FETS-HIPSTER

(Front End Test Stand – High Intensity Proton Source for Testing Effects of Radiation)

Proposal for a new high-intensity proton irradiation source, based on an existing accelerator at the Rutherford Appleton Laboratory

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Radiate Technical Meeting

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HIPSTER
key points in proposal

- Extension of the Front End Test Stand (FETS) research accelerator currently being commisioned at RAL could provide a unique high-intensity materials irradiation facility.

- Material samples could be located within or upstream of a FETS beam dump and remote handling facilities would be constructed to enable transfer of material samples.

- Activated samples would be supplied to collaborating institutes for post-irradiation examination, for example the NNUF irradiated materials test facility at CCFE (Culham Centre for Fusion Energy).

HIPSTER
key points in proposal

- HIPSTER would be capable of enabling:

- deep (~30 microns), near-uniform radiation damage to moderate levels within reasonable timescales (up to ~100 dpa per annum)

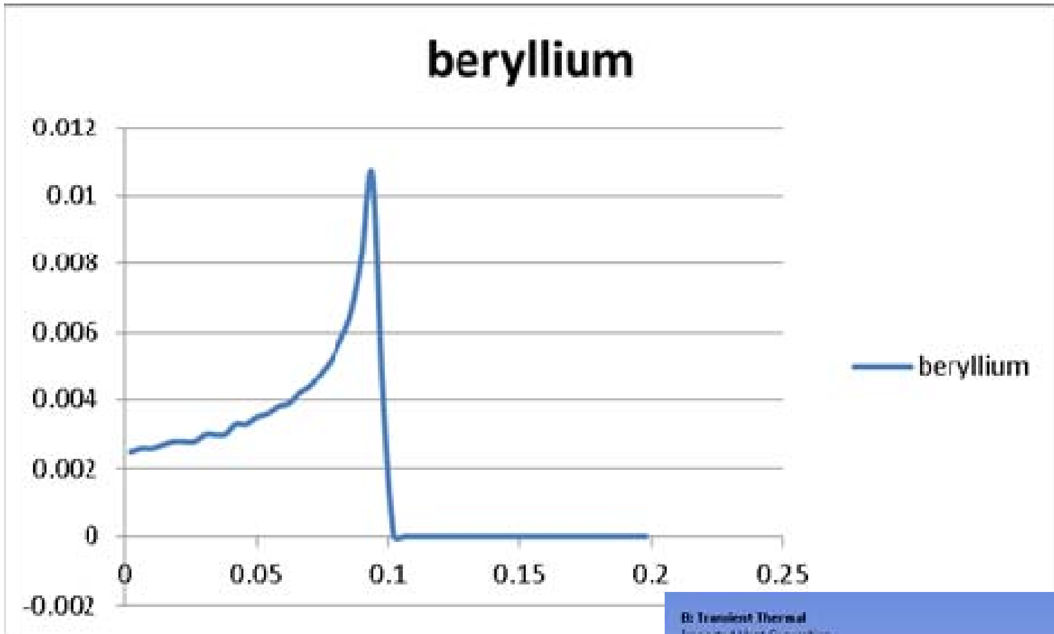
- studies of irradiation induced microstructural changes and bulk mechanical properties and behaviour including: hardening, embrittlement, creep, stress-corrosion cracking, and thermal property changes such as thermal conductivity

- Protons shown to be excellent surrogates for reactor neutrons
- FETS beam can generate radiation damage at end-of-life dpa levels for fission and fusion reactors
- Upgrade to 15-20 MeV attractive to mimic fusion neutrons
- High heat flux source (ref fusion divertor)

FETS beam parameters

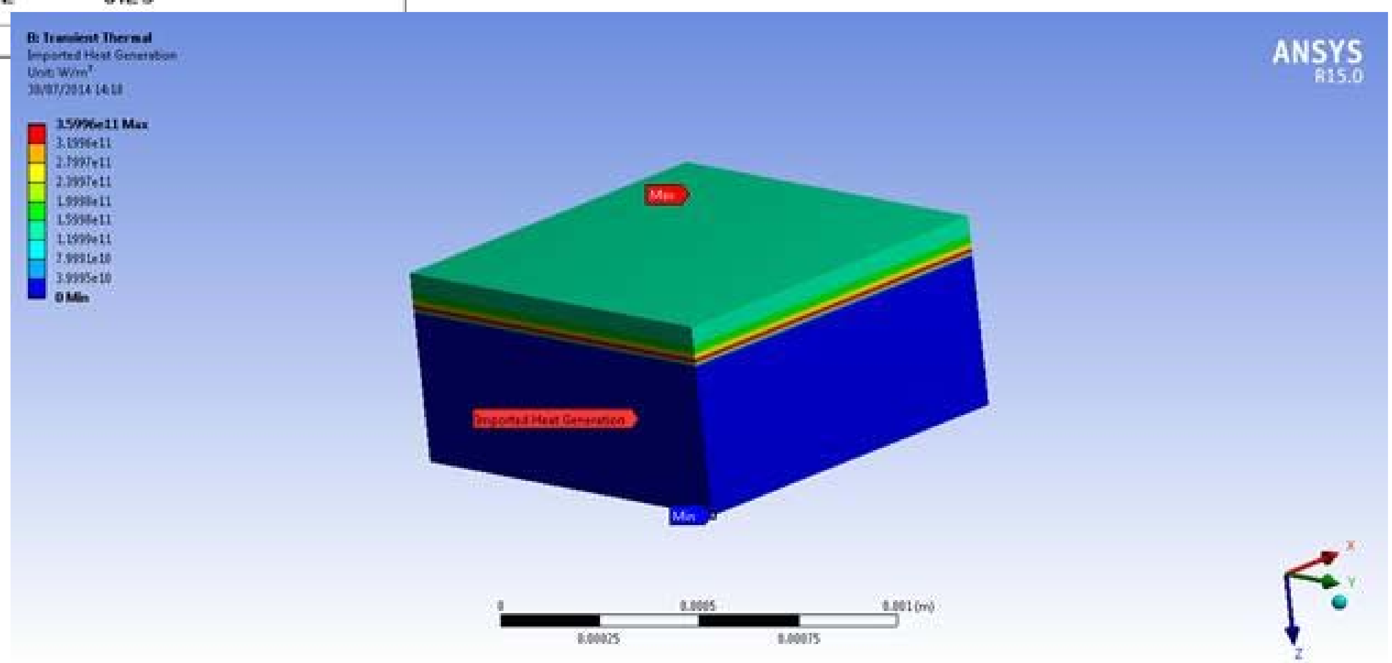
- Proton beam energy = 3MeV
- Beam spot size = 100 to 1e4 cm^2
- Beam Pulse length = 2ms
- Beam Frequency = 50Hz
- Time averaged beam current = 6mA
- Current during beam pulse = 60mA

Example of energy deposition



beam stopped within 0.1mm in a beryllium sample

FLUKA Material	Beam stopping distance [mm]
Ti	0.06
W	0.03
C	0.08
Be	0.1



Thermal Management Challenges

Consider an irradiation sample attached to a water cooled back plate

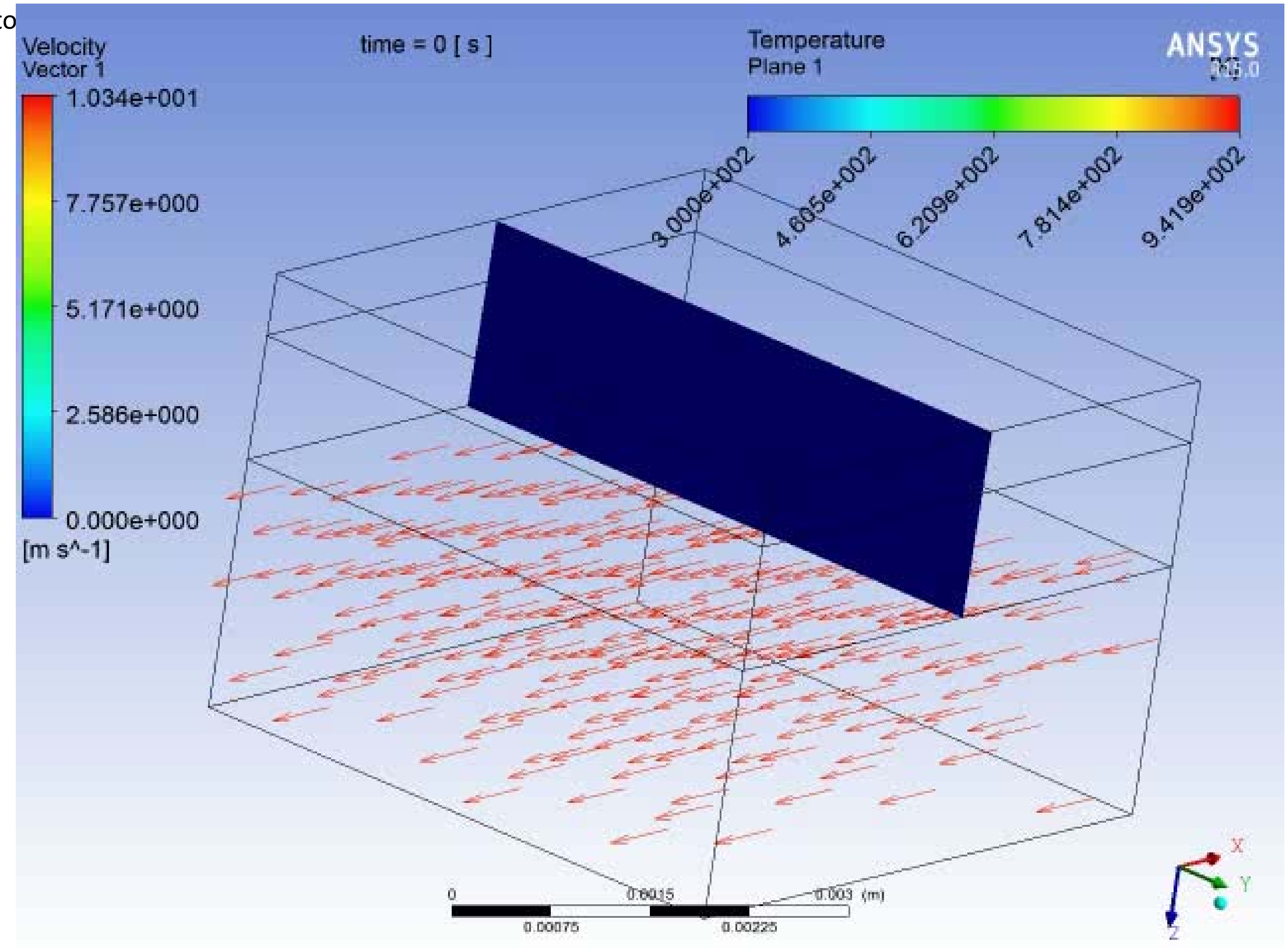
Main Challenges –

Potentially high heat flux to cooling water

Pulsed power density results in unsteady sample temperature

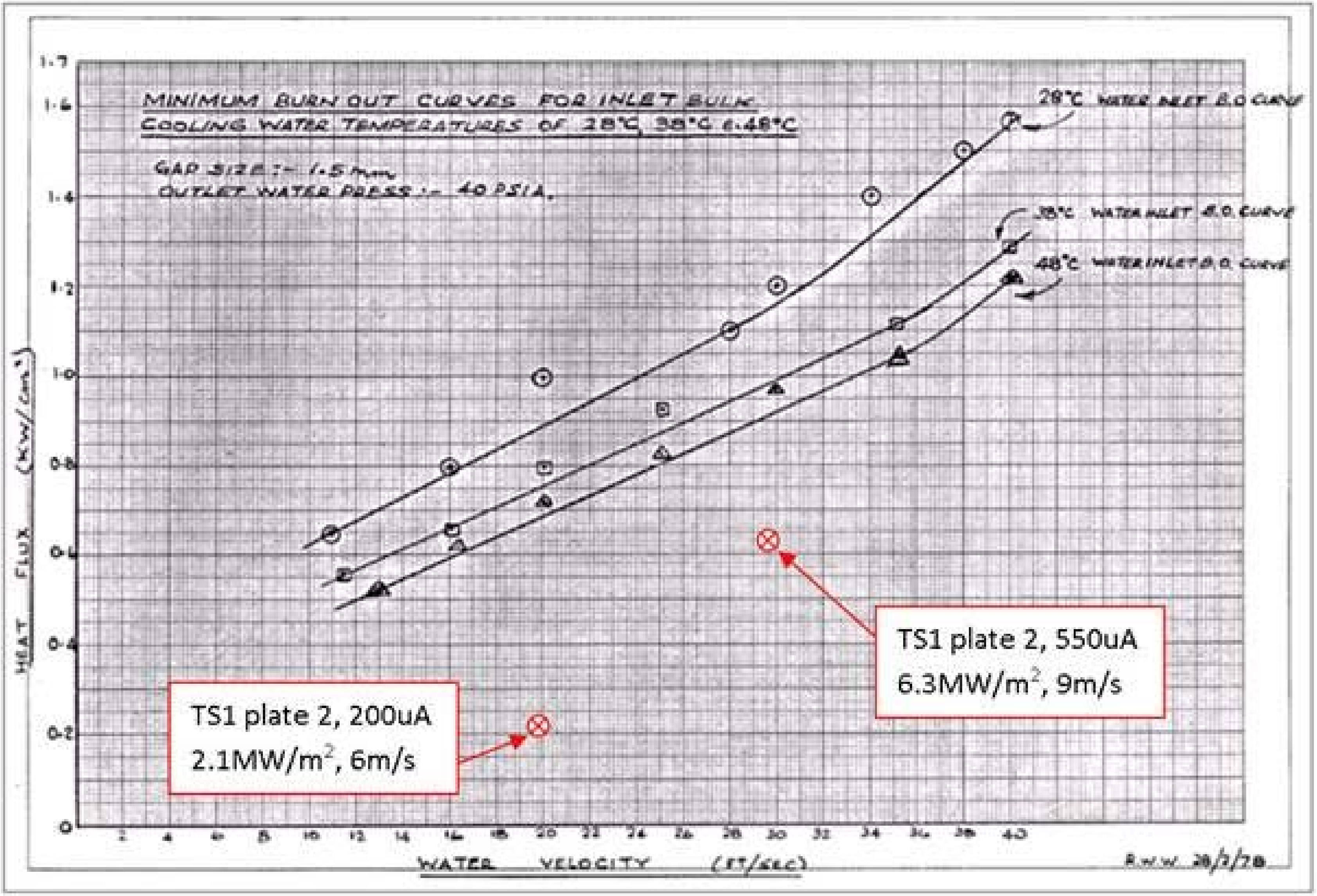
Temperature difference between sample and cooling plate

Click on image to

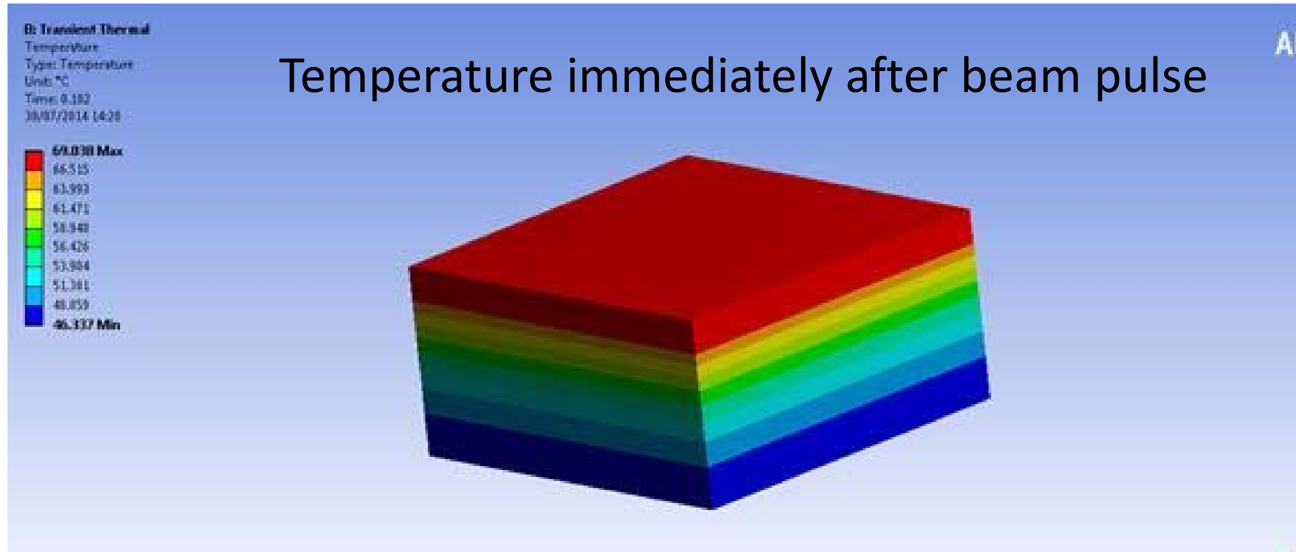


Heat Flux

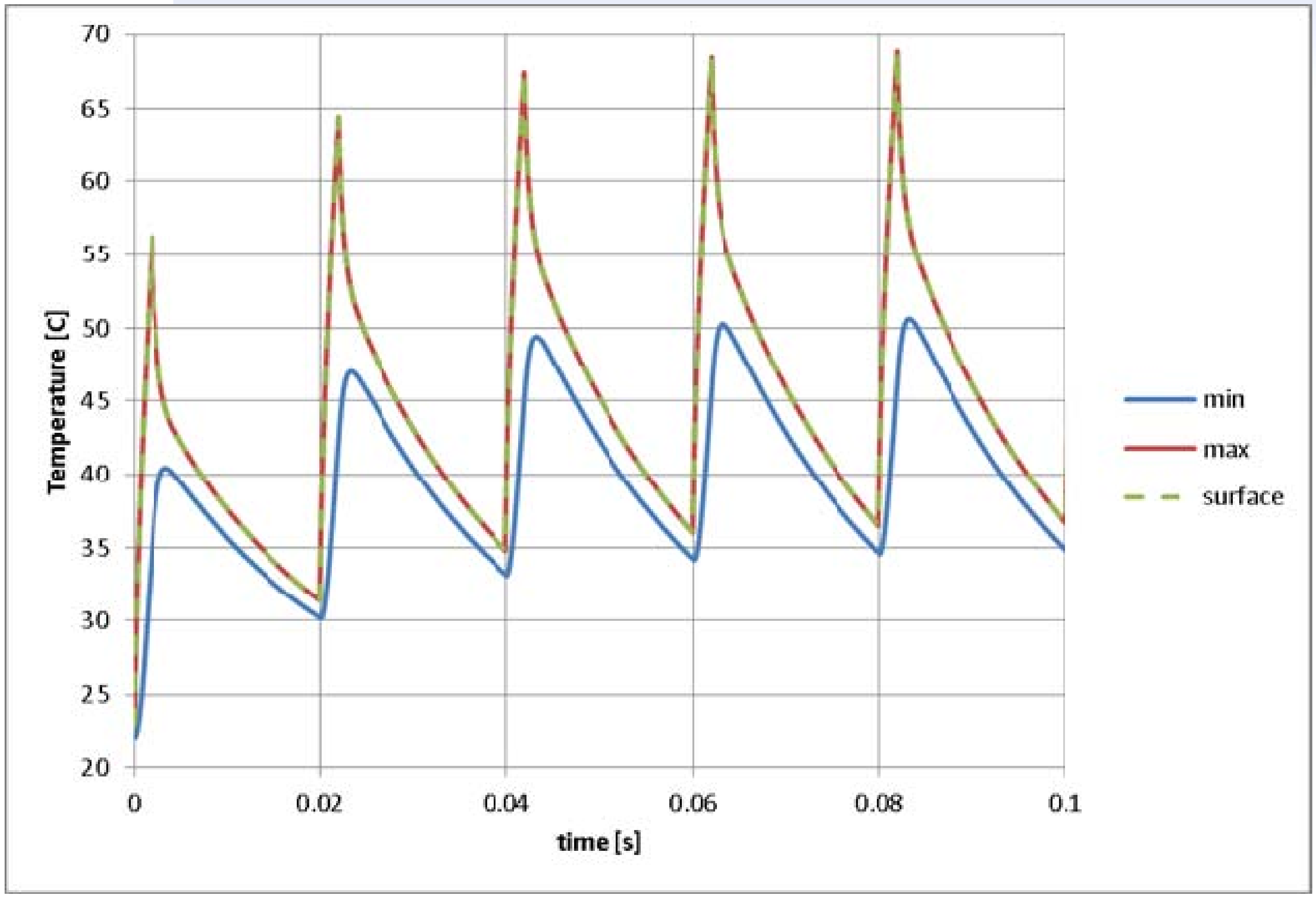
For the range of beam size considered the required heat flux would be a maximum of 1.8MW/m², this is below the heat flux achieved in the ISIS Neutron target TS1 at RAL



Pulsed thermal power deposition

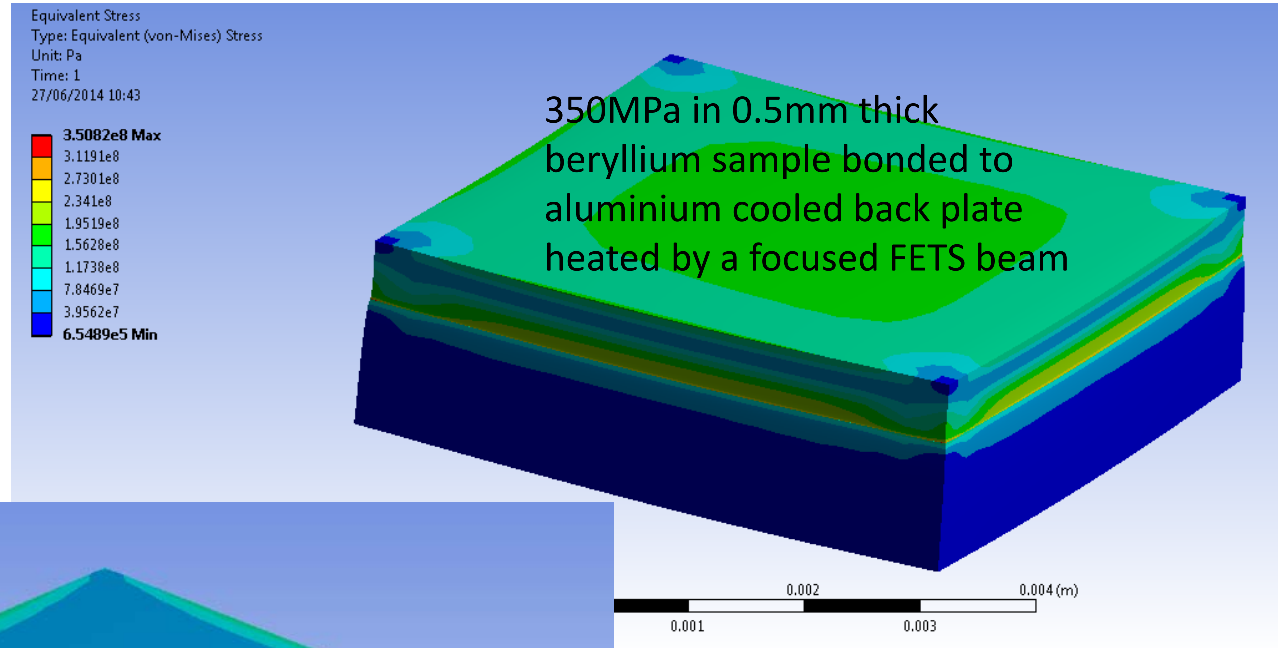


- Resultant temperature fluctuation depends on beam size
- Conduction in the sample during the 2ms beam pulse affects peak temperature
- Surface temperature similar to maximum temperature

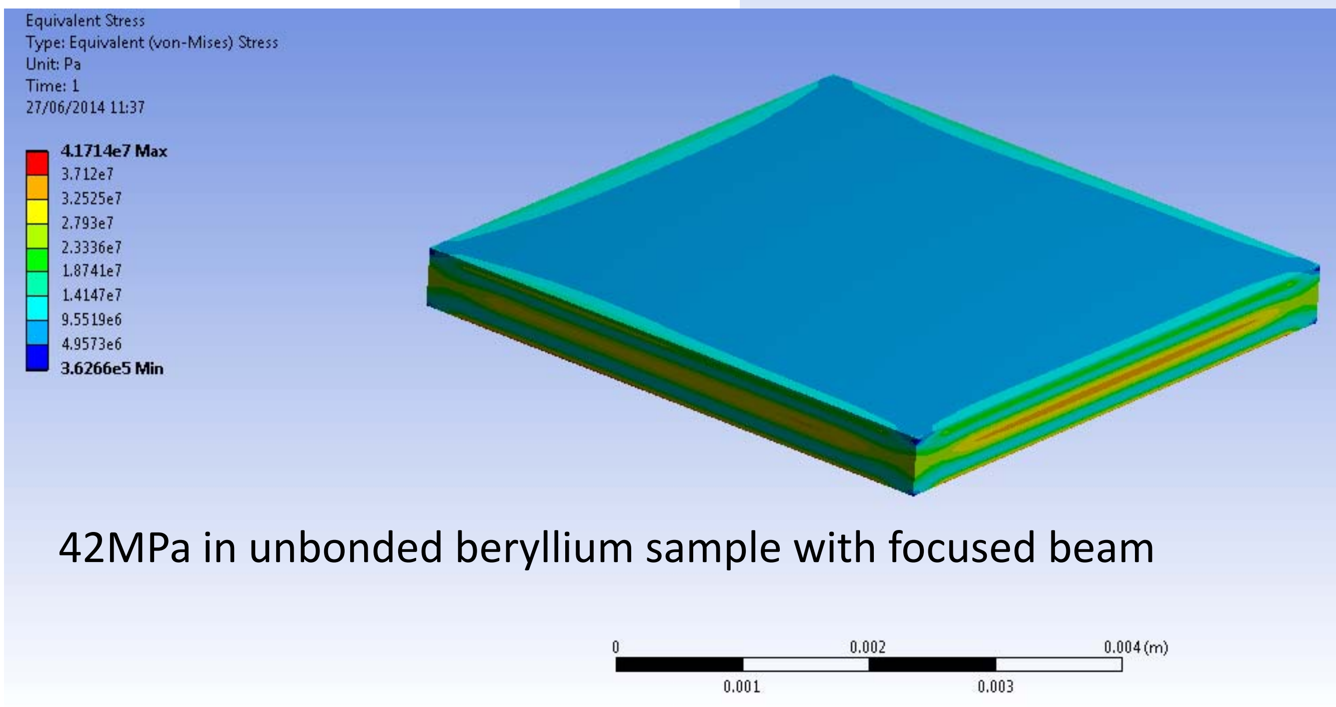


Induced Stress in Sample

High stresses arise with a focused beam on the sample especially if it is perfectly bonded to a cooled back plate



350MPa in 0.5mm thick beryllium sample bonded to aluminium cooled back plate heated by a focused FETS beam



42MPa in unbonded beryllium sample with focused beam

Maximum temperature and stress in samples depends on beam size, sample shape, and attachment to cooled back plate.

Summary of FETS HIPSTER Operating Parameters

Target side length	Target area	Power density	Dpa/s			days/dpa			Max temperature °C			Temperature Fluctuation per pulse		
cm	cm^2	W/cm^2	Fe	W	Be	Fe	W	Be	Fe	W	Be	Fe	W	Be
10	100	180	1.33E-05	2.37E-05	1.22E-06	0.87	0.49	9.49	86	75	69	46	42	33
20	400	45	3.32E-06	5.92E-06	3.05E-07	3.48	1.96	37.97	38	35	33	11.5	10.6	8.2
50	2500	7.2	5.32E-07	9.47E-07	4.88E-08	21.76	12.22	237.3	25	24	24	1.8	1.6	1.3
100	1.00E+04	1.8	1.33E-07	2.37E-07	1.22E-08	87.04	48.91	949.19	23	23	23	0.5	0.4	0.3

A wide range of target area (beam spot size) have been considered.

SRIM calculations highlight that large dpa values are achievable even with the most blown up beam considered

The larger the beam the easier the thermal management issues are to deal with.

With a beam area of 2500 cm^2 the required cooling heat flux is easily manageable at $0.07 MW/m^2$, the predicted sample temperature fluctuation is less than 2K and yet 20dpa/fpy in Tungsten is still possible.

FETS-HIPSTER Summary

- FETS can deliver beam currents far in excess of any existing proton irradiation facilities
- Beam energy of 3MeV (possibly upgradeable to 15-20MeV) is of interest for fission and fusion communities
- High levels of dpa achievable in short time frames
- ‘Deep’ irradiation (30 microns) enabling evaluation of bulk material mechanical properties
- Manageable deposited thermal power density
- Cheaper and shorter realisation time than proposed future irradiation facilities such as FAFNIR and IFMIF
- Brought to attention of joint UK Research Council ‘fusion for energy’ strategy