



UNIVERSITY OF
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Science and
Technology
Facilities Council

Boulby Underground
Laboratory



Universität Hamburg

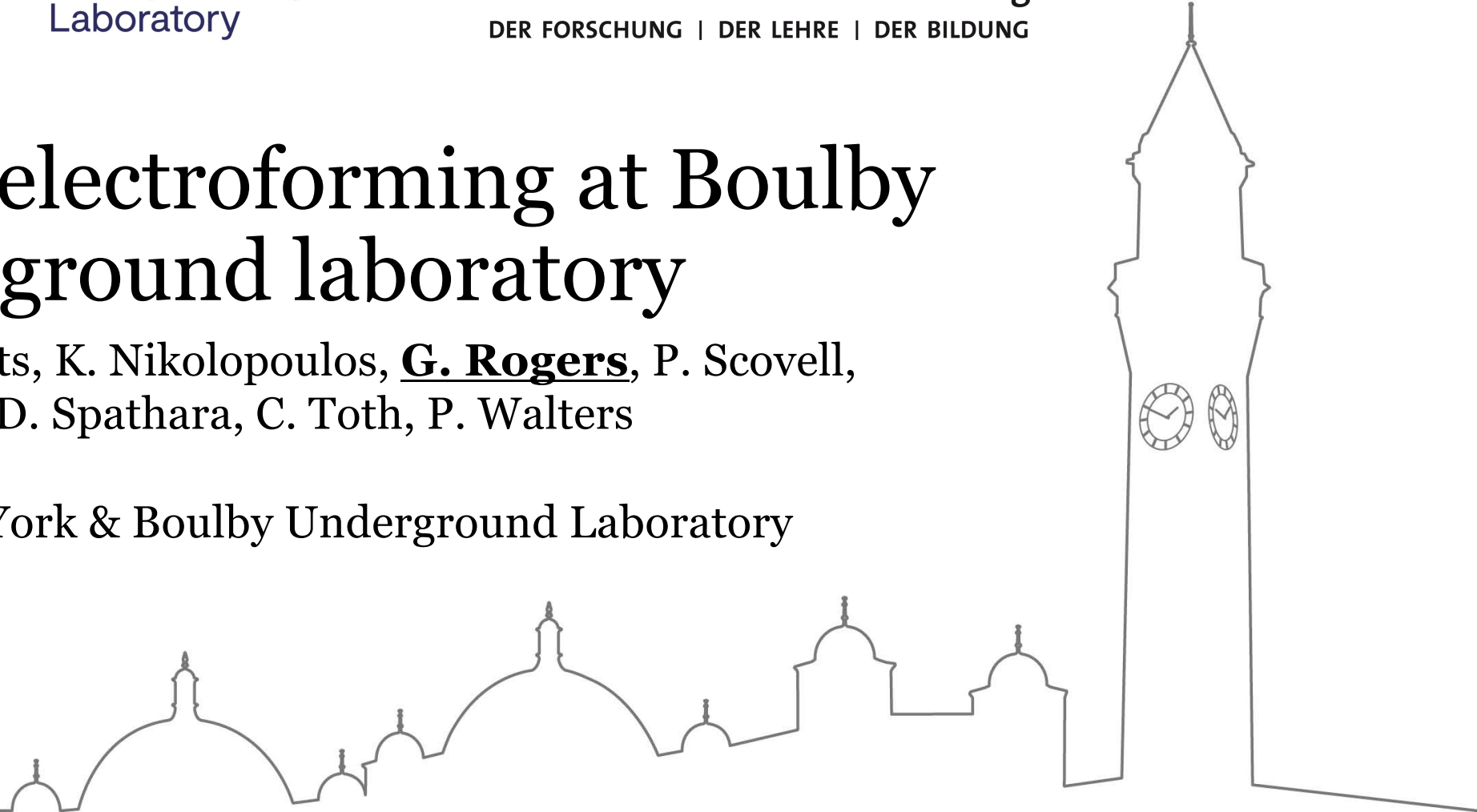
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Ultra-pure electroforming at Boulby deep underground laboratory

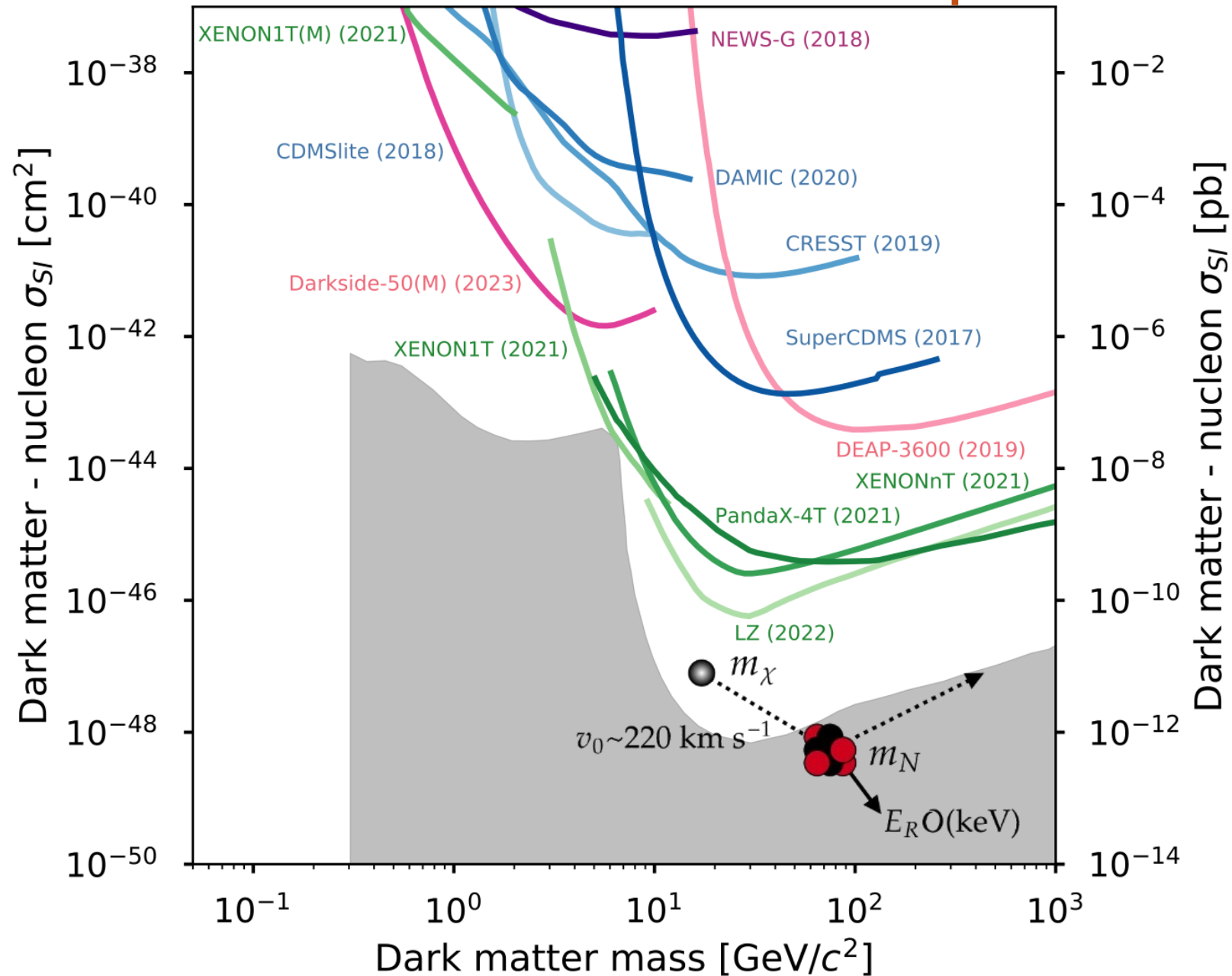
K. Johnson, P. Knights, K. Nikolopoulos, **G. Rogers**, P. Scovell,
E. Shoemark-Banks, D. Spathara, C. Toth, P. Walters

LRT – University of York & Boulby Underground Laboratory

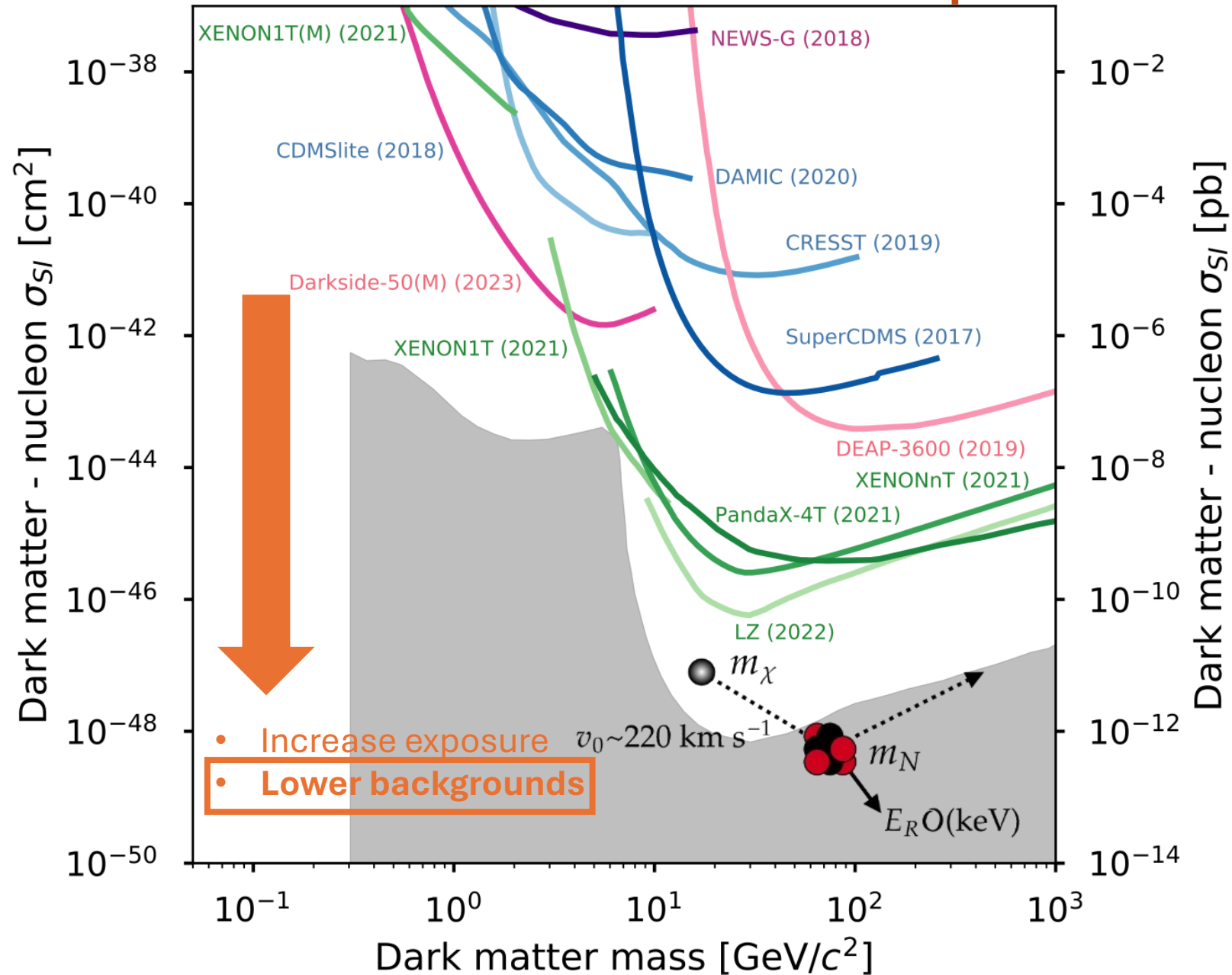
24/09/2026



Direct dark matter detection landscape

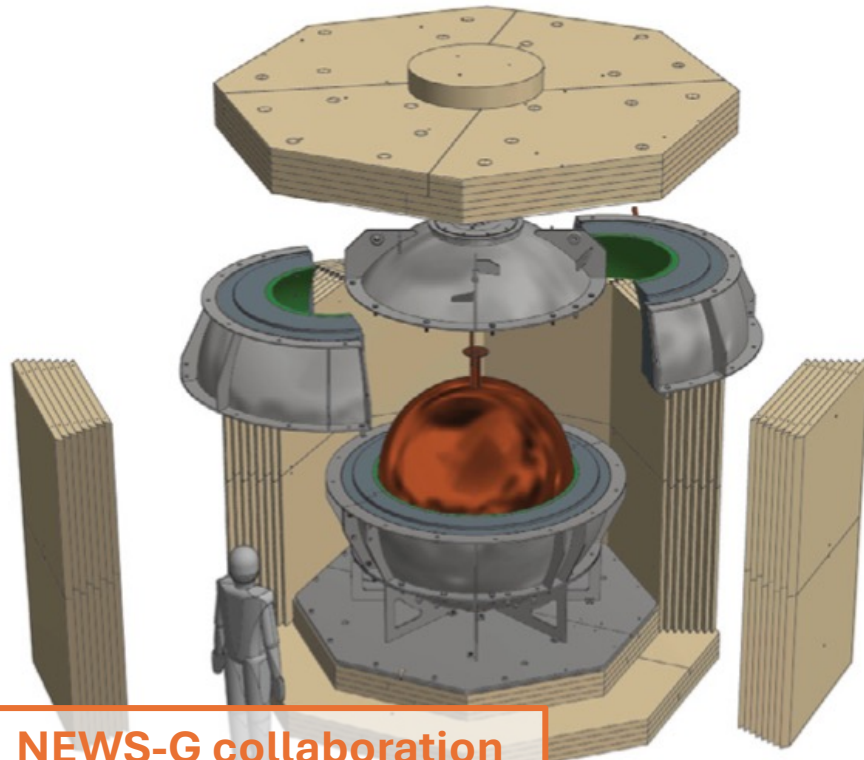


Direct dark matter detection landscape



Copper as a detector material

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



NEWS-G collaboration

<https://www.snolab.ca/experiment/news-g/>

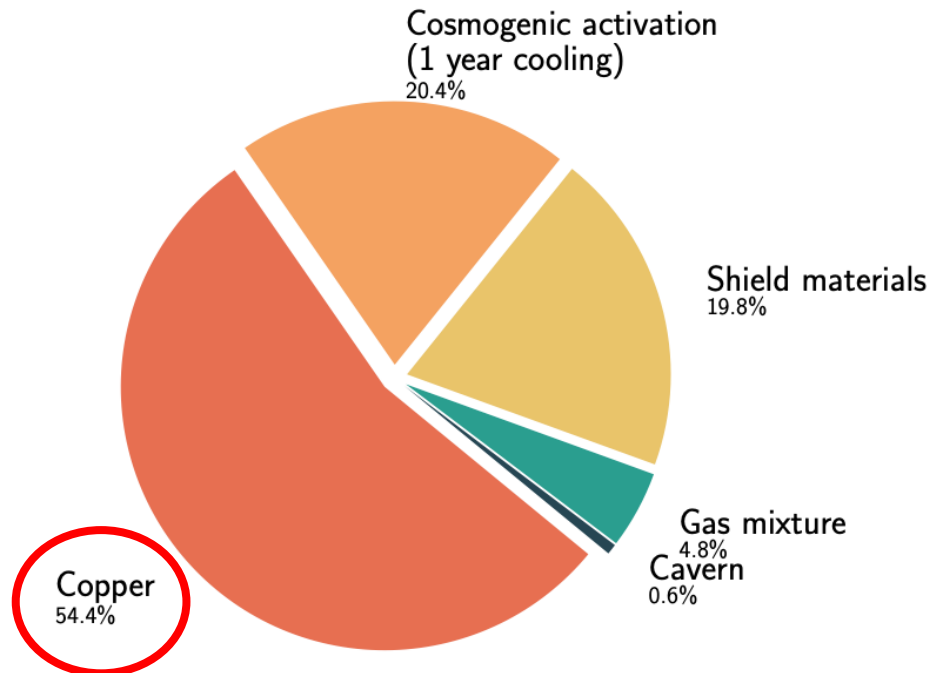


CUORE collaboration

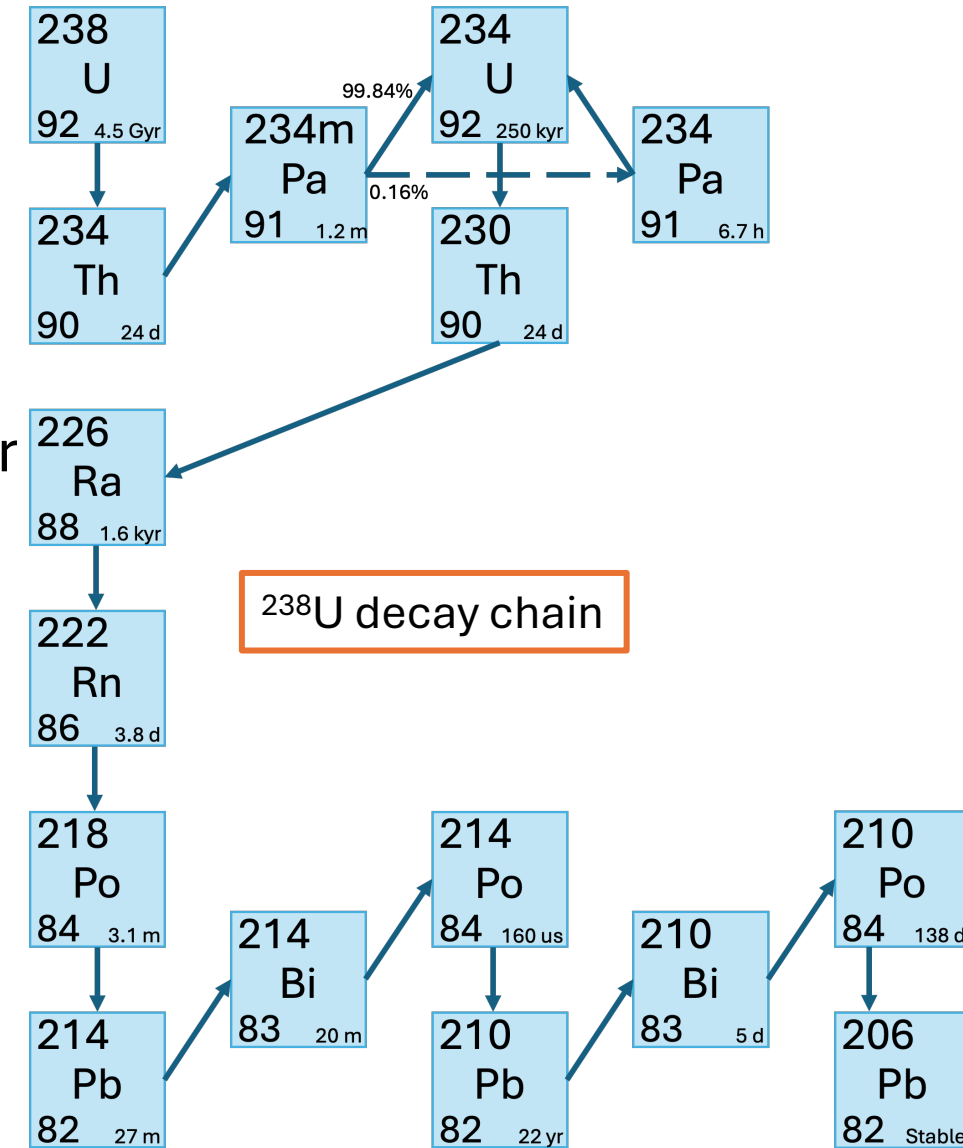
<https://cuoreexperiment.org>

Copper background

- Copper can still represent an important background
- Commercial copper contaminated - ^{238}U and ^{232}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



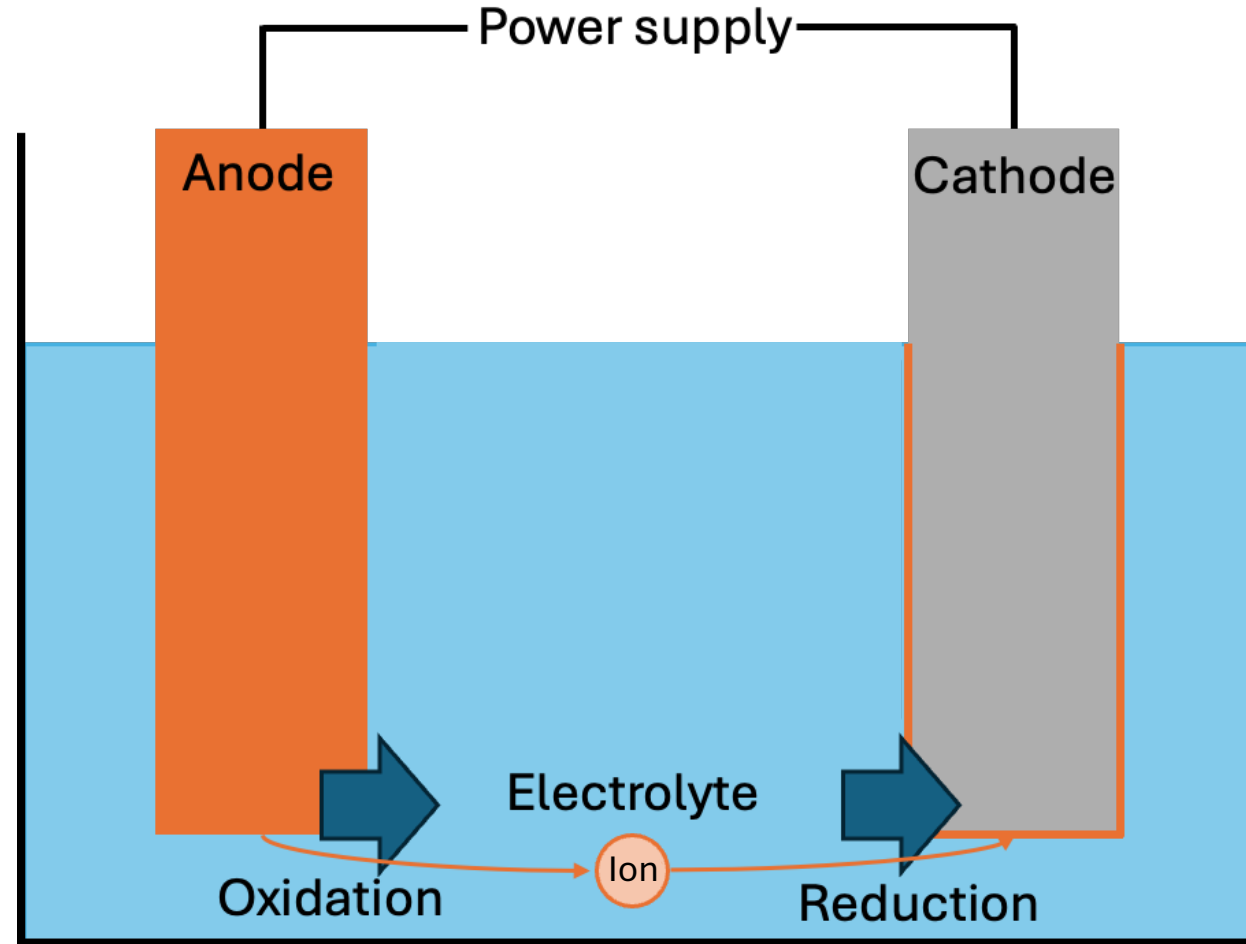
Electrodeposition

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

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

Diagram illustrating the components of the equation:

- M : Deposited mass
- m_r : Molar mass
- $I(t)$: Current
- z : No. e^-
- F : Faraday constant



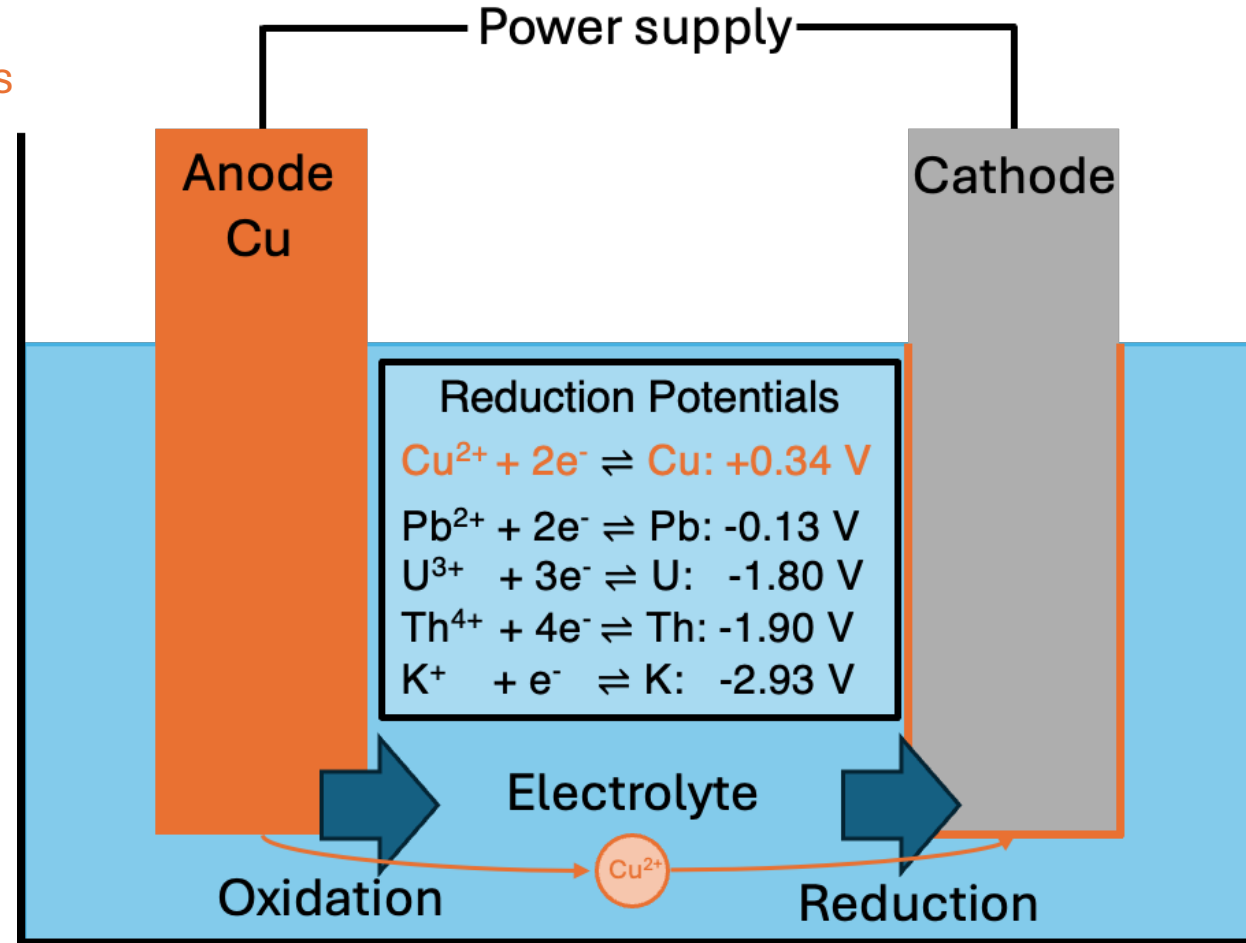
Copper electrodeposition

- 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

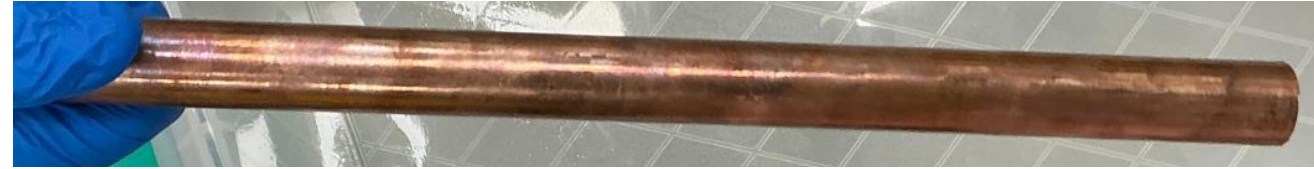
How this differs from industry – **prioritise purity**

- Procedure principally developed by **PNNL** for Majorana Demonstrator
- **Additive free pure** 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}Th [uBq/kg]	^{238}U [uBq/kg]
Commercial C10100 <i>NIMA 828 (2016) 22-36</i>	8.7 ± 1.6	27.9 ± 1.9
NEWS-G plated copper <i>NIMA 988 (2021) 164844</i>	<0.24	<0.11
Majorana demonstrator electroformed <i>NIMA 828 (2016) 22-36</i>	<0.119	<0.099

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

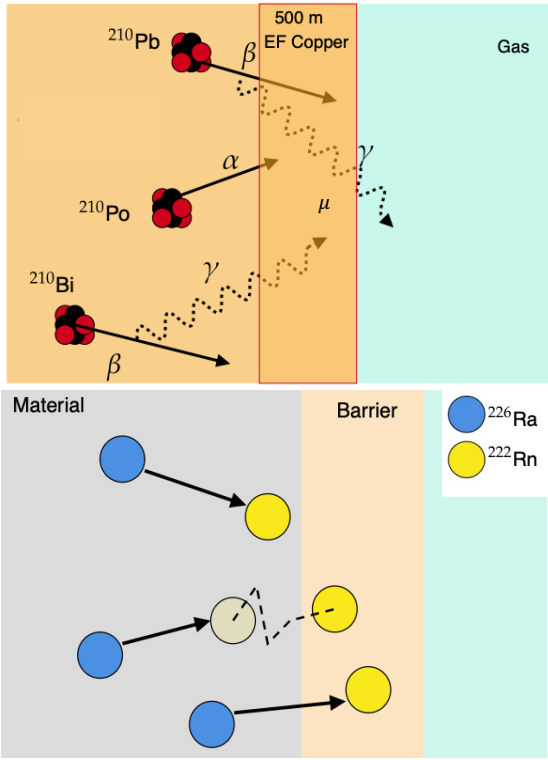
How this is/can be used for experiments

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



NEWS-G electroplated Cu

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



Majorana Demonstrator Electroformed Cu

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



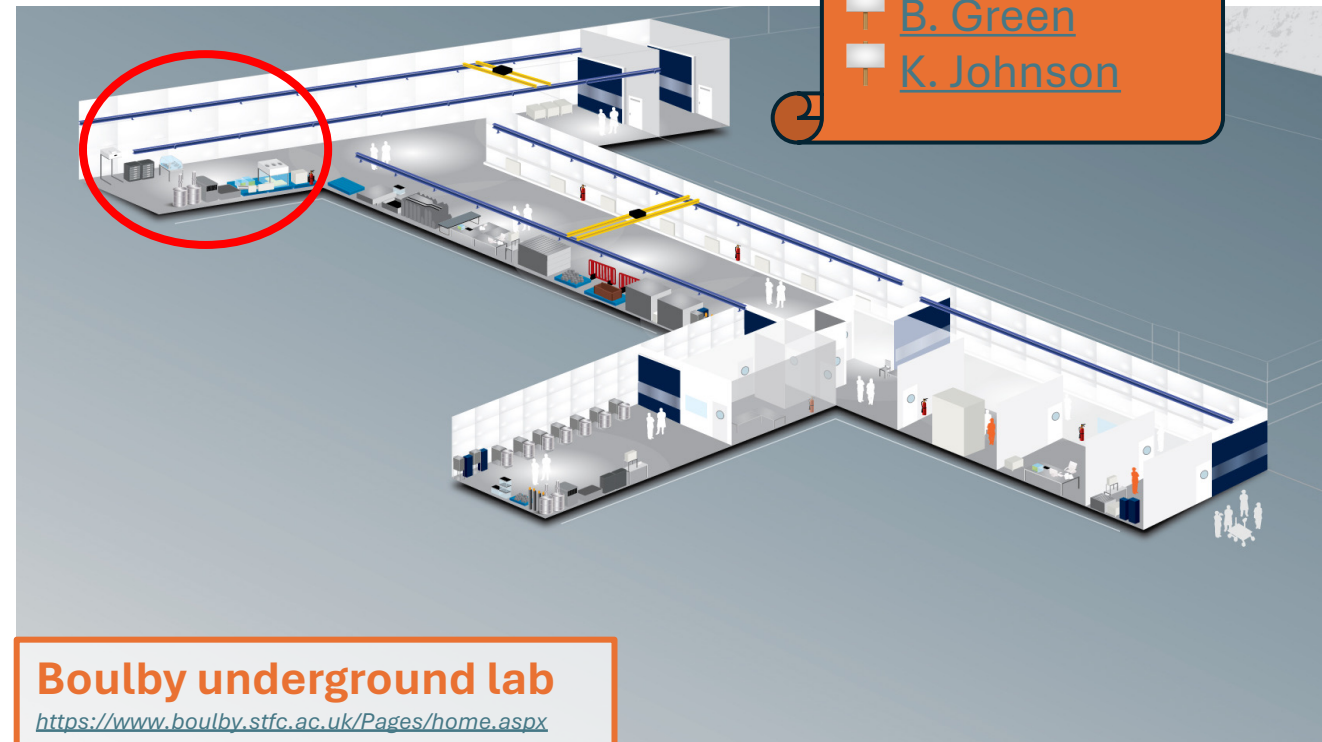
Electroforming facility at Boulby

- 1.1km underground at the UK's deep underground laboratory Boulby
- Dedicated ISO-6 cleanrooms within the larger Boulby cleanroom equipped with laminar flow, particle counter, type-1 water
- XIA UltraLow-1800 + ICP-MS + HPGe on site at Boulby

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

See posters on
Boulby assay:

- [A. Hammer](#)
- [B. Green](#)
- [K. Johnson](#)



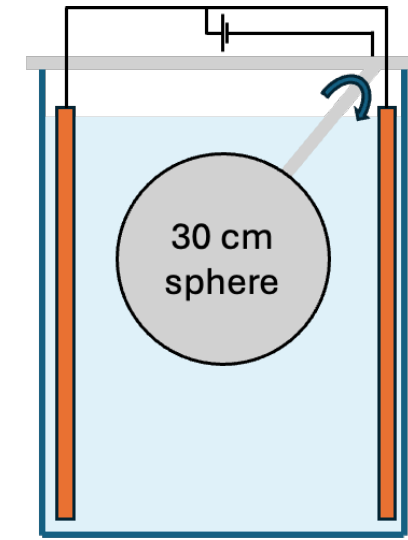
Boulby underground lab

<https://www.boulby.stfc.ac.uk/Pages/home.aspx>

Electroforming facility at Boulby

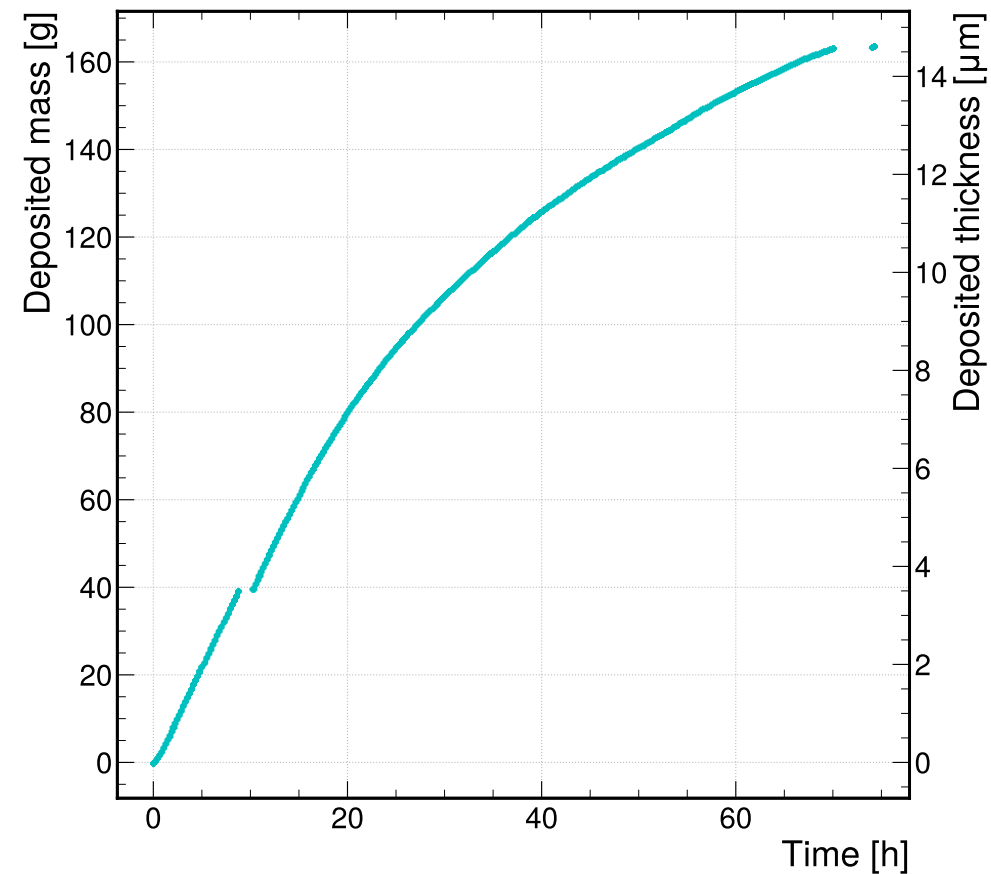
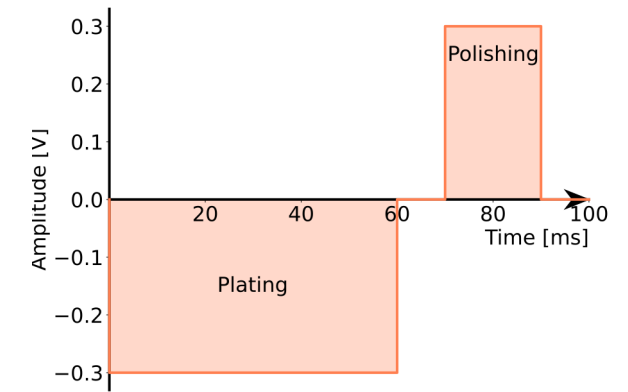
- Pure PP/PVDF pipework leached with 6M nitric acid
- Electrolyte made in house from 5.5N copper feedstock etched with acidified peroxide
- Multiple setups for different geometries and sizes
- Larger setup's first goal to fully electroform a 30 cm spherical proportional counter underground: DarkSPHERE-30

Near-future plans



Current status

- Copper pulse plated onto stainless $\varnothing 30$ cm stainless steel cylinder
- Peeled copper off mandrel -> ICPMS and XIA results pending analysis
- Recently transitioned to **reverse pulse plating** – better throwing power & purity
- Exploring nitrogen cover gas and storage



Physics Potential

- Fully electroformed spherical proportional counters will have world leading sensitivity to low-mass dark matter
- DarkSPHERE-30 to begin construction
- Alloys being explored to improve the properties of electroformed copper – PureAlloys and PureCuAlloys projects

- [NIMA 1082 \(2026\) 170970](#)
- [Communications Physics \(2025\) 8 464](#)
- [arXiv:2059.07406](#)
- [arXiv:2606.24524](#)

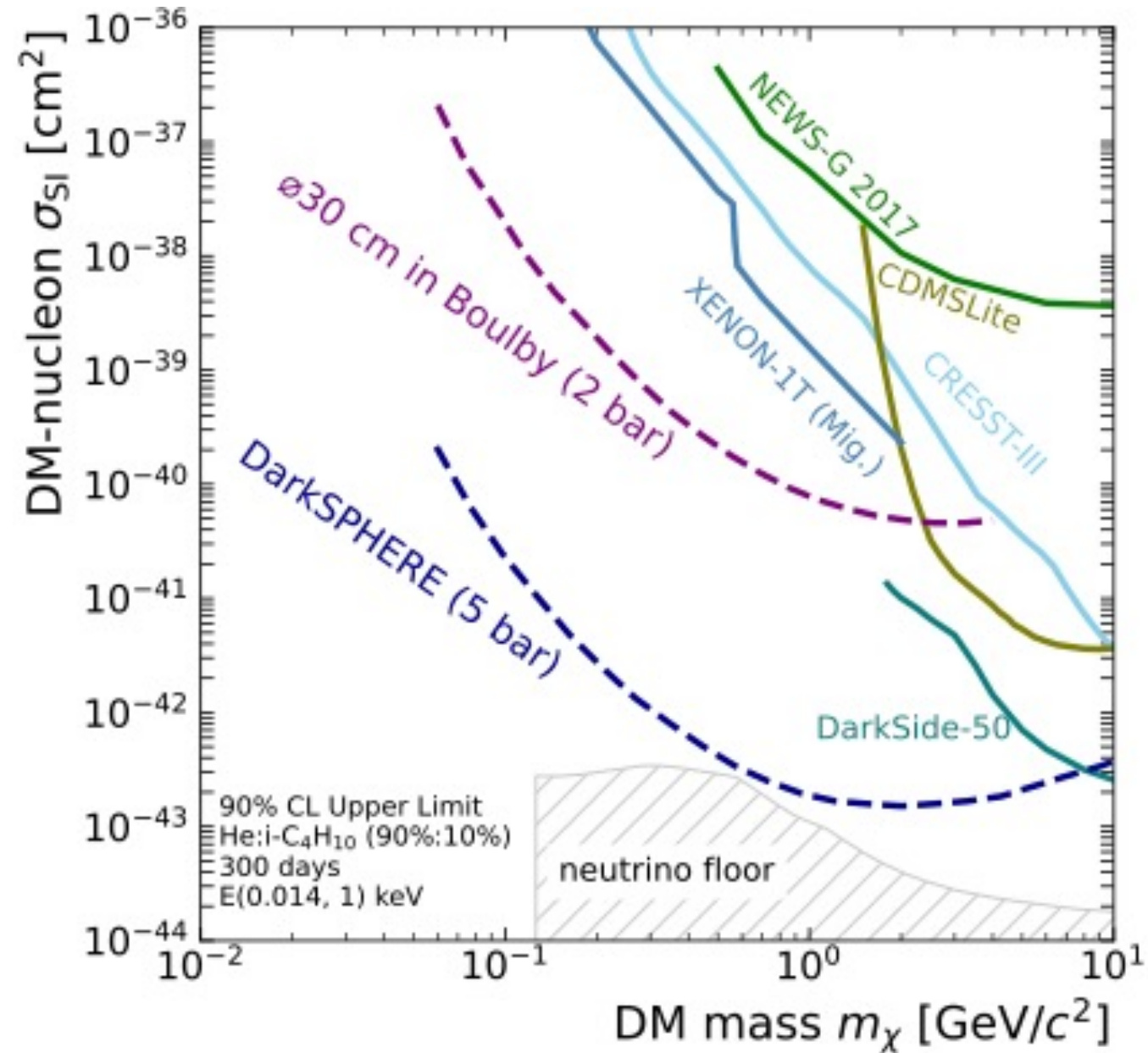
See talk on Cu alloys:
 [D. Spathara](#)

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

