Science & Technology Facilities Council
Rutherford Appleton Laboratory

PASI Targets Kick Off Meeting
High Power Targets Group Interests

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Science & Technology Facilities Council
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WP1 Generic tools for high power target development and operation
WP2 ISIS upgrades

WP1 Tasks:

To investigate the maximum allowable operating temperature and allowable operating stress in high Z target materials.

To investigate the maximum allowable power density a solid target can take based on current ISIS beam power and beam profile and using the thermal shock test rig described in Work Package 4 and tests at the HiRadMat facility in CERN.

To identify reliable long term temperature measurement systems (circa 5 years) in a high radiation environment.

The evaluation of corrosion / erosion rates of target and target cladding materials, e.g tantalum when interacting with the target coolant flow; the proton beam and the target containment vessel atmosphere.

To develop a new suite of monitoring systems which allow reliable online and real time monitoring of the:

- **structural integrity;**
- **coolant flow integrity;**
- **heat transfer integrity; and**
- **Erosion / corrosion resistance integrity of a high power target.**

To identify reliable long term strain measurement systems (circa 5 years) for use in the high radiation target environment.

WP2 Tasks:

Modelling of the existing TS1 at ISIS and a study of the likely beam power limit due to the beam energy deposition.

Modelling of the neutron moderation system to determine if the neutron flux delivered to the experiments can be increased.

Study modifications to the existing TS1 for operation with a 0.5 MW beam, if necessary.

Study the SNS and ESS target technologies and target stations and investigate their applicability for ISIS.

Participate in ESS target project by modelling their moderation system and contributions to their R&D project.

Conceptual design of a 1 MW target for ISIS.

Conceptual design of a 5 MW target for ISIS.

Underway **Expect HPTG to have significant involvement**

Limits of target materials

The targets section of the PASI meeting held at fermilab in Jan2012 identified radiation damage of materials as one of the key challenges in target design.

HPTG and P.Hurh (Fermilab) have submitted a proposal to work in conjunction with Oxford University Materials Science Department and the National Nuclear Laboratory (NNL).

This proposal would enable professional materials scientists to work closely with target engineers on important material damage issues.

Proton Accelerators for Science and Innovation

Joint post-doctoral positions: call for proposals

FNAL and the STFC plan to develop a coherent programme of R&D aimed at delivering the systems and technologies required at future proton-accelerator facilities and the R&D necessary to realise the associated instrumentation and detectors. As part of a programme recently reviewed and approved by STFC, up to three post-doctoral positions are available to be supported jointly by FNAL and the STFC.

These posts are available to begin from October 2012.

Limits of target designs

HPTG has long term interest in limits of targets

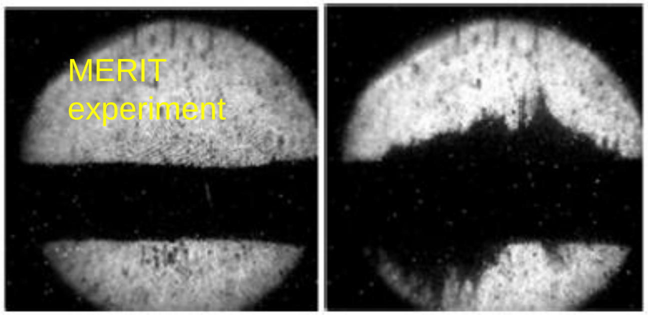
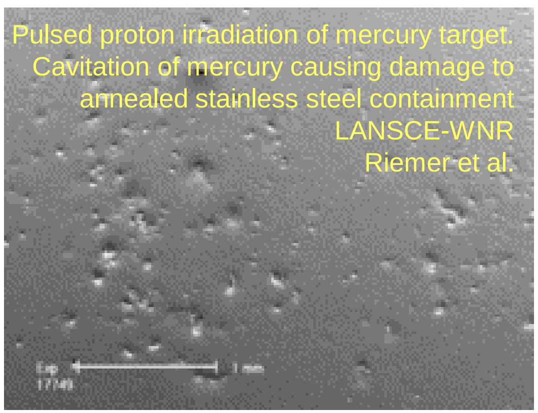
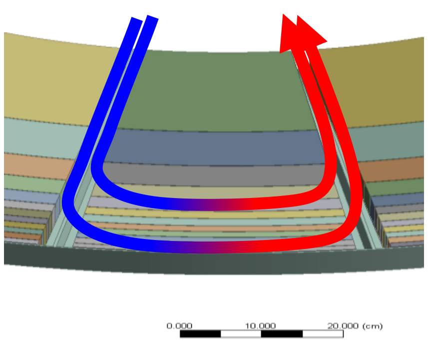
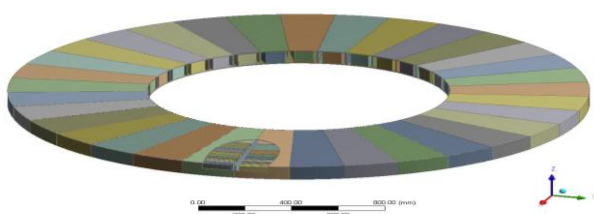


Figure 5: A proton beam/jet interaction as viewed in view port 2: Left image: before interaction; Right image: 350 μs after proton beam arrival.

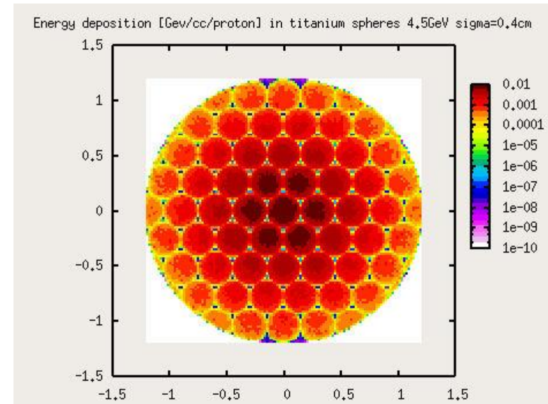


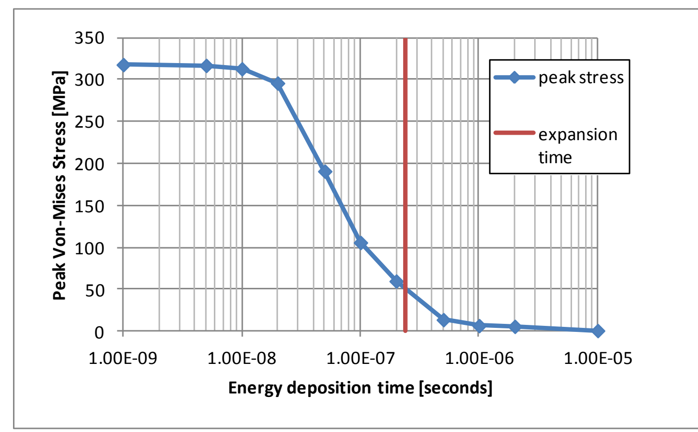




5MW ESS target wheel concept

Euronu superbeam
Target requires new design to accommodate 4MW beam





Packed bed target adopted as baseline design
Increased surface area. Coolant reaching maximum energy deposition region. Reduced static and dynamic stresses.

ISIS Upgrades

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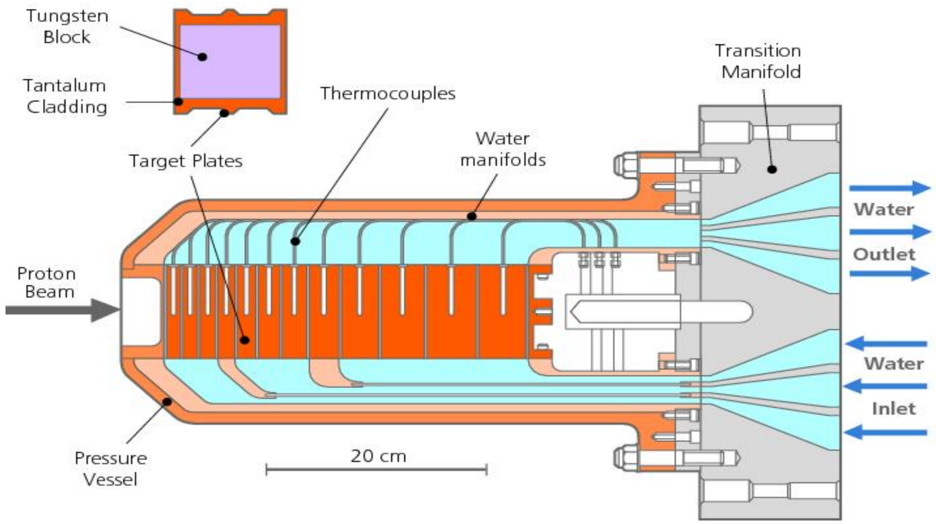
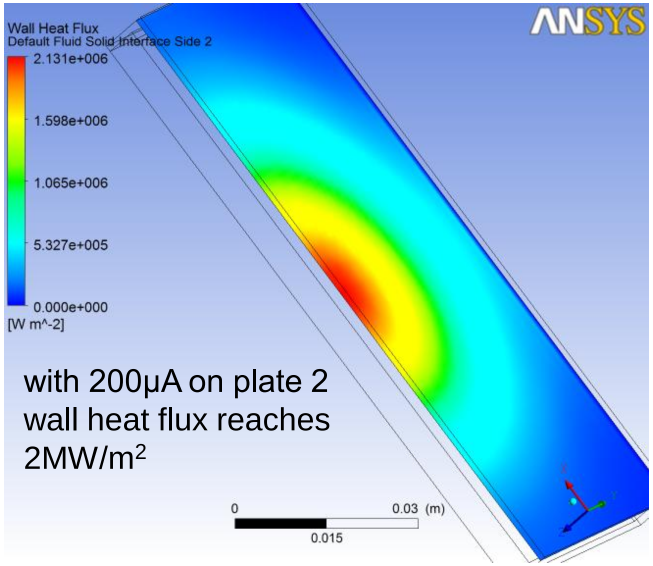
ISIS

ISIS upgrade option		Proton energy	Rep. rate	Mean current	Mean power	Neutrons *cf.* present
Linac + TS-1 refurb.	TS-1	800 MeV	40 pps	200 µA	0.16 MW	× 2
	TS-2	800 MeV	10 pps	50 µA	0.04 MW	× 1
Linac upgrade	TS-1	800 MeV	47 pps	552 µA	0.44 MW	× 4
	TS-2	800 MeV	3 pps	48 µA	0.04 MW	× 1
3.2 GeV synch.	TS-3	3.2 GeV	48 pps	308 µA	0.98 MW	× 6
	TS-2	3.2 GeV	2 pps	13 µA	0.04 MW	× 1
800 MeV ch. exch. inj.	TS-3	3.2 GeV	49 pps	1177 µA	3.77 MW	× 12
	TS-2	3.2 GeV	1 pps	24 µA	0.08 MW	× 2
	TS-3	*3.2 GeV*	*48 pps*	*1153 µA*	*3.69 MW*	× *12*
	TS-2	*800 MeV*	*2 pps*	*48 µA*	*0.04 MW*	× *1*

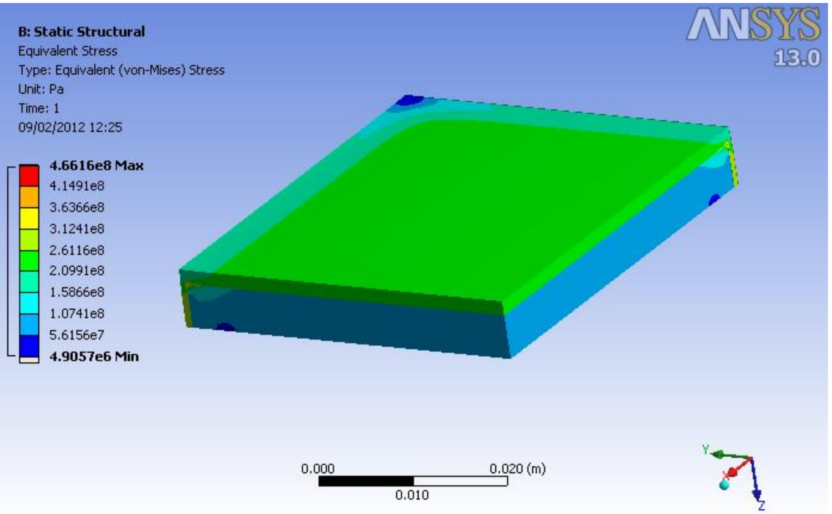
Useful neutrons scale less than linearly with power

Existing TS1 target

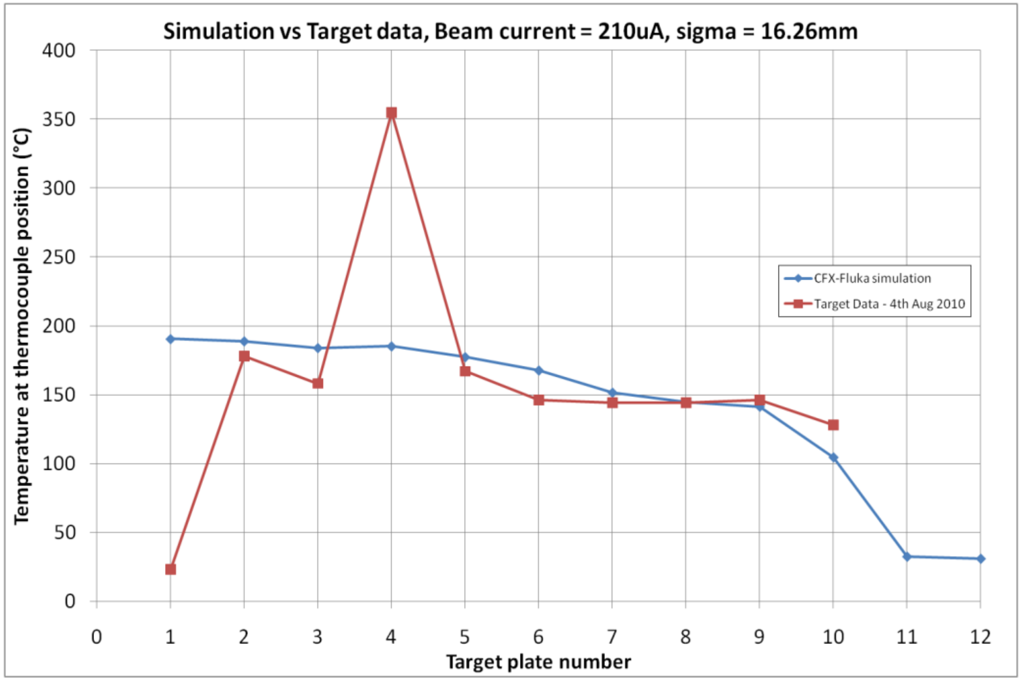




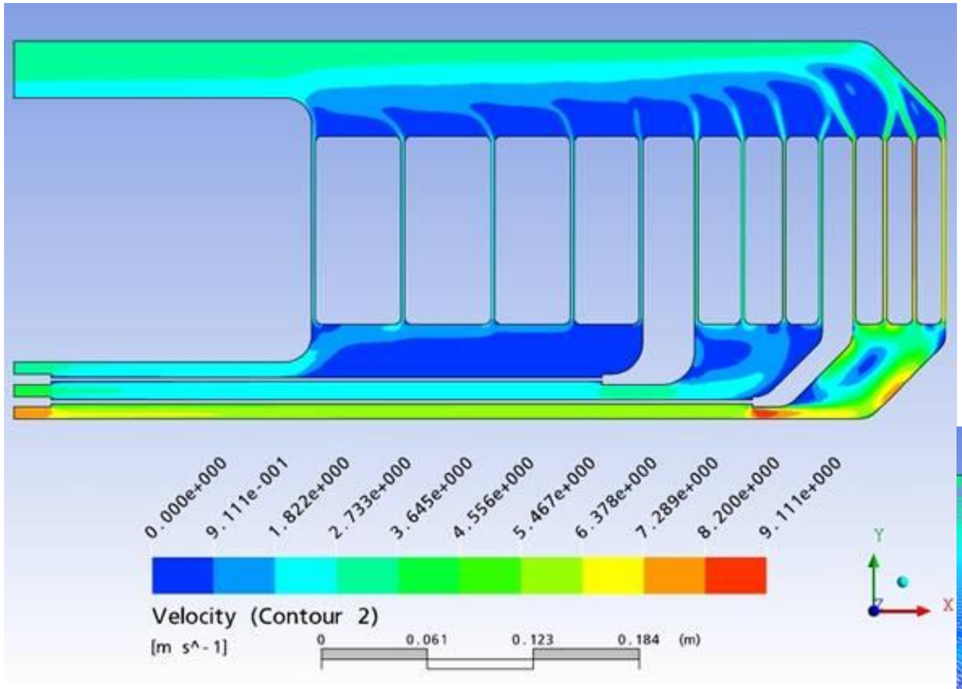
with 200μA on plate 2 wall heat flux reaches $2MW/m^2$

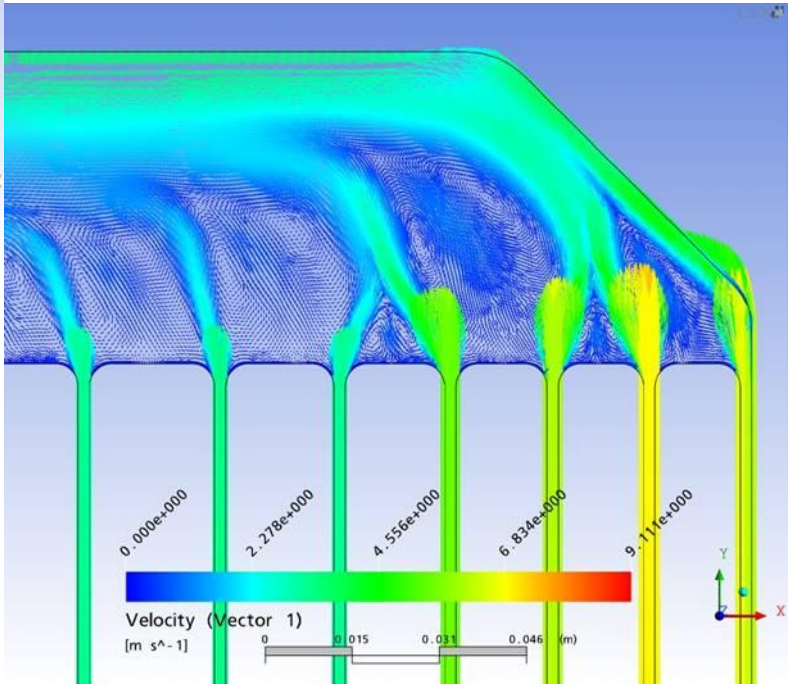


Stress in tantalum clad tungsten plate as a result of cooling from joining temperature at 500°C to 22°C at 466MPa

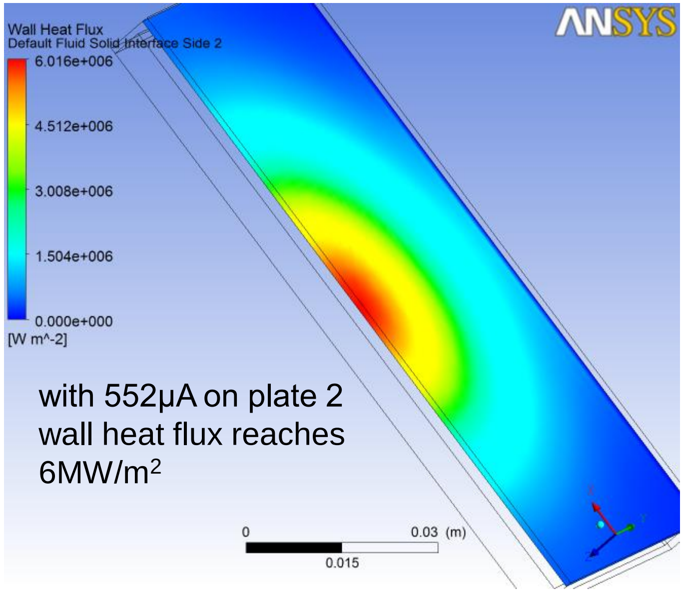


Transient flow behaviour in TS1 outlet manifold

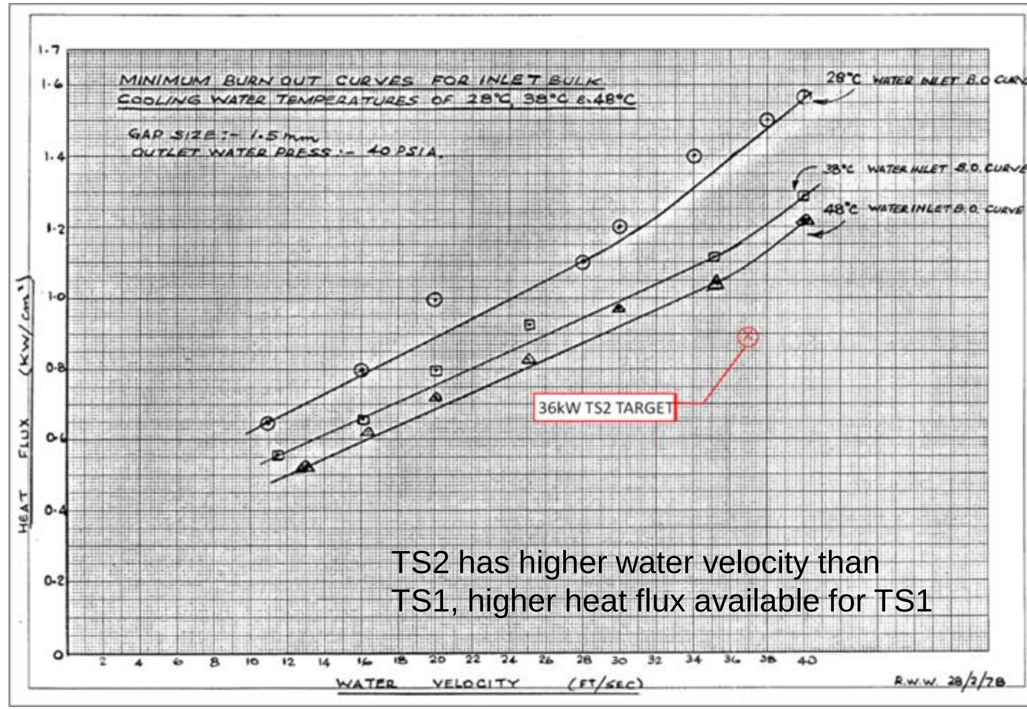




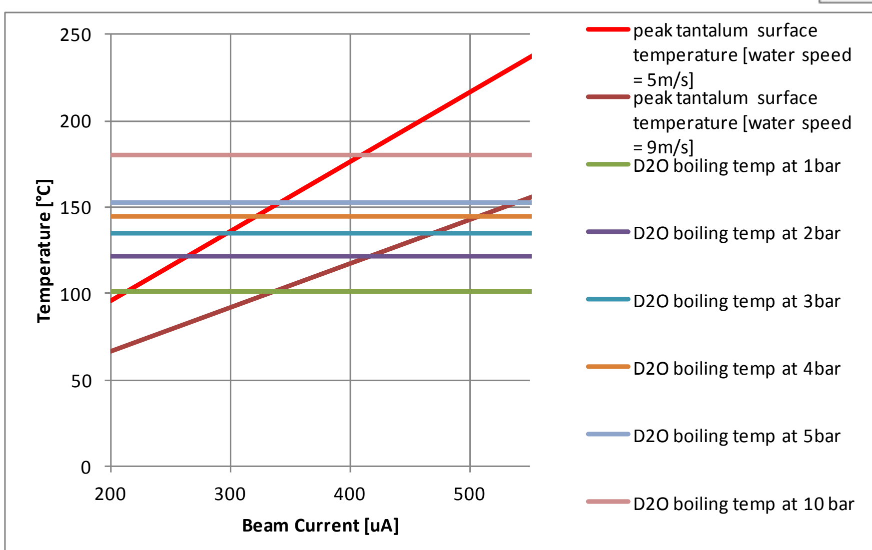
Limits of TS1 target



with 552μA on plate 2 wall heat flux reaches $6 MW/m^2$

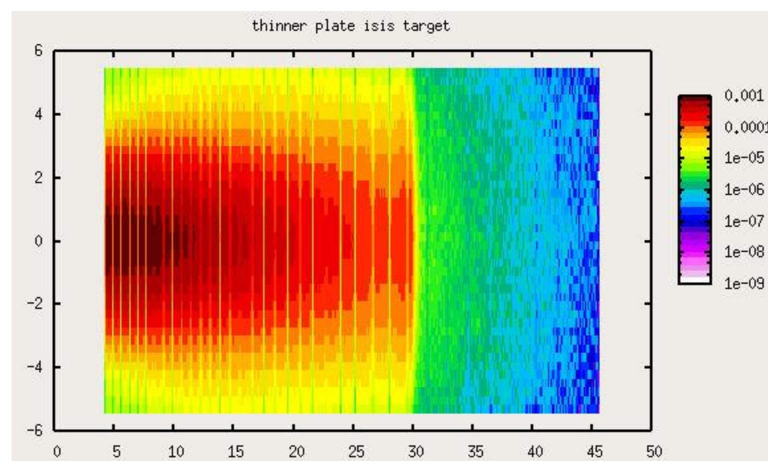


TS2 has higher water velocity than TS1, higher heat flux available for TS1



552μA is possible with 9m/s water flow

Heat flux and stress reduced with thinner plates



HPTG interest in WP1 and WP2

Collaboration with Oxford University Material Science, NNL and Fermilab to specifically look at radiation damage of target materials **WP1**

Long term and continued interest in the limits of various target technologies (paper on the subject recently accepted for publication with Journal of Nuclear Materials) **WP1**

<u>HPTG would like to offer support to ISIS in the development of any target upgrades</u>

Initial analysis suggests existing TS1 target could accommodate more beam power as higher water velocity and heat fluxes possible according to TS2 experience **WP2**

Further modelling on target stresses including the effect of the hipping process, optimizing hipping thickness and flow stability checks at higher flow rate **WP2**

Only minor design changes required to accommodate 500kW beam power **WP2**

For 1MW and 5MW beam power complete target redesign expected, water cooled highly segmented target would be of primary interest for 1MW+. HPTG also has transferable experience of target design at 5MW from close working links with ESS target development team. **WP2**

Experimental Rig foreseen in R12 next to powder rig **WP1 & WP2**

- Test critical features of prototype ISIS target designs (water flow stability, peak heat fluxes etc)
- Provide test bed for off line testing of monitoring systems

For best results need close working relationship with neutronics experts

Work Package 8: Generic fluidised powder target research?

WP8 Tasks:

Flow rig development for tungsten powder

a) Flow optimization to achieve solid dense phase flow (ie full pipe flow), and investigation of low-flow limit.

b) Gas lift and recirculation optimization.

c) Upgrade to CW operation.

d) Erosion tests and development of mitigation techniques.

Heating and cooling tests of heat transfer between powder and pipe wall.

Develop concept for pipe wall and cooling in e.g. Neutrino Factory scenario.

Develop suitable diagnostics for monitoring and control.

Pulsed proton beam test at HiRadMat facility, CERN, using Laser Doppler Vibrometer to measure stress waves generated in powder container.

Off-line investigation of magnetic field effects on fluidized powder.

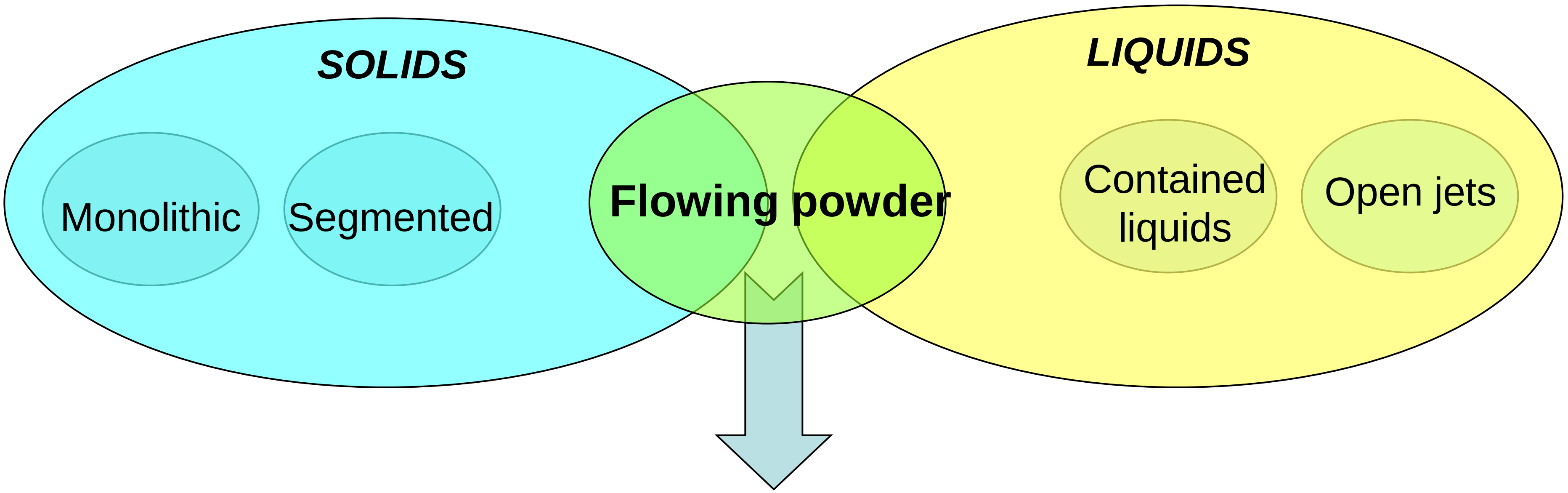
In-beam investigation of magnetic field effects on fluidized powder at HiRadMat facility, CERN.

Identify suitable low Z powder and repeat of 1-6 above.

Outline circuit design including active powder handling issues.

Conceptual design of Target Station.

Powder Target Background



Some potential advantages of a flowing powder:

Resistant to shock waves

Quasi-liquid: can be conveyed in a pipe

Offline cooling

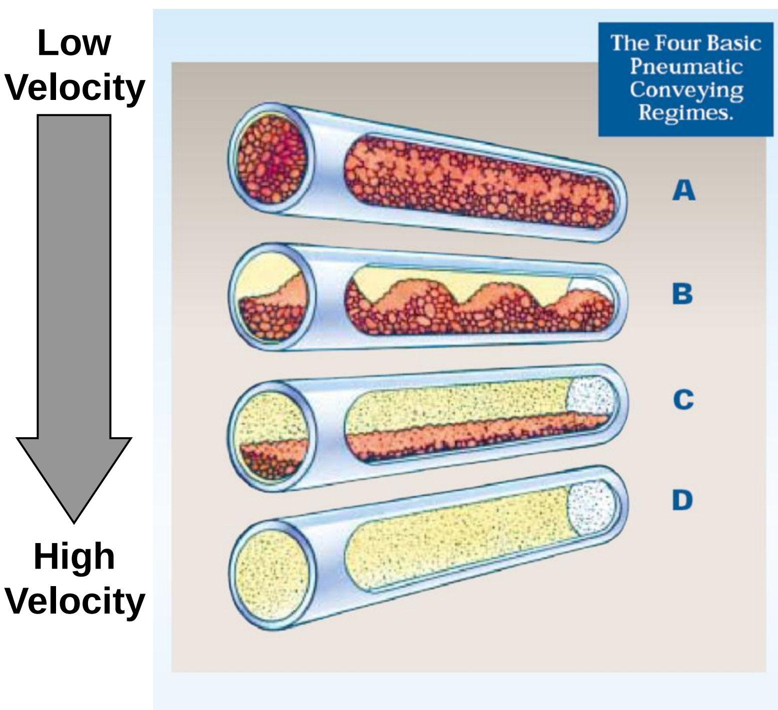
Few moving parts

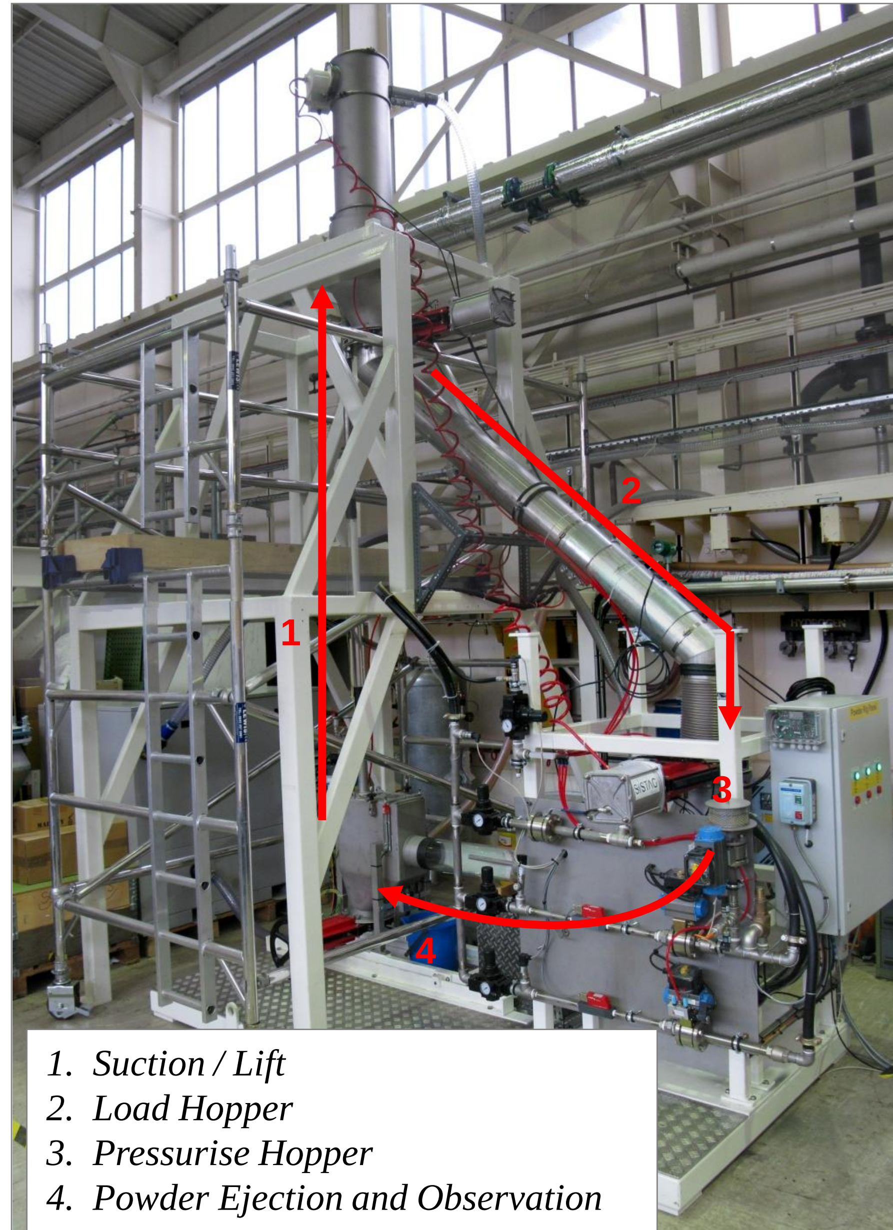
Mature technology

Areas of concern can be tested off-line

Tungsten Powder Test Programme Off-line Flow Rig Development underway

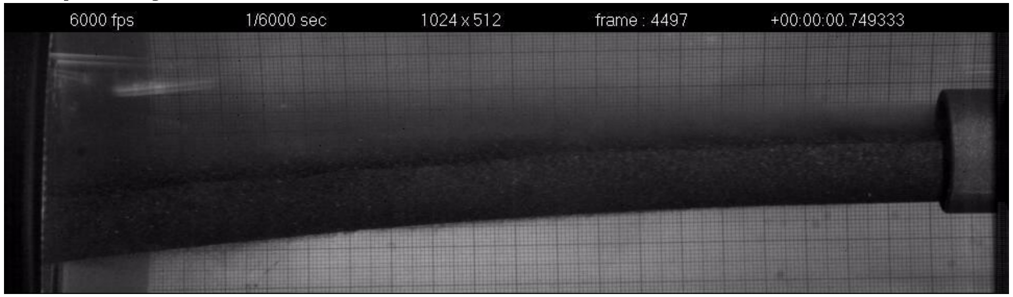
- Dense phase and lean phase studies
- Erosion studies
- Suction at the same rate as ejection achieved
- Theoretical models to predict powder lift pressure drop and choking velocity



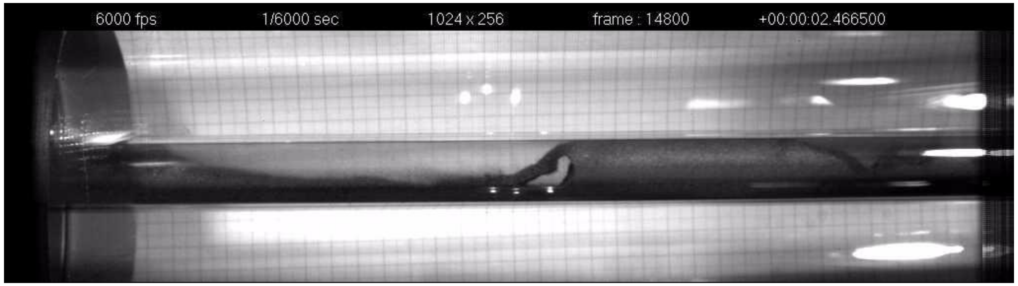


Potential Multi-MW Powder Target Applications

Open jet:



Contained discontinuous dense phase:



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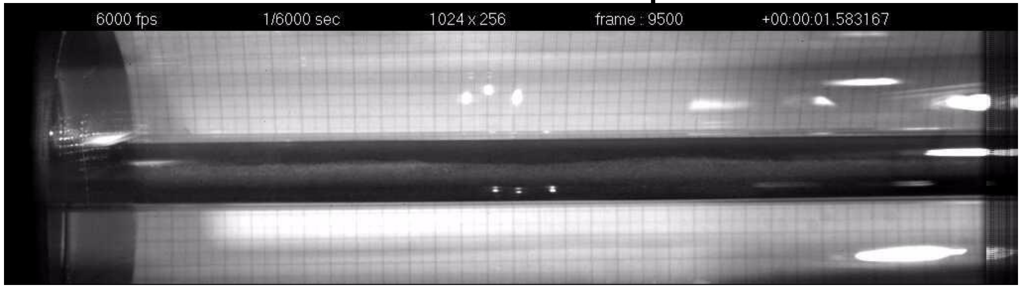
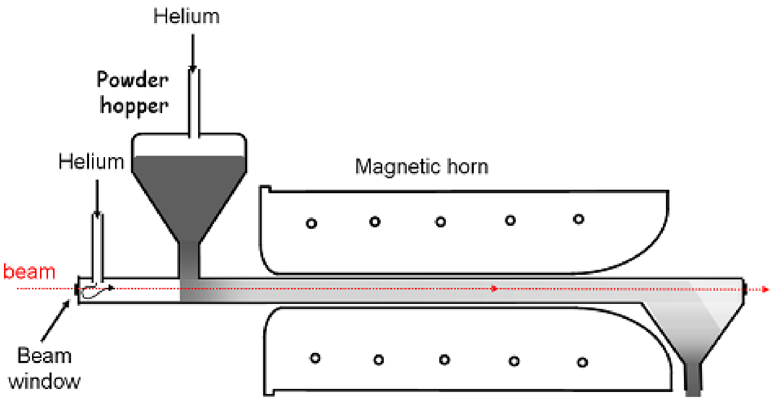
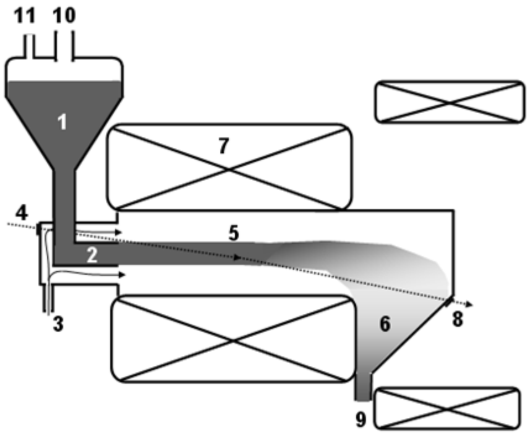




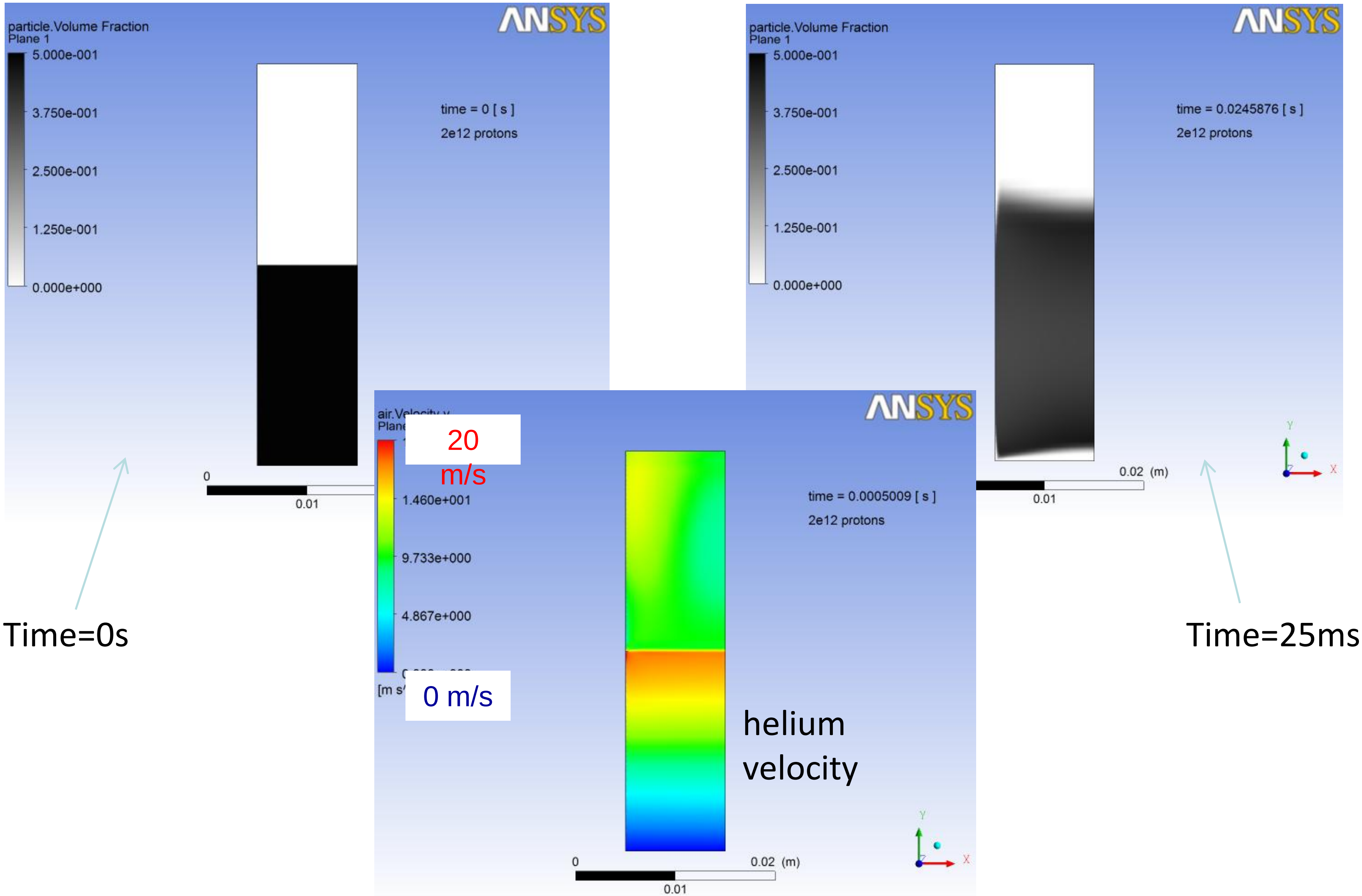
Powder target integrated with magnetic horn for superbeam



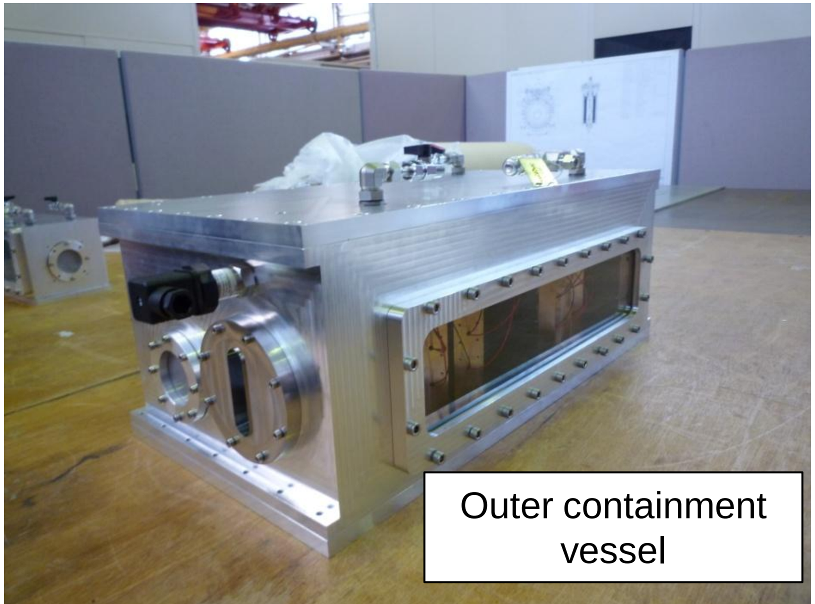
Powder target integrated with solenoid for Neutrino factory

Hiradmat experiment at CERN

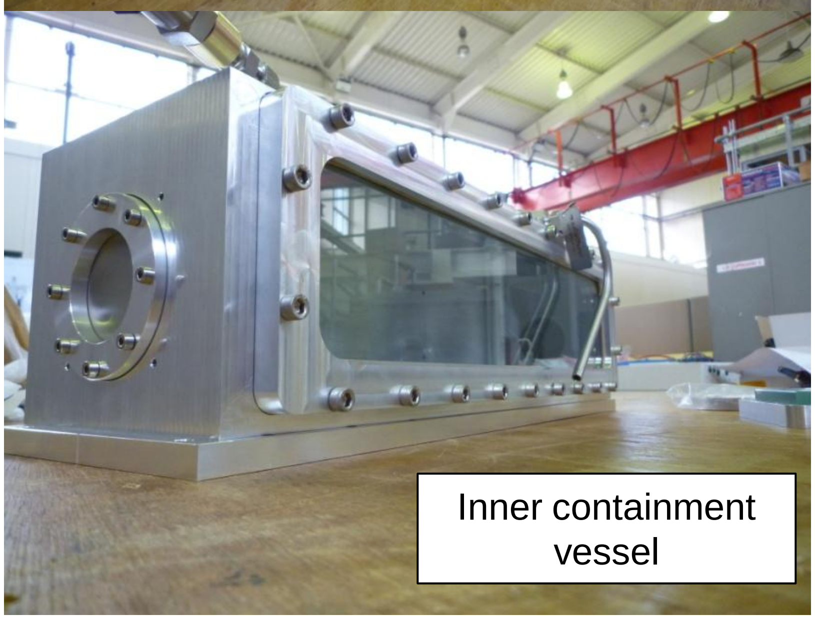
Investigate in-beam response of a tungsten powder sample



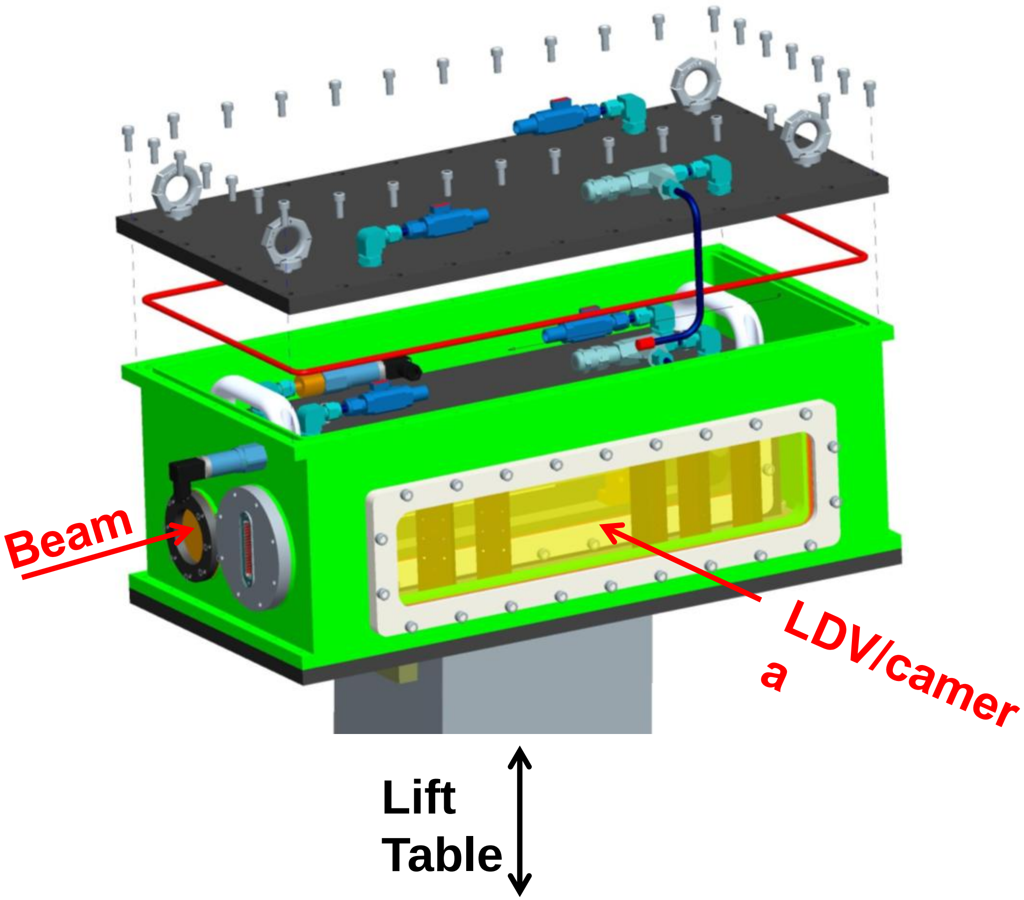
Double Containment Vessel



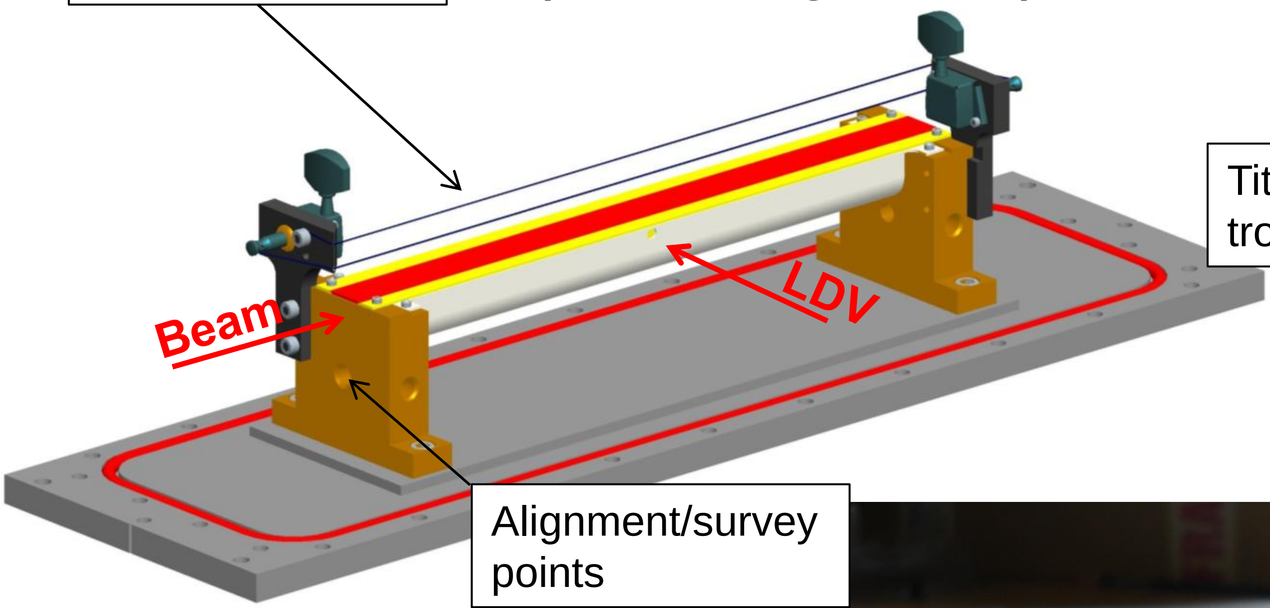
Outer containment vessel

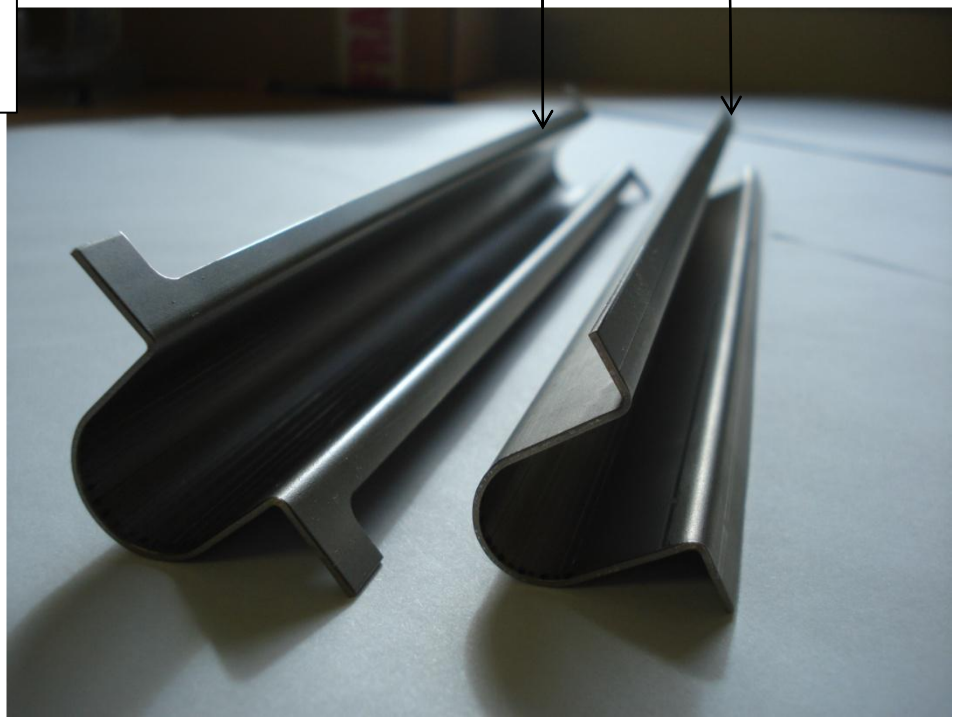


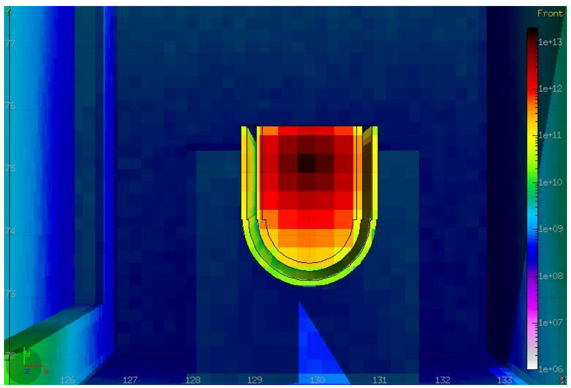
Inner containment vessel



Open Trough Sample Holder







Energy deposited in a cross-section through the sample

Planned Future Work

- Further suction lift experiments
  - Measure particle velocity
  - Measure pressure drop profile
  - Vary powder size distribution

- Continuous flow upgrade

- Erosion studies
  - Identify areas at risk
  - Design to minimise damage

- Heat transfer experiments
  - Fit heat exchanger to powder circuit
  - Reverse heat transfer test
  - Powder cooling of pipe wall

Continuous Flow Upgrade Plan

- Timing of rig processes
- Test powder drop with applied suction

- Replace slide valves with butterfly valves [1]
- Fit additional pressure hopper [2]
- Shorten test section and gravity chute
- Replace rubber tube with bellows [3]

- Reprogram control system