Subterranean Science and Ultra-Low Background Studies at Boulby

ED BANKS

Boulby Underground Laboratory

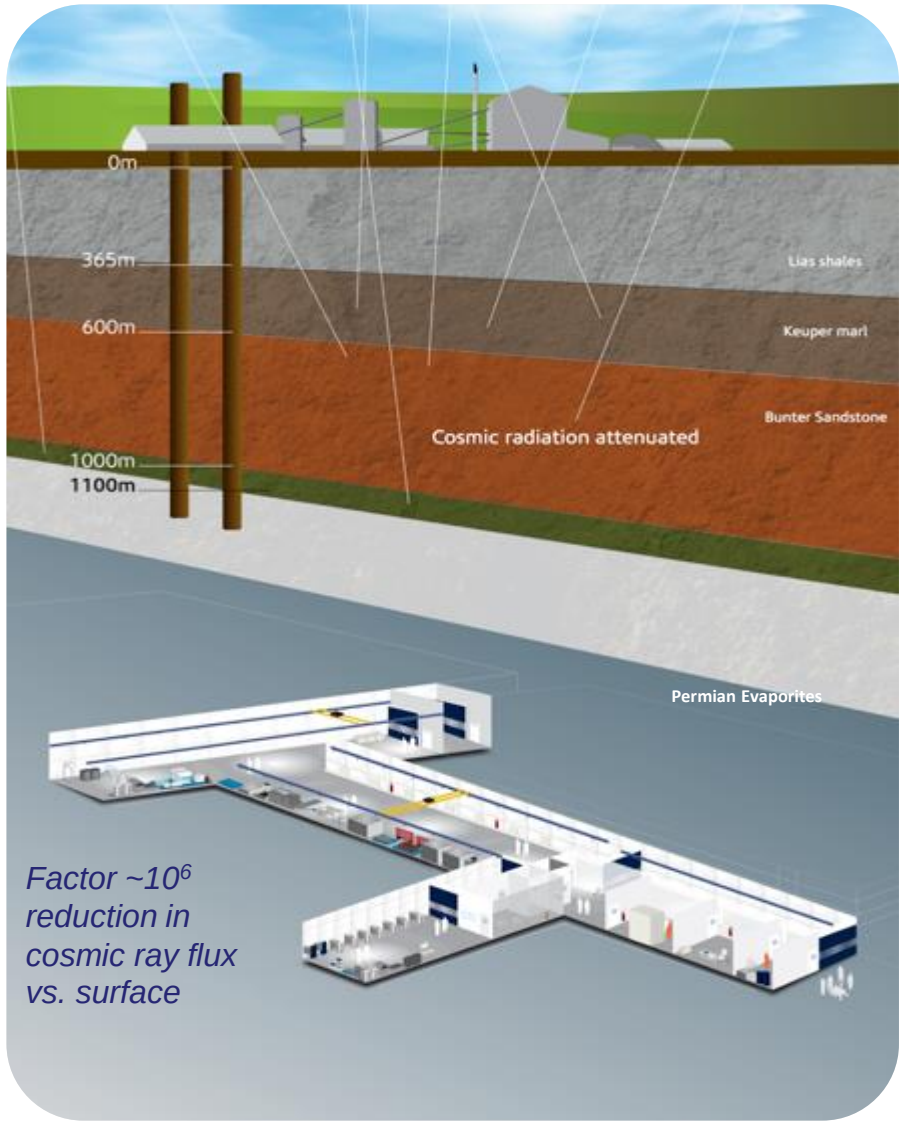
Science and Technology Facilities Council

Boulby Underground Laboratory

The UK's deep underground science facility operating in a working polyhalite and salt mine.

1.1km depth (2805 mwe). With low background surrounding rock-salt

Operated by the UK's Science & Technology Facilities Council (STFC) in partnership with the mine operators ICL



Factor ~10^6 reduction in cosmic ray flux vs. surface

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Underground Science

- DRIFT/CYGNUS: Dark Matter Search
- NEWS-G: New technology for dark matter searches
- BUGS: Ultra-low background materials screening (for LUX-ZEPLIN and Super-K-Gd and more)
- RESOURCE: Battery earth research for energy storage
- SELLR: Life in Low background radiation
- BISAL: Geomicrobiology / Astrobiology studies
- MINAR: Space Exploration Tech. Development
- Misc. Geology / Geoscience
- AWEGe and WATCHMAN: Nuclear security
- Etc... (More to come).

BOULBY UNDERGROUND LABORATORY

CYGNUS Dark Matter R&D

UKRI Science and Technology Facilities Council

Boulby Facility Details

- The UK's deep underground science facility. One of 4 in EU. ~15 in the world.
- Supports work of 9 collaborative projects; astrophysics to climate, geology, environment etc
- 40 institutions, >150 scientists and students.
- Facility funded and operated by the Science and Technology Facilities Council (STFC).
- Operations, H&S & science programme managed by 8 onsite staff and supported by Rutherford Appleton Lab (PPD).
- Mine operators CPL provide wide-ranging operational & higher level support.

How does Boulby Compare?

- Lowest Radon levels (3 Bq/m^3)
- Most diverse science prog.
- Science and Industry partnership

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Surface support and staging building

Office space, chemistry & clean prep lab, storage and staging space, IT room, conference room


3000m^3 Outside Experimentation Area


BUGS Material screening

Boulby Underground Lab Facilities 2019:

>4000m^3 class 1k & 10k clean room lab space

100Mb Internet AC, Air filtration, 5T & 10T lifting,

LN generation, fume hood & clean prep space.

3000m^3 Outside Expt. Area. With power & internet

Working alongside mining at Boulby…

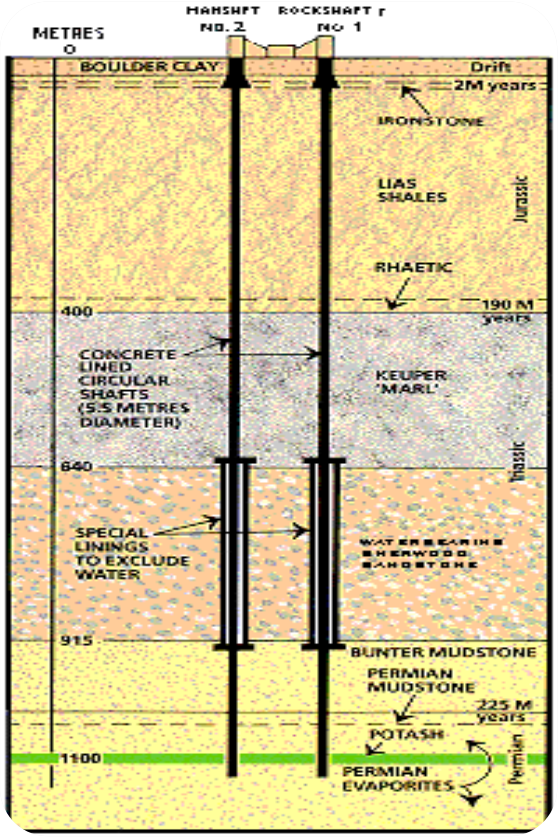
Boulby Lab responsibility:
Facilitate the Science
Manage Safety
Operations Impact
Outreach & Media

CPL/ICL support us:
Keep the mine operating and safe
Emergency H&S
Materials transportation
Misc. Facility maintenance

Boulby Geology & Mining

Excavations are in Salt (NaCl) & Polyhalite 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.



Boulby Geology

U: 67 ± 6 ppb
Th: 125 ± 10 ppb
Low γ & n backgrounds
Low Rn (<3 Bqm^{-3})

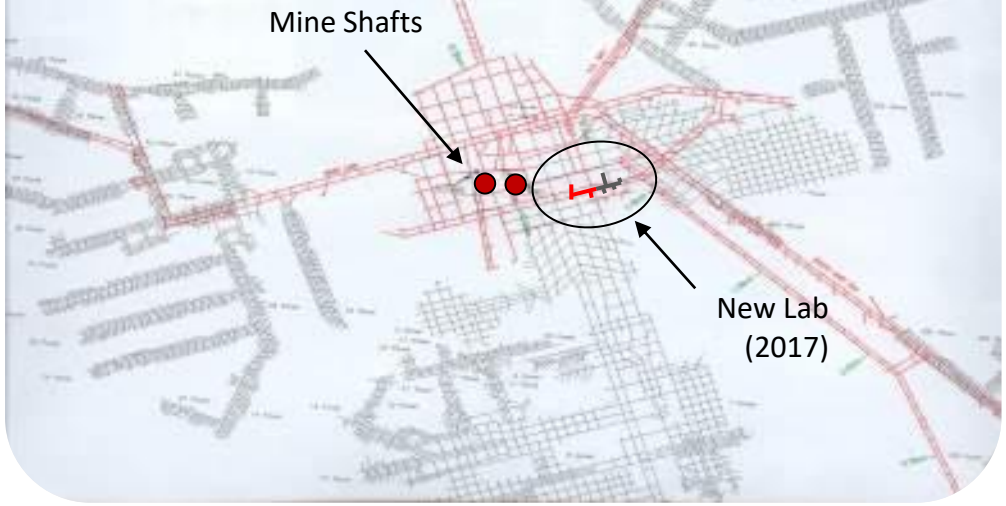
Potash

Rock-Salt

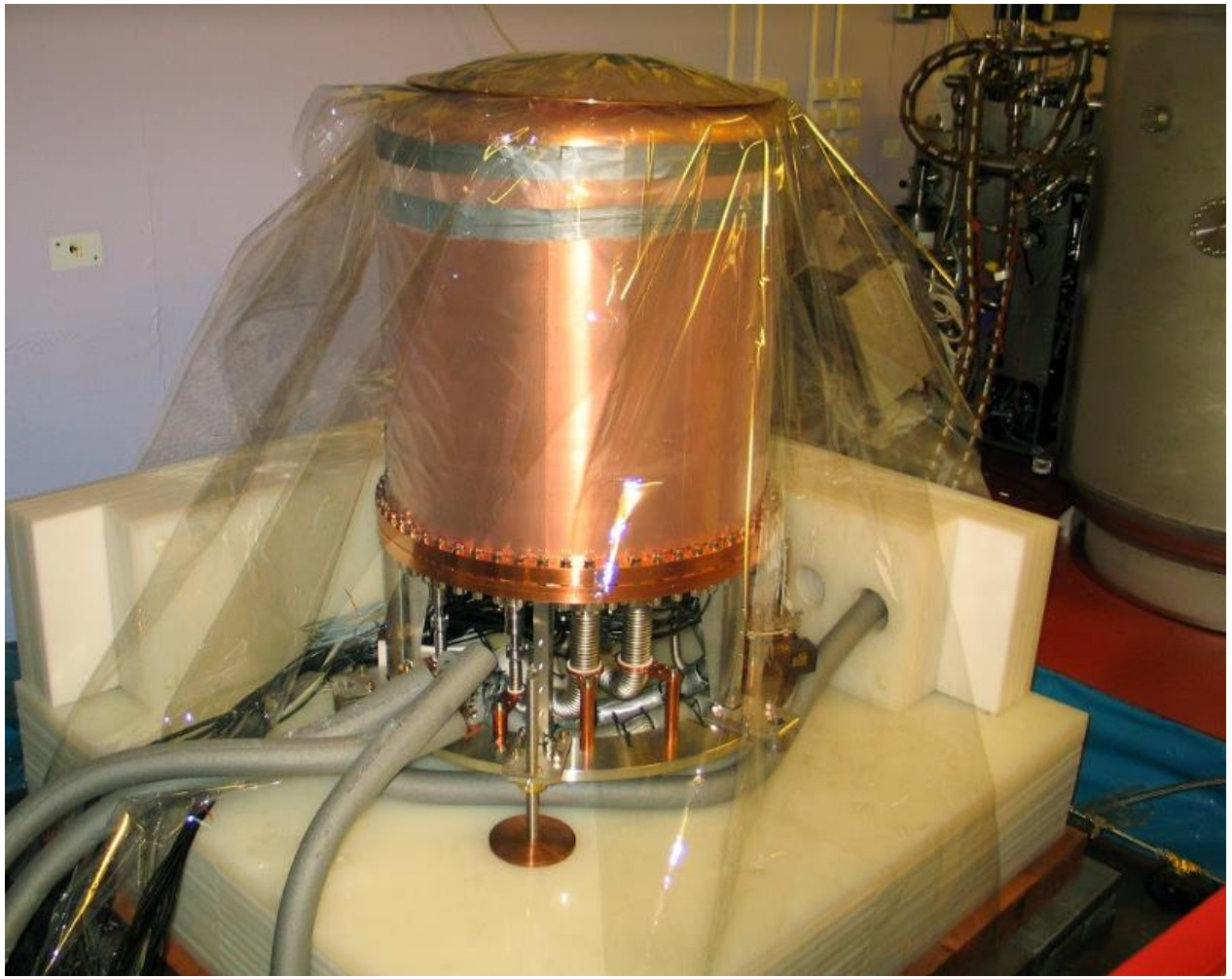
Polyhalite

Typical Boulby Salt Roadway

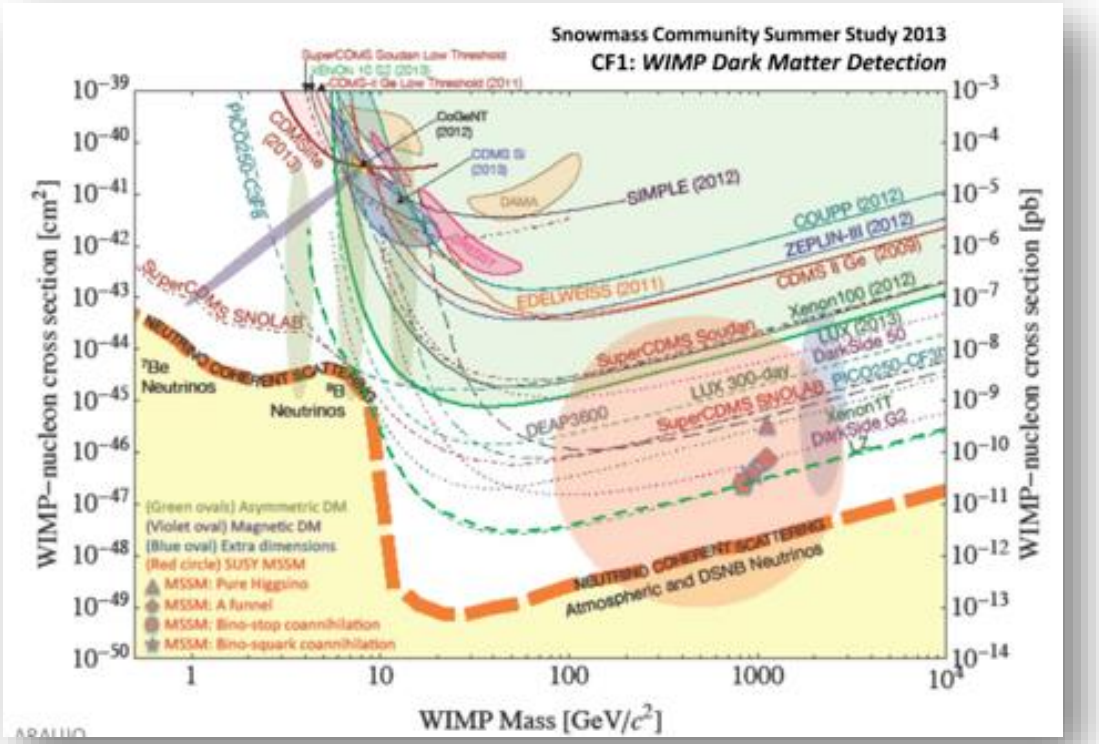
Zechstein Sea



Dark Matter Searches



- NAIAD
- ZEPLIN-III
- ZEPLIN-II was the first dual-phase liquid xenon dark matter detector*



Dark Matter Searches

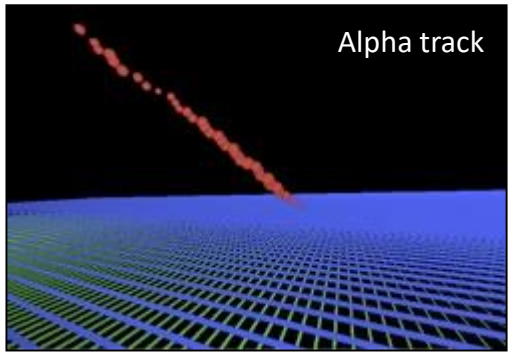
CYGNUS: R&D for DIRECTIONAL Dark Matter detection.

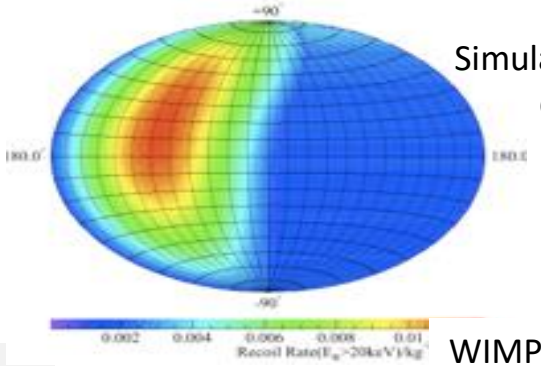
STATUS: Programme operating at Boulby since 2001. Currently limit-setting and conducting system performance & scale-up R&D. Plans for further R&D & expansion / collaboration (**CYGNUS**).

DRIFT-IId @ Boulby

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

Directional detection





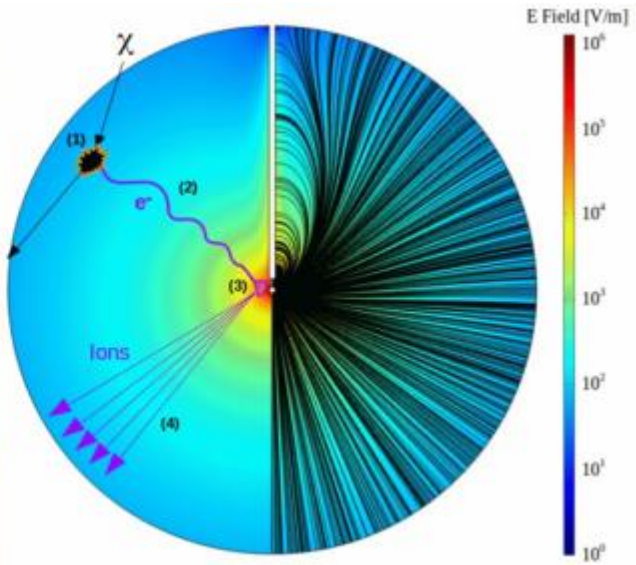
Simulated data

WIMP flux

Status: DRIFTII-d limit setting and R&D exploring issues and technologies for scale up - CYGNUS

Directional DM detection – providing the most powerful direct detection signature

Dark Matter Searches



SEDINE detector

- NEWS-G
- Using SPC- Spherical Projection Chambers
- Searching for light dark matter
- Run by University of Birmingham particle physics group
- Installation of R&D vessel in December 2019

UNIVERSITY OF BIRMINGHAM

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BUGS Material Screening

Growing suite ('BUGS') of Ultra-Low-Background (ULB) germanium detector systems to support Dark Matter & misc 'rare-event' studies

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

In collaboration with UCL, DMUK, Sheffield, Edinburgh and others

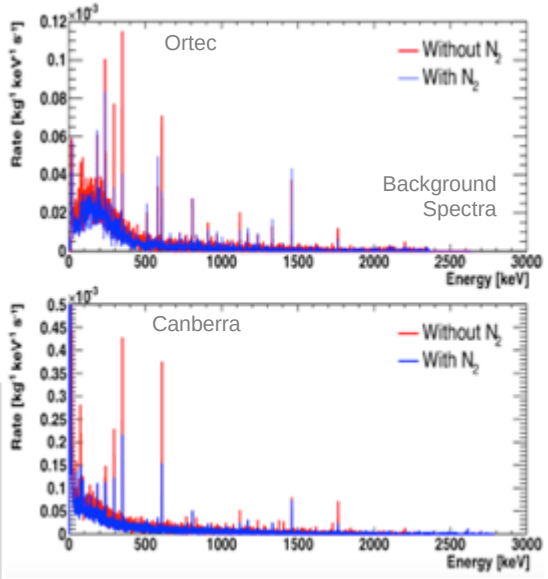
Boulby undertaking major role in material selection for **LUX-ZEPLIN** and **SK-Gd/T2K**

XIA- for investigating surface and bulk alphas, and for cleaning procedures

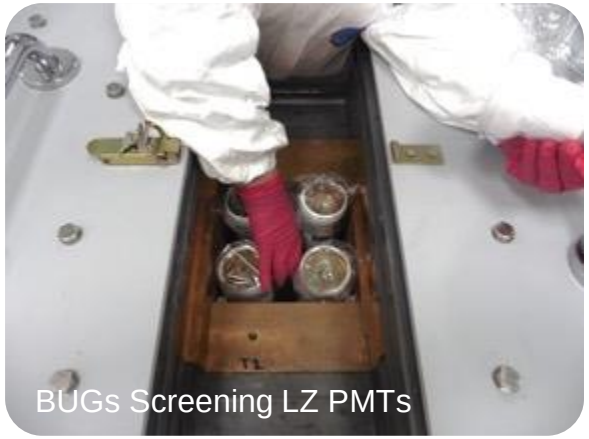

Boulby Underground Germanium Suite (BUGS)

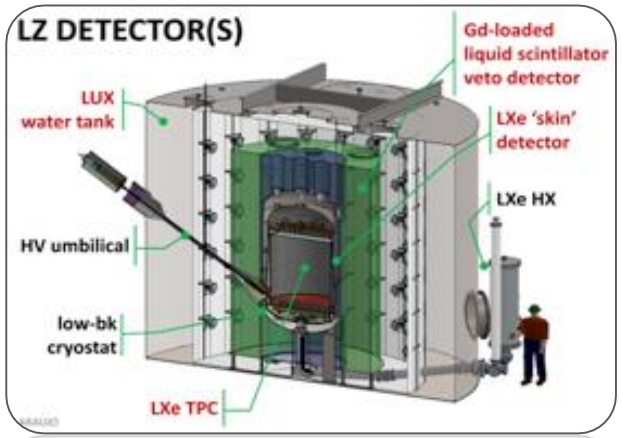
Sensitivity down to <50ppt U/Th per sample, & improving

Our Current Detectors;
- Ortec 1.8 kg (72%) p-type (ULB)
- Canberra 2.0 kg (112%) & 3.2 kg (171%) p-types (S-ULB)
- 2x Canberra BEGe detectors (5030 ULB, 6530 S-ULB)
- Canberra SAGe Well-type (LB)
- XIA Surface Particle detector



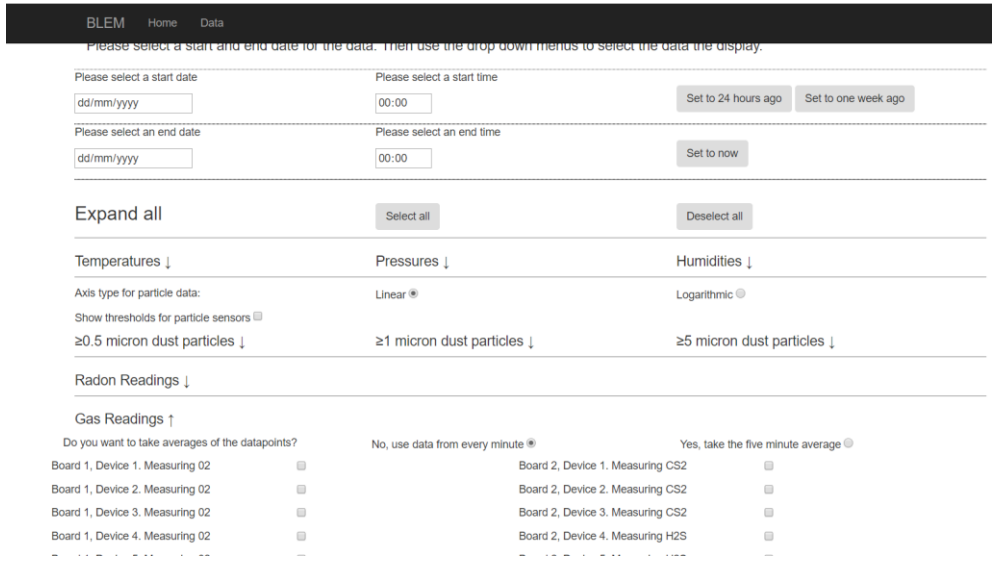

New automated LN2 filling system

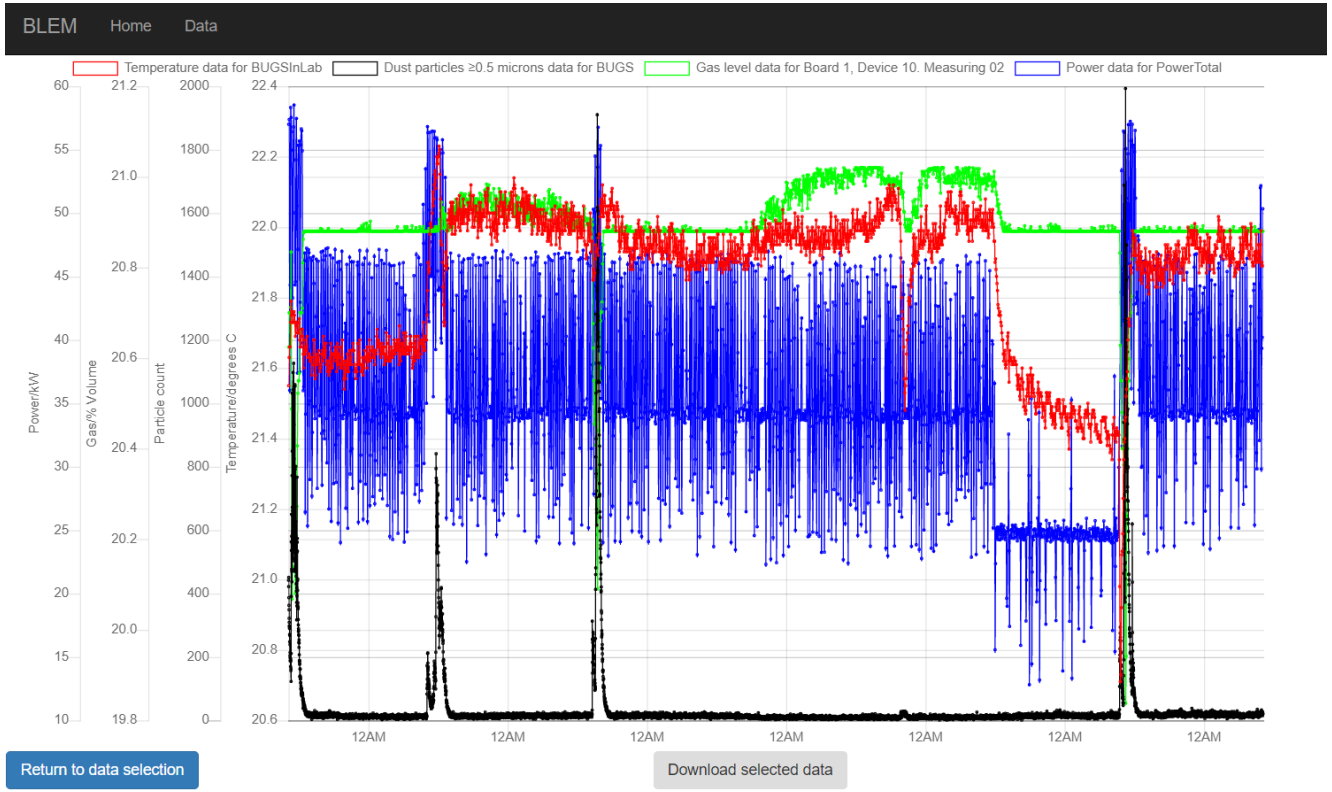

BUGs Screening LZ PMTs



LUX-ZEPLIN

Environment Monitoring - BLEM

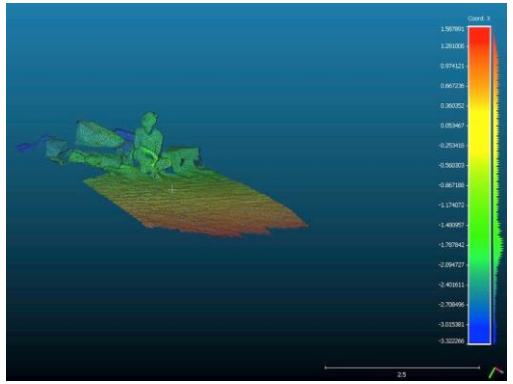




MINAR

- Testing of instruments and methods for subsurface exploration of planets/moons
- Develop new educational material
- Astronaut training
- Outreach and live-links


MINAR - SPLIT




MINAR – Pac Man, HABIT & many more

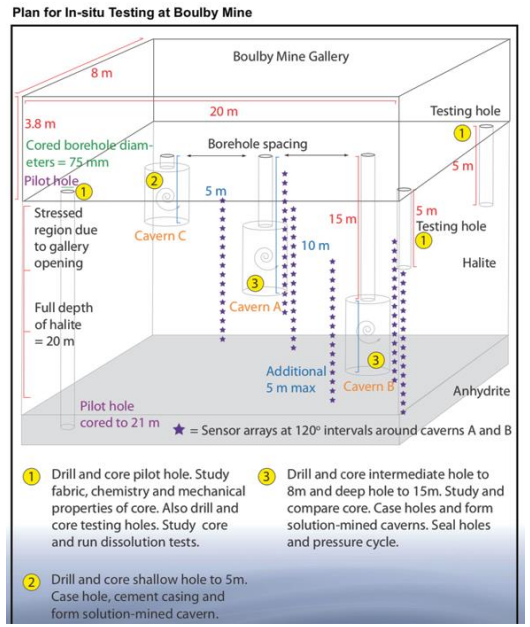
RESOURCE

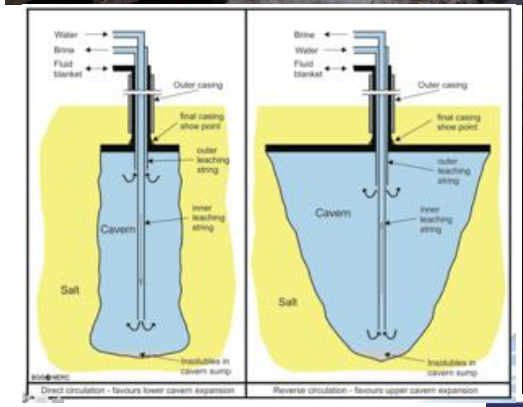
British Geological Survey

Expert | Impartial | Innovative

BOULBY UNDERGROUND LABORATORY

- British Geological Survey
- Large scale energy storage for renewable energy
- Uses compressed air, stored in cavities in the rock
- This air is released to turn turbines when energy is needed
- Small scale study at Boulby initially is testing the techniques to create these cavities





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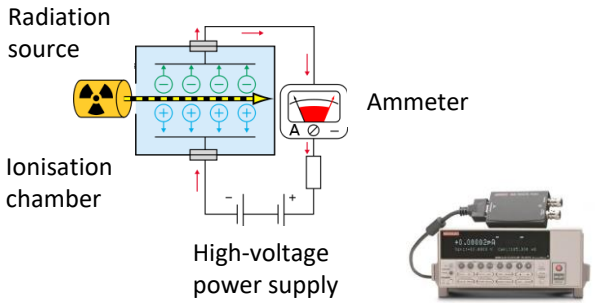
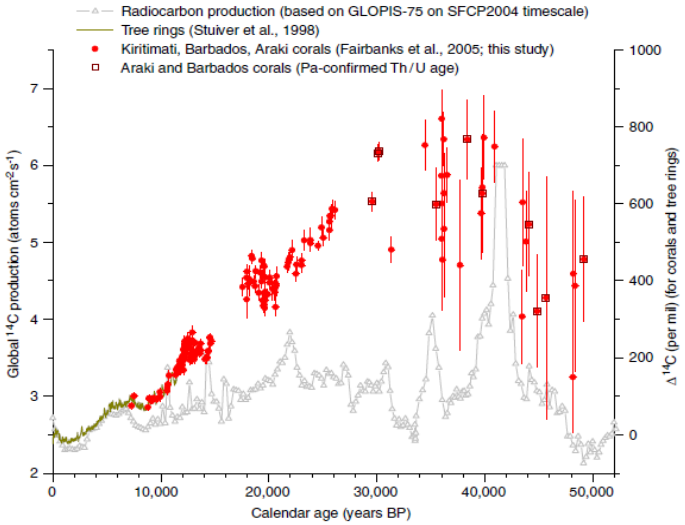
C14

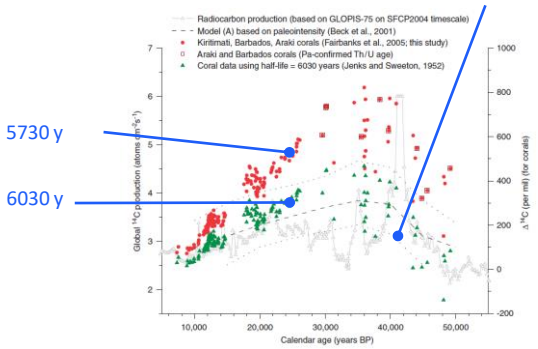
National Physical Laboratory

BOULBY UNDERGROUND LABORATORY

- National Physical Laboratory
- Looking to improve the half-life measurements of Carbon-14
- Discrepancy between existing measurements
- Measurement challenge lies in getting the most stable equipment over a long period of time







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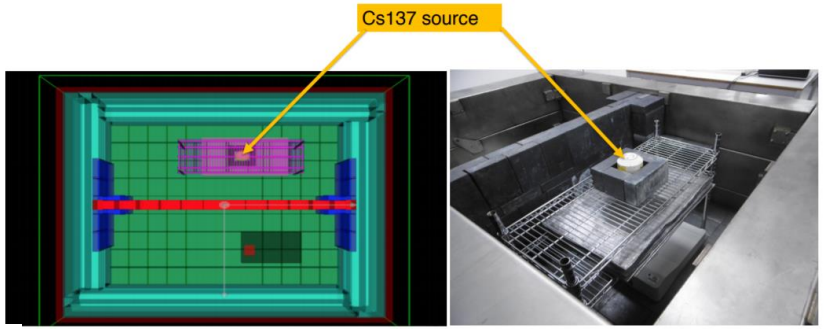
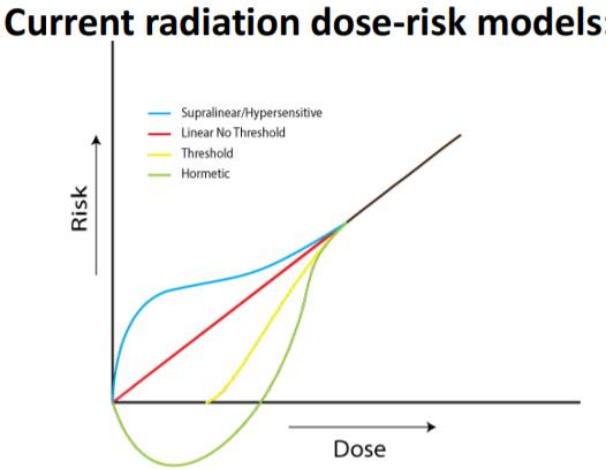
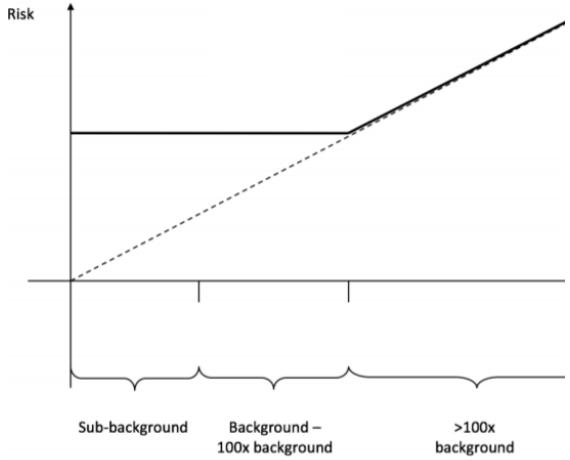
SELLR

- How does life respond to low levels of radiation?
- Using bacteria (bactilla subtillis) exposed to varying levels of radiation, the response below normal background can be found



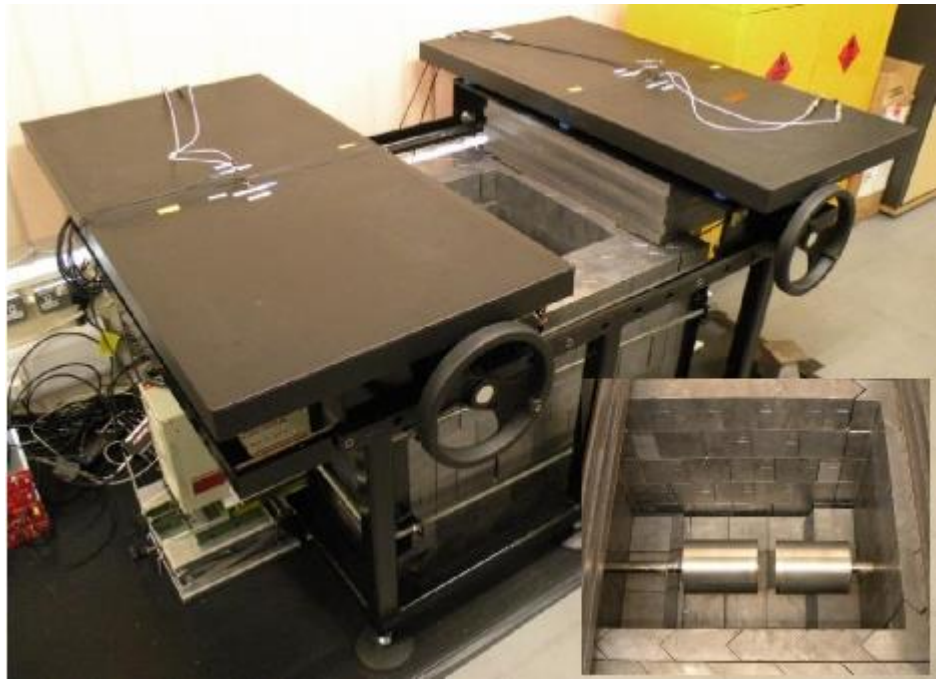




Science and Technology Facilities Council

AWE-Ge

- Atomic Weapons Establishment
- Testing air filtration samples for telltale signs of nuclear experimentation
- CTBT verification
- An ongoing study to see what benefits being underground would give them, compared to their existing lab



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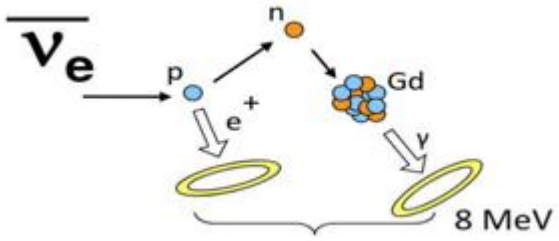
AIT/WATCHMAN/NE1

World antineutrino flux levels

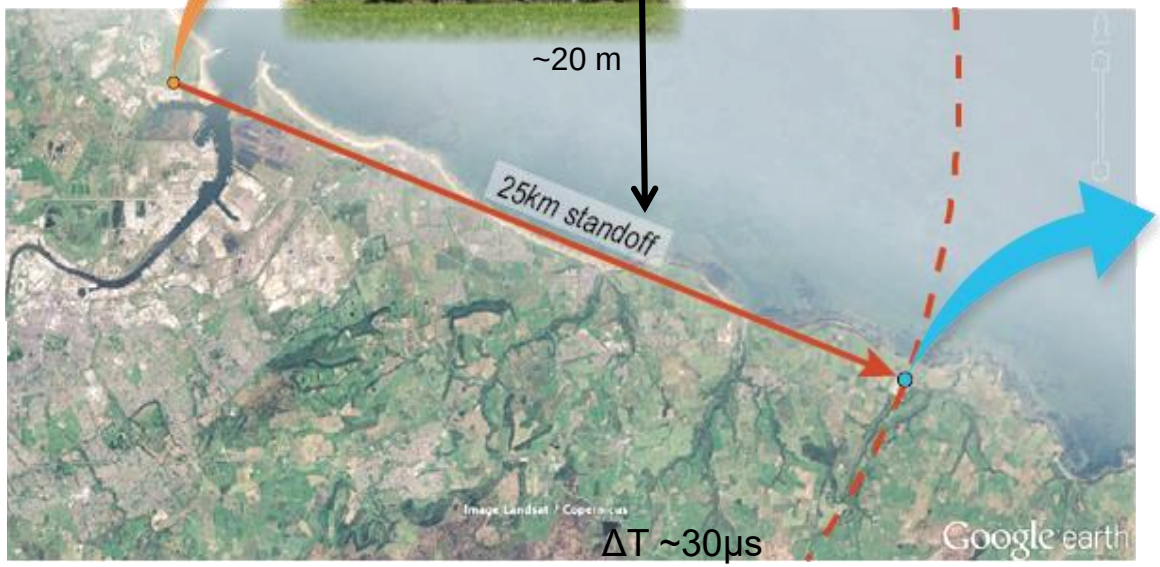
- A WATer CHerenkov Monitor of ANtineutrinos
- 6kT prototype detector: R&D for anti-neutrino monitoring of nuclear reactors for Global Nuclear Non-Proliferation purposes & more



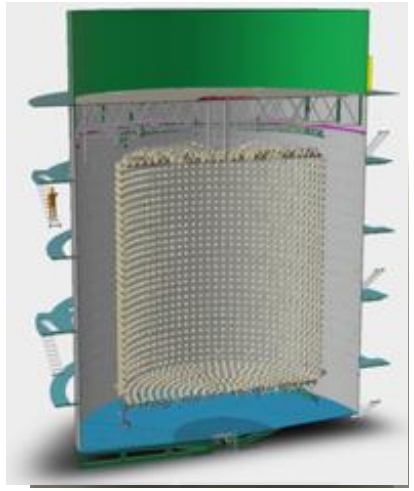
Planned excavation, installation & operation 2020 to 2025(+)

HARTLEPOOL REACTORS

- 2 cores
- 1570 MWt per core
- 25 km standoff



WATCHMAN detector at the Boulby mine



A 6kT Gd-loaded water detector looking at anti-neutrinos from Hartlepool nuclear reactor

- 3500 tons of gadolinium doped water
- 3000 photomultiplier tubes
- Signal: ~11 events/month/core
- Background: ~20 events/month

AIT-WATCHMAN Technology & Science

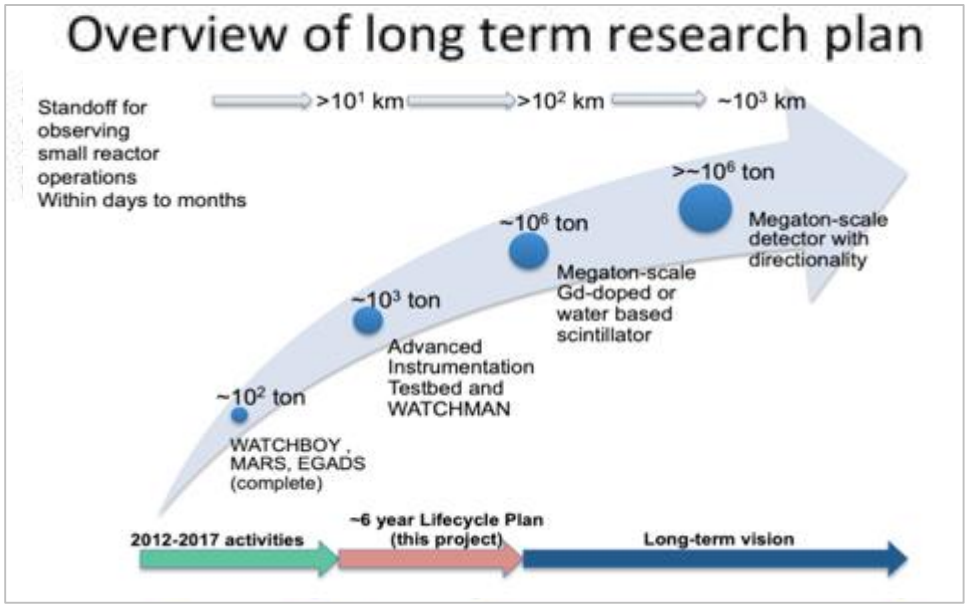
1) Reactor Monitoring for Nuclear Non-proliferation

A prototype R&D detector for proof-of-principle and R&D for remote monitoring of distant reactors

2) Technology Development & Fundamental Science

A world-class research detector for technology development and fundamental neutrino science R&D

A world-class pure & applied neutrino science project

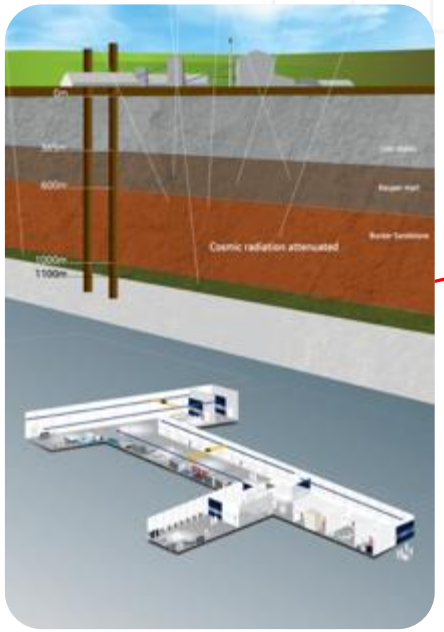


Supernovae Neutrinos: Studies of exploding stars (immediate capability)

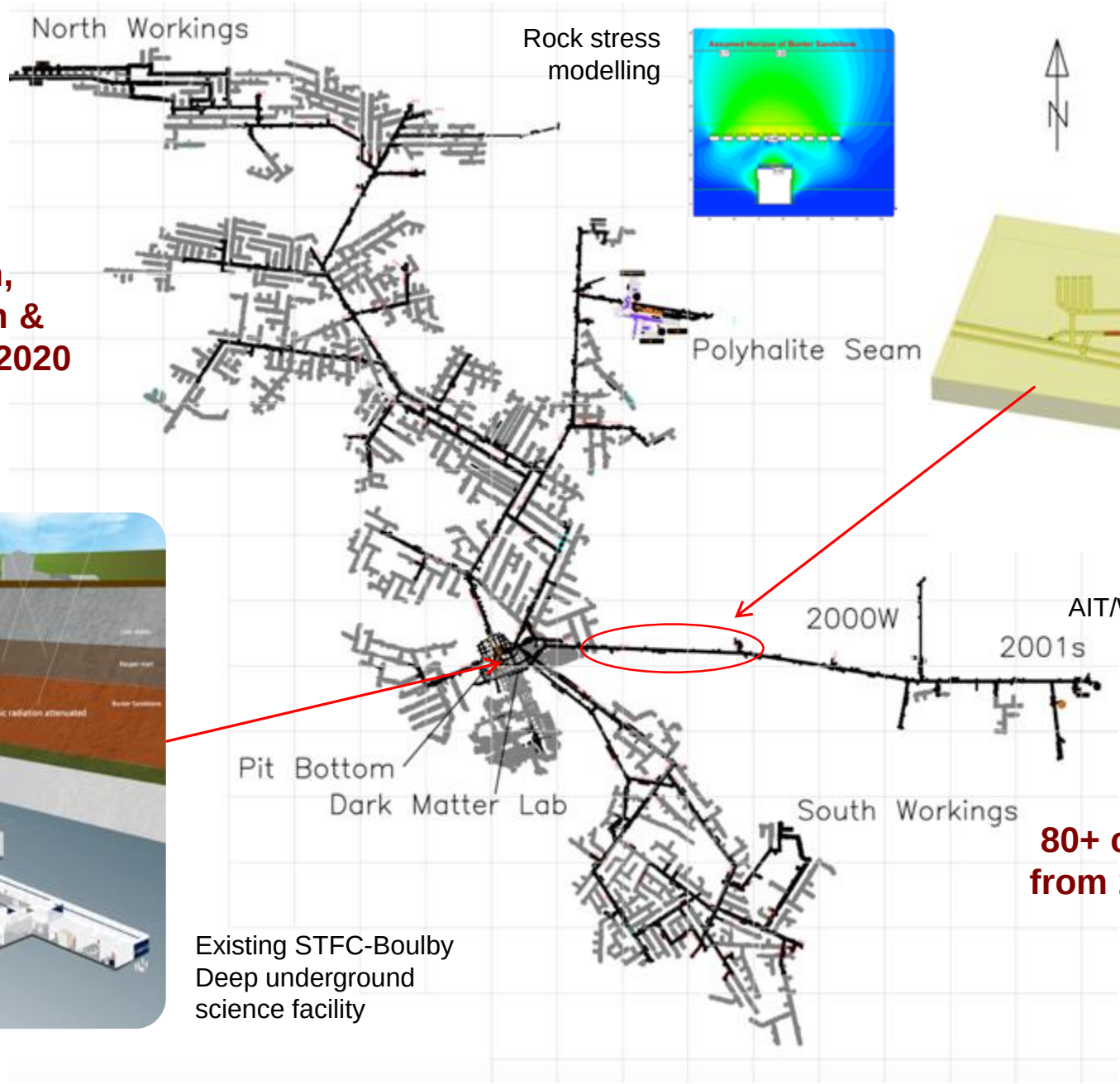
Geo-neutrinos: Studies of the Earth's centre (possible with later AIT phases)

New excavation required

Planned excavation, installation & operation 2020 to 2025(+)



Existing STFC-Boulby Deep underground science facility



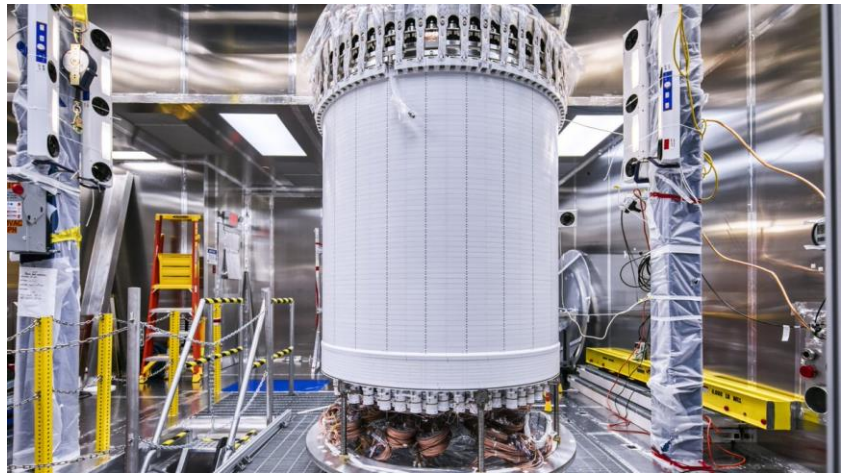
Rock stress modelling

15,000m^3
AIT/WATCHMAN site

80+ collaborators from 20+ US & UK institutions

Generation 3 Rare Event Detector

- Feasibility study started
- Space and facilities need to be thoroughly evaluated
- Simulations of current background and additional shielding
- Technical and cost suitability



STFC Opportunities Call 2019

Feasibility Study for Developing the Boulby Underground Laboratory into a Facility for Future Major International Projects

H Araújo, J Dobson, C Ghag, V Kudryavtsev, P Majewski, S Paling, R Saakyan, P. Scovell, N Smith, T J Sumner

Imperial College London, University of Sheffield, University College London, Rutherford Appleton Laboratory, Boulby Underground Laboratory, [SNOLAB]

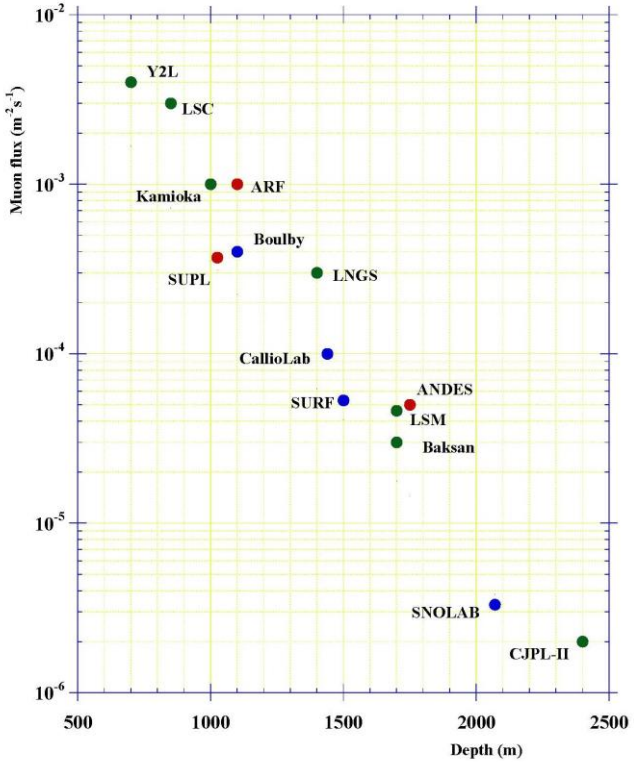
Case for Support

Project Description & Objectives

We propose a feasibility study into the use of the Boulby Underground Laboratory (hereafter Boulby) as a host facility for future major international rare event search experiments in an ultra-low background environment. The outcome will be a report detailing typical experimental requirements and expectations for the construction and operation of a host facility, informed by a conceptual design level engineering study. Use cases from the fields of direct dark matter (DDM) searches, using 50-500 tonnes of liquid target, and neutrinoless double-beta decay (0νBB), with up to 1000kg of solid targets within large volume liquid veto systems, will form the first input. There will be consultation with the wider community on possible candidate experiments. The study will include a recommendation on future development steps for Boulby to evolve as an international facility together with the associated estimated costs involved.

Scientific Justification

Boulby[1] has already successfully hosted a number of international projects, including DDM searches DRIFT I and II [2,3], NAIAD [4], ZEPLIN I, II and III [5,6,7], and a study of aerosol nucleation, SKY[8]. Currently it houses a number of international activities, including one of the world's best screening facilities for low-radioactivity materials, BUGS [9], laboratories for life in extreme conditions (BISAL/MINAR) [10,11] and low-radiation environments [13], and muon tomography



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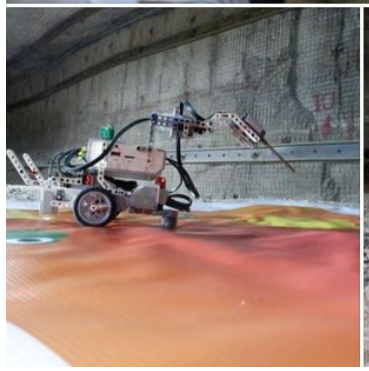
Outreach

This week the Rutherford Appleton Lab have been hosting a group of children for their annual Summer Coding week. This year Boulby was chosen as a site to test their robots as if they were Mars Rovers. The kids have worked hard coding these robots and the live tests are underway now!



Did you know that we run a regular talks programme with different guest speaker, here at the museum? They're great for anyone who loves social and local history or simply for those who want to grab a cuppa and meet like-minded people.

Most of our talks are drop-in on the day and cost £2 which includes a cup of tea or coffee.

The next talk will take place on Tuesday 22 October and is presented by scientist Christopher Toth from STFC's Boulby Underground Laboratory.

Find out more here https://www.prestonparkmuseum.co.uk/home/events/

Science and Technology Facilities Council

Thanks for listening!

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