

# Modeling Wakefield Damping for the LHC Crab Cavity

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# Outline

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- Parallel electromagnetic tools for cavity design and simulation
- ILC crab cavity LOM/HOM coupler design
- LHC crab cavity RF parameter & coupler studies - preliminary



# SLAC Parallel EM Codes

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## Frequency Domain:

**Omega3P** – eigensolver for mode damping

**S3P** – S-parameter

## Time Domain:

**T3P** – transients & wakefields

**Pic3P** – self-consistent particle-in-cell

## Particle Tracking:

**Track3P** – dark current and multipacting

**Gun3P** – space-charge beam optics

## Multi-physics:

**TEM3P** – EM-thermal-mechanical

## Graphics:

**V3D** – visualization of meshes, fields and particles



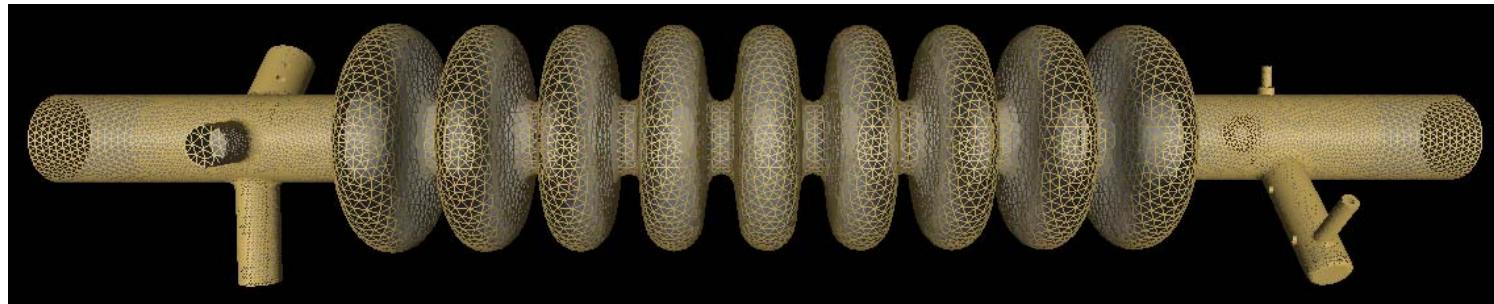
# ILC Crab Cavity LOM/HOM Couplers

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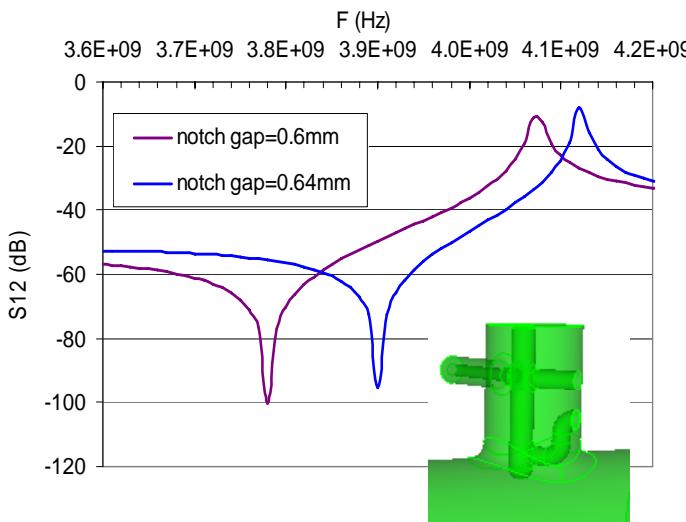
- Cockcroft, FNAL, SLAC Collaboration
- ILC crab cavity based on FNAL 3.9GHz deflecting mode cavity
- SLAC work involved in
  - optimizing the LOM/HOM couplers for wakefield damping
  - multipacting analysis of the cavity and the LOM/HOM couplers



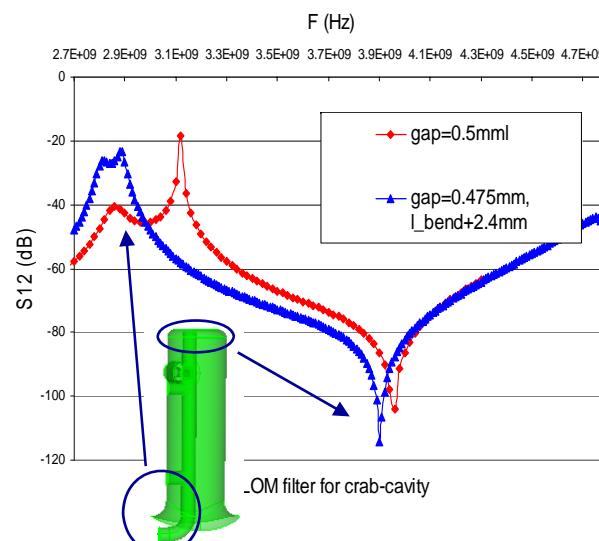
# ILC Crab Cavity HOM/LOM Coupler Notch Filter



*Original HOM/LOM Couplers*

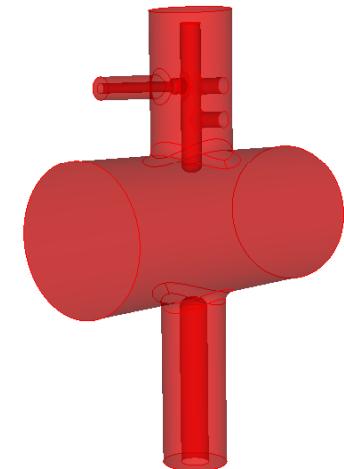


*HOM:  $df/dg_{\text{gap}} = 1.6 \text{ MHz}/\mu\text{m}$*



*LOM:  $df/dg_{\text{gap}} = 2.2 \text{ MHz}/\mu\text{m}$*

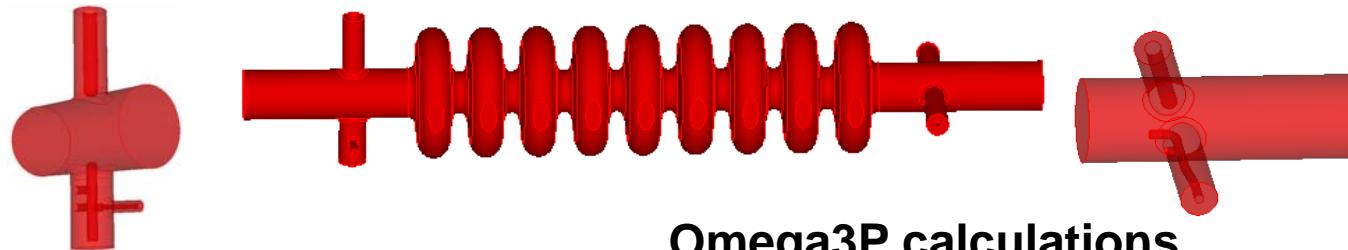
*New HOM design*



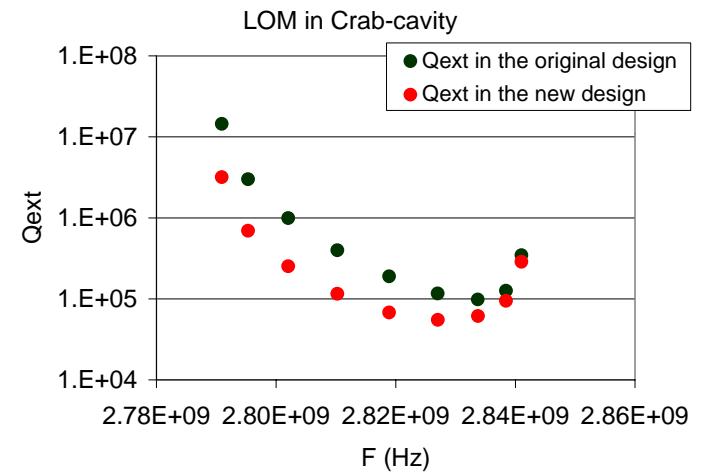
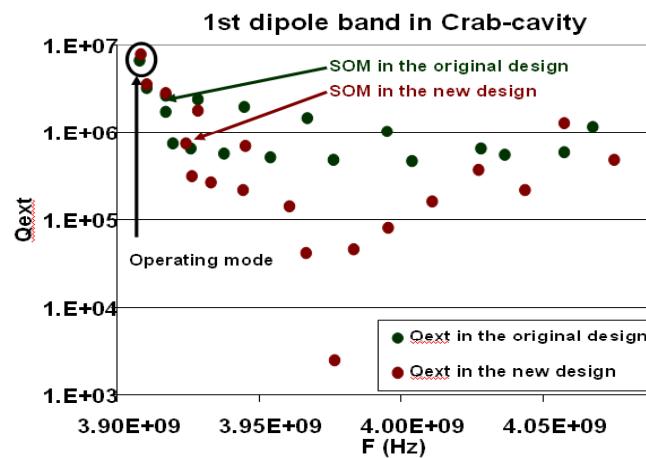
$df/dg_{\text{gap}} = 0.1 \text{ MHz}/\mu\text{m}$

(TESLA:  $0.13 \text{ MHz}/\mu\text{m}$ )

# LOM/HOM Damping

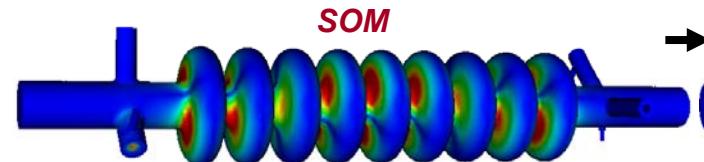
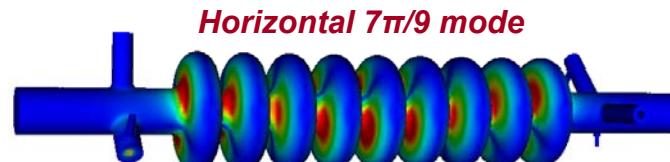


**Omega3P calculations**



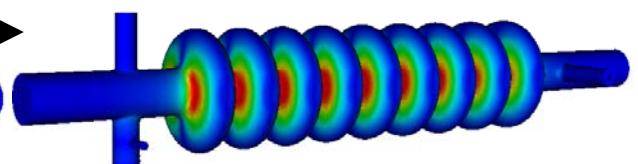
Improved LOM/HOM damping

Improved mode separation through cell shape modification



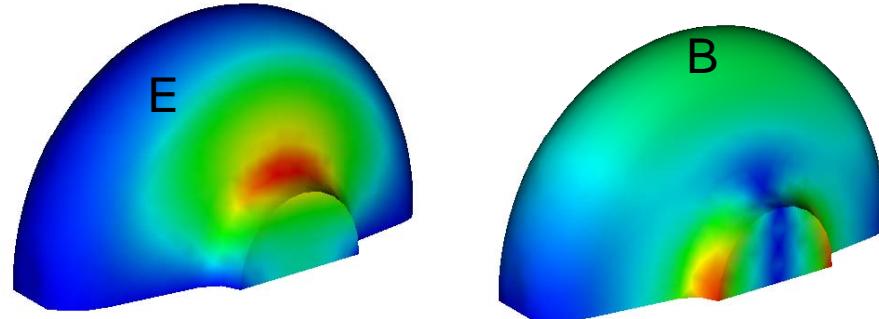
x-y coupled modes

*Vertically aligned SOM*

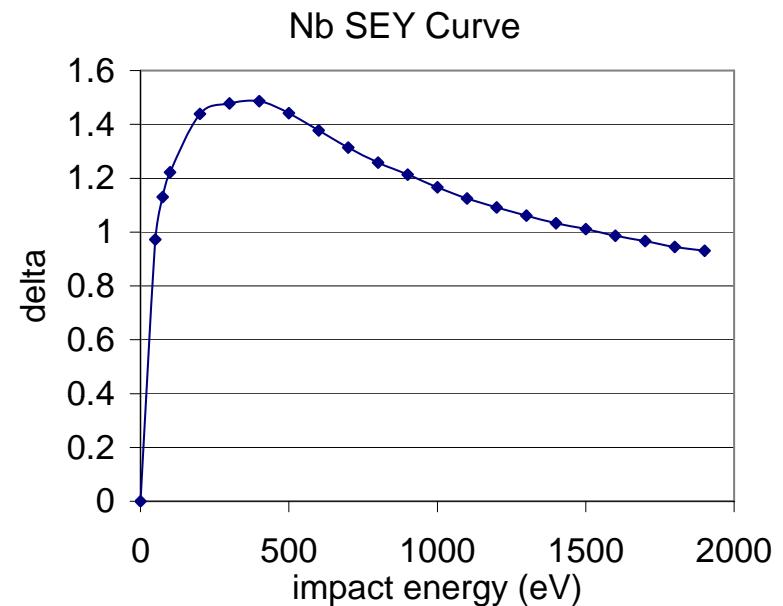


# Multipacting in Crab Cavity

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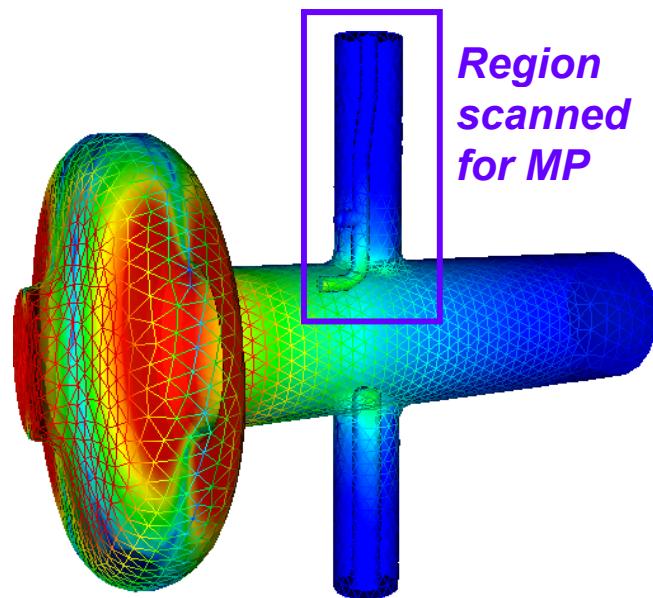
E & B field distributions in cell



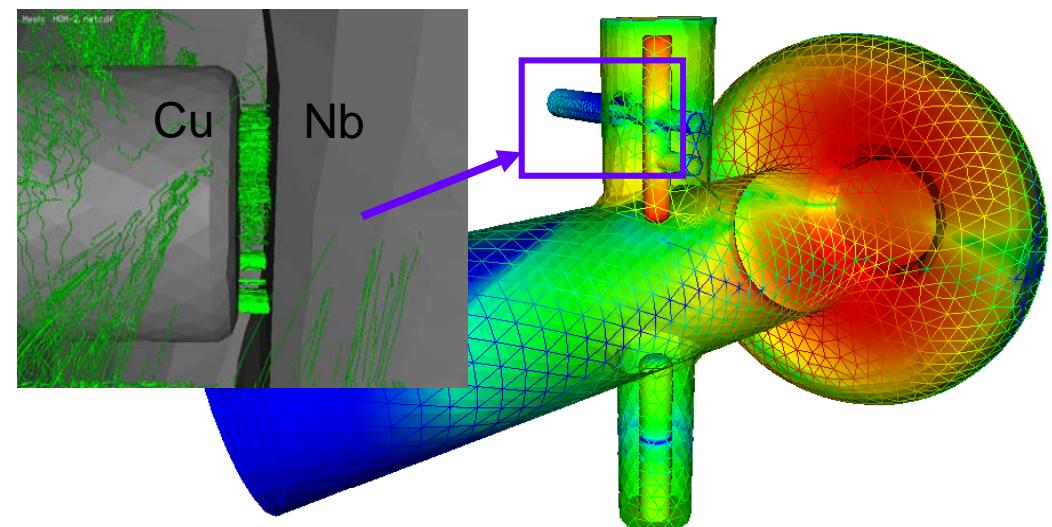
- Simulated using Track3P
- Deflecting field level scanned up to 5 MV/m
- No multipacting activities observed

# Multipacting in LOM and HOM Couplers

*LOM Coupler*



*HOM Coupler*



- No resonant trajectories found up to 5 MV/m deflecting gradient

- Resonant particle trajectories found for field gradient at 3-5 MV/m
- Impact Energy at 85–240 eV
- No MP for Cu antenna

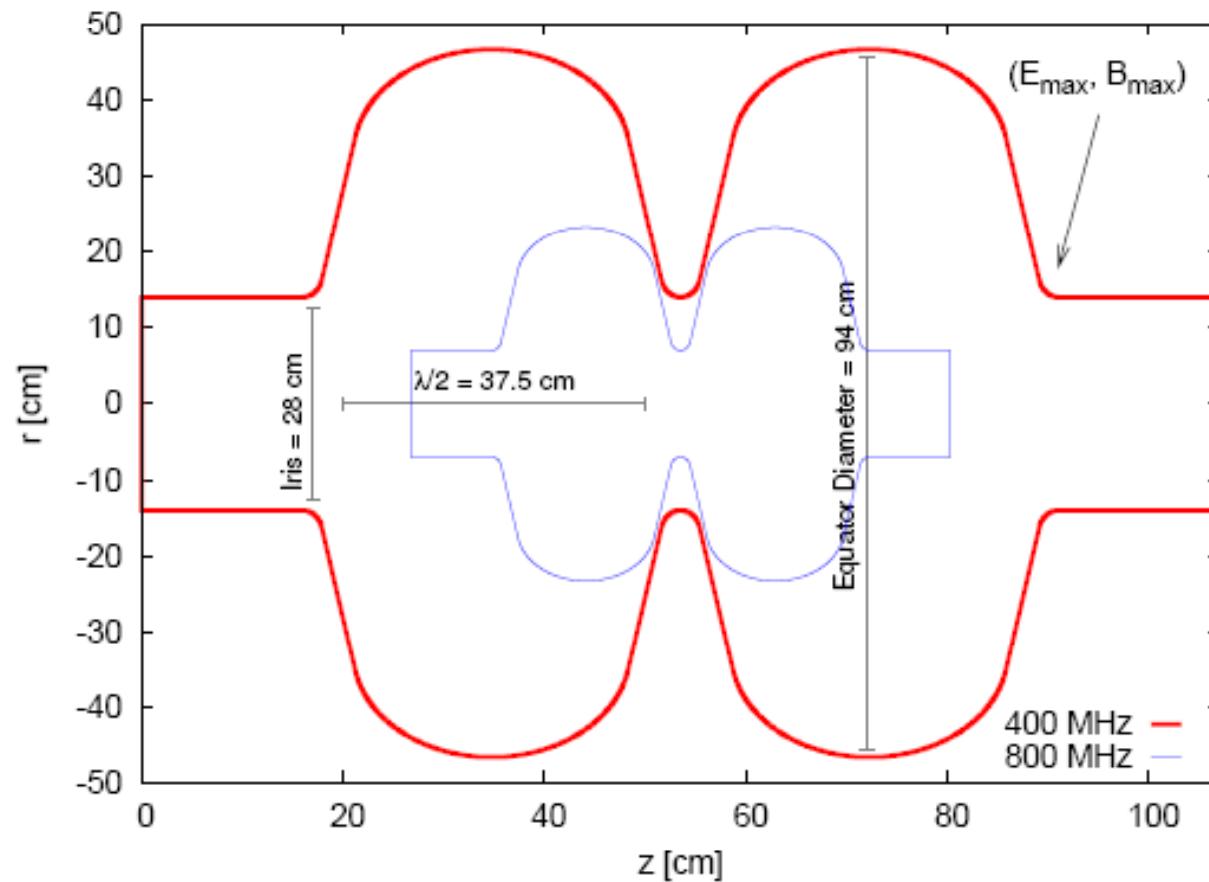
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# Preliminary Studies for LHC Crab Cavity RF Parameters & Couplers



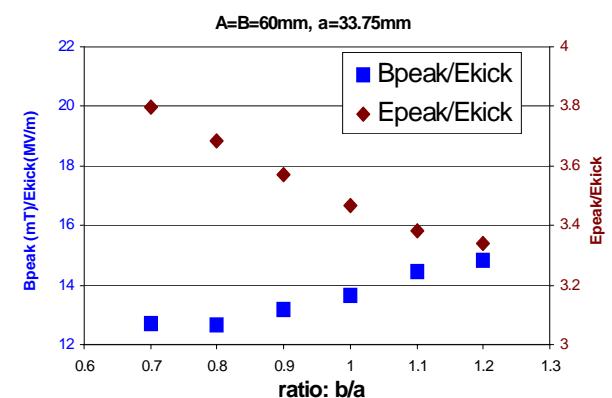
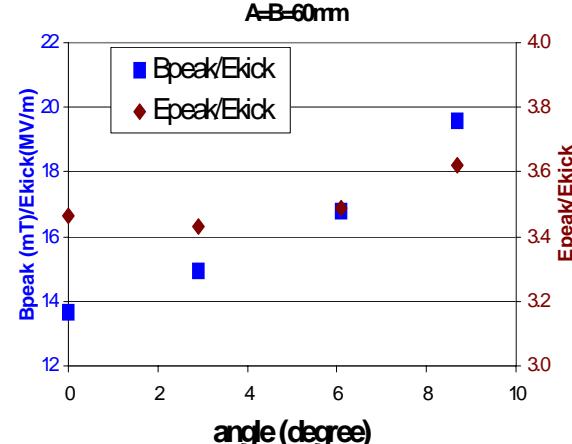
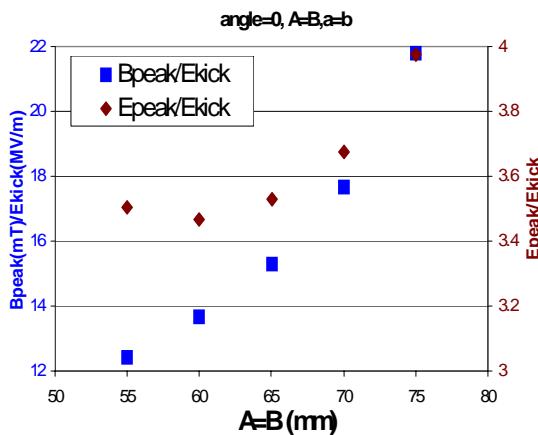
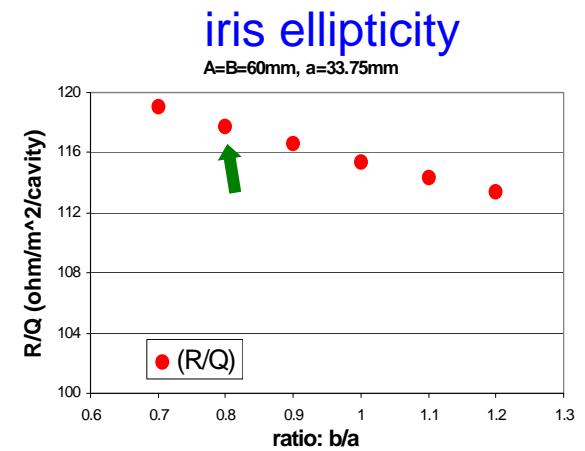
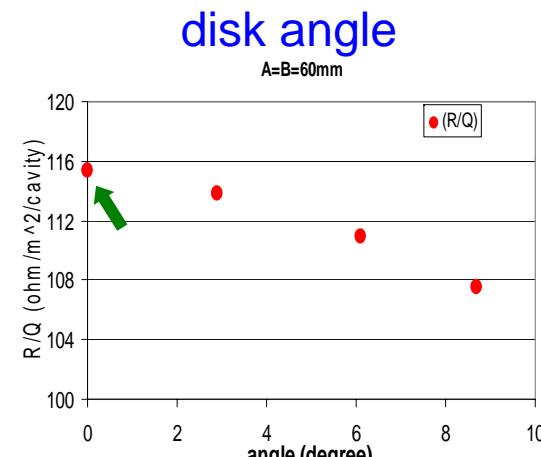
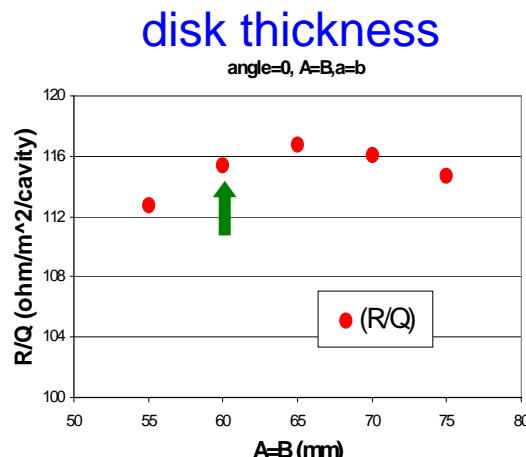
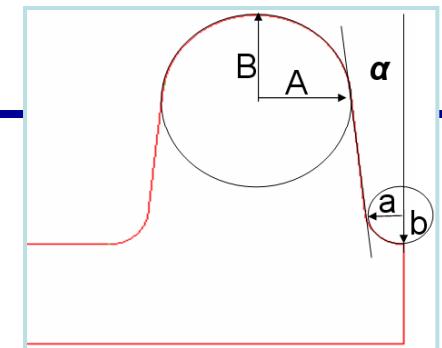
# 800 MHz Cavity Design For LHC Crab-Cavity

- Scaled from Rama Calaga's 400 MHz baseline design

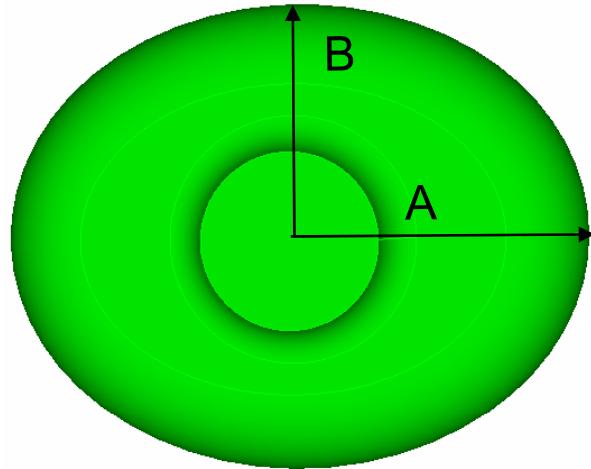


# RF Parameter vs Cavity Shape

- Maximum kick gradient limited by  $B_{peak}$
- Optimize disk parameters for optimal  $E_{peak}$  and  $B_{peak}$
- $r_{bp}=r_{iris}=70\text{mm}$ , cell length=187.5mm



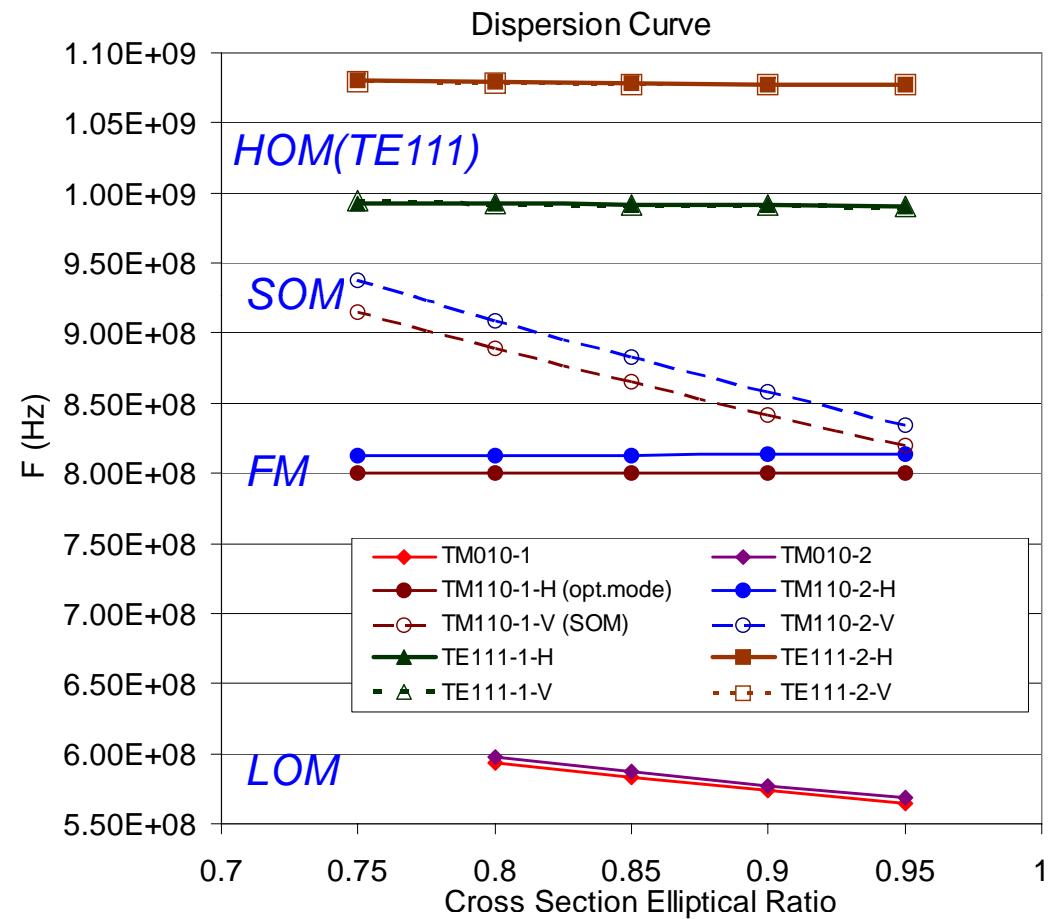
# Cell Squash Ratio



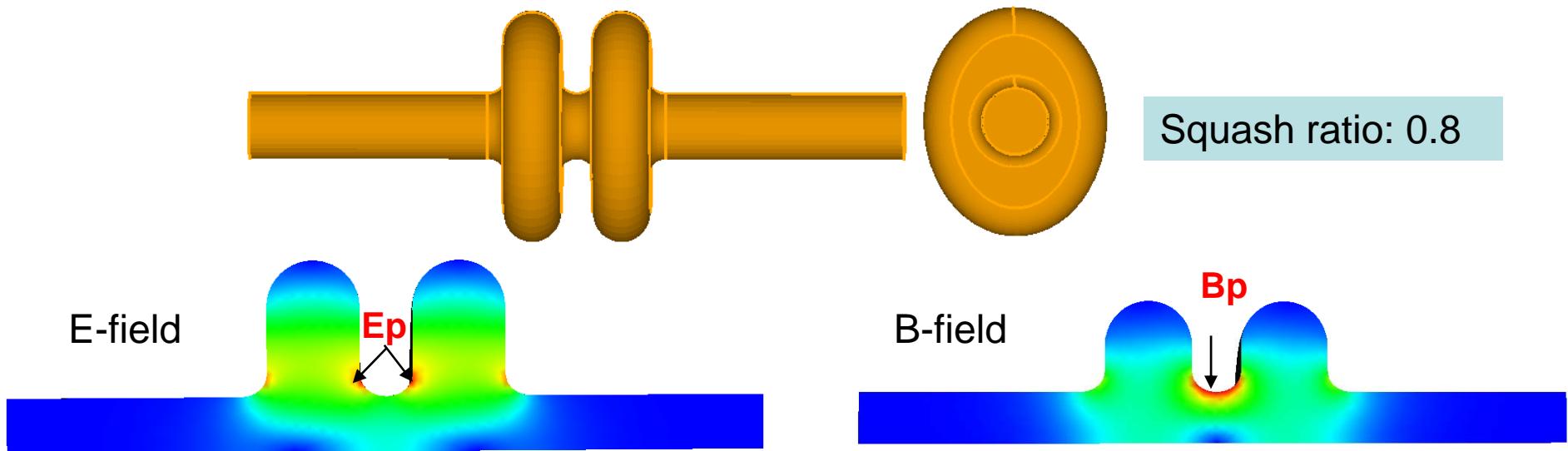
- Racetrack or Elliptical
- Chose squash ratio to optimize mode spectrum

B/A	A	$(F_y - F_x)$ (MHz)
0.90	235.97	42
0.85	240.10	65
0.80	244.92	89

Fc=1.2GHz @ Riris=70mm



# Preliminary Cavity RF Parameters

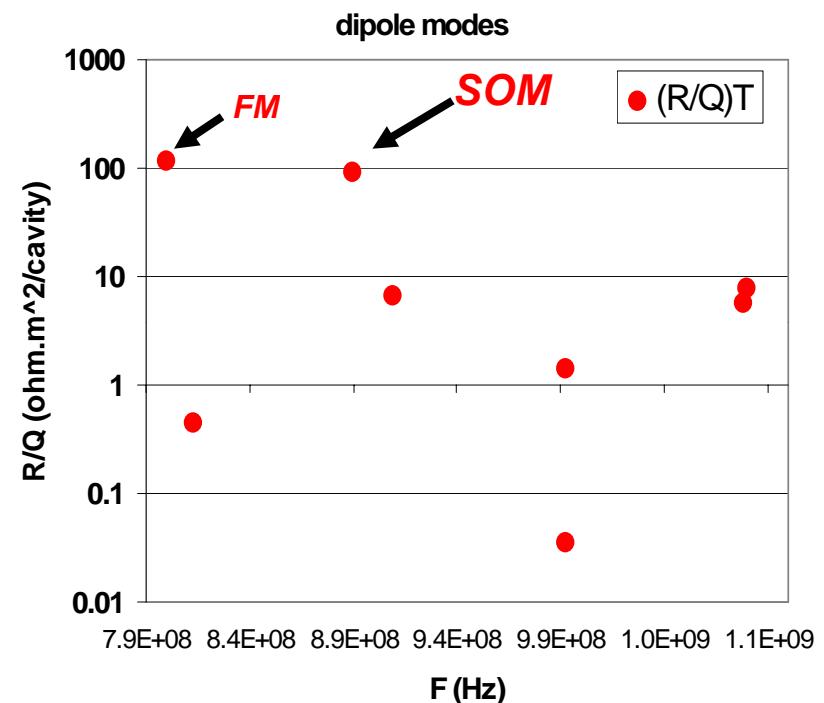
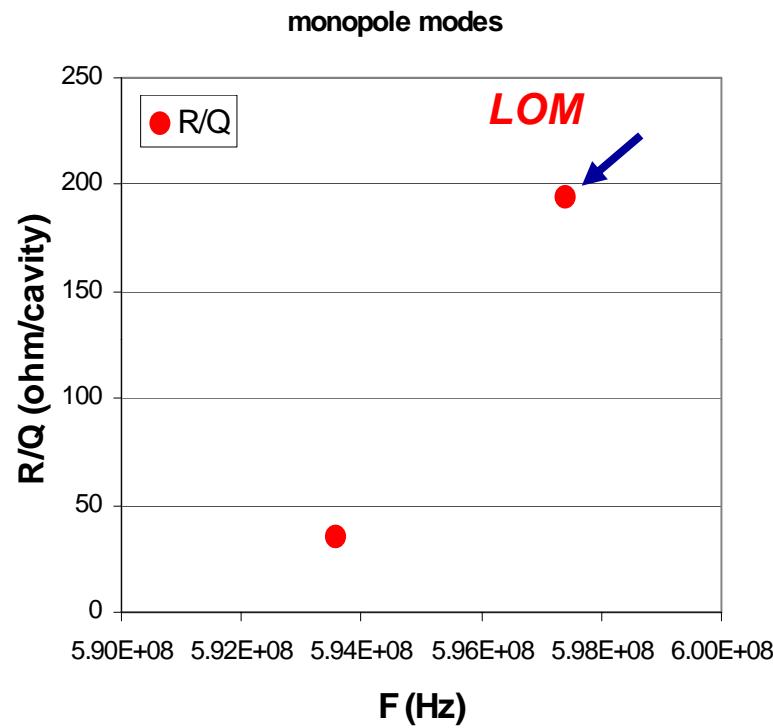


Frequency	800MHz
(R/Q)	117ohm/m <sup>2</sup> /cavity
Deflecting Voltage $V_T$	2.5MV
Deflecting Gradient Ekick	6.67MV/m
Epeak	24.72MV/m
Bpeak	82.75mT
Mode separation (Opt.-SOM)	89MHz

TESLA TDR cavity peak fields  
for comparison  
(Eacc: 37-47MV/m):  
Epeak: 70-90MV/m  
Bpeak: 150-190mT



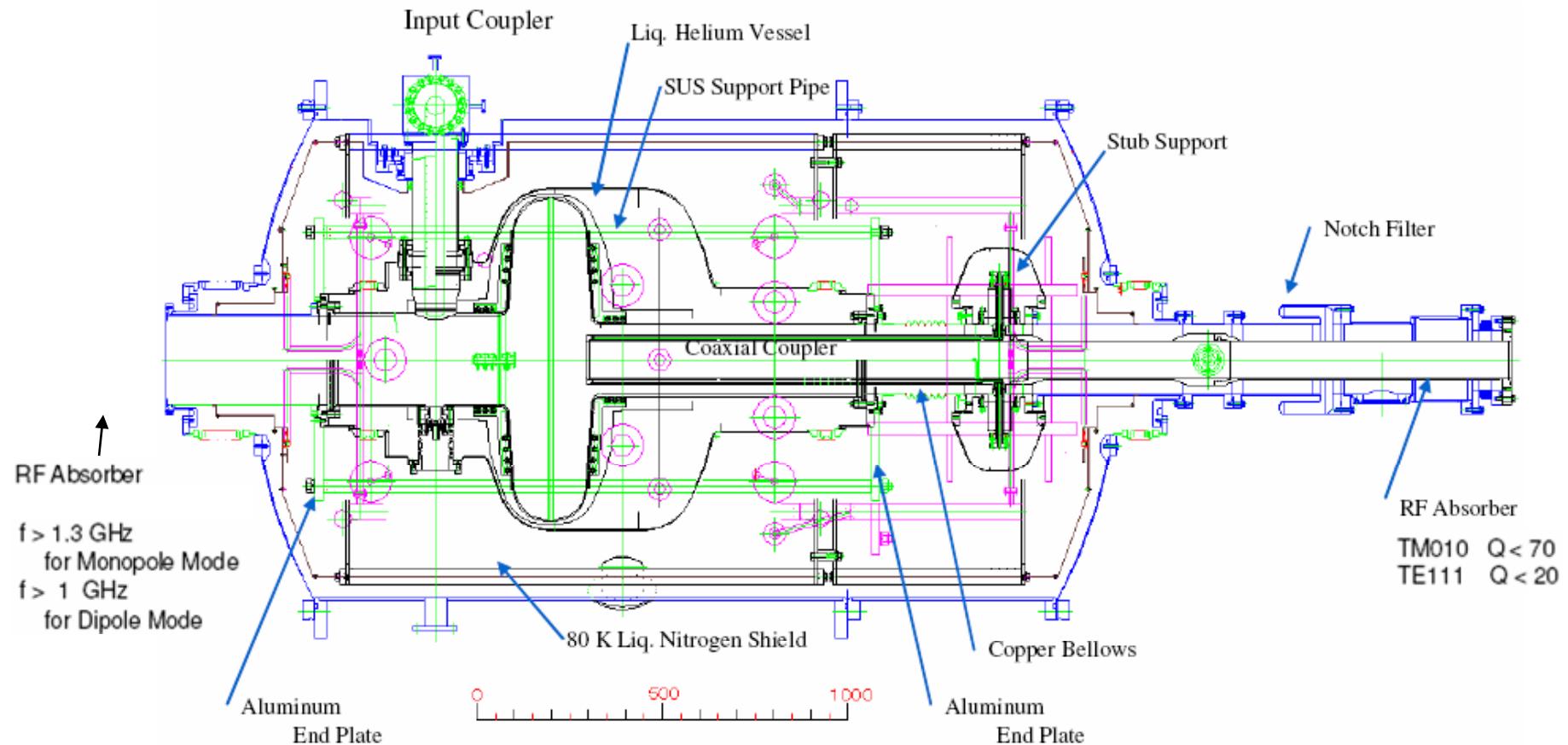
# LOM/SOM and HOM Damping



- Need specifications on damping requirements of LOM and SOM and HOM
- Choice of damping scheme may depend on Qext requirements

# KEKB Crab Cavity & Damping Scheme

Courtesy of K. Hosoyama



KEKB crab cavity utilizes a choked coaxial-coupler damping scheme

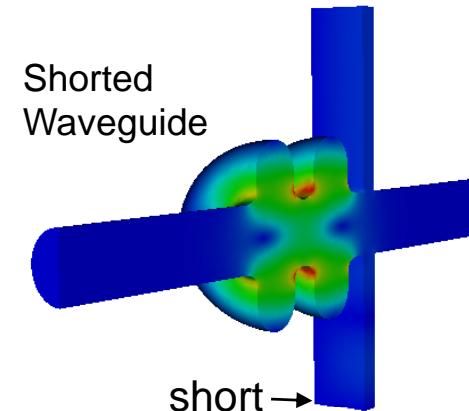
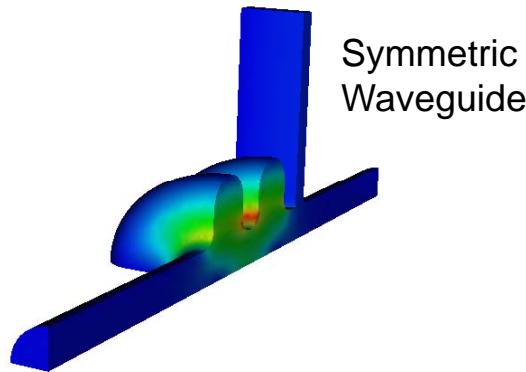
# Conceptual Damping Studies

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- LOM/SOM damping
  - Waveguide coupler
  - Coaxial coupler
  - Coaxial coupler in coaxial beampipe
  - Hoop coupler
- HOM damping
  - Waveguide coupler
    - Needs to cut off operating mode. “ $\pi/2$ ” mode may not be damped.
  - Coupler with choke or filter, e.g. ILC crab cavity HOM coupler



# Waveguide LOM/SOM Coupler



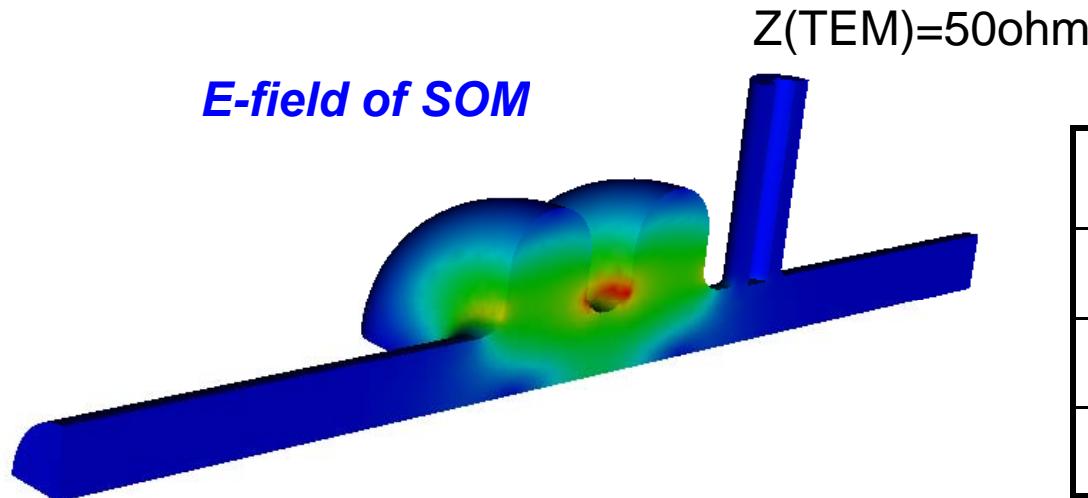
mode	F(MHz)	Qext
LOM-1	593	8.55e3
LOM-2	597	8.80e3
<b>SOM</b>	<b>889</b>	<b>4.86e3</b>

mode	F(MHz)	Qext
LOM-1	593	3.05e3
LOM-2	597	2.65e3
<b>SOM</b>	<b>889</b>	<b>3.93e3</b>

- Spacing between cavity and coupler is 25mm.
- Waveguide cutoff = 536MHz
  - Waveguide with short on one end improves damping
  - Optimal short position is frequency dependent
  - Can be optimized to damp both LOM and SOM effectively

# Coaxial LOM/SOM Coupler

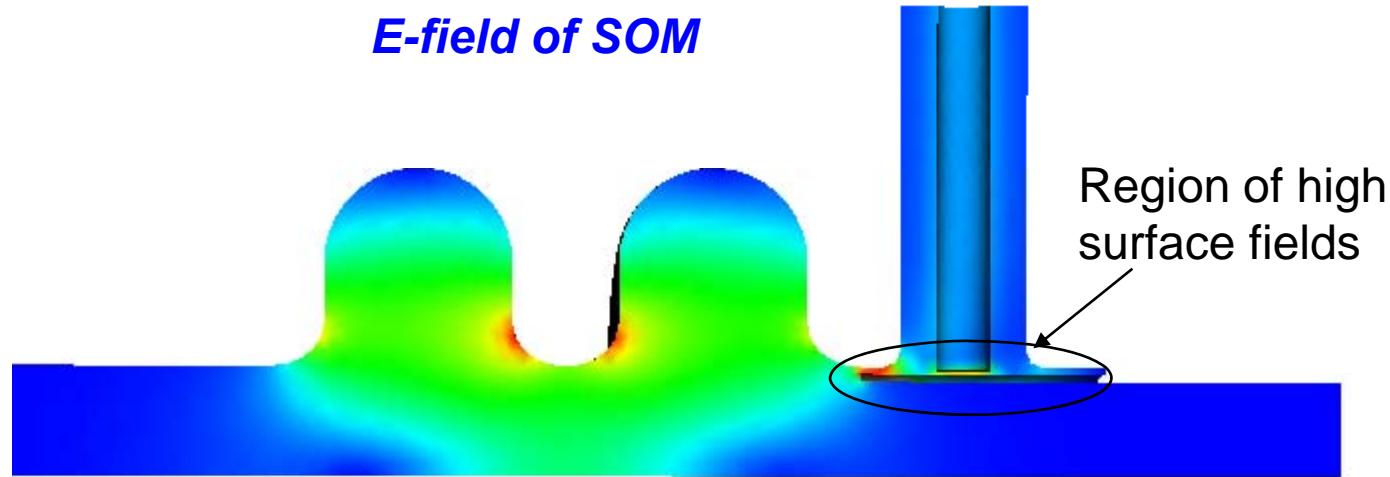
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mode	F(MHz)	Qext
LOM	593	7.22e5
LOM	597	7.29e5
<b>SOM</b>	<b>890</b>	<b>1.23e5</b>

- Hard to achieve much lower Q

# Coaxial LOM/SOM Coupler in Coaxial beampipe

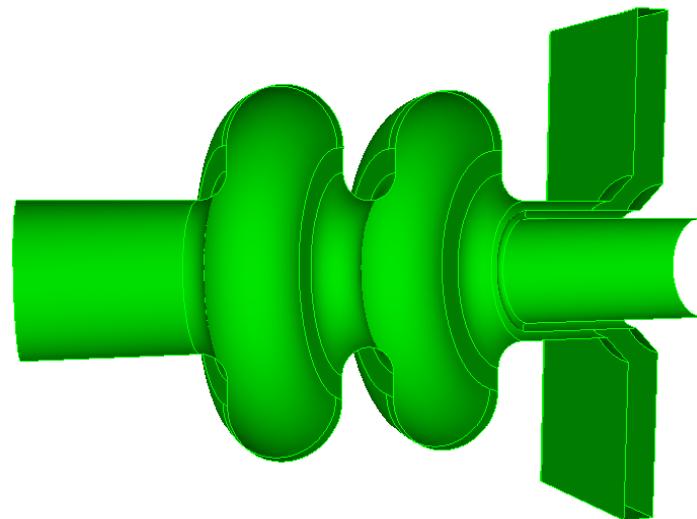


mode	F(MHz)	Qext
LOM	593	1.60e4
LOM	597	1.71e4
<b>SOM</b>	<b>890</b>	<b>749</b>

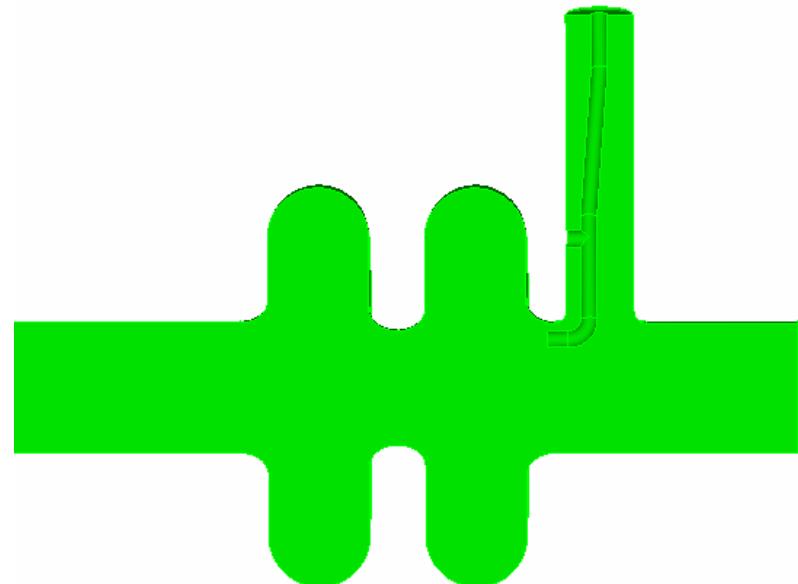
- Need optimization for damping both LOM and SOM
- Multipacting and surface field effects need to be analyzed

# Other Damping Considerations

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Coaxial-waveguide to enhance waveguide coupling



Hook type coupler similar to ILC crab cavity LOM coupler.

# Summary

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- SLAC parallel electromagnetics and beam dynamics codes facilitate the design and optimization of cavities
- LOM and HOM coupler designs and multipacting analysis for the ILC crab cavity have been performed
- Design and optimization of the LHC crab cavity are being studied for
  - Cavity RF parameters
  - Wakefield damping schemes for LOM, SOM and HOM modes
  - Multipacting

