

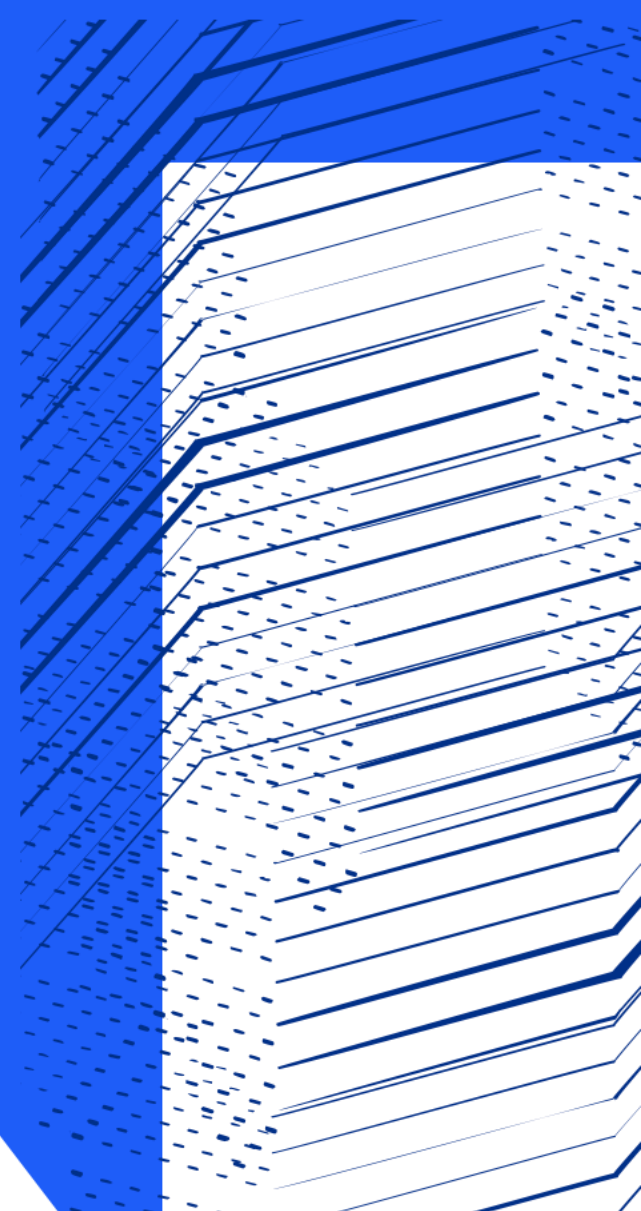


Science and  
Technology  
Facilities Council

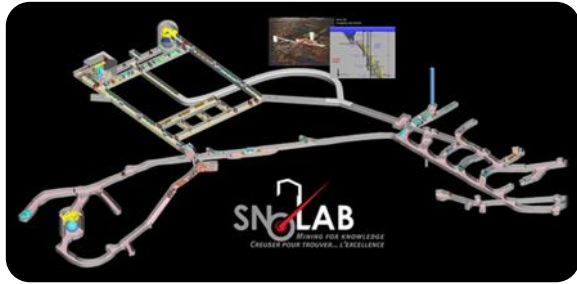
Boulby Underground  
Laboratory

# An Update from the Boulby Underground Laboratory

Paul Scovell – STFC Boulby Underground Laboratory  
and University of Edinburgh



# World deep underground laboratories...

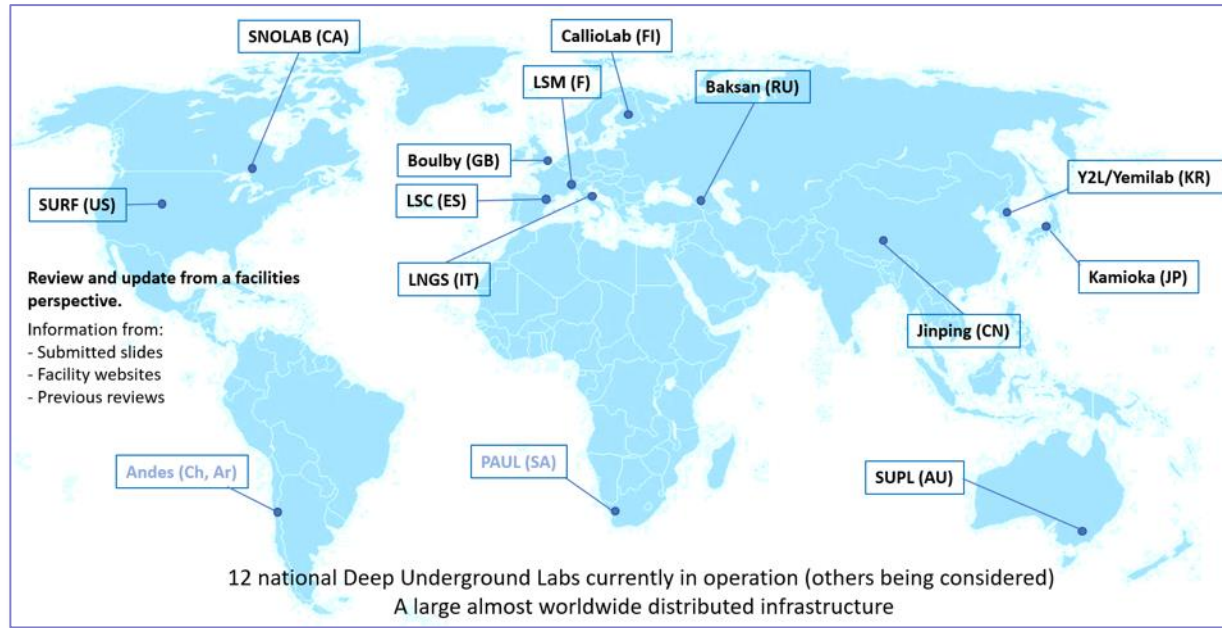


**SNOLAB (Canada)**  
 Active Mine, 5890 mwe  
 Current vol: 30,000m<sup>3</sup>  
 SNO+, SuperCDMS, Deep3600,  
 PICO, Next Gen 0vBB (to come?)

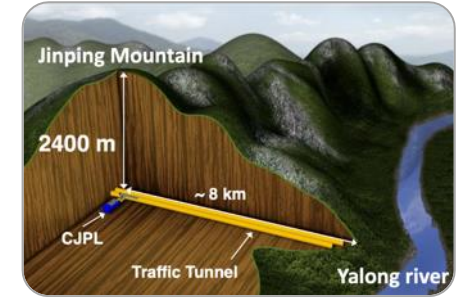


**UKRI** Science and Technology Facilities Council  
**Boulby Underground Laboratory**

## World Underground Labs



**Boulby Underground Laboratory (UK)**  
 Working Mine, 2850 mwe  
 Current vol: 7,200m<sup>3</sup>  
 ZEPLIN (past), BUGS, News-G, RECON,  
 BUTTON & more...



**CJPL Jinping (China)**  
 Hydro power plant, >6000 mwe  
 Current vol: 330,000m<sup>3</sup>  
 Panda-X, CDEX, JUNA,  
 GeoDEX, JNE and more to come

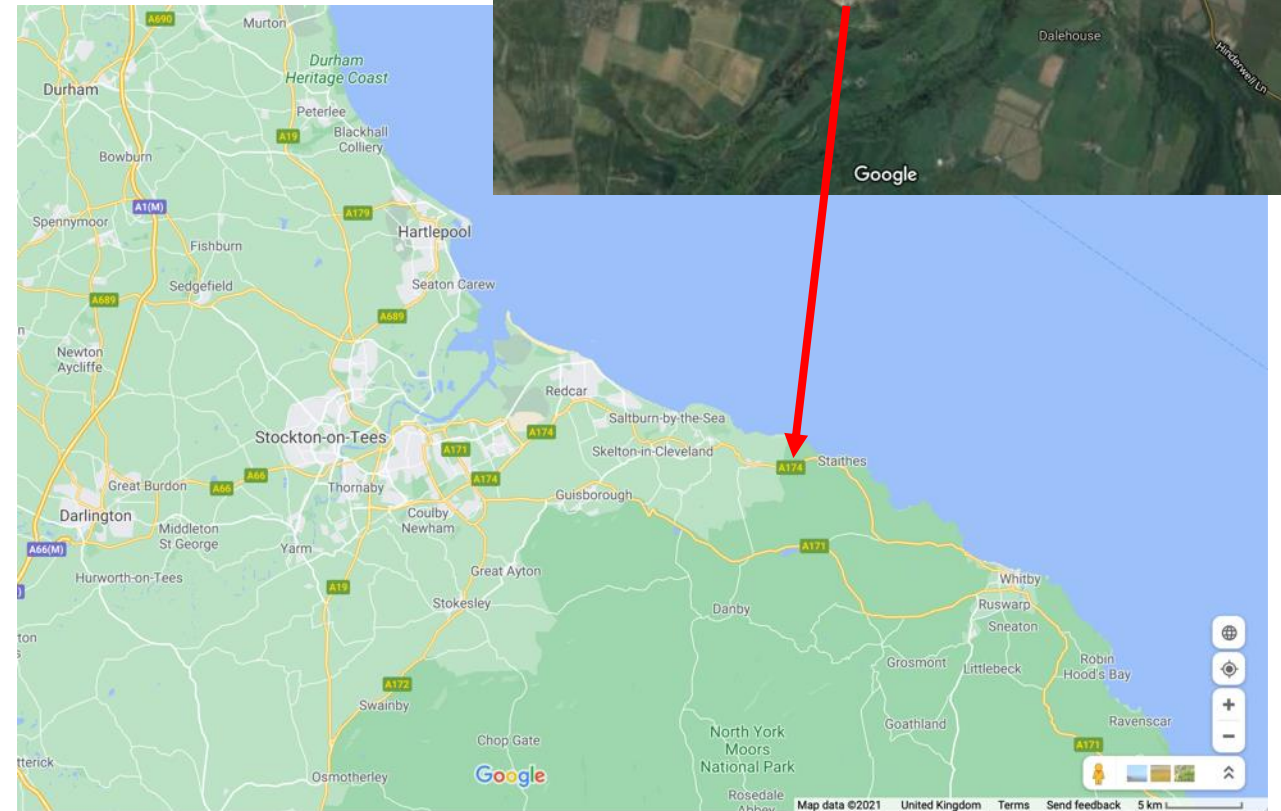
**SURF Laboratory (USA)**  
 Disused Mine, 4200 mwe  
 Current vol: 7,100m<sup>3</sup>  
 LZ, MJD, DUNE (to come)

**Gran Sasso National Laboratory**  
 LNGS (Italy)  
 Under mountain, 3800 mwe  
 Current vol: 180,000m<sup>3</sup>  
 Borexino, Xenon, DarkSide +



# Boulby Mine

- Boulby Mine is located in the north-east of England
- About 25 minutes north-west of Whitby
- Commercial Polyhalite and Salt mine



# Boulby Mine

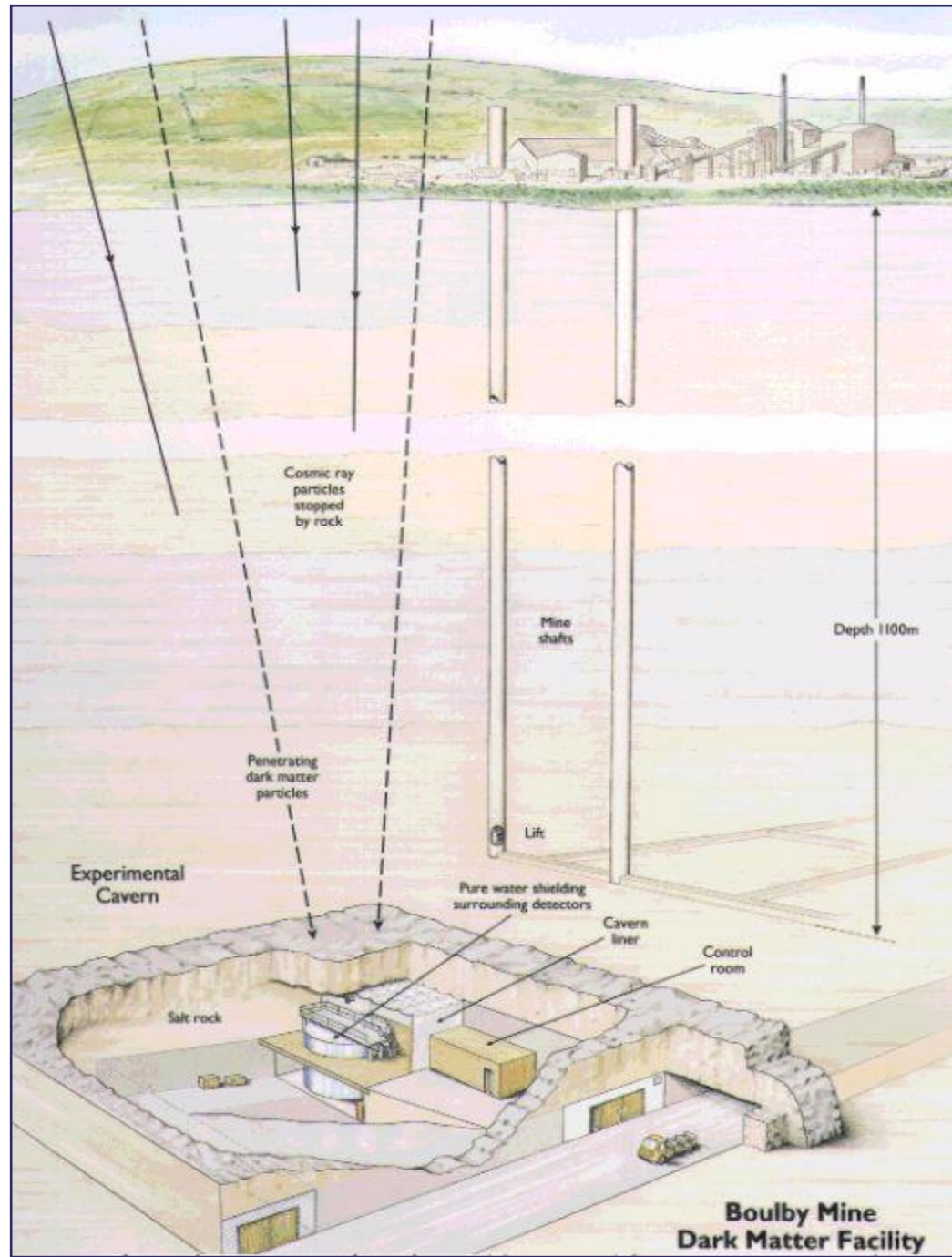


# How did it all start?



John Barton first Published Holborn work on cosmic ray muon showers in 1965

In fact, there had been neutrino experiments even as far back as the 1930s



# A Rich History

- There has been science at Boulby for over 30 years

1989 – earliest known picture



  
ELSEVIER

Physics Letters B 351 (1995) 70–76

25<sup>th</sup> May 1995

Results from the first stage of a UK Galactic dark matter search  
using low background sodium iodide detectors

J.J. Quenby <sup>a</sup>, T.J. Sumner <sup>a</sup>, J.P. Li <sup>a</sup>, A. Bewick <sup>a</sup>, S.M. Grant <sup>a</sup>, D. Shaul <sup>a</sup>,  
N.J.T. Smith <sup>a</sup>, W.G. Jones <sup>a</sup>, G.J. Davies <sup>a</sup>, C.C. Zammit <sup>a</sup>, A.D. Caplin <sup>a</sup>,  
R.A. Stradling <sup>a</sup>, T. Ali <sup>a</sup>, C.H. Lally <sup>a</sup>, P.F. Smith <sup>b</sup>, G.J. Homer <sup>b</sup>, G.T.J. Arnison <sup>b</sup>,  
J.D. Lewin <sup>b</sup>, G.J. Alner <sup>b</sup>, A.M. Cruise <sup>b</sup>, M.J.J. van den Putte <sup>b</sup>, N.J.C. Spooner <sup>c</sup>,  
J.C. Barton <sup>d</sup>, P.R. Blake <sup>e</sup>, M.J. Lea <sup>f</sup>, P. Stefanyi <sup>f</sup>, J. Saunders <sup>f</sup>

<sup>a</sup> *Blackett Laboratory, Imperial College of Science, Technology and Medicine, London SW7 2BZ, UK*

<sup>b</sup> *Rutherford Appleton Laboratory, Chilton, Oxfordshire OX11 0QX, UK*

<sup>c</sup> *Physics Department, University of Sheffield, Hounsfield Road, Sheffield S3 7RH, UK*

<sup>d</sup> *Physics Department, Birkbeck College, Malet Street, London WC1E 7HX, UK*

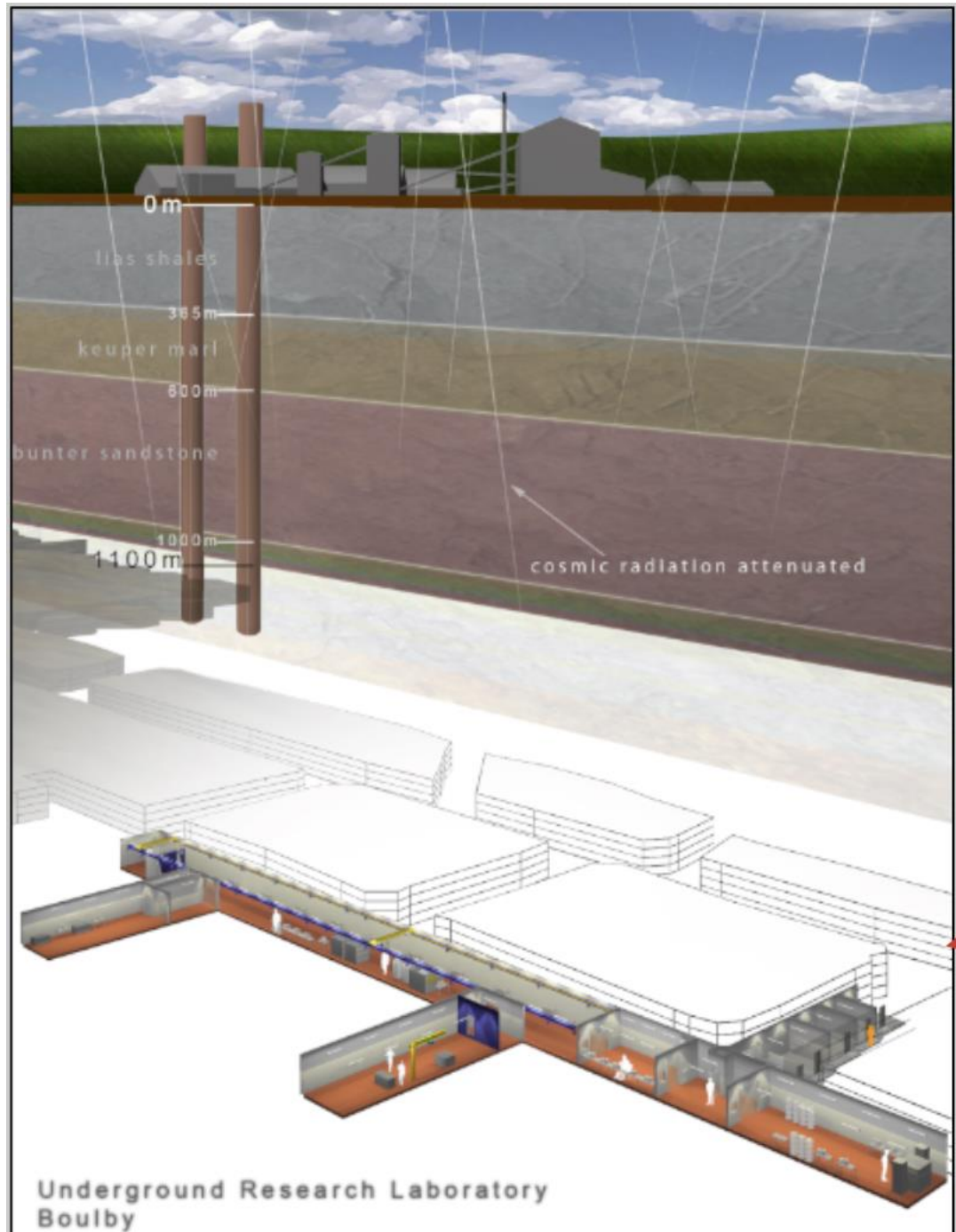
<sup>e</sup> *Physics Department, University of Nottingham, University Park, Nottingham NG7 2RD, UK*

<sup>f</sup> *Physics Department, Royal Holloway & Bedford New College, Egham, Surrey TW20 0EX, UK*

# A Rich History

NAIAD

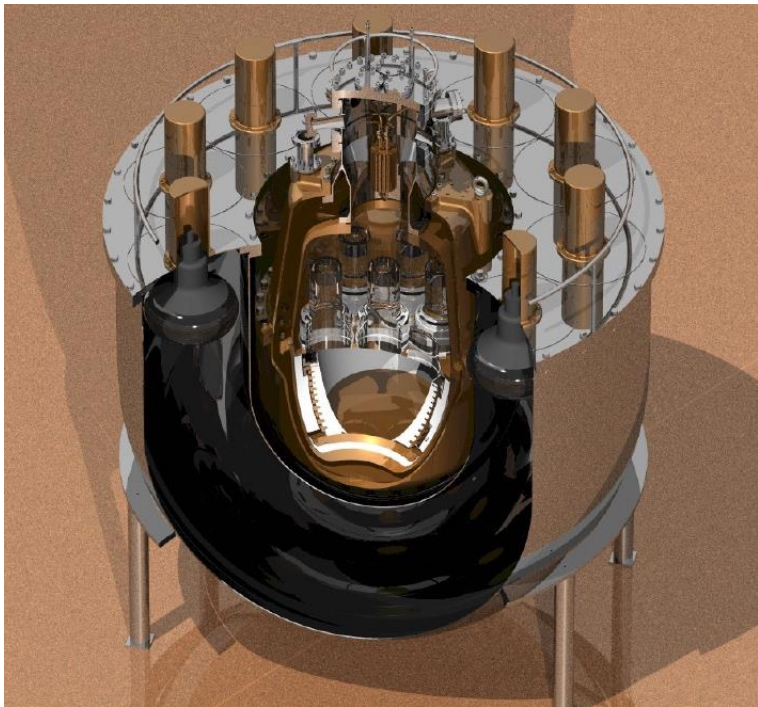




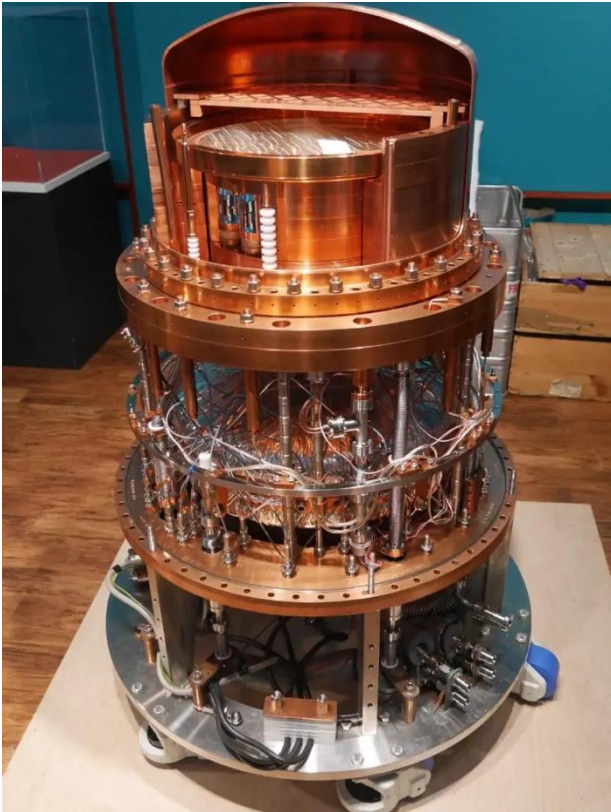
# A Rich History



# A Rich History



# A Rich History



# Current Science Programme

- Low Background Particle & Nuclear Physics
- Earth & Environmental Science
- Astrobiology & Planetary Exploration
- Quantum Sensors & Computing
- Outreach & Education

# Boulby Underground Lab 2026

The UK's deep underground science facility operating in a working potash 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-UK

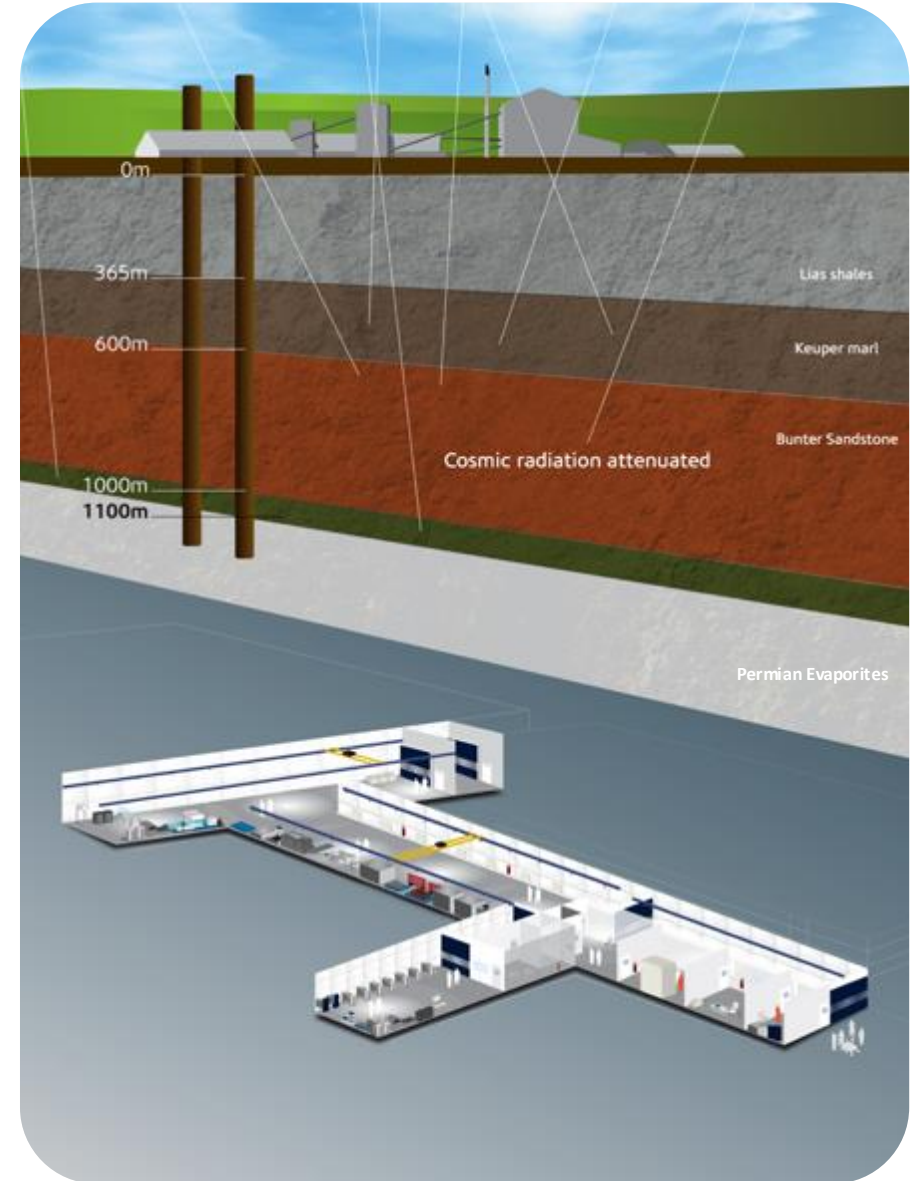


Outside Experimentation Area (OEA)



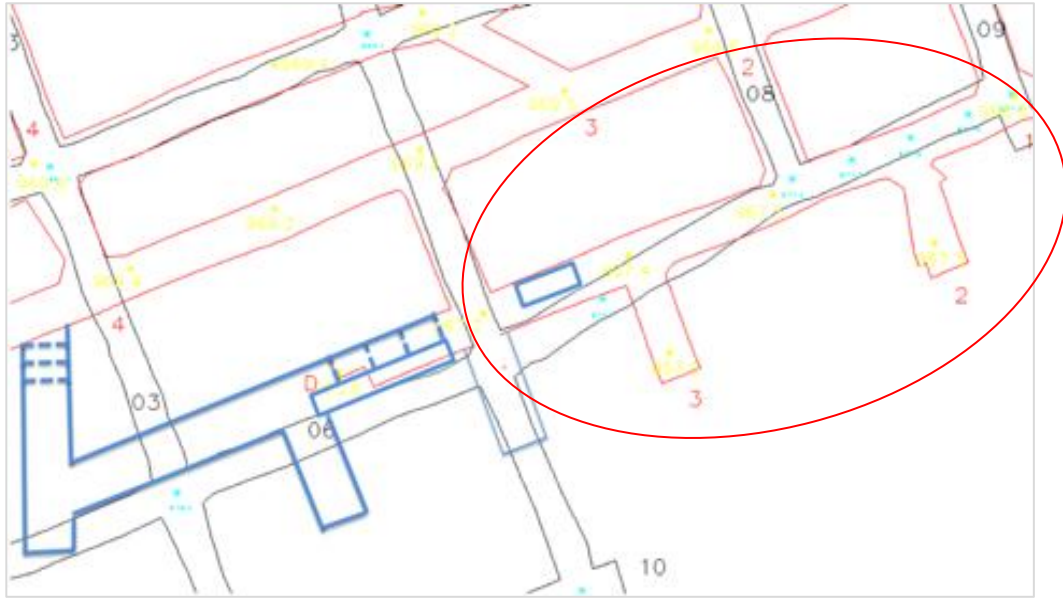
Lab entrance

*Factor ~10<sup>6</sup> reduction in cosmic ray flux vs. surface*



A **QUIET** place in the Universe

# OEA



Lighting, 240/110V power, Internet / WIFI. Ventilation, doors, MINAR Base Station Hut

## 'Outside Science'

Geology & Geophysics  
Astrobiology,  
MINAR, Mars  
Analogue space



Boulby Underground  
Laboratory

# BUGS

See:  
 A. Hamer Talk  
 K. Johnson & B. Green Posters



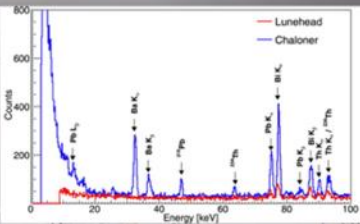
XIA alpha particle counter



**BUGS (Boulby UnderGround Screening).** World-class material screening for current and future ULB experiments. Towards PPT sensitivity for G3 DM and Neutrino experiments



8 ULB Ge detector systems, 2 XIA alpha counters, 2 Rn emanation systems, ICPMS



Aiming for **ALL** key ULB screening systems under one (1.1km) roof.



**BUGS (UG):** A range of HPGe detectors and alpha particle detectors for intrinsic and surface radioactivity measurements.



**ICP-MS (Surface):** Newly installed system for trace element analysis and isotopic ratio measurements.

**BUGS Facility:** (Boulby Under-Ground Screening)

- ULB Germanium (8)
- XIA: Surface alphas (2)
- Radon Emanation (2)
- ICPMS-QQQ \* All now in operation

# BUTTON: a technology testbed for future (anti)neutrino detection



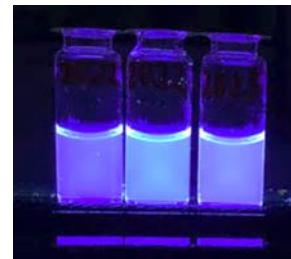
World antineutrino flux levels



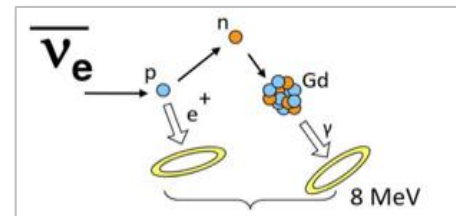
Jan 2025.  
BUTTON-30 now assembled and preparing for liquid fill

BUTTON-30 is a proof of concept for a future 1-kT detector providing 100-tonne fiducial volume

Part of a worldwide effort to develop WbLS detector technology. Other experiments include EOS at LBNL and the Brookhaven 30-ton at BNL.

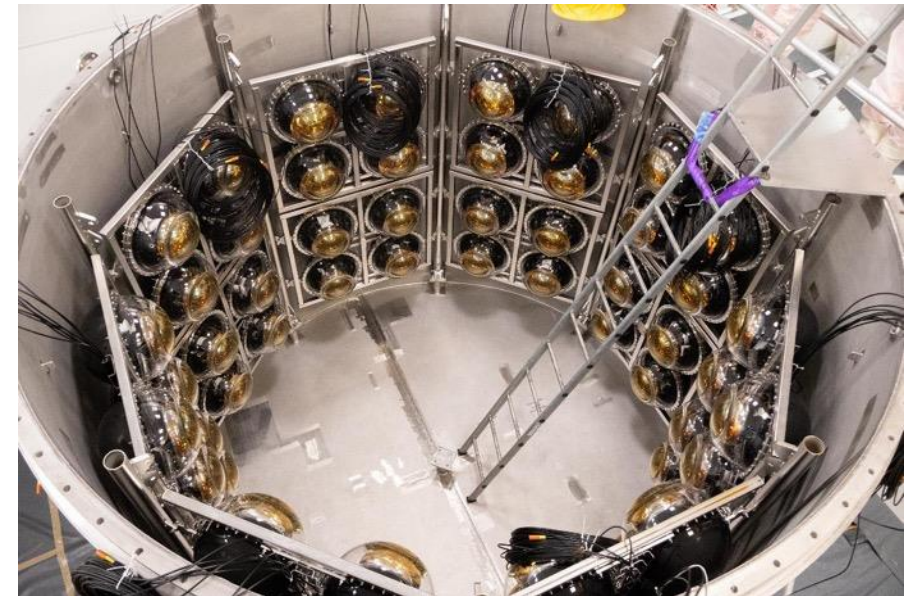


Water Based Liquid Scintillator (WbLS)



Anti-neutrino discrimination with Gd-H<sub>2</sub>O

~50 members across 16 institutions in the UK and U.S.



Button @ Boulby Feb 25

# Spherical Proportional Counters (SPC) at Boulby

# DarkSPHERE

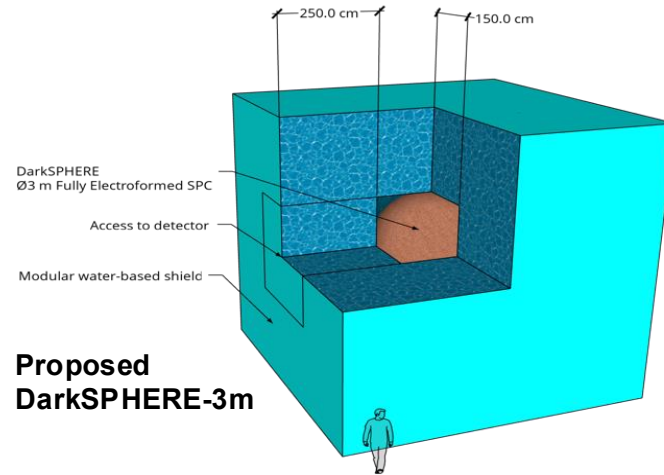
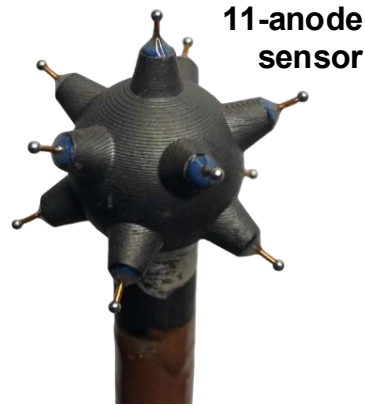
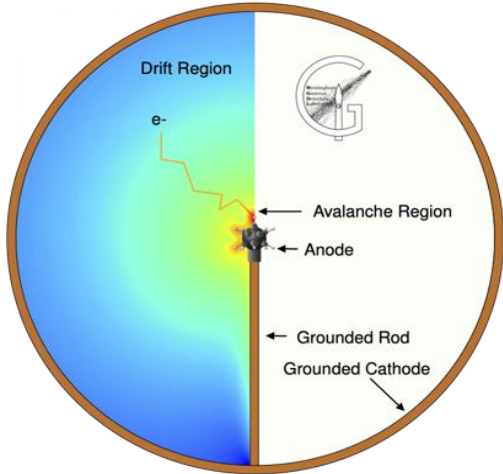
[Phys. Rev. D 108, 112006](#)

P. Knights, I. Manthos, L. Milligan, L. Millins, K. Nikolopoulos, G. Rogers, D. Spathara, P. Walters  
 University of Birmingham, University of Hamburg  
 and international NEWS-G Collaboration



## Activities at Boulby

- Instrumentation developments
  - Multi-anode sensor
  - Gas filtration
  - Rate effect studies
- Neutron spectroscopy (with N<sub>2</sub> gas)
  - Neutron background surveys
  - Industrial applications
- High-purity copper electroformation
- **Towards scaled-up, electroformed, detector at Boulby, 3m diam. 5 bar**  
 He:CH<sub>4</sub>H<sub>10</sub> **DarkSPHERE**

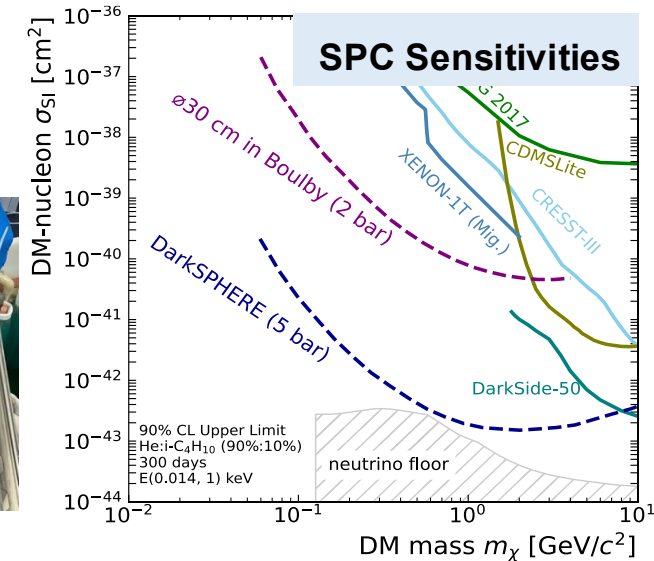
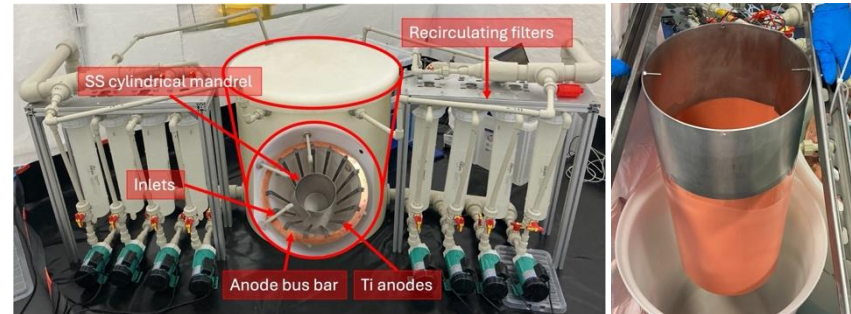


See: L. Milligan Talk  
 G. Rogers Talk  
 P. Walters Talk

SPC concept: Variable target  
 Low E<sub>th</sub>, Low mass sensitivity

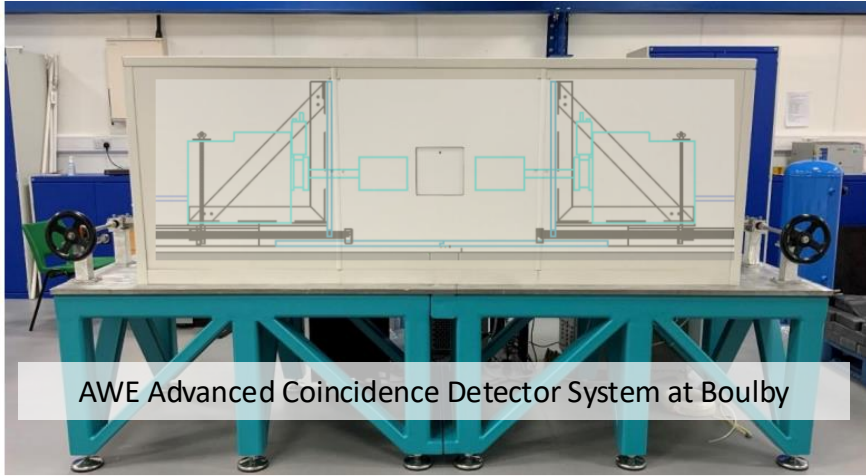


Boulby Underground Laboratory

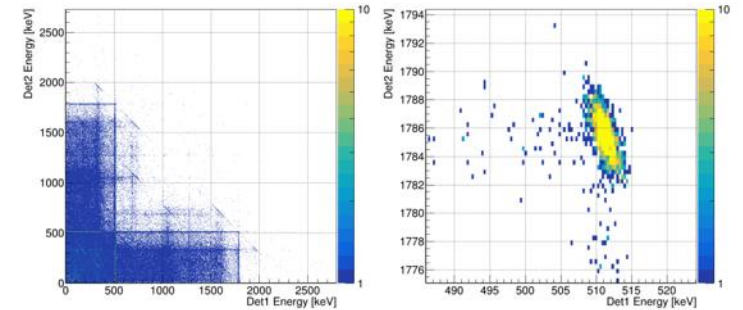


# RECON – CTBT Verification.

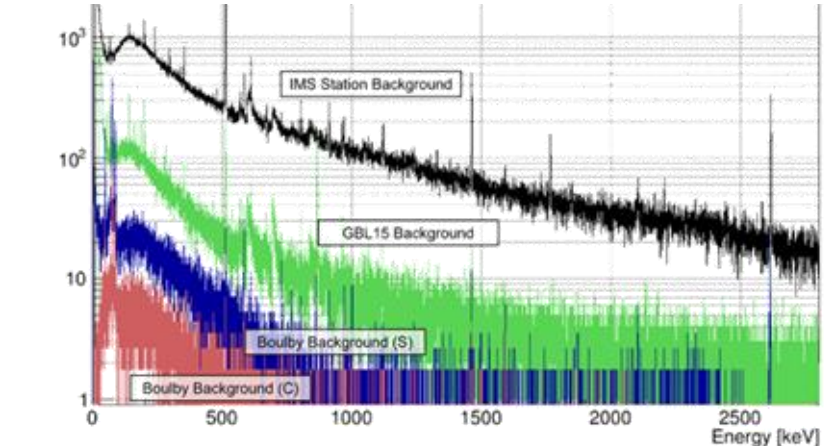
Enhancing the capability to monitor for signs of nuclear testing



AWE and STFC Boulby have recently established a collaboration framework



AWE-Boulby systems are ~100x more sensitive for some radionuclides



AWE have been collaborating with STFC Boulby for ~ 8 years to develop an advanced coincidence detector system capable of improving measurement sensitivity for radionuclide samples used for verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT).



Boulby Underground Laboratory

Figures from Goodwin *et al.*, (2025)

# Multidisciplinary Science

Applied low background particle physics, Earth and Environmental science, Astrobiology & Planetary Exploration Technology Development.

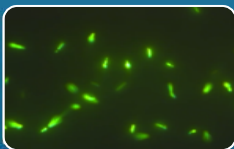
Deep CARBON: Muon Tomog R&D for CCS & more

MINAR: Astrobiology and planetary exploration technology development

## MINAR Programme 2018 - present



NASA-JPL Signatures of life studies



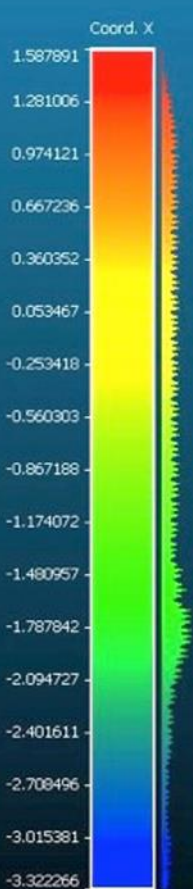
Lulea University KORE rover 3D area mapping

Remote<sup>3</sup> Public Engagement



Birmingham University BIOSPHERE Human Habitability Studies

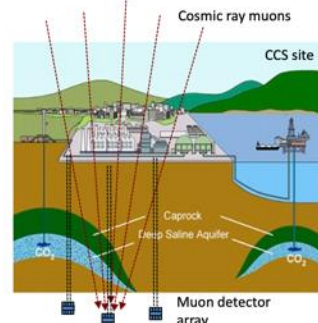
Edinburgh University MUFFHINS water activity monitoring payload



## Muon Tomography / Geo-survey

Development of a Muon Tomography techniques for deep 3D geological surveying - inc Carbon Capture @ Storage (CCS)

STFC-Boulby, Durham, Sheffield, Bath, NASA



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)

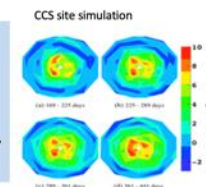


Muon-tides detector development



Bore hole detector installation

**Status:** Project phase 1 complete. Spin-out company for Muon Tomog applications created (Sheffield, Durham).  
**Next:** UK-Japan proposed study of Muon Tomography for Tsunami early warning (2020)



**Deep-Carbon Project:** £1.4M funding from UK Dept of Energy & Climate change (DECC) & Premier Oil.

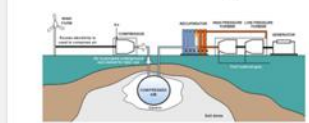
- Bore-hole detector development & testing
- Muon-Tides technology demonstrator
- Simulations of technique performance in CCS

RESOURCE: Compressed gas energy storage R&D

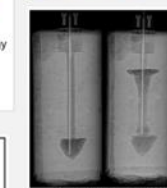
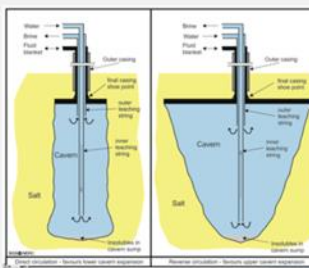
## Renewable Energy StORage in UnderGround CavErns (RESOURCE)

RESOURCE Collaboration: British Geological Survey, Boulby Underground Lab, University of Cardiff

### Low Carbon Technologies

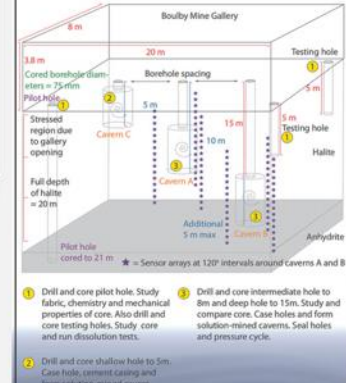


- Engineering solutions have been devised to store energy whilst production is high and feed it into the grid when production is low (e.g. CAES, hydrogen storage)
- Helps to regulate the production of renewable energy



Above: Slowing salt-based dissolution rate of salt from Boulby Mine, giving insight into the solution mining process.

### Plan for In-situ Testing at Boulby Mine



Mid-scale rock engineering tests of gas containment in salt cavities for energy storage

- 1 Drill and core pilot hole. Study fabric, chemistry and mechanical properties of core. Also drill and core testing holes. Study core and run dissolution tests.
- 2 Drill and core shallow hole to 5m. Case hole, cement casing and form solution-mined cavern.
- 3 Drill and core intermediate hole to 8m and deep hole to 15m. Study and compare core. Case holes and form solution-mined caverns. Seal holes and pressure cycle.

# Boulby Future Earth and Environmental Science

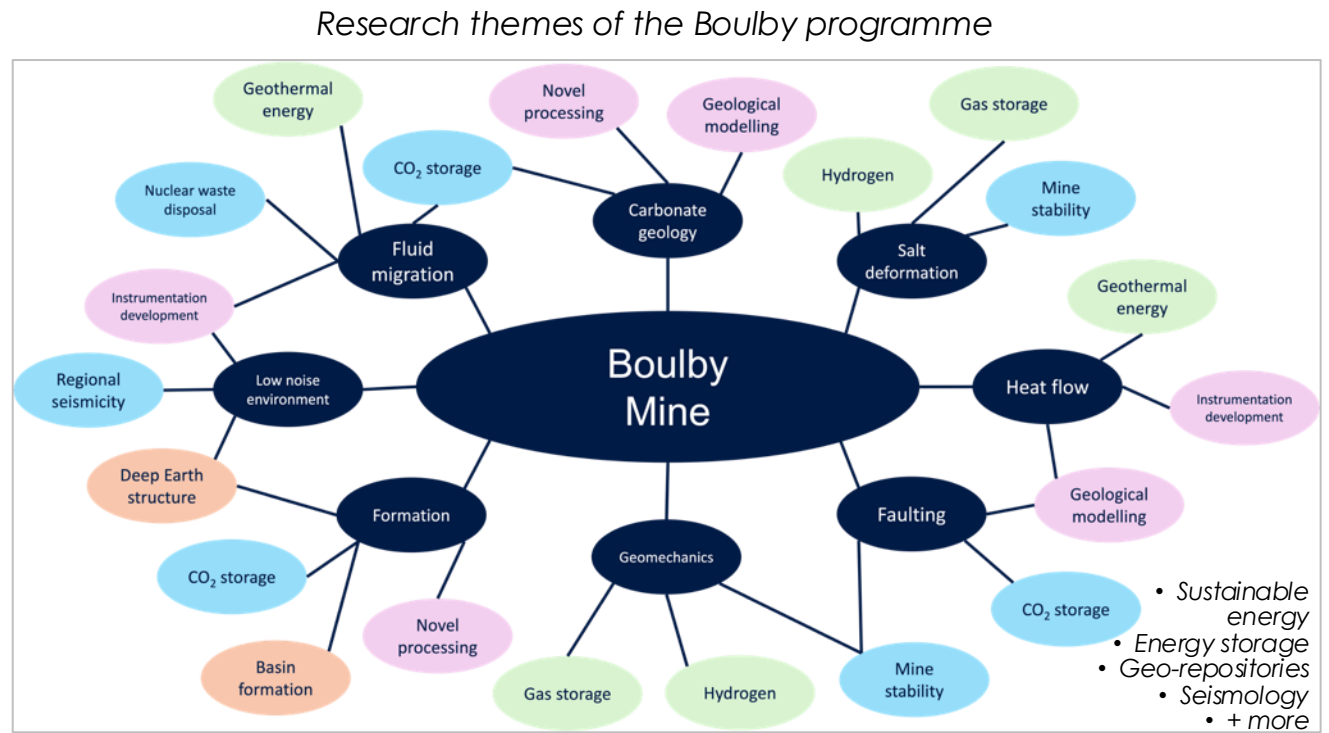
Developing program of Earth science research at Boulby by a consortium of UK universities and industry.

## Earth science at Boulby workshop August 2024

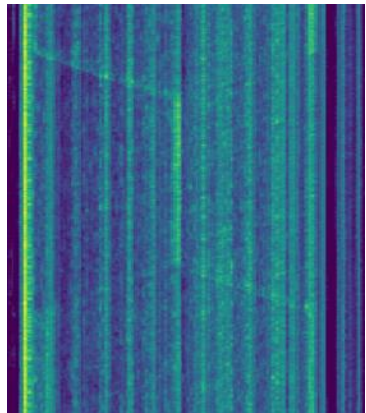
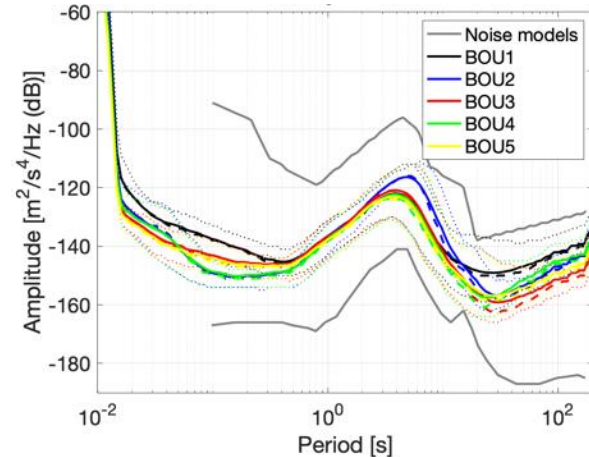


Workshop of 17 universities and 4 companies has led to a proposal of an integrated program of Earth science research, currently being considered by NERC.

NERC scoping study proposal



## Developing a community coordinated programme of Earth Science @ Boulby



Seismometers and fibre optic acoustic sensors deployed to baseline vibration levels for AION experiment and North Sea regional earthquake monitoring.

# Quantum Sensors and Computing @ Boulby...

**AION-100 & AION-1000 @ Boulby?**

**AION** Atom Interferometer Observatory and Network

1. Strontium atoms are cooled to a ultra-low temperature and trapped in the center of a vacuum chamber.  
2. The atoms are launched vertically and allowed to fall freely.  
3. An external laser pulse is used to split the atoms into two paths, one of which is deflected by a mirror. The atoms are then recombined and their interference pattern is measured.  
4. A second pulse is used to recombine the atoms, which are then detected. The resulting interference pattern is used to measure the acceleration of the atoms.  
5. The resulting interference pattern is used to measure the acceleration of the atoms, which is then used to measure the acceleration of the atoms.

Given the technique is proven at the 10 metre scale, the project will be scaled up to a 100 metre facility that will be constructed within an existing infrastructure at the Boulby Underground Laboratory. The hope is that the project can then be scaled up to 1000 metres, which will require a new underground facility.

Boulby Underground Laboratory 2023

AION-20, 100 & 1000: Atomic interferometry for GW and light DM studies

Quantum Computing in Ultralow background environment?

**Quantum Computing Going Underground**

Quantum computers may be heading underground to shield from cosmic rays  
31 Aug 2020

Future quantum computers may have to be built UNDERGROUND to protect them from cosmic rays and other natural radiation that can hinder their performance, study claims

MailOnline

PUBLISHED: 09:34, 27 August 2020

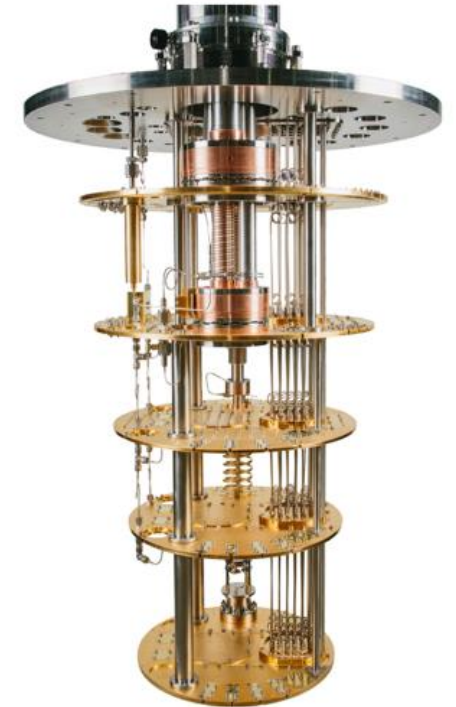
**Environment Required:**

- Low cosmic ray rate and ambient ionising background Underground
- Cryogenic capabilities
- High data rate capabilities
- Secure space, reliable services (power, cooling etc)

physicsworld

Quantum Computing | RESEARCH UPDATE  
Cosmic-ray threat to quantum computing greater than previously thought  
28 Jul 2021 Margaret Harris

Coming to Boulby v.soon!  
Oxford Instruments  
Proteox MX Dilution Fridge



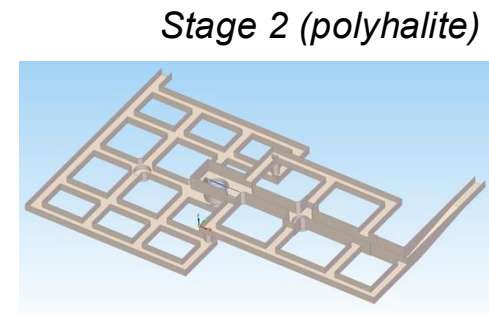
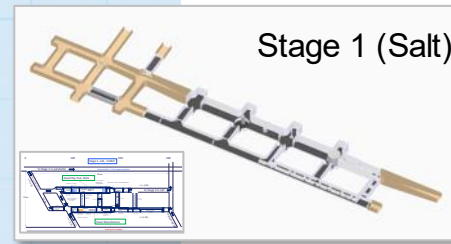
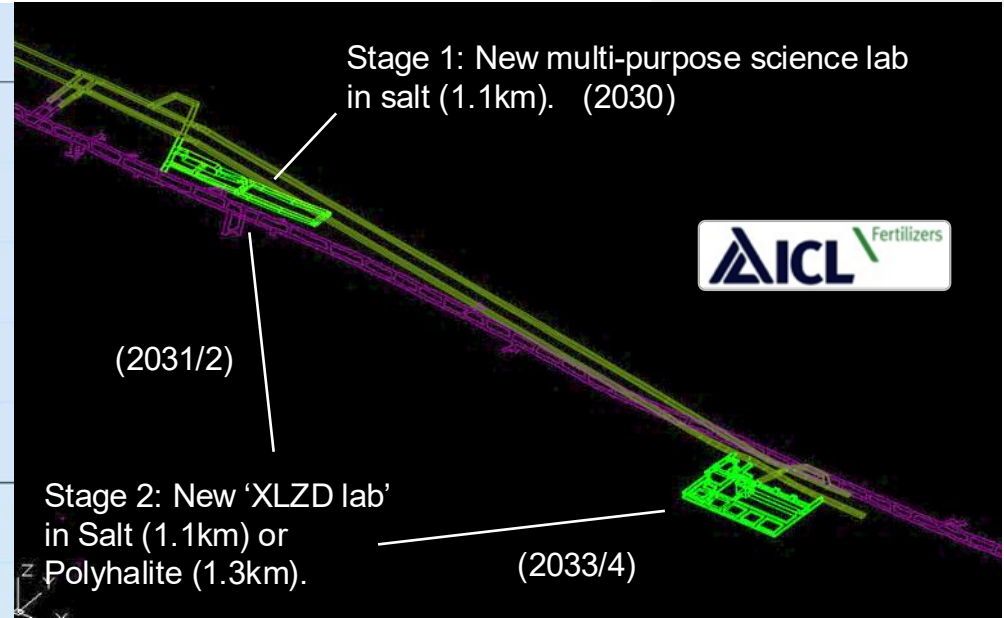
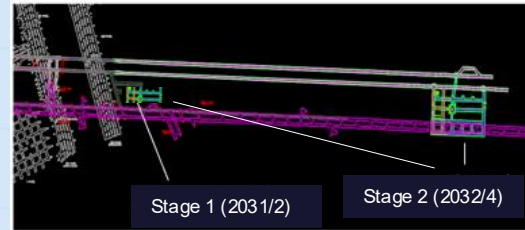
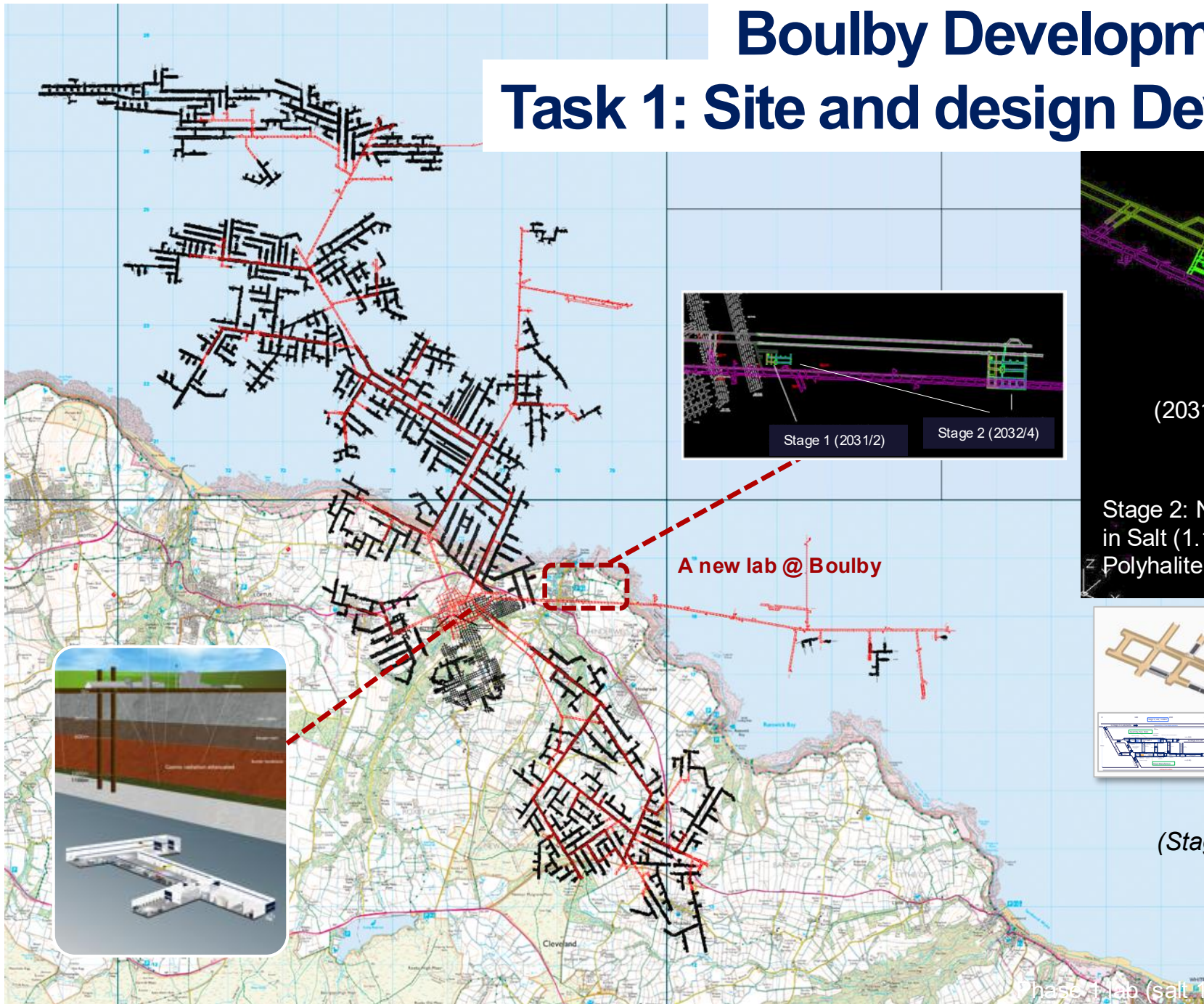
In collaboration with NQCC  
Will be available for use by wider community.

## A growing Quantum @ Boulby community:

- Planning future quantum sensors and computing R&D and operation
- Helping to specify technical infrastructure needs for a future hosting facility
- Community meetings held Sept 24, October 25
- **Durham laser cold atom project (QuASAR) being installed @ Boulby (3/26).**

# Boulby Development Project

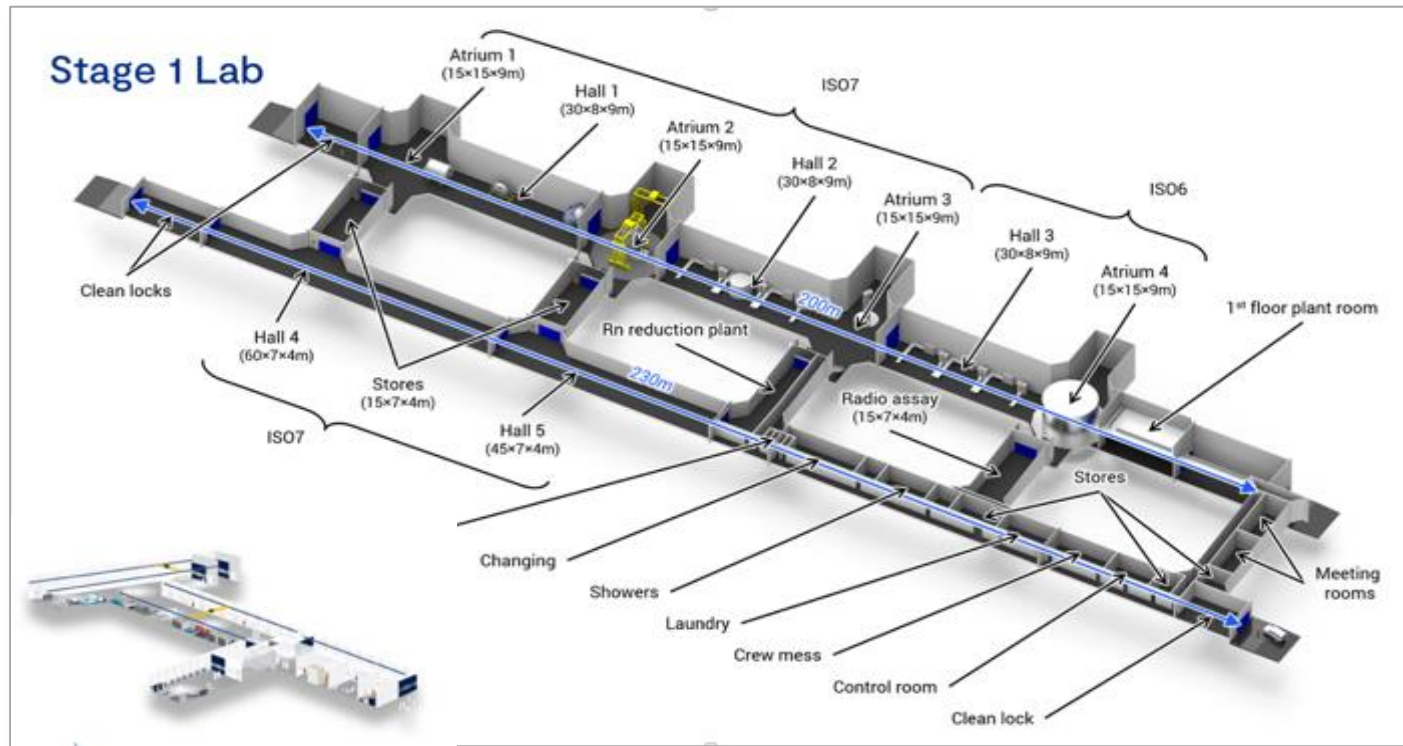
## Task 1: Site and design Development.



Total volume  
(Stage 1 + stage 2)  
~120,000m<sup>3</sup>

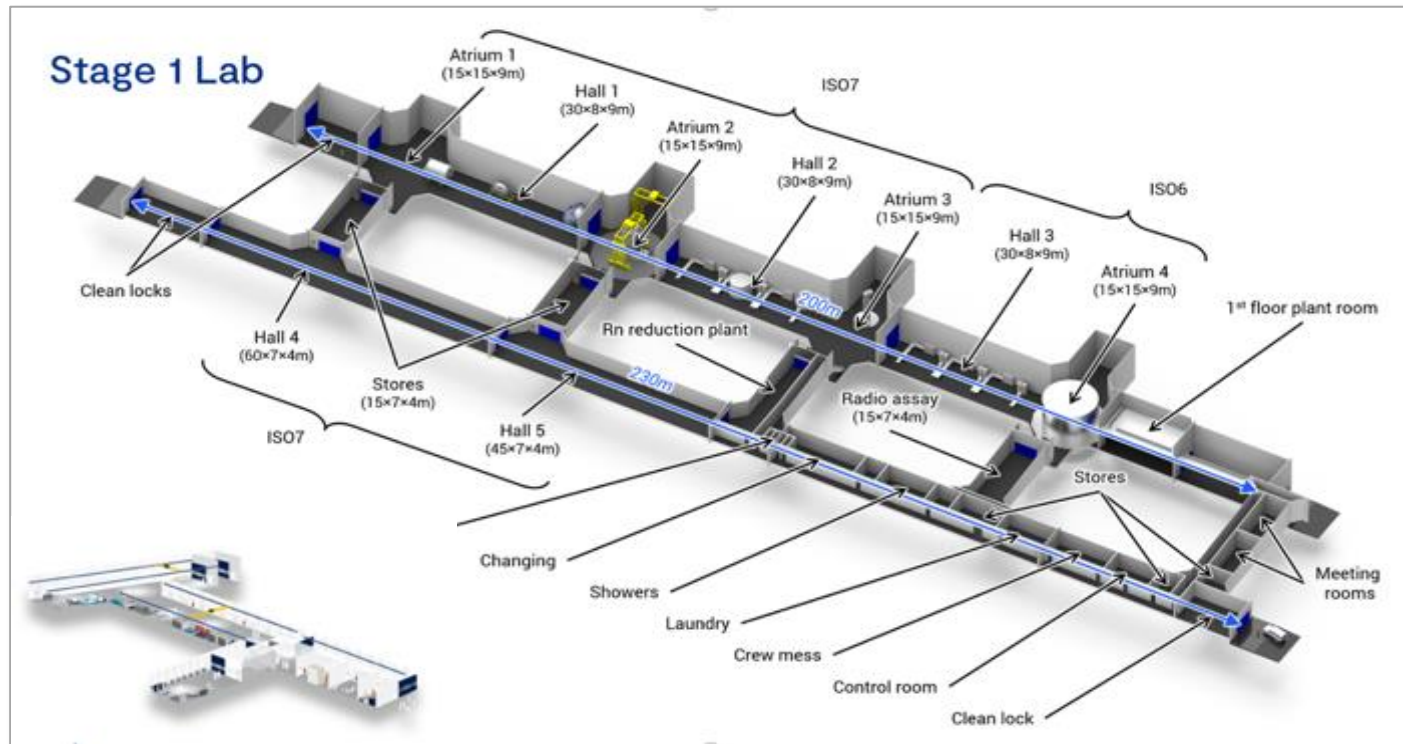
**Excavations for stage 1 of expansion by ICL-UK began in mid-2024.**

# Stage 1: A new world-class multi-disciplinary deep underground science facility.



Excavation underway – Aug 24

# Stage 1: A new world-class multi-disciplinary deep underground science facility.



# Stage 1 Outfitting

A new, world-class multidisciplinary science facility, complementing and succeeding the current Boulby laboratory



Surface Building Development

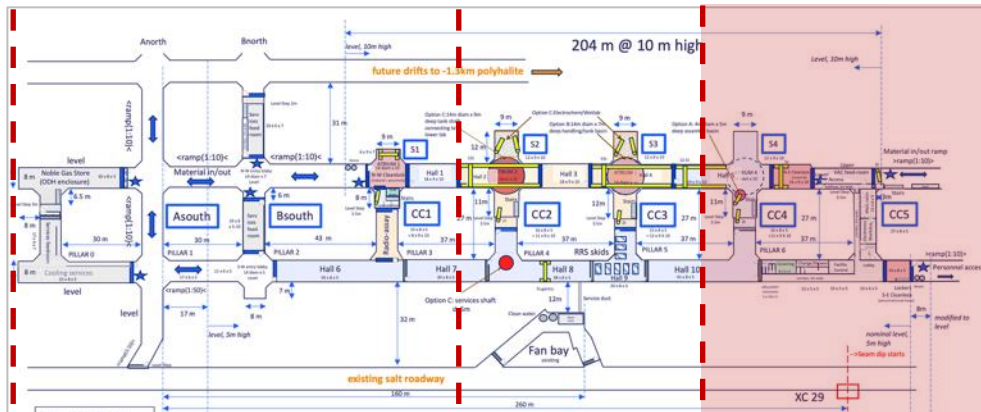


Stage 1 Lining Options

**Costs and schedule:**  
 SOP 1: 2028 (~£20m)  
 Total (SOP 1+2+3): 2030/1 (~£50m)  
 Total (inc surface etc): ~£65m

Possibility for single shot or phased outfitting

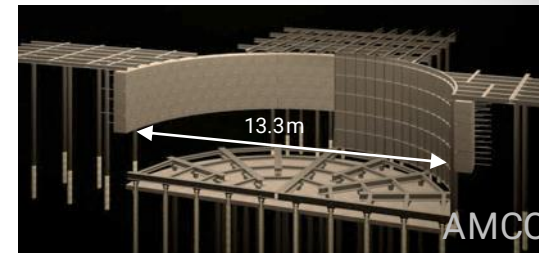
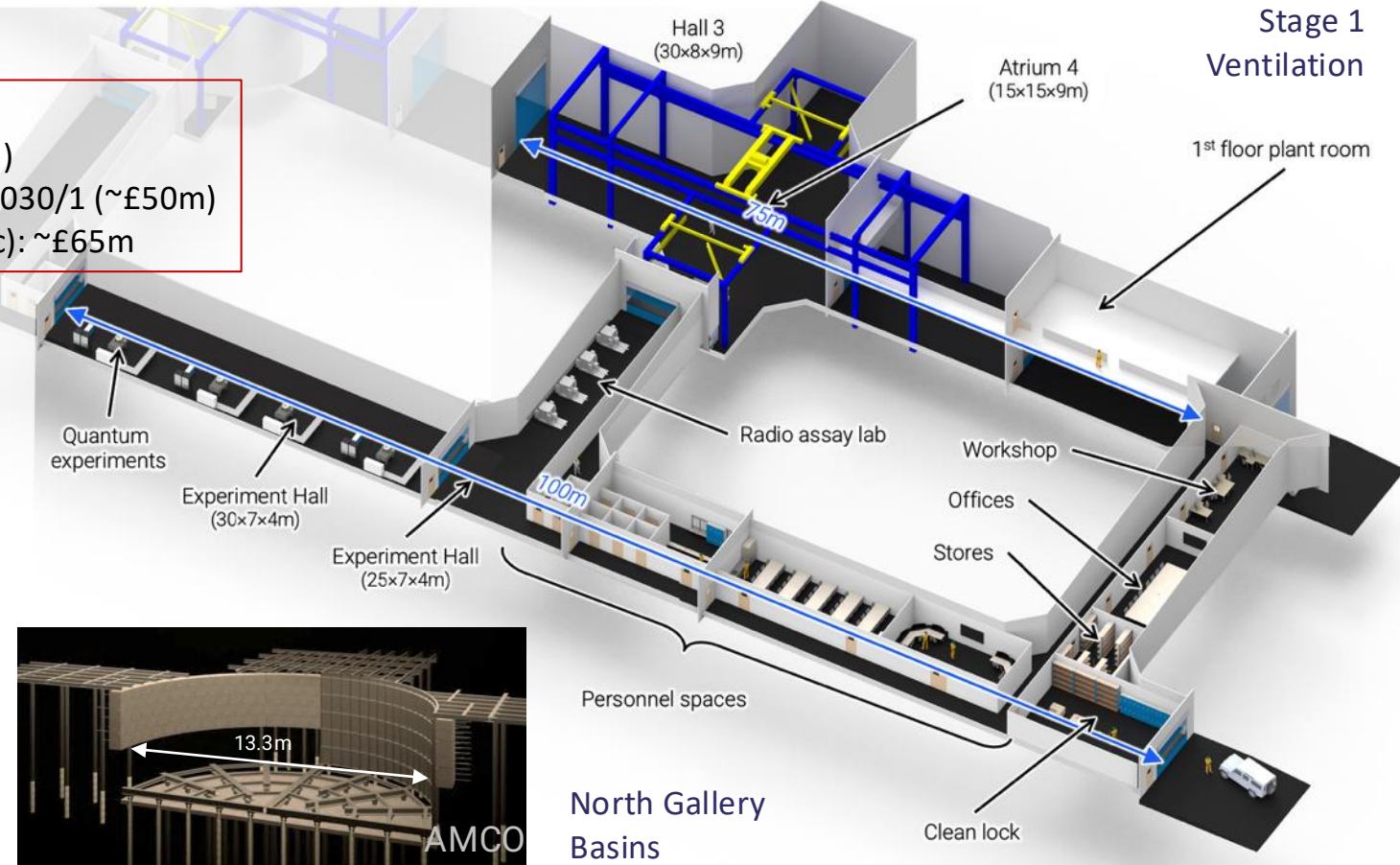
Staged Outfit Phase 1 (SOP1)



SOP3

SOP2

SOP1

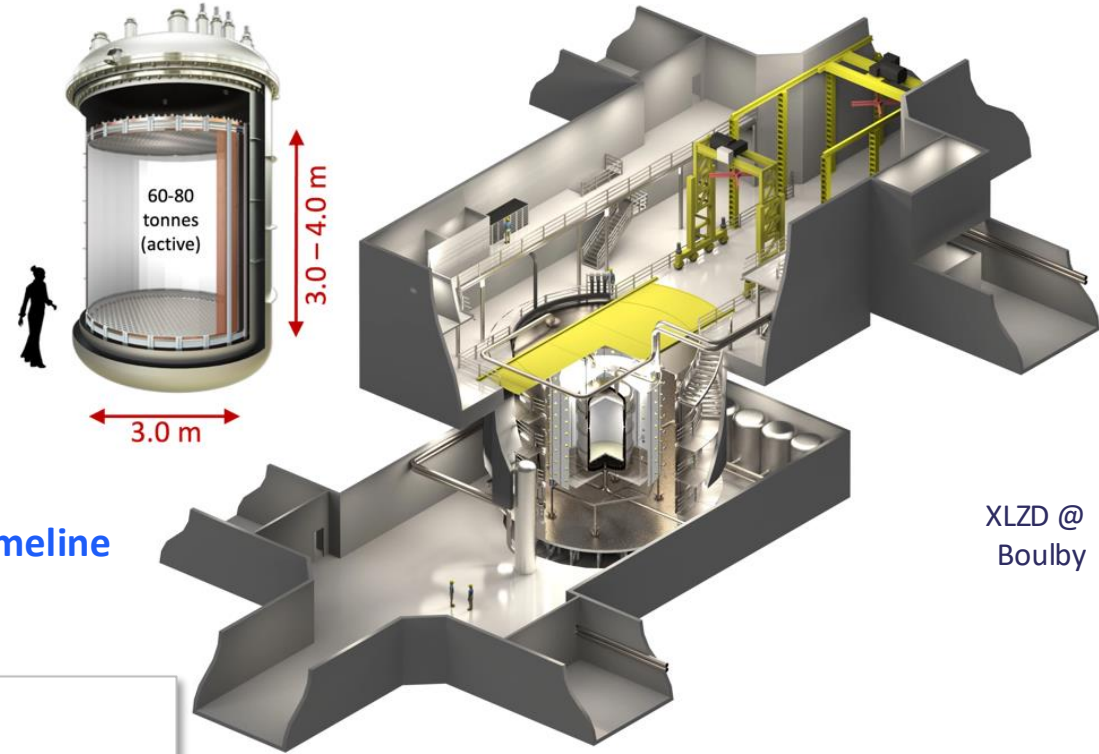


AMCO

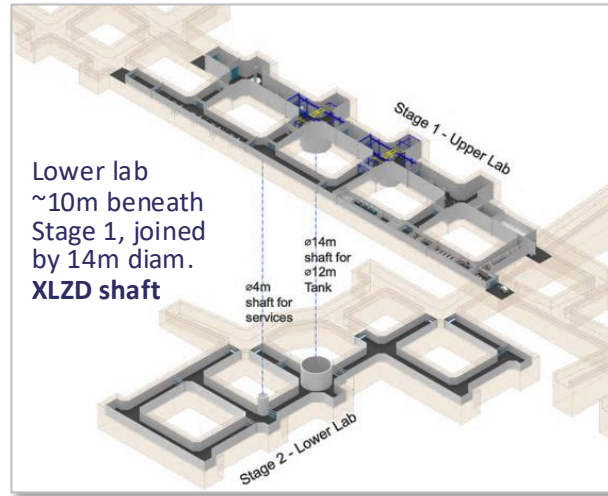
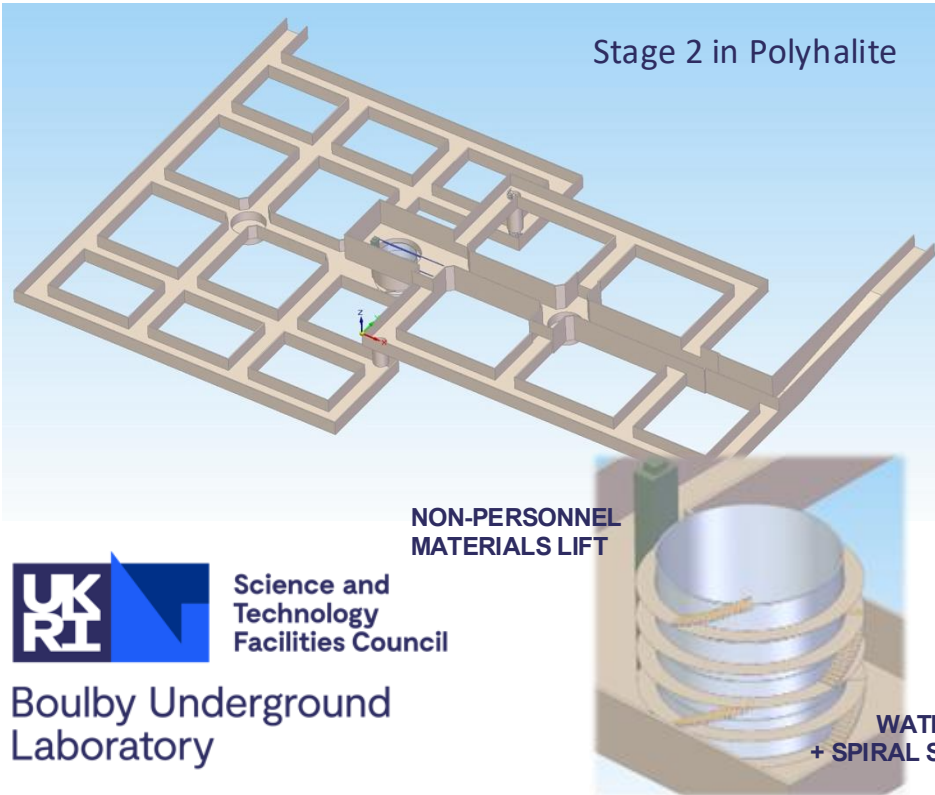
# What about XLZD?

The international XLZD collaboration are looking at 4 potential Underground Labs to host the project:

- SURF (USA)
  - SNOLAB (Canada)
  - LNGS (Italy)
  - **Boulby (UK)**
- Decision factors:**
- Physical/practical suitability
  - National science capability
  - Local political & financial support
- **Phased outfitting of Stage 1 planned to complement XLZD construction timeline**



XLZD @  
Boulby



Stage 2 & Stage 1 in Salt



**XLZD-UK**



# Boulby Development Project: **Impact**

## ✓ **Unique National Asset**

Boulby is the UK's only deep underground science facility, providing ultra-low-background conditions that underpin **world-leading research** and strengthen the UK's international scientific leadership.

## ✓ **Strategic Impact for UK Science**

Boulby advances STFC priorities and delivers cross-disciplinary breakthroughs that **support UKRI's mission and align with Government strategies** including the Industrial Strategy and Net Zero and other IS-8 sectors.

## ✓ **Catalyst for Regional Growth**

Boulby positions Tees Valley and the North East as a global science hub, attracting investment, **creating high-value jobs and driving regional economic growth**

## ✓ **Innovation and Industrial Partnerships**

Boulby **generates opportunities for UK industry** in advanced engineering and clean manufacturing while fostering innovation clusters in quantum technology, clean energy and sustainable computing.

## ✓ **Skills and Workforce Development**

Boulby provides training, apprenticeships and research opportunities that **develop a highly skilled talent pipeline** supporting UK academia, industry and future technology competitiveness



Boulby Underground Laboratory

**UKRI Investment according to LT1 area**



Boulby Underground Laboratory

**Boulby's development is positioning the region as a global centre for underground science, technology, innovation, and industry collaboration.**

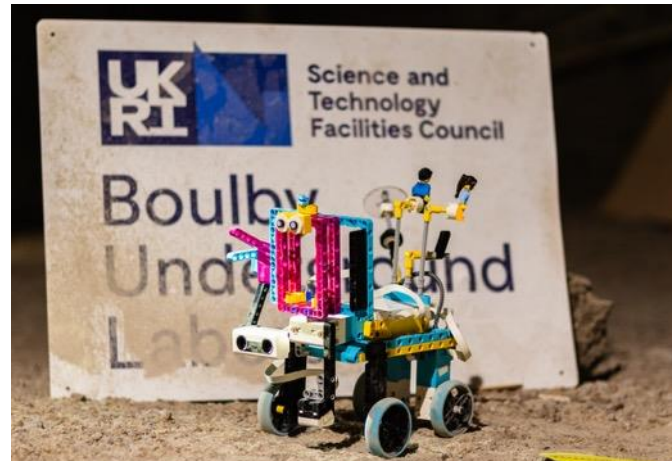
# Boulby People, Teamwork, Outreach and skills...



See *J. Gutteridge* Poster



NETA Training Provider – promoting apprenticeships @ BUL



Remote<sup>3</sup> programme – partnership with the University of Edinburgh & RAL

## **Boulby engagement 2025/26:**

- 6196 people engaged with through PE programmes
- Across 68 events

## **Boulby Public Engagement**



BUL “live links” – versatile virtual tour format for a variety of audiences



# Finally: An Advertisement

- Boulby is proud to be hosting LRT 2026 at the York Guildhall



- 21-24 Sept 2026 – call for abstracts opening soon



Science and  
Technology  
Facilities Council

Boulby Underground  
Laboratory

# Thank you

[boulby.stfc.ac.uk](http://boulby.stfc.ac.uk)

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