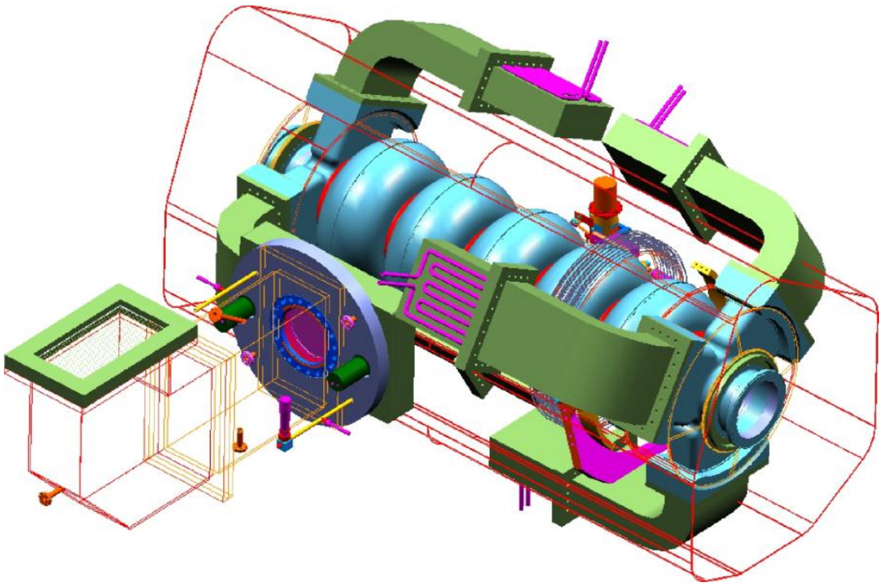
Waveguide HOM damping studies at JLab



R. Rimmer et. al. HOM10, Cornell

Outline

- Motivation
- Solution(s)
- 748.5 MHz version
- 1497 MHz version
- Future applications
- SPX crab cavity
  - HOM, LOM and SOM damping
  - On-cell alternative design
- Conclusions

Motivation

- 100 mA to “Ampere class” ERL for the Navy
- Compact design for shipboard FEL
  - High gradient, high packing factor
- Proven technology wherever possible
- R&D path consistent with Jlab capabilities and experience
- Eye to future light source projects for DOE

Requirements:

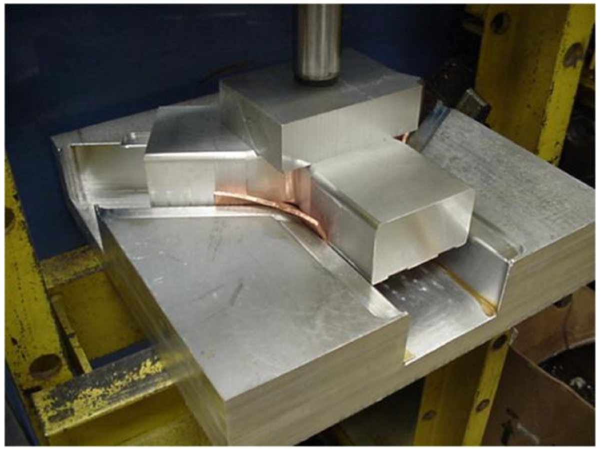
JLab Ampere-class module specifications.

Voltage	100-120 MV
Length	~10m
Frequency	748.5 MHz
Beam Aperture	>3” (76.2mm)
BBU Threshold	>1A
HOM Q’s	$<10^4$
Beam power	0-1MW

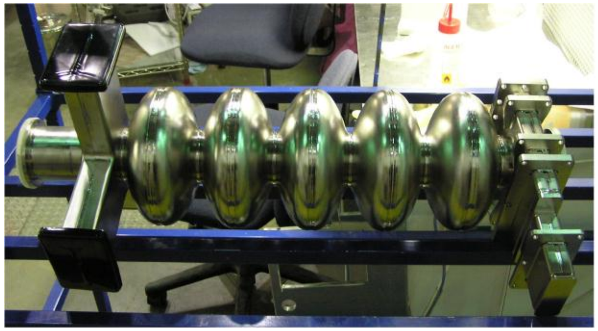
Plus: reasonable cryogenic cost, maintainability, flexibility

Why consider waveguides?

- Waveguide is a natural high-pass filter
- High power-handling capability
- Small beamline length required
- Loads can be at higher temperature
- Static loss is tolerable
- Good experience at PEP-II and CEBAF
- Easy to fabricate



Concepts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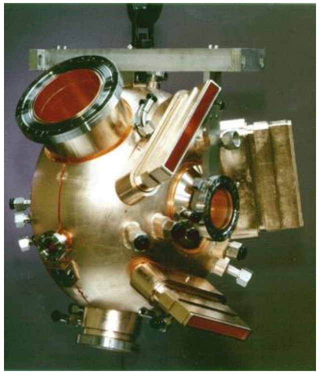
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Take the best from Jlab experience and high-current storage ring technology.

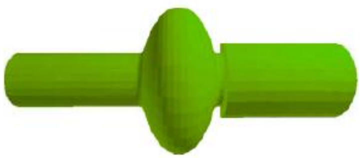
General layout:

- Symmetrical waveguide-damped 5-cell cavities.
- Six cavities per cryomodule at 16.7 MV/m - 20 MV/m.
- Good packing factor with real-estate gradient ~10-12 MV/m.
- HOM power dissipated at room temperature.
- Cell with a good HOM frequency spectrum.
- High-current optimized cell shape gives good efficiency

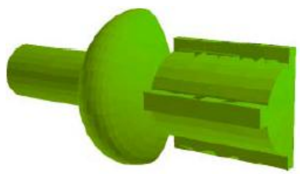
JLAB HC Cryomodule Development
Cavity Cell Shape and Number of Cells

- ❑ Wide range of cell shapes existing (e.g. High Gradient (HG), Low Loss (LL), Original Cornell, ILC)
- ❑ Storage ring light sources and colliders routinely operate with strongly damped single-cell cavities
- ❑ Various HOM damping schemes have been investigated for models at 1.5 GHz (MAFIA T3)

b-pipe

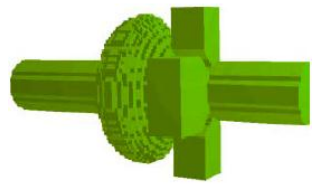


fluted



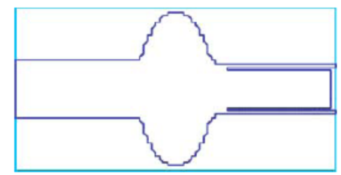
Enlarged (fluted) beam tube
(e.g. Cornell and KEK SRF cavity designs)

wguide



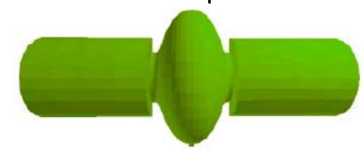
Waveguide dampers
(e.g. CEBAF OC)

bp-coax



Coaxial beam pipe dampers
(e.g. crab cavity for KEKB)

2 x bp



Enlarged beam tubes
on both sides

- ❑ Damping of monopole (TM_{011}) and dipole modes (TE_{111}, TM_{110}) can be efficient
- ❑ Comparably low Qs obtained for all concepts for most parasitic modes (monopole < 8 □ 10^2, dipole < 1.6 □ 10^3)
- ❑ All damping schemes principally suited for next generation ERL's

Table 1. TM_{011} mode for various damping methods

	freq MHz	Q	R* (Ω)	R/Q (Ω)
b-pipe	2803	252	3001	11.9
flutes	2803	137	1010	7.3
wguide	2800	353	5040	14.3
bp-coax	2783	725	11879	16.4
2xbp	2822	121	1481	12.2

$*R=V^2/2P$

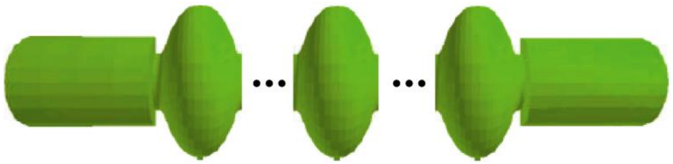
Table 2. Dipole modes for various damping methods

	TE_{111} f,MHz	TE_{111} Q	TE_{111} R*, (Ω)	TM_{110} f, MHz	TM_{110} Q	TM_{110} R* (Ω)
b-pipe	1853	83	246	2028	130	1567
flutes	1857	79	239	2029	130	1479
w-guide	1867	553	1594	2027	1131	14419
coax	1924	341	1496	2065	502	5150
2xbp	1830	37	192	2018	53	735

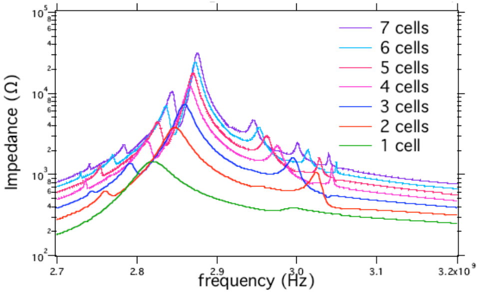
*R calculated at 25mm offset in the cavity

JLAB HC Cryomodule Development
Cavity Cell Shape and Number of Cells

- ❑ Study damping efficiency by adding cells (beam pipe loaded structure)



Enlarged beam tubes
(Original Cornell (OC) shape cavity cells)



TM_{011} passband mod vs. # cells

- ❑ Damping efficiency better in shorter structures

Table 3. Strongest TM_{011} passband mode vs # cells

#cells	freq MHz	Q	R* (Ω)	R/Q (Ω)
1	2822	121	1481	12.2
2	2848	167	3856	23.0
3	2860	219	7369	33.7
4	2866	295	12140	41.1
5	2870	362	17795	49.1
6	2873	455	24360	53.5
7	2876	527	31463	59.7

$*R=V^2/2P$

Table 4. Strongest TE_{111}/TM_{110} passband modes vs # cells

#cells	TE_{111} f,MHz	TE_{111} Q	TE_{111} R*, (Ω)	TM_{110} f, MHz	TM_{110} Q	TM_{110} R* (Ω)
1	1830	37	192	2018	53	735
2	1907	46	569	2101	2641	10103
3	1940	45	1193	2093	2023	14362
4	1867	94	1844	2101	4058	29270
5	1892	121	3232	2097	3233	40923
6	1910	139	4859	2102	5029	46740
7	1922	135	6088	2099	4177	72101

*R calculated at 25mm offset in the cavity

- ❑ However: Overhead length of HOM load(s) may reduce the real estate gradient of cryomodule (may want to share HOM loads with adjacent cavities)

JLAB HC Cryomodule Development
Cavity Cell Shape and Number of Cells

❑ Study effect of cell shape on coupling strength

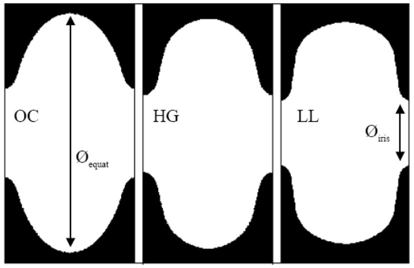


Figure 1: Geometry of three inner cells.

Parameter		OC	HG	LL
$Ø_{equator}$	[mm]	187.0	180.5	174.0
$Ø_{iris}$	[mm]	70.0	61.4	53.0
k_{cc}	[%]	3.29	1.72	1.49
E_{peak}/E_{acc}	[-]	2.56	1.89	2.17
B_{peak}/E_{acc}	[mT/(MV/m)]	4.56	4.26	3.74
R/Q	[Ω]	96.5	111.9	128.8
G	[Ω]	273.8	265.5	280.3
R/Q·G	[Ω·Ω]	26422	29709	36103

Proceedings of the 2003 Particle Accelerator Conference

CAVITIES FOR JLAB'S 12 GEV UPGRADE

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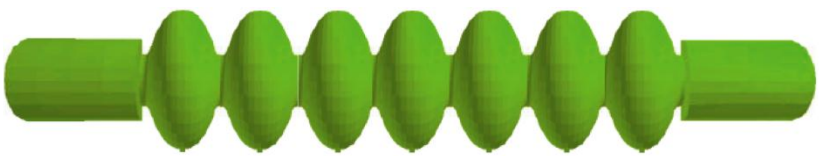
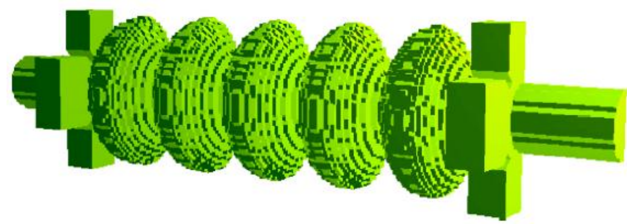
❑ 7-cell cavities with open beam tubes



7-cell OC, HG and LL cavity



5-cell OC with waveguide damping endgroups

Table 5. TM_{011} mode data for multi-cell cavities.

	#cells	Freq,MHz	Q	R† (Ω)	R/Q (Ω)
OC	7	2876	527	31463	59.7
HG	7	2876	1348	90380	67.0
LL	7	2629	985	53556	54.4
OC	5	2870	362	17795	49.1
OC*	5	2871	707	35453	50.1

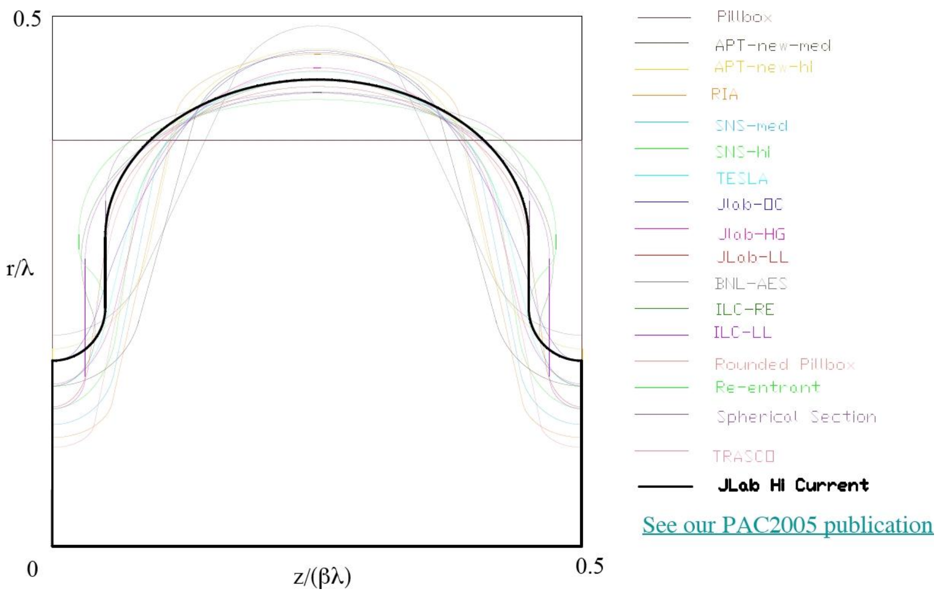
*waveguide damped †$R=V^2/2P$

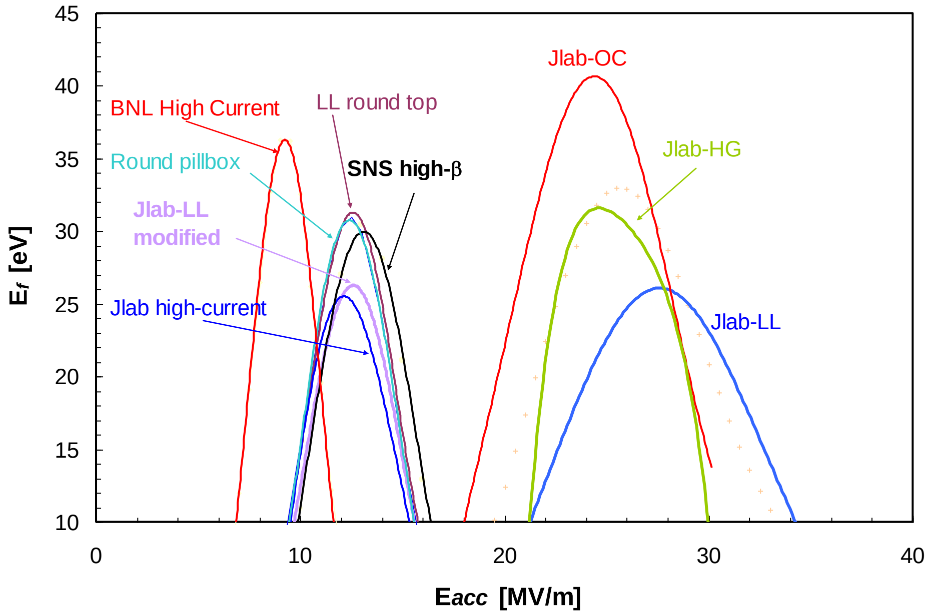
Table 6. TE_{111}/TM_{110} mode data for multi-cell cavities.

	# cells	TE_{111} f,MHz	TE_{111} Q	TE_{111} R†, (Ω)	TM_{110} f, MHz	TM_{110} Q	TM_{110} R† (Ω)
OC	7	1922	135	6088	2099	4177	72101
HG	7	2014	185	11359	2156	5694	146409
LL	7	2021	490	14107	2209	2071	39510
OC	5	1892	121	3232	2097	3233	40923
OC*	5	1894	956	22949	2103	3274	47064

*waveguide damped †R calculated at 25mm offset in cavity.

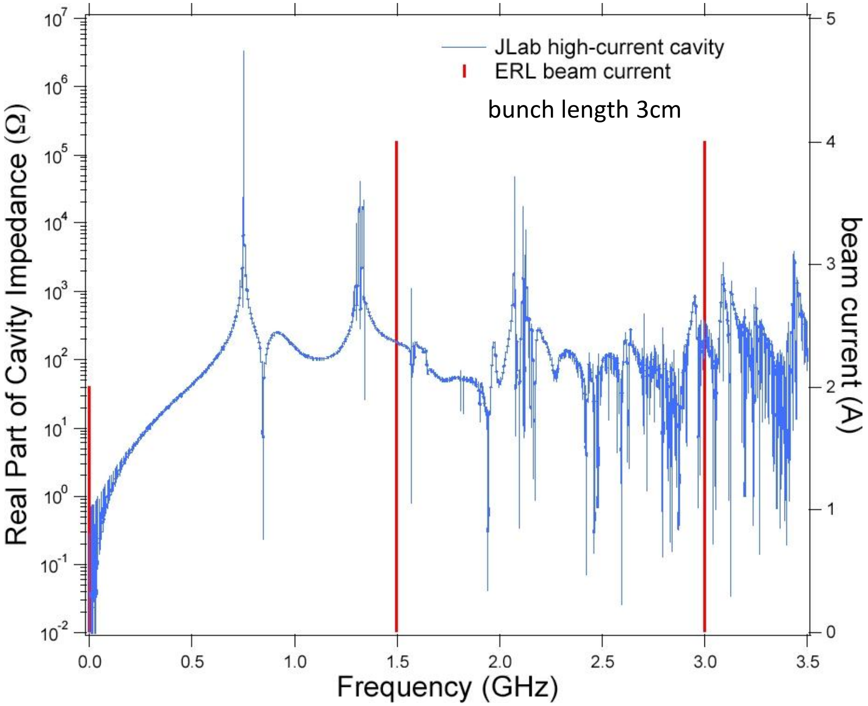
Cavity cell shape optimization concept for High Current



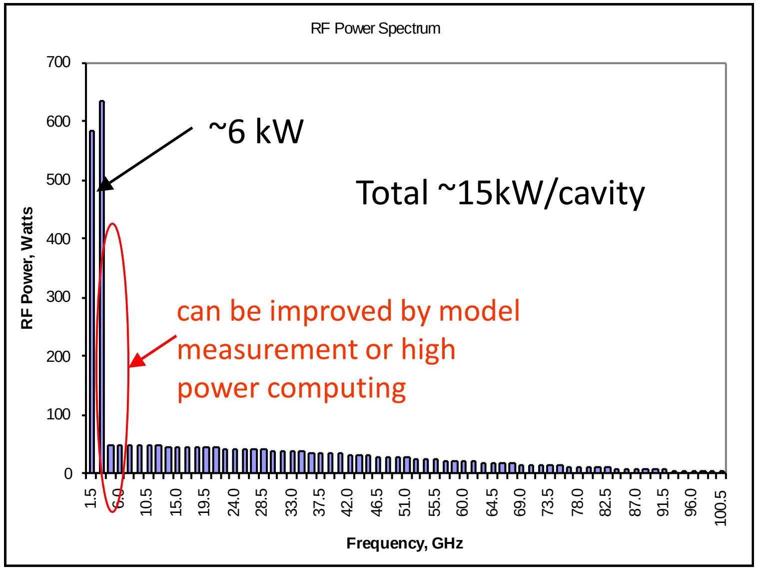


- Optimize shape to keep trapped HOMs (below beam pipe cut-off frequency) away from beam resonance to avoid huge HOM power.
- Preserve reasonable fundamental mode efficiency but maintain the iris size to give good HOM damping.
- Optimized shape also has to avoid multipacting barriers.

Estimation of total HOM power extracted from the beam



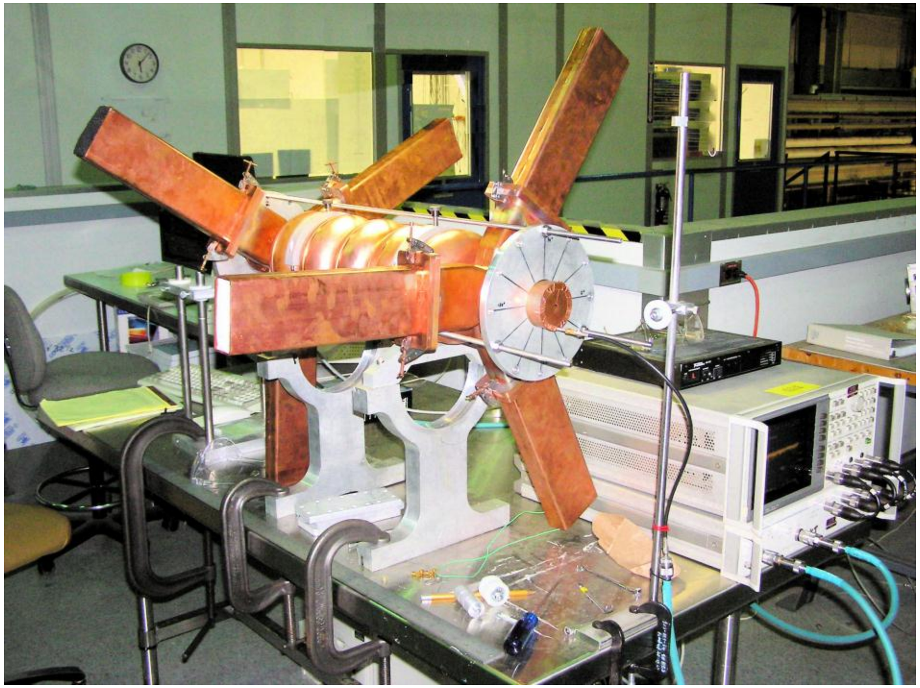
Monopole modes excited by on-axis beam

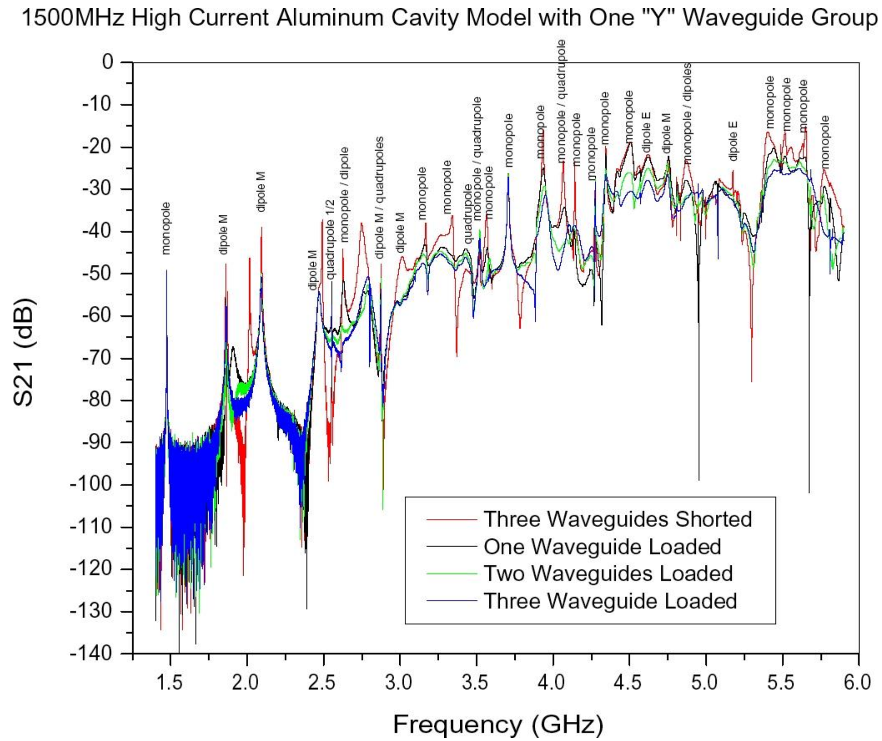


High-frequency tail estimated from broad-band impedance (loss parameter). Below cut-off from calculated impedance spectrum. In between is uncertain so round up to ~20 kW.

beam excitation Frequency (GHz)	monopole modes only impedance (Ω)	dipole modes only impedance (Ω) at 1cm off-axis	beam peak current (A)	Monopole HOM power (W)	Dipole HOM power (W)	beam power (W)
1.497	180.713	2.326	4.000	2891	37	2929
2.994	196.794	1.578	4.000	3149	25	3174

Copper 5-cell model measurement and data fitting techniques



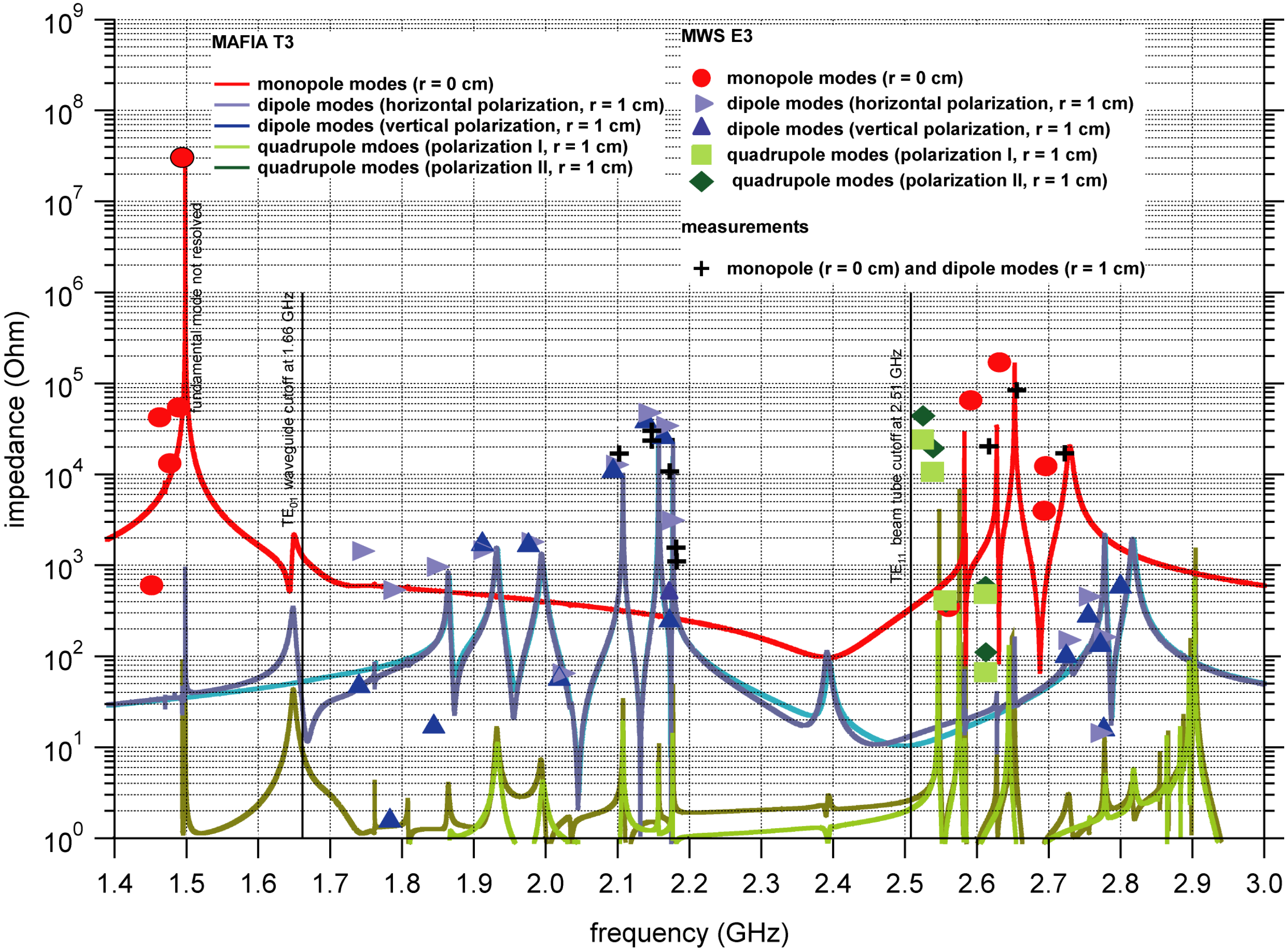


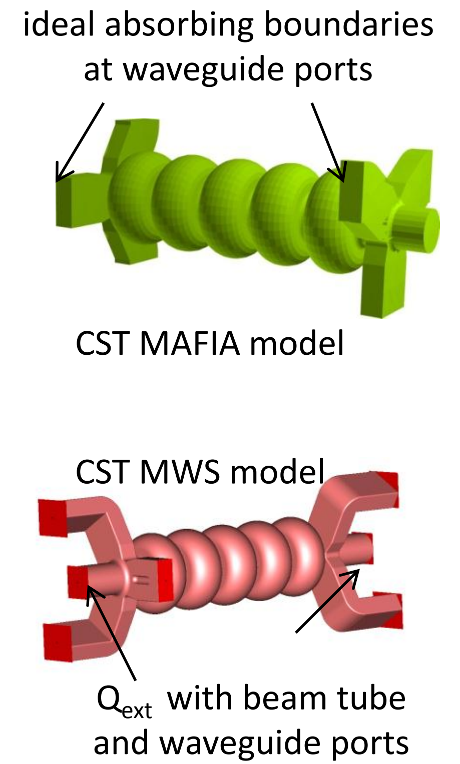
- S21 from beam pipe to beam pipe.
- Labview automation.
- Ceramic bead-pull on-axis or off-axis.
- End groups staggered 30^{o} or 60^{o}.
- 5, 6, 7-cell assembly.
- Data sets with dummy loads or shorts.
- Rotatable coupling antennas.

- Data set can be fitted by the 5-peak fitting algorithm first developed at LBNL to get freqs and Qs and amplitudes.
- Data analysis for mode successful
- BBU threshold needs to be verified in compact lattice.

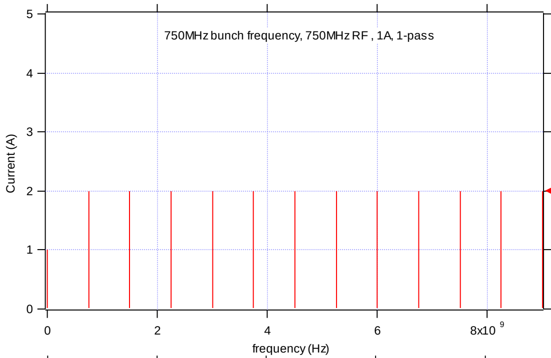
JLAB HC Cryomodule Development
Broadband HOM Damping Efficiency

- ❑ Most parasitic HOMs measured on warm model (“2 bead-pull measurement method”)
- ❑ Simulation also performed with Eigenmode solver of CST Microwave Studio (MWS)
- ❑ Conclusion: HOM damping requirements can be met to support Ampere-level of current
- ❑ Simulation and measurement in good agreement



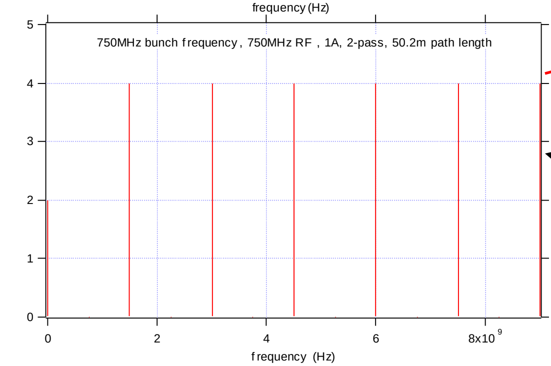


Beam excitation spectrum depends on operation modes



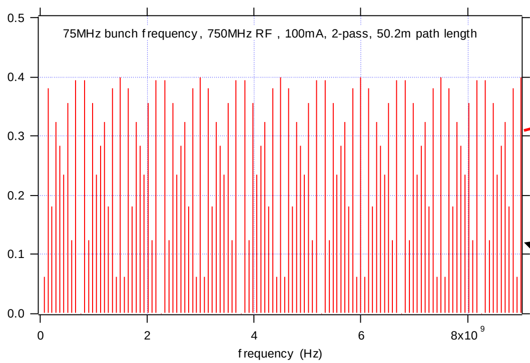
750MHz laser, 750MHz RF
1A, 1-pass.

Single pass beam
(every bucket filled)



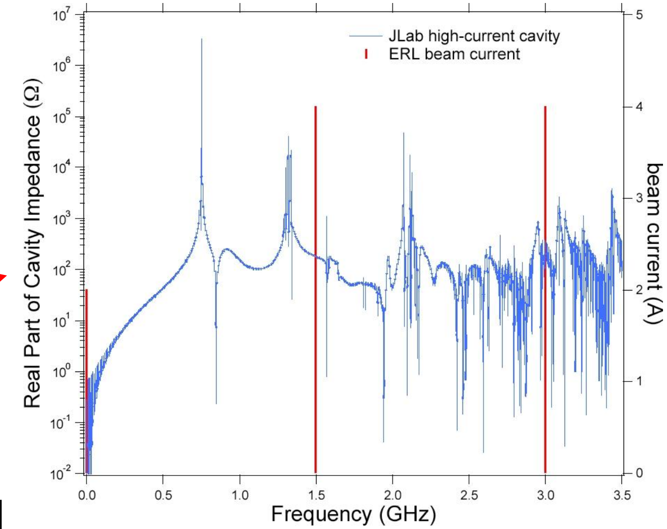
ERL (every bucket filled)

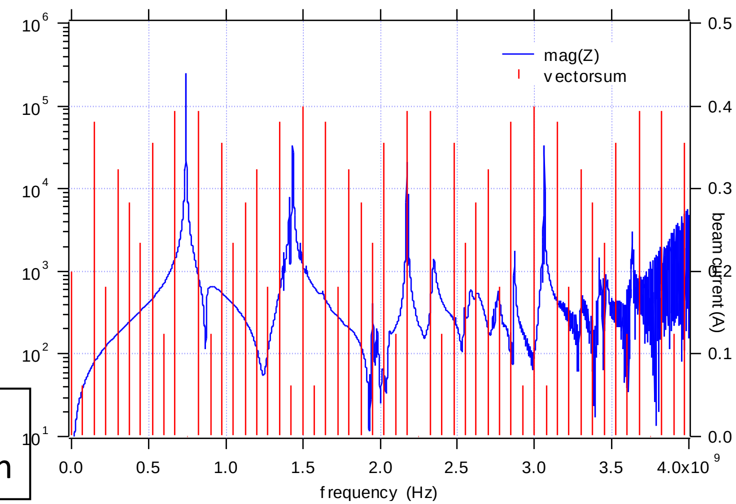
750MHz laser, 750MHz RF
1A, 2-pass, 50.2m path length



ERL (sparse fill)

75MHz laser, 750MHz RF
100mA, 2-pass, 50.2m path length





See JLAB TN-05-047

Jlab Cryomodule experience

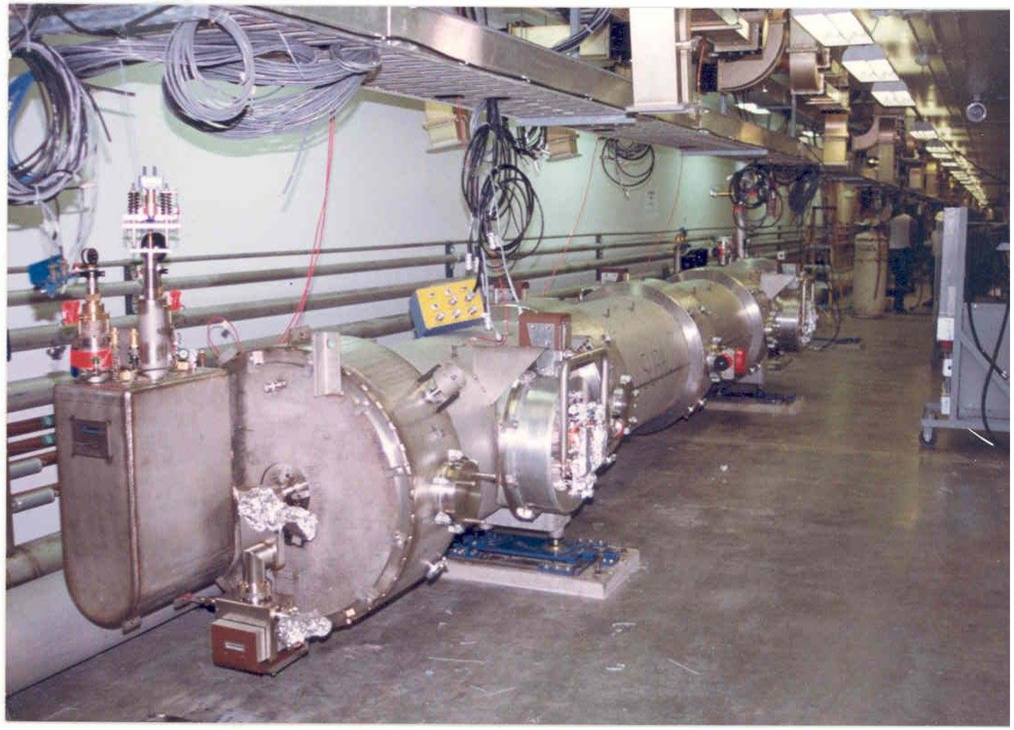
JLab has built ~74 Cryomodules of ~6 different types and built or processed >500 Multi-cell cavities.

CEBAF Cryomodules

6 GeV CEBAF

- 50 MV(after rework)
- 12.5 MV/m CW average
- 1497 MHz
- 5-cell cavities
- Waveguide HOMs
- ~25 mA capable*
- 6 kW FPC's
- Modular construction
- Waveguide FPCs
- Dog-leg cold waveguides

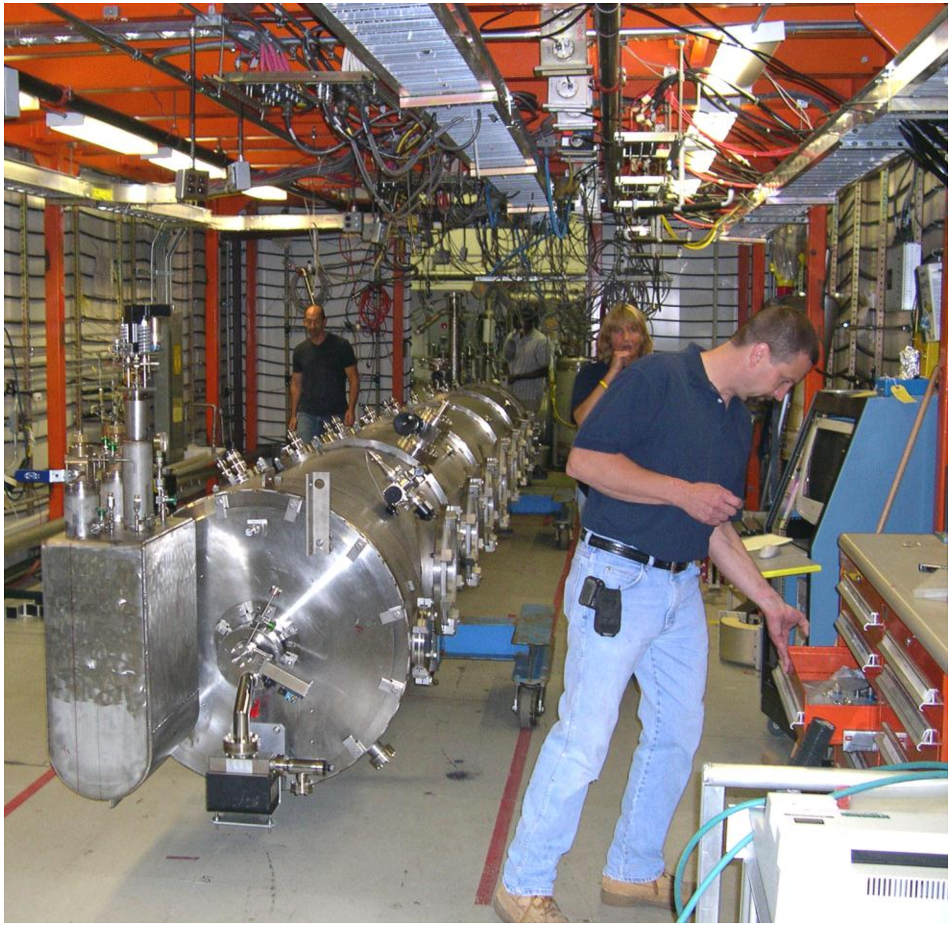
*in Jlab ERL/FEL



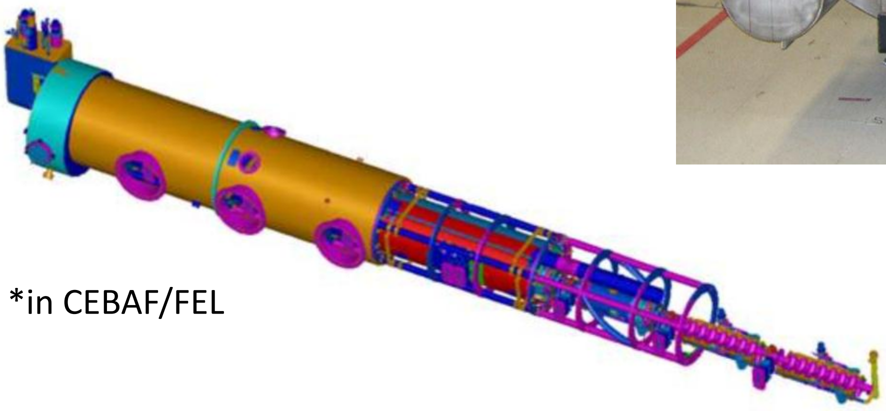
CEBAF cryomodules

12 GeV upgrade

- 100 MV
- 20 MV/m CW
- 1497 MHz
- 7-cell low-loss cavities
- TESLA type HOMs
- ~1-10 mA capable*
- 13 kW FPC's



“Renascence” in test cave

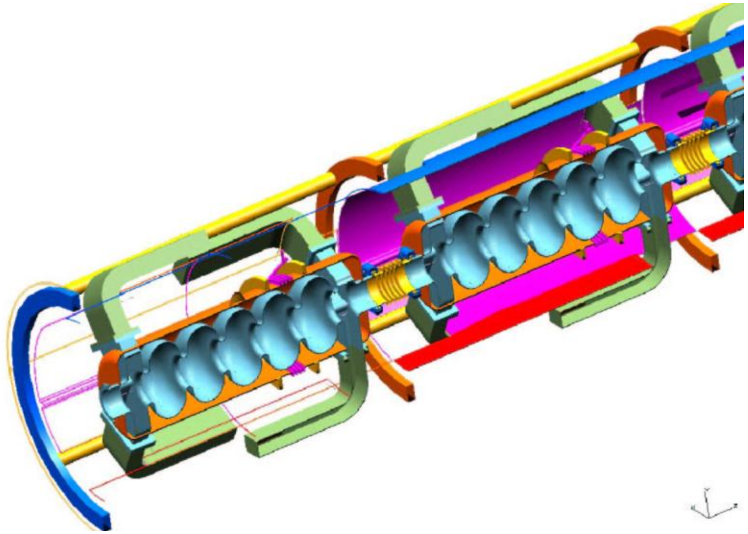


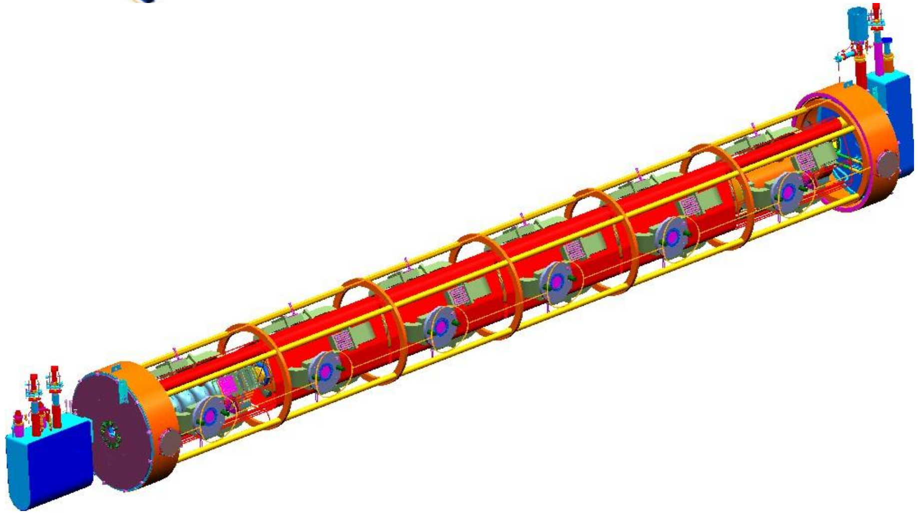
*in CEBAF/FEL

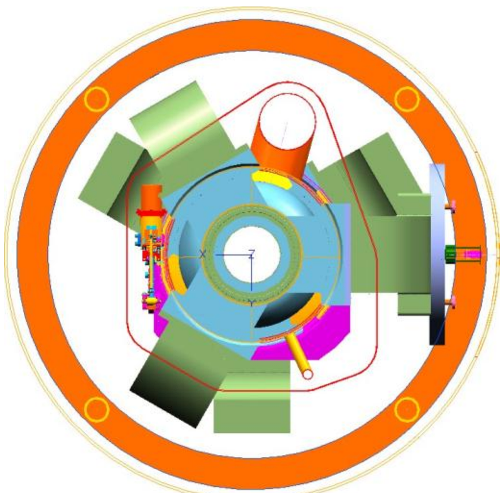
General layout

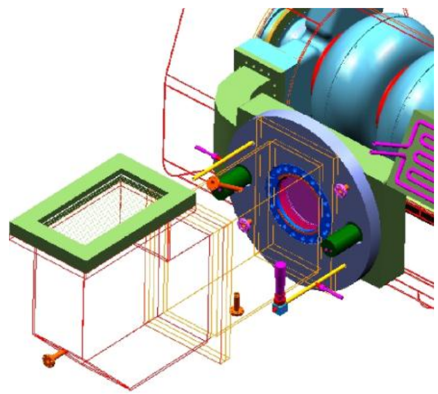
750 MHz cryomodule with six five-cell cavities with waveguide damping

Frequency	750 MHz
# cells	5
Damping Type	Waveguide
Cavity Length	1.4m
Iris Diameter	14 cm (5.5”)
# Cavities	6
Min. Module Length	10.4m
Nominal Module Voltage	100 MV (120 MV peak)
Cavity Gradient (Eacc)	16.7 MV/m (20 MV/m max)
Real Estate Gradient	~10 MV/m
TE_{111} freq, Q_{ext}	947 MHz, 9.5e2
TM_{110} freq, Q_{ext}	1052 MHz, 3.3e3
TM_{011} freq, Q_{ext}	1436 MHz, 7.1e2
HOM Power/Cavity	~20 kW(est)
BBU Threshold	>1A

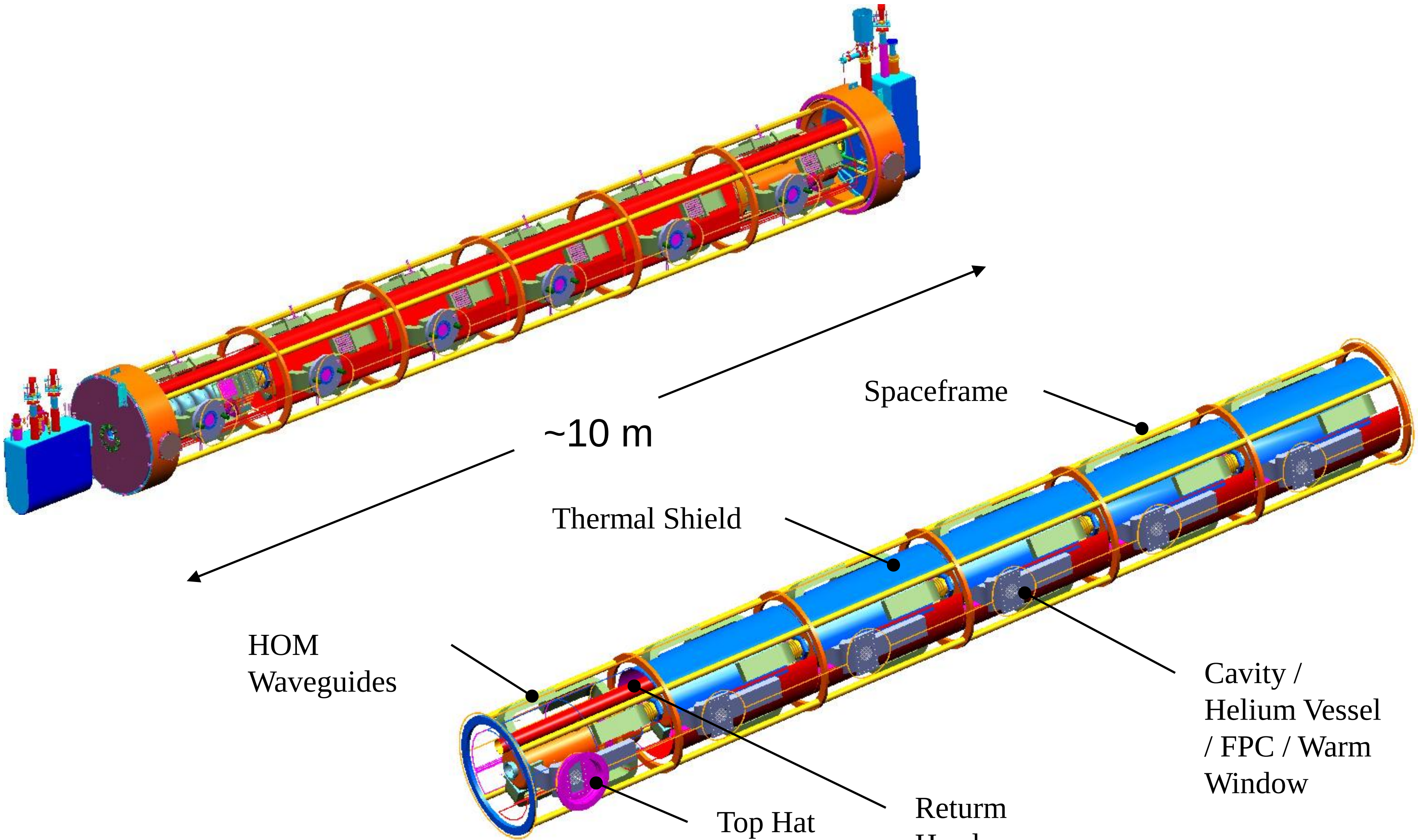








Jlab Ampere-class Cryomodule Concept

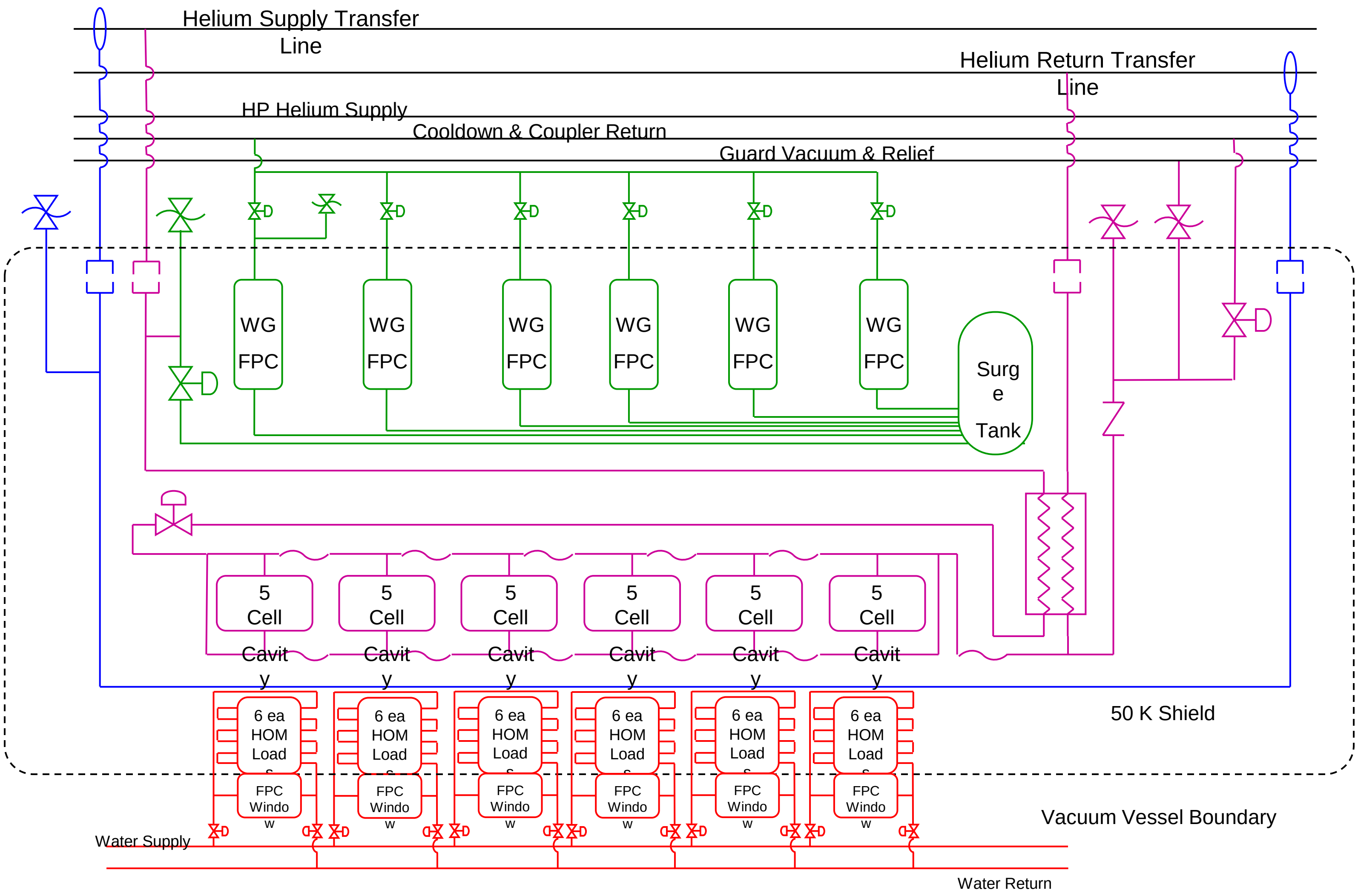


Preliminary Heat Load Estimates (748.5 MHz)

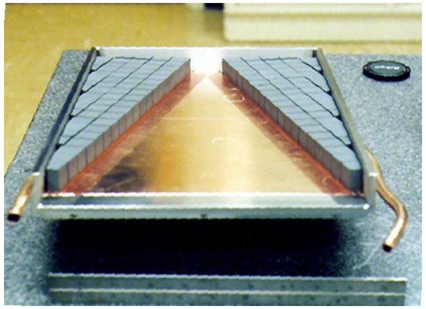
	2 K	50 K
Static	73 W	362 W
(mainly FPC and HOMs)		
Includes u-tubes (10 W @ 2K, 30 W @ 50 K)		
May be improved?		
Dynamic	382 W	188 W
(cavity FPC and HOM RF losses)		
Total	455 W	550 W

Coupler Cooling ~ 1 gram/sec cool outer conductors

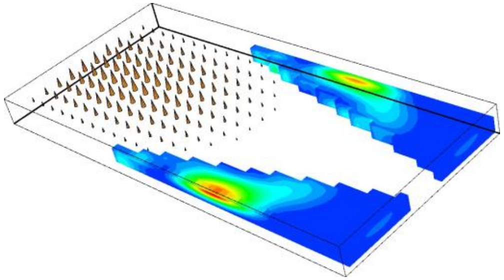
Cryomodule Flow Schematic



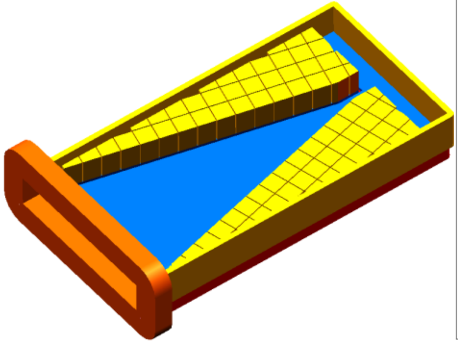
HOM load and window based on existing designs



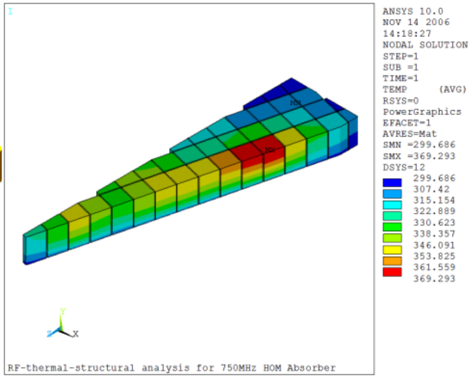
PEP-II HOM load



MAFIA model

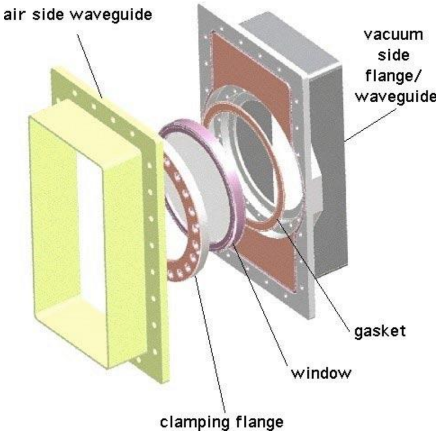


748.5 MHz version

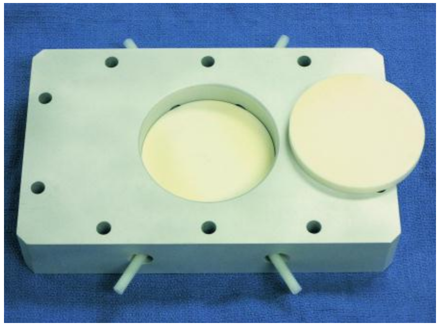


ANSYS multiphysics analysis

PEP-II window 476 MHz (WR2100)



LEDA 700 MHz, 1 MW (WR1150)



Cold model 1.3-1.5 GHz (WR650)

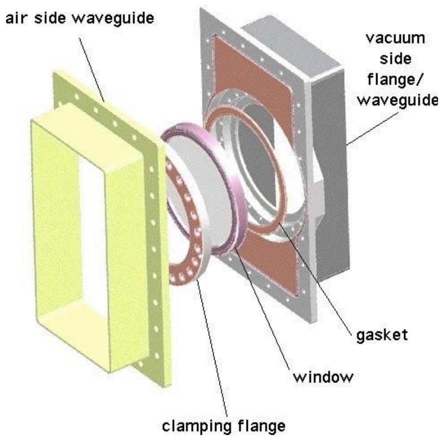
First Jlab built pre-stressed window

Fundamental power coupler for 1 A CM

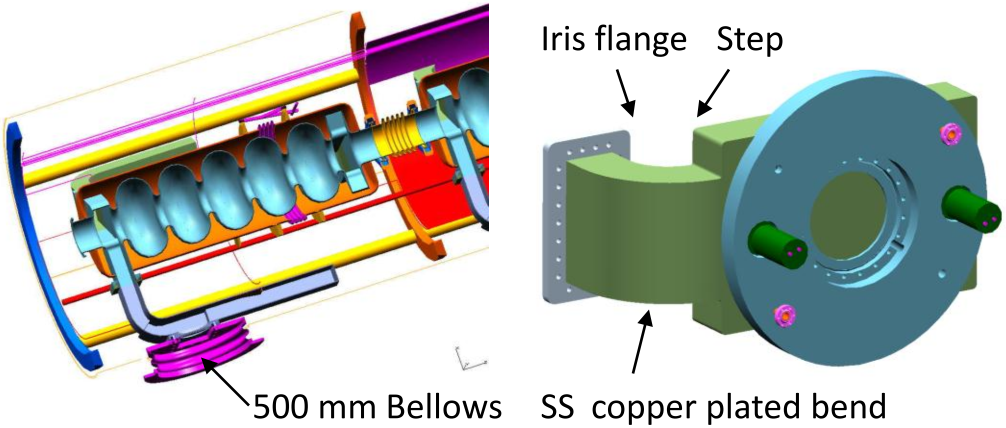
- Operating frequency: **748.5 MHz**
- Max FWD RF power **200 kW CW***
- Sustain local peak RF power of **800 kW**
- No line of sight from the beam to the ceramic window
- Adopt proven pre-stressed waveguide window design
- Coupling set by distance from beam center line to waveguide step

* could go higher because of transient demands

PEP-II window 476 MHz
600 kW, (WR2100)

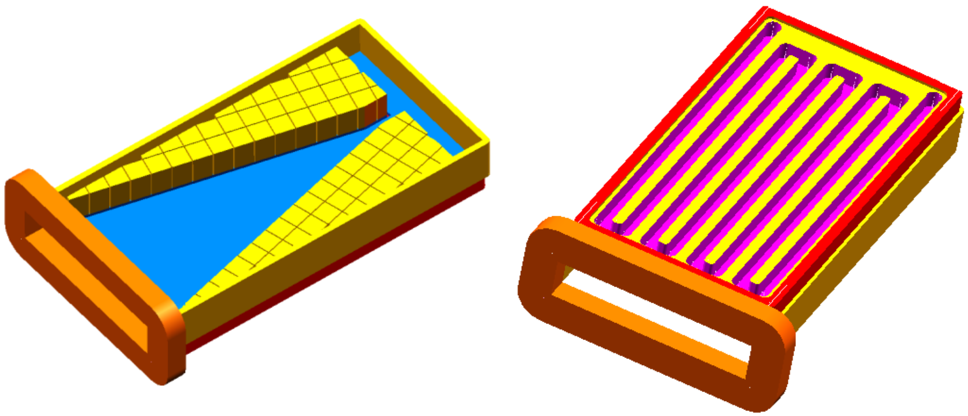


LEDA 700 MHz, 1 MW
(WR1150)



1ACM 748.5MHz concept

HOM load



High-power HOM load concept

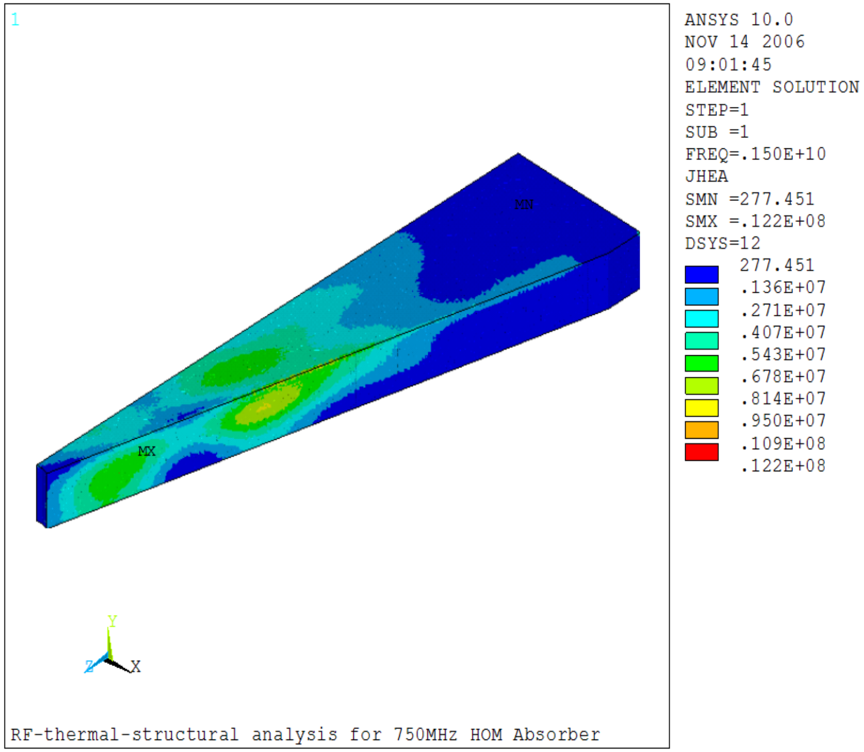
- **RF heat summary**

Freq. GHz	Input Power, W	Dielectric Loss, W	Surface loss, W	Total power loss, W
1.497	1775.200	1764.876	7.7799	1772.6557
2.994	1923.921	1909.972	8.6038	1918.5754
4.5	150.700	149.195	0.8314	150.0267
6	150.179	148.113	1.0018	149.1147
Sum	**4000**	3972.156	18.217	**3990.372**

99.5% of the RF heat is absorbed in tiles. Only ~0.5% surface heat loss.

- **Joule heat densities**

Joule heat densities at the interested four frequencies are calculated and superimposed for thermal analysis.

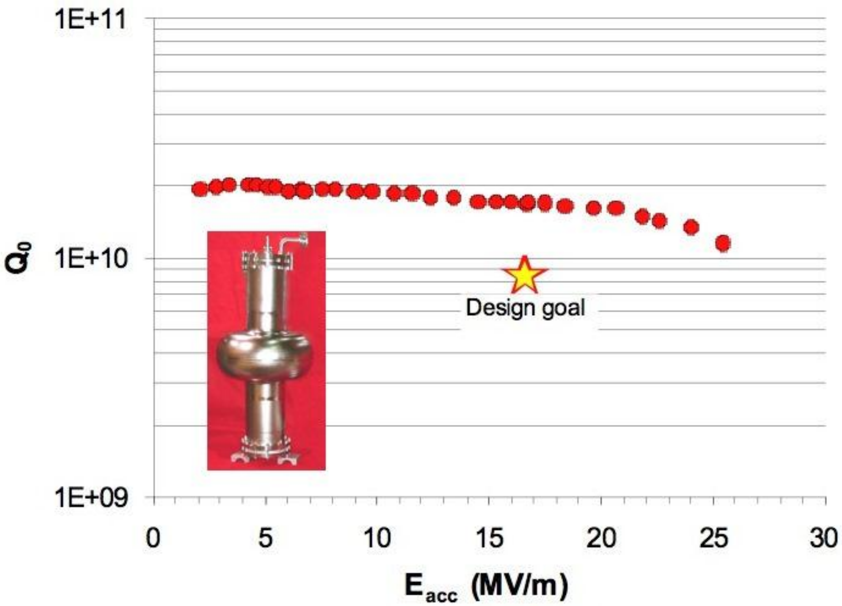


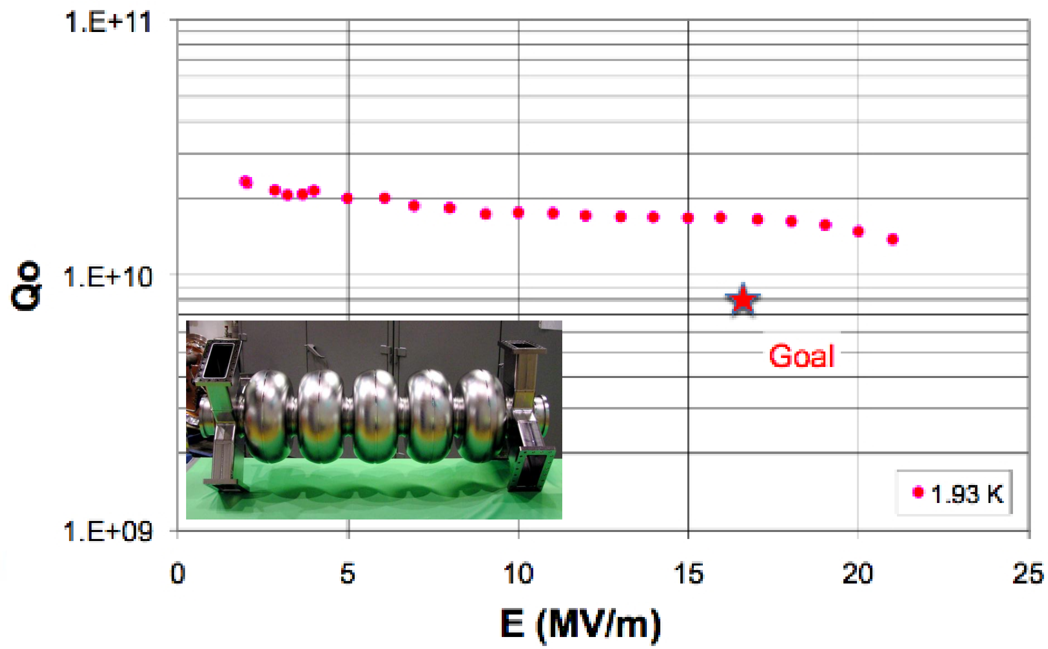
Thanks to the JLAB "High Current" Team

From left to right:

H. Wang
P. Kneisel
F. Marhauser
R. Rimmer
T. Elliot
K. Smith
E. Daly
G. Cheng
B. Manus
L. Turlington
S. Manning
B. Clemens
M. Stirbet

748.5 MHz HC first tests



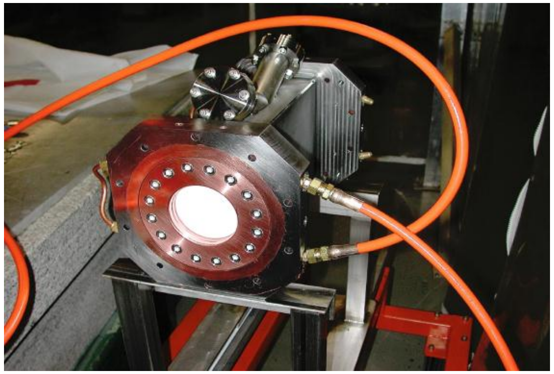


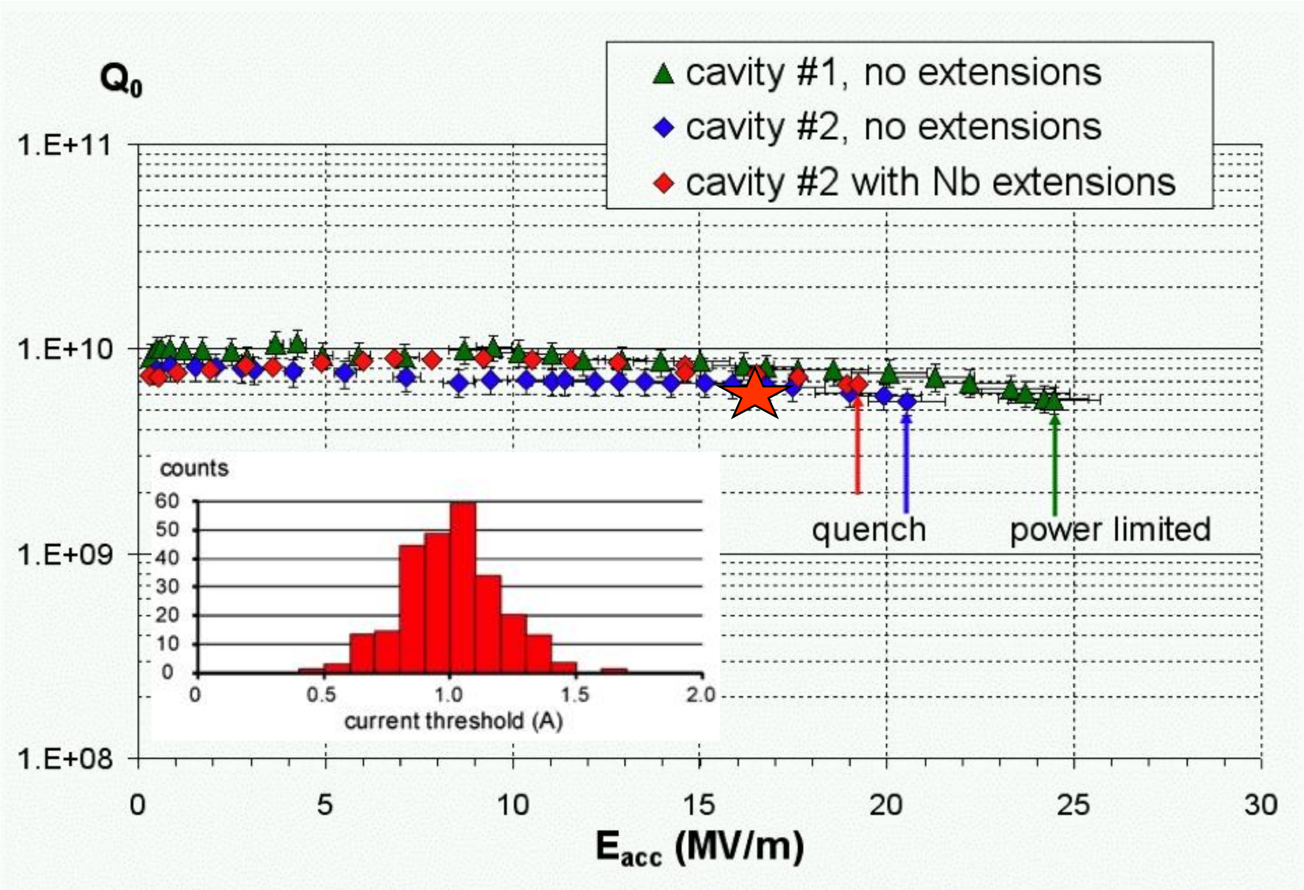
No Multipacting, RF power limited
Bulk BCP + 600C furnace outgass + light BCP

Multipacting seen from 3 MV/m but processed away in a few hours. FE/RF power limited.
Bulk BCP only, no furnace outgas

JLab 1497 MHz high-current cryomodules

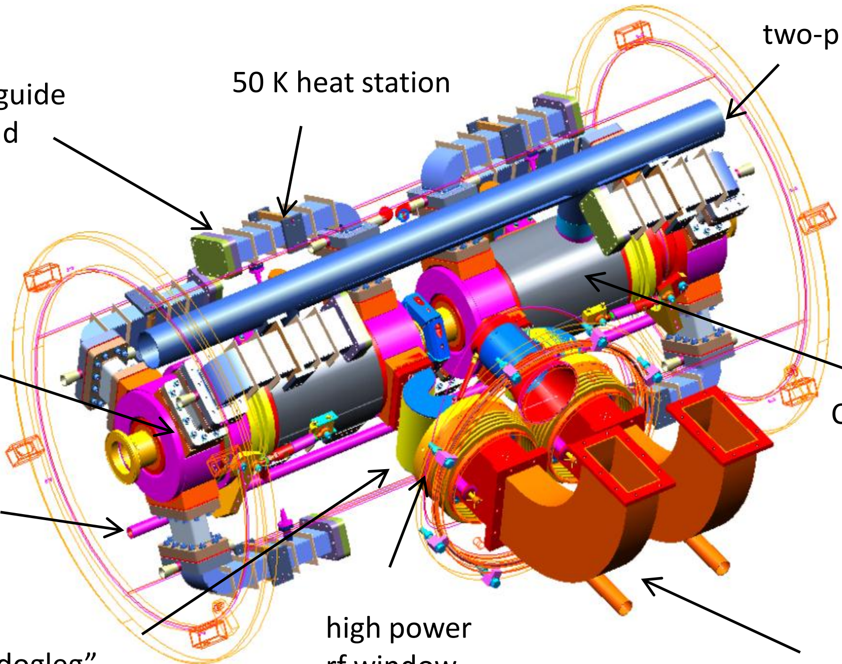
- Two half-scale prototypes of FEL high current cavity built and tested
  - Results exceed requirements for 4th gen. light source
  - Planned to build demo cryounit for beam test in FEL.

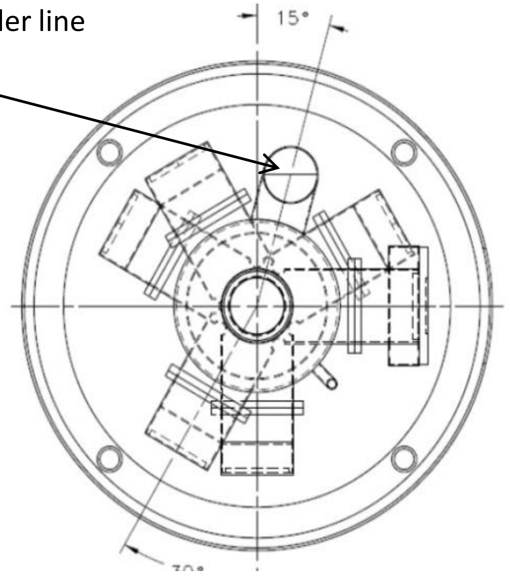




JLAB 1497 MHz HC Cryomodule Development

HC optimized cell shape, 5 cells, WG FPC, WG HOMs
Planned for beam test in JLab FEL in 2010 (funding lost)



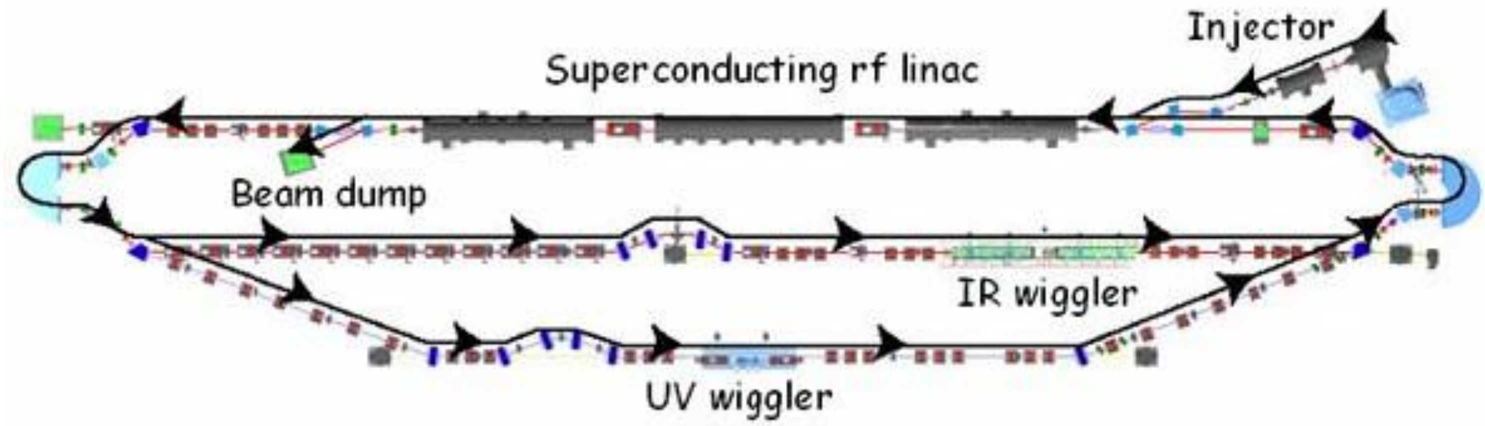


Conceptual design of a cavity-pair injector cryomodule (L=2.6m)

F. Marhauser ERL09

JLab 10 kW FEL

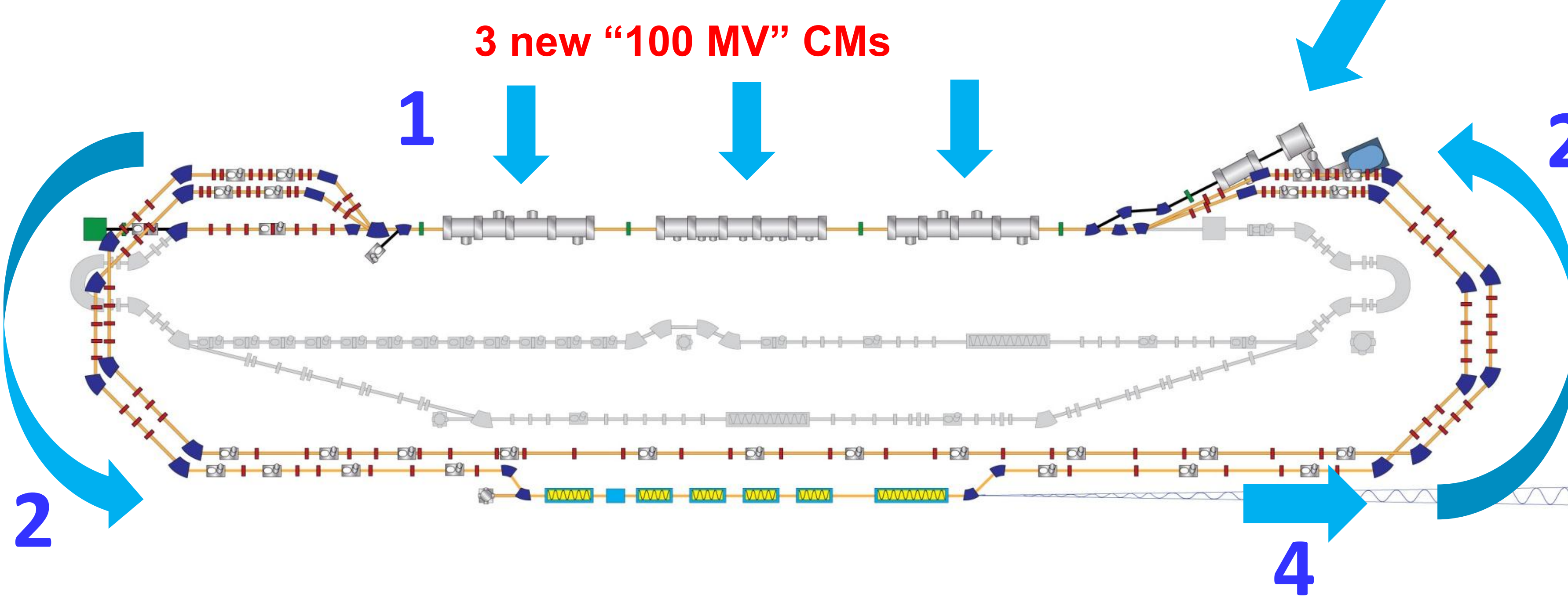
- Fourth-generation light source with energy recovery
- The IR branch is operational (14 kW world record), while the UV branch is now under commissioning.



	IR Branch	UV Branch (under construction)
Wavelength range (microns)	1.5 – 14	0.25 - 1
Bunch Length (FWHM psec)	0.2 - 2	0.2 - 2
Laser power (kW)	> 10	> 1
Repetition Rate (cw operation, MHz)	4.7 – 75	4.7 - 75

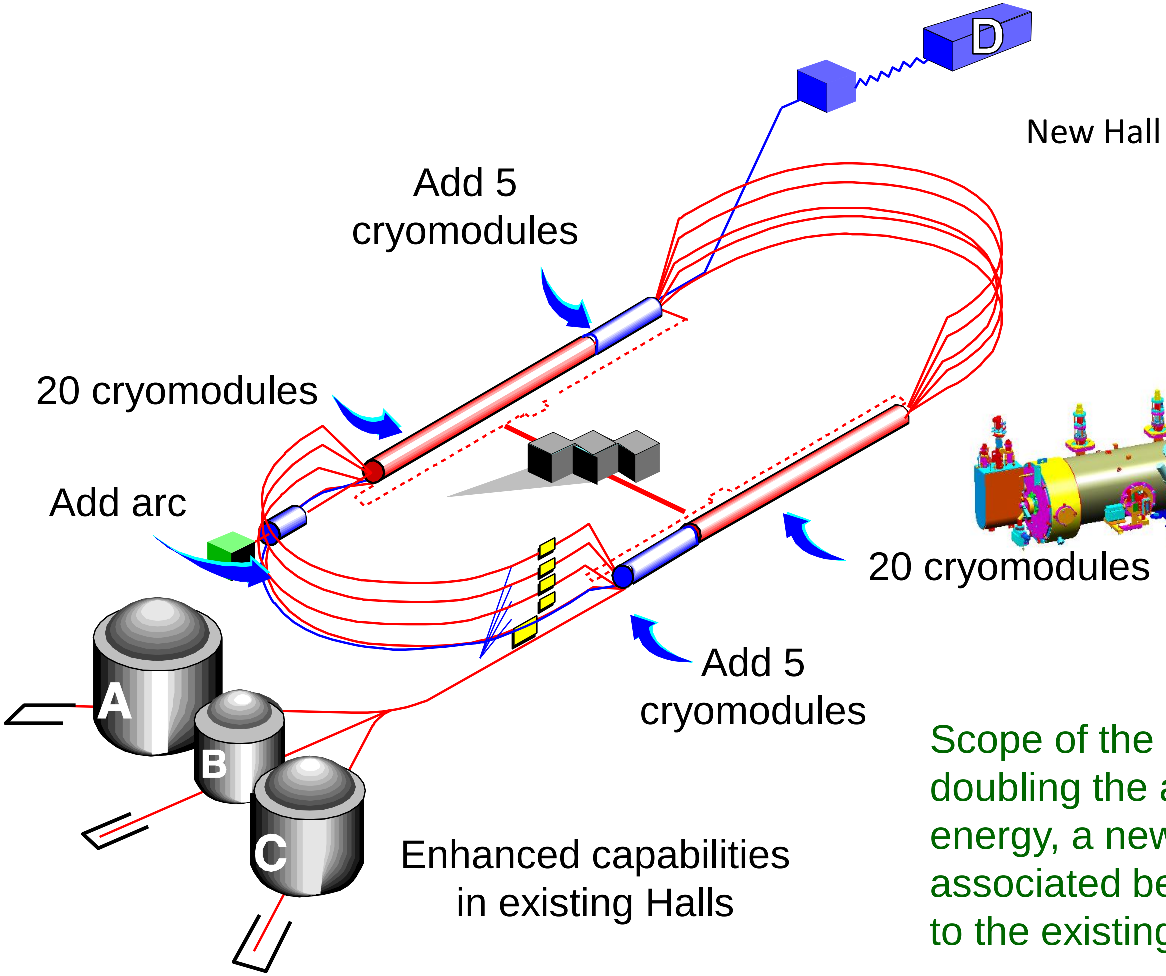
Proposed: JLab FEL Conversion to JLAMP

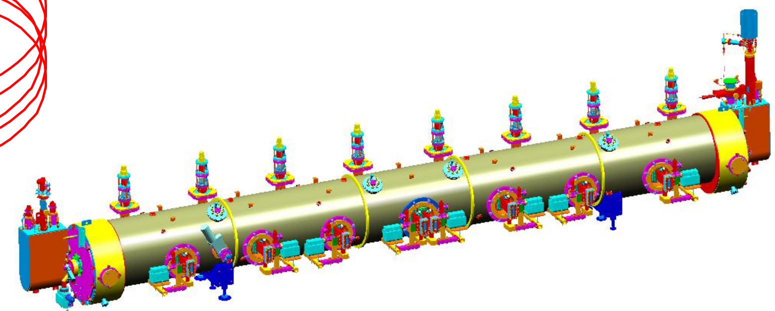
- **4 steps**
- **600 MeV, 2 pass acceleration**
- **200 pC, 1 mm mrad injector**
- **Up to 4.68 MHz CW repetition rate**
- **Recirculation and energy recovery**
- **10 eV – 100 eV fundamental output, harmonics to 2nm**
- **Pulse widths down to 50 fs**



SCOPE OF 12 GeV UPGRADE

Upgrade is designed to build on existing facility:
vast majority of accelerator and experimental equipment have continued use

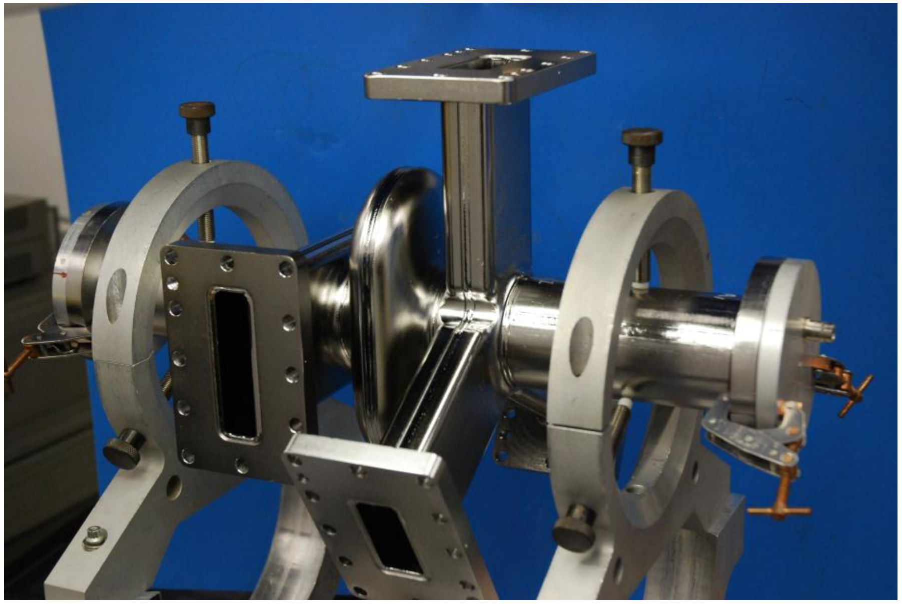




Scope of the proposed project includes doubling the accelerator beam energy, a new experimental Hall and associated beamline, and upgrades to the existing three experimental Halls.

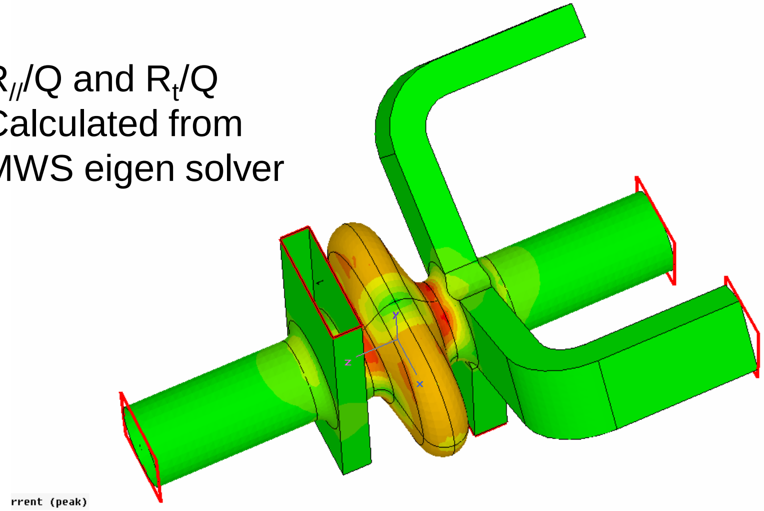
New applications

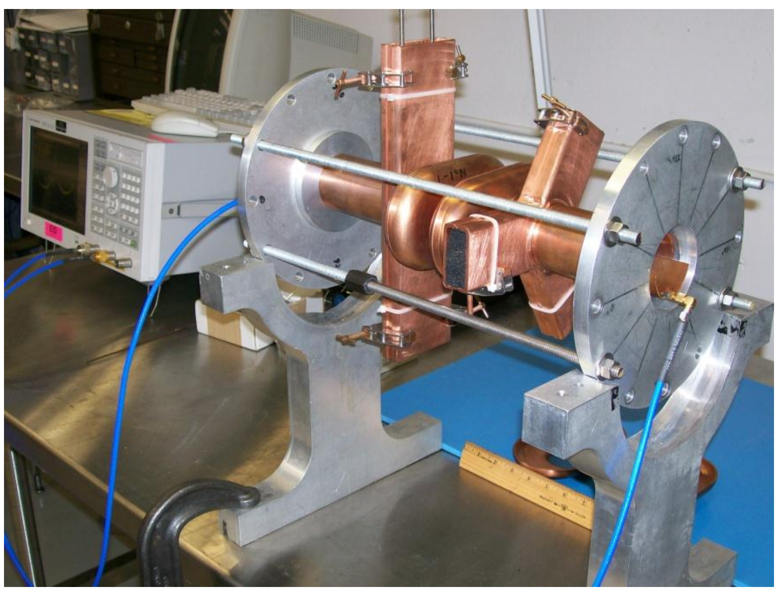
- ANL SPX baseline cavity
  - Up to 200 mA, 2x 8-cavity CM required
  - Strong HOM/LOM/SOM damping required
  - Possibility of moderate HOM power to loads
  - Short space available

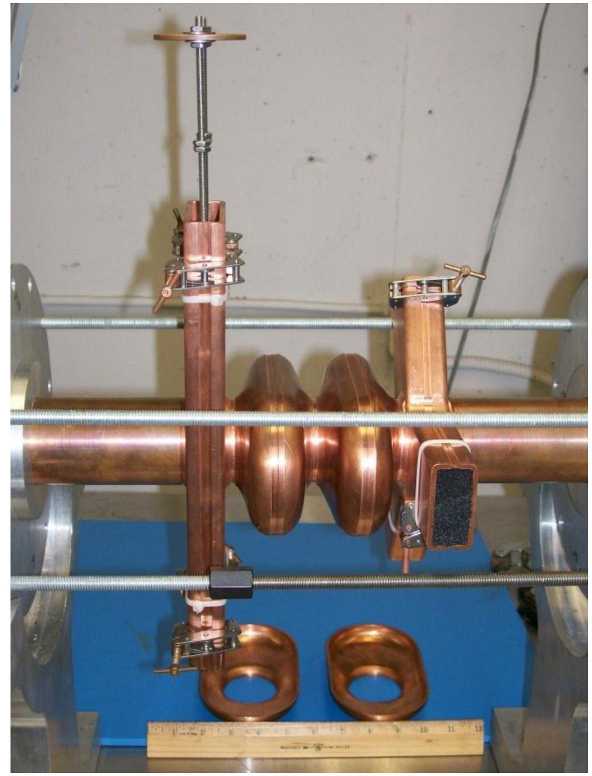


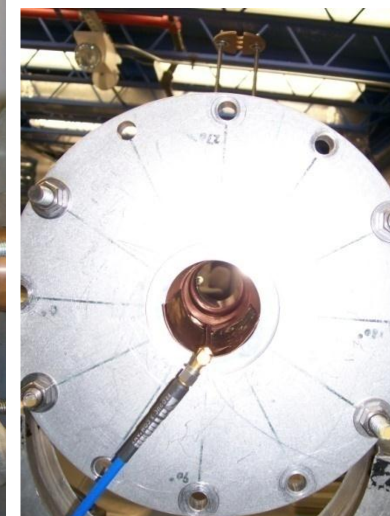
Copper prototype, first reported in ICFA Shanghai Workshop, April, 2008

$R_{//}/Q$ and R_t/Q
Calculated from
MWS eigen solver







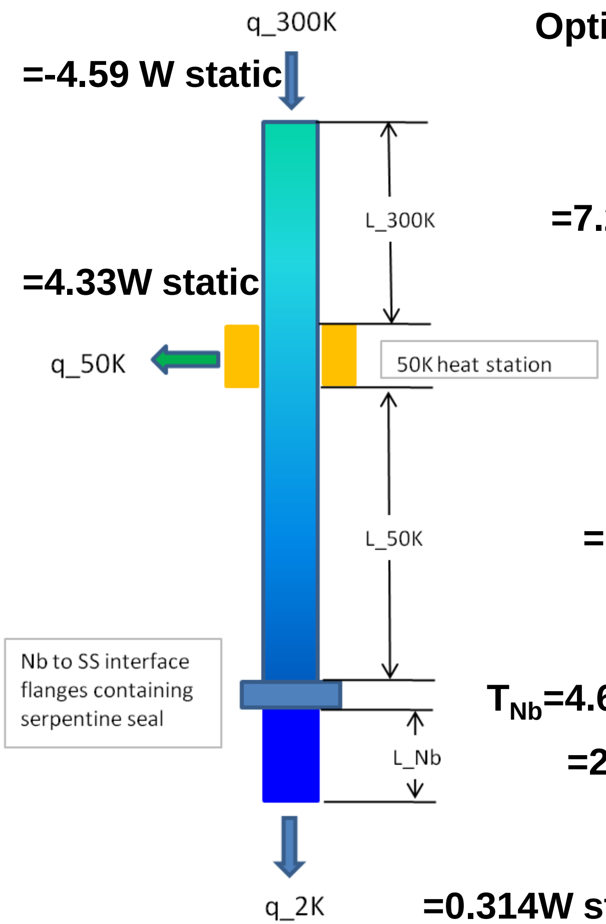


Bench Qext measurement by using

- RF absorbers on WG ports
- Clamping copper parts (low contact loss)
- Weak coupling to VNA
- Rotatable antennas to suppress the unwanted modes.

Single-cell cavity LOM/HOM WG damper cryostat solution update

1-D RF-thermal model with SS WG, flange interface (AlMg seal) and heat station for HOM waveguides



Optimized lengths

=-4.59 W static

=7.25 inch

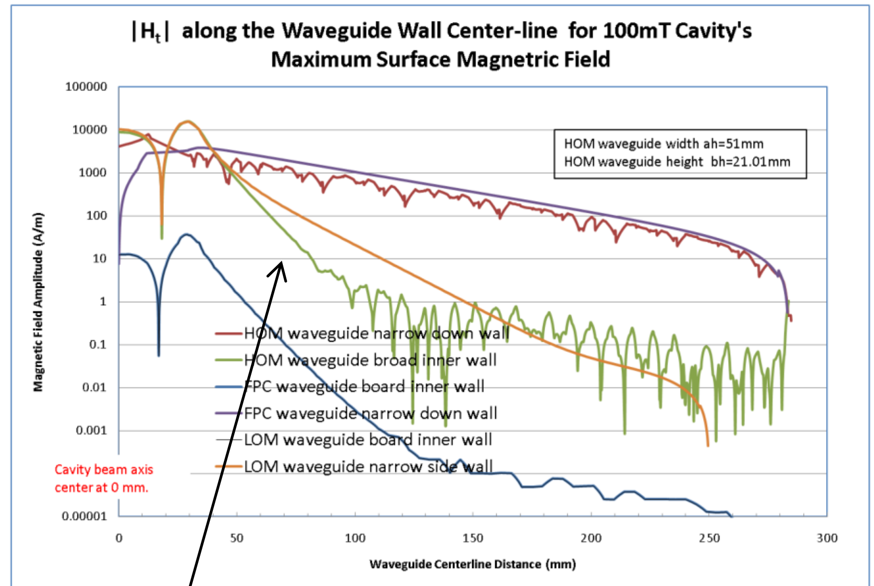
=4.33W static

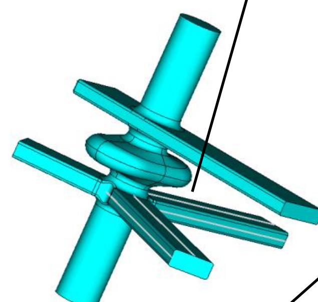
=12.25 inch

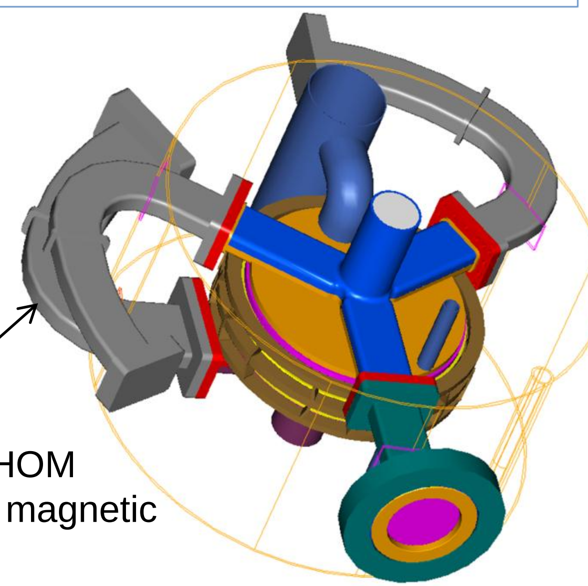
T_{Nb}=4.61K (max)

=2 inch

=0.314W static

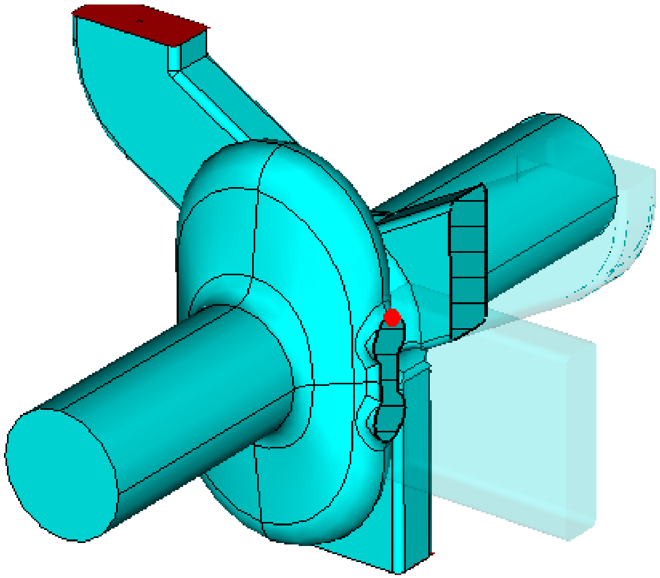


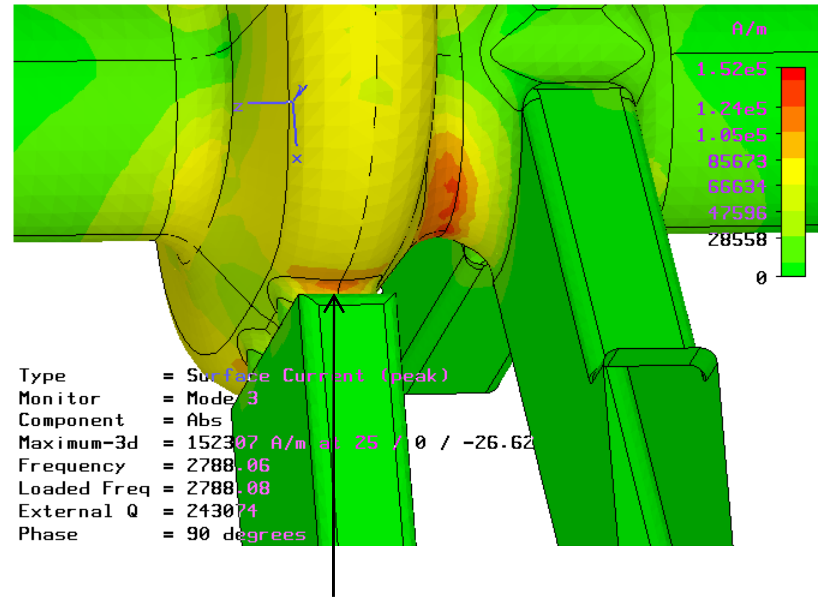




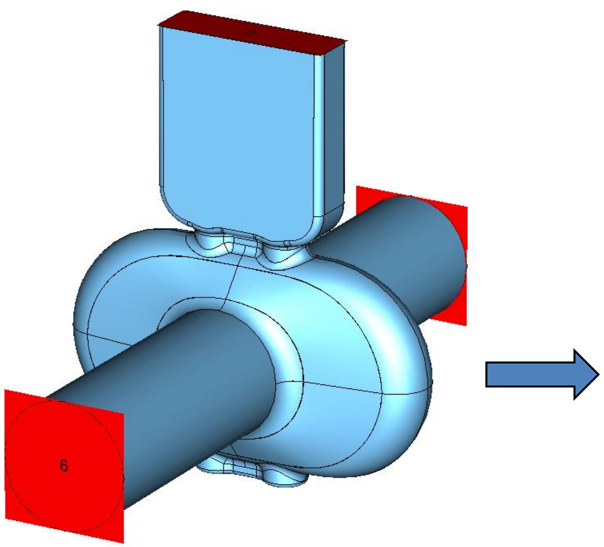
LOM WG is shorter than HOM WGs due to fast decay of magnetic field.

Something new? On-cell LOM/HOM Damping





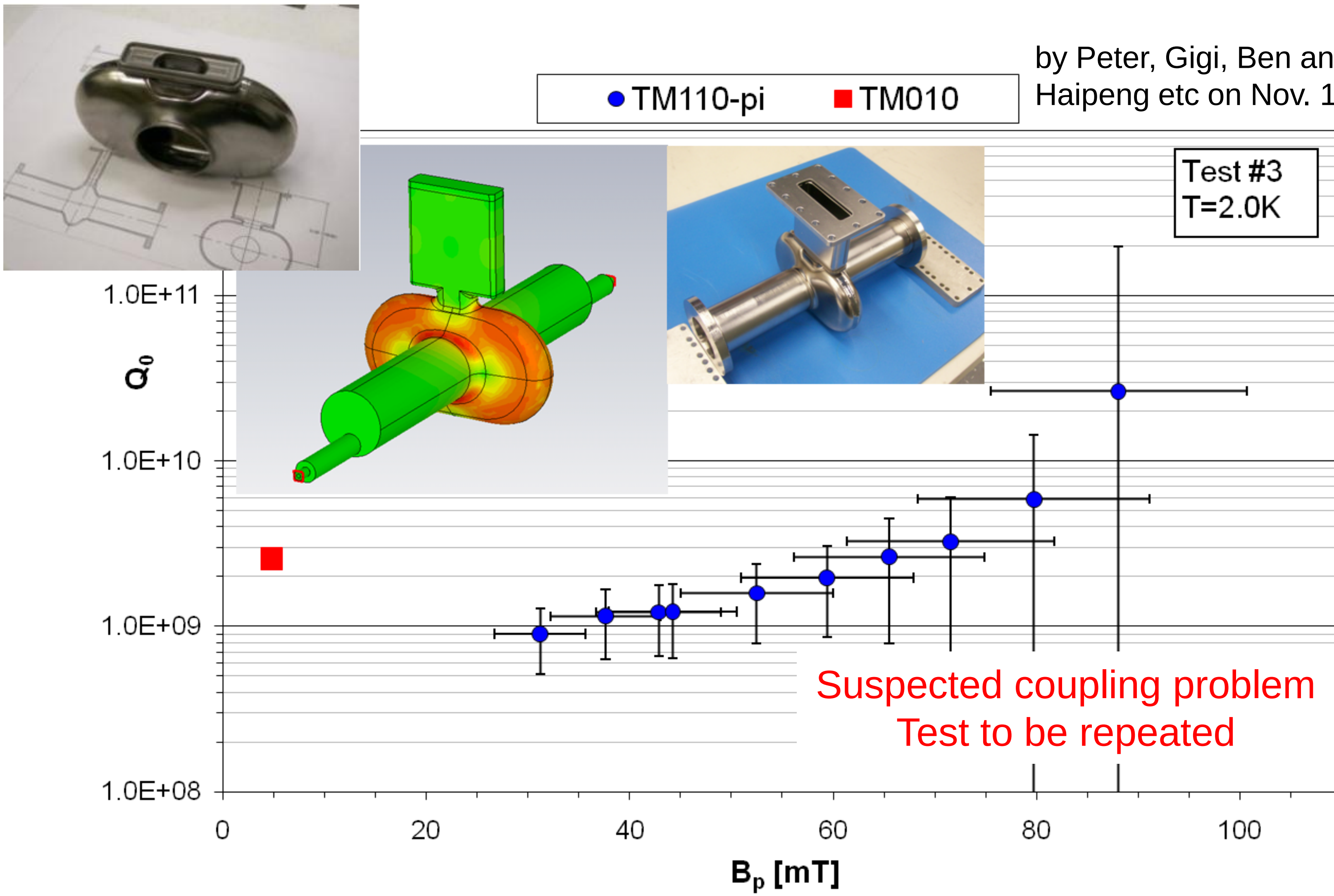
- B_{neck}/B_{iris}=~0.8
- B_{max}/V_{def}=157.7mT/MV (single-cell iris) to 195.6mT/MV (+end WG iris)



- dummy “dog bone” stub, one on-cell damper is better than two, more promising.
- LOM-WG mode, 2.176GHz, R/Q=22.3Ω Qext=21.
- To be confirmed

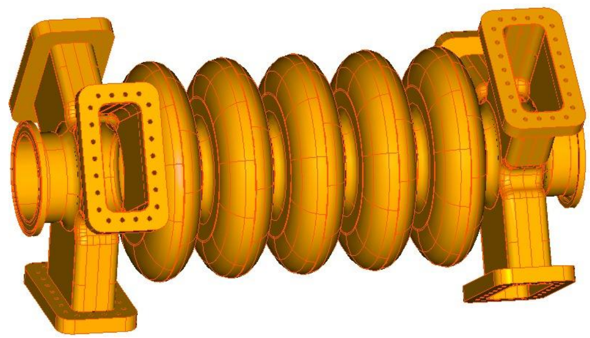
Proof-of-principle model of on-cell damper crab cavity

by Peter, Gigi, Ben and
Haipeng etc on Nov. 11, 2009.

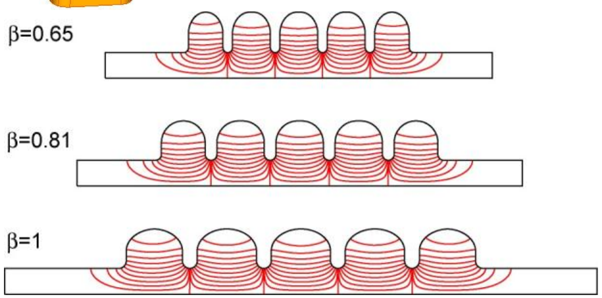


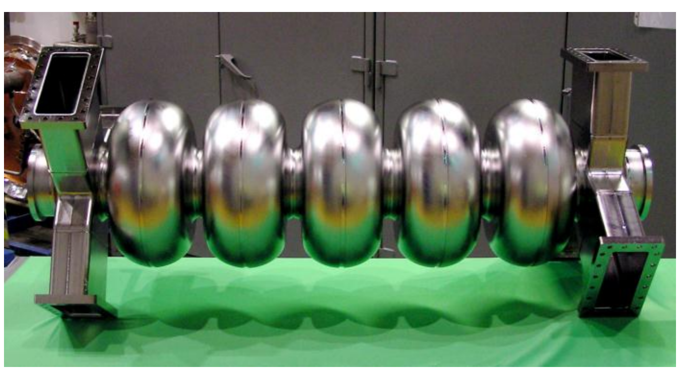
High-current Proton driver cavity?

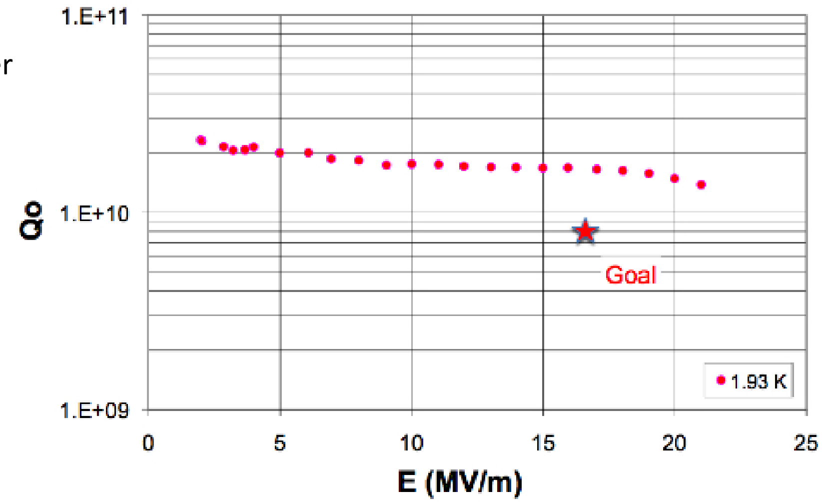
- Development from electron cavity for ≥100 mA

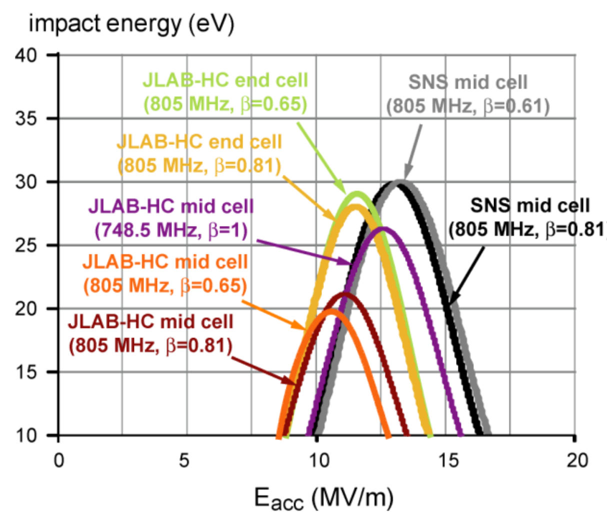


F. Marhauser
PAC09



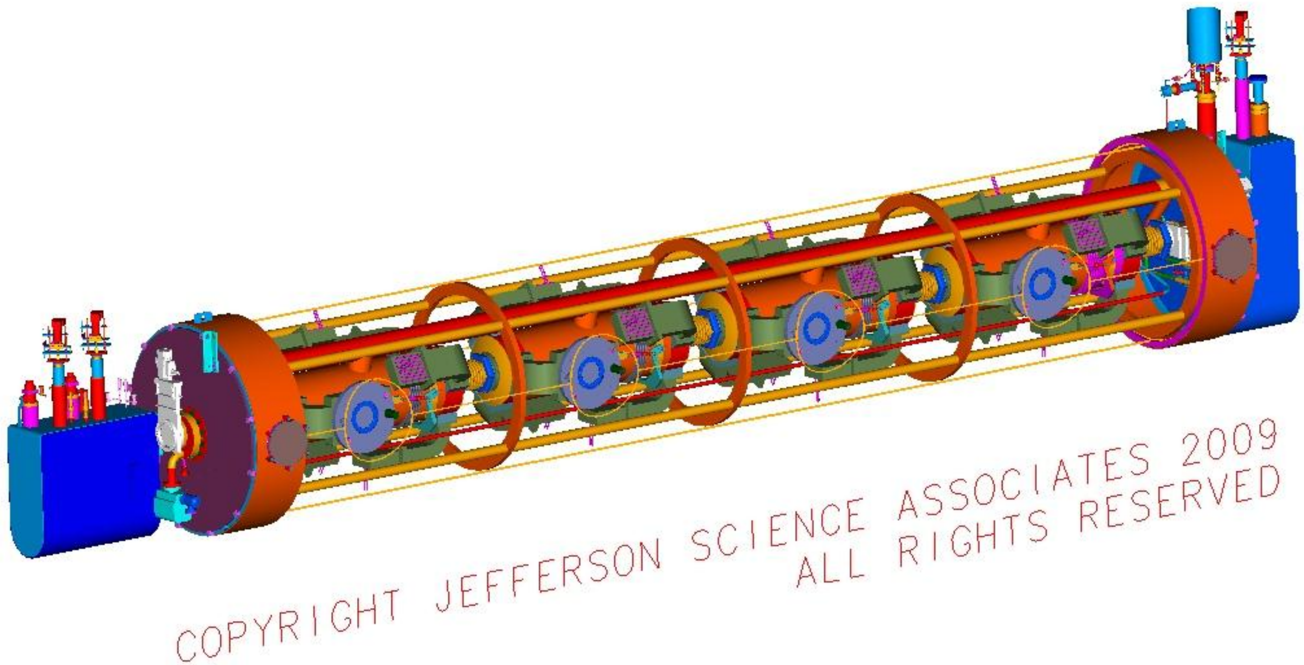






E.g. high current cryomodule

- JLab 704 MHz module (based on modified SNS layout)
- Could be economical if can operate in BCS dominated regime
- Very large apertures (halo!) Very high BBU threshold
- Use TV band RF sources



WG Summary

- HC Cavity shape chosen for good efficiency, HOM properties
- 5-cells good compromise at 748.5 MHz.
  - BBU > 1A.
  - Good packing factor, ~10 MV/m real estate gradient.
  - Fits in existing Jlab infrastructure (just).
- Waveguide HOM dampers give good Q's, loads at 300K.
- Waveguide FPC/warm window has high power capacity.
- Module concept is compact and based on experience.
- Hardware prototypes Successful at 748.5 & 1497 MHz
- May find new applications
- On-cell damper looks promising

Discussion

Effective HOM damping frequency range Cut-off to infinity

Coupling to high frequency modes? Yes?

Measured and/or simulated HOM Q-values for given cavity design vs. frequency Good agreement between simulation and measurement

TJNAF designs and results yes, see above

Maximum HOM power handling and extraction >20 kW

Estimate of the heat load to ~2K and all other intercept temperatures at full HOM power 12 static, 64 dynamic W per cavity, ~92W at 50K.

Coupling to the fundamental mode and suppression anything you want

Cleanness challenges and solutions no problem

Cleaning of waveguide sections standard procedures

Extra beamline length required per cavity (compared to linac without HOM damping) less than 1 cell length

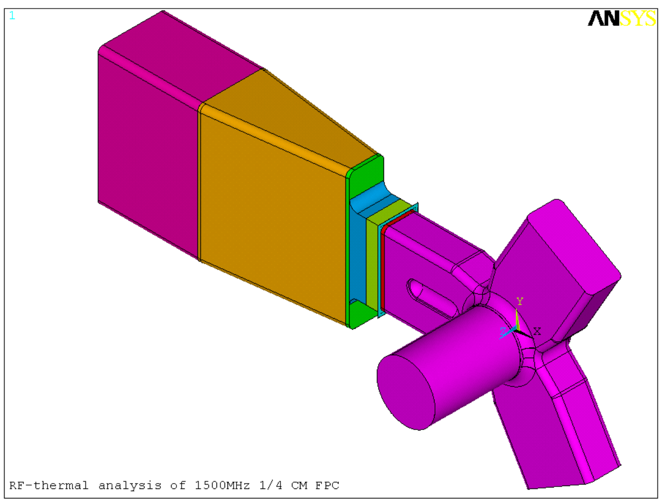
Discussion 2

- Mechanical / fabrication challenges and solutions He vessel
- Cost vs. design and material choices Cheap and easy
- Superconducting or normal conducting waveguide sections? NC, warm loads for anything above 200 uA
- Number of waveguides per cavity required 1-6
- Length of waveguide section just long enough?
- Absorber inside or outside of vacuum vessel? Inside for broad-band
- Water cooling vs. cryogens; risks involved Water, if needed
- Temperature of loads at end of waveguides Toasty?
- Shielding of IR radiation from warm load Not an issue?
- Water cooling and mechanical cavity vibrations Possible?
- Other challenges, limitations and solutions FUNDING

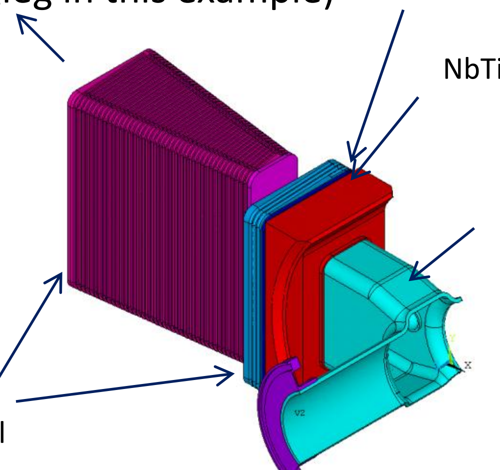
Backup material

JLAB HC Cryomodule Development
Fundamental Power Coupler (FPC)

- ❑ One HOM waveguide steps up in size and used as FPC (does double duty)
- ❑ Length of small waveguide and incorporated bumps determine the coupling factor (10mA injector (not energy recovered): Qext = 9.5e5)
- ❑ Issue: Static leak and rf heat leak to 2K needs to be intercepted/minimized
- ❑ Active cooling necessary (e.g. He gas trace cooling of the waveguide)
- ❑ Optimization is challenging, since He gas heats up and covers regime of laminar, transient and turbulent flow → highly non-linear problem only solvable with multi-physics code (ANSYS)
- ❑ Warm-to-cold transition still needs to be further optimized



ANSYS vacuum model for RF solution

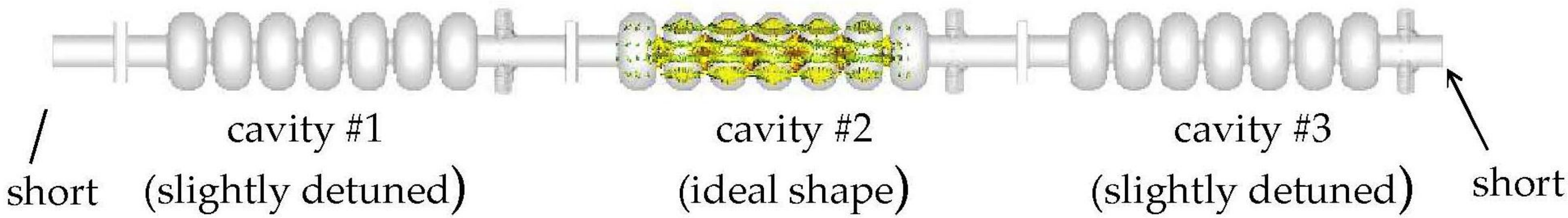


ANSYS He gas trace cooled FPC
hardware model for thermal solution (design G. Cheng)

Simulation of real module conditions

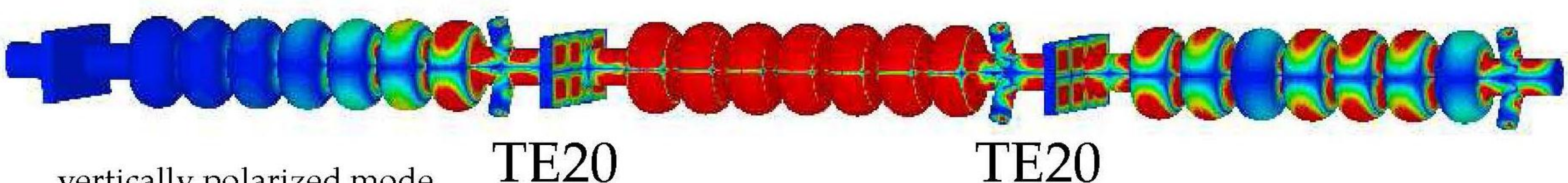
CST Microwave Studio Eigenmode Solver Simulations (MWS)
- Trying to resemble real World -

- ❑ Simulation of cavity string



- ❑ how far and strong the field propagates in neighboring cavities may depend on detuning
- ❑ cavities share 2 HOM couplers and 2 FPCs (except for cavity at end of cryomodule)

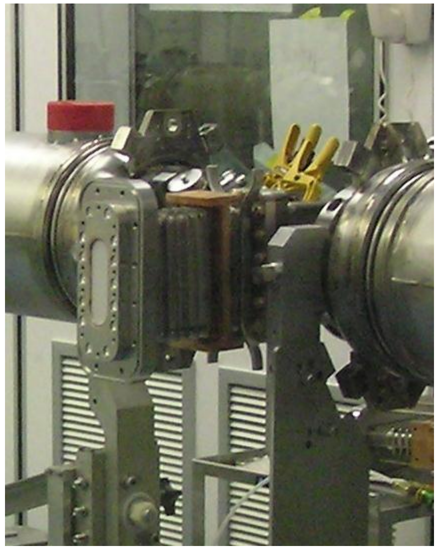
Log Contours

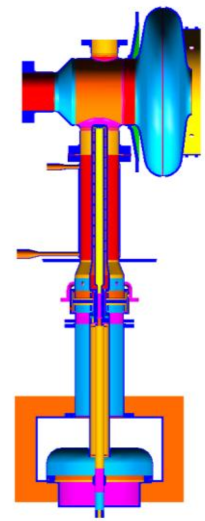


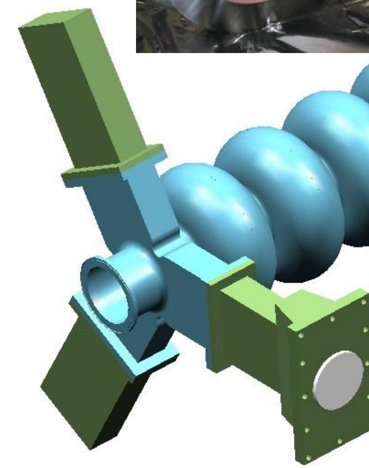
vertically polarized mode
up to $|E_{max}|/10$ (Log. scale)

Power couplers

- Various coupler configurations are available







CEBAF waveguide

- **Peak power up to 6 kW CW**
- **2K and 300 K windows**
- **Dogleg shields cold window from beam.**

Upgrade WG coupler

- **Peak power in up to 13 kW CW**
- **300 K window**
- **Cooling: WG heat stationed at 50K**
- **Optional active cooling**
- **Optional double warm window**

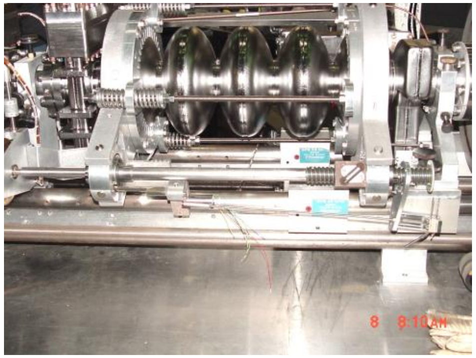
SNS coax coupler

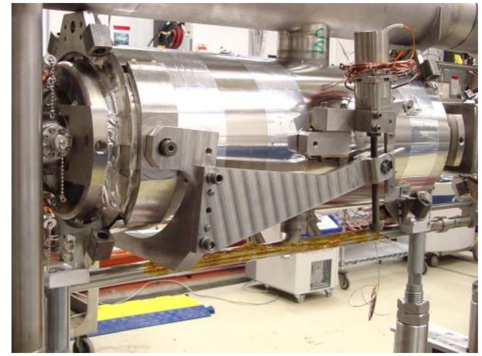
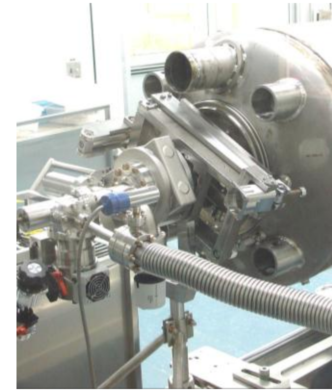
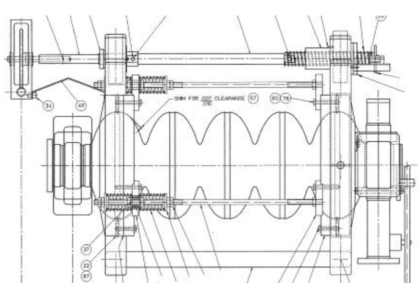
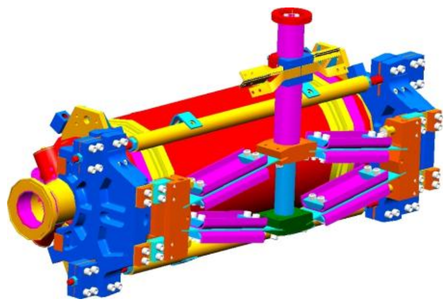
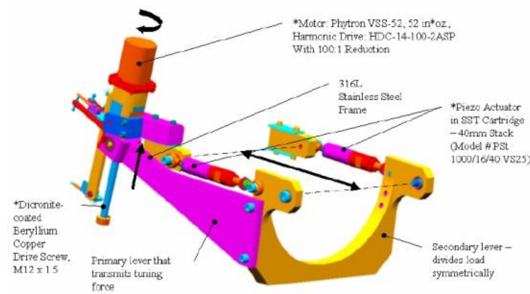
- **Peak power in up to 550 kW (tested up to 2 MW)**
- **1.3 ms RF on. 60 pps**
- **Up to 50 kW average power**
- **Q_{ext} ~ 7 x 10 ^{5}**
- **300 K window**
- **Cooling: Inner conductor extension: water. Inner conductor: conduction cooling. Outer conductor: GHe flow**

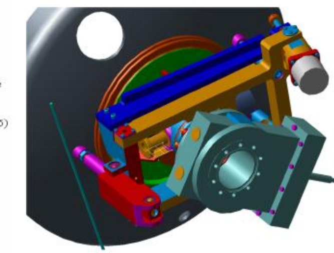
FEL high-power WG

- **Peak power in up to 200 kW (Window tested to 1 MW CW)**
- **300 K window**
- **Cooling: Window: water. WG transition: GHe flow**
- **Dogleg or bend (not shown) to avoid exposure to beam**

Tuners





Original CEBAF tuner
- Mechanism in LHe.
- Fairly large hysteresis.
- Warm motor (external).
- Rotary feedthroughs
- 10+ years service in CEBAF/FEL

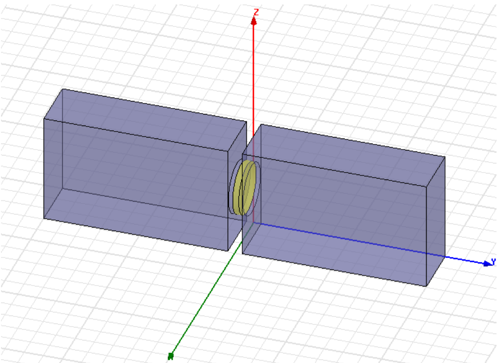
Upgrade Scissor-type tuner
- Very Low hysteresis.
- Warm motor (external).
- Linear feedthrough (Bellows)
- In service in CEBAF/FEL

Upgrade zero length tuner
- Low hysteresis.
- Cold motor.
- Tested but not yet installed

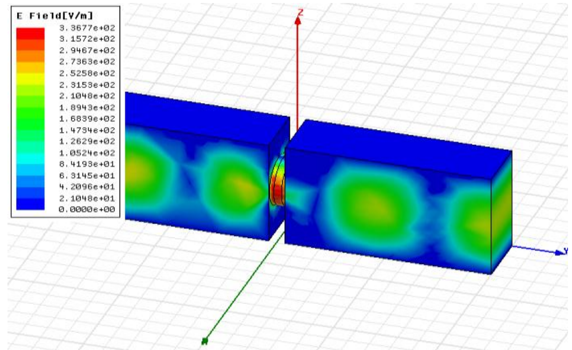
SNS-type tuner
- End mount
- Low hysteresis.
- Cold motor.
- In service in SNS

- **JLab has practical experience of several different types of tuners. All have Pros and cons.**

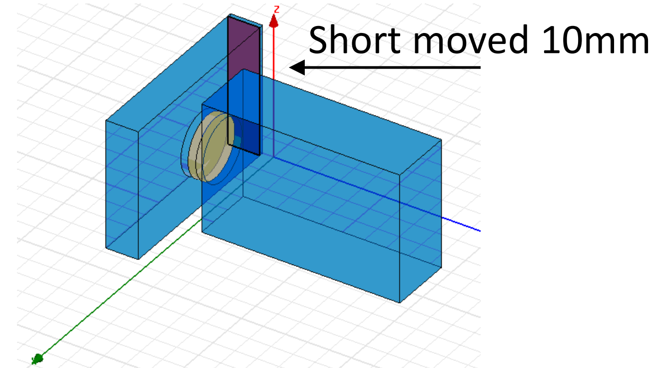
Ceramic window Matching at 748.5 MHz



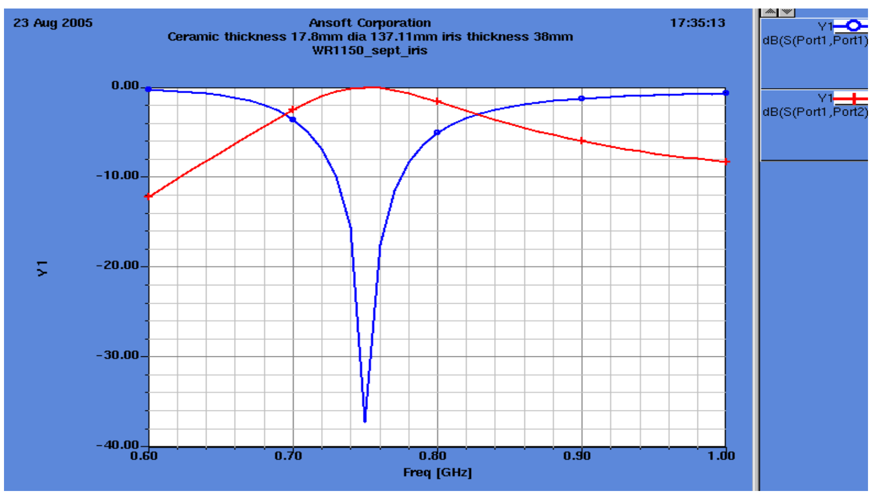
WR1150 ceramic matched in 38.1mm thick iris



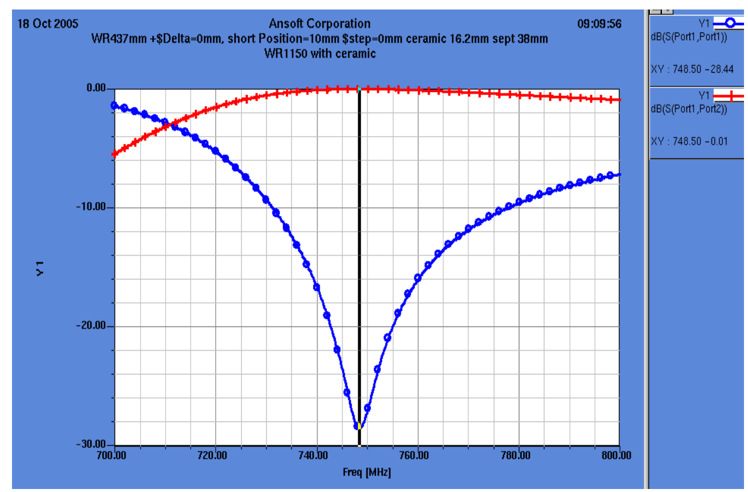
E fields at matching frequency



Ceramic window Matching on T model

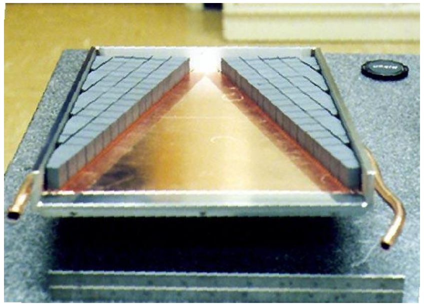


S11 at matching frequency. Ceramic thickness 0.7007in (17.8mm) at 748.5 MHz -37dB

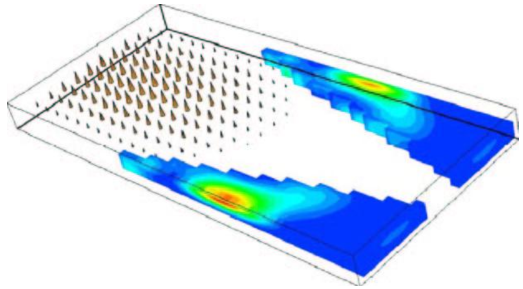


Matching in T model at 748.5 MHz was obtained by changing the iris height from 38.1mm to 50mm and position of the short with 10mm. S11 at matching frequency -28.5dB.

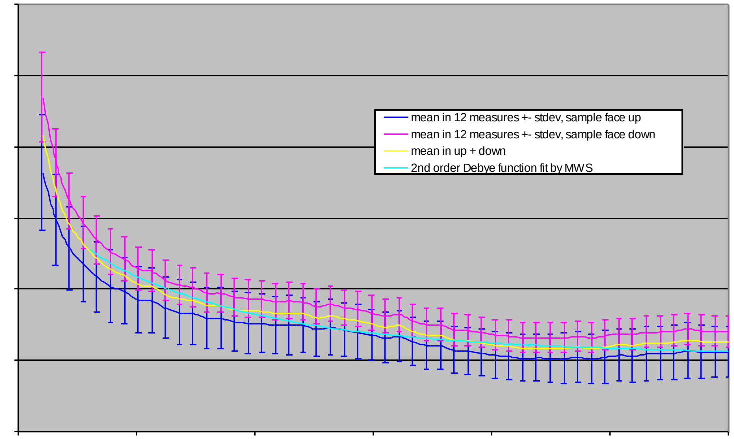
HOM load match design by MAFIA/HFSS/ANSYS/MWS

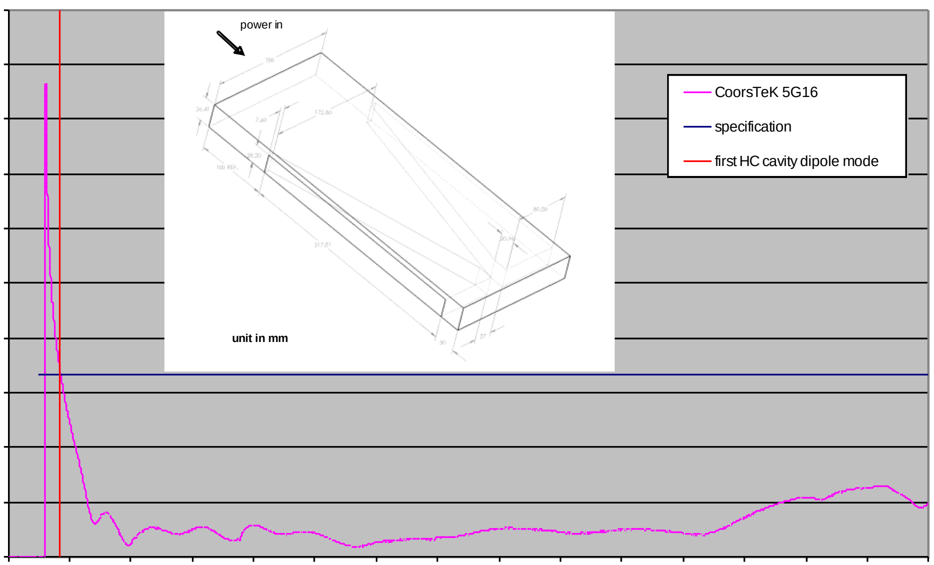


Original SLAC B-factory HOM load

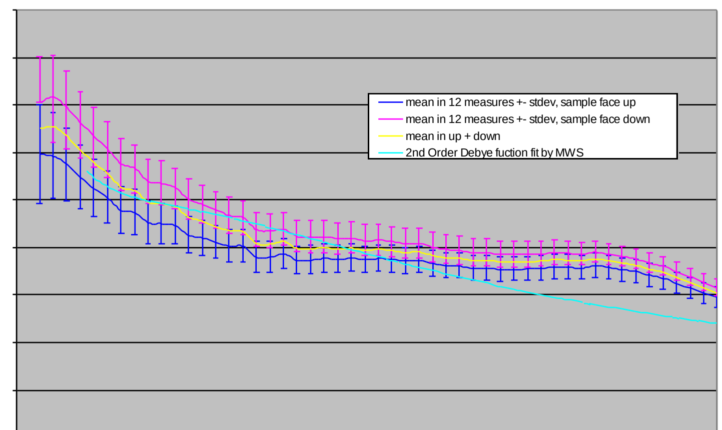


MAFIA simulated electric field plot





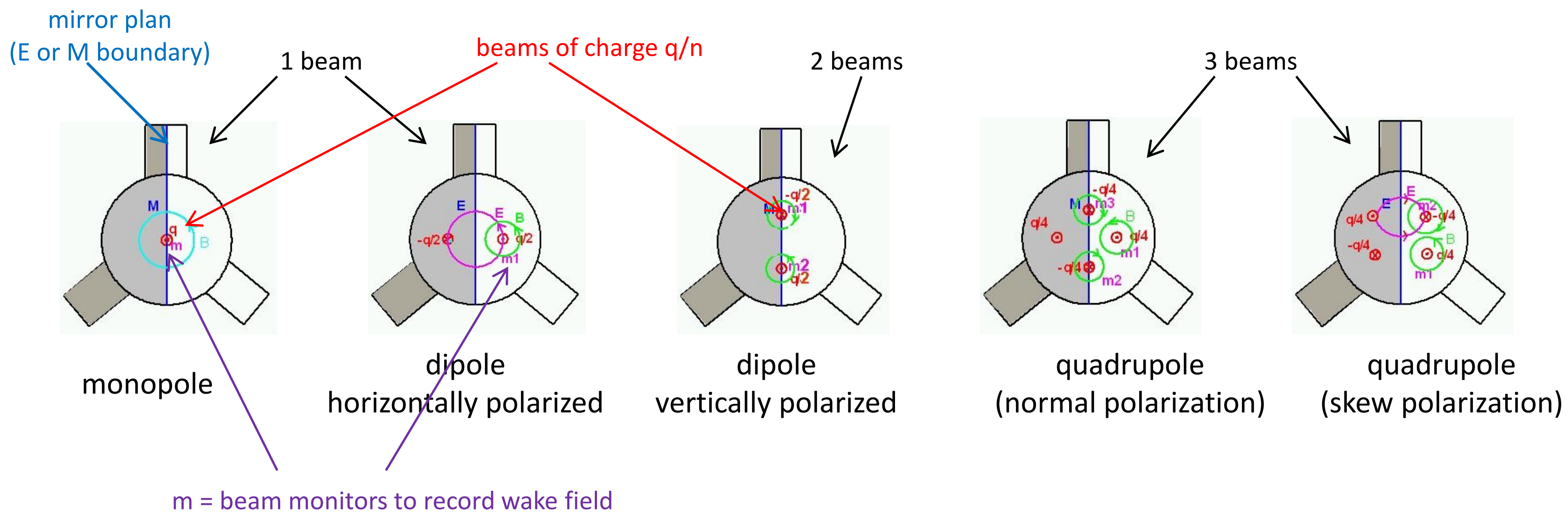
More than 5 material vendors and >20 samples have been measured. Many are potentially usable.



JLAB HC Cryomodule Development
Broadband HOM Damping Efficiency

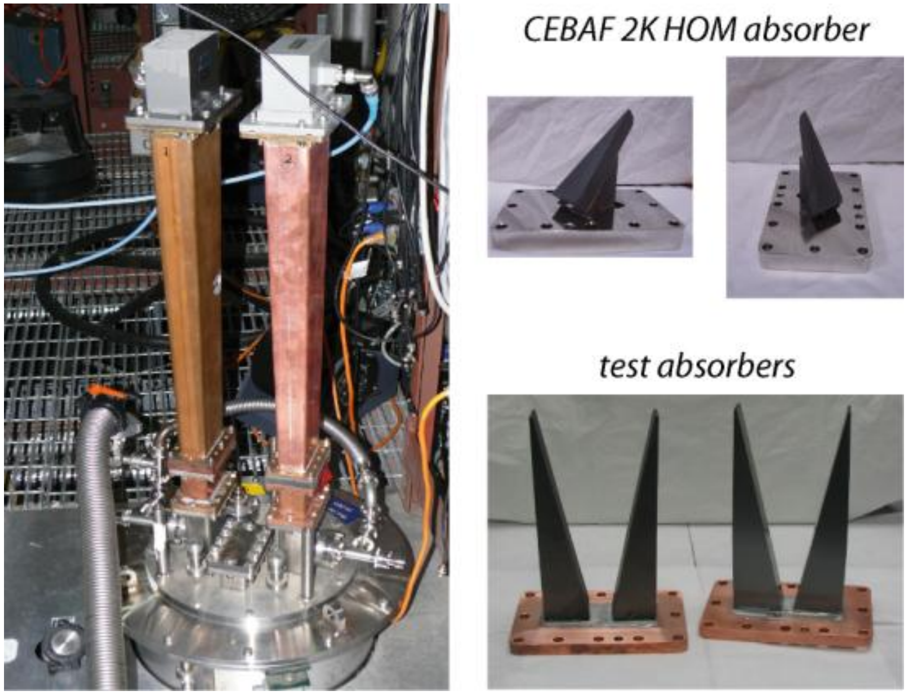
- HOM damping efficiency is most important aspect of the HC cavity design
- Cavity broadband coupling impedance simulated using multi-beam excitation scheme
- Works with MAFIA T3 (does not work yet to our knowledge with CST Particle Studio or GdfidL)
- Benefit: We can distinguish between HOMs of different field nature and polarizations (monopole, dipole, quadrupole, sextupole,…)
- Valuable information for high current ERLs (other than dipole modes may become important)

Multi-Beam Excitation Scheme (MAFIA T3)

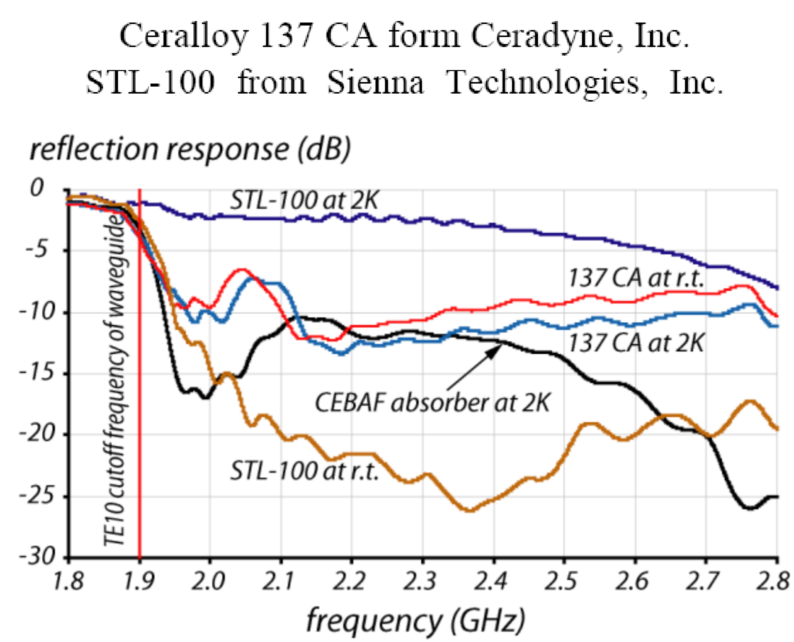


JLAB HC Cryomodule Development
HOM Load Material Studies

- ❑ VTA setup built for measurements from room temperature down to 2K
- ❑ Aim: Investigate various HOM material candidates
- ❑ Variability of material complex properties (batch to batch and lot to lot) may be important for large scale installation
- ❑ Further investigations planned on different materials



Test setup in the vertical Dewar (left), CEBAF absorber (top right) and two different wedge absorber assemblies (bottom right) made of ceramic AlN-based composites



Reflection response of different AlN-based composites measured at room temperature (r.t.) and 2 K.