COMPACT SUPERCONDUCTING CAVITIES FOR DEFLECTING AND CRABBING APPLICATIONS

Jean Delayen

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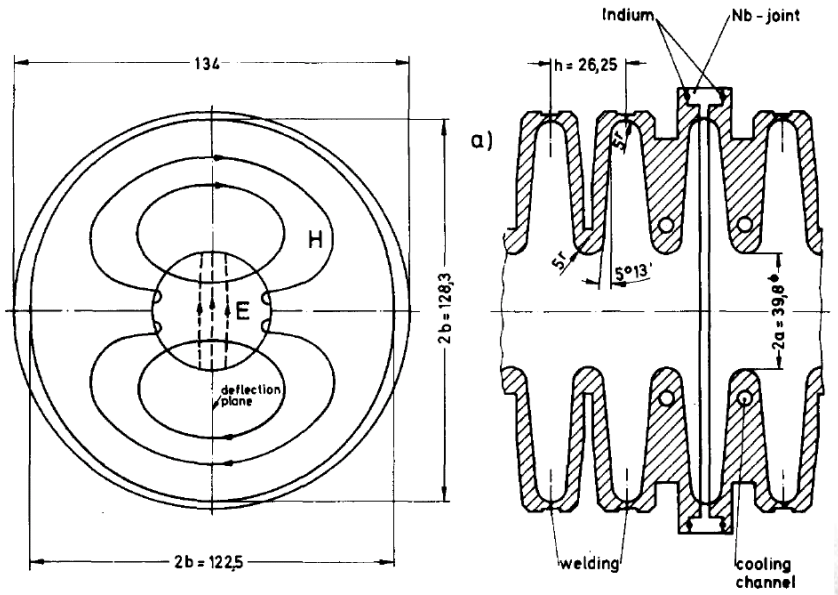
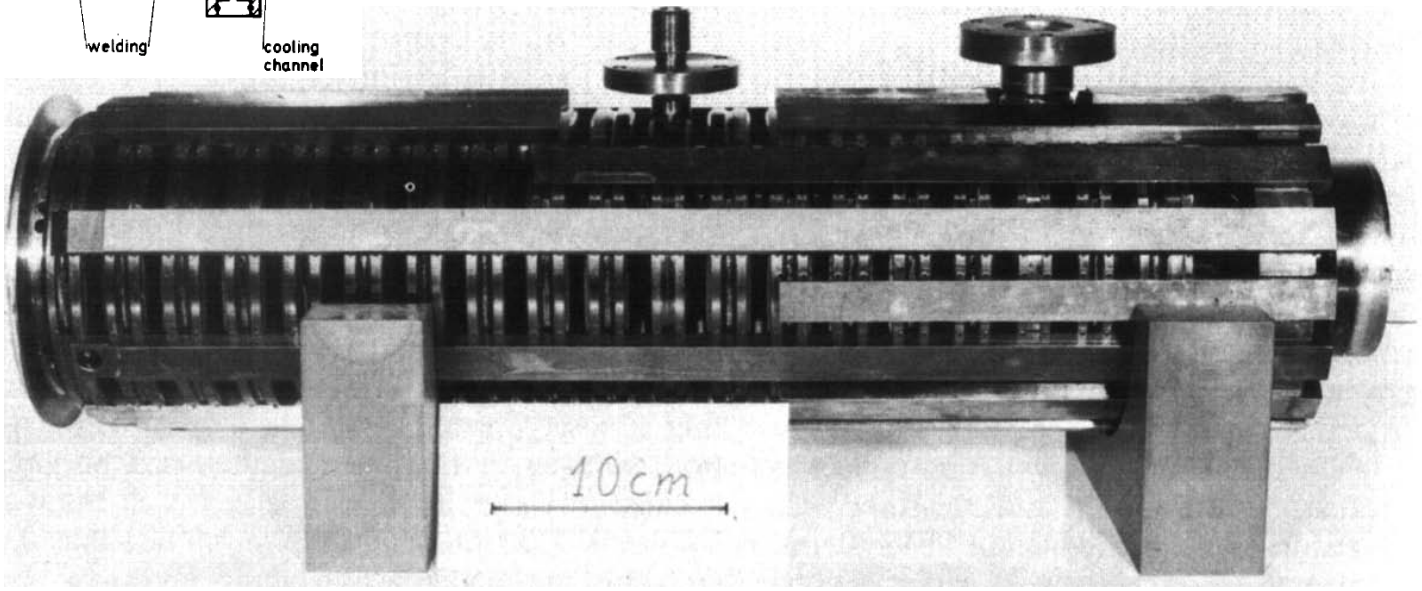
Old Dominion University
and
Thomas Jefferson National Accelerator Facility

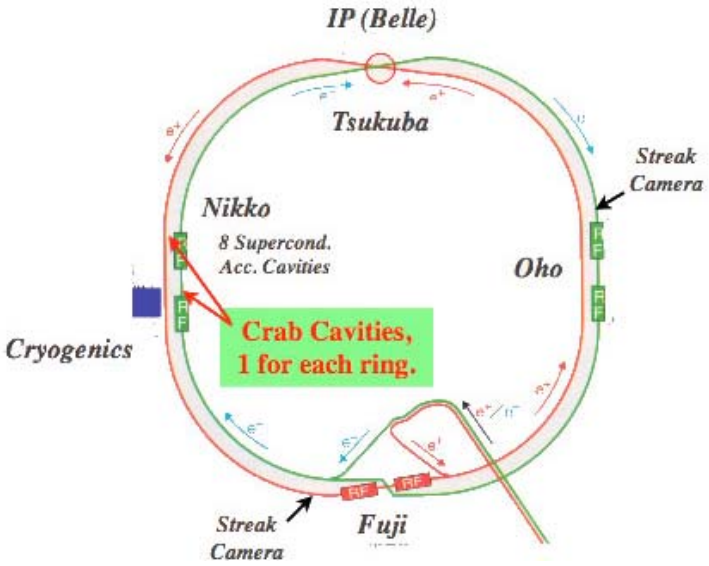
Some History (Karlsruhe/CERN)

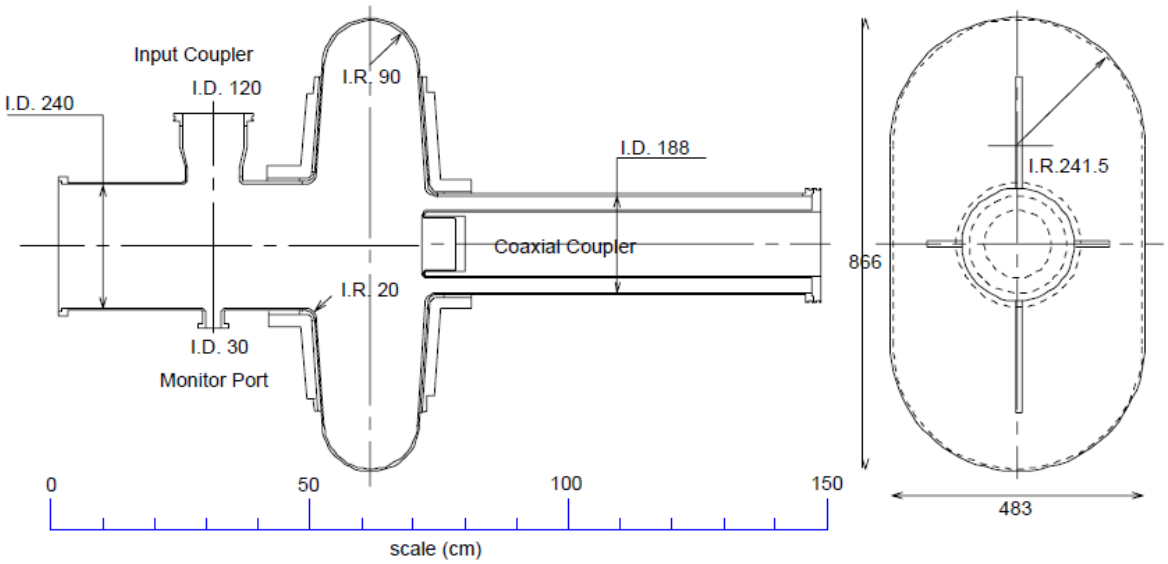


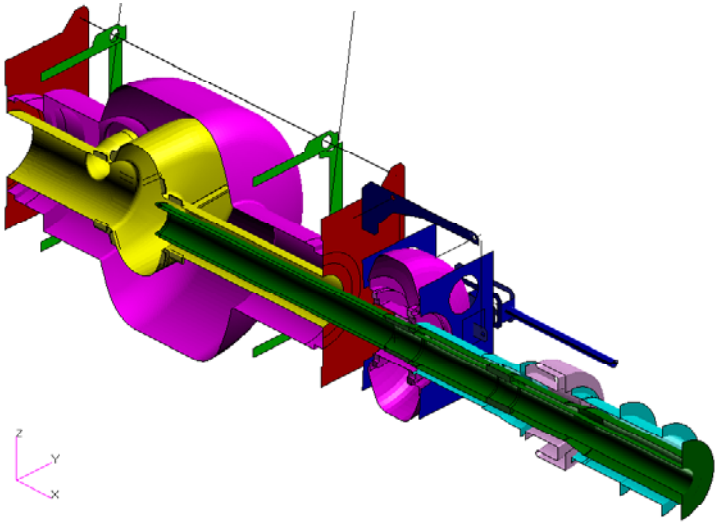
2.865 GHz Karlsruhe/CERN Separator
104 cells
Designed 1970, operated 1977-1981
At IHEP since 1998



Some History (KEK)





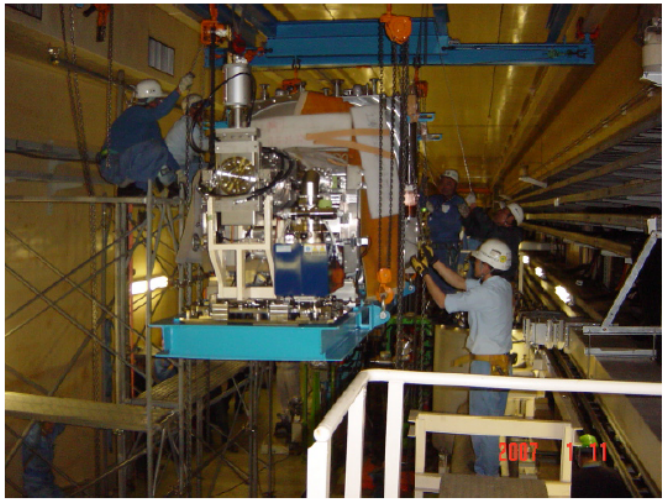


R / Qo	48.9 [Ω]
Γ	227
Esp/Vkick	14.4 [MV/m/MV]
Hsp/Vkick	415 [Oe/MV]

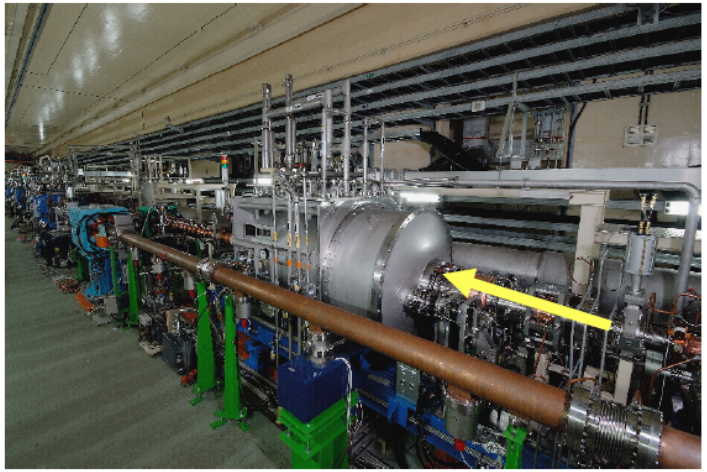
Some History (KEK)

Installation of Crab Cavities
for HER Jan. 8, 2007,
for LER Jan. 11, 2007

Crab Cavity for HER



Carrying the Crab cavity using crane track

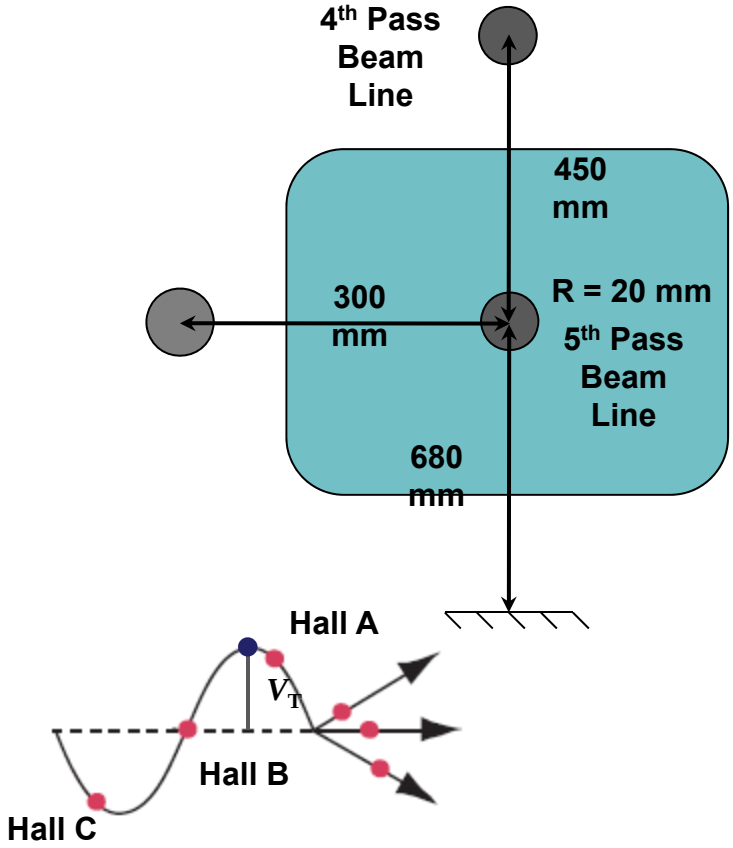


Crab Cavity for LER

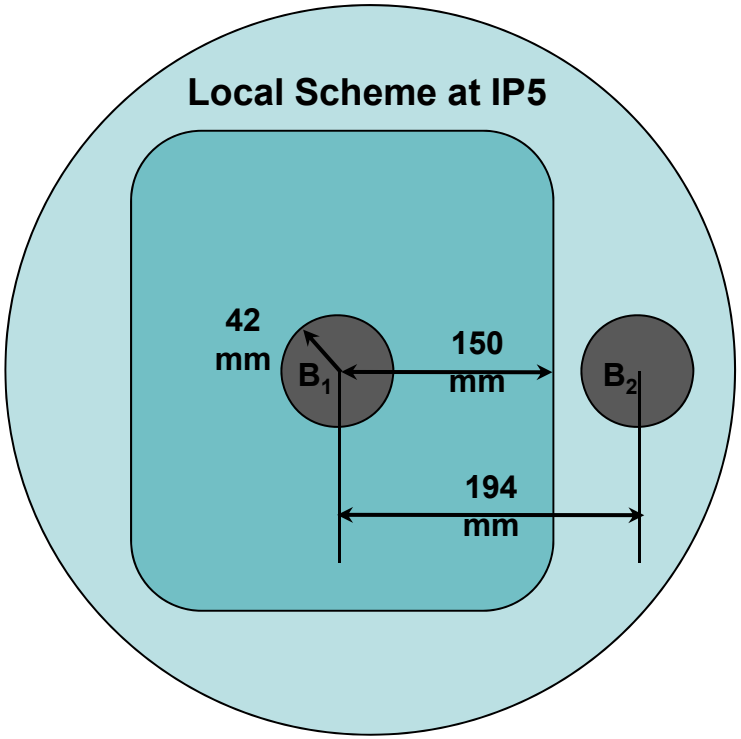
Cool-down of Crab Cavities
Jan. 29 , 2007
Beam Operation Start
Feb. 13

Dimensional Constraints

499 MHz Deflecting Cavity for JLab Upgrade



400 MHz Crabbing Cavity for LHC



Global scheme :
Separation between beam pipes – 420 mm

No dimensional constraints in Project-X and ELIC deflecting/crabbing designs

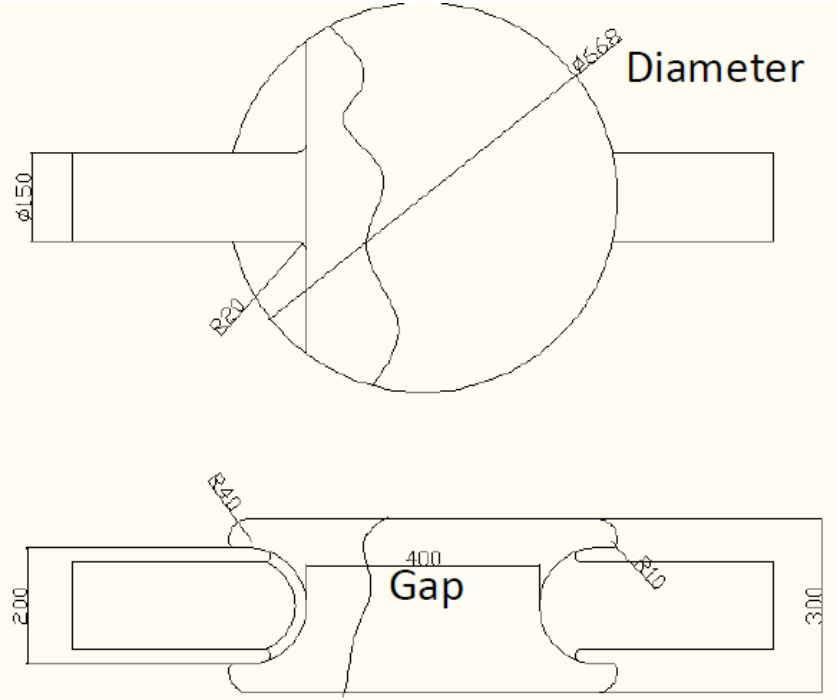
Pill-Box Cavity (KEK)

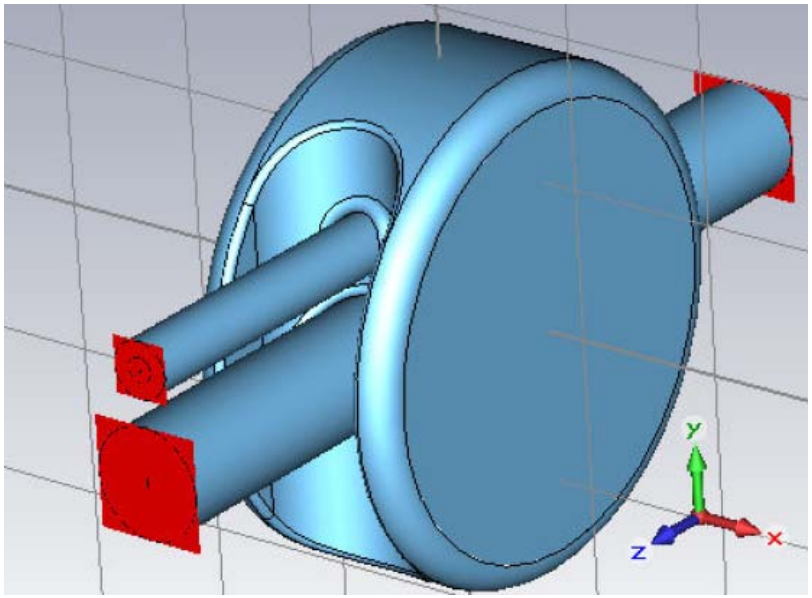
Use the lowest (TM010) mode

Beamline is diameter instead of axis

Deflection produced by electric field

Gaps need to reduce effect of cancelling magnetic field





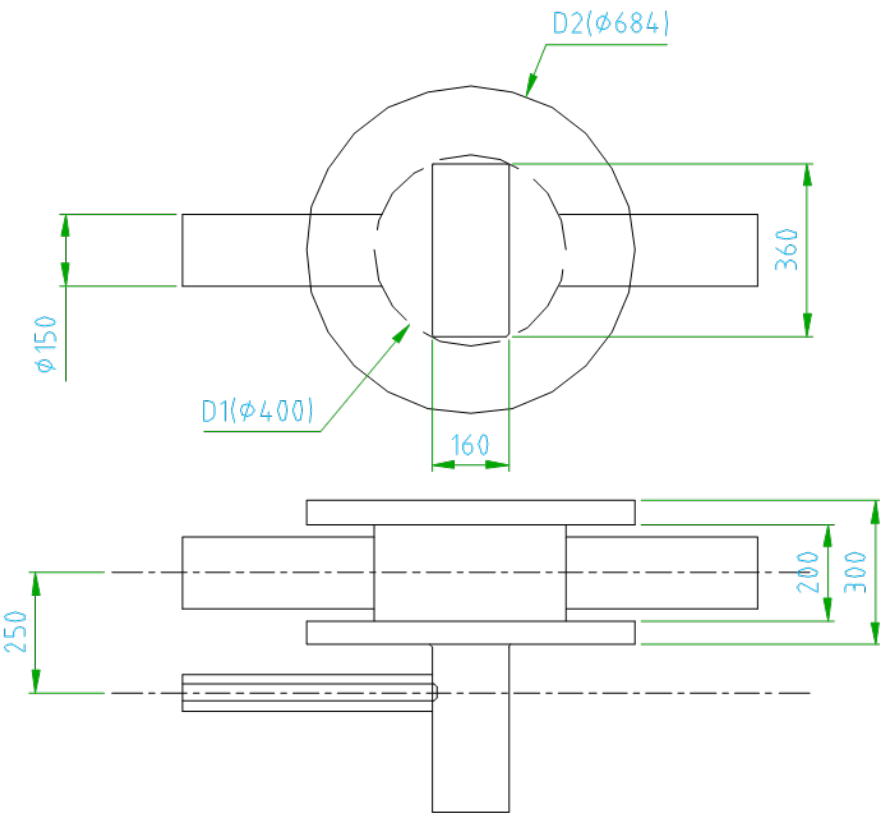
Pill-Box Cavity (KEK)

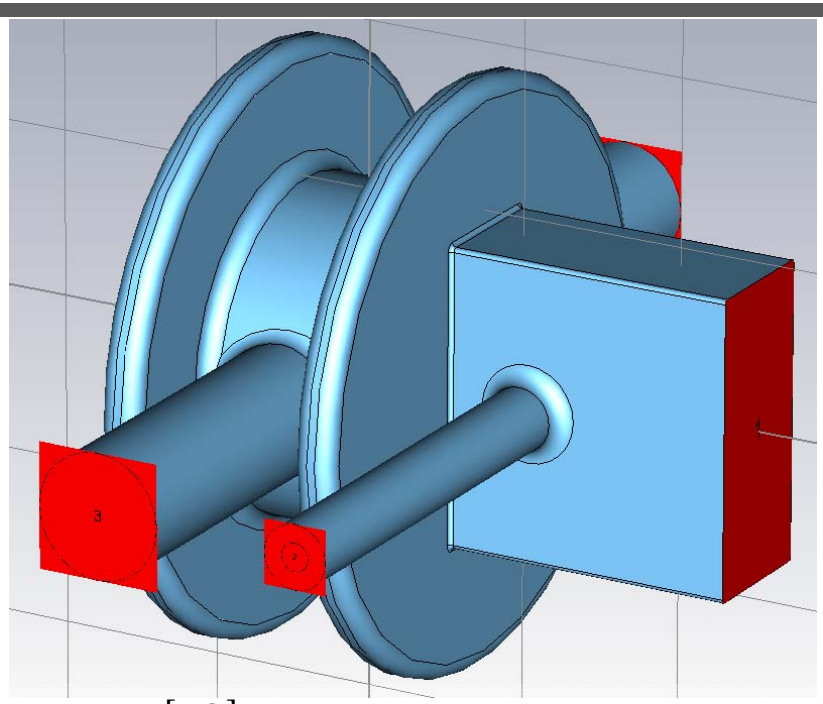
HOM distribution

mode	Frequency [MHz]	V_kick [V/J^1/2]	Vz [V/J^1/2]	R_z/Q [Ohm]	E_sp [MV/m/J^1/2]	H_sp [Oe/J^1/2]
TM010*	400.389	238192	0.290838	0	4.08	156
TE111	440.813	0.296713	464509	78	9.27	107
TM011	471.037	0.089472	453144	69	7.74	127
TM110	574.368	40614.4	0.290216	0	8.44	152
TE211	576.627	0.633024	0.123273	0	10.1	484
TM110	587.357	0.131659	0.005841	0	3.26	175
TE211	600.556	0.593295	0.344733	0	10.4	589
TM111	678.981	0.43519	313611	23	7.03	135
TE111	681.778	0.058524	0.05005	0	3.75	130
(TM310)**	700.339	253646	0.466292	0	9.28	229

*:Crab mode

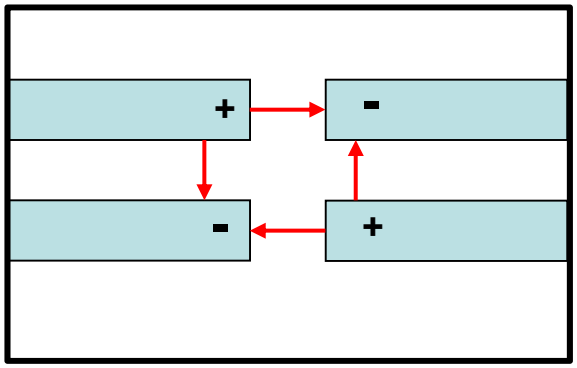
Reel Cavity (KEK)





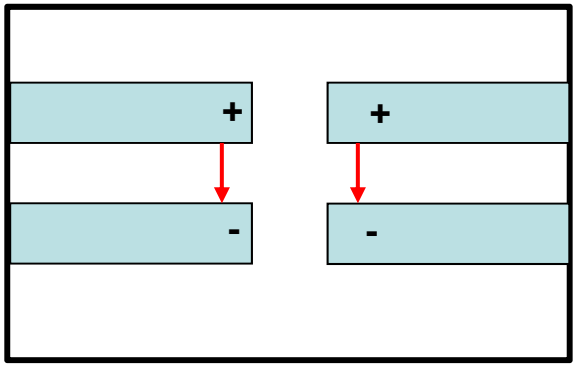
Rs [nΩ]	100~140
Esp [MV/m]	25
Hsp [A/m]	33000(43mT)
Vkick [MV]	0.86
Stored energy [J]	17.4
Q_0	$5.6x10^8$~$7.8x10^8$
Heat load [W]	56~78

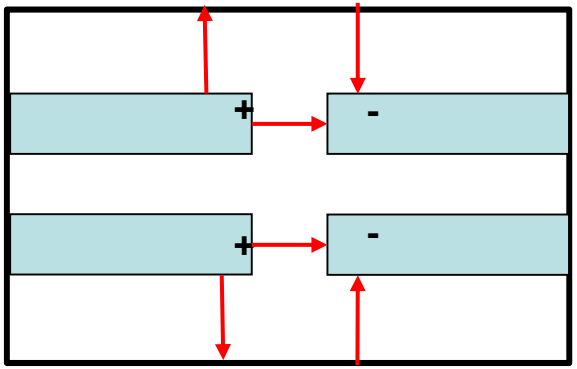
4-Rod Cavity (U. Lancaster/JLab)



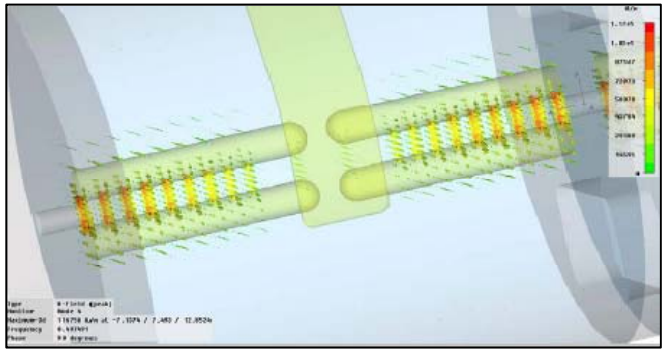
Fundamental deflecting mode

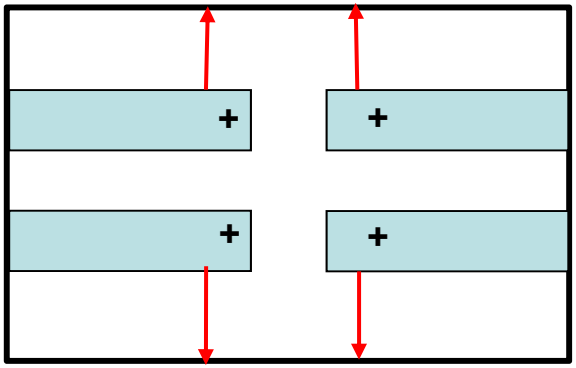
499 MHz NC separator at JLab



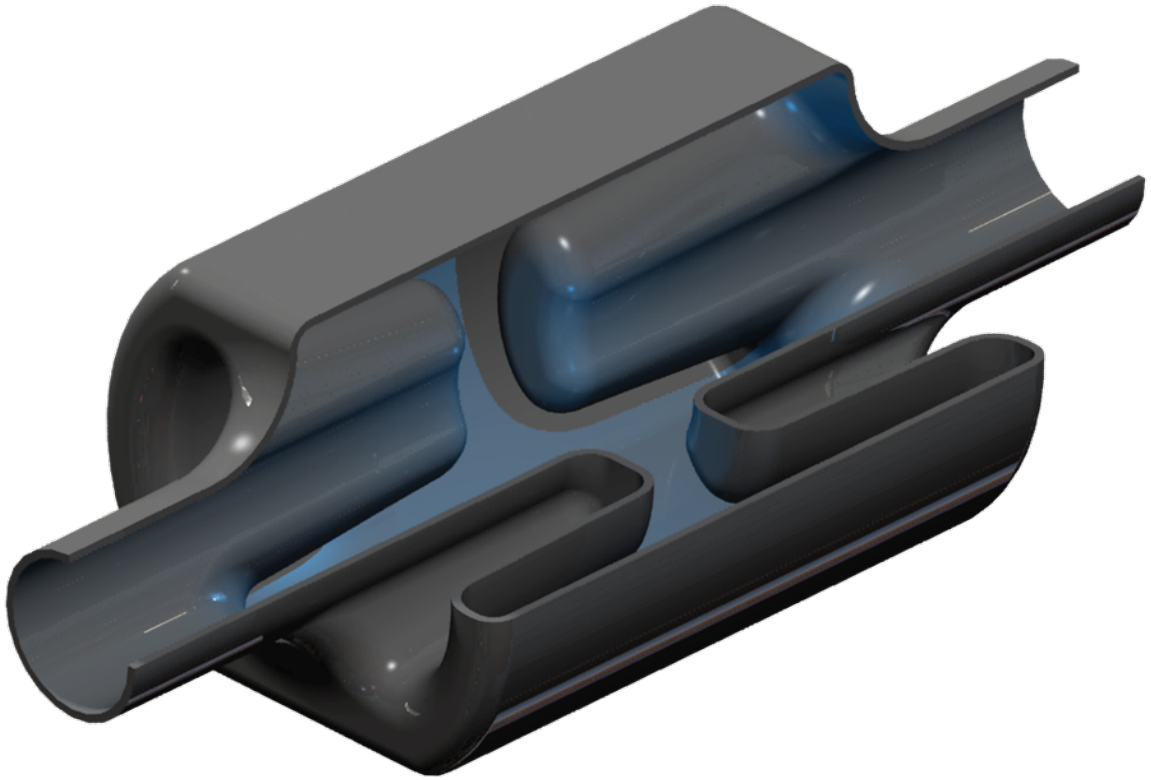


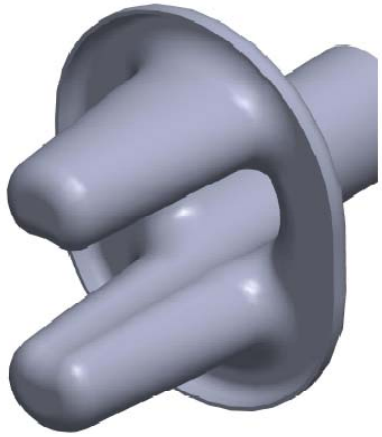
accelerating lower order mode

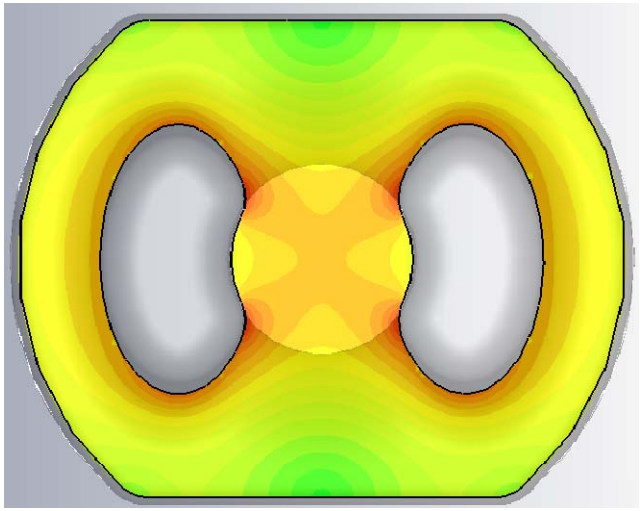




4-Rod Cavity (U. Lancaster/JLab)

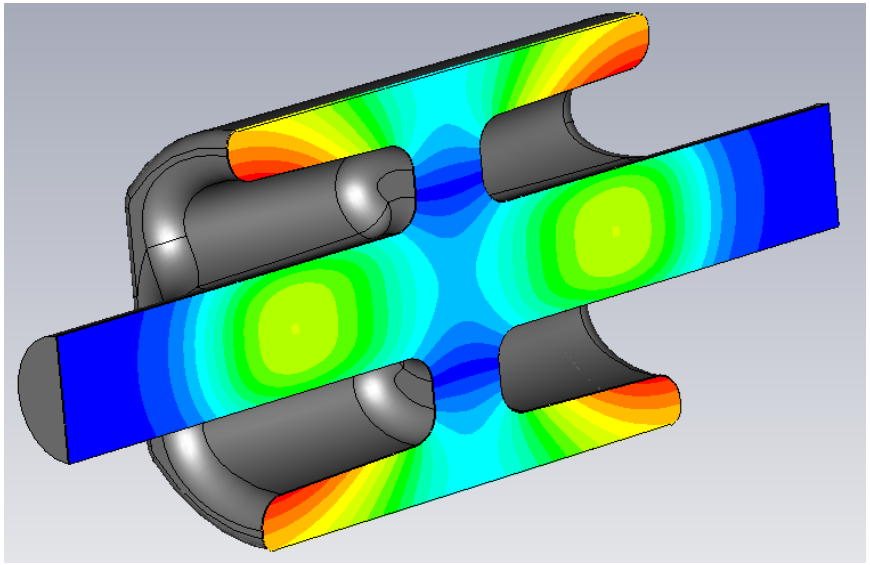




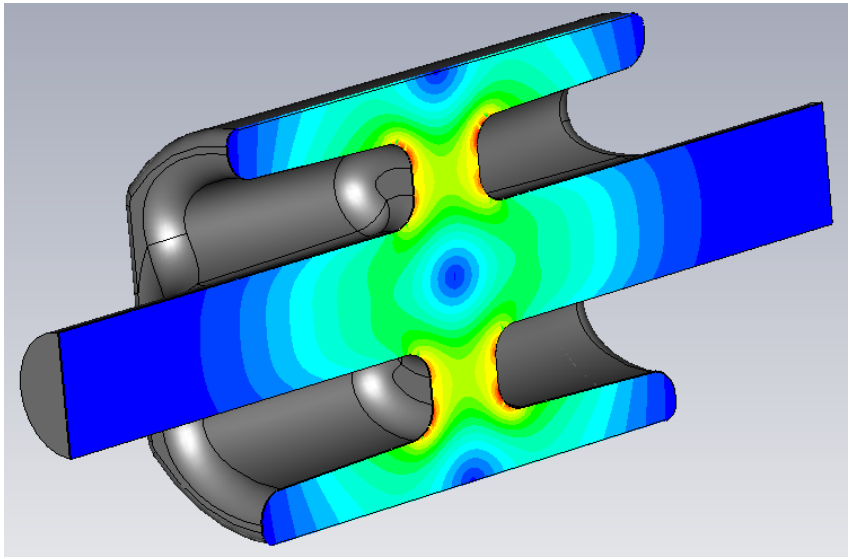


Rod shaping to reduce surface electric and magnetic fields, and the offset nonlinearities

4-Rod Cavity (U. Lancaster/JLab)



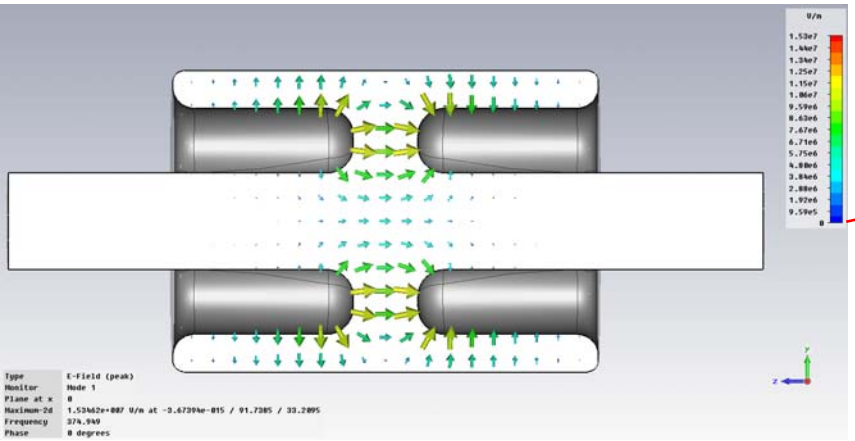
Magnetic Field



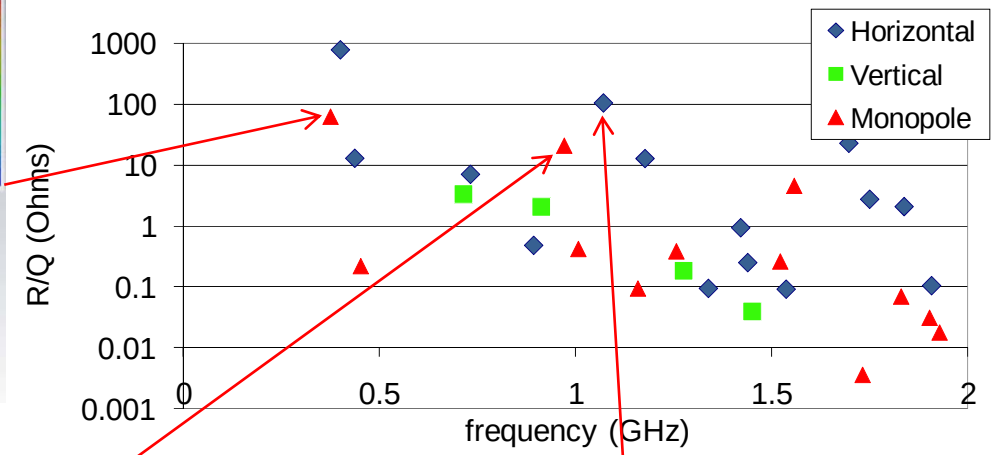
Electric Field

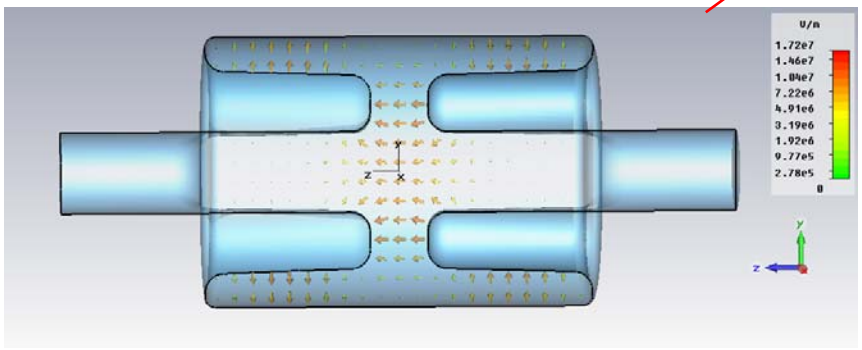
Emax @3MV	32.0 MV/m
Bmax @3MV	60.5 mT
Transverse R/Q	764.6 Ohms

Lower and Higher Order Modes

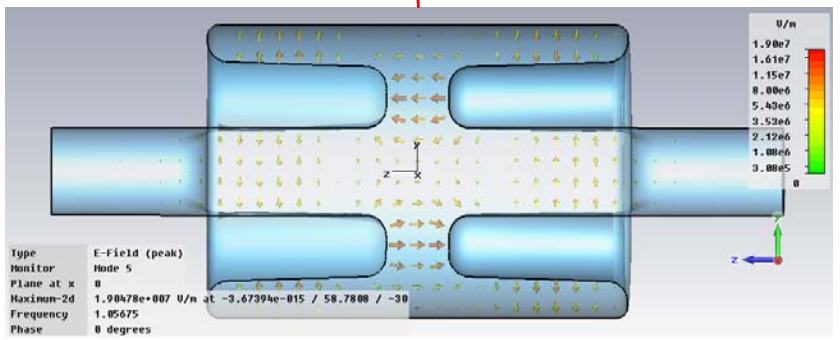


LOM Monopole



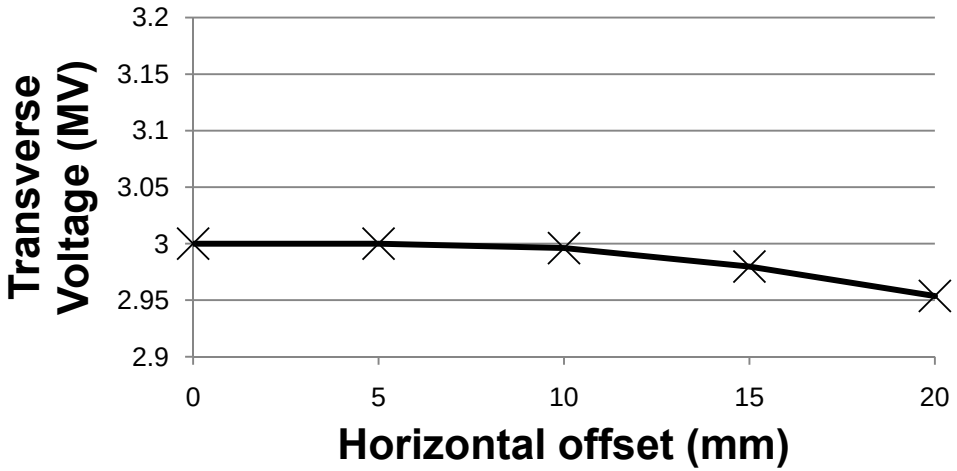


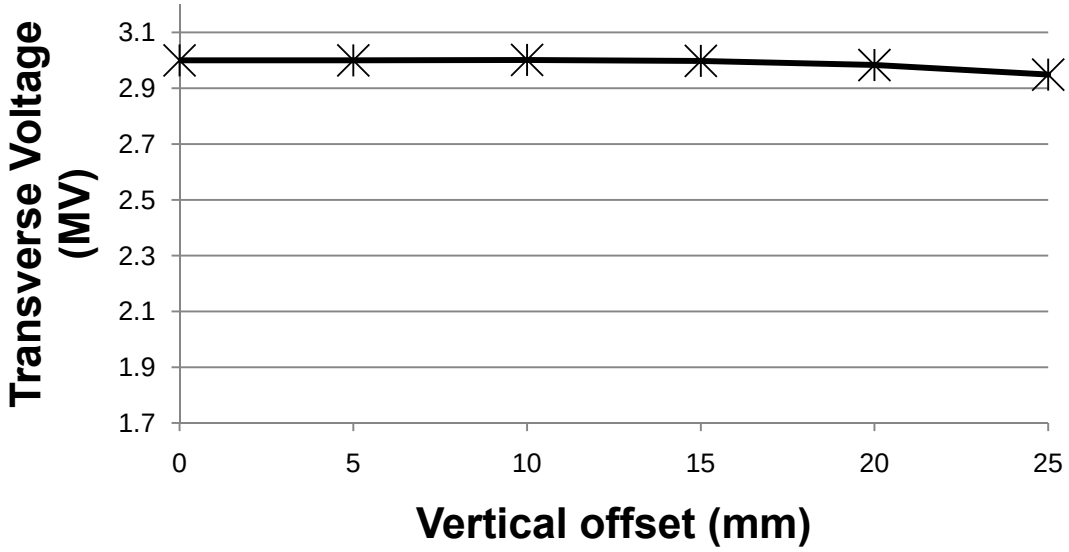
HOM Monopole 3π/4 resonator

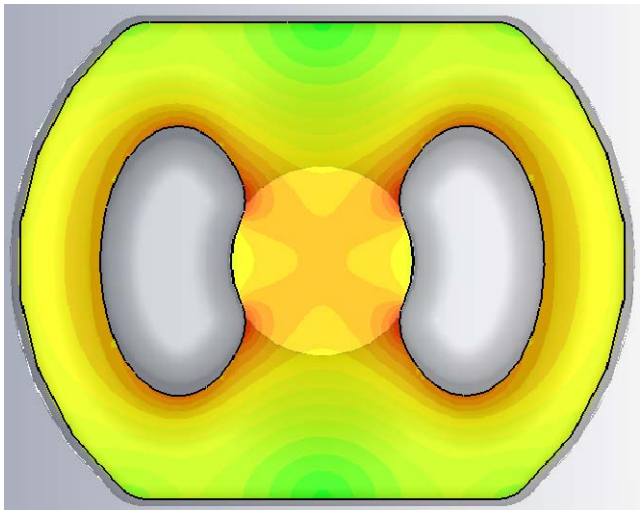


HOM Dipole 3π/4 resonator

4-Rod Offset Nonlinearities

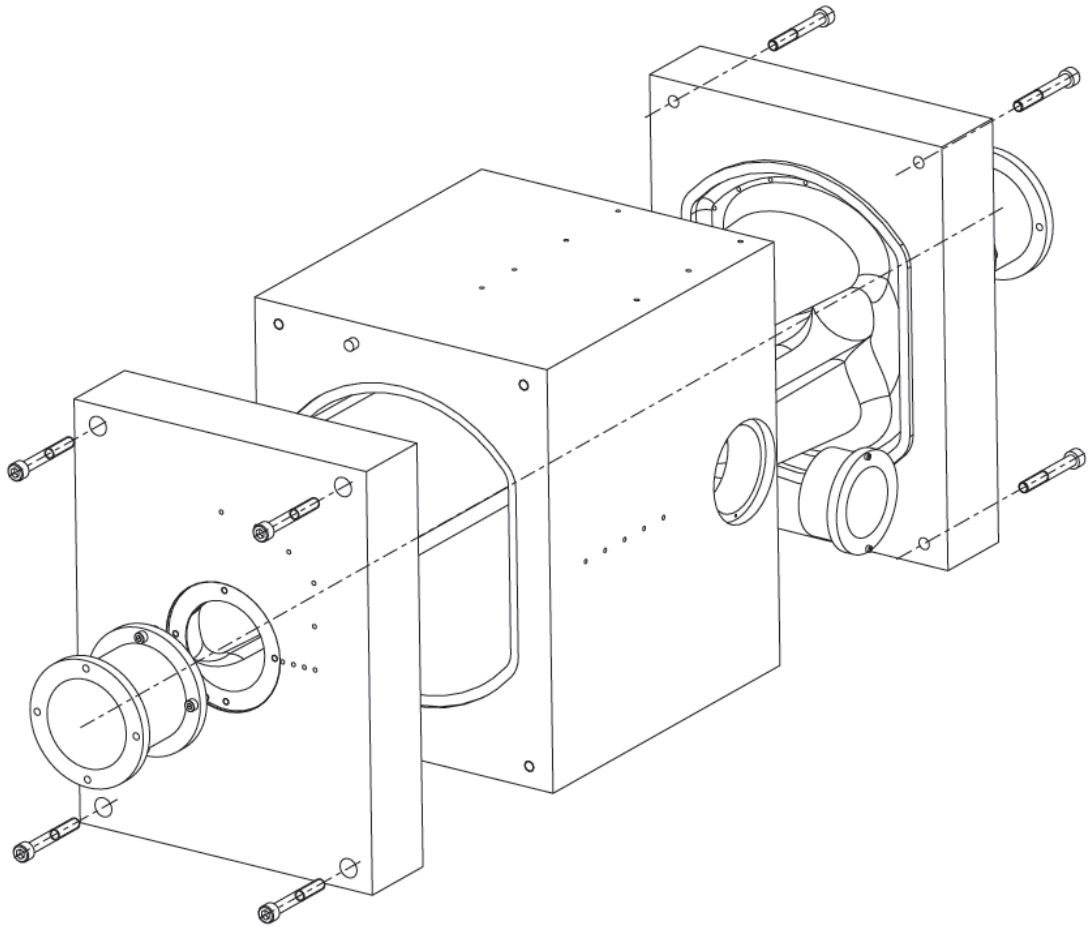


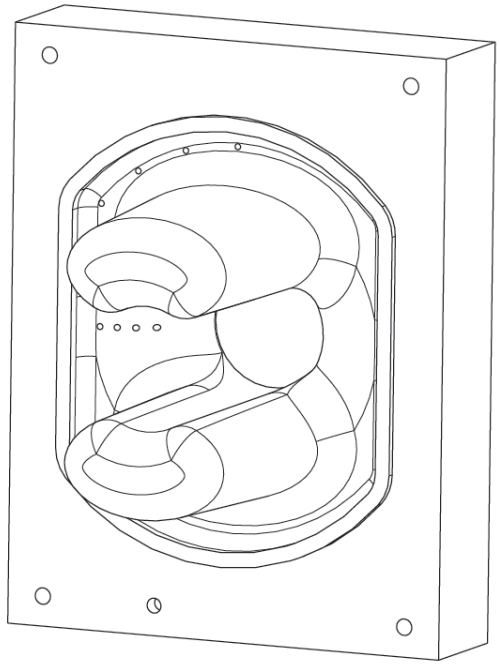




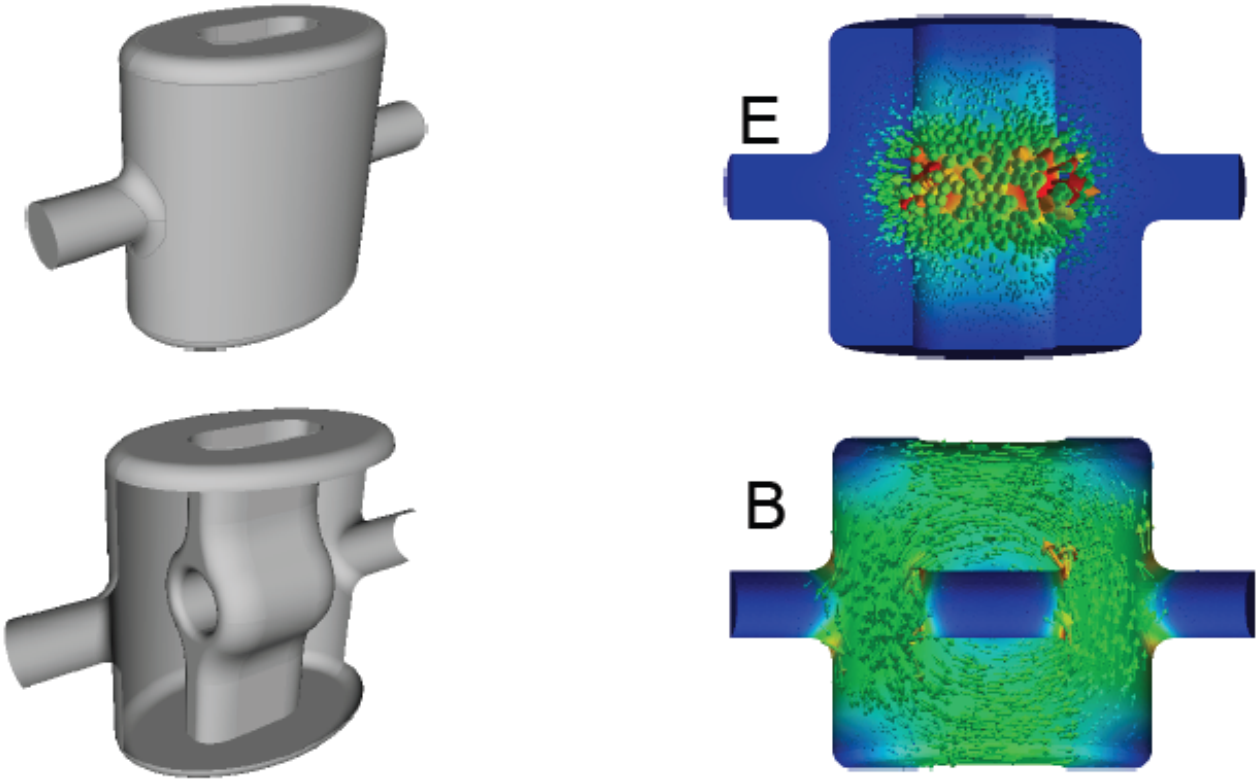
4-Rod Prototyping

Aluminum prototype cavity under construction



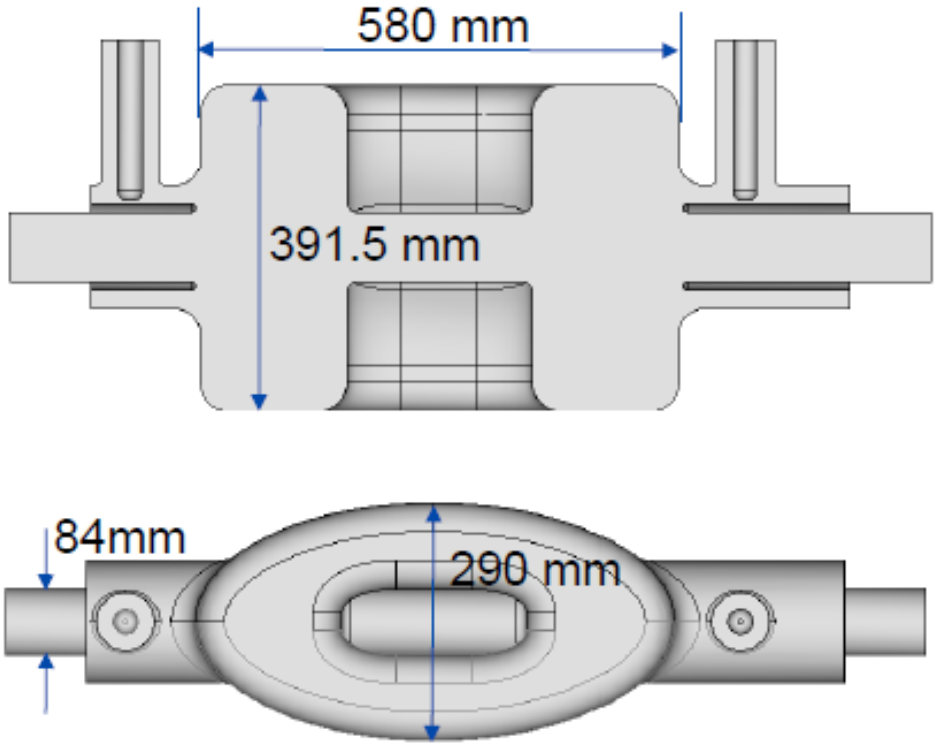


Half Wave (SLAC)



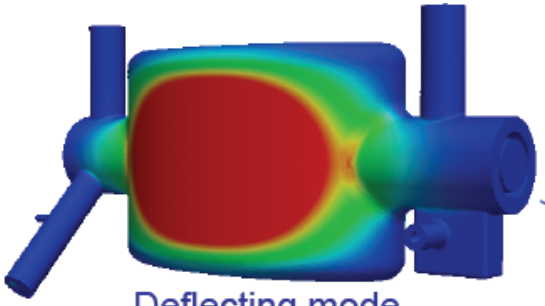
TE11-like mode - Frequency determined by longitudinal and vertical dimensions

Half Wave (SLAC)



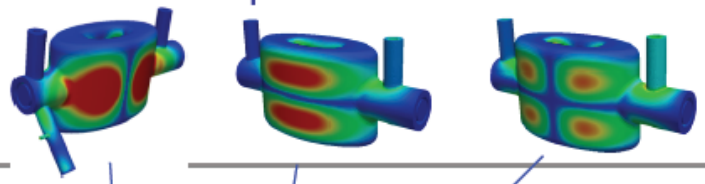
Parameters	
Cavity Width (mm)	290
Cavity Height (mm)	391.5
Cavity Length (mm)	580
Beam pipe radius (mm)	42
$(R/Q)_T$ (ohm/cavity)	215
E_S/V_T ((MV/m)/MV)	**10.4**
B_S/V_T (mT/MV)	**19.5**

Half Wave (SLAC)

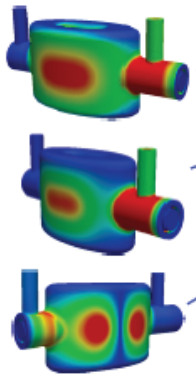


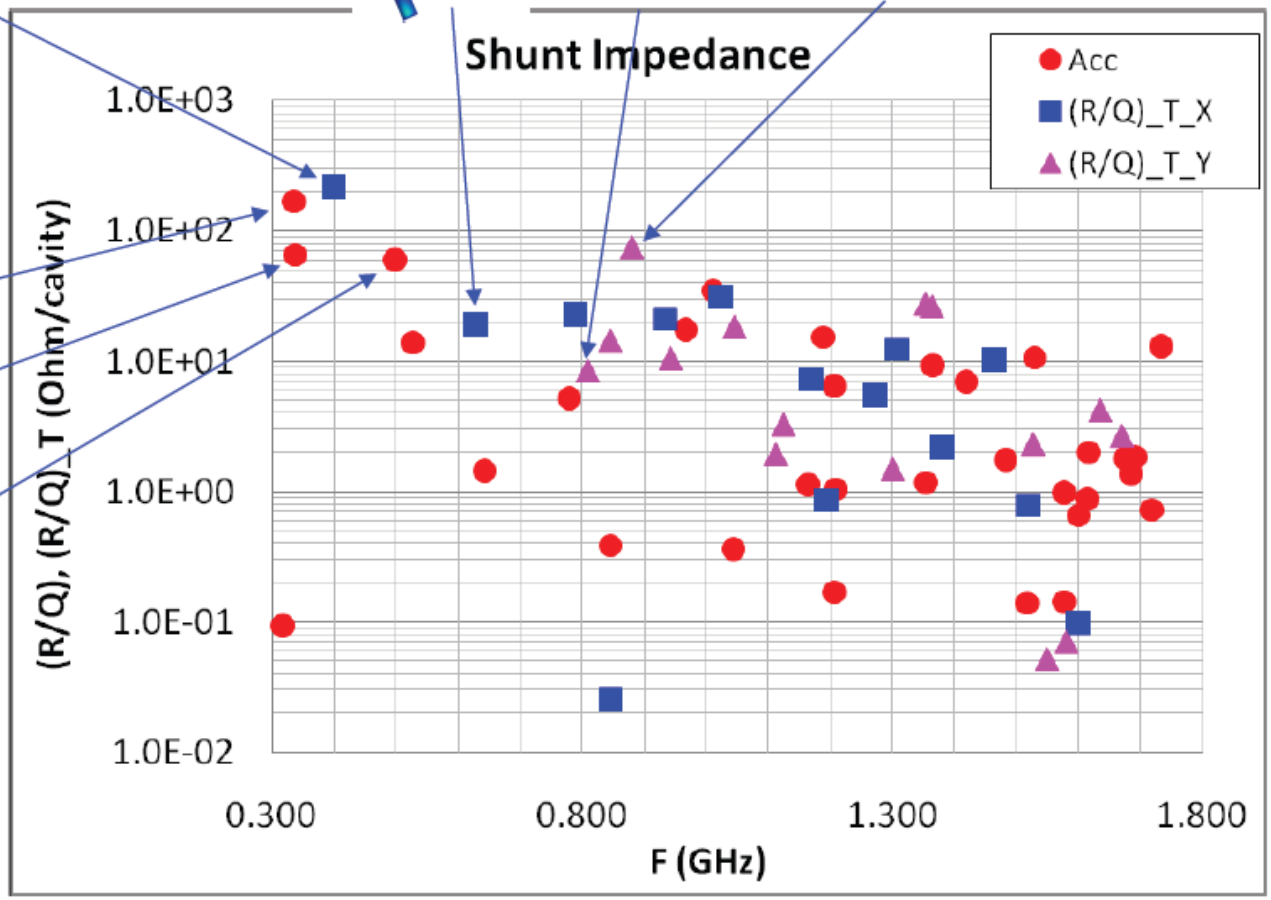
Deflecting mode

dipole HOMs



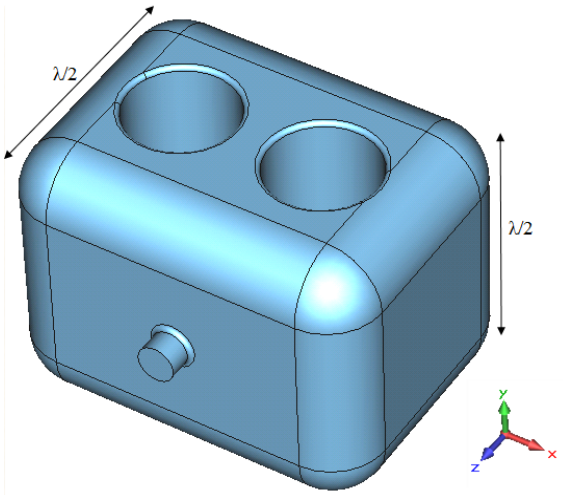
Acc modes

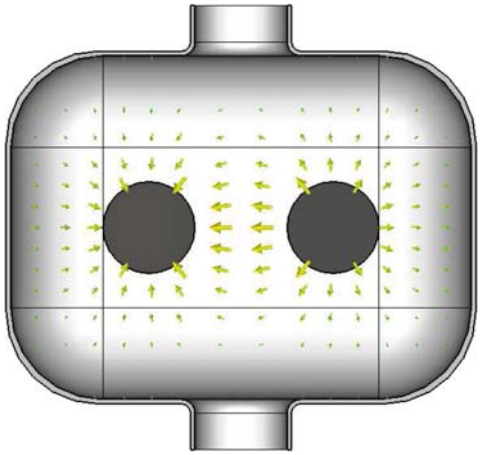




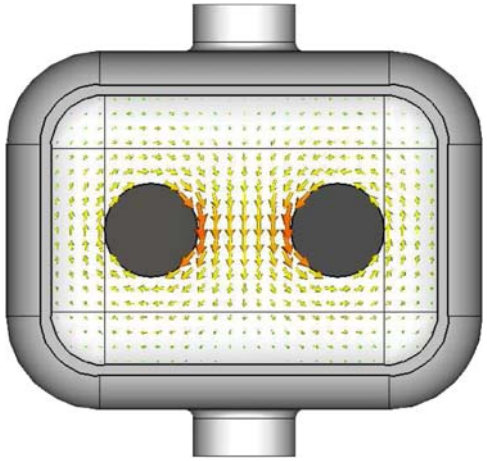
- No SOM !
- LOM 65 MHz below deflecting mode

Parallel-bar (ODU)



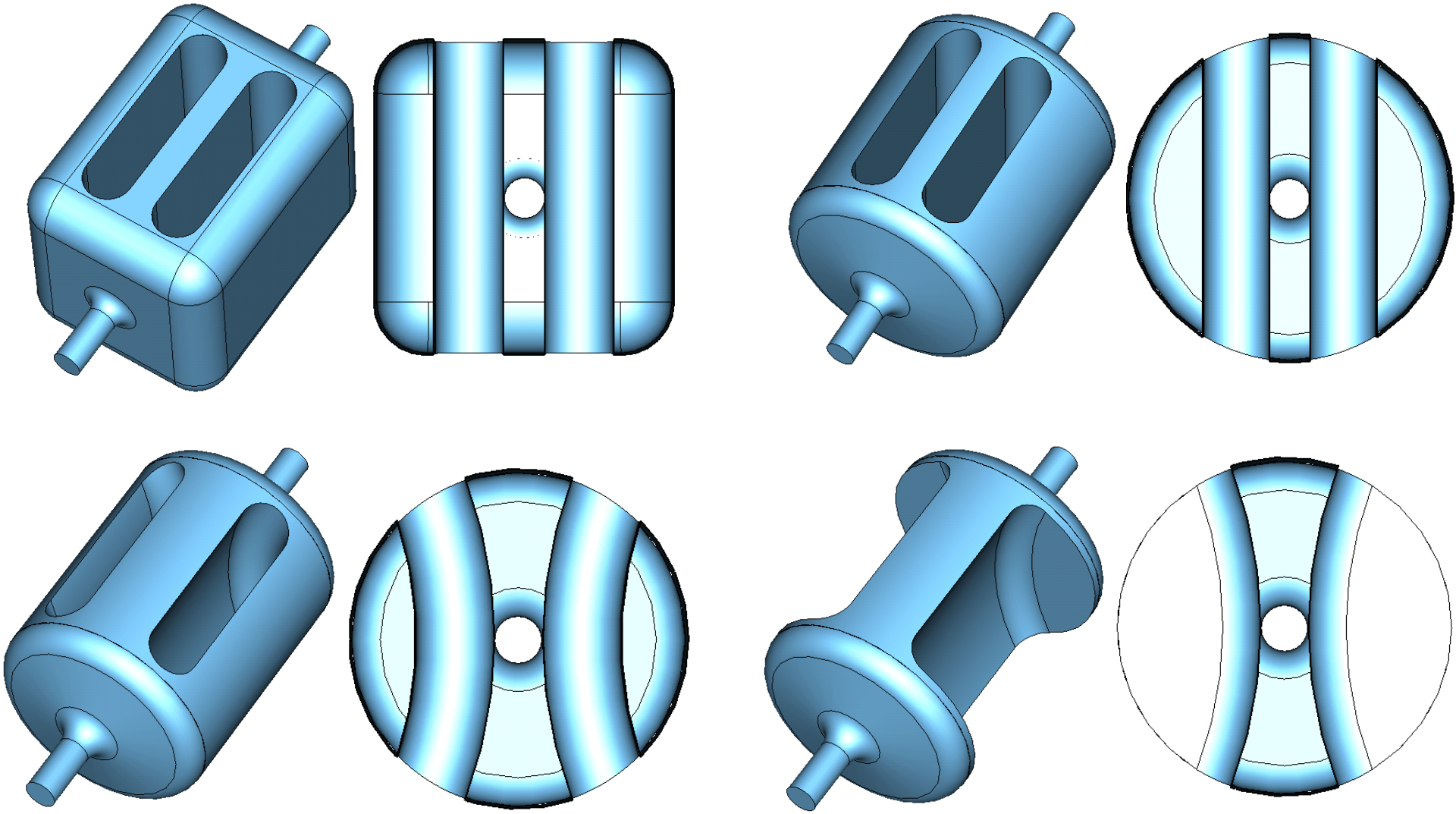


E field on mid plane
(Along the beam line)

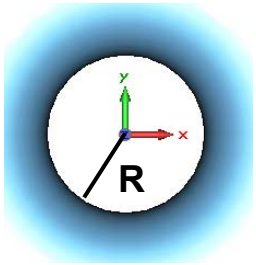


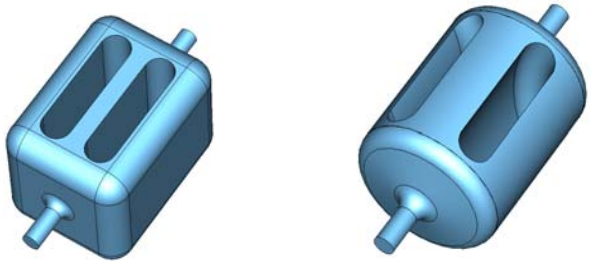
B field on top plane

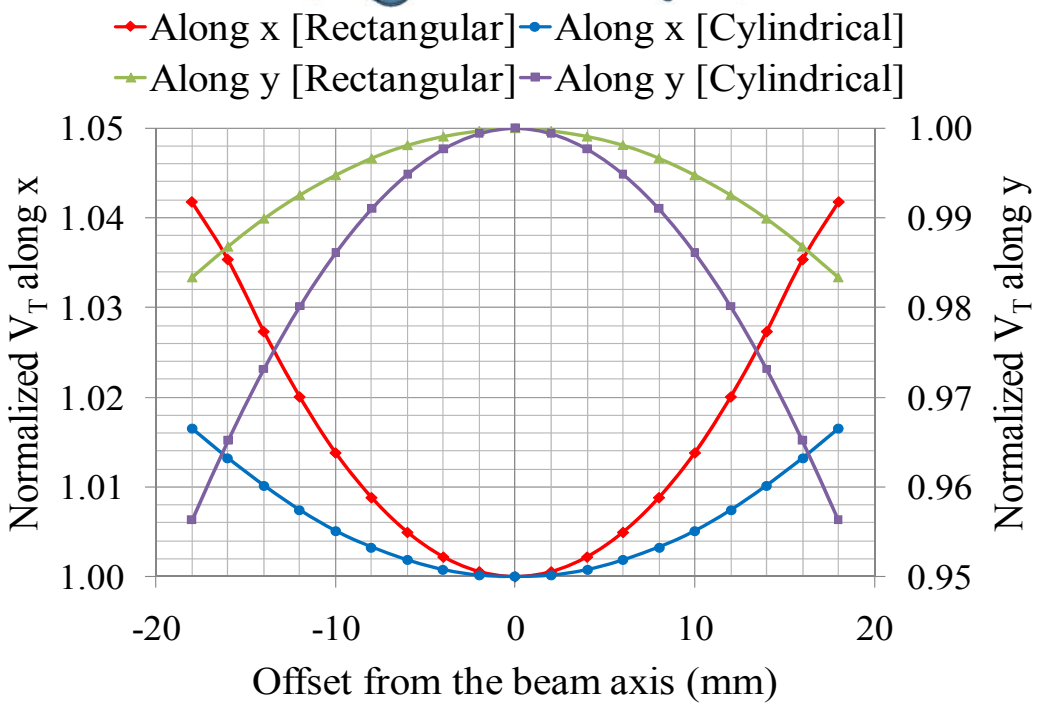
Evolution of Parallel-bar Designs



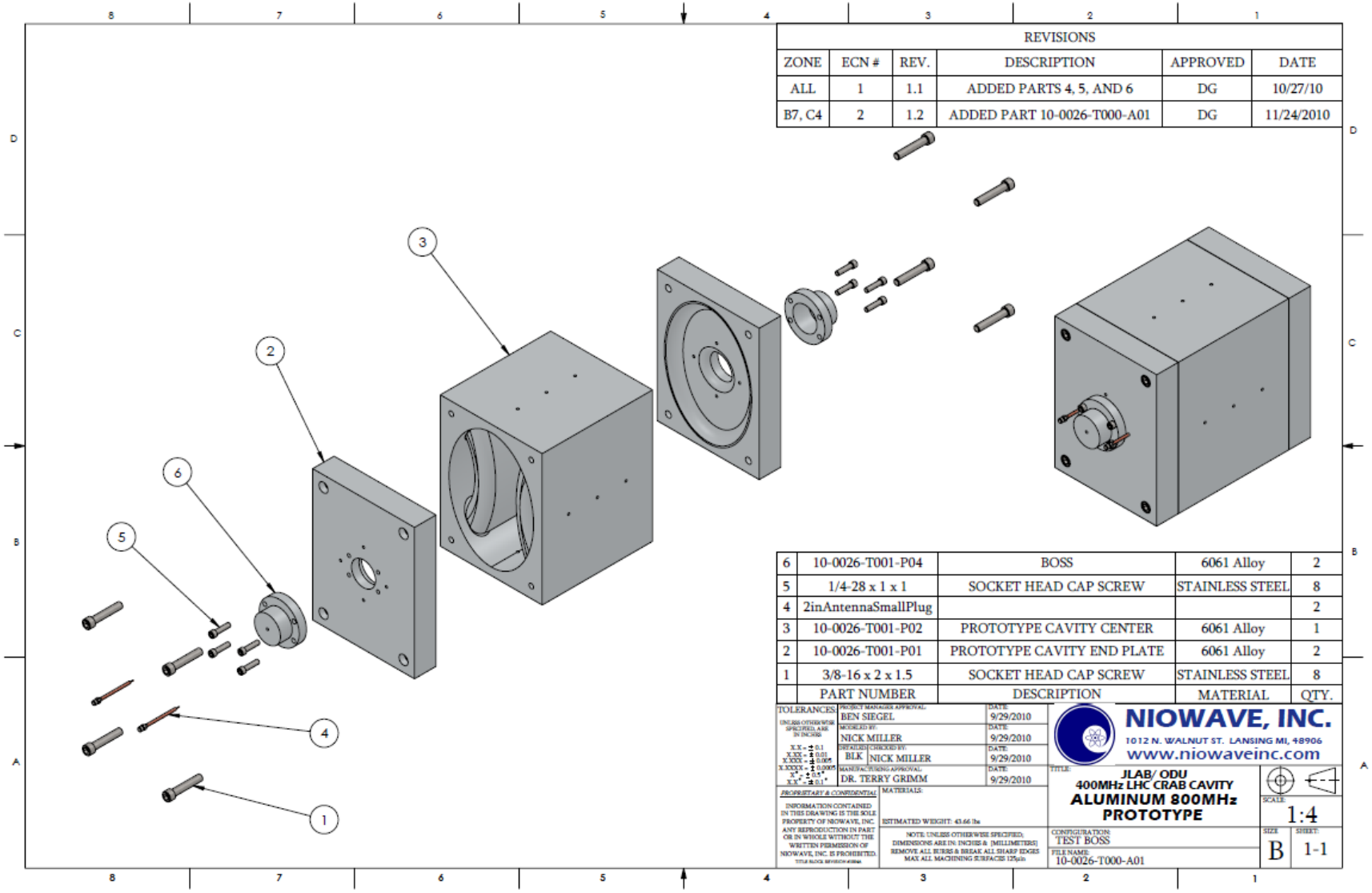
Off Axis Nonlinearities







400 MHz LHC Crab Cavity
800 MHz Aluminum model



REVISIONS					
ZONE	ECN #	REV.	DESCRIPTION	APPROVED	DATE
ALL	1	1.1	ADDED PARTS 4, 5, AND 6	DG	10/27/10
B7, C4	2	1.2	ADDED PART 10-0026-T000-A01	DG	11/24/2010

PART NUMBER	DESCRIPTION	MATERIAL	QTY.
6	10-0026-T001-P04	BOSS	6061 Alloy	2
5	1/4-28 x 1 x 1	SOCKET HEAD CAP SCREW	STAINLESS STEEL	8
4	2inAntennaSmallPlug			2
3	10-0026-T001-P02	PROTOTYPE CAVITY CENTER	6061 Alloy	1
2	10-0026-T001-P01	PROTOTYPE CAVITY END PLATE	6061 Alloy	2
1	3/8-16 x 2 x 1.5	SOCKET HEAD CAP SCREW	STAINLESS STEEL	8

TOLERANCES: UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES
X.X = ± 0.1
X.XX = ± 0.01
X.XXX = ± 0.005
X.XXXX = ± 0.0005
X° = ± 0.5°
X.X° = ± 0.1°

PROJECT MANAGER APPROVAL: BEN SIEGEL — DATE: 9/29/2010
MODELED BY: NICK MILLER — DATE: 9/29/2010
DETAILED BY: BLK — CHECKED BY: NICK MILLER — DATE: 9/29/2010
MANUFACTURING APPROVAL: DR. TERRY GRIMM — DATE: 9/29/2010

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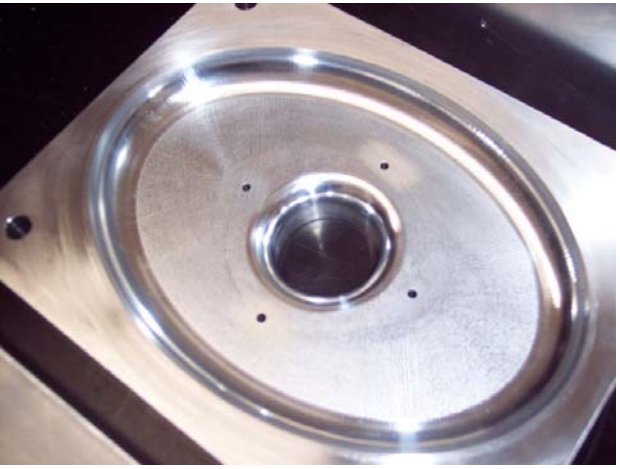
MATERIALS:
ESTIMATED WEIGHT: 43.66 lbs

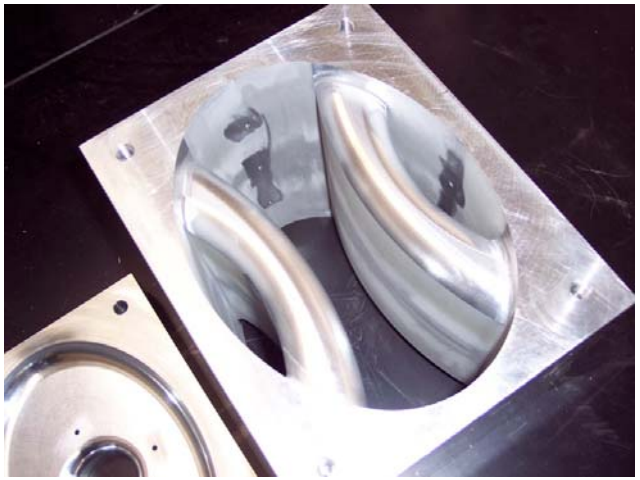
NOTE: UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES & [MILLIMETERS] REMOVE ALL BURRS & BREAK ALL SHARP EDGES MAX ALL MACHINING SURFACES 125µin

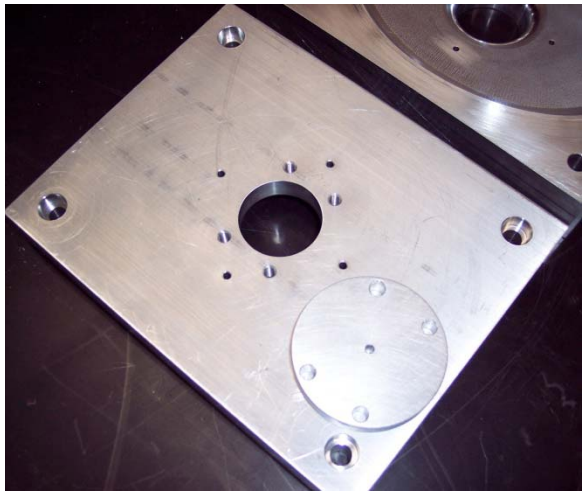
NIOWAVE, INC.
1012 N. WALNUT ST. LANSING MI, 48906
www.niowaveinc.com

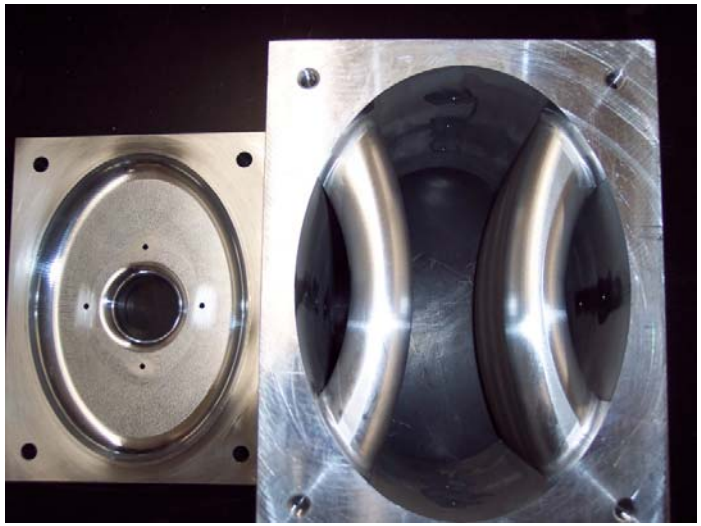
TITLE: JLAB/ ODU 400MHz LHC CRAB CAVITY ALUMINUM 800MHz PROTOTYPE
CONFIGURATION: TEST BOSS
FILE NAME: 10-0026-T000-A01
SCALE: 1:4
SIZE: B
SHEET: 1-1

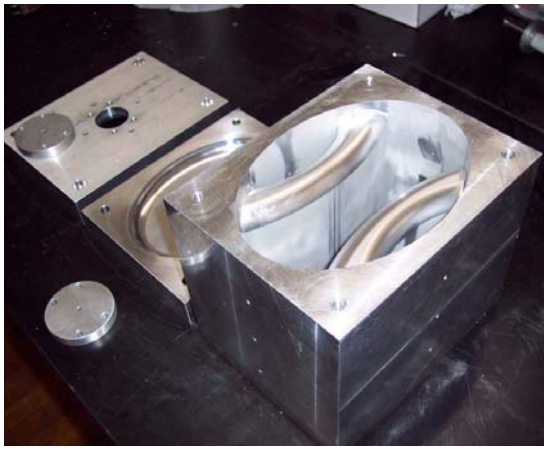
400 MHz LHC Crab Cavity
800 MHz Aluminum model



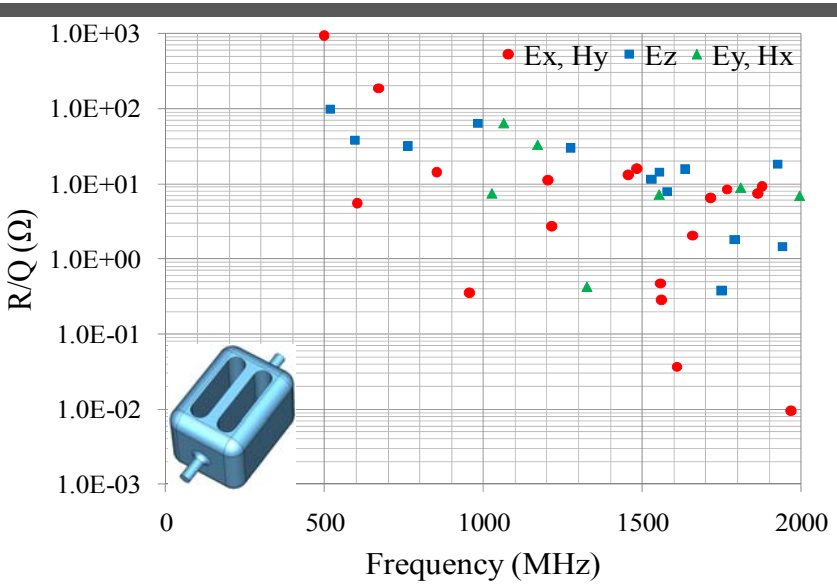


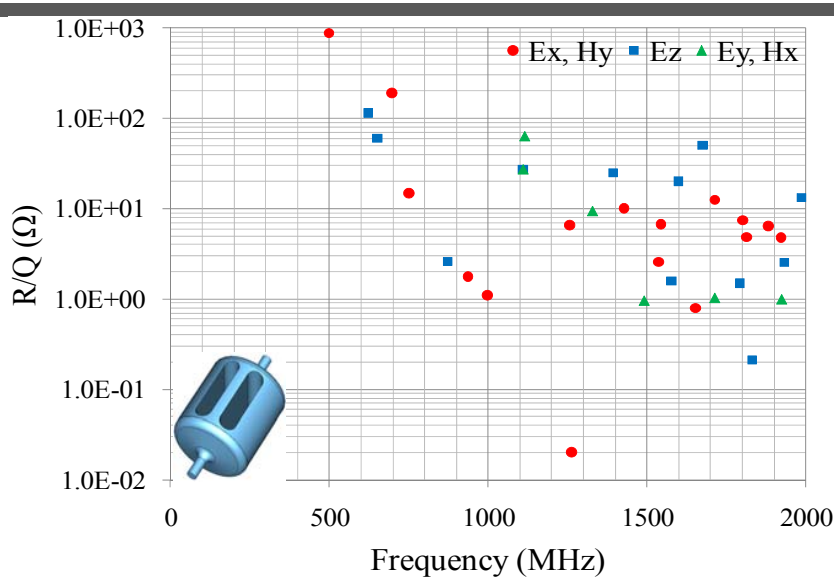


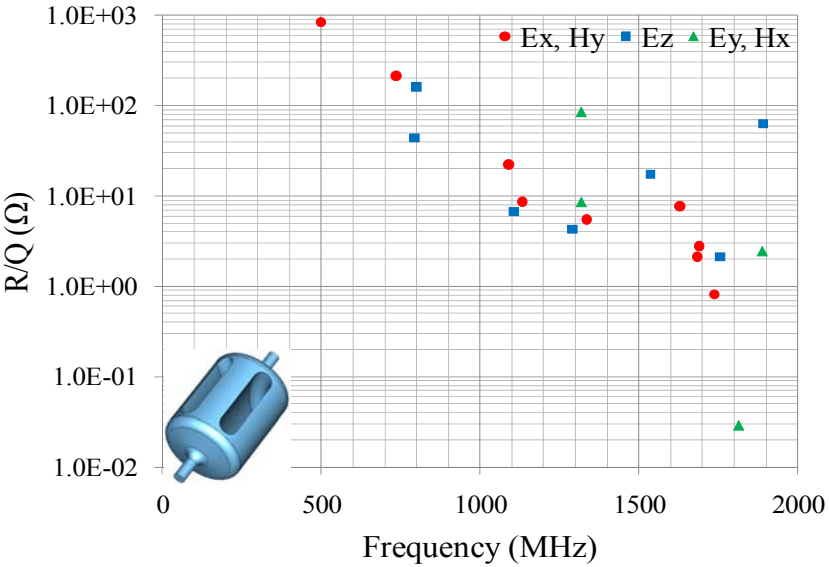


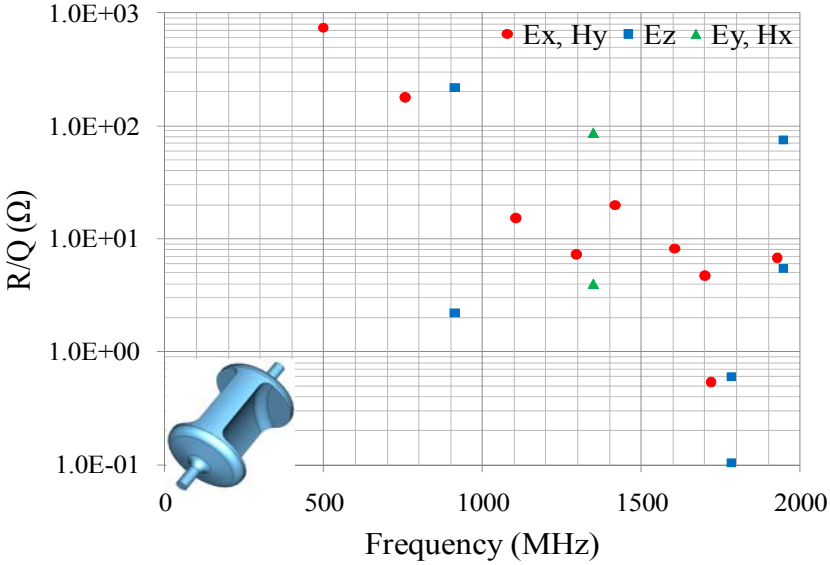


HOM Properties of Parallel-bar Designs

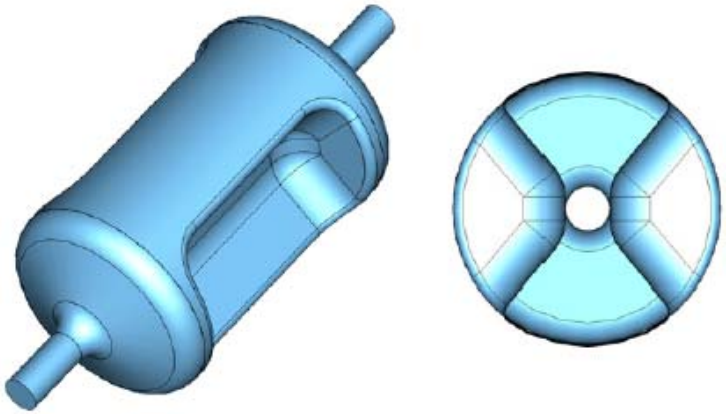




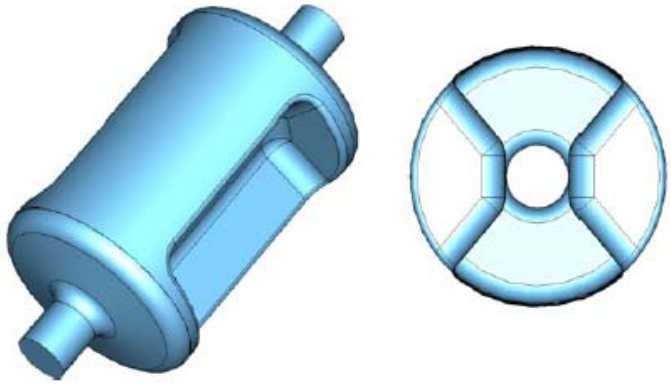




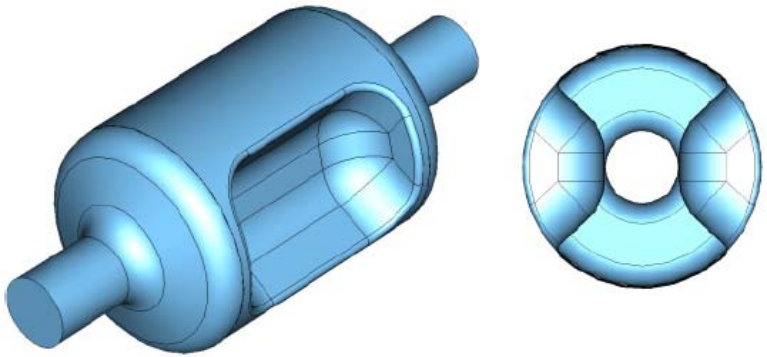
Parallel-Bar / Ridged Waveguide (ODU)



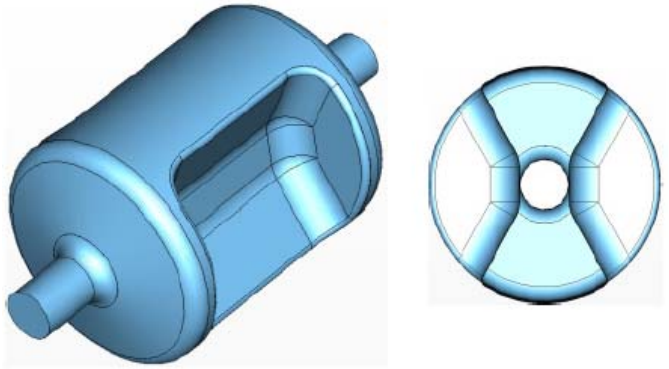
499 MHz JLab Upgrade Deflector
Fabrication under way



400 MHz LHC Crabbing System
Fabrication under way

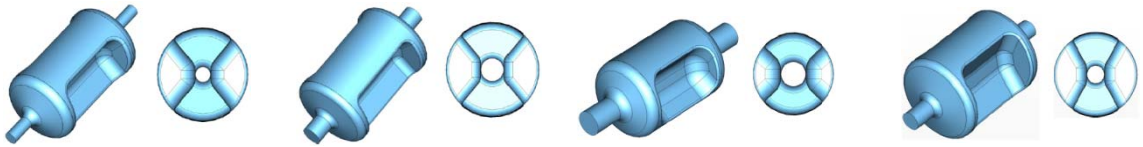


750 MHz ELIC Crabbing System
Final design underway



365 MHz Project X Deflector

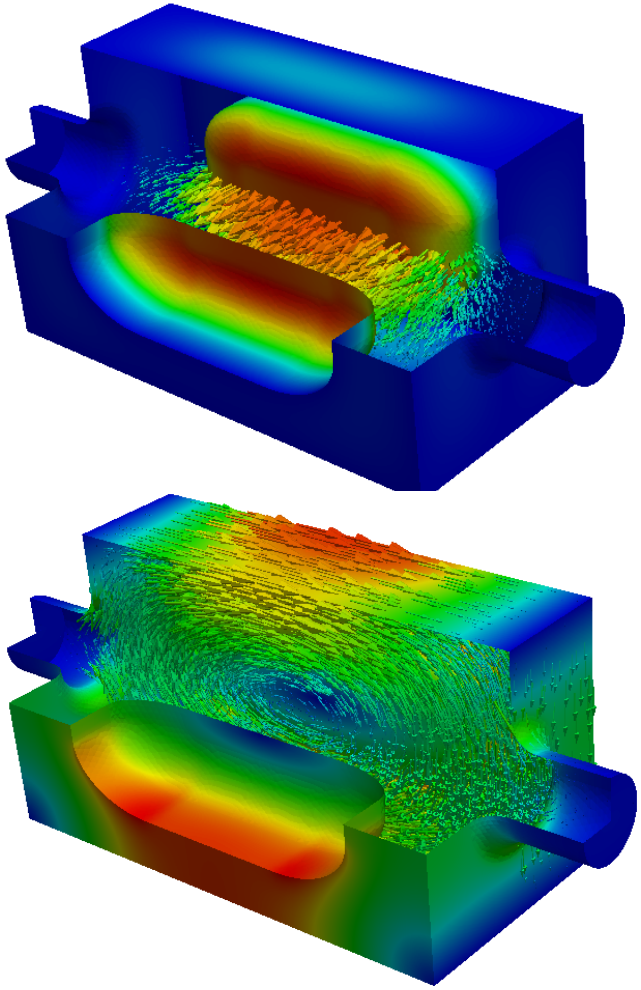
Parallel-Bar / Ridged Waveguide (ODU)



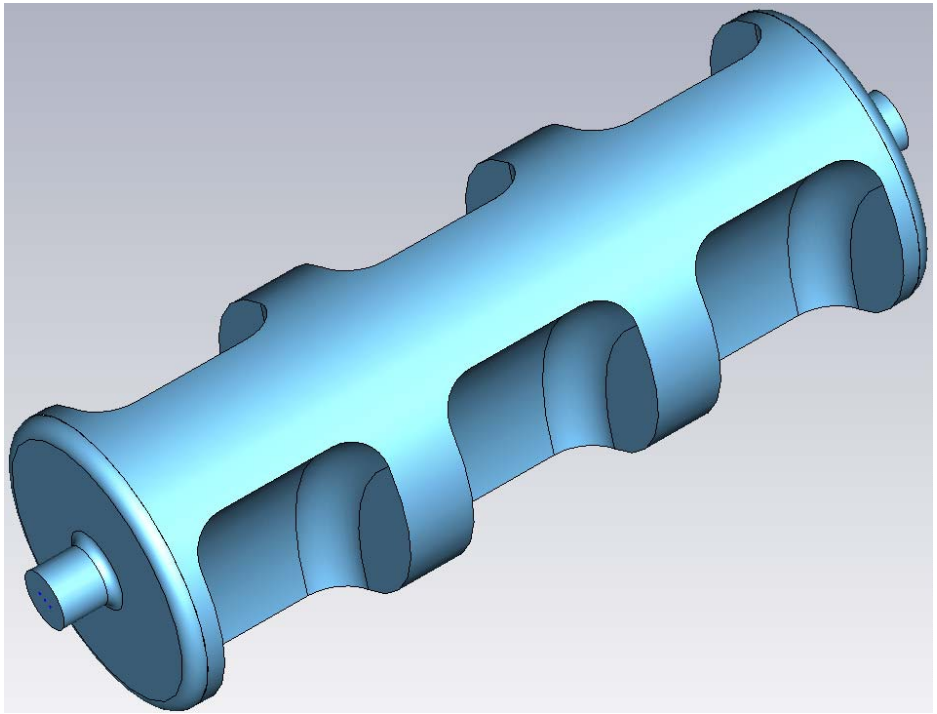
Parameter	499 MHz	400 MHz	750 MHz	365.6 MHz	Units
Frequency of π mode	499.0	400.0	750.0	365.625	MHz
λ/2 of π mode	300.4	375.0	199.9	410.0	mm
Frequency of 0 mode	1035.9	729.5	1314.4	659.7	MHz
Frequency of near neighbour mode	771.2	593.4	1143.1	571.9	MHz
Cavity length	440.0	520.0	300.0	530.0	mm
Cavity diameter	241.9	339.8	193.0	388.4	mm
Bars length	260.0	345.0	185.0	350.0	mm
Bars inner height	50.0	80.0	57.5	85.0	mm
Angle	50.0	50.0	36.2	55.0	deg
Aperture diameter	40.0	84.0	60.0	84.0	mm
Deflecting voltage (V_T^*)	0.3	0.375	0.2	0.41	MV
Peak electric field (E_P^*)	2.96	3.82	4.95	3.61	MV/m
Peak magnetic field (B_P^*)	4.49	7.09	8.74	6.41	mT
B_P^* / E_P^*	1.52	1.86	1.77	1.77	mT/(MV/m)
Energy content (U^*)	0.029	0.19	0.056	0.19	J
Geometrical factor	105.6	119.7	136.9	115.9	Ω
$[R/Q]_T$	982.2	312.2	152.9	378.5	Ω
$R_T R_S$	1.04×10^5	3.7×10^4	2.1×10^4	4.4×10^4	Ω^2

At $E_T^* = 1$ MV/m

Ridged Waveguide (SLAC and FNAL)

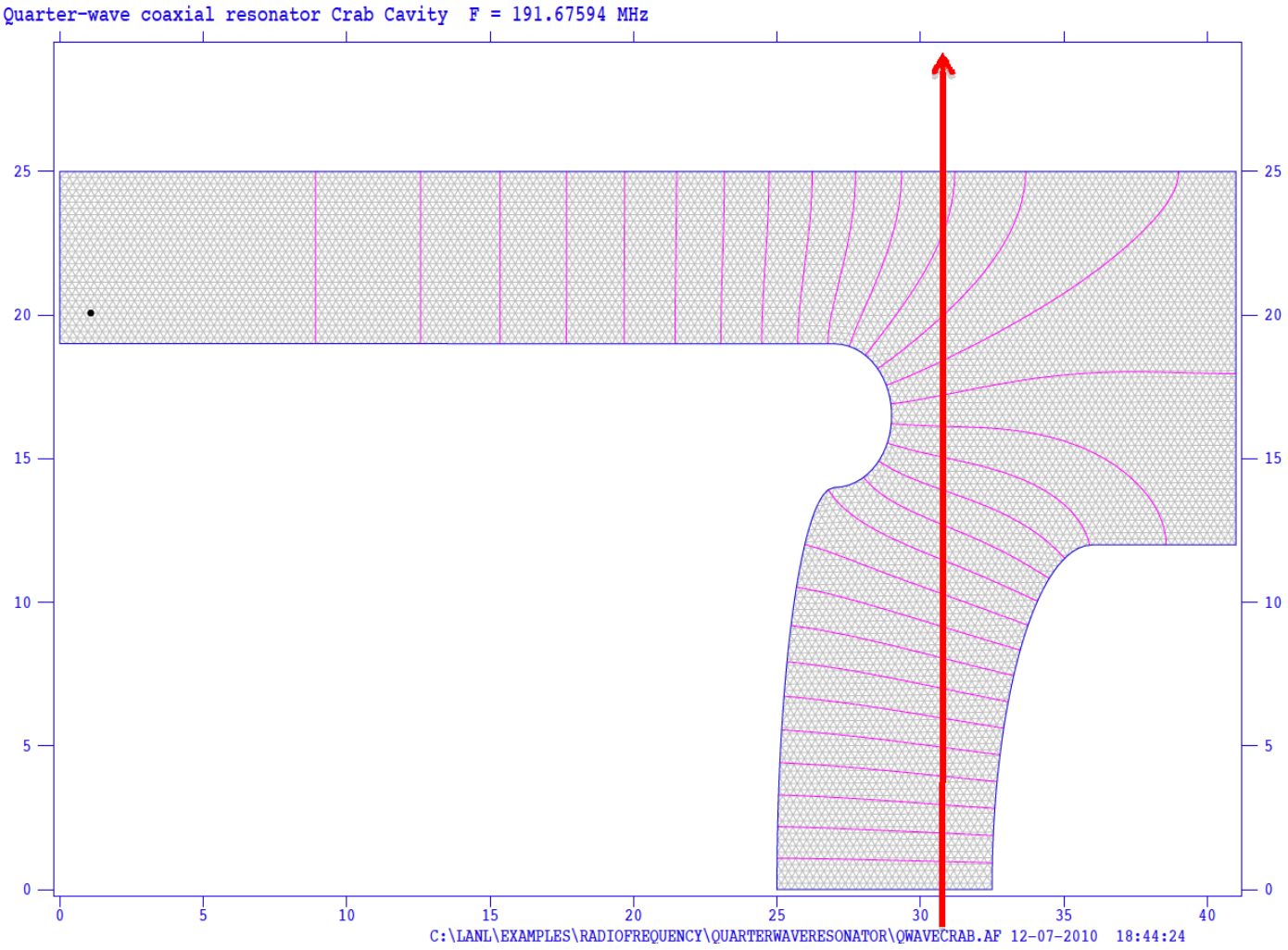


400 MHz LHC Crabbing System

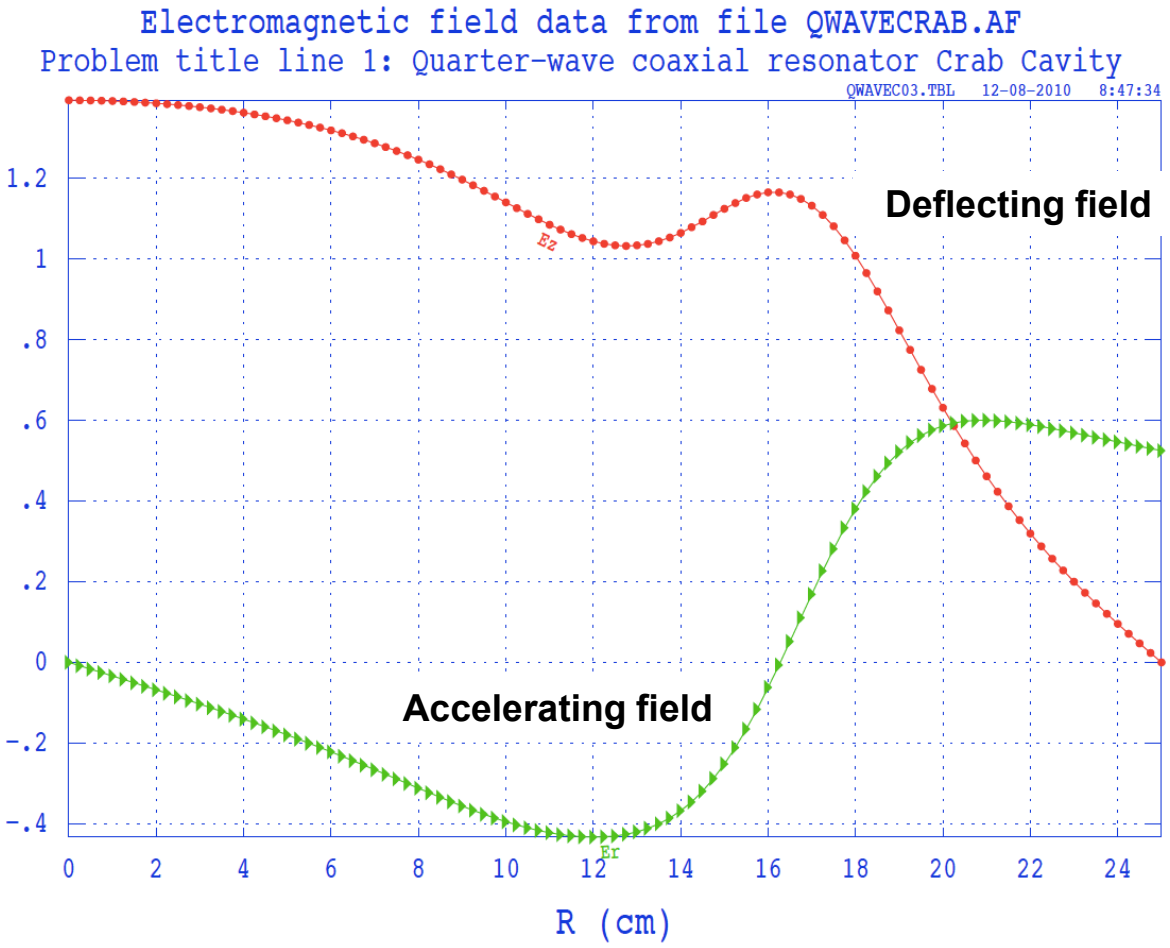


3-cell Project X Deflector

Quarter-wave (BNL)



Quarter-wave (BNL)



Quarter-wave (BNL)

Preliminary design for eRHIC

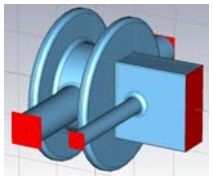
	Units	Parameter
Crab mode frequency	MHz	181
Nearest other mode frequency	MHz	251
Cavity length	cm	75.2
Cavity width	cm	38.1/25.1
Deflecting voltage*	MV	6.1
Peak surface electric field*	MV/m	39
Stored energy*	Joules	100
$R_t/Q\#$	Ohm	291
Accelerating voltage	MV	0

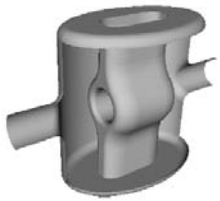
(*) for peak surface magnetic field of 100 mT.

$E_t = 2V_t/\lambda$

E_p/E_t	5.3
B_p/E_t mT/(MV/m)	13.6

Properties of 400 MHz Crabbing Cavities for LHC






	Reel	4-rod	Half-wave	Par-bar/ Ridged
E_p/E_t	10.9	4	3.9	3.8
B_p/E_t mT/(MV/m)	18.7	7.6	7.3	7.1

Aperture : 84 mm
$E_t = 2V_t/\lambda$ $V_t = 375$ kV at $E_t = 1$ MV/m

Parting Words

- New applications for deflecting and crabbing systems with strict dimensional requirements have required new cavity geometries
- The challenge has been met
- Prototyping and fabrication are under way
- Hopefully results will be presented at SRF 2013
- Thanks to colleagues at BNL, Fermilab, KEK, Lancaster U., Niowave Inc., SLAC

- THPO007 *Novel Deflecting Cavity Design for eRHIC*, Qiong Wu, Sergey Belomestnykh, Ilan Ben-Zvi
- MOPO053 *Designs of Superconducting Parallel-Bar Deflecting Cavities for Deflecting/Crabbing Applications* Jean Delayen, Subashini De Silva
- MOPO027 *Analysis of HOM Properties of Superconducting Parallel-Bar Deflecting/Crabbing Cavities* Subashini De Silva, Jean Roger Delayen
- MOPO043 *Mechanical Study of Superconducting Parallel-Bar Deflecting/Crabbing Cavities* HyeKyoung Park, Subashini De Silva, Jean Roger Delayen