

LBNF Target and Associated Equipment Status Report

11th January 2023

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MATERIALS
RESEARCH
FACILITY



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BRISTOL



Science and
Technology
Facilities Council



WARWICK
THE UNIVERSITY OF WARWICK

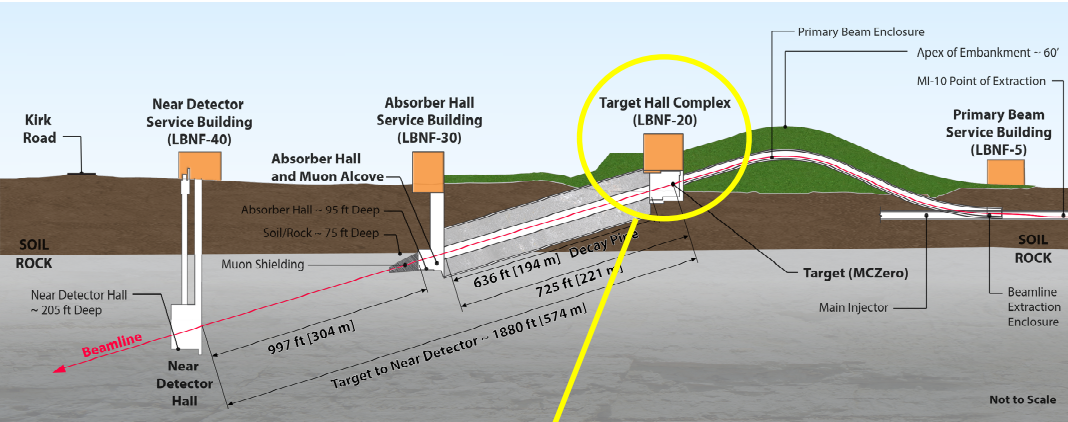


DEEP UNDERGROUND
NEUTRINO EXPERIMENT

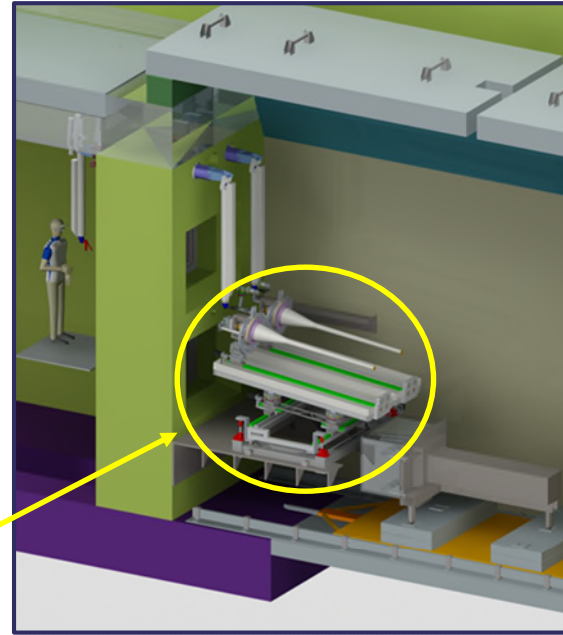


Fermilab
Long-Baseline Neutrino Facility

Scope of UK In-Kind Contribution

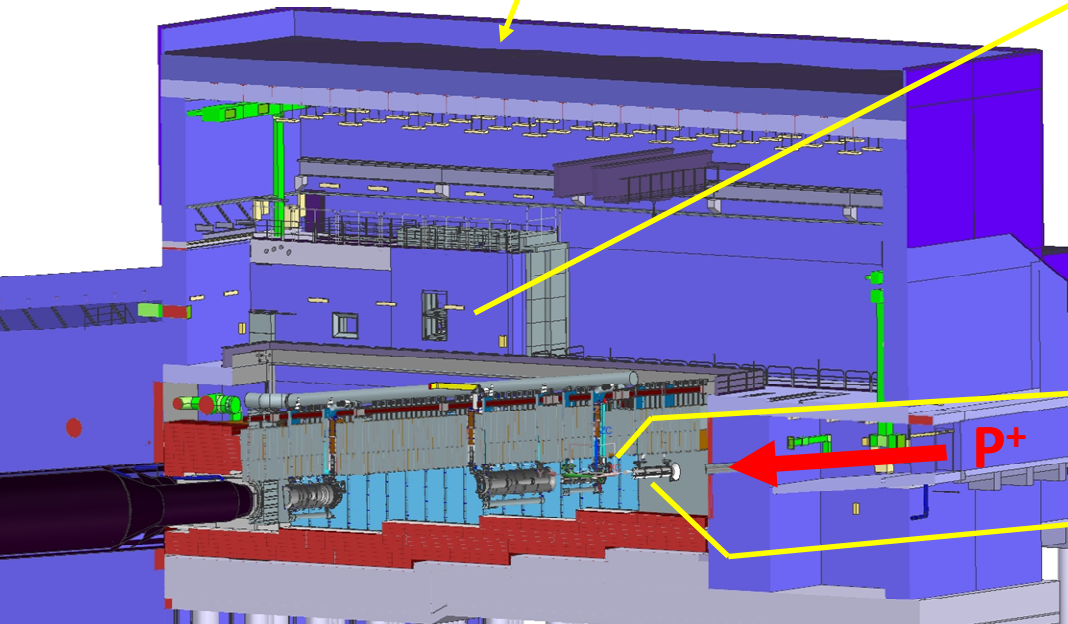


1x Target Exchange System:

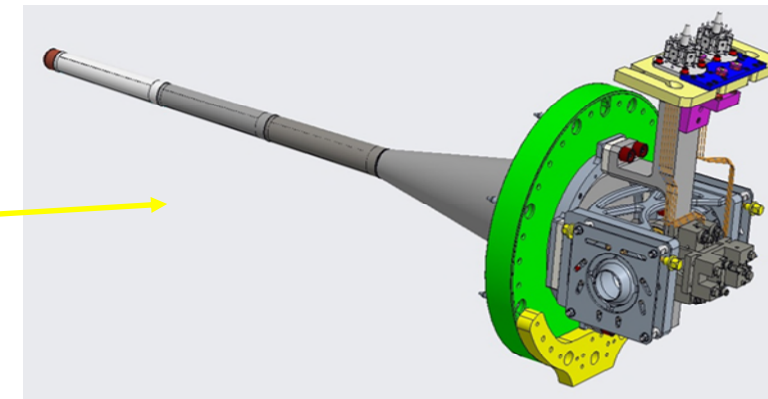
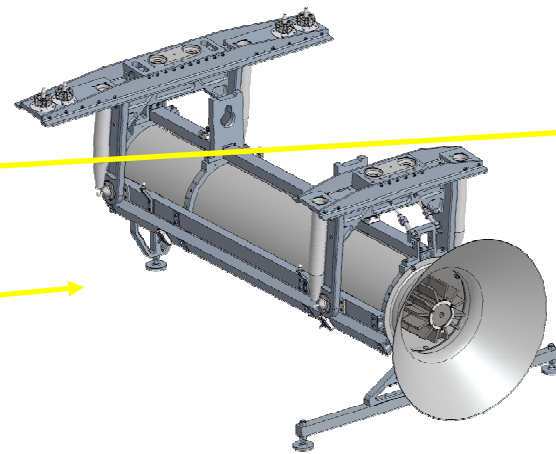


Various Helium Plant Components inc. Blower and Coolers:

<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



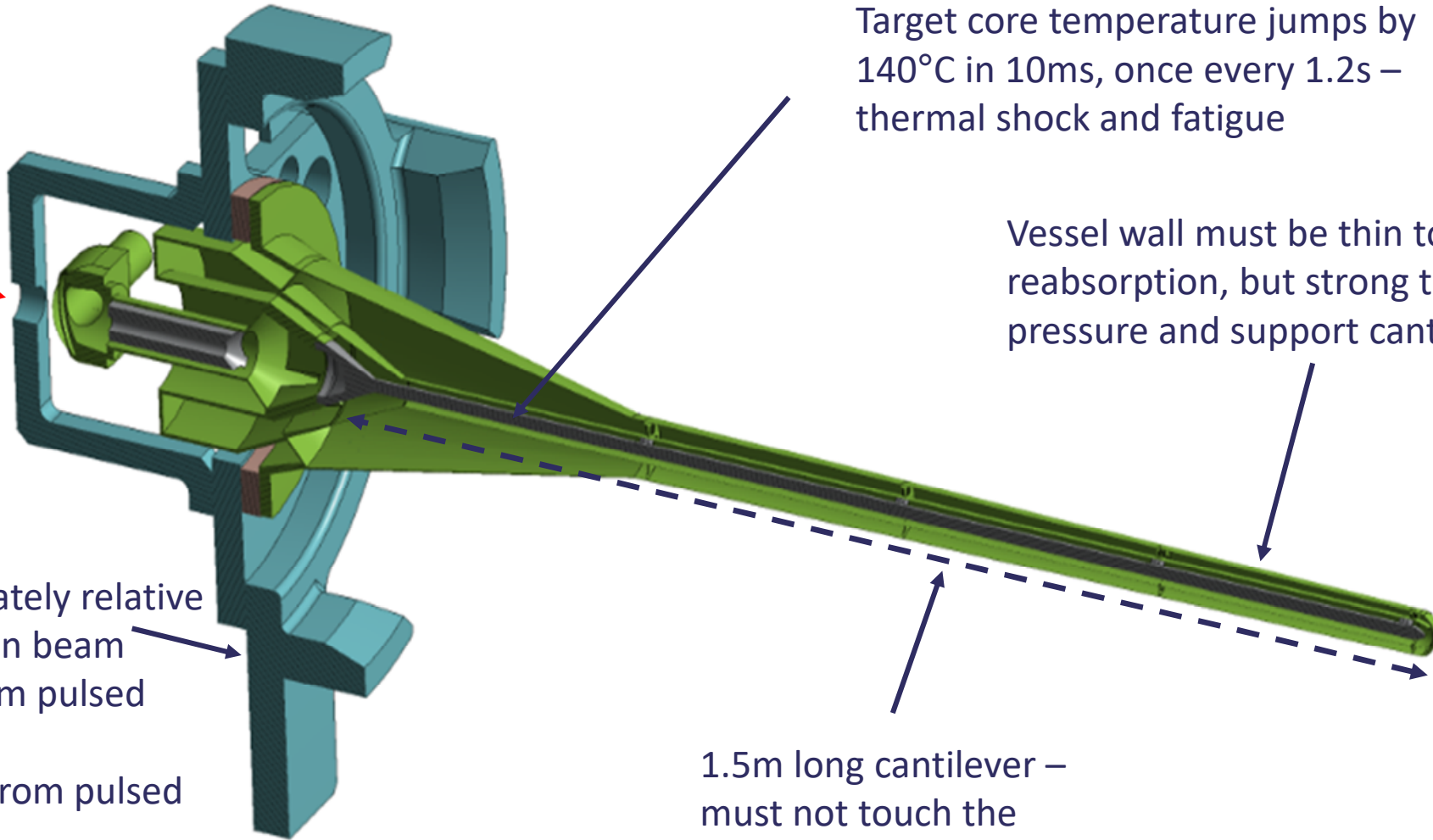
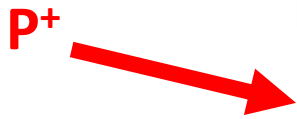
1x Instrumented Baffle:



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

Target Engineering Challenges

Proton beam causes very high heat deposition and radiation damage (several DPA/yr along beam centreline)



Target core temperature jumps by 140°C in 10ms, once every 1.2s – thermal shock and fatigue

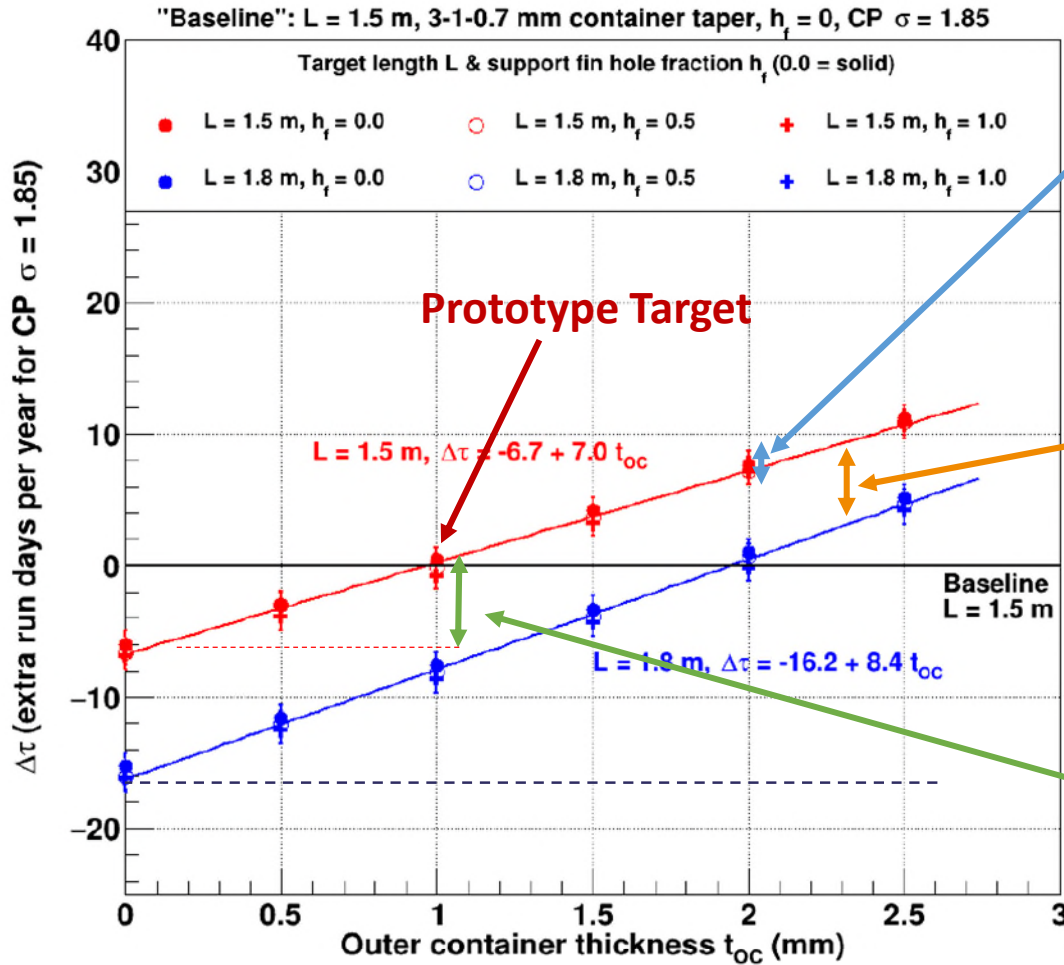
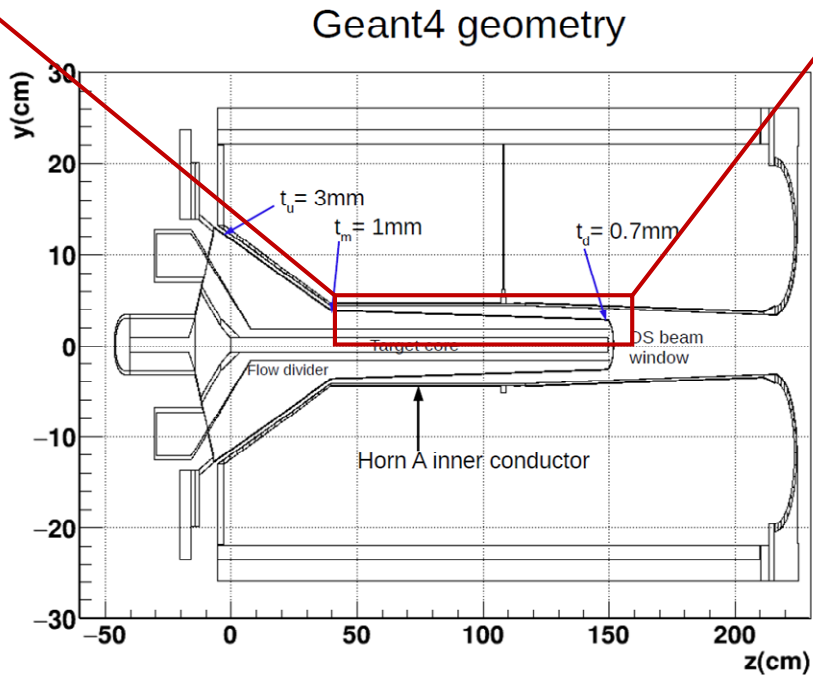
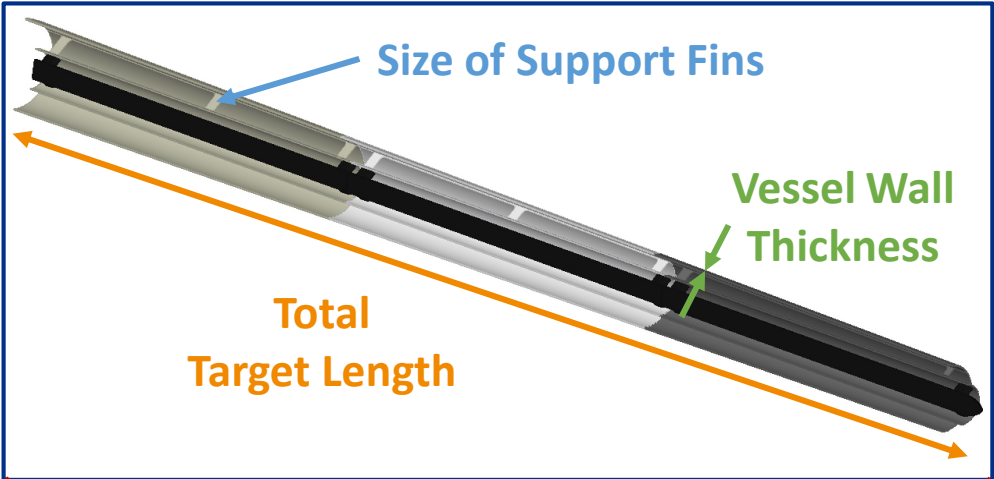
Vessel wall must be thin to prevent pion reabsorption, but strong to contain pressure and support cantilever

Support structure must:

- align the target accurately relative to the horn and proton beam
- Isolate electrically from pulsed horn
- Isolate mechanically from pulsed horn

1.5m long cantilever – must not touch the inside of the horn

Combined Physics & Engineering Optimization



Small effect of varying support fin hole fraction

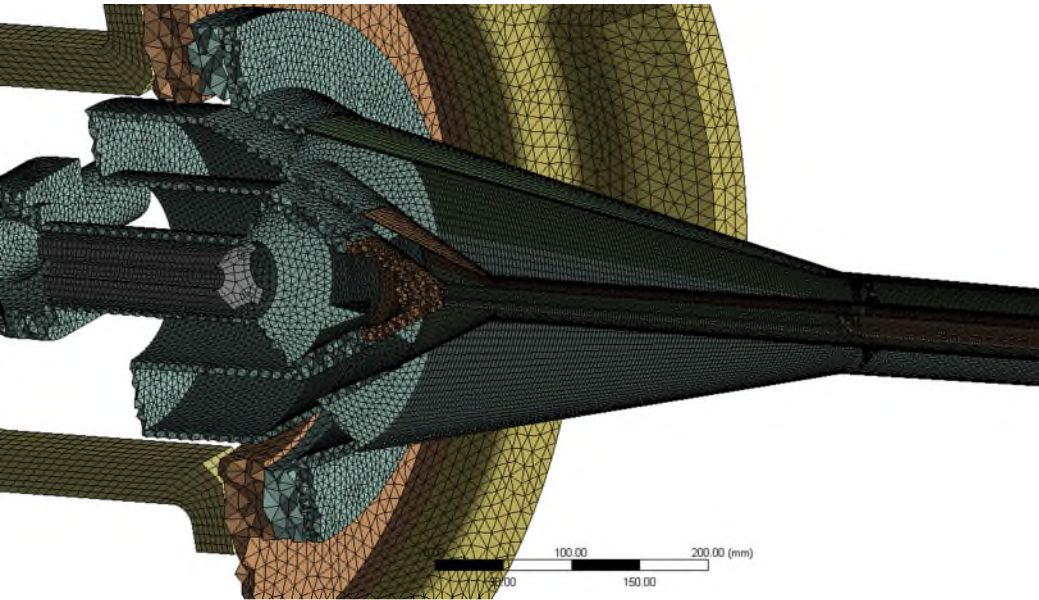
Large effect of increasing target length

Large effect of vessel thickness

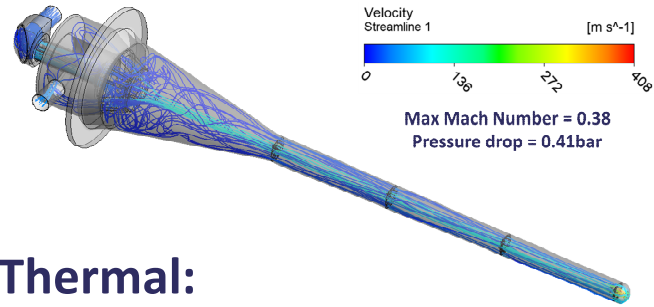
c/o John Back (Warwick University)

Detailed Target Analysis

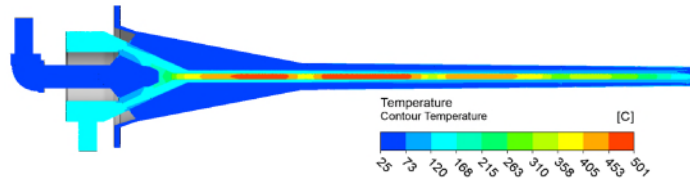
Mesh:



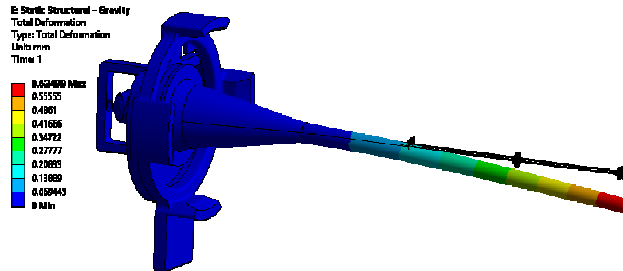
Fluid:



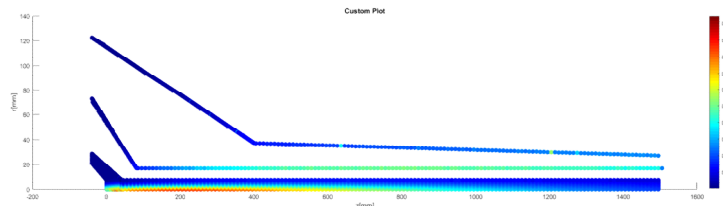
Thermal:



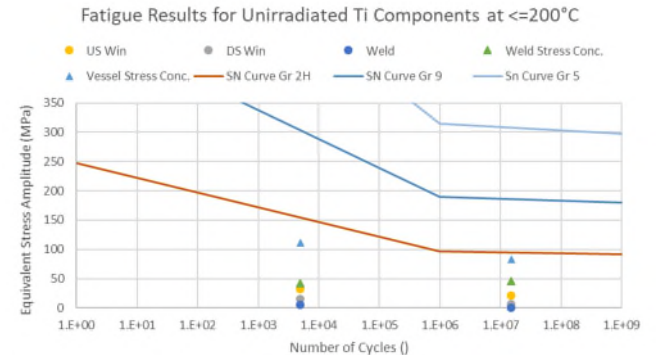
Structural:



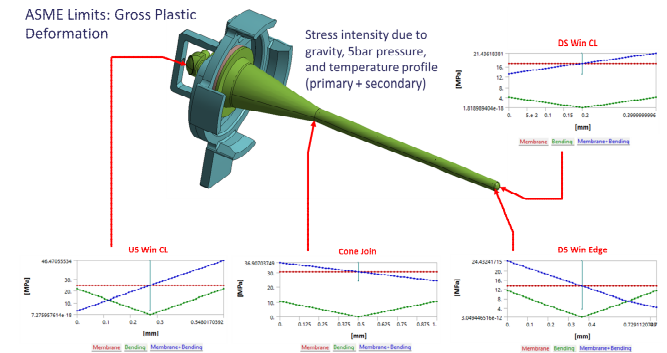
Irradiation:



Fatigue:



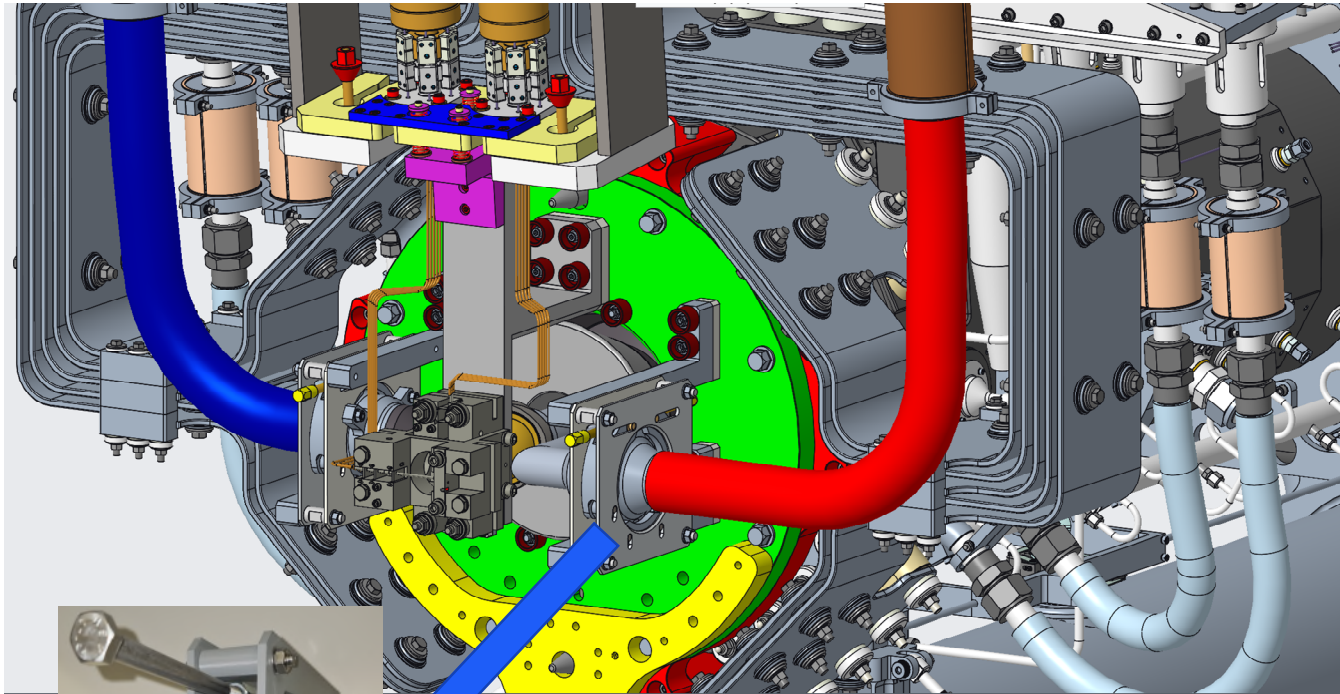
Stress Linearisation:



**Path to Pressure Vessel
Code Approval**
(FESHM and ASME BPVC)

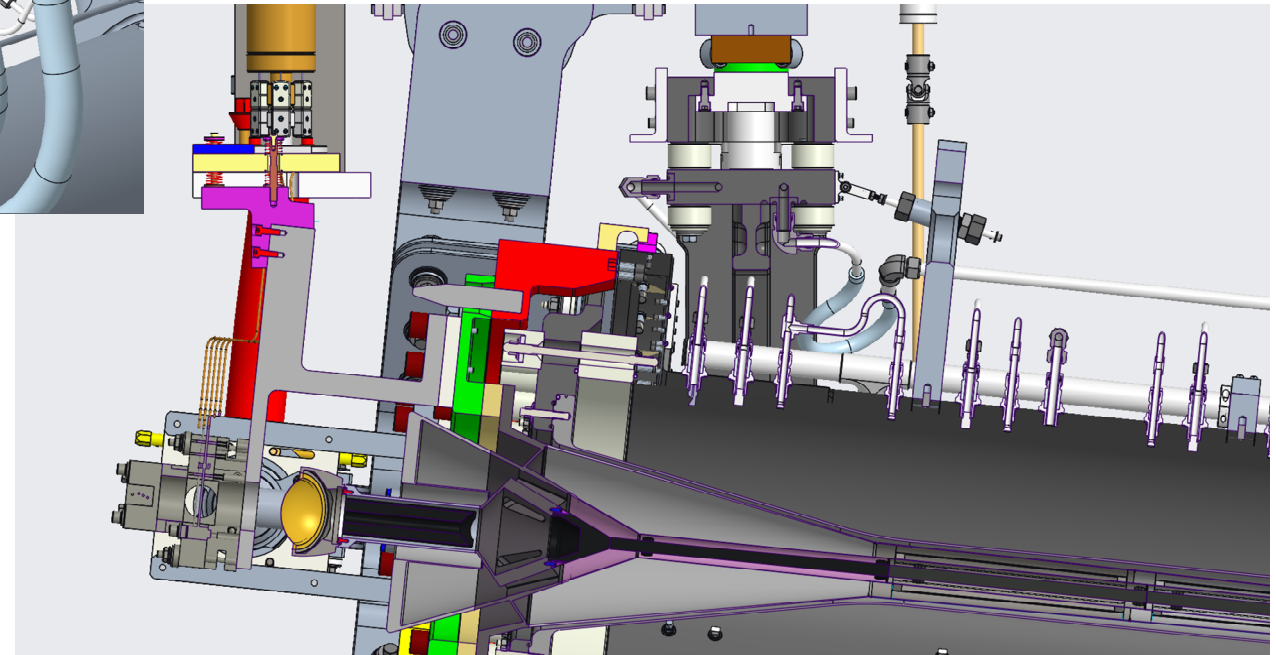


Target, magnetic horn, services and instrumentation integration



Remotely operable
helium line connector
Designed and prototyped by
Year In Industry student

- Target, magnetic horn, services & supports closely integrated
- Always trying to keep things as simple as possible...



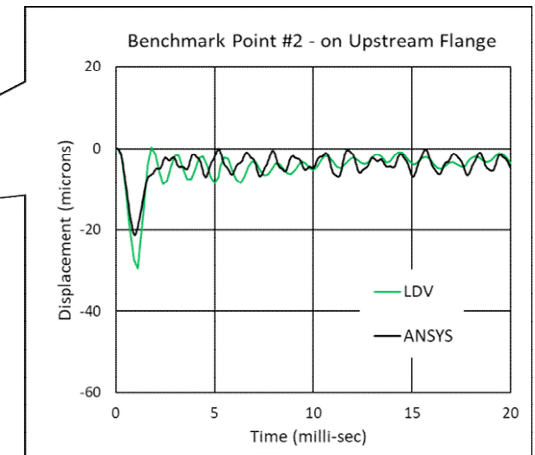
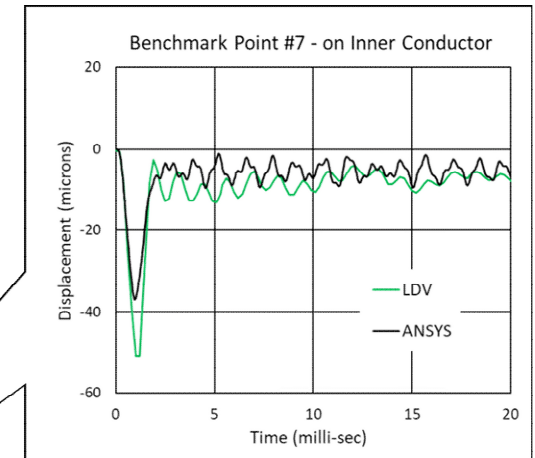
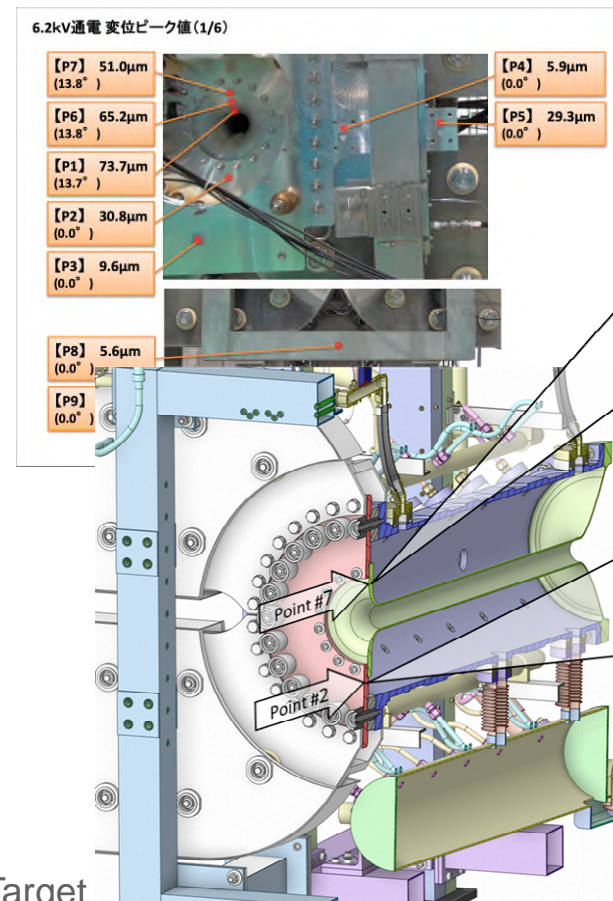
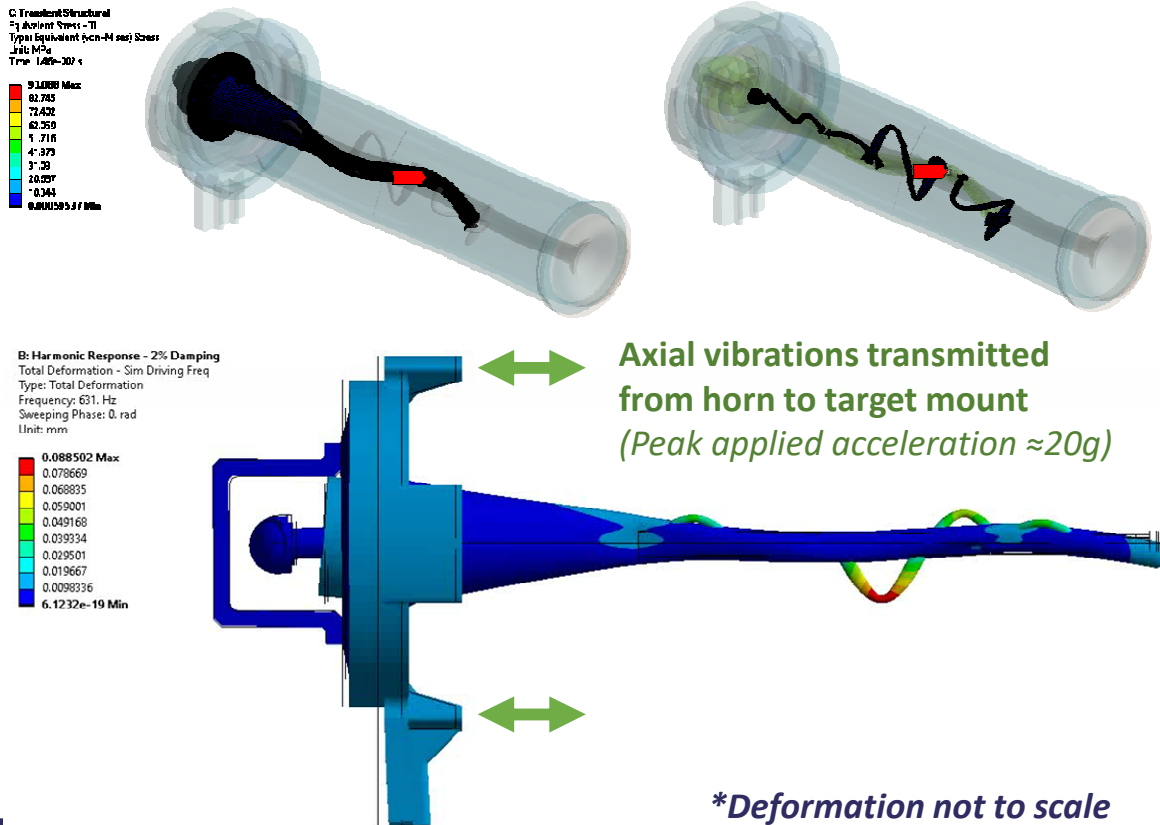
Lorentz force induced vibrations of magnetic horn and target system

300 kA current pulse in horn generates & transmits large forces & vibrations in target

➤ Physical testing not possible for several years: simulations used to study issue & identify solution

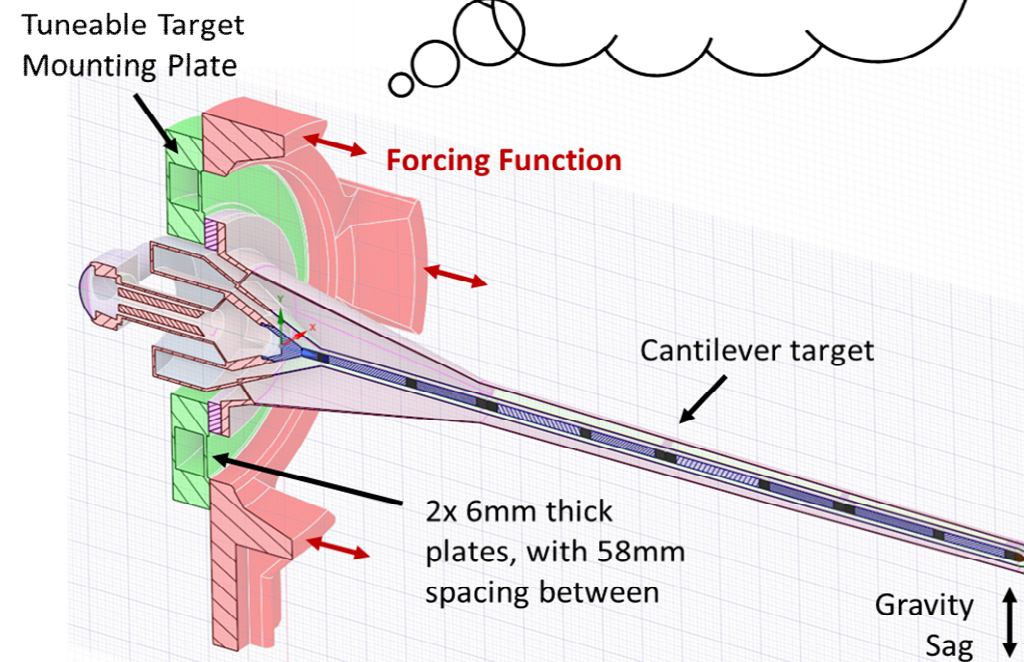
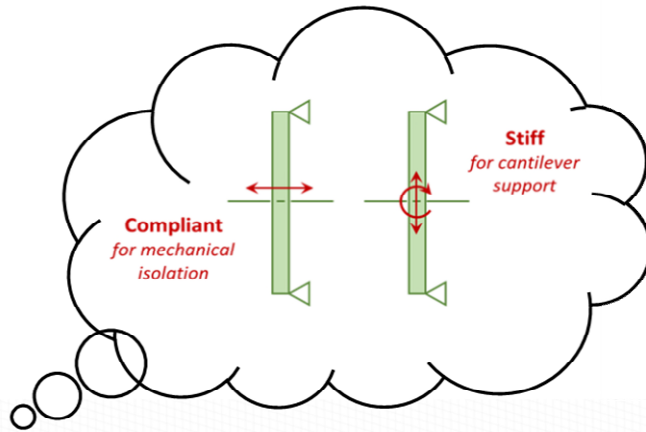
Combined simulation of horn and target:

Benchmark against T2K Horn measurements:

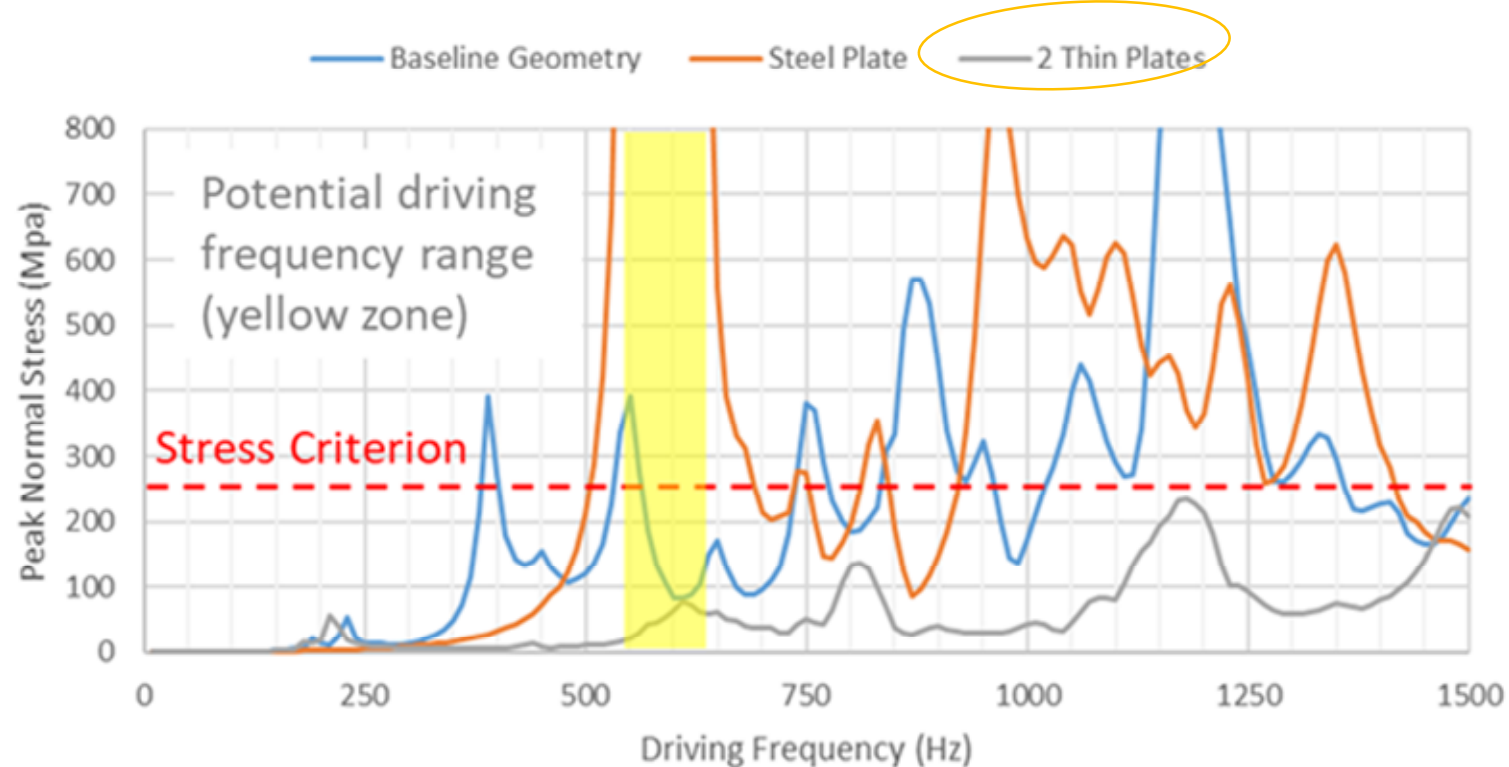


Target support system to minimise transmission of Lorentz force vibrations

- Axially compliant support geometry (2 thin plates) gives a broad frequency range where fatigue response looks acceptable and easy to modify to (de-)tune

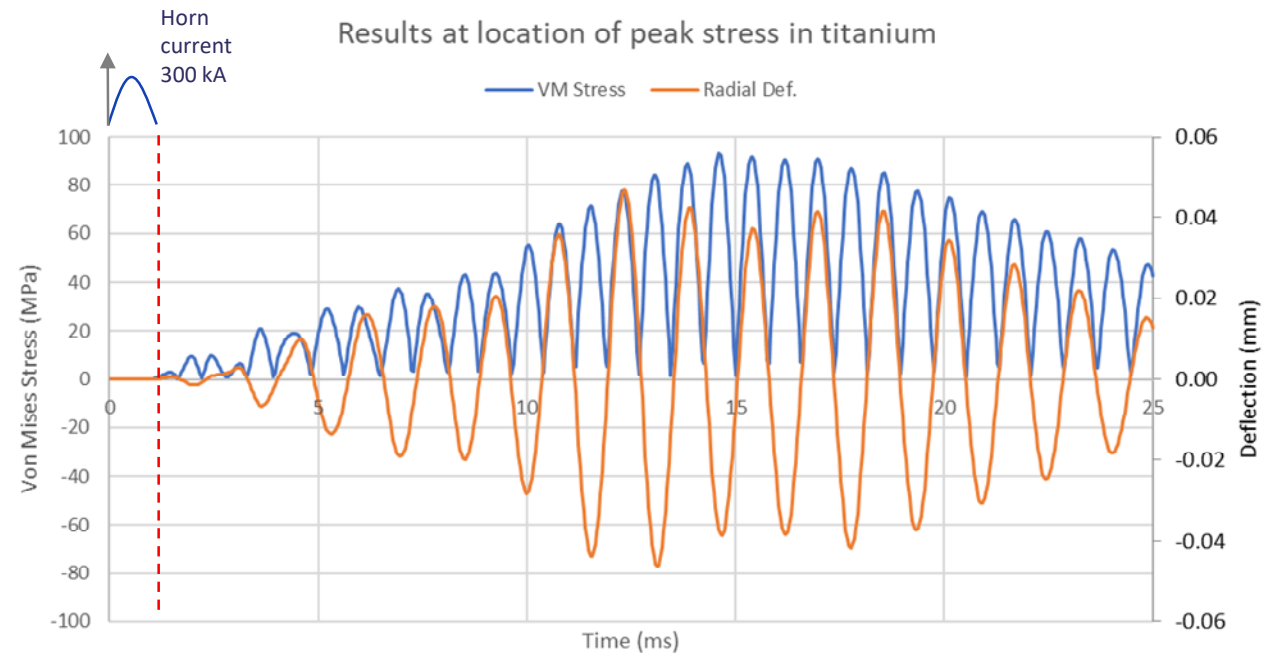
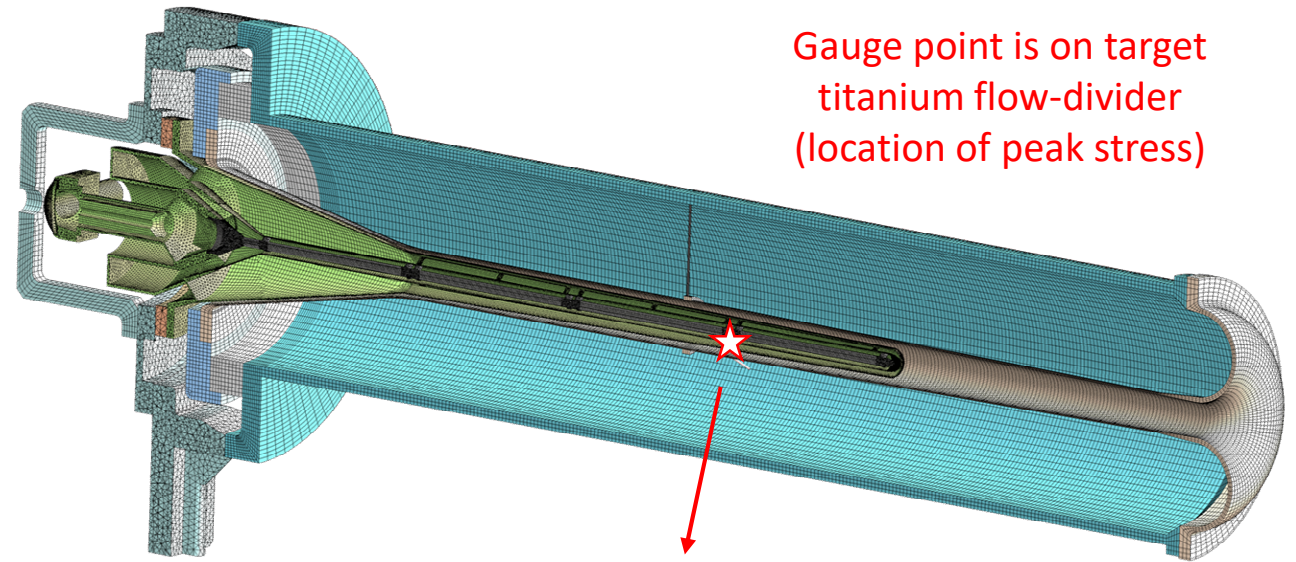


Peak Normal Stress - Titanium - 2% Damping

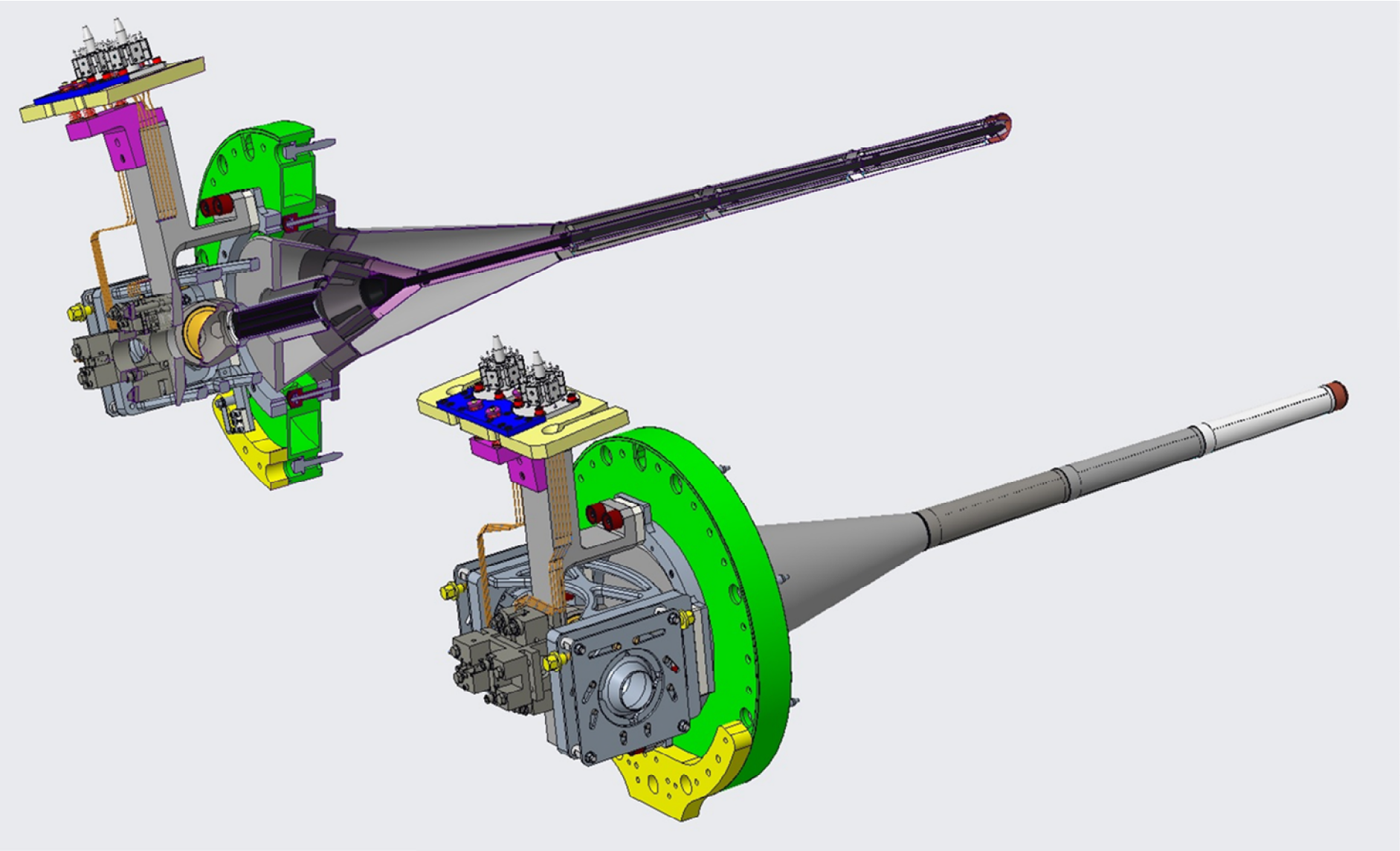


Present Modelling Effort: “Full Transient”

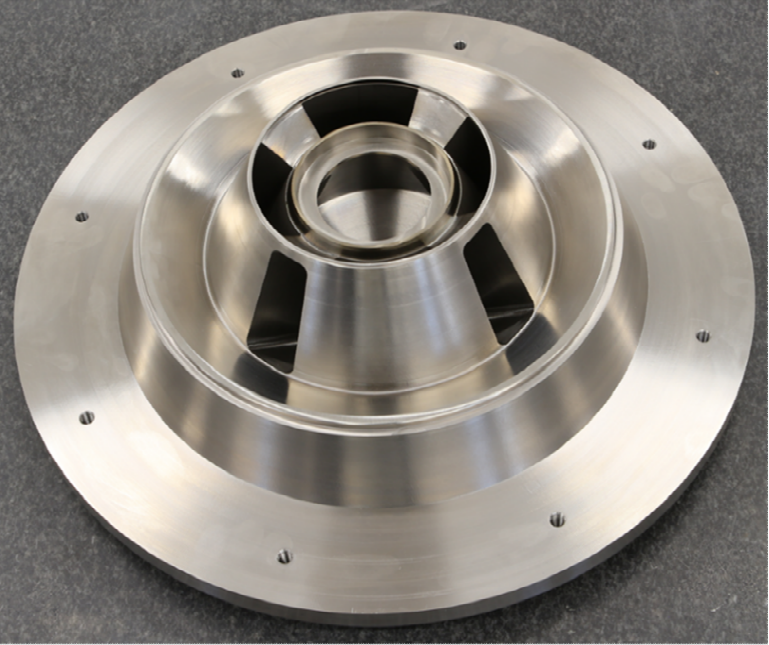
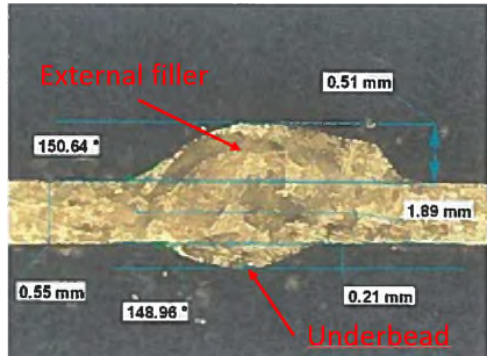
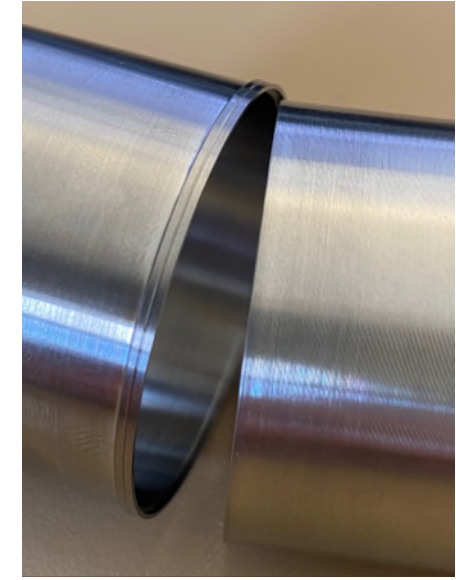
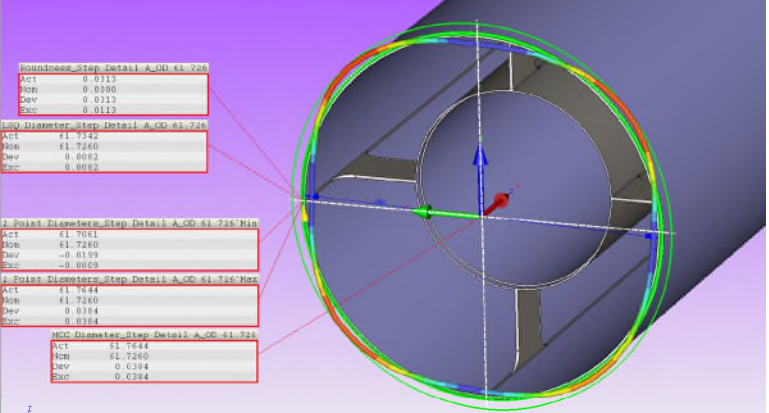
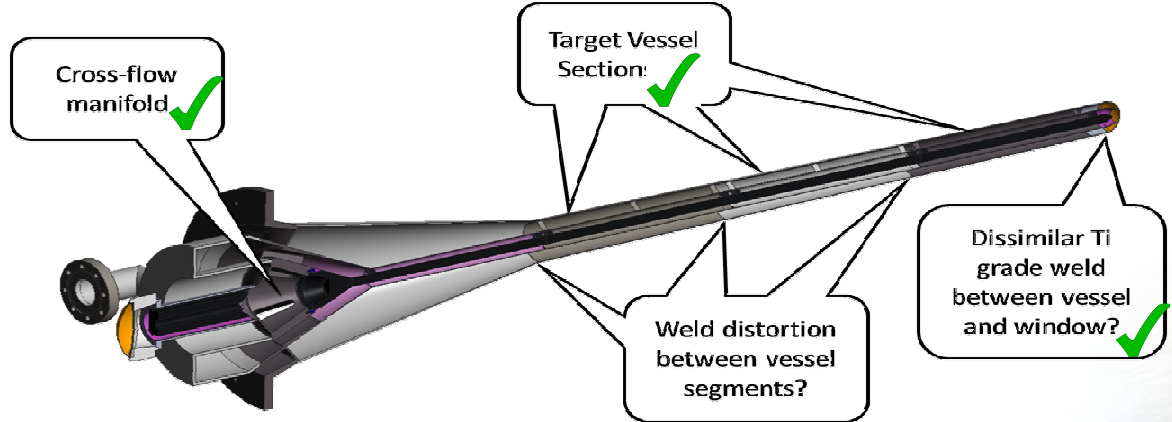
- ❑ Combined target + horn model with double thin-plate support
- ❑ Full transient analysis with 300 kA, 1 ms horn current pulse
- ❑ Two-way dynamic coupling
- ❑ Driving frequency (axial deformation at the horn flange) is ~640Hz, c.10 μm amplitude
- ❑ Similar frequency response in target, but direction is lateral (c.50 μm max. amplitude)
- ❑ Safety factor of 2.5 for titanium fatigue life of 1.5×10^9 cycles (c.1 year operation)
- ❑ On the limits of what we can solve with available computational fire-power!



Integrated model of target & instrumentation with vibration + electrical isolating supports

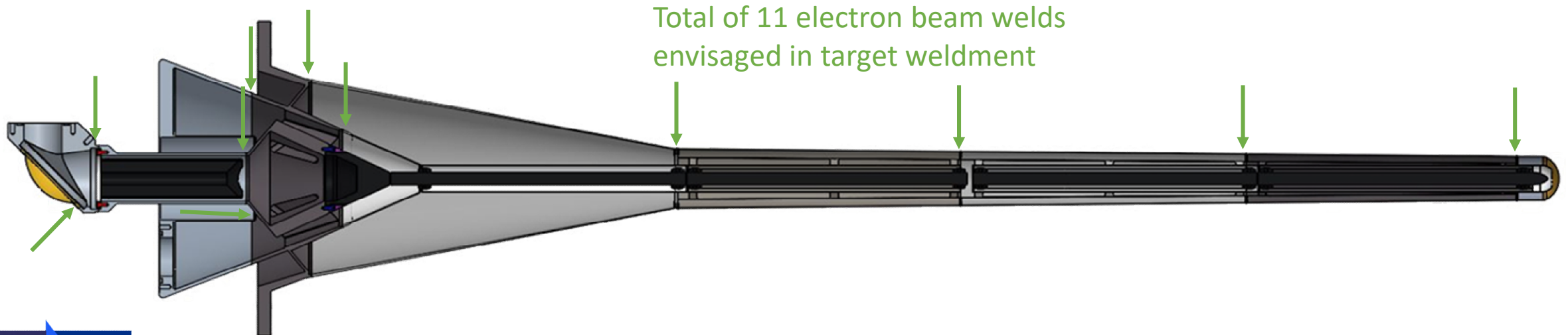


Feature Prototyping Highlights



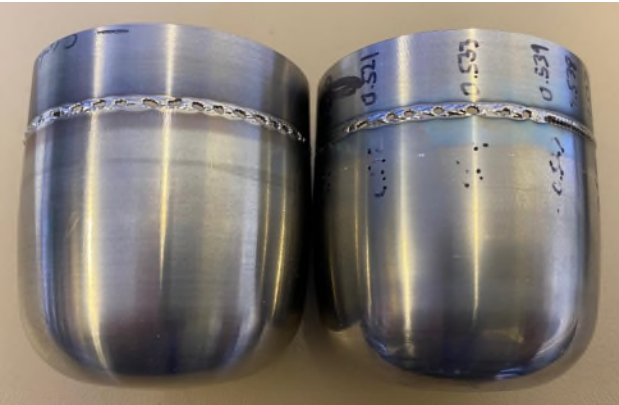
Target Welding Challenges

- ❑ 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
- ❑ Only 1-2 suitable UK welding vendors identified. They are accredited to various European standards including NADCAP (Aerospace welding) and ISO9001 (Quality), but not ASME

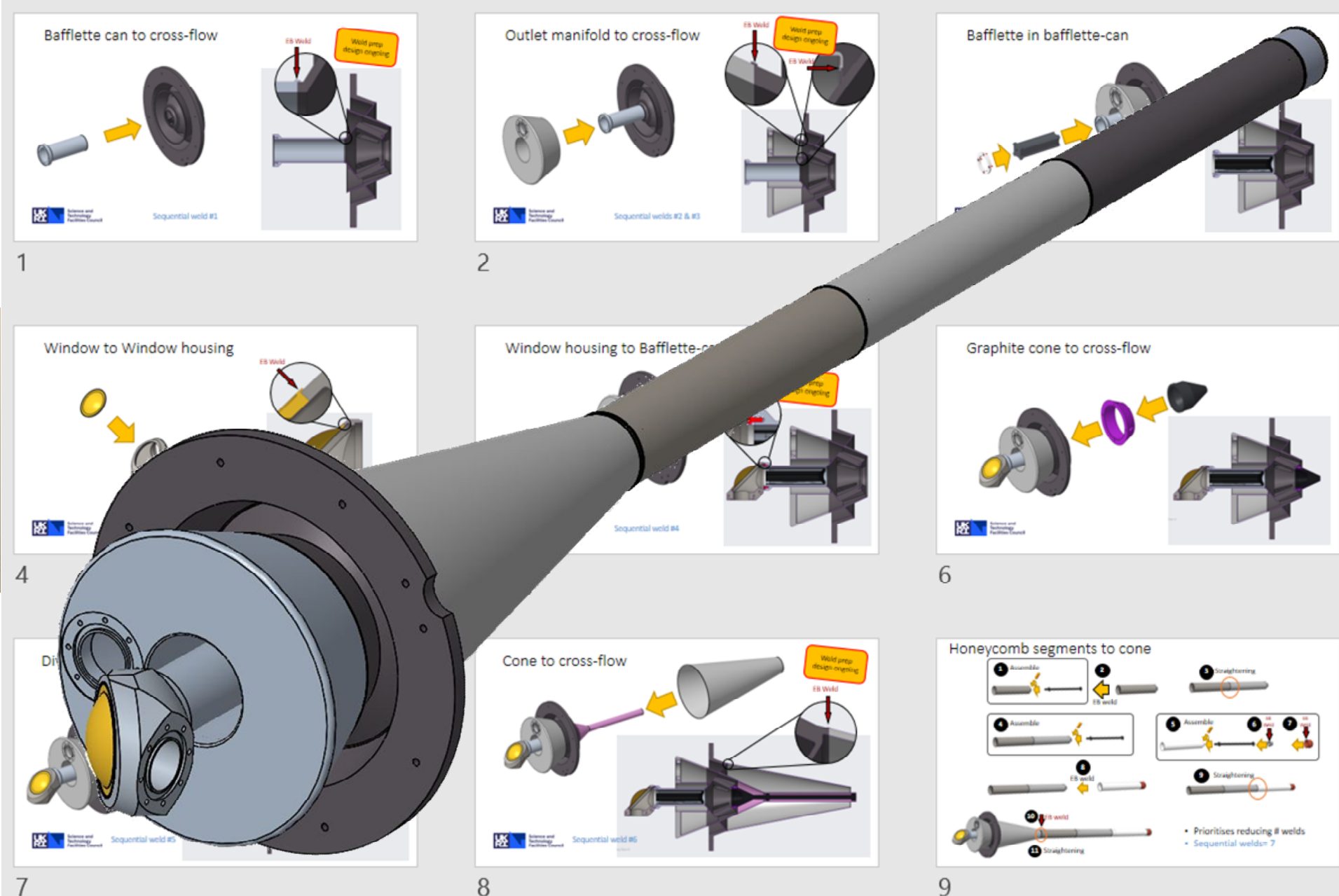


Currently proposed welding sequence – high reliability of each weld step required

Experience: welding of titanium container for 1.3 MW T2K target prototype



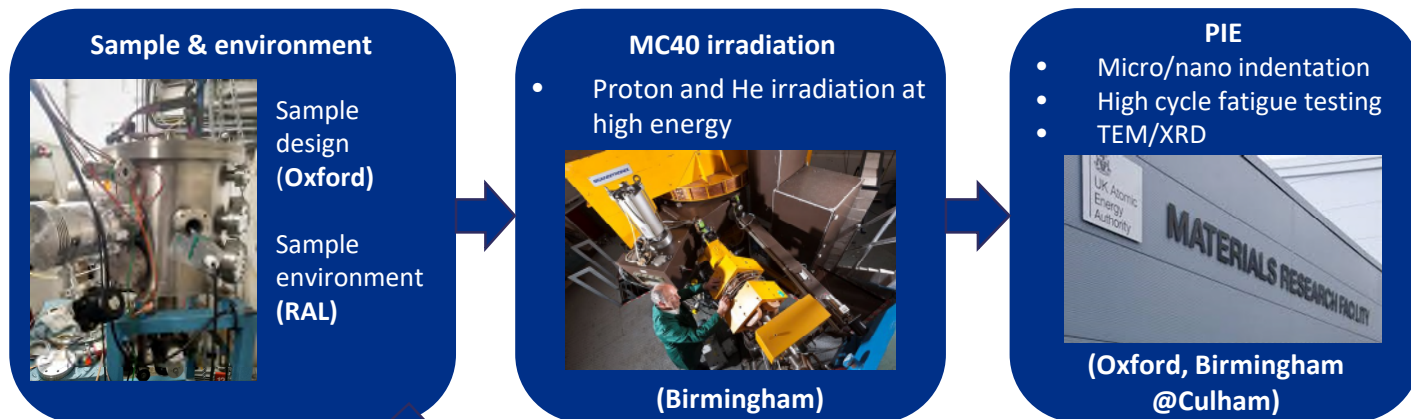
What could possibly go wrong?



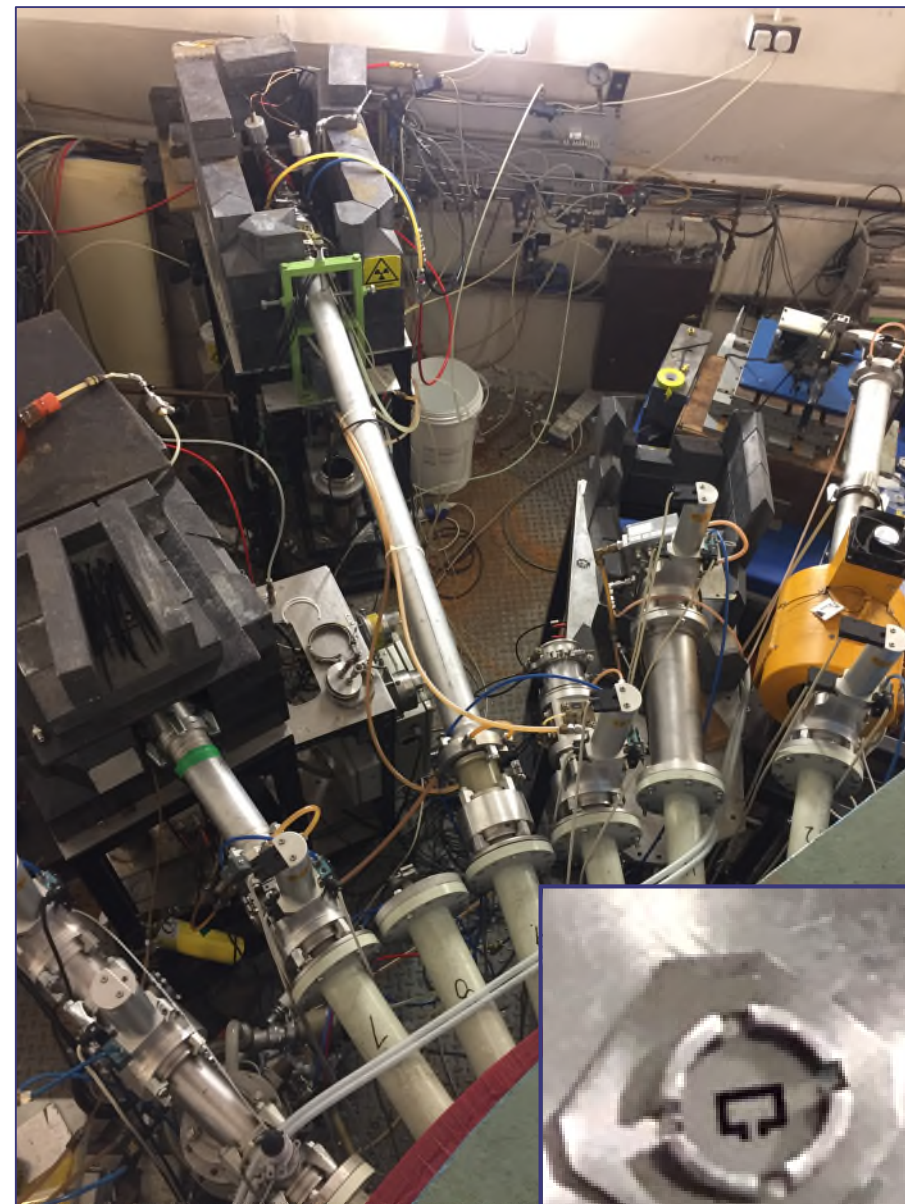
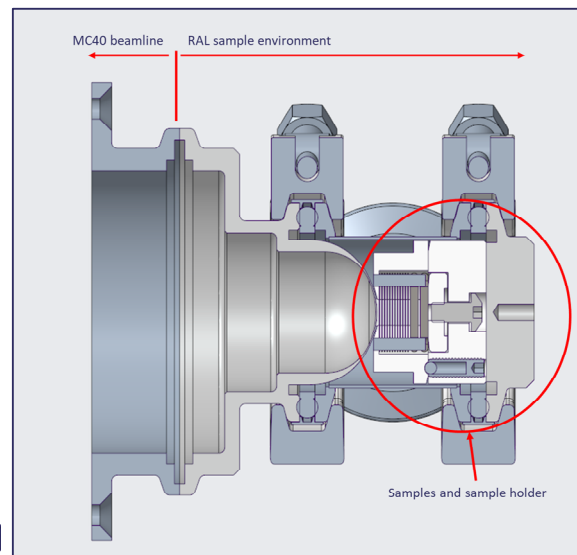
Science and Technology Facilities Council

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 sample environment

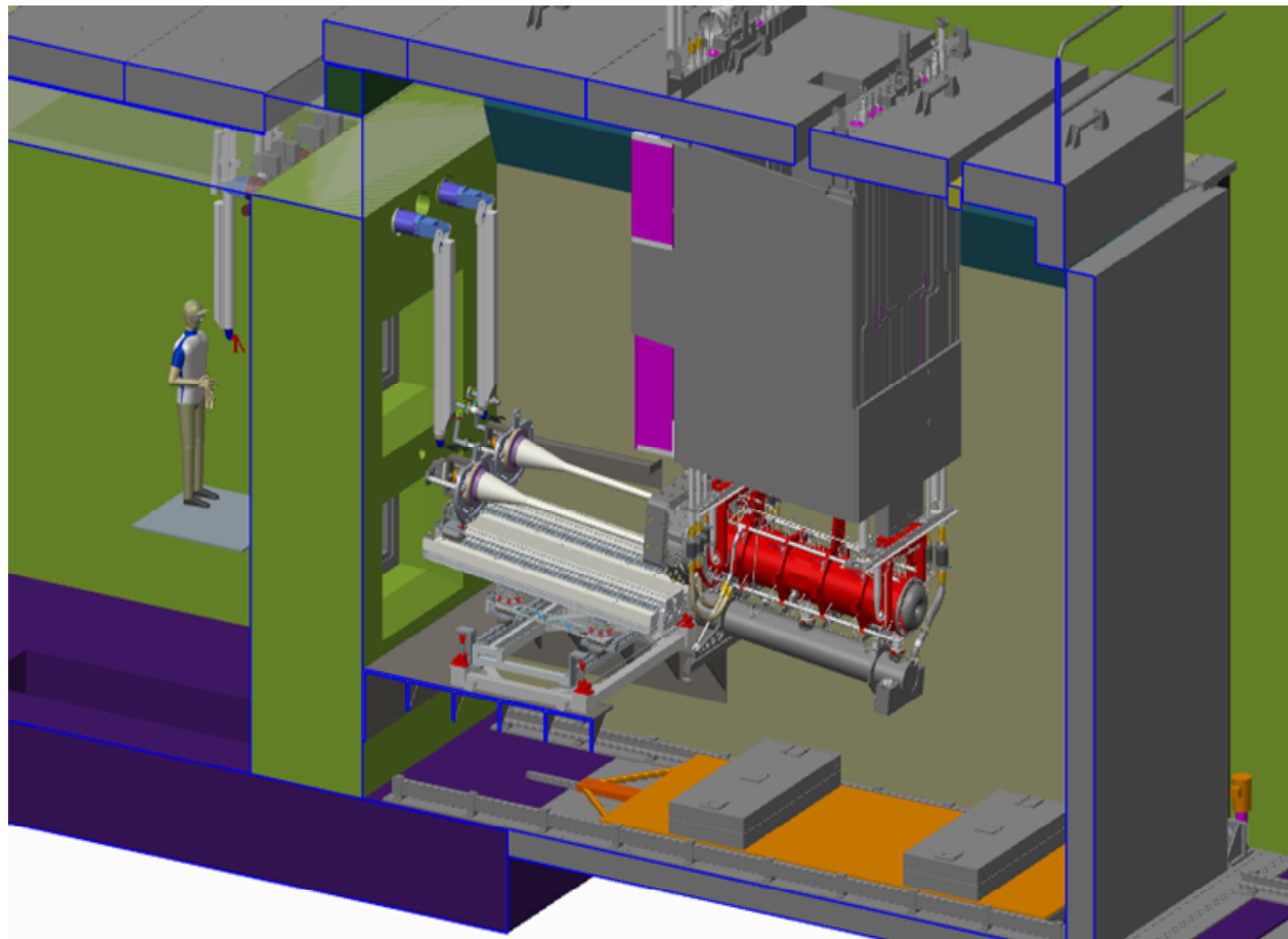
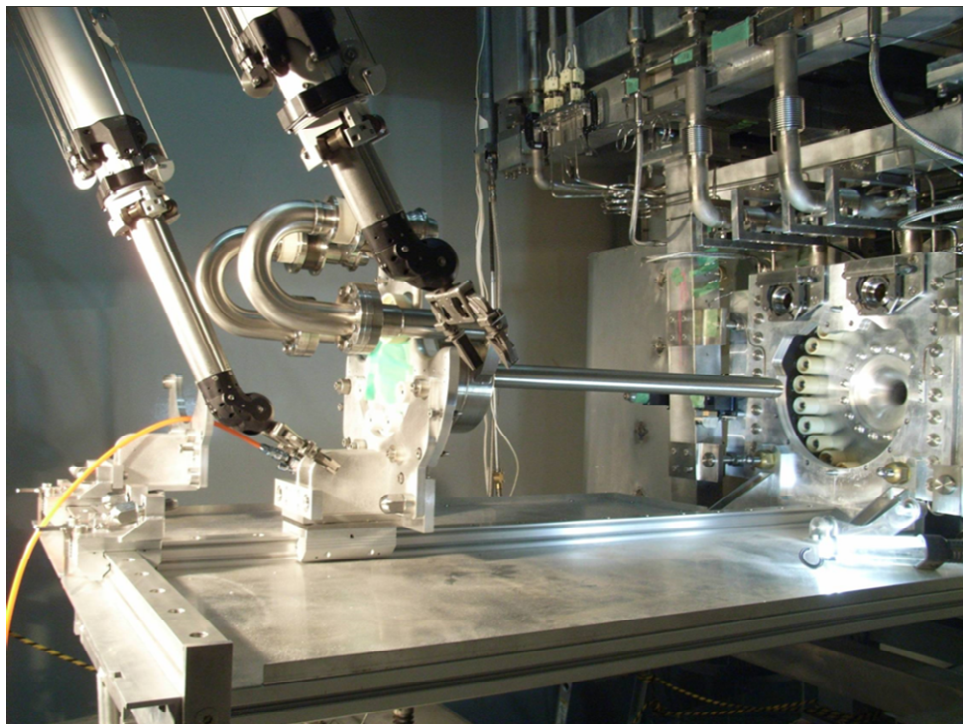


NA61 experiment on SPS, CERN

- ❑ **NA61/DUNE** planning on taking **graphite target replica data Summer 2024**
 - Reduce hadron production systematic uncertainties for neutrino flux (similar to T2K)
- ❑ Simple **graphite cylinder** $L = 1.5 \text{ m}$, $r = 8 \text{ mm}$ to mimic **LBNF prototype target**
 - Need to decide on target support options
- ❑ Will be **built by RAL HPT group**
- ❑ **Warwick** plans to contribute to **NA61 physics studies**
- ❑ **Warwick** applying for **limited NA61 membership** (no fees)
 - Access to NA61/SHINE physics (simulation) software
 - Become member of **NCR** (Neutrino & Cosmic Ray) working group
 - Implement replica target in simulation & perform tracking/detector studies
 - Trying to sort out signing of collaboration agreement with Warwick Research Office

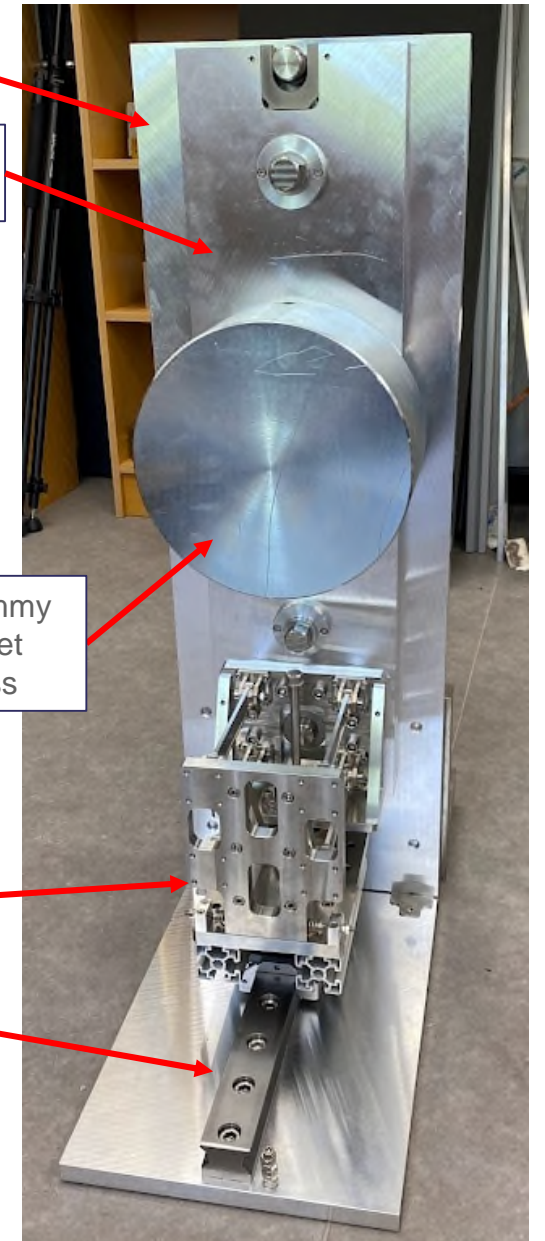
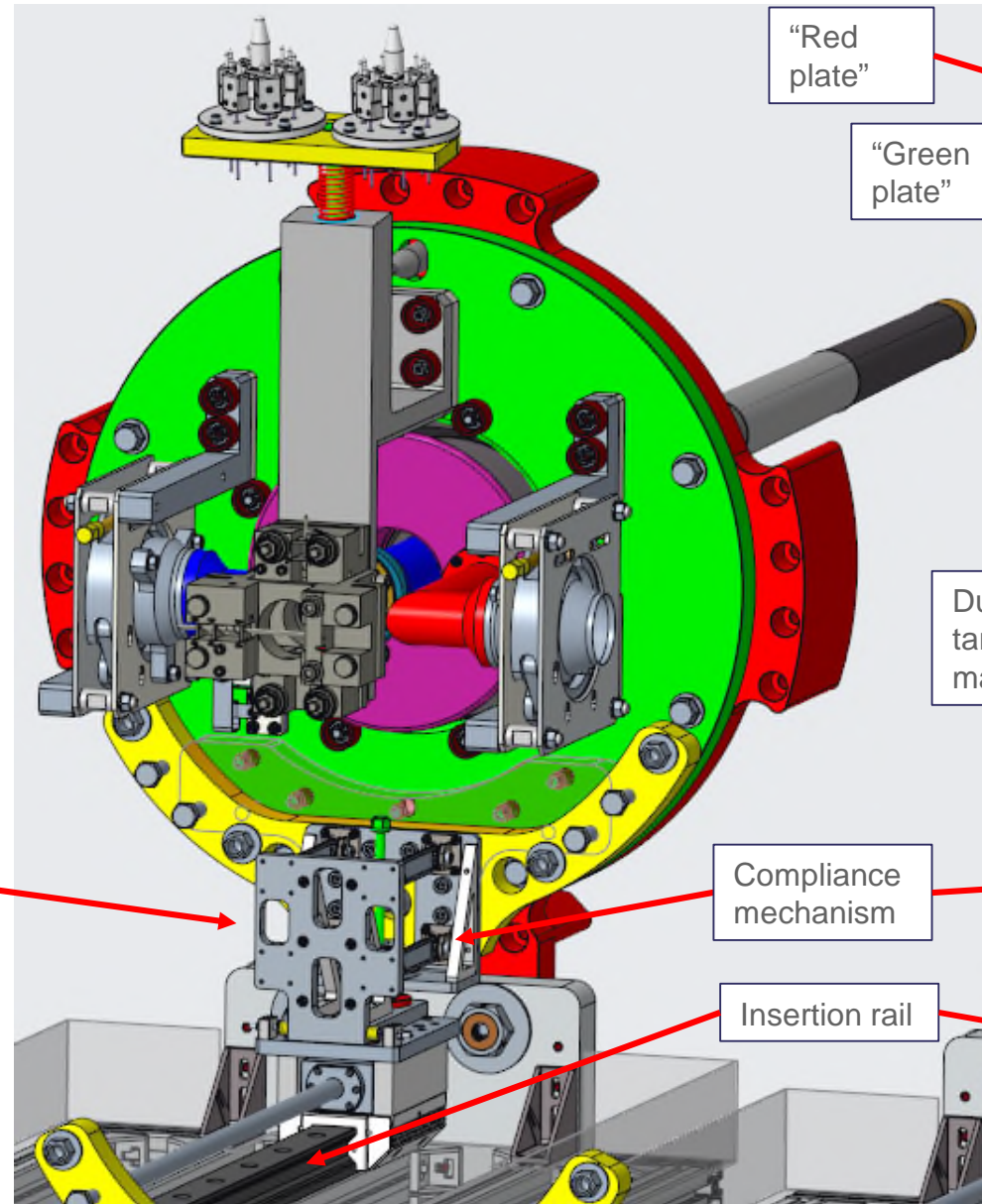
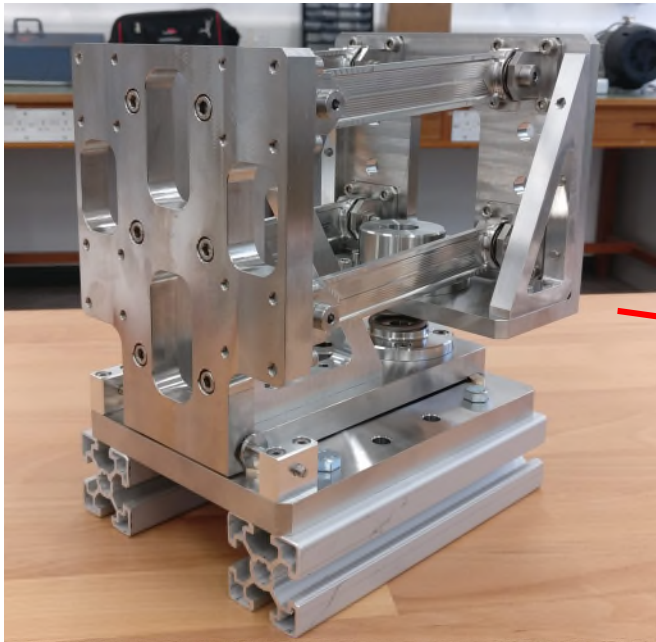
Target Exchange System (TXS)

- 'Cross-rail' system for remote exchange of targets in hot cell
- Design based on similar system developed at T2K by RAL team



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

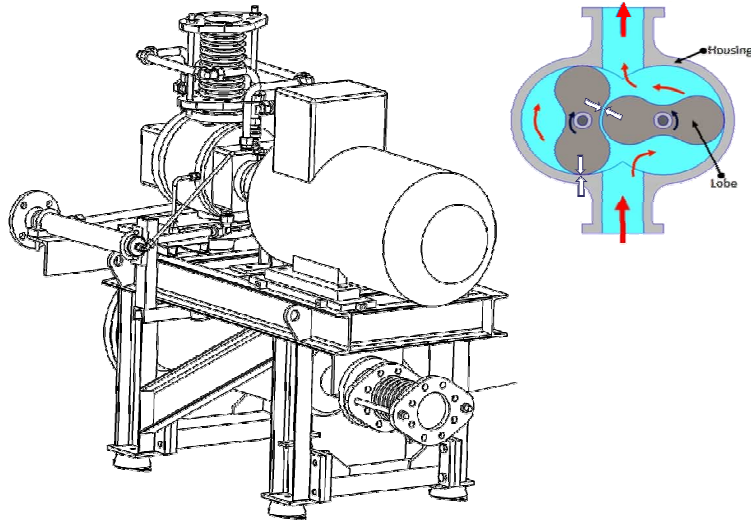


Helium plant deliverables – looking to bring purchases forward

- 1x Positive Displacement Blower
- 1x back-up blower (Working Allowance scope opportunity)

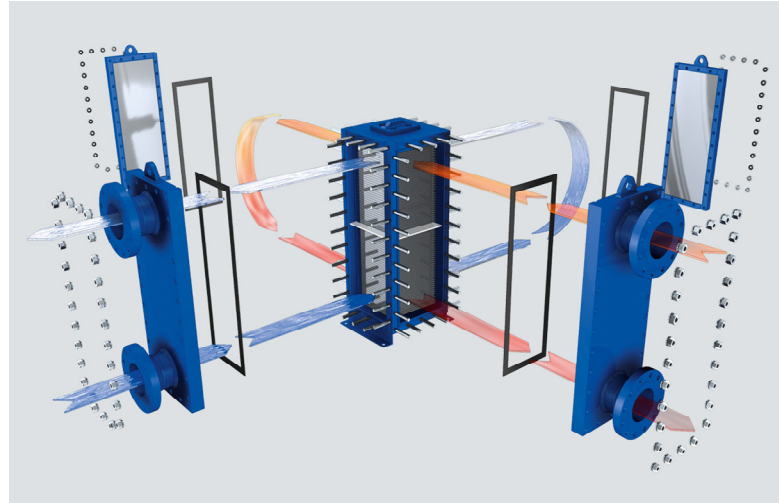
- 1x Target RAW Cooler
- 1x Compressor Pre-cooler
- 1x Compressor After-cooler

- 1x remote operable gas purity monitoring system



*Custom machine:
identified two potential
European Suppliers*

x 1(1/2)



*e.g. Kelvion:
Welded Plate and Frame
Heat exchanger*

x 3



*e.g. Hiden:
HPR-20 benchtop
mass spectrometer*

x 1

Neutrino Beam Instrumentation workshop (NBI2022) and RaDIATE meeting in Oxfordshire

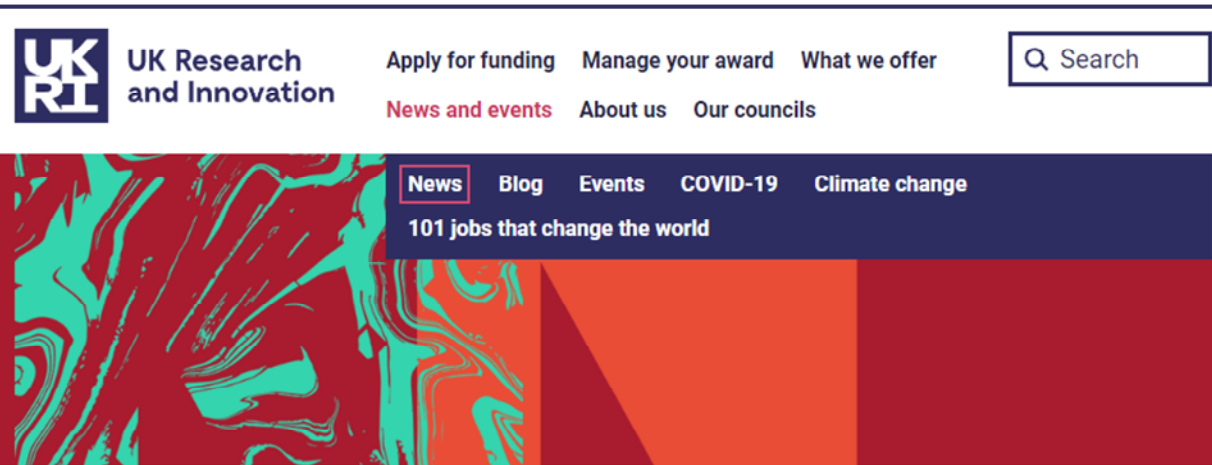


Hosted by RAL team 19th- 23rd September

Press & PR

❑ <https://www.ukri.org/news/uk-engineers-build-critical-link-for-global-neutrino-experiment/>

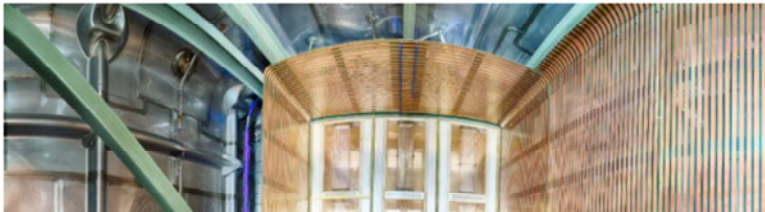
❑ <https://www.theengineer.co.uk/content/news/uk-engineers-build-critical-link-for-global-flagship-neutrino-experiment>



The screenshot shows the top navigation bar of the UK Research and Innovation website. On the left is the UKRI logo. To its right are links for 'Apply for funding', 'Manage your award', and 'What we offer'. A search box is located on the far right. Below these are links for 'News and events', 'About us', and 'Our councils'. A dark blue navigation bar contains links for 'News', 'Blog', 'Events', 'COVID-19', and 'Climate change'. Below this bar is a red banner with the text '101 jobs that change the world'.

[Home](#) > [News](#) > [UK engineers build critical link for global neutrino experiment](#)

UK engineers build critical link for global neutrino experiment



Related content

⇒ [UK scientists build core components of global neutrino experiment](#)



The screenshot shows the top of an article on 'THE ENGINEER' website. The logo 'THE ENGINEER' is in red. On the right is a hamburger menu icon. Below the logo are two red buttons: 'Energy & environment' and 'Materials'. The article title is 'UK engineers build critical link for global flagship neutrino experiment'. Below the title are the words 'News' and a clock icon with '2 min read'. The date '27 Jul 2022' is displayed. At the bottom are social media icons for Facebook, Twitter, LinkedIn, and a plus sign for more options.

UK engineers are producing a crucial element of an international flagship experiment which will allow scientists to answer fundamental questions about the Universe.

