JLAB Tritium Target

Dave Meekins et al

28 May 2014

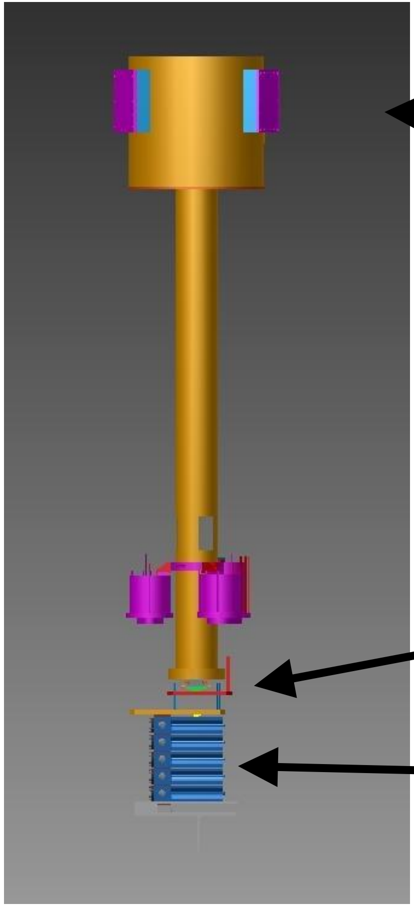
Overview

1. Design and major subsystems
2. Thermal/structural analysis of cell
3. Cell filling
4. Vent and stack
5. T2 detection and monitoring
6. Outstanding issues
7. Discussion

Subsystems

- Target assembly
  - Cells
  - Positioning system
  - HX
- Scattering chamber
  - Pumps
  - T2 recovery
- Vent and stack
- Beamline
- Tritium detectors/monitors

Complete target assembly



Cryostat

- Use 15K He from ESR to stabilize and cool the cells.
- Use the standard cryotarget cryostat for this

Positioning system

Target Stack

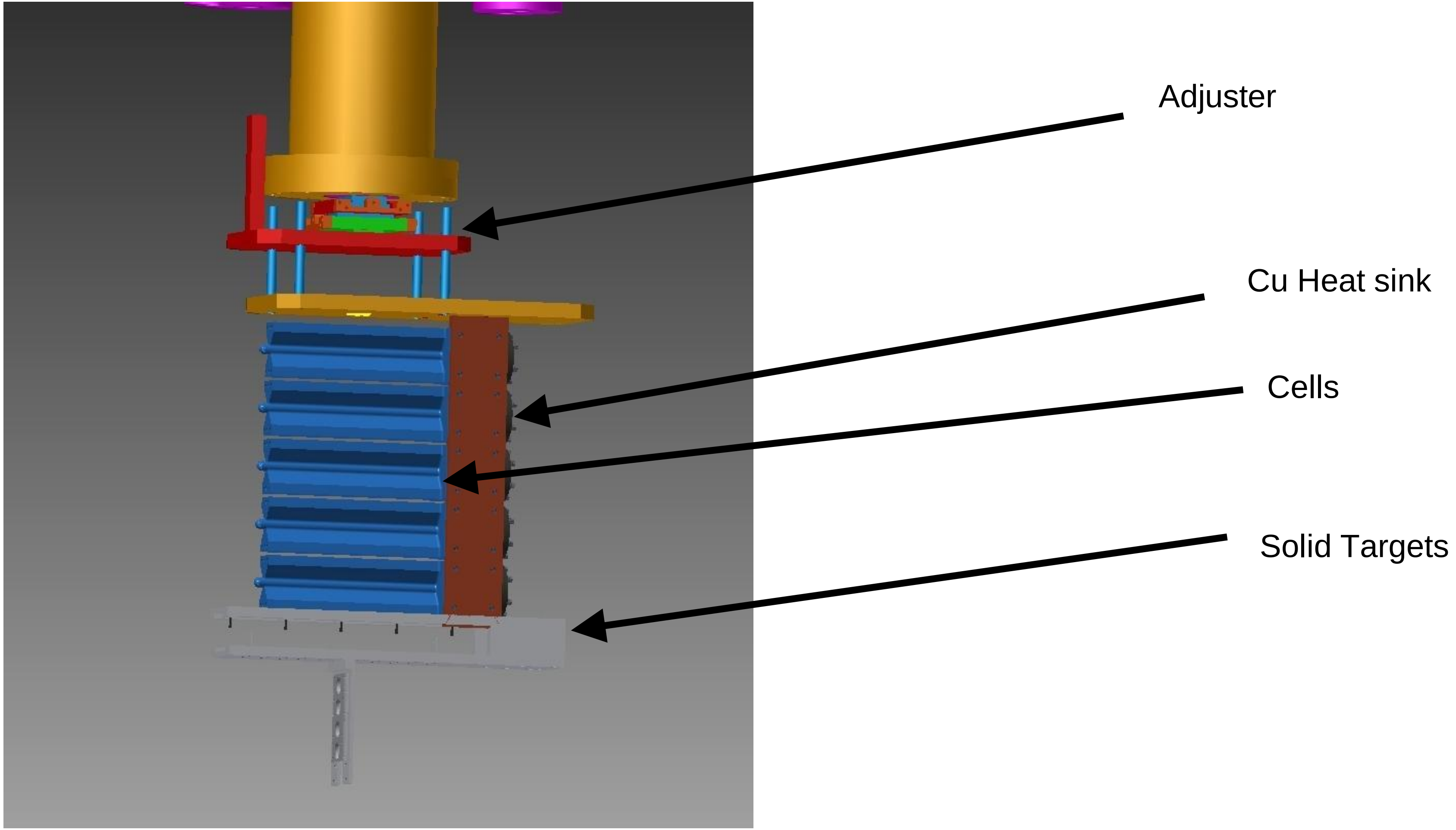
Current Hall A Target

- Mount target stack where normal cryotarget cells go
- Lift system remains the same
- Mounts in current scattering chamber
- Saves money
- Controls nearly identical to cryotarget
- What happens if T2 cell fails

Mount cells here

Target Stack

- Stack mounted to heat sink
  - Heat sink is cooled with 15K He from ESR
  - Heat sink is temp stabilized at ~35-40K
- Alignment and optics targets
- Positioned with cryotarget system
  - Alignment prior to vacuum and cool down ~0.25 mm
  - Target may move ~2 mm
- Total stack height is ~24 inches
  - Within crytarget limits (26 in)


Adjuster
Cu Heat sink
Cells
Solid Targets

Target Cells

- Challenging machine work: JRP Machine
- Made from Al 7075-T651
  - Swagelok valves (metal bellows)/VCR fill ports
  - Extensive H_2 service at JLAB
- Entrance windows attached with CF flange
  - Extensive service record with CF at low temperature
- Fill Pressures
  - T_2: ~200 psi
  - He: ~375 psi
- Contains 1.1 kCi of T_2
- Window thicknesses
  - Entrance: 0.01 inch
  - Exit (beam): 0.011 inch
  - Wall 0.018 inch (0.015 in minimum)

Major concerns

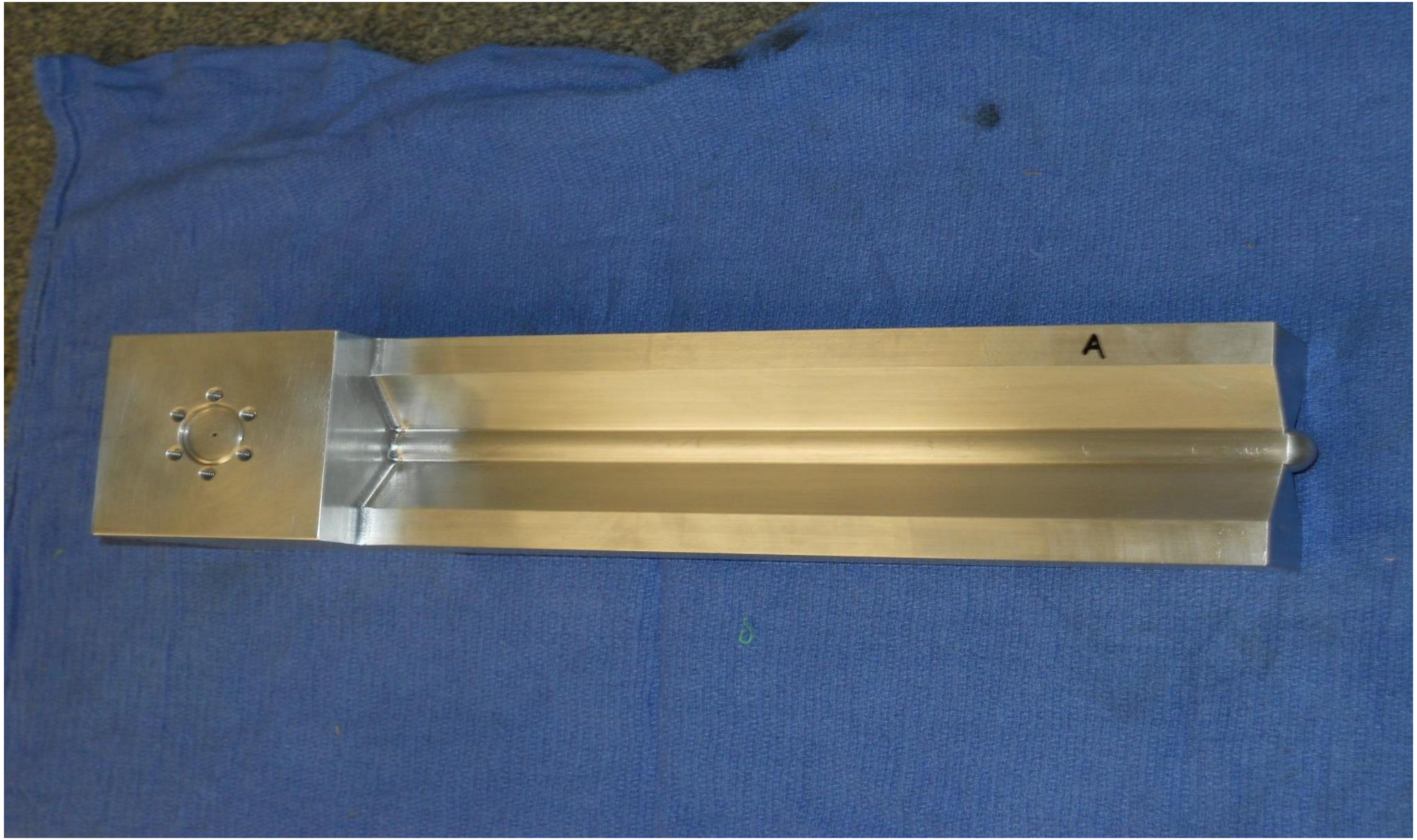
- Cells have thin sections
  - Needed for electron beam and particle detection
- Diffusion through cell will occur
- Possible T2 embrittlement
- Possible loss of integrity from electron/T2/Al interactions
- Cell failure from beam damage

Design Pressure

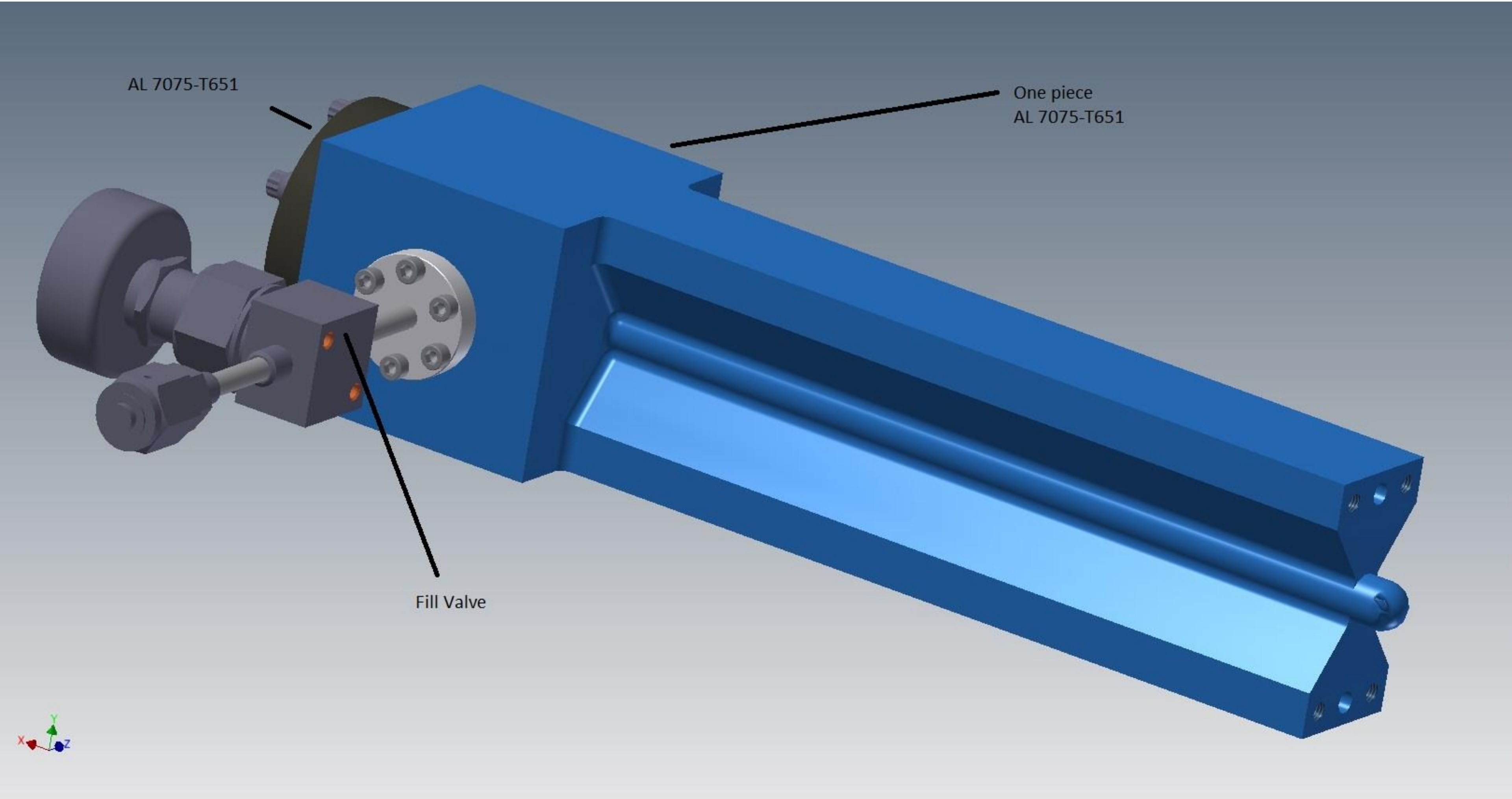
- ASME B31.3
  - Unlisted material 7075 –T651
  - ASTM B209
    - Sy=38 ksi
    - Su=71 ksi
  - B31.3 302.3.2 Design stress basis
    - 1/3 Su
    - 2/3 Sy
- Design pressure is above 1100 psi for 0.015” walls

Design Evolution

- SST welded construction
- Aluminum 2219 welded construction
- Aluminum 7075 bolted construction
  - Mod 0 First generation difficult to machine
  - Mod 1 easier to machine but thermo more challenging
  - Mod 2 Smaller entrance tube diameter to meet experiment needs (not prototyped)

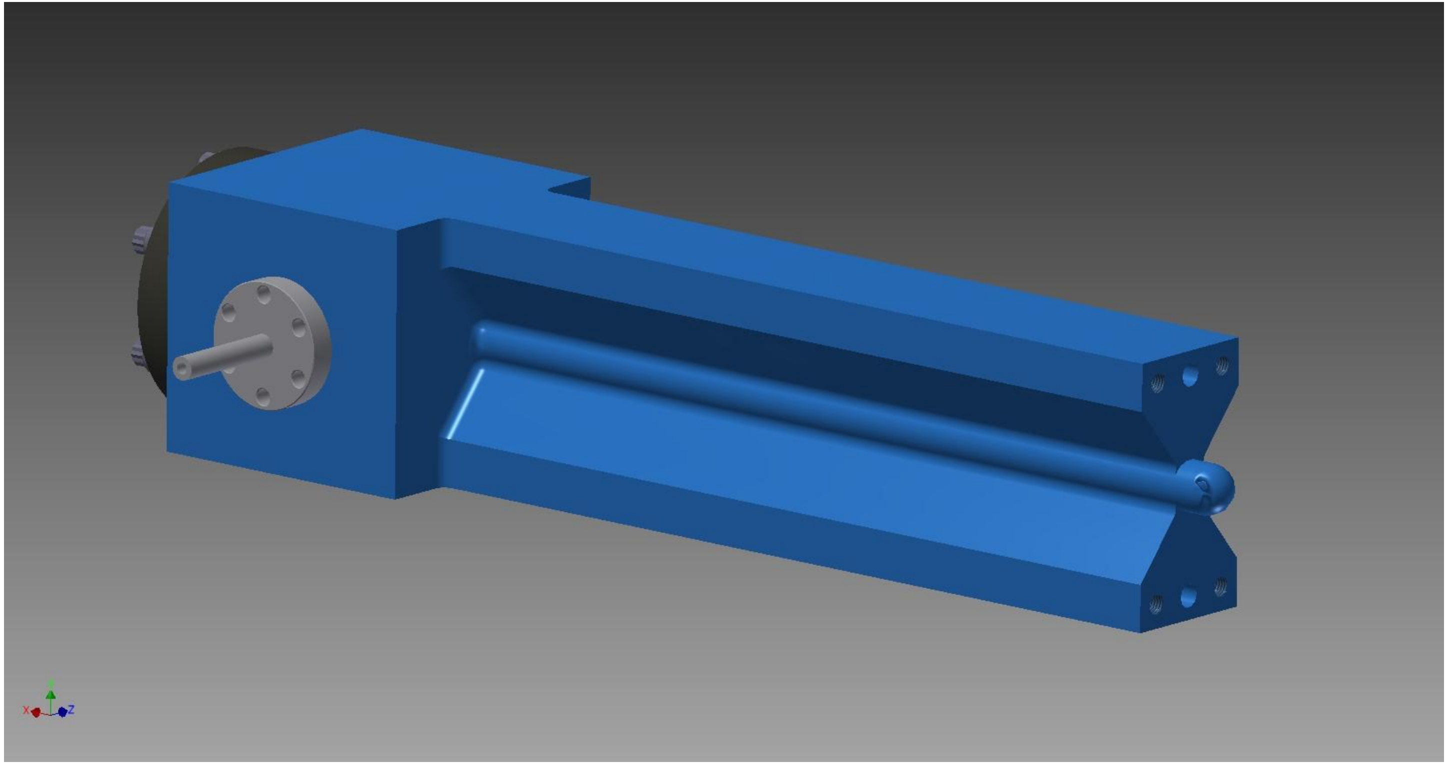


Cell Design Mod 0

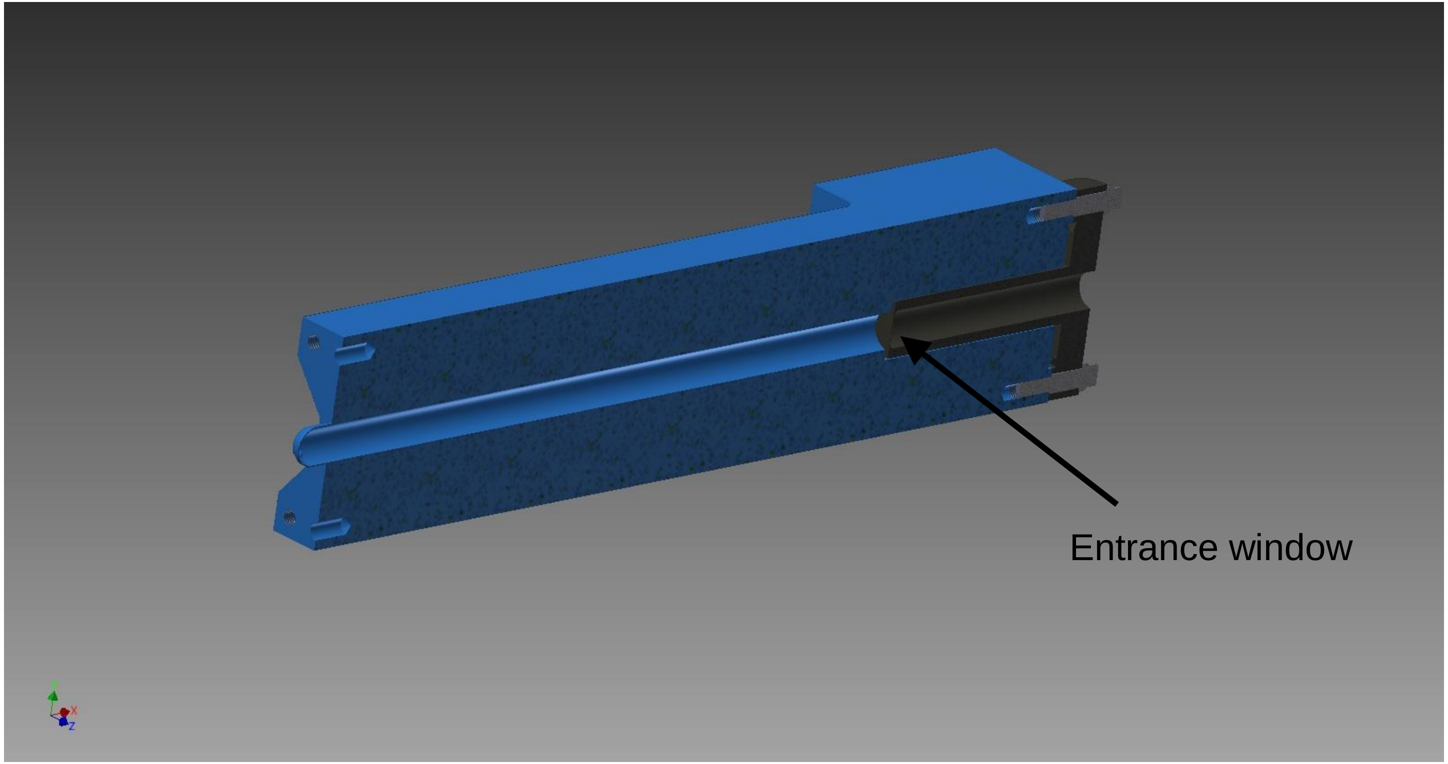


AL 7075-T651
One piece
AL 7075-T651
Fill Valve

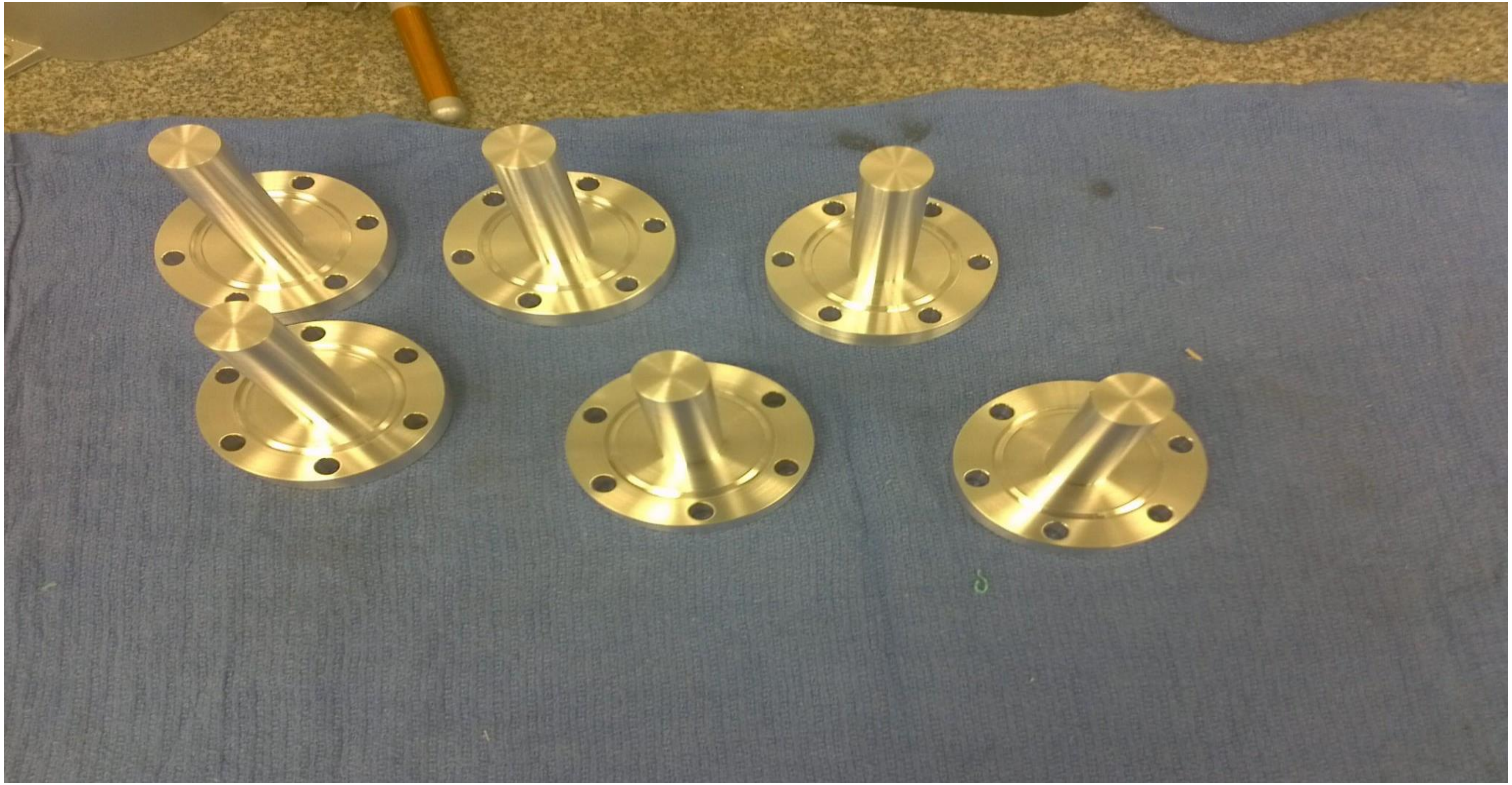
Cell Design Mod 1



Section View of Cell

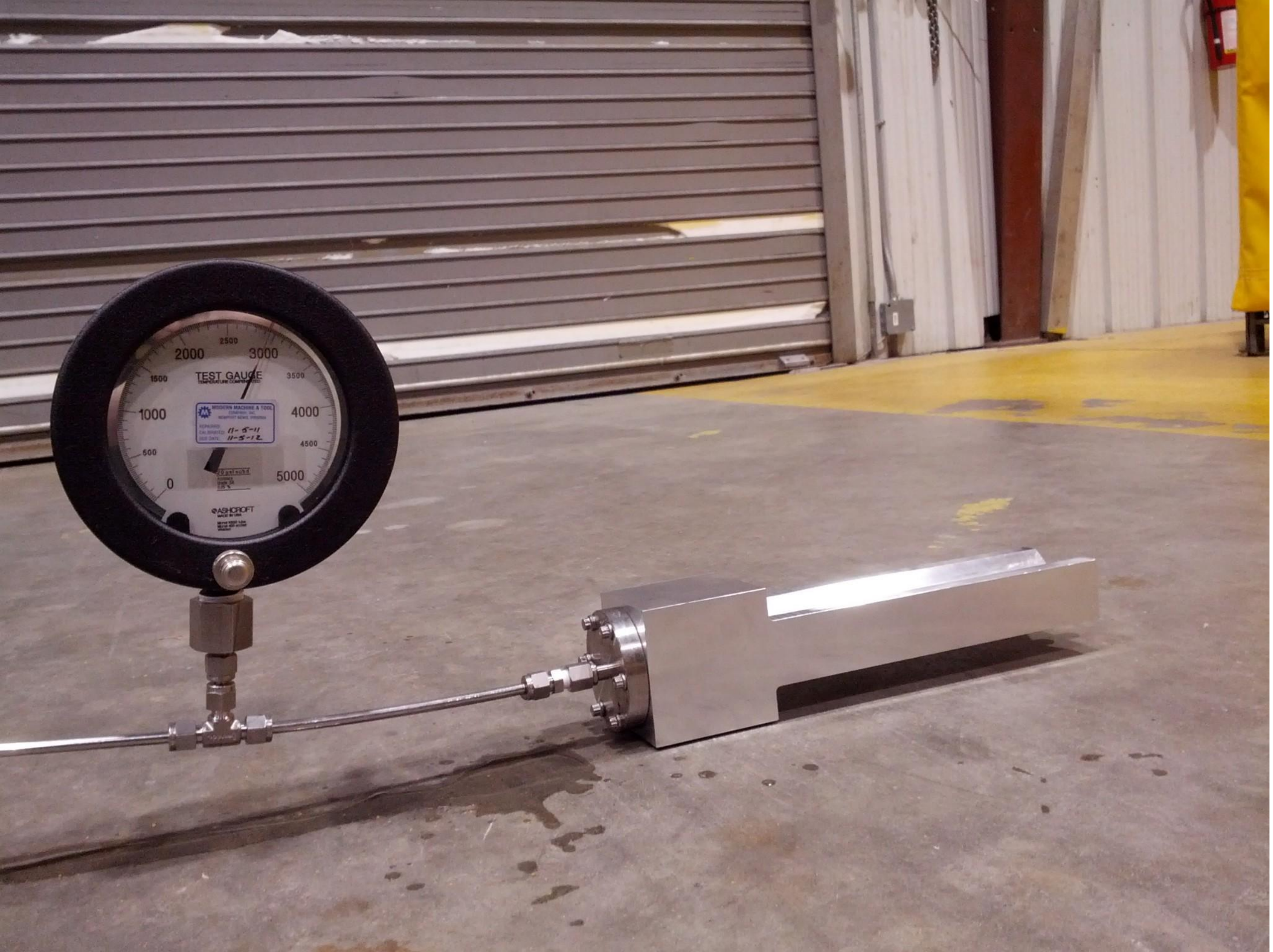


Entrance windows

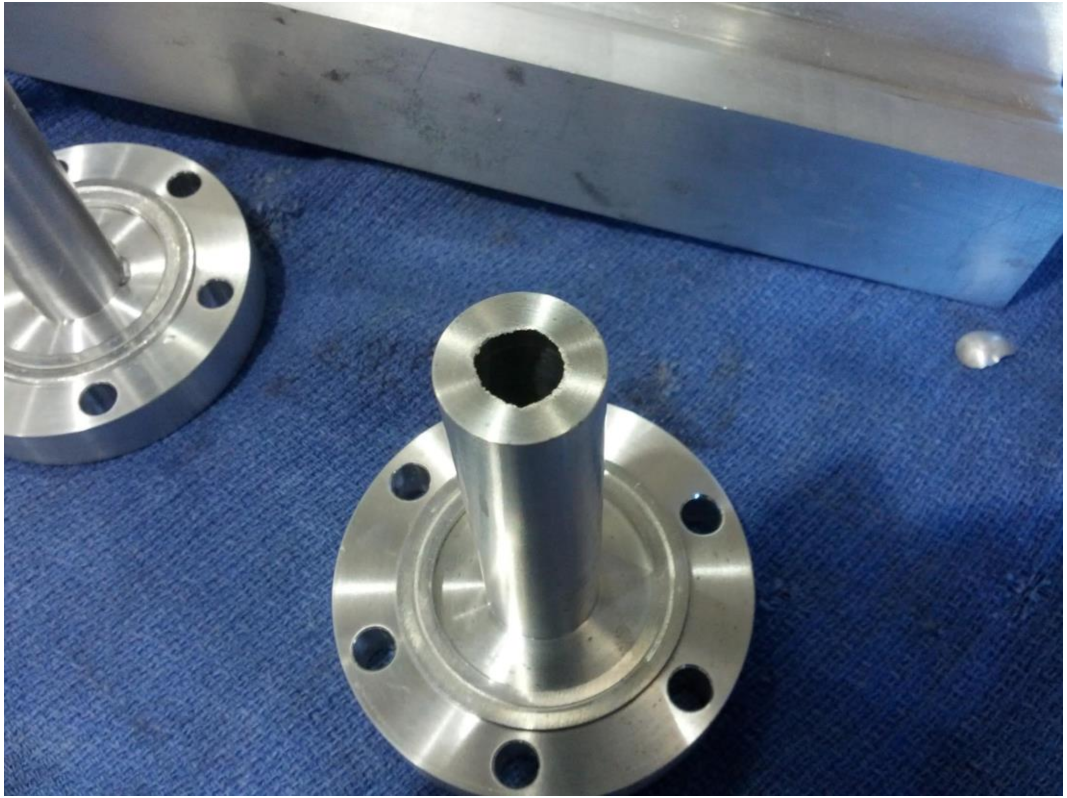


Pressure test of Mod 1 cell

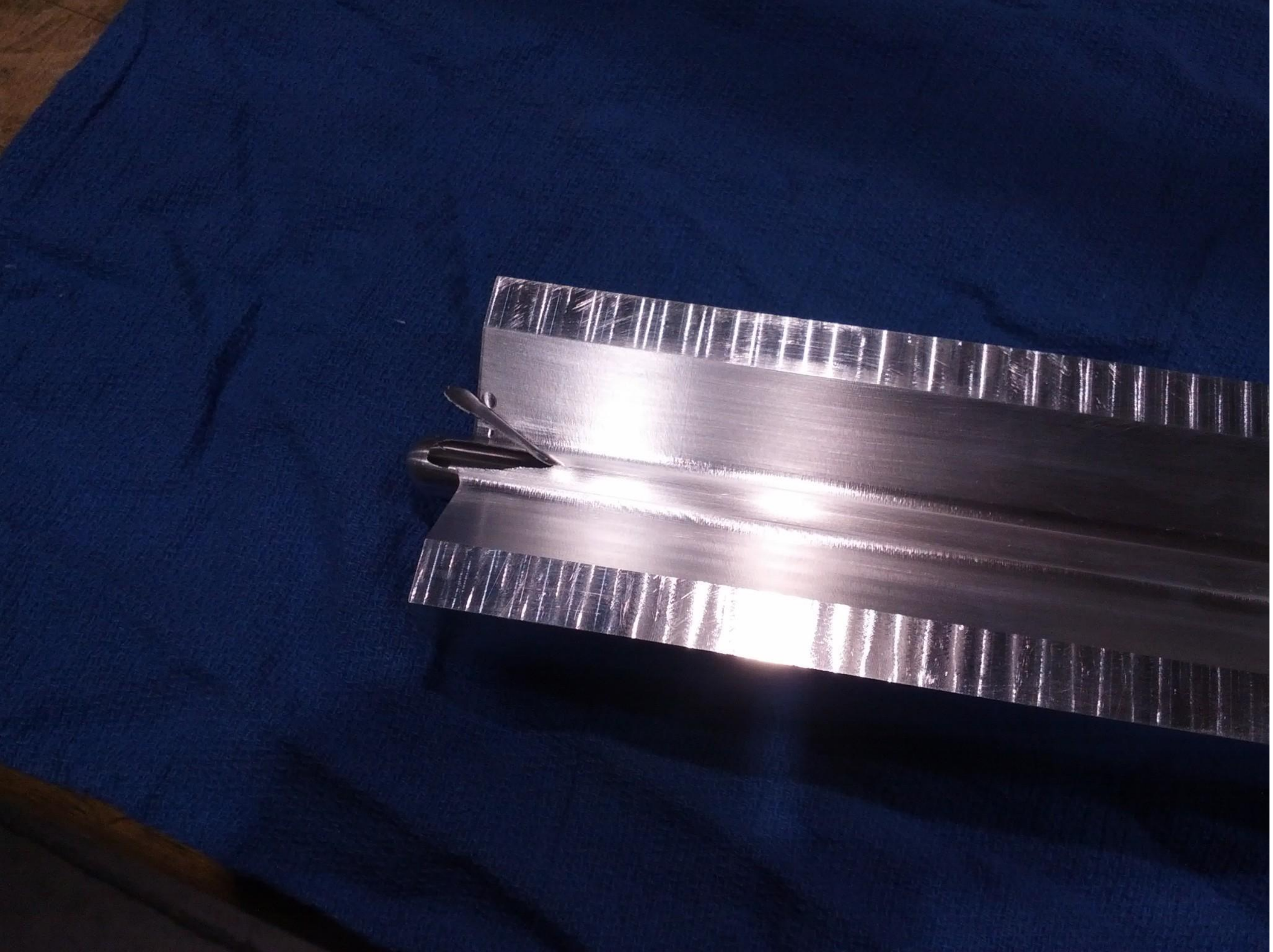
- Cell wall thickness at thinnest point was 0.014 inch
- Main cell body burst pressure above 3500 psi
  - Factor of ~10 for safety
  - Static condition
  - Need to account for cyclic temperature/pressure loads
- Entrance windows
  - Burst Pressure ~2900 psi
- Operating pressure
  - 70 to 100 K running
  - 200 psi warm/standing


TEST GAUGE
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
ASHCROFT

Cell Entrance Window



Cell Entrance Window
Burst ~2900 psi



Burst Test
Cell exit burst above 3500 psi

Max Diffusion/Permeation

Assumes:
conservative diffusion coefficient for Al 7075.
1 year at room temperature

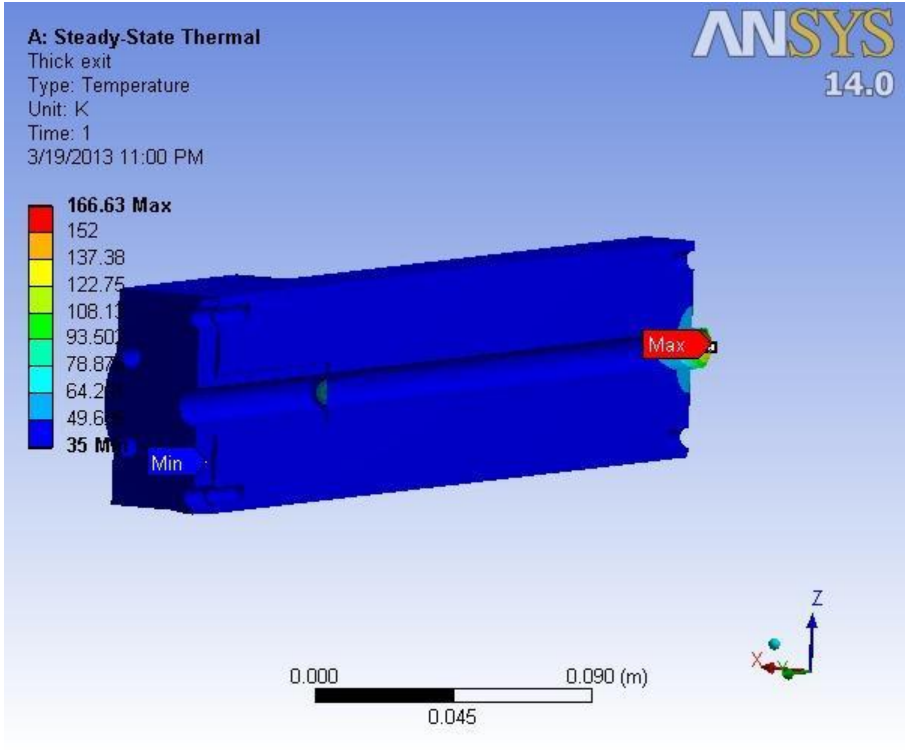
Cell Location	J (mol/s)	Activity (Ci/s)
Entrance window	6.14E-15	6.6
Walls and exit window	1.29E-13	137.5
Flanges &fittings	1.77E-14	19.2
Total	1.5E-13	163.3

Total loss = 142 mCi/year

Beam-induced and tritium embrittlement of cell

- Beam induced H2 corrosion of Al has been observed.
  - Threshold temperature for this is about 180K
  - This effect has not be evidenced in JLAB cryotargets
- Beam will ionize/disassociate the T2
  - T2 permeation could be a factor of 10 larger when beam is on
  - Estimated T2 permeation loss <350 mCi/year (50% beam on 30% T2 cell in beam)

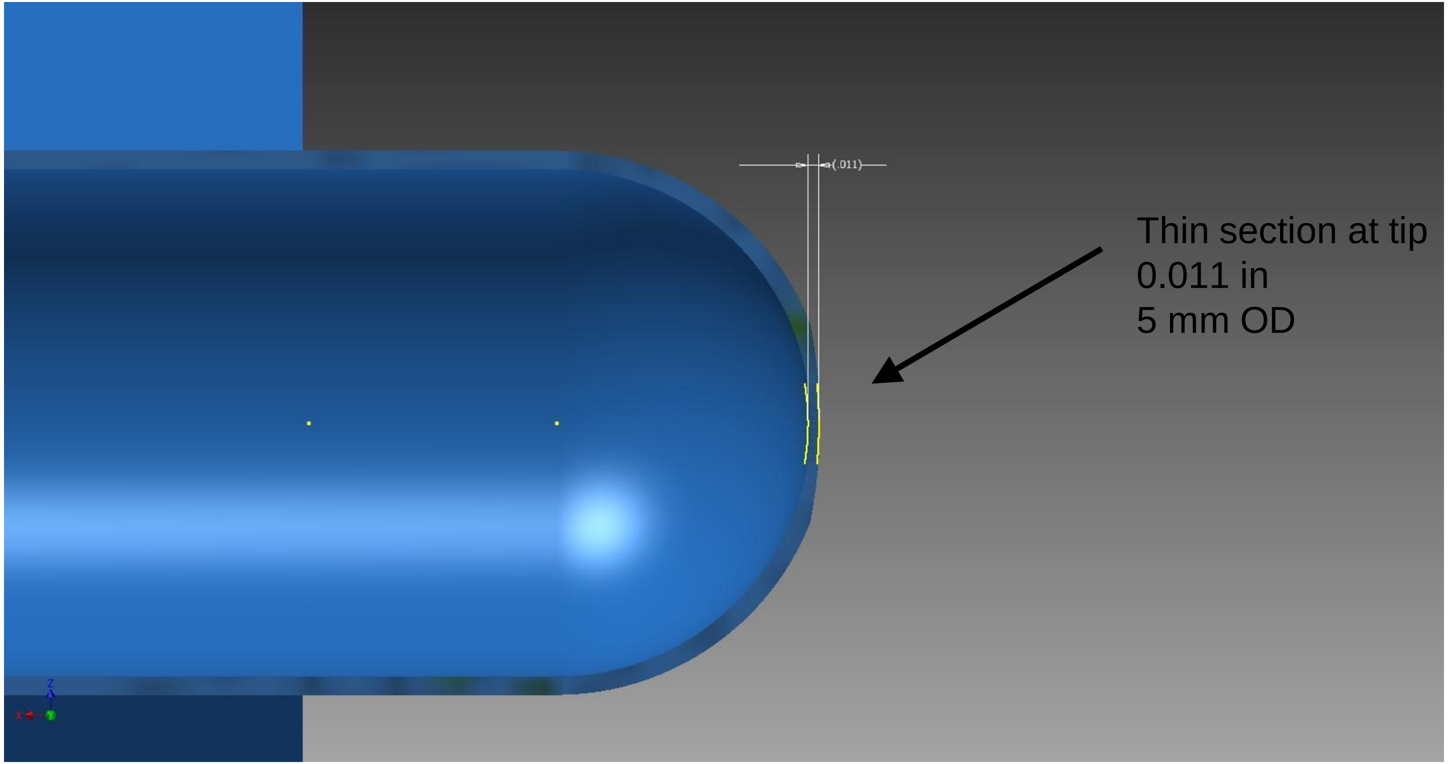
Section view of thick cell



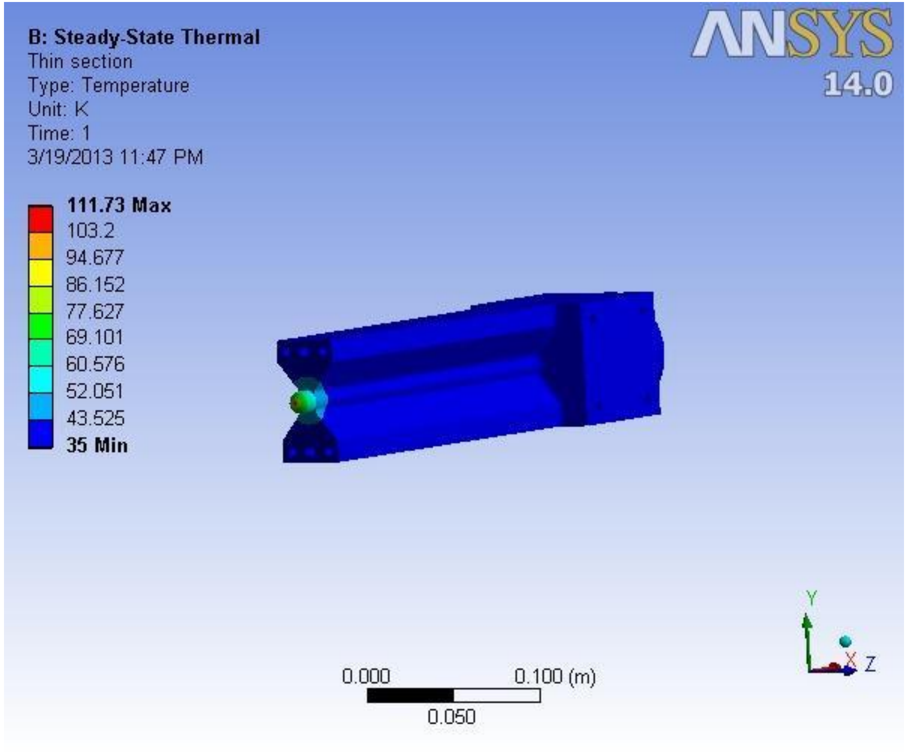
Thermal and Mechanical Analysis

- Mechanical analysis:
  - ASME B31.3 304.7.2 (design pressure >1100 psi)
  - ASME VIII D2 Section 5 analysis
    - Elastic plastic model shows safe design
- Thermal Design
  - Not as effective for the newer cell
  - Max temp exceeds 160K for 35K heat sink
  - Older design ~90K
- Modification: thin exit window
  - Thin by hand work
  - no real impact on mechanical properties

Thin Section

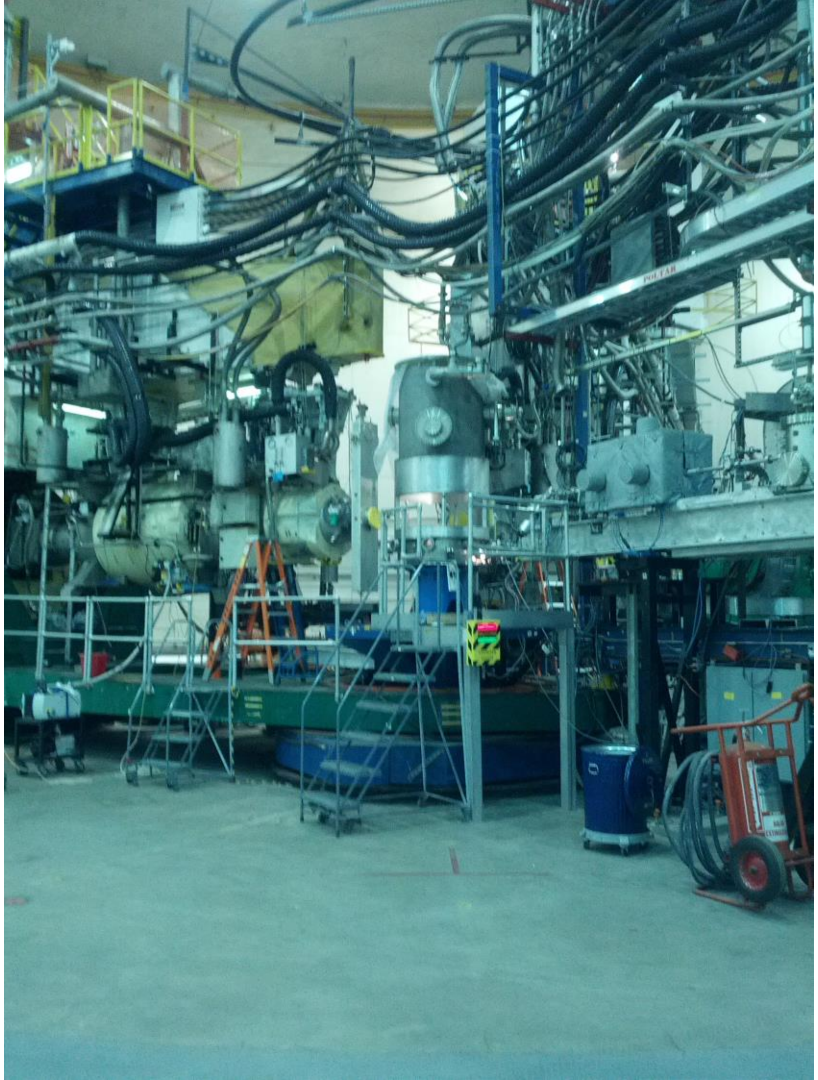


Thermal model for thinned cell

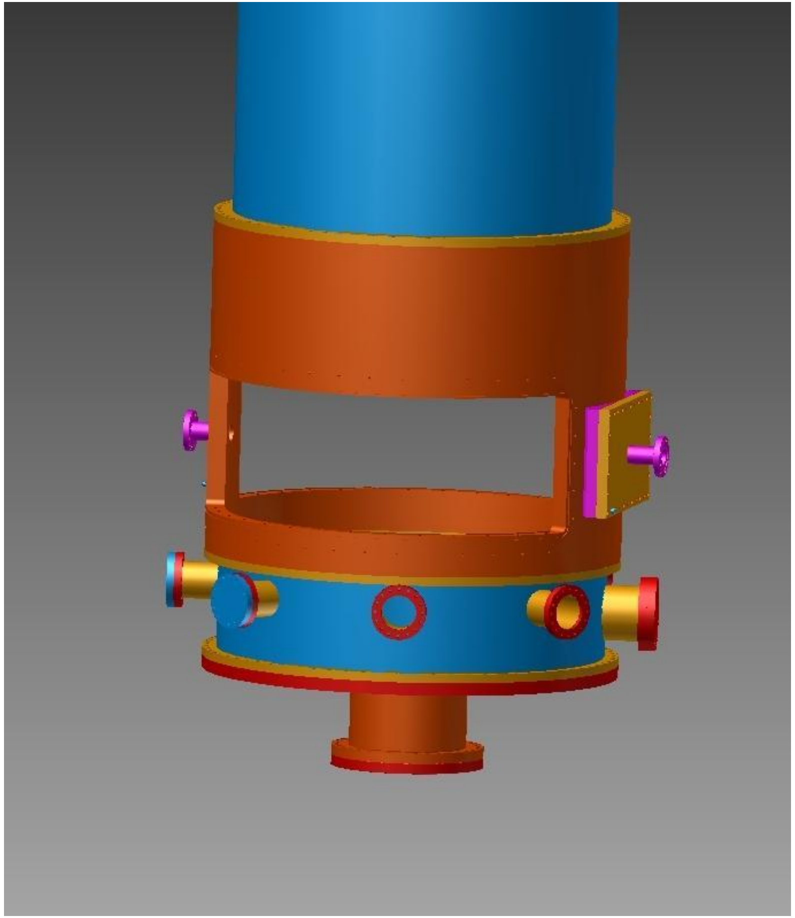


Scattering Chamber

- Secondary containment
  - Not ideal with thin aluminum windows
- T2 detection in scattering chamber
  - RGA with remote head for low P
  - High pressure vacuum switch
- Reuse the Hall A Target Chamber
  - Saves considerable money
  - Reuse could contaminate the chamber
    - It is activated already
    - Decon by pumping ???
  - Scattering angle limit of ~12.5 deg
- Require a hood system connected to vent

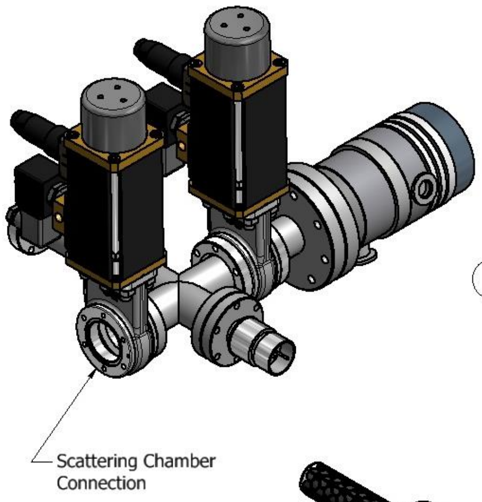


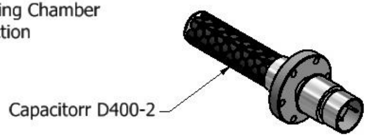
Scattering Chamber

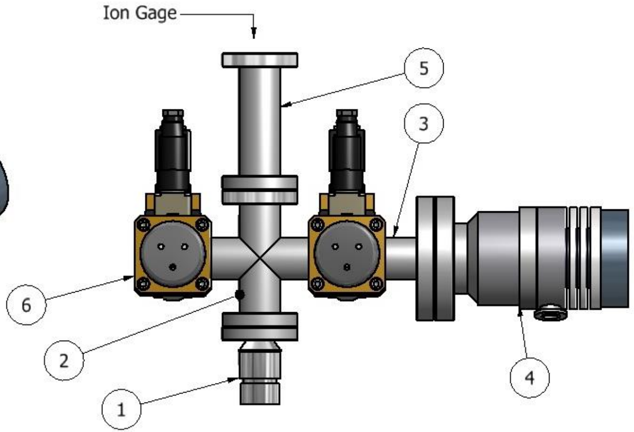


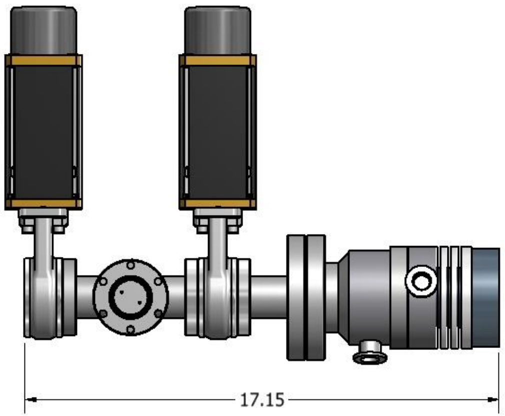
Hall A scattering chamber

- Large vacuum vessel with large openings for scattered particles
- Openings covered with 0.016” aluminum sheet (thin windows)
- Secondary containment
- Vacuum pumps are vented to stack
- “protected” by secondary getter pump (CapaciTorr D400-2)









PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Capacitorr D 400-2
2	1	2.75-inch, 4 way cross
3	1	4.5-inch to 2.75-inch reducing nipple
4	1	Turbovac 50, Leybold
5	1	2.75-inch nipple
6	2	2.75-inch Gate Valve, VAT, Pneumatic

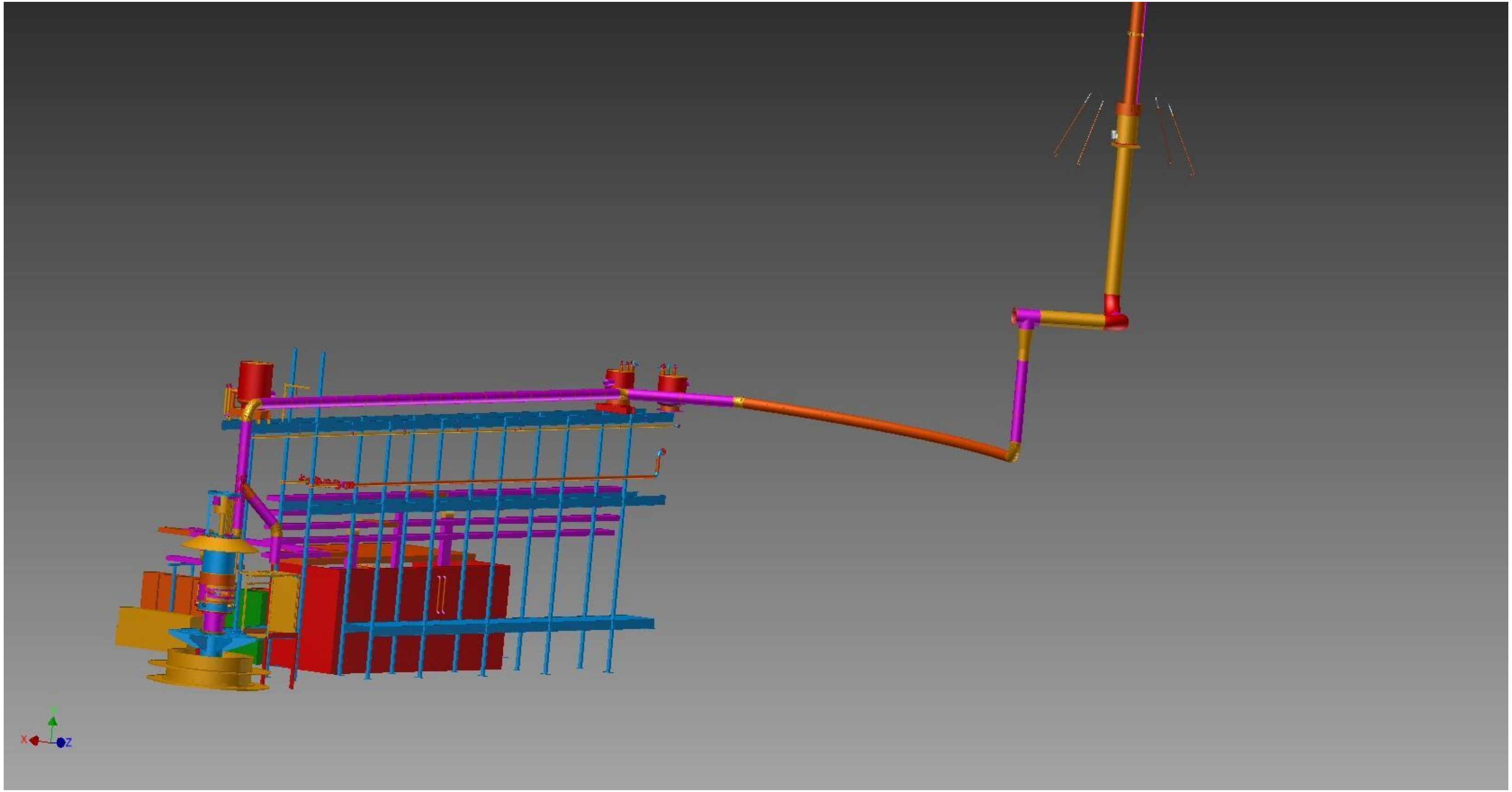
Vent Stack

- We would really like advice on this
- External stack of ~20m above grade
  - Civil/Facilities/Hall A
  - Route to back of Hall and out existing smoke removal system
  - Position near ESR
- Vent piping system connected to stack
  - extraction fan for handling and T2 detection in Hall
  - Detection in piping for T2
- Vacuum pumps exhaust to separate line

Purpose of vent(s)

- Prevent T2 from contaminating Hall and personnel during normal ops and installation
  - Exhaust vacuum pumps to outside
  - Forced air cell handling hut with separate large bore vent
- Each vent must be stacked.
  - Stack height to be 20m above grade. Top of Hall A is 15m above grade.
- Vent connected to “hood” over chamber
  - triggered remotely during a release event

Vent and Stack (J. Miller)



Beamline

- Require FSD on Raster
- Beamline isolation
  - Design by accelerator personnel
  - Collimator/Window
- Collimator
  - Prevent miss steer and cell damage
  - Design by accelerator
- Best place for extra components
  - last girder before chamber
- Isolation window at scattering chamber entrance
- Hall A beamline liaison: Yves Roblin
  - feels that these requests are reasonable
  - Offered design help

Cell handling

- Do not remove from shipping container until last.
- Install within chamber and temporary hut?
- Forced air from vent system
- PPE?
- Really like advice here
- Return ASAP to SRS

Temporary cell handling hut

- Hut needs to be connected to the vent
- Needs a seal on the chamber
  - Maybe tape
- enclosed when handling the cell
  - install
  - removal
- negative air pressure so T2 will go out vent in case of accident
- Maybe something like the pictures
  - commercial?

Alarms/Failure modes

- Fan flow/power fail
- T2 in stack
- T2 in Hall triggers “scram” button/smoke removal system
- T2 in scattering chamber
  - high pressure
  - low pressure
- Vacuum failure
- T2 cell failure
  - Getter system to absorb catastrophic cell fail

Filling Cells

- We are hopefull that SRS/SRNL still willing to help but, understand the following concerns:
  - Cell design and testing passes engineering requirements
  - Reviewed by SRS
  - Shipping in standard BTSP is OK?
  - complete vessel drawing(s), includes all dimensions and materials and types of welds (if any)
  - type of filling valve(s)...or do you want a filling stem which we could pinch weld closed (pinch welding requires an extensive performance study and would have to be compatible with our equipment)
  - any burst pressure data and the method/procedure applied
  - any proof pressure data and the method/procedure applied (done at operating temperature?)
  - estimated activated residual...quantity, isotope, radiation form, flux and half-life...is there a hottest location?

Outstanding Issues

- Stack design finalized
- plan for handling tritium cell needs to be formalized
- Requirements for beamline and scattering chamber must be formalized
- Detection of T_2 in the Hall must be formalized
  - Baseline for T_2 already in Hall
  - Low pressure we have
- Review
  - Another safety review will be required