TS1 Target Upgrade

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PASI Targets Meeting

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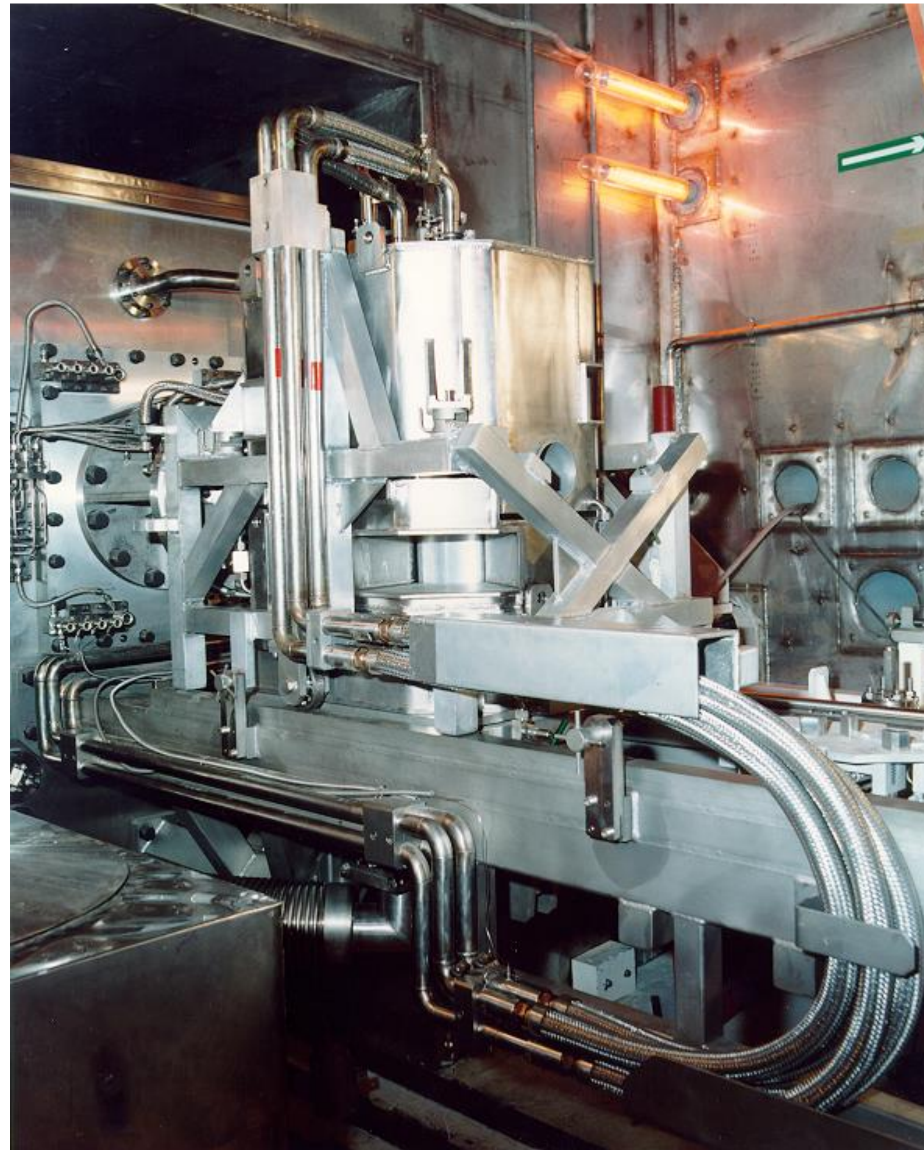
Overview

- Background / Aims
- Target Design
  - Target Concepts: optimising for neutronics
  - Design 1: Parallel Flow
  - Design 2: Series Flow
  - Initial FEA Modelling
  - Extra neutronic gains
- Increasing Beam Power
  - Engineering
  - Neutronics
- Conclusions



Aims

- Increase the useful neutronic output of TS1
  - Use knowledge, experience and modern computational tools to optimise output from existing beam
  - Upgrade accelerator to deliver higher beam powers

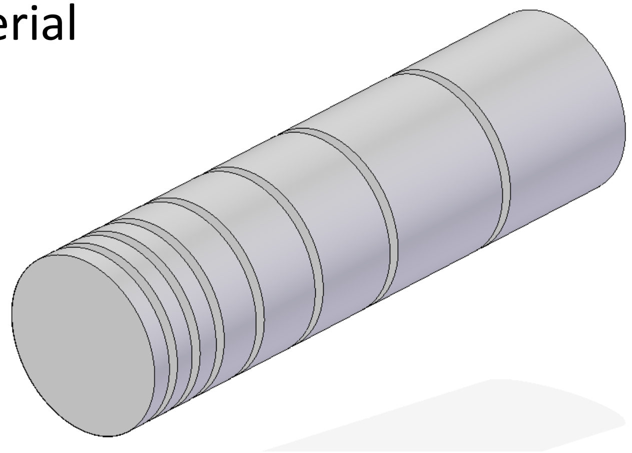
- PASI WP2:
  - Detailed design for up to 0.5MW (625μA at 800MeV)
  - Conceptual target design for 1MW and 5MW

- TS1 Upgrade Project:
  - Increase useful neutronic output as much as possible, with low operational risk, on a limited budget, for implementation by ≈2020

Target Concepts

- For 180 - 625μA we need a plate target
  - Thermal stress limits solid rod targets to <60μA
  - Cannelloni targets are not neutronically worthwhile until ≈1MW (too much water)

- Minimise volume of water and non-target material
  - Water anywhere is bad for pulse width



- Circular cross section is best for neutronics

- Leave space for a water pre-moderator

- Avoid stainless steel – it generates a high neutron background

- Neutronic design order is; reflectors, then moderators, then pre-mod, then target

Plate Thickness Optimisation

- Regardless of target shape, it is important to minimise the number of plates used
  - More plate gaps = more water and tantalum

- Current TS1 has high stress in plates 1 and 2, but not in 3-12
  - Use FEA to optimise the stress distribution across all plates
  - Do not exceed the stress limits in current TS1 (we know it works!)

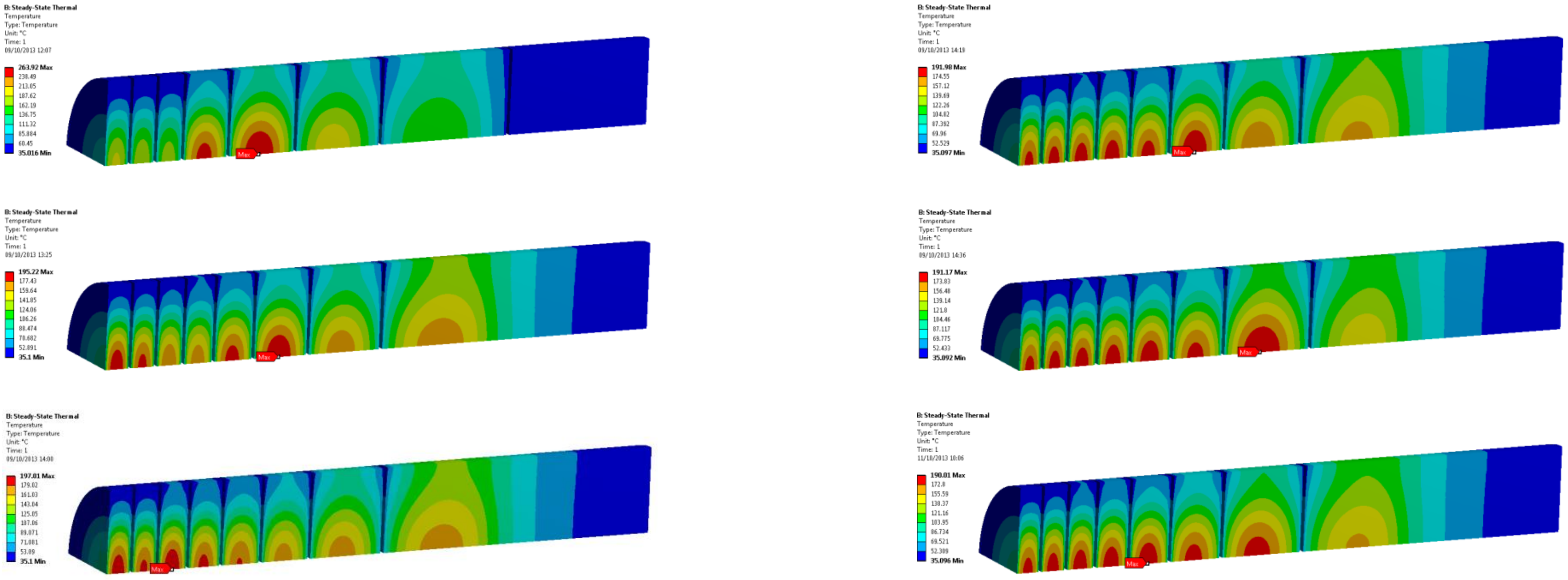
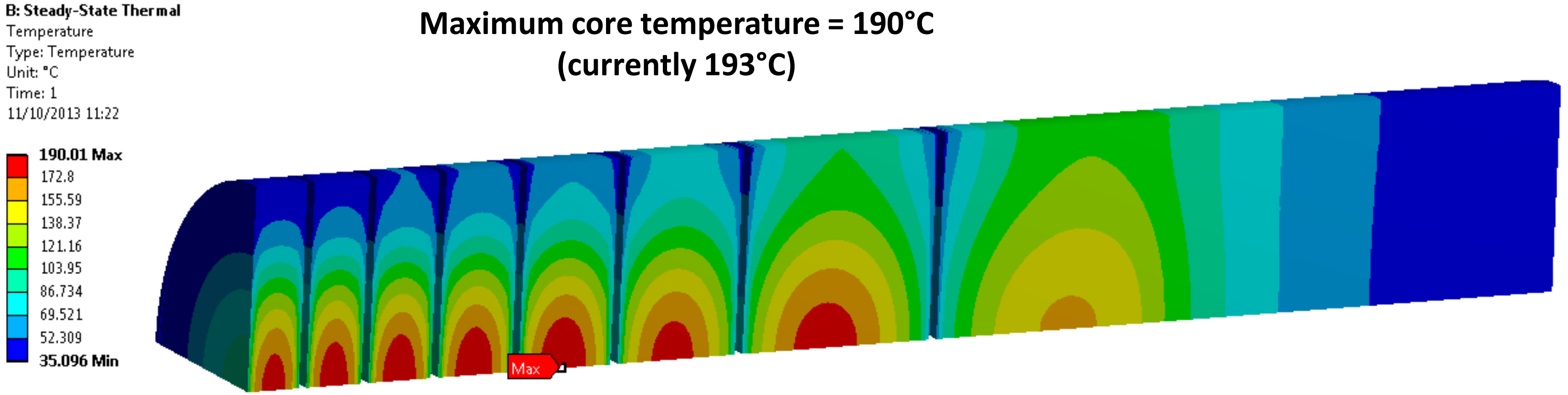
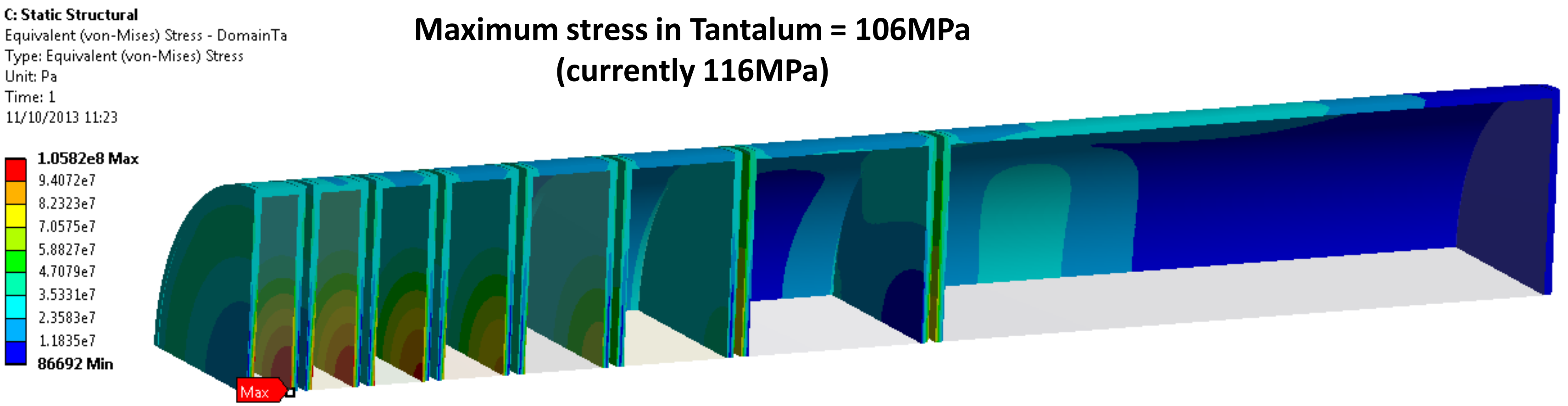


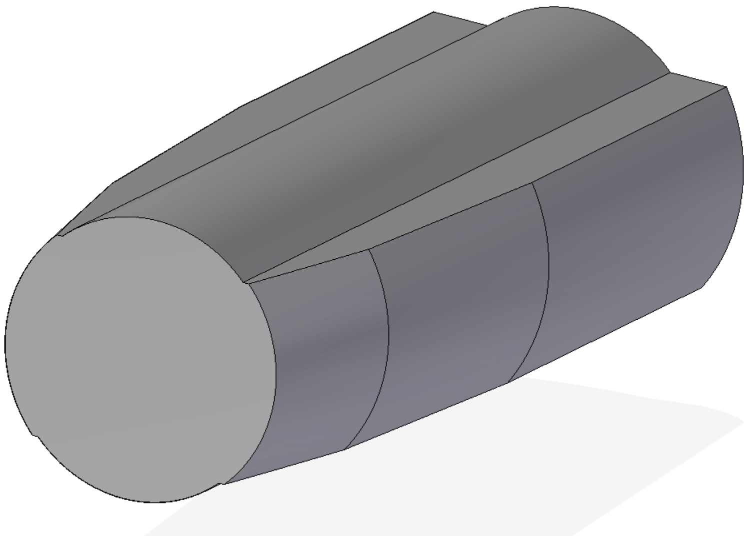
Plate Thickness Optimisation

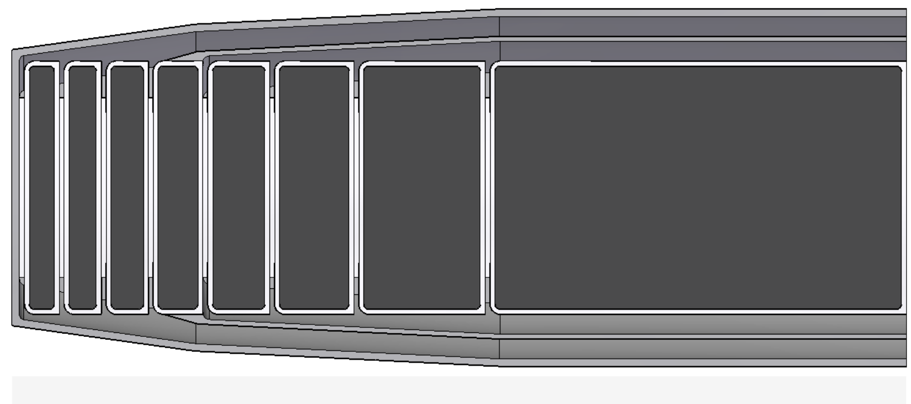
- Result: 8 plates required at 180μA

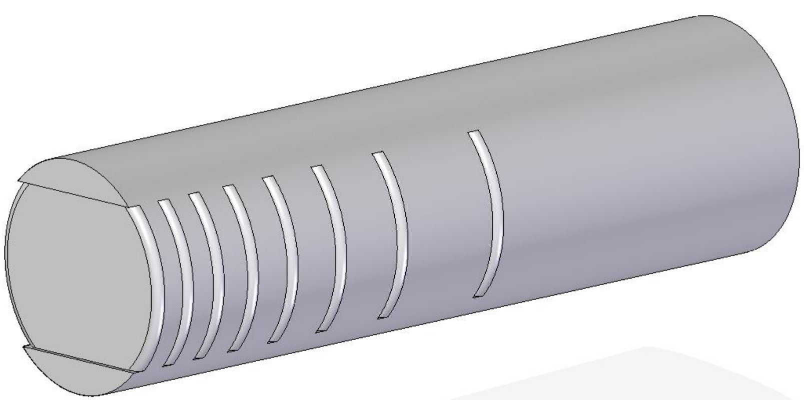


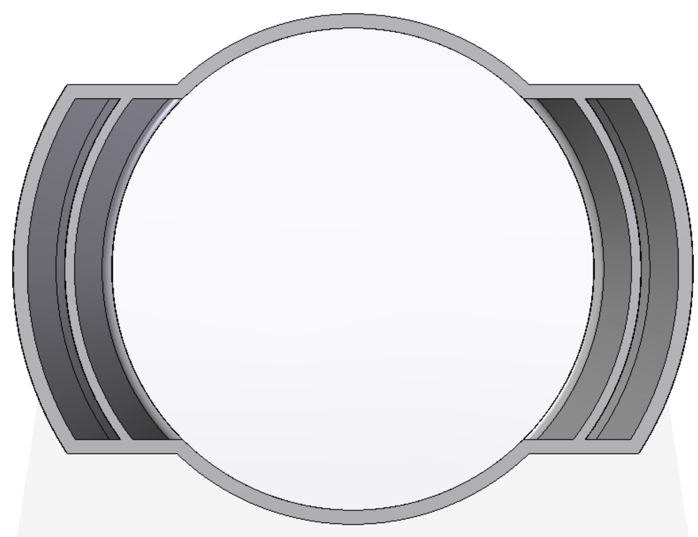


Target Design 1: Parallel Flow





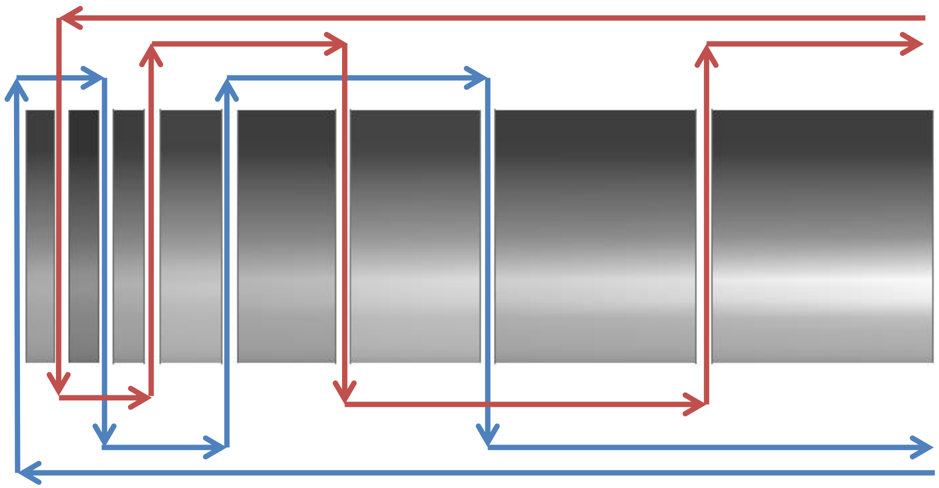


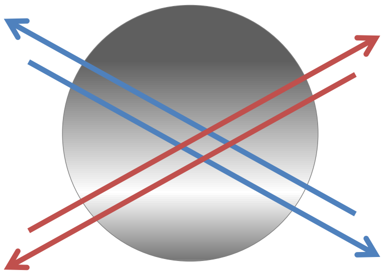


Target Design 2: Series Flow

- Can reduce water volume further by having one water channel cross several plates – 'series flow'

- A 2 channel scheme is proposed:

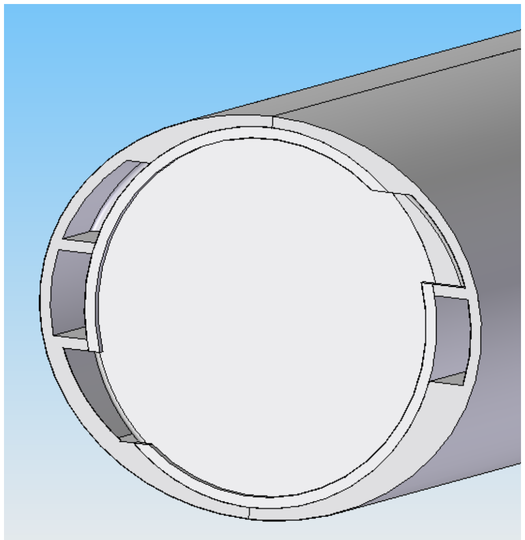


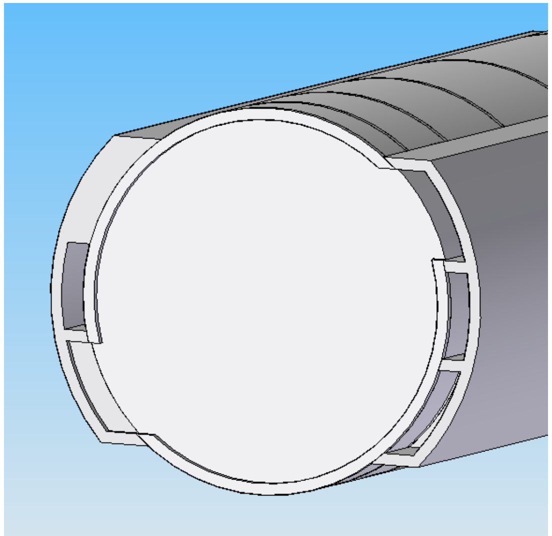


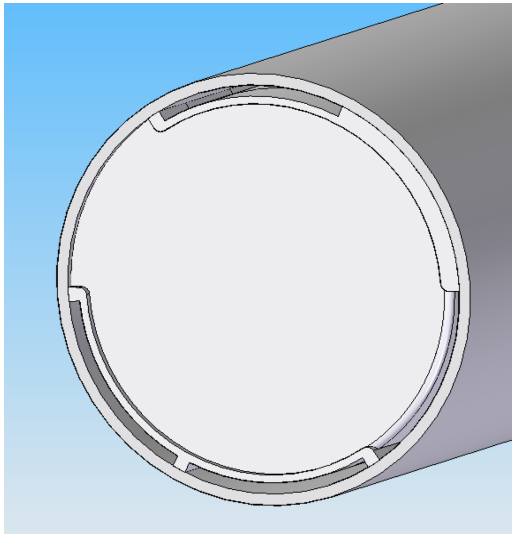
  - Every plate is cooled by both channels
  - Less face coverage, but channels are offset diagonally
  - Lower flowrate, higher pressure drop

Target Design 2: Series Flow

- There are several options for cross section geometry:



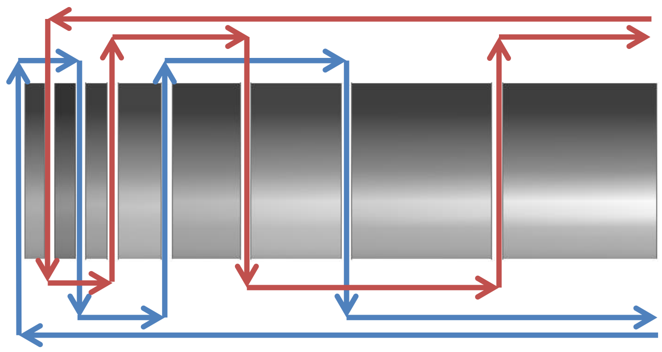


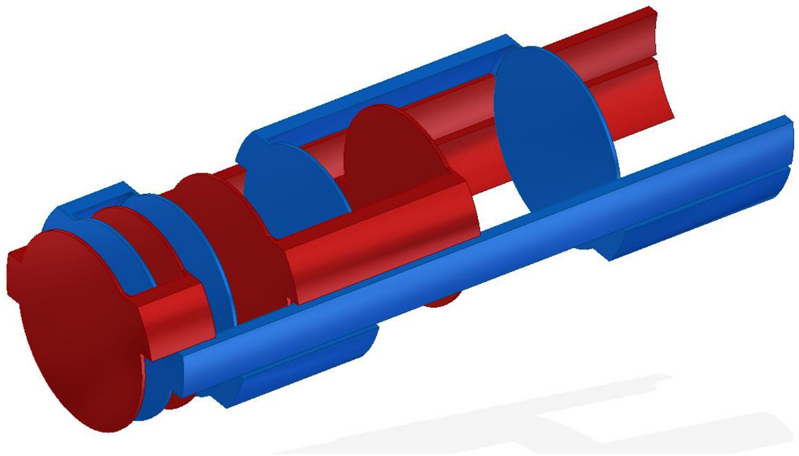


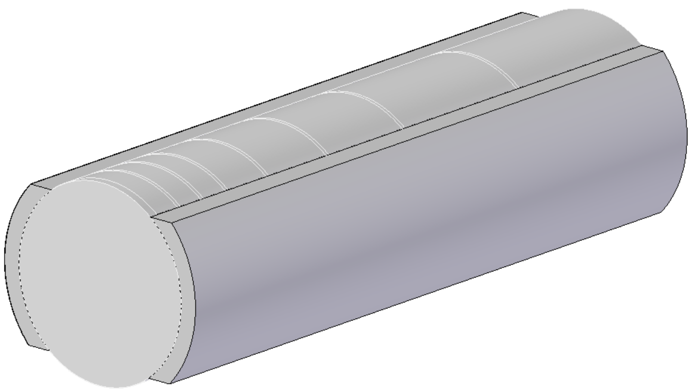
Better Neutronics ⟷ Easier Manufacture

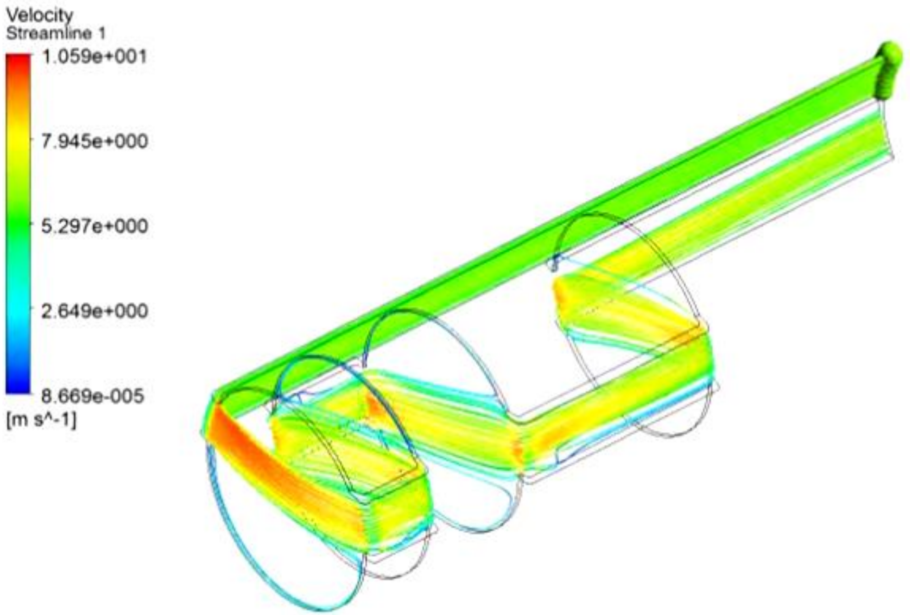
- There are also various options for plate face cooling
- Optimisation of cooling flow is still in progress

Target Design 2: Series Flow

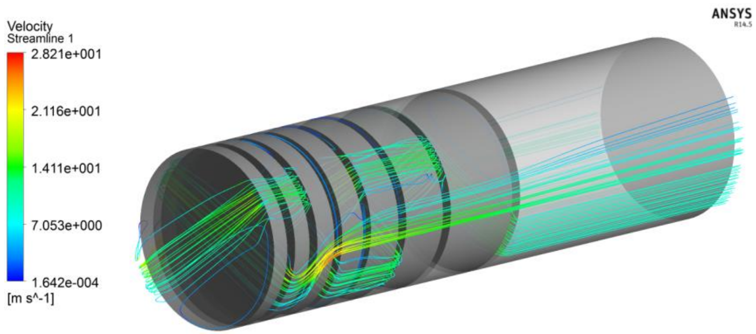


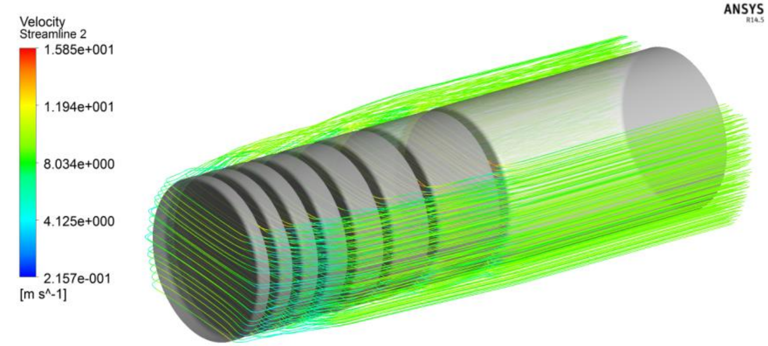


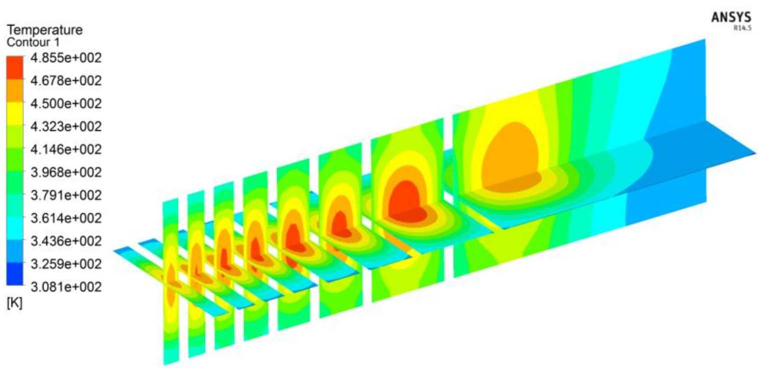


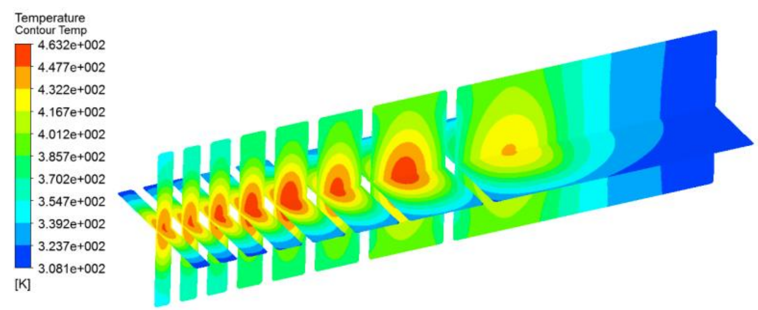


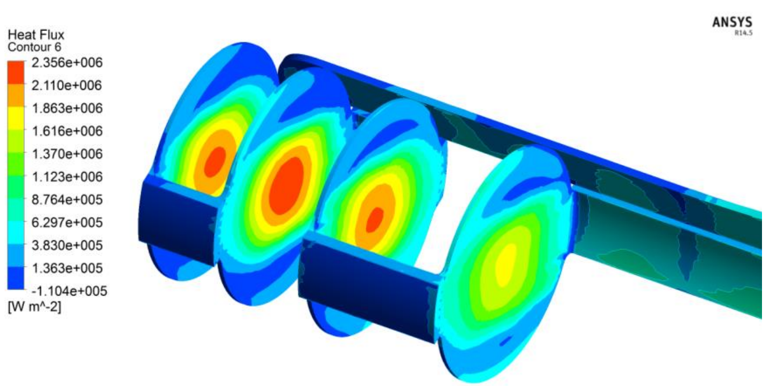
Initial FEA Modelling

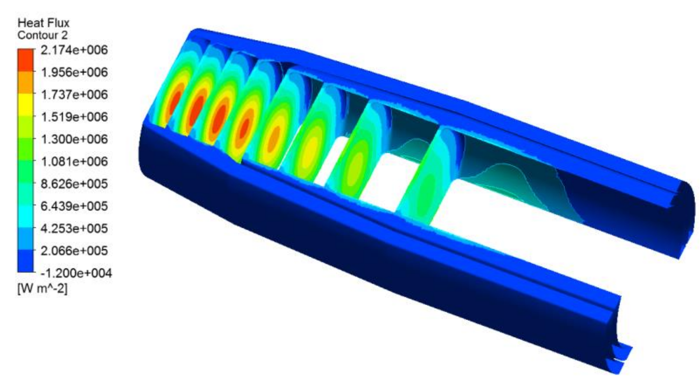












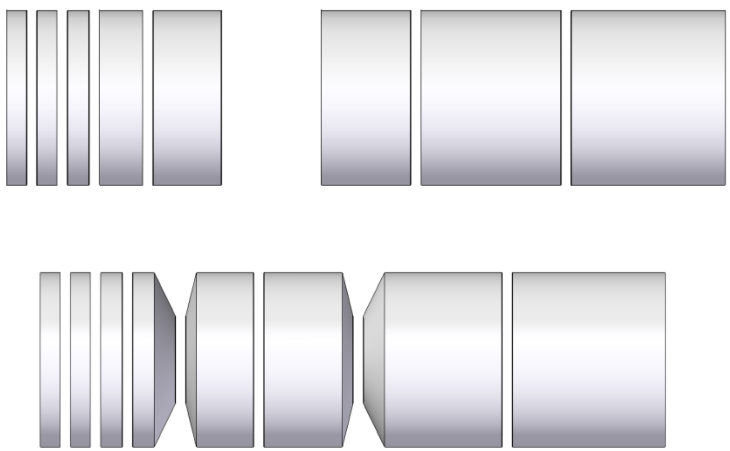
Comparison

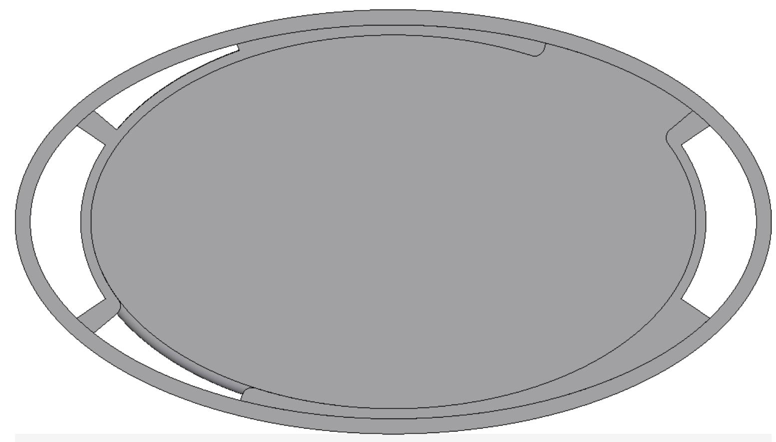
	Series Flow (9m/s)	Parallel Flow (6m/s)
Max core temp (°C)	212	205
Max surface temp (°C)	170	132
Max heat flux (MW/m^2)	2.4	2.1
Max pressure drop (bar)	5.0	0.3
Water mass flow rate (kg/s)	1.6	8.0
Total water volume (cm^3)	250	840

- Series flow target has higher temperatures (but within acceptable limits)
- Heat flux is acceptable in both targets
- Series flow target has much higher pressure drop, but lower flow rate
- Parallel flow target has a significantly higher volume of water

Extra Neutronic Gains

- Can add a flux trap to get more neutrons out
- Can use a horizontally elliptical beam – wider area seen by the moderators

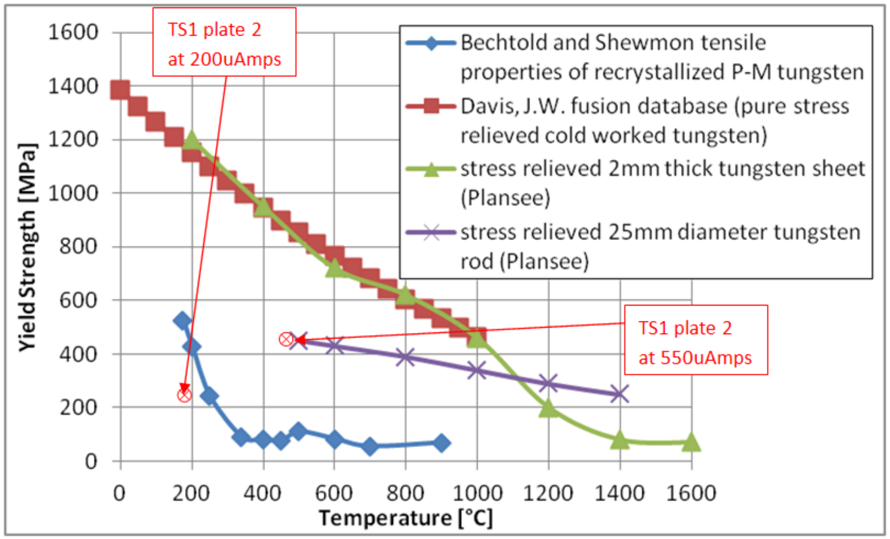


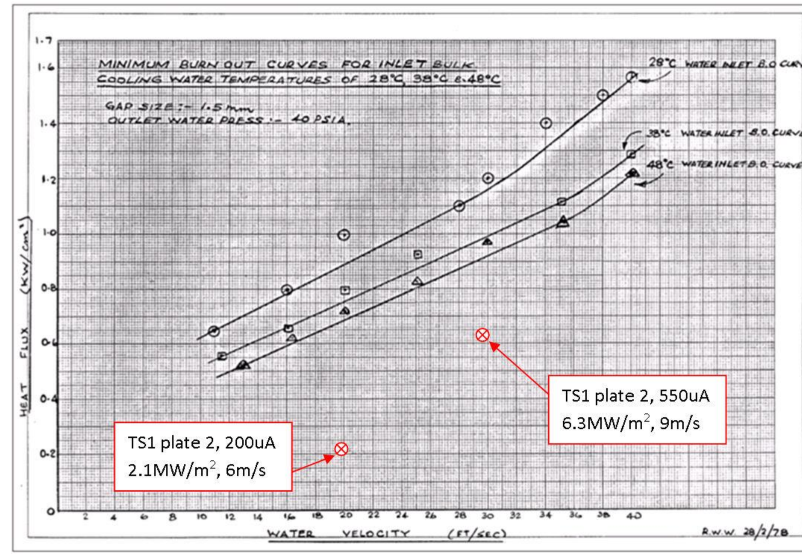


- … but these options will also increase manufacturing cost and complexity
- Further engineering design and neutronic modelling will help quantify the costs and benefits

Increasing Beam Power – Engineering

- Tristan Davenne modelled plate 2 of the current target at 200 and 550μA

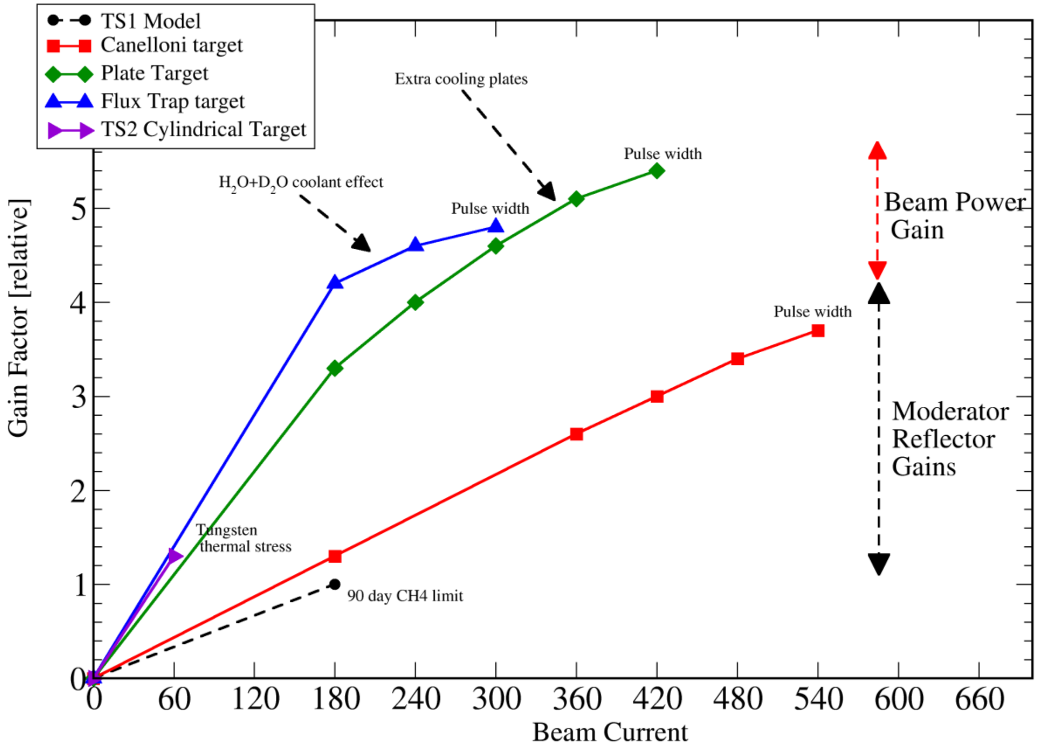




- At 550μA:
  - Heat flux exceeds ISIS design limits: still below burnout curve, but lower factor of safety. May need to increase water pressure to prevent boiling.
  - Tungsten may exceed its yield stress (according to some sources). ISIS design limit is 275MPa.
  - Tantalum stress appears to depend more on HIP pre-stress than beam heating – this will be validated using pre-stress measurements from ENGIN-X

Increasing Beam Power – Neutronics

- Stuart Ansell and Goran Skoro modelled neutronic gain as a function of beam current for several target types:



- Higher beam power => more plates required => more water in target => longer neutron pulse width

Increasing Beam Power

- For neutronics, plate targets are undesirable at above ≈420μA
- This limit could be raised by reducing the number of target plates used at a given beam power – but go too far and reliability will be compromised
- The current beam window can only withstand ≈300μA; this will probably be the limiting factor for first upgrade
- At 1MW and above, a radically different target design will be required
  - SINQ uses a cannelloni target at 1MW – but as a pulsed source, ISIS may have problems with thermal shock and neutron pulse width
  - SNS second target station will be 1MW long pulse, rotating tungsten and liquid mercury targets under consideration

Conclusions

- The coming TS1 upgrade will require a target to operate at 200-300μA
- Parallel flow target is a conservative baseline
  - Significantly better neutronic performance without compromising reliability
- Series flow target should be neutronically better, if it is worthwhile from an engineering/manufacturing perspective
- Both designs can be adapted to include a flux trap and/or elliptical plates, if this is found to be worthwhile
- Parallel flow target should be suitable at 500μA or more, however…
  - Limited by neutronics at ≈420μA
  - Limited by beam window at 300μA
- At 1MW+ plate targets are no longer suitable and a completely new target design will be required