Calibration in Hyper-K

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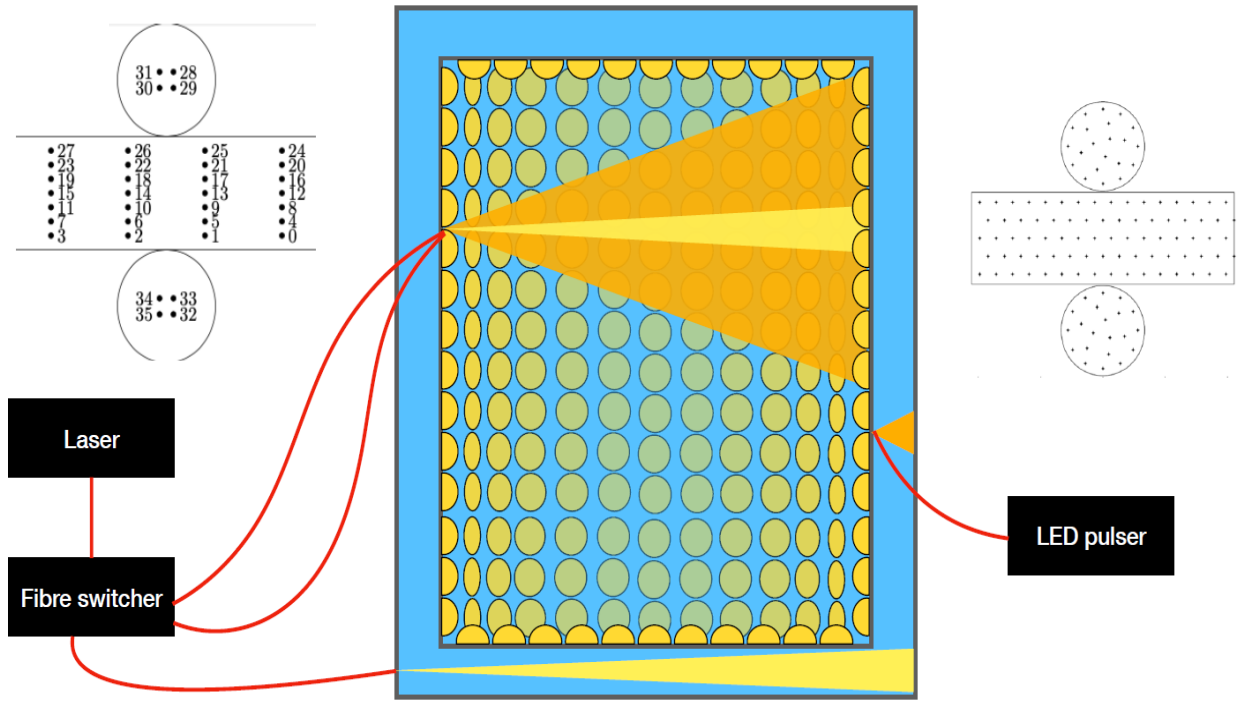
Calibration in Hyper-K

- Calibration drives the detector systematic in Hyper-K
  - Must be reduced over the Super-K/T2K era
  - Improved Calibration
- Multiple calibration activities
  - PMT Precalibration
  - **Light Injection**
  - **Radioactive Sources**
  - **Electron LINAC**
  - **Gadolinium Concentration Monitor**
  - Photogrammetry
- Major contributions and leadership from Jennifer members

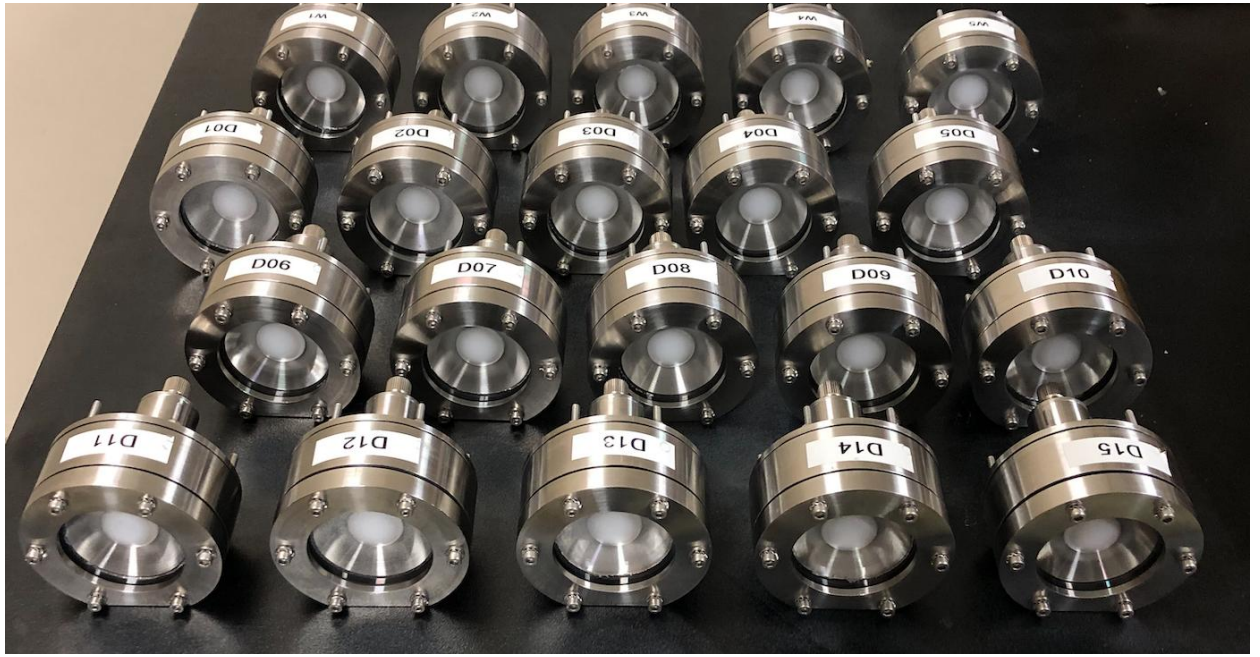
Light Injection

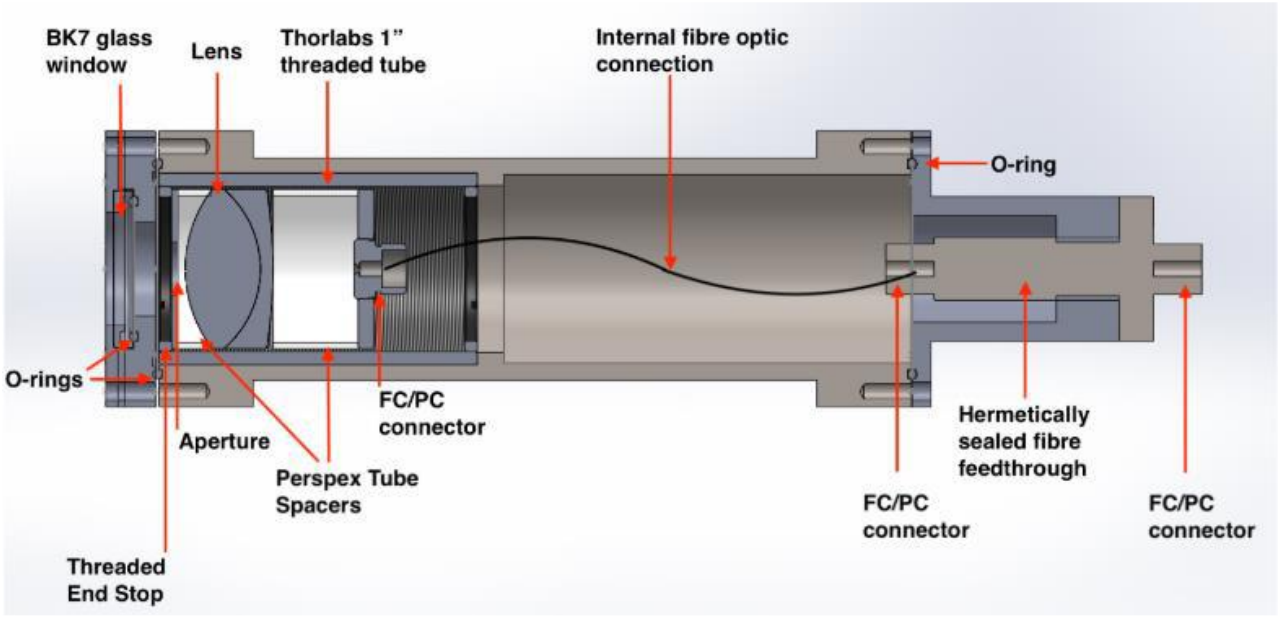
- Light injection is essential for Hyper-K calibration
  - PMT properties
  - Water Absorption and Scattering
- Fast, Multiwavelength pulses
- Multiple injection sites in ID and OD
- Shaped light pulses
  - Diffusers - 40º opening angle
  - Collimators - 2º opening angle



Injectors

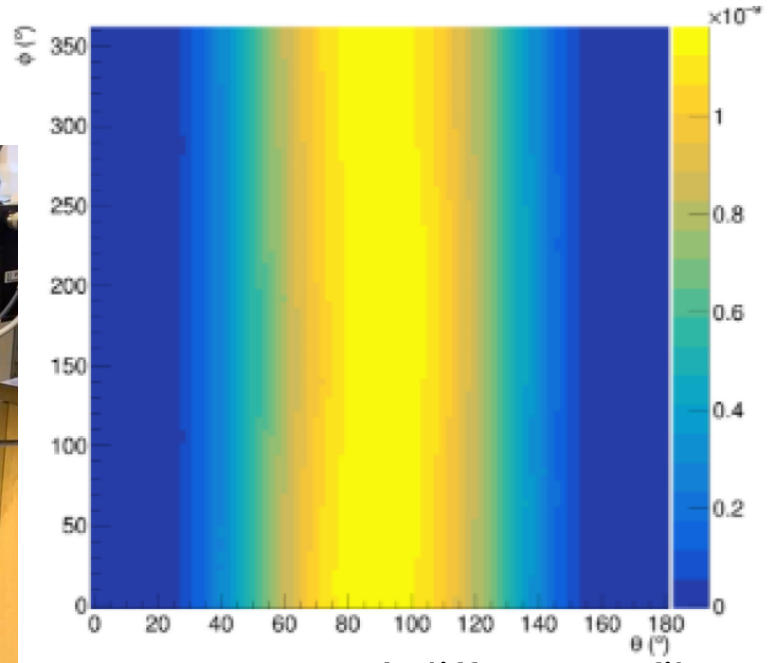
- Diffusers
  - 40º opening angle
  - PTFE diffuser in custom housing
  - Vacuum feedthrough to avoid water leakage
  - Construction at Warwick now completed
- Collimators
  - 2º opening angle
  - Illuminates 5x5 PMT spot on far side of detector
  - Lens to focus light from fibre
  - Specifically designed to measure scattering
  - Assembly to commence soon





Injector Characterisation

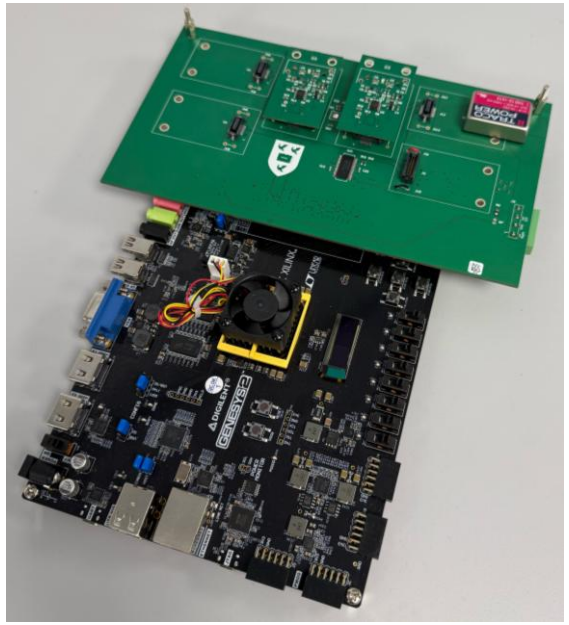
- Each injector will be characterised in the custom water tank at Sheffield
- Approximately 70% of diffusers measured
- Individual measurements will be used to simulate injectors



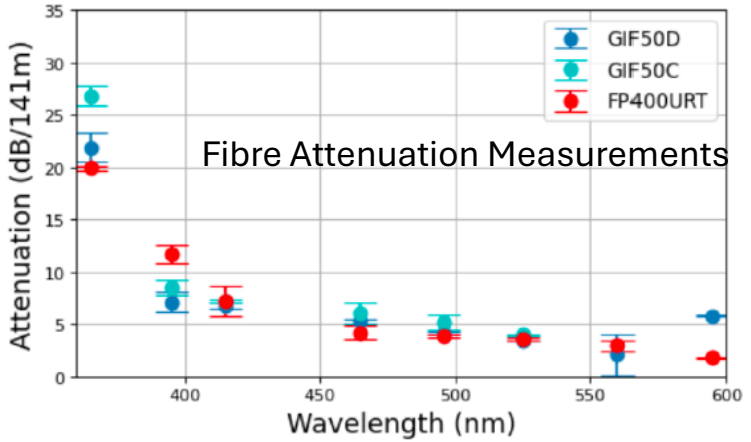
A diffuser profile

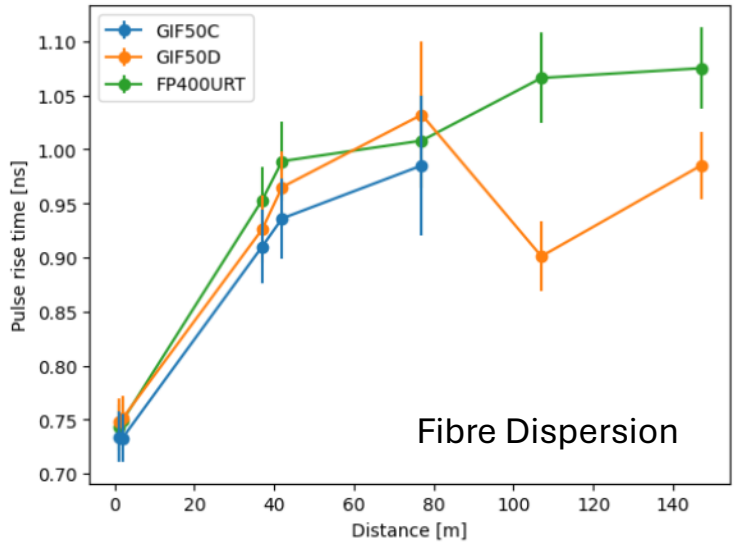
Light Sources

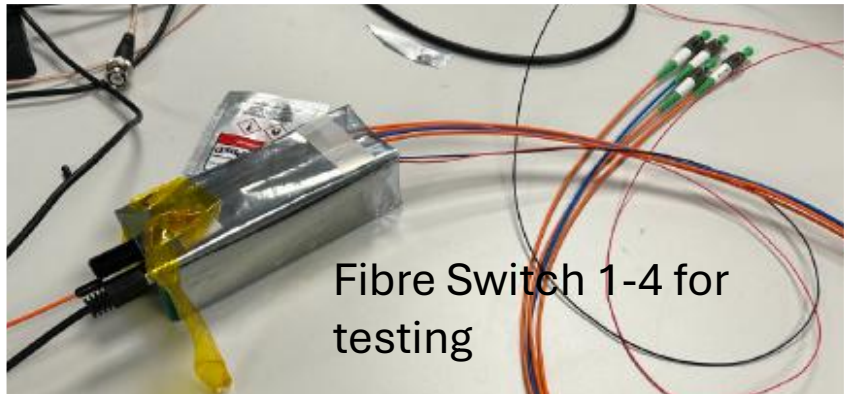
- Fibre Optics have been characterised at Liverpool
  - Attenuation and dispersion measurements
- Fibre Optic Switches have been characterised
  - Good performance
- ID Laser system identified
- Final prototype of OD LED system in test



LED Pulser for OD

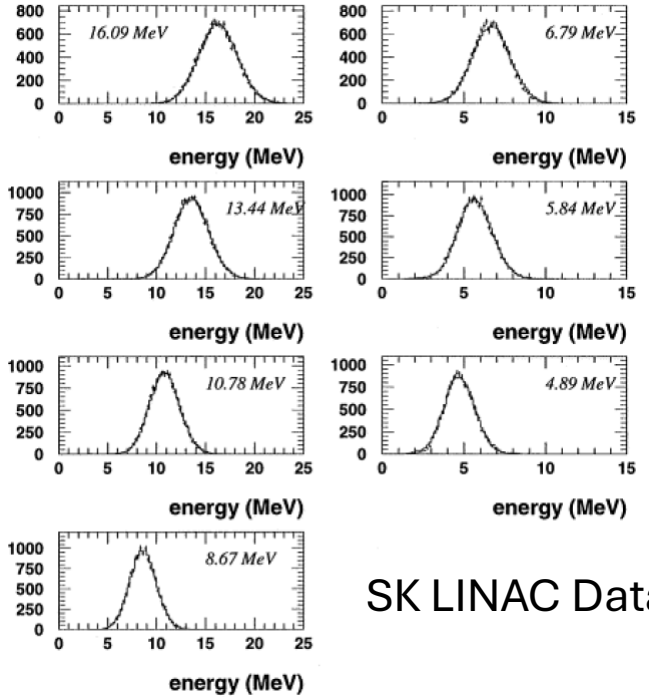




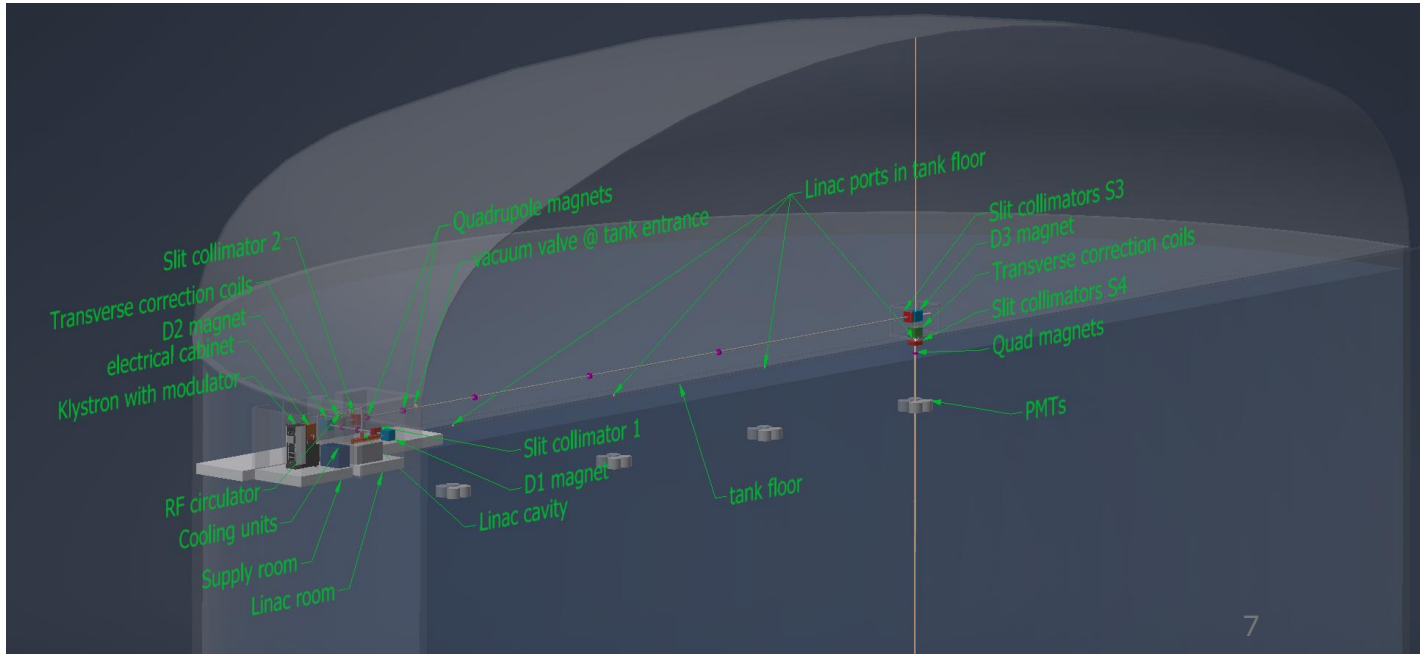


The HK LINAC

- The LINAC provides electrons from 3 – 25 MeV
  - Central to the low energy calibration of HK
- Unique challenges:
  - Very low intensity
  - Beam transport into the detector
  - Deployment of beam pipe at high pressure
- 7 calibration ports
  - 3 depths in each

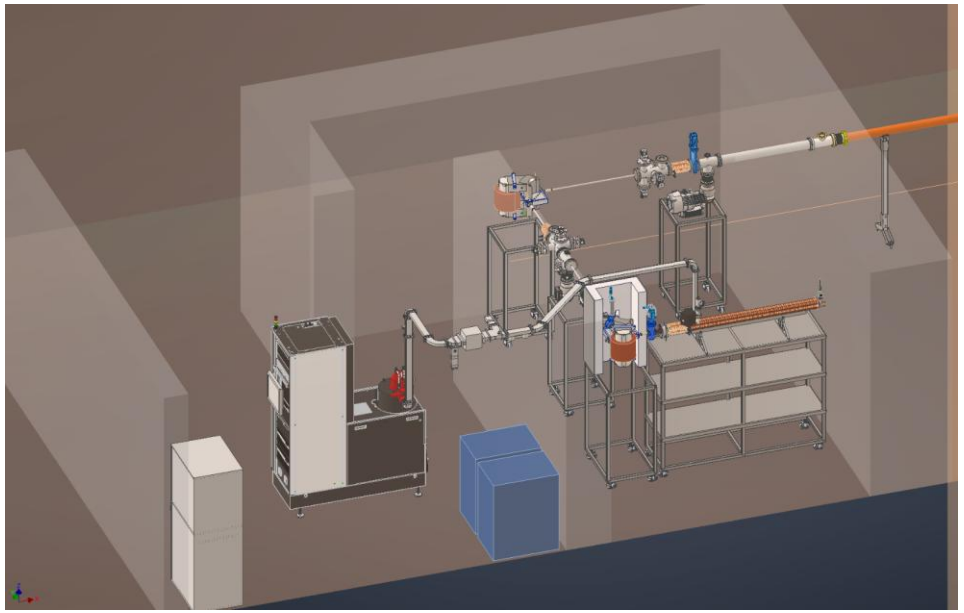


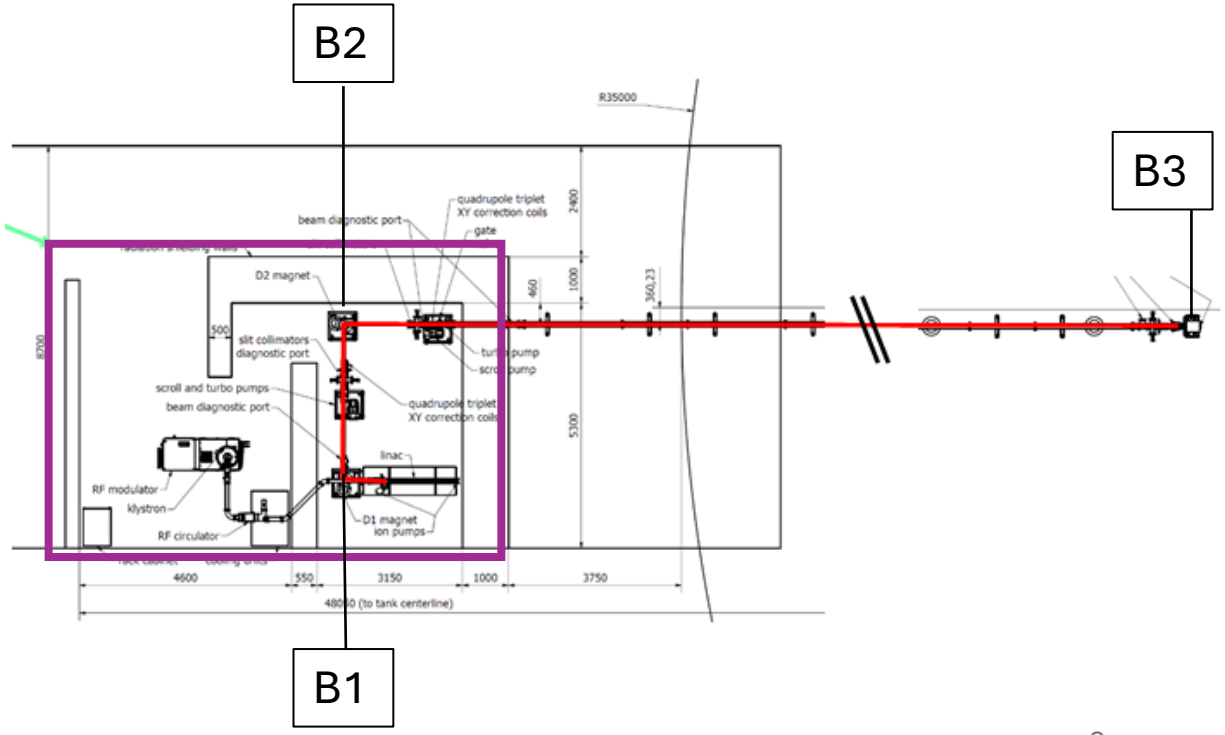
SK LINAC Data



The LINAC Bunker

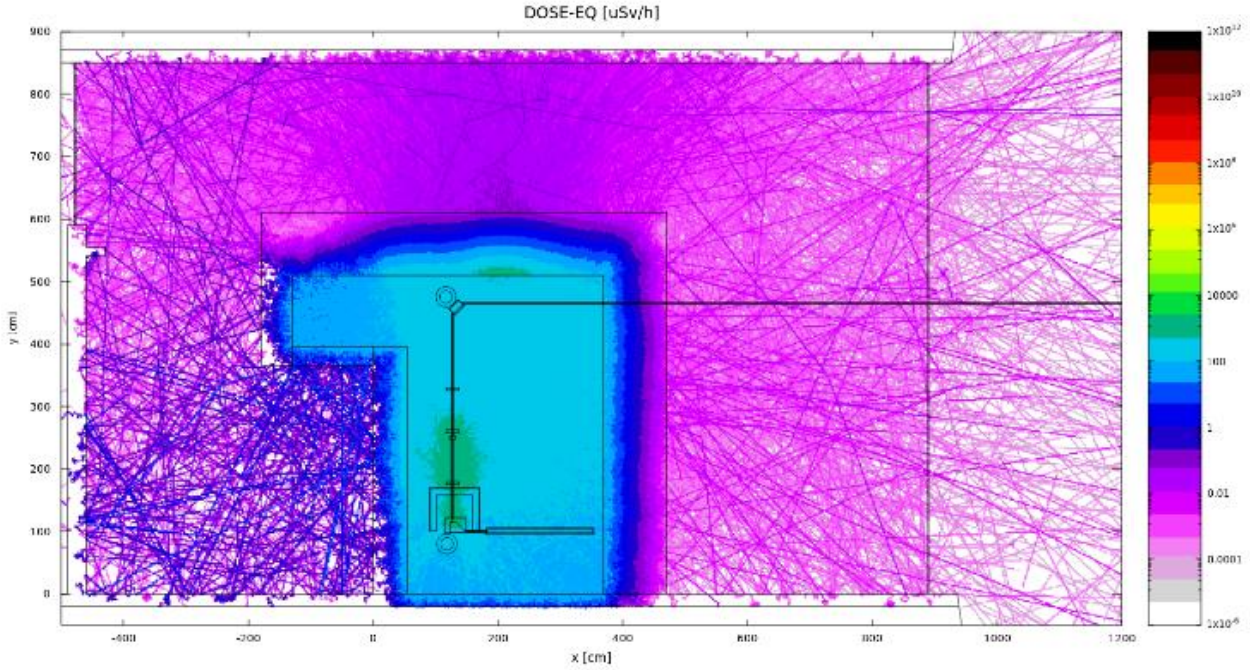
- Main Radiation Area
  - Houses the LINAC, klystron and first 2 bending magnets
- Also home for
  - Control systems
  - Accelerator vacuum system
  - Beam monitors
- Radiation area includes both rooms





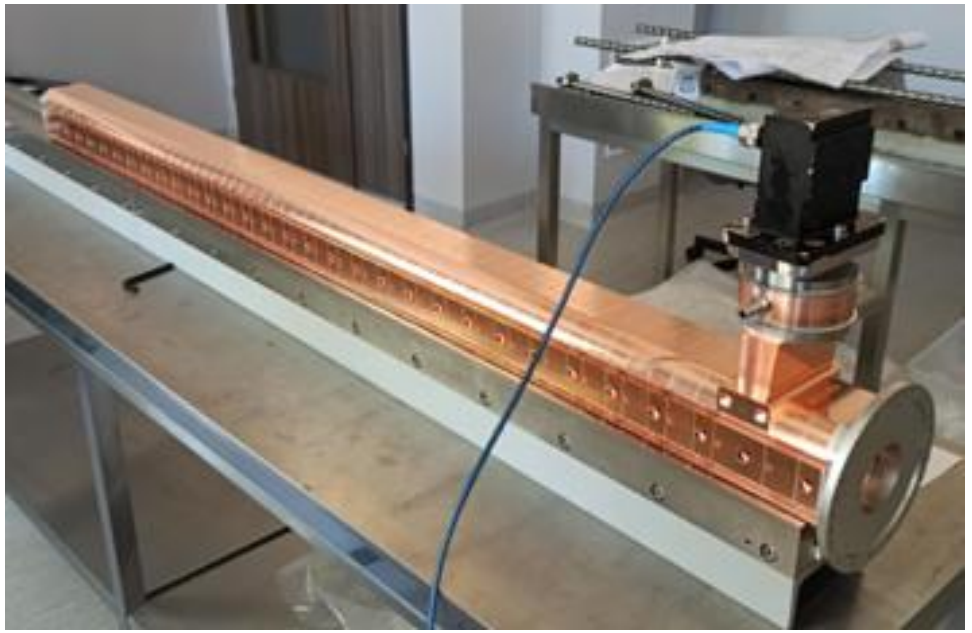
Radiation Dose

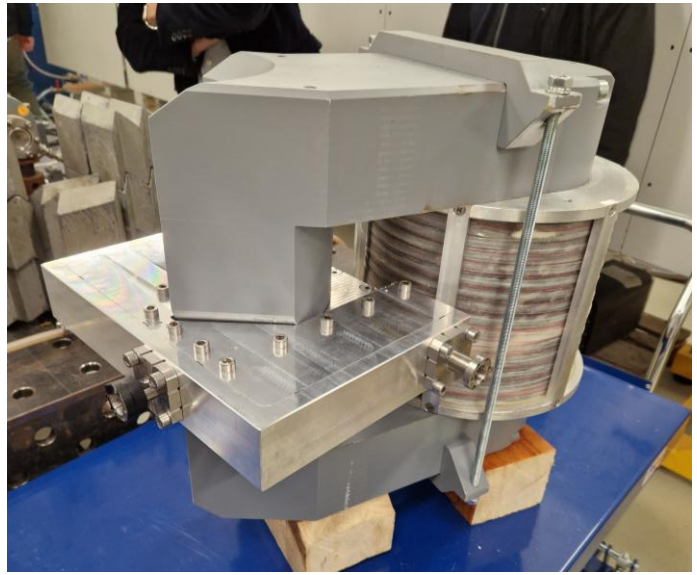
- Control of dose is crucial
  - Corridor past LINAC room must be safe
- Calculations inspired some design changes
  - Control of current
  - Direction of LINAC accelerator
  - Shielding at B1 magnet
- Safe dose achieved
- No radiation reaches HK



Accelerator + Magnets

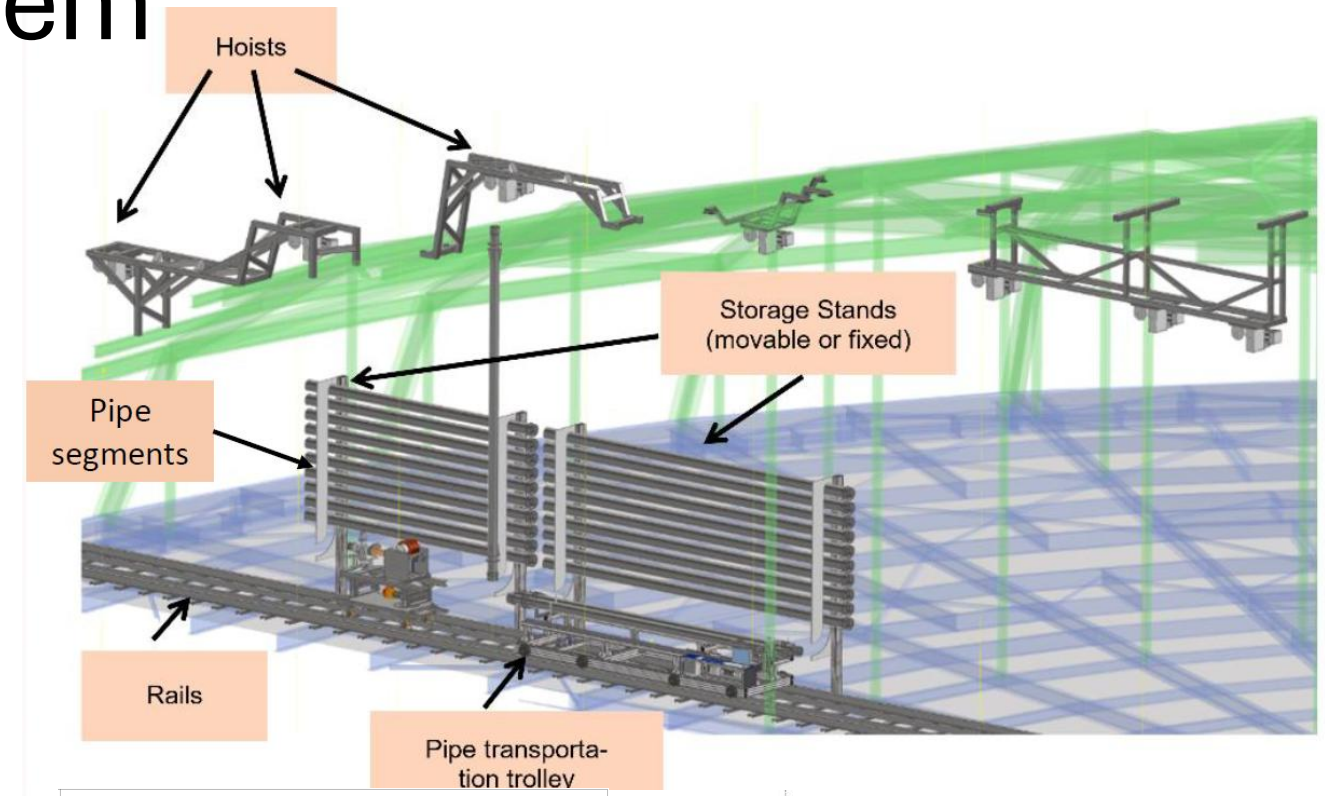
- Accelerator and Klystron are now at NCBJ
  - Long lead times meant early order
- 1st acceleration tests in very soon
- Plan for full recreation of LINAC bunker at NCBJ
  - Radiation measurements in this setup important for radiation certification in Japan
- B1 magnet and vacuum chamber built and tested

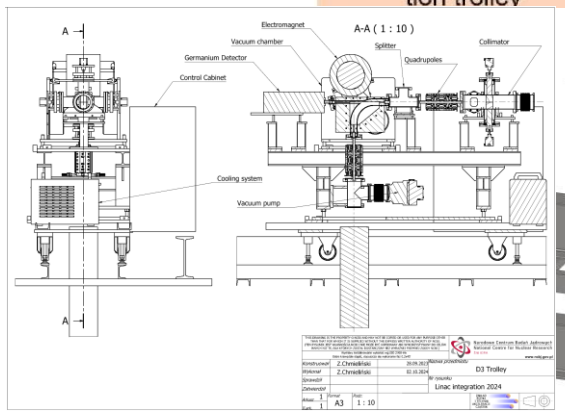


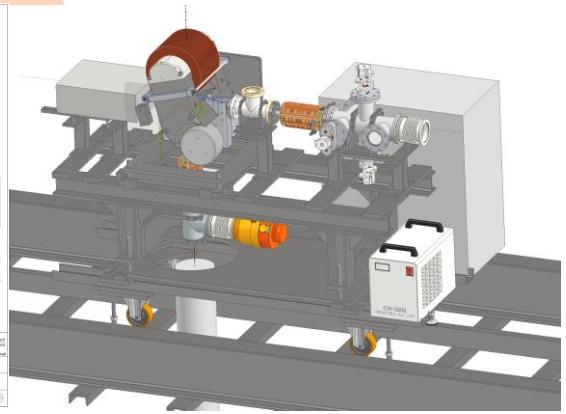


Beam transport system

- Transport electron beam across top of detector and vertically into HK
- Use fixed hoists for deployment into 7 calibration ports
- Two trolleys
  - D3 trolly
  - Pipe transportation
  - Custom dual-rail system
- D3 Trolley
  - Final bending magnet D3
  - Vacuum system

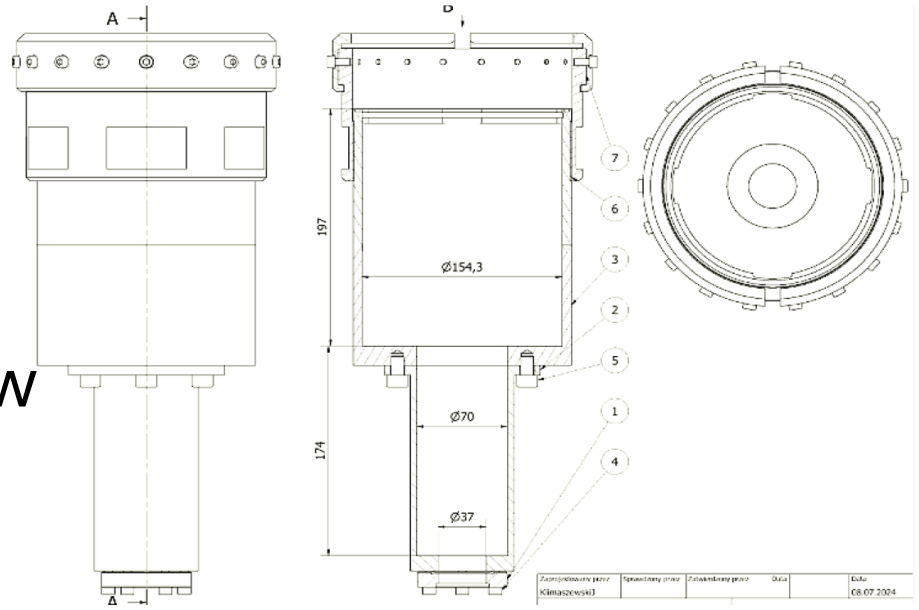


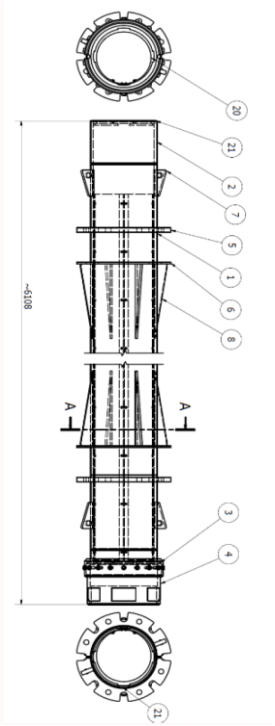




Beam Pipes and Window

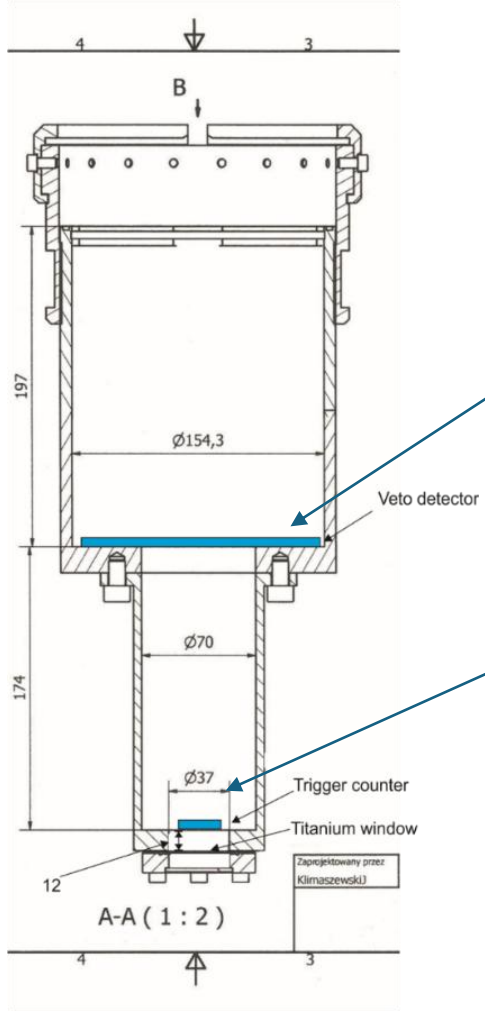
- LINAC head, beam window and beam pipes designed
- Window
  - 0.05 mm Ti foil
- Pressure tests
  - 200 cycles of 0-7 bar
  - Overpressure of 10 bar
  - System maintained vacuum at all times
  - Similar tests for beam pipe connections and window



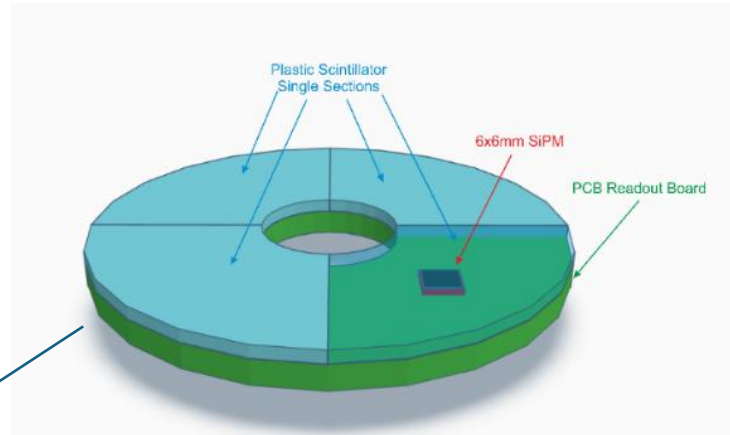


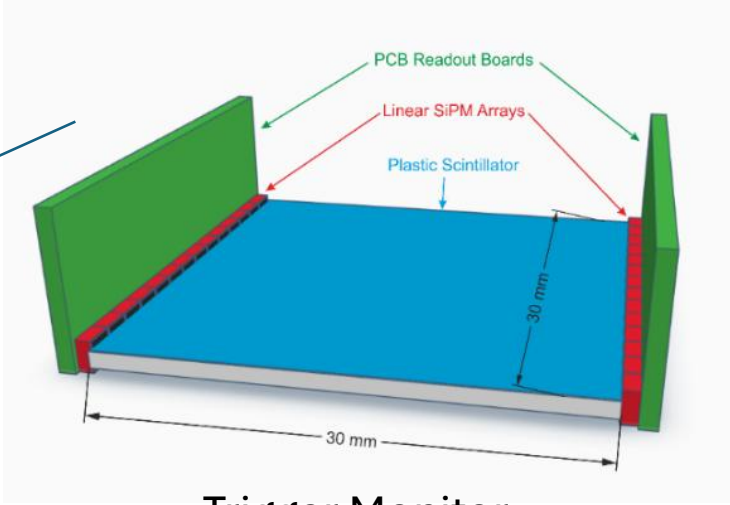
Beam Monitors

- Beam monitoring detectors
  - Measure position of single electrons along the beam line
- Plastic Scintillator with SiPM readout
- Trigger Monitor
  - Provide a trigger to HK
    - Counts electrons so can veto if > 1
- Veto
  - An electron was off target but reached the LINAC head
    - Veto for analysis
- Beam Monitor
  - In horizontal beam
  - Used to steer beam



Beam Monitor & Veto



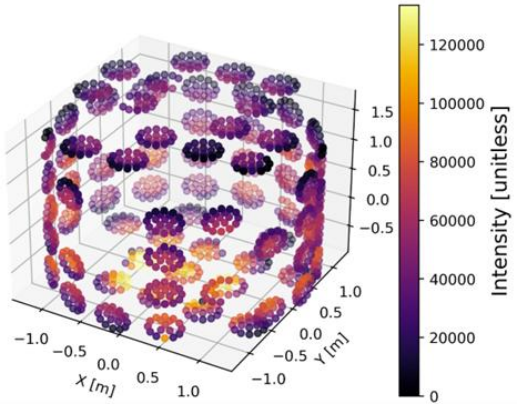


Trigger Monitor

Calibration Sources in WCTE

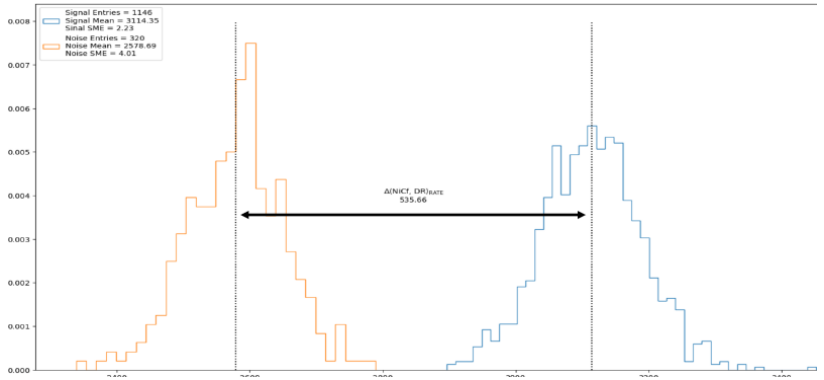
- WCTE is a great testing ground for our sources
- Diffuser ball deployed
  - Low intensity in first run
  - Fixes made and working as expected in second deployment
- NiCf source deployed
  - ~9 MeV γ-cascade
  - Working as expected
- AmBe source ready
  - Neutron source
  - Will be deployed in Gd phase

Diffuser ball deployment



Diffuser ball hit map

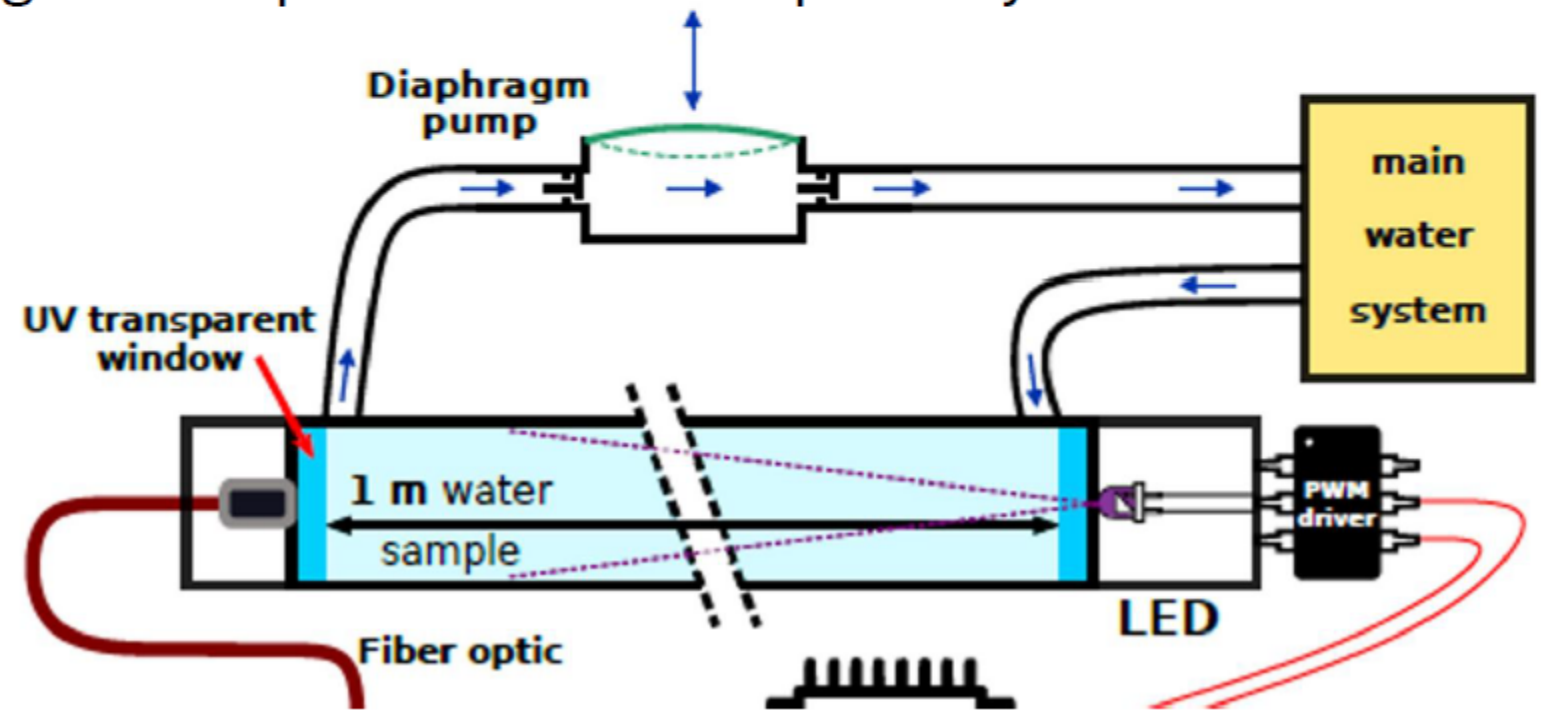
NiCf Data



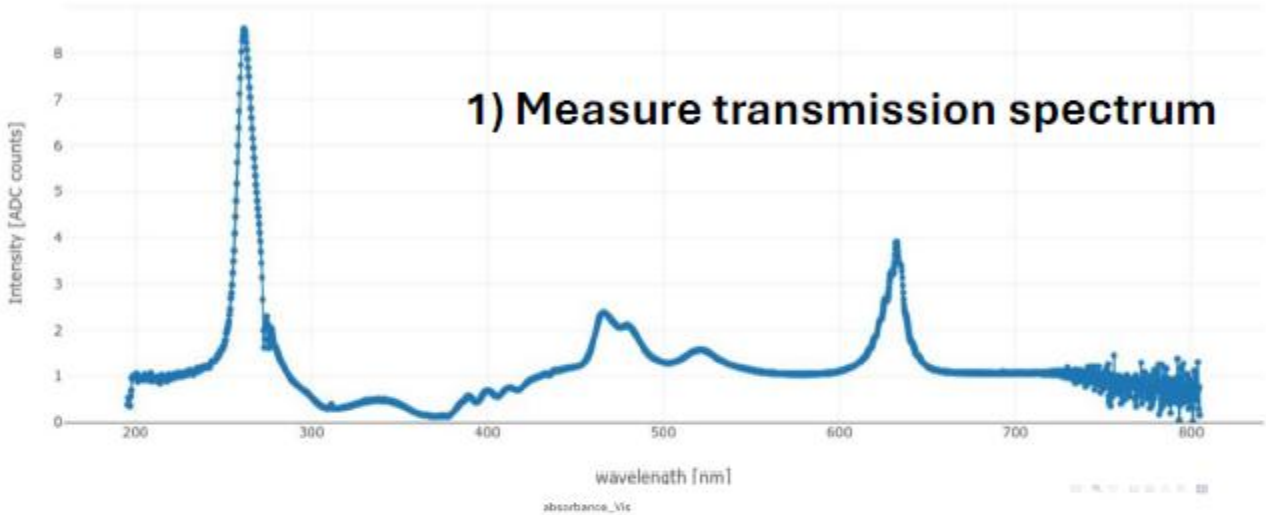
NiCf Deployment

Gadolinium Absorbance Detector

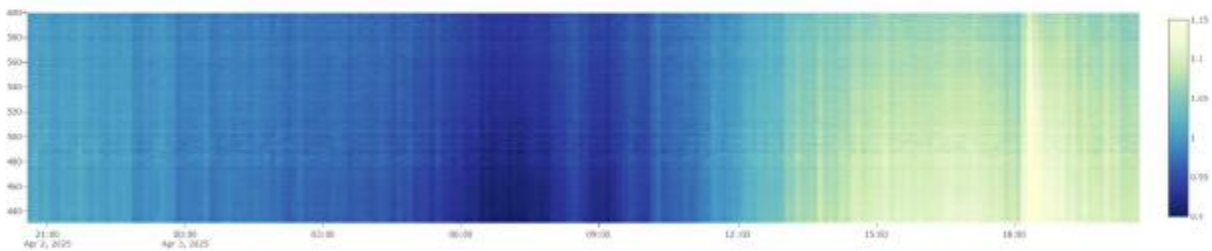
- GAD is continuous water monitoring device that has been developed in the UK for the past 7+ years
- I comprises of a modular fluid flow cell (~1.3m) and an led array with a collimated fibre coupled spectrometer
- It was originally designed to measure Gd concentration but also can measure general optical water transparency from 200-800nm



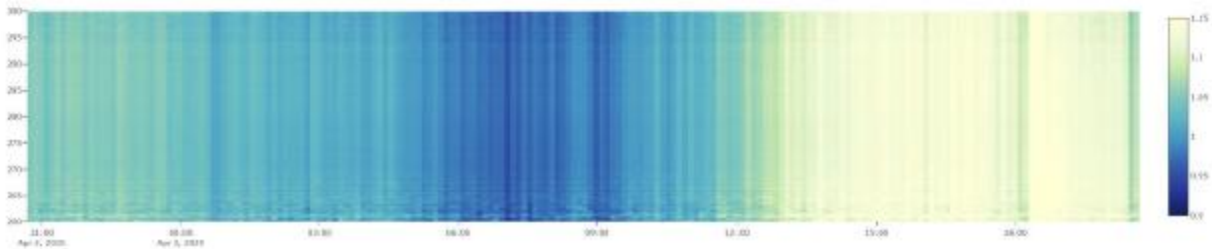
Principle of operation

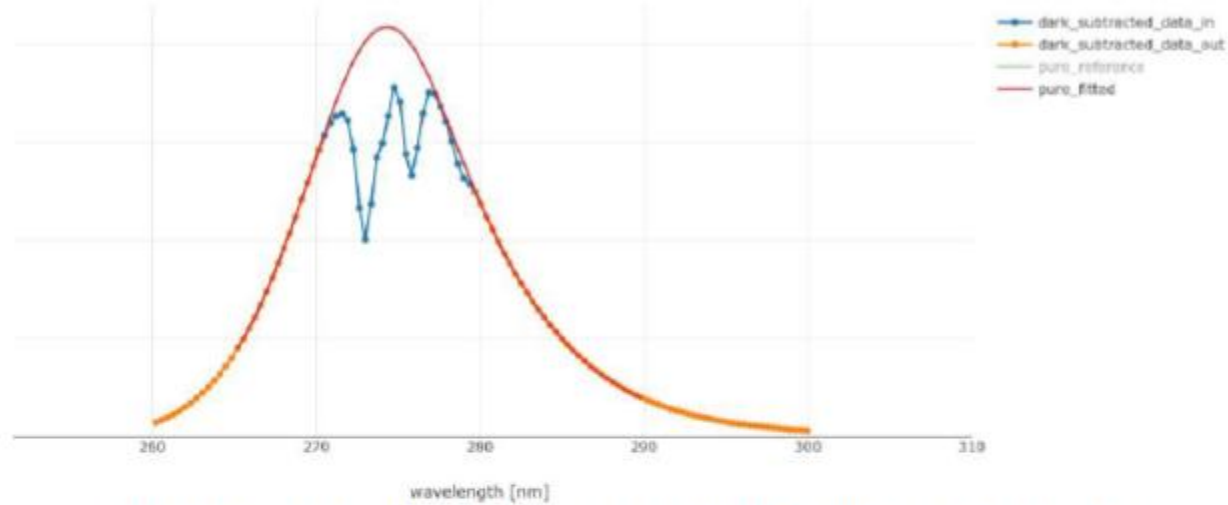


1) Measure transmission spectrum

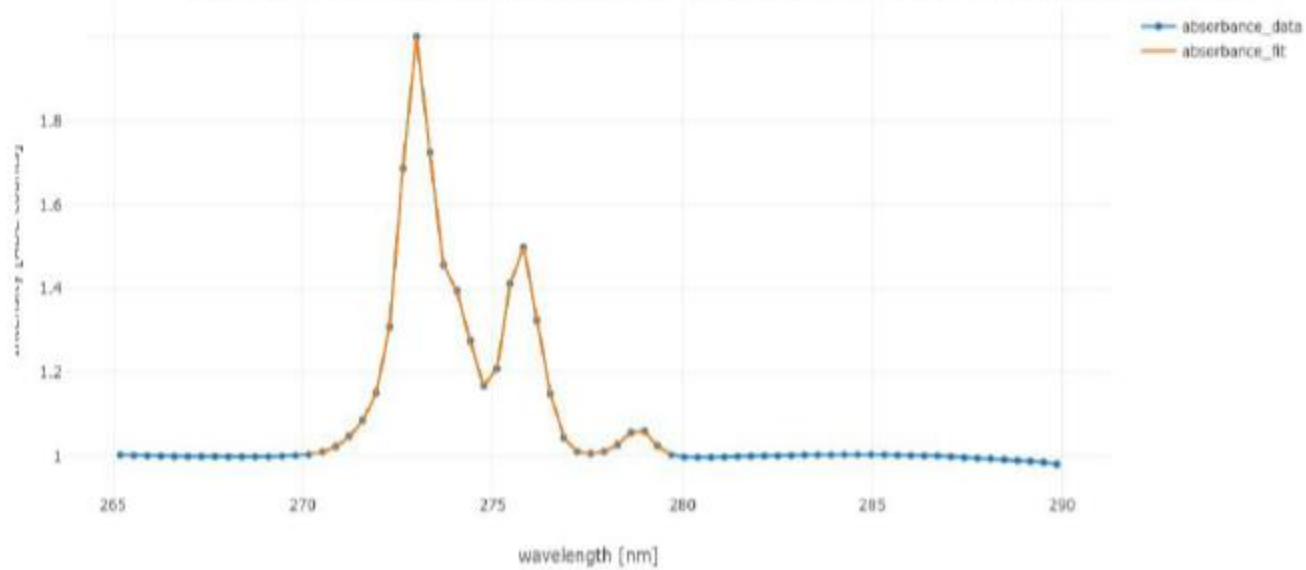


2) Track changes over time in UV and Visible





3) Calculate absorbance and fit Gd concentration

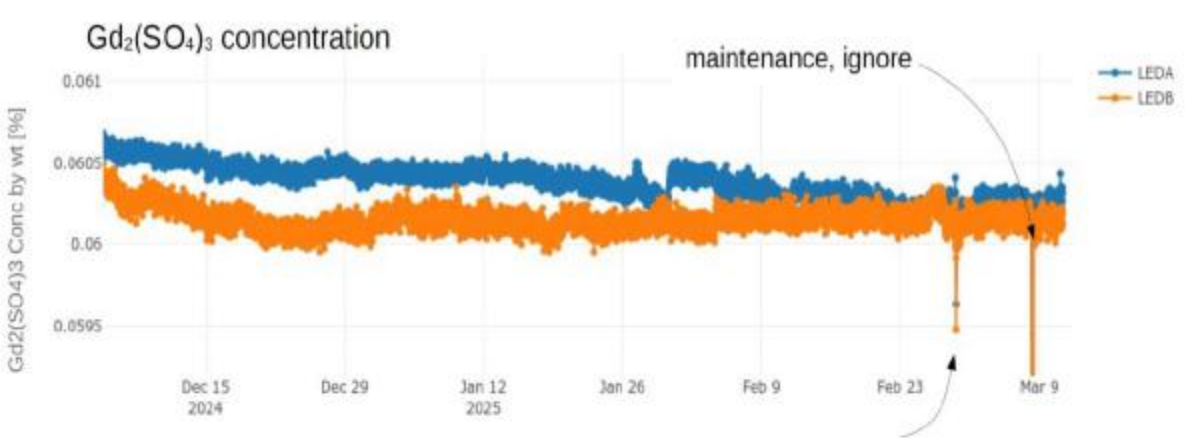


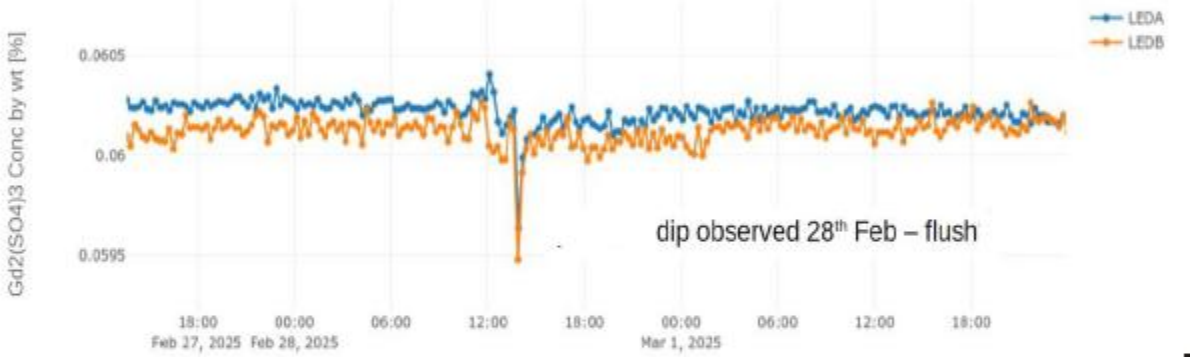
GAD Deployments

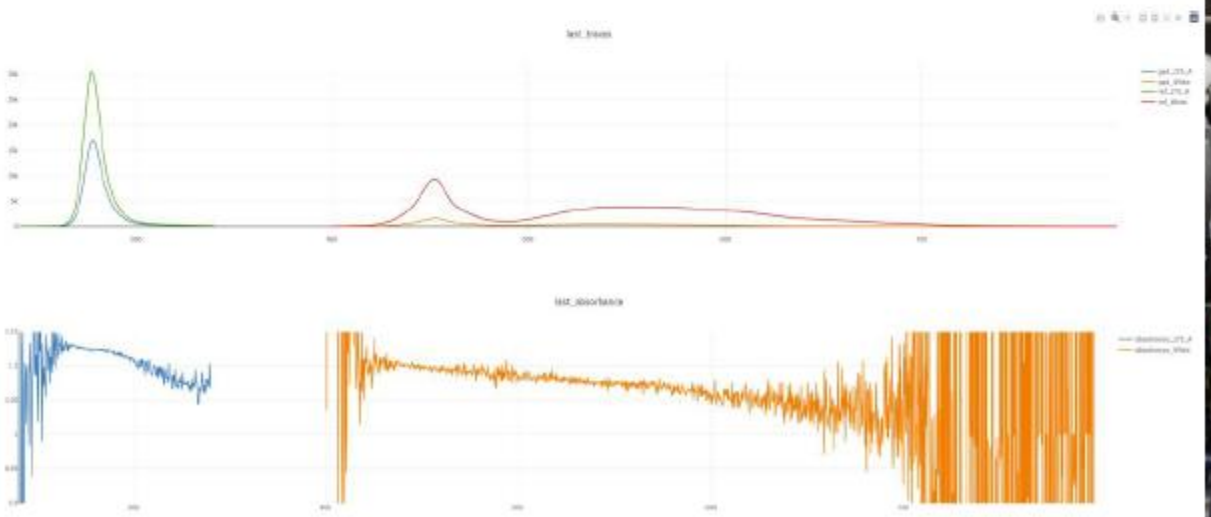
Two GAD devices have been deployed in active detectors:

1. Version 3: In Japan Kamioka in the EGADS detector. Has been running for 5 years. Measuring Gd concentration continuously to 1% precision

2. New Version 4: In CERN WCTE detector since 2024 with parallel optical reference and improved modularity, faster to produce, install and operate. Ready for Gd filling of the detector this year.







Summary

- Improved calibration is essential for the success of Hyper-Kamiokande
- Contributions from Jennifer members are key to the improved calibration
- Systems are currently under construction
- Light injection systems are in construction for the ID and OD
- Radioactive sources are prepared and will be used in WCTE