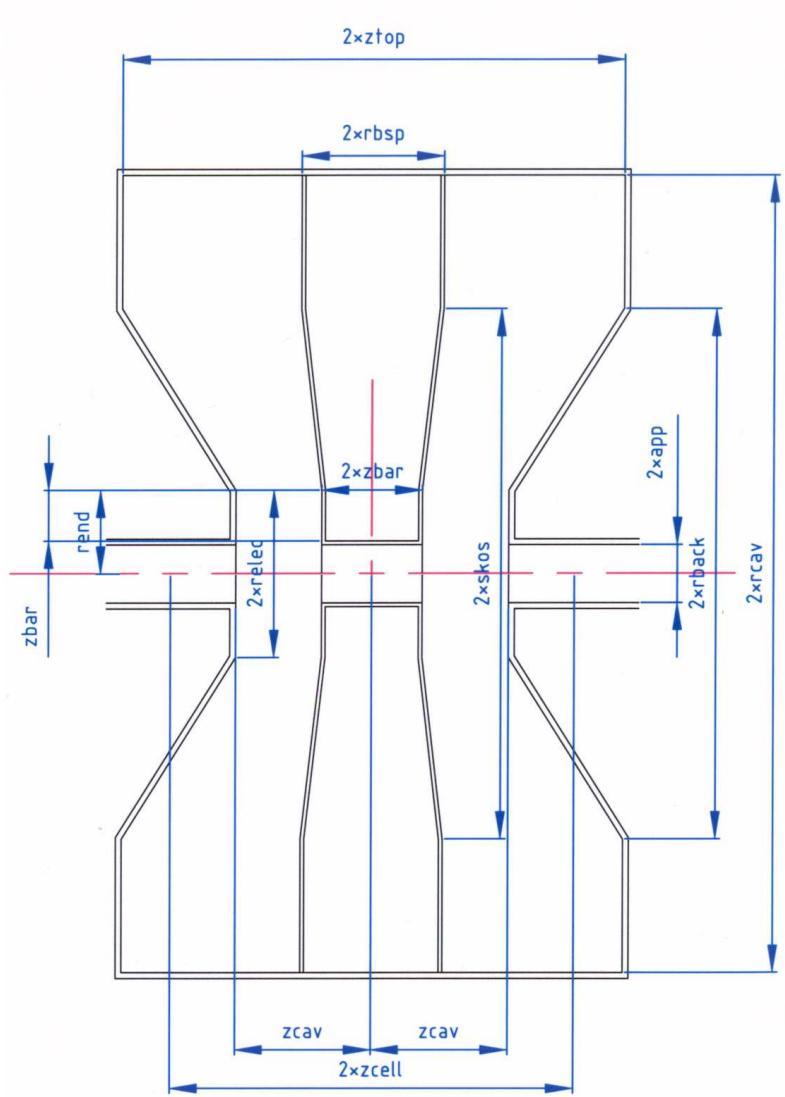
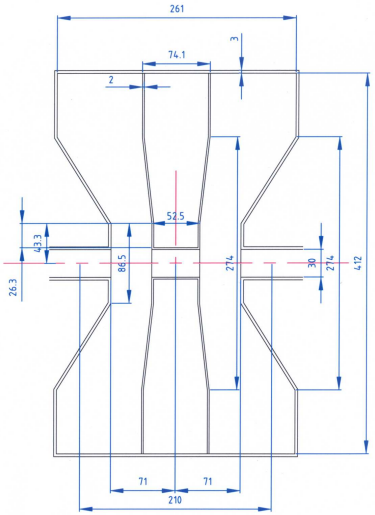
ELECTRODYNAMICS & MECHANICS OF MULTYGAP LOW-β SC STRUCTURES

Evgeny N. Zaplatin

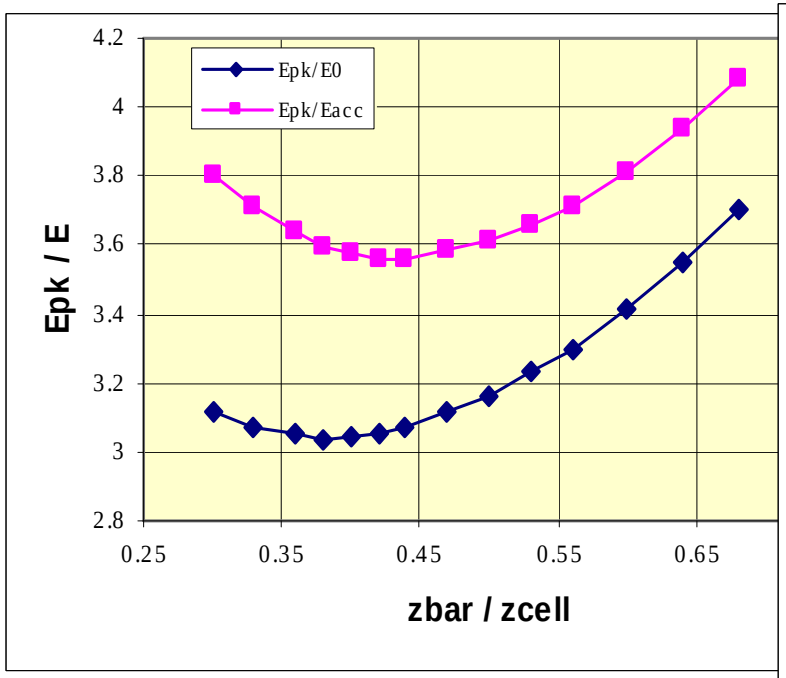
SPOKE CAVITY GEOMETRY

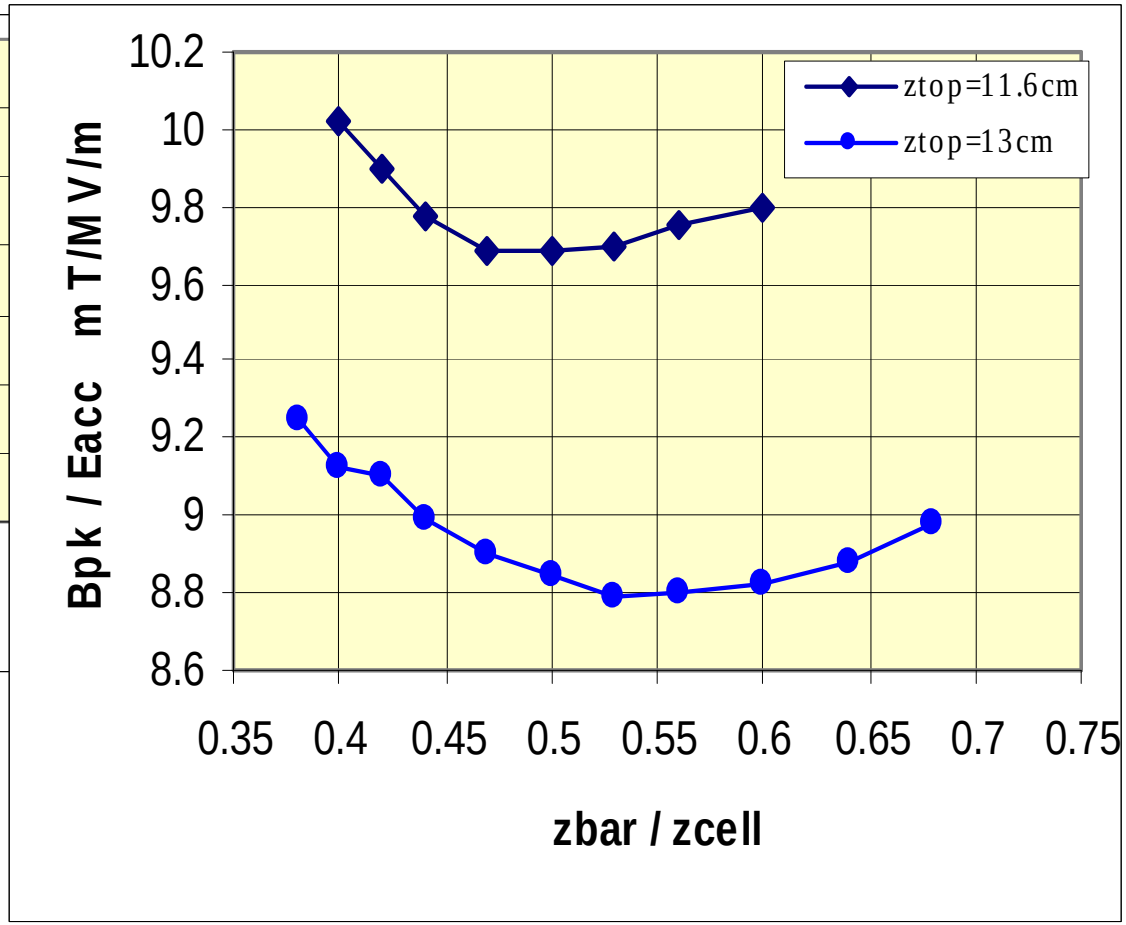


spoke 320-0.224-0.50



SPOKE CAVITY (320 MHz , β=0.224)

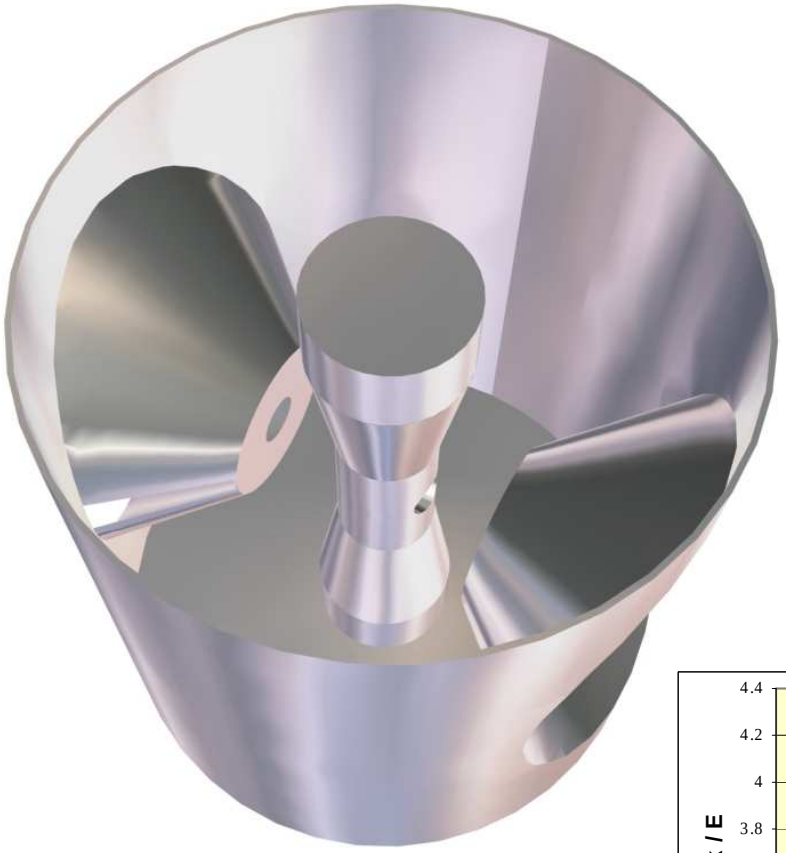


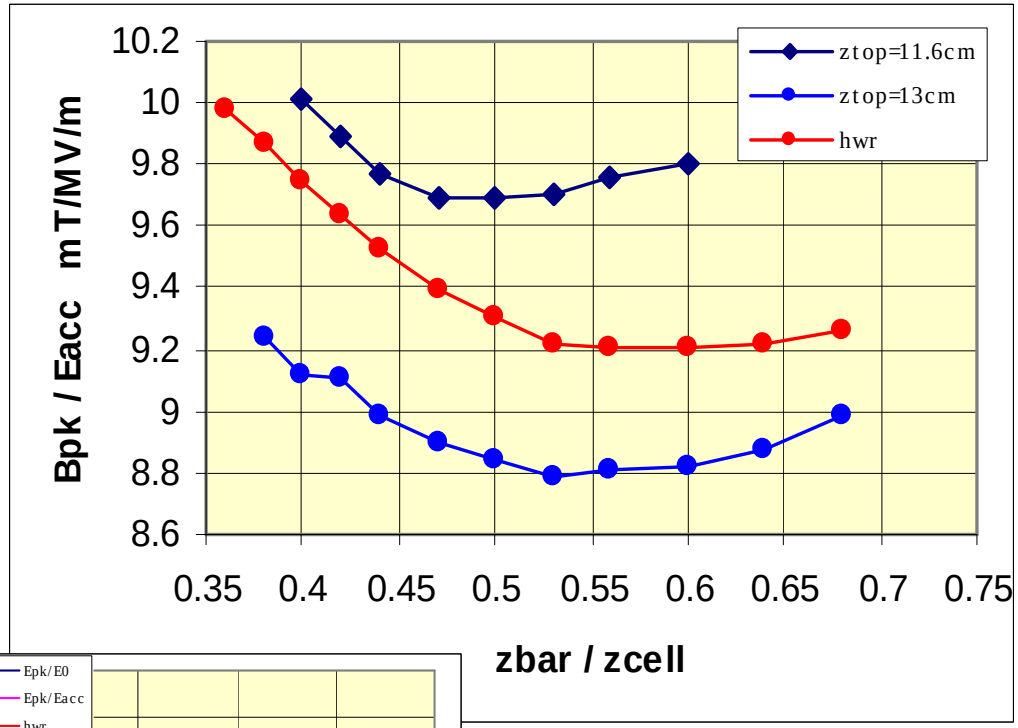


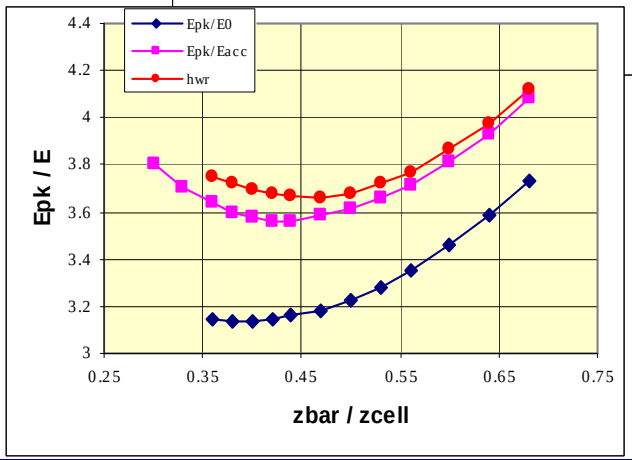
ztop=11.6cm @ B_{pk} = 66.(6) mT => E_{acc} = 6.88 MV/m (E_{pk} = 24.5 MV/m)

ztop=13.0cm @ B_{pk} = 66.(6) mT => E_{acc} = 7.58 MV/m (E_{pk} = 28 MV/m)

HALF-WAVE COAXIAL CAVITY (320 MHz , β=0.224)







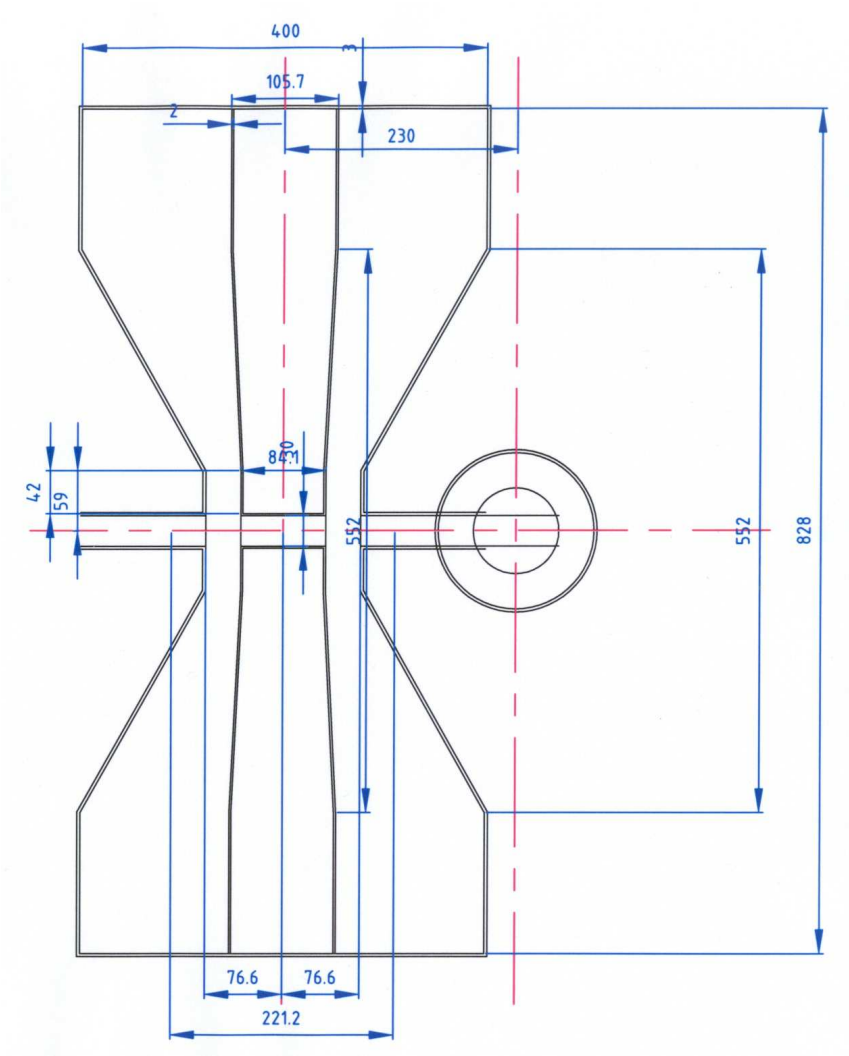
ztop = 13 cm

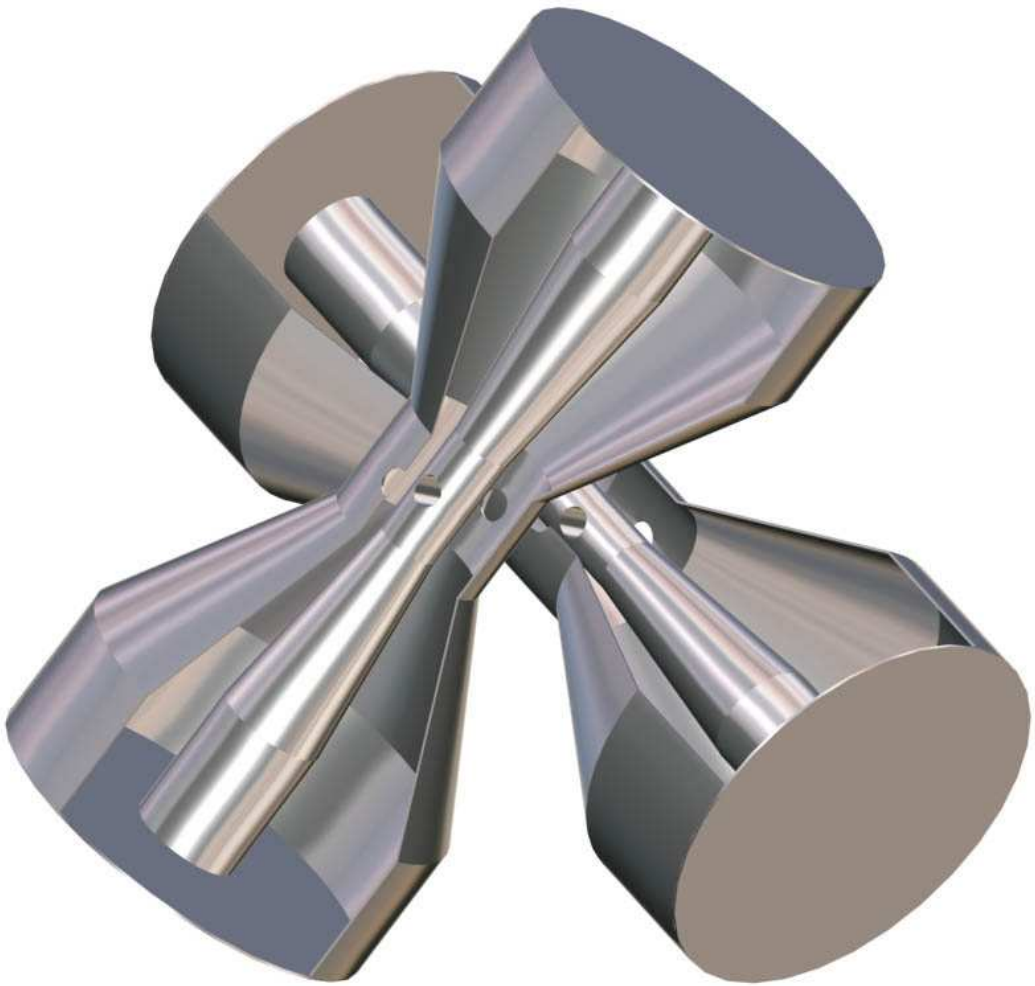
@ B_{pk} = 66.(6) mT
=>

E_{acc} = 7.25 MV/m

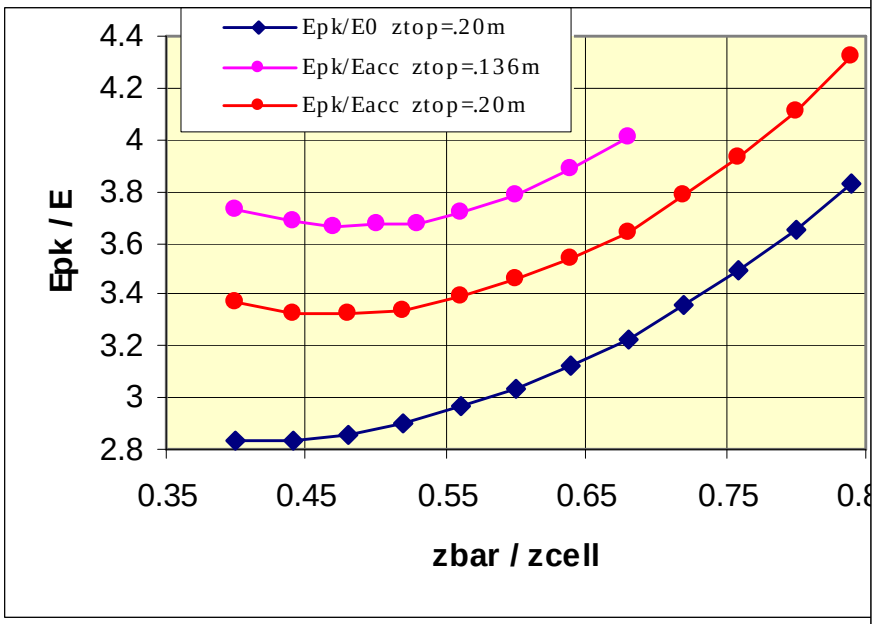
(E_{pk} = 28 MV/m)

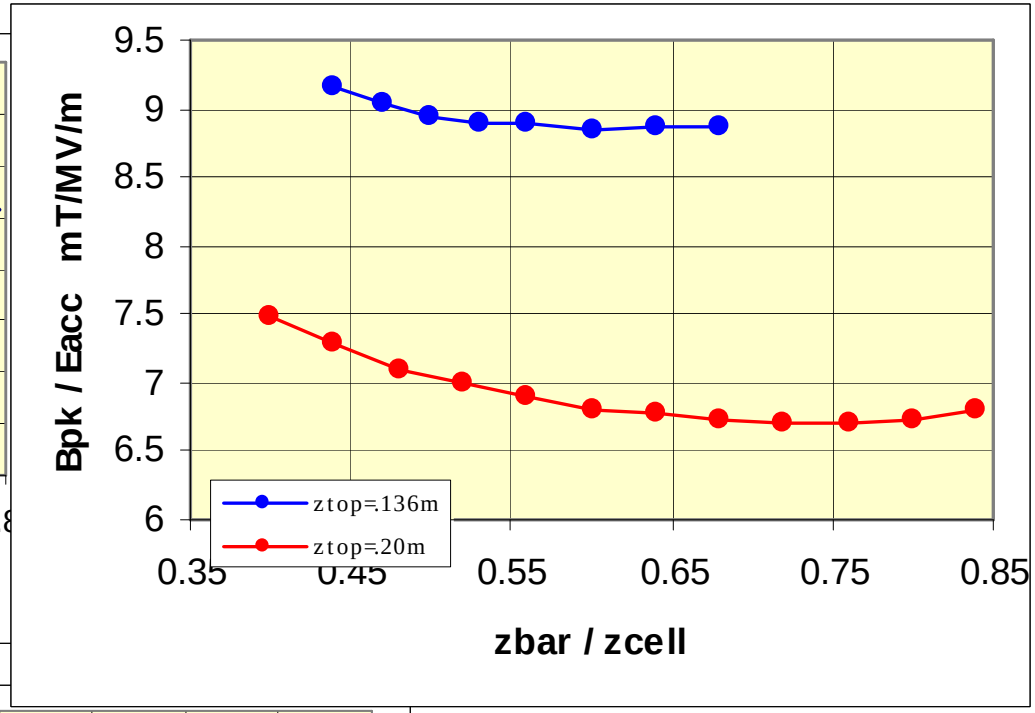
HALF-WAVE COAXIAL CAVITY (160 MHz , β=0.118)

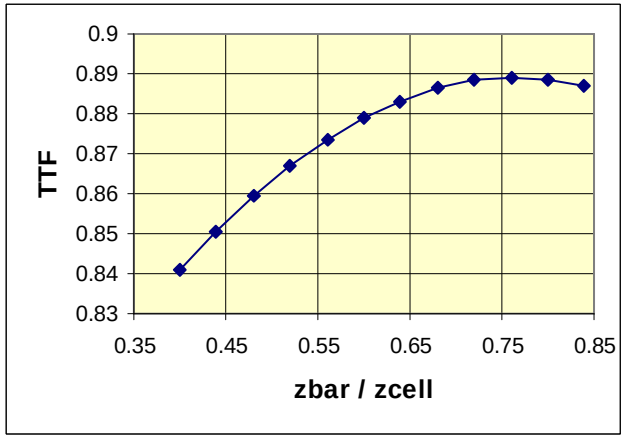


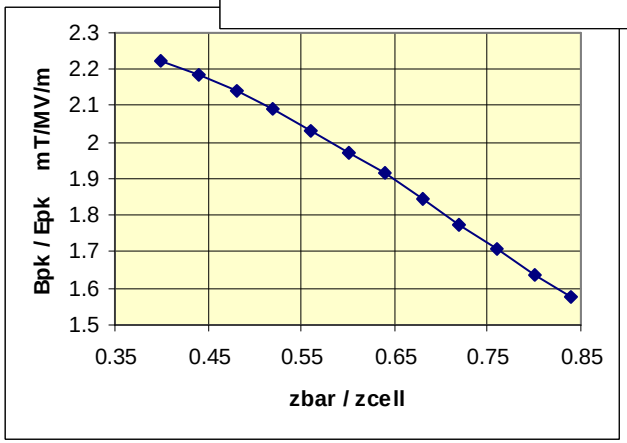


HALF-WAVE COAXIAL CAVITY (160 MHz , β=0.118)









zbar/zcell = 0.72

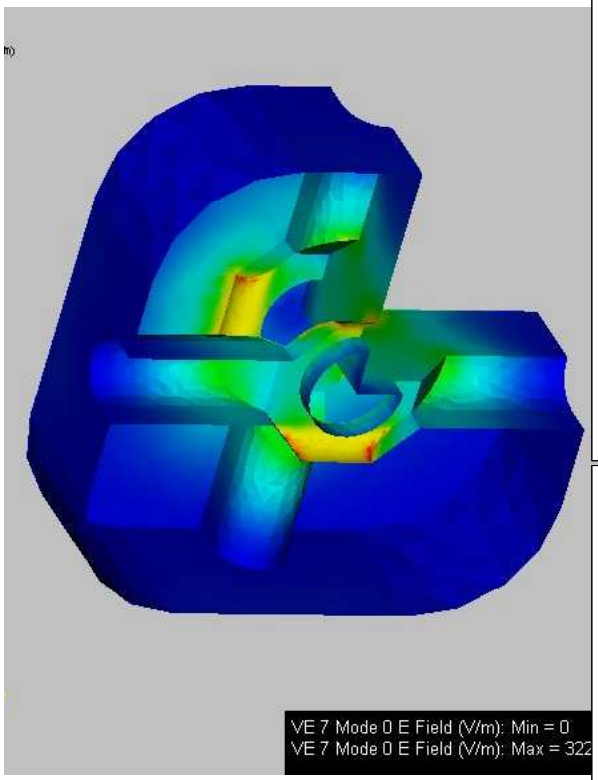
ztop = 20.0 cm

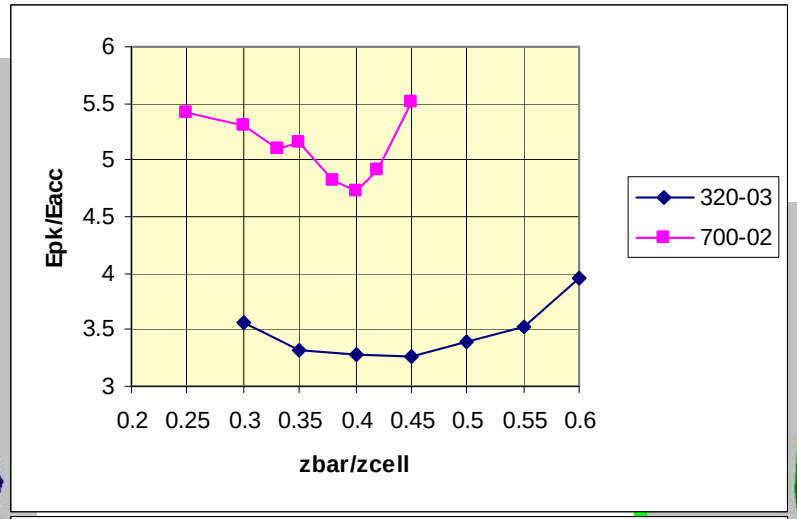
@ B_{pk} = 66.(6) mT =>

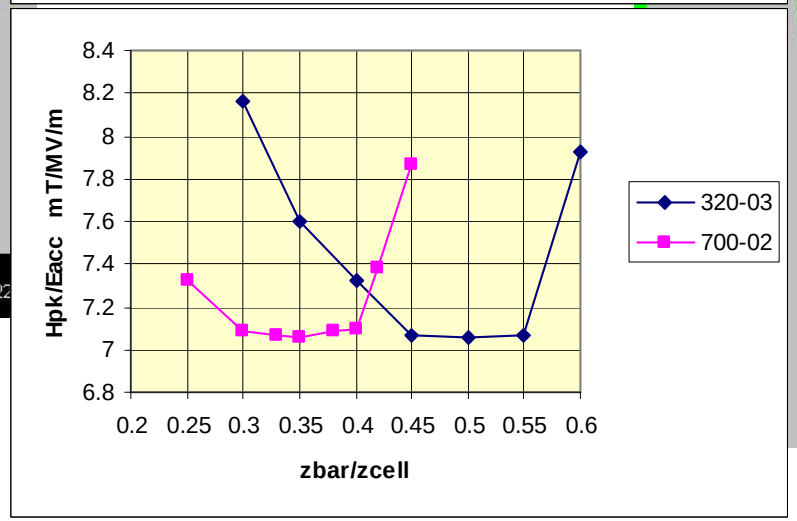
E_{acc} = 9.94 MV/m

(E_{pk} = 37.6 MV/m)

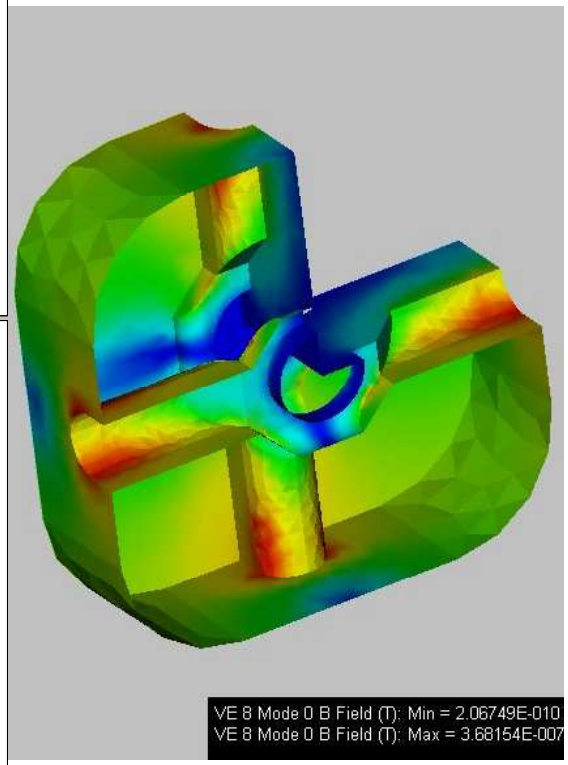
E_{pk} & B_{pk} OPTIMISATION BY ACC. GAP GEOMETRY





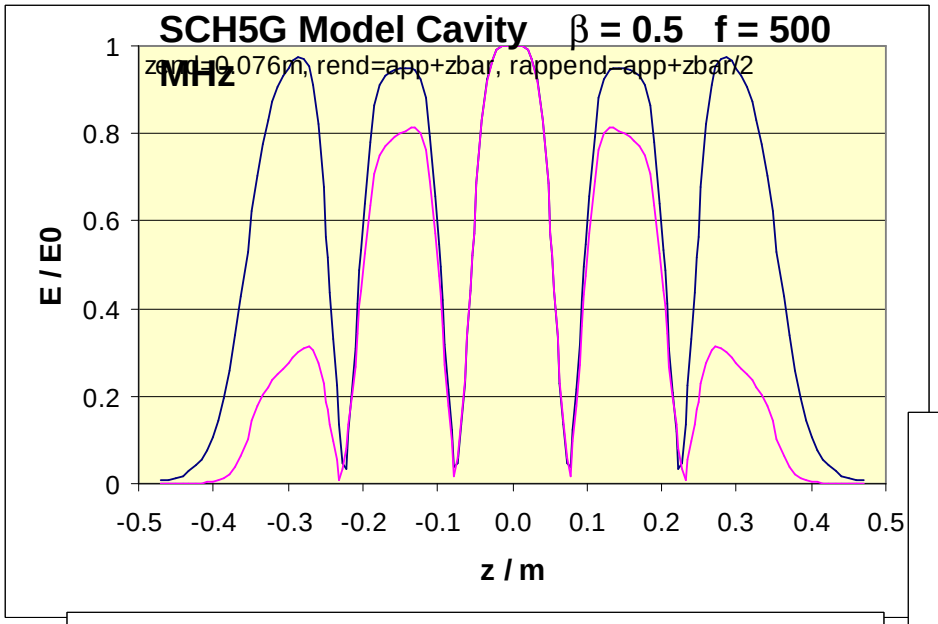


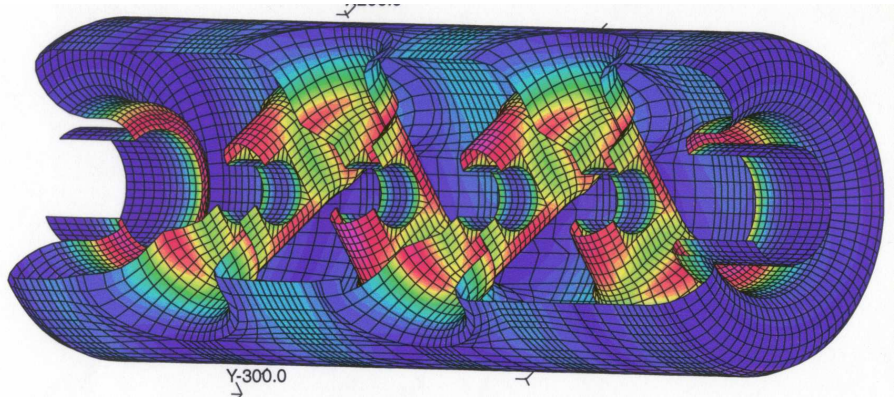
Magnetic RF field distribution

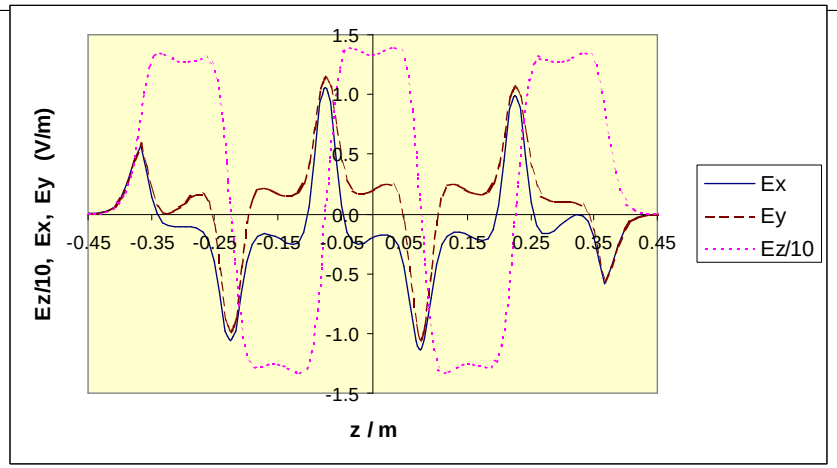


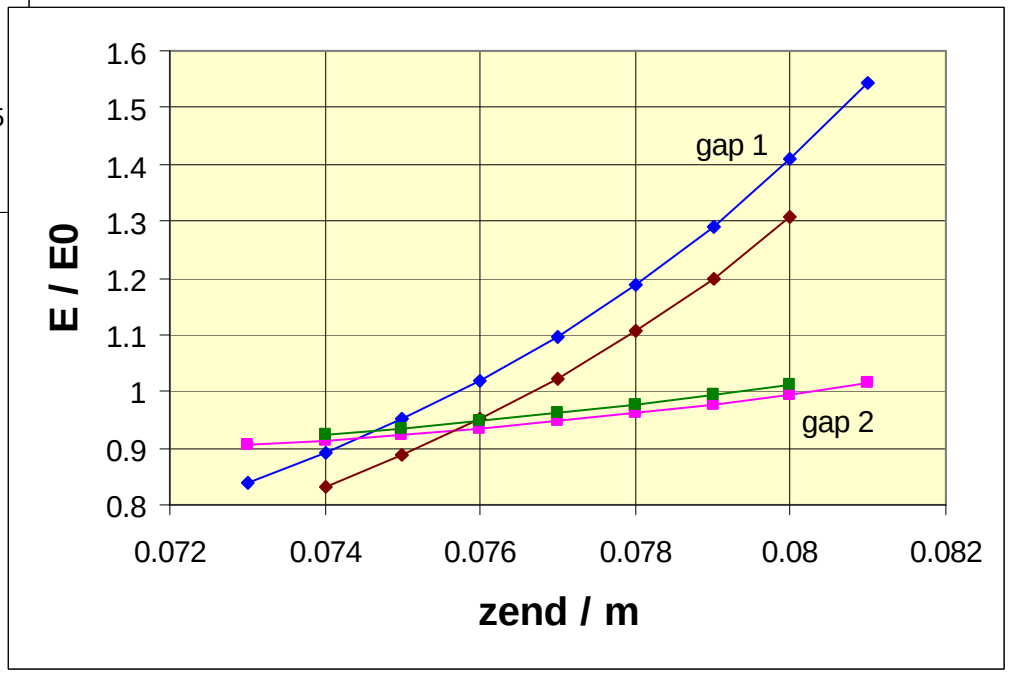
Electric RF field distribution

E-FIELD PROFILE OPTIMISATION BY END ELECTRODE LENGTH CHANGE

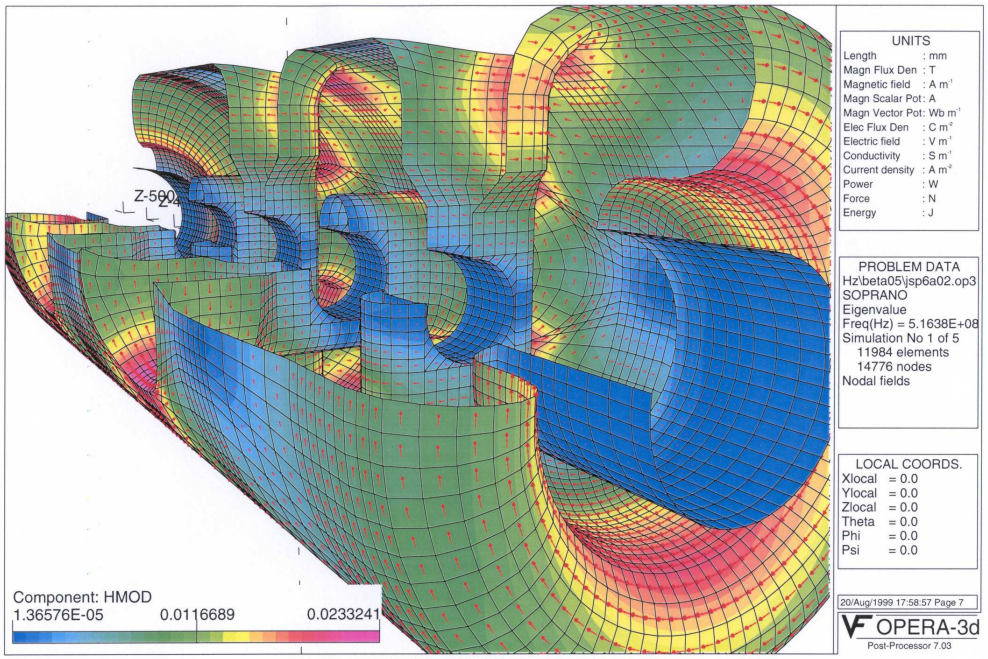


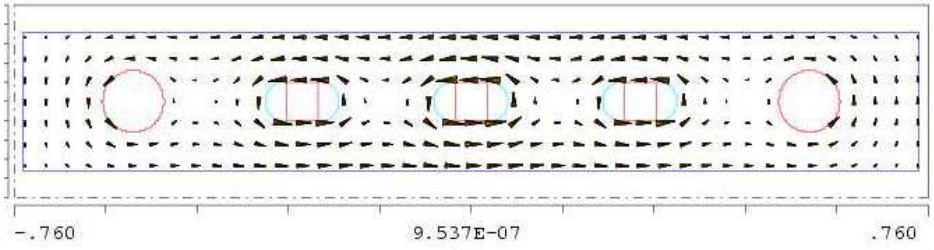


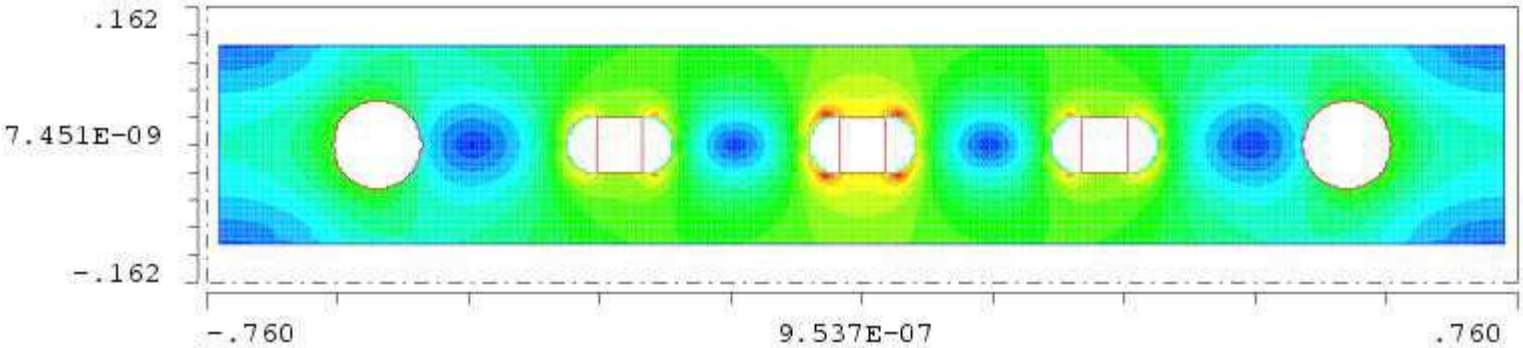




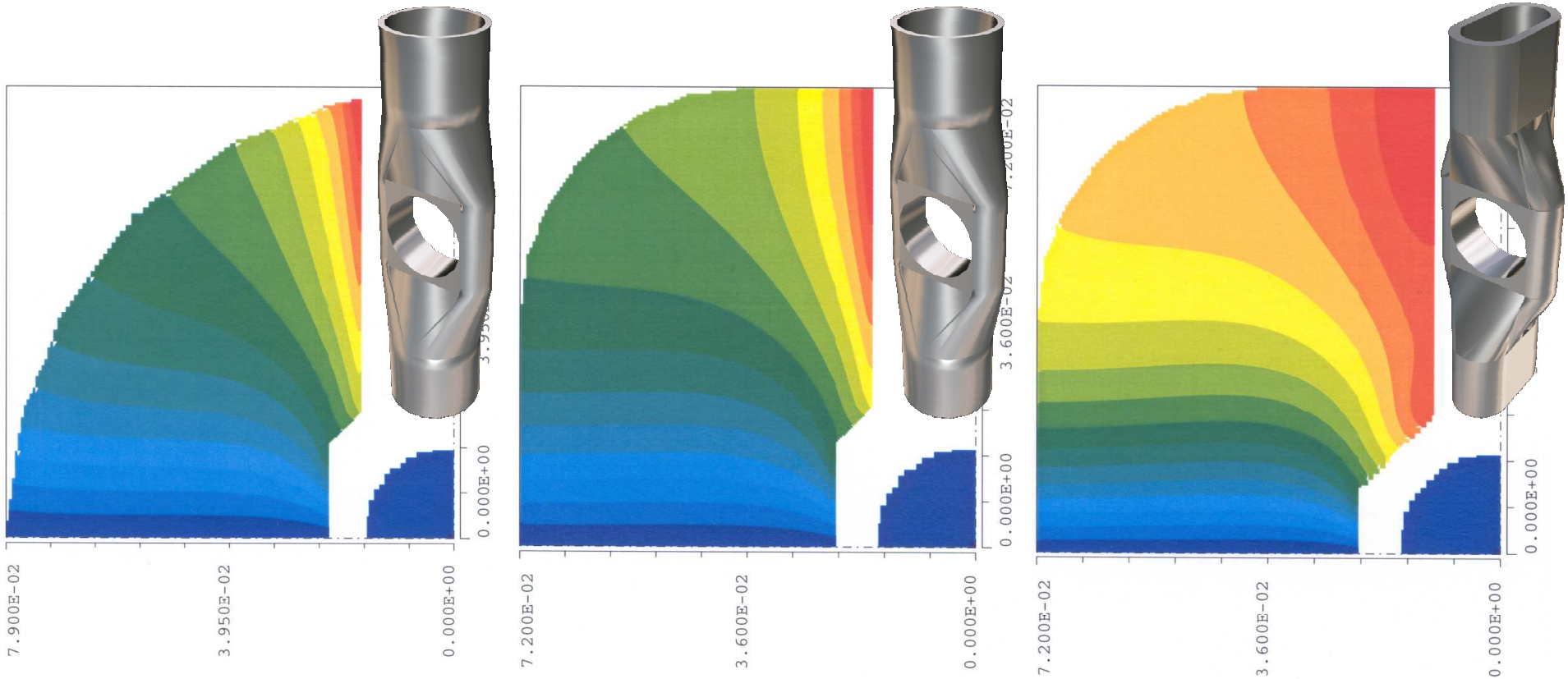
SC H-CAVITY RF MAGNETIC FIELD DISTRIBUTION







B_{pk} OPTIMISATION BY CROSS CAVITY GEOMETRY



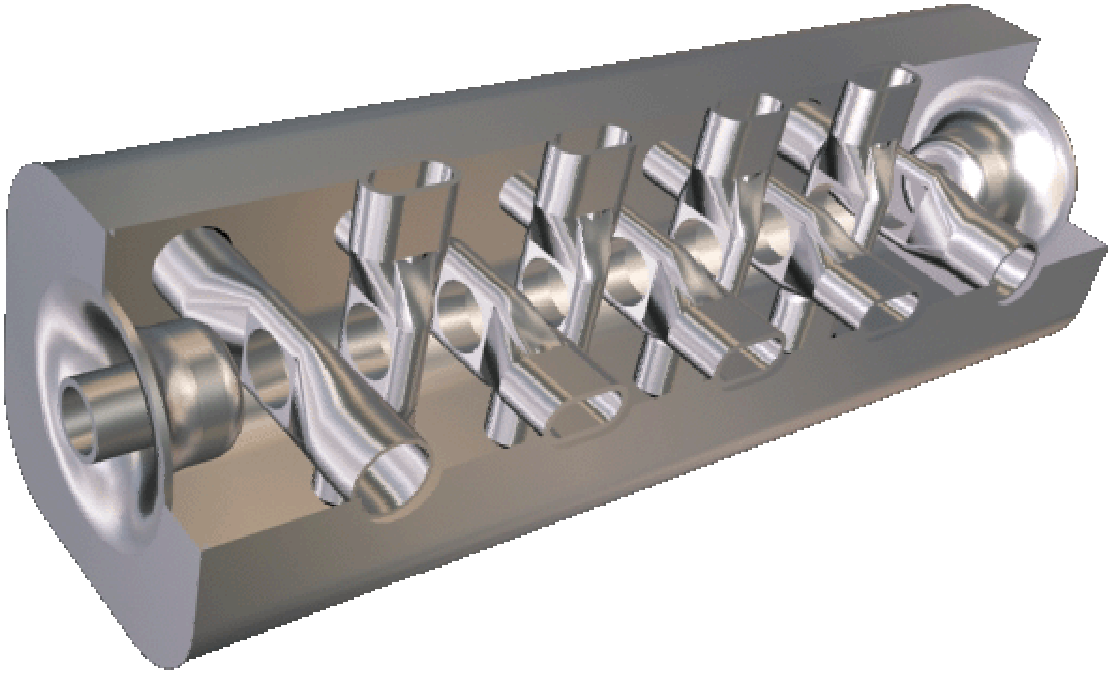
B_{pk}/E_{acc} = 9.20 mT/MV/m

B_{pk}/E_{acc} = 8.17 mT/MV /m

B_{pk}/E_{acc} = 7.06 mT/MV /m

SC H-CAVITY (700 MHz , β=0.2)

frequency	MHz	700
$\beta = v/c$		0.2
R_{cav}	cm	7.15
L_{cav}	cm	48.5
app. R_i	cm	1.5
cell	cm	4.283
wall	mm	2.0
thickness		/ 1.0
ttf		0.778
E_{pk} / E_{acc}		5.10
B_{pk} / E_{acc}	mT/MV/m	7.06
B_{pk} / E_{pk}	mT/MV/m	1.38

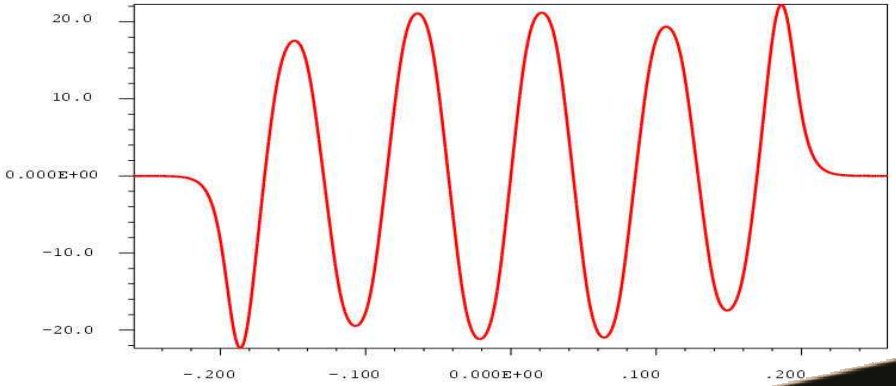


SCH-CAVITY PARAMETRS

frequency	MHz	700	700	700	320	352
$\beta = v/c$		0.2	0.4	0.55	0.22	0.1
R_{cav}	cm	7.15	9.10	9.20	15.15	11.3
app. R_i	cm	1.5	1.5	1.5	1.5	1.5
cell	cm	4.283	8.565	11.78	10.3	4.26
cav. length	cm	48.5	87.5		113.5	53.4
No. of gaps		10	10	10	10	10
ttf		0.778	0.778	0.783	0.888	.813
E_{pk}/E_{acc}	MV/m	5.10	3.88	3.79	4.61	5.61
B_{pk}/E_{acc}	mT/ (MV/m)	7.06	8.03	9.76	6.42	3.85
B_{pk}/E_{pk}	mT/ (MV/m)	1.38	2.07	2.58	1.39	0.69

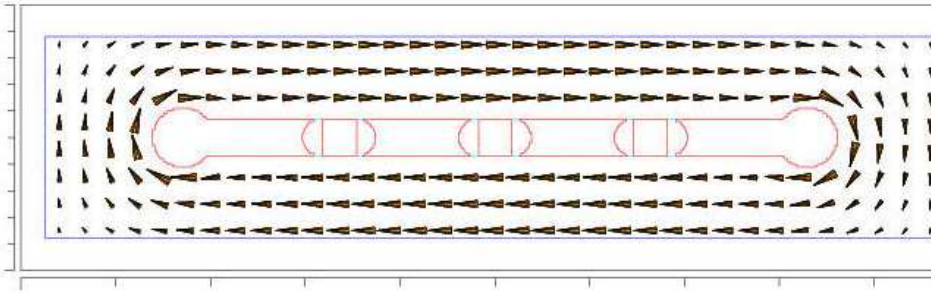
10-GAP SC H-CAVITY (320 MHz , β = 0.3)

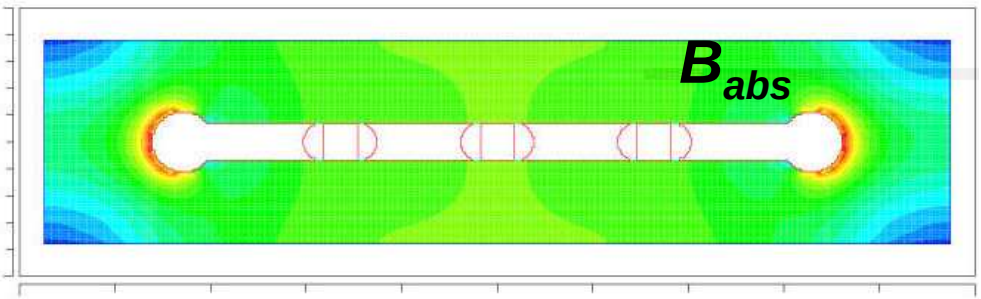
Bars



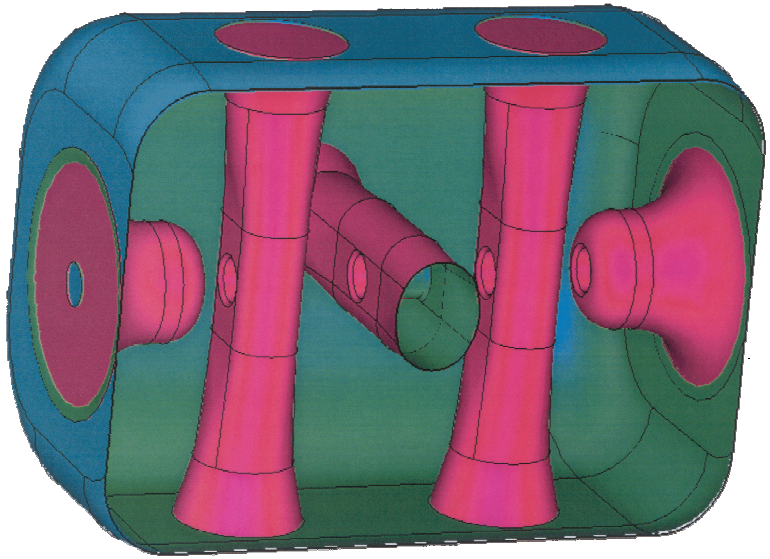
E_z along beam path

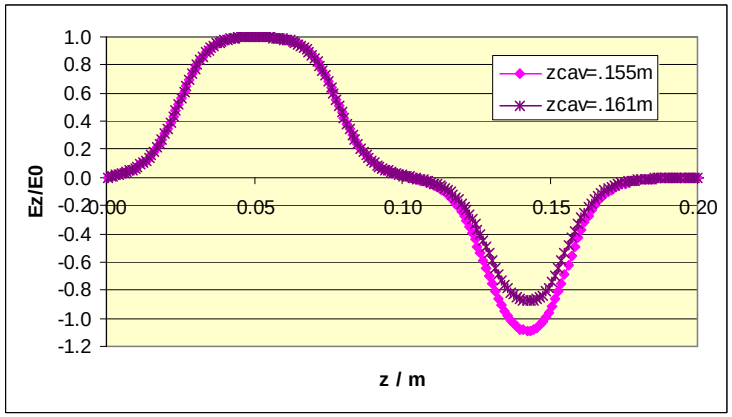
RF magnetic field distribution



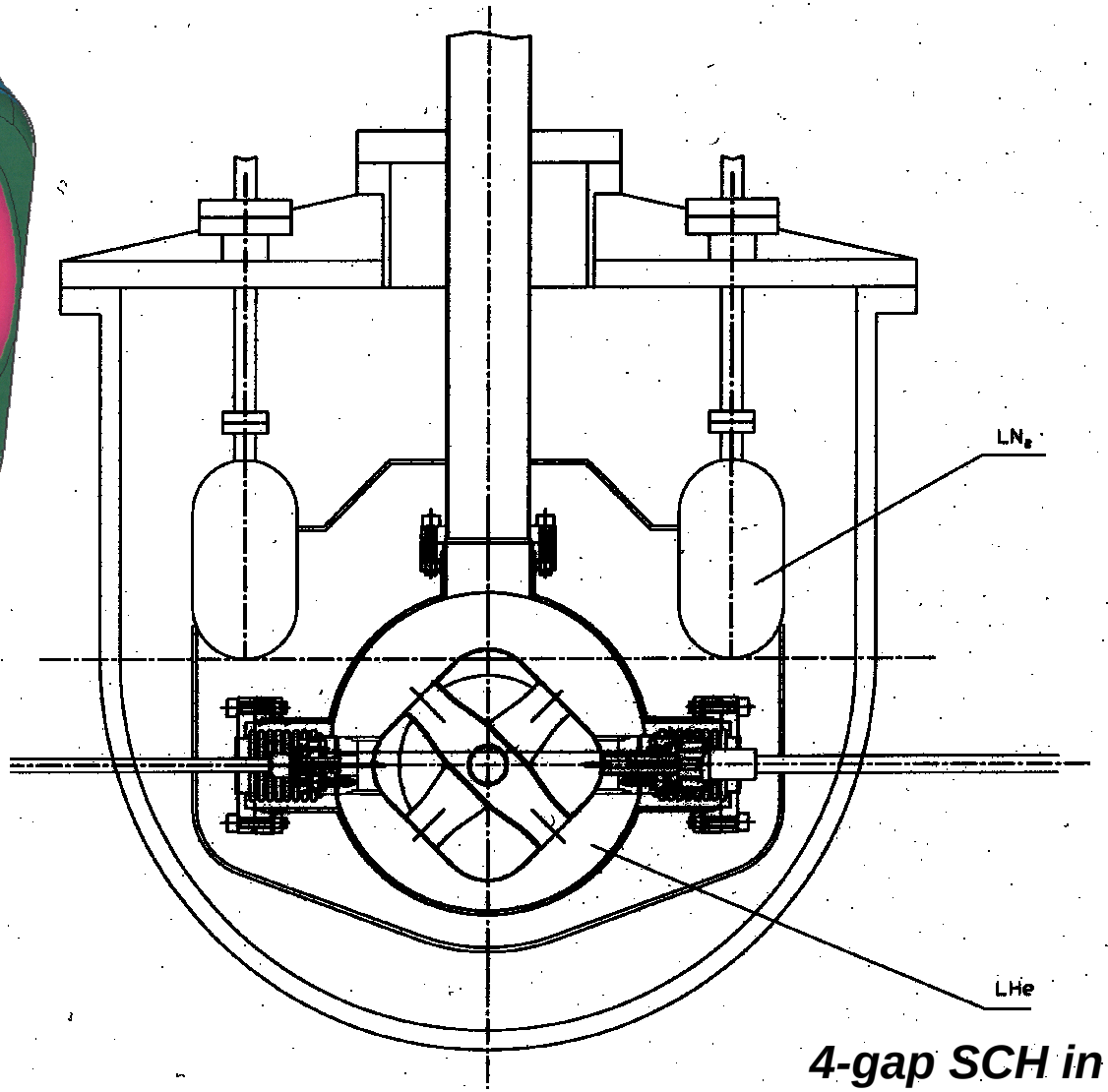


4-GAP SC H-CAVITY (320 MHz , β=0.2)



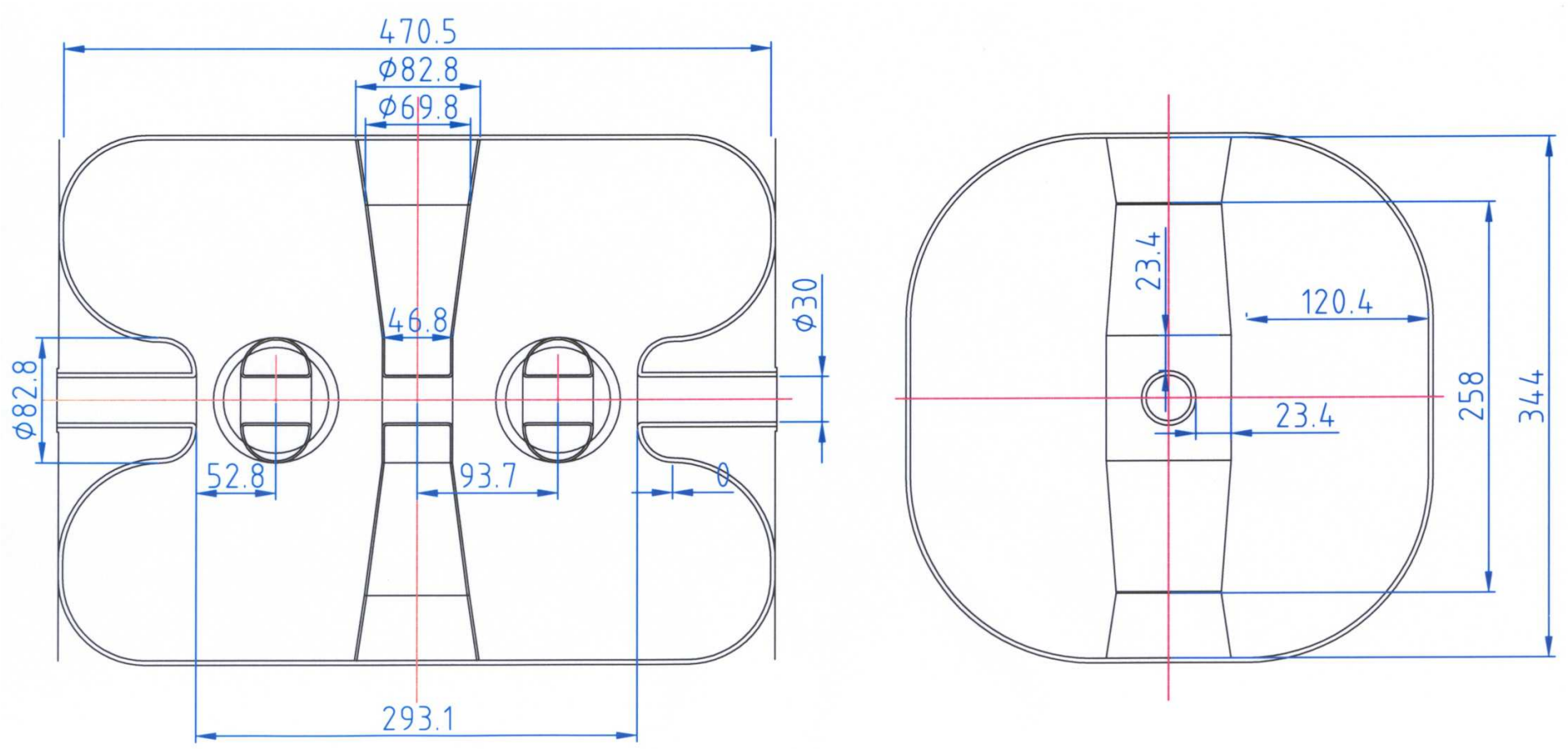


E_z field in 4-gap SCH



4-gap SCH in Cryostat

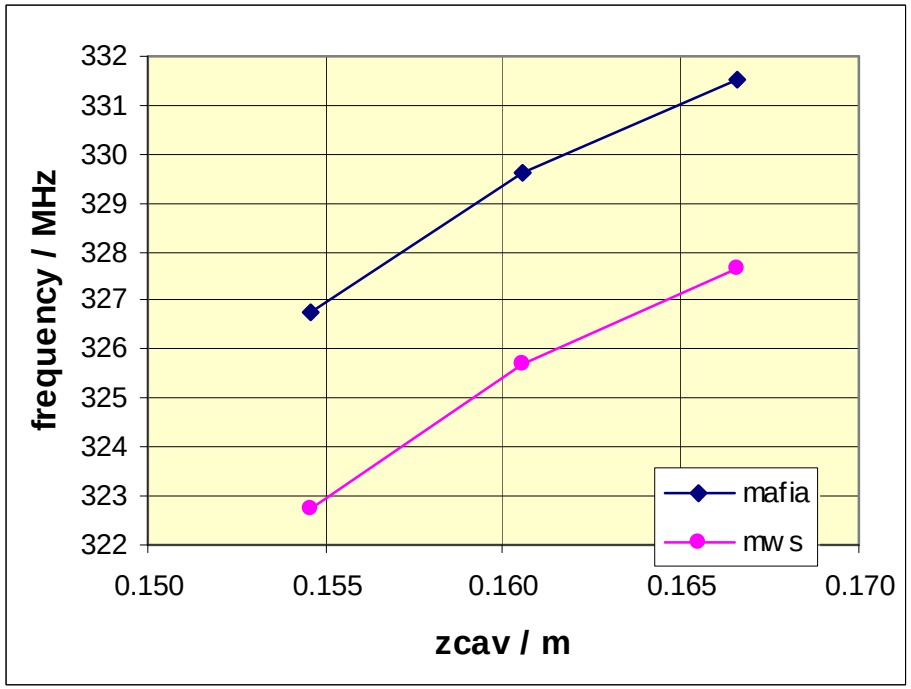
4-GAP SC H-CAVITY (320 MHz , β=0.2)



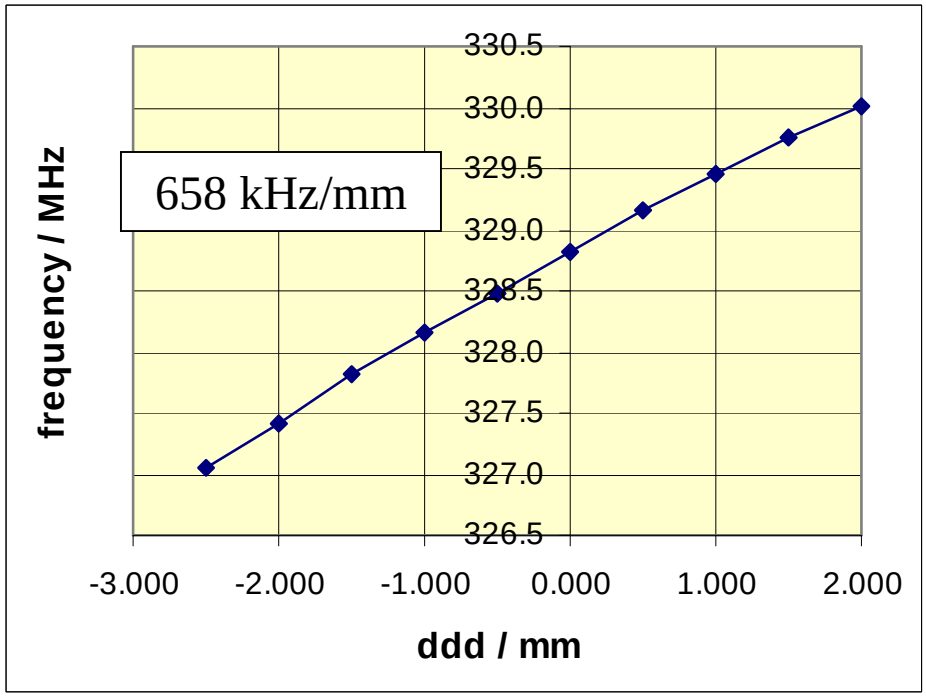
4-GAP SC H-CAVITY (320 MHz , β=0.2)

(tuning)

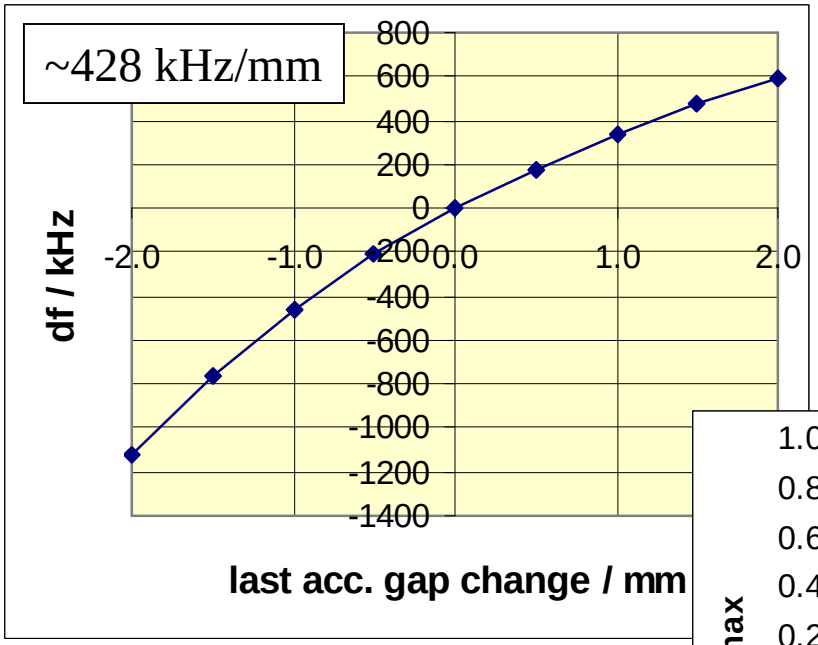
tuning by cavity length change

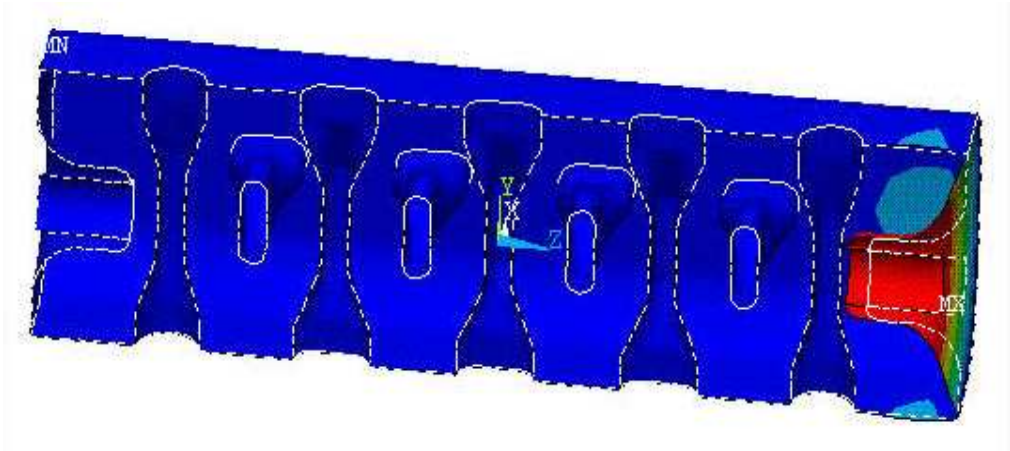


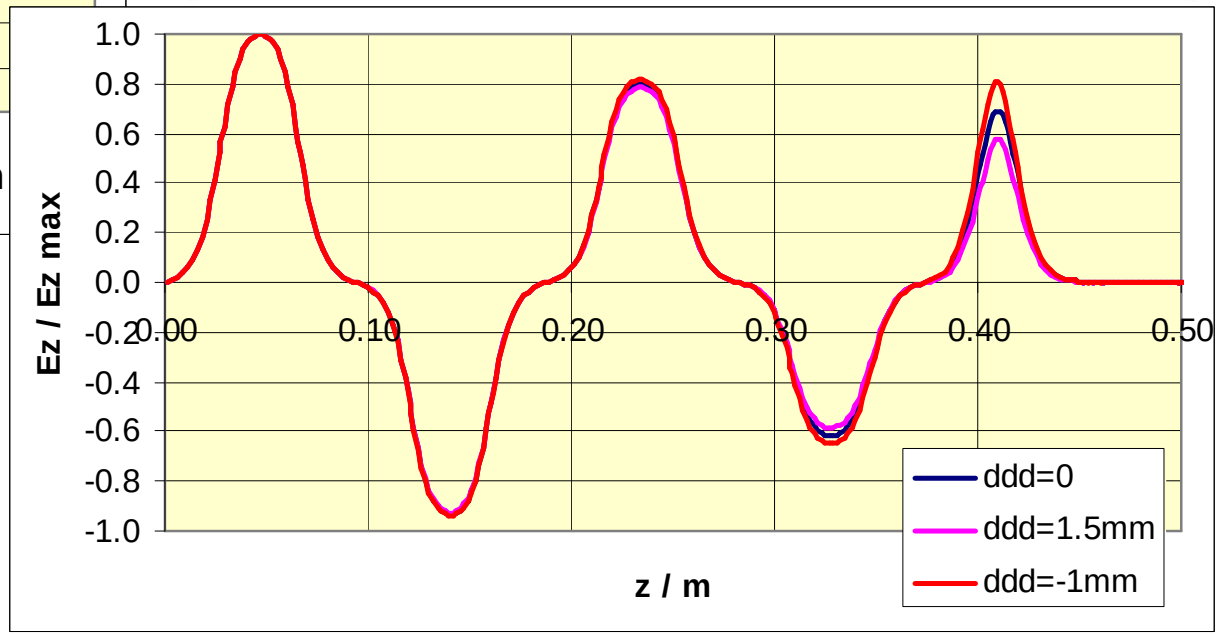
tuning by accelerating gap change



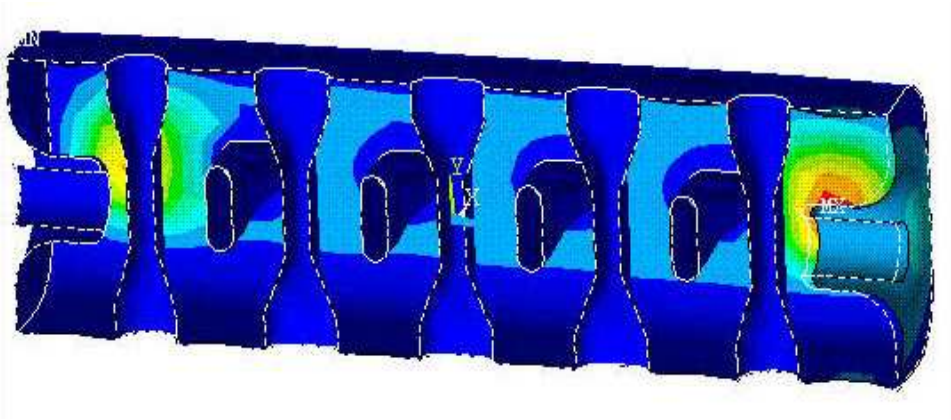
10-GAP SC H-CAVITY (320 MHz , β=0.2)
(tuning)

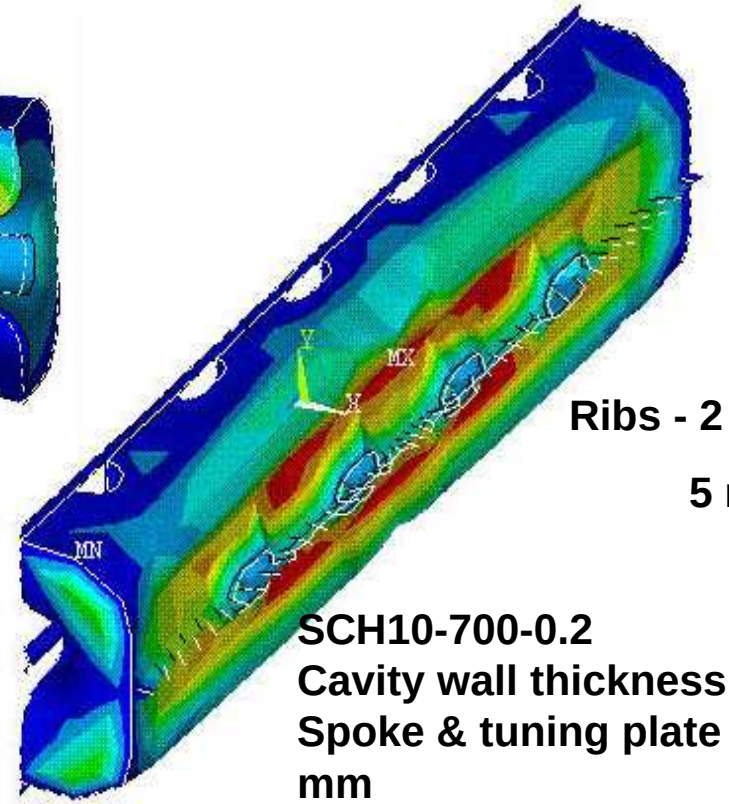






SCH-CAVITY UNDER 1 Bar PRESSURE





Ribs - 2 cm high

5 mm thick

SCH10-700-0.2
Cavity wall thickness – 2 mm
Spoke & tuning plate walls – 1 mm
Max deformation = 0.0185 mm
Max Stress von Mises = 9.9 MPa

SCH10-320-0.3
Cavity wall thickness – 3 mm
Spoke & tuning plate walls – 1 mm
Max deformation = 1.579 mm
Max Stress von Mises = 193 MPa

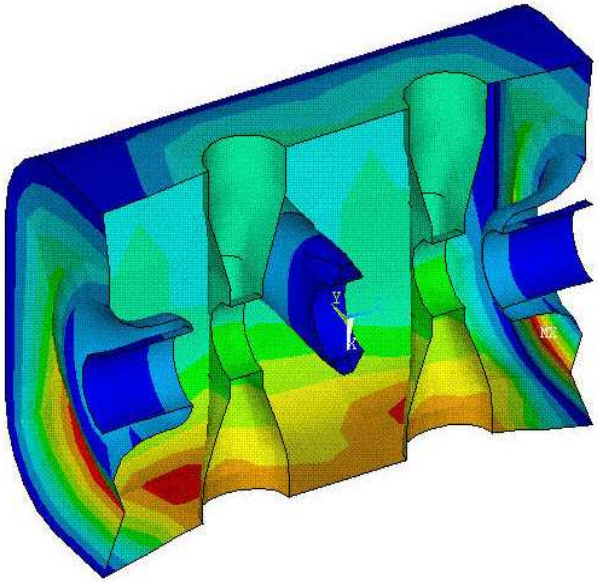
SCH10-700-0.2
Cavity wall thickness – 2 mm
Spoke & tuning plate walls – 1 mm
Max deformation = 0.00834 mm
Max Stress von Mises = 9.3 MPa

SCH10-320-0.3
Cavity wall thickness – 3 mm
Spoke & tuning plate walls – 1 mm

SCH-CAVITY UNDER 1 Bar PRESSURE & COOL-DOWN

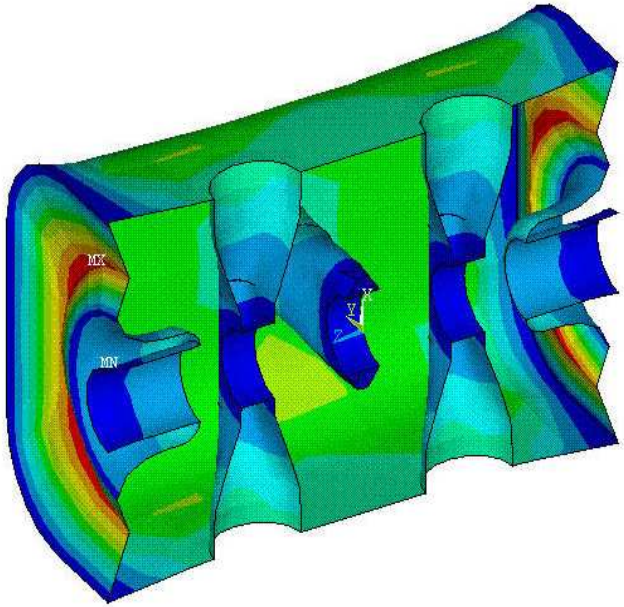
700 MHz, β=0.2

cool-down process



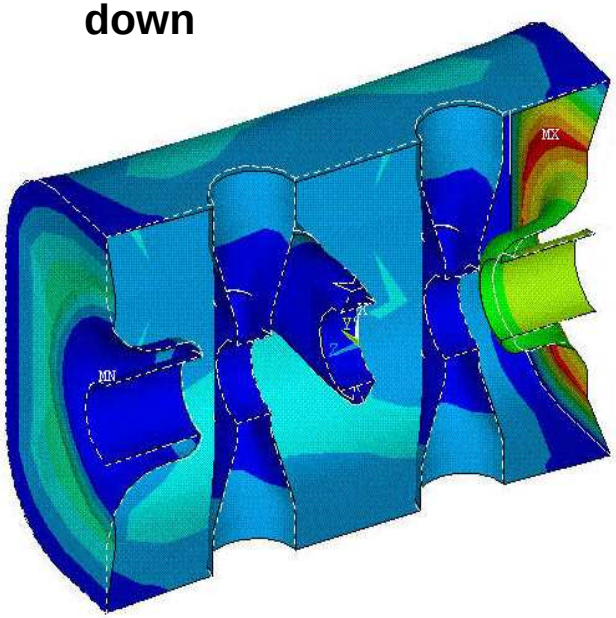
max displacement 0.273 mm
max von Mises stress 431 Pa

cool-down to 2K



max displacement 0.413 mm,
max von Mises stress 633 Pa

1 bar + tuning + cool-down

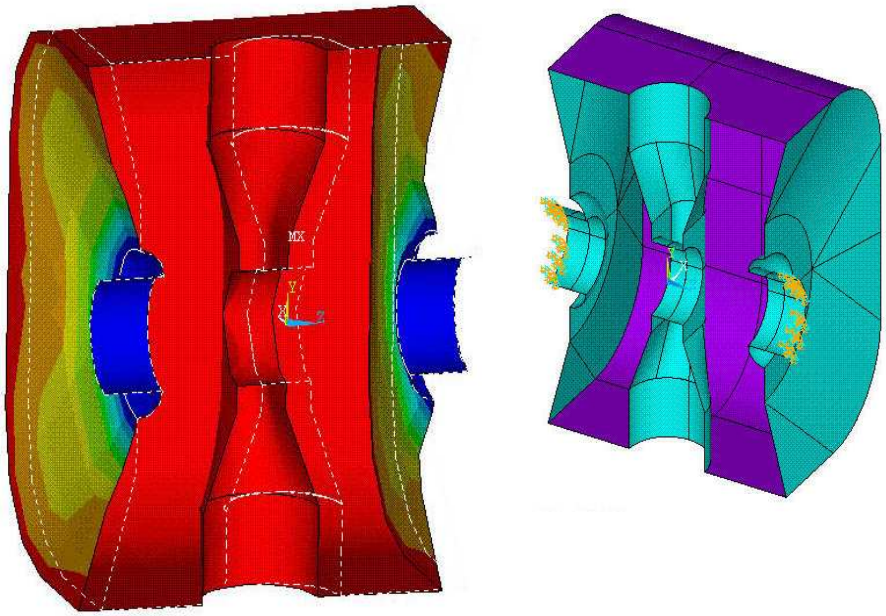


end electrode shift +/-2 mm
max displacement 2/2.26 mm,
max von Mises stress 679/870 MPa
tuning pressure 55.33/16.37 kN

SPOKE-CAVITY DYNAMIC ANALYSIS

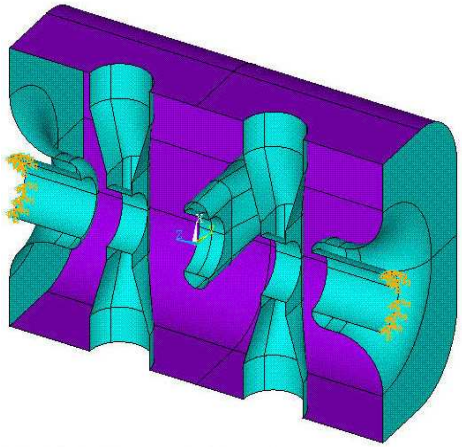
Table 3. Modal Analysis Results of Spoke Cavity

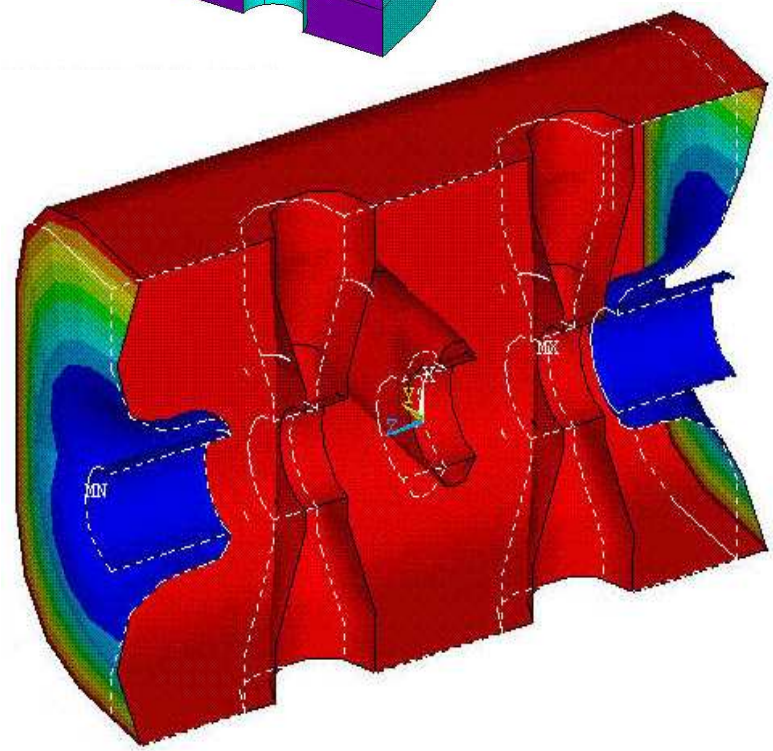
Spoke Cavity 700 - 0.2		**Spoke Cavity 320 – 0.3**	
Frequency / Hz	*frequency / Hz*	*frequency / Hz*	*frequency / Hz*
Full	half YZ	full	full
walls 2/1	walls 2/1	walls 2/1	walls 3/3
275.179	274.245	50.1	94.853
492.504		57.452	75.506
589.763	570.286	74.267	150.375
698.115	697.078	74.606	152.544
698.122		86.655	144.097
815.524		92.018	
877.013	876.885	162.638	
1053	1005	164.155	255.193
	1307		176.949
	1507		266.892
	1609		



Mode 1 is an elementary swinging (first eigen frequency) along the longitudinal ax of the cavity.
Mode 2 is a torsion oscillation.
Mode 3 is a tilted oscillation relative to the cavity ax.
Mode 4 is an oscillation of the cavity walls without spokes.
Modes 5 & 6 are similar to mode 3 with different directions of oscillations.
Mode 7 is the same as mode 4 of wall oscillations but with p phase shift.
Mode 8 is an oscillation of end plate walls.

SC 4-GAP CAVITY DYNAMIC ANALYSIS





sch4g 700-0.2					
Freq / Hz	*Freq / Hz*	*Freq / Hz*	*Freq / Hz*	*Freq / Hz*	*Freq / Hz*
full		half YZ		half XZ	
walls 2/1	walls 3/3	walls 2/1	walls 3/3	walls 2/1	walls 3/3
125.435	327.659	123.518	321.375	123.848	323.281
235.935	434.449			233.693	426.4
238.875	449.598	235.475	432.86		
251.018	333.436				
283.487	550.072			282.279	542.559
285.227	568.97	285.838	564.032		
543.119	732.491	490.546	703.532		
569.819	831.133			547.355	814.254
		844.565	1195	658.441	877.497
		867.63	1365	857.749	1158
		884.88	1175	935.021	1242
		938.662	1441	1002	1389

SC 10-GAP CAVITY DYNAMIC ANALYSIS

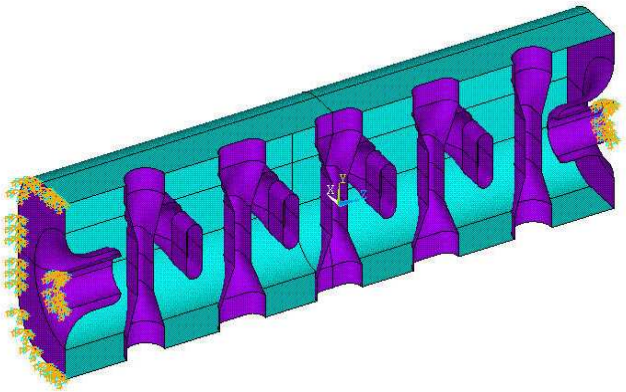
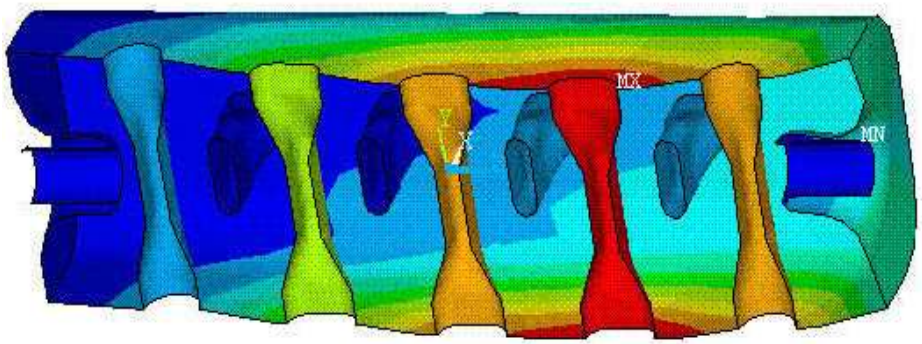


Table 6. Modal Analysis Results of SC 320 MHz, β=0.3 10-gap H-Cavity

sch10g 320–03 both ends fixed				
frequency / Hz	*frequency / Hz*	*frequency / Hz*	*frequency / Hz*	*frequency / Hz*
half YZ	half YZ	half YZ	half YZ	half YZ
walls 2/1	walls 3/1	walls 3/3	walls 3/1 + ribs	walls 3/1 + 2ribs
63.141	86.512	82.499	113.552	94.078
84.428	114.539	105.034	196.821	153.138
103.745	145.107	129.279	287.855	225.853
117.236	165.344	148.337	306.677	275.263
118.234	167.795	149.269	306.677	286.433
184.267	240.284	267.676	316.893	303.925
186.075	256.78	268.447	322.188	339.284
199.696	263.74	306.674	351.981	349.741

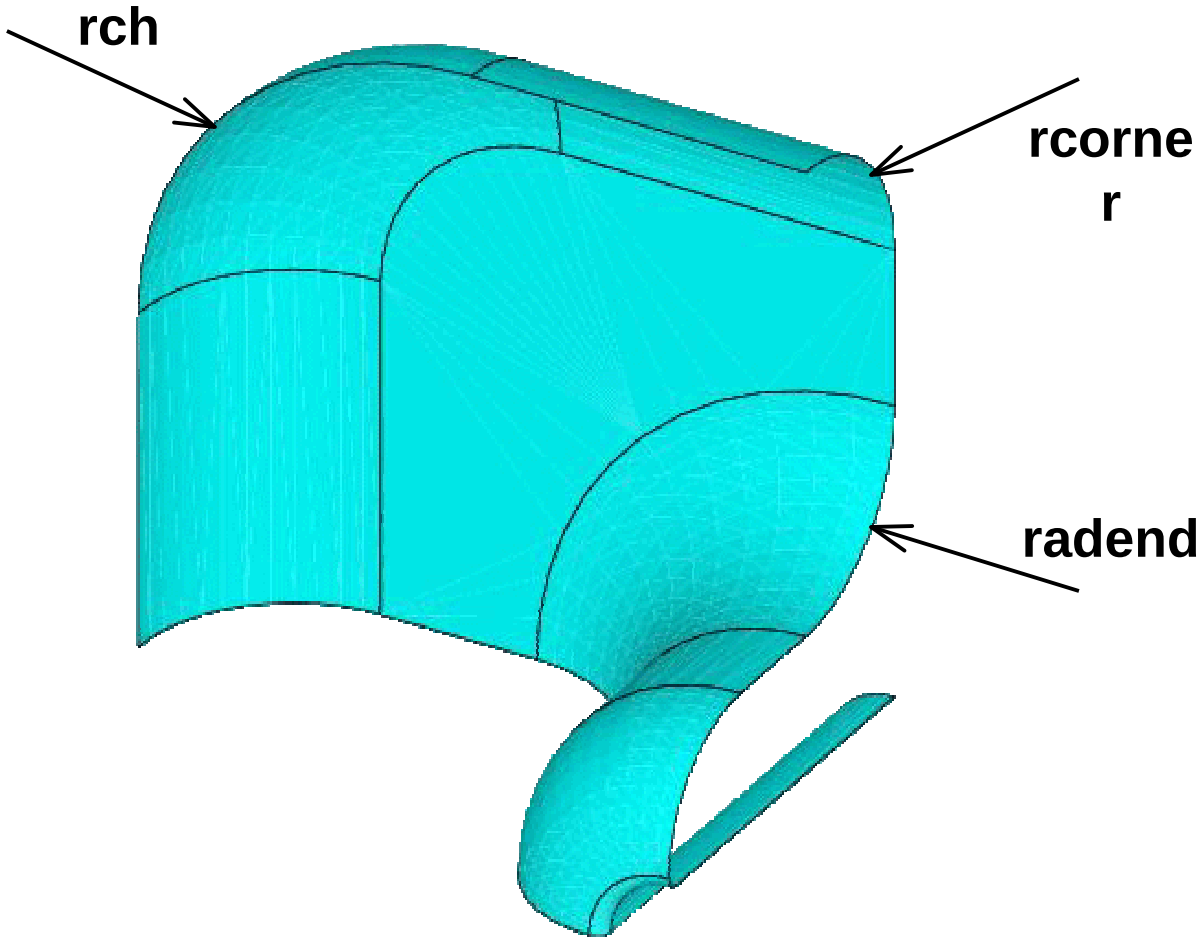
Sch10g 700-0.2		**sch10g 320-03**			
Freq / Hz	*Freq / Hz*	*Freq / Hz*	*Freq / Hz*	*Freq / Hz*	*Freq / Hz*
half YZ	half XZ	half YZ		half XZ	
walls 2/1	walls 2/1	walls 2/1	walls 3/3	walls 2/1	walls 3/3
284.287				57.009	71.639
	284.418	57.216	71.825		
	387.09			75.987	93.3
392.318		78.718	95.532		
	469.385			93.002	113.722
477.744		95.572	114.115		
	542.391			104.955	124.138
562.876		106.058	131.076		
624.596				110.145	134.229
	640.763	117.734	148.742		
667.11		124.691	155.22		
	795.167			138.156	218.446
	911.822			153.267	232.248
	921.408			159.683	238.188
924.334		162.453	245.489		
997.703		184.448	268.03		



mode 1

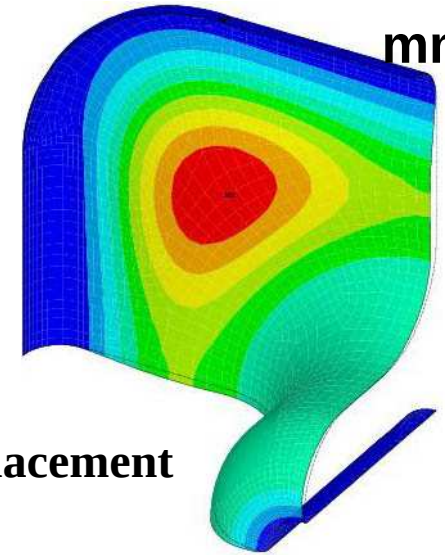
TUNING PLATE GEOMETRY OPTIMISATION

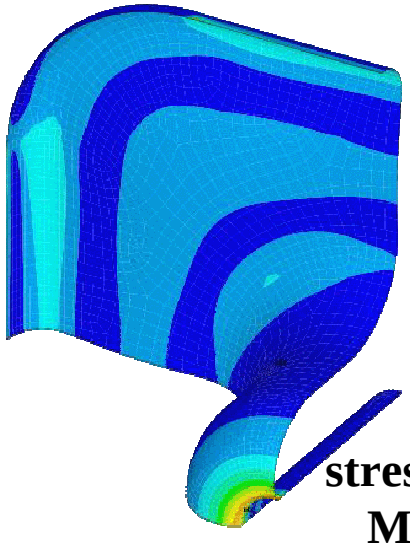
(320 MHz , β=0.2)



TUNING PLATE UNDER 1 Bar LHe PRESSURE (rcorner)

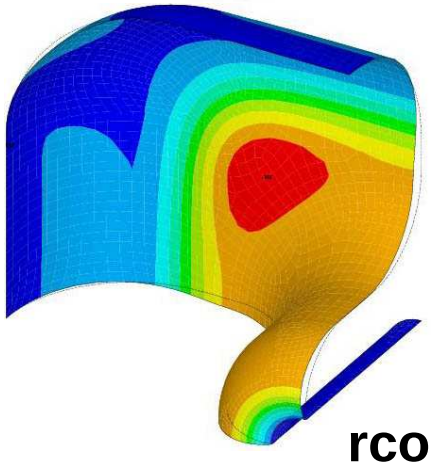
rcorner = 15 mm

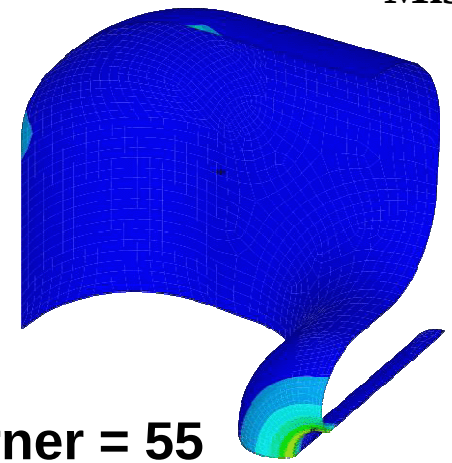


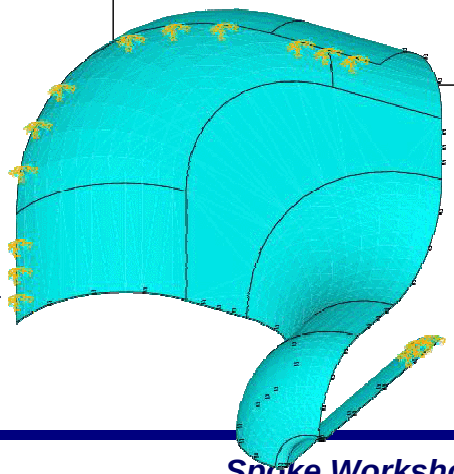


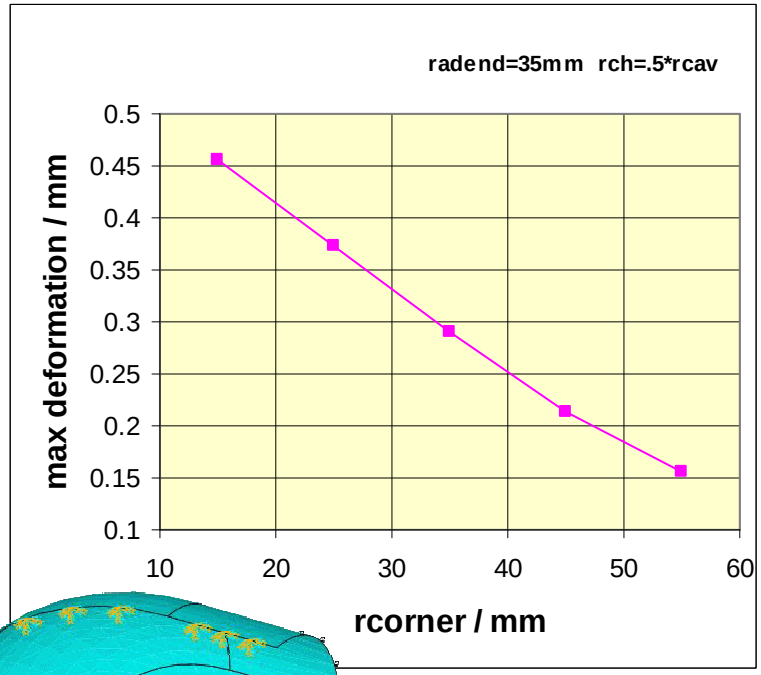
displacement

stress von Mises



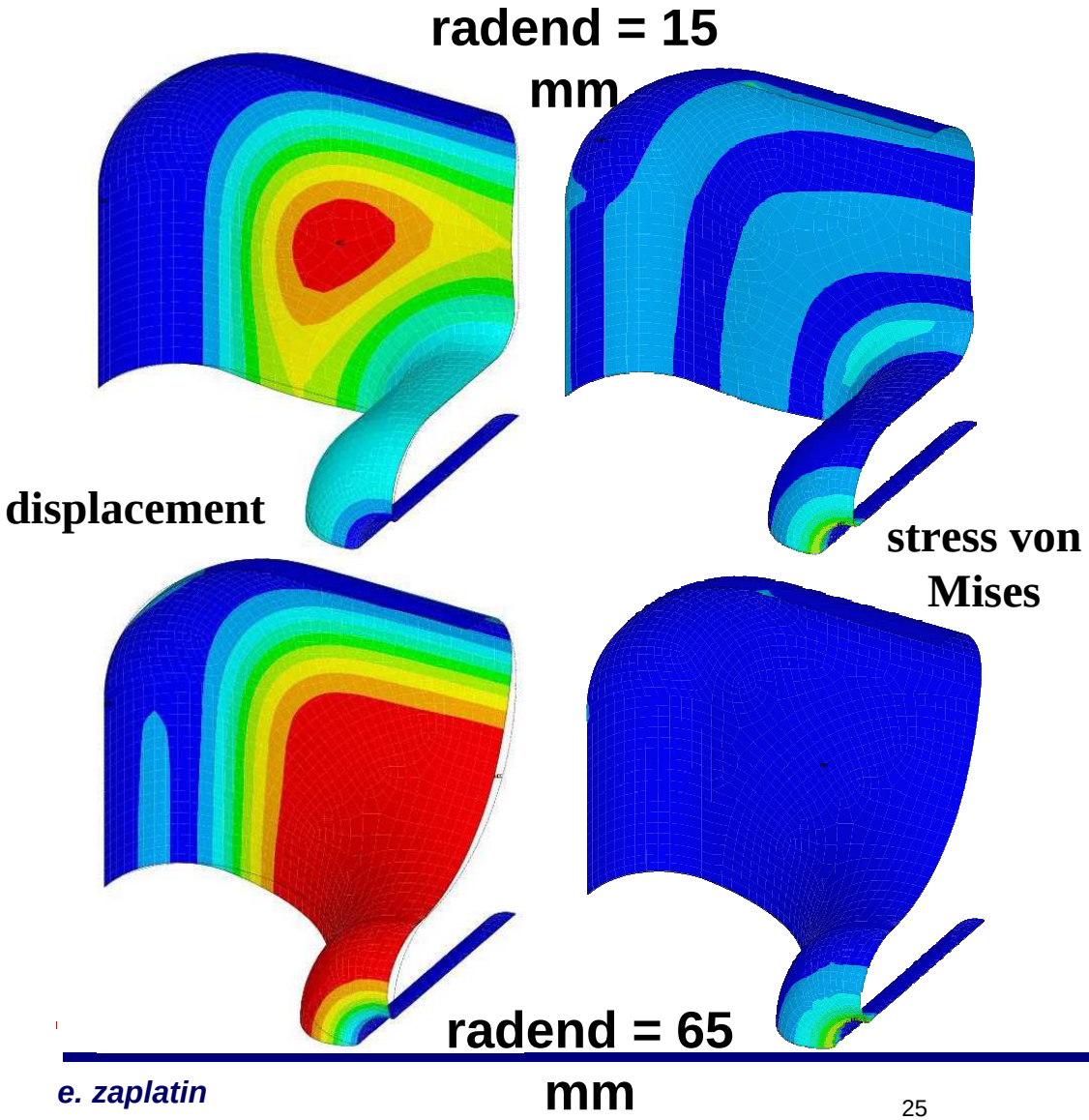


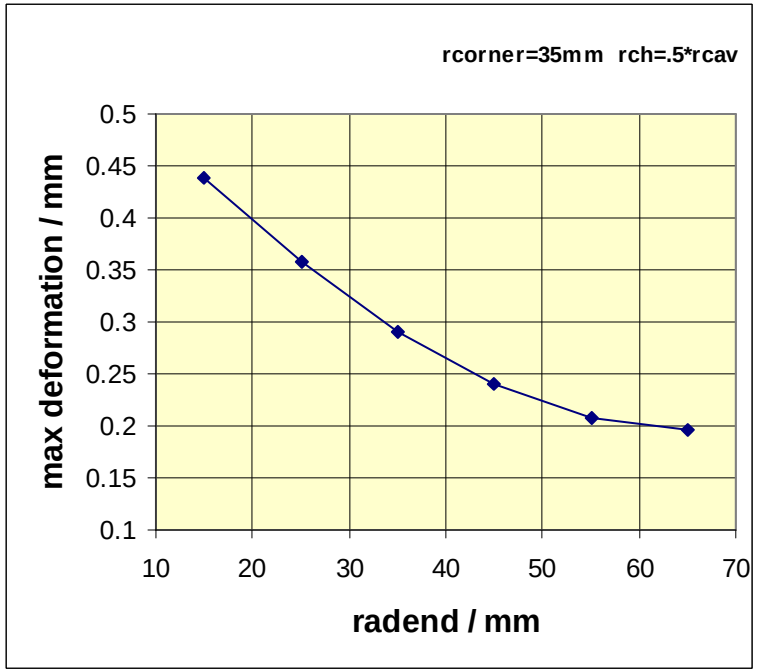




rcorner = 55 mm

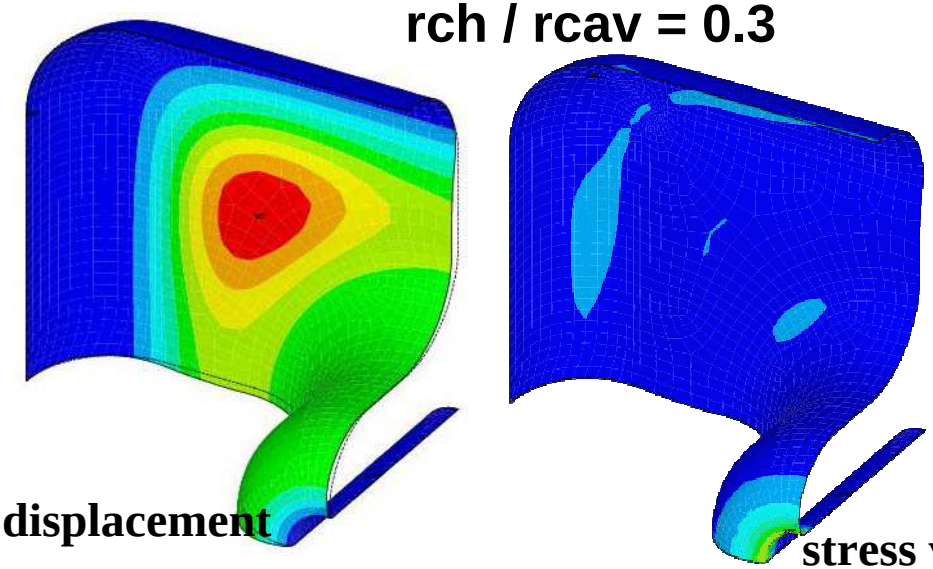
TUNING PLATE UNDER 1 Bar LHe PRESSURE (radend)

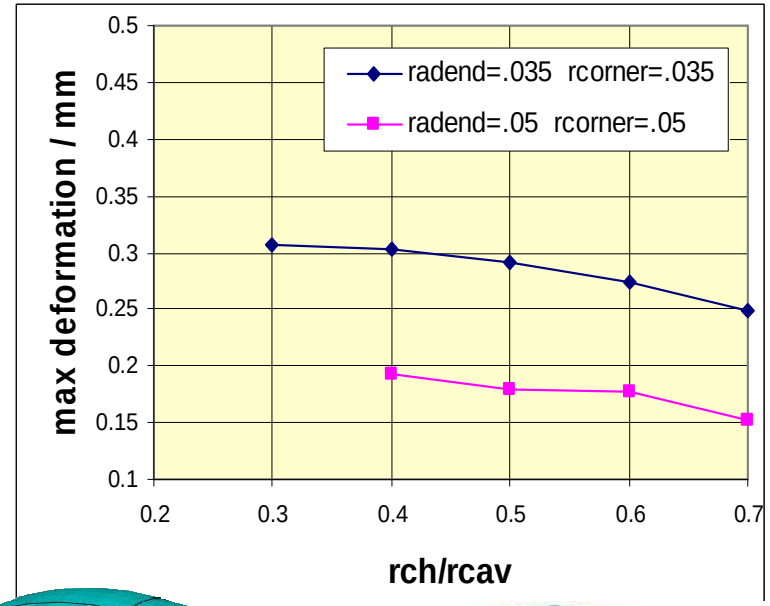


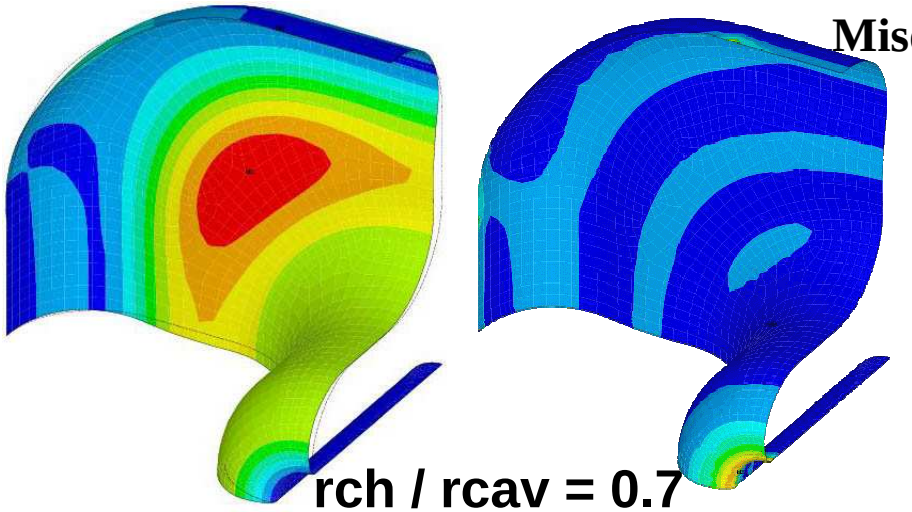


TUNING PLATE UNDER 1 Bar LHe PRESSURE (rch)

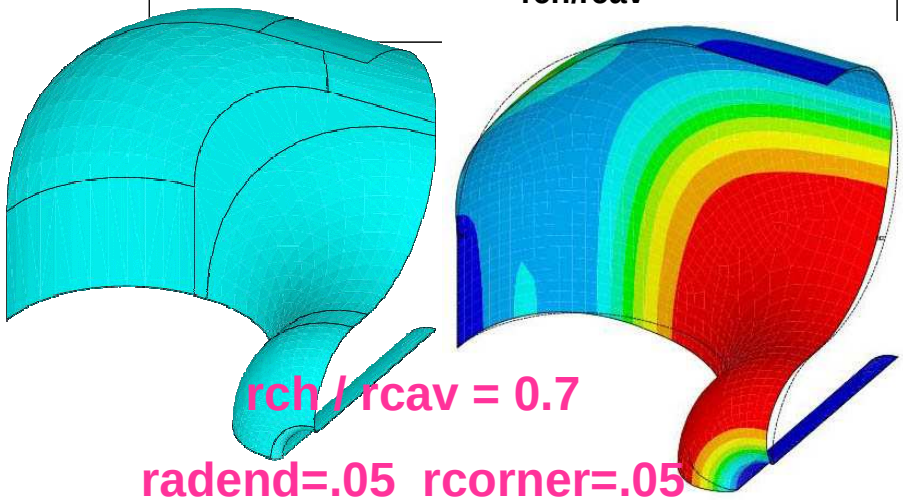
rch / rcav = 0.3







rch / rcav = 0.7

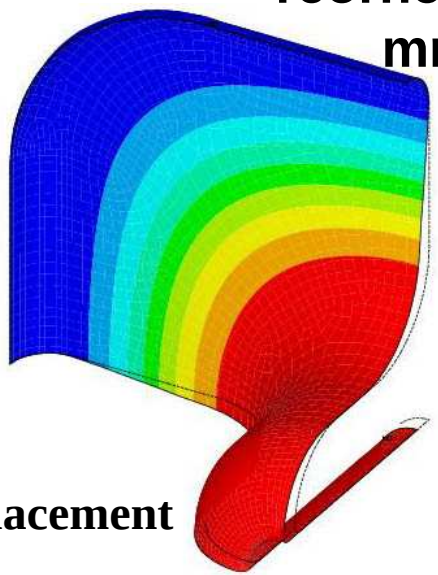


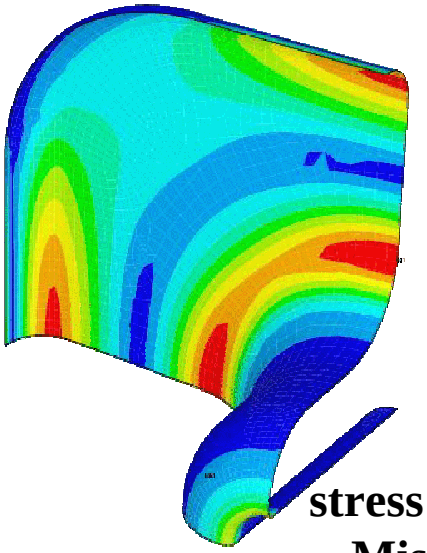
rch / rcav = 0.7

radend=.05 rcorner=.05

TUNING PLATE UNDER TUNING FORCE (rcorner)

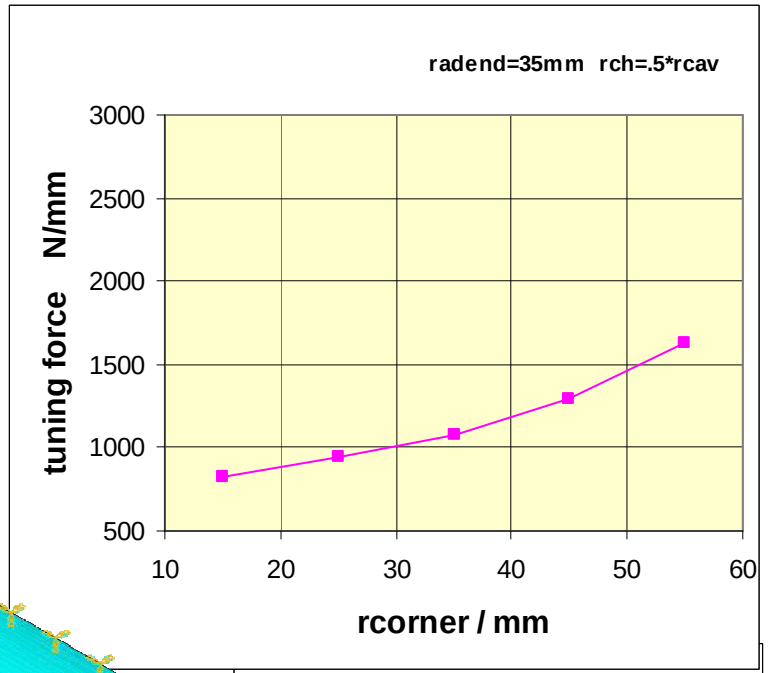
rcorner = 15 mm

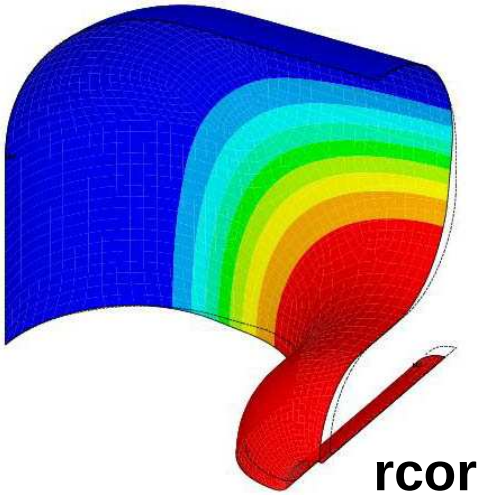


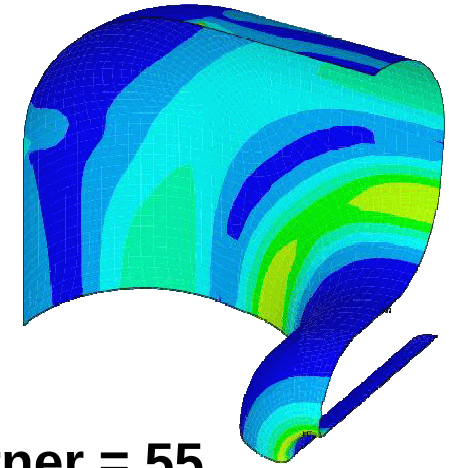


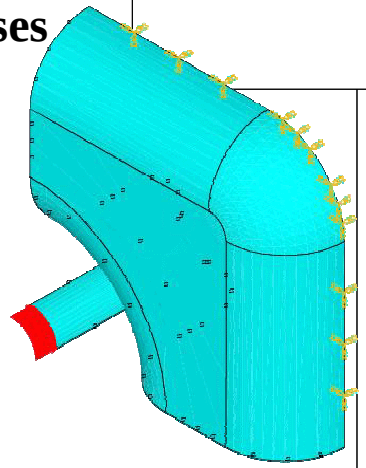
displacement

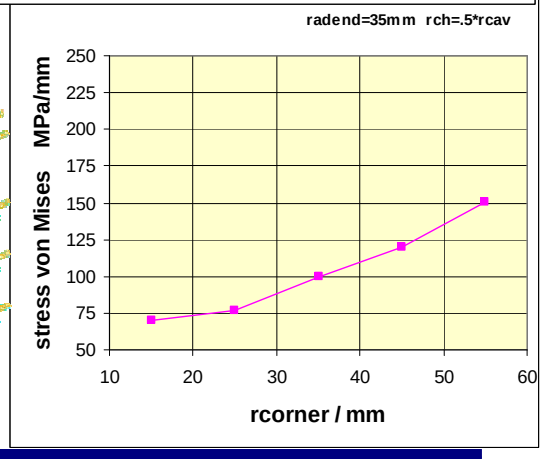
stress von Mises





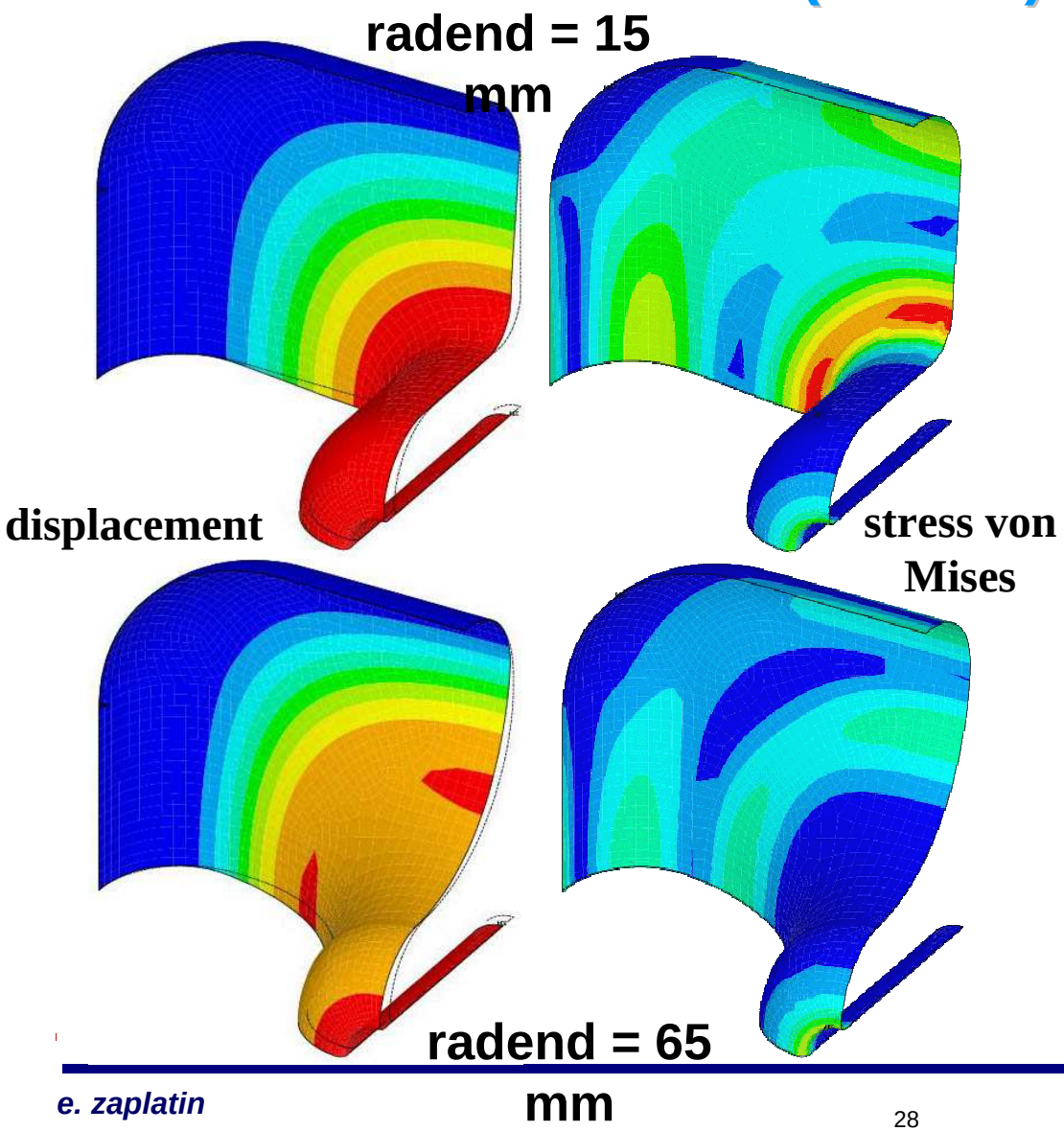


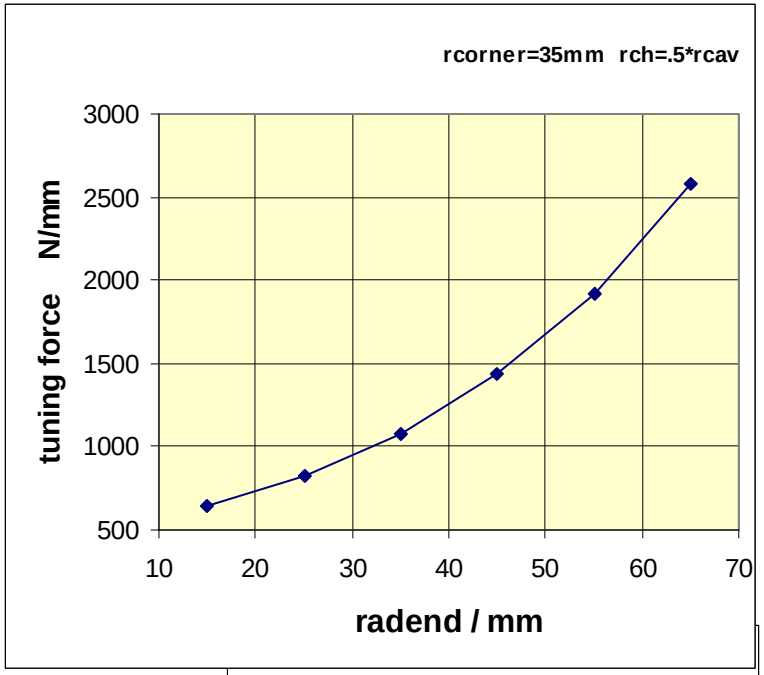


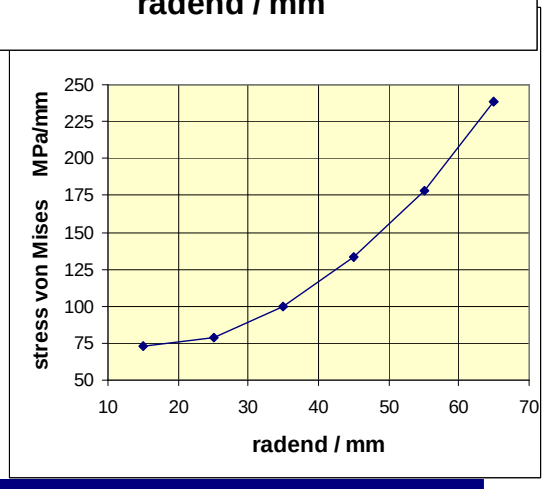


rcorner = 55 mm

TUNING PLATE UNDER TUNING FORCE (radend)

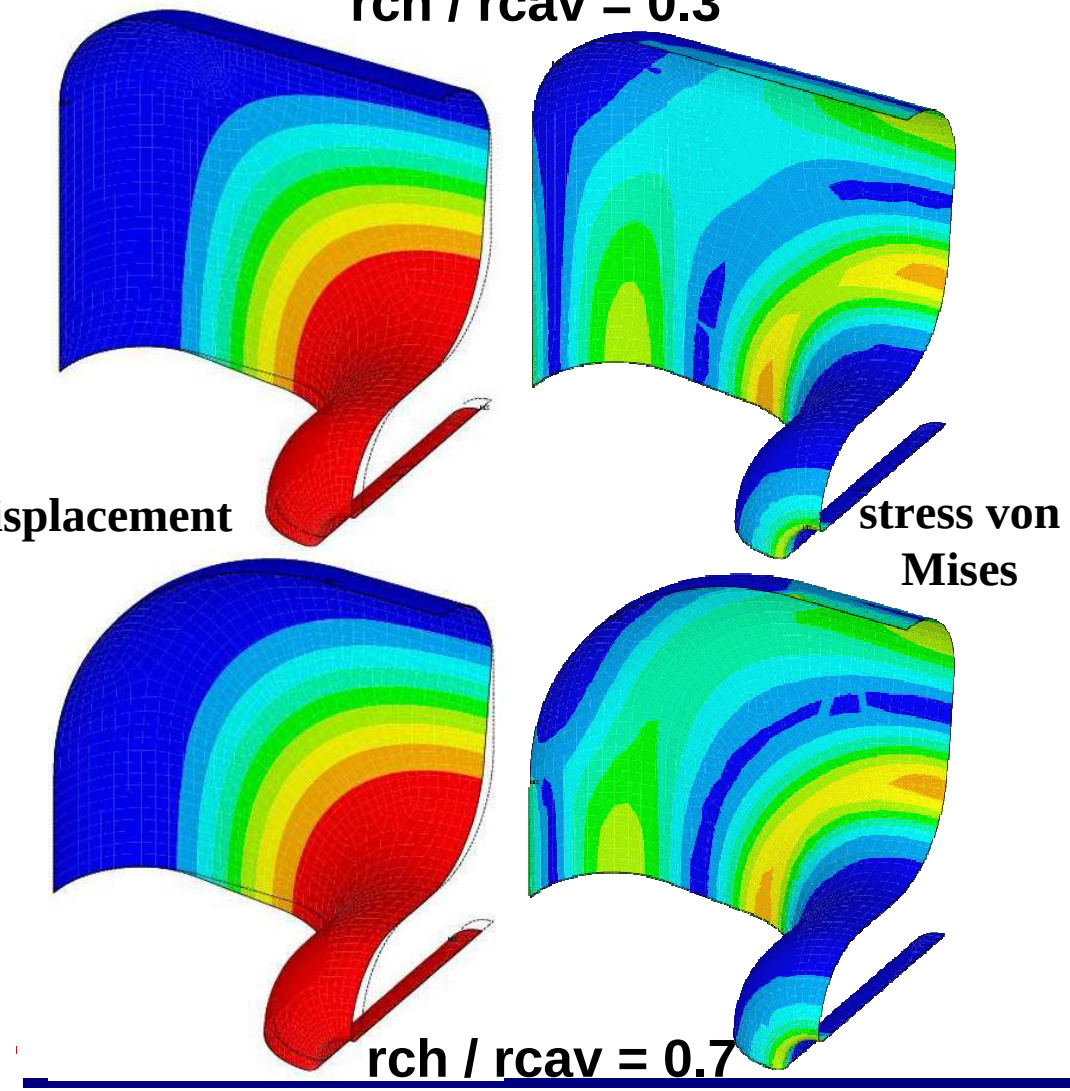




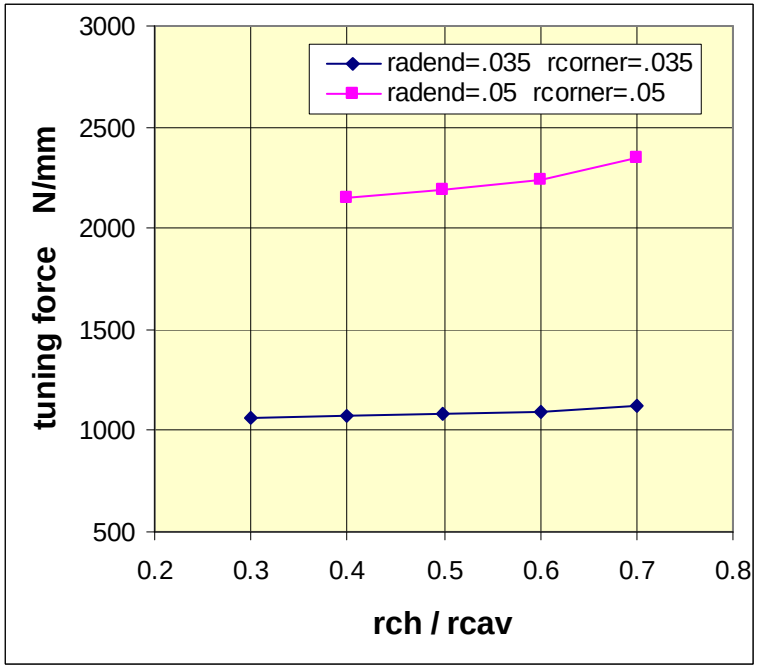


TUNING PLATE UNDER TUNING FORCE (rch)

rch / rcav = 0.3

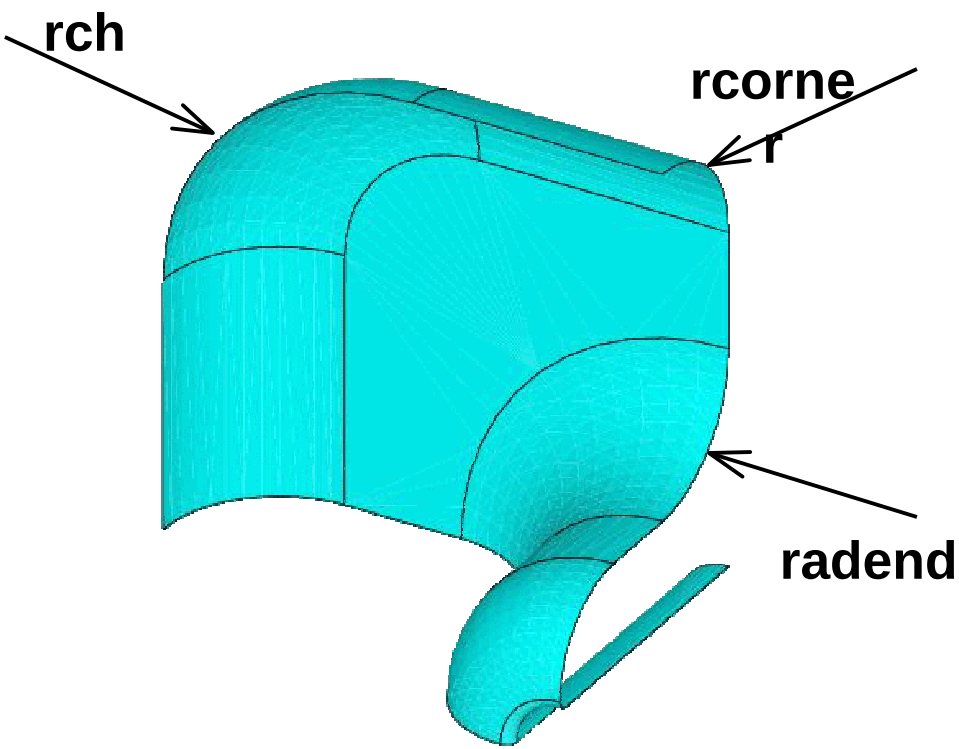


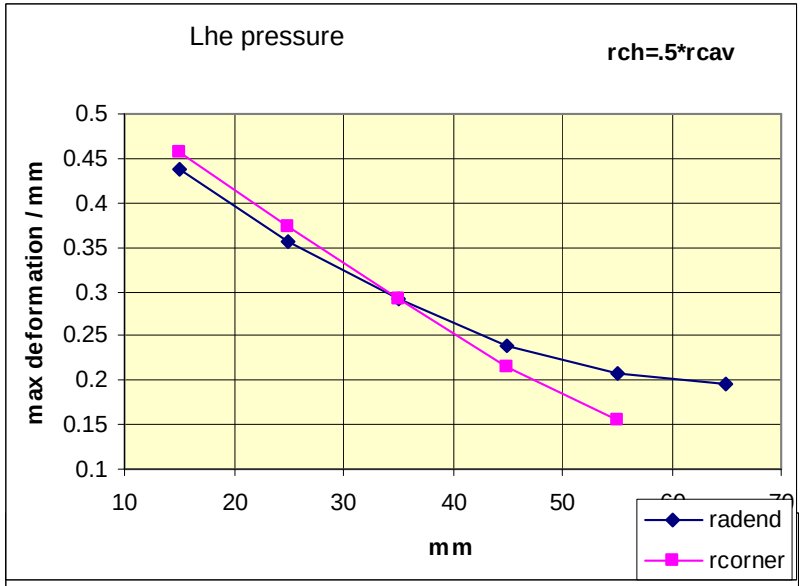
rch / rcav = 0.7

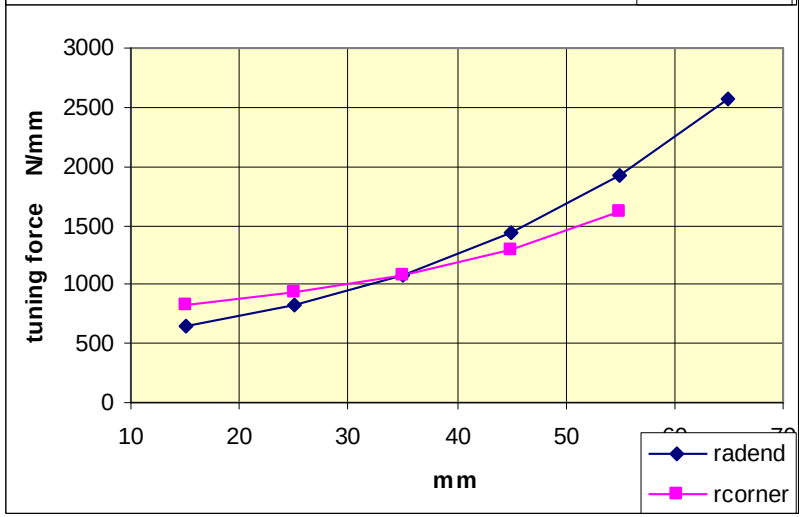


TUNING PLATE GEOMETRY OPTIMISATION

(320 MHz , β=0.2)

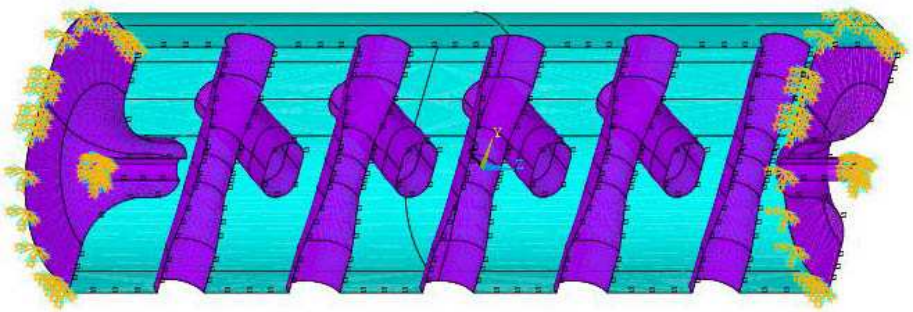


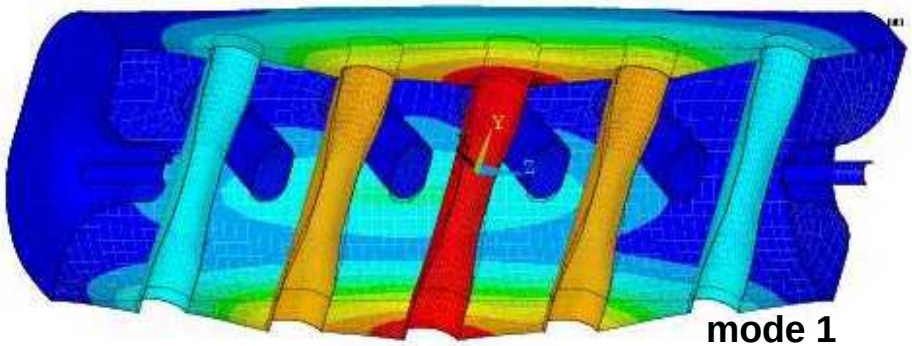




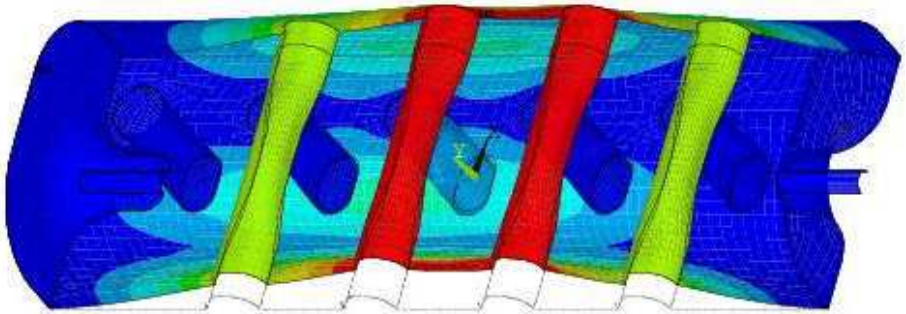
SCH10G MODAL ANALYSIS

(320 MHz , β=0.2)

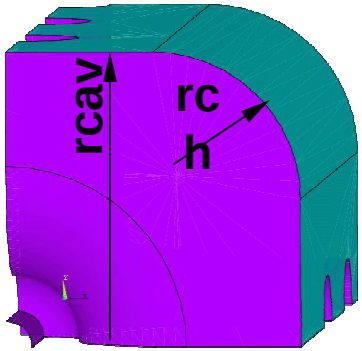
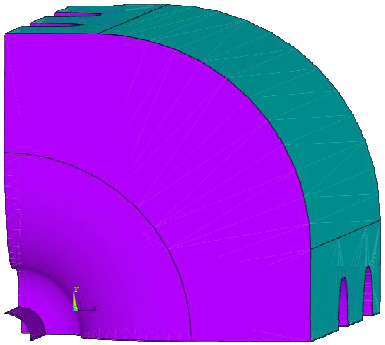




mode 1



mode 2

mode	rch=0.5*rcav	rch=0.7*rcav
	Hz	Hz
1	130.045	175.789
2	131.699	176.504
3	174.513	247.326
4	178.395	250.752
5	216.88	304.761
6	217.045	305.744
7	242.665	338.451
8	250.708	343.285

*) walls 4 / 2