Design and Computational Fluid Dynamic analysis of the T2K Target

Neutrino Beams and Instrumentation
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Aims of Design

- Graphite target to be completely encased in titanium to prevent oxidation
- Helium should cool both upstream and downstream titanium window before target due to material limits
- Pressure drop in the system should be kept to a minimum due to high flow rate required (less than 0.7bar)
- Target to be uniformly cooled (but kept above 400°C to reduce radiation damage)
- It should be possible to remotely change the target in the first horn

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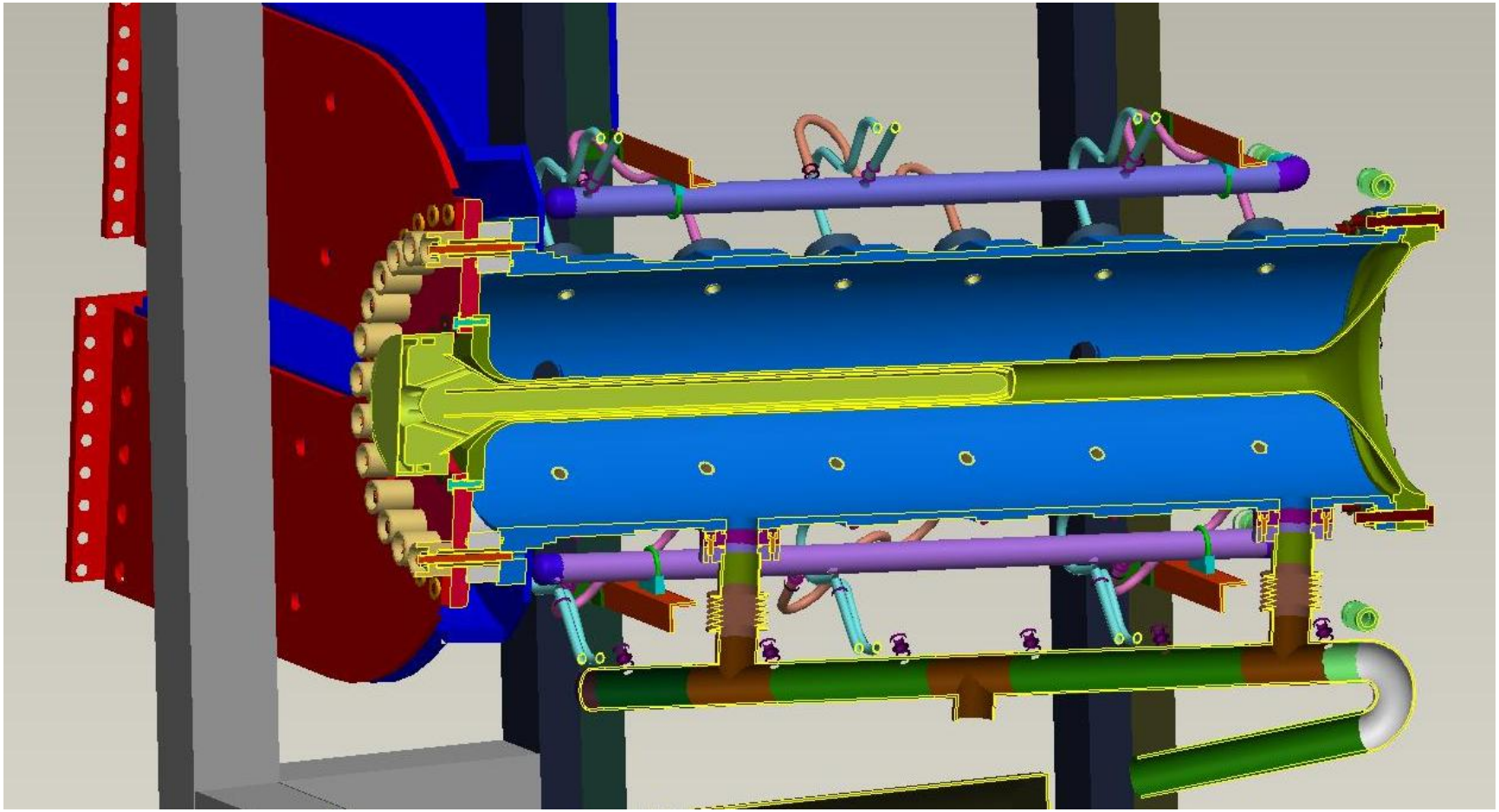
Target in the 1st Horn



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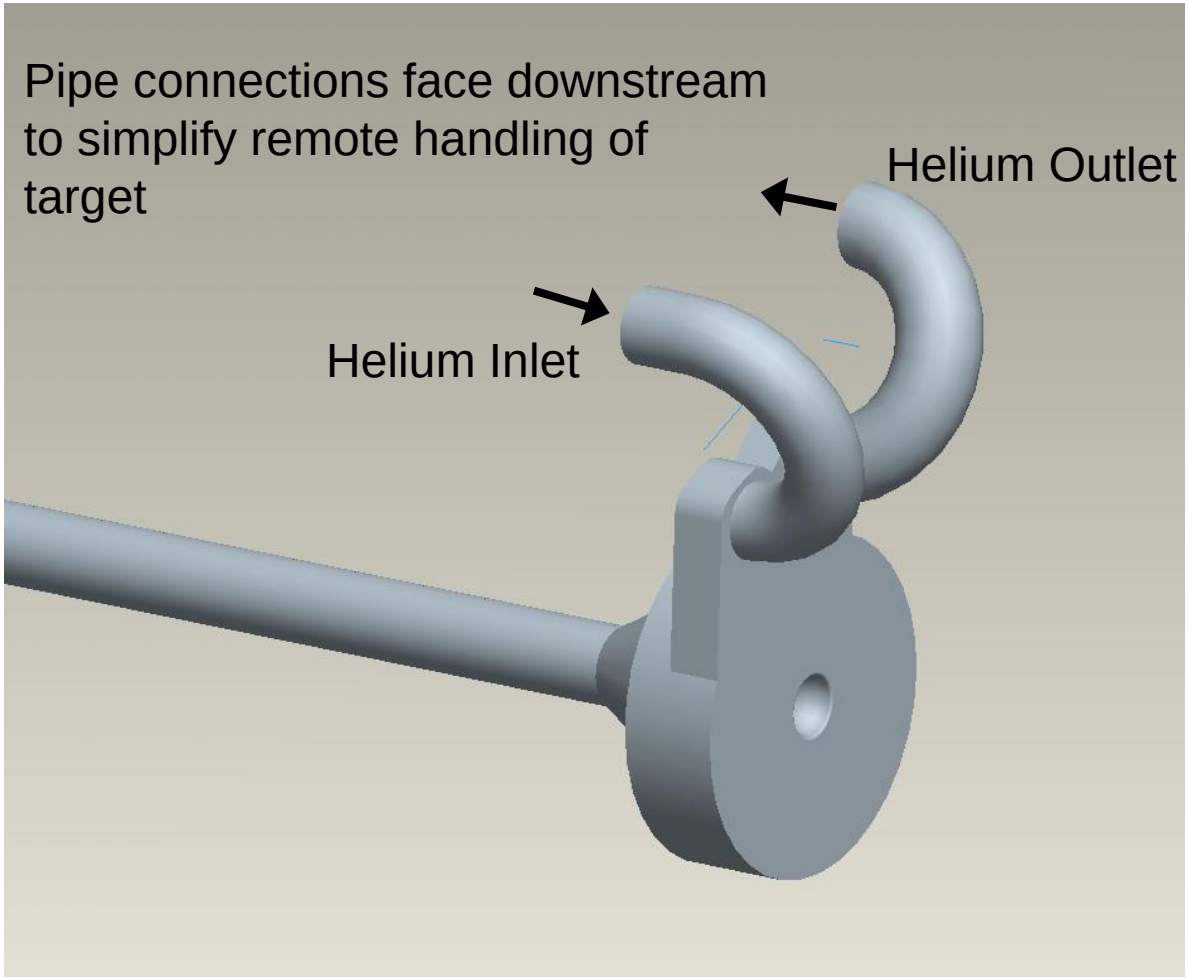
Current geometry



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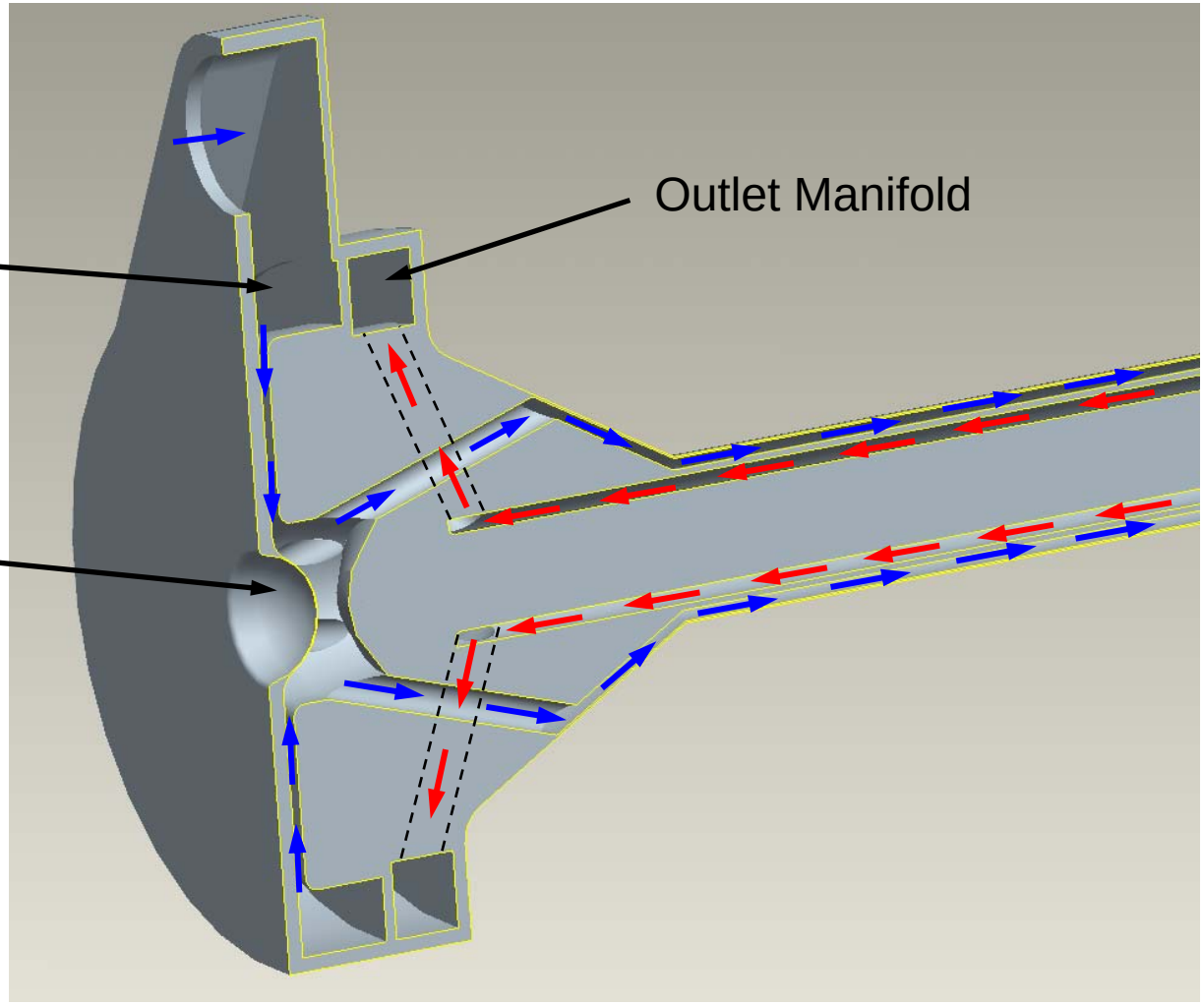
Section of target



Matt Rooney's initial calculations suggest this window is ok for pressure and shock.

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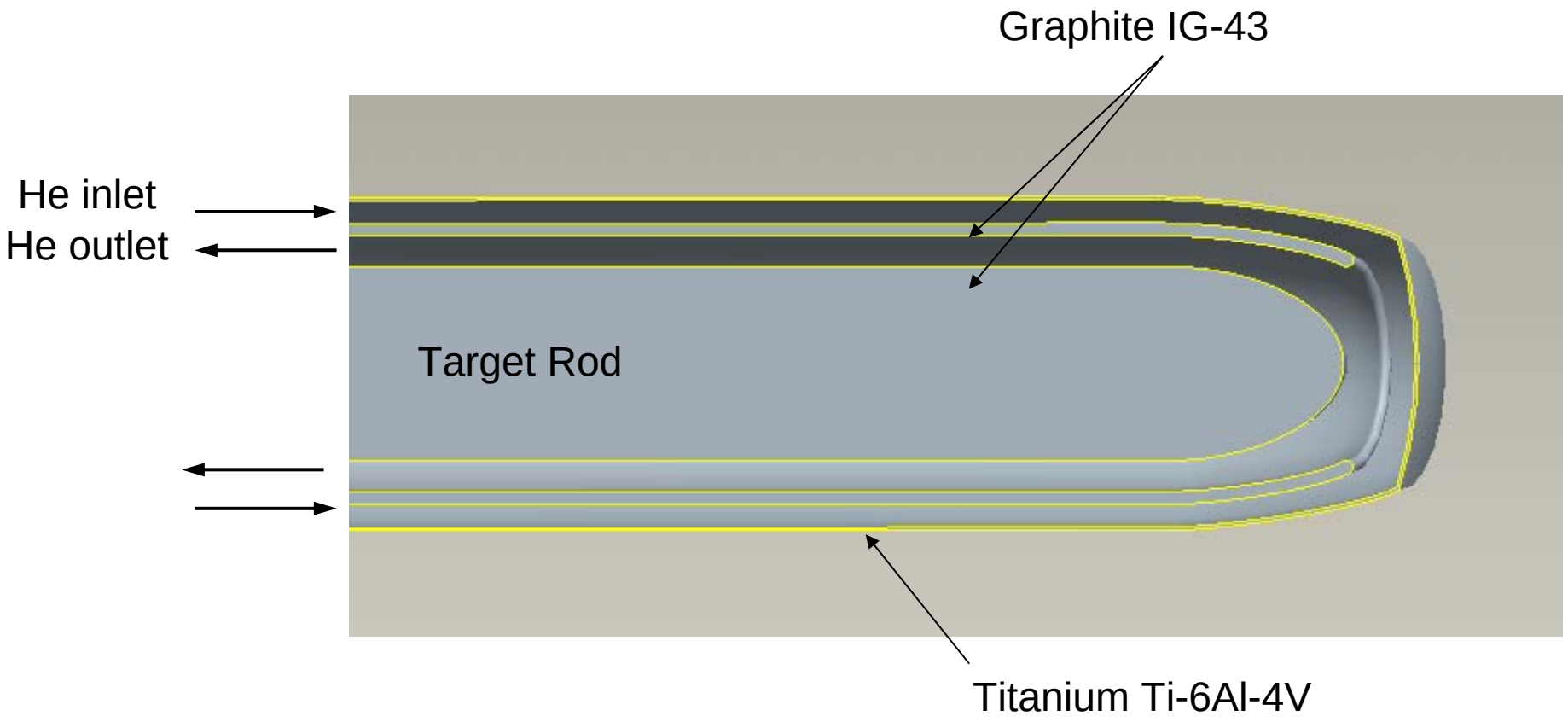
Cross Section of Downstream end



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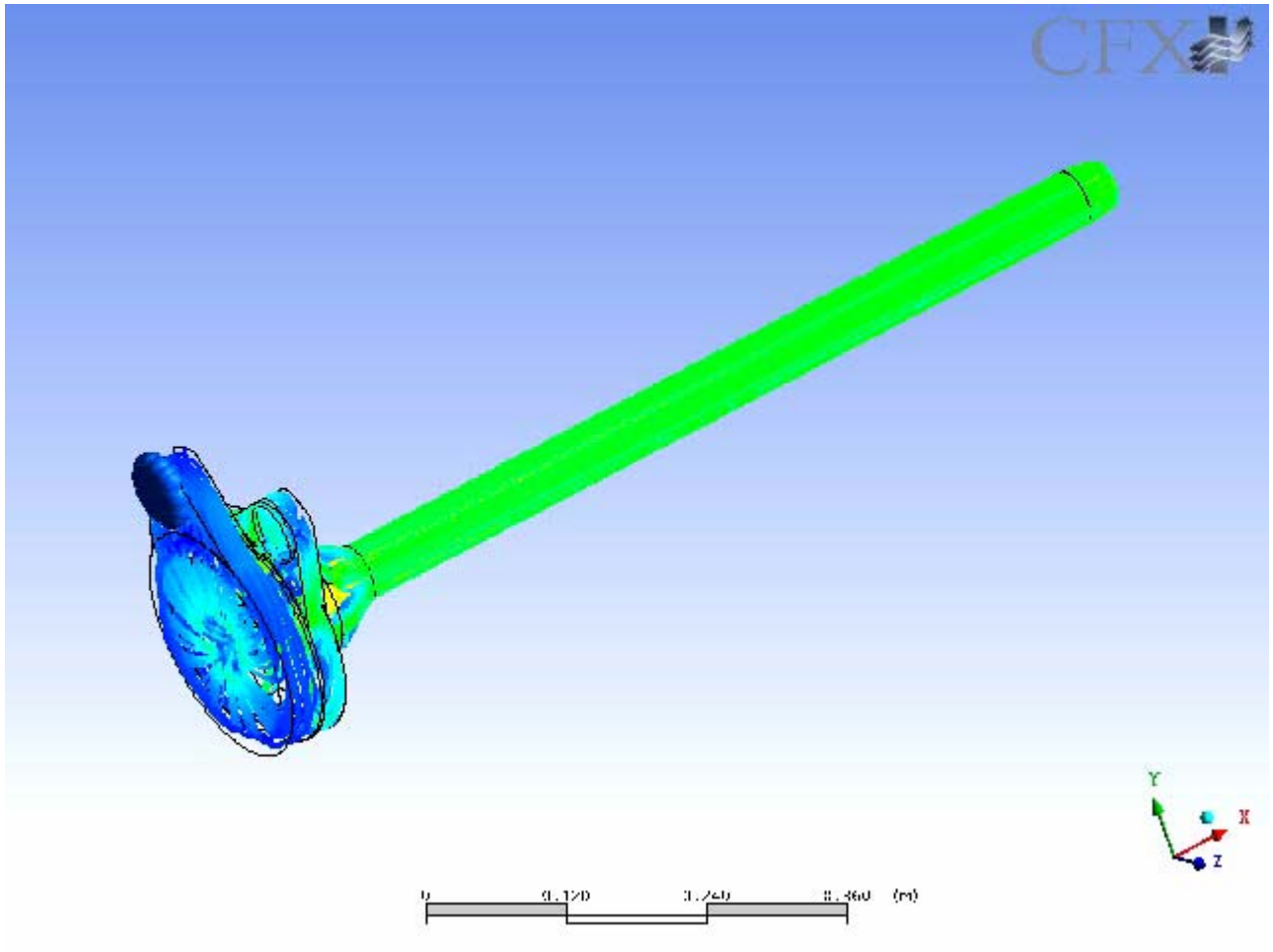
Animation of flow



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Target Analysis Outline

Boundary conditions
(Helium – Ideal gas model)
Inlet Mass flow rate = 0.032kg/s (Max compressor flow rate)
Inlet helium temperature = 300K
Outlet Pressure = 0.9 bar (gauge)

Heat deposited

- On target as cloud of point (x,y,z,heat)
- On Graphite upstream structure as total source
- On upstream and downstream window as radial function
  (NOTE - Downstream heat scaled from 50GeV and needs verifying)

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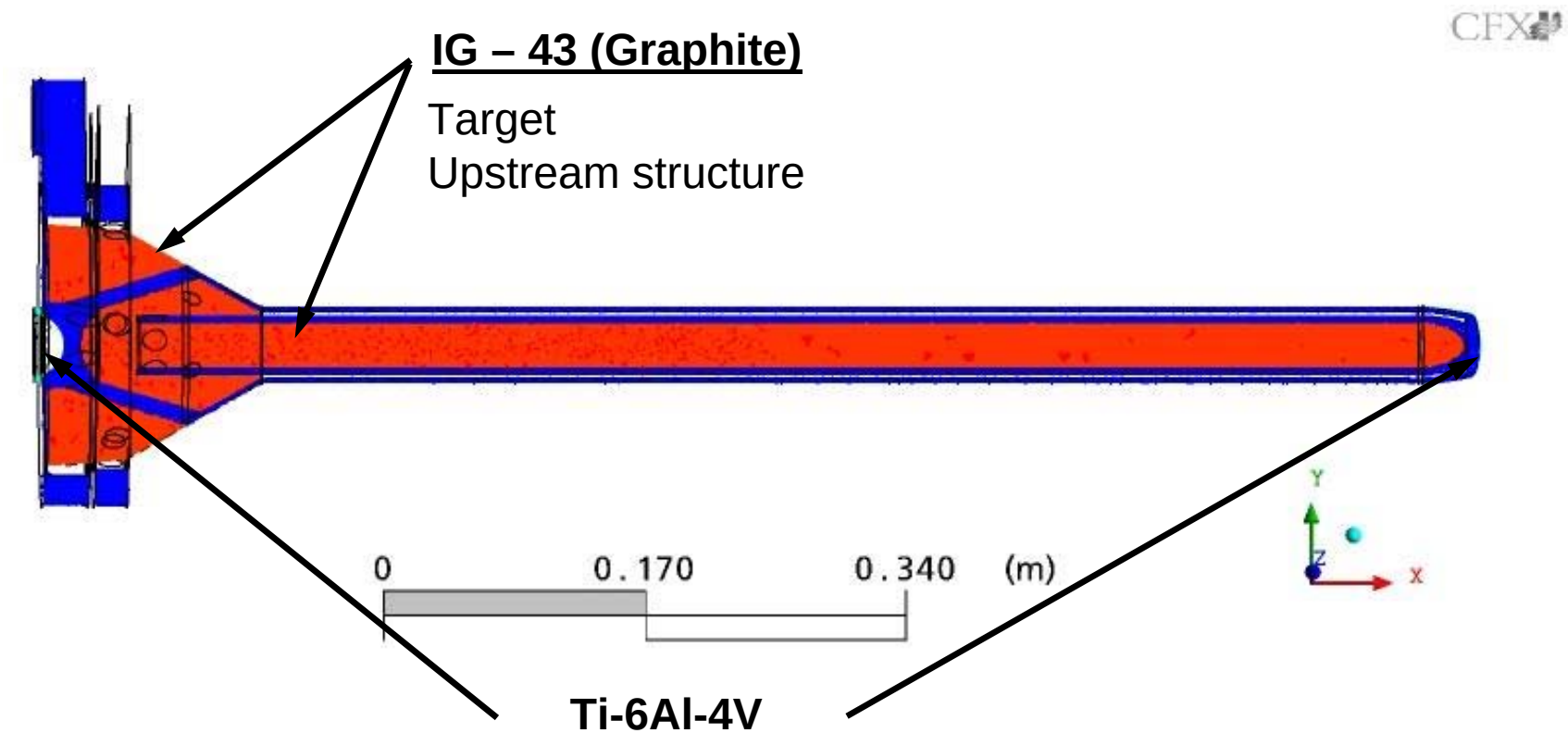
Materials



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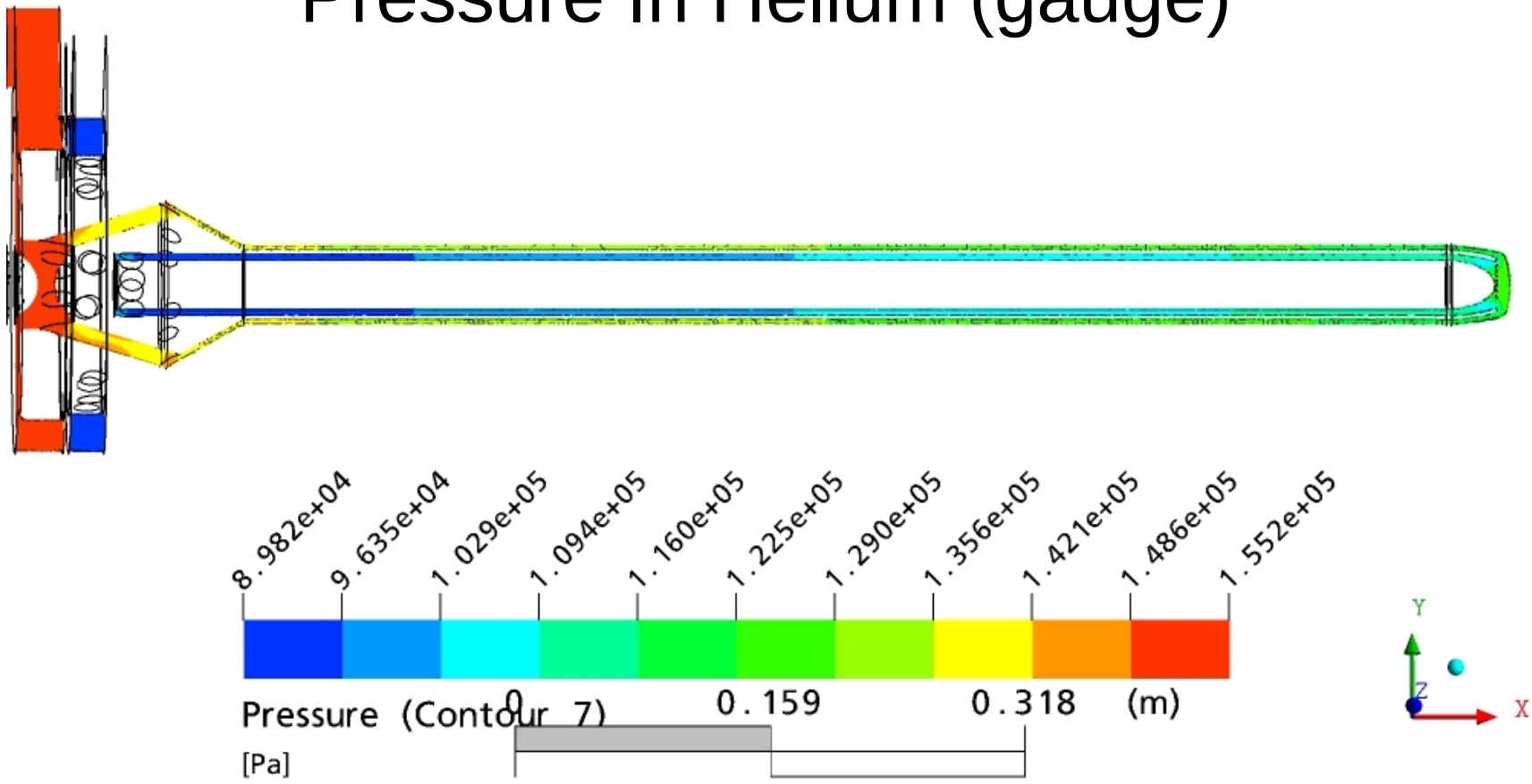
Pressure In Helium (gauge)



Area average pressure drop (inlet to outlet) = 0.65 bar

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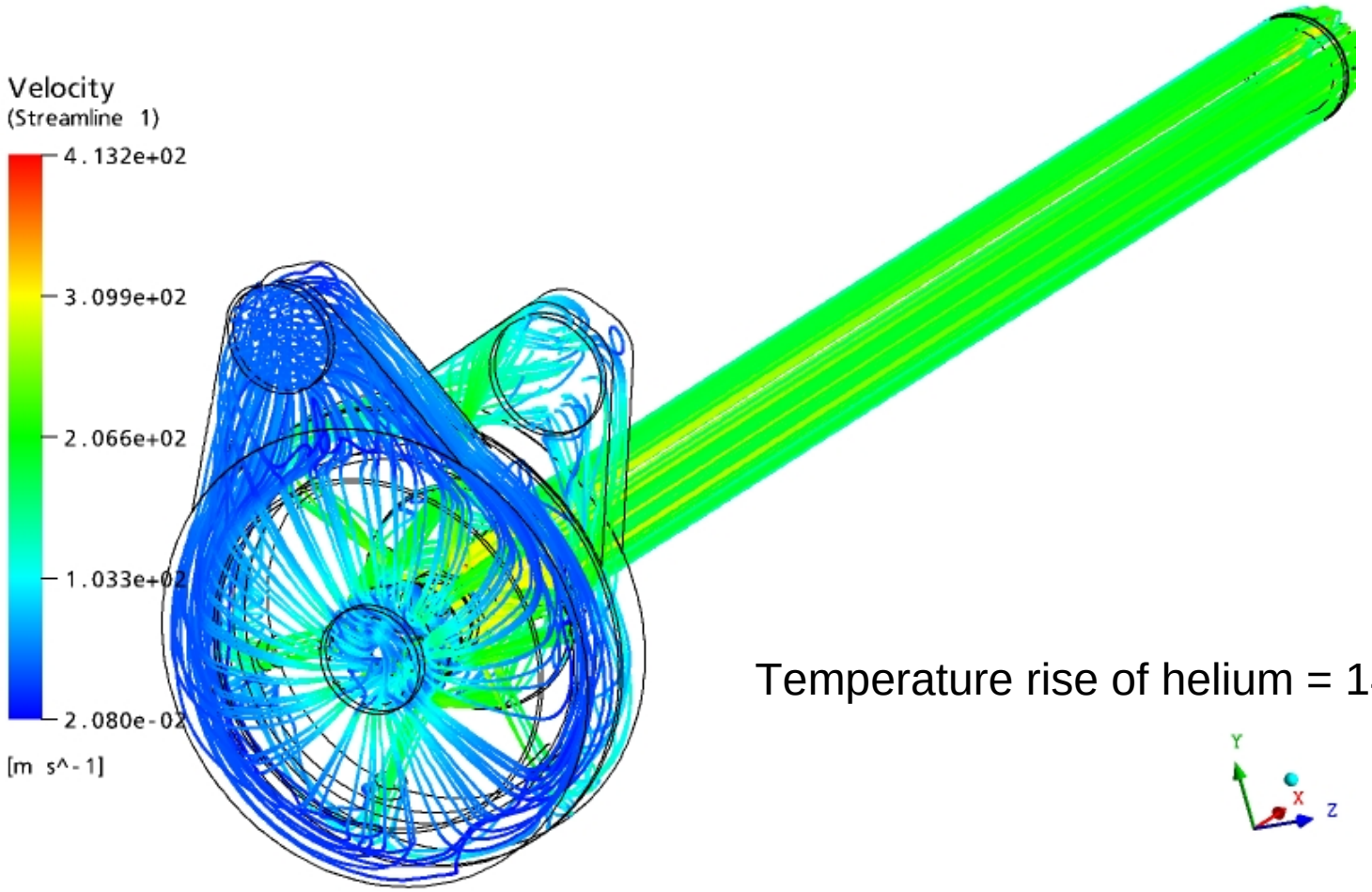
Velocity Streamlines

CFX



Temperature rise of helium = 141˚C

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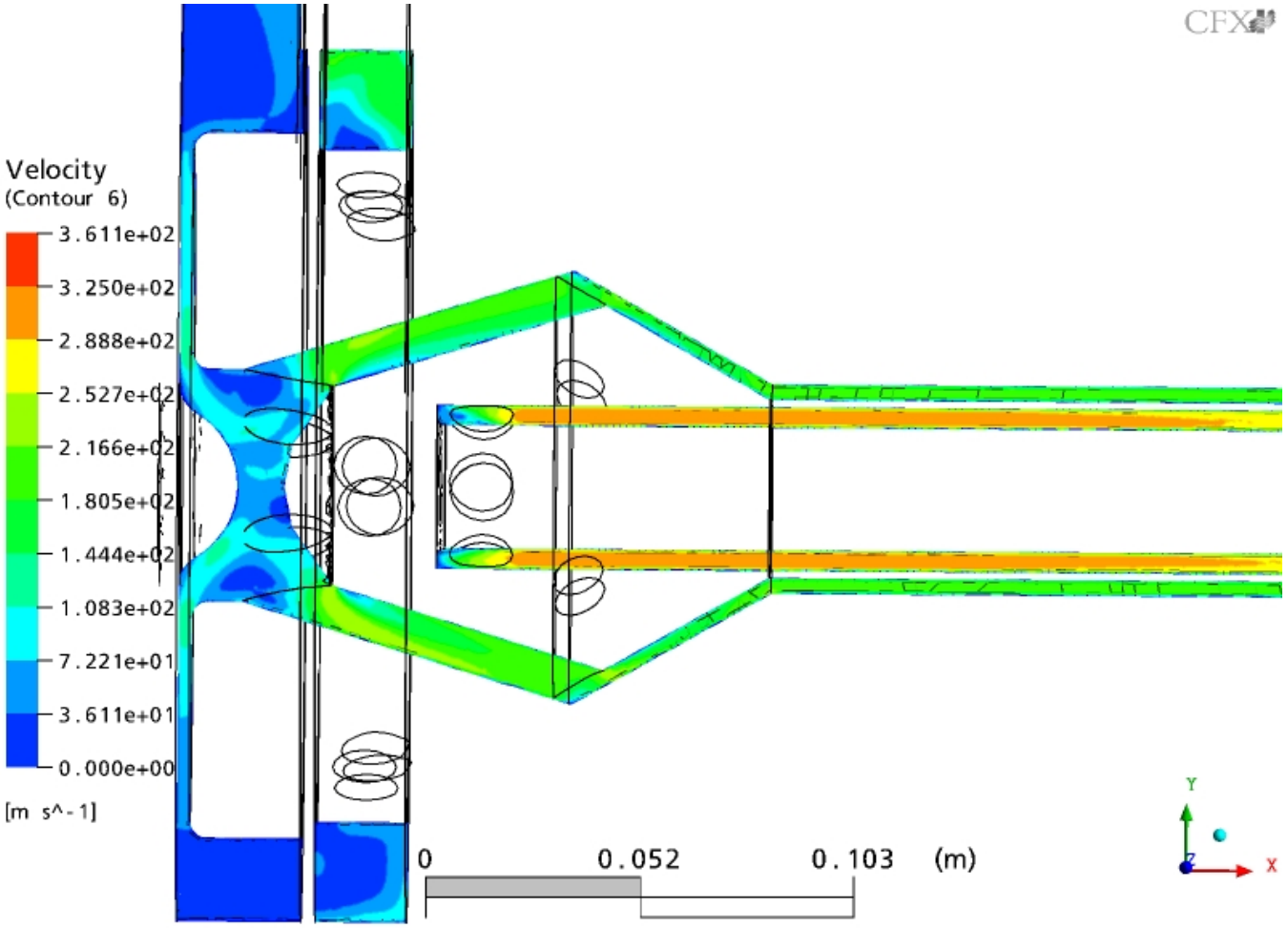
Velocity profile at upstream window



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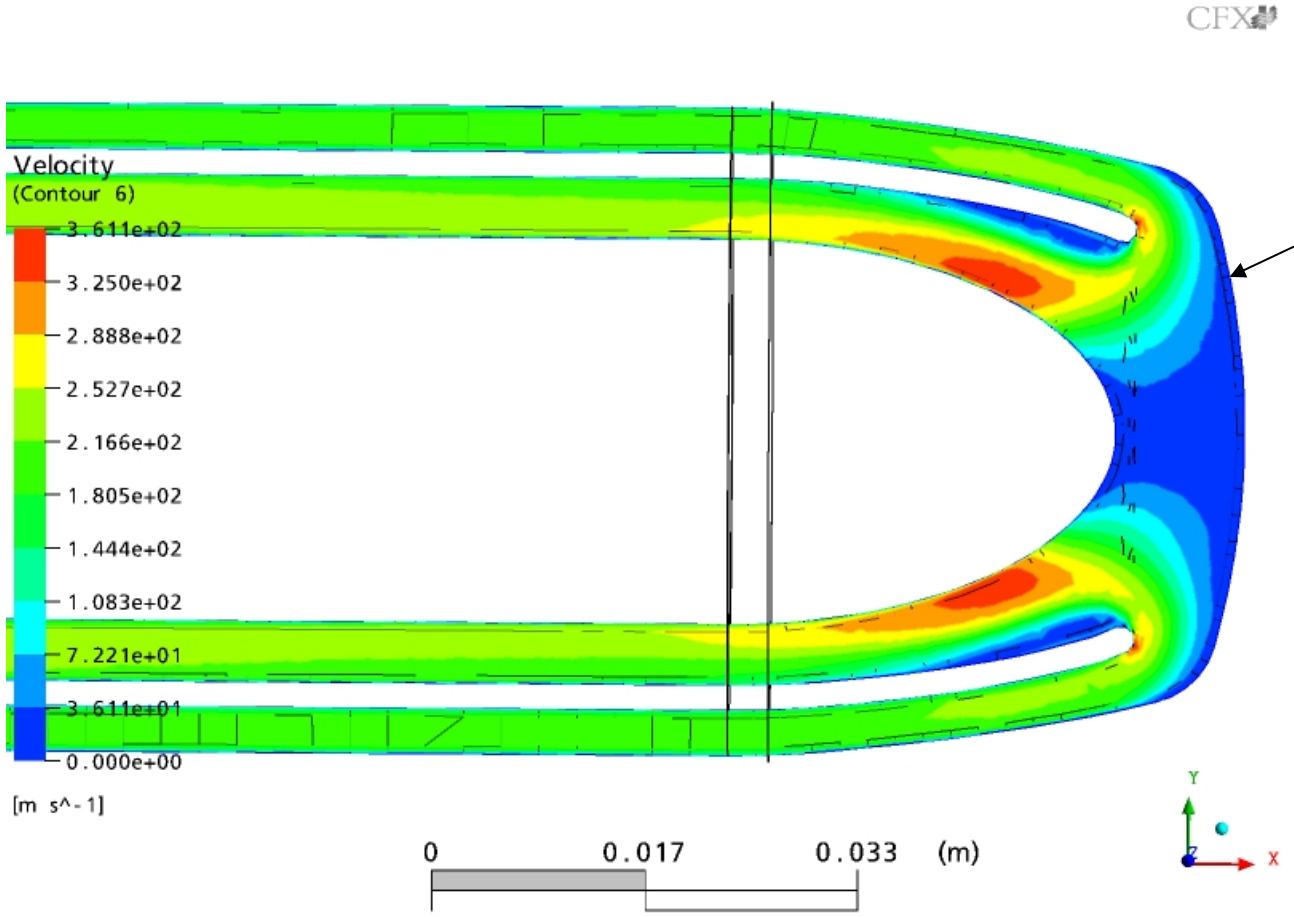
Velocity profile at downstream window



Downstream window needs final optimisation at operating pressure

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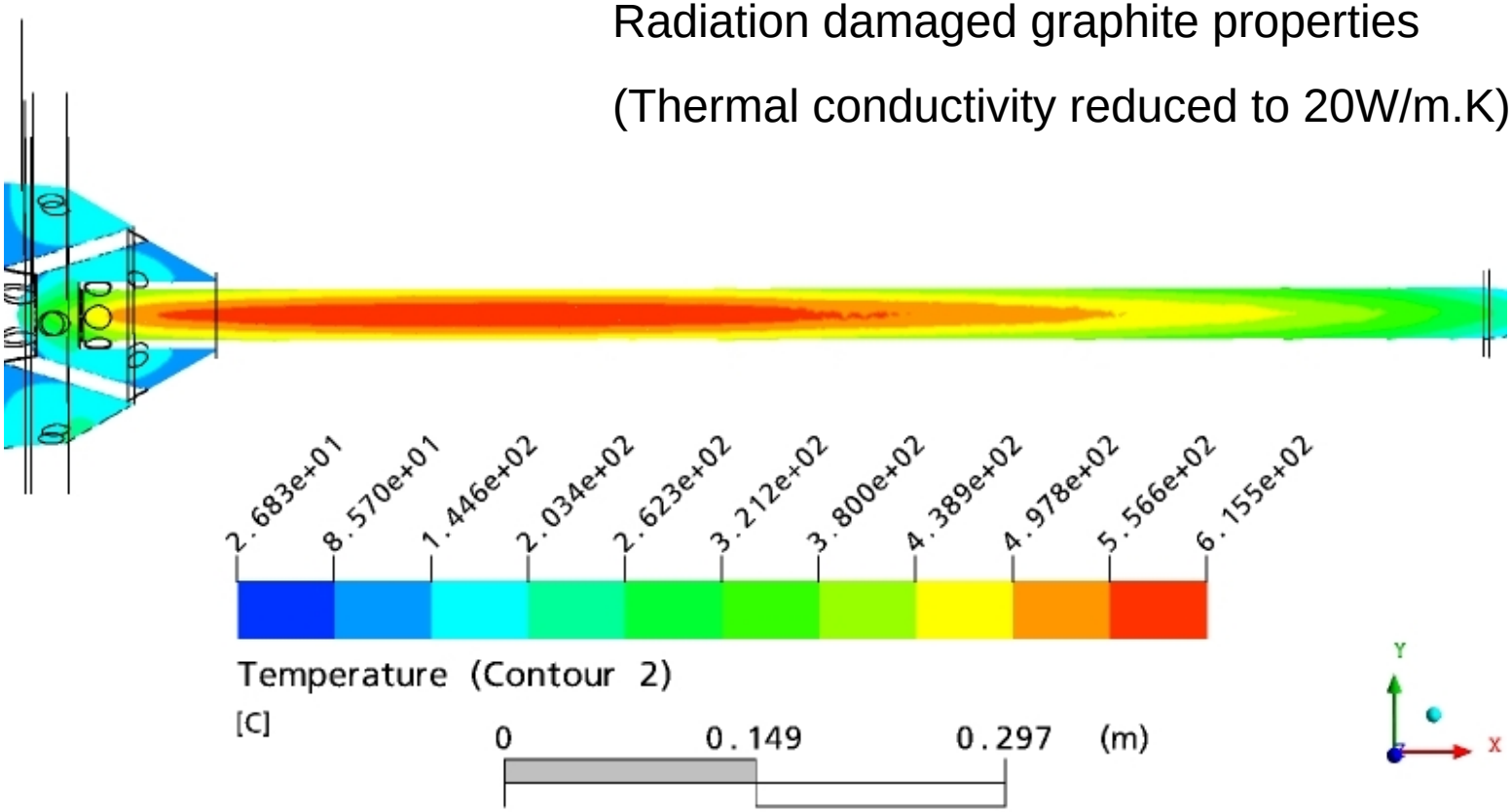
Steady state temperature through centre of target

30 GeV, 0.4735Hz, 750 kW

Radiation damaged graphite properties

(Thermal conductivity reduced to 20W/m.K)



Maximum temperature = 615˚C

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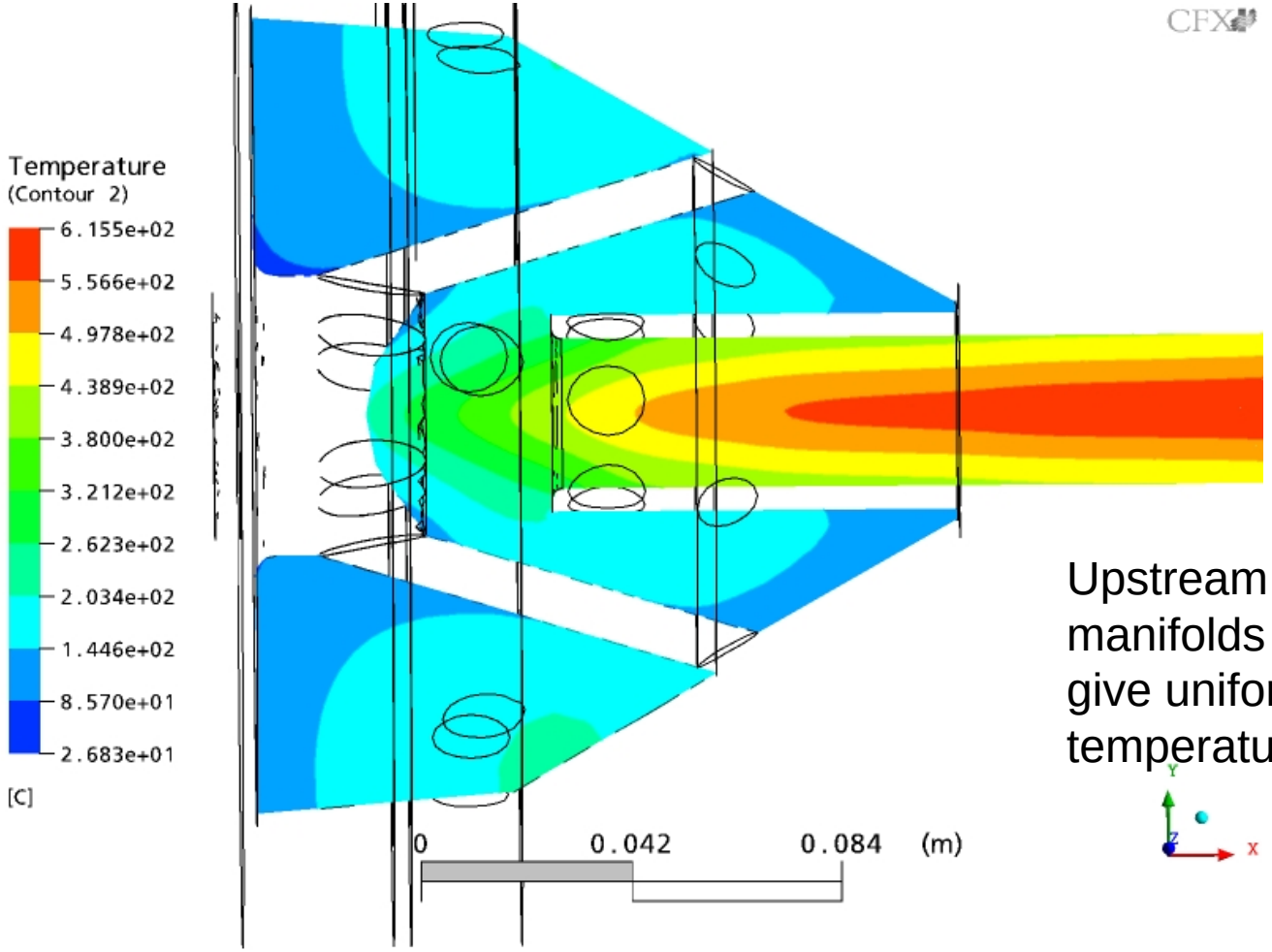
Upstream Temperature distribution (steady state)



Upstream structure and manifolds designed to give uniform temperature distribution

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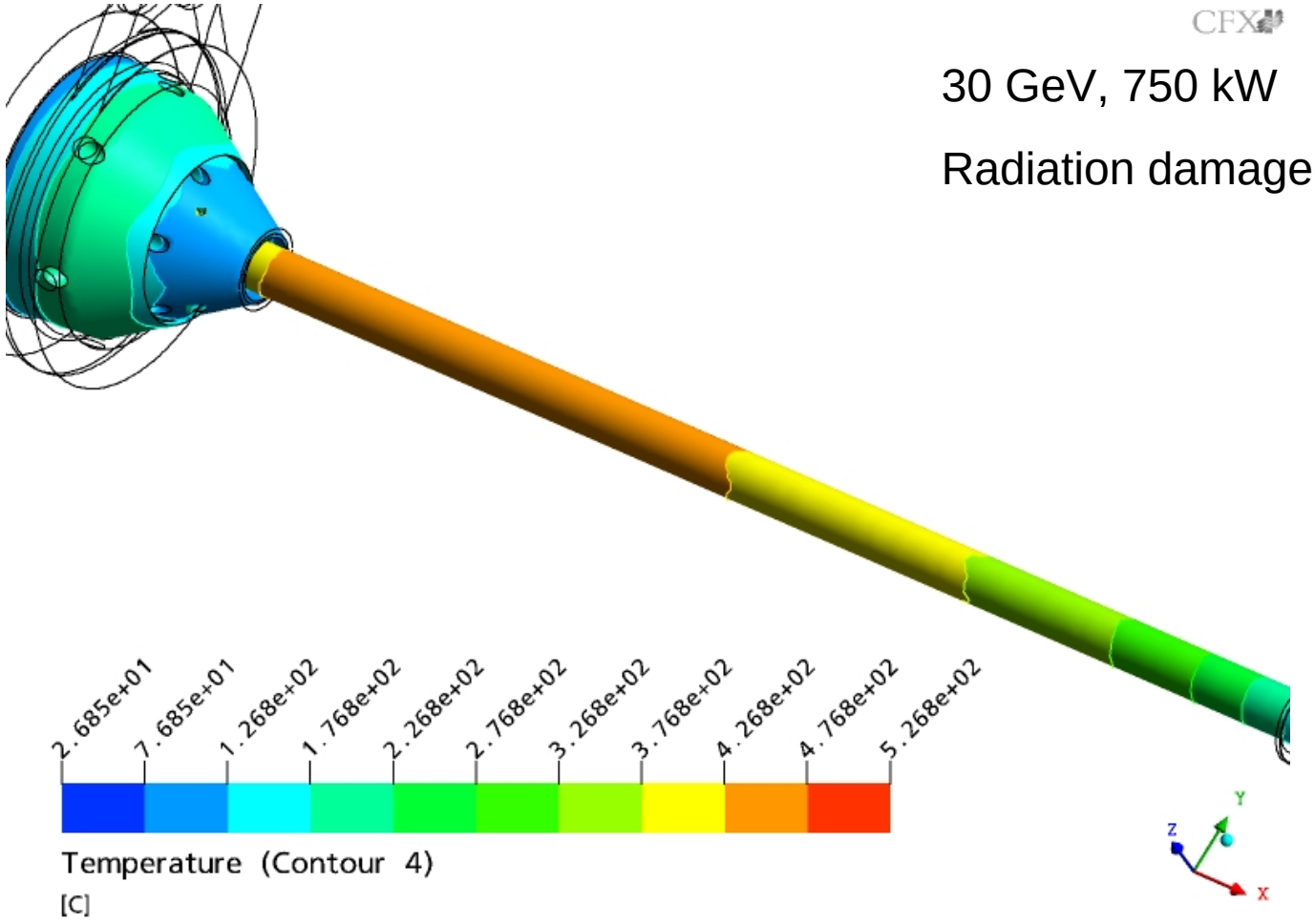
Overall Temperature distribution (steady state)



30 GeV, 750 kW

Radiation damaged graphite

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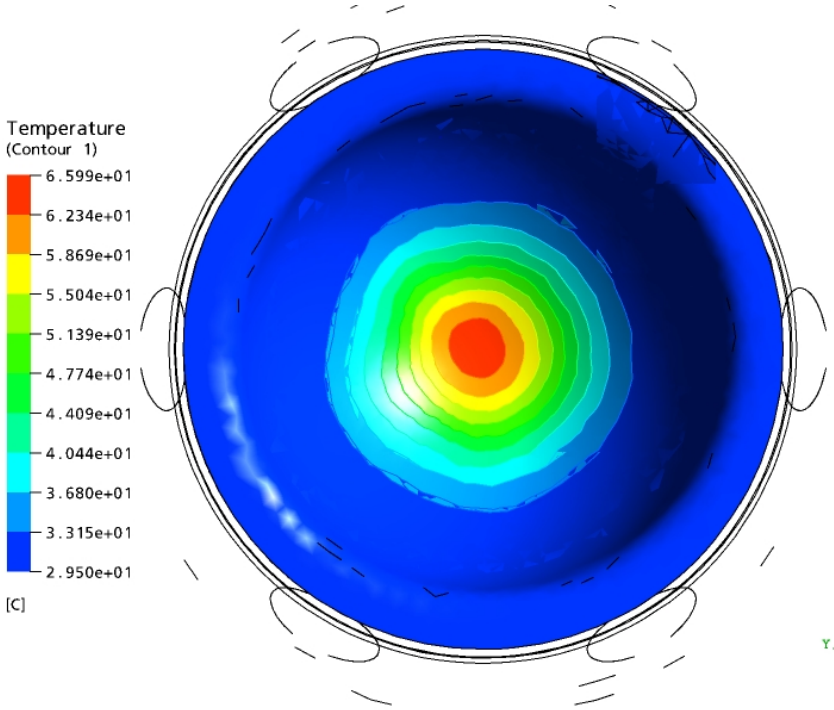
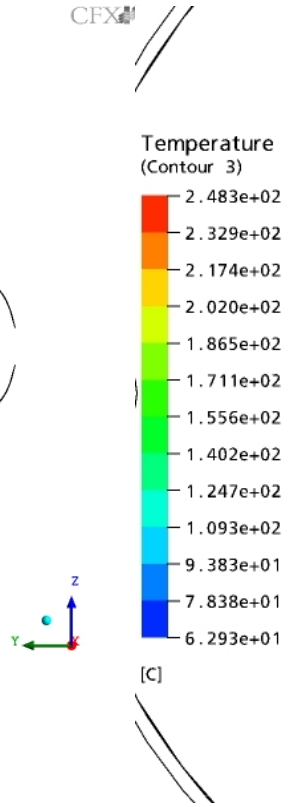
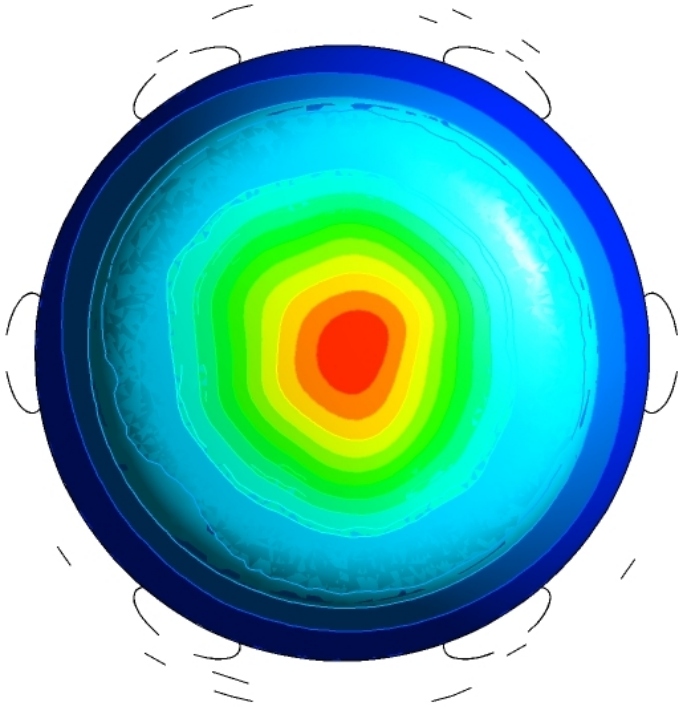
Window temperatures (steady state)



Upstream window

T_{MAX}= 66°C





Downstream window

T_{MAX}= 248°C

(Heat load scaled from 50GeV)

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Summary

- Temperature rise of helium at 0.032kg/s = 141° (23.4kW heat load)
- Pressure drop from inlet to outlet = 0.65 bar (specification was 0.7 bar)
- Analysis shows the upstream window is sufficiently cooled
- Downstream window needs fine tuning to reduce temperature
- Temperature distribution is reasonably symmetric
- Single forward facing inlet and outlet pipes will simplify remote handling

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Future work

- Model to be repeated for 13mm radius target
- Next design needs to focus on ease of manufacture
- Heat load on target and tubes needs more work (e.g. apply heat as a function of radius and z

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