BNL Plans

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C-ASE
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High Current Cavities at BNL

- BNL working with AES developed a high current $\beta=1$ cavity at 704 MHz.
- The cavity was tested to a high gradient.
- BNL and AES have been developing advanced cavity fabrication and processing capabilities.
- Work will be done in the context of the Stony Brook University Center for Accelerator Physics and Education.

703.75 MHz 5-cell β=1 cavity

Fundamental Power Couplers

Cavity during initial chemistry

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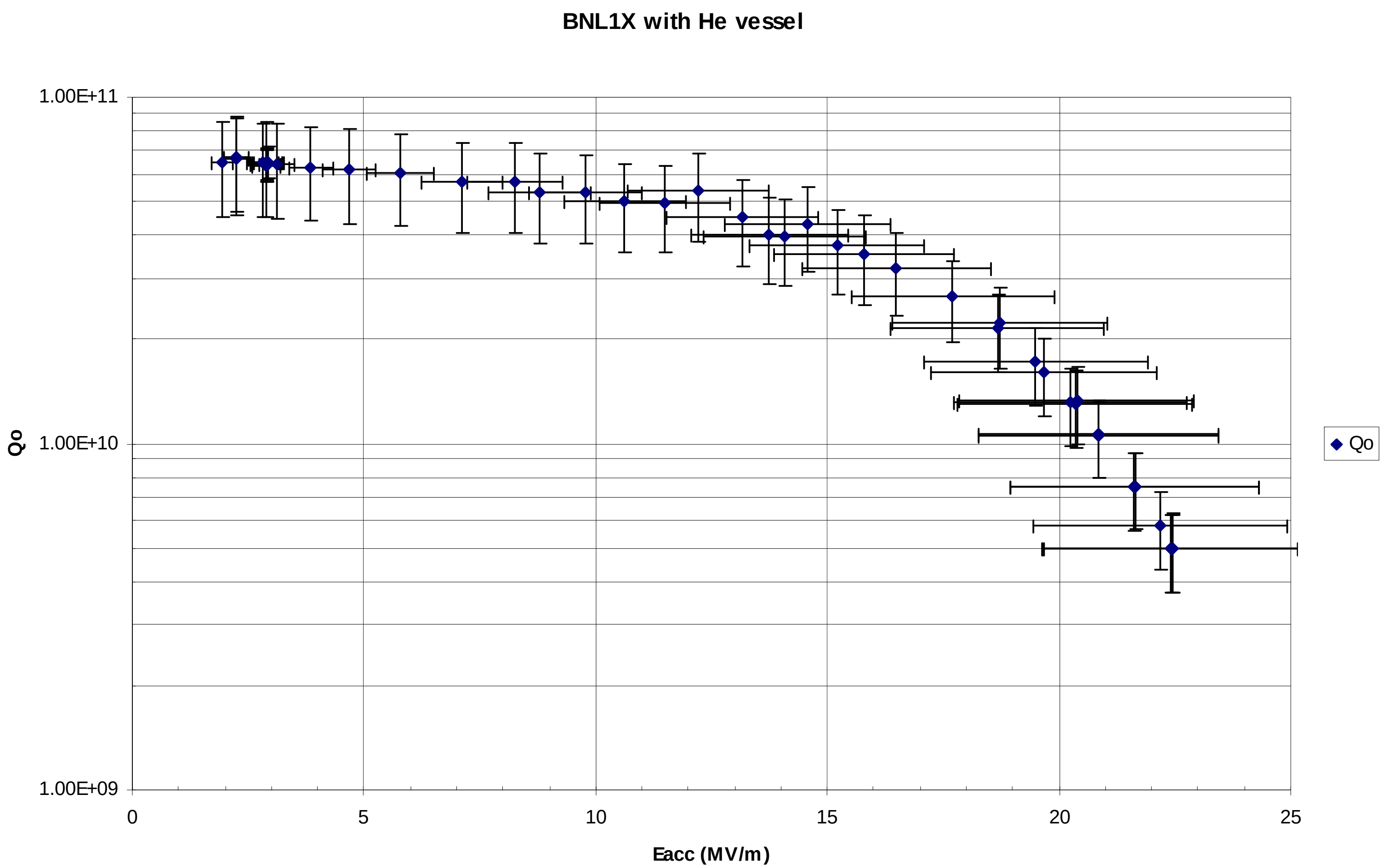
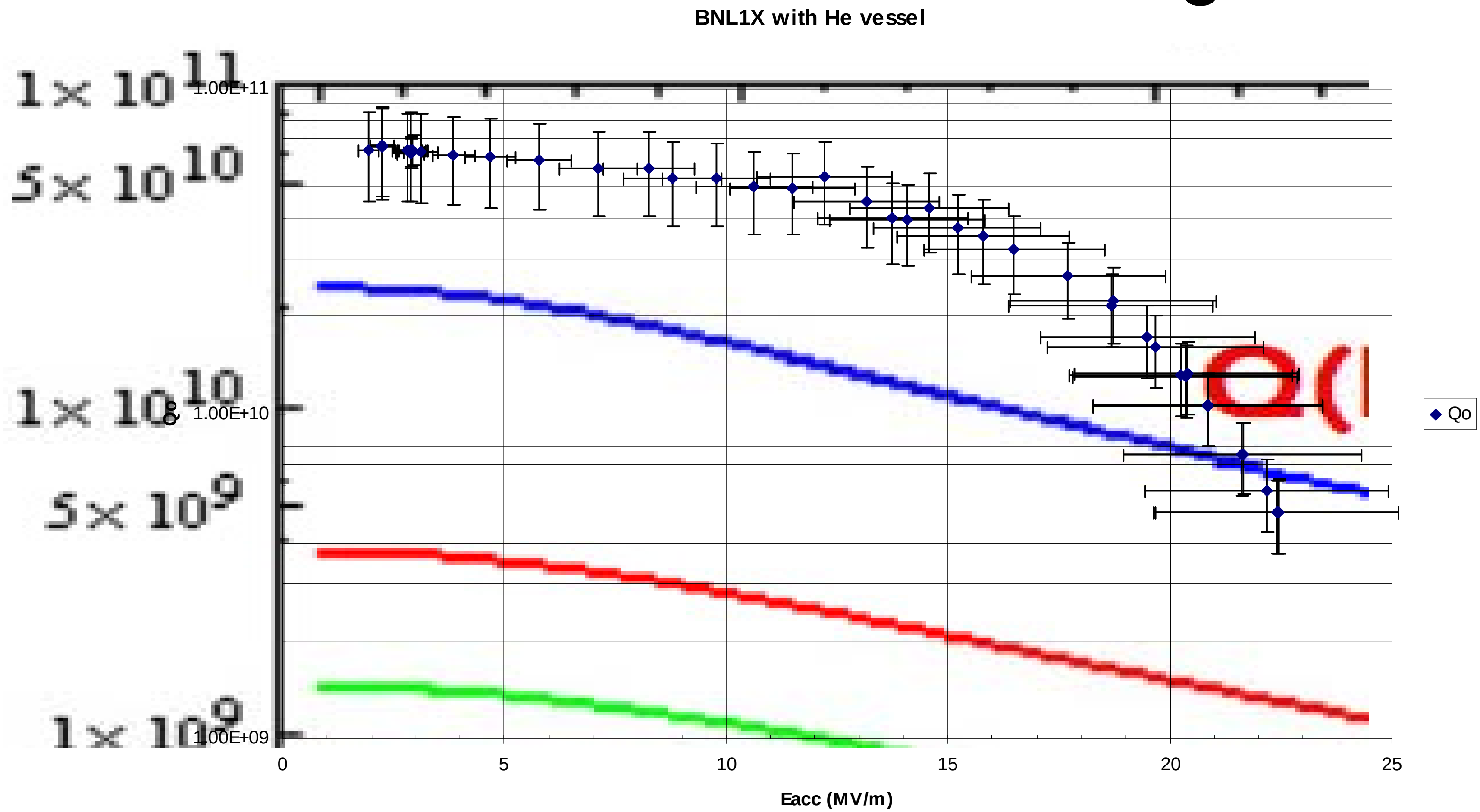
Excellent field performance



Measurement at Jefferson Laboratory

Comparison to CERN-AB-2008-064, F. Gerigk et al.



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5-cell
Cryomodule
in ERL Hall

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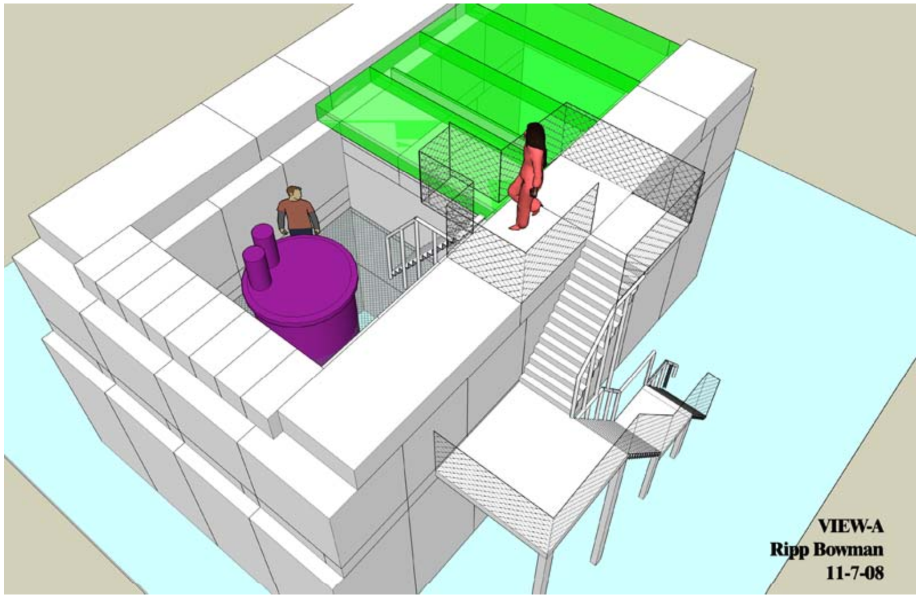
High Power Couplers

- We are developing an SRF gun aimed at 1 MW beam power.
- The gun will be fed with two FPCs, intended for 0.5 MW CW each (higher design power)
- Test of the couplers will take place early next year.

New facilities

Niobium BCP facility



Vertical Test Facility

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Plans:

- BNL is interested in collaborating in the SPL
- Together with Stony Brook University and Advanced Energy Systems and in collaboration with CERN we will submit a proposal to DOE to design, build and test a 704 MHz β=0.92 cavity for the SPL.
- We plan to pursue DOE funding for support of the SPL collaboration.

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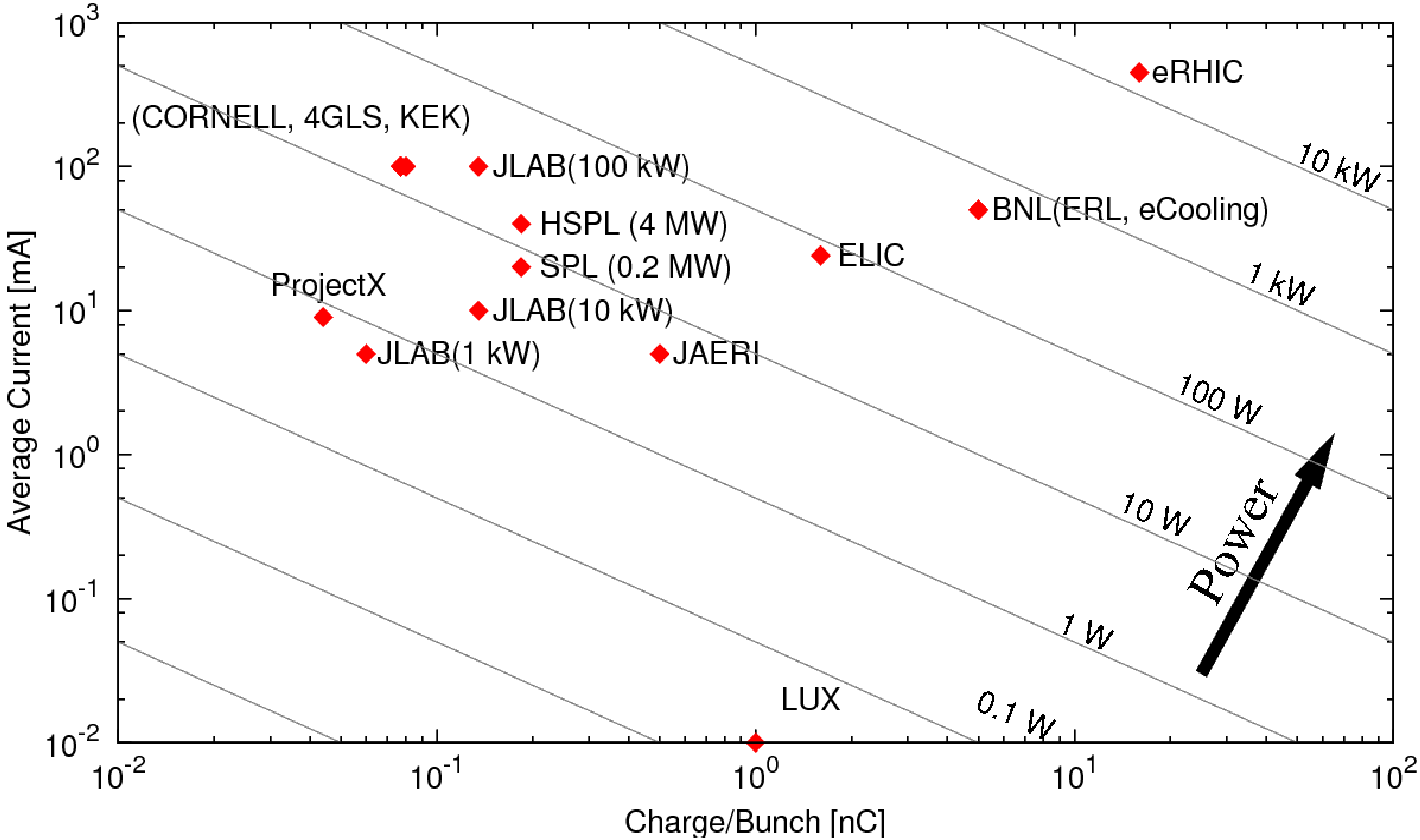
BNL cavities for SPL

I. Ben-Zvi, R. Calaga
BNL, Stony Brook
SPL Workshop, Dec 12, 2008

Ack: A. Burrill, H. Hahn, J. Sekutowicz, P. Kneisel, G. McIntyre, Y. Xiao & AES

- Design strategy, measurements
- Improvements & SPL cavity
- Conclusions

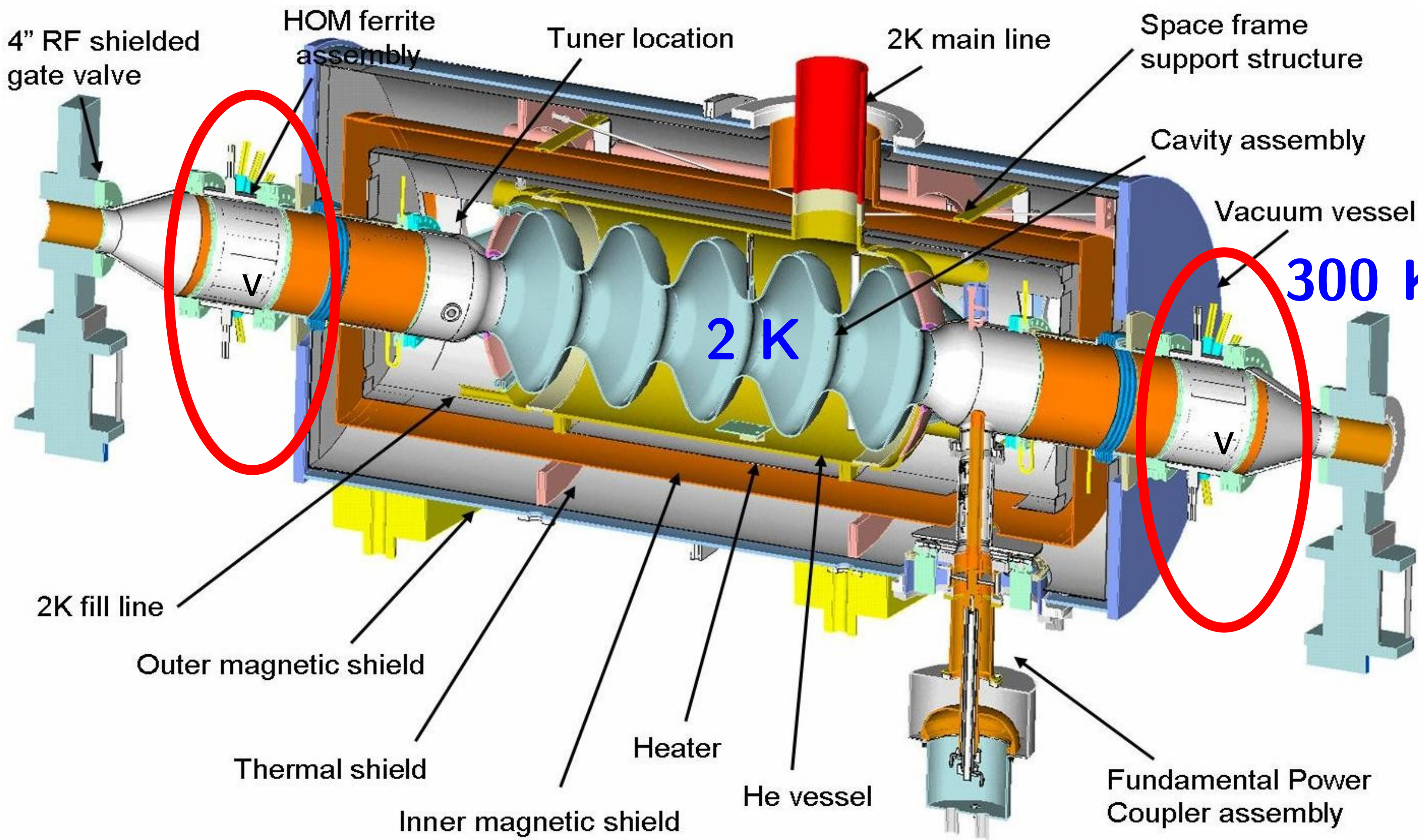
The Problem



for 1 V/pC

The Solution

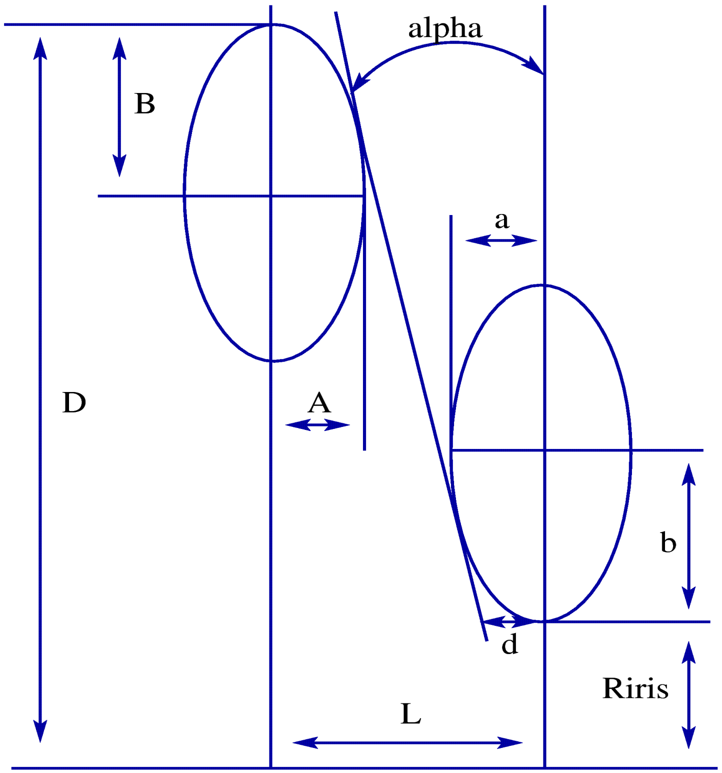
Graphic courtesy AES



Main mantra for high currents: <u>Simple & Robust</u>

704 MHz, Cavity Stiffness, Large Apertures, Warm Ferrites

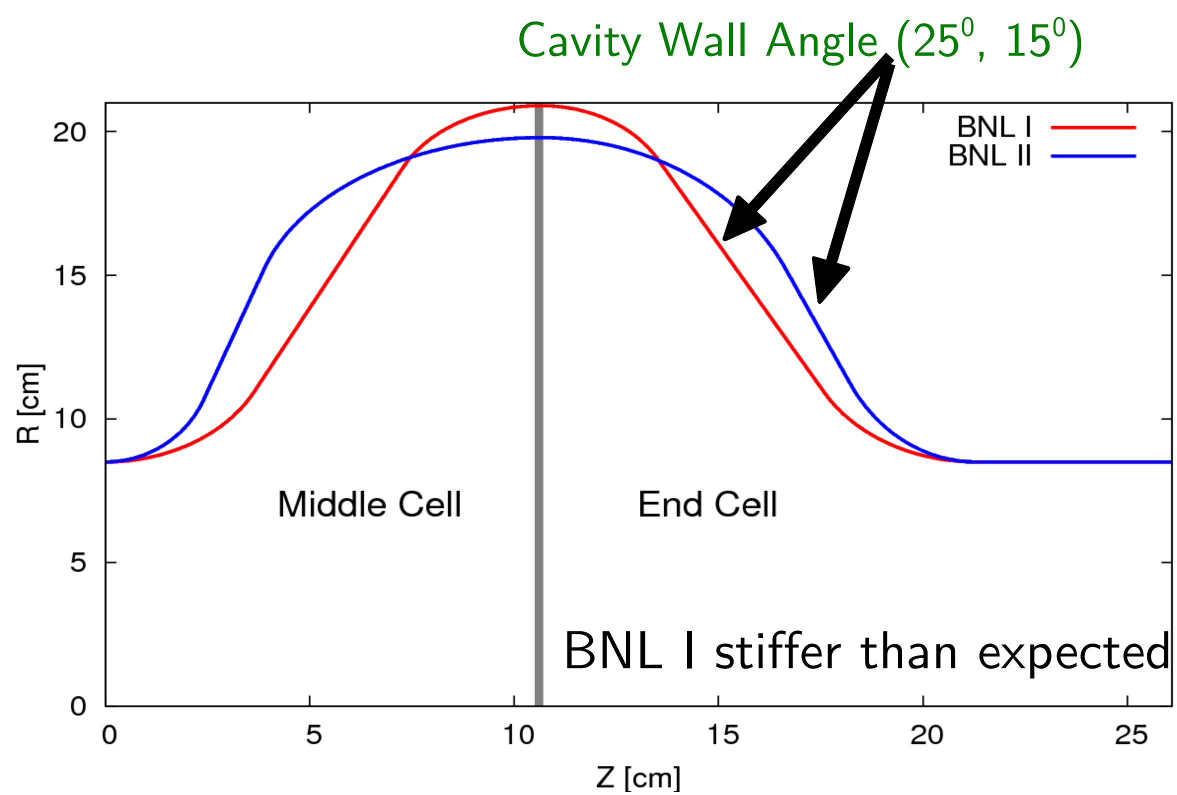
Cavity Design



Parametrization, Pierini et al.

Scan geometrical parameters as a function of RF/Mechanical parameters:

- E_{pk}, B_{pk}, R/Q, cell-to-cell coupling
- HOM frequencies, BP cutoff
- Microphonics, stiffness, cleaning etc...

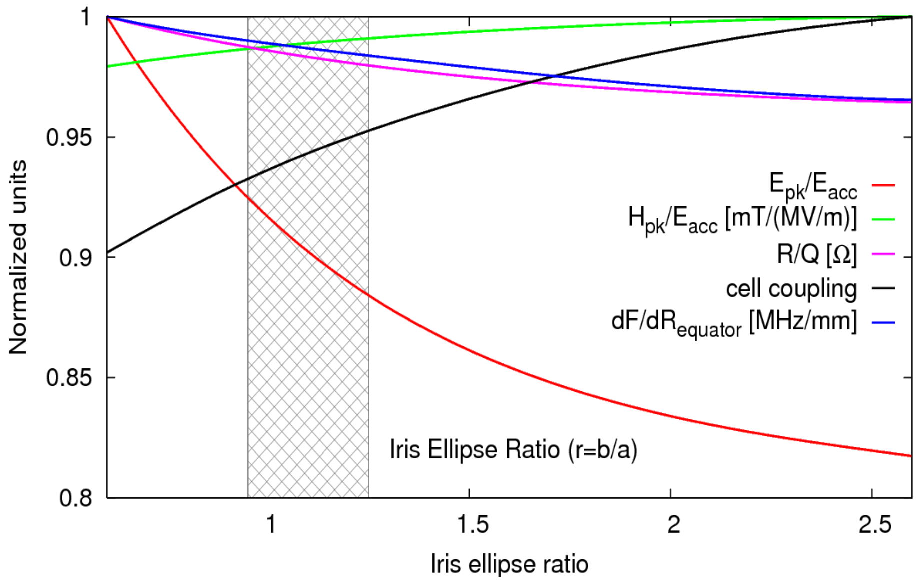


Scan is not completely orthogonal -or- unique

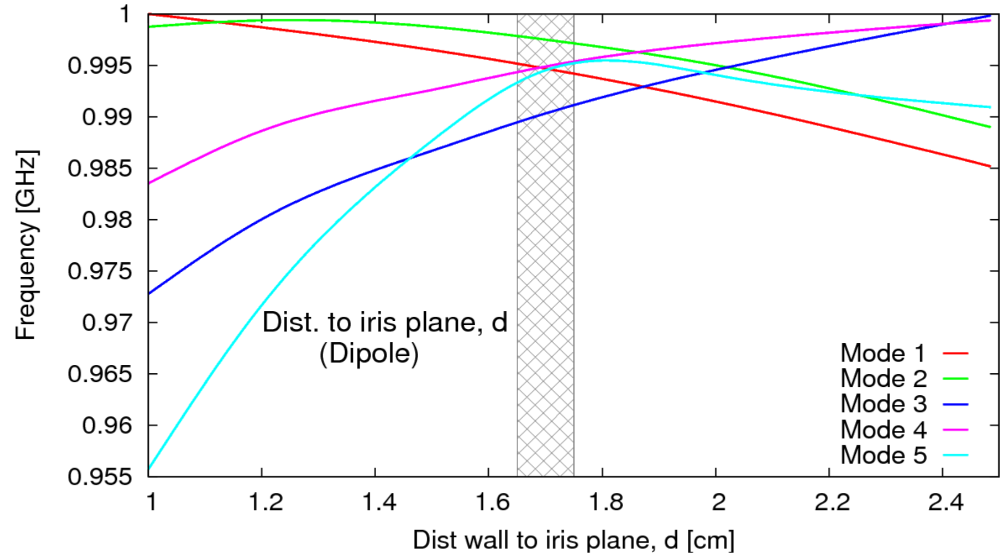
Note: BNL I is fabricated & tested, BNL II is under optimization

3 Stage, Parametric Scans

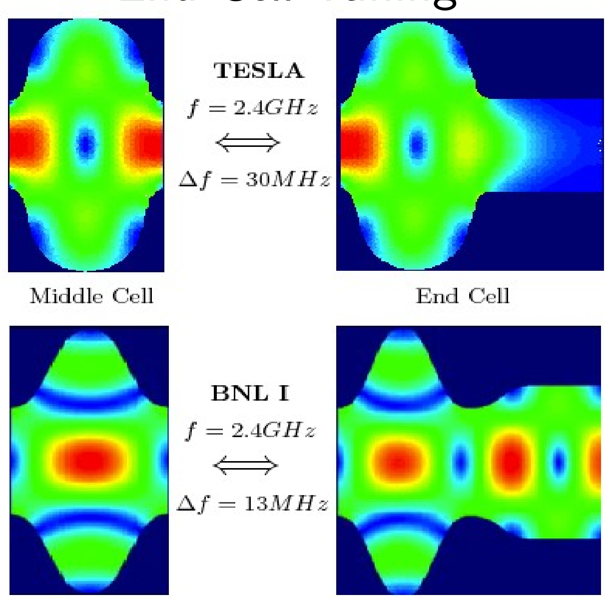
Fundamental Mode



Frequency Scan, HOMs



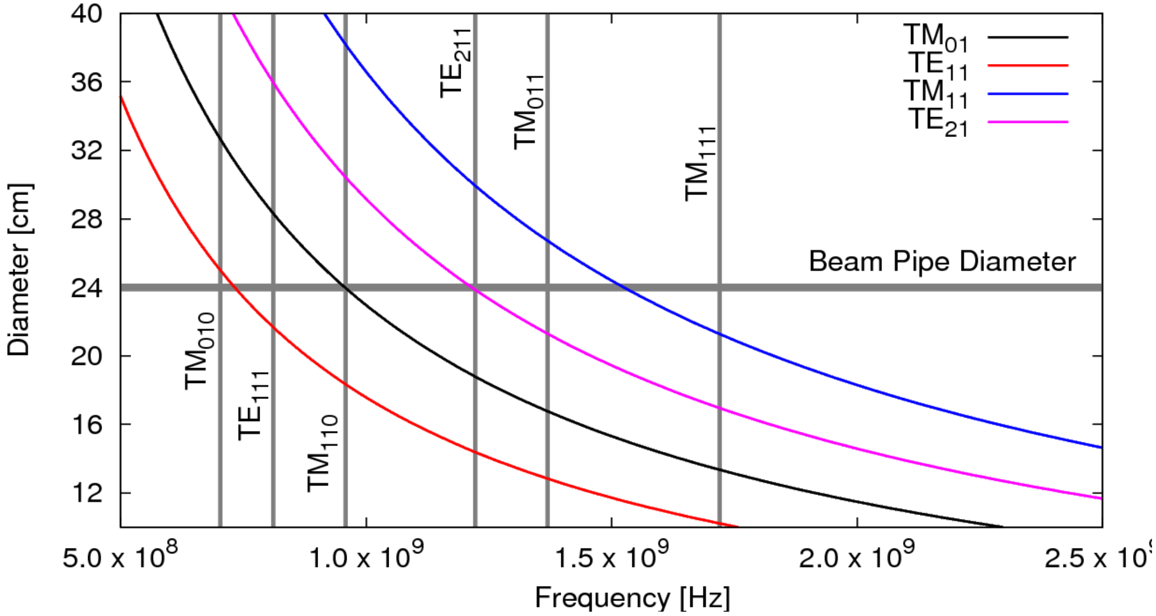
End Cell Tuning

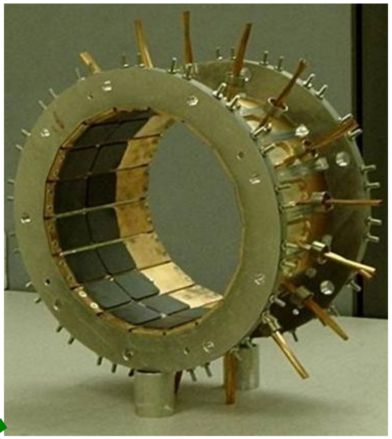


Critical, often forgotten:

- Field enhancement as a result of freq tuning & additional entities on beam pipe
- HOM frequencies differ significantly between mid & end cells due to large variations

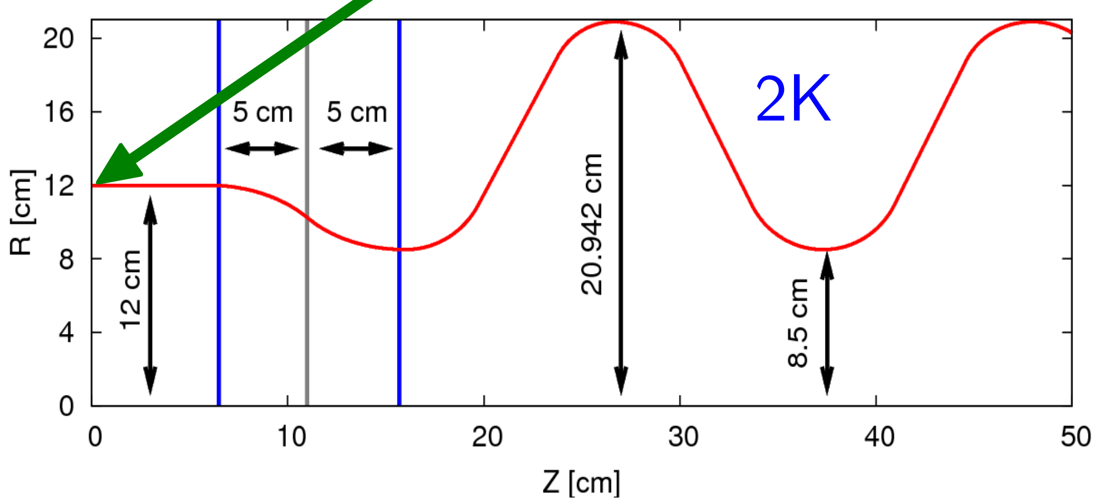
Natural Conduit, BP





Propagating HOMs:

- Enlarged beam-pipe (tapered end cell)
- Large aperture end cell, flutes
- Loop couplers (non-ideal for CW)



Naturally better for coupler kicks

Some Facts

Difference mainly in wall angle

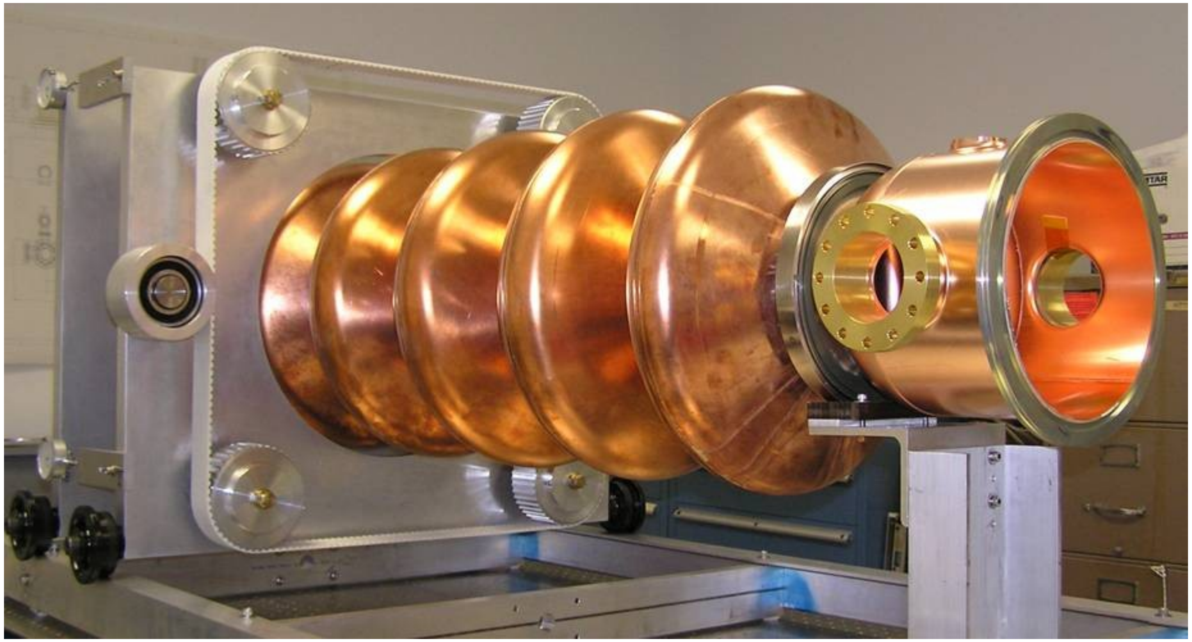
Parameter	Unit	BNL 1(HC)	BNL 2 (HC)	CEBAF(HG)	TESLA(HG)
Frequency	[MHz]	703.75	703.75	1497	1300
Number of cells	-	5	5	7	9
$(R/Q)*G$	$[\Omega^2]$	9×10^4	9.69×10^4	2.1×10^5	2.8×10^5
E_p/E_a	-	1.97	2.36	1.96	1.98
H_p/E_a	$[mT/MV/m]$	5.78	4.76	4.15	4.15
Cell to cell coupling (k_{cc})	-	3%	4.68%	1.89%	1.87%
Sensitivity Factor ($\frac{N^2}{\beta k_{cc}}$)	-	8.3×10^2	5.3×10^2	2.6×10^3	4.1×10^3
Field Flatness	-	97.2%	97.3%	97.5%	95 %
Lorentz detuning coeff.	$[Hz/(MV/m)^2]$	1.28 (UnStiff)	NE	2	1

B_{Peak} reduced by 18% from BNL I → II

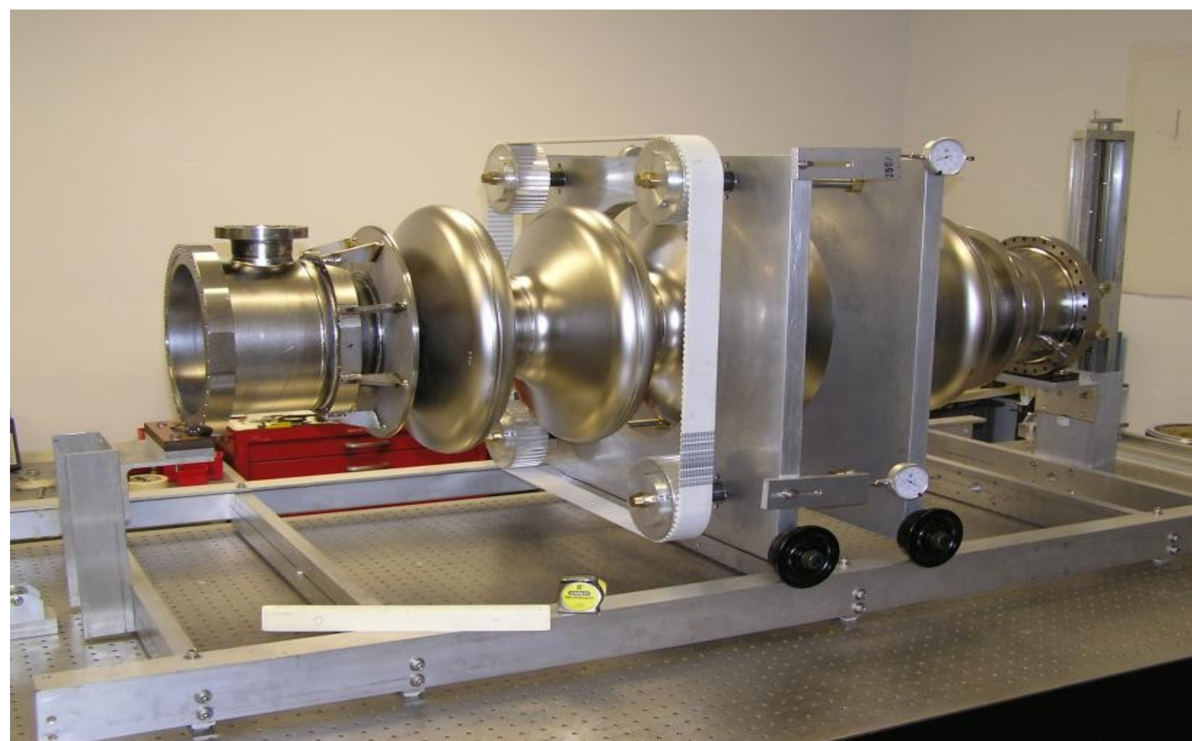
Q_{slope} Vs. Gradient to proportionally increase

Improvements in cavity treatment to go beyond

Copper & Niobium Cavities

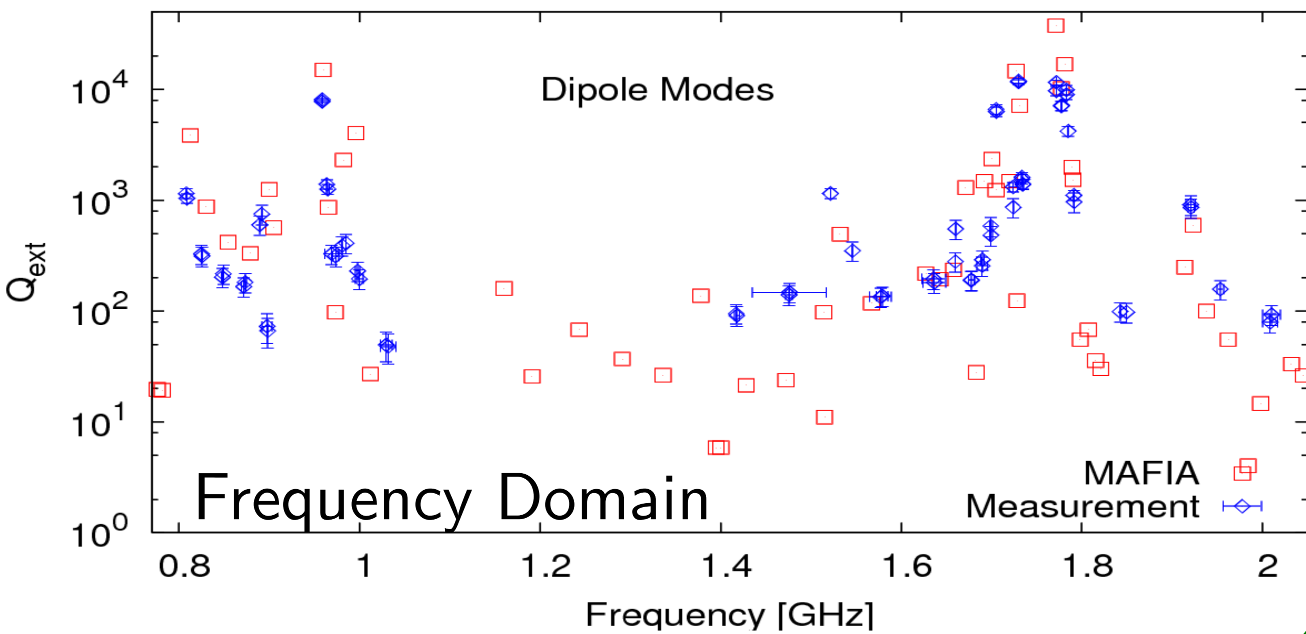


Fabricated & tested
2004-05



Fabricated & tested
2005-06

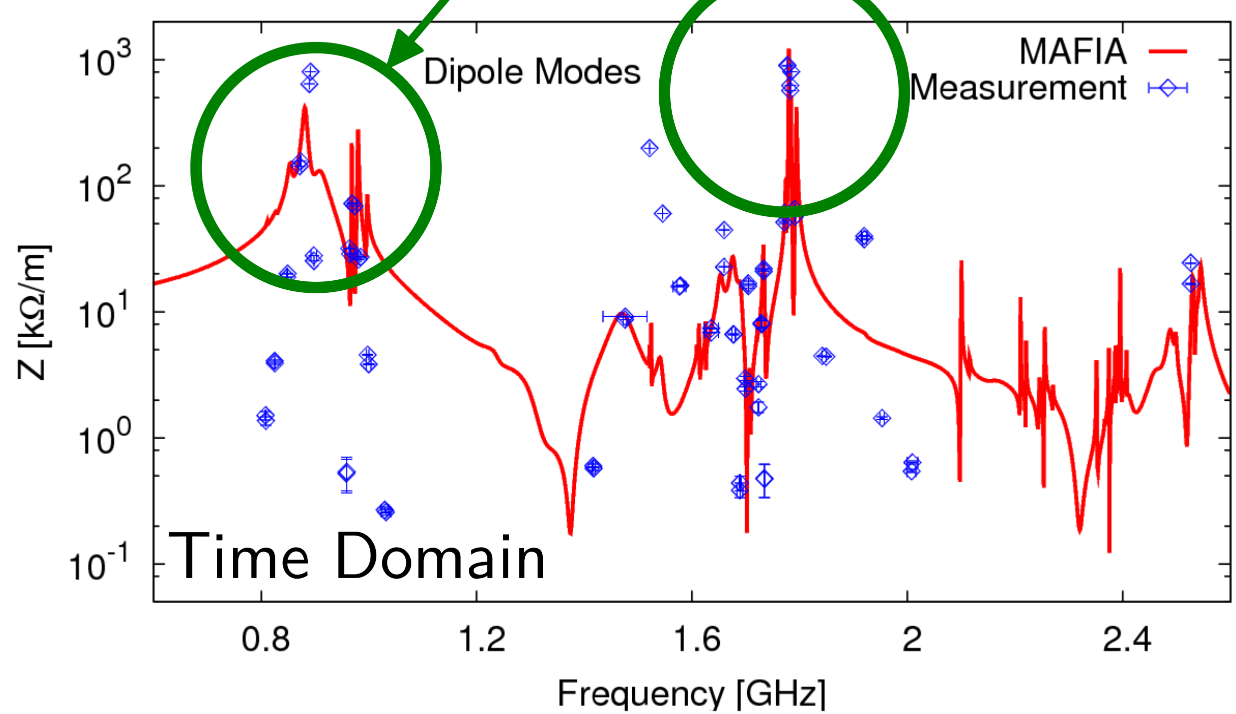
HOM Damping, Cu



Two passbands of interest

Q_{ext} well above the ampere beam-breakup thresholds

Excellent agreement between simulations & measurements

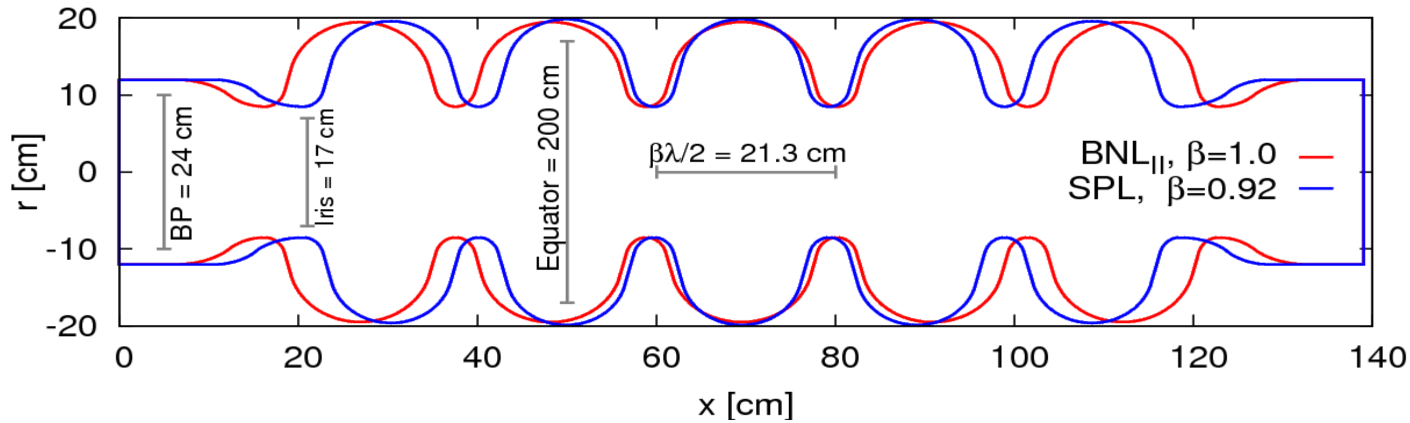


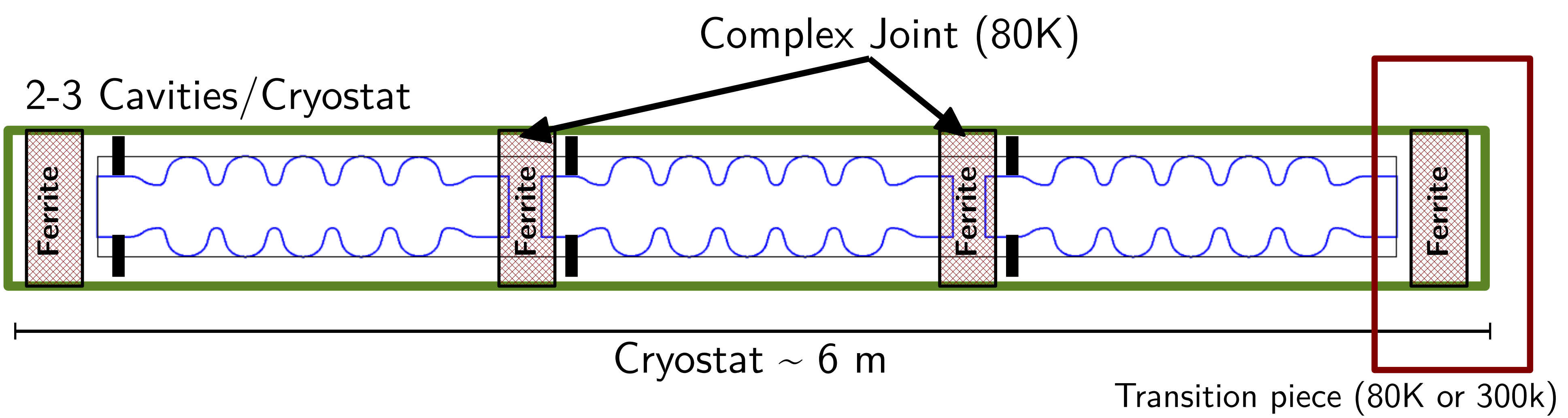
SPL Cavity, 704.4 MHz

½ Cell Length: 8 % change

Trans. Cavity Height: 0.8 % (15 mm)

Parameter	Unit	BNL 1(HC)	BNL 2 (HC)	SPL
E_p/E_a	-	1.96	2.34	2.54
H_p/E_a	[mT/MV/m]	5.73	4.69	5.14
R/Q	[Ω]	825	920	756
dF/dR	[MHz/mm]	2.57	3.68	3.59
Cell-cell coupling	-	3%	4.68%	5.11%





Conclusions

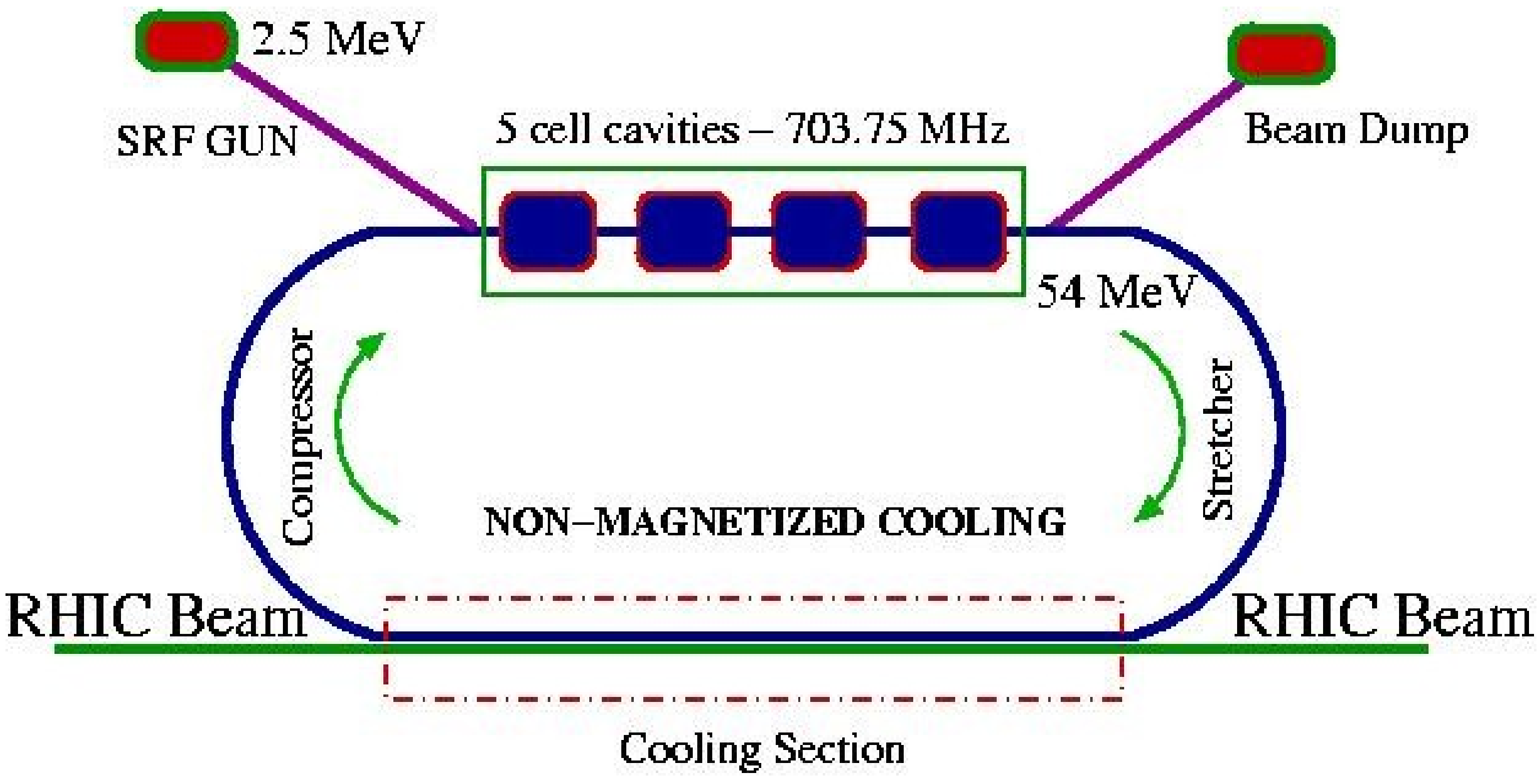
- BNL type 704 MHz cavity for high currents in place

- Detailed study for optimum cavity design improvements proposed from 1st cavity experience

- SPL 704 MHz cavity is a small modification (β-dependent)

- R&D on cold ferrites (80k) -or- "cold joints" can improve real estate gradient (~1-2 m for 2-3 cavities/cryostat)

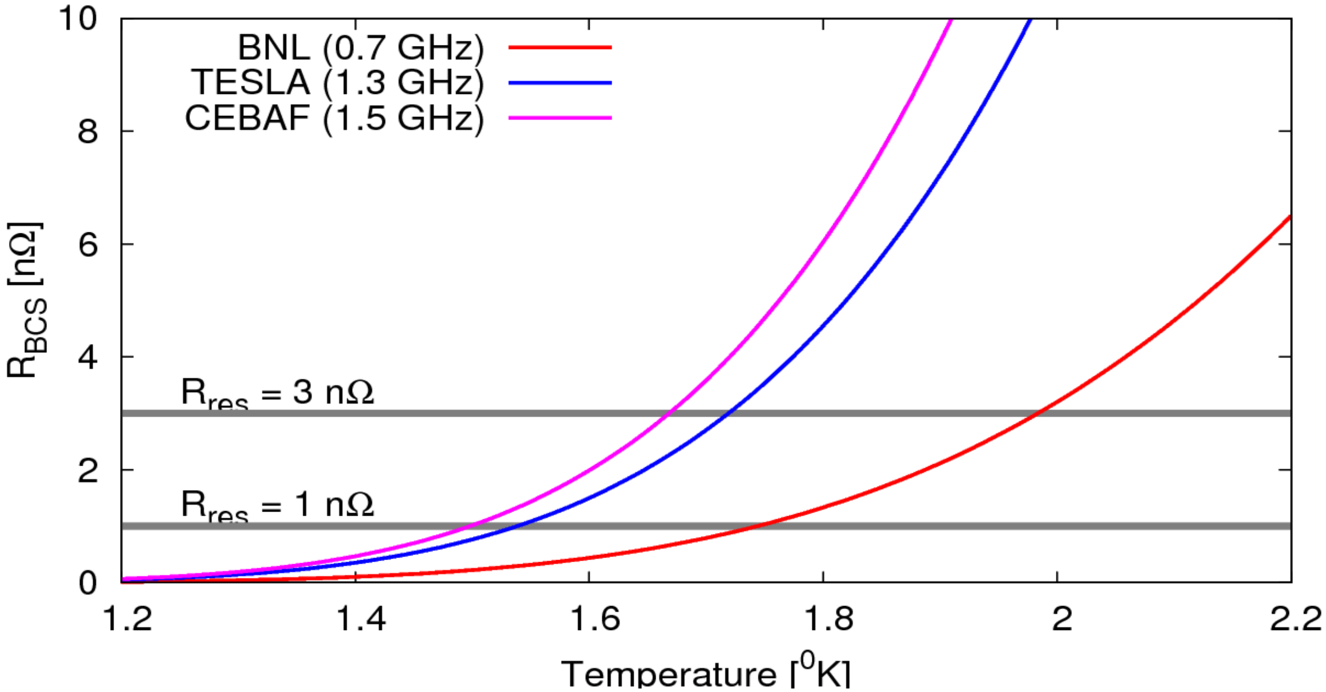
Electron Cooler & SRF



RHIC Electron Cooling:

- High energy (54 MeV), high current, high charge
- Replenish e^- every cycle: Energy Recovery
- Very low emittance beams

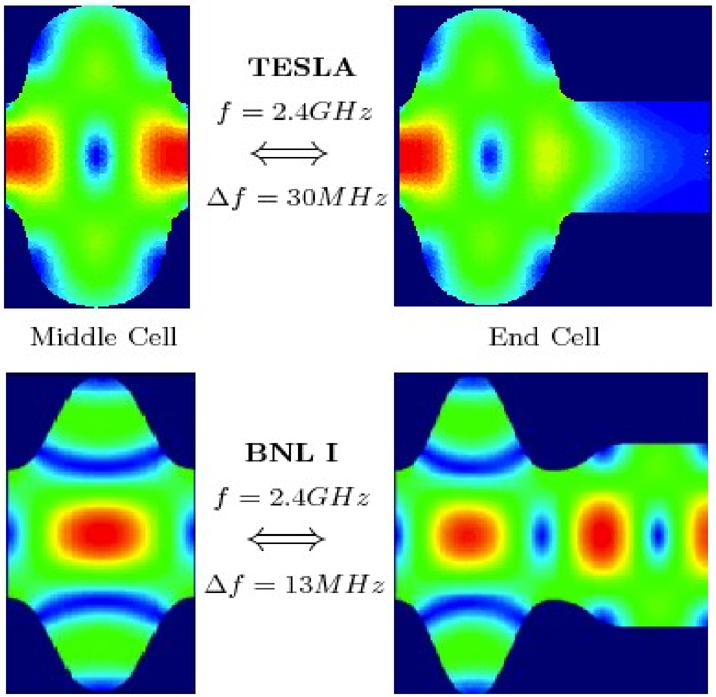
Why 700 MHz



Choice of frequency:

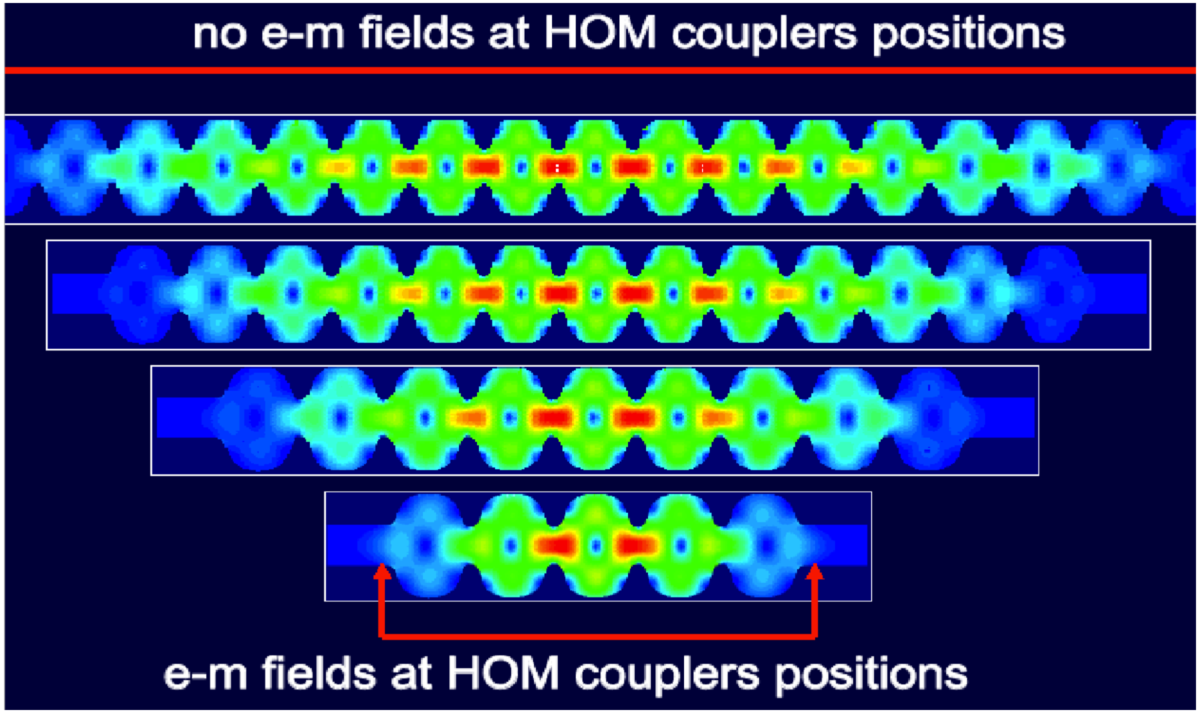
- Surface resistance: $R_{BCS} + R_{residual}$
- Wakefields, HOMs $\propto$ 1/aperture $\rightarrow$ 1/freq
- Availability of power sources, chemical treatment etc..

Design Criteria



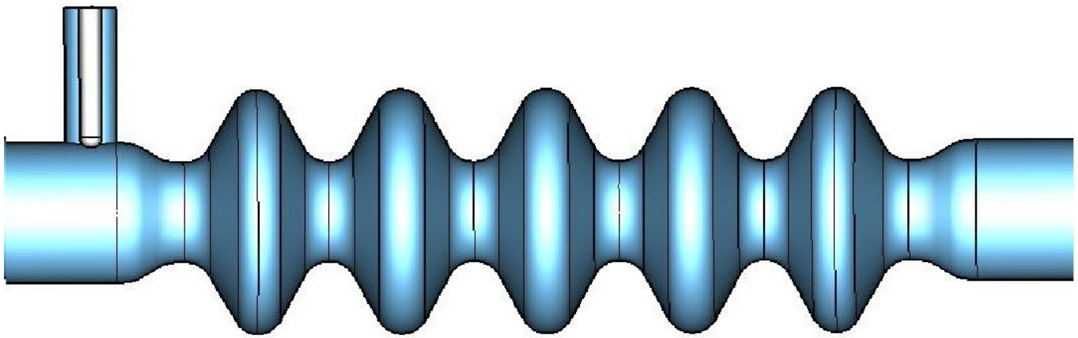
Freq difference between mid & end cells important for multi-cell structures

Too many cells non-ideal for HOM damping

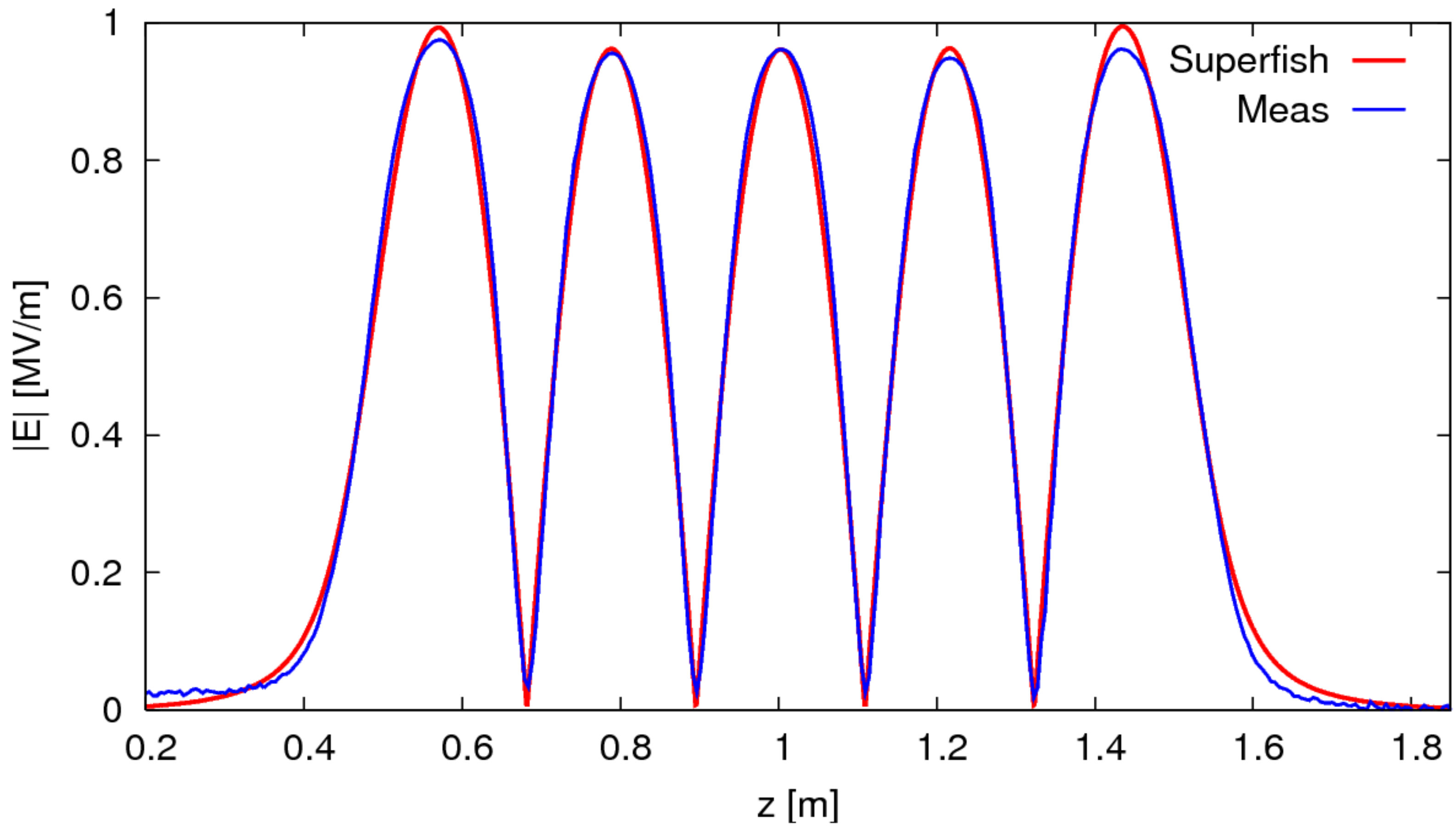


Graphic courtesy J. Sekutowicz

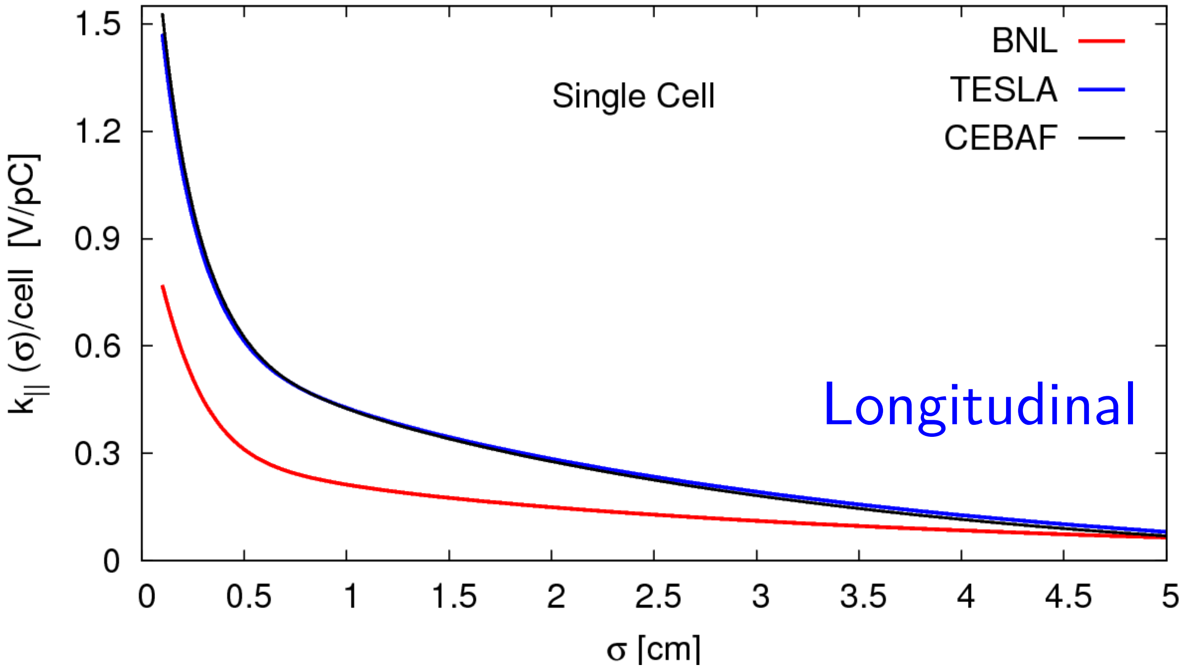
Backup: Field Flatness



First cavity gives excellent agreement without any tuning

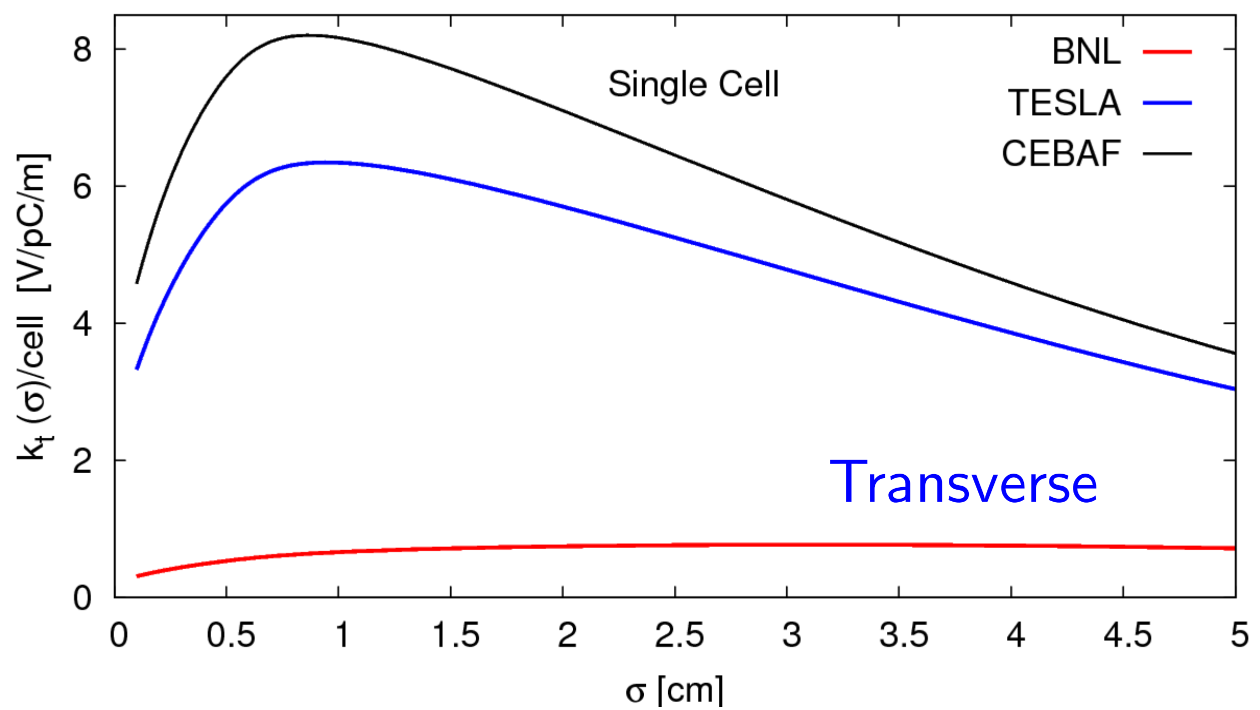


Loss Factors

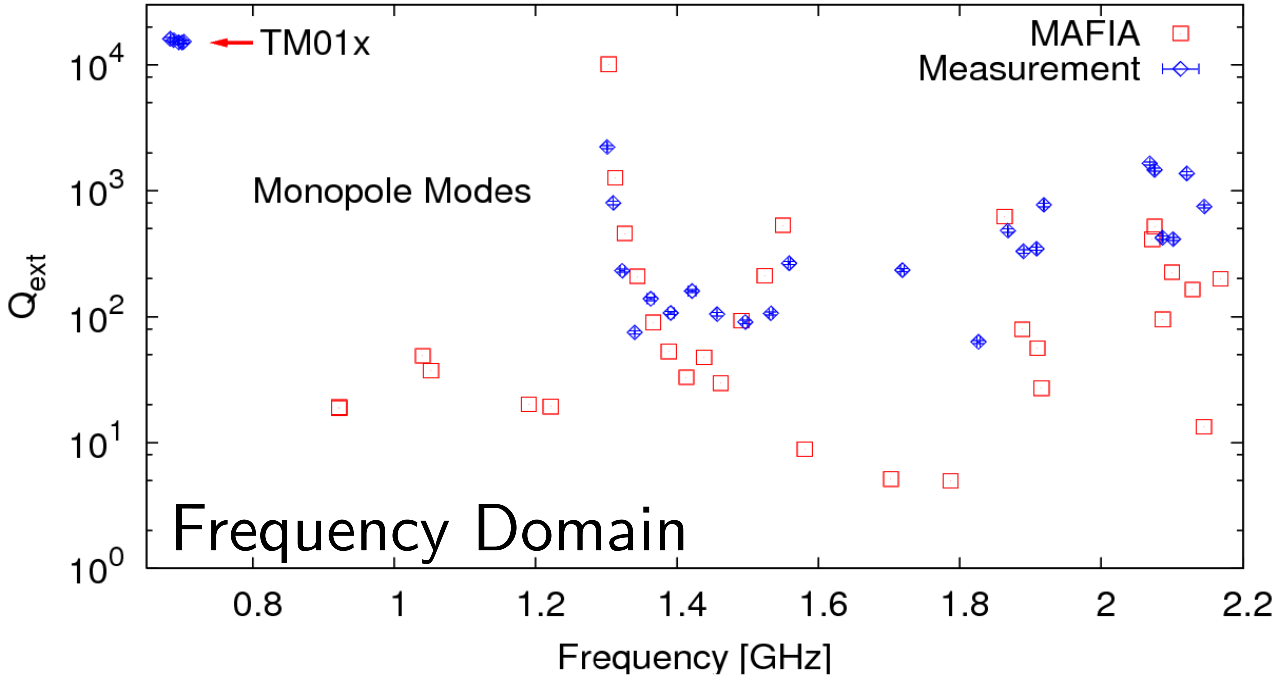


Limitation of maximum power dissipated into cryo-environment

Limitation of maximum current due to transverse instabilities

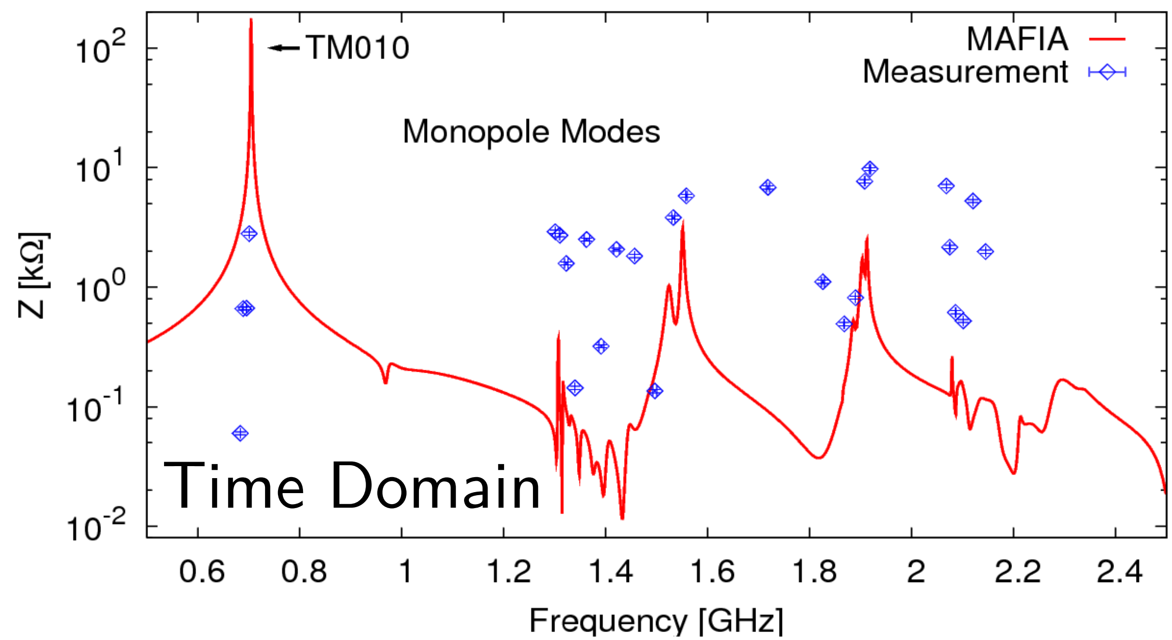


HOM Damping Measurements



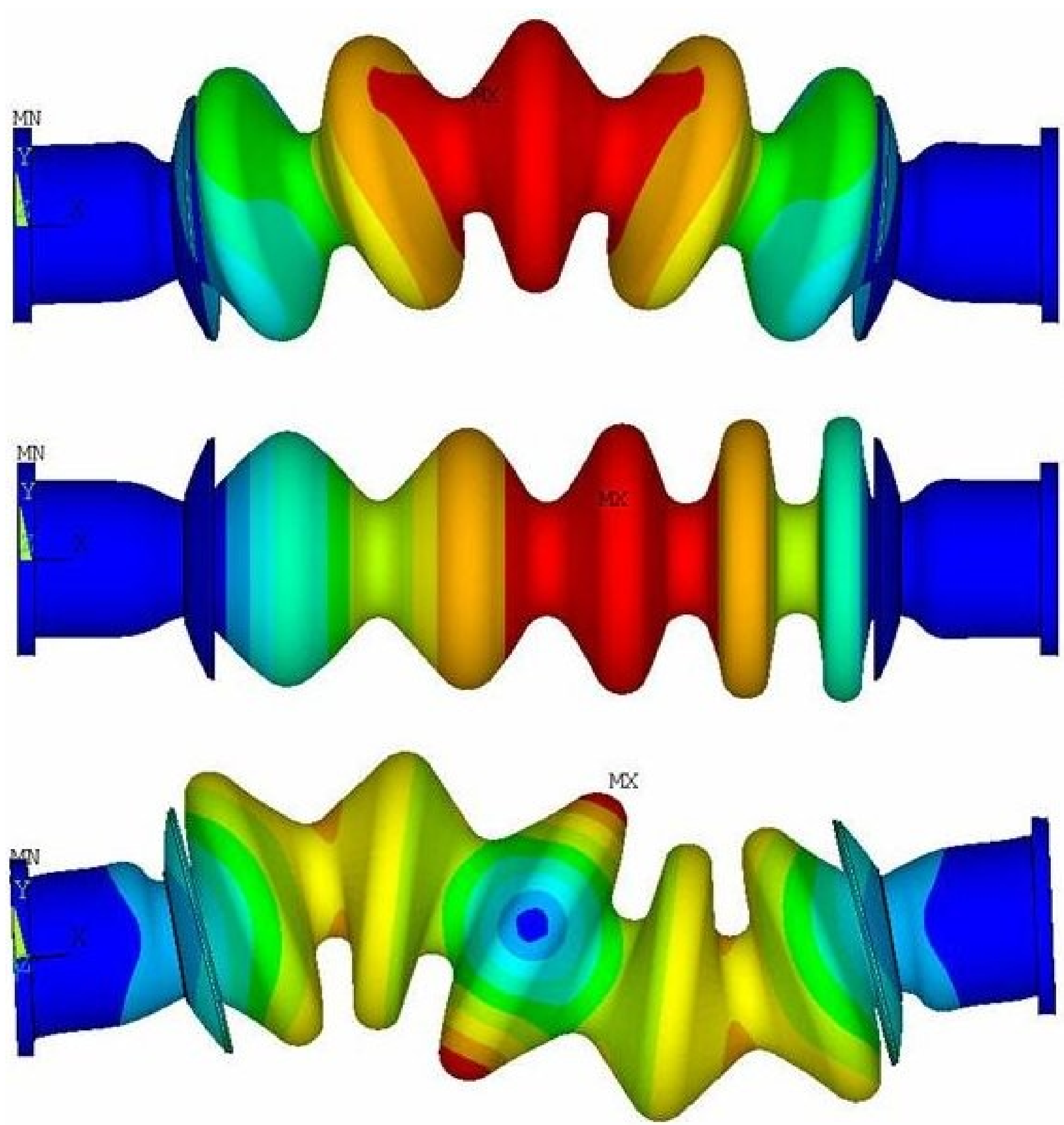
Q_{ext} well below the ampere beam-breakup thresholds

Excellent agreement between simulations & measurements



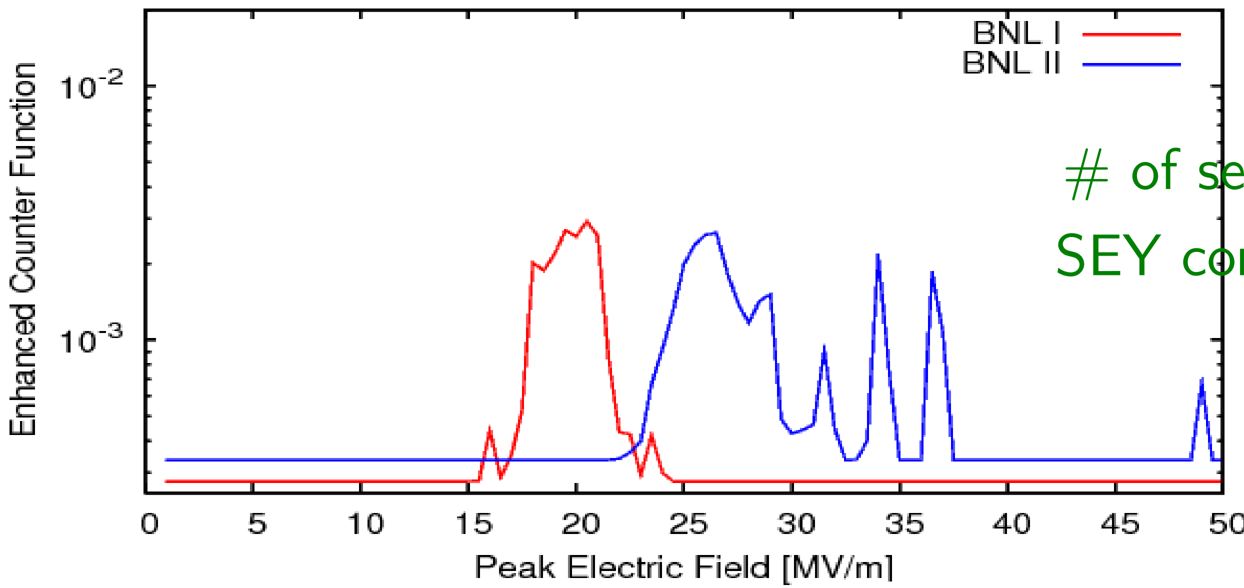
Backup: Mechanical Analysis

Modes: 96 – 214 Hz



Courtesy AES

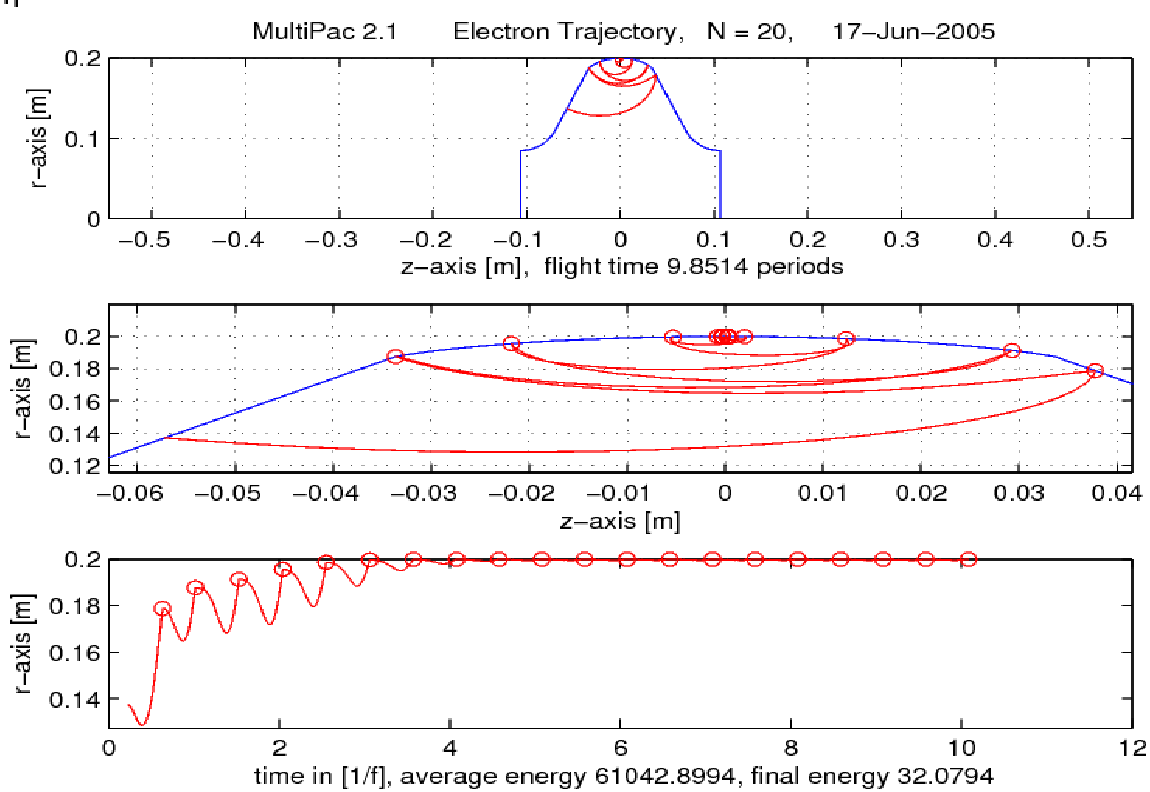
Backup: Multipacting



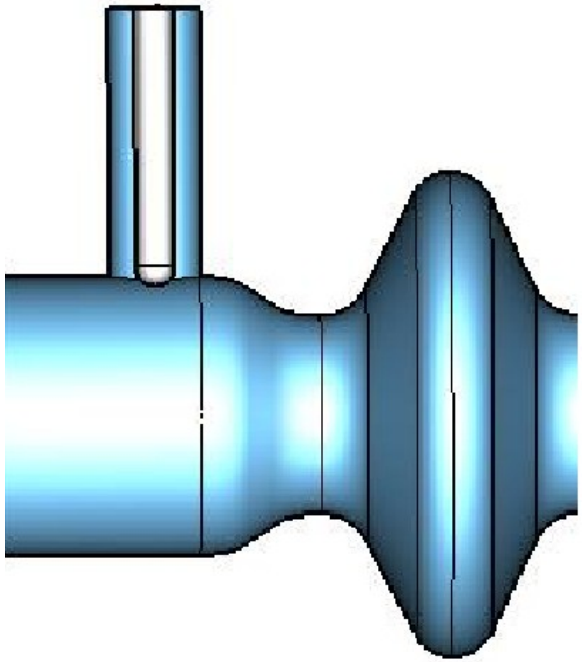
# of secondary electrons normalized to SEY corresponding to the impact energy

WELL BELOW ONE

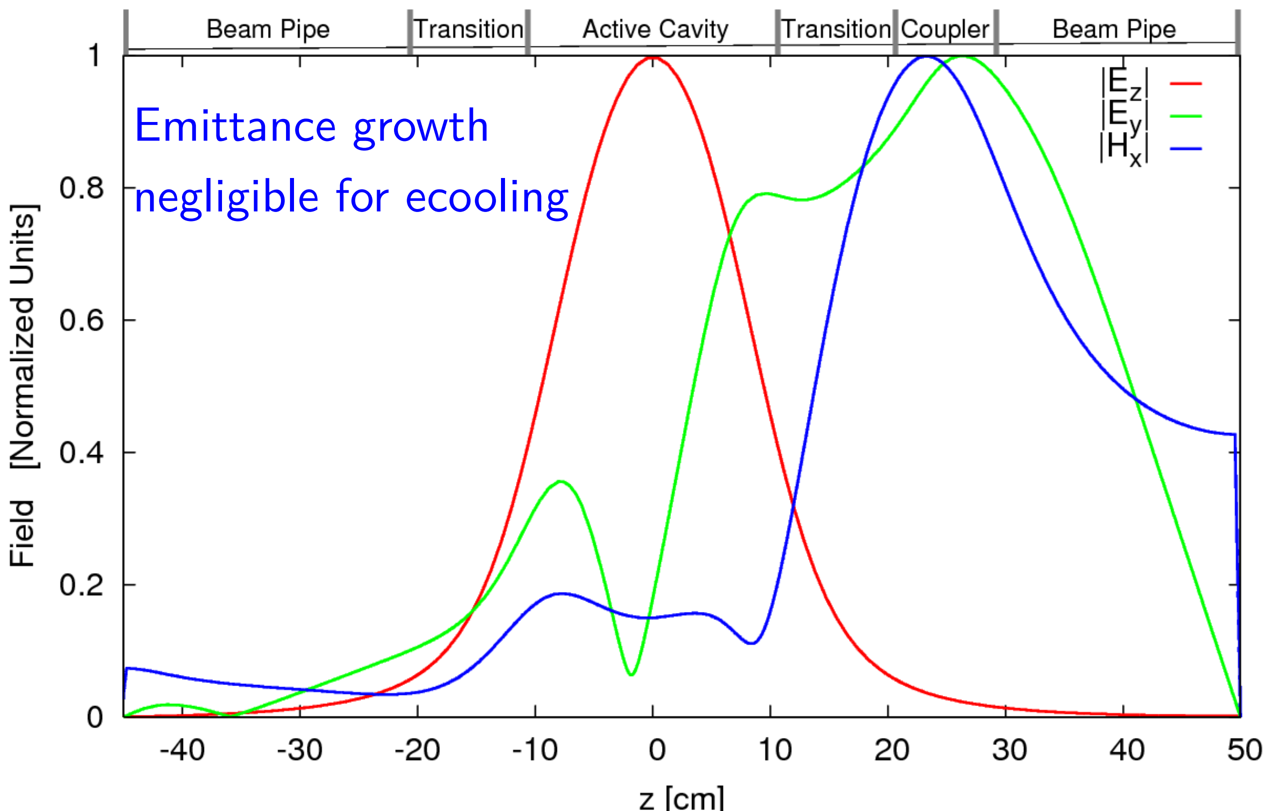
Electron trajectories for Epk = 33 MV/m



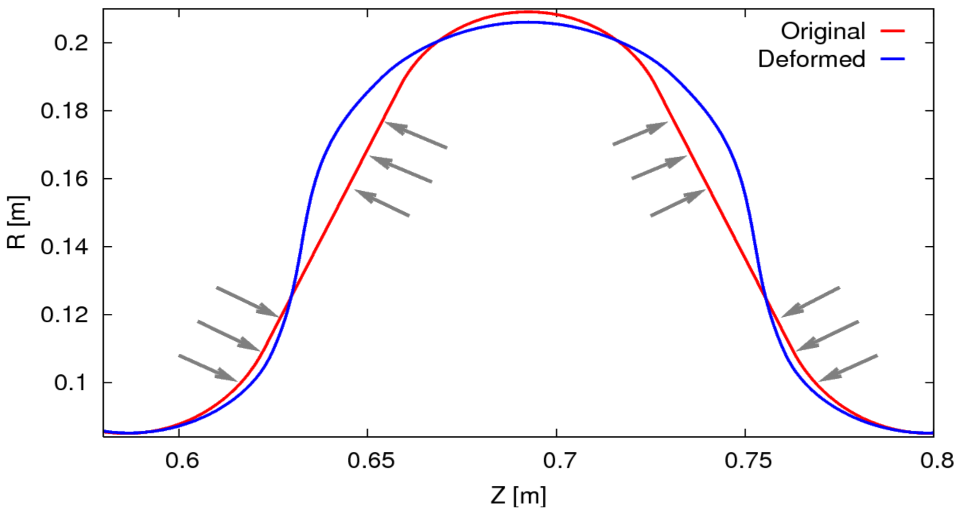
Backup: Coupler Kicks

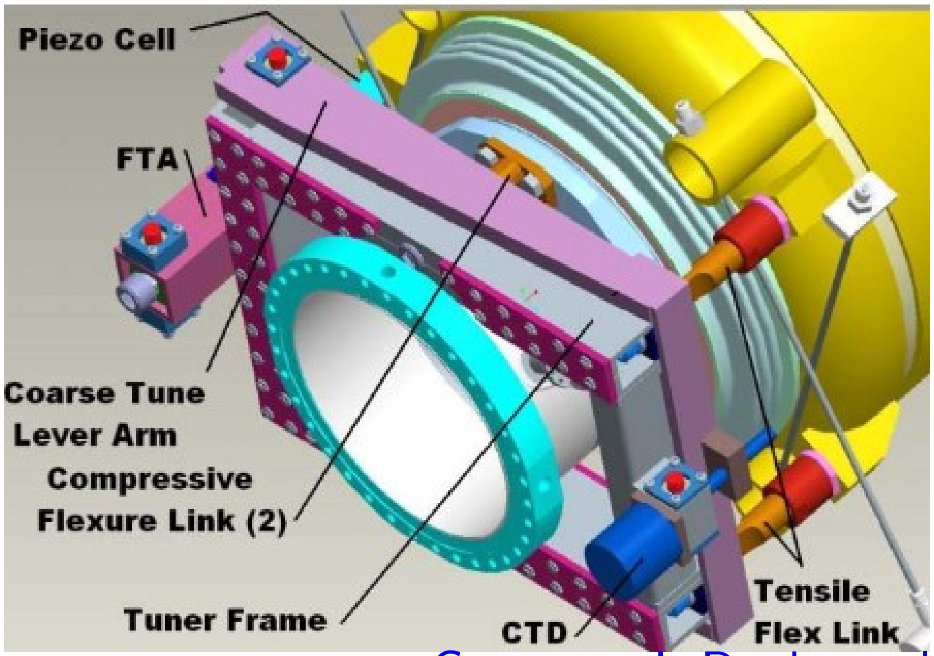


- Large beam-pipe, natural remedy
- Opposing couplers -or- stub -or- alternating couplers to make the transverse kick negligible



Static & Dynamic Tuning





Courtesy J. Rank et al.

Corrections:

- Chemical treatment & retuning
- 300k $\rightarrow$ 2k contraction
- Lorentz force detuning (static, ...)
- Microphonics, hysteresis, ...