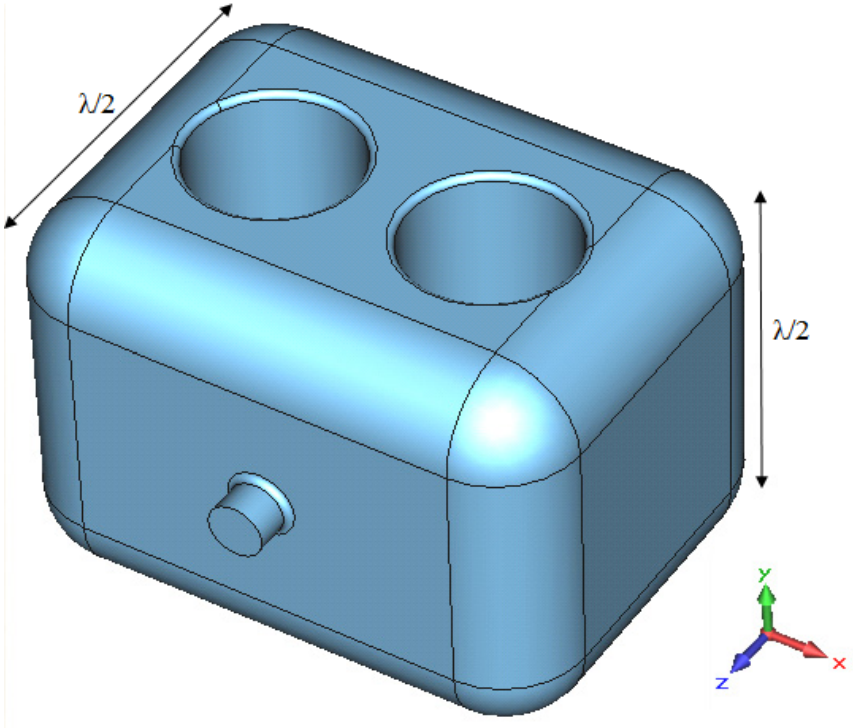
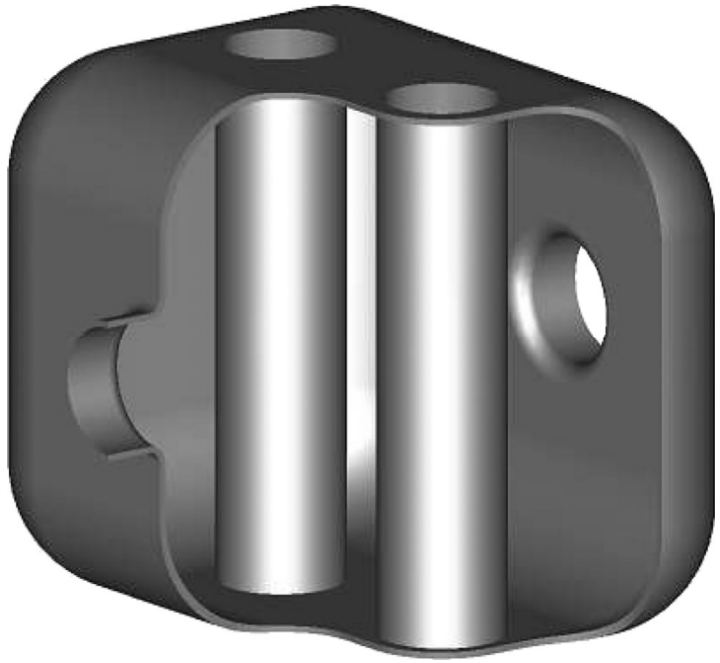
Parallel Bar Deflecting and Crabbing Cavities

Jean Delayen
Subashini de Silva

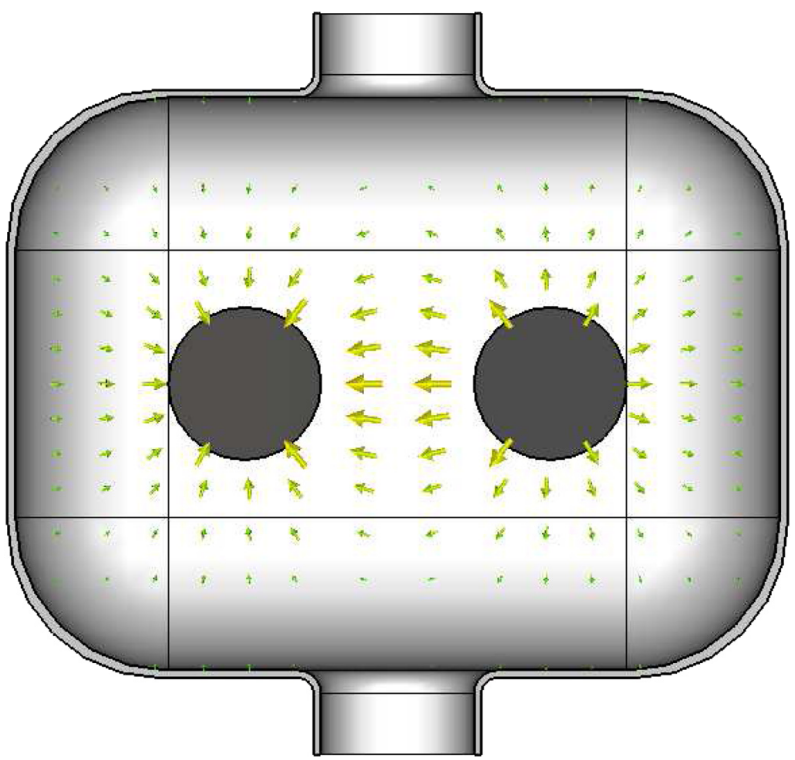
Center for Accelerator Science
Old Dominion University
and
Thomas Jefferson National Accelerator Facility

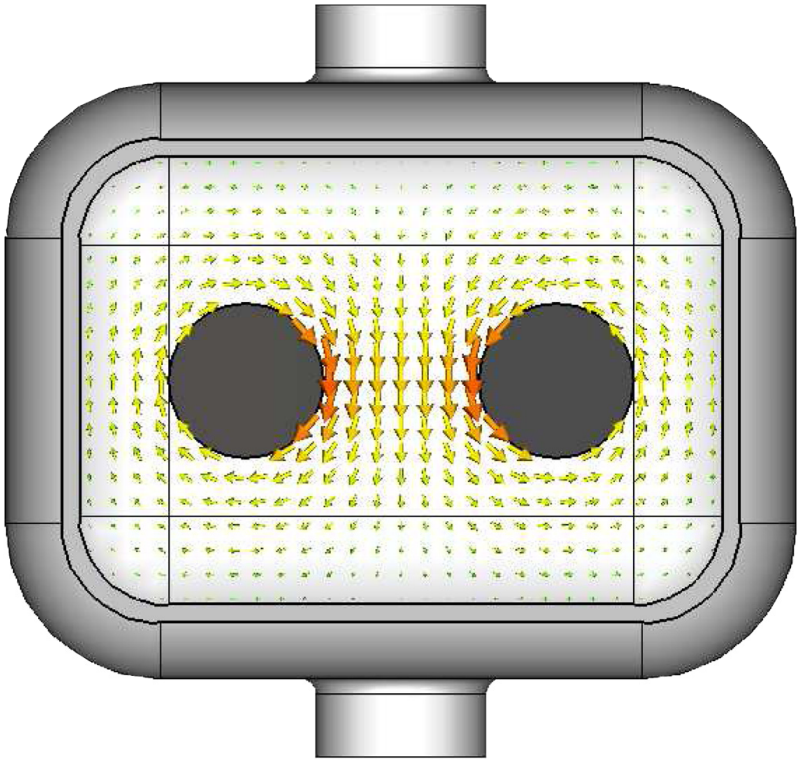
Parallel Bar Cavity Concept





Parallel Bar Cavity Concept





Parallel Bar Cross Section

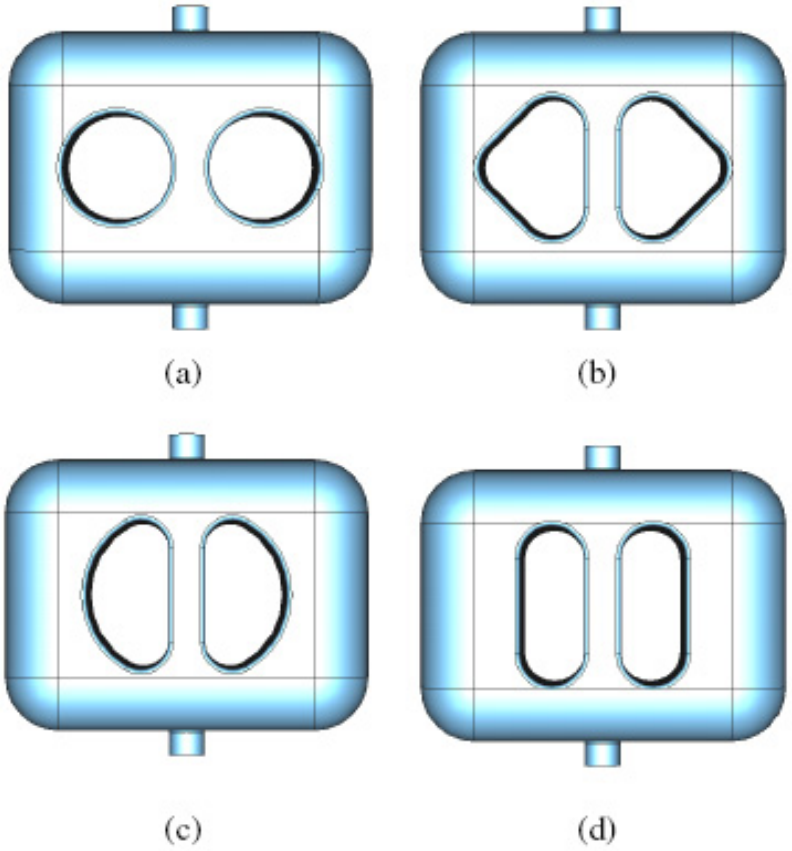


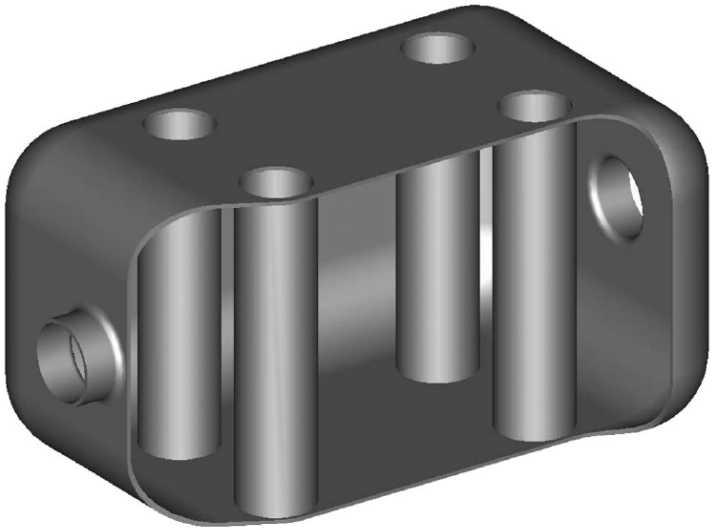
Figure 2: Design structures for CEBAF 499 MHz deflecting cavity with (a) circular, (b) triangular, (c) half circular and (d) race track shaped parallel bars.

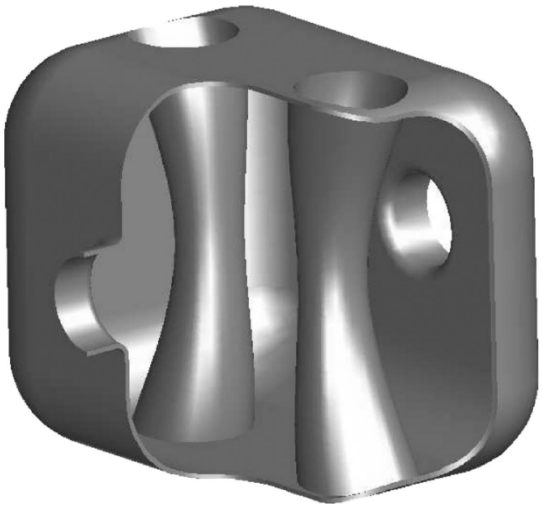
Table 1: Transverse voltage and peak surface fields for the four design structures

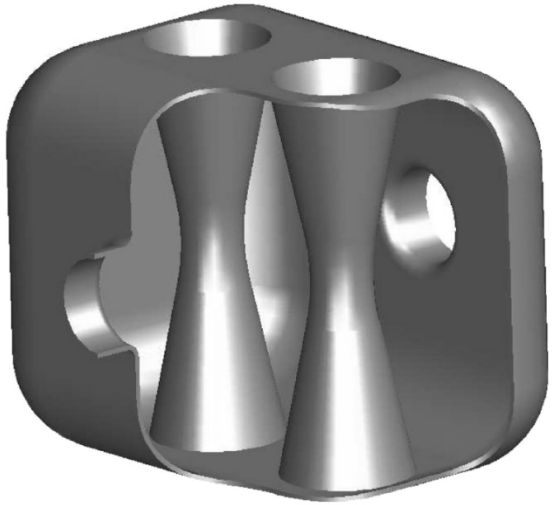
Design structure	E_P / E_T^* (MV/m)	B_P / E_T^* (mT)
(a)	3.45	8.86
(b)	2.47	6.60
(c)	2.30	6.15
(d)	2.28	5.94

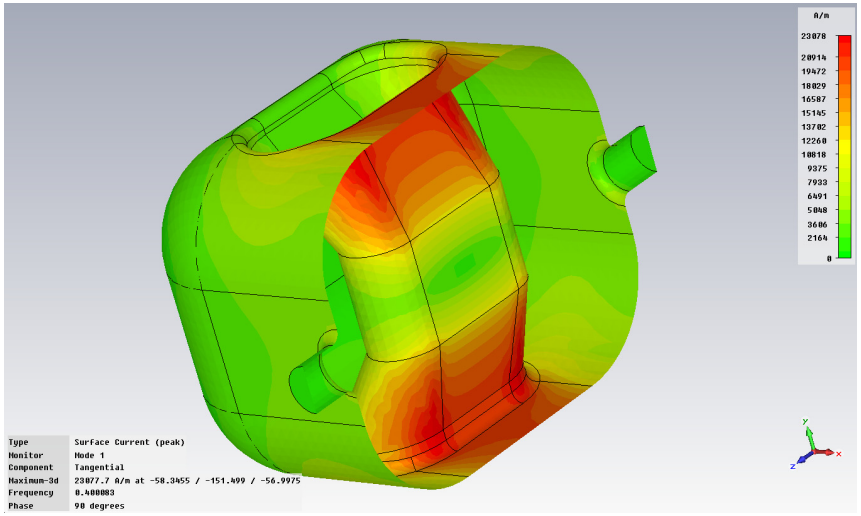
At $E_T^* = 1$ MV/m

Other Options

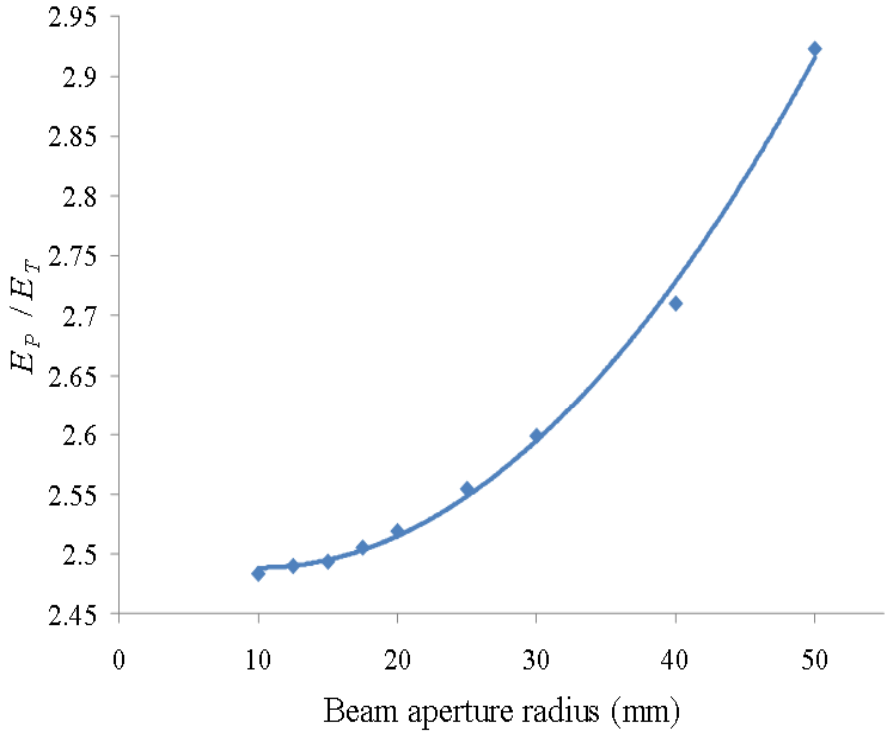


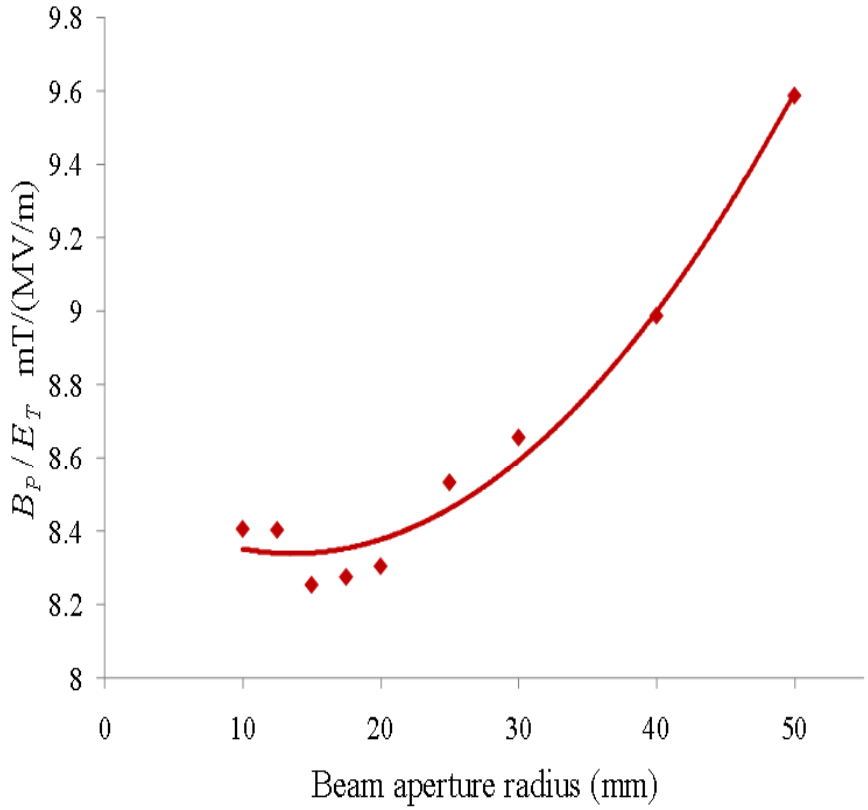




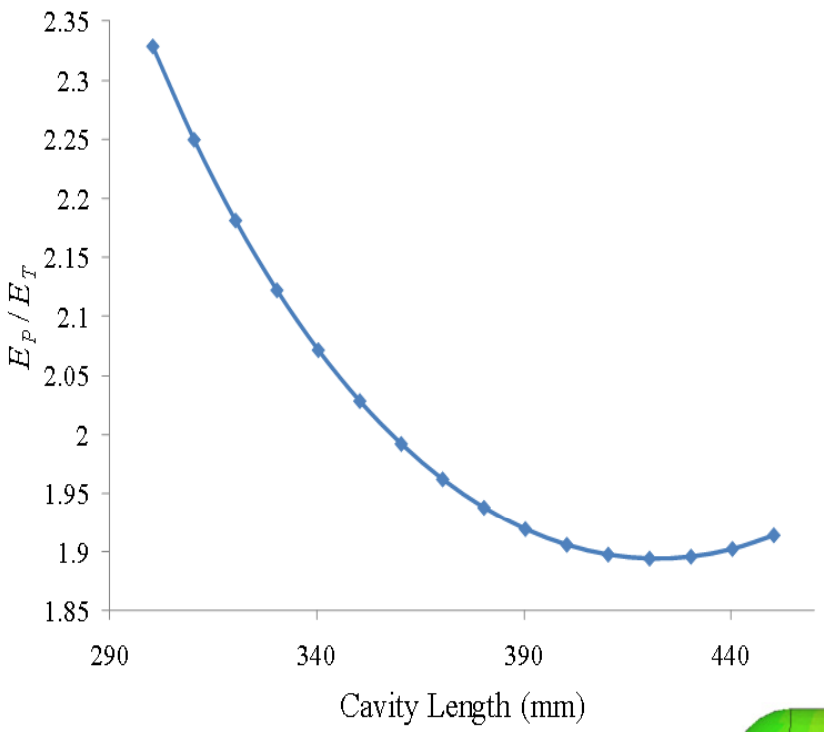


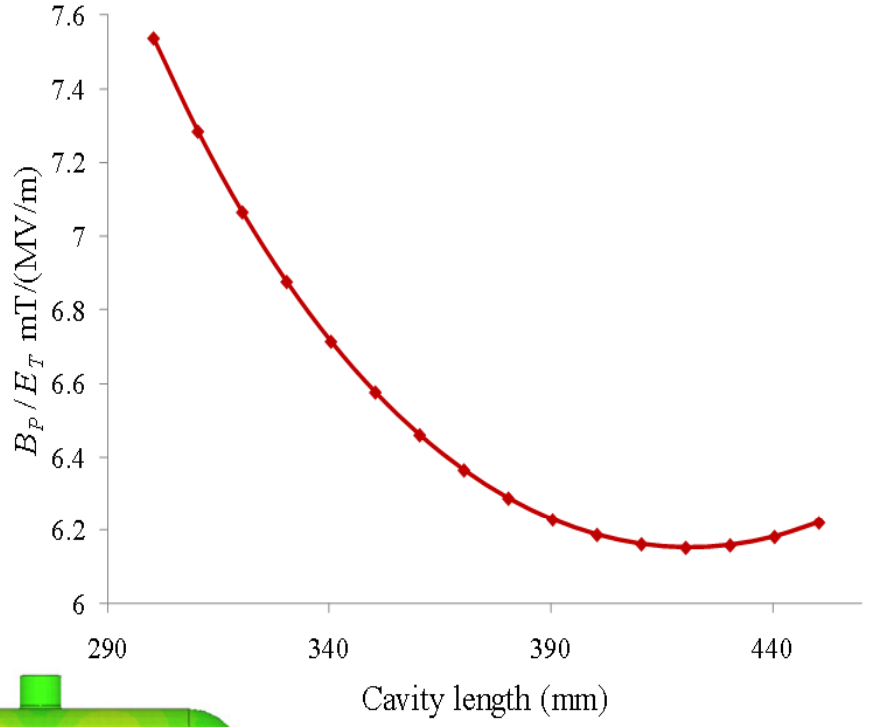
Influence of Beam Line Aperture (499 MHz)

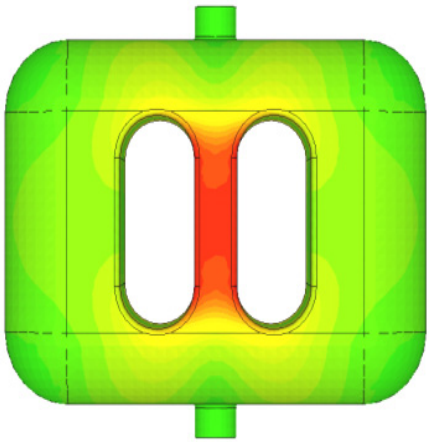




Influence of Bars and Cavity Length (499 MHz)







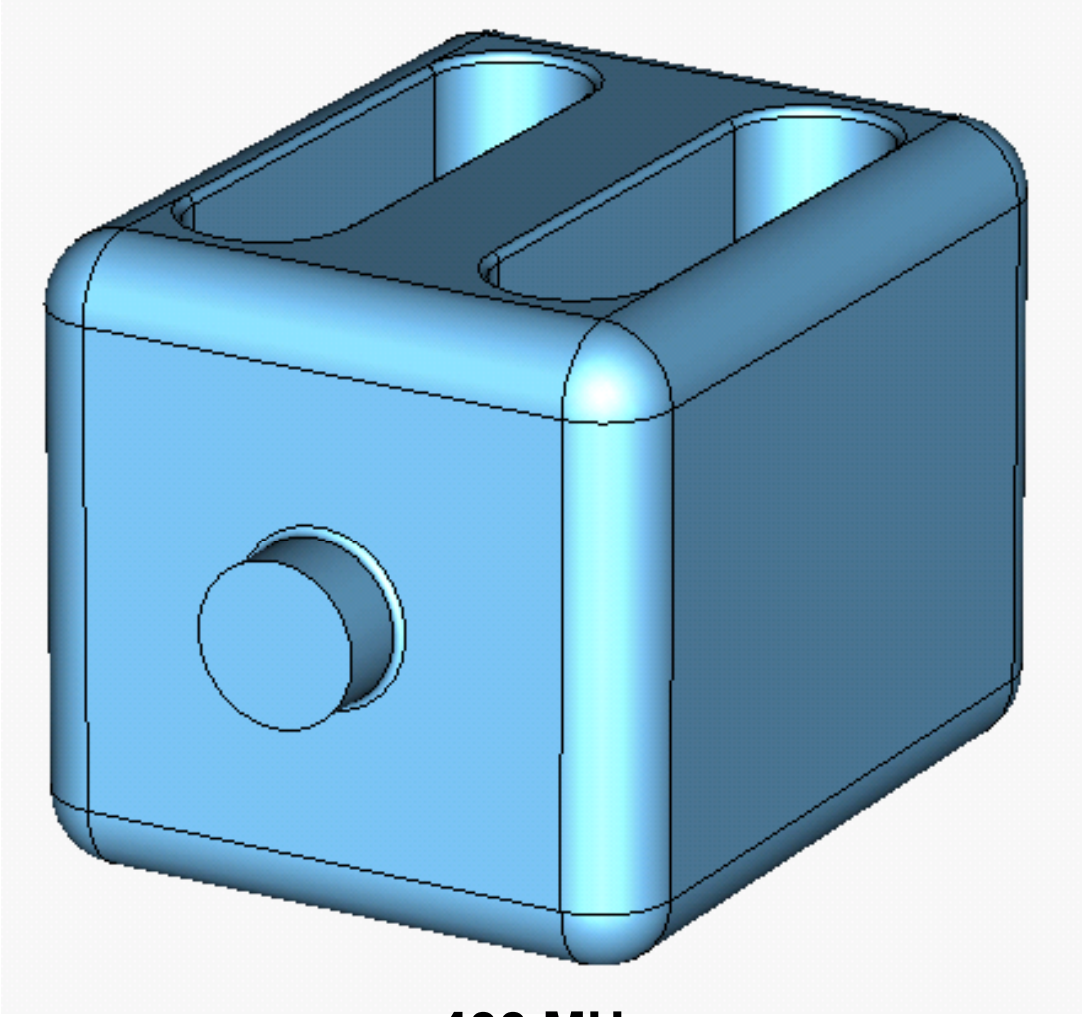
JLab 499 MHz Deflecting Cavity

Table 2: Properties of parallel-bar structure (d) of Fig. 3 and comparison with CEBAF's separator cavity

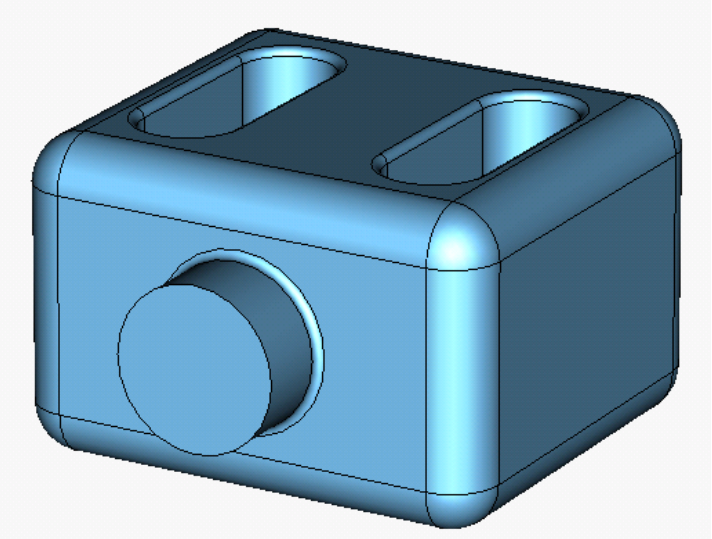
Parameter	Structure (d)	CEBAF	Units
Freq. of π mode	499	499	MHz
$\lambda/2$ of π mode	300.4	300.4	mm
Freq. of 0 mode	521.9	~537	MHz
Cavity length	420.4	~300	mm
Cavity width	320	292	mm
Bars height	305.5	20	mm
Bars width	70	20	mm
Bars length	295	135	mm
Aperture diameter	40	15	mm
Deflecting voltage (V_T*)	0.3	0.3	MV
Peak electric field (E_P*)	1.9	3.39	MV/m
Peak magnetic field (B_P*)	4.9	8.87	mT
Energy content (U*)	0.028	0.0012	J
Geometrical factor	69.4	34.9	Ω
$[R/Q]_T$	1045.3	24921	Ω

At $E_T^* = 1$ MV/m

Crab Cavity Geometry

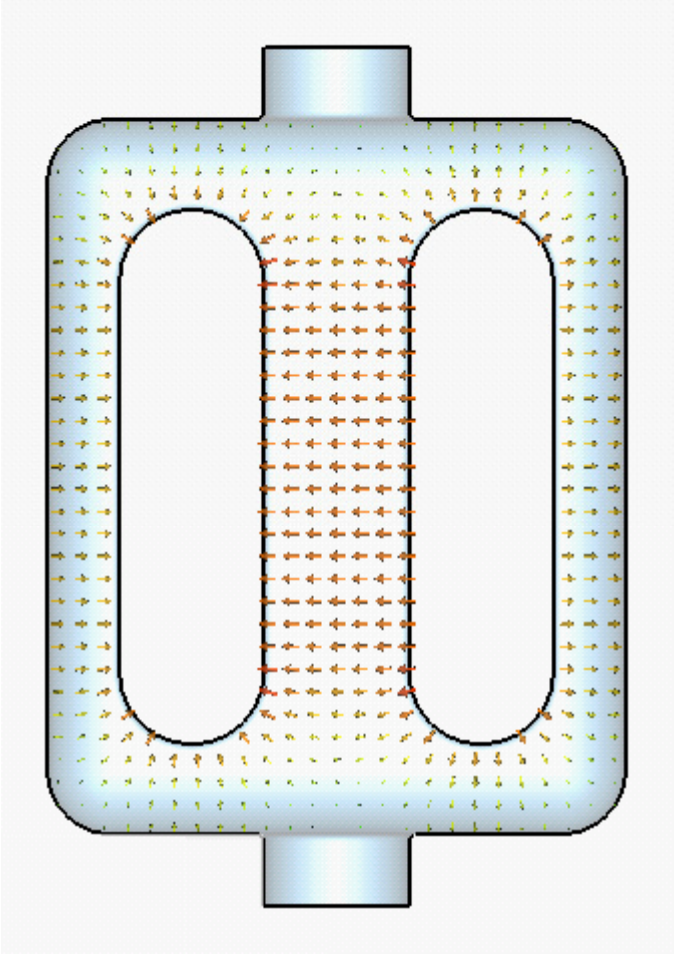


400 MHz

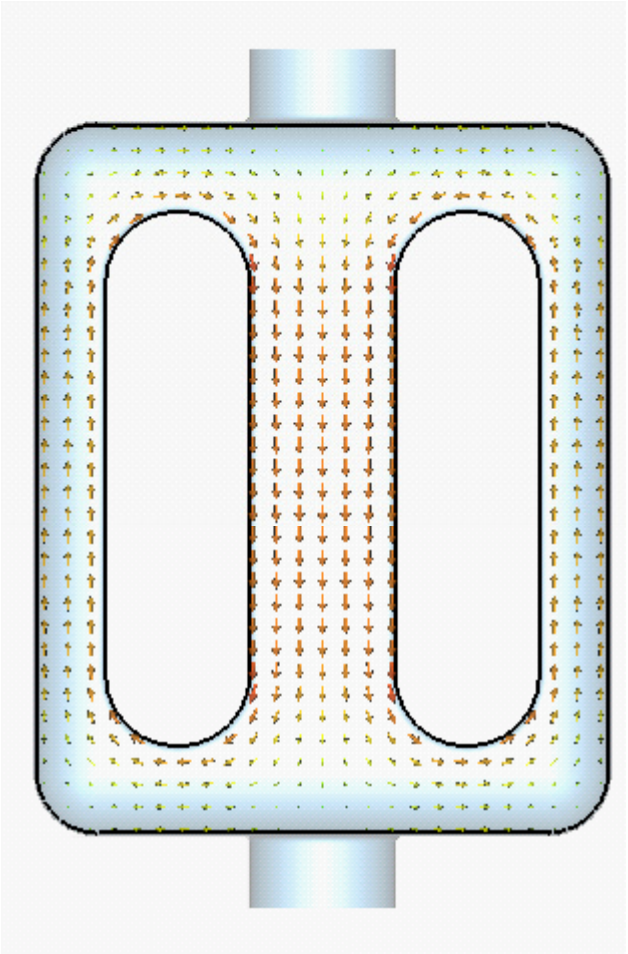


800 MHz

E and H Fields in 400 MHz Cavity

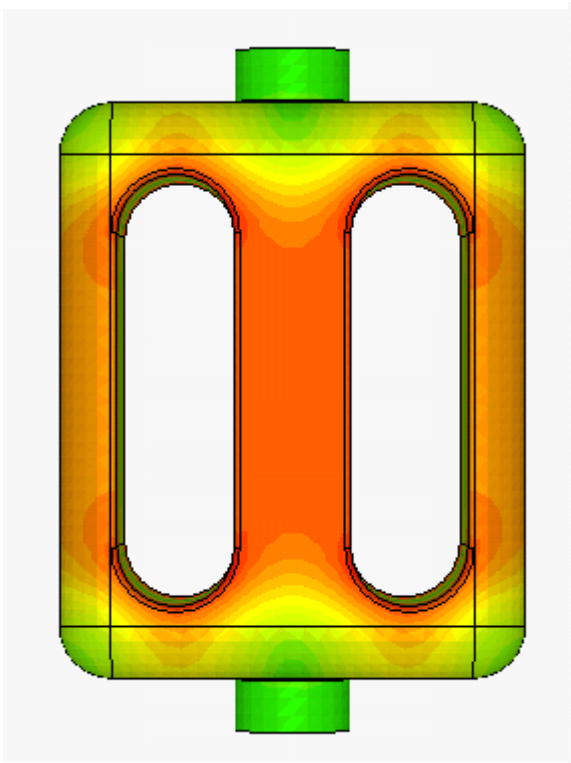


E field in the mid plane

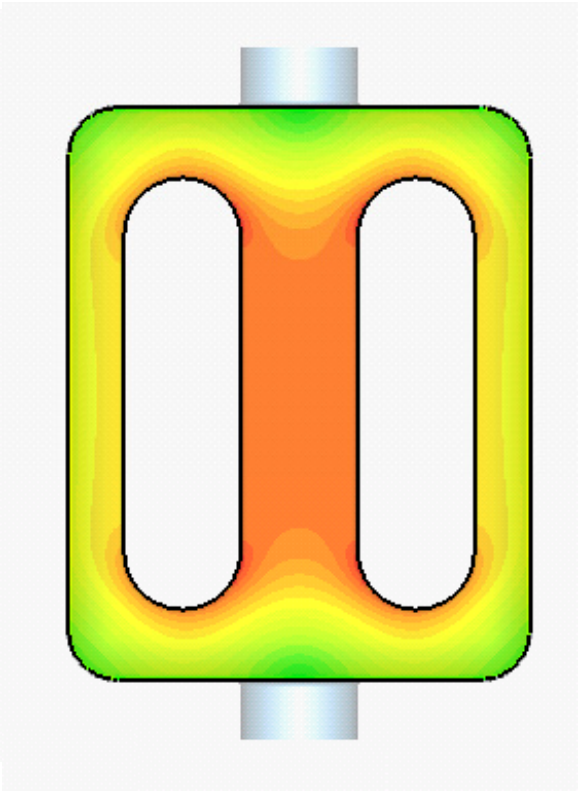


H field in the top plane

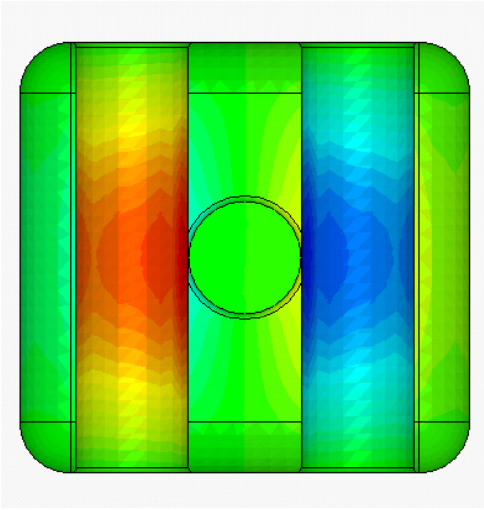
E and H Fields in 400 MHz Cavity



H field at top plane

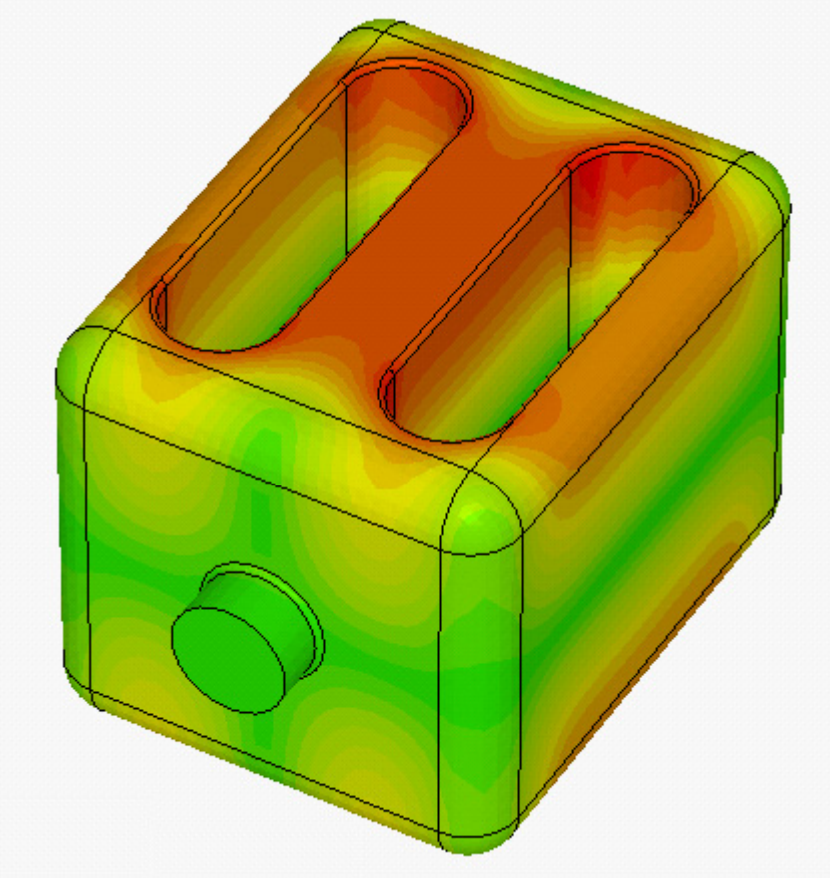


E field at mid plane

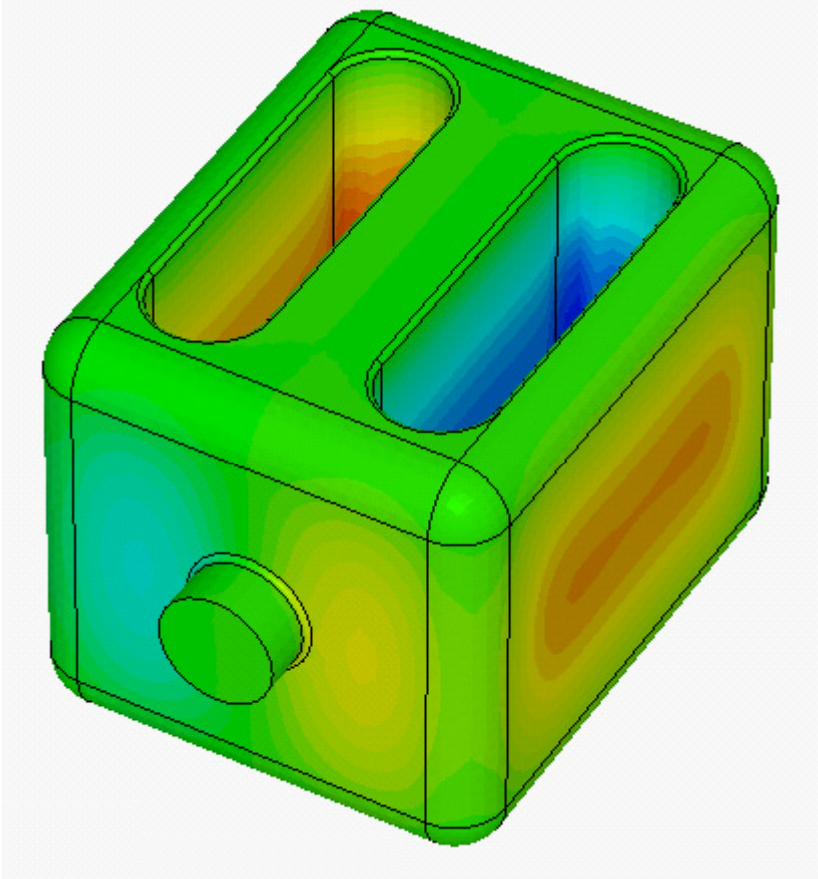


Surface E field on parallel bars

E and H Fields in 400 MHz Cavity

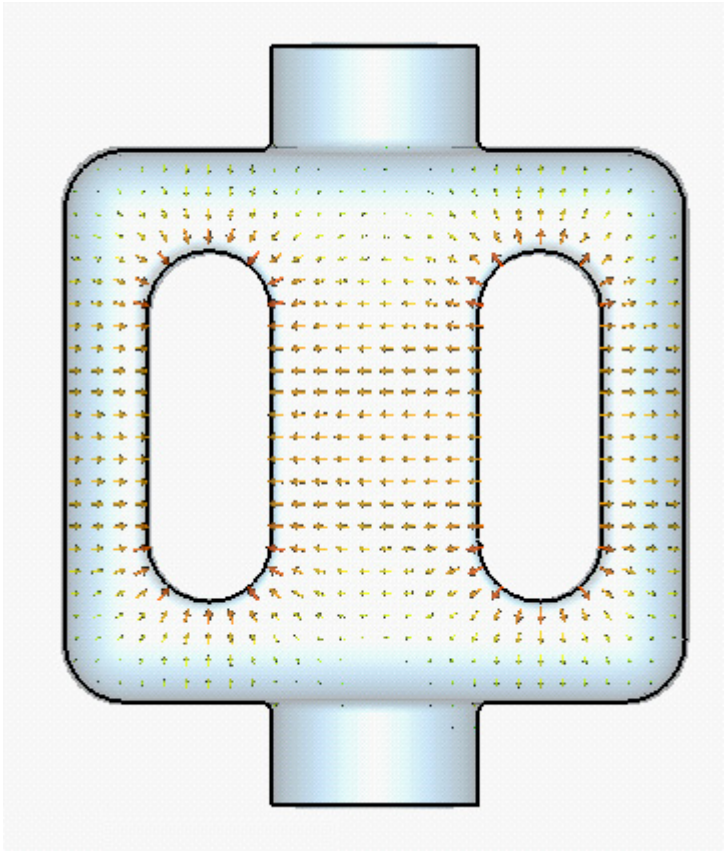


Surface H field

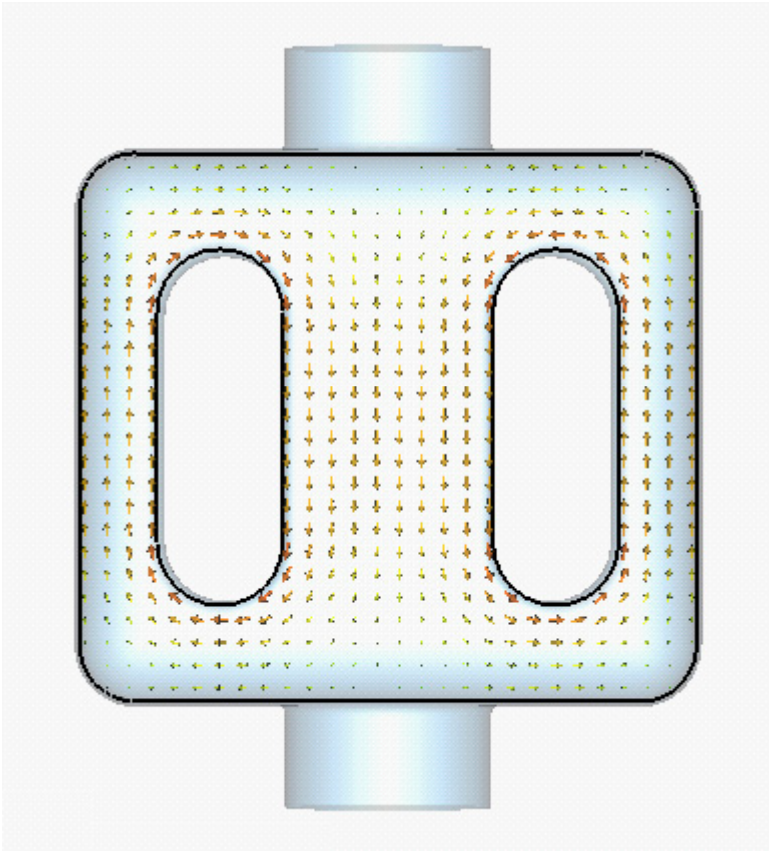


Surface E field

E and H Fields in 800 MHz Cavity

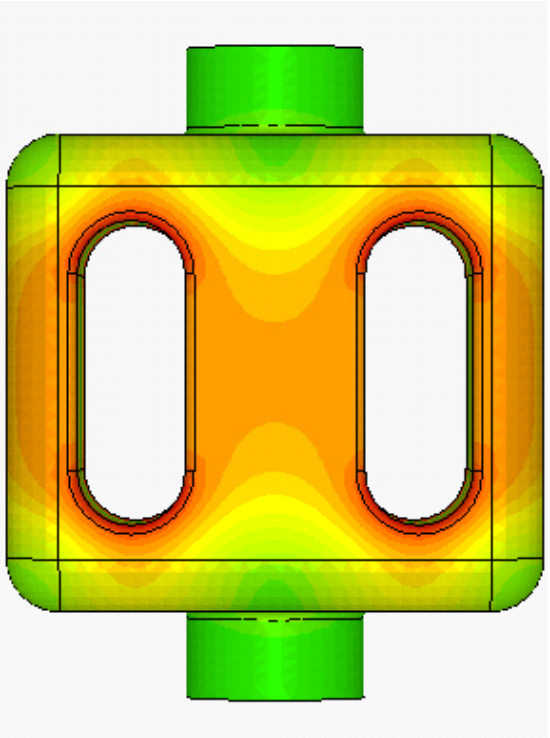


E field in the mid plane

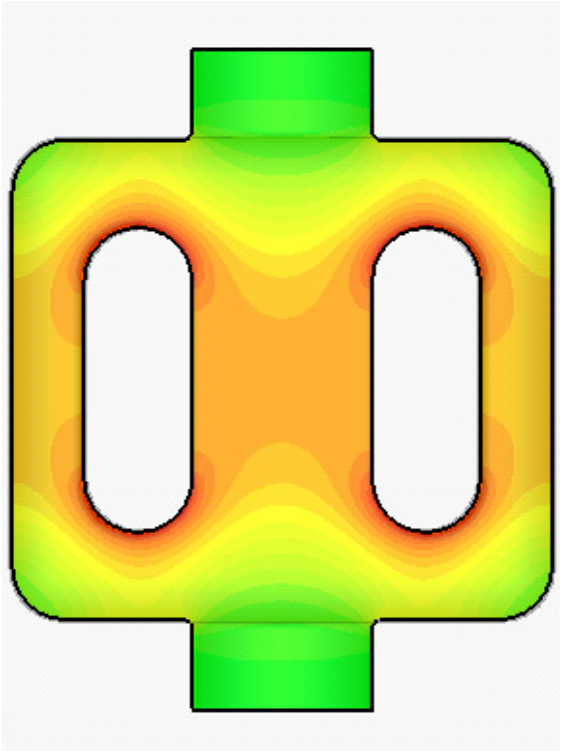


H field in the top plane

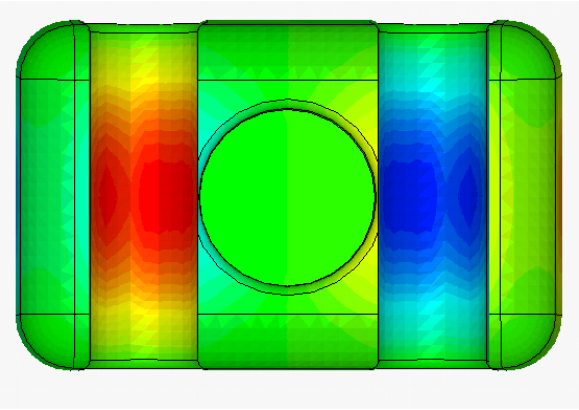
E and H Fields in 800 MHz Cavity



H field at top plane

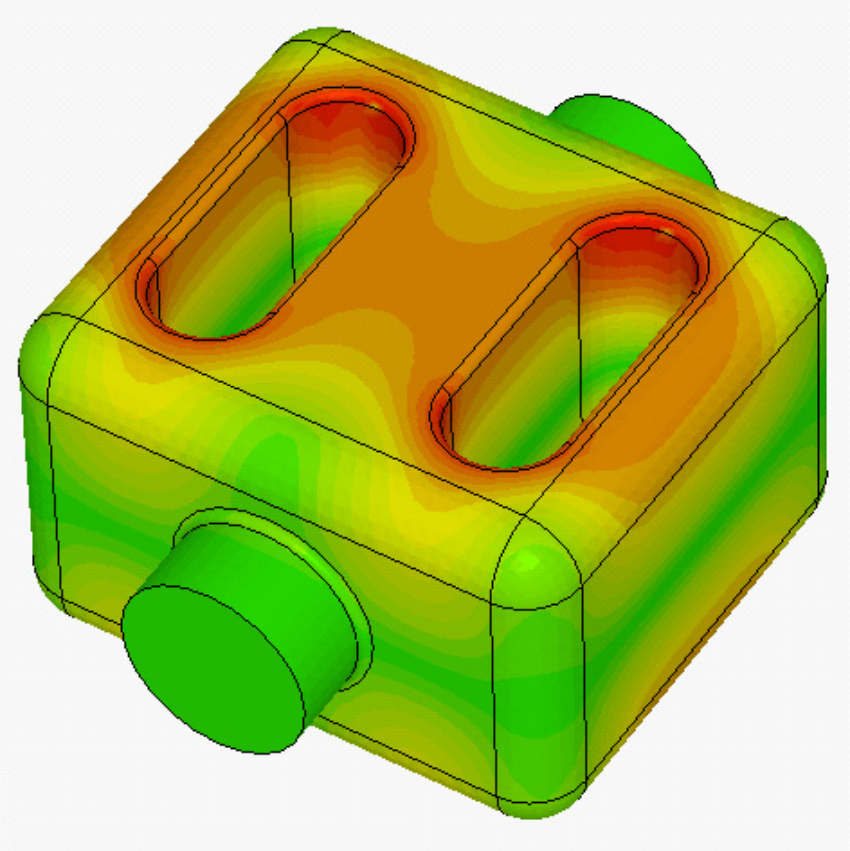


E field at mid plane

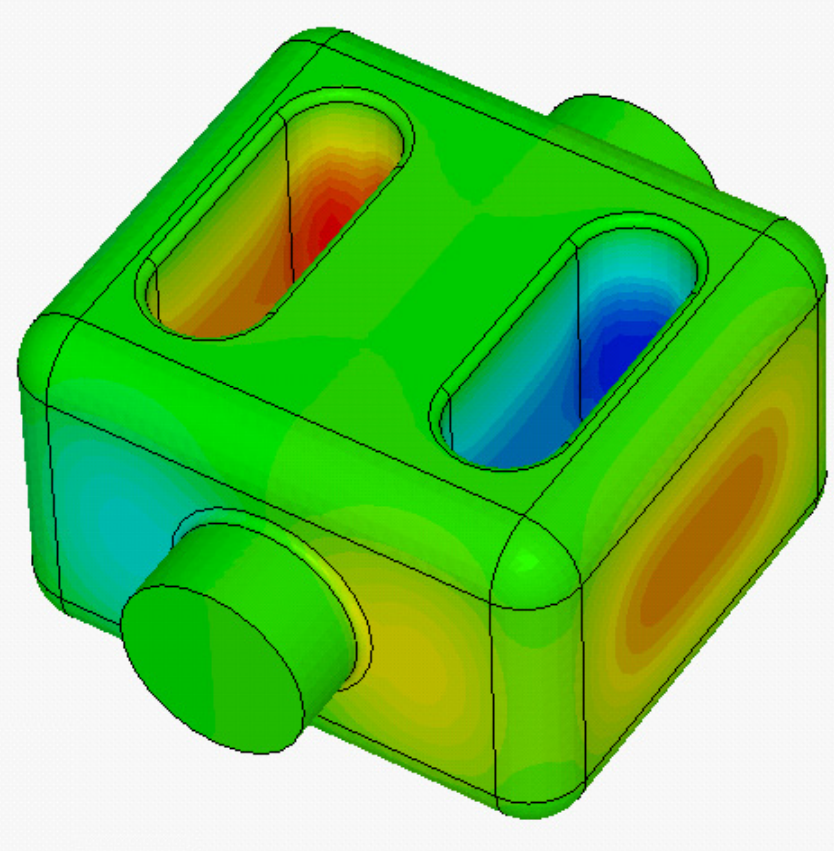


Surface E field on parallel bars

E and H Fields in 800 MHz Cavity



Surface H field



Surface E field

Cavity Properties

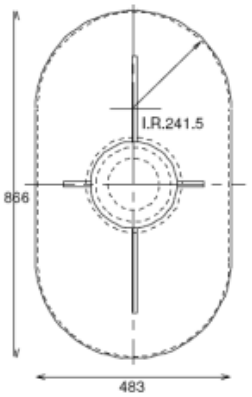
Parameter	400 MHz Cavity	800 MHz Cavity	Unit
Frequency of π mode	400.0	800.0	MHz
λ/2 of π mode	374.7	187.4	mm
Frequency of 0 mode	407.1	815.4	MHz
Cavity length	494.7	267.4	mm
Cavity width	400.0	300.0	mm
Bars length	382.2	191.8	mm
Bars thickness (2R)	100.0	60.0	mm
Bars width	370.0	170.0	mm
Bars axes separation (2A)	200.0	160.0	mm
Aperture diameter	100.0	100.0	mm
Deflecting voltage (V_t*)	0.375	0.187	MV
Peak electric field (E_p*)	2.32	3.14	MV/m
Peak magnetic field (B_p*)	7.58	11.03	mT
Energy Content (U*)	0.203	0.078	J
Geometrical factor ($G = QR_s$)	81.37	112.3	Ω
$[R/Q]_t$	275.96	89.28	Ω
R_tR_s	2.2×10^4	1.0×10^4	Ω^2
At E_t* = 1 MV/m			

400

615
1101

305
0.375
4.25
12.24

220
46.7
10274

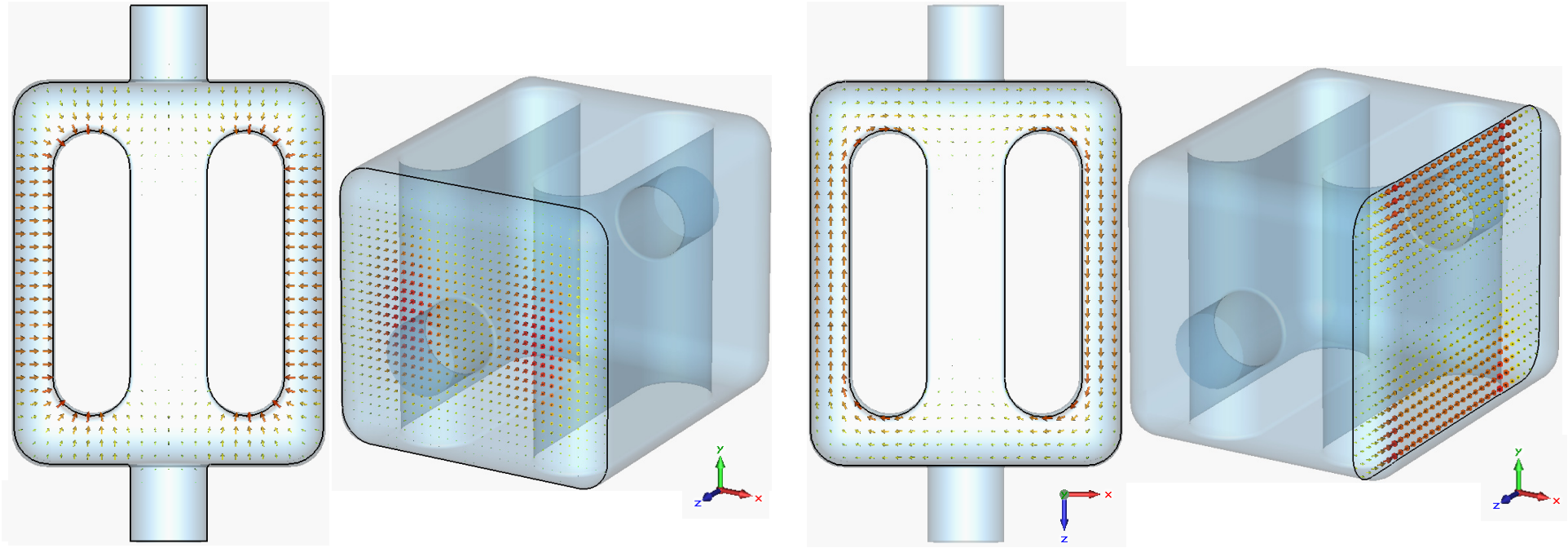


Higher Order Modes – 400 MHz

Mode	Freq. (MHz)	Mode of Operation	Field direction on beam axis		R/Q (Ω)	
			E	B	Direct Integration Method	Using Panofsky Wenzel Theorem
						(r_0 = 5 mm)
1	400.149	Deflecting	x	y	275.616	275.825
2	407.372	Accelerating	z		67.278	-
3	470.514	Accelerating	z		20.864	-
4	470.728	Deflecting	x	y	9.005	9.022
5	510.128	Deflecting	x	y	68.84	68.882
6	583.504	Accelerating	z		45.376	-
7	670.148	Deflecting	x	y	8.651	8.658
8	704.917	Deflecting	x	y	1.313	1.307
9	735.338	Accelerating	z		56.344	-
10	795.916			z	0.0	-
11	807.890	Deflecting	y	x	2.096	2.092
12	833.700	Deflecting	y	x	52.455	52.349
13	842.542			z	0.0	-
14	859.350			z	0.0	-
15	886.062	Deflecting	x	y	17.337	17.288
16	905.119	Deflecting	y	x	15.198	15.163
17	949.554	Deflecting	x	y	0.965	0.963
18	960.319	Accelerating	z		15.926	-
19	965.730			z	0.0	-
20	991.230			z	0.0	-
21	1011.586	Deflecting	y	x	3.748	3.743
22	1090.853	Deflecting	x	y	12.914	12.873
23	1133.203			z	0.0	-
24	1168.467	Accelerating	z		0.338	-
25	1177.638			z	0.0	-
26	1183.096	Deflecting	y	x	8.747	8.735
27	1187.916	Deflecting	x	y	3.869	4.049

Modes of Interest – Mode 2

E Field **B Field**



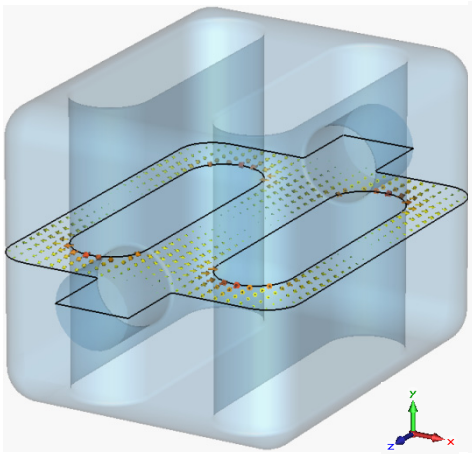
On the mid plane | On the front plane | On the top plane | On the right plane

Frequency = 407.37 MHz
Mode of Operation – Accelerating

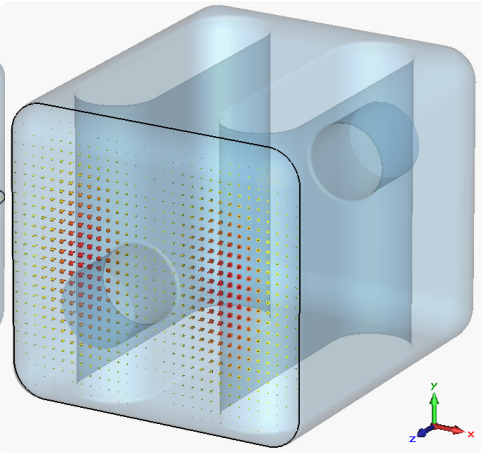
$$\left[\frac{R}{Q}\right] = 67.28$$

Modes of Interest – Mode 5

E Field

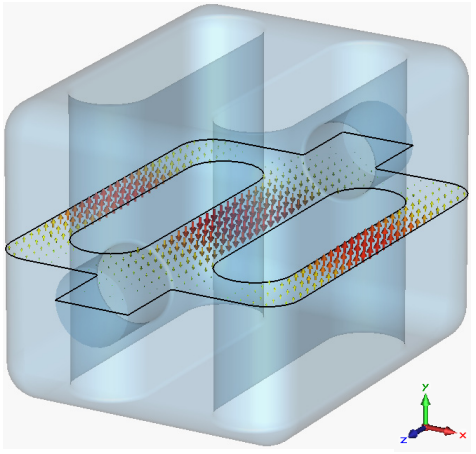


On the mid plane

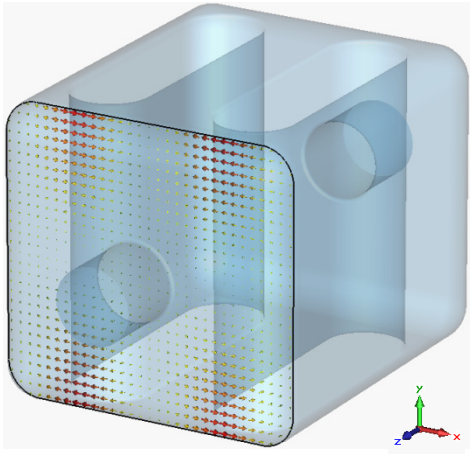


On the front plane

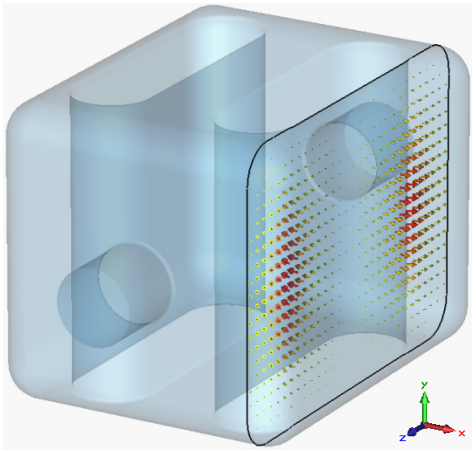
B Field



On the mid plane



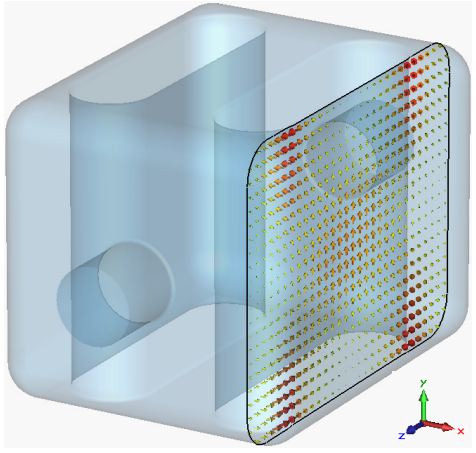
On the front plane



On the right plane

Frequency = 510.13 MHz
Mode of Operation – Deflecting

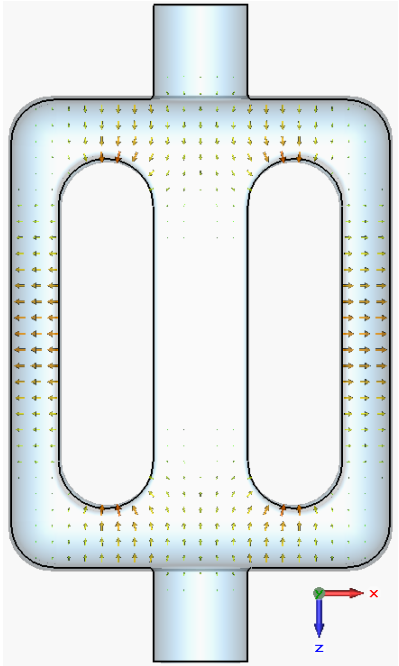
$$\left[\frac{R}{Q}\right]_T = 68.84$$

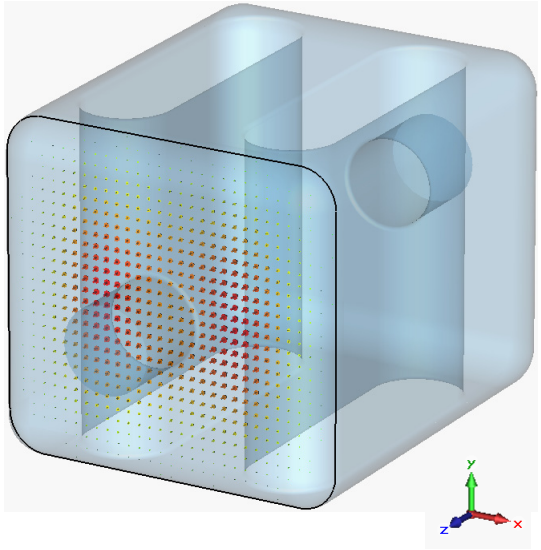


On the right plane

Modes of Interest – Mode 6

E Field

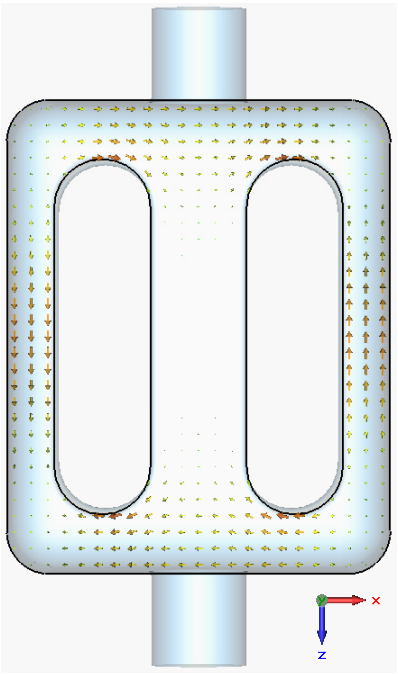


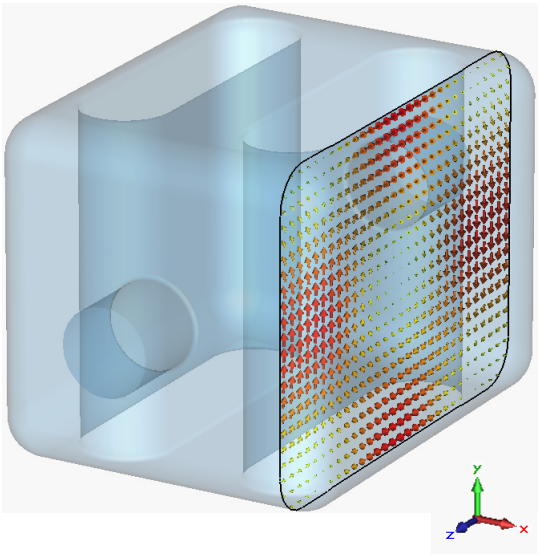


On the mid plane

On the front plane

B Field





On the top plane

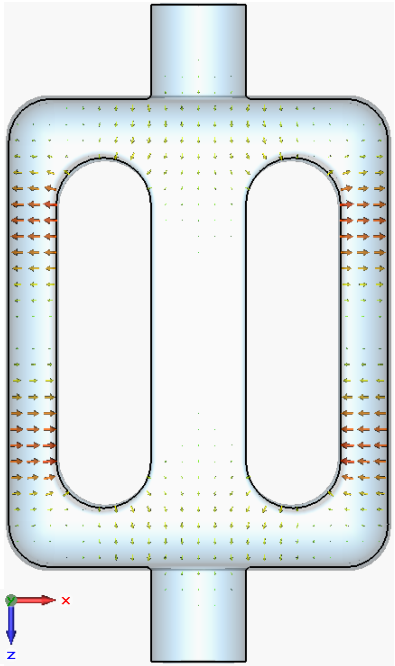
On the right plane

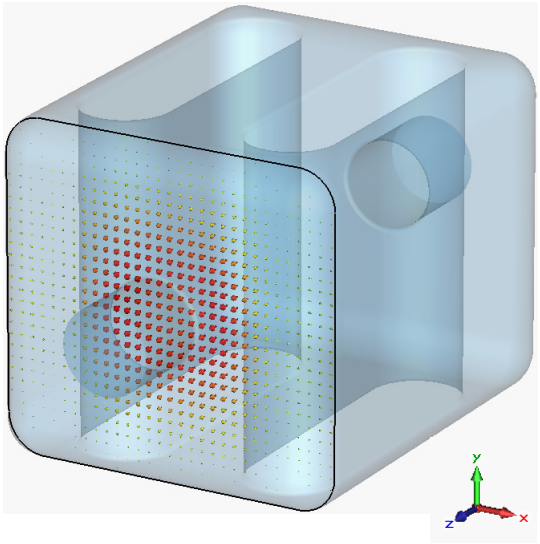
Frequency = 583.5 MHz
Mode of Operation – Accelerating

$$\left[\frac{R}{Q}\right] = 45.38$$

Modes of Interest – Mode 9

E Field

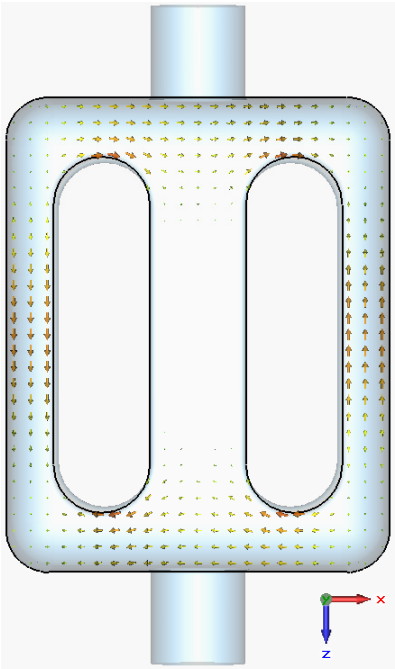


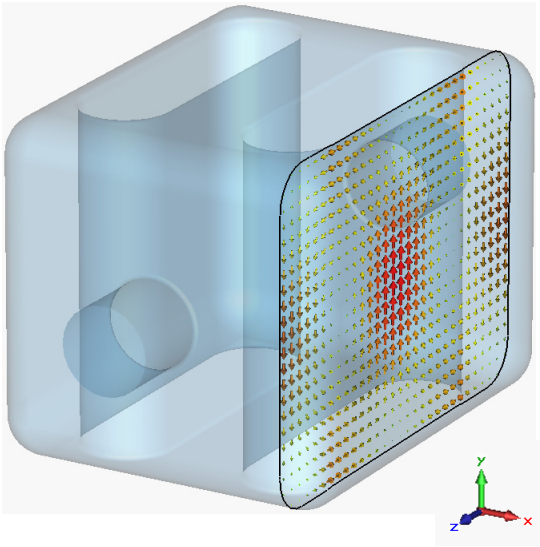


On the mid plane

On the front plane

B Field





On the top plane

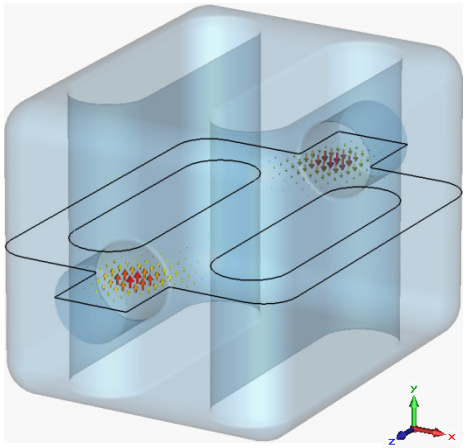
On the right plane

Frequency = 735.34 MHz
Mode of Operation – Accelerating

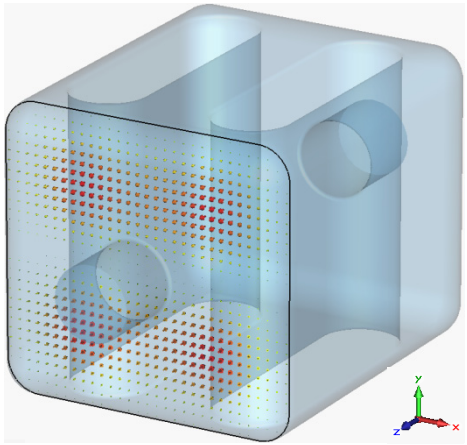
$$\left[\frac{R}{Q}\right] = 56.34$$

Modes of Interest – Mode 12

E Field

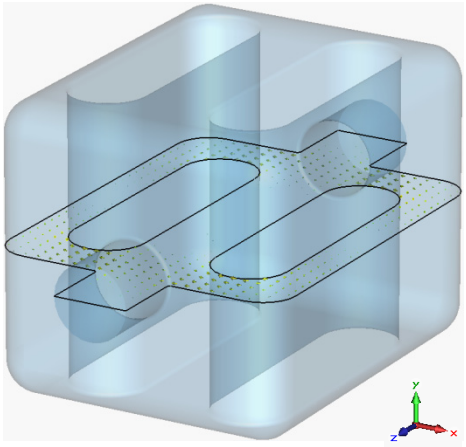


On the mid plane

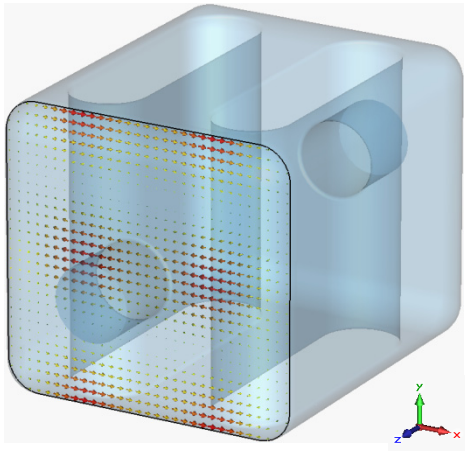


On the front plane

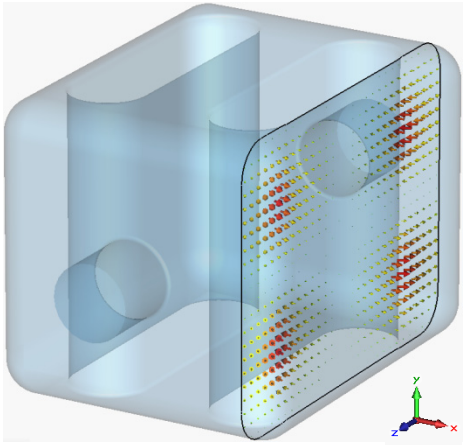
B Field



On the mid plane



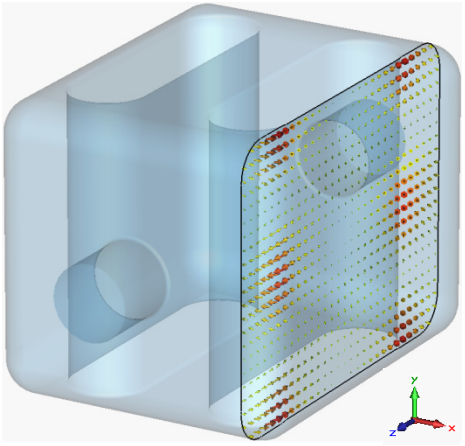
On the front plane



On the right plane

Frequency = 833.7 MHz
Mode of Operation – Deflecting

$$\left[\frac{R}{Q}\right]_T = 52.45$$



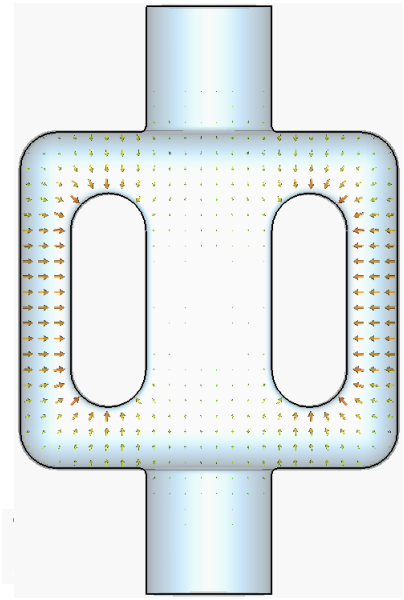
On the right plane

Higher Order Modes – 800 MHz

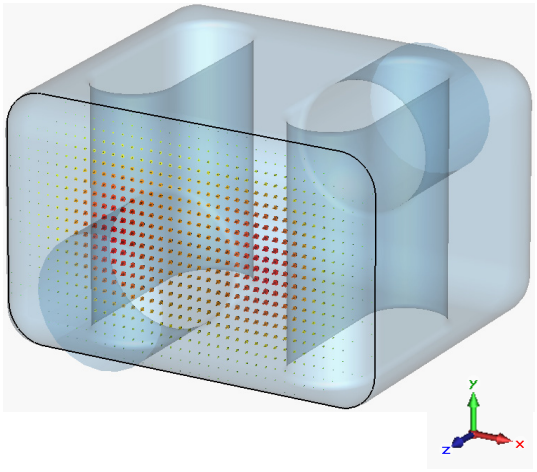
Mode	Freq. (MHz)	Mode of Operation	Field direction on beam axis		R/Q (Ω)	
			E	B	Direct Integration Method	Using Panofsky Wenzel Theorem
						(r_0 = 5 mm)
1	799.753	Deflecting	x	y	89.432	89.643
2	814.917	Accelerating	z		57.297	-
3	909.850	Accelerating	z		9.434	-
4	918.503	Deflecting	x	y	1.419	1.456
5	982.163	Deflecting	x	y	21.546	21.580
6	1073.406	Accelerating	z		52.474	-
7	1251.361	Deflecting	x	y	6.261	6.225
8	1280.867	Deflecting	x	y	0.000463	0.00179
9	1348.458	Accelerating	z		24.548	-
10	1470.414	Deflecting	y	x	0.295	0.259
11	1505.083	Deflecting	x	y	19.916	19.706
12	1529.967	Deflecting	y	x	22.177	21.874
13	1586.937			z	0.0	-
14	1606.693	Deflecting	y	x	0.382	0.363

Modes of Interest – Mode 2

E Field

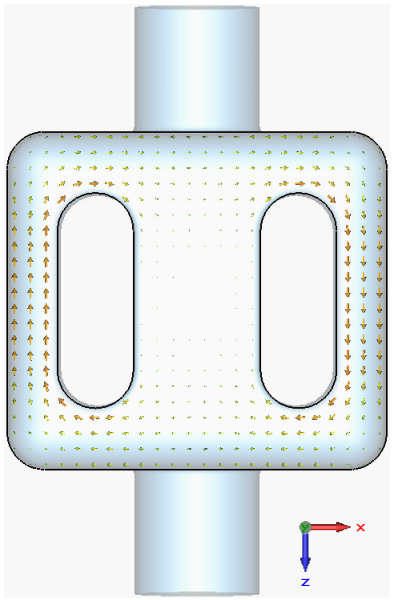


On the mid plane

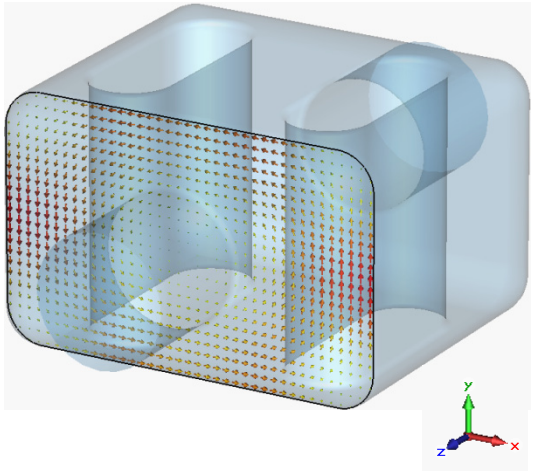


On the front plane

B Field



On the top plane



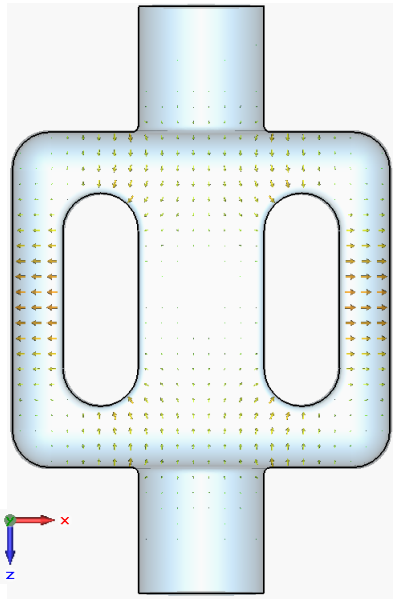
On the front plane

Frequency = 814.92 MHz
Mode of Operation – Accelerating

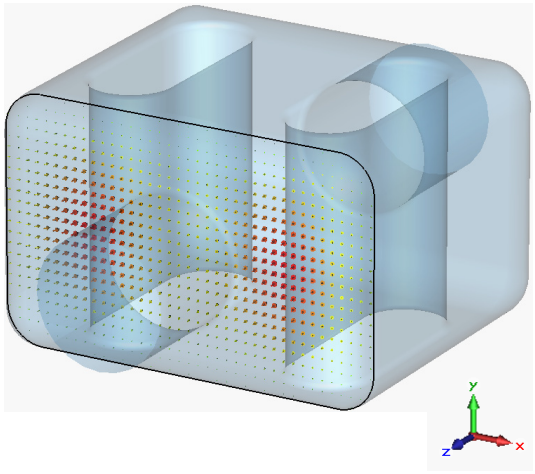
$$\left[\frac{R}{Q}\right] = 57.3$$

Modes of Interest – Mode 6

E Field

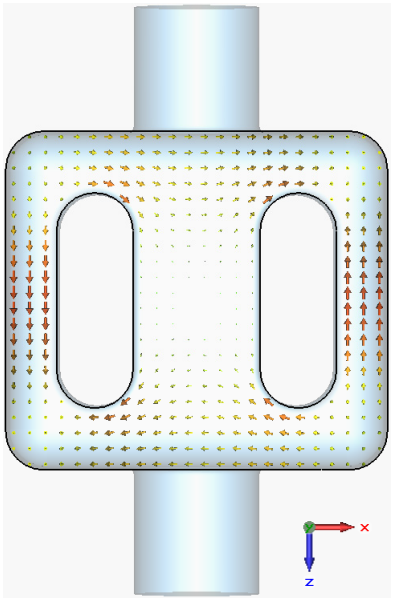


On the mid plane

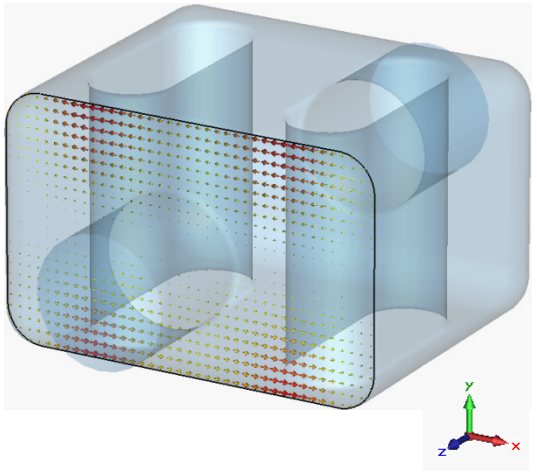


On the front plane

B Field



On the top plane



On the front plane

Frequency = 1073.4 MHz
Mode of Operation – Accelerating

$$\left[\frac{R}{Q}\right] = 52.47$$