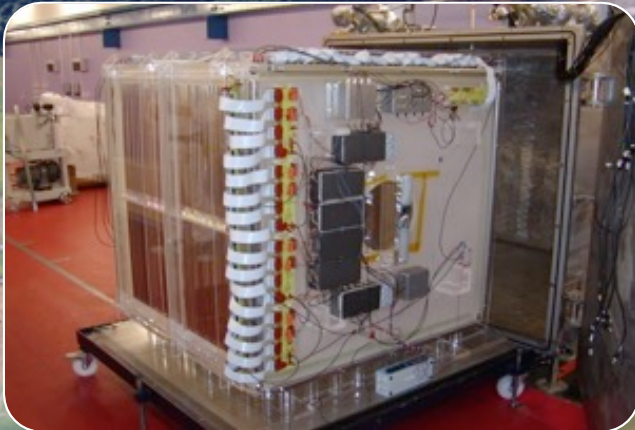




Sean Paling  
STFC Boulby Underground Science Facility

Dark Matter Search & ULB  
counting



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.



New Underground lab @  
Boulby



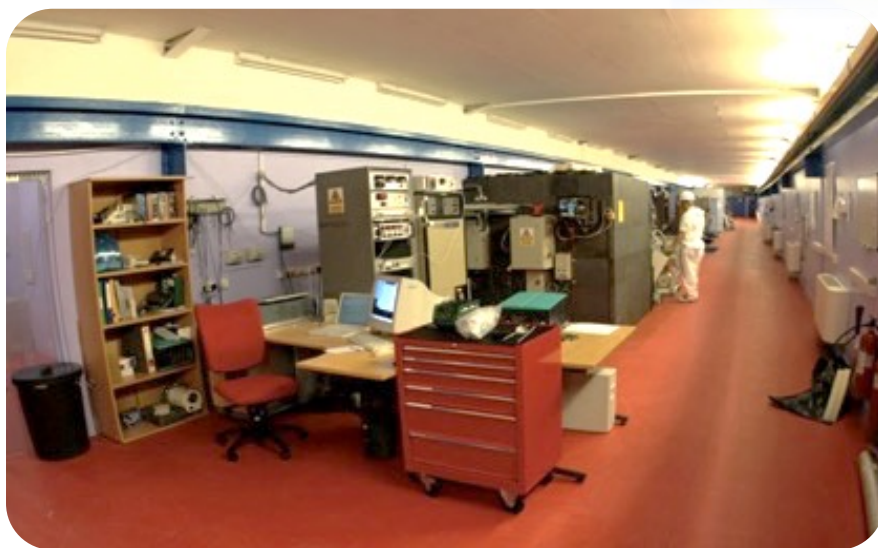
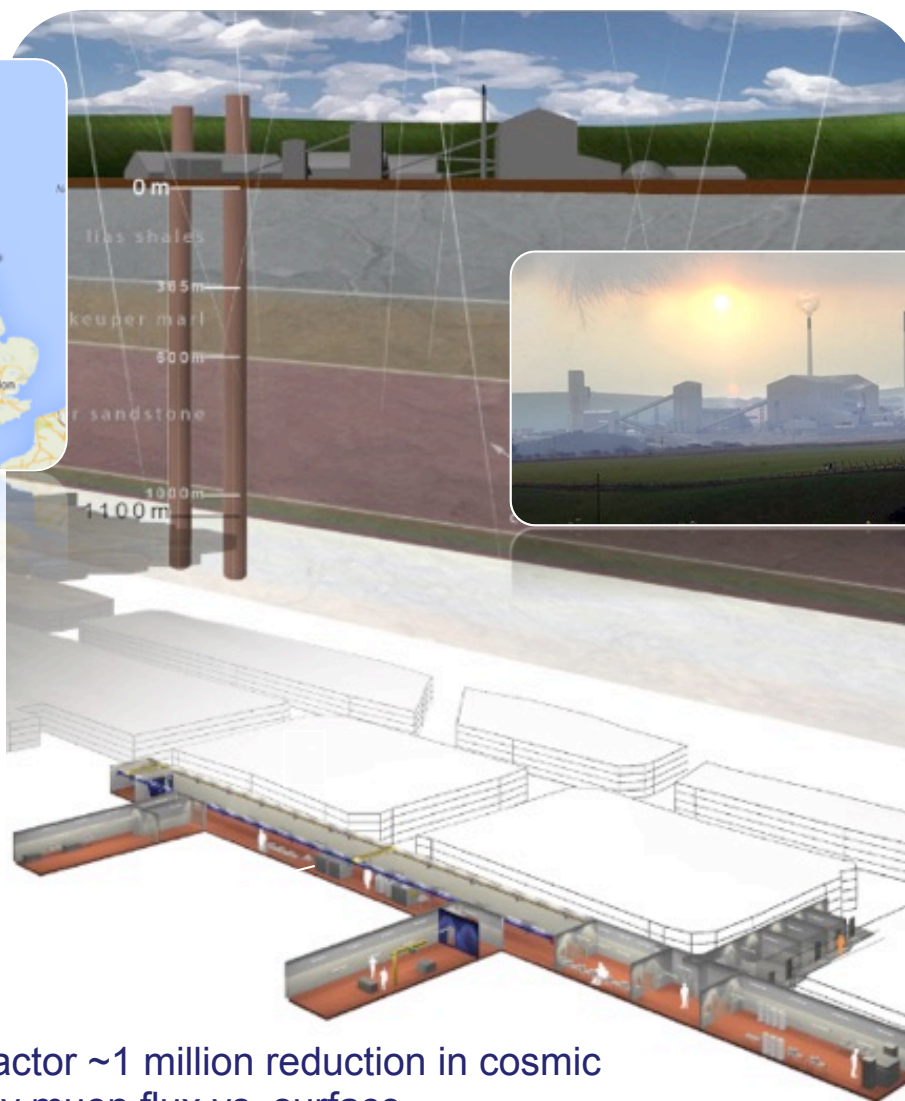


# Boulby Underground Laboratory

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<sup>2</sup> floor space. Operating since 2001

[sean.paling@stfc.ac.uk](mailto:sean.paling@stfc.ac.uk)

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



# Underground Science @ Boulby Mine

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

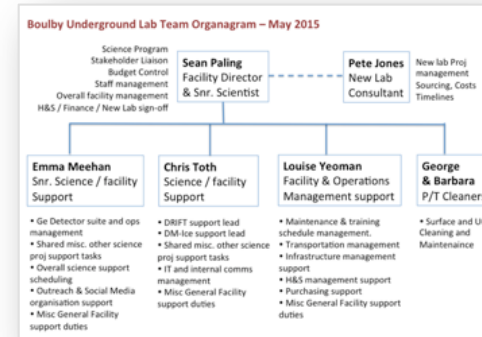
A growing multi-disciplinary science programme:  
from astrophysics (Dark Matter) to studies of geology,  
climate, the environment, life on Earth and beyond.





# 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.



Management



Environment monitoring



User and science support



H&S, medical support



Materials transport

**PROJECT RESOURCE SUMMARY (UPDATED)**

Project Name: **EUCLID III**

Contact Person/ Institution: **Benjamin Azeiteiro (Imperial College London, RAL)**

Brief Description: **A 4kg two phase silicon dark matter detector**

Summary of resource requirements from the facility:

Space requirement, Width/Depth/Height	3.5m / 10.5m / 3.5m
Crane requirement (size/weight and height)	4000 kg / 10m / 3.5m
Electrical power/voltage/phase requirements	380V single phase 50 Hz
Transportation requirements (Installation & Normal operation)	Installation: Forklift, 3x 4000kg capacity, 10m x 10m x 3.5m. During operation: Forklift, 10m x 10m x 3.5m. Relocation of load inside from Sub 2 to Sub 100 (10m x 10m x 3.5m). Operation: None
Maximum tolerable transportation shock	0.5g
Experiment team size underground (Installation/operation)	Installation: 4 Operation: 4
Cryogenic requirements (LN <sub>2</sub> )	During installation: 150L During emergency recovery: 40L

Project tracking, H&S



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





# Mining at Boulby...





# How does Boulby compare?

- 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)

1.1 km deep (2,850 $\pm$ 20 mwe)  
CR muons attenuated by  $\sim 10^6$   
( $3.79 \pm 0.15$ ) $\times 10^{-8}$  cm $^{-2}$ s $^{-1}$

Salt = low in U/Th (67 $\pm$ 6/125 $\pm$ 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 $\times$ 2 $\times$ 2m cage)  
+ Transport underground

#### Proximity of services / civilisation

20 min → Whitby, Saltburn  
1 hr → York, Leeds, Middleborough  
< 5 hrs → London, Manchester etc.

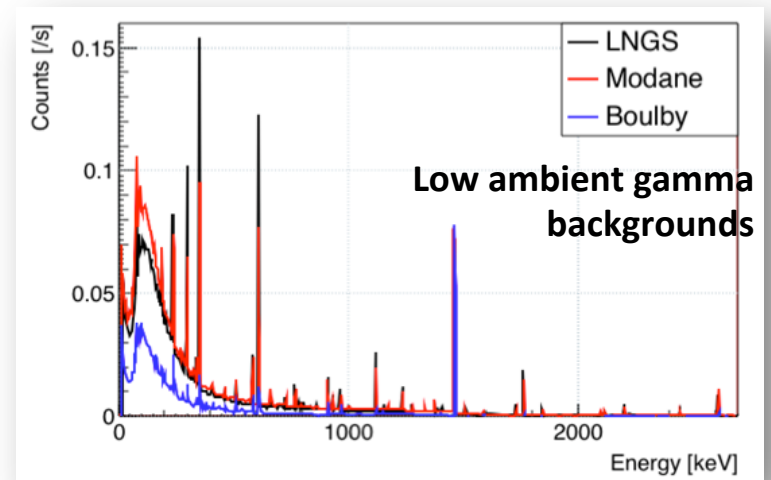
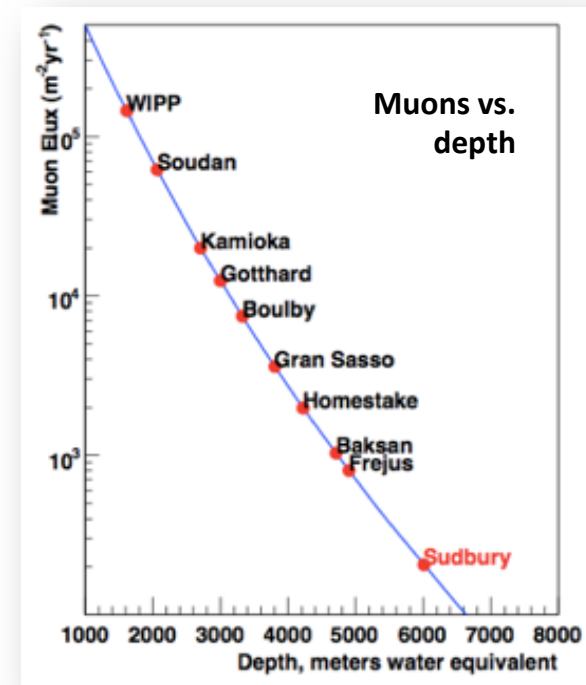
#### Good infrastructure + support

- JIF Underground & surface facilities
- Wide-ranging support from mine operators (Cleveland Potash Ltd)

A unique science / industry partnership

- Low ambient gamma backgrounds
- VERY low ambient Radon background: **<3 Bq/m $^3$**
- Interesting geology, diverse science programme
- Good support and potential for expansion...

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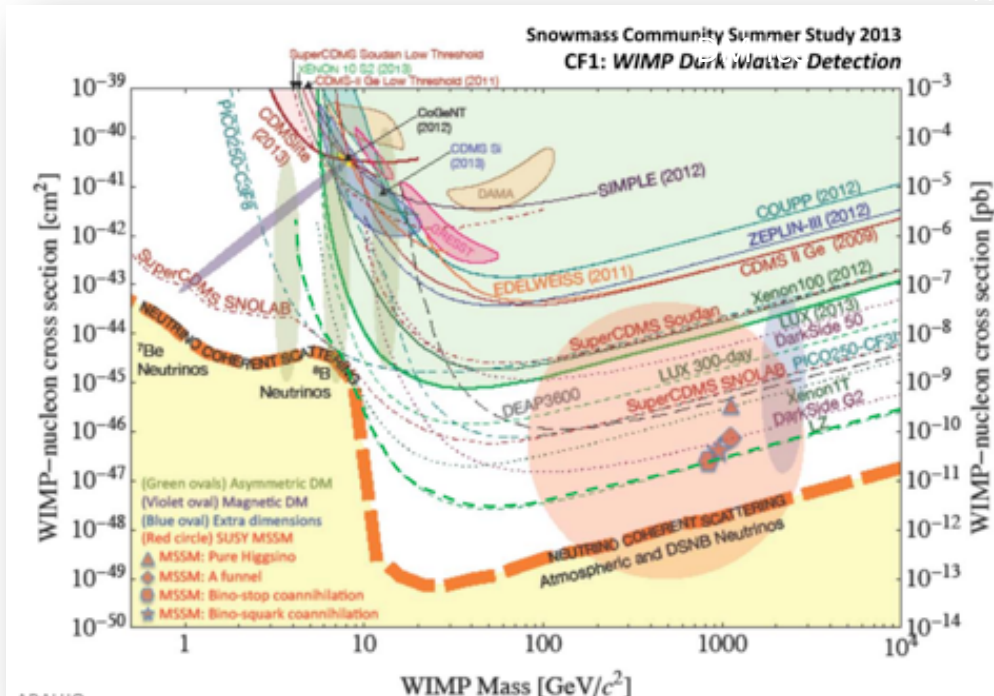
# Boulby Dark Matter Studies

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

Boulby now hosts DRIFT Directional DM programme, doing R&D for DM-Ice & providing ULB material screening for other studies, inc **LUX-ZEPLIN**



ZEPLIN-III @ Boulby



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



Current limits & future projections



# DRIFT-II (etc) @ Boulby...

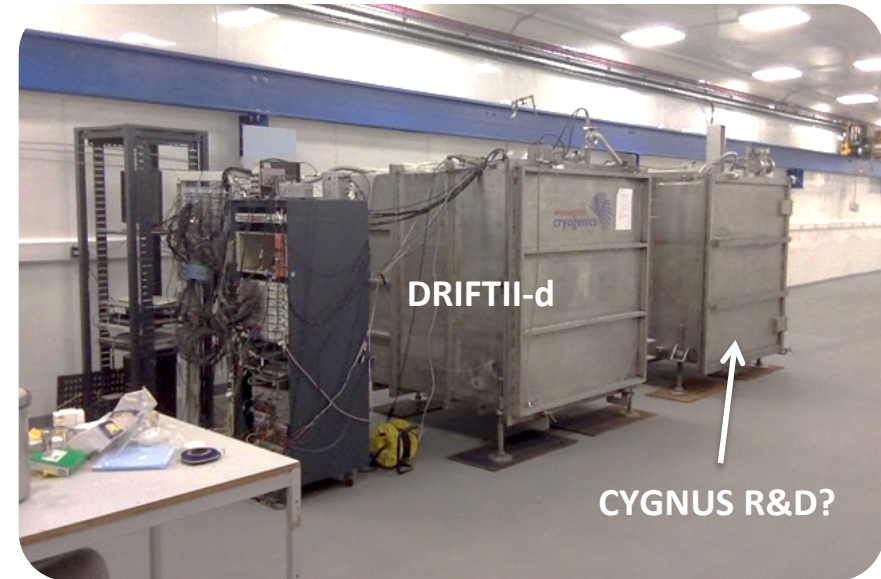
A DIRECTIONAL Dark Matter Detector.

*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**).

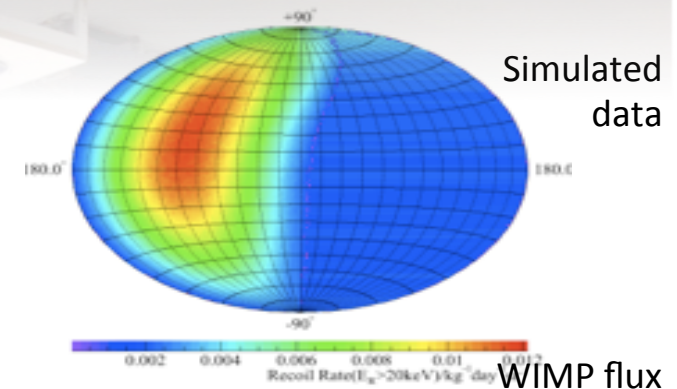


Talks @ IDM by: N. Spooner / A. Scarff (21/7/16)



DRIFT-II-d @ Boulby

Directional detection



Directional DM detection – providing the  
most powerful direct detection signature



# ULB Material Screening

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

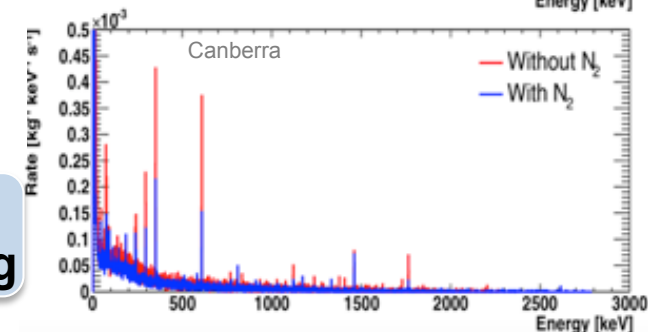
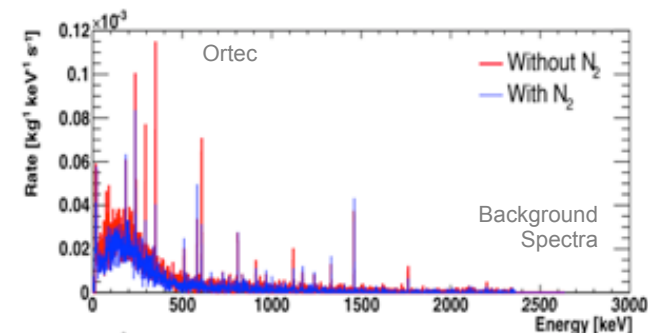


Boulby Underground  
Germanium Suite (BUGS)



Activity testing steel  
samples

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

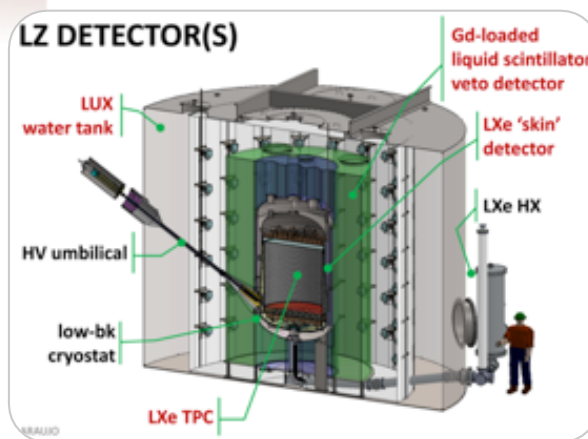


**Sensitivity down to <50ppt  
U/Th per sample, & improving**

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

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

Working in collaboration with UCL, Oxford, DMUK, STFC-RAL



Boulby undertaking major role (50%) in material selection for **LUX-ZEPLIN**



**BUGS move to new lab complete...** All detectors successfully installed and operating.



**Funding for new detectors secured.** To support current and future LB experiments (towards PPT sensitivity)





# Boulby Multi-Disciplinary Studies



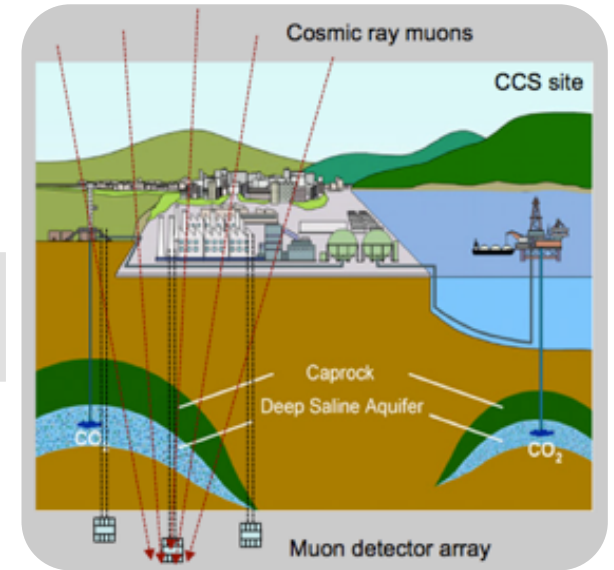
**ERSaB:** Gamma spectroscopy & low background counting environmental radioactivity studies

*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.*



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

Life in Boulby Salt...



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



## 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: Summer 2016**



Mars Analogue Area & outside testing area

Materials Entrance 1

Materials Entrance 2

Main hall:  
Internal Lab  
height/width of  
4m/7m

Offices &  
People  
Entrance

Material  
Store

BUGS ULB  
Counting facility

Large Expt. Cave Area:  
Internal lab height/  
width of 6.5m/7m



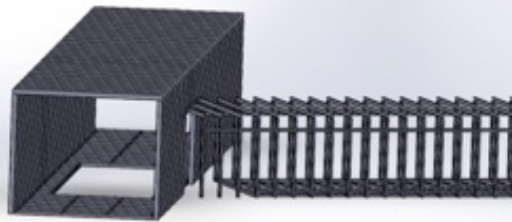
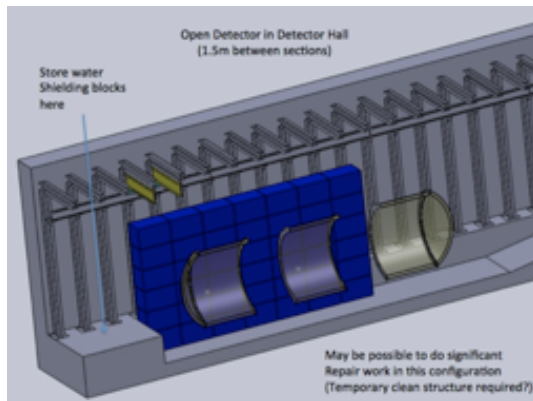
Fully-equipped 4000m<sup>3</sup> lab. Class 10K & 1K clean room throughout. 5-10T lifting capacity.

50m

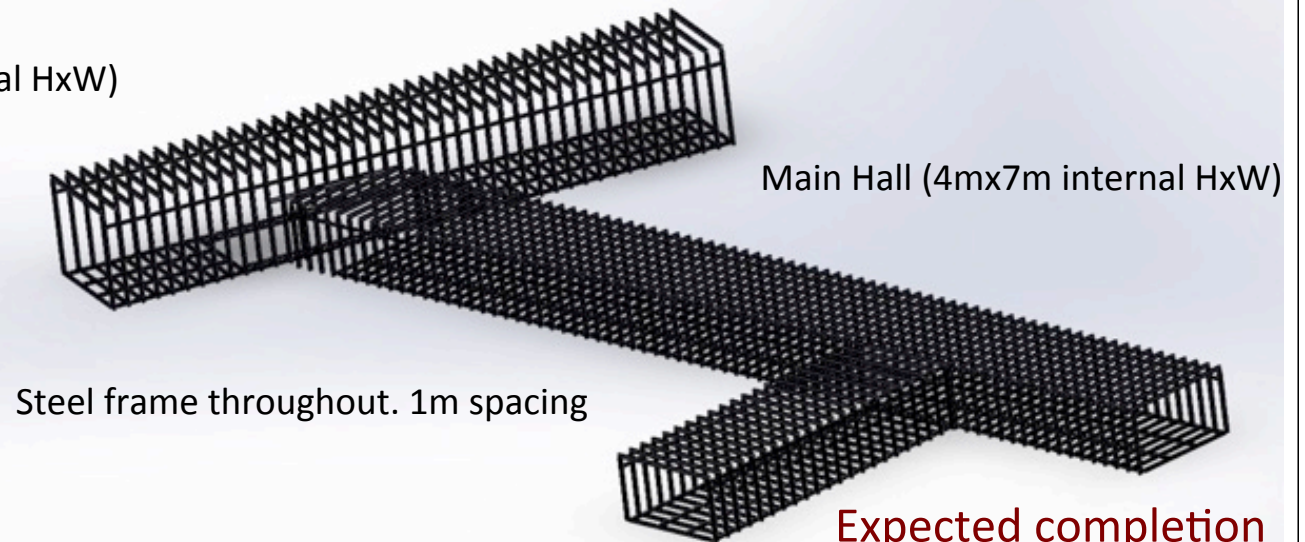
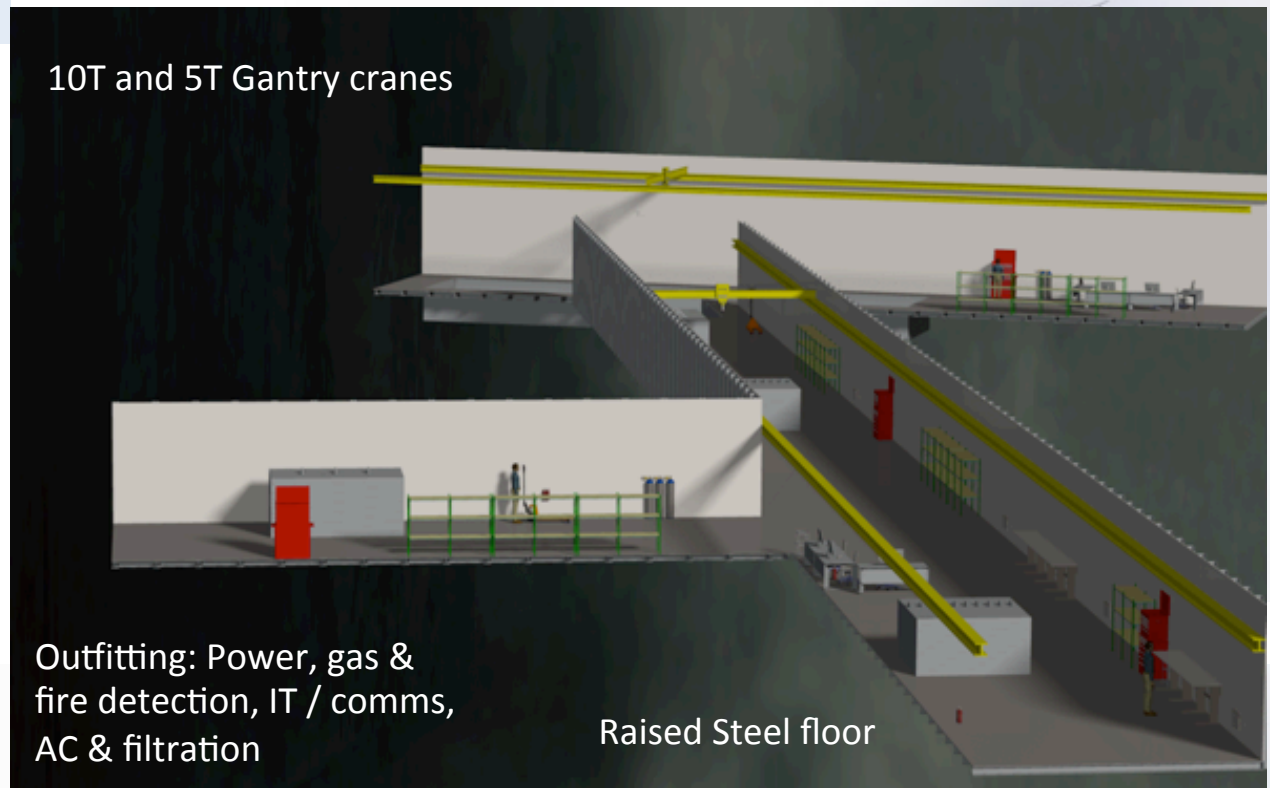
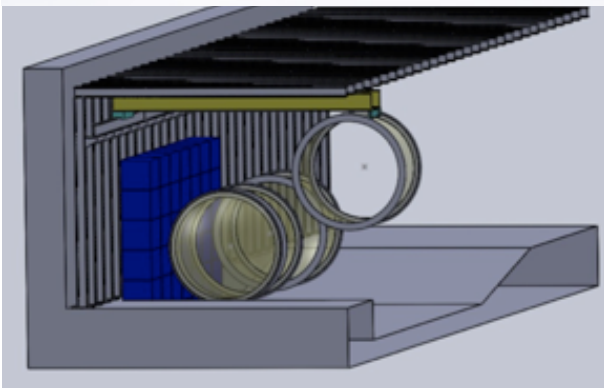
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## New Laboratory Details



Large Experimental Cavern (6mx7m Internal HxW)



Expected completion  
July 2016



Main Experimental Hall (7x4x60m)



'BUGS' ULB Germanium Facility



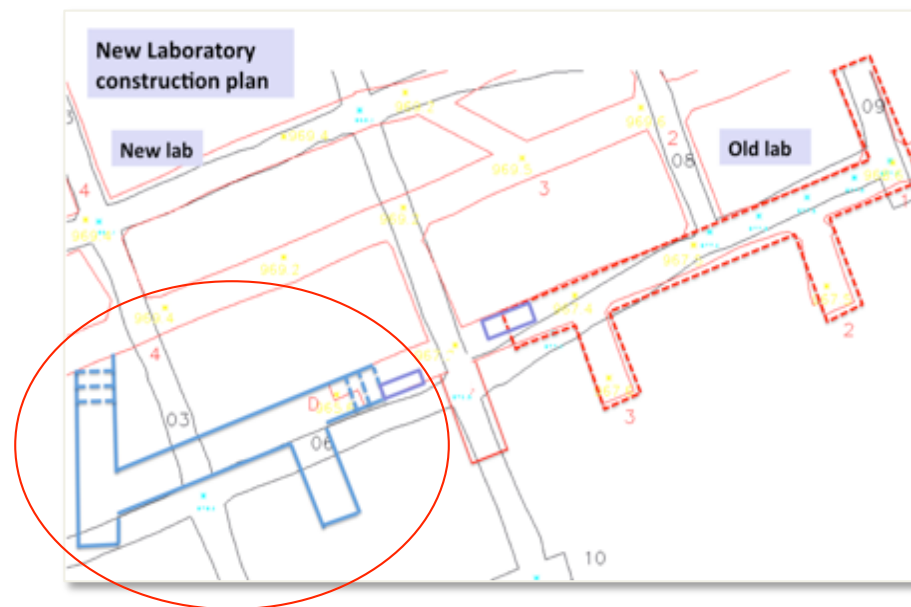
Boulby New Lab  
Construction  
March 2016

> **4000m<sup>3</sup>** of well supported **class 1,000** and **class 10,000** clean room experimental space



Large Experimental Cavern (LEC)  
(7x7x35m)

Air conditioning, HEPA filtration, internet / comms, 5 & 10 Tonne lifting capacity.



Now moving experiments in from old lab.

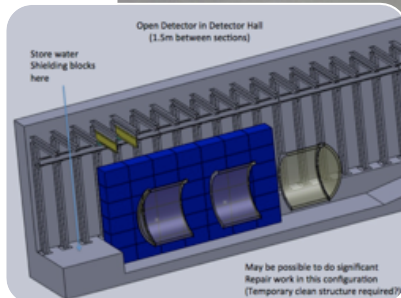


Boulby New Lab Large Experimental Cavern (LEC)  
July 2016





# Directional DM search @ Boulby





# Directional DM search @ Boulby



- ❖ Proven ability to operate detectors in general. Experience operating, fixing & supporting low pressure TPCs specifically.
- ❖ We have great new UG lab – with free space.
- ❖ We are gathering flagship projects to associate with the new lab. We have a longer history with DRIFT... and this fits.
- ❖ What support can we give?
  - Proven history of extra material & manpower support to DRIFT along the way.
  - New lab designed with CYGNUS-Like detector in mind.
  - Can count on the fact we will support as we can (e.g. shielding? manpower? vessel? politics? etc).
- ❖ CYGNUS @ Boulby? .... We would support early R&D  
Leading to later full system.





# Boulby Underground Laboratory

## Review of expressions of interest

### Coming Soon (early 2017)

# Thank You....



**Come and visit / work-with us...**

Email: [Boulby@stfc.ac.uk](mailto:Boulby@stfc.ac.uk)

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

Sean Paling  
STFC Boulby Underground Science Facility

Facebook: Boulby Underground  
Laboratory