The Low-Background Screening and Measurement Facility at the Boulby Underground Laboratory in the UK

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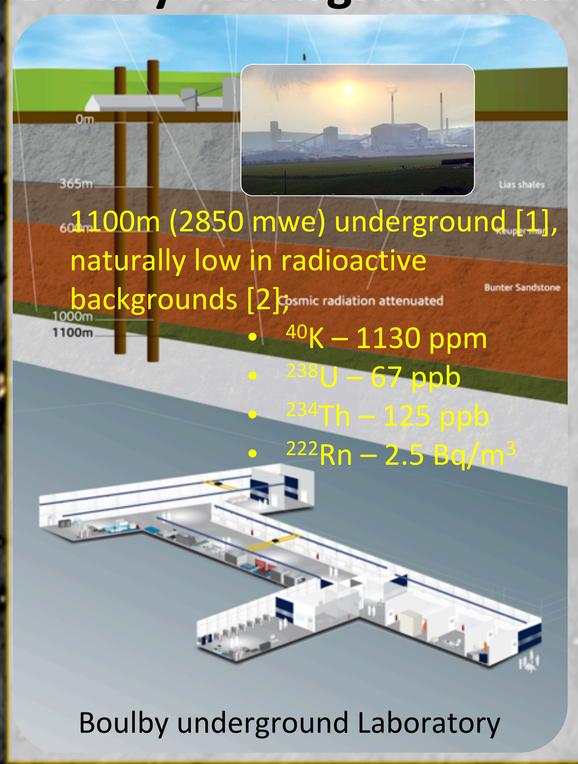
Abstract

Radio-purity requirements remain the main challenge facing current and future generations of neutrino and dark matter experiments e.g. SuperNEMO, SuperK/HyperK and LUX-ZEPLIN experiments. Along with material selection, screening data is critical for building the background model against which any signal is evaluated. As construction materials continuously improve in terms of radio-purity, their measurement is limited by current detection methods and detectors. To answer this critical demand a new world-class screening facility has been established at the newly completed 4000 m^3 Boulby Underground Laboratory.

Boulby Underground laboratory



1100m (2850 mwe) underground [1], naturally low in radioactive backgrounds [2];

- ^{40}K – 1130 ppm
- ^{238}U – 67 ppb
- ^{234}Th – 125 ppb
- ^{222}Rn – 2.5 Bq/m^3

Boulby underground Laboratory

Located on the N.E coast of England, the laboratory is situated in a working potash, polyalite and rock-salt mine.

It is host to 9 projects involving 20 institutions on a wide range of topics from astro/particle physics to geophysics, life in extreme environments and technology development for planetary exploration.

Ultra-low Background Facility

- A class 1000 cleanroom with the lowest radon levels of any underground laboratory was established to support UK DM and neutrino communities.
- Currently 7 ultra-low background gamma-spectroscopy detectors, including 3 new S-ULB class detectors from Mirion (Canberra) and a new XIA UltraLo-1800 alpha counter.

Boulby Underground Germanium Suite (BUGS)

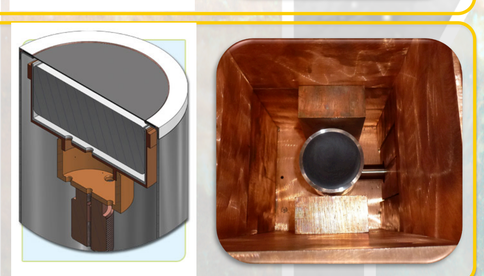
Germanium Detectors

Coaxial Detectors

- Optimised for large samples (few 1000 cm^3)
- Eγ > 100 keV.

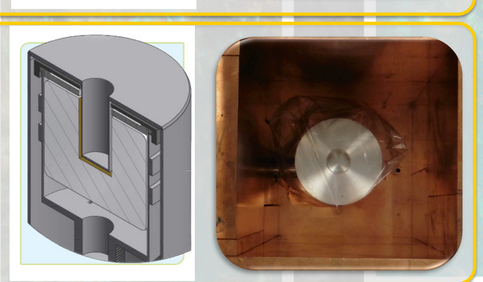
Broad Energy (BEGe) Detectors

- Optimised for low energy gammas with high resolution (~ 1000 cm^3)
- Eγ > 10 keV.



Well Type Detector

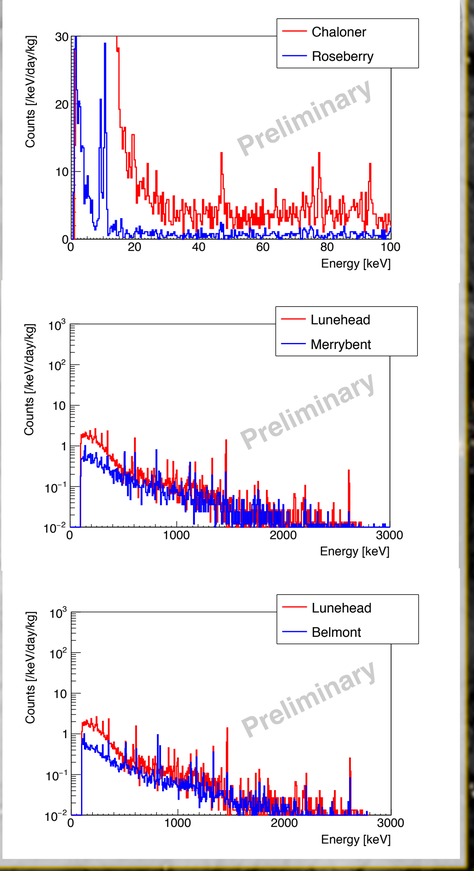
- Optimised for small samples with high detection efficiency (few cm^3)
- Eγ > 40 keV.



- The Boulby Underground Germanium Suite (BUGS) aims to become one of the world's most sensitive germanium detector facilities.
- Roseberry (BEGe) has the potential to achieve world leading sensitivity in the HPGe assay of Pb210.

Detector	Type	Ge Mass (kg)	Bkg counts (c/day/kg)	14-day Detection Limit (mBq/kg)*		
			100-3000 (keV)	U	Th	^{210}Pb
Belmont	Coax	3.2	200	<0.25	<0.09	-
Merrybent	Coax	2	255	*<0.64***	<0.19	-
Roseberry	BEGe	0.9	280	<0.18	<0.14	<2.5

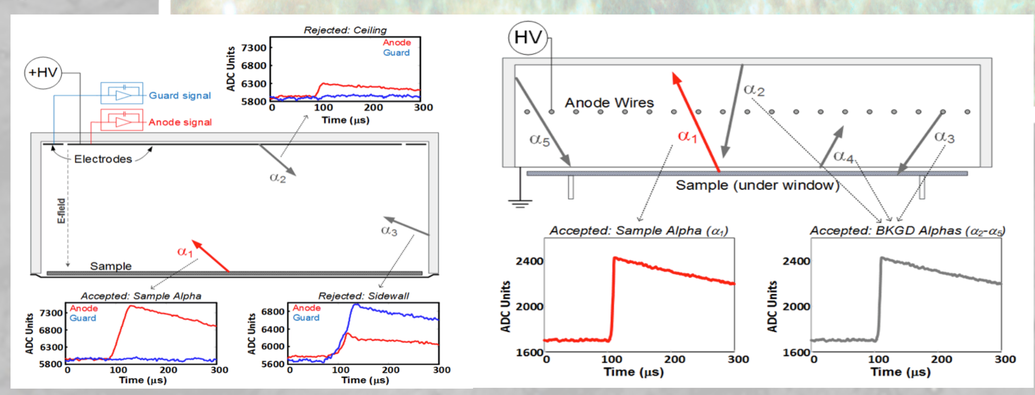
**For U/Th a 3.5kg copper sample is used. For Pb210, an 8kg PTFE sample is used*
***N2 Purge not yet optimised for Merrybent*



XIA UltraLo-1800

- Currently developing analysis software to tag surface radon emanation from samples and monitor radon emanation rate over time.

- The UltraLo is a ultra-low background surface alpha counter which employs electronic background suppression to achieve background rates of 0.0001 alphas/cm^2/hr.
- Precise measurement of surface alphas will be critical to the next generation of dark matter detectors which will have significantly increased surface area due to their increase in size.



UltraLo-1800 (left) vs Conventional Proportional Counter (right) [3].

Future Outlook

- The ultra-low background facility plans to expand with additional S-UBL germanium detectors and the construction of radon emanation measurement capabilities with the aim to place Boulby as a center of excellence for both assay and cleanliness.
- Service current and future onsite experimental programmes.
- BUGS can also carry out science measurements, such as using Ge to measure ^{96}Zr double beta decay to 1st excited state [4].
- Screening for current and next generation neutrino experiments such Gd for SuperK, SuperNemo post demonstrator, Dune and the WATCHMAN experiment.

References

[1] H. Araujo, et al., Astroparticle Physics 29 (2008) 471–481
[2] P. R. Scovell, et al., Astroparticle Physics 97 (2018) 160–173
[3] http://www.xia.com/UltraLo/index.html
[4] X. R. Liu, PhD Thesis, University College London, 2017