

400MHz HWSR Crab Cavity

Development For LHC Upgrade

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LARP CM15
November 1-3, 2010, SLAC

Work supported by U.S. DOE under contract DE-AC02-76SF00515

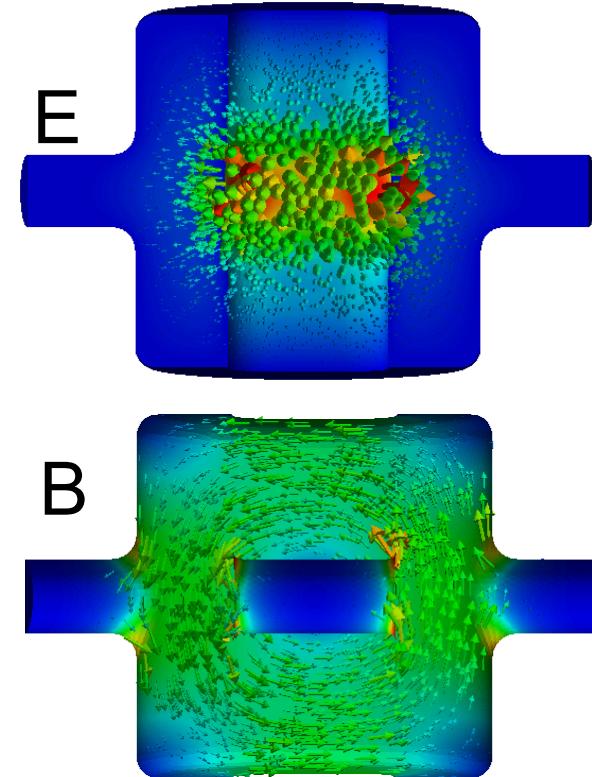
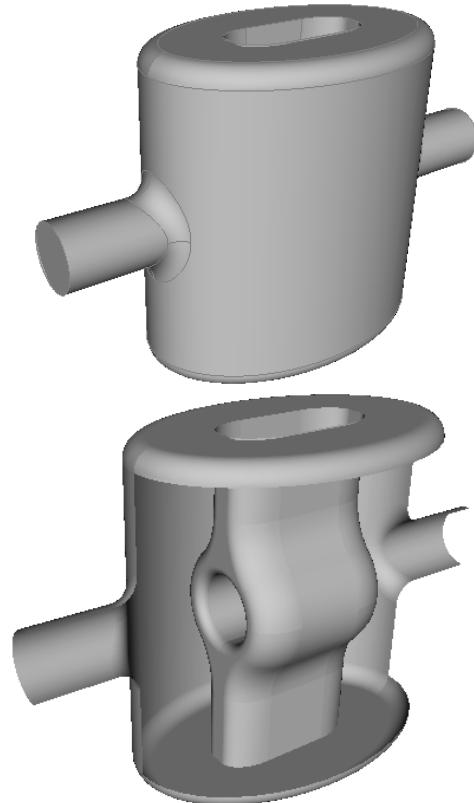


Outline

- Cavity RF parameters
- Deflecting mode – $V_T(x,y)$
- LOM, HOM damping couplers
- FP coupler
- Multipacting
- Summary

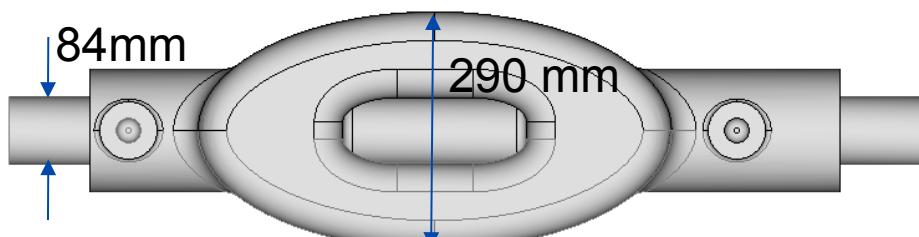
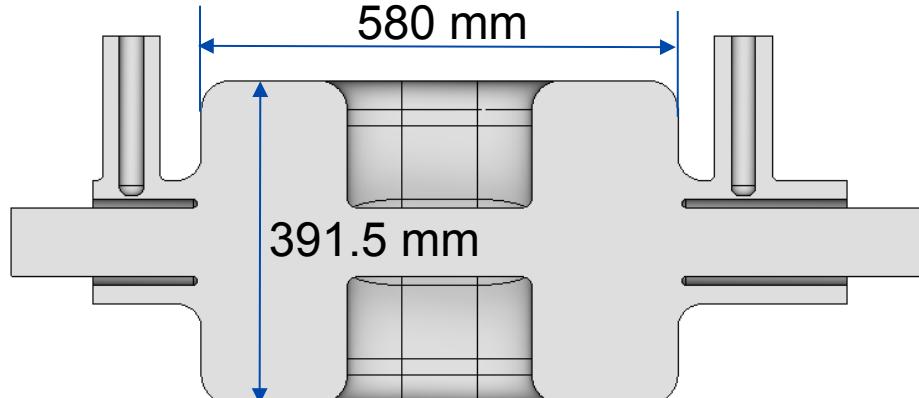
Compact 400-MHz HWSR Crab Cavity

Half-Wave Spoke Resonator (HWSR)



TE11-like mode - Frequency determined by longitudinal and vertical dimensions

400 MHz HWSR Cavity Parameters

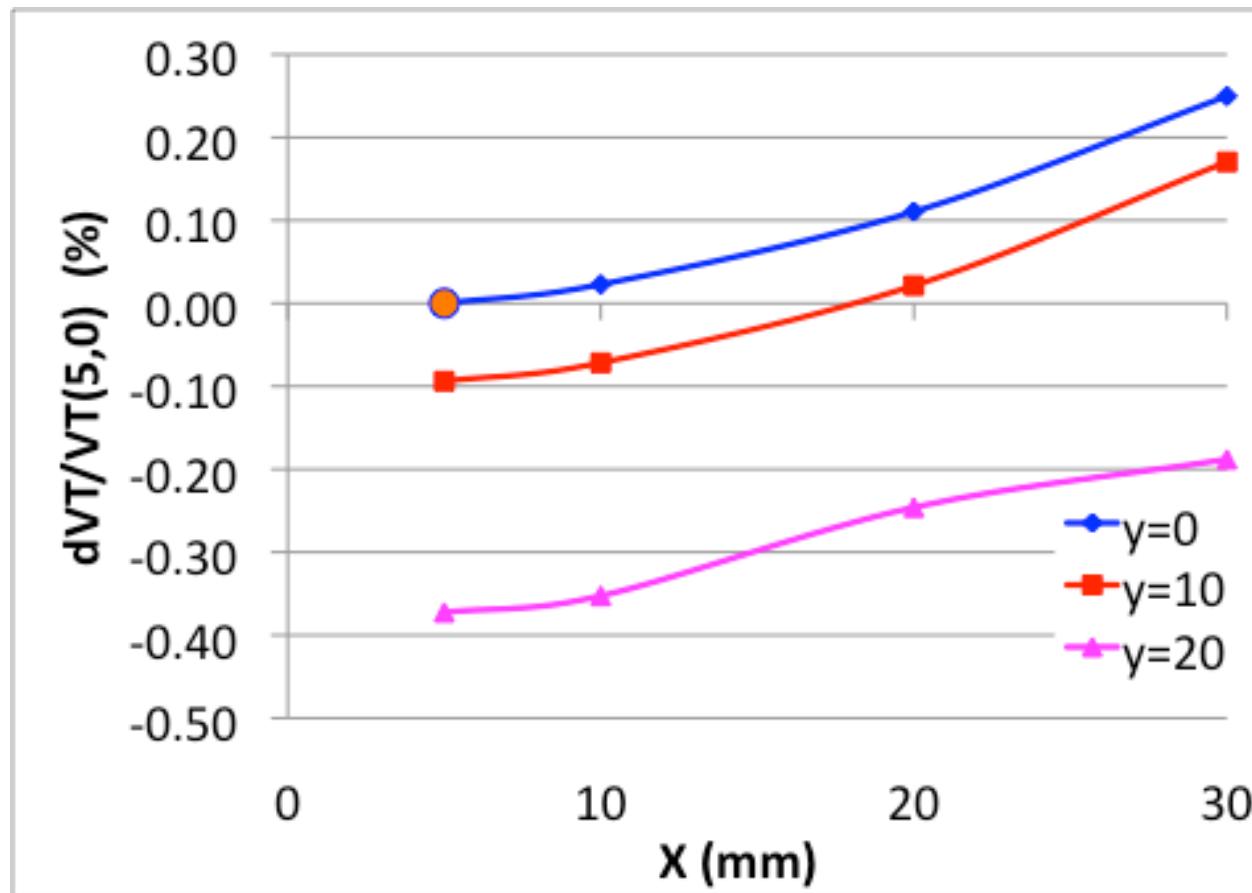


Parameters	
Cavity Width (mm)	290
Cavity Height (mm)	391.5
Cavity Length (mm)	580
Beam pipe radius (mm)	42
$(R/Q)_T$ (ohm/cavity)	215
E_S/V_T ((MV/m)/MV)	10.4
B_S/V_T (mT/MV)	19.5

RF parameters calculated with all damping features included

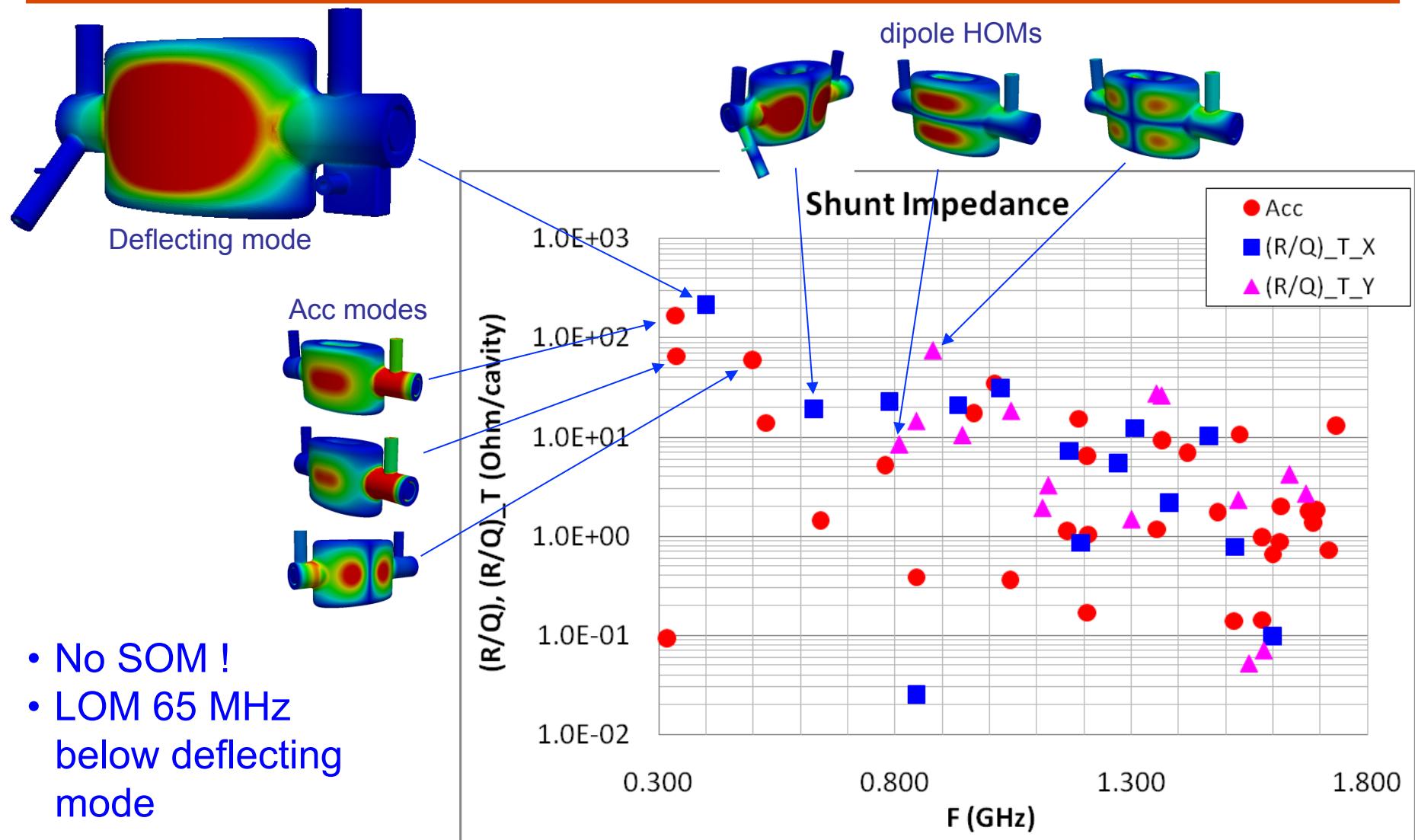
- 8 MV deflecting voltage required
- 2 cavities/beam, 4 MV each

Deflecting Mode: $V_T(x,y)$



Relative V_T variation (in %)

RF Modes in Cavity – R/Q



Damping Requirement

Impedance Budget (LHC-cc09)

- Longitudinal (R): 80 kohm
- Transverse (Z_T): 2.5 Mohm/m

Longitudinal shunt impedance

$$R_L = \left(\frac{R}{Q} \right) \bullet Q_{ext} = \frac{|V_z|^2}{\omega U} \bullet Q_{ext}$$

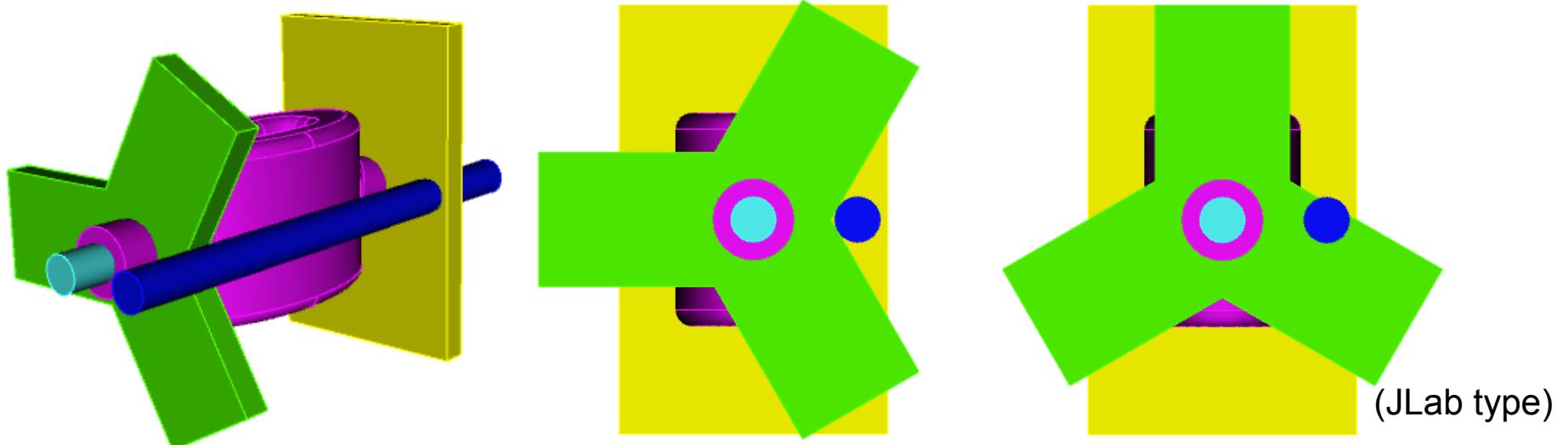
Transverse shunt impedance

$$R_T = \left(\frac{R}{Q} \right)_T \bullet Q_{ext} = \frac{|V_z(r_0)|^2}{\omega U \left(\frac{\omega}{c} r_0 \right)^2} \bullet Q_{ext}$$

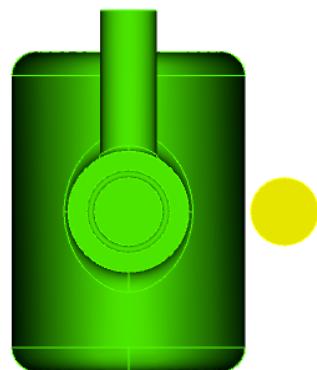
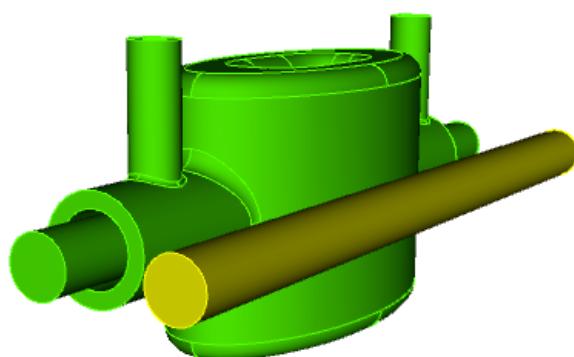
Impedance for beam instability

$$Z_T = \left(\frac{Z_T}{Q} \right) \bullet Q_{ext} = \frac{\omega}{c} R_T$$

Damping Coupler Options

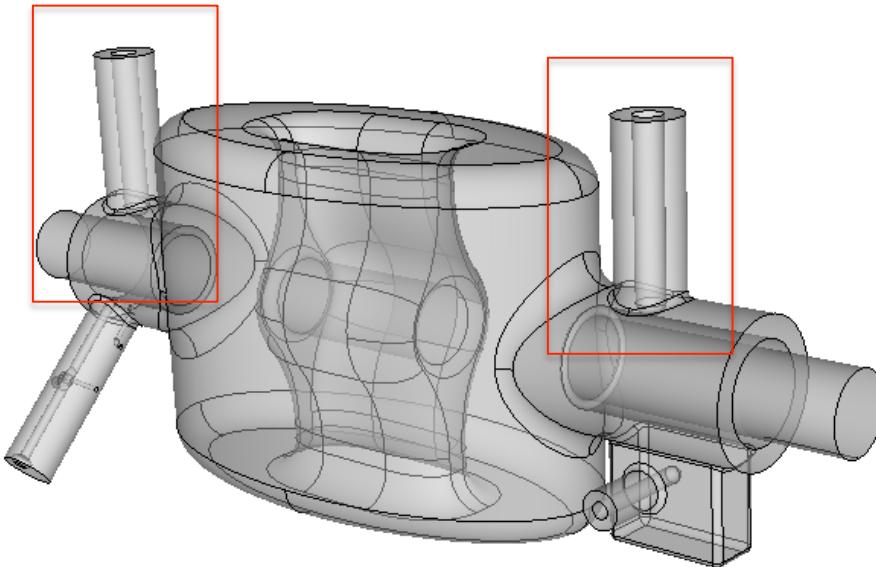


Waveguide couplers become large at low frequencies



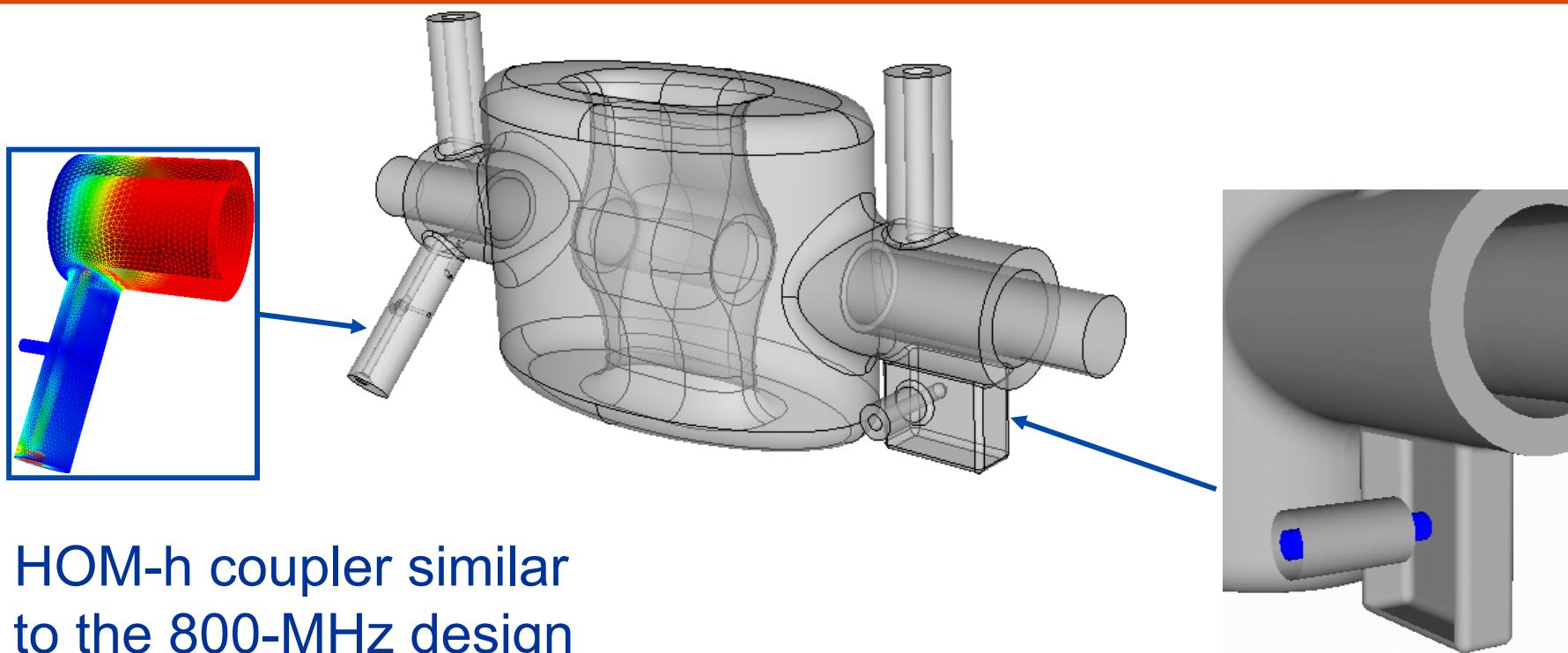
present design
coaxial couplers
compact in size

LOM/HOM-v Couplers



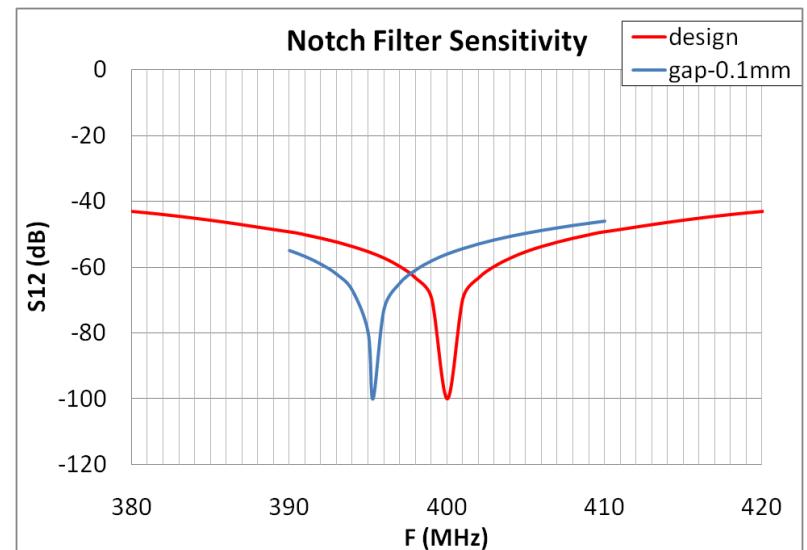
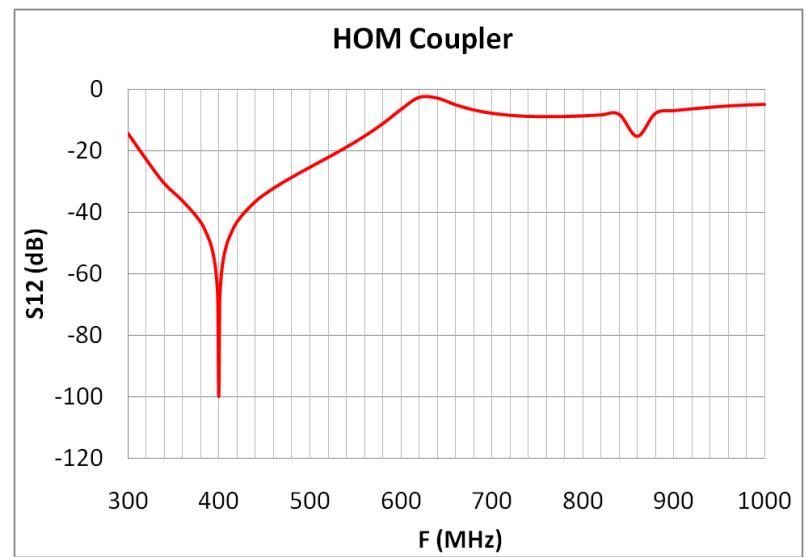
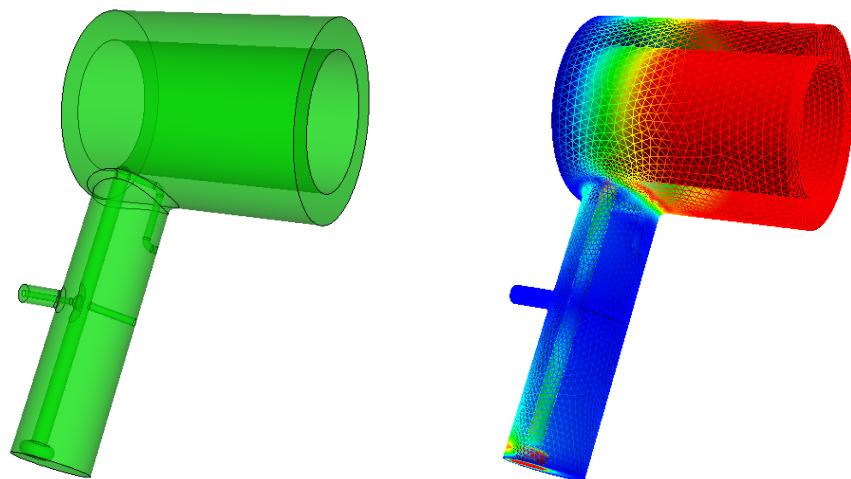
- On beam pipe coax-coax LOM/HOM-v damping couplers
- Naturally rejects horizontal operating mode

HOM and FPC Couplers

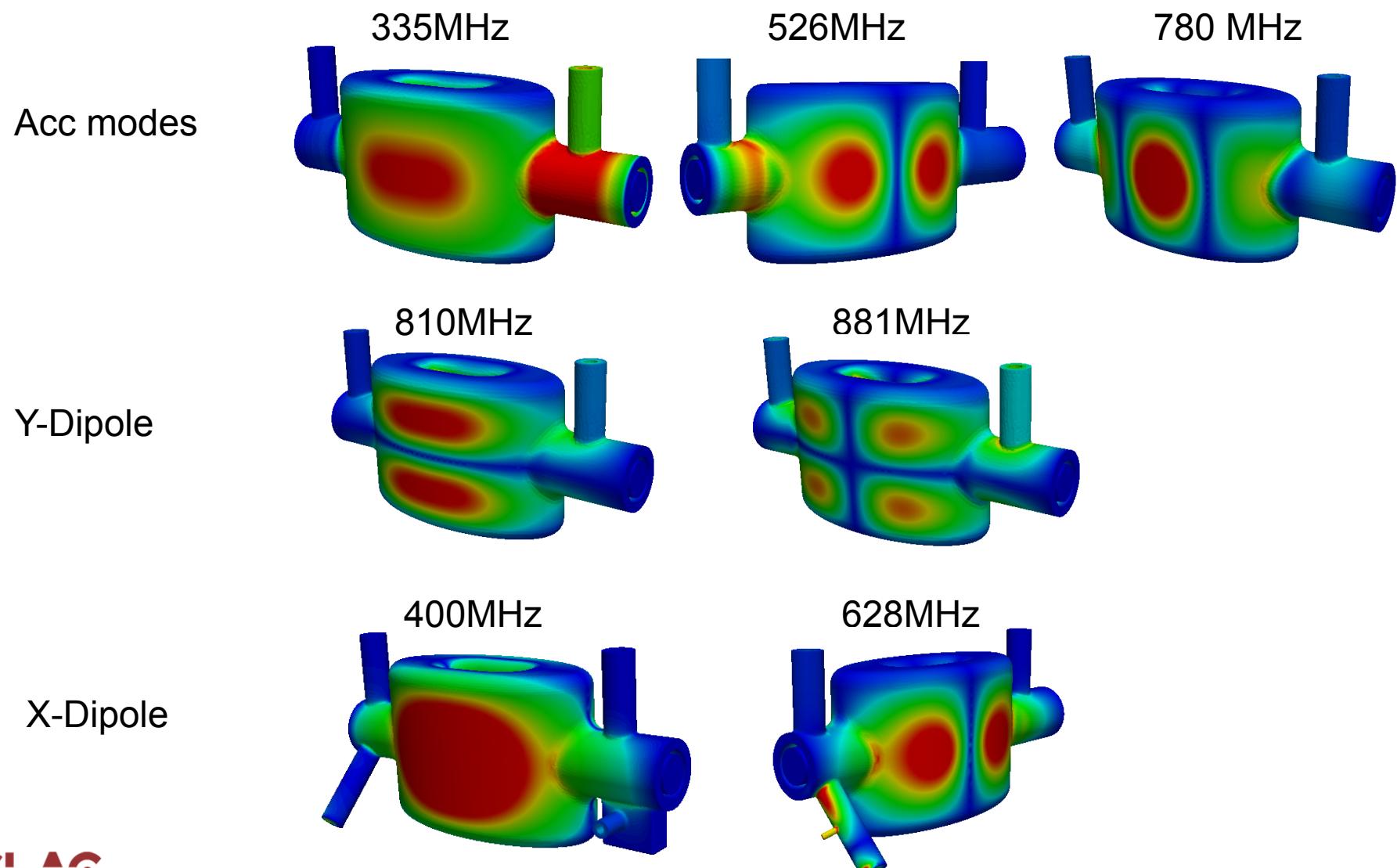


- HOM-h coupler similar to the 800-MHz design
- Notch filter to reject deflecting mode
- Input coupler with magnetic coupling
- Eliminates direct coupling from FPC to LOM/HOM-v

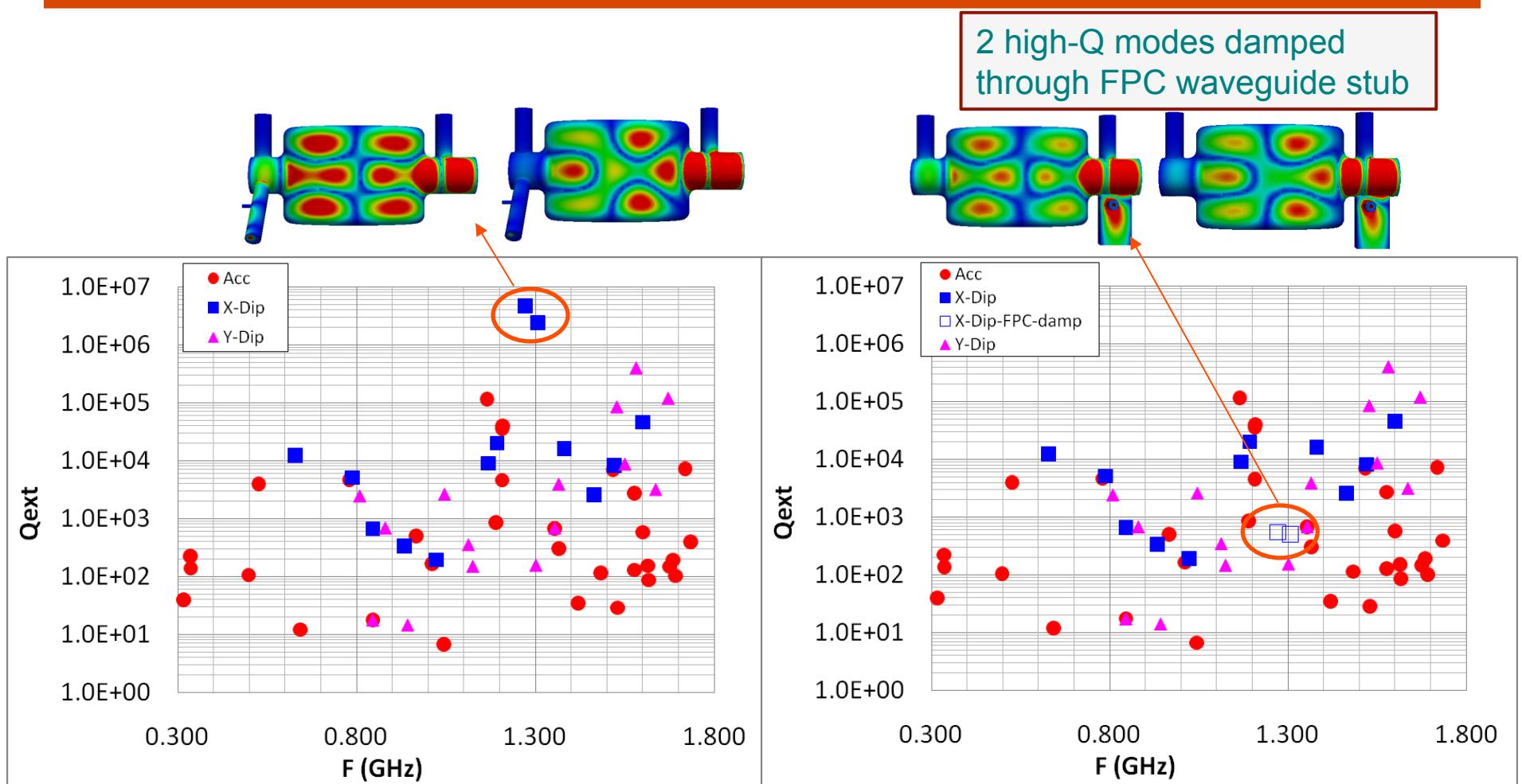
HOM Coupler Notch Filter



LOM/HOM Damping

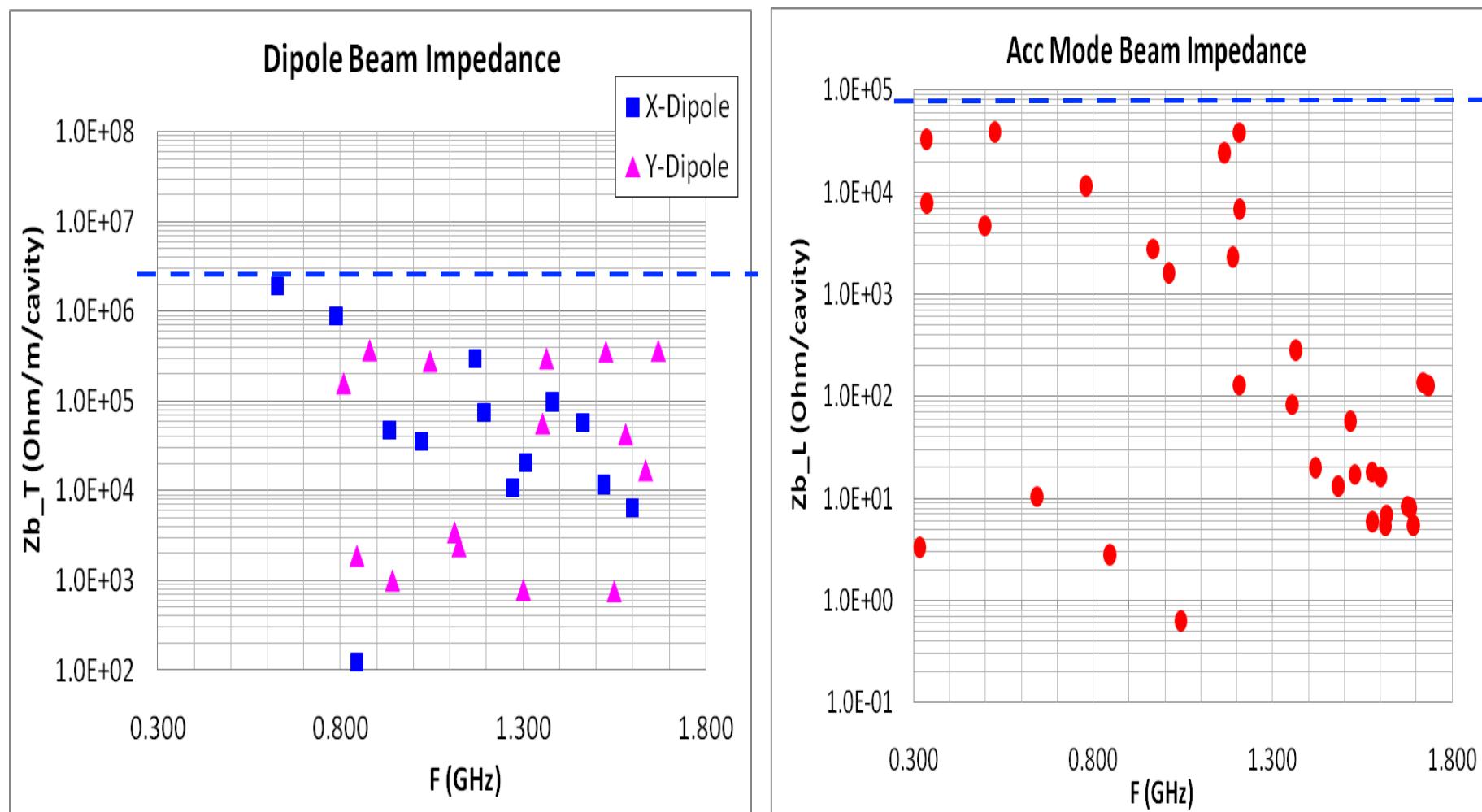


Damping Qext



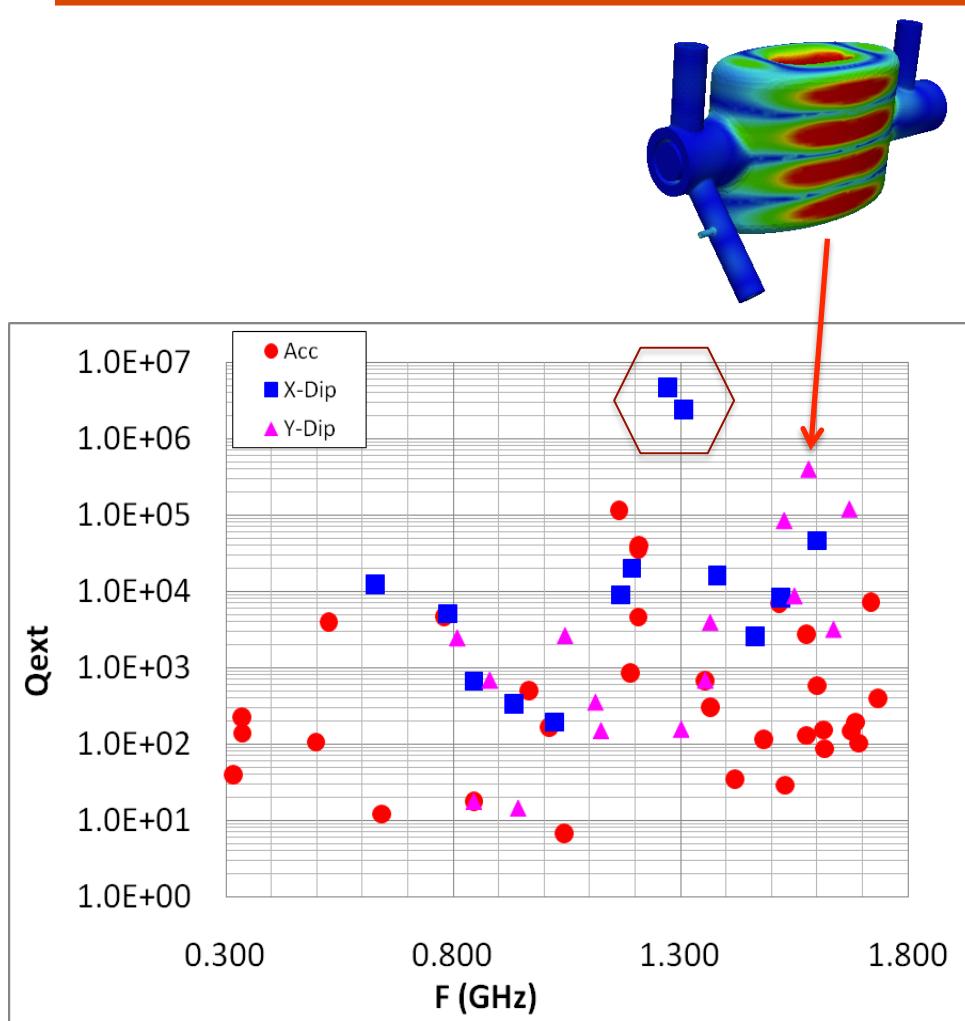
Effective damping demonstrated with these coupling schemes

Damping Requirement Achieved

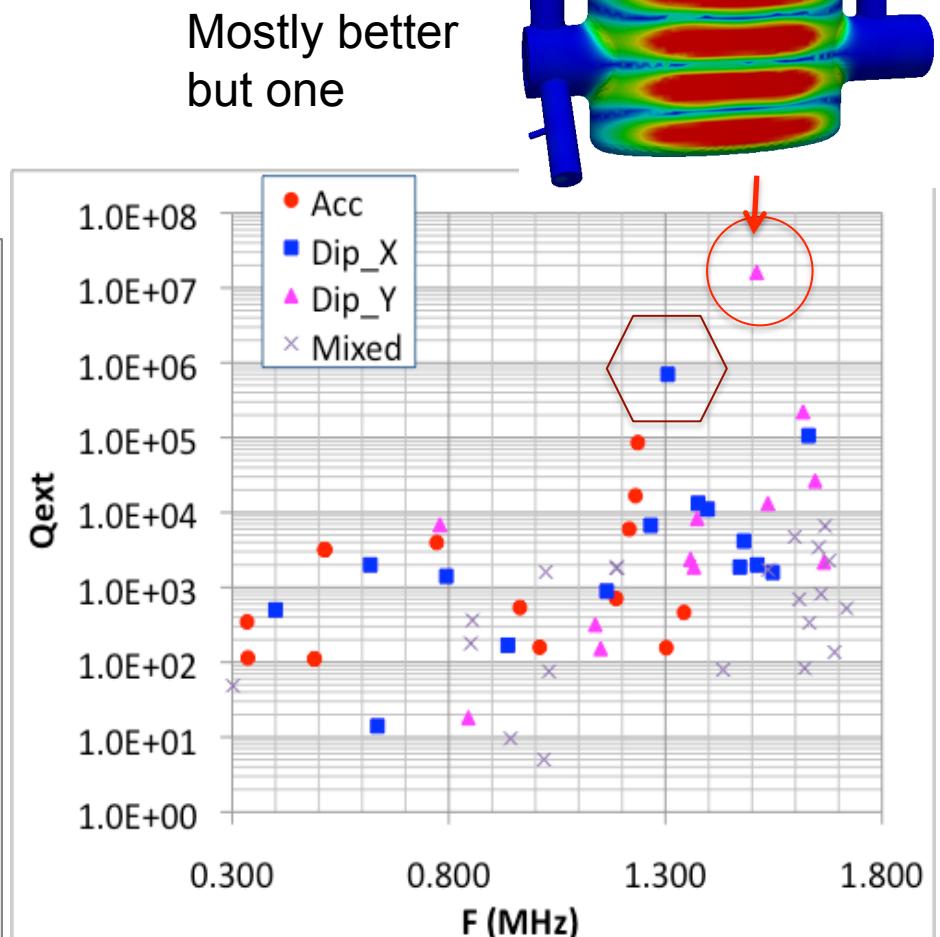


- Dashed line is the beam instability requirement

Coupler Optimization ...



Old HOM coupler



New HOM coupler

Beam Power To HOM coupler?

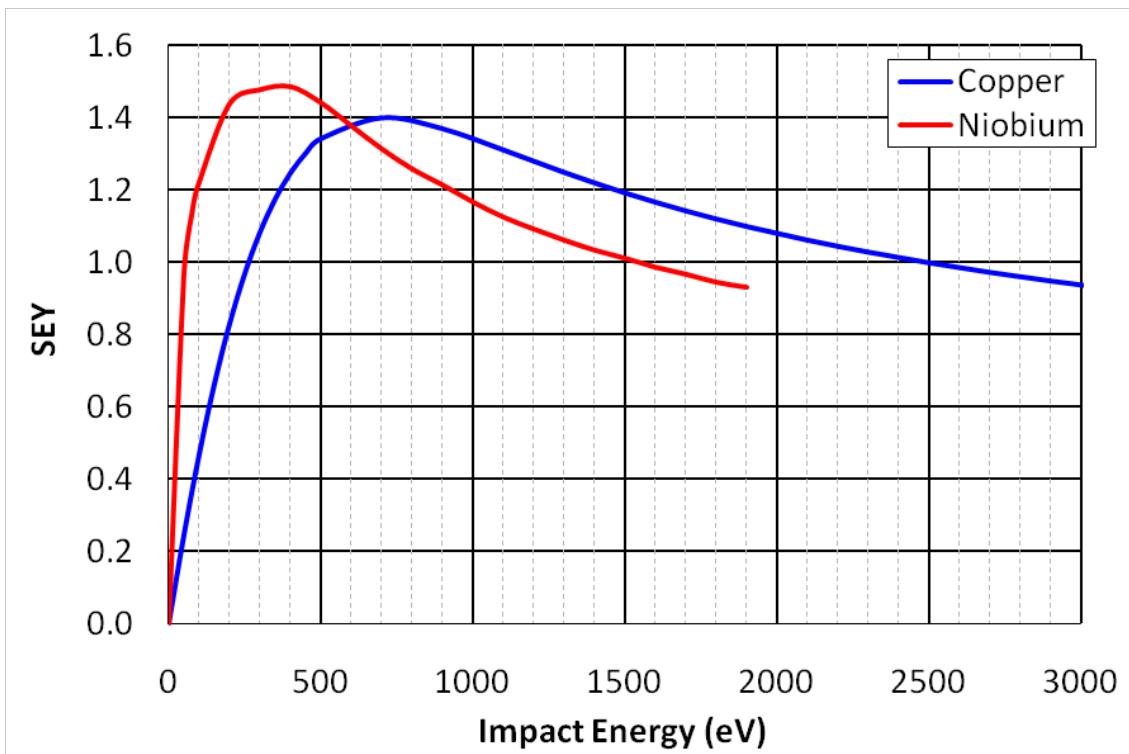
- Accelerating modes leak to HOM coupler
- Need to evaluate HOM coupler beam power handling

F (GHz)	Qext mono (All couplers)	Qext mono (HOM coupler)	R/Q
0.334389	damp to <250	1374348070	181
0.336271	114	13244469	41
0.490216	111	845	56
0.513701	3194	12027	13

Multipacting Analysis

- MP simulation performed for both operating mode and the LOM mode
 - Operating mode: deflecting voltage scanned up to 5MV
 - LOM: beam loss power scanned up to 10kW (on resonance, max)
- Regions scanned for MP
 - Cavity
 - LOM/HOM-v couplers
 - FPC coupler
 - HOM-h coupler

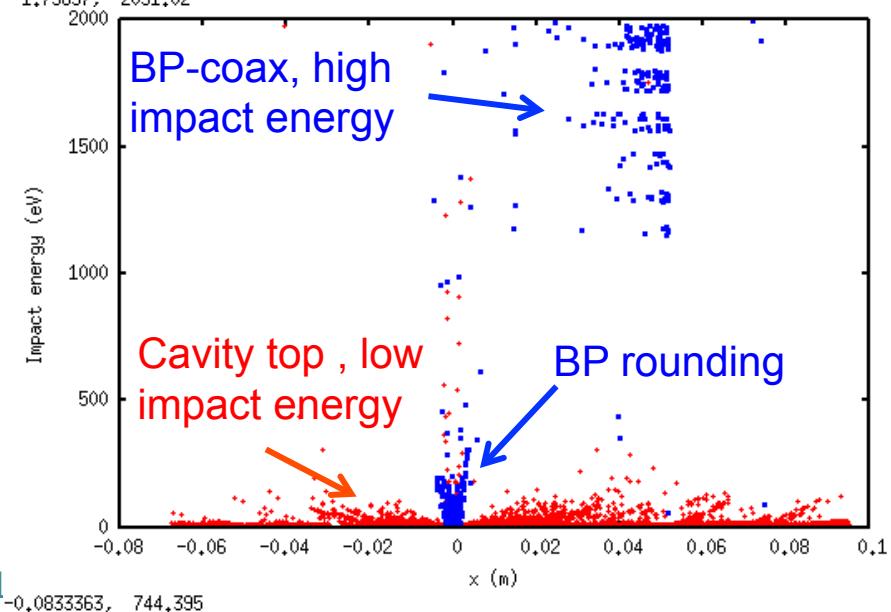
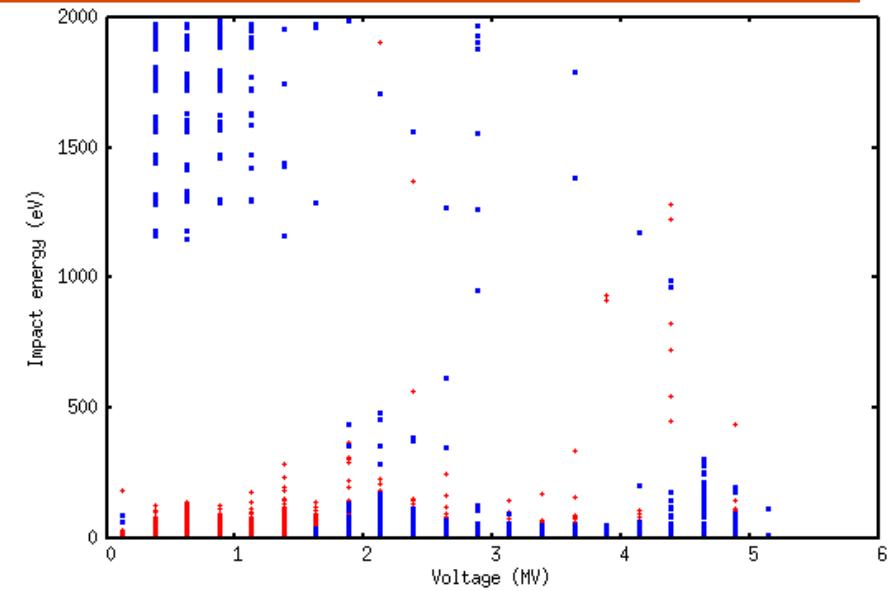
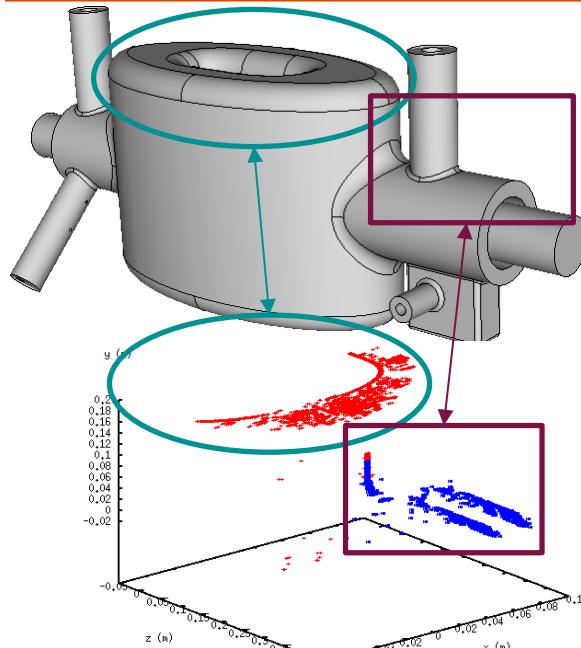
SEY for Niobium and Copper



Niobium: cavity body, HOM coupler loop

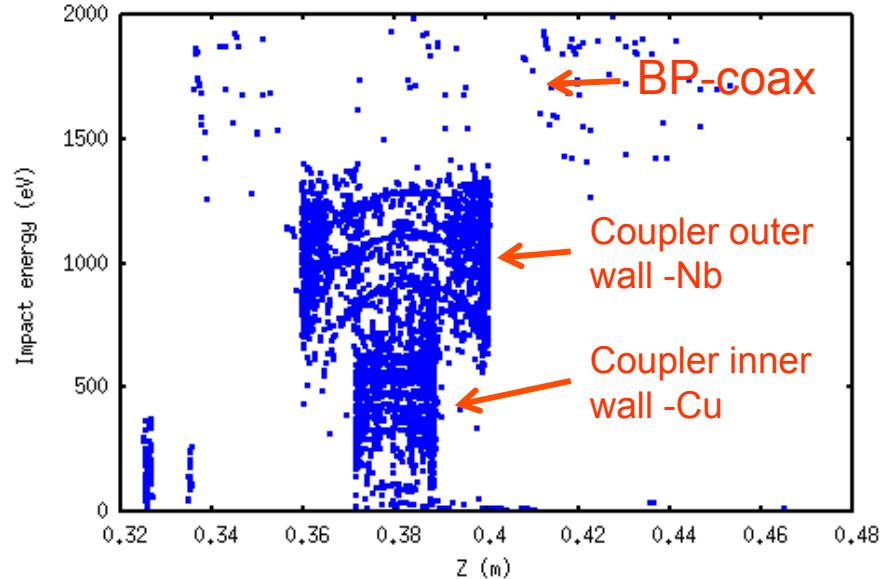
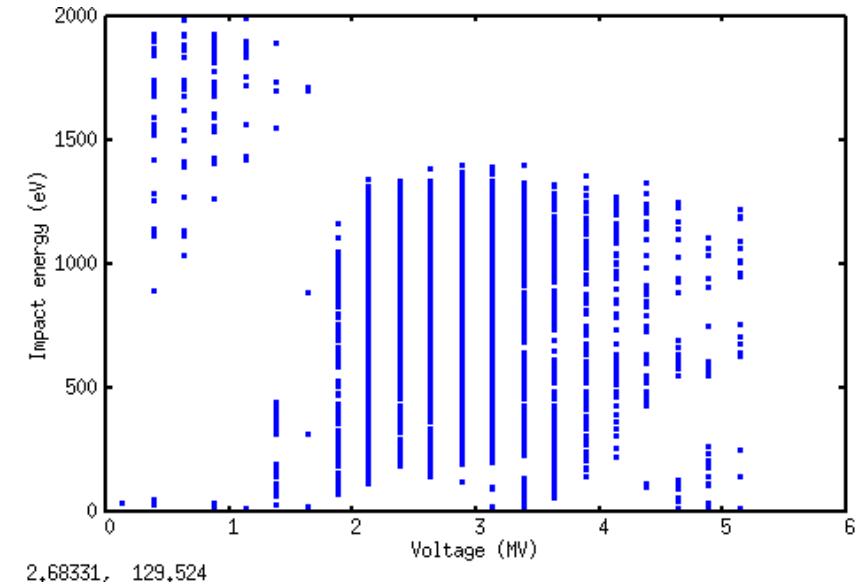
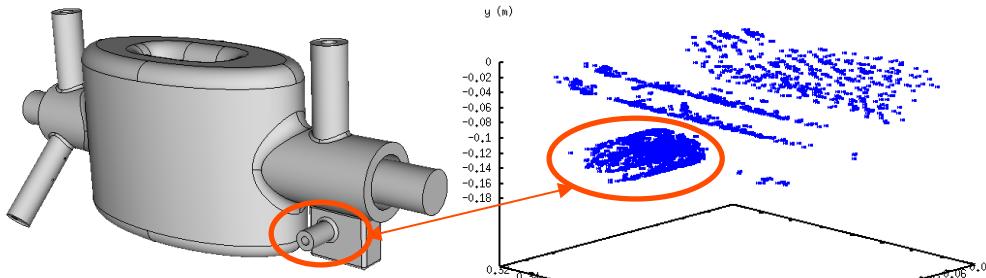
Copper: Inner conductor of FPC and LOM/VHOM couplers

MP Of Operating Mode (1)



- Impact energy of most resonant trajectories not at the SEY peak
- Only low impact energy resonant trajectories at operating voltage

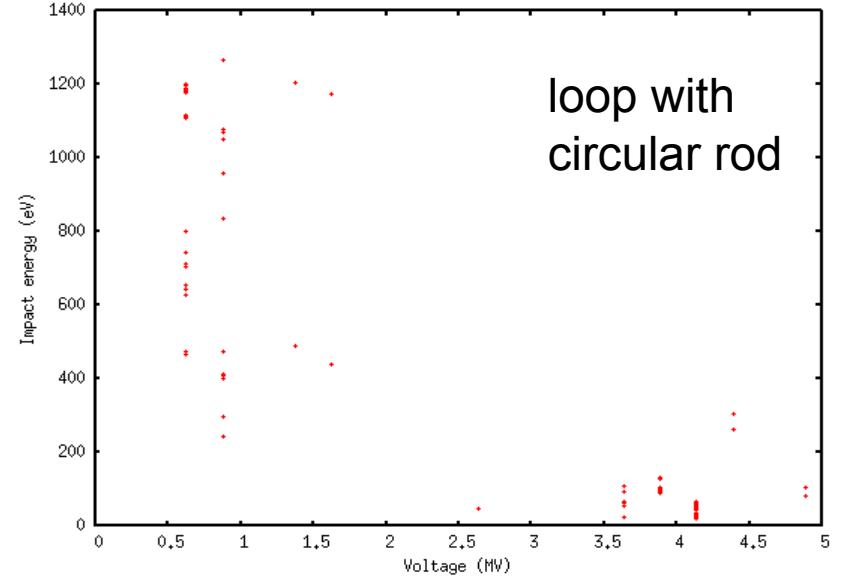
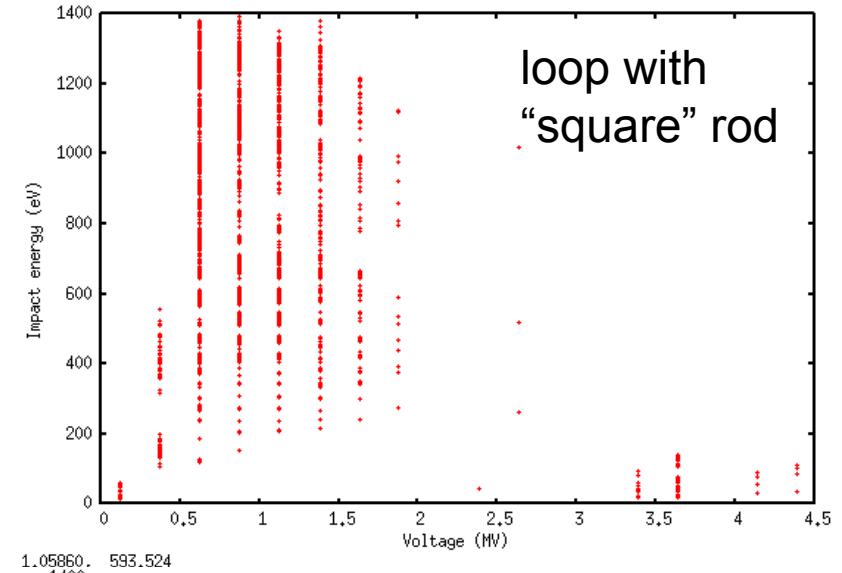
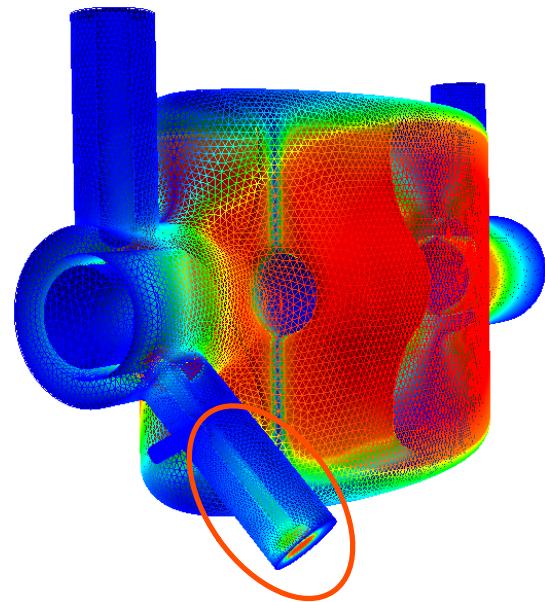
MP of Operating Mode (2) - FPC Coupler



Resonant trajectories in the coax coupler region

- Impact energy higher on outer surface (Nb), lower on inner wall (Cu)
- Use coax of different impedance may help to mitigate the problem

MP of Operating mode (3) - HOM Coupler



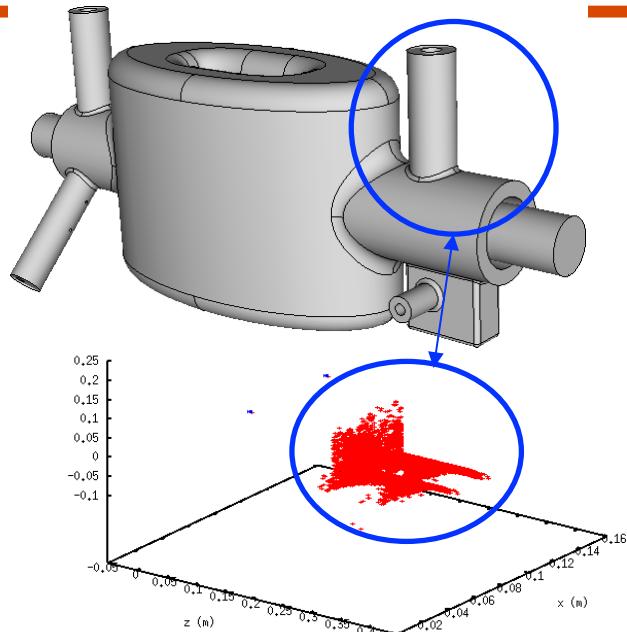
- “square” rod

2-point MP between straight section
of the loop and outer cylinder wall

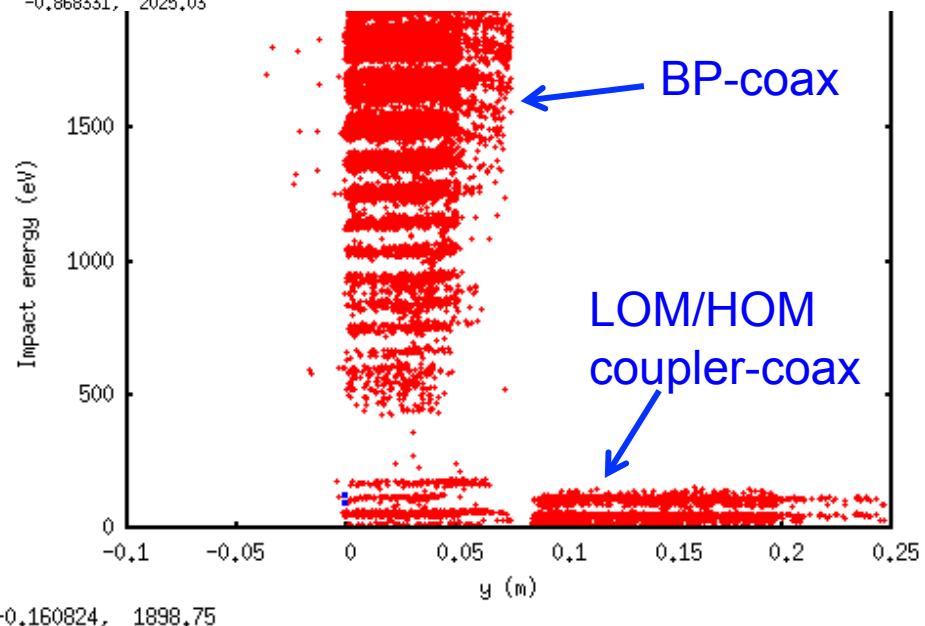
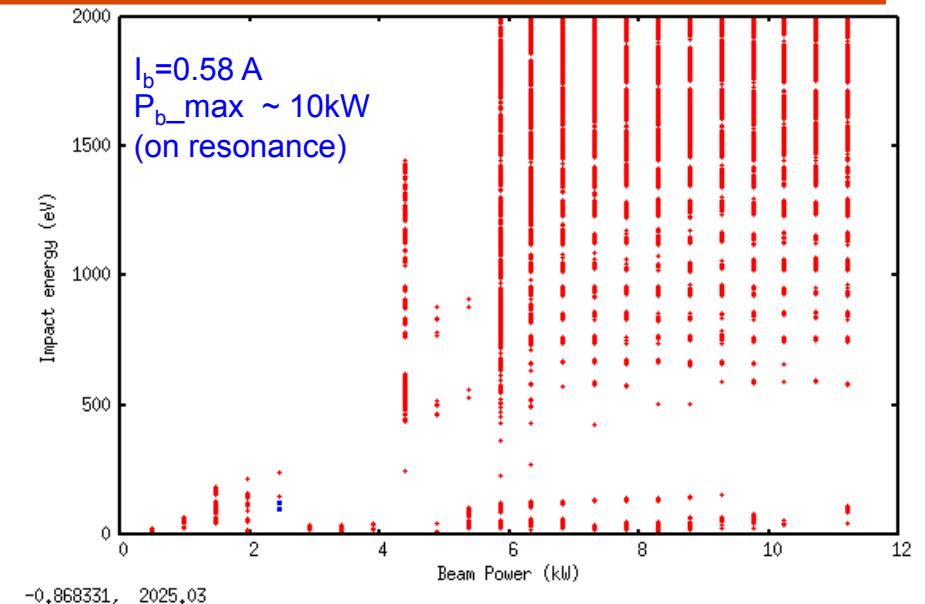
- Circular rod

MP significantly suppressed

MP of LOM Accelerating Mode

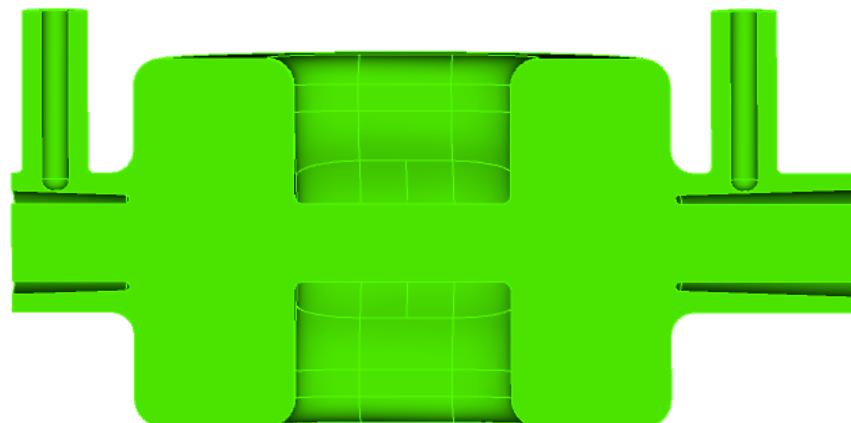


- Max beam power ~ 10 kW
- Resonant trajectories in BP coax above 4 kW beam power, with mostly high impact energy
- Resonant trajectories in coupler coax, with mostly low impact energy



Possible MP Improvements ...

- Coupler coax: coax of different impedance may minimize resonant conditions
(there are existing coaxial coupler operate at various power levels)
- Beam-pipe coax region: using tapered coaxial geometry or grooves
- ...



Summary

- 400-MHz HWSR cavity fits both local and global schemes
- Cavity shape and couplers optimized.
- LOM/HOM damping would meet requirement.
- MP analyses performed. Study continues.
- Design ready for preliminary engineering studies
- Further cavity/coupler optimization continues.