The Cockcroft Institute of Accelerator Science and Technology

Jefferson Lab

LHC-4R crab cavity

B Hall

Lancaster University / Cockcroft Institute

Lancaster University

The Cockcroft Institute of Accelerator Science and Technology

Cavity Design Team

- G. Burt (CI-Lancs)
- B. Hall (CI-Lancs)
- C. Lingwood (CI-Lancs)
- D. Doherty (CI-Lancs)
- A. Dexter (CI-Lancs)

- C. Hill (STFC)
- P. McIntosh (STFC)
- P. Goudket (STFC)
- S. Pattalwar (STFC)

- H. Wang (JLab)
- B. Rimmer (JLab)
- L. Turlington (Jlab)

- Peter Stoltz (TechX)
- David Smithe (TechX)

The Cockcroft Institute of Accelerator Science and Technology

Science & Technology Facilities Council

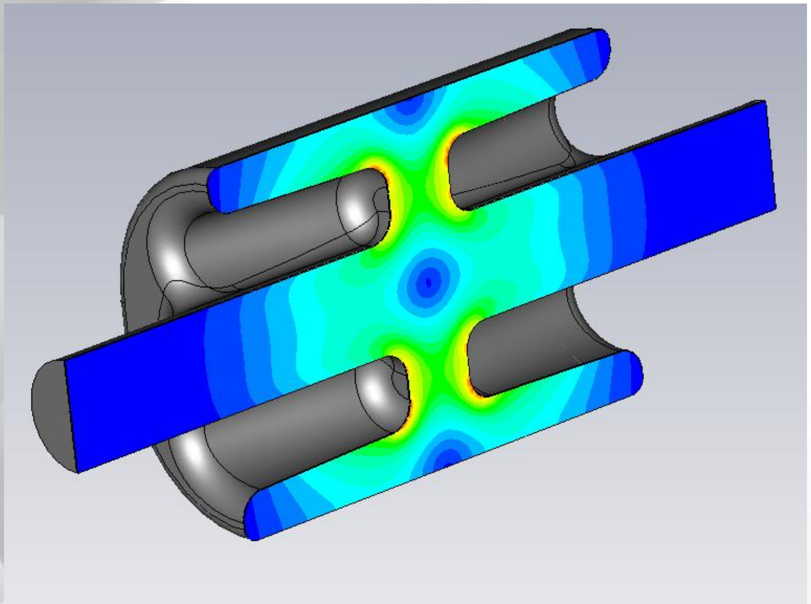
Jefferson Lab

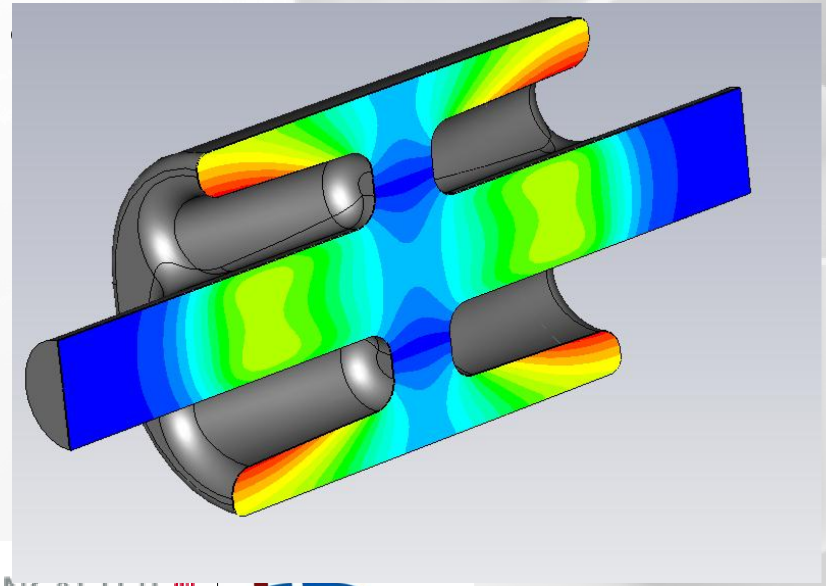
+ CERN (Erk Jensen and Ed Ciapala) + Rama on cavity integration

Last Years Cavity Shape

Cavity fitted LHC scenario (84 mm aperture compact transverse size) and has tolerable fields at the design gradient.

Significant variation was seen in the deflecting voltage at offset from beam

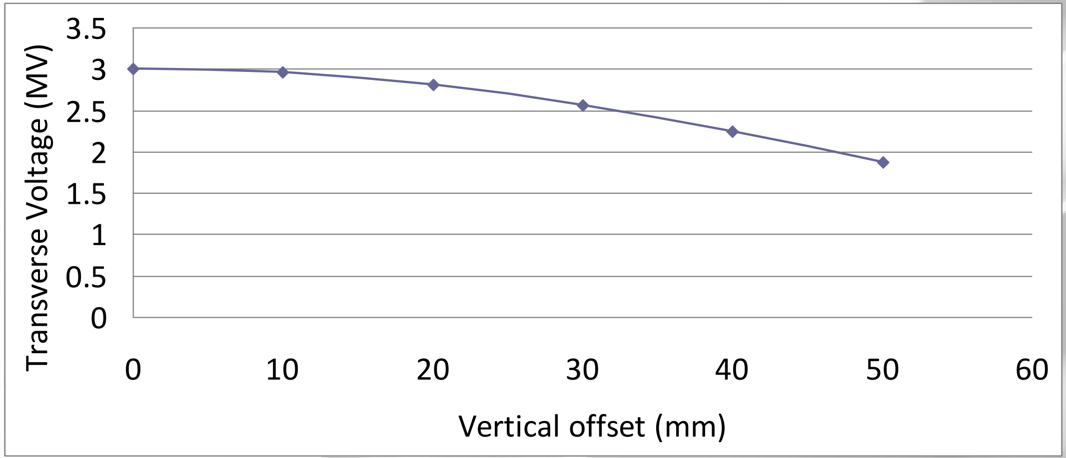




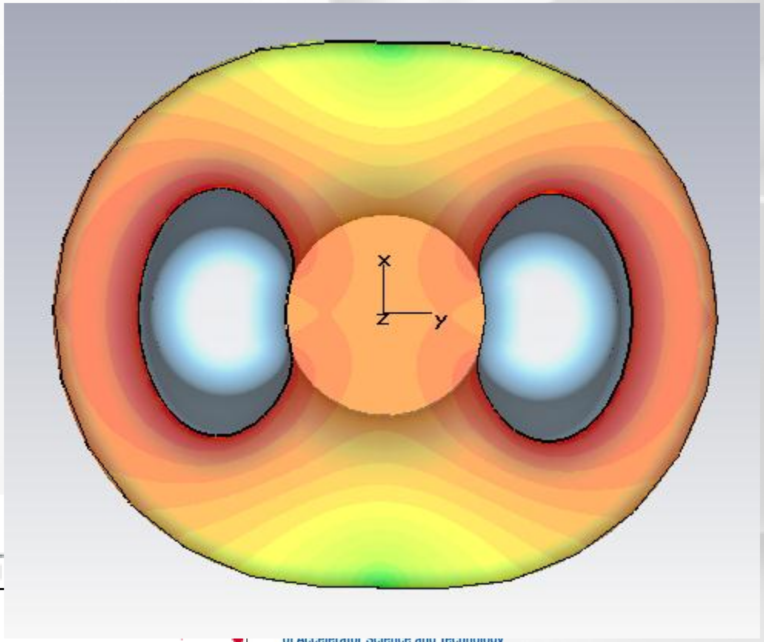
Emax @3MV	39.2 MV/m
Bmax @3MV	59.1 mT
Transverse R/Q	953 Ohms

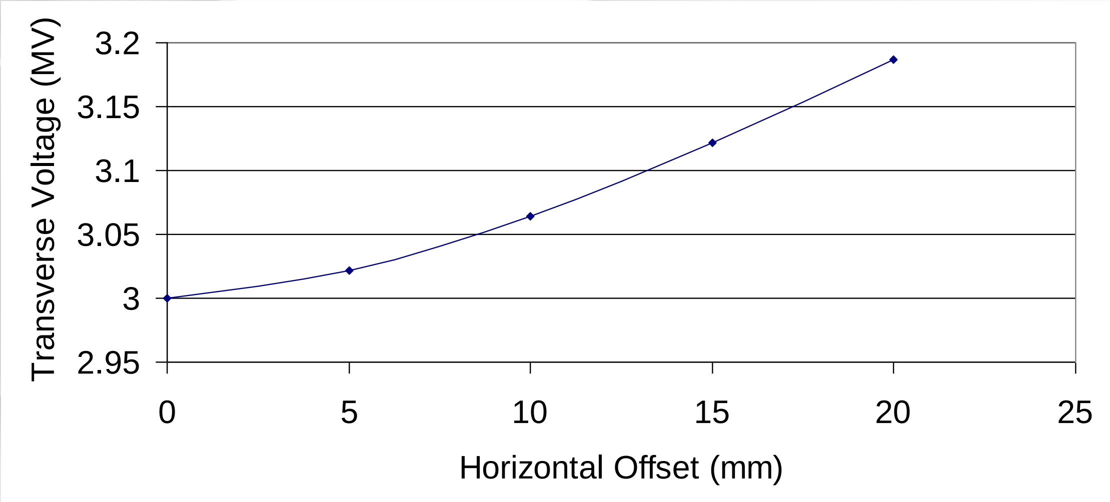
$R_T/Q=(V(a)^2/wU)*(c/\omega a)^2$

Variation in Transverse Voltage



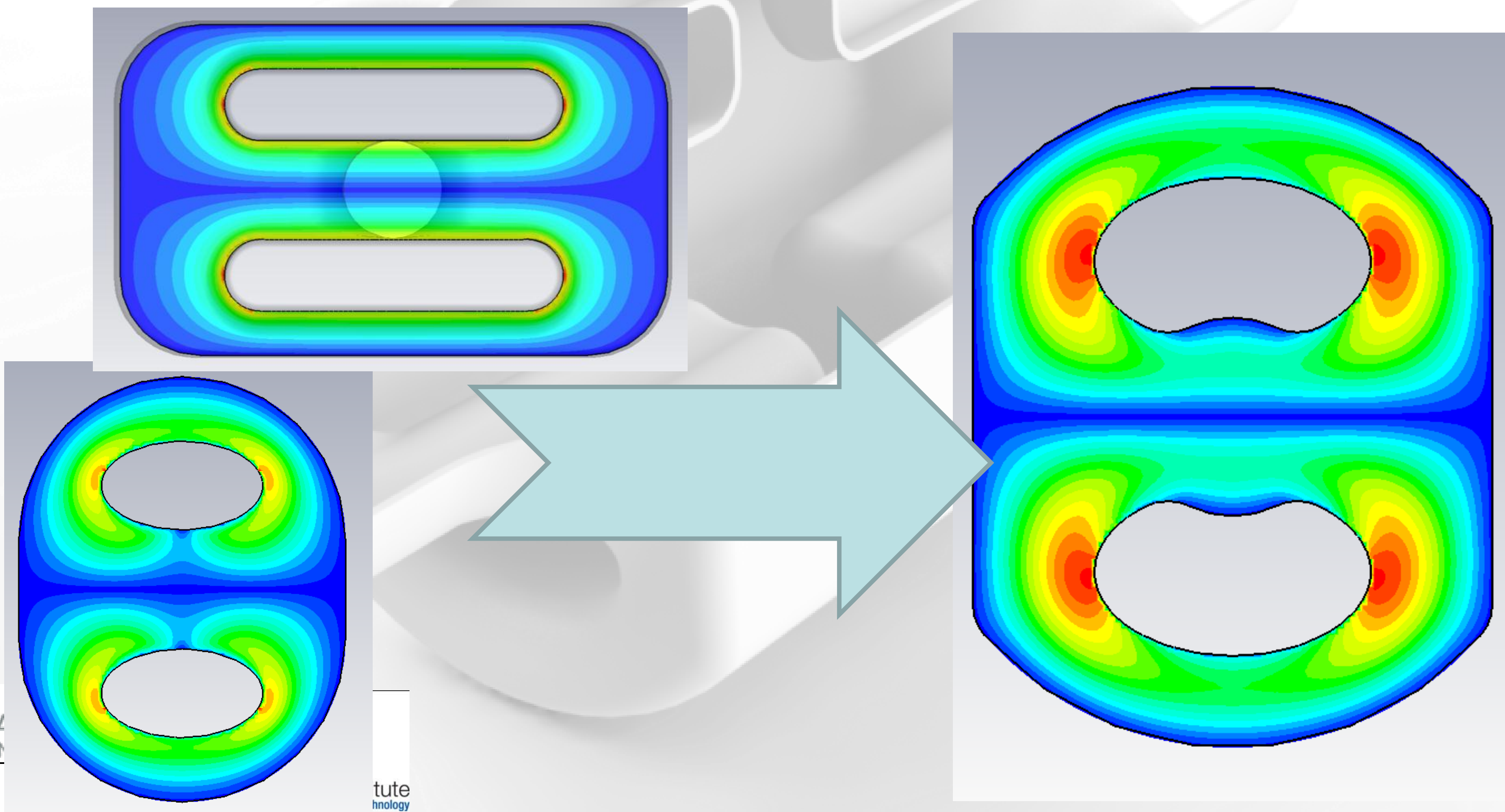
There was some change in transverse voltage when there were horizontal and vertical offsets.



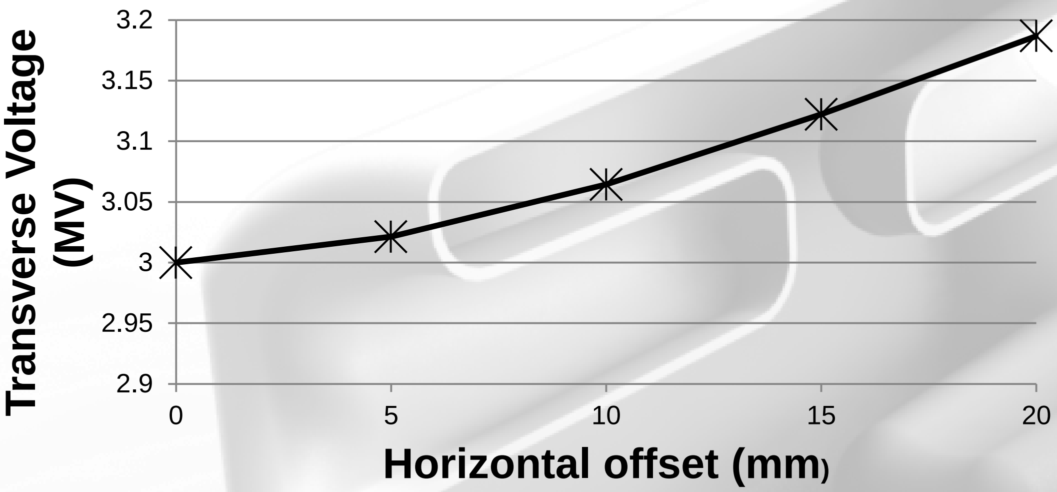


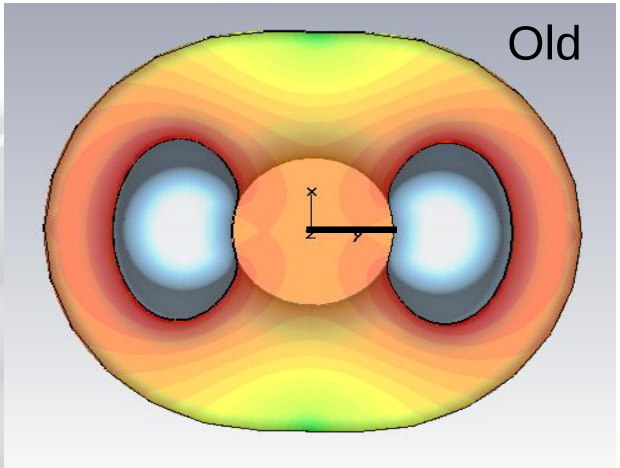
New shape

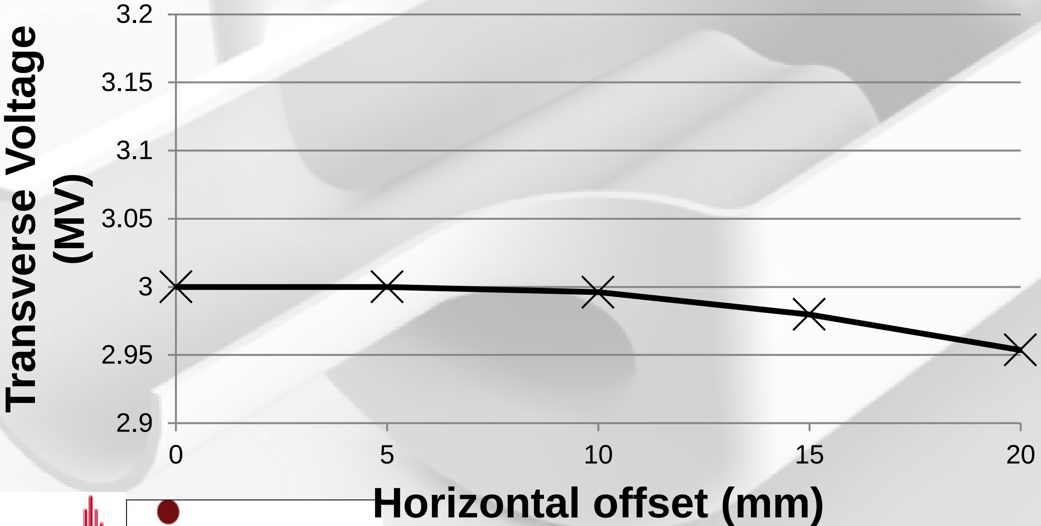
Adding focussing electrodes to narrow rods, can however provide parallel equipotential lines emulating the wider rods.

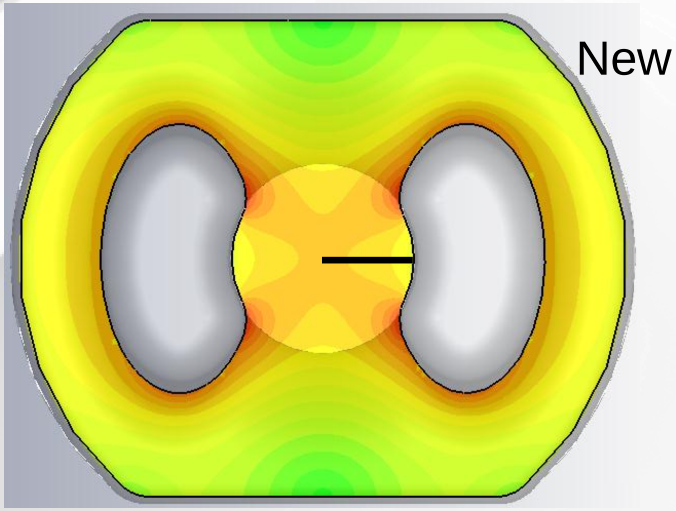


Horizontal variation





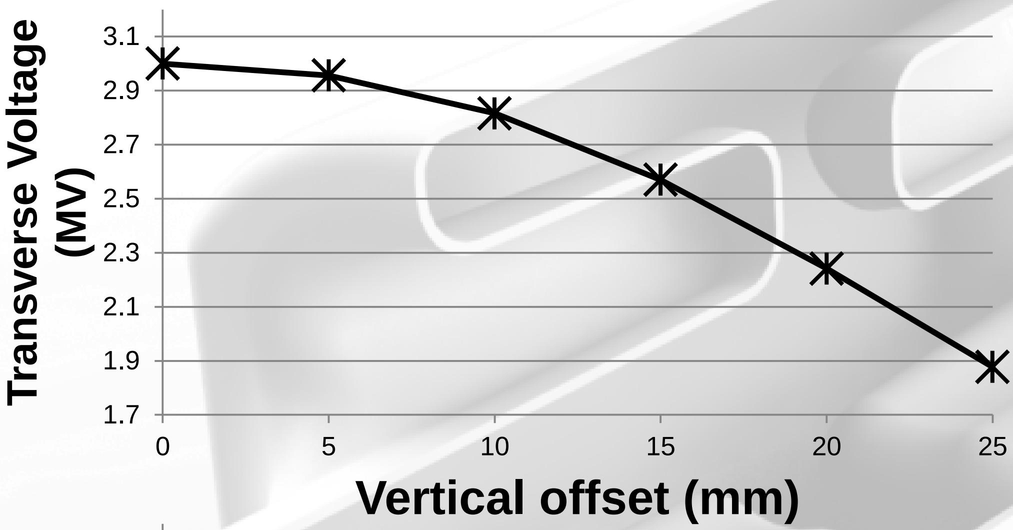


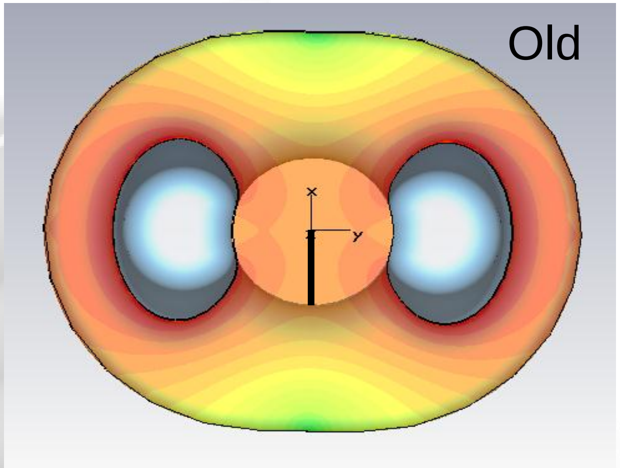


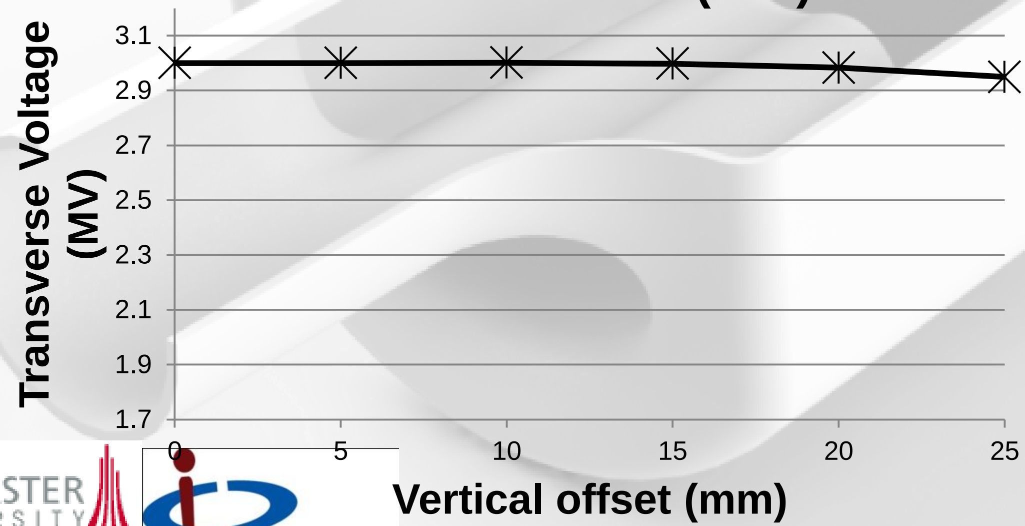
LANCASTER UNIVERSITY

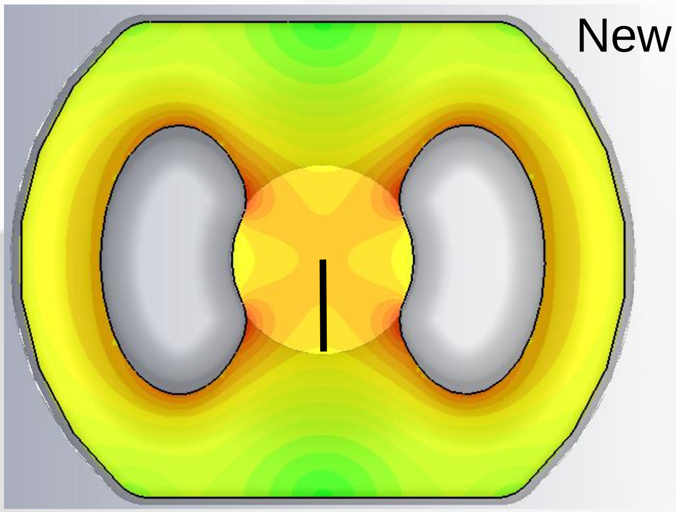
The Cockcroft Institute of Accelerator Science and Technology

Vertical variation









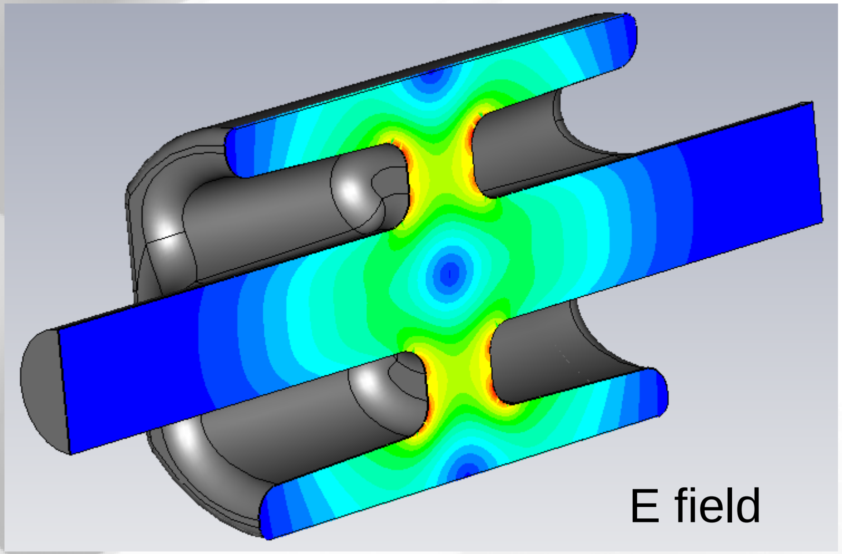
LANCASTER UNIVERSITY

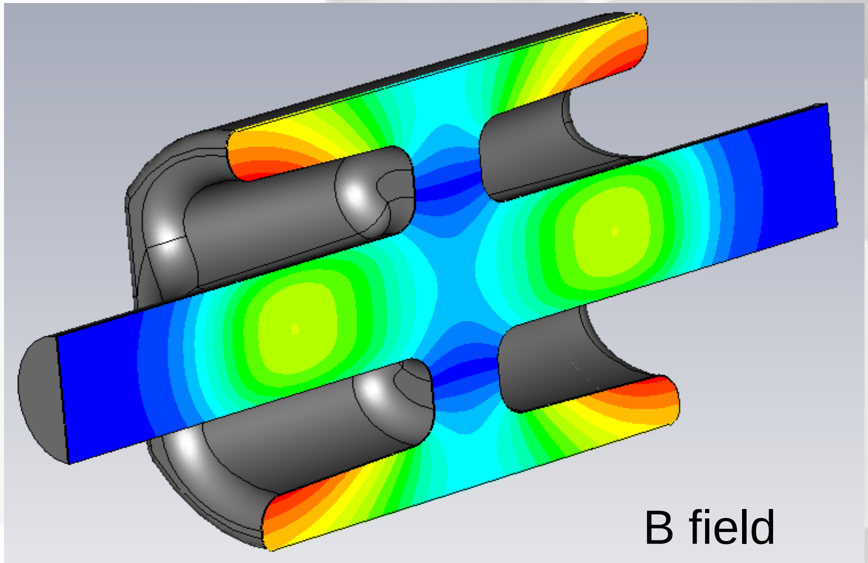
The Cockcroft Institute of Accelerator Science and Technology

Final Cavity Shape

Trade off in Electric vs. Magnetic field performance due to changed rod shape

Cavity still fits in all LHC scenarios and has tolerable fields at the design gradient.

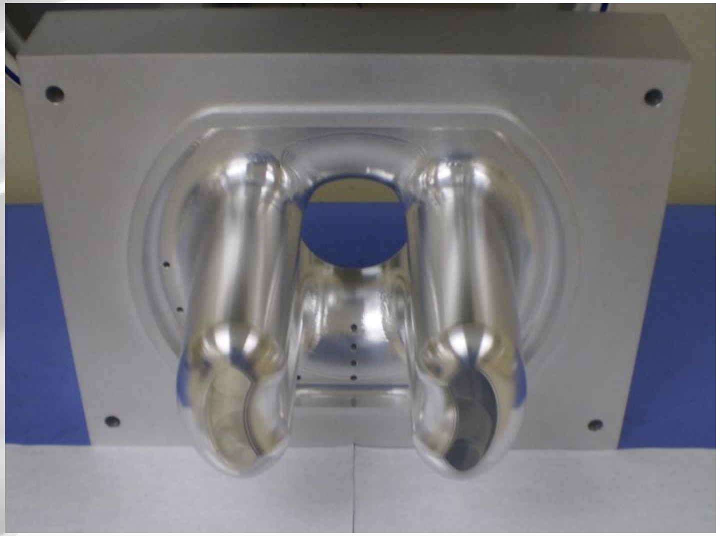


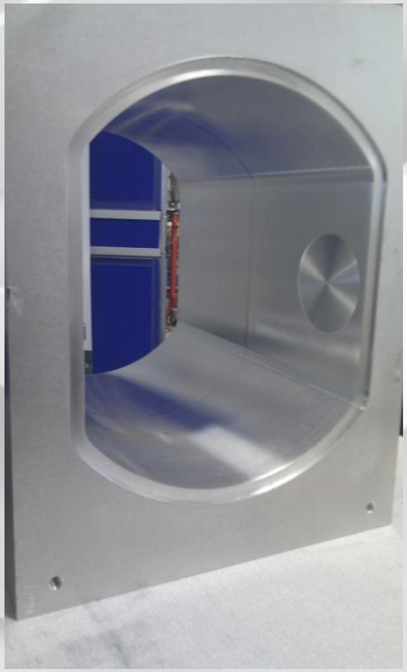


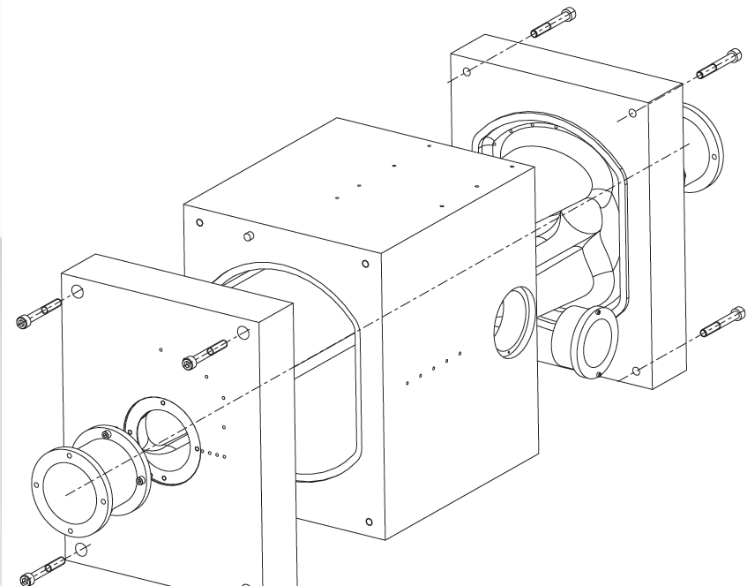
Emax @3MV	32.0 MV/m
Bmax @3MV	60.5 mT
Transverse R/Q	915 Ohms

Aluminium Prototype

- Beadpull measurements are being performed on a to scale aluminium prototype.
- Coupler ports present to allow verification of damping.





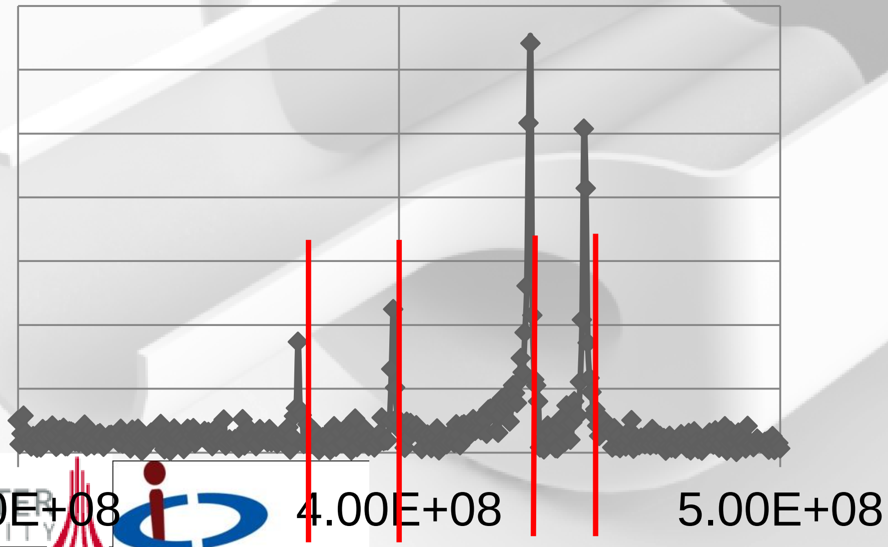


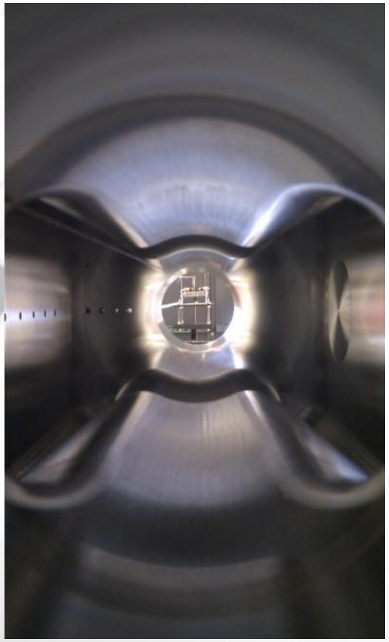
LANCASTER UNIVERSITY

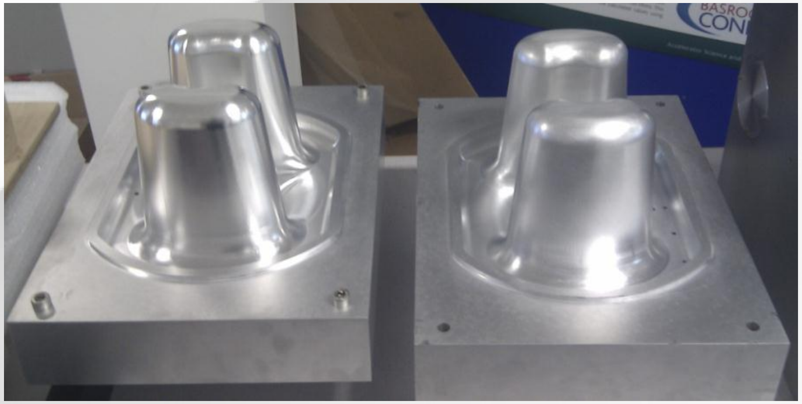
The Cockcroft Institute of Accelerator Science and Technology

Prototype testing

- Initial results show good correlation with simulations
- Slight shift in frequency across all modes due to initial assembly and manufacturing tolerances.





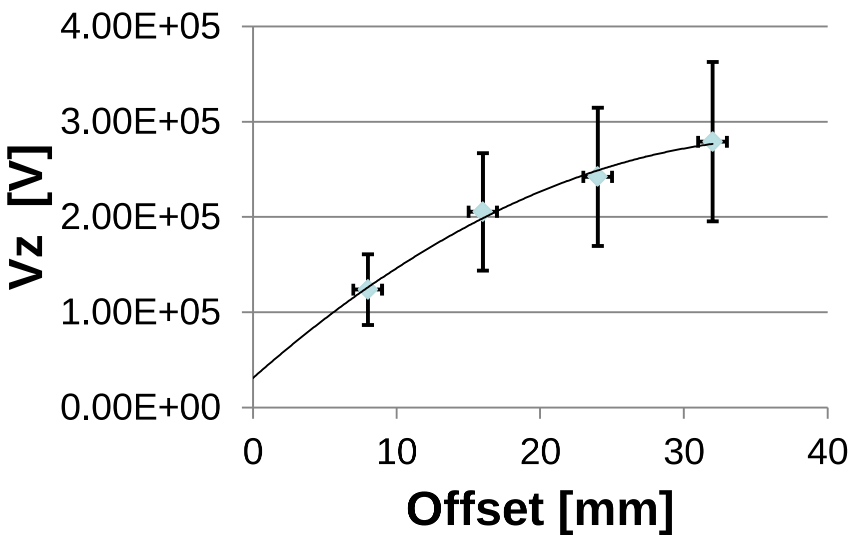


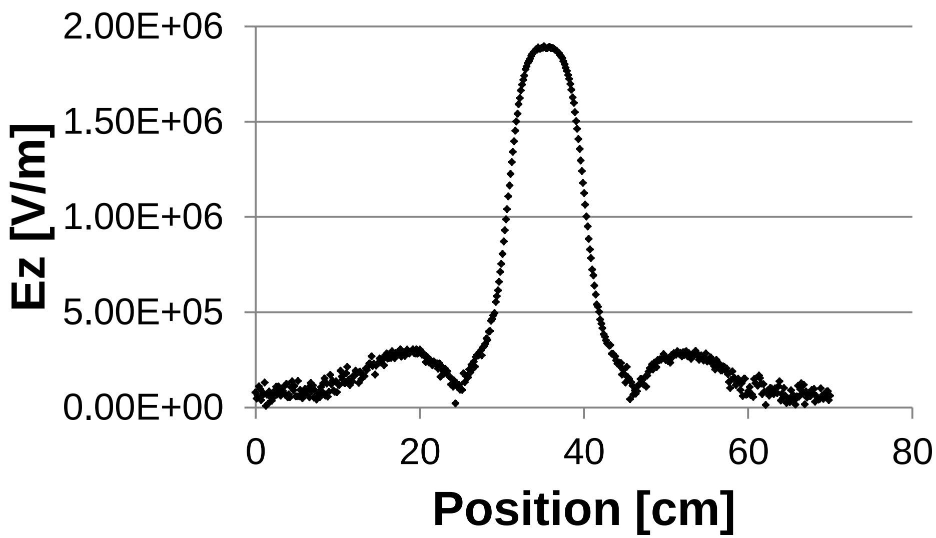
LANCASTER UNIVERSITY

The Cockcroft Institute of Accelerator Science and Technology

Bead pull

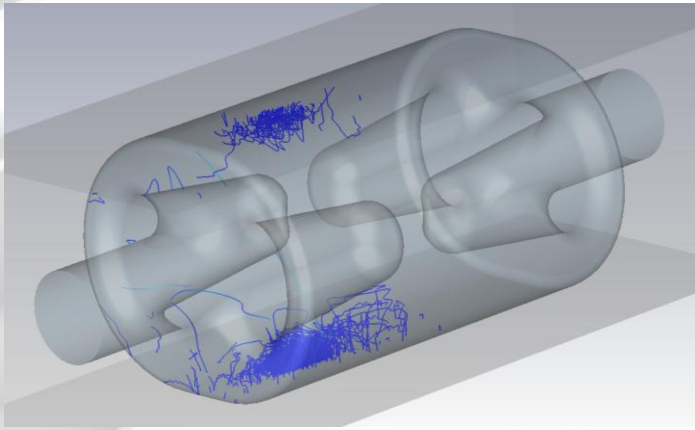
- Bead pull currently setup in RF lab, measurements will be taken in the next month to check field flatness vs simulation.
- Significant errors were seen in initial data sampling
  - Needle size is critical to minimising errors.
- Full profile of cavity fields will be taken in the coming month.

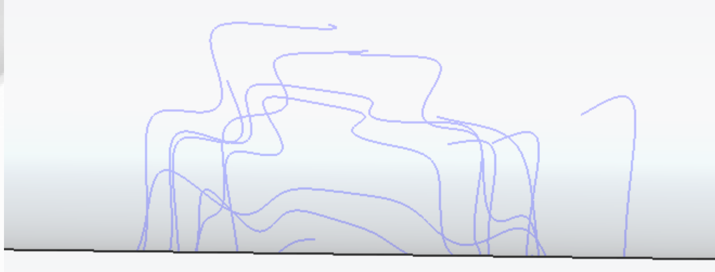


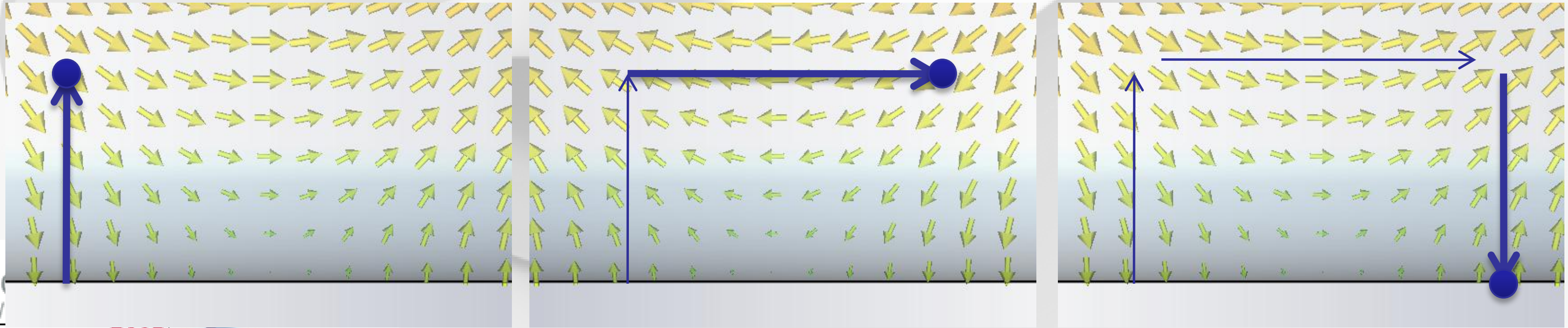


Multipacting

- Some weak multipacting on the outer can has been found at low E field. $V_t \sim 150$ kV.
- As cavity voltage increased the multipacting is pushed towards the base of the rods.
- This is close to the region where we plan to place the LOM coupler so this may disrupt the multipactor.
- Outer can trajectories follow a square step like path over several phases. There are 3rd and 7th order trajectories.

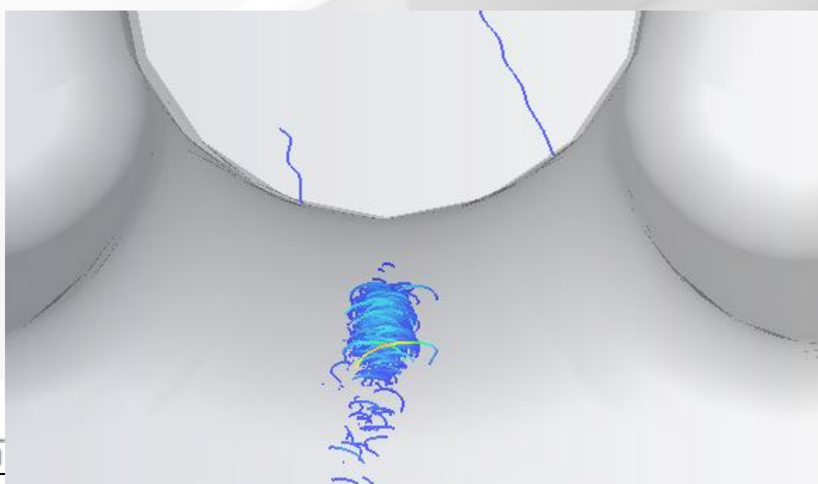


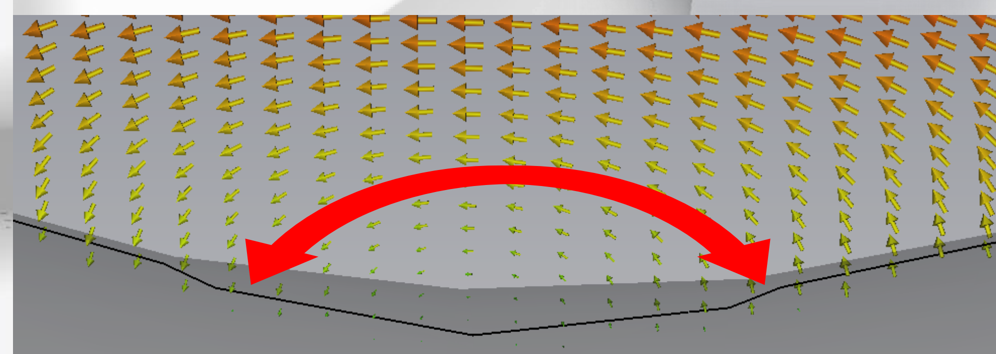




Multipactor Trajectories

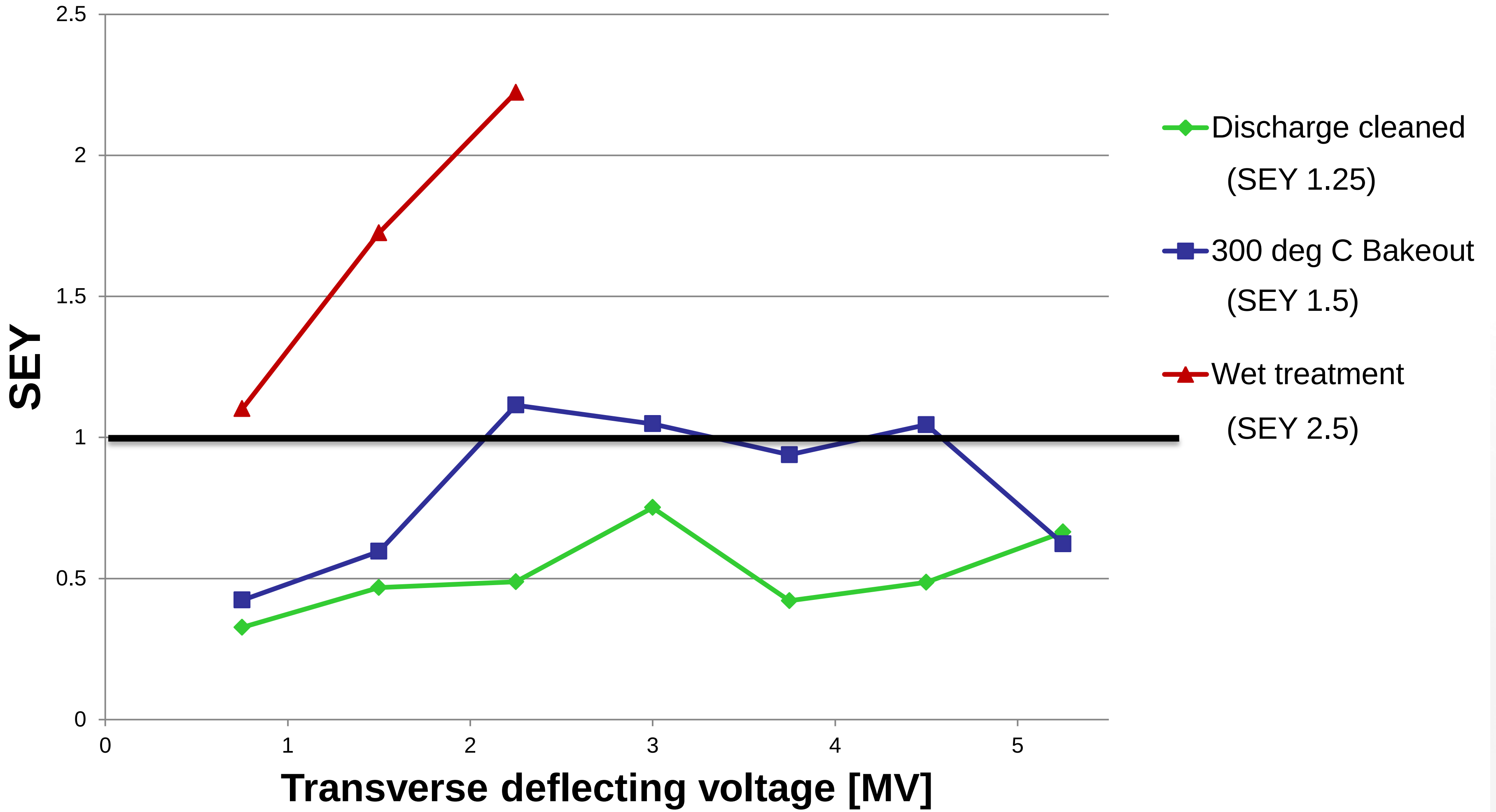
- Multipactor on the beam pipe was found on the beam pipe at ~1.6MV.
- Same multipacting was seen on KEKB crab cavity.
- Methods of removing the multipactor are being looked into, including;
  - Altering the beam pipe shape,
  - Adding ridges to disrupt local field patterns.





The Cockcroft Institute
of Accelerator Science and Technology

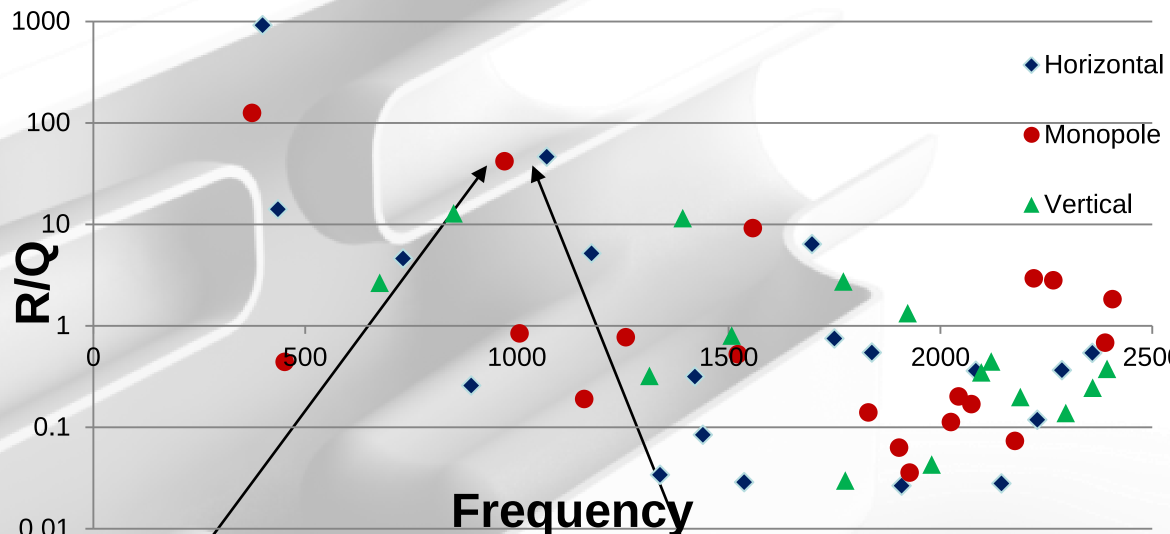
Multipactor Yields (preliminary)

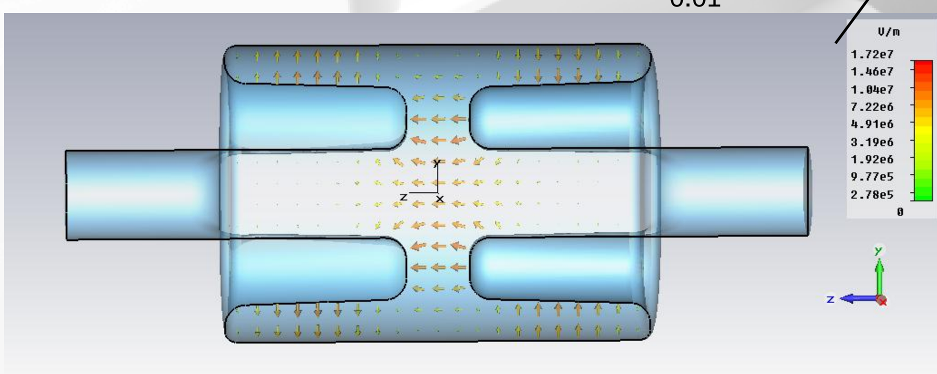


Higher Order Modes

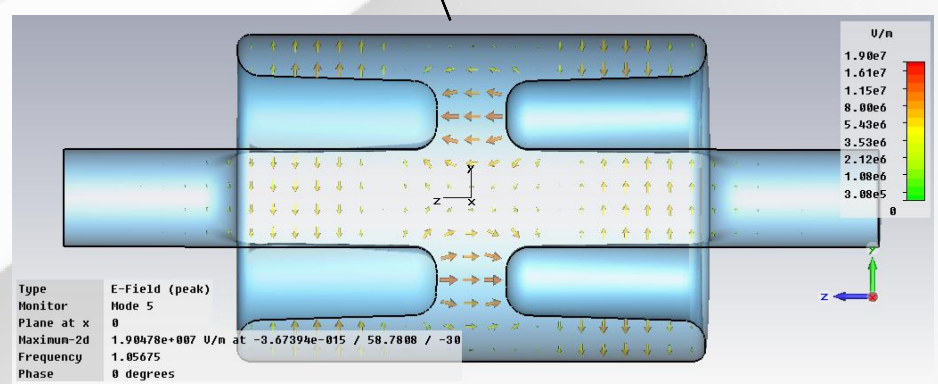
We also have some TEM HOMs.

As the cavity is compact in the vertical plane most of the TM modes are at higher frequencies, and the TE modes have low shunt impedances.





Monopole 3π/4 resonator

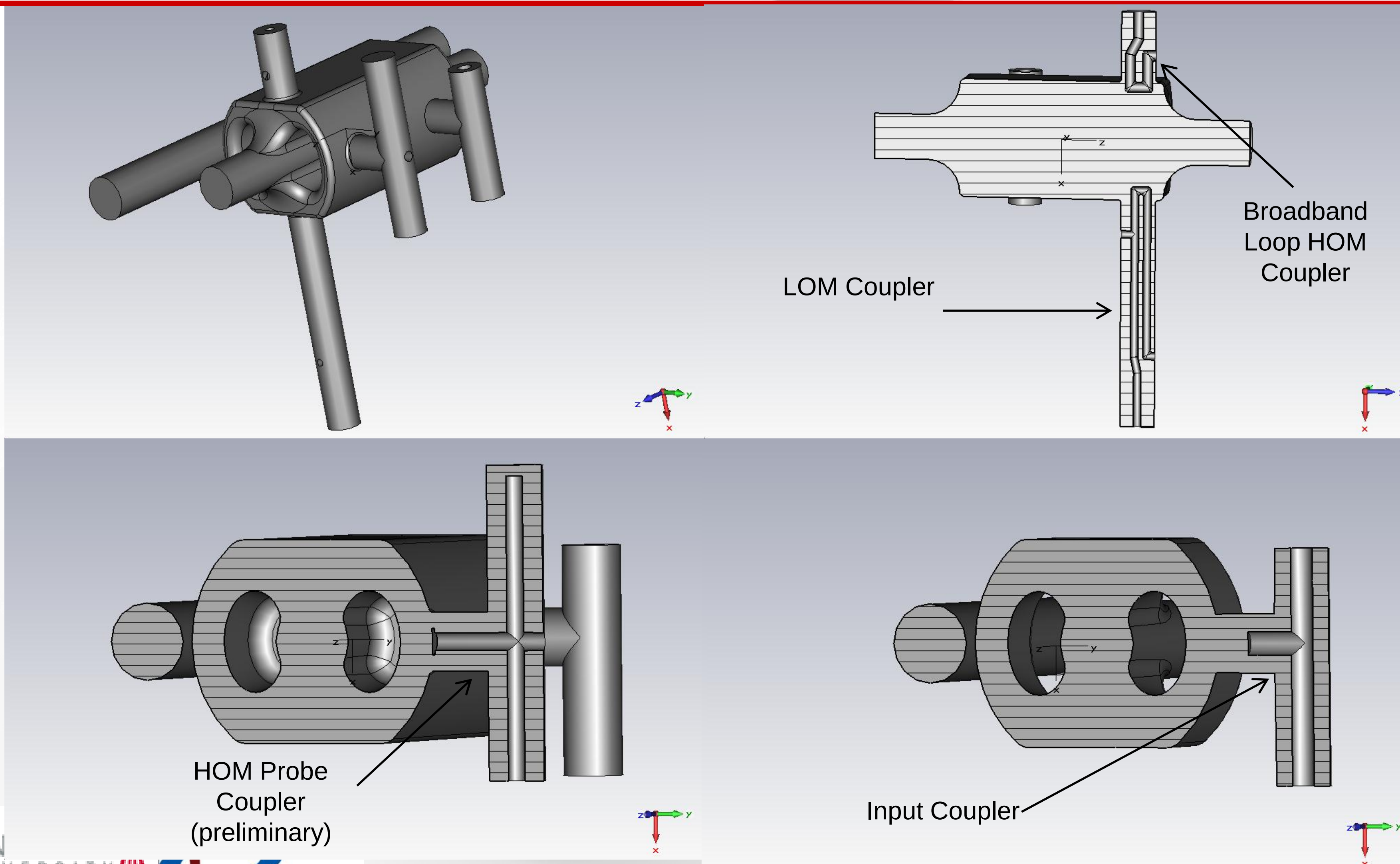


Dipole 3π/4 resonator

LANCASTER UNIVERSITY

The Cockcroft Institute of Accelerator Science and Technology

Crab Cavity and Couplers



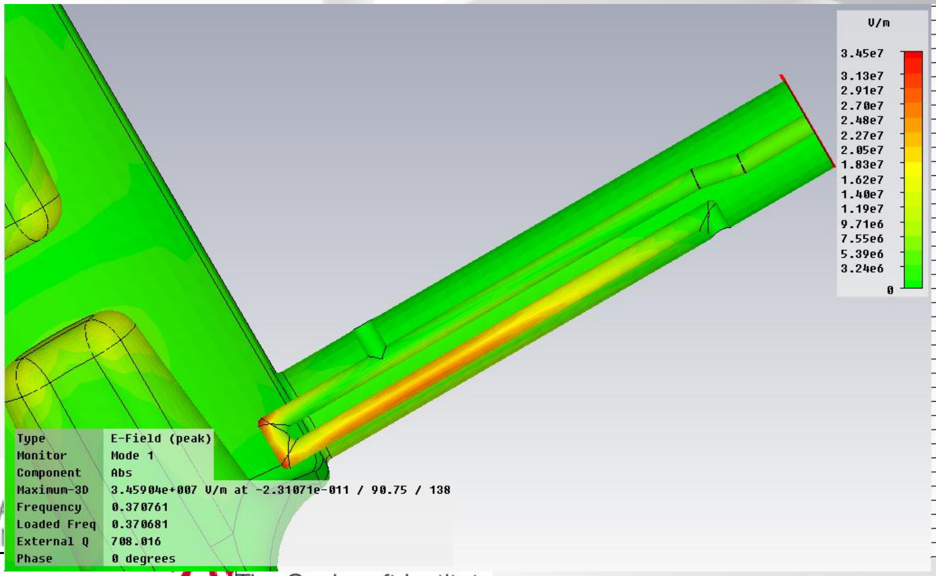
LAN
UNIVERSITY

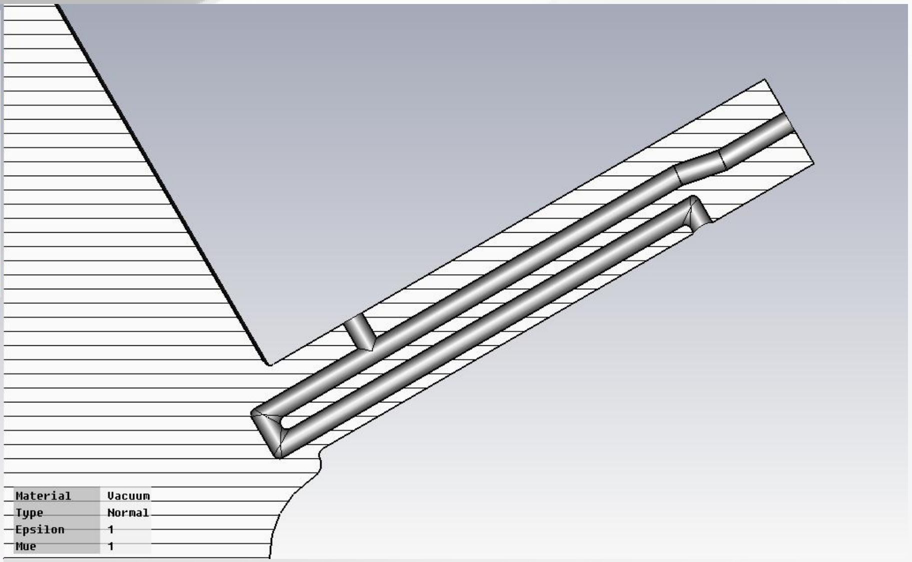
The Cockcroft Institute
of Accelerator Science and Technology

Demountable Coaxial Narrowband Coupler

- We use a resonant loop to damp the LOM at 370 MHz
- Coupler is demountable to allow access for cleaning cavity.
- LOM Mode splits into two due to resonance in coupler and resonance in cavity matching.
- External-Q's down to 109.6 and 115.6 have been achieved.
- Crabbing mode does not couple due to symmetry

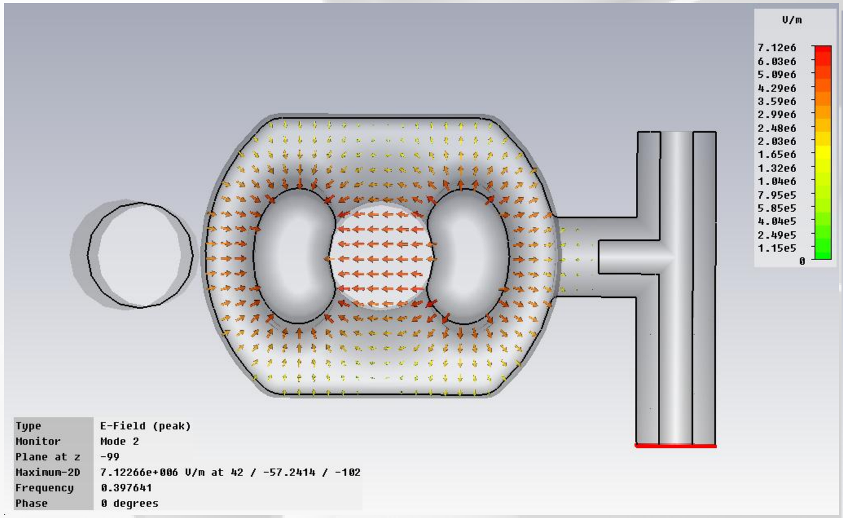
Type	Frequency (MHz)	R/Q	Qext	(R/Q).Qext
Monopole	371.8	56.9	109.7	6237.542
Monopole	378.9	75.7	115.6	8745.14

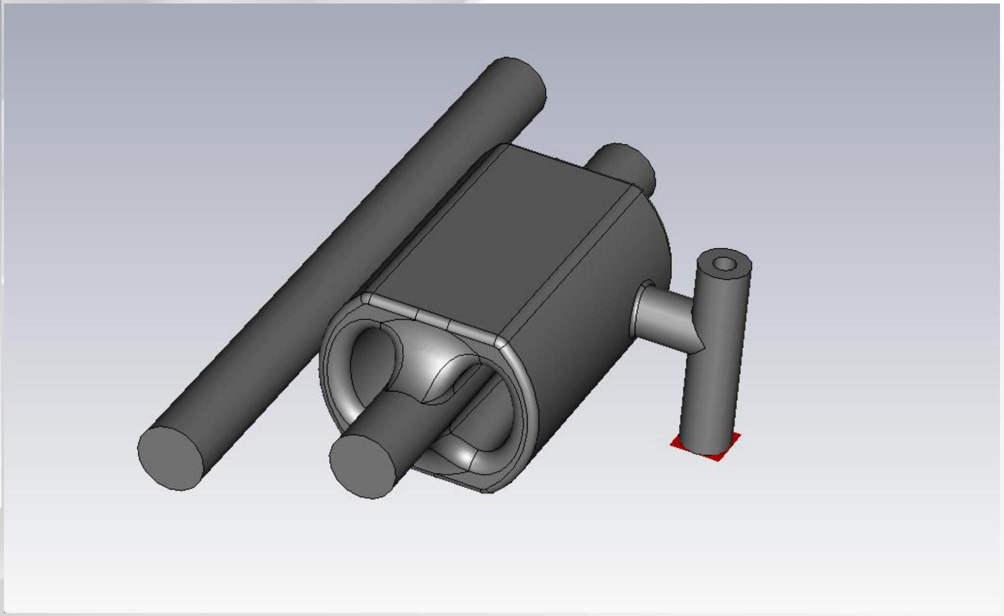




Input coupler

- The input coupler couples to the electric field in the plane of the rods.
- A T-section is required to extract the coupler vertically hence fitting in the required space.
- May also remove the HOM at 436 MHz.

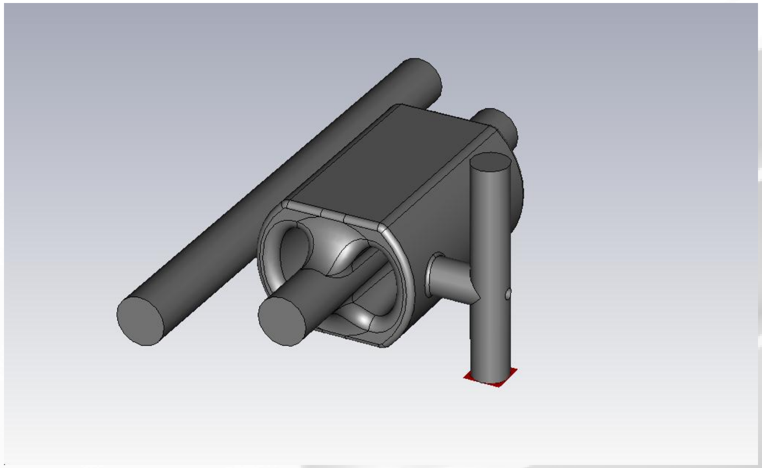


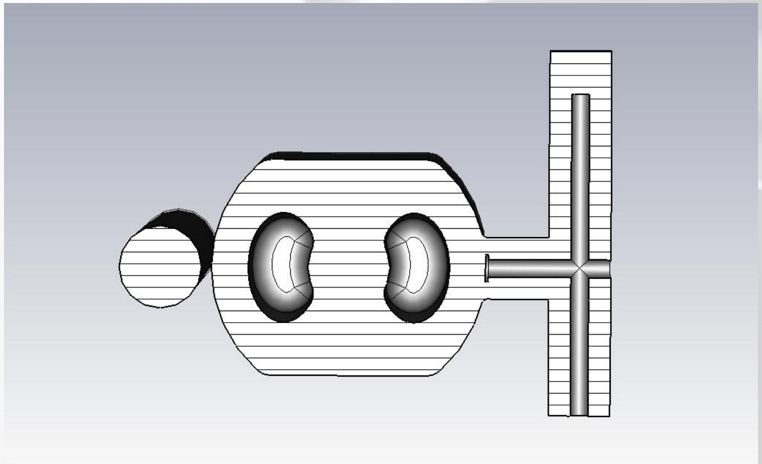


LANCASTER UNIVERSITY

The Cockcroft Institute of Accelerator Science and Technology

HOM Probe Coupler (preliminary)

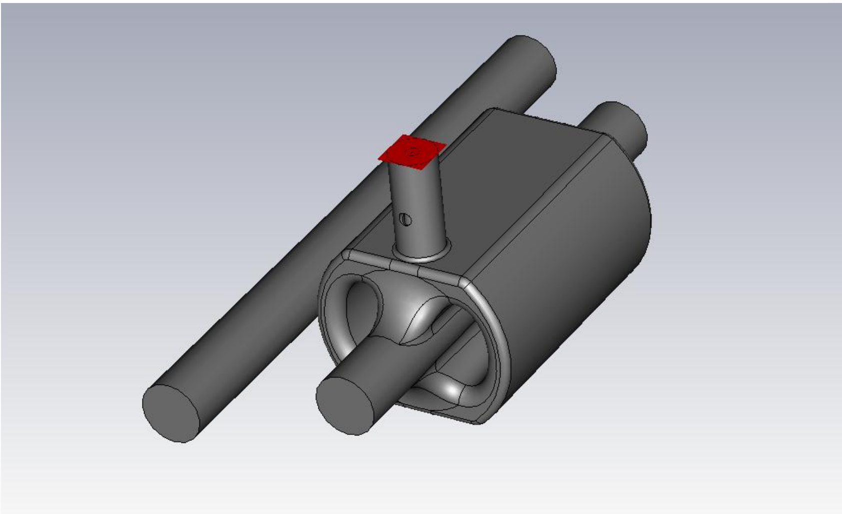


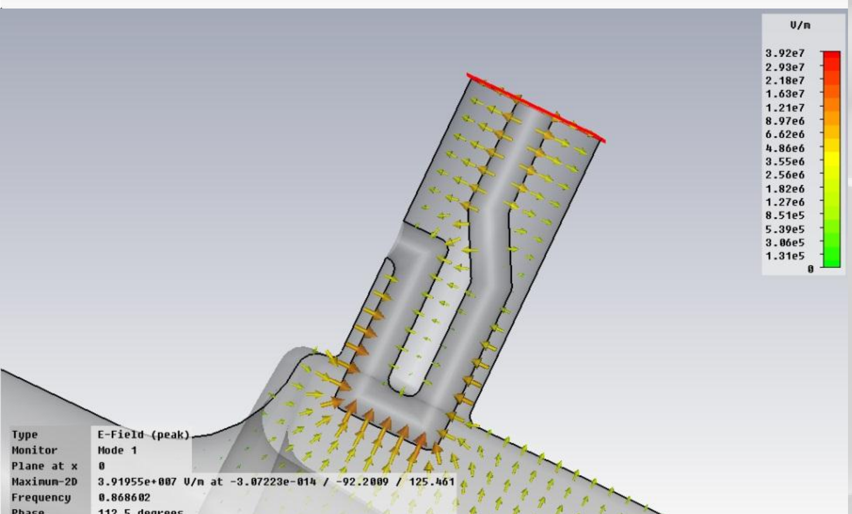


- Couples electrically to most horizontal dipole modes.
- Utilises a quarter wave resonant filter to filter out the crabbing mode.
- Needs further work and may be integrated with input coupler.
- Very little work done on this coupler yet.

LANCASTER UNIVERSITY
The Cockcroft Institute of Accelerator Science and Technology

Demountable Coaxial Broadband Loop Coupler



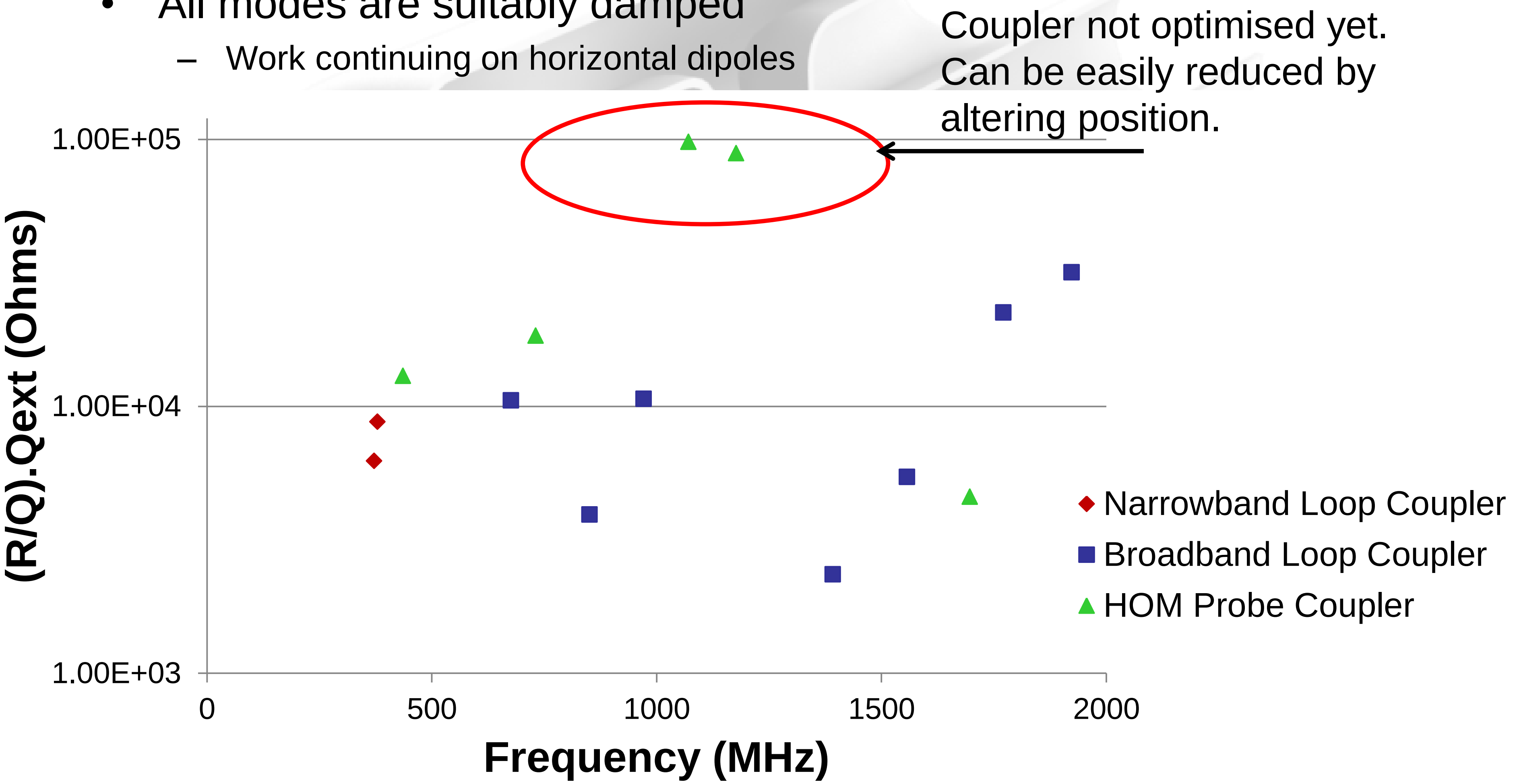


- The Broadband Loop coupler couples to the monopole and vertical dipole HOM’s
- This doesn’t couple to the crabbing mode due to symmetry (located at magnetic field null).

	Frequency (MHz)	R/Q	Qext	(R/Q).Qext
Monopole	1557	9	604	5436
Vertical Dipole	676	2.6	4046	10519.6
Vertical Dipole	851	12.6	312	3931.2
Vertical Dipole	1392	11	213.3	2346.3
Vertical Dipole	1771	2.7	8323	22472.1
Vertical Dipole	1923	1.3	24430	31759

(R/Q).Qext

- All modes are suitably damped
  - Work continuing on horizontal dipoles



2K vs 4K

- Expect significant losses though couplers.
- 2K operation - Preferable.
  - More complicated.
- 4k Operation.
  - Non superfluid helium could lead to gas trapping in rods.
  - Boiling could induce microphonics not found in superfluid.

Ohmic power loss into helium bath	
4.2 K	8.17 w
2 K	0.16 w

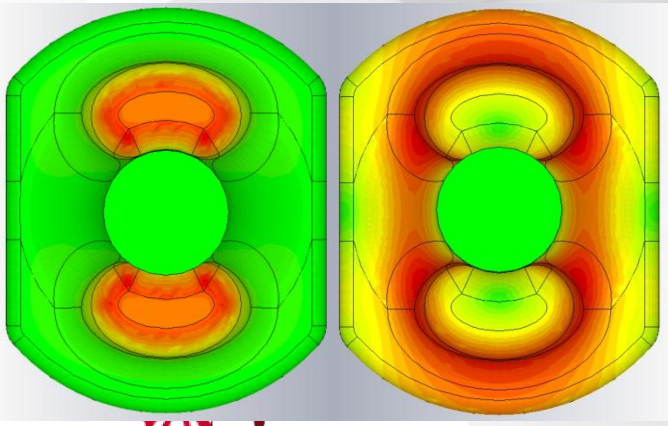
LANCASTER UNIVERSITY

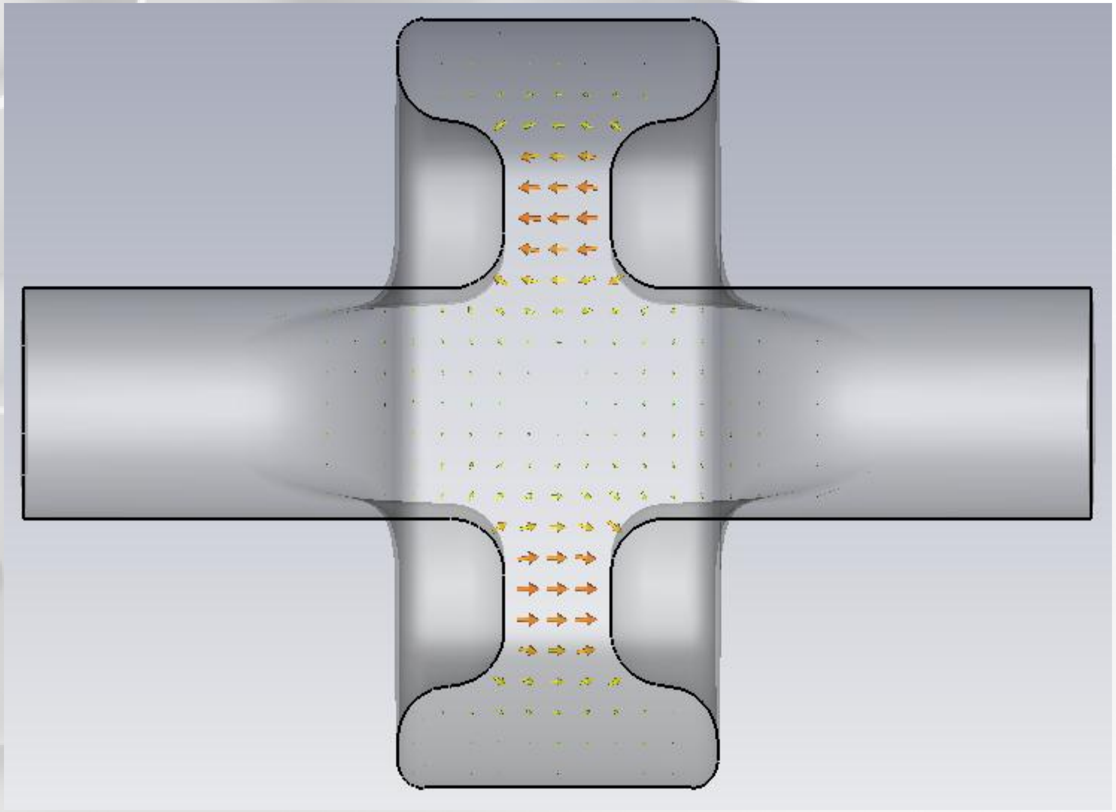
The Cockcroft Institute of Accelerator Science and Technology

800MHz design

- Design performance drops slightly for 800 MHz
- The cavity basically becomes a re-entrant cavity hence manufacture is simplified. Could be considered “conventional”.
- Could be made more “elliptical” like

Emax @1.5MV	41.0 MV/m
Bmax @1.5MV	57.3 mT





Conclusion

- Variation in transverse voltage have been minimised.
- Aluminium prototype has been produced.
  - Measurements agree with simulations.
- Multipacting has been studied.
- Coupler designs are on going.

- The 4R-LHC crab cavity shows no major issues at present and is a strong contender for use in HL-LHC.

LANCASTER UNIVERSITY
The Cockcroft Institute of Accelerator Science and Technology