OLD DOMINION UNIVERSITY

CRABBING AND FREQUENCY IN THE MEIC

Alejandro Castilla

CASA/CAS-ODU

acast020@odu.edu

U.S. DEPARTMENT OF ENERGY

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Outline

- **Motivation/History.**
- **RF-Dipole Vs Elliptical Cavities.**
- **Significant Figures as Function of Frequency.**
- **RF-Dipole [**proof of principle**] & Test Results.**
- **P.o.P Vs. Real Cavity Design.**
- **HOM Damping Scheme (the LHC case).**
- **Discussion….**

Motivation 1 (crabbing)

- **The luminosity "turning knobs" come with a trade-off.**
- **Restoration of geometrical reduction is a "preferable" path.**

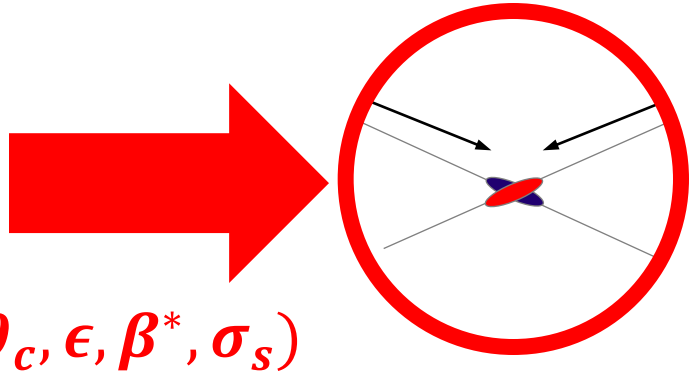
injector and beam-beam

$$\mathcal{L} = \frac{1}{4\pi}(nfN_b)\cdot\frac{n}{\epsilon_N}\cdot\frac{\gamma}{\beta^*}\cdot R(\theta_c,\epsilon,\beta^*,\sigma_s)$$

total beam current

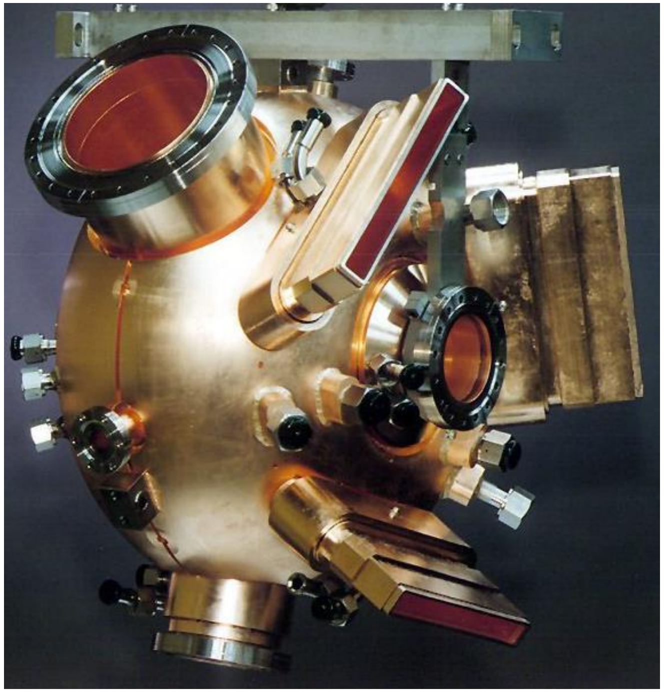
energy and β^*

Reduction factor: hourglass effect, crossing angle…



Motivation 2 (freq. change)

- **The PEP-II RF systems [476 MHz] offer a considerable hardware advantage.**

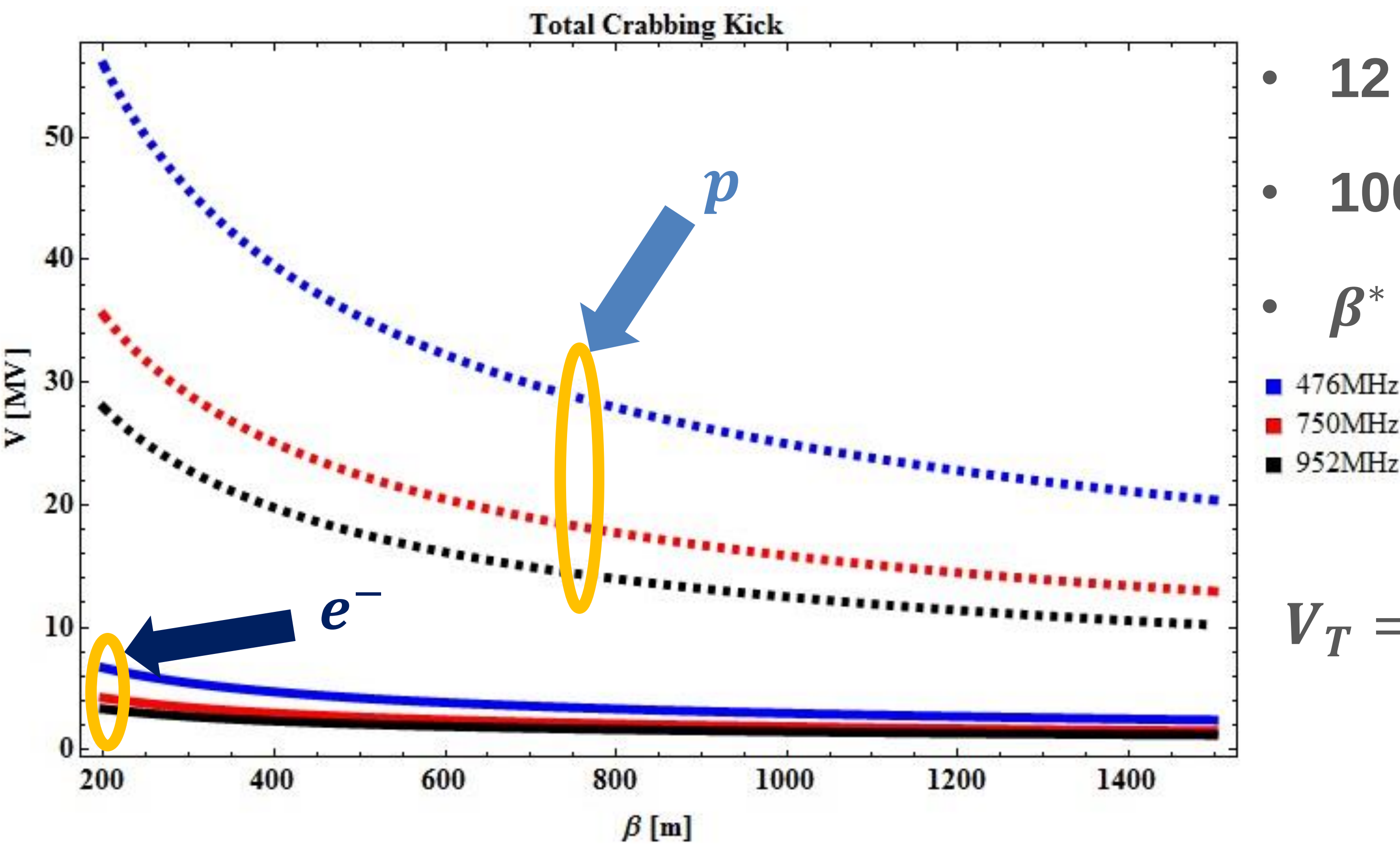


*SLAC PEP-II archives.

.

Crabbing & Frequency

- **The voltage needed to restore a 50 mrad crabbing angle:**

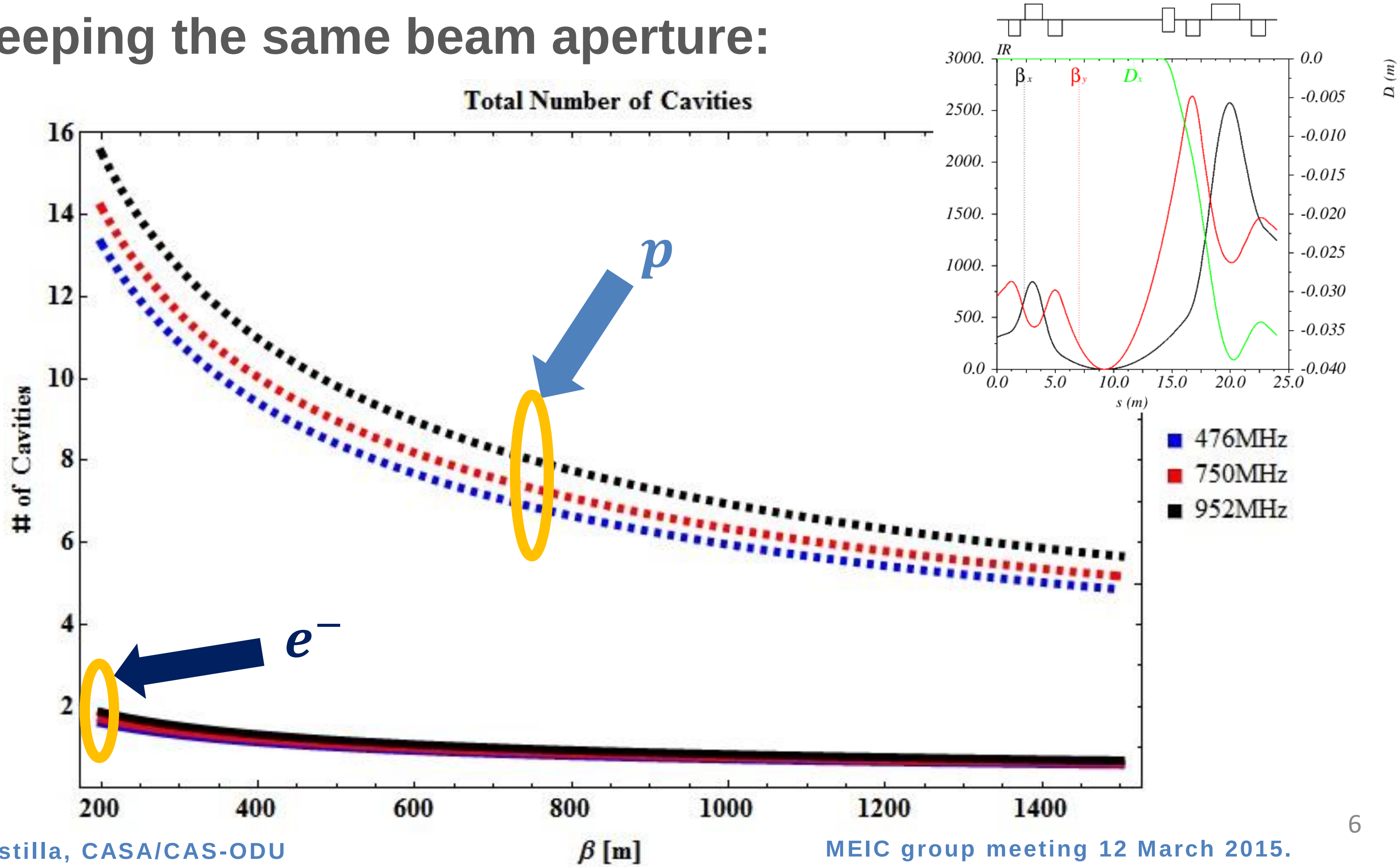


- **12 GeV electrons.**
- **100 GeV protons.**
- $\beta^* = 10$ cm.

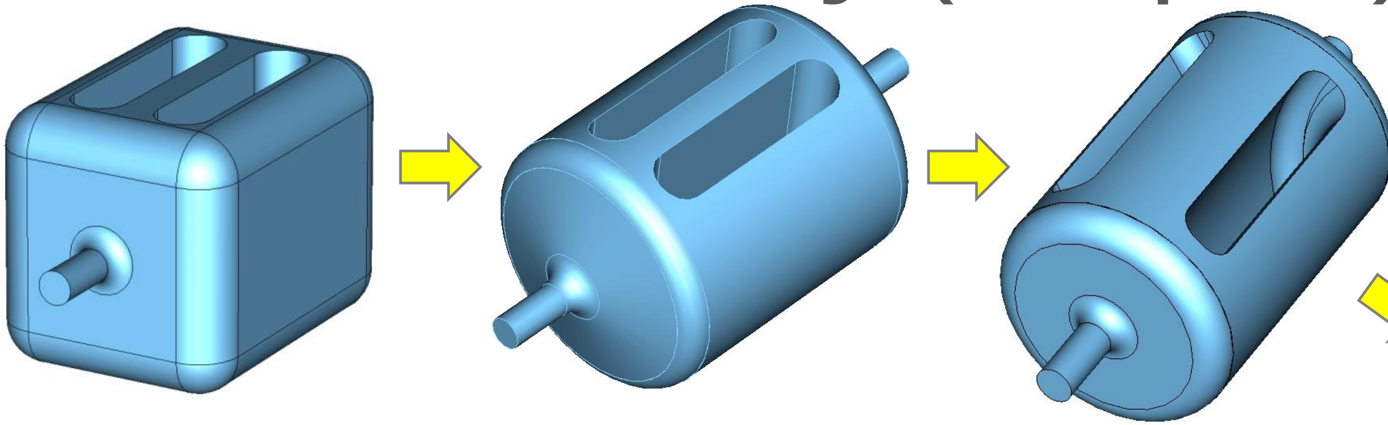
$$V_T = \frac{cE_b \tan\frac{\varphi_c}{2}}{\omega_{rf}\sqrt{\beta_x^*\beta_x^c}}$$

Crabbing & Frequency (cont.)

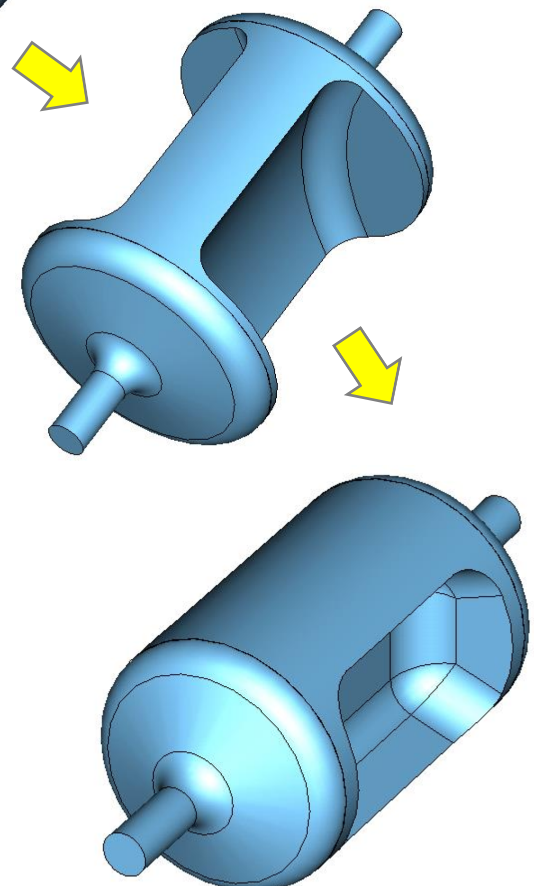
- **The case of the rf dipole geometry, at constant field and keeping the same beam aperture:**



History (rf dipole)

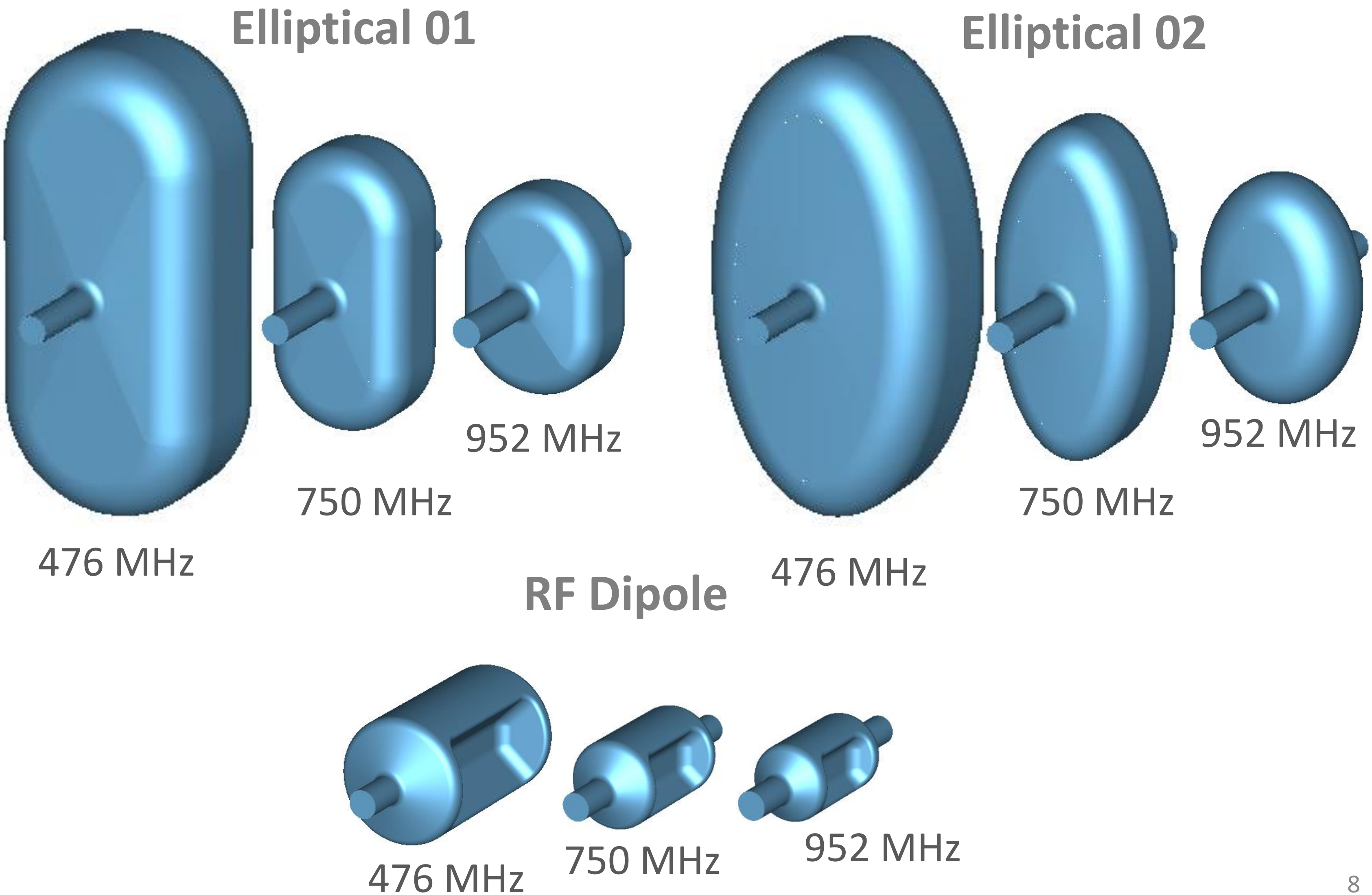


S. De Silva, ODU-Jlab 2012.



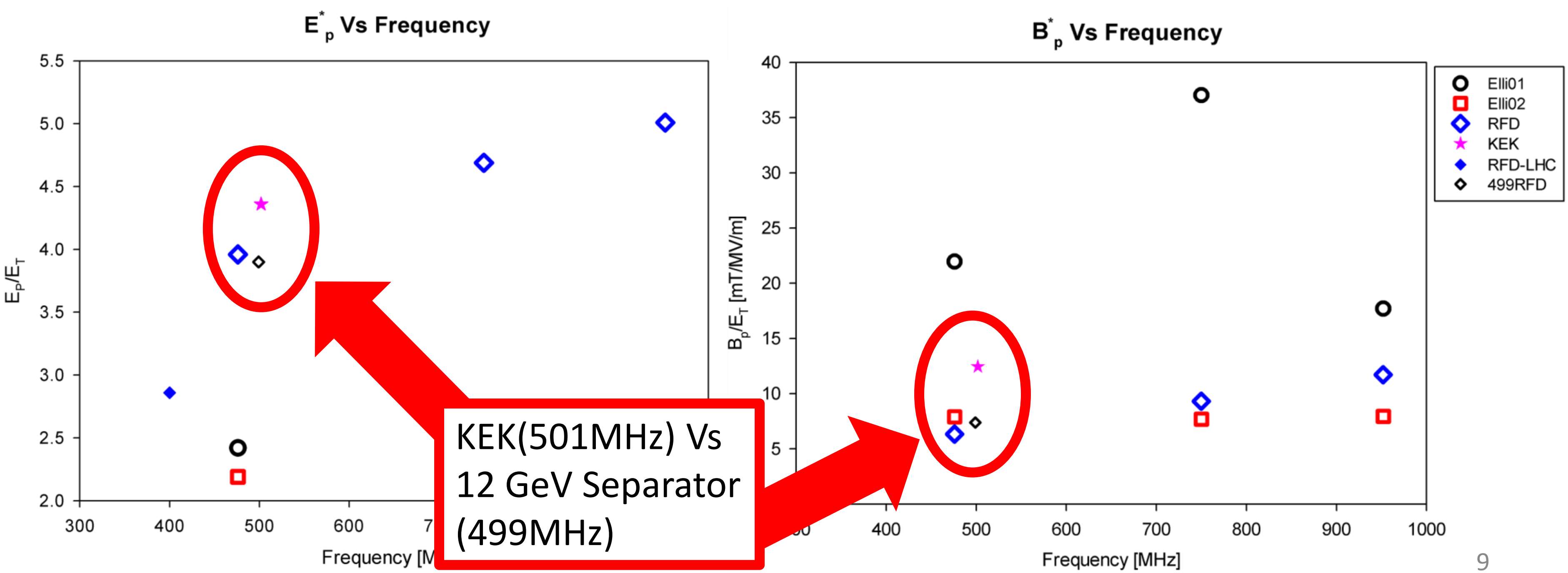
- Aspects of optimization
  - Lower and balanced peak surface fields
  - Stability of the design
    - ➢ Cylindrical shape is preferred to reduce flat surfaces
  - Cavity processing
    - ➢ Curved end plates for cleaning the cavity
  - Wider separation in Higher Order Mode (HOM) spectrum
  - Multipacting

A Sense for Sizes



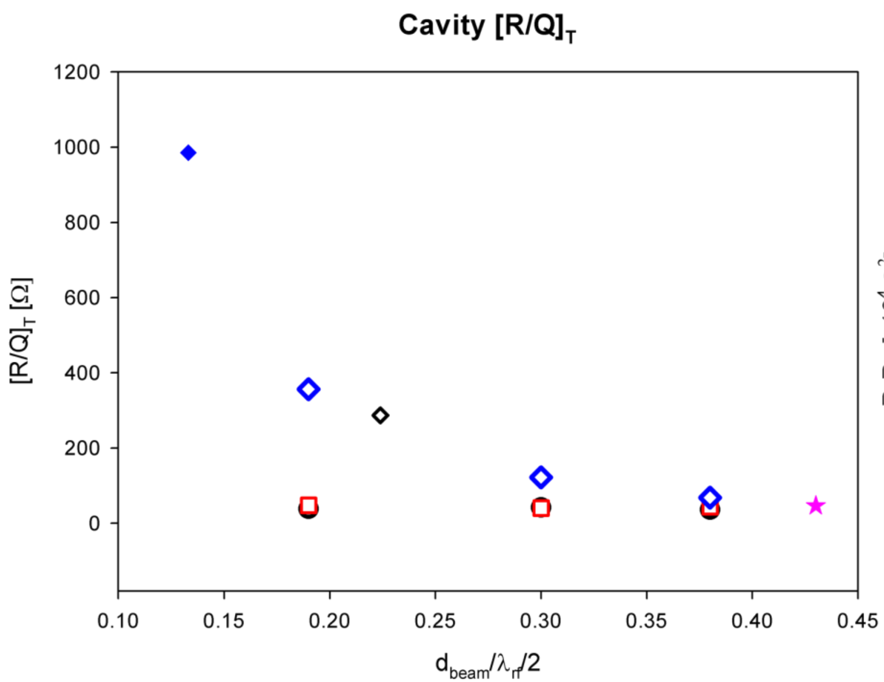
Significant Figures

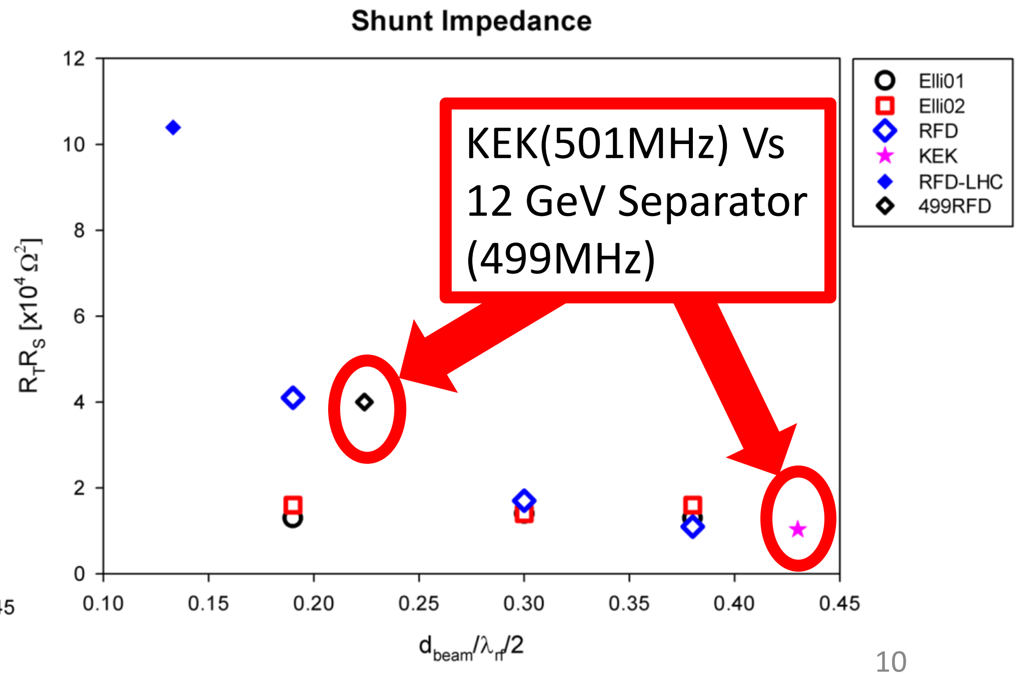
- Realistic models of elliptical cavities will include bigger beam pipe apertures to extract the HOMs.
- RF-Dipole has lower and more balanced Ep/Bp.



Significant Figures (cont. 1)

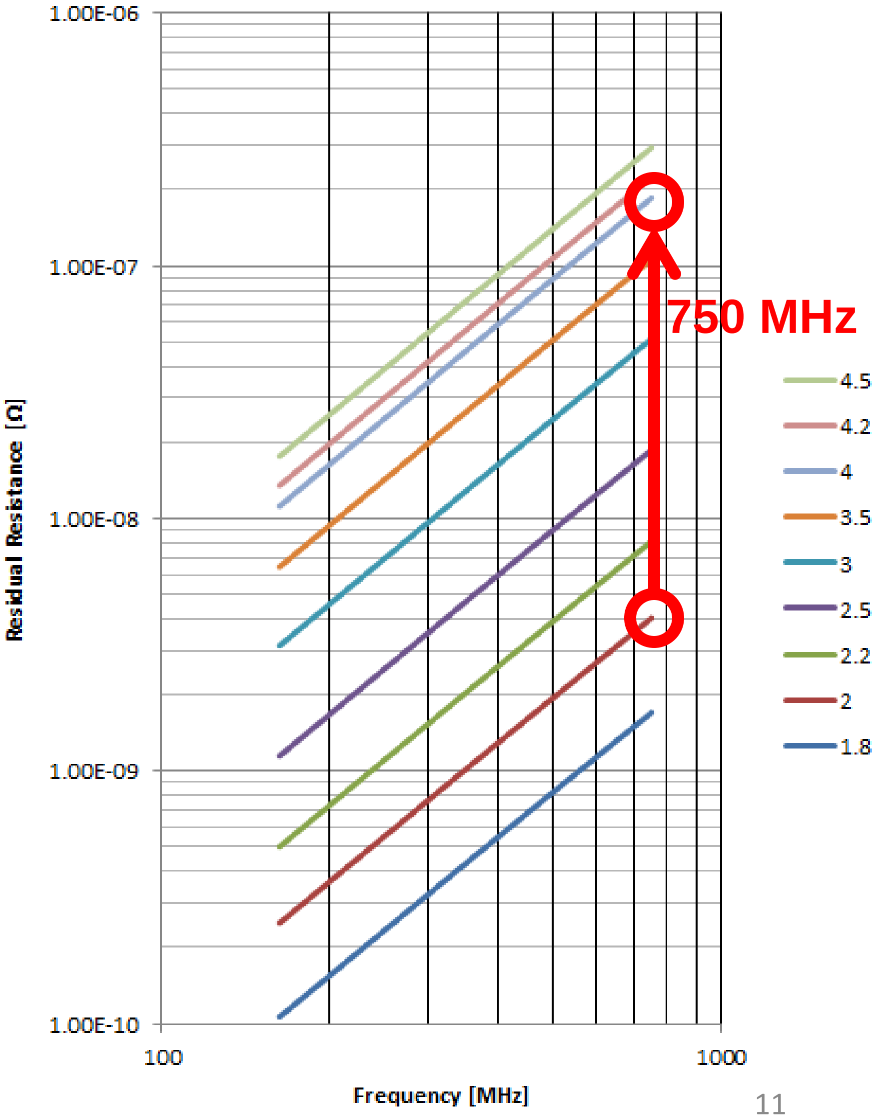
- **Single cell (P.o.P) shunt impedances.**
- **More important than just the frequency is the beam aperture to effective length ratio.**





Significant Figures (cont. 2)

- **The residual resistance of Nb is a function of frequency and temperature.**
- **Therefore Q_0 is as well:**
  - ➢ Higher frequency = lower Q_0.
  - ➢ Higher temperature = lower Q_0.

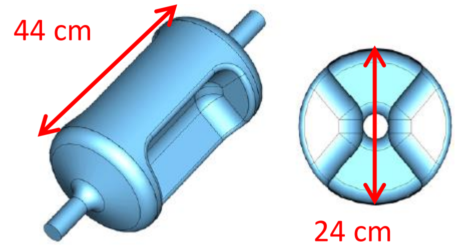


RF- Dipoles (proof of principle)

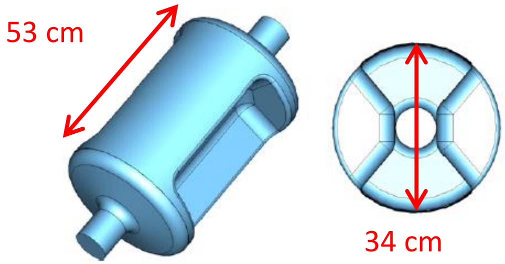
Frequency	499.0*	400.0*	750.0	MHz
Aperture Diameter (d)	40.0	84.0	60.0	mm
d/(λ/2)	0.133	0.224	0.3	
LOM	None			MHz
Nearest HOM	777.0	589.5	1062.5	MHz
E_p^*	2.86	3.9	4.29	MV/m
B_p^*	4.38	7.13	9.3	mT
B_p^*/E_p^*	1.53	1.83	2.16	mT/ (MV/m)
$[R/Q]_T$	982.5	287.0	125.0	Ω
Geometrical Factor (G)	105.9	140.9	136.0	Ω
$R_T R_S$	1.0×10^5	4.0×10^4	1.7×10^4	Ω^2
At $E_T^* = 1$ MV/m				

*S. De Silva, ODU-Jlab 2014.

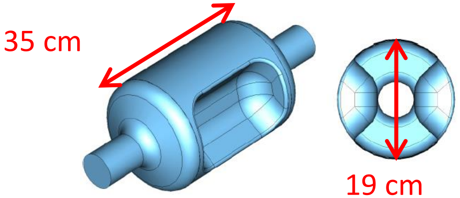
499 MHz Deflecting Cavity for Jefferson Lab 12 GeV Upgrade*



400 MHz Crabbing Cavity for LHC HiLumi Upgrade*

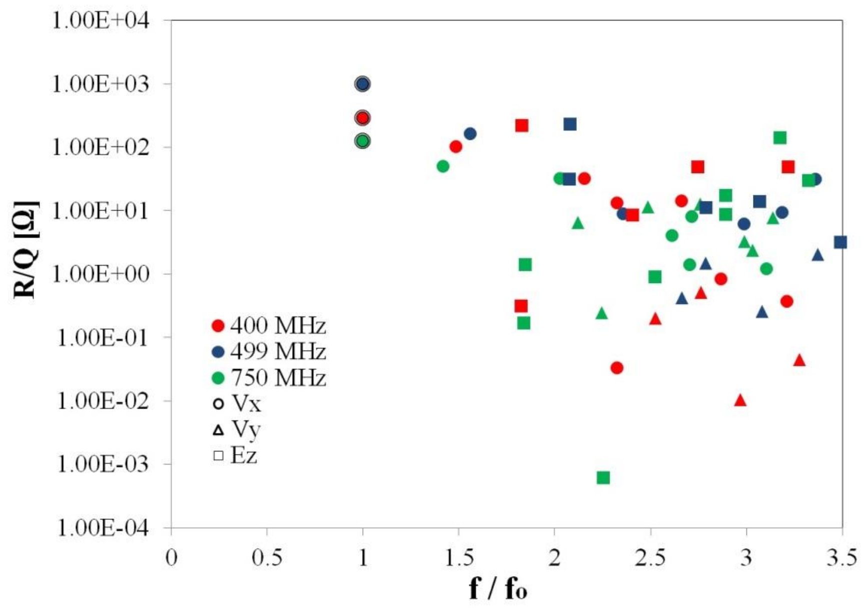


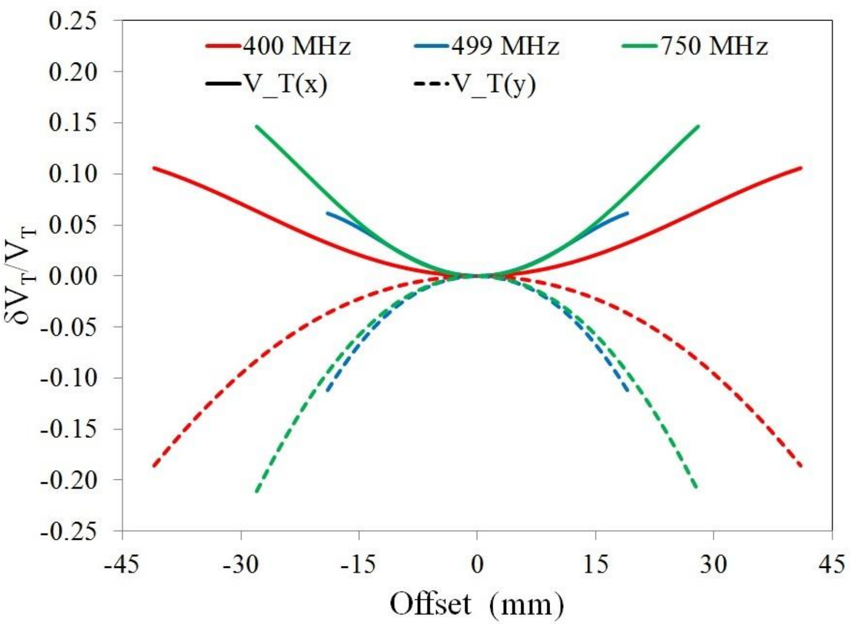
750 MHz Crabbing Cavity for MEIC at Jefferson Lab



RF- Dipoles

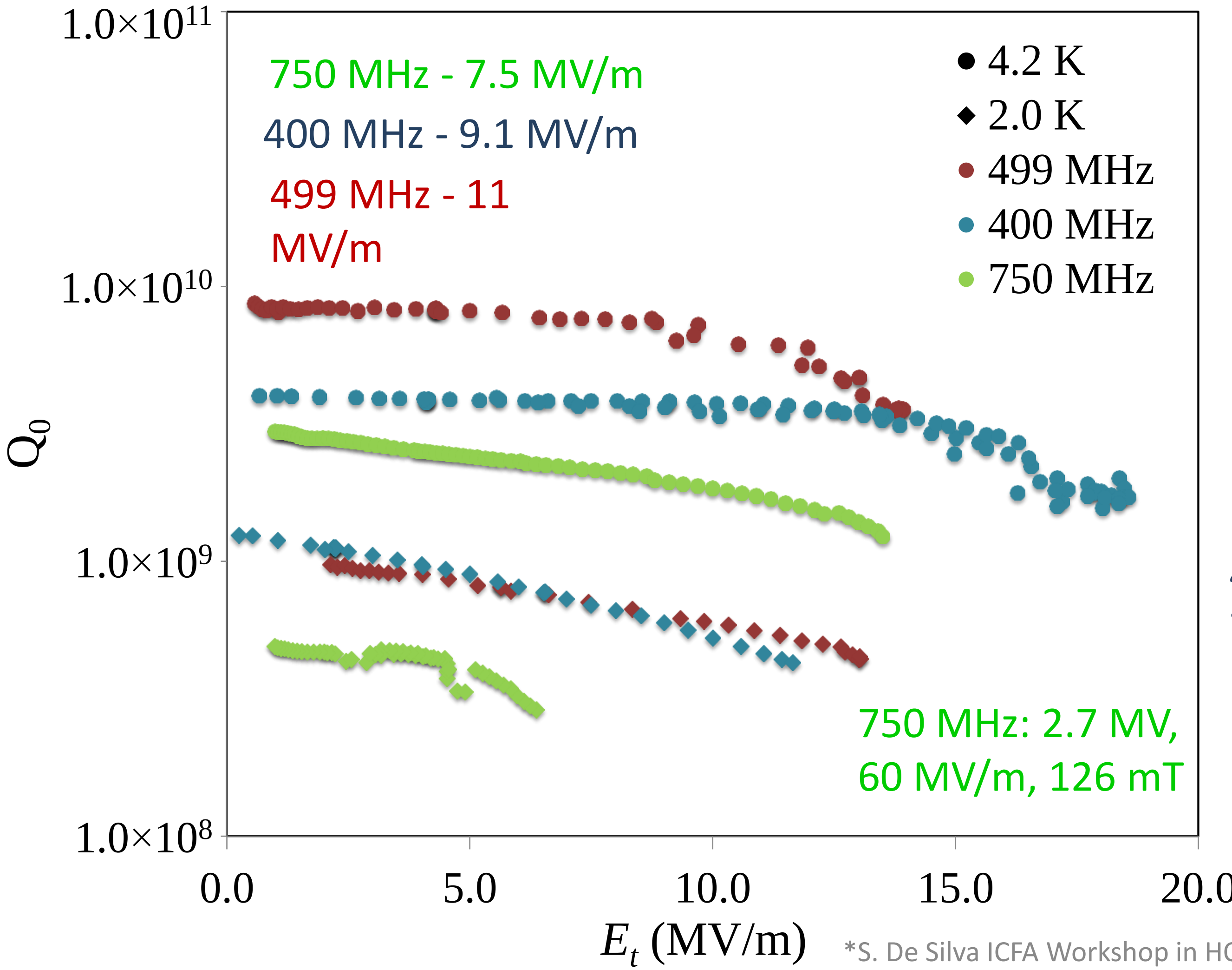
- No Lower Order Modes.
- Far separation with closest mode.
- Field flatness can be “tailored”.





*On IPAC2013 Proceedings.

Test Results (P.o.P)

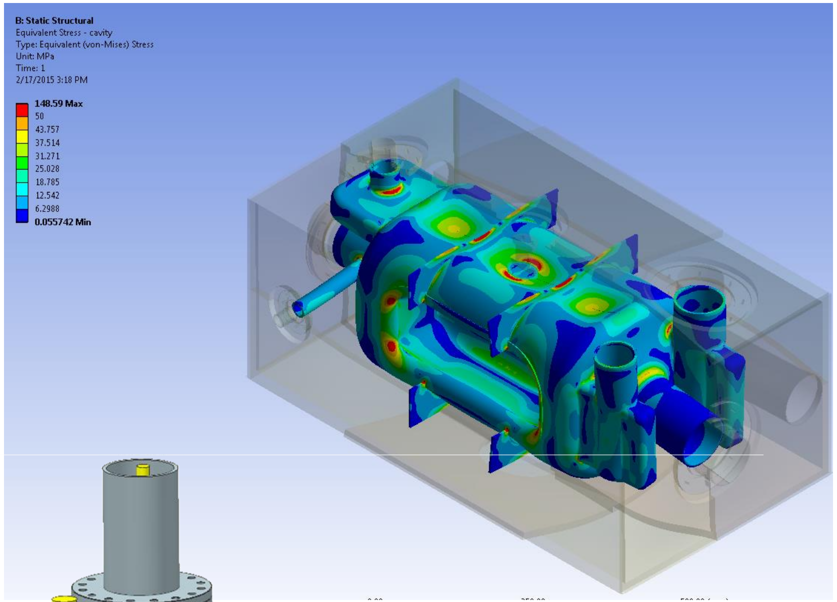


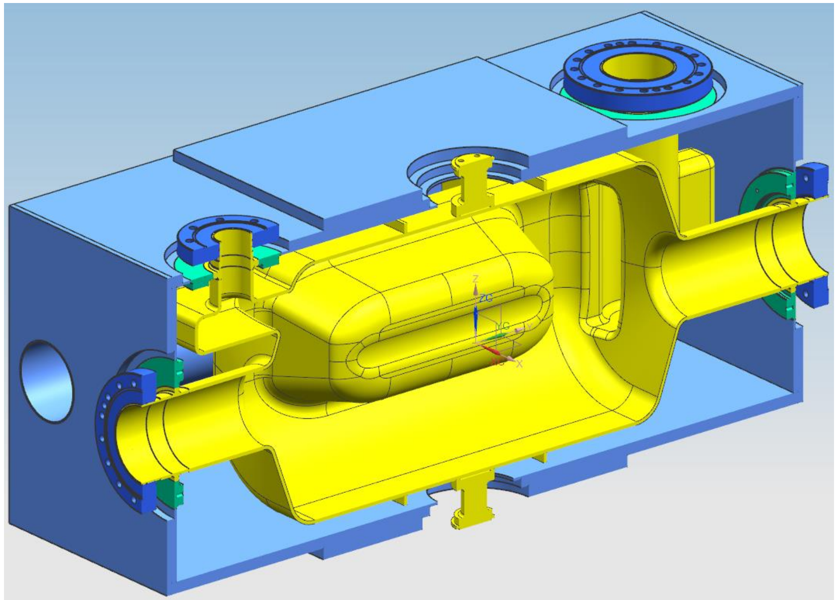
499 MHz: 4.2 MV, 40 MV/m, 61.3 mT

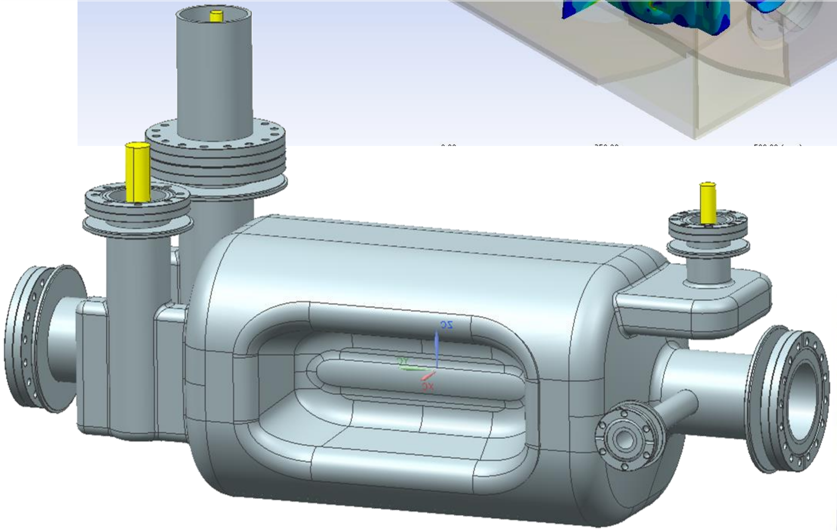
400 MHz: 7.0 MV, 75 MV/m, 131 mT

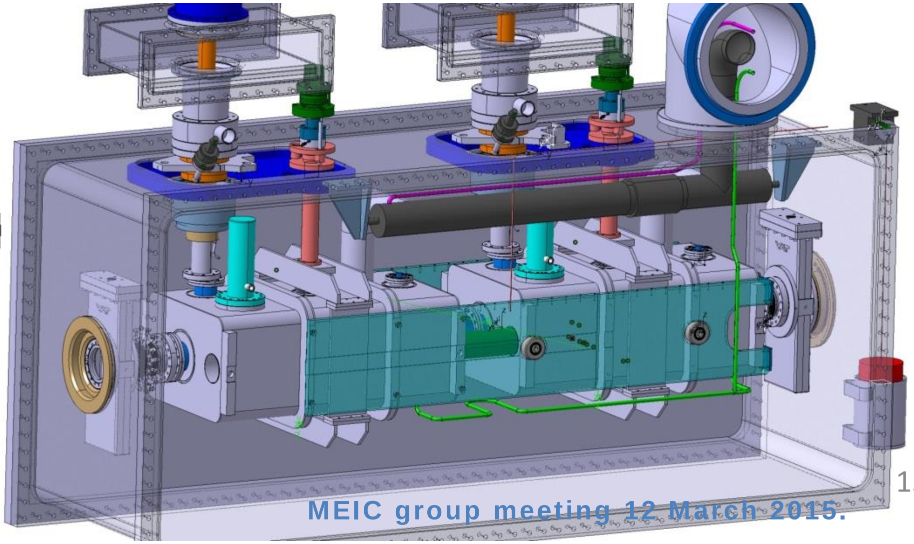
*S. De Silva ICFA Workshop in HOMs for SRF 2014..

Beyond a P.o.P.





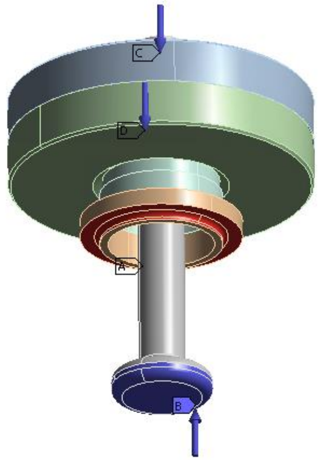


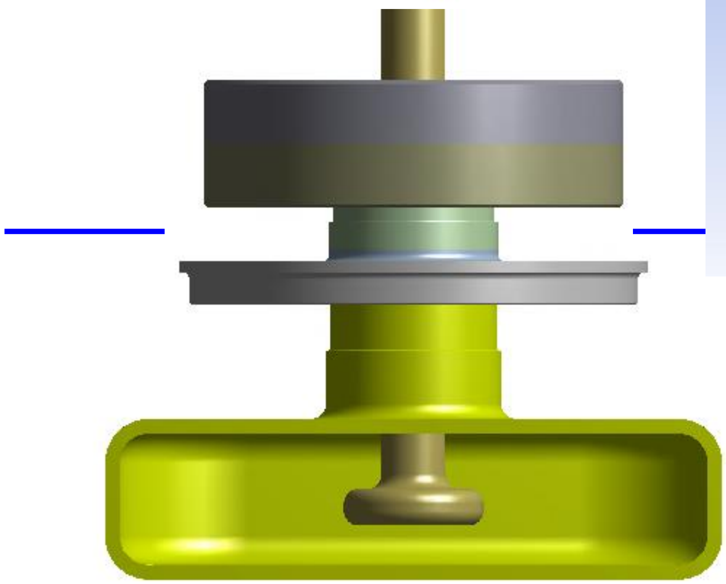


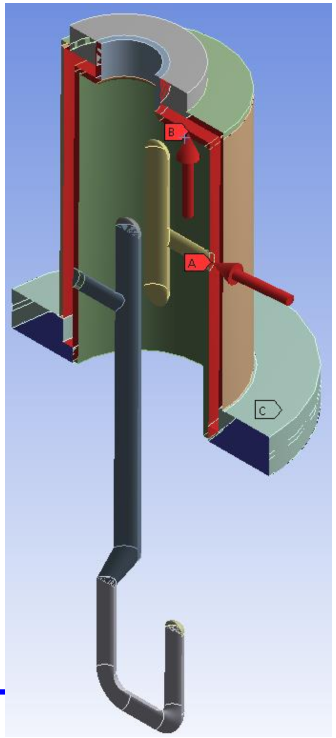
*T. Nicol, HiLumi LHC HOM Coupler Review II, Feb. 2015.

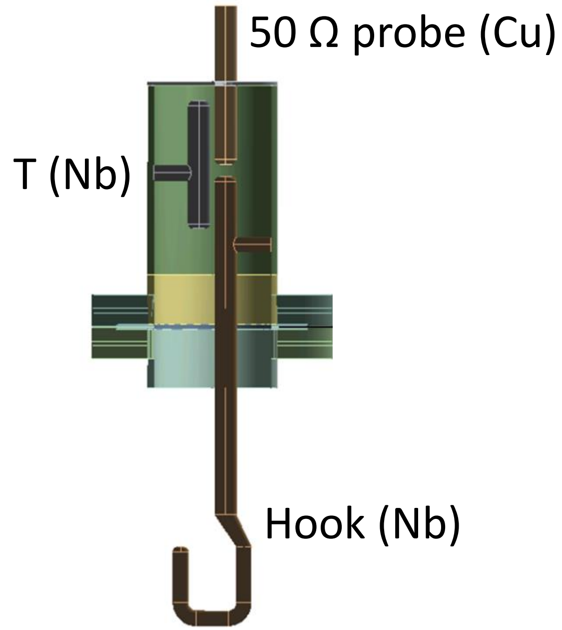
.

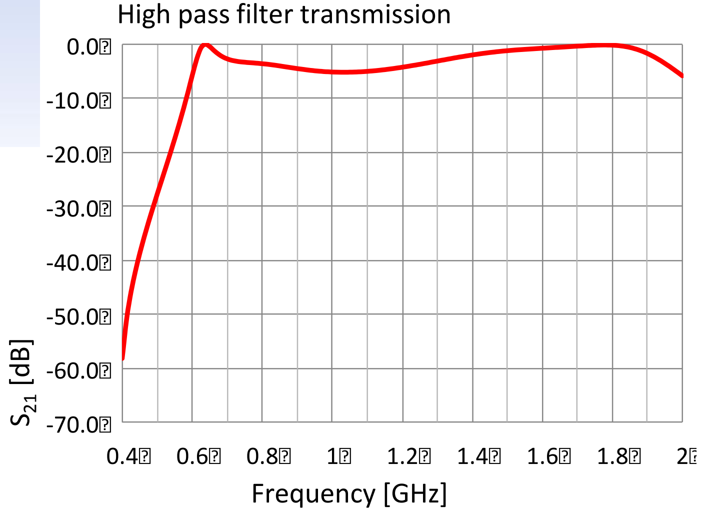
Damping HOMs for LHC







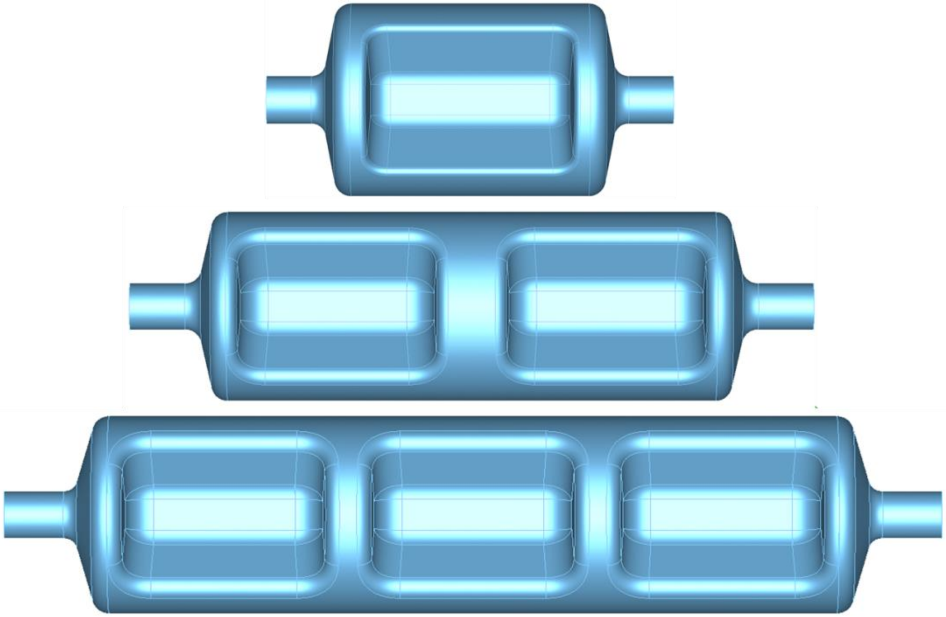


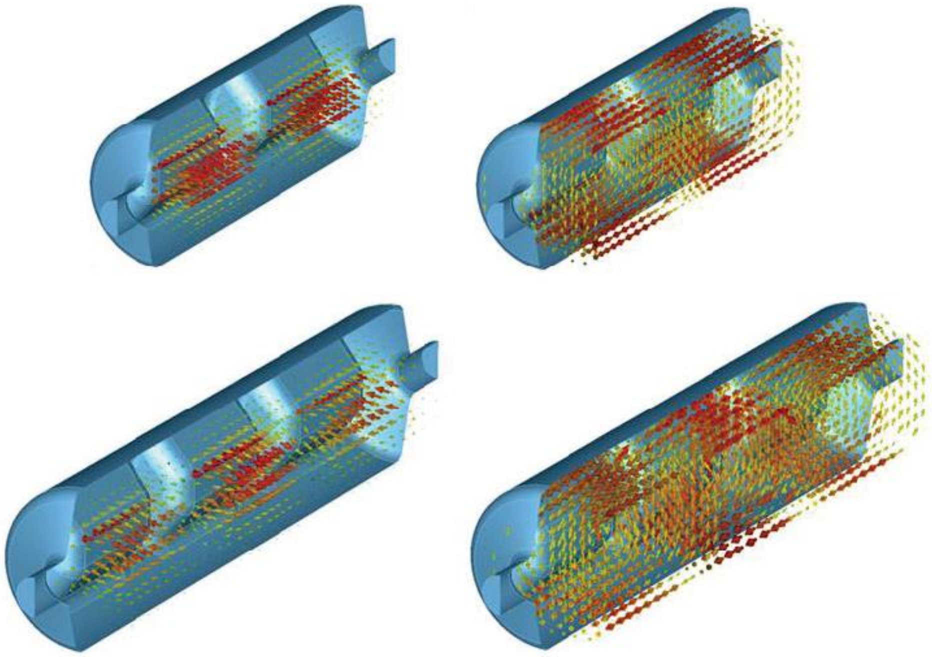


*H. Park, HiLumi LHC HOM Coupler Review II, Feb. 2015.

RF-Dipole Multi Cell

- **PROs: Shorter cavity and cryomodule length, [R/Q] scales with number of cells.**
- **CONs: Similar Order Modes go as number of cells.**



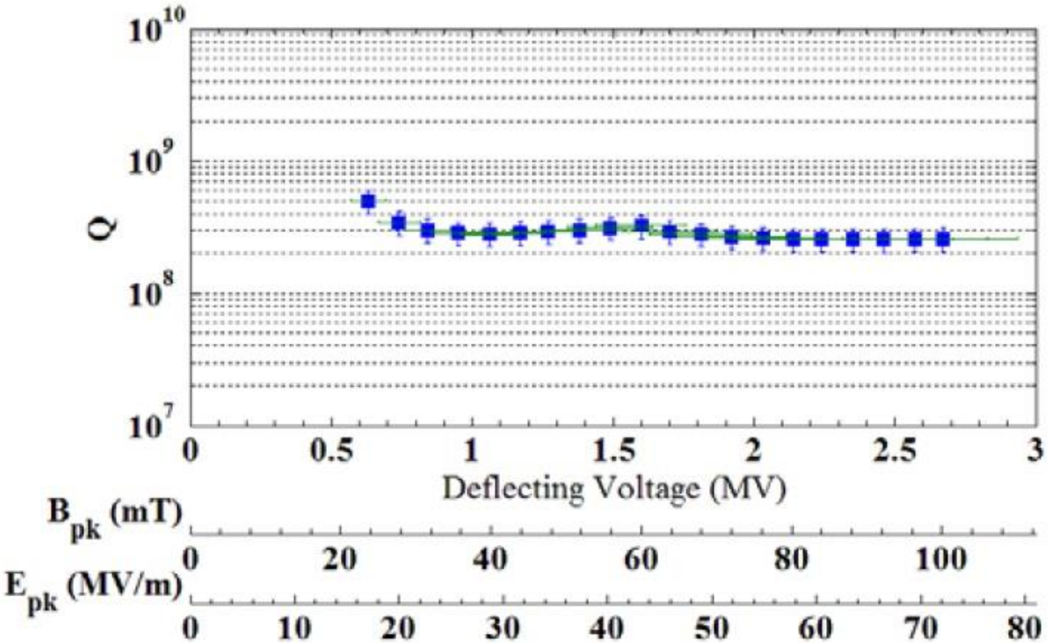


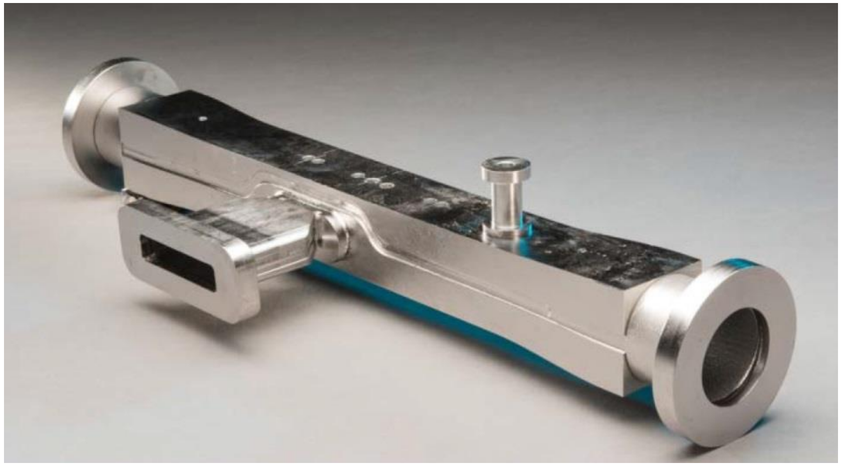
*S. De Silva in SRF2013 proceedings.

.

ANL Quasi-WG

- 2.815 GHz.
- $R_T R_S = 6.77 \times 10^4 \Omega$.





*Z. A. Conway WEPRI050 in IPAC2014 proceedings.

.

Funding

- **MEIC Crab:** 1 Fulltime PhD. Student for the past “3 1/2 years”
  - **ODU and Niowave, Inc. SBIR/STTR Phase I and II**
  - **JSA through ODURF**
- **Jefferson Lab 12 GeV Separator:** 1 PhD. Student
  - **JSA through ODURF**
- **LHC Crab:** 1 to 2 PhDs and 1 to 2 Postdocs
  - **ODU and Niowave, Inc. SBIR/STTR Phase I and II**
  - **LARP**
- **Next?**
  - **ODU for NP-DOE project, LDRD?**

References

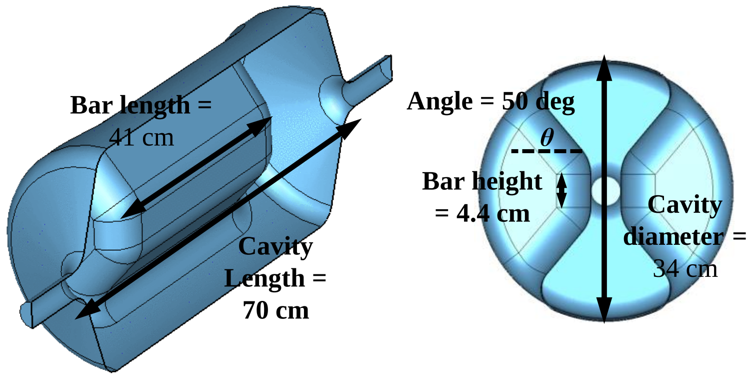
- S. U. de Silva PhD Thesis, College of Science, ODU. (2014)
- S. U. de Silva and J. R. Delayen, PRSTAB 16, 012004 (2013).
- S. U. de Silva and J. R. Delayen, PRSTAB 16, 082001 (2013).

+ countless conference proceedings, internal reports, and technical notes…..

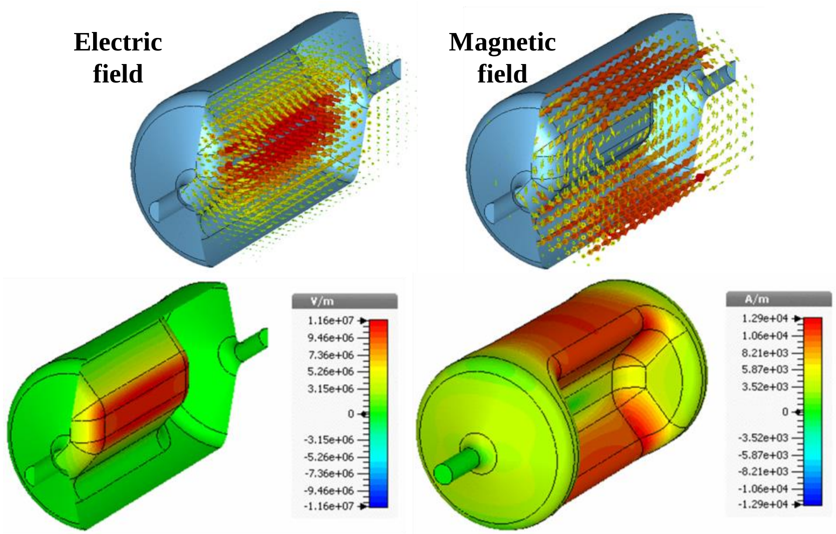
Extras

LCLS II SRF-Dipole Spreader

- SRF Dipole preliminary design



- RF Fields and Surface Fields



S. De Silva, et al. Dec 2013.

- Beam aperture of 40 mm
  - Considering cavity processing
  - Low wakefield impedance budget
- Any dimensional constraints ?

	SC RFD Cavity	Units
Frequency	**325**	**MHz**
Nearest HOM	508	MHz
V_T^*	0.46	MV
E_p^*	2.6	MV/m
B_p^*	3.6	mT
B_p^*/E_p^*	1.4	mT/ (MV/m)
U^*	0.049	J
$[R/Q]_T$	2133	Ω
Geometrical Factor	91.5	Ω
$R_T R_S$	1.95×10^5	Ω^2
At $E_T^* = 1$ MV/m		