Crab Cavity Design for the ILC BDS

Liling Xiao, Zenghai

ACD, SLAC

ILC BDS meeting, Mar.6, 2007

Collaboration with FNAL and UK lab on this project.

1. Introduction;
2. FNAL 3.9GHz deflecting mode cavity (Workshop on 3.9 GHz Deflecting Mode Cavity Simulation", 5/8-5/9/2006 FNAL);
3. New HOM/LOM couplers;
4. Mode mixing effect;
5. Wakefield study
6. Future plan.

1. Introduction

BDS Report: Deepa Angal-Kalinin, Hitoshi Yamamoto, Andrei Seryi

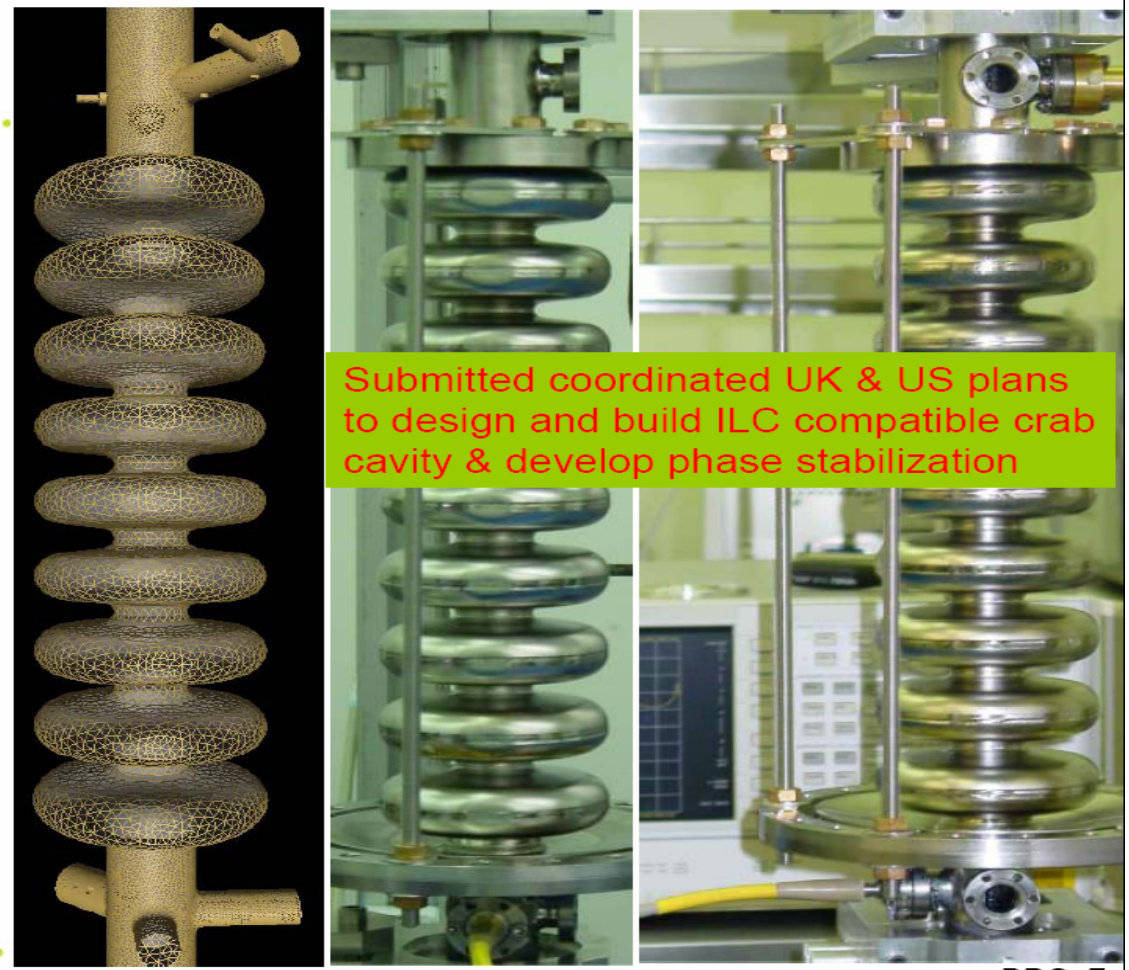
Crab cavity

Right: earlier prototype of 3.9GHz deflecting (crab) cavity designed and build by Fermilab.

Left: Cavity modeled in Omega3P, to optimize design of the LOM, HOM and input couplers.

FNAL T. Khabibouline, L.Bellantoni, et al., SLAC K.Ko et al., Daresbury P. McIntosh, G.Burt, et al.

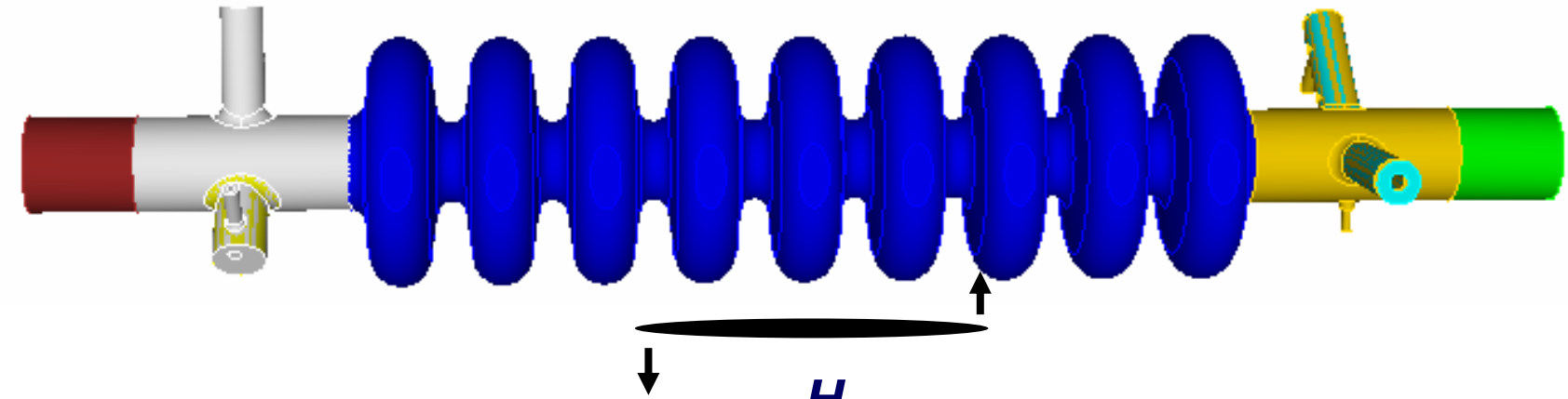
Collaboration of FNAL, SLAC and UK labs is working on the design.

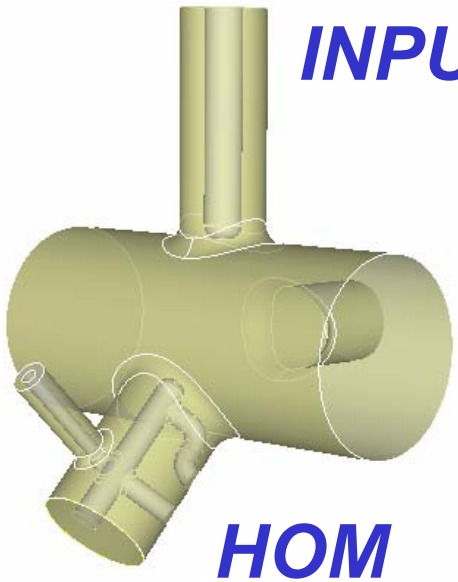


Submitted coordinated UK & US plans to design and build ILC compatible crab cavity & develop phase stabilization

July 20, 06, VLCW06 Global Design Effort BDS: 7

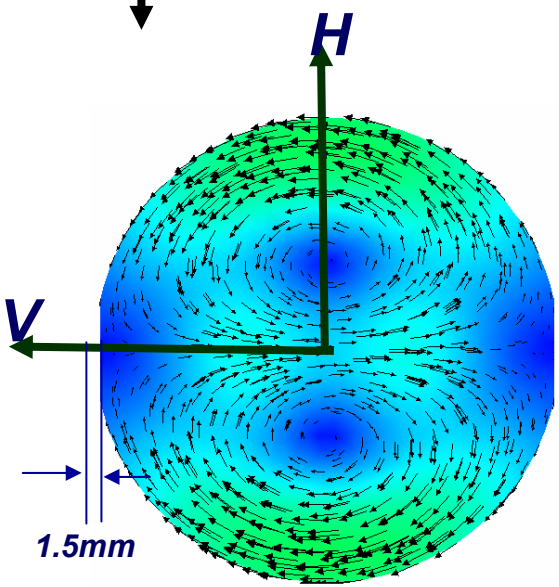
2. FNAL 3.9 GHz Deflecting Cavity Model





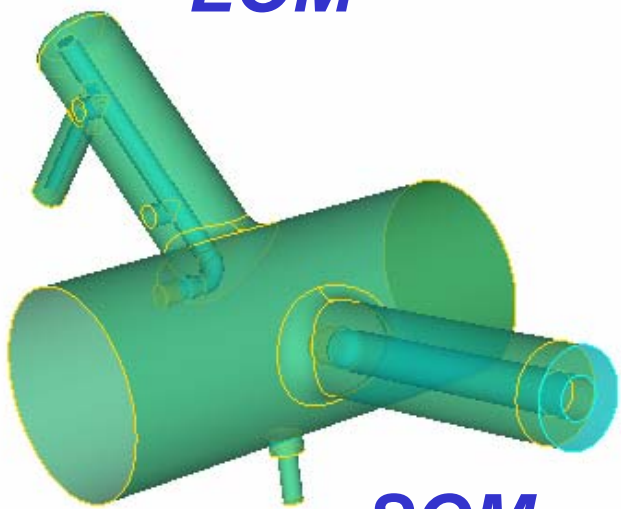
INPUT

HOM

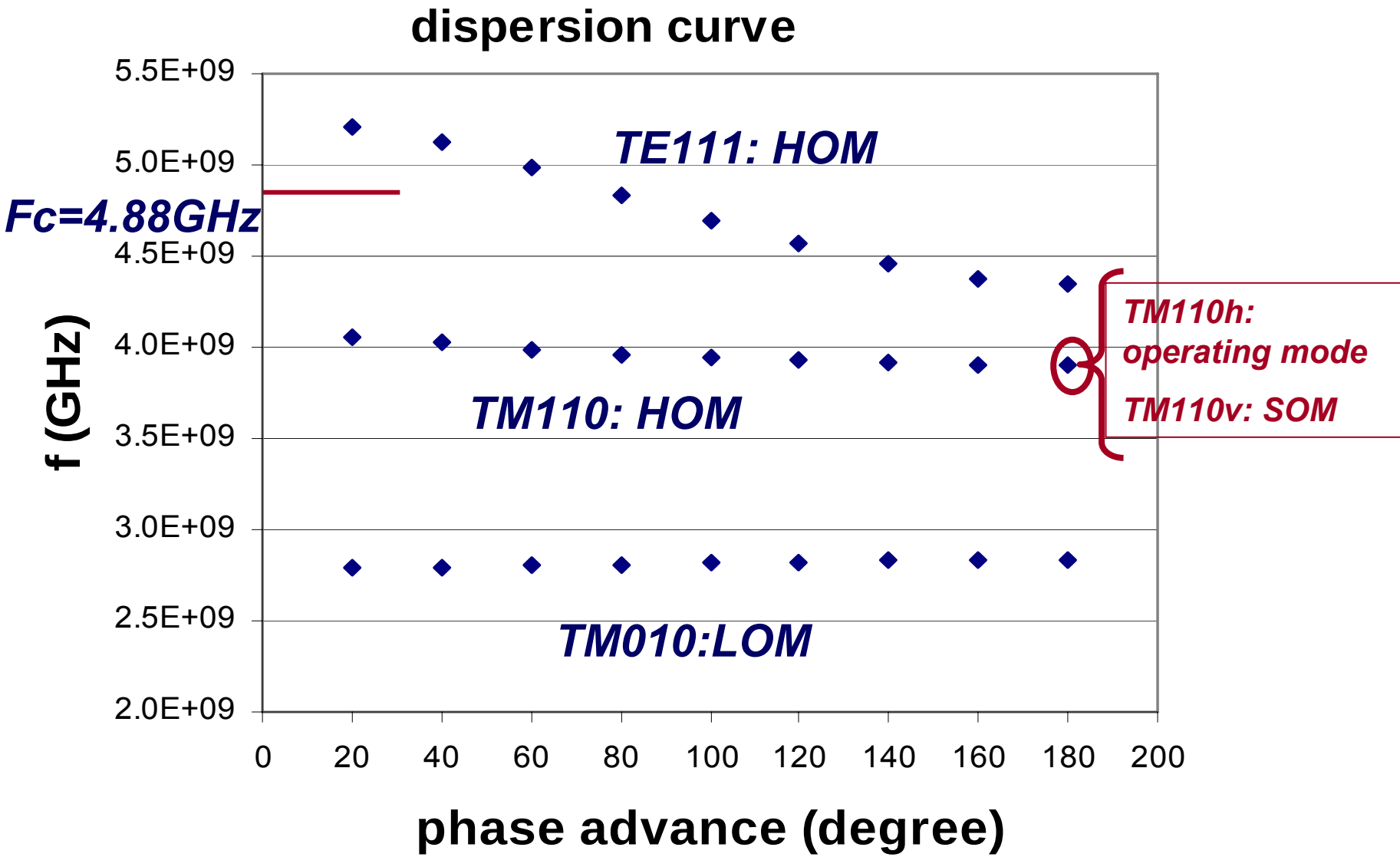


Operating mode
TM110 π mode

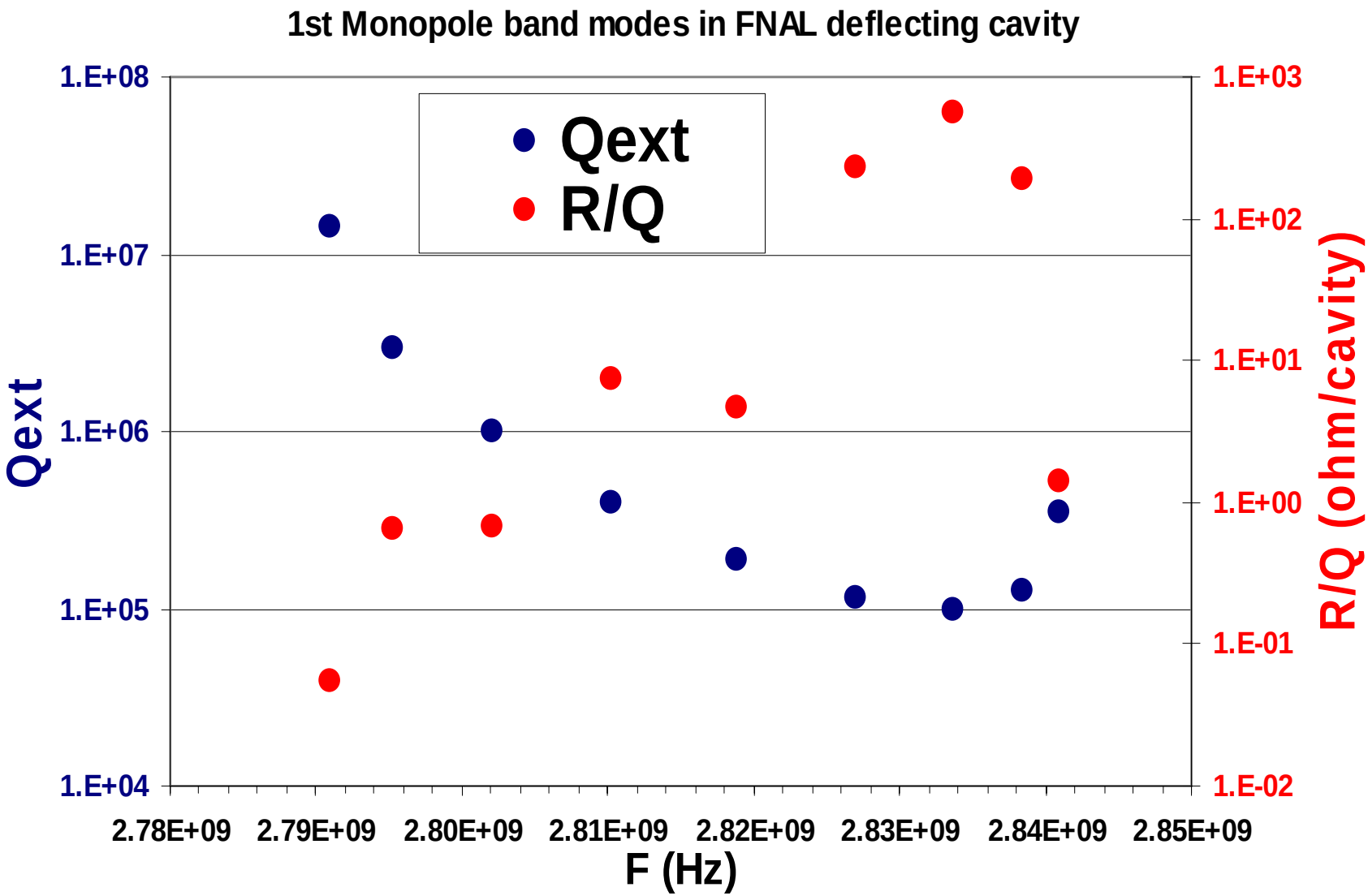
LOM



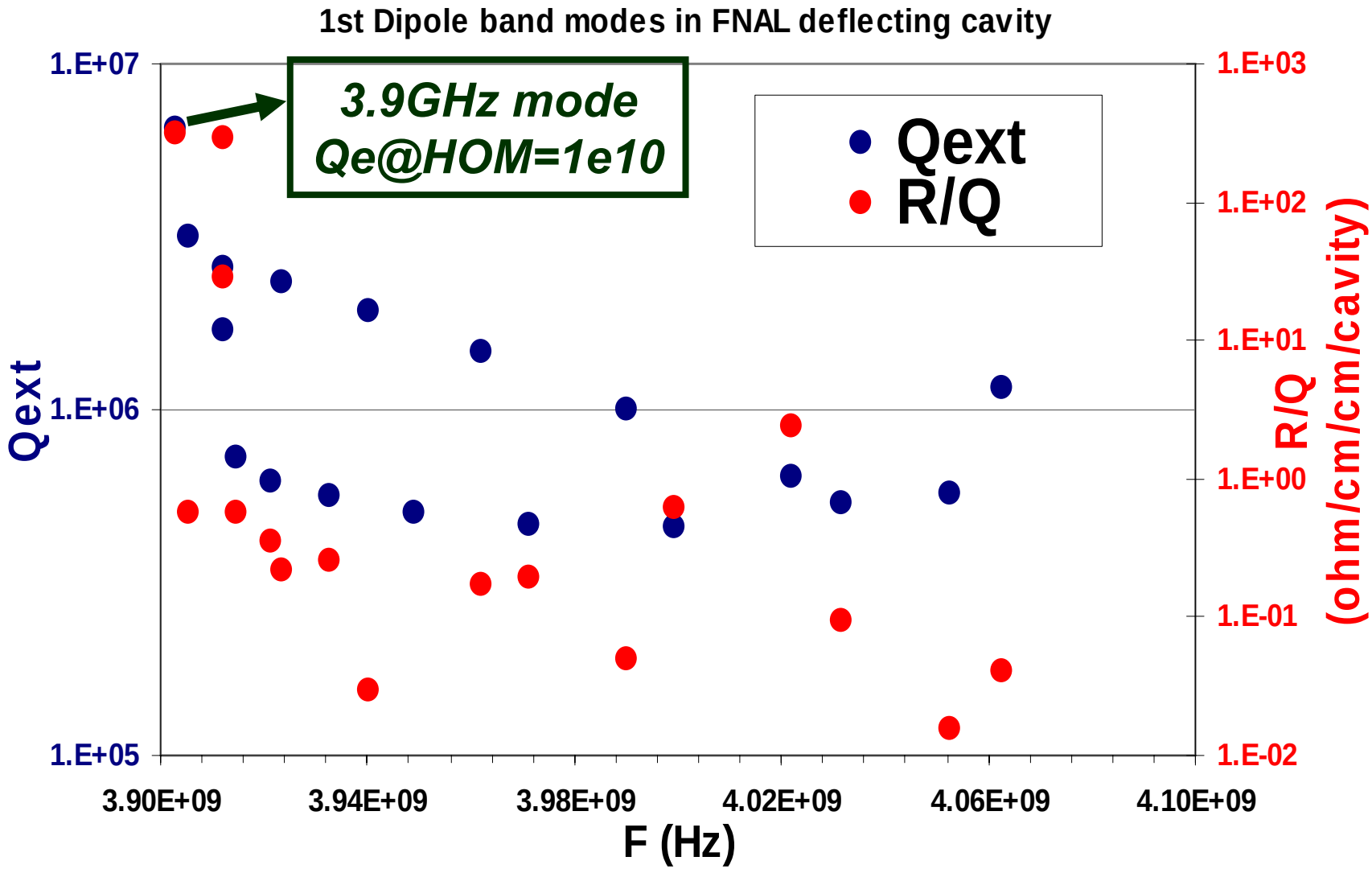
SOM


dispersion curve
5.5E+09
5.0E+09
4.5E+09
4.0E+09
3.5E+09
3.0E+09
2.5E+09
2.0E+09
f (GHz)
Fc=4.88GHz
TE111: HOM
TM110: HOM
TM010:LOM
TM110h:
operating mode
TM110v: SOM
0
20
40
60
80
100
120
140
160
180
200
phase advance (degree)

2.1. TM010 modes: Omega3P results with LOM tuning



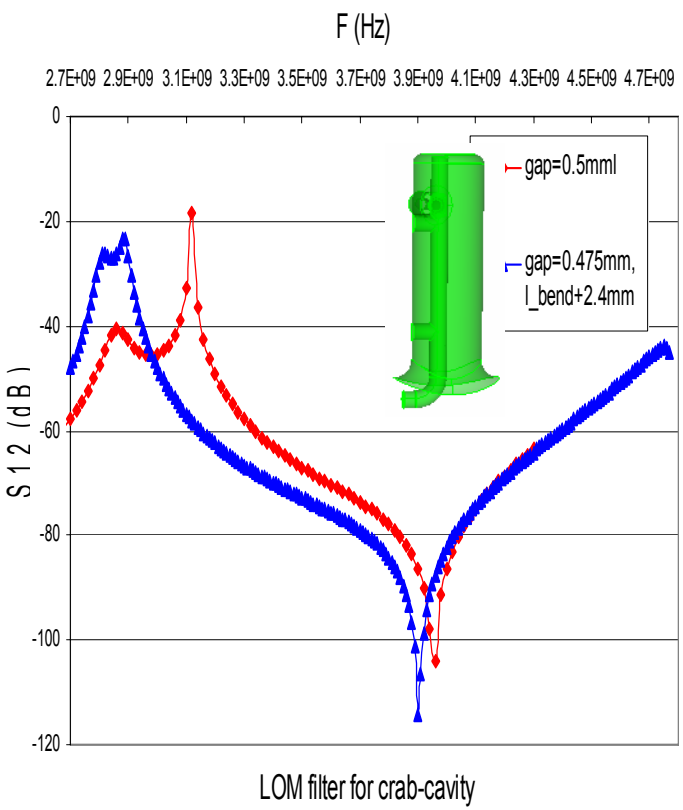
2.2. TM110 modes: Omega3P results with HOM tuning



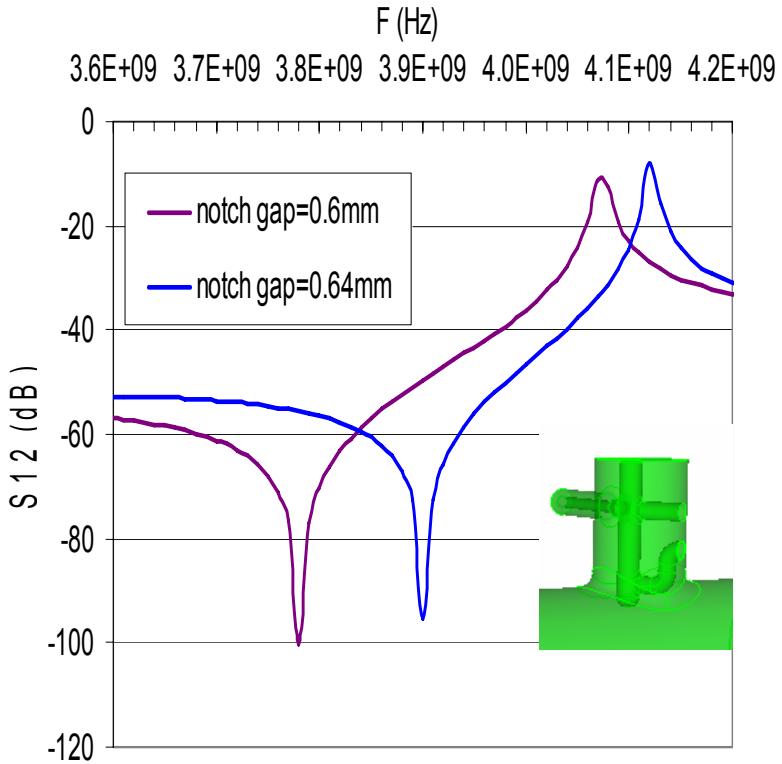
2.3. Two problems current FNAL 3.9GHz deflecting mode cavity.

1). The notch filter in HOM/LOM coupler is too sensitive.

LOM: df/dgap=2.20MHz/micro

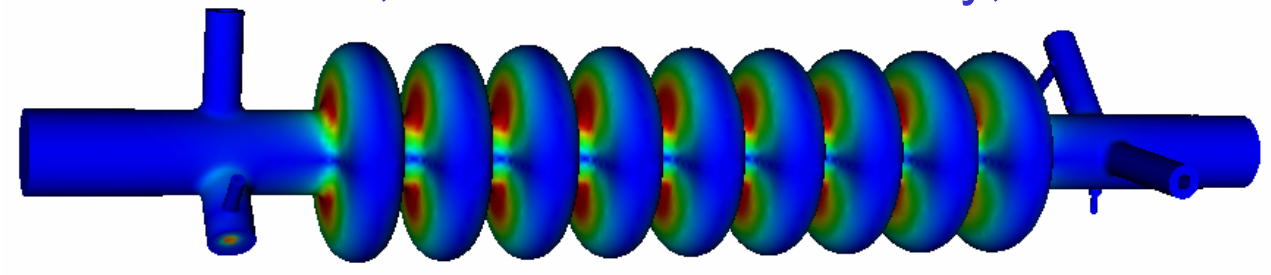


HOM: df/dgap=1.60MHz/micro



2). Mode mixing between ***7π/9 mode and the unwanted π mode***

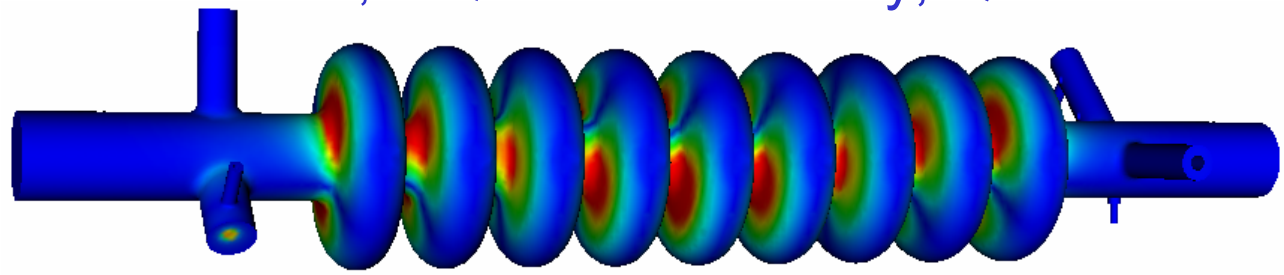
F = 3.9030GHz, R/Q=318 Ω /cm^2/cavity, Qext=6.5e+6



3.9GHz mode

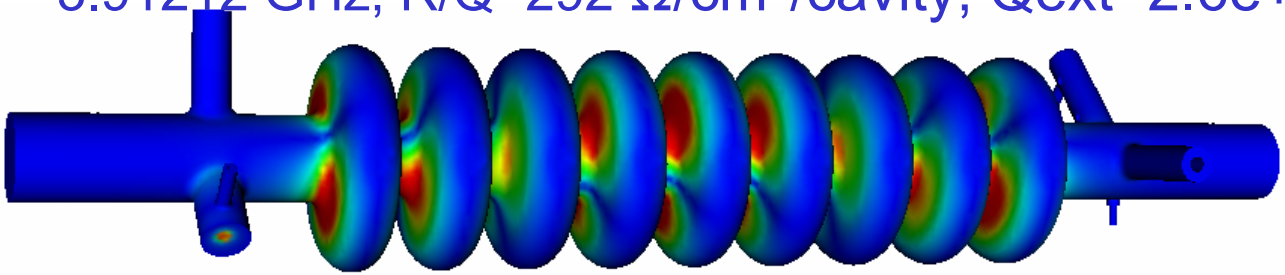
"Mode Overlap"

F = 3.91209 GHz, R/Q=28 Ω/cm^2/cavity, Qext=1.7e+6



7π/9 mode

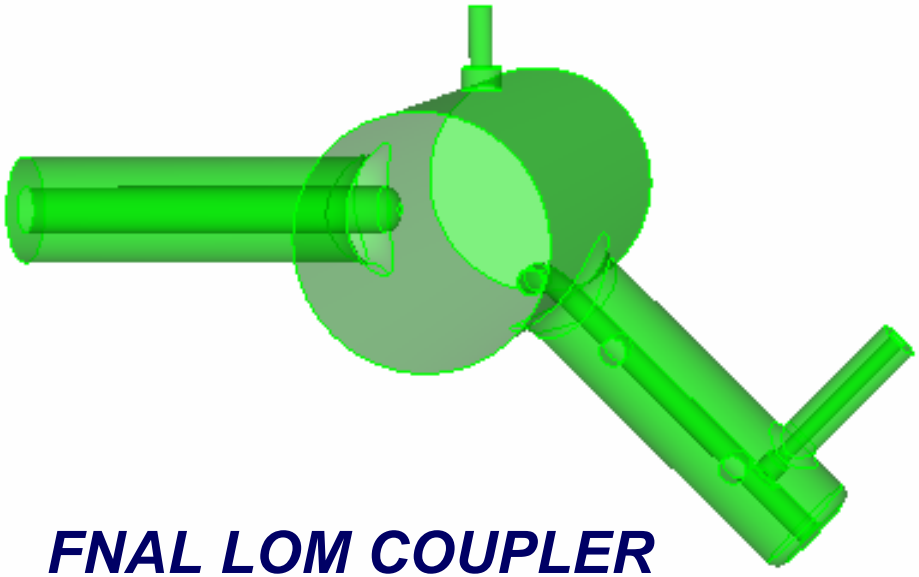
F = 3.91212 GHz, R/Q=292 Ω/cm^2/cavity, Qext=2.6e+6



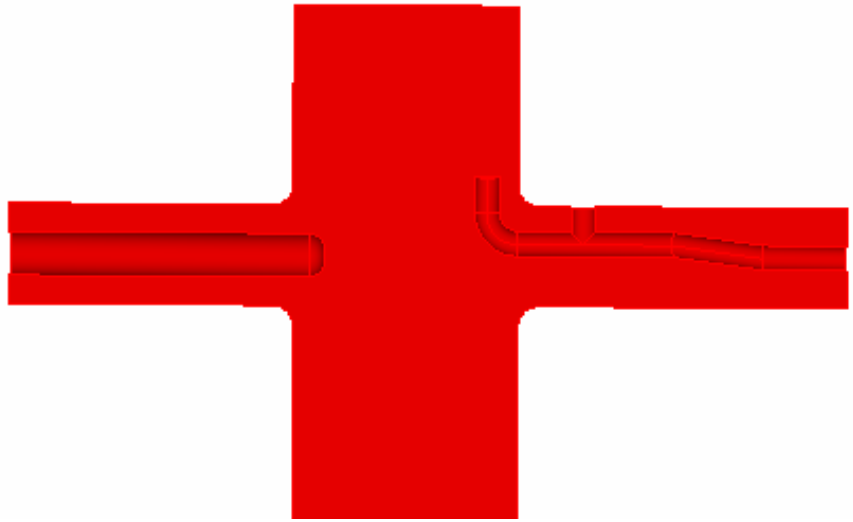
SOM

3. New LOM/HOM Coupler

3.1 Redesign LOM Coupler



FNAL LOM COUPLER

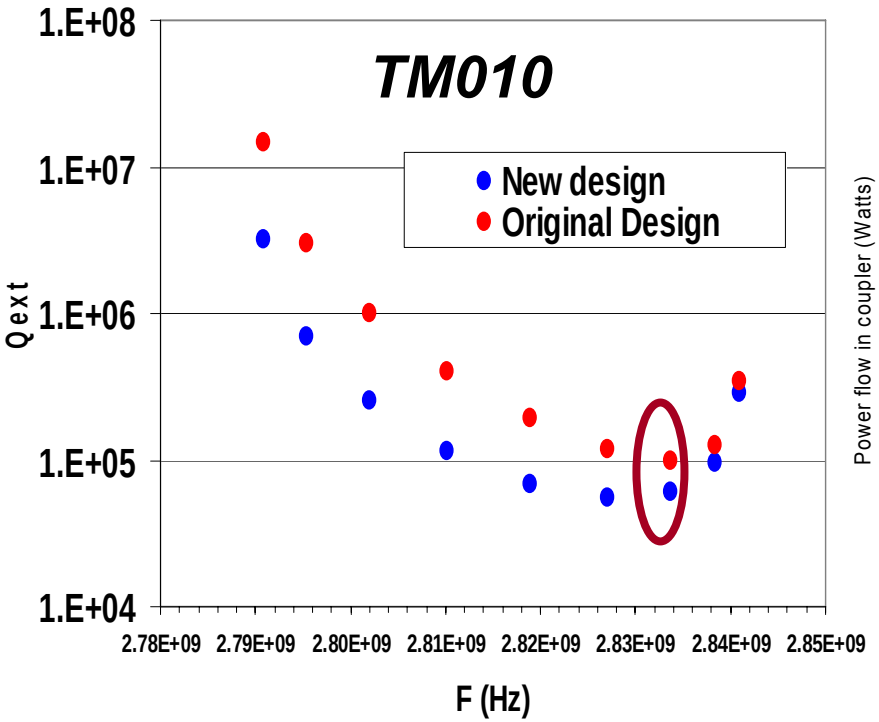


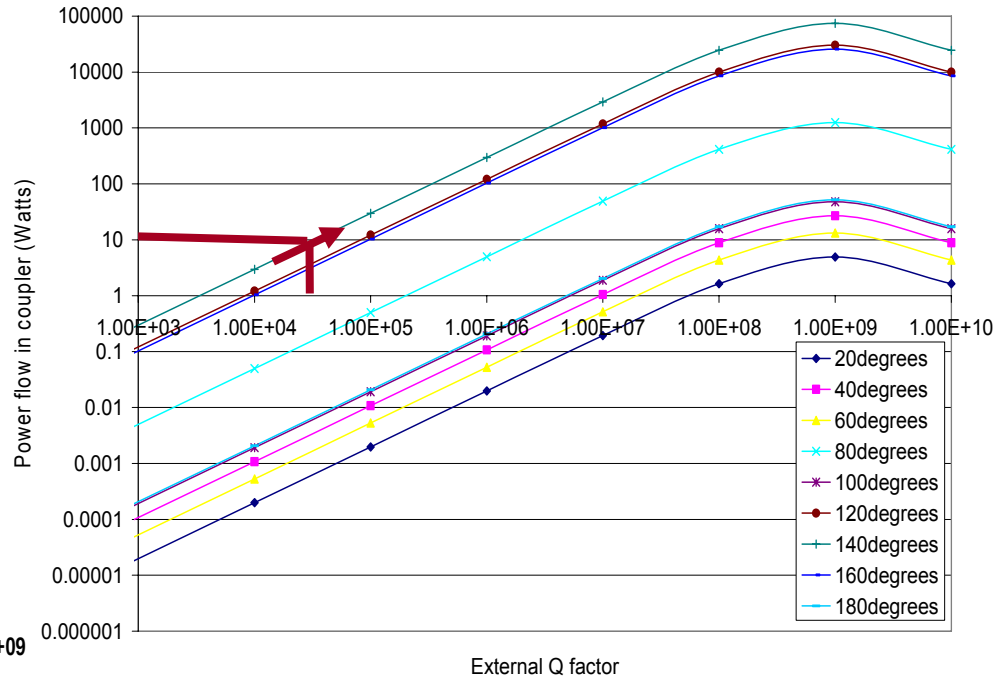
SLAC LOM COUPLER

Rotate to opposite side of SOM and eliminate notch filter through symmetry.

Simplify the structure and increase the power handling.

LOM coupler damping and heating

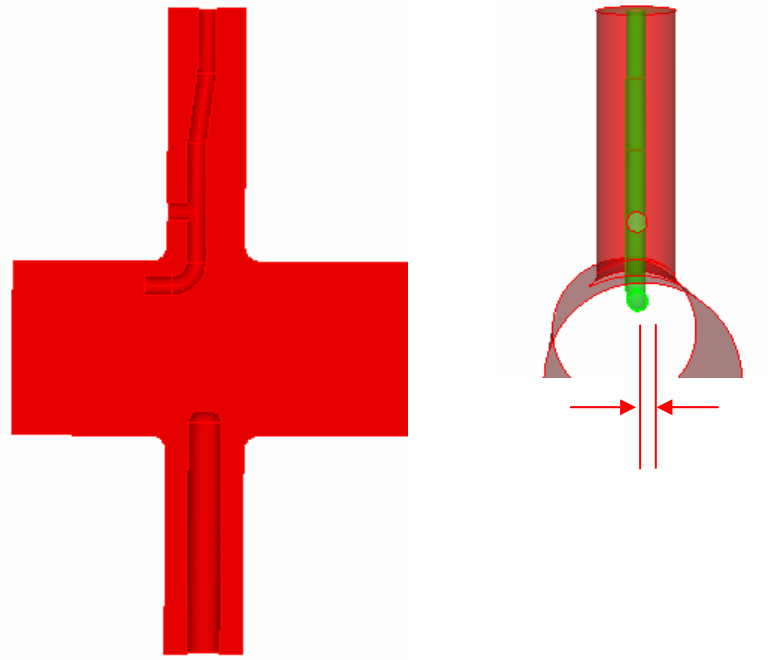




Omega3p results

G Burt: Crab cavity Video meeting, 2/07/07

LOM central conductor misalignment test



For operating π mode:

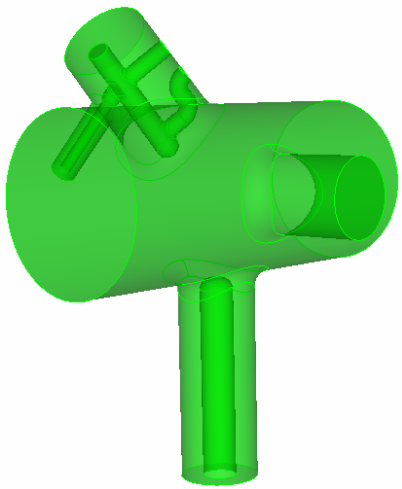
LOM center rod is on the center

Qext @ LOM>1.0e+12

LOM center rod shift 1mm

Qext @ LOM=1.3e+9

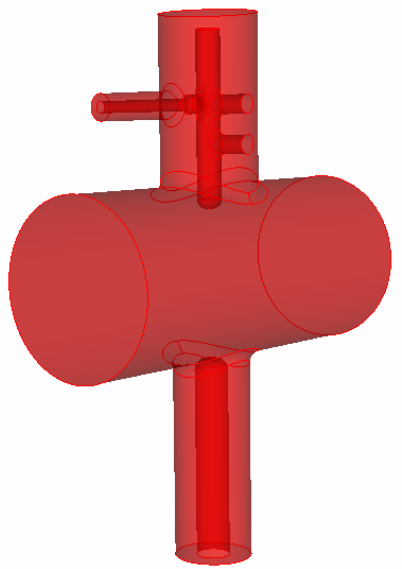
3.2. Redesign HOM Coupler



FNAL DESIGN

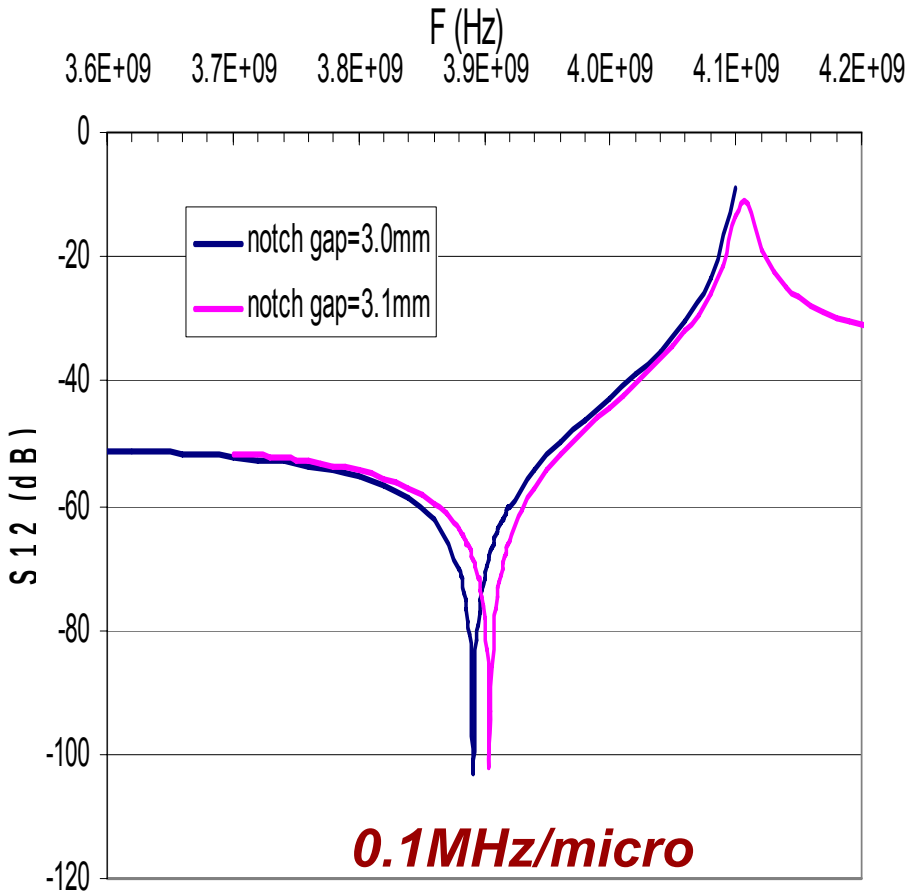
loop coupling:

Reduce Notch Gap Sensitivity



SLAC DESIGN

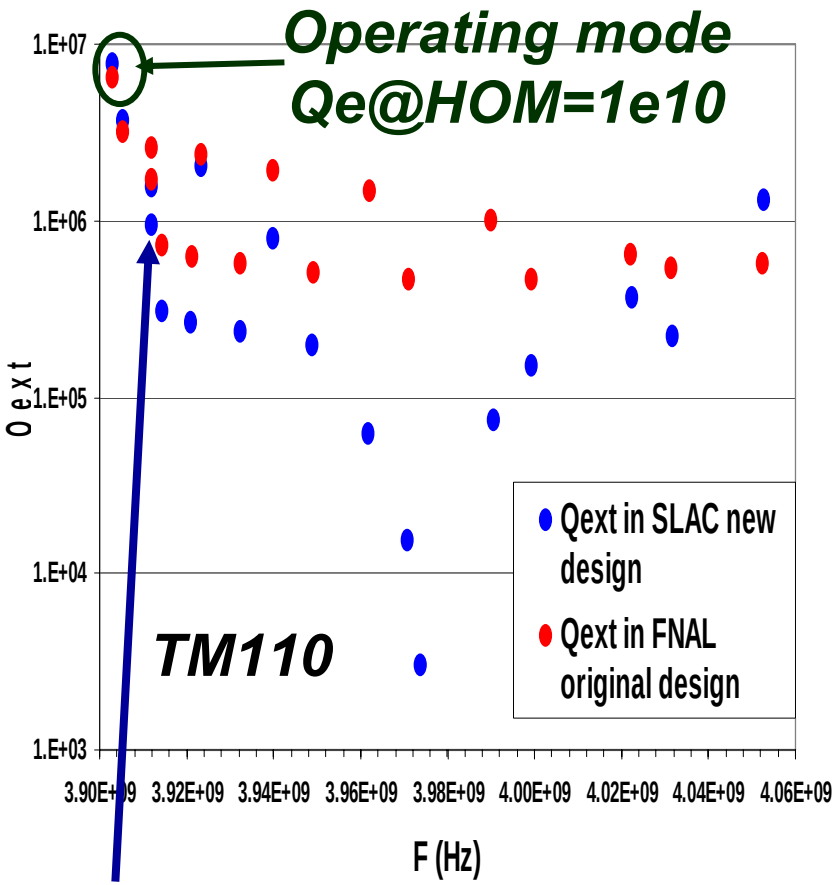
probe coupling



~TESLA(0.13MHz/micro)

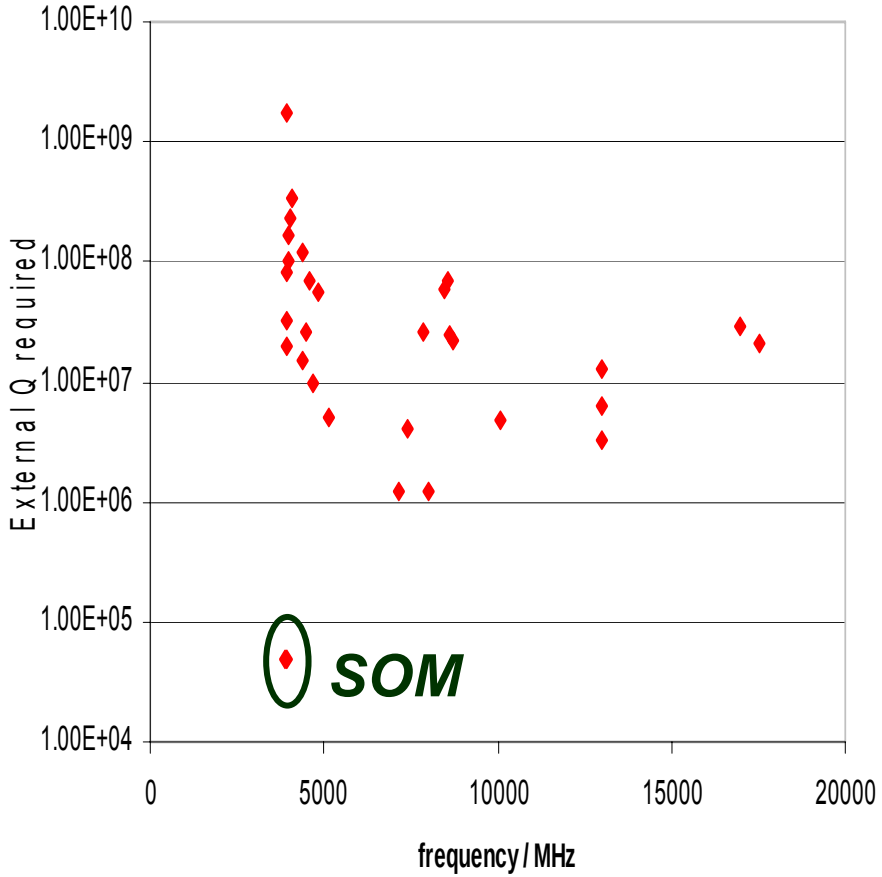
HOM/SOM coupler damping

Omega3p results



SOM damping not effective due to mode mixing

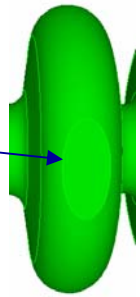
Required Damping

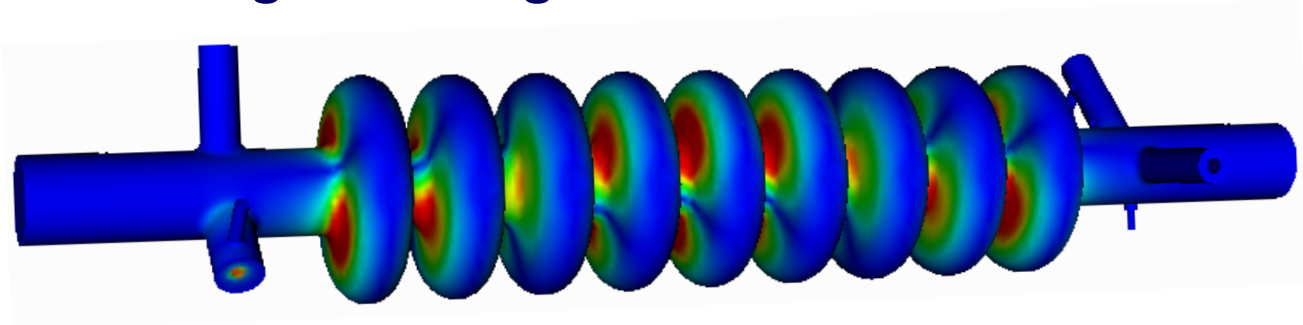


G Burt: Crab cavity Video meeting, 2/07/07

4. Mode mixing effect

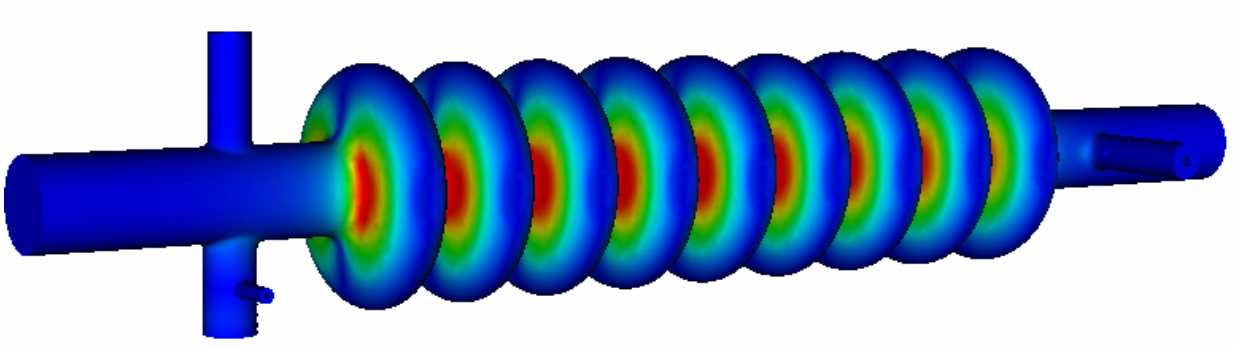
Original design: cell indent=1.5mm





F = 3.91212 GHz, R/Q=292 Ω/cm^2/cavity, Qext=2.6e+6

cell indent=2.0mm



F = 3.91917 GHz, R/Q=320 Ω/cm^2/cavity, Qext=7.2e+5

5. To do

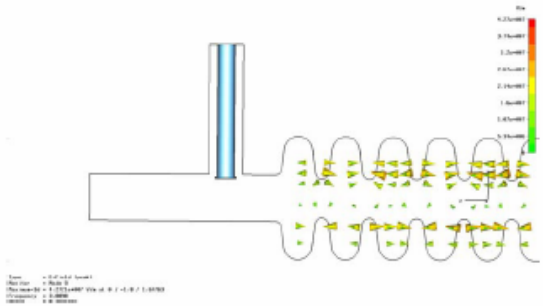
5.1. Finish the HOM/LOM/SOM coupler design;

a) Check the SOM Qext requirement and optimal SOM coupler;

b) Check the operating mode coupling requirement and optimal input coupler;

c) Consider combining LOM and SOM together.

Power Coupler



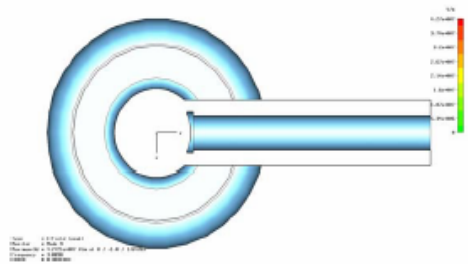
40 Ohm coaxial line, 27mm OD

Shaped tip for maximum coupling.

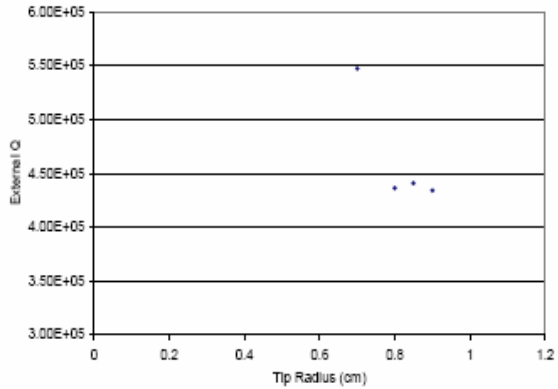
Centre line 40mm from cavity.

3mm beampipe penetration

Qe=4.5x10^5



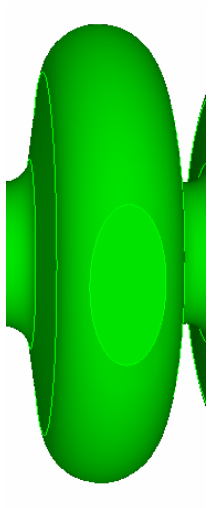
Need to check if this can be adapted for a SOM coupler as well.



Crab cavity video meeting, Sept.06,

G.Burt, P.Goudket, R.Jones

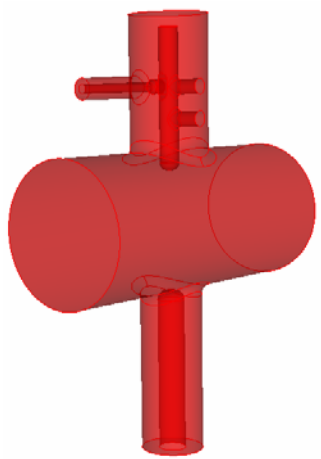
5.2. Optimize the cell shape;

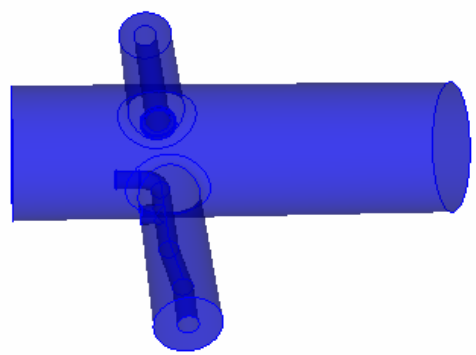


Modify cavity indents or use elliptical cavity shape to avoid mode overlap;

5.3. Study multipacting in cavity and couplers;

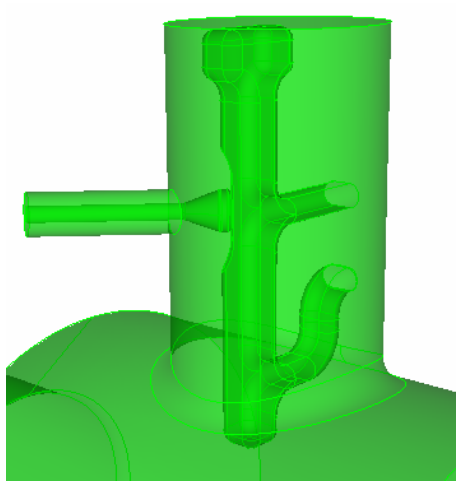
Multipacing activities had been found in Ichiro cavity and 3rd harmonic cavity HOM coupler.

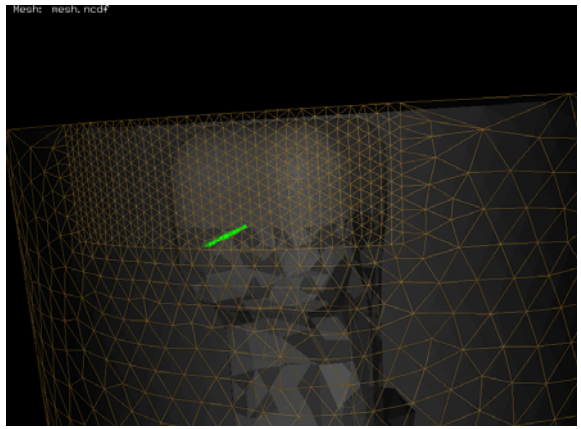


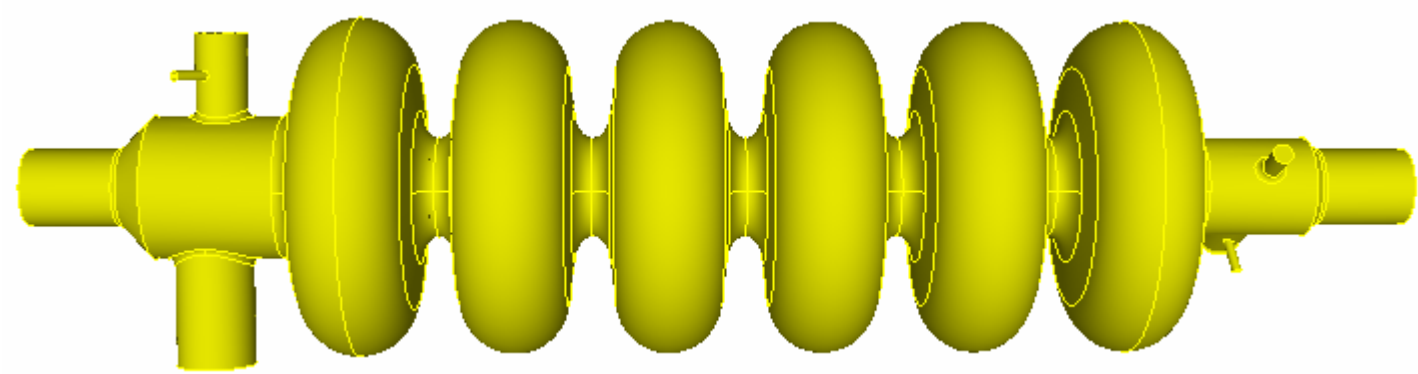


Example of SNS cavity HOM MP simulation

- *SNS Cavity HOM coupler MP barriers Were found*
- *The gradient levels match that of the measurement*

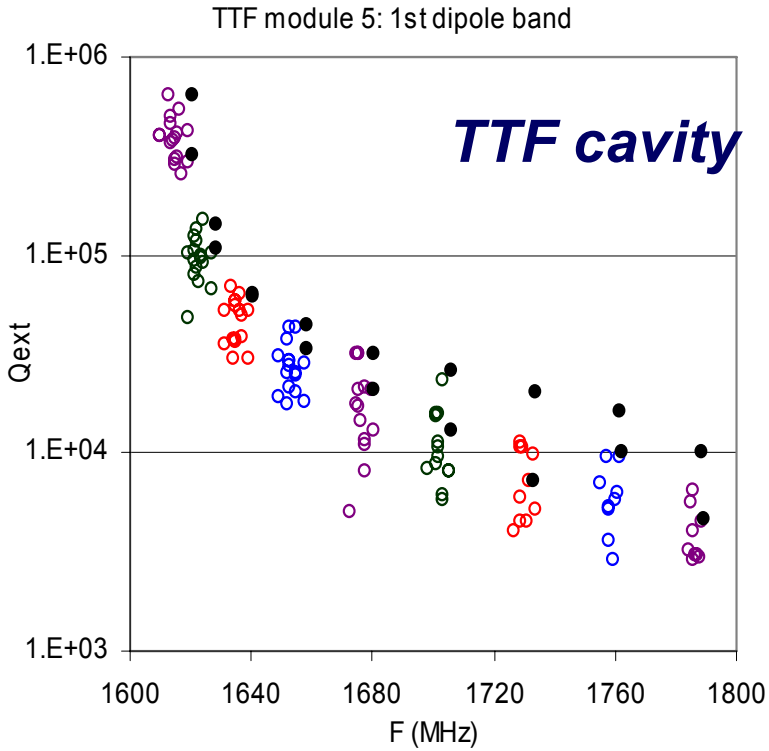


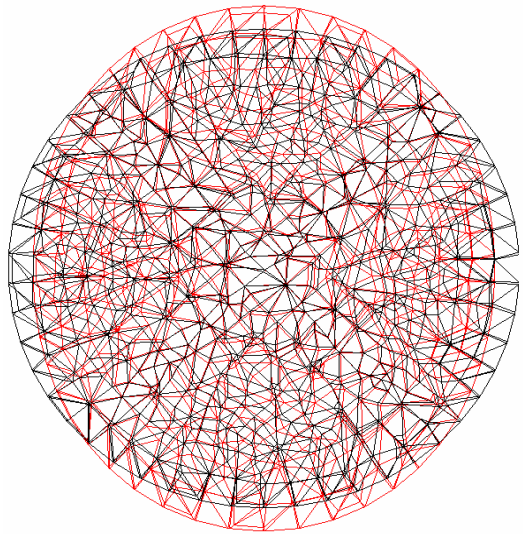




SNS beta0.81 cavity

5.4. Calculate effect of cavity imperfections on beam dynamic



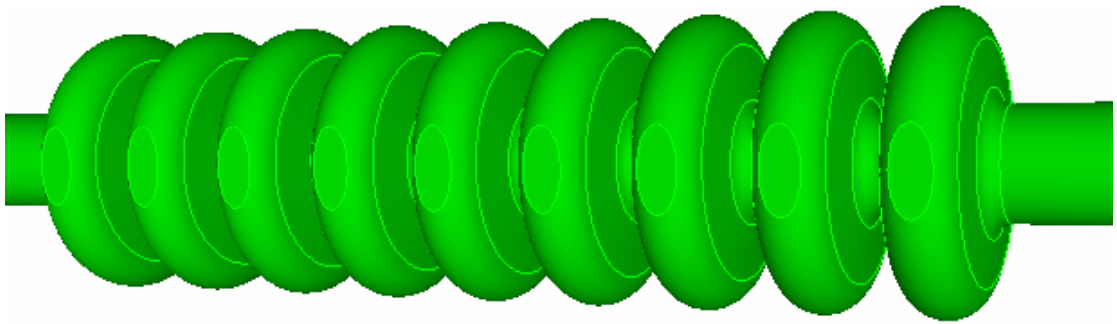


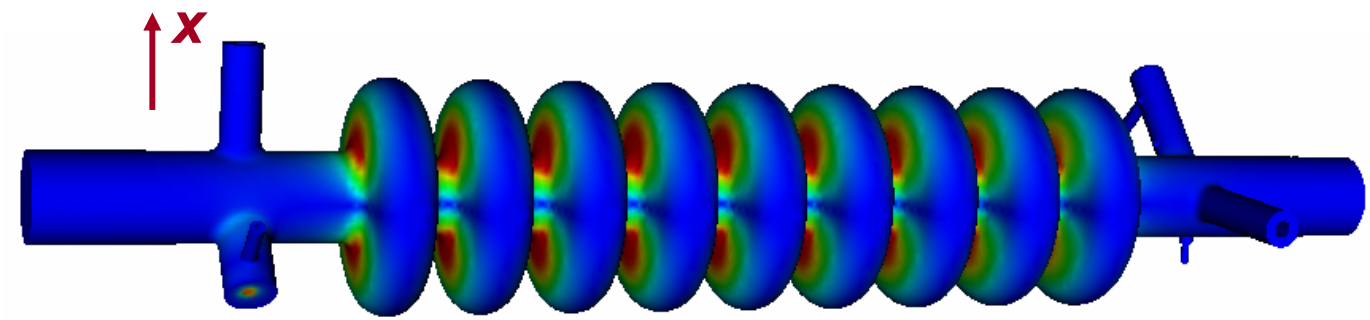
Meshing moving method was used to study the ILC cavity imperfections

5.5. Compute the trapped modes between cavities;

Crab Cavity - Wakefields

- Cell indented in one plan to split the x-y degenerate dipole modes



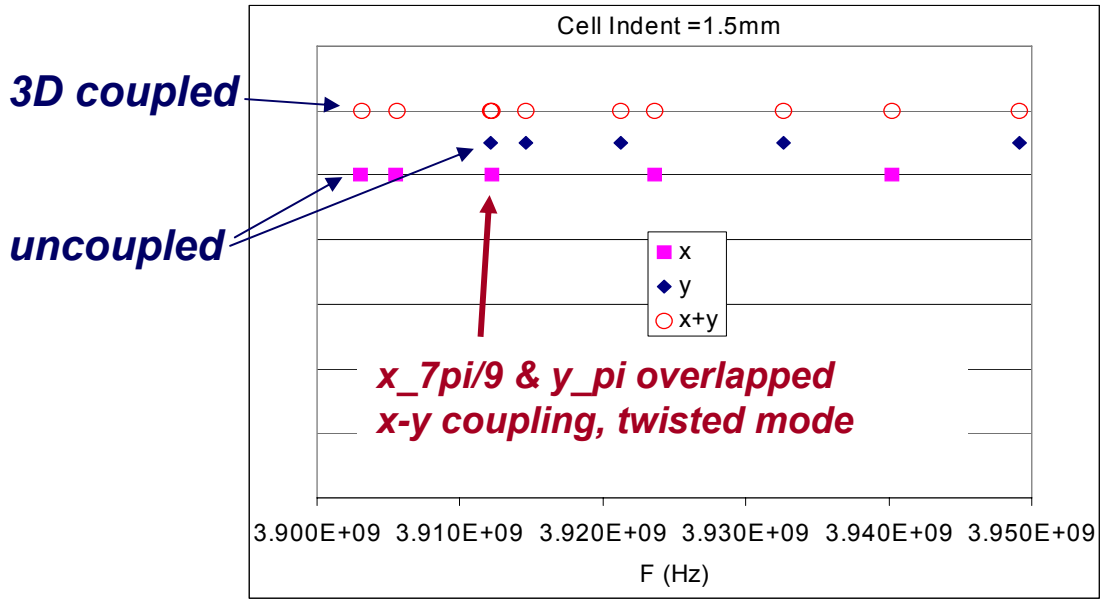


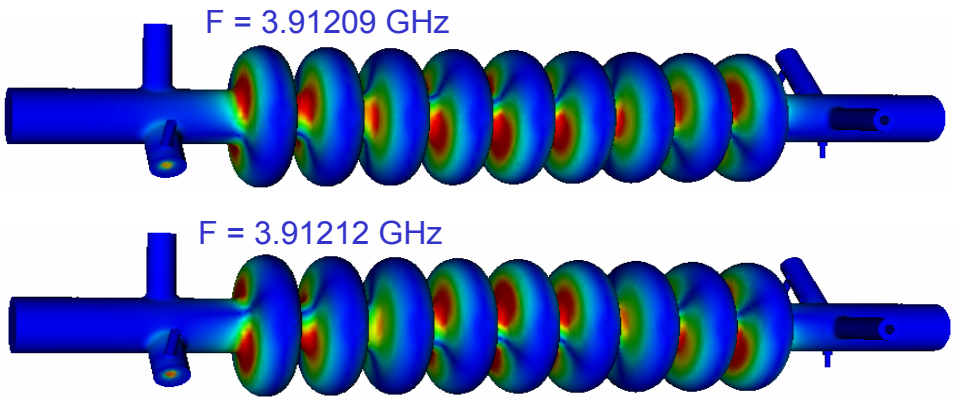
Operating PI mode in X plane

Original Indent – X_7pi/9 and Y_pi overlap

X-y uncoupled spectrum

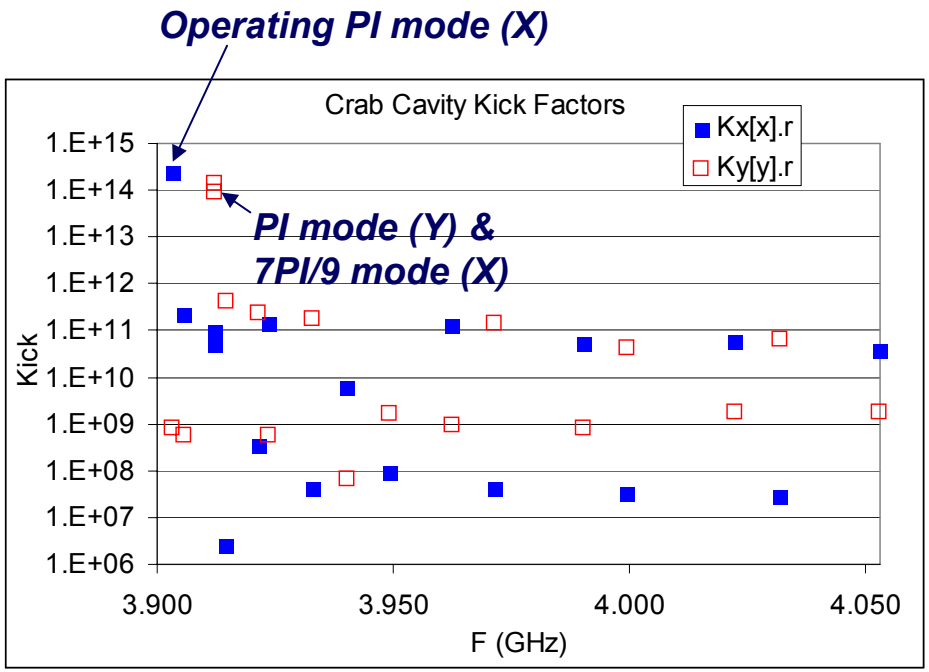
x	y
3.9031E+09	3.9121E+09
3.9055E+09	3.9146E+09
3.9122E+09	3.9212E+09
3.9236E+09	3.9326E+09
3.9402E+09	3.9491E+09
3.9624E+09	3.9713E+09
3.9903E+09	3.9993E+09
4.0223E+09	4.0317E+09
4.0527E+09	4.0627E+09

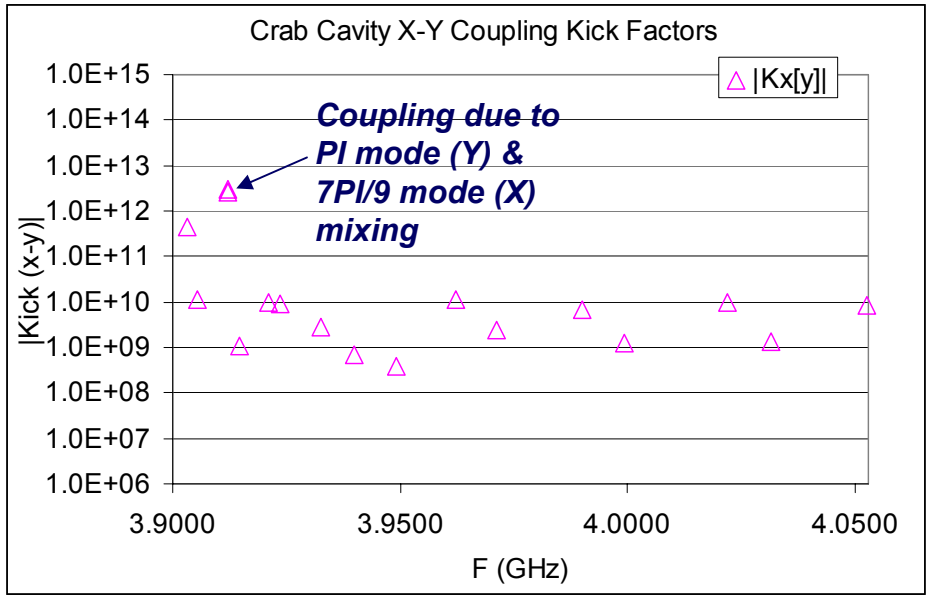




- ***Mode coupling resulted in twisted mode***
- ***Cause x-y wakefield coupling***
- ***Modes are not aligned with x,y at the ends – mode damping issues***

Wakefield Coupling of Twisted modes

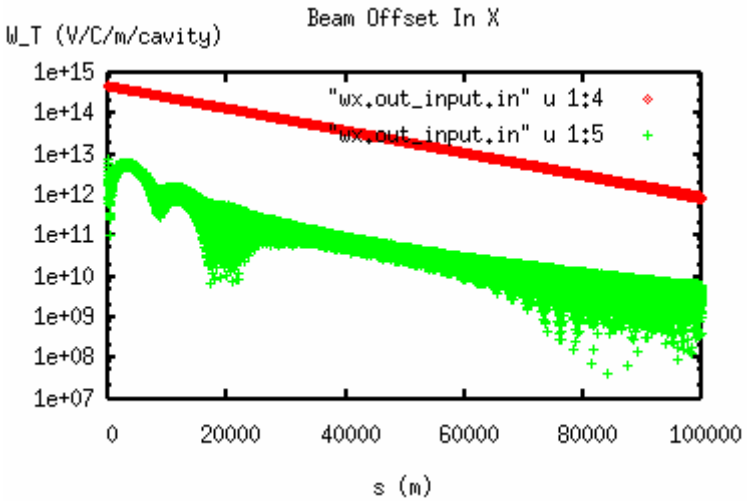


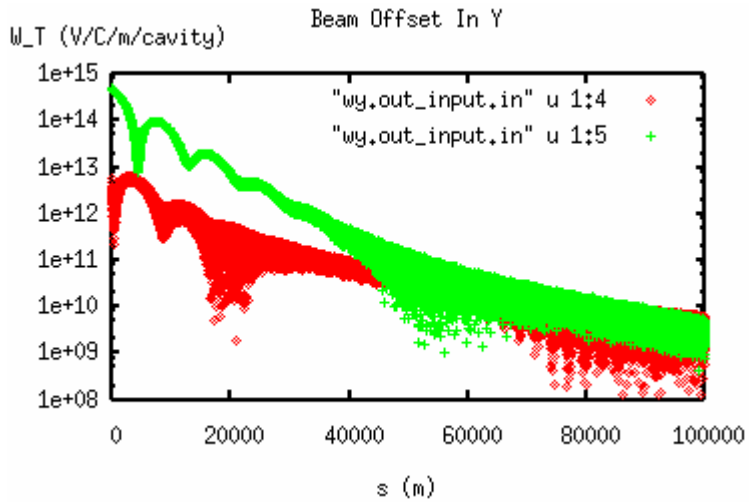


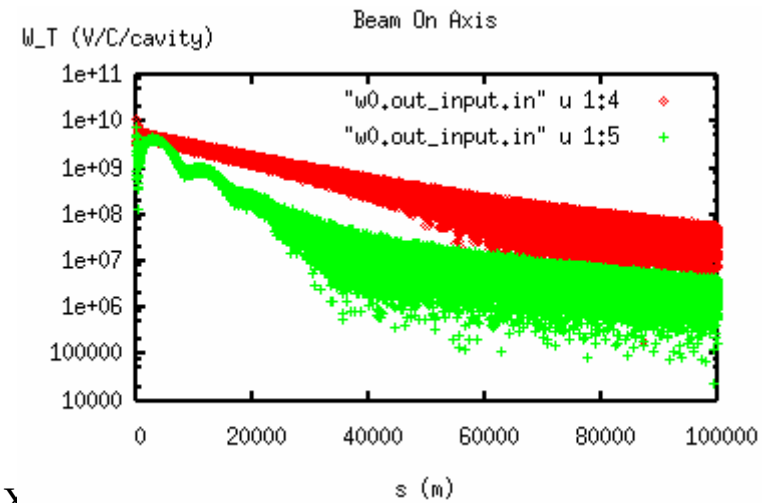
- The Y-PI mode is coupled to the X-7PI/9 mode
- Both modes have large kick factors in the Y plan
- Mode mixing cause X-Y coupling
  - coupling kick factor is about 1% of the PI mode
  - because of looser beam jitter tolerance in X and large beam aspect ratio, need to understand the effect

Single Bunch Wakefield

- Qext for dominate modes ~ 10^5

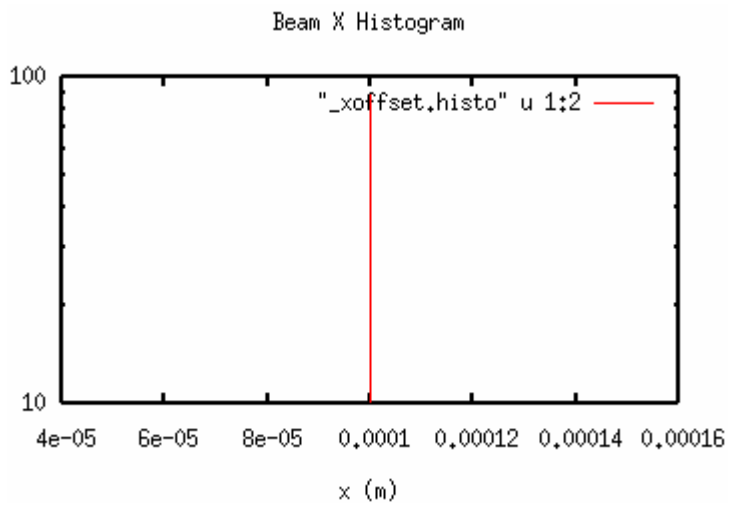


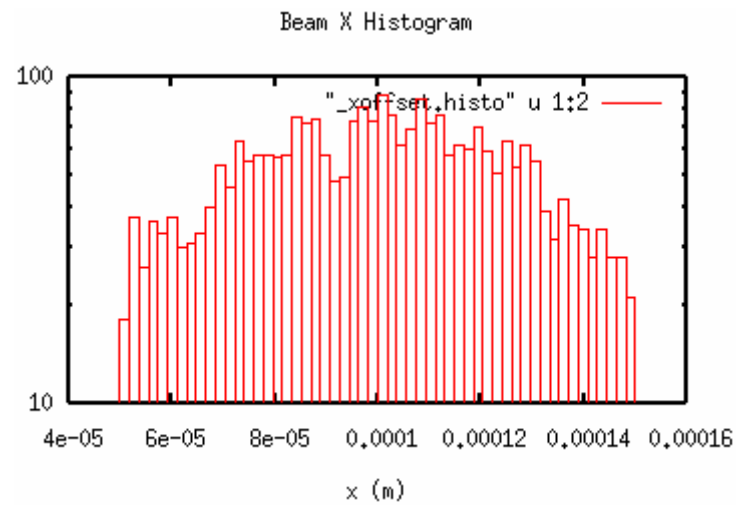


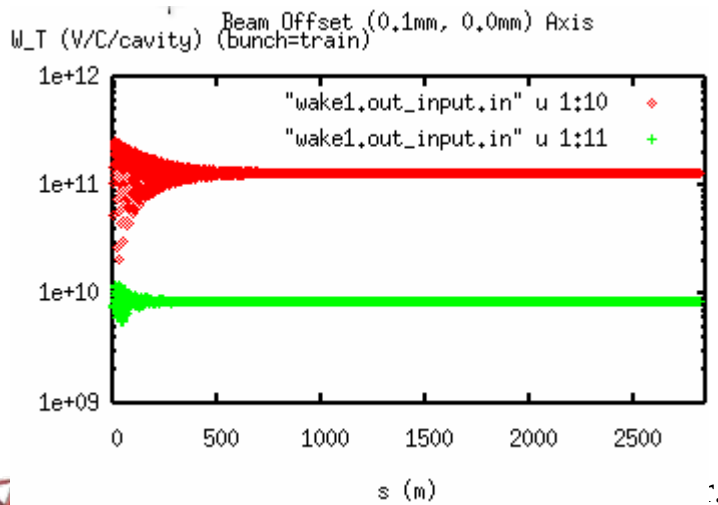


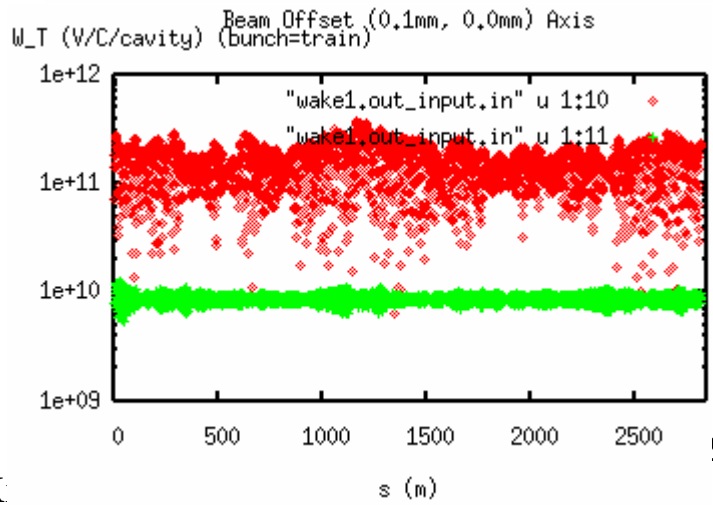
Bunch Train Wakefield

- Qext ~ 10^5
- Beam offset in x (0.1 mm)







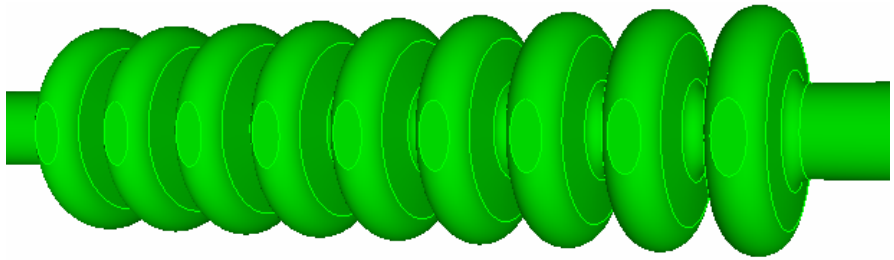


Avoiding X-Y Mode Coupling

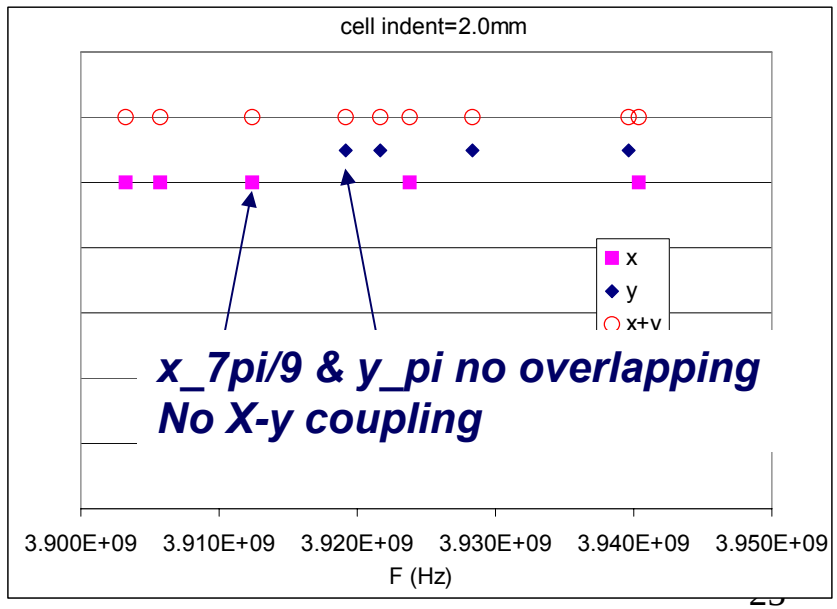
Use more cell indent to shift the Y-mode frequencies

- 12 MHz separation between 7pi/9 and 6pi/9 modes in the x plane
- Pi mode in the y plane can be shifted to the middle of these modes

Other side effects of indentation need to be studied



x	y
3.9032E+09	3.9192E+09
3.9057E+09	3.9217E+09
3.9124E+09	3.9283E+09
3.9238E+09	3.9396E+09
3.9404E+09	3.9561E+09
3.9626E+09	3.9783E+09
3.9904E+09	4.0063E+09
4.0225E+09	4.0390E+09
4.0529E+09	4.0705E+09



Plan For Crab Cavity Design - Summary

- HOM coupler
  - notch filter re-design
  - Multipacting
- LOM coupler & SOM coupler
  - New filter-free LOM coupler and Qext Optimization
  - Single combined LOM and SOM coupler
  - Multipacting in the LOM/SOM coupler
  - Tolerance study
- Cavity cells
  - Minimize surface E and H fields
  - Modify cavity indents or use elliptical cavity shape to avoid mode overlap
  - Multipacting simulation of the indented cell
- Calculate effect of cavity imperfections
  - Mode overlapping
  - Twisted modes
  - Effects on Qext - trapped modes
- 3D coupler kicks
- Compute trapped modes between cavities
- Beam dynamics modeling to determine Qe requirements on cavity modes considering beam jitter, kicks and heat loads