RF DIPOLE DESIGN UPDATE

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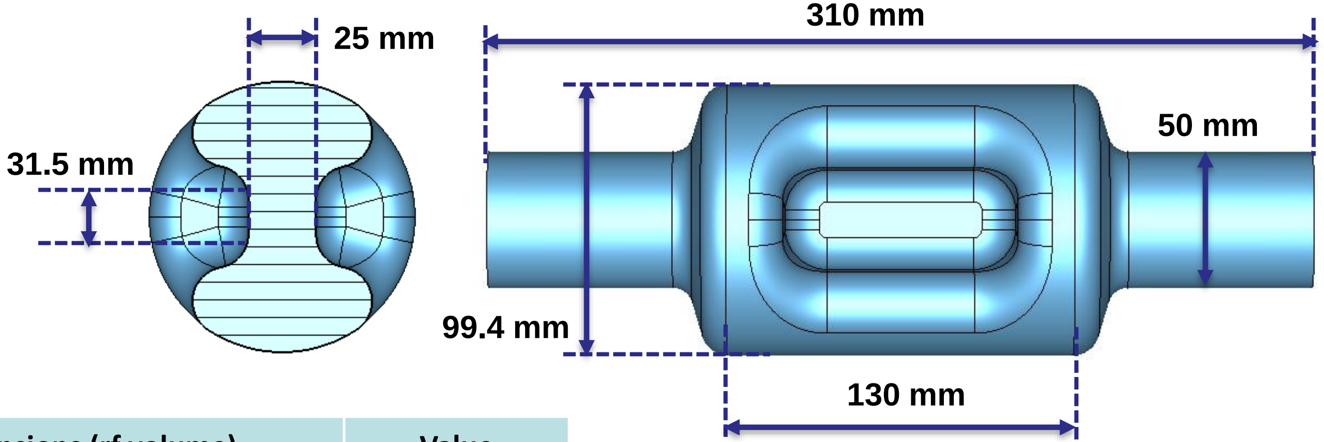
Outline

- RF Design
- Updated HOM Damping
- Stress Analysis
- Cavity Components for Fabrication
- Cavity Fabrication Sequence
- Material Dimensions
- Next Steps

1.3 GHz RFD Cavity Design

- Pole separation = 25 mm and beam aperture = 50 mm
- Optimized the pole shape (pole height and length):
  - To achieve peak surface field requirements of E_p < 45 MV/m and B_p < 80 mT

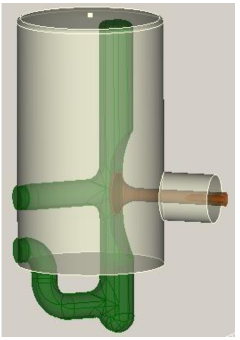


Cavity Dimensions (rf volume)	Value
Pole separation [mm]	25
Beam aperture [mm]	50
Cavity Length [mm] (flange-to-flange)	310
Cavity Diameter [mm]	99.4
Pole Length [mm]	85
Pole Height [mm]	31.5
Angle [deg]	22.5

	250 GeV	1 TeV
Max V_t per cavity [MV]	1.36	1.36
Total V_t [MV]	1.845	7.4
Number of cavities	2	6
V_t per cavity [MV]	0.9225	1.234
$V_{t,max} / V_{t,operational}$	1.47	1.10

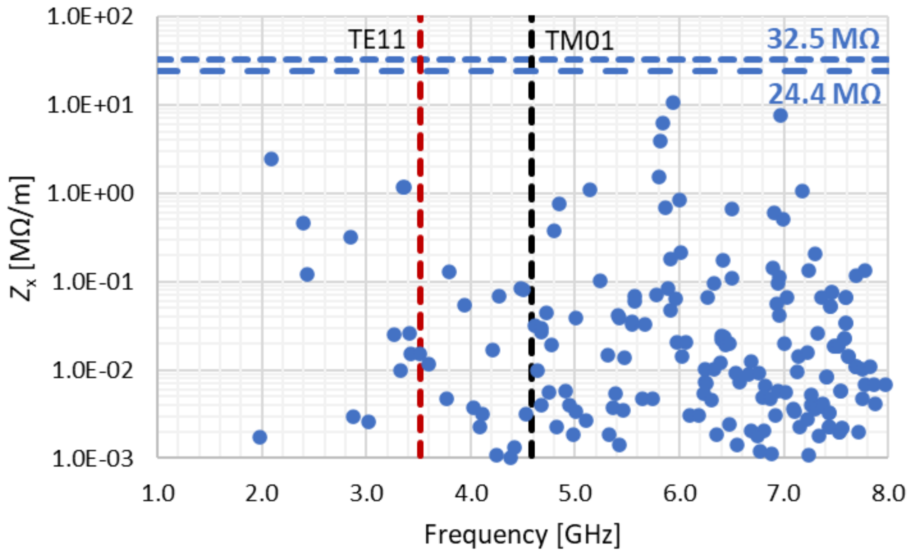
Property	Value
Operating frequency [GHz]	1.3
1st HOM [GHz]	2.089
E_p/E_t^*	3.81
B_p/E_t^* [mT/(MV/m)]	6.78
B_p/E_p [mT/(MV/m)]	1.78
G [Ω]	129.88
R/Q [Ω] (V^2/P)	439.51
R_tR_s [Ω²] (V^2/P)	5.71×10^4
*Reference length $V/E_t = \lambda/2$ [mm]	115.3
V_t max per cavity [MV]	1.36
E_p [MV/m]	44.94
B_p [mT]	79.96
V_t per cavity [MV] (@ 125 GeV)	0.9225
Stored energy (U) [J]	0.237
P_{diss} [W] (for R_s = 30 nΩ)	0.45
Q_0 (for R_s = 30 nΩ)	4.33×10^9

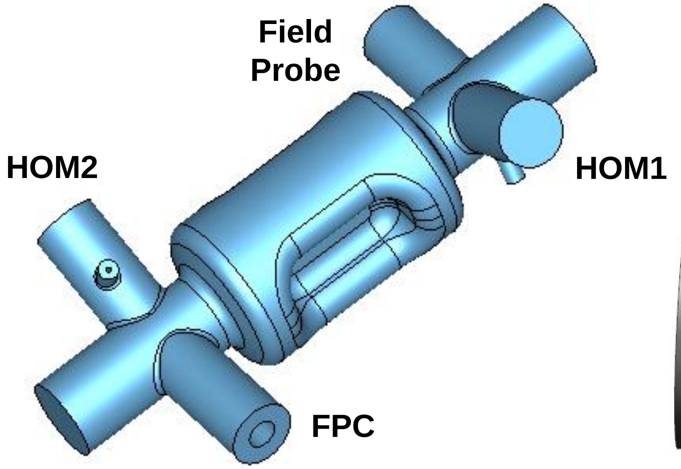
Updated Higher Order Mode Damping

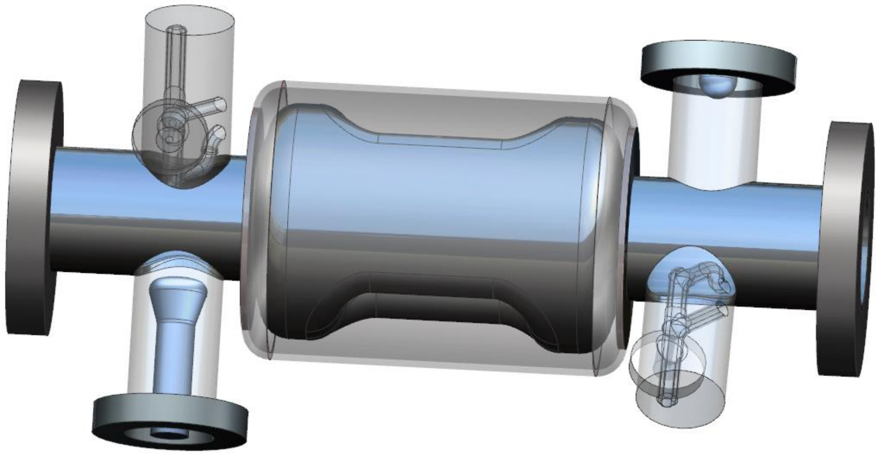


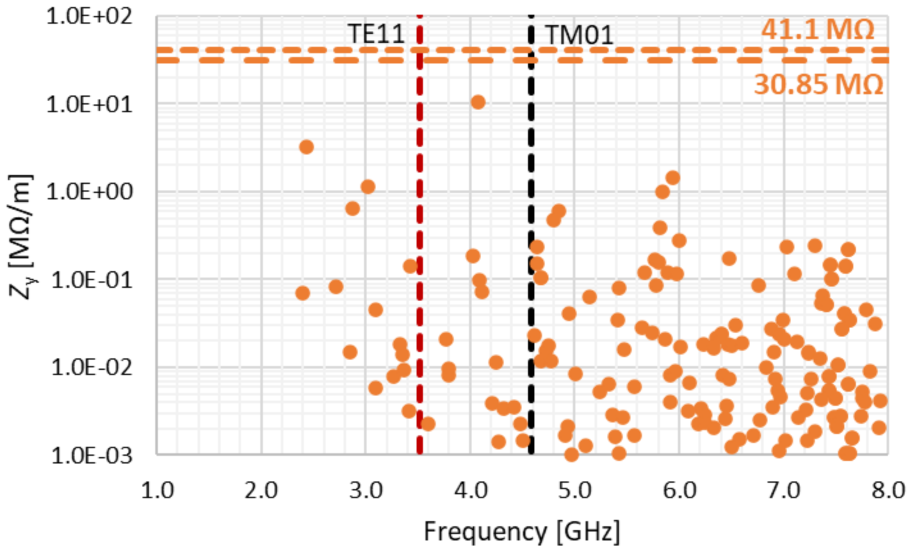
TESLA type HOM coupler

- Total impedance threshold:
  - For 125 GeV → Z_x = 48.8 MΩ/m and Z_y = 61.7 MΩ/m
  - For 500 GeV → Z_x = 195.2 MΩ/m and Z_y = 246.8 MΩ/m
- Damping achieved with two TESLA style HOM couplers placed on each of the beam pipes
  - No interference with He jacket





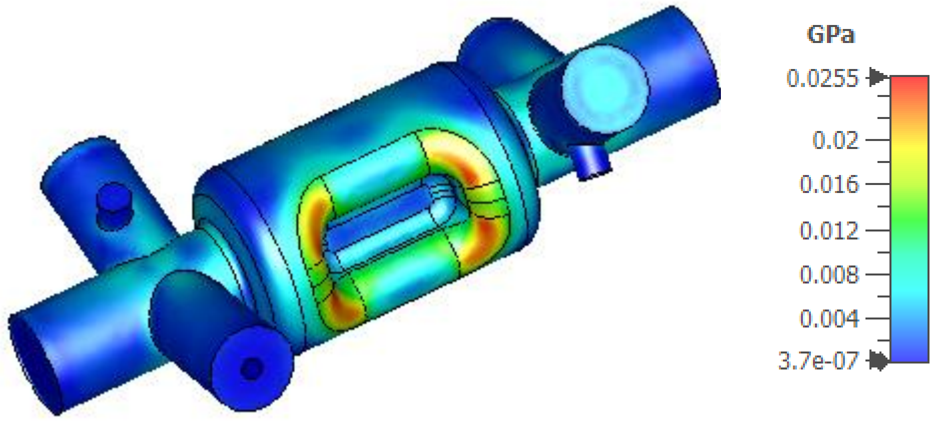


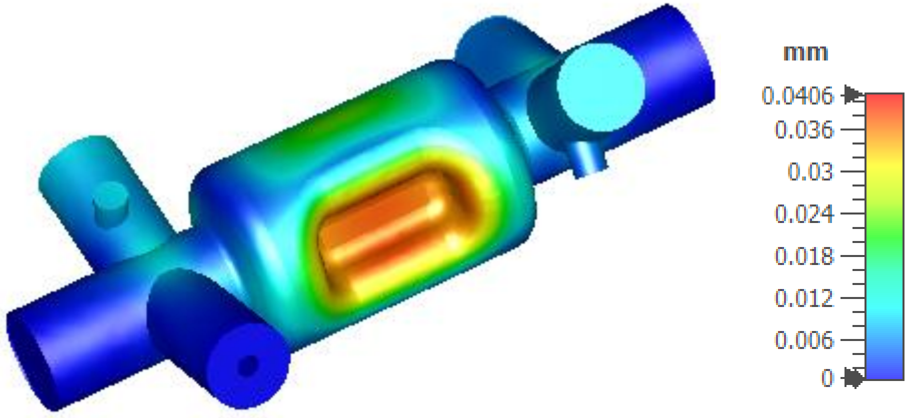


Stress Analysis

- Fine Grain Nb material properties at room temperature
  - (JLAB-TN-09-002 – C100 Cryomodule Niobium Cavity Structural Analysis)
  - Young's modulus – 82.7 GPa (1.2×10^7 psi)
  - Poisson's ratio – 0.38
- Allowable stress < 43.5 MPa (For FG)
- Cavity thickness – 3 mm
- Boundary conditions – Cavity constrained at beam pipes and FPC

- Maximum stress is 25.5 MPa
  - Doesn't require stiffening

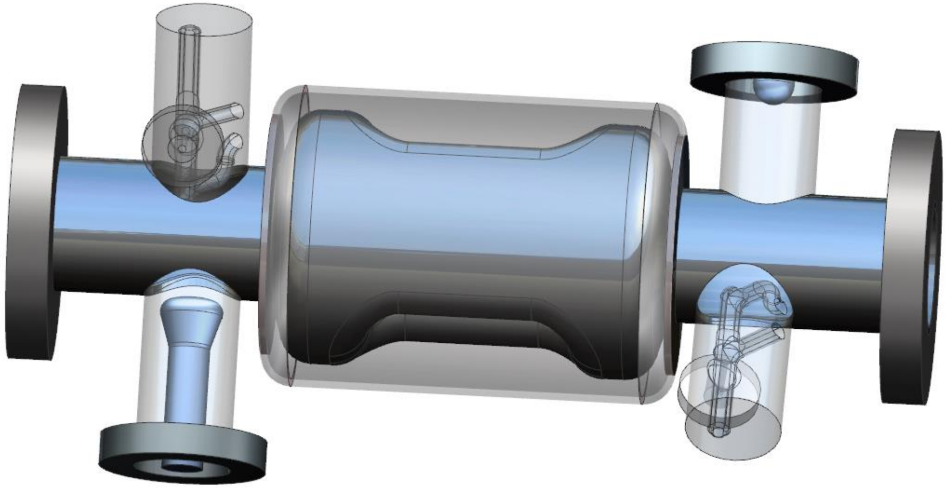




Cavity Components of 1.3 GHz RFD Cavity

- Goal – To fabricate and test a cavity prototype including couplers (FPC, FP with test antennas and HOMs)

- Cavity body thickness - 3mm
- Thickness of beam pipes, HOM cans – 3 mm
- HOM hooks and probes – Nb
- FPC and FP probes – Cu
- Cavity flanges – SS 316LN with Cu gaskets



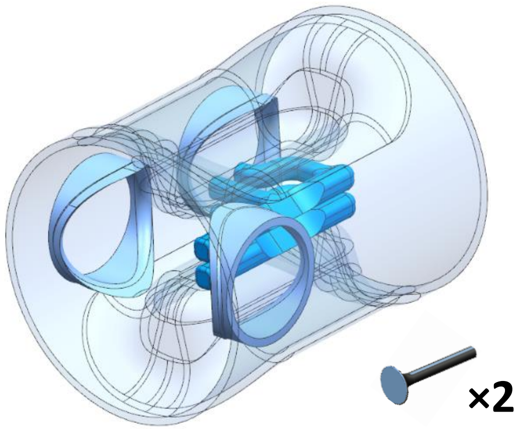
- Machined center body and end caps
- Ports fabricated by rolling Nb sheets (or from tubes)
  - Flanges brazed to Nb ports

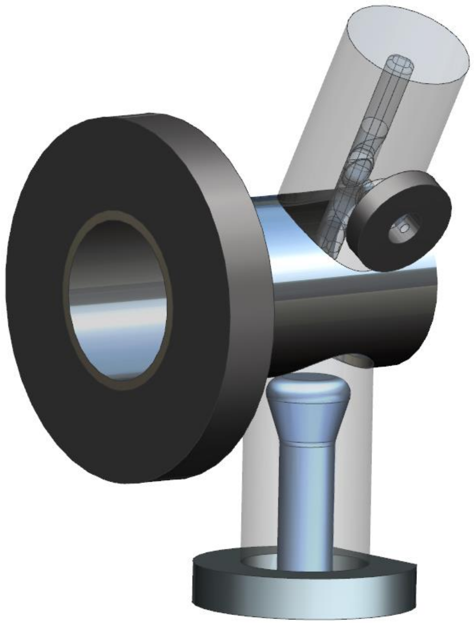
Fabrication Sequence – Beam Pipe Assemblies

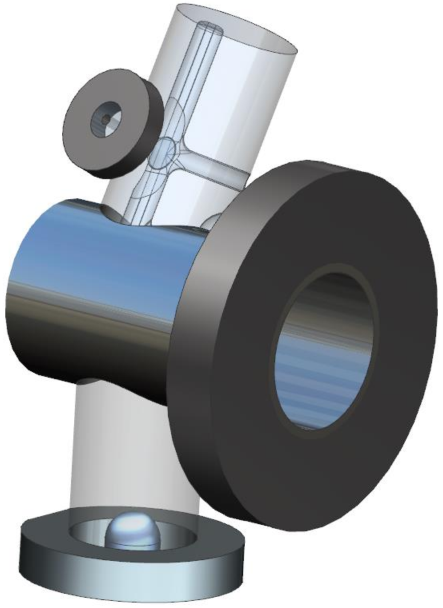
1. Form tubes for FPC, FP and 2 HOM couplers
2. Machine HOM hooks and probes from remaining material from center body
3. Machine transition piece from remaining material from center body
4. Weld HOM hooks to tubes

5. Weld transition pieces to beam tube
6. Weld HOM couplers, FPC and FP ports to beam tube

7. Braze HOM coupler flange, FPC and FP flanges
8. Braze beam tube flanges

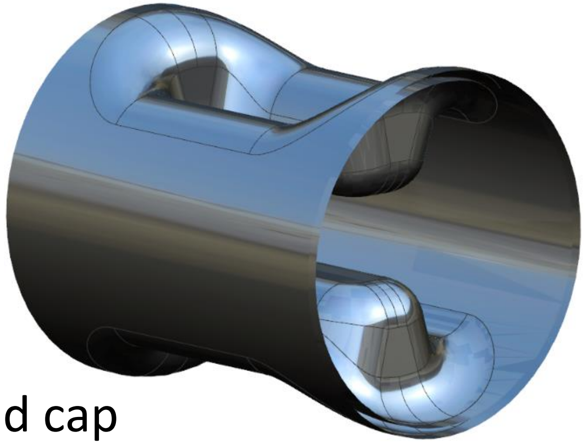


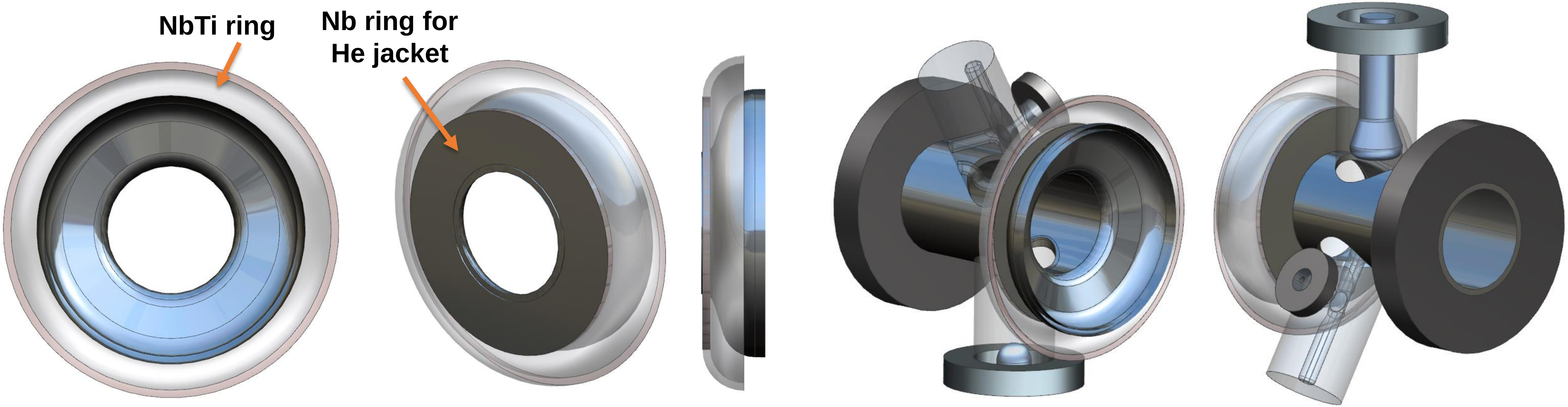




Fabrication Sequence – Center Body and End Cap

1. Machine center body
   - No tuner adapter in the prototype cavity
2. Machine end caps including He jacket transition rings
3. Form NbTi rings for He jacket
4. Weld NbTi ring to end caps
5. Weld beam tube assemblies to end caps – full penetration weld from inside the end cap

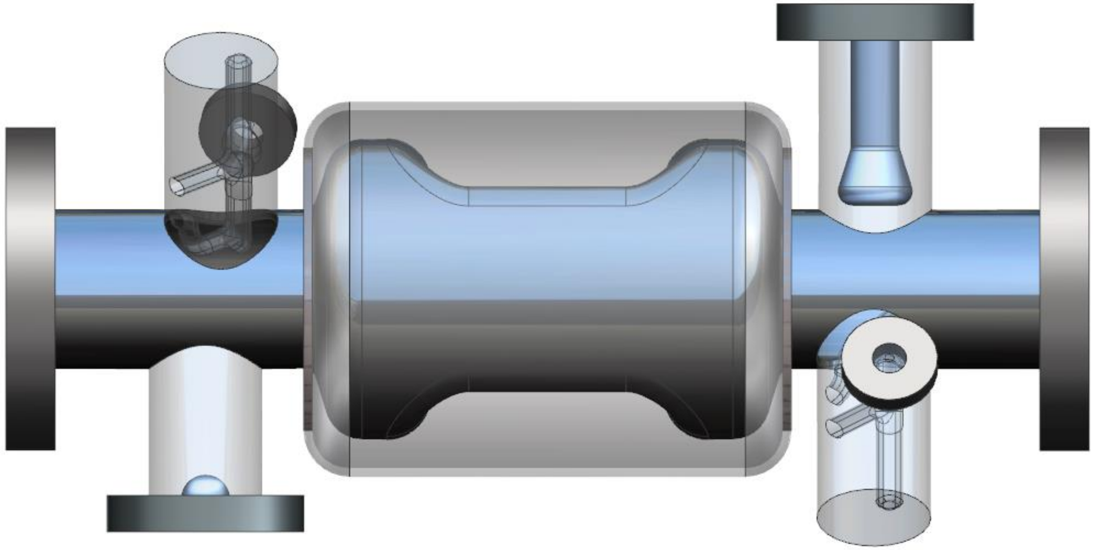




Fabrication Sequence – Cavity

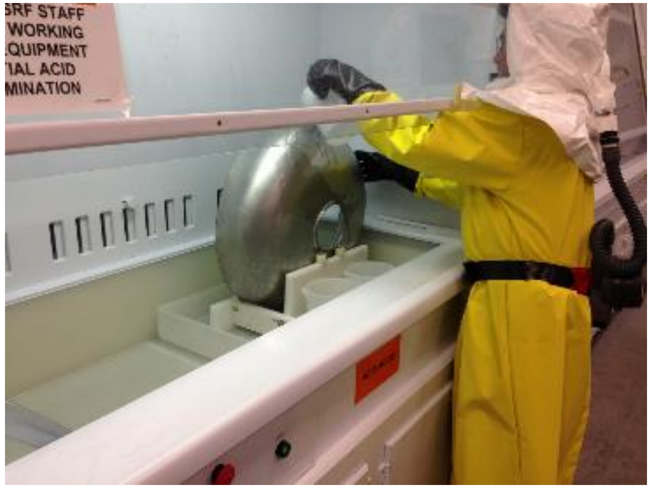
1. Weld cavity center body to end cap assemblies
    - Clearance on NbTi rings to EBW the center body to end caps

2. TIG weld Ti He jacket
    - Ti He jacket will be welded in two halves



Cavity Processing

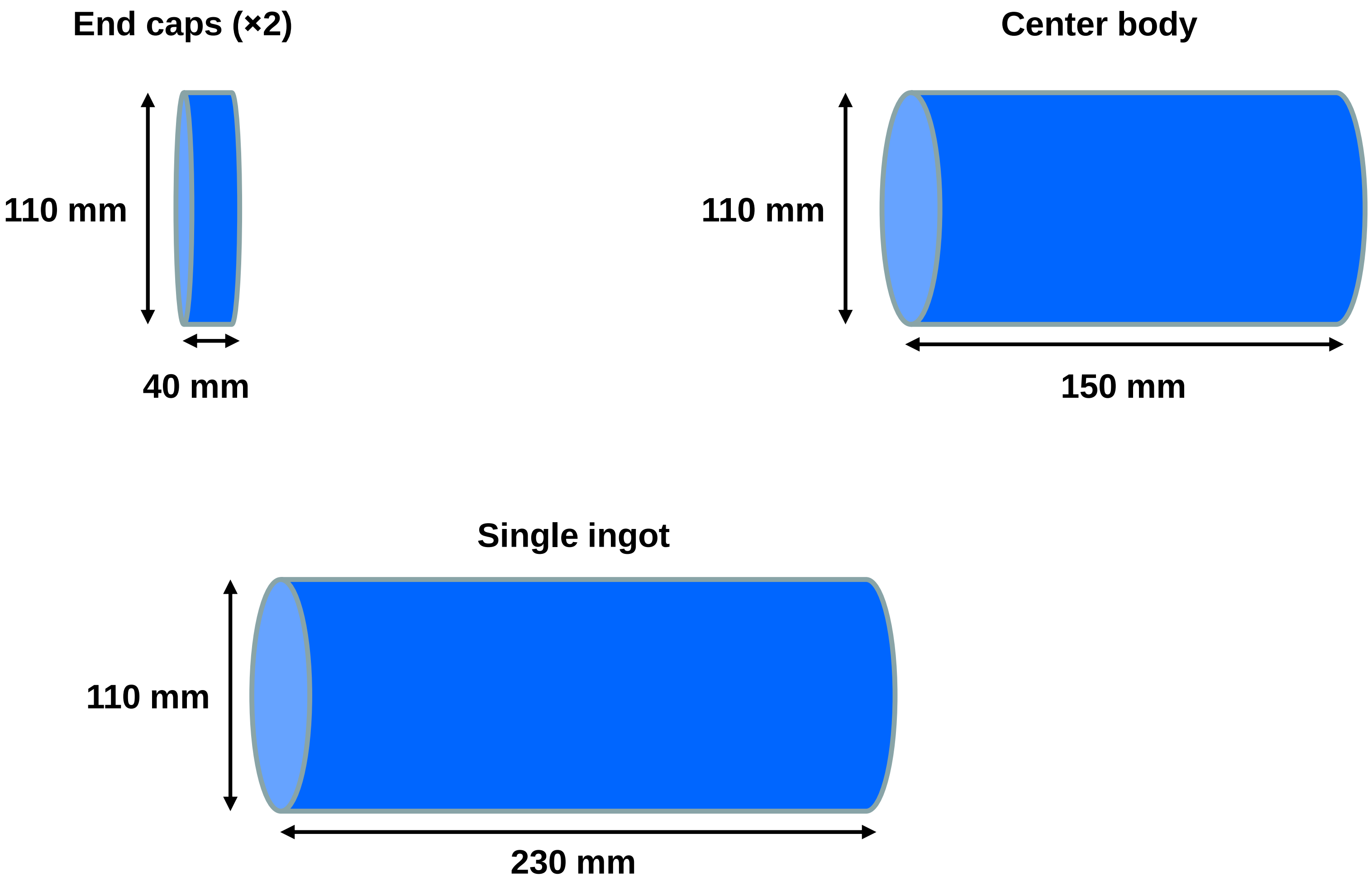
- Electropolishing of parts for bulk removal (120 microns)
  - Immerse parts EP acid bath in the fume hood
  - Need to develop procedure



- Light BCP on fully welded cavity in the BCP cabinet
  - Removal of 30 microns

Material Dimensions

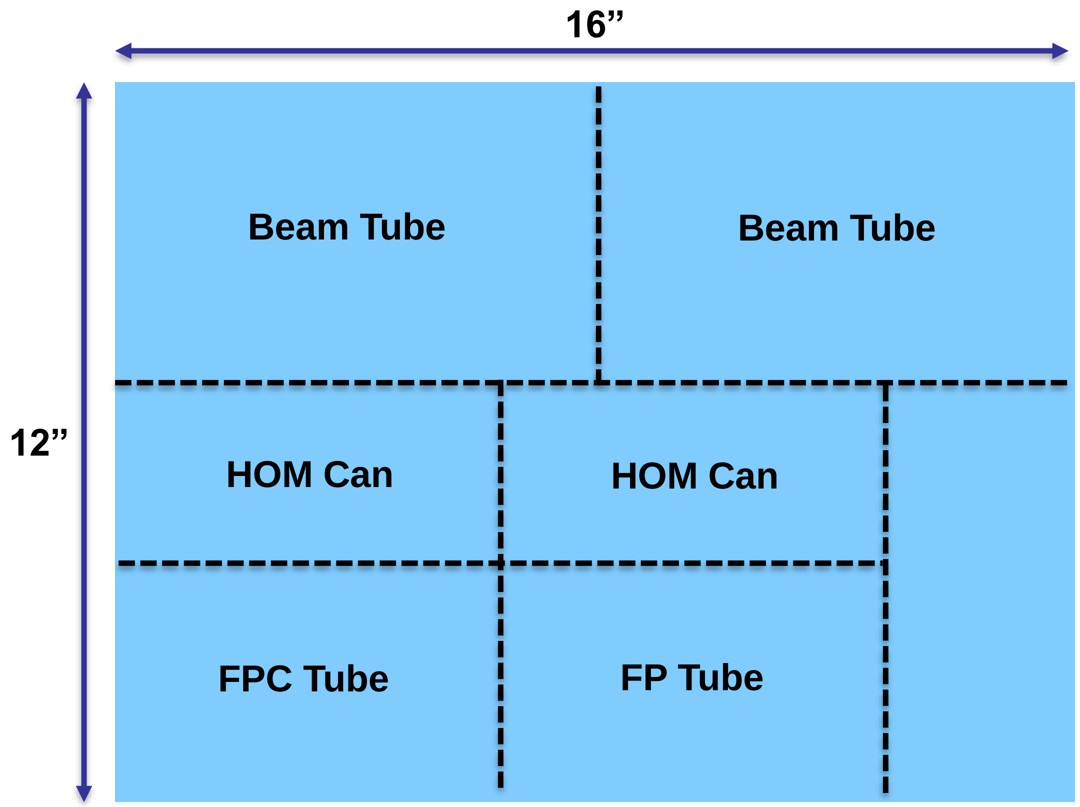
- FG ingots for center body and two end caps



Material Dimensions

- FG Nb sheet for
  - Beam pipes
  - FPC and FP ports
  - HOM coupler cans

Cavity Part	Material Type	Dimensions [mm]	Qty
Beam tubes	Sheets	115 mm × 180 mm × 3 mm	2
HOM cans	Sheets	65 mm × 148 mm × 3 mm	2
FPC tube	Sheets	84 mm × 148 mm × 3 mm	1
FP tube	Sheets	84 mm × 148 mm × 3 mm	1



- Extra width included in all parts
- No spare pieces

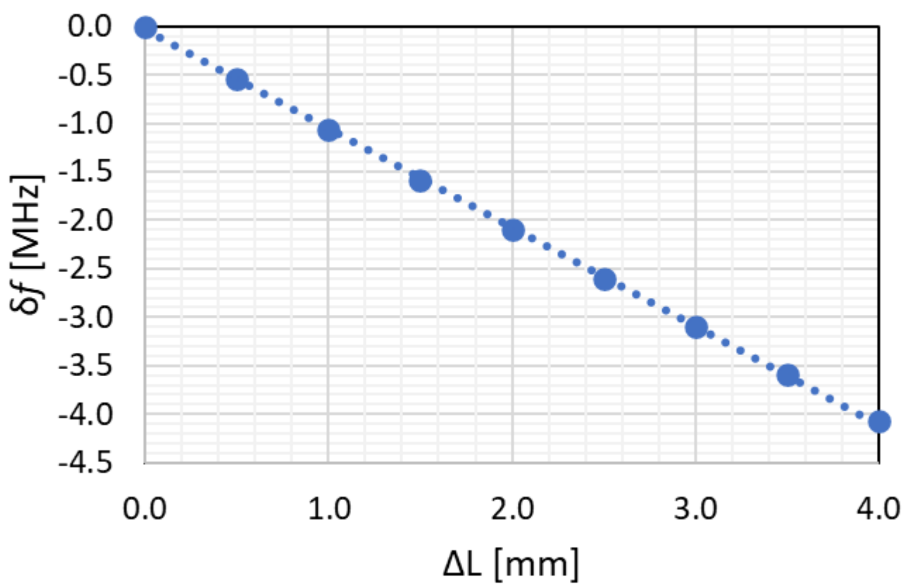
Next Steps

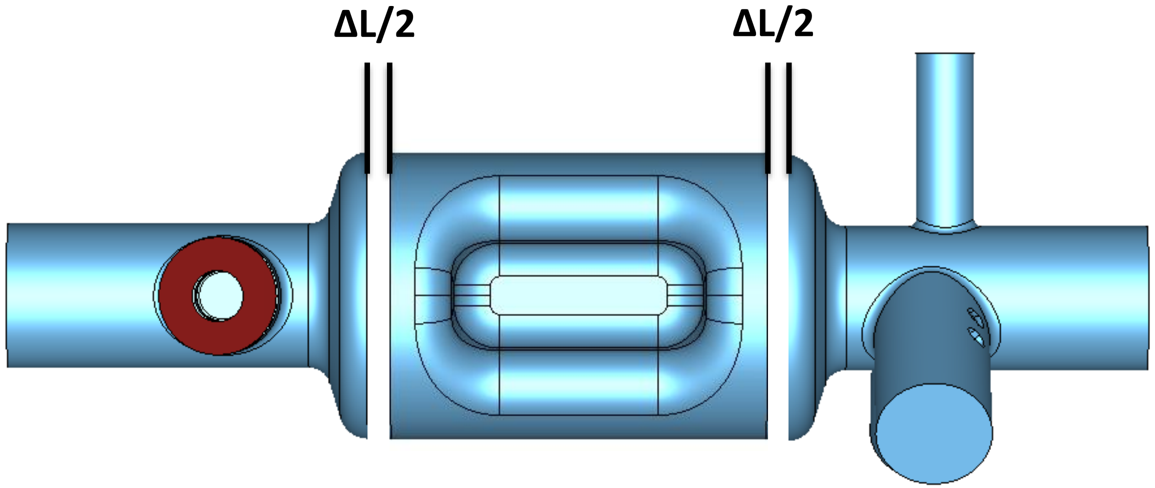
- Full engineering analysis and design
- Develop detailed fabrication plan including
  - Forming dies
  - Machining and welding fixtures
  - Cavity drawings package
- Cavity processing procedures and tools

Back Up Slides

Final Frequency Tuning

- Frequency tuning before the final weld of end cap assemblies to center body
- Trim tuning done by trimming center body symmetrically in a vertical stacked assembly
- Trimming sensitivity = –1.017 MHz/mm





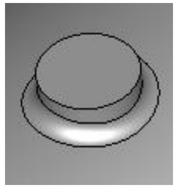
Tuning Sensitivity

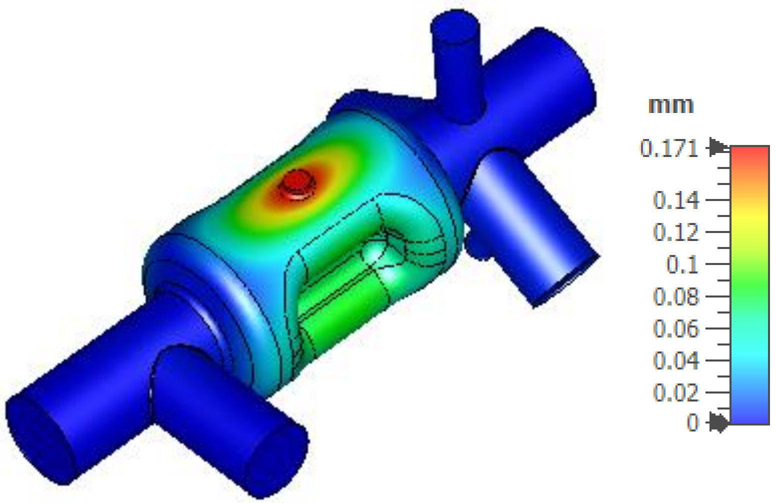
- Nb material properties at cryo temperature for annealed MG
  - Young's modulus – 114 GPa (1.65×10^{7} psi)
  - Allowable stress < 283 MPa (For MG)
- Cavity thickness – 3 mm
- Cavity constrained at beam pipe ports and FPC

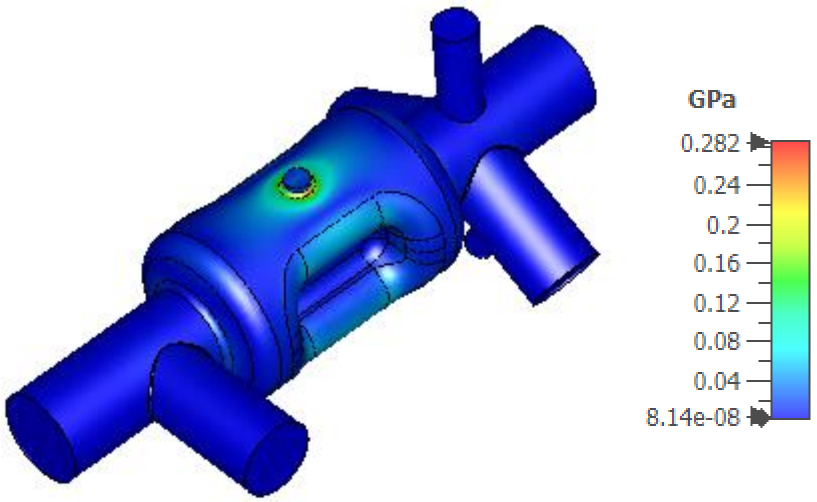
- Required tuning range – 100-180 kHz
- Tuning force (Both push and pull) – 175 N

Total Displacement	Tuning Sensitivity	Tuning Range
0.34 mm	9.5 MHz/mm	±3.24 MHz

Tuner Adapter
Ø 1.5 cm



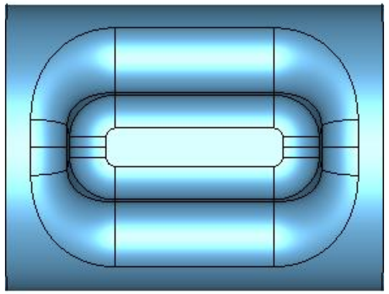
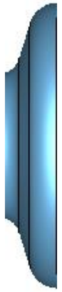




Main Cavity Components

- Center body and 2 end caps to be machined from ingot
- Include additional length and diameter to include tolerances

$$L_{RT} = L_{CT} \times 1.001432$$

Part	RF Dimensions	RT Dimensions	Ingot Size	Notes
	Diameter = 99.4 mm	Diameter = 99.6 mm	Diameter = 125 mm	Including 3 mm sheet thickness + 10 mm for tuner adapter
	Length = 130.2 mm	Length = 130.4 mm	Length = 150 mm	Including extra length for trim tuning
	Diameter = 99.4 mm	Diameter = 105.6 mm	Diameter = 115 mm	Including 3 mm sheet thickness
	Length = 30.5 mm	Length = 30.6 mm	Length = 40 mm	