Experience with ERL Beamline Load Prototypes

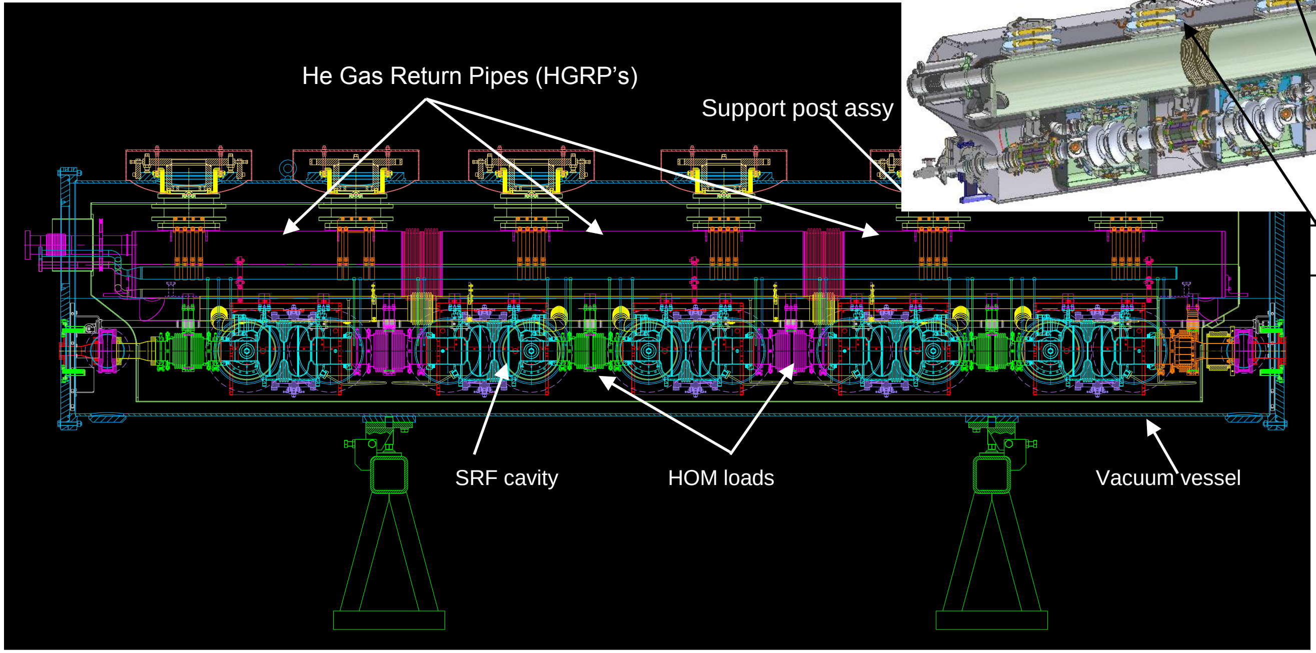
Eric Chojnacki
HOM - 2010

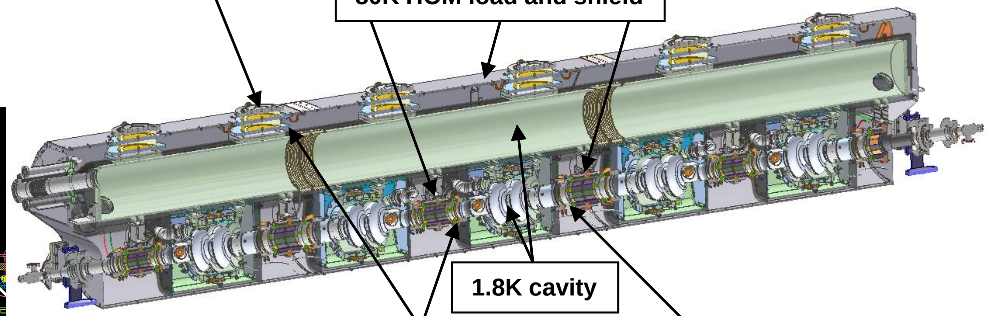
ERL Injector Beam Requirements

- Energy gain 5-15 MeV
- High CW current
  - 100 mA (77 pC/bunch) @ 5MV, **0.5 MW**, ε=1 mm-mrad
  - 33 mA (26 pC/bunch) @ 15MV, **0.5 MW**, ε=0.1 mm-mrad
- Low emittance, 0.1-1 mm-mrad
- Short bunch, 0.6 mm, 2 ps

ERL Injector Prototype

- A beamline HOM load is adjacent to each of the five 2-cell SRF cavities
- The RF absorber heat sink ~80K with 5K flange intercepts prior to the 1.8K cavity
- The loads are also prototypes for the ERL Linac, where there will be ~200W of HOM power per load

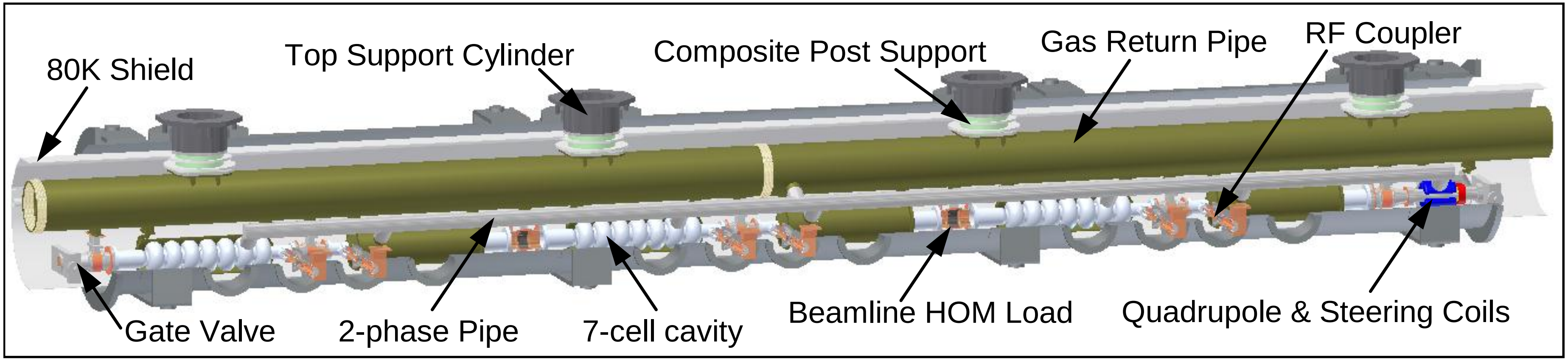




ERL Main Linac

The ERL Main Linac cryomodule is based on TTF technology, will have:

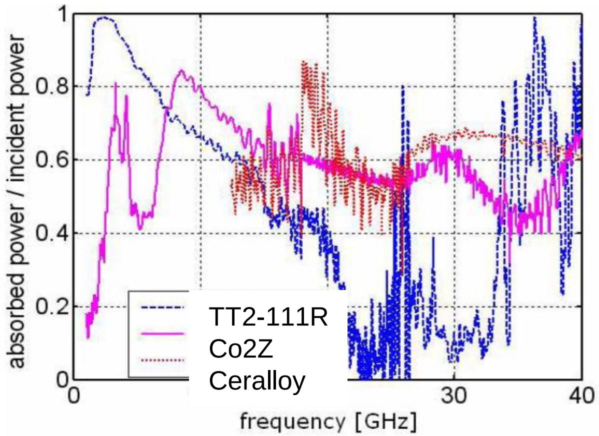
- six 7-cell cavities
- 7 beamline HOM loads, 200W typical, up to 400W possible
- one 2 kW avg coupler per cavity
- one quad and steering coil

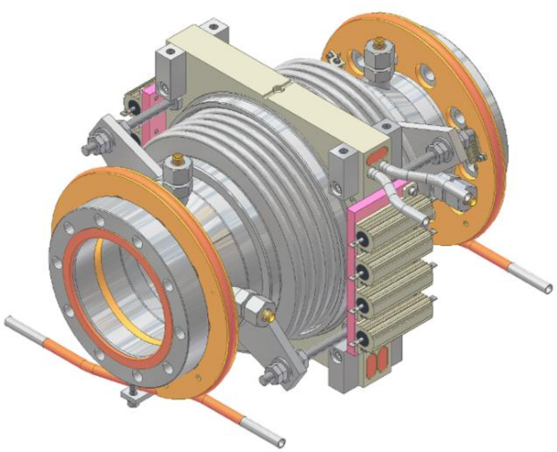


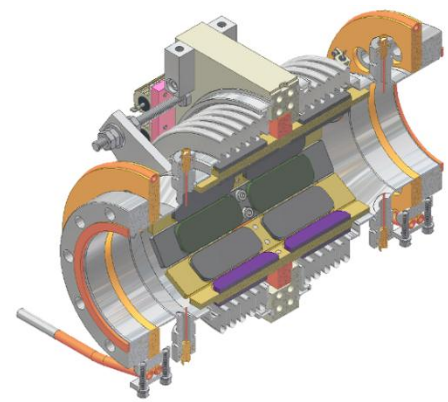
ERL Prototype HOM Loads

V. Shemelin, M. Liepe, and H. Padamsee, "Characterization of Ferrites at Low Temperature and High Frequency" Nucl Instr and Meth in Phys Res A Vol. 557, p.268 (2006).

Total # loads	3 @ 78mm + 3 @ 106mm
Power per load	26 W (200 W max)
HOM frequency range	1.4 – **100 GHz**
Operating temperature	80 K
Coolant	He Gas
RF absorbing tiles	TT2, Co2Z, Ceralloy

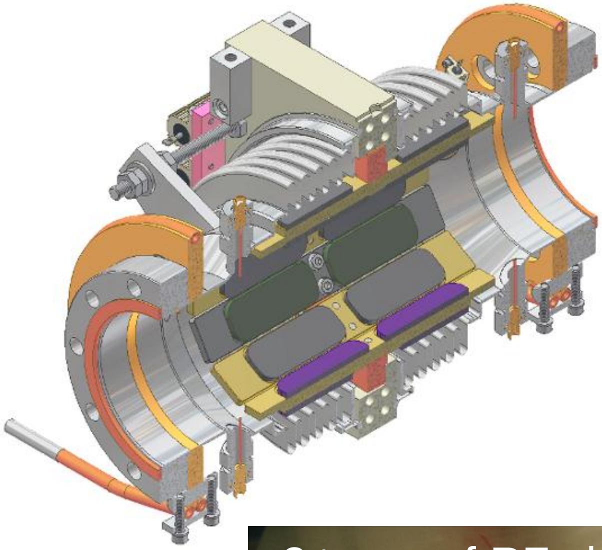


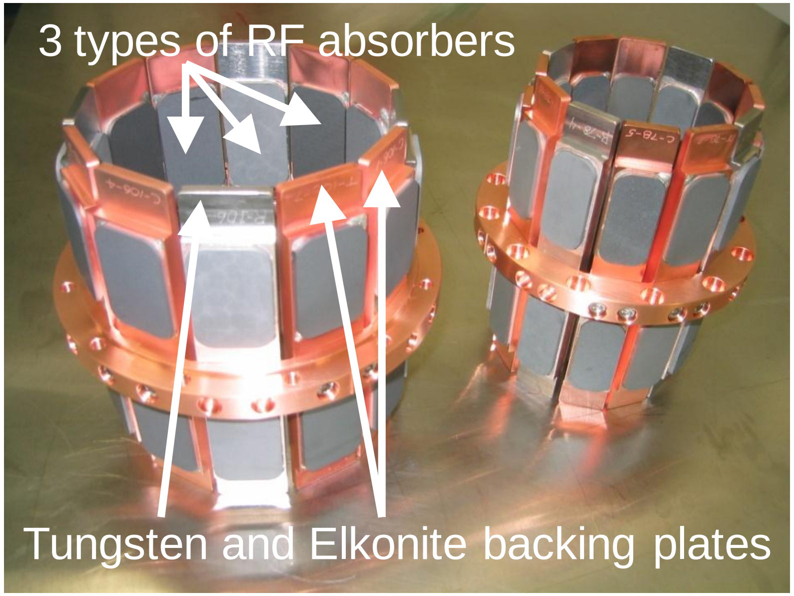




2 proto-types fab'ed by LEPP
6 production loads fab'ed by Research Instruments (ACCEL)

ERL Prototype HOM Loads



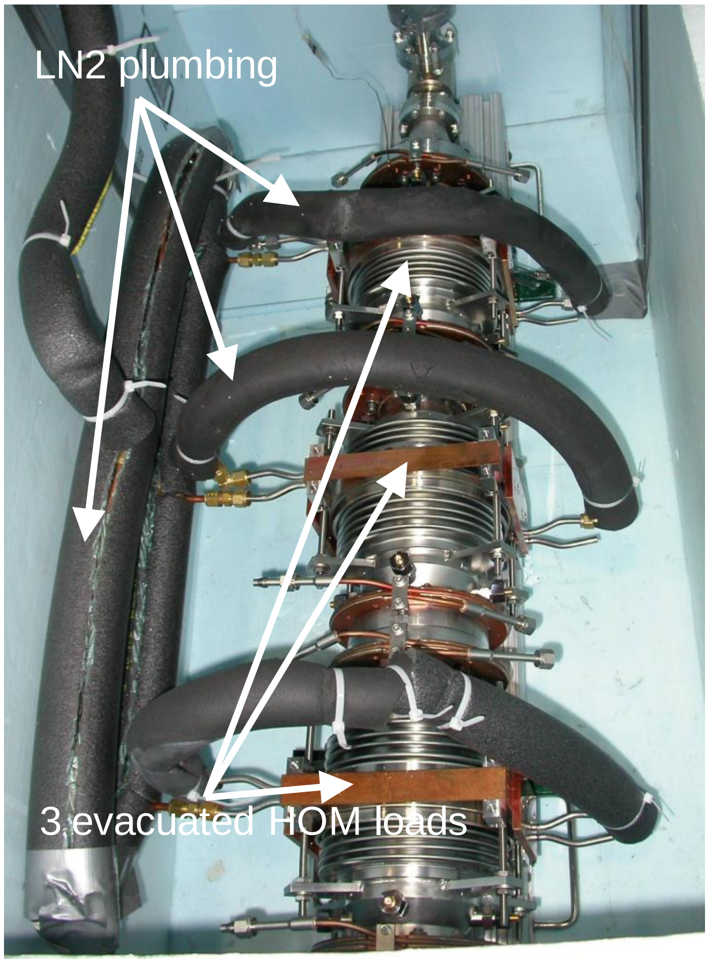


Beamline load assembly

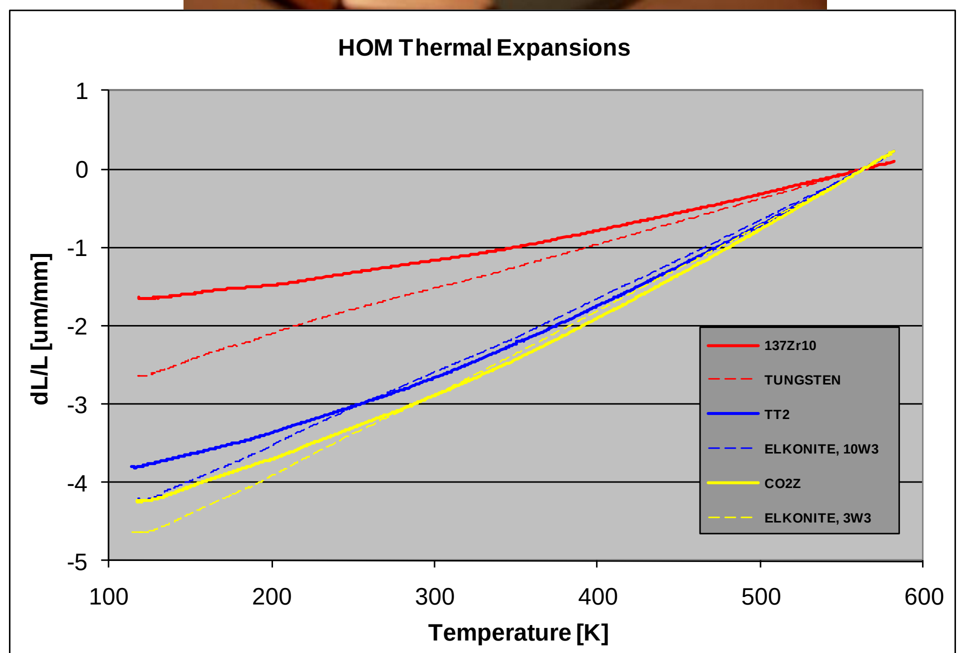
Problem #1: Delamination

Observed upon delivery of loads and after cold test

Cold test of loads



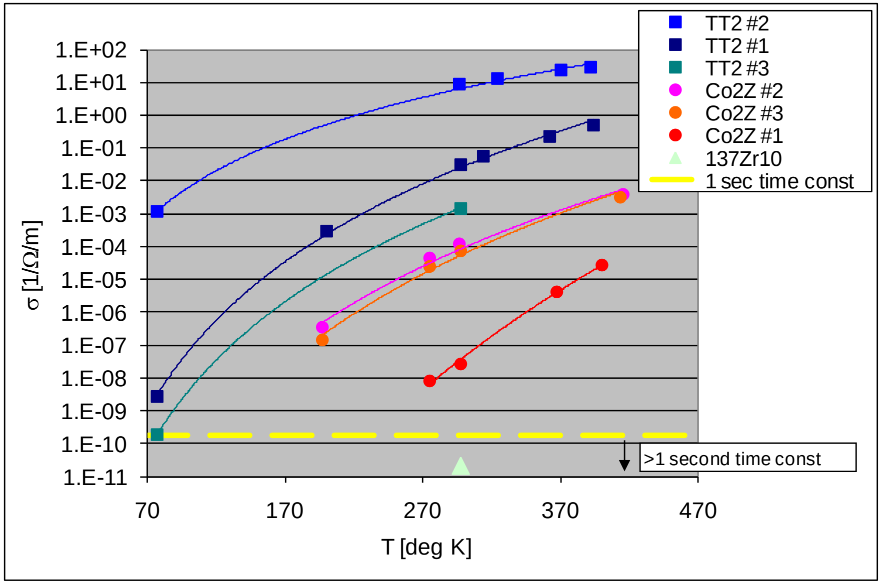
TT2 – 10W3 bond fracture



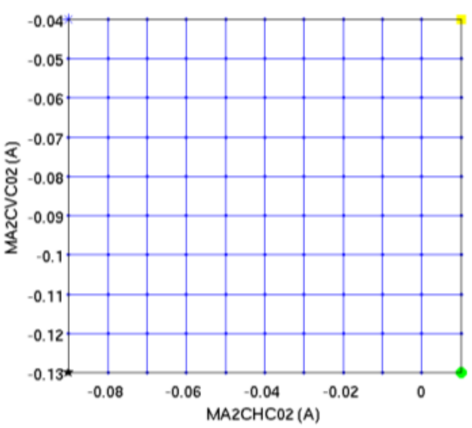
Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Problem #2: Static Charging

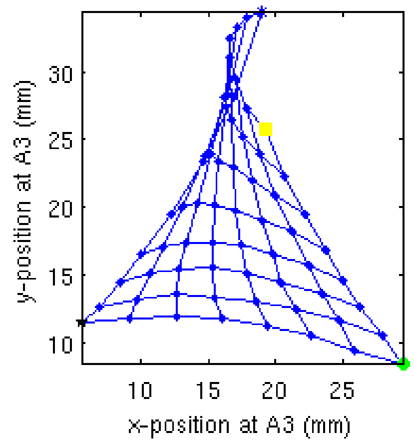
DC Conductivity Decline with Temperature

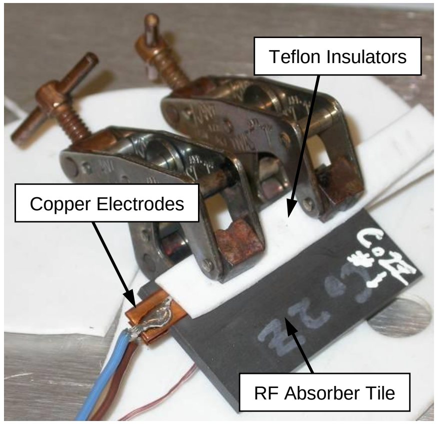


Expected raster scan of beam through the Injector



Measured raster scan of beam through the Injector





77K Conductivity Measurement

IEEE TRANSACTIONS ON MAGNETICS, VOL. MAG-4, NO. 3, SEPTEMBER 1968

Mechanism of Electrical Conductivity in Nickel–Iron Ferrite

CLINTON F. JEFFERSON AND C. KENNETH BAKER

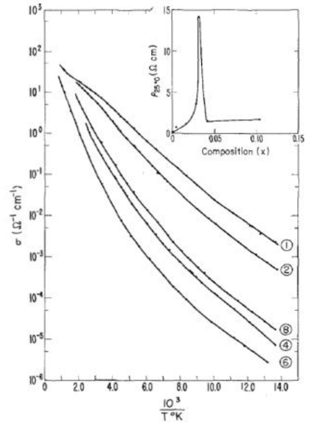
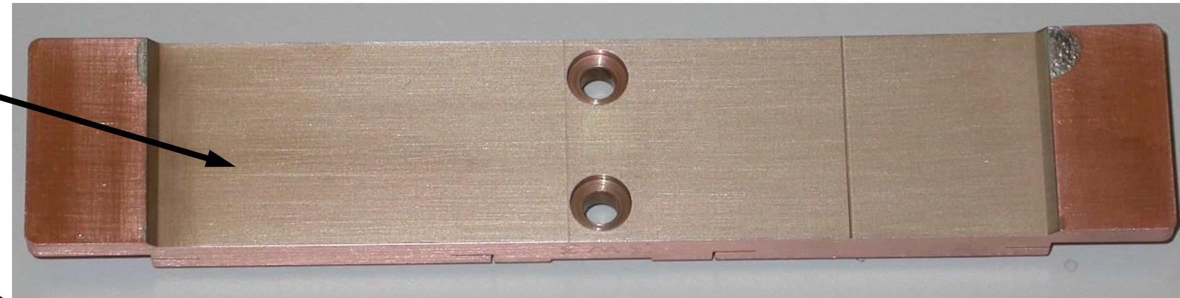


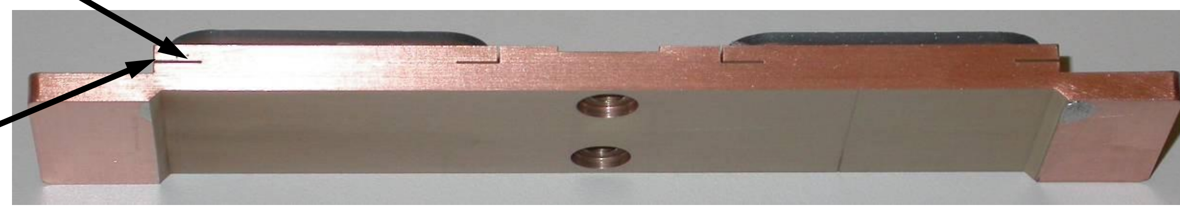
Fig. 1. Dc conductivity for several compositions as function of temperature. Compositions identified by sample numbers from Table I.

RF Absorber Panel Rehabilitation

Perform EDM wire cuts of RF absorber panels **facing the beam**. The reduction in HOM damping is likely acceptable for the Injector.

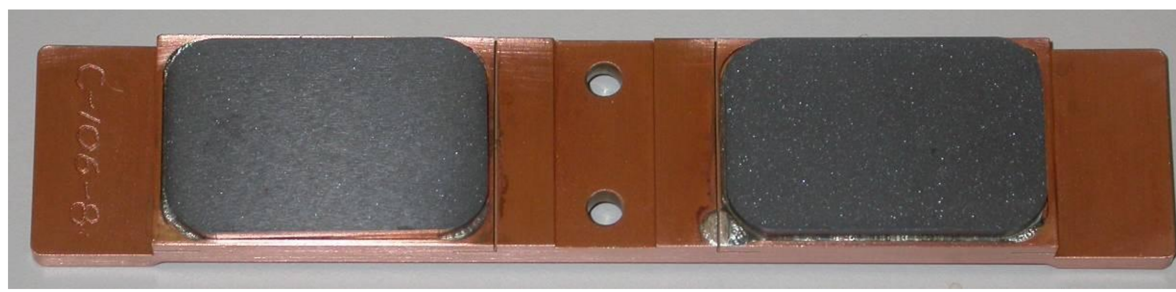
Also perform “stress relief” cuts.



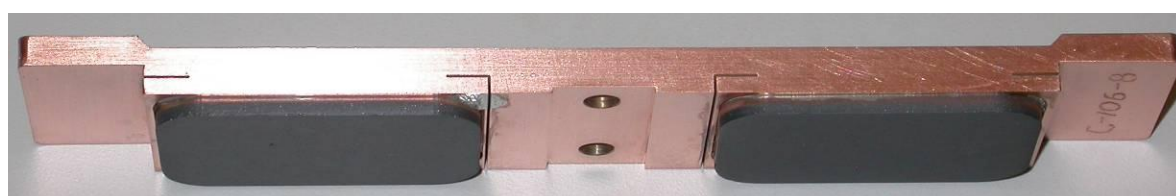


Clean EDM oxide residue by scrubbing with scotch-brite and mild soap

Remove residue from the stress relief slots by passing a thin wire/mylar through the slots.

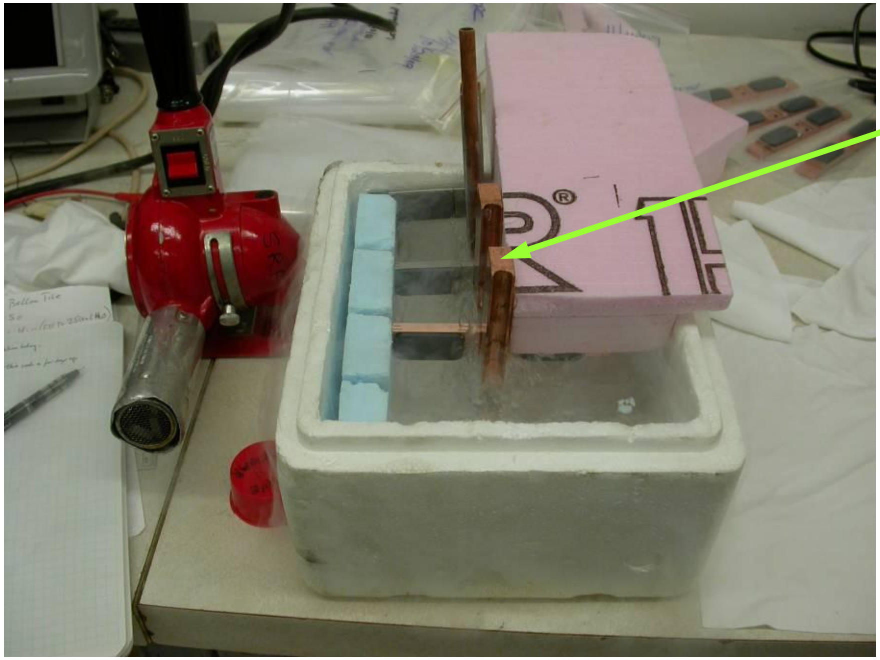


Ultrasound the clean panels in filtered methanol for 15 minutes, standing them on edge to allow residue to exit slots.



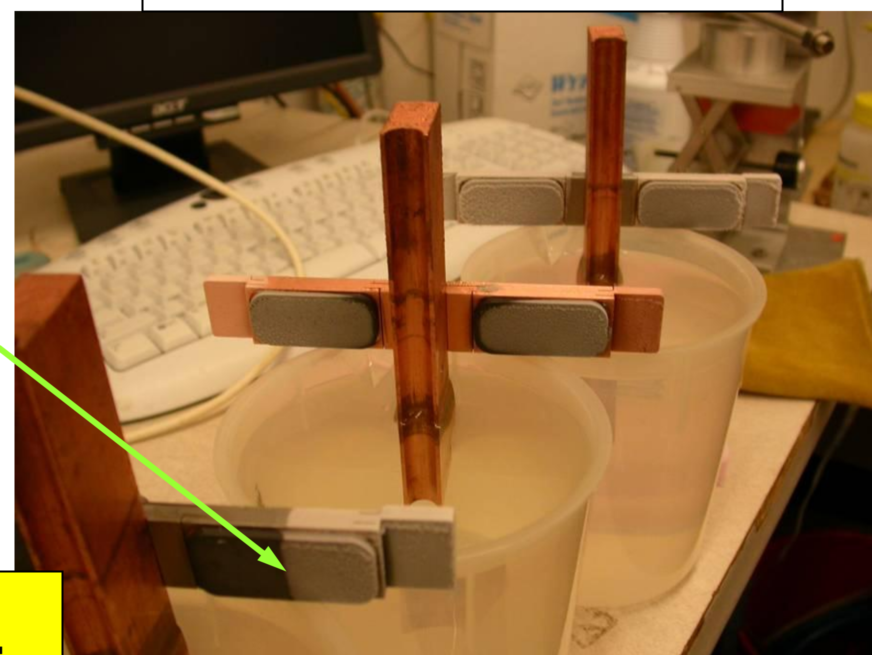
(A modest effort with conductive coatings was not proving fruitful on a short time scale)

RF Absorber Panel Cold Cycles



Bolt absorber panels to a copper bar, immerse the Cu bar in LN2, but do not immerse the absorber panel.

Remove absorber panels from LN2, immerse the bottom of the copper bar in warm tap water, 40-50 degC.



After 10-15 minutes, the frost will melt from the panels. **The rate of progression of the frost line across the ferrite is indicative of its solder bond integrity**. The frost line should progress symmetrically on the left and right sides.

- ***Eric N. Smith***

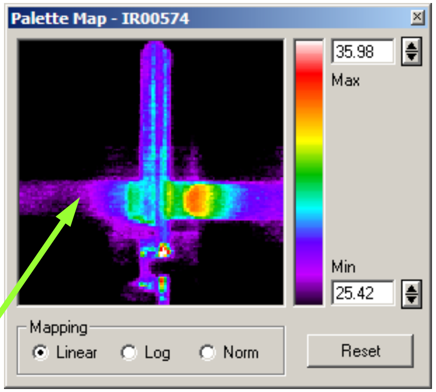
Iterate ~20 times…

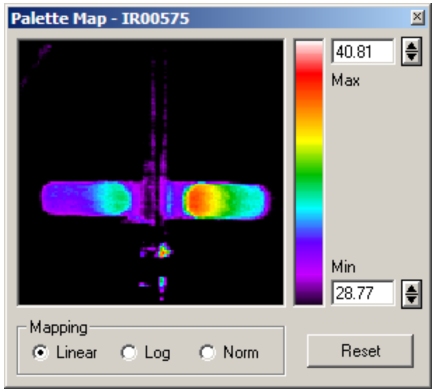
RF Absorber Panel IR Test

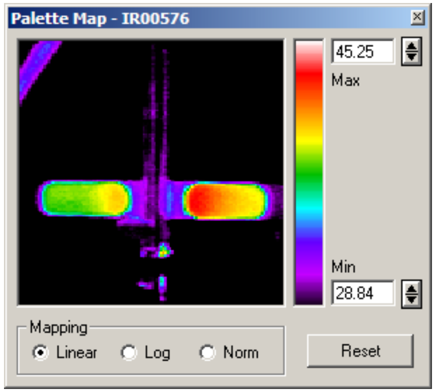
2 of 12 TT2 ferrite tiles were observed to begin delamination (frost line) after ~10 thermal cycles.

Additionally test the ferrite solder bond by alternating hot and cold tap water through a tube soldered to the copper test bar while observing the ferrite with an IR camera.

Poor solder bonds are observed as thermal lag, as seen in these IR images where the left-side ferrite is starting to delaminate and lags in temperature transient.





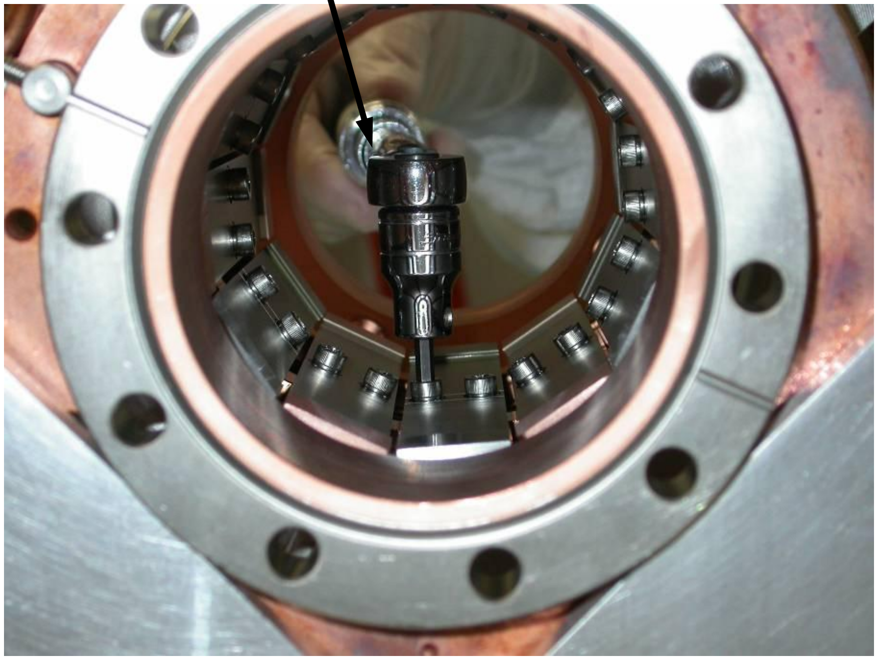


Use only RF Absorber panels with Co2Z ferrite and Ceralloy 137Zr10 (eliminate all TT2 ferrites)

RF Absorber Panel Re-Installation

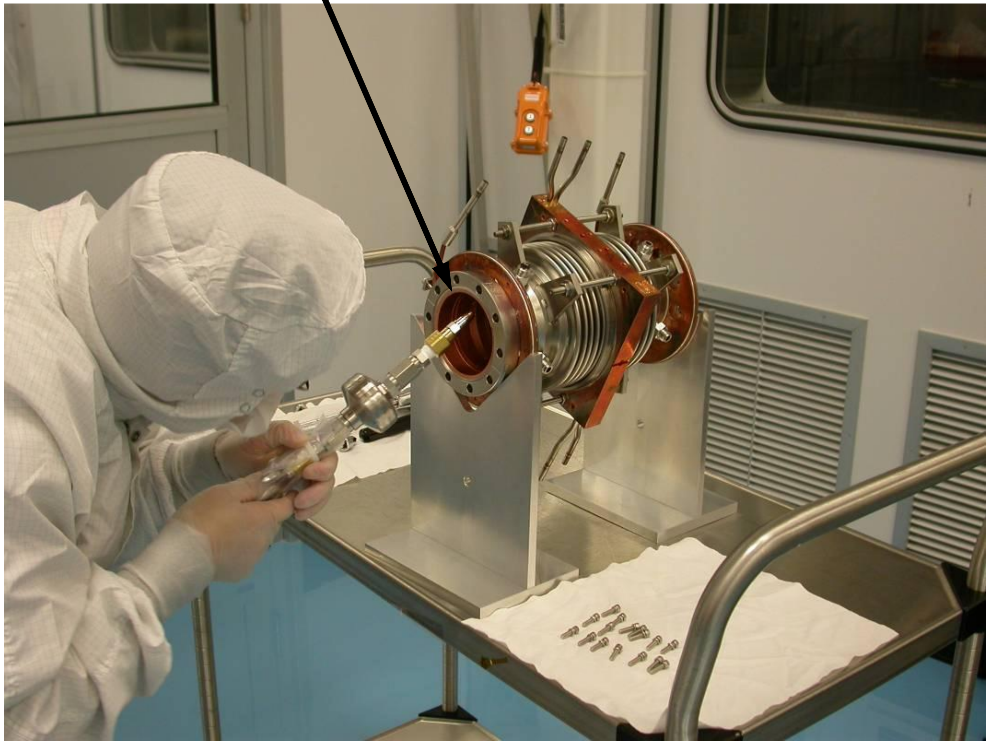
A person with careful work habits and small hands is preferable.

Tighten screws to 50 in-lbs.

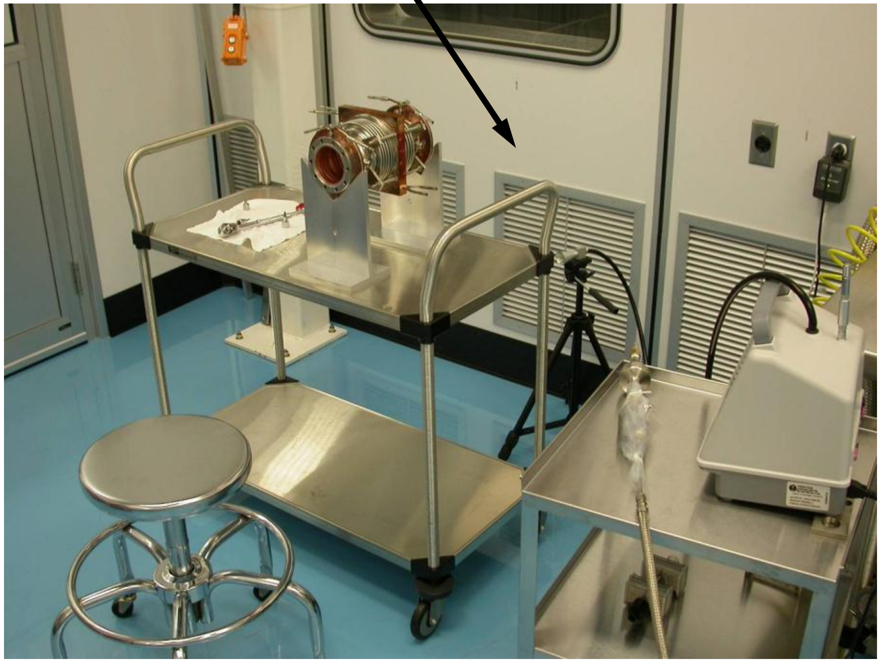


RF Absorber Panel Re-installation

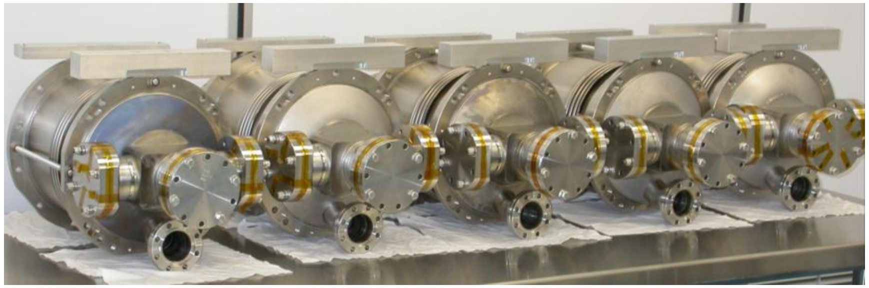
Perform filtered N2 jetting after each panel is installed, and thoroughly jet after all panels are installed.



Locate the particle counter intake about 30cm from the HOM flange.

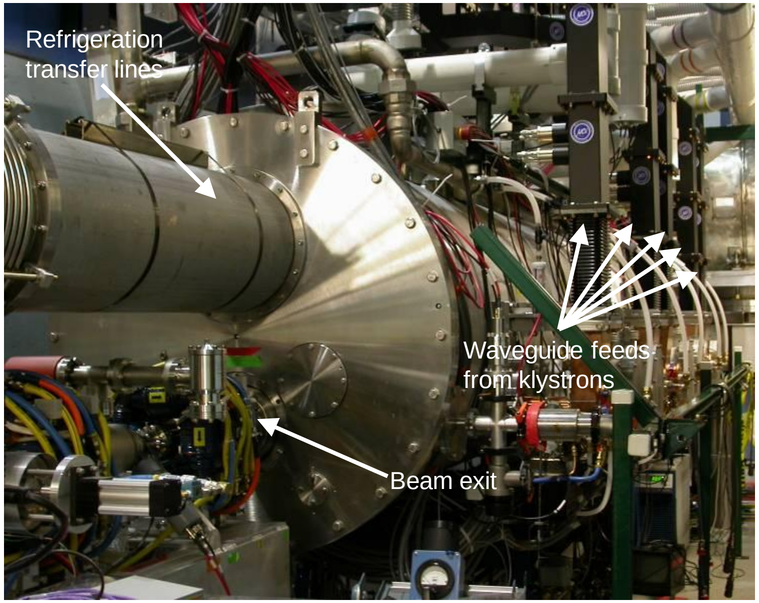


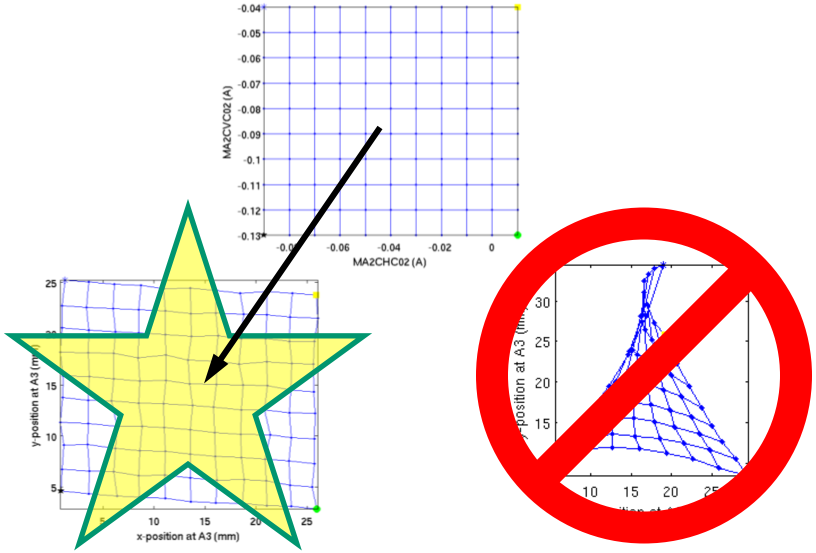
ERL Injector Prototype Assembly



ERL Injector Re-work

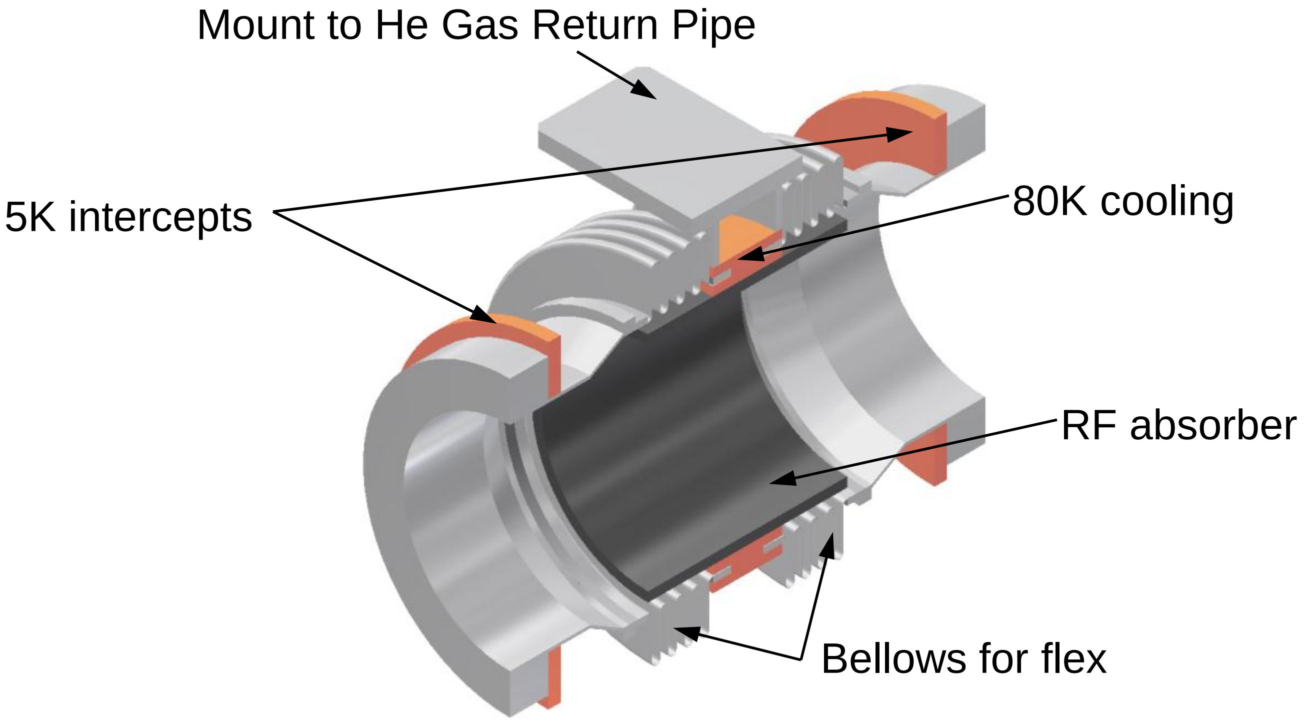
- ICM re-work initiated August 2009
- Complete ICM disassembly
  - EDM cut off beamside RF absorber tiles
  - SRF Cavity HPR
- ICM re-assembly complete February 2010, cooldown and test March 2010





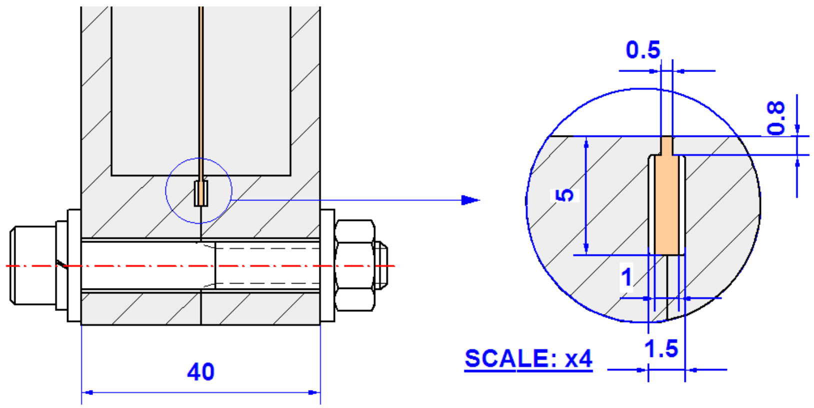
Next-generation ERL Beamline Load

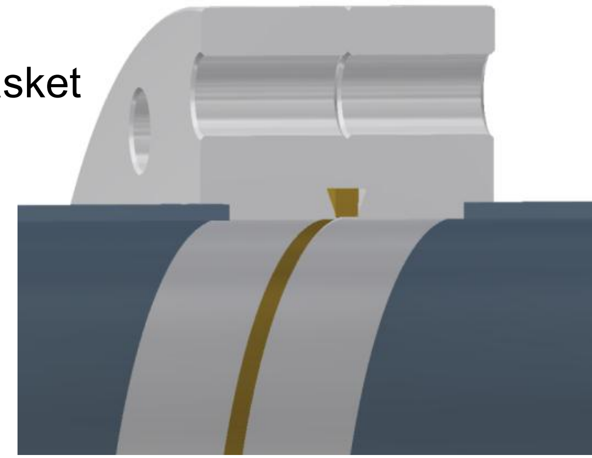
- Use a unitary broadband RF absorbing cylinder
- Only dielectric loss for now, reject ferrites and Ceralloy due to static charging and inconsistent properties (*see materials presentation*)
- Incorporate a full-circumference heat sink to allow >500W dissipation @ 80K
- New beamline flanges, variations of the "Zero Impedance Flange"



Next-generation Vacuum Flange

- DESY “diamond” seal leaves a small pocket on the beamline
- Investigating the KEK ZIF flange using an Al alloy gasket
- Investigating a “taper seal” flange per EVAC et al. using Al alloy gasket





RF Absorber

- Coorstek Si-C per JLAB (thanks to F. Marhauser for samples)
- Cylinders delivered, 110mm ID, 120mm OD, 140mm Long
- Broadband RF loss, $\varepsilon \sim 50 - i25$, not the ideal absorber, but the best available today
- Sufficient DC conductivity @ 80K
- No measured particulate generation
- Vacuum properties acceptable

Next-generation ERL Beamline Load

- A conservative approach for ERL HOM damping includes:
  - broadband damping provided by beamline loads, less likelihood of a stray mode located in a damping notch
  - larger beampipes on each cavity end (110 mm) to propagate modes with energy in either end cell
  - HOM power out of the coupler may provide additional safety factor
- Very useful lessons learned from the prototype loads
- A few fabrication details to be worked out for the next-generation load
- Confident that a robust beamline HOM load will result