Mark IV Upper Target Design for the Lujan Center 1L Target at LANSCE

High Power Targetry Workshop

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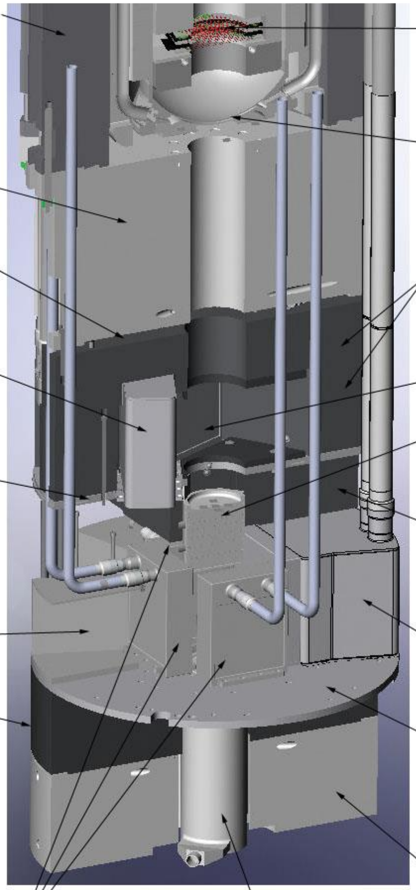
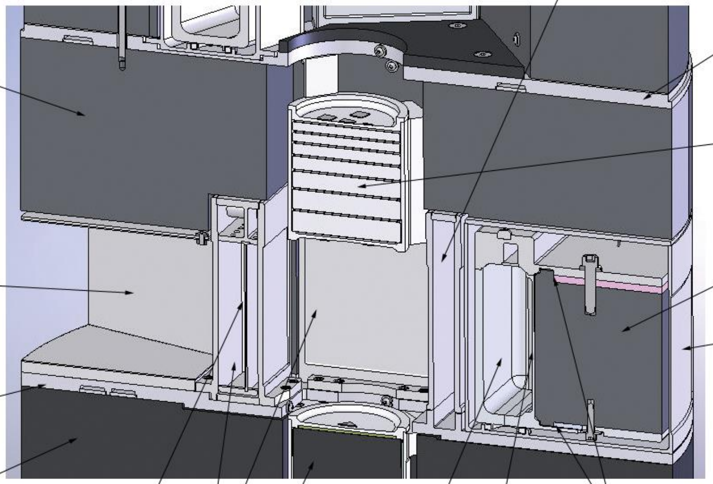
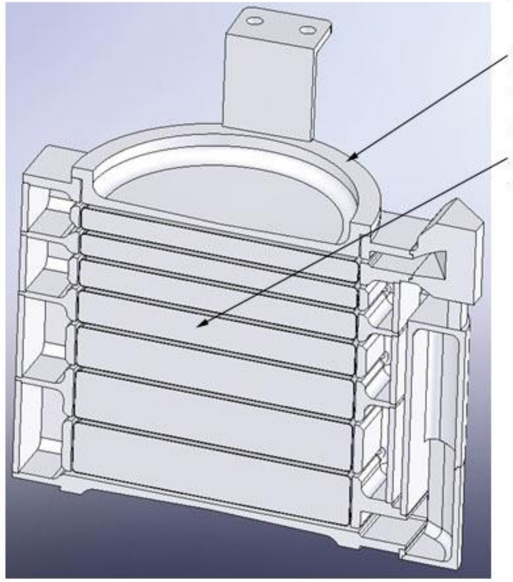
Introduction

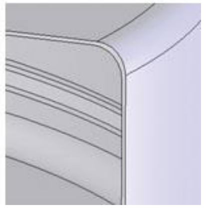
- **1L target assembly has a vertical, downward, beam entry.**
- **Nominal beam design parameters: 800 MeV, 200 μA, 3.53 cm FWHM**
- **Focused (off-normal) beam: 800 MeV, 200 μA, 1.015 X 2.431 cm FWHM**
- **Mark III design has 2 targets (upper and lower). Upper target is a tungsten disk stack, lower target is a long tungsten cylinder.**
- **Mark IV intends to add a third target comprised of one disk from Mark III turned on edge and placed above the Mark III upper target…didn't quite work out that way.**
- **This talk:**
  - Description of Mark III design for reference and spatial orientation
  - Physics and performance motivation for new upper target
  - Mark IV upper target design iteration evolution, with analysis and discussion

Mark III: Upper stacked disk target and lower cylindrical target.



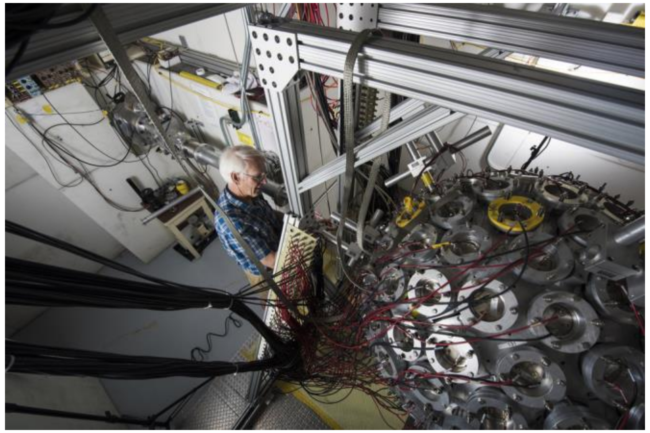




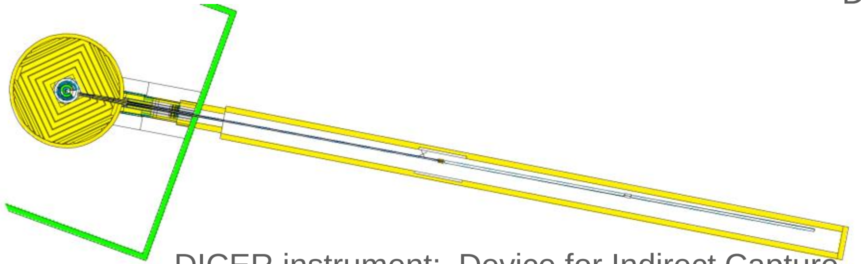


New upper target physics motivation: Increased flux and spectral resolution

- **Improving quality of Mark III measurements**
  - Neutron capture (DANCE instrument)
  - Supporting new experimental efforts better spectral characteristics
  - Neutron capture
  - Neutron induced fission experiments
  - Total cross section measurements in resonance region (new DICER instrument)
- **Experiments supporting wide variety of applications**
  - Fast reactor development and design
  - Nuclear astrophysics
  - Stockpile stewardship
  - Nuclear forensics
  - Radiochemical diagnostics



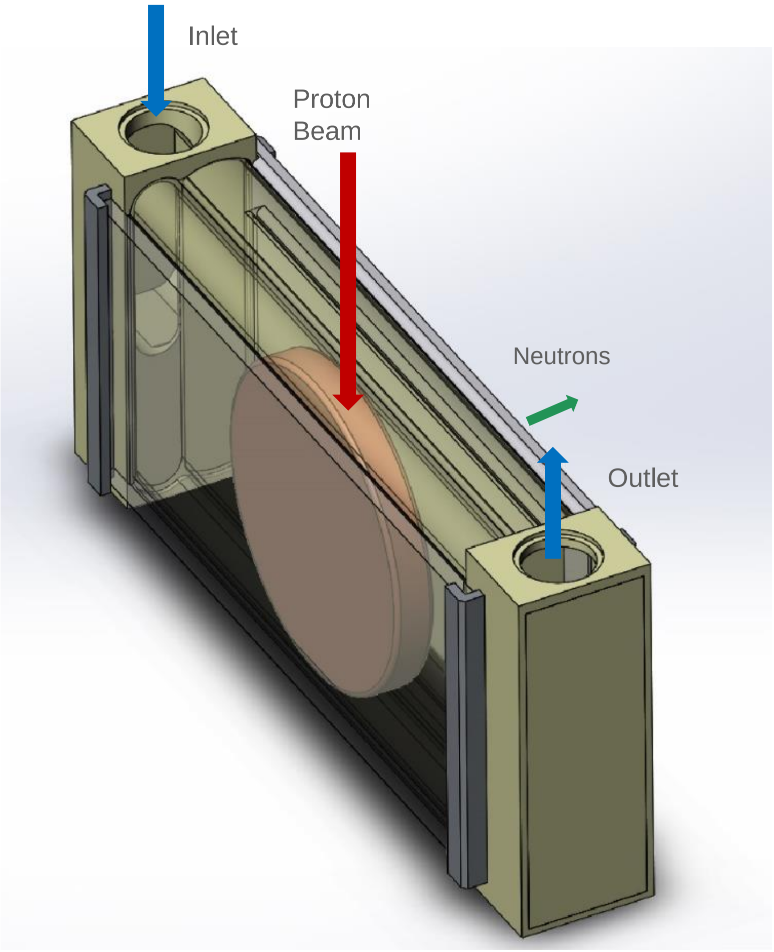
DANCE instrument
Detector for Advanced Neutron Capture Experiments



DICER instrument: Device for Indirect Capture Experiments on Radionuclides

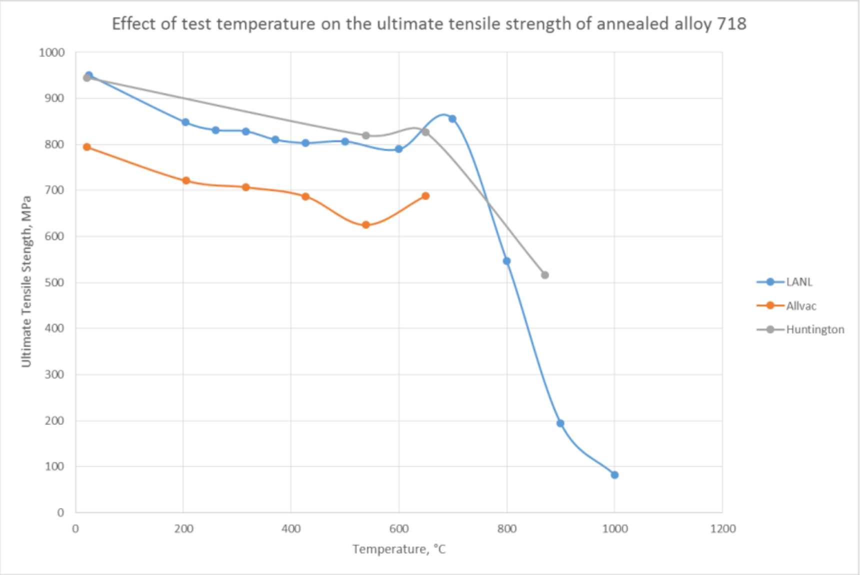
Plan A: Take disk 4 from middle target and turn it on edge

- Design beam spot 3.53 cm FWHM
- Disk 4: 10.1 cm dia. X 1.249 cm thick
- Disk is arranged vertically with water cooling across the faces. A water moderator in added on one side.
- Strongbacks used to minimize wall thickness.
- Beam entry surface curved for pressure containment.
- Cooling water at 100 psi and 20 gpm.



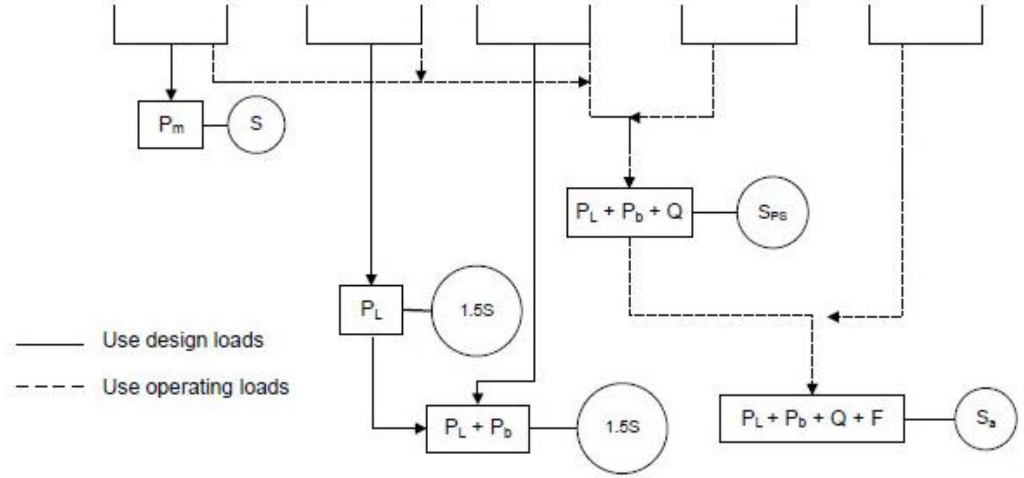
Housing stress analysis methodology

- **Wall thickness and curvatures changed iteratively to achieve stress below ASME BPVC allowable.**



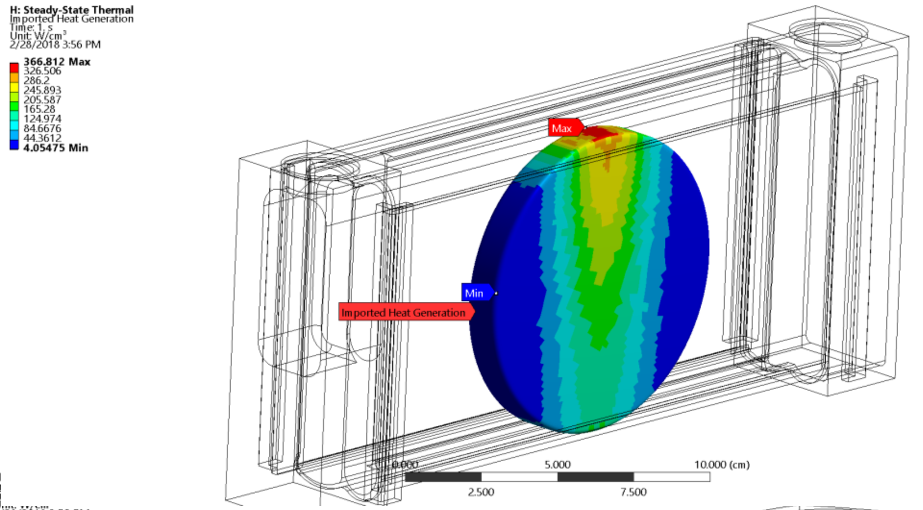
Design allowable stress, S_m = 230 MPa

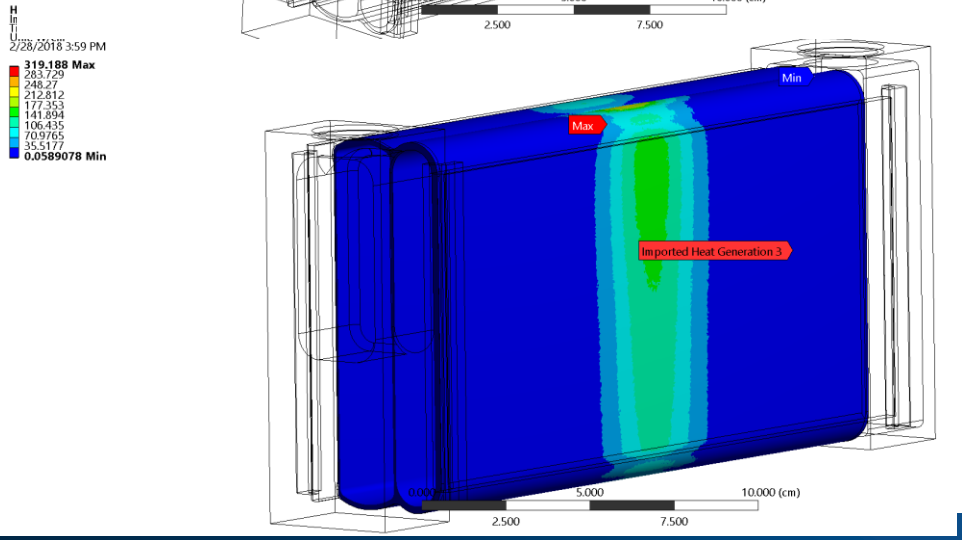
Stress Category	Primary			Secondary Membrane plus Bending	Peak
	General Membrane	Local Membrane	Bending		
Descrip-tion (For examples, see Table 5.2)	Average primary stress across solid section. Excludes dis-continuities and concentrations. Produced only by mechanical loads.	Average stress across any solid section. Considers dis-continuities but not concentra-tions. Produced only by mech-anical loads.	Component of primary stress proportional to distance from centroid of solid section. Excludes dis-continuities and concentrations. Produced only by mechanical loads.	Self-equilibrating stress necessary to satisfy contin-uity of structure. Occurs at struc-tural discontinui-ties. Can be caused by mechanical load or by differential thermal expansion. Excludes local stress concentrations.	1. Increment added to primary or secondary stress by a concentration (notch). 2. Certain ther-mal stresses which may cause fatigue but not distor-tion of vessel shape.
Symbol	P_m	P_L	P_b	Q	F



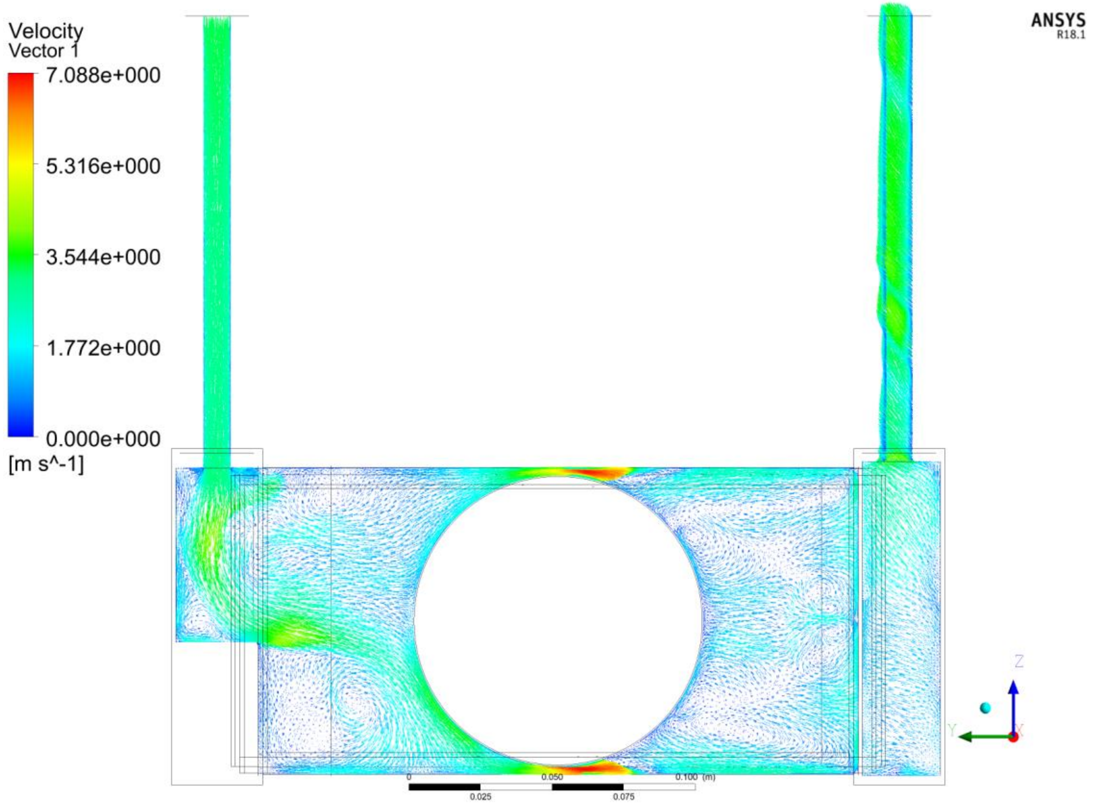
Plan A: Analysis

Beam heating profiles. 16 kW in target, 2.8 kW in Inconel housing, 367 W/cm^3 peak





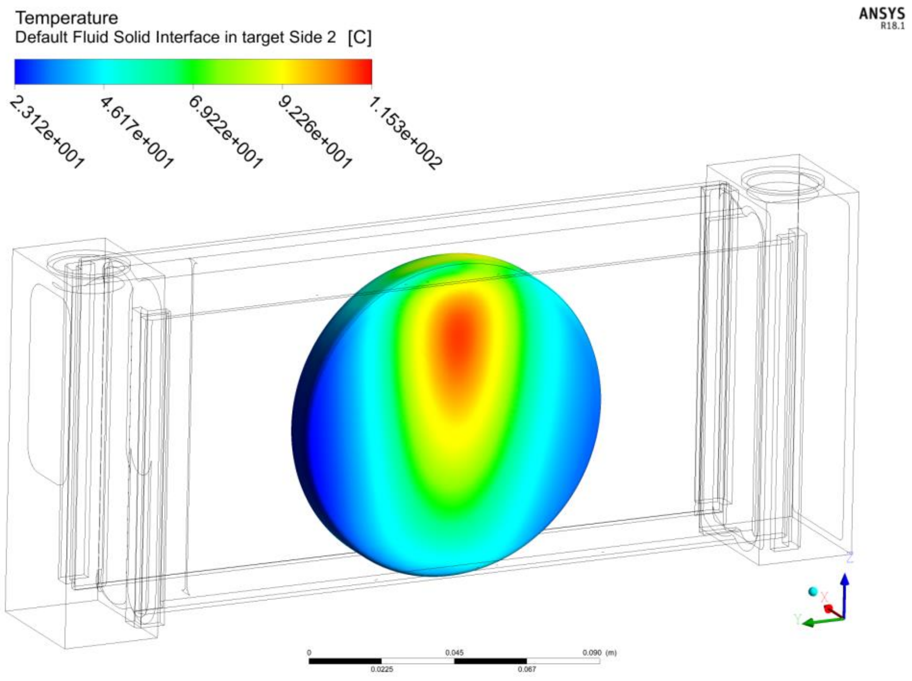
Velocity vector plot. Good acceleration over top of disk for enhanced cooling.

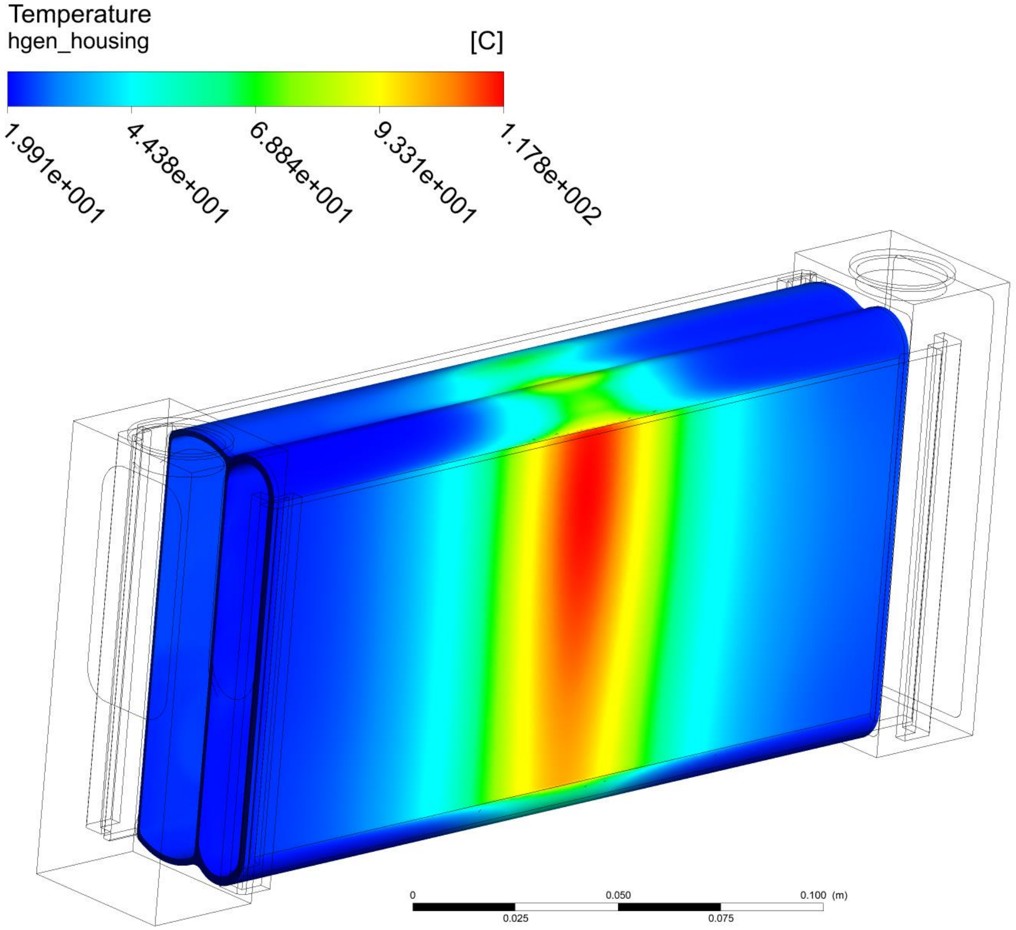


Plan A: Analysis

- **Solid-liquid interface temperature below saturation everywhere. All is good…so far.**

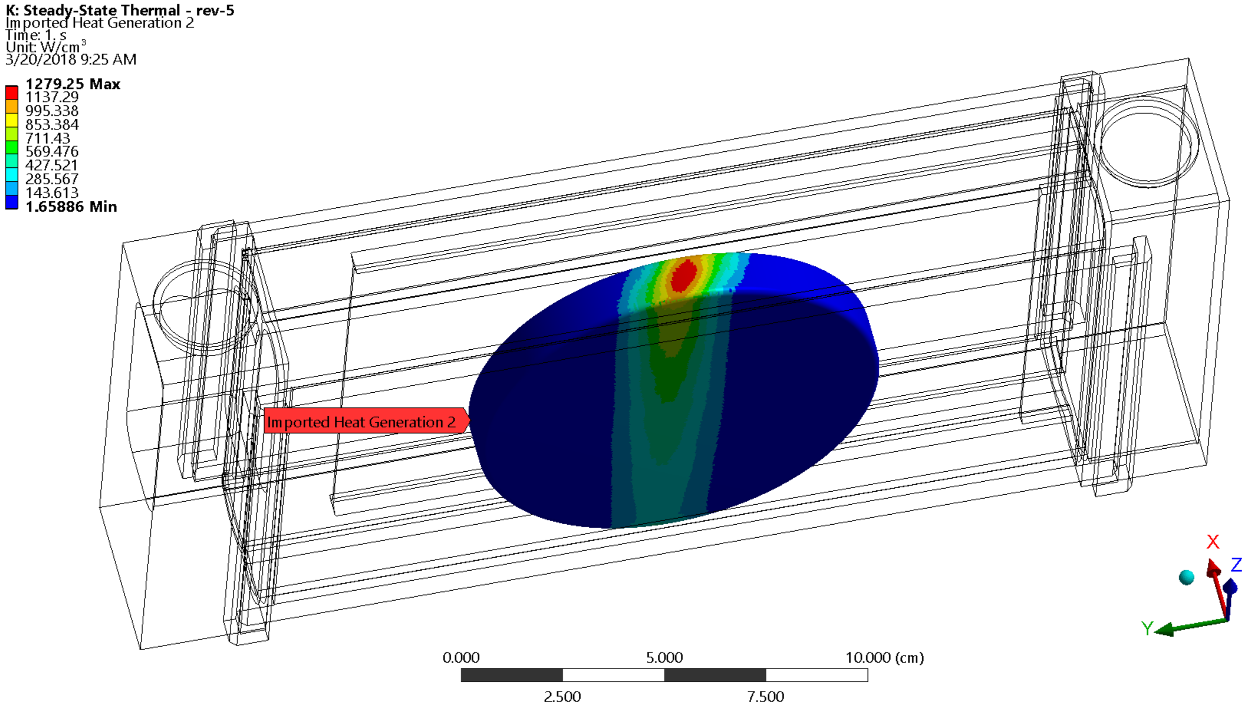
Saturation temperature at 0.698 MPa (100 psi) is 170°C.



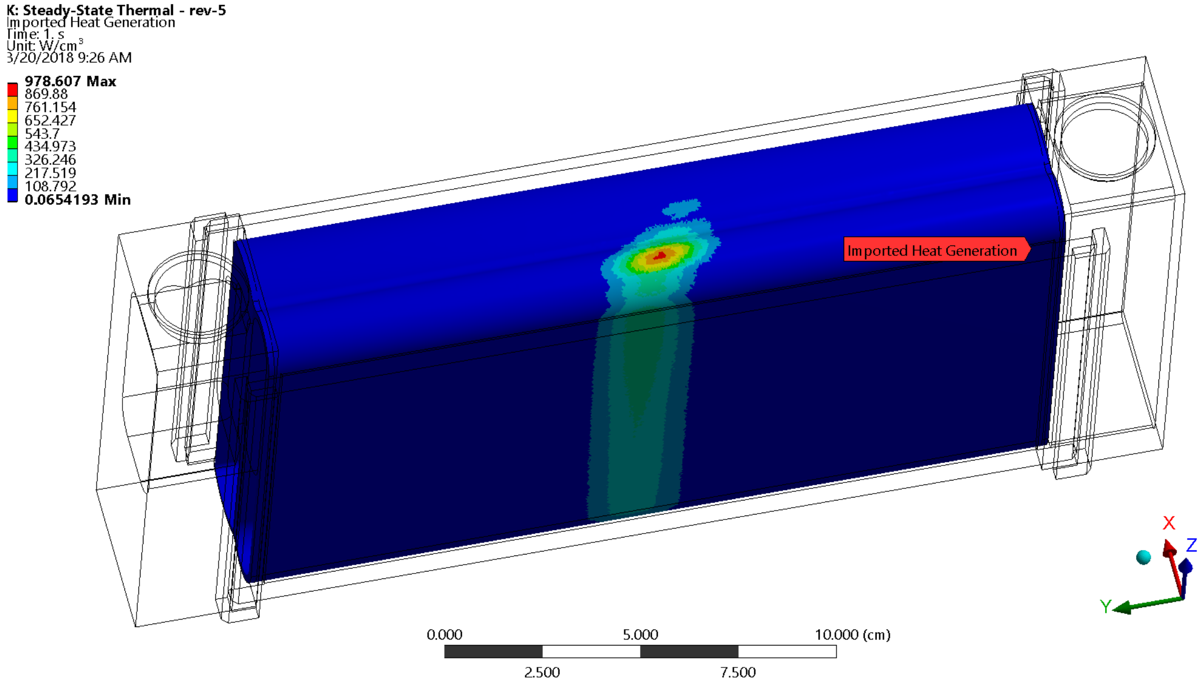


Plan A works great nominal beam but focused beam, 1.015 X 2.431 cm FWHM, must be anticipated

- Peak volumetric heating now 1279 W/cm3.



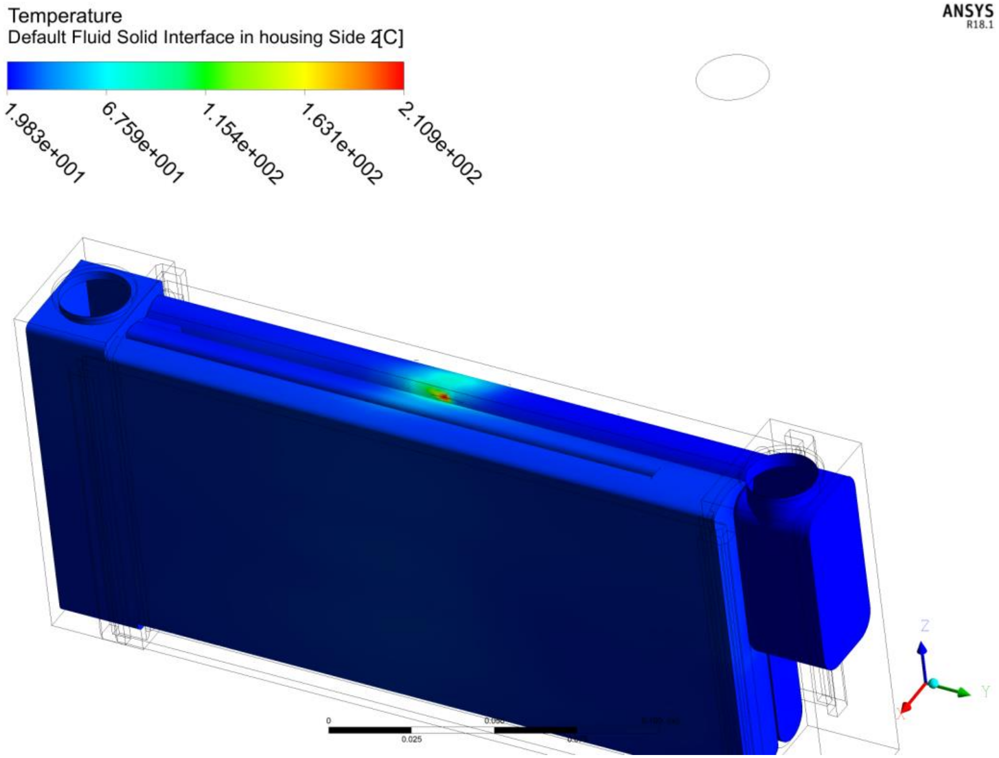
28 kW

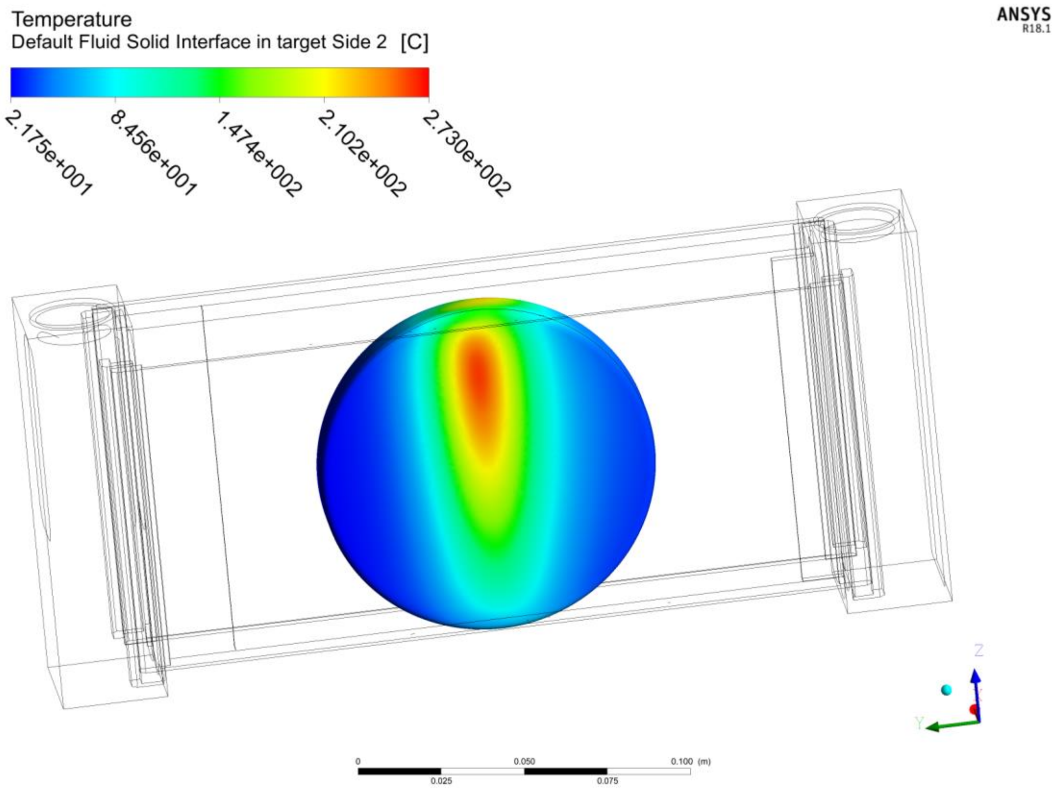


3.6 kW

Plan A focused beam: Above CHF

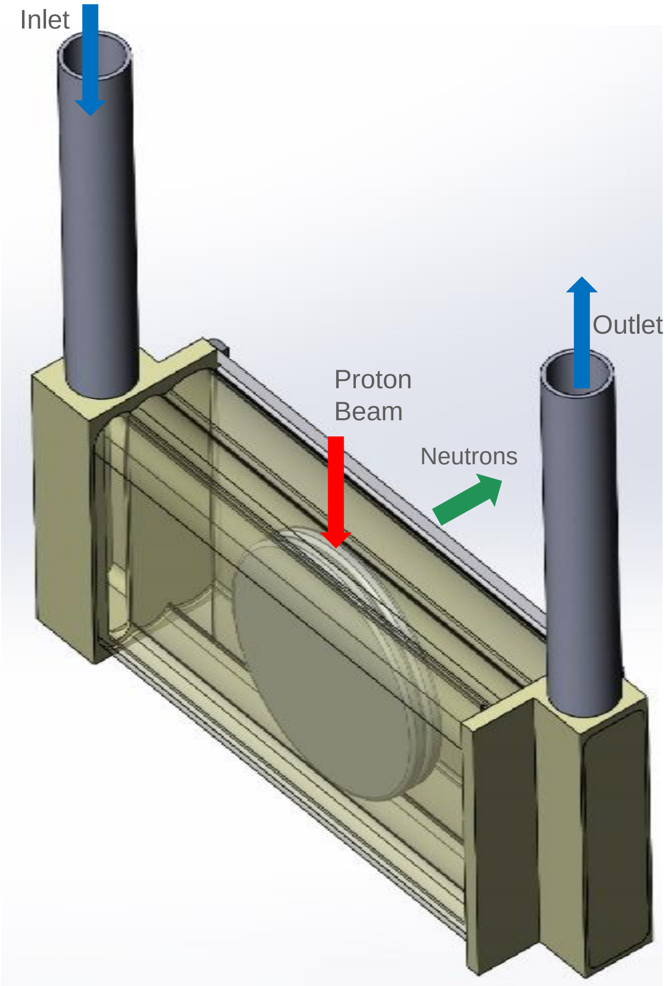
- Housing has small hot spot but target cannot be cooled.





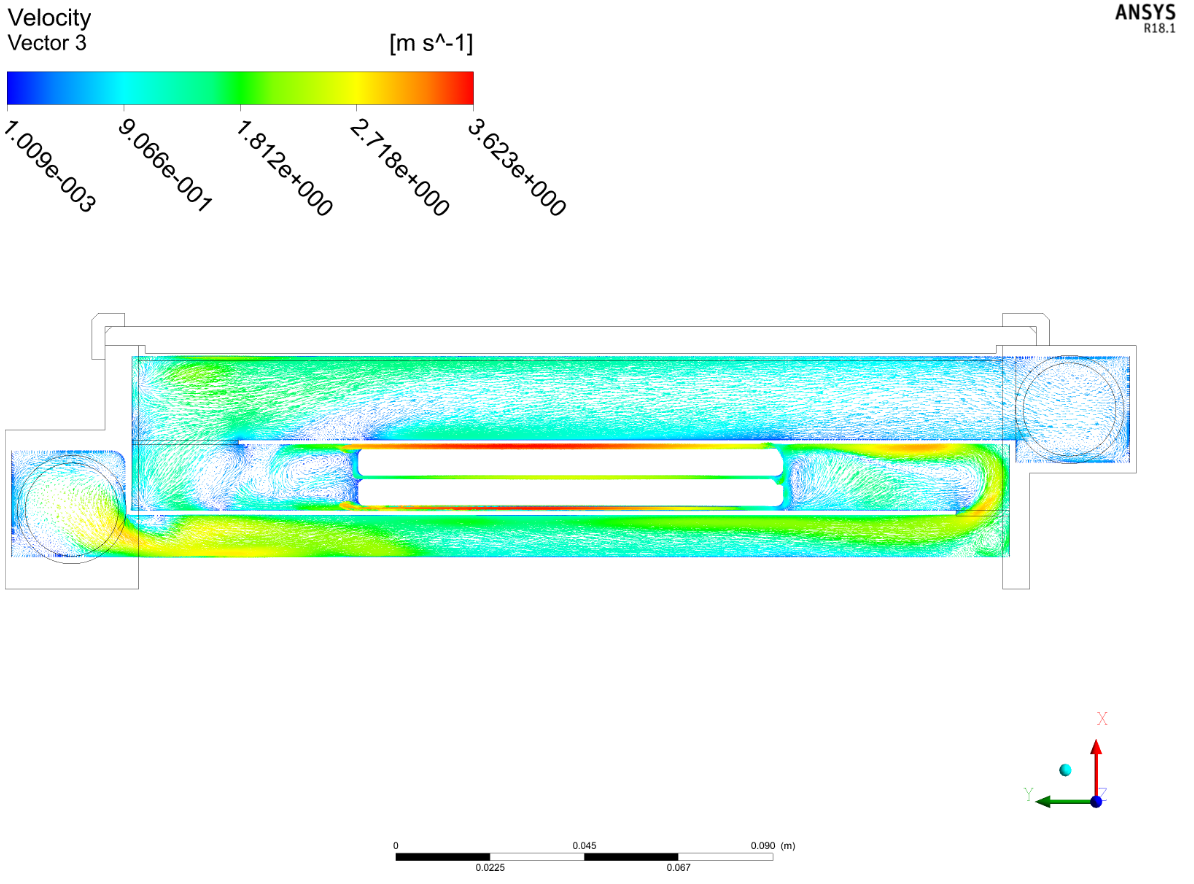
Plan B: Split the disk, double cooling surface

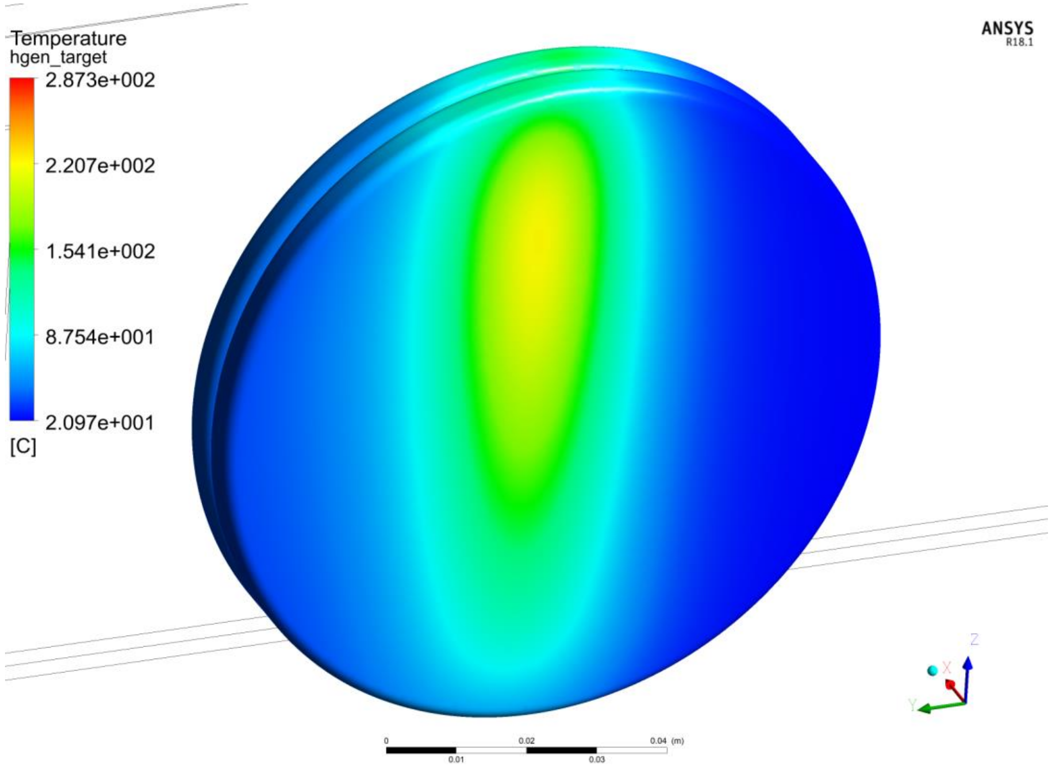
- Water moderator added to back side to move miss-steered beam away from vertical housing wall.
- Strongback on front side changed from Al to Be.



Plan B analysis, focused beam

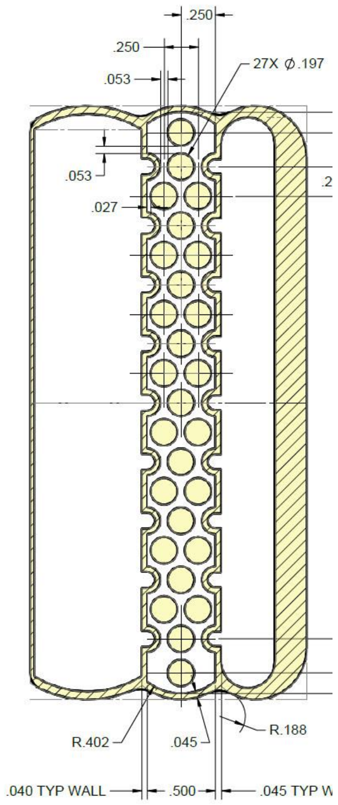
- Center cooling channel is too narrow, but clearly not acceptable, with surface temperature near 220 C.

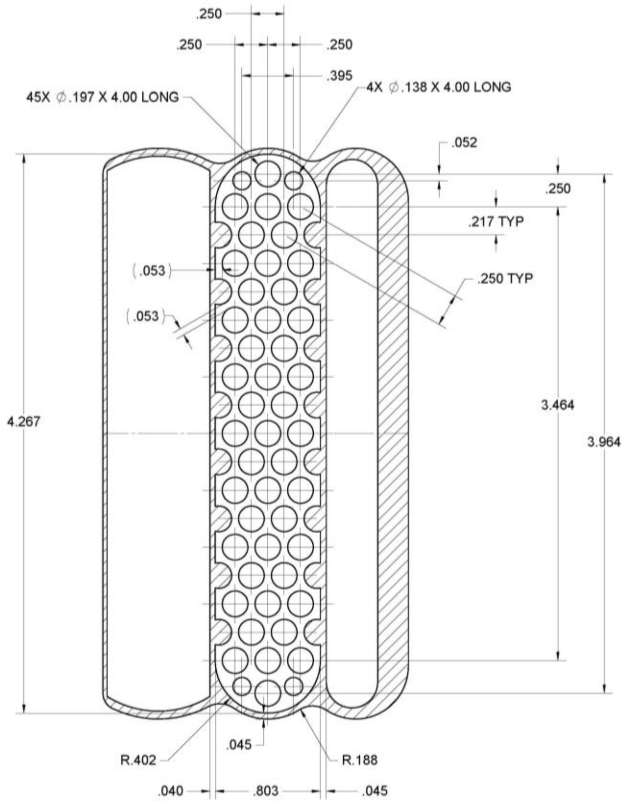


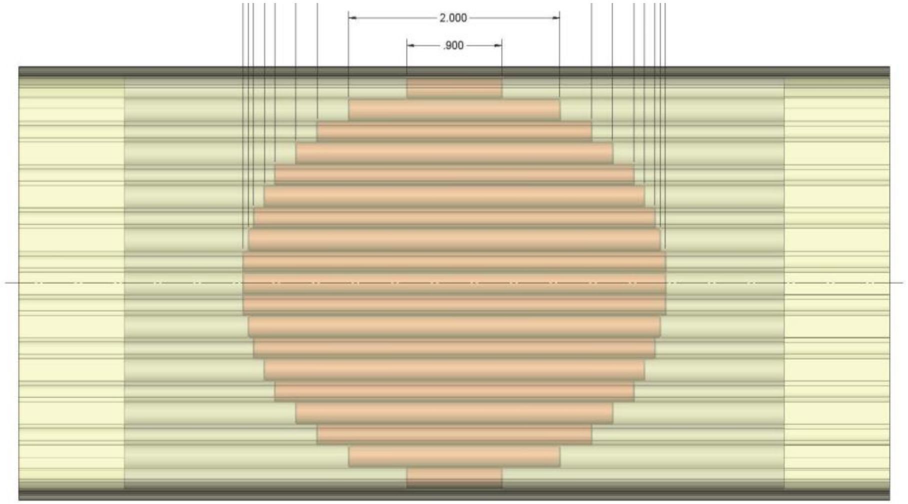


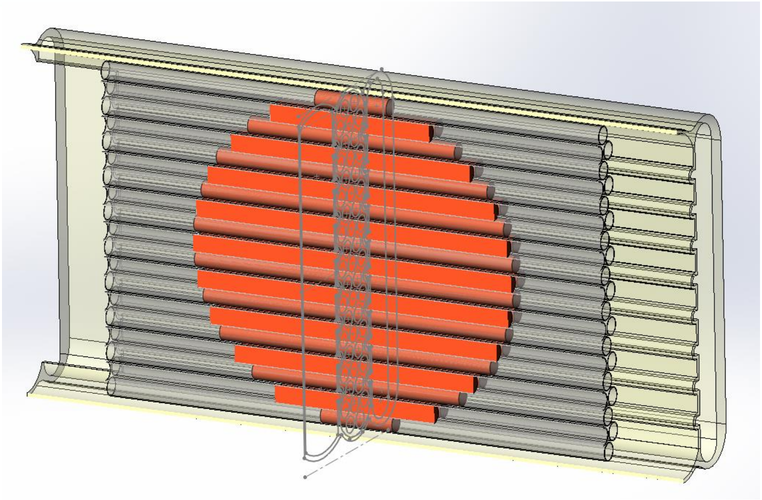
Plan C: Rod stack

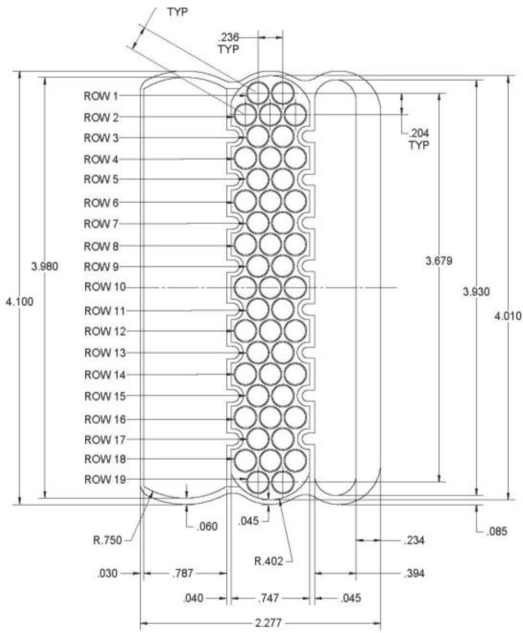
- **With rods, surface area to volume ratio can be set by rod diameter, so heat flux can be set as necessary**







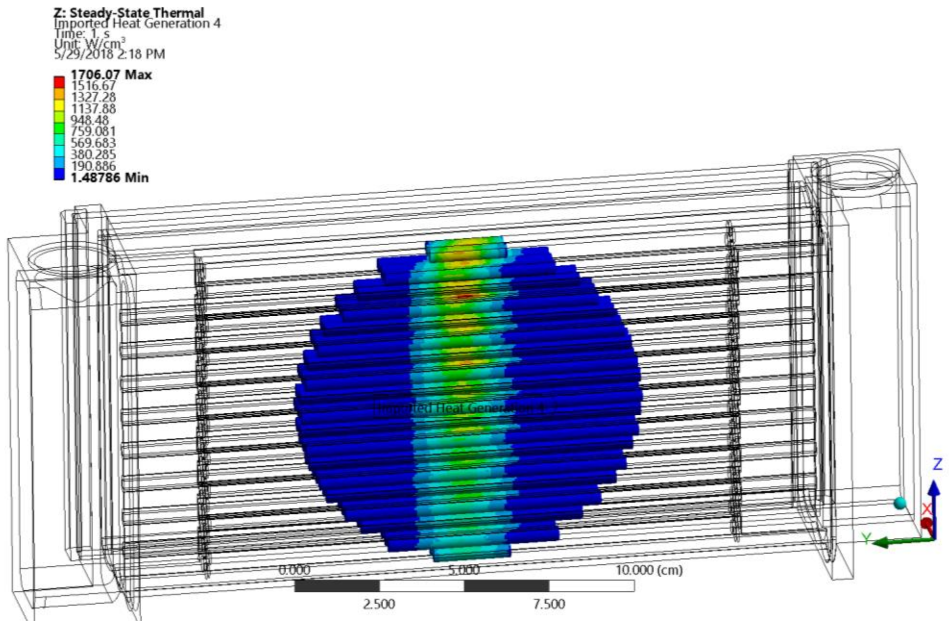




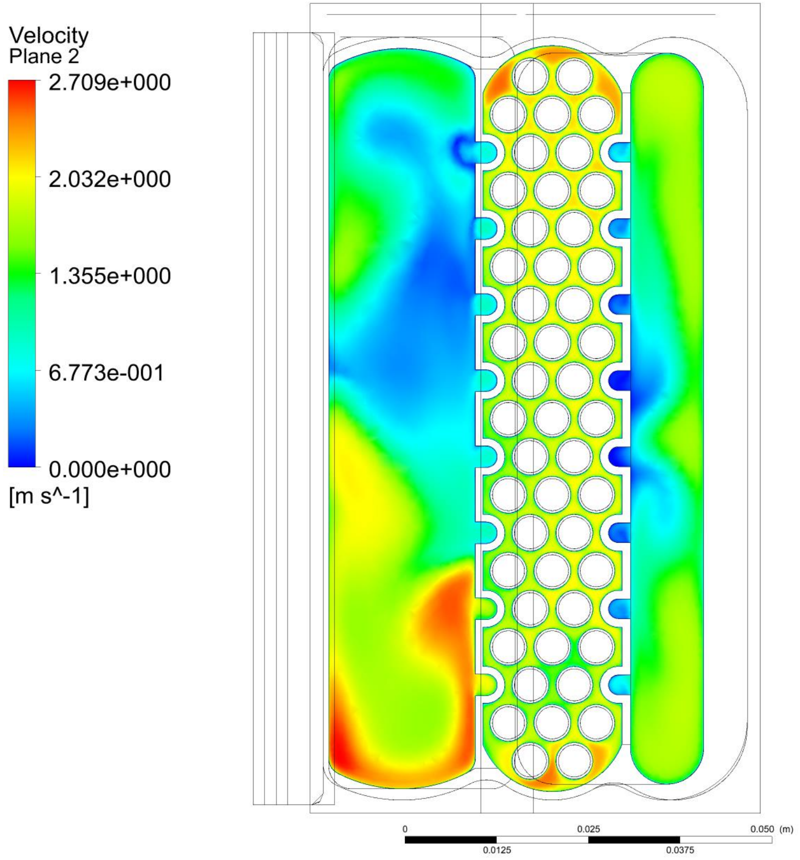
Plan C: Rod stack

- **Even with modest coolant velocity, peak temperature 151 C at solid-liquid interface.**

Volumetric heating: Peak is 1706 W/cm^3

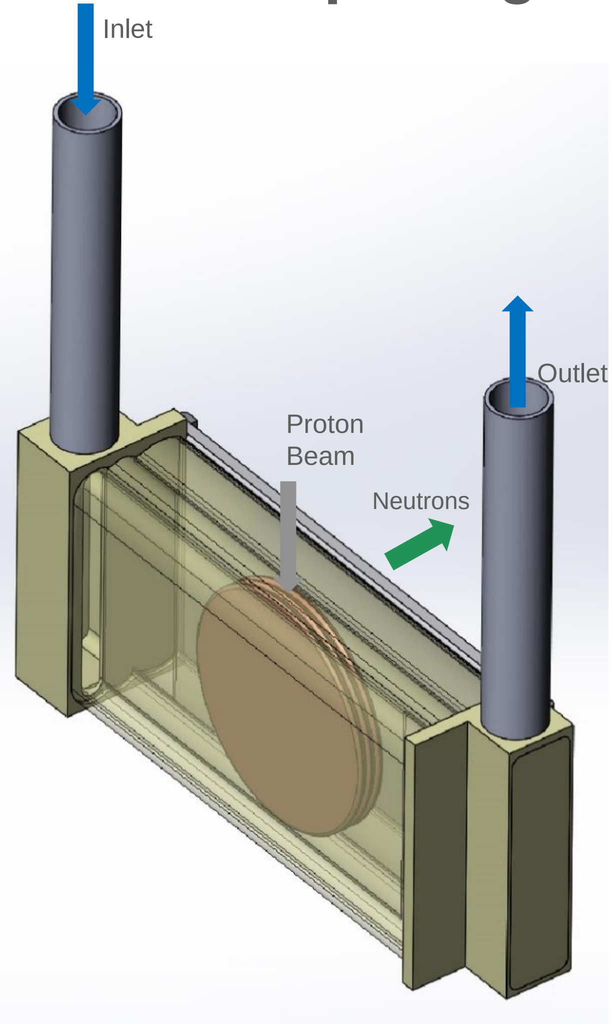


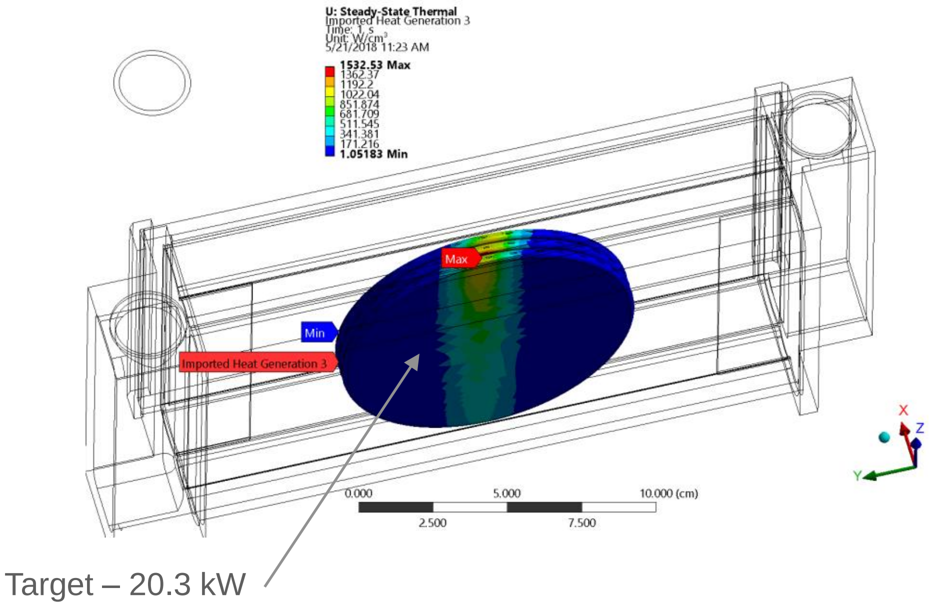
Rods: 16 kW
Ta tubes: 3 kW
Water: 10 kW

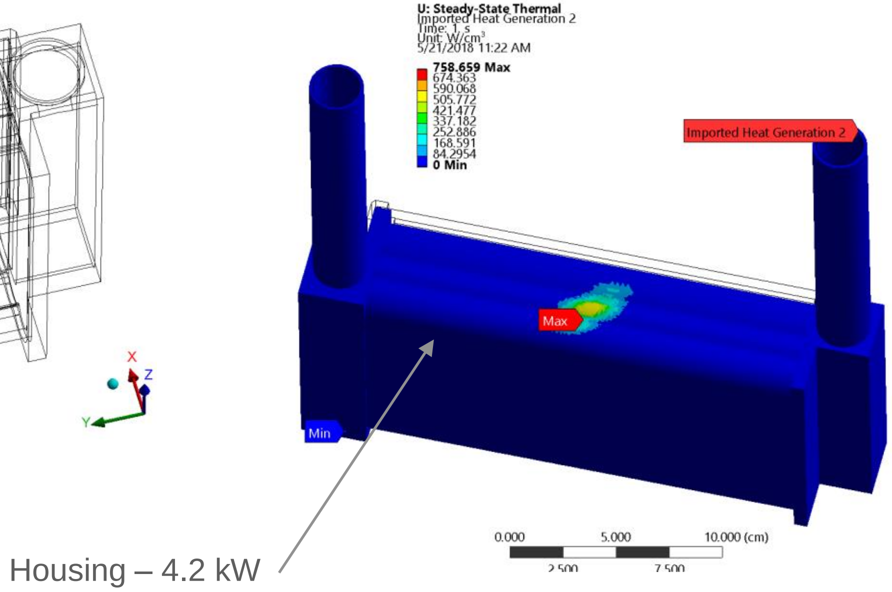


Plan D: 3 disk target

Splitting the disk yet again further reduces heat flux

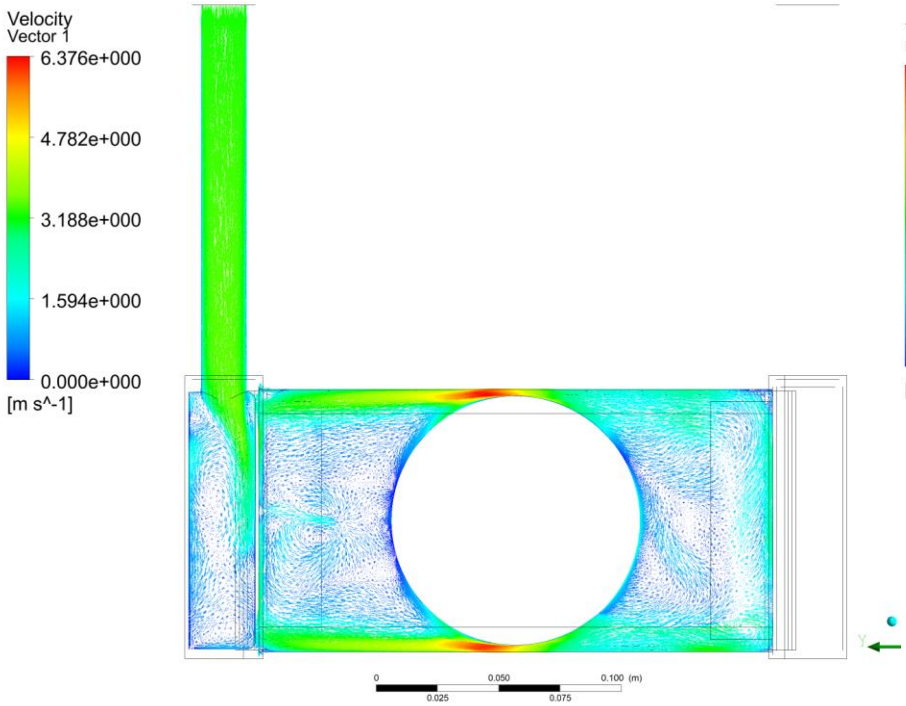


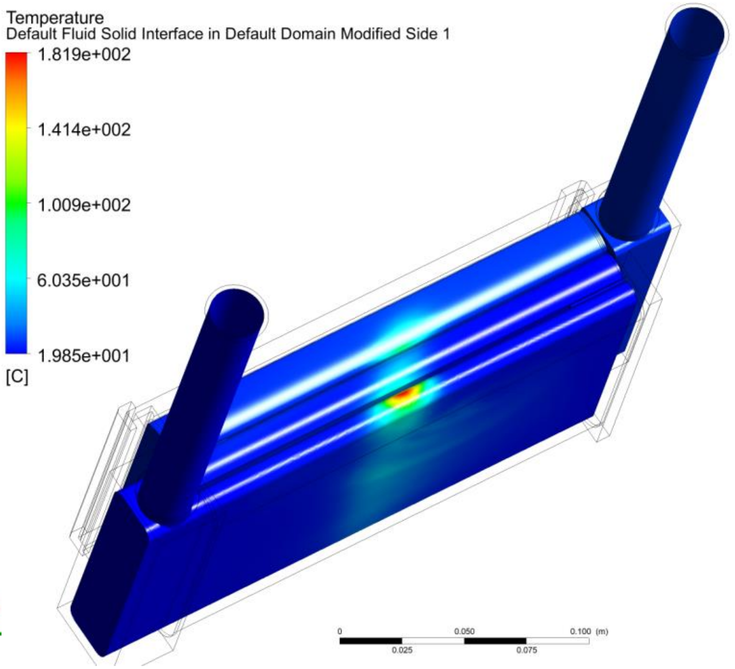


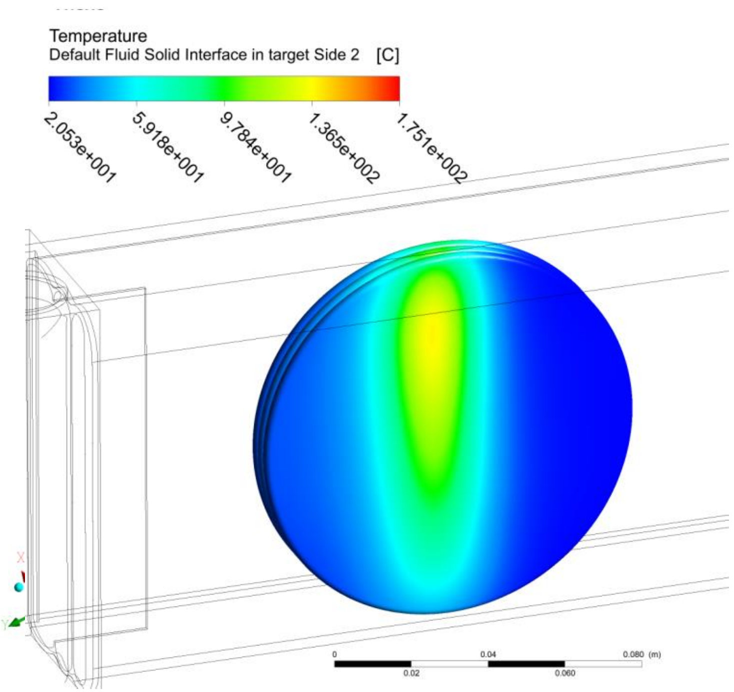


Plan D: 3 disk target

Some optimization needed, but we have a second target option







Concluding remarks

- High power targets often come down to increasing surface area to volume ratio without adverse performance effects.
- 3-disk design has benefit of proven fabrication and HIP process.
- Rod design needs development of details but potentially very robust. Variations on number of rods and pitch/diameter ratio ongoing.