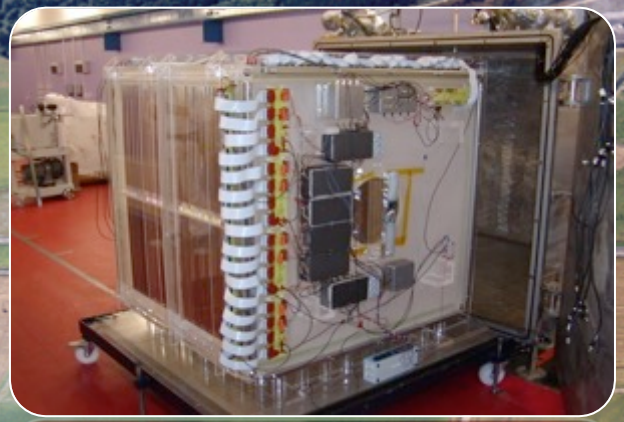
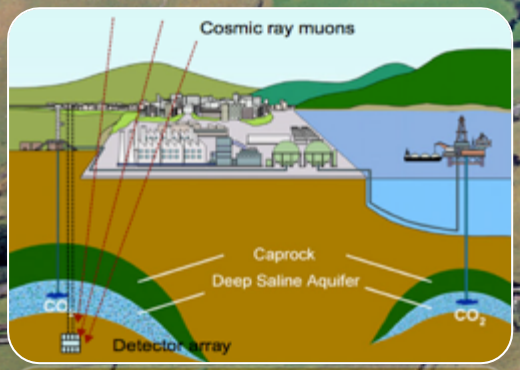
Sean Paling
STFC Boulby Underground Science Facility

DRIFT- Directional Dark Matter Search





Multi-disciplinary studies: climate, the environment, life on earth & beyond!

Deep Science at Boulby Underground Laboratory:

Current studies & details of new underground facilities to support UK & international underground science.

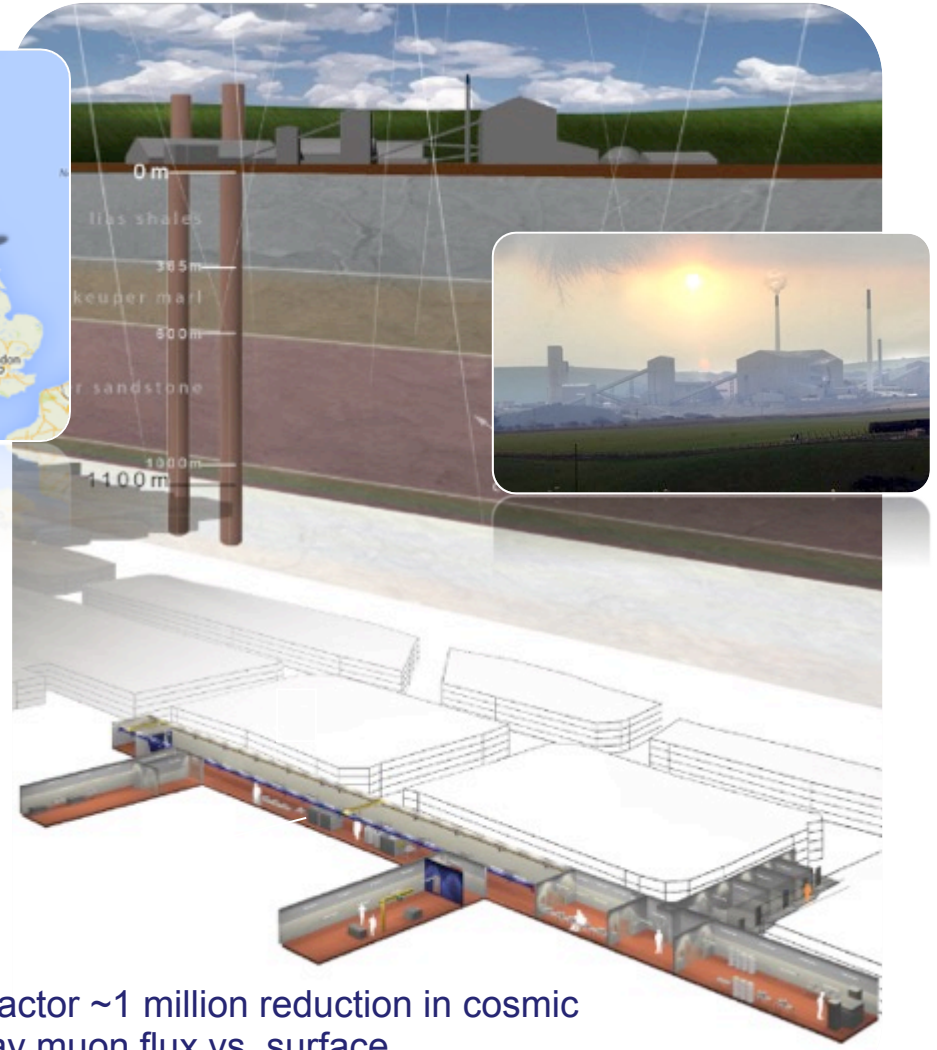
Low background counting

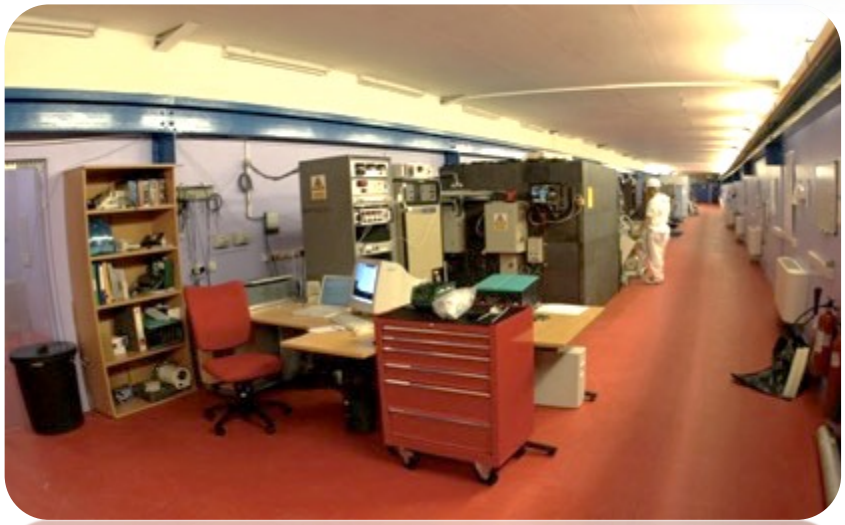
Boulby Underground Laboratory

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





Boulby Palmer lab. >800m^2 floor space. Operating since 2001

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

ICL Fertilizers

Science & Technology Facilities Council

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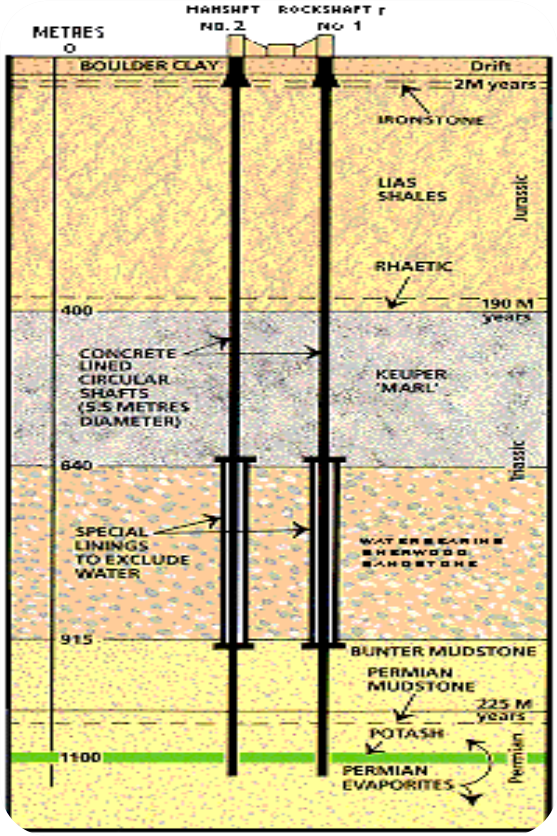
Boulby Geology & Mining

Excavations are in Salt (NaCl) & 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.



Boulby Geology

Typical Boulby Salt Roadway

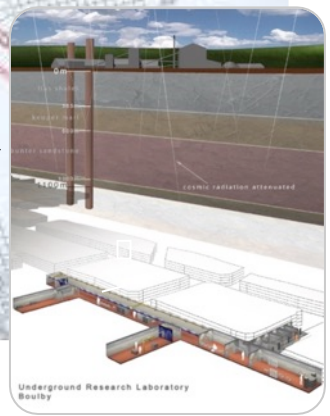
Boulby Mine

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

Mine Shafts

Rock-Salt

Potash



Palmer Lab

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Underground Science @ Boulby Mine

- DRIFT: Directional Dark Matter Search
- DM Ice: NaI(Tl) Dark Matter detector
- 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
- Misc. Geology / Geoscience
- Misc. Low-background support projects
- Etc... (More to come).

Science & Technology Facilities Council

BOULBY UNDERGROUND LABORATORY

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

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Boulby Facility Details…

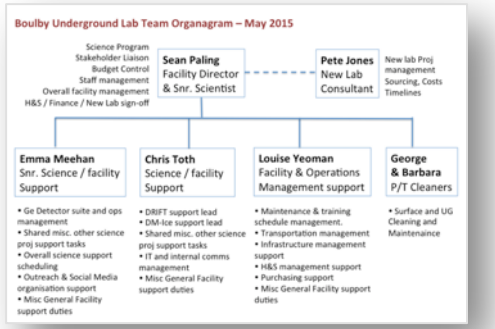
- Supports work of 9 collaborative projects (astrophysics to climate, geology, environment, life etc), 20 institutions, > 70 scientists and students.

- Facility funded and operated by the Science and Technology Facilities Council (STFC) in partnership with CPL/ICL.

- Operations, H&S & science programme managed by 4(+3) onsite staff and supported by Rutherford Appleton Lab (PPD).

- CPL / ICL provide wide-ranging operational & higher level support.

'A hole in the ground does not make a facility'



Management


Environment monitoring


User and science support


H&S, medical support


Materials transport

Project tracking, H&S

World Deep Underground Science Labs

Overview of status & future plans of (some of) the world's underground facilities…

Europe
- Gran Sasso
- Modane
- Canfranc
- Boulby

Asia
- Kamioka
- Jinping
- Yangyang
- Ino

North America
- SNOLAB
- SURF
- Soudan
- WIPP

Southern Hemisphere
- Andes
- Stawell

Lots going on. Many and varied science projects and laboratories progressing and emerging.

How does Boulby compare?

- **6 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)

→ 1.1 km deep (2,850+/-20 mwe)
CR muons attenuated by ~10^6
$(3.79\pm0.15)\times10^{-8}$ $cm^{-2}s^{-1}$

→ Salt = low in U/Th (67±6/125±10ppb)
→ Low gamma & neutron backgrounds
→ Low Radon (<3Bq/m^3)

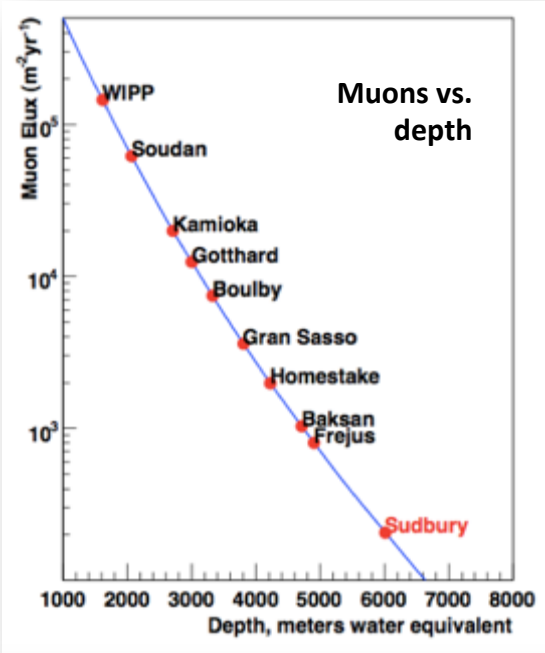
Plenty of Laboratory space → >1000 m^2 existing lab space & **excellent potential for expansion.**

Easy access for equipment → Via mine shaft (5m diam. – 2×2×2m cage) + Transport underground

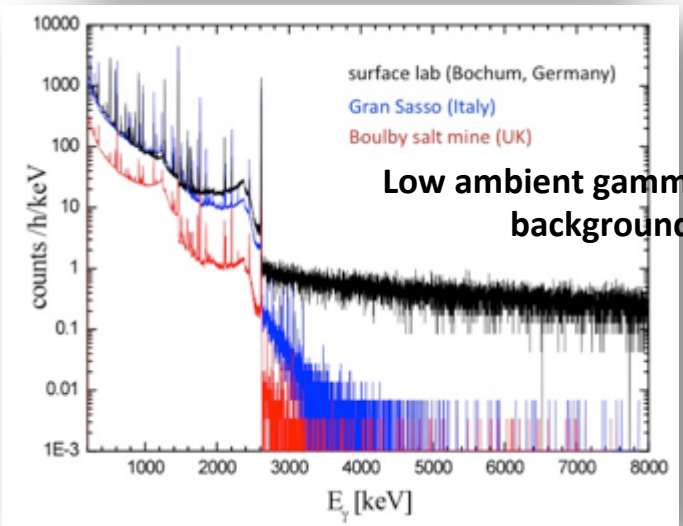
Proximity of services / civilisation → 20 min → Whitby, Saltburn
1 hr → York, Leeds, Middleborough
< 5 hrs → London, Manchester etc.

Good infrastructure + support →
- JIF Underground & surface facilities
- **Wide-ranging support from mine operators (Cleveland Potash Ltd)**

A unique science / industry partnership



Muons vs. depth



Low ambient gamma backgrounds

- <u>Low</u> **ambient gamma backgrounds**
- <u>VERY low</u> **ambient Radon background:** <u>**<3 Bq/m^3**</u>
- **Interesting geology, diverse science programme**
- **Operations well-supported by mine owners ICL**

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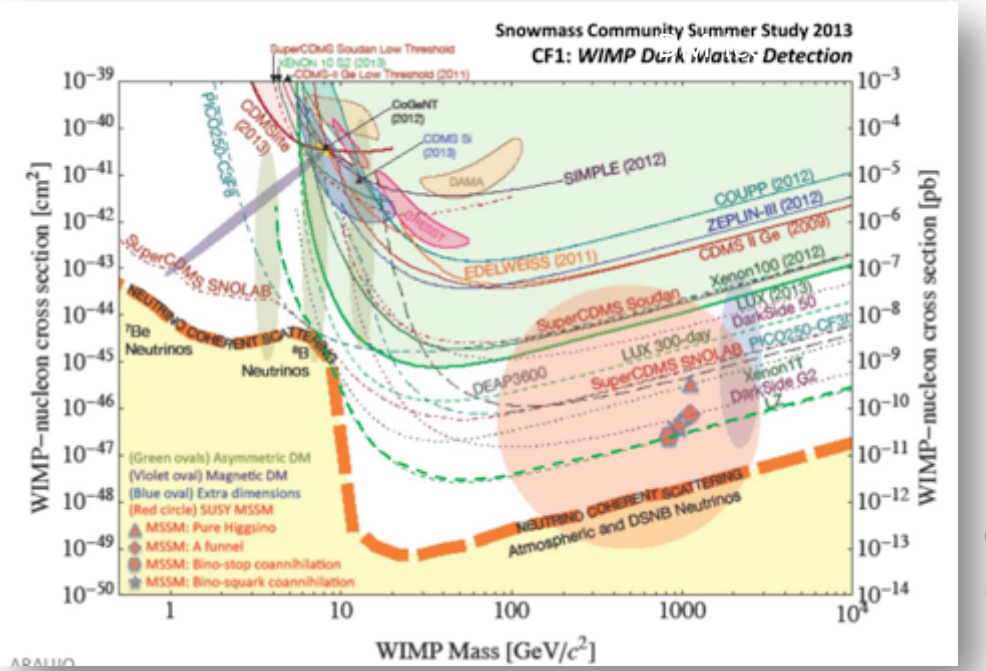
Boulby Dark Matter Studies

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

Boulby now hosts two on-site dark matter studies (**DRIFT** & **DM-Ice**) & provides ULB material screening for other studies, inc **LUX-ZEPLIN**


ZEPLIN-III @ Boulby



Current limits & future projections

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

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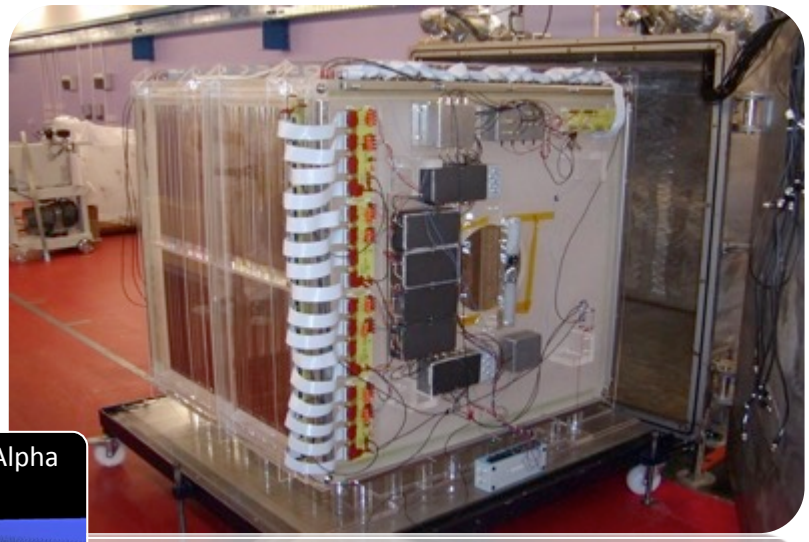
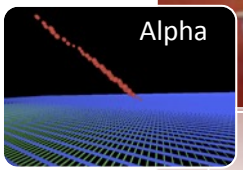
Boulby Dark Matter Studies

DRIFT-II: A DIRECTIONAL Dark Matter Detector…

Participants: Occidental College, New Mexico, Colorado State, Hawaii, Wesley Coll. Sheffield, Edinburgh, Boulby

STATUS: Programme operating at Boulby since 2001. Currently limit-setting and conducting system performance and scale-up R&D





1m^3 (Fiducial) Low-pressure gas TPC with MWPC readout

~18kg ULB NaI(Tl) detector units

DM-Ice: NaI(Tl) array for studying WIMP wind annual modulation

Participants: Wisconsin, Yale, Fermi Nat. Accel, Lab, Illinois, Alberta, Sheffield, Boulby

STATUS: ULB NaI (Tl) detector array assembly, characterisation & operation prior to installation at the South Pole.

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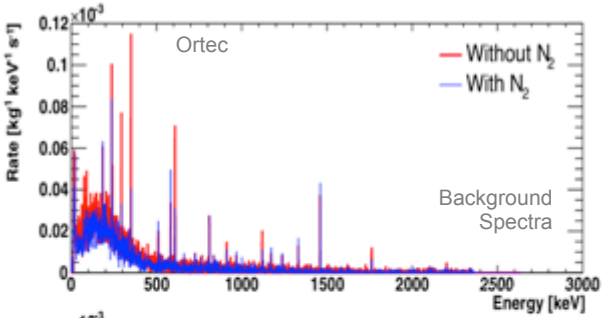
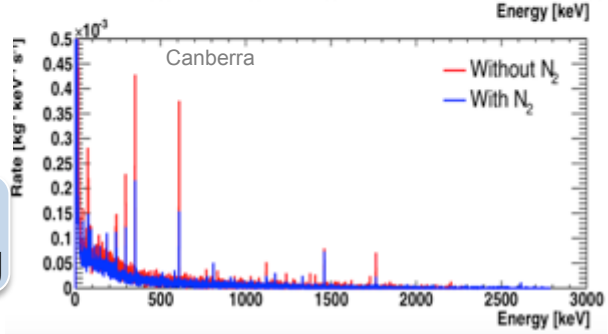
ULB Material Screening

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





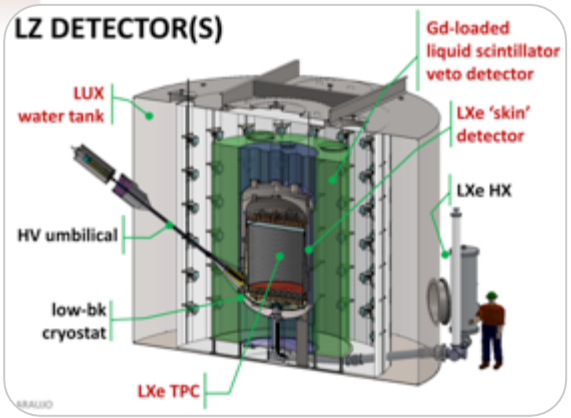
- Ortec 2kg Coax (90% eff).
- 2 Canberra BEGe detectors
- Canberra SAGe Well-type

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

Ultra Low background counting studies supporting UK DM (**LZ**) & 0nuBB communities.

Now **EXPANDING** low BG counting capabilities to meet international demand.

Working in collaboration with UCL, Oxford, STFC-RAL



Boulby undertaking major role in material selection for **LUX-ZEPLIN**

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SURF Lab and LZ project management team visit to Boulby Ge Suite – Aug 2015

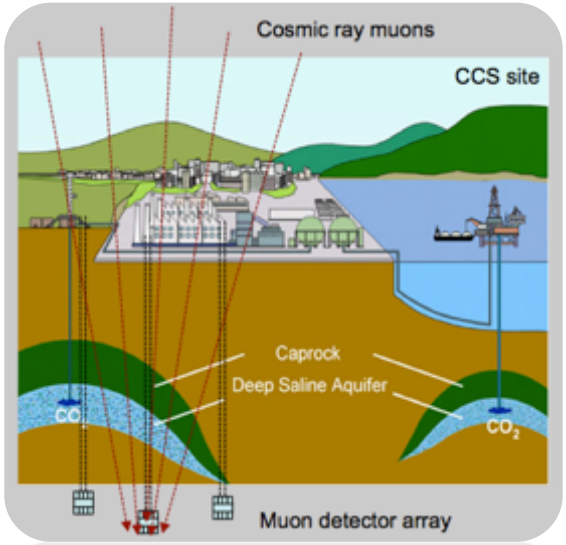
Expanding Multi-Disciplinary Studies

ERSaB: Gamma spectroscopy & low background counting environmental radioactivity studies

Boulby, Scottish Universities Env. Research Ctr (SUERC)

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

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



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

MINAR: Space Technology Development

Boulby, Edinburgh, NASA, DLR, CPL etc.

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

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

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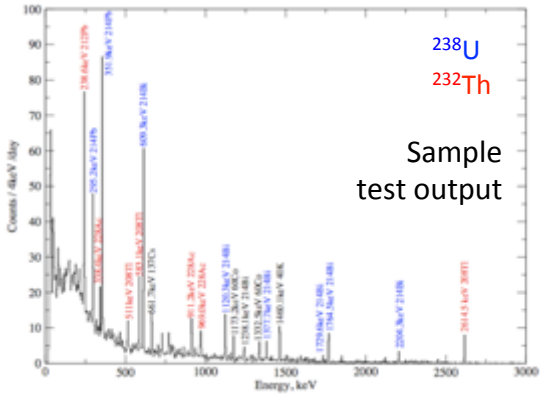
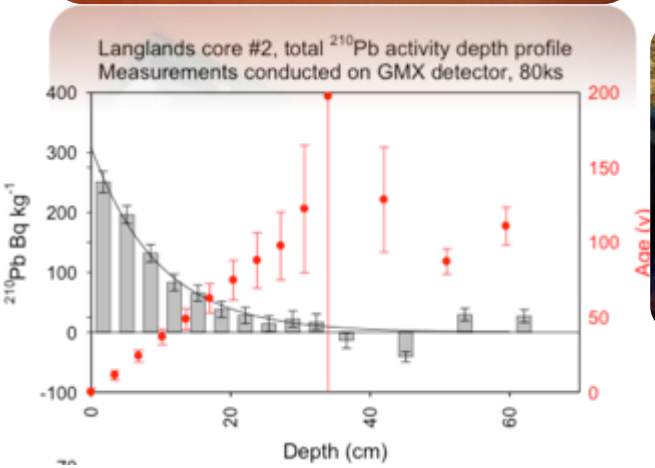
Low-BG Gamma Spectroscopy

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 Sedement dating

Pb-210 Radio-dating of the 50-250 year timescale is important for understanding RECENT affects of climate change.

Scottish Universities Environmental Research Centre

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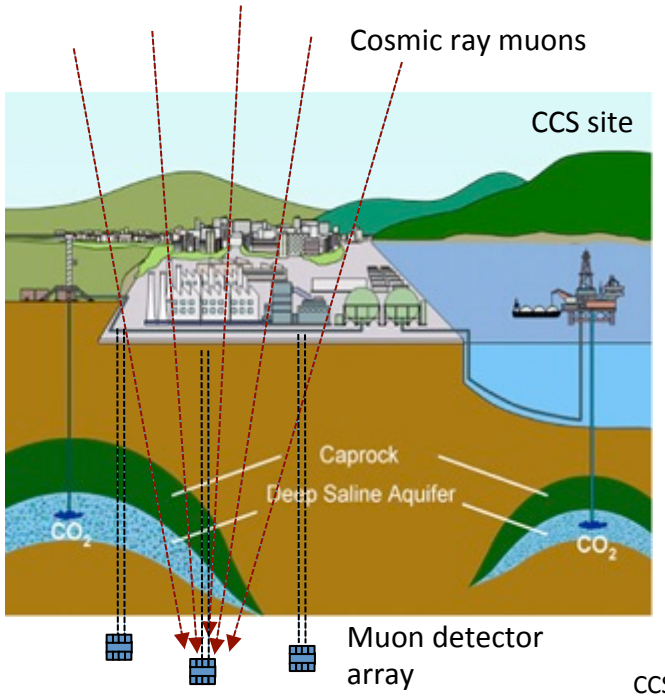
Muon Tomography / Geo-survey

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:

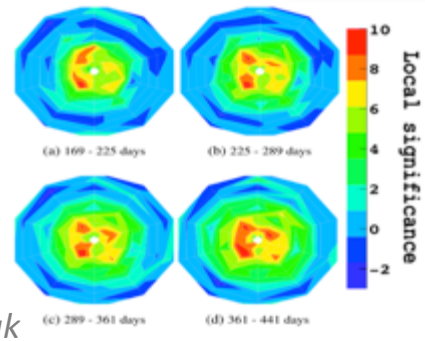
- Deep geological repository monitoring.
- Monitoring in Carbon Capture & Storage (CCS)

Muon-tides detector development

Bore hole detector installation

Boulby site and skills uniquely well-suited for development and testing: appropriate depth and geology, ease of access, infrastructure & expertise

CCS site simulation



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

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Astrobiology & Mars Analogue

Sampling life in Boulby Brine

Subsurface Astrobiology Laboratory

BISAL
Boulby International Subsurface Astrobiology Lab

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

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

Led by Edinburgh, UKCA

MINAR
Mine Analogue Research

Mining & extraplanetary exploration instrumentation development

Boulby and Instrumentation for Earth and Space Exploration

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Misc Geology / Geoscience

Misc. geology & geoscience studies @ Boulby.

Improved mining technologies

E.g. enhanced extraction but reduced subsidence?

Rock deformation studies

E.g. salt deformation and oil reservoirs?

Seismology

E.g. how does stress change induce earthquakes?

Carbon Capture & Storage

E.g. The effect of fractures on the sealant properties of anhydrite for CCS

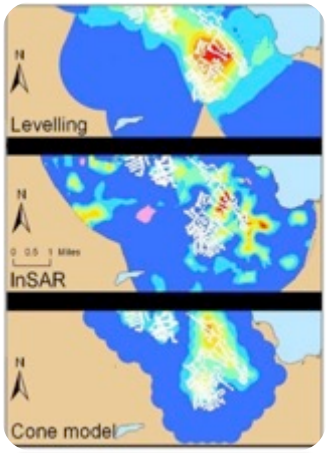
Geochemistry

E.g. how does fluid (oil) move through rock masses?

Geomicrobiology

E.g. What effect do microbes of rock stuctural integrity (cliff, geological repositories)

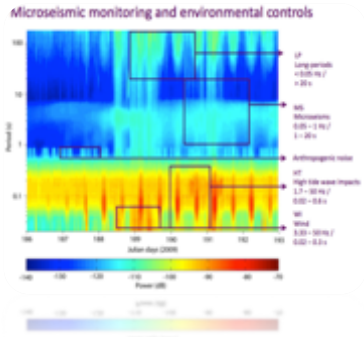
Funding past and present: One NE, CPL / ICL NERC, Crown Estate

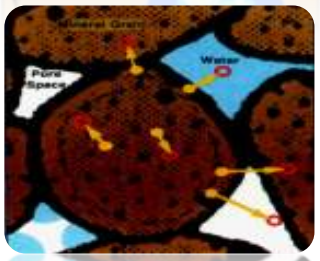


Subsidence mapping

Durham, Imperial College, Boulby, Edinburgh British Geological Survey (BGS)

Micro-seismic monitoring





Geochemistry

Cliff erosion mapping

Anhydrite mechanical properties

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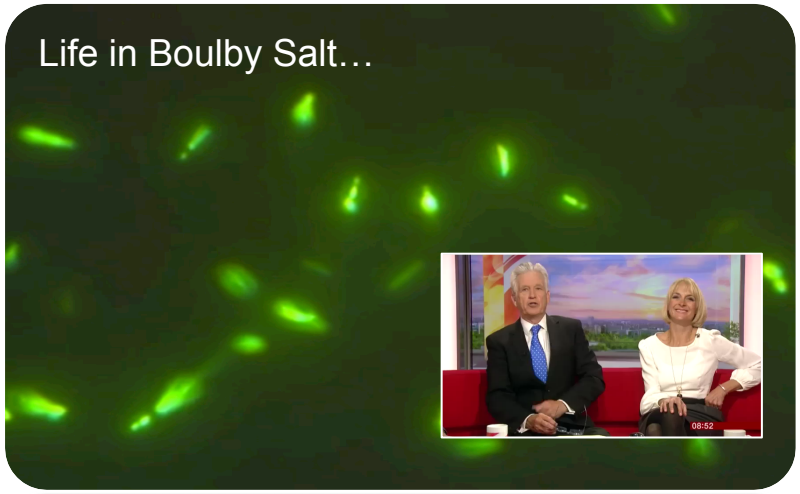
Astrobiology/geomicrobiology

Boulby International Subsurface Astrobiology Facility (BISAL). Studies of life in Boulby rock, life on Earth and beyond…

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

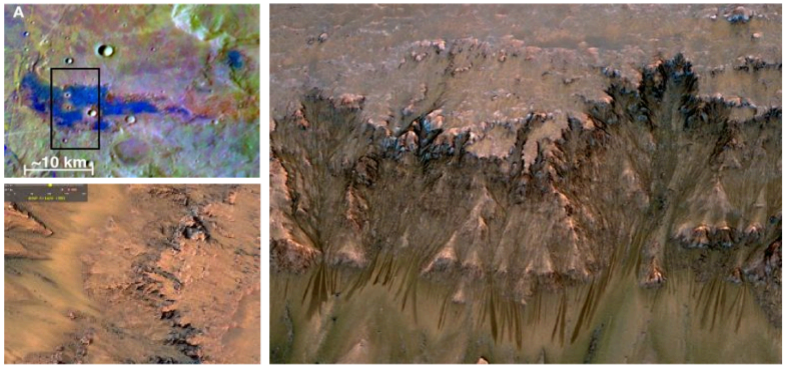


A base for studies of life in Boulby rock – with relevance to limits of life on earth and other planets

The search for life on Mars

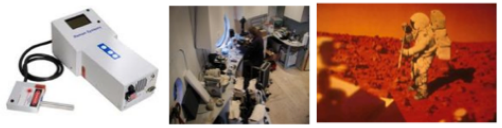
'Mars is covered in table salt'

We need to know about life in salty environments to be able to explore Mars



Seeps of salty water on Mars
McEwan et al. (2011) *Science* **333**, 740

Boulby and Instrumentation for Earth and Space Exploration



Boulby facility provides:
- Clean contamination-free labspace
- Access to interesting geology
- Technology and physics expertise

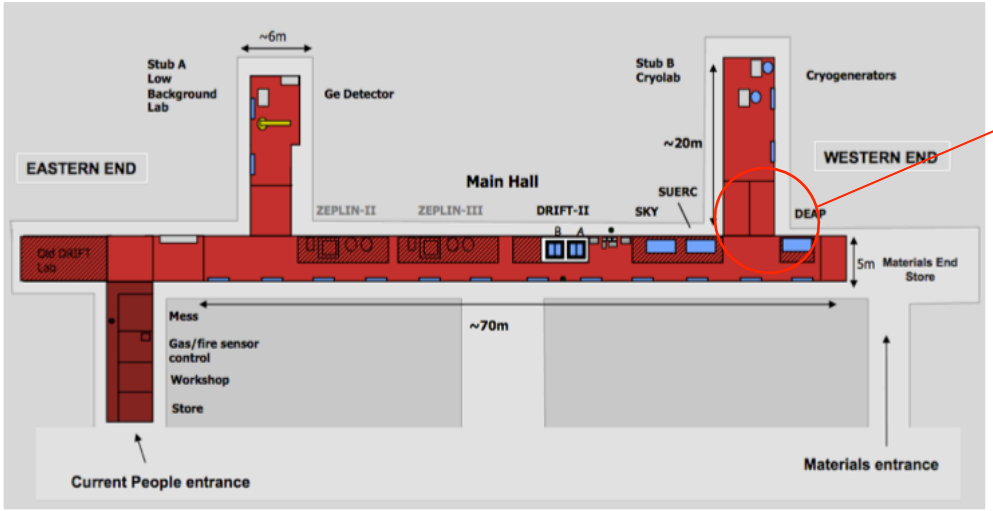
An important 'Mars Analogue site' – with geology & conditions to allow explorations & astrobiology technique & instrumentation development

BISAL: Studies of subterranean life

Sampling life in Boulby Brine

Subsurface Astrobiology Laboratory

BISAL
Boulby International Subsurface Astrobiology Lab

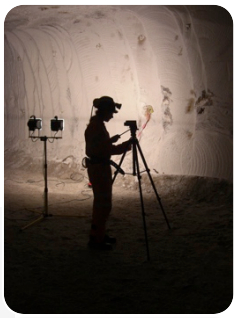


Dark Matter to Dark Life… A large proportion of the world's biomass is in the deep subsurface…

BISAL: Studies of life in Boulby salt. For what it can tell us about extremes in life on Earth and beyond.

RCUK Relevance: Environment, Geological Repositories.
Misc: BBSRC links

MINAR: Mars Analogue & Mining Technology…



THE CROWN ESTATE

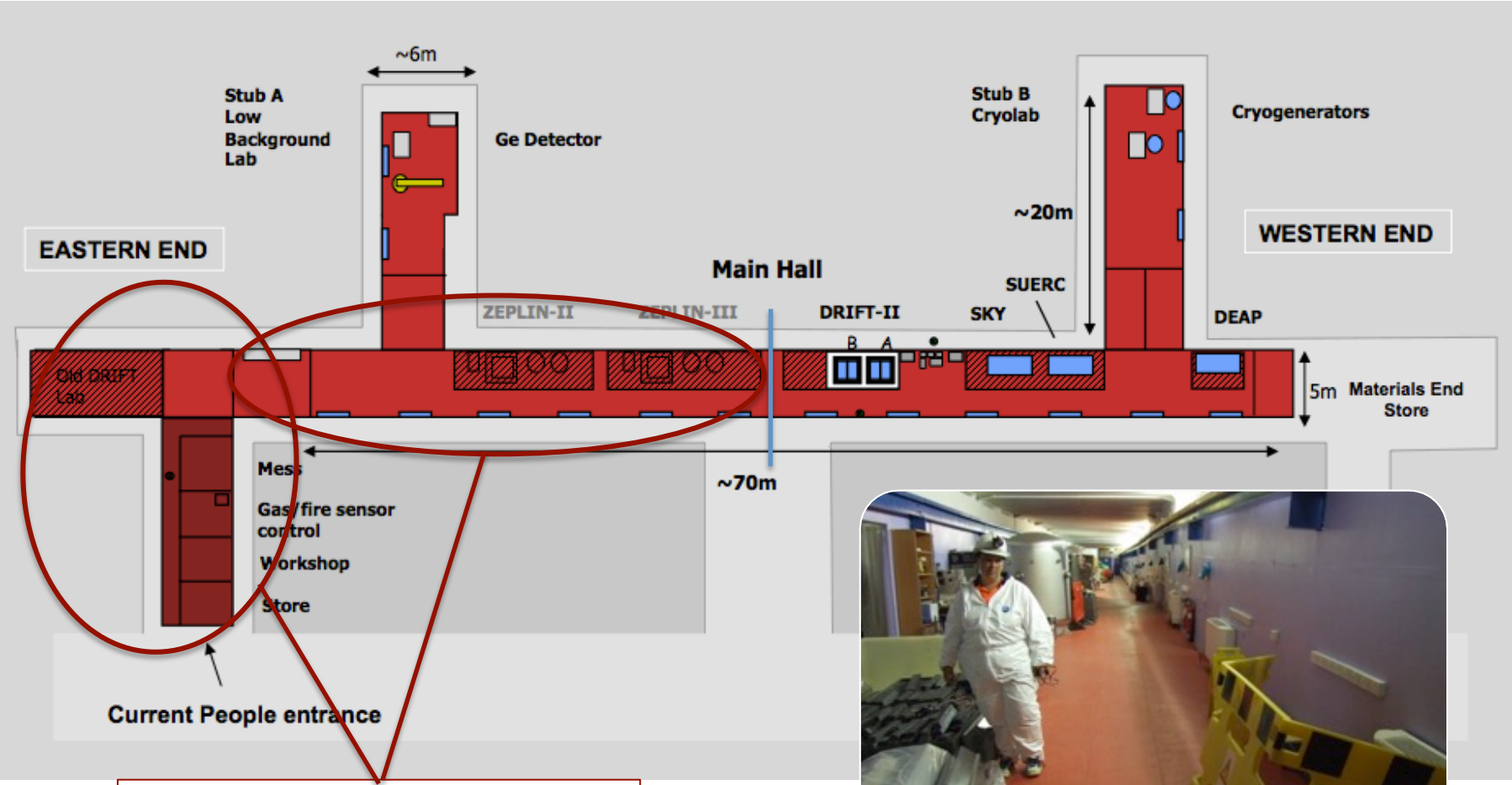
MINAR: Mine Analogue Research Programme

Status: €5M EU-SPACE funding granted for Mars Analogue work – Led by BISAL's Charles Cockell

BOULBY UNDERGROUND LABORATORY

Building a New UG Laboratory

Problems with the current lab…



Eastern end: Degradation of lab – due to local fault line

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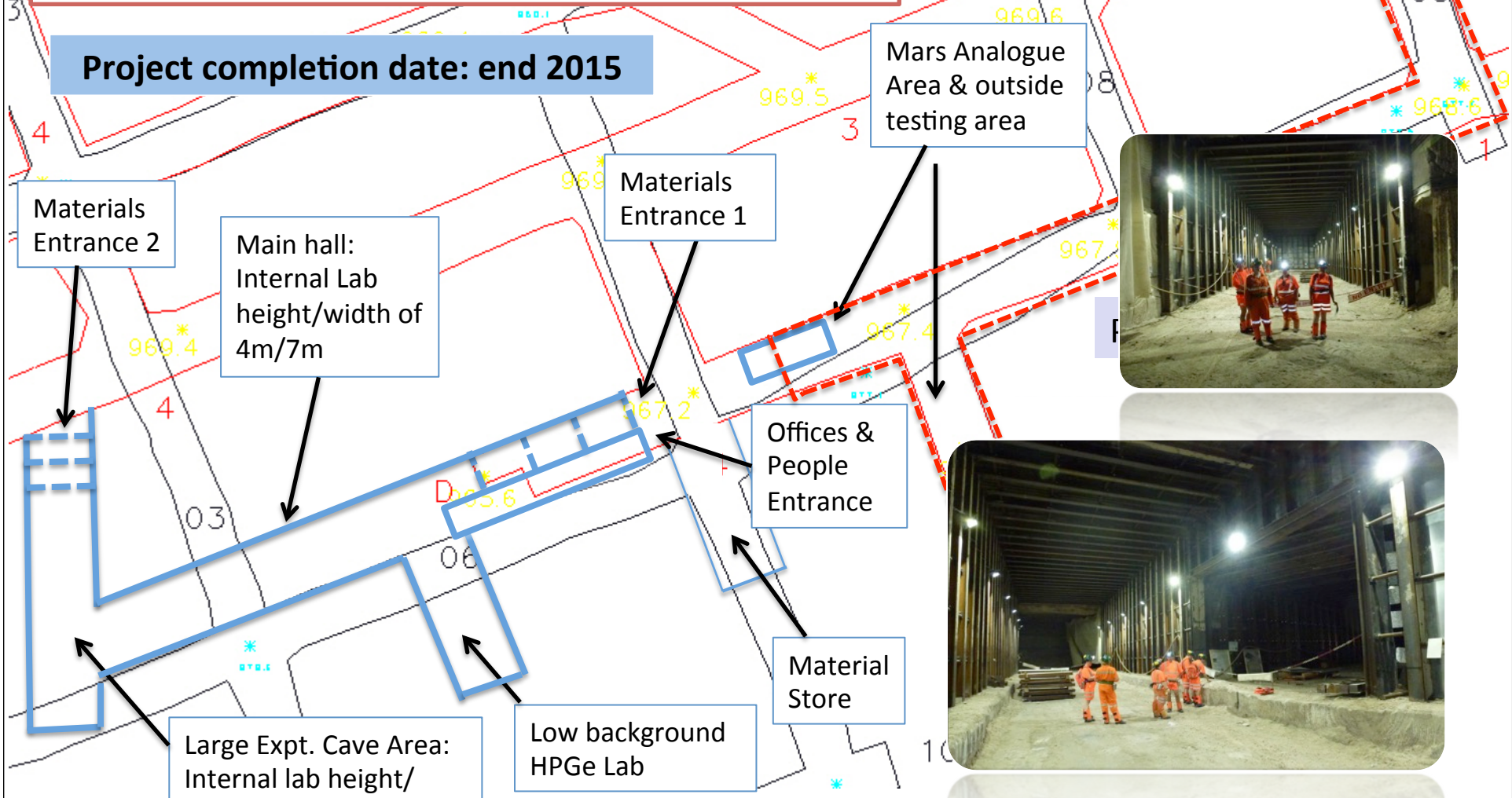
A NEW LABORATORY now being built at Boulby

To replace current facility and host **planned & new projects** for the next decade and more…

Project completion date: end 2015



Fully-equipped 1000m^2 lab. Class 10K & 1K clean room throughout. 5-10T lifting capacity.

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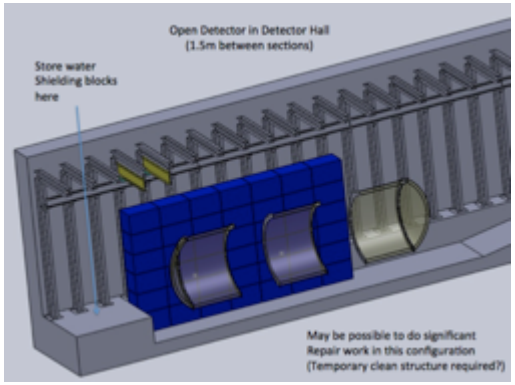
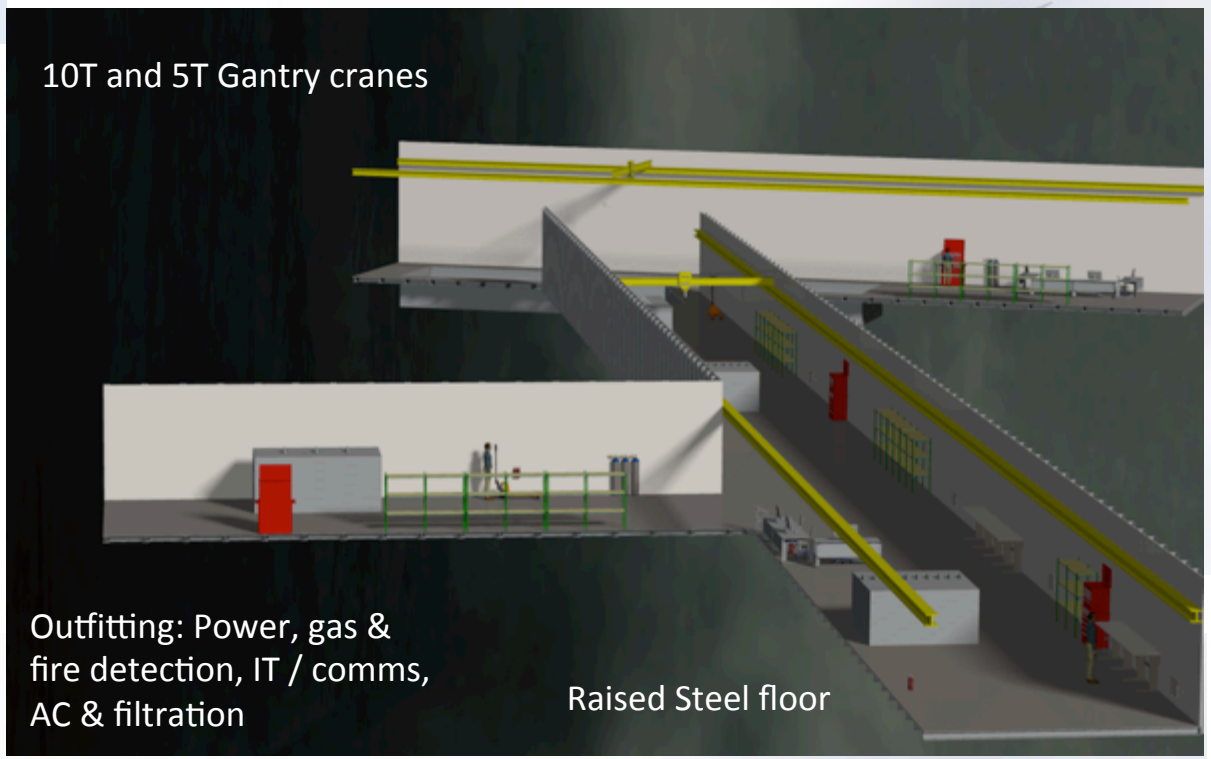
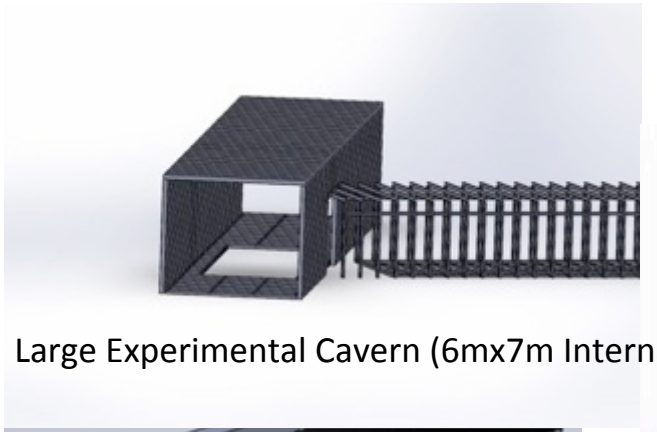
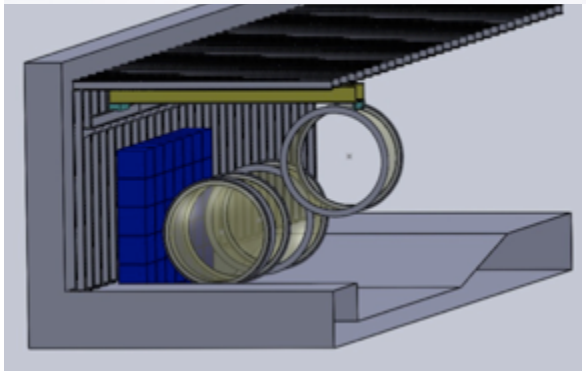
New Laboratory Details

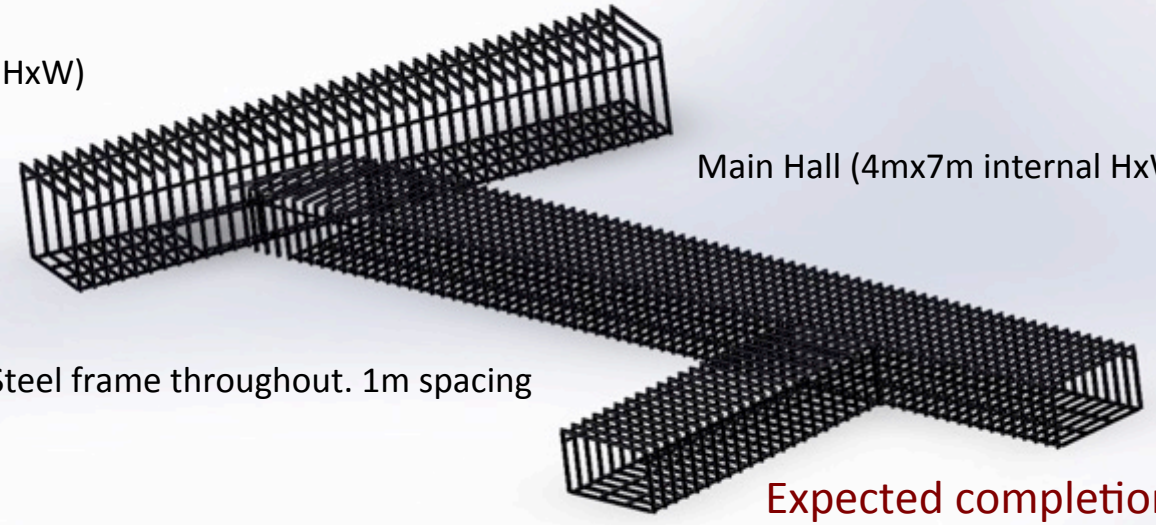






Large Experimental Cavern (6mx7m Internal HxW)





Expected completion
July 2015

S.M.Paling - Boulby@stfc.ac.uk

Main Hall

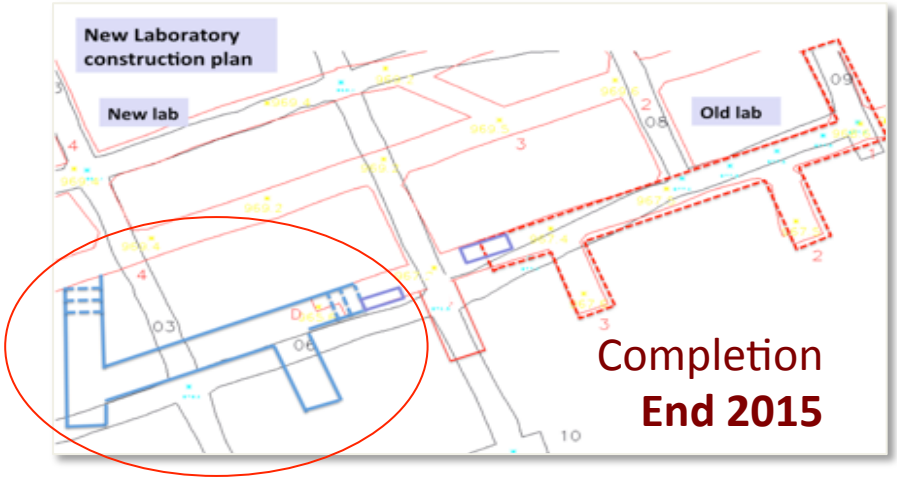

'BUGS' ULB Germanium Facility

BOULBY UNDERGROUND LABORATORY

Boulby New Lab Construction Aug 2015

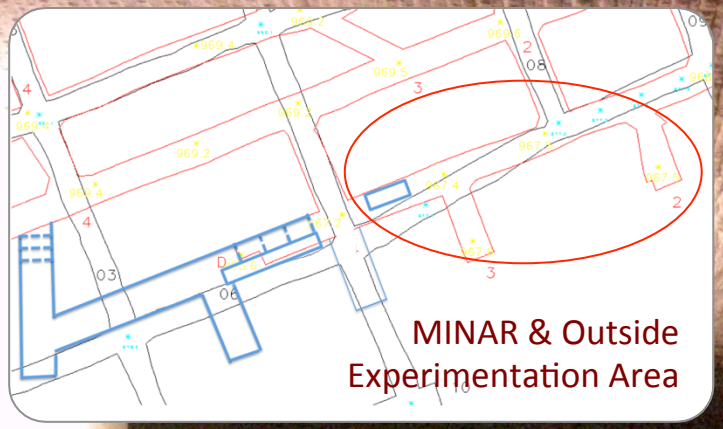

Large Experimental Cavern (LEC)

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



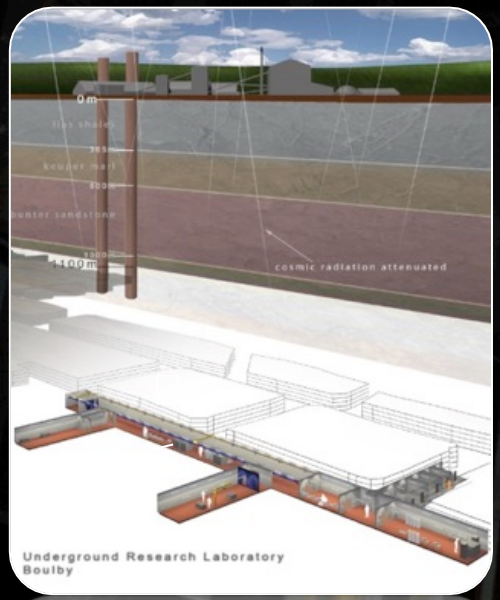
Air conditioning HEPA filtration, 10 & 5 T lifting capacity.

Seeking expressions of interest from new projects early 2016



MINAR & Outside Experimentation Area to be completed ~April 2016…
For Mars Analogue, robotics, misc. geology (etc) studies.

Thank You….



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