

2024/02/08

NEWS-G/ECuME

Guillaume Giroux

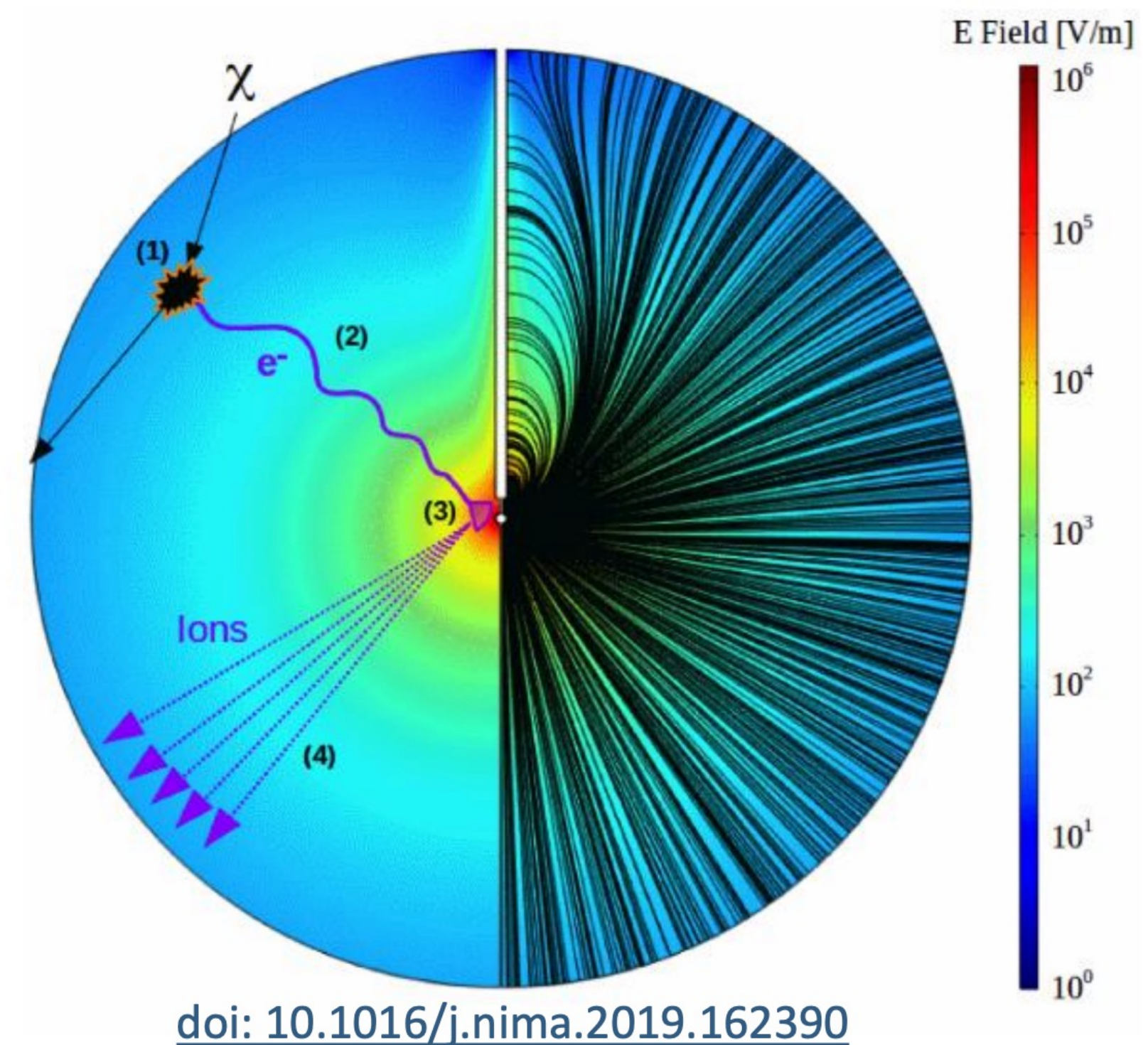
Associate Professor, Queen's University



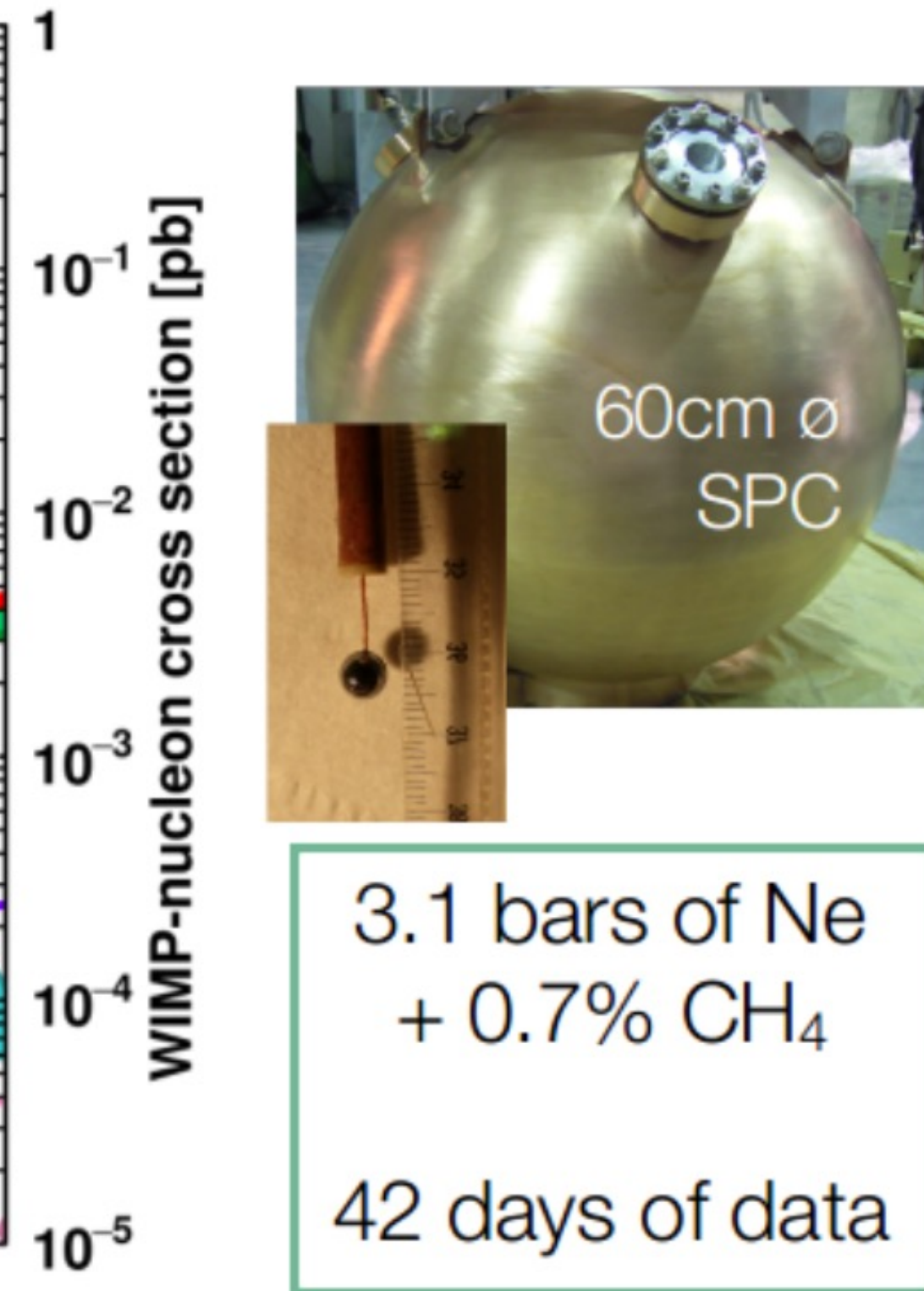
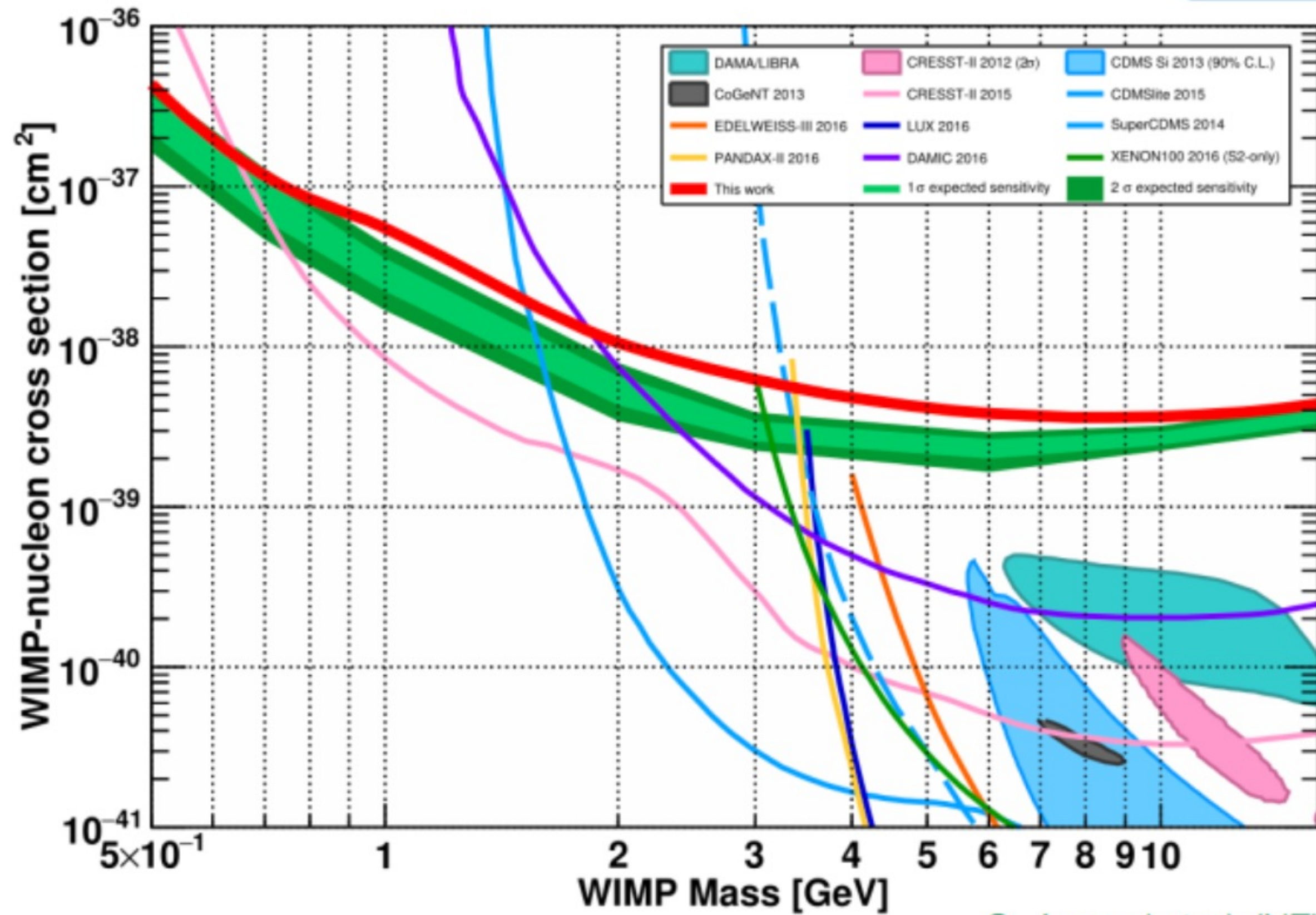
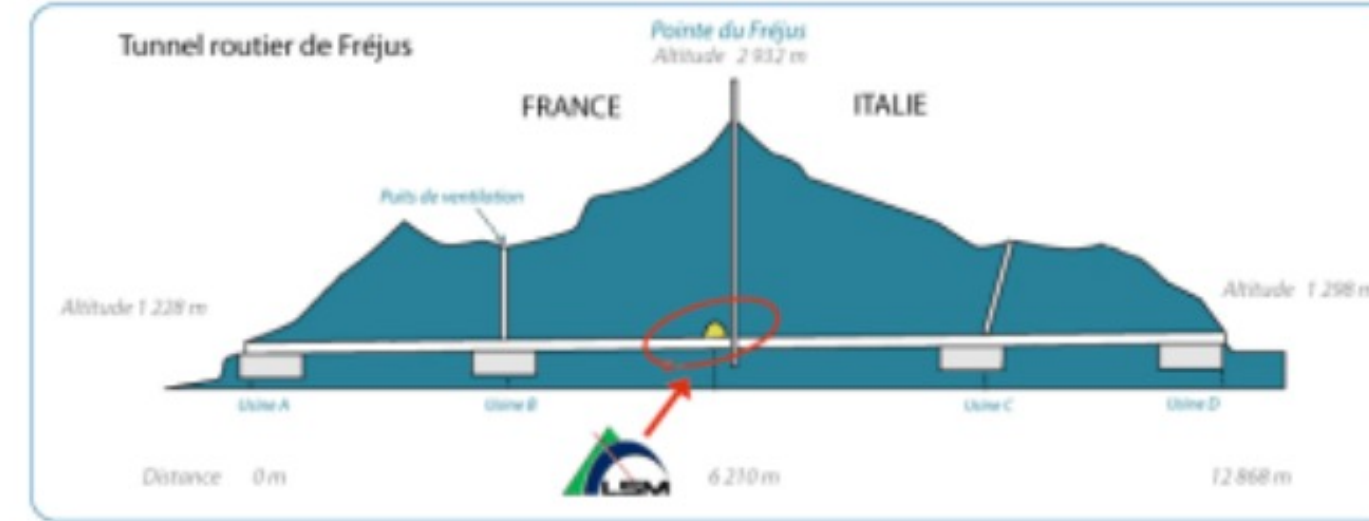
NEWS-G Overview

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



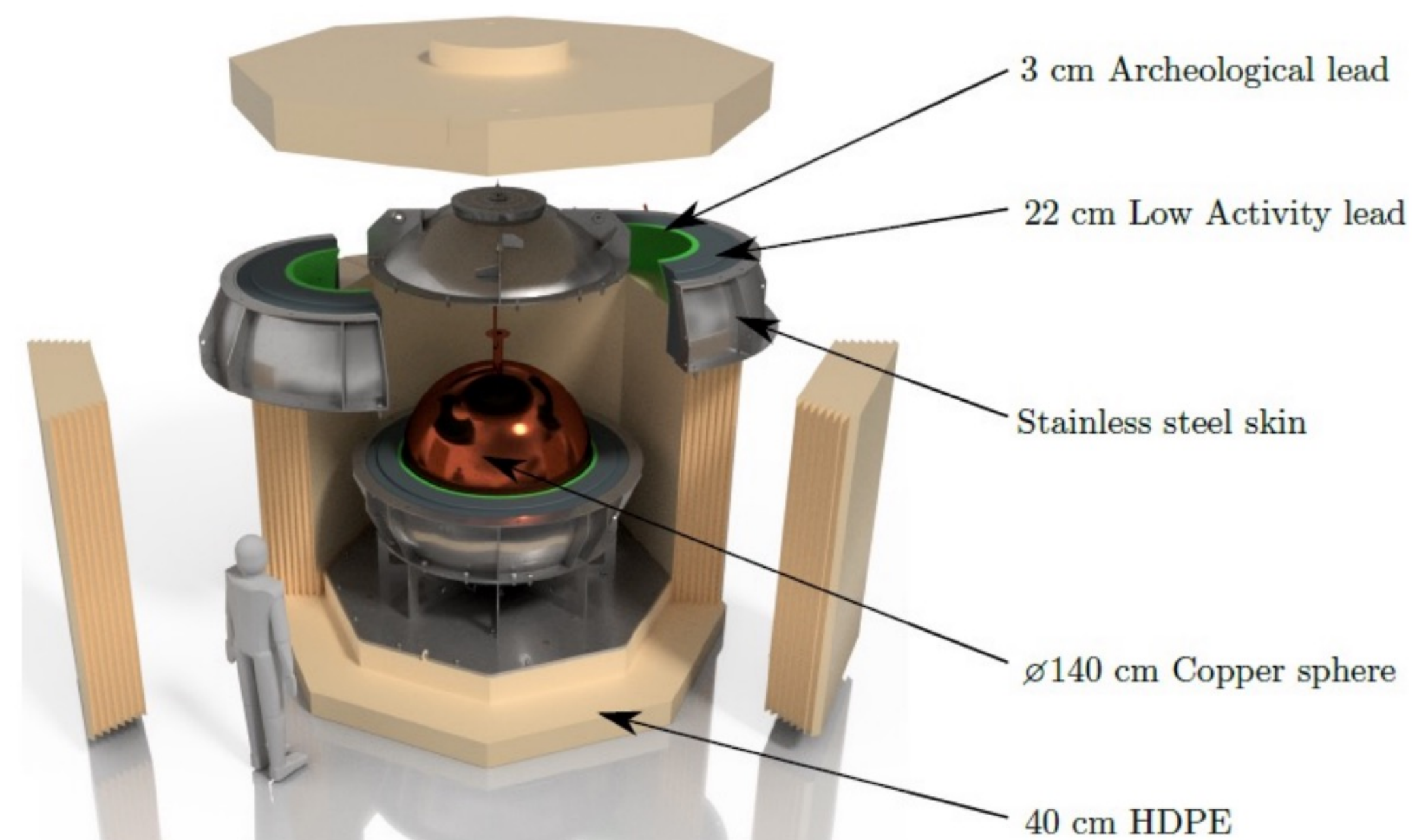
Competitive low-mass WIMP limit with a neon target at the Laboratoire Souterrain de Modane



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

NEWS-G Overview

- 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



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 CH₄) 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 ²¹⁰Pb in copper bulk

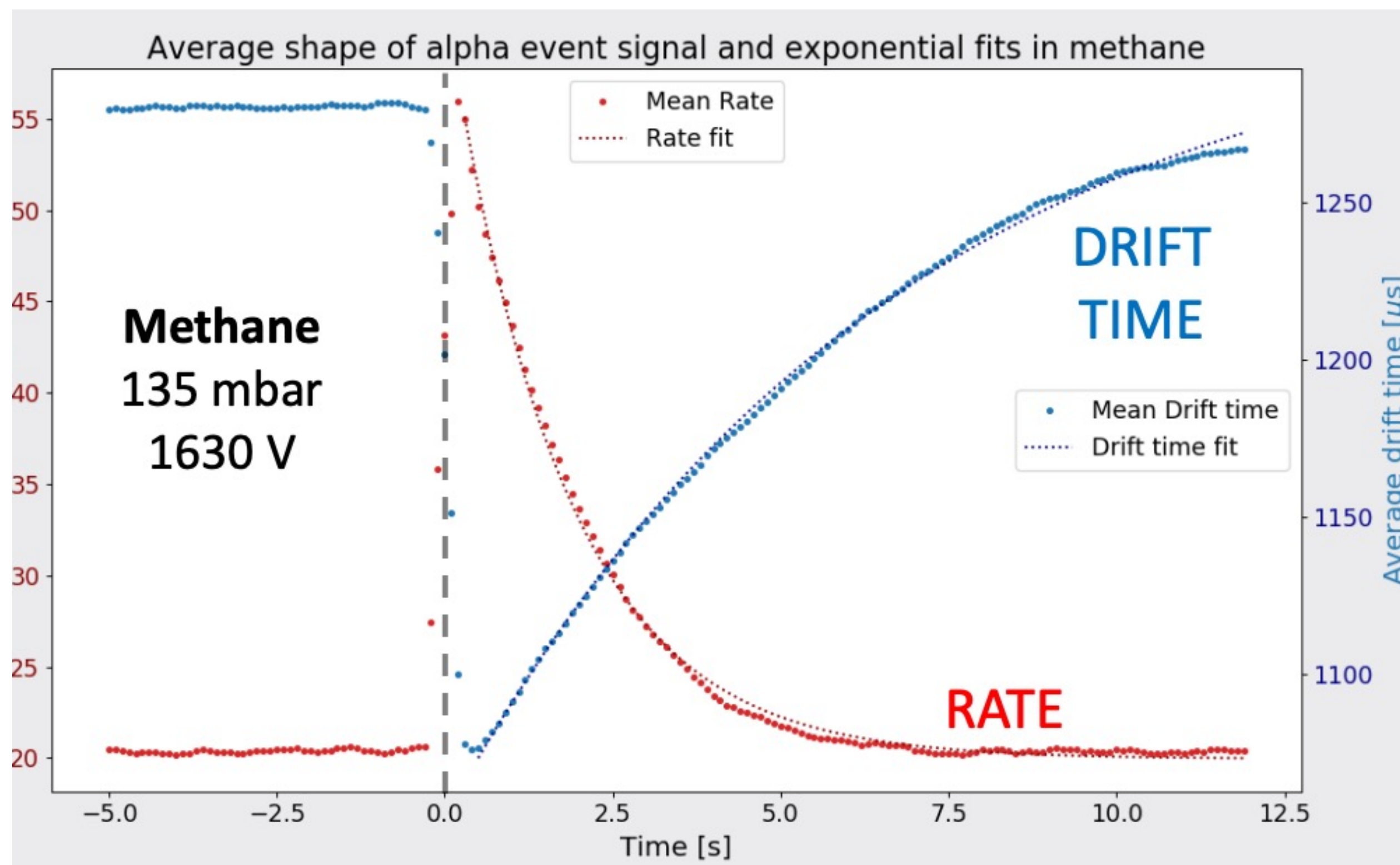


Sphere in Pb shield installed in temporary water shield in summer 2019



NEWS-G shipping to SNOLAB after commissioning at 1 week physics run with 135 mbar pure CH₄

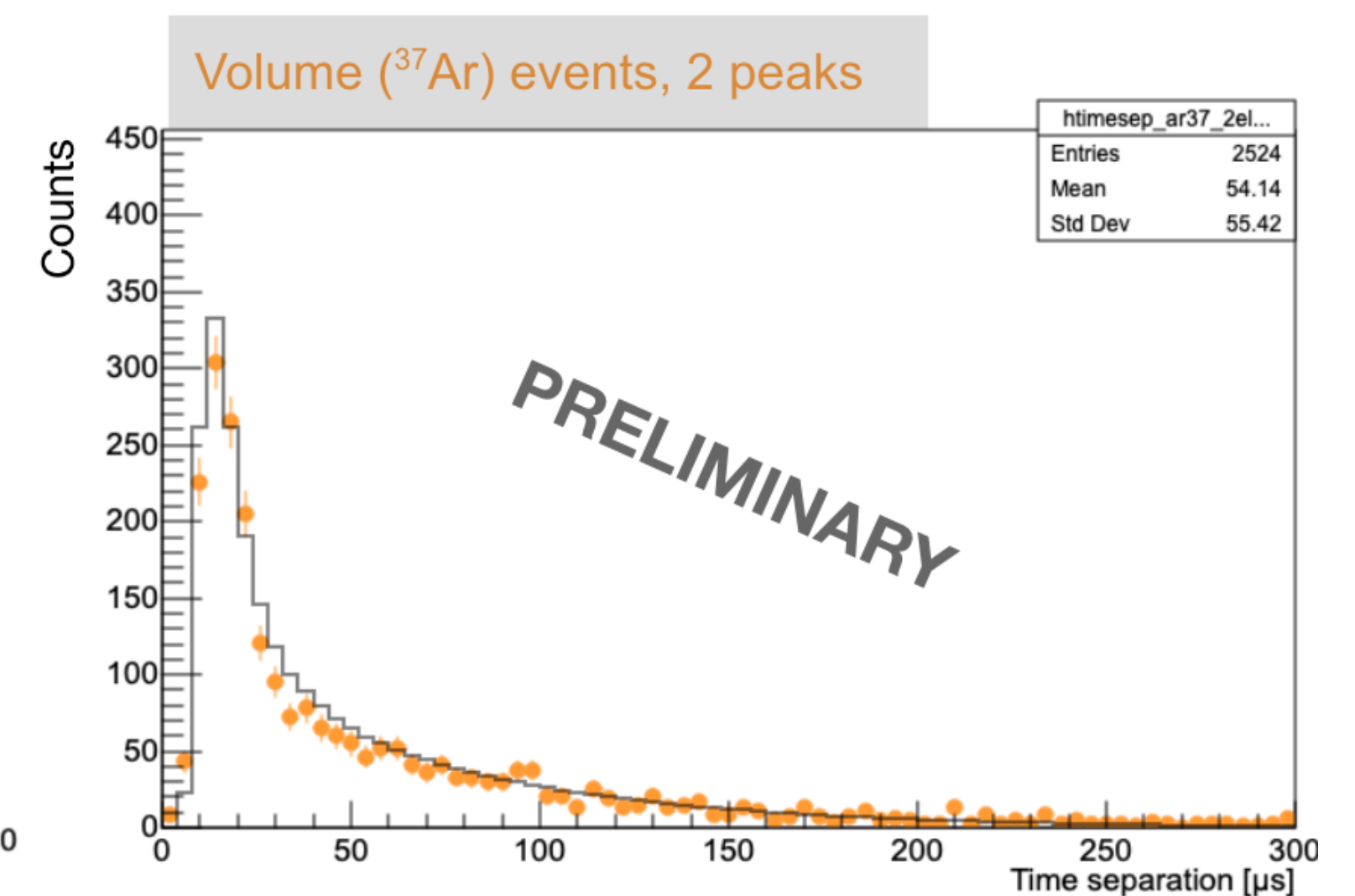
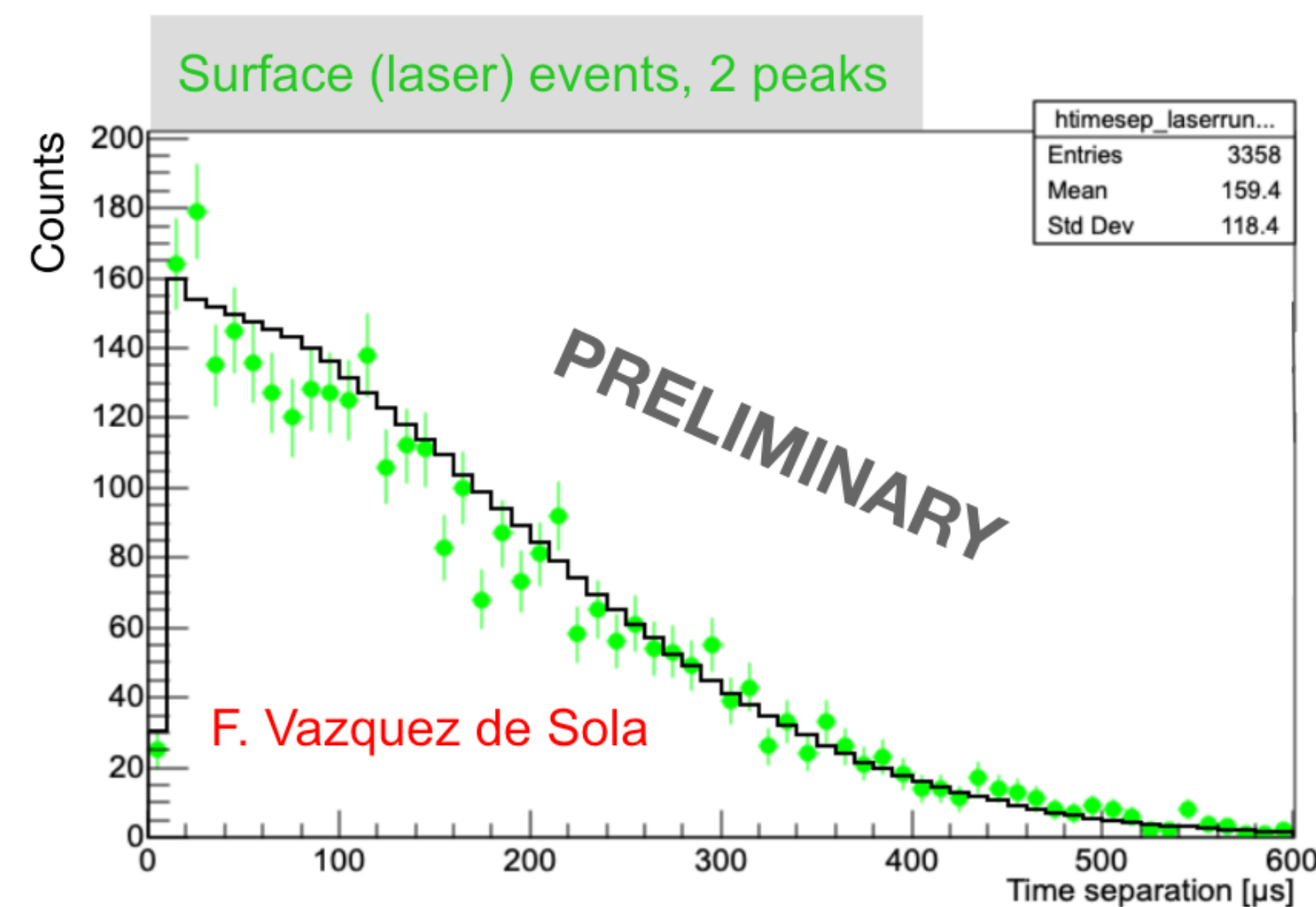
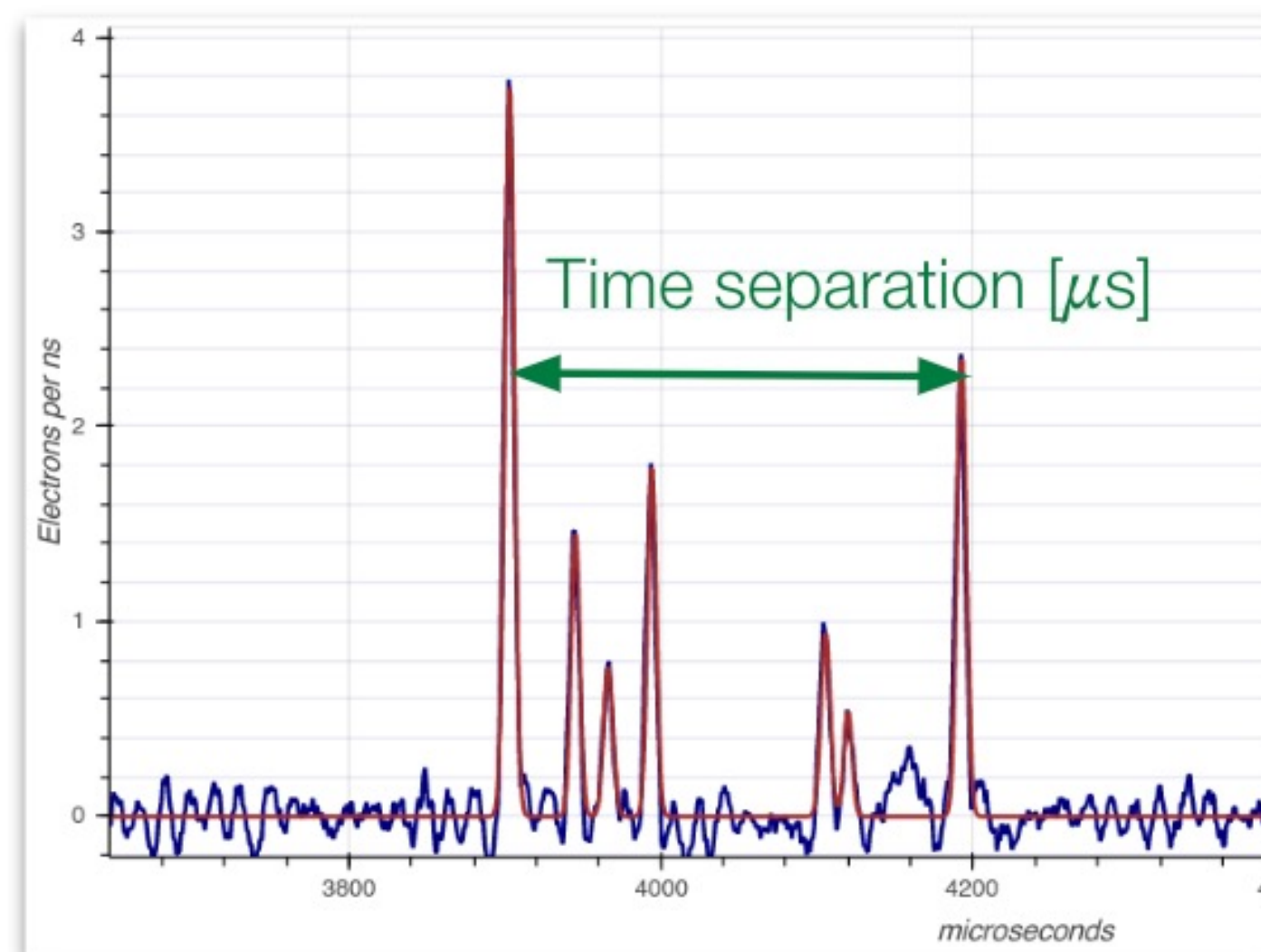
Single-Electron Noise



- 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 reveal this is correlated with gas purity, and is related to attachment

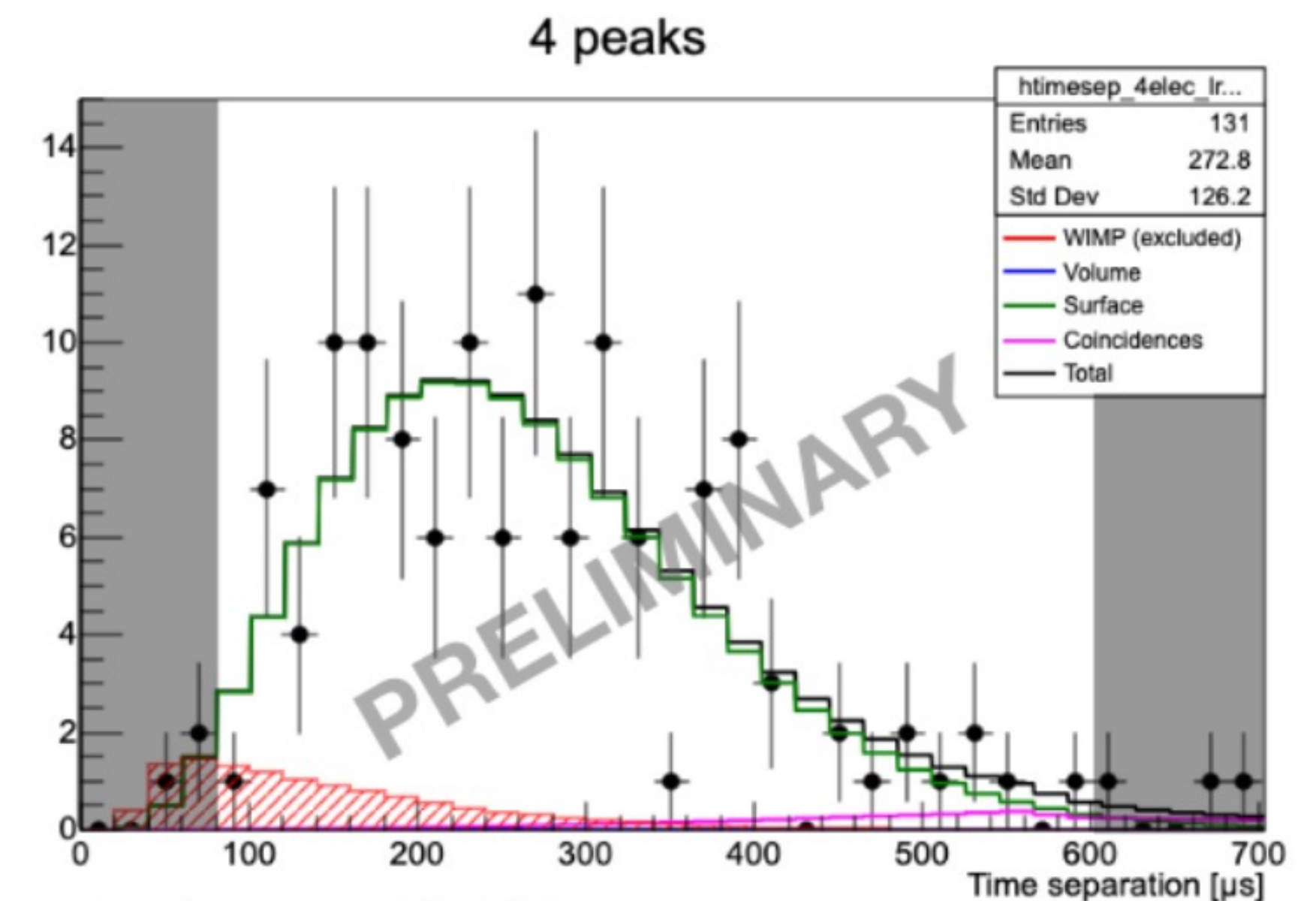
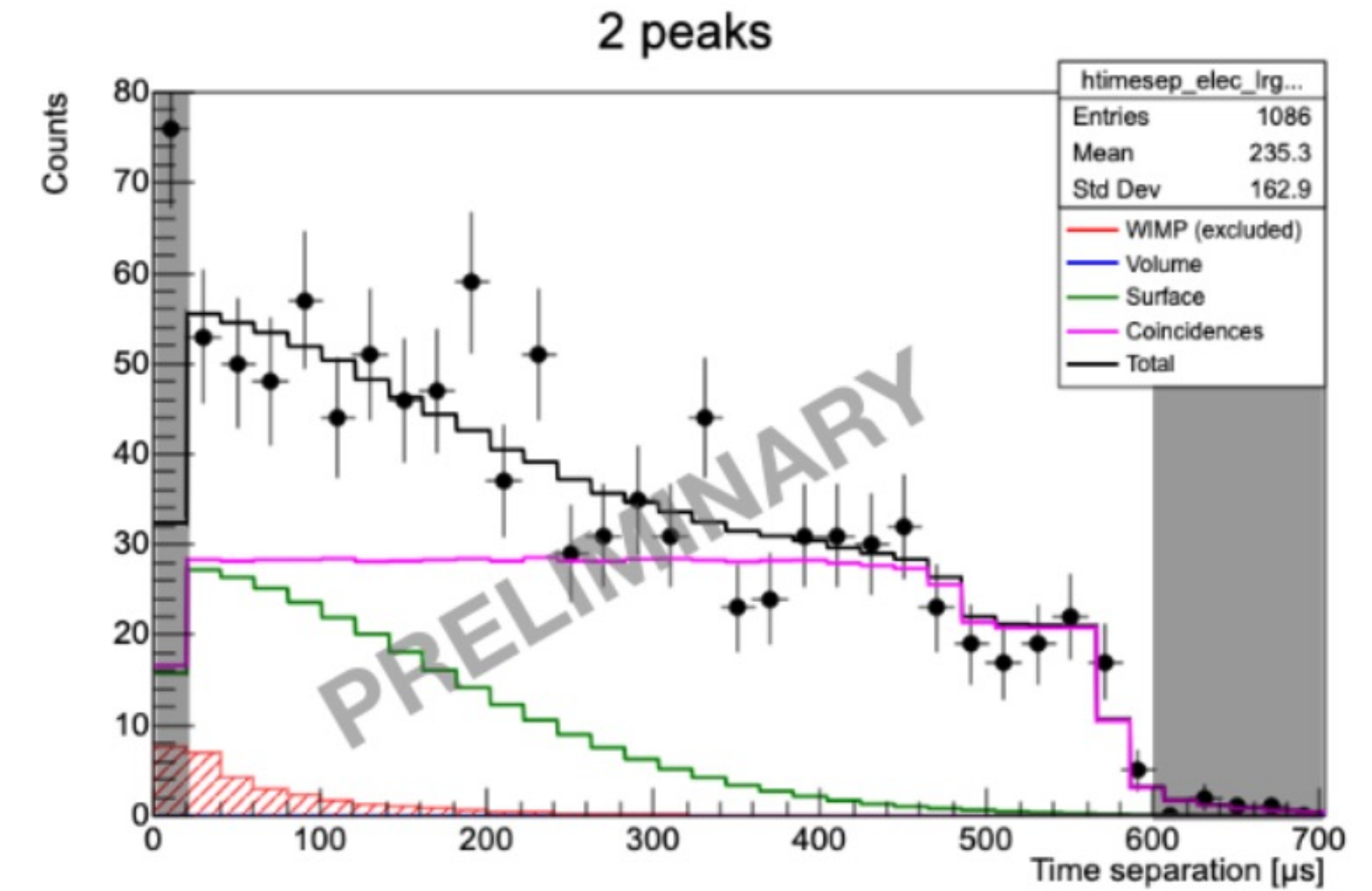
NEWS-G at LSM: Results

- 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}Ar (volume) data



NEWS-G at LSM: Results

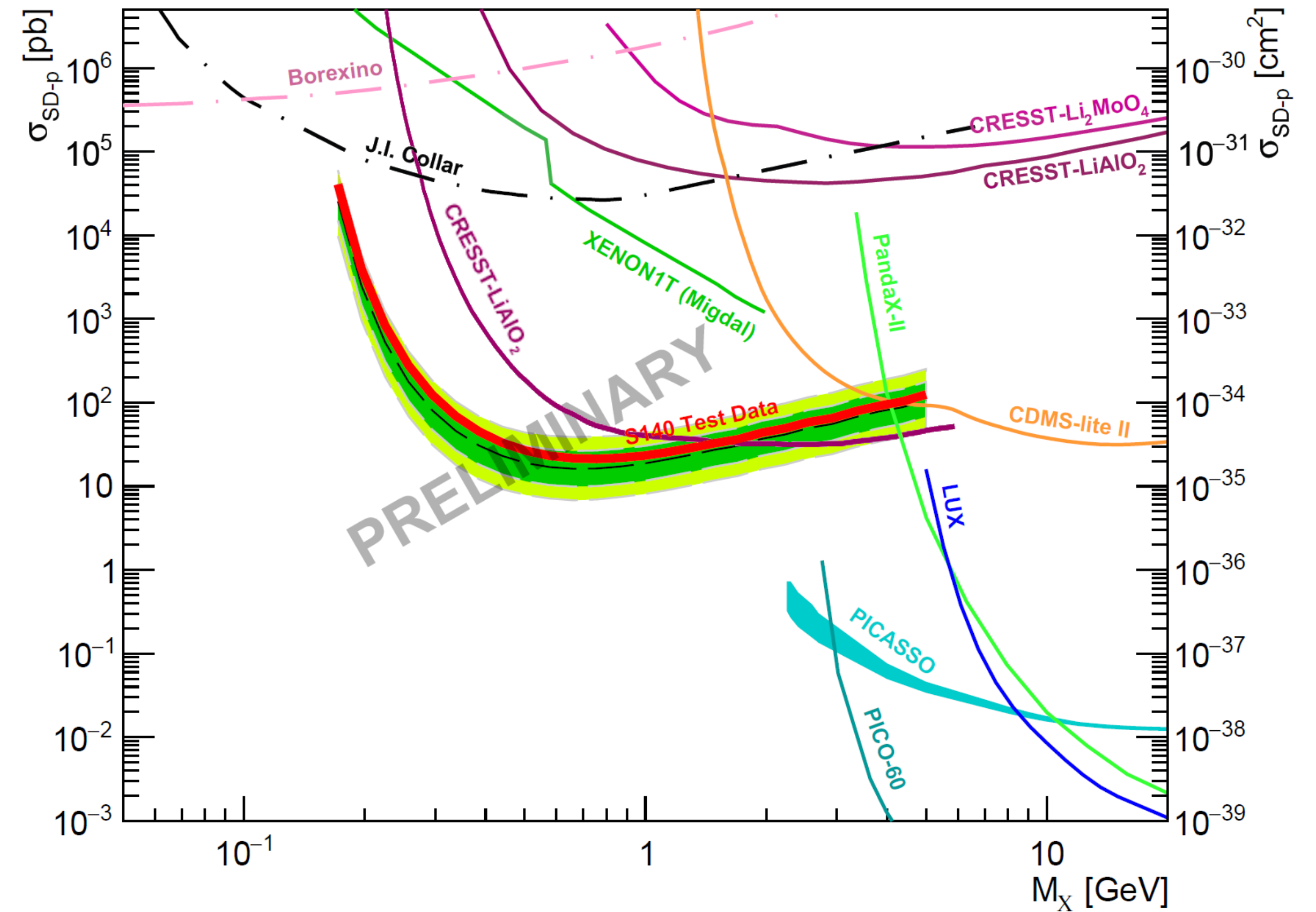
- Data divided into subsets with 2/3/4 peaks found. The 1 peak signal was not used due to lack of surface/volume discrimination
- Leading backgrounds are single electron pile-up and surface contamination (unknown origin)
- Time separation (time between first and last peak) is used for surface/volume 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/c²)
- No significant WIMP signal is observed



F. Vazquez de Sola

NEWS-G at LSM Results

- Results with test data (~ 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!



Collaboration Health

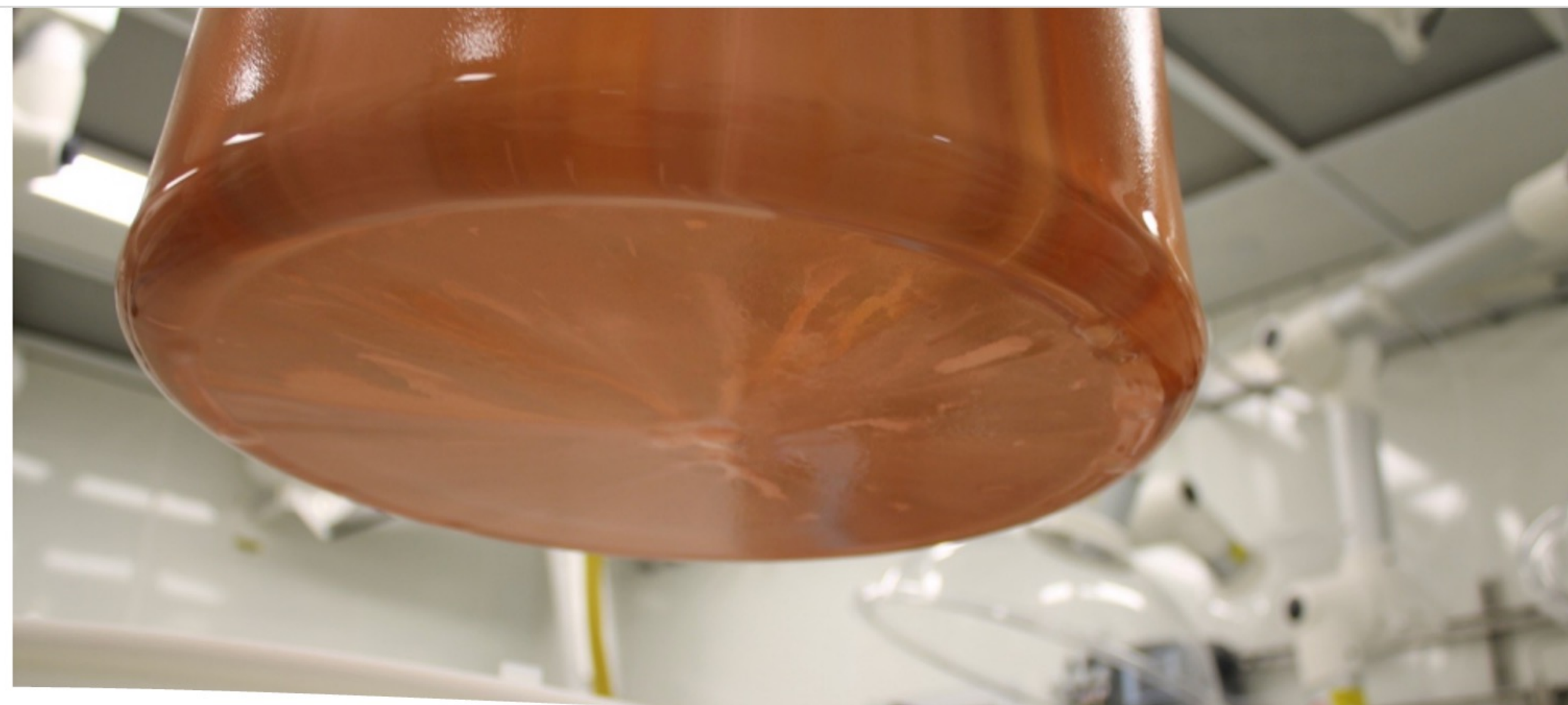
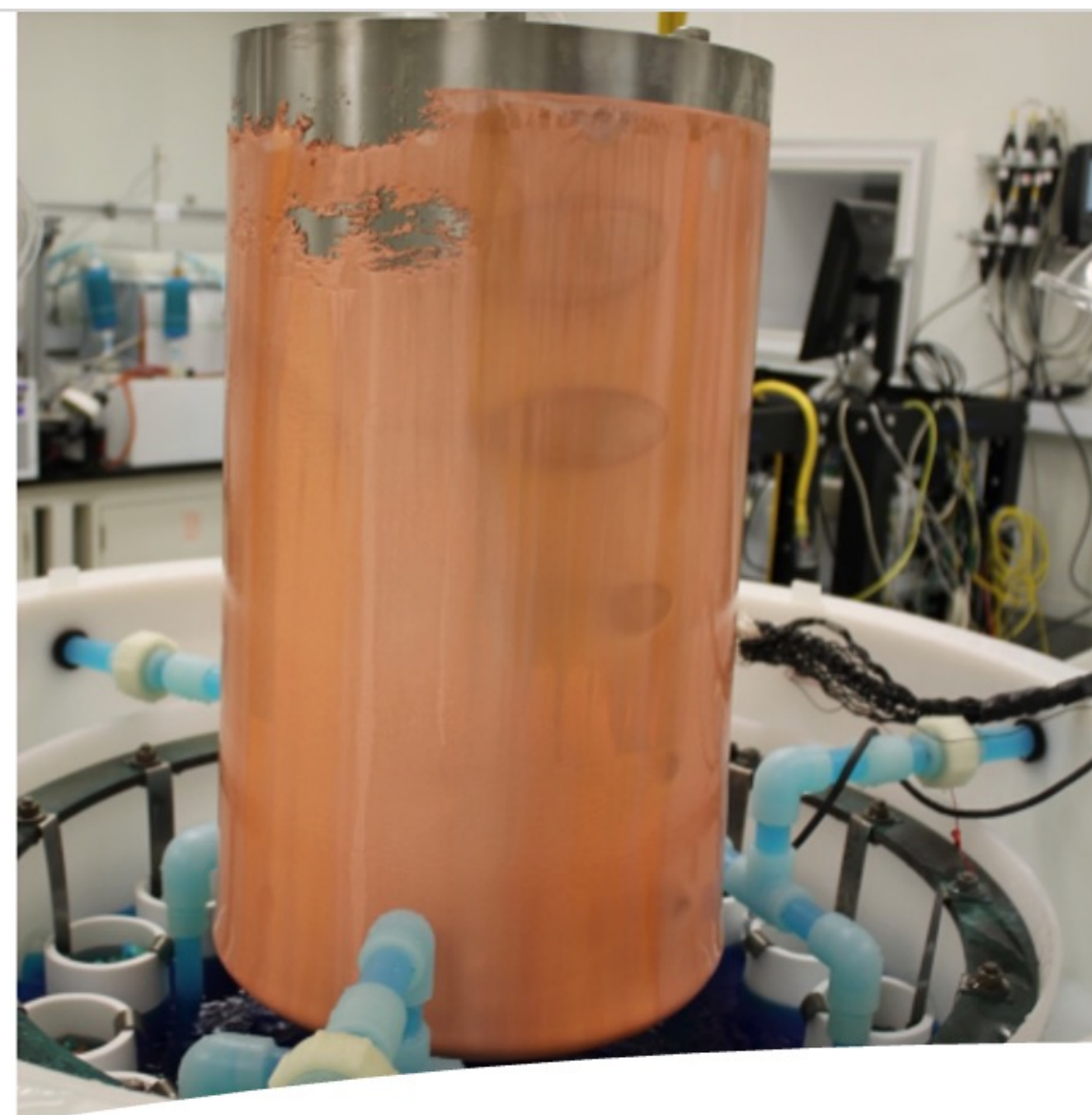


- The NEWS-G Code of Conduct addresses how we create an environment where everyone fulfils their potential
- The Code of Conduct sets the expectation that the NEWS-G collaboration promotes a positive and inclusive community that values the diversity of its members
- NEWS-G has elected a collaboration ombudsperson
- G. Giroux has taken the initiative to utilize and evaluate the newly developed Diversity and Equity Assessment and Planning (DEAP) Tool through the McDonald Institute at Queen's University. This initiative serves as a testing ground for the tool's effectiveness and practicality before its broader implementation, showcasing our commitment to continuous improvement in EDI within the academic and research community.

NEWS-G Status

- NEWS-G is operational at SNOLAB
- Low noise and high gain operation has been achieved
- Physics data was collected with Ne-CH₄
- Authorized to operate with pure CH₄
- Gas purification with a getter was implemented
- We are addressing wall rate with etching





Copper Electroforming

ECuME status:

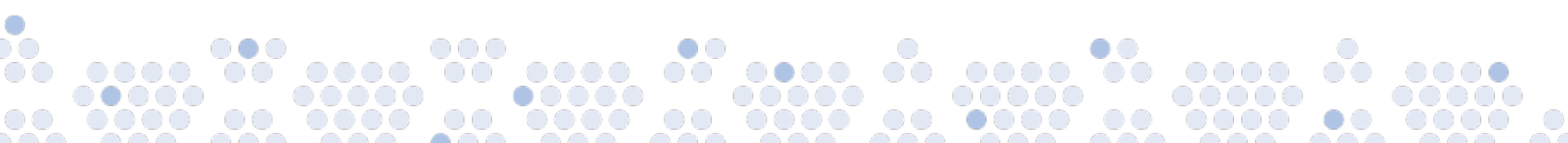
- 30-cm MiniECuME has not yet started to electroform
- Electroforming on cylindrical mandrel was performed to assess copper quality using lower-grade acids (cost driver for ECuME).
 - ICPMS results indicate sufficient copper purity.
 - Measurement of mechanical properties is underway

A spherical mandrel made from acrylic is under preparation at PNNL

Schedule impacts & milestones

- **Summer 2021:** NEWS-G installation completed at SNOLAB
- **Summer 2022:** High gain operation achieved
- **Fall 2022:** First physics run with Ne-CH₄ (Laser issues, low-frequency acoustic noise, leak in the gas system)
- **Spring 2023:** Second physics run in low noise conditions and working laser
- **Spring 2023:** New understanding of single electron rate correlation with gas purity
- **Summer 2023:** testing of gas recirculation and purification in Ar-CH₄. HV stability issues appear.
- **October 2023:** In-Situ etching (~0.5 um removal), no effect on surface alpha rate. Sensor issues limit high gain operation. HV feedthrough change
- **November 2023:** HV issues persist
- **January 2024:** Second in-situ etching (~3 um removal). Sensor change
- **February 2024:** HV issues fixed, high gain operation resumed. Laser is broken.

January 2024 In-Situ Etching and Sensor Replacement



Schedule impacts & milestones

Anticipated schedule and milestones:

- **Winter - Spring 2024:**
 - Implementation of radon trap along with gas purification system, assessment of single electron rate
 - Installation of repaired Laser
 - Fill with Ne-CH₄: assessment low energy surface backgrounds and physics run
- **Summer 2024:** Physics runs with pure CH₄ and He-CH₄
- **End of 2024:** Installation of MiniECuME
- **2025:** Background characterization in MiniECuME

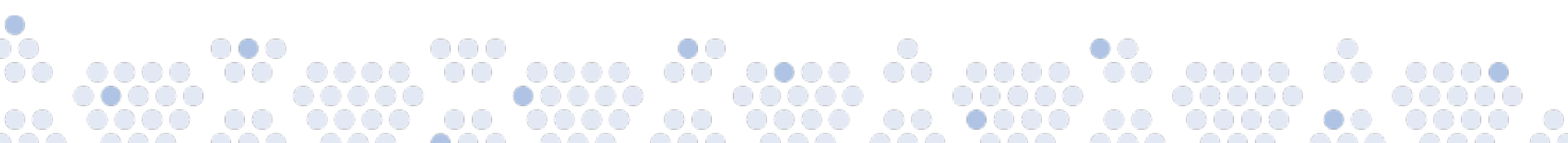
Challenges

- **Control on the single electron rate will need to be reduced significantly to suppress 2-electron pile-up background. We still have to demonstrate what factor of reduction can be achieved with gas purification.**
- **Recent etching seem to be ineffective in removing surface Po-210.** The nature of the low-energy surface is not understood yet, and we don't know yet if it can be managed with etching
- Originally, ECuME was proposed to address our leading sources of background (on paper): Pb-210 in the bulk of the copper, and copper cosmogenic activation. **In reality, background is heavily dominated by single electron pile-up and low-energy surface rate.** MiniECuME will tell us if electroformed copper gives an advantage on the latter.

Conclusion – any other pertinent business

- World leading WIMP-proton SD constraints using a hydrogen target at LSM will be submitted to PRL soon
- Higher than expected backgrounds are observed:
 - Single electron pile-up in the 2-electron ROI: new breakthrough, single electron rate is related to gas purity
 - Surface rate: we will soon measure if recent etchings had an impact
- Physics data was collected in Ne-CH₄ at SNOLAB, data analysis is underway to determine achievable WIMP-nucleus SI sensitivity at current level of low-energy background
- We will address single electron background with gas purification and radon removal
- Once our Laser is fixed, we will resume data taking with Ne-CH₄, pure CH₄, and He-CH₄
- Mini-ECuME will be installed in the NEWS-G shield when it is ready and will constitute a demonstration of a fully electroformed SPC, informing the strategy for a full-scale ECuME at SNOLAB and/or with DarkSPHERE at Boulby

EXTRA SLIDES



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)
- The next leading source of background is copper cosmogenic activation

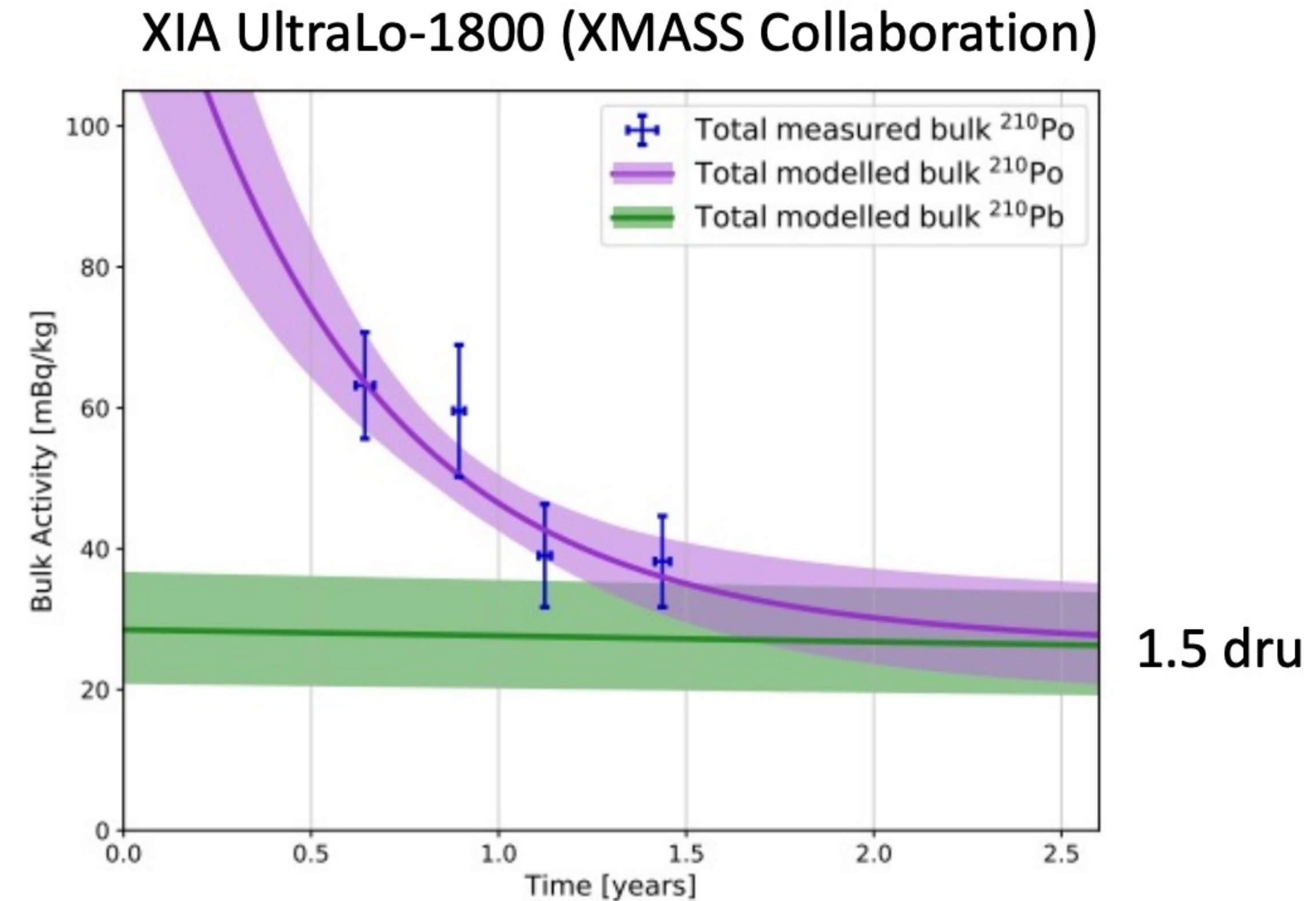
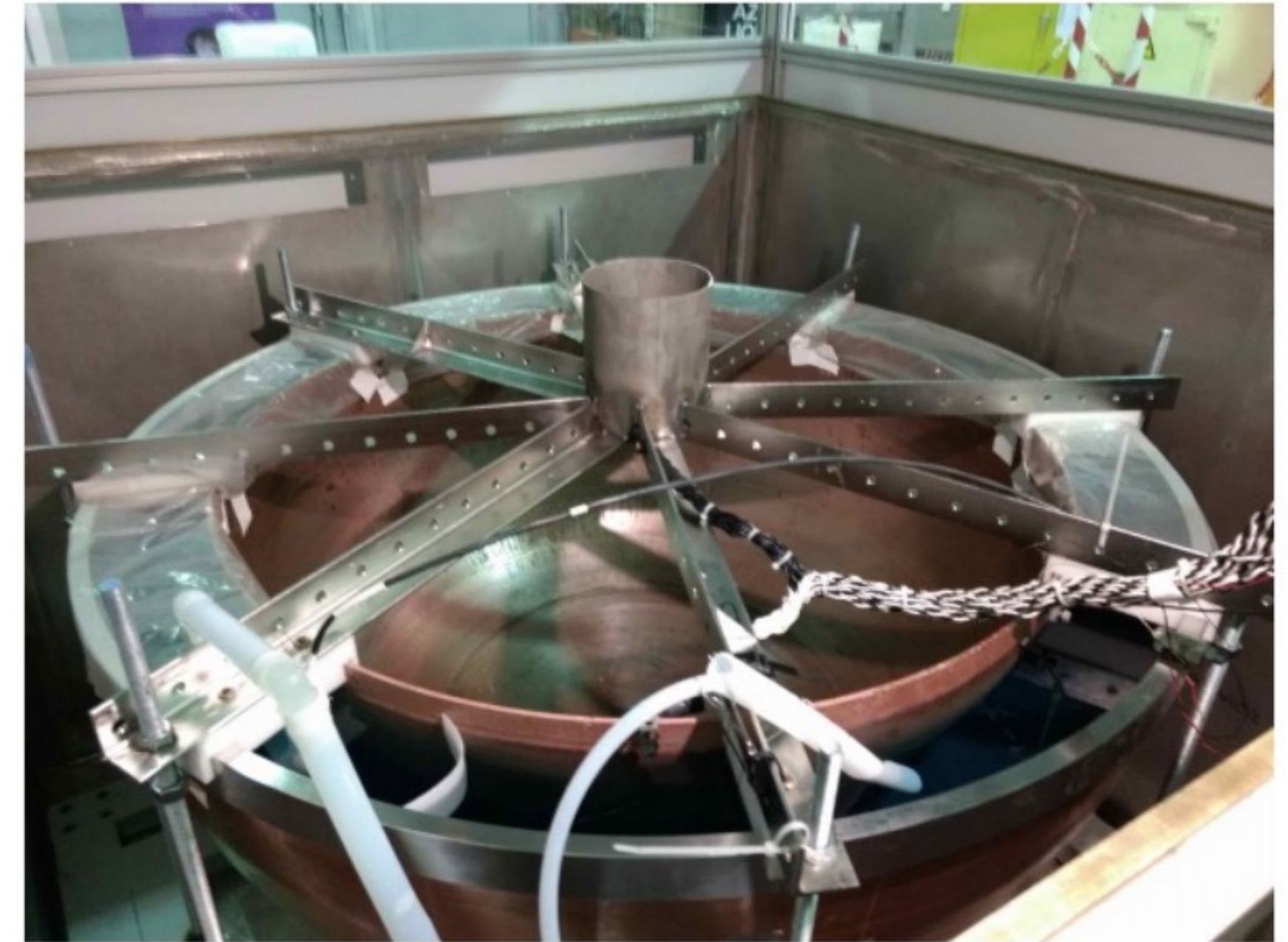
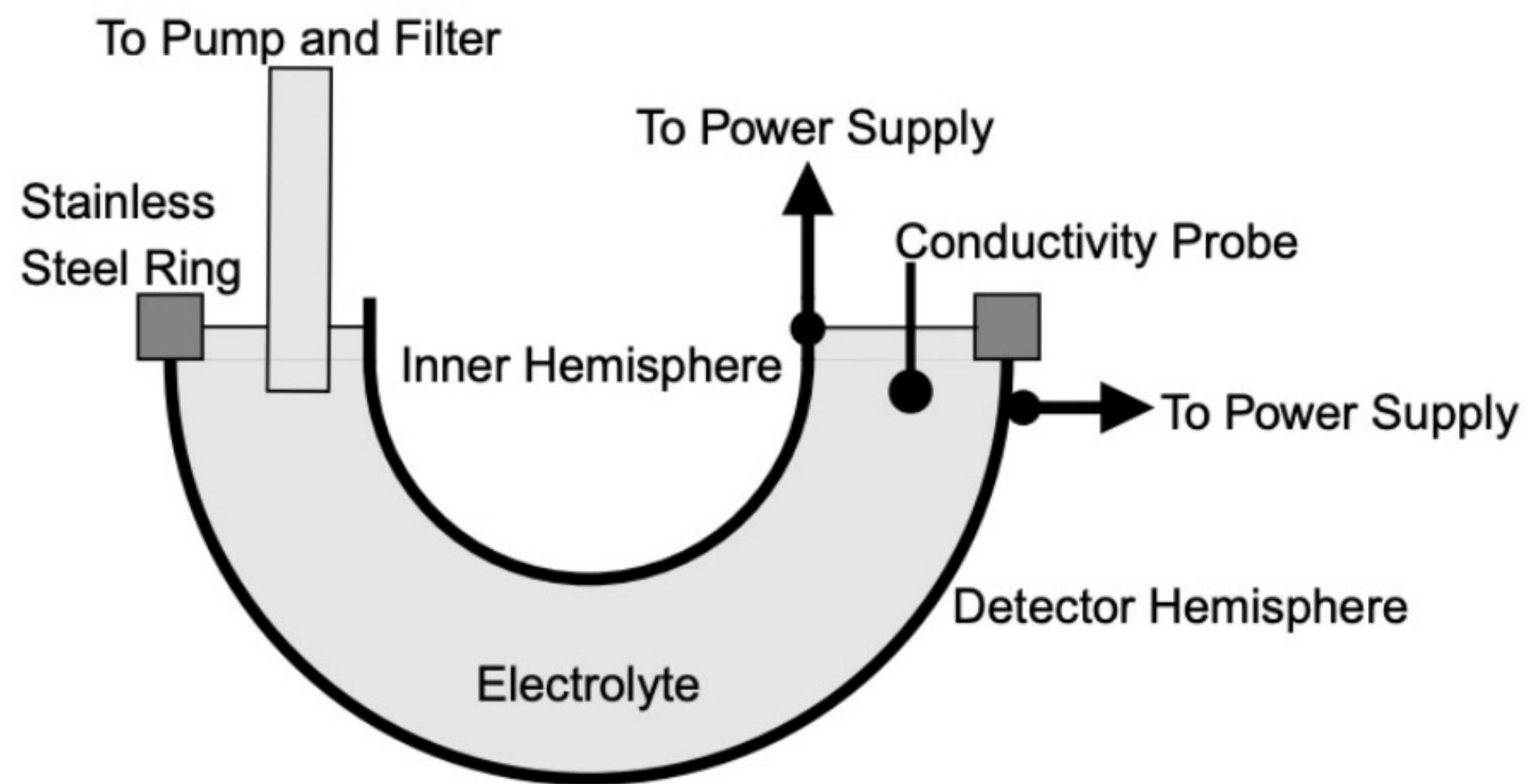


Figure 3: Measurements of the α particles from the decay of ^{210}Po in a sample of C10100 copper used in the production of the NEWS-G detector. Time is measured from the estimated production date of the copper. The purple (green) line shows the fitted ^{210}Po (^{210}Pb) activity over time, with the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

Copper Electroplating

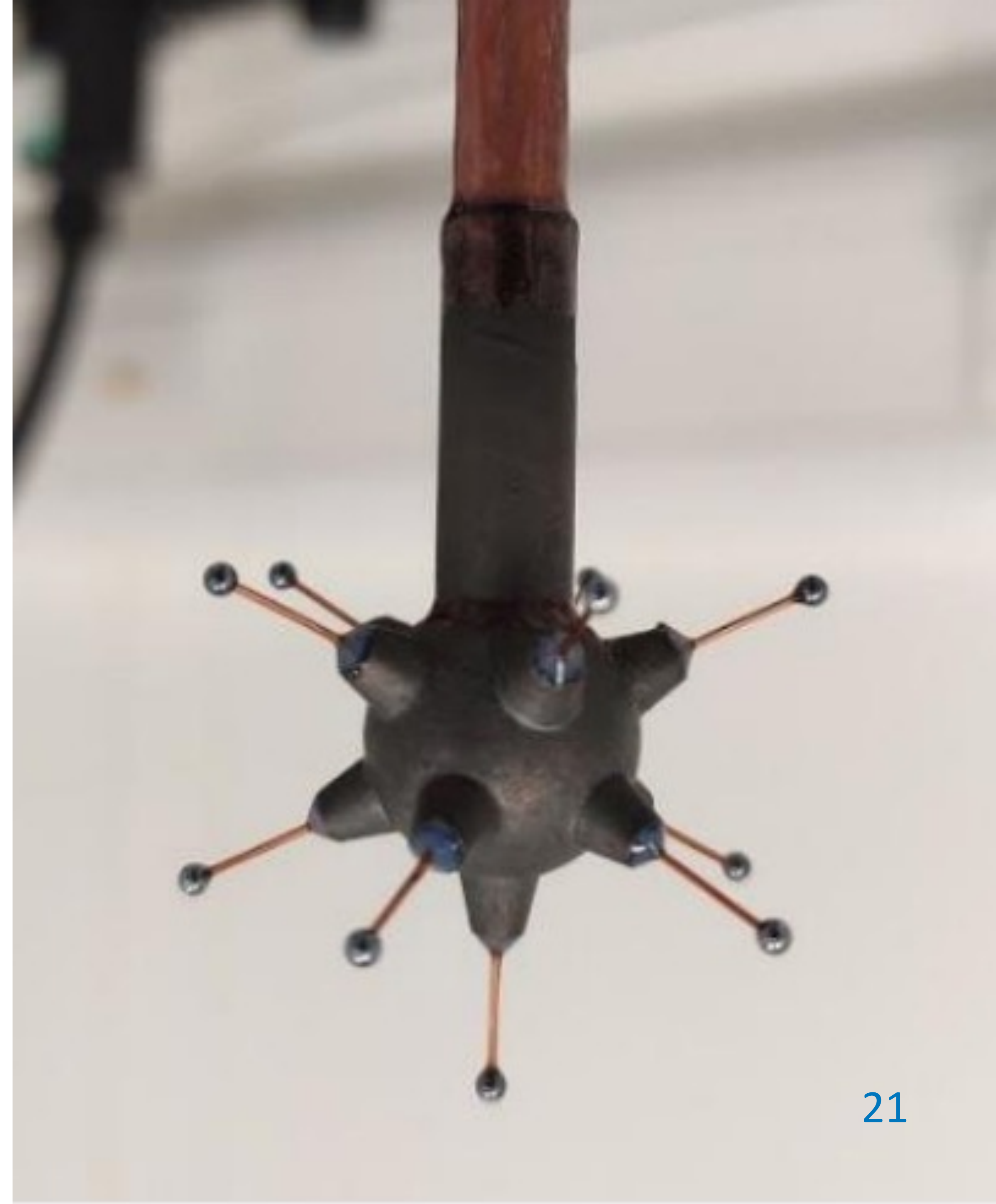
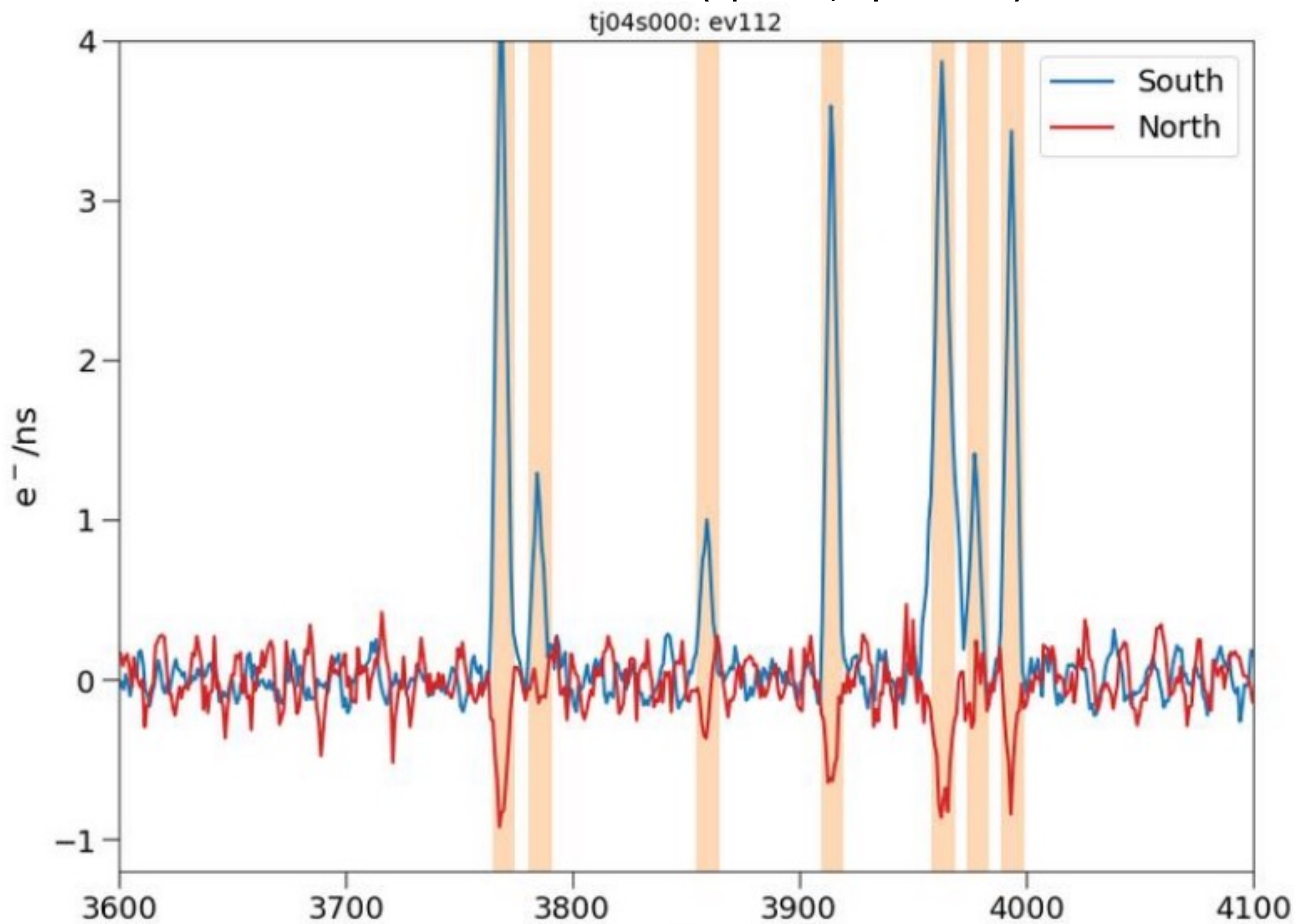
To mitigate bulk ^{210}Pb backgrounds, the 140-cm NEWS-G SPC hemispheres were electroplated with 0.5 mm pure copper at LSM



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

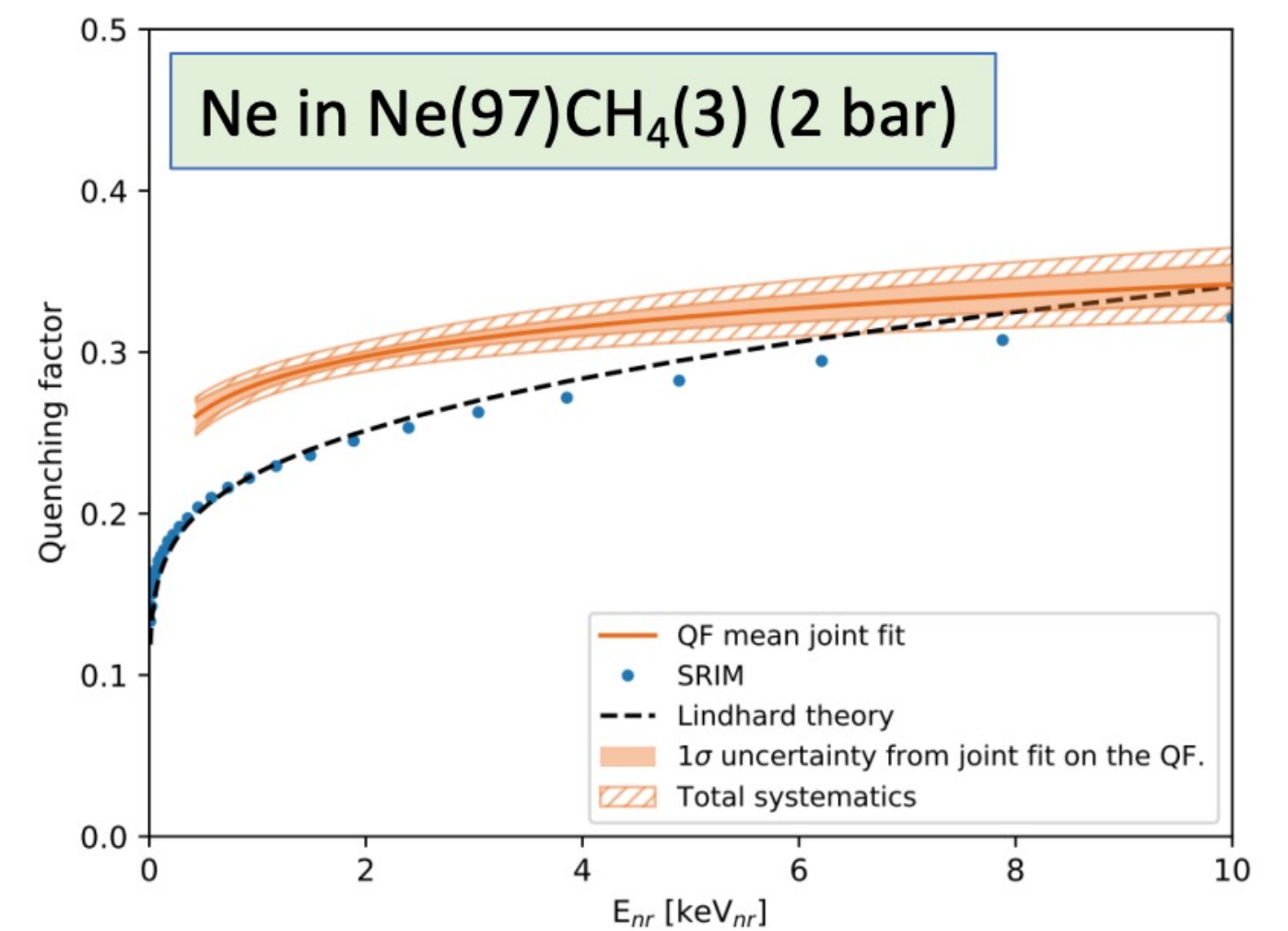
The ACHINOS sensor

- 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-CH₄ (TUNL) and pure CH₄ (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)

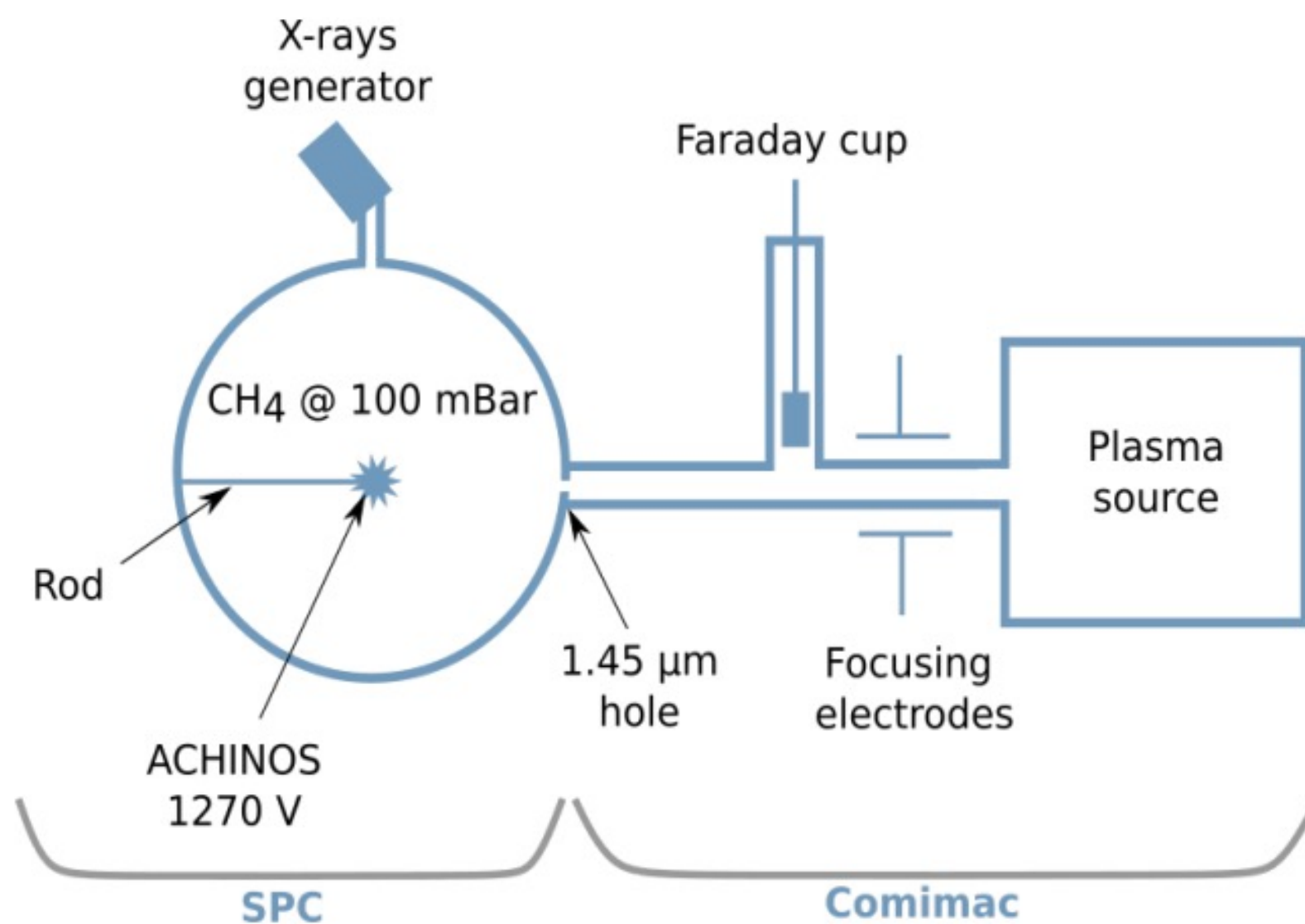
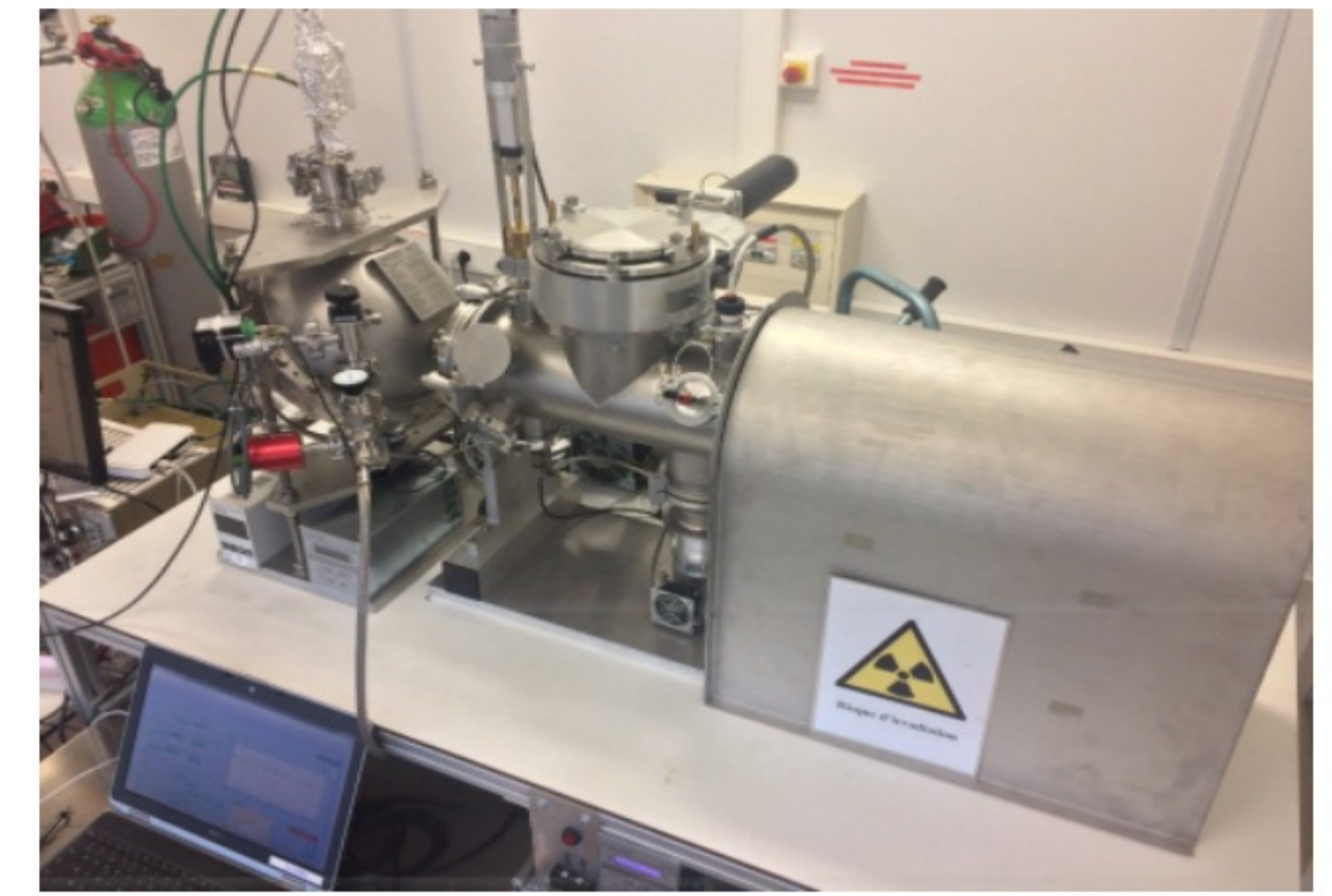


[1] I. Katsioulas et al, Astropart. Phys. 141, 102707 (2022)

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

Quenching Factor

- Ionization yield of proton recoils in CH₄ 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 CH₄

