ISIS Second Target Station

Project Summary

Target design, analysis and optimisation

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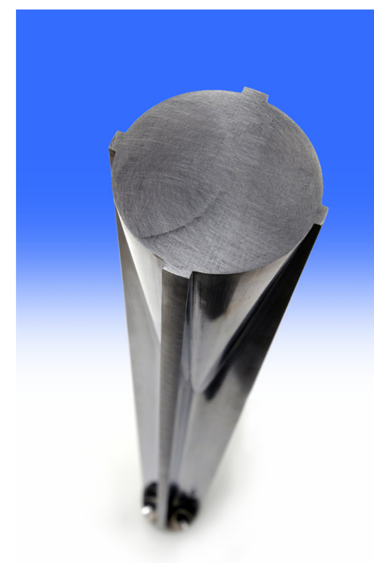
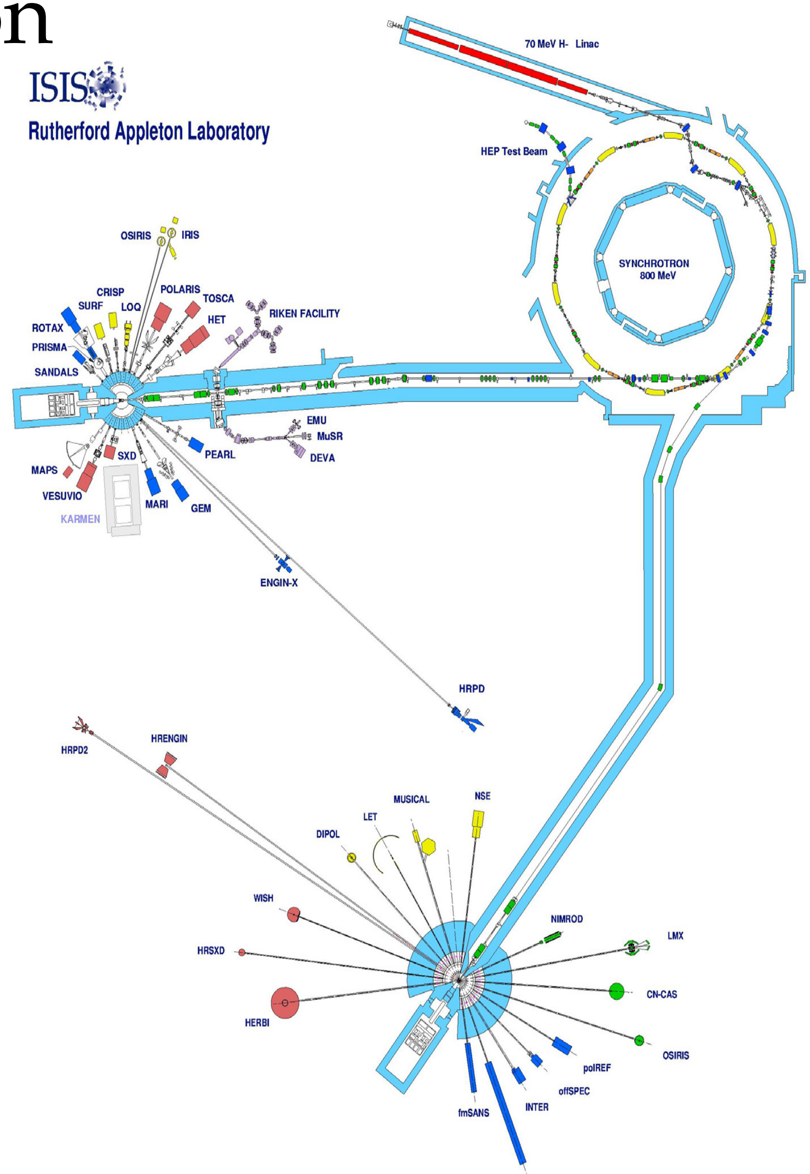


ISIS Second Target Station

- Upgrade of ISIS – accelerator based, pulsed neutron source
- Synchrotron accelerator shared between both target stations
- Double the number of instruments



ISIS Second Target Station

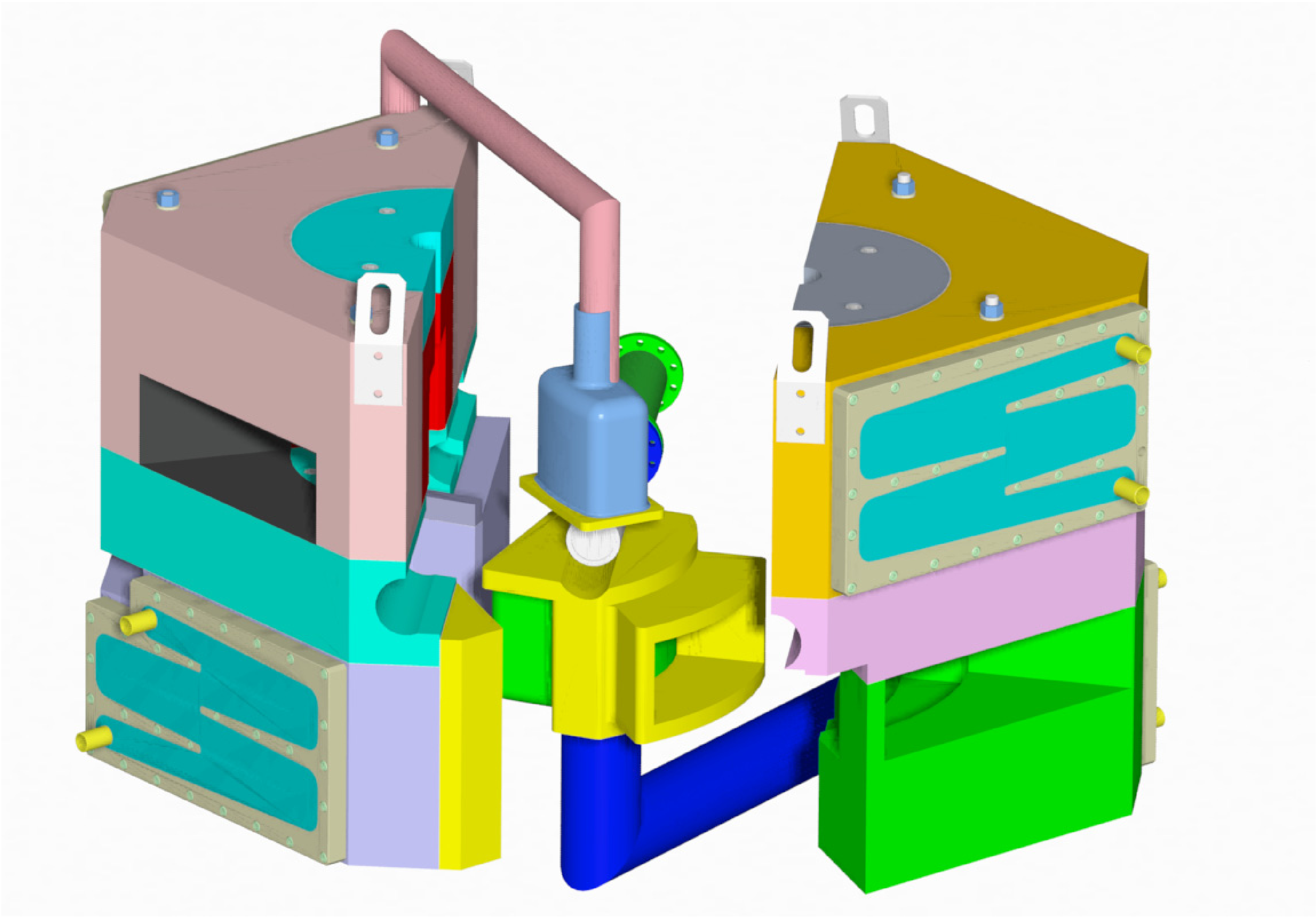
- **Designed for key future scientific needs:**
  - Soft matter
  - Advanced materials
  - Bio-molecular science
  - Nano-technology

- **Scientific requirements imply need for specific flux characteristics:**
  - Significantly enhanced cold neutron flux
  - Broad spectral range
  - High resolution

- **Moderators designed to provide excellent conditions for required flux characteristics:**
  - Low frequency :
    - 10Hz
    - 100ms frame

    } Wide dynamic range
  - Low power:
    - 48kW
    - 60μA

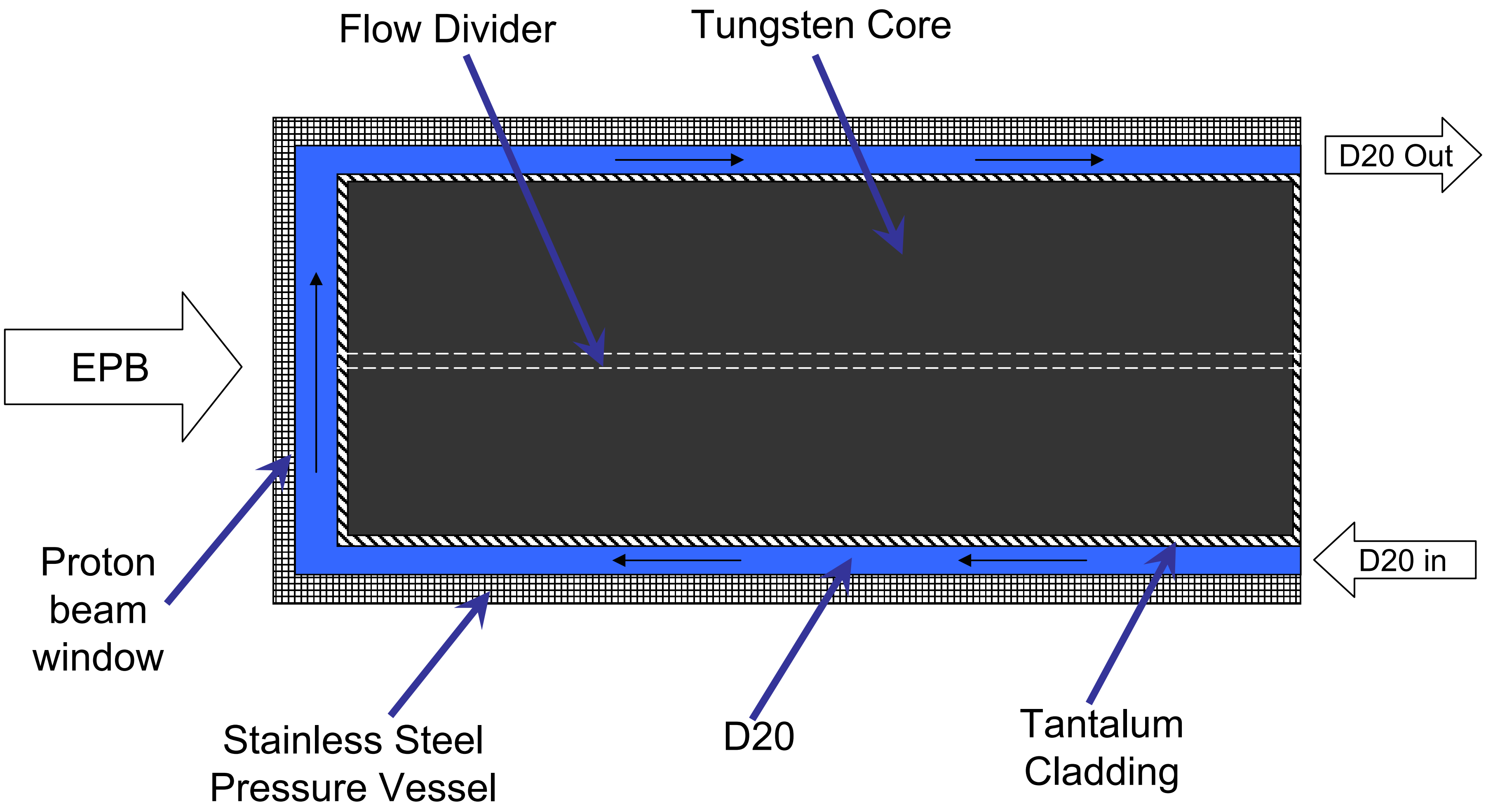
    } Optimised for cold neutron production



Neutronically efficient target design

- **Maximise use of ‘target’ materials**
- **Design target geometry to match proton beam**
  - Maximises target neutron yield, while minimising absorption
- **Optimise cross-sectional area**
- **Minimise volume of coolant channels**
  - Maximises solid angle which moderators view

Baseline target design

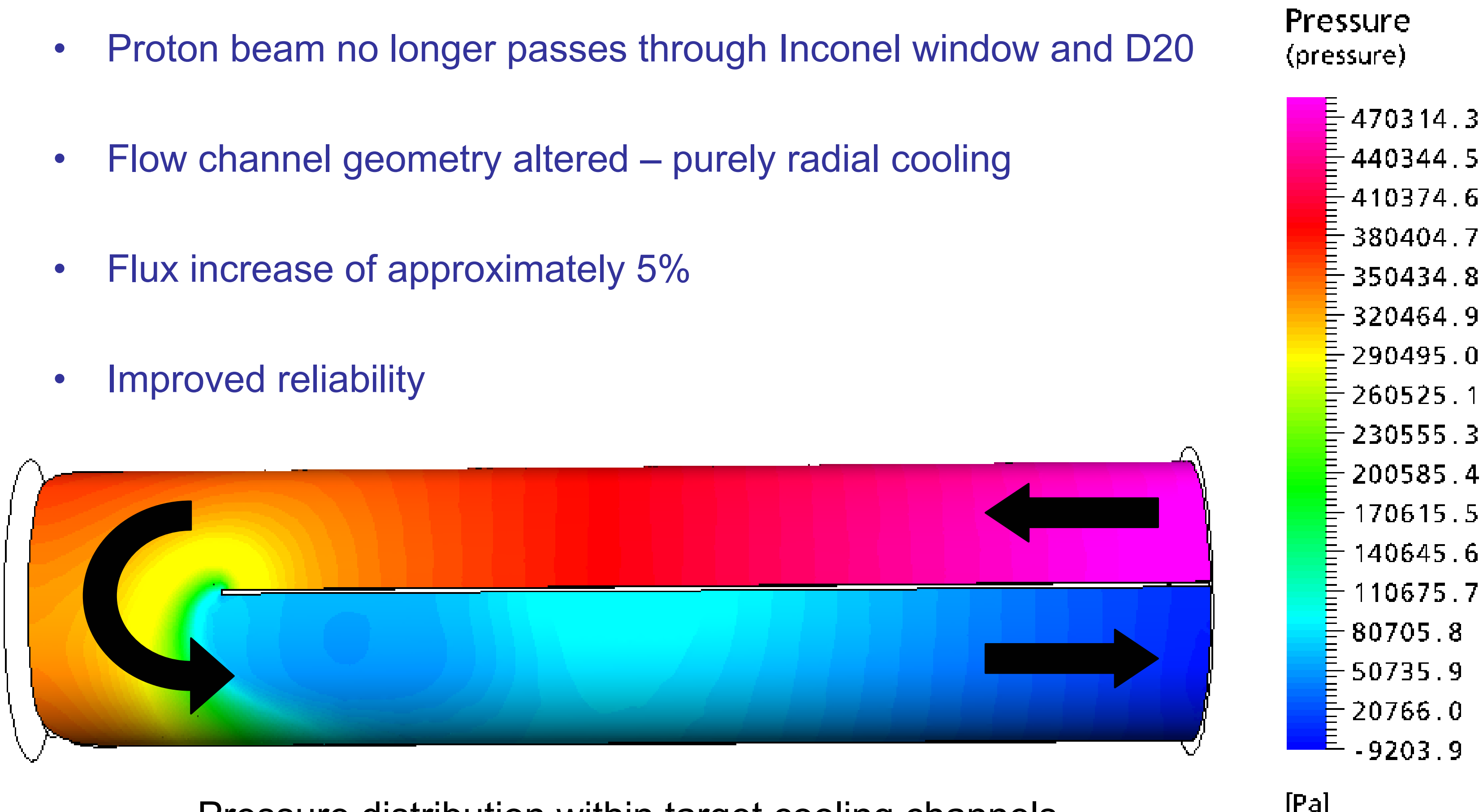


Optimisation of baseline target design

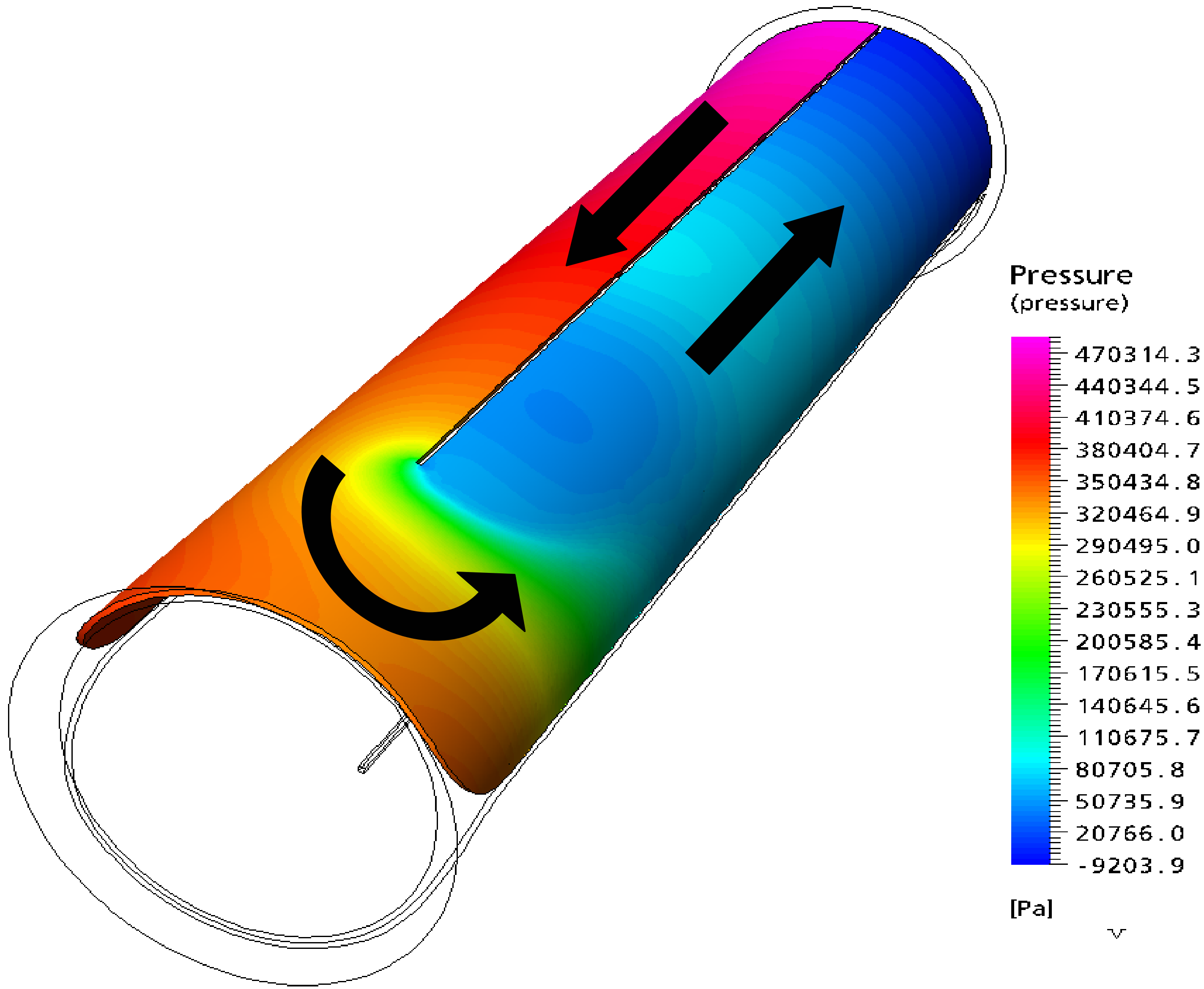
- **Reduction in pressure vessel wall by 70%**
- **Reduction in coolant channel depth by 80%**
- **Overall reduction in Target diameter of 28%**
    - Allows moderators to move closer to neutron producing core
    - Increases solid angle which moderators view
    - Reduces probability of neutron absorption within target
- **Resulted in significant increases in neutron flux (60%)**

Back to the drawing board!

- **Removal of proton beam window & introduction of new cooling channel concept**
  - Proton beam no longer passes through Inconel window and D20
  - Flow channel geometry altered – purely radial cooling
  - Flux increase of approximately 5%
  - Improved reliability



Pressure distribution within target cooling channels


Pressure
(pressure)
470314.3
440344.5
410374.6
380404.7
350434.8
320464.9
290495.0
260525.1
230555.3
200585.4
170615.5
140645.6
110675.7
80705.8
50735.9
20766.0
-9203.9
[Pa]

Materials

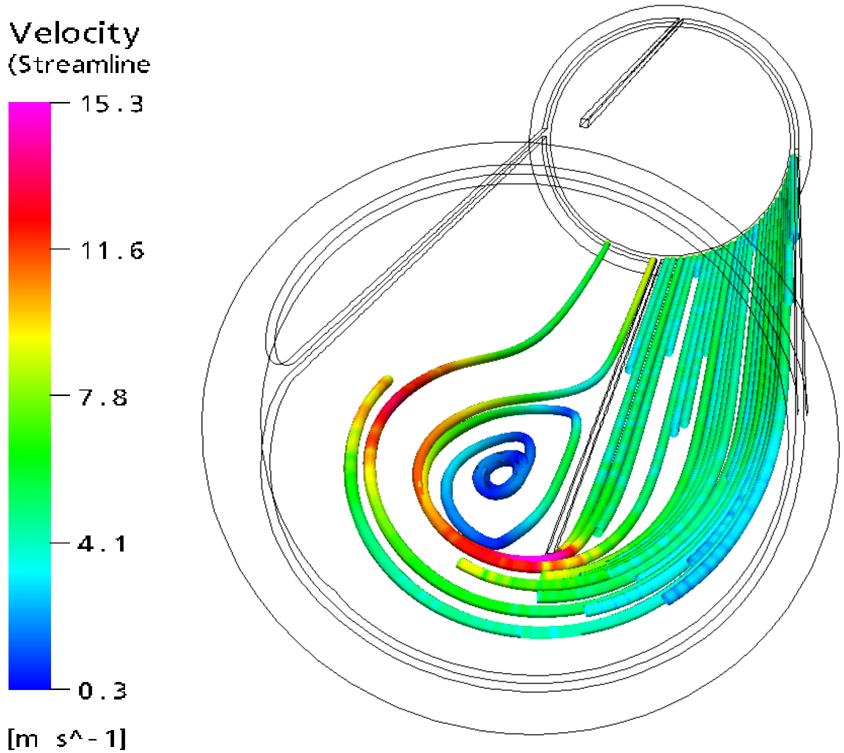
- **Pressure vessel material choice**
  - Replace stainless steel with Tantalum
  - Further reductions in target diameter (now 63% of original size)
  - Further 15% flux increase

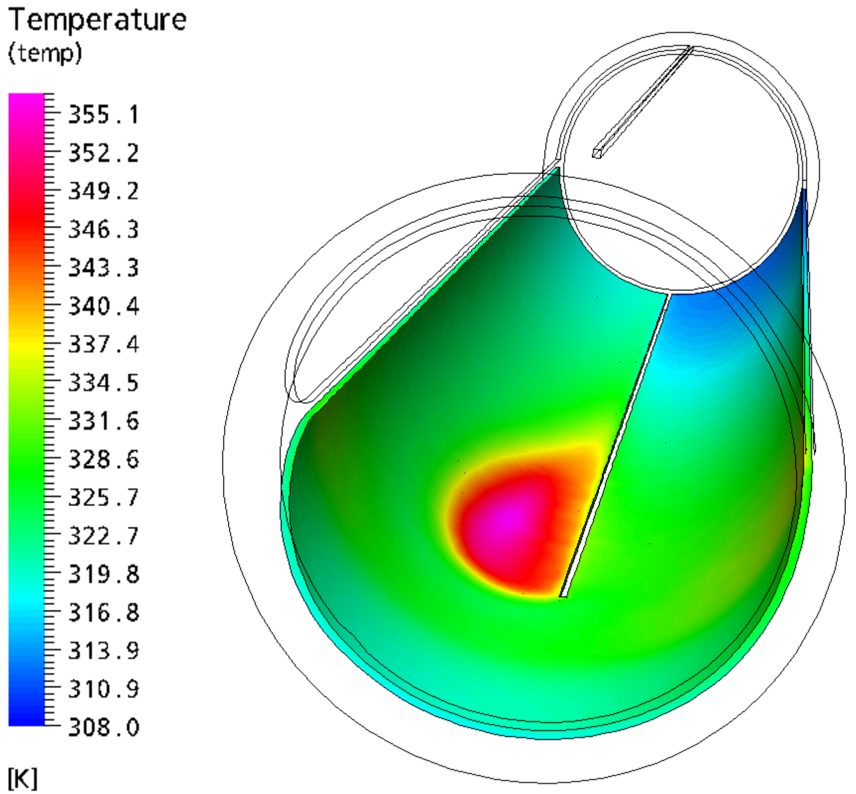
Consequences of design alterations

- **Total predicted flux increase due to design alterations ≈ 75 - 80%**
  - Neutron flux 95% of pure Tungsten target
- **However new cooling channel concept must be proven**
  - Computational Fluid Dynamics (CFD) employed for analysis and optimisation of coolant channels
  - CFD subsequently verified using flow tests

CFD Analysis of initial design

- **CFX used to Computational Fluid Dynamics analysis**
- **CFD revealed problematic separation & pressure drop at inside of bend**
- **Resulting recirculation would heat coolant excessively**



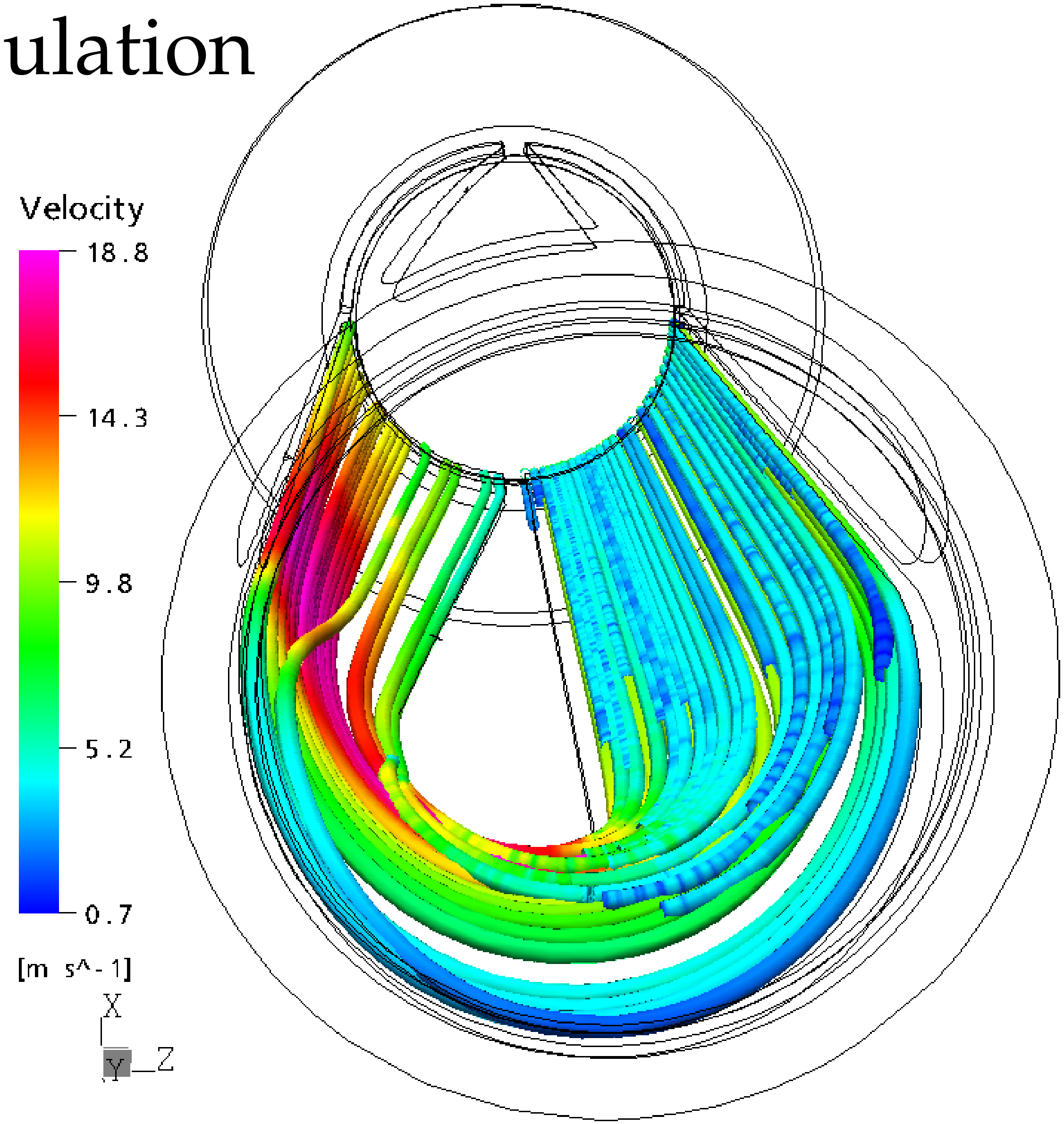


Removal of recirculation

•A solution was required to remove the recirculation

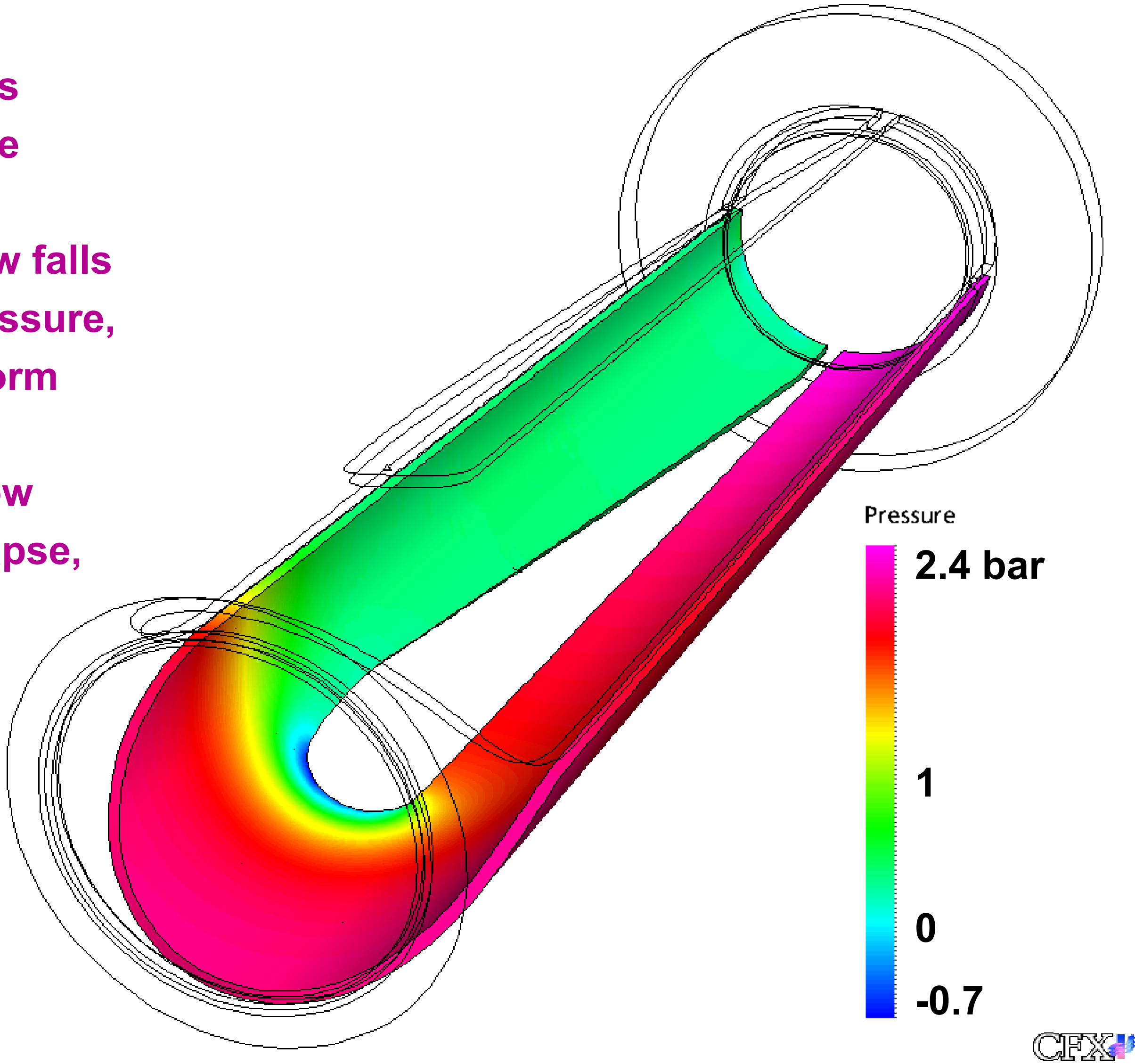
•The flow guide was modified into an aerofoil form

- Prevents separation and subsequent recirculation

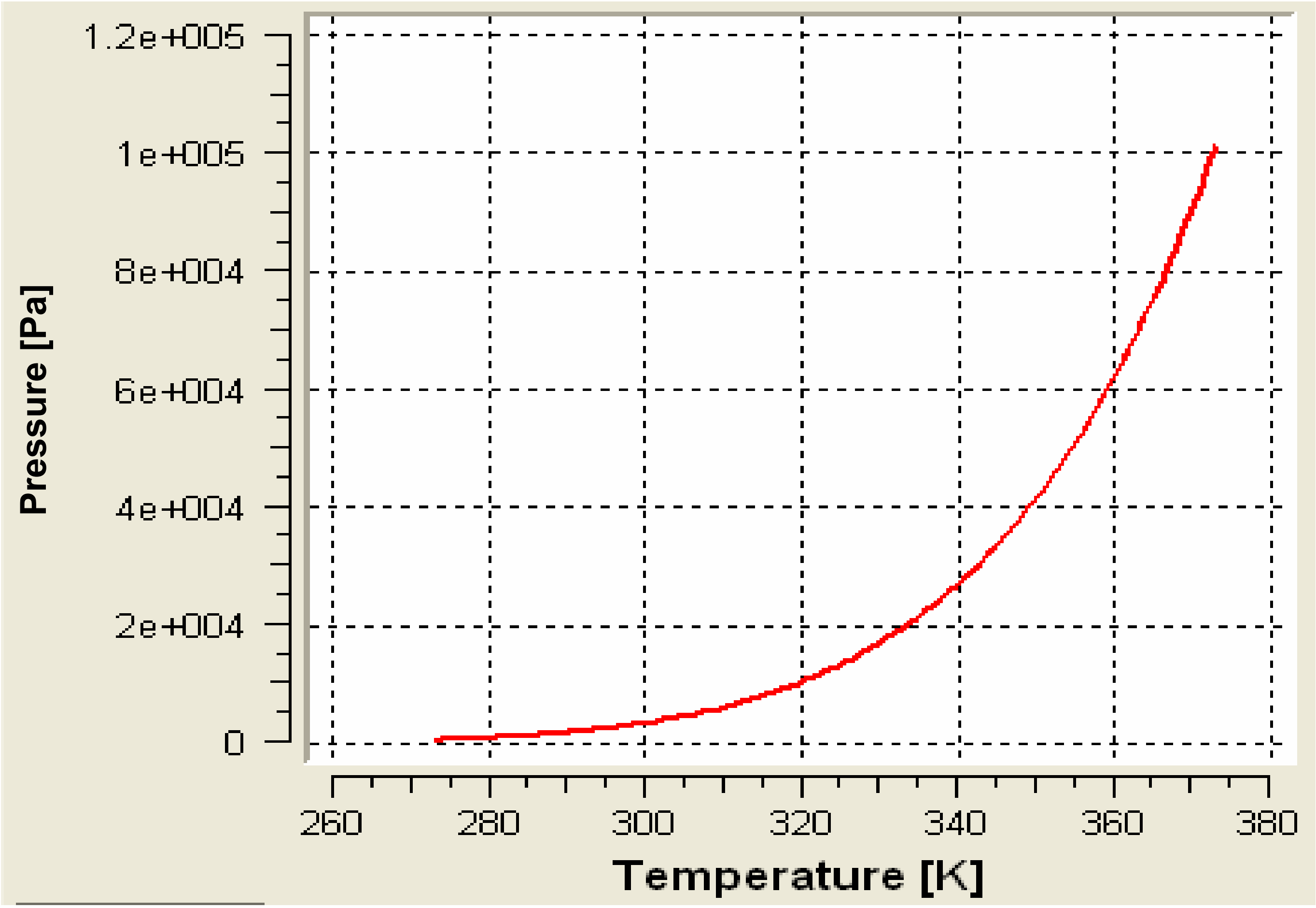


Cavitation

- A fluid's vapour pressure is proportional to temperature
- If the pressure within a flow falls below the local vapour pressure, cavities (or bubbles) will form
- As the cavities leave the low pressure region, they collapse, damaging the vessel wall

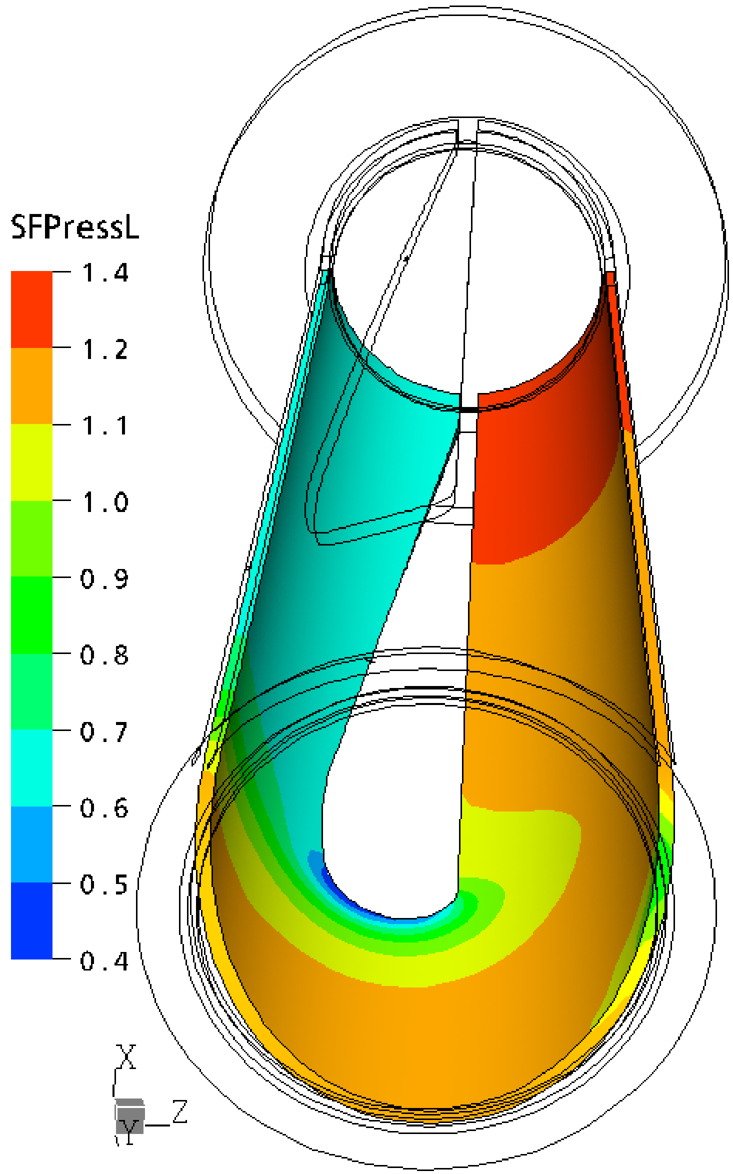


Vapour Pressure H20



Cavitation Prevention

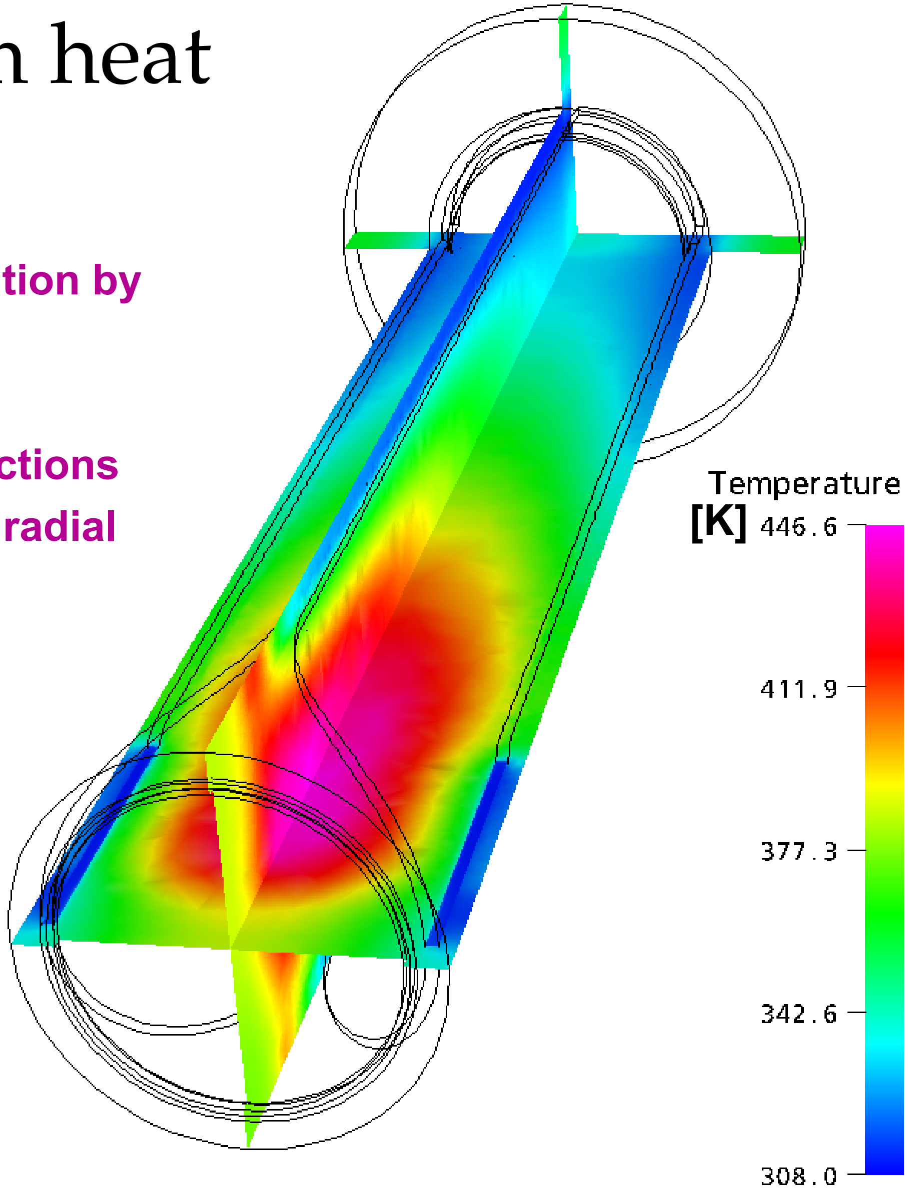
- **High flow velocities within the target cause a pressure drop on the inside of the bend**
  - If local vapour pressure is greater than local pressure, cavitation will occur
- **Solution**
  - Map vapour pressure onto flow model
  - Increase inlet and outlet pressures (maintaining differential) until pressure in all regions are above local vapour pressure
  - Final inlet pressure 5 bar



Modelling proton beam heat load within the target

- **MCNPX used to calculate energy deposition by the proton beam within target**

- **Curve fitting allowed the creation of functions which accurately describe the axial and radial variation of heat load**

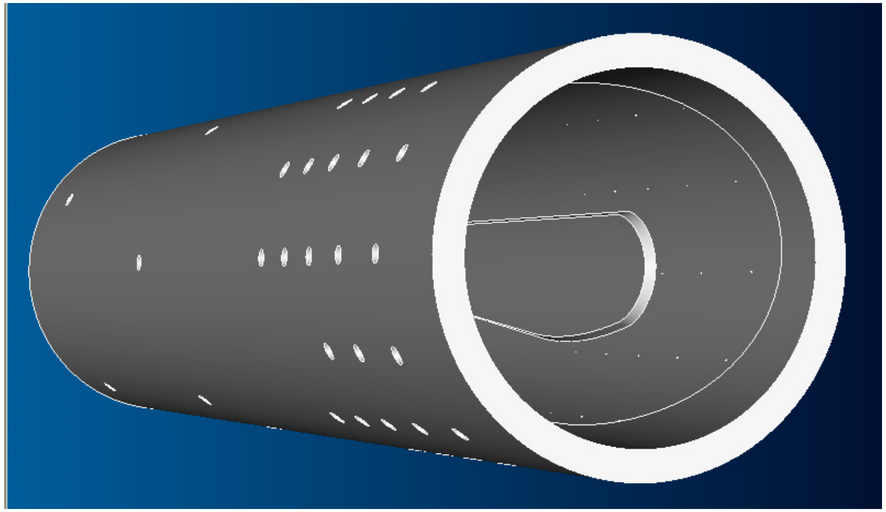


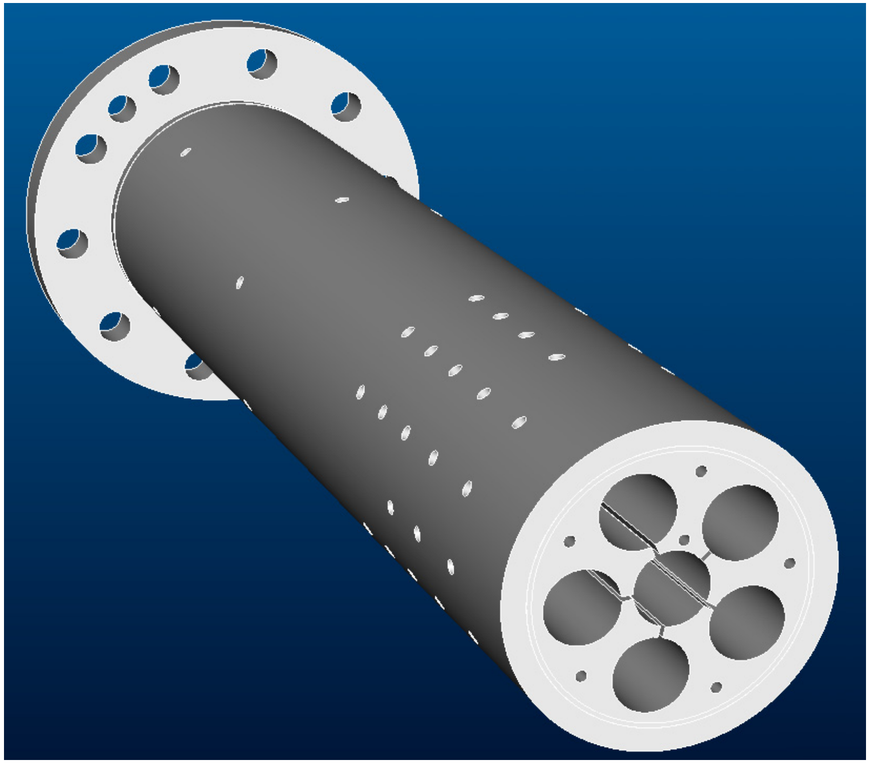
Thermally induced stress

- **Temperatures within target are calculated using CFD**
    - Temperatures exported to an FEA package (ANSYS)
    - Thermally induced expansions are then calculated
    - Resultant stresses and are then calculated
- **Differing coefficient of thermal expansion**
    - Tungsten & Tantalum differ by 2μm/m/°C
    - Small stresses

Verifying CFD Results

- **Prototype thermal test target, installed with a dense network of pressure tappings**
- **5 cartridge heaters will supply 37kW of power, to test the cooling**
  - Power varied axially along the target

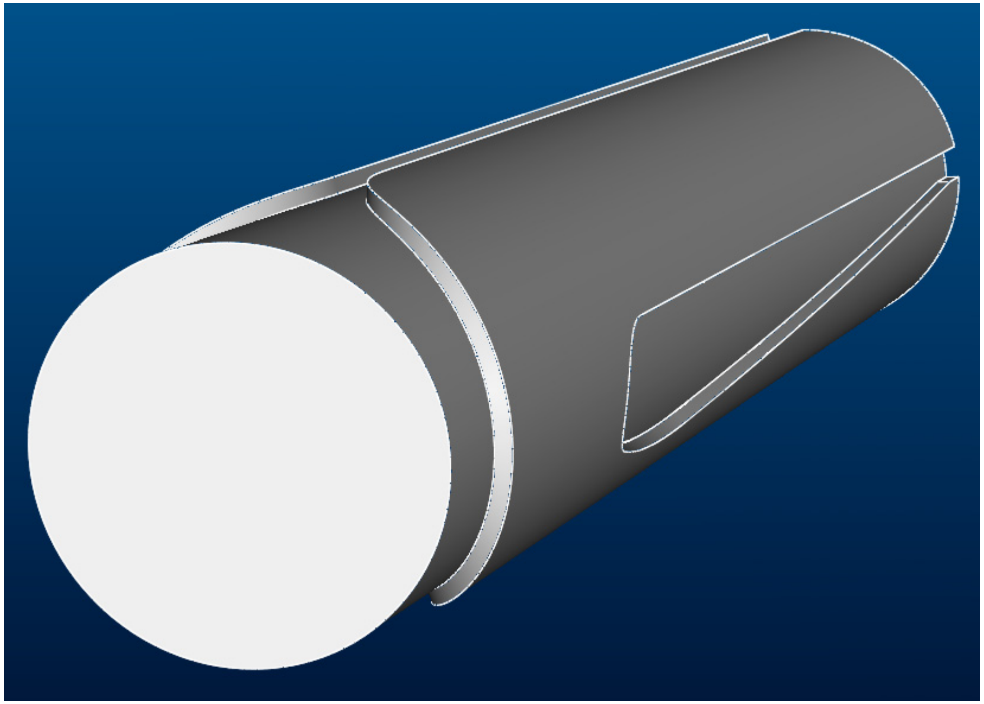




Manufacturing

- **Majority of target simple to manufacture:**
  - Tungsten core is encased in a 1mm sleeve of Tantalum
  - Sleeve is e-beam welded, creating a hermetic seal
  - Assembly is hot isostatically pressed (HIP)
  - Ultrasonic NDT used to test HIP bond

- **Tantalum pressure vessel complex to manufacture**
    - Incorporates aerofoil structures on ID!
    - Former created on CNC mill
    - Hot Isostatic Pressing is used to create the vessel from powder
    - Former leached away after vessel created
- **Pressure vessel shrink fitted onto core, then assembly e-beam welded**



Project Uncertainties

- **Potential for erosion due to high coolant velocities**
- **Pressure vessel manufacturing method yet to be proven**