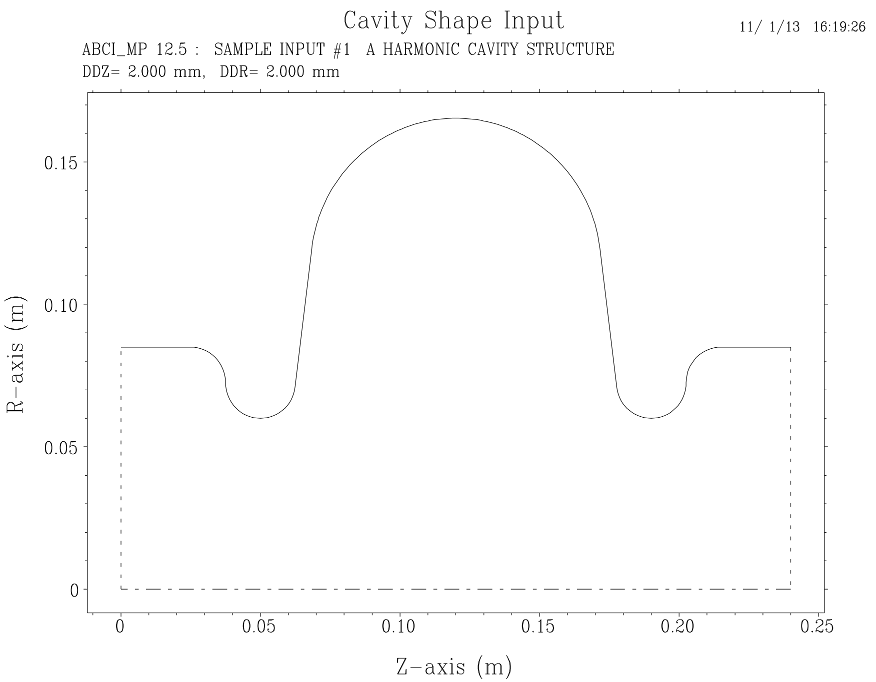

absorber
niobium
130
100
400
R85
R60
R12.5

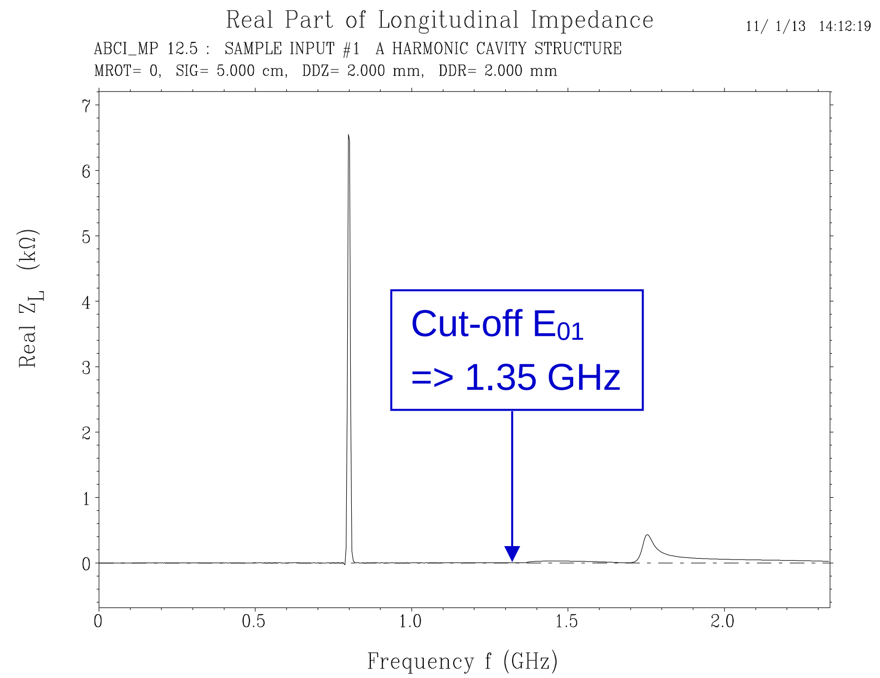

SLGParser
y
(x ; y)
(51.6120 ; 119.6701)
rx2
ry2
ry1
rx1
r2
(57.5932 ; 70.9762)
r1
len
x
(0;0)
Regular
r1 60
len 70
r2 165.33
rx1 12.5
rx2 52
ry1 12.5
ry2 52
Left Bound
PEC
E
H
Right Bound
PEC
E
H
Geometry
Cells 4
Full End Cells
Write File

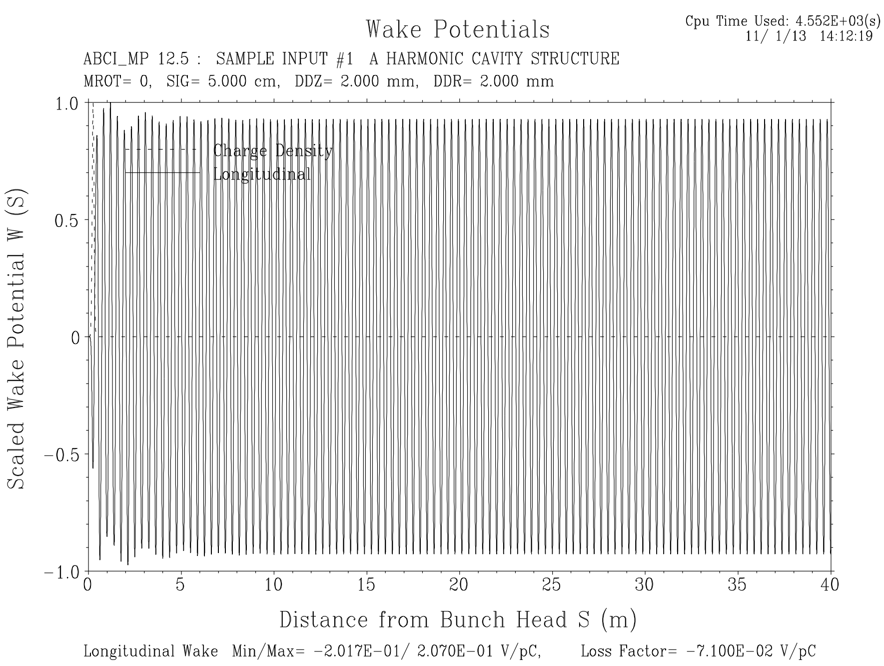
Fundamental Mode

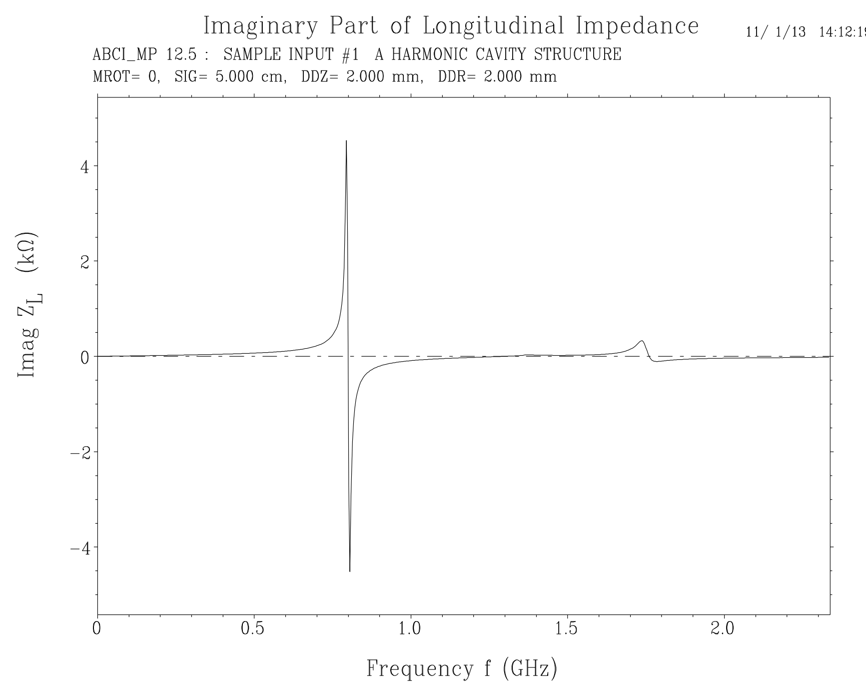


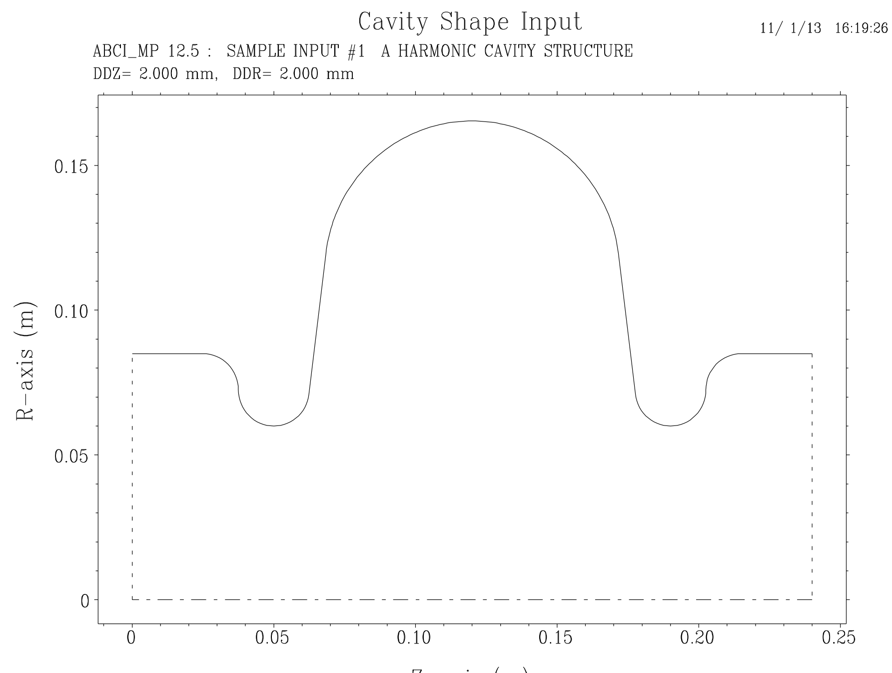
$f = 800$ MHz, $R/Q_0 = 53.33$, $Q_0 = 1.91\text{x}10^{10}$

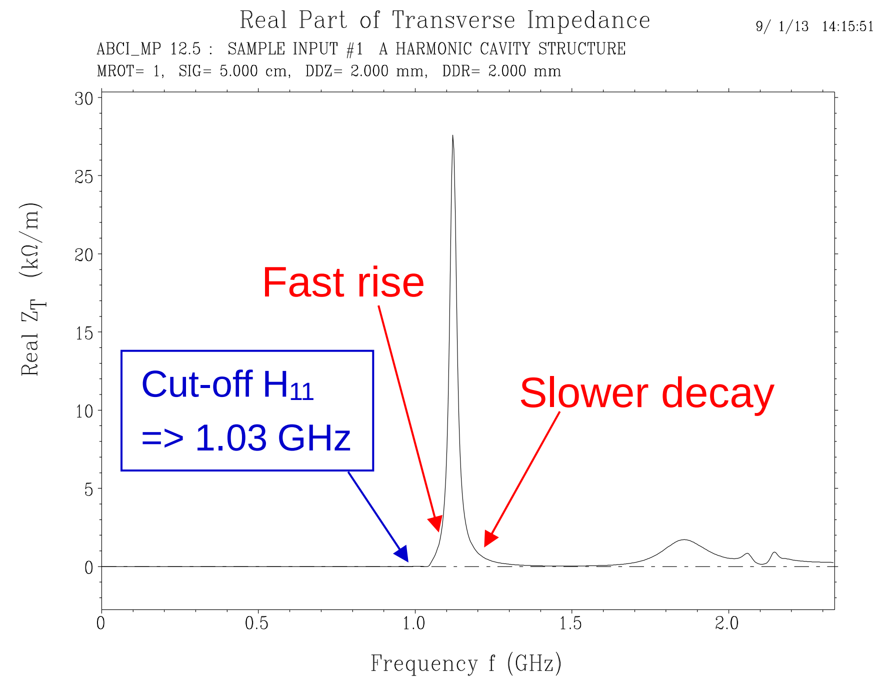

Cavity Shape Input
11/ 1/13 16:19:26
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
DDZ= 2.000 mm, DDR= 2.000 mm
R−axis (m)
Z−axis (m)

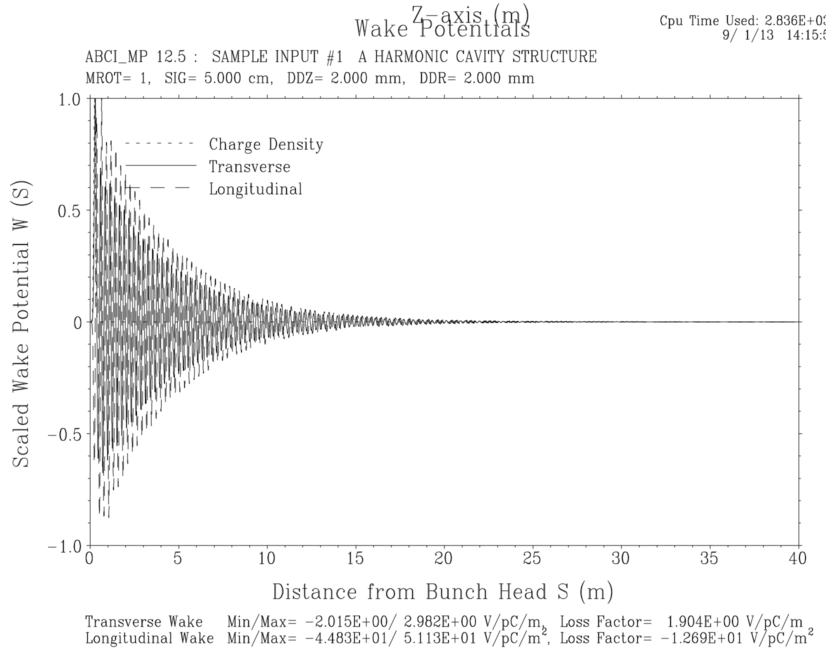

Real Part of Longitudinal Impedance
11/ 1/13 14:12:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 5.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Real Z_L (kΩ)
Frequency f (GHz)
Cut-off E01
=> 1.35 GHz

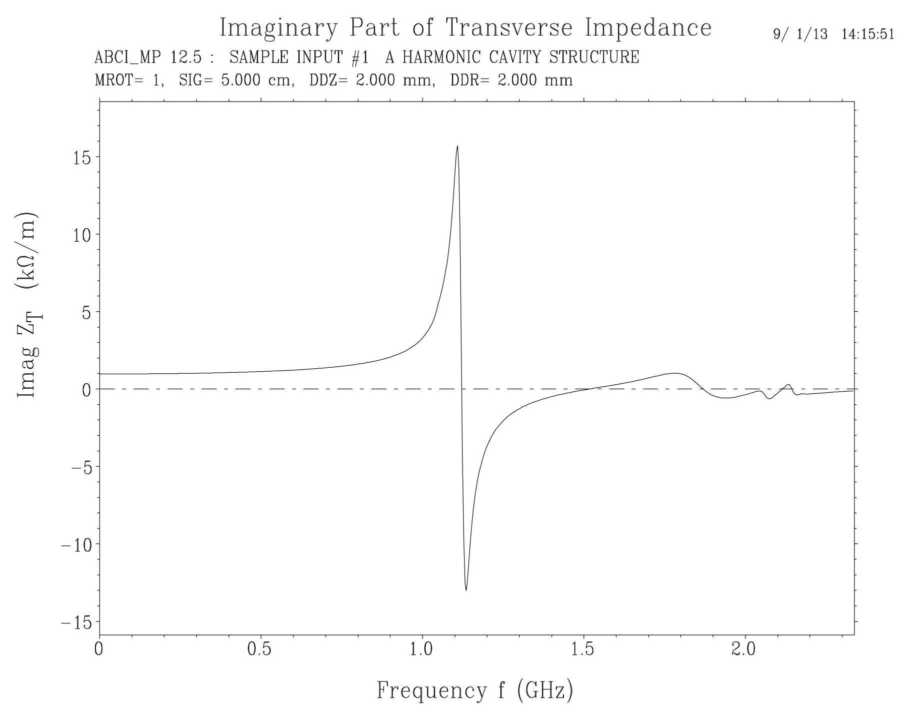

Wake Potentials
Cpu Time Used: 4.552E+03(s)
11/ 1/13 14:12:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 5.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Charge Density
Longitudinal
Scaled Wake Potential W (S)
Distance from Bunch Head S (m)
Longitudinal Wake Min/Max= −2.017E−01/ 2.070E−01 V/pC, Loss Factor= −7.100E−02 V/pC


Imaginary Part of Longitudinal Impedance
11/ 1/13 14:12:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 5.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Imag Z_L (kΩ)
Frequency f (GHz)


Cavity Shape Input
11/ 1/13 16:19:26
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
DDZ= 2.000 mm, DDR= 2.000 mm
R−axis (m)
0.15
0.10
0.05
0
0
0.05
0.10
0.15
0.20
0.25
Z−axis (m)

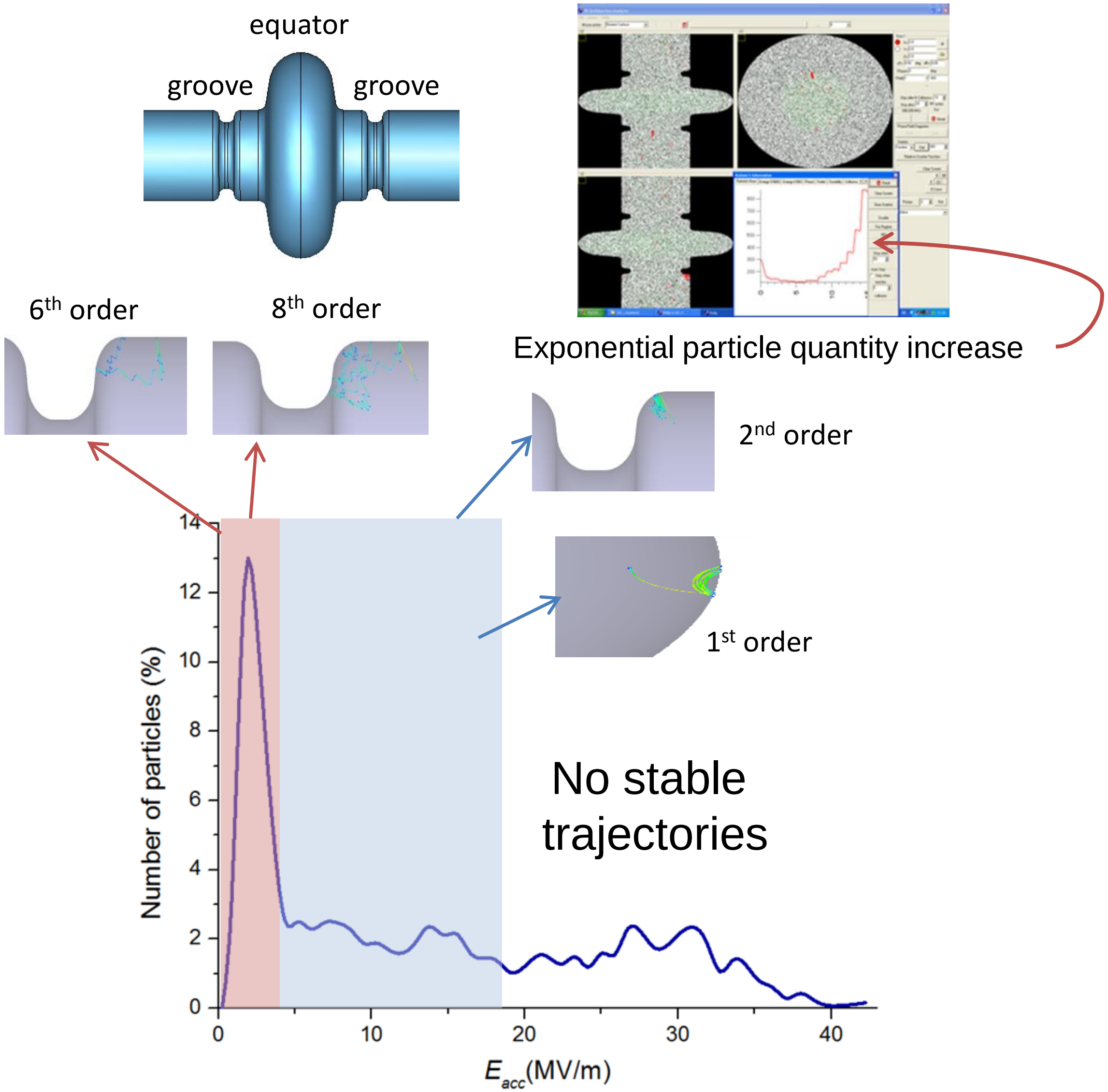

Real Part of Transverse Impedance
9/ 1/13 14:15:51
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 5.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Real Z_T (kΩ/m)
30
25
20
15
10
5
0
0
0.5
1.0
1.5
2.0
Frequency f (GHz)
Fast rise
Slower decay
Cut-off H_{11}
=> 1.03 GHz


Wake Potentials
Cpu Time Used: 2.836E+03(s)
9/ 1/13 14:15:51
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 5.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Scaled Wake Potential W (S)
1.0
0.5
0
−0.5
−1.0
Charge Density
Transverse
Longitudinal
0
5
10
15
20
25
30
35
40
Distance from Bunch Head S (m)
Transverse Wake Min/Max= −2.015E+00/ 2.982E+00 V/pC/m, Loss Factor= 1.904E+00 V/pC/m
Longitudinal Wake Min/Max= −4.483E+01/ 5.113E+01 V/pC/m², Loss Factor= −1.269E+01 V/pC/m²

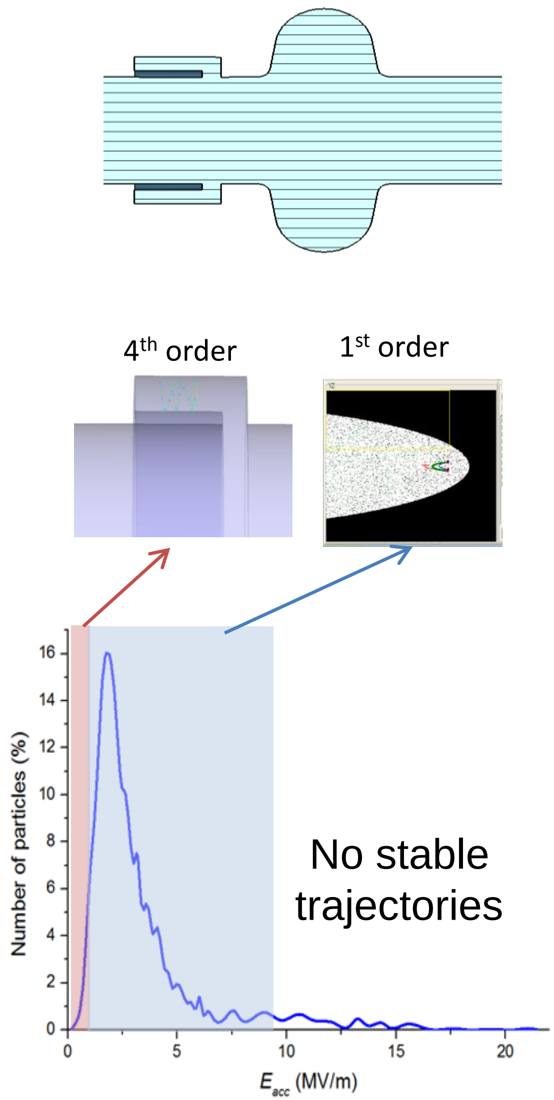

Imaginary Part of Transverse Impedance
9/ 1/13 14:15:51
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 5.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Imag Z_T (kΩ/m)
15
10
5
0
−5
−10
−15
0
0.5
1.0
1.5
2.0
Frequency f (GHz)

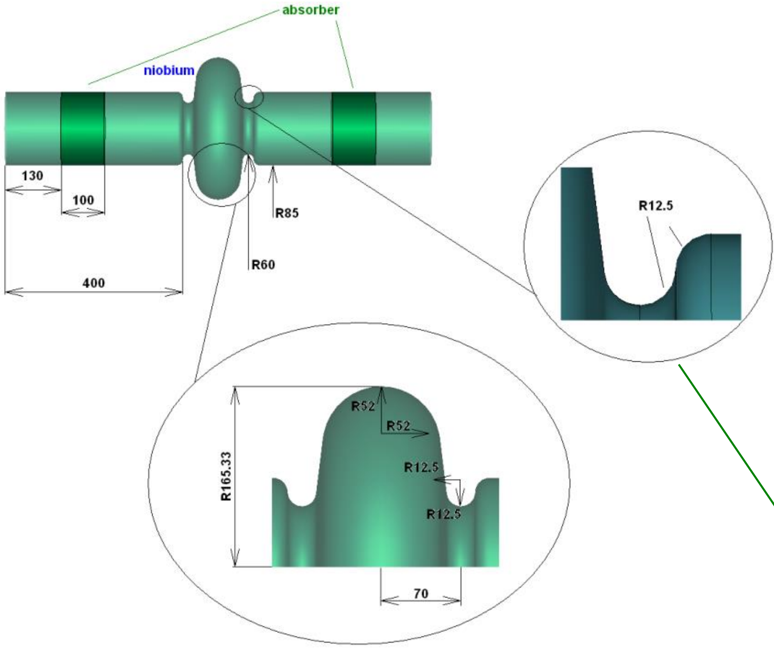
Multipacting simulations for the SC cavities – MultP-M code

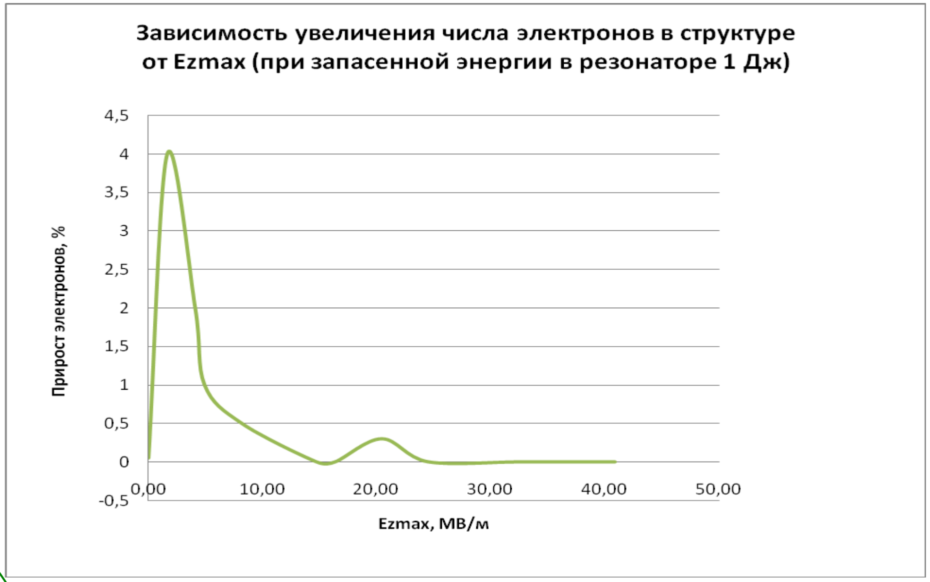
Cavity with grooves on the drift tubes

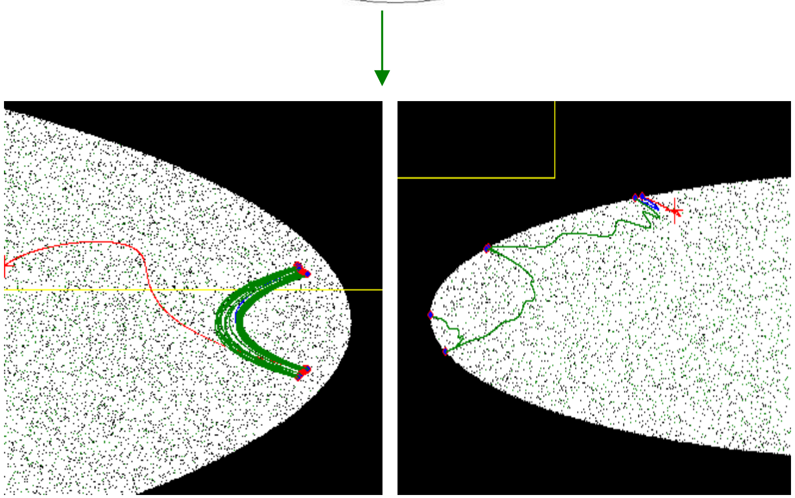


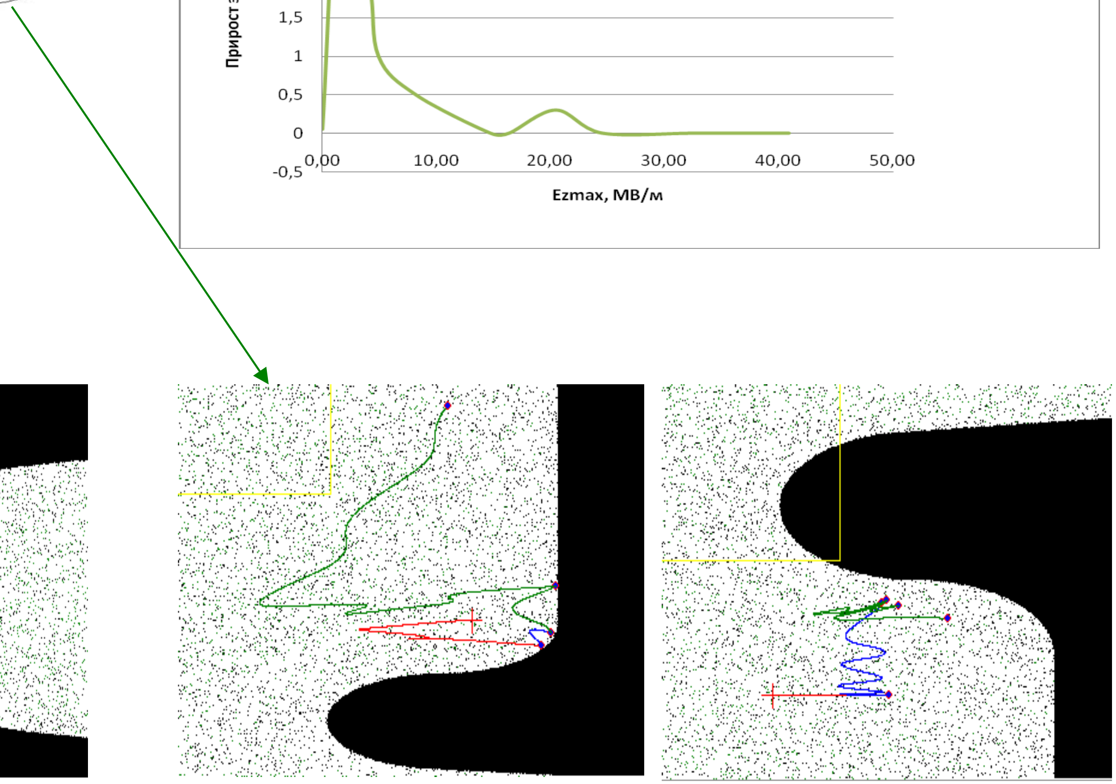
Cavity with the notch filter







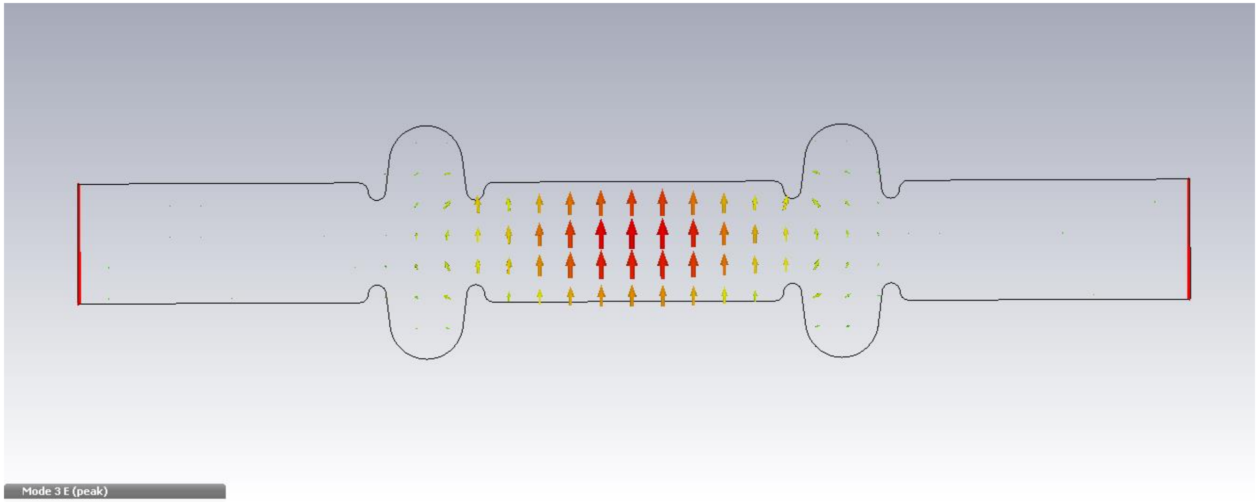


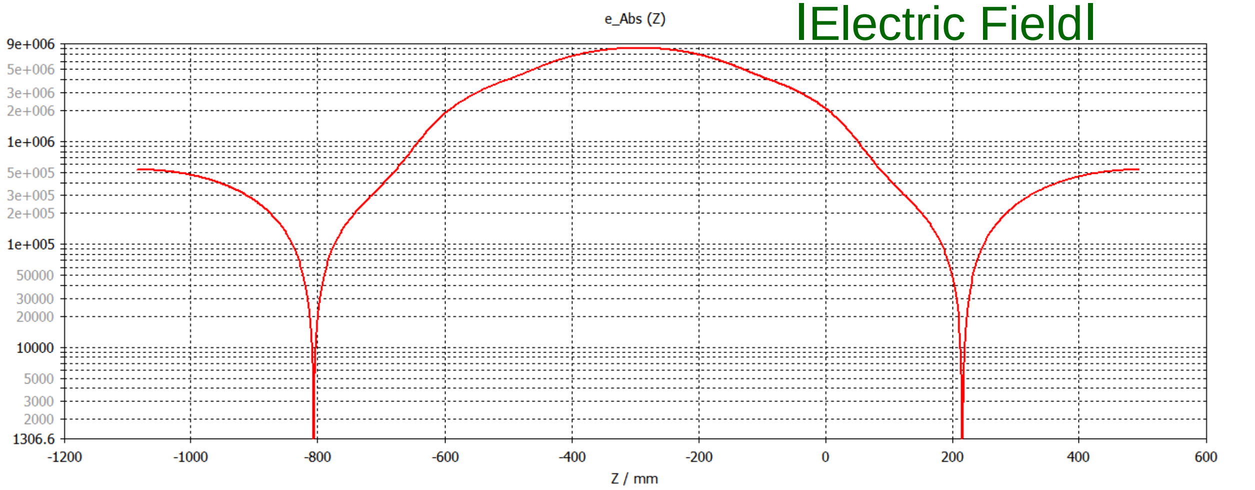


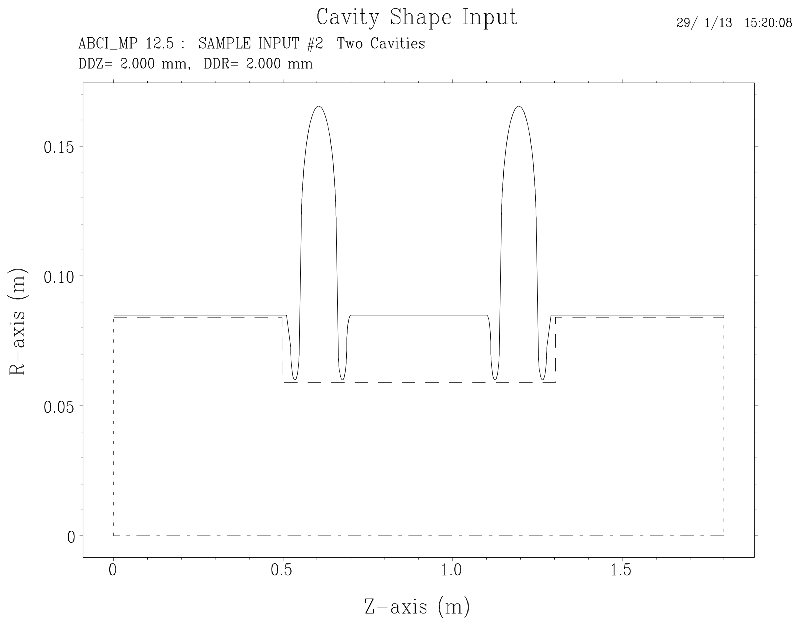
Possible multipacting for E_z in the range from 1.7-7 MV/m

No stable trajectories are found

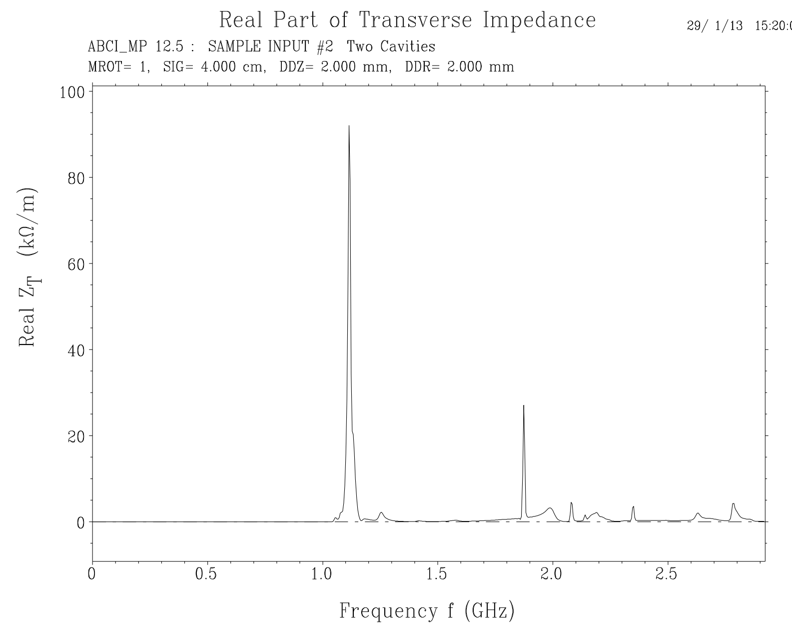
TE_{111} at 1068 MHz



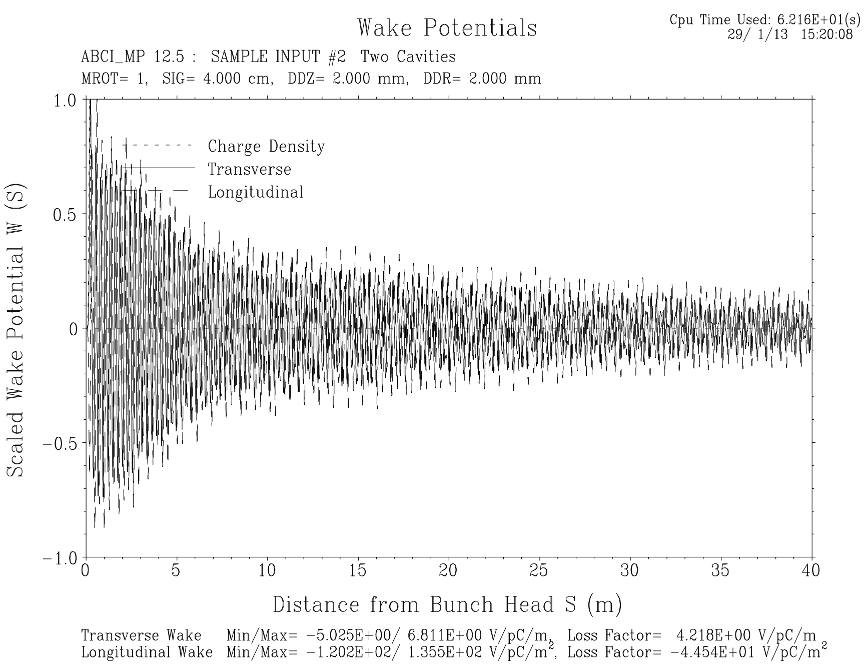




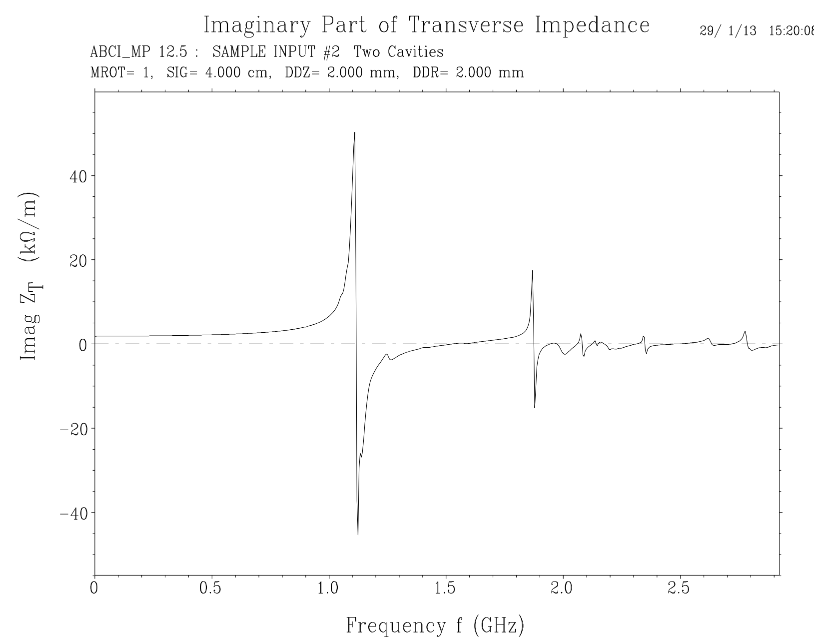
Cavity Shape Input
29/ 1/13 15:20:08
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
DDZ= 2.000 mm, DDR= 2.000 mm
R-axis (m)
Z-axis (m)



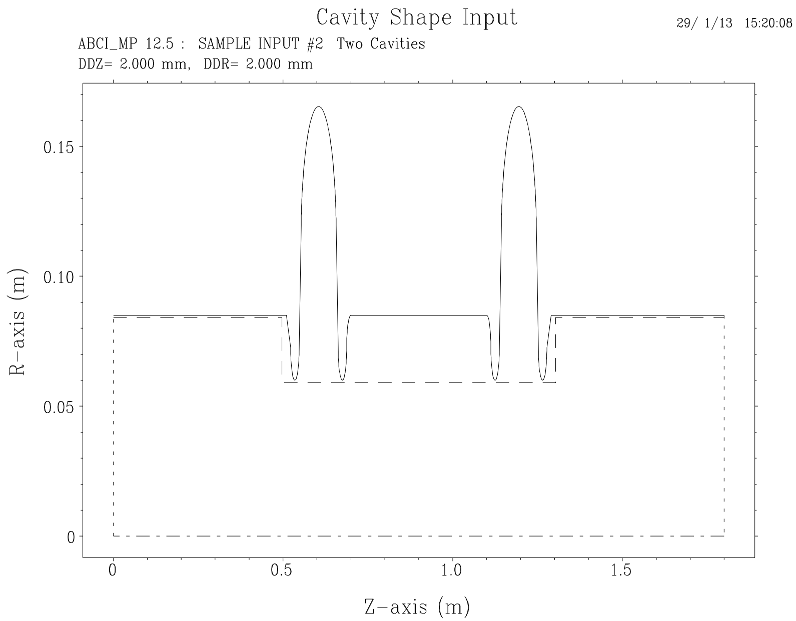
Real Part of Transverse Impedance
29/ 1/13 15:20:08
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
MROT= 1, SIG= 4.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Real Z_T (kΩ/m)
Frequency f (GHz)

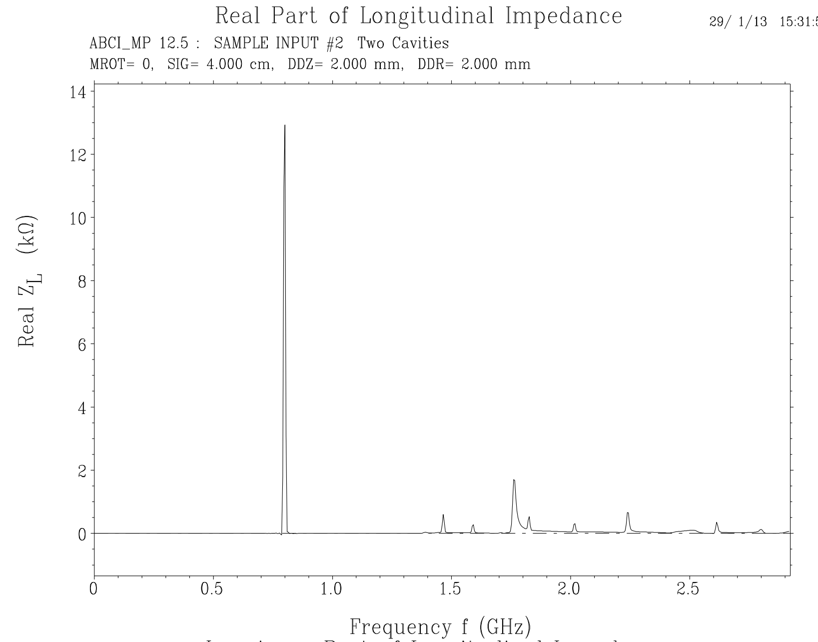


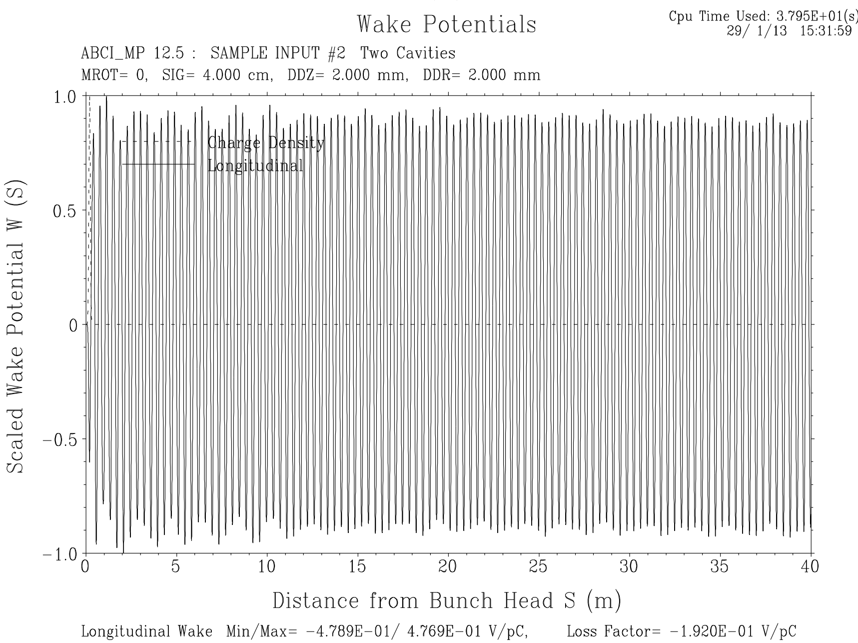
Wake Potentials
Cpu Time Used: 6.216E+01(s)
29/ 1/13 15:20:08
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
MROT= 1, SIG= 4.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Charge Density
Transverse
Longitudinal
Scaled Wake Potential W (S)
Distance from Bunch Head S (m)
Transverse Wake Min/Max= −5.025E+00/ 6.811E+00 V/pC/m, Loss Factor= 4.218E+00 V/pC/m
Longitudinal Wake Min/Max= −1.202E+02/ 1.355E+02 V/pC/m², Loss Factor= −4.454E+01 V/pC/m²

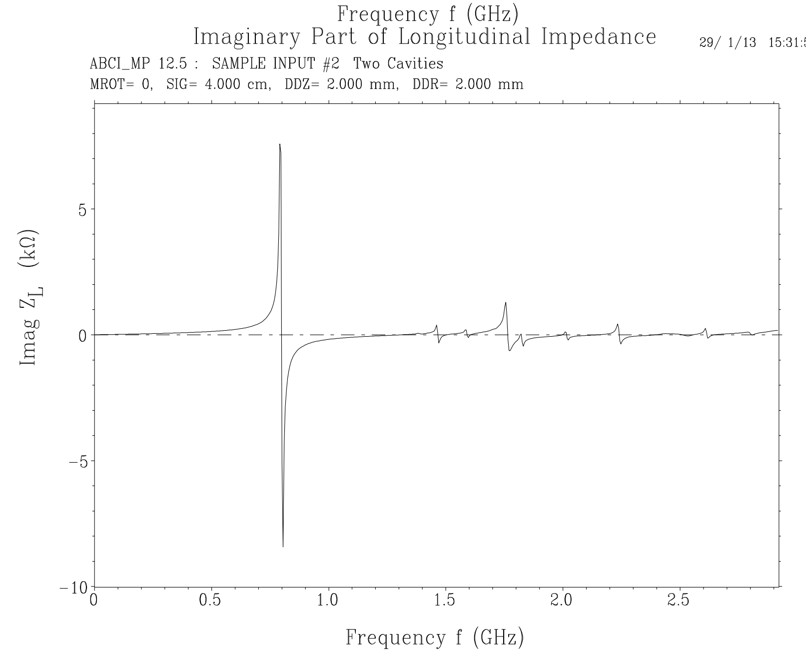


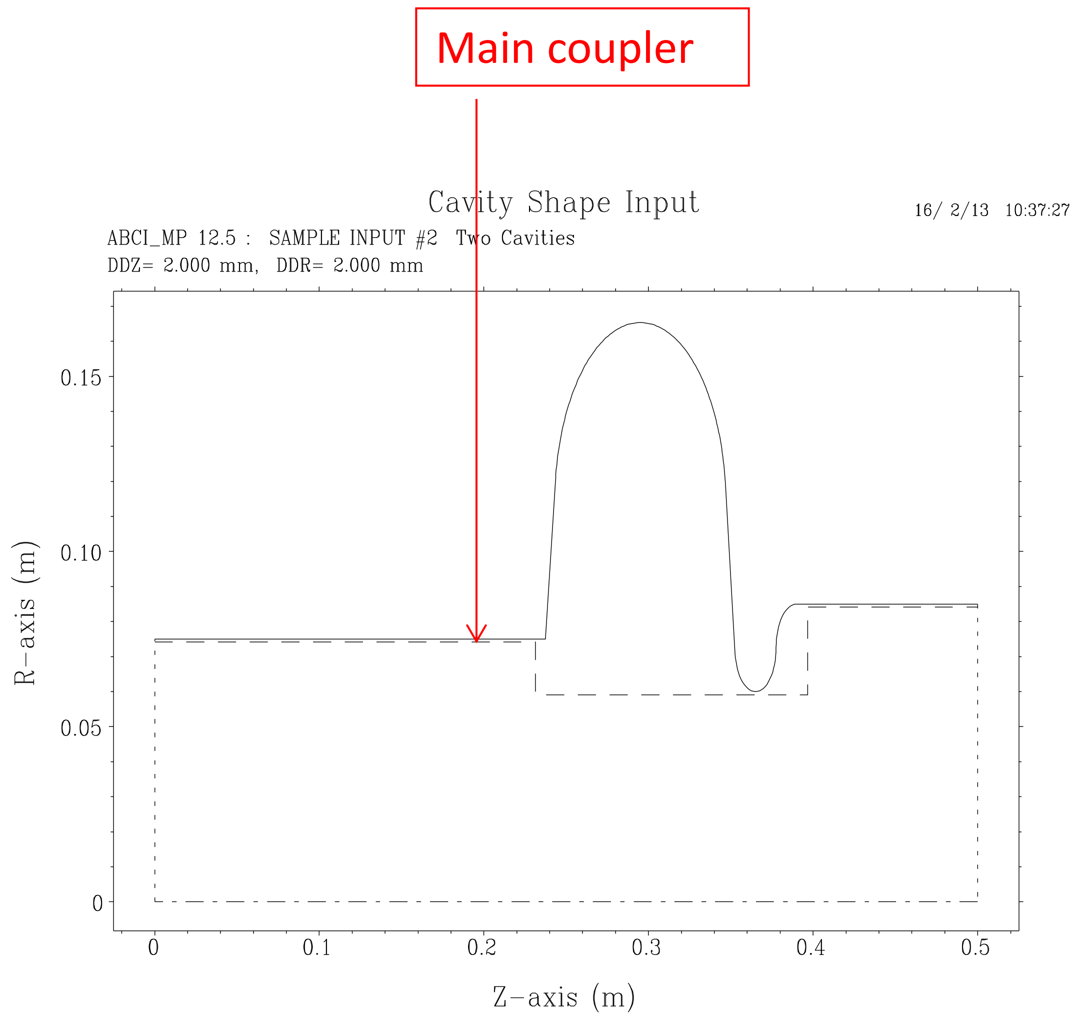
Imaginary Part of Transverse Impedance
29/ 1/13 15:20:08
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
MROT= 1, SIG= 4.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Imag Z_T (kΩ/m)
Frequency f (GHz)


Cavity Shape Input
29/ 1/13 15:20:08
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
DDZ= 2.000 mm, DDR= 2.000 mm
R-axis (m)
Z-axis (m)
0.15
0.10
0.05
0
0
0.5
1.0
1.5

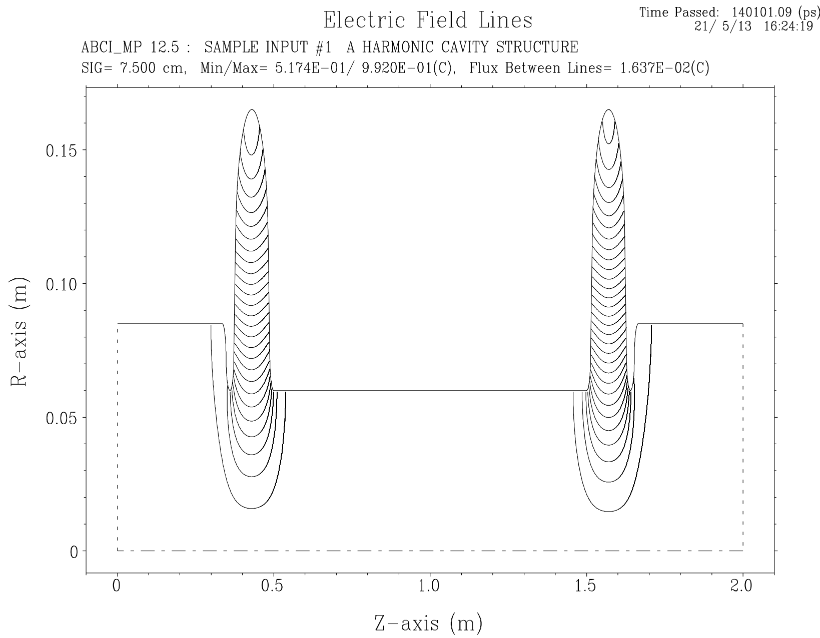

Real Part of Longitudinal Impedance
29/ 1/13 15:31:59
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
MROT= 0, SIG= 4.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Real Z_L (kΩ)
Frequency f (GHz)
14
12
10
8
6
4
2
0
0
0.5
1.0
1.5
2.0
2.5

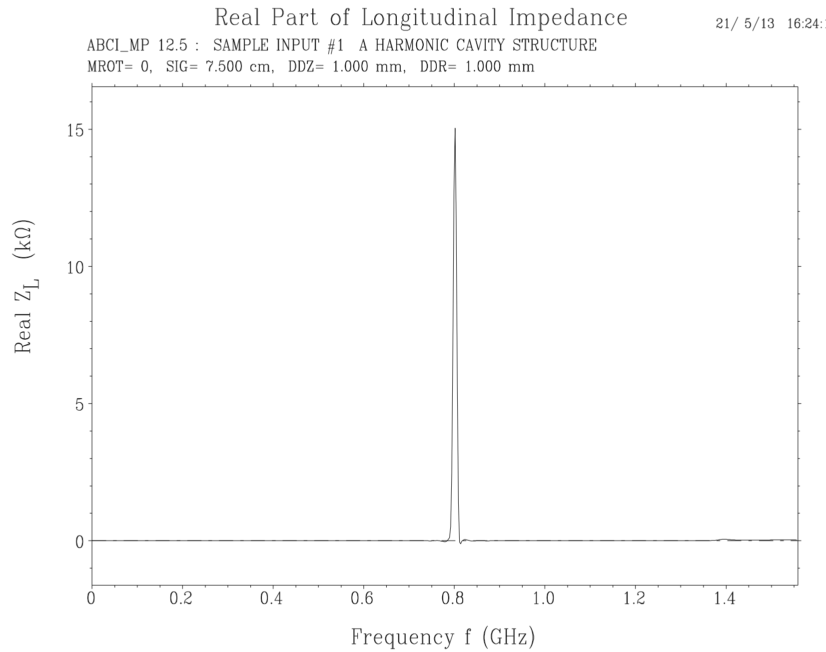

Wake Potentials
Cpu Time Used: 3.795E+01(s)
29/ 1/13 15:31:59
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
MROT= 0, SIG= 4.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Charge Density
Longitudinal
Scaled Wake Potential W (S)
Distance from Bunch Head S (m)
1.0
0.5
0
−0.5
−1.0
0
5
10
15
20
25
30
35
40
Longitudinal Wake Min/Max= -4.789E-01/ 4.769E-01 V/pC, Loss Factor= -1.920E-01 V/pC

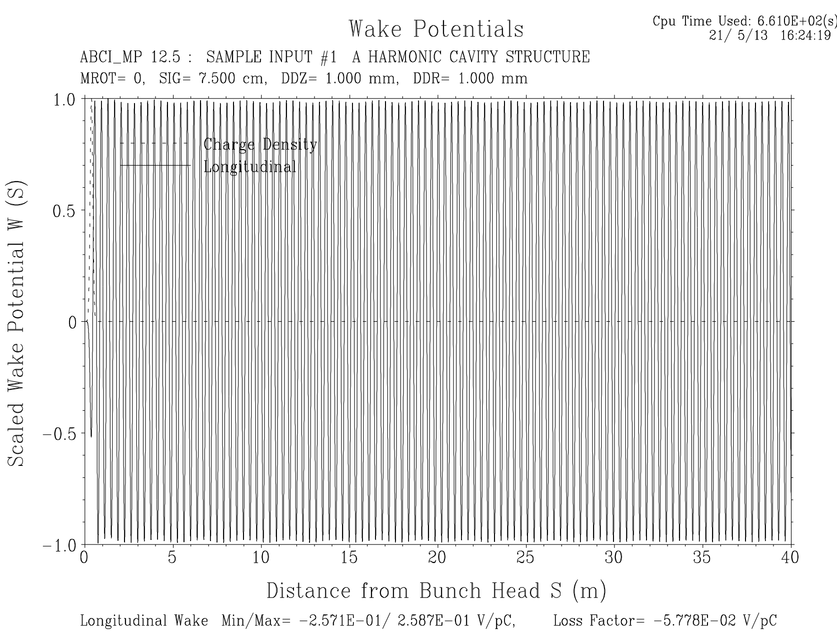

Imaginary Part of Longitudinal Impedance
29/ 1/13 15:31:59
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
MROT= 0, SIG= 4.000 cm, DDZ= 2.000 mm, DDR= 2.000 mm
Imag Z_L (kΩ)
Frequency f (GHz)
5
0
−5
−10
0
0.5
1.0
1.5
2.0
2.5

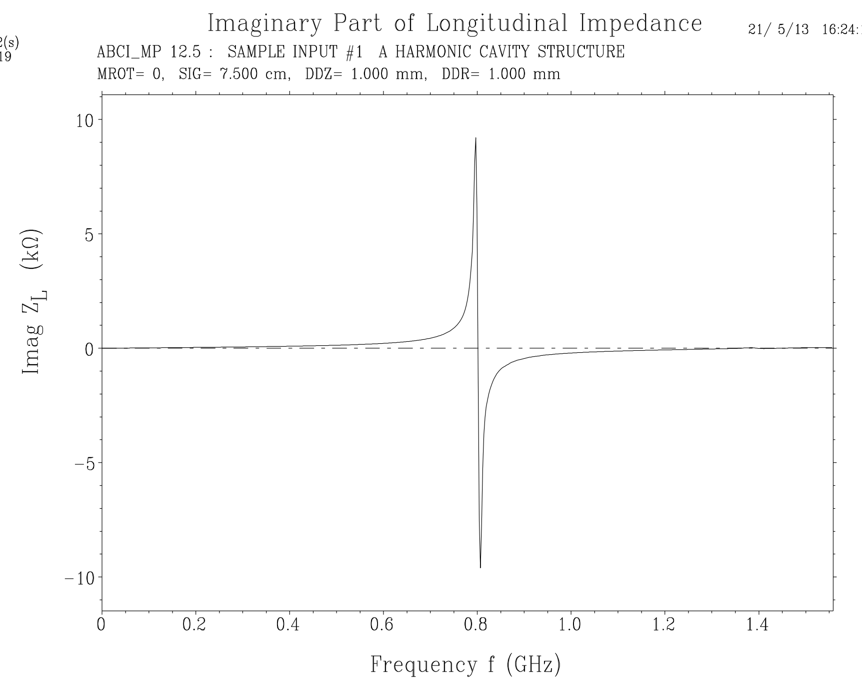


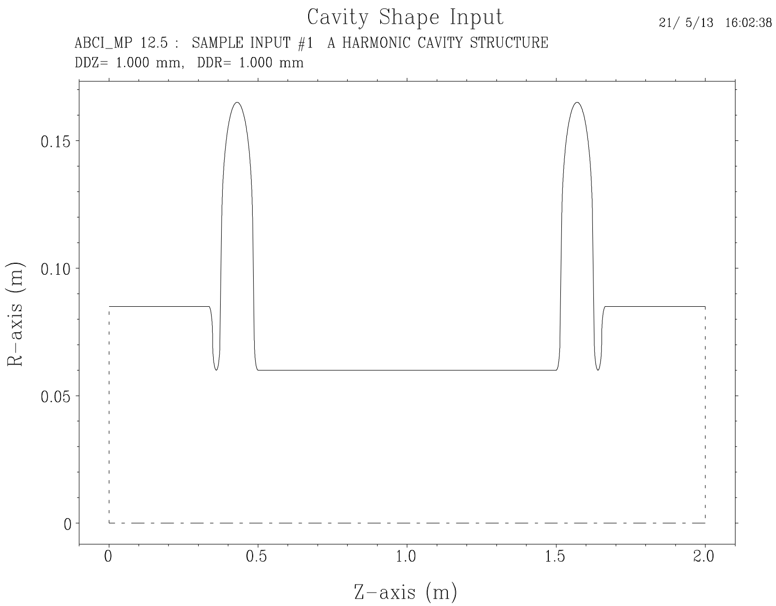
Main coupler
Cavity Shape Input
16/ 2/13 10:37:27
ABCI_MP 12.5 : SAMPLE INPUT #2 Two Cavities
DDZ= 2.000 mm, DDR= 2.000 mm
R−axis (m)
0.15
0.10
0.05
0
0.1
0.2
0.3
0.4
0.5
Z−axis (m)


Electric Field Lines
Time Passed: 140101.09 (ps)
21/ 5/13 16:24:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
SIG= 7.500 cm, Min/Max= 5.174E-01/ 9.920E-01(C), Flux Between Lines= 1.637E-02(C)
R-axis (m)
0.15
0.10
0.05
0
0
0.5
1.0
1.5
2.0
Z-axis (m)

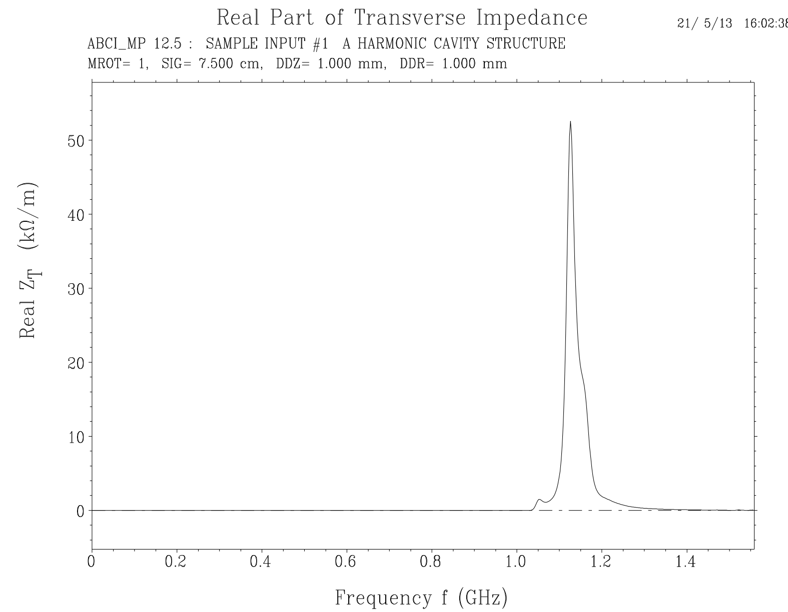

Real Part of Longitudinal Impedance
21/ 5/13 16:24:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Real Z_L (kΩ)
15
10
5
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Frequency f (GHz)


Wake Potentials
Cpu Time Used: 6.610E+02(s)
21/ 5/13 16:24:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Charge Density
Longitudinal
Scaled Wake Potential W (S)
1.0
0.5
0
−0.5
−1.0
0
5
10
15
20
25
30
35
40
Distance from Bunch Head S (m)
Longitudinal Wake Min/Max= −2.571E−01/ 2.587E−01 V/pC, Loss Factor= −5.778E−02 V/pC

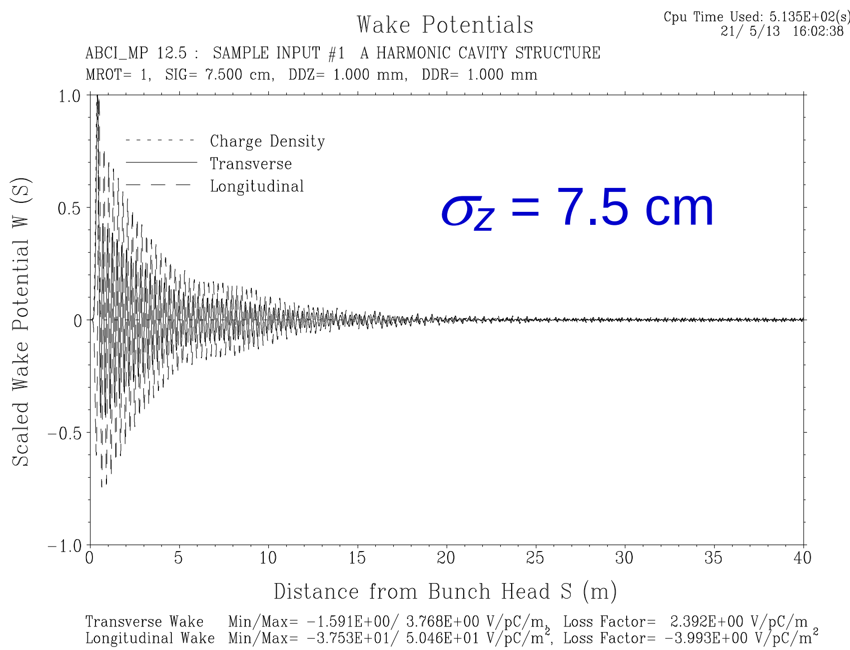

Imaginary Part of Longitudinal Impedance
21/ 5/13 16:24:19
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Imag Z_L (kΩ)
10
5
0
−5
−10
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Frequency f (GHz)



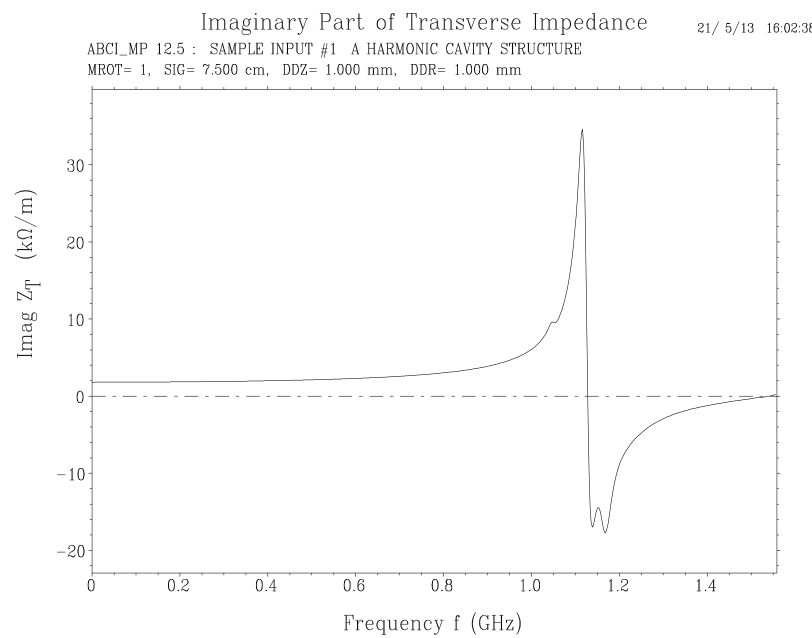
Cavity Shape Input
21/ 5/13 16:02:38
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
DDZ= 1.000 mm, DDR= 1.000 mm
R-axis (m)
Z-axis (m)



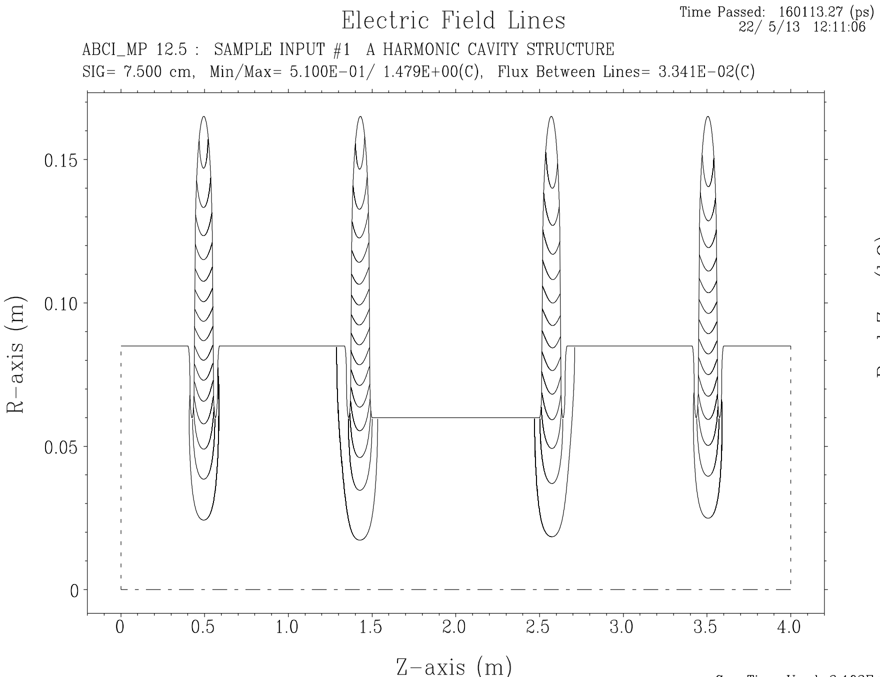
Real Part of Transverse Impedance
21/ 5/13 16:02:38
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Real Z_T (kΩ/m)
Frequency f (GHz)

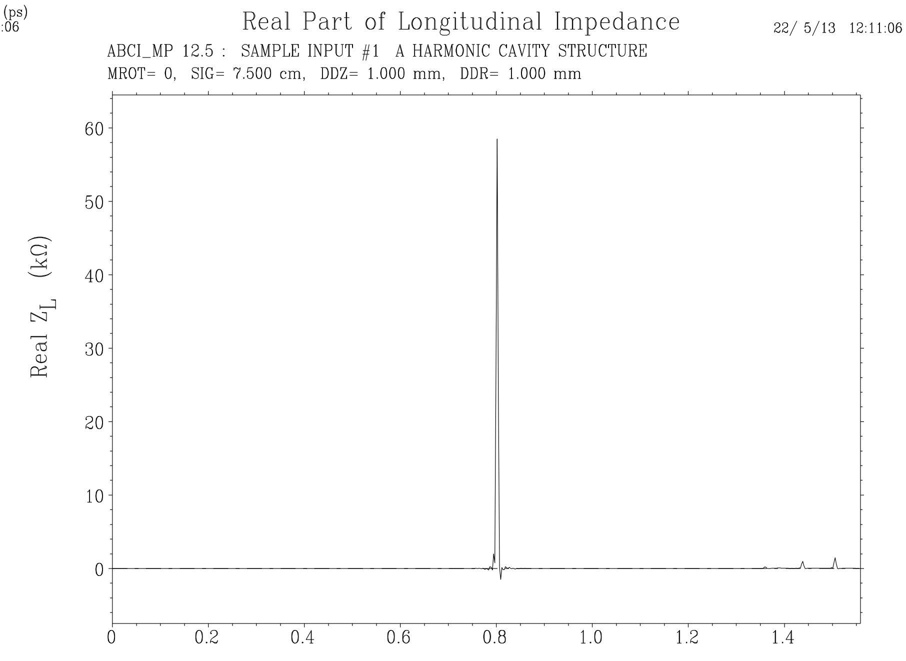


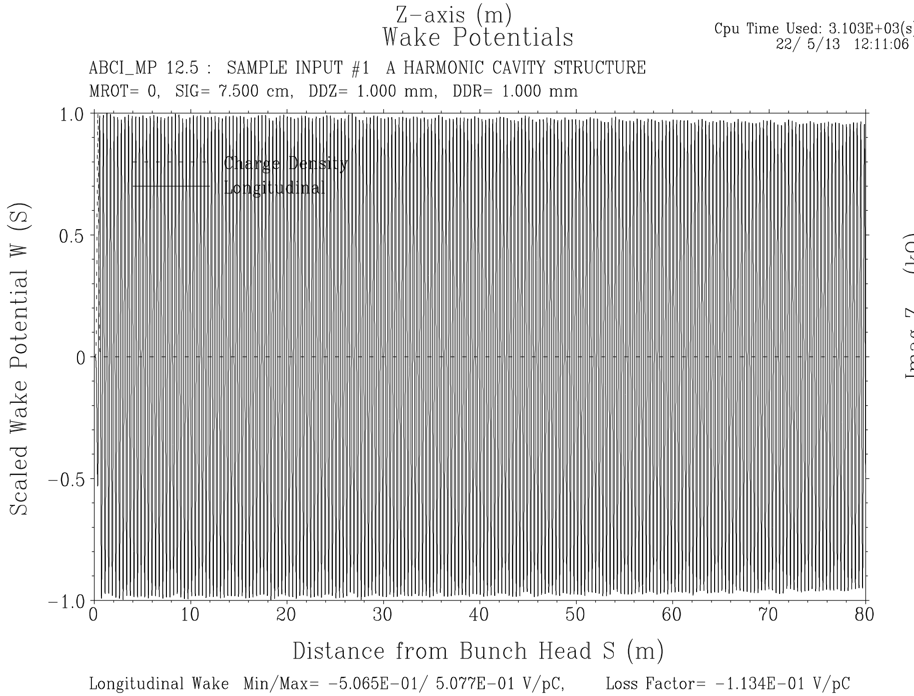
Wake Potentials
Cpu Time Used: 5.135E+02(s)
21/ 5/13 16:02:38
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Charge Density
Transverse
Longitudinal
σ_Z = 7.5 cm
Scaled Wake Potential W (S)
Distance from Bunch Head S (m)
Transverse Wake Min/Max= −1.591E+00/ 3.768E+00 V/pC/m, Loss Factor= 2.392E+00 V/pC/m
Longitudinal Wake Min/Max= −3.753E+01/ 5.046E+01 V/pC/m², Loss Factor= −3.993E+00 V/pC/m²

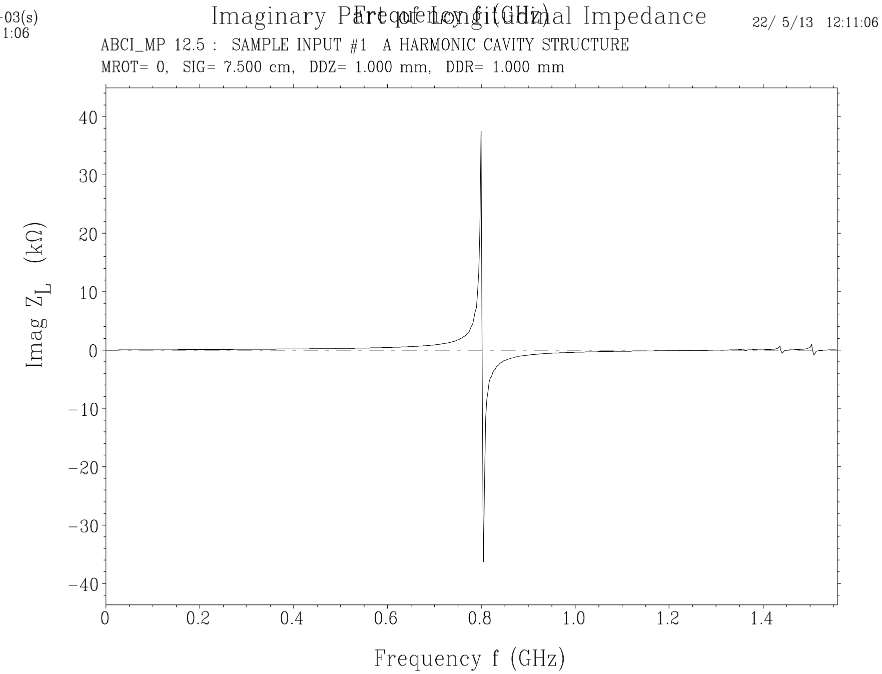


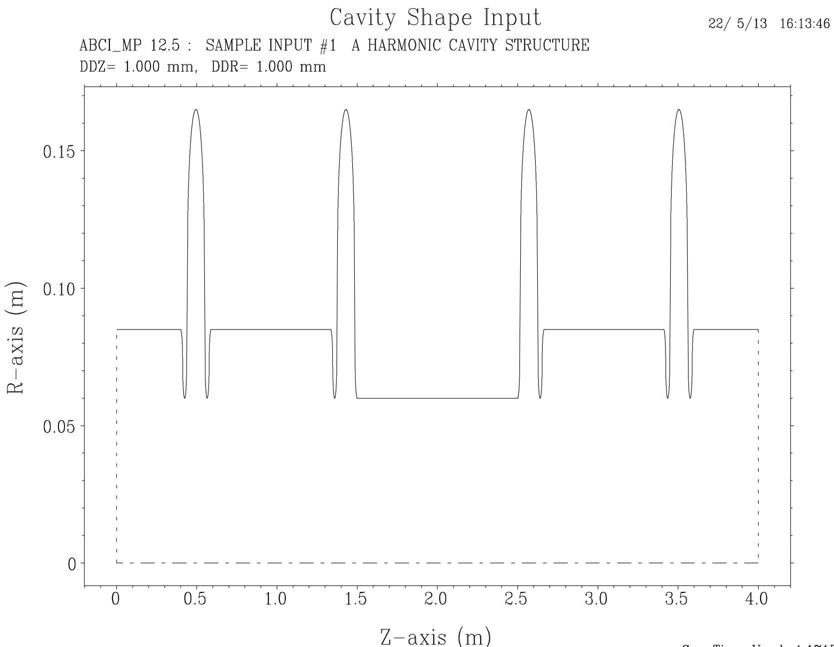
Imaginary Part of Transverse Impedance
21/ 5/13 16:02:38
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Imag Z_T (kΩ/m)
Frequency f (GHz)

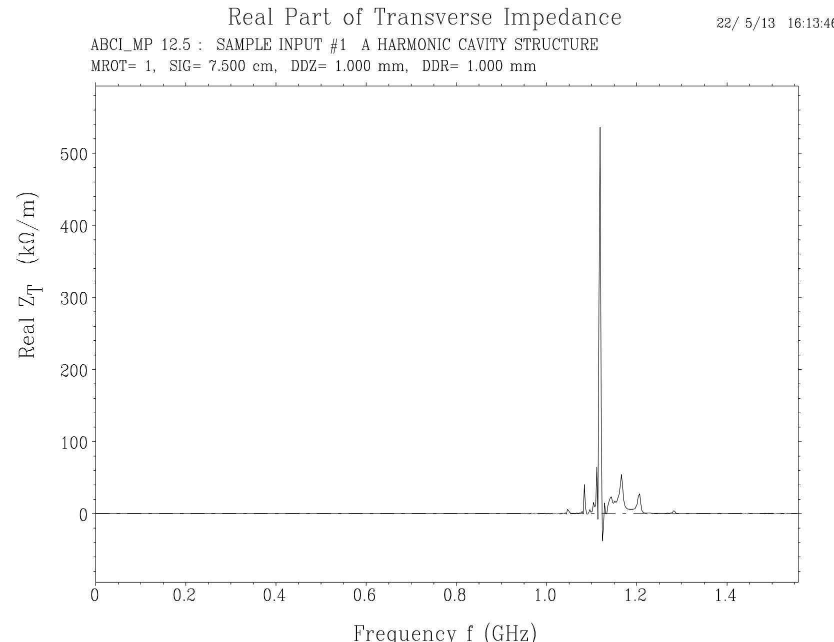

Electric Field Lines
Time Passed: 160113.27 (ps)
22/ 5/13 12:11:06
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
SIG= 7.500 cm, Min/Max= 5.100E-01/ 1.479E+00(C), Flux Between Lines= 3.341E-02(C)
R-axis (m)
0.15
0.10
0.05
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Z-axis (m)

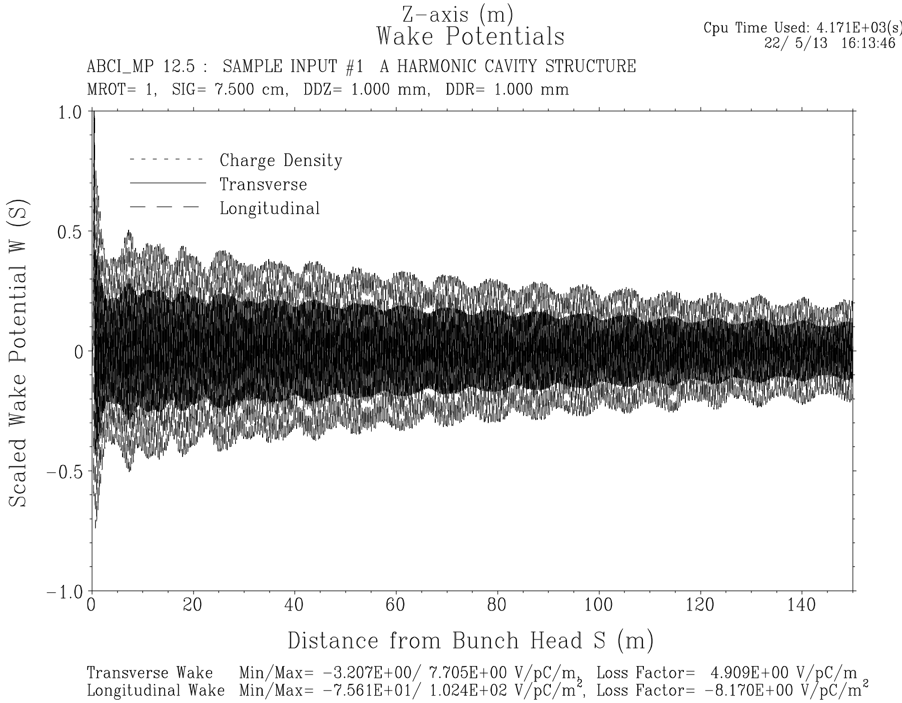

Real Part of Longitudinal Impedance
22/ 5/13 12:11:06
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Real Z_L (kΩ)
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Frequency f (GHz)

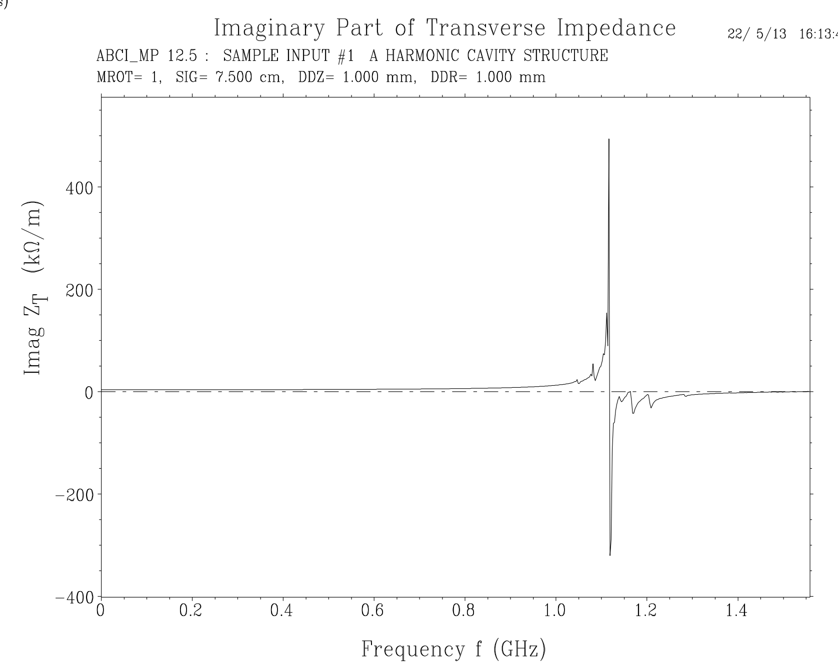

Wake Potentials
Cpu Time Used: 3.103E+03(s)
22/ 5/13 12:11:06
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Charge Density
Longitudinal
Scaled Wake Potential W (S)
1.0
0.5
0
−0.5
−1.0
0
10
20
30
40
50
60
70
80
Distance from Bunch Head S (m)
Longitudinal Wake Min/Max= −5.065E−01/ 5.077E−01 V/pC, Loss Factor= −1.134E−01 V/pC


Imaginary Part of Longitudinal Impedance
22/ 5/13 12:11:06
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 0, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Imag Z_L (kΩ)
40
30
20
10
0
−10
−20
−30
−40
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Frequency f (GHz)

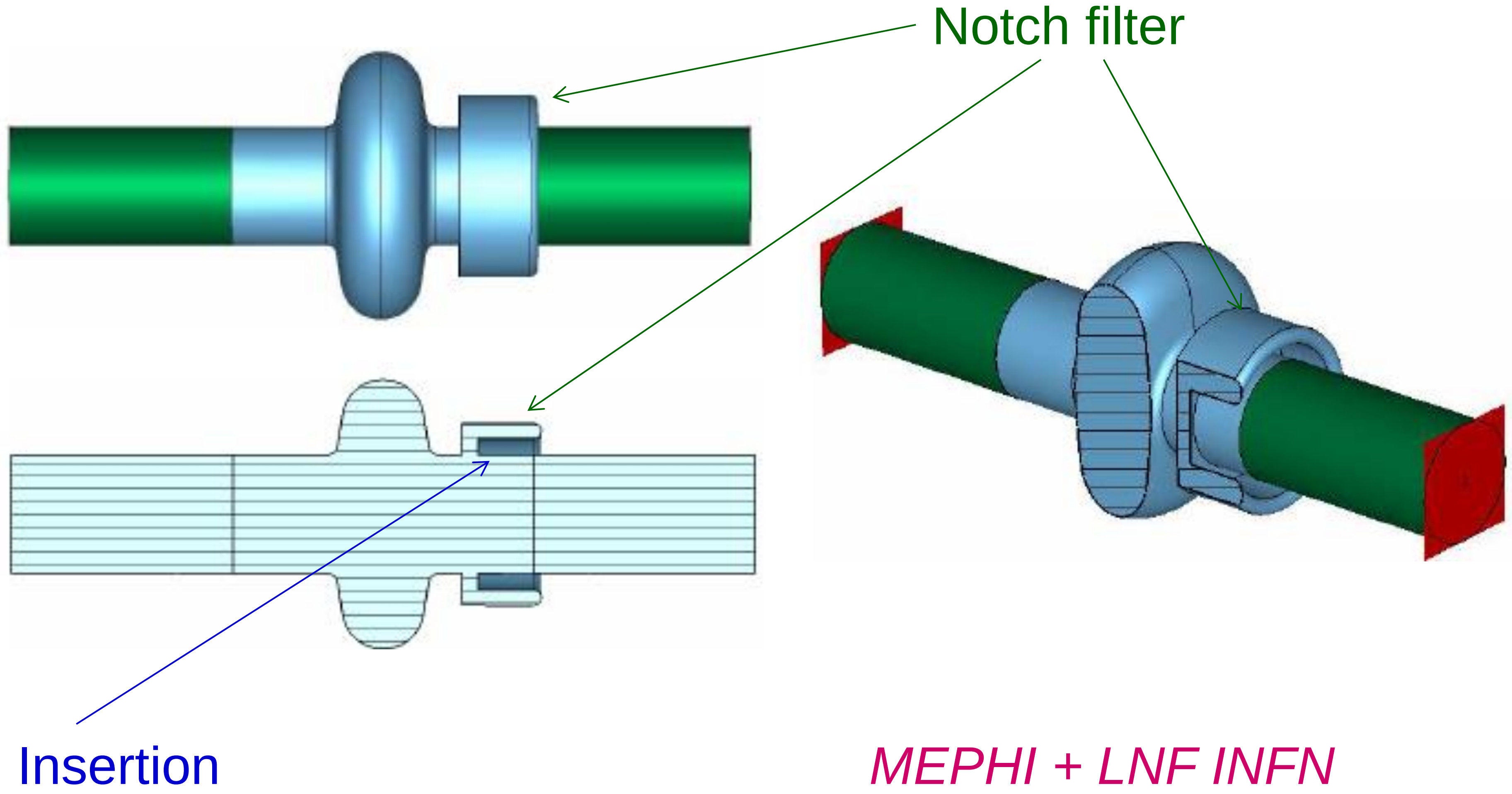

Cavity Shape Input
22/ 5/13 16:13:46
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
DDZ= 1.000 mm, DDR= 1.000 mm
R-axis (m)
Z-axis (m)
0.15
0.10
0.05
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0


Real Part of Transverse Impedance
22/ 5/13 16:13:46
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Real Z_T (kΩ/m)
Frequency f (GHz)
500
400
300
200
100
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4


Wake Potentials
Cpu Time Used: 4.171E+03(s)
22/ 5/13 16:13:46
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Charge Density
Transverse
Longitudinal
Scaled Wake Potential W (S)
Distance from Bunch Head S (m)
1.0
0.5
0
−0.5
−1.0
20
40
60
80
100
120
140
Transverse Wake Min/Max= −3.207E+00/ 7.705E+00 V/pC/m, Loss Factor= 4.909E+00 V/pC/m
Longitudinal Wake Min/Max= −7.561E+01/ 1.024E+02 V/pC/m², Loss Factor= −8.170E+00 V/pC/m²


Imaginary Part of Transverse Impedance
22/ 5/13 16:13:46
ABCI_MP 12.5 : SAMPLE INPUT #1 A HARMONIC CAVITY STRUCTURE
MROT= 1, SIG= 7.500 cm, DDZ= 1.000 mm, DDR= 1.000 mm
Imag Z_T (kΩ/m)
Frequency f (GHz)
400
200
0
−200
−400
0.2
0.4
0.6
0.8
1.0
1.2
1.4

Cavity with highly resistive insertion and notch filter



USING A RESISTIVE MATERIAL FOR HOM DAMPING*

Valery Shemelin# and Sergey Belomestnykh
CLASSE, Cornell University, Ithaca, NY 14853, U.S.A.

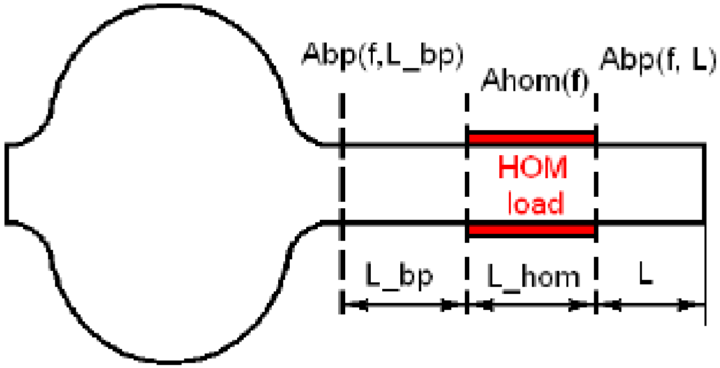
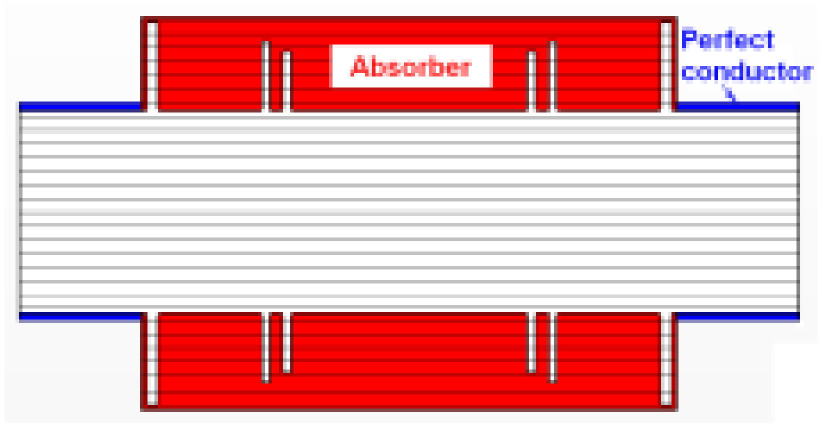


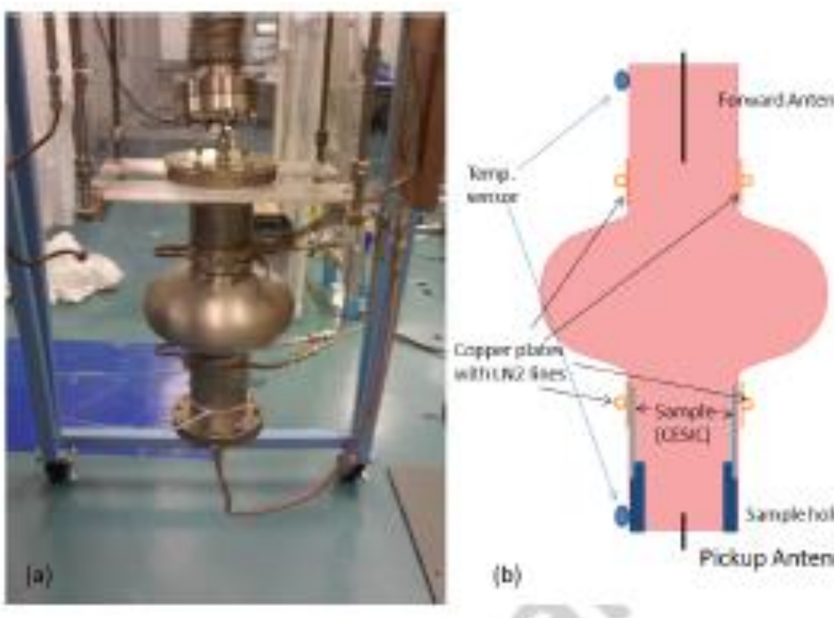
Figure 4: A cavity connected to a beam-line HOM load.

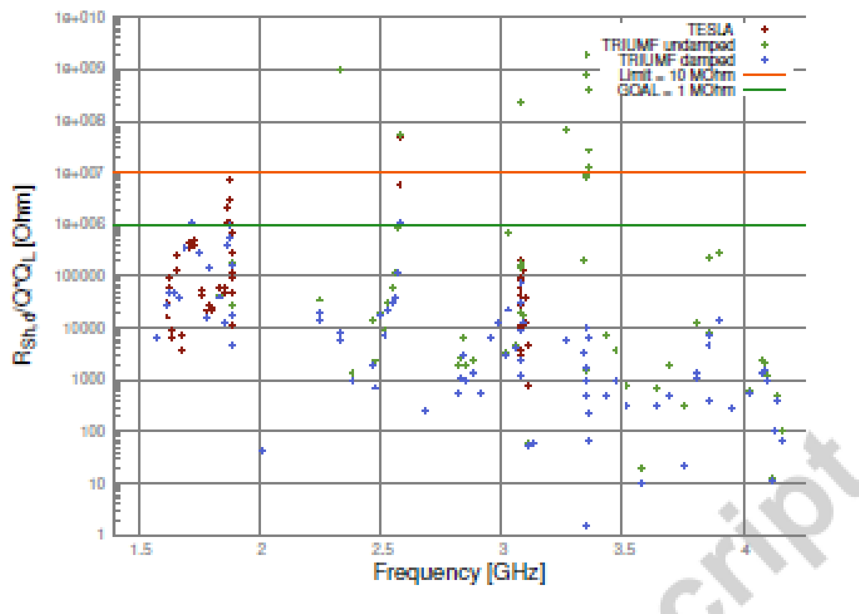


Cold Tests of HOM Absorber Material for the ARIEL eLINAC at TRIUMF

P. Kolb[a,b], R.E. Laxdal[a], V. Zvyagintsev[a], Y.C. Chao[a], B. Amini[a,b]

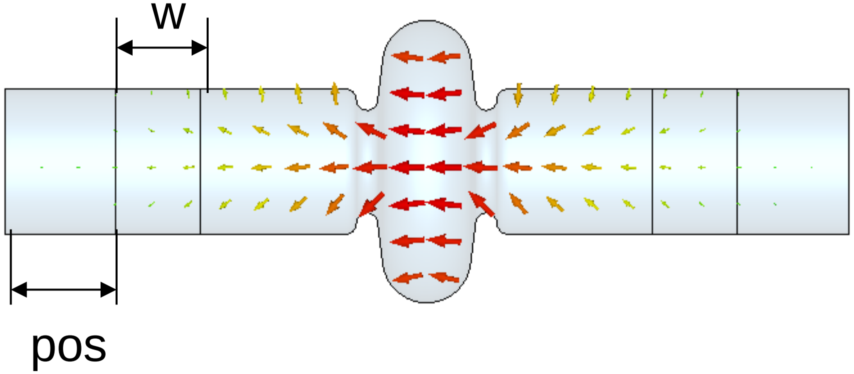
[a]*TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, 4004 Wesbrook Mall, Vancouver, B.C., V6T 2A3, Canada*
[b]*University of British Columbia, Department of Physics and Astronomy, 6224 Agricultural Road, Vancouver, B.C., V6T 1Z1, Canada*

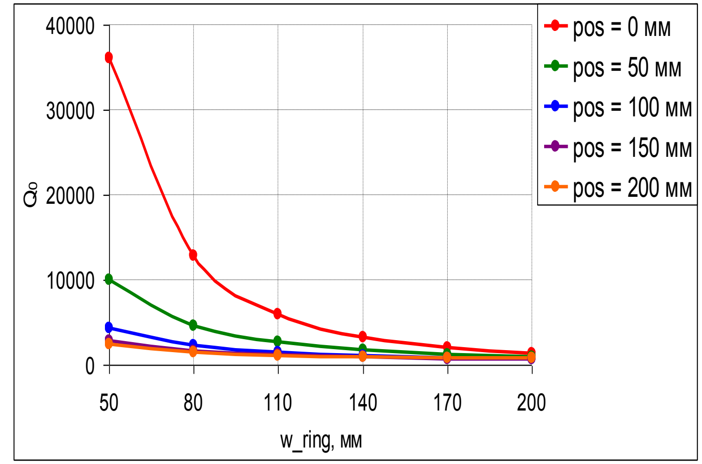




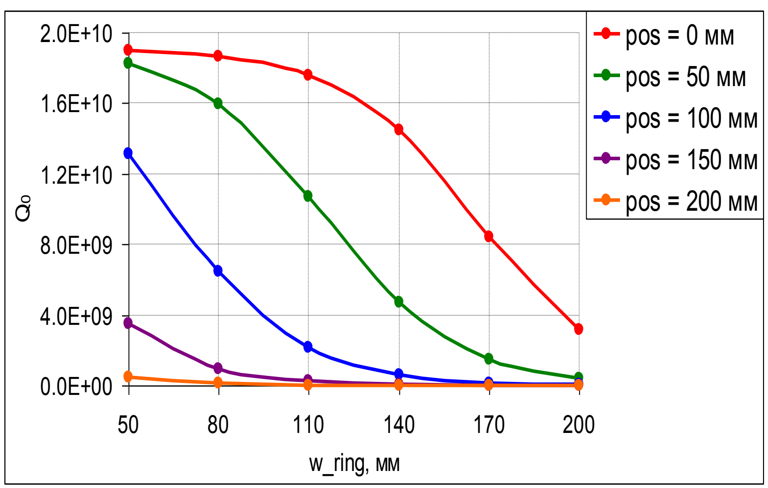
Accepted for publication in NIM

HOM Suppression with Resistive Damping Rings

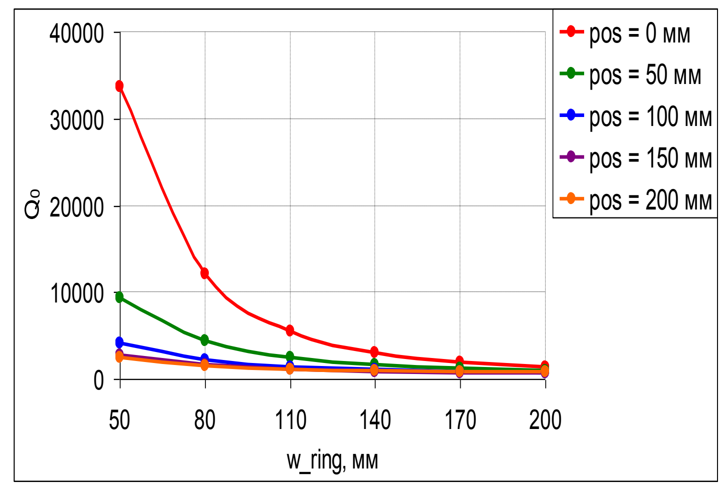




$H_{111} \rightarrow Q_0 = 1.57\text{x}10^{10}$ (w = 0 mm)



$E_{010} \rightarrow Q_0 = 1.91\text{x}10^{10}$ (w = 0 mm)



$E_{011} \rightarrow Q_0 = 1.57\text{x}10^{10}$ (w = 0 mm)

Third harmonic cavity design and RF measurements for the Frascati DAΦNE collider

David Alesini, Roberto Boni, Alessandro Gallo, Fabio Marcellini, and Mikhail Zobov
INFN Laboratori Nazionali di Frascati, P.O. Box 13, I-00044, Frascati (Roma), Italy

Mauro Migliorati and Luigi Palumbo
INFN Laboratori Nazionali di Frascati, P.O. Box 13, I-00044, Frascati (Roma), Italy
and Department Energetica, University "La Sapienza," Via Antonio Scarpa 14, 00161 Roma, Italy
(Received 19 December 2003; published 7 September 2004)

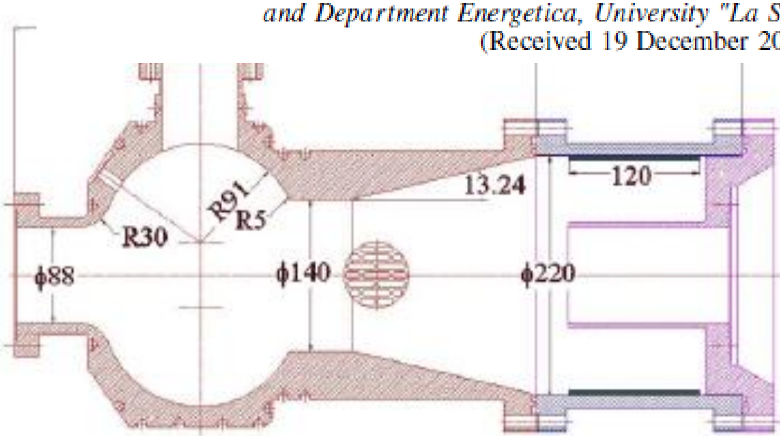


FIG. 1. (Color) Sketch of the DAΦNE third harmonic cavity.

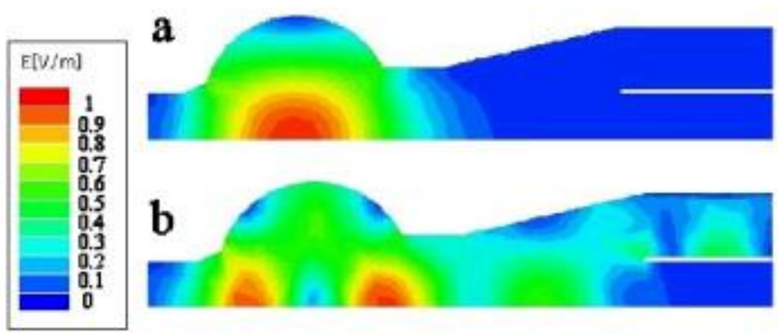


FIG. 3. (Color) Magnitude of the electric field of the working mode M_1 (a) and of the HOM M_4 (b) obtained by HFSS.

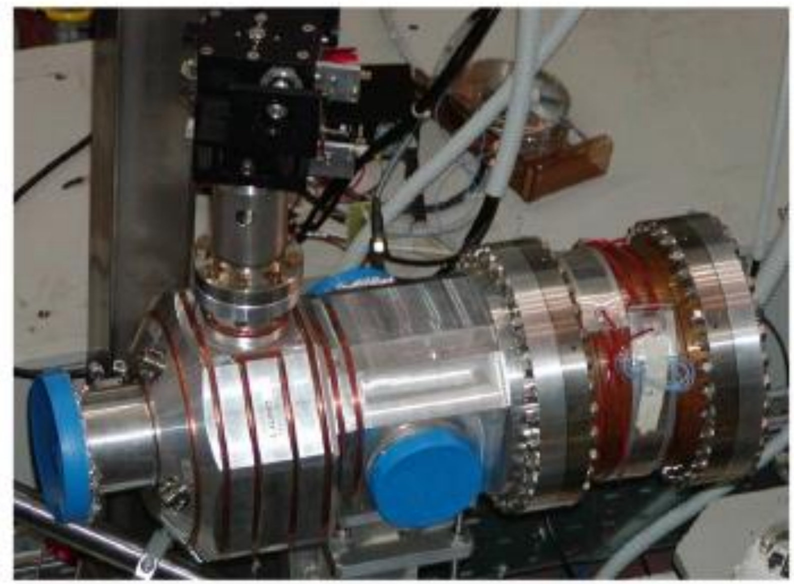
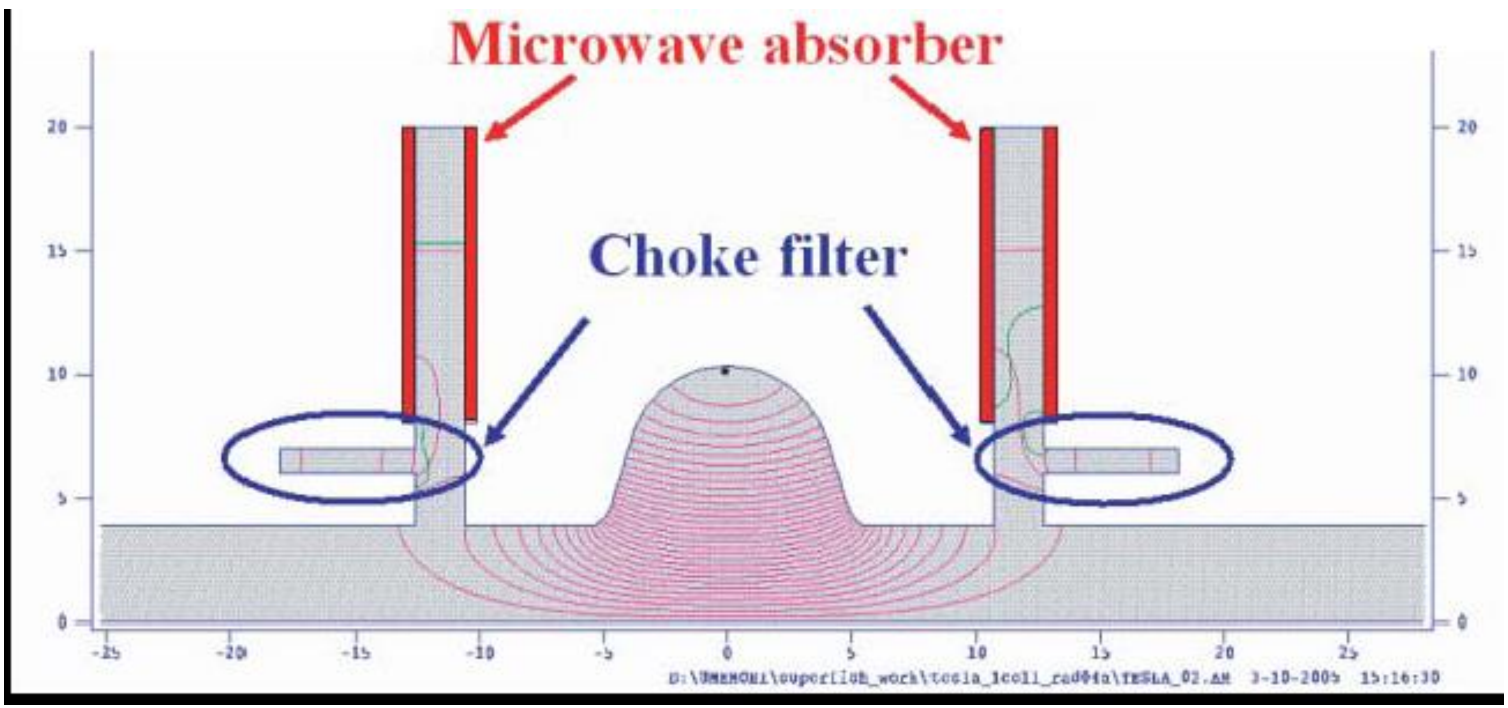


FIG. 7. (Color) Picture of the DAΦNE harmonic cavity.

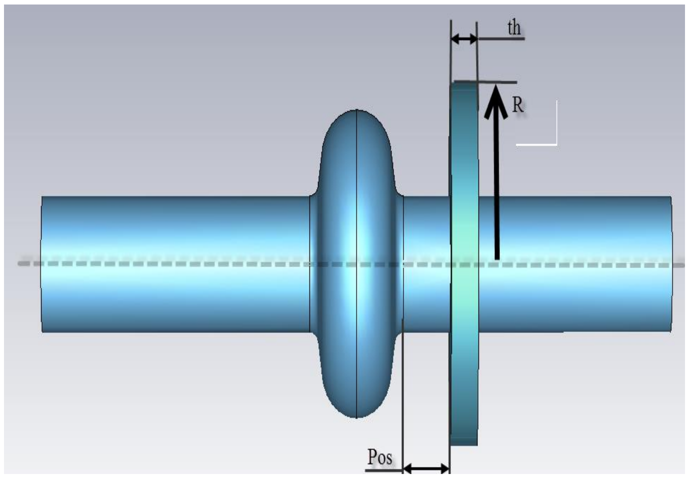
Proceedings of 2005 Particle Accelerator Conference, Knoxville, Tennessee

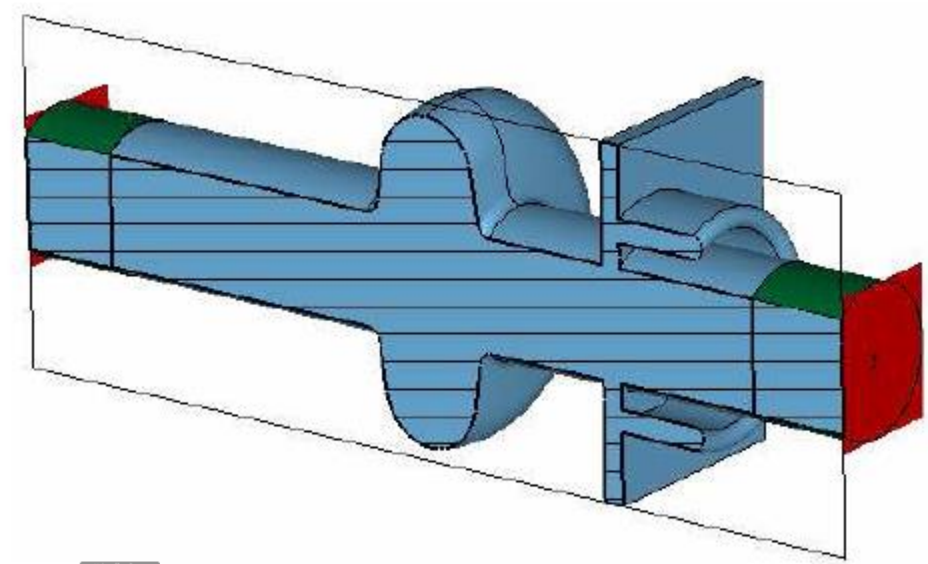
HIGHER-ORDER-MODE DAMPING OF L-BAND SUPERCONDUCTING CAVITY USING A RADIAL-LINE HOM DAMPER *

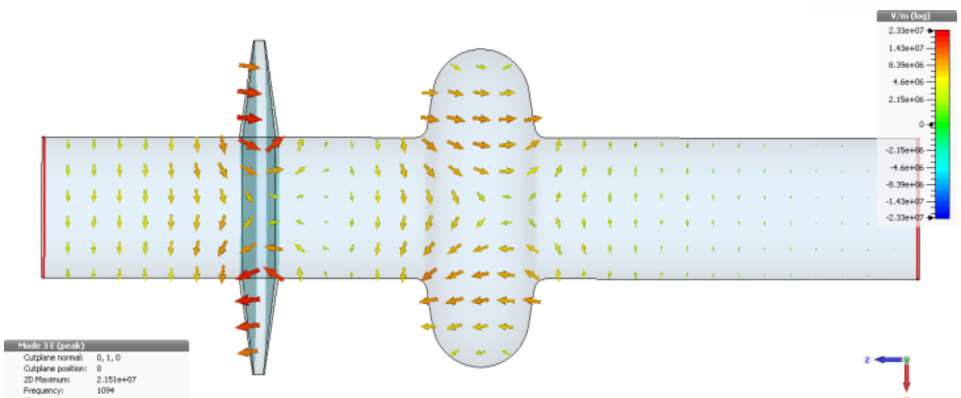
K. Umemori, M. Izawa, K. Saito, S. Sakanaka, High Energy Accelerator Research Organization(KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan



Considered Different Designs with Radial Lines







Can be effective for HOM suppression!

MEPHI + LNF INFN

Comparison of the Predicted and Measured Loss Factor of the Superconducting Cavity Assembly for the CESR Upgrade*

S. Belomestnykh†, W. Hartung, J. Kirchgessner, D. Moffat, H. Muller, H. Padamsee, and V.Veshcherevich†
Laboratory of Nuclear Studies, Cornell University, Ithaca, NY 14853 USA

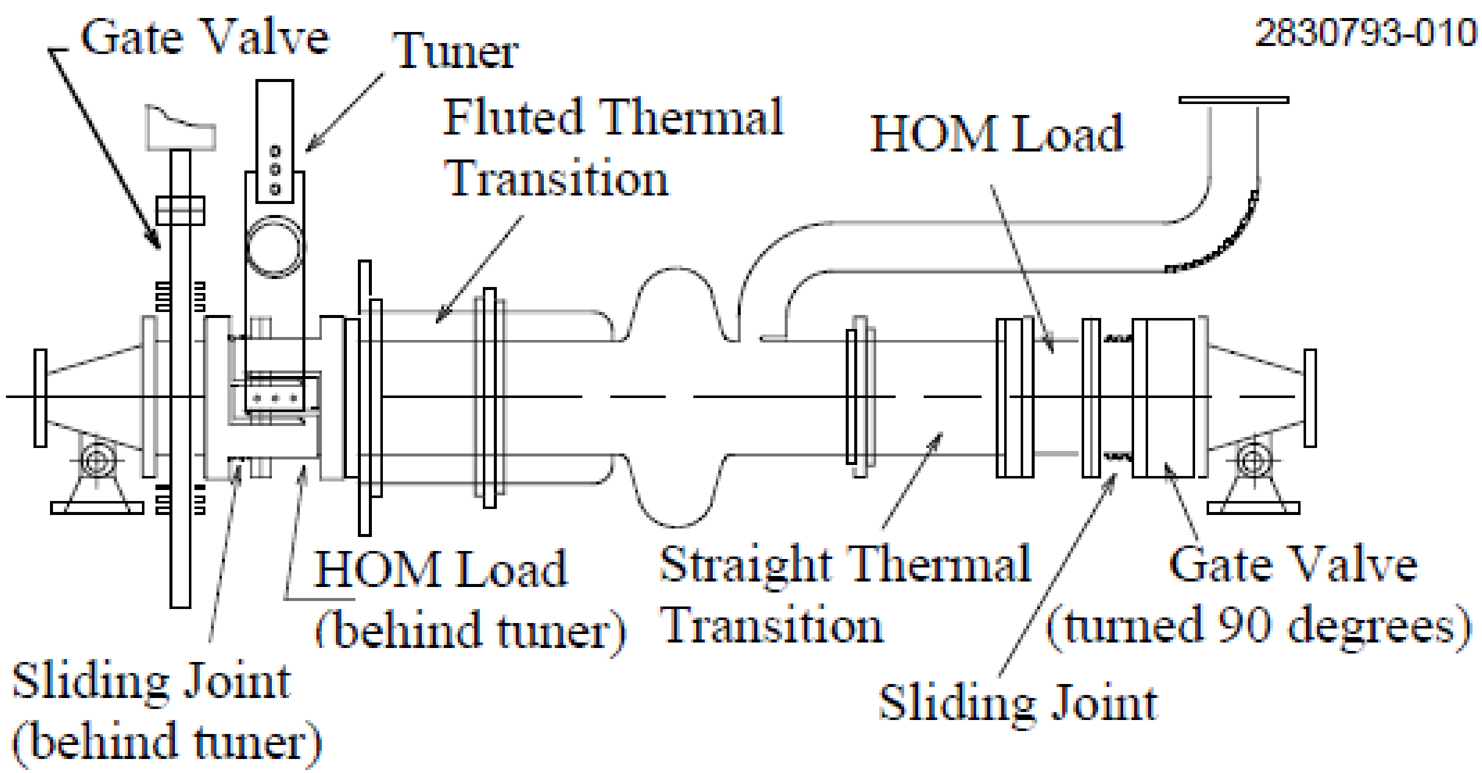


Figure 1. Schematic of the SRF cavity module.

CPC(HEP & NP), 2012, **36**(5): 447–451 Chinese Physics C Vol. 36, No. 5, May, 2012

Design and simulation of a new type of 500 MHz single-cell superconducting RF cavity

LU Chang-Wang(陆昌旺)[1,2,3] LIU Jian-Fei(刘建飞)[1,3;1)] HOU Hong-Tao(侯洪涛)[1,3]
MA Zhen-Yu(马震宇)[1,3] MAO Dong-Qing(毛冬青)[1,3] FENG Zi-Qiang (封自强)[1,3]
ZHAO Shen-Jie (赵申杰)[1,3] LUO Chen(罗琛)[1,3] ZHAO Yu-Bin(赵玉彬)[1,3]
ZHANG Zhi-Gang (张志刚) [1,2,3] ZHENG Xiang(郑湘)[1,3] WEI Ye-Long(韦业龙)[1,2,3]
YU Hai-Bo(于海波)[1,2,3] LI Zheng(李正)[1,3] XU Kai(徐凯)[1,3]

[1] Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China
[2] Graduate University of Chinese Academy of Sciences, Beijing 100049, China
[3] Shanghai Key Laboratory of Cryogenics & Superconducting RF Technology, Shanghai 201800, China

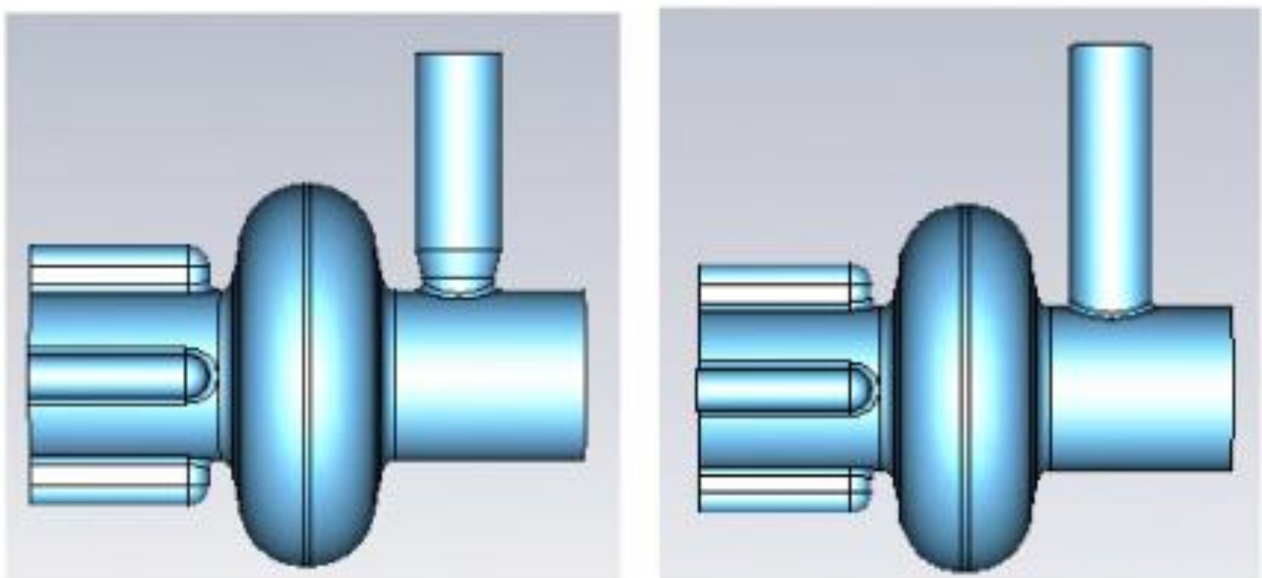


Fig. 7. Taper-type (left) and straight-type (right) input couplers.

To conclude:

In order to proceed with the cavity design we need more precise indications on requirements imposed by both beam dynamics and by mechanical constraints (allowable space, beam pipe radius, cryostat etc.)