

# RF-Dipole Cavity: Processing and RF Measurements Procedure

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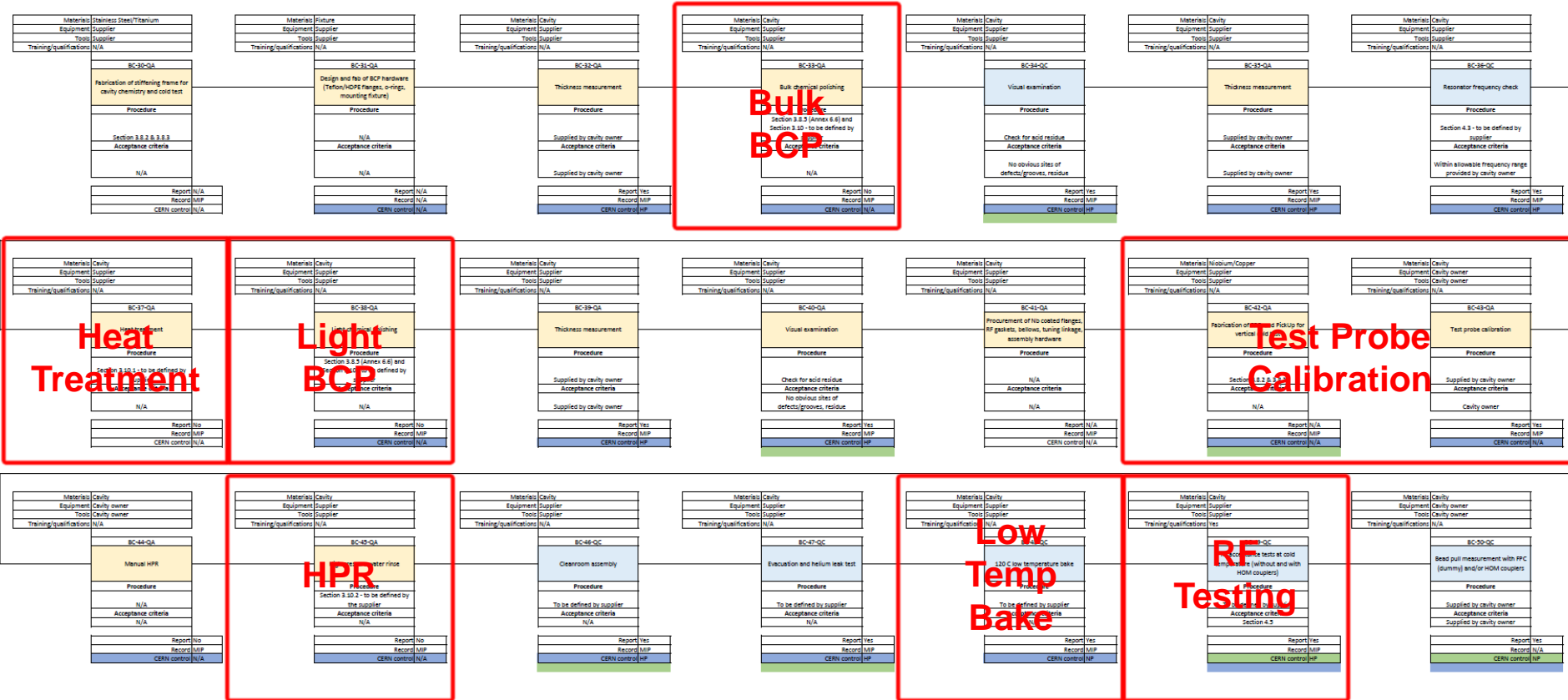
**Center for Accelerator Science  
Old Dominion University**

# Outline

- Cavity processing procedure
  - Bulk and light BCP
  - Heat treatment
  - High pressure rinse
  - Assembly procedure
- RF measurements
  - Bare cavity rf tests with and without HOM couplers
  - Helium vessel assembly and preparation
  - RF tests with helium vessel
- Tooling for tuning
  - Pre weld tuning
  - Post weld warm tuning
- Frequency sensitivity and field enhancement due to
  - Weld imperfections
  - Misalignment in subassemblies at welding

# Plan Outline

- Manufacturing process – Cavity processing and rf testing process



Color Code for Participation by Cavity Owners:  
 BNL will participate in hold point verification with travel  
 Participation / performed by ODU

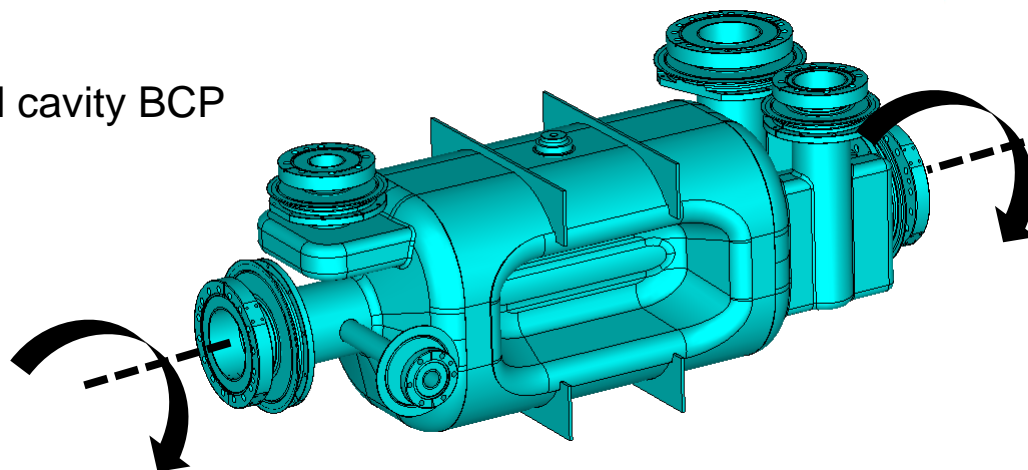
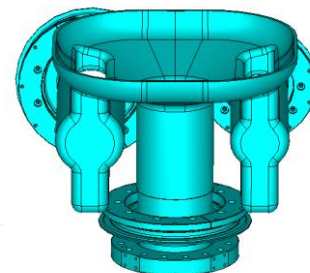
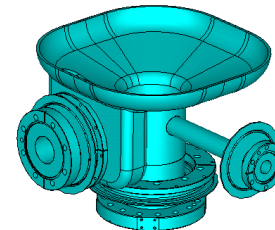
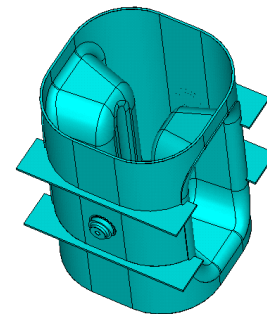


# Cavity Processing and Testing Sequence

- Bare Cavities (2 cavities)
  - Bulk BCP of 150  $\mu\text{m}$
  - Furnace Treatment at 600 °C for 10 hours
  - High Pressure Rinsing (HPR) – 2 passes
  - Light BCP of 30  $\mu\text{m}$
  - Low Temperature Baking at 120 °C for 12 hours
  - RF Test
- Bare Cavities with HOM Couplers
  - HPR
  - Assemble HHOM & VHOM couplers
  - RF Test
- Dressed Cavities (2 cavities)
  - HPR
  - Assemble HHOM & VHOM couplers
  - RF Test

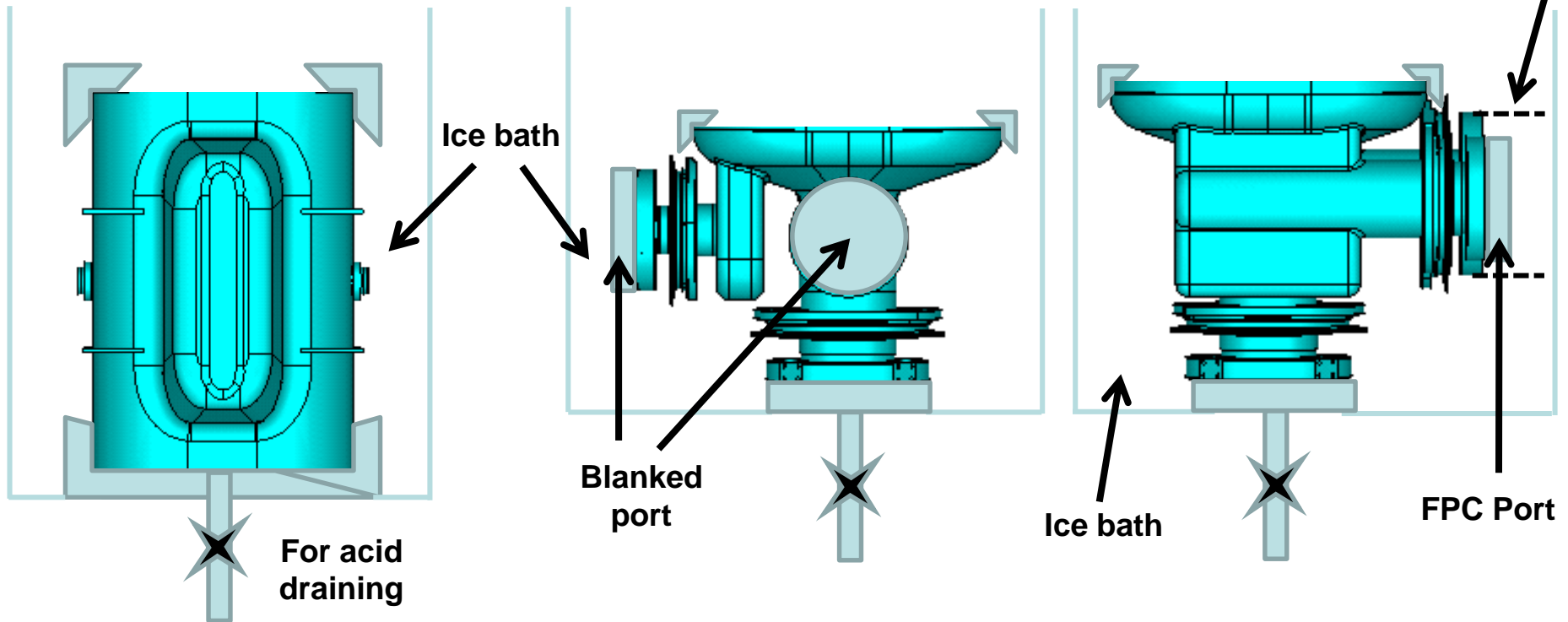
# Bulk/Light BCP Challenges and Methods

- Achieve uniform removal
- Prevent any trapped air during acid fill
- Drain acid completely before rinsing
  - To prevent any acid residue
- During BCP process
  - Temperature control of acid bath
  - Thickness measurement
- Possible BCP methods:
  - BCP of sub assemblies
  - Rotation of the cavity during full cavity BCP



# Bulk/Light BCP Methods – Method 1

- Trimmed sub assemblies
- Cavity welded after bulk BCP
- Light BCP of full cavity after heat treatment



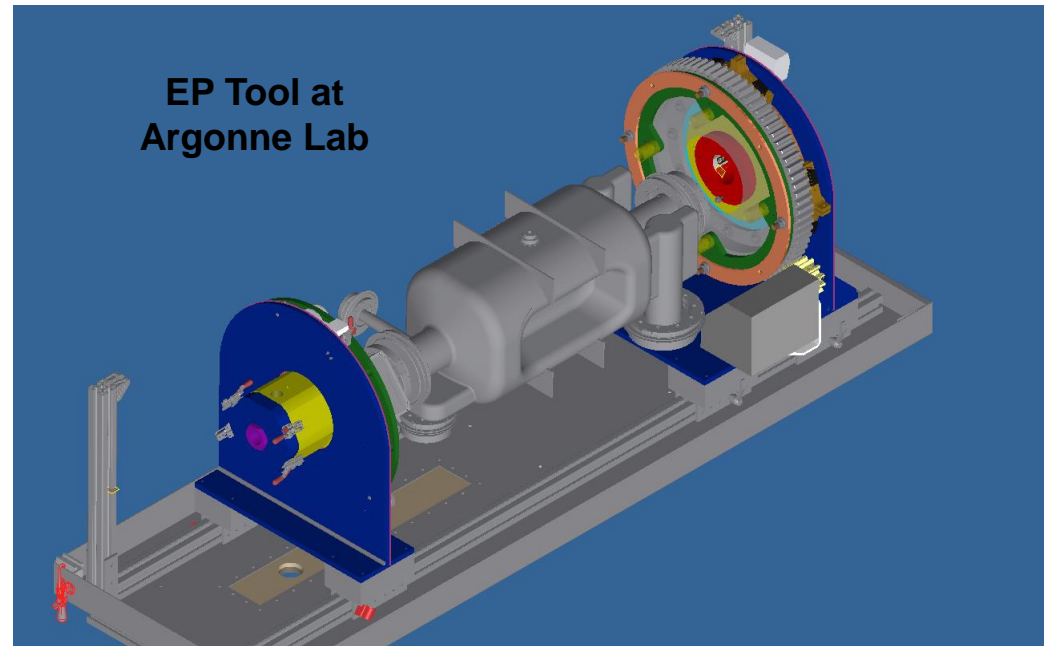
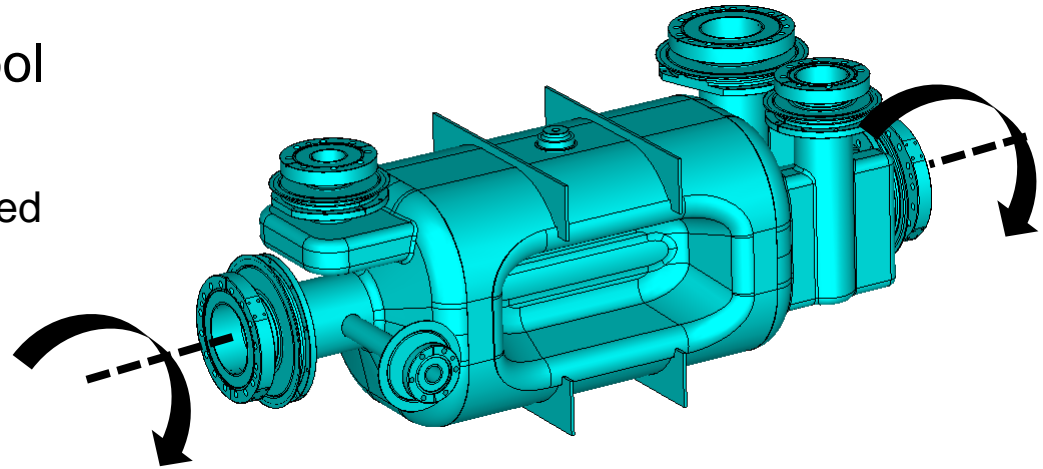
Weight – 43.3 lb  
Volume – 2.32 liters

Weight – 24 lb  
Volume – 1.4 liters

Weight – 35.4 lb  
Volume – 2.0 liters

# Bulk/Light BCP Methods – Method 2

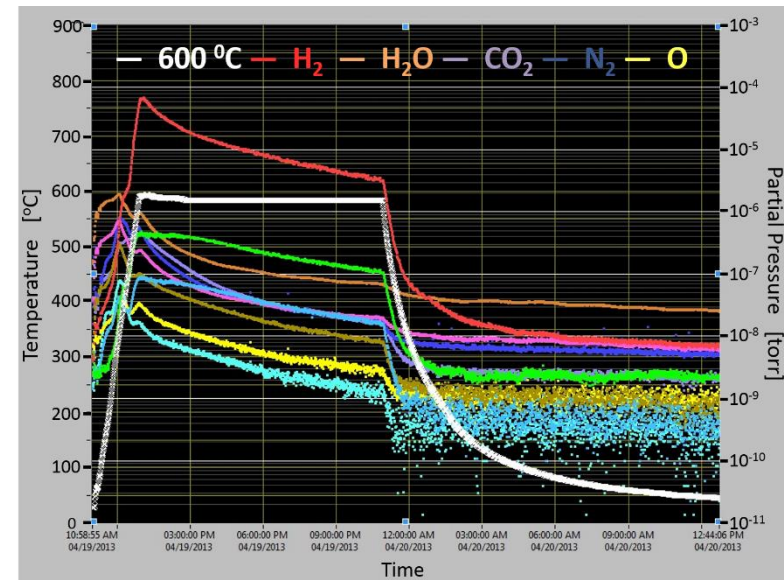
- Bulk/Light BCP using EP tool
- Cavity
  - 40%-45% of cavity volume filled
  - Rotates around its axis
- Cavity filled through a single port
- All the FPC, HHOM, VHOM and Pick Up ports are blanked
- Requires tilting the cavity to drain acid completely





# Heat Treatment

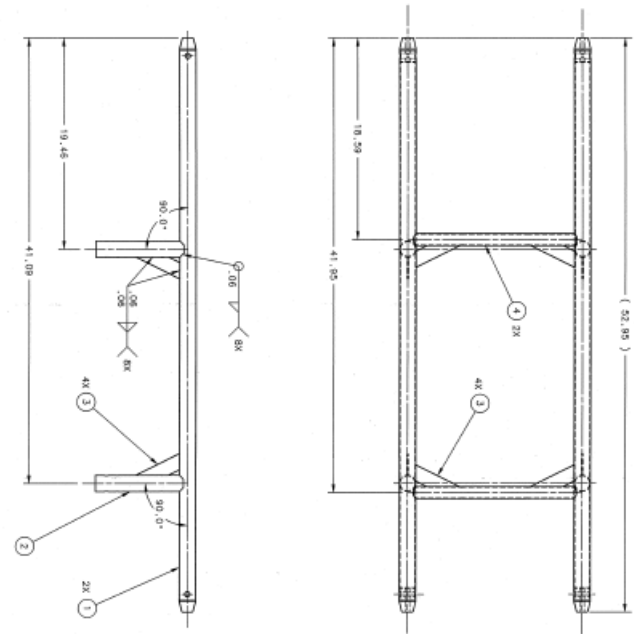
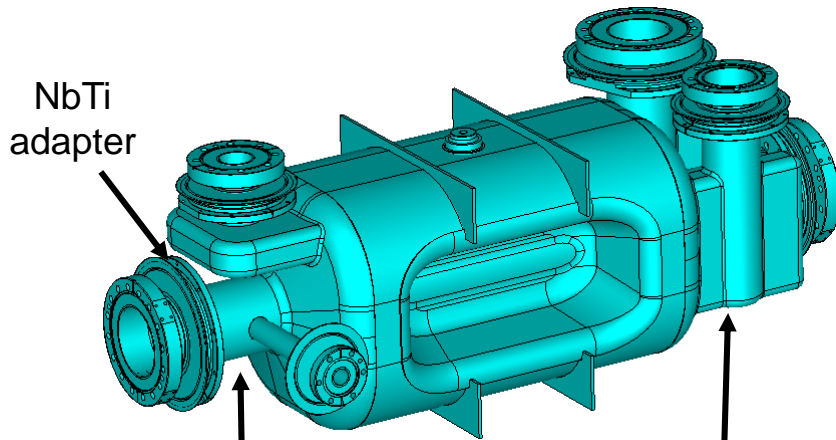
- In preparation for heat treatment cavity is rinsed in ultrasonic bath and bagged
- Heat treatment settings
  - At 600 °C
  - For 10 hours
- Partial pressure monitoring of H<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>O, CO<sub>2</sub> and O<sub>2</sub> through RGA
  - Can monitor up to 9 elements



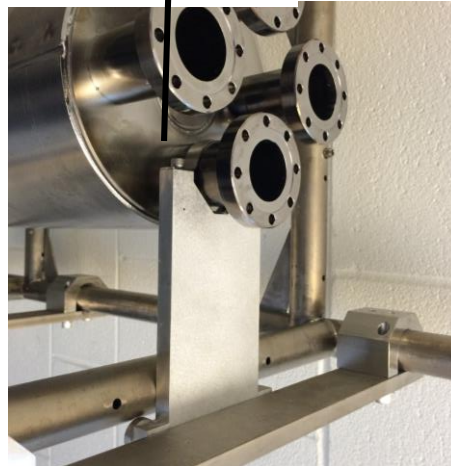
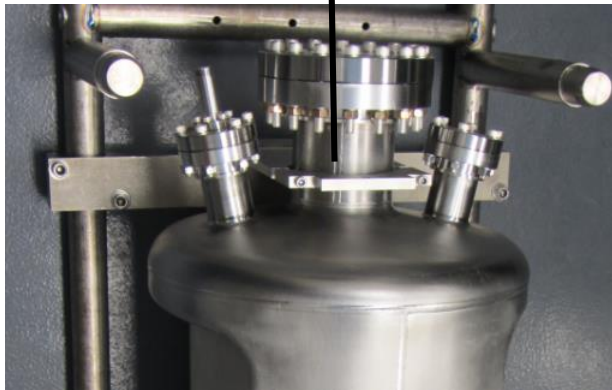


# Initial Cavity Assembly

- Brackets for cavity assembly

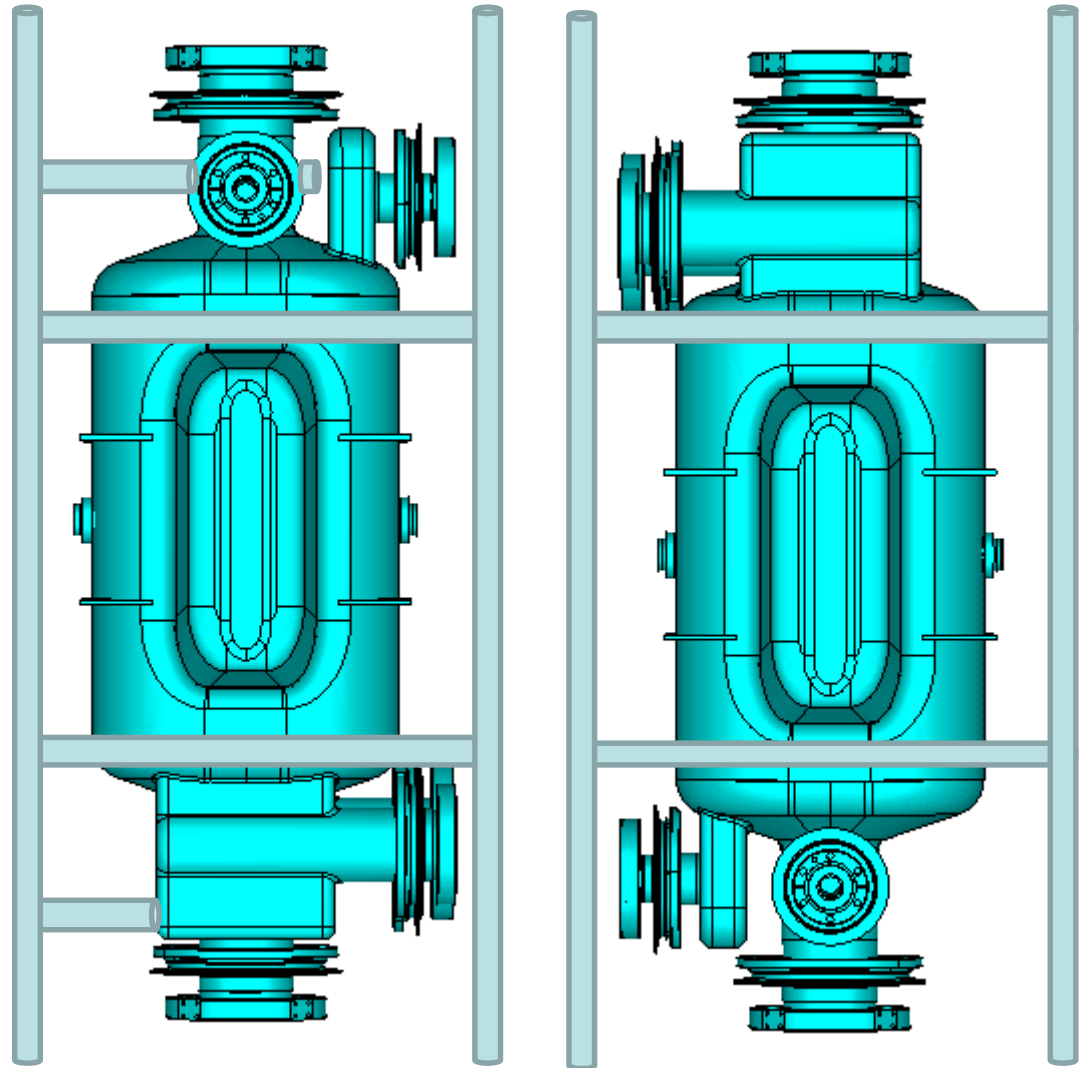


Standard 16" Ti cage at Jefferson Lab



# High Pressure Rinsing

- Cavity will be assembled in cage for HPR
- Manual wash prior to HPR
- 2 passes – Flip cavity during HPR
- Drain cavity completely beam port and VHOM port
- Let cavity dry in cleanroom before assembly



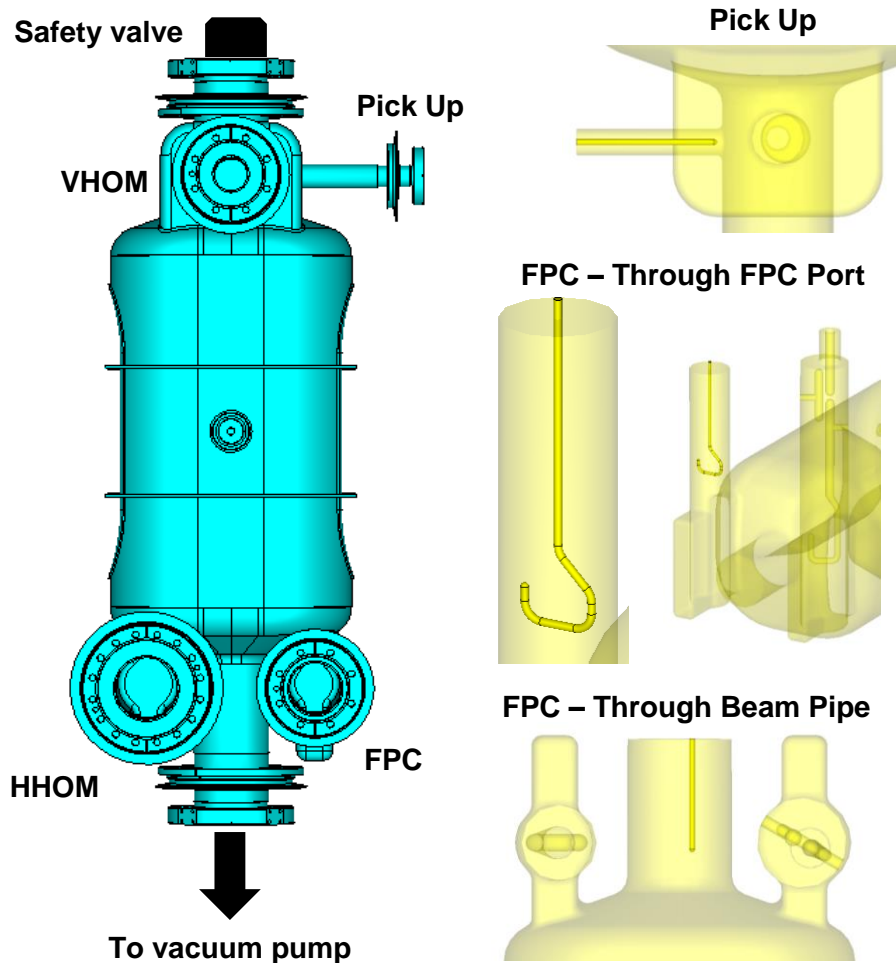
# Low Temperature Bake

- Low temperature baking performed using the bake box
- Fully assembled cavity is loaded in to the bake box
- Specifications: 120 °C for 12 hours
- Data are monitored through a lab view program



# Test Probe Calibration

- Test probe assembly set up
  - Probe diameter = 4.5 mm



- FPC and Pick Up ports are used for test FPC and Pick Up probes

Parameter	Value
$G$	107 $\Omega$
$R_s$ at 2.0 K with $R_{res}=10$ n $\Omega$	11.3 n $\Omega$
$Q_0$ at 2.0 K	$9.4 \times 10^9$

- Probe calibration:
  - $Q_{ext}$  (FPC):  $\sim 10^{10}$
  - $Q_{ext}$  (Pick Up):  $\sim 10^{11}$
- Use same probe for all the tests
  - Bare cavity test
  - Bare cavity test with HOM couplers
  - Cavity with He-vessel test



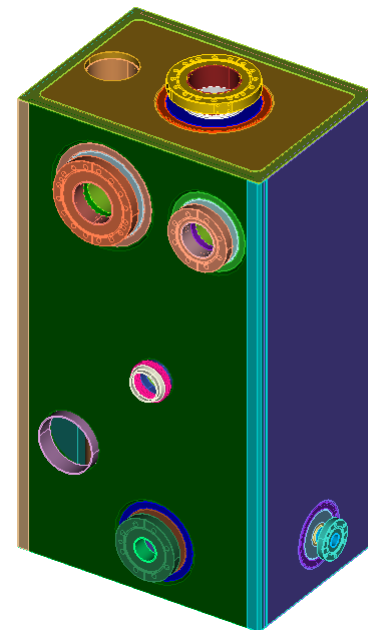
# Assembly for RF Measurements

- Assembly procedure
  - Assemble ancillary (Test probes, vacuum valve, safety valve, vacuum valve) in the class 10 clean room
  - For bare cavity test HOM ports are blanked
  - Assemble cavity mounted in the test stand
  - Cavity evacuation
- RF measurements procedure
  - Cavity cool down to 4.2 K
  - Frequency measurement and cable calibration
  - High power test at 4.2 K
    - Multipacting processing
  - RF measurements for surface resistance estimation during cold down from 4.2 K to 2.0 K
  - High power test at 2.0 K
  - Helium processing if needed
    - To process field emission



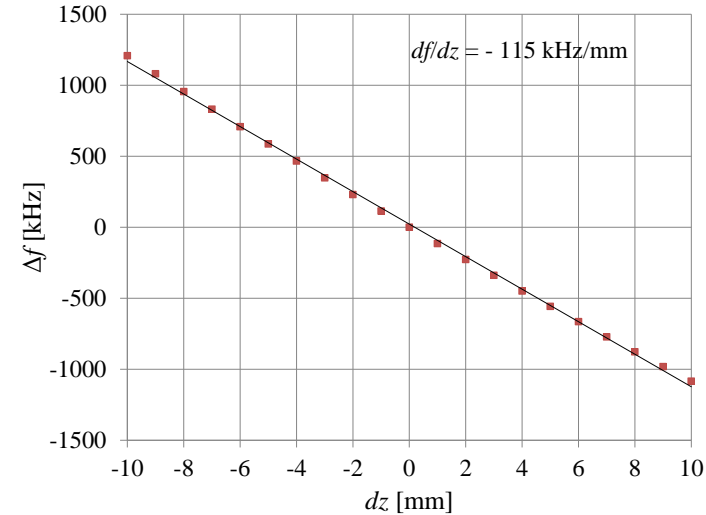
# Preparation for RF Test with Helium Vessel

- Preparation for rf test with He-vessel
  - Mount cavity on cage
    - Must support total weight of He-vessel including HOM couplers and tuner parts
  - High pressure rinse
  - Assembly of HOM couplers and other hardware
  - *Requires He-vessel specifications from CERN*
    - *Dimensions*
    - *Weight including shielding, HOM couplers and tuner*
- RF test procedure
  - Cavity cool down to 4.2 K
  - Frequency measurement and cable calibration
  - High power test at 4.2 K
  - RF measurements for surface resistance estimation during cold down from 4.2 K to 2.0 K
  - High power test at 2.0 K
  - *HOM measurements*

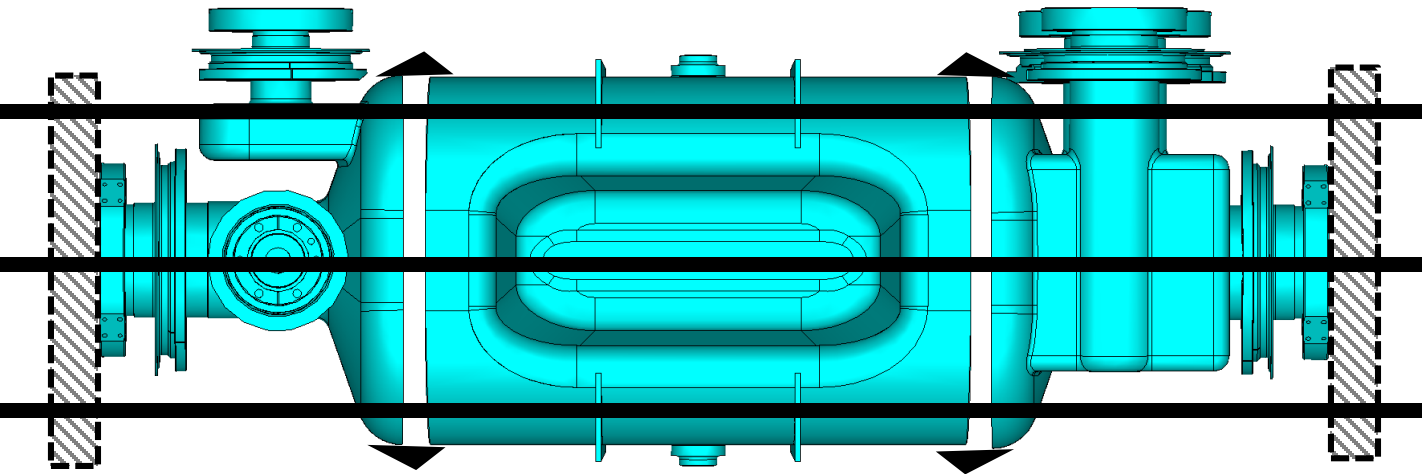


# Pre Weld Tuning

- Trimming of center body to achieve pre-weld frequency
- Tooling required to clamp the 3 sub-assemblies
  - Alignment along center axis
  - Minimize any rotational errors or translational shifts



499 MHz Set Up for Trimming



Column to adjust shifts

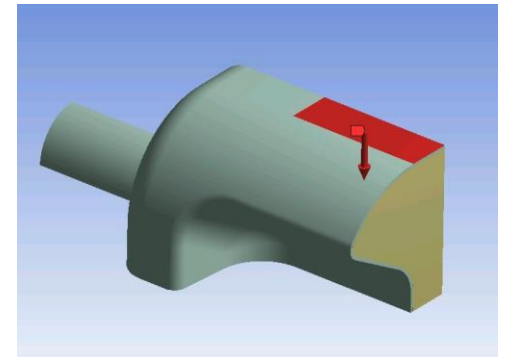


# Post Weld Warm Tuning

Tuning force (N)	Tuning range (kHz)	Deformation each side (mm)	Peak Stress Intensity (MPa)	Sensitivity (kHz/mm)
4448	730	1.057	368	690
1500	240	0.357	124	680

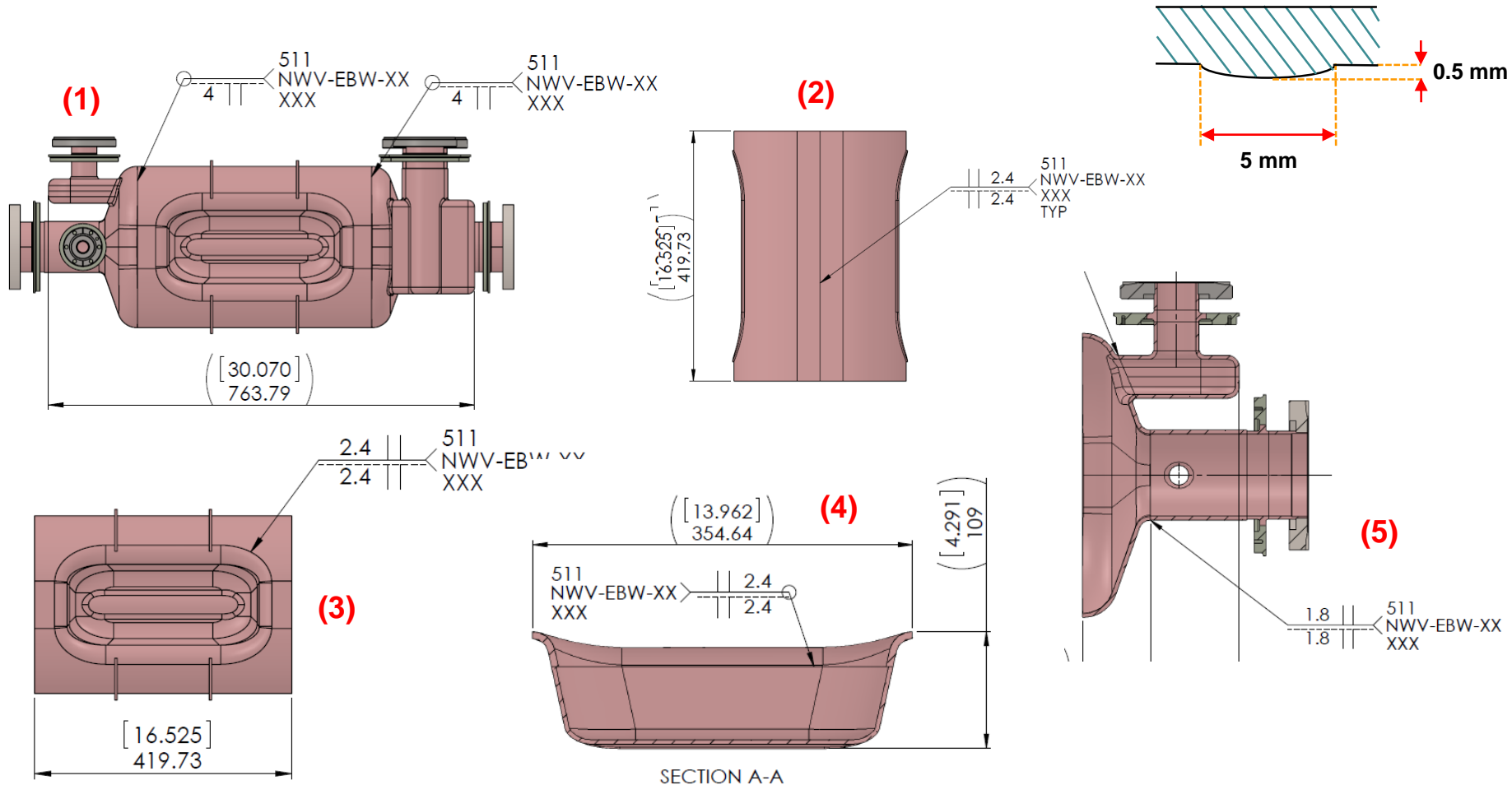
HyeKyoung Park

- RFD cavity tuning sensitivity  $\sim 680$  kHz/mm
- Room temperature cavity frequency adjustments can be compensated by the tuner
- Warm tuning not needed



# Weld Imperfections

- Major welds analyzed with a weld bead of 0.5 mm depth and 5 mm thickness

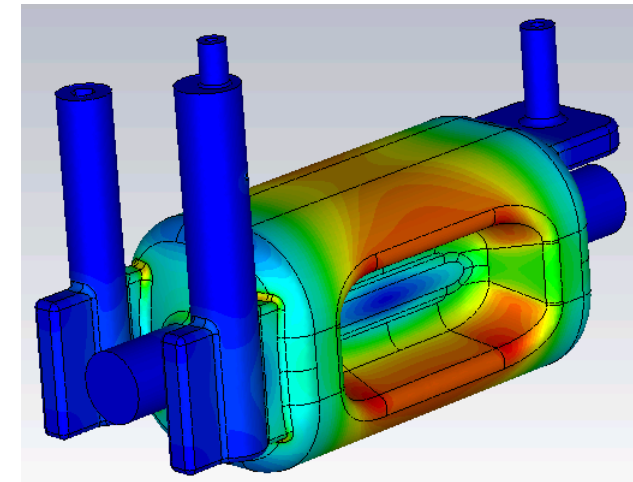
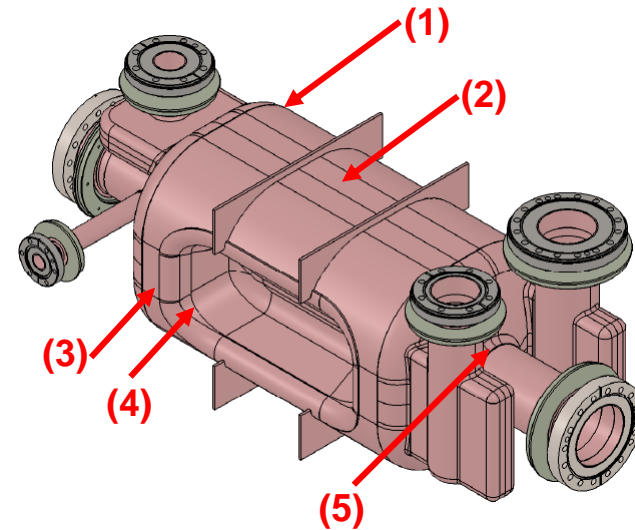
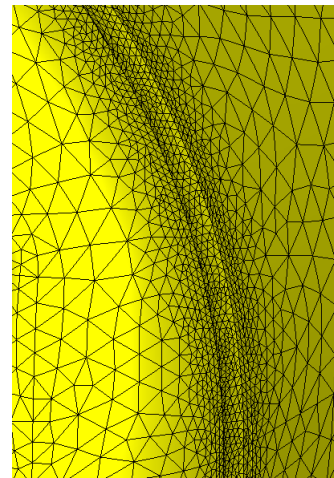
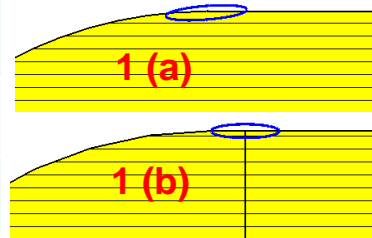


# Weld Imperfections

Weld	Frequency [MHz]	$\Delta f$ [kHz]	$B_p^*$ [mT]
Ideal Cavity	400.664013	-	56.37
Weld 1 (a)	400.673775	9.8	55.55
Weld 1 (b)	400.666337	7.4	55.55
Weld 2	400.680087	16.1	55.55
Weld 3	400.726685	62.7	55.59
Weld 4	400.702314	38.3	56.49
Weld 5	400.665127	1.2	56.33

\* At 3.4 MV

- Study does not include thermal shrinkage or BCP removal
- Frequency and field enhancement comparison with SLAC – ACE3P suite is on going

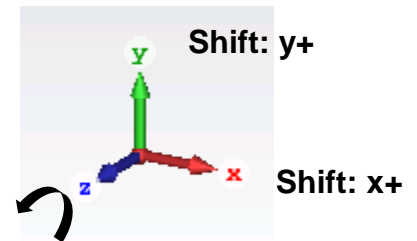
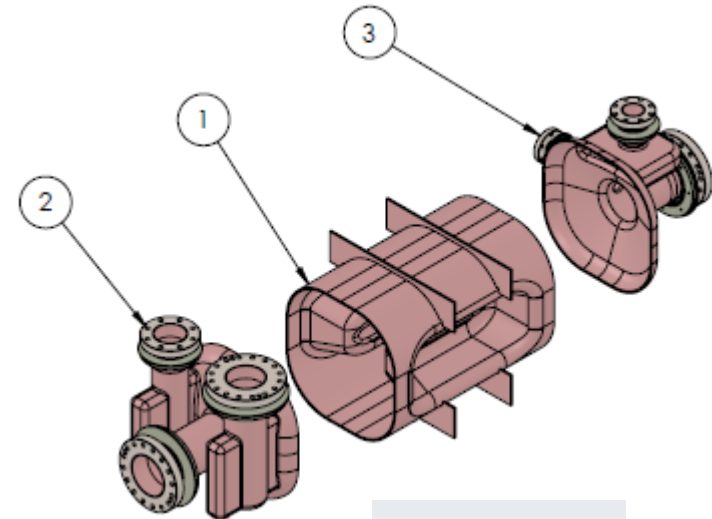
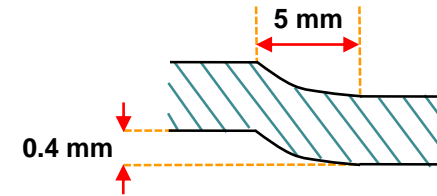


Surface Magnetic Field

# Weld Misalignments

- Misalignment in final subassembly weld

Weld	Frequency [MHz]	$\Delta f$ [kHz]
Ideal Cavity	400.664013	-
Shift 2:x+ 3:x+	400.665363	1.35
Shift 2:x+ 3:x-	400.663756	-0.26
Shift 2:y+ 3:y-	400.663053	-0.96
Rotation: 2:z+ 3:z+	400.663740	-0.27
Rotation: 2:z- 3:z-	400.665136	1.12
Rotation: 2:z+ 3:z-	400.663707	-0.31



- No field enhancement
- Frequency shift is negligible

# Cavity Frequency Change

Step	Frequency [MHz]	$\Delta f$ [kHz]	Notes
<b>SPS/LHC frequency</b>	400.73 – 400.79	–	
<b>Target frequency</b>	400.760	–	With tuner applied
<b>Design Frequency</b>	400.660	– 100.0	Cavity operating at 2 K and 3.4 MV
<b>Lorentz Detuning Shift</b>		4.5	
<b>Due to Pressure Sensitivity</b>		1.84	
<b>Cavity Cooled Down</b>			Cavity in vacuum at 2 K (Not measurable)
- <b>With Probes</b>	400.6664	6.04	LT + PS
- <b>No Probes</b>	400.6596	-6.77	For VTA test only
<b>Evacuated Cavity</b>	400.0867	– 572.9	Cavity in vacuum and at room temperature (20 °C)
<b>BCPed Cavity</b>	399.9687	– 118.0	<ul style="list-style-type: none"> <li>▪ Cavity in air at room temperature (20 °C)</li> <li>▪ Removal of 150 <math>\mu\text{m}</math></li> </ul>
<b>Welded Cavity</b>	400.0287	60.0	Cavity in air at room temperature (20 °C)

# Summary

- Electromagnetic and mechanical studies in preparation for cavity processing and testing is completed
  - Weld imperfections
  - Probe calibration
  - Tuning requirement study
- Finalized procedures on
  - Heat treatment, High pressure rinsing, Low temperature baking, and assembly
  - RF measurements procedure
- Currently finalizing BCP procedure
  - With Jefferson Lab
  - CFD analysis by Tom Jones
- Next steps:
  - Cavity fixturing and tooling drawings
  - Pre weld tuning fixtures
  - Tooling for optical inspection

# Acknowledgements

- ODU – HyeKyoung Park, Rocio Olave, Jean Delayen
- SLAC – Zenghai Li
- CERN – Rama Calaga, Ofelia Capatina, Raphael Leuxe, Carlo Zanoni, Teddy Capelli, and the team
- Alex Ratti - LBNL
- Tom Nicol - Fermilab
- STFC/UK – Graeme Burt, Tom Jones, Nik Templeton, Adam Tutte, and the team
- JLAB
- Niowave



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# THANK YOU