DESIGN OF SUPERCONDUCTING PARALLEL-BAR CAVITIES FOR DEFLECTING/CRABBING APPLICATIONS*

J. R. Delayen#1,2 and S. U. De Silva[1,2]

[1] Center for Accelerator Science, Old Dominion University, Norfolk, VA 23529, U.S.A.

[2] Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, U.S.A.

ABSTRACT

The superconducting parallel-bar cavity is a deflecting/crabbing cavity with attractive properties, compared to other conventional designs, that is currently being considered for a number of applications. The new parallel-bar design with curved loading elements and circular or elliptical outer conductors have improved properties compared to the designs with rectangular outer conductors. We present the designs proposed as the deflecting cavities for the Jefferson Lab 12 GeV upgrade and for Project-X and crabbing cavities for the proposed LHC luminosity upgrade and electron-ion collider at Jefferson Lab.

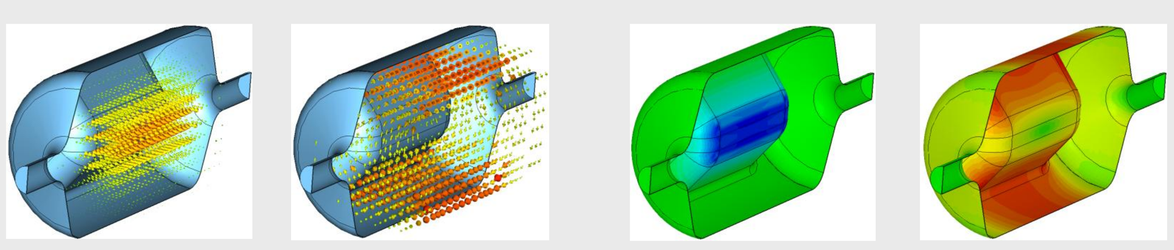
INTRODUCTION

The superconducting parallel-bar cavity [1] geometry with a cylindrical outer conductor and trapezoidal shaped bars is proven to have better properties compared a variety of geometries with rectangular, cylindrical and elliptical outer conductors and straight, curved bars [2, 3].

The geometry has

- lower and balanced surface fields
- higher shunt impedance
- wider mode separation in the HOM spectrum

Field Profile — *Surface Fields*



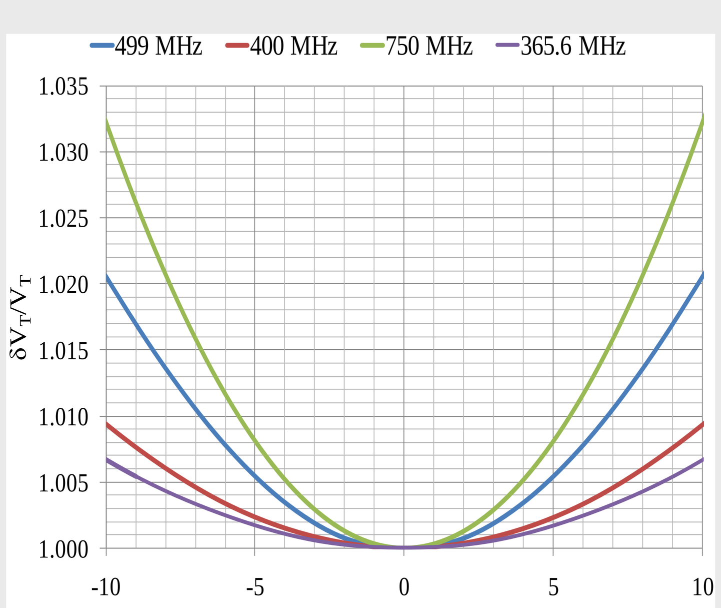
Electric Field — Magnetic Field — Surface Electric Field — Surface Magnetic Field

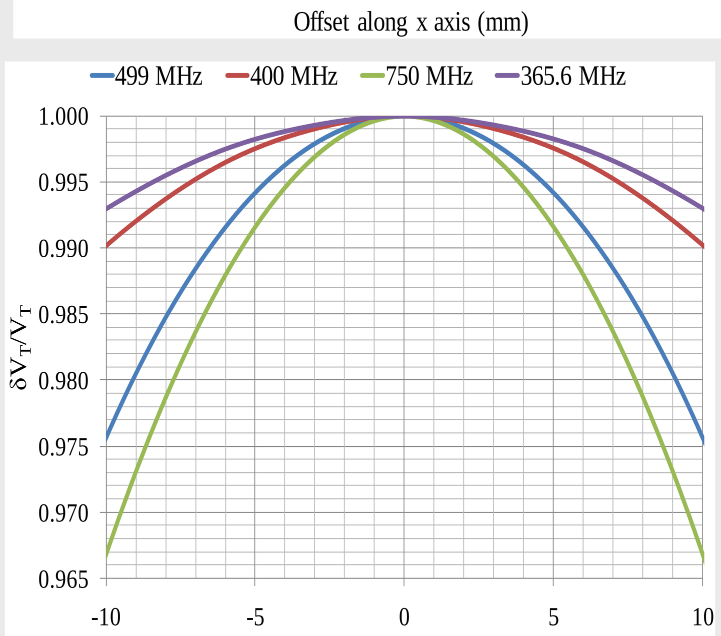
Applications of the Parallel-Bar Cavity

- 499 MHz deflecting cavity for the Jefferson Lab 12 GeV upgrade
- 400 MHz crabbing cavity for the proposed LHC luminosity upgrade
- 750 MHz crabbing cavity for medium energy electron ion collider (MEIC) at Jefferson Lab
- 365.625 MHz deflecting cavity for Project-X

ANALYSIS OF FIELD NON-LINEARITY

- Change in the transverse voltage across the beam aperture is determined in horizontal (along x axis) and vertical (along y axis) directions
- If needed, the non-linearity can be reduced by increasing the inner bar height and/or by giving it a curvature

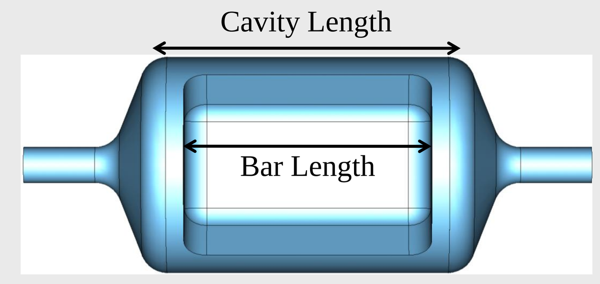




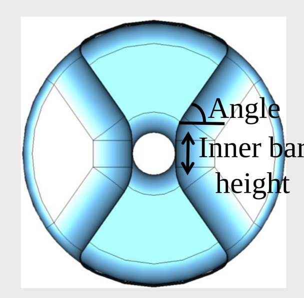
DESIGN OPTIMIZATION AND PROPERTIES FOR EACH APPLICATION

Design Optimization

- Cavity length and bar length is optimized to lower peak surface electric (E_P) and magnetic (B_P) fields



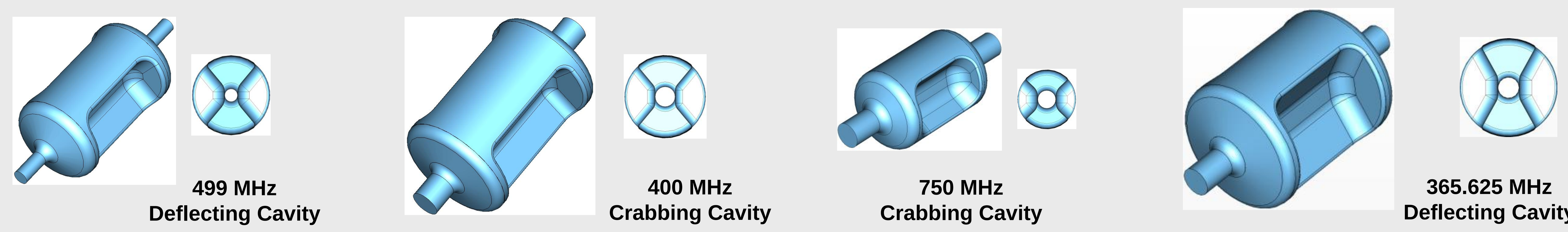
- Shape of the bar is optimized for lower and balanced surface fields by changing the inner bar height and angle



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

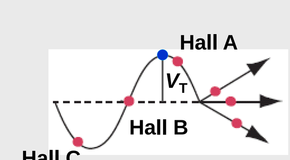
CAVITY DESIGNS FOR EACH APPLICATION



499 MHz Deflecting Cavity — **400 MHz Crabbing Cavity** — **750 MHz Crabbing Cavity** — **365.625 MHz Deflecting Cavity**

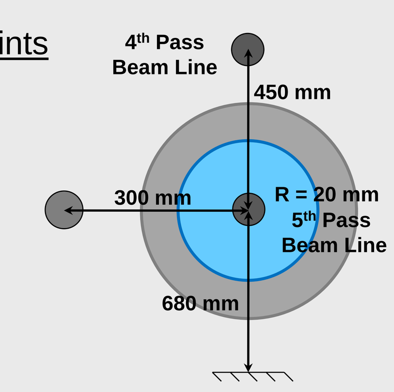
499 MHz DELFECTING CAVITY

- Is required to separate the 11.025 GeV beam in to 3 beams



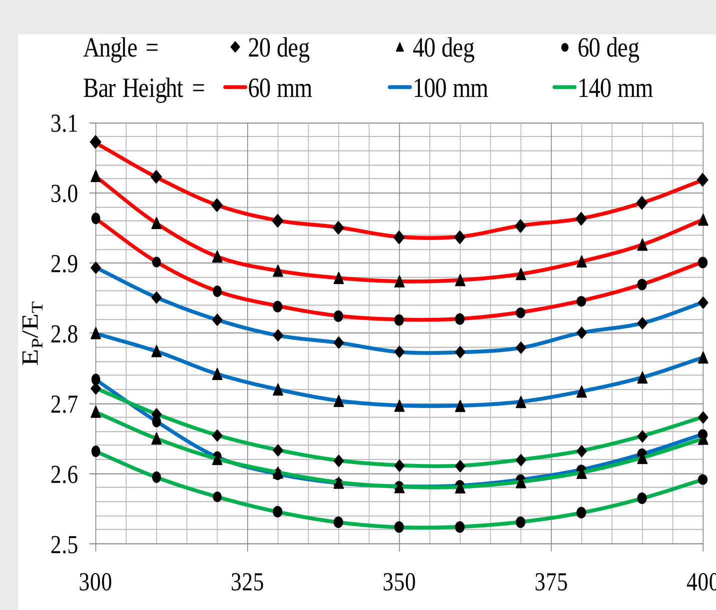
- Required peak transverse voltage = 5.6 MV

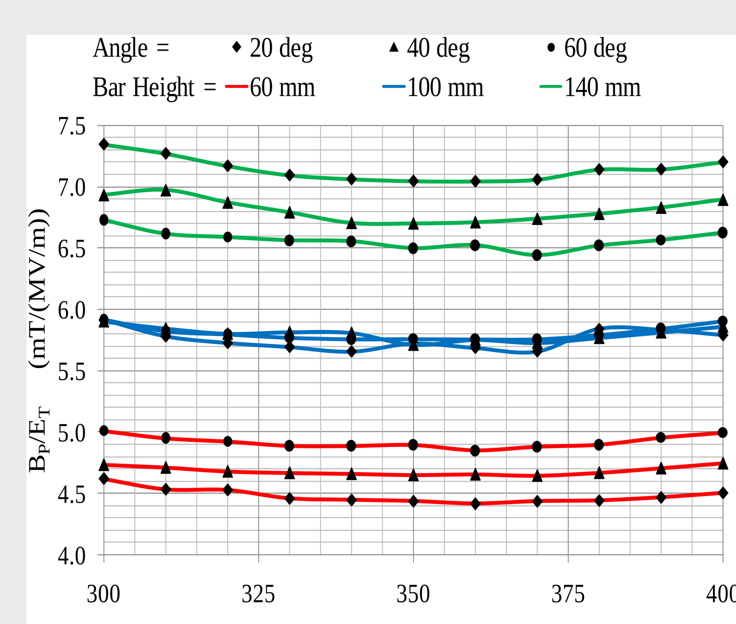
Dimensional Constraints

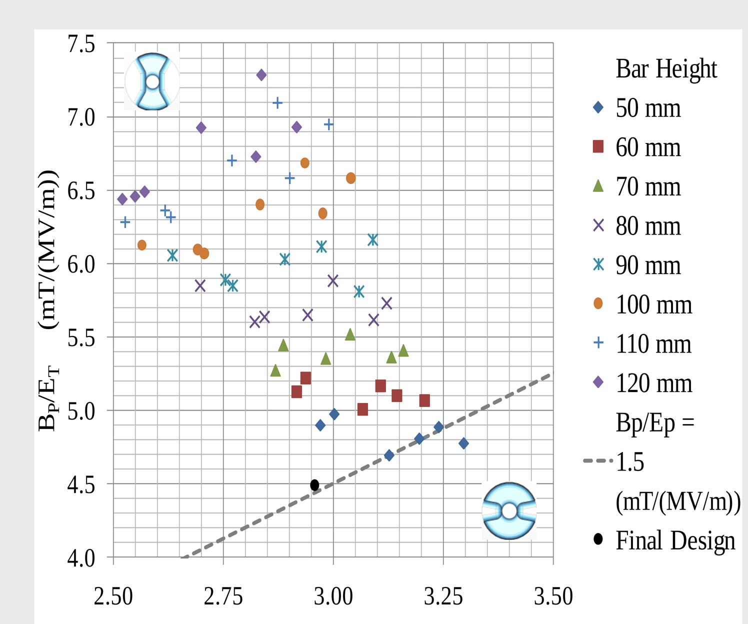


- Shape of the bar is optimized to achieve a field balancing ratio of B_P/E_P=1.5 mT/(MV/m)

E_P/E_T	B_P/E_T (mT/(MV/m))	E_P at V_T=3 MV	B_P at V_T=3MV
2.96	4.49	30 MV/m	45 mT



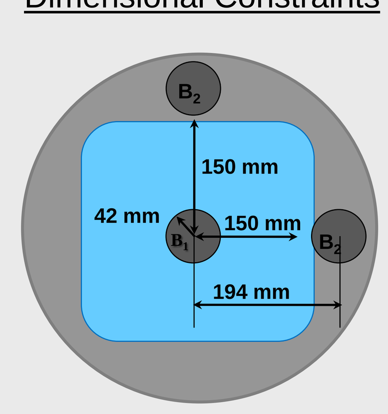


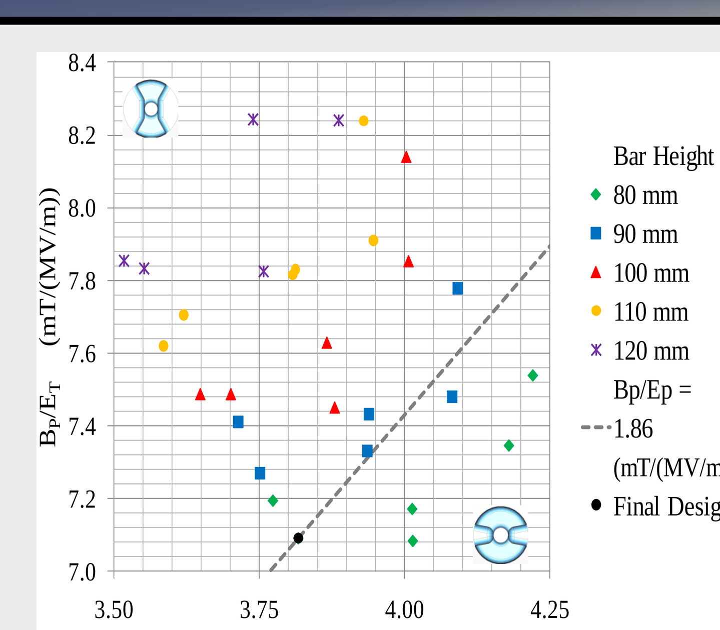


400 MHz CRABBING CAVITY

- Required peak transverse voltage = 10 MV
- Shape of the bar is optimized to achieve a field balancing ratio of B_P/E_P=1.86 mT/(MV/m)

Dimensional Constraints





E_P/E_T	B_P/E_T (mT/(MV/m))	E_P at V_T=3 .4MV	B_P at V_T=3 .4MV
3.82	7.09	34.6 MV/m	64.3 mT

750 MHz CRABBING CAVITY

- Is required for head on collision of the 60 GeV proton beam and the 12 GeV electron beam
- Design is very compact and has higher surface fields

365.625 MHz DEFLECTING CAVITY

- Is required to separate the 3 GeV proton beam into 3 beams
- Required peak transverse voltage = 10 MV
- Shape of the bar is optimized to achieve a field balancing ratio of B_P/E_P=1.77 mT/(MV/m)

E_P/E_T	B_P/E_T (mT/(MV/m))	E_P at V_T=3 .4MV	B_P at V_T=3.4MV
3.61	6.41	30.0 MV/m	53.2 mT

CONCLUSION

The parallel-bar geometry with the cylindrical outer conductor and trapezoidal shaped bars has proven to have improved properties compared to other parallel-bar geometries, therefore have been considered for a number of deflecting/crabbing cavity applications. This geometry is capable of delivering lower and well balanced peak surface fields with higher shunt impedance. Another attractive feature is the fact that this geometry has no lower-order mode and the nearest higher-order mode is far removed from the fundamental mode [3]. The shape of the bars connecting to the outer conductor with sloped end plates adds rigidity to the design in terms of mechanical deformations [4].
The parallel-bar geometry for the applications of the 499MHz and 365.625 MHz deflecting cavities and 400 MHz crabbing cavities have shown very attractive properties in meeting the requirements.
The 499 MHz deflecting and 400 MHz crabbing cavities are in the stage of prototype fabrication [4].

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#delayen@jlab.org

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