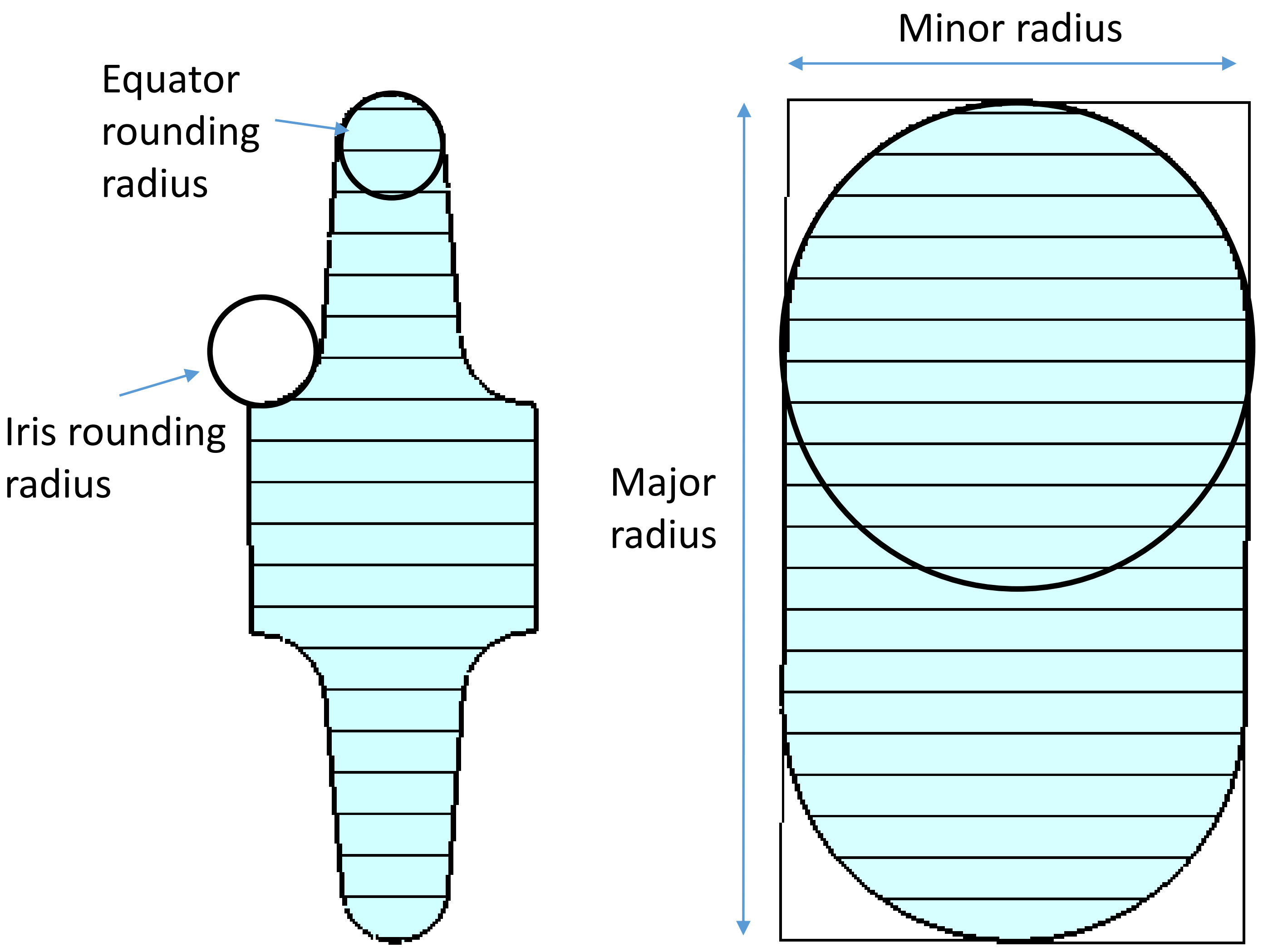
ILC Racetrack Crab Design

Prof Graeme Burt, Lancaster University / Cockcroft Institute

On behalf of the UK team at Lancaster and STFC

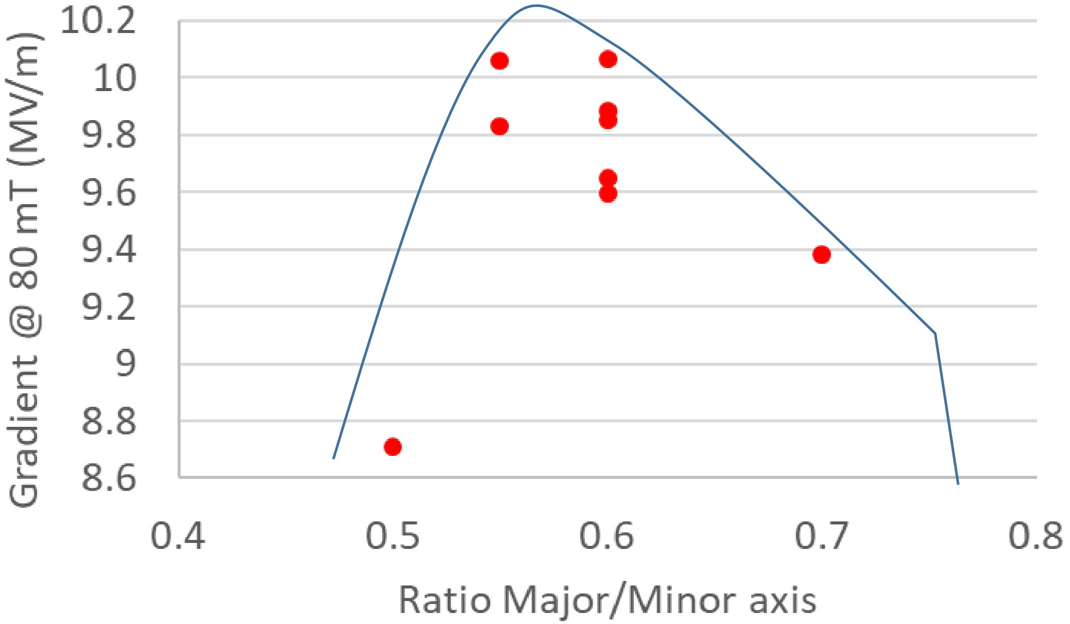
Re-optimizing the ILC crab

- Decided to re-optimise the ILC crab cavity to increase the gradient and separate the SOM
- Kept frequency at 3.9 GHz as its compact and required gradient decreases linearly with frequency
- 250 GeV ILC requires a 3-cell cavity @ 5 MV/m, or 2 cells at @8 MV/m
- 3 x 3 cells or a single 9 cell @7.5 MV/m at 1 TeV



Improved geometry

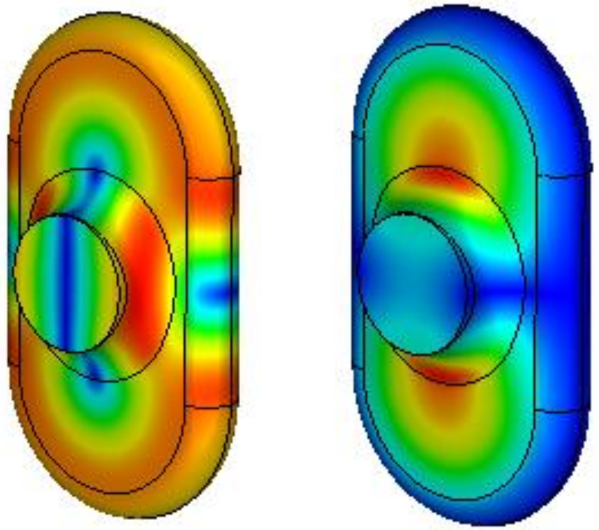
25 mm aperture



- The surface magnetic field decreases as the ratio of minor to major axis decreases (below 0.5 its starts to increase but with our aperture this is not an allowed geometry anyway)
- The surface electric field is too low to worry about
- It appears we want a small equator radius and a large equator radius (ie short cavity with a thick iris)
- Since last time reoptimized for a 25 mm iris

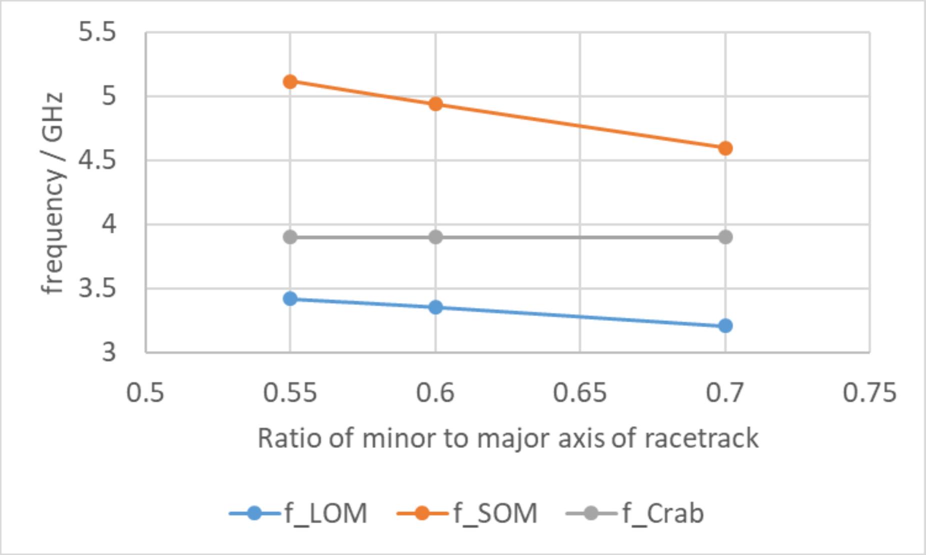
Magnetic

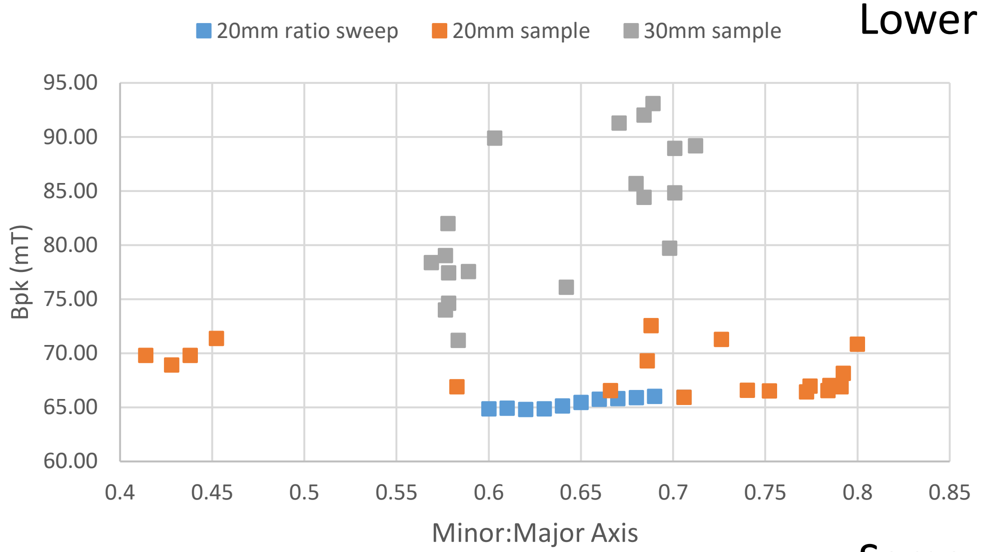
Electric



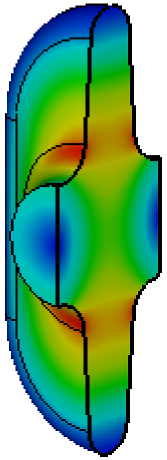
Varying the ellipticity to tune the LOM/SOM

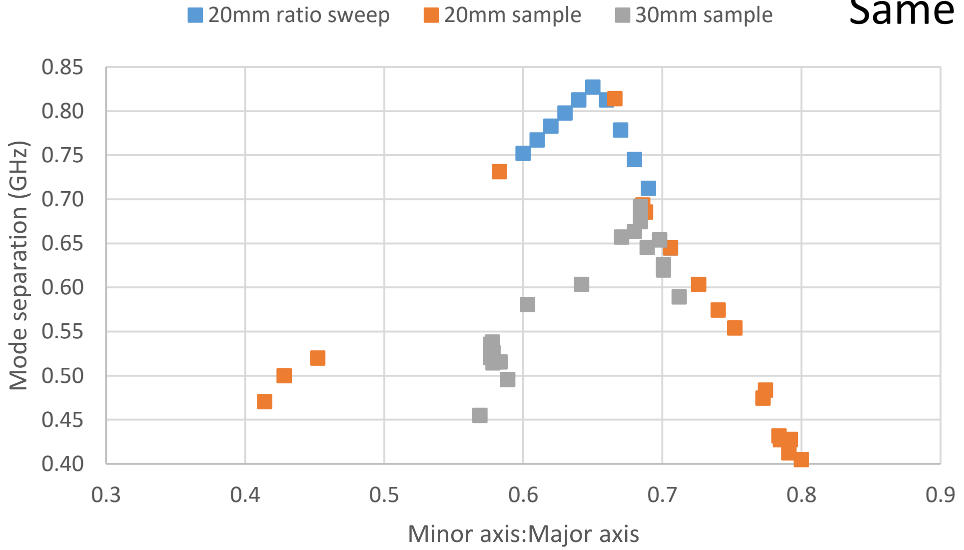
- Making the cavity elliptical pushes the other polarization of the dipole mode to higher frequencies
- One issue with making the cavity highly elliptical is the lower order mode moves closer to the crabbing mode
- Ideally LOM and SOM spacing equal
- Making more elliptical also drops Bpk until it gets close to the aperture



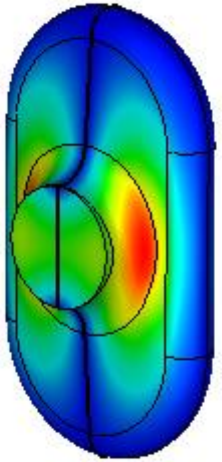


Lower order mode (LOM)





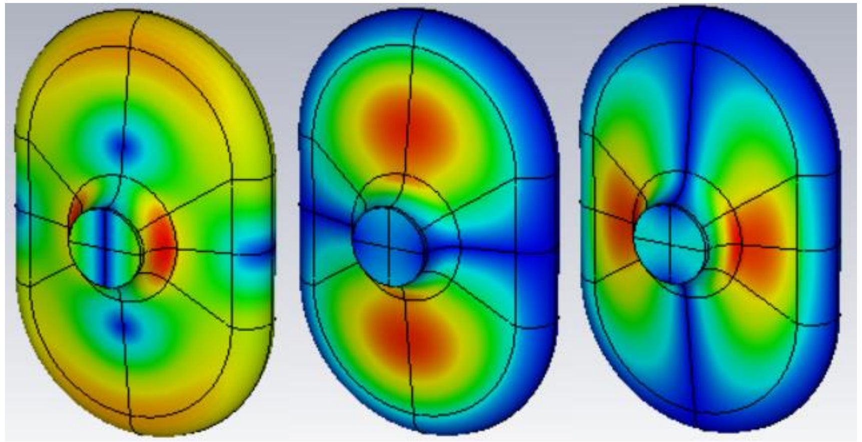
Same order mode (SOM)



20mm - 30mm single cell final results

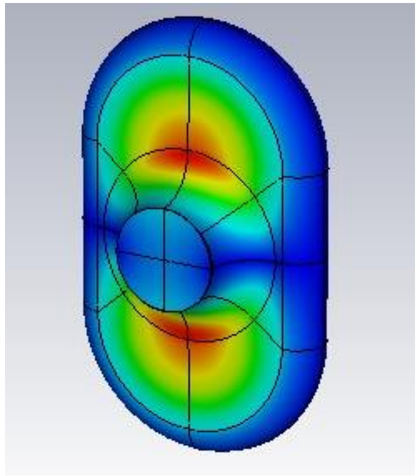
20mm

- Rt/Q =53.47 Ohms/m
- B_{pk} = 65.43565 mT @ grad=8MV/m
- E_{pk} = 22.62528 MV/m @ grad=8MV/m
- LOM = 3.073 GHz
- SOM = 4.74718 GHz
- Rt/Q_{SOM} =52.86581 Ohms/m



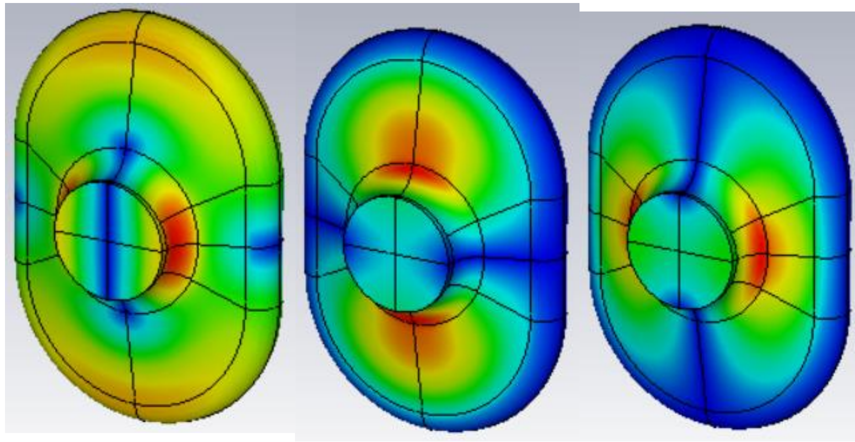
25mm

- Rt/Q = 47 Ohms/m
- B_{pk} = 64 mT @ grad=8MV/m
- E_{pk} = 33.2 MV/m @ grad=8MV/m
- LOM = 3.3 GHz
- SOM = 5.08 GHz
- Rt/Q_{SOM} =37.3 Ohms/m



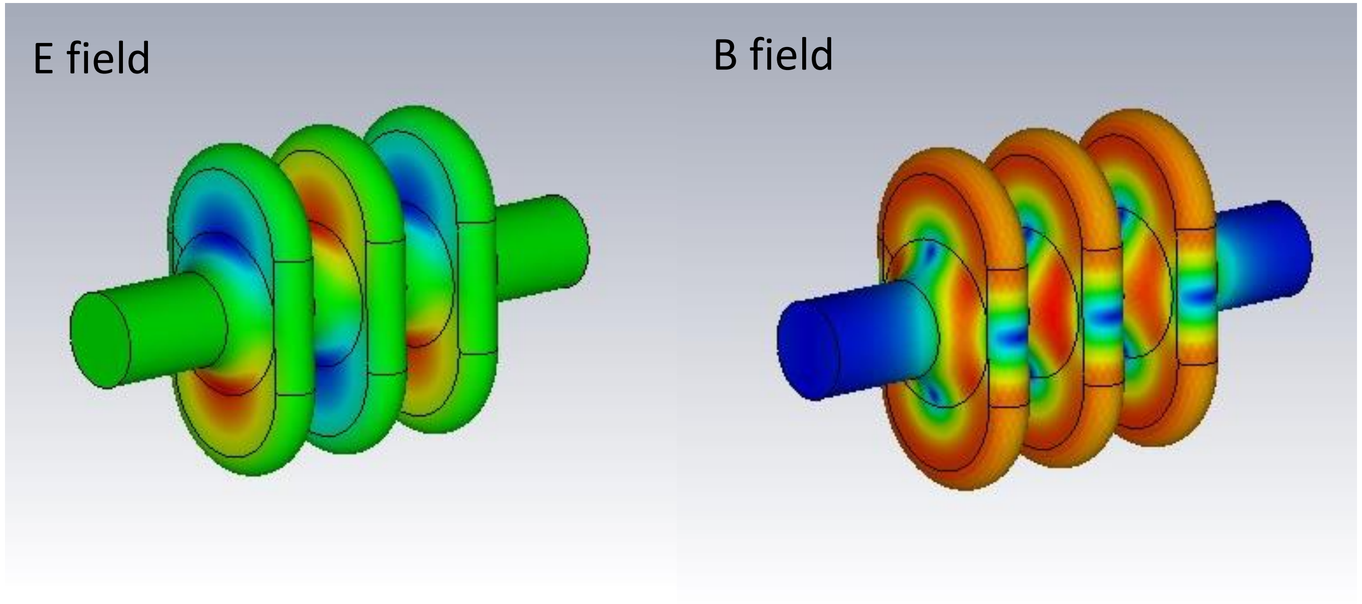
30mm

- Rt/Q = 44.03 Ohms/m
- B_{pk} = 79.706 mT @ grad=8MV/m
- E_{pk} = 27.230 MV/m @ grad=8MV/m
- LOM = 3.21817 GHz
- SOM = 4.57387 GHz
- Rt/Q_{SOM} =40.77031 Ohms/m



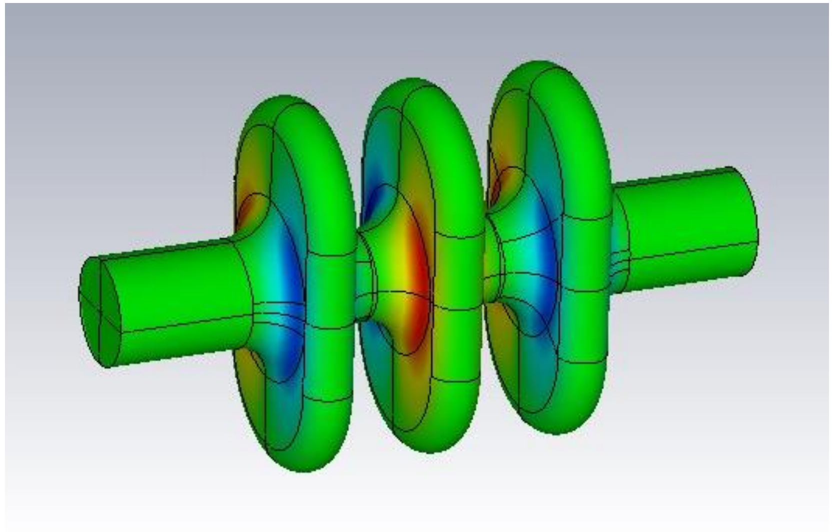
3 cell cavity

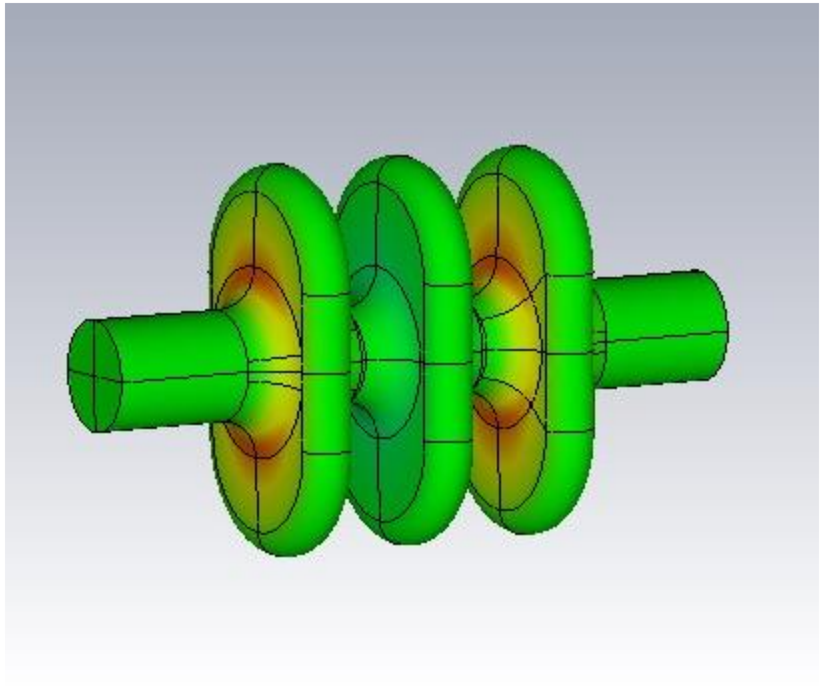
- End cells initially had lower peak magnetic field
- Larger beampipes were used on the end cells to aid damping (30 mm)
- Slightly higher B field means that gradient is limited to 9.7 MV/m at 80 mT
- R_t/Q=132 Ohms



Same order and lower order modes

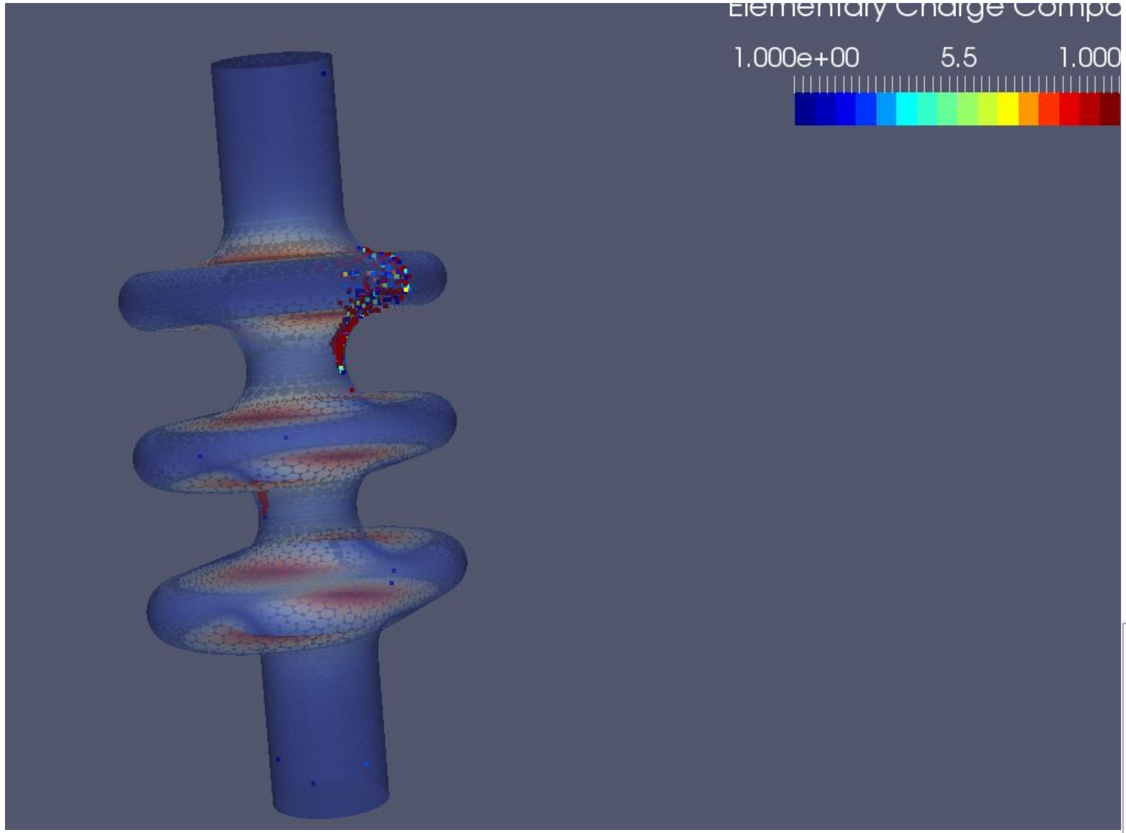
- Highest impedance SOM is the pi mode at 5.07 GHz, Rt/Q is only 50 Ohms due to frequency not being synchronous.



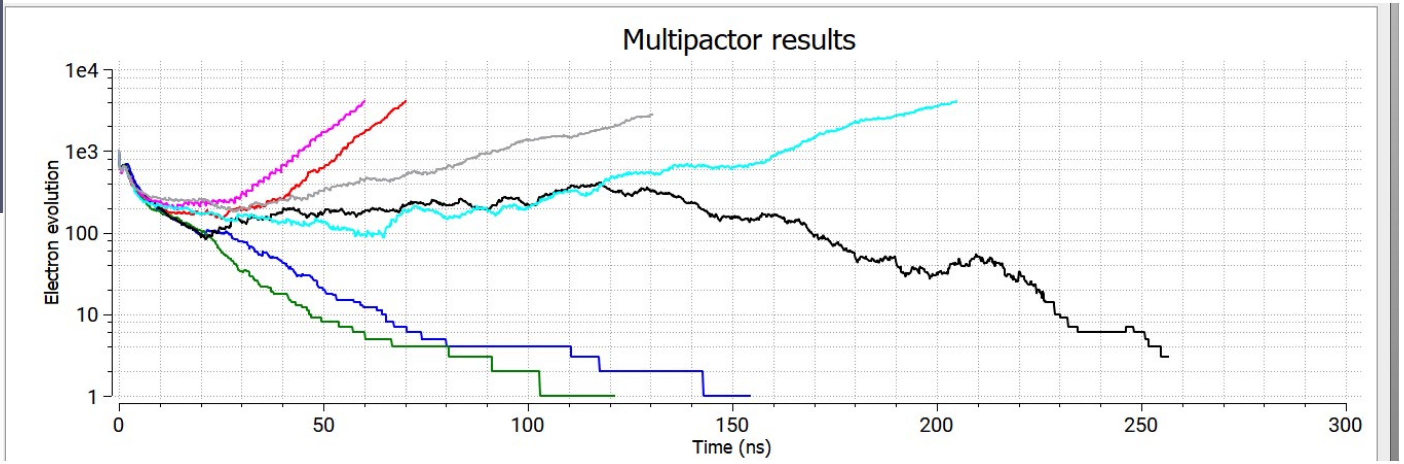


- Highest impedance LOM is the pi/2 mode at 3.32 GHz, Rt/Q is only 134 Ohms

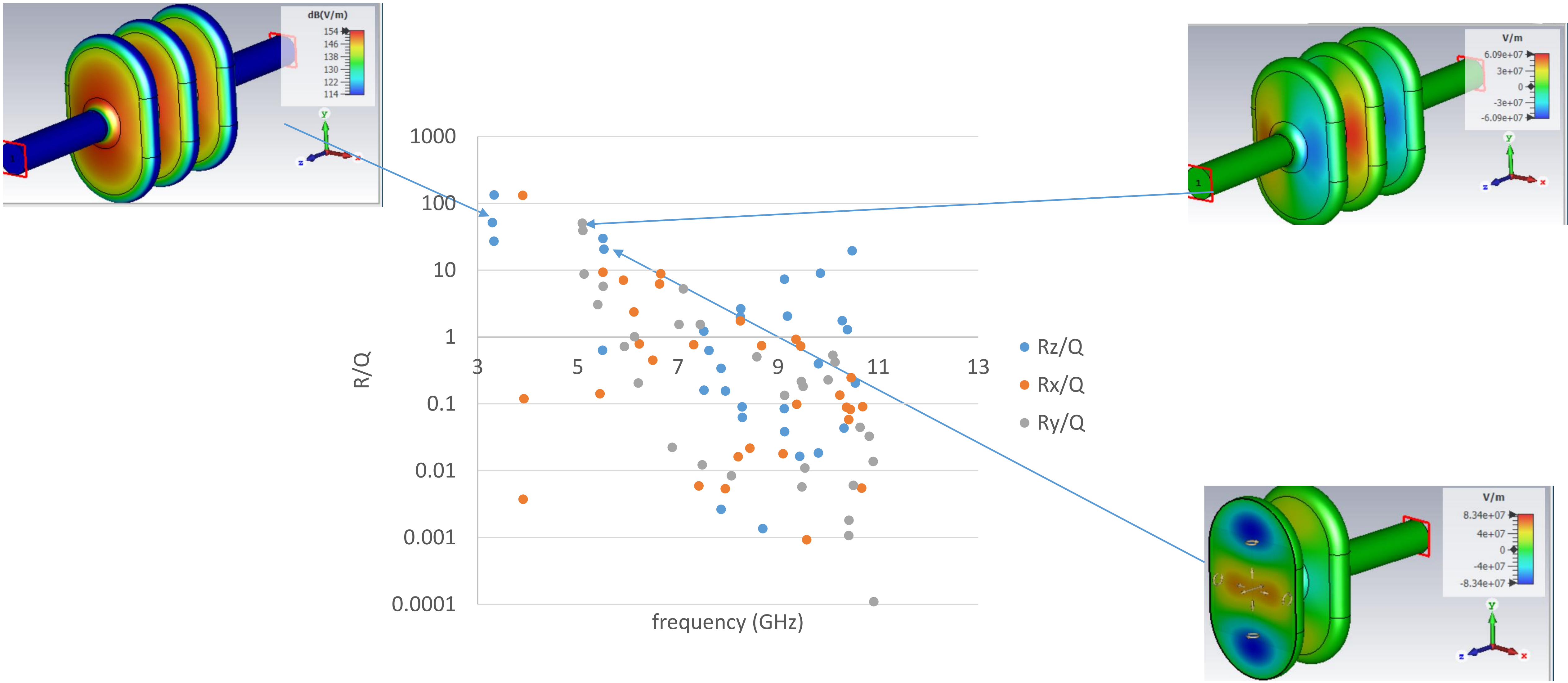
Multipactor



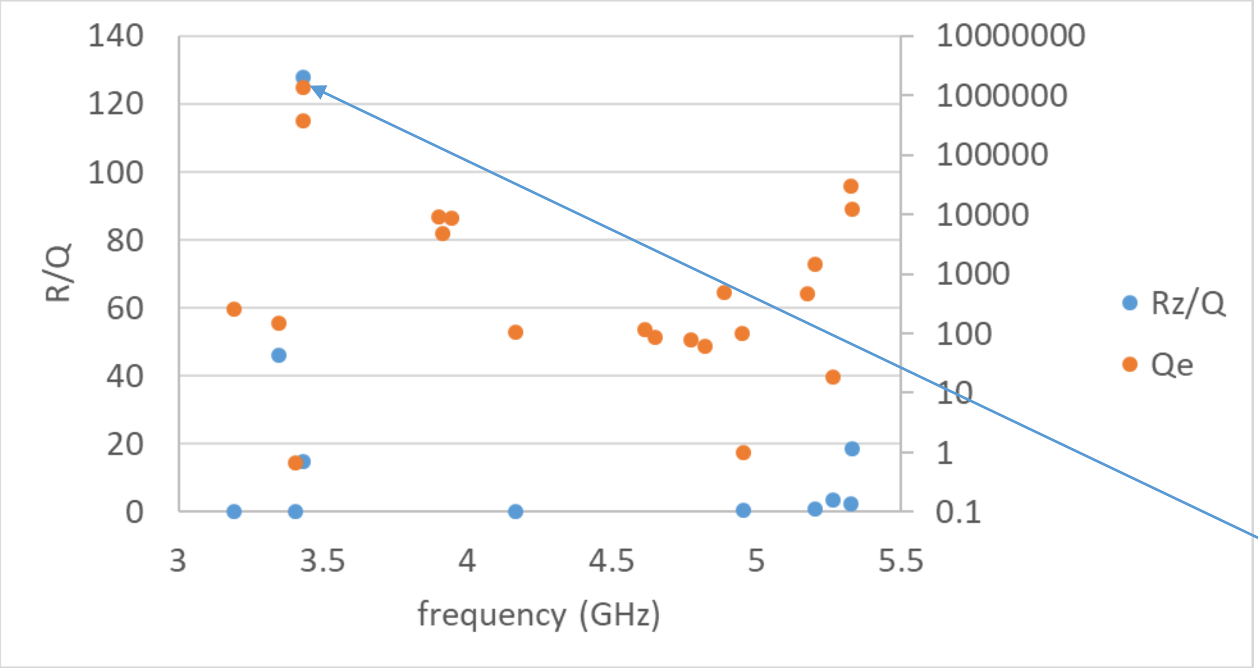
- Multipactor band found at 7.15 MV/m on minor axis iris.
- Either need to modify iris or limit gradient to 7 MV/m
- Appears very narrow band (not at 7 or 7.3 MV/m)
- ILC spec need 7.5 MV/m for 1 TeV with only 3 cavities or a single 9 cell.



Mode spectrum

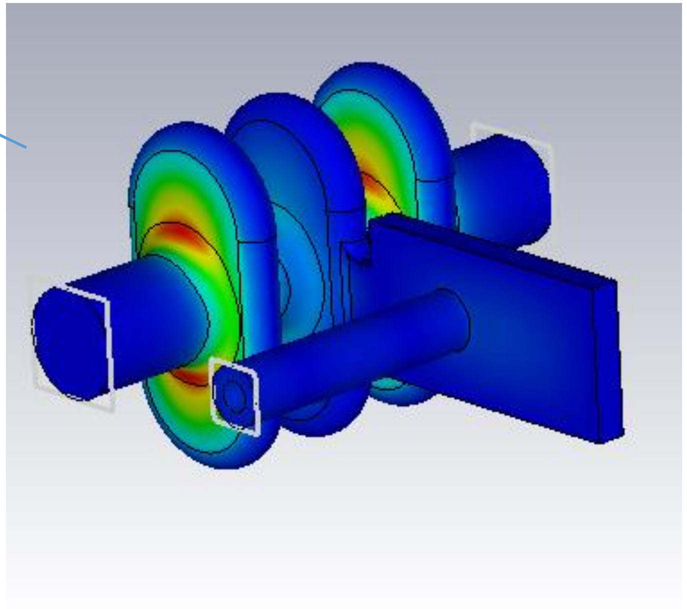


Waveguide damping



Considering a waveguide section with a coax coupled to it to minimize size and heat leak. Coax can be positioned to prevent coupling to the crabbing mode.

Good damping overall except one mode, unfortunately the highest impedance mode.

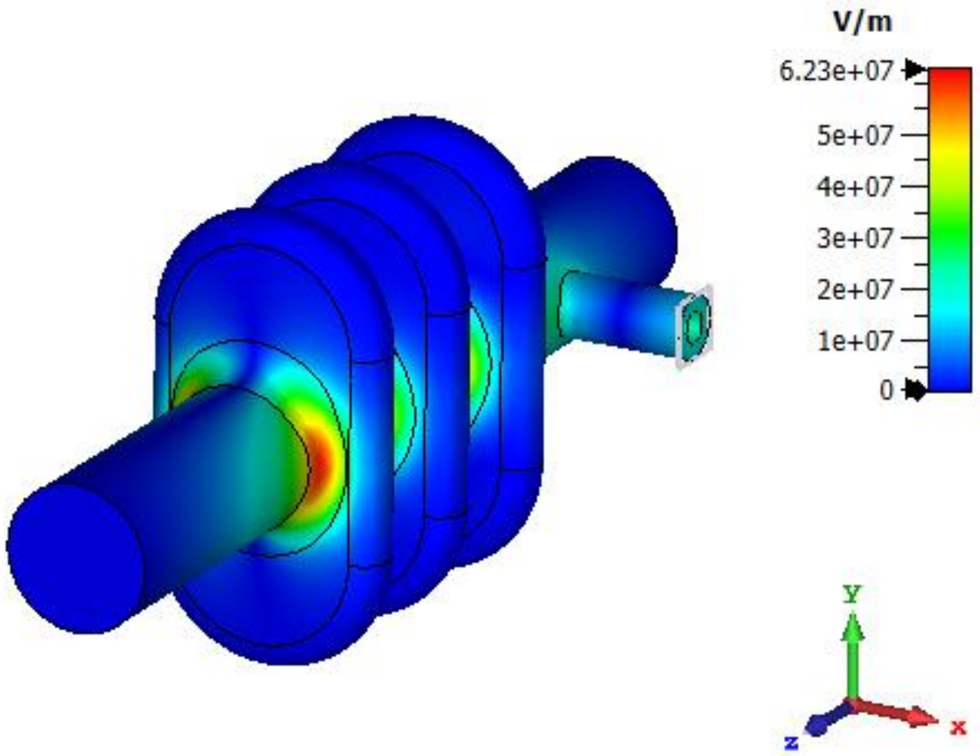


- Waveguide damper does damp the pi and 0 modes well but doesn't damp the pi/2 modes but these will be damped strongly by a coax damper in the beampipes.
- Also investigating putting the waveguide in an end cell.

Coaxial damper (30 mm aperture)

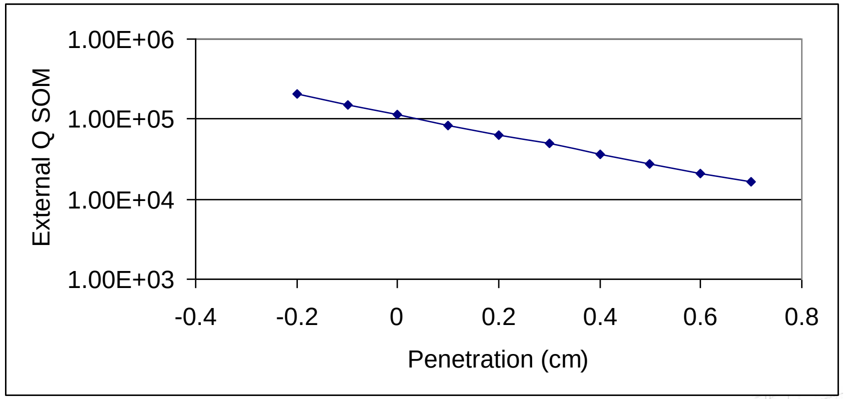
- Specification is Rt/Q*Qe = 60 MOhm/m
- Rt/Q_SOM=40 hence Qe= 1.5e6

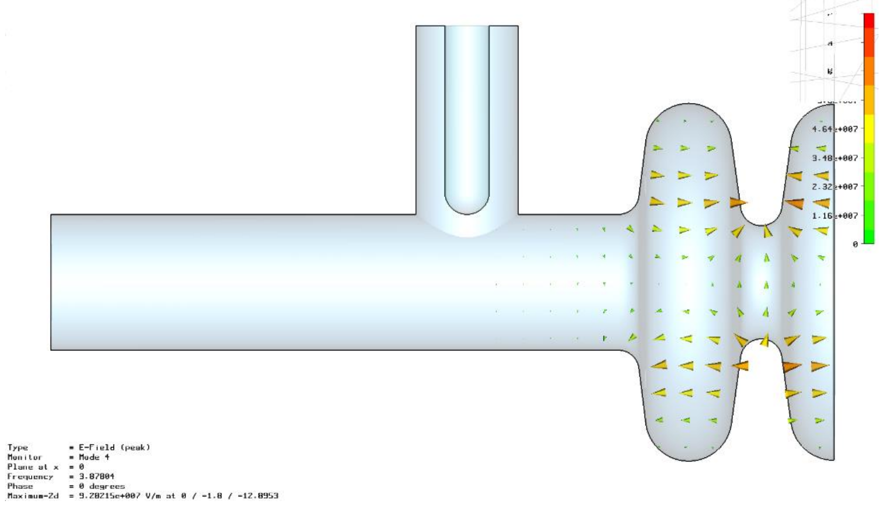
- Initial trials suggest this is simple to achieve
- Q_crabbing mode=2e8 - 1e9
- Q_SOM=1500 – 6000
- Q_LOM=1e6 – 1e7



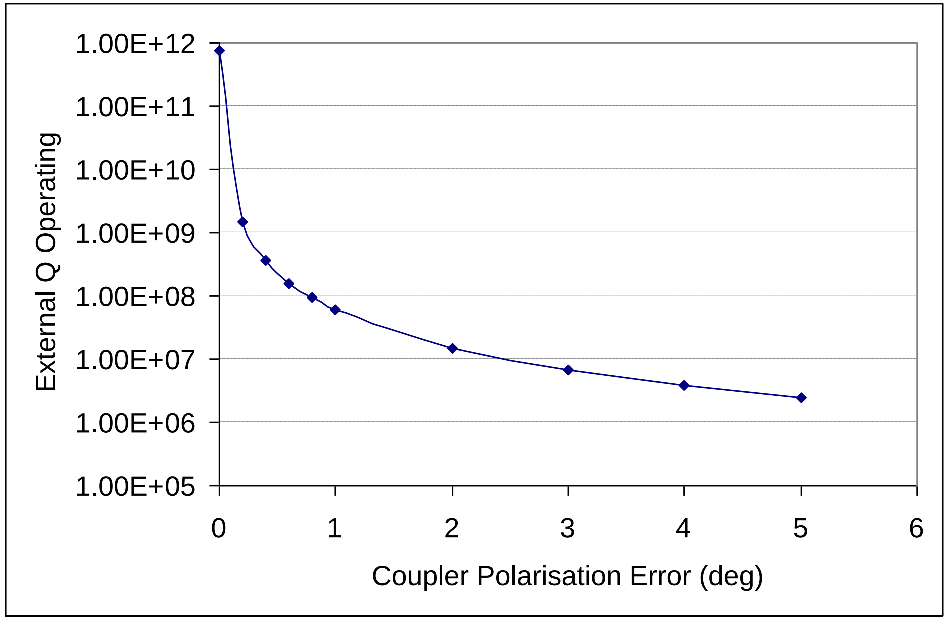
Cockcroft SOM Coupler design

The SOM coupler is currently a simple coaxial structure.





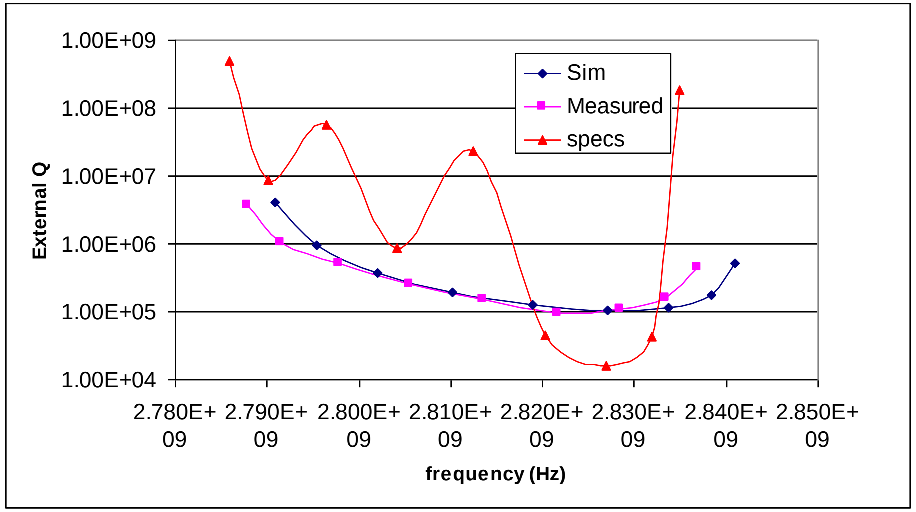
The problem is that as we decrease the SOM external Q we make the coupler susceptible to damping the operating mode.

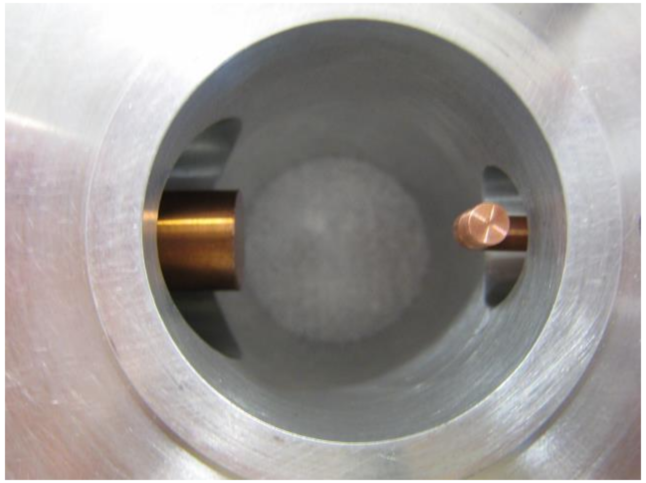


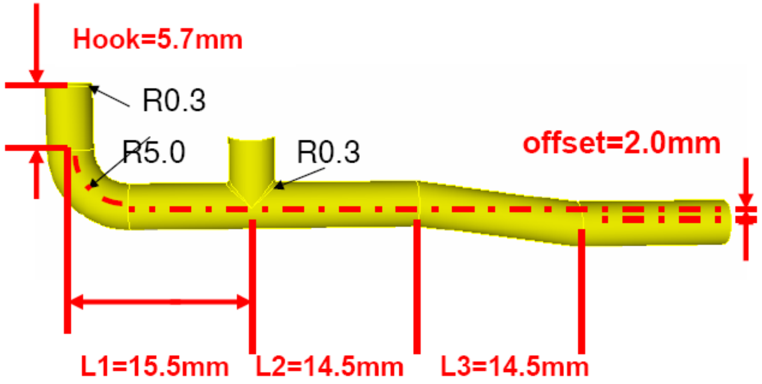
Assuming 10 Watts mean power flow in the coupler, and we meet the SOM damping spec then we need to align the coupler to within 1.4 degrees.

May be better to use a racetrack cell shape to separate the vertical and horizontal mode in frequency and use a filter

Lower Order Mode Coupler



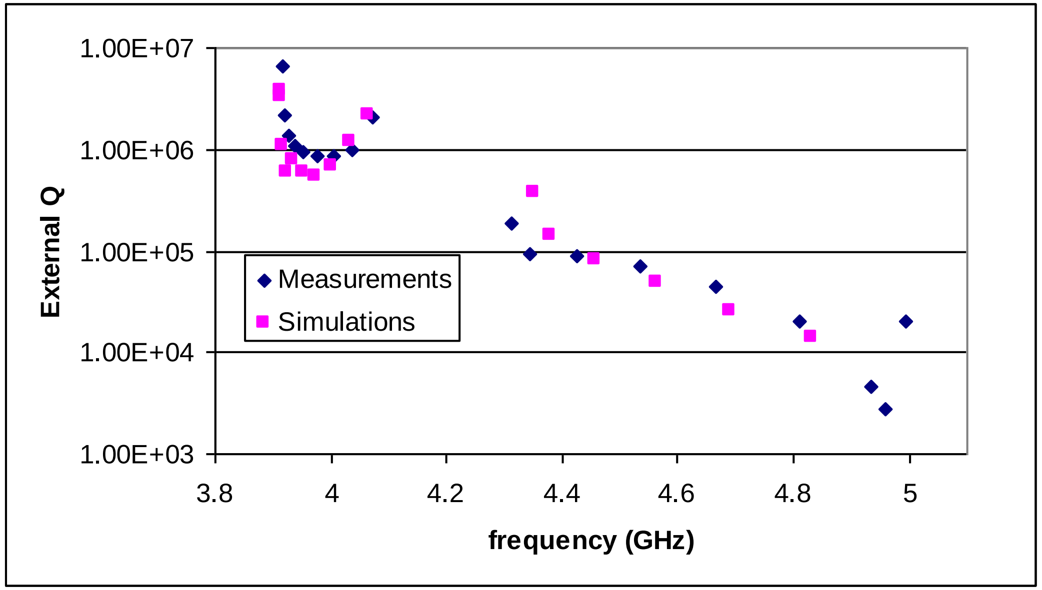




Hook type LOM coupler designed by FNAL/Lancaster and improved by SLAC

No filter, uses polarisation to avoid coupling to the crabbing mode

The LOM coupler prototype was found to give good agreement with both MWS and Omega3P simulations.



Conclusions

- We believe 3.9 GHz elliptical is still optimal as can achieve same gradient as a 1.3 GHz compact crab but needs a 3rd of the length and could use a single cavity per IP at 1 TeV so simpler than 9 single cells.
- Investigating a racetrack cell shape which allows a higher gradient and better mode speration to LOM and HOM.
- Based on fields can reach 9.7 MV/m but MP limited to 7 MV/m.
- LOM/SOM/HOM couplers needs some redesign
- Coax, & WG damping being considered.