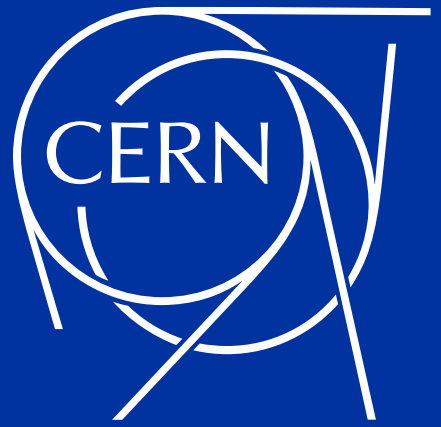


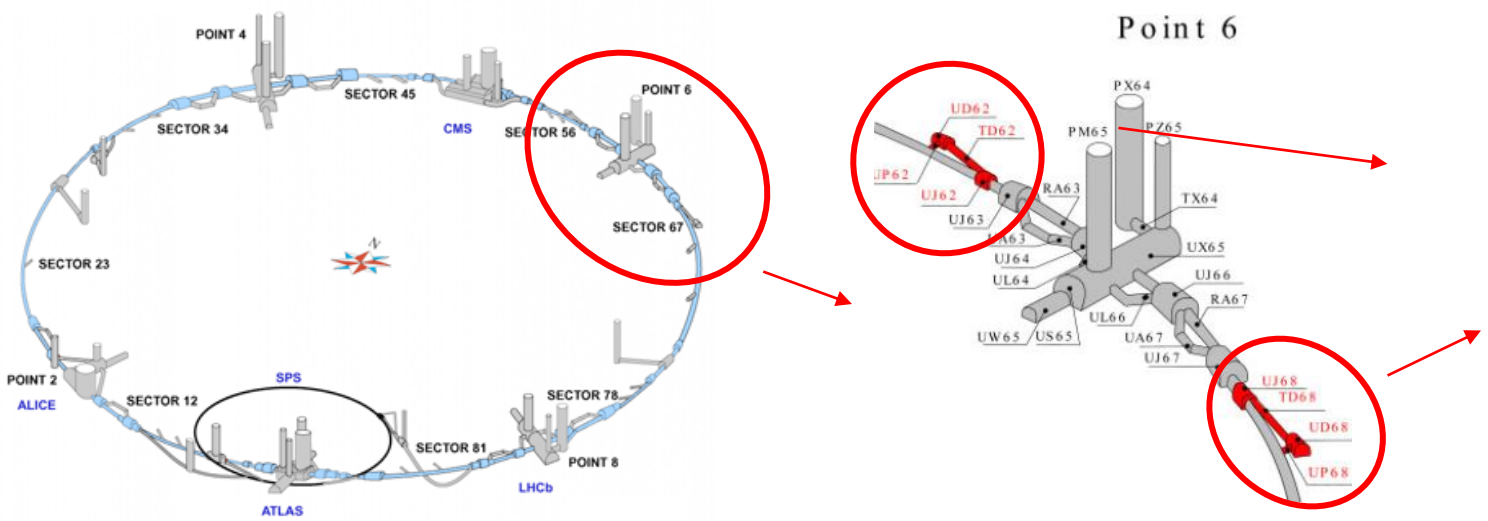
HRMT User Day
HRMT-65 HLTDE

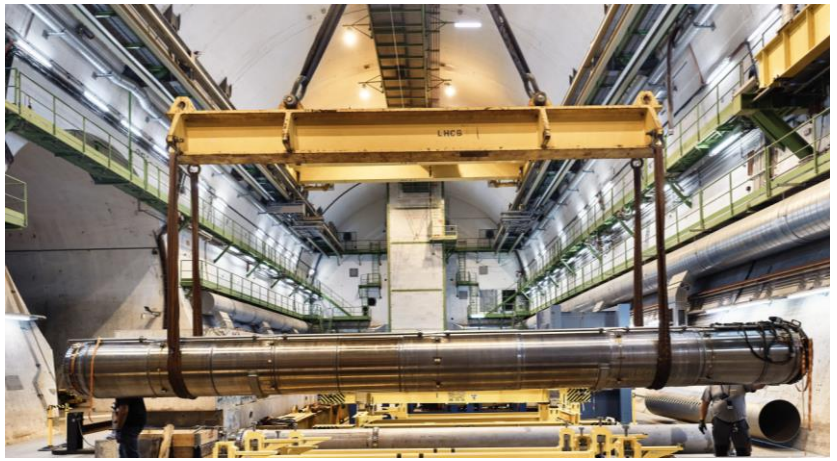
Gabriel Banks

2nd December 2024

Background

LHC Beam Dumps (TDE)

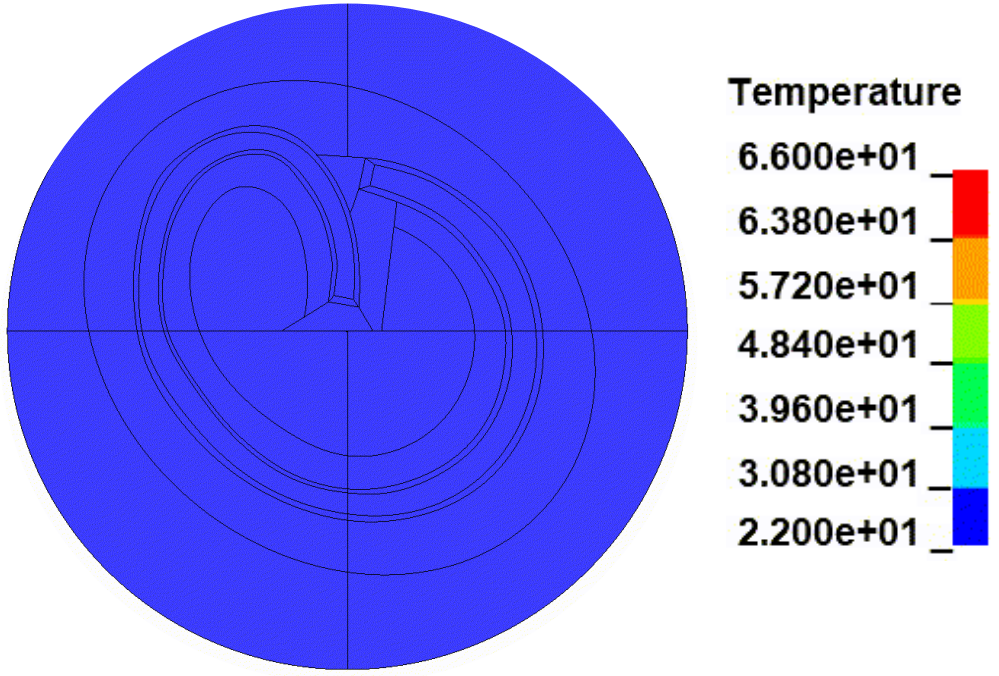




- Two dumps located at Point 6 in the LHC
- 8.5 m-long, Ø700 mm, 6.2 t weight
- LHC beam can be dumped at any **time**, **energy** or **intensity**

LHC Beam Dumps Dilution System

- Beam **swept** (in 86 µs) onto the dump face to minimise local **energy density** peak



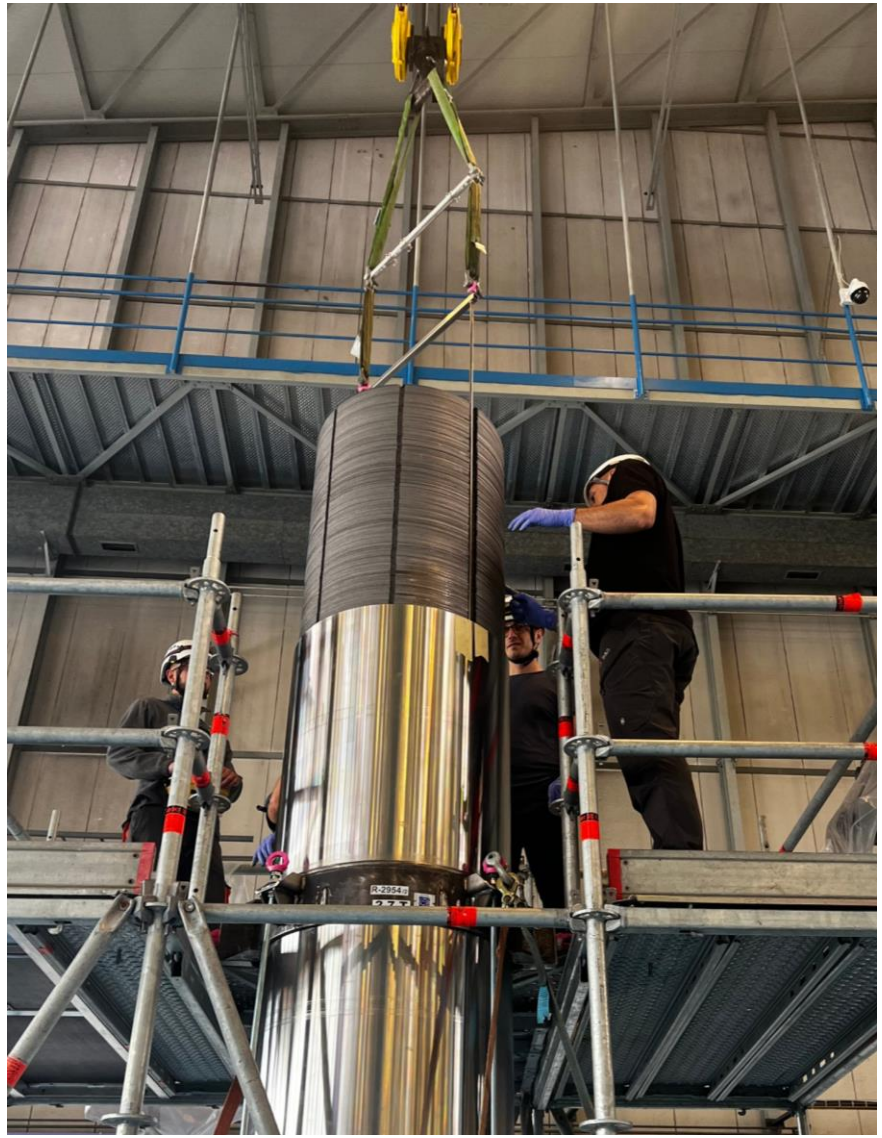
- Sweep pattern is achieved using four horizontal and six vertical **kicker magnets**
- Design of beam dump must also be compatible with the **accidental scenario**, where 2/4 horizontal kickers fail, leading to a **less effectively diluted** beam

Experimental objectives

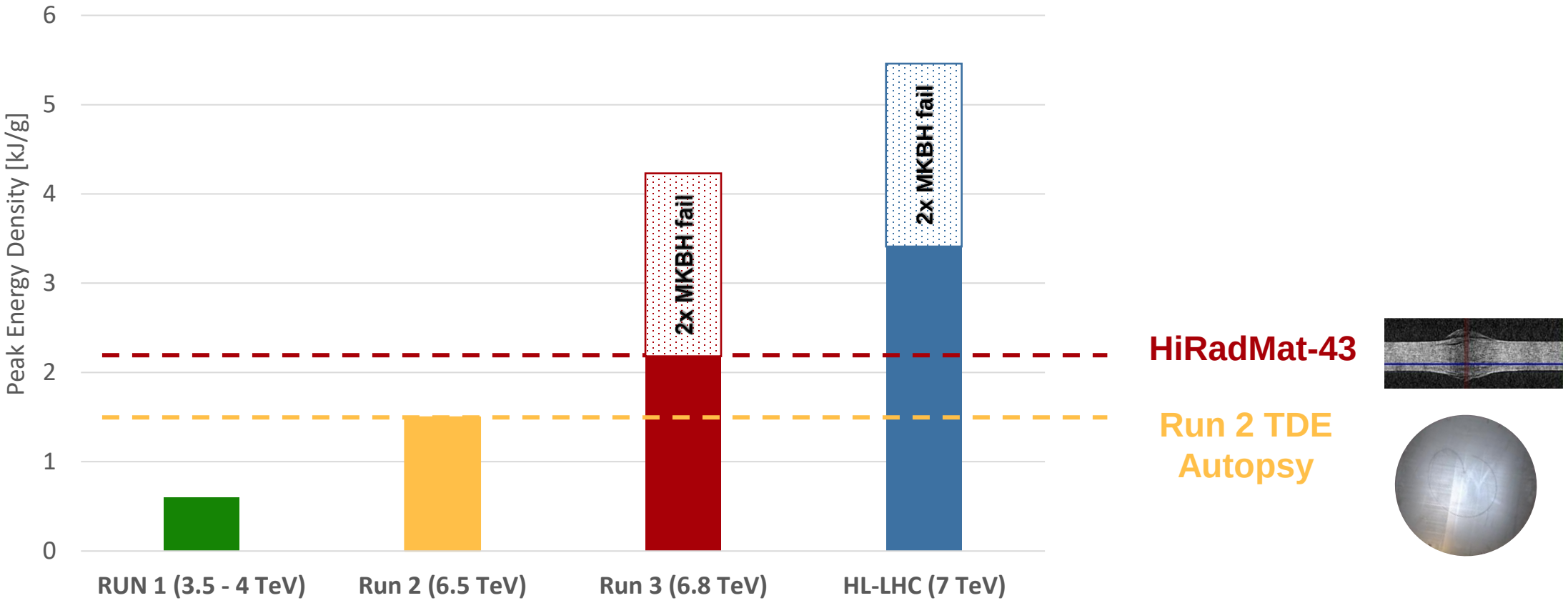
Test candidate materials for the HL-LHC beam dump (TDE) core

- Isostatic Graphite (**IG**)
- Carbon Fibre Reinforced Carbon (**CFC**)
- Flexible graphite, **Sigraflex®**

Aim: induce **energy density**, **thermal shock** and **number of shots** representative of HiLumi **nominal** operation and **accidental** scenarios



Summary of past results with graphitic materials



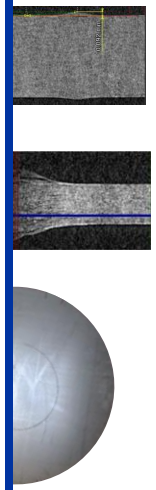
- Run 2 TDE Autopsy → No out-of-plane deformation, minor darkening on some disks
- HiRadMat-43 (2018) → ***Simplified*** experiment, aiming at reproducing Run 3-like conditions
  - ⚠ Massive delamination (thickness locally doubled)
  - ~ Very strong simplifications

Summary of past results with graphitic materials

Missing Aspects:

- **Resistance of Isostatic Graphite**
- **Resistance to long-term dumping**
- **Resistance to failure scenarios**

HiRadMat-HLTDE (2024)

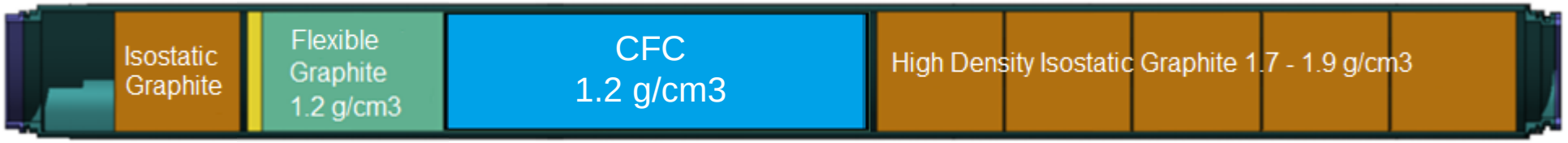


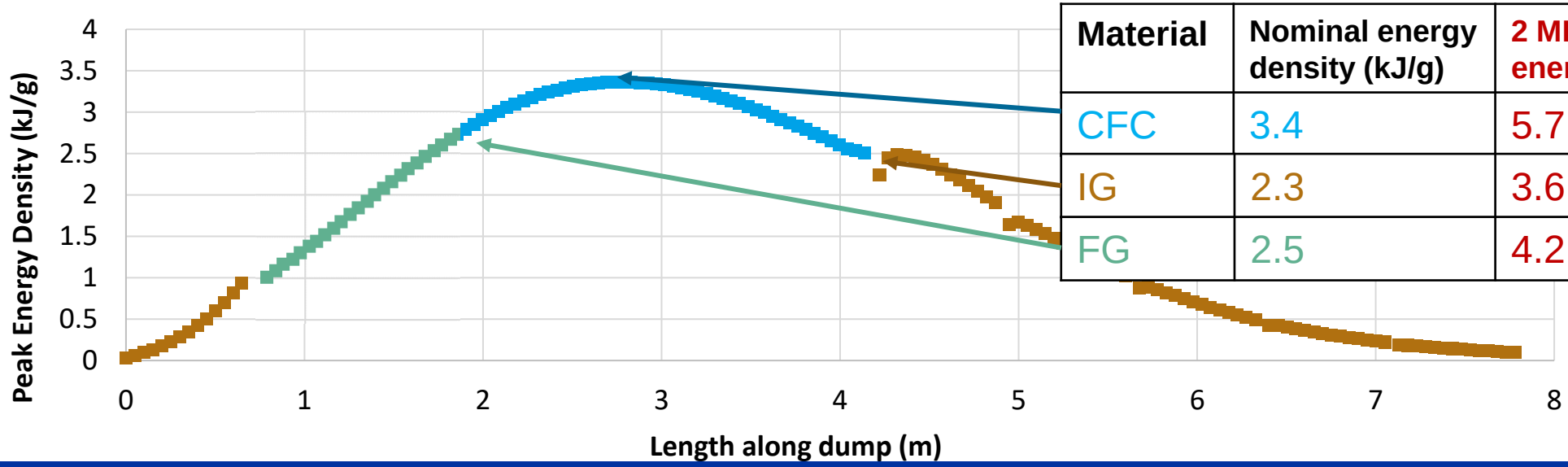
- HiRadMat-56 irradiated graphitic materials up to **3.2 kJ/g** (near HiLumi nominal value, but in *simplified configurations* and *maximum 3 shots*)
- **Demonstrated excellent response of CFC**
- **HL Failure scenarios not reproducible**→ Surpassing this limit required **upgrade of HiRadMat** to 1.8 x 10^{11} ppb

Conceptual design as basis for experiment

Conceptual layout of graphitic materials based on simulations, experience and past HiRadMat studies

- **CFC** is baseline for low-density sector due to **mechanical** and **thermal** advantages
- Partial use of **flexible graphite** was also studied

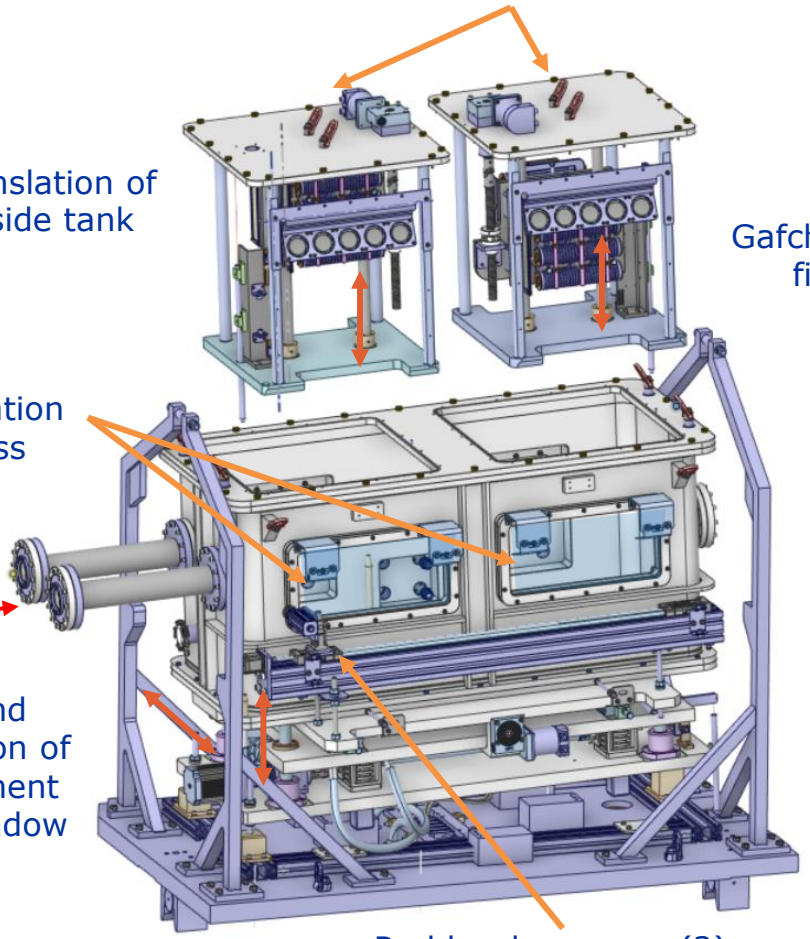


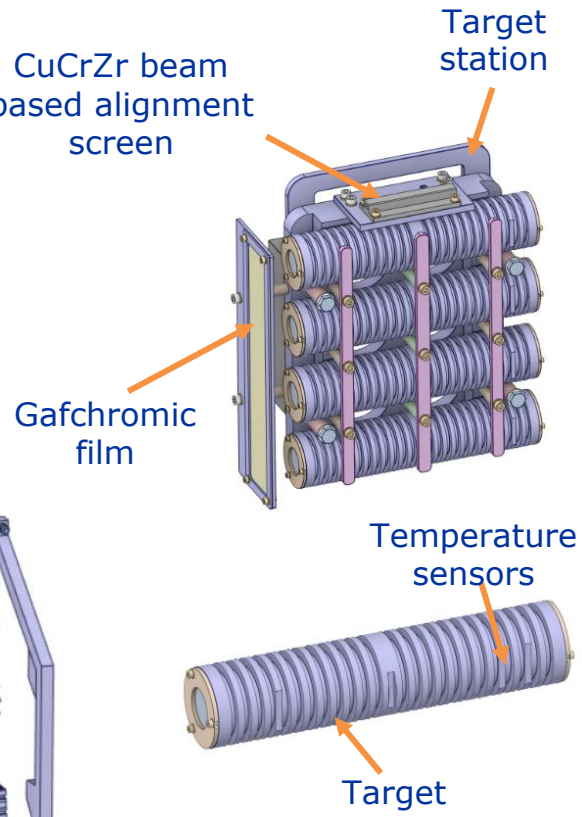


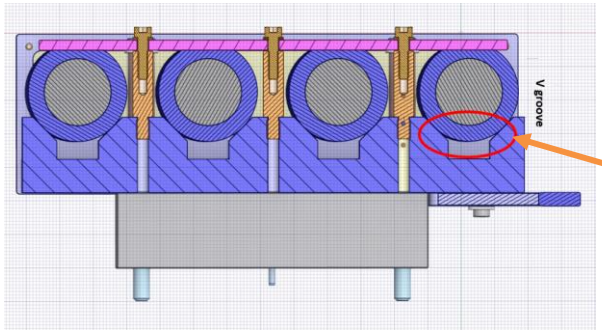
Material	Nominal energy density (kJ/g)	2 MKBH missing energy density (kJ/g)
CFC	3.4	5.7
IG	2.3	3.6
FG	2.5	4.2

Experiment description

Setup





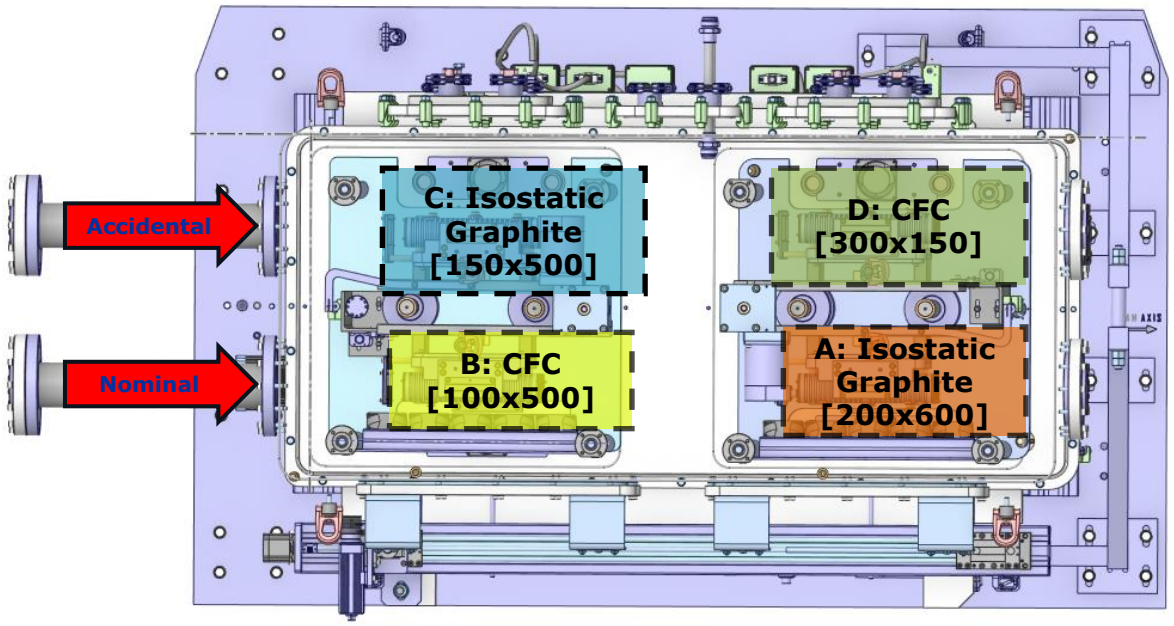


HRMT Multipurpose Tank reused

- Previously used for HRMT-46, 48, 49, 56

Experiment layout – top view

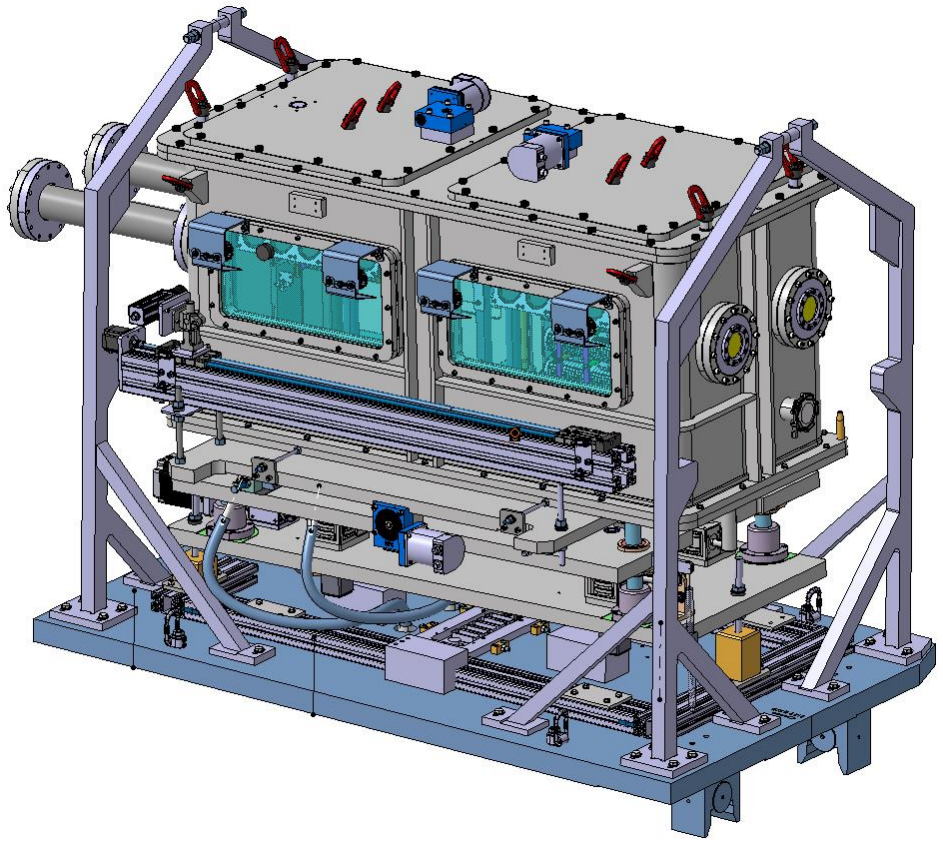
TT61 side

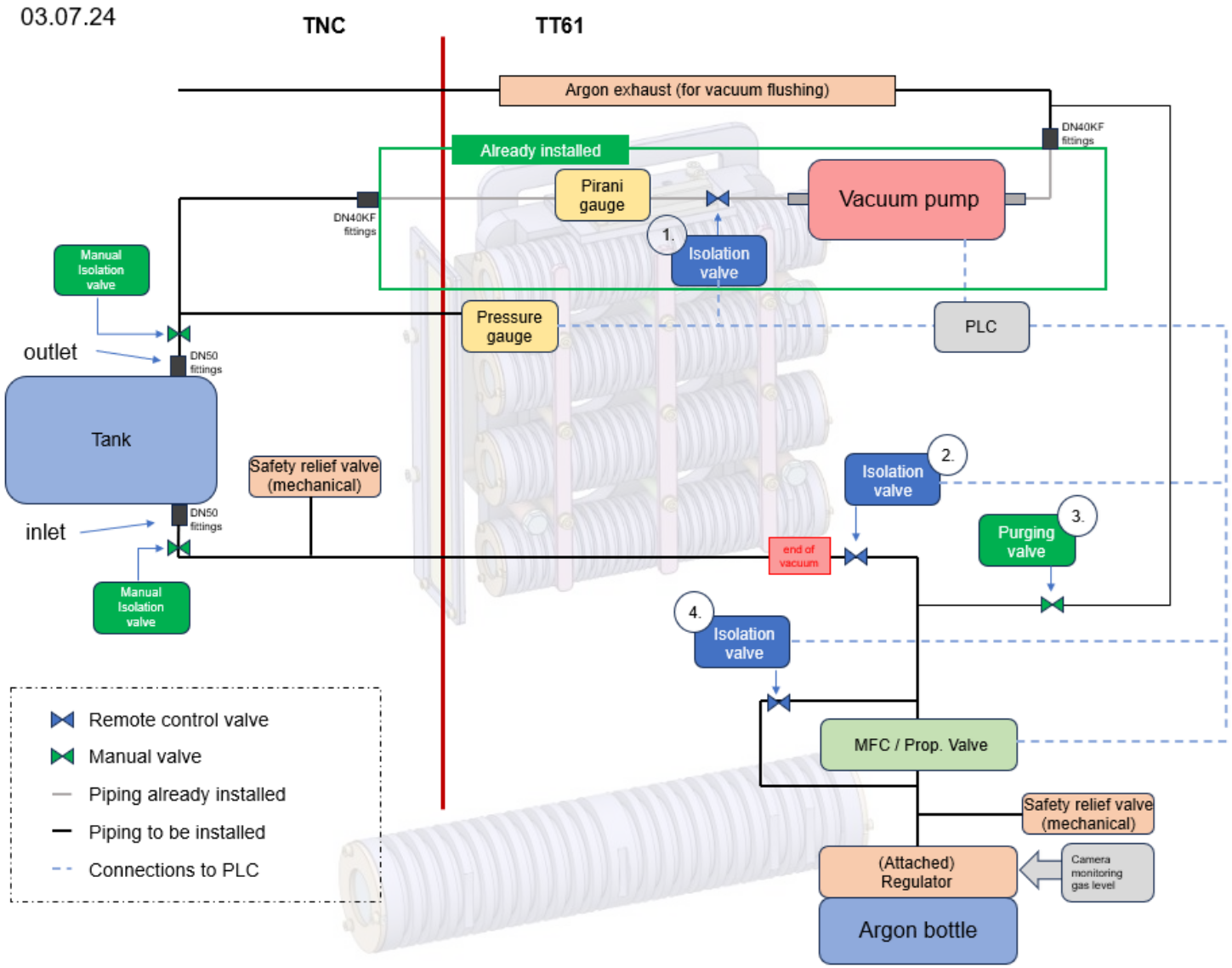


Passage side

- Four target types
- **16 targets** in total
- Square brackets show selected **beam dimensions** at target (µm)
- 50 cm **extensions** to reduce energy density in upstream windows

Argon System



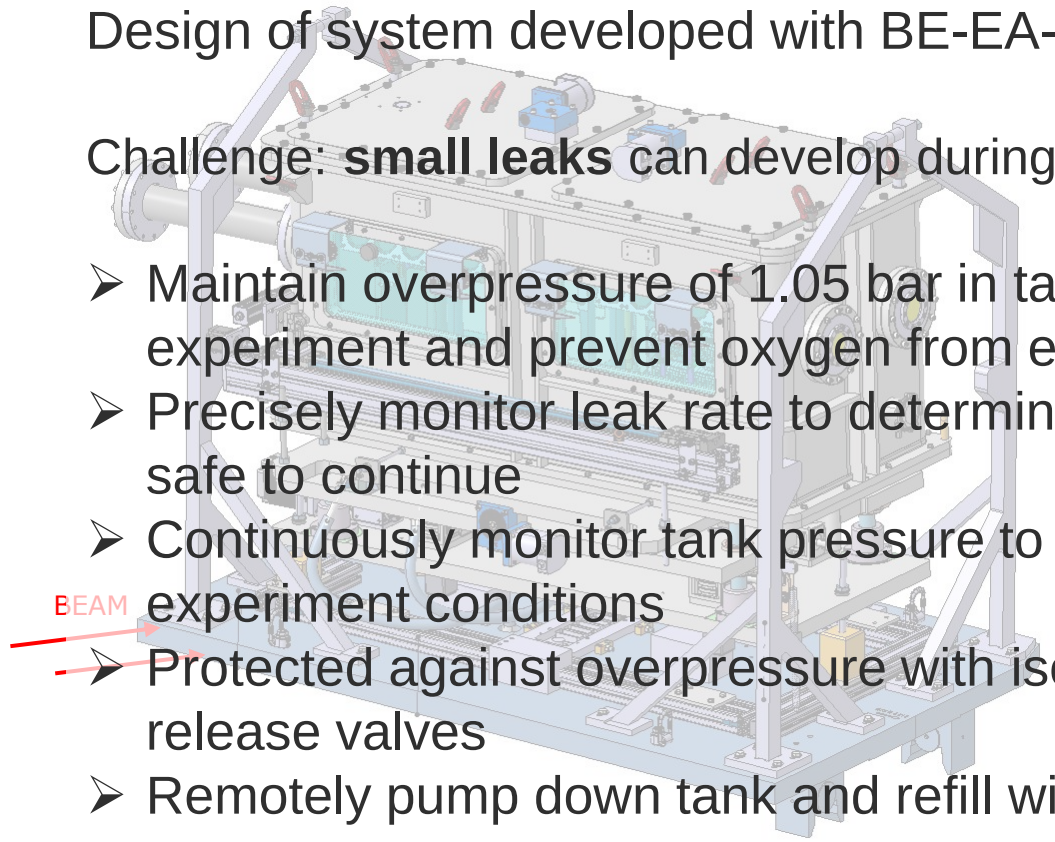


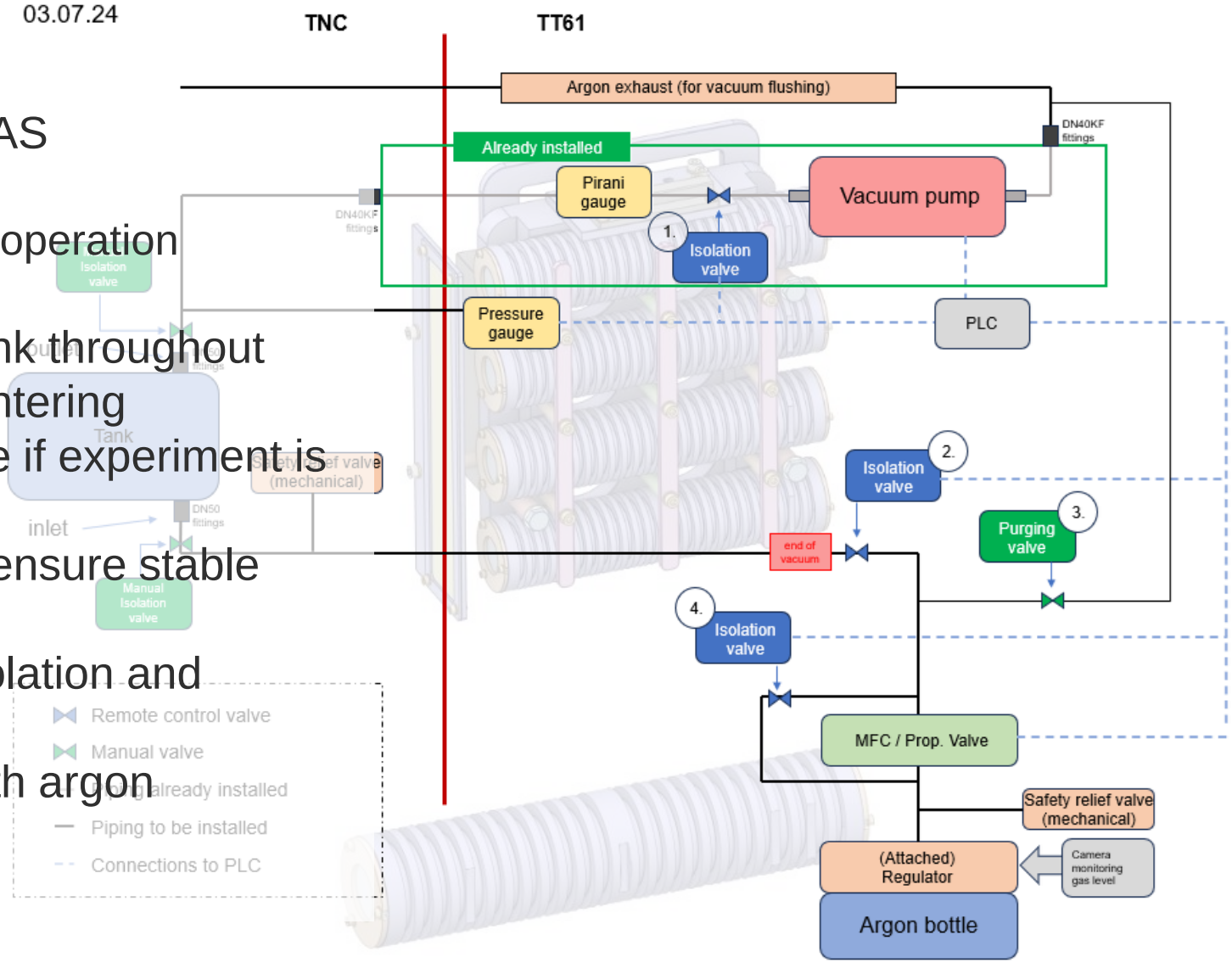
Argon System

Design of system developed with BE-EA-AS

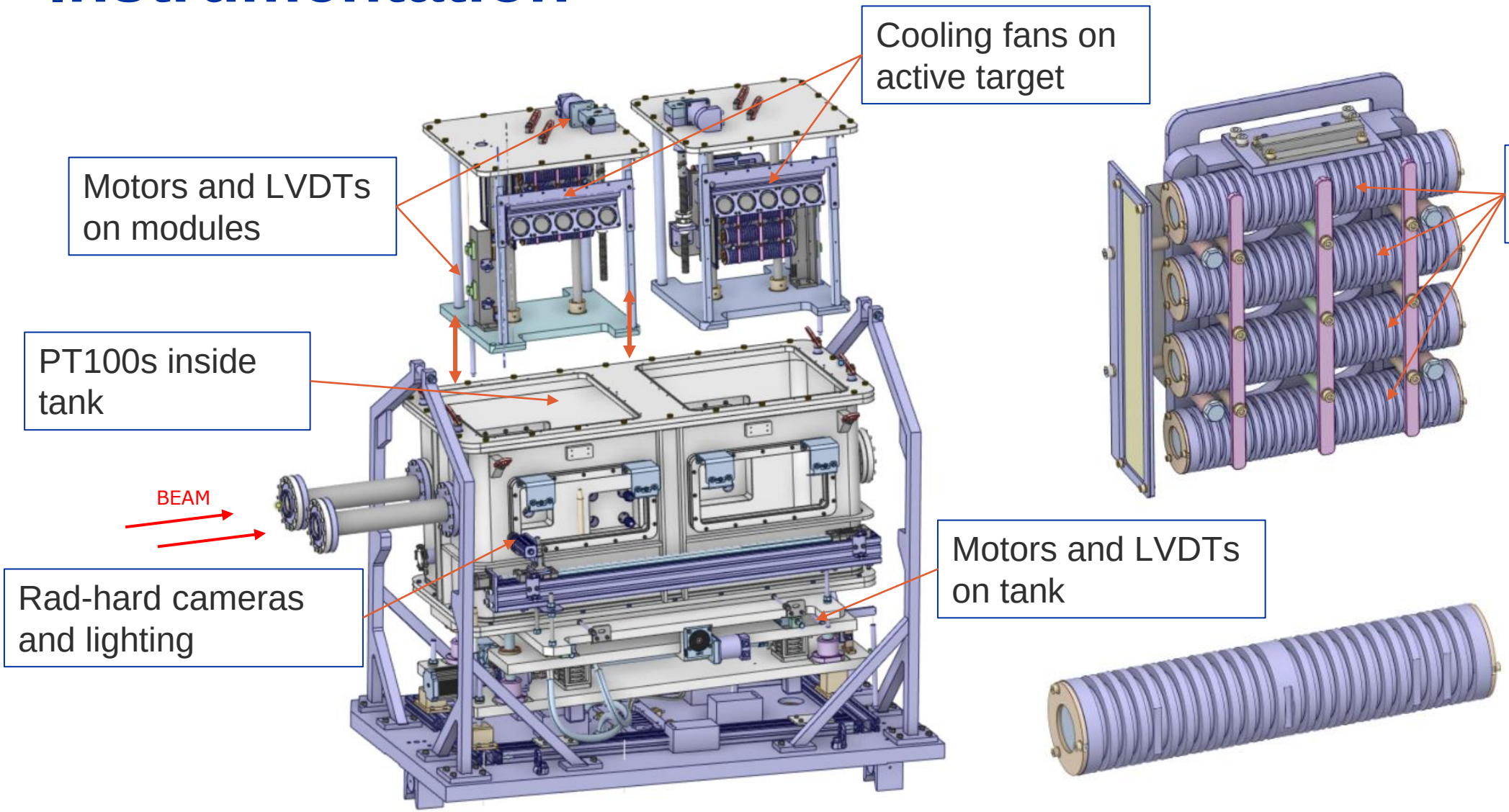
Challenge: **small leaks** can develop during operation

- Maintain overpressure of 1.05 bar in tank throughout experiment and prevent oxygen from entering
- Precisely monitor leak rate to determine if experiment is safe to continue
- Continuously monitor tank pressure to ensure stable experiment conditions
- Protected against overpressure with isolation and release valves
- Remotely pump down tank and refill with argon





Instrumentation

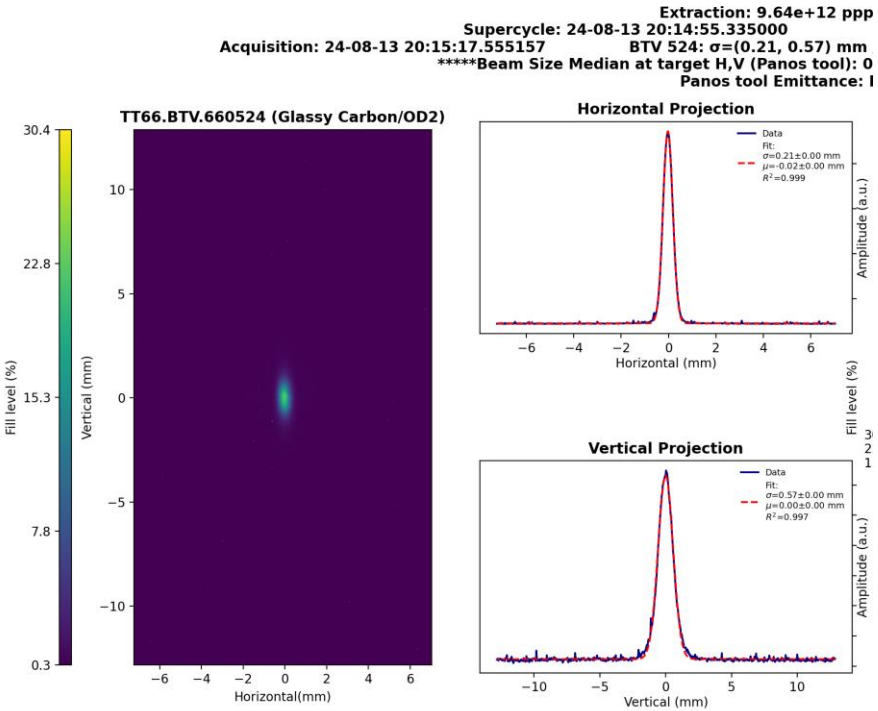


Shots, monitoring and recording

Beam steering, beam based alignment and optics tested using single bunches

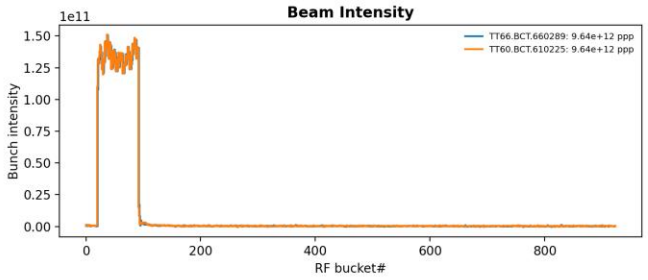
First time deployment of Monte Carlo tool

- Estimate beam size/uncertainties at target
- Inputs: BTV measurements, beam emittance and momentum spread in SPS
- Highlighted issues with some of the optics which would not otherwise have been noticed



Before and during shots, check:

- Motor positions, align active target with beam
- Temperatures on targets, tank and in dump
- Beam size and intensity within limits



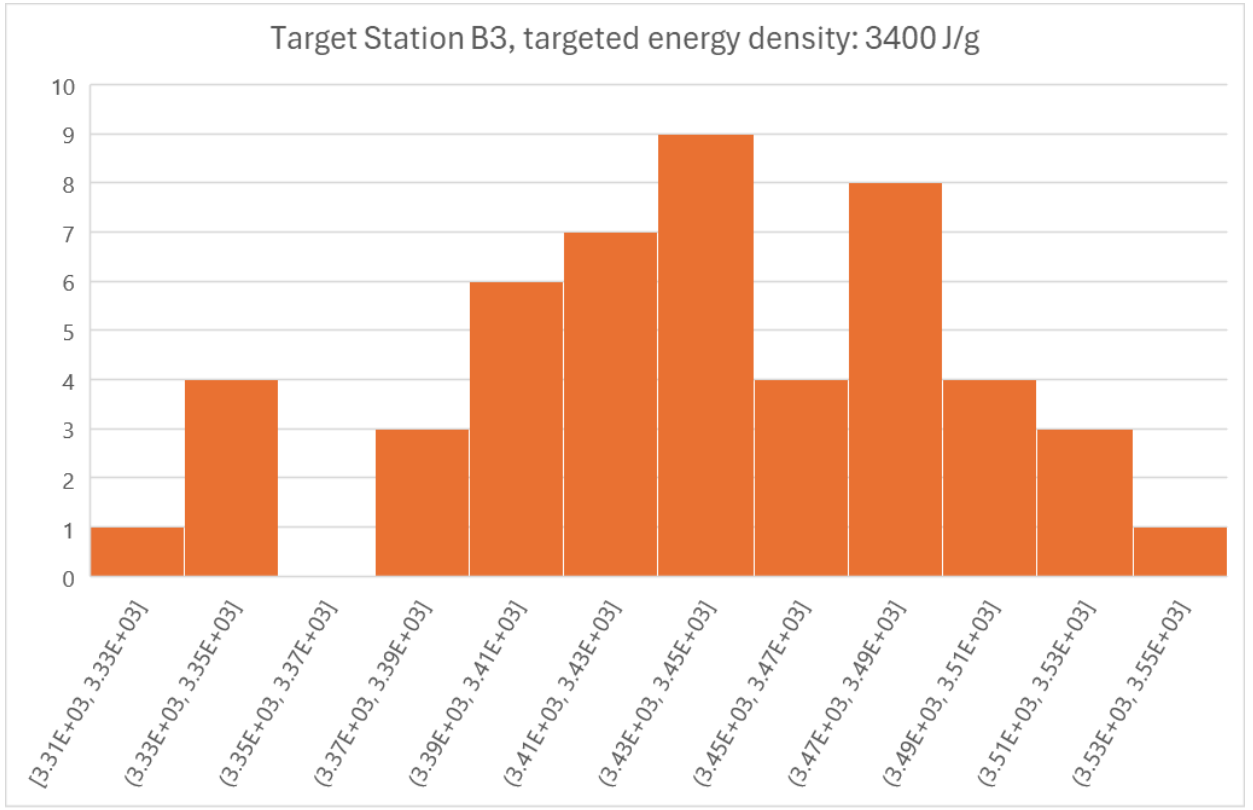
Post-experiment analysis

Analysis of shots achieved

Beam size estimated by script + actual measured intensity =

Histogram of estimated energy density in all 50 shots per nominal target

Energy density achieved was within 15% of requirement for all 16 targets



Transport and modules extraction

TRANSPORT
Out of tunnel

HANDLING
Remove tank and put in bunker

HANDLING
Remove modules

Cut wires
Place on table

Dismount targets

Radioactivity measurements

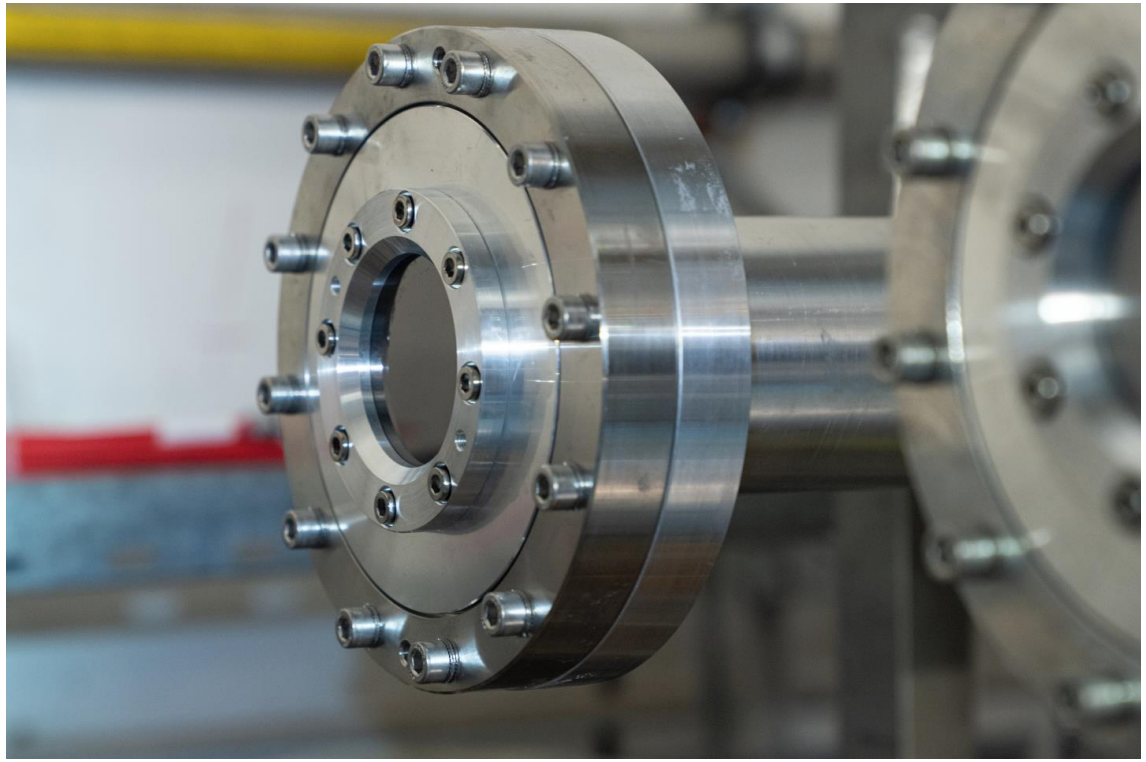
Beam Windows Observations

Following experiment extraction, **slight blemish** seen two Glassy C and one Be window

Very small increase in **leak rate** could indicate this was a small fissure

A change in beam optics led to a much **larger energy density** in the DS glassy carbon window than previously tested

Findings will be concluded with **SEM** analysis and **FLUKA** simulation

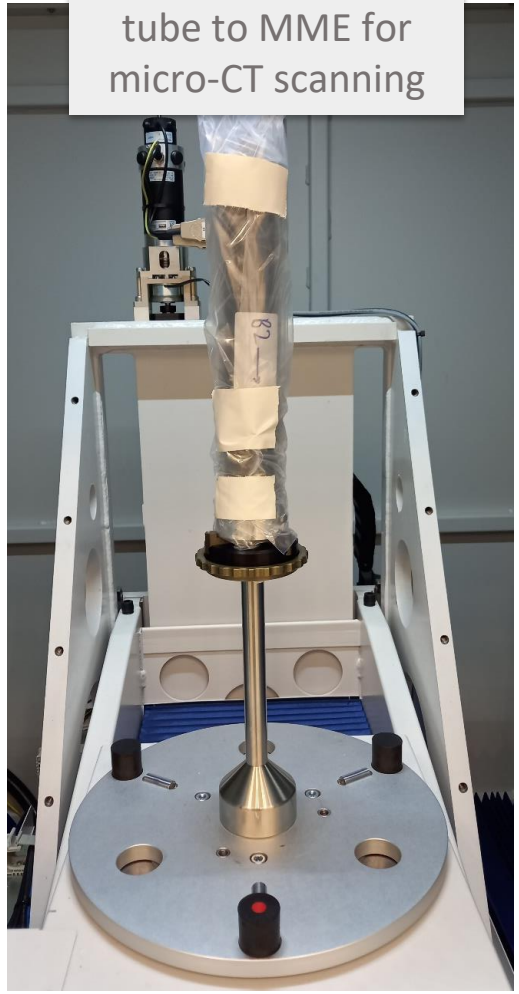


Target disassembly and PIE

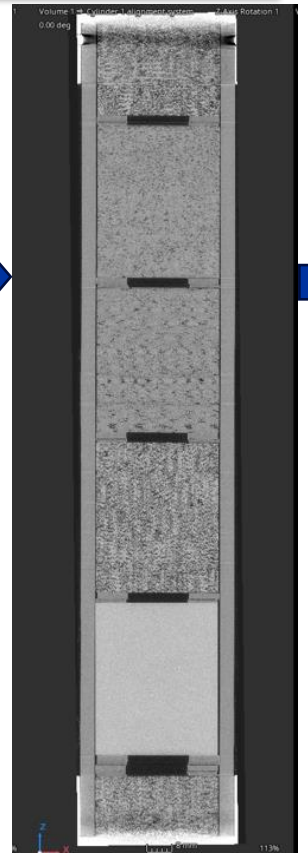
Extract specimens into plexiglass tube

Seal plexiglass tube with end caps

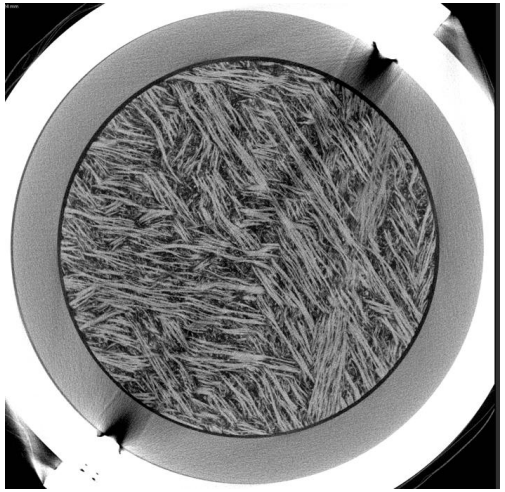
Transfer plexiglass tube to MME for micro-CT scanning



Determine presence of any damage to target materials

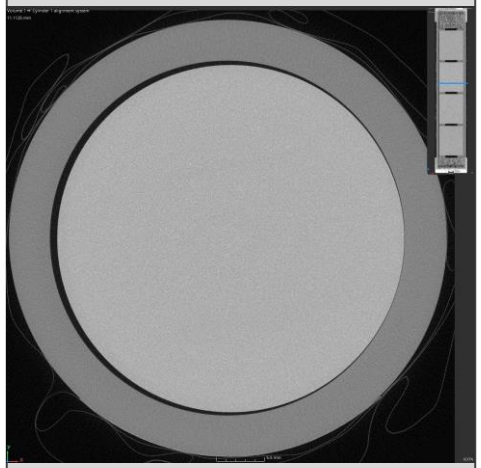
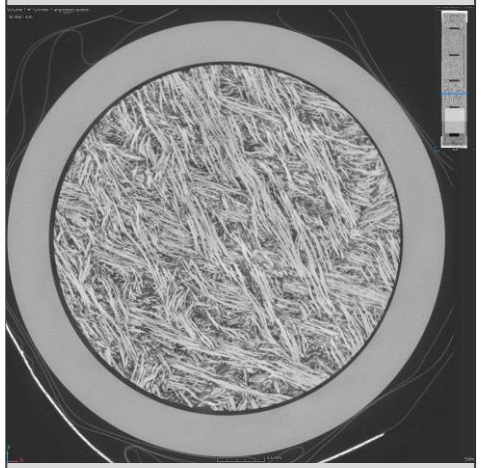
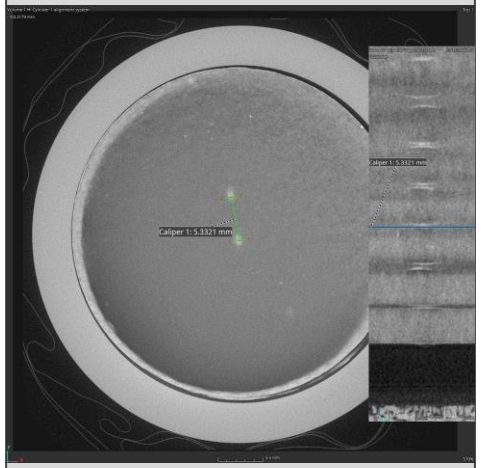
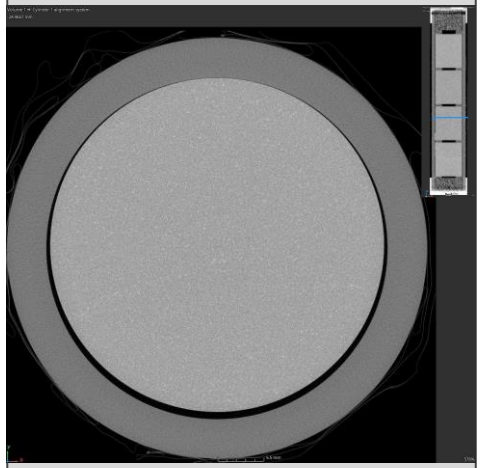
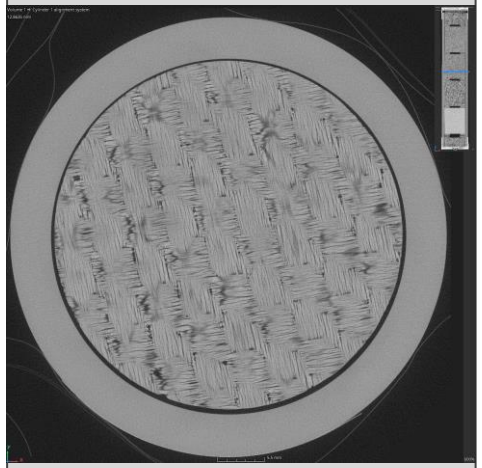


This PIE methodology has been used extensively in the past and refined base on lessons learnt



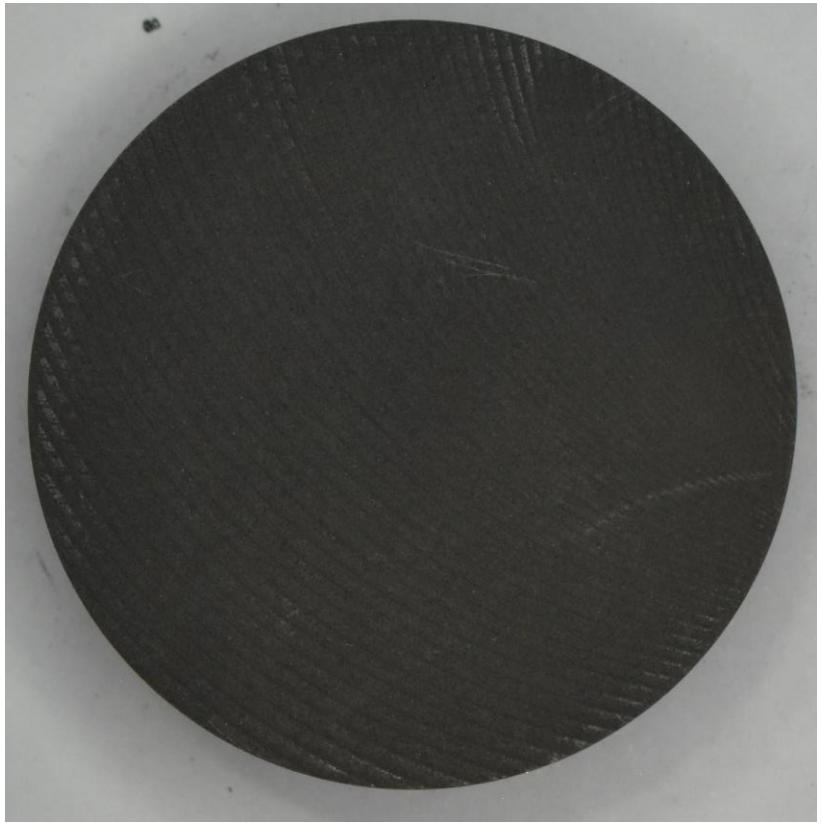
Results

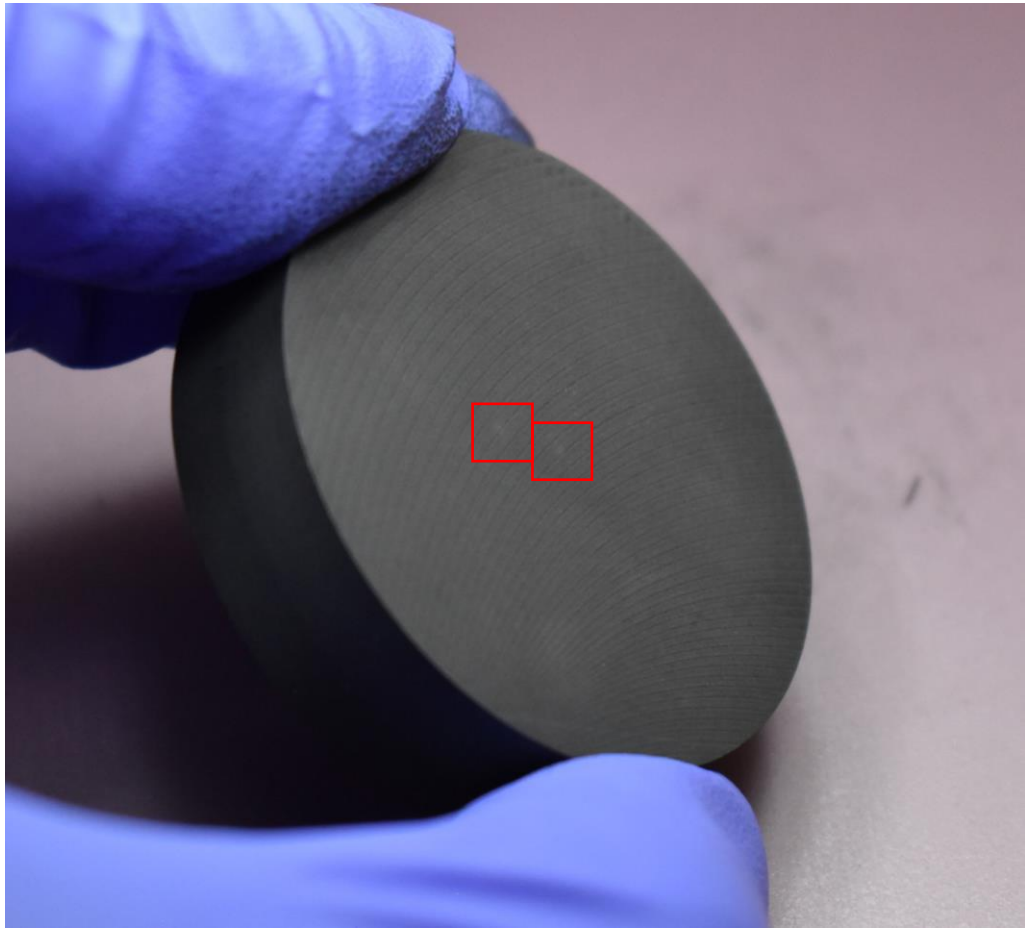
Micro-computed tomography scans

IG nominal	CFC nominal	Sigraflex nominal	IG accidental	CFC accidental
				
No change seen	No change seen	Out of plane deformation and delamination in all cases	No change seen	No change seen 50% higher energy density than ever tested in graphitic materials in HRMT

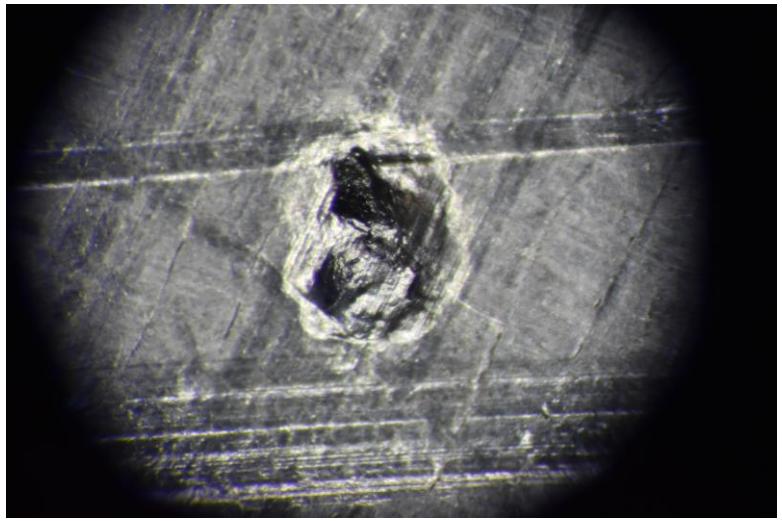
Visual examination

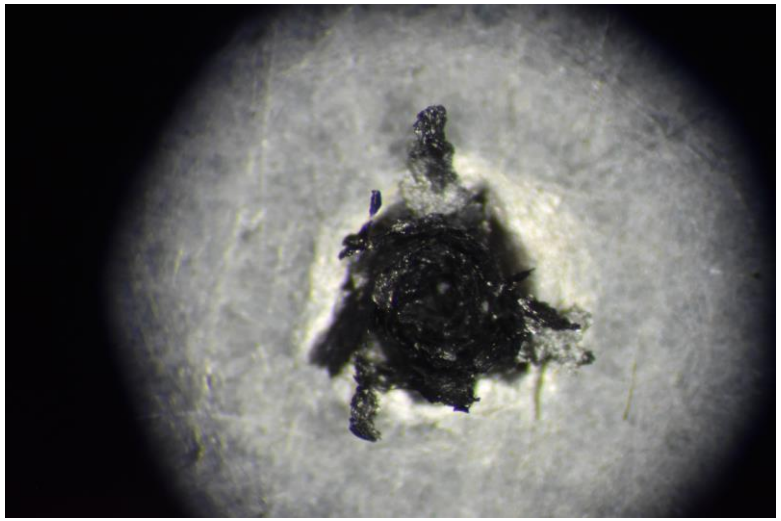
Barely perceptible spot on some faces of isostatic graphite specimens, nominal and accidental cases

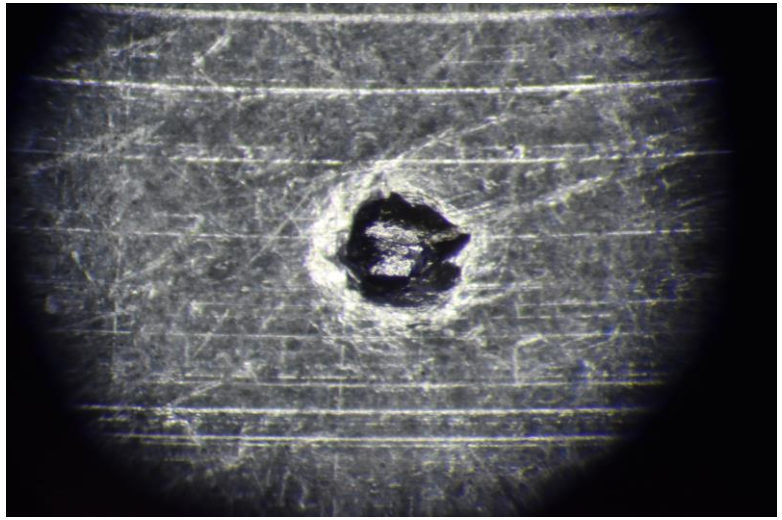


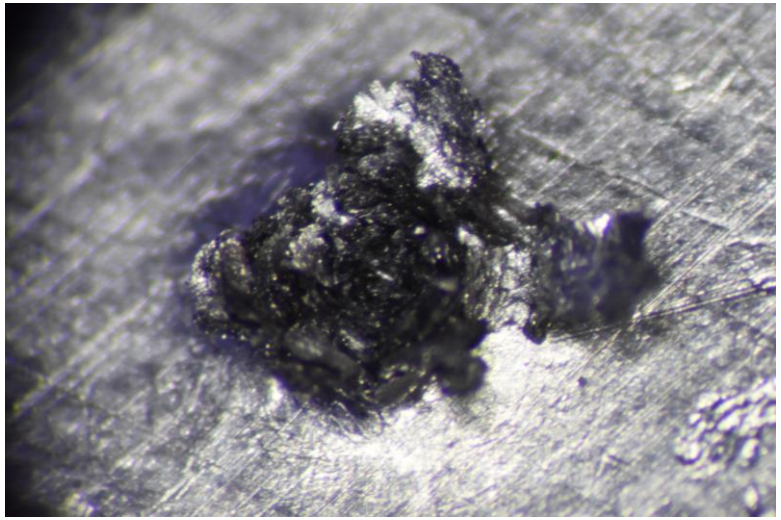


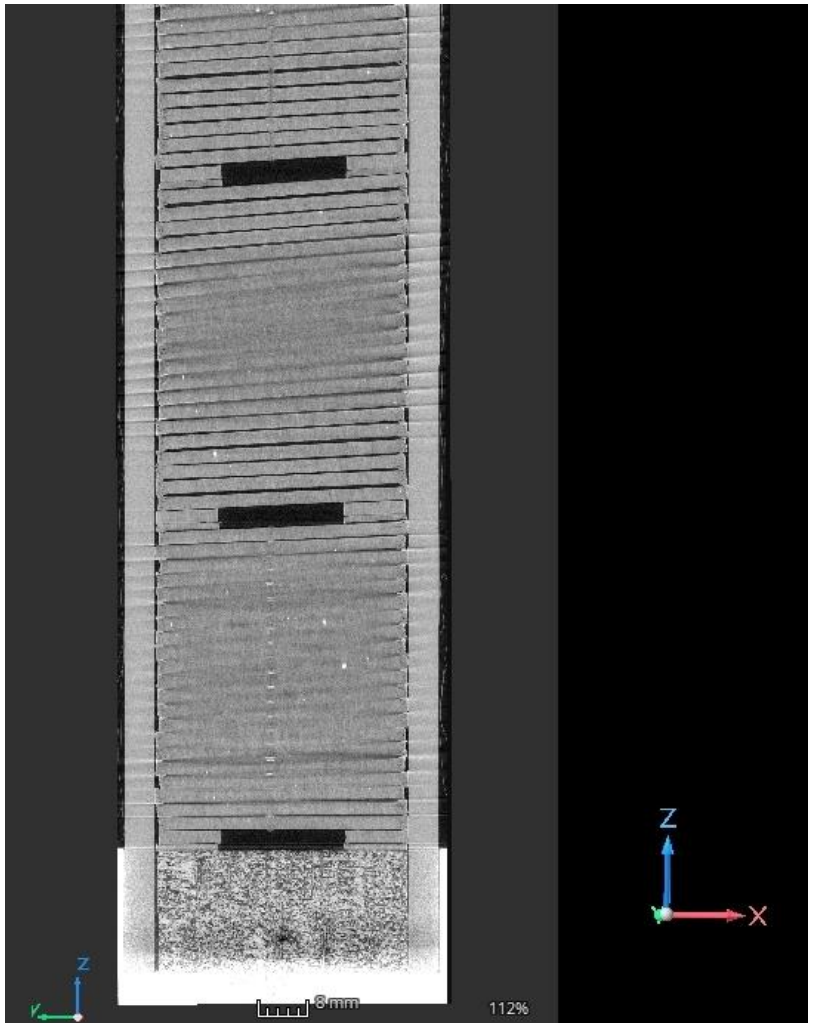
Sigraflex under optical microscope











Conclusions

- Isostatic graphite and CFC qualified for HL TDE project
- CFC and isostatic graphite survived much higher energy densities than previously tested
- Energy densities and simpler target design made possible by HiRadMat upgrade
- Progress made in measuring/predicting actual beam size achieved at experiment and uncertainties