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Boulby Underground Laboratory

# Update from the Boulby Underground Laboratory

Paul Scovell – DMUK– 16/11/2021

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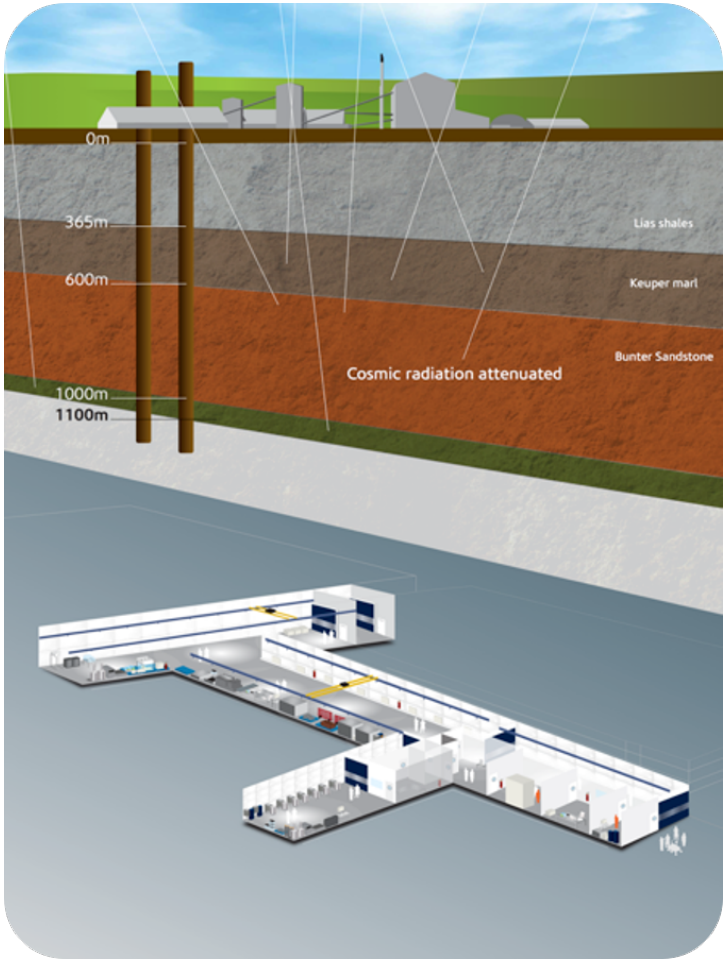
# Introduction

- The Boulby Underground Laboratory is a multi-disciplinary facility in the north-east of England
- 1.1 km underground
- $10^6$ reduction in muon background
- Operated by STFC in partnership with ICL-UK



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# Dark Matter Studies at Boulby

- Boulby has hosted dark matter searches for more than two decades
  - NaIAD, DRIFT, ZEPLIN
- Boulby now hosts part of the CYGNUS directional DM programme, NEWS-G/Dark-Sphere R&D
- Boulby provides ULB material screening for other studies
  - LZ, DarkSide, etc

# Dark Matter Studies at Boulby

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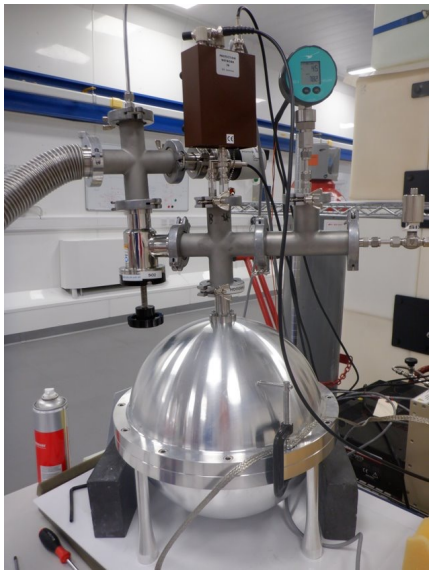
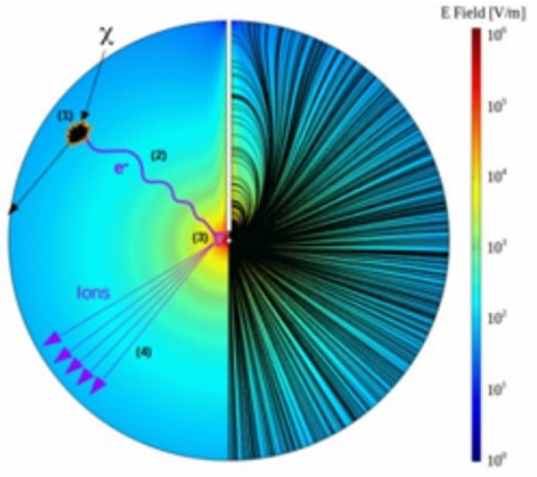
- NEWS-G dark-sphere R&D vessel running for 2 years
- Developing sensors for spherical TPC
- Using SPC – Spherical Projection Chamber






- New plans for CYGNUS R&D under development
- Recently reopened vessel for first time since pre-lockdown
- Move away from $CS_2$ to $SF_6$

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# BUGS Today

- Detectors purged with 3 lpm radon reduced nitrogen
- Nitrogen produced onsite
  - In process of upgrade
- Minimal Rn reduction
  - ~2.5 Bq/m$^3$ ambient
- No encapsulation of shields (e.g. acrylic)
- No delays after sample insertion
- Class 1000

*Pic: Trevor Palin*

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# BUGS Today

Before

After


- Recently commissioned upgraded N2 gas system to provide gas for
  - Ge – Purge Gas
  - Ge – $LN_2$ generator input
  - XIA – dry gas for periods of downtime
  - RnEM – carrier gas/purge gas

** Roughly to scale!*

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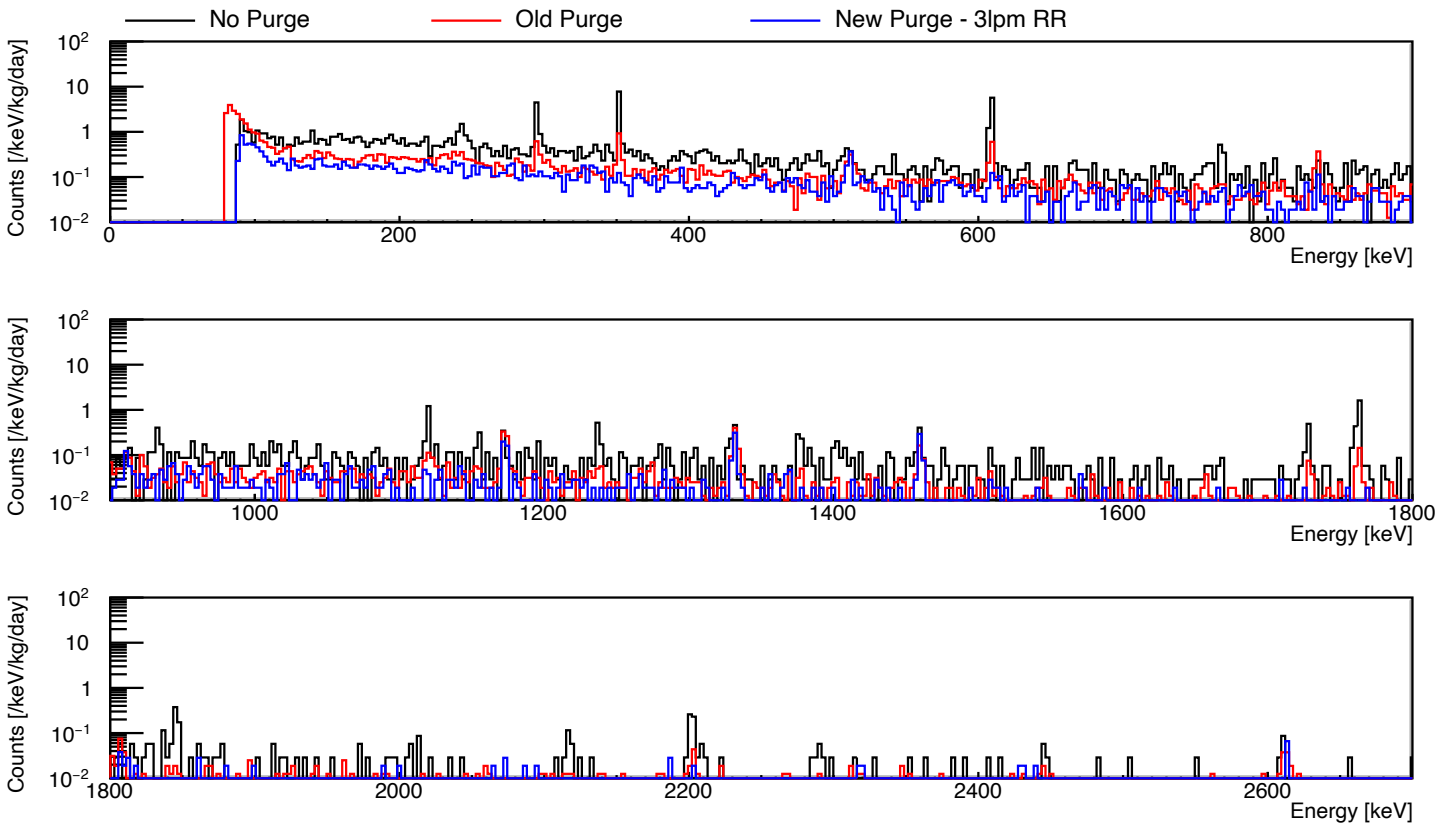
# Detector Backgrounds

Belmont
600cc p-type



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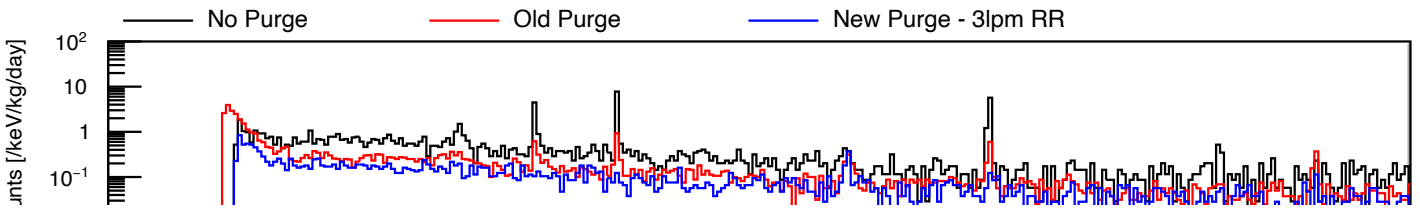


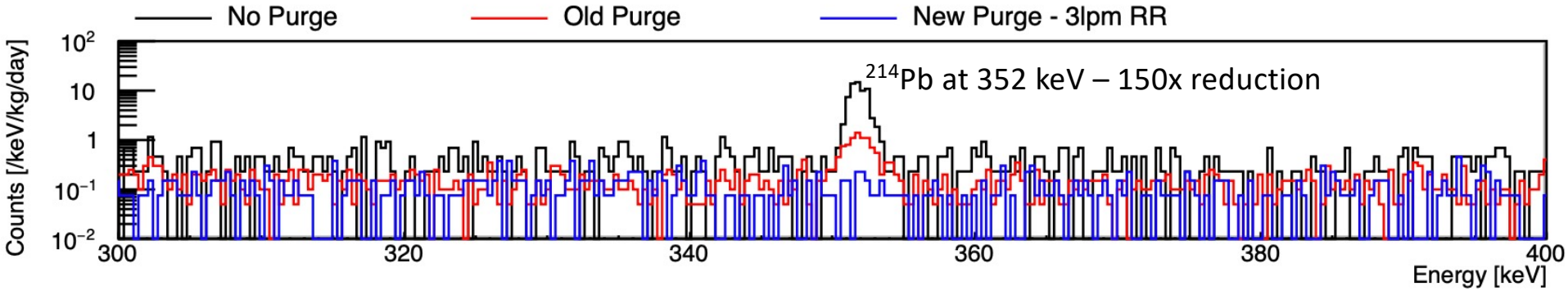


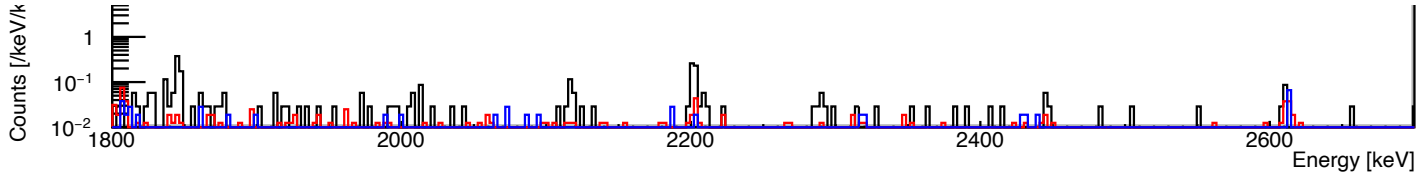

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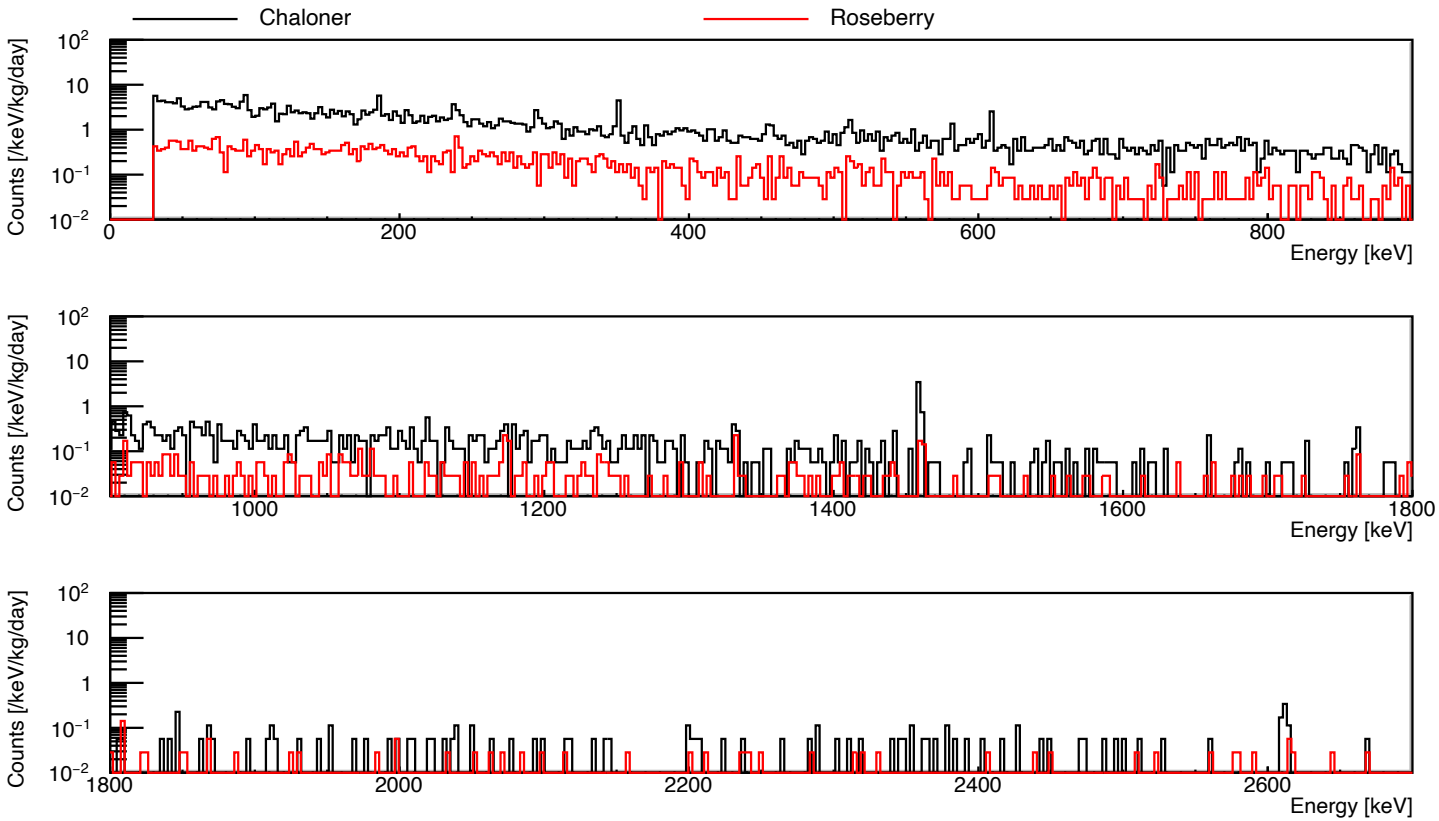
# Detector Backgrounds

Comparing LB and S-ULB BEGe detectors



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# Detector Backgrounds

| Detector | Relative Efficiency or type | Count rate (/kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | 351 keV ($^{214}$Pb) | 609 keV ($^{214}$Bi) | 238 keV ($^{212}$Pb) | 1461 keV ($^{40}$K) | 2615 keV ($^{208}$Tl) |
| Roseberry | BE6530 | 0.15(7) | 0.15(7) | 0.8(3) | 0.8(2) | 0.2(1) |
| Chaloner | BE5030 | 5(1) | 4(1) | 7(1) | 8.4(14) | 2.1(5) |
| Belmont | 160% | 0.7(2) | 0.4(1) | 0.13(6) | 1.0(2) | 0.3(1) |
| Merrybent | 100% | 2.5(3) | 1.8(3) | 0.3(1) | 1.9(3) | 0.8(2) |
| Lunehead | 100% | 5.6(5) | 4.7(4) | 8.3(5) | 9.1(6) | 2.0(3) |
| Lumpsey | SAGe-Well | 104(2) | 60(2) | 166(3) | 7.0(6) | 12(1) |

Able to hit O(100) µBq/kg with Belmont and Roseberry. However, clearly SAGe well not great

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# SAGe Well - PRELIMINARY

- Everything presented here is **preliminary**
  - New S-ULB SAGe well added
  - Detector only shielded in August!

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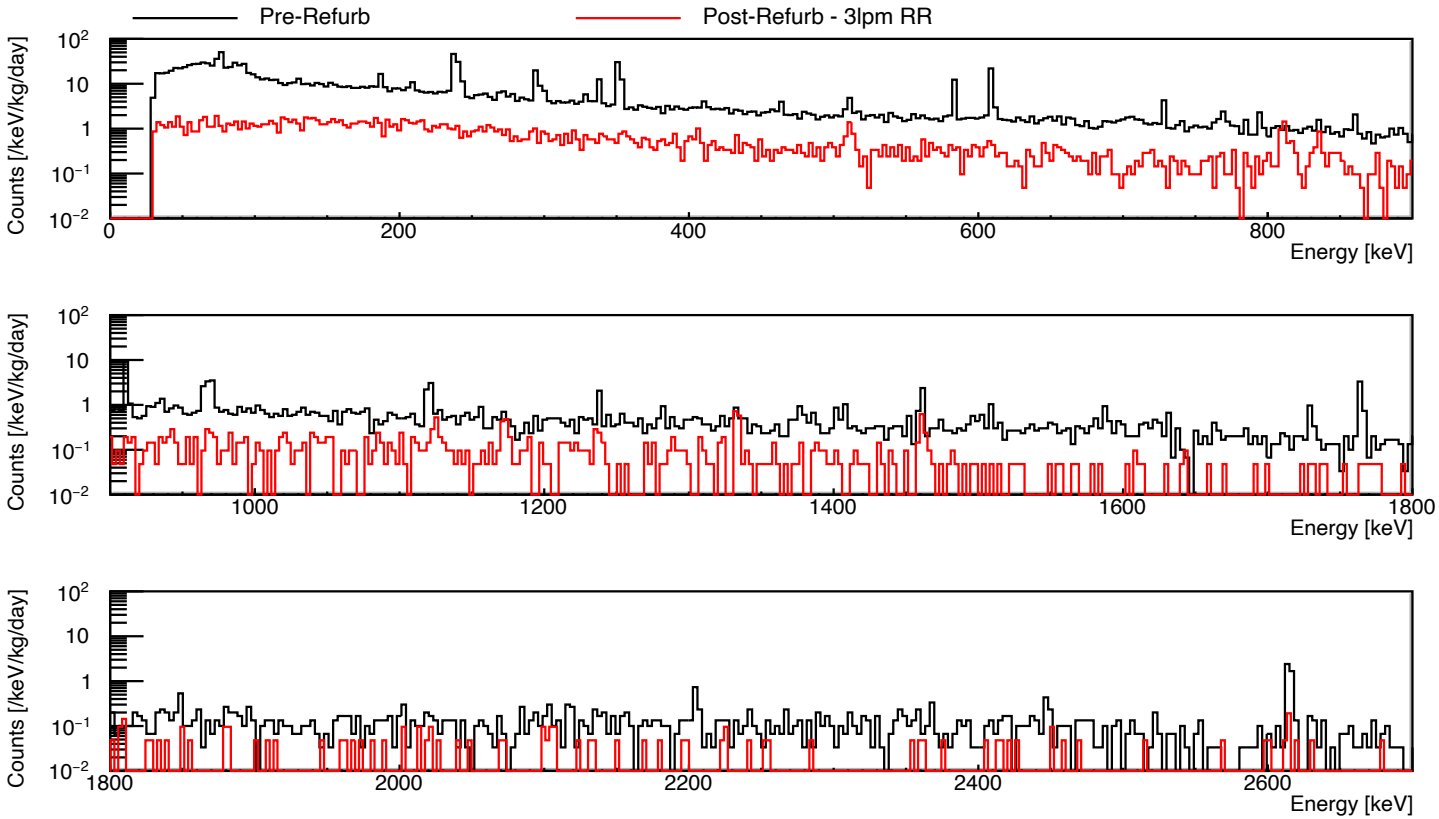

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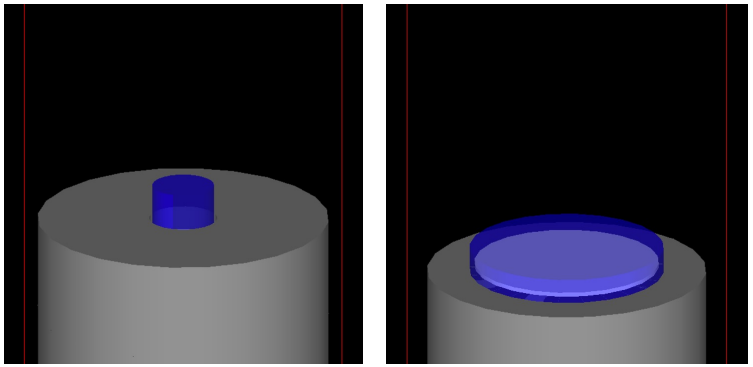
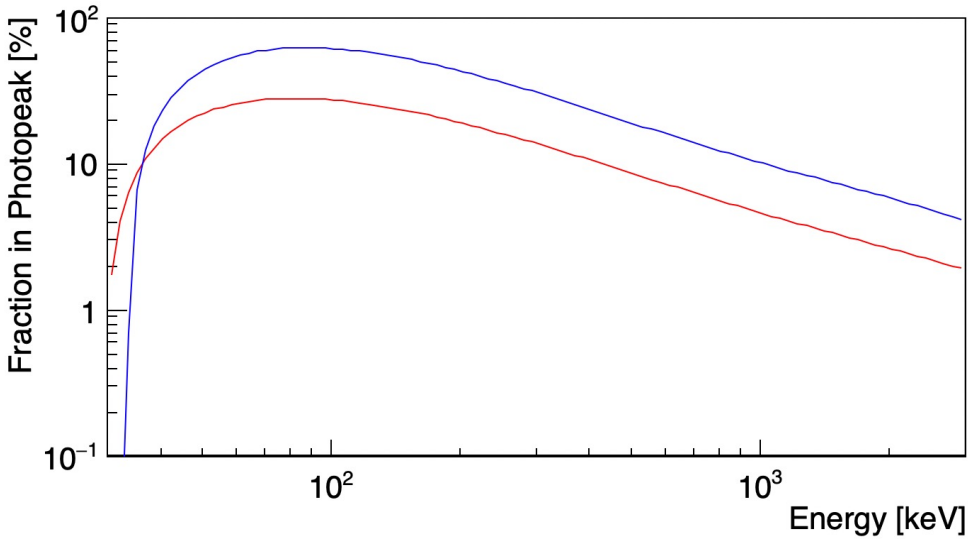
# SAGe Well – Minimum Detectible Activity

- Compare well pot sample of 9g on Lumpsey with 9g sample in a petri-dish on Roseberry






Preliminary background in Lumpsey at 46.5 keV is ~3x higher than Roseberry and efficiency is ~1.9x higher

*X.R. Liu*

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# XIA UltraLo-1800

- As of 2021, two XIA UltraLo-1800 surface alpha counters running at Boulby – Kettleness & Ormesby (both old mines, naturally)
- Dedicated argon gas is supplied to the counters via boil off from the 240l dewar. Typical flowrate is 3 lpm during measurement and 15 lpm during purging. The detector is kept under constant gas flow.

- Developing material cleaning techniques to complement surface assay capabilities.
- Surface measurements of LZ detector components and ultra-pure PNNL copper.
- Installed liner to reduce detector backgrounds.

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# UltraLo Results

- The lowest published measurement so far with XIA is XMASS at LRT2015 where they got 0.14 ± 0.03 $\alpha$/khr/cm$^2$.
- Factor three improvement compared to surface lab due to more cosmics which can mimic background events.

| Sample | Duration (hrs) | Alphas | Surface Area (cm$^2$) | Emissivity ($\alpha$/khr/cm$^2$) | Activity (mBq/m$^2$) |
|---|---|---|---|---|---|
| **Background (SS Tray)** | 168 | 342 | 1800 | 1.24 ± 0.07 | 6.88 ± 0.38 |
| **Background (PTFE Liner)** | 168 | 103 | 1800 | 0.38 ± 0.04 | 2.12 ± 0.22 |
| **PNNL Copper** | 168 | 13 | 707 | 0.13 ± 0.04 | 0.72 ± 0.22 |

*X.R. Liu*

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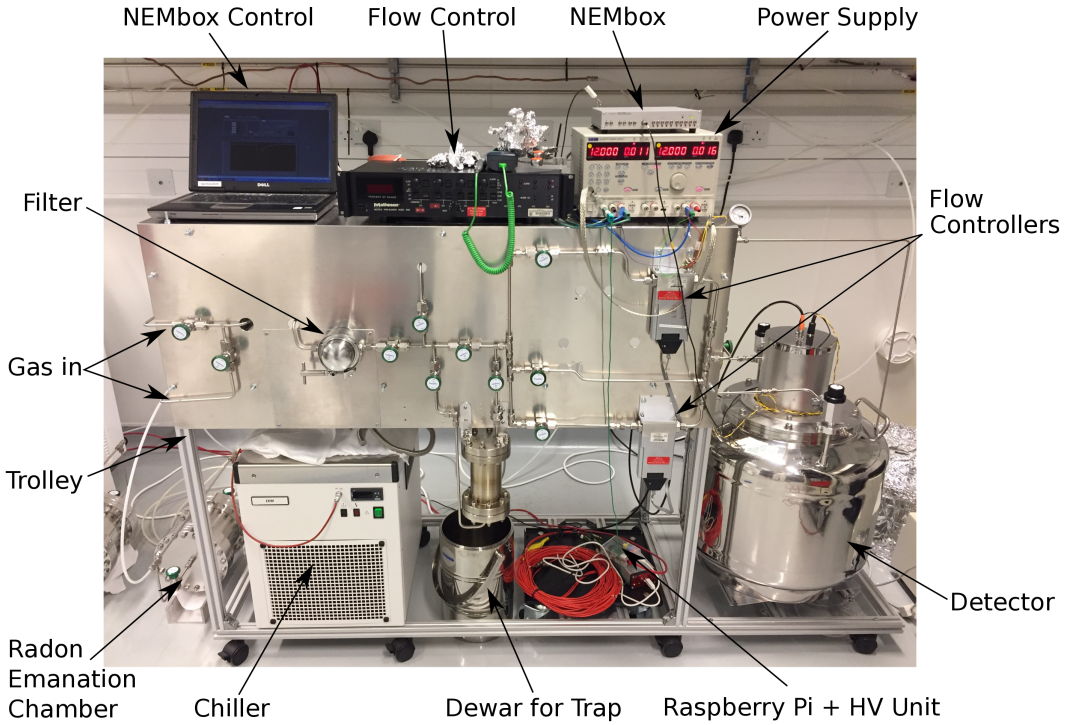
# Radon Emanation

- Low background Rn Emanation Detector *coming soon*
- Based on MSSL system used for SuperNemo
- Detectors from Cosmotec Co., Ltd
- Additional cleanliness facility on the surface
- “everything under one roof”




*Pic: X. R. Liu*

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# Conclusion

- There is a comprehensive array of assay facilities at Boulby
- Looking to remain on the cutting edge
- Developments underway for next generation low-background physics experiments
- All techniques under one (1.1 km thick) roof