High Current Superconducting Linac

Rama Calaga

BNL

March 16, 2004

Outline

- Electron Cooling and requirements

- 5-Cell SRF Cavity

- HOM calculations - Mafia

- Longitudinal loss factor - ABCI

- Beam breakup thresholds

- 3D time domain calculations

- Future Calculations and superstructures

Requirements:

- Cooling of 100 GeV bunched ions - 54 MeV e^- beam

- High bunch charge [10nC] and high average current [100mA]

- Replenish e^- every cycle − energy recovery

RF gun

Beam dump

4 x 700MHz 5-cell cavities

Compressor

Stretcher

RHIC ring
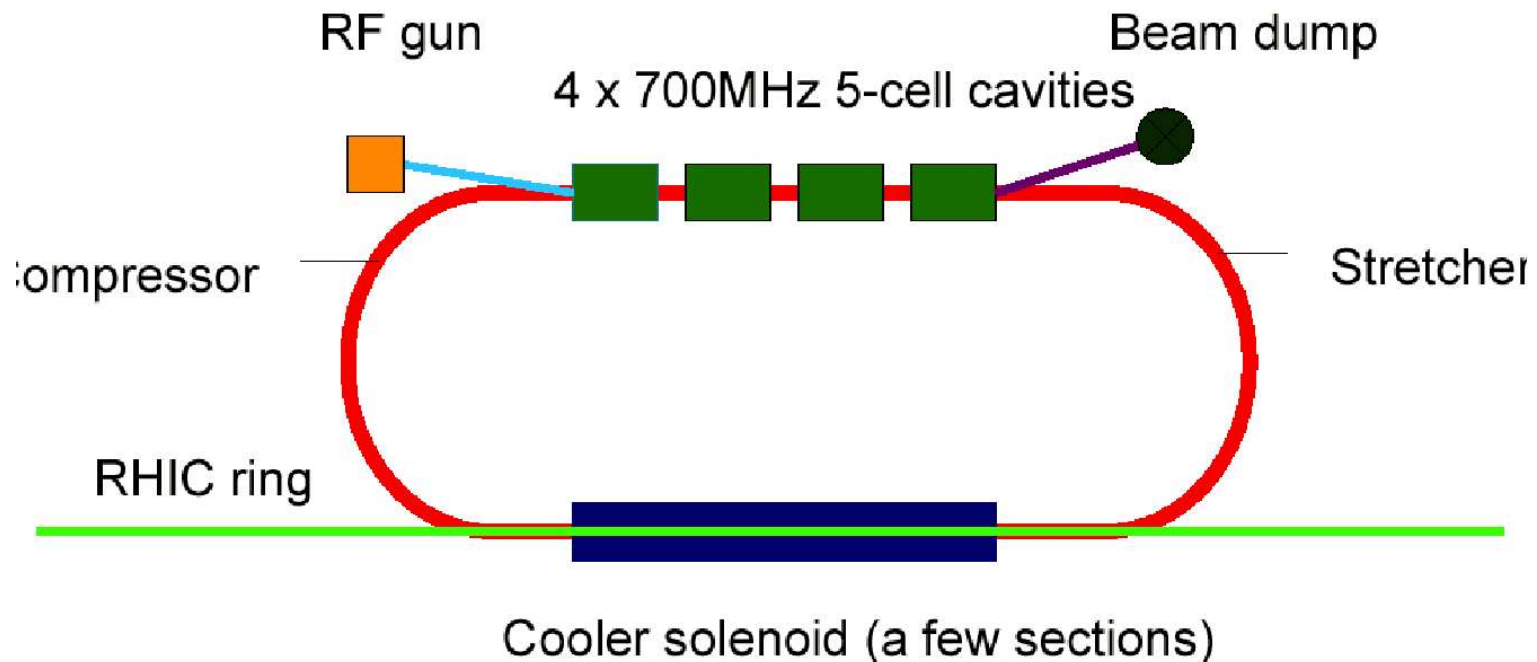
Cooler solenoid (a few sections)

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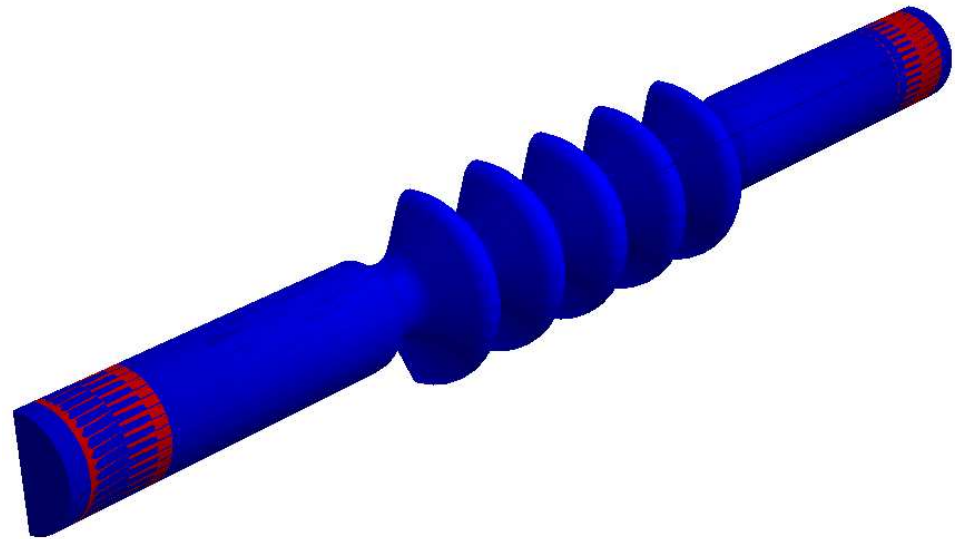
Diameter	17 cm	19 cm
Freq (MHz)	703.75	703.75
G (Ω)	225	200
R/Q (Ω)	807	710
Q BCS @ 2K	4.5×10^{10}	4×10^{10}
E_p/E_a	1.97	2.10
H_p/E_a (mT/MV/m)	5.78	5.94
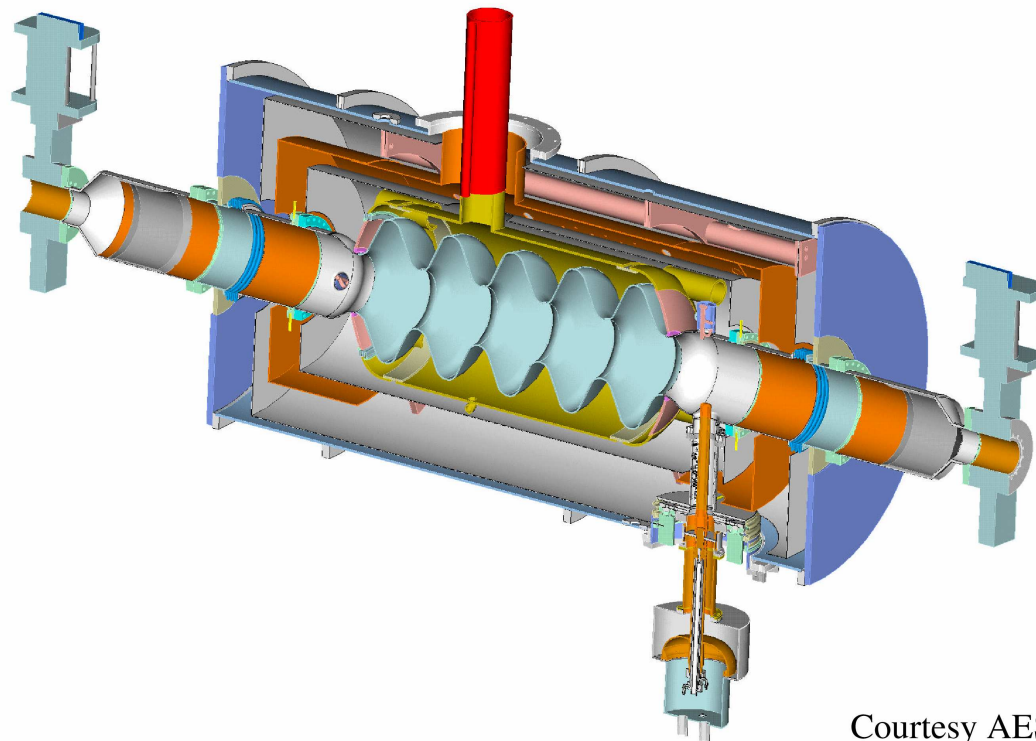
Courtesy AES

Limitations for high current SRF:

- Multibunch bunch instabilities - high Q HOMs

- Large HOM power - loss factor

$$P_{HOM} = f_b k q^2 \tag{1}$$
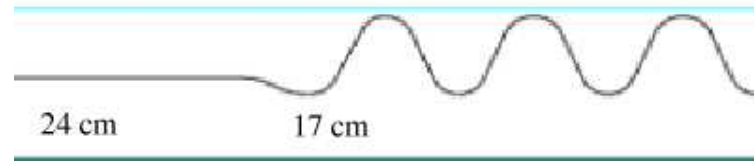
Possible trapped modes due to:

- Cell to cell coupling and end cell geometry

- Cutoff Frequency of beam pipe

$$f_c = \frac{c}{\pi D} X \tag{2}$$

24 cm   17 cm

Lowest monopole mode: 959 MHz
Lowest dipole mode: 748 MHz
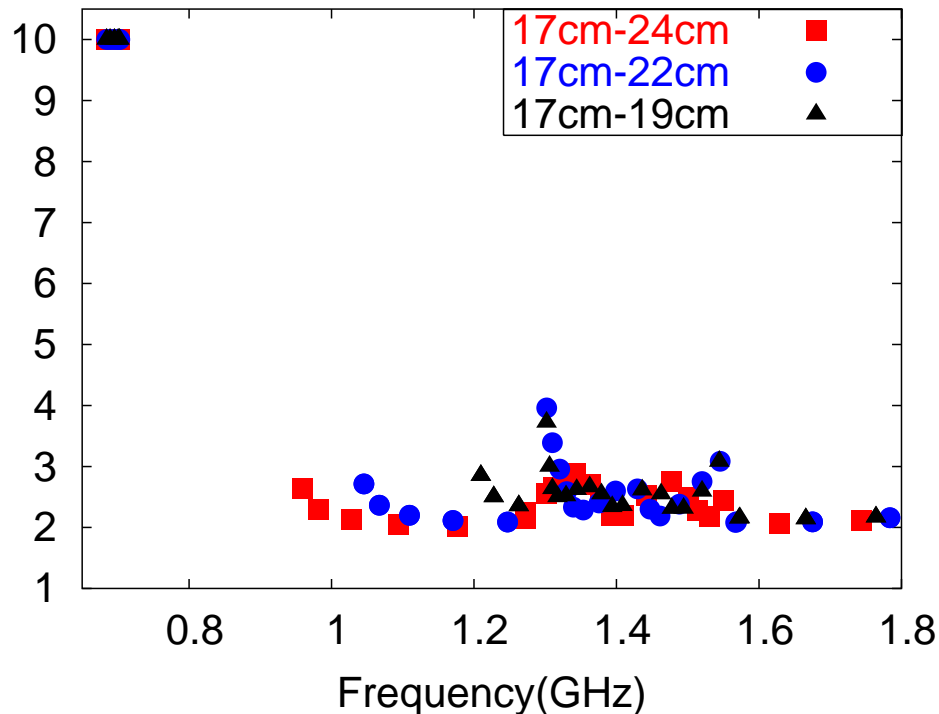
Cut-Off Frequencies for Select Modes

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)

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

$$log(\frac{1}{k}) \approx \begin{cases} 0 & : & untrapped \\ \infty & : & trapped \end{cases} \qquad (4)$$
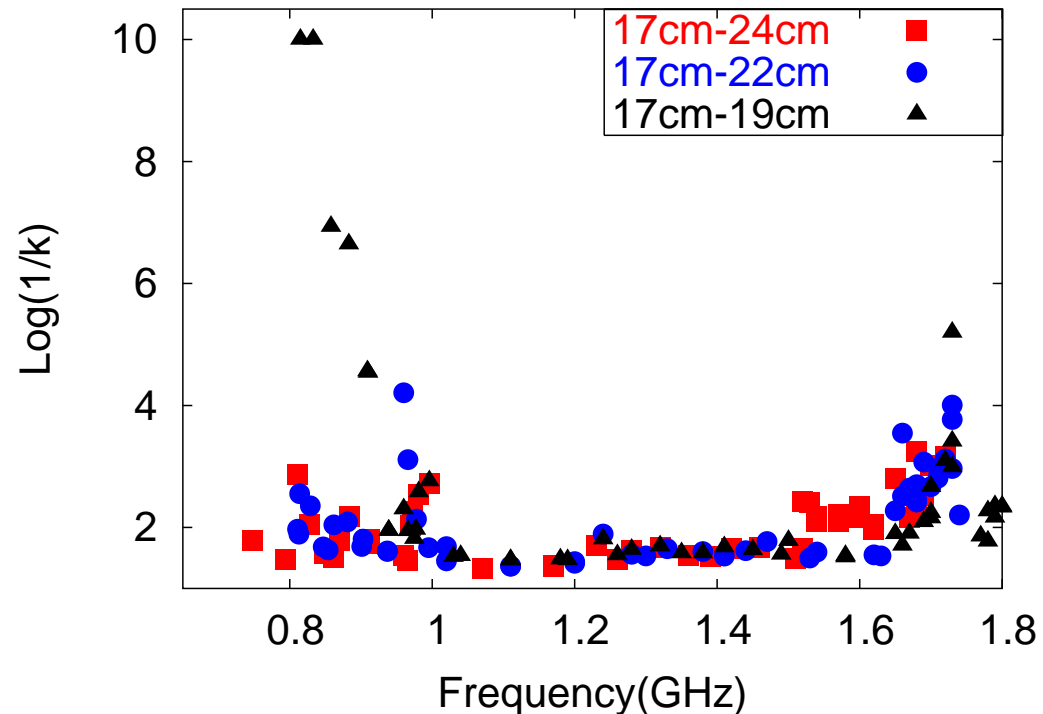
Frequency domain calculations in Mafia (lossy)
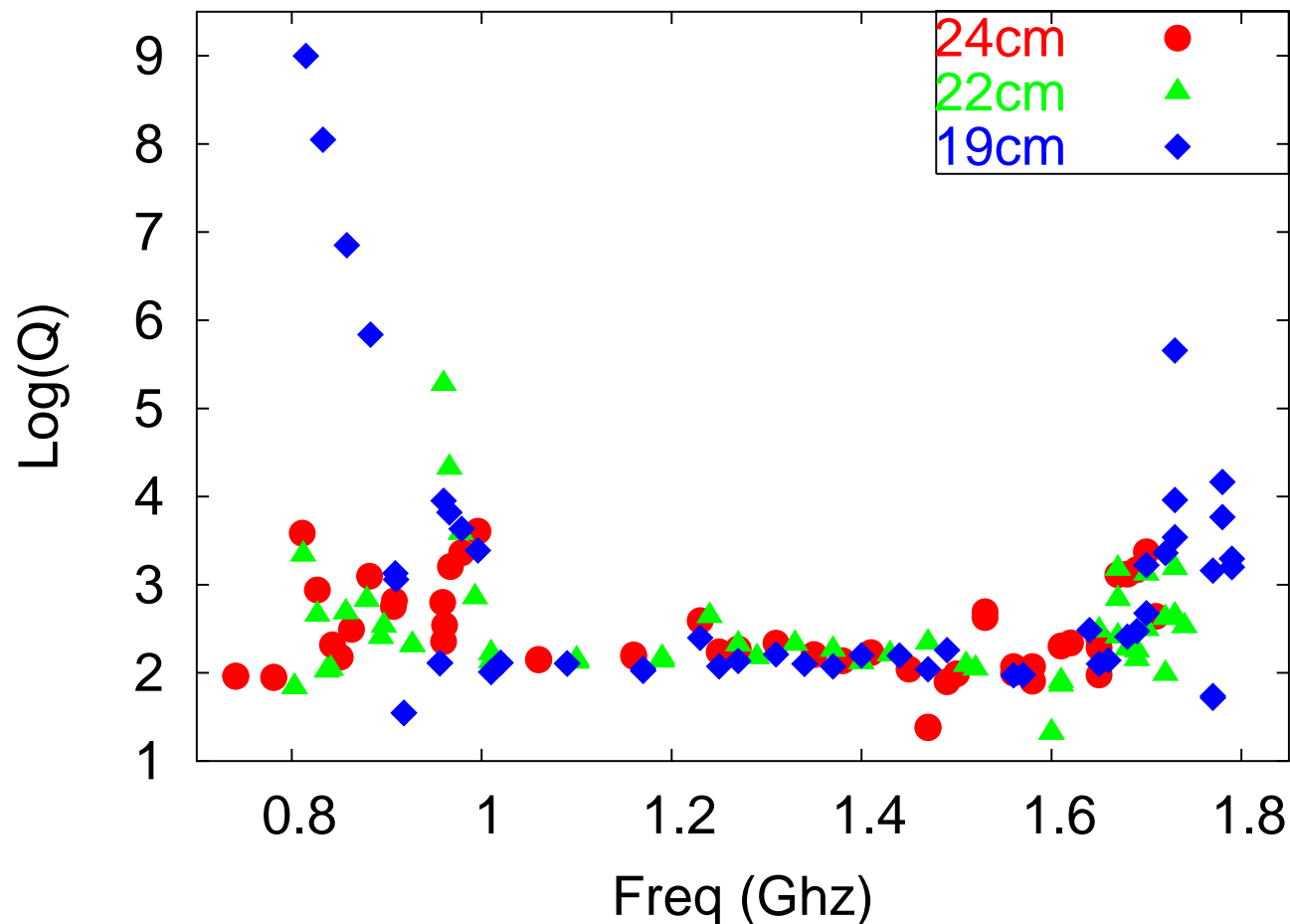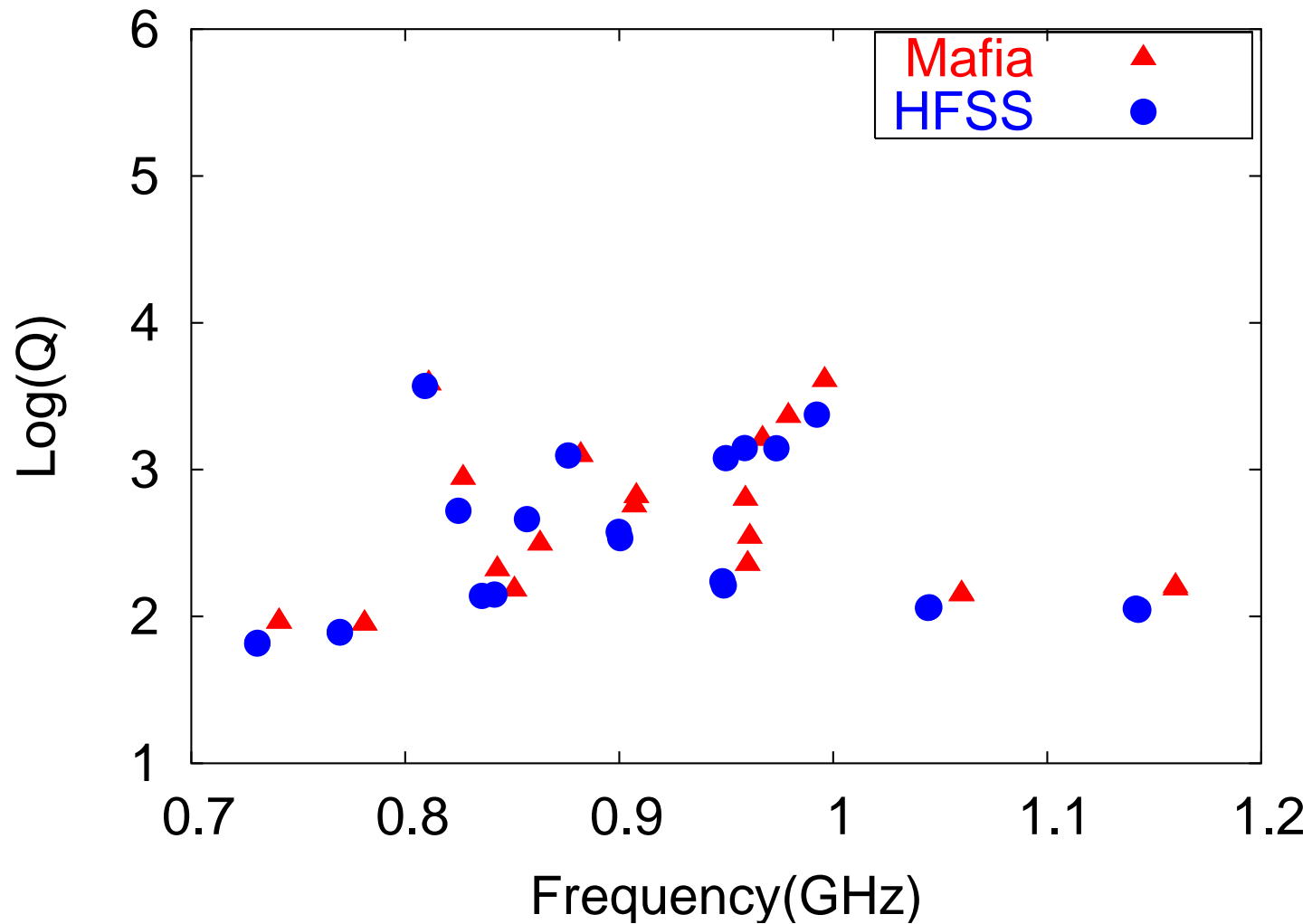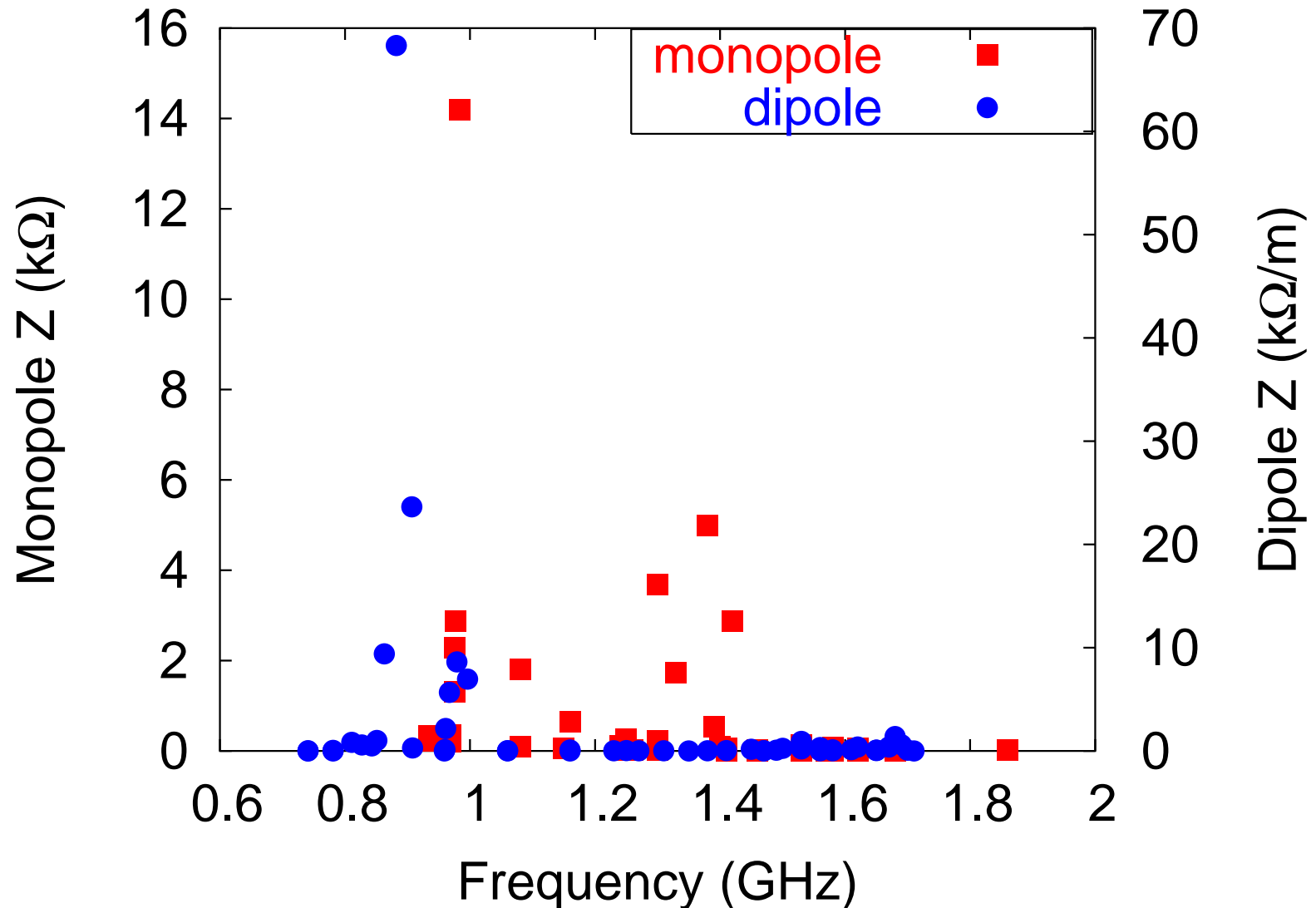
$$Q = \frac{F_{real}}{2F_{img.}}$$

(5)

Dipole modes of interest in Mafia compared to HFSS.

Courtesy Genfa Wu, JLab

Impedance Spetrum of HOMs

Impedance spectrum estimated in frequency domain.

Beam Breakup
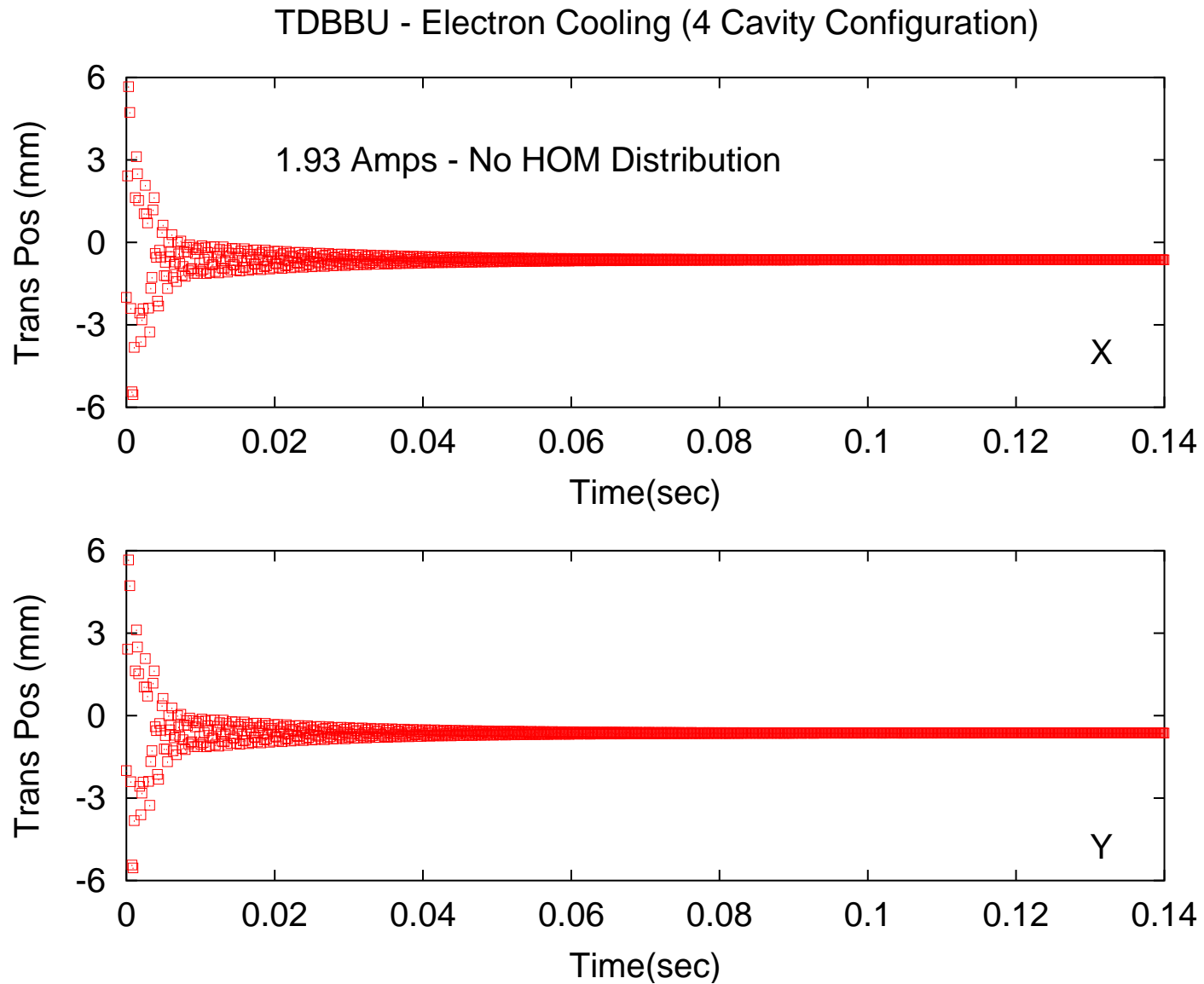
Multibunch instabilities giving rise to beam breakup:

- High Q dipole modes

- Feedback loop between beam and cavities

- Worse for high current - high bunch charge
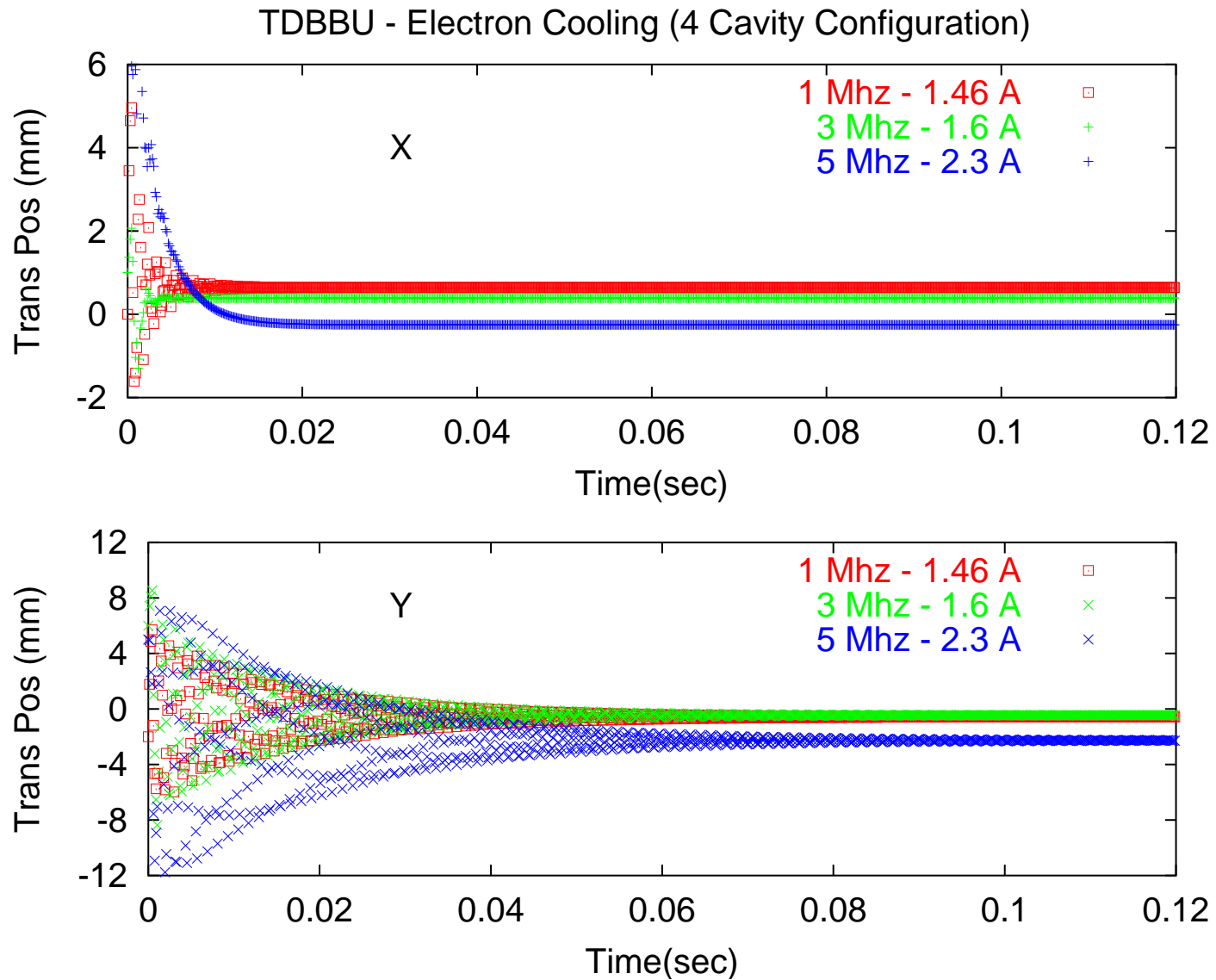
Threshold current for a simple case:

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

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

TDBBU - Electron Cooling (4 Cavity Configuration)
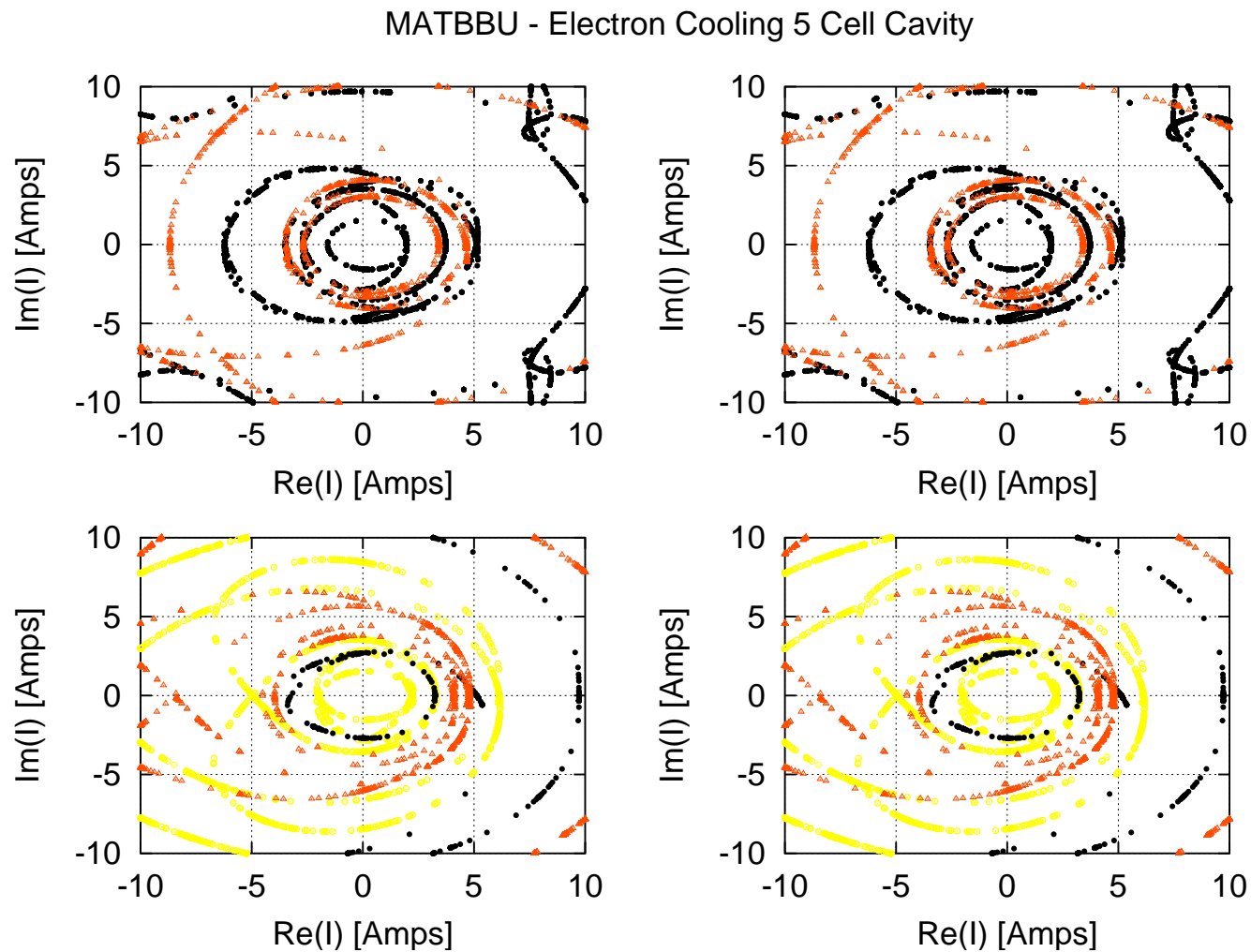
TDBBU - Electron Cooling (4 Cavity Configuration)

Regions of interest between <u>810-1000 Mhz</u>
(3 & 5 Mhz HOM Distributions)

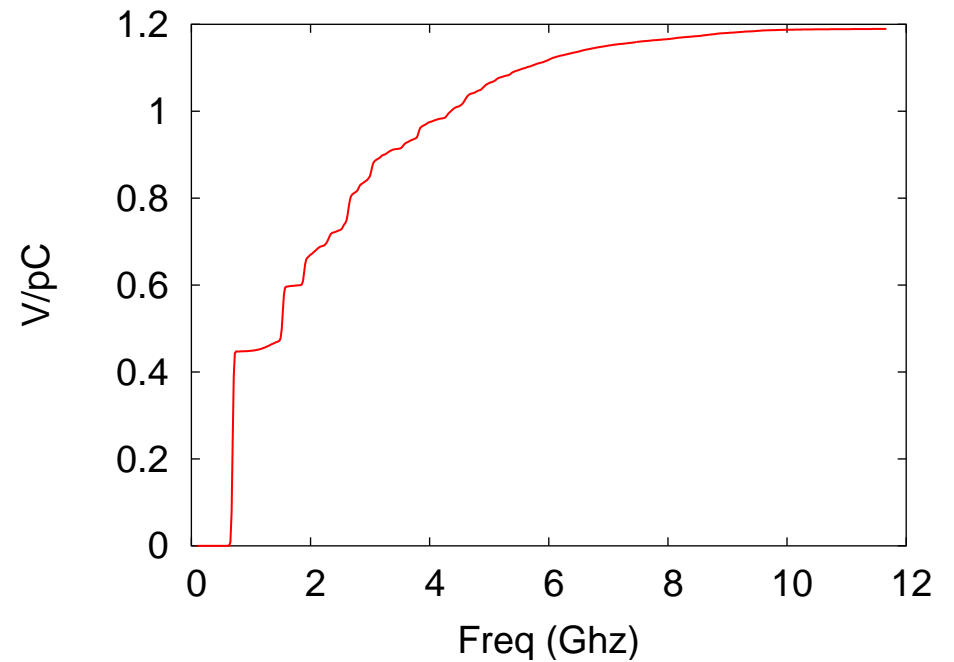
MATBBU - Electron Cooling 5 Cell Cavity

MATBBU - Electron Cooling 4 x 5 Cell Cavity
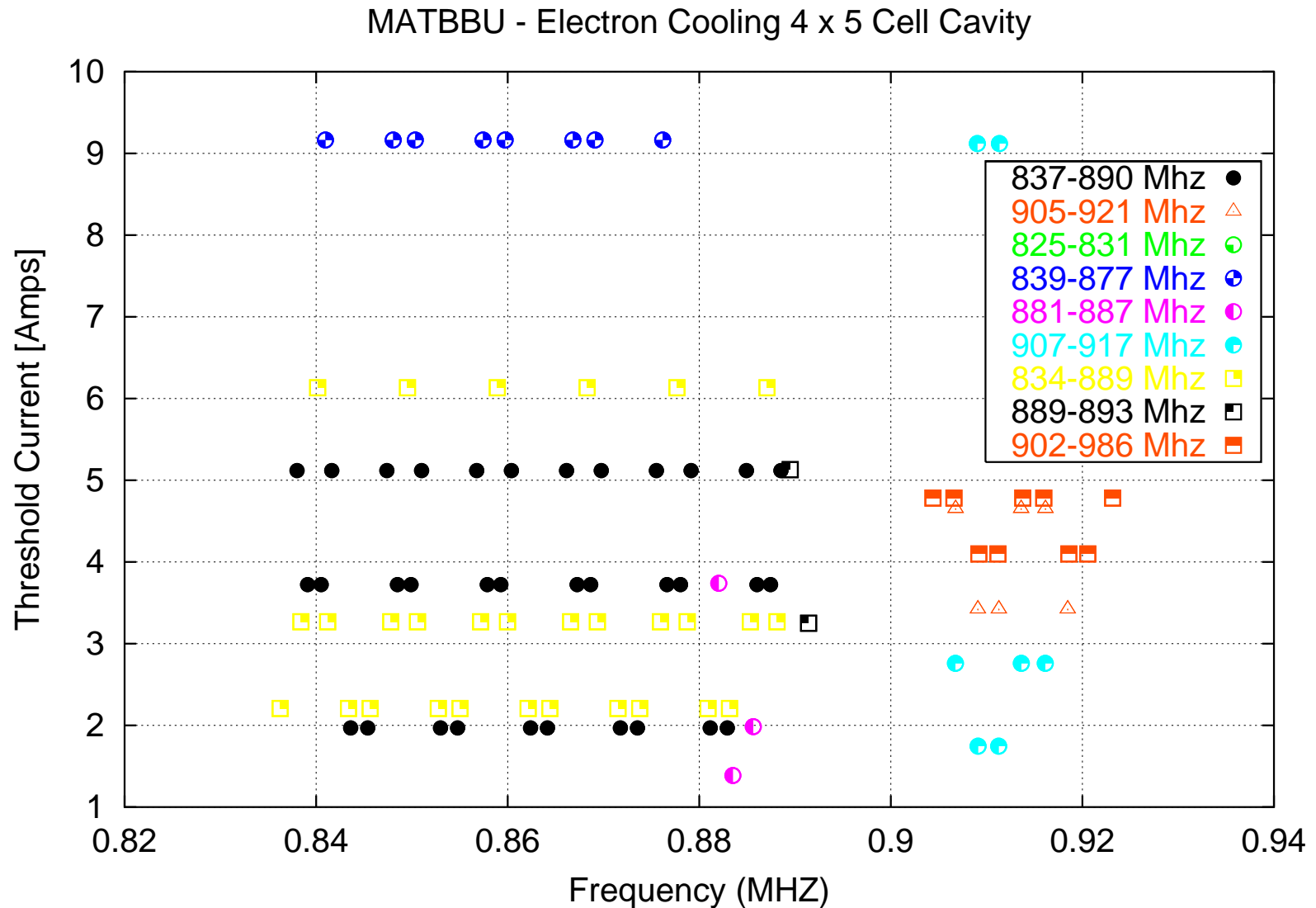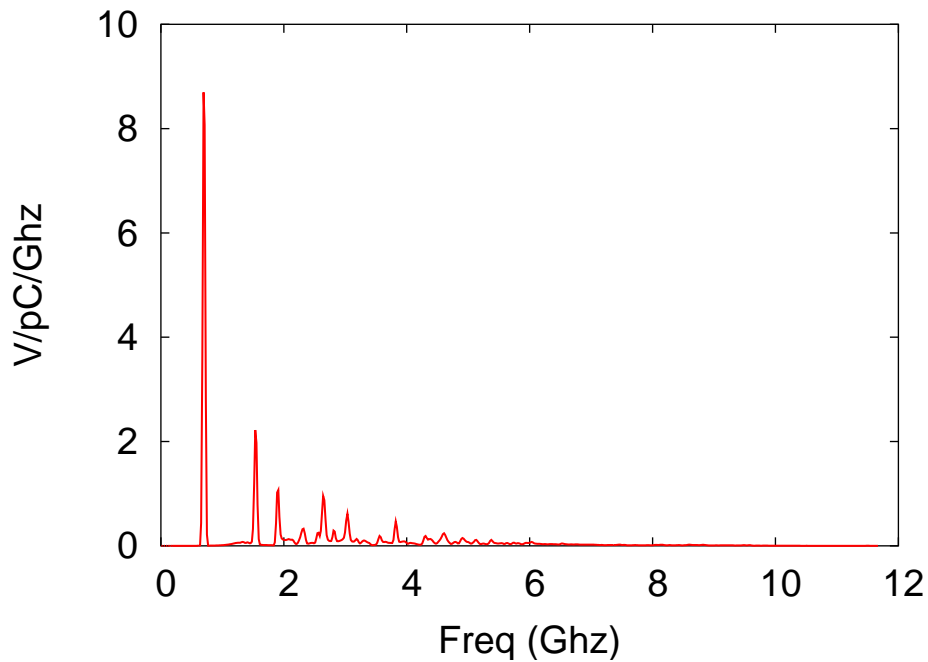
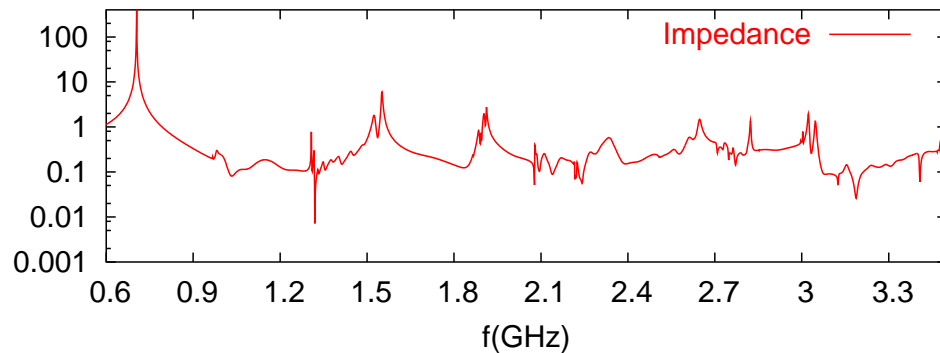# Longitudinal Loss Factor

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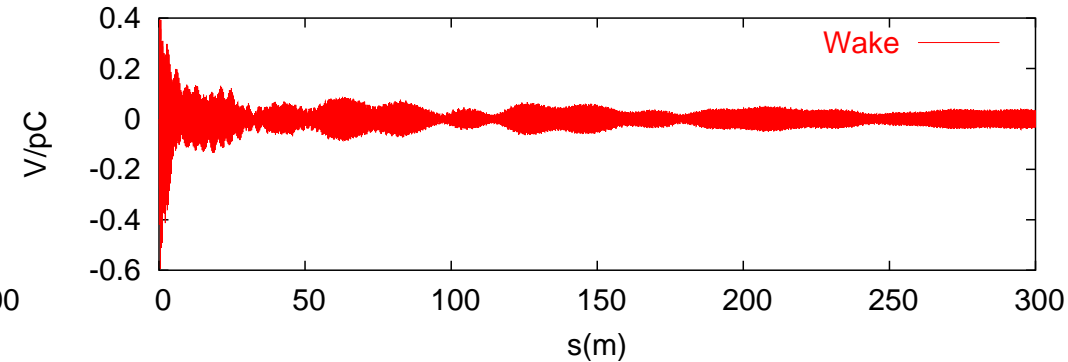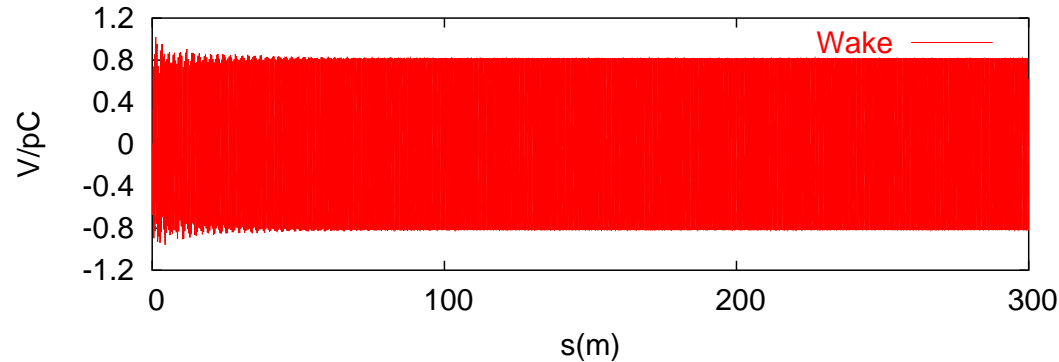

Integrated loss factor - 1.2 V/pC ≈ 6KW of HOM power

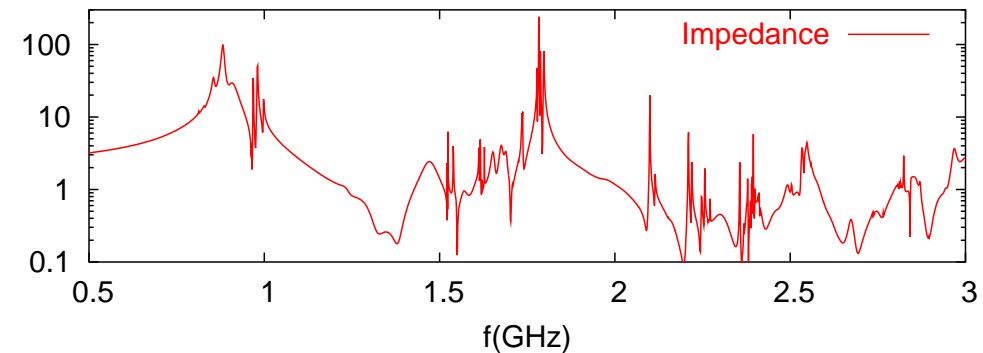# 3D Time Domain Impedance Calc.

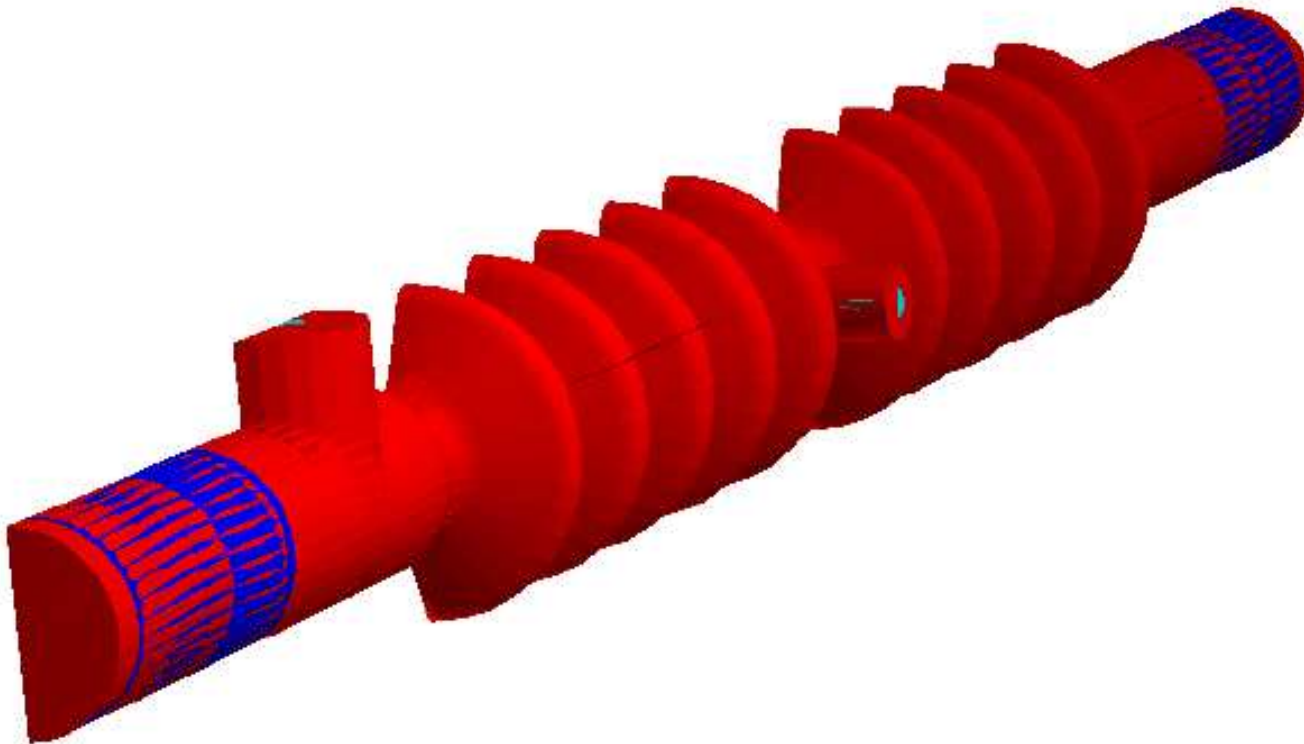Mafia 3D calculations using single bunch (bunch length-3cm).

Detailed calculations using complete 3D design (couplers) is under investigation

More Calculations

- 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