

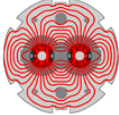
LARP



Crab Cavity – RF Design and Modeling

Zenghai Li

Nov. 20, 2014



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Acknowledgments

- **ODU**
Subashini De Silva, Jean Delayen,
Rocio Olave, HyeKyoung Park
- **BNL**
Qiong Wu, Silvia Verdú-Andres, Binping Xiao
- **Cockcroft, Lancaster**
Graeme Burt, Ben Hall

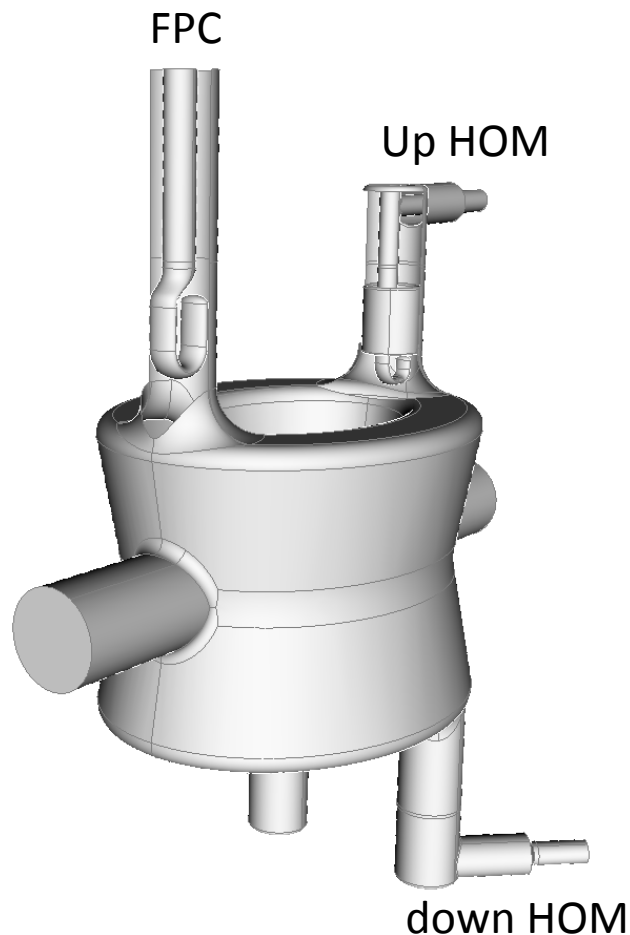


Outline



- DQW cavity (2014-08-08 model)
 - Coupler RF heating
 - Coupler Multipacting analysis
- RFD cavity
 - Coupler multipacting analysis
 - Coupler RF heating
 - HOM coupler filter dimension sensitivity
 - HOM coupler window and 90-degree bend
 - HOM coupler thermal and engineering design
- Summary

DQW RF Heating

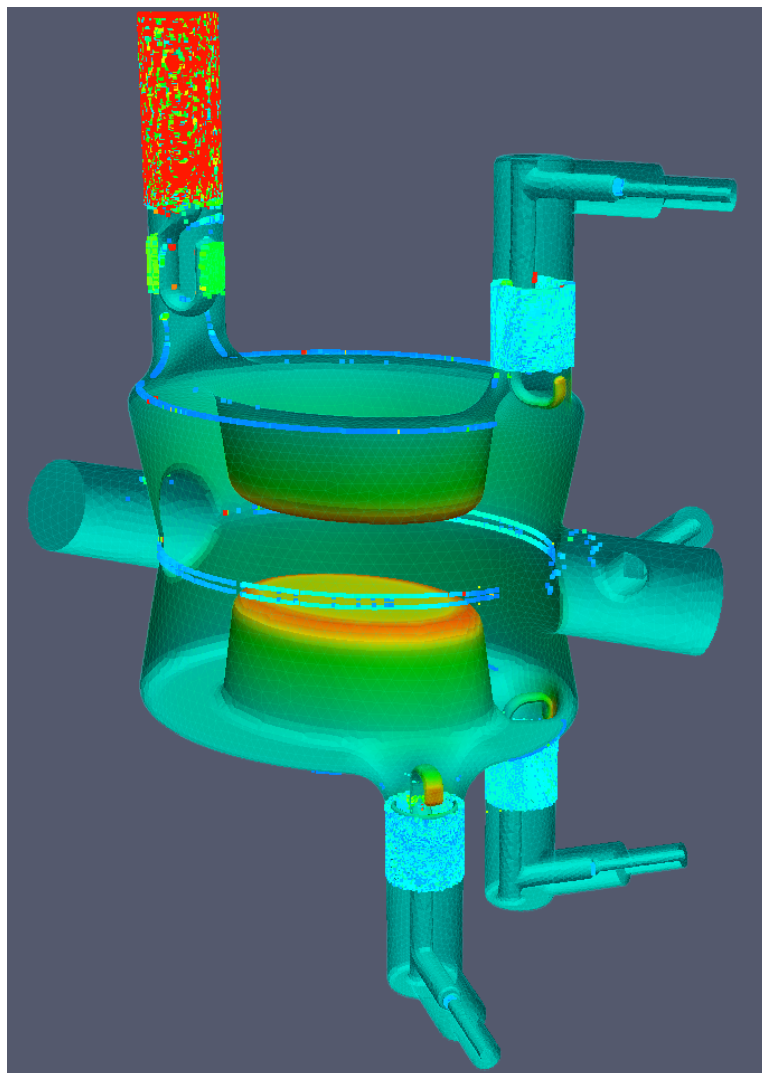


(based on 2014-08-08
DQW cavity model)

Part	Loss at $V_T=3.34\text{MV}$ (W)
FPC hook (Cu)	1.03E+02
down HOM gasket (Cu)	4.88E-03
down HOM probe (Cu)	2.64E-04
down HOM hook (Nb)	1.74E-02
down HOM tank (Nb)	2.23E-07
up HOM gasket (Cu)	4.34E-03
up HOM probe (Cu)	2.32E-04
up HOM hook (Nb)	1.43E-02
up HOM tank (Nb)	1.83E-07

- Nb: 10 n Ω
- Cu (gasket): 1 m Ω
- Cu (probe): 5 m Ω

DQW MP Simulation



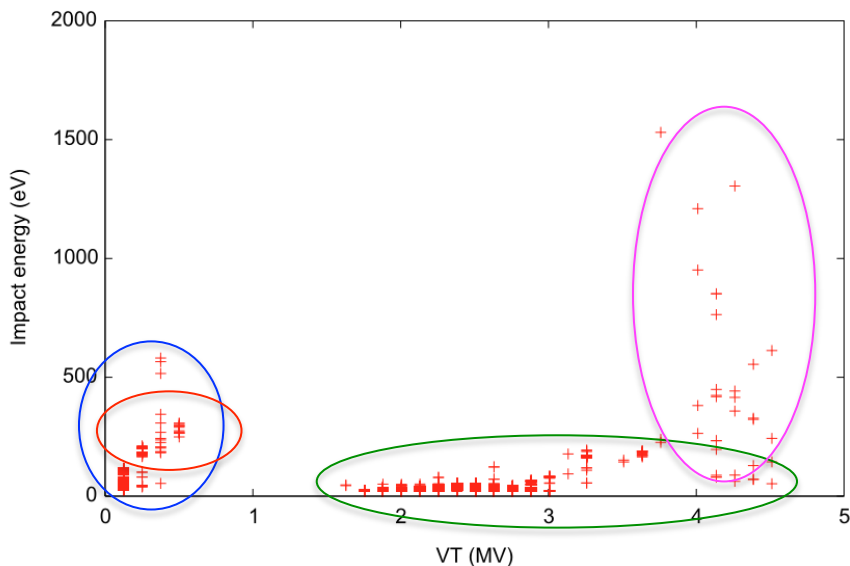
- Result shown are for the 2014-08-08 DQW cavity model
- Couplers are being re-optimized (based on some of these results)
- New model to be analyzed when ready



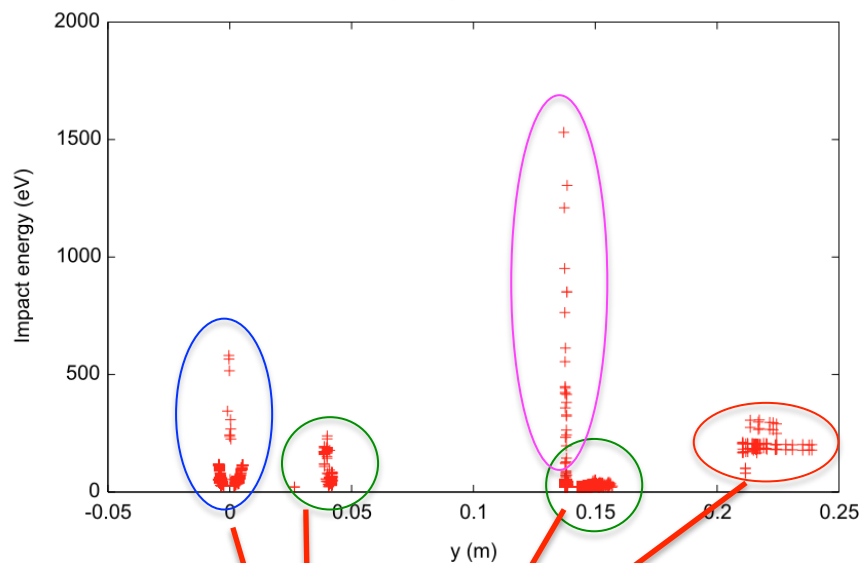
DQW: MP on cavity body (FPC end)



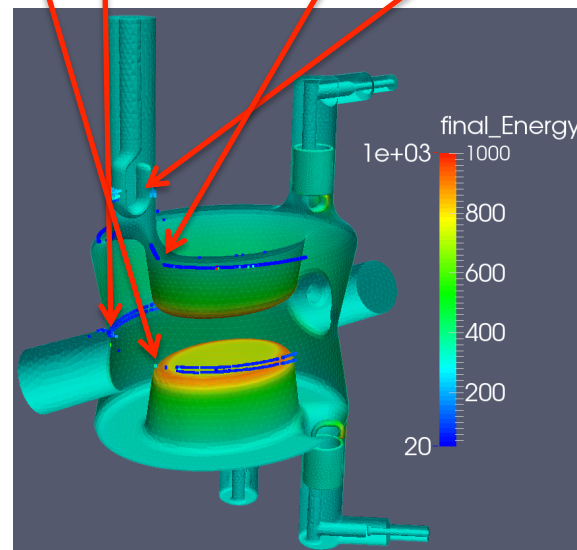
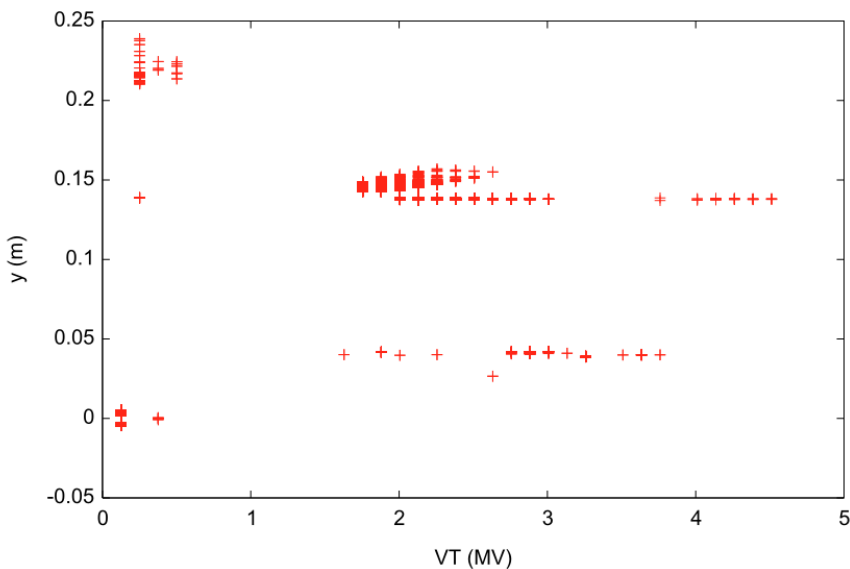
Multipacting on Cavity Body

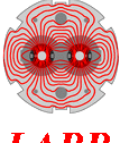


Multipacting on Cavity Body



Multipacting on Cavity Body

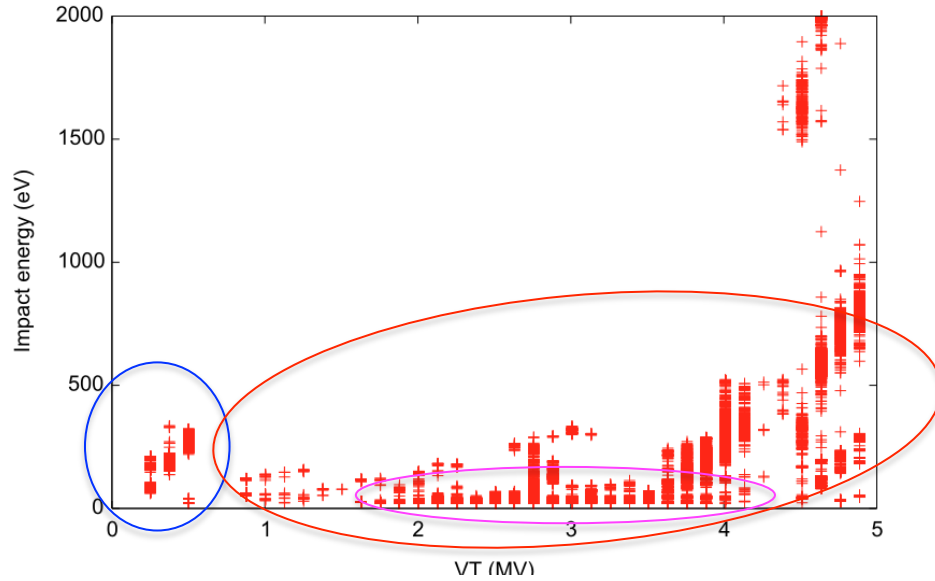




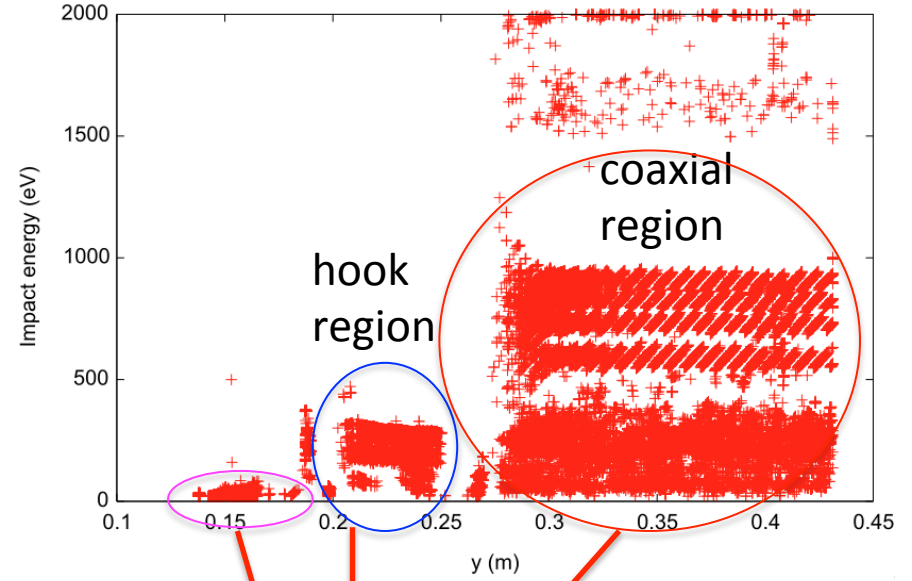
DQW: MP in FPC



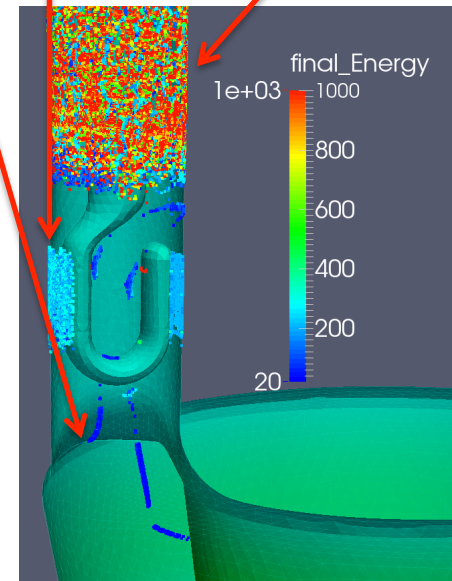
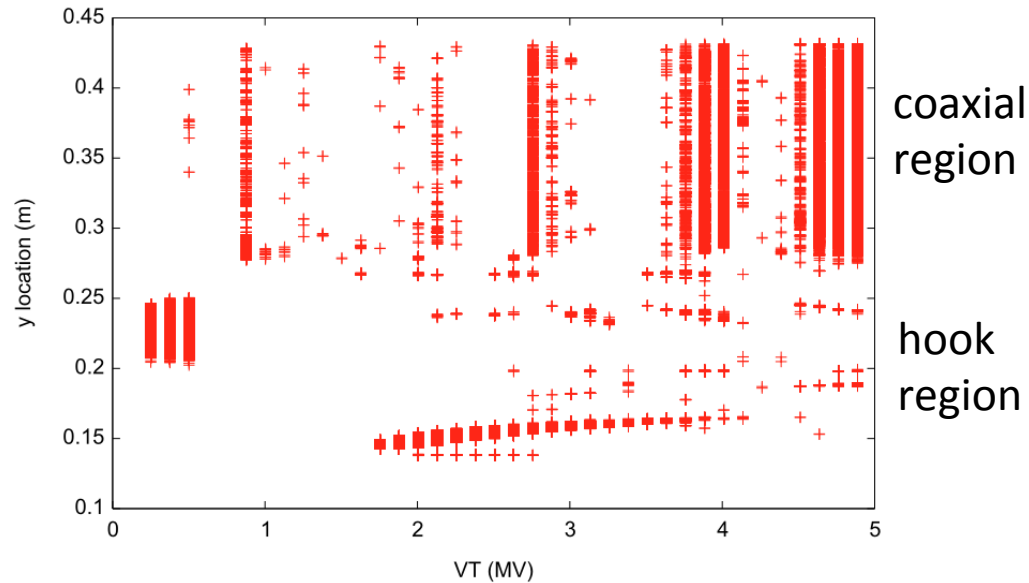
Multipacting on FPC Coupler

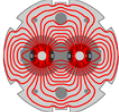


Multipacting on FPC Coupler

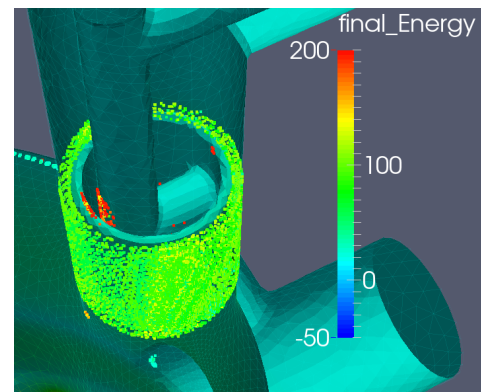
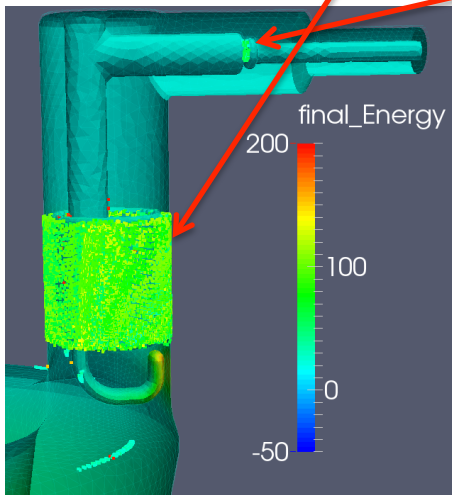
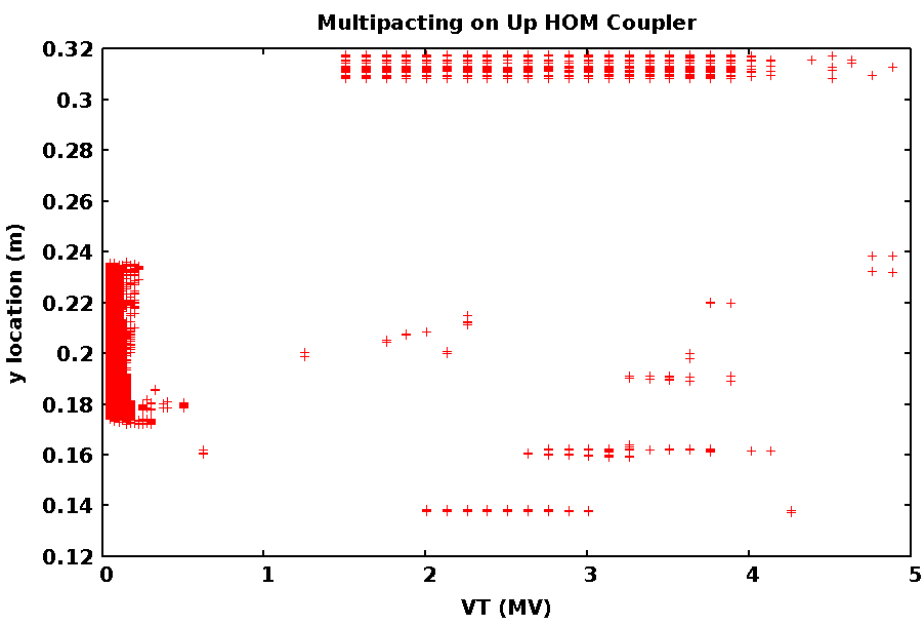
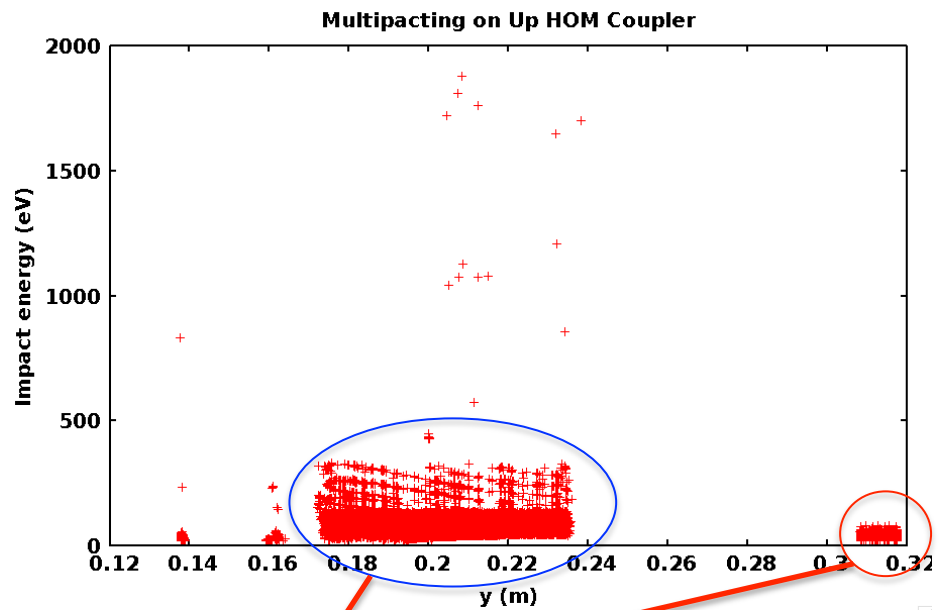
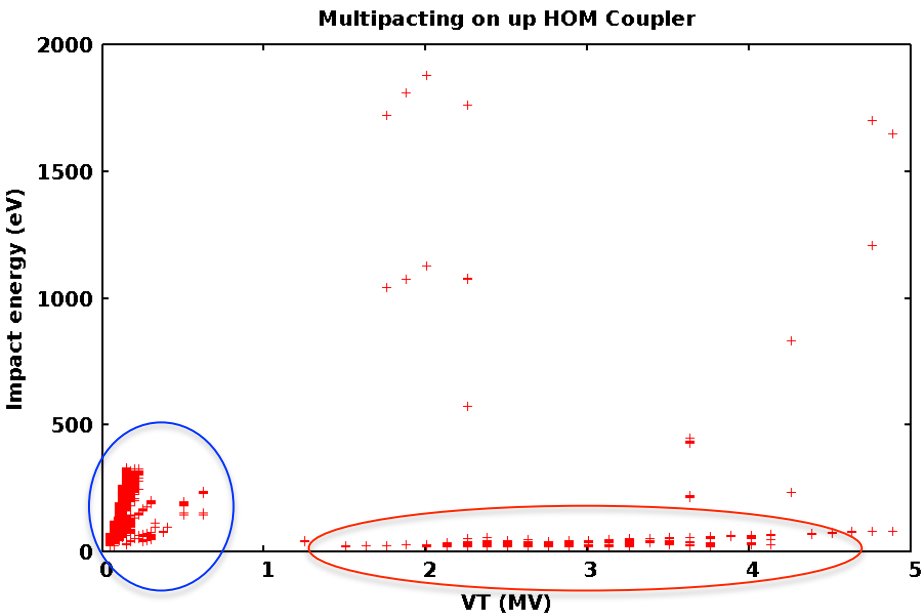


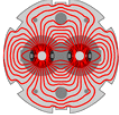
Multipacting on FPC Coupler





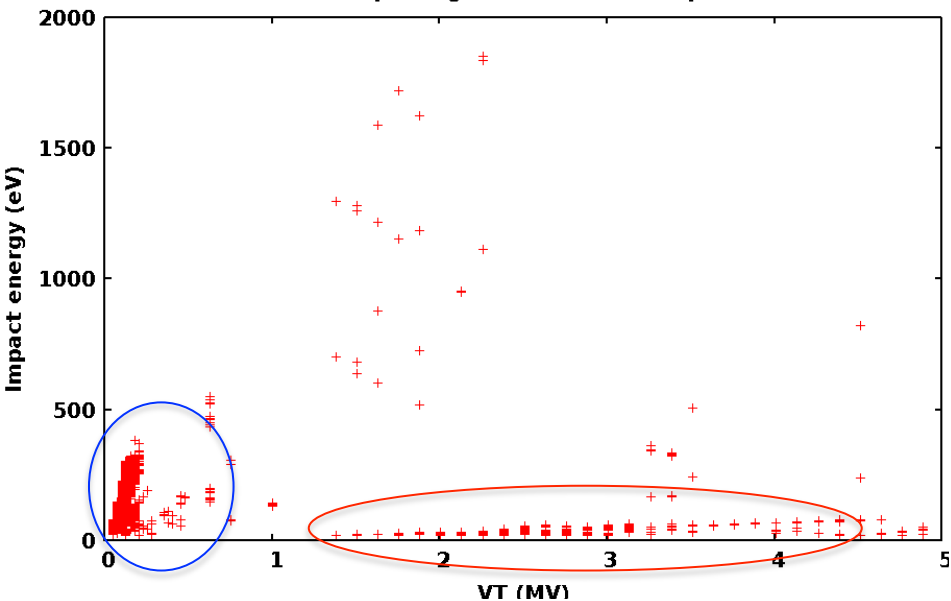
DQW: MP in HOM Coupler (Top HOM)



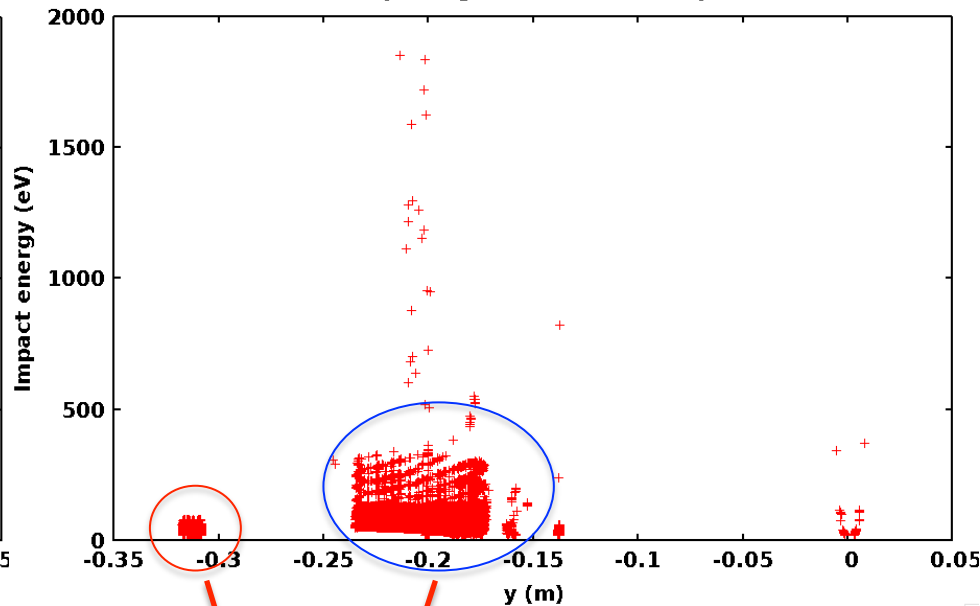


DQW: MP in HOM coupler (bottom HOM)

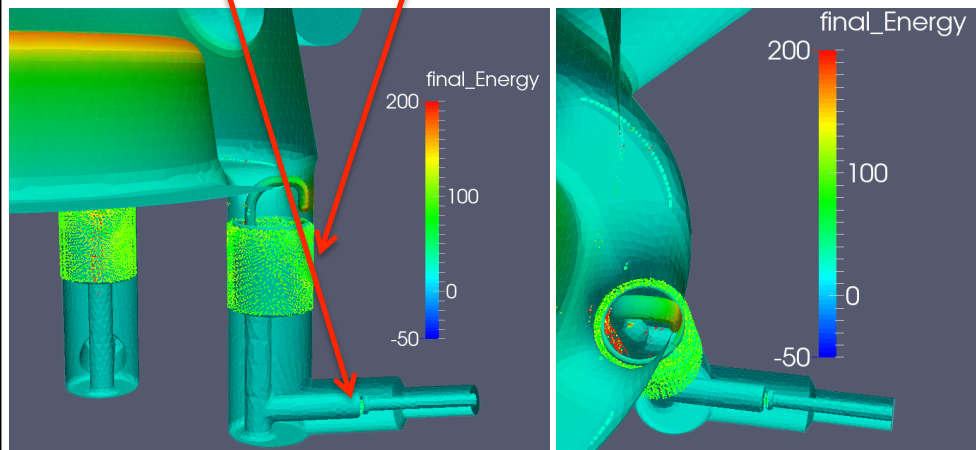
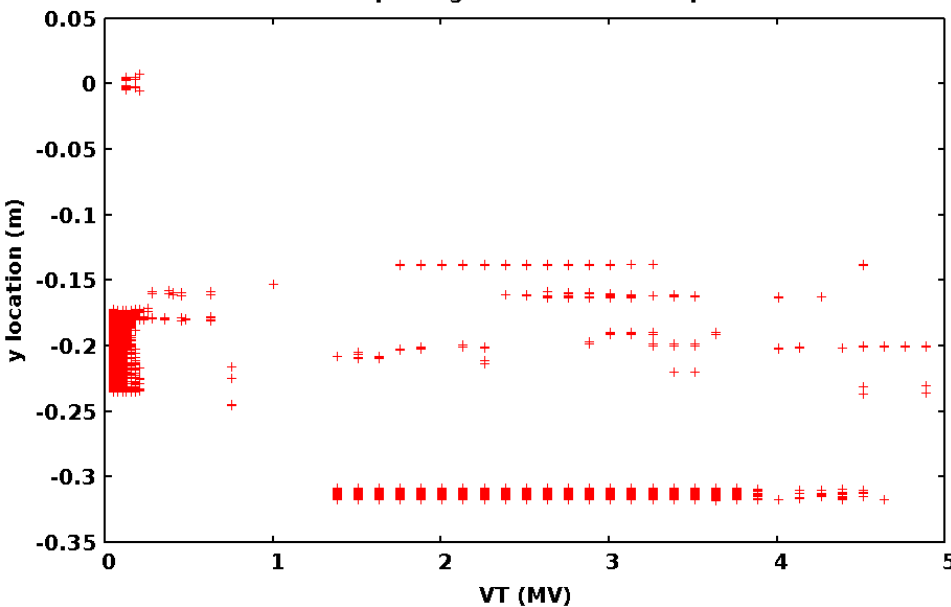
Multipacting on Down HOM Coupler



Multipacting on Down HOM Coupler

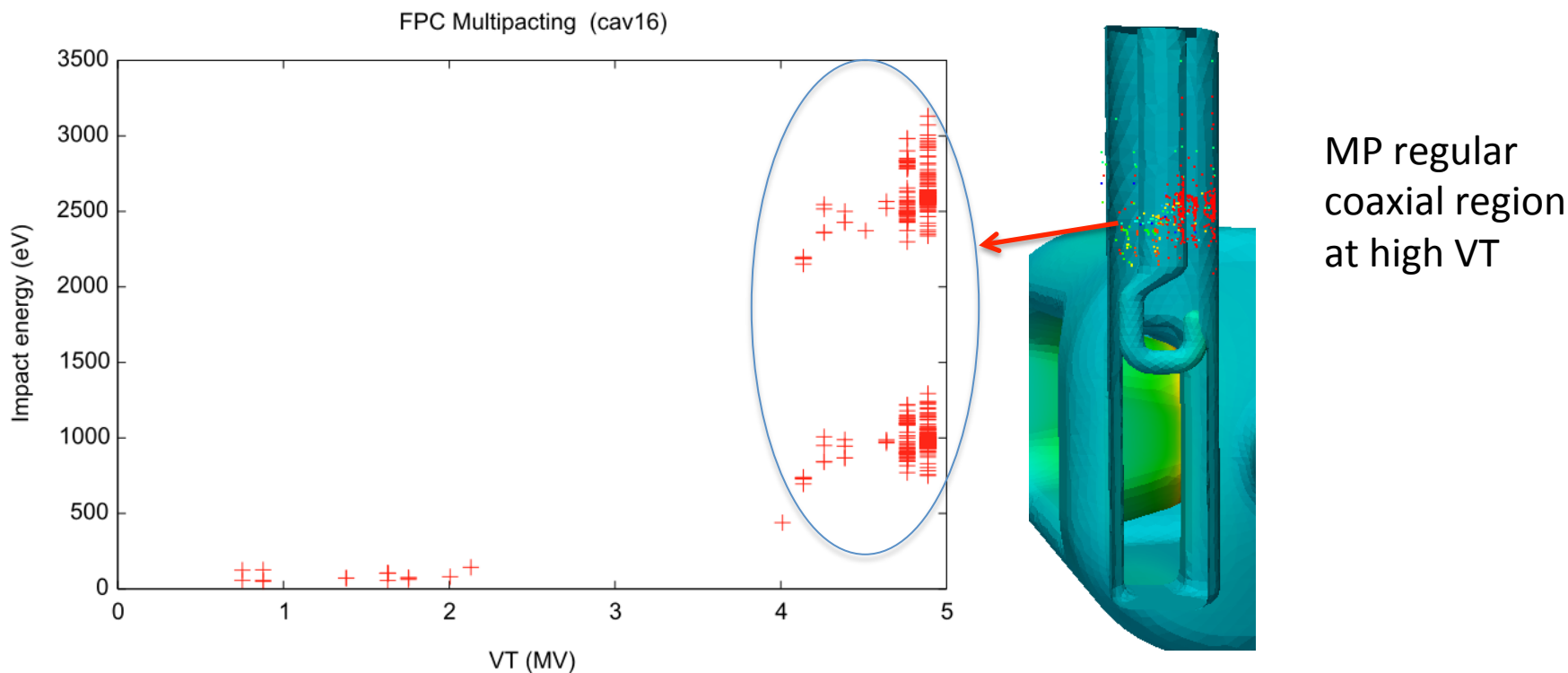


Multipacting on Down HOM Coupler



RFD: Multipacting in FPC Coupler

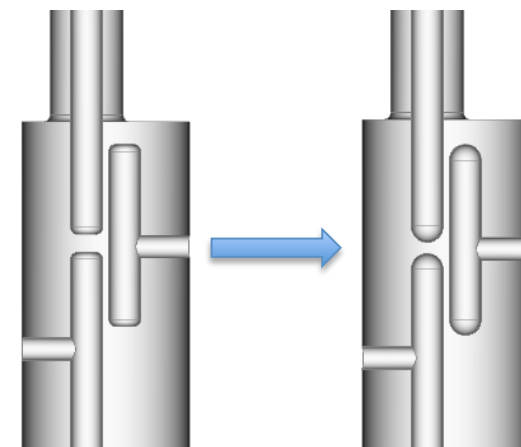
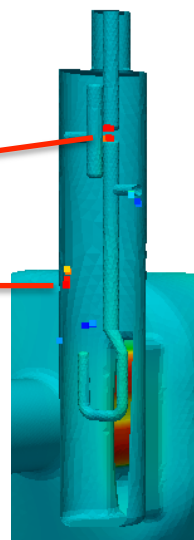
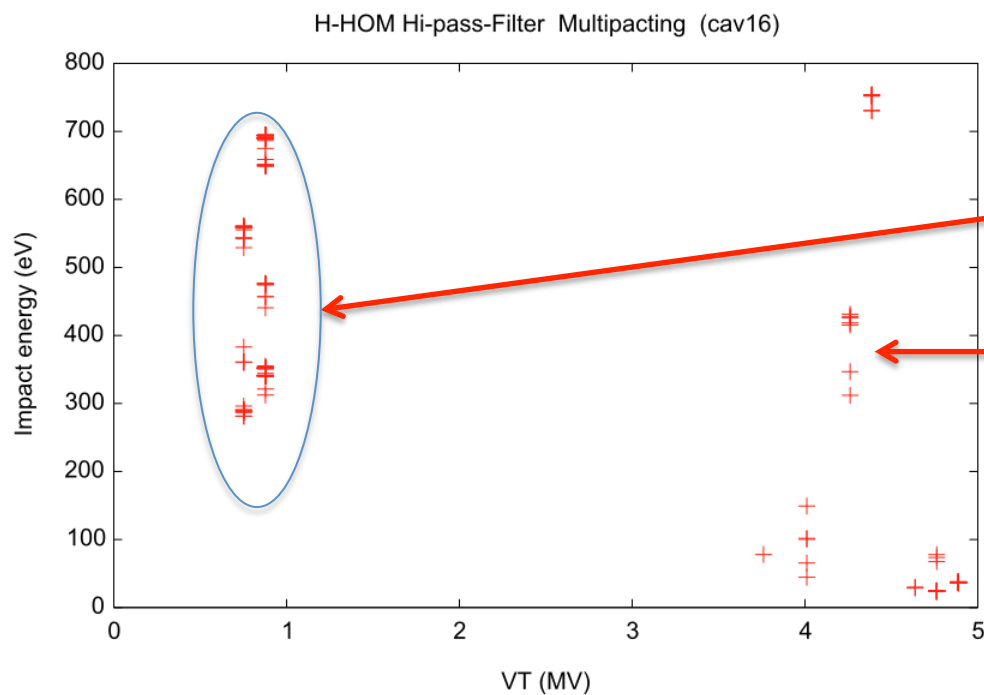
- No multipacting in the hook region
- Has resonant trajectories in the coaxial region at higher deflecting voltages
- Nominal deflecting voltage $V_T = 3.4$ MV





RFD: Multipacting in Hi-pass Filter H-HOM Coupler

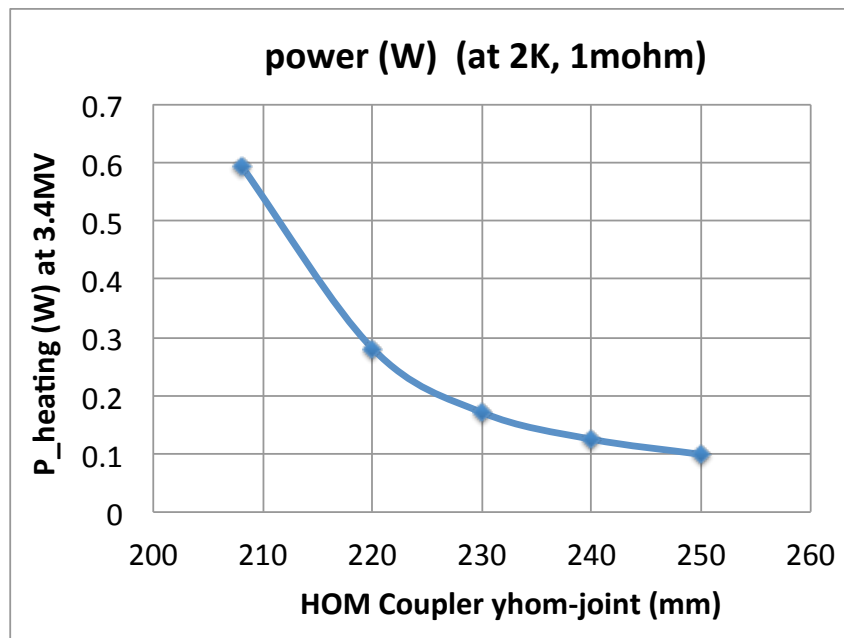
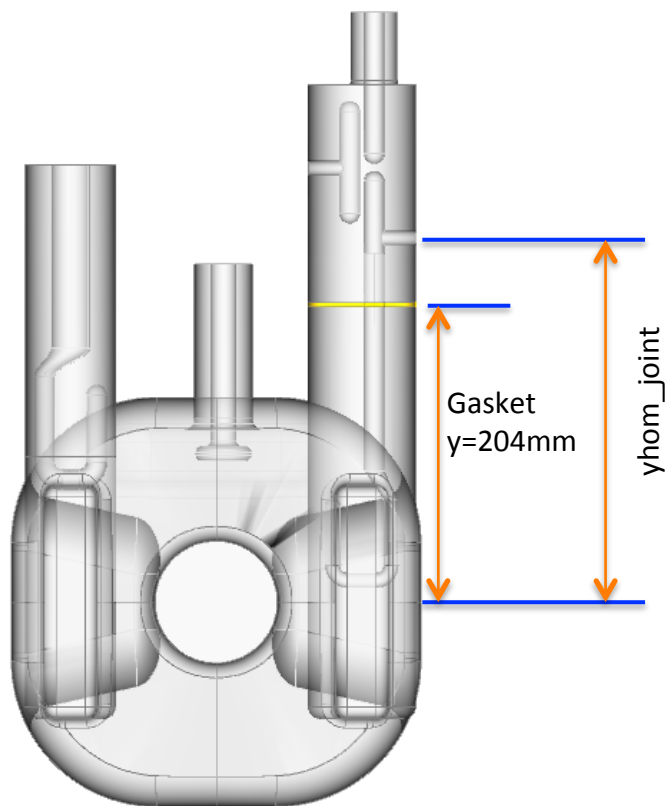
- MP resonances found in the gap if there are flat surfaces
- Eliminated MP with a full rounding
- Nominal deflecting voltage $V_T = 3.4\text{MV}$



MP trajectories in the gap Removed

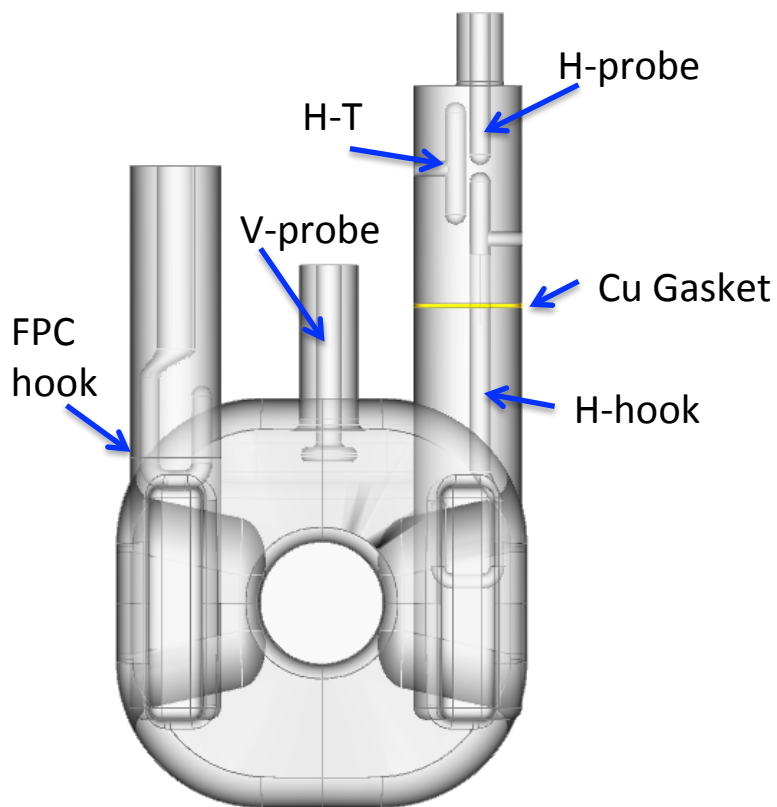
HOM Gasket Heating

- At 3.4MV deflecting voltage
- Copper gasket at 2K ($R=1\text{mohm}$)



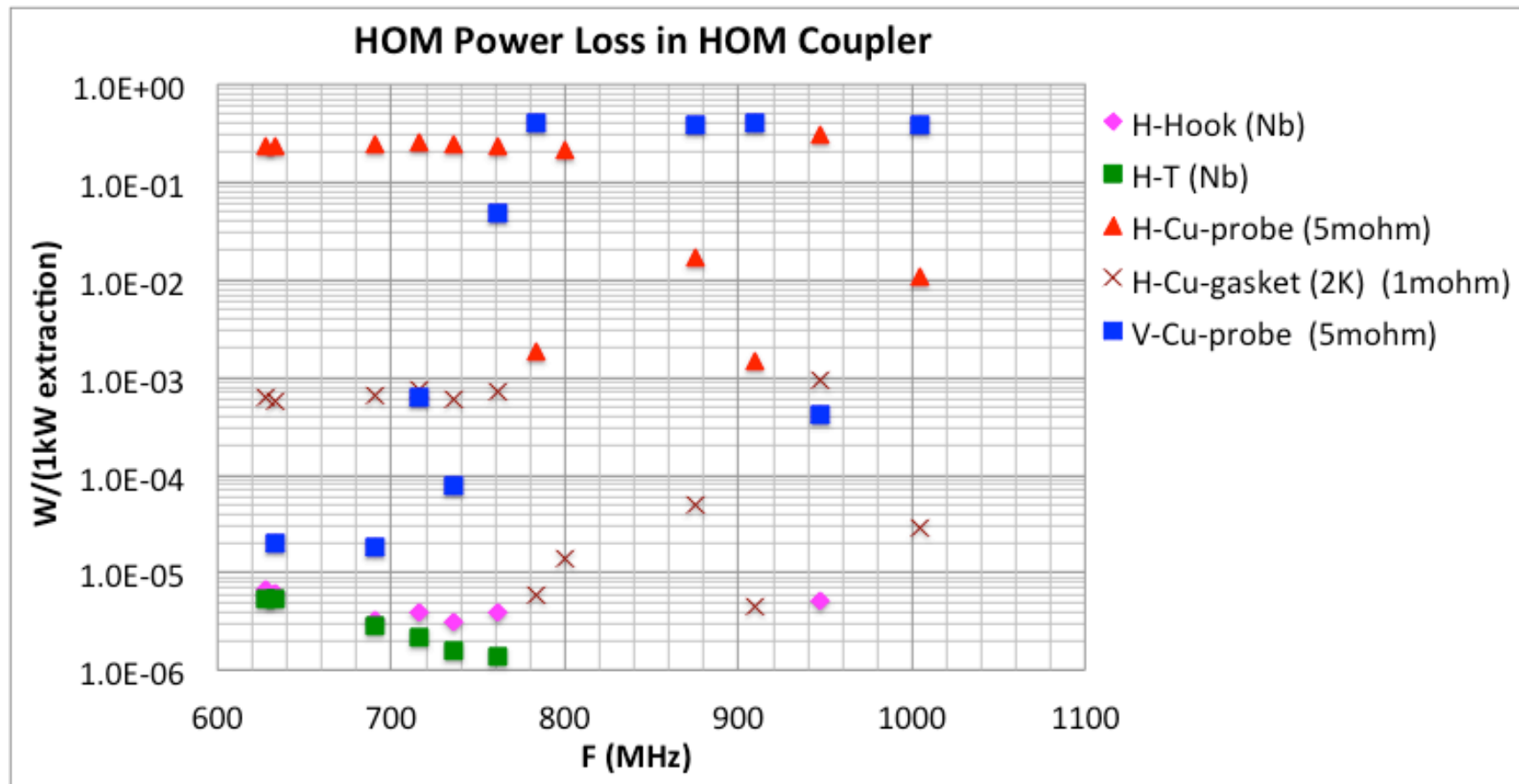
HOM Gasket Heating

- At 3.4MV deflecting voltage
- Copper gasket at 2K ($R=1\text{mohm}$)



Coupler part	RF Heating (W)	
fpc-hook	6.75E+01	
HHOM Cu gasket	1.07E-01	2K
H-hook	5.99E-04	2K
H-T	1.44E-06	2K
H probe	4.90E-02	2K
V-probe	4.66E-01	RoomT

HOM Power Heating in Couplers



HOM heating calculated assuming 1kW power extraction for each mode



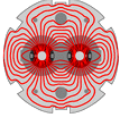
HOM Power Heating in Couplers

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)	V-Cu-probe (5mohm)
400	5.989E-04	1.442E-06	4.899E-02	1.073E-01	4.665E-01
0.0	6.846E-06	5.421E-06	2.329E-01	5.110E-04	1.776E-08
0.0	6.236E-06	5.324E-06	2.384E-01	4.820E-04	2.013E-05
0.0	3.358E-06	2.854E-06	2.475E-01	5.710E-04	1.813E-05
0.0	3.870E-06	2.199E-06	2.525E-01	6.850E-04	6.218E-04
0.0	3.100E-06	1.602E-06	2.497E-01	5.600E-04	7.741E-05
0.0	3.902E-06	1.373E-06	2.330E-01	6.830E-04	4.892E-02
0.0	3.215E-08	9.550E-09	1.883E-03	5.590E-06	4.034E-01
0.0	1.366E-07	2.548E-07	2.185E-01	1.370E-05	4.355E-08
0.0	2.675E-07	5.408E-08	1.671E-02	5.140E-05	3.796E-01
0.0	2.458E-08	4.433E-09	1.472E-03	4.860E-06	4.046E-01
0.0	5.139E-06	8.659E-07	3.036E-01	1.050E-03	4.163E-04
0.0	1.586E-07	2.617E-08	1.058E-02	3.230E-05	3.888E-01

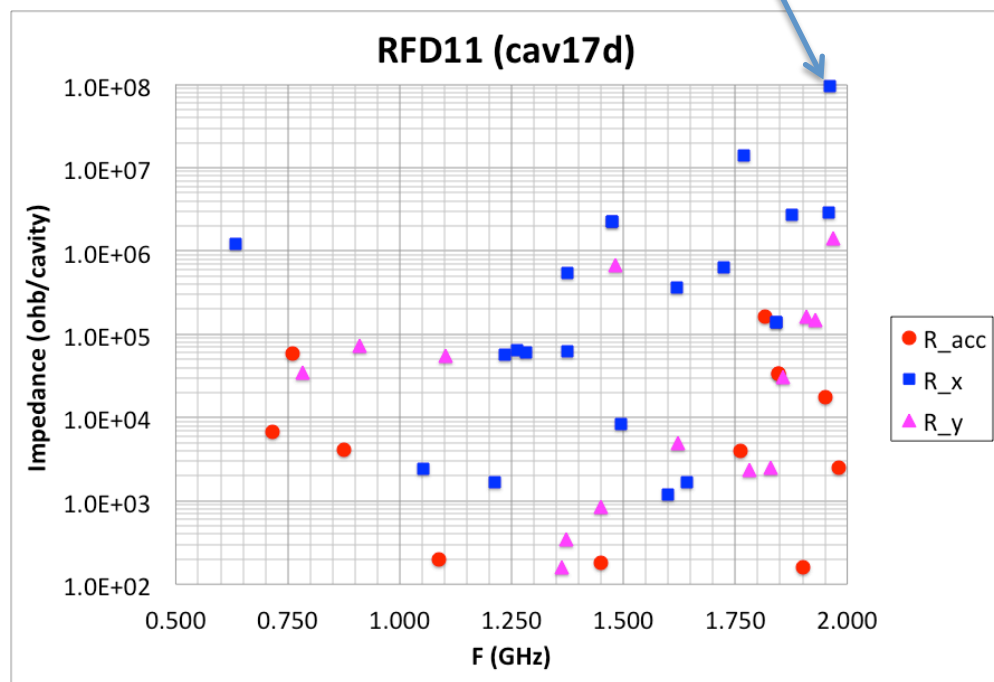
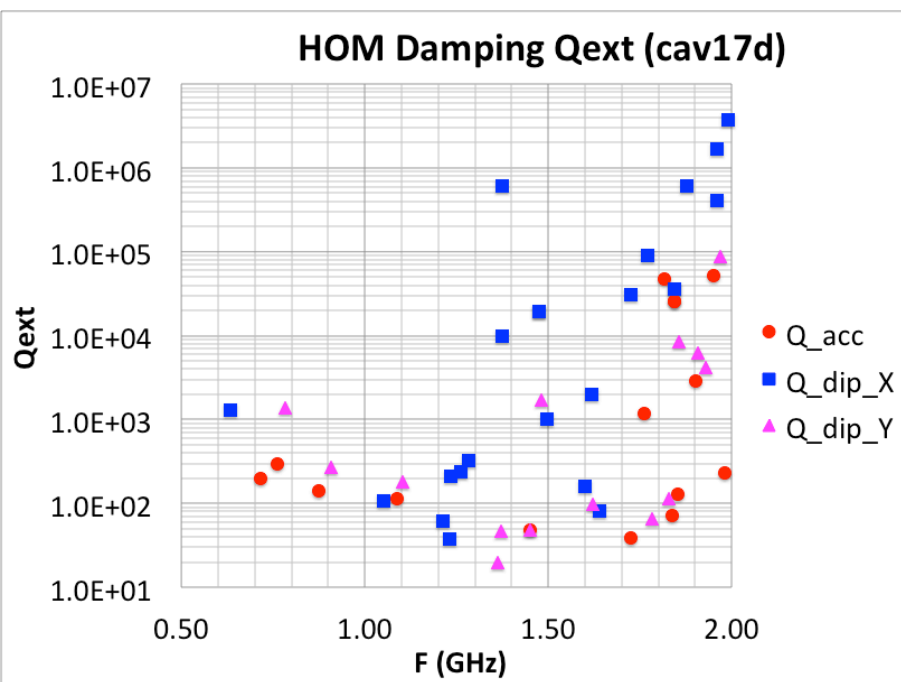
Hook joint at 240mm

HOM heating calculated assuming 1kW power extraction for each mode

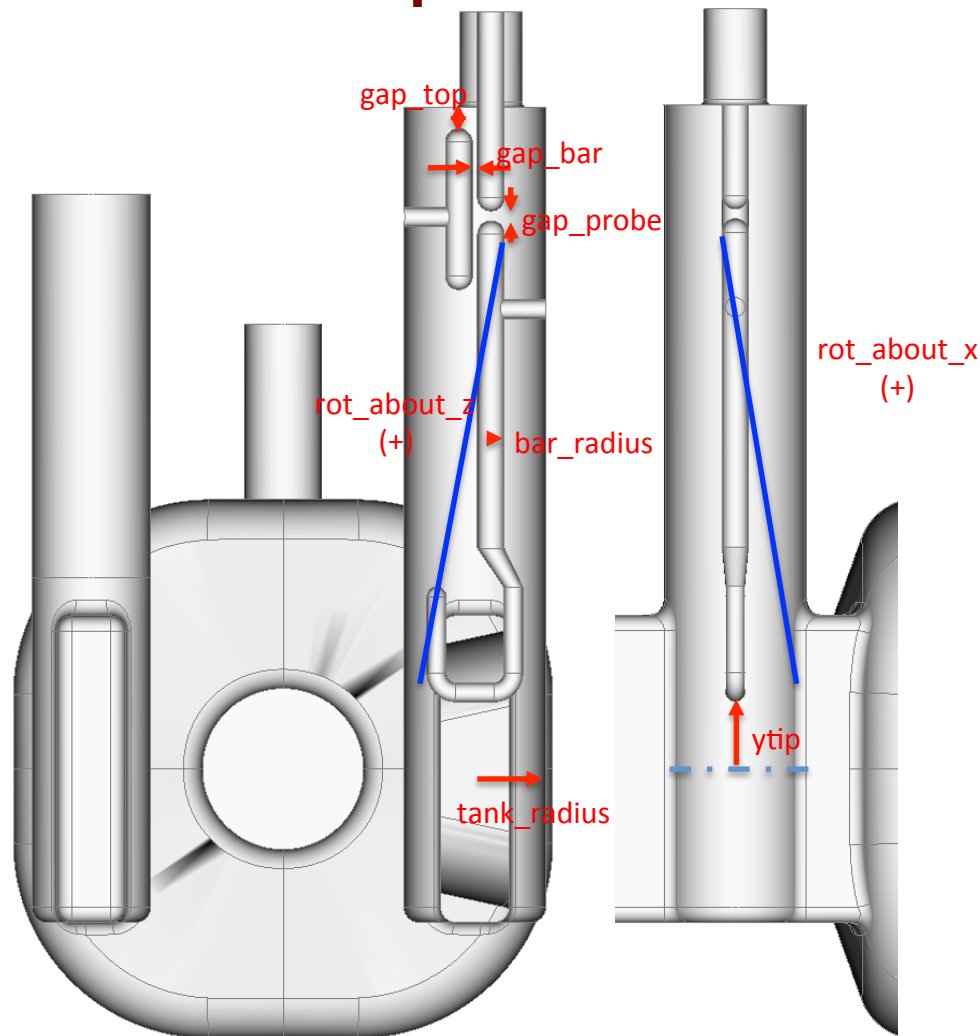


RFD (cav17d) HOM Parameters

Can be reduced by shaping the profile of the V-coupler probe tip



Impedance definition does not have the (1/2) factor

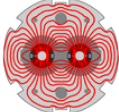


Impact of dimension deviation on:

- HOM damping
- Operating mode rejection



Engineering tolerance

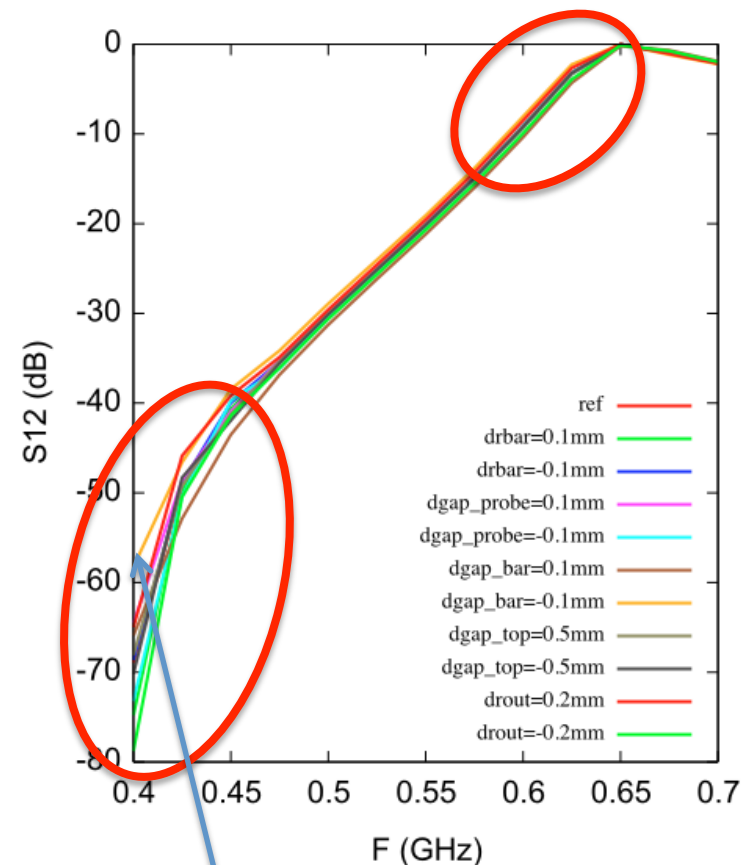
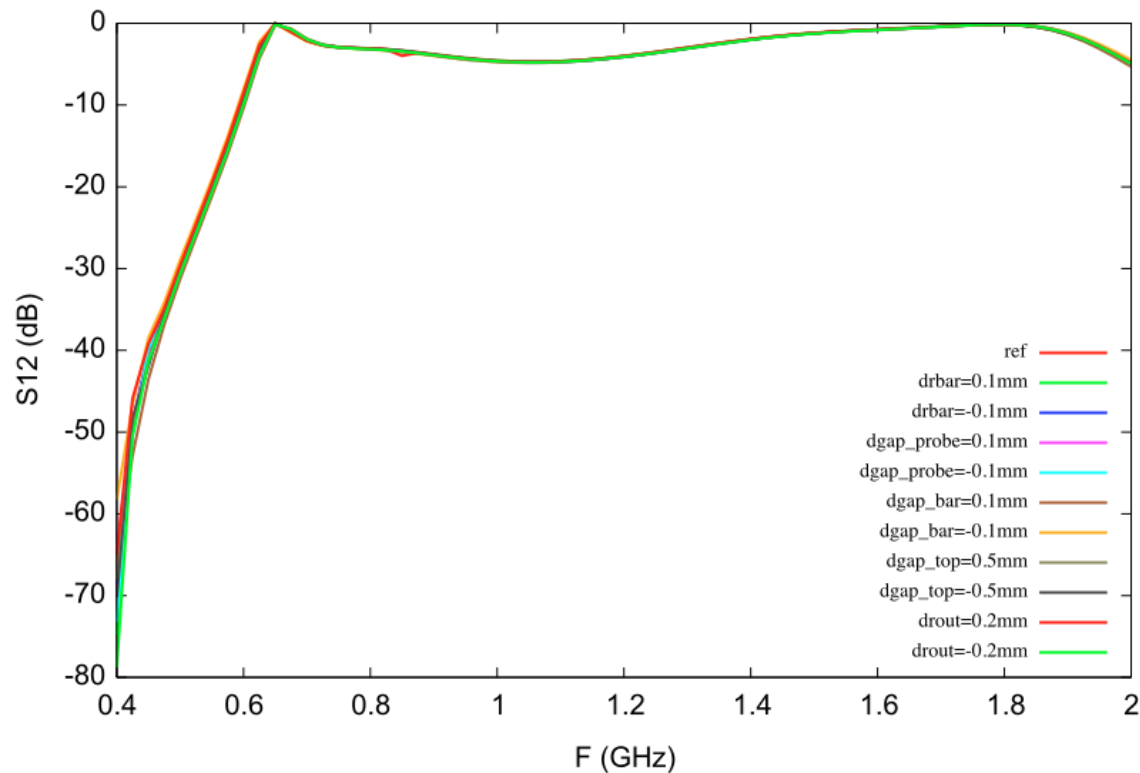


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Filter S21 vs dimension deviations

RFD HOM Hi-Pass Filter Coupler: S12 vs Dimension Deviation



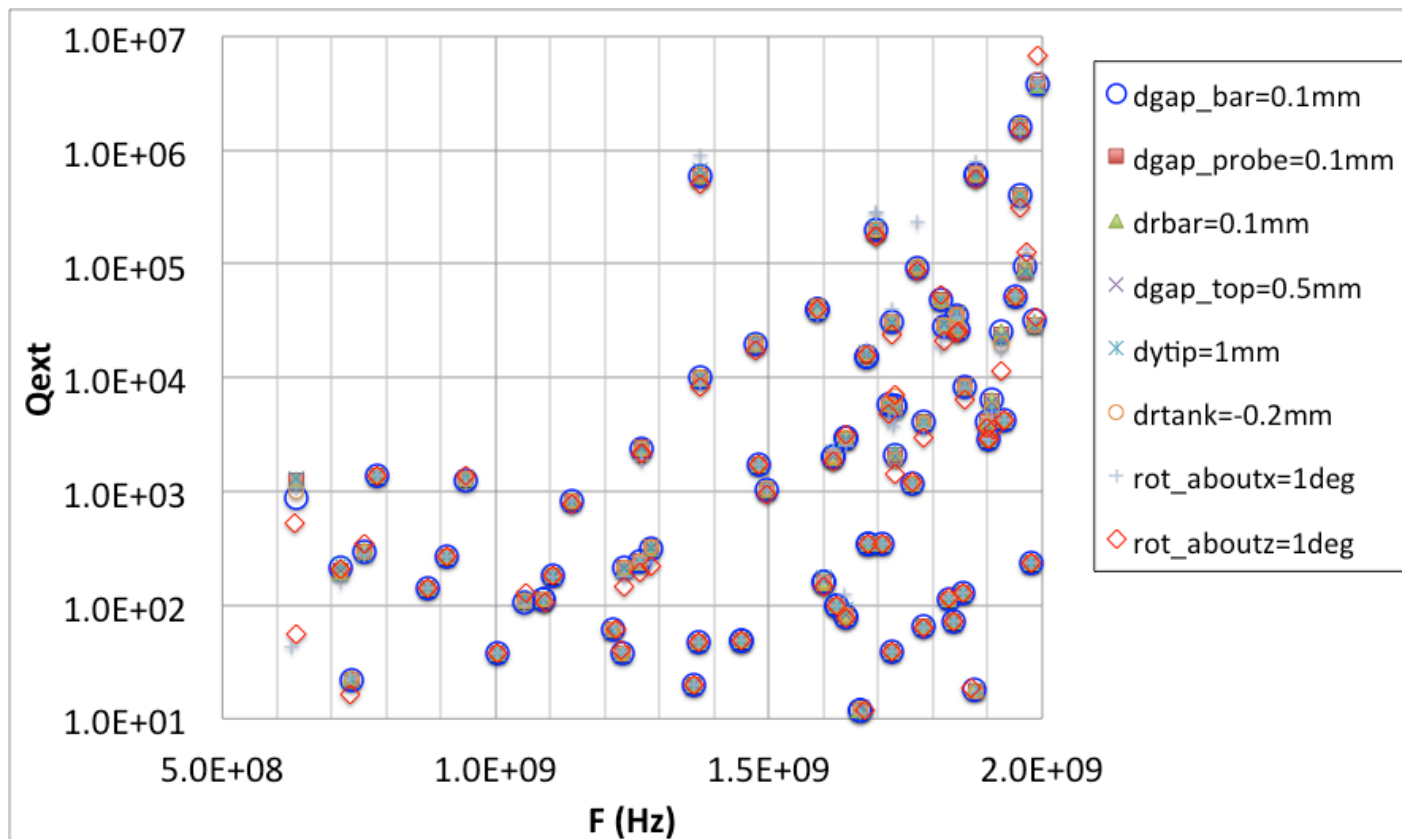
HOM coupler filter dimension sensitivity:

- Insensitive at frequencies above 0.65 GHz
- Damping of 1st dipole mode at 0.63 GHz and operating mode rejection determine the filter dimension tolerance

- $Q_{ext_def}=9.8E10$
- Power leakage at 3.4MV: 0.27 W



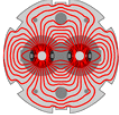
HOM Qext vs Filter Dimension Errors



HOM damping is general quite insensitive

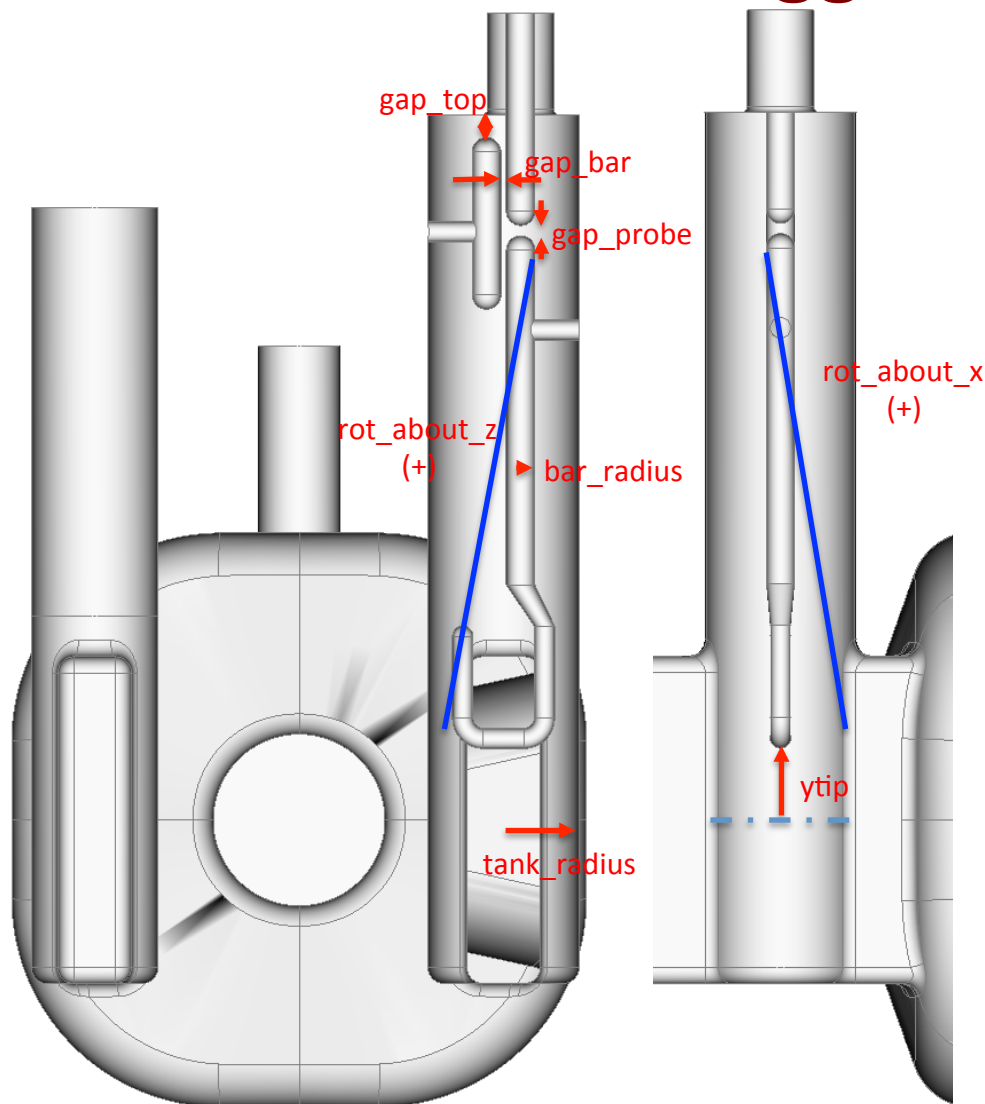
- The lowest dipole mode slightly more sensitive to dimension errors
- Operating mode rejection slightly more sensitive to hook rotation, gap between metal bars

Max power leakage < 0.7W with calculated dimension errors



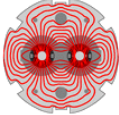
RFD HOM Coupler Tolerance

- Suggestions



Parameters	Tolerance
dbar_radius	-0.1/+0.1 mm
dgap_bar	-0.05/+0.1 mm
dgap_probe	-0.1/+0.1 mm
dgap_top	-0.5/+0.5 mm
dypit	-1/+1 mm
dtank_raius	-0.2/+0.05 mm
rot_about_x	-1/+1 deg
rot_about_z	-1/+1 deg

- Evaluated based on Qext change
- Offset only one of the parameters while others kept unchanged

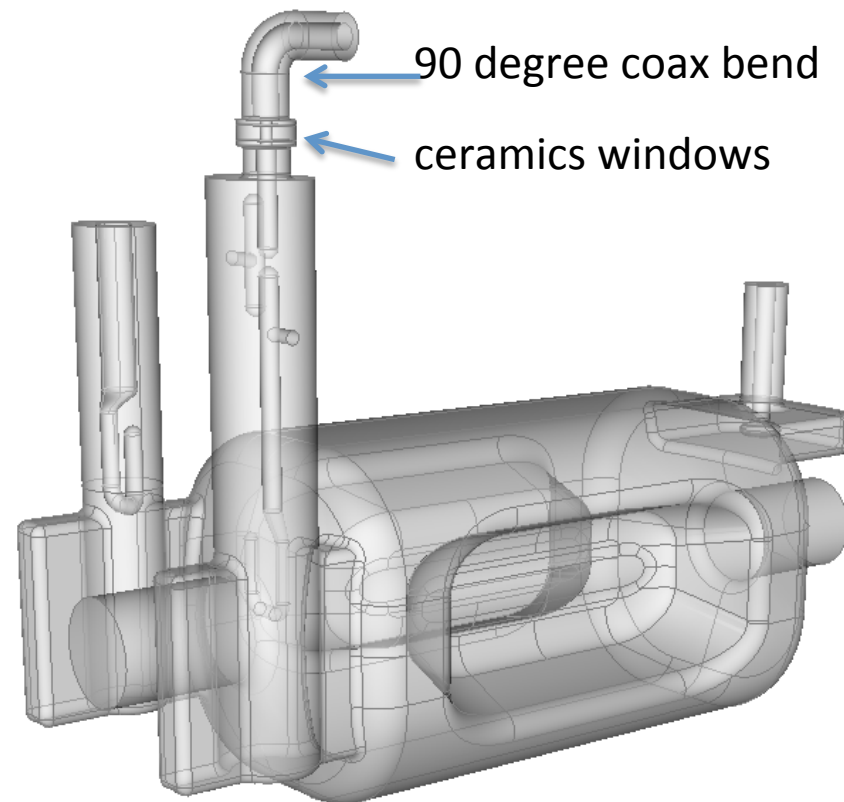


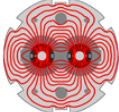
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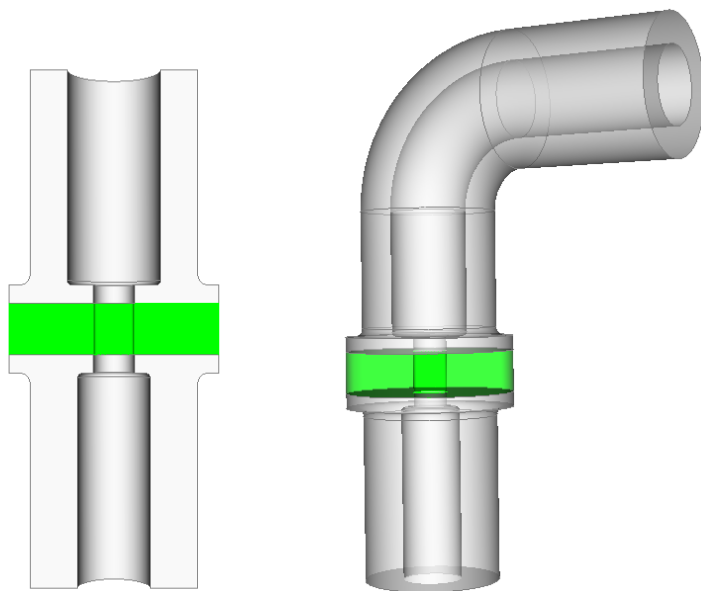
HOM Coupler Window and Bend

- 10-mm ceramics windows
- Match to the 50 ohm pickup port
- 90 degree coax bend to load
- Broadband up to 2 GHz



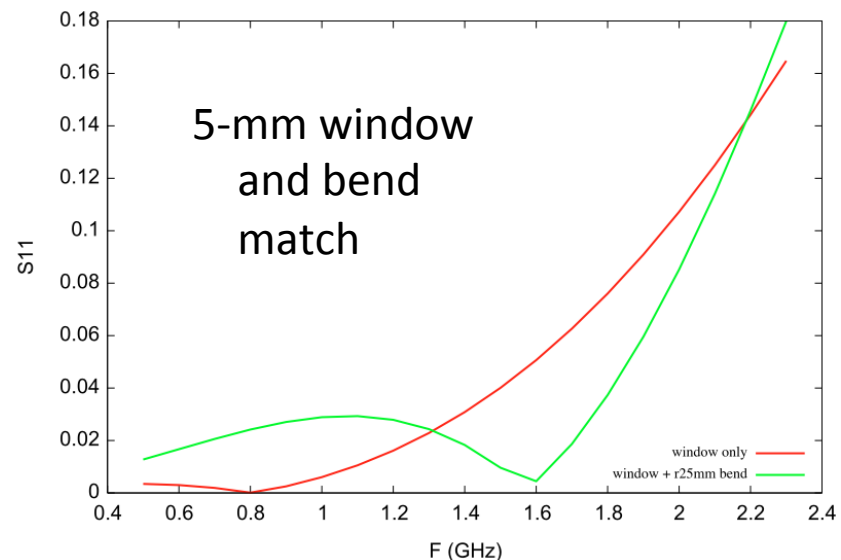


LARP HOM Window and Bend - preliminary

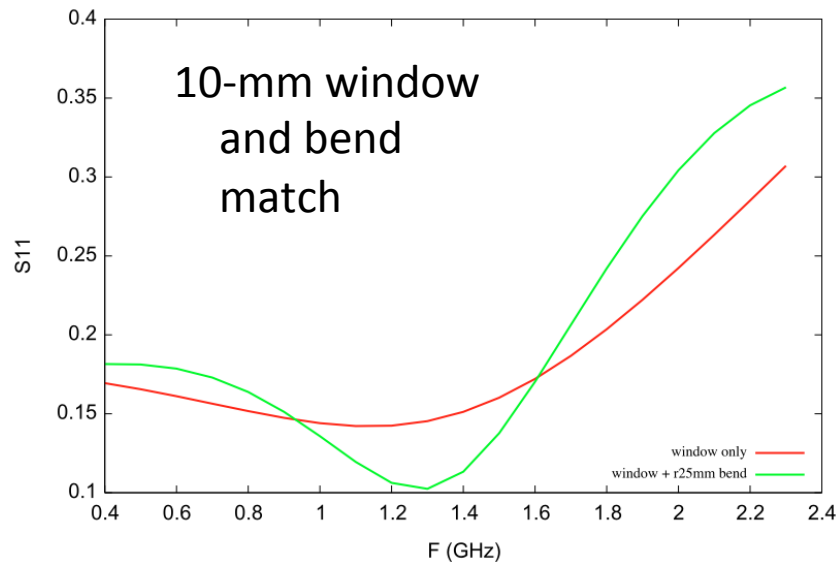


- 10-mm window adopted
- Impact on Qext to be evaluated

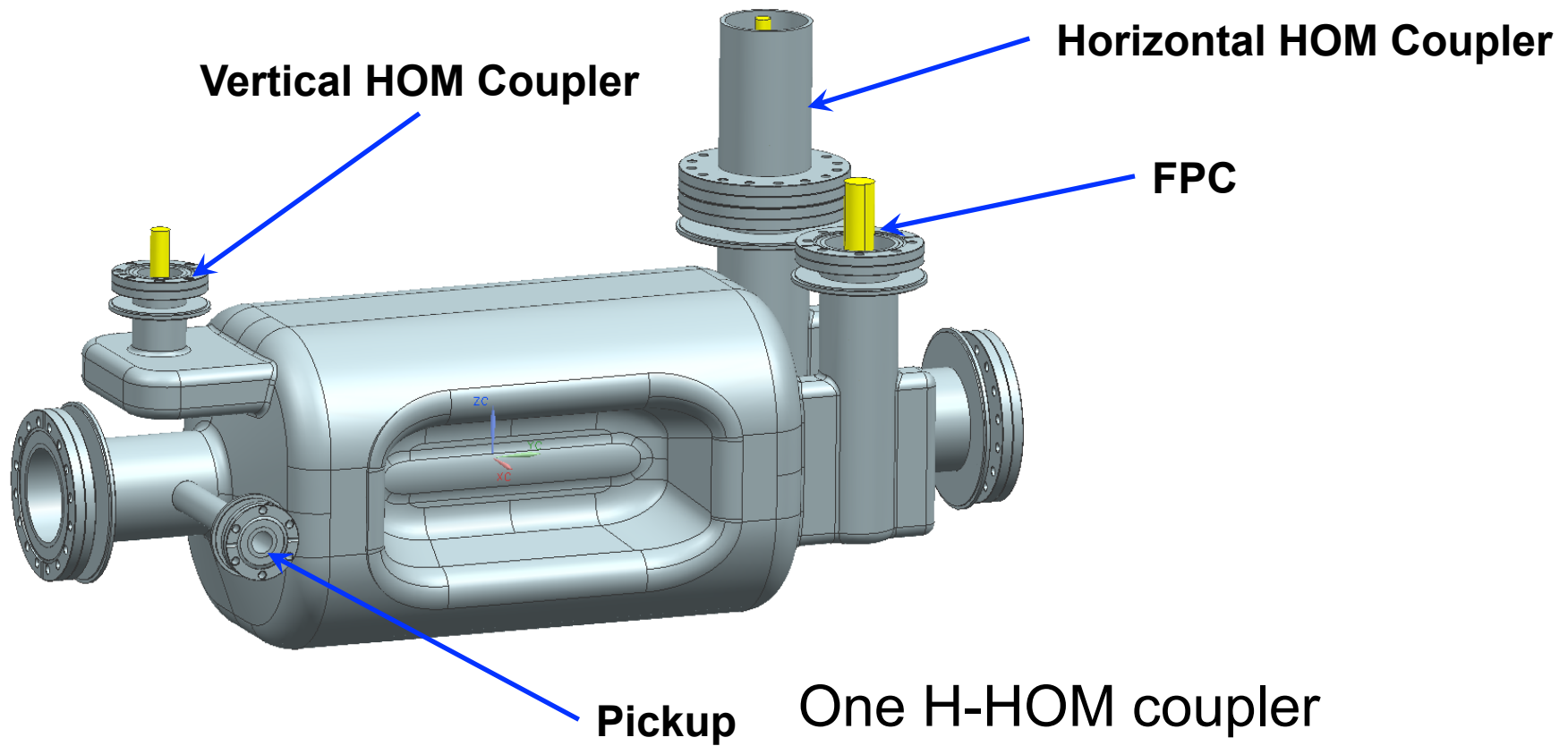
HOM Coax 5-mm Window and 90-degree Bend



HOM Coax 10-mm Window and 90-degree Bend



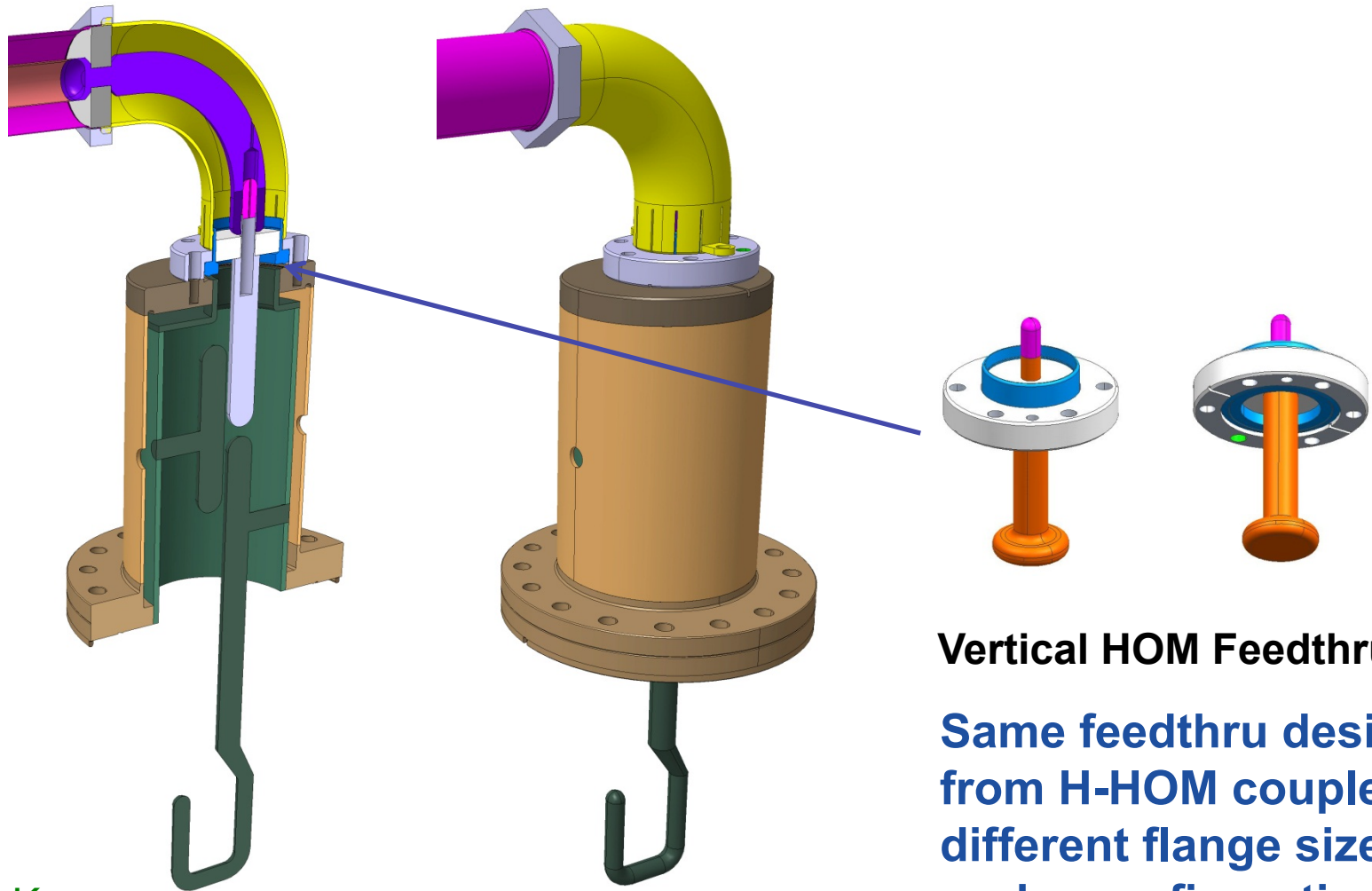
HOM Coupler Requirements



- One H-HOM coupler
- One V-HOM coupler – simple feedthru type
- One Pickup feedthru

HyeKyoung

Coupler Designs



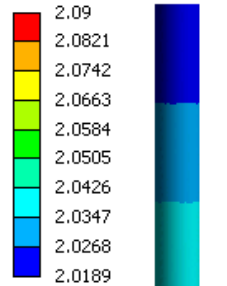
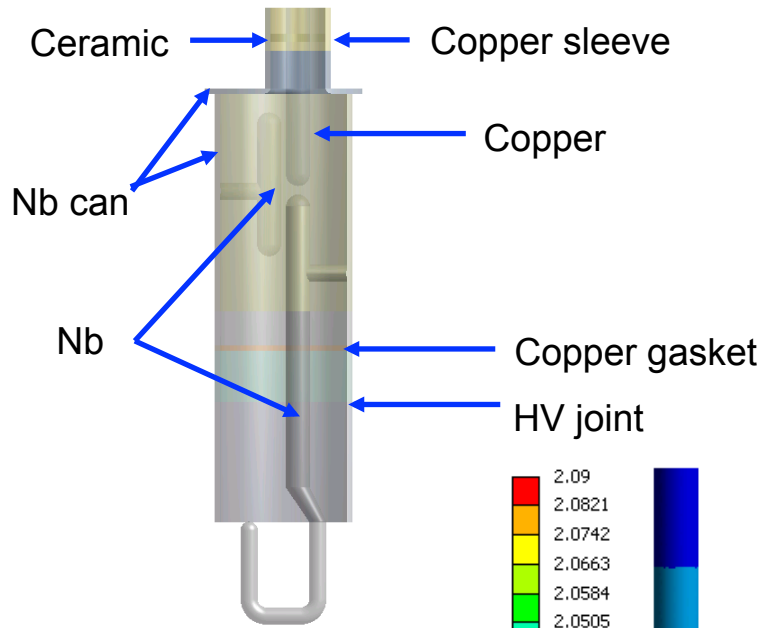
HyeKyoung

Horizontal HOM Coupler

Vertical HOM Feedthru

Same feedthru design from H-HOM coupler with different flange size and probe configuration

Thermal Study Details



Nb hook

Nb hook remains SC and does not require internal cooling

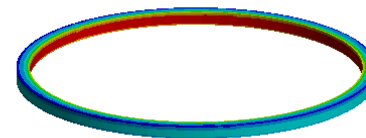
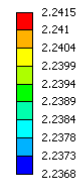
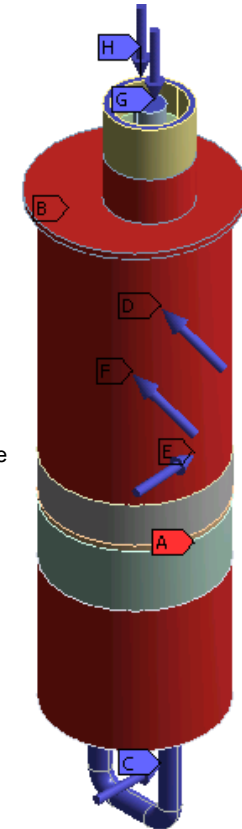
HyeKyoung



G: Steady-State Thermal
Steady-State Thermal
Time: 1, s
10/16/2014 2:49 PM

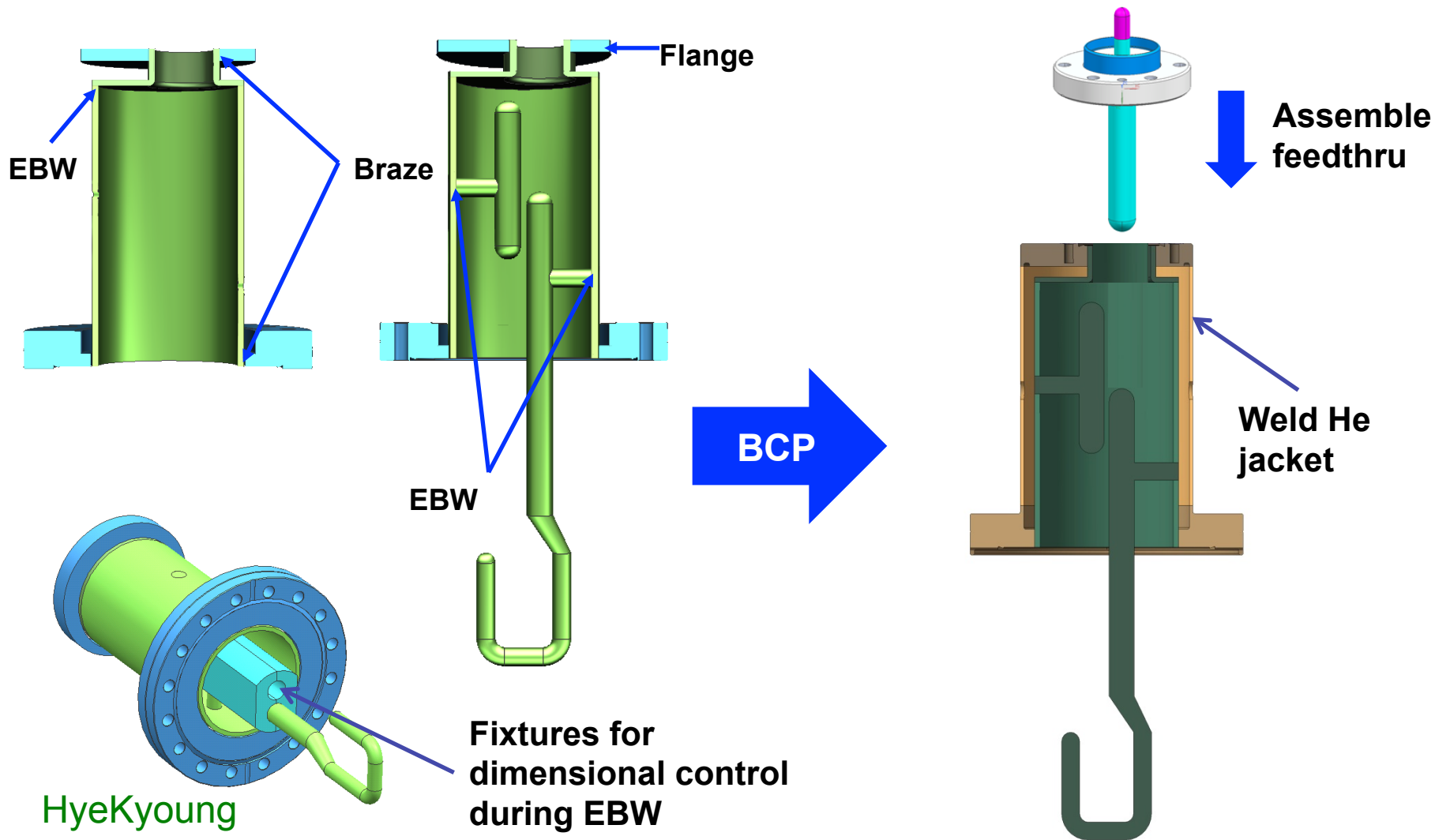
- A** Temperature: 2, K
- B** Temperature 2: 2, K
- C** Heat Flow: 6.07e-004 W
- D** Heat Flow 2: 0.53 W
- * E** Heat Flow 3: 0.216 W
- F** Heat Flow 4: 7.e-006 W
- G** Heat Flow 5: 1, W
- H** Heat Flow 6: 1, W

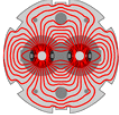
* 1mohm increased to 2mohm to account the roughness and strain effect of copper.
(Anomalous skin effect and resistive wall heating by Weiren Chou and Francesco Ruggiero, 9/8/1995 CERN)



Copper gasket

Assembly Process





Summary

- DQW cavity (2014-08-08 model)
 - analyzed for RF heating and multipacting.
 - re-optimization of the HOM coupler in progress by the DQW team
- RFD
 - analyzed multipacting in the couplers
 - tolerance of HOM hi-pass filters analyzed
 - design and optimization of the coax window and bend in progress