ESS medium beta cavity HOMs

319+9

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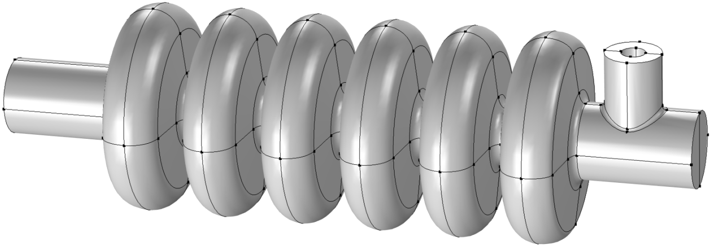
Table of contents

Design[1]

Frequency [MHz]	704.4234
Accelerating field [MV/m]	16.7
Geometric β	0.67

Design constraints

1. Cavity wall angle ≥ 7
2. Only 2 cups
3. Symmetric cavity



[1] More information on the specs. of the accelerator in: *The ESS Superconducting Linear Accelerator*, SRF2013, Paris, France. C.Darve, M.Eshraqi, M. Lindroos, D. McGinnis, S. Molloy, ESS, Lund, Sweden. P.Bosland, CEA/IRFU, Saclay, France. S. Bousson, CNRS/IPN Orsay, France

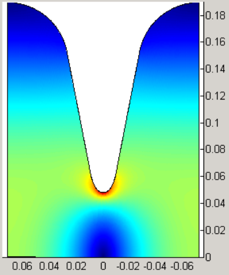
prova2

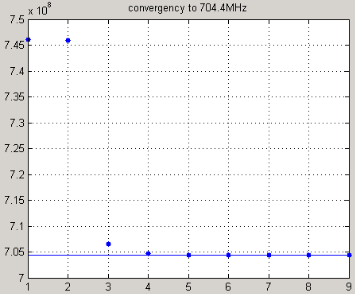
Untitled 1

Inner cell simulator. 704.42 MHz pi mode

A	0.045	0.05	3
B	0.045	0.05	3
a	0.01	0.013	3
b	0.02	0.023	3
Riris	0.048		
L	0.1426		

Simulate



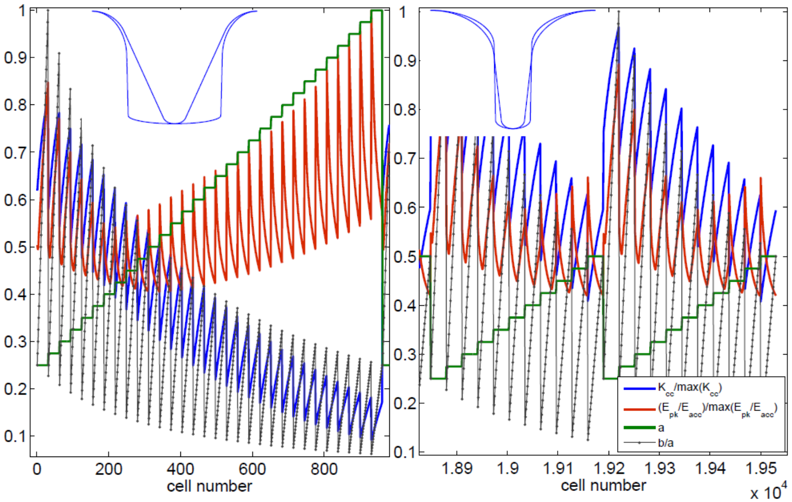


Now simulating cell number:2

	A	B	a	b
1	0.0450	0.0450	0.0100	0.0200
2	0.0450	0.0450	0.0100	0.0215
3	0.0450	0.0450	0.0100	0.0230
4	0.0450	0.0450	0.0115	0.0200
5	0.0450	0.0450	0.0115	0.0215
6	0.0450	0.0450	0.0115	0.0230
7	0.0450	0.0450	0.0130	0.0200
8	0.0450	0.0450	0.0130	0.0215
9	0.0450	0.0450	0.0130	0.0230
10	0.0450	0.0475	0.0100	0.0200
11	0.0450	0.0475	0.0100	0.0215
12	0.0450	0.0475	0.0100	0.0230
13	0.0450	0.0475	0.0115	0.0200
14	0.0450	0.0475	0.0115	0.0215
15	0.0450	0.0475	0.0115	0.0230
16	0.0450	0.0475	0.0130	0.0200

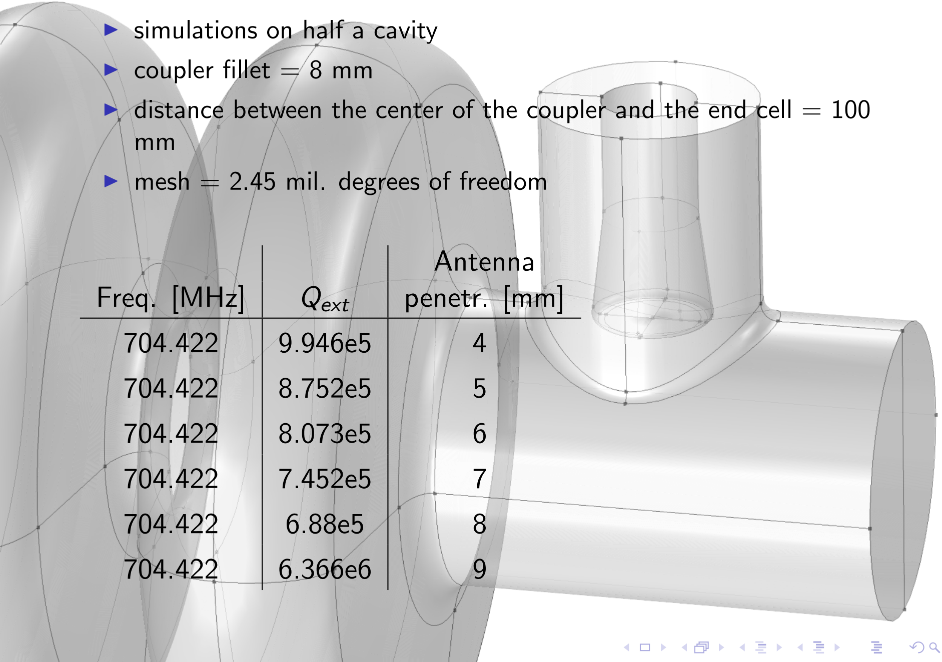
	R_over_Q	G	Epk_over_Eacc	Bpk_over_Eacc	Kcc
1	60.9636	197.4279	3.4541	4.9228	1.5936

```
Simulation completed in 142.194697 seconds
-------------------------- Cycle number 1. Simulation number 3 out of 81 ------------------------------
Tuning.... Now using D = 180.000000 mm
>>
```



- The design cannot be orthogonalized because of the strong correlation between the RF parameters
- Helps to identify the part of the parameter space that is most convenient and to understand why you can't have the best of both worlds unless you relax the constraints such as the slope of the side wall of the cells, number of cups, Q_{ext}
- It is possible to build a model of the RF parmeters and make predictions. The design can be greatly automatized.

External Q of the fundamental mode vs. antenna penetration

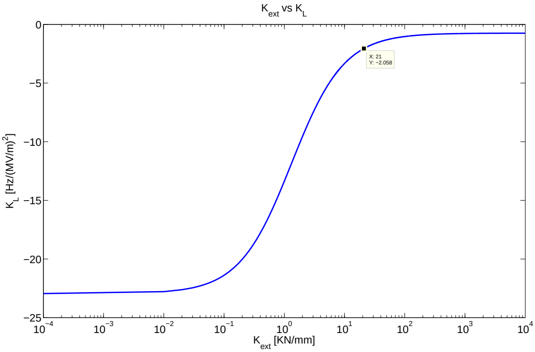


- simulations on half a cavity
- coupler fillet = 8 mm
- distance between the center of the coupler and the end cell = 100 mm
- mesh = 2.45 mil. degrees of freedom

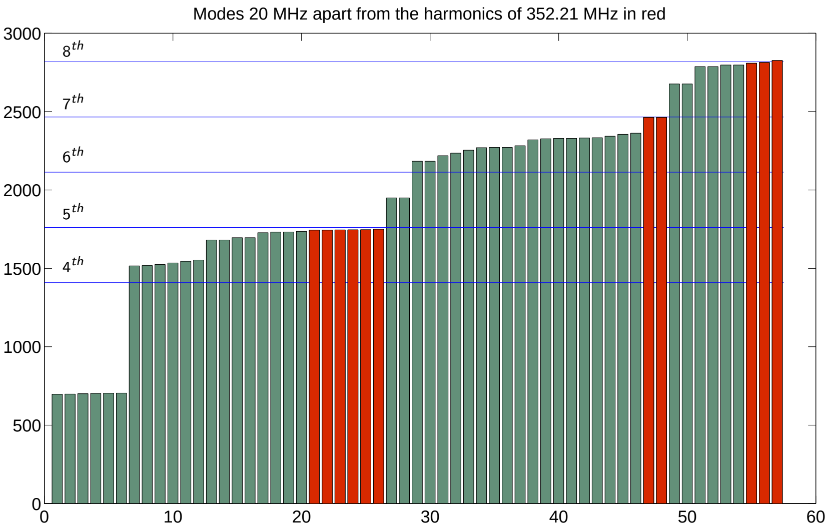
Freq. [MHz]	Q_{ext}	Antenna penetr. [mm]
704.422	9.946e5	4
704.422	8.752e5	5
704.422	8.073e5	6
704.422	7.452e5	7
704.422	6.88e5	8
704.422	6.366e6	9

Extensive mechanical simulations

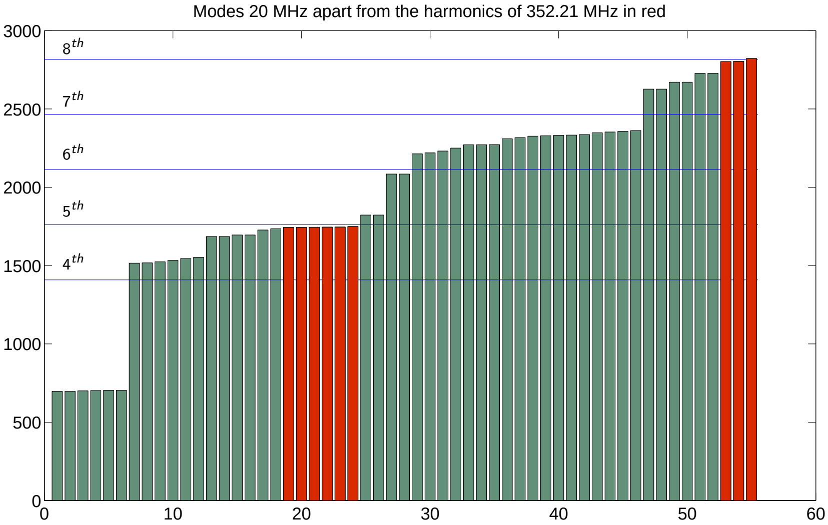
Stiffening Rings Radius [mm]	70
Tuning Sensitivity $\Delta f/\Delta z$ [KHz/mm]	214.83
Cavity Stiffness Kcav [KN/mm]	1.286
LDF coeff. fixed ends KL $[Hz/(MV/m)^2]$ @$\beta = 0.67$	-0.735
LDF coeff. free ends KL $[Hz/(MV/m)^2]$ @$\beta = 0.67$	-23.35
LFD @ Kext = 21 KN/mm $[Hz/(MV/m)^2]$ @$\beta = 0.67$	-2.04
Pressure Sensitivity fixed ends Kp [Hz/mbar] (1 mbar applied)	23.08
Pressure Sensitivity free ends Kp [Hz/mbar] (1 mbar applied)	-364.94
Max VM stress fixed ends [MPa] (1 bar applied)	20.5b/19i



PEC boundary condition at the beam tubes ends



PMC boundary condition at the beam tubes ends



PEC (perfE) or PMC (perfH) are applied at the end of the beam tubes

freq [MHz] (perfE)	Δf [MHz] from 5^{th} harm.	freq [MHz] (perfH)	Δf [MHz] from 5^{th} harm.
1743.905	-17.145	1743.789	-17.261
1744.021	-17.029	1744.021	-17.029
1744.704	-16.346	1774.704	-16.346
1745.544	-15.505	1745.545	-15.505
1746.221	-14.829	1746.221	-14.829
1749.588	-11.462	1749.566	-11.484

Table: Modes close to the 5^{th} harmonic 1761.1 MHz

freq [MHz] (perfE)	Δf [MHz] from 7^{th} harm.	freq [MHz] (perfH)	Δf [MHz] from 7^{th} harm.
2463.291(1^{st})	-2.179	n.d.[1]	n.d.[1]
2463.291(2^{nd})	-2.179	n.d.[1]	n.d.[1]

Table: Modes close to the 7^{th} harmonic 2465.5 MHz

freq [MHz] (perfE)	Δf [MHz] from 8^{th} harm.	freq [MHz] (perfH)	Δf [MHz] from 8^{th} harm.
2808.352	-9.328	2802.285	-15.395
2812.679	-5.000	2804.512	-13.168
2825.223	7.543	2821.817	4.137

Table: Modes close to the 8^{th} harmonic 2817.7 MHz

[1] the mode is not present with the PMC BC

R/Q vs. β. Fundamental passband.

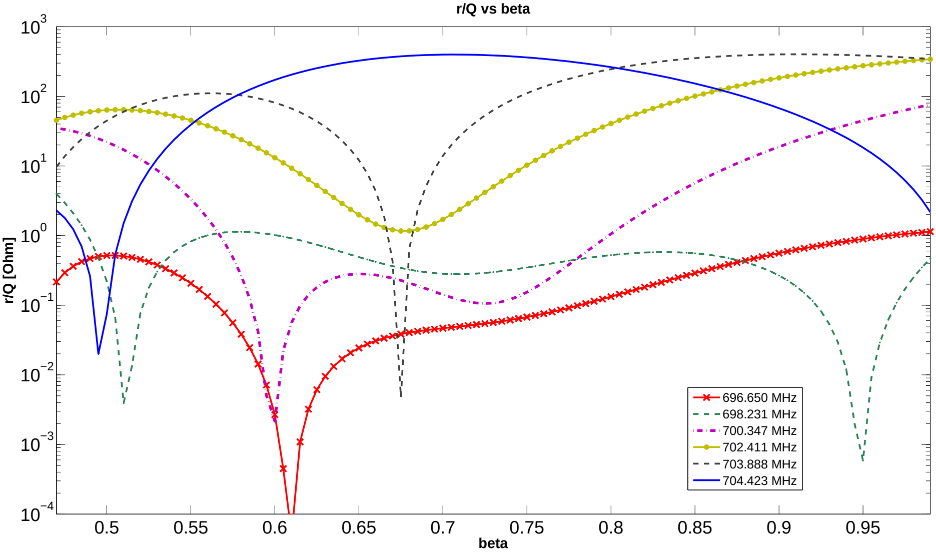


Figure: R/Q vs. β for the fundamental passband

R/Q vs. β. Modes close to the 5^{th} harmonic (1761.05 MHz)

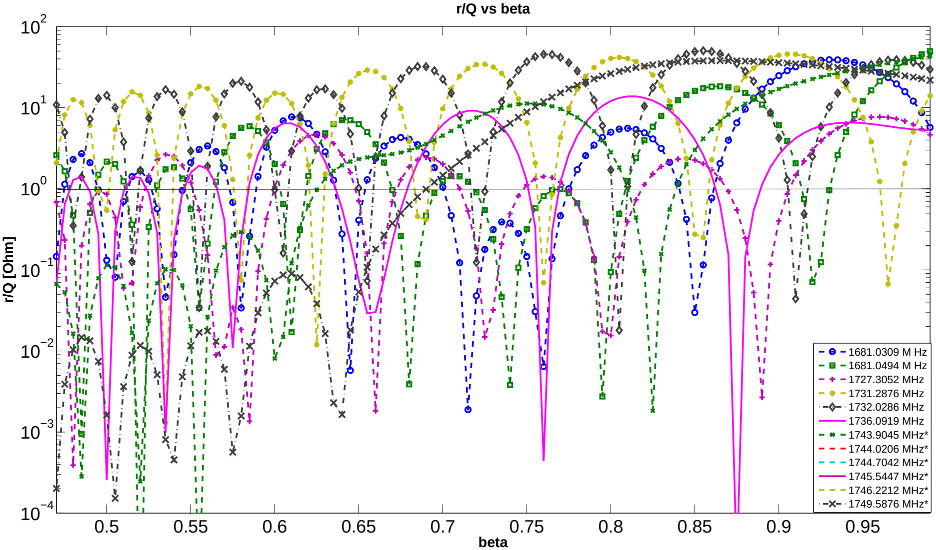
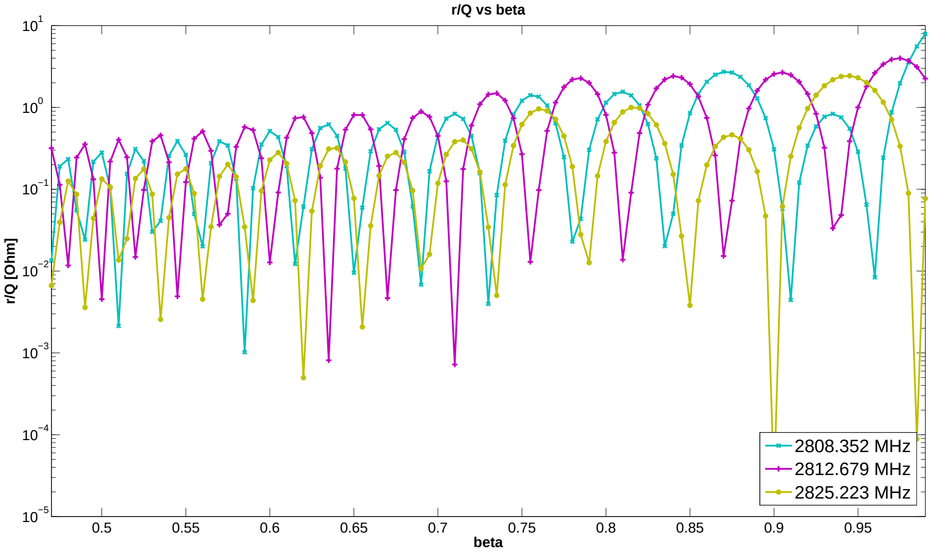


Figure: *) Modes within 20 MHz from the 5^{th} harmonic. Some modes with a non negligible R/Q are far from the 5^{th} harmonic.

R/Q vs. β. Modes close to the 8^{th} harmonic (2817.7 MHz)



Electric field norm of the modes close to the 5^{th} harmonic

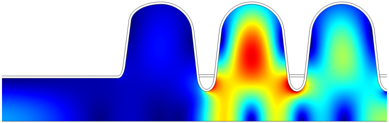


Figure: 1743.905 MHz (PEC)

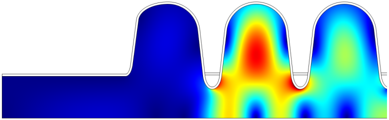


Figure: 1743.789 MHz (PMC)

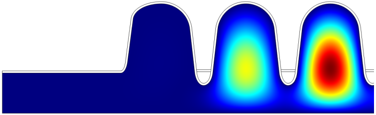


Figure: 1744.021 MHz (PEC)

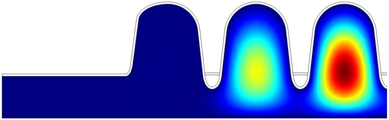


Figure: 1744.021 MHz (PMC)

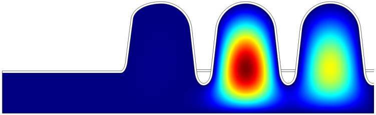


Figure: 1744.704 MHz (PEC)

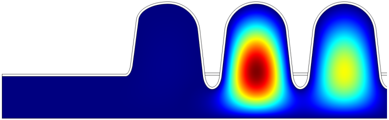


Figure: 1744.704 MHz (PMC)

Electric field norm of the modes close to the 5^{th} harmonic

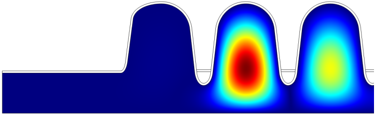


Figure: 1745.545 MHz (PEC)

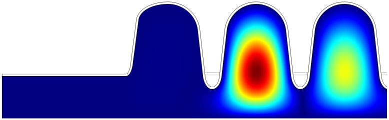


Figure: 1745.545 MHz (PMC)

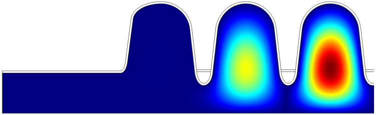


Figure: 1746.221 MHz (PEC)

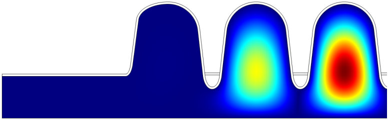


Figure: 1746.221 MHz (PMC)

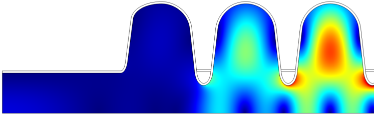


Figure: 1749.588 MHz (PEC)

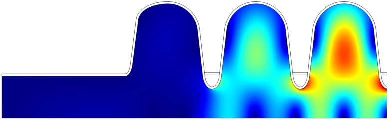


Figure: 1749.566 MHz (PMC)

Electric field norm of the modes close to the 7^{th} harmonic

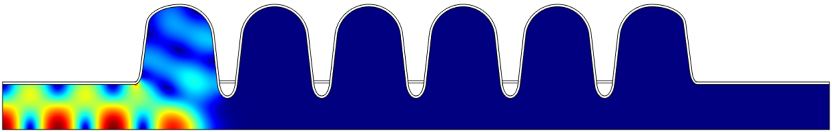


Figure: 2463.291(1) MHz (PEC)

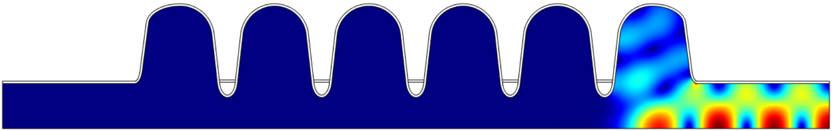


Figure: 2463.291(2) MHz (PEC)

Electric field norm of the modes close to the 8^{th} harmonic

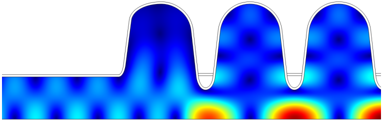


Figure: 2808.352 MHz (PEC)

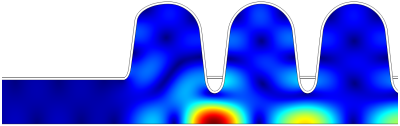


Figure: 2802.285 MHz (PMC)

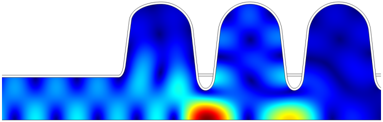


Figure: 2812.679 MHz (PEC)

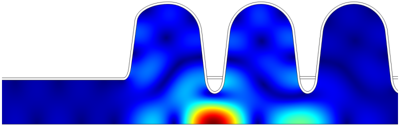


Figure: 2804.512 MHz (PMC)

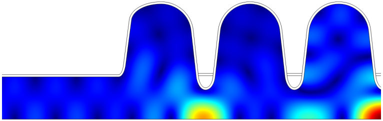


Figure: 2825.223 MHz (PEC)

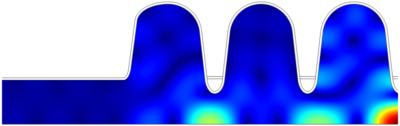
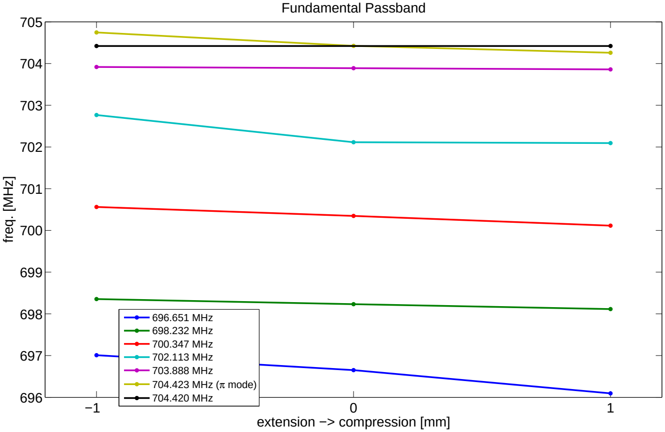
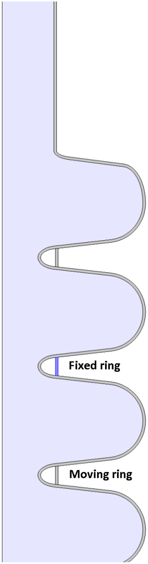


Figure: 2821.817 MHz (PMC)

Tuning. Extending or compressing the 3^{rd} cell

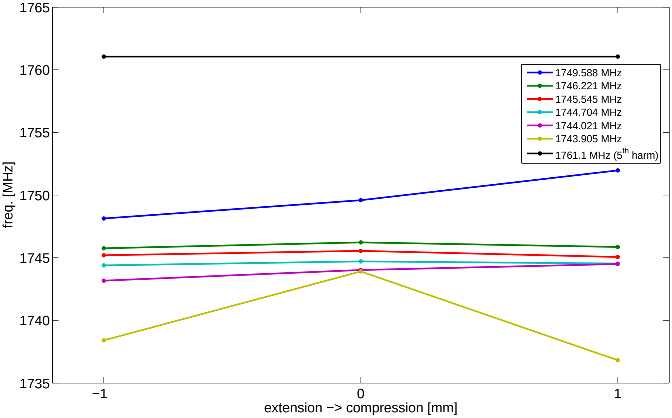


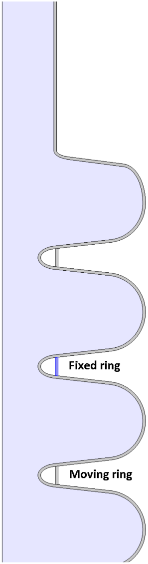


extension 1 mm	original	compression 1 mm
697.01	696.651	696.095
698.354	698.232	698.115
700.562	700.347	700.114
702.766	702.113	702.094
703.917	703.888	703.859
704.745	704.423	704.258

Table: Modes of the fundamental passband

Tuning. Extending or compressing the 3^{rd} cell

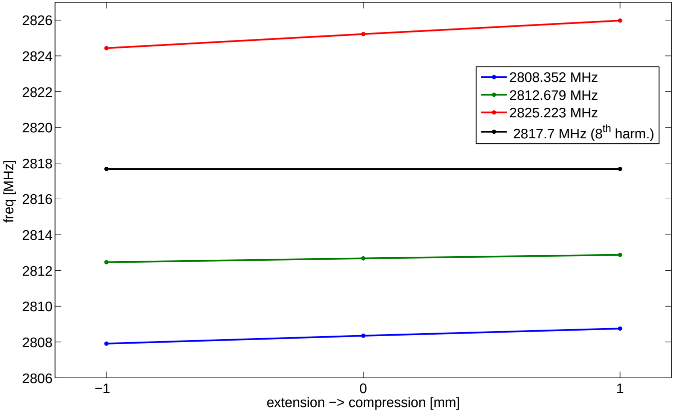


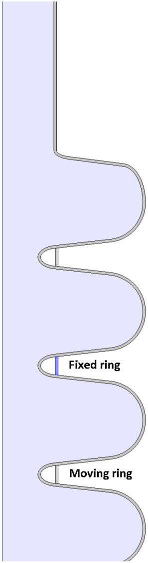


extension 1 mm	original	compression 1 mm
1748.127	1749.588	1751.969
1745.75	1746.221	1745.859
1745.194	1745.545	1745.058
1744.385	1744.704	1744.537
1743.167	1744.021	1744.495
1738.401	1743.905	1736.821

Table: Modes close to the 5^{th} harmonic. The closest mode is 9 MHz apart from the 5^{th} harmonic for 1 mm of compression.

Tuning. Extending or compressing the 3^{rd} cell





extension 1 mm	original	compression 1 mm
2807.911	2808.352	2808.754
2812.459	2812.679	2812.874
2824.436	2825.223	2825.978

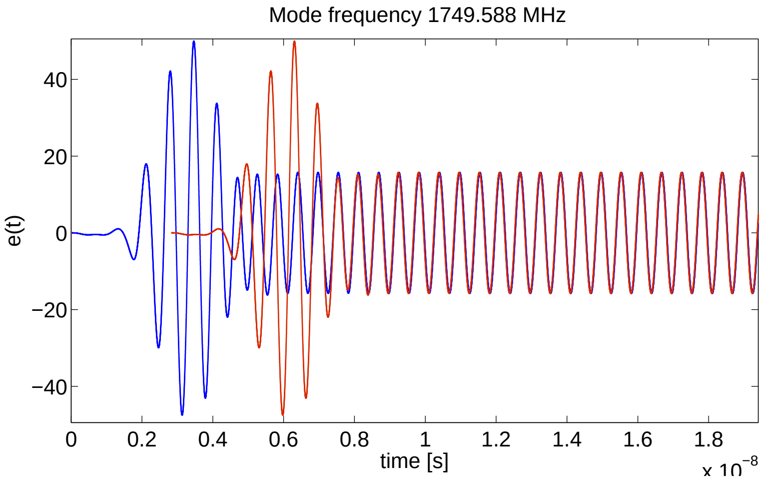
Table: Modes close to the 8^{th} harmonic. The closest mode is 4.8 MHz apart from the 8^{th} harmonic for 1 mm of compression.

HOMs power

Development of 2 codes

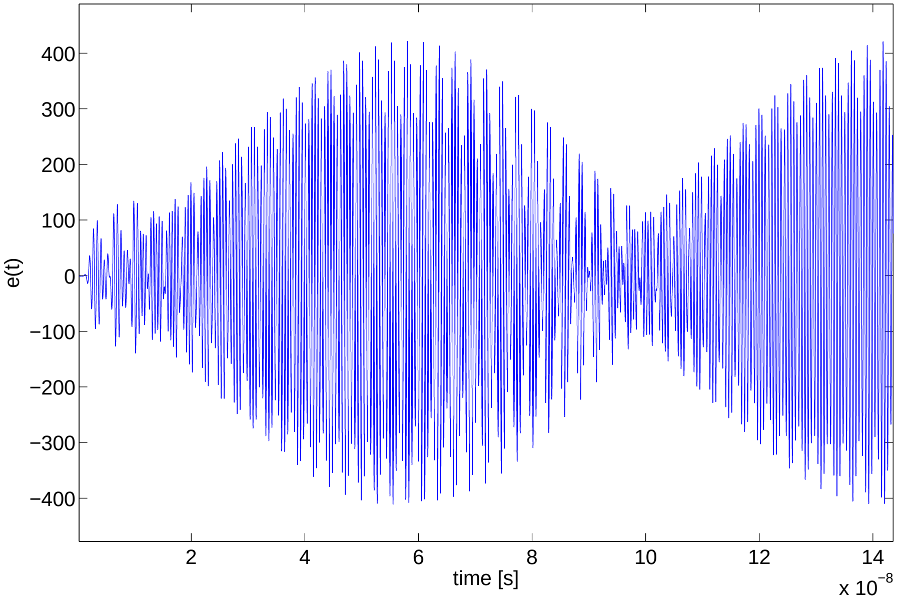
- Power Spectrum
  - Both time and frequency domain, based on a ODE
  - Includes transient! Evolution of the fields in time domain
  - accurate
  - physical interpretation
  - slow, very CPU intensive so only 1e5 bunches of 1 nC
- Average power with voltage envelope
  - only the envelope
  - no evolution of the fields in time
  - no power spectrum
  - fast, 1e6 bunches of 1 nC

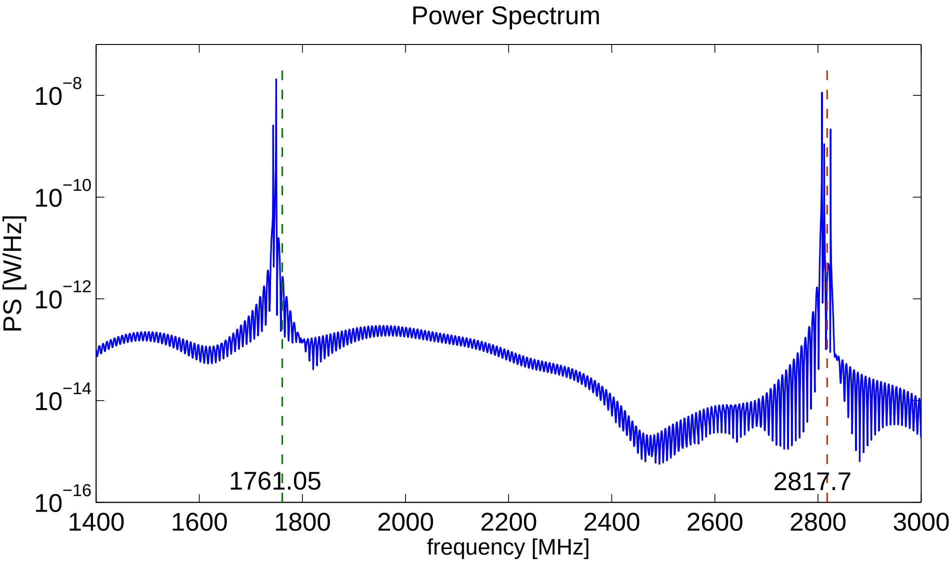
All the results at $\beta = 0.67$, $Q_{ext} = 10^6$



- Coherency between the RF field and the current leads to a resonant excitation of the mode
- Modes far from a multiple of the bunch frequency are not coherent with the current

Mode frequency 1749.588 MHz




Power Spectrum
PS [W/Hz]
10^−8
10^−10
10^−12
10^−14
10^−16
1400
1600
1800
2000
2200
2400
2600
2800
3000
frequency [MHz]
1761.05
2817.7

Average powers. 1e6 bunches, 1nC of charge, $T = 1/14$ Hz, $Q_{ext} = 1e6$

P_{avg} [W]	Frequency [MHz]	P_{avg} [W]	Frequency [MHz]
0,0012	696.650	3,9524e-29	1695.760
0,0136	698.231	2,2896	1727.305
0,0219	700.347	0,1152	1731.287
0,4138	702.411	1,0979	1732.028
0,2555	703.888	0,0270	1736.091
	704.423	0,0960	1743.904
0,0013	1515.651	1,1768e-25	1744.020
1,4619e-06	1517.185	6,7243e-26	1744.704
3,5717e-05	1524.349	2,8381e-27	1745.544
0,0004	1534.231	2,0787e-27	1746.221
9,7069e-05	1544.856	0,0591	1749.587
1,3934e-07	1553.281	0,4142	2808.351
0,0117	1681.030	4,0973e-05	2812.679
0,0004	1681.049	0,8040	2825.223
Total $P_{avg}[W]$	5		

Conclusions

- A bad case scenario has been assumed: Some modes which contribute to the total HOM power have a low Q_{ext} (beam pipe modes), these modes have to be investigated further. They couple well with the FPC and the bellows which help to dissipate some power
- Preliminary results show that the HOM power is low, to be verified with other codes
- Remember that some HOMs close to the harmonics of the beam line have a low R/Q and some other HOMs have a non negligible R/Q but are far from the harmonics

Next

- Complete the power spectrum with 1e6 bunches, add bunch noise
- Consider the dynamics of the beam
- Compare with existing codes