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The T2K Beam Window

Neutrino Beam and Instrumentation Conference
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- Window assembly design
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  - Pillow seals
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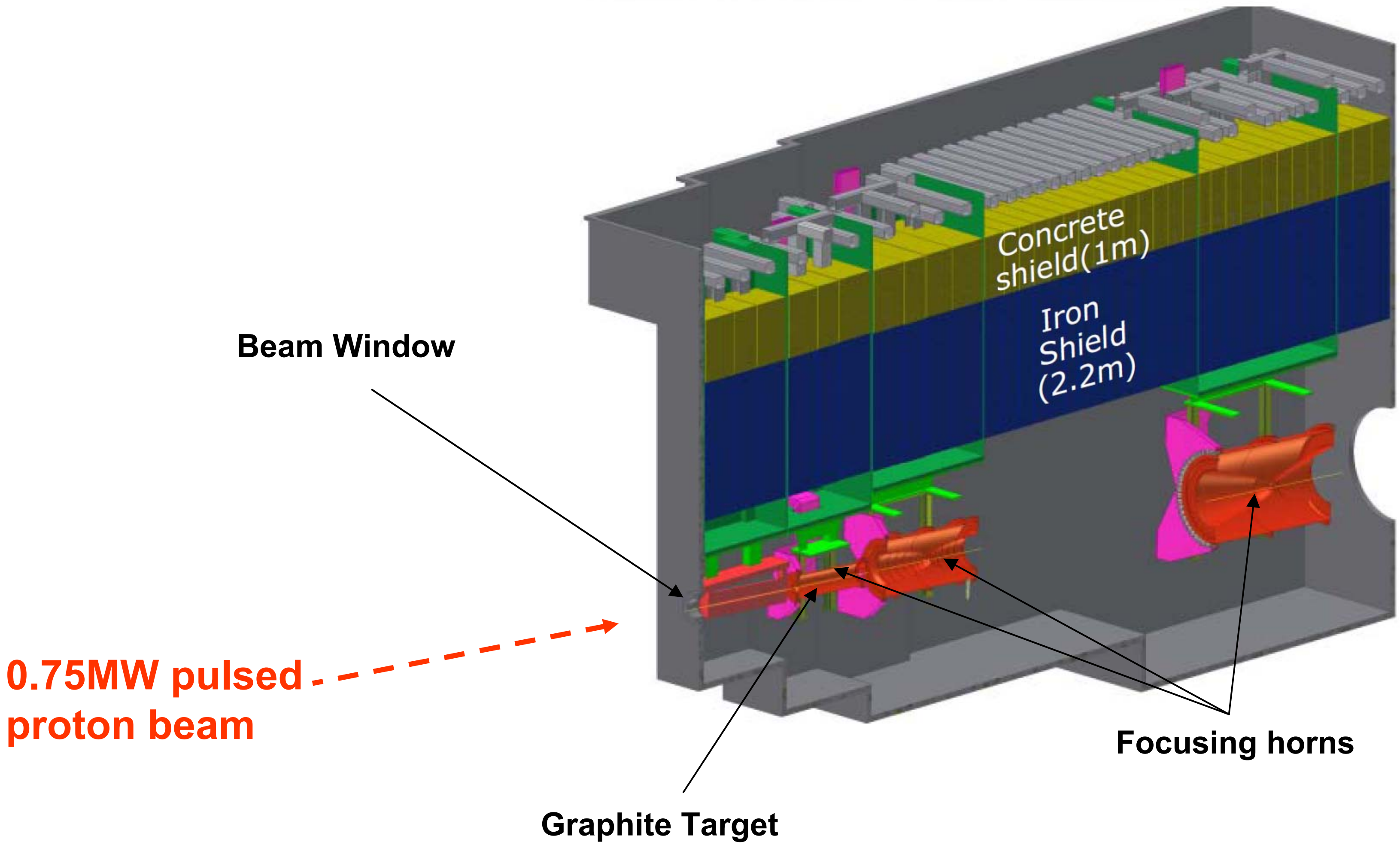
T2K Target Station



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Transient Stress Analysis

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The proton beam

- 8 bunches 58 ns each separated by 598 ns gaps
- Total pulse length approximately 5 μs
- For 30 GeV beam energy, 1 pulse every 2.1 seconds
- 3.3×10^{14} protons per pulse deposited

Induced stresses in window

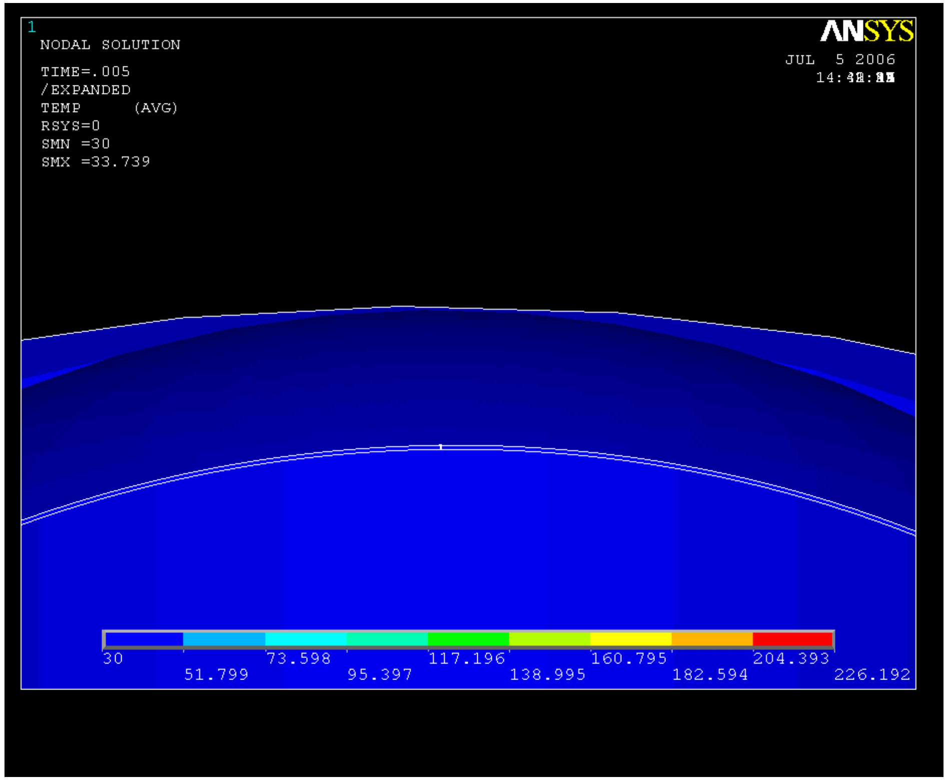
- Constant internal pressure on upstream window
- Window heating and cooling between pulses results in transient thermal stress
- “Shock” due to pulsed beam induces stress waves

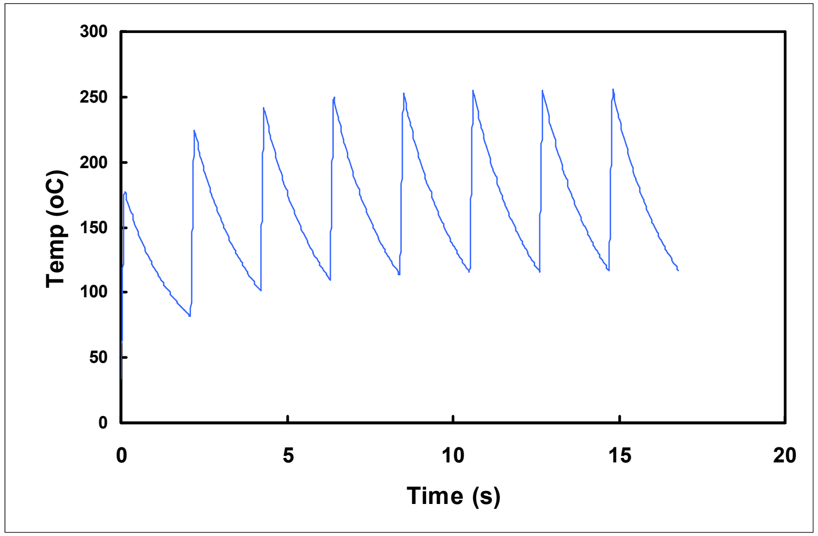
Preliminary Analysis[1]

- Ti-6Al-4V considered most suitable material.
- Adopting hemispherical shape makes stress due to pressure negligible, compared with thermal stress.
- Average thermal stress controlled by helium cooling.
- Dominant stress mode results from temperature rise due to the pulsed nature of the proton beam.

1. Y. Yamada (KEK).

Transient window temperature





Heat transfer coefficient
= 200 Wm2/K external and 10 W/m2K internal
Beam energy = 30 GeV
Frequency = 0.48

Simulation shows temperature distribution over 5 pulses (10 seconds)

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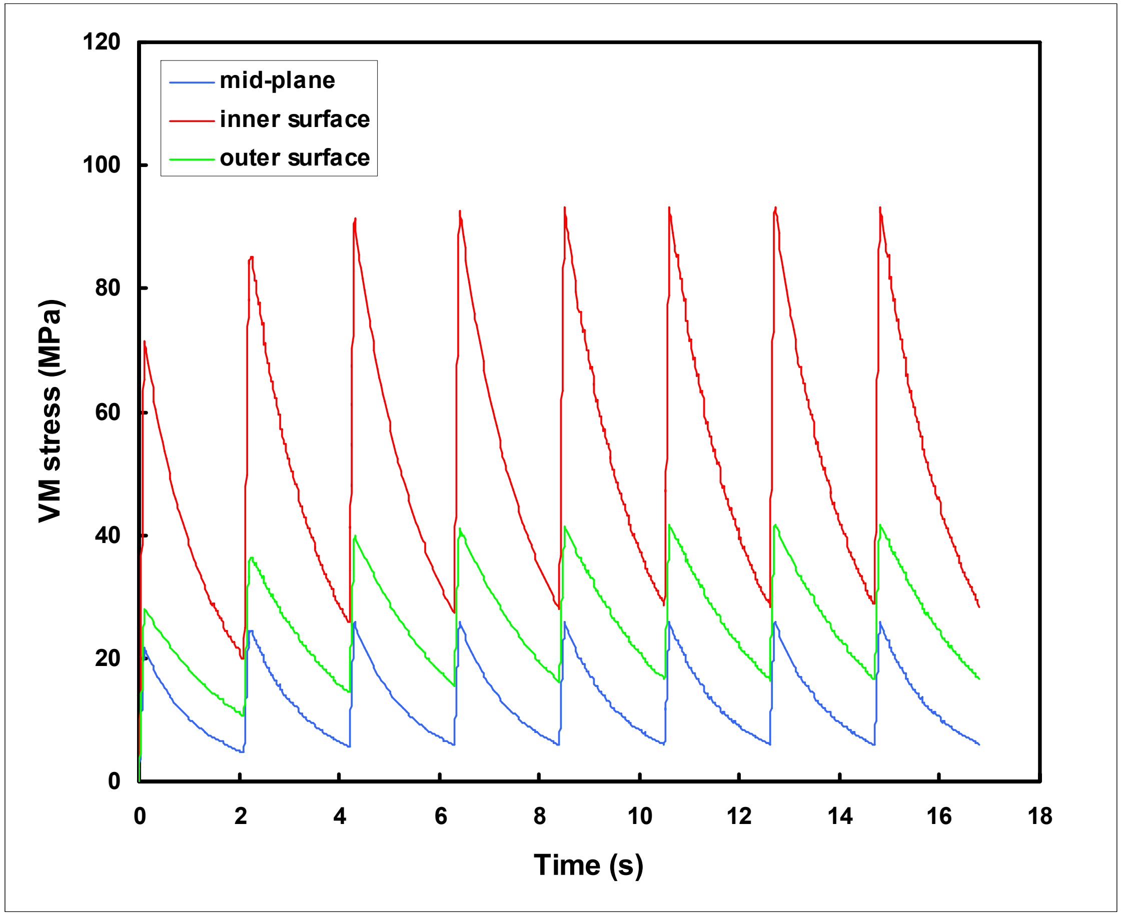
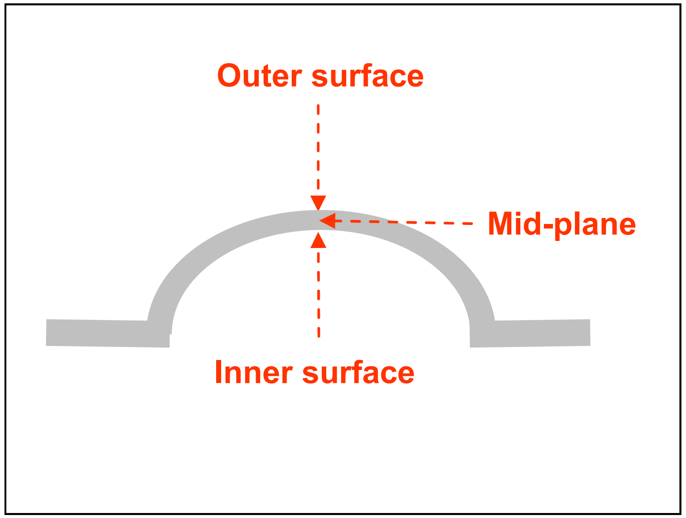
Transient window stress





<u>30 GeV – 8 consecutive pulses</u>

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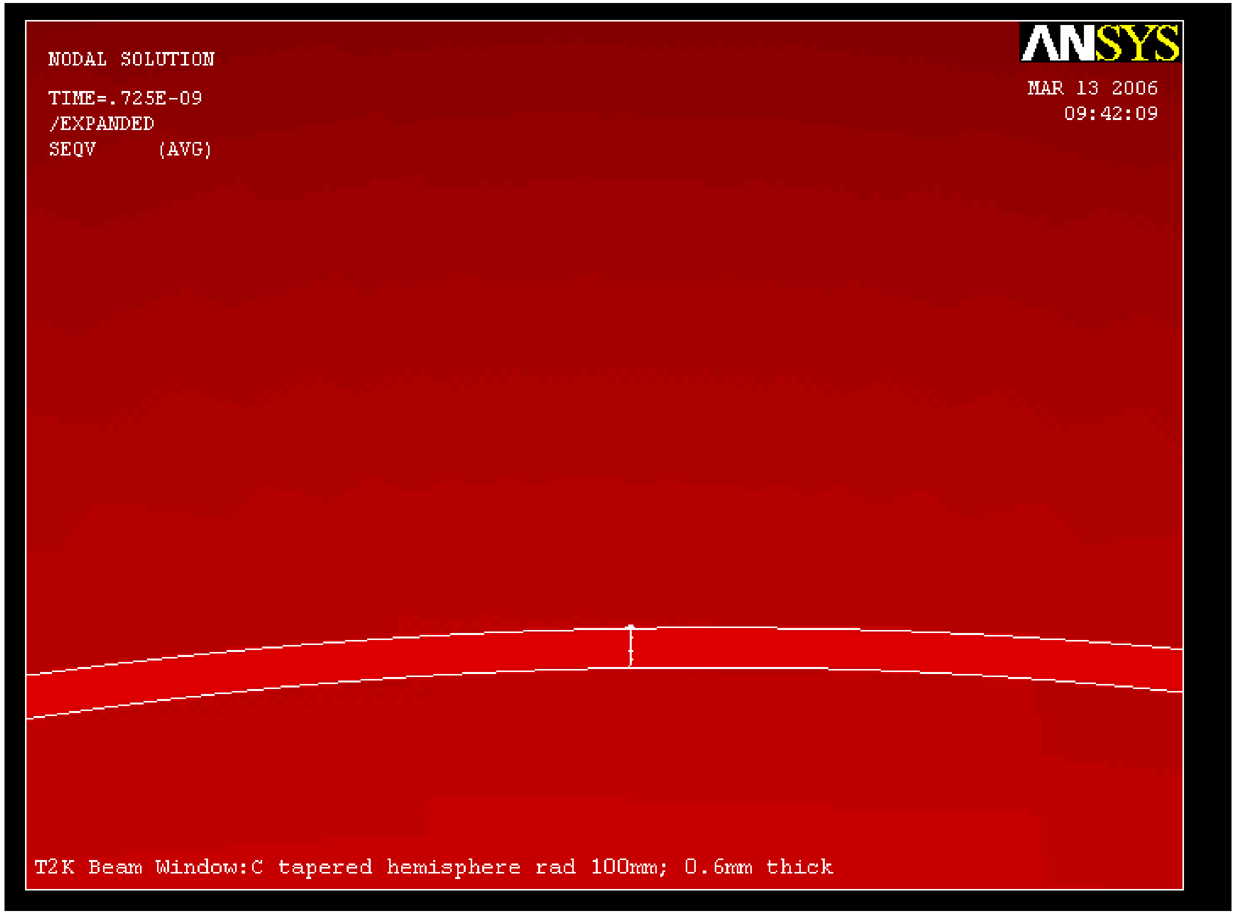
Stress Waves in Hemispherical Window



Simulation shows stress wave development in a 0.6 mm thick hemispherical window over first two bunches of pulse.

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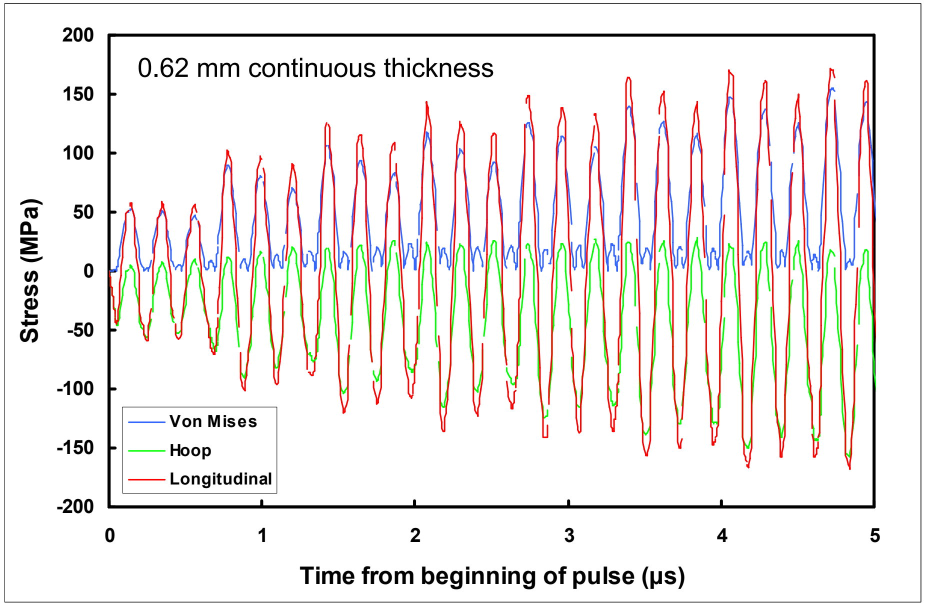
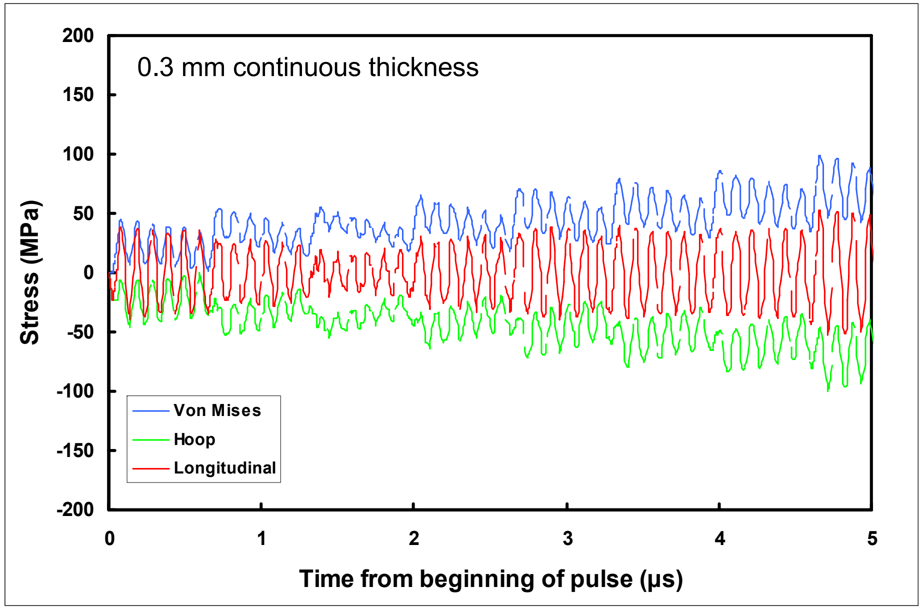
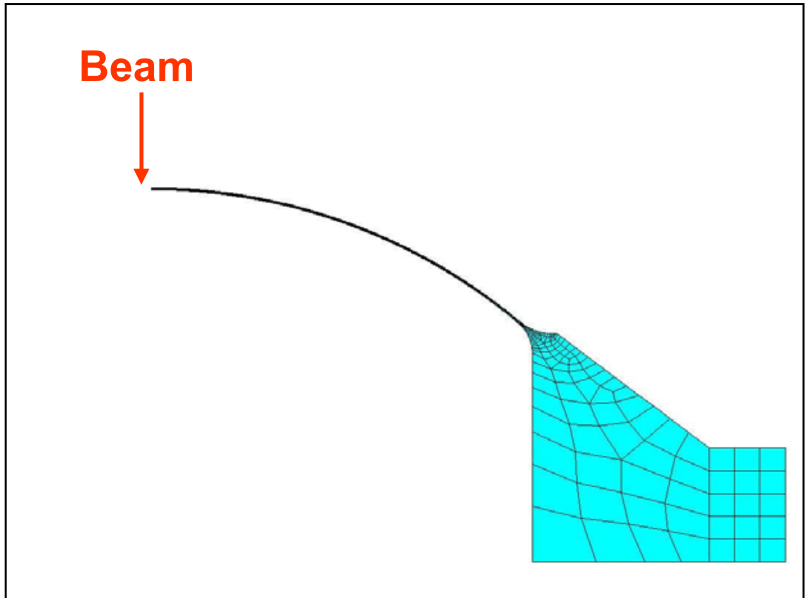
Stress waves over 8 bunches







ANSYS axisymmetric model

For 0.62 mm thickness, constructive interference between bunches amplifies the longitudinal stress waves.
For 0.3 mm thickness, longitudinal stress is not cumulative as each bunch arrives. Stress waves are not in step with pulse bunches. Constructive interference of through-thickness stress waves does not occur.

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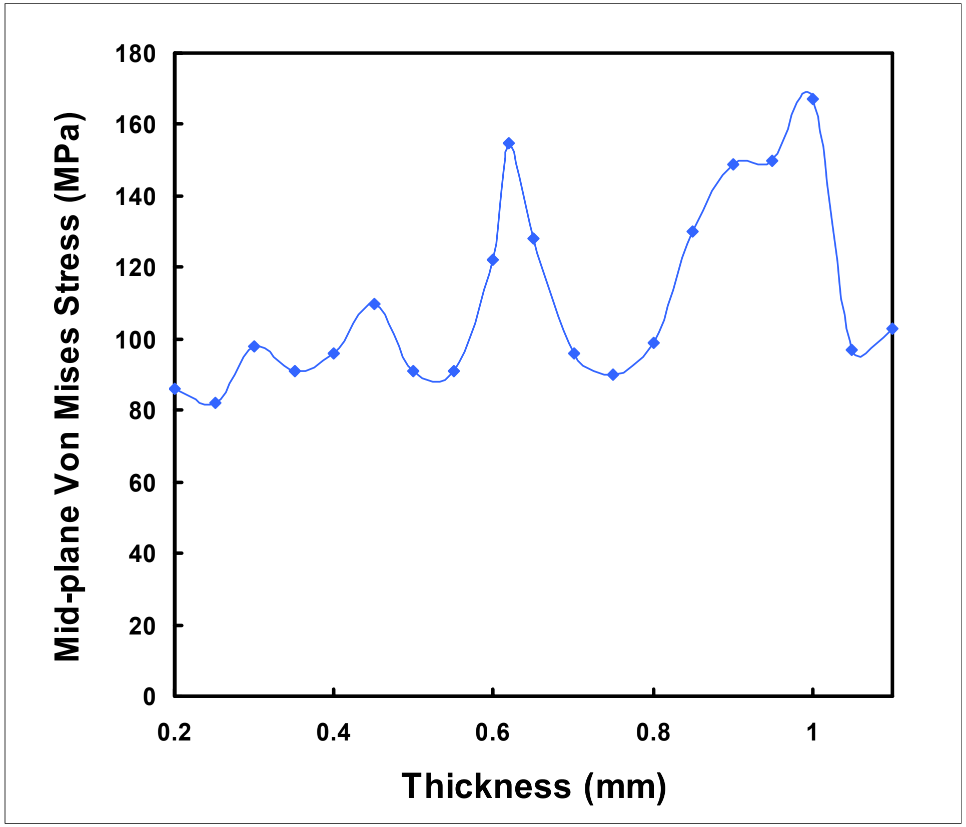
Variation in Shock Stress with Window Thickness



Graph shows Von Mises stress at window mid-plane at the end of a single pulse for a variety of window thicknesses. Results were derived using the FEA Package, ANSYS Mechanical. Results produced by Sheffield University using ANSYS LS-DYNA are in good agreement with those presented above.

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Stress Analysis Overview

- Max stress due to beam ≈ 100-150 MPa.
- Room temp Ti-6Al-4V yield strength ≈ 900 MPa.
- Elevated working temperature reduces UTS and yield strength. At 200 °C, yield strength is 70% of room temp value (630 MPa).
- Fatigue and radiation effects require further investigation.
- Safety factor acceptable to expect a useful lifetime for 0.75 MW beam.
- Upgrade to 3 MW beam will need more study and possible design modifications.

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Window Design

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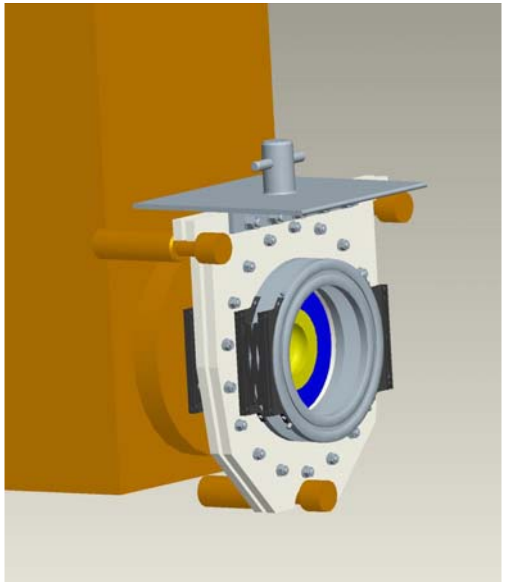
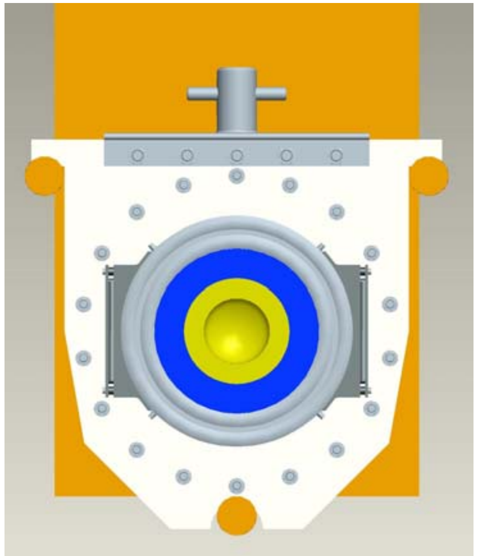
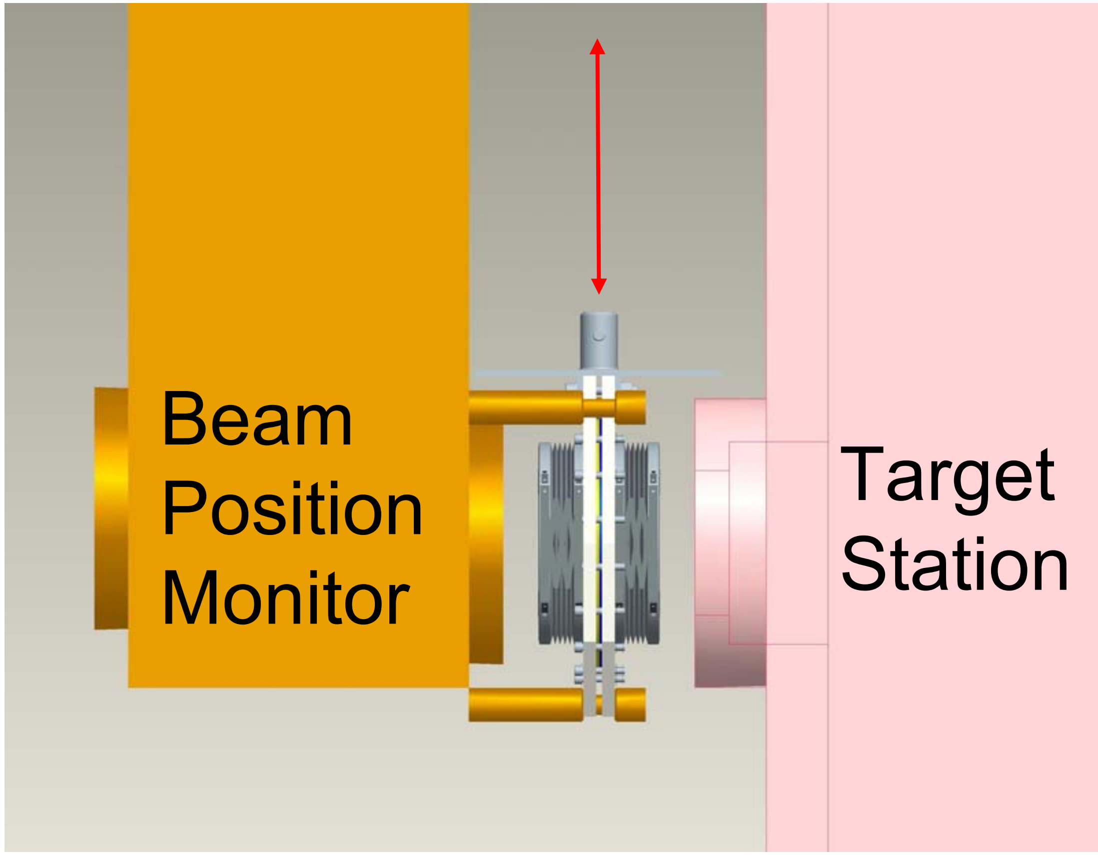
Window in position







Window inserted and removed remotely with bayonet tool from above. Top plate provides rough guidance until contact with three support bars is initiated to provide accurate final location.

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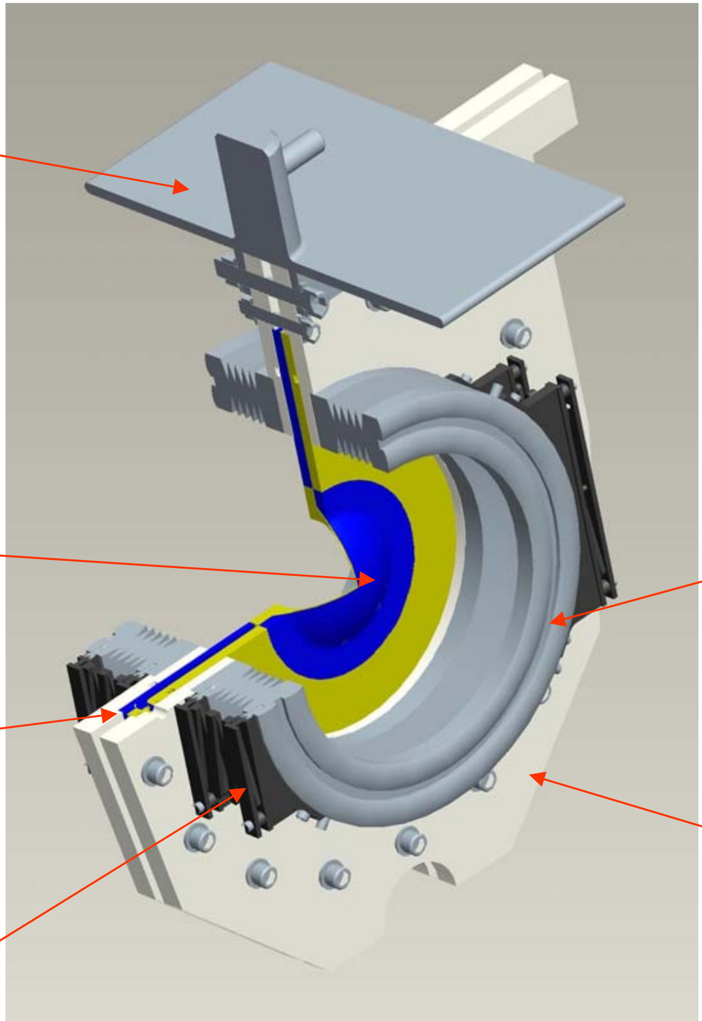
Window assembly



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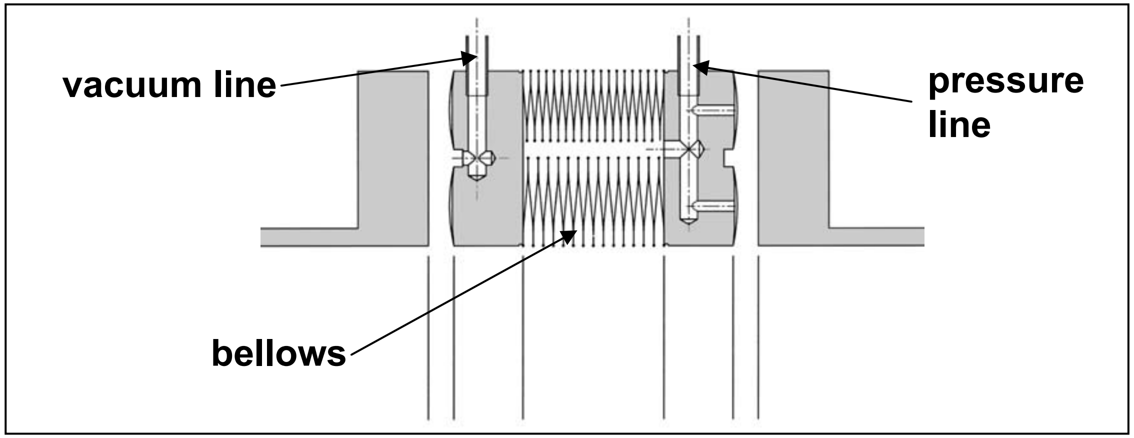
Pillow seals

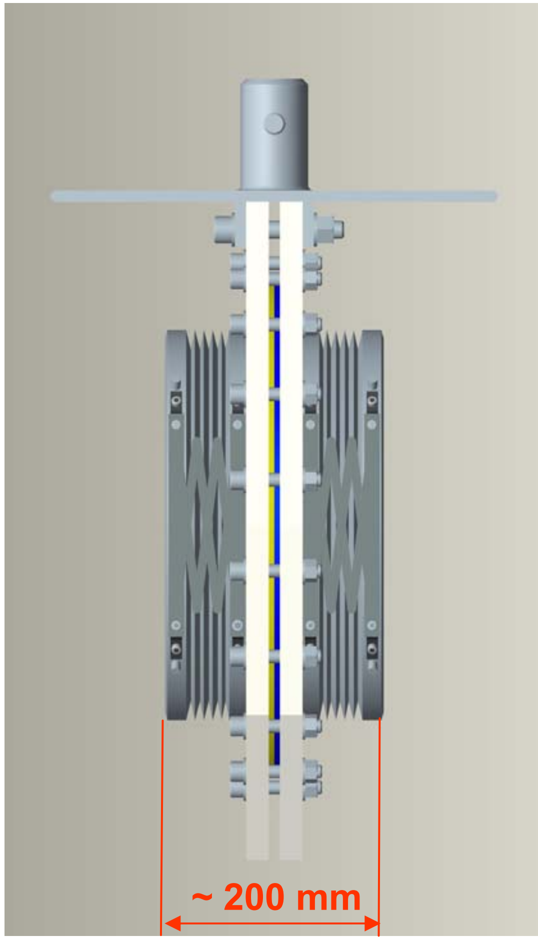
Section view



KEK Muon Group pillow seal

Pictures courtesy of Y. Miyake (KEK)

Window – side view



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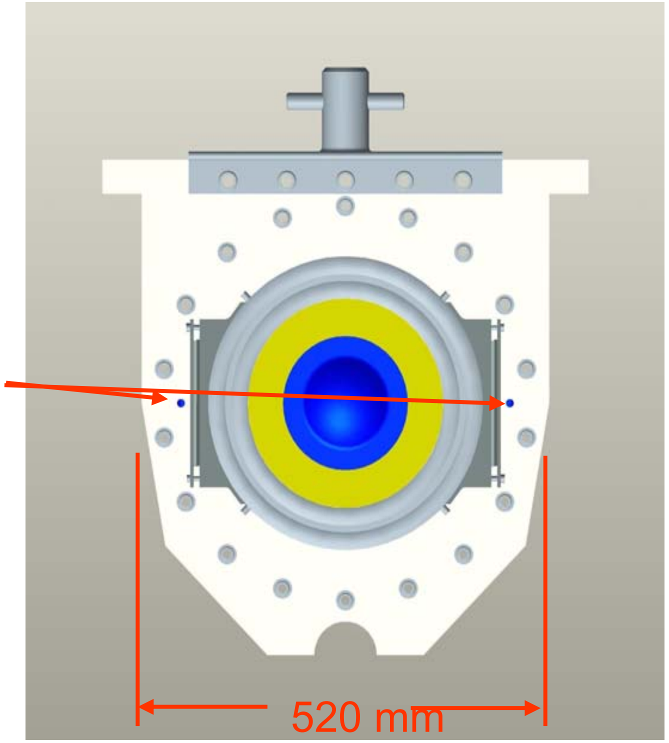
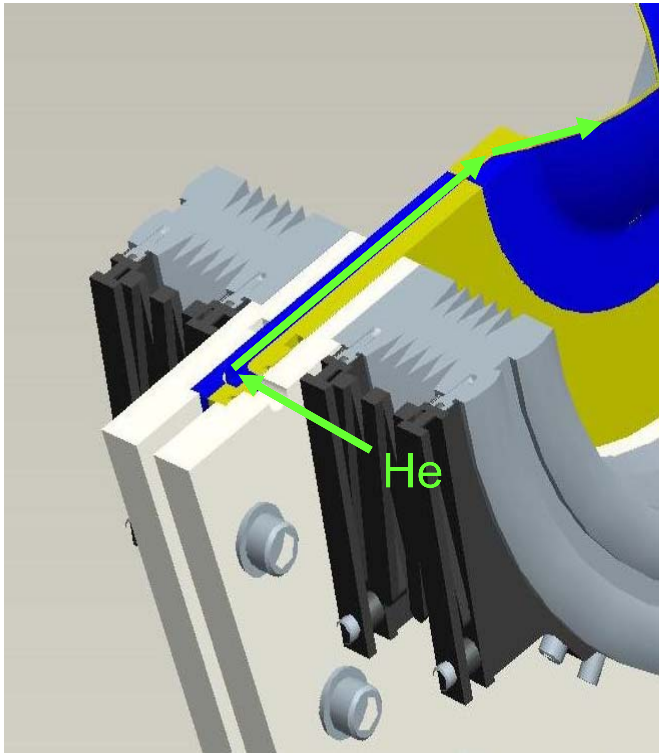
Helium cooling

Helium inlet and outlet





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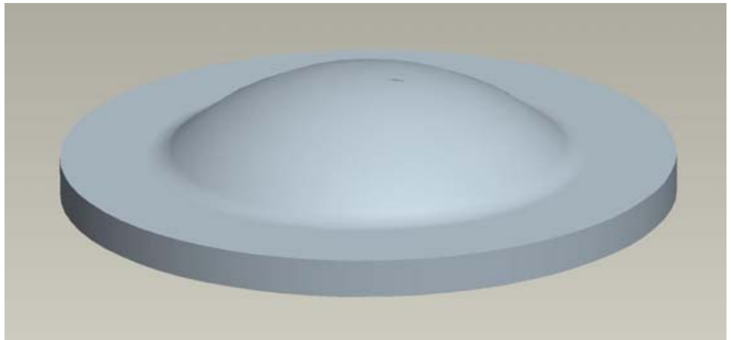
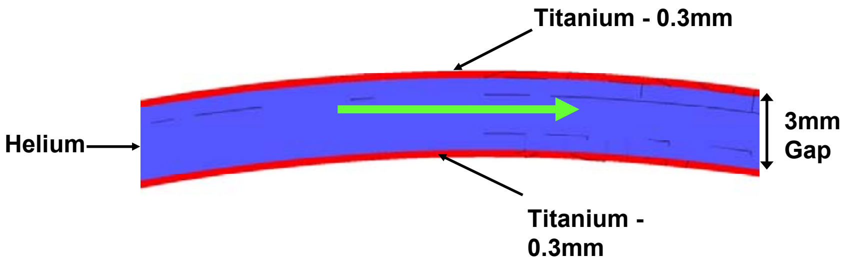
Helium cooling

Upstream

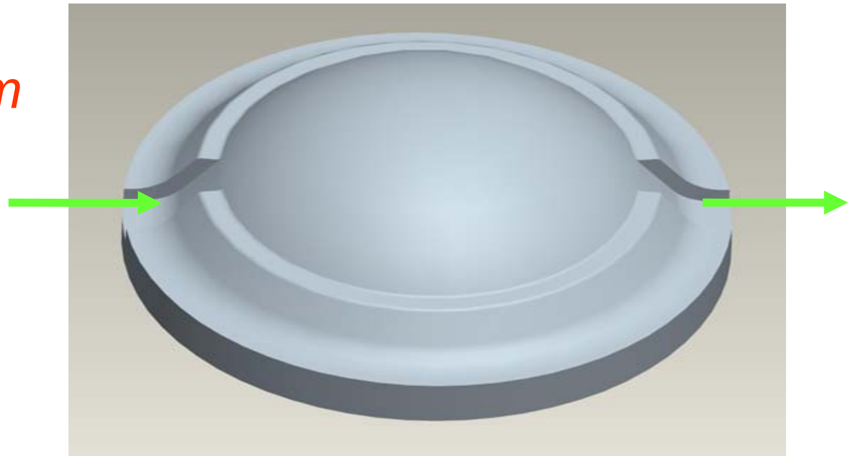


Annulus



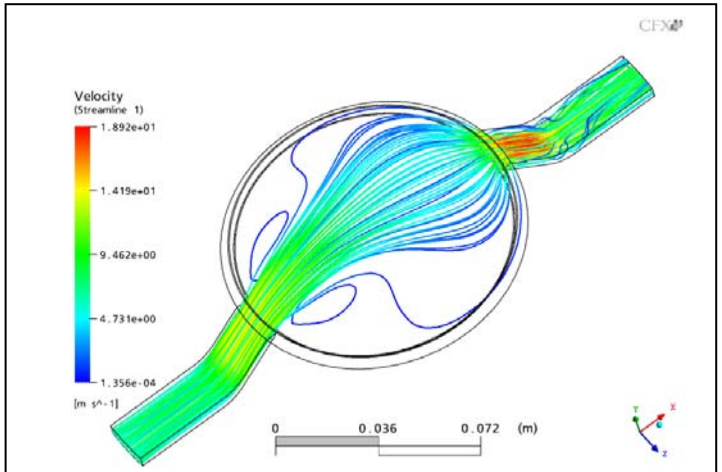
Downstream

He in



He out

CFD plot by Mike Fitton (RAL)



Helium velocity ≈ 5 m/s
Heat transfer coefficient ≈ 150 W/m2K

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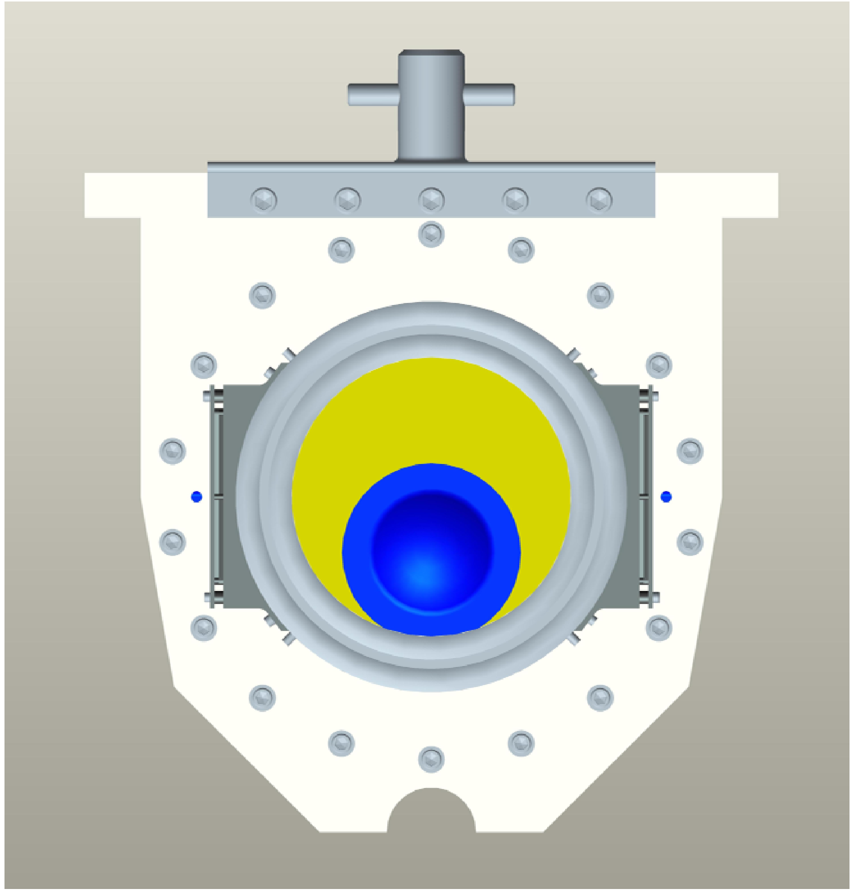
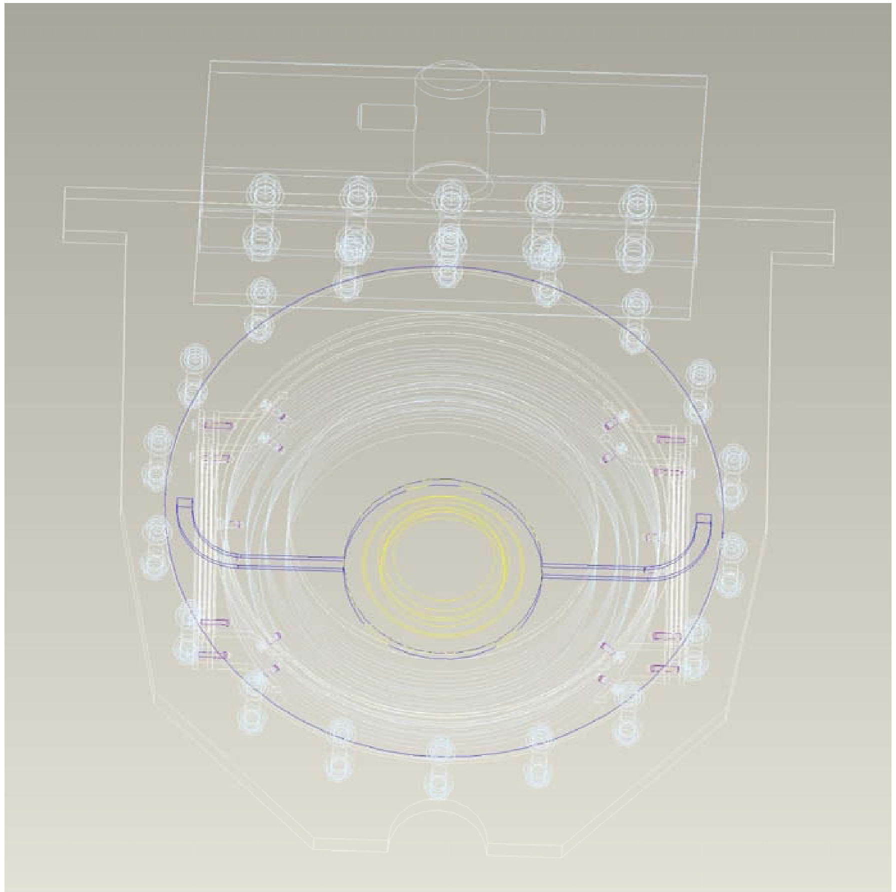
Window modification for change in off-axis beam angle





Double window is lowered 50 mm for 0.5 degree change in beam angle

Helium flow must be rerouted on the surrounding titanium plate

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Outline of Future Work

- Complete window design – October 2006
- Prototype manufacture and testing throughout 2007
- Transport and installation – Early 2008

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Thank you!

Questions?

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