

Calibration in Hyper-Kamiokande

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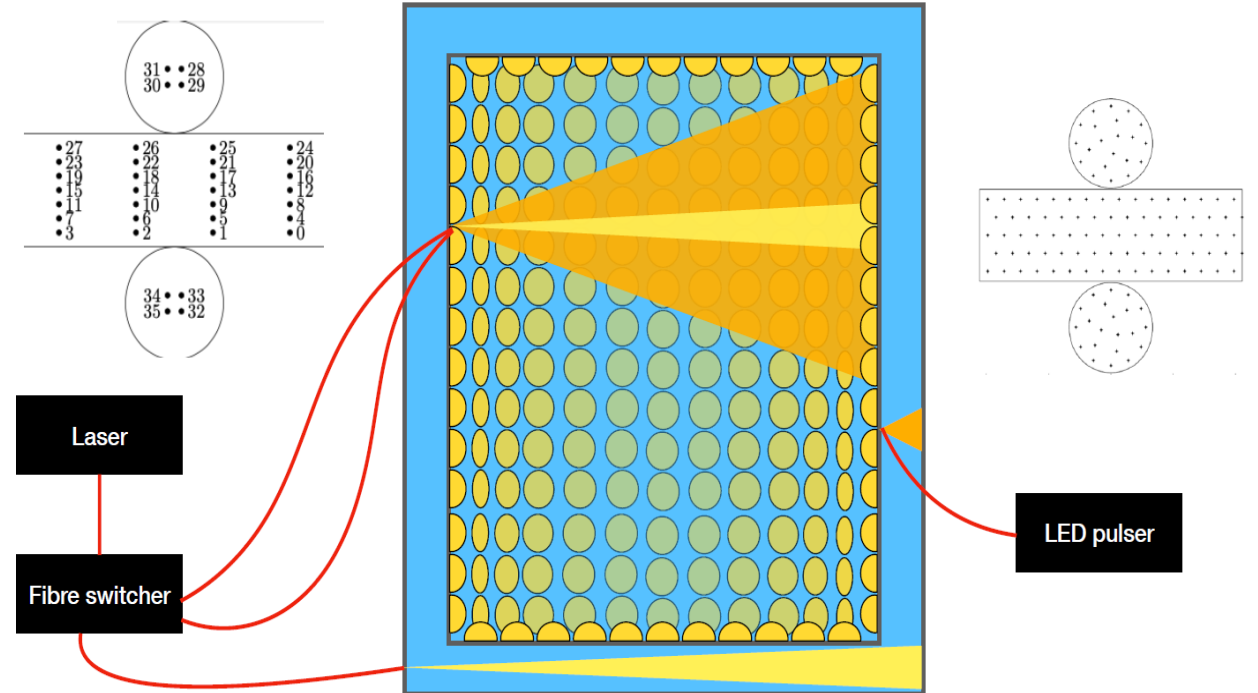


Calibration in Hyper-K

- 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**
 - Photogrammetry
- Major contributions and leadership from Jennifer members

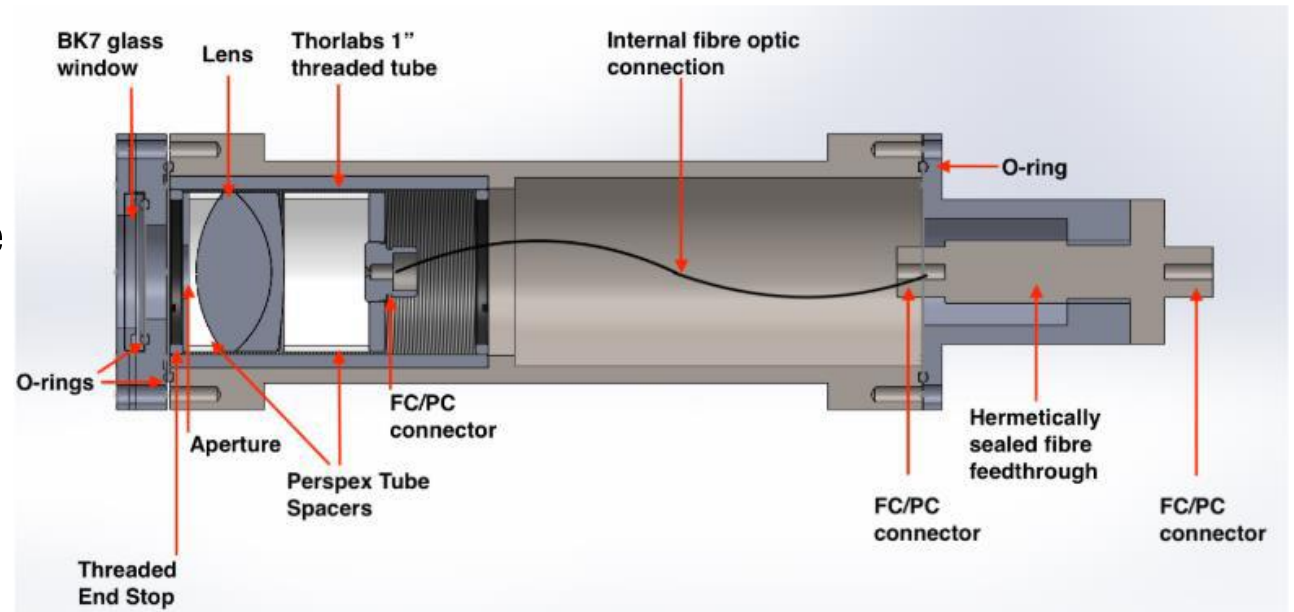
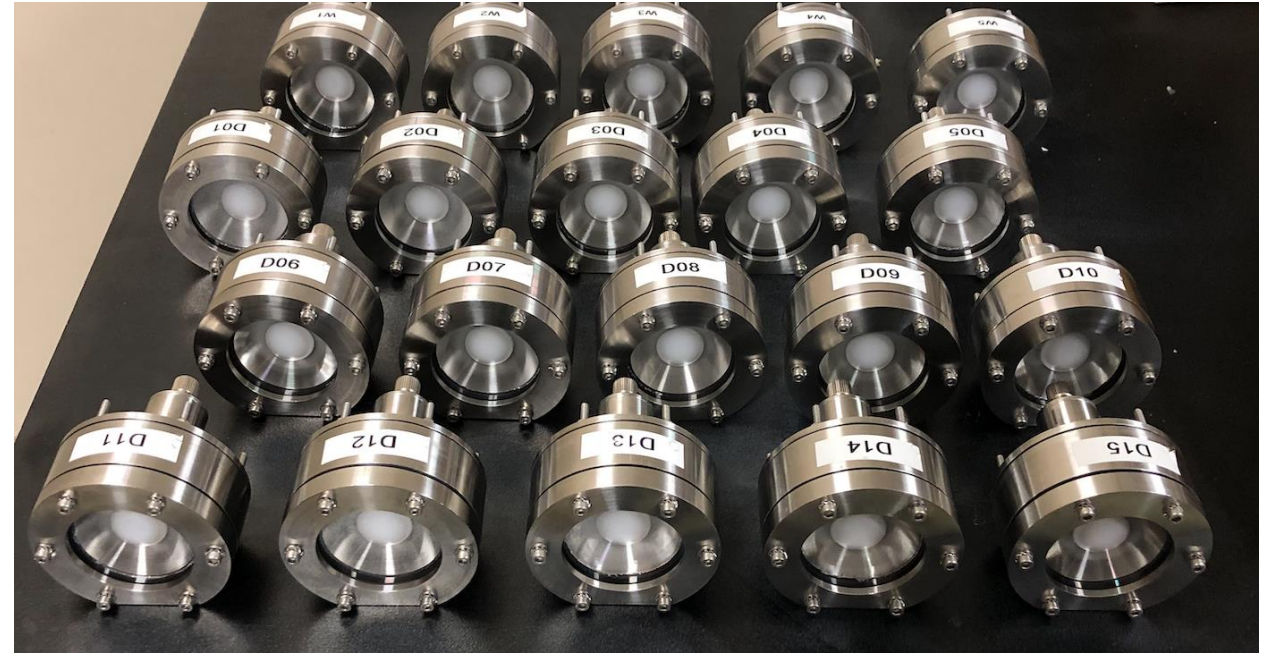
Light Injection

- 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 - 40° opening angle
 - Collimators - 2° opening angle



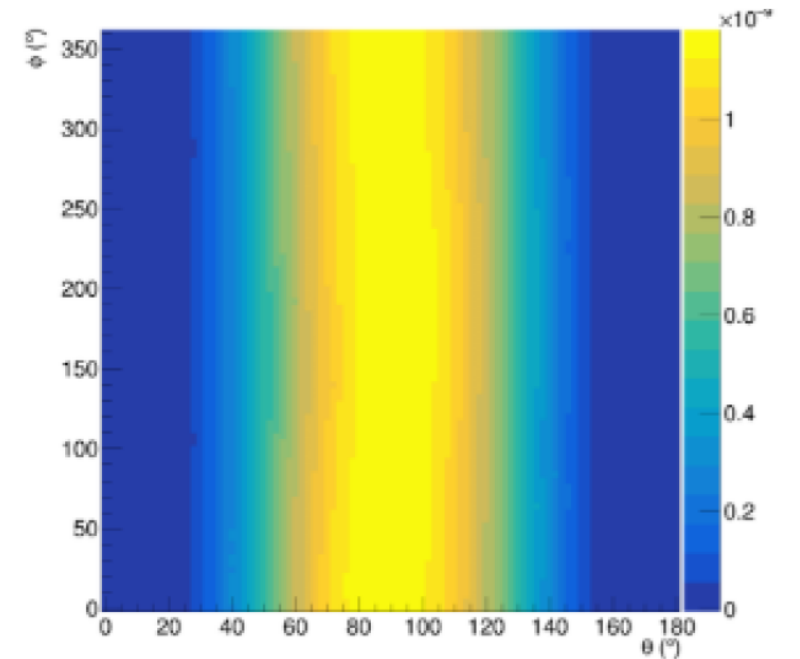
Injectors

- Diffusers
 - 40° opening angle
 - PTFE diffuser in custom housing
 - Vacuum feedthrough to avoid water leakage
 - Construction at Warwick now completed
- Collimators
 - 2° 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

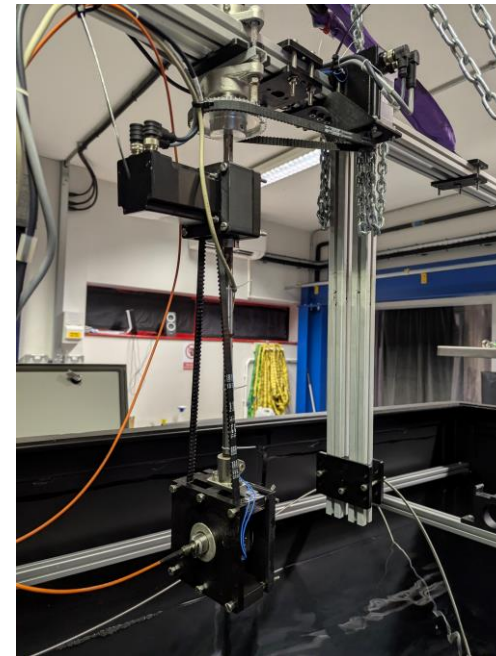


Injector Characterisation

- Each injector will be characterised in the custom water tank at Sheffield
- Approximately 30% of diffusers measured
- Individual measurements will be used to simulate injectors

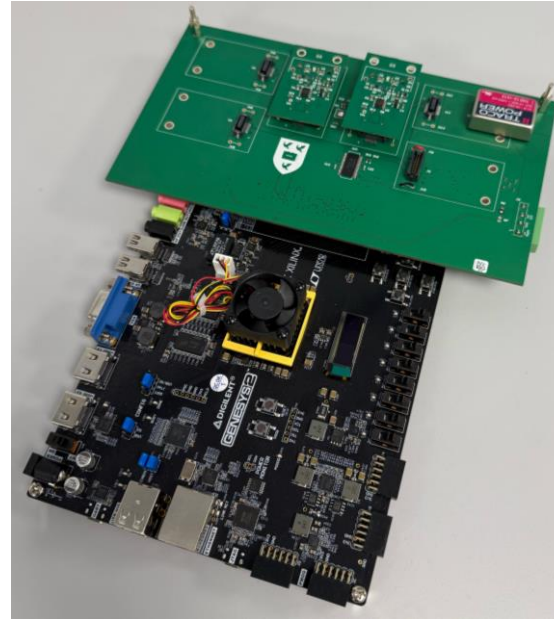


A diffuser profile

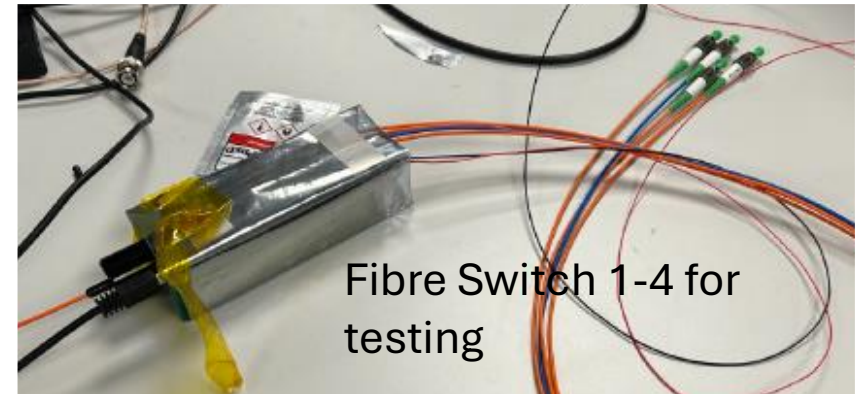
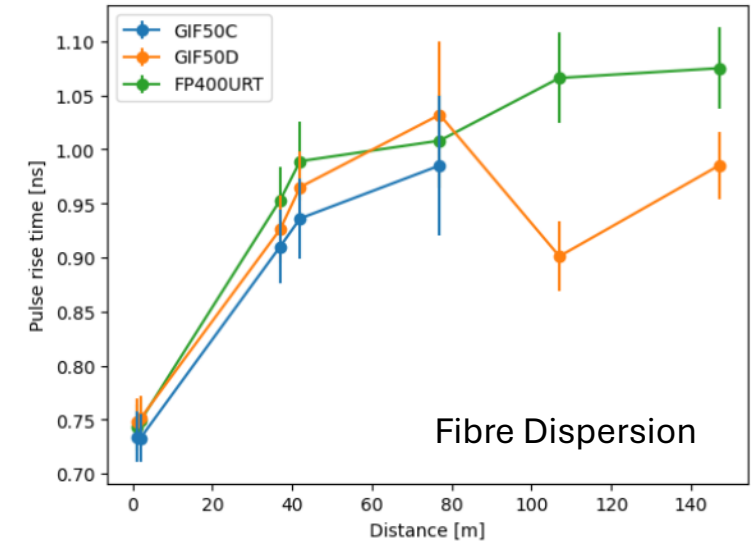
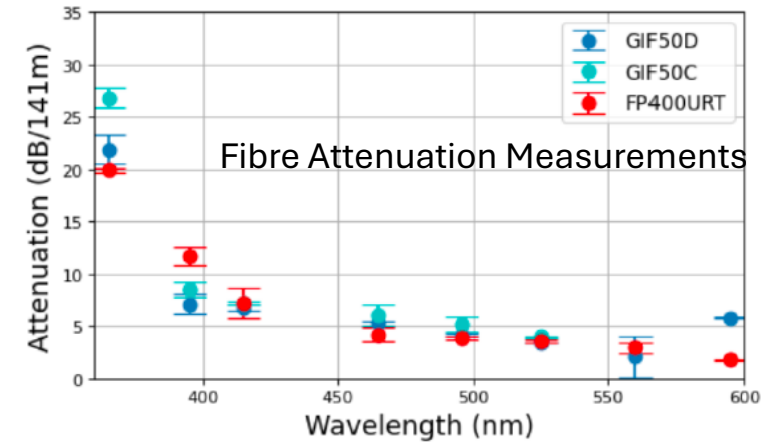


Light Sources

- 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



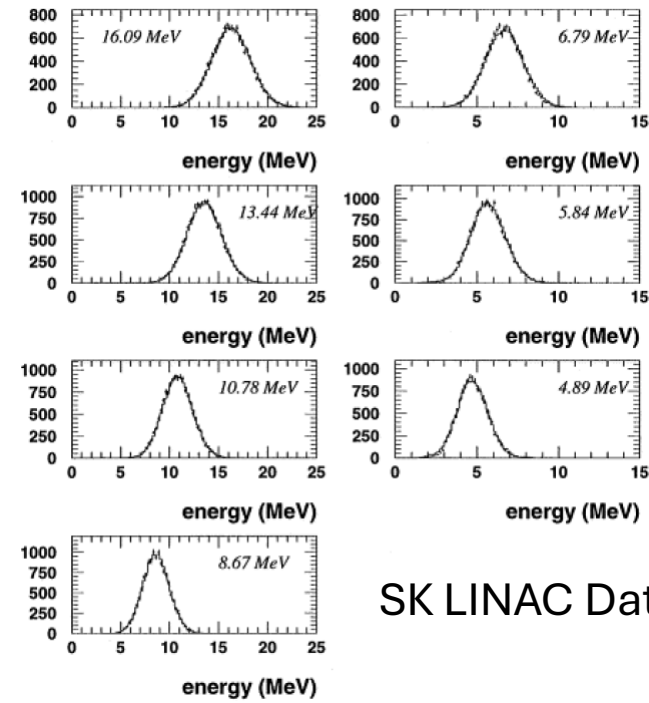
LED Pulsar for OD



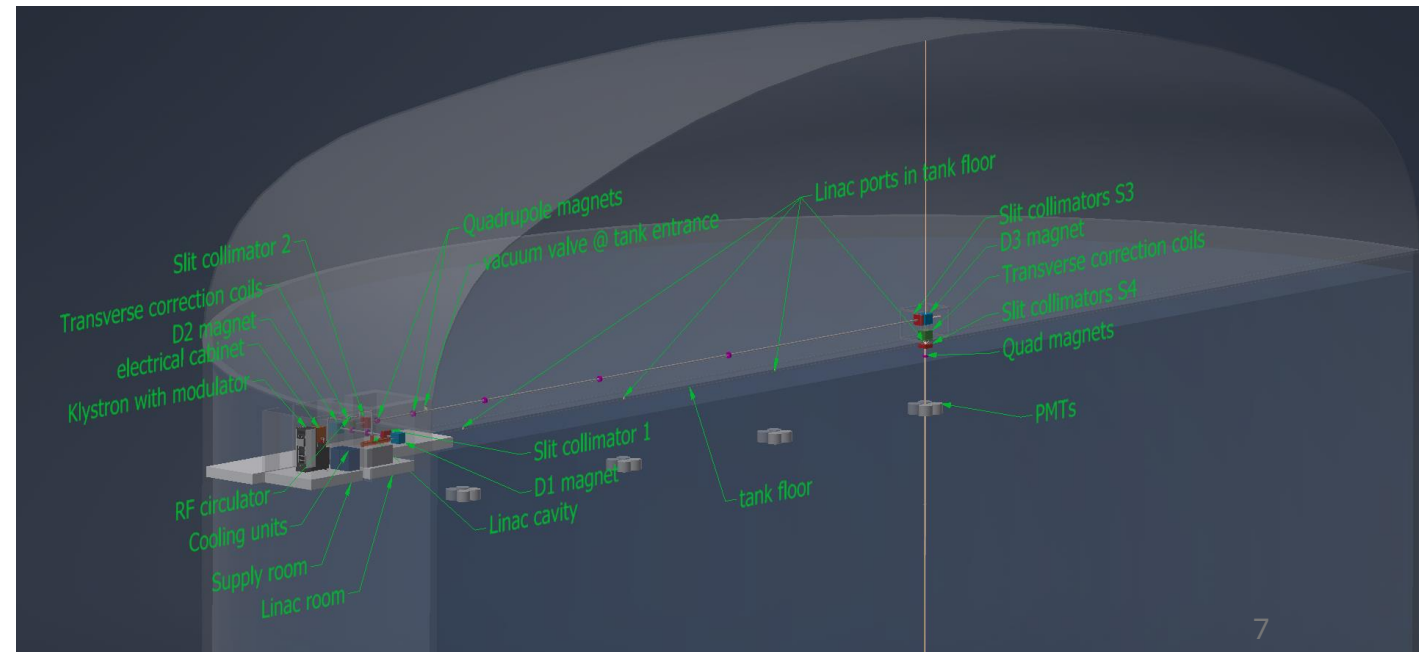
Fibre Switch 1-4 for testing

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

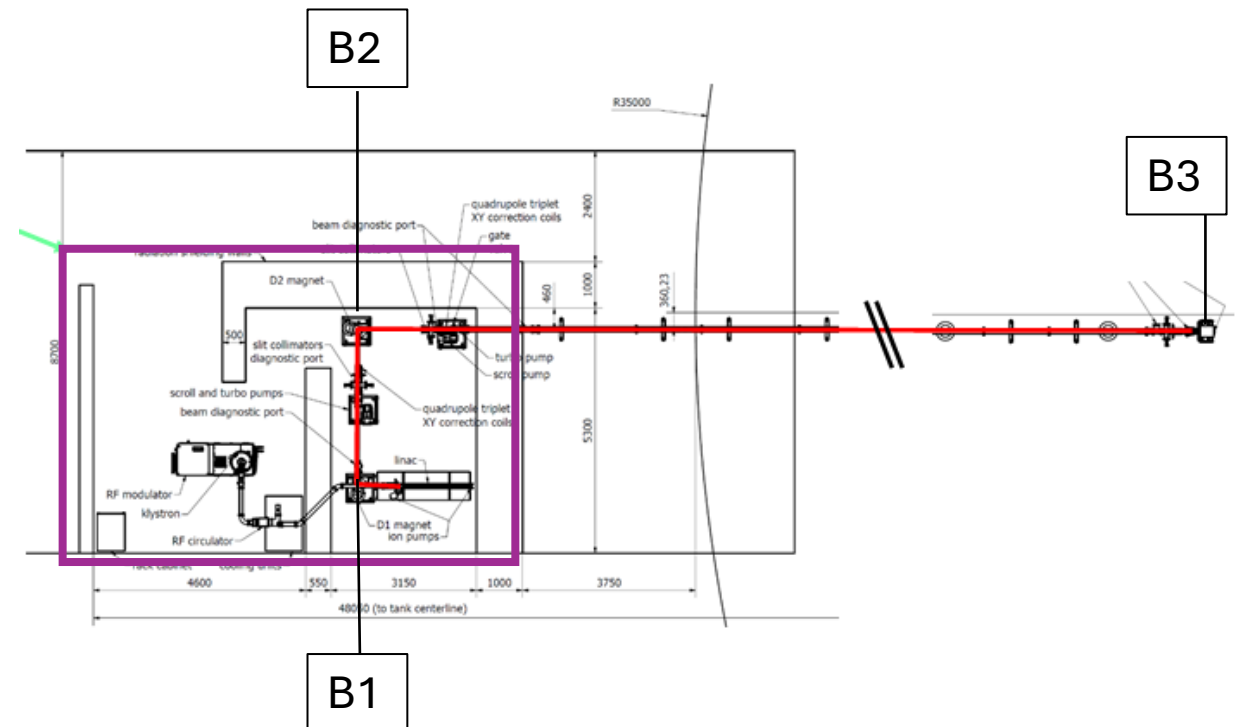
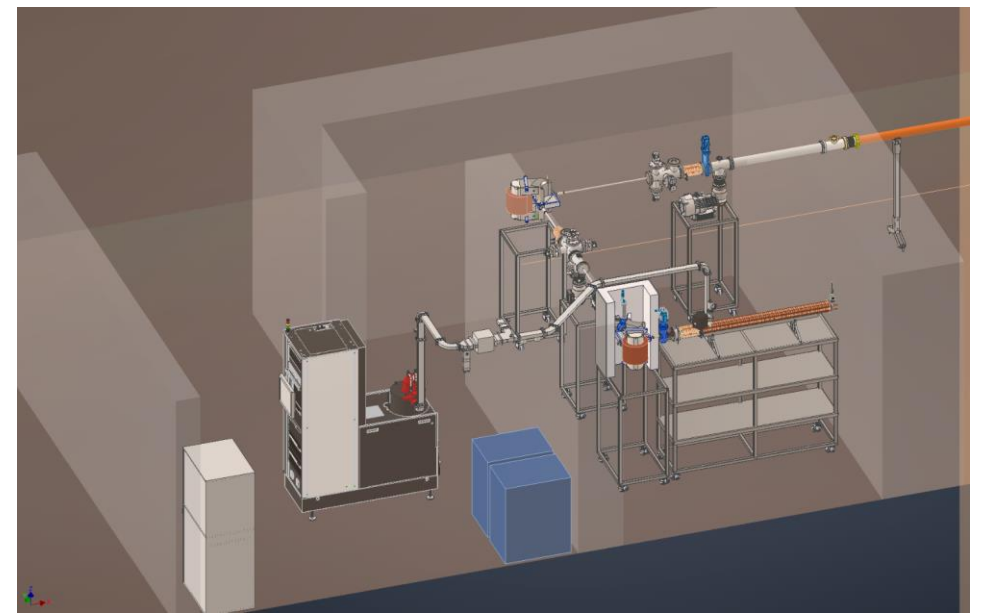


SK LINAC Data



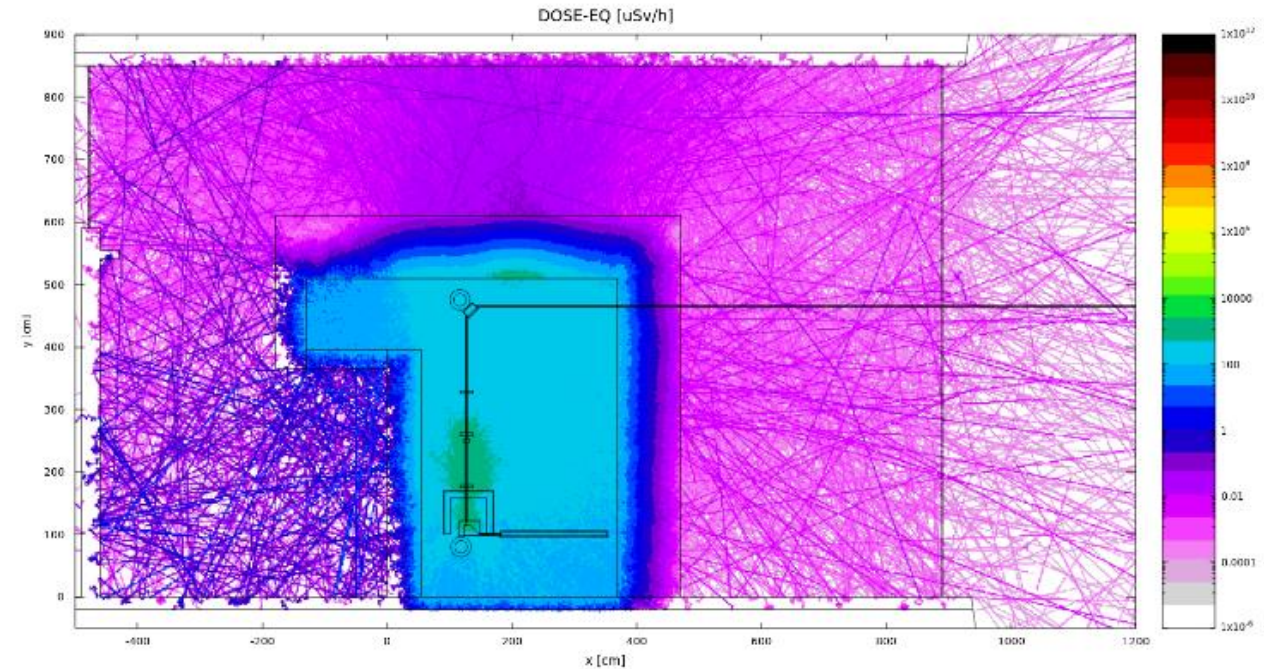
The LINAC Bunker

- 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



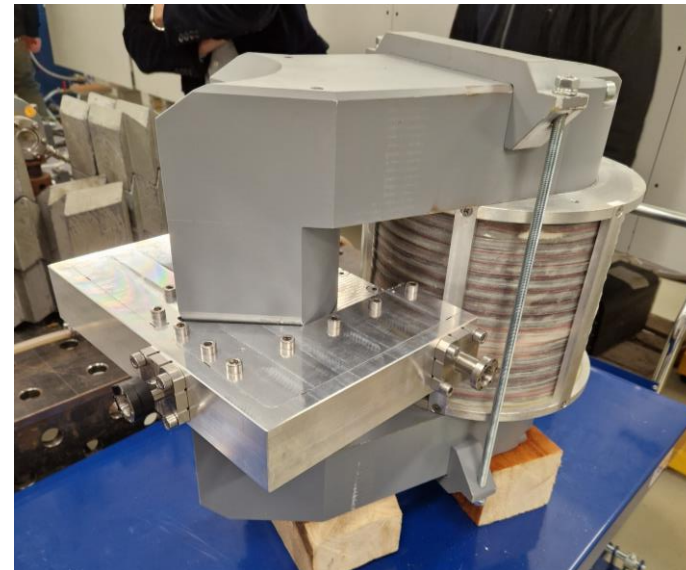
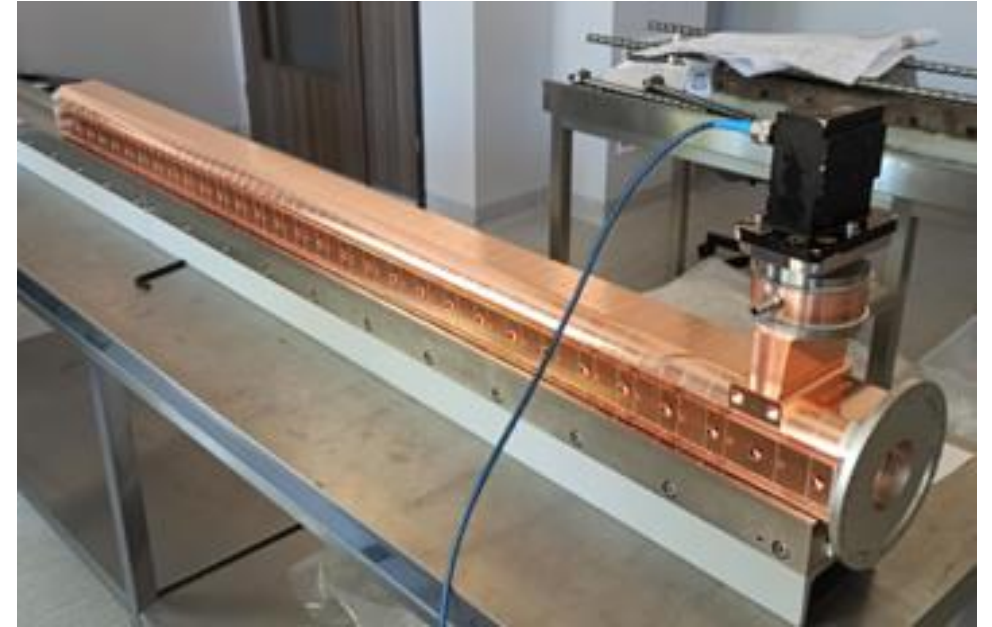
Radiation Dose

- 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



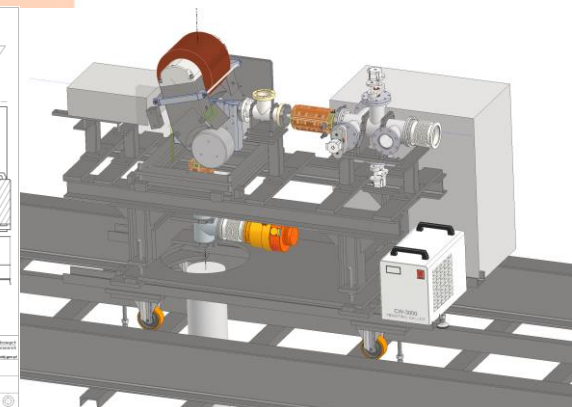
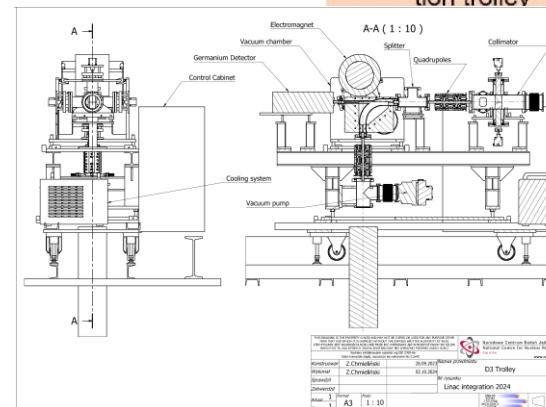
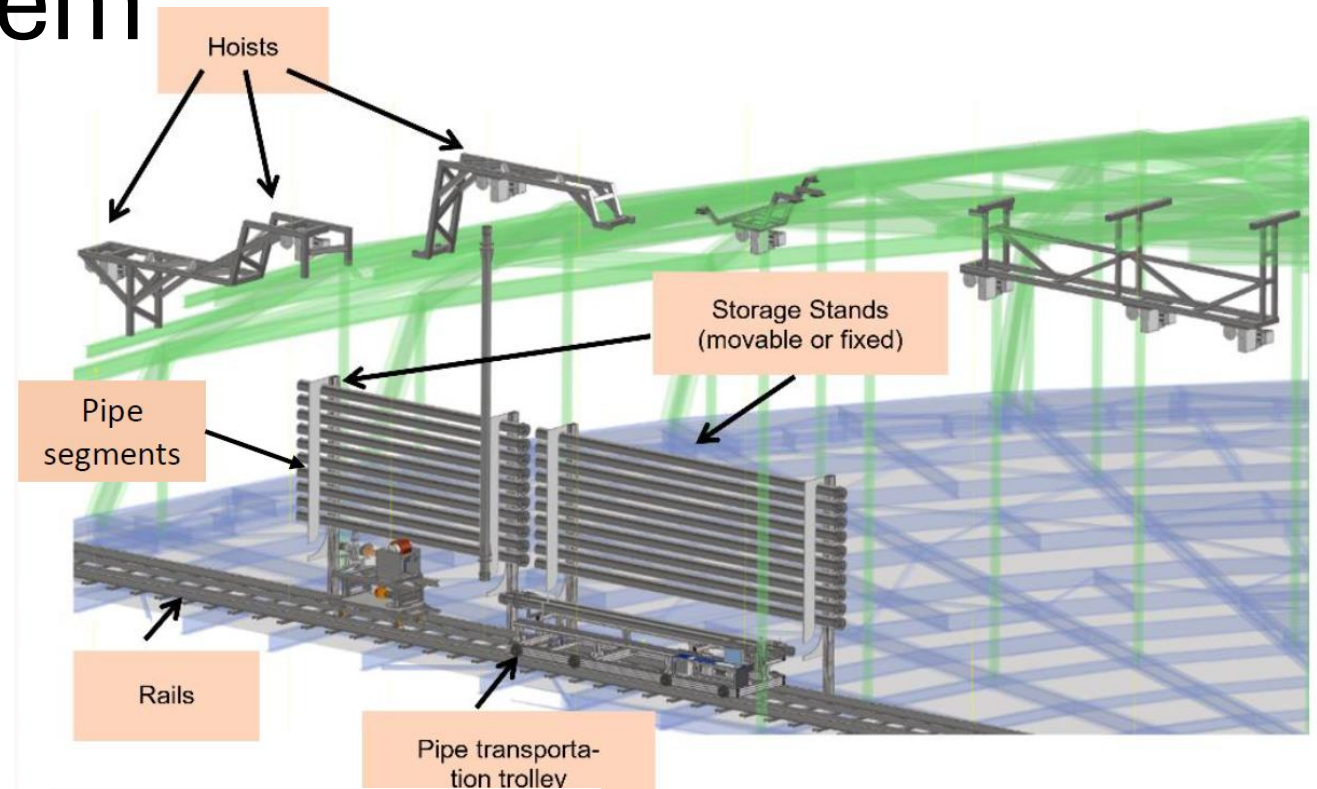
Accelerator + Magnets

- 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



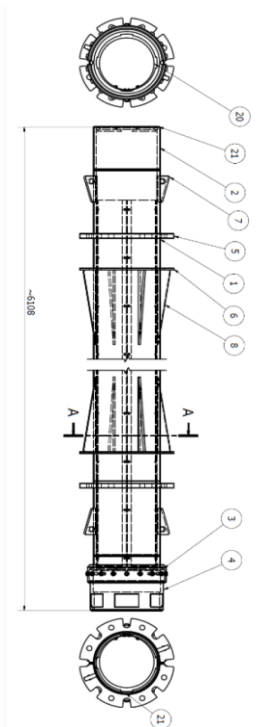
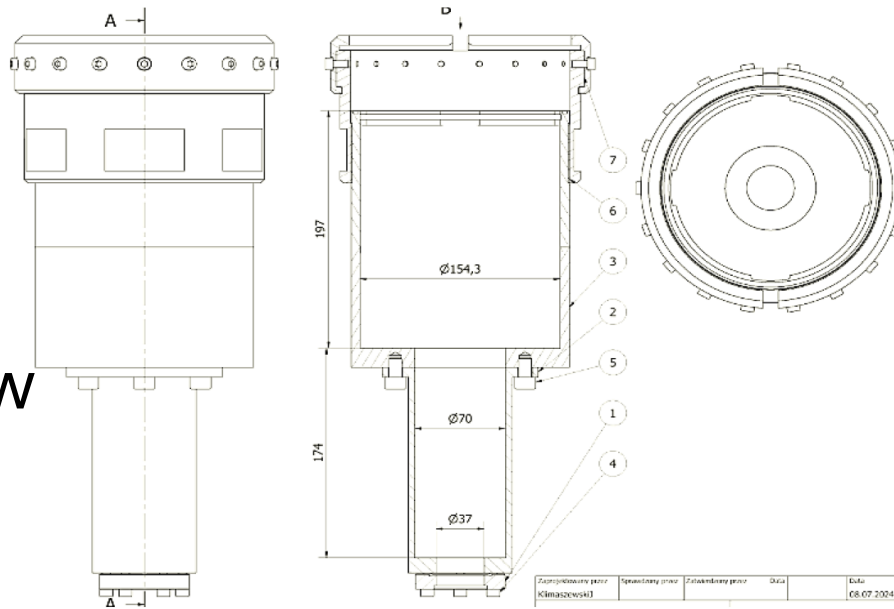
Beam transport system

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



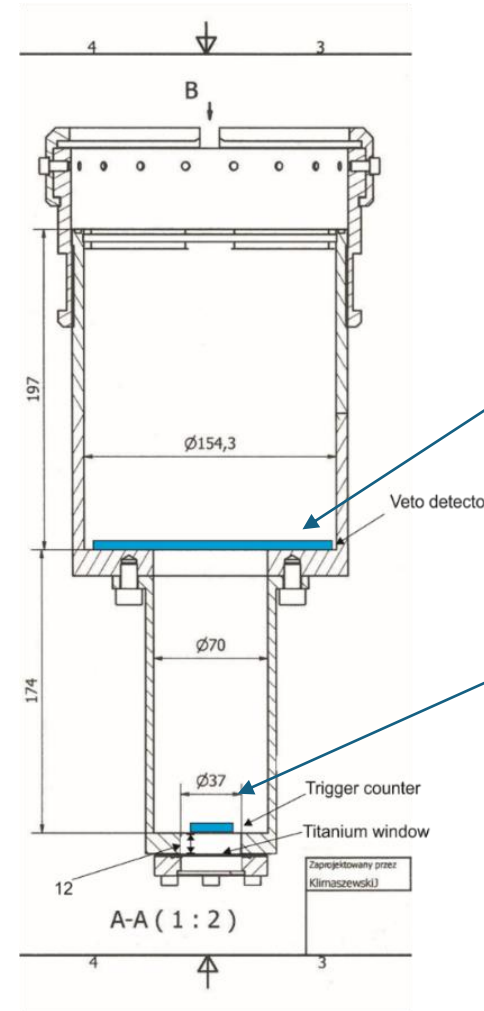
Beam Pipes and Window

- 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

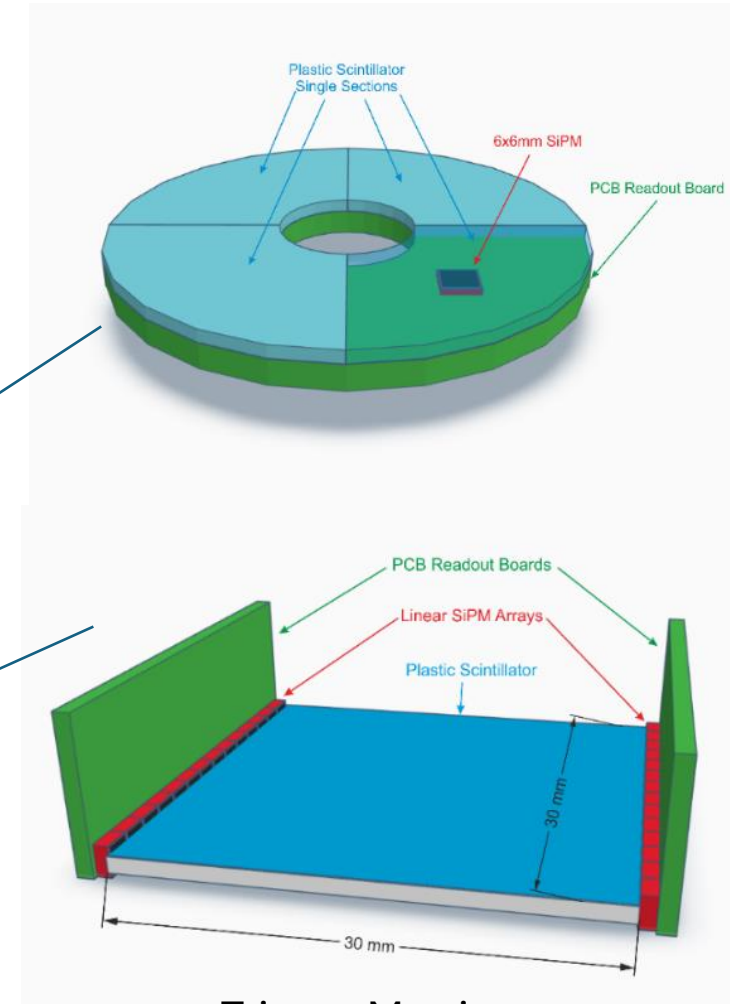


Beam Monitors

- 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



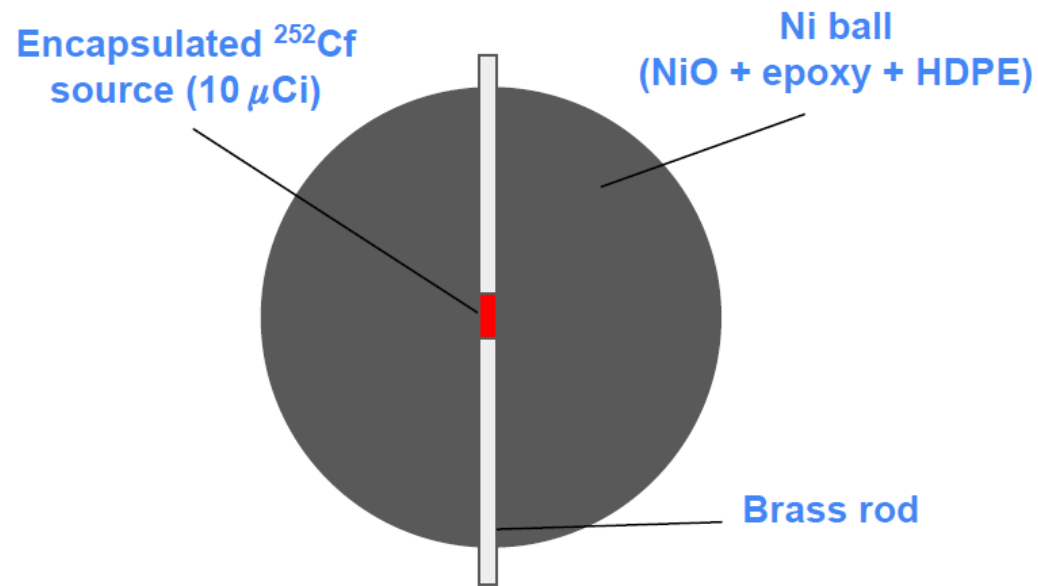
Beam Monitor & Veto



Trigger Monitor

CfNi Source

NiCf γ -source



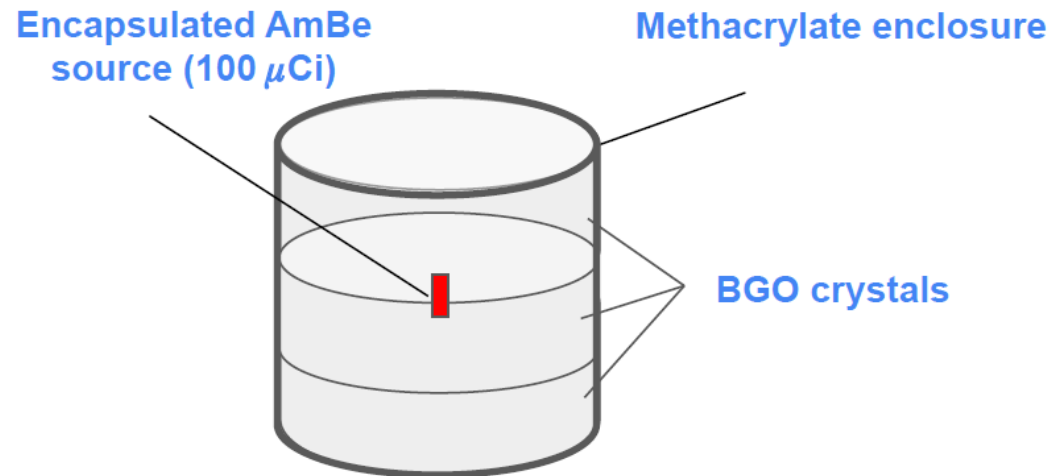
- Thermal neutron capture on nickel
 $\rightarrow {}^{58}\text{Ni}(n,\gamma){}^{59}\text{Ni}$ ($\sim 9\ \text{MeV}$ in γ energy)

- New NiCf source designed and built
- Had to understand how to make NiO – Epoxy ball
- First testing in WCTE



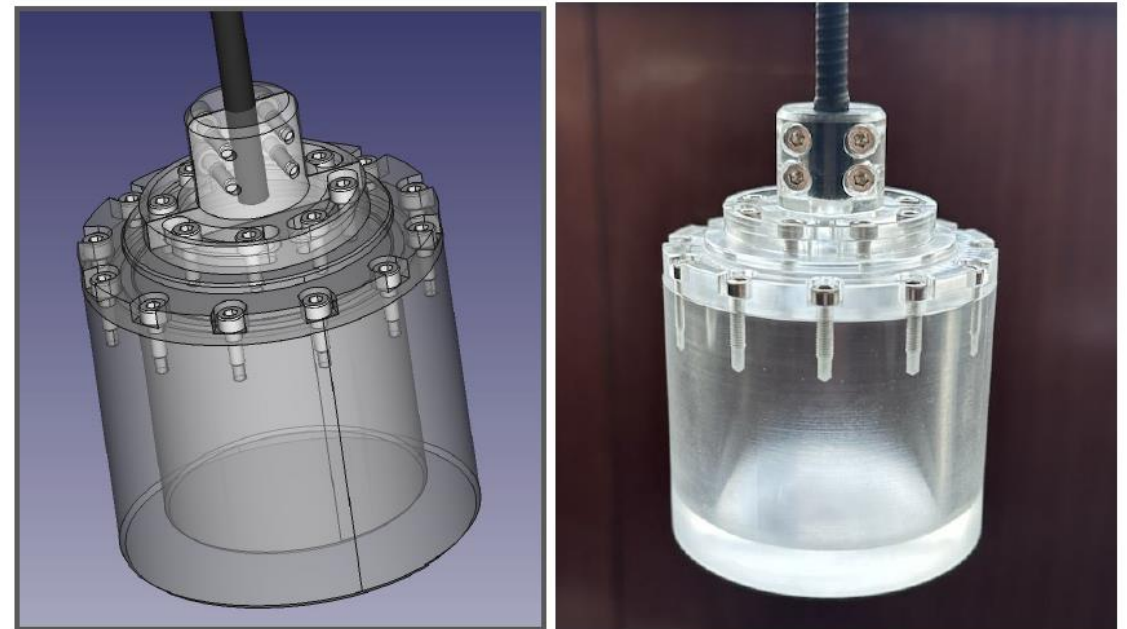
AmBe Source

Tagged AmBe source



- AmBe neutron source
- 4.4 MeV γ -ray in coincidence with neutron emission tagged by scintillation in BGO crystals

- Tagged neutrons
- New source designed and built
- To be tested in WCTE Gd phase



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
- LINAC system design completed, and first hardware delivered
- Radioactive sources are prepared and will be used in WCTE