

# NEWS-G Research Update

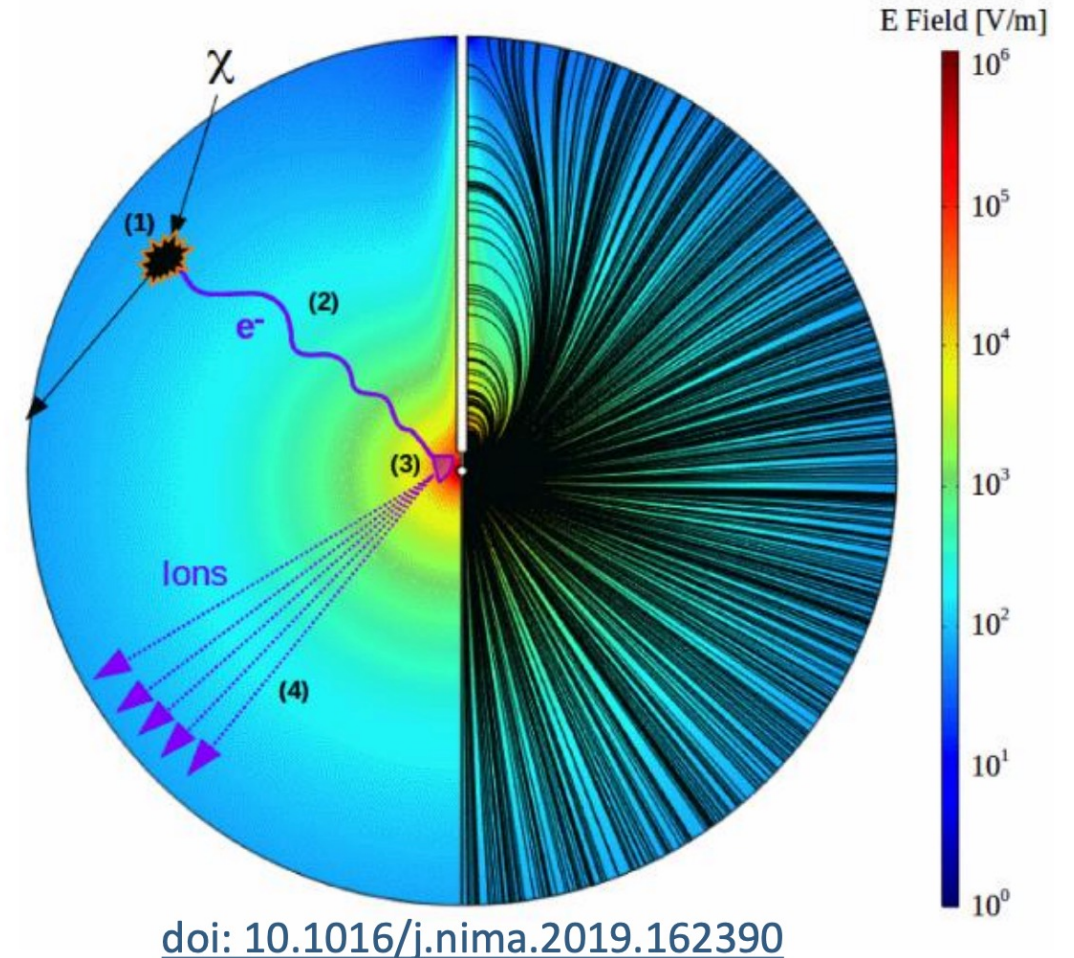
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Guillaume Giroux  
Queen's University  
August 2023



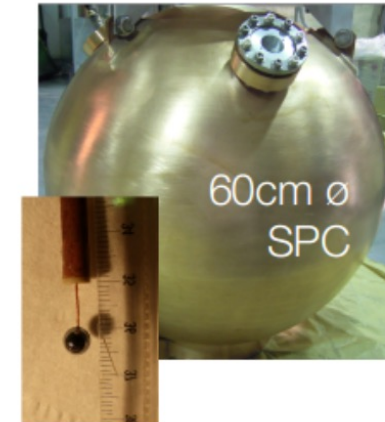
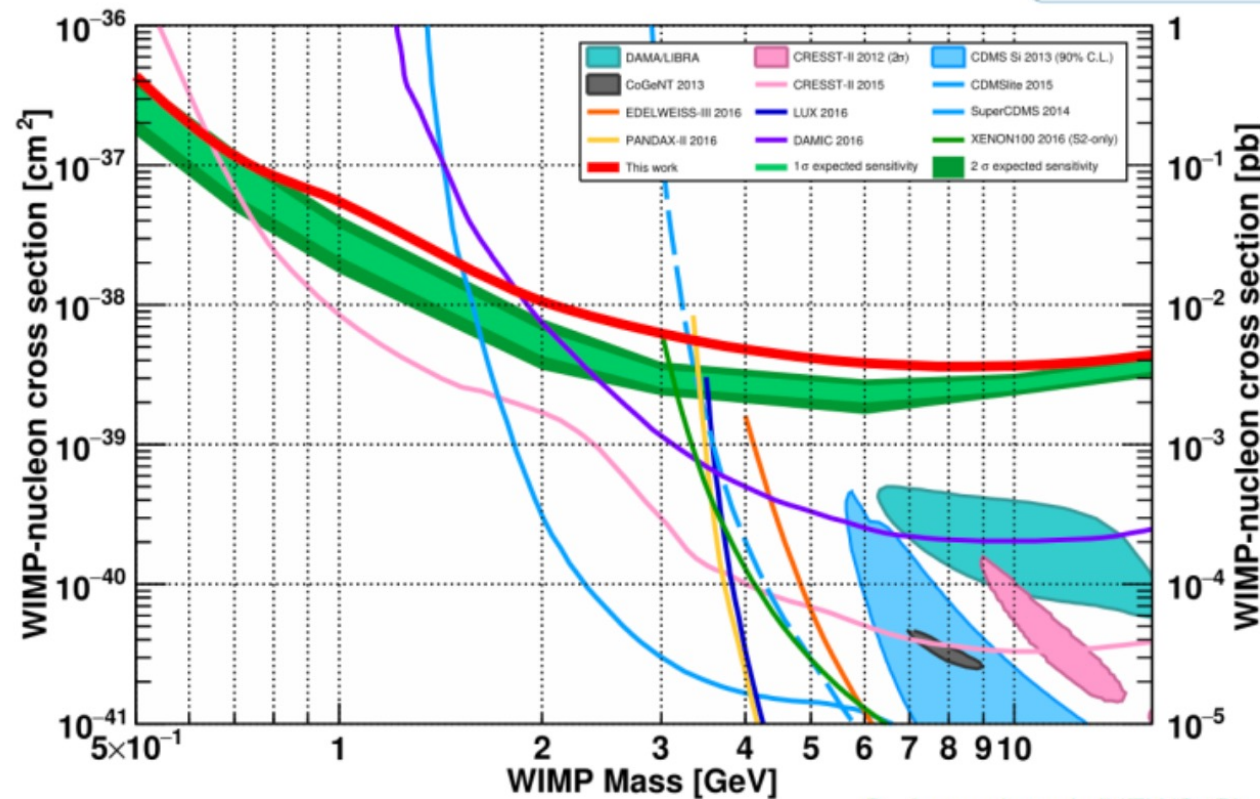
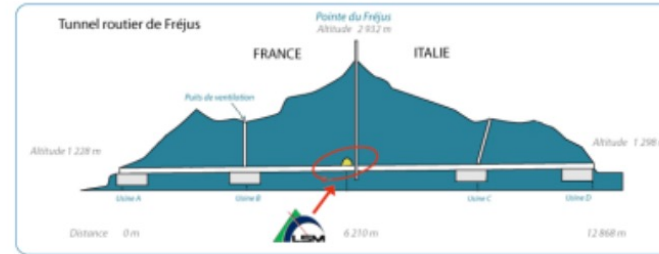
# Search for low mass dark matter

- 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



# First Demonstration: SEDINE at LSM

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



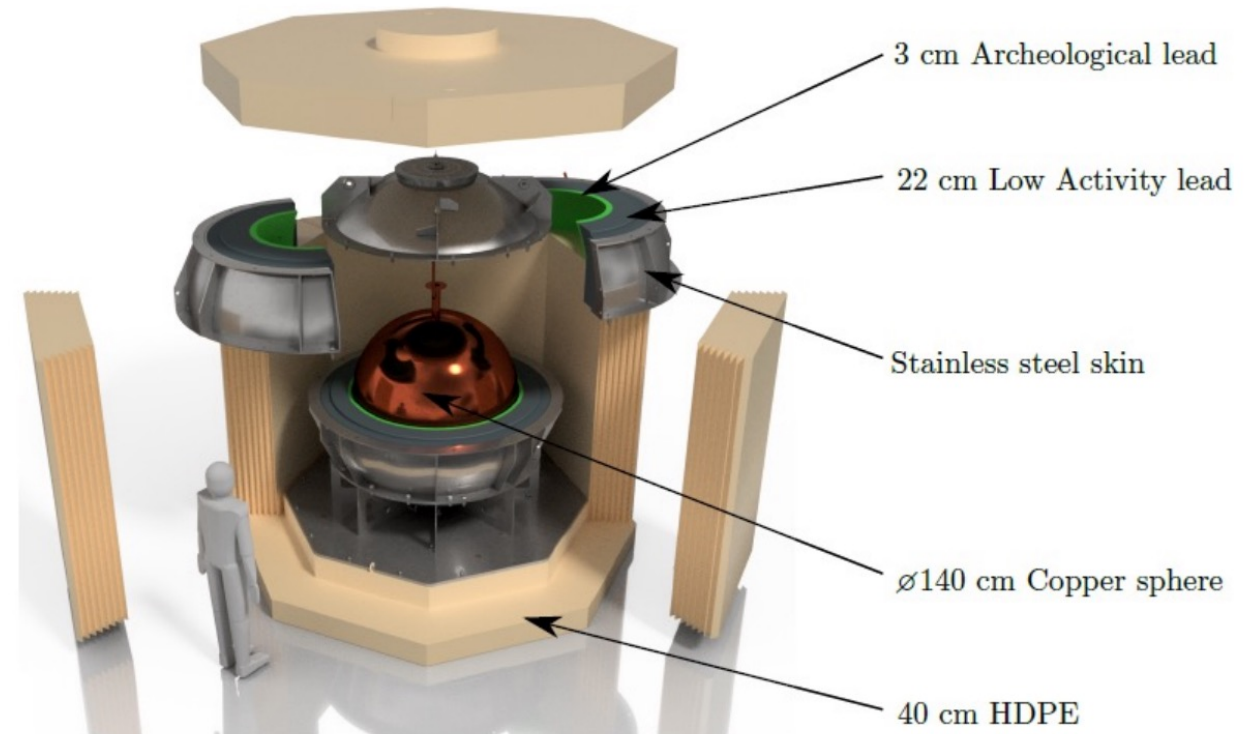
60cm  $\varnothing$   
SPC

3.1 bars of Ne  
+ 0.7% CH<sub>4</sub>

42 days of data

# 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 in summer 2021



# Copper Backgrounds

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

XIA UltraLo-1800 (XMASS Collaboration)

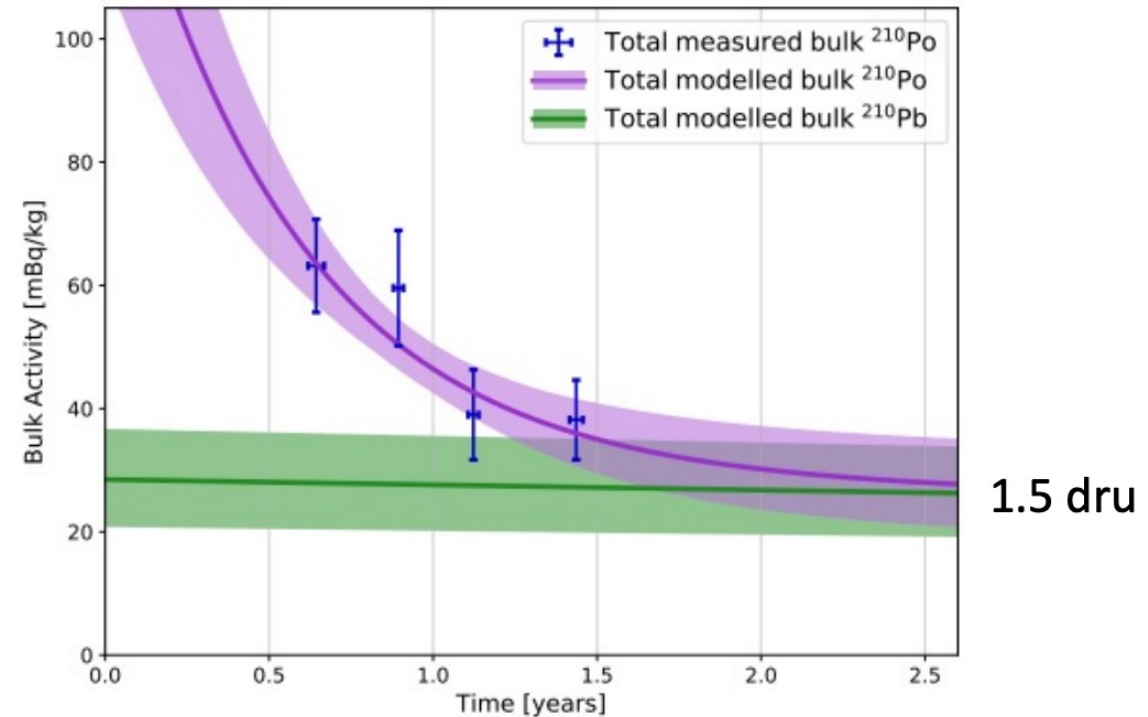
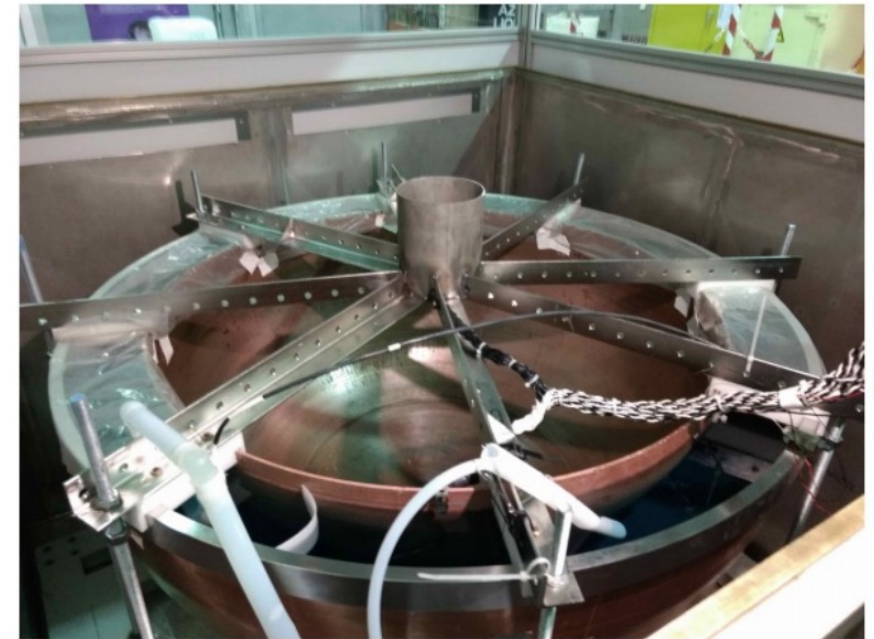
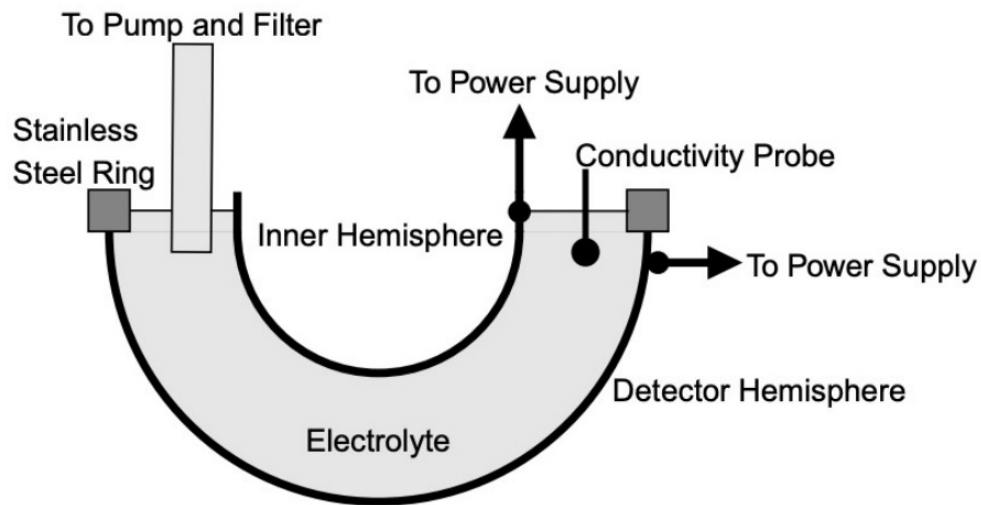


Figure 3: Measurements of the  $\alpha$  particles from the decay of  $^{210}\text{Po}$  in a sample of C10100 copper used in the production of the NEWS-G detector. Time is measured from the estimated production date of the copper. The purple (green) line shows the fitted  $^{210}\text{Po}$  ( $^{210}\text{Pb}$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

# Copper Electroplating

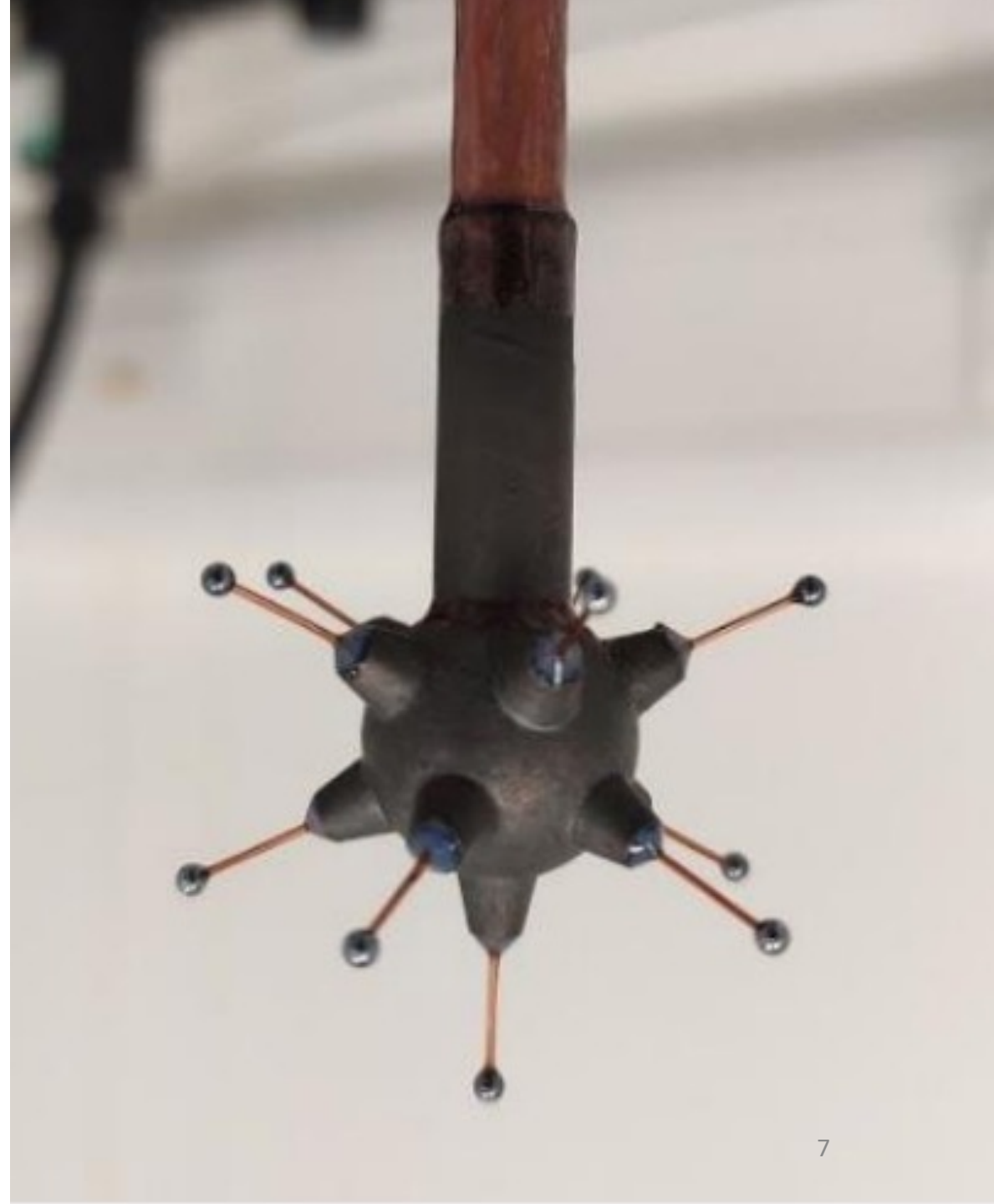
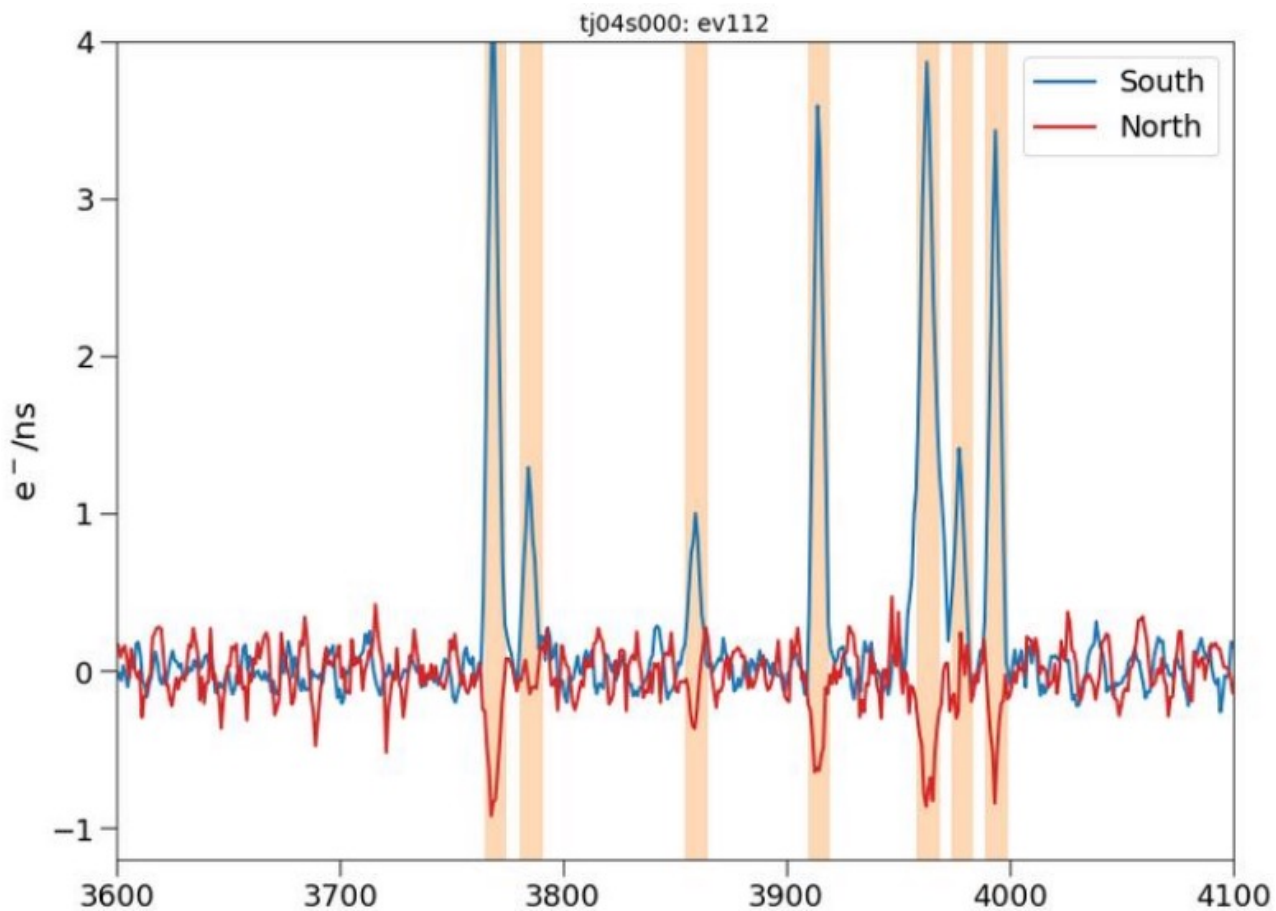
To mitigate bulk  $^{210}\text{Pb}$  backgrounds, the 140-cm NEWS-G SPC hemispheres were electroplated with 0.5 mm pure copper at LSM



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

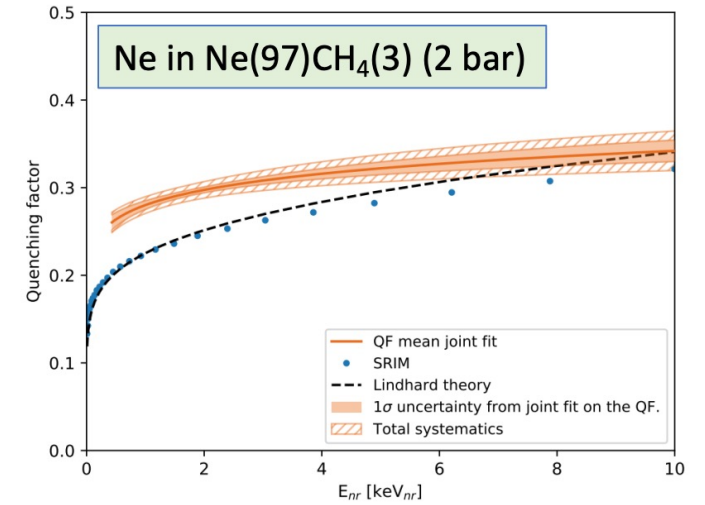
# The ACHINOS sensor

- 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)



# Quenching Factor Measurements

- NEWS-G has measured the QF in Ne-CH<sub>4</sub> (TUNL) and pure CH<sub>4</sub> (Comimac)
- More measurements are needed:
  - At lower energy
  - With varying gas mixtures and pressures
  - In helium
- Measurements are planned at multiple facilities



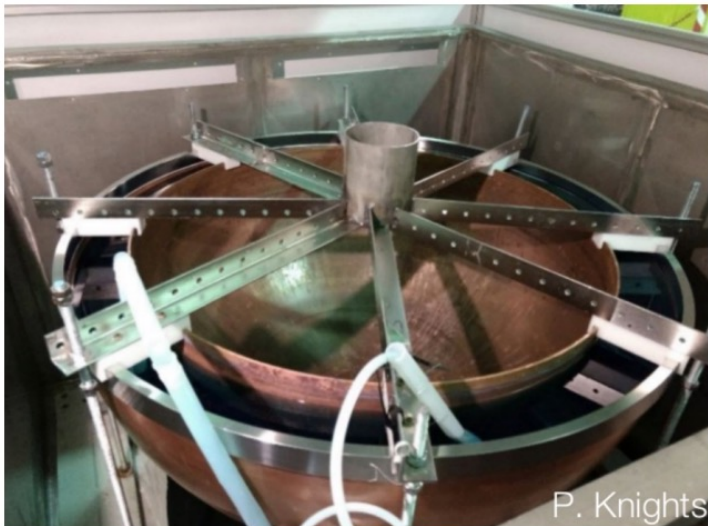
L. Balogh, *et al.* (NEWS-G Collaboration), *Quenching factor measurements of neon nuclei in neon gas*, Phys. Rev. D **105**, 052004 (2022)





## 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<sub>4</sub>) at LSM in summer-fall 2019 before DAMIC-M needed the space (from installation to shipping in 5 months!)



0.5 mm copper plating on hemispheres at LSM to manage <sup>210</sup>Pb in copper bulk

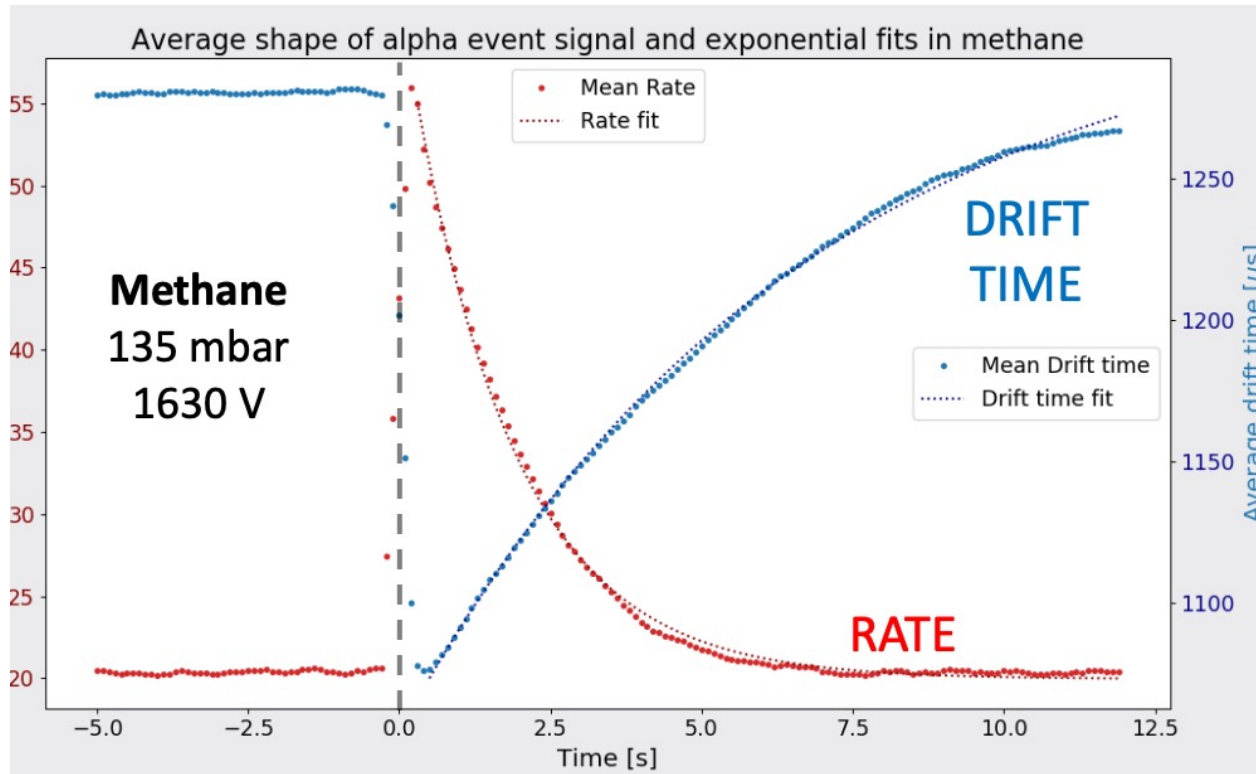


Sphere in Pb shield installed in temporary water shield in summer 2019



NEWS-G shipping to SNOLAB after commissioning at 1 week physics run with 135 mbar pure CH<sub>4</sub>

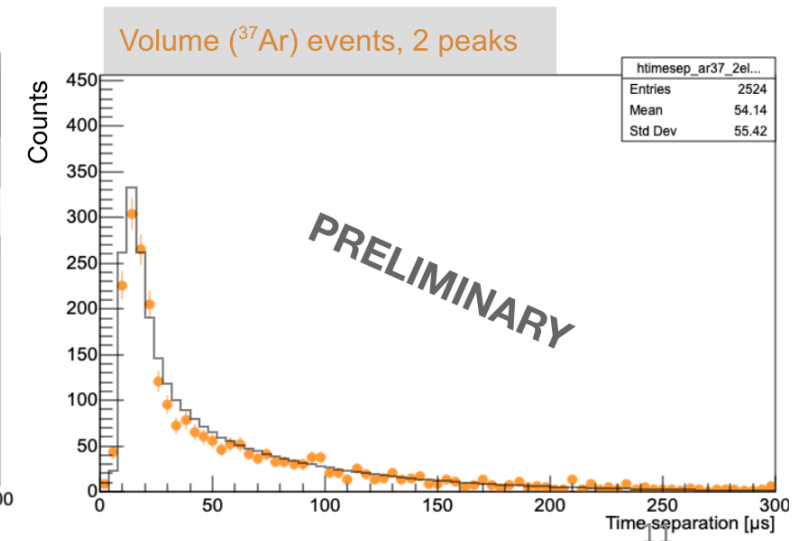
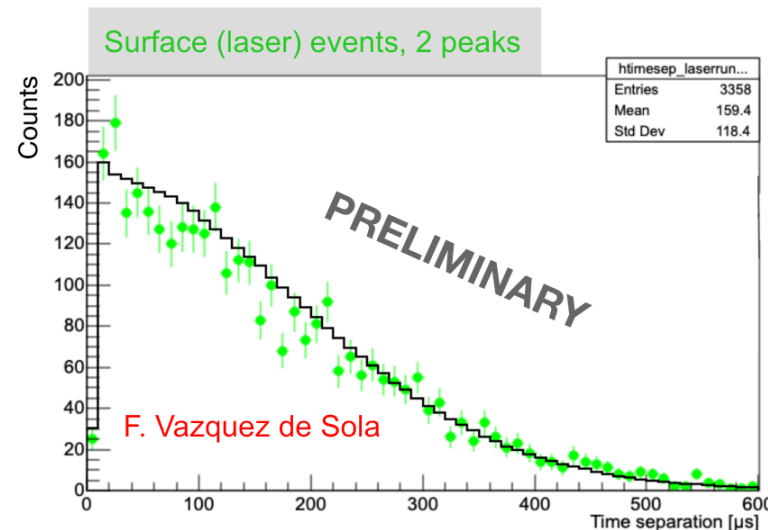
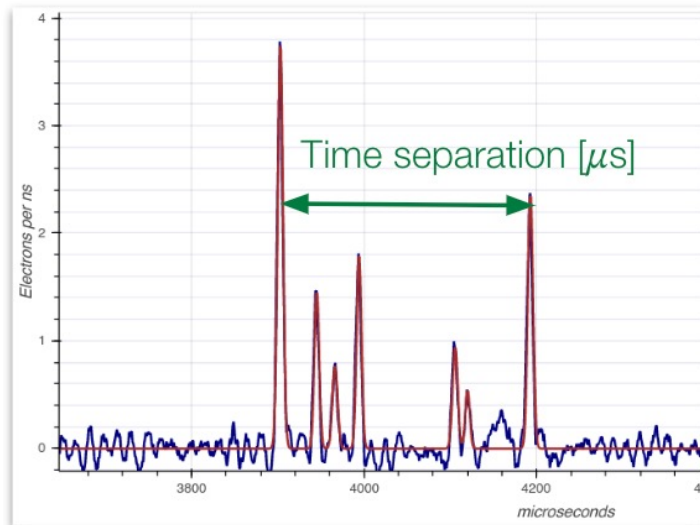
# Single-Electron Noise



- A high rate of single electron events was observed
- The rate is especially high after alpha decays, where the presence of space-charge (drifting ions) is observed
- A 5 seconds cut after alphas removes 70% of background and keeps 88% of the exposure
- Recent observations suggest this would be correlated with gas purity, and might be related to ion attachment

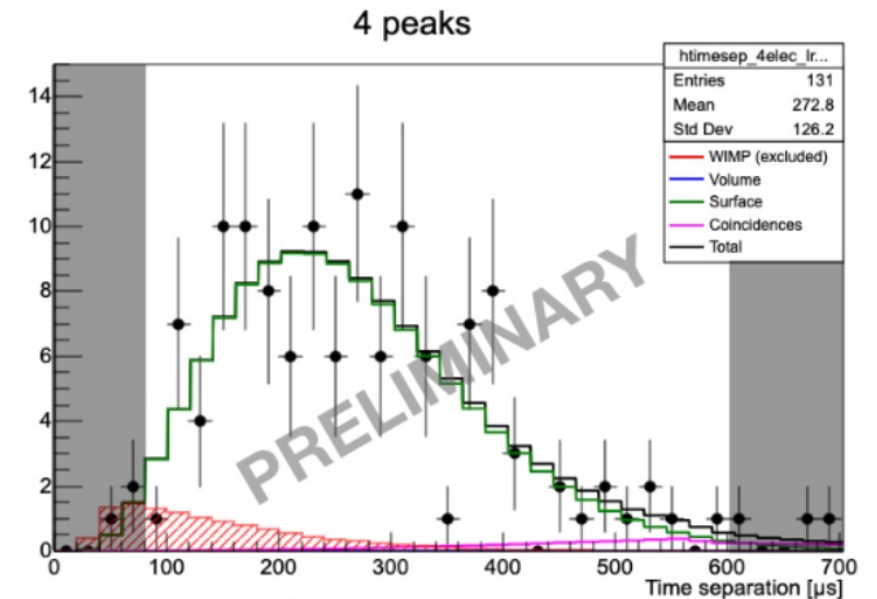
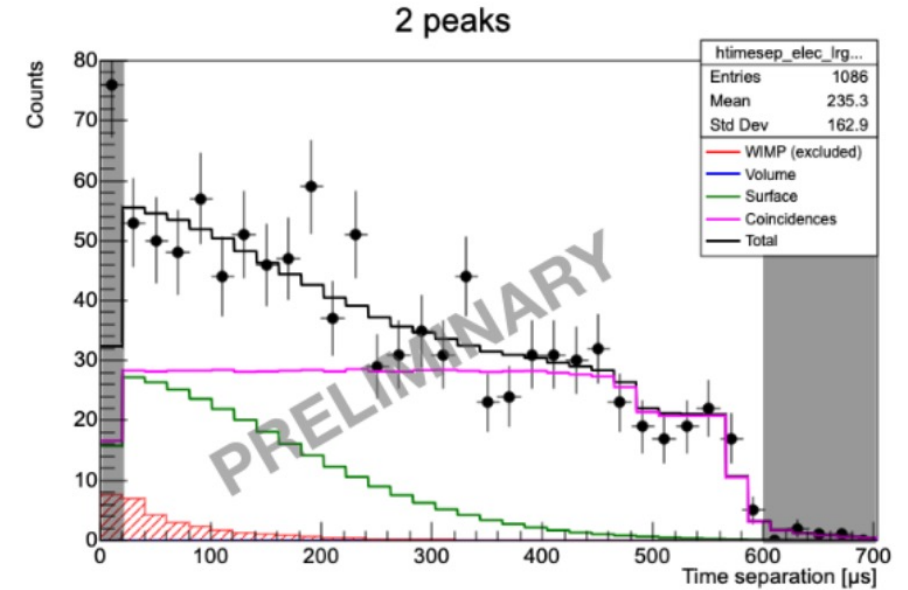
# NEWS-G at LSM: Results

- Time separation between the first and last peak is used as the primary analysis variable
- Allows for discrimination between surface, volume, and pile-up events
- Calibrated with laser (surface) and  $^{37}\text{Ar}$  (volume) data



# NEWS-G at LSM: Results

- Data divided into subsets with 2/3/4 peaks found. The 1 peak signal was not used due to lack of surface/volume discrimination
- Leading backgrounds are single electron pile-up and surface contamination (unknown origin)
- Time separation (time between first and last peak) is used for surface/volume event discrimination, address coincident event background
- The physics data was split into test and blind data (~30/70%); here the fit of the test data is shown, including a WIMP signal component for demonstration (760 MeV/c<sup>2</sup>)
- No significant WIMP signal is observed



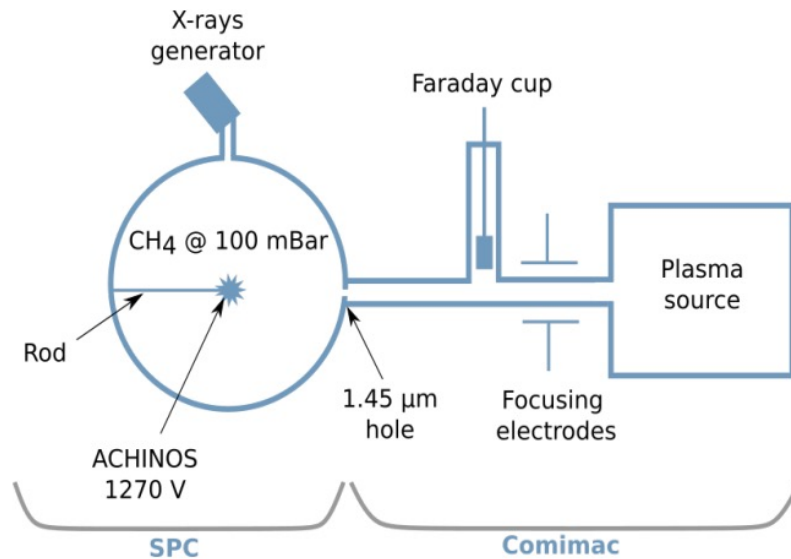
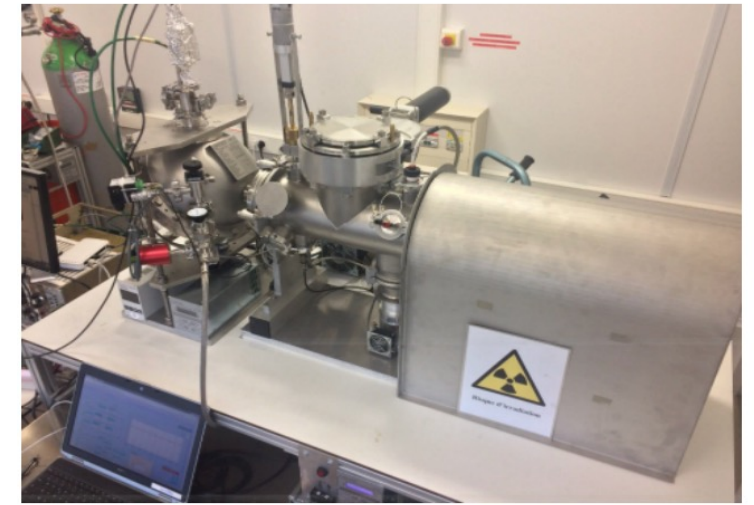
F. Vazquez de Sola

[1] I. Katsioulas et al, *Astropart. Phys.* 141, 102707 (2022)

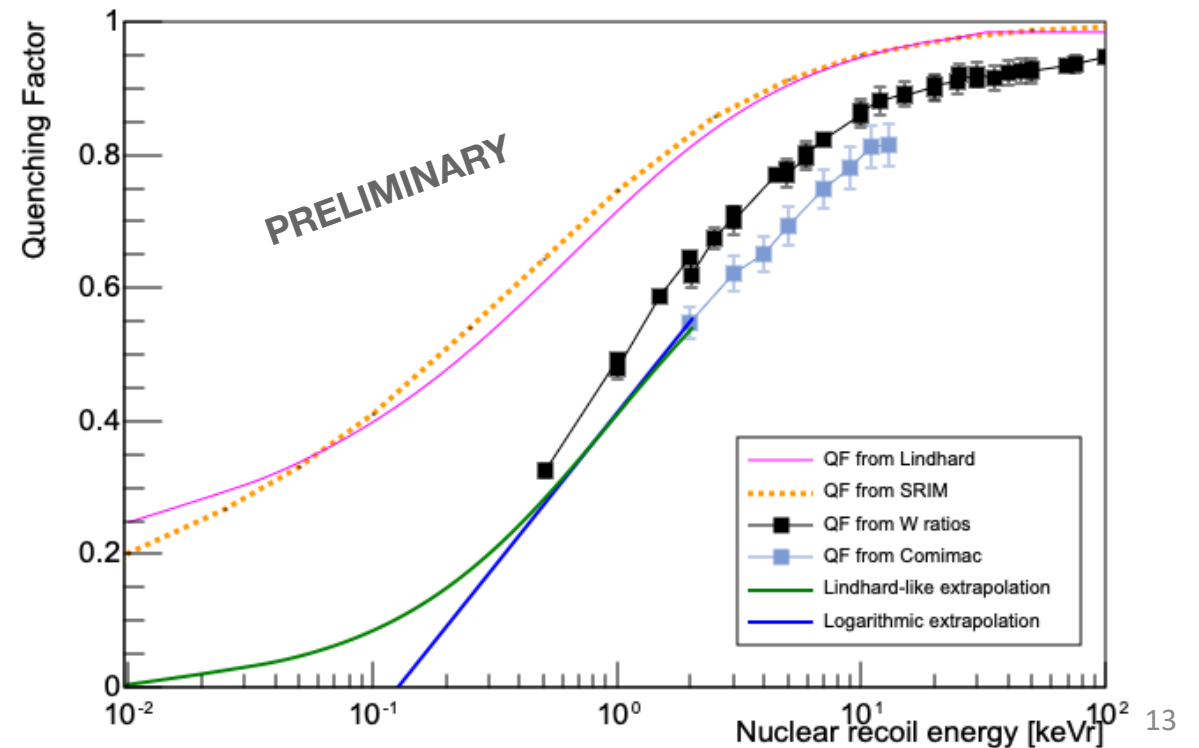
[2] L. Balogh et al, *EJP C*, 2022

# Quenching Factor

- Ionization yield of proton recoils in  $\text{CH}_4$  were performed at the COMIMAC facility
- Compared with W-value ratios from literature
- Conservative logarithmic extrapolation
- Lower energy measurements are needed

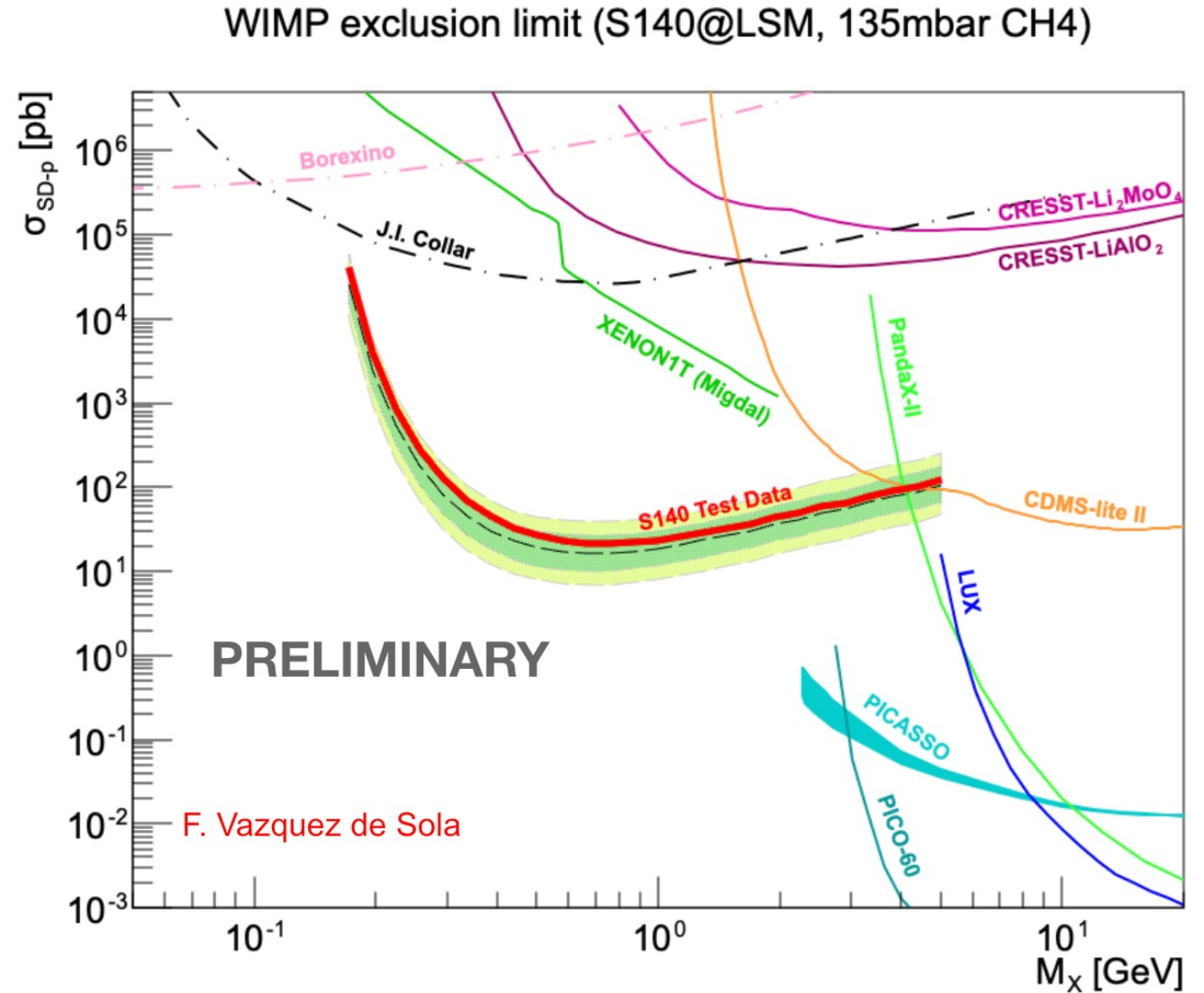


Quenching Factor of H in  $\text{CH}_4$



# NEWS-G at LSM Results

- Results with test data ( $\sim 0.12$  kg.days)
- Profile likelihood ratio method used to calculate 90% exclusion limit on WIMP-proton SD cross-section
- Full results with blind data expected within weeks – world-leading constraints on SD-p WIMP interactions below 1 GeV!



# 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 11<sup>th</sup>, 2019**



**Jan 29<sup>th</sup>, 2020**

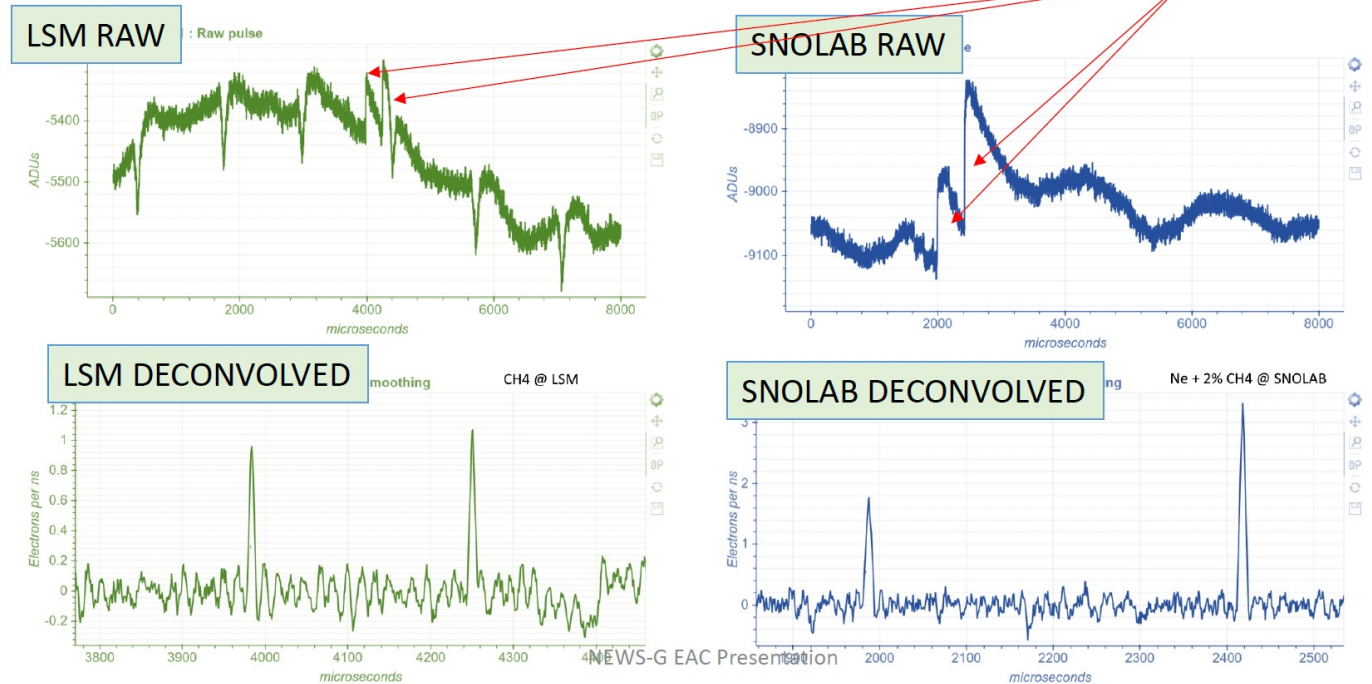


**Mar 24<sup>th</sup>, 2021**

# NEWS-G at SNOLAB

- Installation completed spring 2021
- Commissioning with argon-methane in summer 2021
- Noise mitigation:
  - Floating ground
  - Acoustic noise shielding
- Low noise and high gain achieved in summer 2022

- Trigger rate at LSM: 15 Hz
- Trigger rate at SNOLAB: 1 Hz



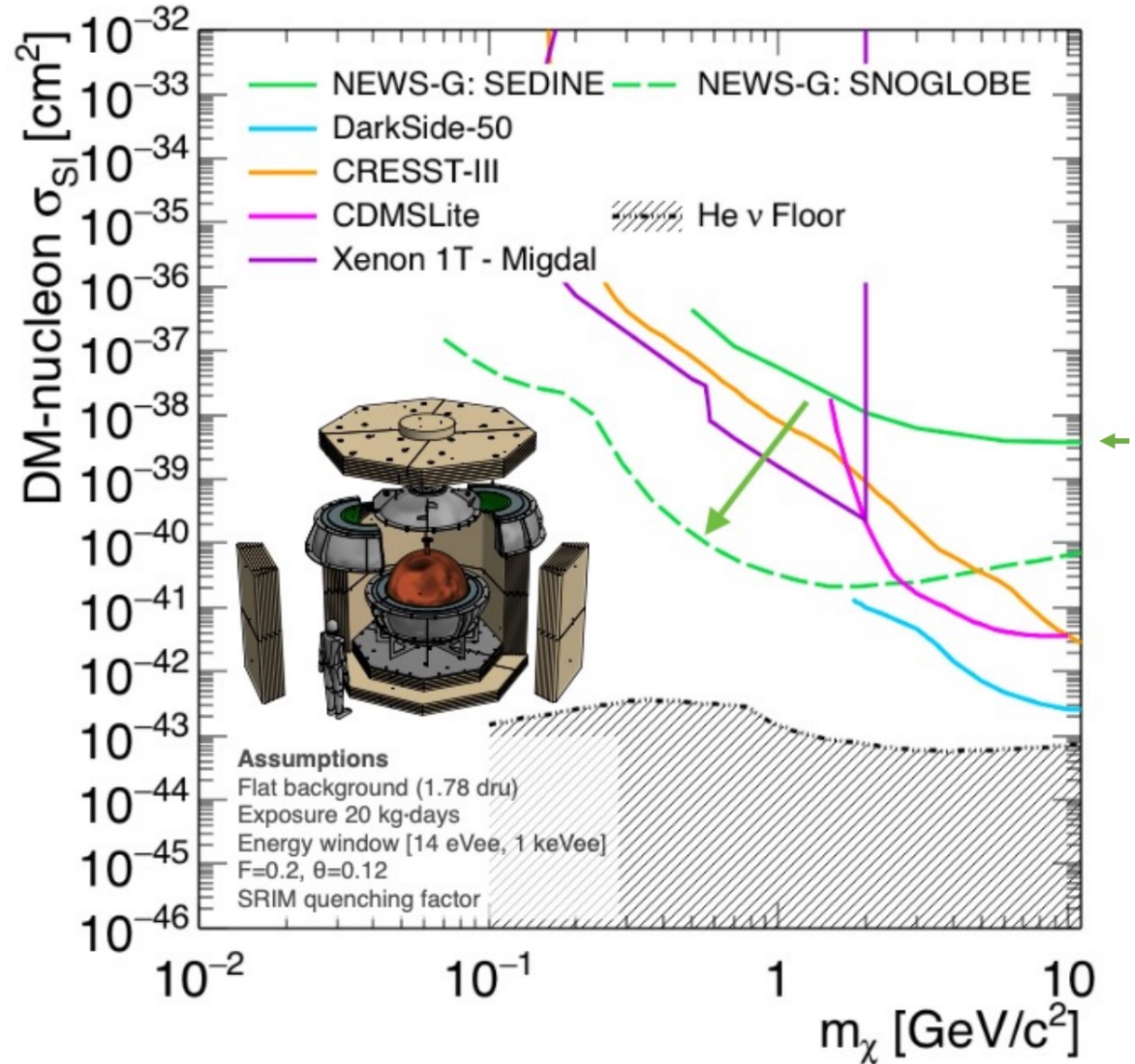


# NEWS-G at SNOLAB: Current Status

- Physics data acquired with neon-methane mixture
  - Analysis underway
- Surface background still present after etching at SNOLAB
  - After etching and during covid shutdown, lab air ingress in the SPC
  - New etching is planned in-situ after SNOLAB summer shutdown
- Single electron background still present
  - Less intense in neon methane than in pure methane
  - Implementation of gas filtering (getter) and radon trap will be implemented soon

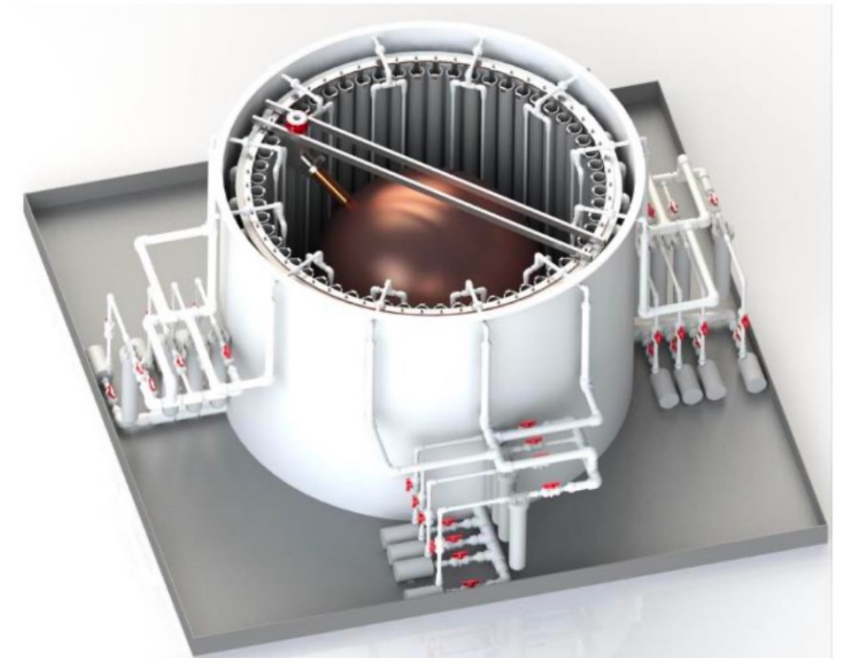
# NEWS-G at SNOLAB: Future

- Space allocation until December 2025
- With better control of surface background and single electron background, physics exploration with:
  - Ne-CH<sub>4</sub>
  - He-CH<sub>4</sub>
  - CH<sub>4</sub>
- MiniECuME implementation
- Full scale ECuME

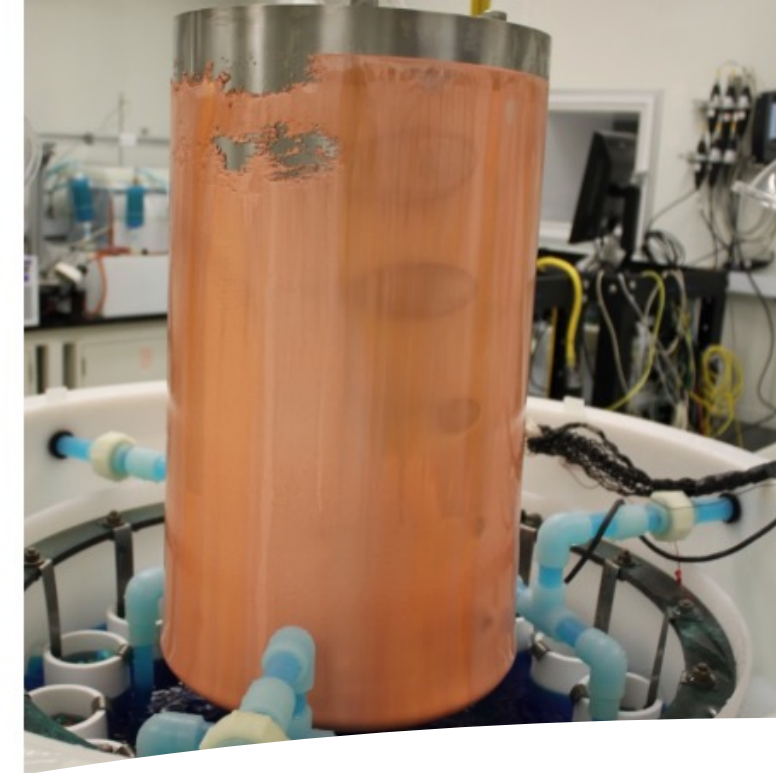


# Copper Electroforming

- The background from commercial copper (bulk  $^{210}\text{Pb}$  and cosmogenics) will ultimately limit the sensitivity of NEWS-G
- ECuME (Electroforming Copper Manufacturing Experiment) is a project in partnership with PNNL to electroform a full-size NEWS-G SPC at SNOLAB
- The first stage is a scale model (MiniECuME) electroformed at PNNL to demonstrate the principle and assess low-energy backgrounds



Conceptual design of the ECuME electroforming bath for a 140-cm diameter NEWS-G spherical proportional counter at SNOLAB



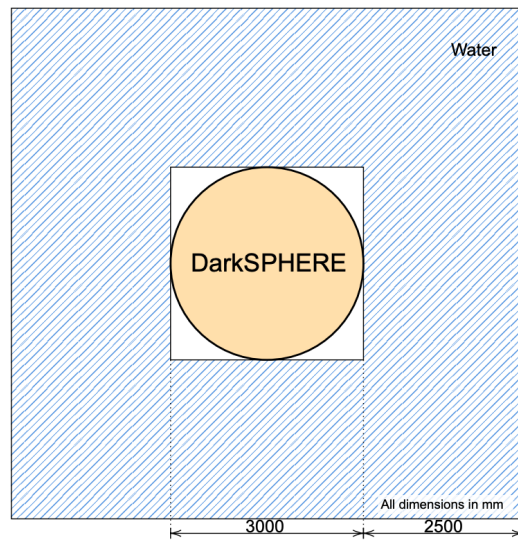
# Copper Electroforming

## **ECuME status:**

- 30-cm MiniECuME has not yet started to electroform
- Electroforming on cylindrical mandrel was performed to assess copper quality using lower-grade acids (cost driver for ECuME).
  - ICPMS results indicate sufficient copper purity.
  - Measurement of mechanical properties is underway

# DarkSphere

- Proposed project to electroform a 3-meter SPC at Boulby Underground Laboratory



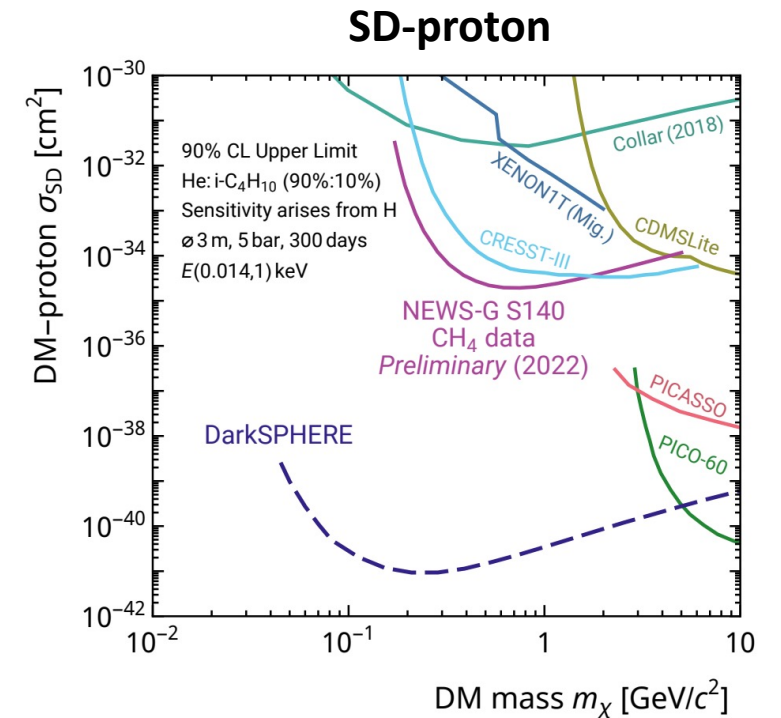
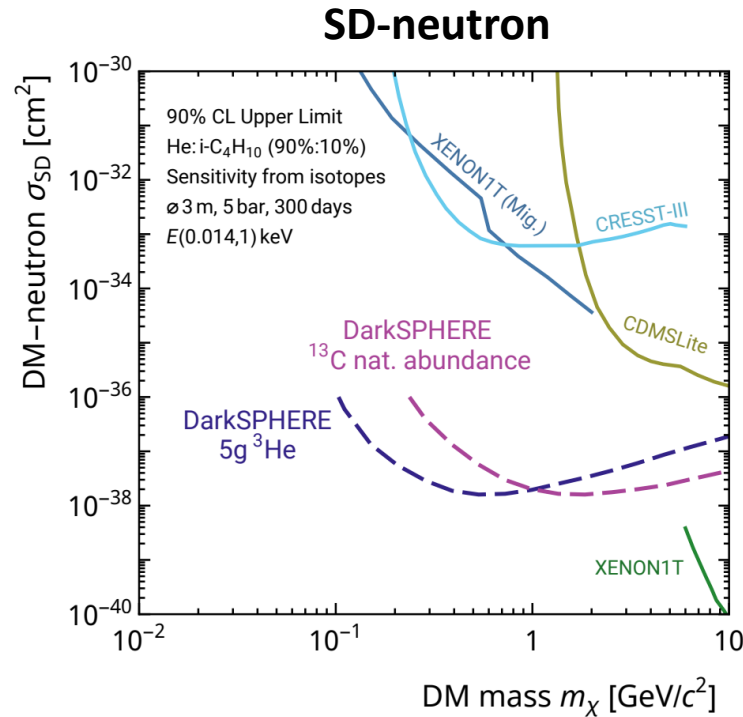
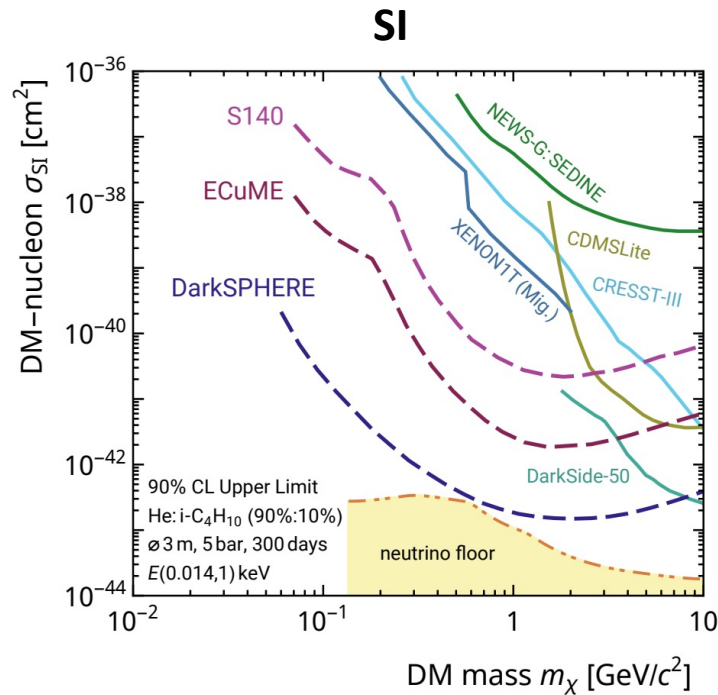
Proposed shielding



The NEWS-G Collaboration at Boulby

[arXiv:2301.05183](https://arxiv.org/abs/2301.05183) [hep-ex]

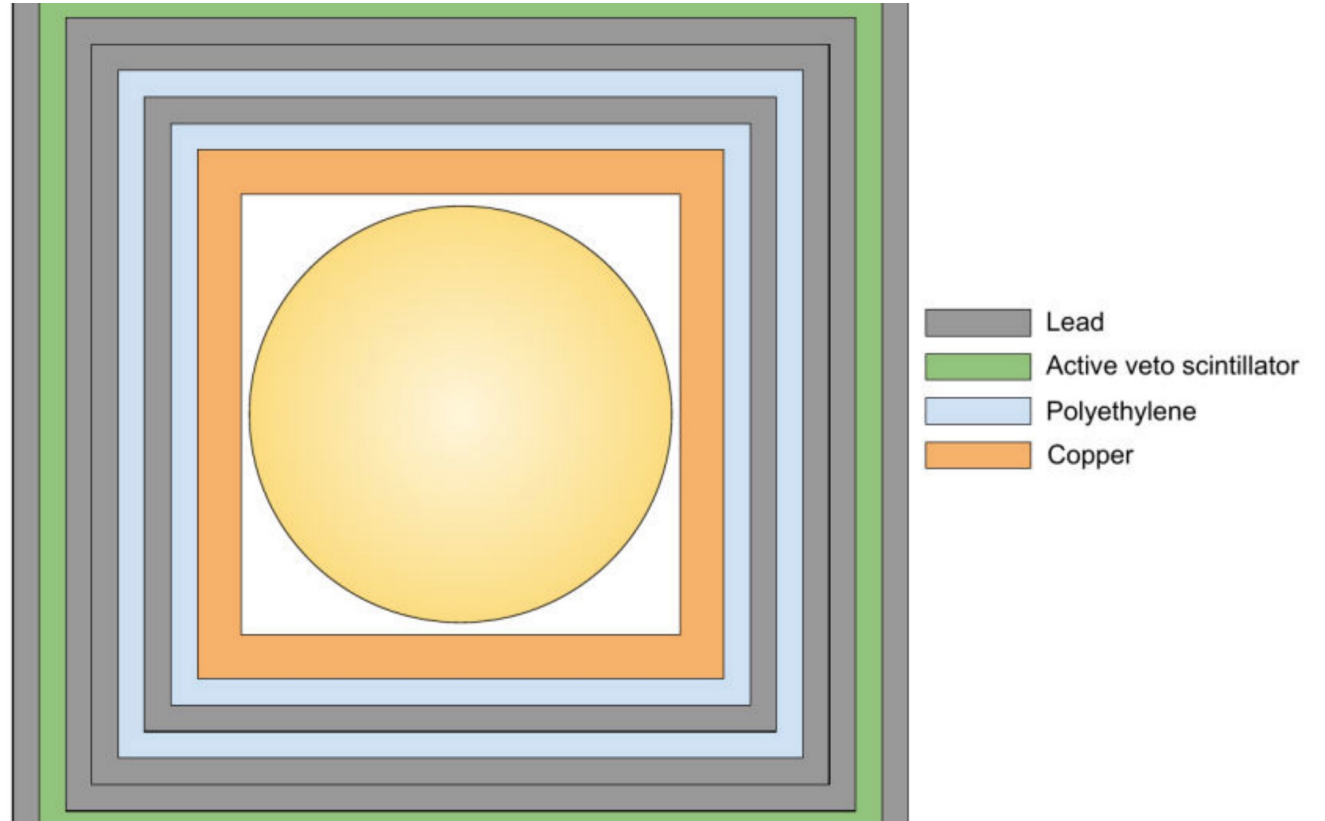
# DarkSphere: Physics Potential



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

# NEWS-G3: Coherent neutrino scattering

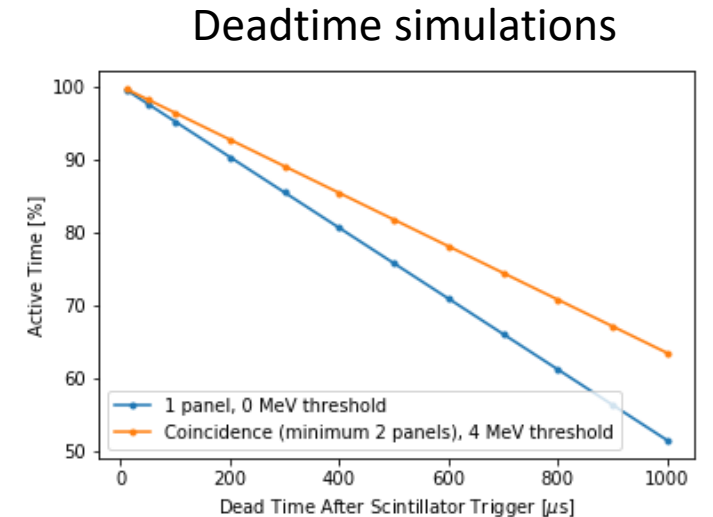
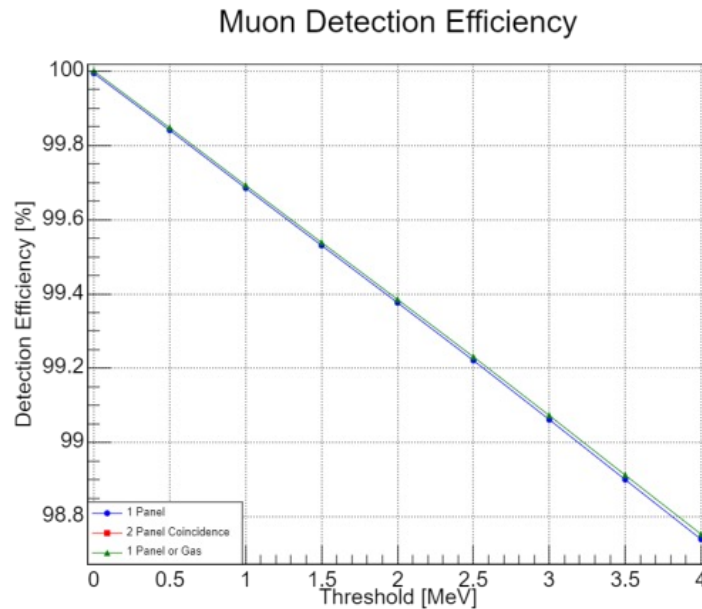
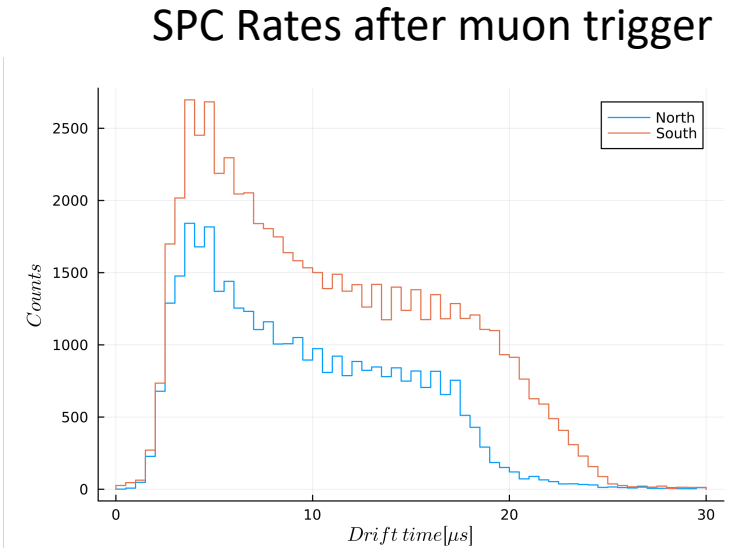
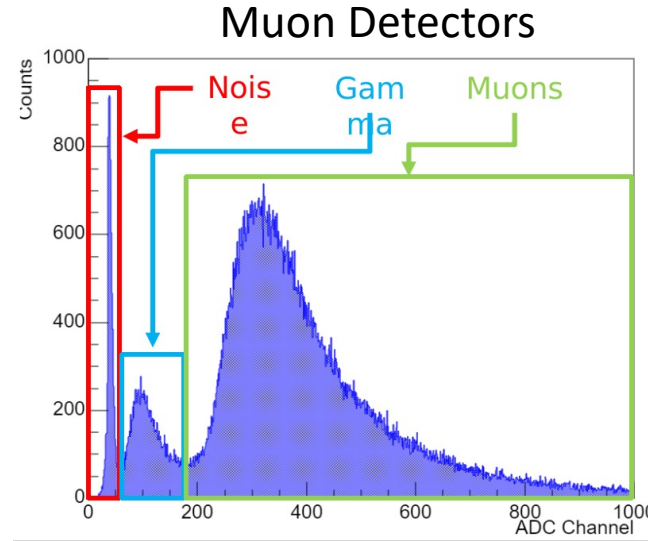
- The NEWS-G3 compact shield will host a 60-cm high pressure (10 bar) SPC for low-background characterization and study the feasibility of a CEvNS measurement at a nuclear reactor
- Design was inspired from the GIOVE/CONNUS experiment



Visit me in Stirling Hall!

# NEWS-G3: Muon Veto Performance

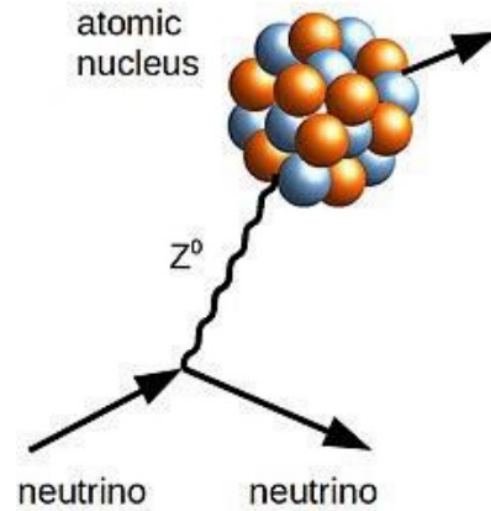
- Geant-4 simulations are being developed to understand the muon veto performance and project expected backgrounds
- Measurements performed with 30-cm steel SPC
- SEDINE 60-cm NOSV Copper SPC will soon be available
- Studying the possibility to build a TSSA approved 10-bar SPC



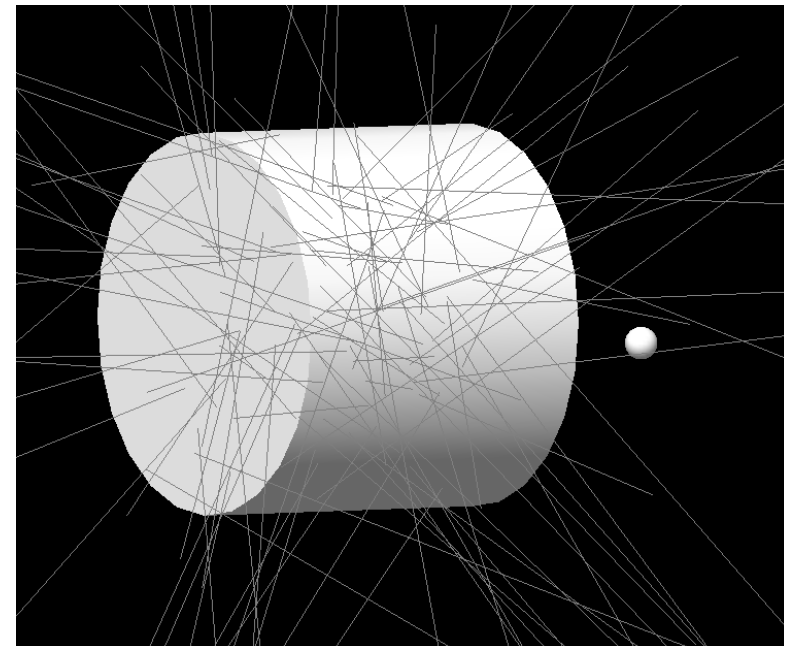
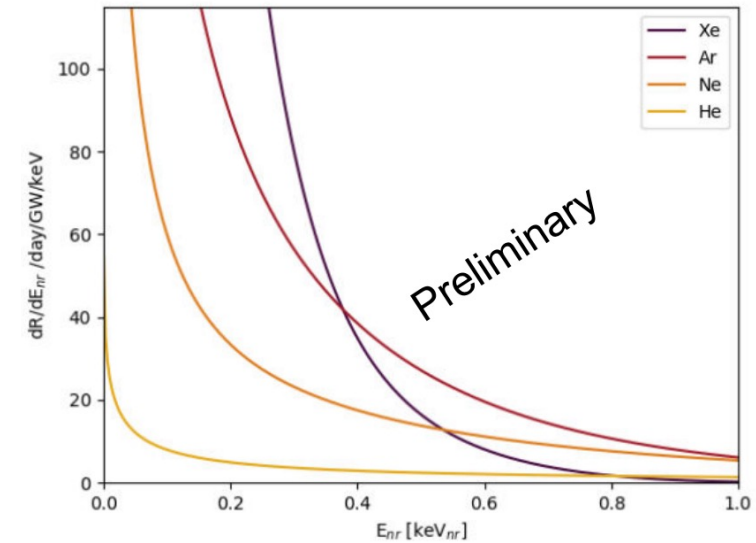


# NEWS-G3: CEvNS at a nuclear reactor

- Potential to study neutrino coherent interaction on multiple targets: He, Ne, Ar, Xe.
- Currently searching for a site
- Contact established with CNL, Darlington (CANDU 2.7 GW<sub>th</sub>)



CEvNS rate vs Recoil energy





# Conclusions

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- **NEWS-G has taken physics data at LSM and SNOLAB**
  - Upcoming world-leading results on WIMP-proton SD interactions
  - Analysis of WIMP-nucleus SI interactions on Neon underway
- **Several orders of magnitude improvement in sensitivity are possible without scale up**
  - Control of single electron background: gas purification
  - Determination of QF at low energy
  - Control of surface backgrounds: etching
  - Electroformed copper: MiniECuME, ECuME
- **Discussions are going well with Boulby to host next-gen DarkSphere**
- **NEWS-G3 has the potential to measure neutrino coherent interactions at a nuclear reactor**



Thank you!