The Search For Low Mass Dark Matter With NEWS-G

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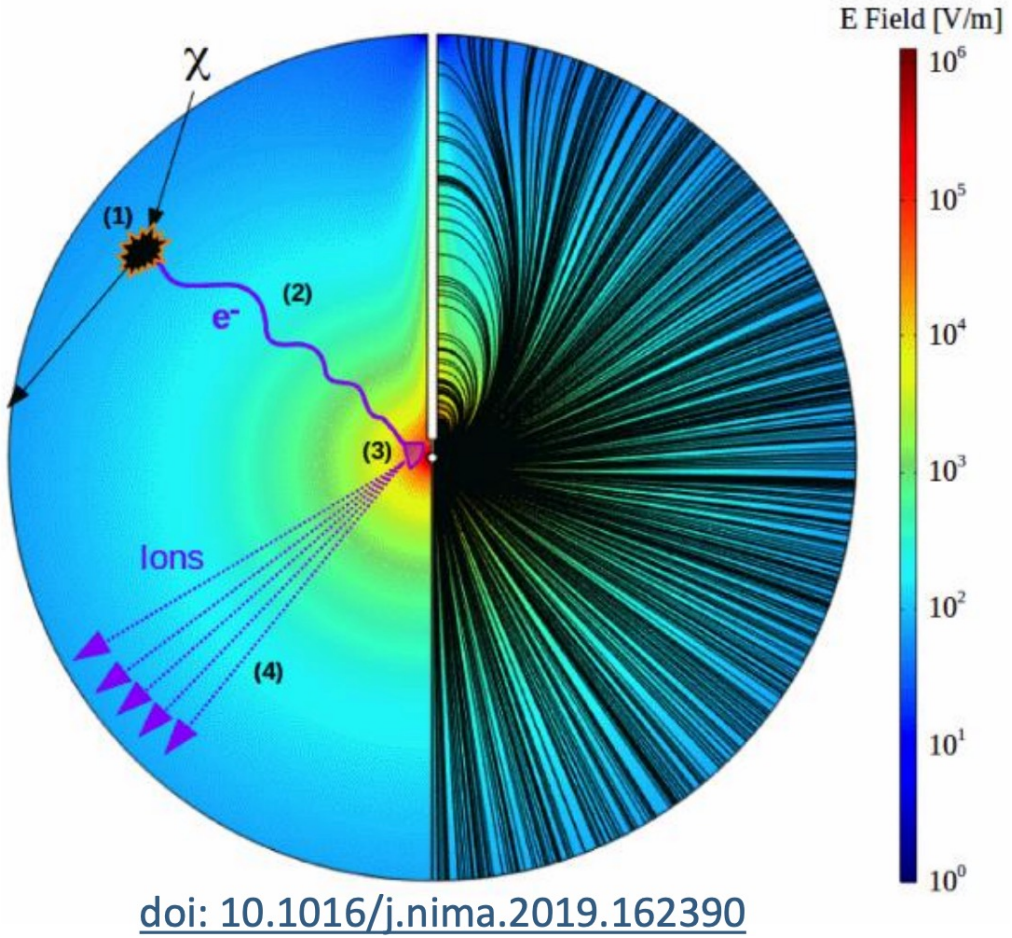
IDM 2026

Search for low mass dark matter with SPCs

- NEWS-G uses **Spherical Proportional Counters (SPCs)** to search for low mass WIMPs.
- **Low mass sensitivity** is reached with:
  - **Light atomic mass targets (H, He, Ne)**
  - **Low threshold**
    - Low electronic noise
    - High amplification
  - **Low background**
    - Simple configuration, high purity copper
    - Surface electron rejection with pulse shape
- **Single electron counting**

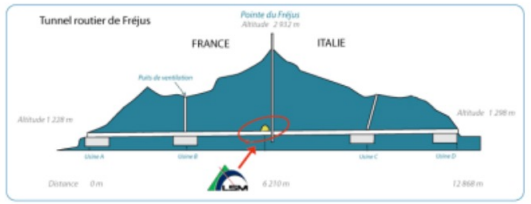


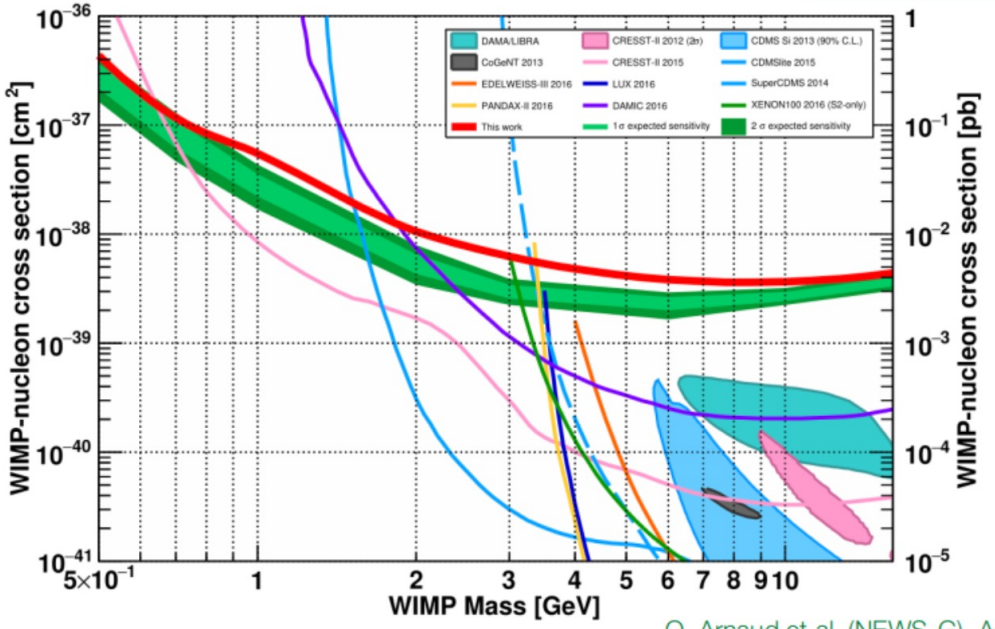
doi: 10.1016/j.nima.2019.162390

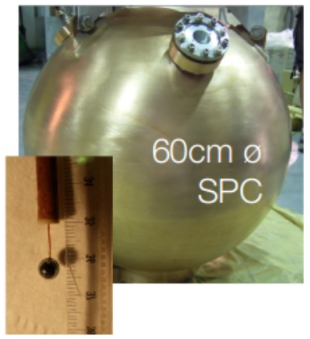
First demonstration: SEDINE at LSM

- First DM search results with a 60-cm SPC in 2018.
- Simple analysis featuring a booster decision tree to choose the ROI in the rise time vs. energy parameter space
- Observation of an "exponential rise" at low energy (discussed at EXCESS 2022)

Competitive low-mass WIMP limit with a neon target at the Laboratoire Souterrain de Modane

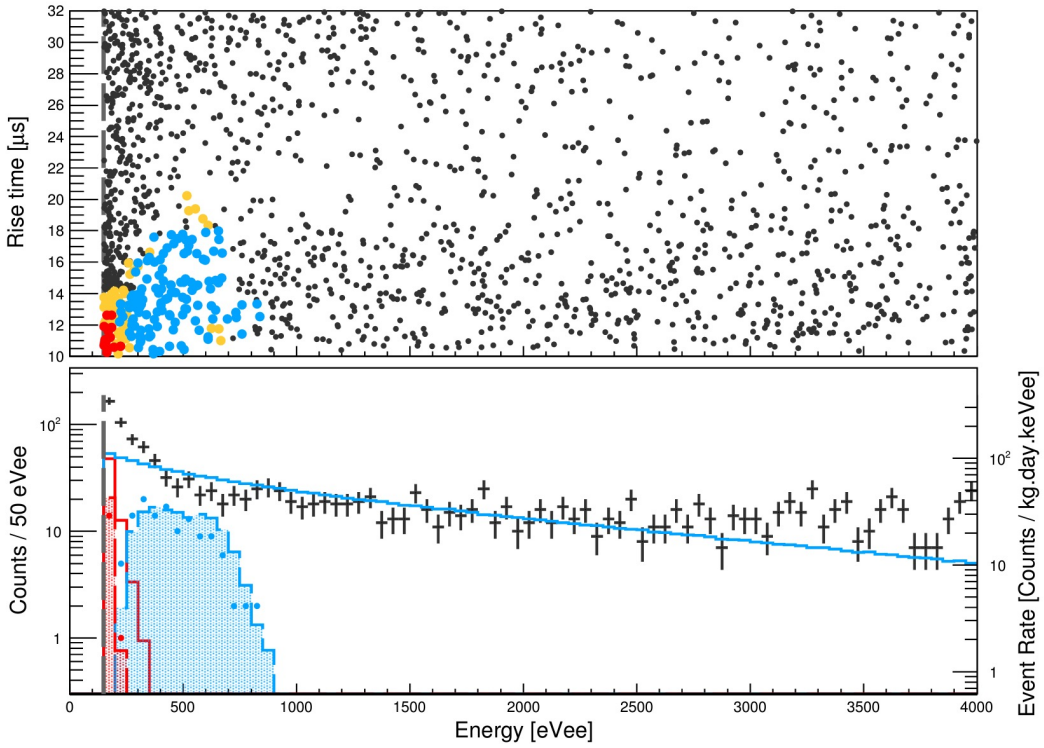






3.1 bars of Ne
+ 0.7% CH_4

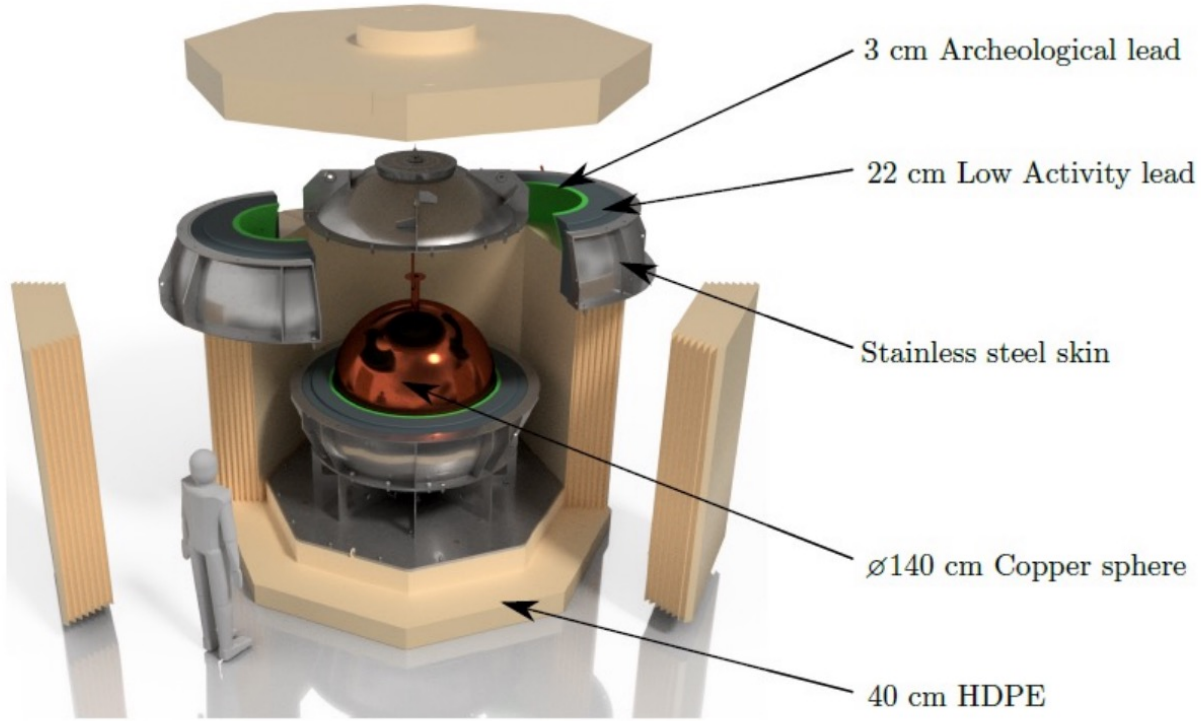
42 days of data



Q. Arnaud et al. (NEWS-G), Astropart. Phys. 97, 54 (2018)

The NEWS-G experiment

- 140-cm SPC made from commercial C10-100 copper, electroplated with 0.5 mm copper
- Compact shield with innermost layer **archeological Pb**
- Stainless steel shell flushed with nitrogen
- Gas circulation and radon trapping
- Installation completed at LSM (2019) and then SNOLAB (2021)

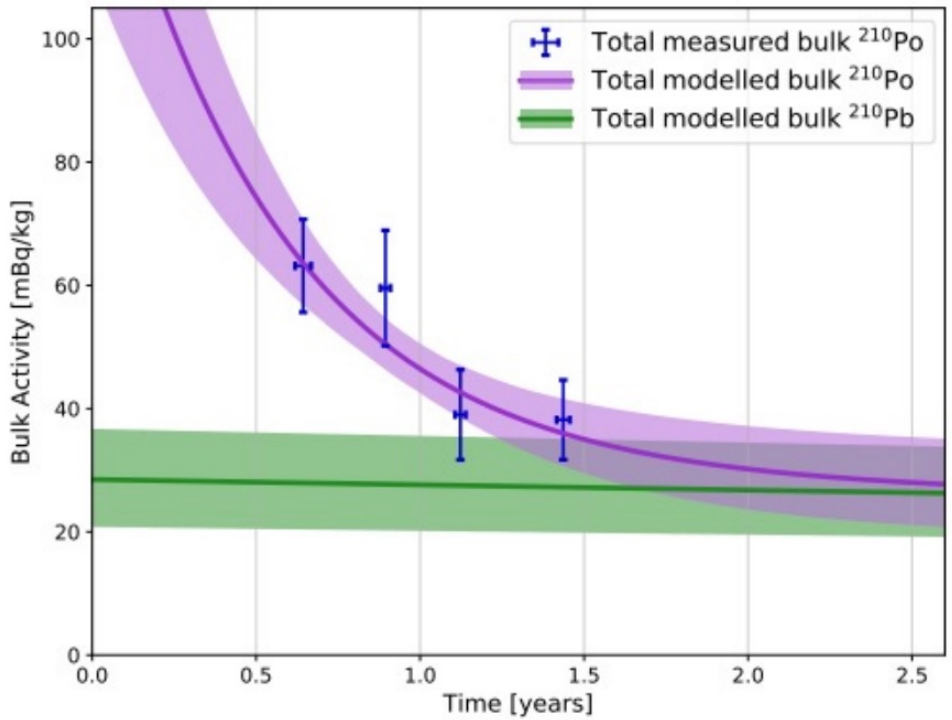


L. Balogh *et al* 2023 *JINST* **18** T02005

Copper Backgrounds

- Surface ^{210}Pb can be mitigated with surface etching
- Measurements of alpha particles with XIA surface alpha counter can be used to assess ^{210}Pb in the bulk
- For C10100 copper (4.5N) we found more (~30 mBq/kg) ^{210}Pb in the bulk than expected from U/Th measurements
- ^{210}Pb in the copper bulk will be the leading source of background in NEWS-G at SNOLAB (^{210}Bi bremsstrahlung)

XIA UltraLo-1800 (XMASS Collaboration)



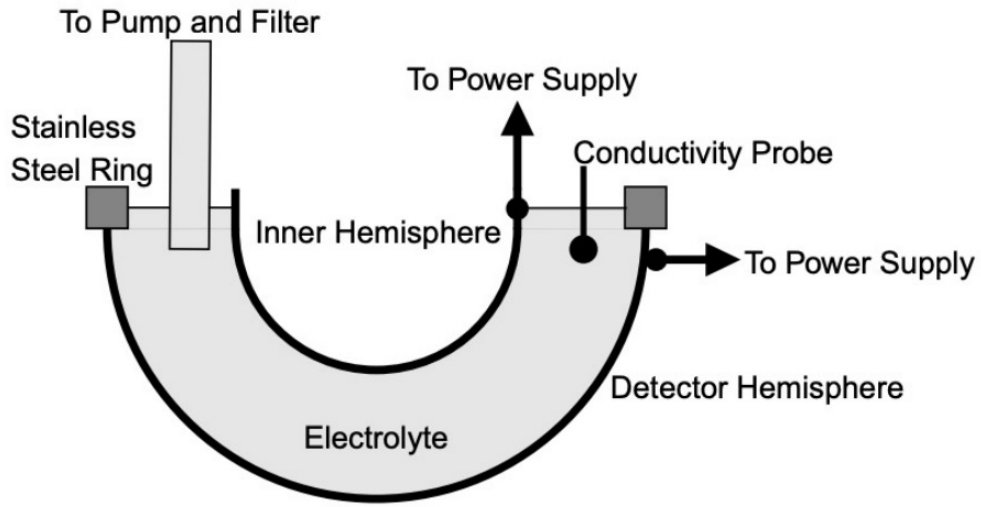
1.5 dru

Figure 3: Measurements of the α particles from the decay of ^{210}Po in a sample of C10100 copper used in the production of the NEWS-G detector. Time is measured from the estimated production date of the copper. The purple (green) line shows the fitted ^{210}Po (^{210}Pb) activity over time, with the bands showing the $\pm 1\sigma$ region.

Nucl.Instrum.Meth.A 988 (2021) 164844

Copper Electroplating

To mitigate bulk ^{210}Pb backgrounds, the 140-cm NEWS-G SPC hemispheres were electroplated with 0.5 mm pure copper at LSM



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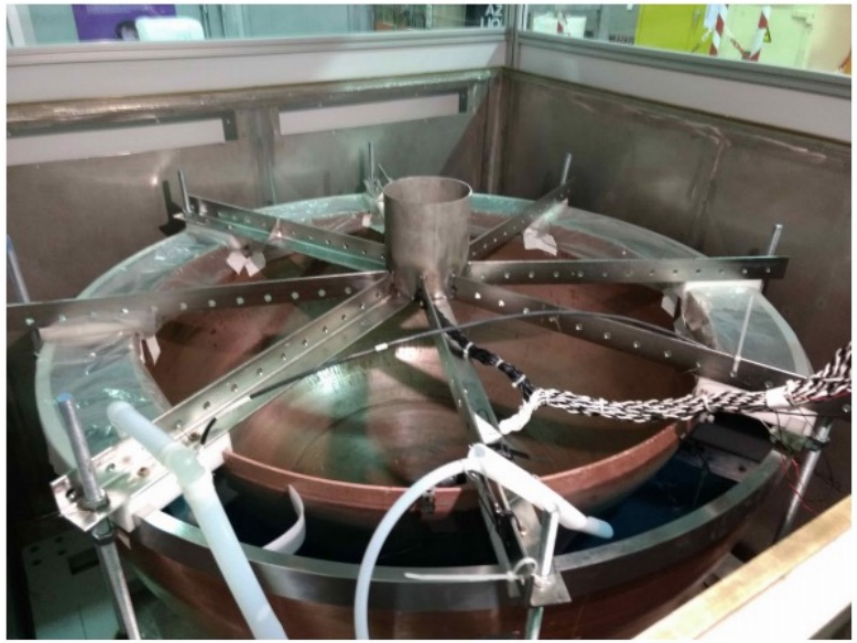
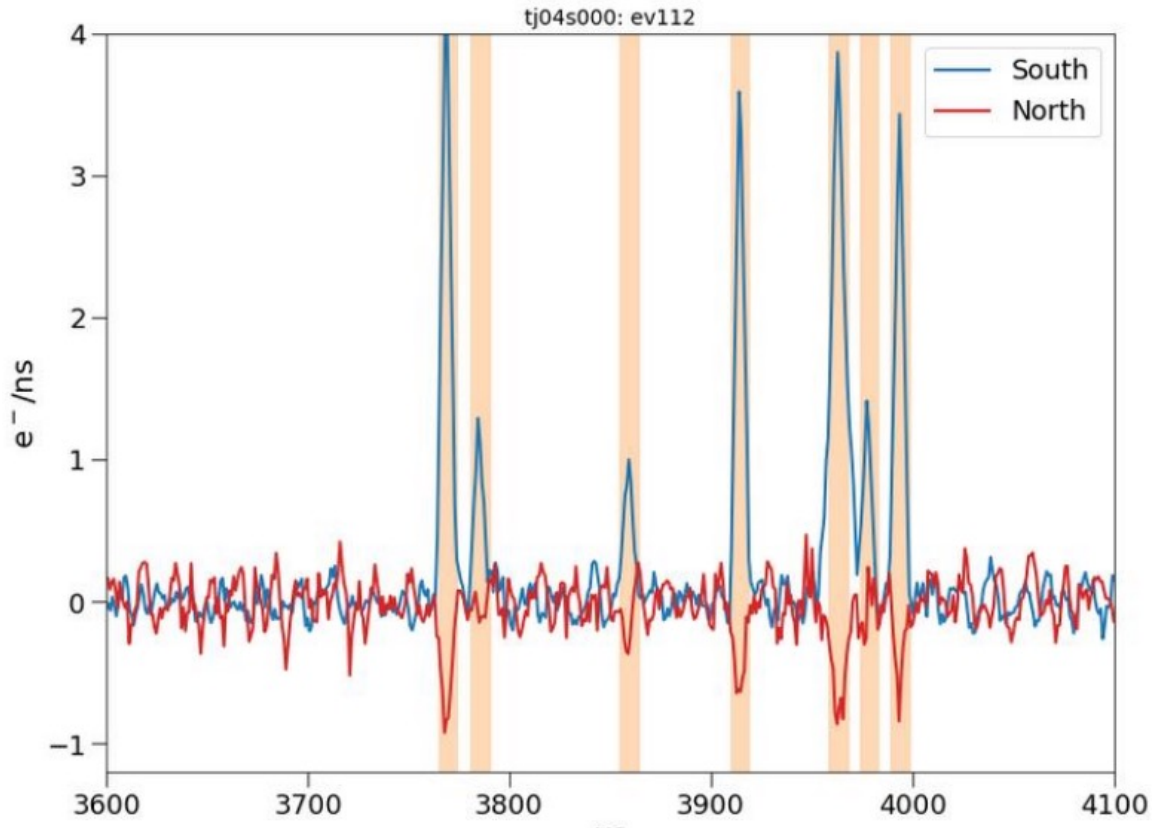
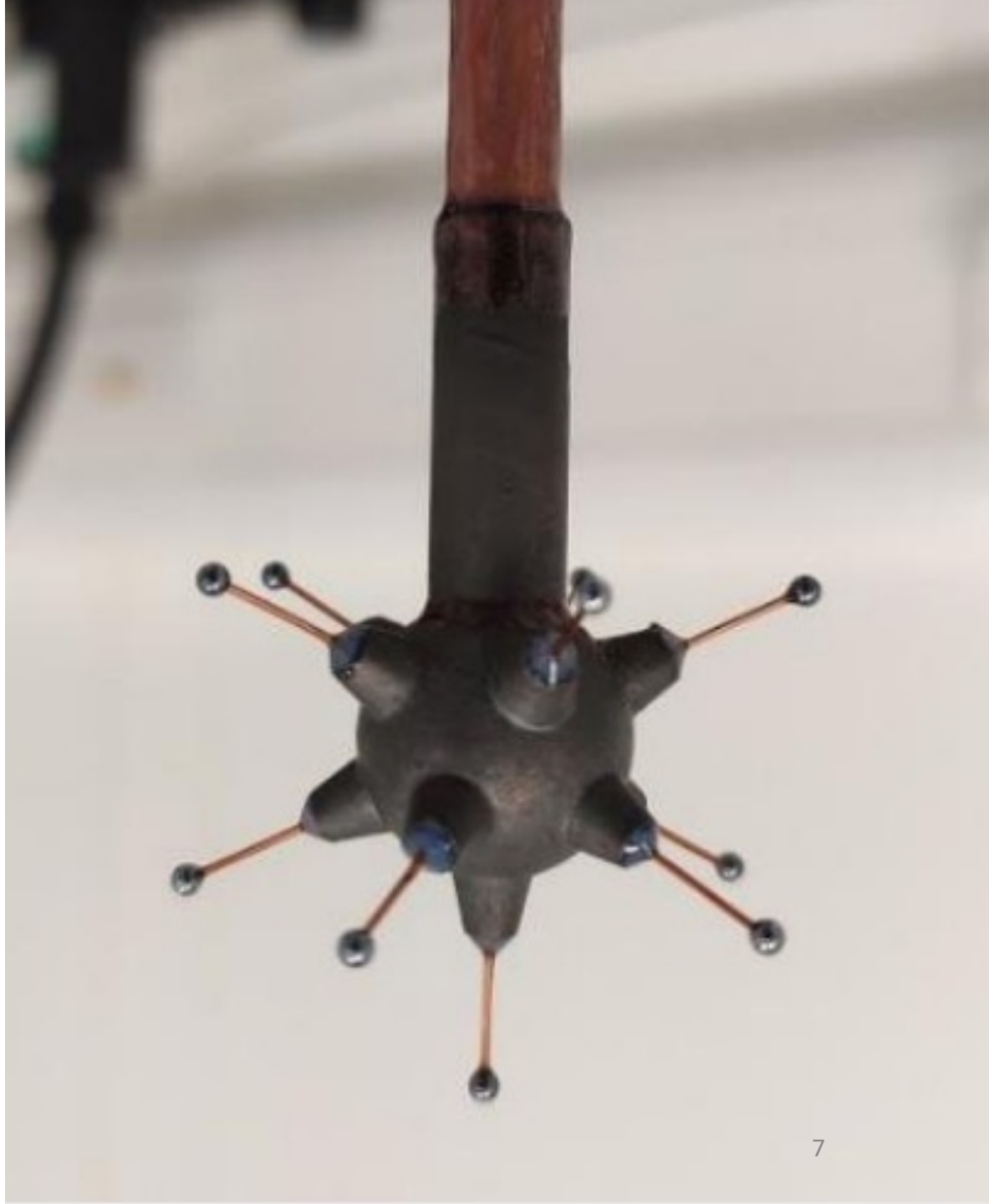


The ACHINOS sensor

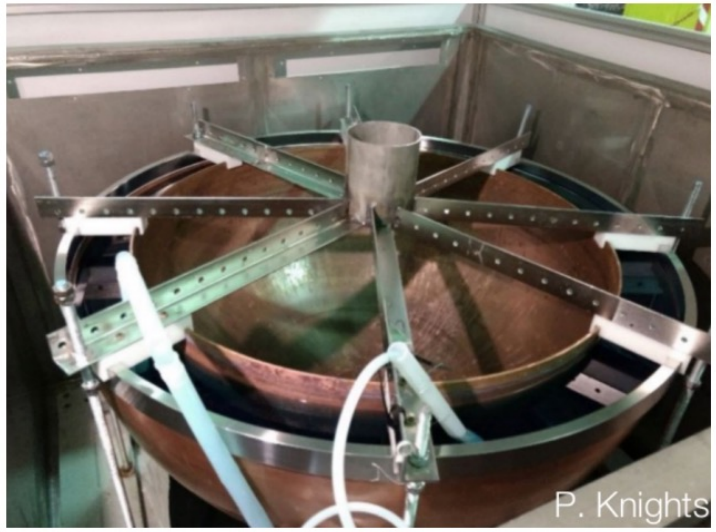
- Multi-ball sensor enhances the E-field at large radius, while conserving strong amplification
- Multi-channel read-out allows for further background rejection (sparks, spurious)





NEWS-G at LSM

- Sphere and Pb shield fabricated in France
- Storage of copper and electroplating at LSM (Laboratoire Souterrain de Modane) to mitigate cosmogenic activation
- Full installation, commissioning and physics run (pure CH_4) at LSM in summer-fall 2019 before DAMIC-M needed the space (from installation to shipping out in 5 months!)



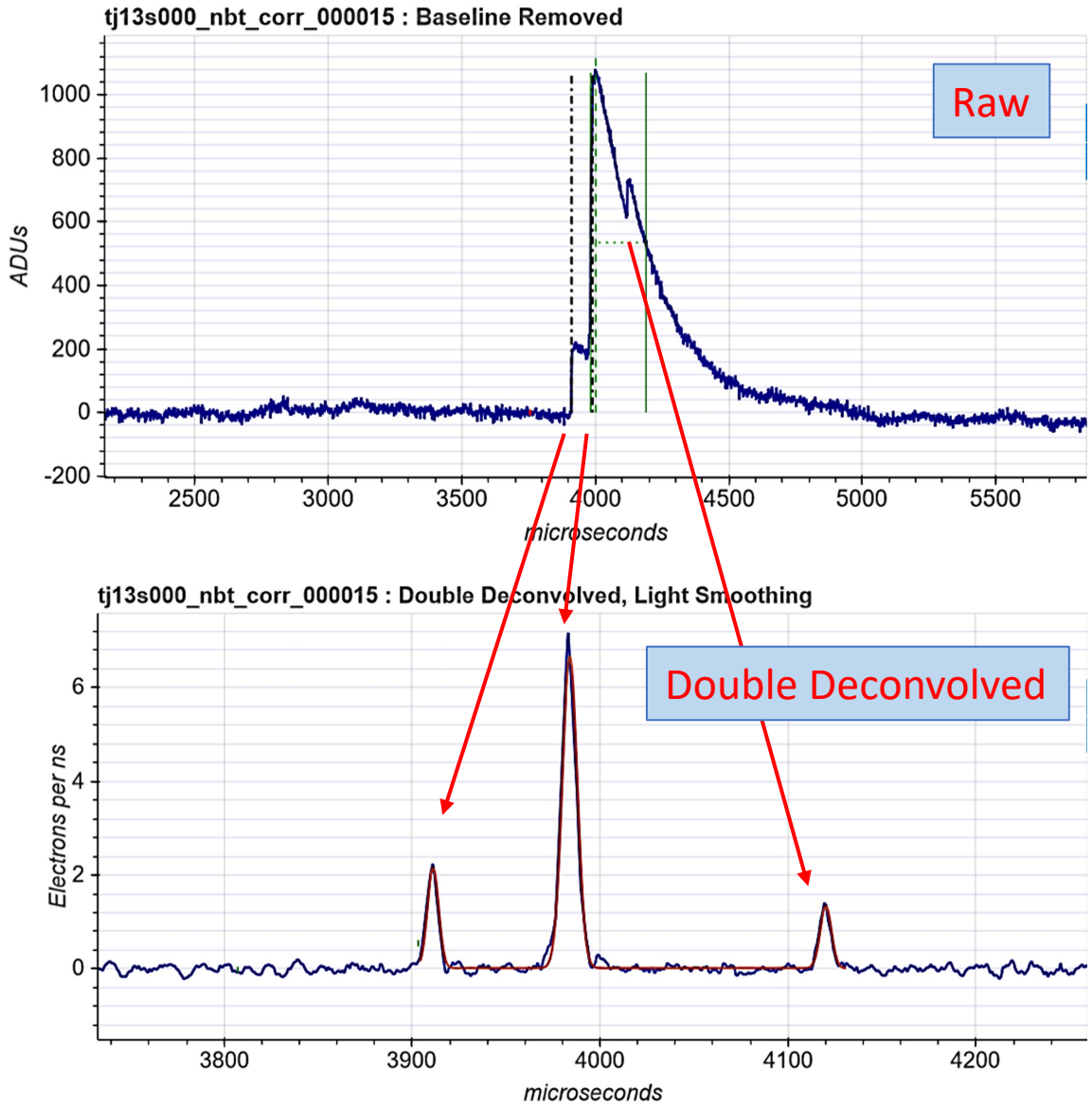
0.5 mm copper plating on hemispheres at LSM to manage ^{210}Pb in copper bulk

Sphere in Pb shield installed in temporary water shield in summer 2019

NEWS-G shipping to SNOLAB after commissioning at 1 week physics run with 135 mbar pure CH_4

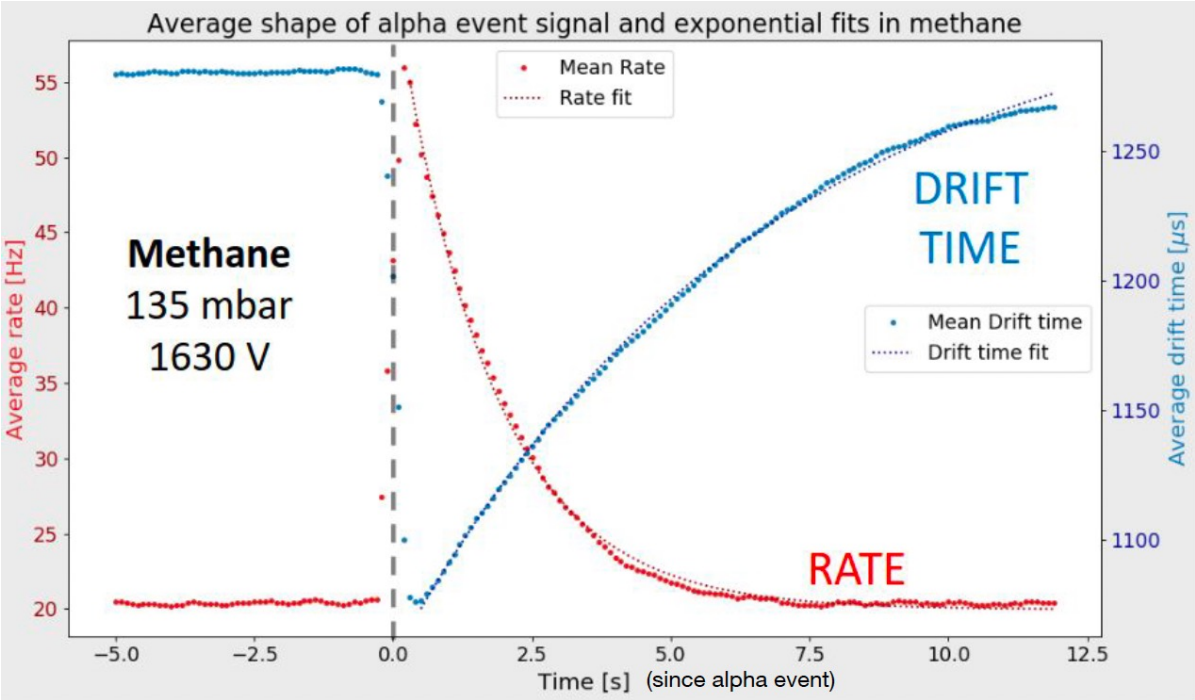
Electron Counting

- Primary electrons diffuse during drift
- After pulse processing (double deconvolution), individual electrons (~30 eV) become visible
- Discrimination between 1 e^- and 2 e^- events (background suppression)

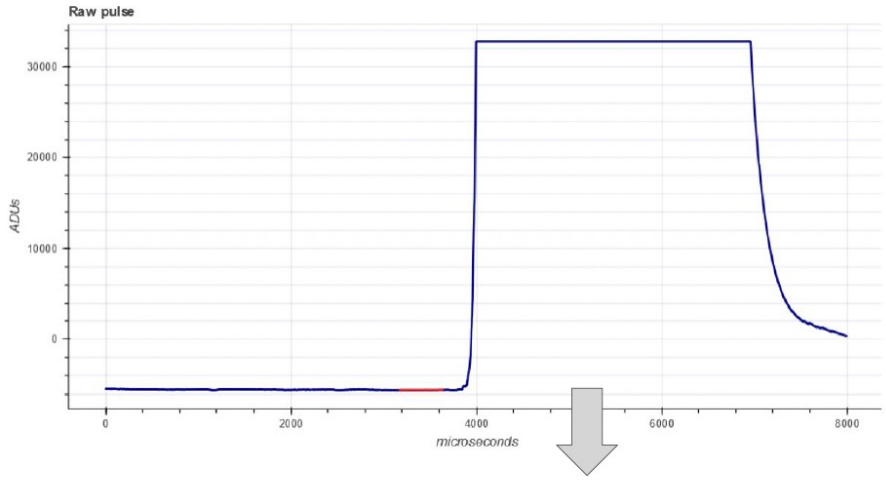


Single electron background

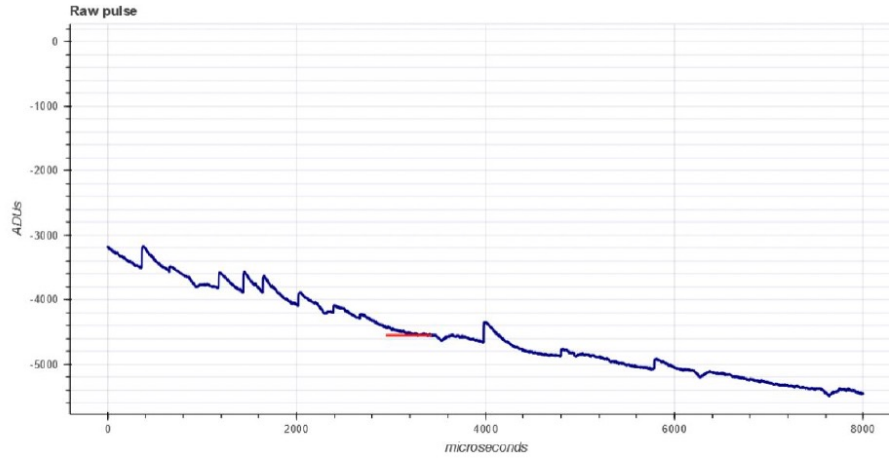
- Observation of an **excess of single electrons**
- Especially high after alpha events
- Removing 5 sec after each alpha reduces background rate by 70% (14% deadtime)



Alpha event J.M. Coquillat

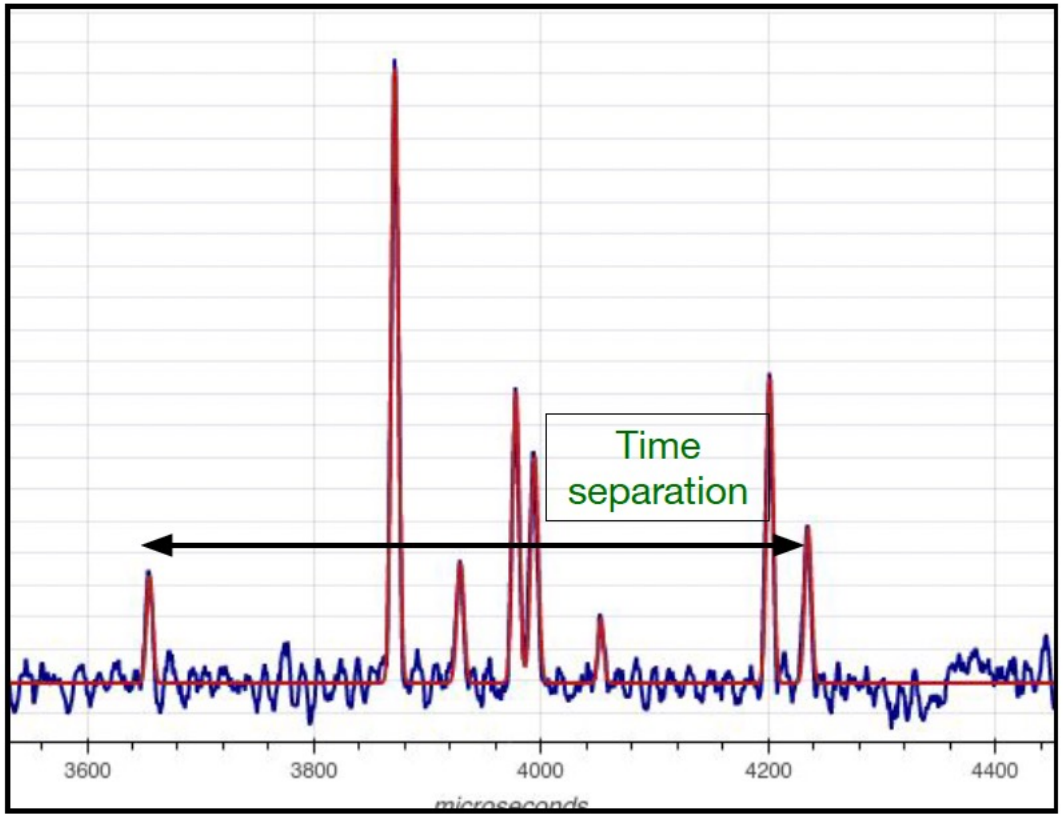


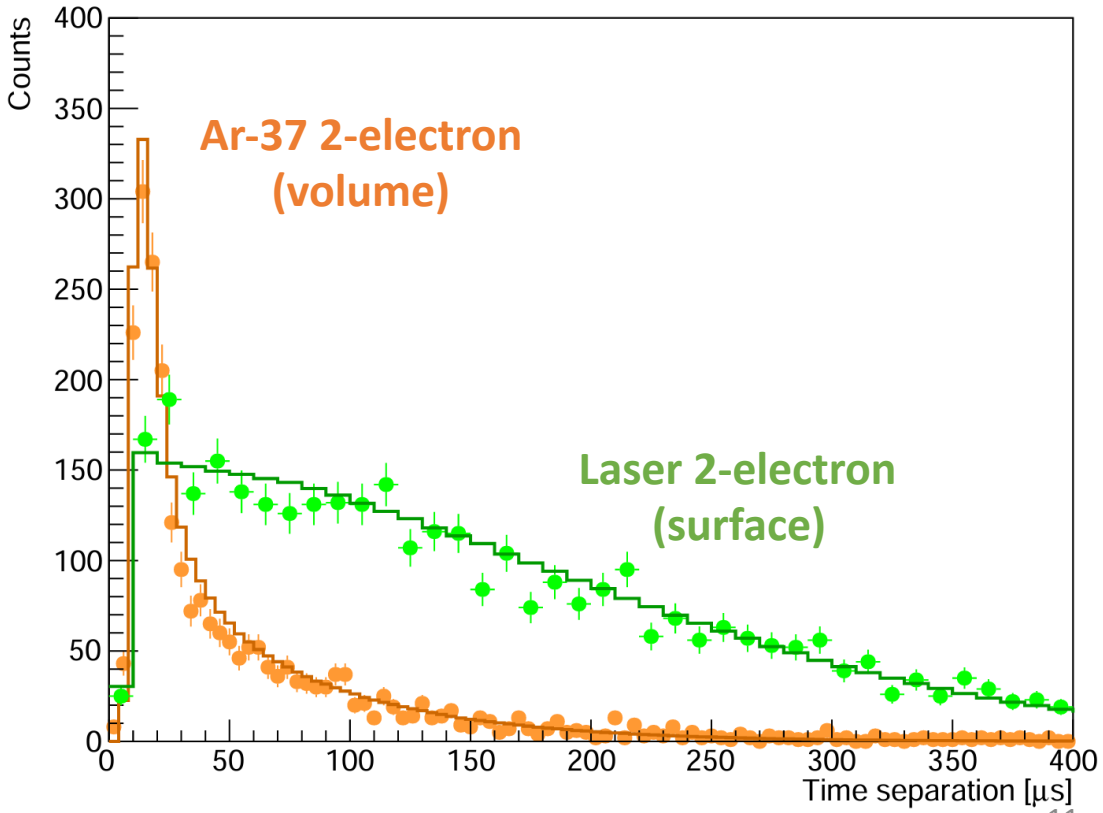
Long tail on following detected event



Electron Time Separation

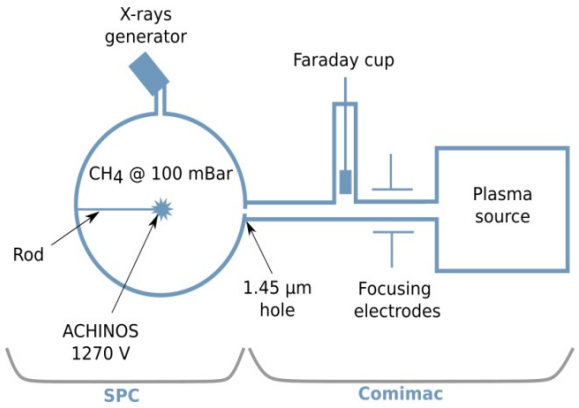
- Single electrons are discarded
- Time separation between electrons in >1 electron events is a measure of diffusion and allows to reject backgrounds from inner surface

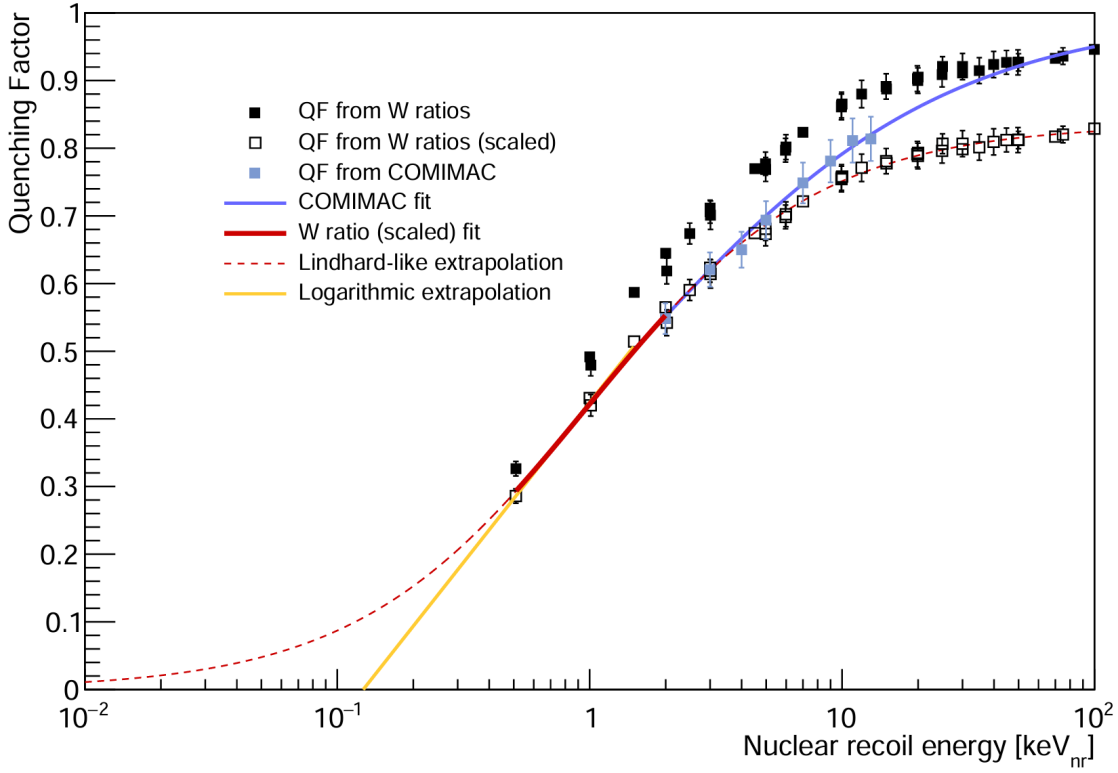




Nuclear Recoil Ionization Yield

- Quenching factor values from existing W-value measurements for ions and measurements from COMIMAC
- The more **conservative logarithmic extrapolation** was used to derive the expected WIMP signal



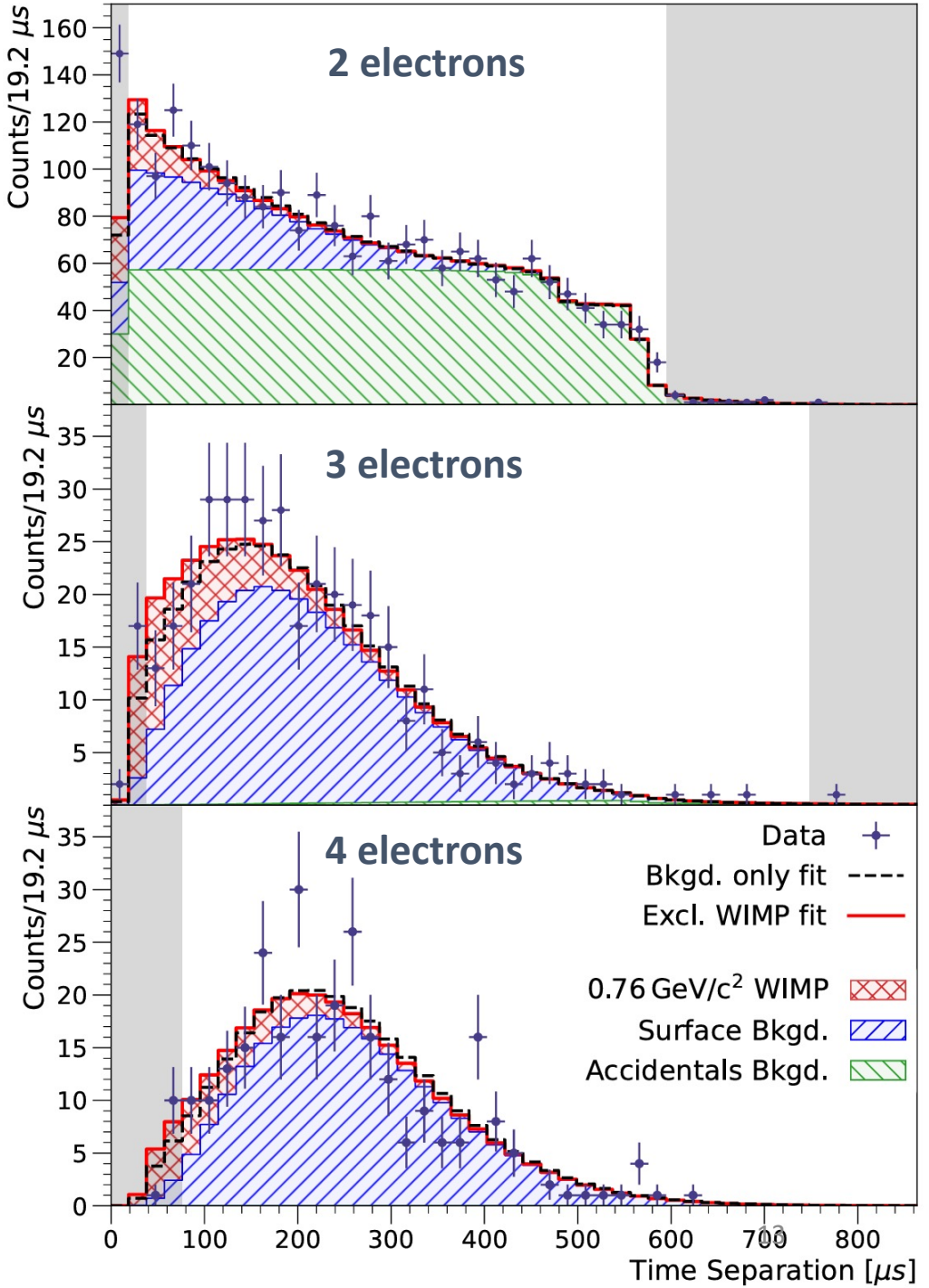


[1] I. Katsioulas et al, Astropart. Phys. 141, 102707 (2022)
[2] L. Balogh et al, EJP C, 2022

Results

Physical Review Letters 134 (14), 141002 (2025)

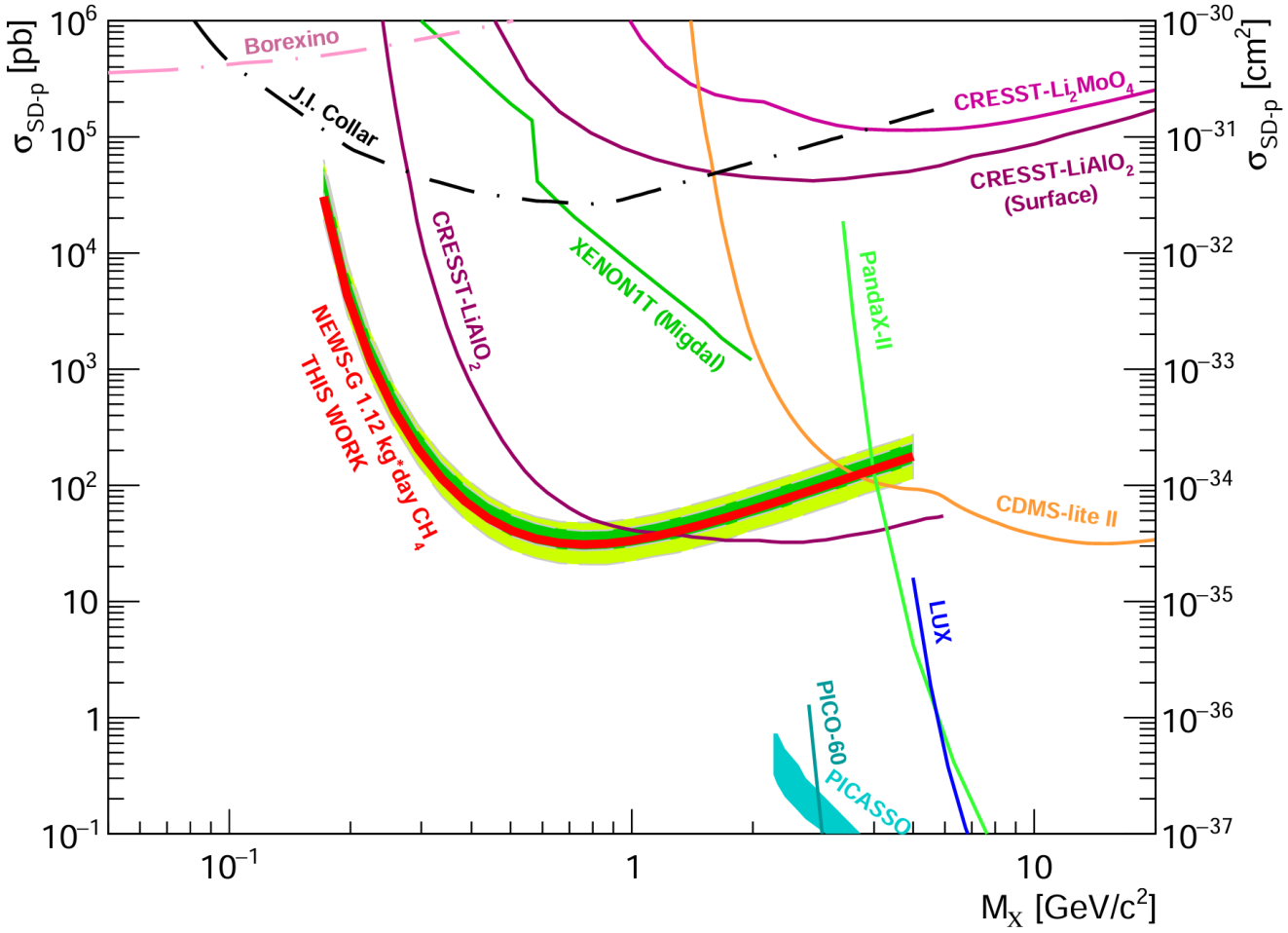
- 1.12 kg-day CH_4 physics run
- Profile likelihood fit on 2,3,4 electron events
- Contribution from WIMP, surface, volume and single electron pileup (accidentals)
- No significant WIMP signal is observed



New WIMP Constraints

Strongest constraints on spin-dependent WIMP-proton (**directly on H**) cross-section in the 0.18 – 1.2 GeV range!

Physical Review Letters 134 (14), 141002 (2025)



NEWS-G at SNOLAB

- Installation and commissioning heavily impacted by pandemic shutdown and restrictions
- Strong support from SNOLAB with contractor team installing NEWS-G during fall 2020
- Complete installation and beginning of commissioning in summer 2021

Dec 11th, 2019

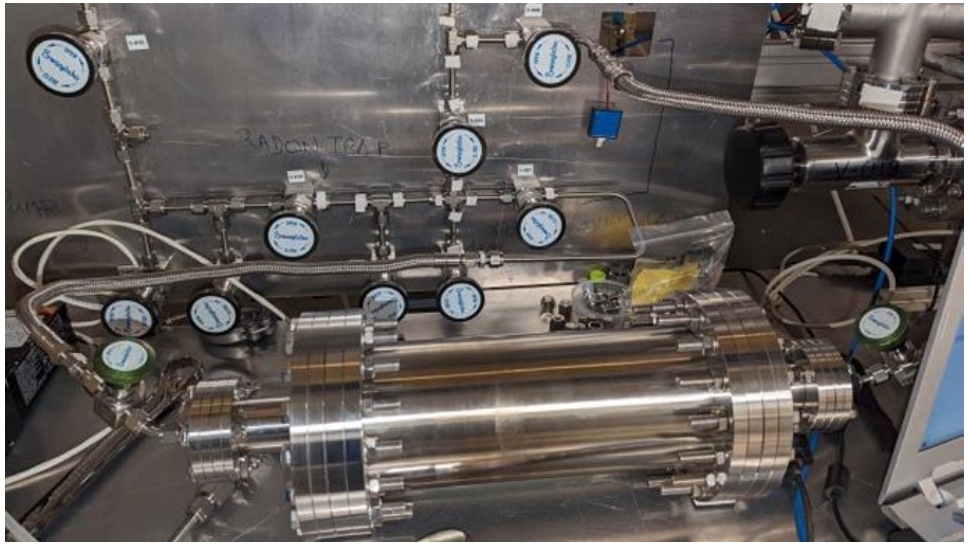
Jan 29th, 2020

Mar 24th, 2021

NEWS-G at SNOLAB

- Physics runs were conducted with **Ne-CH_4 and He-CH_4 targets**
- Surface background is addressed with **in-situ etching**
- Single electron background is addressed with gas purity improvement and radon removal
- Several improvements on gas purity and low-frequency noise are underway
- More physics soon with **Ne-CH_4, CH_4 and He-CH_4**

Radon trap

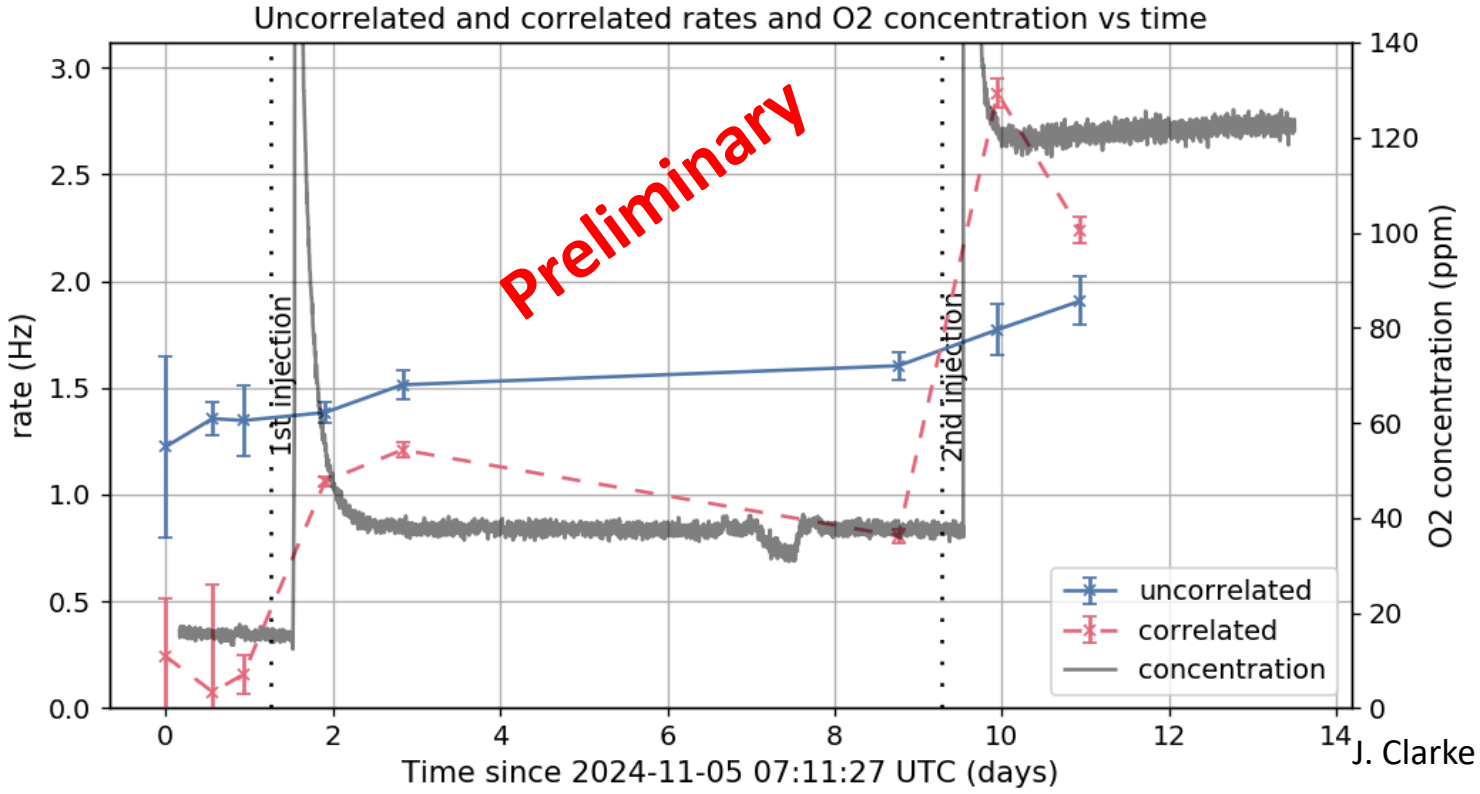


Gas purifier

Single-Electron Background

- Controlled injection of oxygen to understand the effect of electron attachment on the single-electron background (paper in progress)

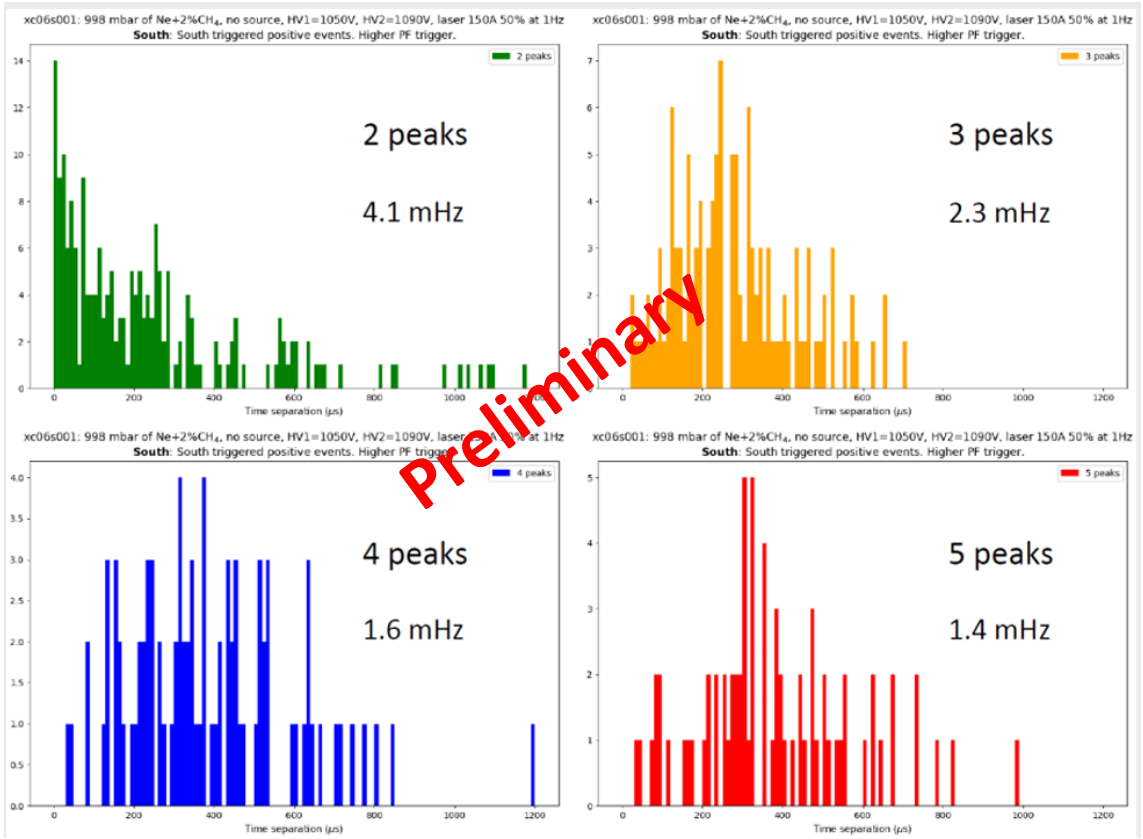
See Jon Clarke's EXCESS 2026 talk
https://indico.cern.ch/event/1644935/contributions/7084825/



J. Clarke

SNOLAB Ne-CH_4 Physics Run Analysis

- 2nd SNOLAB physics run
  - 1-bar Ne(98)-CH_4(2)
  - No gas recirculation
  - High-gain, low-noise
- Analysis work underway to develop the electron diffusion model and the single electron response
- Markov-Chain-Monte-Carlo fitting
- **Indications of a lower single-electron noise compared to LSM with pure CH_4**



Conclusions

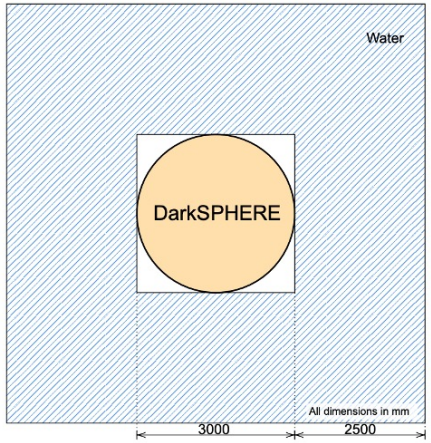
- New, world-leading spin-dependent WIMP-proton constraints at LSM
- Physics data was collected with neon and helium target at SNOLAB, data analysis underway
- Addressing surface background with electrochemistry
- Addressing single-electron background with gas purification
- We continue physics data taking at SNOLAB with Ne, He and H targets
- Electroforming MiniEcume at PNNL is concluding
- New-generation DarkSphere was proposed at Boulby while electroforming efforts have started

Thank you!

Extra slides

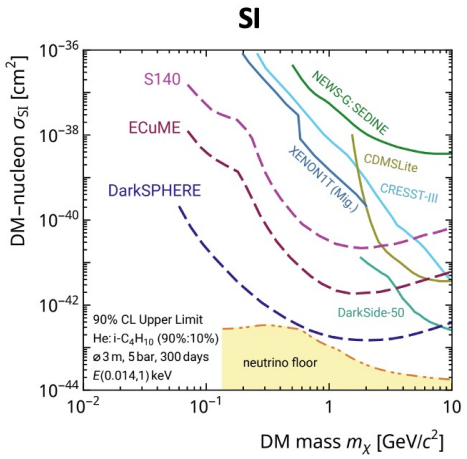
Future of NEWS-G: DarkSphere

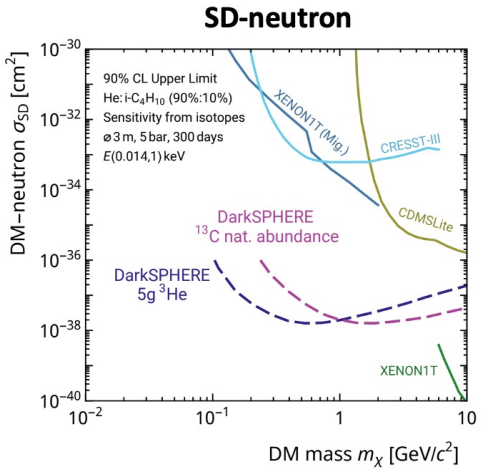
Proposal for a 3-m electroformed SPC at Boulby

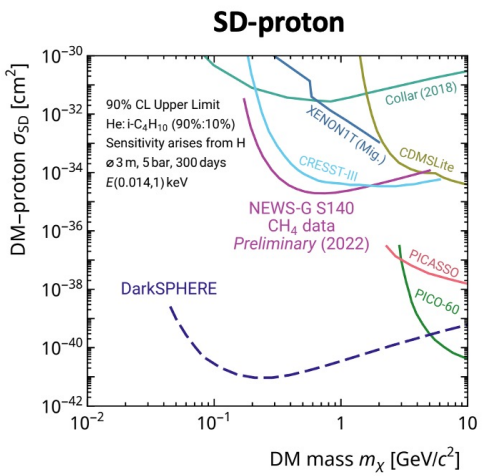


Proposed shielding

The NEWS-G Collaboration at Boulby







Also: SD-neutron on Ne-21, WIMP-electron, Migdal effect, …

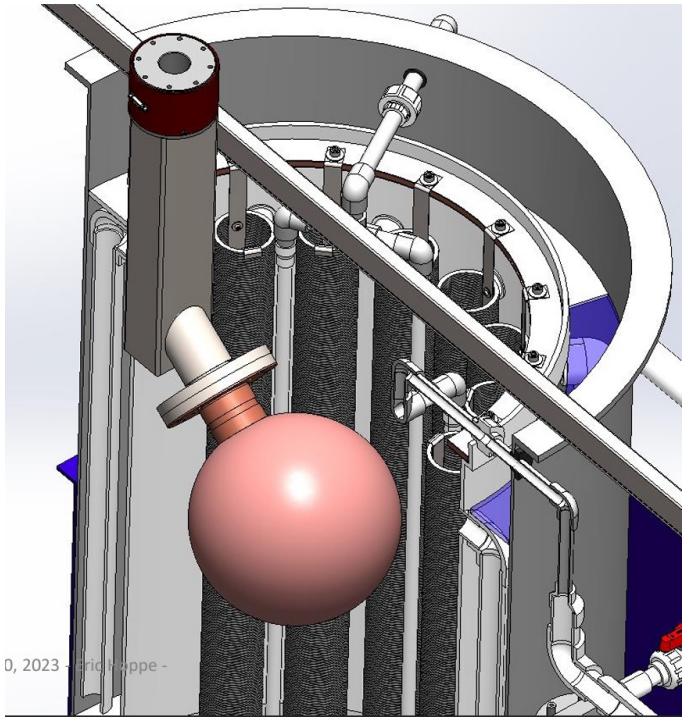
arXiv:2301.05183 **[hep-ex]**

22

MiniECuME: A 30-cm intact underground-electroformed SPC prototype

- Copper and acids samples from platting on a cylindrical mandrel reveal that lower-grade (10X cheaper) acid is viable option
- Mini-ECumE mandrel holder assembled
- Spherical acrylic mandrel was fabricated but present defects in copper non-electro forming and does not correspond to fabrication drawings
- PNNL will proceed with electroforming on spherical mandrel to learn from the experience of platting a spherical object

The ECA electroforming bath at PNNL

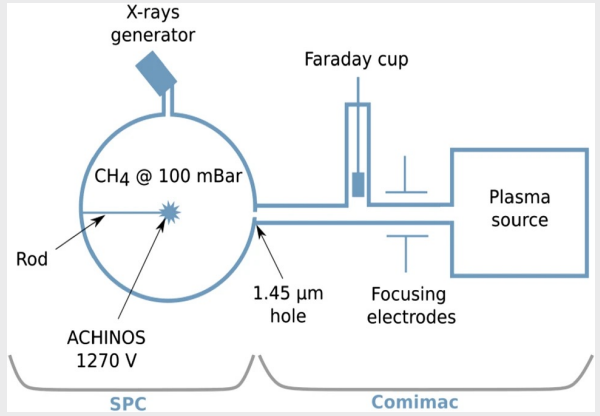


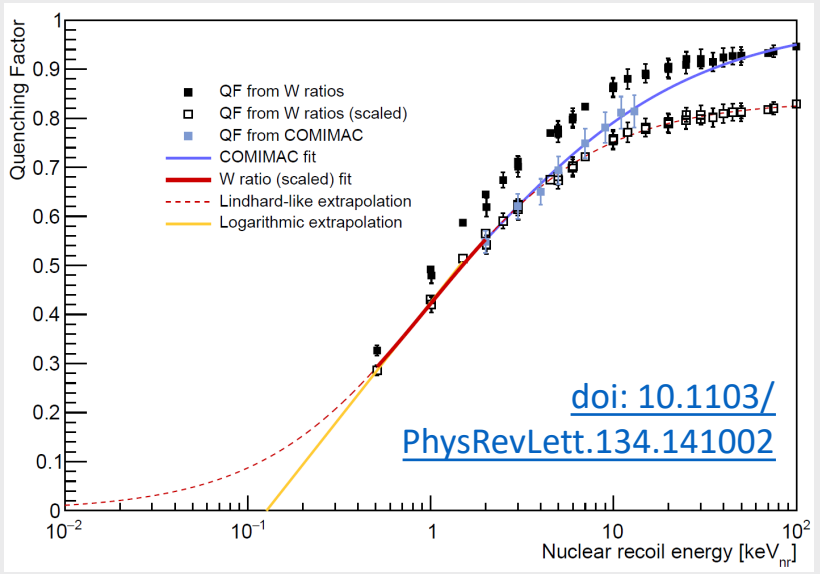
MiniECuME mandrel holder

MiniECuME acrylic mandrel

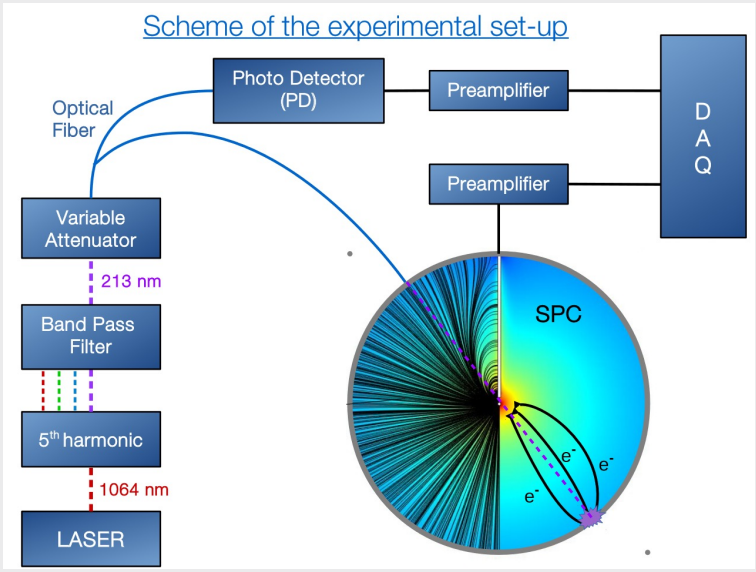
Calibration

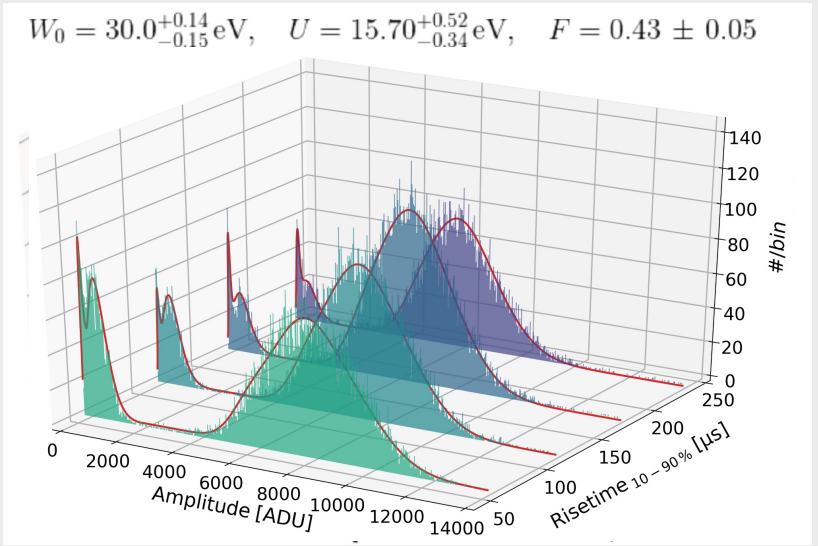
- A UV laser is directed at the inner copper surface of the sphere and releases electrons through the photoelectric effect. The UV light also goes to a photodetector so the laser events can be tagged as a control.
- Some argon-37 is released inside the sphere, and the gas diffuses in the whole volume. This isotope is radioactive and has two peaks that enable energy calibration, as well as ionisation and attachment parametrization .
- The quenching factor was measured at COMIMAC as well as obtained from literature W-values. The ionization yield was measured in situ and in a 30 cm sphere at Queen's University.





doi:10.1140/epjc/s10052-022-11063-9

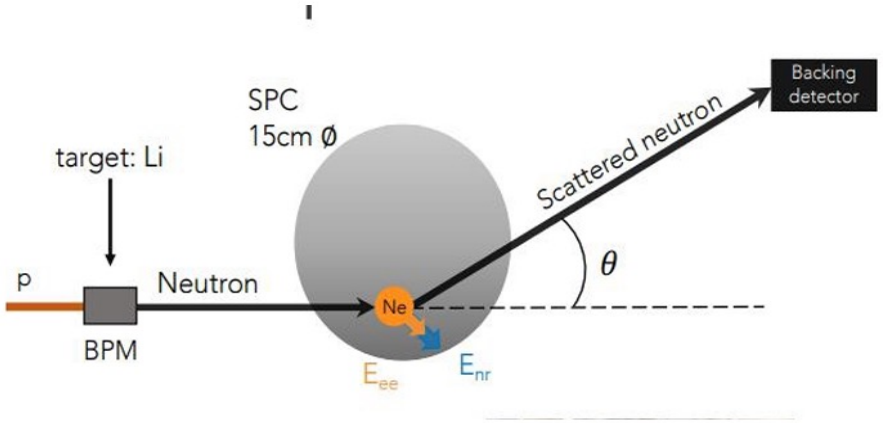


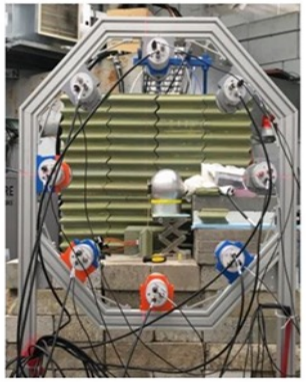


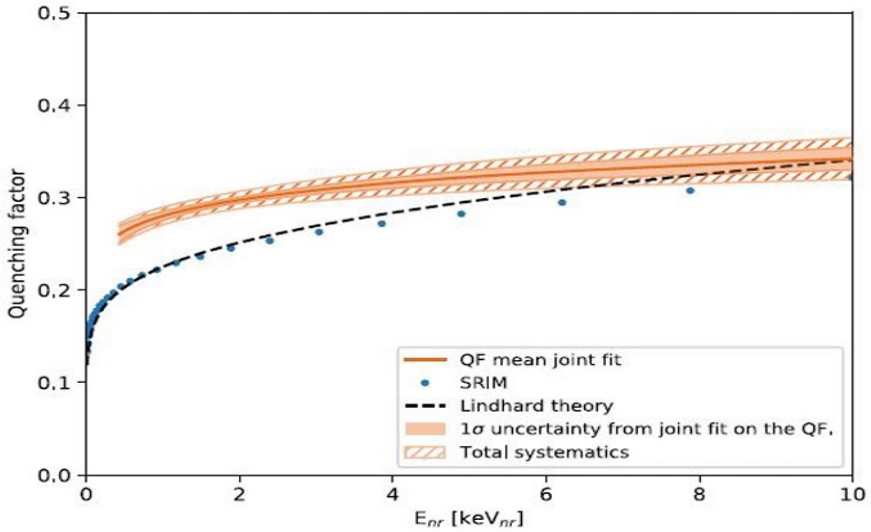
doi:10.1088/1742-6596/2156/1/012059

Past measurement at TUNL

- **Quenching factor measurements at TUNL (Duke tandem facility)**
- The nuclear recoil energies covered were 0.34 to 10 keVnr







Marie et al.

Phys. Rev. D. Vol. 105, No. 5, 052004 (2022)

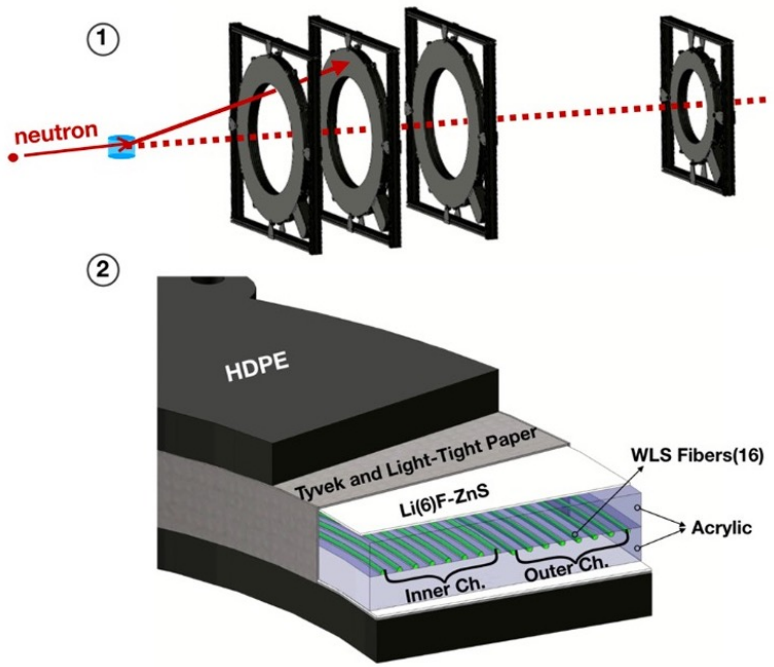
Neha Panchal

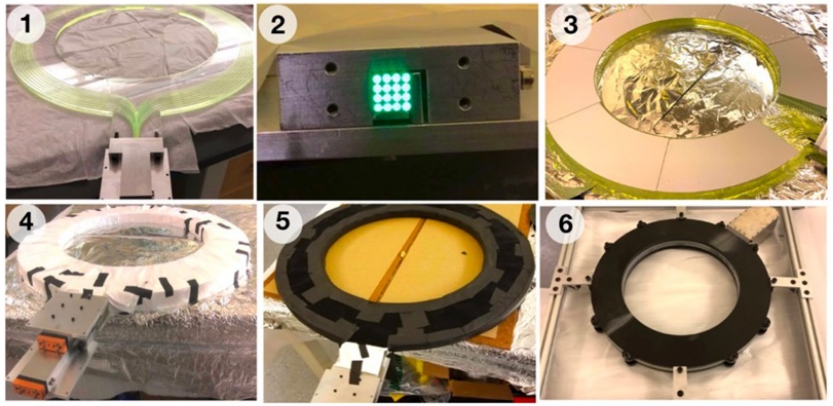
Current plans

UdeM tandem accelerator: planning to do QF measurements

- Possibility to go to ~10 times lower energy than TUNL ~5keV
- $^{51}V(p,n)$ as target offering large number of near threshold resonances
- Better rejection to gamma background by B-10 neutron capture
- Working on building a new backing detector

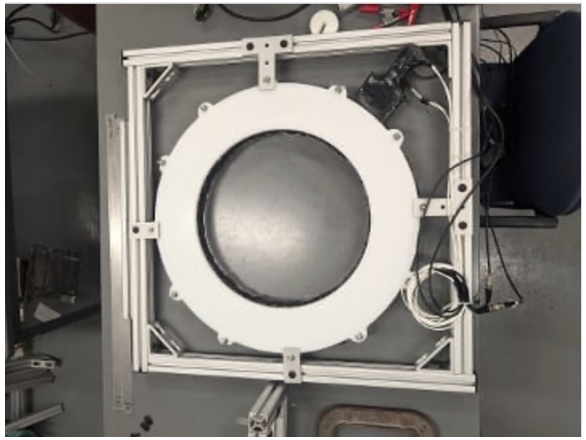
New Backing Detector





- The Backing Detector is an annulus structure
- Provides better angular coverage
- Based on n-capture on Li
- Detection efficiency 27% at 2keV
- Mean neutron capture time 17usec

Pratyush Patel et al.



Neha Panchal