Deep Underground Science in the UK

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ZEPLIN-III

DRIFT-II @ Boulby

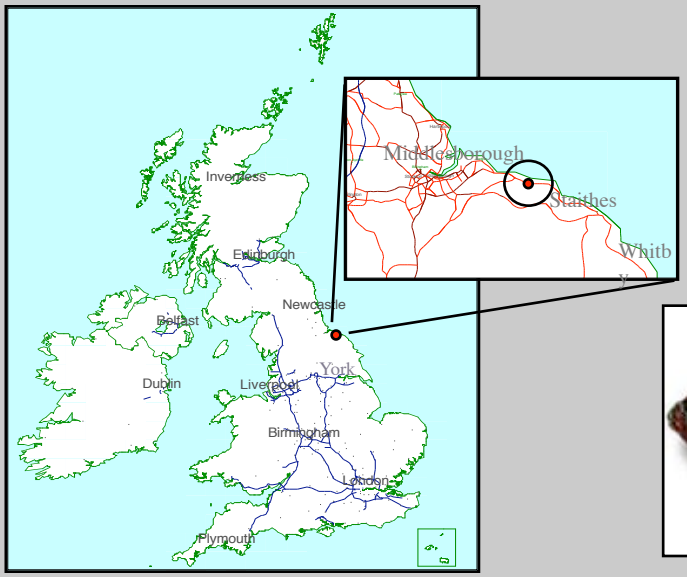
Underground Science in the UK

This Talk

- **The Science Facility @ Boulby Mine**
- **Current Science**
  - Dark Matter – ZEPLIN-III, DRIFT-II
  - SKY-ZERO – Climate / cosmic rays
  - Low Background Counting
- **The Future**
  - Future funding
  - Future Science – DRIFT, SKY-II, LAGUNA, Low Background Counting, Geoscience, etc

Boulby Mine

- A **working potash and rock-salt mine** on the North East Coast of England
- Operated by Cleveland Potash Ltd
- **Major local employer** - ~1000 direct and 4000 indirect employment.
- Deepest mine in Britain – **1100m deep** (2805mwe) – **Cosmic rays reduced by 10^6**

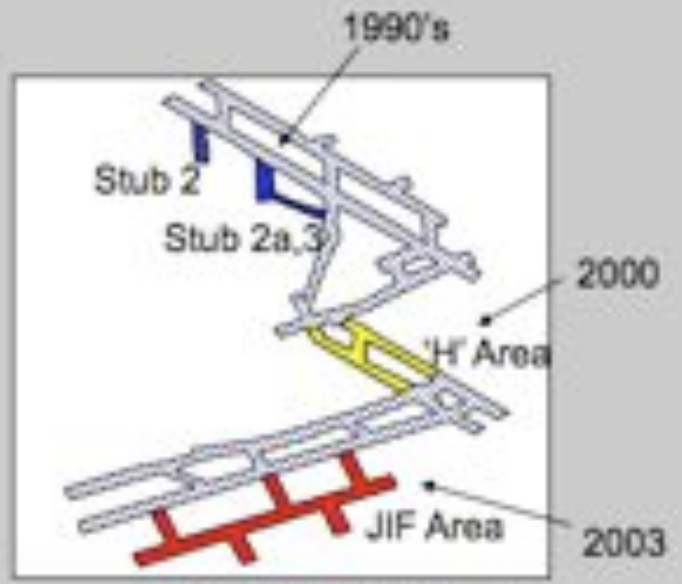


Sylvanite

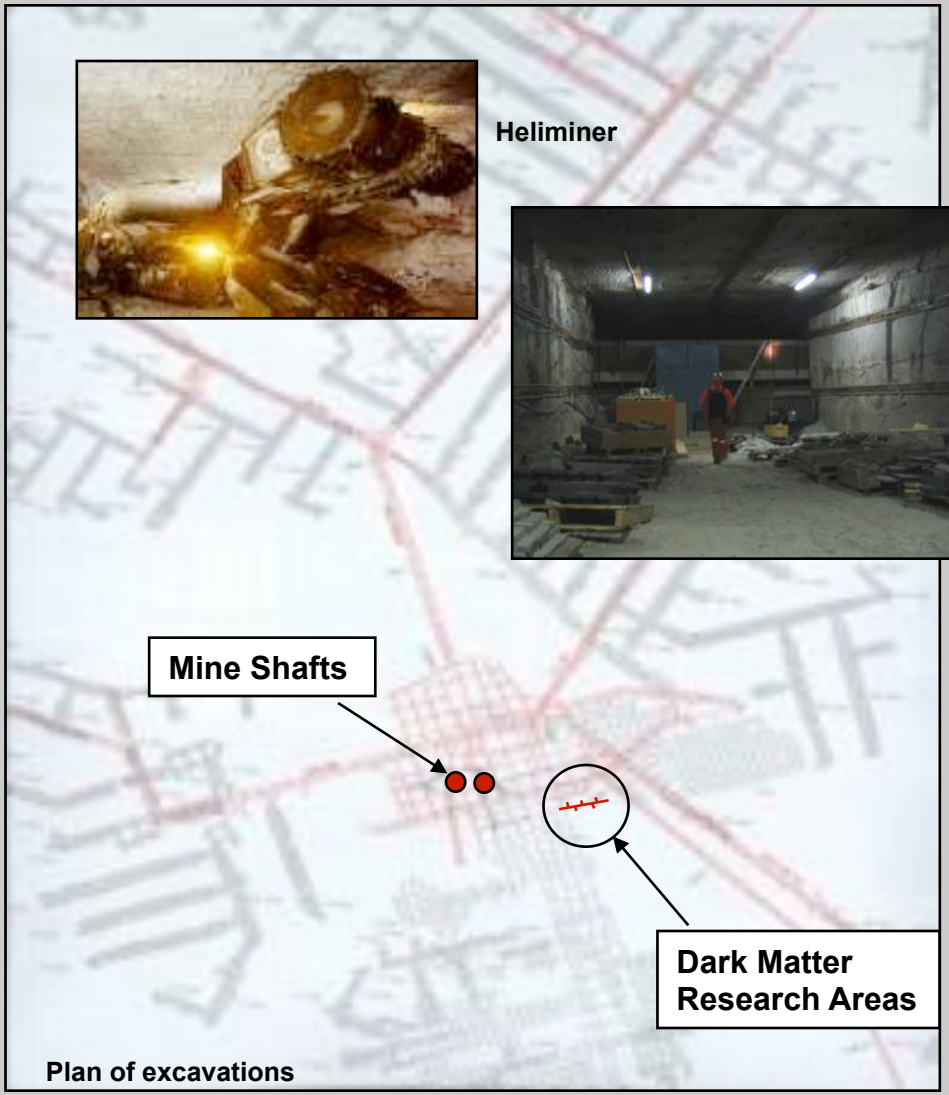
`View from Staithes

Boulby Mine

- Over 40 kms of tunnel mined each year (now >1,000kms in total)
- Long lived roadways cut in salt (NaCl) – giving access to potash (KCl) levels just above
- Boulby salt is very **low in natural radioactive backgrounds.**



Map of the Dark Matter research areas

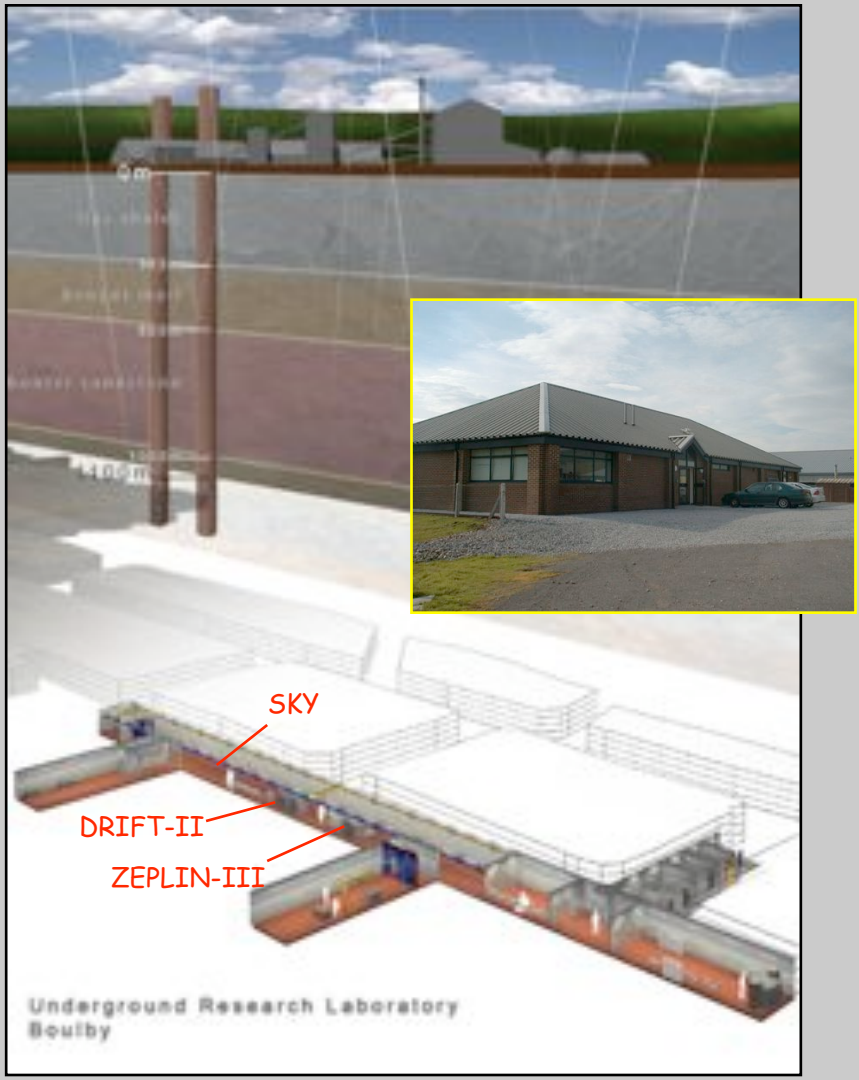


Plan of excavations

Boulby Science facilities

'JIF' Facilities (opened 2003).

- **'Palmer Lab'**: a 100+m, fully equipped underground lab. Power, internet and telephone communications, lifting, air conditioning / filtration, clean room.
- **'John Barton' surface facility**: Workshop, facility monitoring, office and administration, PPE, storage, chemistry lab, changing rooms.

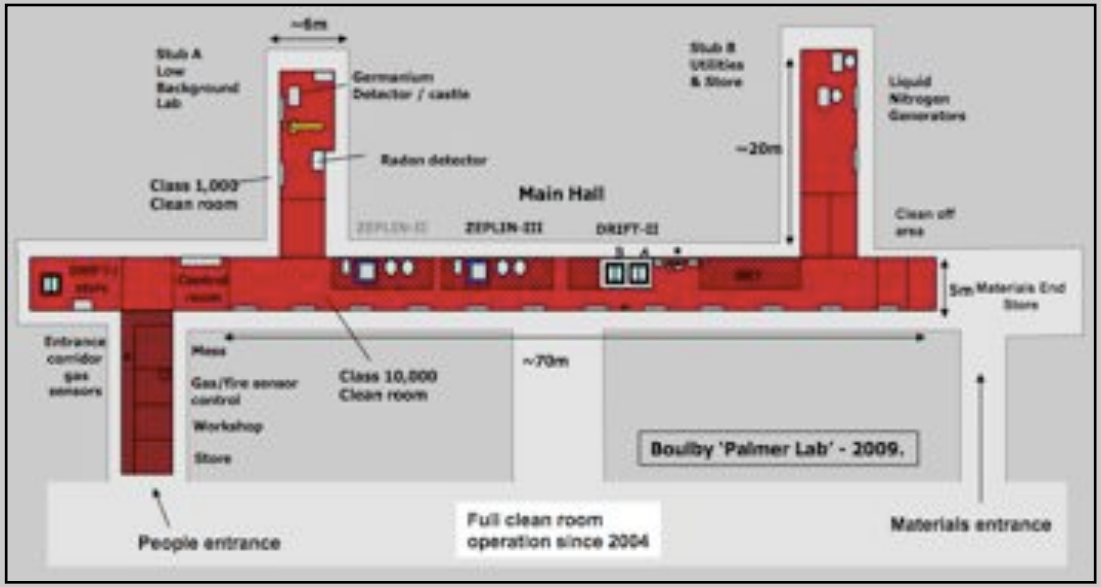


The Palmer laboratory

Low background counting

ZEPLIN-III

Cryogenerators



SKY

DRIFT-II

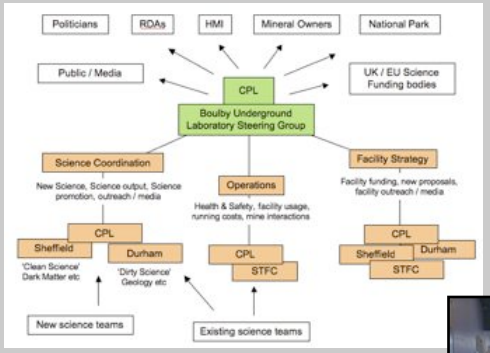
Facility management & operation

- 40 scientist (UK & abroad) directly using site (100 more widely involved)

- Facility operations managed by STFC (Sean Paling, Louise Yeoman on site)
- Health and safety all in line with STFC (and CPL / mine inspectorate).
- Finance and IT systems through STFC

- Facility strategy coordinated through the Boulby Steering Group (STFC, Sheffield, CPL, Crown).
- Operations managed through weekly Boulby Operations meetings (BOMs)

- CPL provide wide ranging operational support (Underground site safety, medical, electricity & water supply, UG and surface transportation)



PROJECT RESOURCE SUMMARY (UPDATED)

Project Name:	ZEPLIN III
Contact Person/ Institute:	Henrique Araújo (Imperial College London, RAL)
Brief Description:	A 6kg two phase xenon dark matter detector

Summary of resource requirements from the facility:

Space requirement, W(dth)/Depth/Height	8.0m / 10.0m / 3.0m
Crane requirement (x/y?), weight and height	x/x/ 2 tonne / 3.0m
Electrical power / voltage / phase requirements	240V single phase: 14 kW
Transportation requirements (Installation & Normal operation):	Installation: Purifier, 2x dump chamber, target, cryogenerator, chiller, DAQ, computing Relocation: of lead castle from Stab 2 to [[I 180 tonnes?]]. Operations: None
Maximum tolerable transportation shock	0.5g
Experiment team size underground (installation/operation)	Installation: 4 Operations: 4
Cryogenic requirements (LN_2)	During cooldown: 150l During emergency recovery: 60l

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 (2,805 mwe)
CR muons attenuated by ~10^6

Salt = low in U/Th
→Low gamma & neutron backgrounds
→ Low Radon

Plenty of Laboratory space

>1000 m^2 existing lab space & v.good potential for expansion.

Easy access for equipment

Via mine shaft (5m diam. – 2×2×2m cage)
+ Transport underground

Proximity of services / civilisation

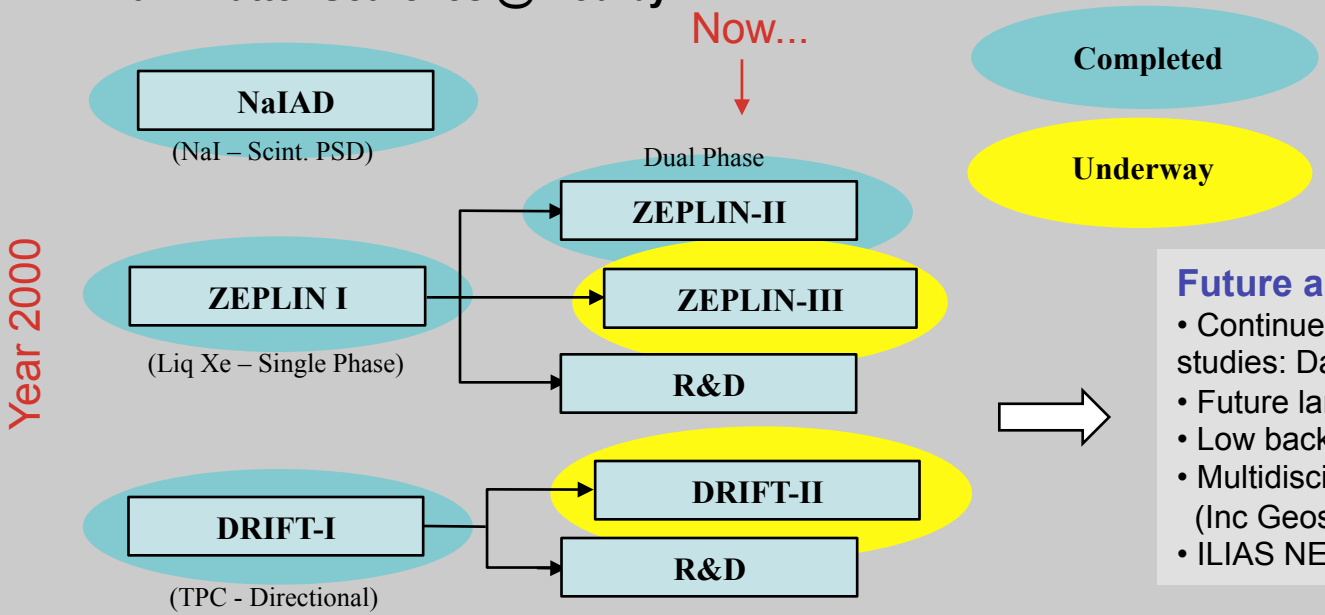
20 min → Whitby, Saltburn
1 hr → York, Leeds, Middleborough
< 5 hrs → London, Manchester etc.

Good infrastructure + support

- JIF Underground & surface facilities
- Wide-ranging support from mine operators (CPL)

Science @ Boulby

Dark Matter Searches @ Boulby



Future aims?

- Continued rare event / low background studies: Dark Matter (DRIFT,), SKY-II?
- Future large scale detectors? (LAGUNA)
- Low background material screening?
- Multidisciplinary Underground Science? (Inc Geoscience)
- ILIAS NEXT

Also...

SKY-ZERO – Ongoing Danish/UK. Cosmic Rays & climatology study

Misc Low Background Studies

- Neutron Background measurements (NUTs, ELENA)
- Muon-induced neutrons (Z-II veto study)
- **High sensitivity Ge detector measurements**
- **Radon emanation Measurements**

ILIAS

- JRA1
- N2
- TARI

Active contributor in both ILIAS and ILIAS-next EU lab programmes

Dark Matter Experiments – Mar 2010

ZEPLIN-III

Imperial College, Edinburgh, RAL, LIP-Coimbra, ITEP-Moscow `

2 phase (liquid/gas) high field Xenon WIMP dark matter detector.
31 PMTs immersed in ~12kg liquid target. High purity Cu construction. Pb shielding & active veto.
Installed 2008. STFC funded to Oct 2010

Preparations underway for 2nd science run – giving world-class sensitivity.

DRIFT-II

Sheffield, Edinburgh, Occidental College, U of New Mexico`

Low pressure gaseous TPC **directional** WIMP dark matter detector.
1m^3 (fiducial) negative ion drift TPC, 167g CS_2 target. Dual 0.5m^3 drift vols with MWPC readout.
Installed – 2005. US (NSF) funded to end 2012 – strong prospects for future increased US funding.

Now running with CF_4 allowing world-competitive WIMP-proton SD limit setting

SKY @ Boulby

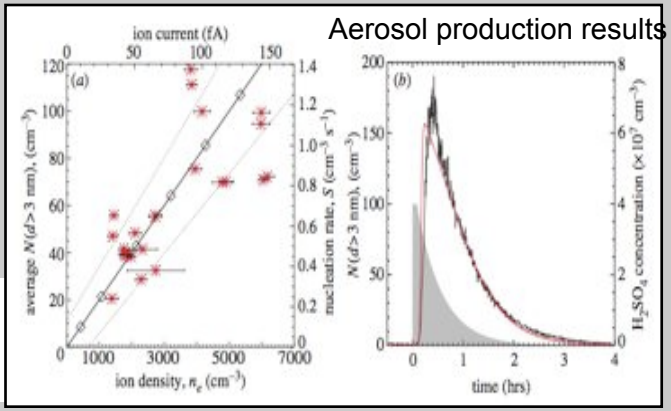
An Danish/UK (**EPSRC**) study of the effect of ions on aerosol nucleation in the atmosphere - the first study in an ultra-low background radiation environment.

Important in climatology: Ionisation from cosmic rays may have an influence on cloud production and mean cloud clover

SKY @ Boulby

Do Cosmic Rays play a role in cloud formation and global climate??

Aerosol production results

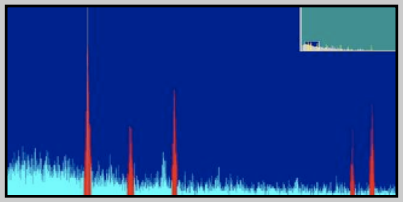


SKY-ZERO: 2008-2010. Primary science runs @ Boulby completed. Analysis and papers underway. Next generation experiment (SKY-II) hoped for for **2011-2012**

Participants: Sheffield University, Danish National Space Centre, CPL.

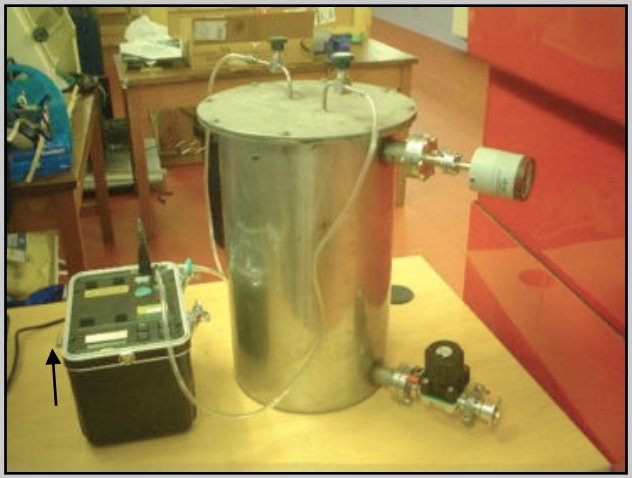
Low Background Counting

Ultra-low background Ge detector for gamma spectrometry & material selection.



Low background, high sensitivity, 2kg (~400cc) Ge detector for material activity measurements.
Sensitivity of ~1-10ppb U/Th for typical samples.

Factor 30 reduction in ZEPLIN-III PMT backgrounds

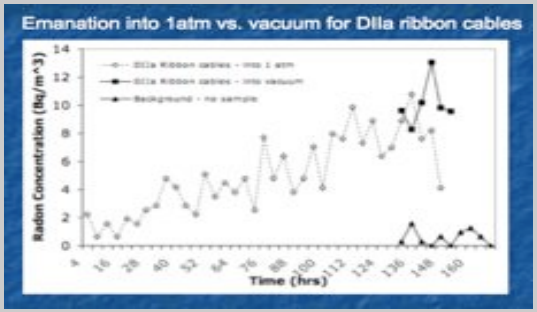


Radon emanation measurement system

Based on a high sensitivity, low background commercial Rn detector (Durridge Rad7).

Sensitivity <0.02Bq/sample.

Factor 20 reduction in DRIFT-II Rn backgrounds



Future Science @ Boulby?

STFC prioritisation...

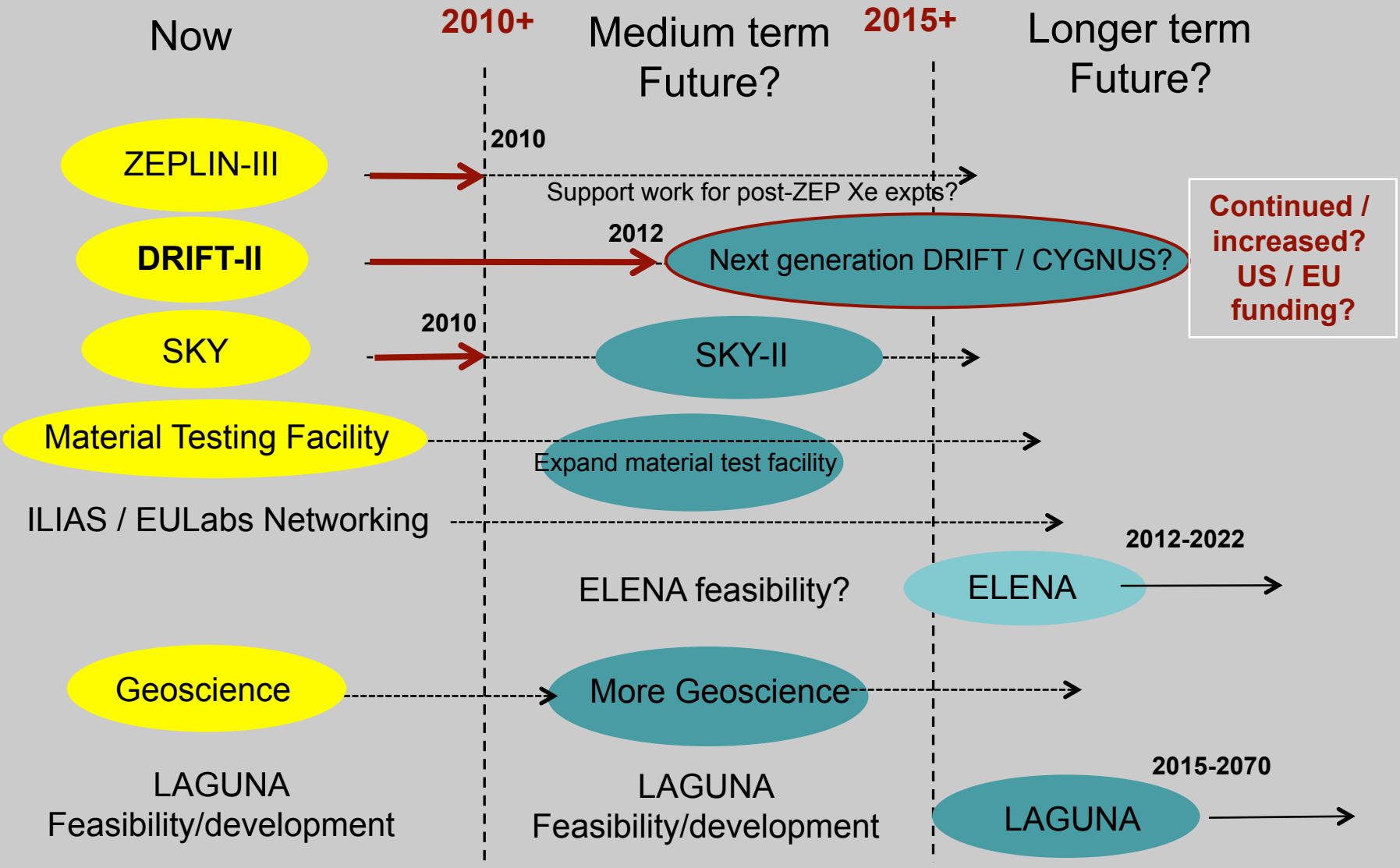
- Alpha1 Boulby facility rating referred to a particular proposal NOT Boulby as a whole

- ZEPLIN not funded beyond Oct 2010 & a couple of key new proposals not funded (so Boulby funding is under review)

- STFC say ‘we will continue to fund Boulby so long as there is a viable science programme’

- Also - ‘No intention to precipitously cut funding in a way that hurts existing experiments or promising future plans

Future Science @ Boulby?



Future Science @ Boulby?


Fig. 2: An impression of SKY-II – a double-skinned chamber with an internal baffle matrix

SKY-II

SKY-ZERO: confirmed effect of ionisation of aerosol formation & shed new light on aerosol production & growth mechanism. 1 paper published, 2 more on the way

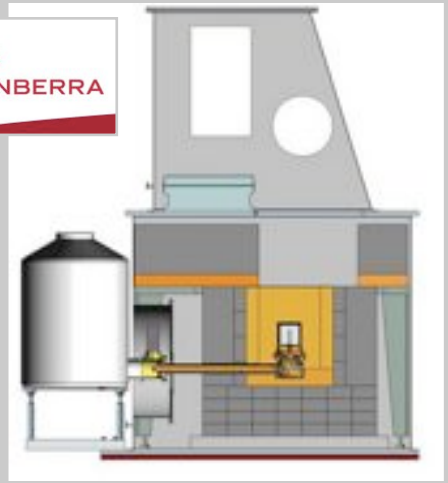
A bigger and better controlled & monitored experiment is needed: SKY-II @ Boulby (2011-12). 1/3rd of equipment funding already secured...

High purity, low background Ge detector

DURRIDGE Radon Instrumentation

CANBERRA

Rn Emanation system



Improved Low Background Counting

Seek funds for world class low background Ge detector & Rn emanation measurement systems.

• A great need in low-background, rare event studies – with **wider applications in industry defence, environment studies.**

Factor 100 improvement in sensitivity needed.

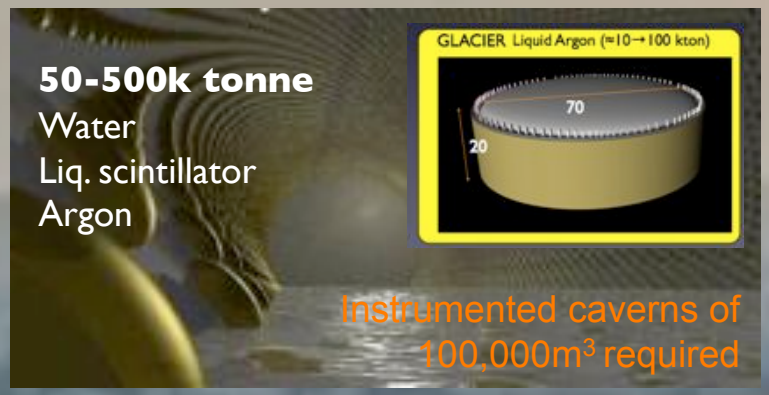
~£300k needed to purchase, commission and operate for 2 years.

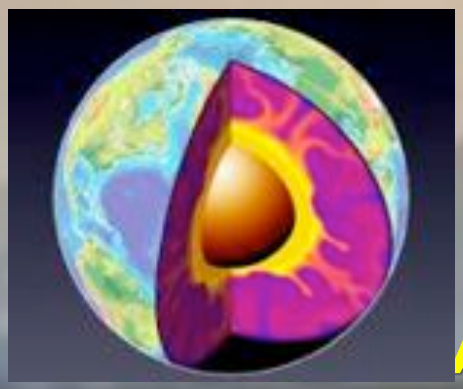
Strong support in low-background community

LAGUNA

Large Apparatus for Grand Unification and Neutrino Astrophysics

FP7 (& beyond) funded design study for infrastructure to house a MEGATON 'rare event' observatory





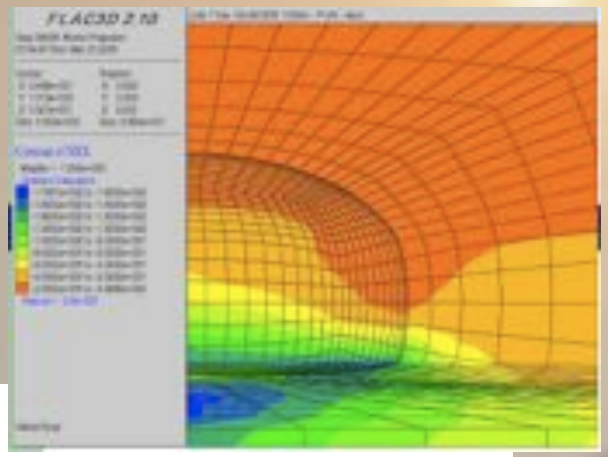
BIG QUESTIONS:

- Proton decay
- Supernova neutrinos
- Diffuse SN neutrinos
- Solar neutrinos
- Atmospheric neutrinos
- Geo-neutrinos
- Reactor neutrinos
- Neutrino beams
- Indirect dark matter (direct DM and DBD)

Boulby is one of 7 potential sites

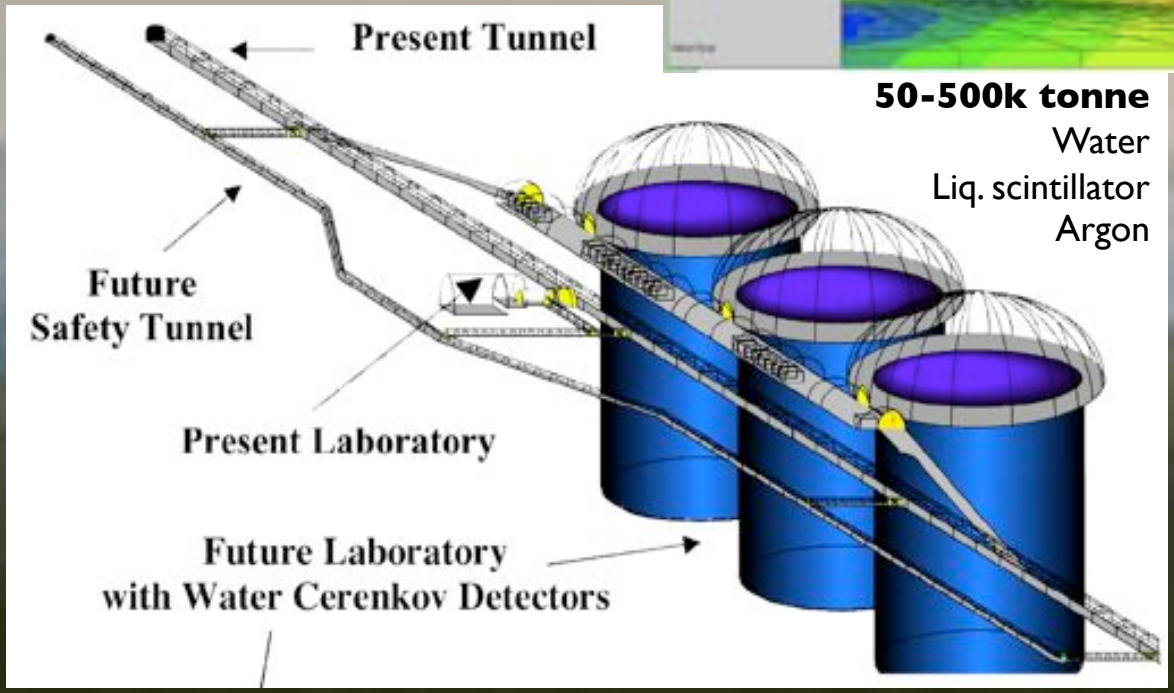
LAGUNA

Large Apparatus for Grand Unification and Neutrino Astrophysics



A HUGE though achievable undertaking

Feasibility & site selection study now underway... Construction/ operation from 2015-2070



50-500k tonne
Water
Liq. scintillator
Argon

Geoscience

Steps towards a Deep Underground Geoscience Laboratory @ Boulby?

Improved mining technologies

E.g. enhanced extraction but reduced subsidence?

Rock deformation studies

E.g. salt deformation and oil reservoirs?

Waste storage

E.g. how can we store waste (e.g. CO_2) underground?

Seismology

E.g. how does stress change induce earthquakes?

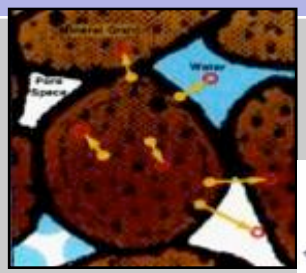
Geochemistry

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

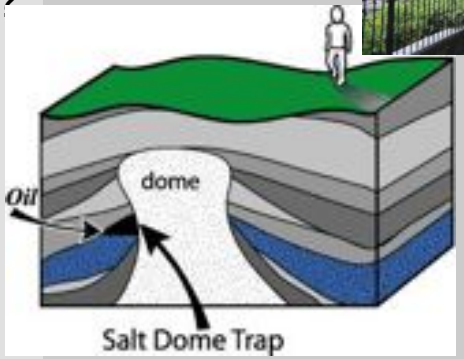
Extremophiles.

E.g. how do microbes survive in extreme environs?

Geo-microbes



Geochemistry



Rock deformation & subsidence

£1M stage 1 funding received: 18 month Boulby Geoscience proof-of-concept study...

Durham University

one NORTH EAST

CLEVELAND POTASH

Deep Underground Science in the UK

With Boulby we have a world class, low cost, deep underground science facility in our own backyard

Distinguished record of world-class, world leading science – and good potential for hosting future small or large scale studies (DRIFT, SKY, Low Background Counting, LAGUNA, Geoscience).

STFC announcement not as harsh as first appeared – but cuts do mean effort is needed maintain/expand science programme ad consider alternative funding schemes.

Support the UK's Deep Underground Science Facility