CEBAF waveguide absorbers

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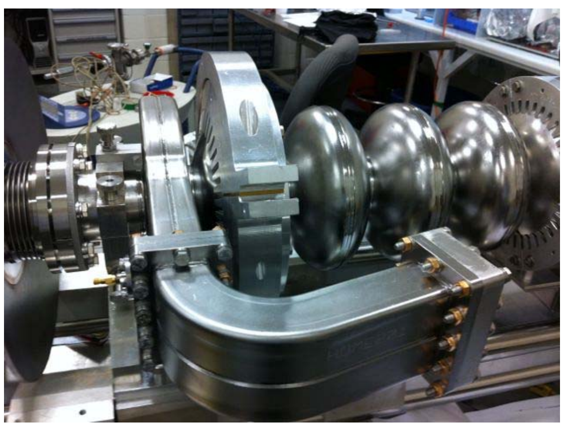
for
JLab SRF Institute

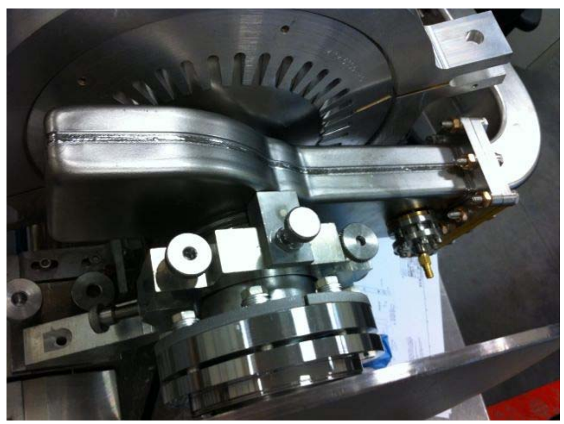
Outline

- Original CEBAF HOM absorbers
- Modified CEBAF loads for FEL
- New materials for replacement loads
- High-power loads for next generation FELs
- Other applications
- Conclusions

CEBAF WG dampers

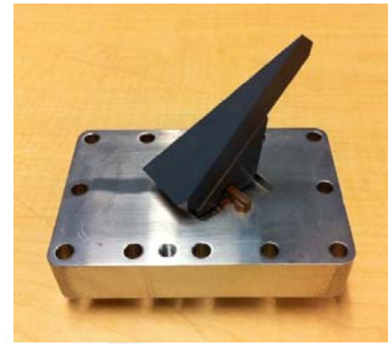
- Original 5-cell cavity has two HOM waveguides and a stub on the opposite end to the FPC
- FPC also provides some useful damping
  - External waveguide filters absorb HOM power (as well as harmonics from the klystron)
- 2K ceramic loads in vacuum, cooled by LHe

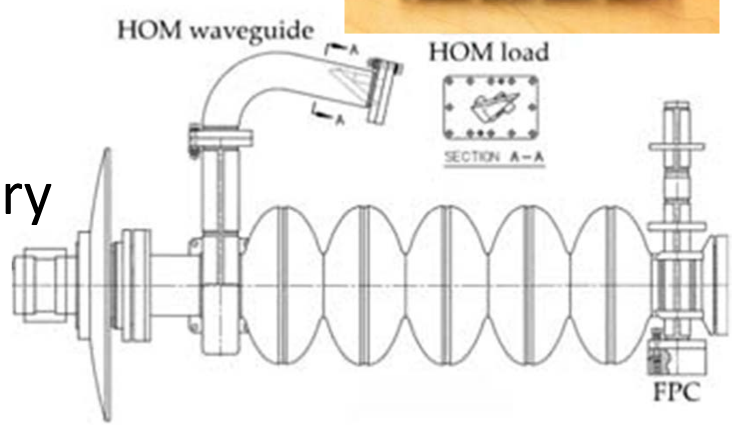




Original CEBAF HOM loads

- Broad-band ceramic absorbers in vacuum (no RF window)
- HOM loads cooled by 2K helium
  - Very low dissipated power at CEBAF current
- “special” glassy-carbon loaded ceramic
  - Only produced by one vendor
  - Variability in properties from batch to batch
  - No longer in production
- Brazing issues resulted in several design iterations
  - Final design included a mechanical constraint but ultimately has been very reliable





Modified CEBAF loads for 10 mA

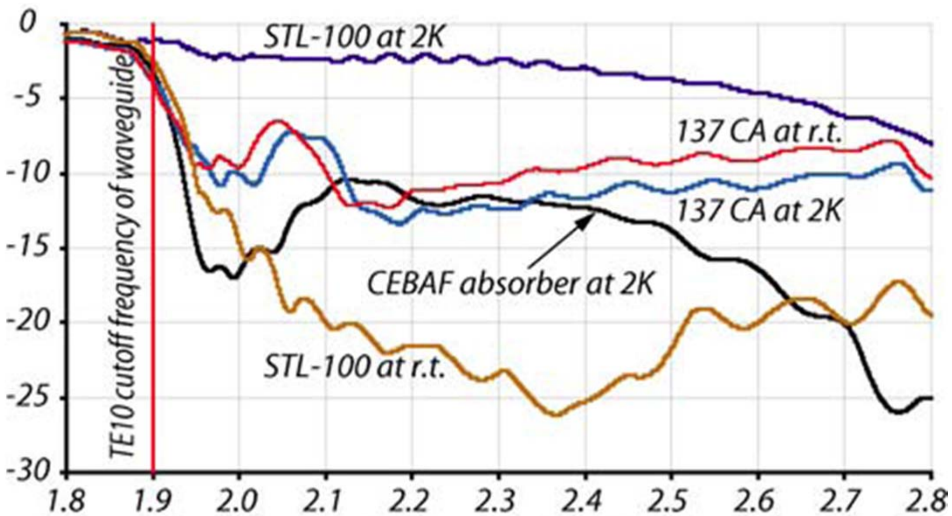
- Designed for use in JLab FEL demo
- Same waveguide and absorber configuration
- However ceramic loads isolated from helium, heat stationed to shield temperature
- Attempts to measure HOM heat still below detectable limits

New materials for 2K loads

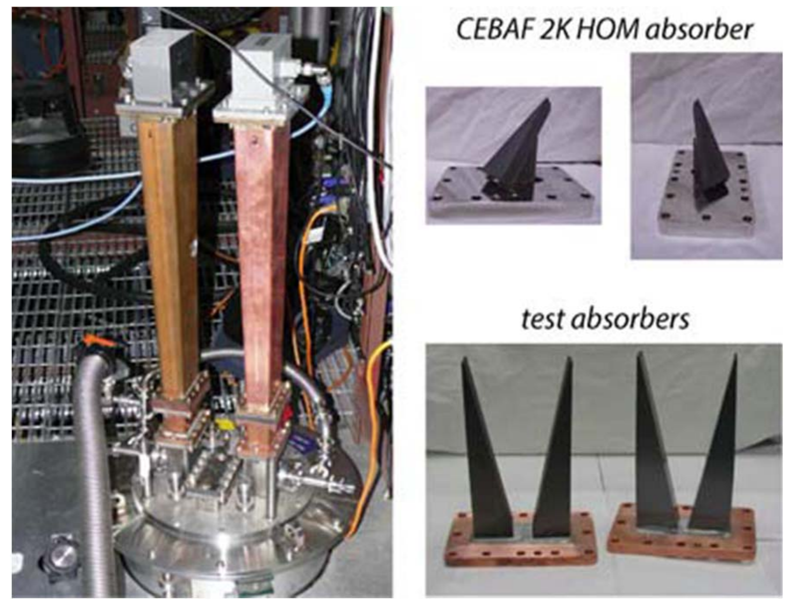
- Study by Frank Marhauser [PAC09] identified several candidate materials having losses at 2K
- One candidate material is a graphite loaded SiC
- VTA measurements confirmed RF response
  - RF shape adapted because of different properties
- Brazing and cryogenic tests are being planned
- Needed in case any HOM loads are damaged in future C50 rework program or for other applications

Cold measurement of new materials

- Special waveguide test insert allows cryogenic RF measurements of test loads and material samples



Example: Reflection response of different AlN-based composites measured at room temperature (r.t.) and 2 K, compared to original CEBAF load.

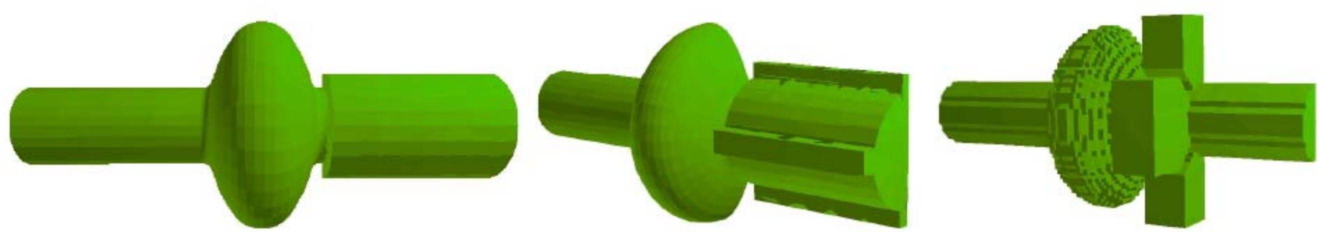


Test setup in the vertical Dewar (left), CEBAF absorber (top right) and two different wedge absorber assemblies (bottom right) made of ceramic AlN-based composites.

MARHAUSER PAC09

High power loads for ERL/FEL's and rings

- High current ERL and storage ring cavities may generate kW's of HOM power
- Power must be transported to higher temperature for dissipation (shield or room temperature)
- Waveguides offer natural rejection of fundamental mode (no notch filter required)
- Can handle very high HOM power
- N.b.: beam pipe dampers are waveguides too
- Waveguides can exit sideways to save space.

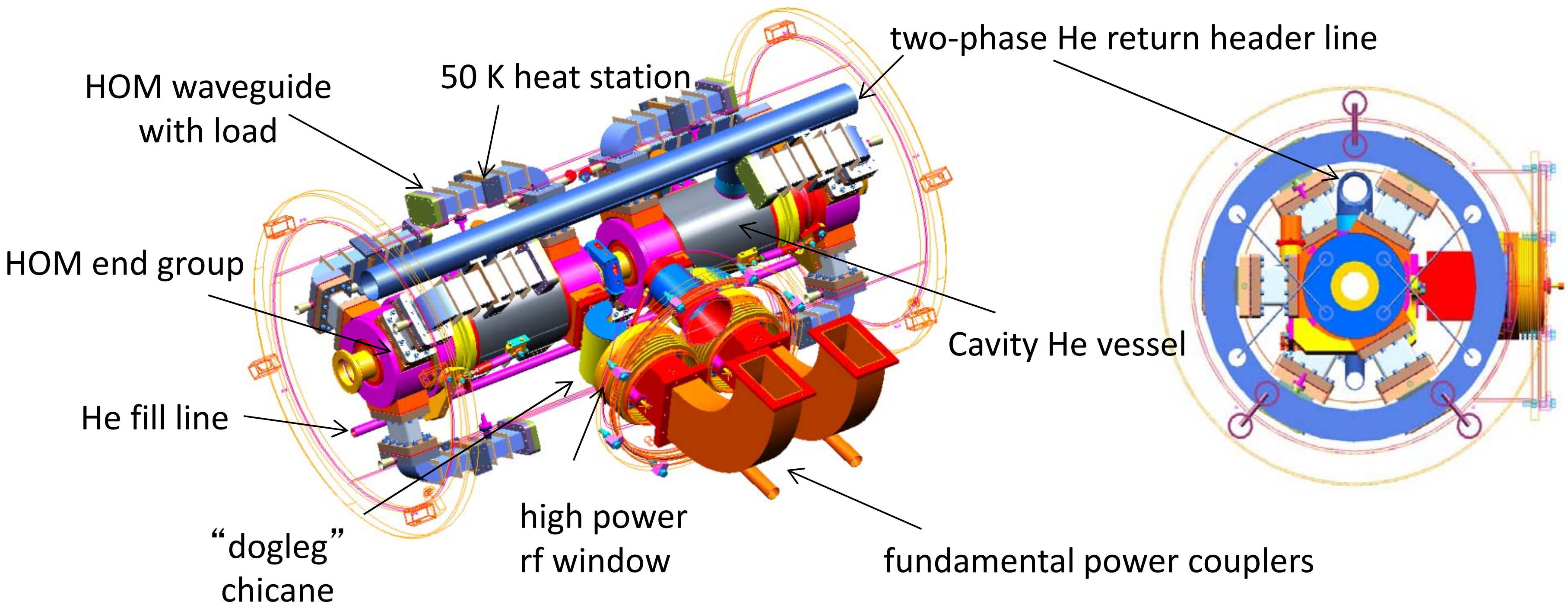


JLab "high-current" cryomodule

- Was an R&D project for next generation ERL/FEL
- Goal of >100 mA at 1.5 GHz (>1A at 750 MHz)
  - Very strong HOM damping required
  - Potentially high HOM power to be extracted
- Waveguide FPC and HOM dampers
- ~100 kW CW max (injector) ~10 kW (ERL)
- Cavities and windows prototyped
- HOM load concept developed
- Module concept developed
- Funding withdrawn ☹
- Some parts may be used in a new FEL booster module

JLAB HC Cryomodule concept

High-current cavity developed for high-power ERL/FELs
HC optimized cell shape, 5-7 cells, WG FPC, WG HOMs



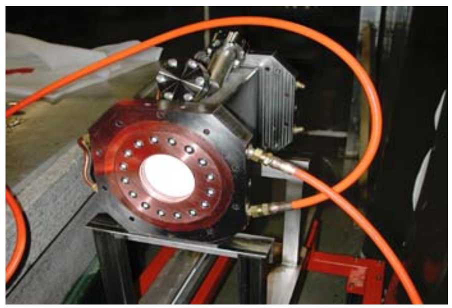
Conceptual design of a cavity-pair injector cryomodule (L=2.6m)

F. Marhauser ERL09

JLab 1.5 GHz high-current cavities

- Two 1.5 GHz 5-cell prototypes built and tested
  - Results exceed requirements
  - High power RF window demonstrated to > 60 kW CW
- May be used for new FEL booster module?

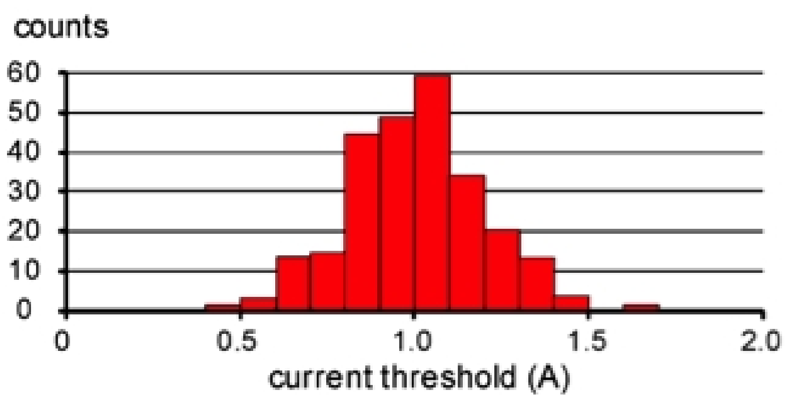
1.5 GHz ERL cavity



1.5 GHz window

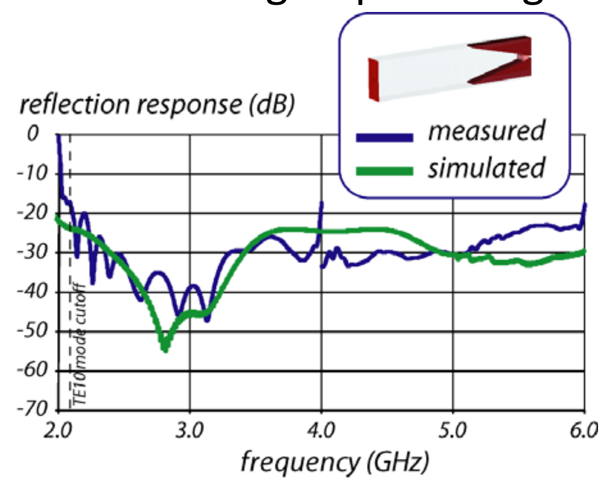
Single cell

End group forming



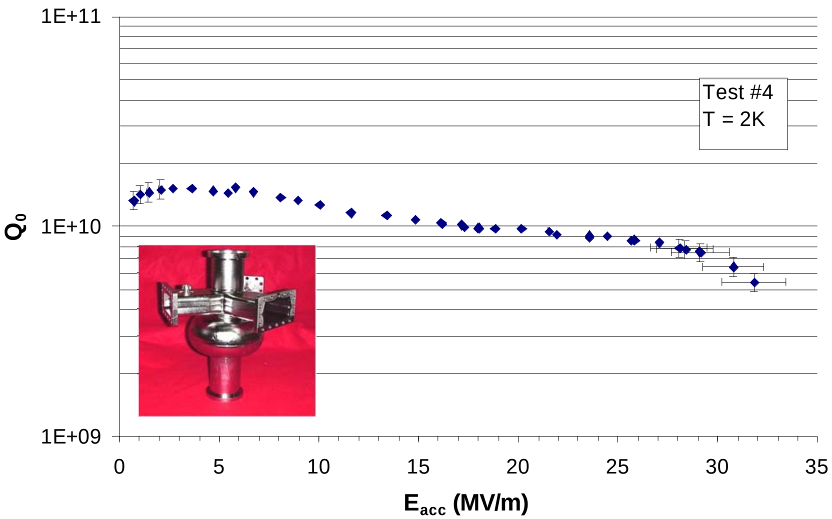
BBU simulations for 1.5 GHz ERL

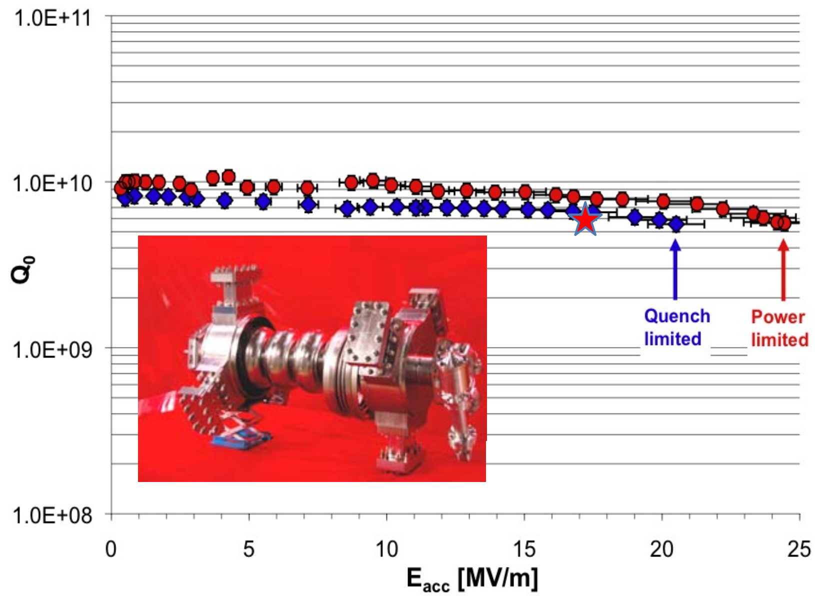
HOM load



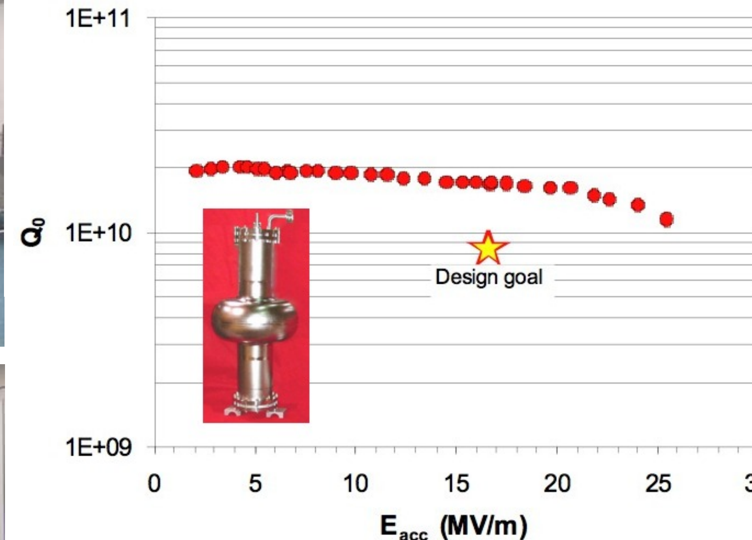
High-current cavity test results

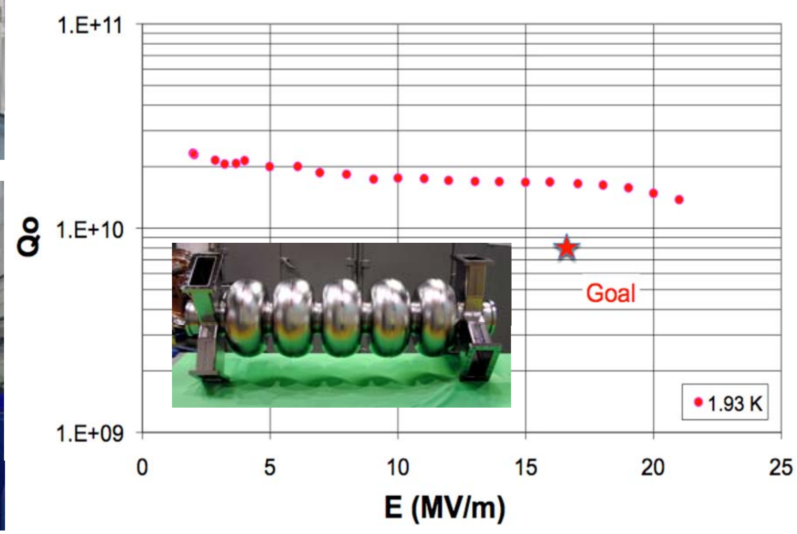
1.5 GHz





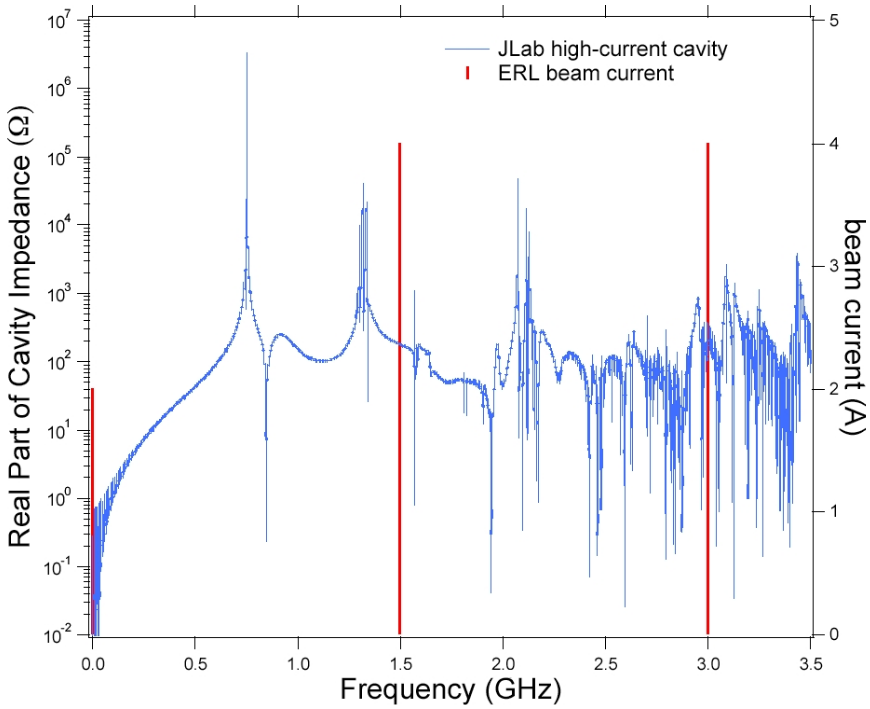
750 MHz





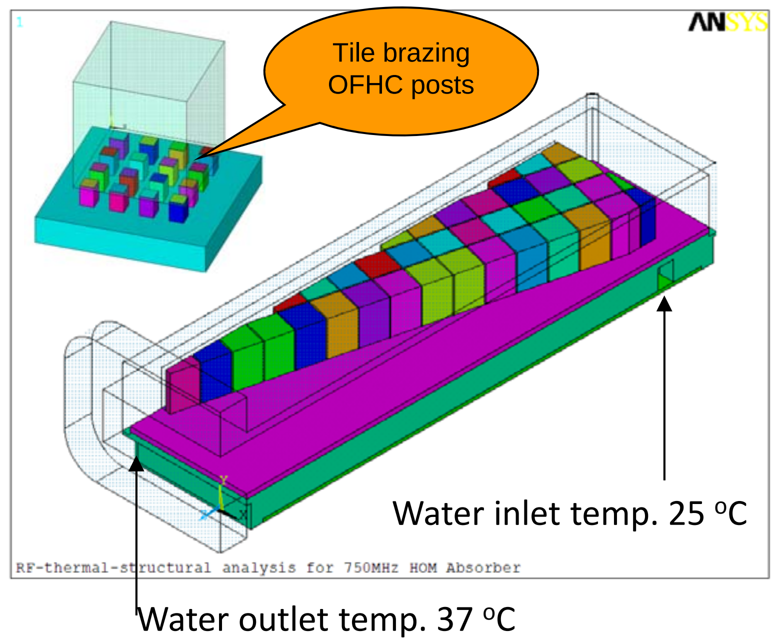
Multipacting seen from low gradient but processed away

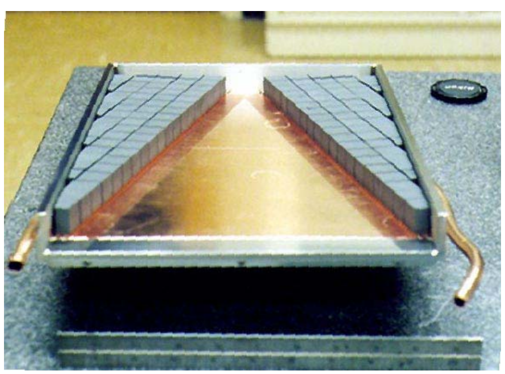
High power loads for ERL/FEL's



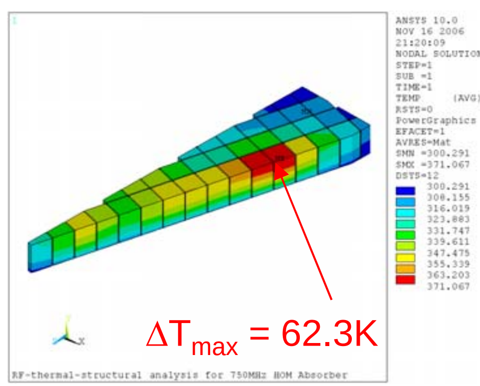
ANSYS RF-thermal coupled simulation
(750 MHz cavity load, 1A beam, ~4kW/load)

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**





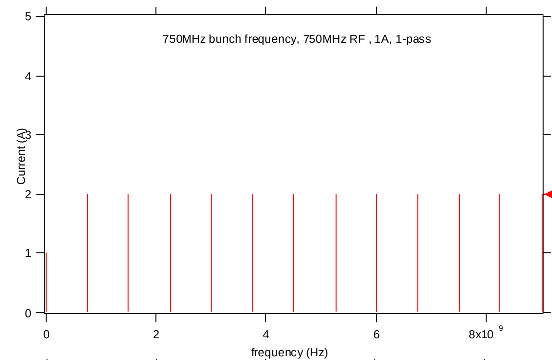
Original 10 kW PEP-II load



Scaled 4 kW load

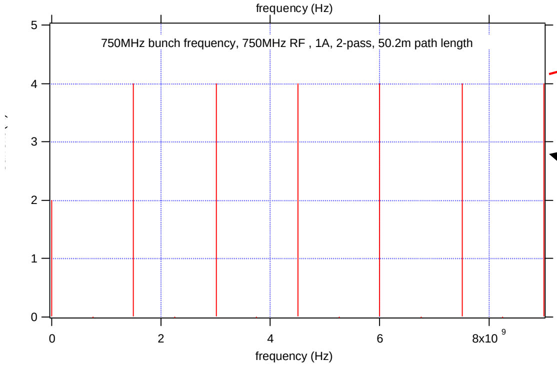
H. Wang, G. Cheng

Beam excitation depending on operation modes



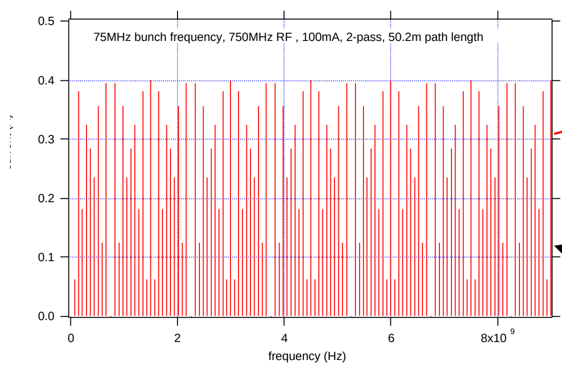
750MHz laser, 750MHz RF
1A, 1-pass.

Single pass beam
(every bucket filled)



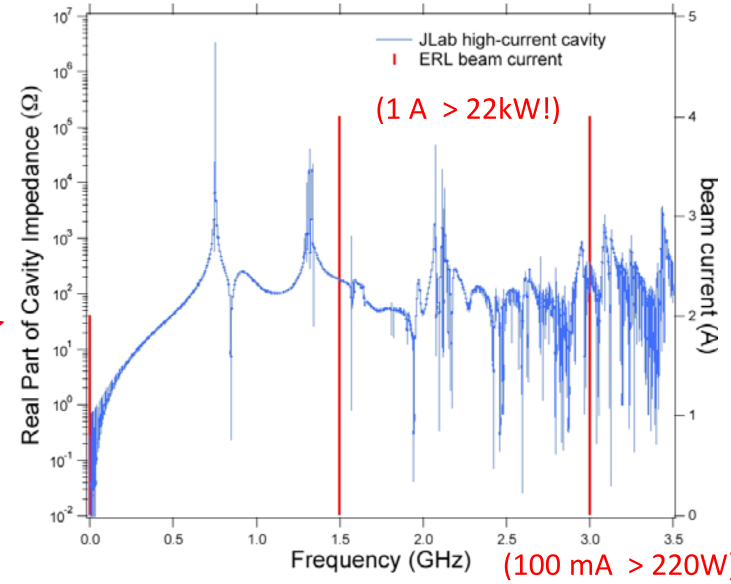
ERL (every bucket filled)

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



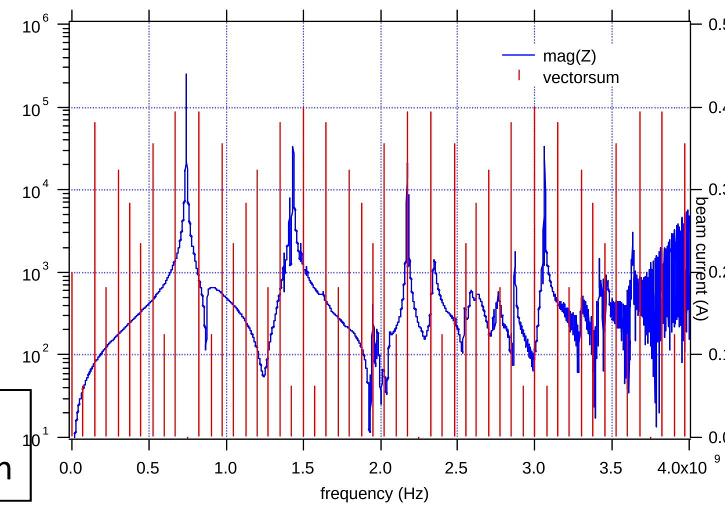
ERL (sparse fill)

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



(1 A > 22kW!)

(100 mA > 220W)



(100 mA > 5kW!)

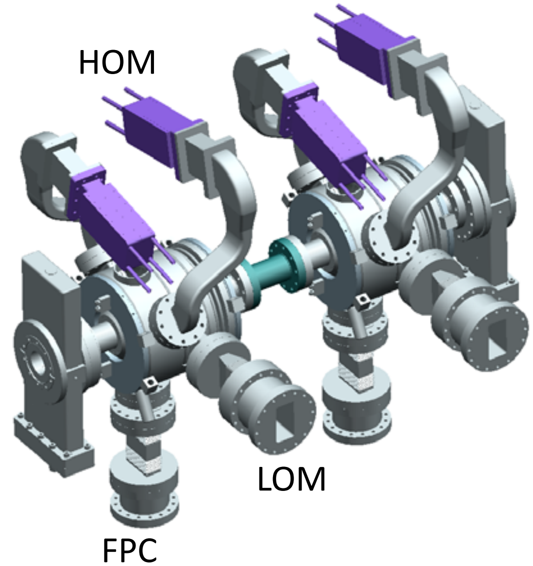
See JLAB TN-05-047

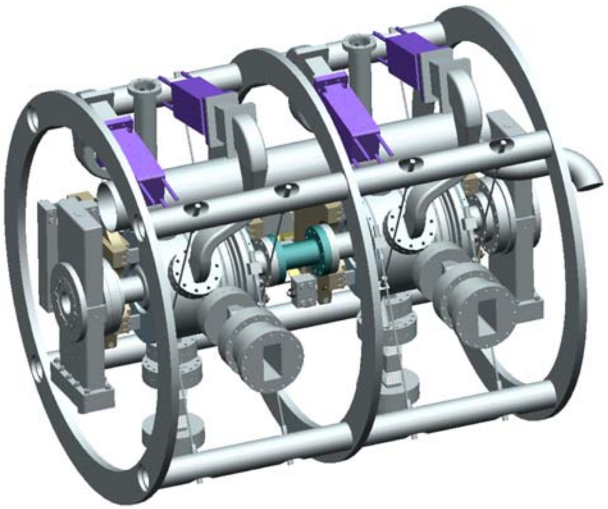
Other applications

- High-current ANL SPX cavity requires very strong HOM damping
  - Y end group scaled from JLab high current cavity
  - Warm in vacuum HOMs
- SPX cavity LOM can have even more power
  - ~kW power but limited bandwidth
  - Exit via double window to room temperature external load
- LOM damper uses experimental “on-cell” waveguide damper
- Proposing to use waveguides for MEIC storage ring cavities HOM damping
- New booster module for JLab FEL injector
- Being considered for Berlin-Pro ERL

ANL SPX crab cavity development

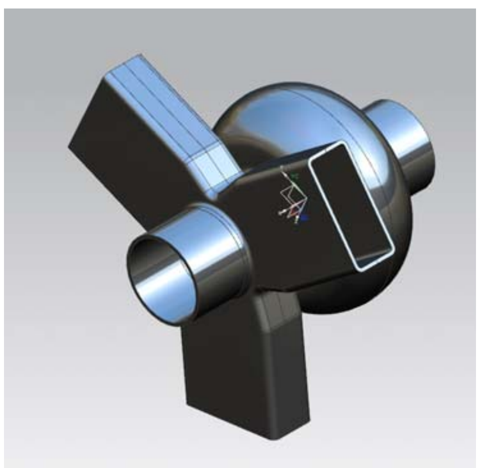
- SPX upgrade project to produce short X-ray pulses at the APS
  - Crab the beam through an insertion device (and un-crab afterwards)
  - Select fraction of radiation with a slit
- JLab developing compact deflecting system
  - SRF crab cavities with HOM/LOM damping
  - Fully integrated cryomodule package
- Waveguide FPC, LOM and HOM's



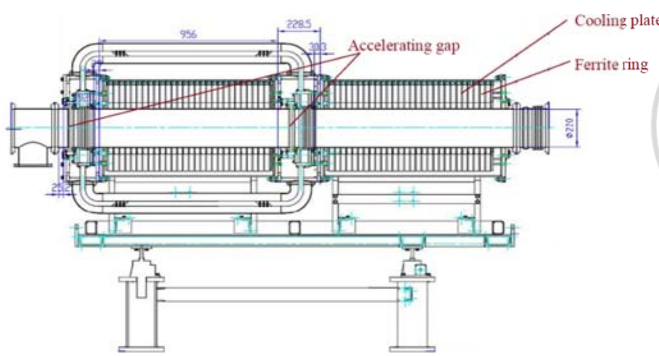


MEIC R&D

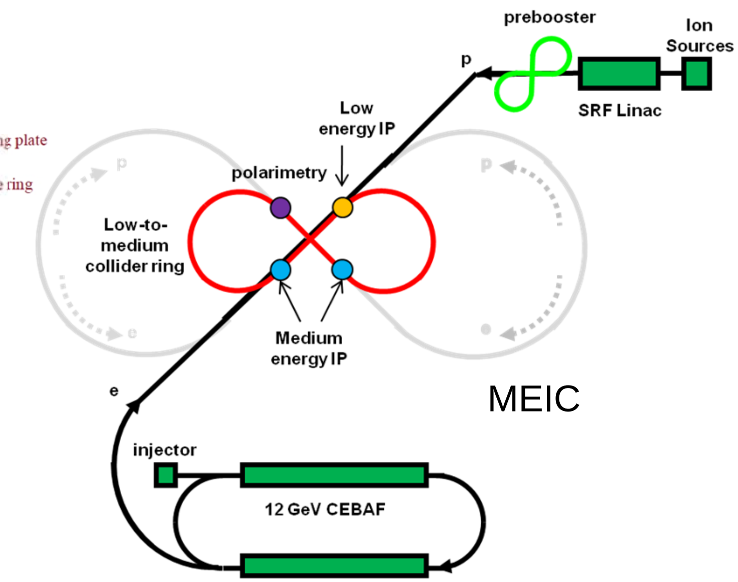
- New SRF Complex for ion acceleration
- Low frequency RF for ion ring ramping
- High frequency RF for Ion bunching and storage
- High-current, high-frequency electron storage ring*
- Crab cavities for high-luminosity collisions



*High frequency, high current cavity concept (single cell with waveguide dampers)



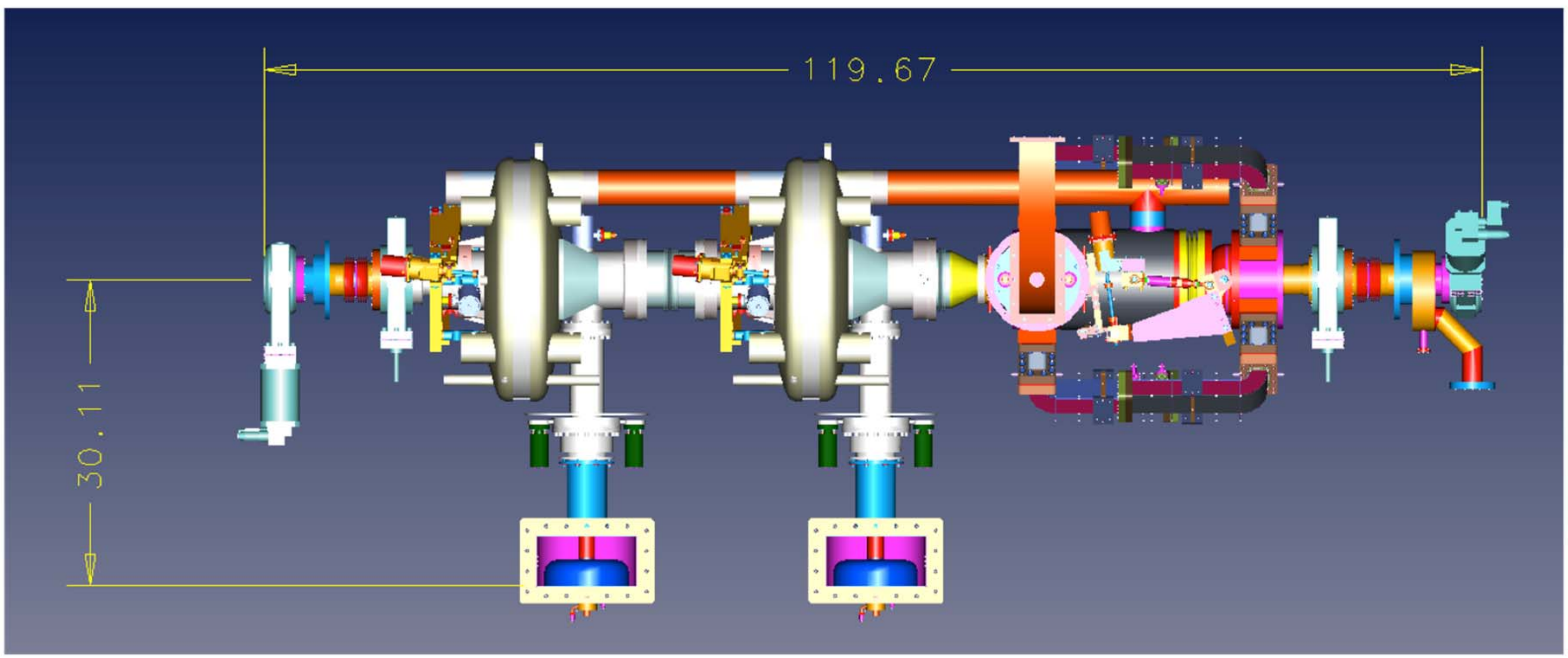
Low frequency NC cavity



MEIC

JLab FEL new booster (proposed)

- Up to 20 mA
- Low emittance (new DC gun)
- High-power couplers
- Two low-β 750 MHz single cells upstream
- High current β=1 1.5 GHz 5-cell with waveguide dampers



Conclusions

- Waveguide HOMs have several advantages
- Natural high-pass filter to reject fundamental Mode
- High power handling capability
- Static load small compared to CW cavity losses
- Simple to make (stamping, welding)
- Can transport HOM power to higher temperature for dissipation
- Can exit the beamline transversely to save space
- May be used “on cell” for extreme HOM damping?