Boulby Underground Laboratory

The UK’s deep underground science facility operating in a working Potash, Polyhaylite and Salt mine

Factor ~ 1 million reduction in cosmic ray muon flux vs. surface

1.1km depth (2805 mwe)

Operated by the UK’s Science & Technology Facilities Council (STFC)

Science & Technology Facilities Council
Excavations are in Salt (NaCl) Polyhalite (SKMgCa) & Potash (KCl) Permian evaporite layers left over from the Zechstein Sea. Over 40 kms of tunnel mined each year (now >1,000kms in total), the long-lived roadways being cut in the lower NaCl layer.

U: 67 ± 6 ppb
Th: 125 ± 10 ppb
Low γ & n backgrounds
Low Rn (<3 Bq m⁻³)
Mining at Boulby...

CPL/ICL support us:
- Keep the mine operating and safe
- Emergency H&S
- Materials transportation
- Misc. Facility maintenance
- High level political support
Underground Science at Boulby Mine

- DRIFT: Directional Dark Matter Search
- BUGS: Ultra-low background material screening
- Deep Carbon: Muon Tomography for CCS (etc)
- ERSaB: Environmental gamma spectroscopy
- BISAL: Geomicrobiology / Astrobiology studies
- MINAR: Space Exploration Tech. Development
- SELLR: Life in Low background radiation
- Misc. Geology / Geoscience
- Misc. Low-background support projects
- Etc... (More to come).

A growing multi-disciplinary science programme:
from astro & particle physics to studies of geology, climate, the environment, life on Earth & beyond.
Boulby Underground Laboratory

4 (+3) onsite staff supporting 70 users from 20 UK & international universities and research institutes

What Makes Boulby Special?

Requirements for an underground laboratory...

- Low Backgrounds
  - Deep (to shield from cosmic rays)
  - Low background rock/lab (and/or adequate shielding)

- Plenty of Laboratory space

- Easy access for equipment

- Proximity of services / civilisation

- Good infrastructure + support

Low ambient gamma & radon levels \((Rn \leq 3 \text{Bq/m}^3)\)

- Good location. Ease of access. Close to services.

- Operations well-supported by mine owners ICL

- Interesting, diverse & impactful science programme

Muons vs. depth

Low ambient gamma backgrounds
Boulby Dark Matter Studies

Boulby has hosted Dark Matter search studies for two decades. Including the NAIAD, DRIFT & ZEPLIN experiment programmes.

Boulby now hosts DRIFT Directional DM programme, CYGNUS Thick GEM R&D & provides ULB material screening for other studies, inc LUX-ZEPLIN

ZEPLIN: The world’s first 2-phase Xenon dark matter detector (Finished 2011)

Current limits & future projections
A DIRECTIONAL Dark Matter Detector.

Occidental College, New Mexico, Colorado State, Hawaii, Wellesley, Sheffield, Edinburgh, Boulby

**STATUS:** Programme operating at Boulby since 2001. Currently limit-setting and conducting system performance & scale-up R&D. Plans for further R&D & expansion / collaboration (**CYGNUS**).

Dual (1m$^3$ total) Negative Ion DRIFT TPC

Simulated data

New Lab December 2016

Directional DM detection – providing the most powerful direct detection signature
Growing suite (‘BUGS’) of Ultra-Low-Background (ULB) germanium detector systems to support Dark Matter & misc ‘rare-event’ studies…

**Sensitivity down to <100ppt U/Th per sample, & improving**

- Ortec 2kg Coax.
- 3 Canberra BEGe detectors
- Canberra SAGe Well-type
- 2 Canberra Coax (180% eff)

ULB counting studies supporting UK DM (LZ) and neutrino study communities.

Now **EXPANDING** ULB counting capabilities to meet international demand.

In collaboration with UCL, Oxford, DMUK, Sheffield
Three additional world-class detectors now being installed (x10 sensitivity). Now better to support current & future ULB experiments (inc. Gd Super-K). Also nearer PPT sensitivity for G3 Dark Matter & Neutrino experiments.

BUGS move to new lab complete… Detectors successfully installed and operating. LZ sample testing well underway…
Boulby Multi-Disciplinary Studies

**DEEP-Carbon:** Muon Tomography for deep geological mapping applications including CCS

*Boulby, Durham, Sheffield, Bath, Premier Oil, CPL.*

**ERSaB:** Gamma spectroscopy & low background counting environmental radioactivity studies

*Boulby, Scottish Universities Env. Research Ctr (SUERC)*

**MINAR:** Space Technology Development

*Boulby, Edinburgh, NASA, DLR, CPL etc.*

**BISAL:** Astrobiology / Geo-microbiology. Studies of life in salt, life on Earth & beyond

Plus Misc. Geology & Geoscience (& more to come)...

__From astrophysics to climate, geology, the environment, life on Earth & beyond...__

Life in Boulby Salt...
Low-BG Gamma Spectroscopy

Gamma spectroscopy and low-background counting for Environment studies & Beyond

The ultra-low background environment and Ge detectors at Boulby allow existing industrial, environmental and climate-related gamma spectroscopy studies to be extended and improved.

Environmental applications:
Radioactive tracers for atmospheric & ecosystem processes
Radio-dating: C-14, Pb-210, Si-32
Dosimetry in the environment
Marine radioactivity
Landscape evolution
Sedimentology...

Pb-210 Radio-dating of the 50-250 year timescale is important for understanding RECENT affects of climate change.
Development of a **Muon Tomography** techniques for deep 3D geological surveying - inc Carbon Capture & Storage (CCS)

Potential for cheap, reliable, practical, real-time long-term monitoring of deep structures. Potential applications:
- Deep geological repository monitoring.
- Monitoring in Carbon Capture & Storage (CCS)

**Deep-Carbon Project**: £1.4M funding from UK Dept of Energy & Climate change (DECC) & Premier Oil:
- Bore-hole detector development & testing @ Boulby
- Muon-Tides technology demonstrator
- Simulations of technique performance in CCS
**Astrobiology & Mars Analogue**

**Sampling life in Boulby Brine**

**Subsurface Astrobiology Laboratory**

**ALSO: An important ‘Mars Analogue site’** – with geology & conditions to allow explorations & astrobiology technique & instrumentation development

**A base for studies of life in Boulby rock** – studies of limits of life on earth and on other planets

**MINAR**

**Mining & extraplanetary exploration instrumentation development**

**Edinburgh, Boulby, NASA, DLR, CPL (etc)**

**Led by Edinburgh, UKCA**

**Life in Boulby salt**

**Boulby and Instrumentation for Earth and Space Exploration**

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A NEW LABORATORY now built at Boulby
To replace current facility and host **planned & new projects** for the next decade and more...

- Large Expt. Cave Area: Internal lab height/width of 6.5m/7m
- Main hall: Internal Lab height/width of 4m/7m
- Materials Entrance 1
- Materials Entrance 2
- Offices & People Entrance
- Mars Analogue Area & outside testing area
- BUGS ULB Counting facility
- Materials Store
- Fully-equipped 4000m³ lab. Class 10K & 1K clean room throughout. 5-10T lifting capacity.
Main Experimental Hall (7x4x60m)

Large Experimental Cavern (LEC) (7x7x35m)

'Bugs' ULB Germanium Facility

> 4000m$^3$ of well supported class 1,000 and class 10,000 clean room experimental space

AC, HEPA filtration, internet / comms, 5 & 10 T lifting capacity.
July 2017: Finishing touches to the lab and getting on with the science...
Old lab collapsed to create ‘outside experimentation area’

Open salt roadway experimental area supported and equipped for ‘out-of-lab’ projects

Boulby New Lab: Outside Experimentation Area

Final part of construction...
A change to work with an amazing team!
Thank you!