

LBNF Target and Associated Equipment Status Report

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MATERIALS
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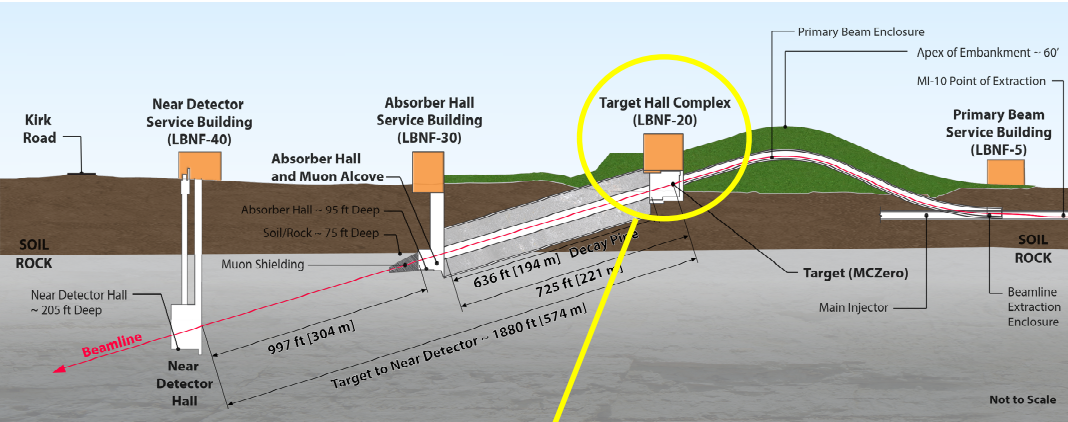


DEEP UNDERGROUND
NEUTRINO EXPERIMENT

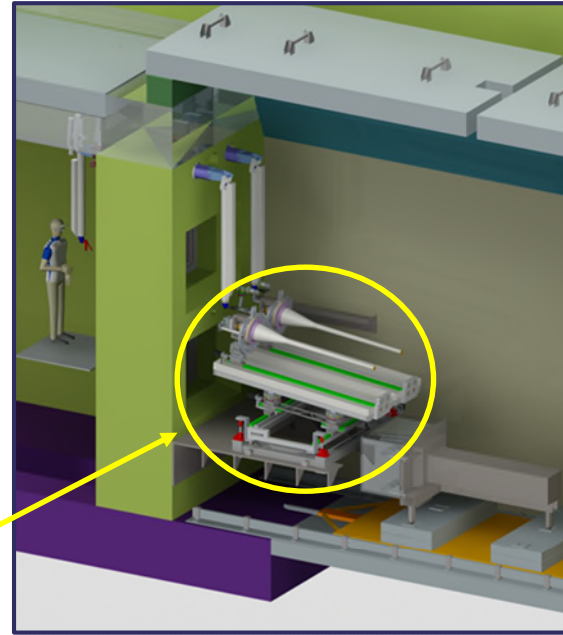


Fermilab
Long-Baseline Neutrino Facility

Scope of UK In-Kind Contribution

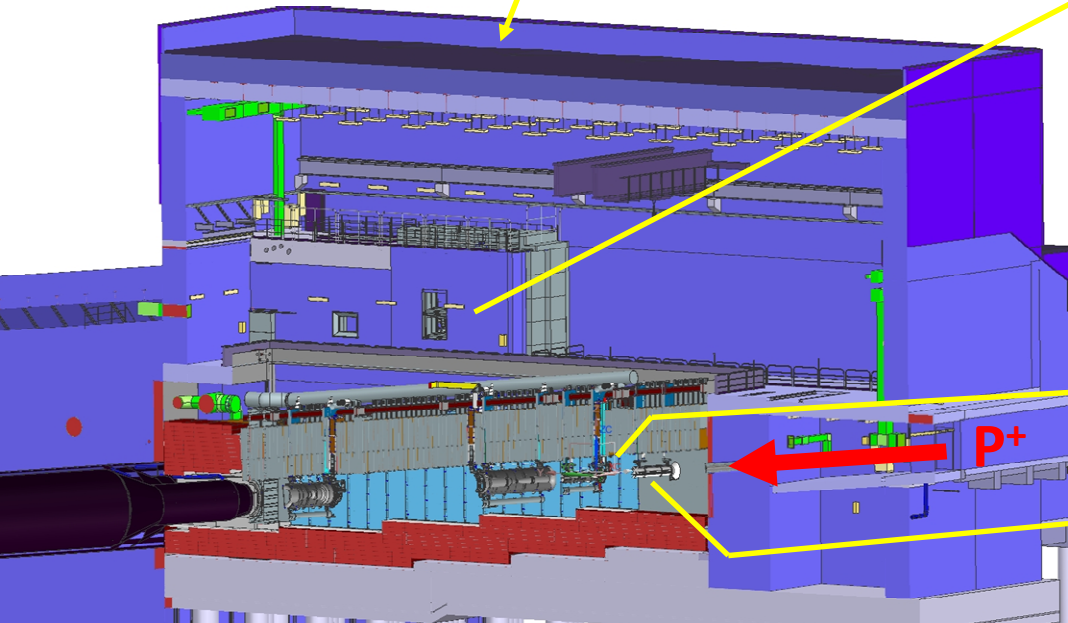


1x Target Exchange System:

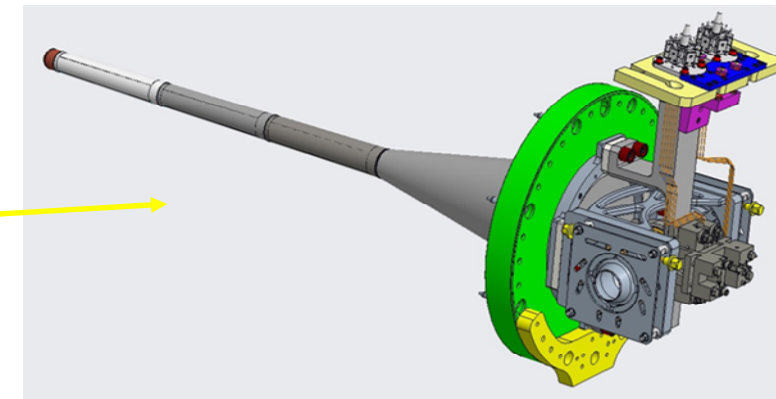
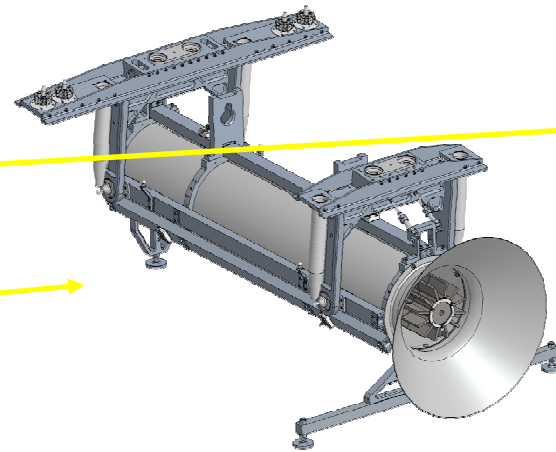


Various Helium Plant Components inc. Blower and Coolers:

<ul style="list-style-type: none"> > 1x Positive Displacement Blower > 1x back-up blower (Working Allowance scope opportunity) 	<ul style="list-style-type: none"> > 1x Target RAW Cooler > 1x Compressor Pre-cooler > 1x Compressor After-cooler 	<ul style="list-style-type: none"> > 1x remote operable gas purity monitoring system



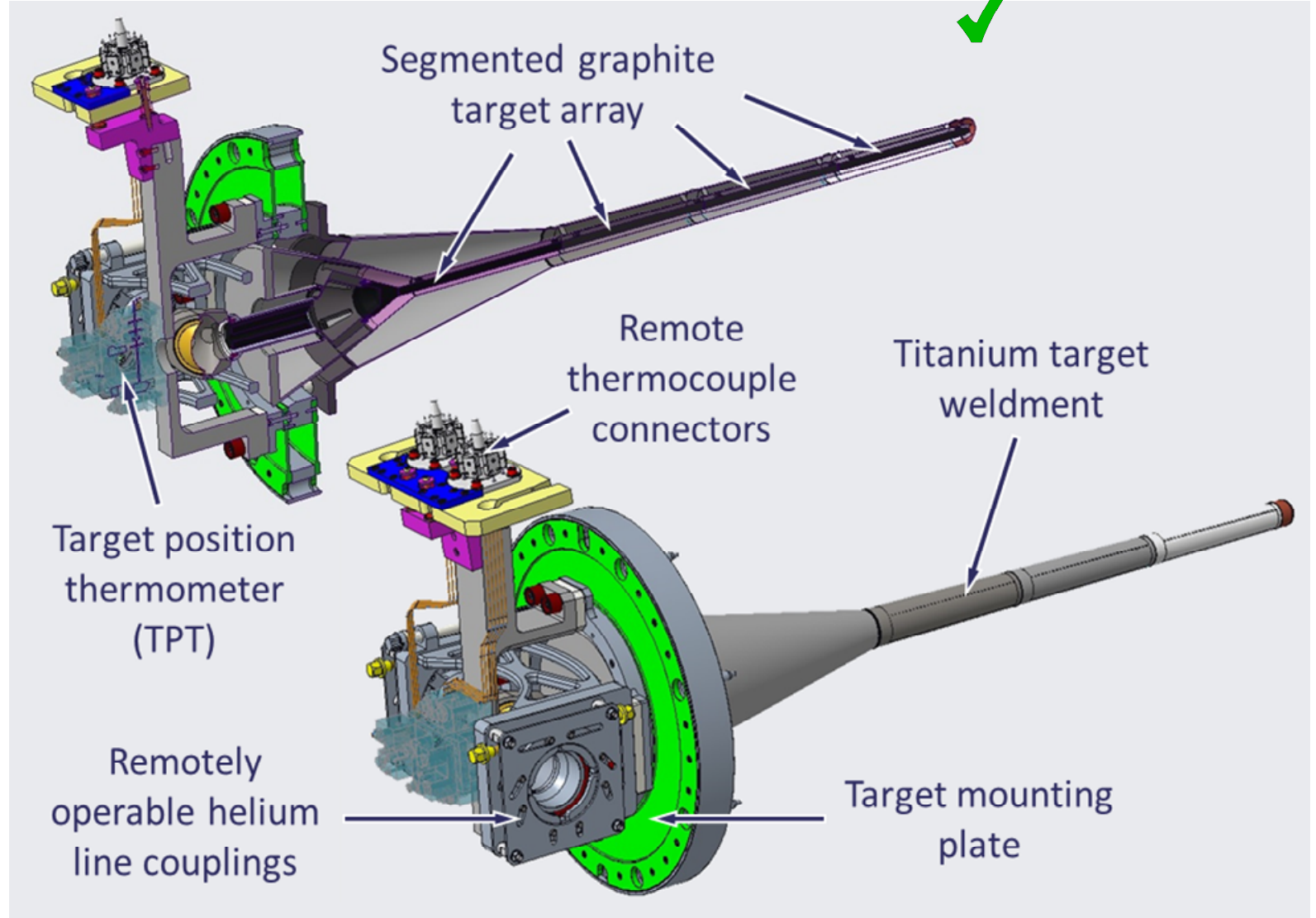
1x Instrumented Baffle:



Targets, Supports, Pipework:
 1x Prototype Target
 1x Production Target

WP1: 'Prototype' Final Design Review for the prototype target: **Approved to build**

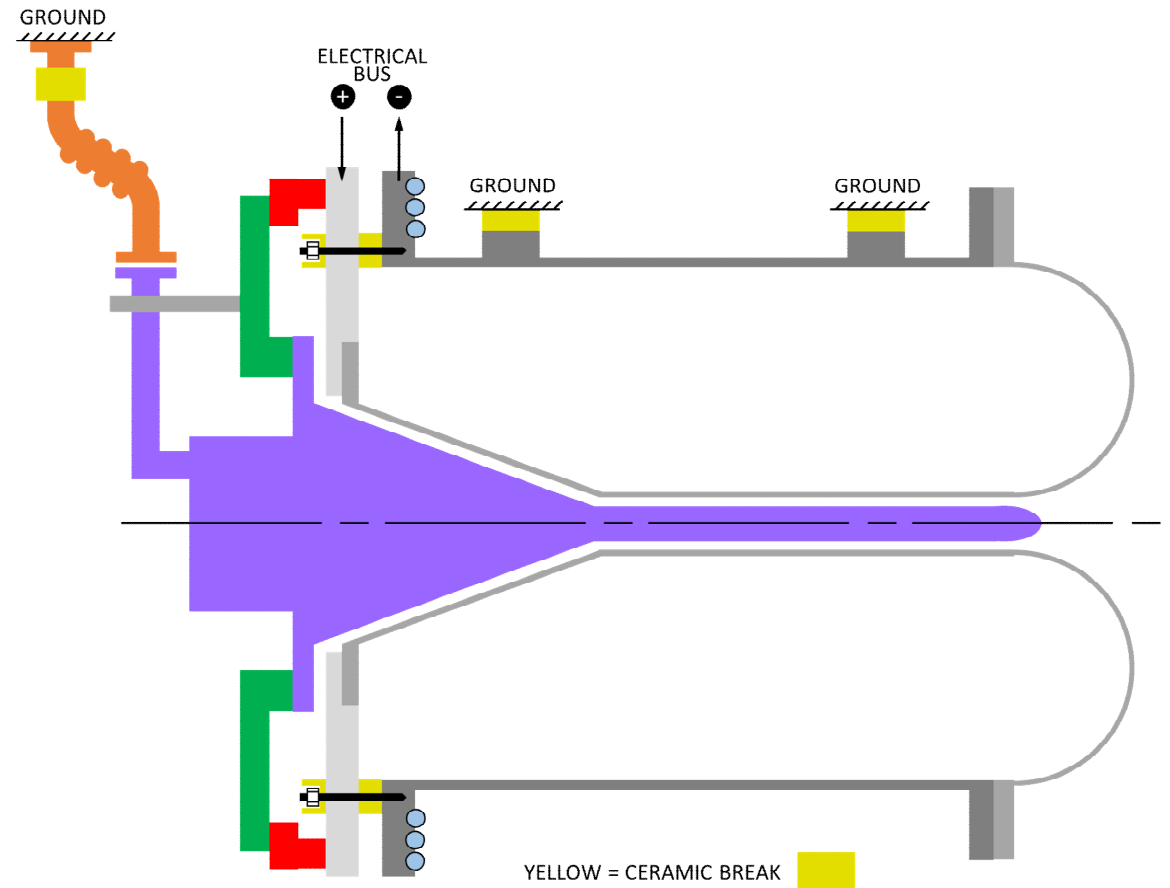
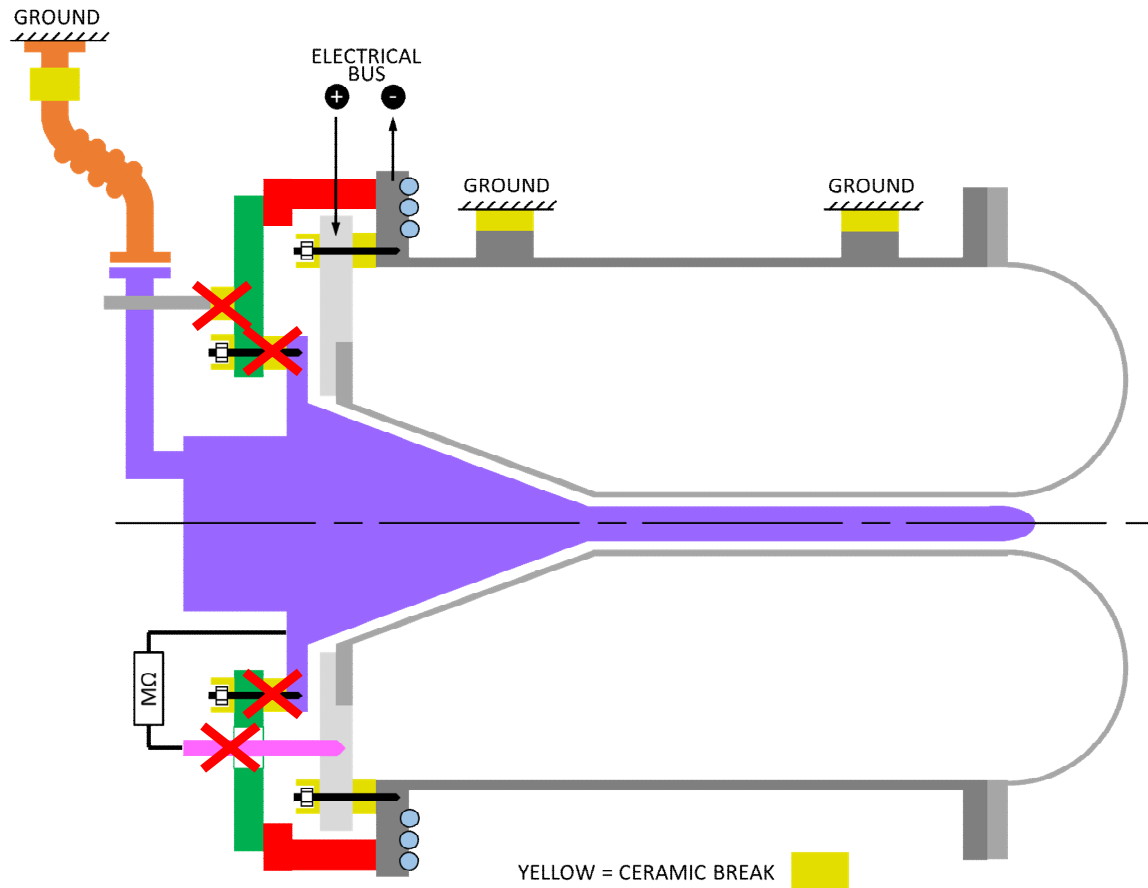
- ❑ Technical Design Review held to approve construction of 1st full size prototype target
- ❑ Viable spare if successful
- ❑ Plan is to install in prototype Horn A at Fermilab, using prototype target exchanger (TXS)
- ❑ Target weldment is on critical path
- ❑ Graphite selection and manufacture also required



Simplification of isolation/supports

- ❑ Previously: Target mechanically mounted from horn **Outer** Conductor Flange
- ❑ Target electrically connected to horn **Inner** conductor via high resistance connector

- ❑ Now: Target mechanically **and** electrically mounted from Inner-Conductor Flange (no complicated resistor and a lot less ceramics)

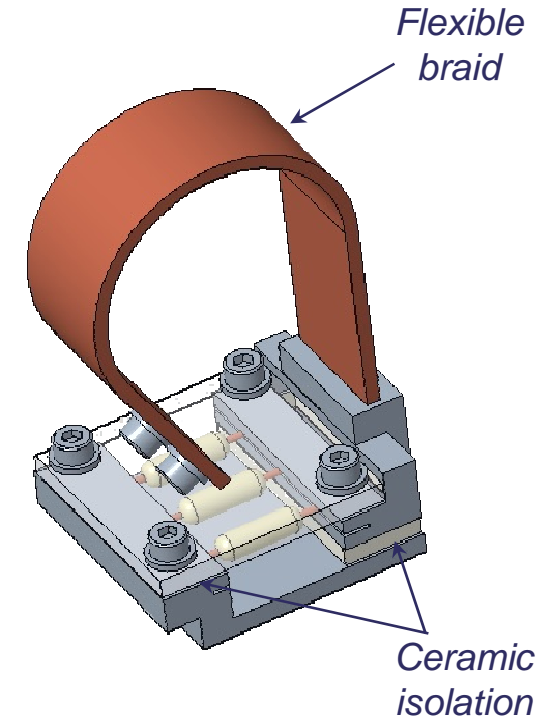
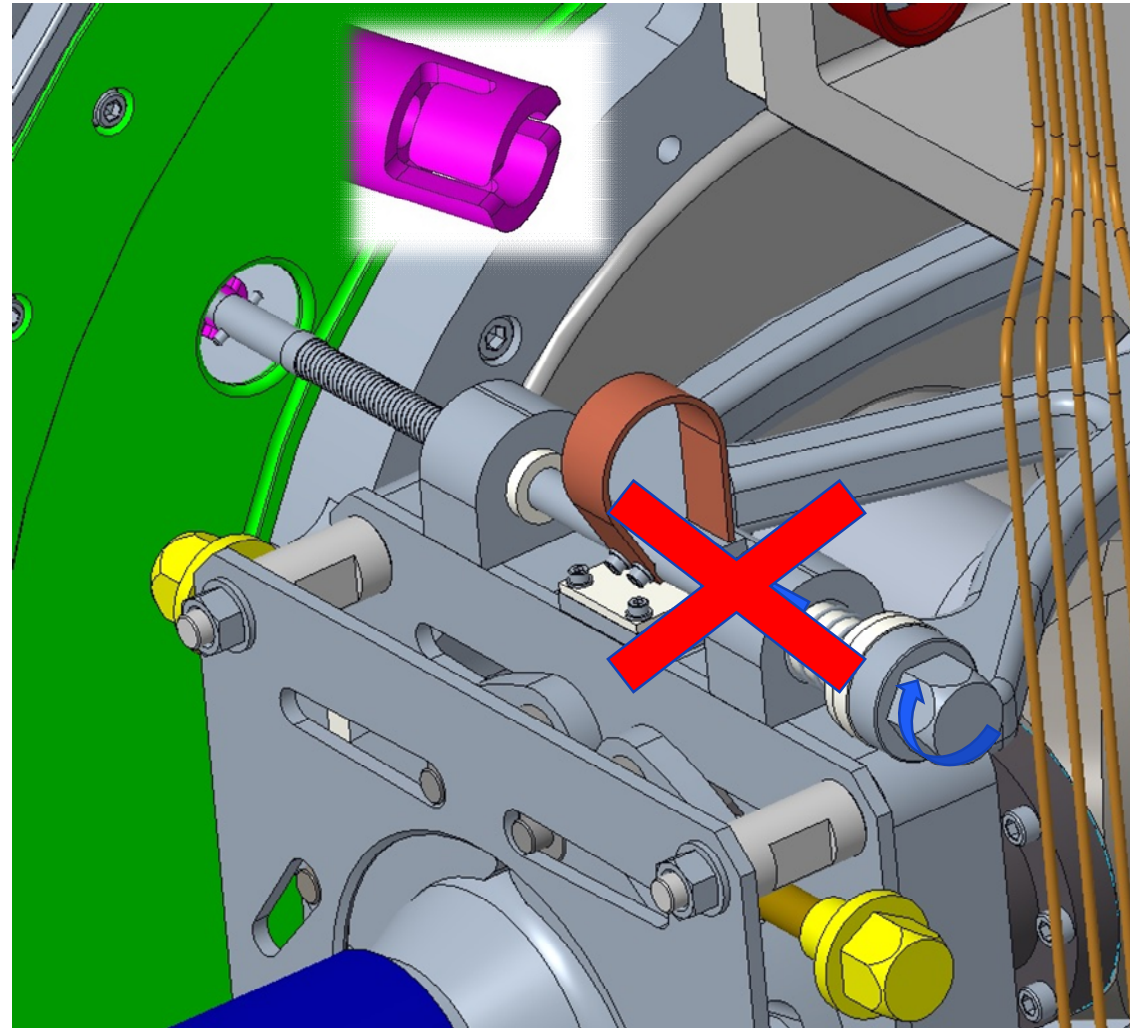


Elimination of complicated & risky electrical connector

The electrical connection bayonet is insulated from the target via ceramic bushes which allow sliding and rotation movement.

The remote handling manipulator slides the spring loaded bayonet forward and rotates 90° to engage the plug end with the horn electrical pin socket.

The electrical connection is maintained via a flexible braid which allows movement of the bayonet assembly.

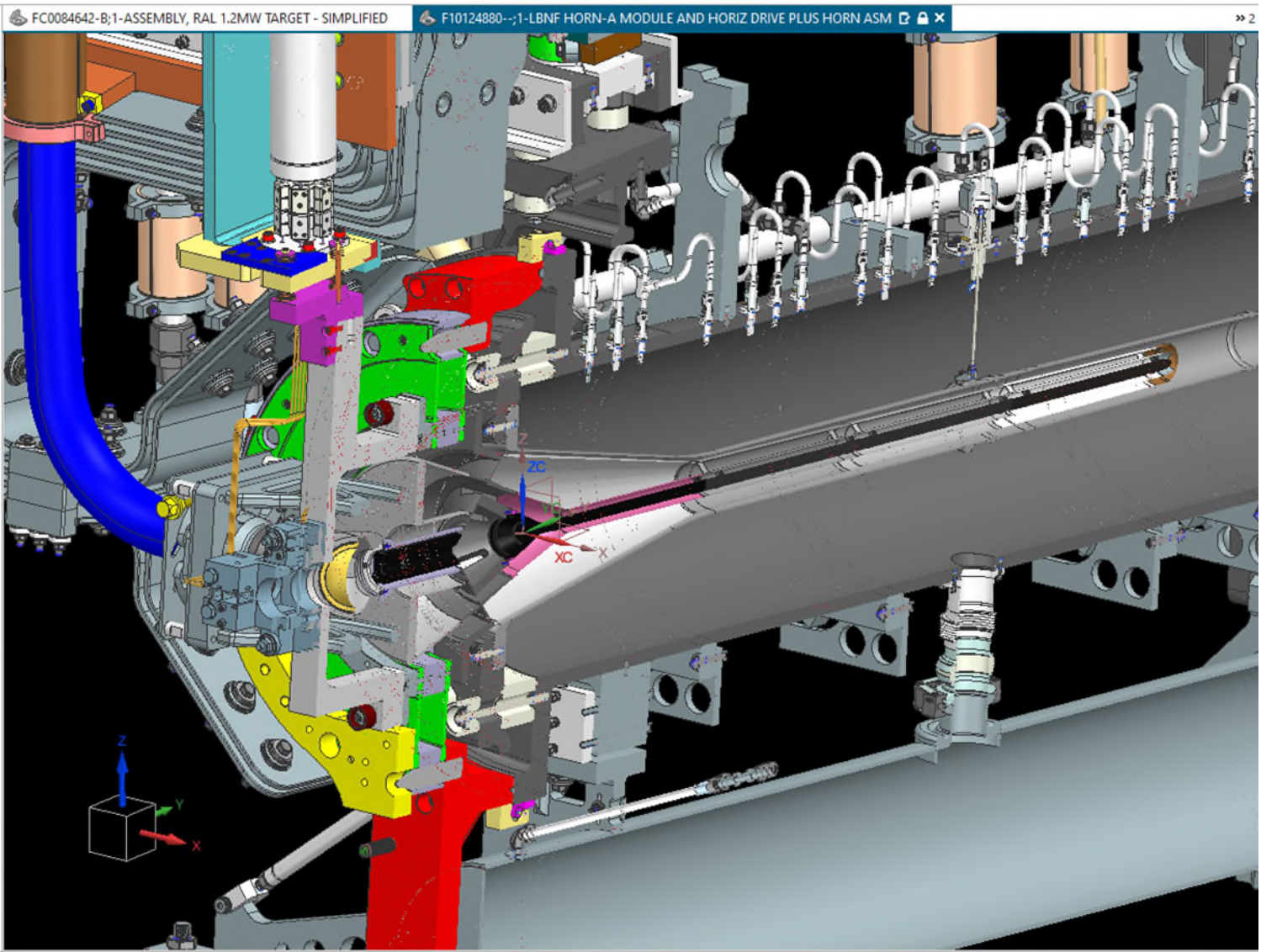


The electrical connection between the horn and target weldment passes through a $\sim 1M\Omega$ resistance. (several resistors in parallel for redundancy)

Assembly Navigator

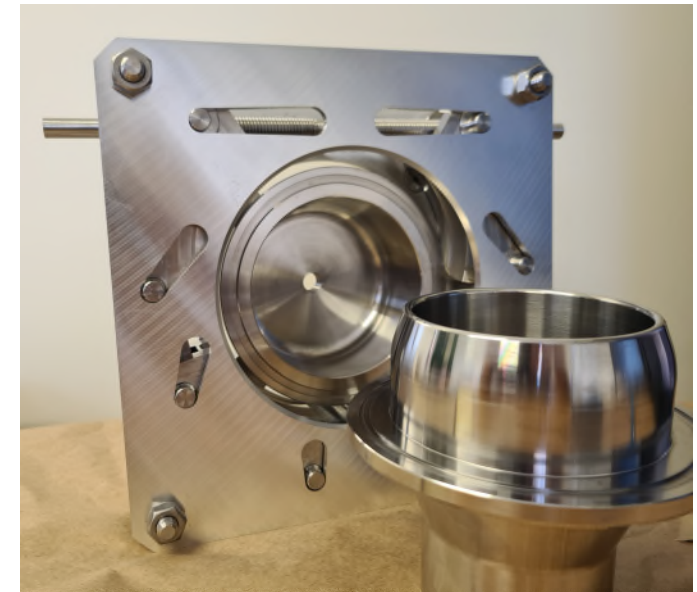
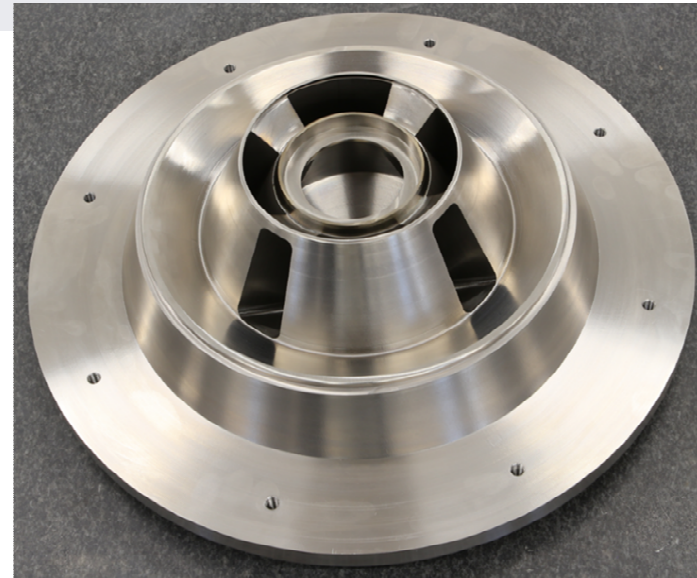
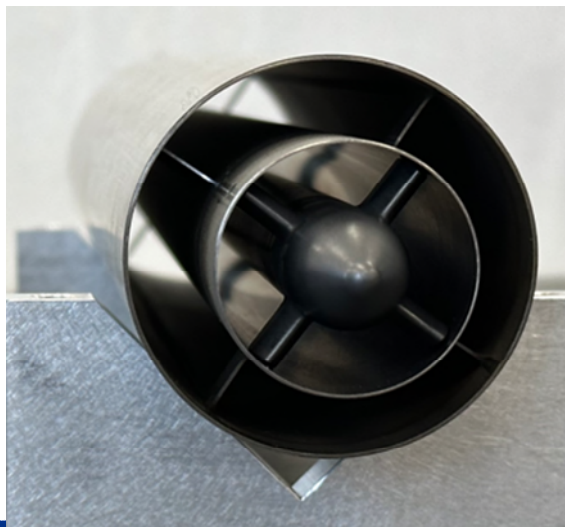
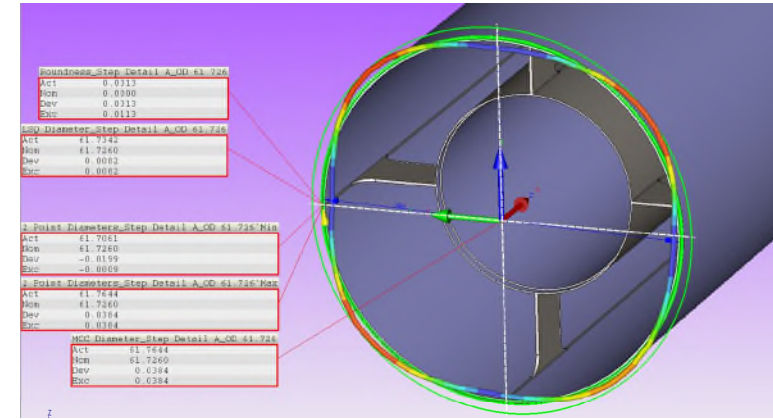
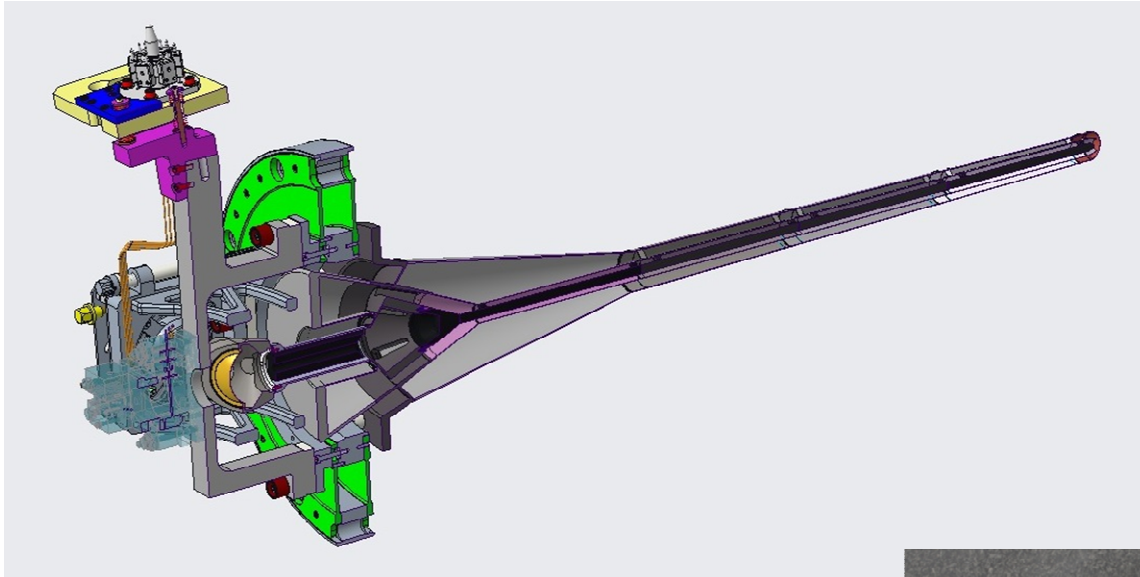
Object	Re...	I...	M	Position	Q...	Mass
Sections						
<ul style="list-style-type: none"> [-] F10124880--:1-LBNF HORN-A MODULE AND HORIZ DRIVE PLUS HORN ASM (Order... [+] F10124733--:1-LBNF HORN-A MODULE ASM [+] F10128551--:1-LBNF HORN-A & BAFFLE MODULE HORIZ DRIVE ASM [+] F10132366-A;1-LBNF MODULE, INSTRUMENTATION LINE MAIN ASSEMBLY x 2 [+] F10132433-A;1-LBNF HORN, 1.000" UTILITY LINE, MAIN ASSEMBLY x 3 [+] F10132434--:1-LBNF HORN, 1.500" UTILITY LINE, MAIN ASSEMBLY x 4 [+] F10132435--:1-LBNF HORN, EJECTOR UTILITY LINE, MAIN ASSEMBLY [+] F10133189--:1-LBNF HORN A STRIPLINE BLOCK, FINAL ASSEMBLY [+] F10132803--:1-LBNF MODULE, SURVEY PLUG ASSEMBLY x 5 [+] F10133341--:1-LBNF MODULE EJECTOR-LINE PLUG ASM [+] F10139442--:1-LBNF HORN A, HLS FEEDTHROUGH ASSEMBLY x 4 [+] F10133752--:1-LBNF HORN, 0.375" UTILITY LINE, MAIN ASSEMBLY x 8 [+] F10149632--:1-LBNF HORN A, TARGET MATING 						1272
Constraints						
<ul style="list-style-type: none"> [+] F10150227--:1-LBNF HORN A, TARGET SUPPORT COMPONENT ASSEMBLY [+] FC0084648-A;1-ASSEMBLY, RAL TARGET HELIUM LINES BELOW TUB [+] FC0084642-B;1-ASSEMBLY, RAL 1.2MW TARGET - SIMPLIFIED 						

[Preview](#)
[Dependencies](#)



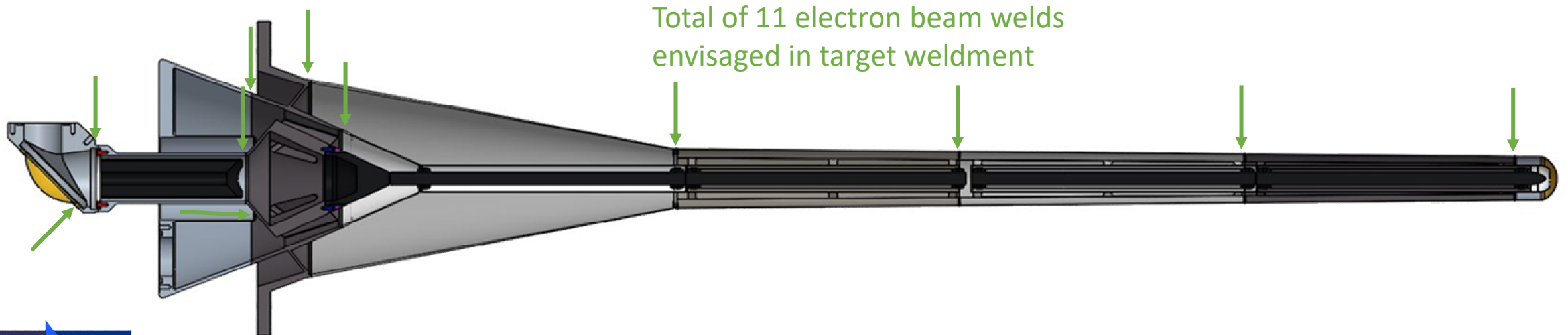
Integration of latest UK target model into full LBNF Target Station CAD assembly

Moving from 'feature' prototyping to construction of 1st full prototype



Target Welding Challenges

- ❑ Complex assembly process with many sequential electron beam welds & tight tolerances
- ❑ Many welds have additional technical challenges:
 - Joining thin-walled titanium sections
 - Maintaining straightness of 1.5m cantilever assembly after multiple welds
- ❑ Currently qualifying welding vendors to meet ASME pressure vessel code



Target graphite choice

- ❑ High density graphite grades being considered
- ❑ New physics performance result c/o John Back over weekend
- ❑ Changing grade of graphite has similar effect to increasing target length by 10 cm

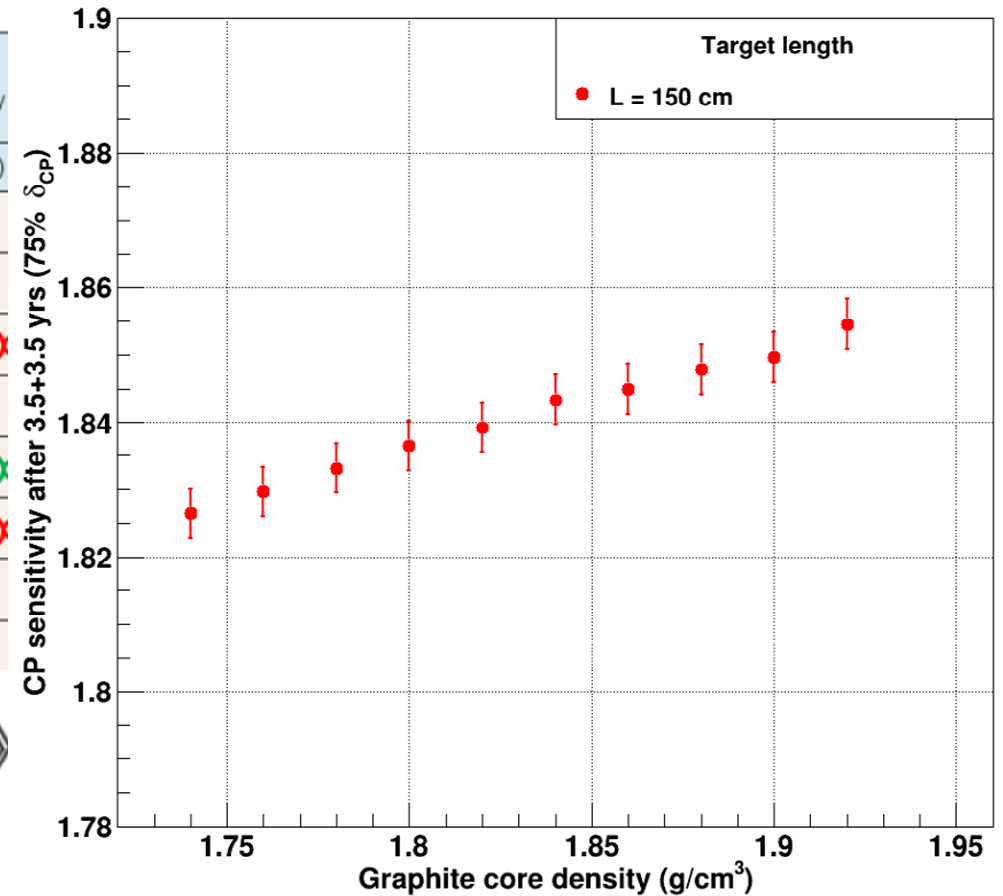
Typical Properties

Grade	Bulk Density	Hardness	Electrical Resistivity	Flexural Strength	Compressive Strength	Tensile Strength	Young's Modulus	Coefficient of Thermal Expansion	Thermal Conductivity
	Mg/m ³	HSD	$\mu\Omega\cdot m$	MPa	MPa	MPa	GPa	$10^{-6}/K$	W/(m·K)
IG-11	1.77	51	11.0	39	78	25	9.8	4.5	120
IG-12	1.78	55	12.5	39	88	28	10.8	4.7	100
IG-15	1.90	60	9.5	54	103	29	11.8	4.8	140
IG-19	1.75	60	17.0	38	88	25	9.5	4.6	80
IG-43	1.82	55	9.2	54	90	37	10.8	4.8	140
IG-45	1.88	55	9.0	60	110	40	12.0	4.9	140
IG-56	1.77	57	12.2	43	88	27	10.3	4.7	100
IG-70	1.83	58	10.0	47	103	31	11.8	4.6	130

 T2K target graphite

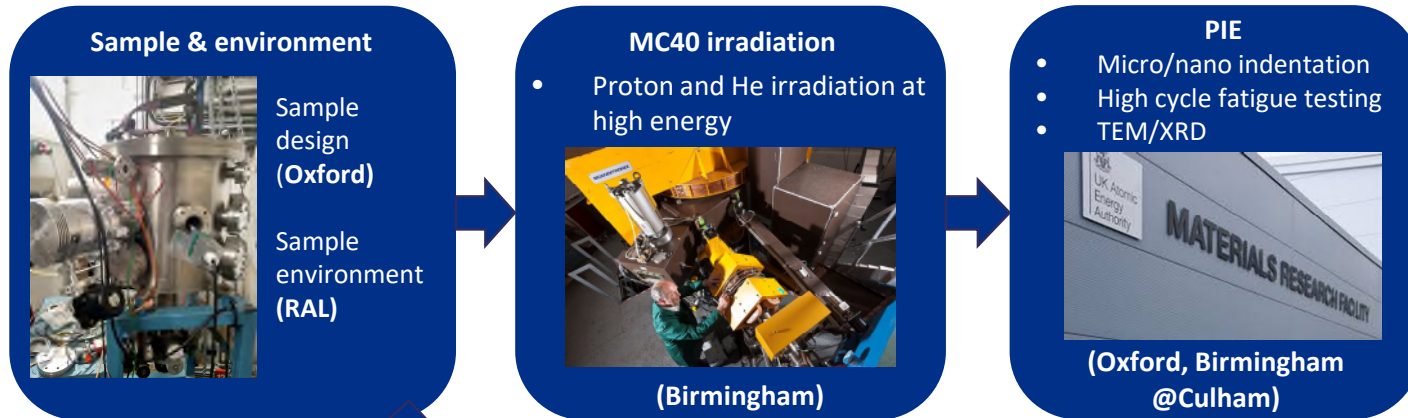
 Candidate graphite?

TOYO TANSO 

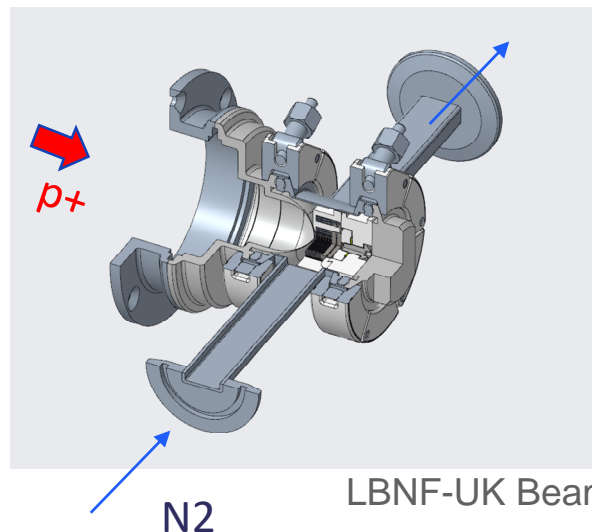


Using the Birmingham MC40 Cyclotron for materials irradiation studies:

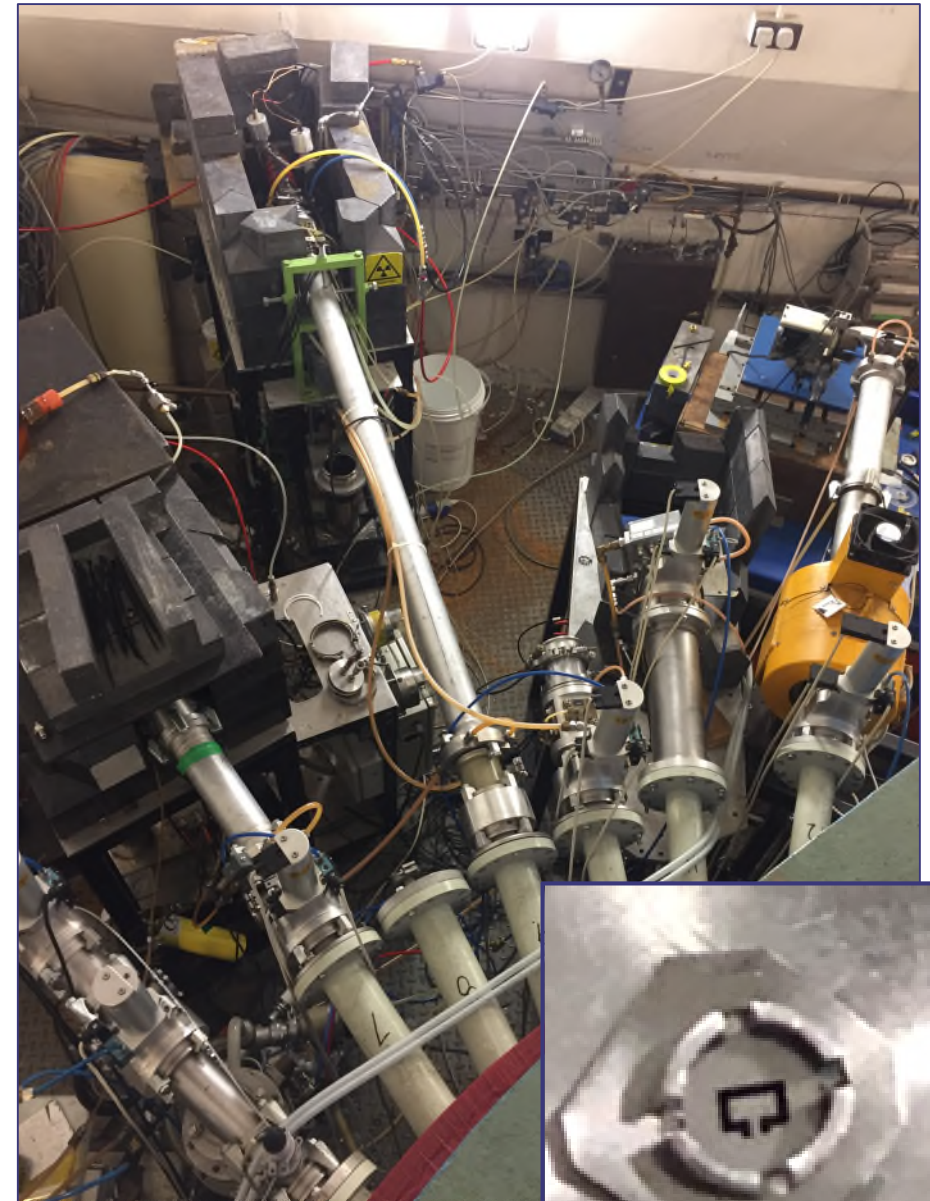
- ❑ Gas cooled material samples could be put into one of several beamlines
- ❑ This study focuses on titanium foils for meso-scale fatigue testing as PIE



Remotely handleable, nitrogen cooled sample environment



LBNF-UK Beam and Target System



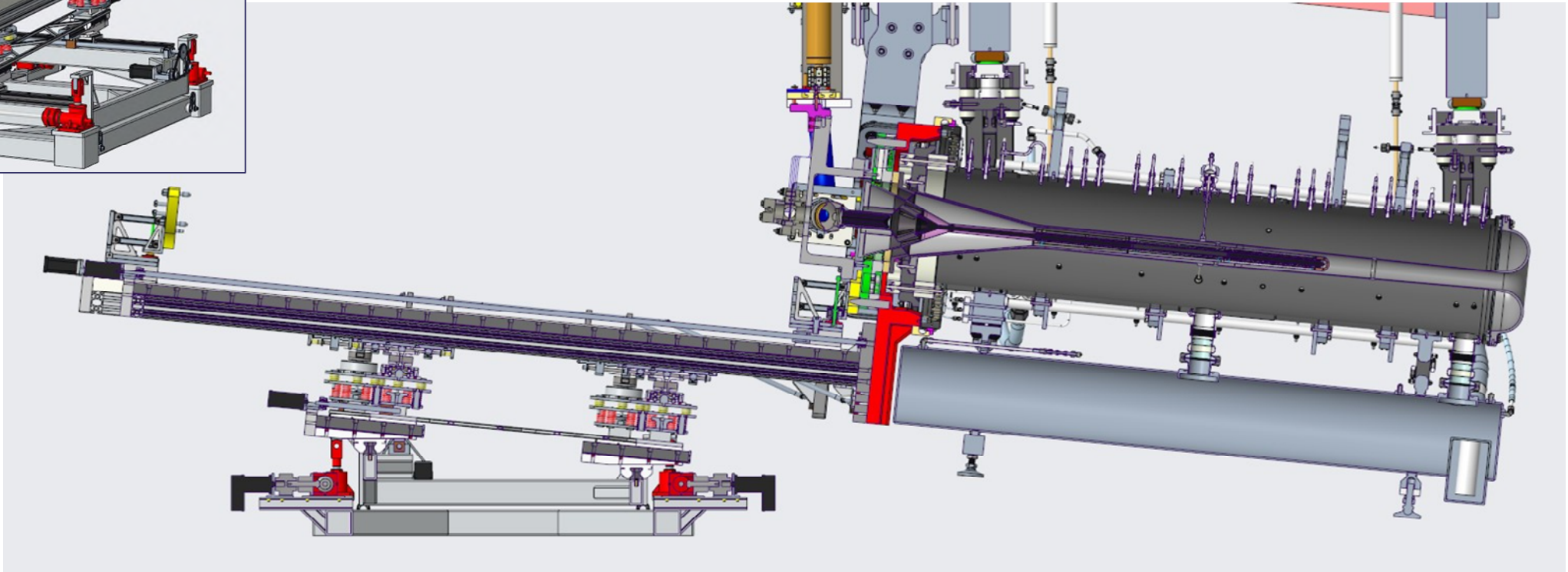
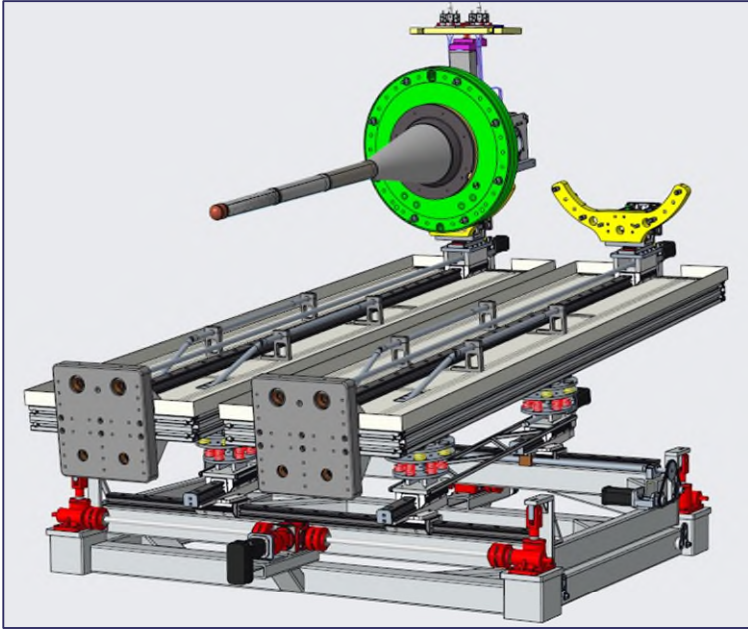
Slide 10

Offline rig at RAL to test effect of cooling flow on meso-scale samples

- ❑ Nitrogen cooling of Ti sample foils required during 30 μ A, 30 mA irradiation
- ❑ 1st test ...->
- ❑ Improved clamping and better spaced samples has resulting in a less dramatic 2nd result:

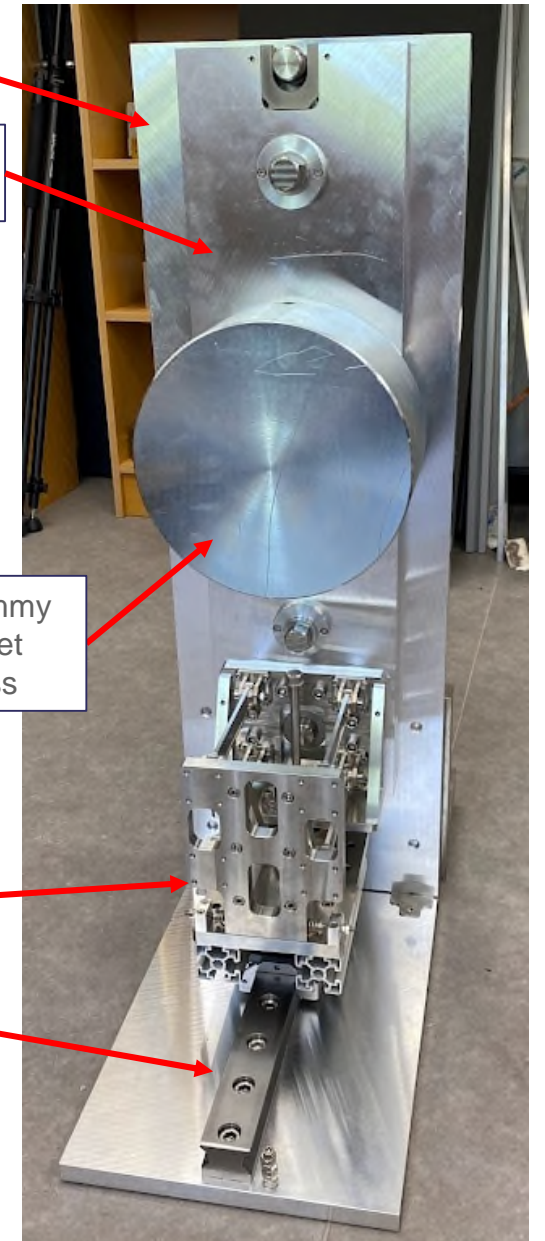
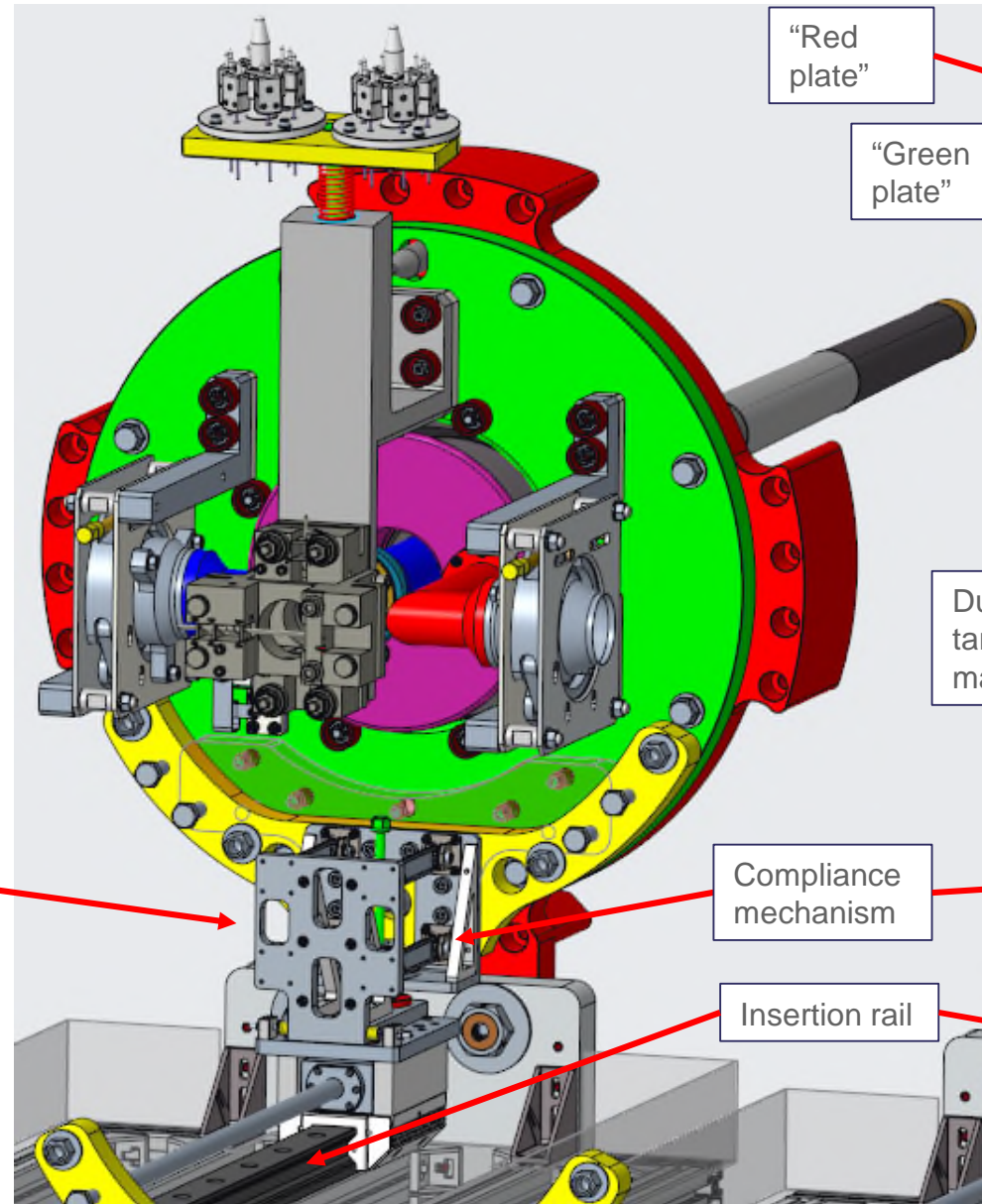
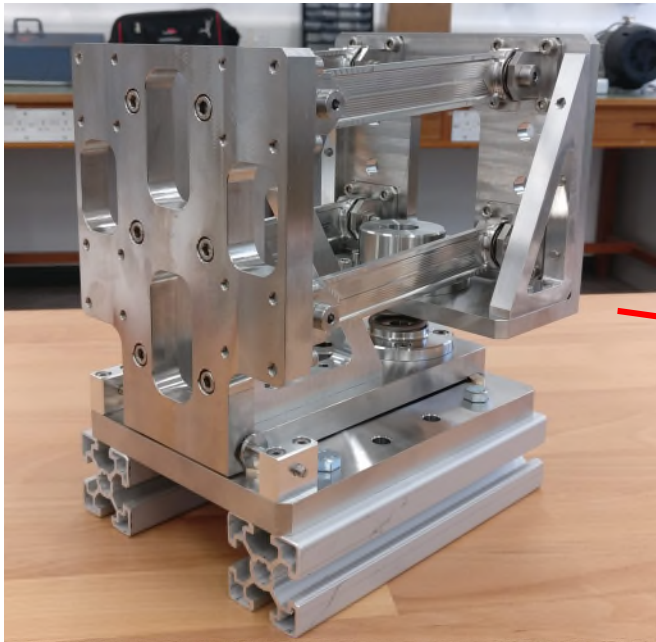


Target Exchange System (TXS) update



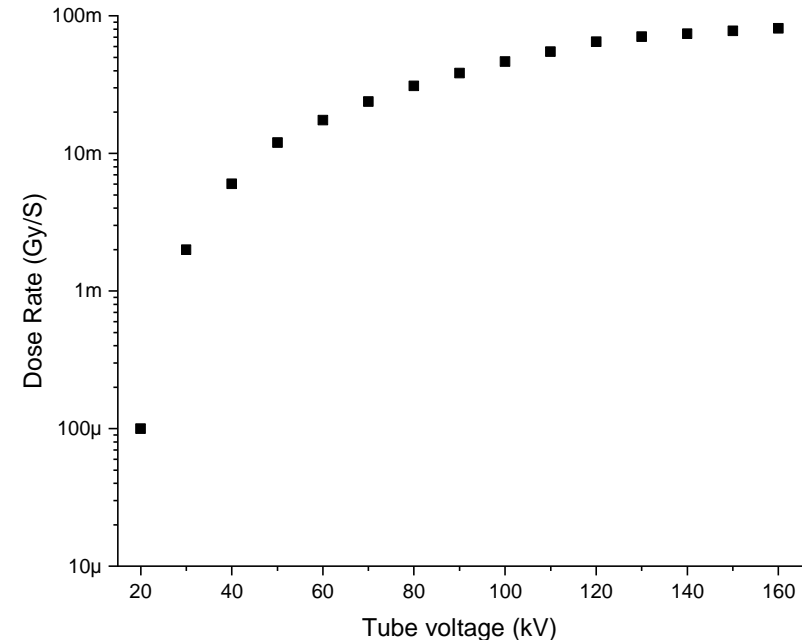
TXS Prototyping

- Precise yet flexible alignment required to avoid damage to target or horn
- Mock-up to test docking & compliance mechanism designed & built at RAL



Radiation testing of candidate (cheap laser disto) TXS proximity sensors using X-Ray Facility at RAL

- ❑ Onsite x-ray bay, Comet 40 to 160kV continuous source
- ❑ Achieved dose rates on sensor of 270uGy/s to 24mGy/s
- ❑ Short 1 minute irradiations at different dose rates
- ❑ 1x 1 hour irradiation at 4.4mGy/s



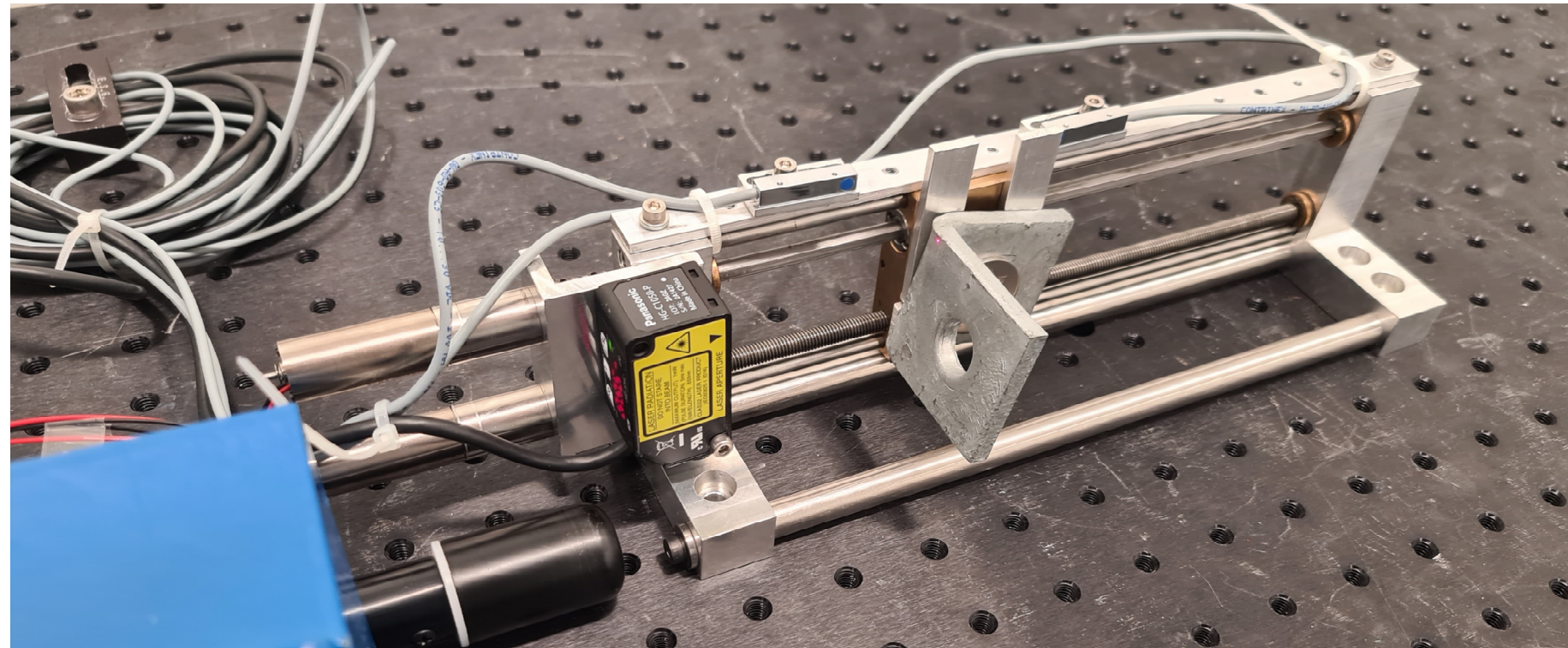
X-ray bay dose rates, 23cm Source to detector, 2.9mm Al filtration, measured with medical grade ion chamber(Sion Richards, STFC Detector Division)



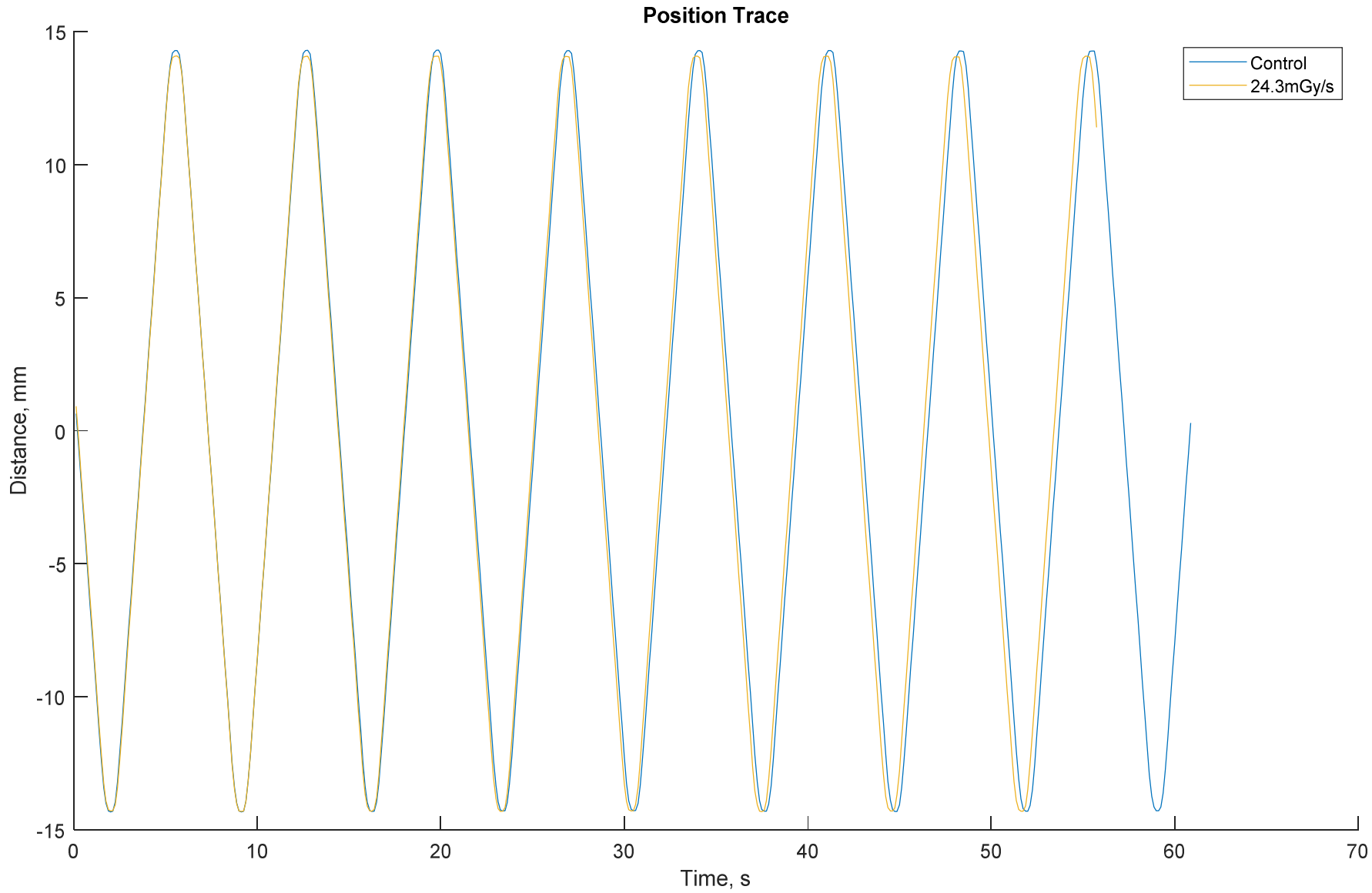
LBNF-UK Beam and Target System X-ray bay used. Continuous source is the red cylinder on the wall

Proximity Sensor

- ❑ Oscillating linear Stage with sensor and target
- ❑ Ion chamber in line with sensor to measure dose
- ❑ Voltage read back to data logger for comparison with unirradiated (125ms sample)



Headline result- no change



Expected dose rate-
1.8mGy/s

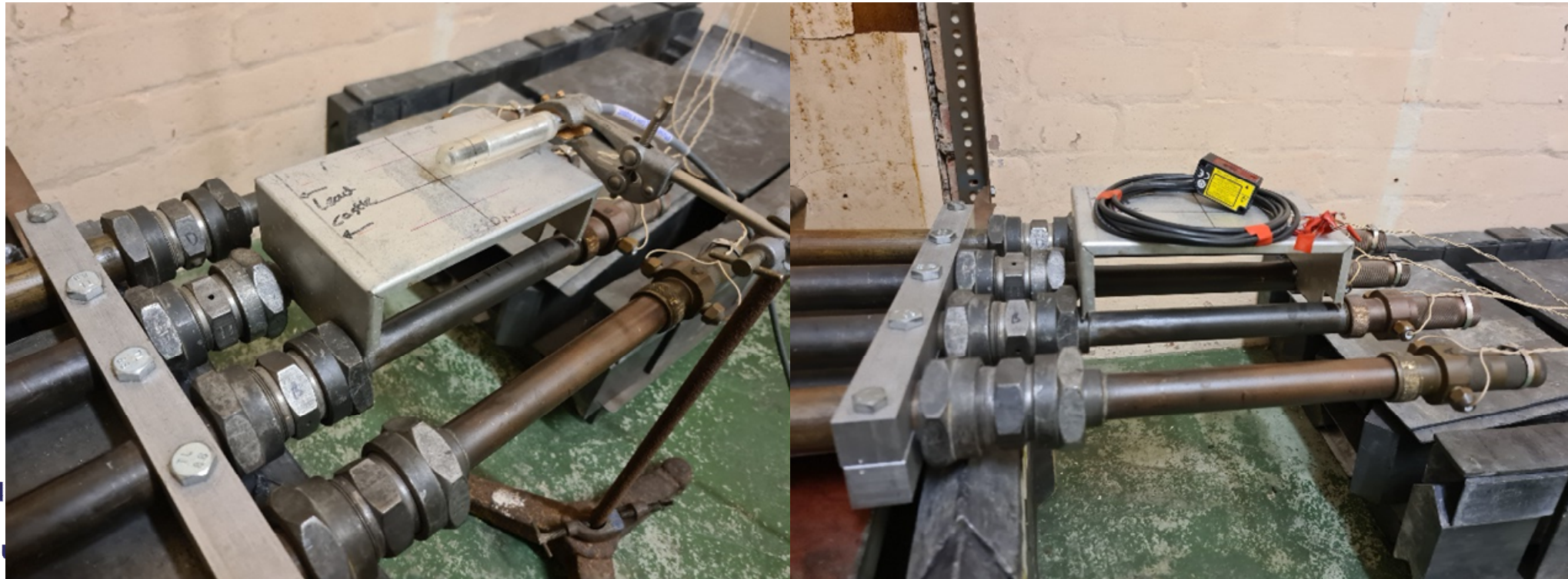
Factor of 13.5 more
severe

No significant noise
effect or offset
(125ms sample)

Time distortion
probably from
rudimentary motor
control and buildup of
wear debris- drive was
screeching after the
long irradiation.

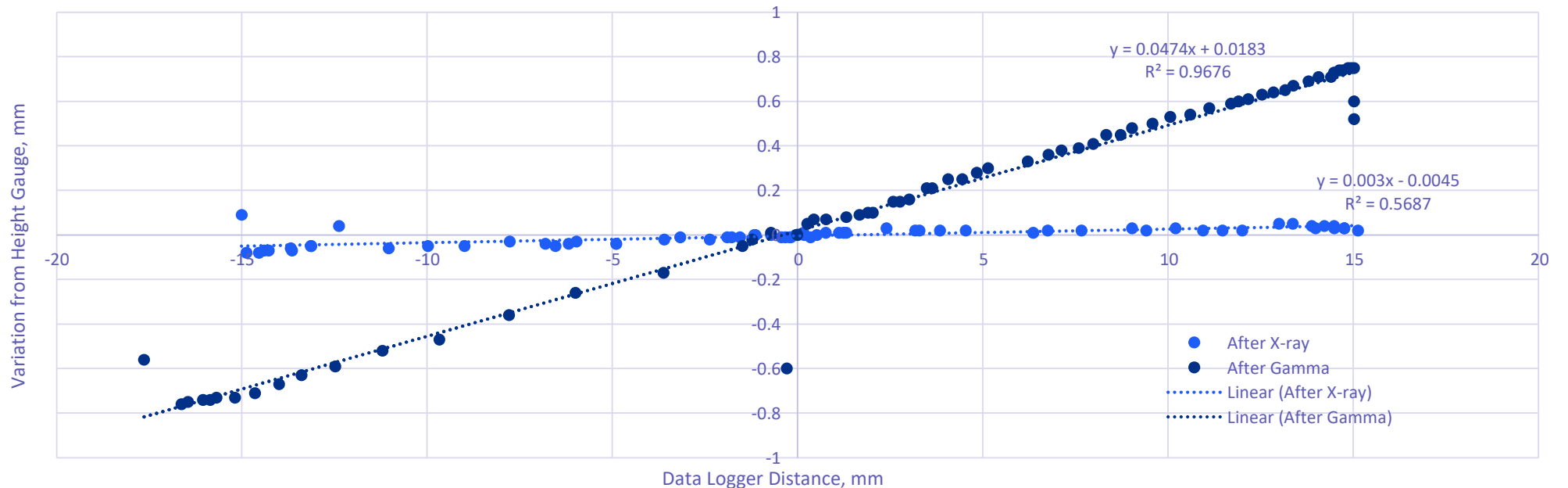
Gamma irradiation test

- ❑ Co-60 Gamma source
- ❑ 5.1 Gy/min = 850mGy/s (470x expected operating condition!)
- ❑ 5 hours = 1.5kGy exposure



Sensor still works! But calibration loss

- ❑ Calibration against height gauge before and after gamma
- ❑ 5% variation- fairly linear- power electronics?
- ❑ Zero point drifted 0.4mm further from sensor
- ❑ Time to try something less cheap – good experience with LVDTs



LBNF target Status Summary

- ❑ WP1: Prototype target beginning construction
- ❑ WP2: Target Exchange System (TXS)
 - Feature prototyping and technology selection e.g. for sensors underway
 - Discussions underway with DL Controls Group
 - Tender process for telemanipulators procurement about to start
- ❑ WP3: Helium Plant
 - P&ID and Controls system responsibility transferred to Fermilab
 - Tender process for helium compressor in advanced state of preparation