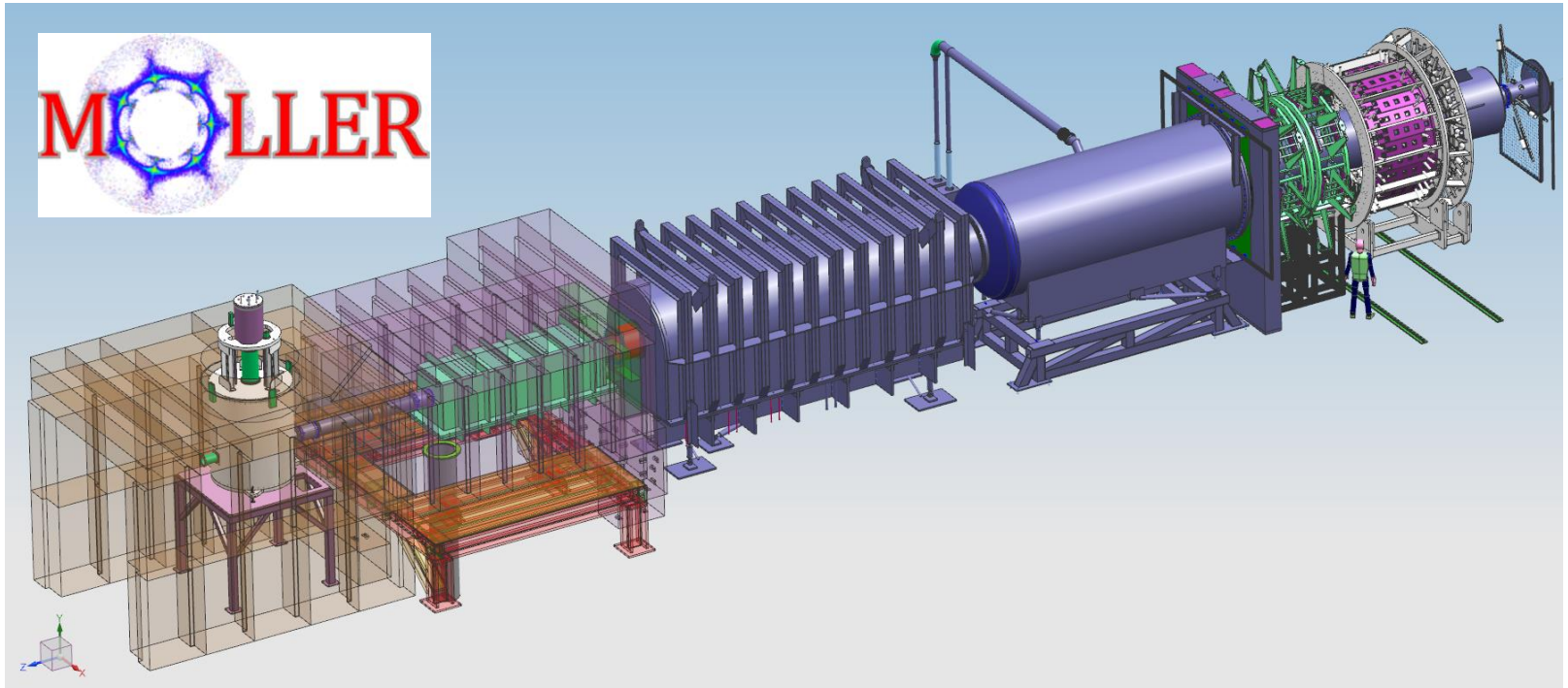
MOLLER Spectrometer – WBS 1.03

MOLLER Collaboration Meeting

June 21-22, 2022

Spectrometer Engineering



David Kashy

Team - Magnet Group/ENP/Engineering and MIT

Jefferson Lab

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

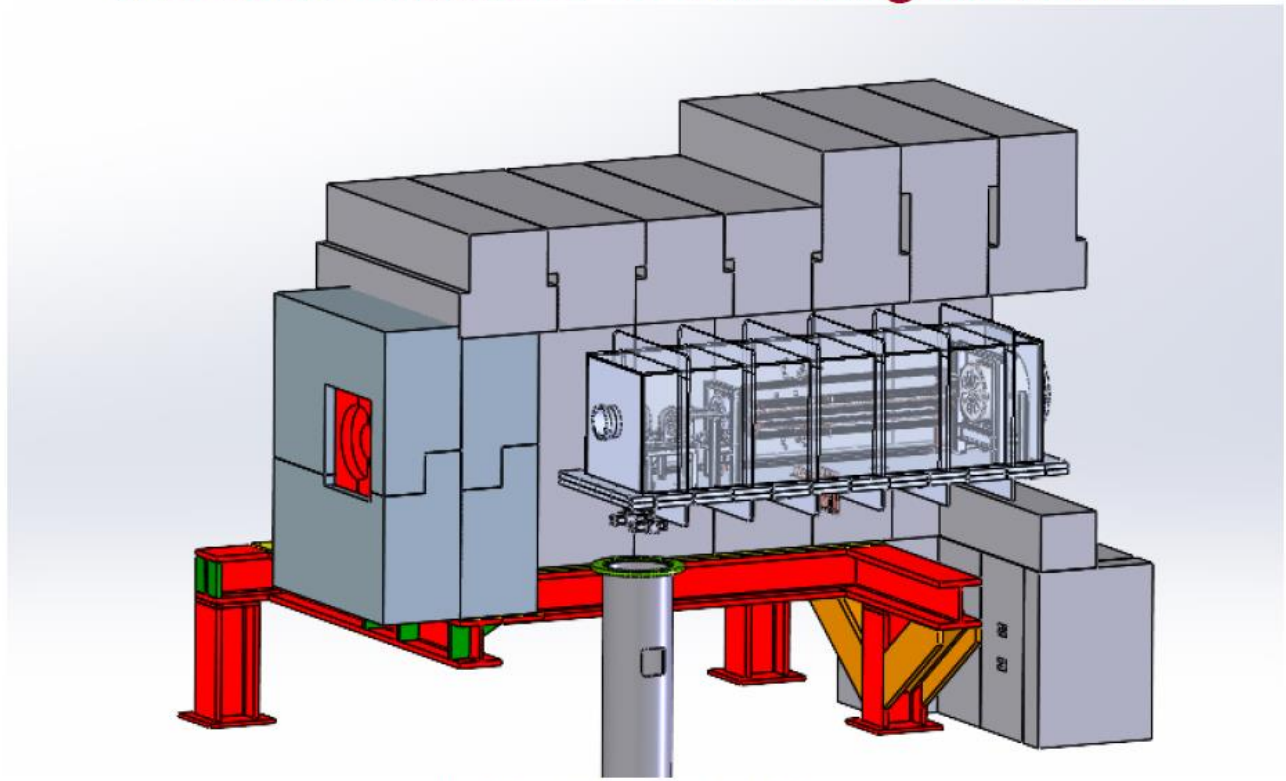
Outline

- Upstream System
  - Enclosure and Upstream Torus
  - Collimators and Blockers
- Downstream System
  - Beam Pipes and Bellows
  - Windows
  - Downstream Torus
    - Magnet Piping
    - Collimators and support
    - Lintels
    - Collar 1
    - Coil Prototype Progress
  - Summary

NOTE!
This presentation will not cover everything in the MOLLER Spectrometer but will give many examples of recent progress

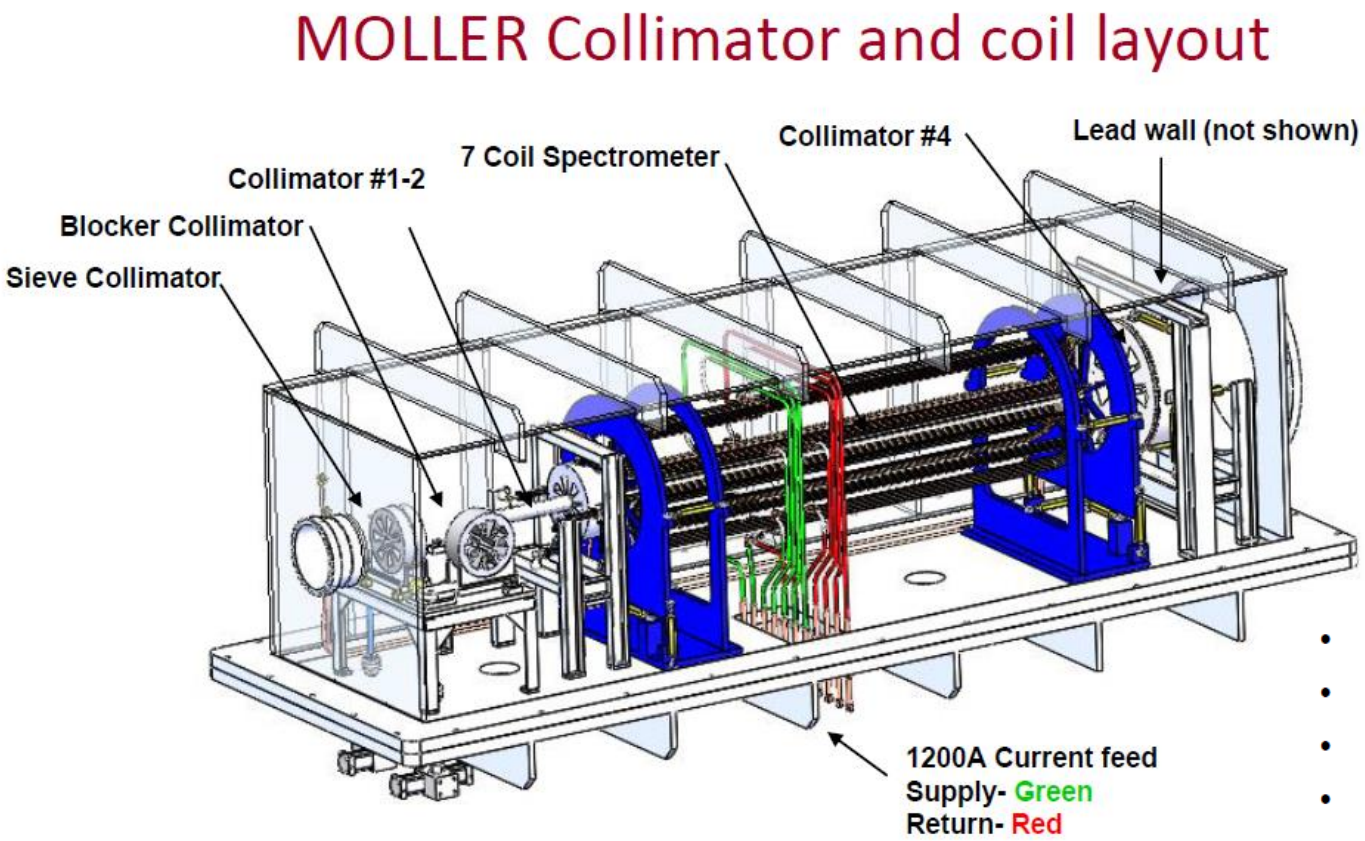
US Enclosure in Shielding

MOLLER Chamber to shielding clearance



- Hardware to top of pivot = 300 mm
- Chamber to red steel = 660 mm
- Chamber top to shielding = 300 mm
- Chamber side to shielding = 500 mm
- Chamber front to shielding upstream = 1,100 mm

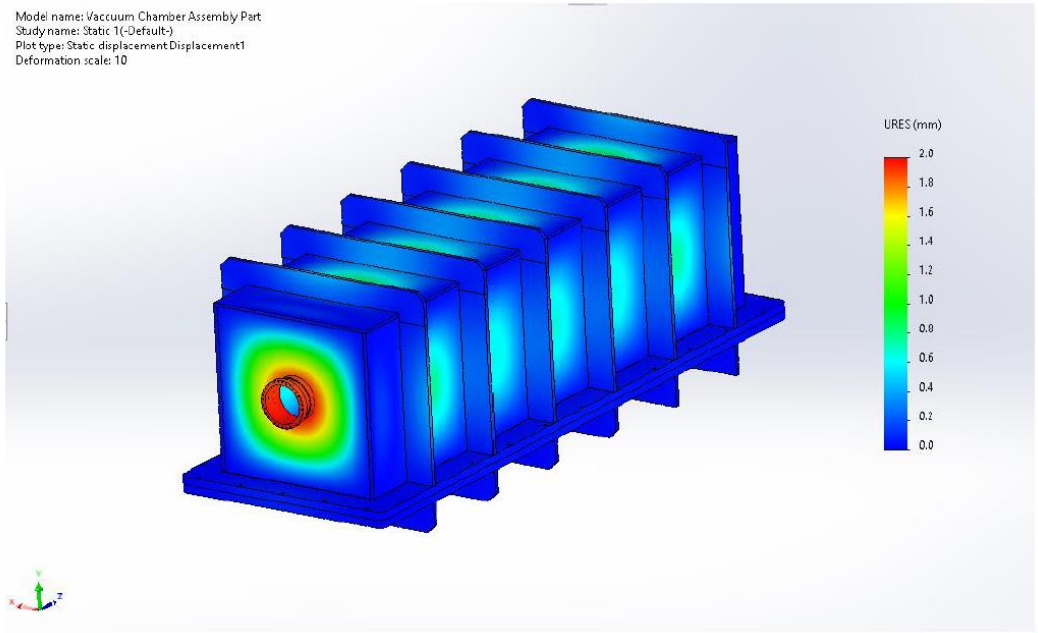
US System Components



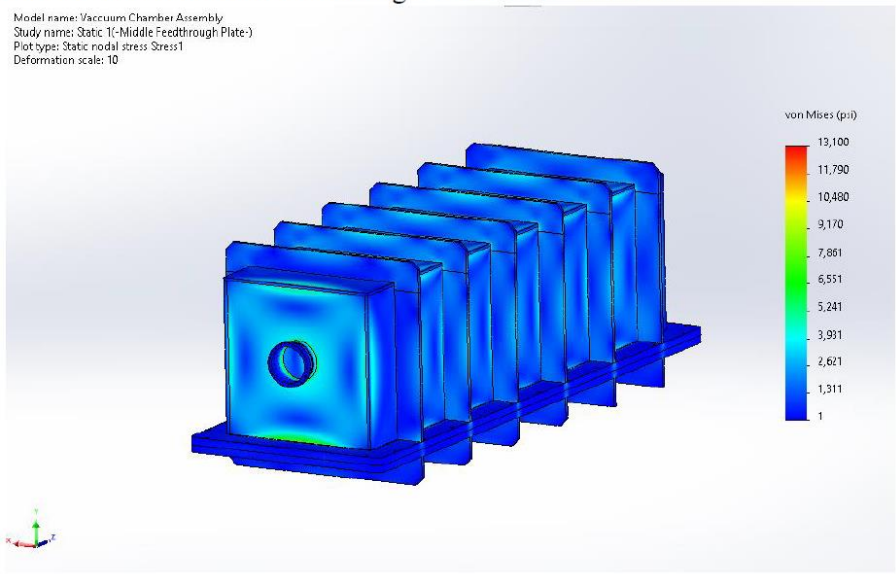
- Removable top cover Large Base flange (per Javier Gomez idea)
- 6061 Welded design to meet JLAB requirement
- MIG on external welds, TIG inside for vacuum
- Designed for the deflection parameter, resulting stress is low
- Weight of chamber Top 2000 kg, Bottom 1200 kg, and contents 4200 kg
- Approximately 5’ x 5’ x 14’ Long

US Enclosure FEA

- Designed for minimum deflection of base flange and side walls



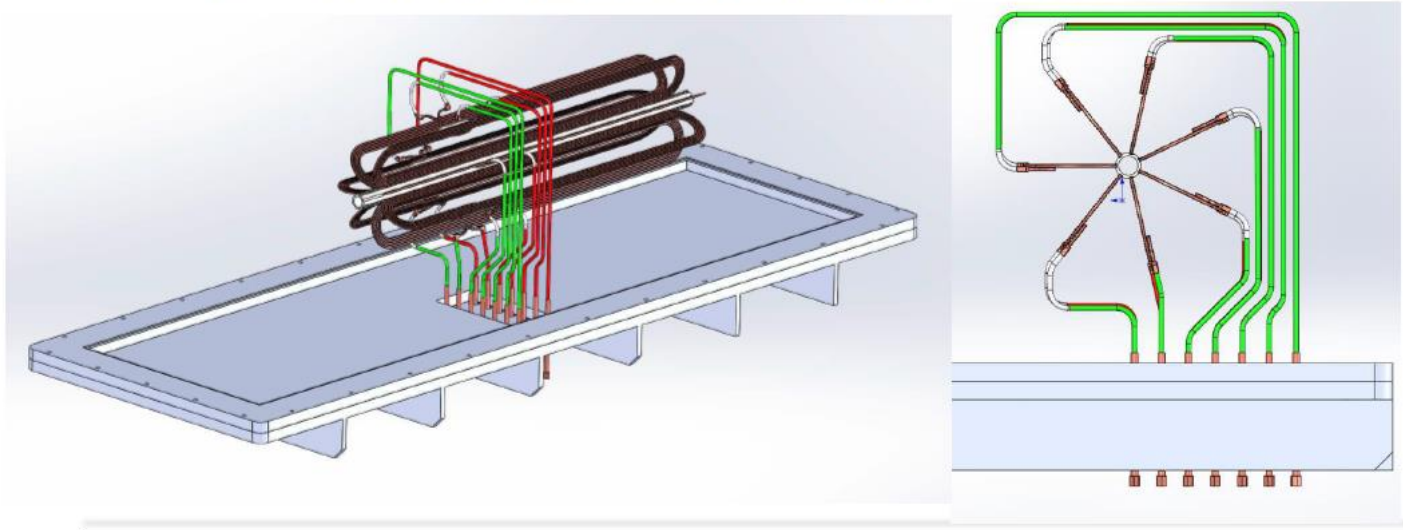
- Resulting stress of in base flange and side walls lower than ASME VIII code allows for 6061-T0. Additional fine tuning of area welds to be done.



US Torus Magnet

MOLLER Spectrometer current feed design

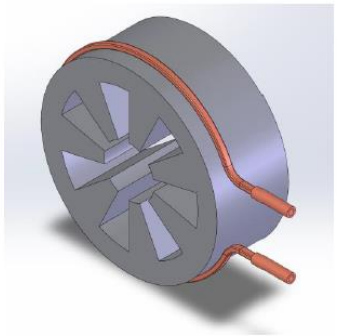
- Seven separate current leads in/out to coils
- Allows for individual coil water circuit measurement and protection
- Balance valves (exterior) and flow switches interlock to power supply
- Use of commercial high current vacuum feedthrough
- Allows for Klixons and RTD on exterior of vacuum on return legs
- Also allows for individual coil voltage drop monitoring
- Allows for operation from 7 small COTS power supplies or one bulk supply
- All Sil-Fos brazed and no uncooled current bus in vacuum.



Blocker and Sieve

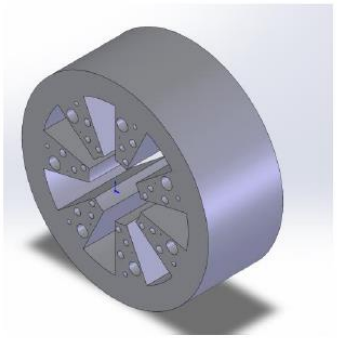
Movable Collimators

Blocker Collimator



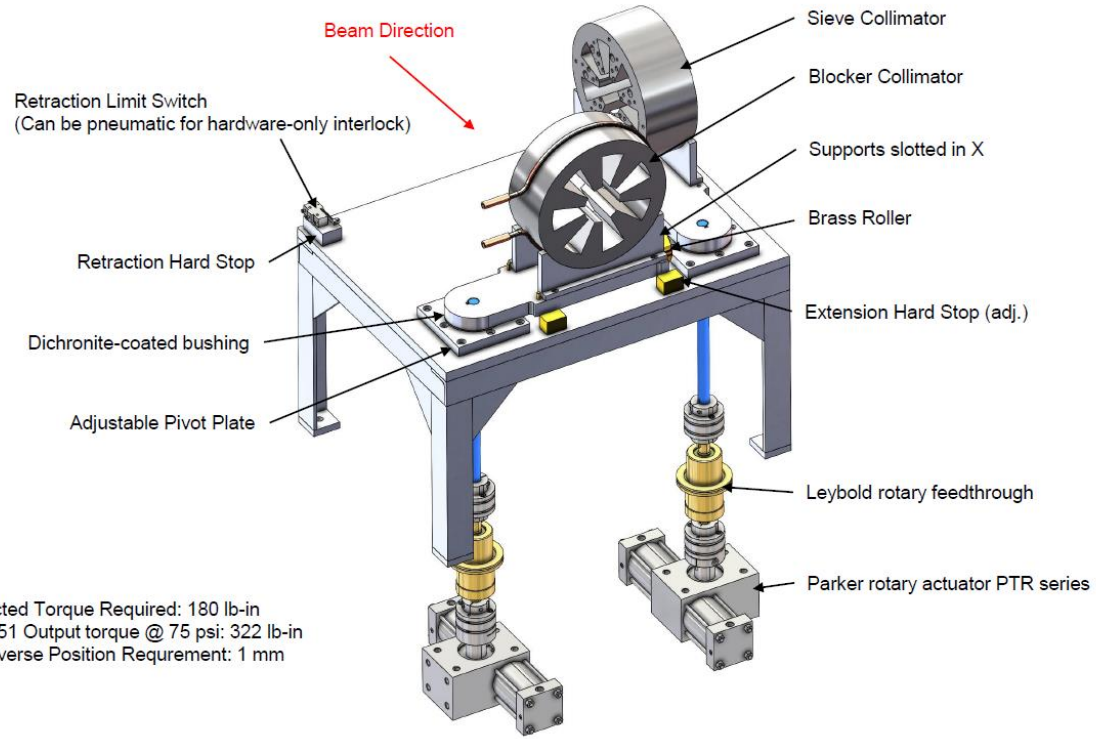
- 250mm diameter x 90 mm thick
- 90W 10Cu
- Min Density 17 g/cc
- Absorbs 1000 W
- +/- 100 um on inner surfaces
- Copper cooling channel brazed to the outside
- Operational temperature: 20-50 C
- 4 GPM water cooling

Sieve Collimator



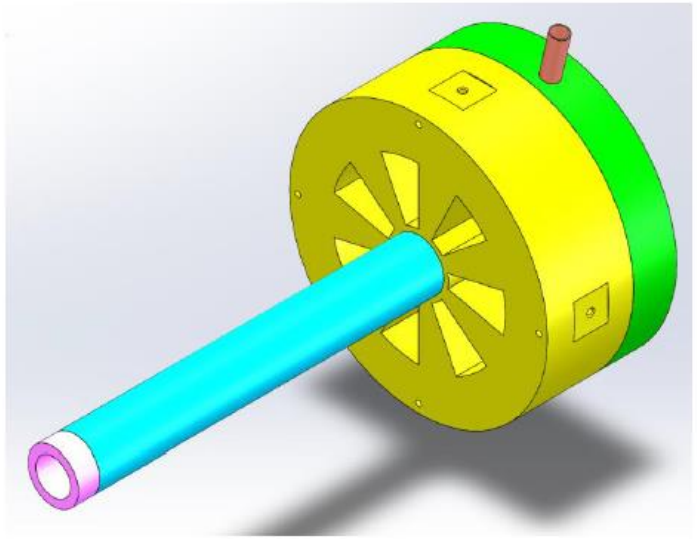
- 250mm diameter x 90 mm thick
- 90W 10Cu
- Min Density 17 g/cc
- Absorbs ~10 W
- +/- 100 um on inner surfaces and holes
- Has array of thru holes from 1 to 10 mm
- Operational temperature: 20-30 C
- Typical running time ~30 mins

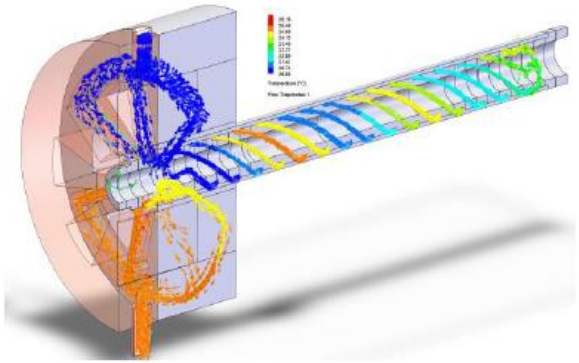
Motion System

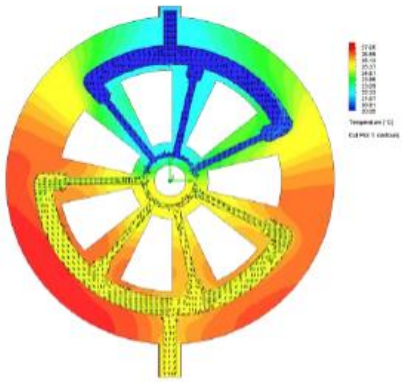


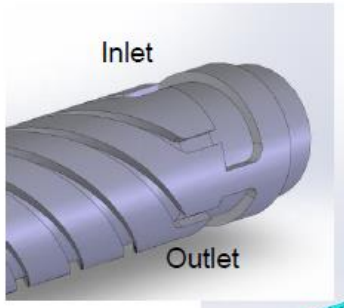
Predicted Torque Required: 180 lb-in
PTC251 Output torque @ 75 psi: 322 lb-in
Transverse Position Requirement: 1 mm

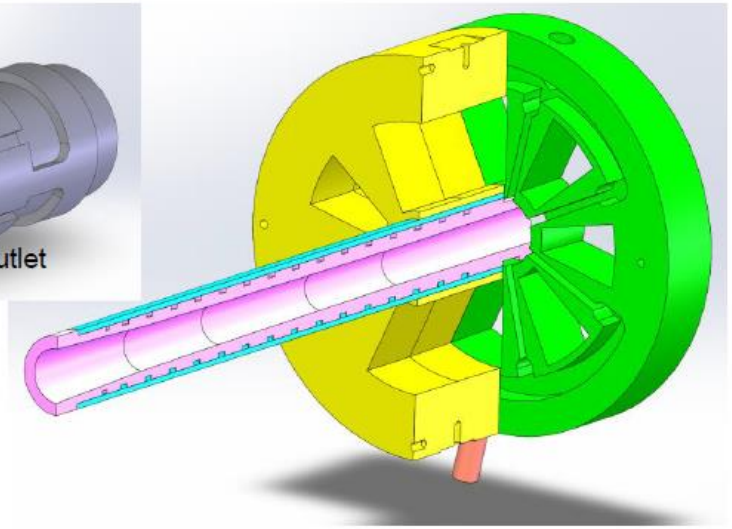
Collimator 1-2







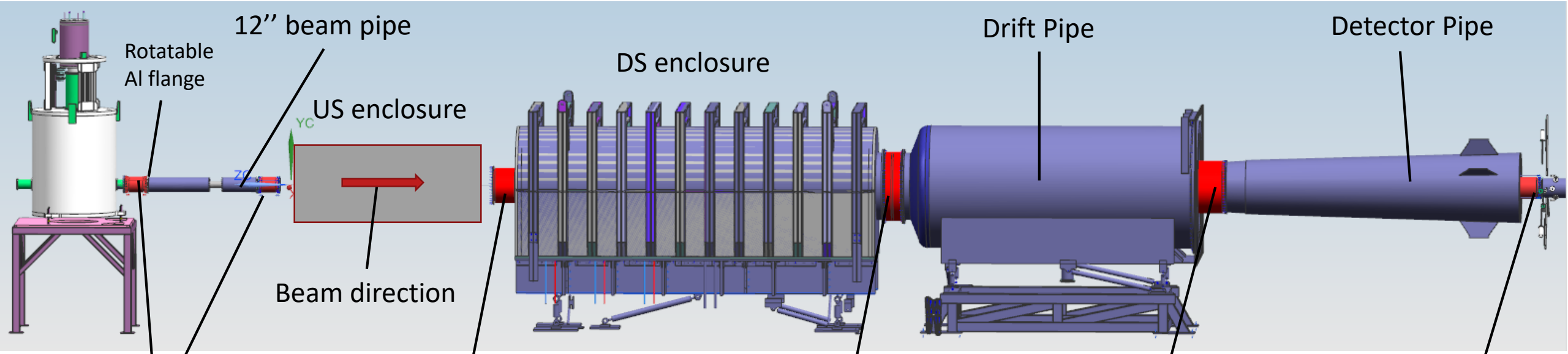




- Disc: 300mm dia x 150mm thick
- Core: 59mm dia x 575 mm long
- 90W 10Cu
- Min Density 17 g/cc
- Absorbs 4500 W in core, 900 W in disc
- +/- 100 um on petal surfaces
- +/-50 um on core inner profile, which has several different tapers along length
- Copper cooling fittings brazed to drilled holes
- Multiple water-vacuum braze interfaces
- Leakage between inlet and outlet channels is permissible, but ideally avoided where possible
- Temperature during operation: 30 - 150 C
- Radiation dose 6.6e11 Rads

Overview of Bellows, Beam Pipe, Drift Pipe, and Detector Pipe

One of two mating aluminum flanges of each bellows is rotatable.



Bellows 1 and 2
Inconel 625
ID = 12’’
Length = 18’’

Bellows 3
Inconel 625
ID = 26’’
Length = 20’’

Bellows 4
Inconel 625
ID = 54’’
Length = 15.75’’

Bellows 5
Inconel 625
ID = 41’’
Length = 24.5’’

Bellows 7
Inconel 625
ID = 16’’
Length = 22’’

Responses to Recommendation 1 and 3 of 60% Review of Beam Pipes Bellows and Windows

- Recommendation 1: Evaluate and document pressure relief system.
  - Response: In progress. We have designed a parallel plate (OD = 9.76”) for any potential pressure rise.
- Recommendation 3: Document failure conditions of materials, such as gaskets.
  - Bellows 1, 2, and 7
    - CF design with one Inconel flange and one aluminum flange
    - Aluminum 1100-O gaskets
  - Dosage results from MOLLER simulation
    - Bellows 3 US/DS: 0.12/ 0.3 MGy
    - Bellows 4 US/DS: 0.01/ 0.05 MGy
    - Bellows 5: 0.9 MGy
    - Detector window: <0.01MGy
    - DS torus box bottom seal: 0.01 – 0.05 MGy
  - Bellows 3, 4, and 5 and detector window
    - EPDM2 is radiation-resistance up 2.0 MGy
    - Peroxide cured EPDM 2 1/4” O-ring is used.
    - 500 ft EPDM2 O-ring has been ordered.

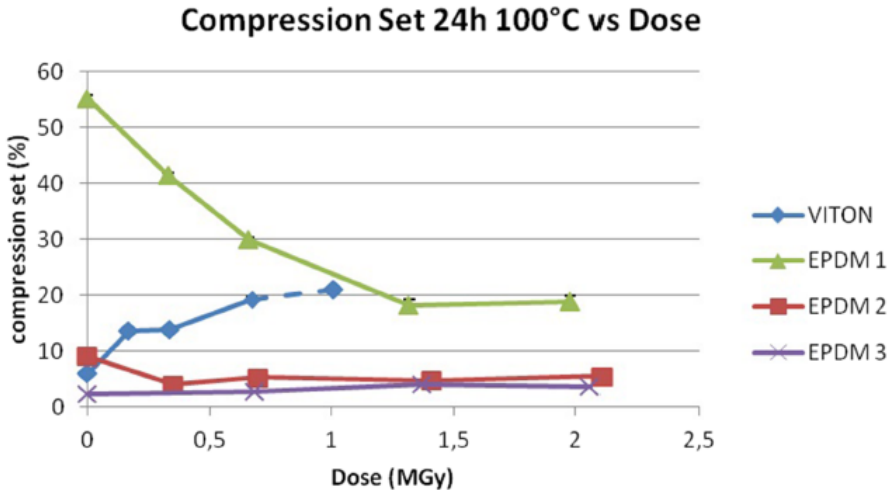
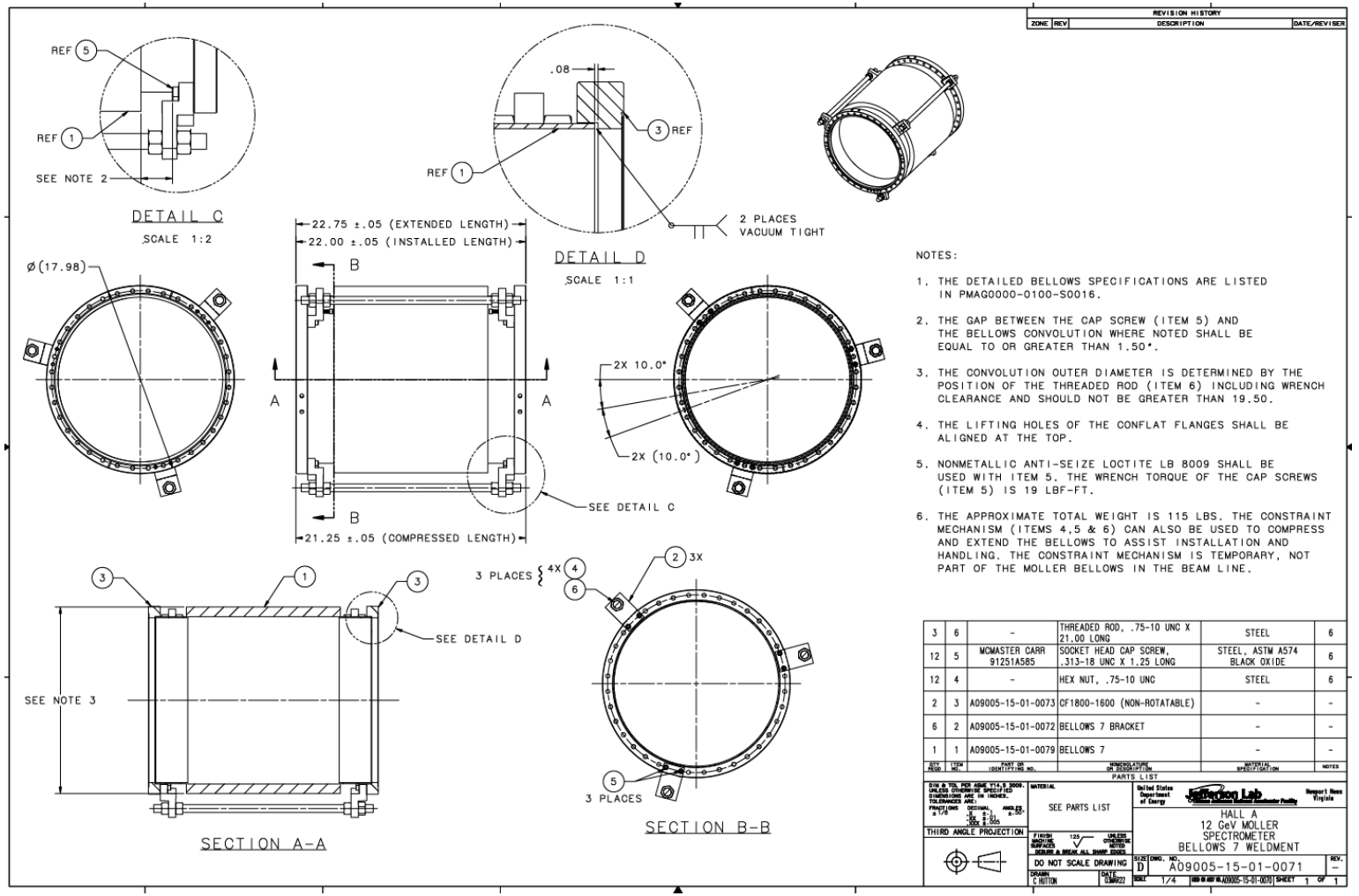


FIG. 6. Compression set values as a function of absorbed dose for the four examined materials. The last segment of the line connecting the VITON data is dashed since the material became brittle and presented local transverse splitting along its length at this level of absorbed dose. The compression set measurement in this latter condition was possible only in few points where the samples remained intact. Error bars are hidden behind the markers.

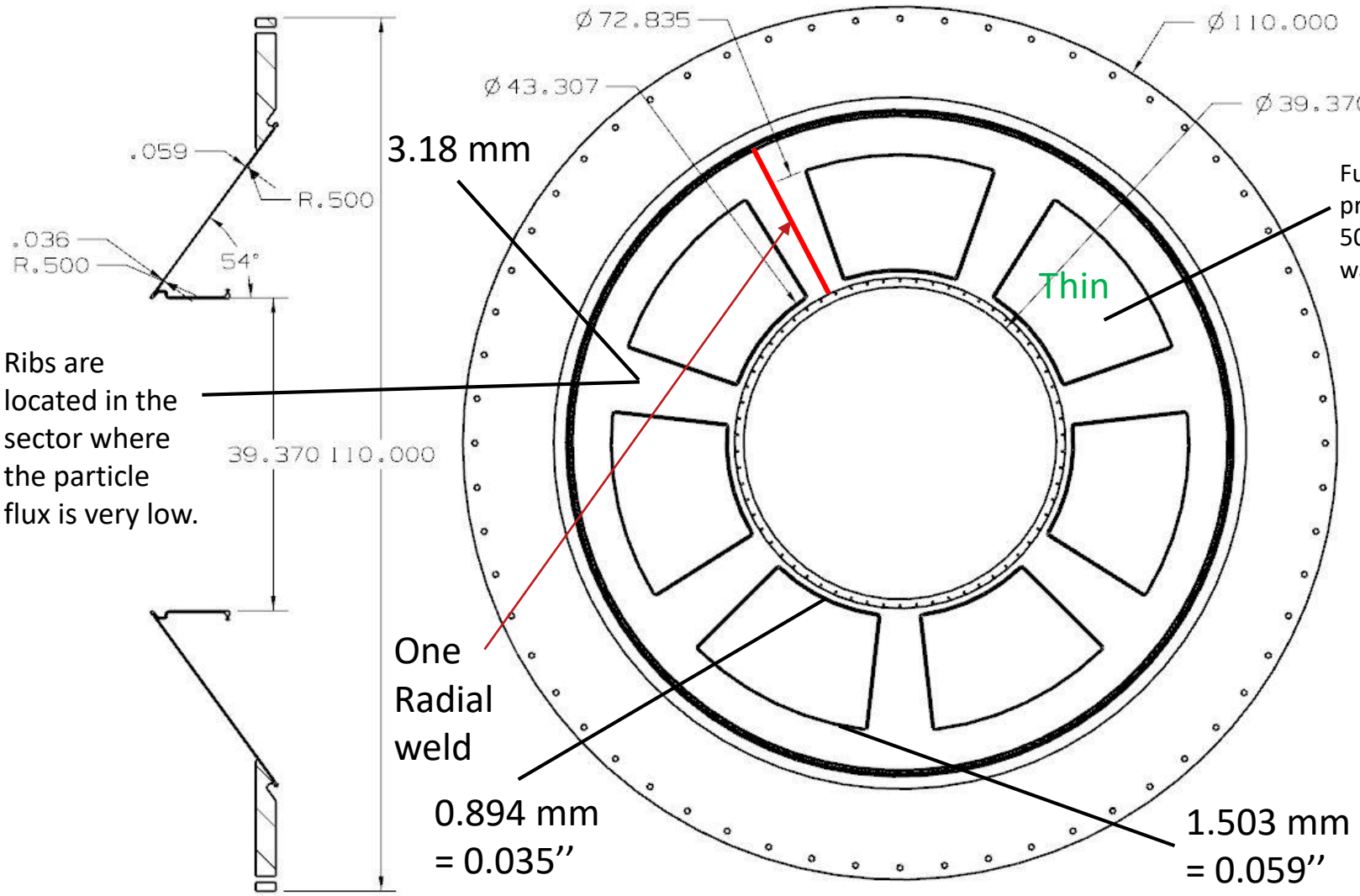
Radiation resistance of elastomeric O-rings in mixed neutron and gamma fields: Testing methodology and experimental results, A. Zenoni, Rev. Sci. Instrum. 88, 113304 (2017)

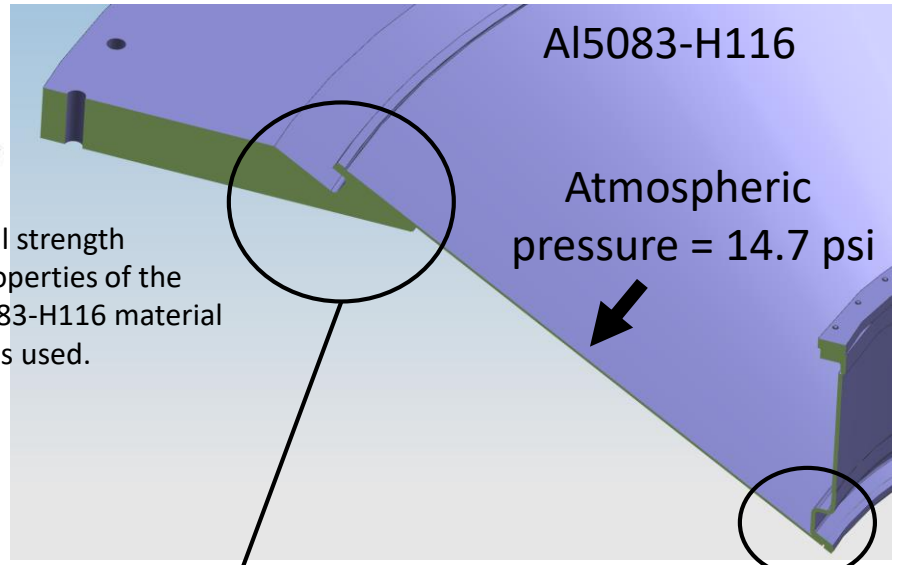
Progress since 60% Review – Drawings of Bellows

- Drawings for bellows 7 were signed and approved. Going for a prototype of this bellows, two vendors have provided budgetary pricing
- Drawings for bellows 3, 4, and 5 were reviewed multiple times and are nearly complete. Bellows 4 being made slightly longer to increase stroke capability
- Flexibility of all bellows better than requirements
- Only one set of updated drawings for bellows 1 and 2 is needed; they are identical.



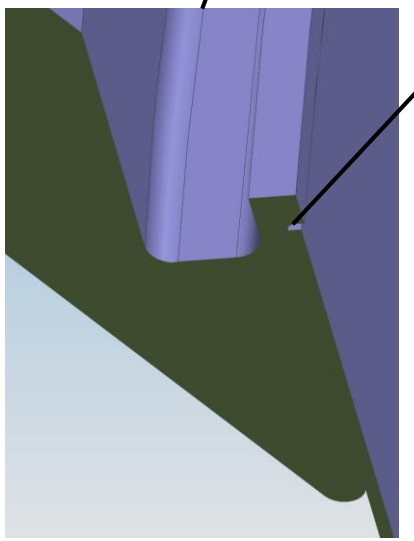
Summary of 60% Beampipe, Bellows & Windows Review Sep 2021

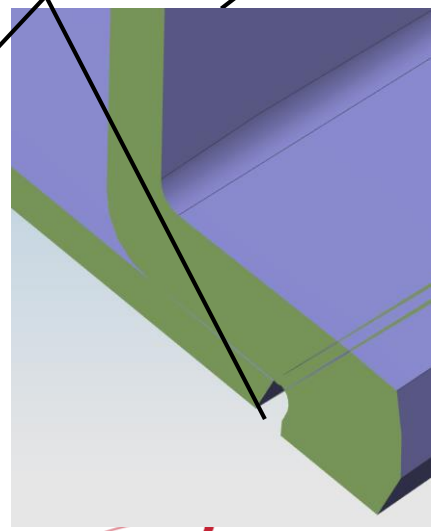




Full strength properties of the 5083-H116 material was used.

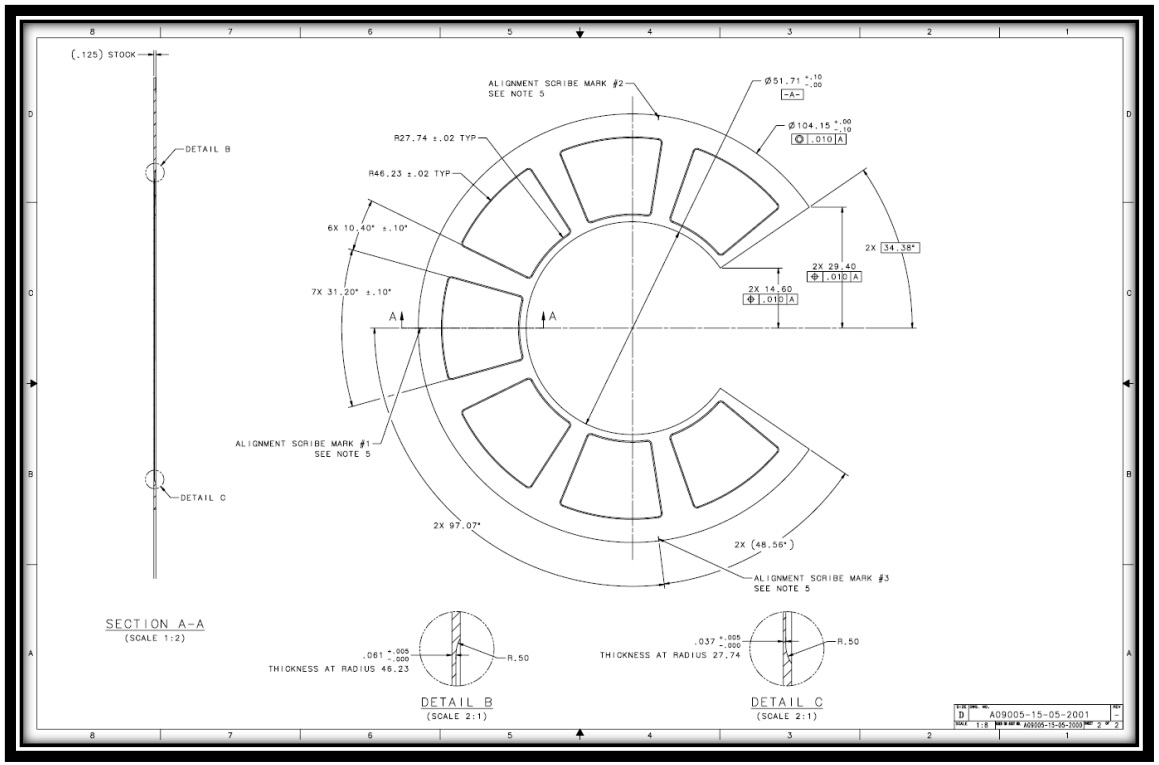
Two groove welds



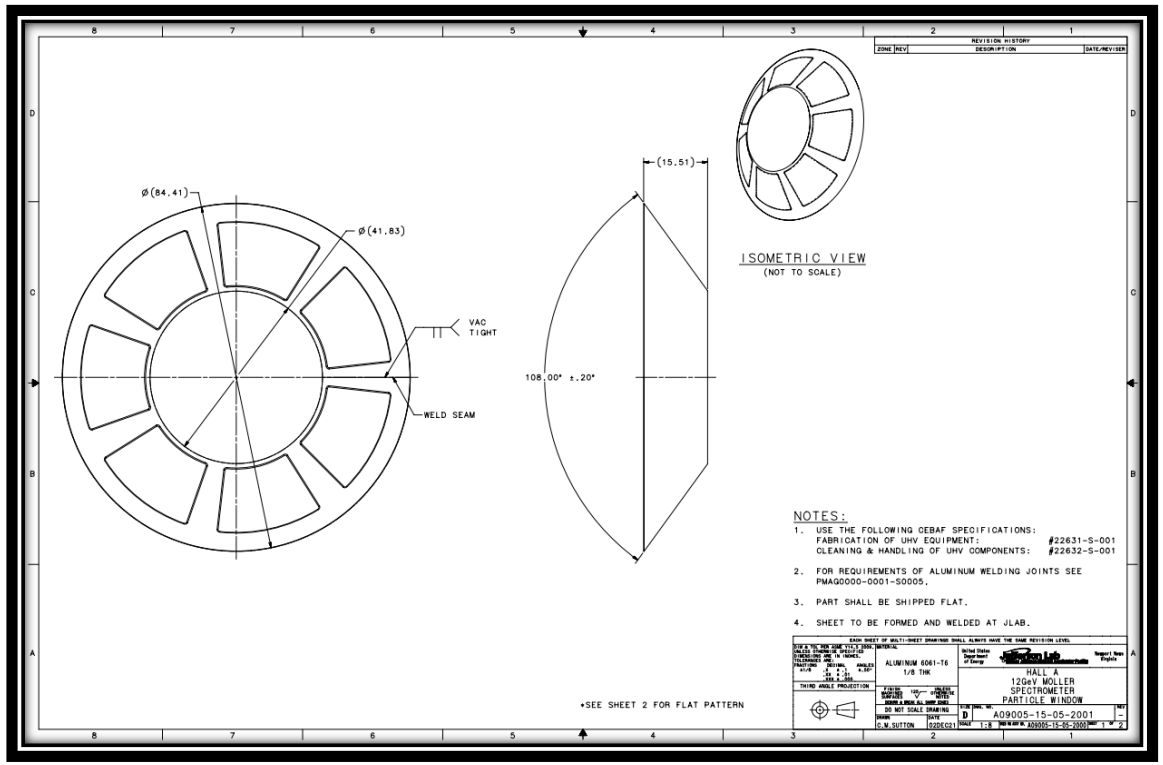


JLab Welder qualified to weld using WPS/PQR #005 (6061 P-No. 23) will be allowed to weld 6061 to 5083 or 5083 to 5083.

Detector Window – Drawings complete with tolerances



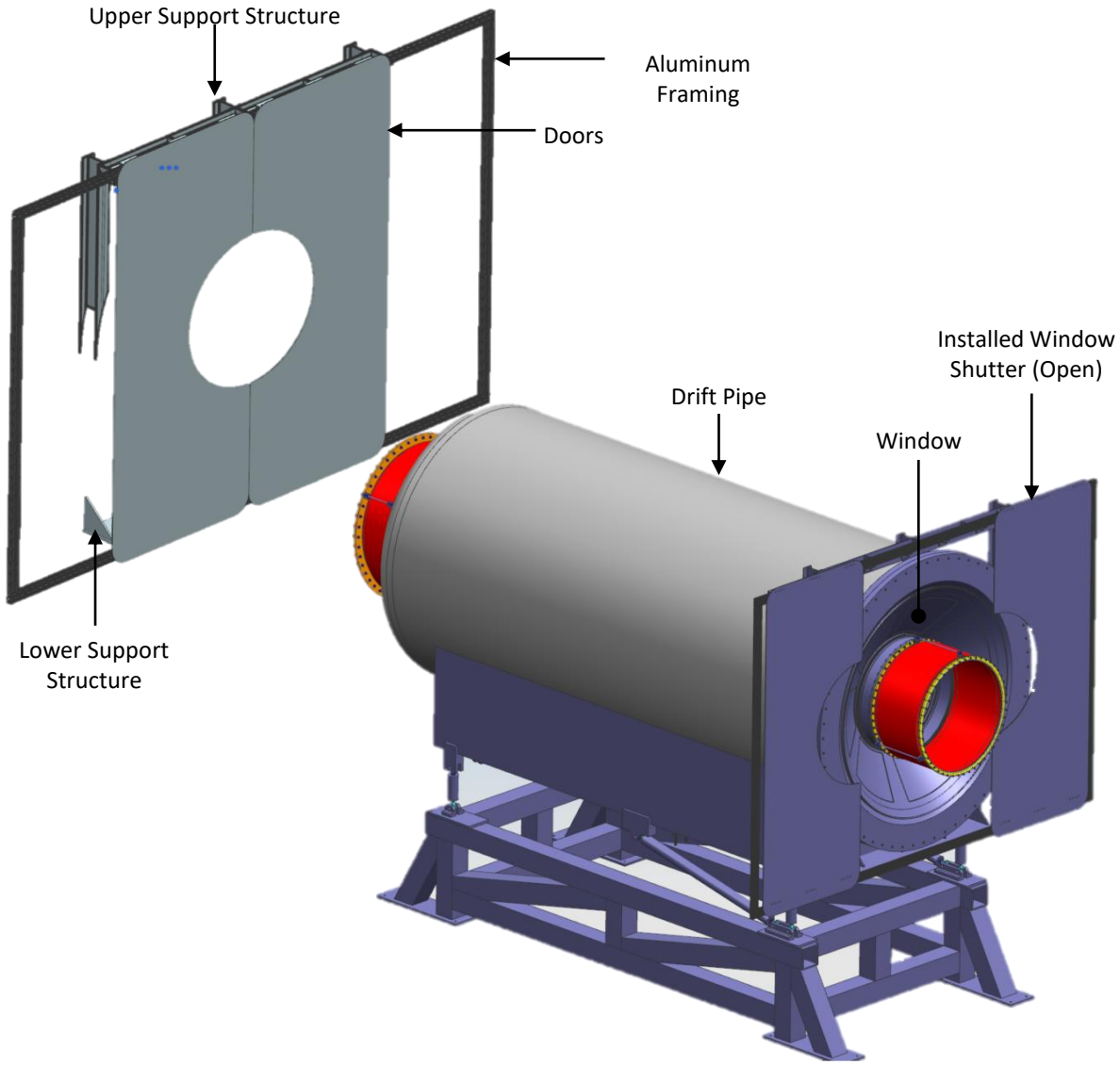
Detector window flat pattern



Detector window cone

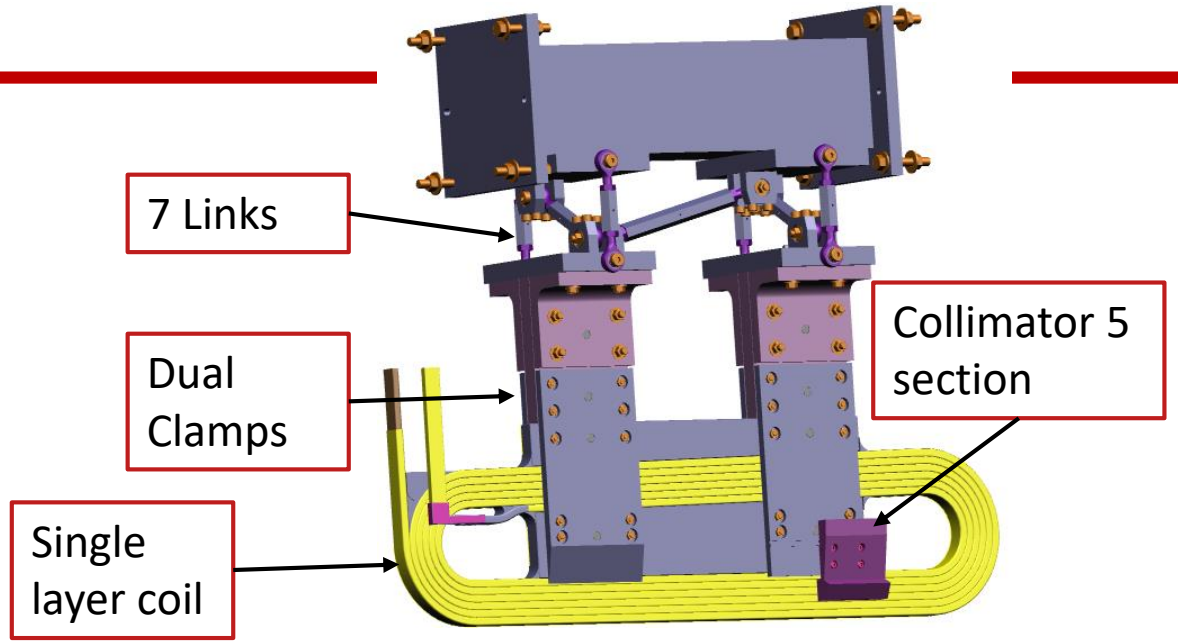
Detector Window Shutter Design

- Purpose: The window shutter shields the window from any accidental contact or loading, thus greatly increasing the overall safety of the equipment and ensuring the safety of personnel.
- Operation: The window shutter is manually operated; the doors can be pushed or pulled into position depending on whether an “open” or “closed” orientation is desired.
- Utilization: The shutter will be closed during assembly and installation. Interlocks will be put in place to check the position of the window before vacuum pumps start. The shutter will be open during beam.

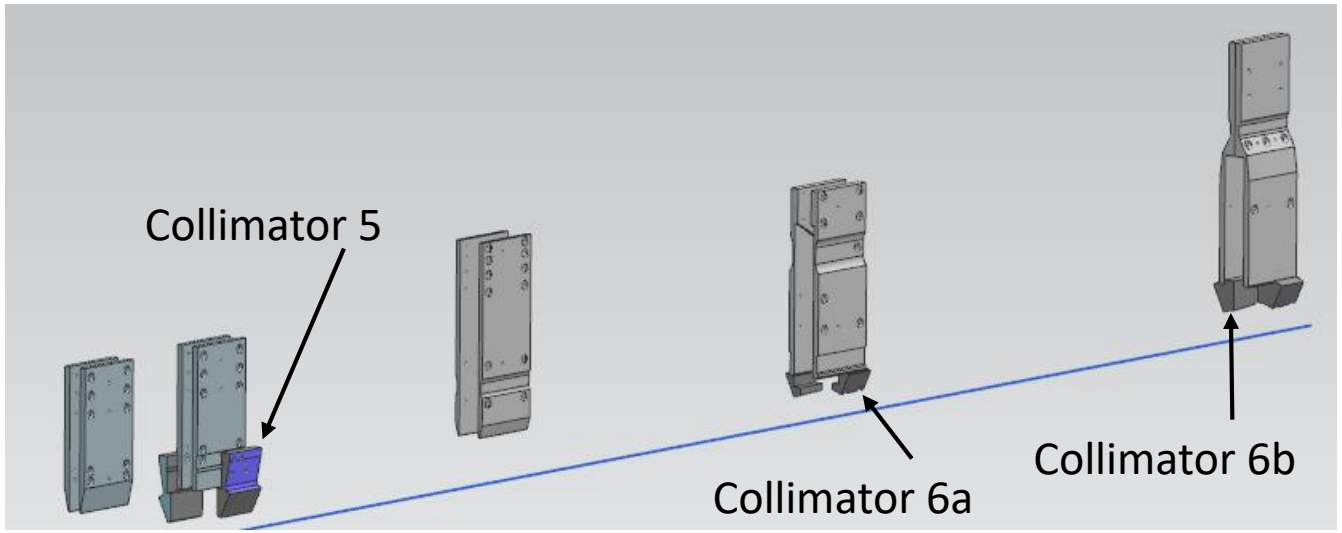


DS Coil Support and Alignment

- Each Coil is supported from a set of clamp plates
- Clamp plate system supported by adjustable links from box beam
- The collaboration Ferrous Materials Group has confirmed that no carbon steel is allowed inside the enclosure thus specialty rod ends are needed in the support. They have also confirmed that brass, bronze fasteners are acceptable
- Clamps of TM3 and TM4 also support the collimators 5, 6a, 6b
- **Support system prototype is in procurement process**
  - **This will help with determining how to survey and align it and locating fiducials**
  - **Drawings for TM1-TM3 and bulkheads have been checked and sent out to potential vendors for pricing**
- Met with entire survey group (engineers, manager and techs) we all viewed a laser scanner device
  - Measured sample coils
  - Looks promising in helping with aligning coils
  - Especially useful to track motion during energization
- Coil and frame deflections are small (<1mm)



TM3 Coil Clamped with Collimator 5 section

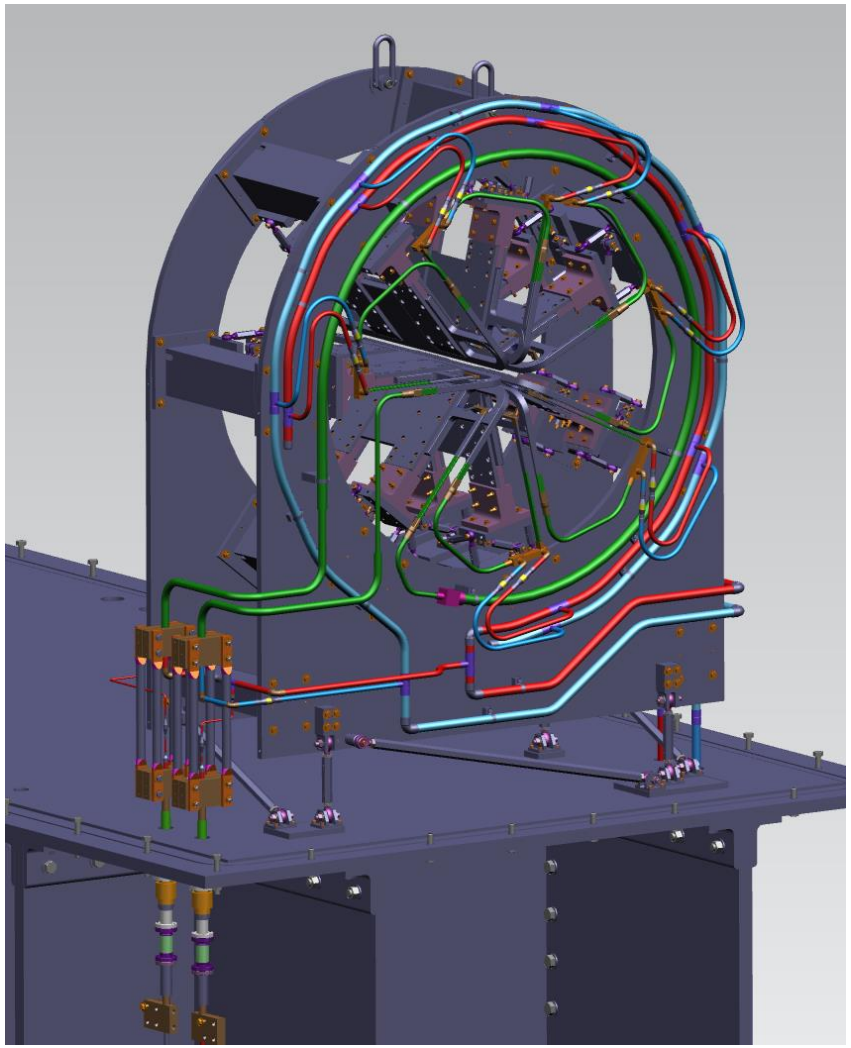


Collimator 6b

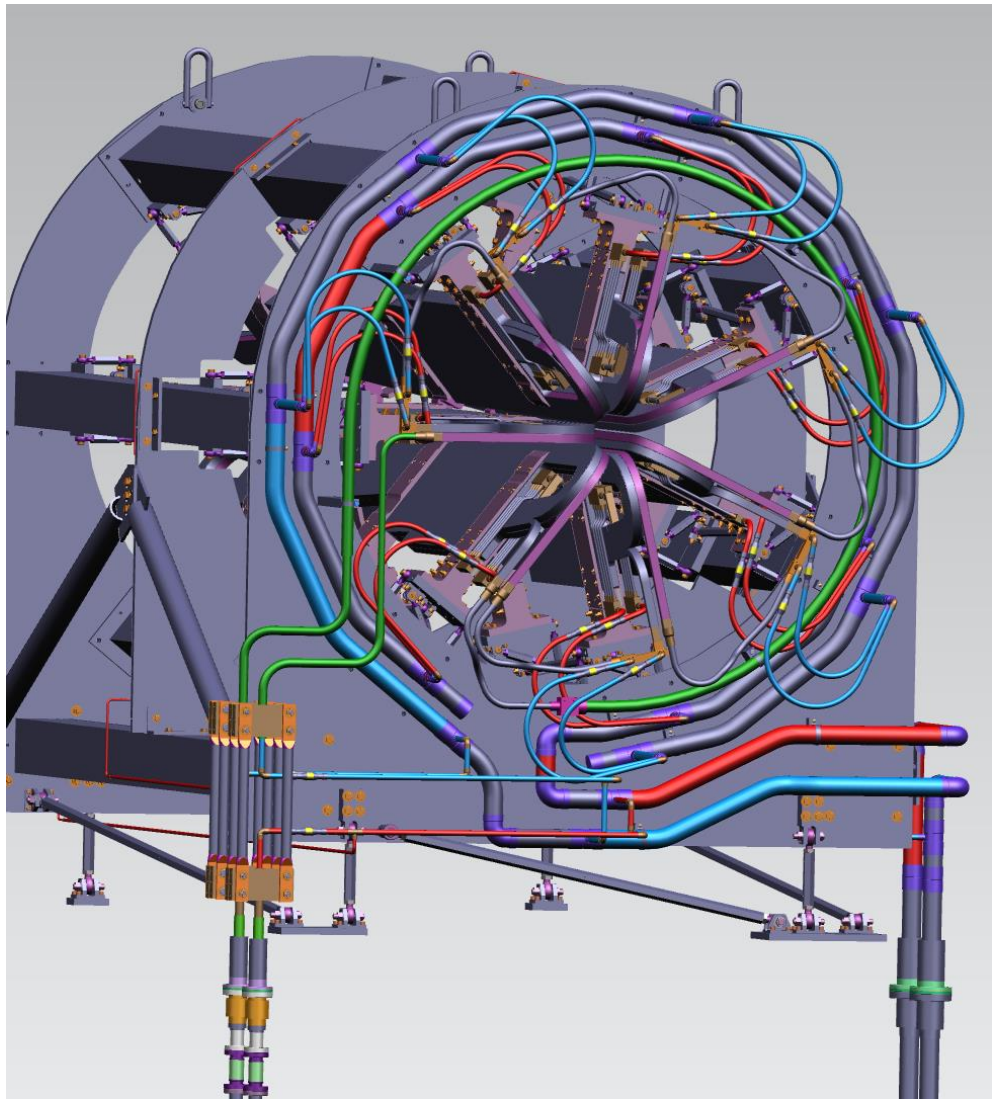
DS TM Magnet Water Piping and Electrical Bus

- TM1 has 7 flow paths, 1 per coil plus the DS bulkhead trace tube
- TM2 and 3 piping nearly identical to TM1
- TM4 has 14 main flow paths (double pancake coils each with its own cooling path), water headers are 2”

Ceramic break passed 1500psig hydro test



TM1



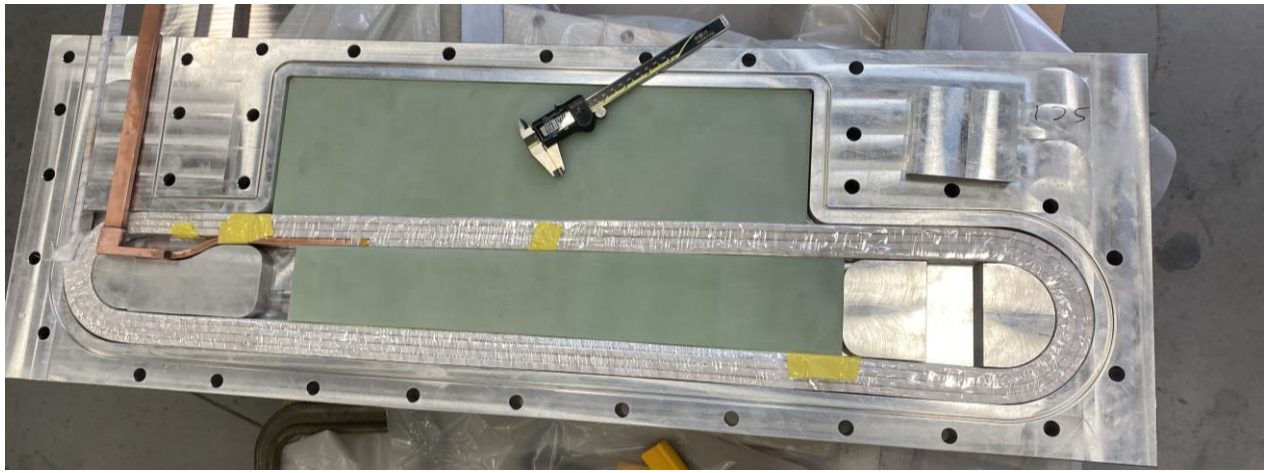
TM4

Prototype Coil Progress

- Traveled to ETI to see progress on Coils June 7-10
- Coil Stack Heights bigger than designed
  - Ground wrap and conductor camber causing this

SC2 with Ground wrap – Did not fit in Mold

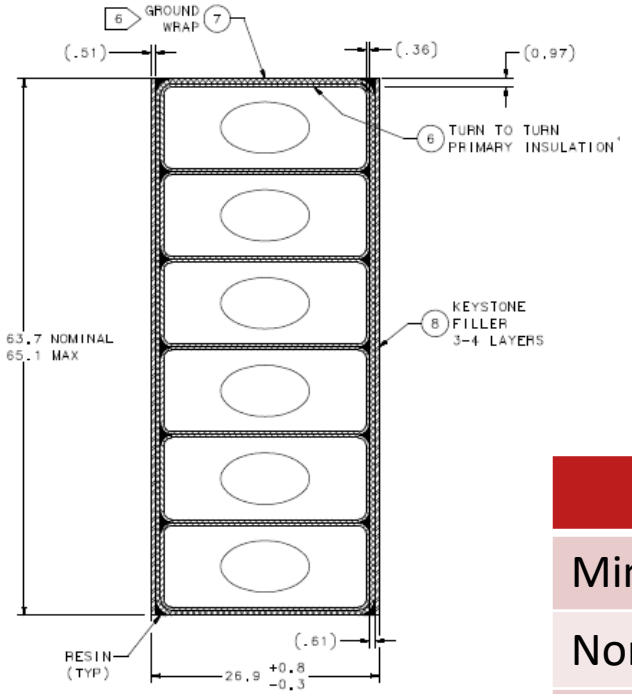
SC1 w/o Ground wrap – bending to attempt fit



SC1 w/o Ground wrap – almost fit into mold but w/o ground wrap

Prototype Coils - Continued

- Coil shape and stack height keeping them from proper fit in the molds
- Procedure for post Winding Bending developed
- Mold Cavity will be increased to accept taller stack heights
- G10 at center of the coils will remain the same size, but outer G10 will be cut smaller



SC3 Post Winding Bending setup with ETI folks performing it

	Original (mm)	Modified (mm)
Minimum	63.4	65.4
Nominal/Goal	63.7	66.2
Maximum	65.1	66.9

Summary

- How to apply and support proposed 3mm shield the inside surface of the coils is not clear
  - Heat load is expected to be quite high (>10W) and needs to be provided ASAP
- Prototyping effort has shown that “ideal” coils are not possible. We have not figured out in detail how accurately we can build or need to be able to “map the coil turns”. Even if we do have precise turn geometry how will we use that data to determine the proper coil alignment
- Need to complete the System Requirement Document (SRD) (Goal was 6/30 not late yet!)
- Need to complete the Interface Control Document’s (ICD) (Goal was 6/30 not late yet!)
- Hall A Beam Dump inlet Pipe (SAM pipe is connected)
  - Have a potential solution for supporting the ~4000lbs vacuum load
  - Located in a Radiologically Contaminated area and thus working there requires Rad II work
- Design/Engineering Team is much larger than last year
- Progress on all topics
- Getting all components to 90% level by late fall 2022 will be a challenge