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ISIS Target Station 2 Proton Beam Window (PBW) Failure and Replacement

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Agenda

- ISIS Target Station 2
- Details of TS2 Proton Beam Window
- Failure Event
- Window Replacement Procedure
- Summary
- Lessons Learnt
- Any Questions

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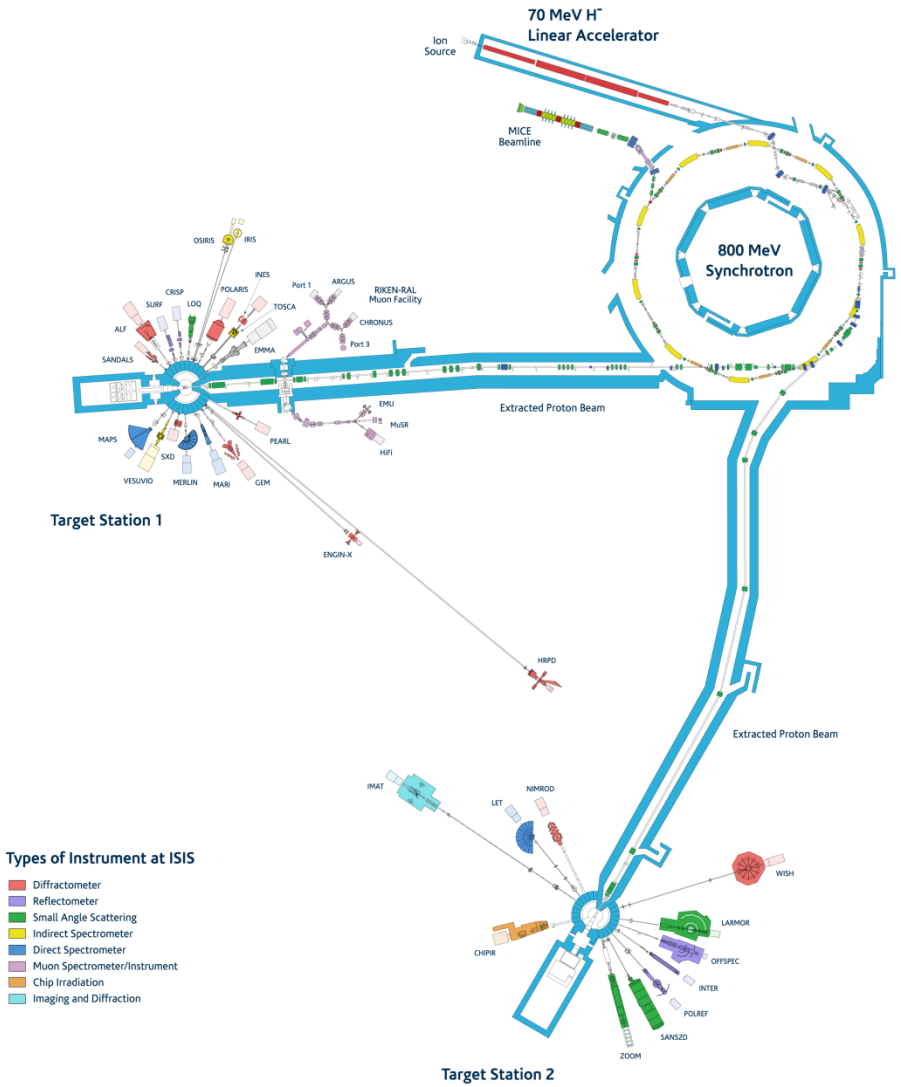
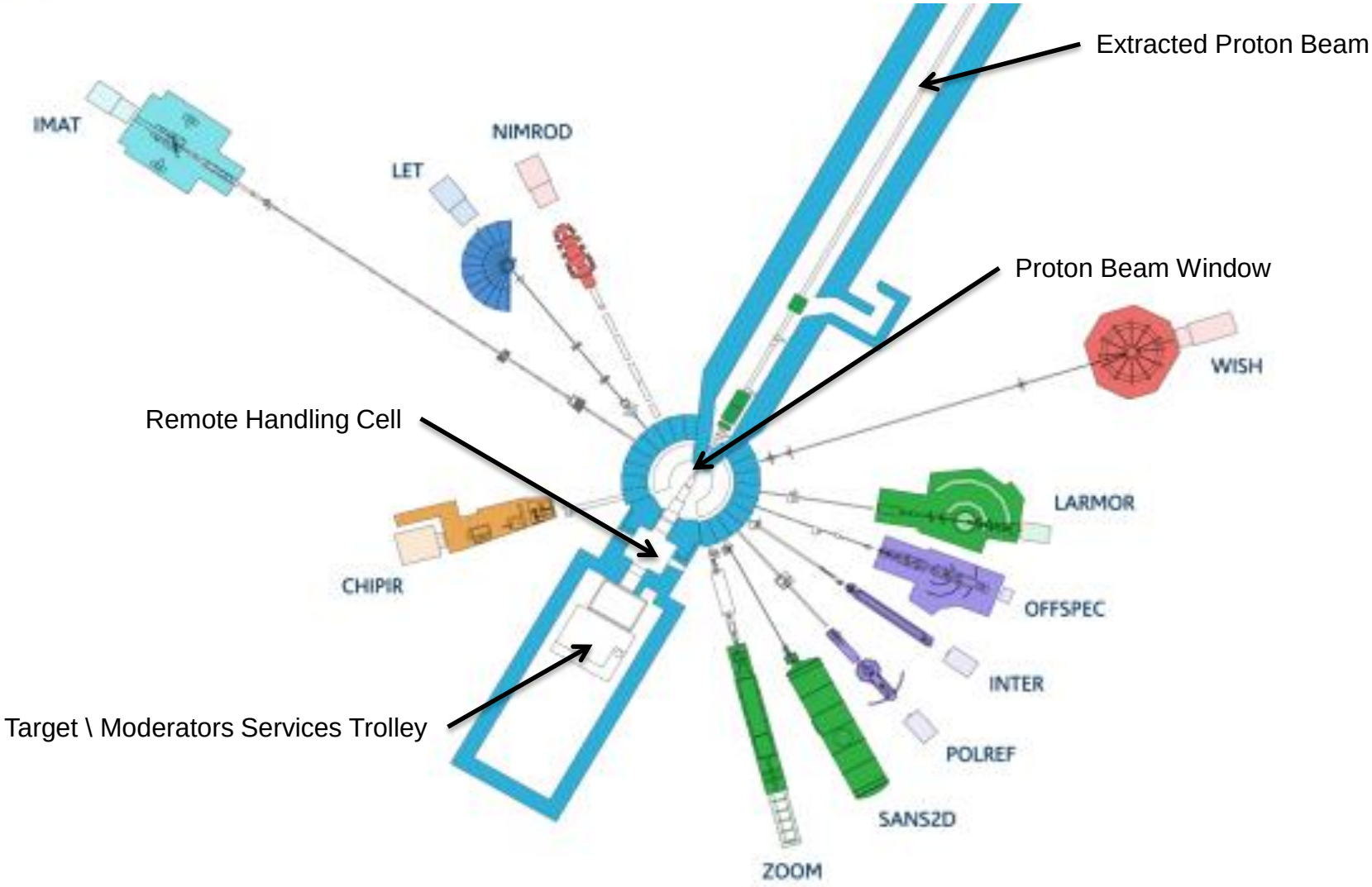
ISIS Pulsed Neutron Source

Reference:-
Daniel Blanco Lopez's previous presentation covers ISIS operational parameters and window specifications in more detail.





Target Station 2

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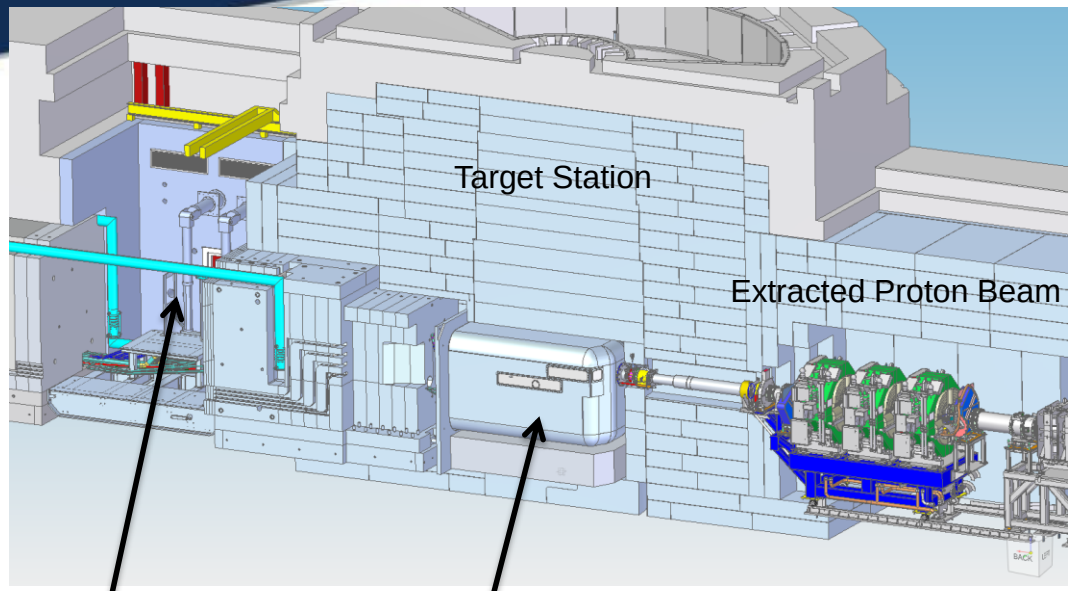
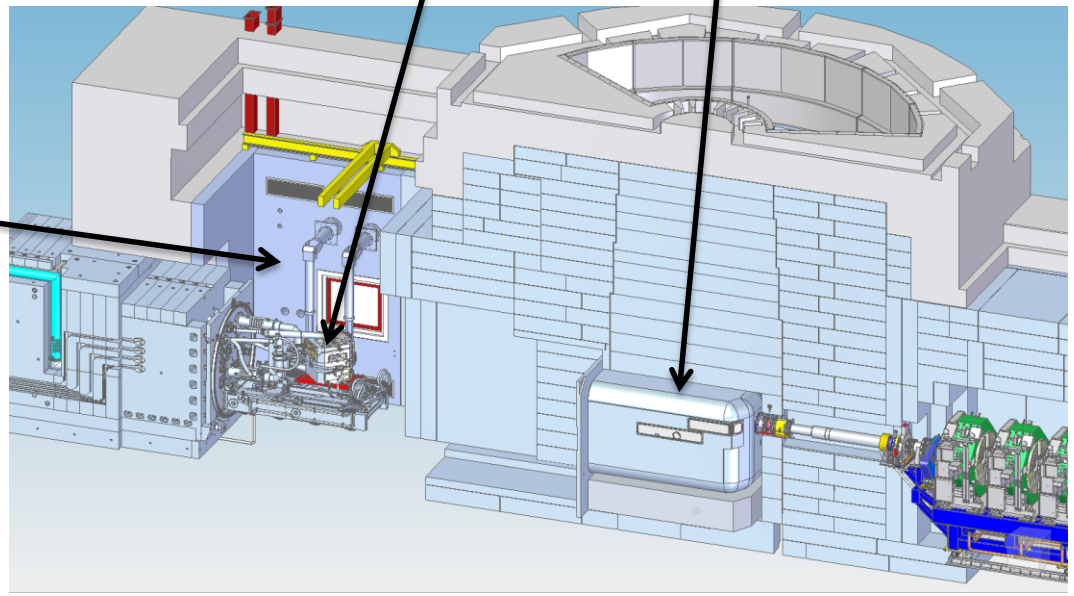
ISIS Target Station 2

Trolley in forward (Beam On) position



Trolley Retracted (Beam Off) Maintenance position



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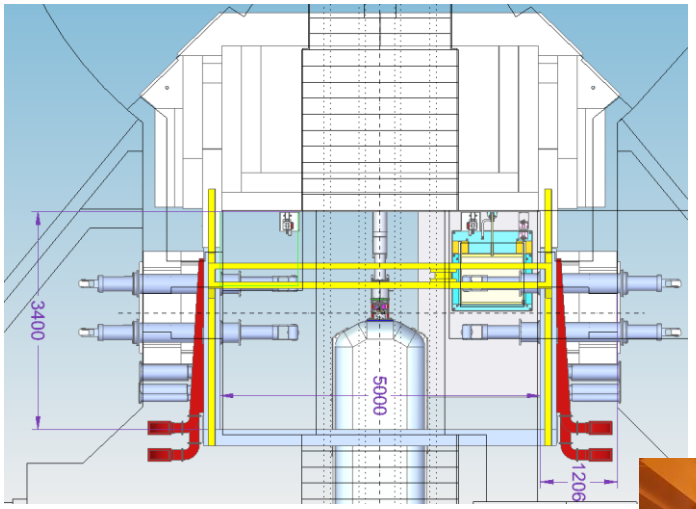
Remote Handling Cell



- 5m X 3.4m Remote handling cell
- 4 non-assisted manipulator arms max rated load 15Kg.
- 1 ton remote crane.
- 1.2m thick lead glass windows on each side.
- 1m^2 Trap door waste route into tunnel
- Cell can be accessed when trolley forward in full respirator protection.
- Equipment can be either transported into the cell either on the target trolley, or by the rear access door.

- 4 remotely operated fixed cameras, Plus 2 mobile cameras.
- Shielded floor safe for active storage.
- Hydraulic cropper for breaking down active waste.
- 2 operators working from each side of the cell with intercom communication.
- The hot cells are for maintenance work, No PIE is carried out in the cells.

CARRS MSM VNE 80, 90 Master slave manipulators

TS2 PBW Spec

TS2 PBW – some additional information

- 40μA Beam heating 10W total.
- 0.5mm thick 5083-O Aluminium alloy window
- 1.4 Meters in length.
- PBW assembly weighs around 65Kg.
- Unlike TS1 there are no cooling services.
- Wire Grid Profile Monitor
- Copper collimator with PRT temperature sensing.
- Attached to the void vessel assembly.
- Retained using Garlock quick disconnect chain clamps, compressing metal Helico-flex gaskets.
- Our first window since beam on in 2008.
- The window change has never been trailed using remote handling.
- No active waste container for this assembly.

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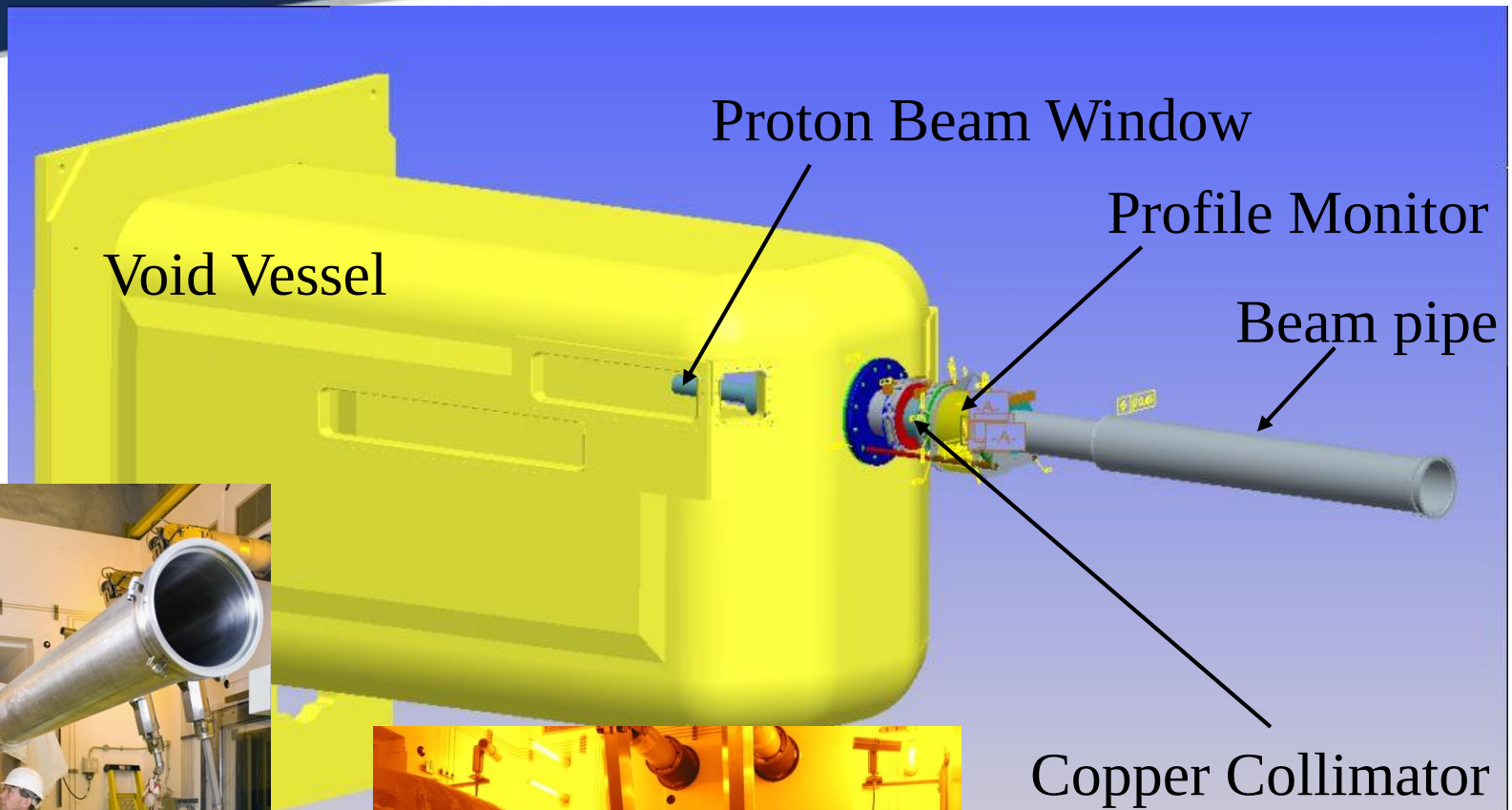
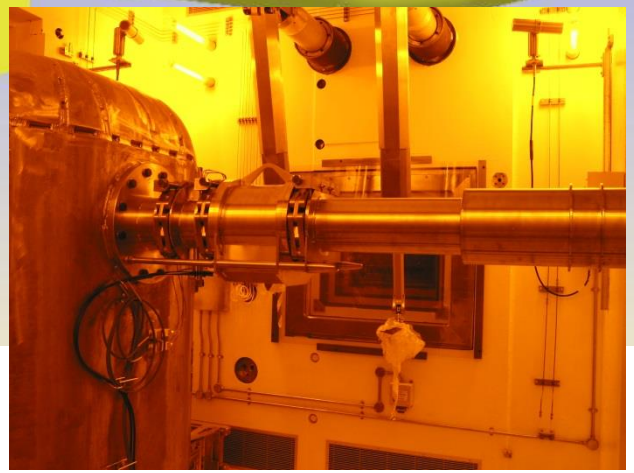
TS2 PBW Assembly





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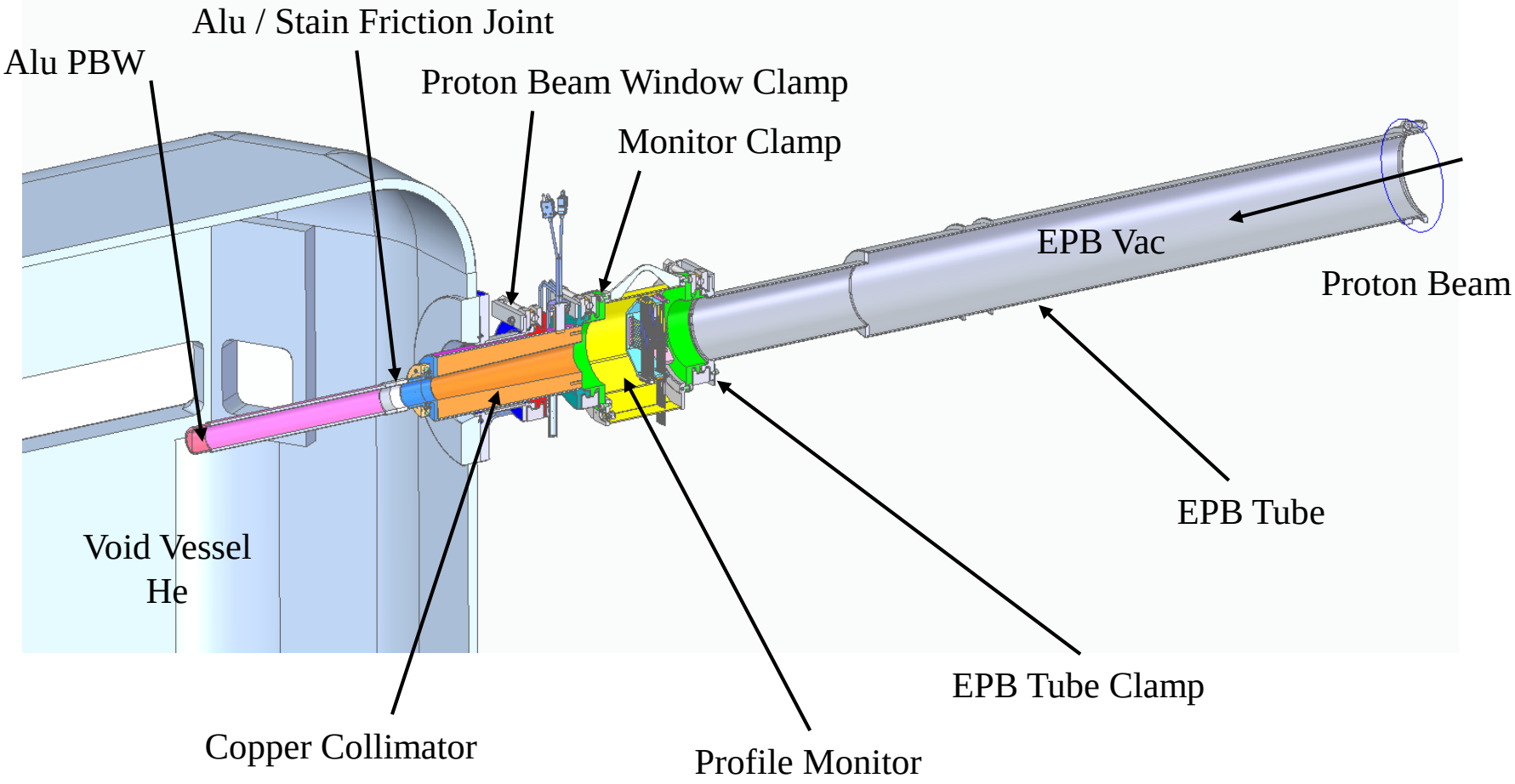
Section of the TS2 PBW

Assembly breaks down into 3 component parts
EPB Tube + Beam Profile Monitor + EPB Window Assembly



PBW Assy = 1.4M, 65Kg

TS2 PBW Failure

- Happened at ~6:20 am 19th Oct in the middle of a user cycle. Whilst establishing MS beam onto TS2 after dipole magnet replacement.
  Void vessel RGA monitor picked up changes within the void vessel environment whilst the synchrotron vacuum rapidly deteriorated

- After event:
  With lower end of EPB2 valved off the synchrotron and EPB1 vacuum recovered very rapidly.

- Lower end EPB2 Vacuum pumping tests immediately after event seemed to confirm suspicions of connection with Void vessel atmosphere.

- Target station 2 was shutdown, ISIS was able to continue it's user cycle with beam on TS1. Full shutdown was scheduled for Dec.

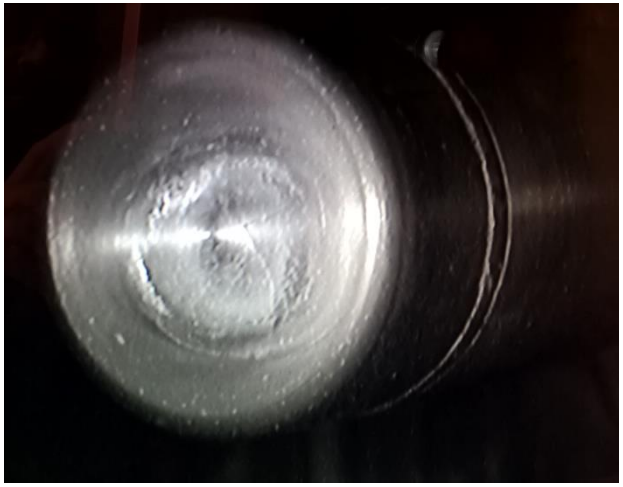
TS2 PBW failure
What was the cause?

Investigation underway to determine why it happened now:

- Expected to do this change in ~2028
- Have we underestimated the lifetime of the window in normal beam operation?
- Or have we had an abnormal event which was not prevented by existing interlocks?

TS2 PBW failure

- A camera was attached to the target trolley and driven into the void vessel to inspect the window.
- The image taken below illustrated some marks on the surface. However, it was difficult to determine the location of the breach. Vacuum was applied but there was no change in the surface of the window.



A decision was made to change the window in the January 2018 shutdown with the aim to have beam on TS2 at the beginning of February.
This gave 2 months to –

- Reconfigure the mock-up area to replicate TS2 remote handling cell layout, with void vessel withdrawn.
- We had a spare window & monitor assembly. But ordered a spare EPB tube for mock-up plus seals.
- Develop tooling - We had a method of handling the window and monitor. No tooling in place to handle the EPB tube.
- To identify risks and develop procedures for carrying out the job for real.

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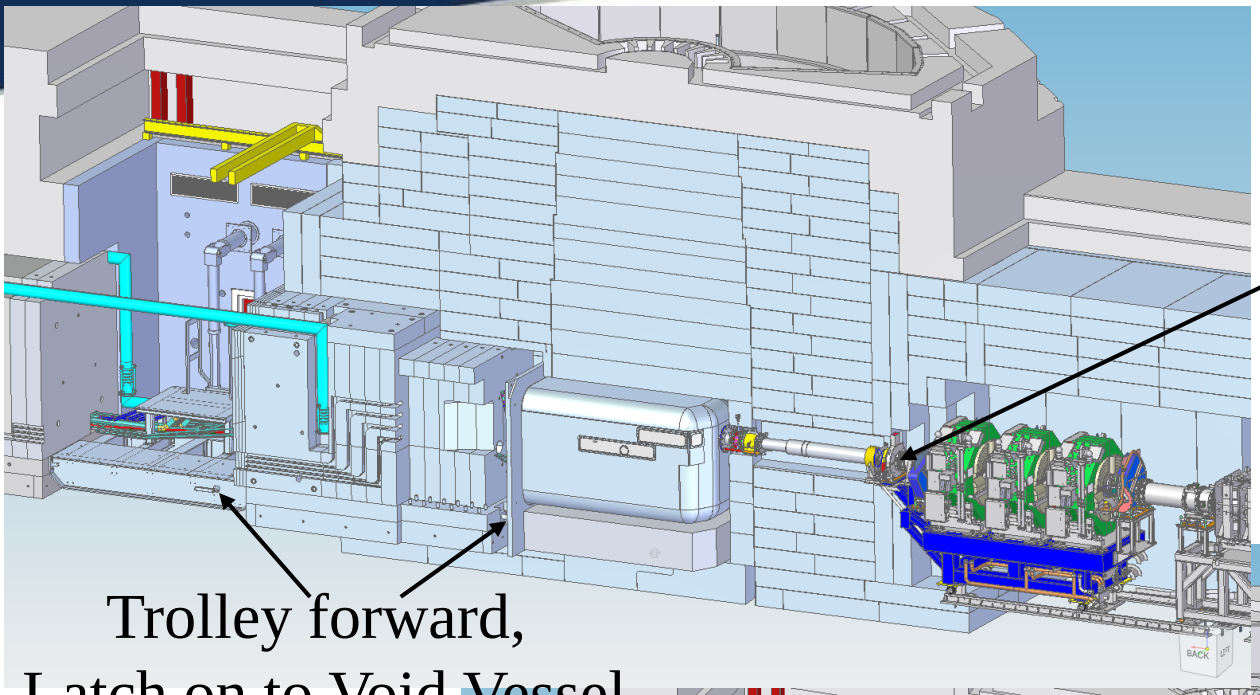
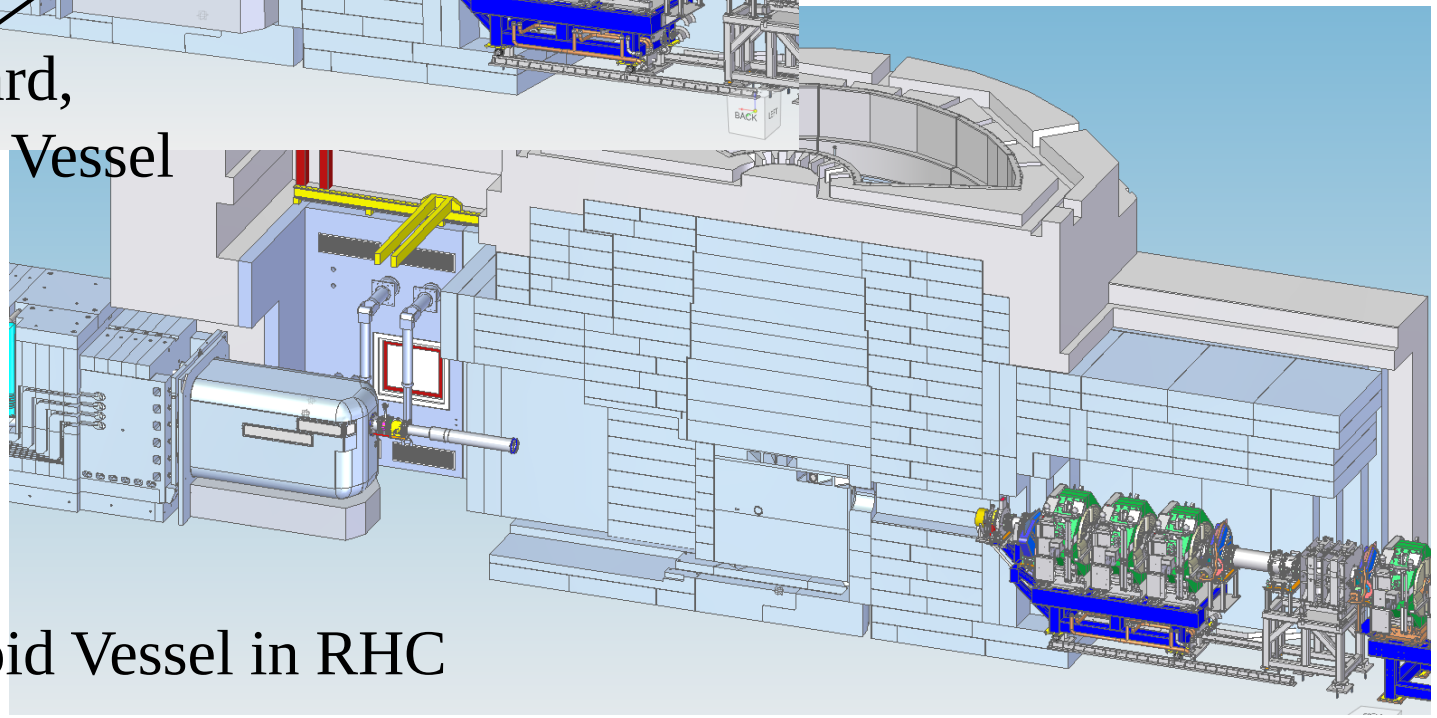
Void Vessel Extraction





Trolley Back, Void Vessel in RHC

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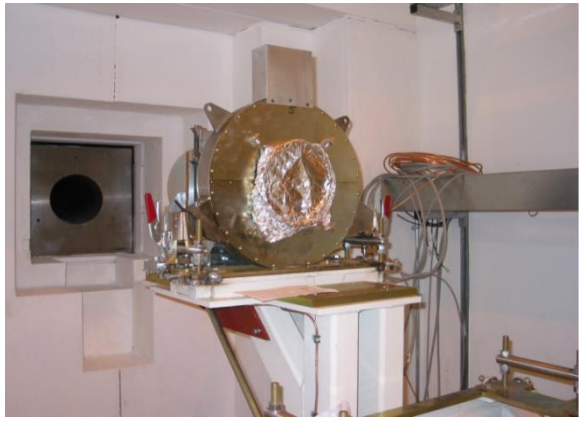
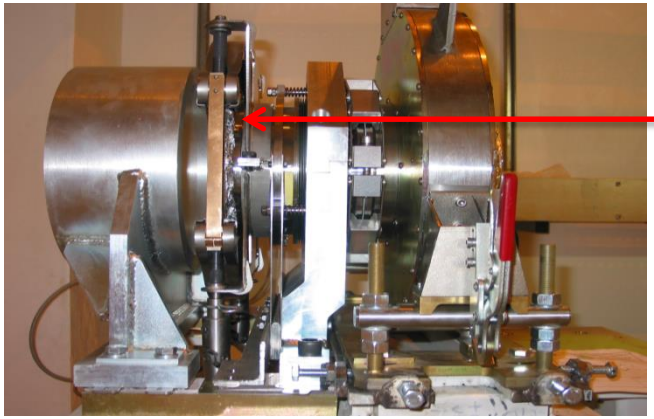
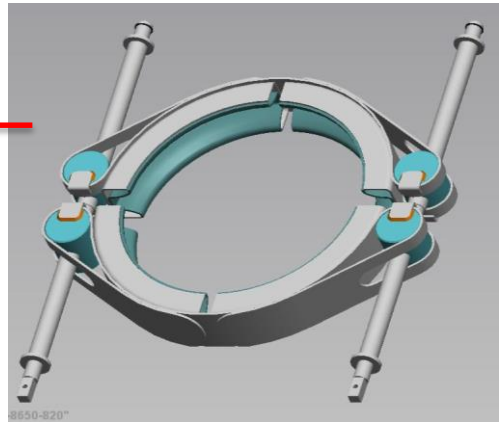
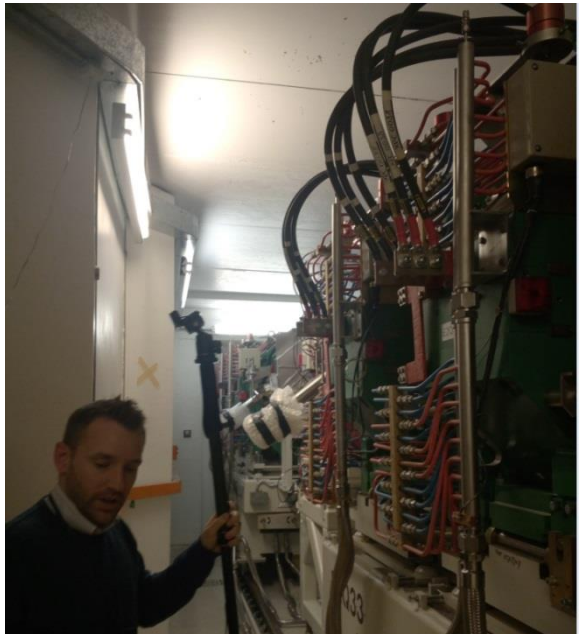
Remote EPB Clamp Assy

Clamp assembly is buried between magnets and shielding. Operation is carried out by hand, driven through universal joints and shafts.









Risks:-

- Clamp actuator seized in place? Very difficult to access location with high on contact radiation levels. (The target was still fitted, but pulled back into the remote handling cell).
- Will the bellow detach from the EPB tube when drawn back?
- When drawing back, would the released EPB tube spring out of alignment due to unknown subsidence? Will it realign when driven back?

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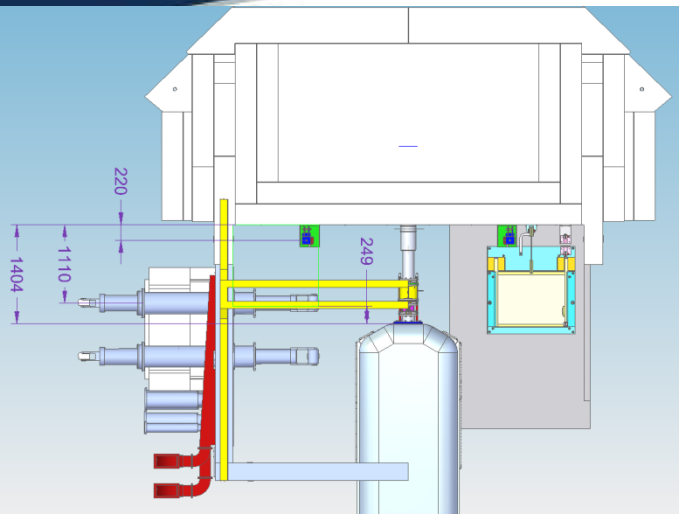
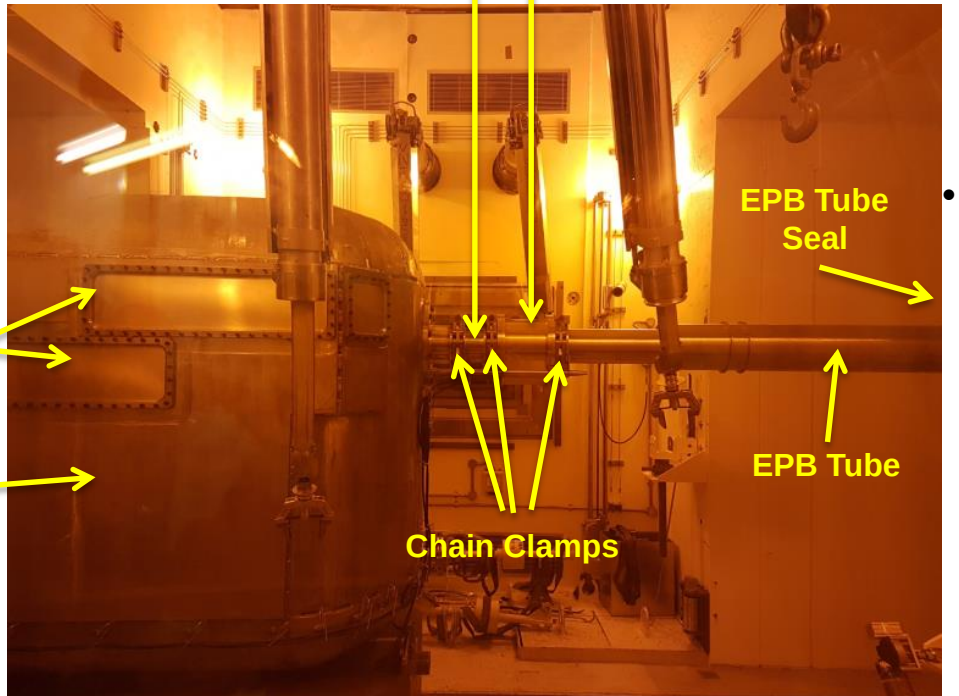
Window Accessibility



- Furthest back the trolley will go
- EPB tube is not directly under crane limits
- Limited manipulator access
- Need to access the furthest end of the EPB tube to change the seal.
- Tooling Required!



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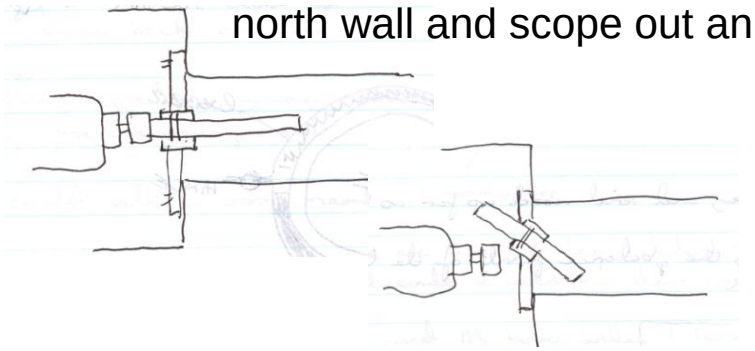
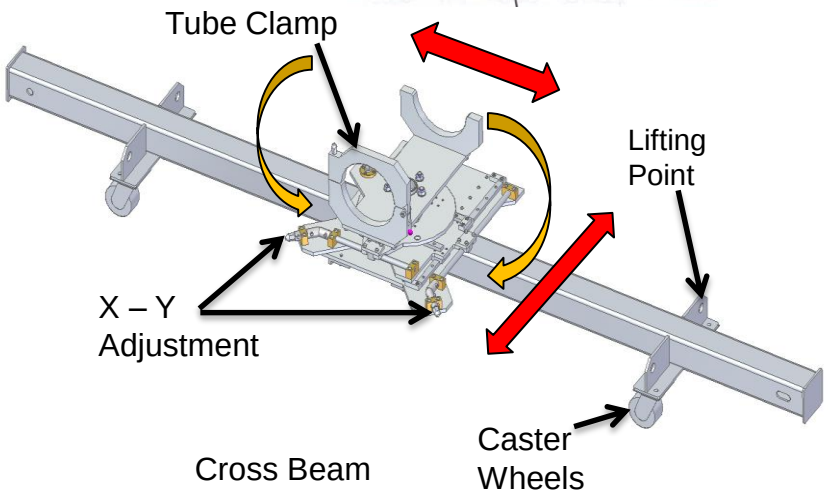
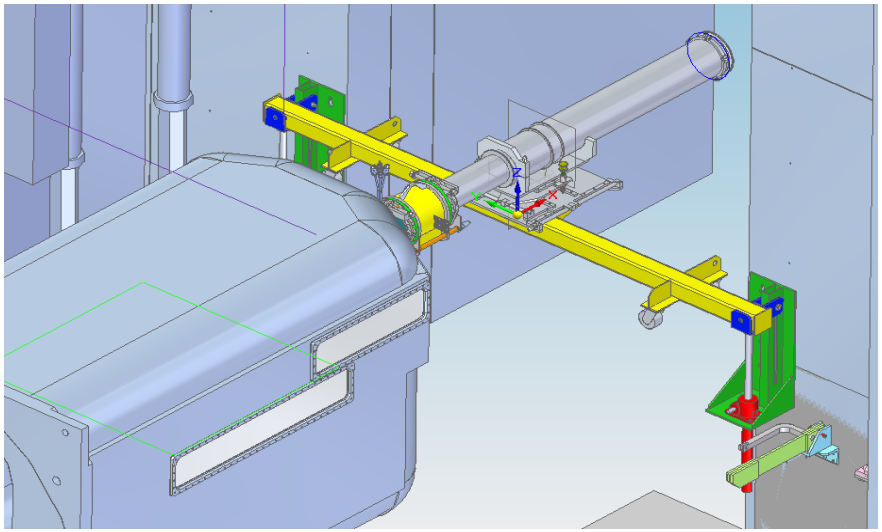
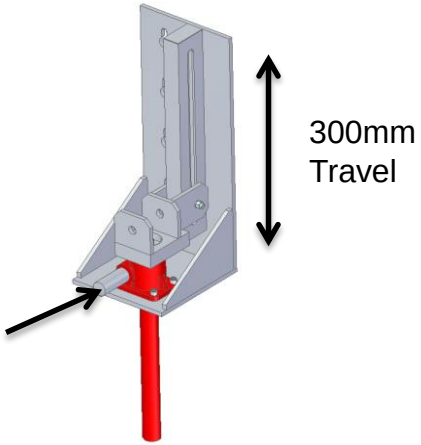
Tooling Design

Nothing in place to handle the EPB tube. However!, the operations manager had the foresight in 2008 before beam to target, to drill some fastening holes in the cell north wall and scope out an idea.









Beam designed to :-

- Capture and support the beam tube
- Swivel the tube to access the EPB Seal
- Lower & stow the tube while the PBW is extracted.

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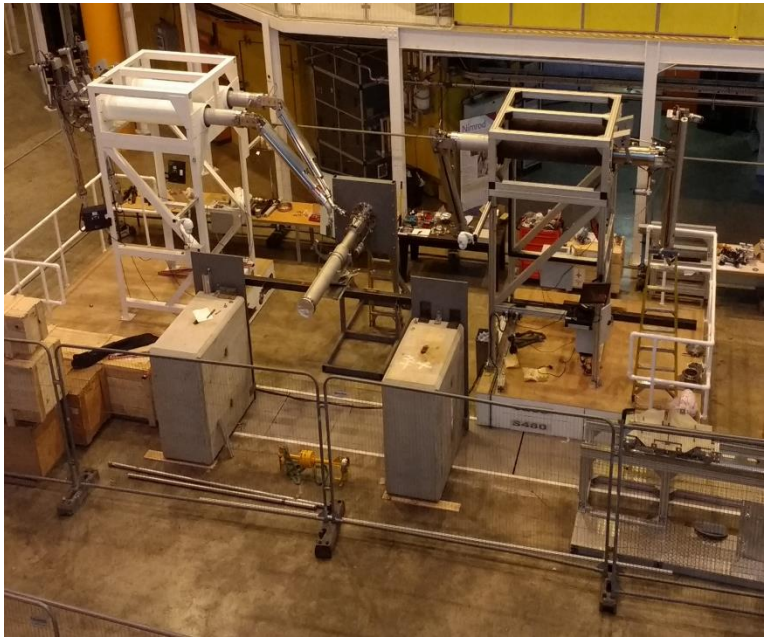
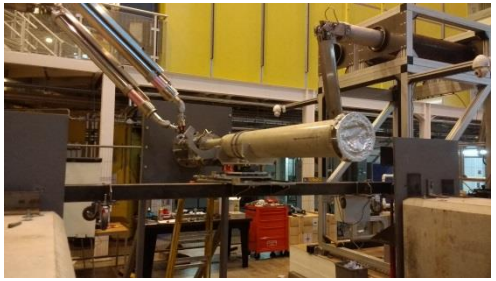
Window Replacement Mock-up

A complete mock-up was constructed with manipulators and cameras within the cell footprint to develop the change process.





From this exercise the following risks and improvement were identified :-

- Some of the fits were too tight on the tooling. These were relieved to prevent seizing.
- To relieve stress on the arms, especially from winding the jacks, a power drive was required.
- All bolt heads were changed to a common size to reduce the number of tools required in the cell.
- Heads of bolts shaped to improve socket location.
- Ordinary mechanical torque wrenches and ratchets were used.
- Created an inventory to equip the cell
- The greatest risk identified was possible crane breakdown with cross beam in place. With the trolley back access to the cell is limited. Jacks were added to lift cross beam out of wall brackets. Always have an exit route!.

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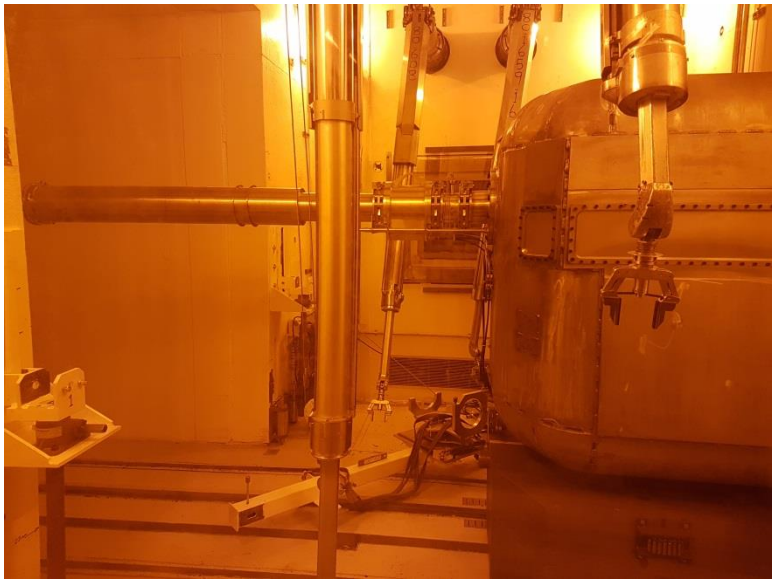
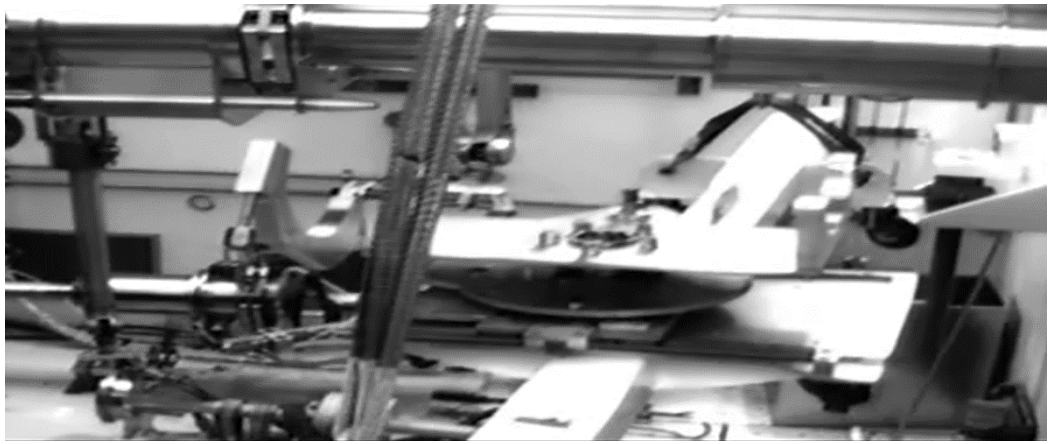
Window Change Process

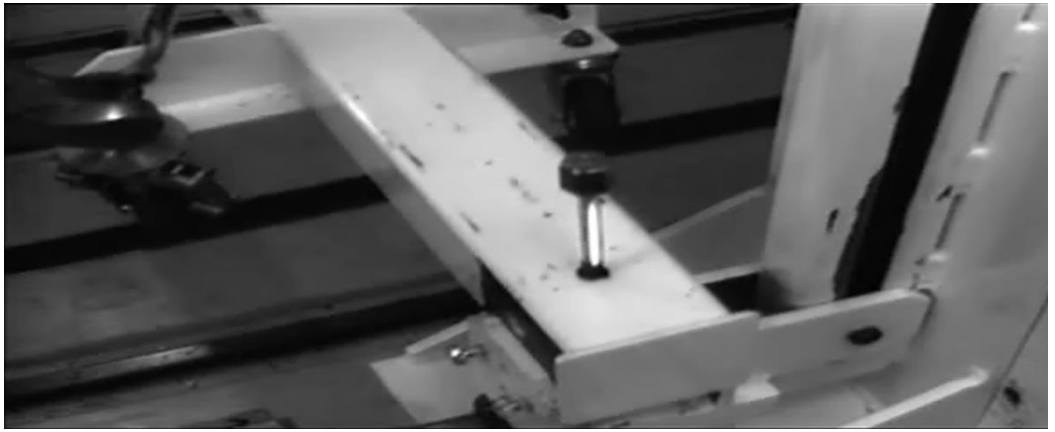
All the tooling, spares and lifting equipment were loaded into the cell before the target trolley was retracted. This was carried out by cell entry. The cross beam jacks were bolted to the walls. The remote EPB clamp was released and the void vessel then retracted. Target, Reflector and Moderators were still in place within the vessel.



Cross Beam wheeled across the floor and rails.



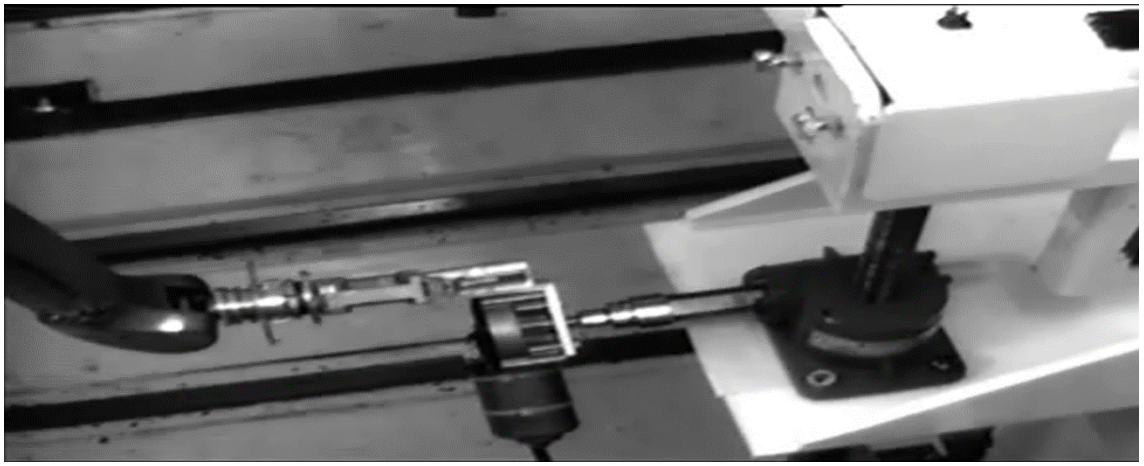
Cross Beam hoisted by crane below the EPB tube



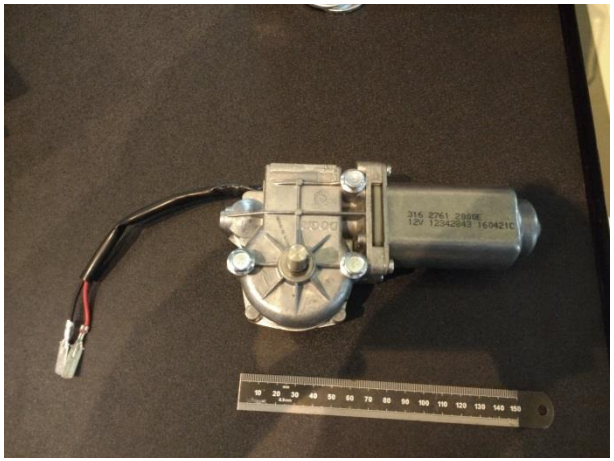
Cross Beam lowered into Wall Jacks

Window Change Process

ISIS developed, power drivers used for the first time. 2 used in tandem to jack the beam. This device was also used to traverse X & Y on the support table.



Power drive in action winding the cross beam jack.



Off the shelf 24V motor and gearbox assembly, before adapting with a gripper block to accept the remote handling grip. A half inch socket drive was pinned to the shaft.

Cross beam jacked up and EPB tube captured

The CARRS manipulator arm grips can only rotate 5 times before releasing the grips and counter rotating to return to the beginning of the drive.

We did try adapting off the shelf battery powered screw drivers. However, due to the 11m cable the voltage drop was too great for them to have sufficient power.

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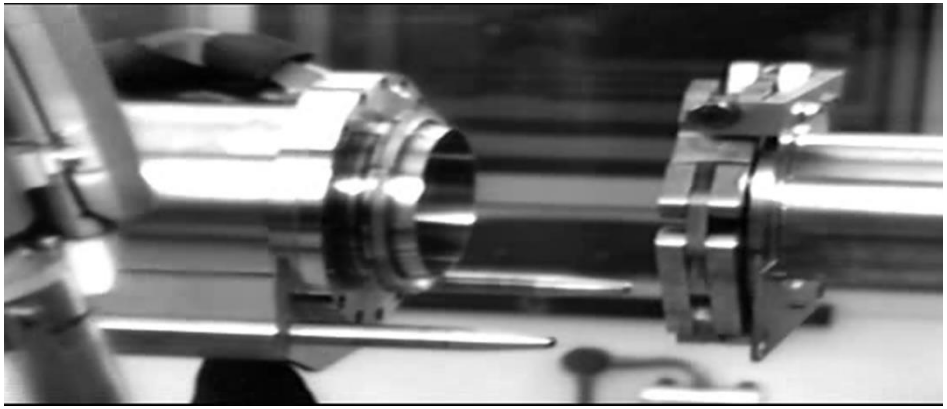
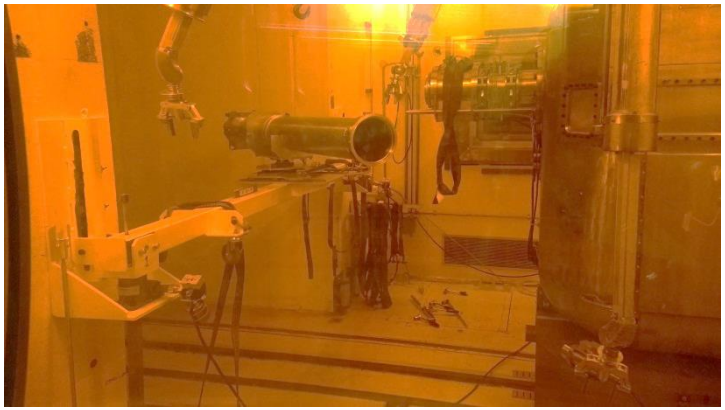
Window Change Process

First job was to change the EPB tube seal

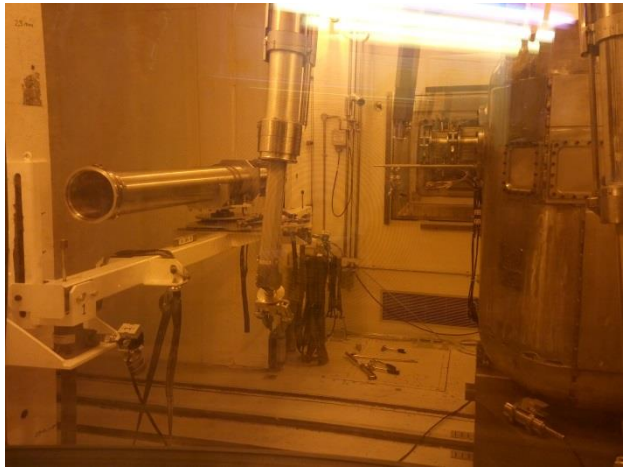


Release the chain clamp and using the XY table, the tube was withdrawn from the guide pins. Clamp remains captive to the EPB tube. The seal remained on the monitor



EPB tube was rotated to access the remote clamp. The seal remains captive to this flange.

The old seal was discarded and the replacement metal seal was located onto the flange.



The EPB tube was aligned with the cross beam and lowered. The tube was stowed in this position. If required cross beam could be removed with the tube in this position.

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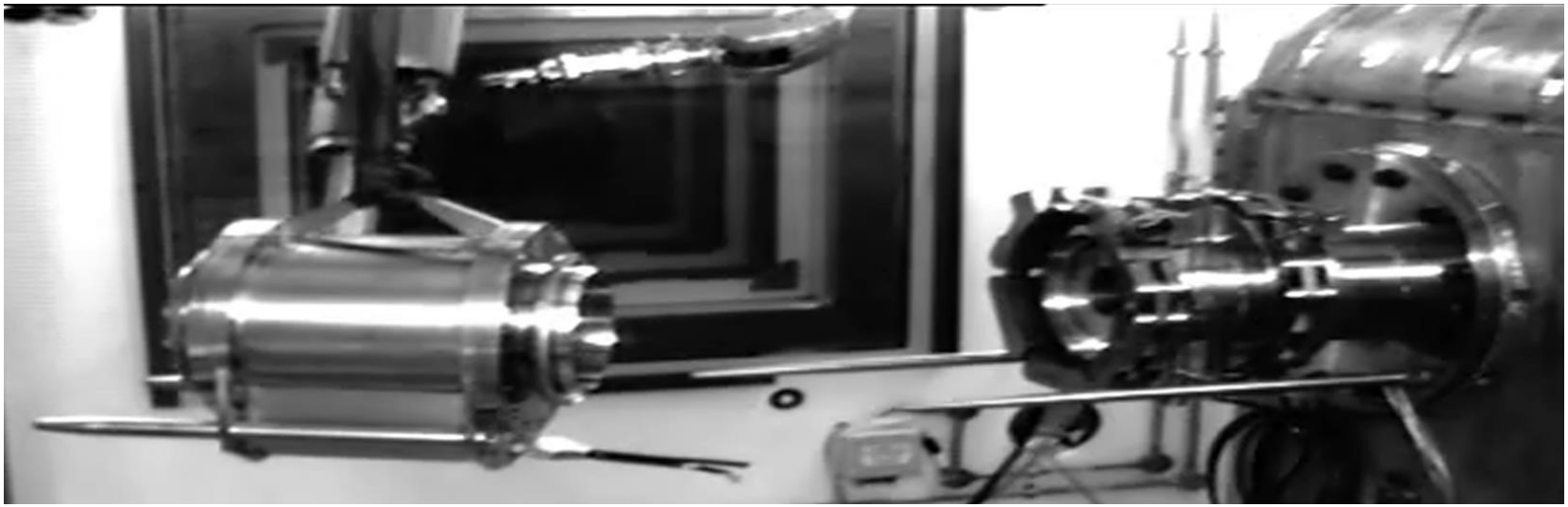
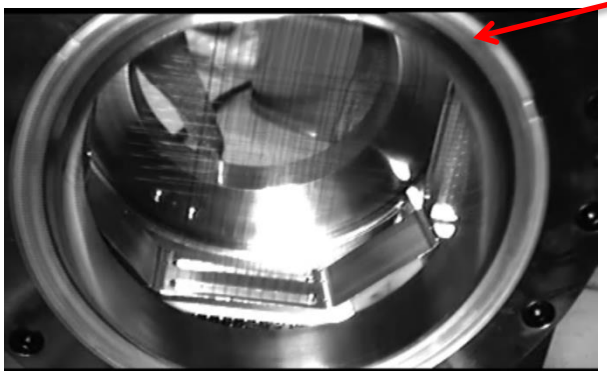
Window Change Process

Beam Profile Monitor Removal

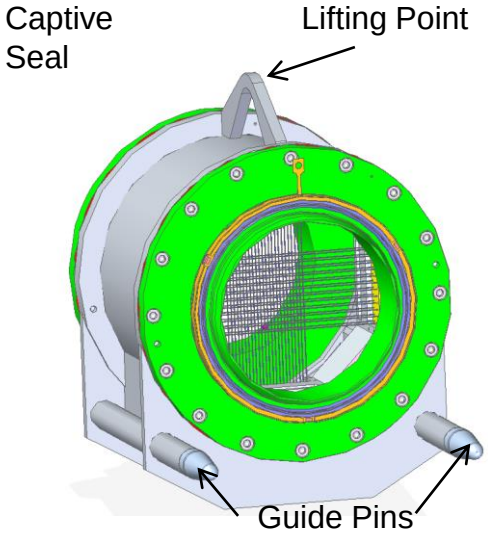


Monitor clamp was released and remained captive to the window assembly. The seal on this side was also captive to the monitor. The monitor was removed off the guide pins and discarded.

Cutting the monitor wires was a 2 man job With a regular pair of pliers. The outer insulation had deteriorated due to rad damage.



Grid wires looked intact within the monitor



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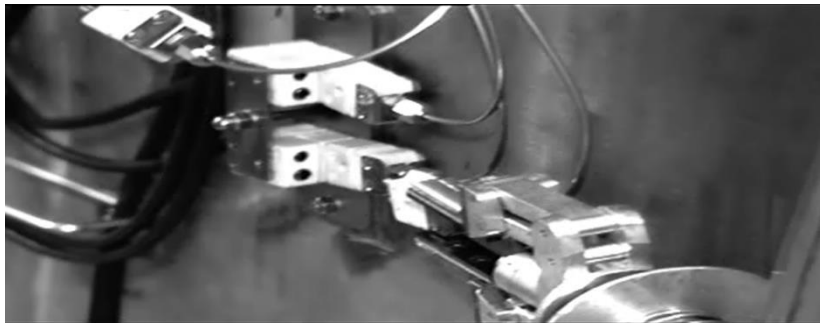
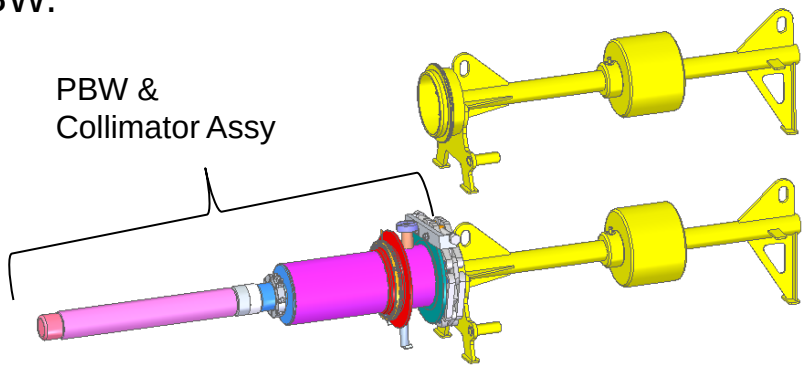
Window Change Process

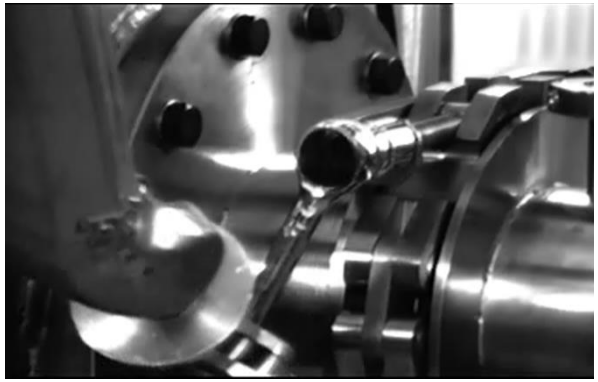
Extracting the PBW.



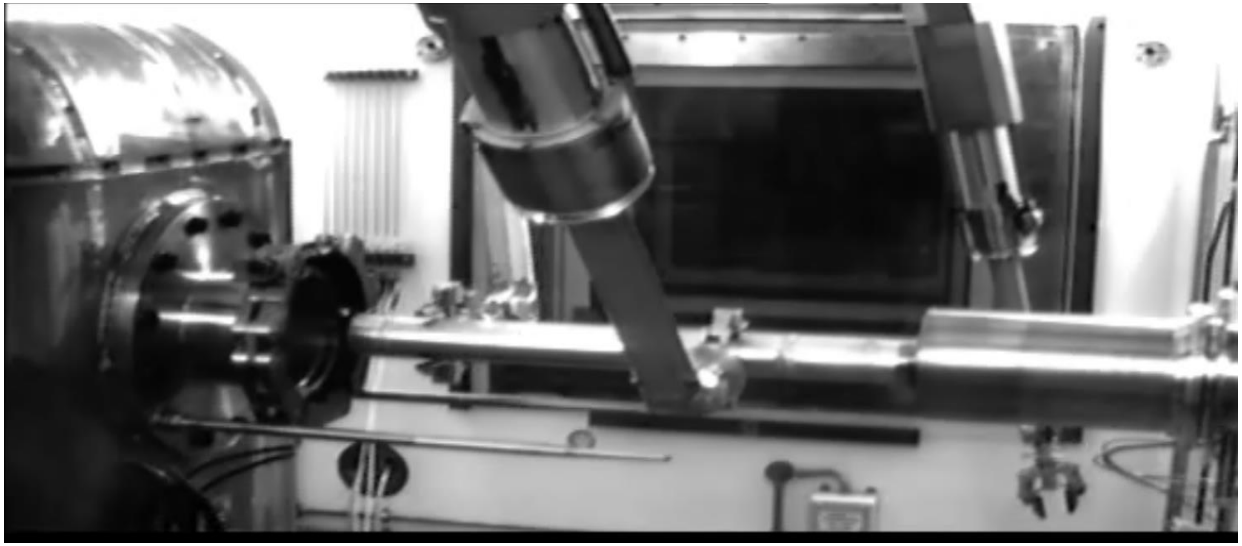
Disconnecting the 4 ceramic connectors for the collimator temperature sensors



Counter balanced lifting tool, attached to the window using captive chain clamp, used to extract the window from the void vessel.



Void vessel chain clamp being released.



Extracting the PBW assembly from the void vessel. The chain clamp remained captive to the void vessel. The metal seal was retained on the window assy.

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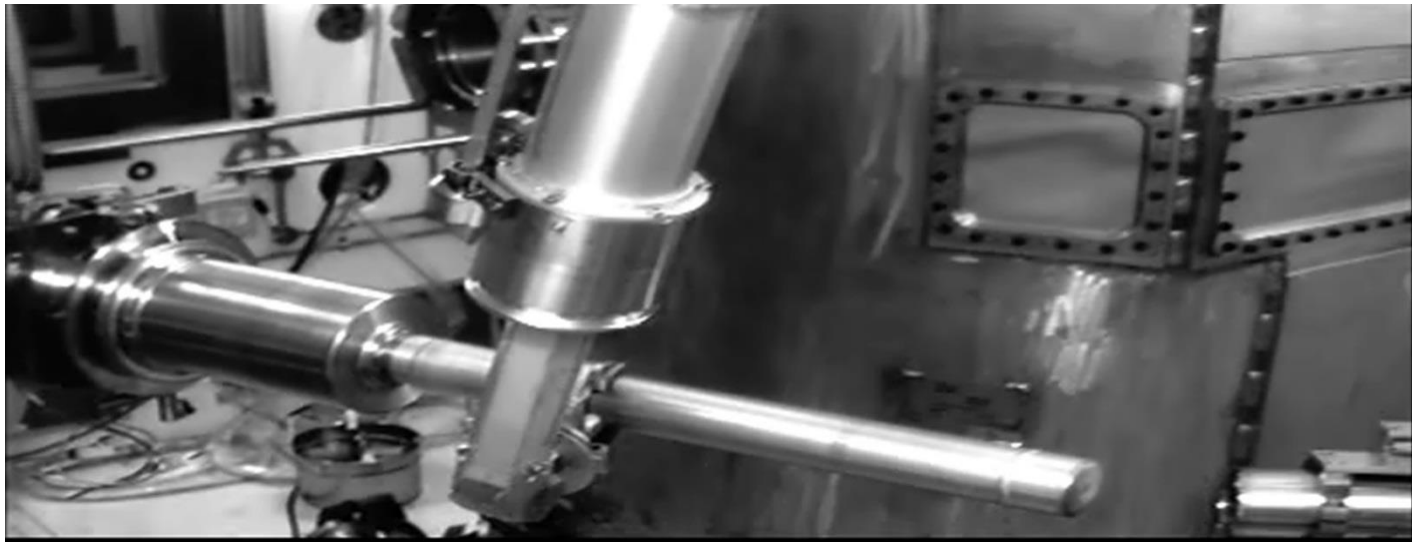
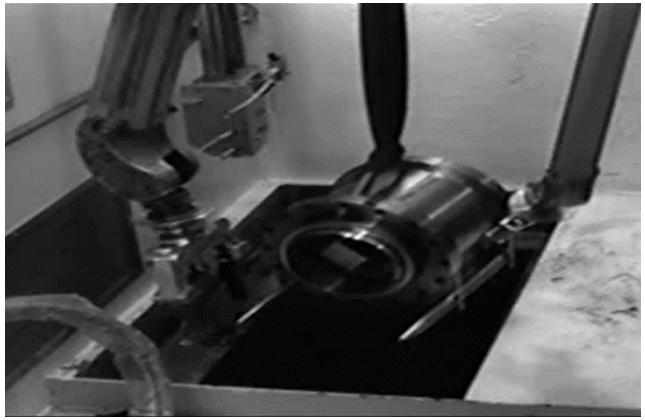
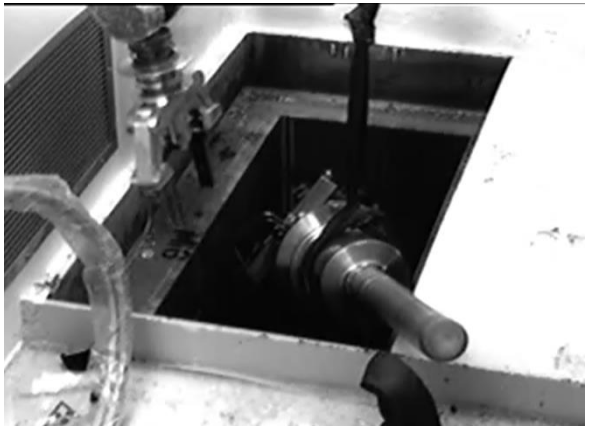
Window Change Process

Extracting the PBW & Inspection

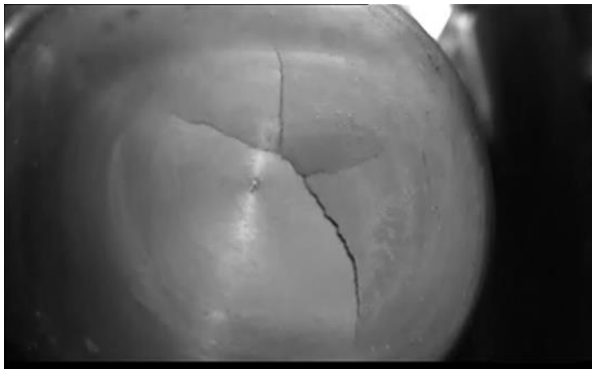


Inspection of the PBW with the flying lead camera





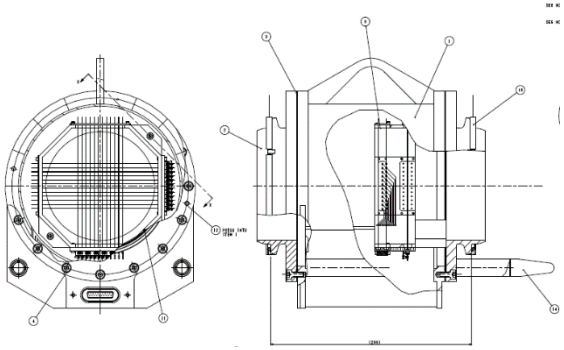
Profile monitor & PBW temporarily stored in the cell floor safe, awaiting processing and disposal flask.



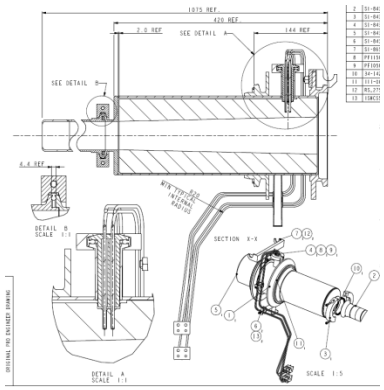
Confirmation of the window failure.

Window Change Process

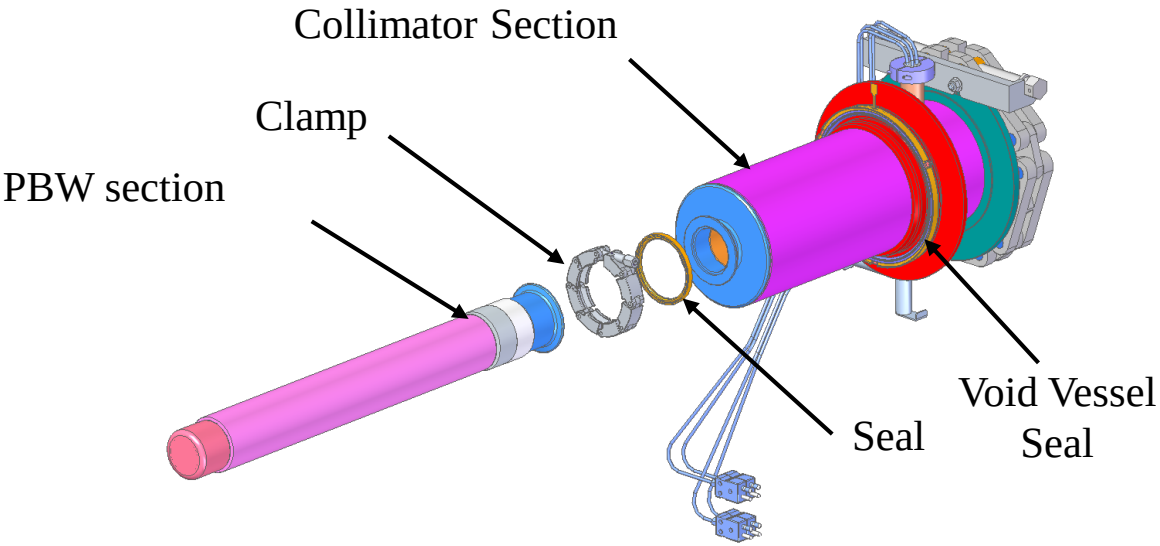
Reassembly was a reverse process.



A new profile monitor of the same design was fitted



- Replacement metal seals were fitted throughout.
- The chain clamps was replaced on the window assembly only.
- Seals couldn't be tested until the void vessel was returned to the forward position and with the EPB remote joint remade.



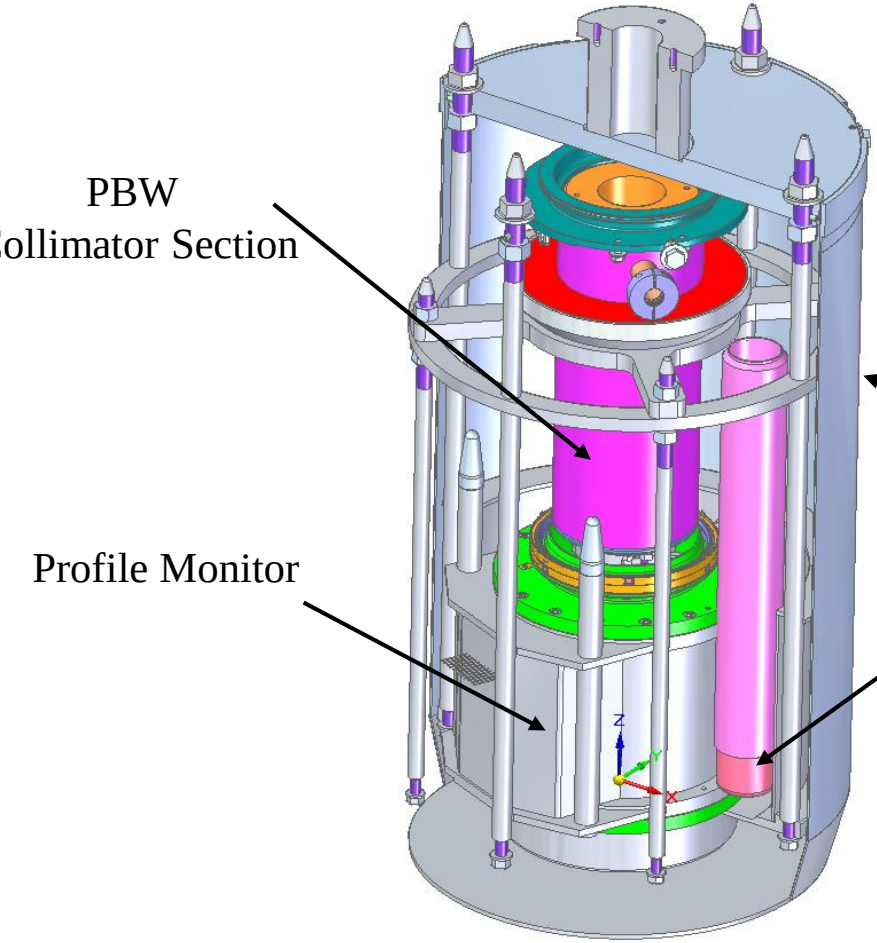
The new PBW and collimator assembly design provides the ability to reuse the collimator section reducing active waste. The window material & dimensions remain the same.

Window Active Disposal

Cradle designed to support window assembly in a standard target flask.

Possibly use a portable band saw to separate the window from the collimator.

Window & Profile monitor support cradle



Summary

Success!!!

- Everything went to plan without any bumps along the way.
- Although planning, design and delivering all the bits and pieces ready for the job took 2 months. The window change process took 3.5 days to carry out.
- Pump down of the synchrotron UHV took a few days due to being open to atmosphere for an extended period.
- TS2 was ready for beam on beginning of cycle before it was discovered that there was a problem with the TS2 Halo. (Pin had become damaged in the door interface). Some spare wiring from another source solved this.
- TS2 Is currently in operation
- Tooling and procedures are in place for future window changes, most likely to take place every 6 years.

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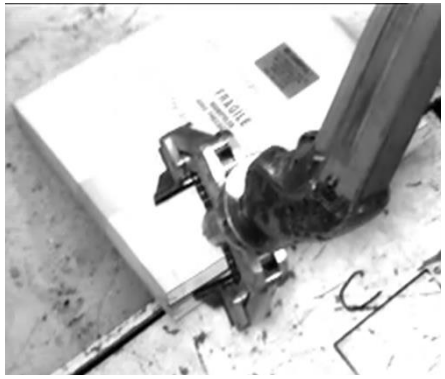
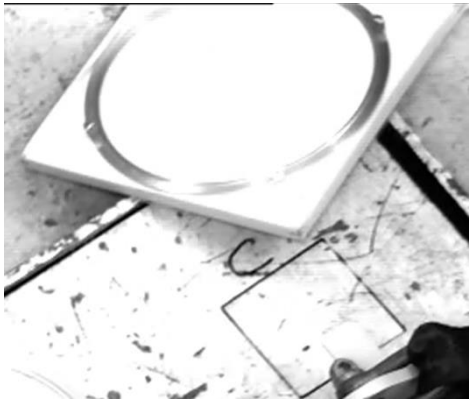
Lessons Learnt?

Always take the lid off the new seal box, before inserting in the cell
(Lots of swearing involved)








Practice with a pizza box required!

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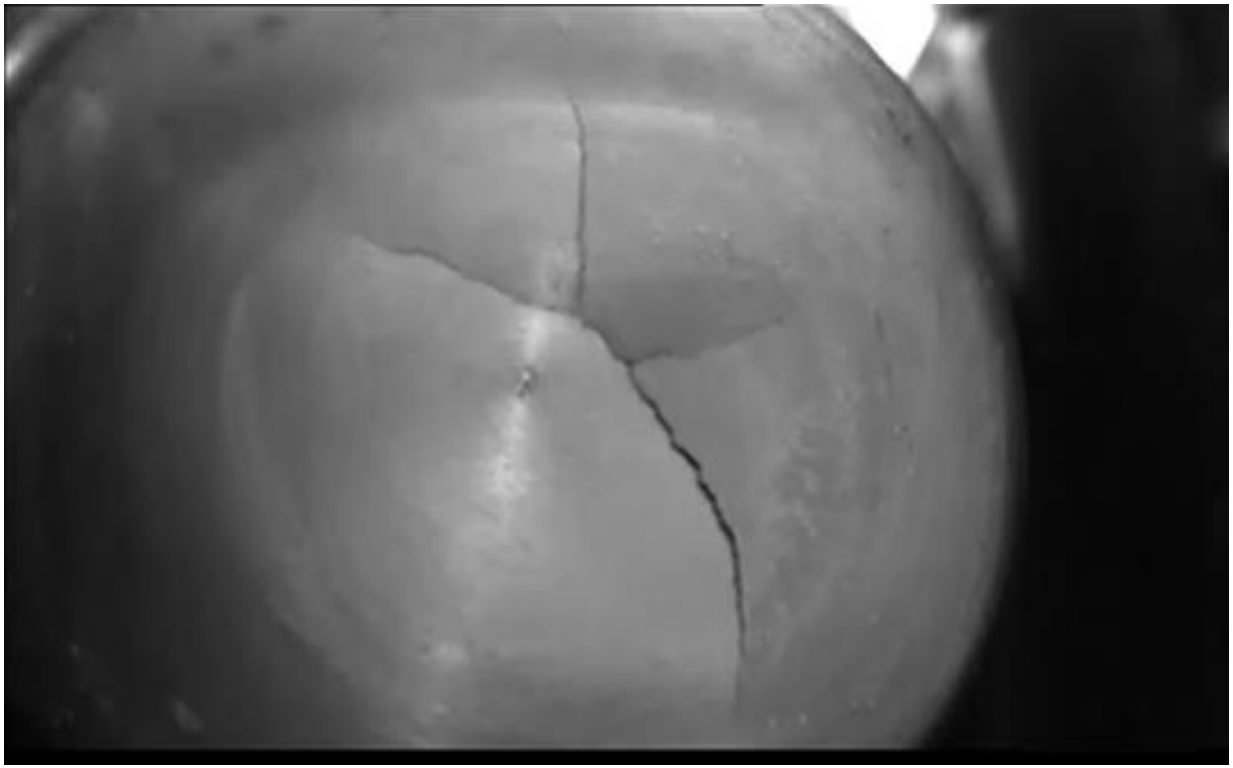
Any Questions?



Panel of Experts

- Leslie Jones– PBW & Monitor Design
- Daniel Blanco Lopez – Waste Flask Design
- Dan Coates – Remote Handling Tool Design