

Superconducting Linac for e-Cooling

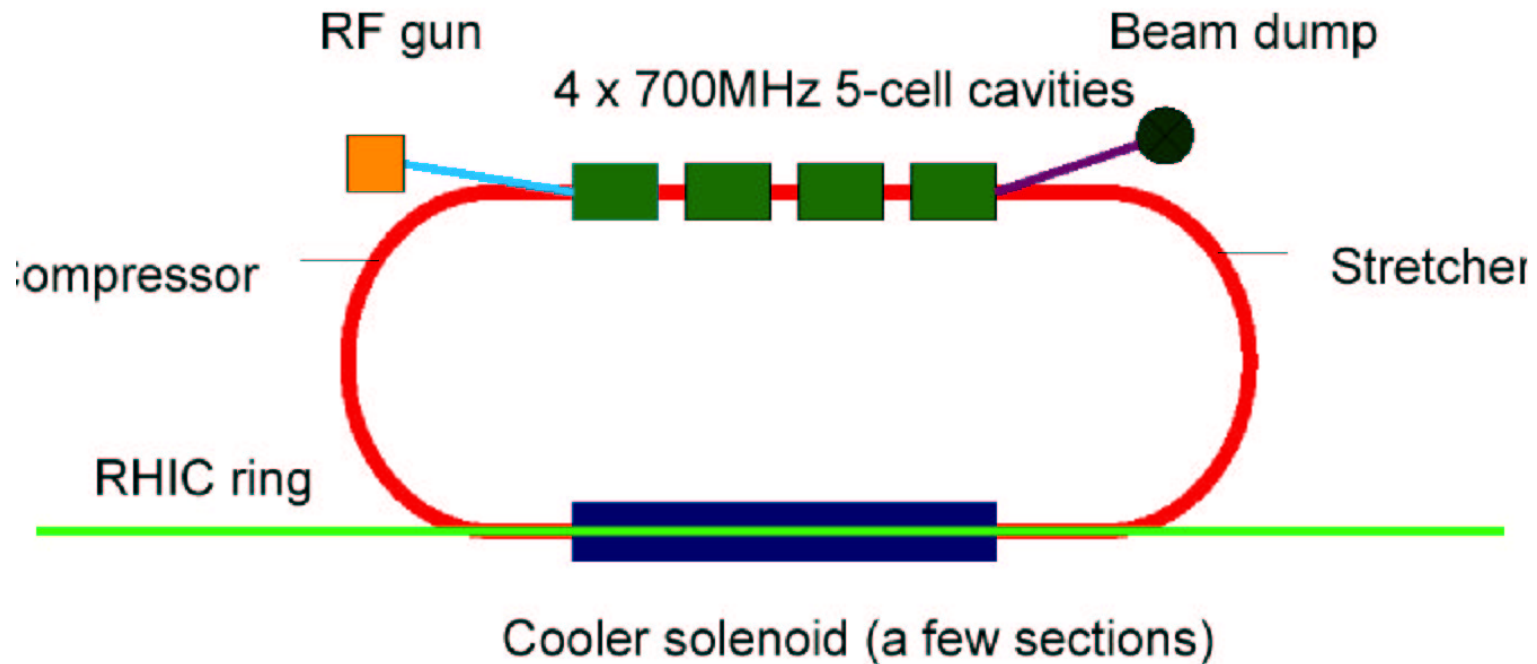
Rama Calaga
BNL

March 10, 2004

- 5-Cell SRF linac module
- HOM calculations - Mafia
- Longitudinal loss factor - ABCI
- Beam breakup thresholds
- Future Calculations and superstructures

Electron Cooling at RHIC

2



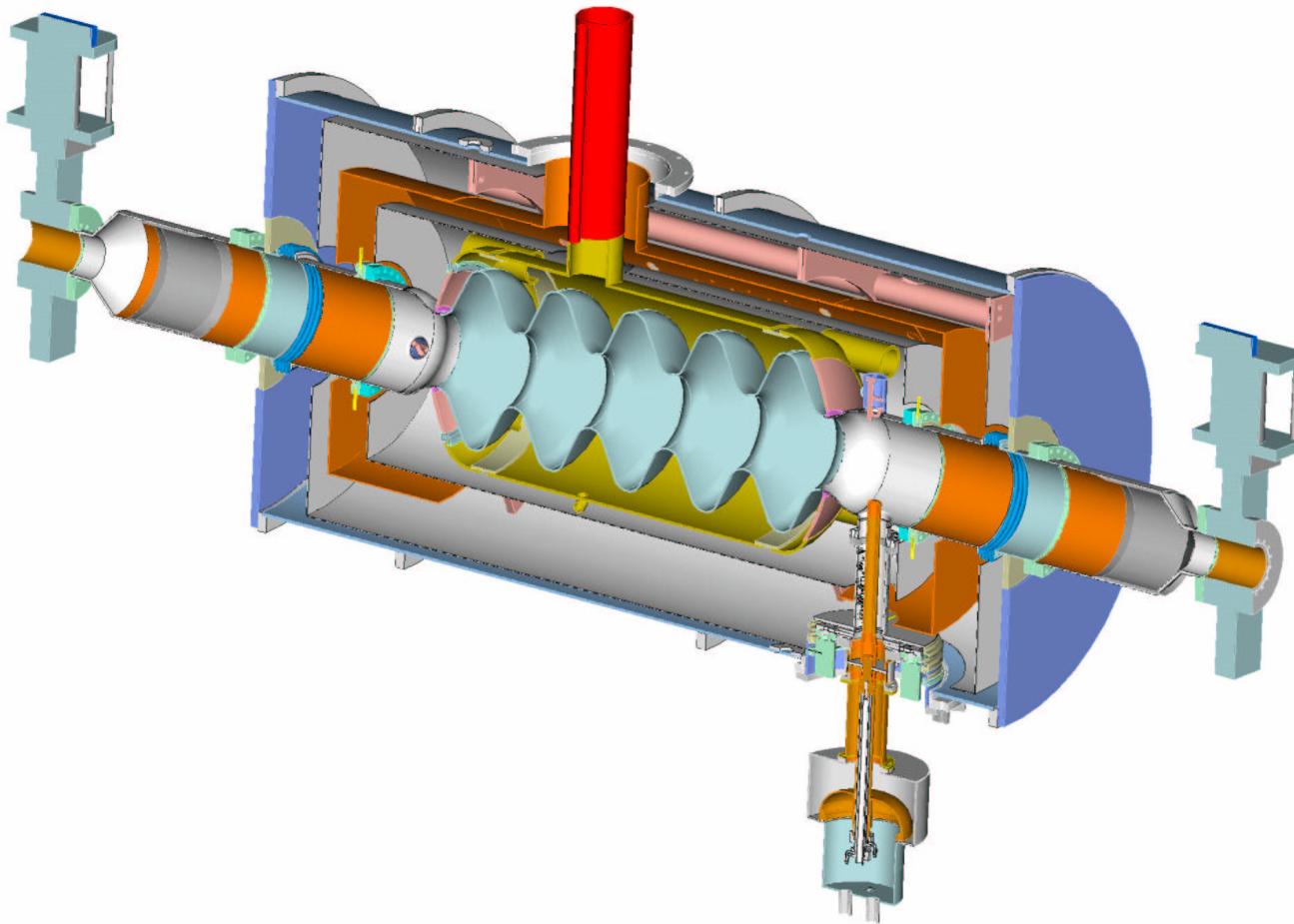
Limitations for high current SRF:

- Multibunch bunch instabilities - **high Q HOMs**
- Large HOM power - **loss factor**

$$P_{HOM} = f_b k q^2 \quad (1)$$

5-Cell SRF Cavity Module

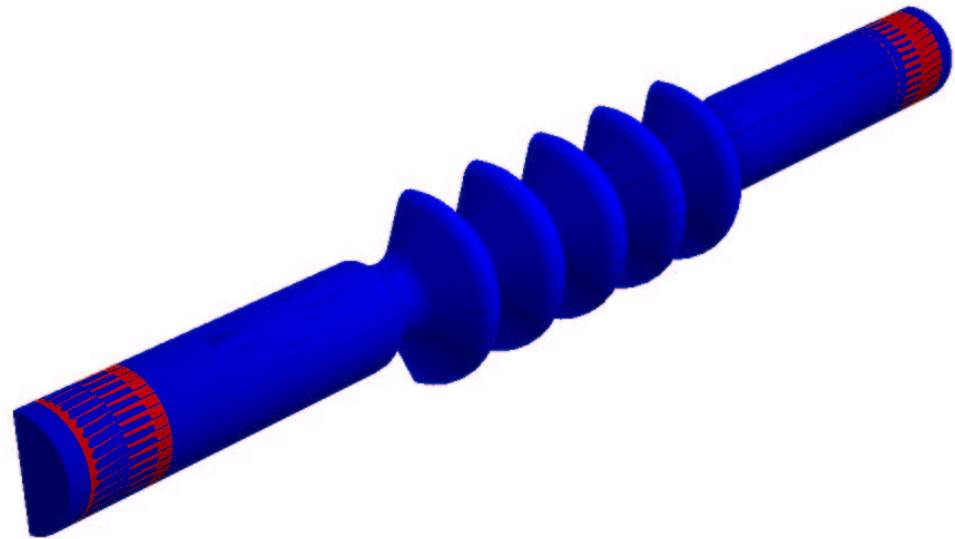
3



Courtesy AES

Cavity Parameters

- Frequency - 703.75 MHz
 - 25th harmonic of RHIC bunch repetition
 - Loss factor, CW power sources & cleaning
- 5 cell cavity structure
 - Fewer cells - fewer trapped modes
 - 17cm iris, 24 cm diameter (HOMs)
- Ferrite absorbers - HOMs
 - Broadband damping & water cooled



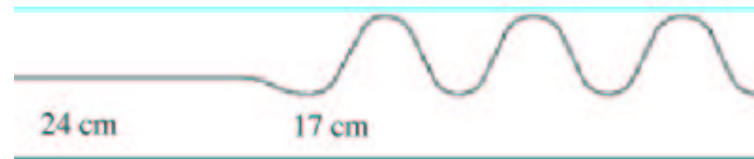
Diameter	17 cm	19 cm
Freq (MHz)	703.75	703.75
G (Ω)	225	200
R/Q (Ω)	807	710
Q BCS @ 2K	4.5×10^{10}	4×10^{10}
E_p/E_a	1.97	2.10
H_p/E_a (mT/MV/m)	5.78	5.94

Higher Order Modes

Possible trapped modes due to:

- Cell to cell coupling and end cell geometry
- Cutoff Frequency of beam pipe

$$f_c = \frac{c}{\pi D} X \quad (2)$$



Lowest monopole mode: 959 MHz

Lowest dipole mode: 748 MHz

Cut-Off Frequencies for Select Modes

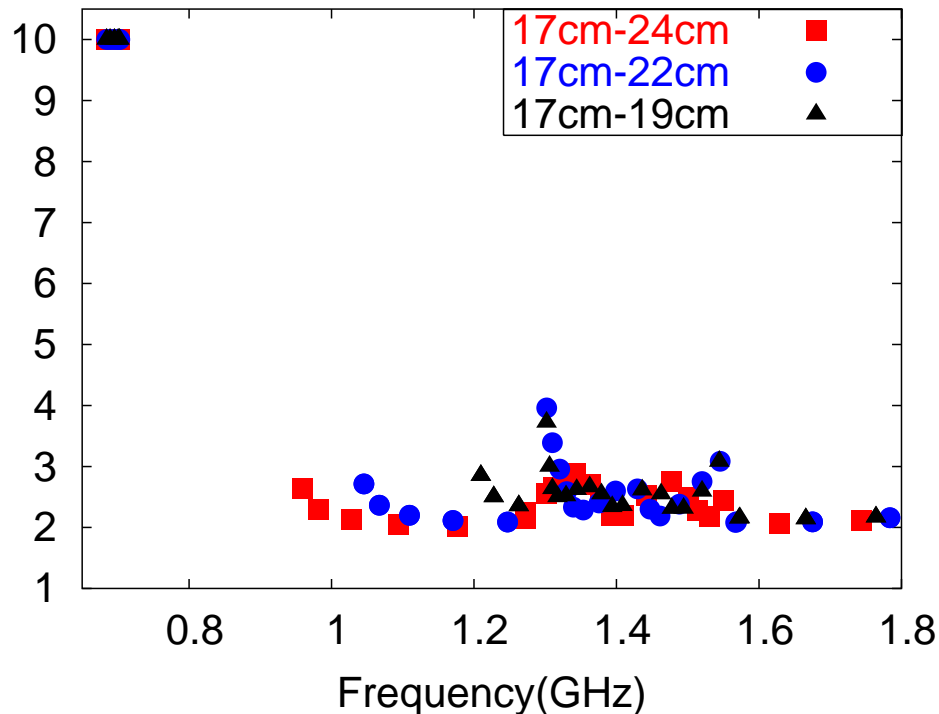
D(cm)	TM_{01} (MHz)	TE_{11} (MHz)	TM_{11} (MHz)
17	1350.94	1034.11	2152.5
19	1208.74	925.28	1925.9
24	956.92	732.51	1524.7

Frequency domain calculations in Mafia (*lossfree*)

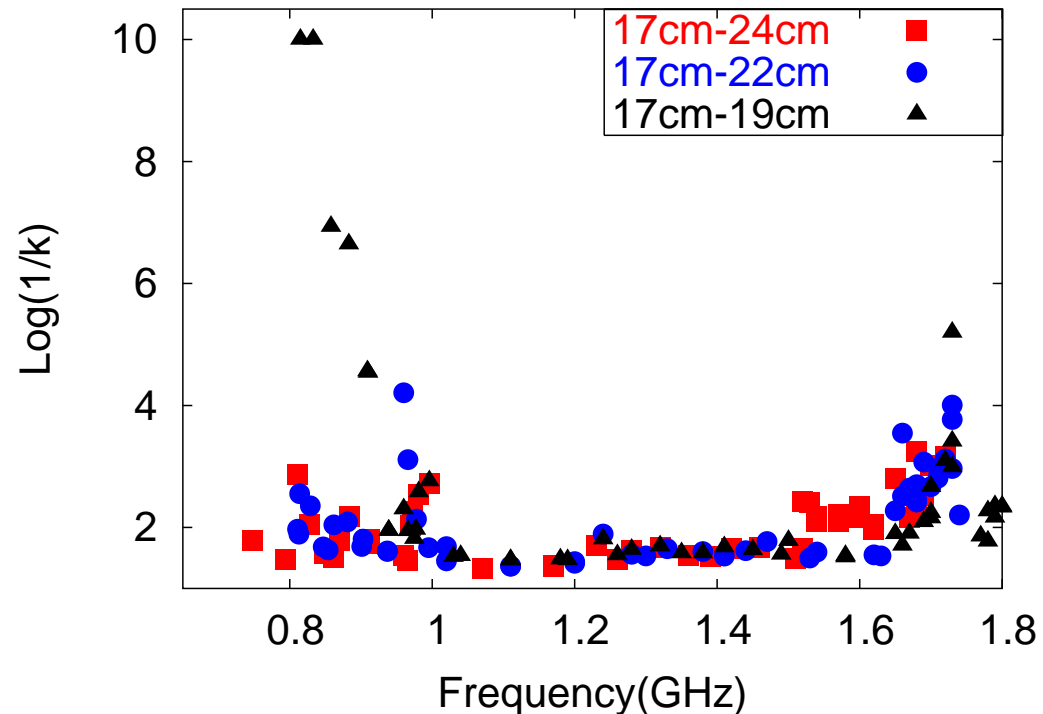
$$k = \frac{1}{2} \left(\frac{f_{mag} - f_{ele}}{f_{mag} + f_{ele}} \right) \quad (3)$$

$$\log\left(\frac{1}{k}\right) \approx \begin{cases} 0 & : \text{untrapped} \\ \infty & : \text{trapped} \end{cases} \quad (4)$$

Monopole



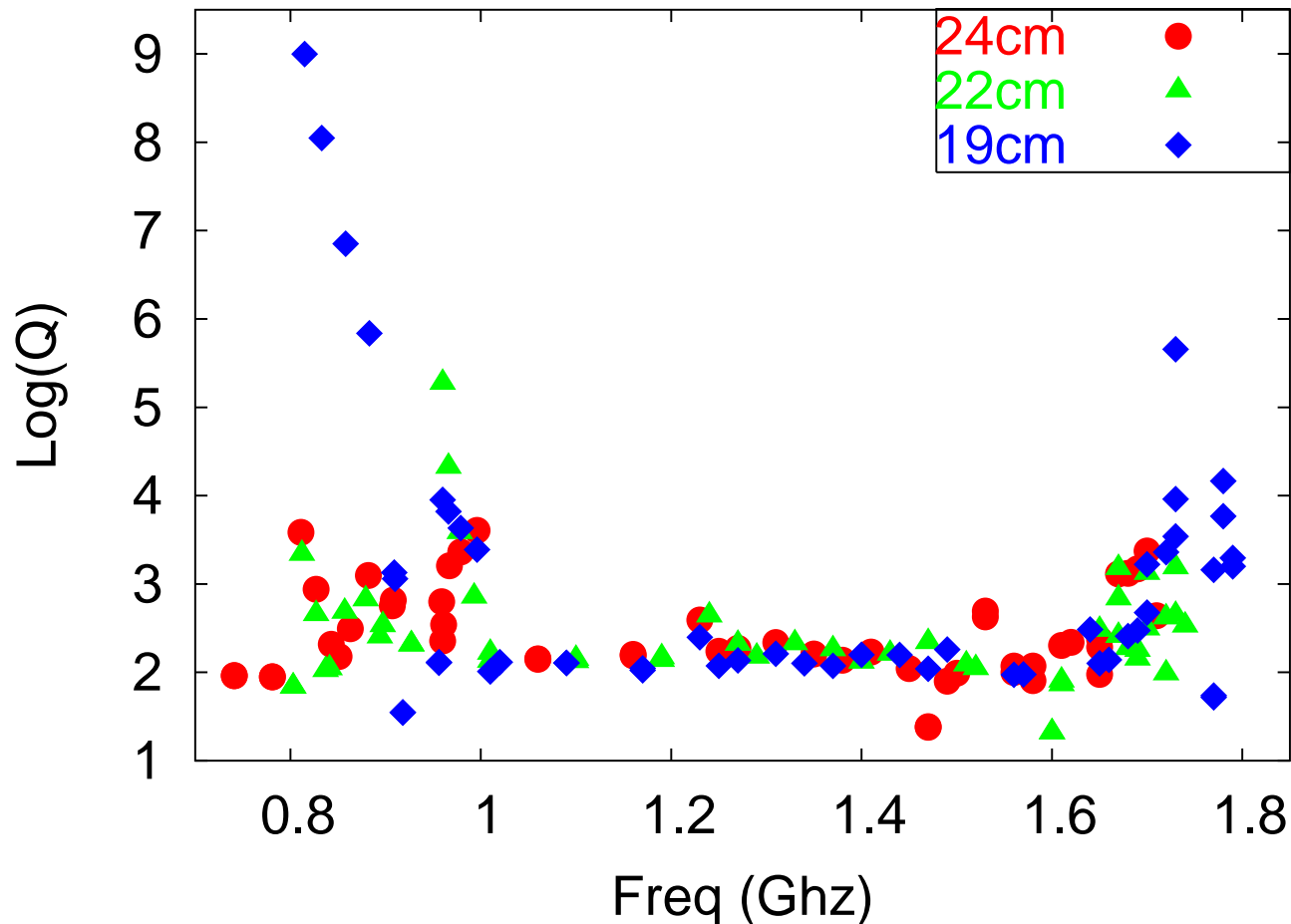
Dipole



Dipole Modes

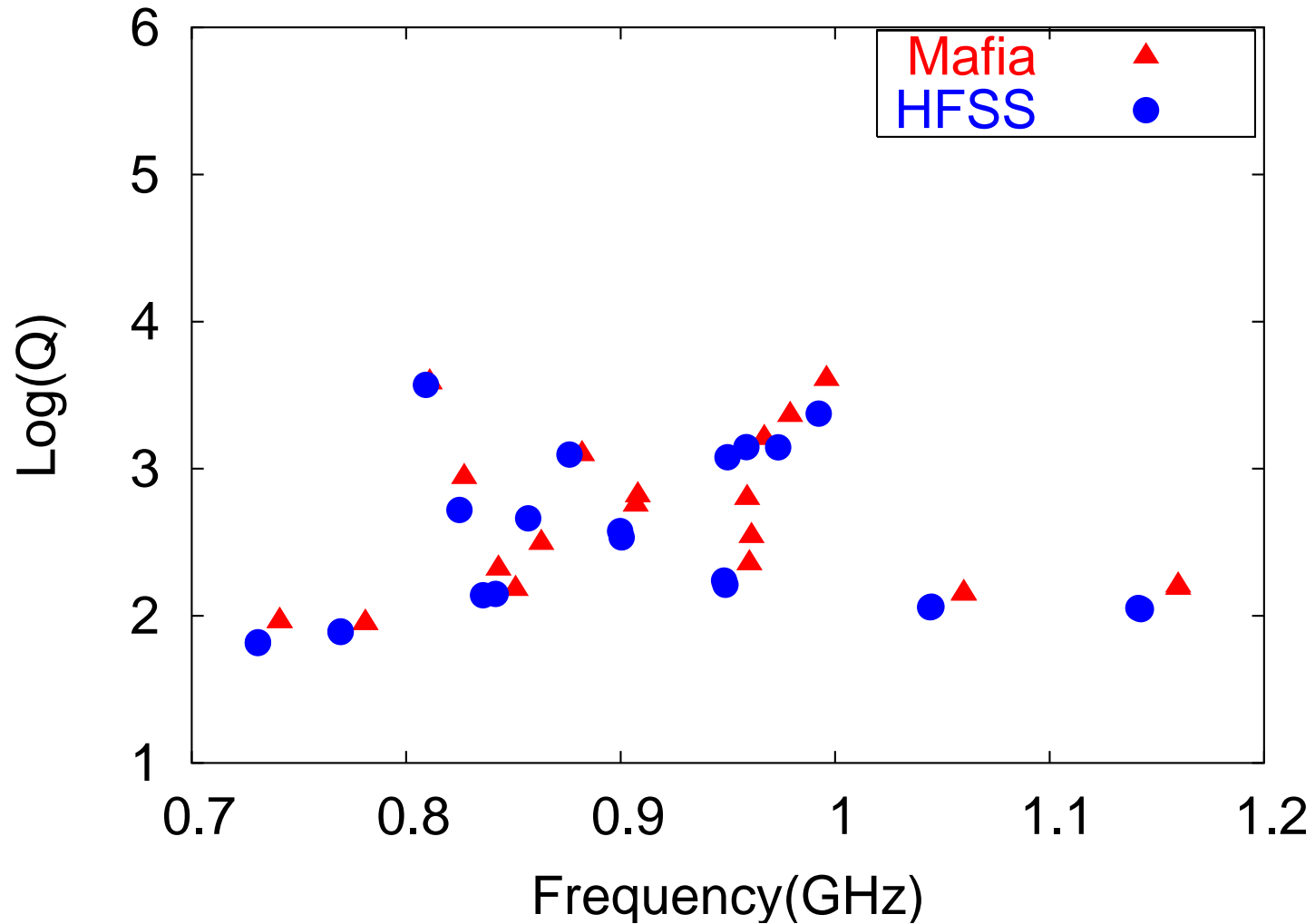
Frequency domain calculations in Mafia (*lossy*)

$$Q = \frac{F_{real}}{2F_{img.}} \quad (5)$$



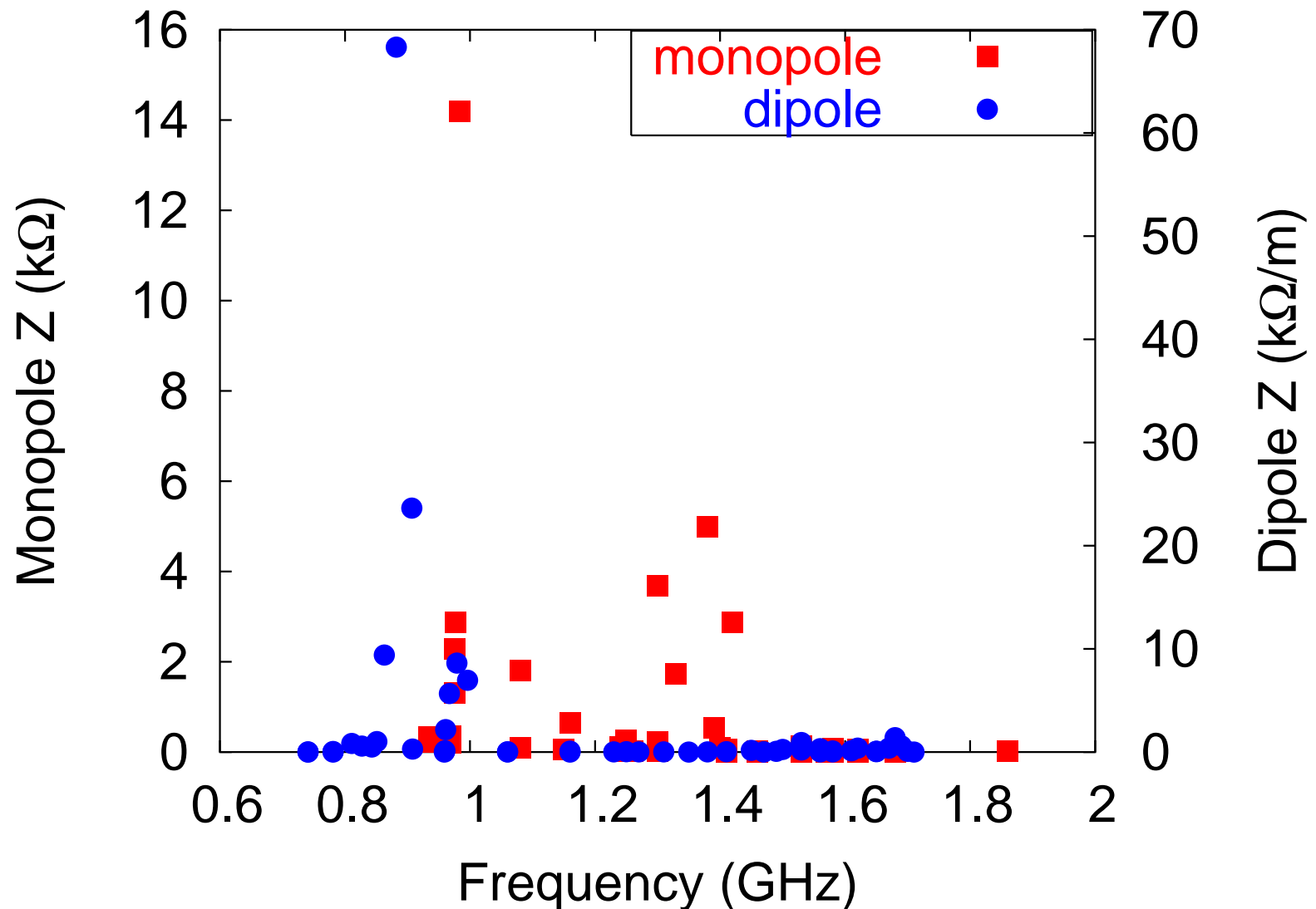
Comparison To Other Codes

Dipole modes of interest in Mafia compared to HFSS.



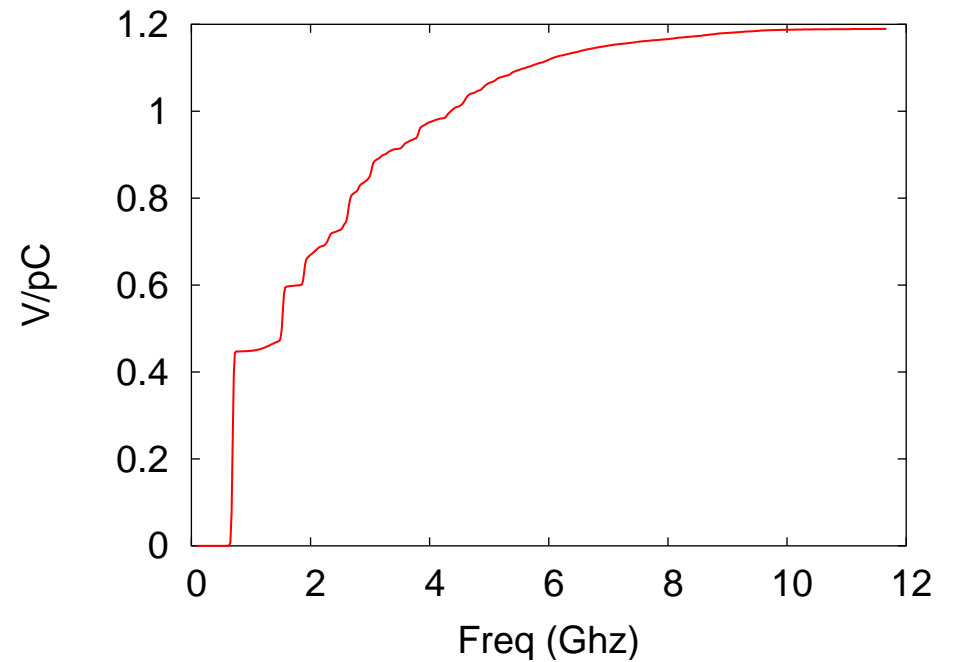
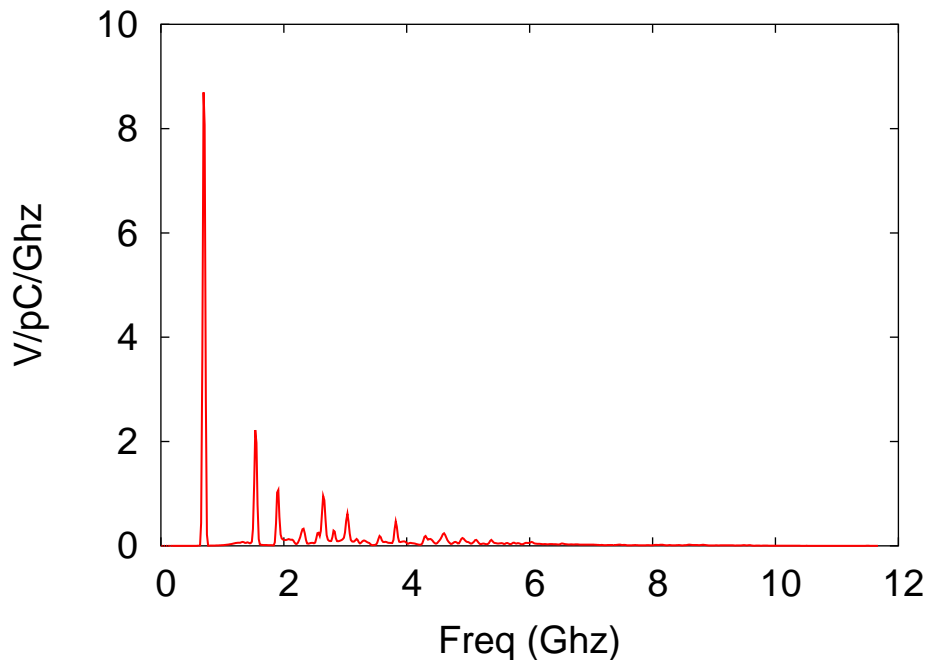
Impedance Spectrum of HOMs

Impedance spectrum estimated in frequency domain.



Longitudinal Loss Factor

ABCI calculation using single bunch (bunch length-1cm).



Integrated loss factor - 1.2 V/pC \approx 6KW of HOM power

Multibunch instabilities giving rise to beam breakup:

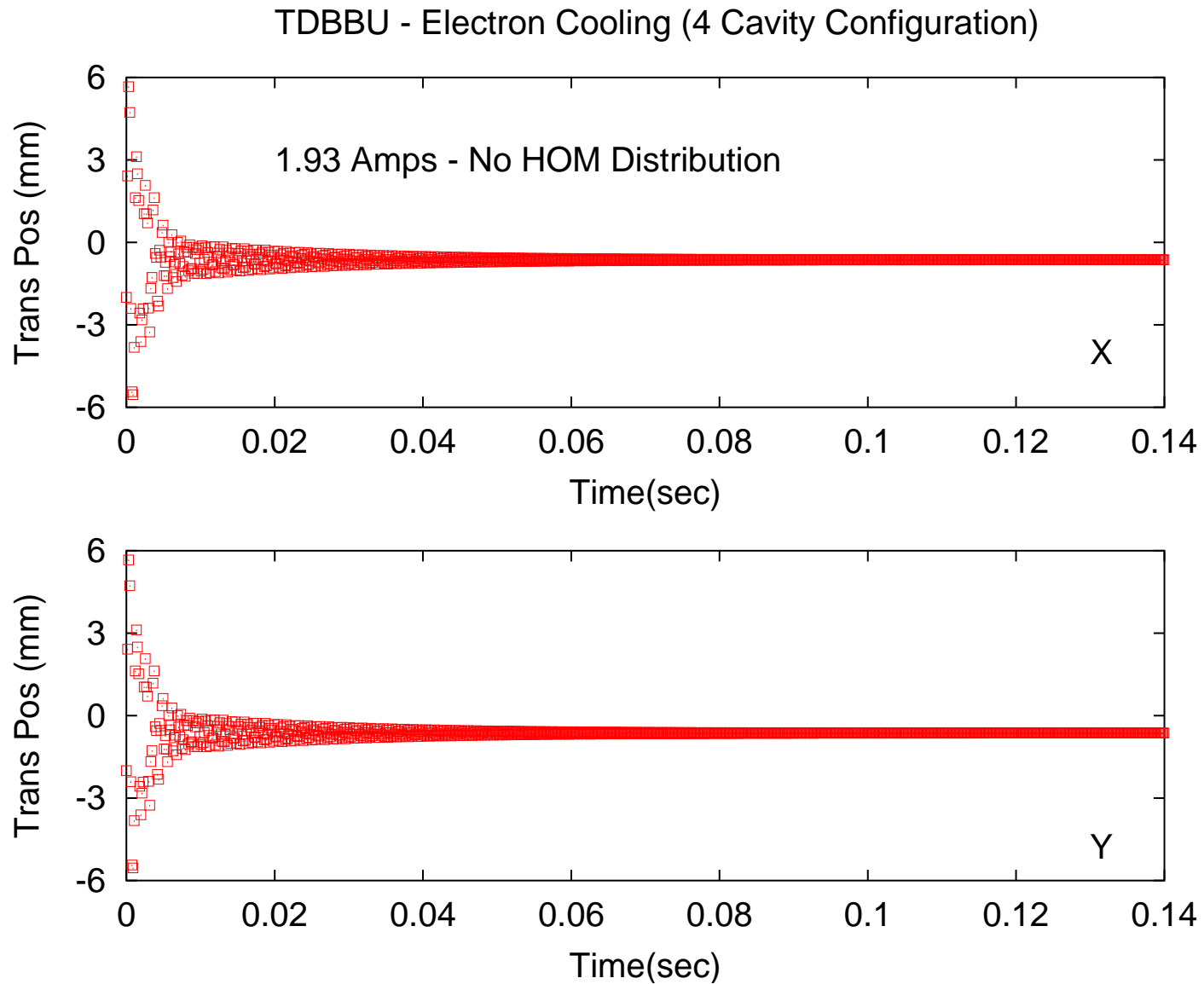
- High Q dipole modes
- Feedback loop between beam and cavities
- Worse for high current - high bunch charge

Threshold current for a simple case:

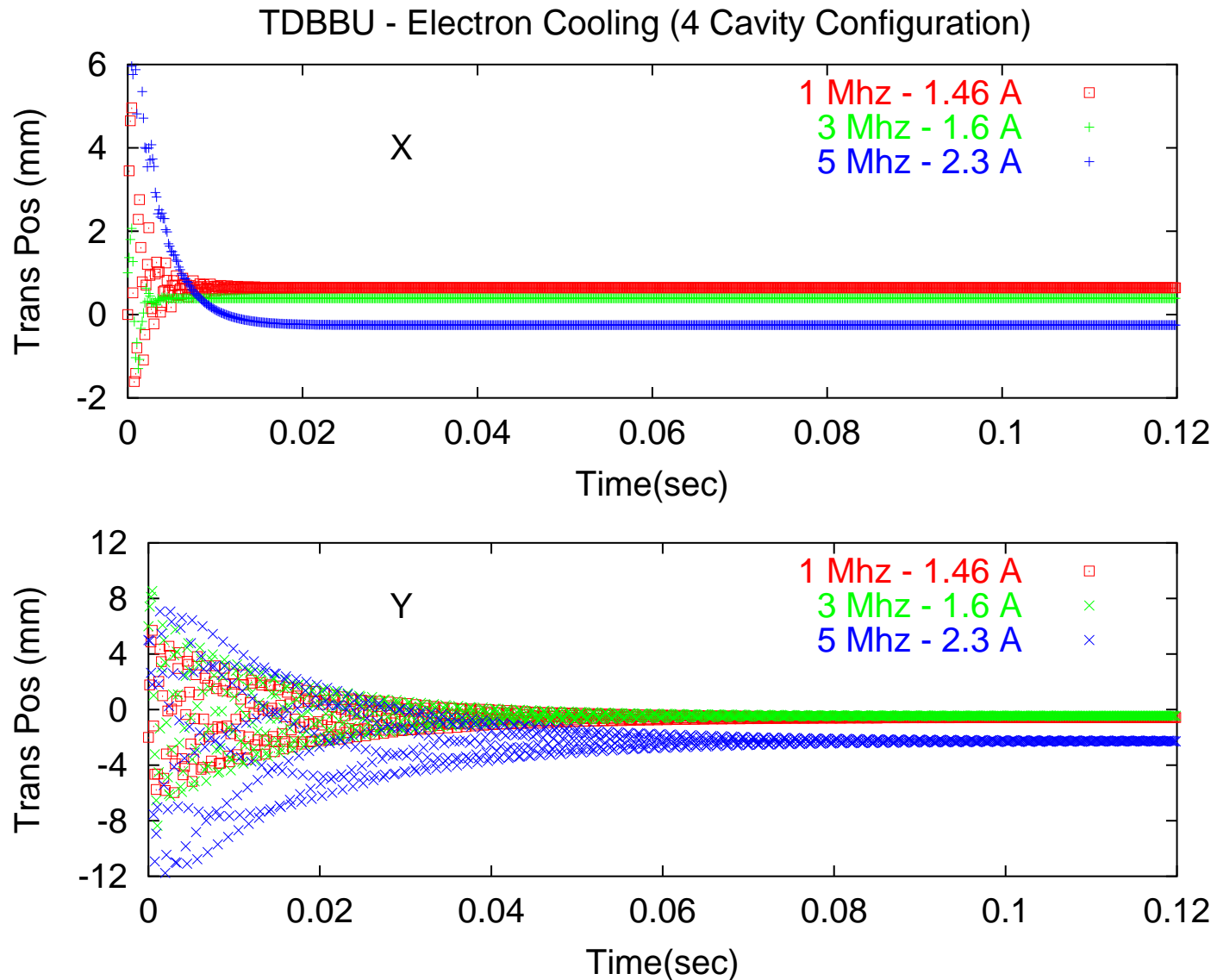
$$I_{th} = \frac{-2p_r c}{e\left(\frac{R}{Q}\right)_m Q_m k_m M_{ij} \sin(\omega_m t_r) e^{\frac{\omega_m t_r}{2Q_m}}} \quad (6)$$

Numerical codes (TDBBU & MATBBU) for complex linac structures (CASA - JLab)

BBU Thresholds - Time Domain



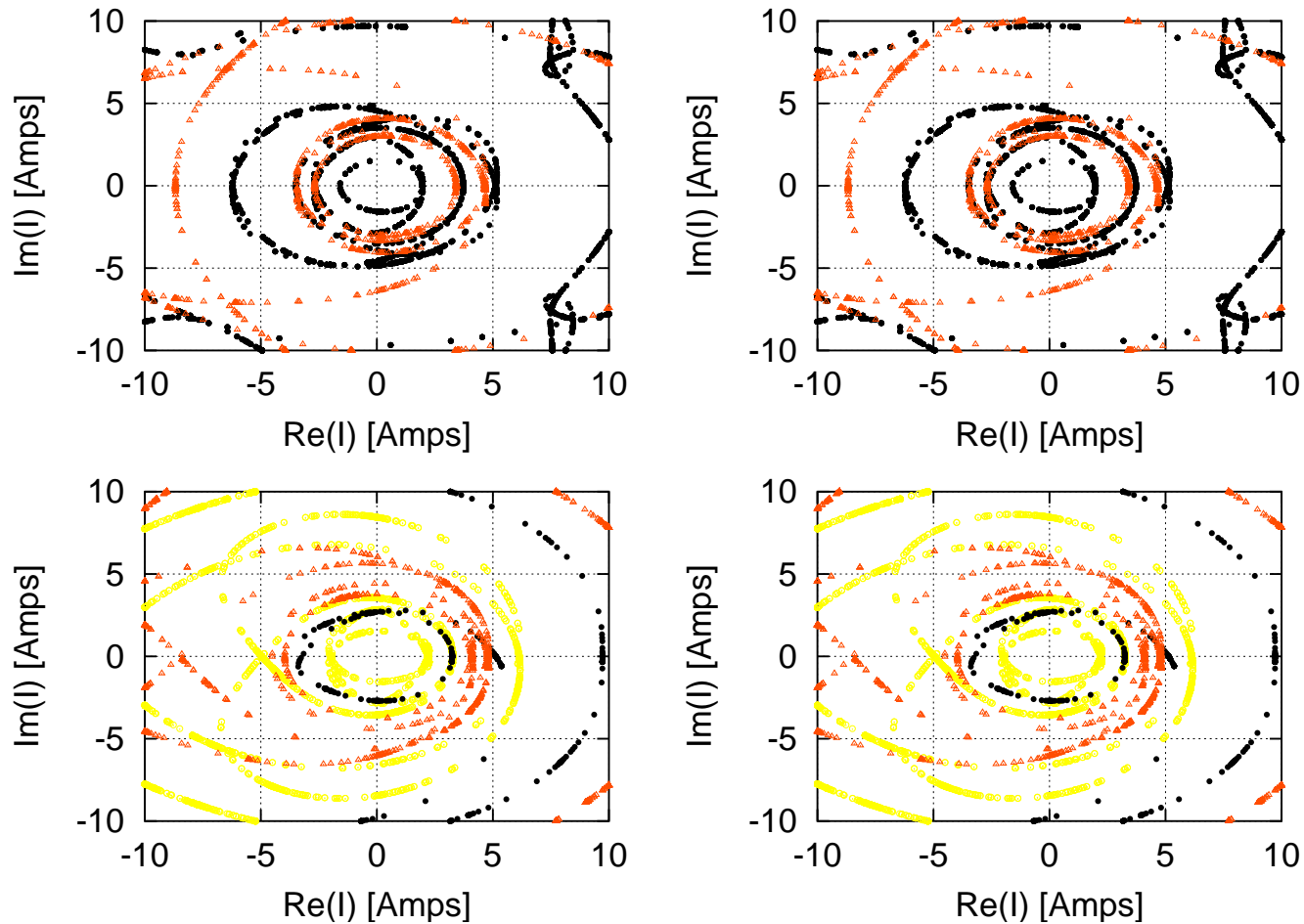
BBU Thresholds - Time Domain



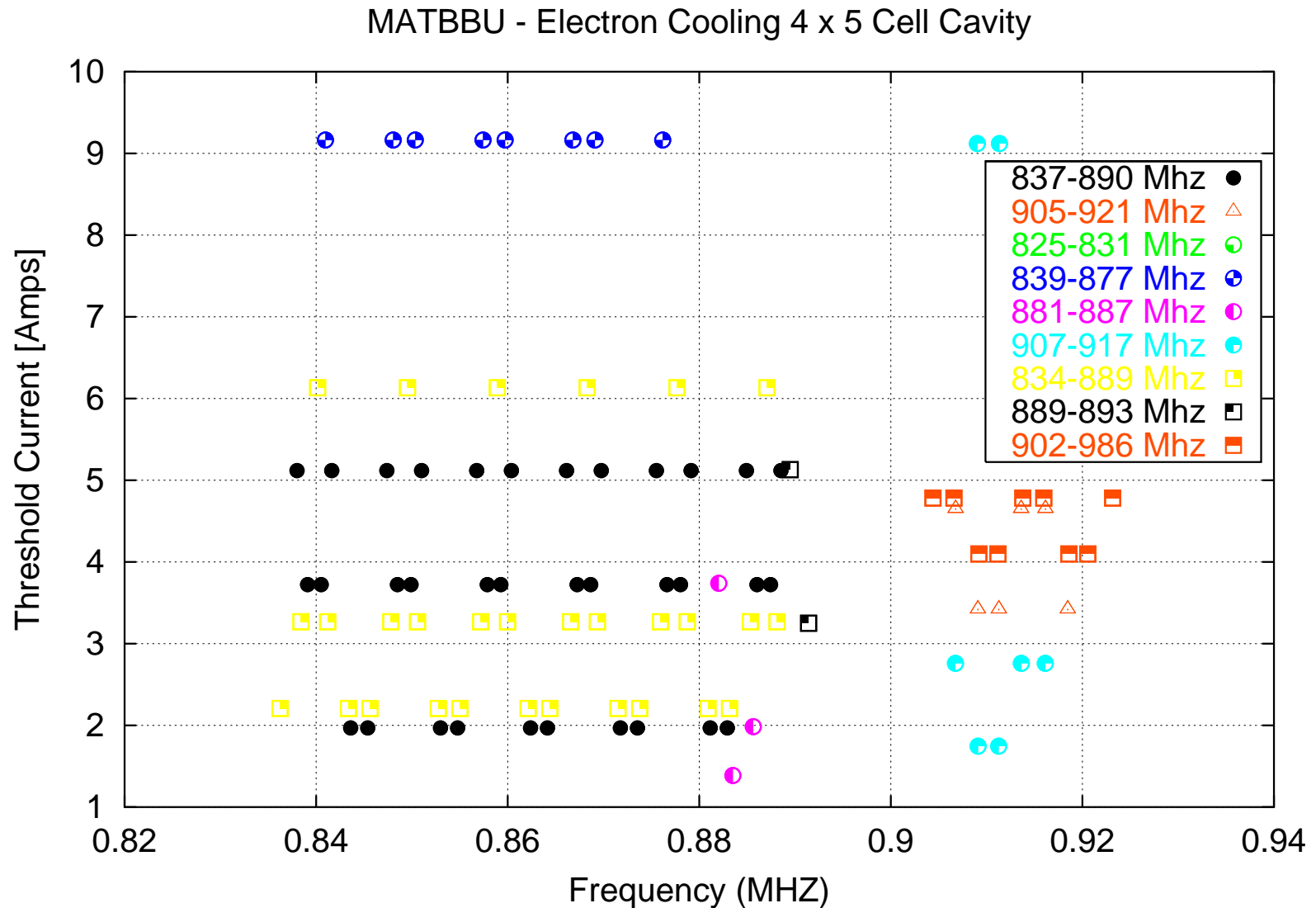
BBU Thresholds - Frequency Domain

Regions of interest between 810-1000 Mhz
(3 & 5 Mhz HOM Distributions)

MATBBU - Electron Cooling 5 Cell Cavity



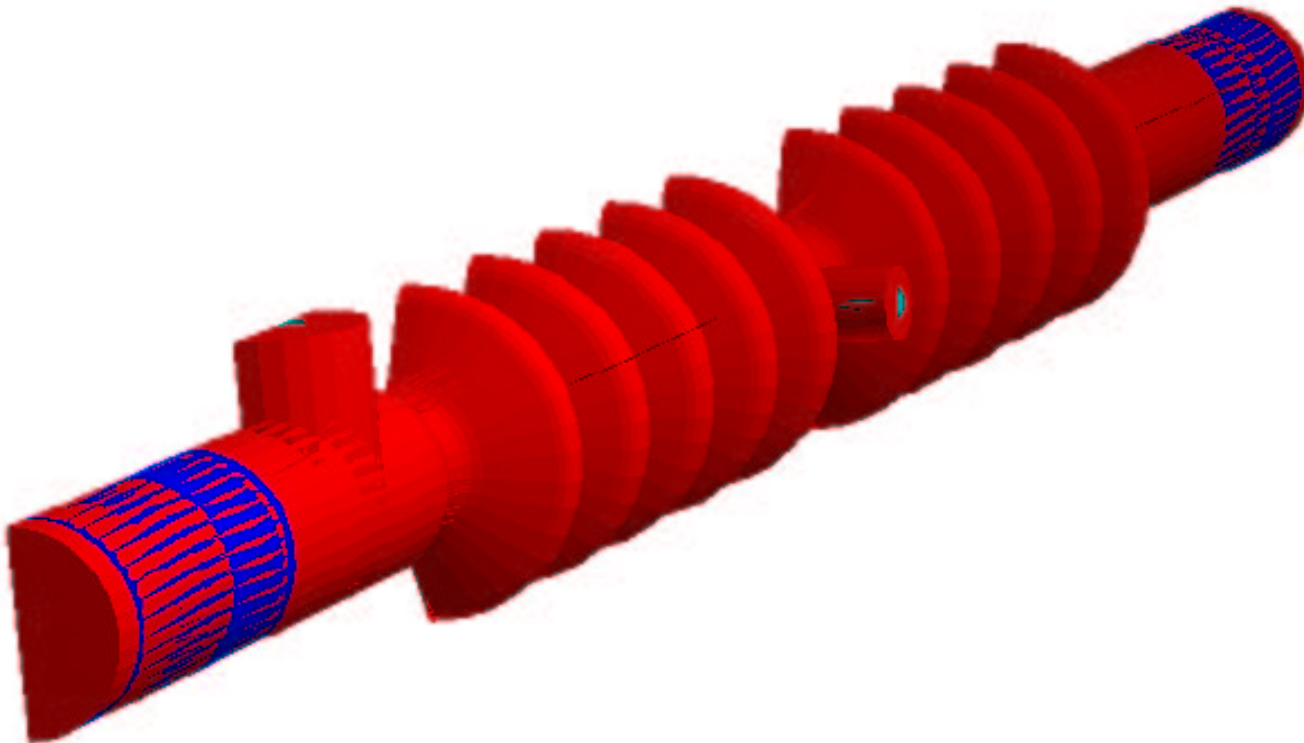
BBU Thresholds - Frequency Domain



- Calculations of beam impedance using Time-Domain in 3D with and w/o couplers
- Calculation of kick received due to fundamental coupler asymmetry
- Comparison of different simulation modules
- Copper model setup and measurements

This cavity exceeds e-cooling requirements!

- Design of 2X2 Super-Structure from existing model in collaboration with Jacek Sekutowicz (DESY)
- Calculations of SS modes and their characteristics
- BBU threshold limits for eRHIC



THE END