



UNIVERSITY OF  
BIRMINGHAM



Science and  
Technology  
Facilities Council

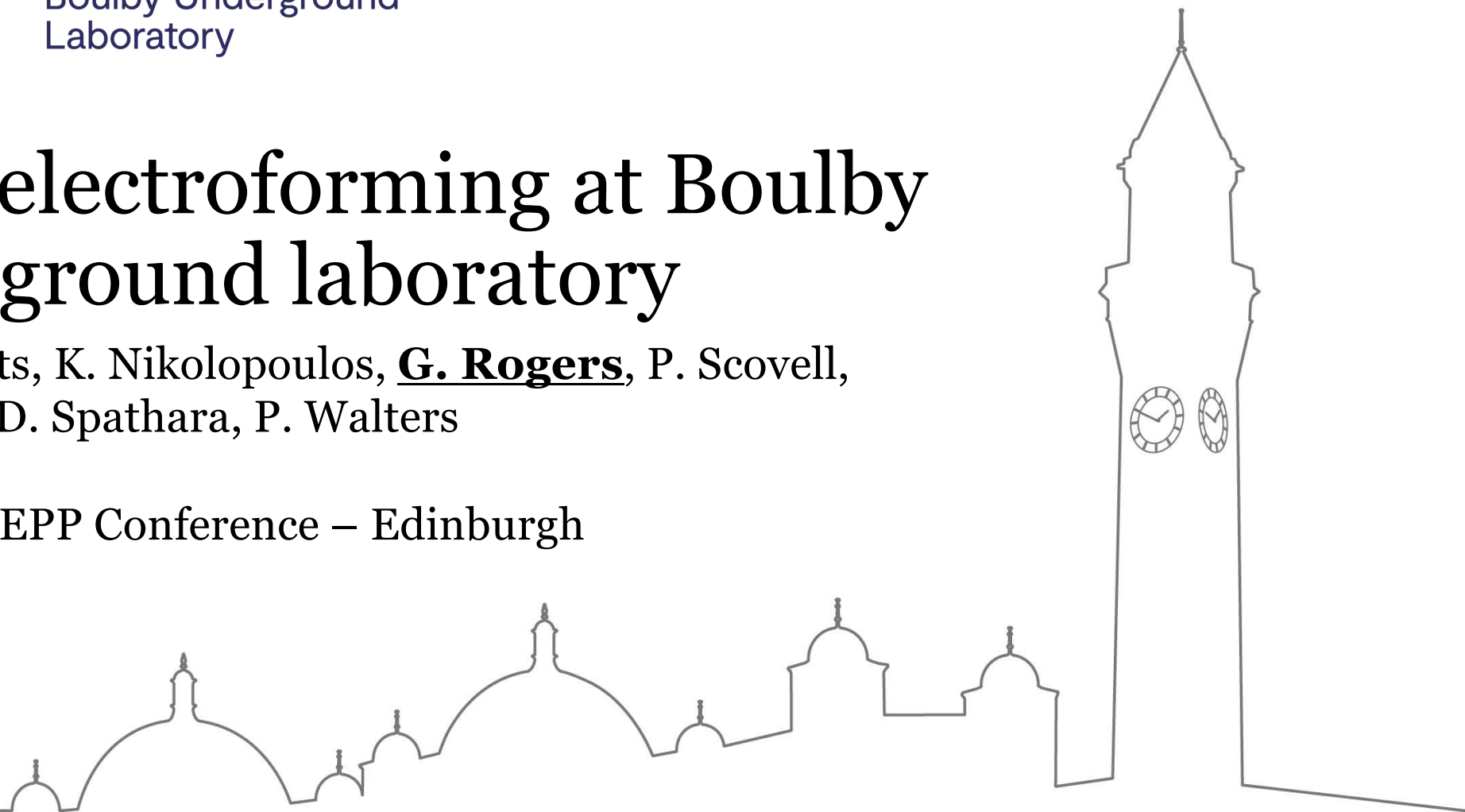
Boulby Underground  
Laboratory

# Ultra-pure electroforming at Boulby deep underground laboratory

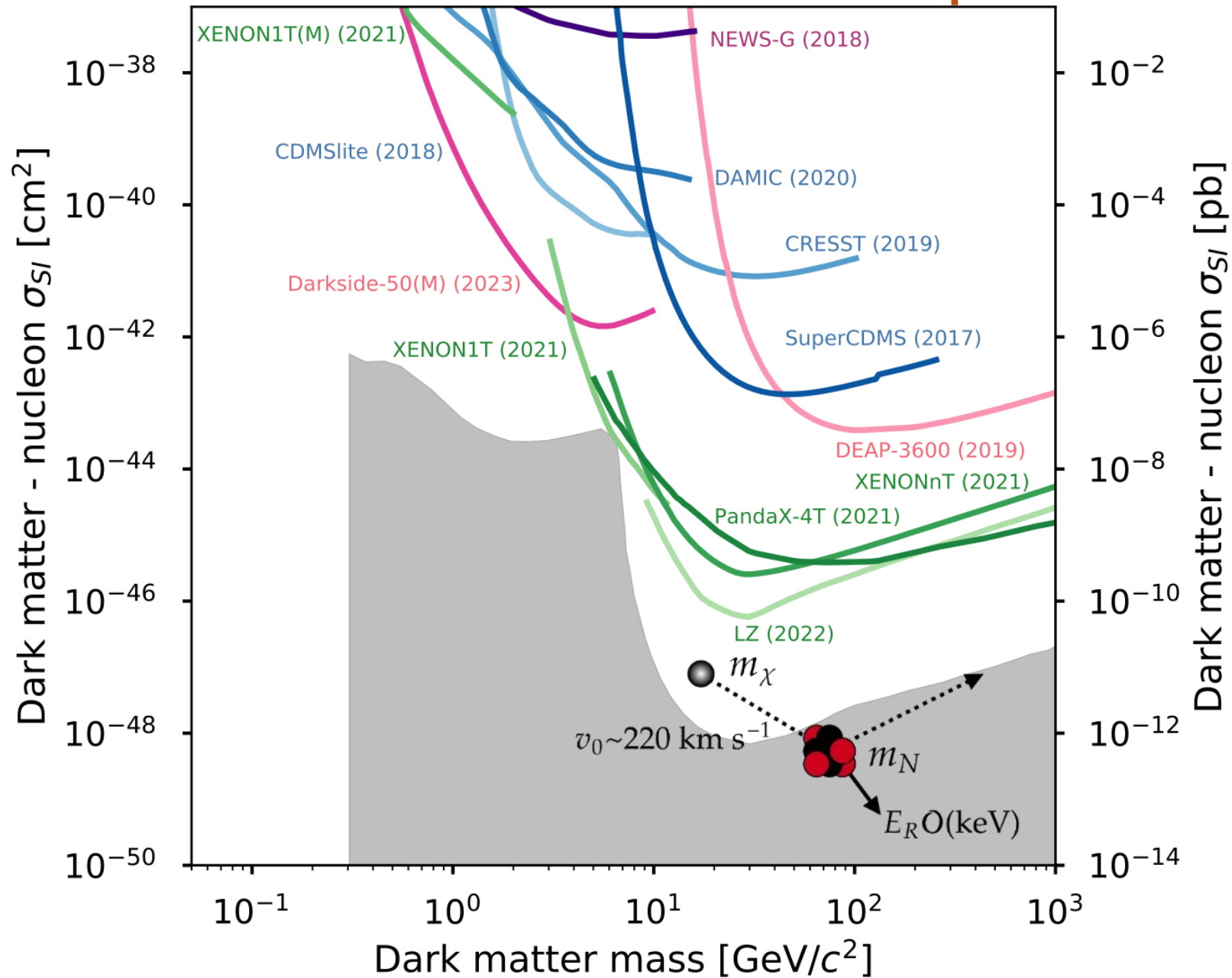
K. Johnson, P. Knights, K. Nikolopoulos, **G. Rogers**, P. Scovell,  
E. Shoemark-Banks, D. Spathara, P. Walters

IOP Joint APP and HEPP Conference – Edinburgh

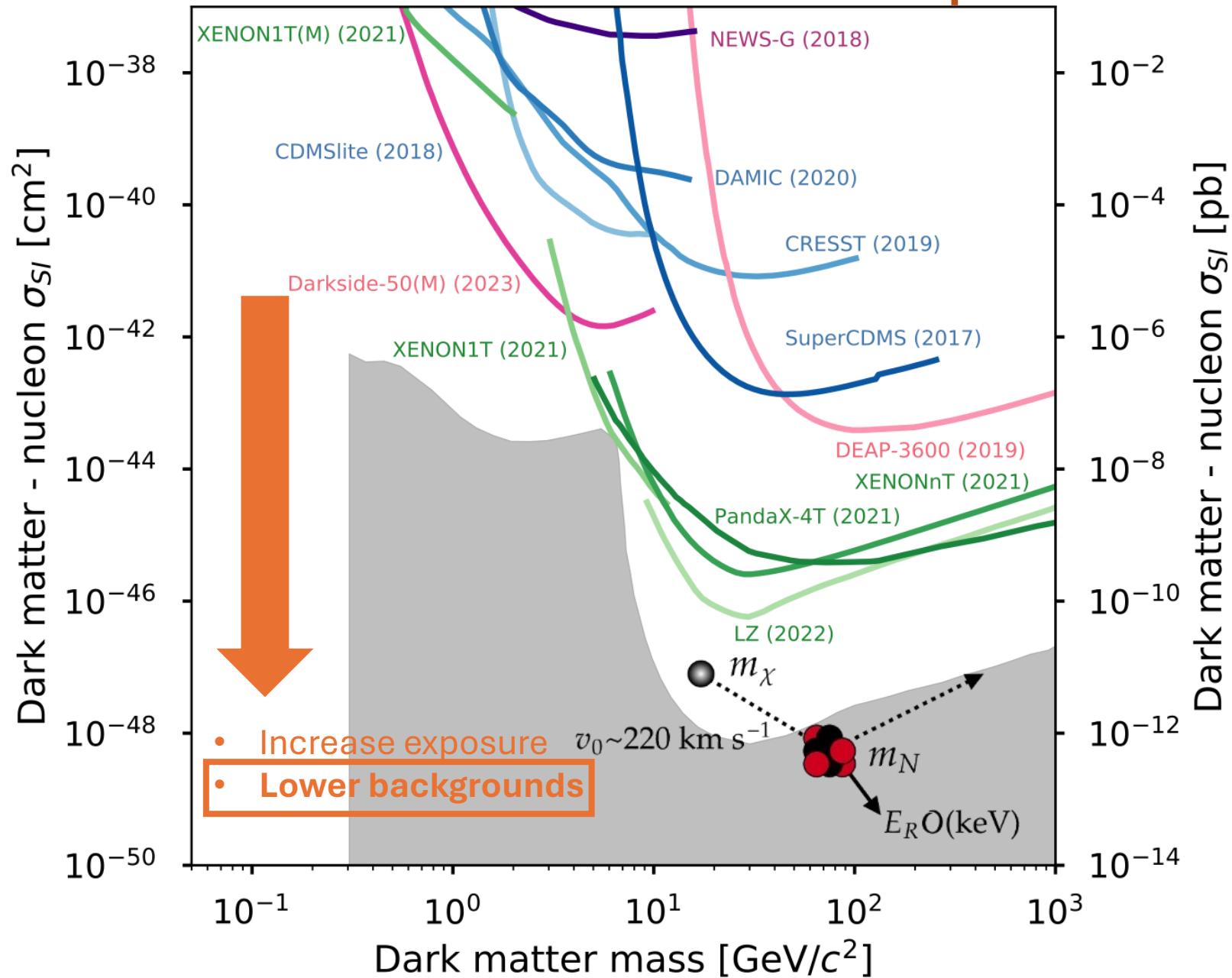
09/04/2026



# Direct dark matter detection landscape

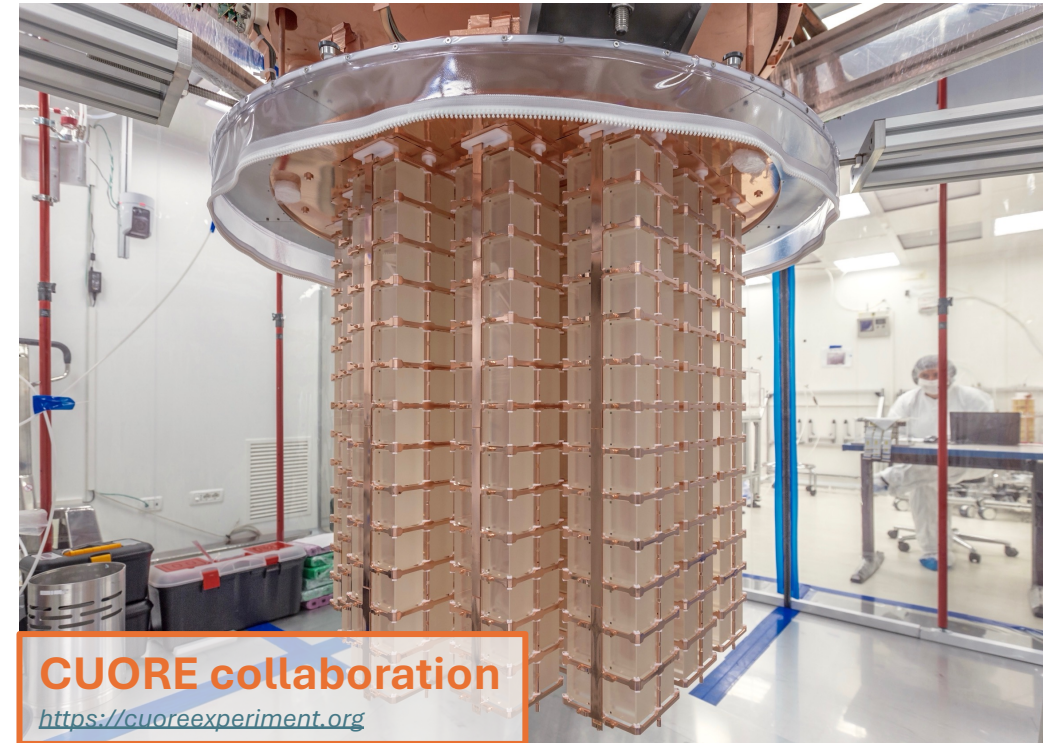
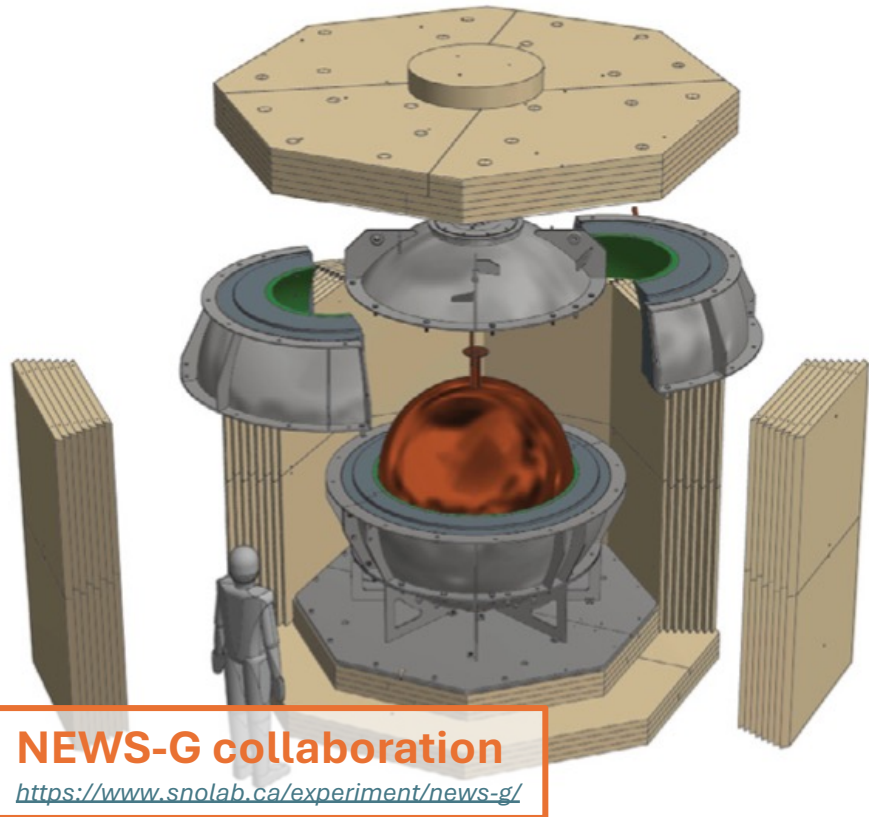


# Direct dark matter detection landscape



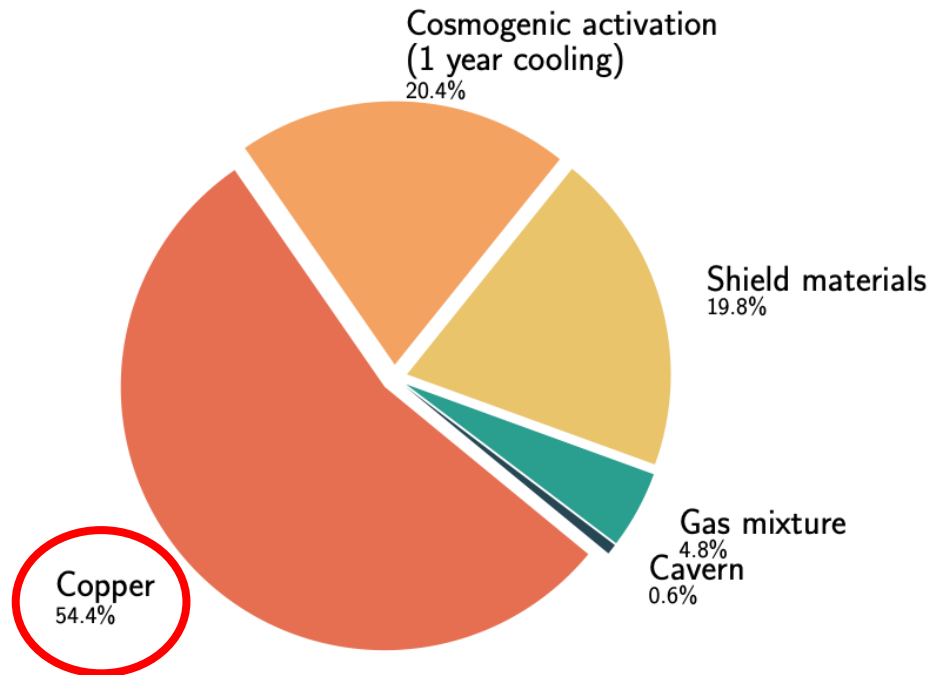
# Copper as a detector material

- **Copper** is an attractive detector material for rare event searches
  - **No long-lived radio-isotopes** – longest  $^{67}\text{Cu}$ :  $t_{1/2} = 62$  h
  - Commercially available at **high-purity**
  - Good mechanical and electrical properties
  - **Favorable electrochemical properties** – more on this later!

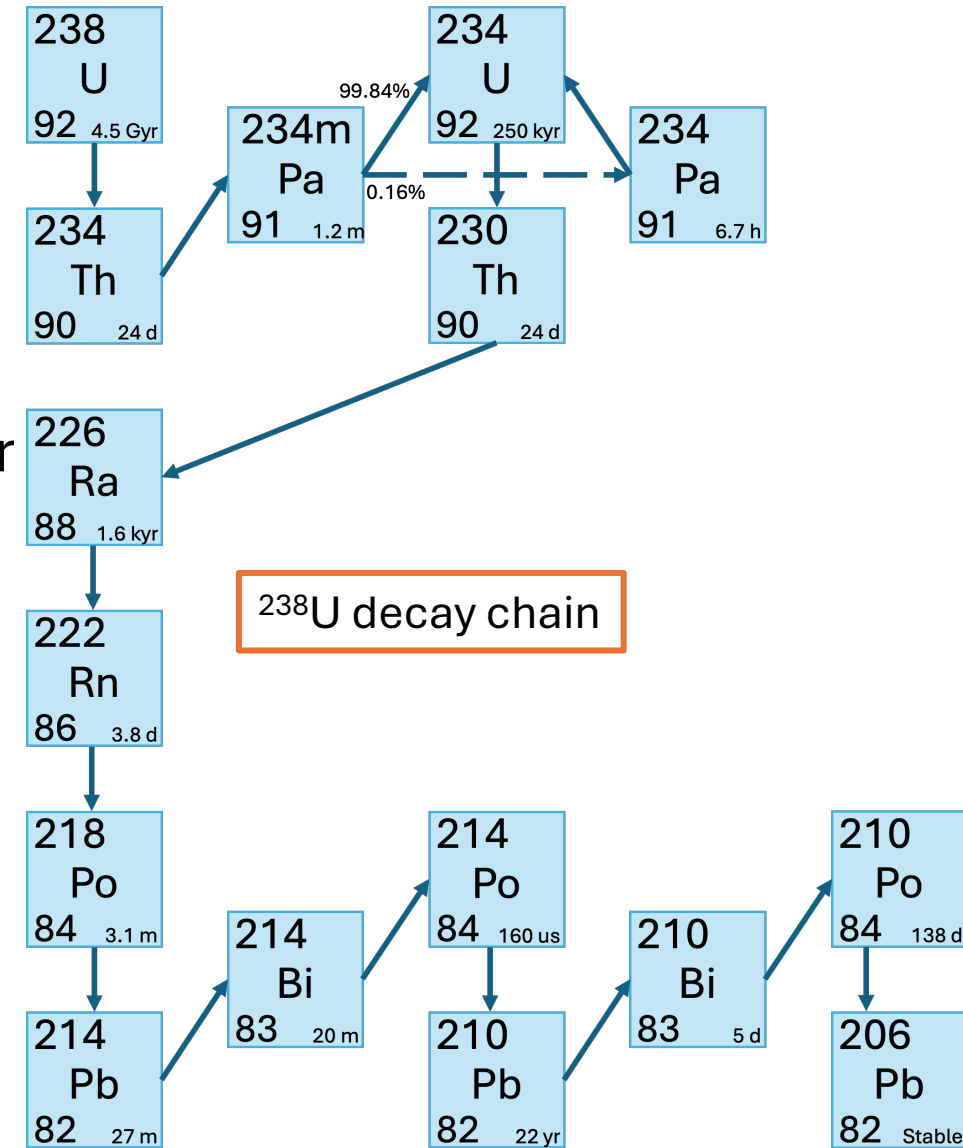


# Copper background

- Copper can still represent an important background
- Commercial copper contaminated -  $^{238}\text{U}$  and  $^{232}\text{Th}$  decay chains:
  - Natural ore contamination
  - Implanted during manufacture and handling
  - Cosmogenic activation -  $^{63}\text{Cu}(n,\alpha)^{60}\text{Co}$   $t_{1/2} = 5.27$  yr



Simulated backgrounds for NEWS-G's current detector

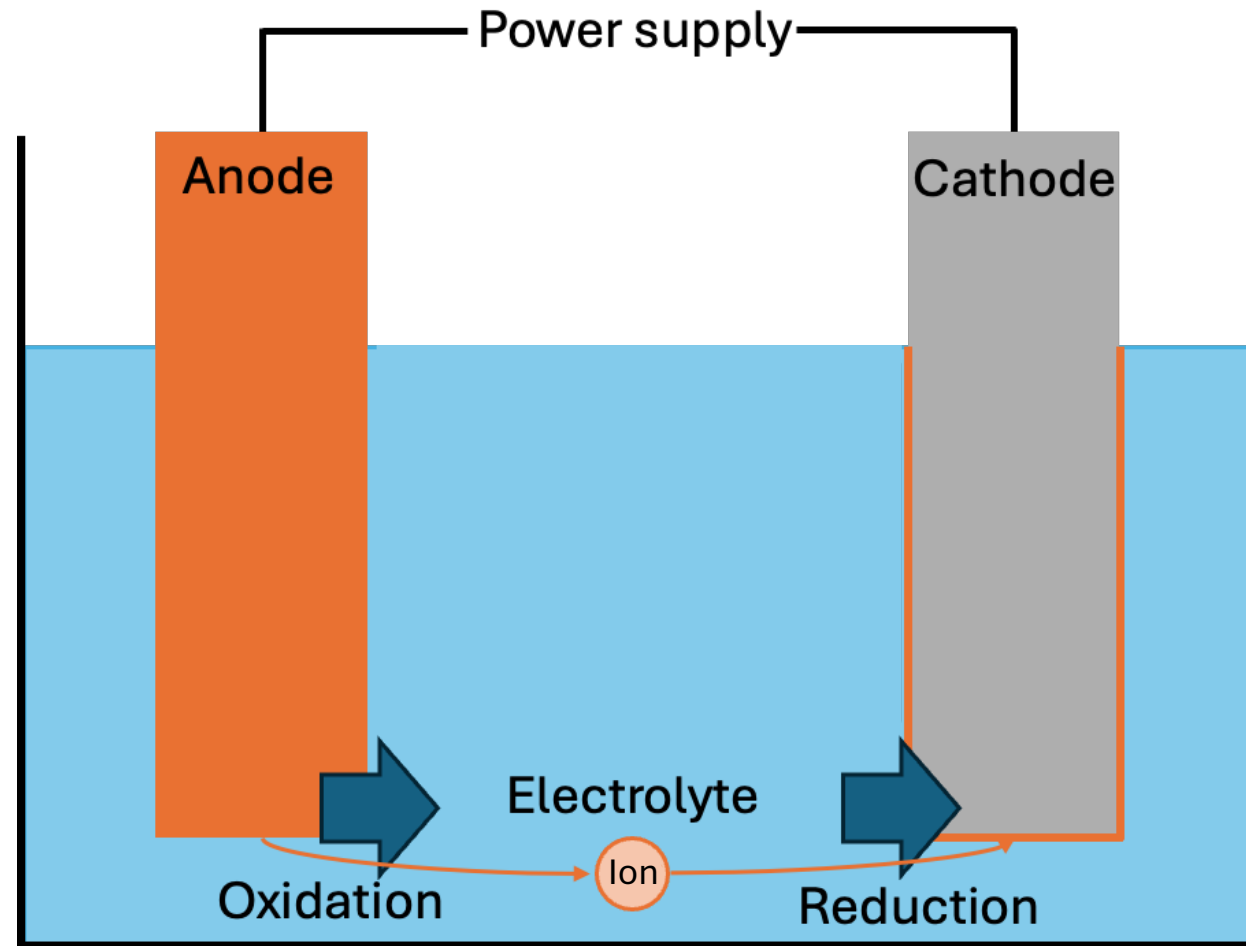


# Electrodeposition

- Deposit ions onto a cathode by applying a voltage
- Governed by oxidation and reduction reactions
- Deposited mass proportional to current

$$M = \frac{m_r \int I(t) dt}{zF}$$

Molar mass      Current  
No. e<sup>-</sup>      Faraday constant



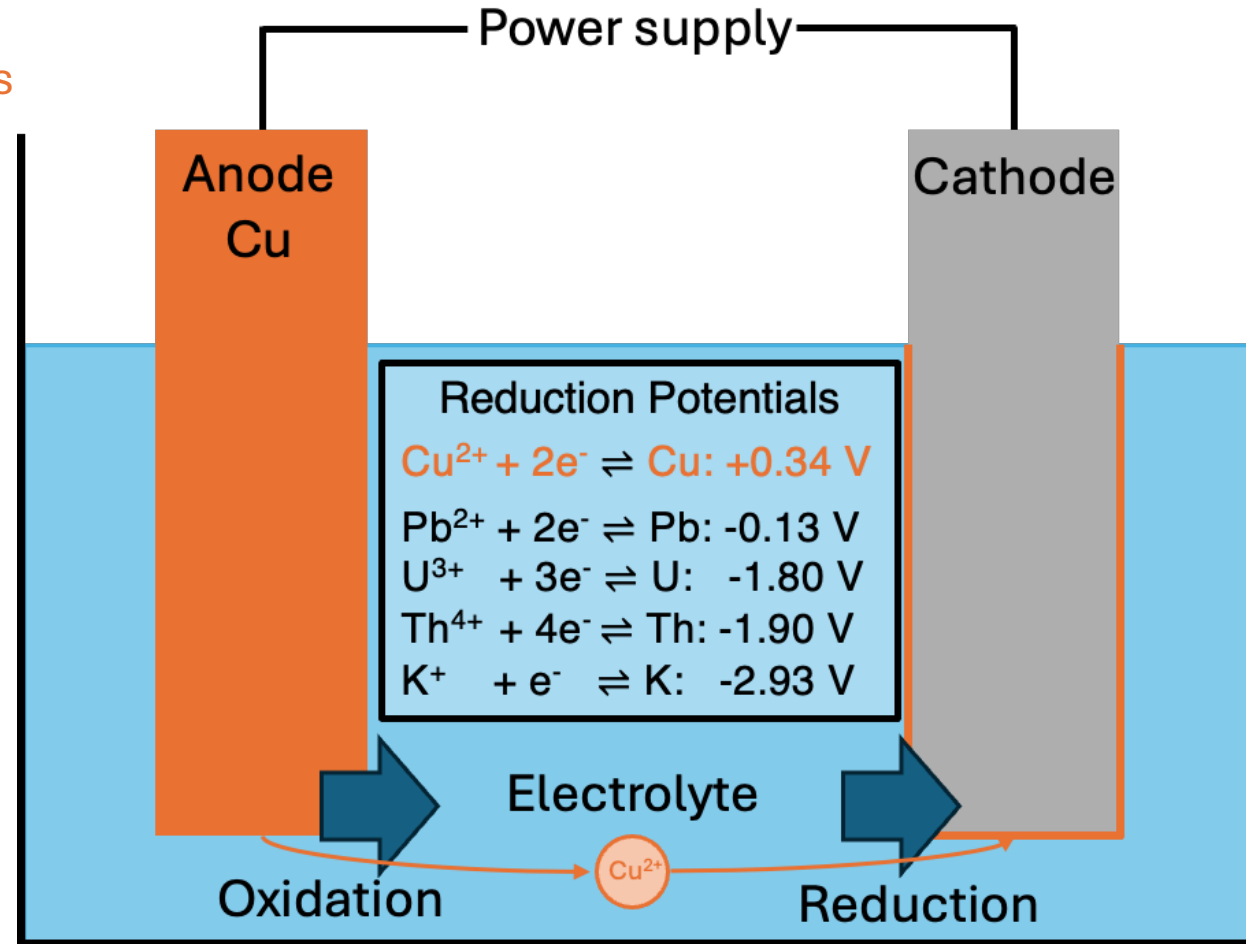
# Copper electrodeposition

- Species plating tendency governed by reduction potentials
- Careful control of applied potential difference allows preferential plating of copper over contaminants

$$E_{cell}^0 = E_{Cathode}^0 - E_{Anode}^0$$

If  $E_{applied} > E_{cell}^0$  reaction proceeds

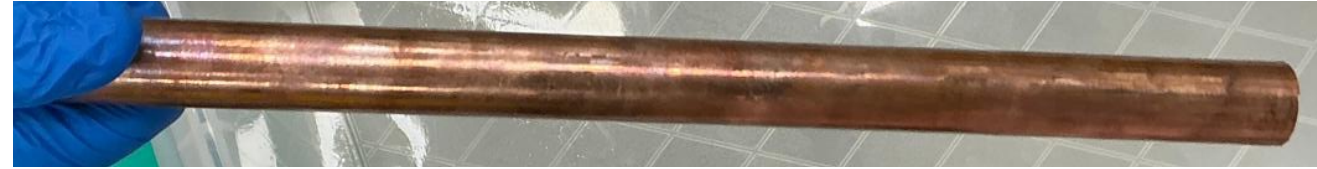
- Used in industry to produce copper with excellent purity



# Ultra-pure copper electrodeposition

How this differs from industry – **prioritise purity**

- Procedure principally developed by **PNNL** for Majorana Demonstrator
- **Additive free** electrolyte
- **Prioritise purity** over speed -> careful voltage selection
- **Cleanroom** environment
- Stringent **radiopure material and reagent** selection
- **Purity monitoring**
- **Comprehensive cleaning** procedures
- [NIMA 579 \(2007\) 486-489](#)  
[RCTR 277 \(2008\) 103-110](#)
- **Plating underground** -> **reduce cosmogenic activation**



**Cu feedstock preparation**



# Results – ICPMS

Sample of copper	$^{232}\text{Th}$ [uBq/kg]	$^{238}\text{U}$ [uBq/kg]
Commercial C10100	$8.7 \pm 1.6$	$27.9 \pm 1.9$
NEWS-G plated copper <a href="#"><i>NIMA 988 (2021) 164844</i></a>	<0.24	<0.11
Majorana demonstrator electroformed <a href="#"><i>NIMA 828 (2016) 22-36</i></a>	<0.119	<0.099

- Orders of magnitude improvement over commercial copper
- Purity results often limited by available assay techniques -> can only set limits

# How this is/can be used for experiments

## Electroplating

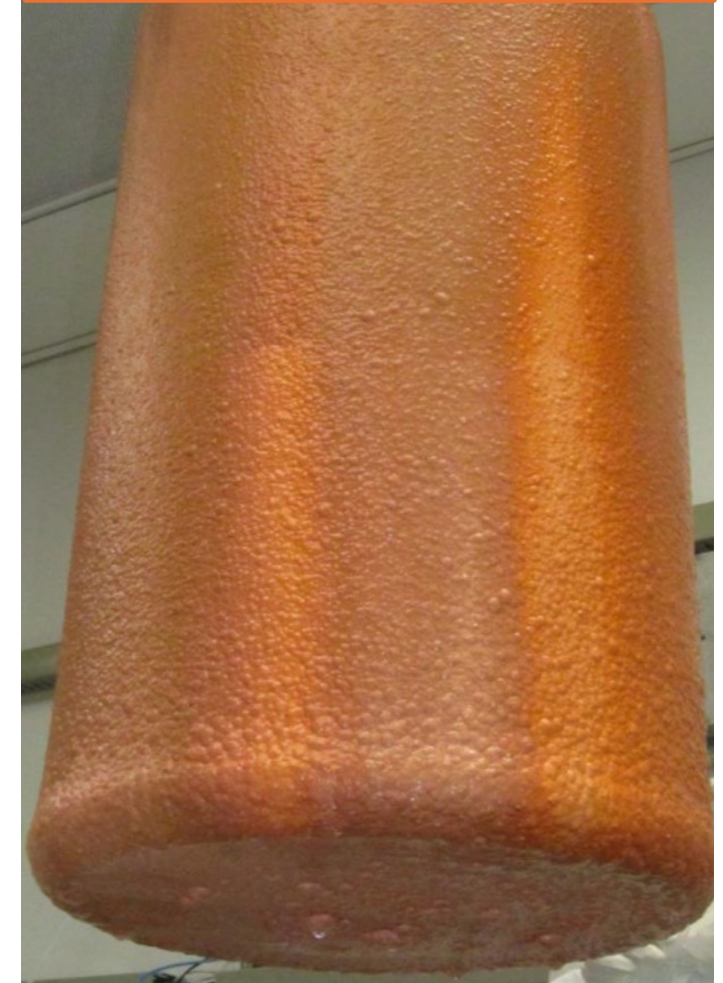
- Cu plated onto existing structure or components
- Acts as an ultra-pure shield
- Reduce radon emanation

## Electroforming

- Cu plated onto a mould (called mandrel)
- Remove the mandrel leaving a pure copper structure
- Construct large structures

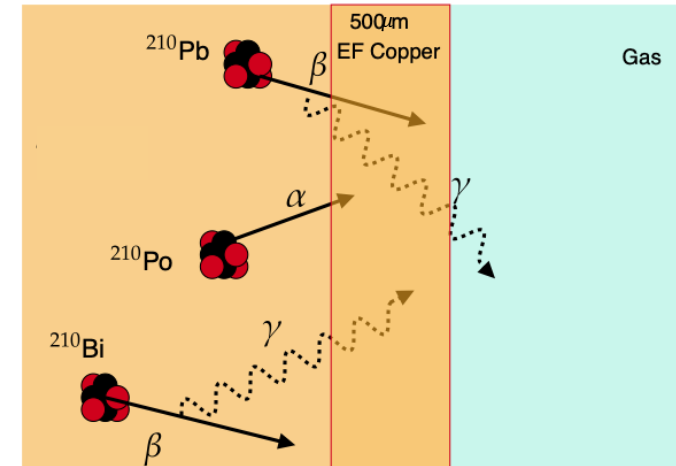
### Majorana Demonstrator Electroformed Cu

[OSTI \(2012\) 1039850](#)



### NEWS-G electroplated Cu

[NIMA 988 \(2021\) 164844](#)

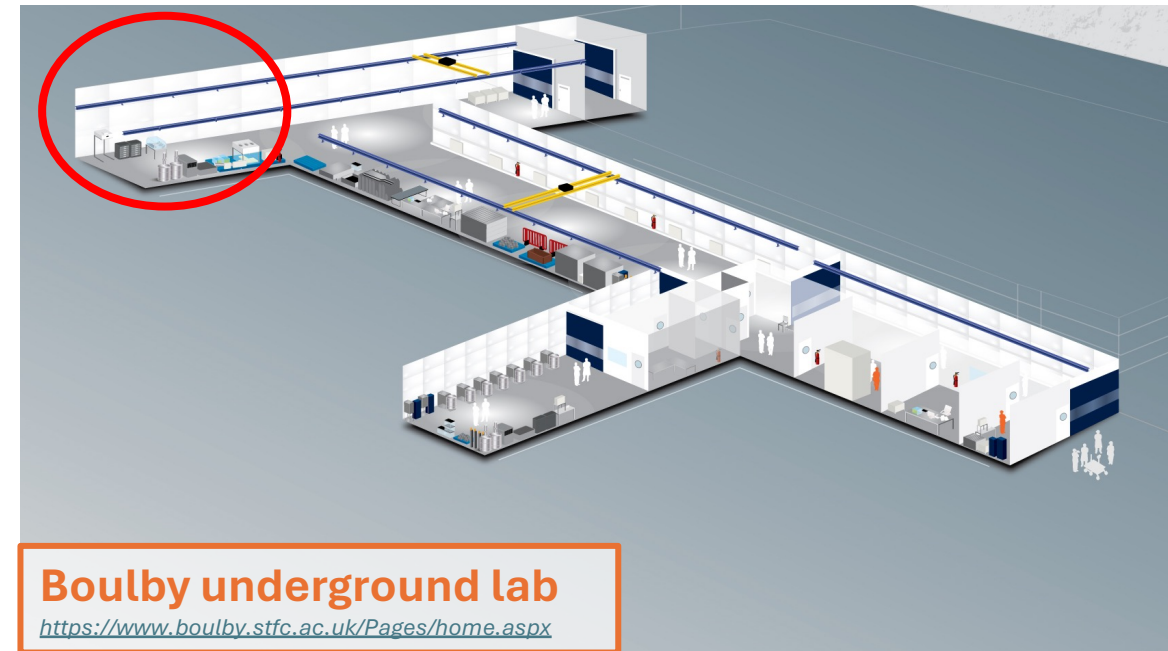
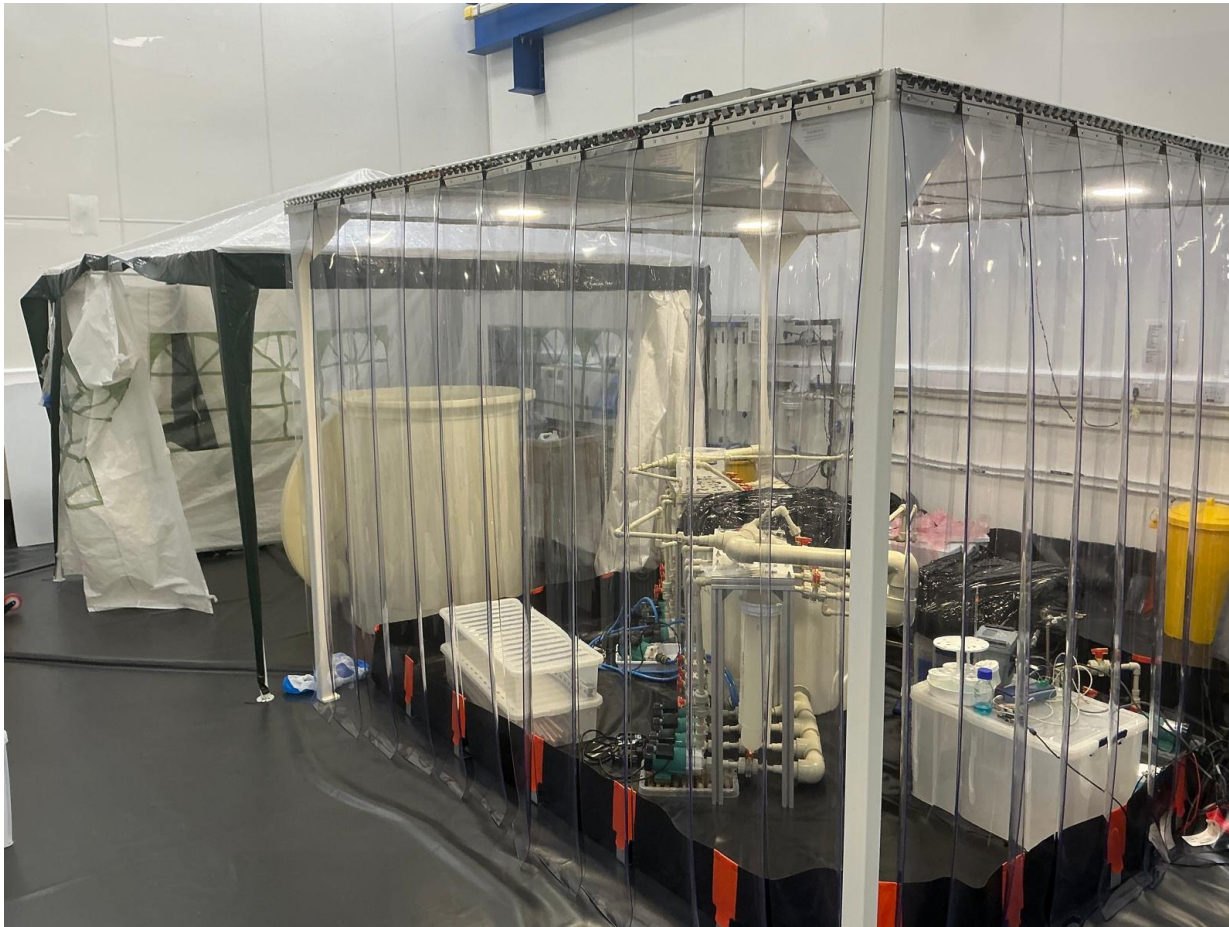


# Electroforming facility at Boulby

- 1.1km underground at the UK's deep underground laboratory Boulby
- Dedicated ISO-6 cleanroom within the larger Boulby cleanroom
- XIA UltraLow-1800 + ICP-MS on site at Boulby

*Front. Phys.* 2023 11:1310146  
*JINST* 2025 20 P06010

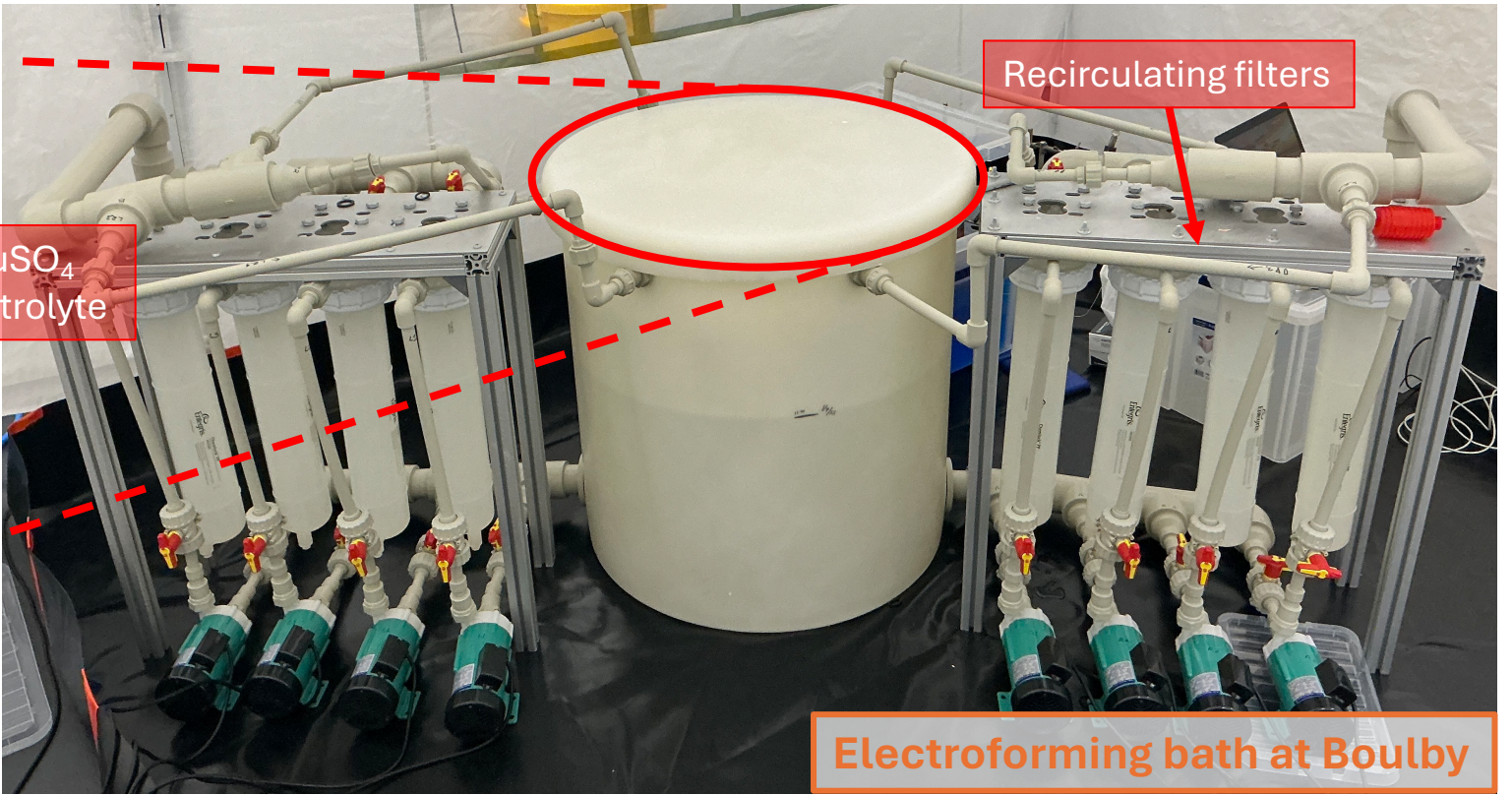
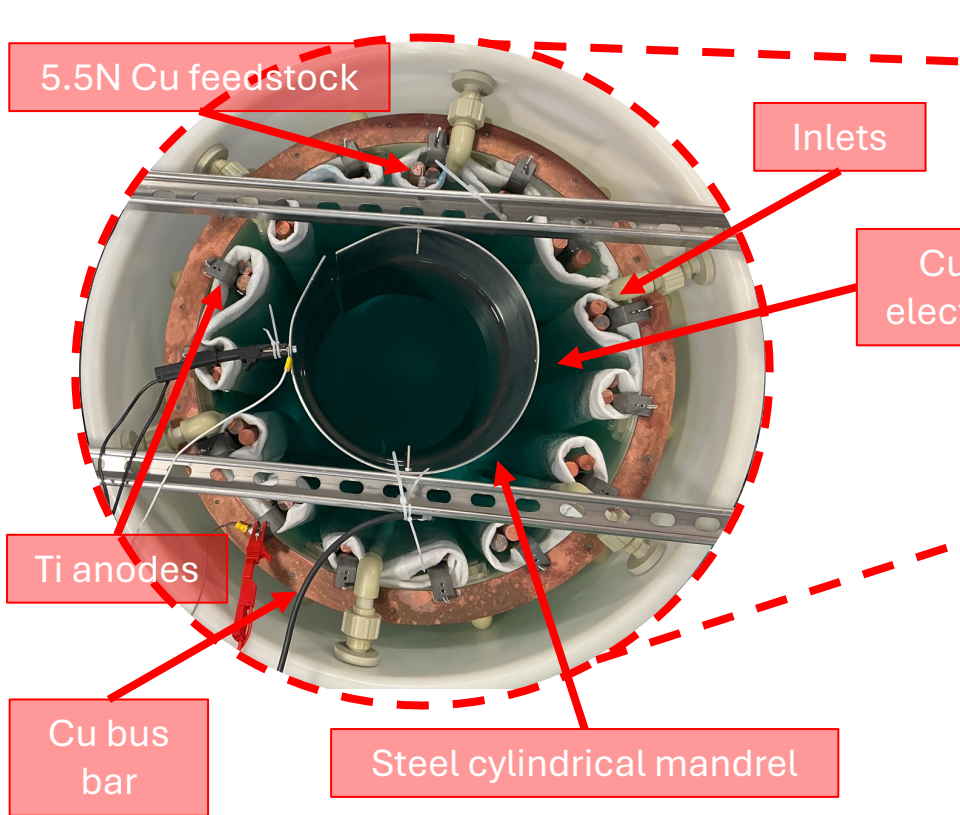
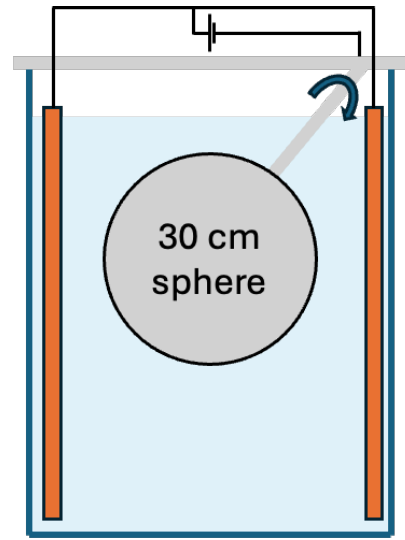
See posters by B. Green and K. Johnson  
And talks by A. Hamer and P. Scovell



# Electroforming facility at Boulby

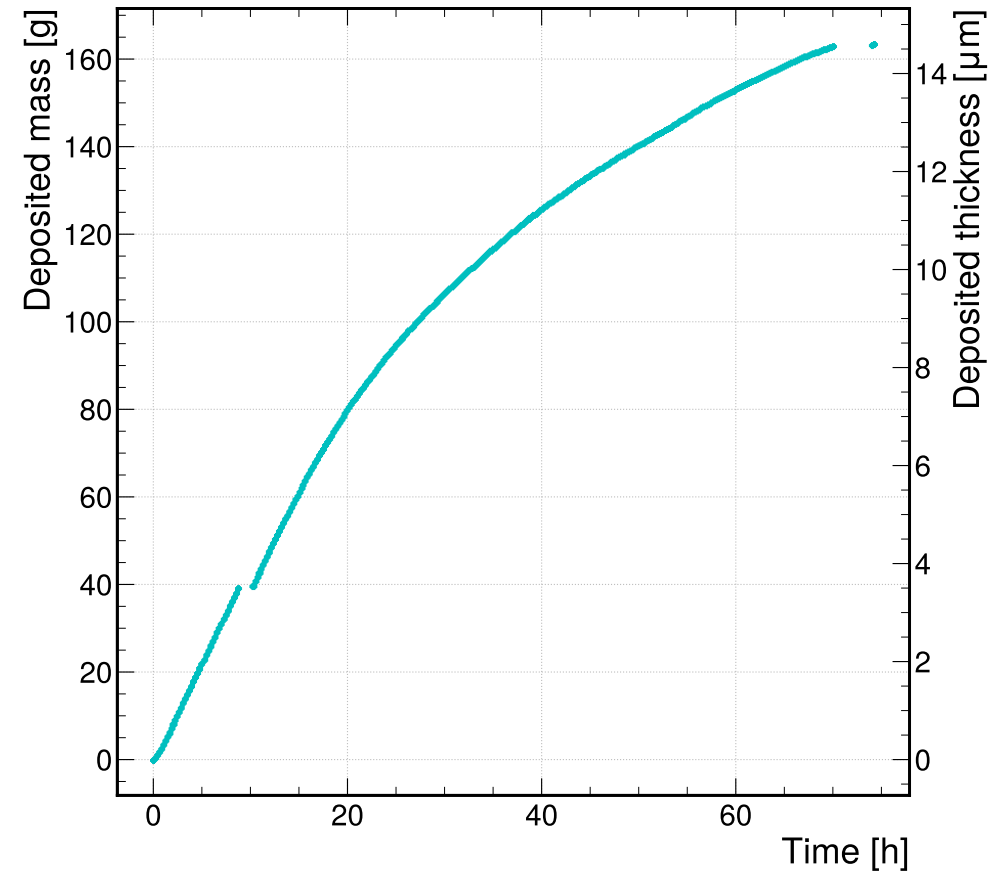
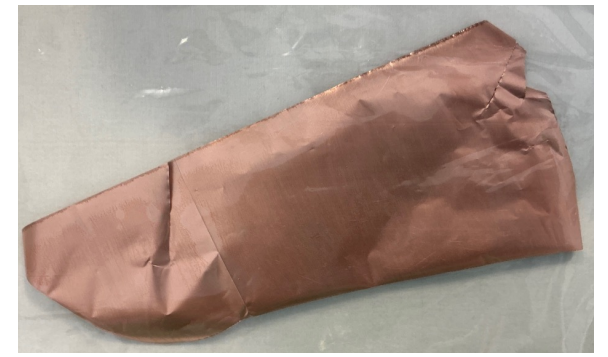
- Small setup used to plate smaller components
- Larger setup's first goal to electroform a 30 cm spherical proportional counter: **DarkSPHERE-30**

Near-future plans



# Current status

- Copper plated onto stainless steel cylinder
- Peeled copper off mandrel -> ICPMS and XIA results pending analysis
- Can use flattened copper from cylindrical mandrel as tray for XIA



# Physics Potential

- Fully electroformed spherical proportional counters will have world leading sensitivity to low-mass dark matter

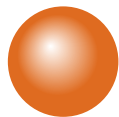
L. Milligan's and P. Walters' talks

- DarkSPHERE-30 to begin construction
- Alloys being explored to improve the properties of electroformed copper – PureAlloys project

- [NIMA 1082 \(2026\) 170970](#)
- [Communications Physics \(2025\) 8 464](#)

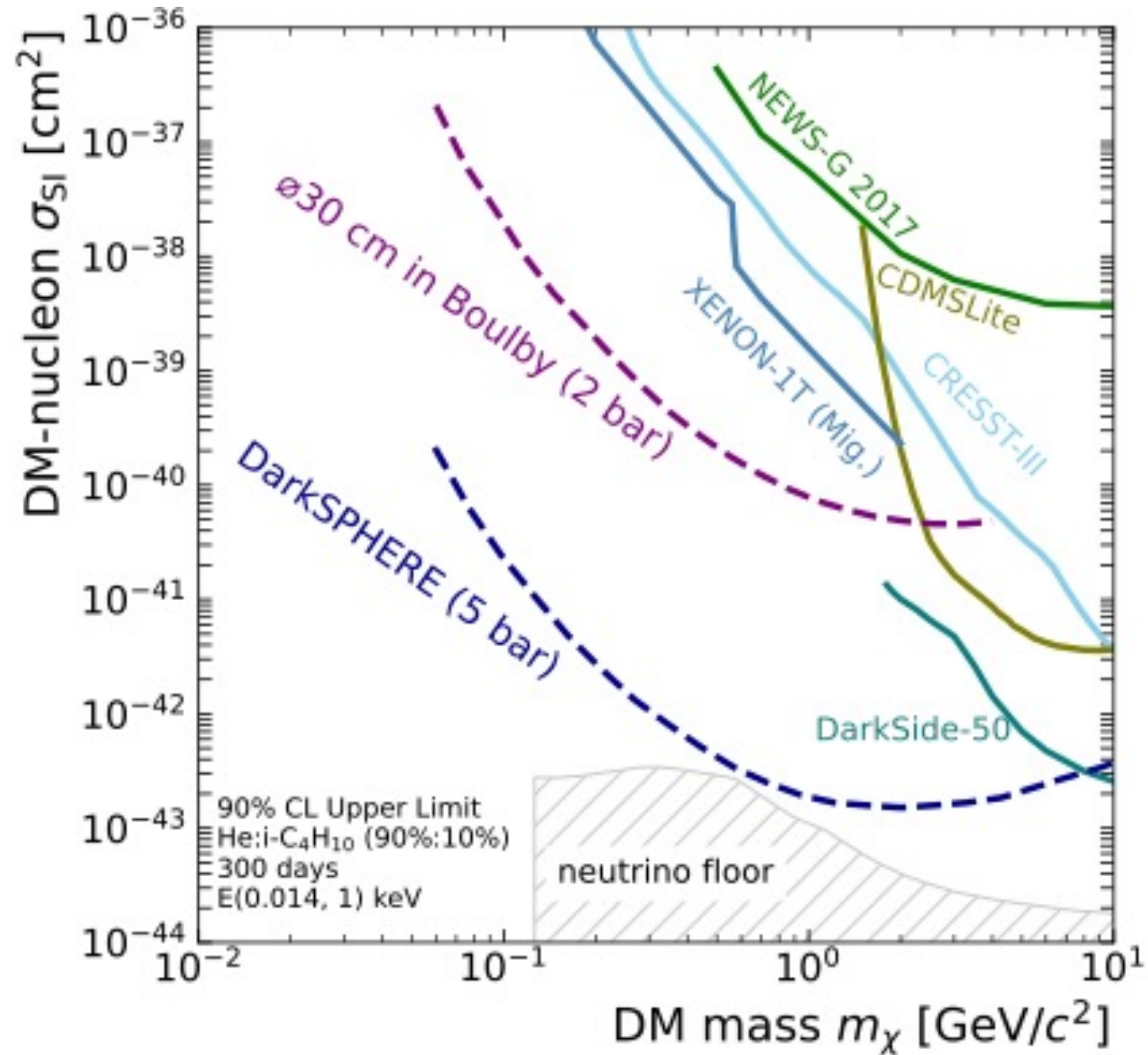
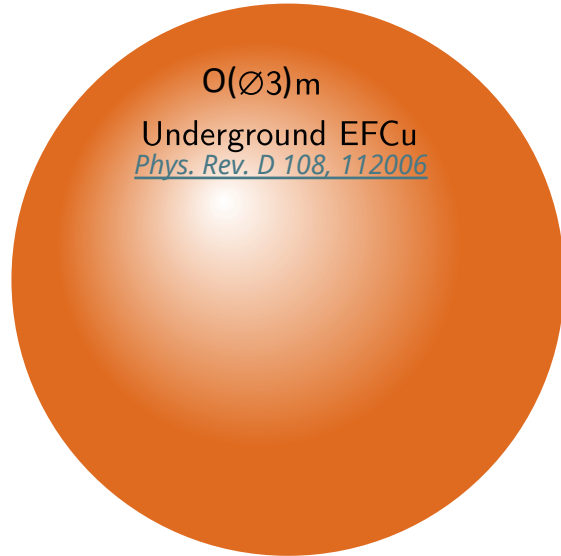
DarkSPHERE-30

Ø30 cm  
Underground EFCu



DarkSPHERE

O(Ø3)m  
Underground EFCu  
[Phys. Rev. D 108, 112006](#)



# Summary

- Copper electroforming for radio-pure detectors
- Orders of magnitude improvement in radiopurity over commercial Cu
- Electroforming facility constructed at Boulby
- First copper produced
- Work ongoing to electroform a  $\varnothing 30$  cm SPC
- Many experiments exploring the use of electroformed and plated Cu

