



Science & Technology
Facilities Council

T2K Beam Window Design

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High Power Targets Workshop

Malmö
May 2, 2011

Comparison of neutrino beams

	EUROnu superbeam (700 kW)	LBNE (700 kW)	LBNE (2 MW) T2K	
Beam power	1	0.7	2	0.75 MW
Beam energy	5	60	60	30 GeV
Protons per pulse	1.50e14	5.60e13	1.6e14	3.30e14
Beam sigma	4	1.5	3.5	4.24 mm
Peak energy dep.	~ 80	~ 200	~ 128	~ 160 J/cc/spill
Pulse length	5	10	5	5 μ s
Frequency	12	1.32	1.32	0.47 Hz

NOTE: Energy deposition is normalised to beryllium.

Main beam window candidate materials

	Beryllium	Titanium alloy	
Density	1844	4540	kg/m ³
Specific heat capacity	1925	558	J/kg.K
CTE	11.5	8.7	
Modulus	303	113	GPa
Thermal conductivity	216	7	W/m.K

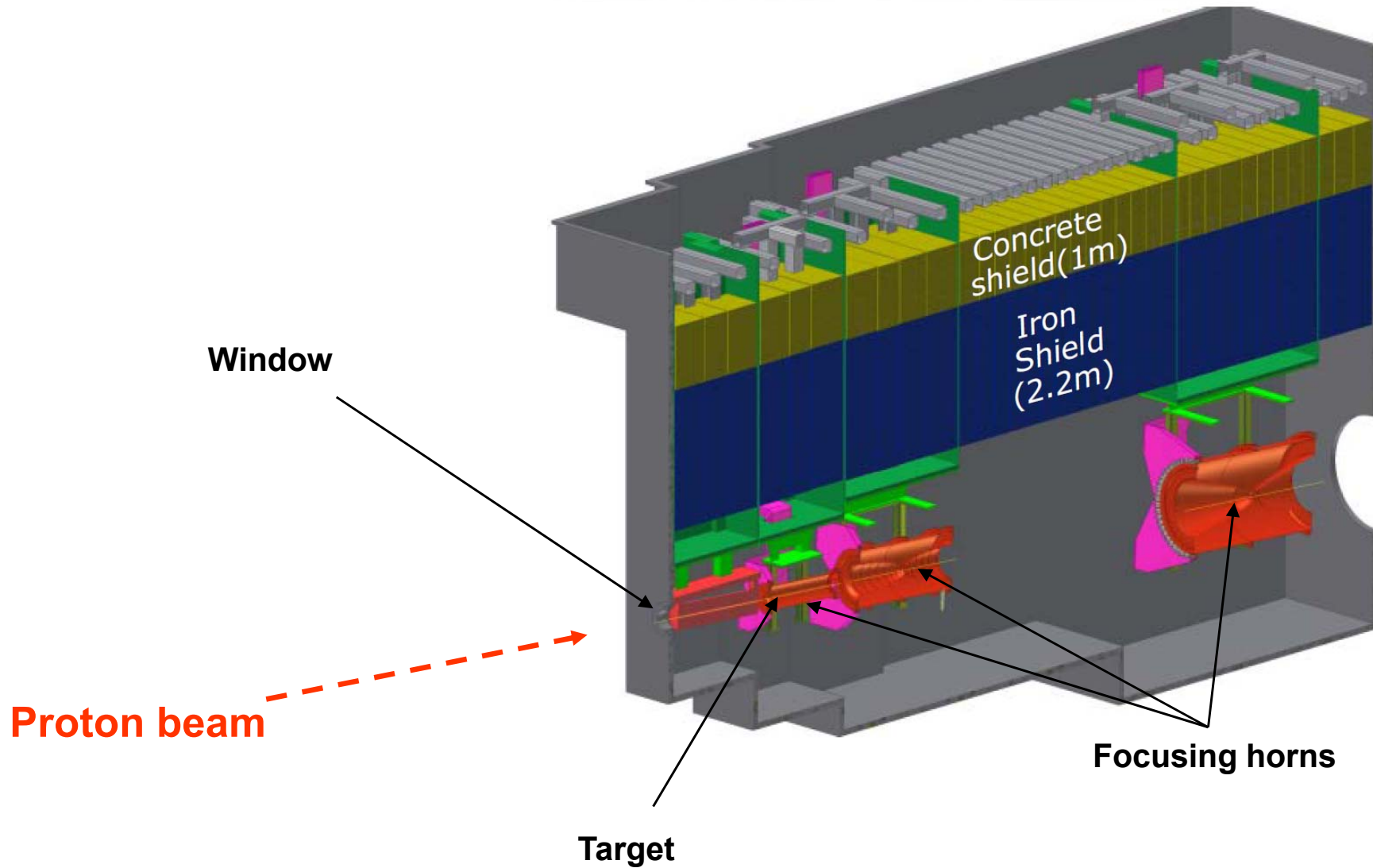
Others candidates: AlBeMet, GUM, INVAR...

T2K beam window

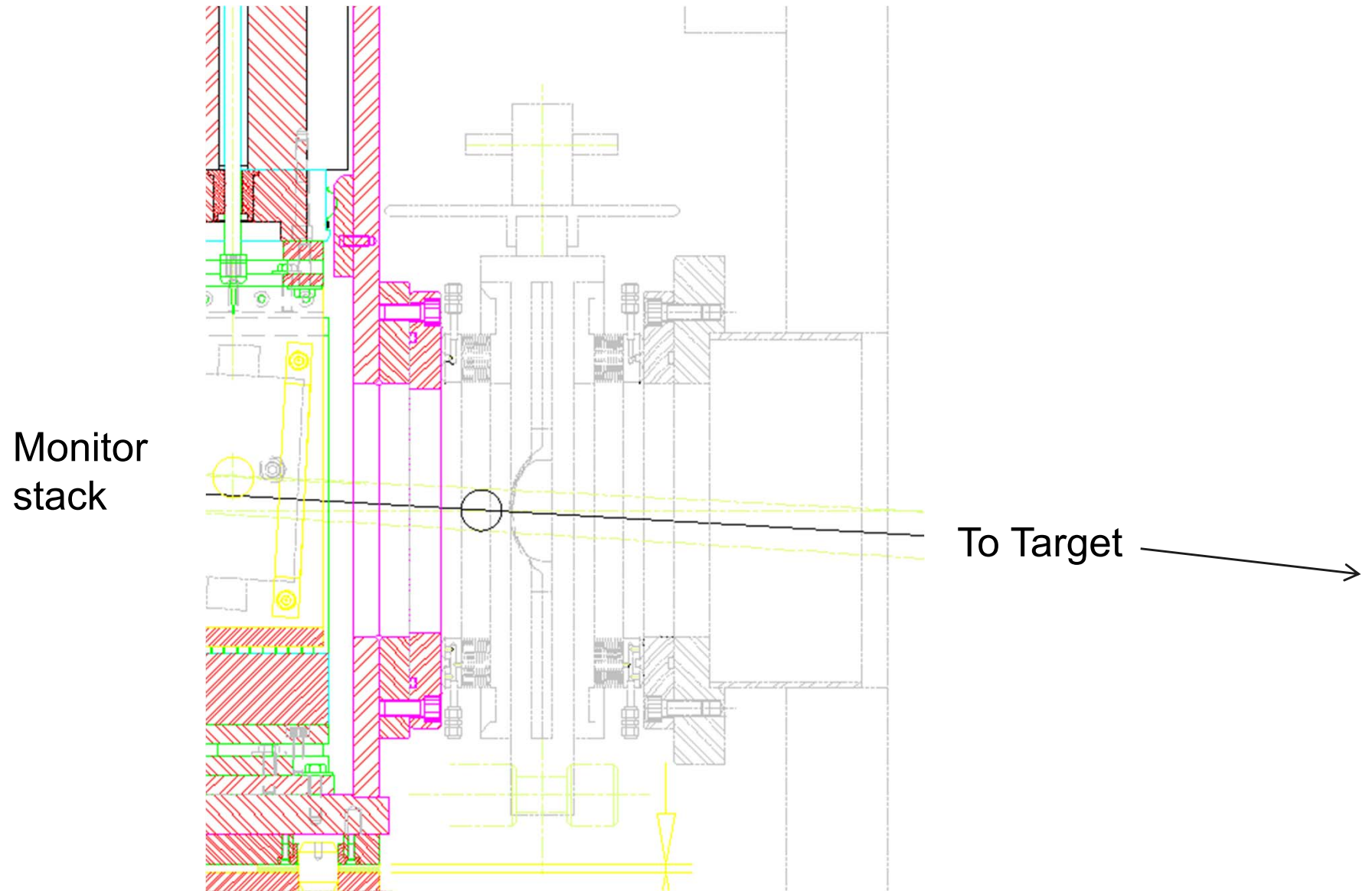
- Double-skinned titanium alloy window, cooled by helium gas.
- Installed October 2009.
- Designed for 0.75 MW beam power.



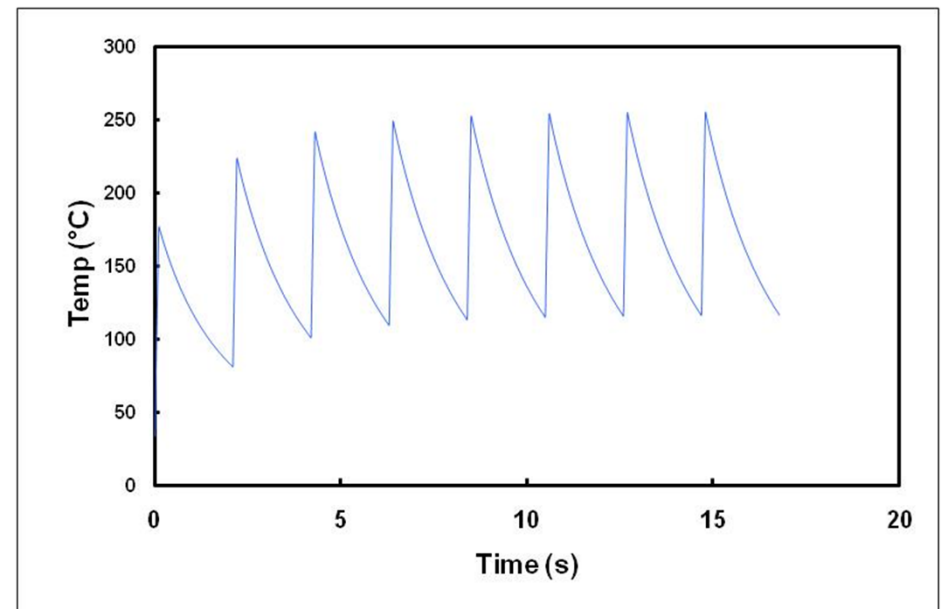
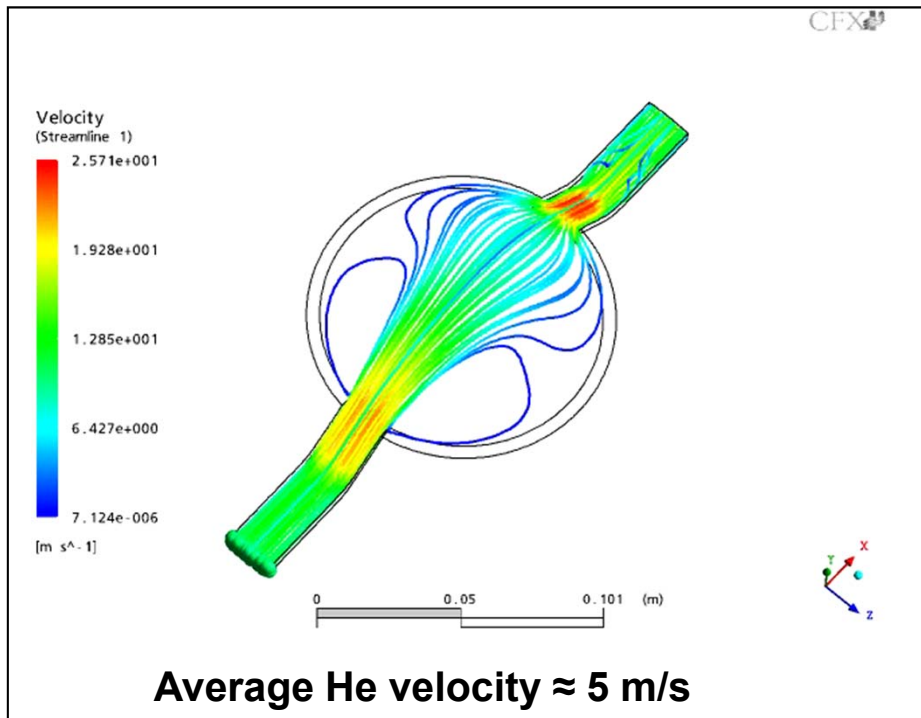
T2K target station



Position in beamline



Double skinned window with helium cooling



Transient temp over first 8 pulses (30 GeV)

Titanium components

Downstream dome

Upstream dome



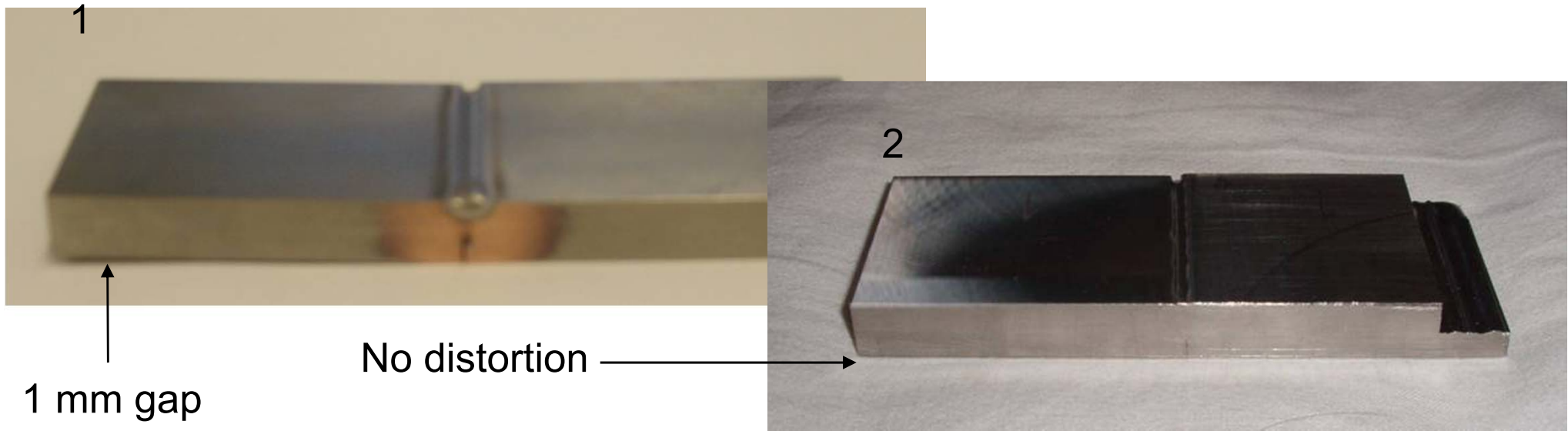
Downstream plate

Upstream plate

Helium flow grooves



Test piece distortion



- Test piece 1 distorted due to welding, no. 2 did not.
- In the worst case, the test pieces distorted by up to 1 mm.
- This distortion could create large stresses in the titanium domes.

Solution



50% stitch weld



Continuous circumferential weld

Main components

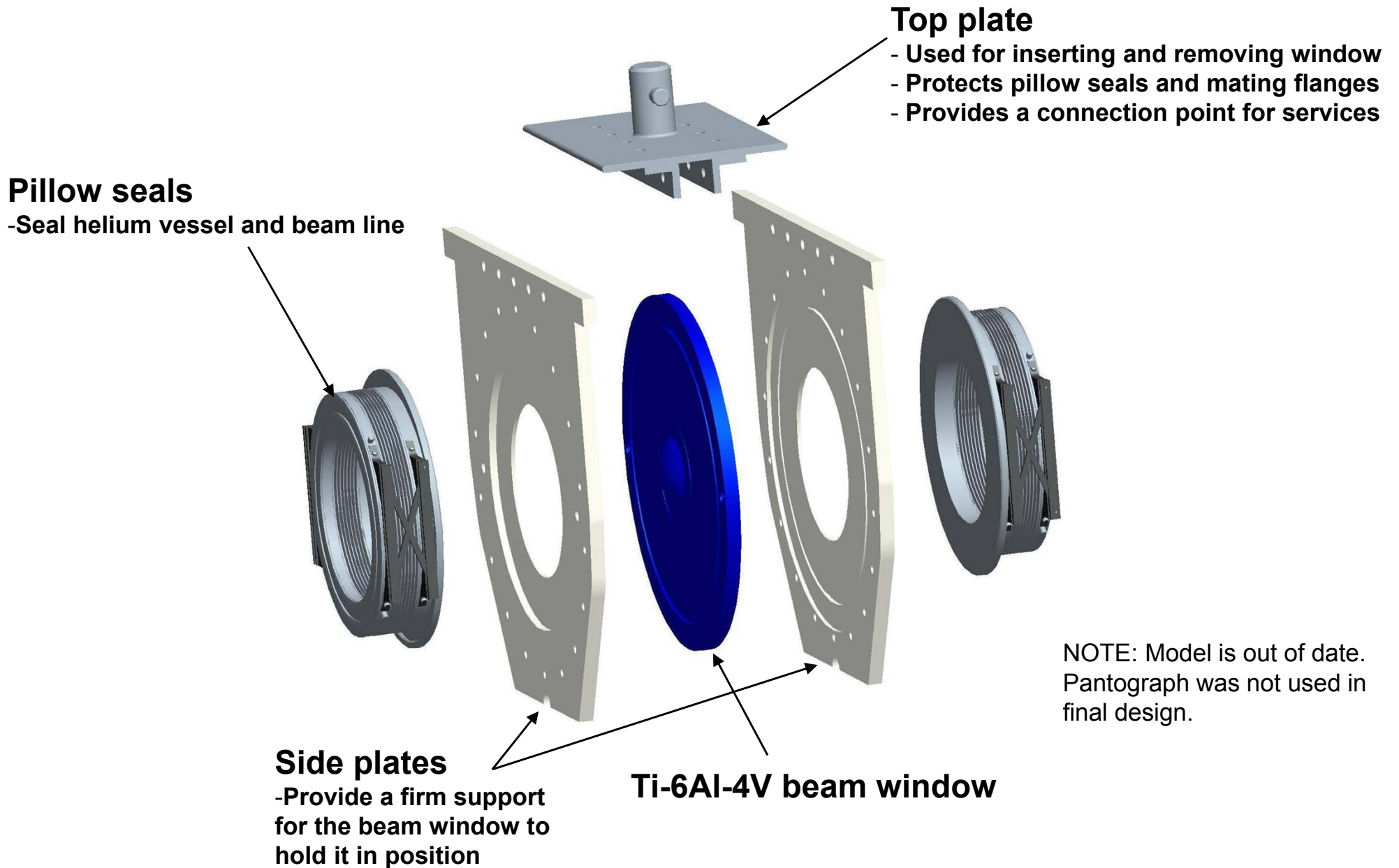
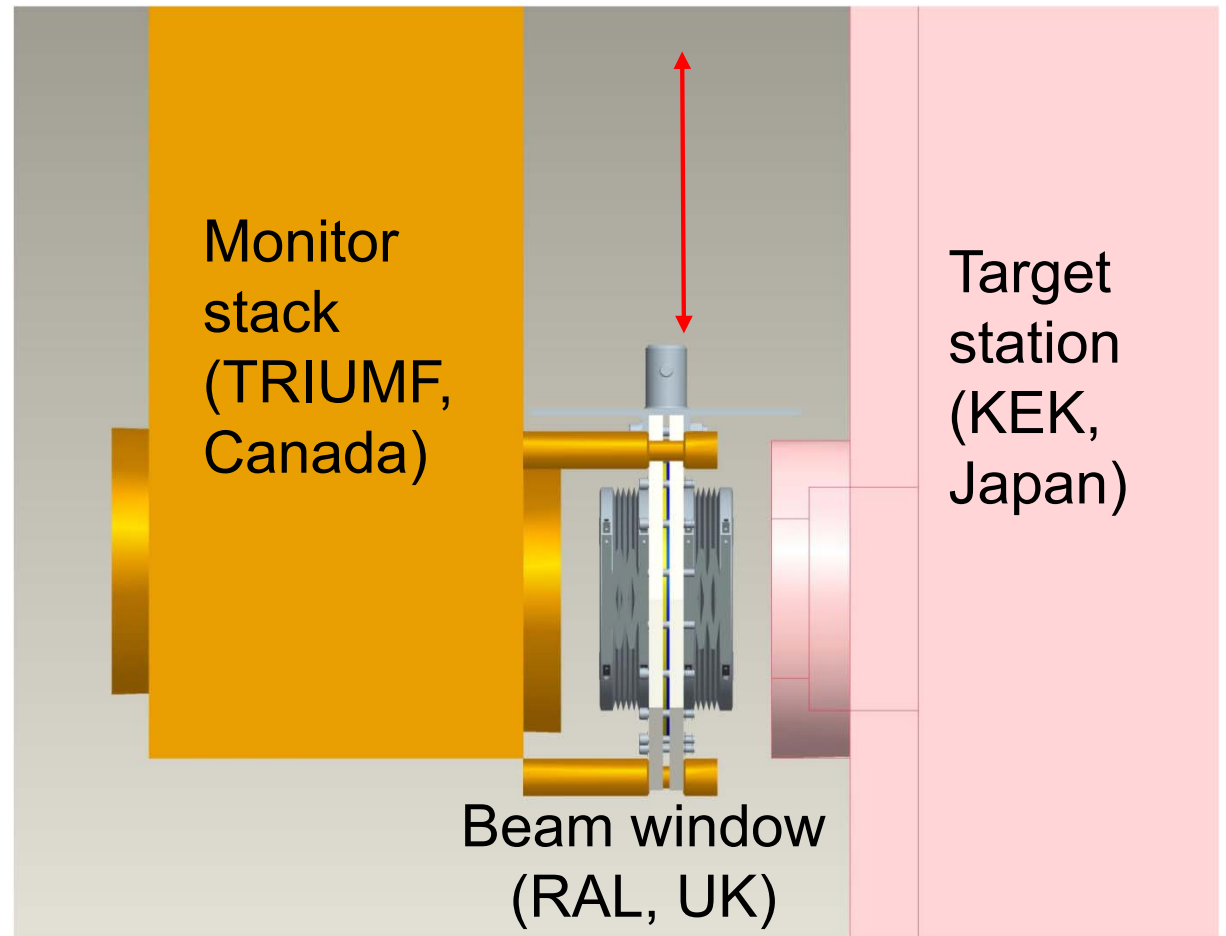
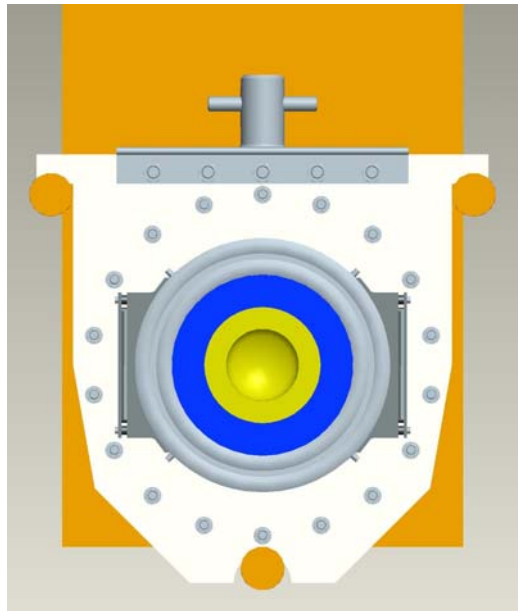
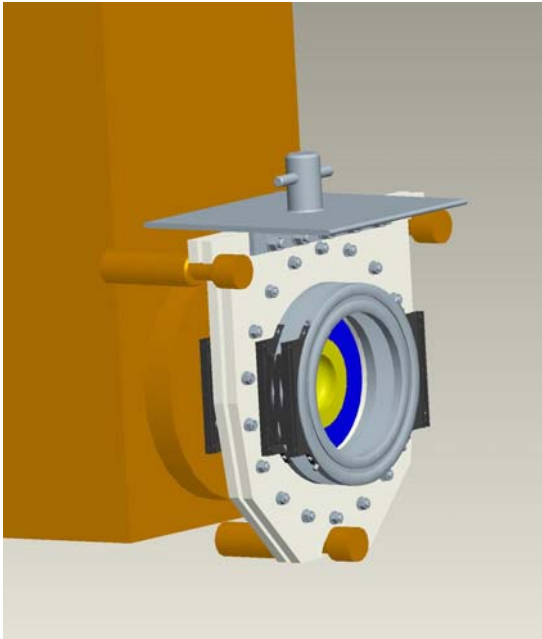


Illustration of window in position



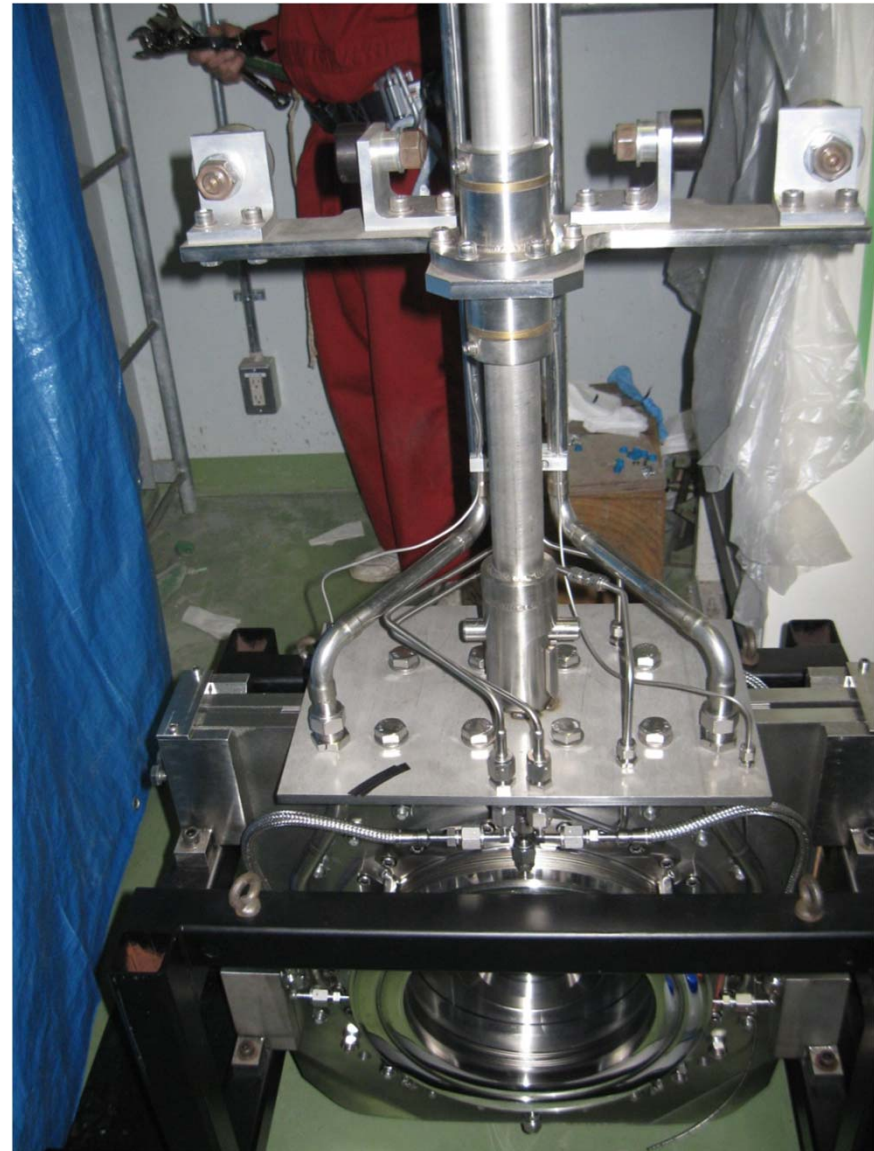
Window inserted and removed remotely with bayonet tool from above. Top plate provides rough guidance until contact with three support bars is initiated to provide accurate final location. Bus bars must withstand ~ 1 tonne resultant pressure load.

Installation and removal



- Installed from above with bayonet tool.
- Operator can stand on top of target station for final alignment and pipe connections once the window is in place.

Installation and removal



Inflatable bellows seals

PSI



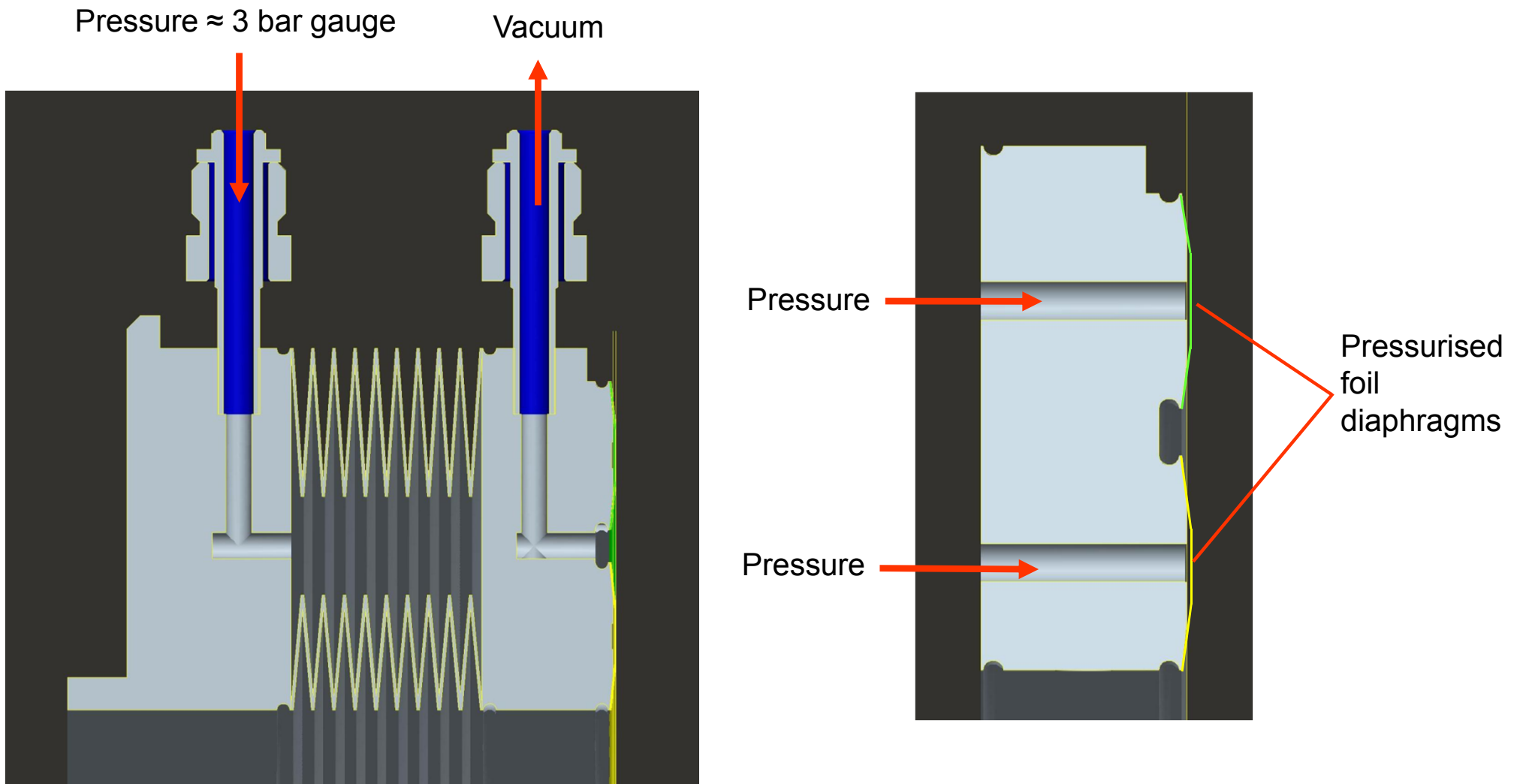
Picture courtesy of PSI

KEK Muon Group



Picture courtesy of Y. Miyake and S. Makimura (KEK)

Cross section through seal



Seal and mating flange

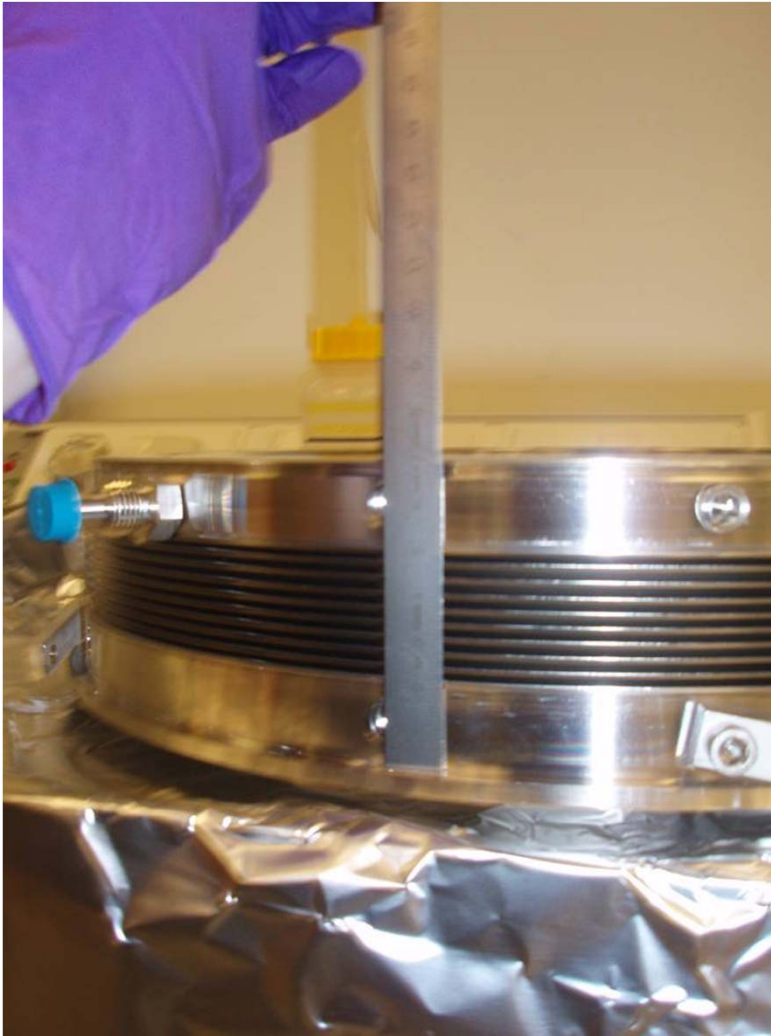


Seal foils (surface roughness,
 $R_a = 0.004 \mu\text{m}$, $R_t = 0.030 \mu\text{m}$)



Polished flange (surface roughness,
 $R_a = 0.020 \mu\text{m}$)

Bellows extension



Plastic deformation of bellows resulted in the natural or 'free' length of the seal increasing from 68 mm to 78 mm.

As a result, a vacuum will need to be applied to bellows on installation and removal to reduce the length of the seals.

Upgrade potential?

- 0.75 MW; 3.3×10^{14} PPP; 4.24 mm beam sigma
- ~ 150 °C temperature jump
- Max stress waves ~ 100 - 150 MPa
- Transient thermal stress ~ 90 MPa
- Yield strength of titanium ~ 900 MPa

Summary

- T2K beam window installed in October 2009
- 1.46×10^{20} protons so far
- No evidence of damage from earthquake
- One spare window available in the event of failure

Thank you

