SPL-SB and NF Beam Window Studies

Stress Analysis

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March 2010

Variables studied

Beam parameters:

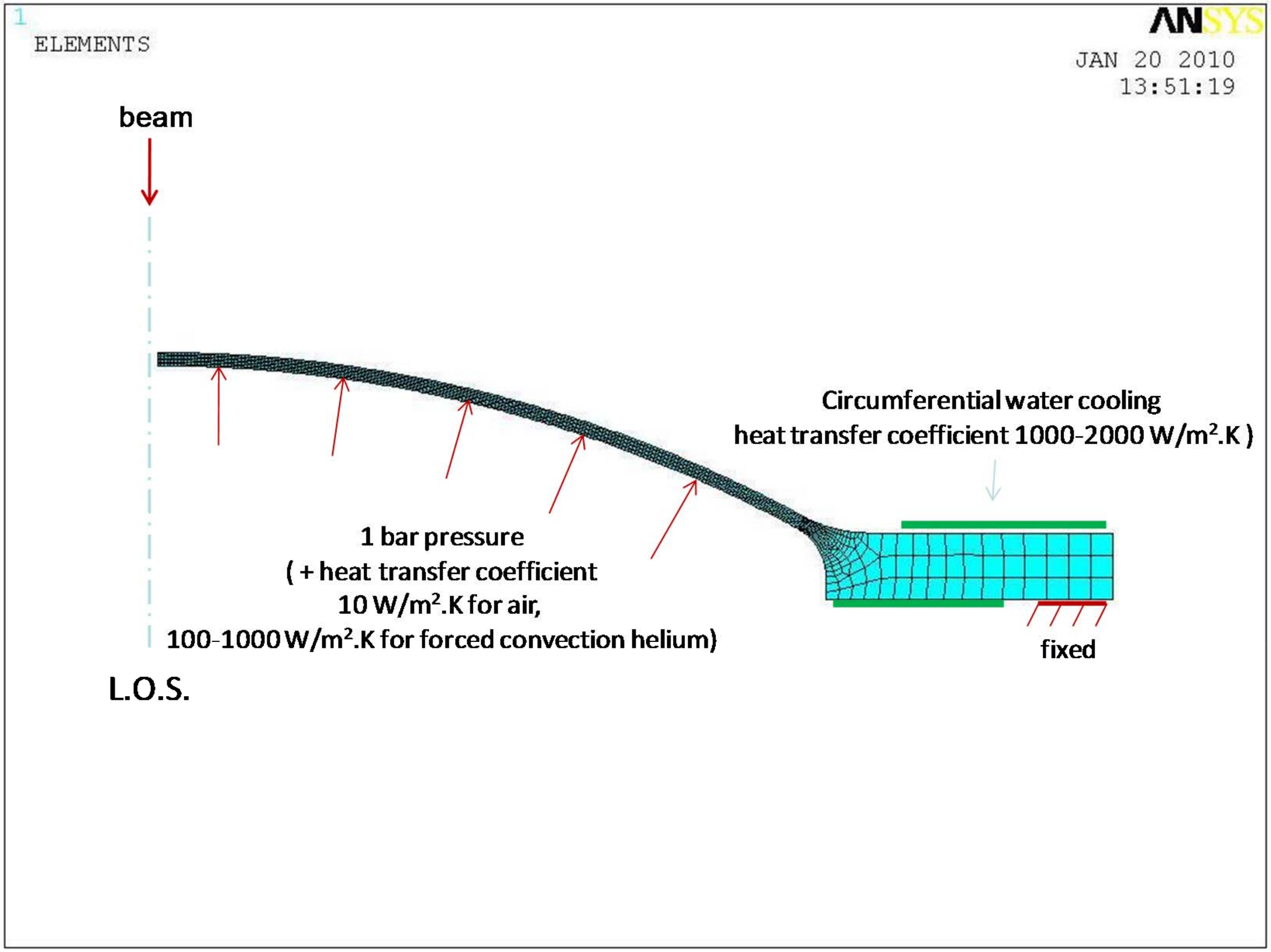
- Power: 4 MW (Divided as1 MW each for four targets/windows)
- Energy: 5 GeV
- 1.5 x 10^{14} protons per pulse
- Frequency: 12.5 Hz
- Pulse length: 5 microseconds
- Beam sigma: 4 mm

Design considerations:

- Materials: Beryllium (S65C), Titanium alloy (Ti-6Al-4V)
- Cooling methods: direct forced convection helium and circumferential water

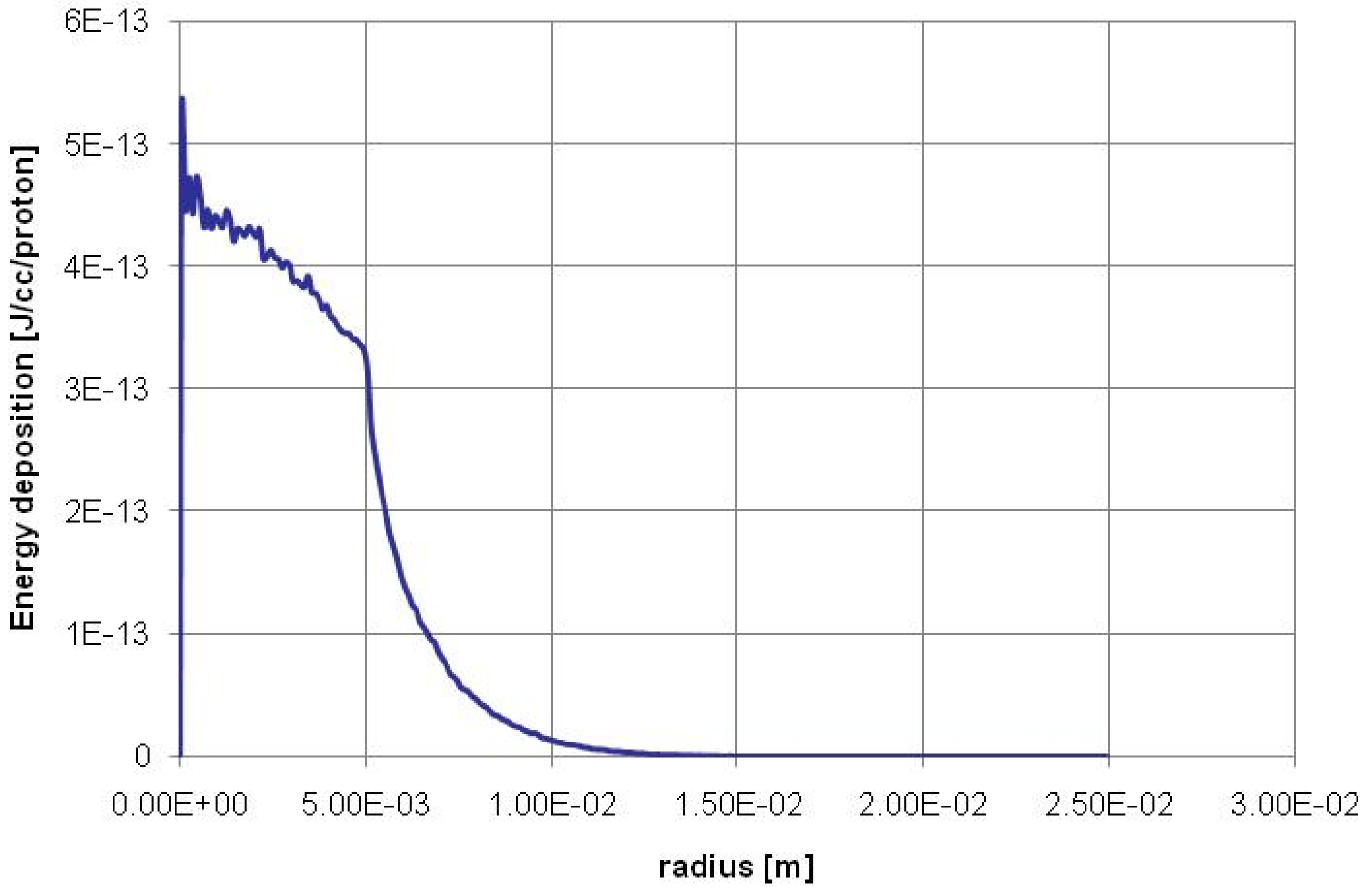
Beam parameters taken from *EUROnu WP2 Note 09-11*

Typical ANSYS model showing cooling options



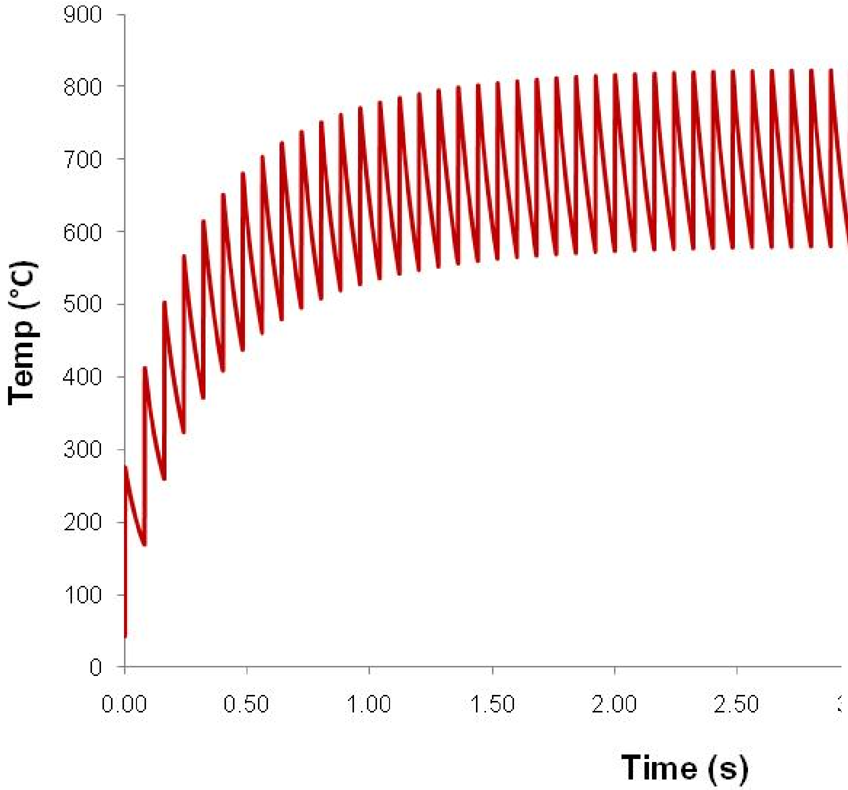
ANSYS Multiphysics v11 used with coupled field elements (axisymmetric model)

Energy deposition profile

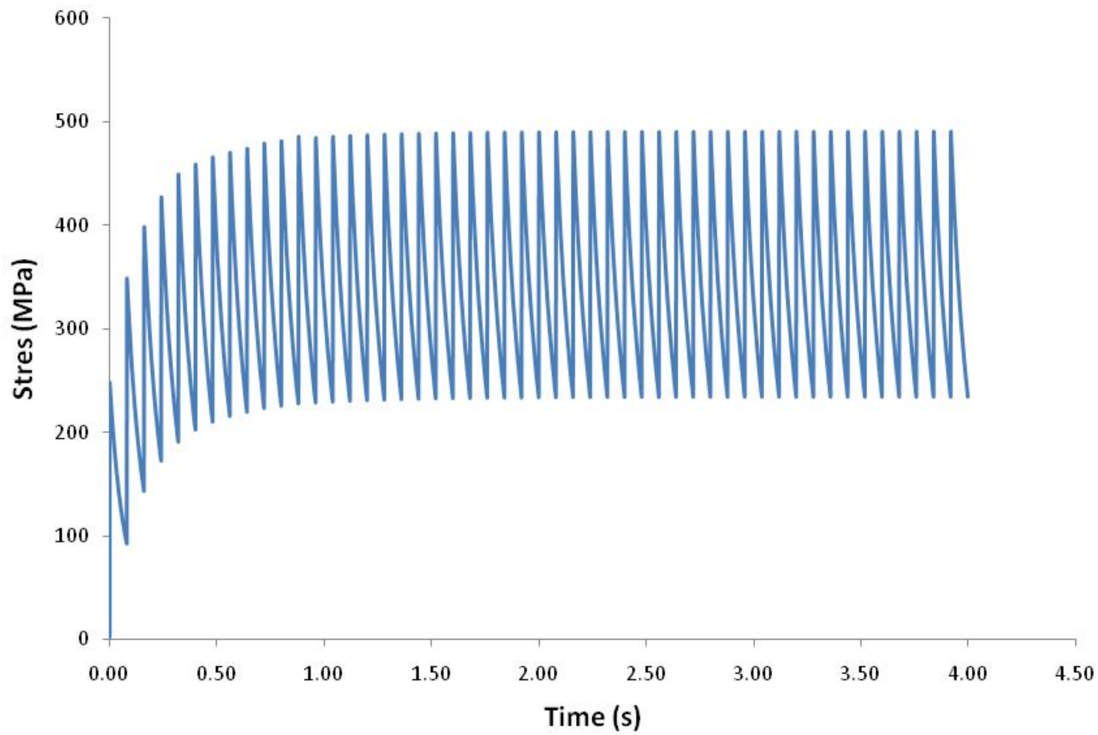


NOTE: Data produced by Tristan Davenne (RAL) using Fluka.
A Gaussian approximation of this data has been used in ANSYS for simplicity.

Helium cooled Ti-6Al-4V window (like T2K) is not an option



50 pulses (4 seconds)



0.25 mm thick titanium alloy window
Direct helium cooling
(assumes 1000 W/m^2K)

Peak stress of 500 MPa is above yield stress for titanium at 800°C.

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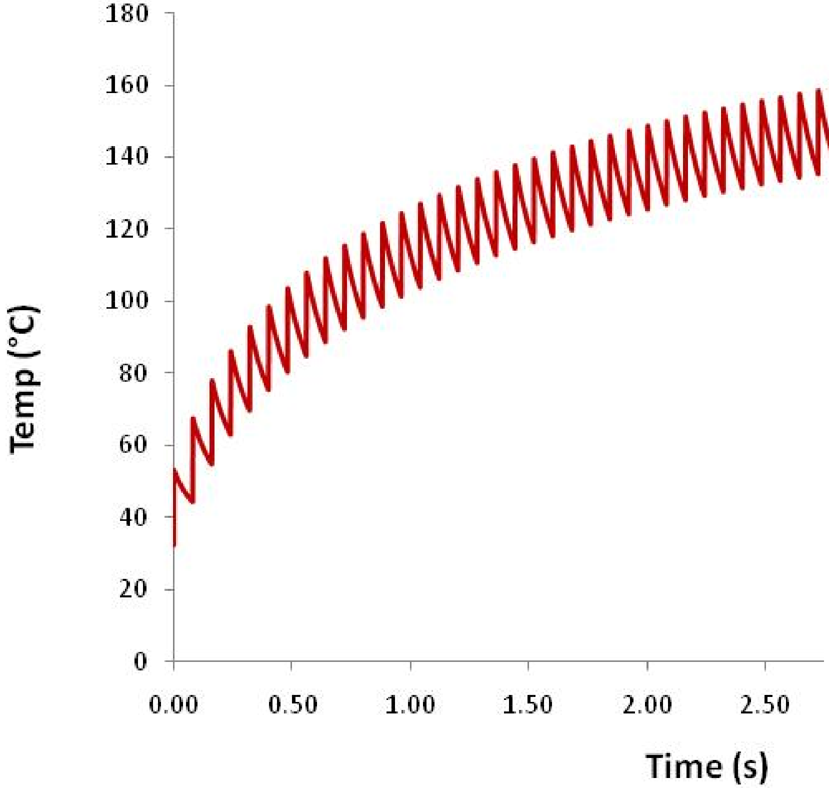
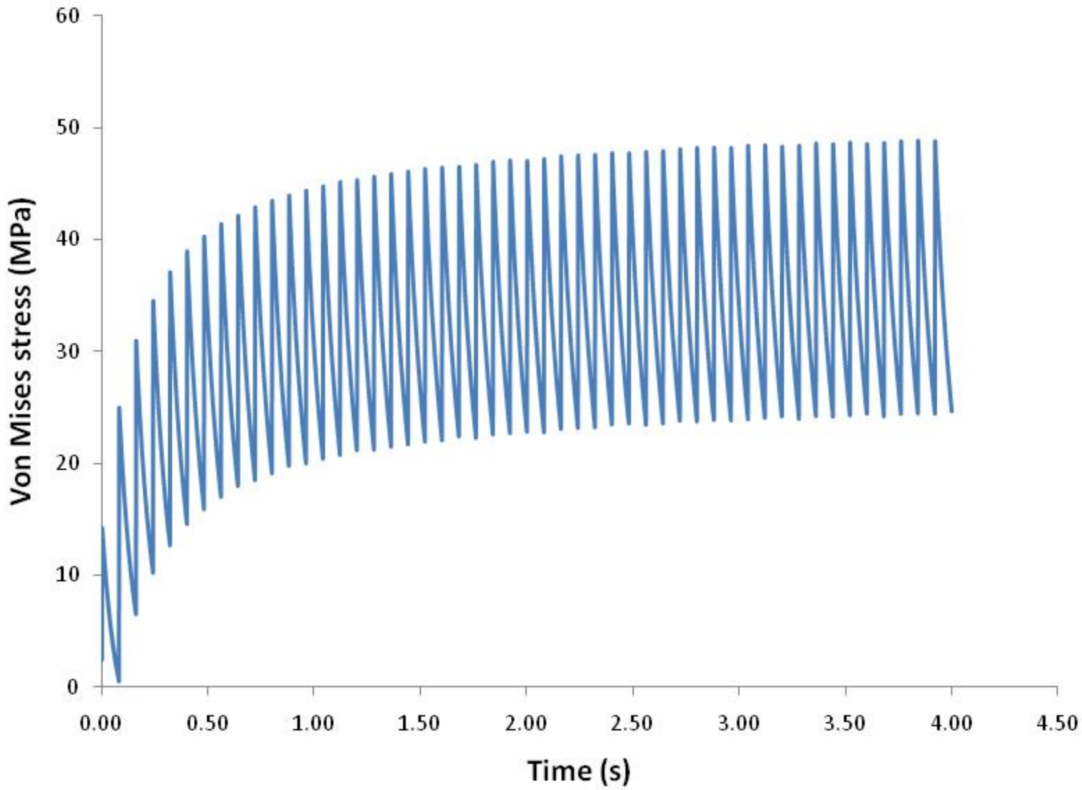
Circumferentially water cooled beryllium window





0.25 mm thick beryllium window
Circumferentially water cooled
(assumes 2000 W/m^2K)
Max temp ~ 180 °C
Max stress ~ 50 MPa (yield ~ 270 MPa)
Acceptable!

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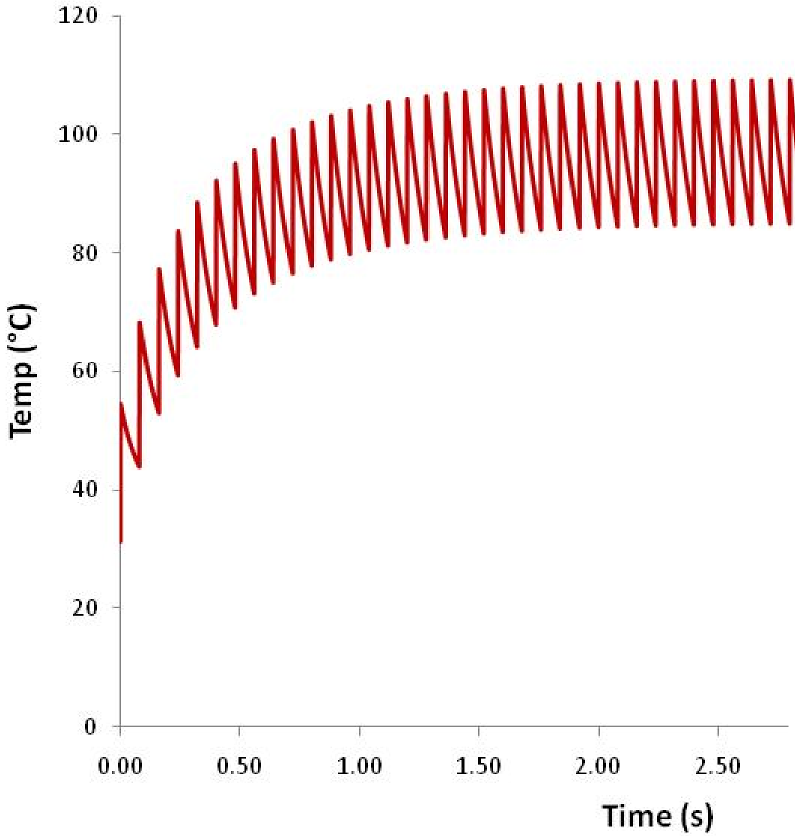
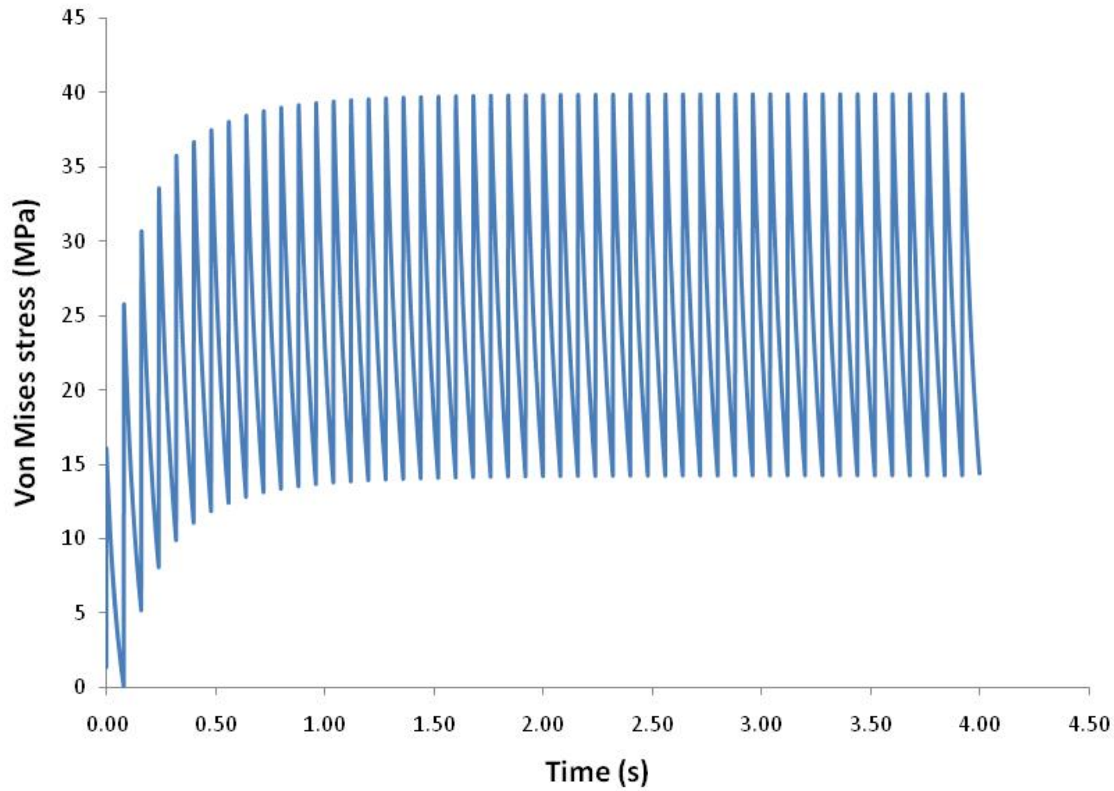
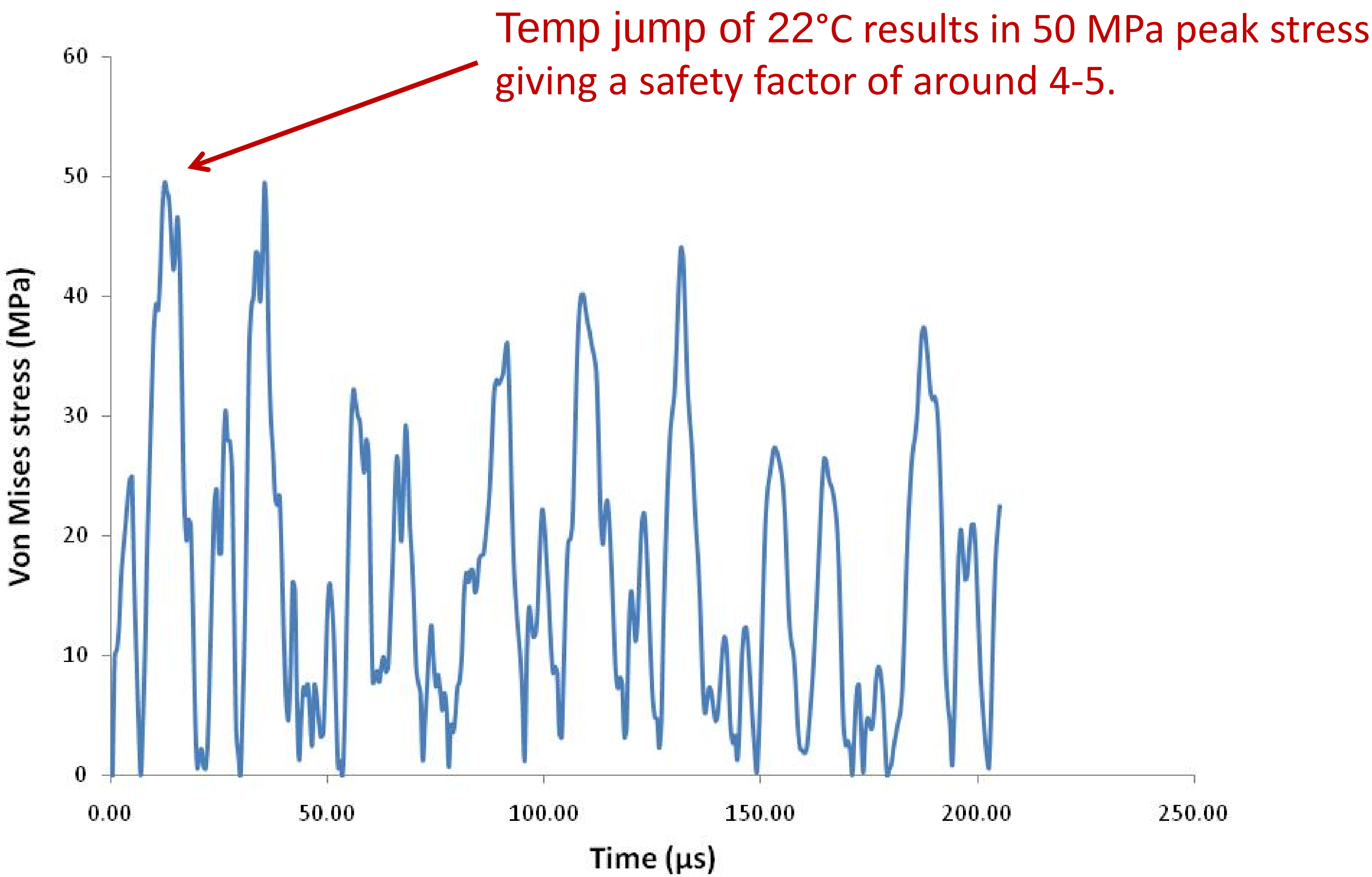
High velocity helium cooled beryllium window



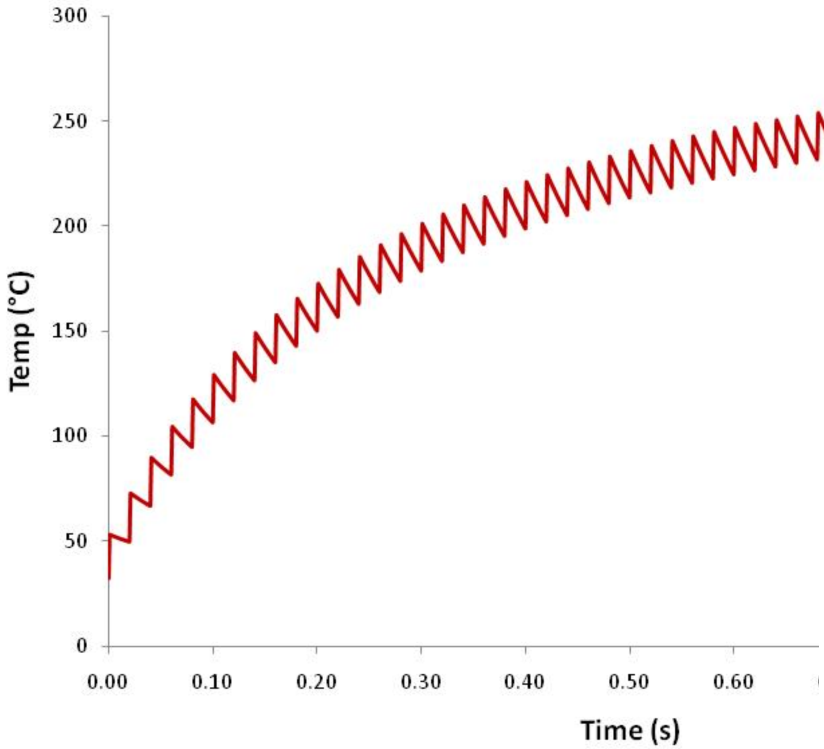
0.25 mm thick beryllium window
Direct helium cooling
(assumes 1000 W/m^{2}K)
Max temp 109 °C
Max stress 39 Mpa
Better!



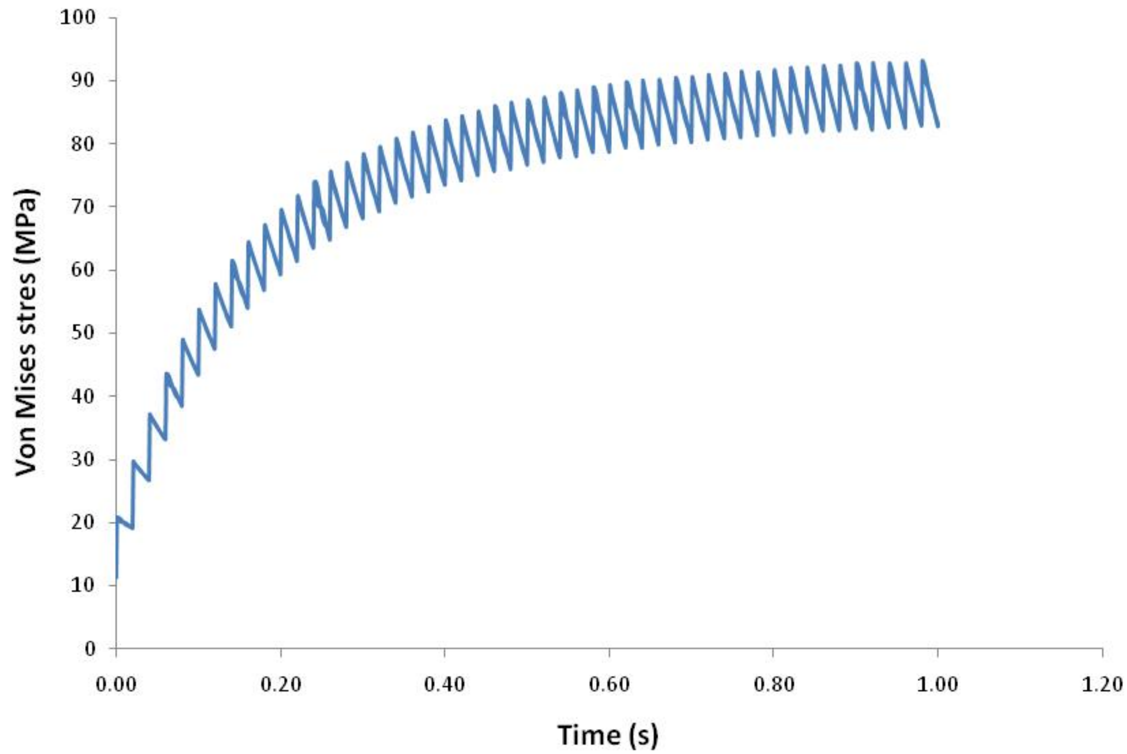
‘Shock’ stress due to single pulse in beryllium window



4 MW window for neutrino factory?



50 pulses (1 second)



Yield strength of beryllium @ 260°C is around 200 MPa. This leaves a safety factor of about 2 for a beryllium neutrino factory window with these beam parameters.

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Conclusions

1. High frequency beam makes cooling the main challenge for any window. Actual thermal stress due to each pulse is within acceptable limits.

2. Difficulty in cooling a titanium window makes this a bad choice for SPL beam parameters.

3. High frequency beam with low protons per pulse makes beryllium window a possibility due to its high thermal conductivity. Either direct helium cooling on the beam spot or circumferential water cooling may be feasible.

4. Neutrino factory window may be possible with this beam parameters, though safety factor is small and radiation damage would quickly become an issue.