Calibration of the UK Hyper-KiloMetric Submarine Deep Detector prototype for undersea muography measurements

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Muography for tidal measurements

- Cosmic ray muons are created by the collision of cosmic rays with the upper atomsphere.
- Muon radiaography (muography) and tomography use the properties of these muons to perform measurements and imaging.
- Recent applications include locating fuel in the Fukushima nuclear plant following the 2011 Tōhoku earthquake [1], and identifying a hidden chamber in the Great Pyramid of Giza [2].
- As rising sea levels become more of a concern to coastal communities, the potential to use muon attentuation for tidal monitoring is of great interest. Significant deviation from expected muon rates can also serve as an early warning system for incoming tsunamis.

TS-HKMSDD

- The Tokyo Bay Seafloor Hyper KiloMetric Submarine Deep Detector (TS-HKMSDD) [3], recently installed in a section of the road tunnel under Tokyo Bay, has shown that muon attenuation can be used to monitor tide heights, and can be preferential in heavy-traffic waterways.
- In support of this, a second prototype in the Boulby Underground Labratory has been commissioned, and calibration work is currently underway.

See the Tokyo Bay HKMSDD live count rates here!

STFC Boulby Underground Lab

- The UK's deep underground science facility.
- Located 1.1 km underground, in the ICL Boulby mine in the North East of England.
- 2805 mwe overburden provides protection from most cosmic radiation.
- Ultra low background environment in which to perform calibration of the system.

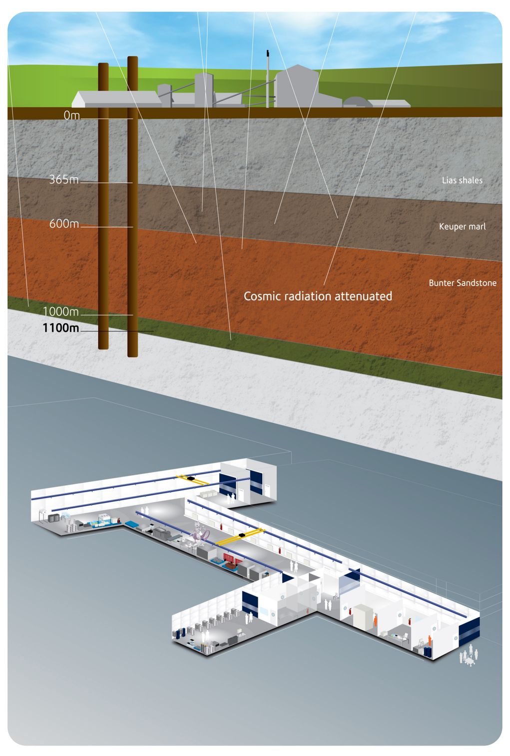

Figure 1: Schematic of the Boulby Underground Laboratory

Detector setup

- UK-HKMSDD prototype consits of 10 detector modules (Figure 2), each made of two scintillation detectors:
  - Single detector composed of a 1500 x 100 x 20 mm piece of ELJEN EJ-200 scintillator, sealed in light tight casing.
  - Coupled to photomultipier tube (PMT) via an acrylic light guide.
  - Signal from both PMTs combined using 2 channel discriminator and coincidence unit.
- High voltage power supplies applies 0 - 2 kV potential difference to PMTs.
- Single and coincidence rates from each module read out to control unit (Figure 3), powered by Raspberry Pi.

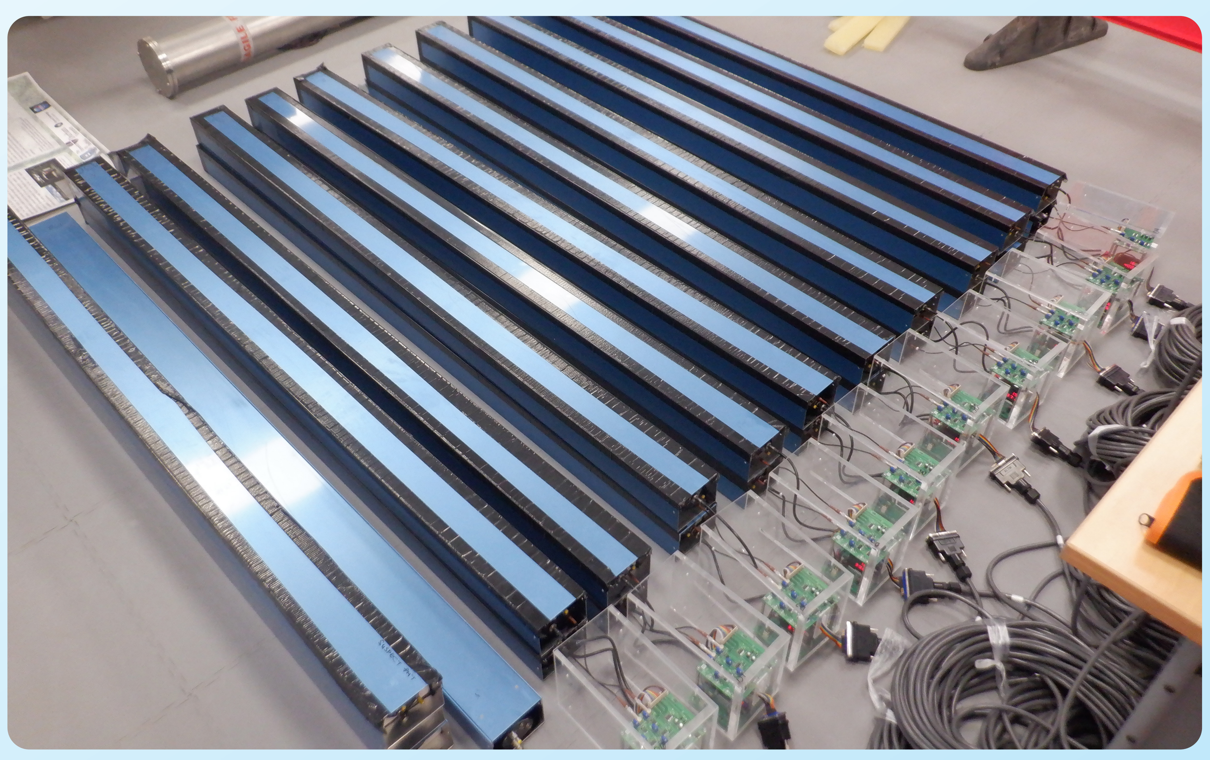

Figure 2 (left): 10 detector modules, composed of 2 scintillation detectors each.

Figure 3 (right): Main control unit. Readouts A and B show PMT singles rates, final readout gives coincidence rates.

Assembly and calibration work

- Full detector assembly performed in October 2021, over course of 2 days.
- Initial calibration work consisted of finding best combination of PMT pairs to balance singles rates. Then adjust high voltage applied to PMT pairs, to balance singles rates across all 10 detector modules.
- Calibration runs performed to assess light tightness of scintillator boxes, using hourly single count rates.
- Ratio of weekday to weekend mean hourly rates plotted, to see effect on count rates of having lab lights on during weekday working hours (Figure 4). Weekends are treated as the 'dark' baseline.
- Most channels show fluctuation around the expected ratio of 1.0.
- A few channels show characteristic rise in ratio during work hours when lab lights are switched on - most prominent in B3.
- Suggests small amount of light leakage in some scintillator boxes, but nothing drastic.

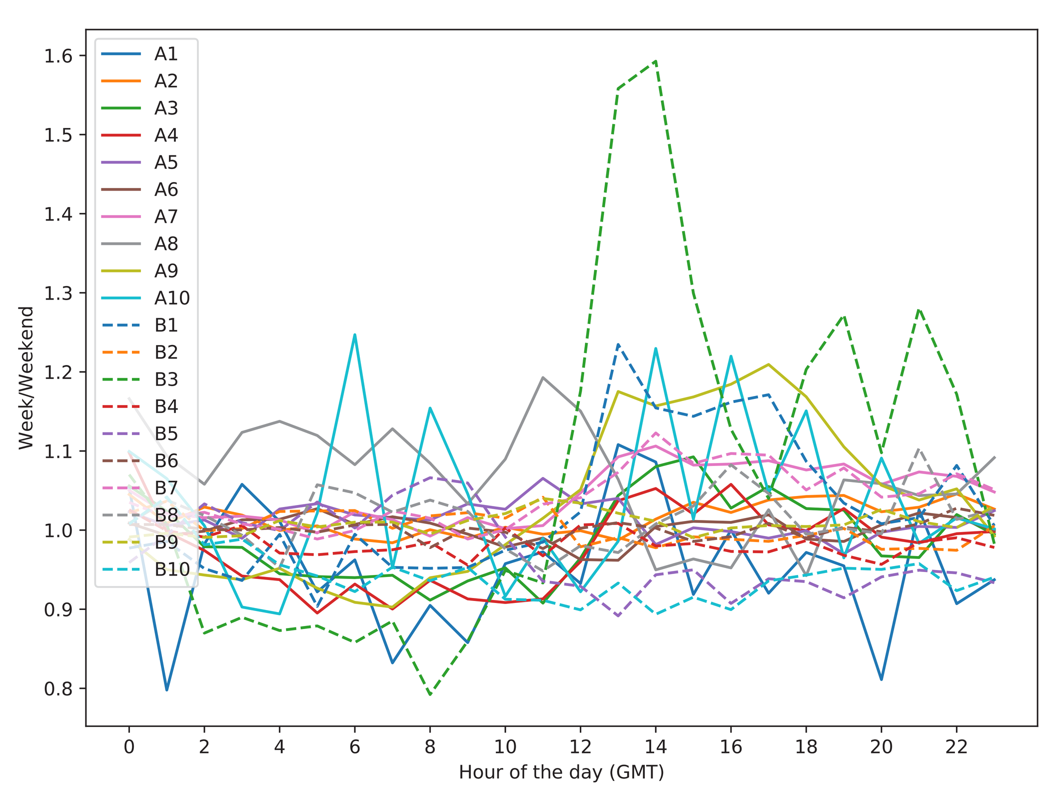

Figure 4: Ratio of weekday to weekend mean hourly detector single count rates.

Future plans

- In lab, expected daily muon rate per detector module is approximately 5 due to overburden - useful for calibration, but not for analysis.
- Following calibration, setup is planned to move to a disused mine shaft which extends out underneath the North Sea.
- A range of overburdens plus tidal movements will provide ability to fully test the system.
- Initial plan to observe standard diurnal and seasonal tidal variations - will also require muon flux simulation as comparison.
- Uniquely situated to observe possible 'meteotsunamis' - a poorly understood phenomenon which can result from atmospheric pressure perturbations [4].

References

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