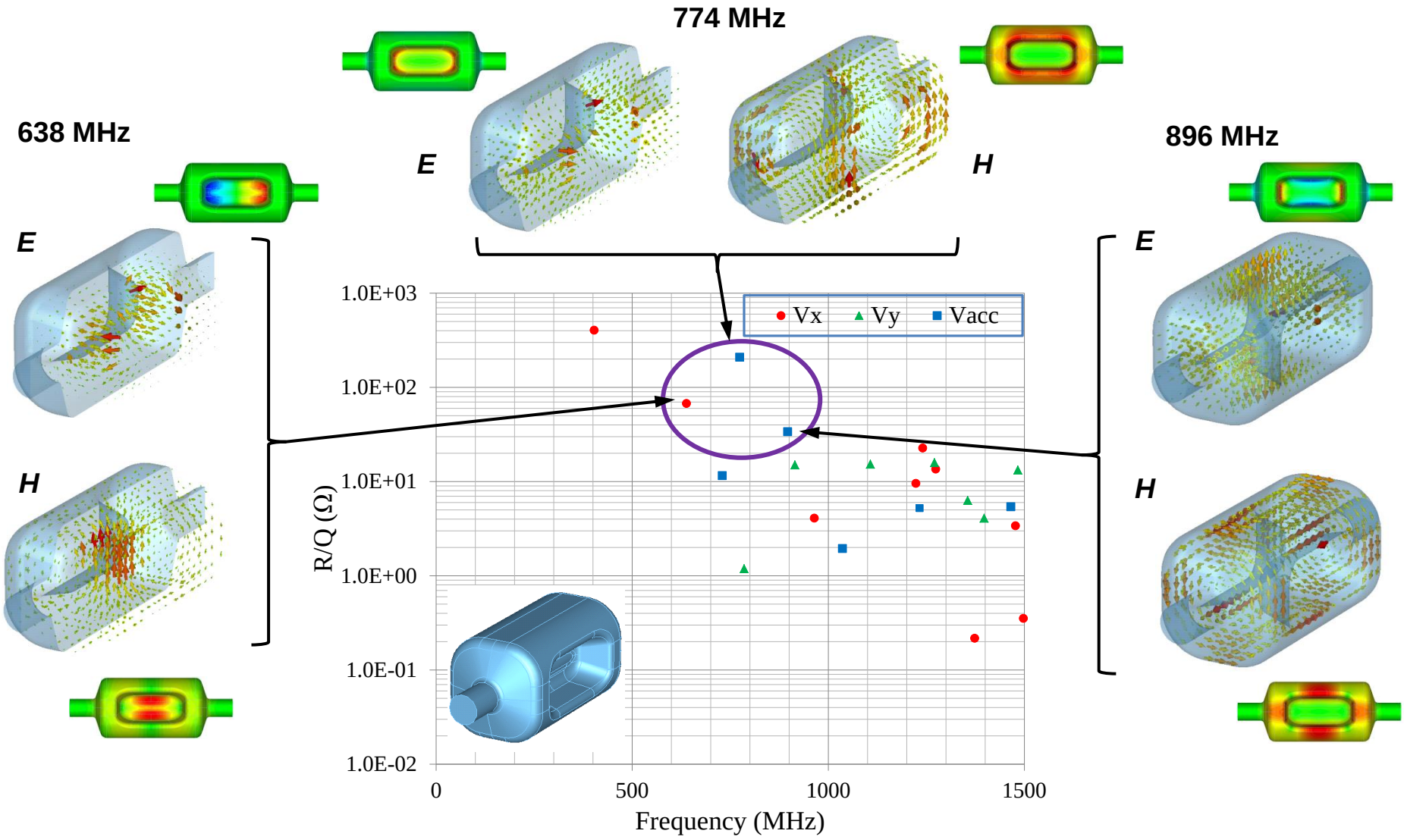
Higher Order Mode Couplers for RFD Cavity

HyeKyoung Park
Center for Accelerator Science
Old Dominion University

Outline

- HOM properties, damping, and multipacting analysis
- HOM coupler locations and configurations
- Thermal study
- Fabrication concepts
- On-going efforts

HOM Properties of RF-Dipole Prototype



HOM Damping of RF-Dipole Cavities

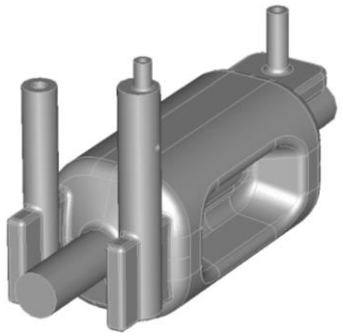
- Impedance budget for ultimate intensity [E. Shaposhnikova – LHC CC-10]
  - Transverse impedance → 0.8 MOhm/m
  - Longitudinal impedance → 200 kOhm
- Estimated HOM Power [B. Salvant, R. Calaga, – LHC CC-13]
  - Worst case scenario → Total HOM power of 1 kW
  - Total power for combined HOM ports

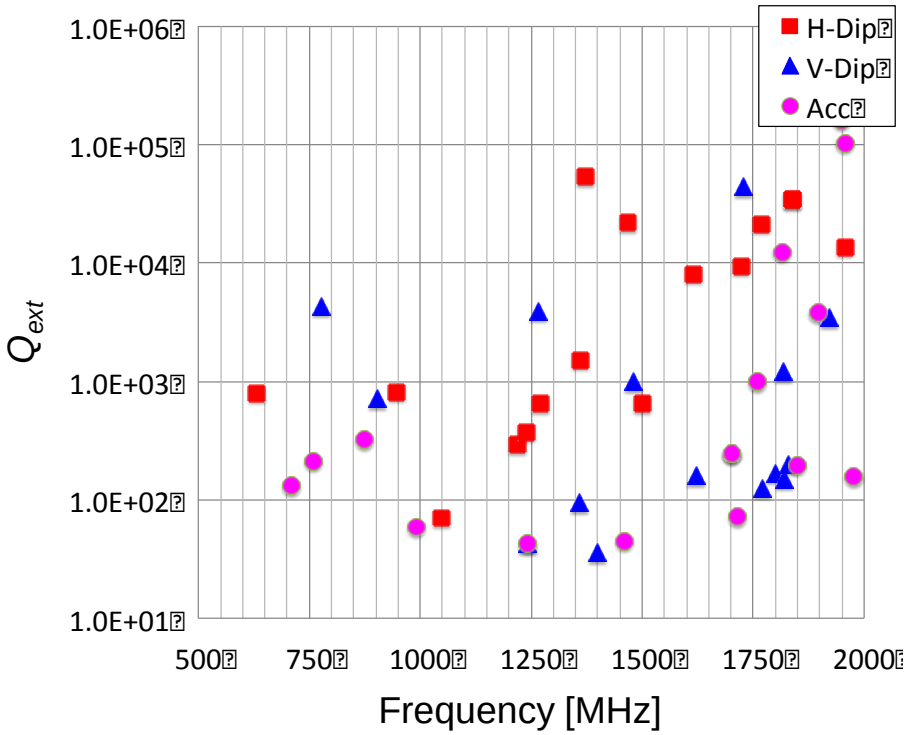
HOM Damping Goals

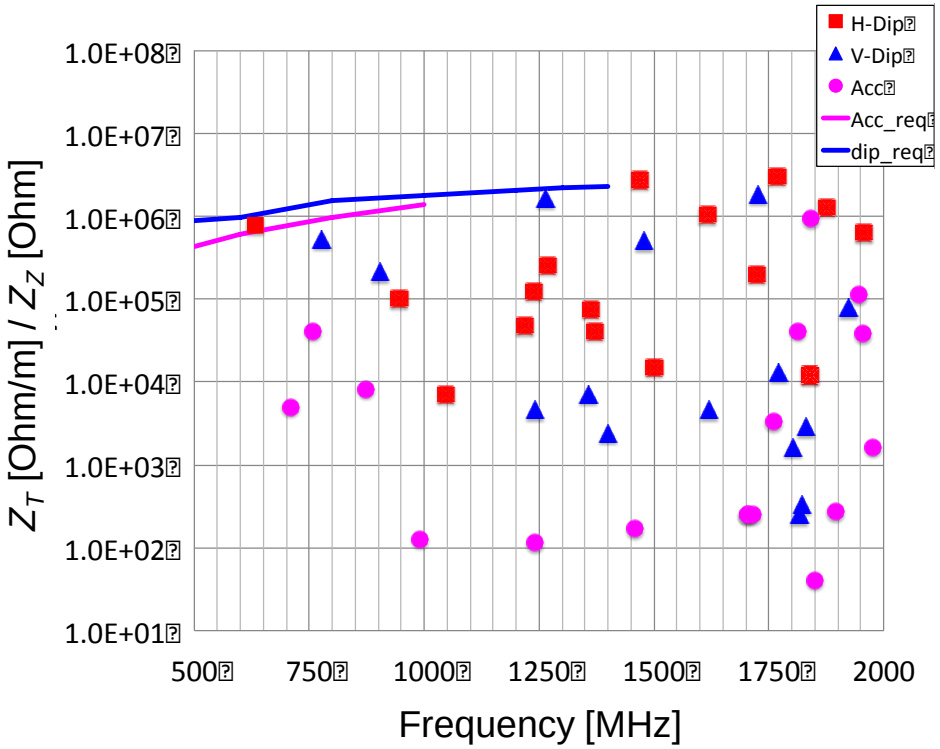
- Achieve required damping with minimum number of HOM ports
- Preserve the symmetry of the fundamental mode
- Minimize the number of filters for fundamental mode

HOM Damping

- Good damping achieved for all modes up to 2 GHz
- HHOM - Couples to both for horizontal deflecting and accelerating modes
- VHOM - To damp vertical deflecting modes and accelerating modes

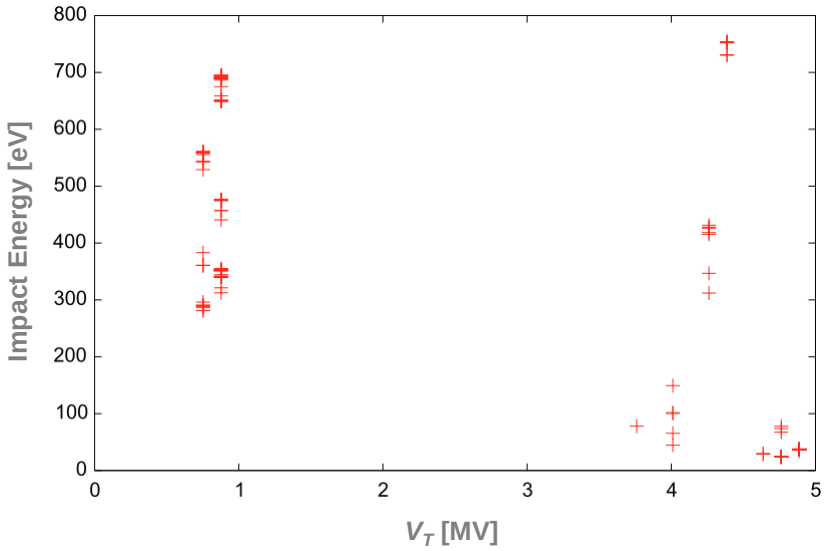


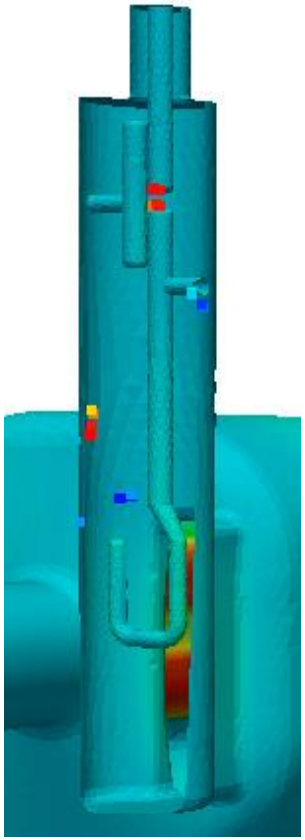


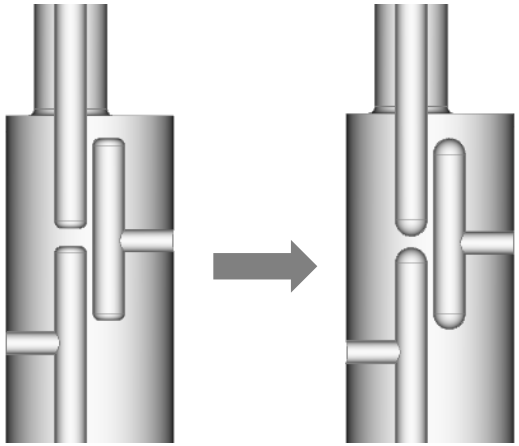


Multipacting Analysis

- Multipacting levels found in the gap
- Eliminated with a full rounding of probe ends

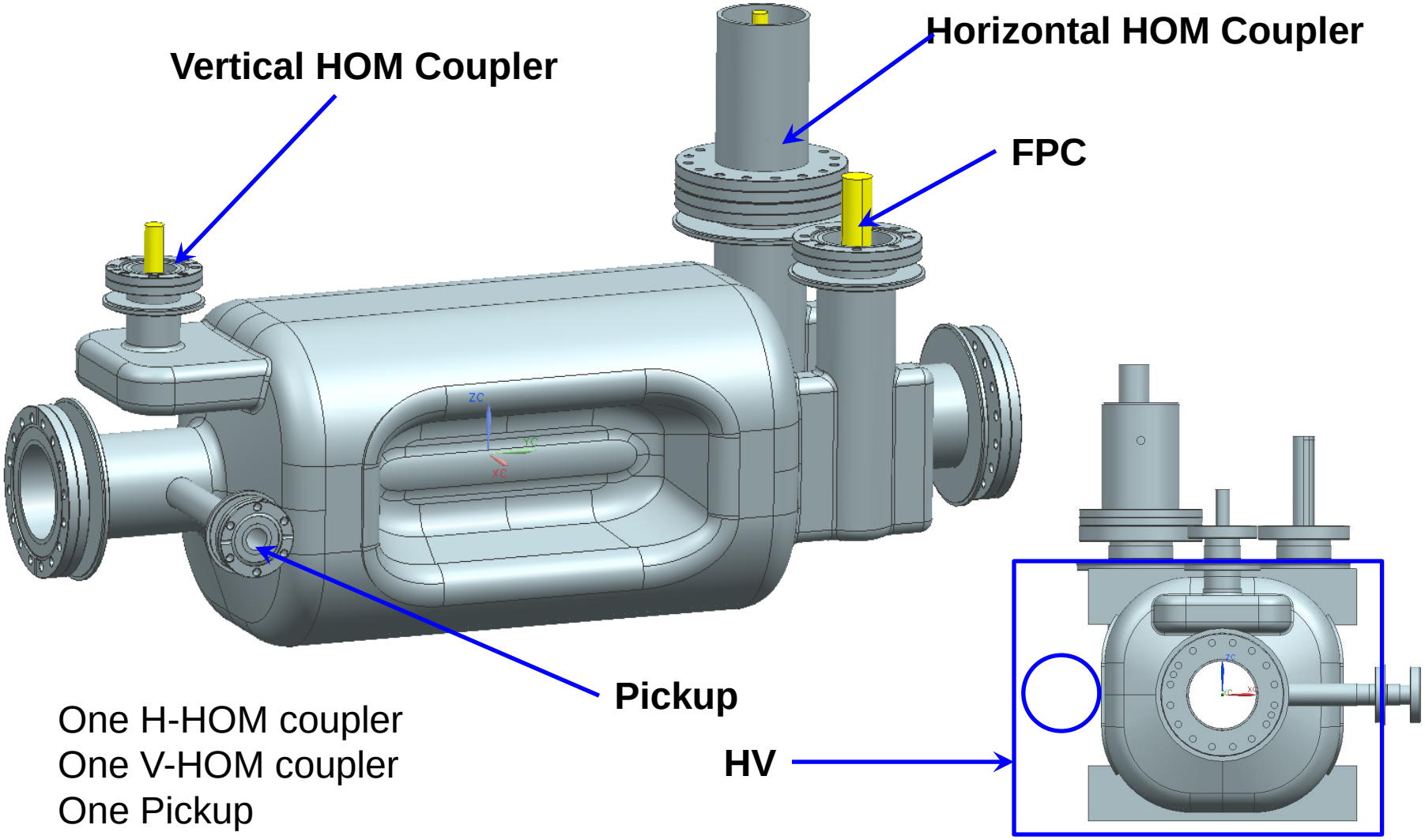




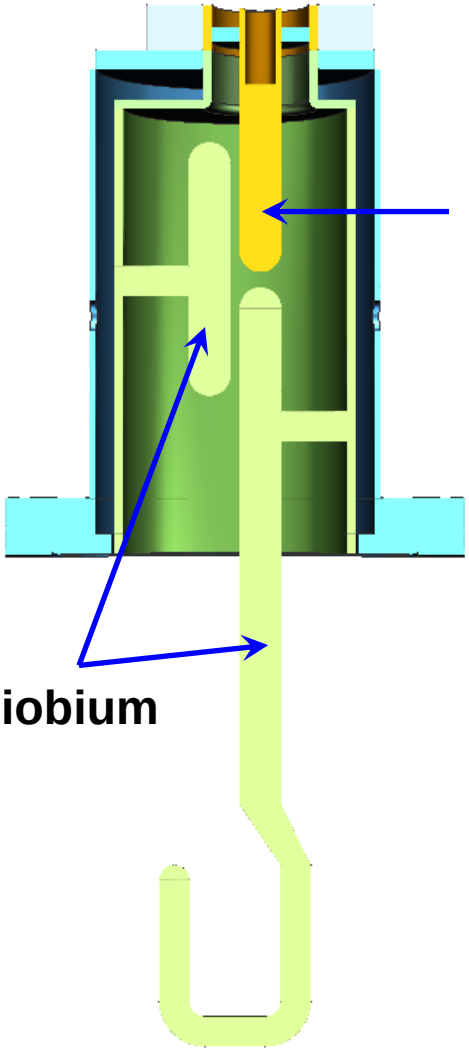


Multipacting trajectories in the gap removed

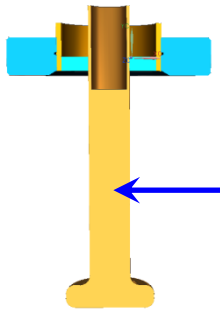
Coupler Locations



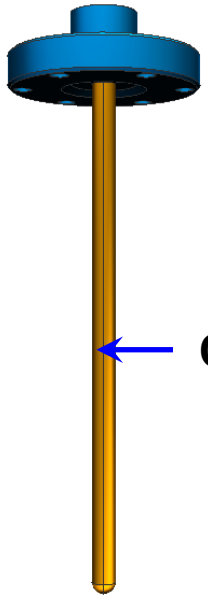
Coupler Design Concepts



Horizontal HOM Coupler



Vertical HOM Coupler

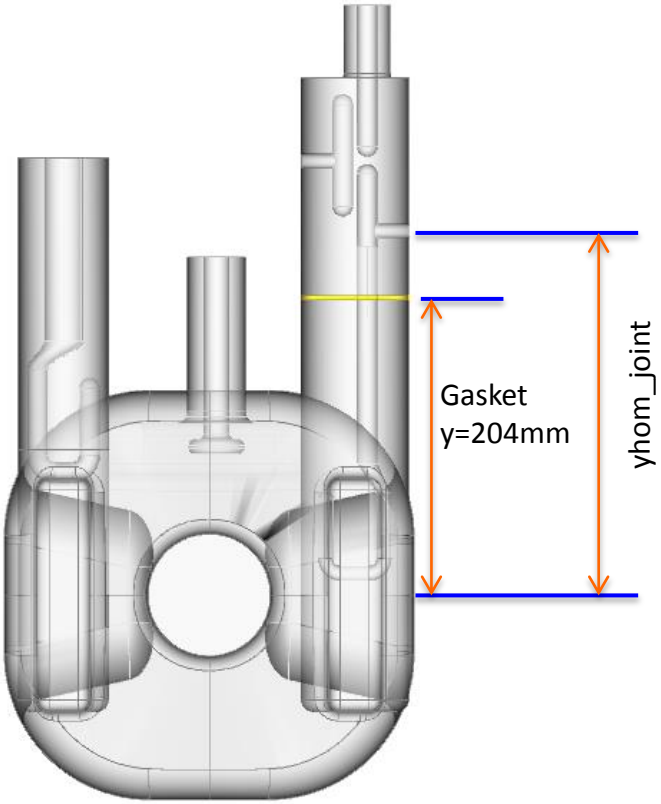


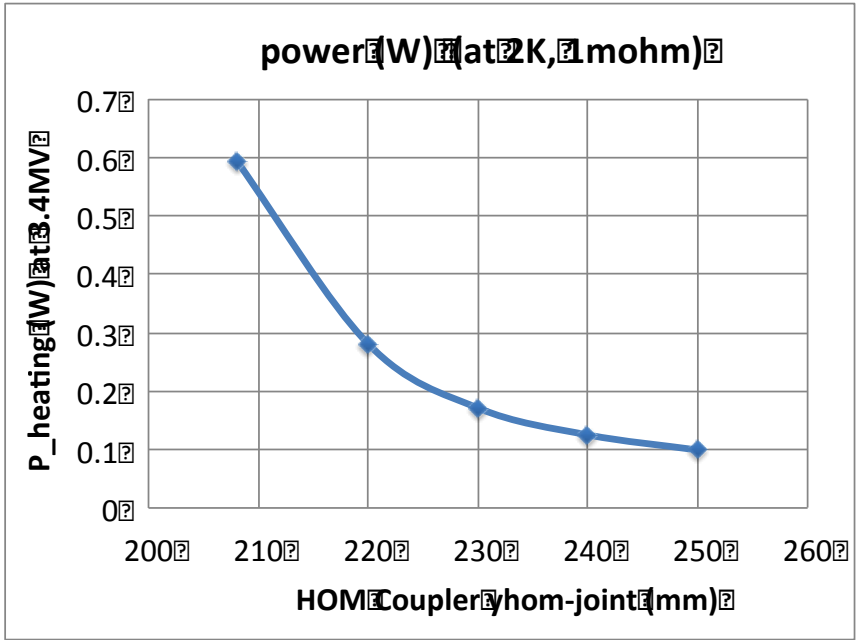
Pickup

Power Dissipation on Gasket

Zenghai Li/SLAC

- At 3.4MV deflecting voltage – Fundamental mode
- Copper gasket at 2K (R=1mohm)





Power Dissipation

Zenghai Li/SLAC

Loss unit (W): HOM at 1kW power extraction; Deflecting at 3.4 MV

F (MHz)	H-Hook (Nb)	H-T (Nb)	H-Cu-probe (5mohm)	H-Cu-gasket (2K) (1mohm)	V-Cu-probe (5mohm)
400	5.989E-04	1.442E-06	4.899E-02	1.073E-01	4.665E-01
627.5	6.846E-06	5.421E-06	2.329E-01	6.146E-04	1.776E-08
633.8	6.236E-06	5.324E-06	2.384E-01	5.761E-04	2.013E-05
690.2	3.358E-06	2.854E-06	2.475E-01	6.443E-04	1.813E-05
716.0	3.870E-06	2.199E-06	2.525E-01	7.544E-04	6.218E-04
735.5	3.100E-06	1.602E-06	2.497E-01	6.056E-04	7.741E-05
761.0	3.902E-06	1.373E-06	2.330E-01	7.225E-04	4.892E-02
783.1	3.215E-08	9.550E-09	1.883E-03	5.799E-06	4.034E-01
800.5	1.366E-07	2.548E-07	2.185E-01	1.403E-05	4.355E-08
875.5	2.675E-07	5.408E-08	1.671E-02	4.948E-05	3.796E-01
909.5	2.458E-08	4.433E-09	1.472E-03	4.560E-06	4.046E-01
946.5	5.139E-06	8.659E-07	3.036E-01	9.602E-04	4.163E-04
1004.4	1.586E-07	2.617E-08	1.058E-02	2.834E-05	3.888E-01

- **Hook joint at 240mm from beam line**
- **Gasket at 204mm from beam line**

Power Dissipation with Freq Dependent Rs

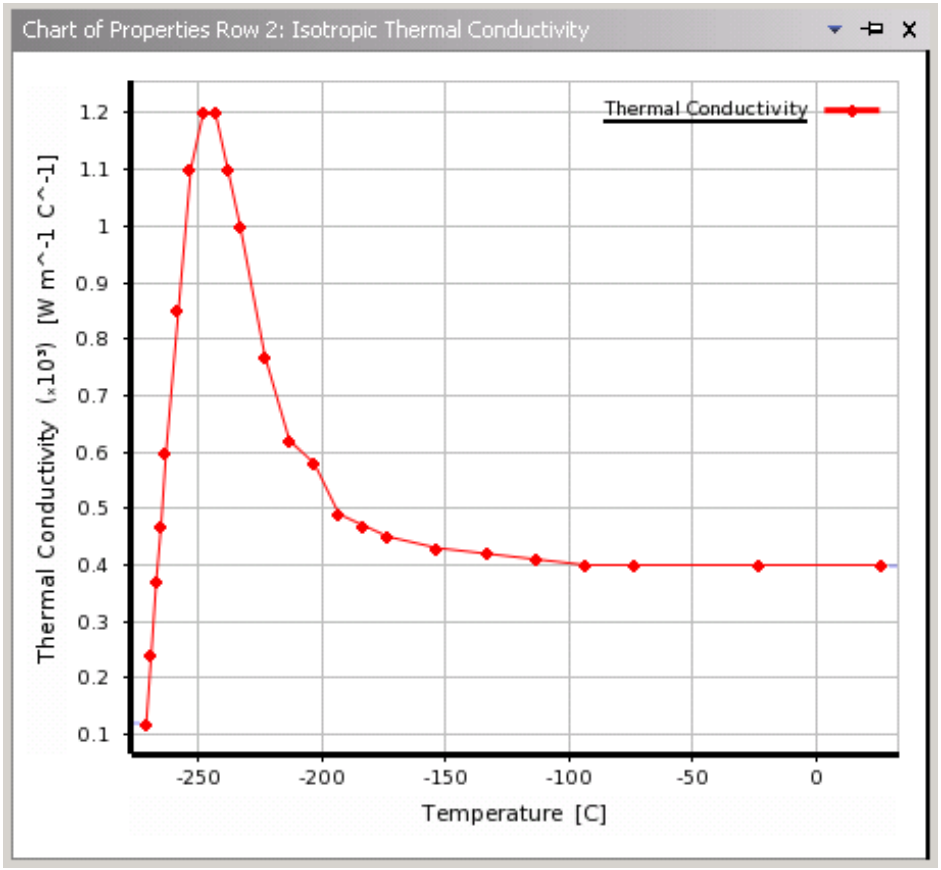
f [MHz]	Rs (Cu) (RT)	H-Hook (Nb)	H-T (Nb)	H-Probe (Cu) (RT)		H-Gasket (Cu) (2K)	V-Probe (Cu) (RT)	
	[ohm]	(2K)		(5 mohm)	(Scaled)	(1 mohm)	(5 mohm)	(Scaled)
400	0.005147386	5.99E-04	1.44E-06	4.90E-02	4.90E-02	1.07E-01	4.67E-01	
627.5	0.006447088	6.85E-06	5.42E-06	2.33E-01	3.00E-01	6.15E-04	1.78E-08	2.29E-08
633.8	0.006479371	6.24E-06	5.32E-06	2.38E-01	3.09E-01	5.76E-04	2.01E-05	2.61E-05
690.2	0.006761518	3.36E-06	2.85E-06	2.48E-01	3.35E-01	6.44E-04	1.81E-05	2.45E-05
716	0.006886733	3.87E-06	2.20E-06	2.53E-01	3.48E-01	7.54E-04	6.22E-04	8.56E-04
735.5	0.006979882	3.10E-06	1.60E-06	2.50E-01	3.49E-01	6.06E-04	7.74E-05	1.08E-04
761	0.007099848	3.90E-06	1.37E-06	2.33E-01	3.31E-01	7.23E-04	4.89E-02	6.95E-02
783.1	0.007202203	3.22E-08	9.55E-09	1.88E-03	2.71E-03	5.80E-06	4.03E-01	5.81E-01
800.5	0.007281778	1.37E-07	2.55E-07	2.19E-01	3.18E-01	1.40E-05	4.36E-08	6.34E-08
875.5	0.007615261	2.68E-07	5.41E-08	1.67E-02	2.55E-02	4.95E-05	3.80E-01	5.78E-01
909.5	0.007761722	2.46E-08	4.43E-09	1.47E-03	2.29E-03	4.56E-06	4.05E-01	6.28E-01
946.5	0.007918028	5.14E-06	8.66E-07	3.04E-01	4.81E-01	9.60E-04	4.16E-04	6.59E-04
1004.4	0.008156617	1.59E-07	2.62E-08	1.06E-02	1.73E-02	2.83E-05	3.89E-01	6.34E-01

Power Dissipation on High Pass Filter

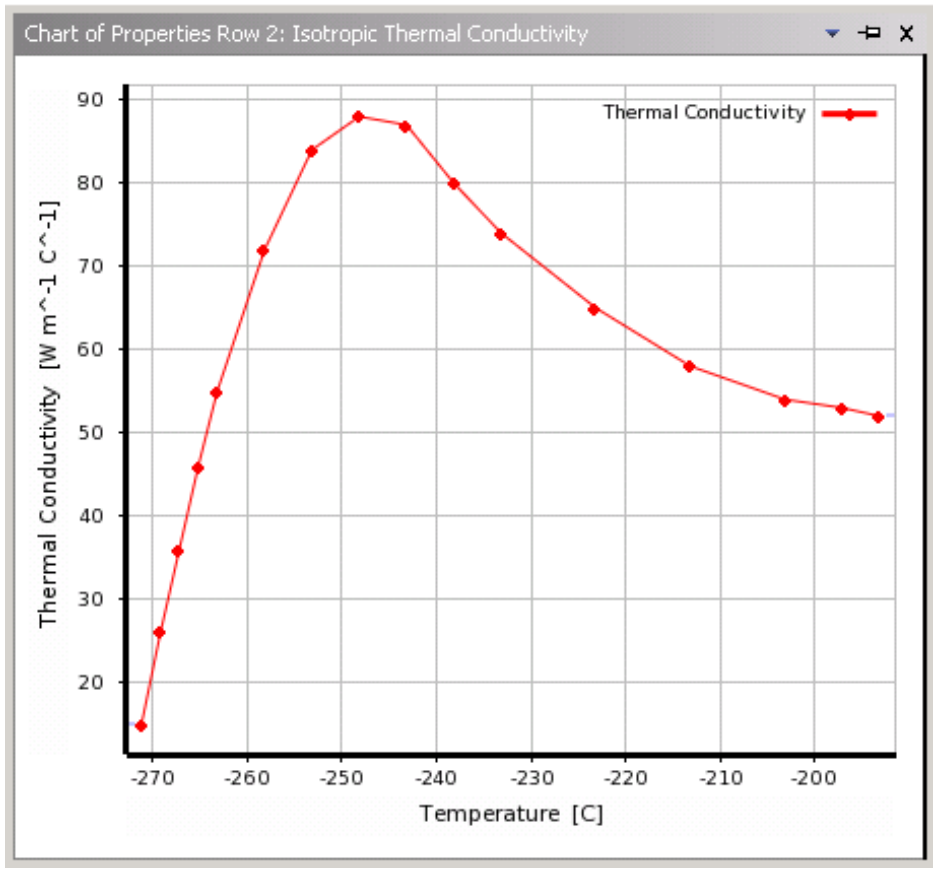
Location	Power dissipation from fundamental mode [mW]	Power dissipation from 1kW HOM [1)] [mW]	Total [mW]	Notes
Hook	0.60	0.0069	0.607	Rs=10 nΩ[2)]
Tee	0.0015	0.0054	0.007	Rs=10 nΩ[2)]
Probe	49	481	530	Rs=5 mΩ for fundamental Rs=8 mΩ for HOM
Gasket	107	0.96	108	Rs=1 mΩ[2)] for both fundamental and HOM

1) Most dominant mode in terms of power dissipation value is selected.
2) To be adjusted according to the resulting temperature. The results show negligible temperature increase. Therefore, the assumed Rs is valid.

Thermal study – Material data



Copper

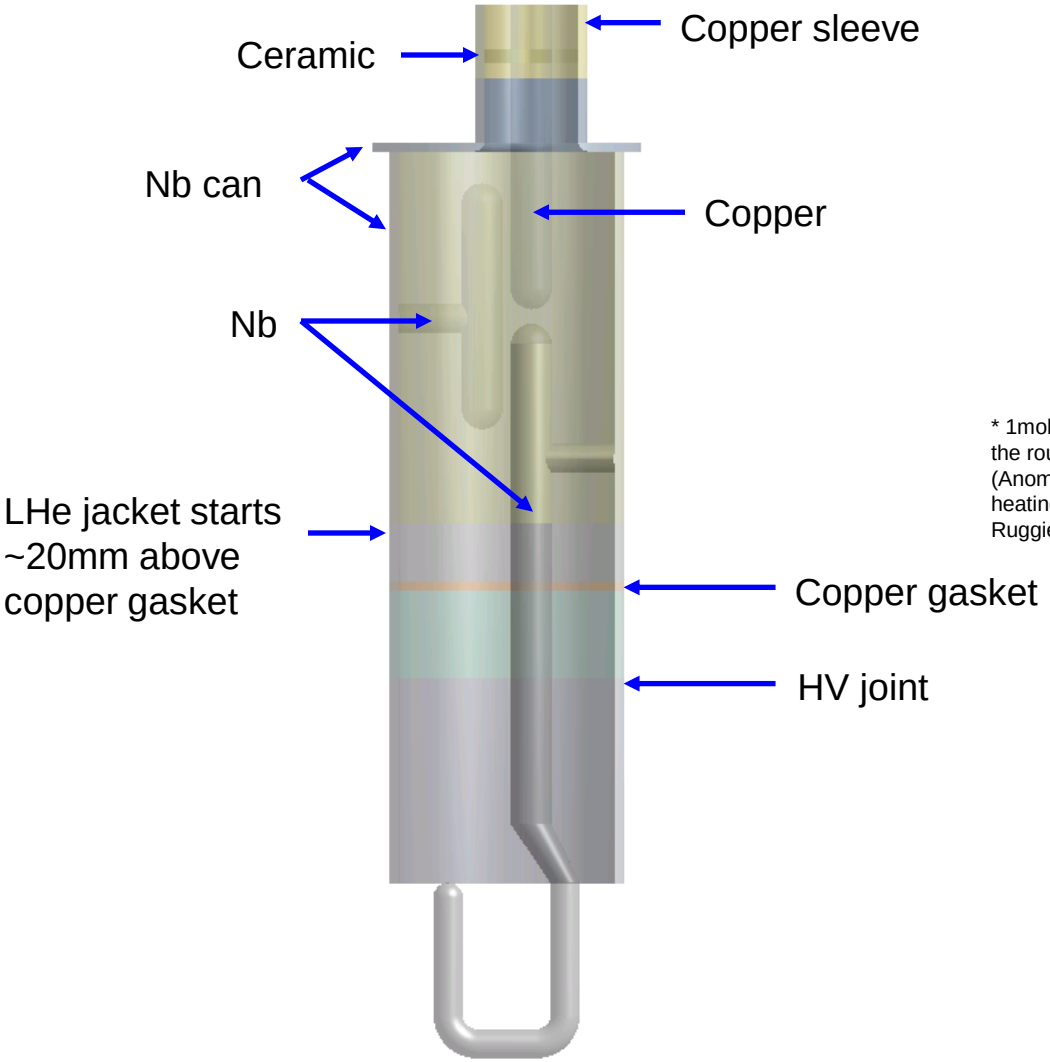


Niobium

Nb and Cu Data from 'BNL SELECTED CRYOGENIC DATA NOTEBOOK'

Ceramic from ANSYS

Boundary Conditions – Case 1

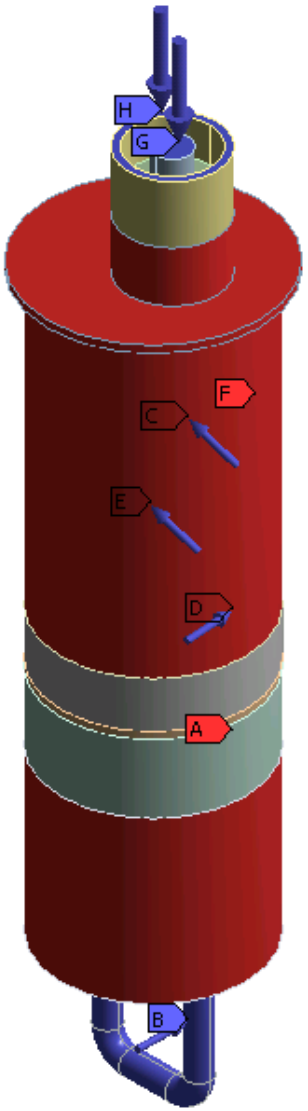


G: Steady-State Thermal
Steady-State Thermal
Time: 1. s

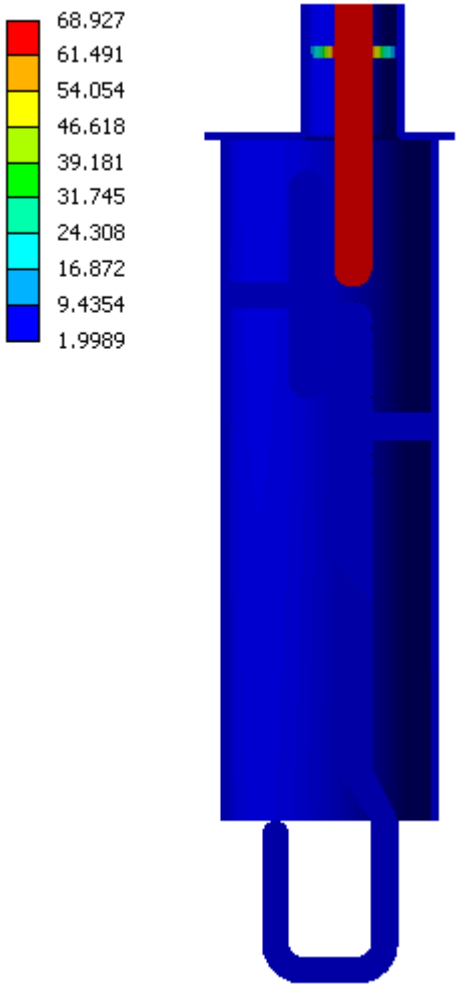
A	Temperature: 2. K
B	Heat Flow: 6.07e-004 W
C	Heat Flow 2: 0.53 W
* D	Heat Flow 3: 0.216 W
E	Heat Flow 4: 7.e-006 W
F	Temperature 2: 2. K
G	Heat Flow 5: 10. W
H	Heat Flow 6: 10. W

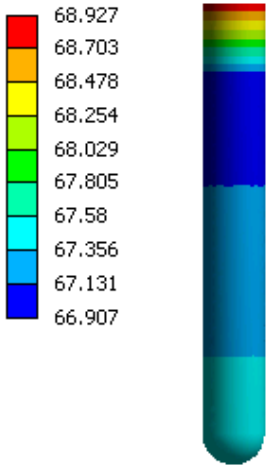
* 1mohm increased to 2mohm to account the roughness and strain effect of copper. (Anomalous skin effect and resistive wall heating by Weiren Chou and Francesco Ruggiero, 9/8/1995 CERN)

Power applied on extremity only

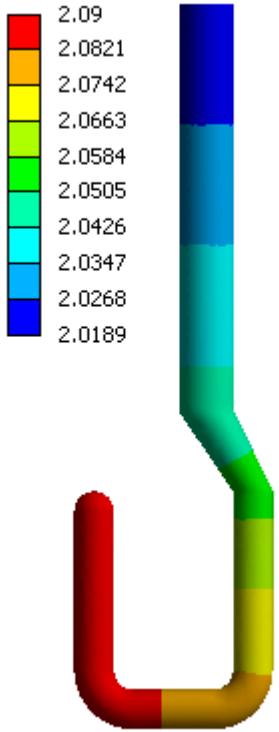


Results – Case 1

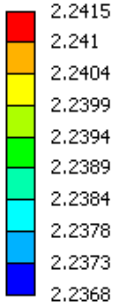


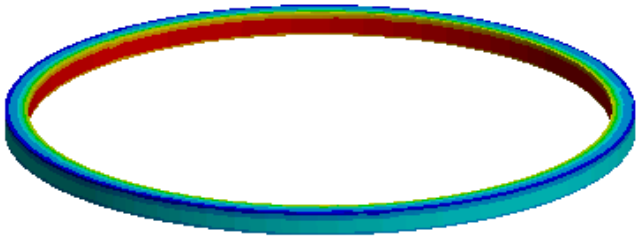


Copper probe



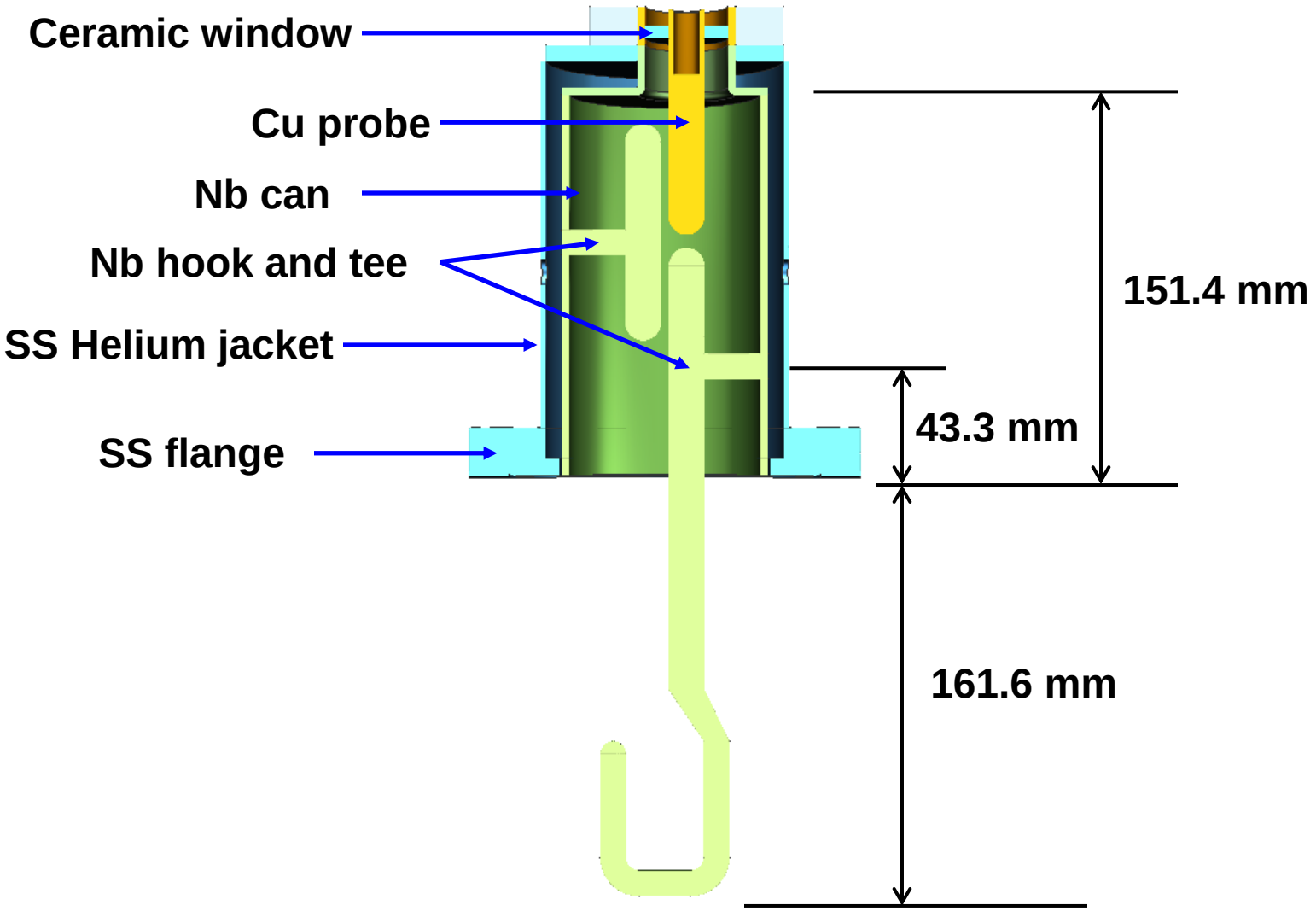
Nb hook



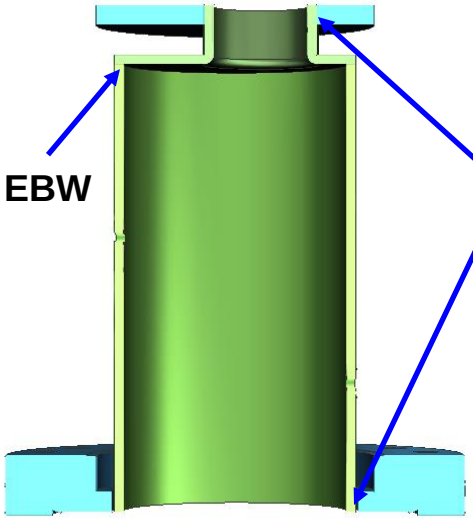


Copper gasket

H-HOM Coupler Fabrication

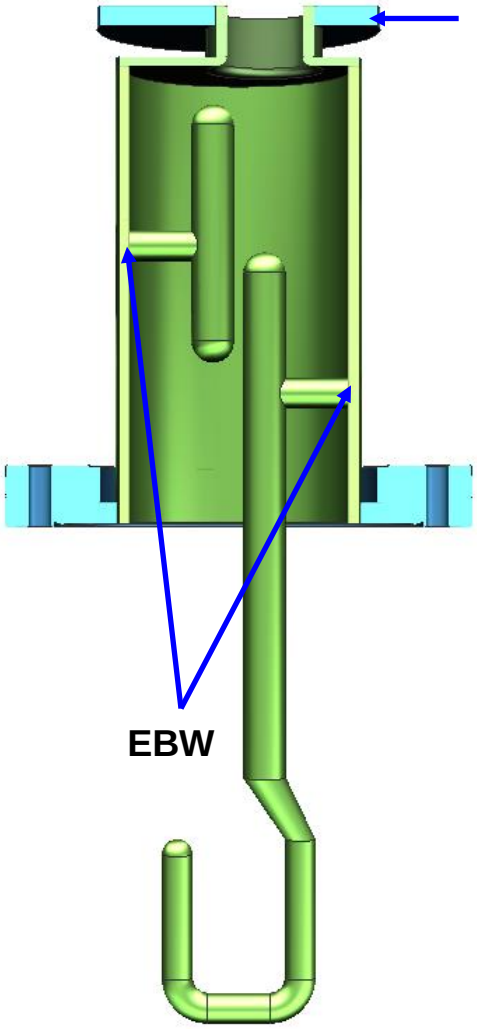


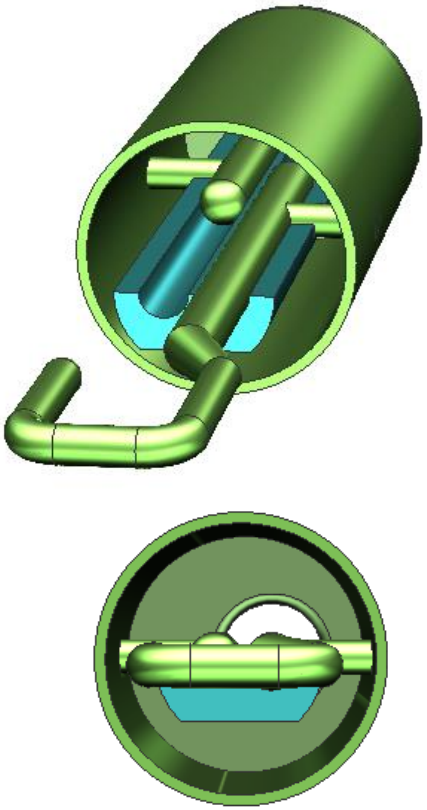
Assembly Process



After completion

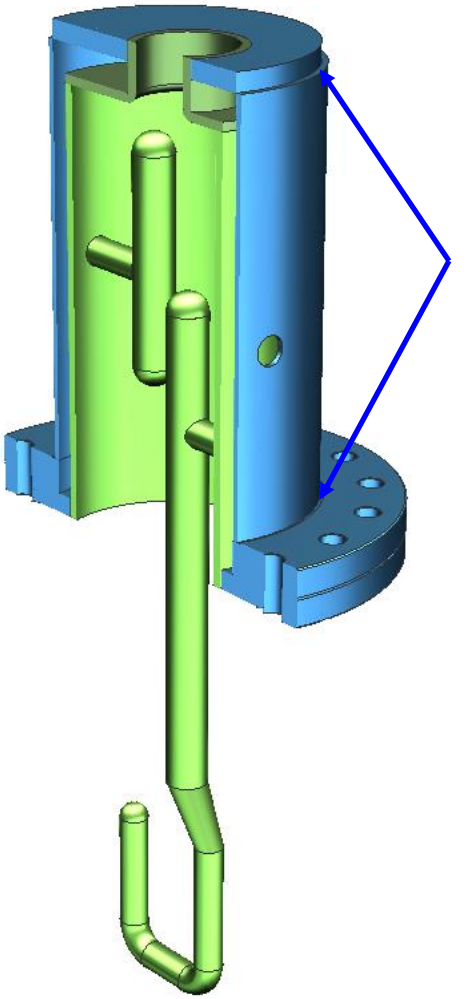
BCP

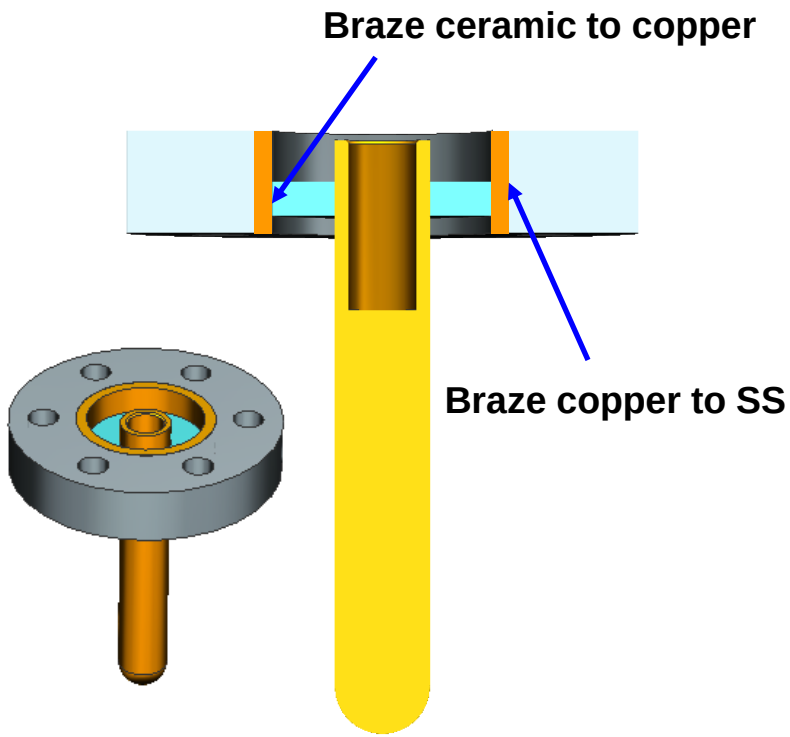




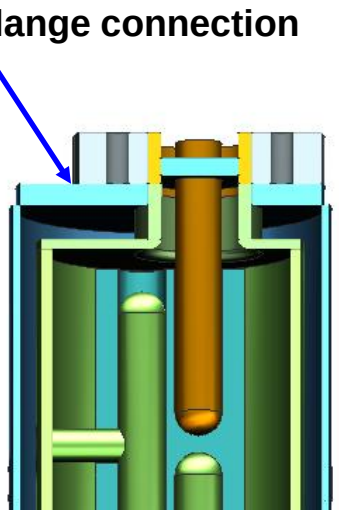
Fixtures for dimensional control

Assembly Process





Probe assembly design should be compatible with connector



Use fixture again during assembly

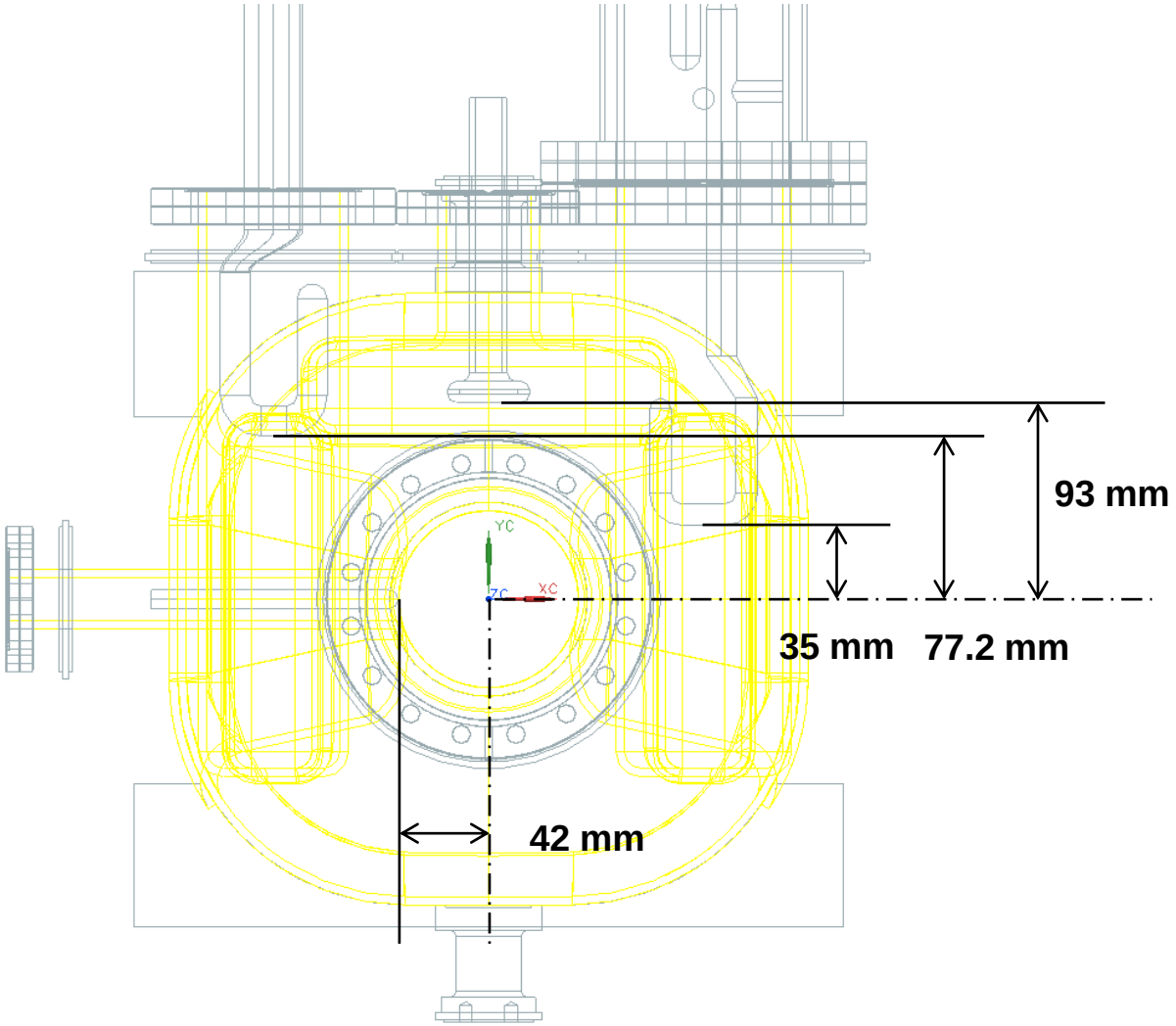
On-going Efforts

- Fabrication tolerance study – dimensional and alignment
- Multipacting study with CST – UK colleagues
- Fabrication process detail
- Coupler test – decoupled with cavity.

Thank You

- Zengahi Li, Suba De Silva, Rocio Olave – ODU/SLAC
- Keith Harding, Ed Daly, Larry Phillips – Jefferson Lab

Backup

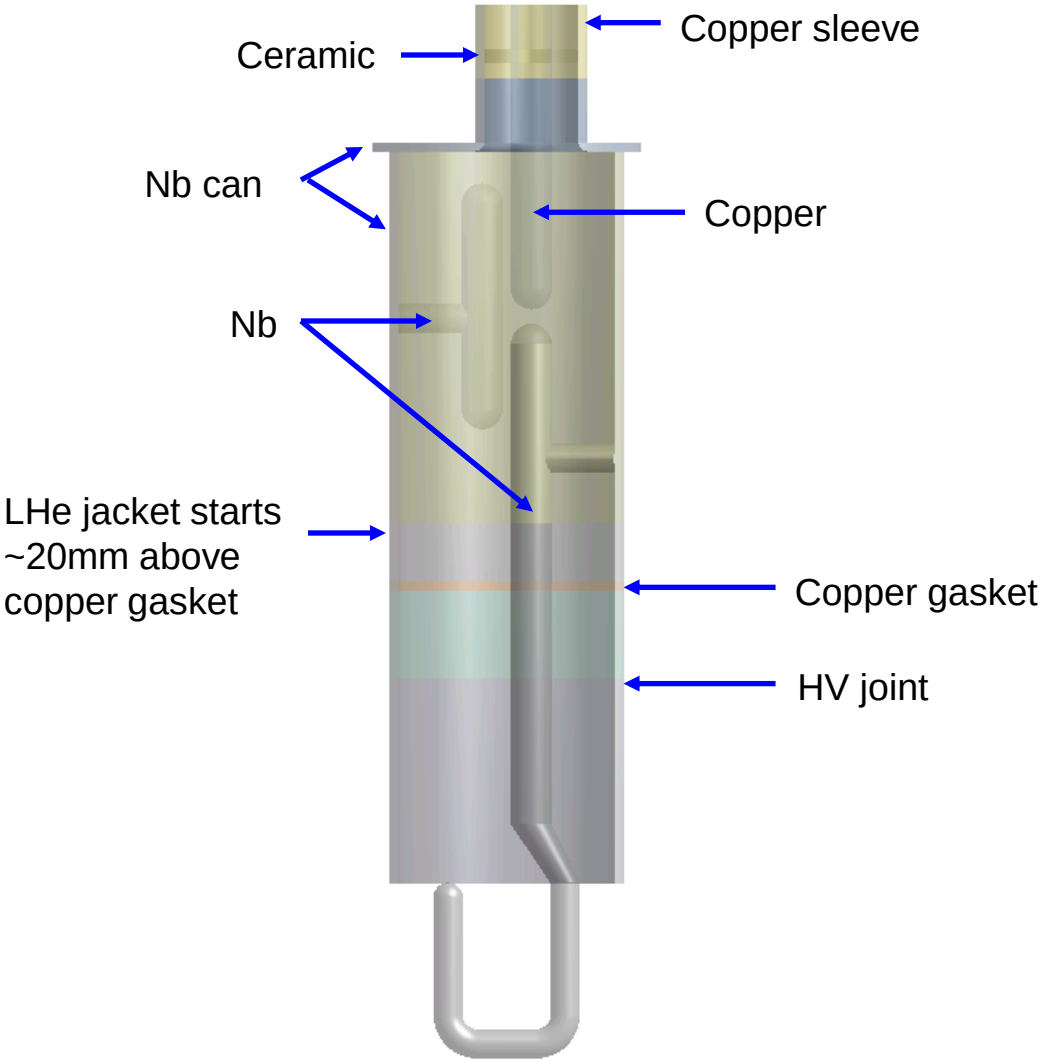


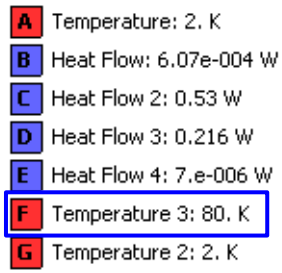
Backup

TABLE 21
Ceramic5 > Constants

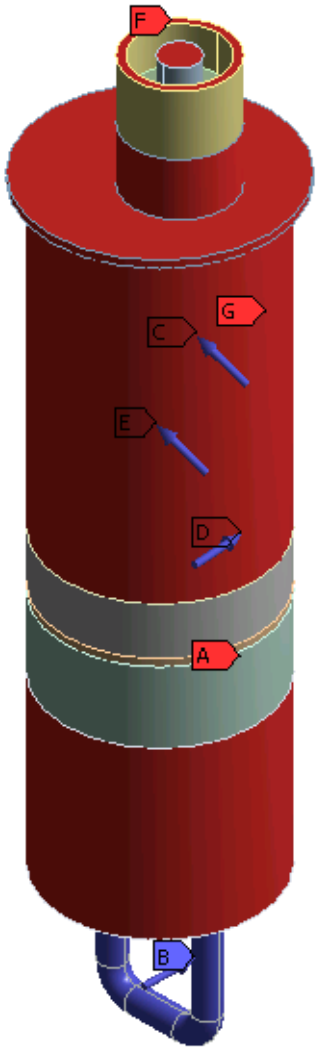
Thermal Conductivity	4.5 W m^-1 C^-1
Density	4900 kg m^-3
Specific Heat	800 J kg^-1 C^-1

Boundary Conditions – Case 2

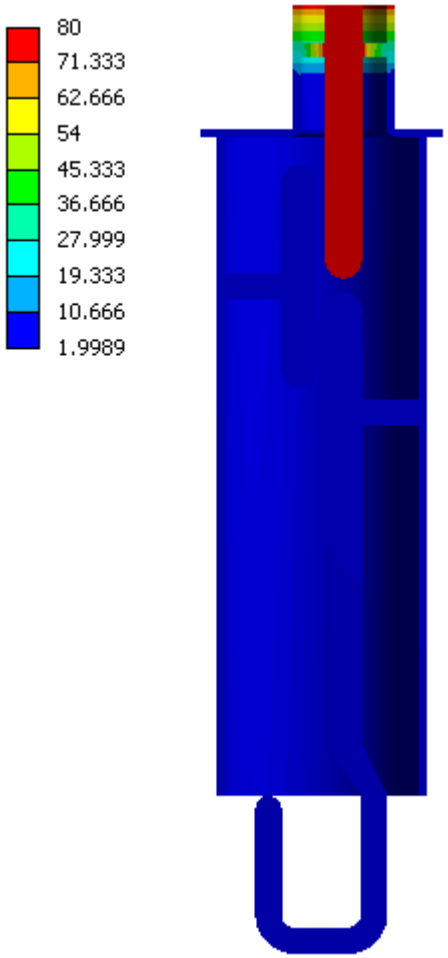


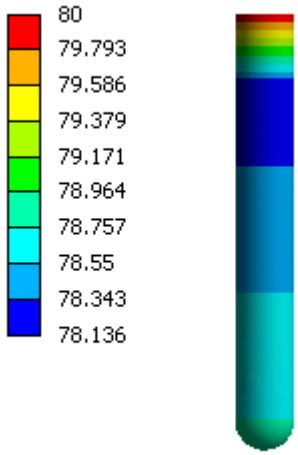


Power applied on extremity only



Results – Case 2





Copper probe

- Nb hook and gasket remains same as the case 1.
- However this case is NOT realistic at all.
- The heat flow to the copper probe and sleeve is