Underwater characterization of a BUTTON optical module

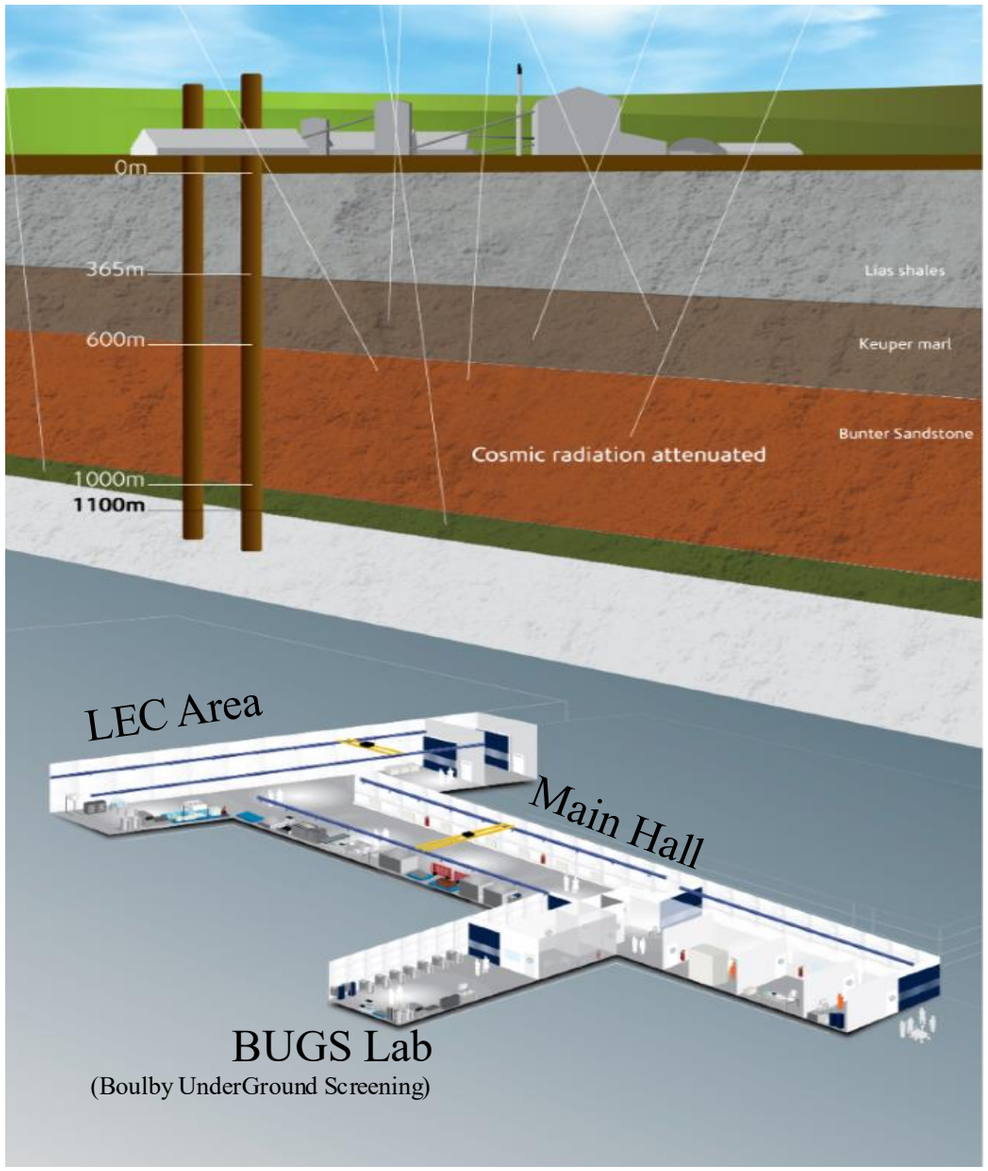
Deb Sankar Bhattacharya
On behalf of the group

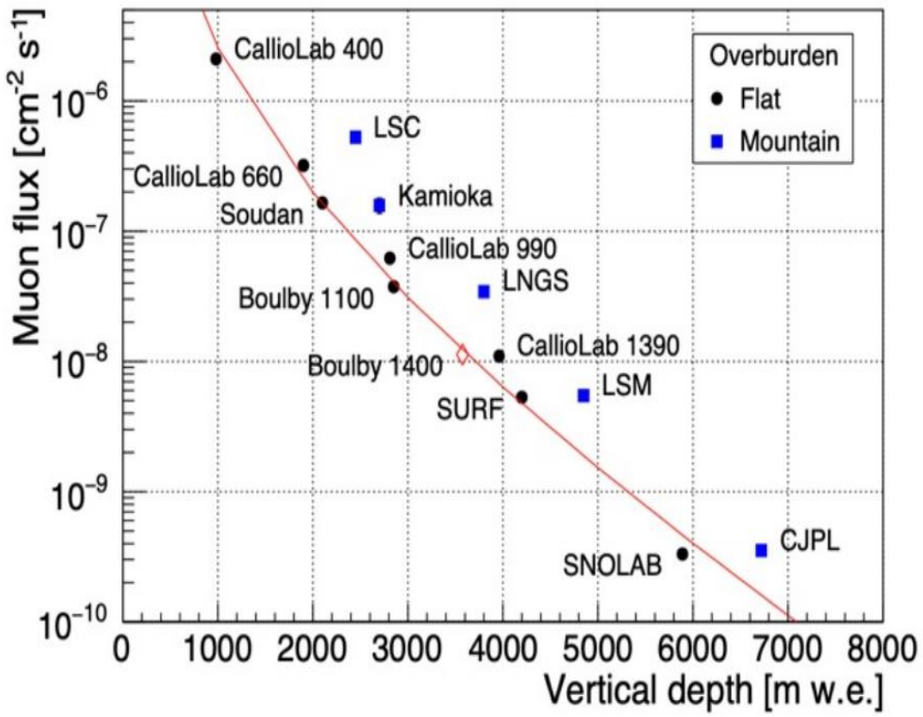
Detector Informal Meeting Particle Physics Experiment, 4 Feb 2026, University of Edinburgh

The BUTTON-30 Experiment

Boulby Underground Laboratory (operated by STFC):

- Muon flux reduced by 10^{-6} at 1.1 km
- Low Radon level: 3 Bq/m^3 .
- 4000 m^3 ISO 6 and 7 clean room lab space
- 3000 m^3 Outside Experimentation Area





Hosted dark matter experiments like **Zeplin** in the last decades

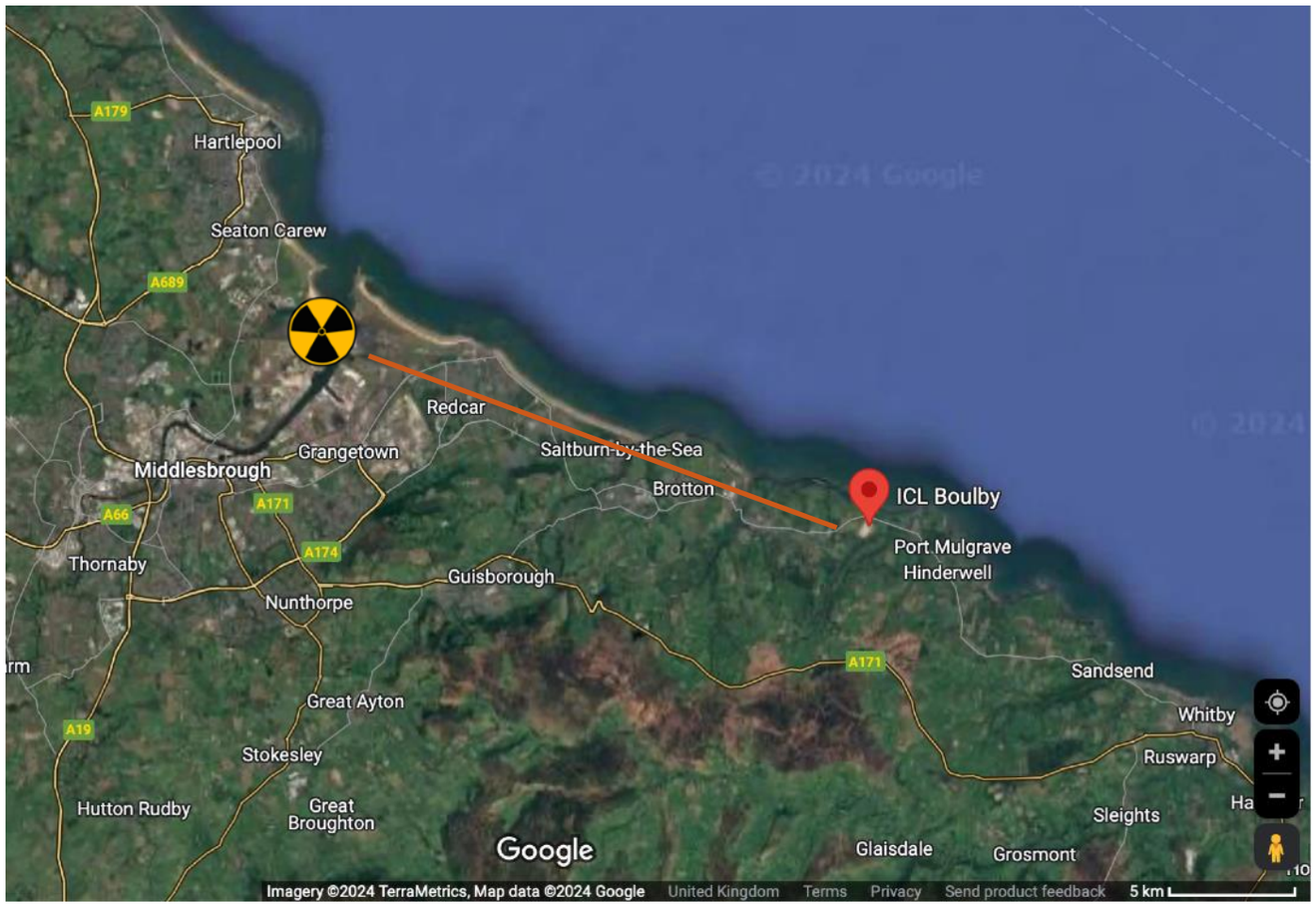
Rich near and far future plans

- Dark matter search
- **Neutrino Physics/ Application**
- Earth/Environmental Science
- Astrobiology

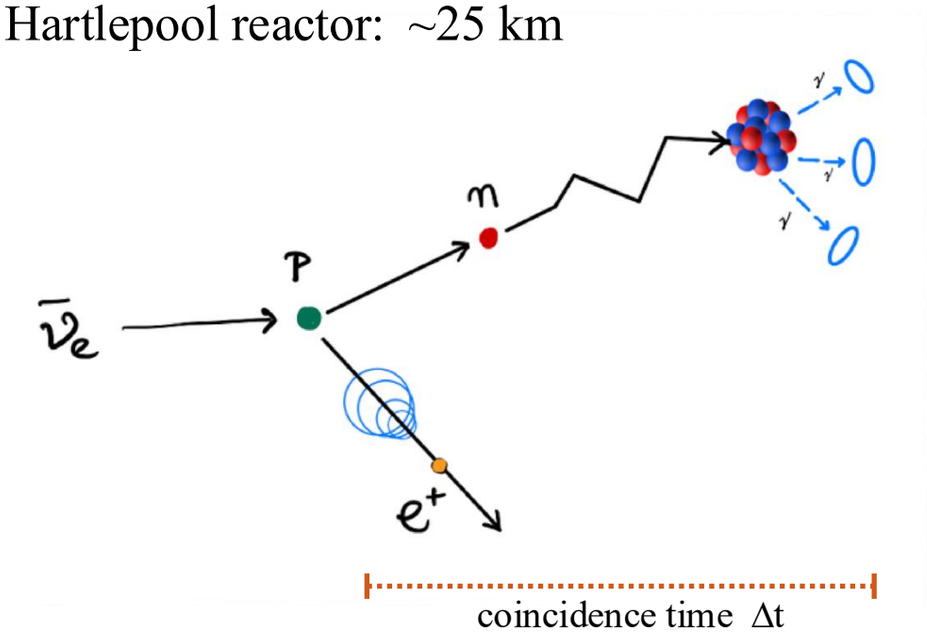
Detecting antineutrino at BUTTON

The **B**oulby **U**nderground **T**echnology **T**estbed for **O**bserving **N**eutrinos (**BUTTON**) is a 30-tonne antineutrino detector

- Traditional media: Water, Liquid Scintillator (LS)
- Advanced media: Water-based Liquid Scintillator (WbLS); and Gd loading (water and WbLS)
- Photosensor: 96 PMT
- Advanced Photosensor: Large Area Picosecond Photo Detector (LAPPD)
- Explore the potential for a future kilo-tonne detector



- Detection process: Inverse Beta Decay (IBD)
- Hartlepool reactor: ~25 km

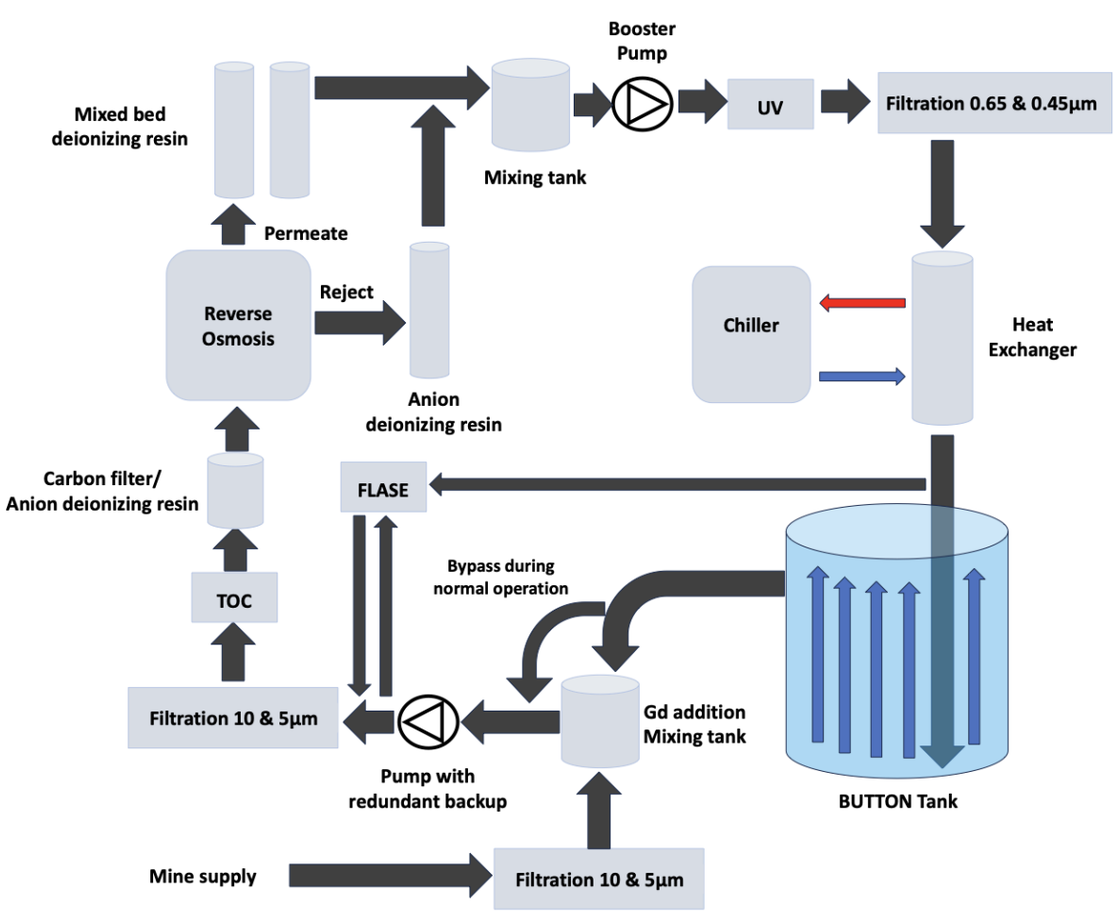


- Pure water (hydrogen) : $\Delta t = \sim 200\ \mu s$ (1-2 MeV)
- Gd-loded water: $\Delta t = \sim 20\ \mu s$ (~ 8 MeV)

- WbLS: (1) directional event reconstruction + (2) better energy resolution and low threshold

Water Tank:

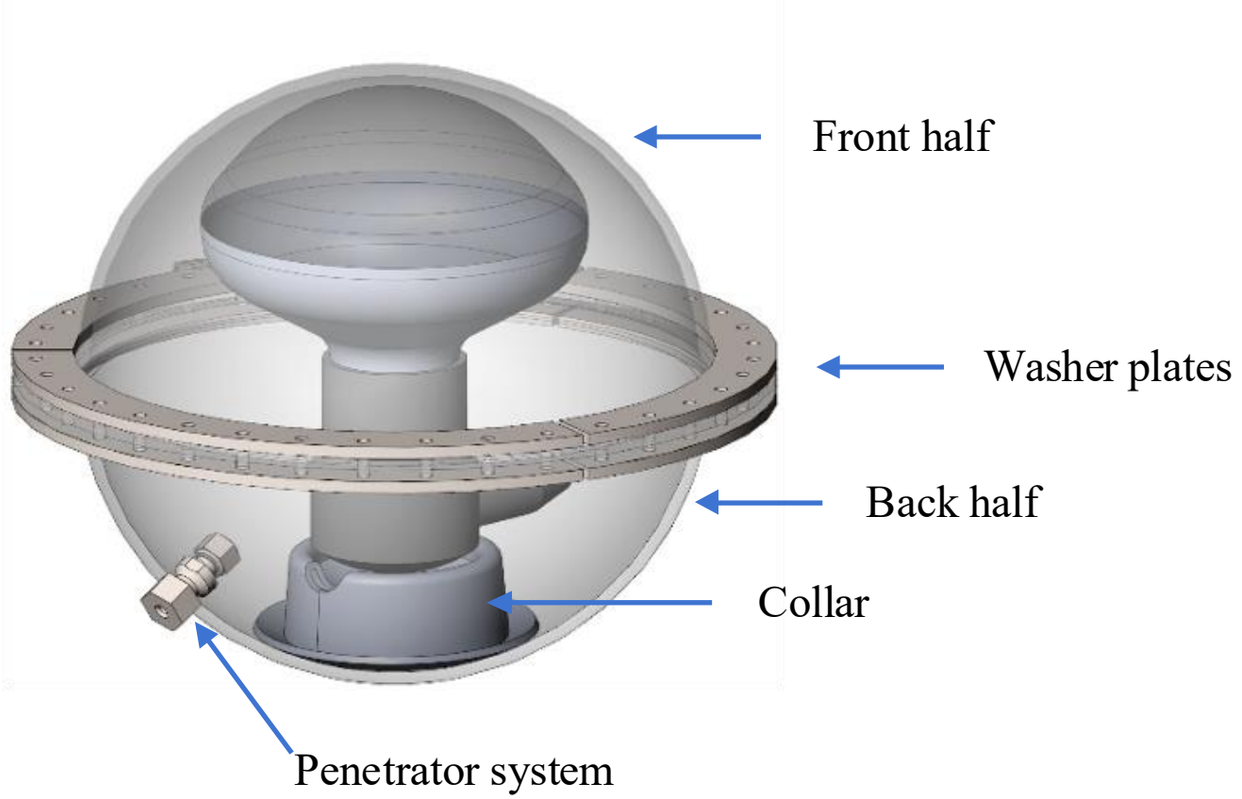
- 30-tonne cylindrical tank,
- inner diameter = 3.7 m
- height = 3 m
- marine grade 316L stainless steel
- Liner material
- Water circulation system: Gd and WbLS compatible
- installation is nearly complete



Optical Module:

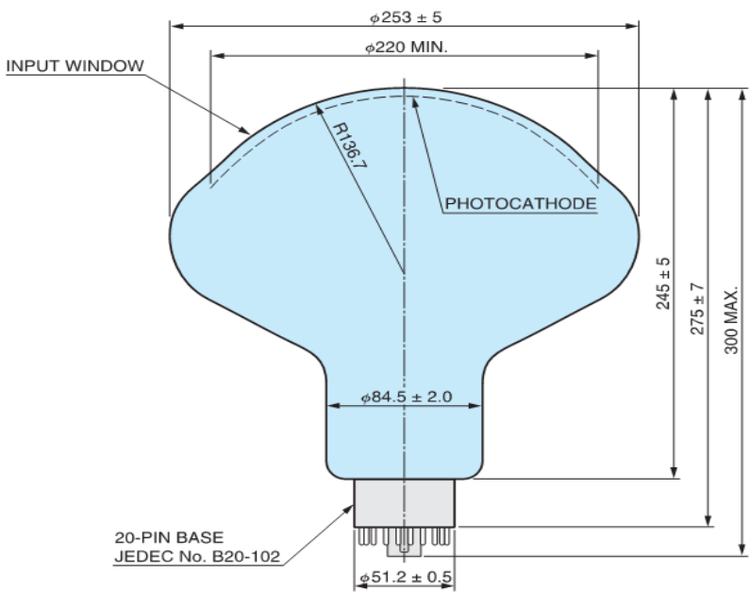
The Acrylic housing

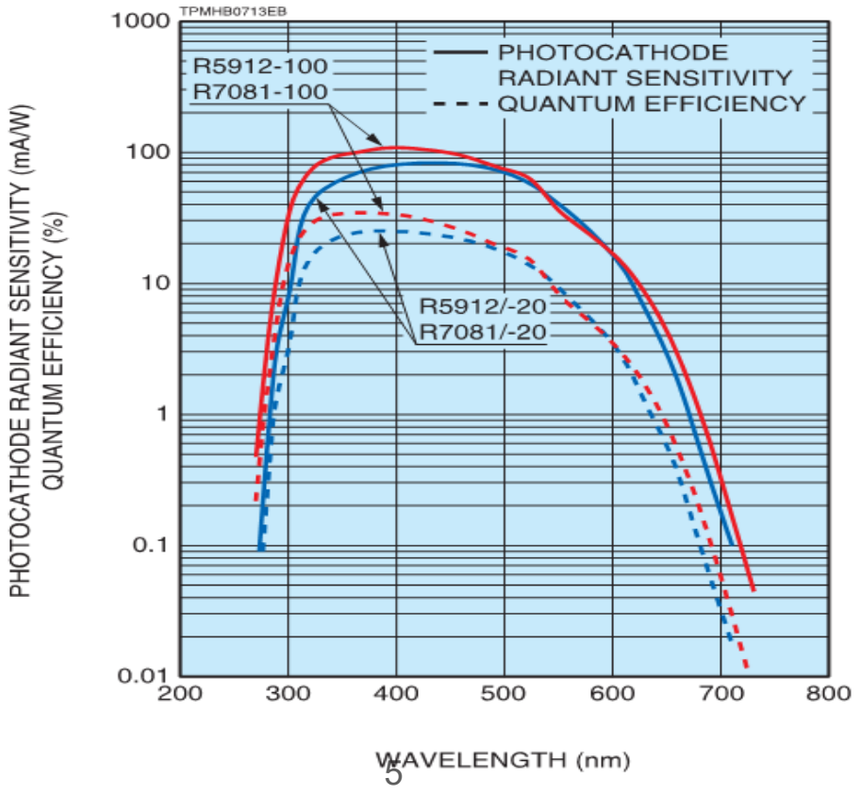
- The PMT is encapsulated in an acrylic housing
- Inner diameter = 40 mm
- Thickness = 6-3 mm
- Two parts: Front half (UV transparent) and Back half

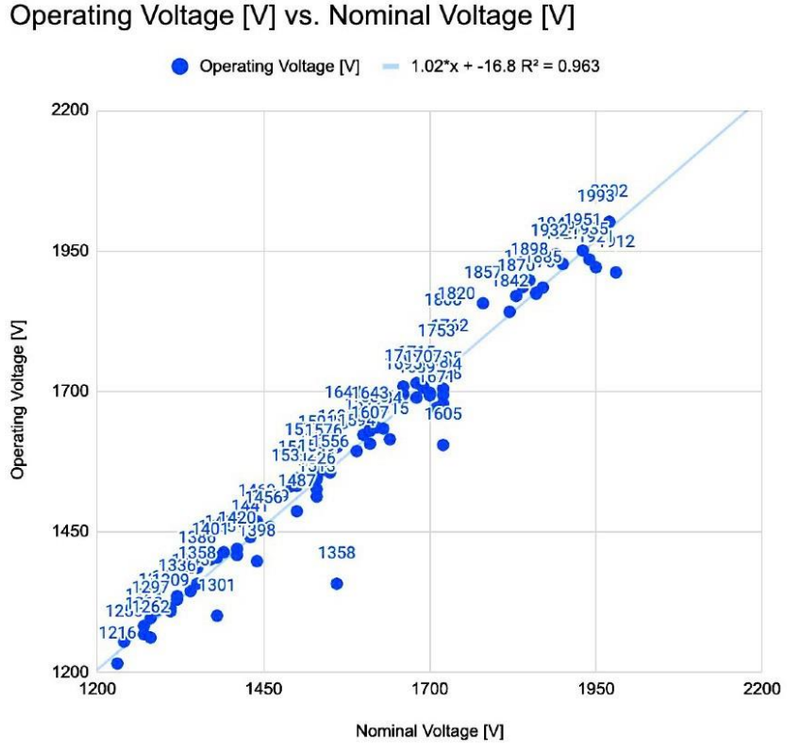


The PhotoMultiplier Tube (PMT)

- 10’’ Hamamatsu R7081-100 PMT
- Takes +ve voltage; outputs inverted signal
- PMT-base is ok for Gd, but not for WbLS



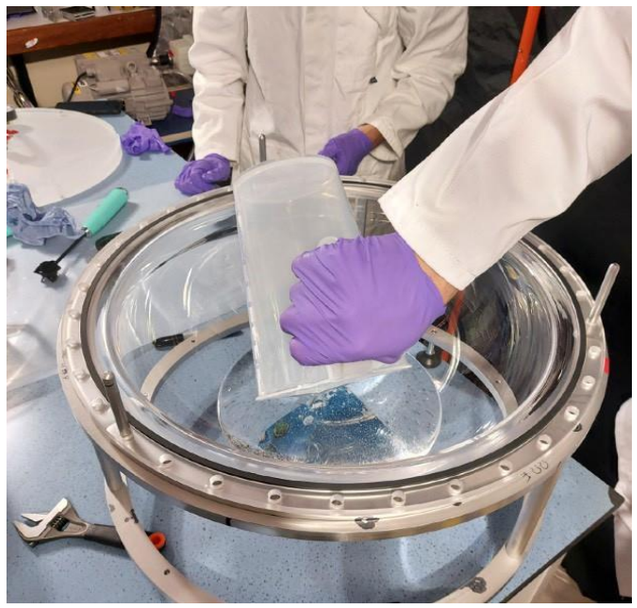




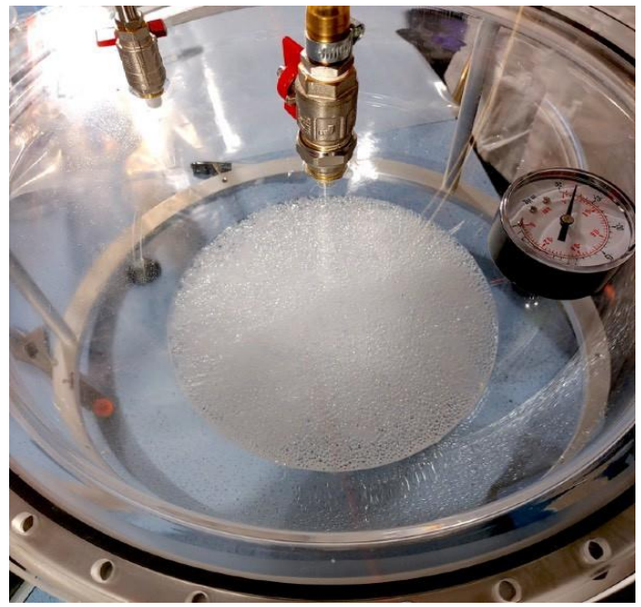
Building BUTTON Optical Detector Modules @ Edinburgh

Degassing optical gel:

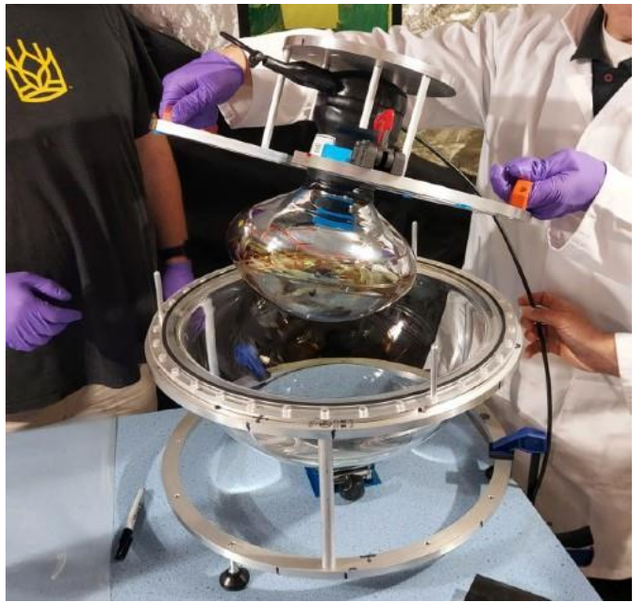
- The PMT is on the rig-mount



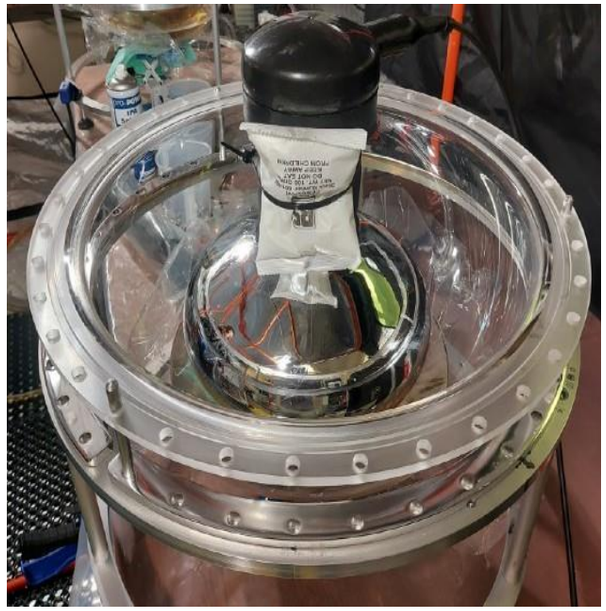
- Mixed gel-A and gel-B (650 ml each)



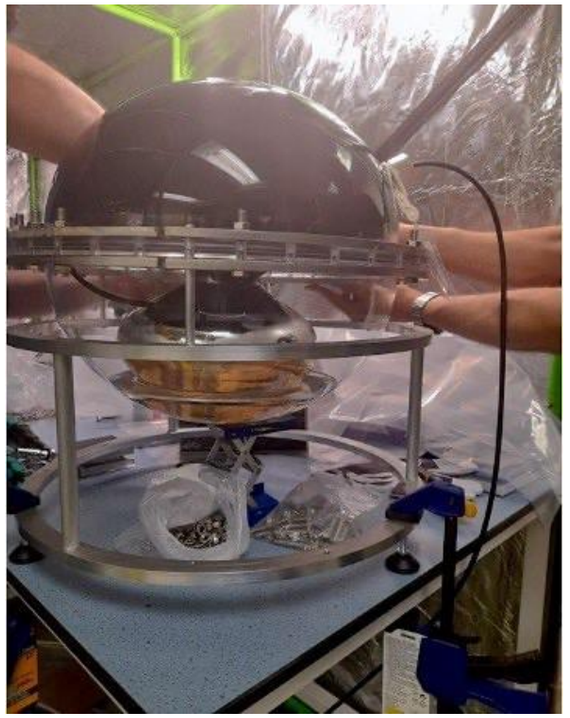
- Degassing the mixture at -1 bar for 15 min



- The PMT goes in the degassed gel (24 hrs)



- Cured gel can support the PMT

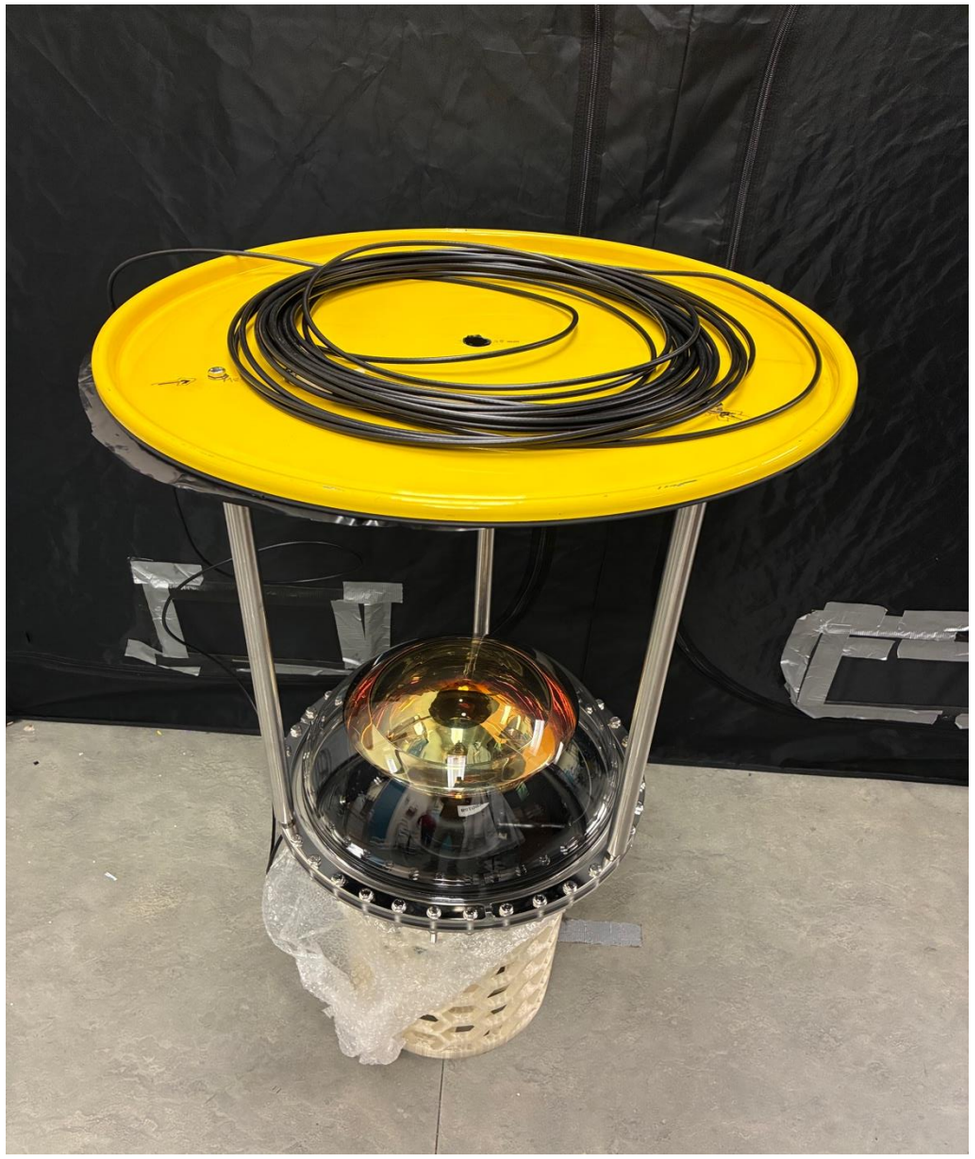


- 2x3 washer plates
- 36 nut-bolts
- Torquing: 4.5 Nm, 6 Nm (3 times)

BUTTON Optical Modules for

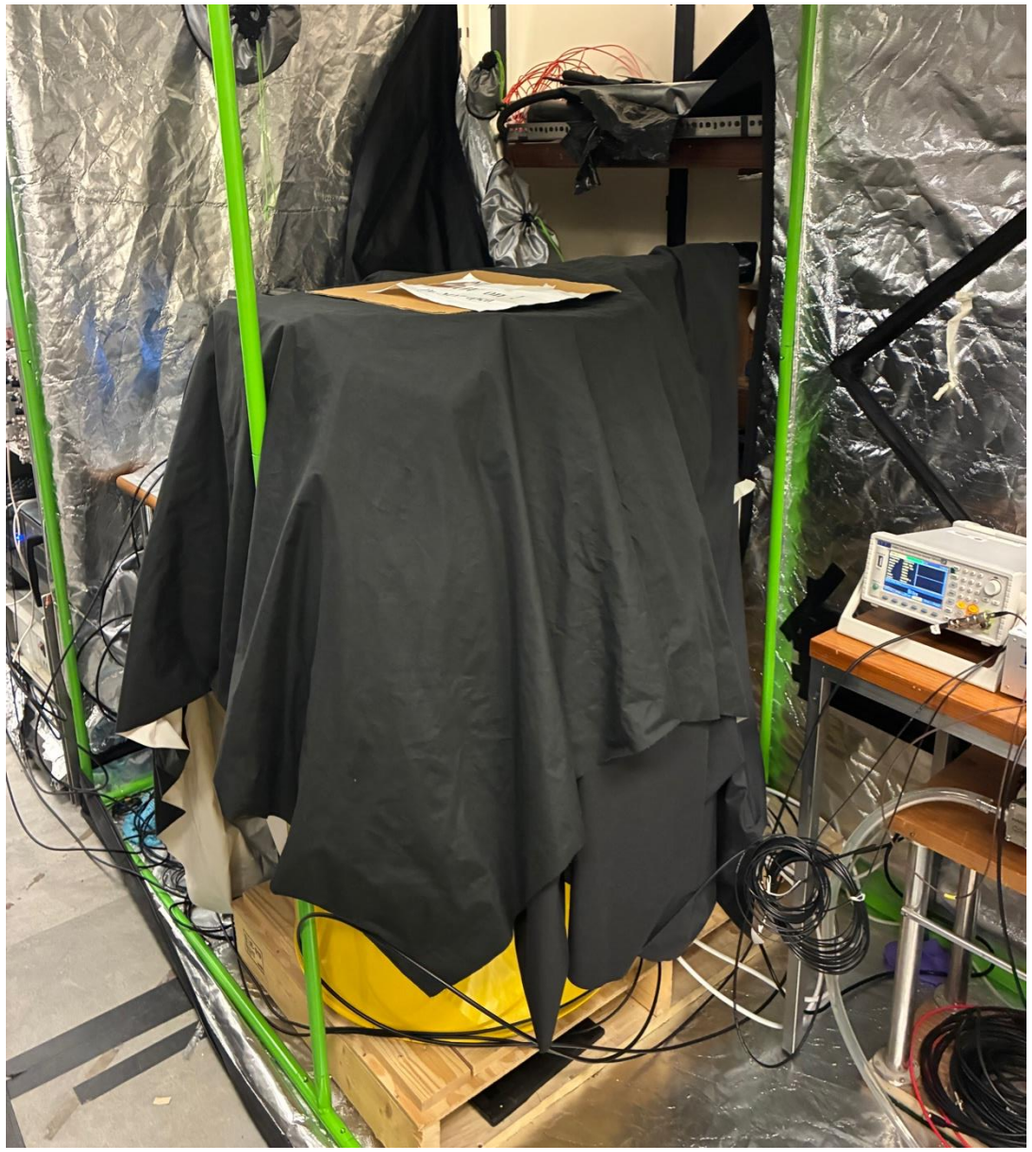
We prepared 99 modules in total

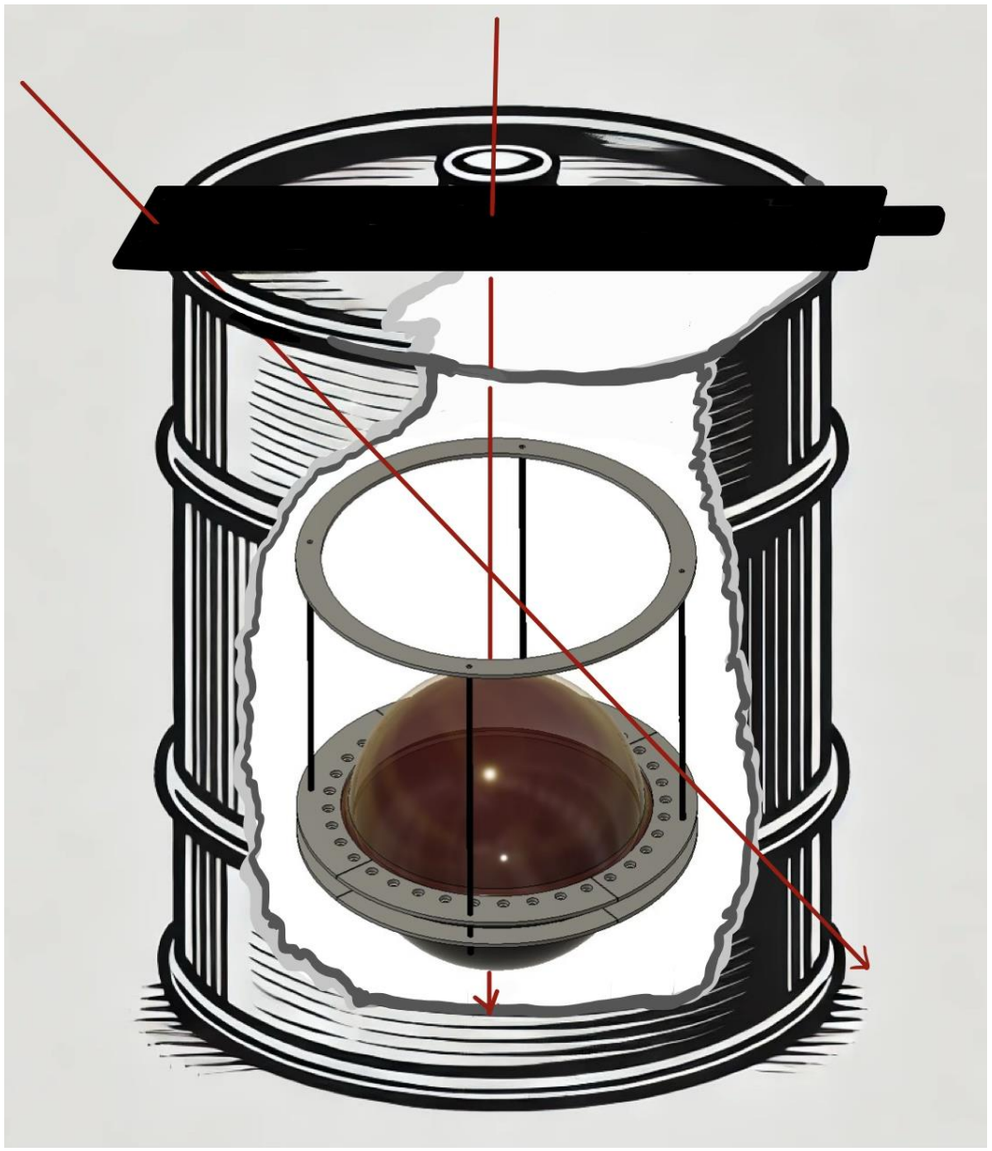
A test stand at Edinburgh



- A 300 litre barrel where a BUTTON or a similar detector can be tested under water
- The BUTTON module is hanged using three metal bars (electropolished)
- The barrel/tank is covered in liner from inside (keeping water from the barrel, darkness)

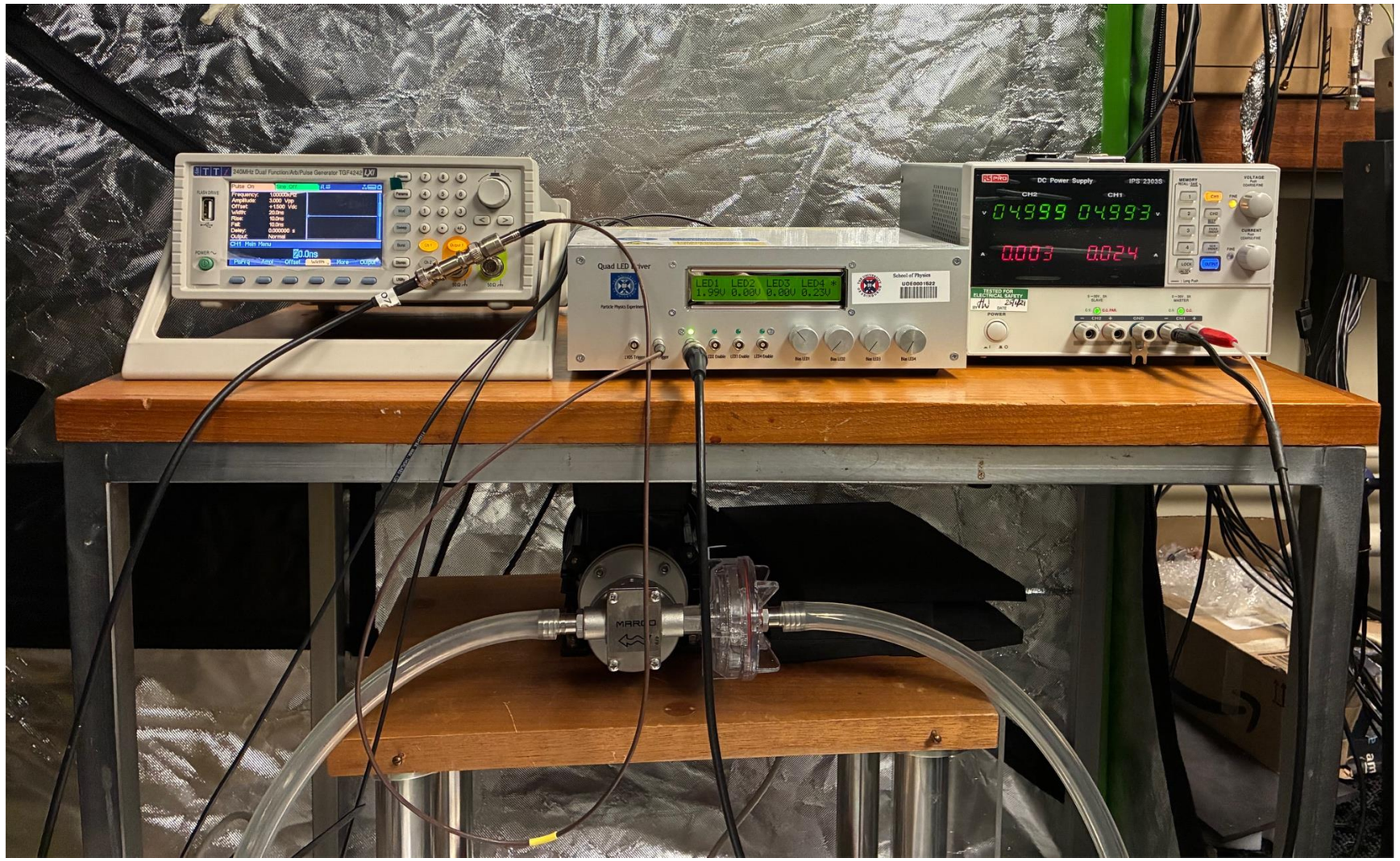
A test stand at Edinburgh





- Two scintillator paddles: one on the top and one at the bottom
- Two-fold coincidence for vertical muons
- Two more scintillators to be installed at the sides (at an angle) for slanted muons

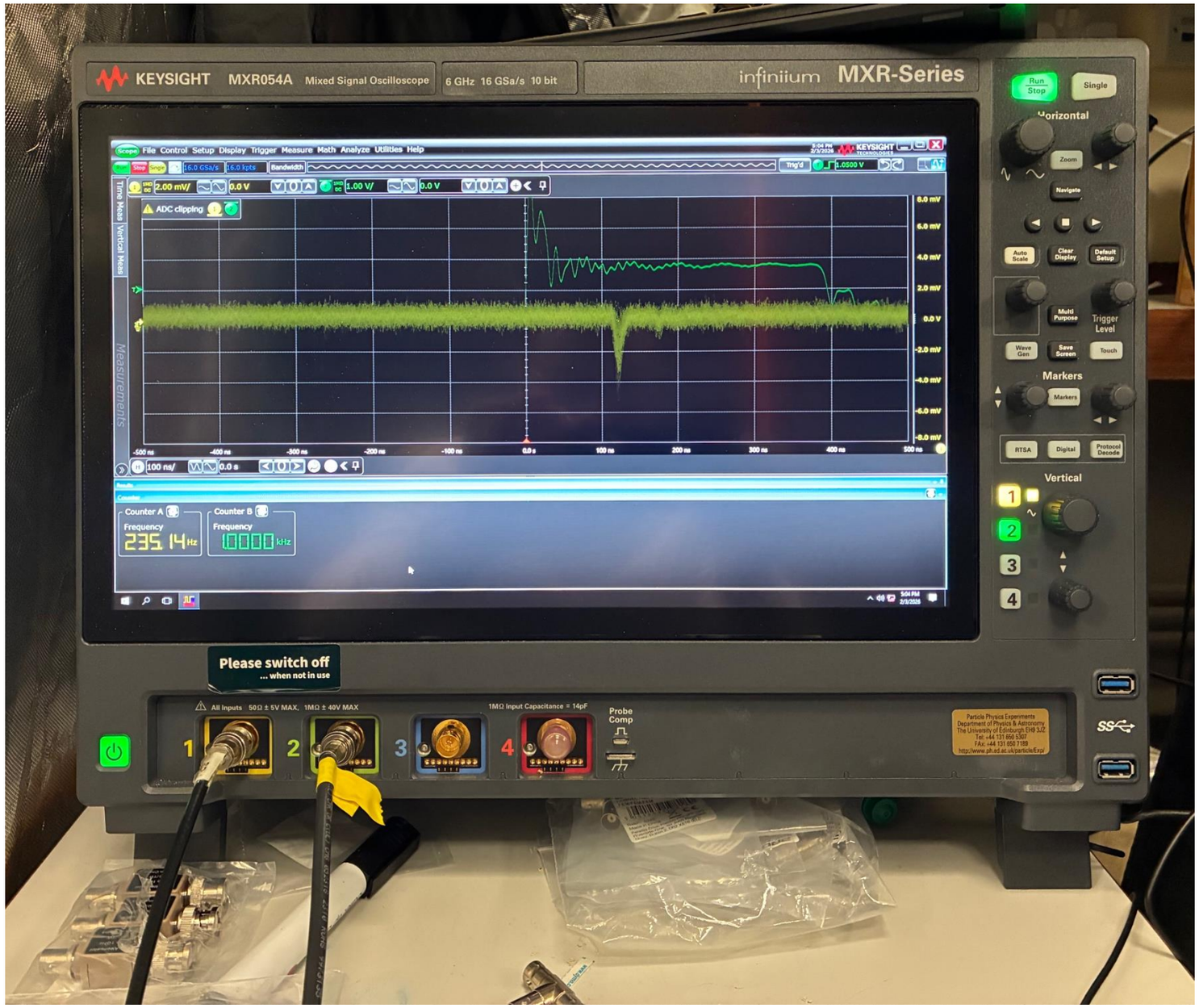
A test stand at Edinburgh



- An LED test driver (4 different frequencies: UV)
- A LV power supply for the LED driver
- A Pulser for the LED driver

- The water pump at the bottom

A test stand at Edinburgh



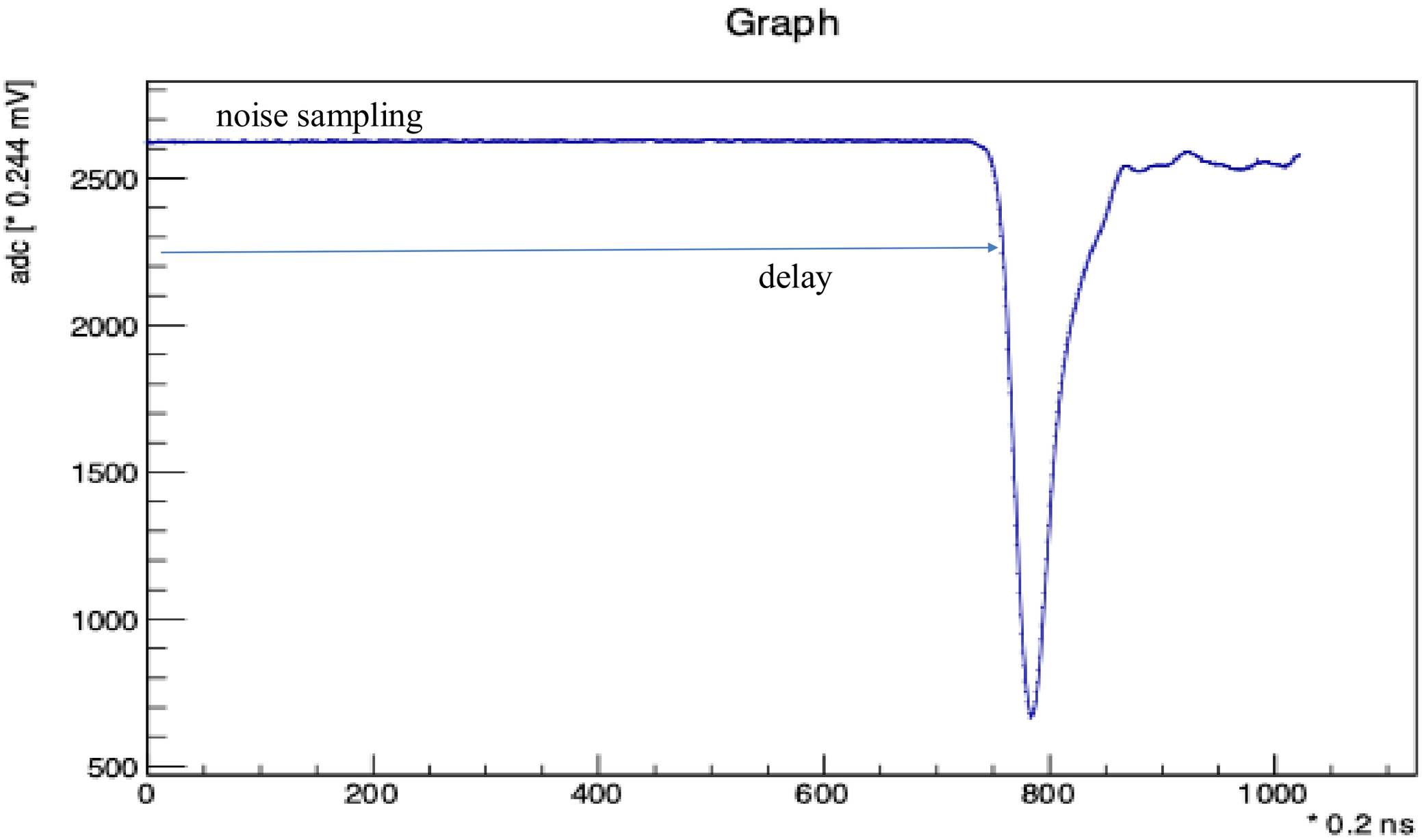
- A Keysight (MXR054A) Oscilloscope: 16 Gs/second, bandwidth newly upgraded 6 GS, 10 bit adc
- An Ortec 416 Gate & Delay Generator
- The Photo-peak is adjusted with the delay with respect to the trigger

A test stand at Edinburgh

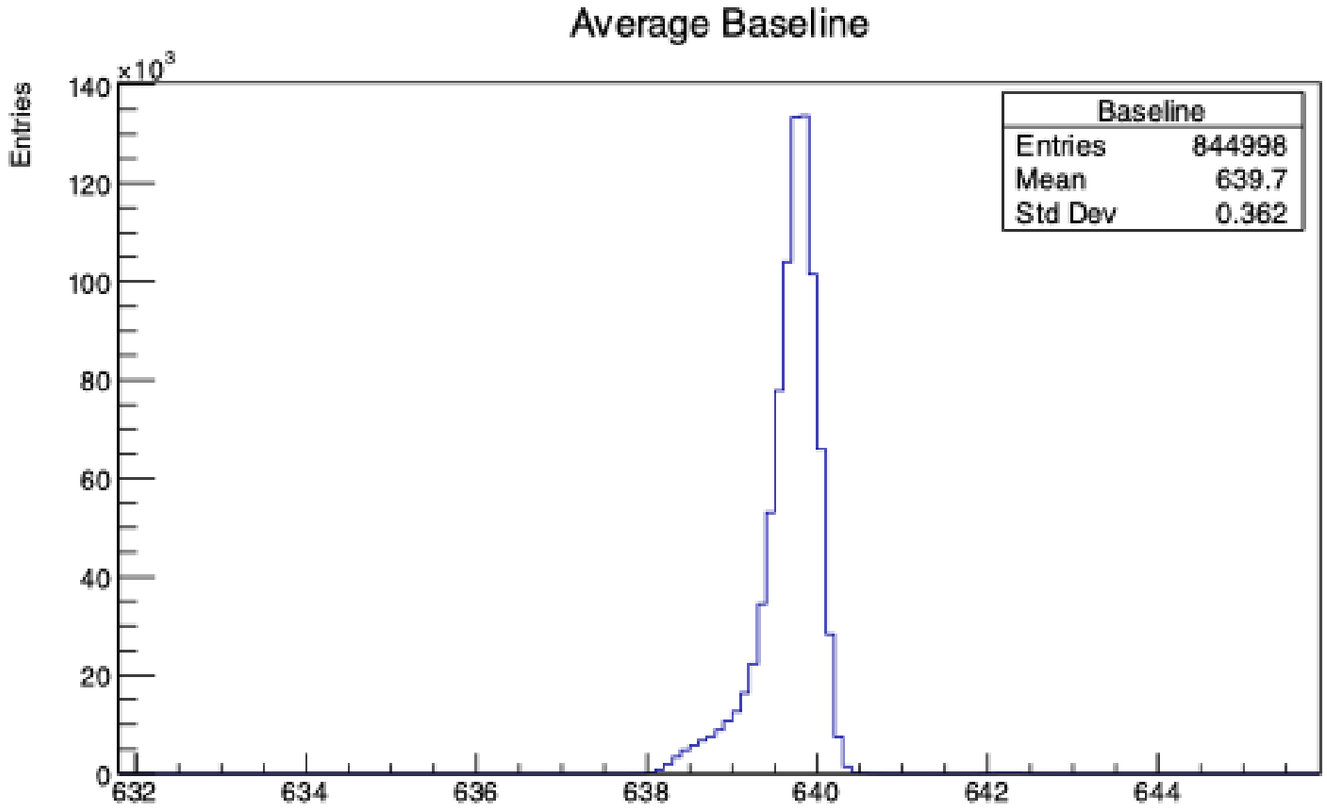
- The final acquisition is a CAEN DT5742
- DRS4 chip-based waveform digitizer
- 12 bit adc with 1 volt peak-to-peak range
- 1024 switch capacitor array => 1024 time samples
- 5 Gs/s => 200 ps width (each 1024 samples) => 204.8 ns time window per event

A test stand at Edinburgh

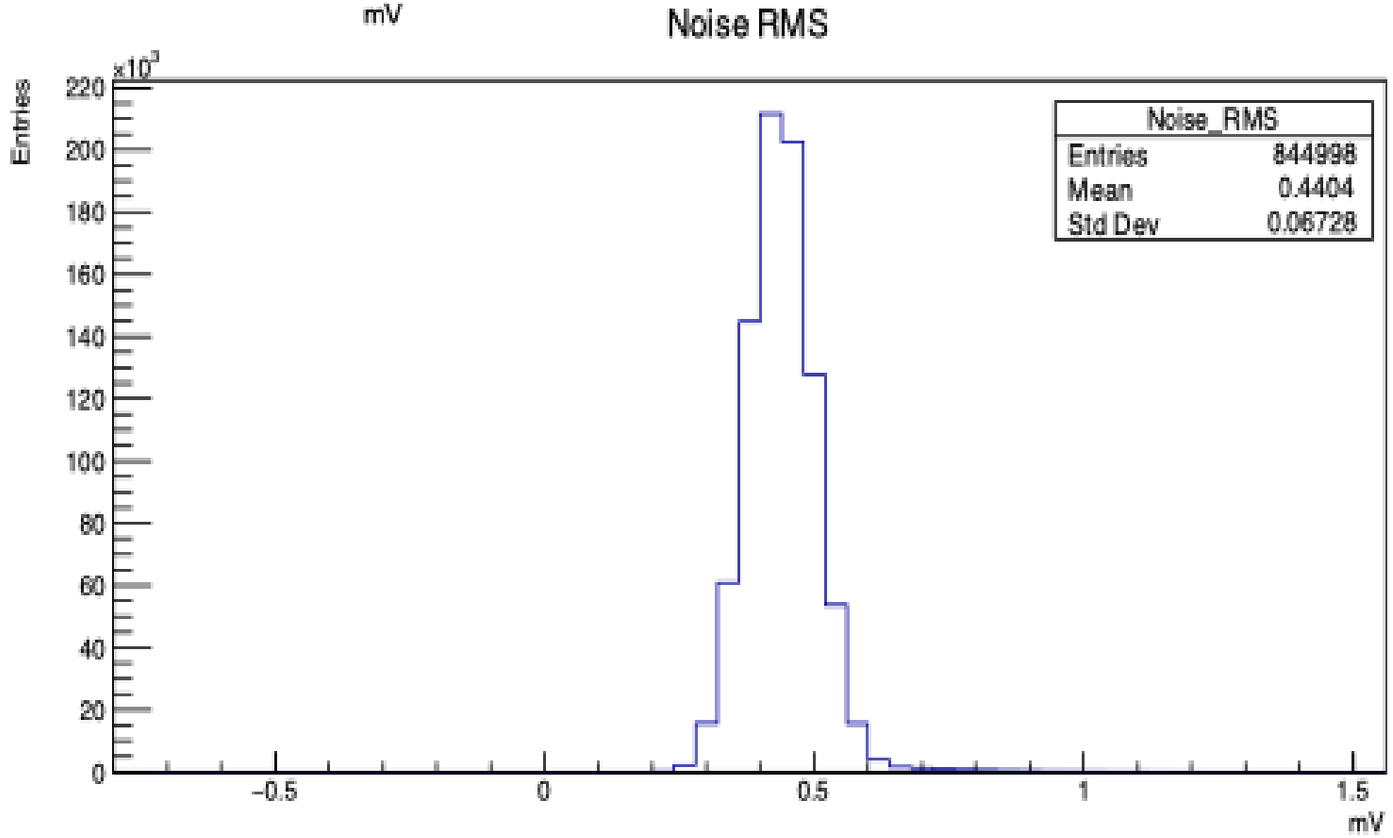
- A sample waveform



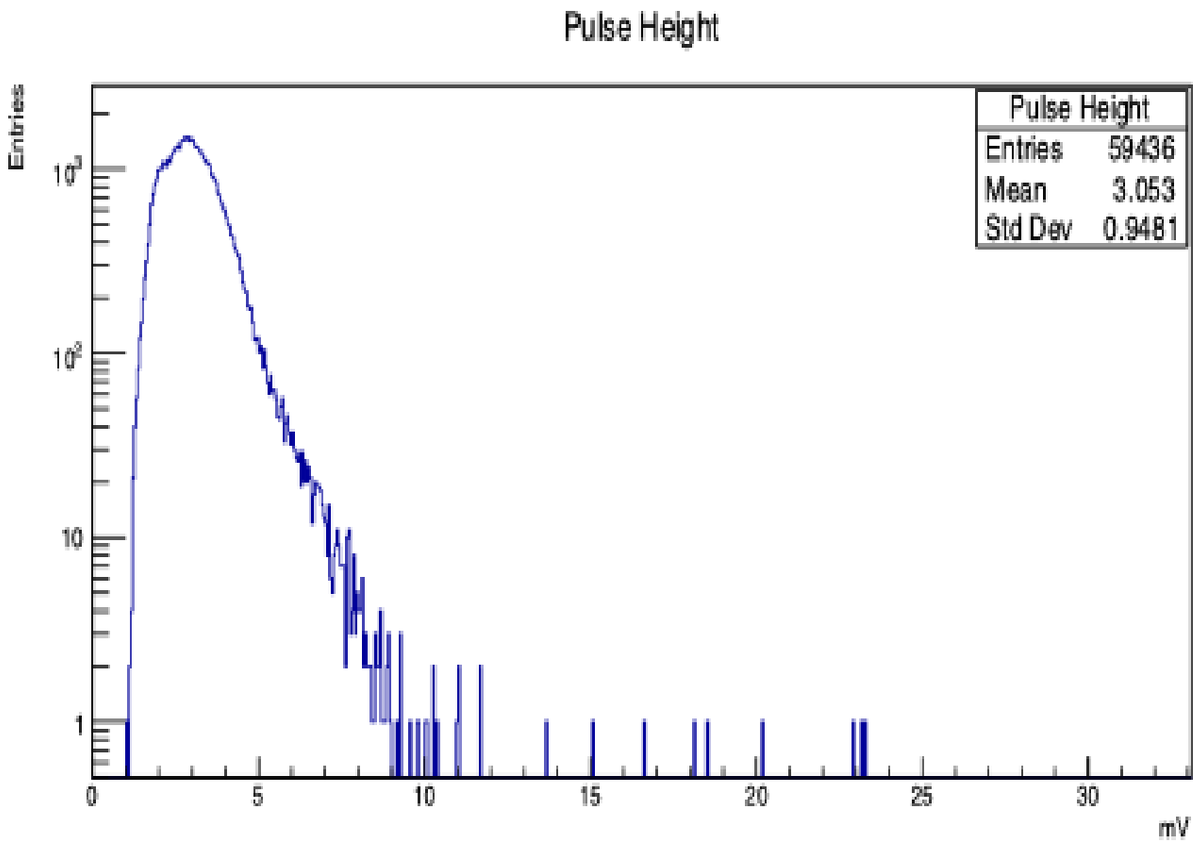
A test stand at Edinburgh



- The average baseline (slightly skewed on the left end -> negative signal)
- The baseline rms (< half a volt)



A test stand at Edinburgh

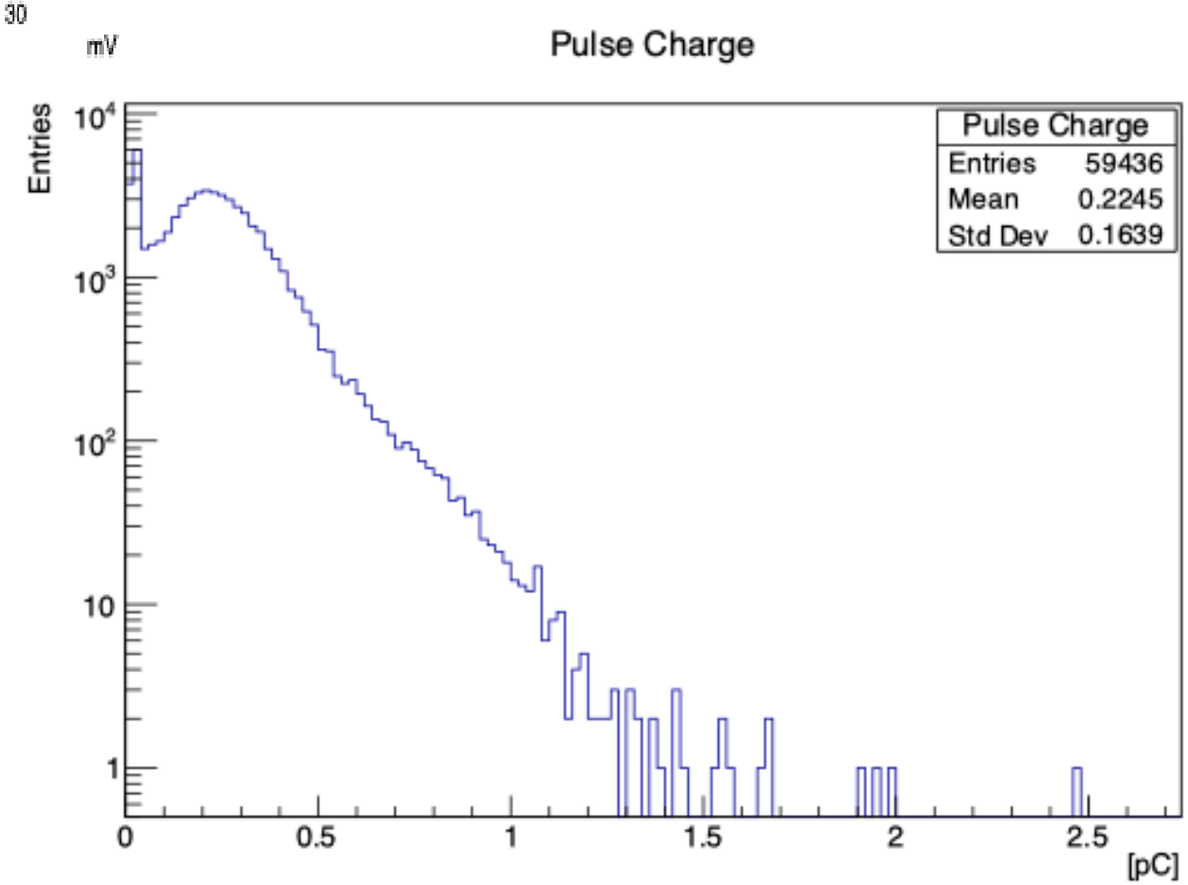


- Peak selection at above 5 * noise_rms
- PHD = baseline – peak
- Charge = area under the curve / input impedance

preliminary results

- Gain calibration done with LED
- ~ 92% empty trigger -> SPE

  - Operating voltage = 1200 V (93 μA)
  - Average pulse height ~ 3 mV
  - Average charge ~ 0.22 pC -> 1.37 * 10^6 gain



Next:

- Can we measure transit time spread with a laser
- Redoing gain calibration with water
- Photon yield with cosmic muons
- Ready for a different detector?
- Ready for a different media?

Thank you for your attention!