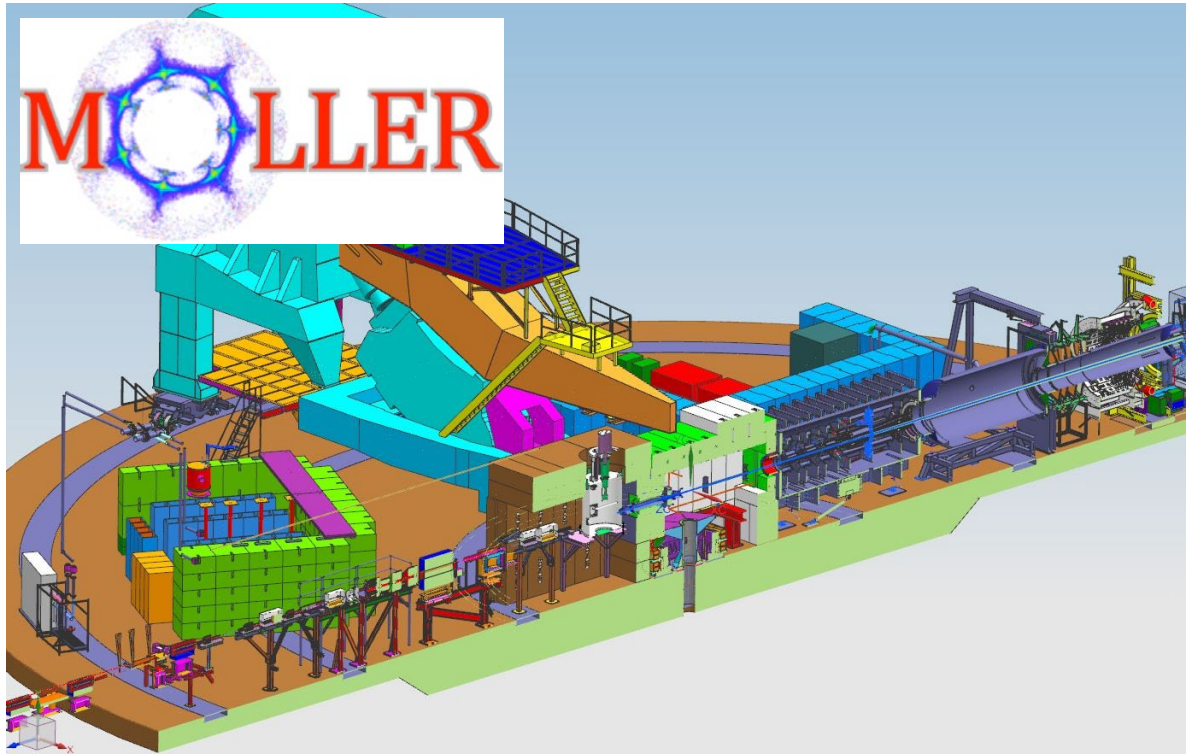
MOLLER Collaboration Meeting

Upstream Collimators Design and Analysis



Jason Bessuille

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Outline

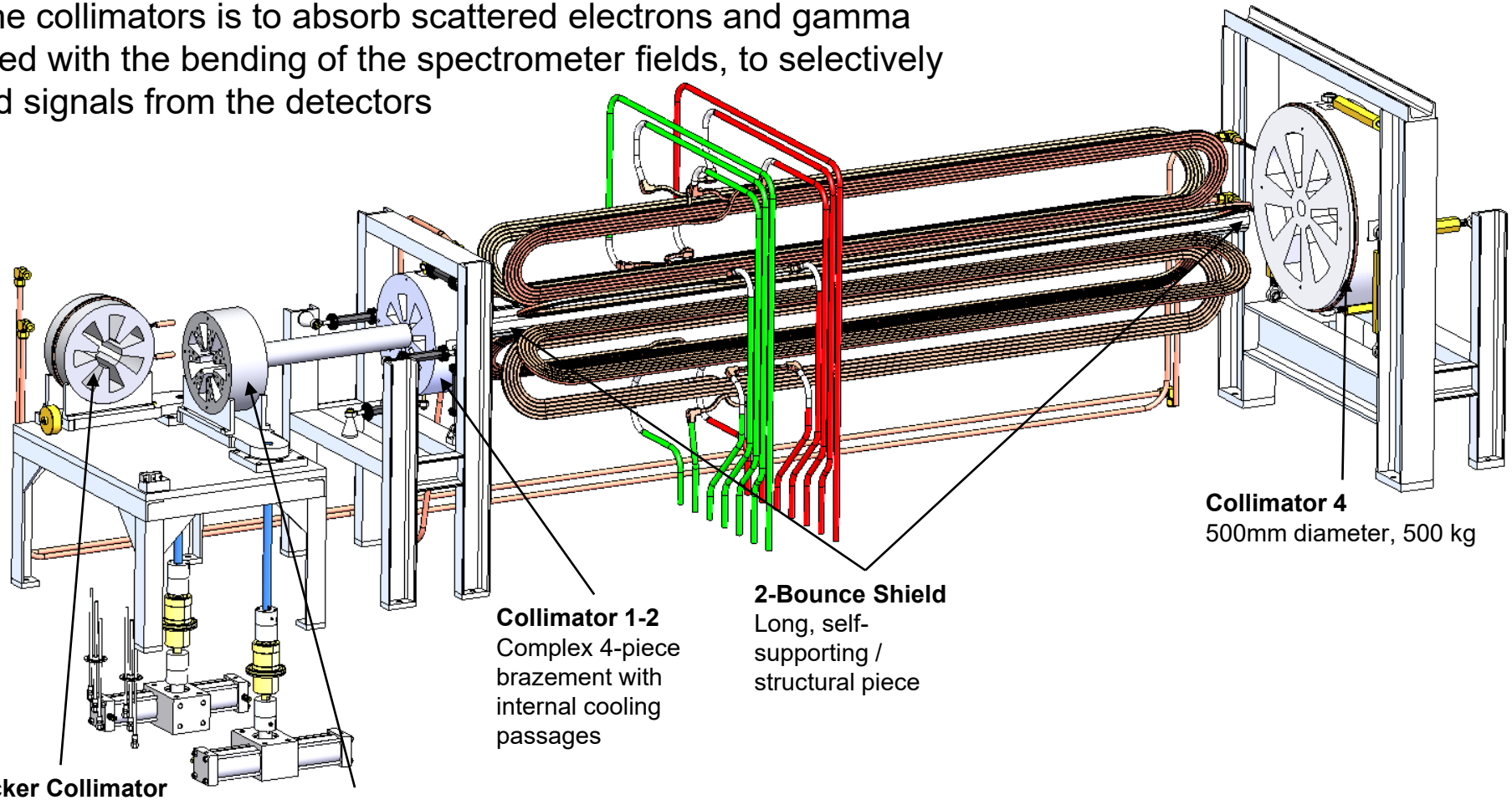
- Upstream Collimators Overview
- Sieve and Blocker
- Collimator 1-2
- Collimator 4
- Collimator Cooling
- Support Structures

- Team Members:
  - Ernie Ihloff, MIT Bates
  - Danielle Petterson, MIT Bates
  - Jason Bessuille, MIT Bates
  - Tricia Smith, MIT Bates
  - Jim Kelsey, MIT Bates

All work done in conjunction with the Jlab MOLLER engineering team and under guidance of the MOLLER collaboration

MIT Collimators

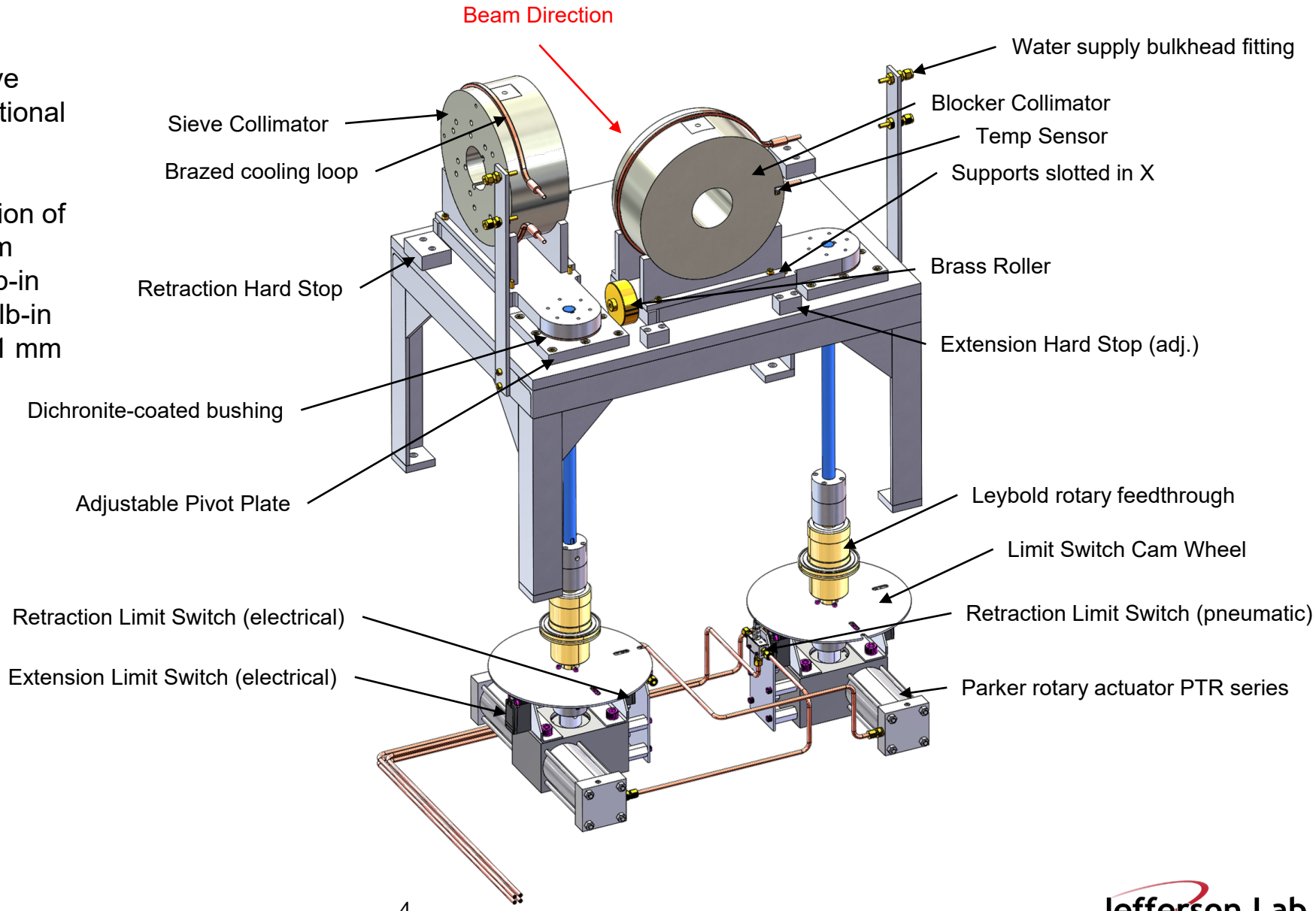
The purpose of the collimators is to absorb scattered electrons and gamma radiation, combined with the bending of the spectrometer fields, to selectively exclude unwanted signals from the detectors



- All collimators are pure W or mixed with 1% La2O3; no nickel or iron is permitted.
- All will be housed in a vacuum chamber at $1x10^{-2}$ Pa
- All except 2-bounce shield support own weight alone

Movable Collimators (Sieve and Blocker)

- 1400 W in blocker, small power in sieve
- Both are cooled, less than 50 C operational temp
- Both are 100% W
- Rotary pneumatic actuators allow motion of diagnostic collimators into/ out of beam
- Predicted Torque Required: 146-180 lb-in
- PTC251 Output torque @ 75 psi: 322 lb-in
- Transverse Position Requirement: +/-1 mm



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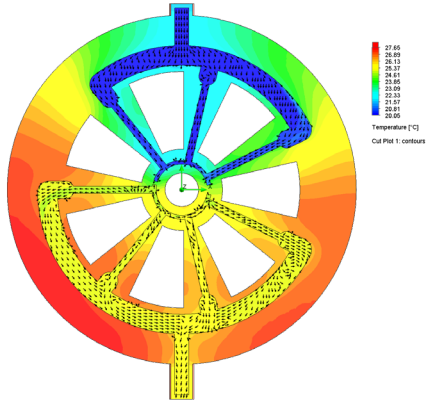
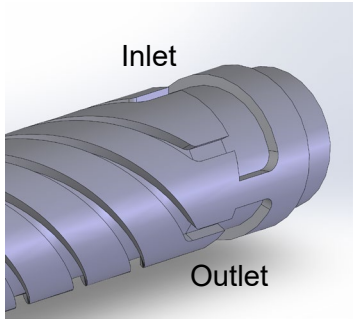
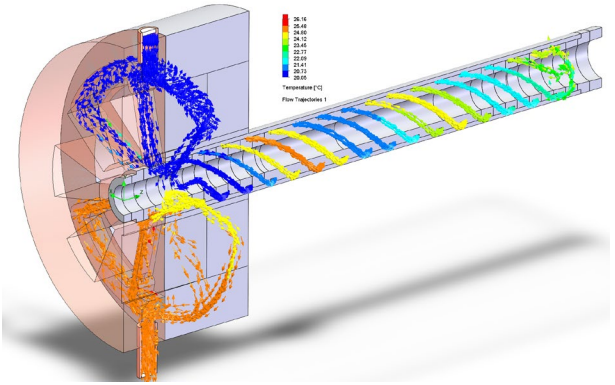
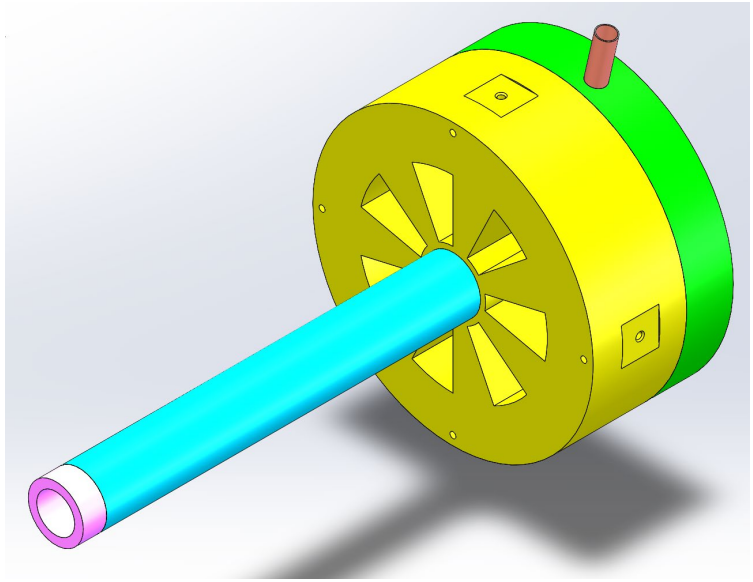
Collimator 1-2

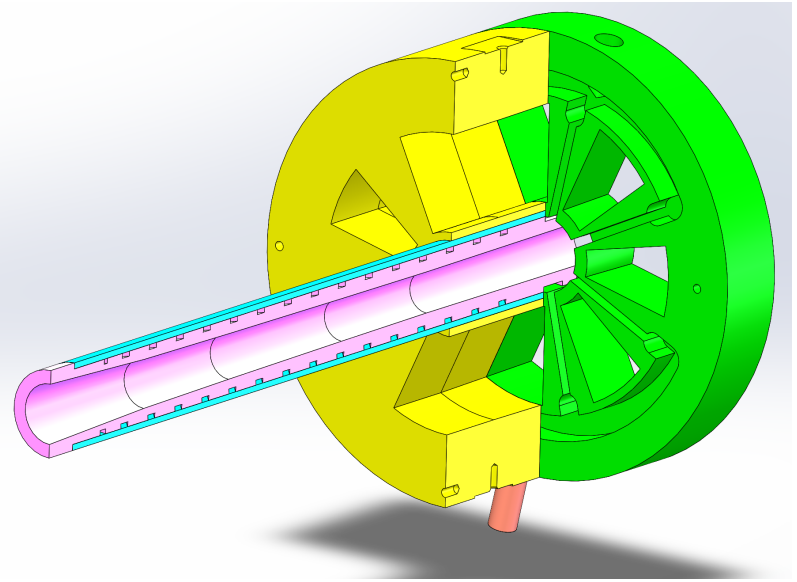
- Disc: 300mm dia x 150mm thick
- Core: 59mm dia x 575 mm long
- 99%W, 1% La2O3
- Min Density 17 g/cc
- Absorbs 4500 W in core, 900 W in disc
- +/- 100 um on petal surfaces
- +/-100 um on core inner profile, which has several different tapers along length
- 0.5 mm concentricity between C1 inner surface and C2 petals
- Copper cooling fittings brazed to drilled holes
- Multiple water-vacuum braze interfaces
- Leakage between inlet and outlet channels is must be avoided
- Temperature during operation: 30 - 150 C
- Radiation dose 6.6e11 Rads











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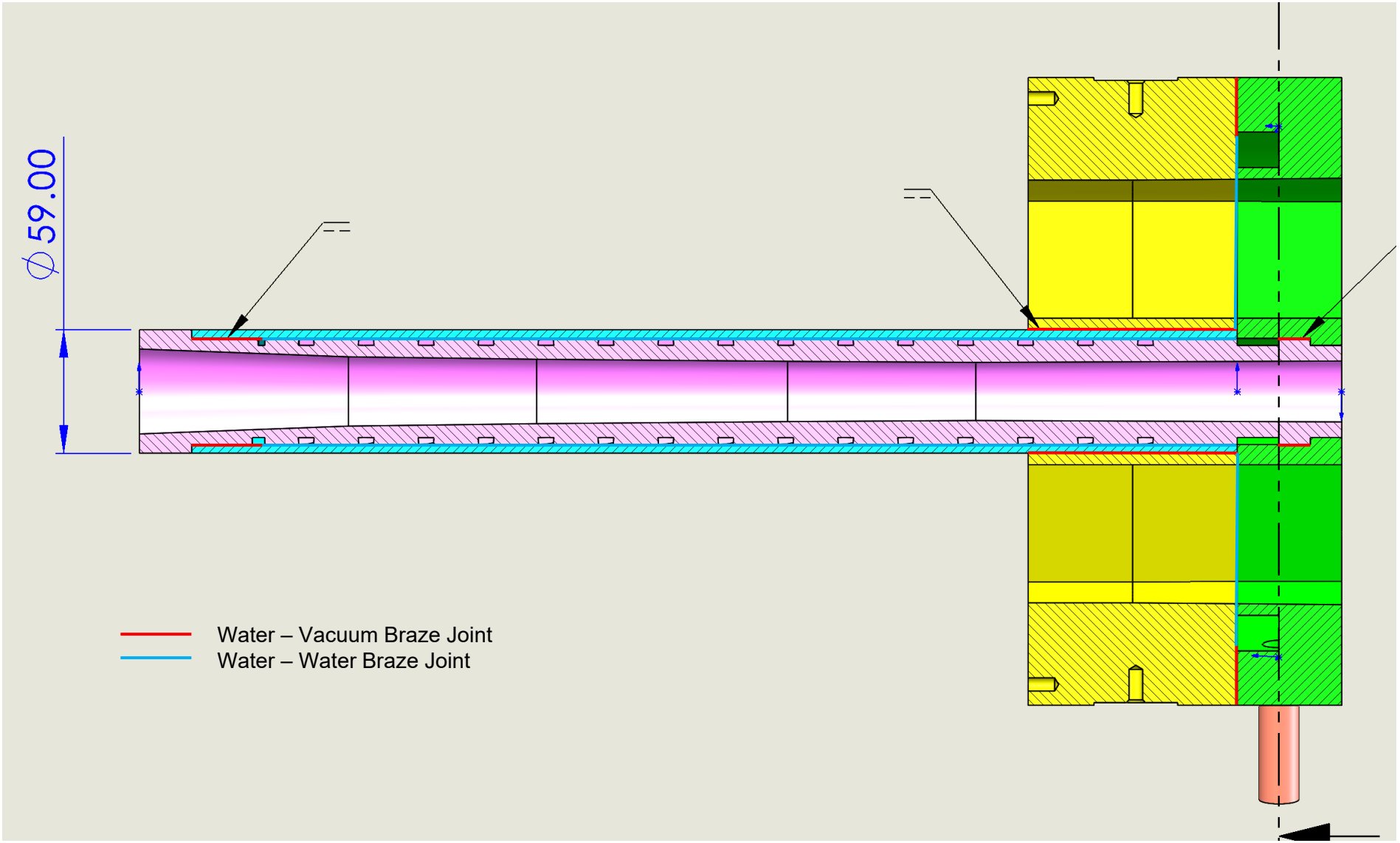
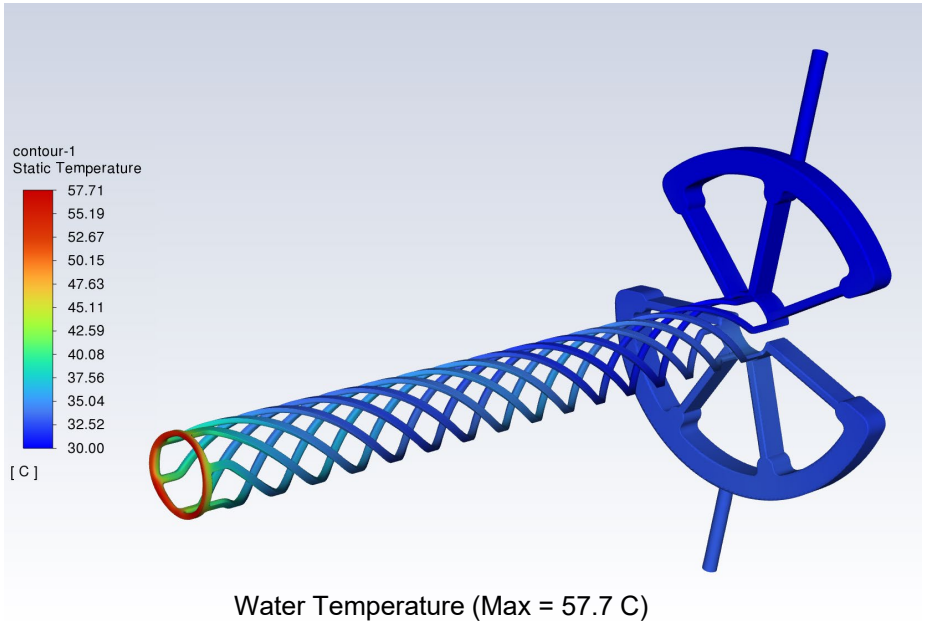
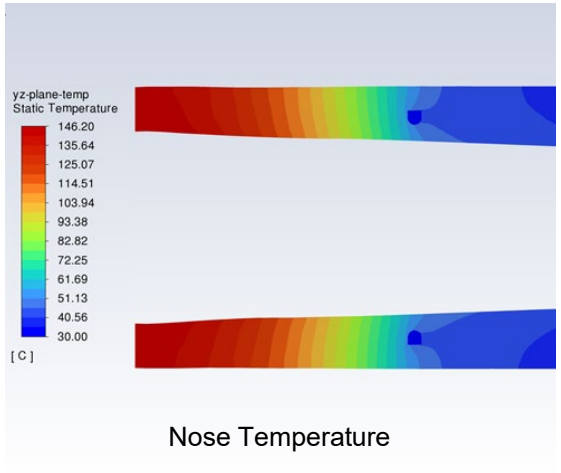
Collimator 1-2 Brazes



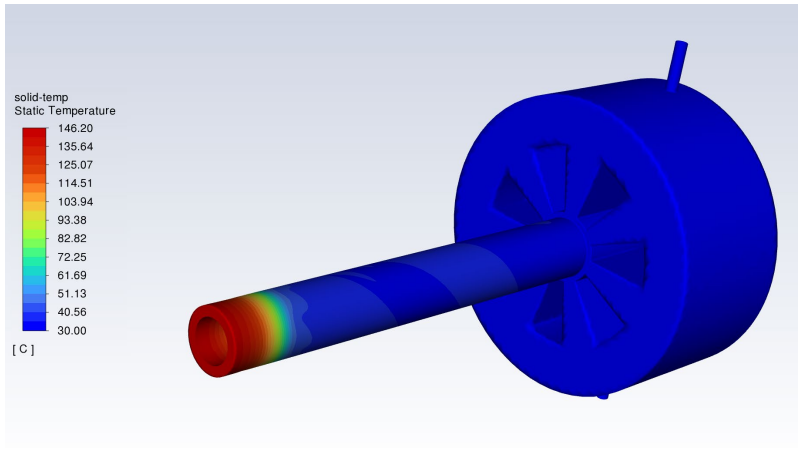
Collimator 1-2 Thermal



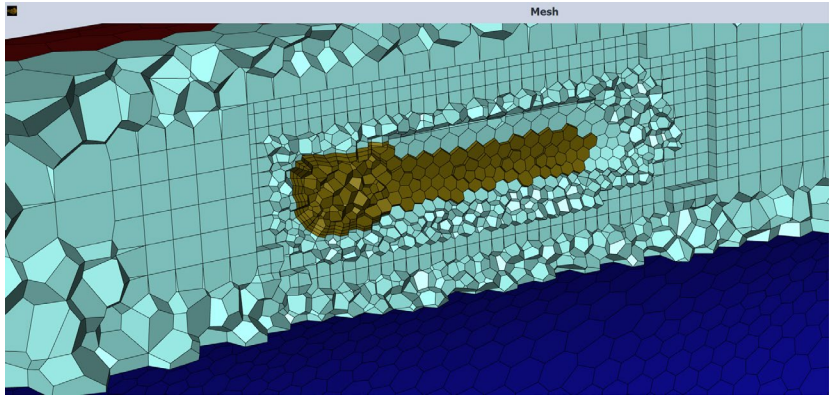
Water Temperature (Max = 57.7 C)



Nose Temperature



Solid Temperature (Max = 146.2 C)

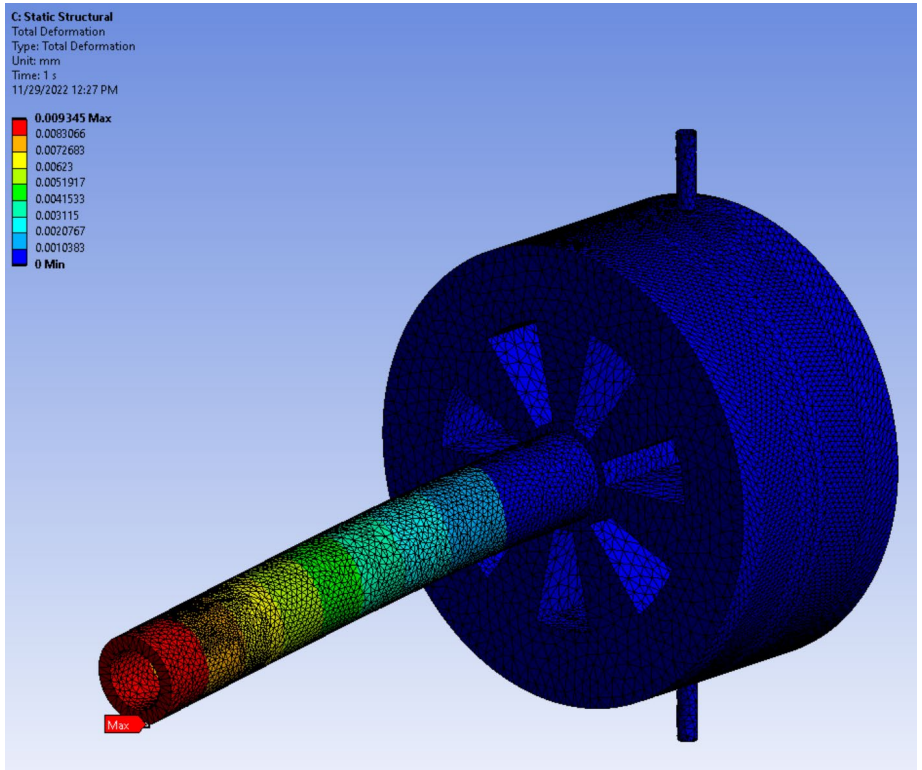


Closeup of mesh in cooling channel – 3.74M cells

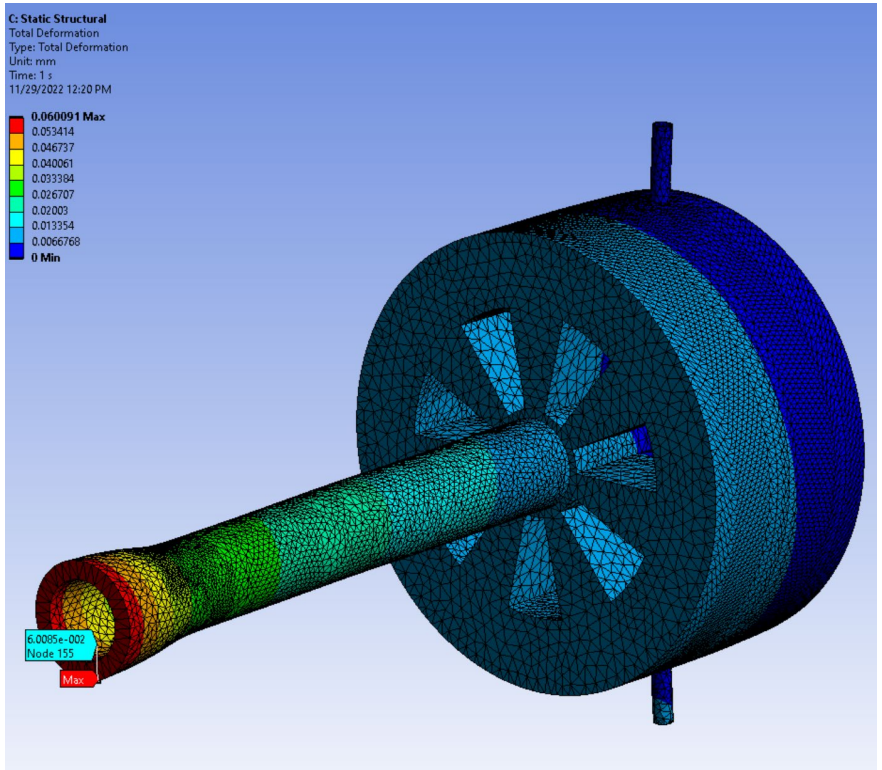
Maximum Tungsten Temperature	**146.2 C**
Maximum Water Temperature (20 C inlet)	57.7 C
Pressure drop	170 kPa (24.6 psi)
Water Temperature Rise	5.7 C

Collimator 1-2 Structural

- Here we use gravity and the CFD temperature map to simulate deformation
- Maximum deformation is 60 microns and very uniform
- Stresses are very low (~2 MPa)

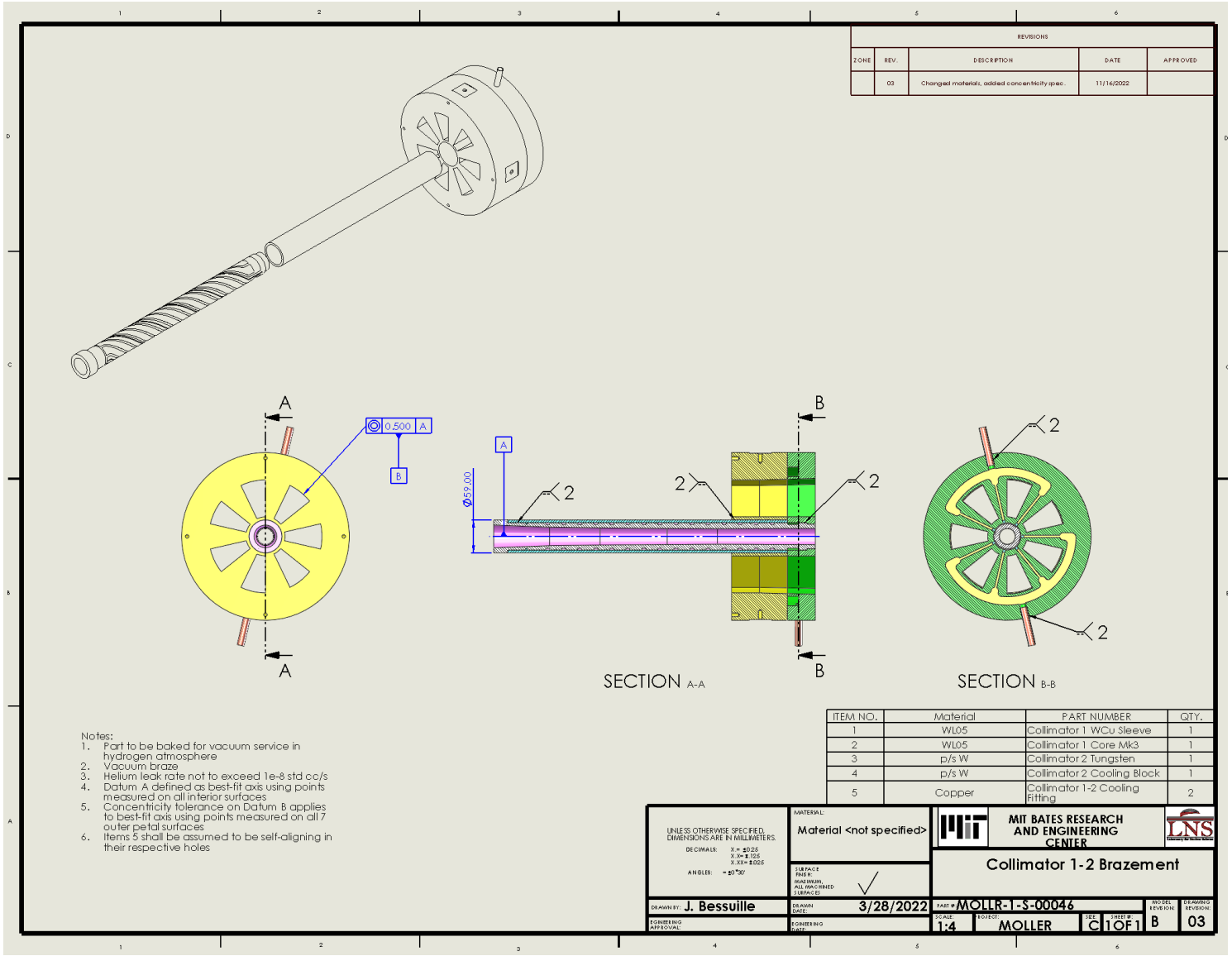


Displacement under gravity only (Max = 9 microns)



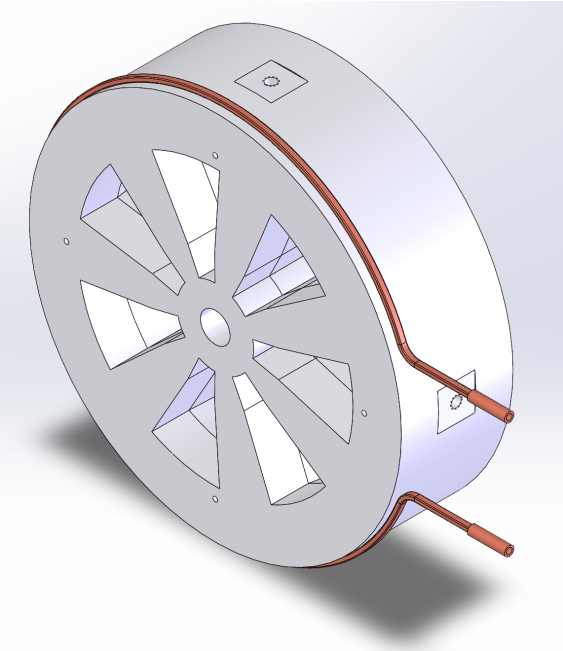
Displacement under gravity and radial thermal growth (Max = 60 microns)

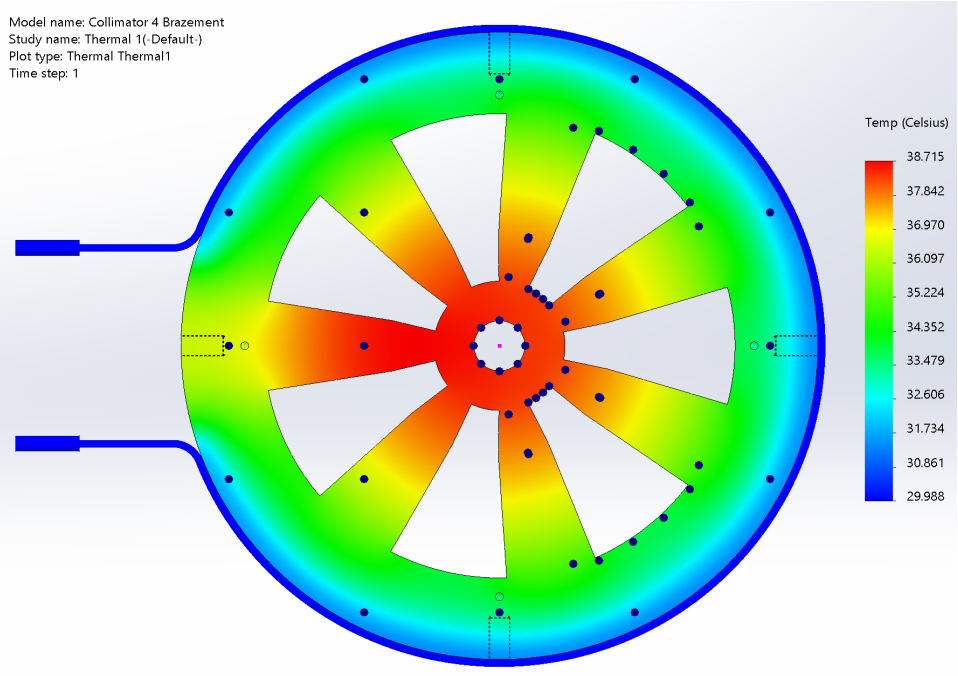
Collimator 1-2 Assembly/Brazement Drawing



Collimator 4

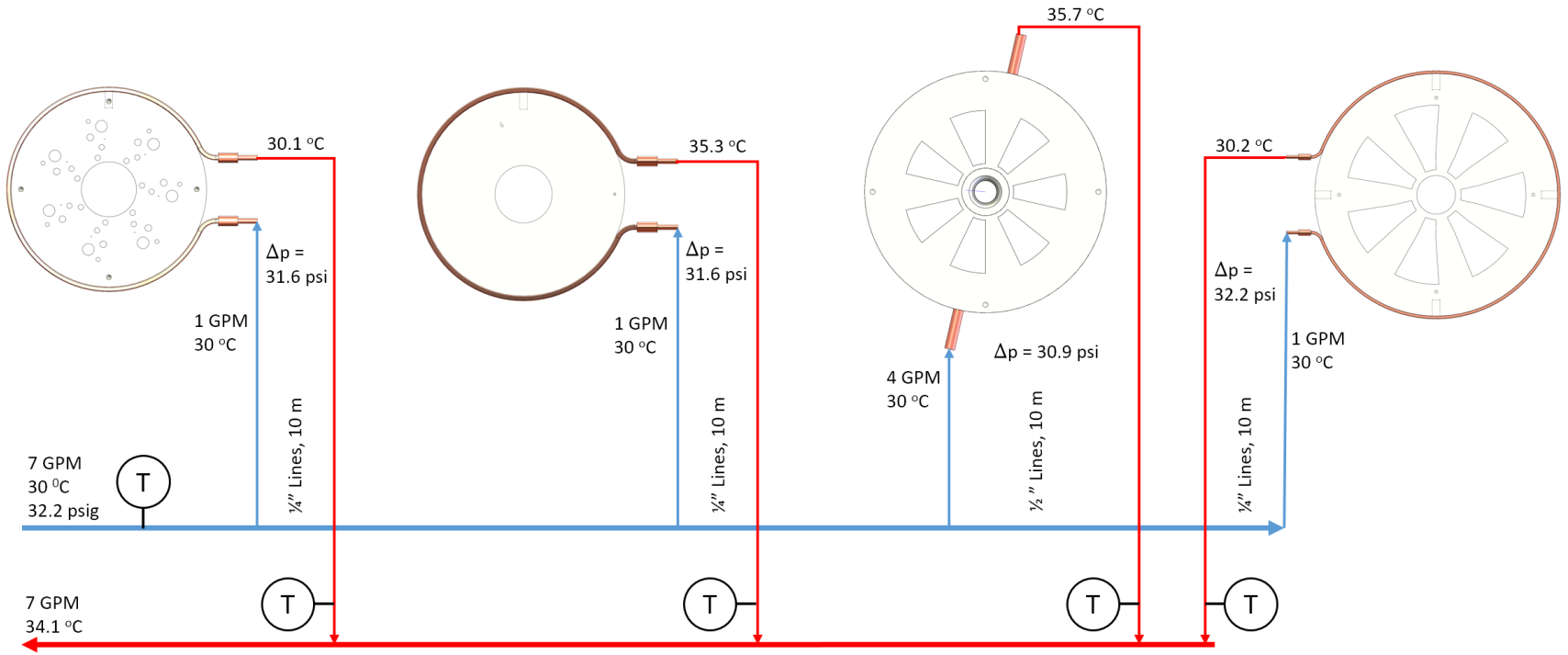
- 500 mm dia x 150 mm thick
- ~500 kg
- 100% W
- Approx. Minimum Density 17 g/cc
  - Actual will be higher
- Absorbs about 60 W
- +/- 100 um on inner surfaces
- 4 tapped holes drilled into 4 flats around circumference
- Operation temperature 20 – 40 C





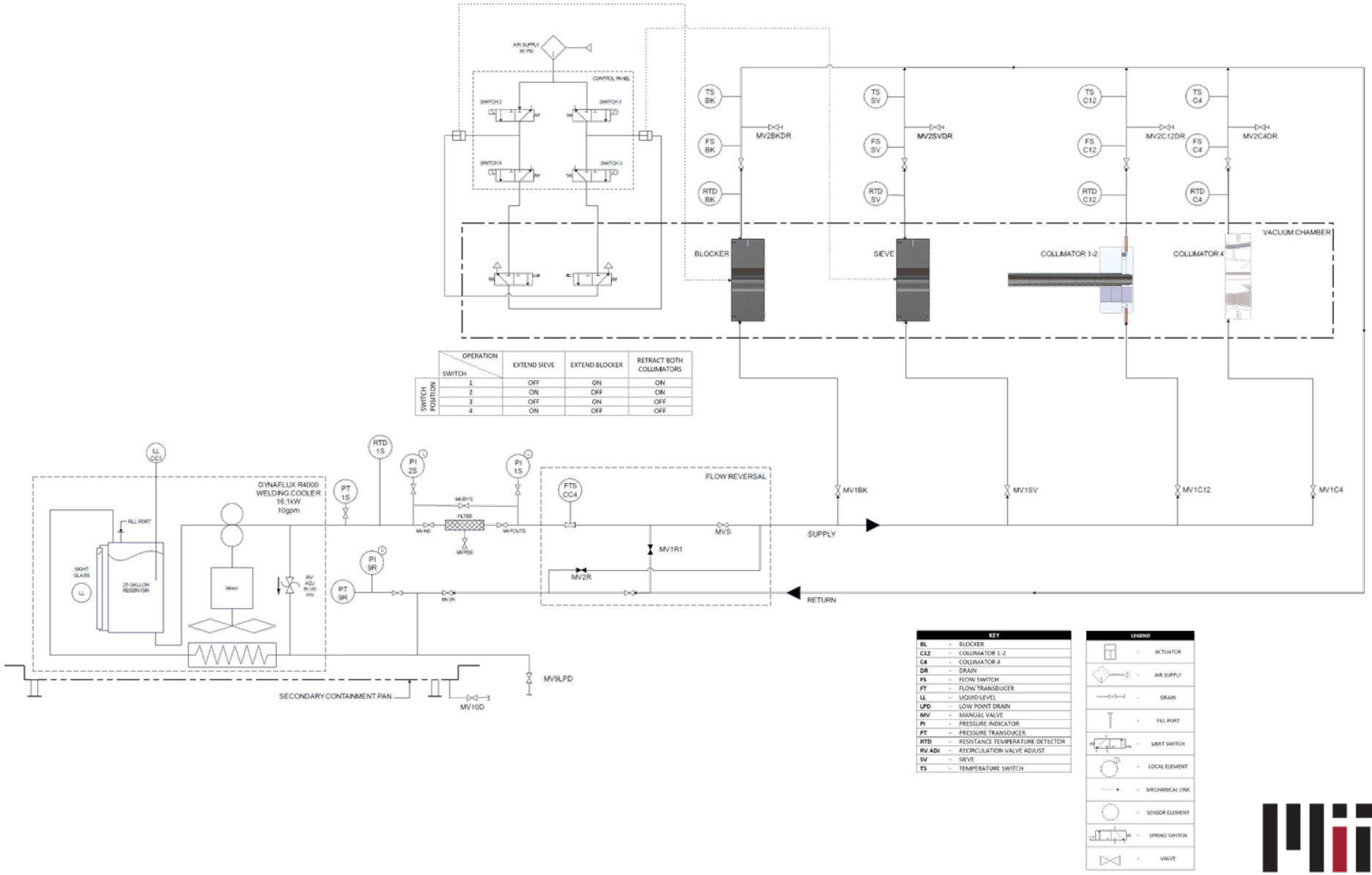
Maximum Tungsten Temperature (30 C tube)	38.715
Maximum Deflection	26 microns

Collimator Cooling



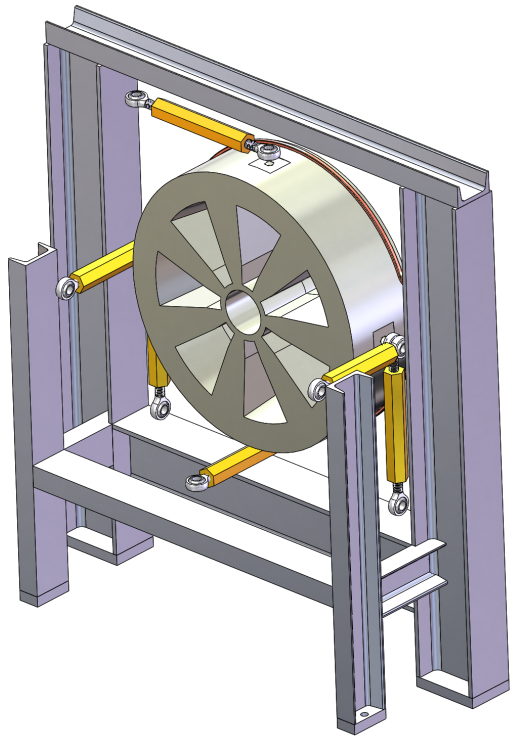
- All collimators fed by 7 GPM water at about 32 psi
- Assumed 10 m long supply / return lines
- Friction factor for pressure drops calculated using Colebrook Equation: $\frac{1}{\sqrt{f}} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$
- Reynold's number 15k-25k (highly turbulent)
- All pressure drops are within 4% of each other at nominal flow rates
- If 10 m assumption is not valid, flow balancing valves will need to be furnished
- Temperature monitors located in shielded area

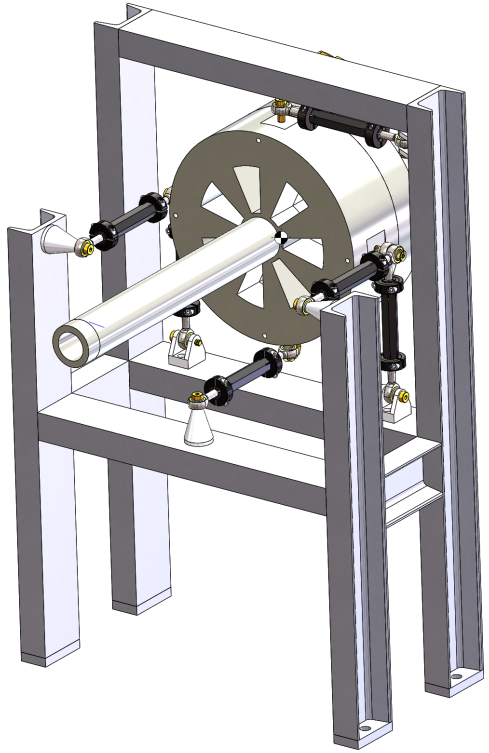
Collimators P&ID



Support and Alignment

- Alignment tolerances defined by physics requirements
- C1-2 and C4 mounted using all-brass, 6-strut kinematic mounts
- Blocker and Sieve shimmed for x-y and phi, adjustable hard stops for z/theta
- All collimators furnished with reamed holes for JLab survey markers
  - CMM data will be provided for each collimator, locating the critical acceptance features to these survey marker holes





	dz	dx, dy	dϕ	dθ
Blocker	3 mm	0.5 mm	TBD	0.2°
Sieve	3 mm	0.5 mm	0.2°	0.1°
C1-2	3 mm	0.5 mm	0.2°	0.1°
C4	3 mm	0.5 mm	0.2°	0.2°

Summary and Status

- Requirements well understood
- Tungsten vendor chosen and providing valuable feedback
- Analysis mostly complete
- Drawings undergoing internal checks and review from tungsten supplier

Component	Analysis Completion	Drawings Completion
Blocker	100 %	90%
Sieve	100 %	90%
Blocker & Sieve Motion	95%	75%
Collimator 1-2	100%	90%
Collimator 4	100%	90%