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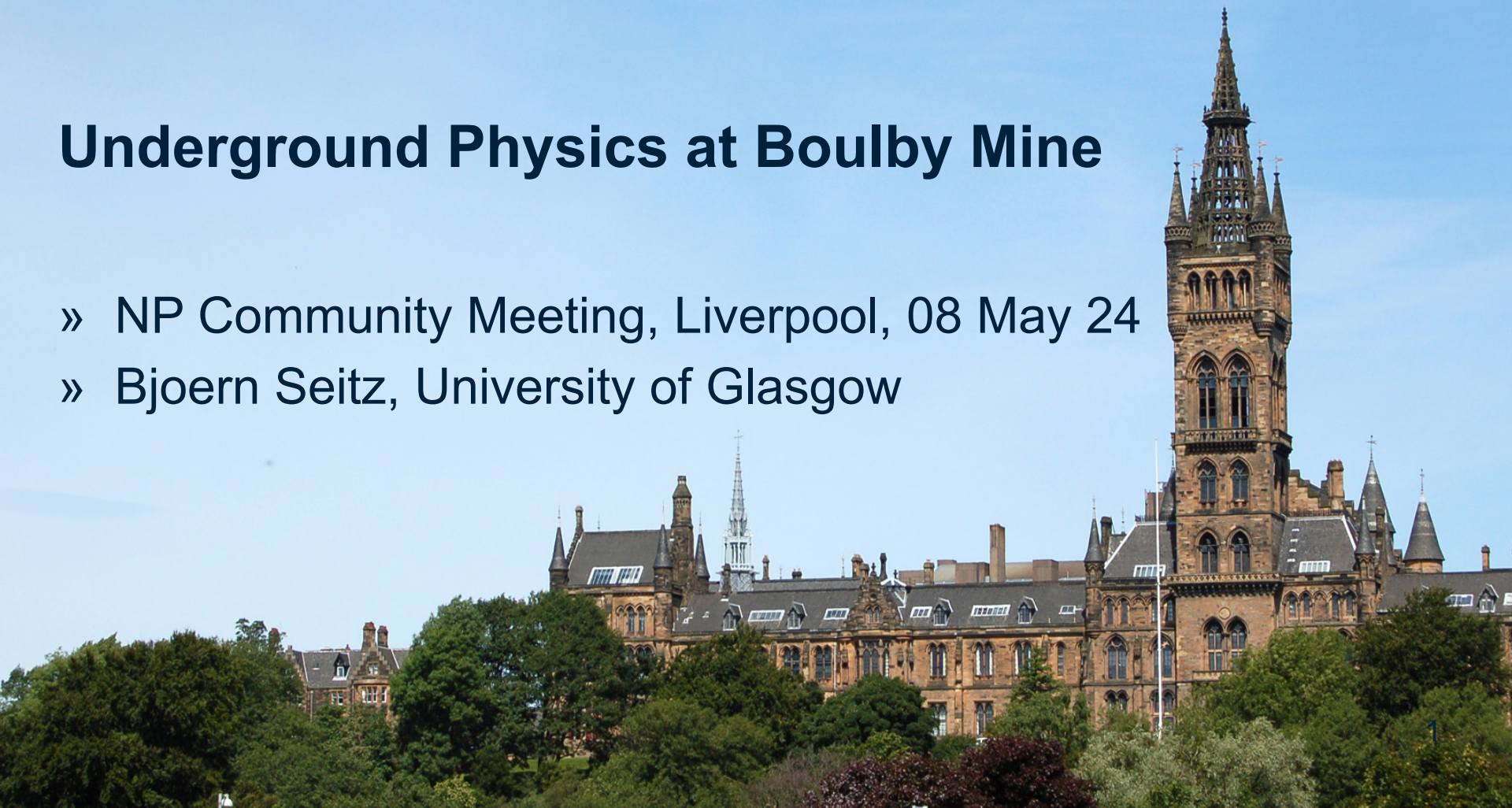
Underground Physics at Boulby Mine

» NP Community Meeting, Liverpool, 08 May 24

» Bjoern Seitz, University of Glasgow



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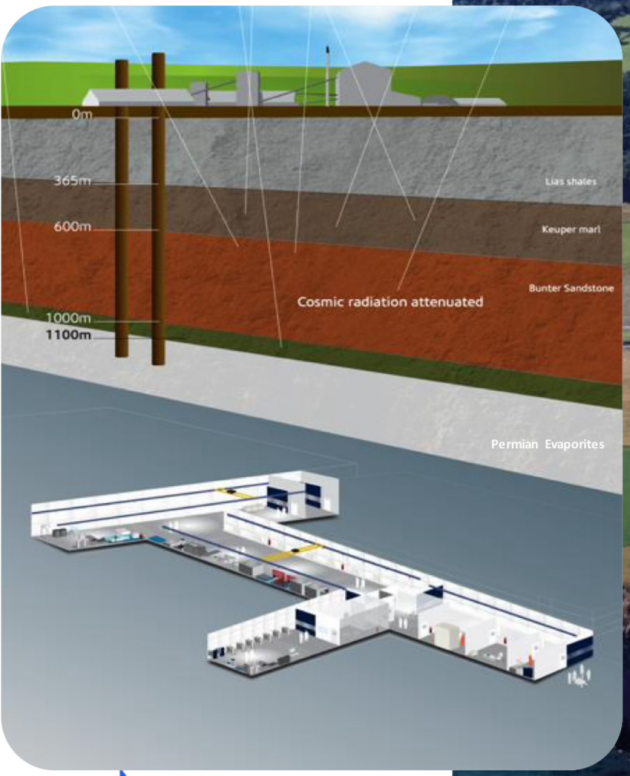
Boulby Underground Laboratory



Science and Technology Facilities Council

The UK's deep underground science facility operating in a working polyhalite & 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

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Boulby Activities Now and Potential Future

Now

	Current Projects	Status
Particle Physics & Low Background	CYGNUS - DM R&D	E/P
	News-G - DM R&D	A
	BUGS: Ge, XIA, RnEm - Material Screening	A
	RECON - Nuclear Security R&D	A
	BUTTON – Nuclear security R&D	A
Earth & Environmental	Muon Tomog – CCS & undersea Geoimaging R&D	A
	RESOURCE – Energy store R&D	A
	Seismology/AION R&D	A
Astrobiology & Planetary Exploration	BISAL – Biology/Astrobiology	A
	MINAR – Planetary Exploration Tech development	A
	Misc. Other. SELLR, C14, Adrok, BIO-SPHERE…	A/P
	Outreach/ Education - Misc events, progs, Remote3…	A

Status: A = Active, P = Paused, E = End, I = Interest confirmed

2023-2030

Medium Term (Current Lab + mods)	Status
BUGS: Ge, XIA, RnEm, ICPMS - Material Screening	A/P
BUTTON-30 – Nuclear security R&D	P
RECON+ - Nuclear Security R&D	A/P
DarkSPHERE – DM Search	I
DATUM – Neutrino Tech R&D	I
SoLAr, SOLAIRE – DM/Neutrino R&D	I
AION-100 & 1000 R&D	I
Seismology Array – Geosurvey R&D	I
RESOURCE+ – Energy store R&D	A/I
Muon Tomog – CCS & undersea Geoimaging R&D	A/I
BISAL+ – Biology/Astrobiology	A/I
MINAR+ – Planetary Exploration Tech development	A/I
Misc. Other. Quantum Computing Tech R&D	-
Outreach/ Education: General Public, Schools +	A

2030-2040+

Long Term (Current lab plus major new lab)

Particle Physics and Low Background Science:

Dark Matter: Major Next Gen Experiments:
- Xenon (XLZD)
- Argon (DarkSideLM+)
- Gas (DarkSPHERE+)

Neutrinos:
- BUTTON-100+
- DATUM (LEGEND Support),
- SoLAr / SOLAIRE+

Mat screening & LB Techniques: A world's best facility:
- Ge, XIA, RnEm, ICPMS, Cleanliness & Engineering R&D

Misc Other:
- AION-100
- AION 1000
- Nuclear Security Gamma spec
- Quantum Computing Tech R&D & Operation

Target projects for **a major new UK underground facility** / campus

Earth & Environmental Science:
- Sustainable Energy R&D
- Seismology Observatory
- Geological Repositories R&D
- Misc geology / Geophysics R&D

Astrobiology & Planetary Exploration:
- Extremophile R&D
- Astrobiology / life beyond Earth R&D
- Human habitation R&D
- Planetary exploration technology development
- Robotics and AI
- Mining and industry application development.

Outreach and Education:
- A National Centre for Science and technology outreach and education.

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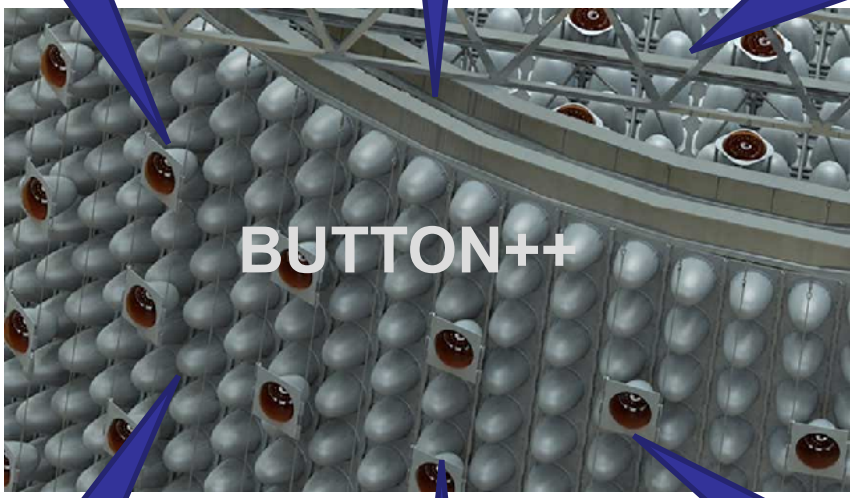
Our Motivation

Nuclear safeguards and non-proliferation

Neutrino physics

Development and characterisation of photon counters



Imaging Cherenkov detectors

New detector concepts

Reactor physics and source terms

Backgrounds in Boulby Lab

Cosmic ray muon backgrounds:

Measured as $(3.79 \pm 0.04(\text{stat}) \pm 0.11(\text{sys})) \times 10^{-8}\ \text{cm}^{-2}.\ \text{s}^{-1}$
(2850 ± 20 mwe)

H. Araujo, et al., Astroparticle Physics 29 (2008) 471–481.

Radon:

Measured as 2.5 +/- 1.6 Bq.m^{-3} (year round)

Internal reports (JIF Lab 2015)

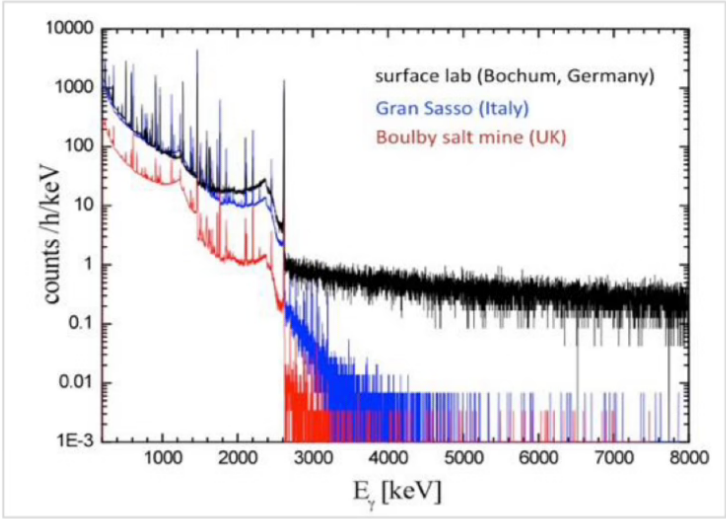
Neutrons:

Simulations based on U/Th content:
1.2×10^{-6} neutrons.$\text{cm}^{-2}\text{s}^{-1}$ (>500keV @rock/cavern bndry).

M.J. Carson et al., Astrop. Phys 21 (2004) 667.

Measured as: $(1.72 \pm 0.61(\text{stat}) \pm 0.38(\text{sys})) \times 10^{-6}\ \text{cm}^{-2}\text{s}^{-1}$

M.J. Tziaferi et al., Astrop. Phys 27 (2007) 326-338.



Gammas:
Germanium detector survey of Boulby JIF Lab Area
Flux = 0.128 $\text{cm}^{-2}\text{s}^{-1}$

D. Malczewski et al. J. Radioanal. Nucl. Chem. 298 (2013) 1483-1489.

Sean Paling, Paul Scovell - 2021

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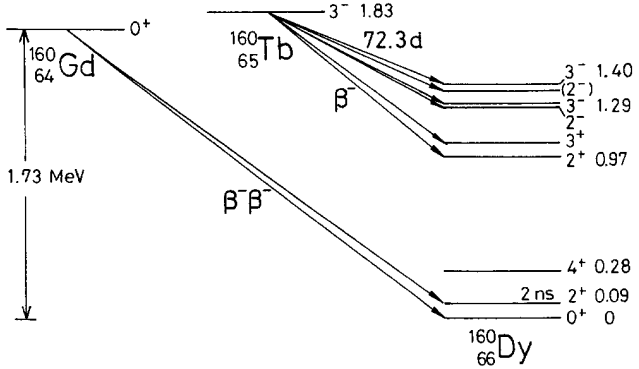
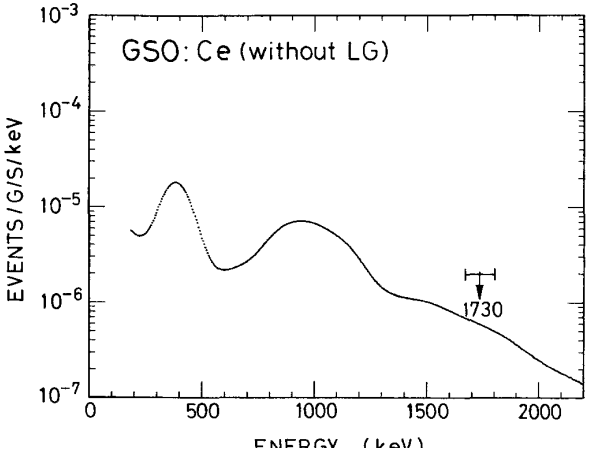
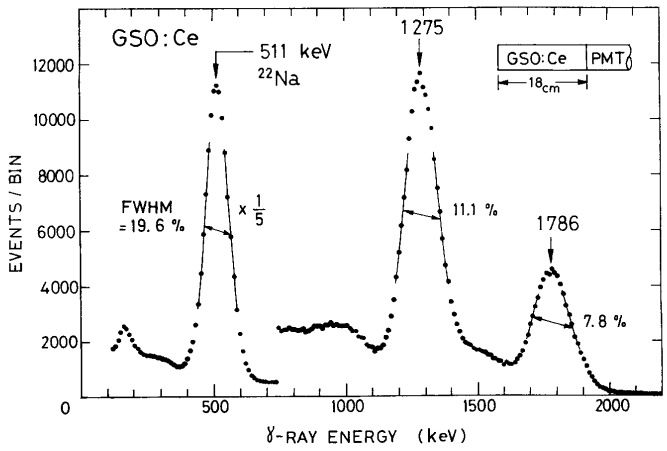
The case

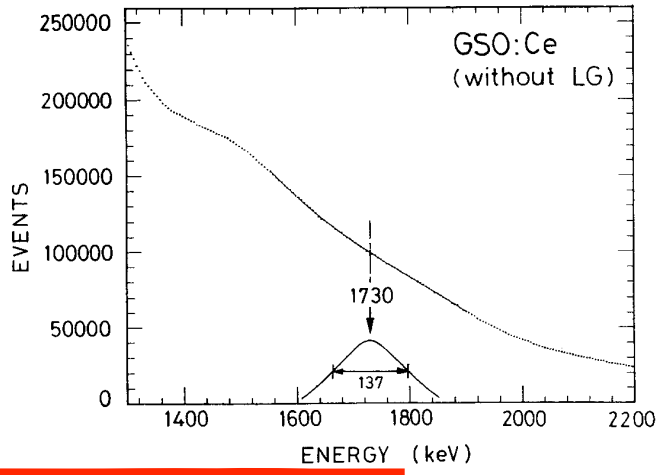
- ^{160}Gd is a candidate nuclide for double β decay
- double β decay in ^{160}Gd has yet to be observed
- Kobayashi/Kobayashi measured lower limit for 0v in GSO
- limited in size, energy resolution and background
- new materials and method promising to improve on that result
- need to study backgrounds and energy resolution further
- need to test radio-purity of candidate materials
- Potential that 2vββ spectrum could be measured in pilot run
- work with nuclear theory on realistic 2vββ spectrum

Double beta decay
Existing work (353cm³ GSO Crystal)









$$T_{1/2}(0\nu) > 3.0 \times 10^{20} \text{y (68 \% CL)}$$

Kobayashi/Kobayahsi Nucl. Phys. A586(1995)457 - dug out by R Svoboda

Background consideration

detection efficiency

target mass

measurement time

$$T_{1/2} > \ln 2 \epsilon \sqrt{\frac{Mt}{b\Delta E}}$$

energy resolution

Intrinsic background (α decays)
Contamination (U, Th)
Cosmogenic radio-isotopes
Neutron capture background
Cosmic rays (active veto)

Initial budget ~ £500k
Full budget: ? (M£)

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Summary

- STFC is developing Boulby mine with a larger laboratory
- World leading facility with very low background levels
- UK led collaborations (BUTTON) to develop neutrino detector technology (new fills, new photon sensors, new analysis) for fundamental science (supernovae, new neutrino detectors) and nuclear threat reduction (reactor monitoring from afar)
- Exiting prospects for a new double beta decay experiment based on UK technology and a UK site