704 MHz Cavities

R. Calaga, BNL, Nov 12, 2009

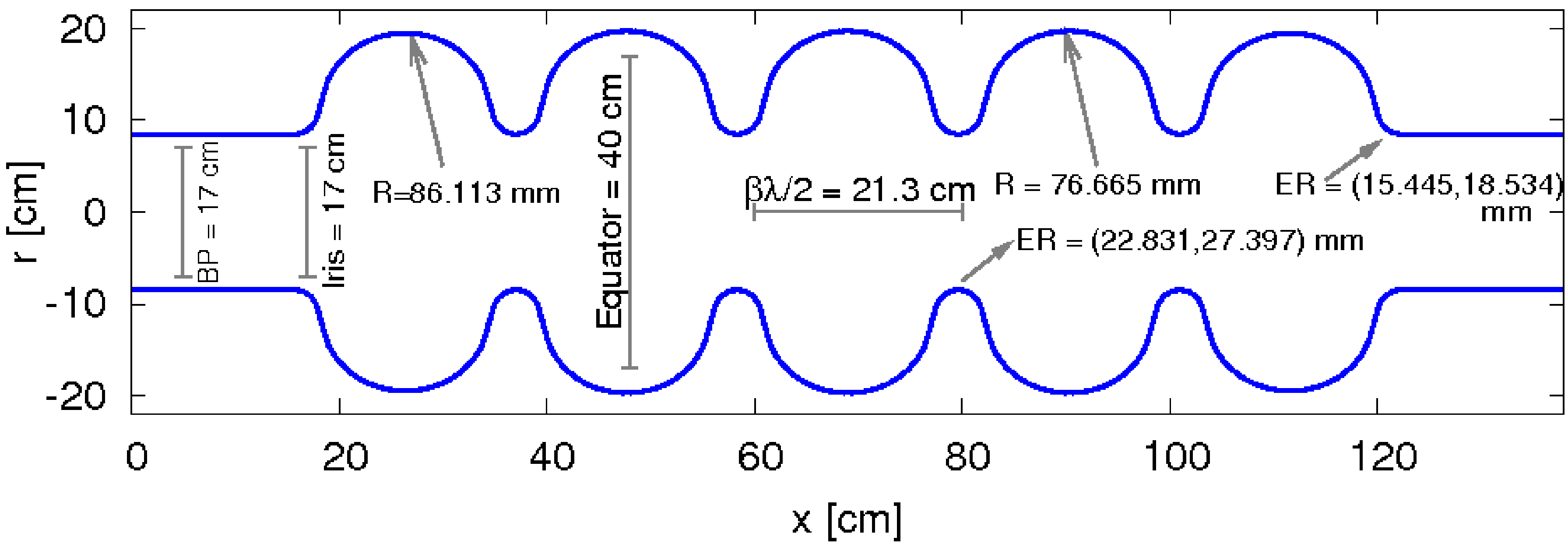
Cavity design (High Q, Less W/m)

Transition section & HOM damping concepts

Future work

Ack: I. Ben-Zvi, H. Hahn, G. McIntyre, J. Sekutowicz, W. Xu, AES

Baseline Cavity Design



Eacc = 18 - 25 MV – 5 cells

Epk/Eacc ~ 41.4 - 57.5 (x2.3)

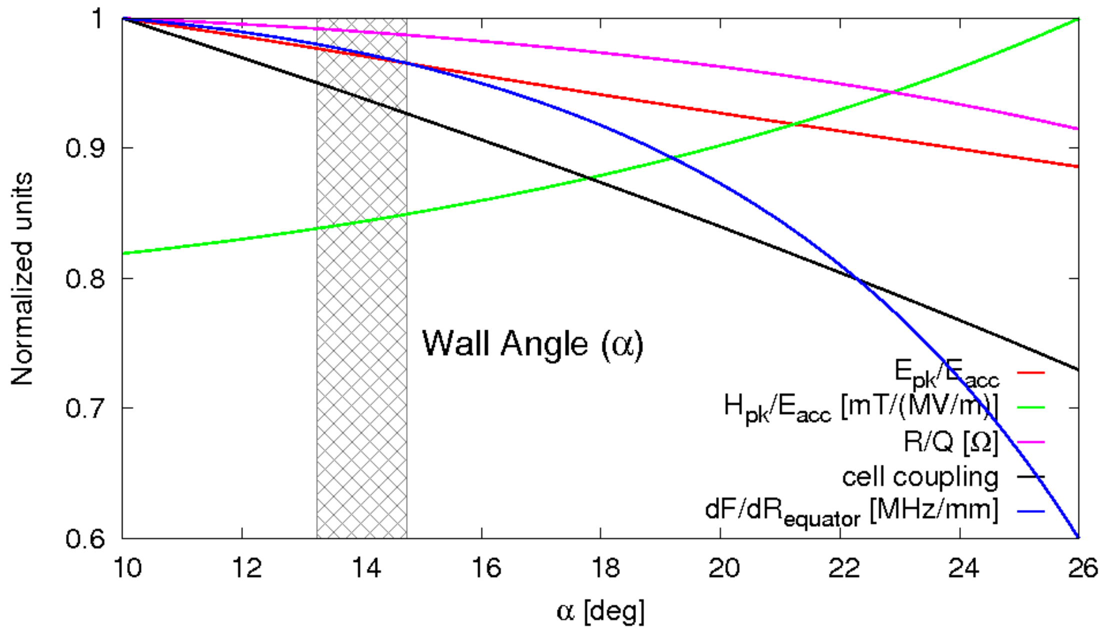
Bpk/Eacc ~ 80.1 – 111.5 mT (4.5 mT/MV/m)

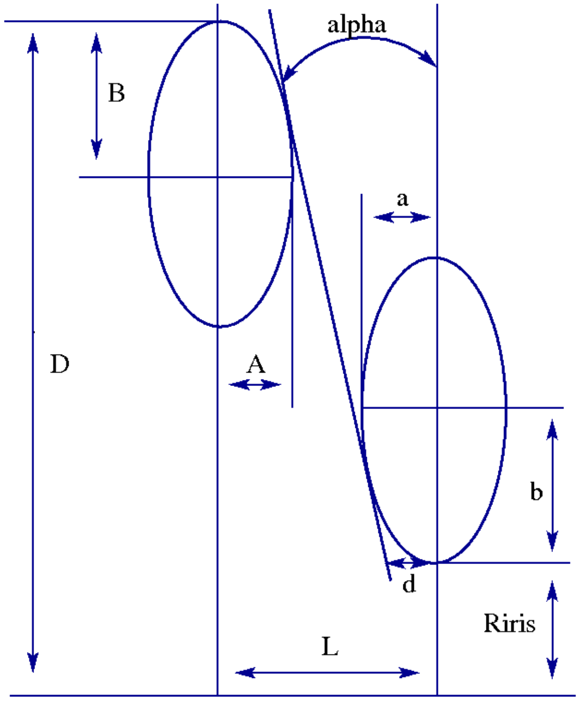
R/Q ~ 490 Ω

Stiffness (thickness: 3mm)

(Tuner Comp ~2.5 mm, Tuner load ~2334 lb, dF ~0.335 MHz)

Single Cell Optimization, Fundamental





Parametric scans of the geometrical parameters with RF observables

Best compromise for surface fields, cell-to-cell coupling & R/Q

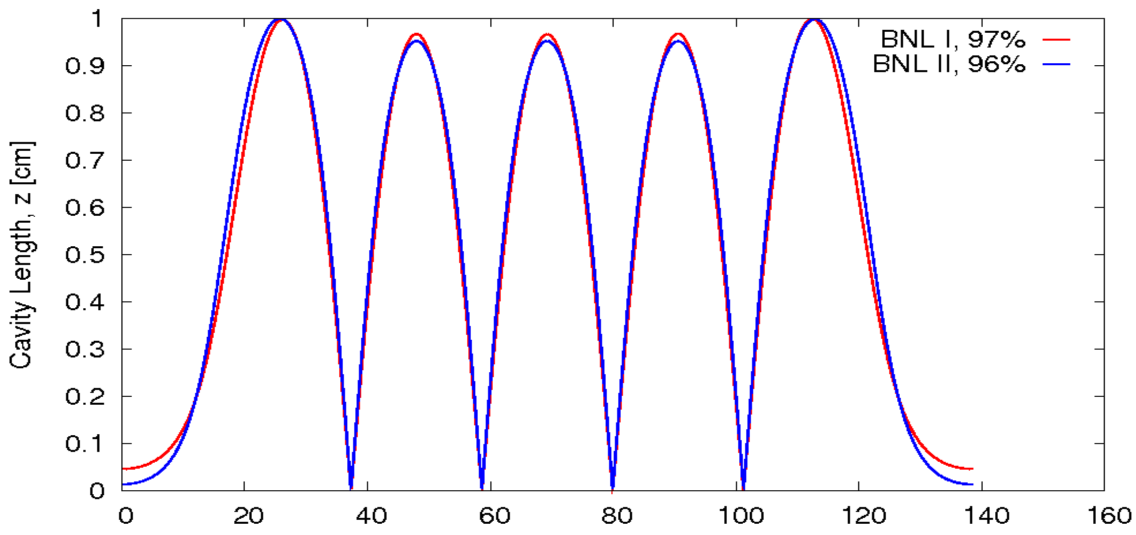
Field Flatness

Adjust end-cells for frequency & field flatness

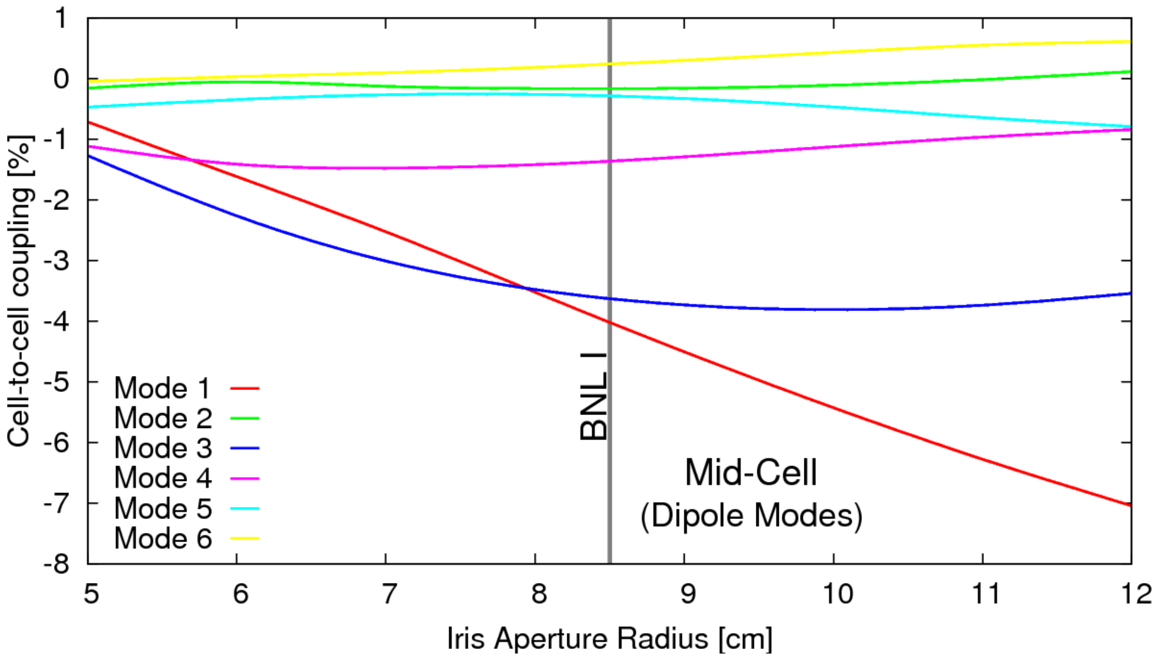
$$\eta = N^2/\beta k_{cc}$$

Fundamental Mode:

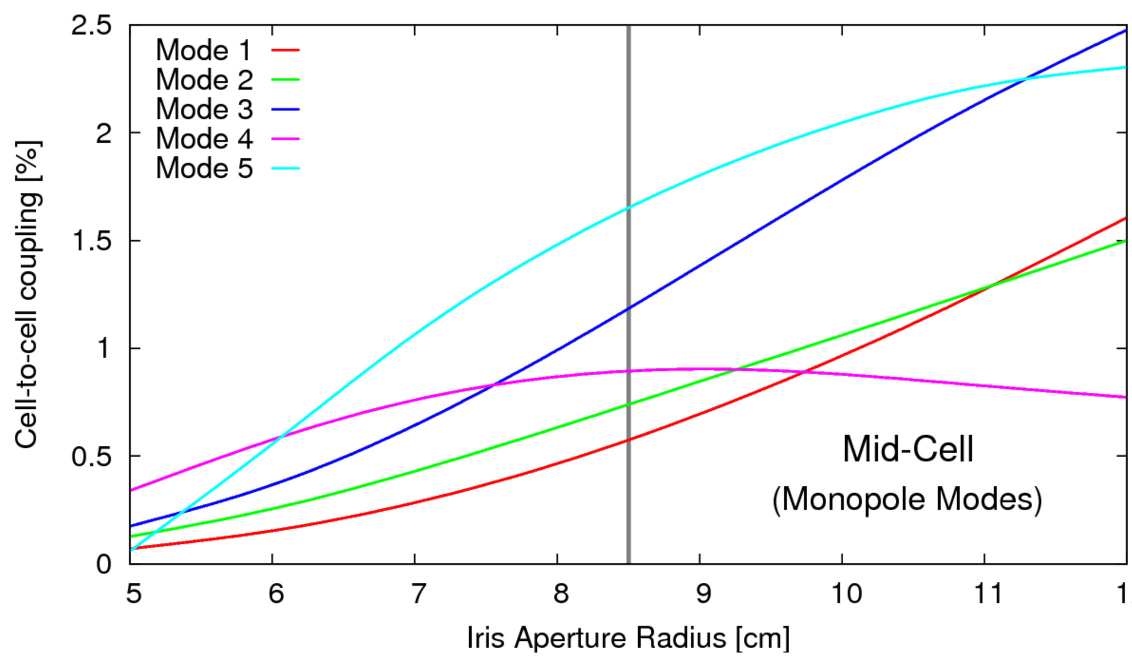
- Field flatness between 95-99 %
- End-cells become significantly different (99%) $\rightarrow$ HOM Trapping
- Fundamental power coupler $\rightarrow$ symmetrizing stub



Single Cell Optimization, HOMs



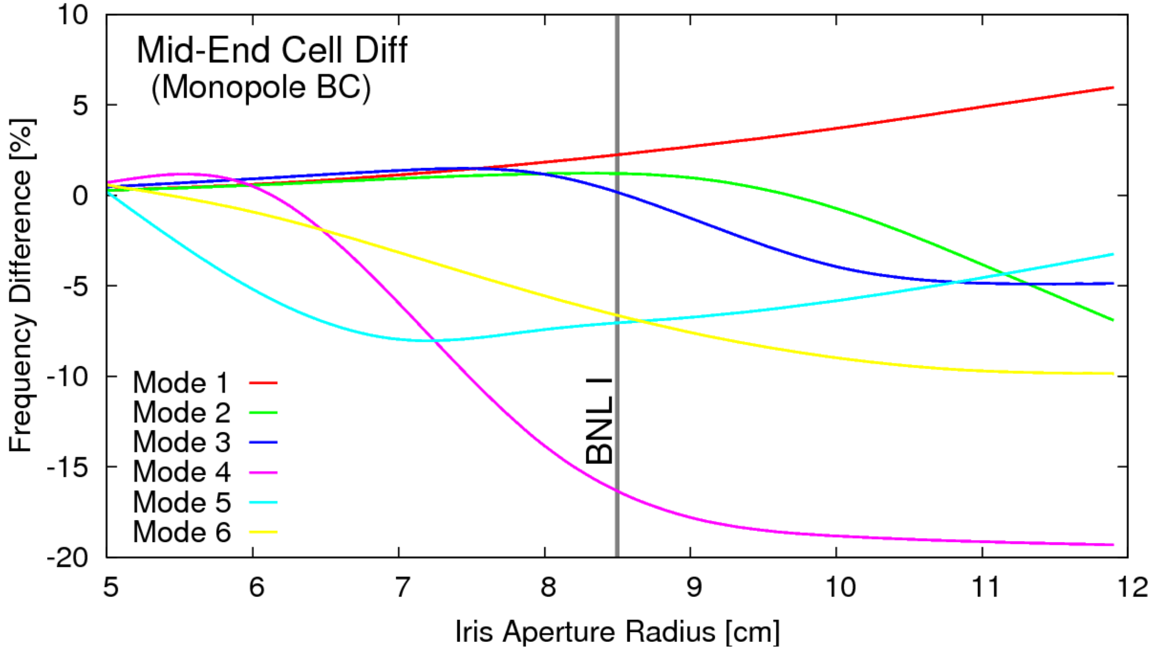
Monopole modes: > 7cm rad



Dipole modes: >7 cm rad

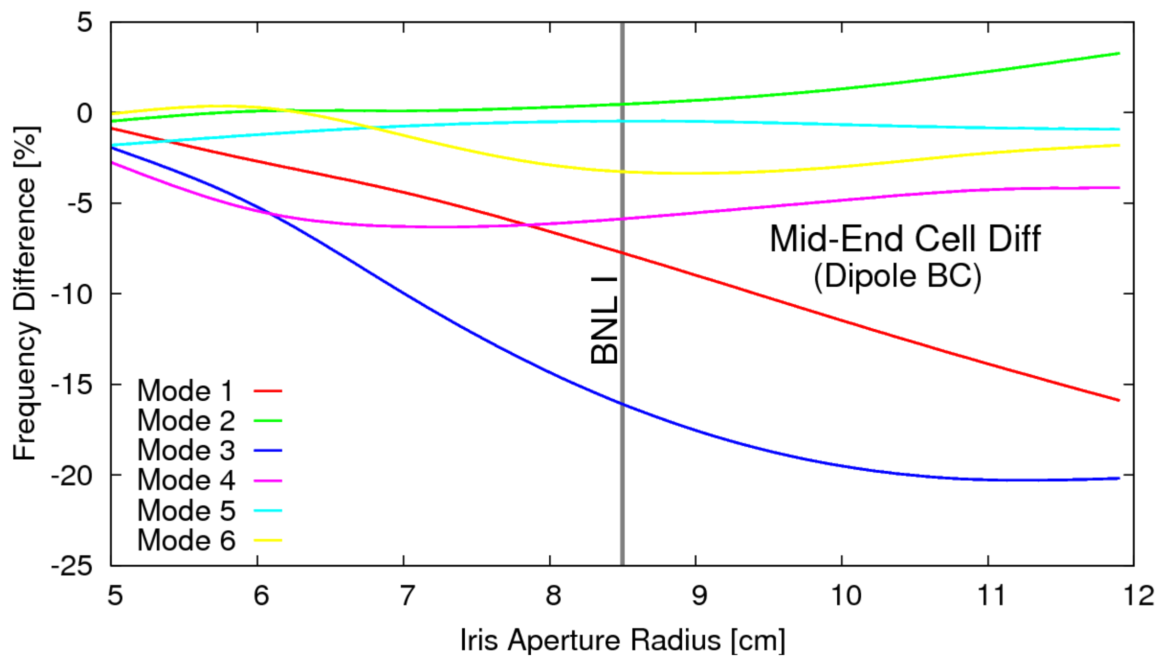
Condition important but
no good threshold
Fundamental mode ~ 4.5%

Frequency Difference, HOMs



Monopole modes: <8cm rad

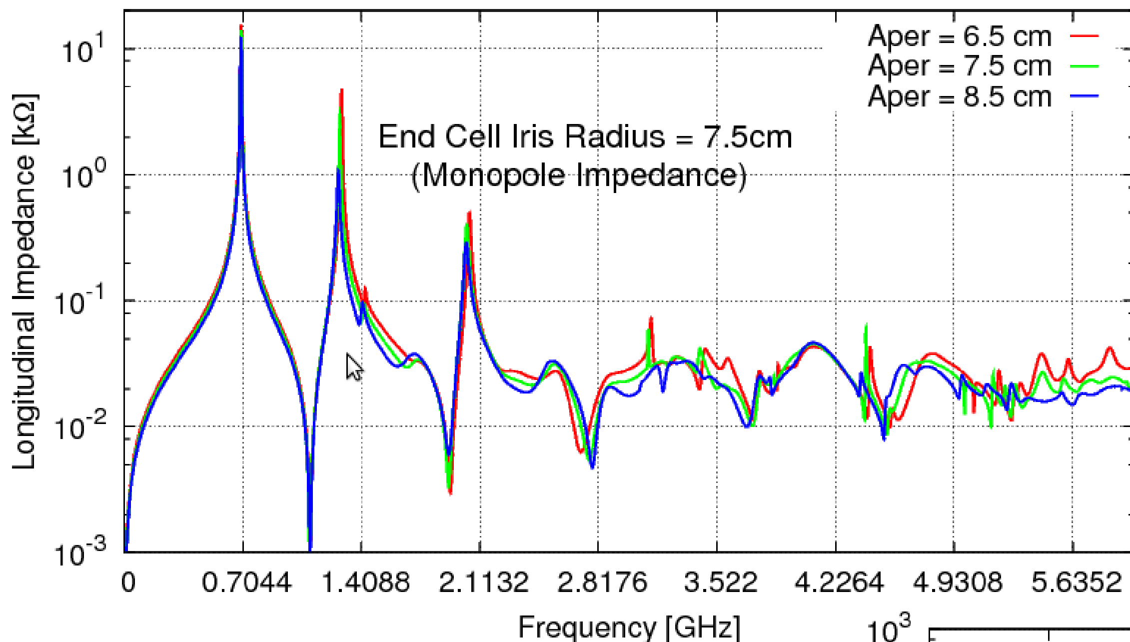
Dipole modes: <8 cm rad



But this condition is less strict

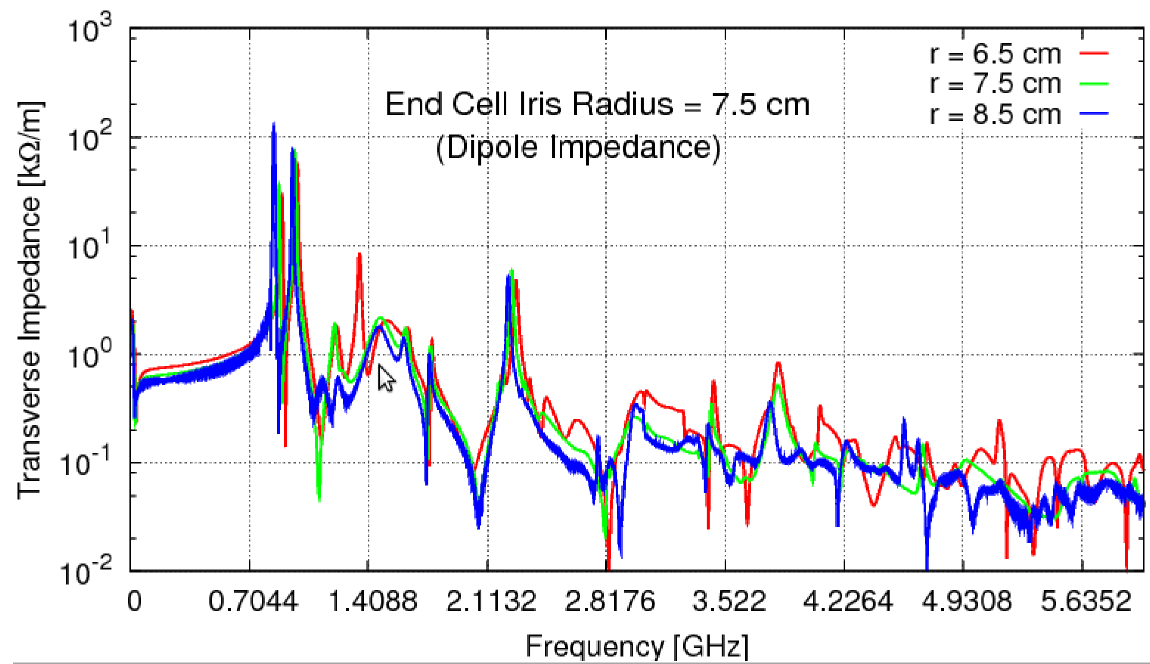
1% @1GHz ~ 10 MHz

Overlap on Harmonics, HOMs



Monopole modes: <8cm rad

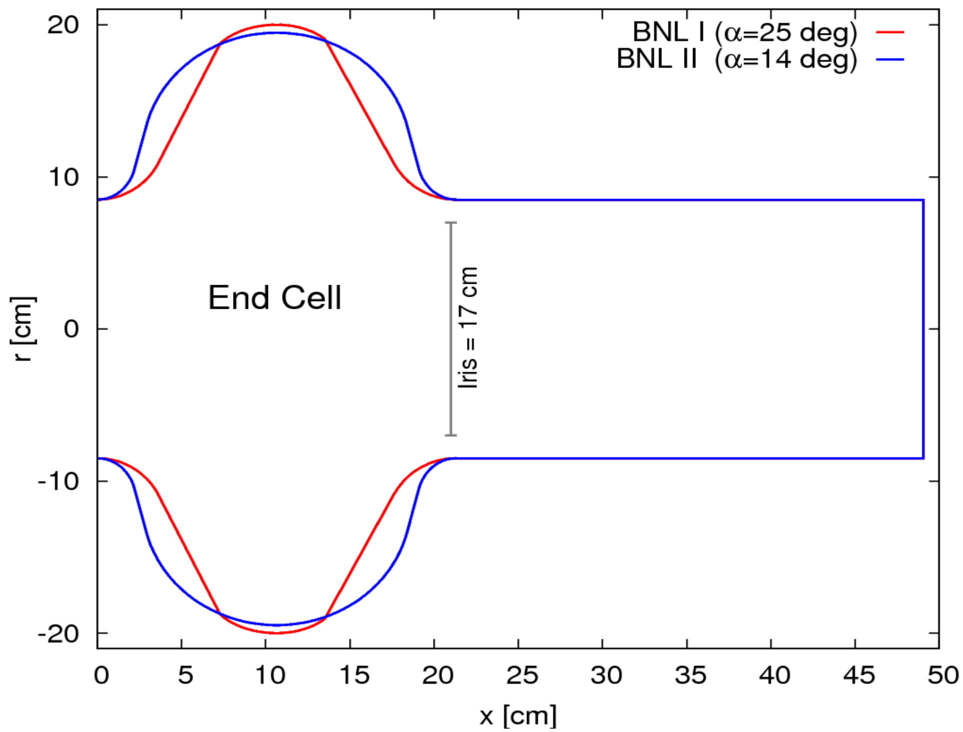
Dipole modes: <8 cm rad

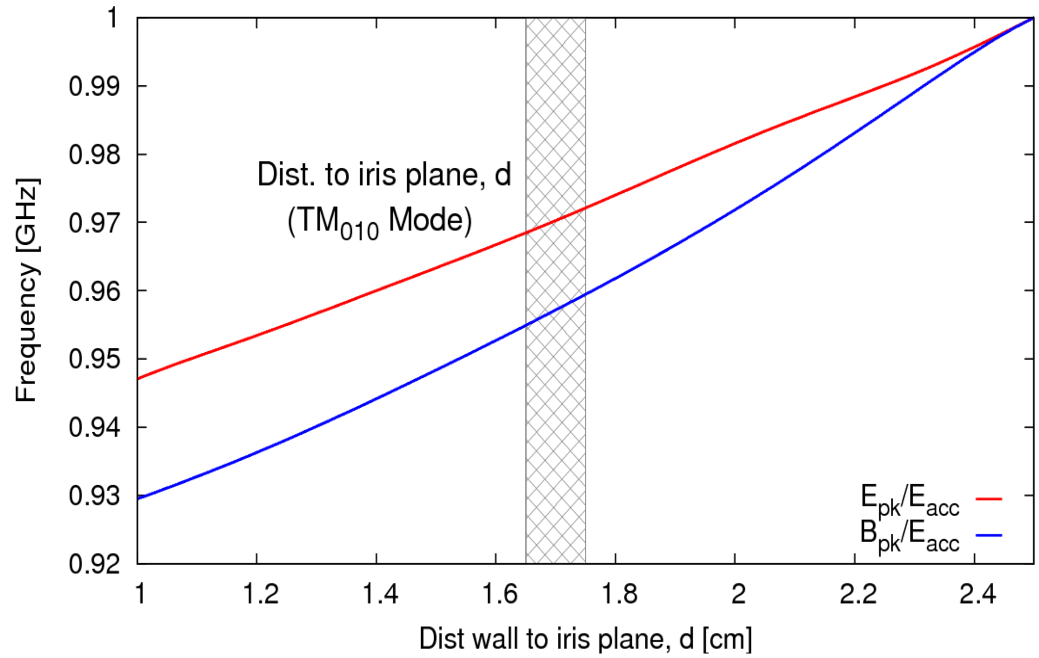


But this condition is less strict

1% @1GHz ~ 10 MHz

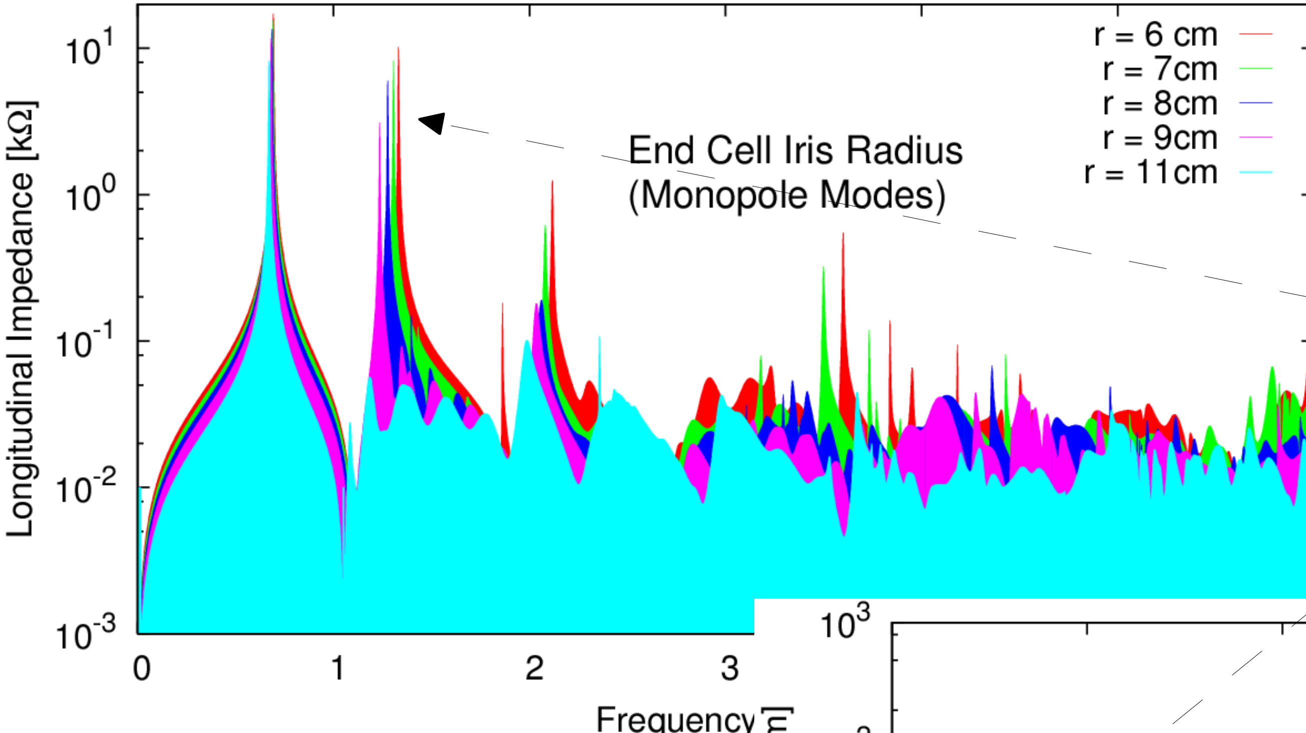
End-Cell Optimization

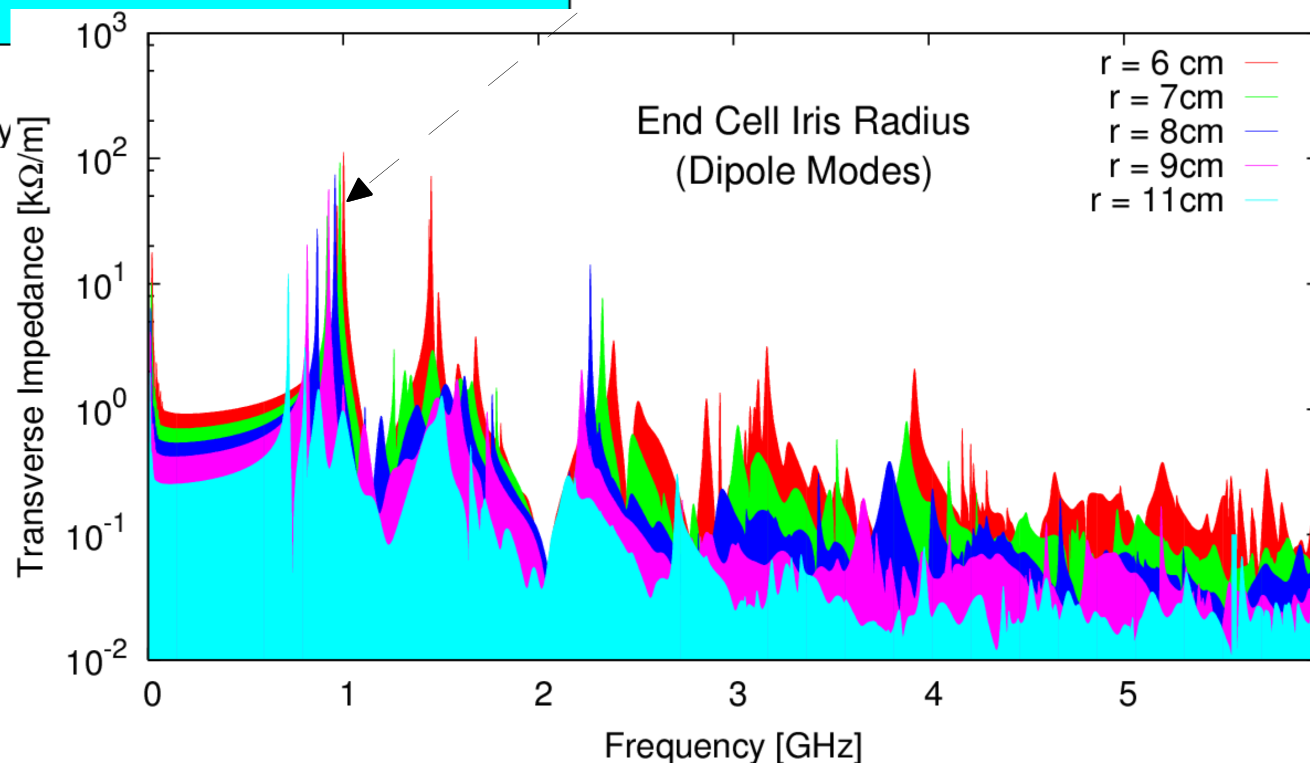




Parameter	BNL I Mid & End Cell	BNL II Mid & End Cell
Frequency [MHz]	703.75	703.75
Iris Radius, R_{iris} [cm]	8.5	8.5
Wall Angle, α [deg]	25	{14,12}
Equatorial Ellipse, $R = \frac{B}{A}$	1.0	1.0
Iris Ellipse, $r = \frac{b}{a}$	1.1	1.2
Cavity wall to iris plane, d [cm]	2.5	{1.7,1.2}
Half Cell Length, $L = \frac{\lambda\beta}{4}[cm]$	10.65	10.65
$H = D - (R_{iris} + b + B)[cm]$	{4.195,3.792}	{19.7124,19.4034}
Cavity Beta, $\beta = \frac{v}{c}$	1.0	1.0

End-Cell Optimization





Mid-cell radius ~ 7.5 cm

End-cell/BP radius = 11cm

HOM Passbands

Monopoles

Mode	Freq [GHz]		Freq [GHz]		R/Q	$\mathcal{K}_{mid}$	$\mathcal{K}_{end}$	Δf
	E	B	E	B	[Ω]	[%]	[%]	[kHz]
1	0.683	0.704	0.694	0.704	169.7	3.0	1.4	1.1
2	1.277	1.346	1.264	1.295	105.2	5.3	2.4	1.3
3	1.415	1.496	1.438	1.486	0.2	5.6	3.3	2.3
4	1.788	1.991	1.831	1.801	23.7	10.7	1.7	4.3
5	1.978	2.088	1.992	2.027	106.3	5.4	1.7	1.4
6	2.105	2.293	2.103	2.279	3.9	8.6	8.0	0.2
7	2.425	2.616	2.349	2.542	36.8	7.6	7.9	7.6
8	2.528	2.645	2.497	2.613	3.3	4.5	4.5	3.1
9	2.710	-	2.616	2.751	24.6	-	5.0	9.4
10	2.801	-	2.736	2.946	0.9	-	7.4	6.5

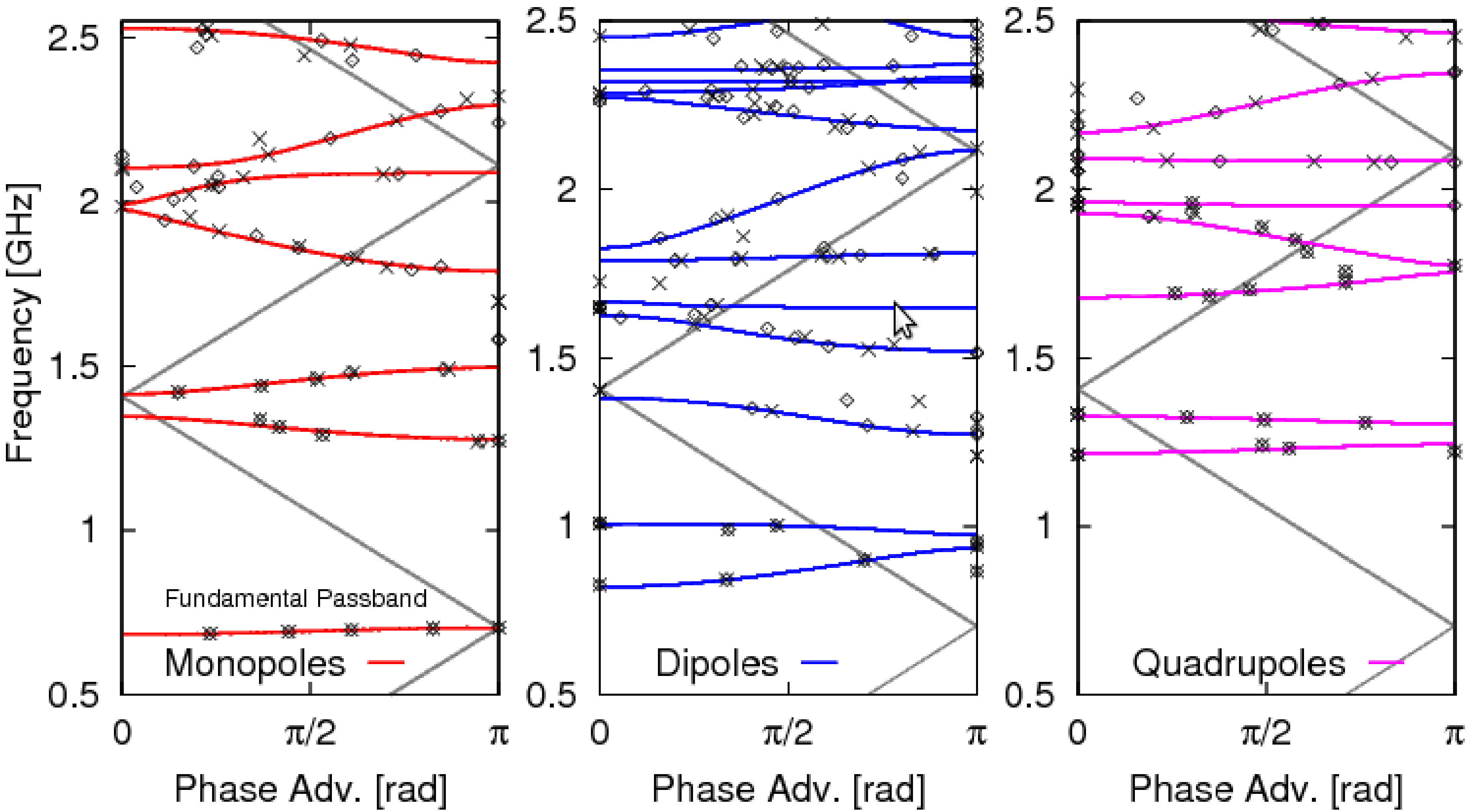
Dipoles

Mode	Freq [GHz]		Freq [GHz]		R/Q	$\mathcal{K}_{mid}$	$\mathcal{K}_{end}$	Δf
	E	B	E	B	[Ω]	[%]	[%]	[kHz]
1	0.975	0.820	0.914	0.839	4.87	17.3	8.6	6.1
2	1.008	0.935	1.011	0.969	29.8	7.5	4.2	0.3
3	1.520	1.272	1.531	1.324	19.7	17.8	14.5	1.1
4	1.649	1.382	1.642	1.497	0.4	17.6	9.2	0.7
5	1.667	1.626	1.743	1.625	2.3	2.5	7.0	7.6
6	1.788	1.809	1.804	1.806	3.0	1.2	0.1	1.6
7	2.175	1.825	2.215	2.055	0.1	17.5	7.5	4.0
8	2.284	2.115	2.256	2.237	2.2	7.7	0.9	2.8
9	2.318	2.273	2.275	2.277	2.7	2.0	0.1	4.3
10	2.334	2.320	-	-	0.04	0.6	-	-
11	2.374	2.355	2.366	2.335	0.05	0.8	1.3	0.8
12	2.452	2.450	2.455	2.364	9.0	0.1	3.8	0.3
13	2.761	2.615	2.789	2.712	17.4	5.4	2.8	2.8
14	2.863	2.830	2.860	2.859	0.07	1.2	0.04	0.3
15	2.892	2.868	2.879	2.879	0.01	0.8	0.0	1.3

Quadrupoles

Mode	Freq [GHz]		Freq [GHz]		R/Q	$\mathcal{K}_{mid}$	$\mathcal{K}_{end}$	Δf
	E	B	E	B	[Ω]	[%]	[%]	[kHz]
1	1.243	1.216	1.219	1.207	0.37	2.2	1.0	2.4
2	1.326	1.304	1.338	1.326	0.36	1.7	0.9	1.2
3	1.775	1.680	1.736	1.687	0.6	5.5	2.9	3.9
4	1.952	1.752	1.877	1.786	0.006	10.8	5.0	7.5
5	1.962	1.928	1.949	1.928	0.22	1.8	1.1	1.3
6	2.092	2.084	2.071	2.071	0.24	0.4	0.0	2.1
7	2.467	2.169	2.474	2.225	0.14	12.9	10.6	0.7
8	2.521	2.343	2.495	2.361	0.03	7.3	5.5	2.6
9	2.585	2.577	2.544	2.534	0.02	0.3	0.4	4.1
10	2.655	2.700	2.608	2.653	-	1.7	1.7	4.7
11	2.711	2.710	2.706	2.706	0.002	0.04	0.0	0.5
12	2.807	3.085	2.799	2.834	0.007	9.4	1.2	0.8

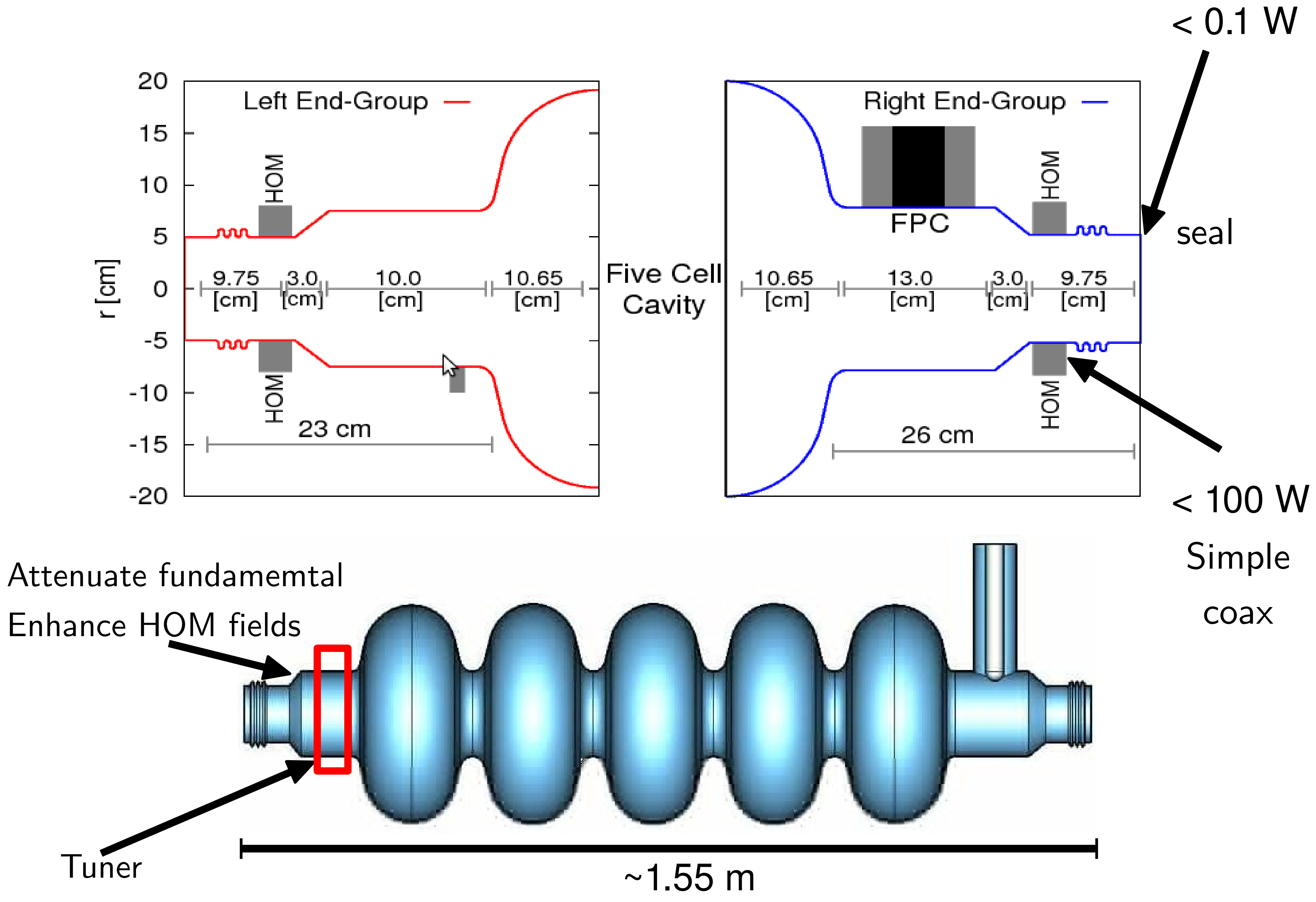
Dispersion Curves



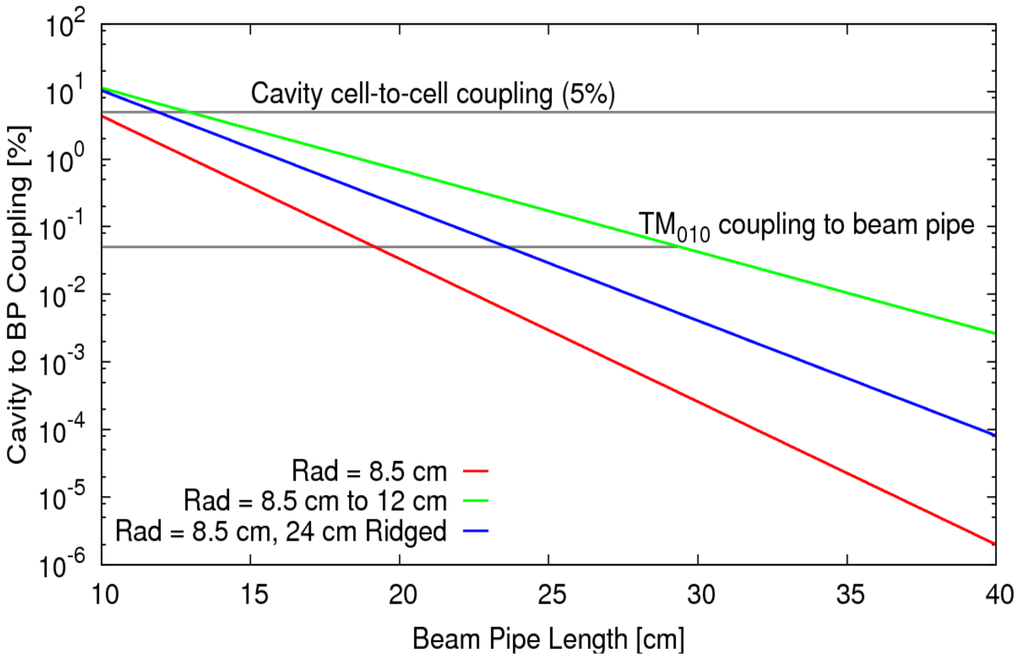
Modes with phase velocity = c are strongly excited (also high R/Q)

HOM analysis and damping ongoing (also at Rostok)

Transition Section



Transition Section



Length of transition:

- Reduce fundamental field at flange
- Minimize cross talk

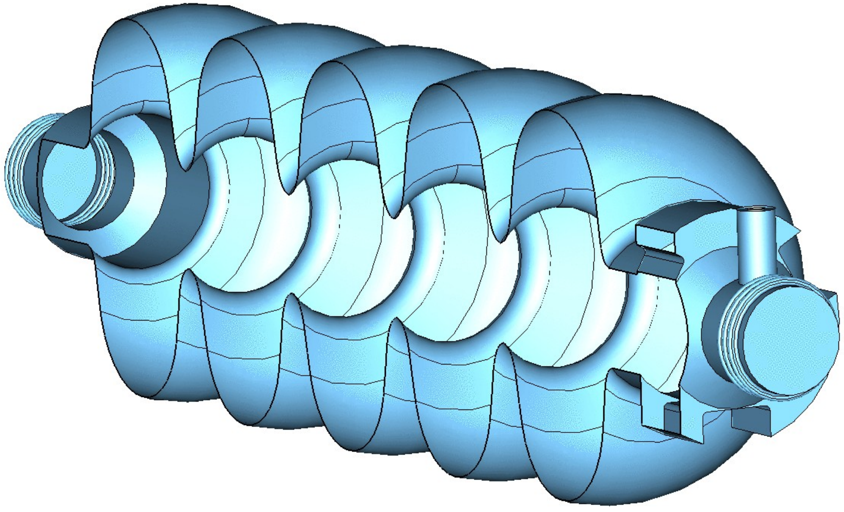
Two choices:

- Straight pipe (or taper) - SPL
- Enlarged (or ridged) - eRHIC

For eRHIC only

The use of ridges can improve HOM damping, modification to baseline design

Enlarged BP (old design) $\rightarrow$ longer transitions



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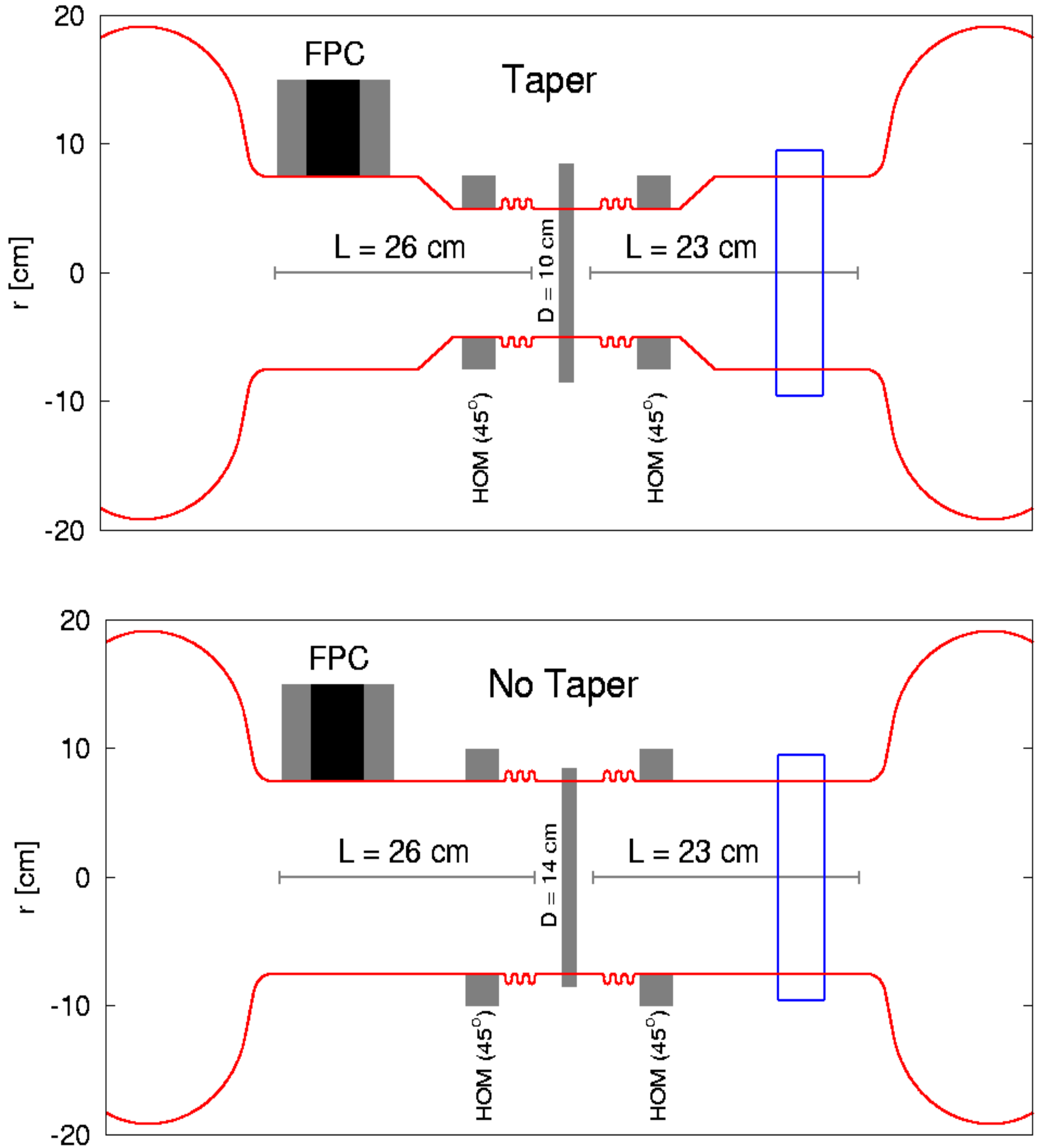


Taper Advantages:

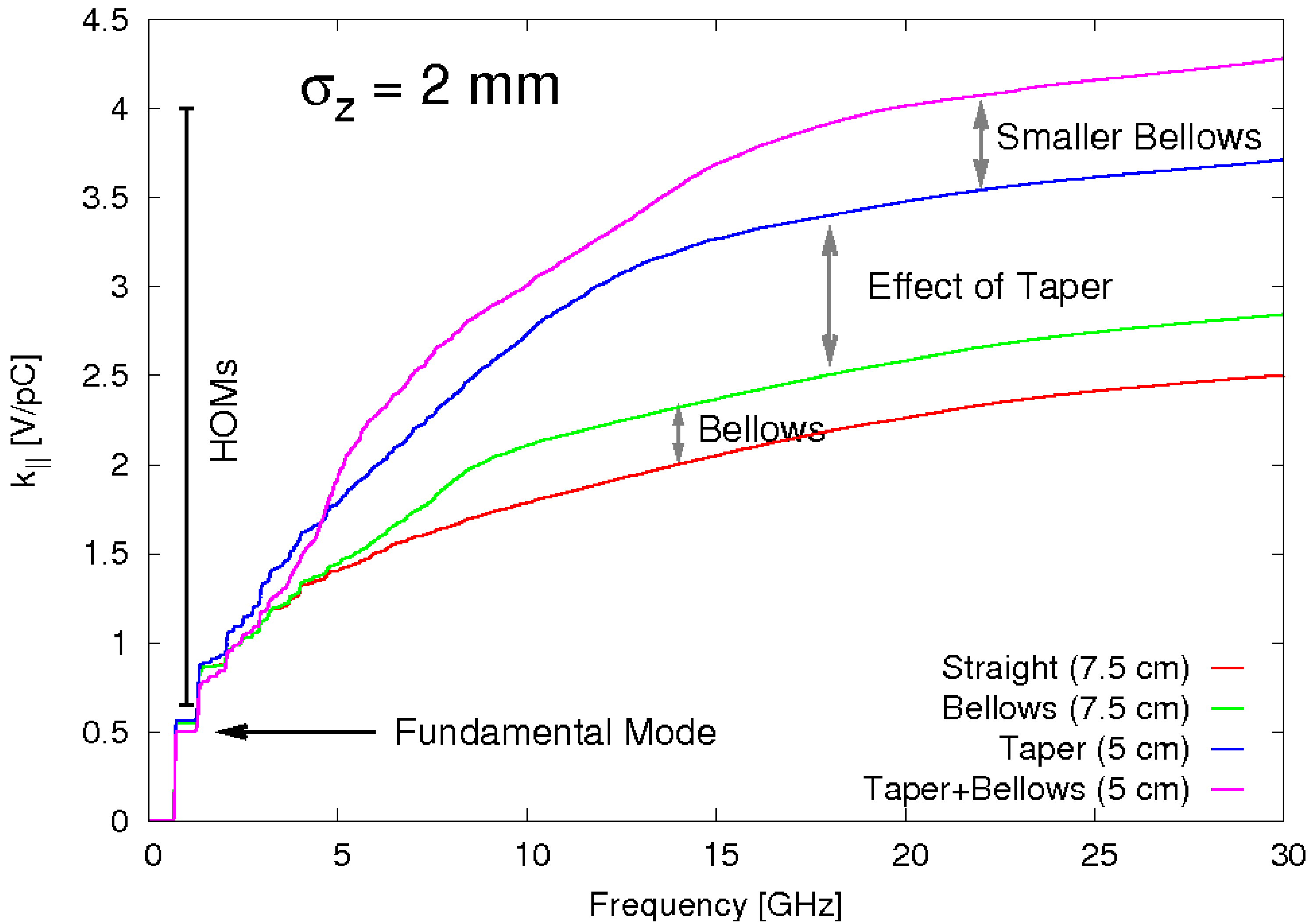
- Damp fundamental mode
- Reduce cross talk

Disadvantages:

- Increased cavity wakes
- Aperture & activation
- Low field multipacting

	k_L (V/pC)	k_T (V/pC/m)
Bellow	3.0	2.81
Taper	4.03	6.47
Taper+B	4.6	7.44

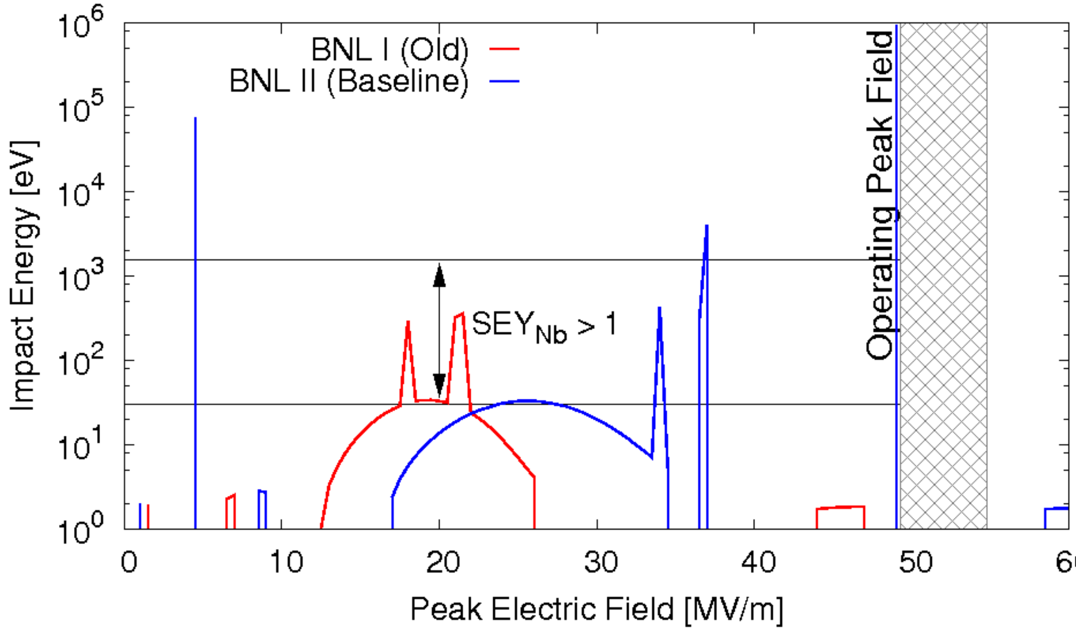
Longitudinal Loss Factor

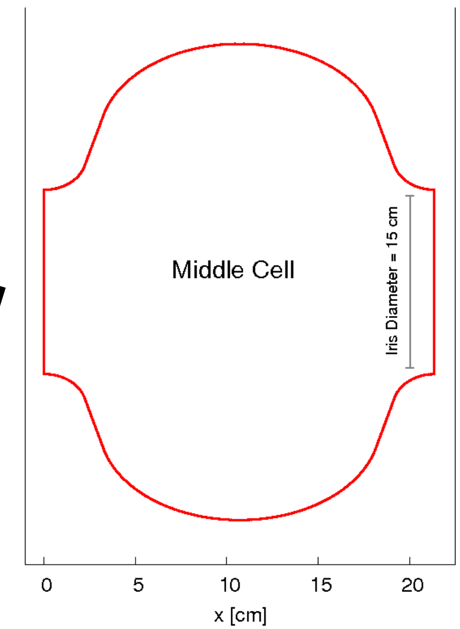


Energy loss & spread (RF, cavity wakes, resistive wall)

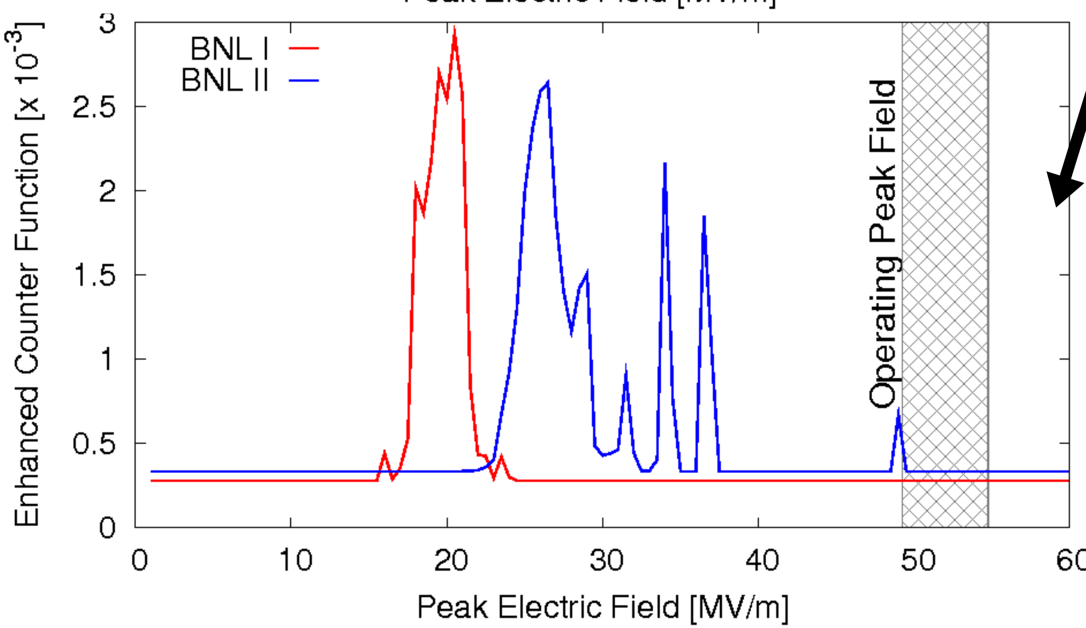
$\delta E \sim Qk_{||}$ (? MeV),

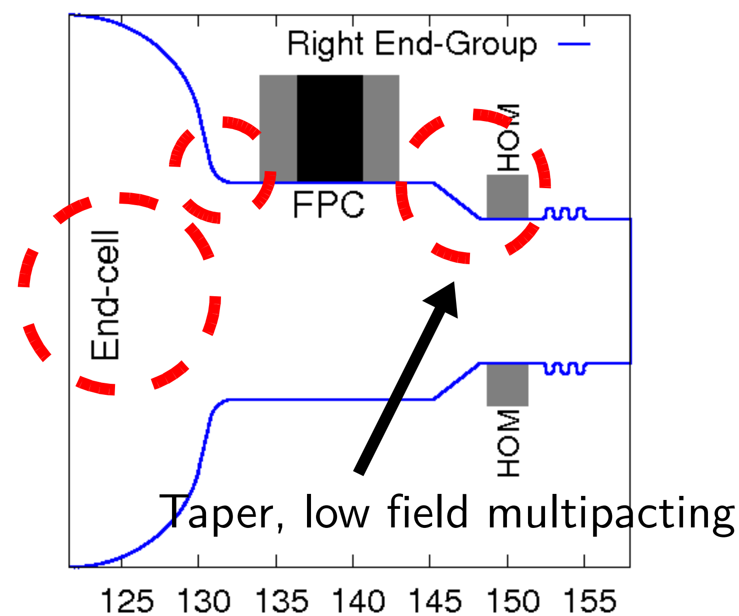
Cavity Multipacting



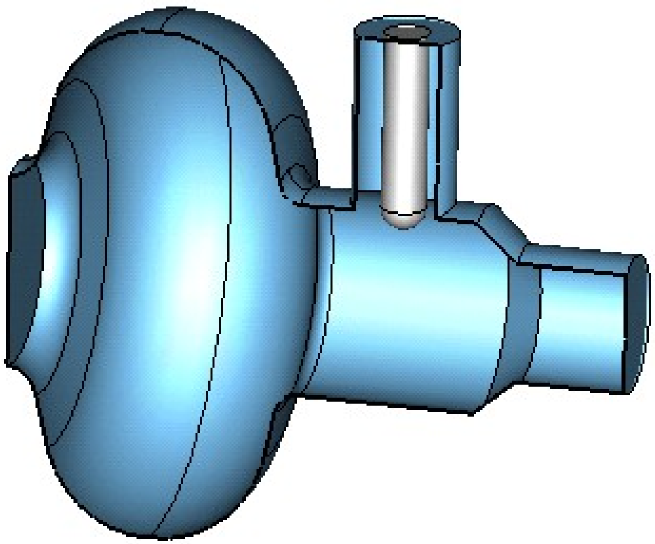


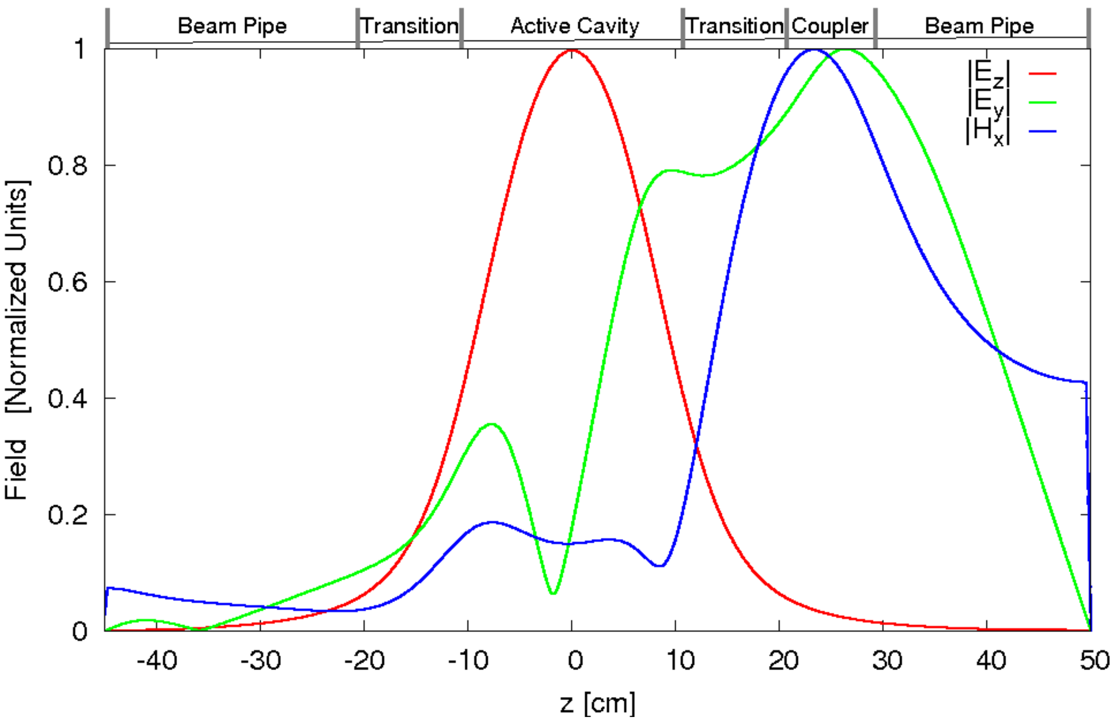
Non-issue





Coupler Kicks





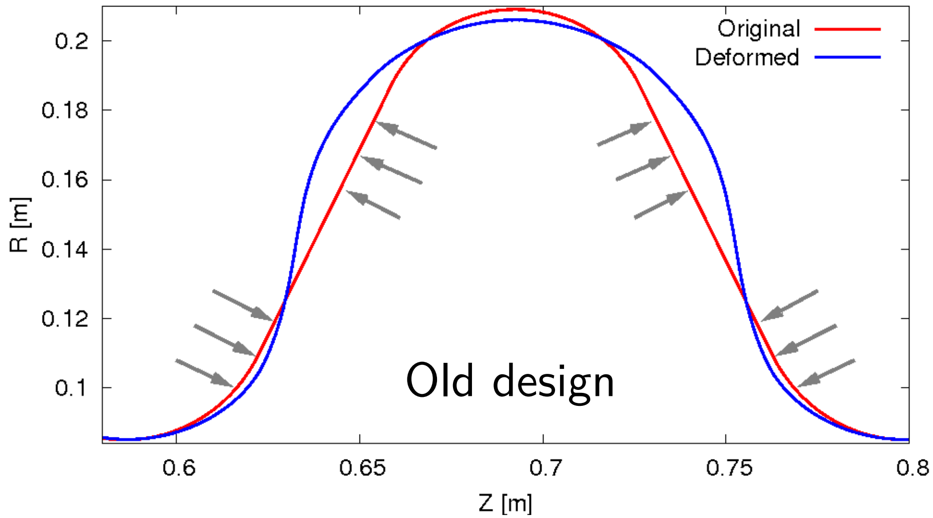
Coupler kicks cannot be neglected (not easy to have alternate couplers)

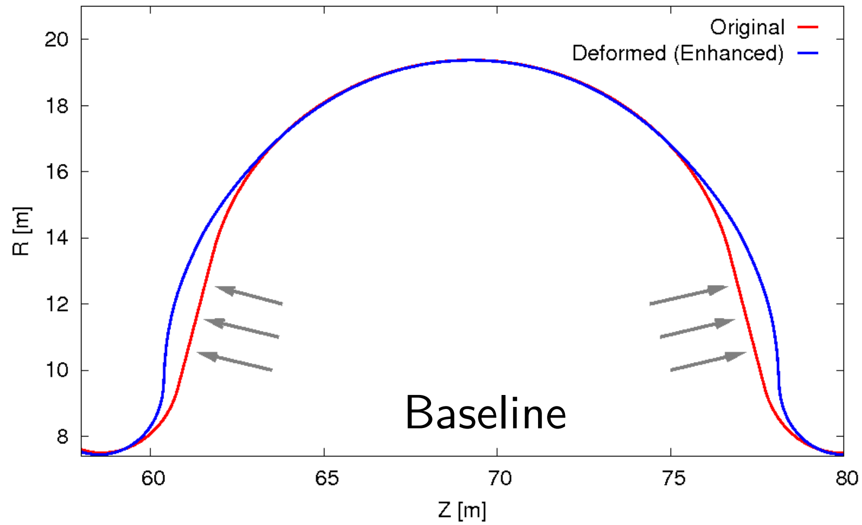
The kicks received and consequent emittance growth depends on Qext

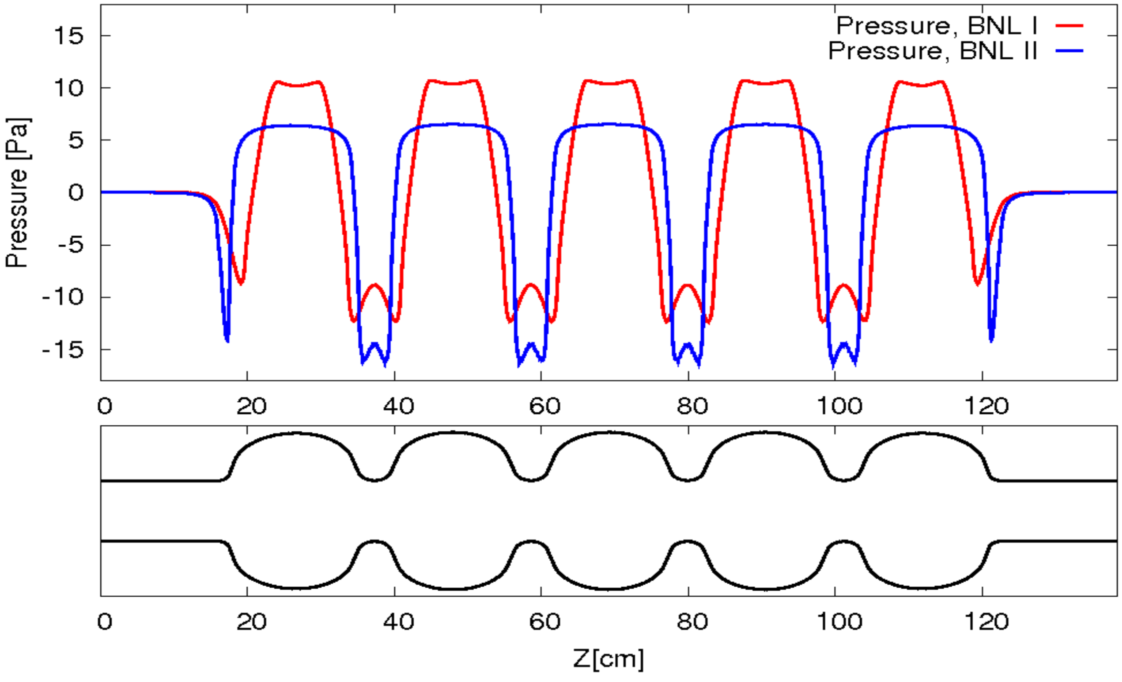
Iteration with optics & beam dynamics required

Partially remedy like symmetrizing studs could be useful

Lorentz Force Detuning







Work ongoing:

Structural differences from old design

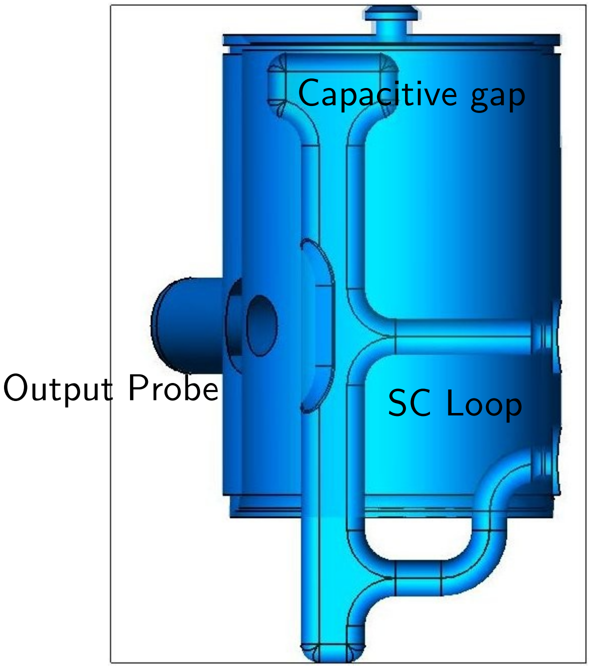
Stiffness x2 smaller from BNL I

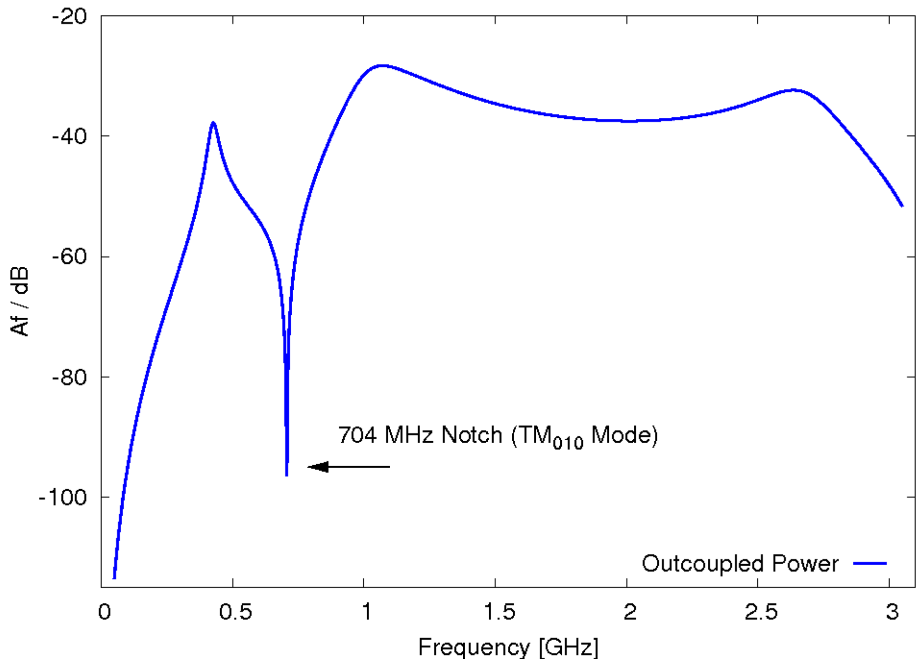
(1.28 Hz/(MV/m)^2)

Cavity stiffeners “may not” be needed

ANSYS: S. Bellavia

HOM Couplers





The "market standard" of tesla-type resonant filters possible but location is NOT in high-field region

Simple coaxial type or more broad-band is robust and appropriate (also BPMs)

Loss materials feasible, but particulates, out-gassing, charge deposition, 2K load

Some Comments

- Detailed cavity design & transition section complete
  - Engineering issues (He vessel, tuner etc..) needs to finalized
  - Mechanical & thermal analysis underway
- The decision of taper needs beam dynamics iteration
  - Taper section: **5cm** $\rightarrow$ suggestion to CEA cavity
  - -Or- a common flange radius if not taper
- Detailed HOM analysis and damping is being carried out