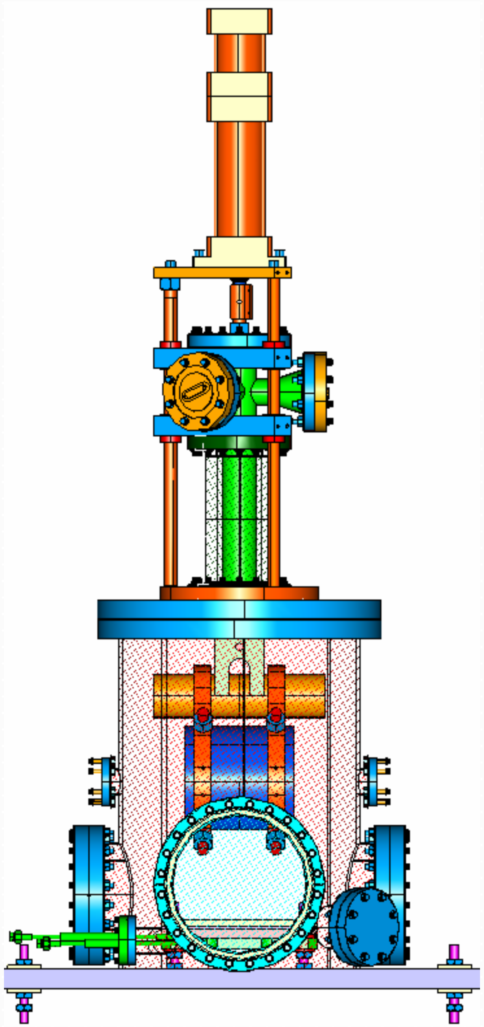
Hall A Calorimeter



M. Bevins

June 9, 2006

Agenda

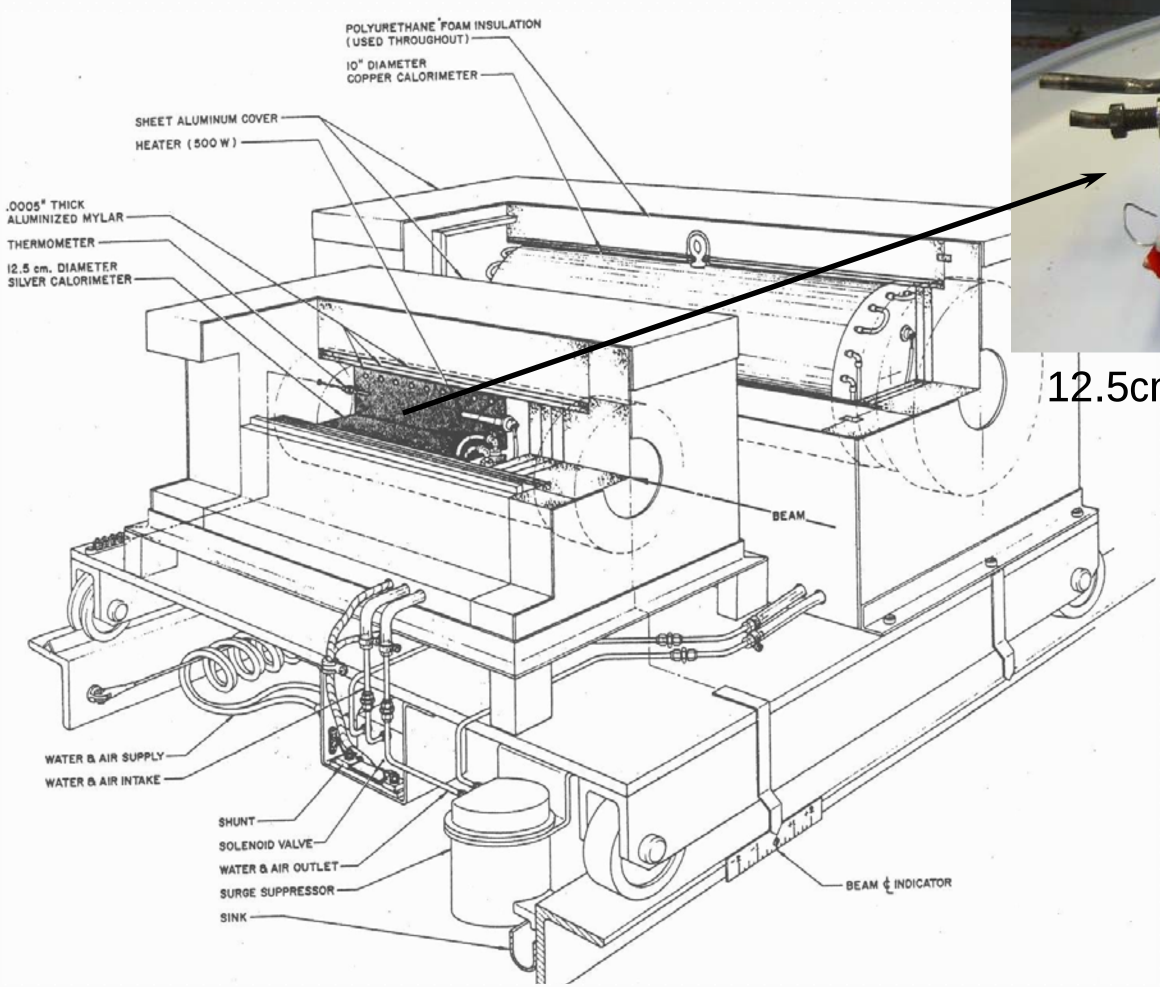
- Overview
- Design
- Thermal Simulations
- Operational Limits
- Pictures
- Status/Schedule

Overview

- Hall A experiment requires *absolute* beam current be measured to the 0.5% - 1.0% level for currents around 1μA
  - Existing absolute current calibration system is designed for much greater currents and would require extrapolation for lower beam currents
- A device based on calorimetry has been built to satisfy this requirement
  - Idea is as follows:
    - Expose block of material to beam for a well defined period of time
    - Measure the temperature rise, due to this exposure
    - Using the heat capacity of the material one can determine the energy[Joules] deposited during the exposure
    - Knowing the beam energy[MeV], the beam current[μA] can be extracted
  - Challenges:
    - Must limit energy loss via particle loss or thermal loss so that the beam current can be extracted without additional uncertainties
    - Heat capacity of materials are not known with the precision required here so it must be measured (used resistive heater inserted into calorimeter and precision power supply)

Overview

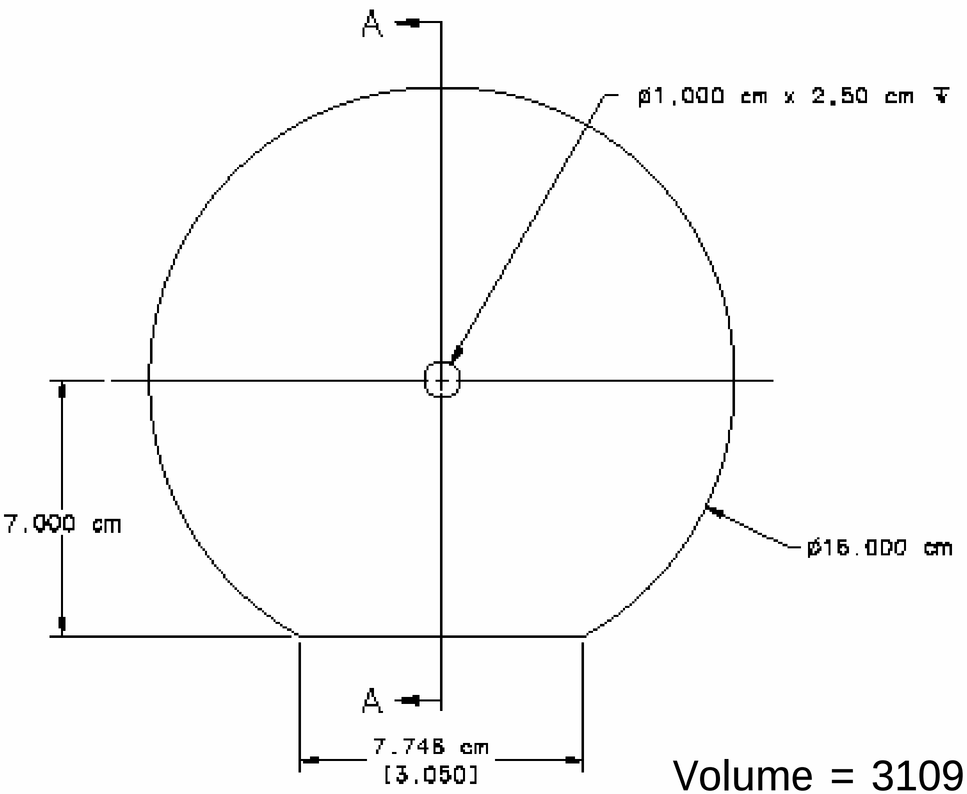
- Large copper and silver calorimeters built at SLAC in the late 1960's reportedly achieved precisions of about 1% and influenced the design of this calorimeter

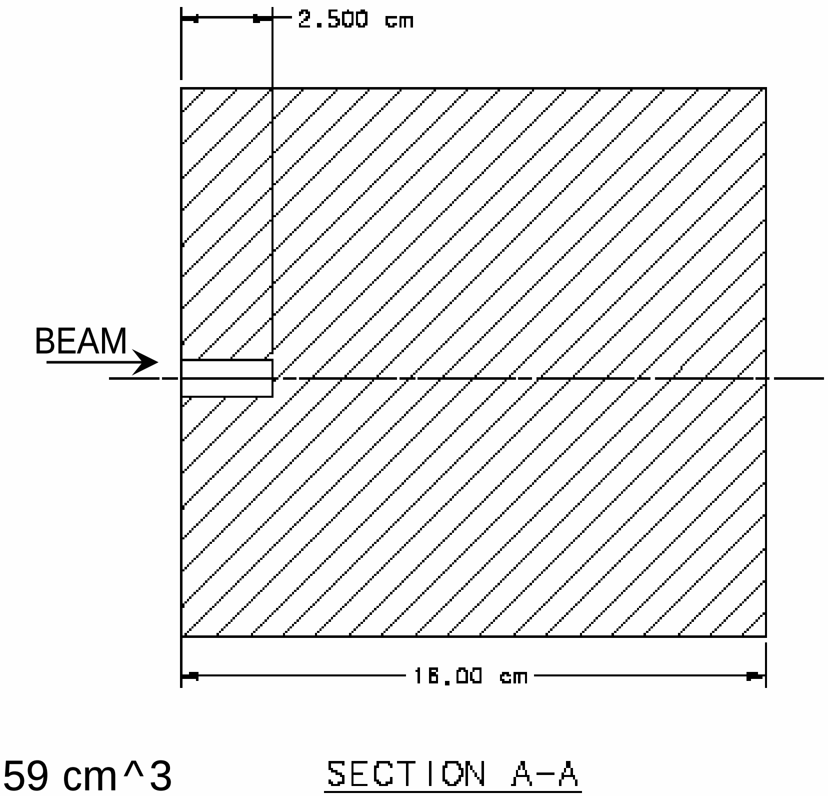


12.5cm dia x 21cm lg silver calorimeter

Design

- The optimal size shape and material for the calorimeter was driven by particle containment studies (P. Degtiarenko)
  - Tungsten 16cm dia x 16cm lg with entrance hole to minimize losses from backscattered particles
    - Thermal response time comparable to larger silver cylinder with equivalent particle loss (larger silver cyl not practical to fabricate)





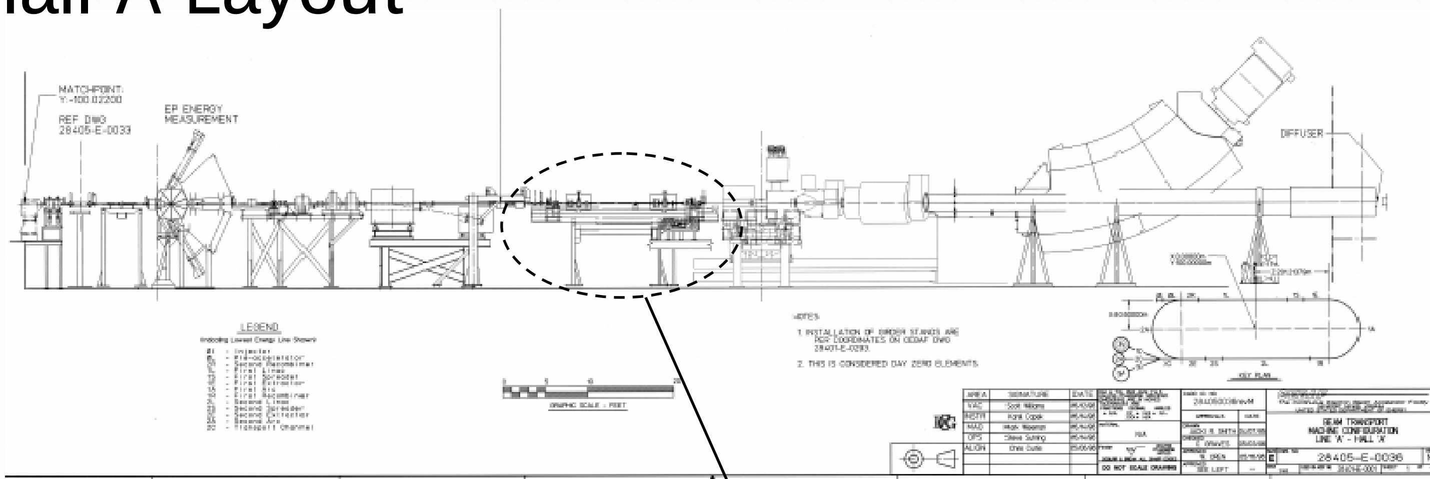
Volume = 3109.59 cm^3

Design

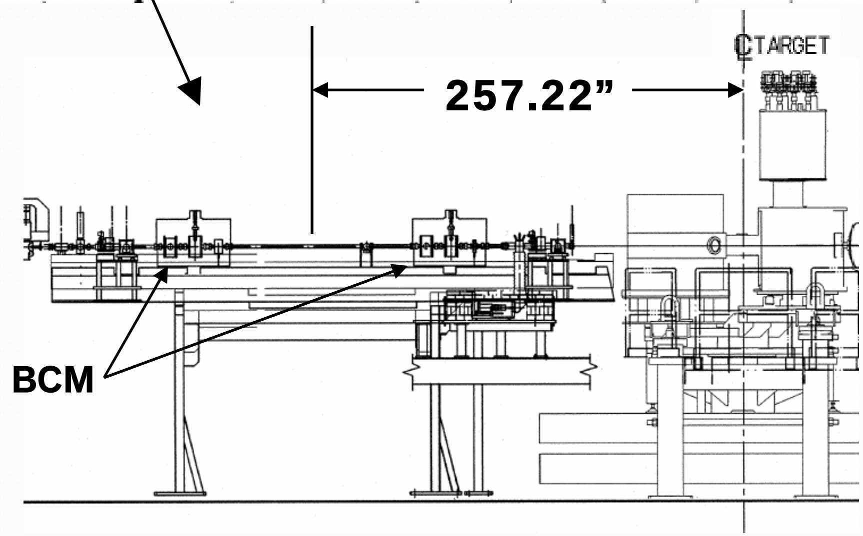
- Calorimeter Material
  - Desire a fully dense, machinable part with good thermal properties
  - *Pure* tungsten shapes typically produced by powder met process (pressing and sintering followed by a extrusion or swaging operation to reduce porosity). Subsequent operations to reduce porosity are not practical for a part a large as ours.
  - Density and machinability can be improved by adding small amounts of Ni and Cu (W,Ni,Cu 95:3.5:1.5) but thermal properties are less desirable.
  - Found a WCu 90:10 pseudo-alloy that is nearly fully dense, homogenous, machinable, and has higher thermal conductivity than the above materials and still retains a high density.

Design

- Hall A Layout



- Super Harp Girder
  - Locate Calorimeter between BCMs on girder



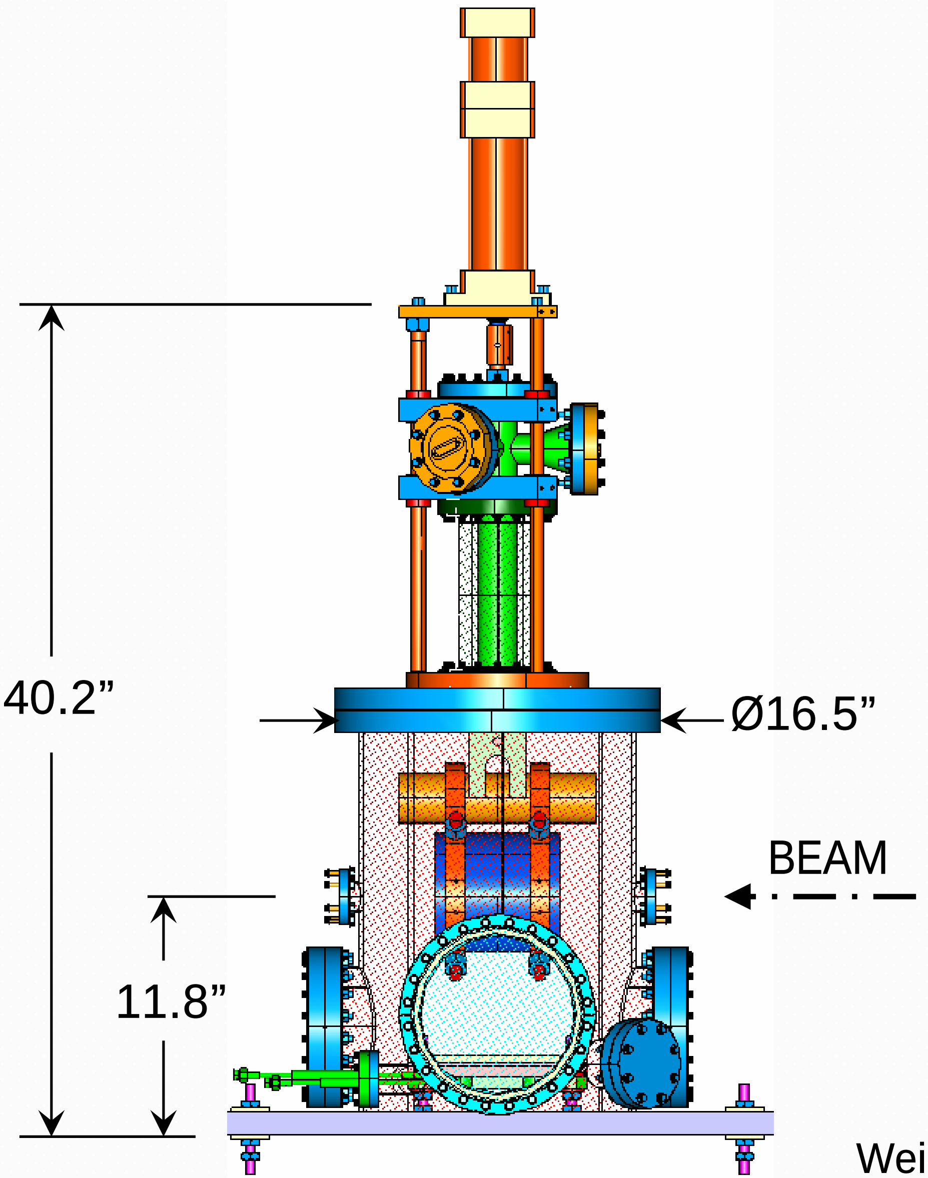
Design

- Invasive nature of measurement requires the calorimeter material to be inserted into and out of the beam line
- An advanced compliant thermal interface material was identified that allows us to cool the slug by placing it in contact with a chilled plate rather than embedding or otherwise attaching cooling tubes
  - reduces heat loss from the slug and simplifies thermal response
- Operational Scheme

  Three positions:

  - *1. In beam*
  - *2. Equilibrating (slightly raised above chilled plate)*
  - *3. Cooling (resting on chilled plate)*

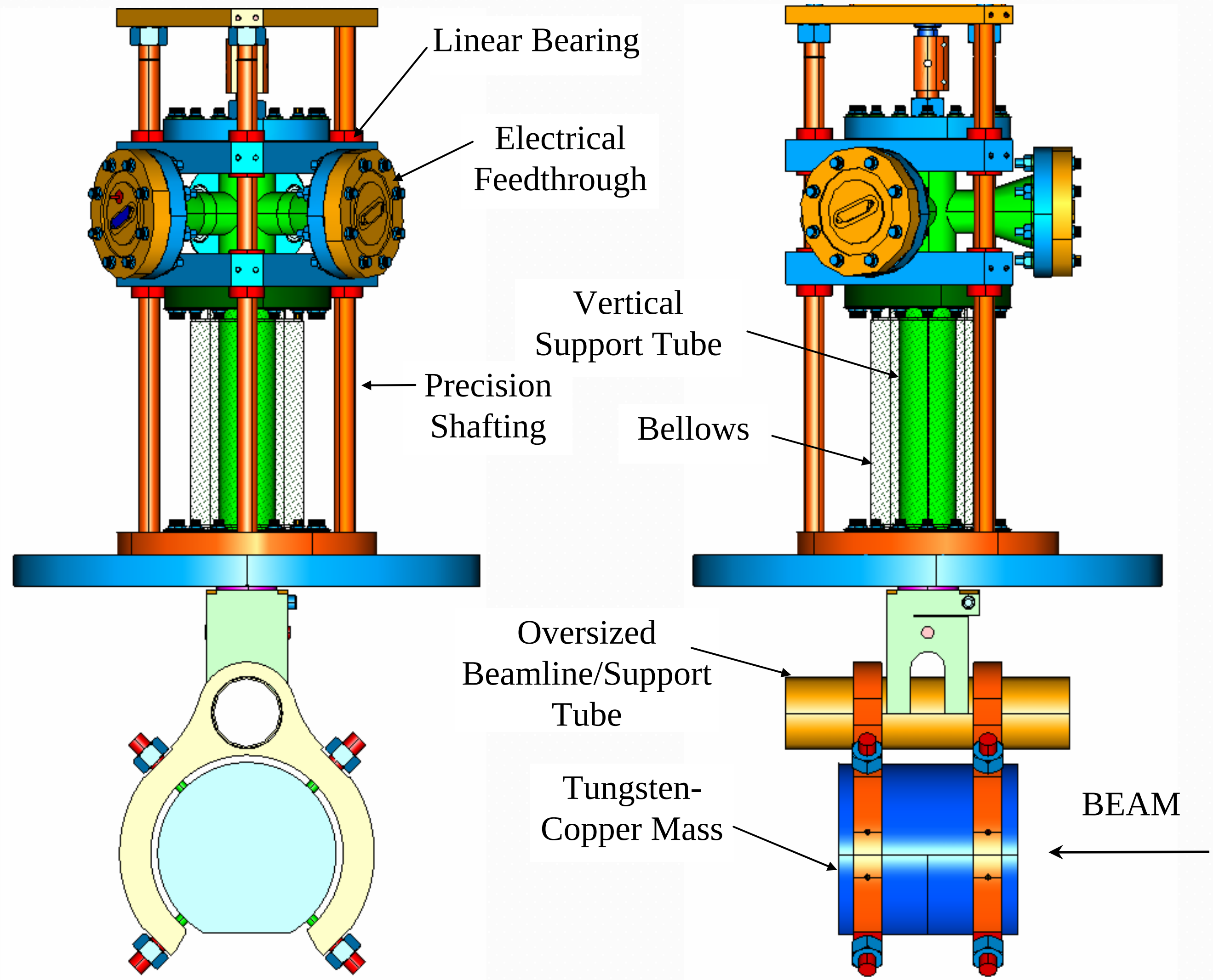
Design



Weight ~500 lbs

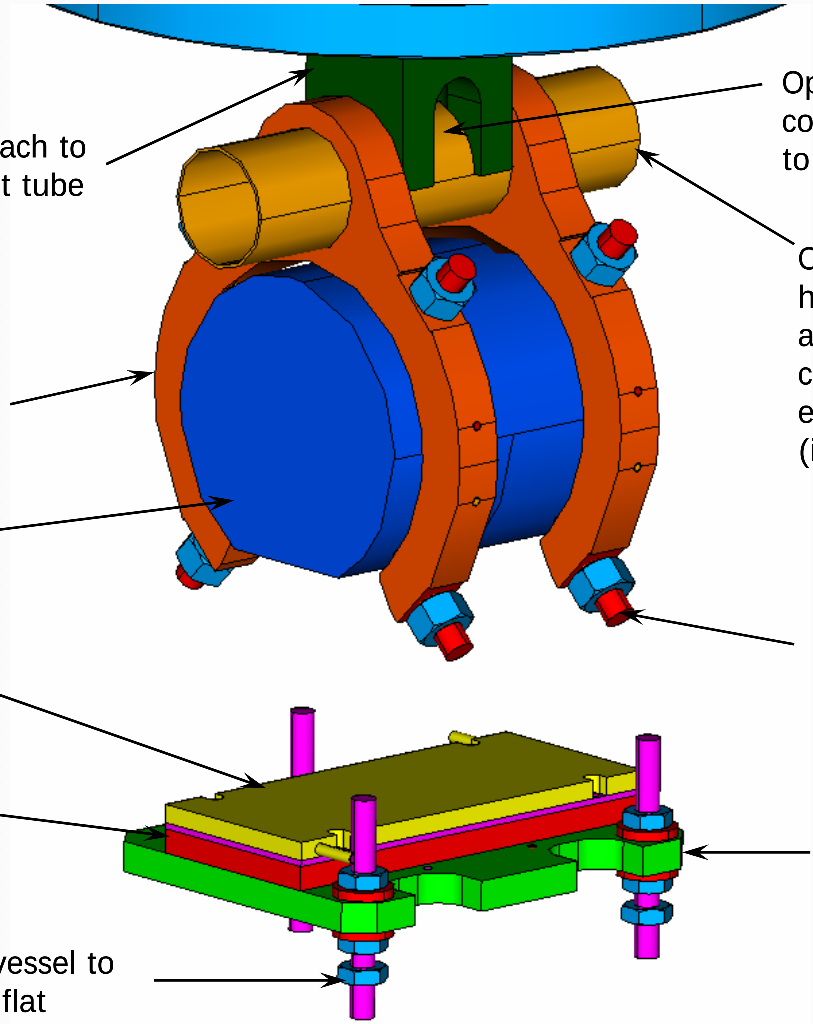
Design

- Mechanism



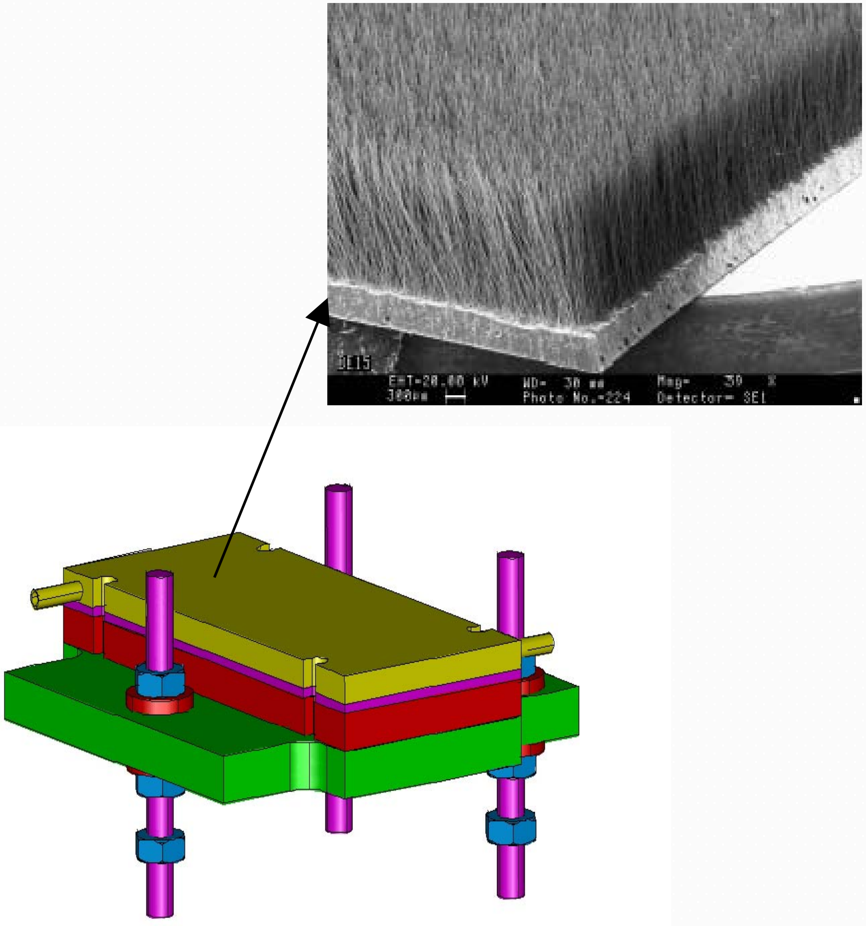
Design

- Slug Support & Cooling Plate



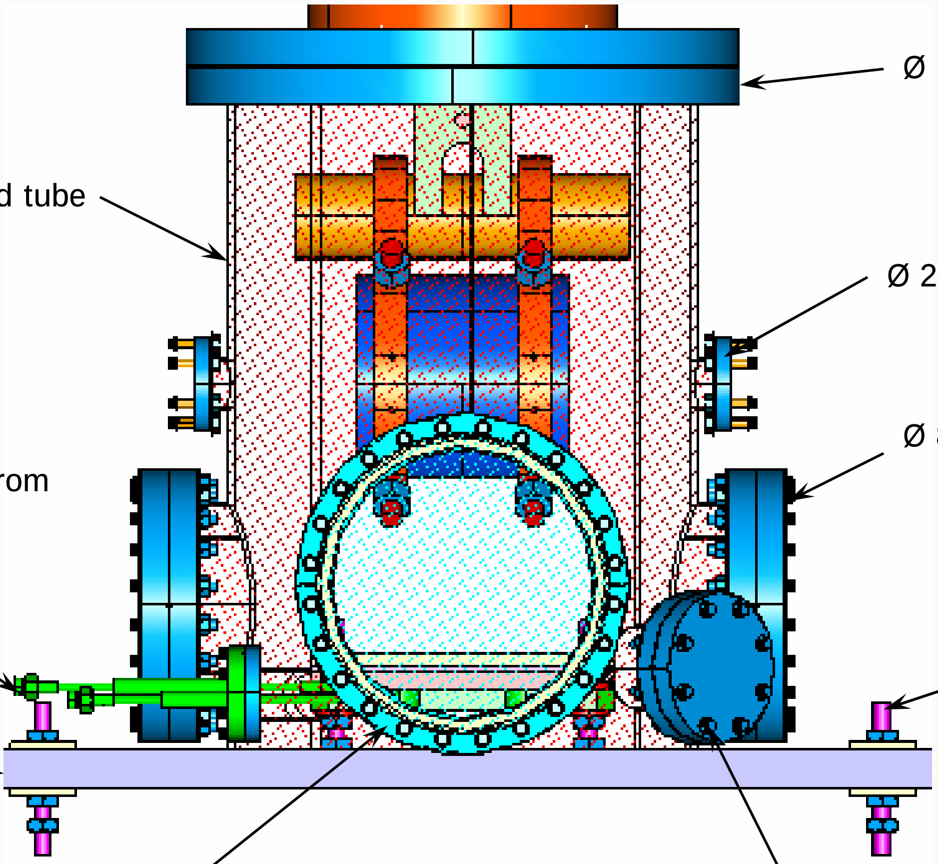
Design

- Compliant Thermal Interface
  - Consists of an array of aligned 7µm diameter carbon fibers
  - Each fiber spans the gap between mating surfaces resulting in improved thermal performance over conventional particle filled pads
  - High aspect ratio provides mechanical compliance (~.006” displacement at 15psi for .020” thk pad)
  - Fibers are directly attached to cooling plate using a thermally conductive epoxy then encapsulated in a silicone.



Design

- Vacuum Vessel

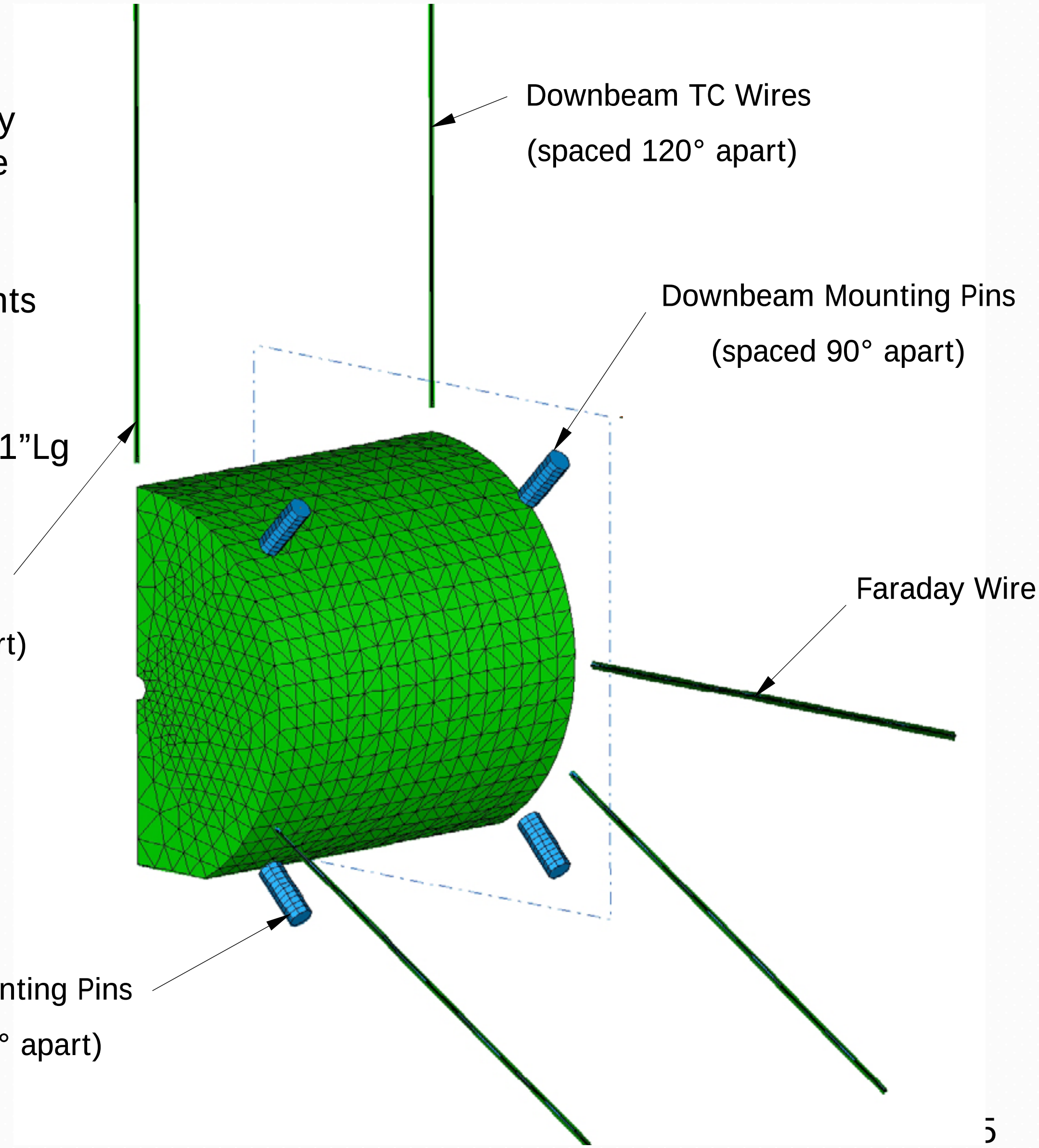


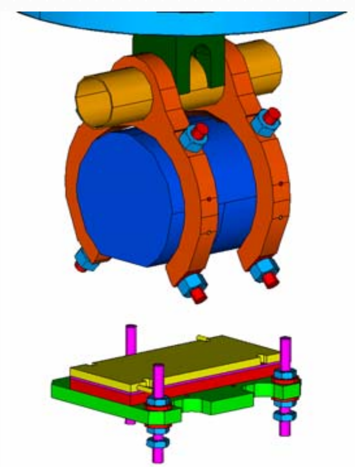
Thermal Simulations

- For initial modeling, a 2d transient axis-symmetric implicit finite difference (FD) model was written using Visual Basic for Applications in Excel (used to compare materials and estimate conductive and radiation loss)
- Lumped mass model used for initial cooldown estimates
- IDEAS TMG transient solver now available at Jlab was used to check results from FD code and conduct more detailed analyses

Thermal Simulations

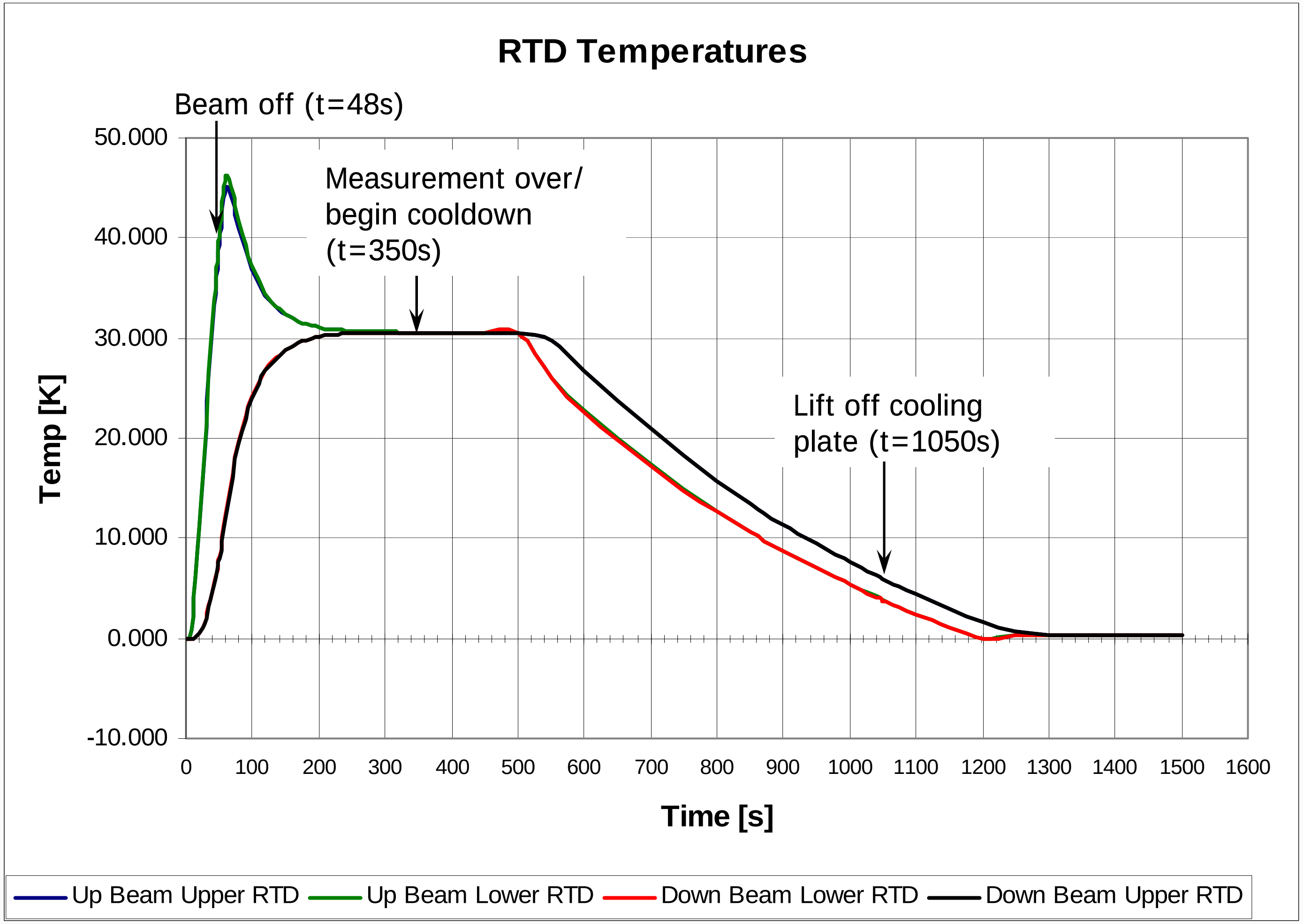
- IDEAS/TMG Model
  - Took advantage of symmetry and modeled only half of the slug
  - Mounting pins and wires modeled using beam elements
  - Slug modeled using solid elements
  - Wires are 8”Lg, mounts are 1”Lg





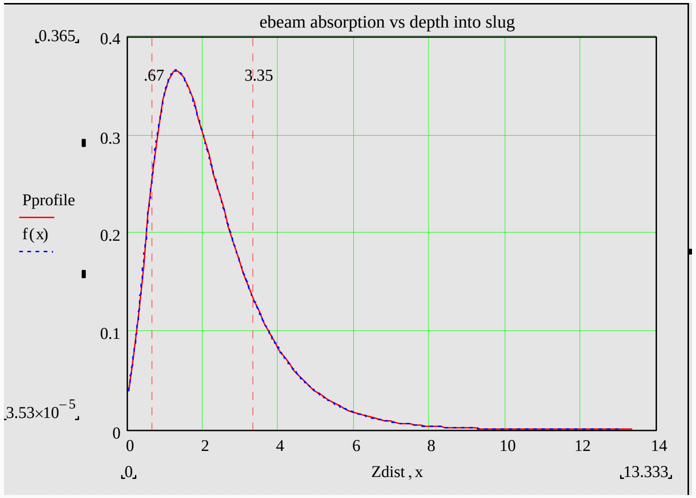
Thermal Simulations

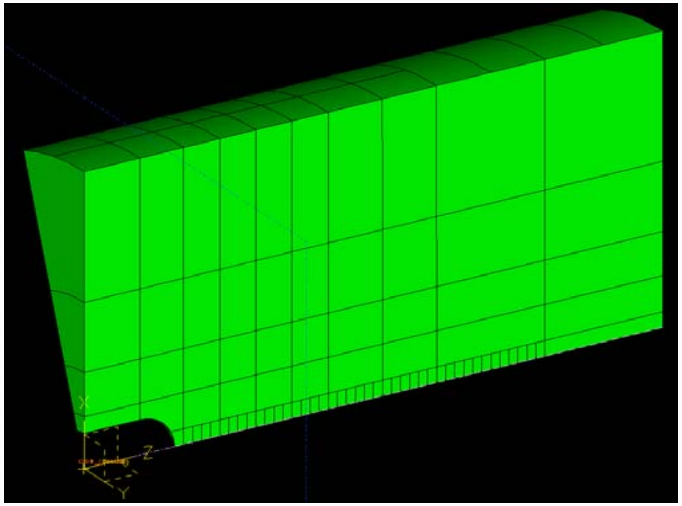
- IDEAS/TMG Thermal Model Results

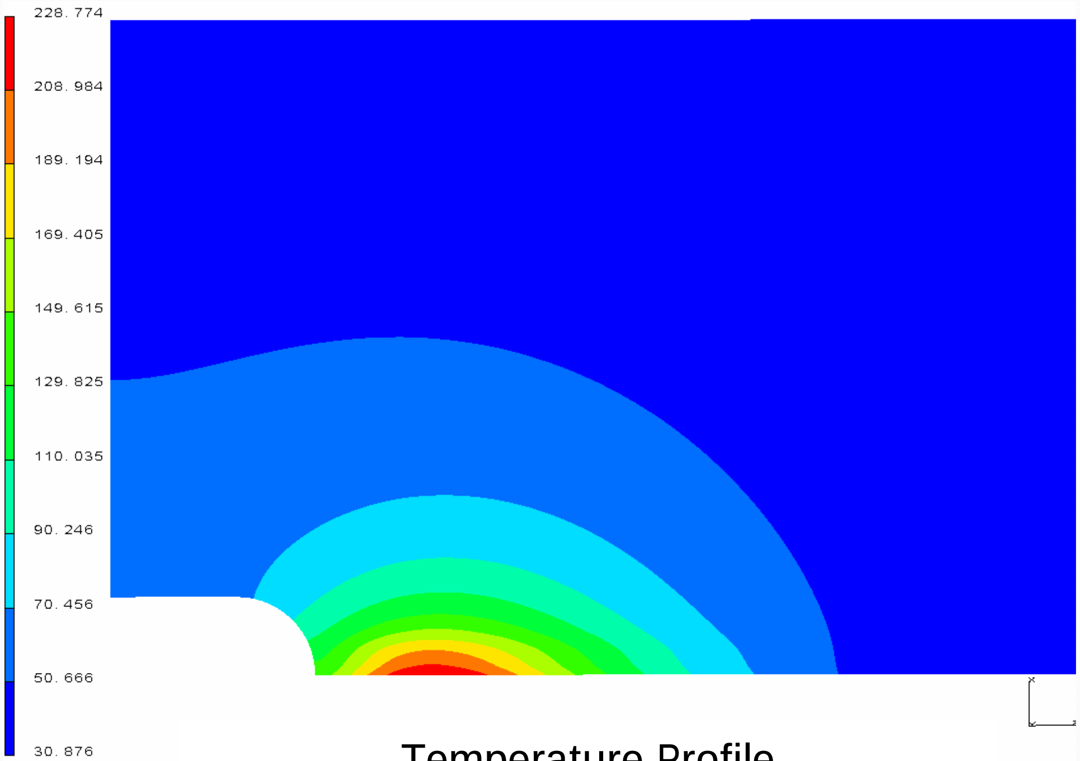


Thermal Simulations

- Peak temperature gradients and resulting thermal stresses were estimated using longitudinal ebeam absorption profile
  - Uniform radial distribution equivalent to 7.5mm x 7.5mm square raster







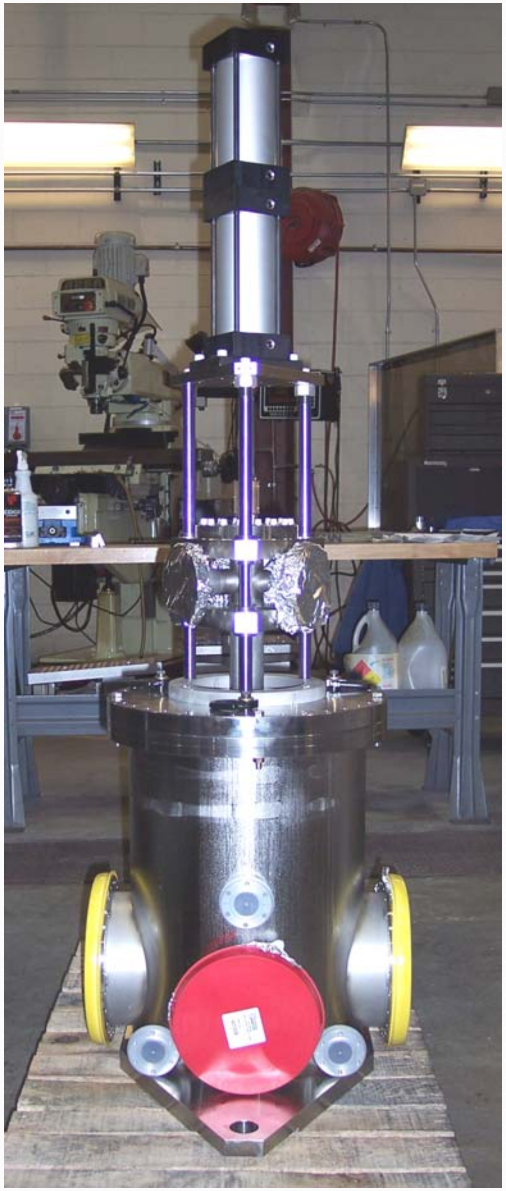
Temperature Profile

2.5kW, 50 sec exposure, ~15K equilibrium temp rise

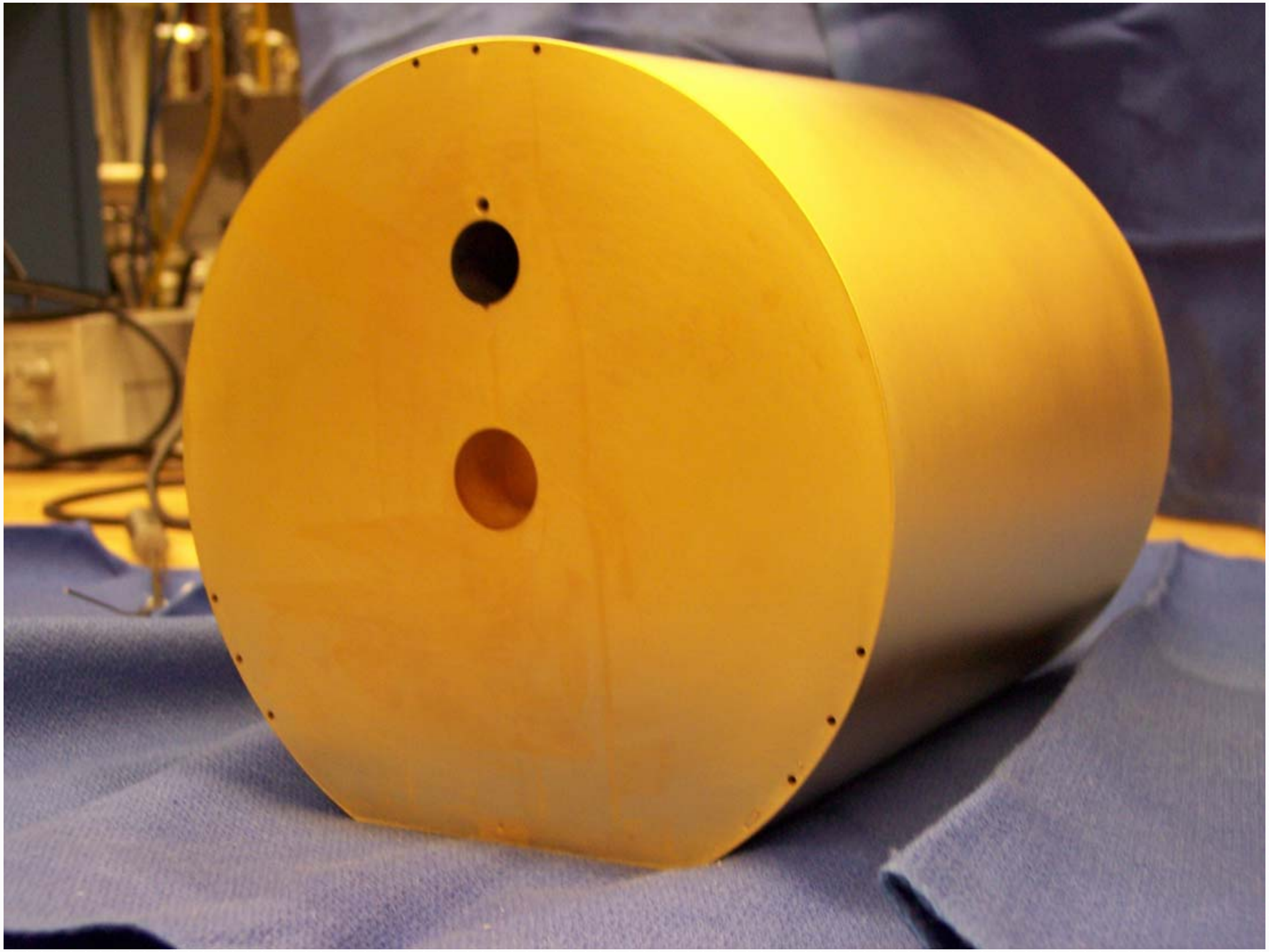
Operational Limits

- Device is an uncooled 2.5kW dump
- Three allowed positions:
  - In beam (completely raised)
  - Equilibrating, slightly raised of the cooling plate (intermediate position)
  - On cooling plate (completely lowered)
- Should not be inserted with beam on
- Should not be exposed to more than 2.5kW of beam
- Beam must be rastered
- Ion chambers/BLM will not like this device

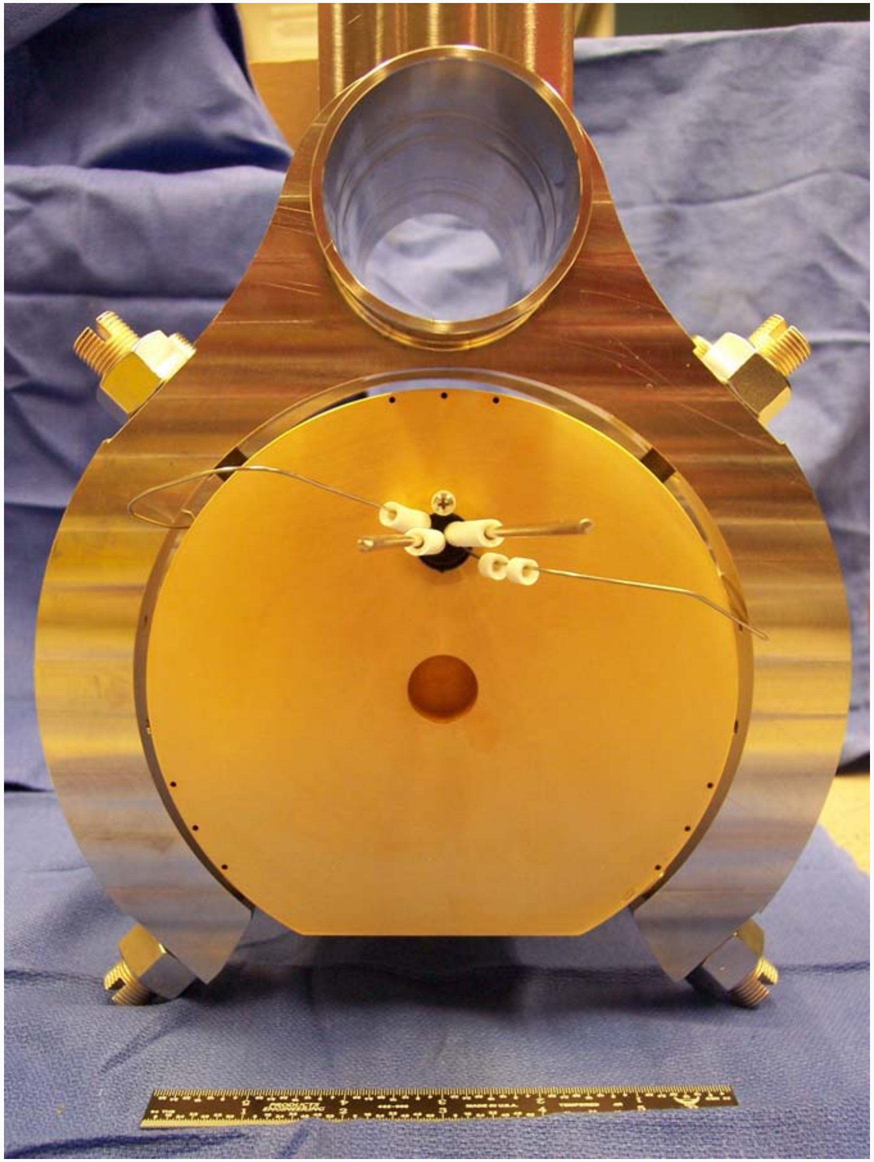
Pictures - *Device in Jlab machine shop*



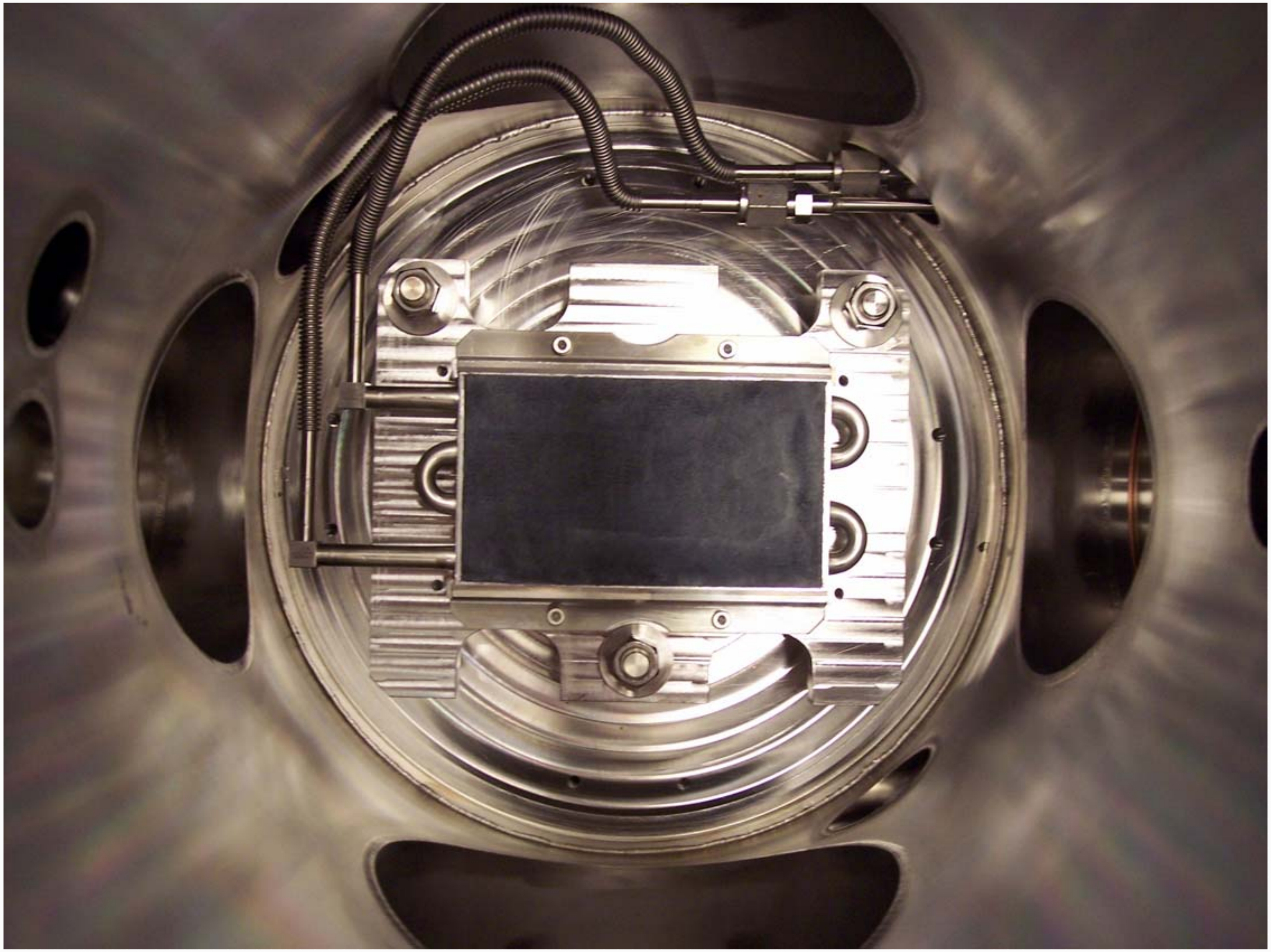
Pictures - *Gold plated WCu cylinder*



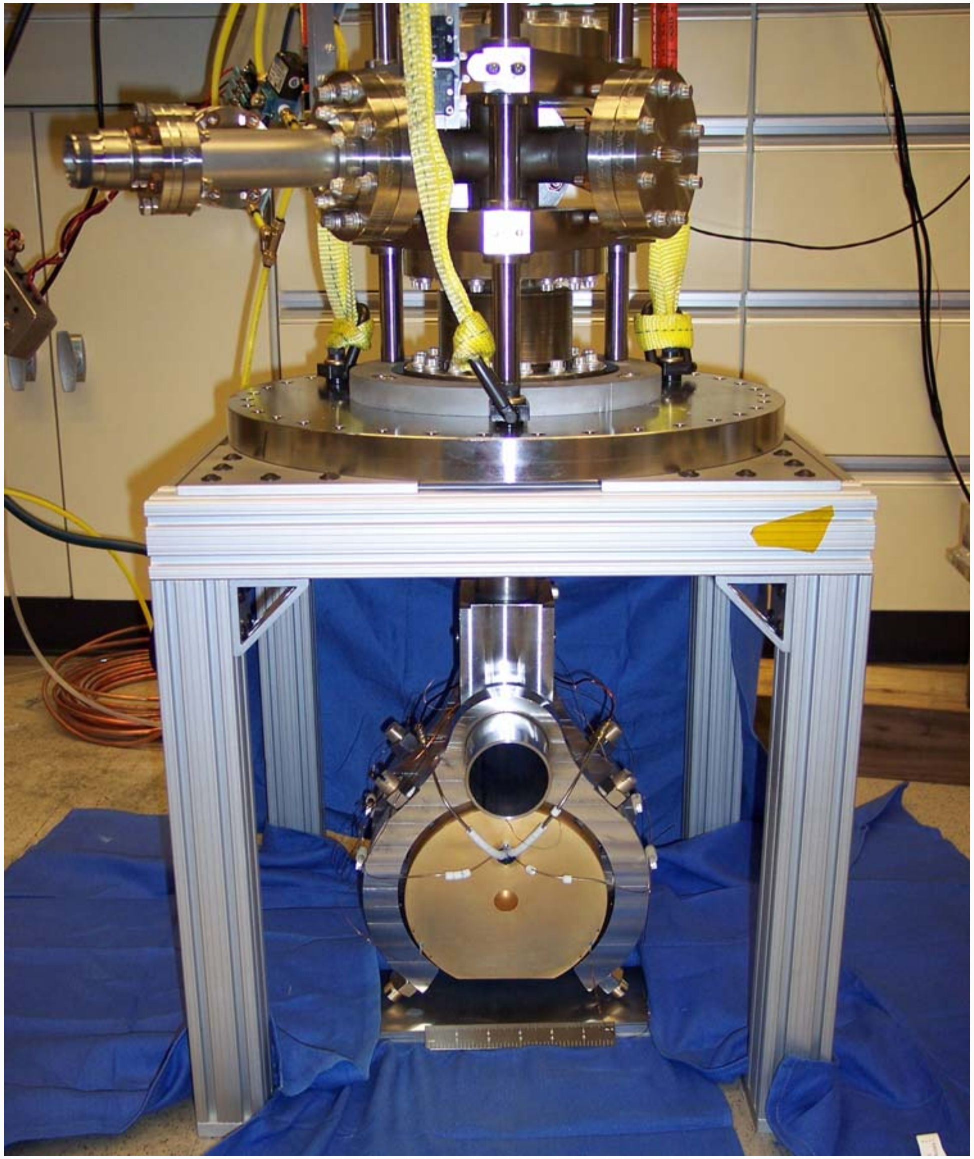
Pictures - *WCu cylinder mounted in assy*



Pictures - *Cooling plate in vessel*



Pictures - *Device on test stand*



Status/Schedule

- Calibrations in lab are going *very* well
- Complete heat capacity measurements by 6/15
- Survey group has marked mounting positions on Hall A girder
- All installation hardware is on hand (cartridges, caps, bellows, flanges, etc.)
- Modifications to Hall A girder completed by ~mid month
- Installation in Hall A last week of June
- Survey and alignment
- Cabling and checkout in the hall first two weeks of July