



UNIVERSITY OF  
ALBERTA



Lauréats  
**KILLAM**  
Laureates

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Institut Pascal, Orsay

# Searching for Light Dark Matter with the NEWS-G Experiment



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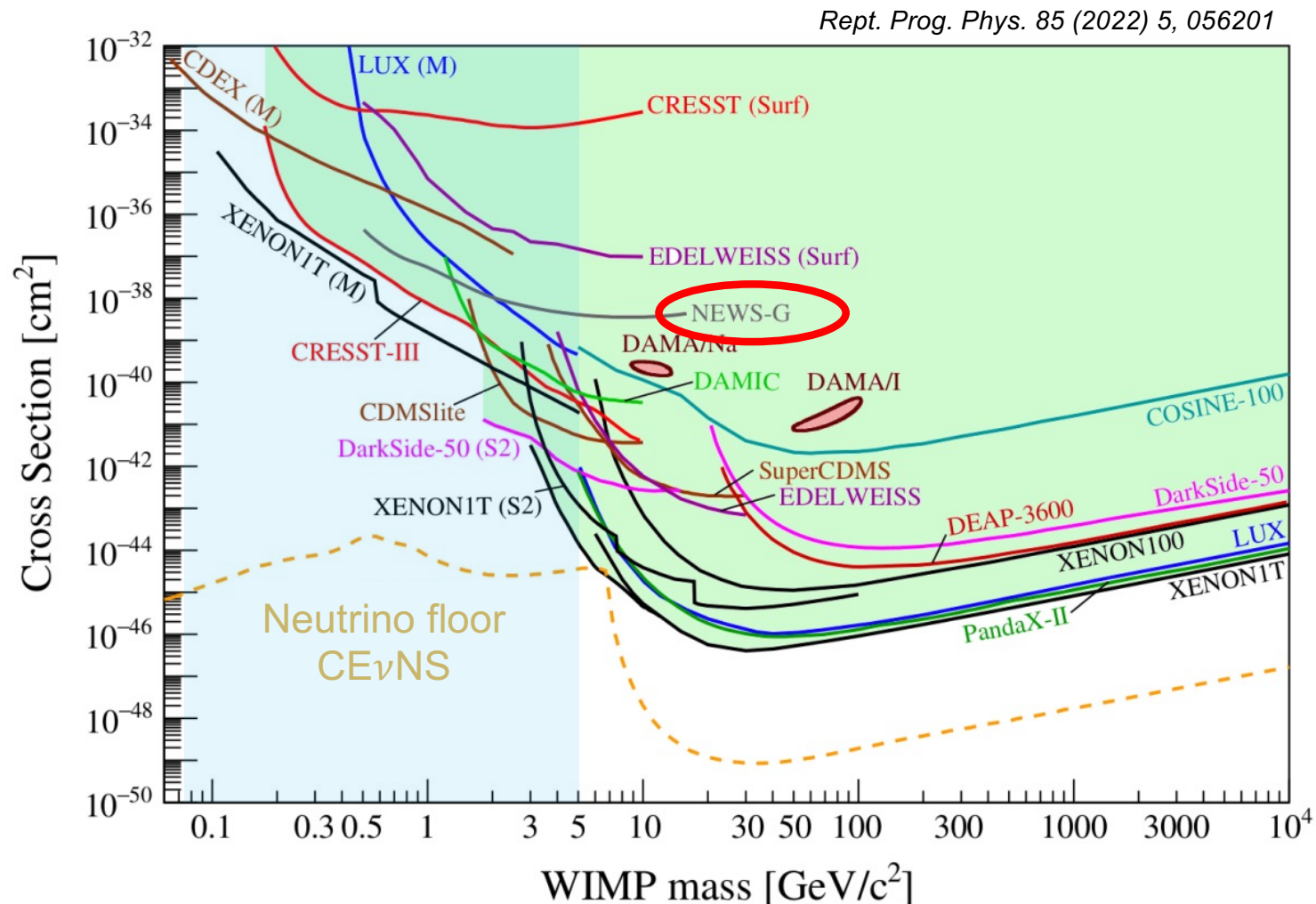
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# Landscape of Dark Matter Detection

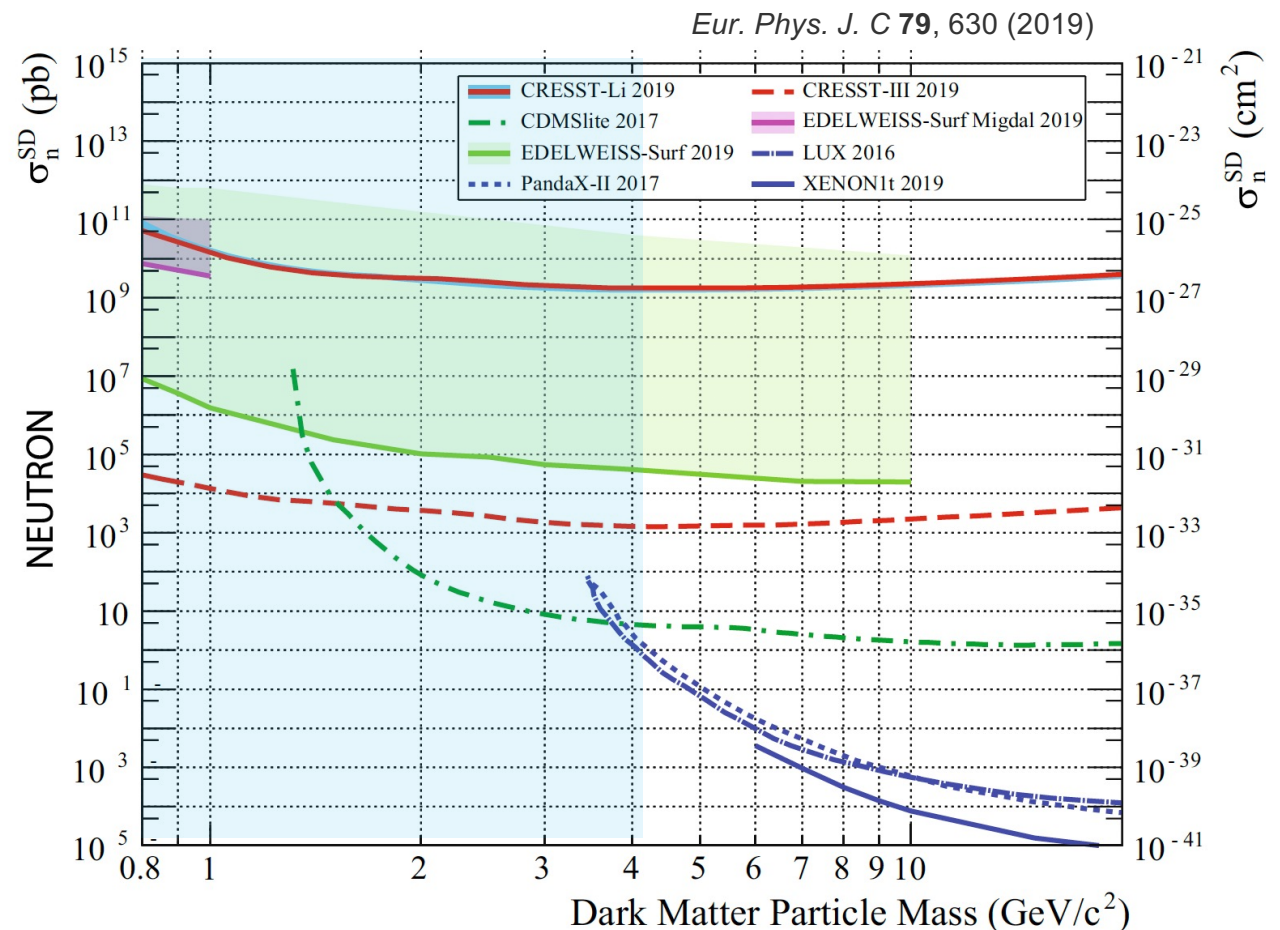
Lower-masses less well constrained and has motivated theoretical models predicting new candidates in this region (SI)





# Landscape of Dark Matter Detection

Lower-masses less well constrained and has motivated theoretical models predicting new candidates in this region (SD)

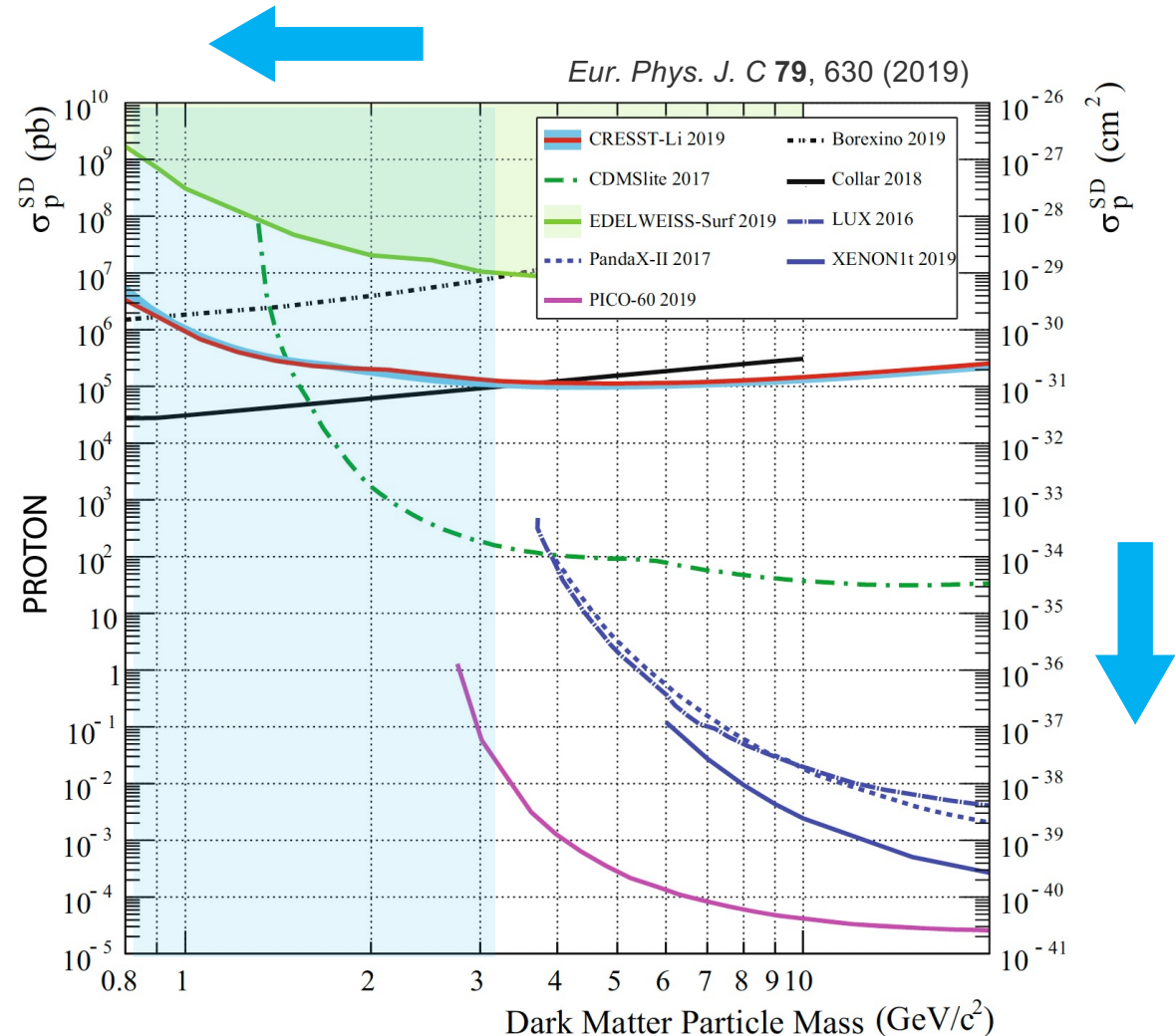




# Landscape of Dark Matter Detection

Lower-masses less well constrained and has motivated theoretical models predicting new candidates in this region (SD)

- Exploring light-DM with nuclear recoils requires:
  - Low energy threshold
  - Low mass nuclei
- New Experiments with Spheres-Gas (NEWS-G)







# NEWS-G Collaboration



M-C.Piro

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Light DM searches with a novel gaseous detector, the spherical proportional counter



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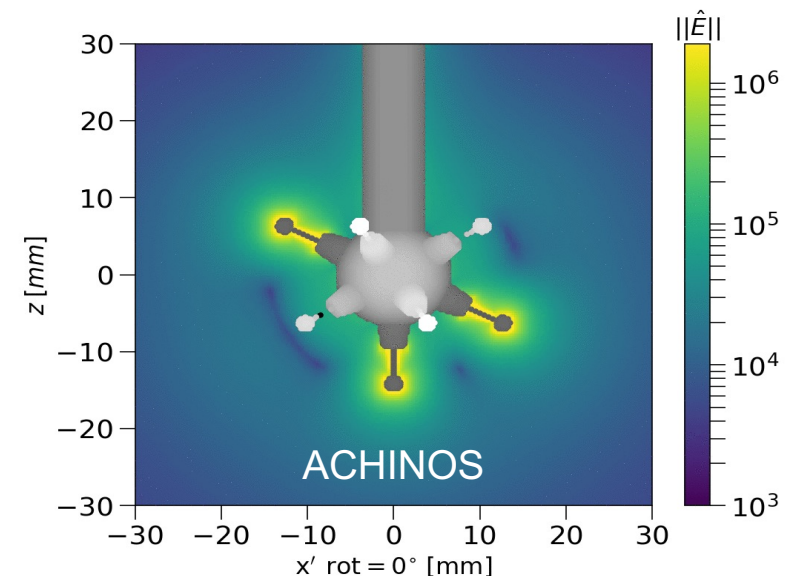
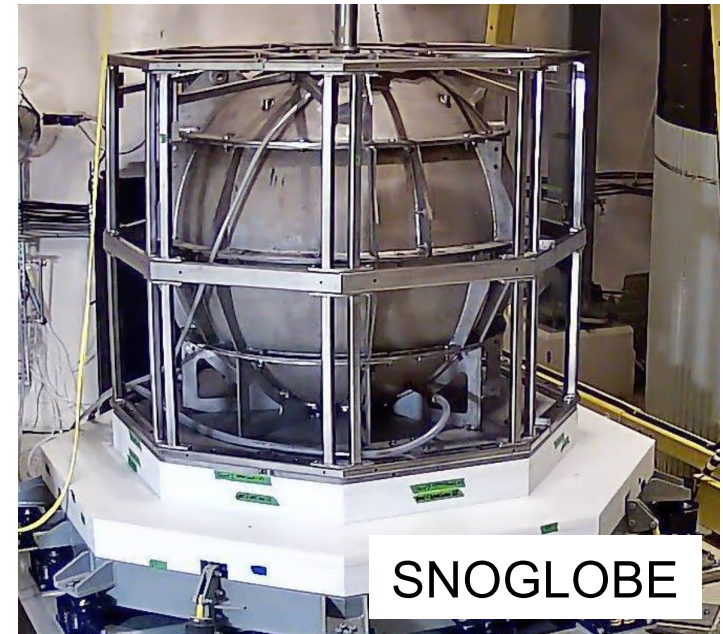


NEWS-G Collaboration meeting at Queen's University



# Spherical Proportional Counter (SPC)

- Detector:  
Spherical copper vessel with a high voltage sensor in its centre  
→ High volume-to-surface ratio
- Active target:  
Gas of neon, hydrogen mixture, helium, argon  
→ Low-A target atoms increase sensitivity to low-mass DM
- Readout:  
Charge-sensitive preamplifier  
→ One or multiple channels



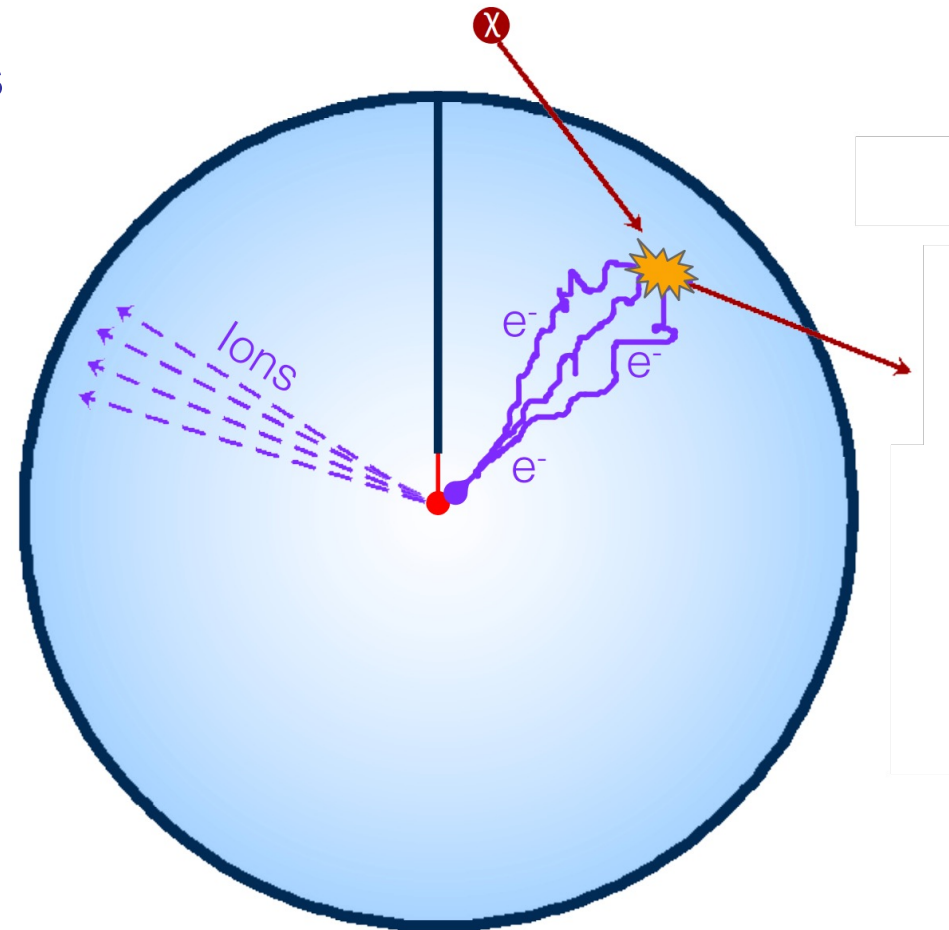




# NEWS-G: Detector principle

## NEWS-G EXPERIMENT:

- Incident particle scatters on target gas  
→ Primary ionization
- Drift of primary  $e^-$  towards sensor  
→ Varies with detector size
- Avalanche of secondary  $e^-$ /ion pairs  
→ Amplification of signal through Townsend avalanche.
- Signal formation  
→ Current induced by the secondary ions drifting away from anode

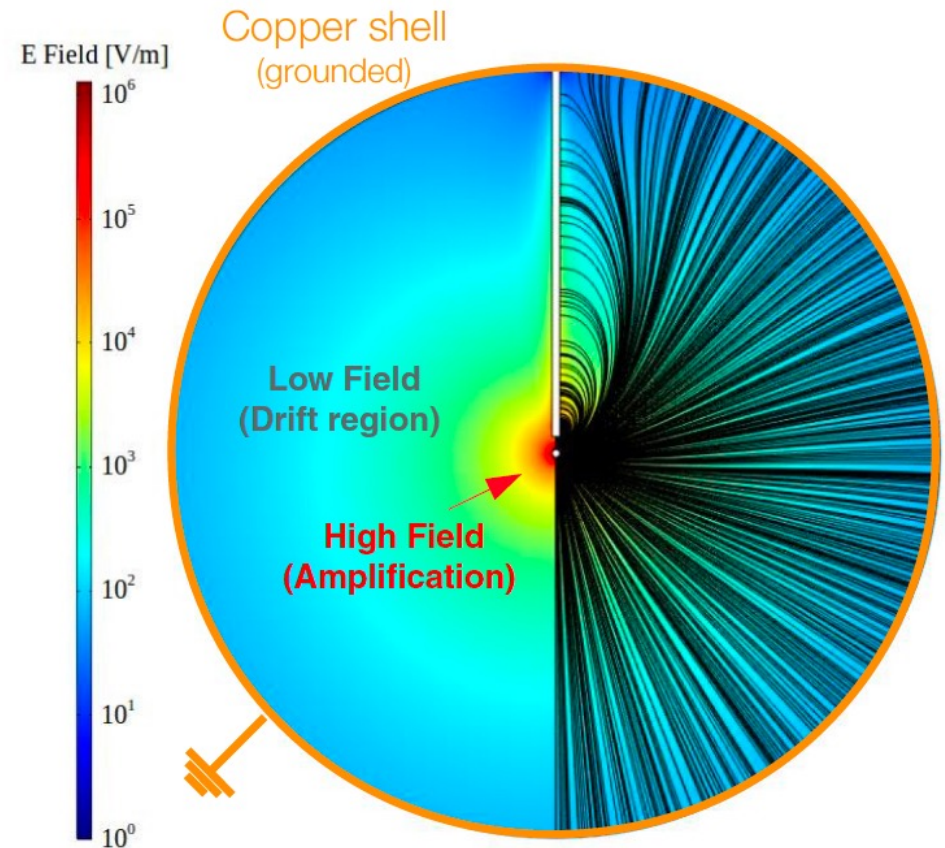




# Advantages of SPC

- Detector:  
High amplification gain  
Radiopure construction
- Active target:  
Choices of gas target and pressure
- Low capacitance:  
Independent of detector size  
→ **Single-electron detection**
- Signal information:  
Volume fidualisation  
Single or few channel readout

Radial electric field that scales as  $1/r^2$   
→ “drift” and “amplification” regions

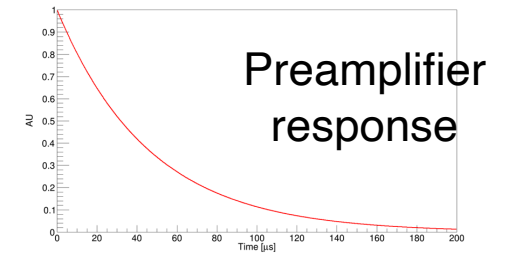
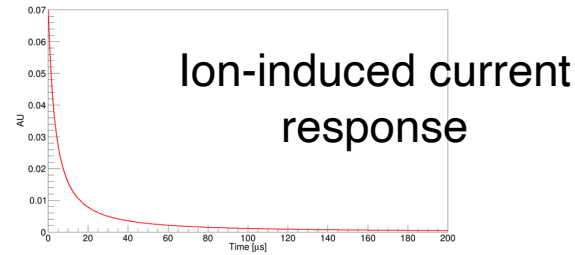
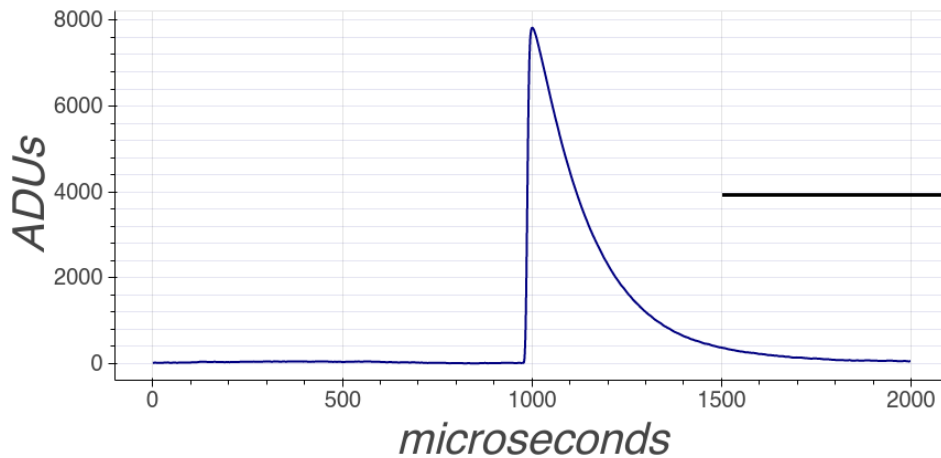




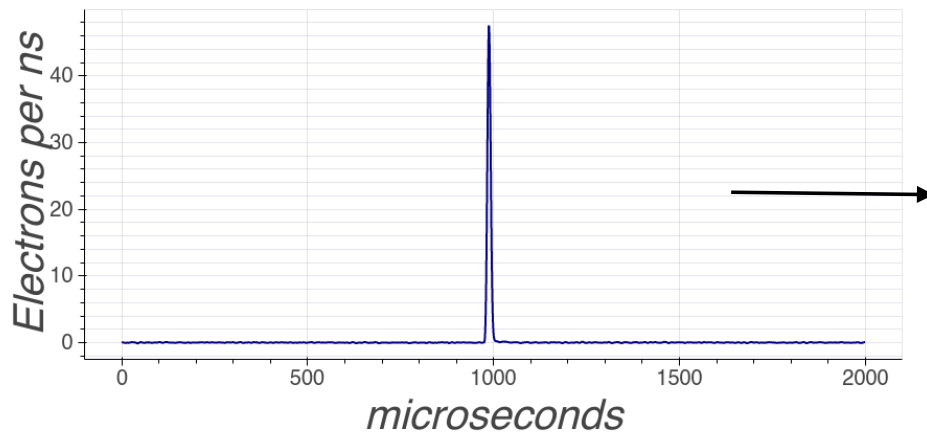


# NEWS-G: Pulse signal

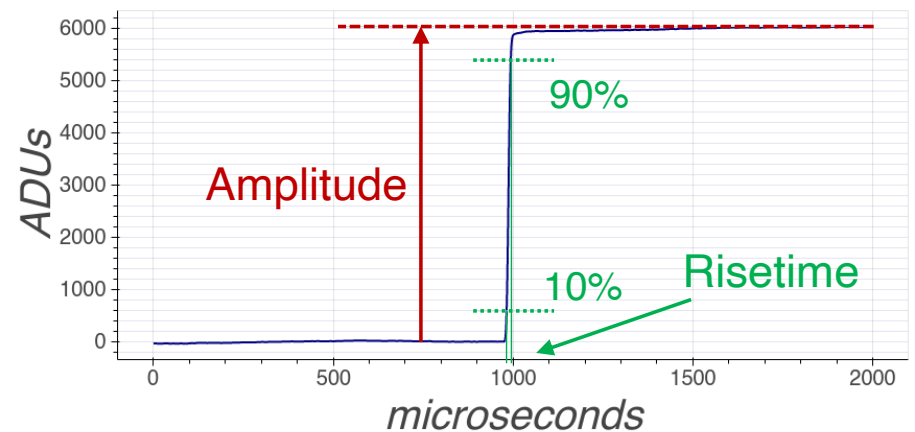
Raw pulse, baseline-subtracted



Double-deconvolved (DD2), smoothed pulse



Cumulative integral of DD2 pulse

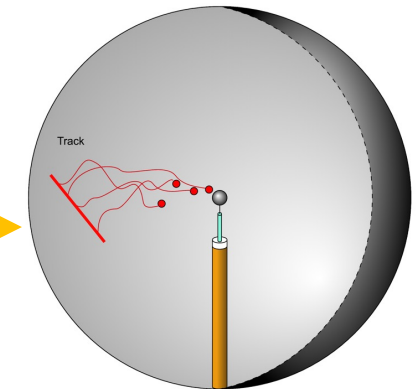
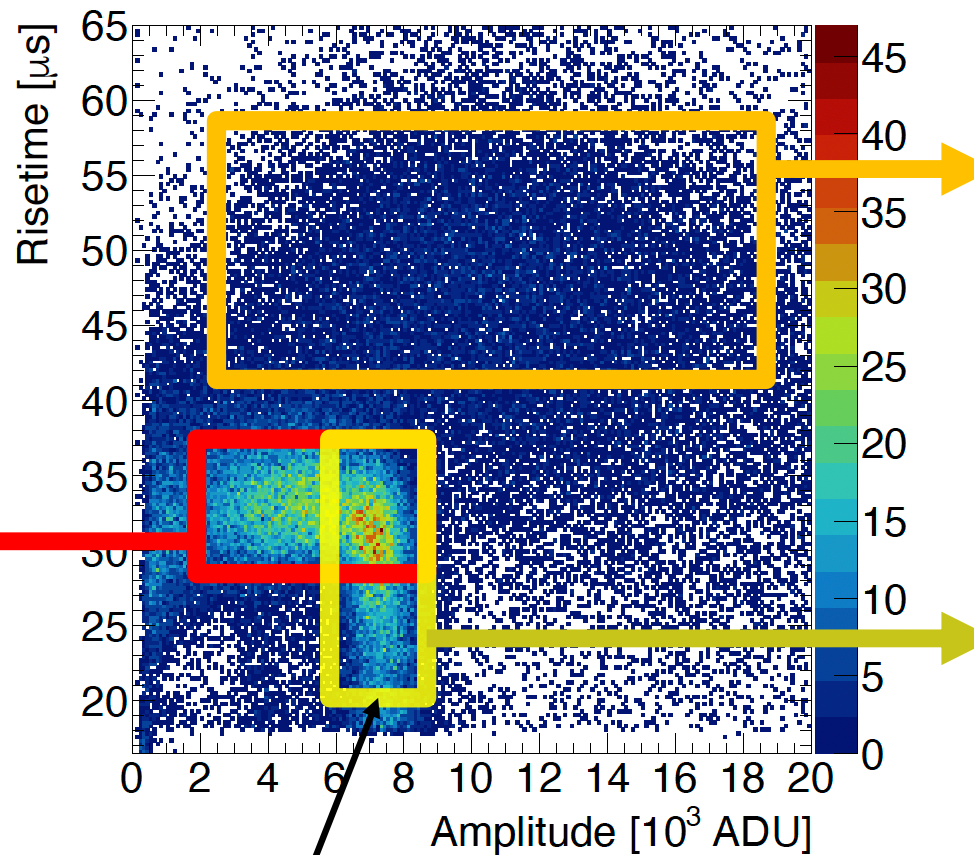
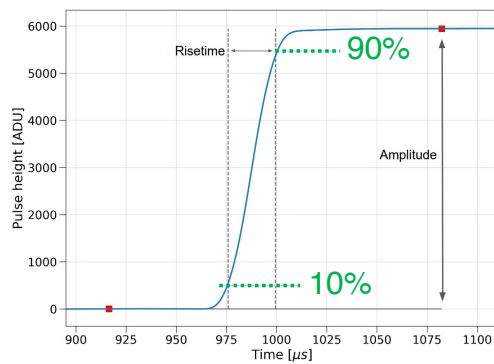




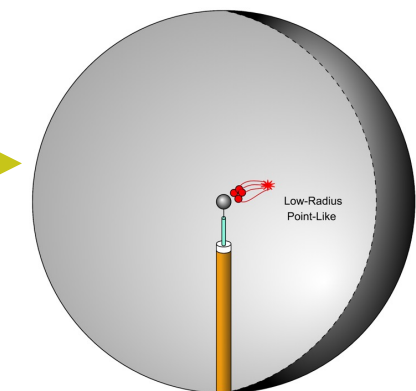
# Pulse Shape Discrimination

Pulse shape parameters (Risetime & Amplitude)  
to differentiate events

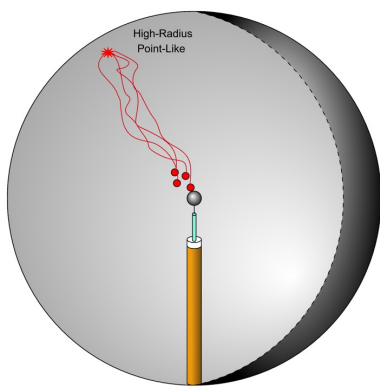
Integrated signal



“Muon”-like events



“Signal”-like events



“Surface”-like events

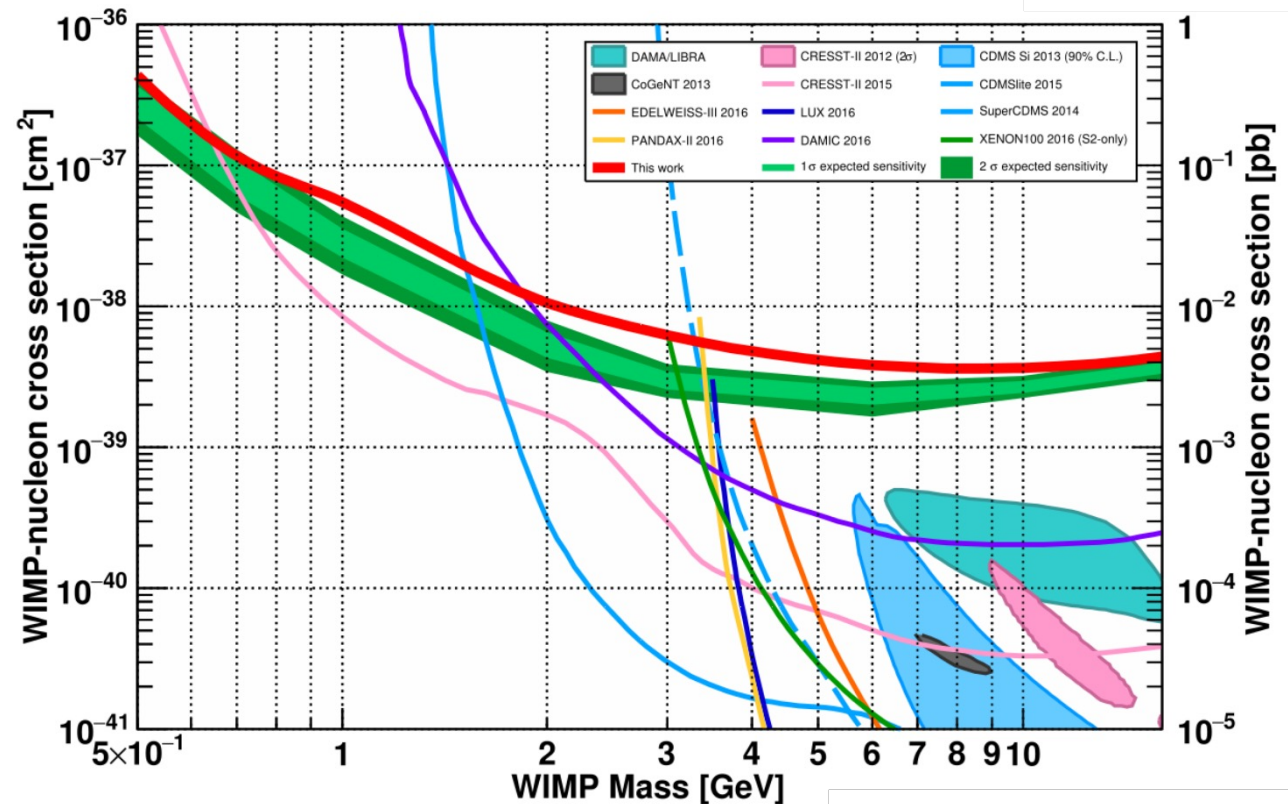
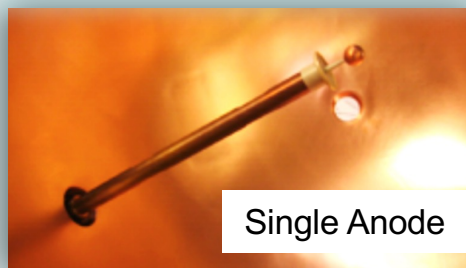
5.9 keV X-rays from  $^{55}\text{Fe}$  decays



# First results @ LSM

## SEDINE:

- 60 cm  $\varnothing$  vessel filled with Neon (+0.7% CH<sub>4</sub>) at 3.1bar
- 42-day long run, total exposure of 9.7 kg.day at LSM
- Best limit SI at that time (2017) on 0.5 GeV candidate





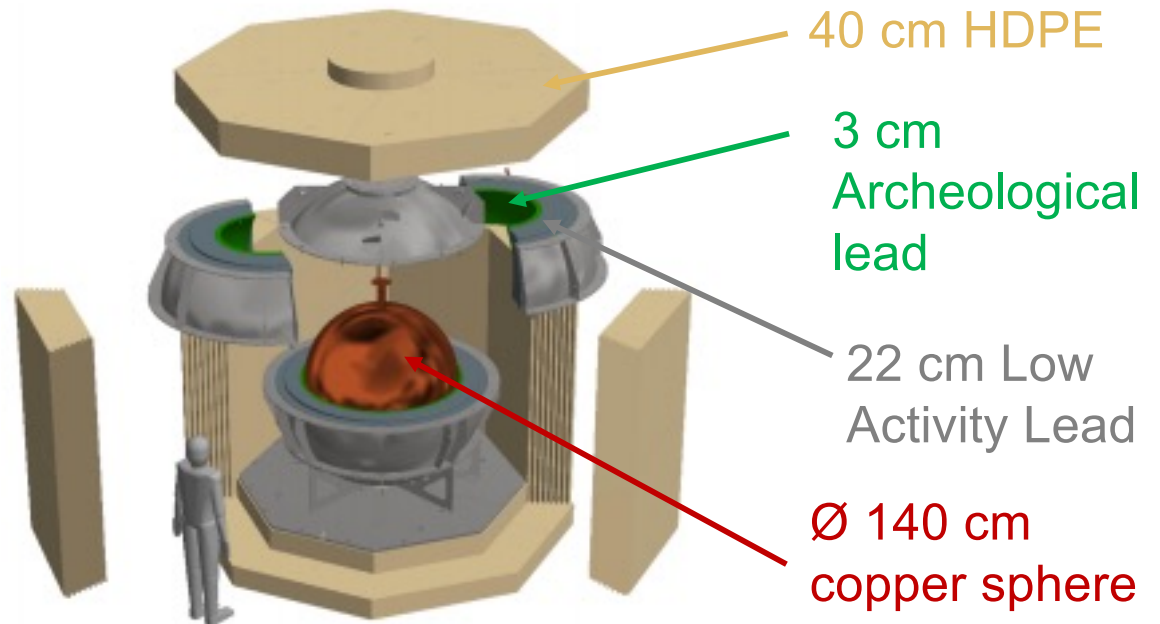
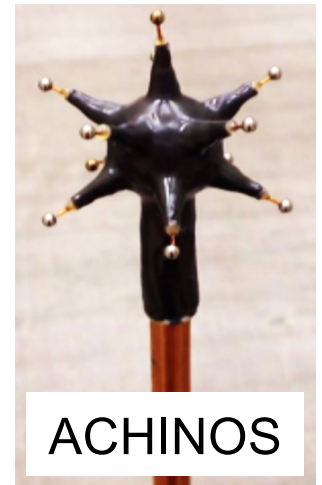


# SNOLGLOBE @ SNOLAB

## SNOLGLOBE (S140):

- 140 cm  $\varnothing$  vessel (bigger)
- Lots of improvements

→ L. Balogh et al 2023 JINST 18 T02005





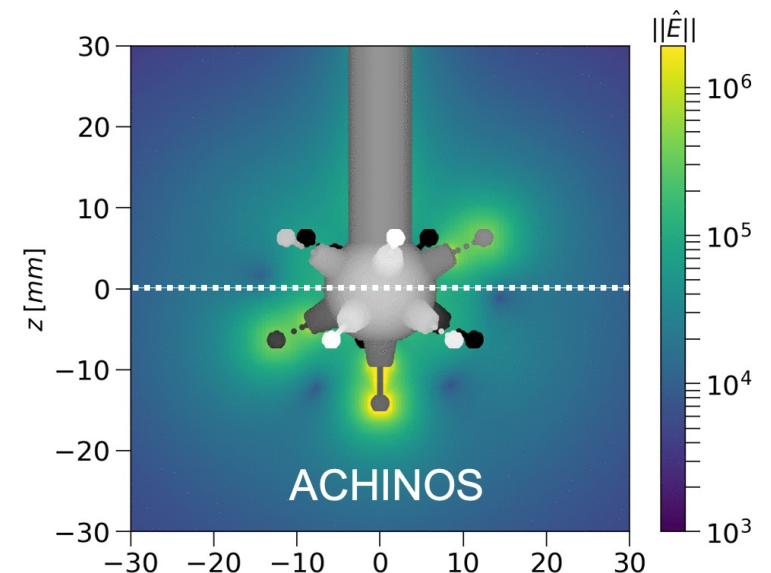
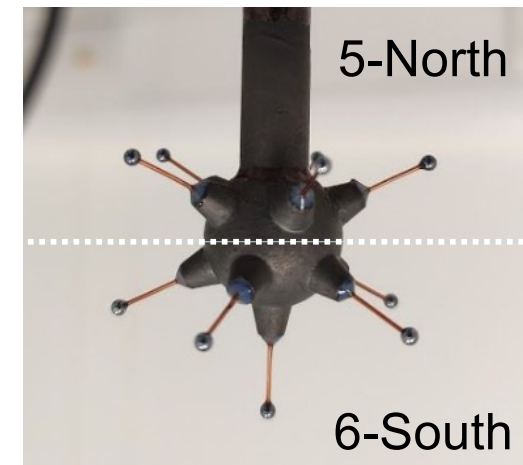
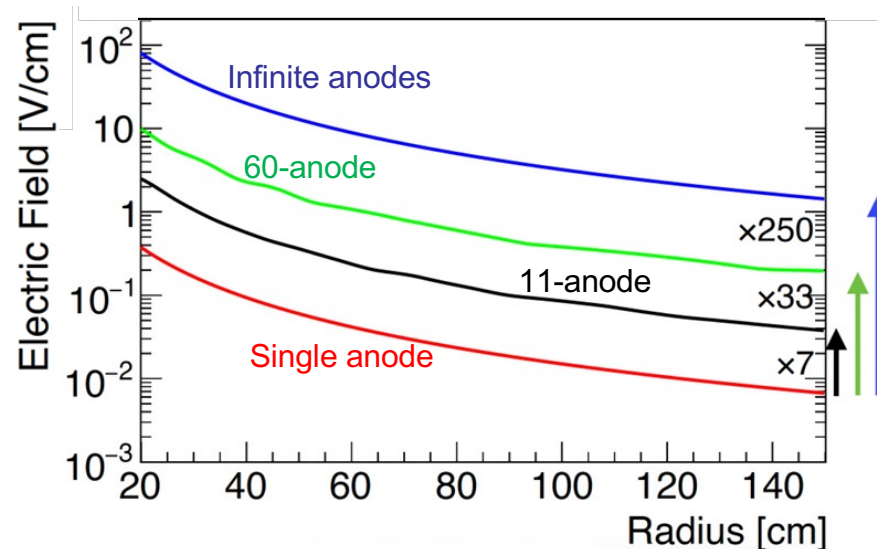


# Multi-sensor readout

The 11-anode sensor is read out in two channels (North and South)

## ACHINOS multi-anode sensor

- High gain while keeping a strong electric field at a large radius
  - Avalanche field: anode radius + voltage
  - Drift field: Collective field of anodes





# SNOGLOBE at LSM

## Constructed and tested at LSM

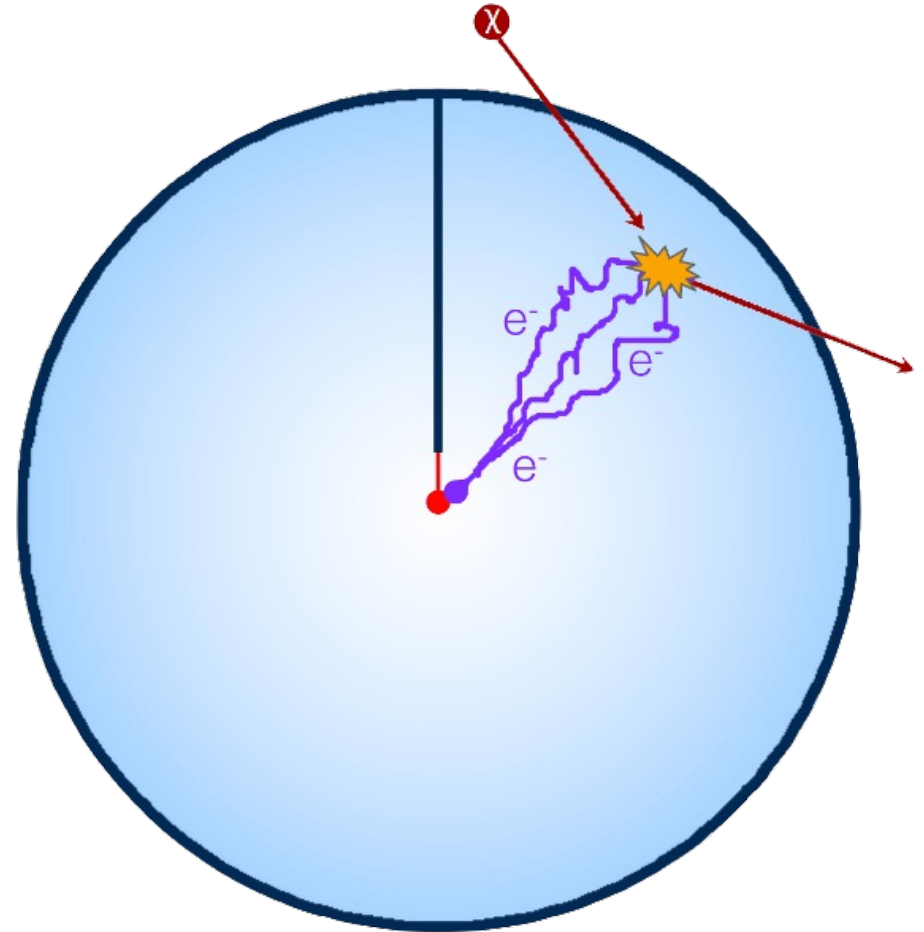
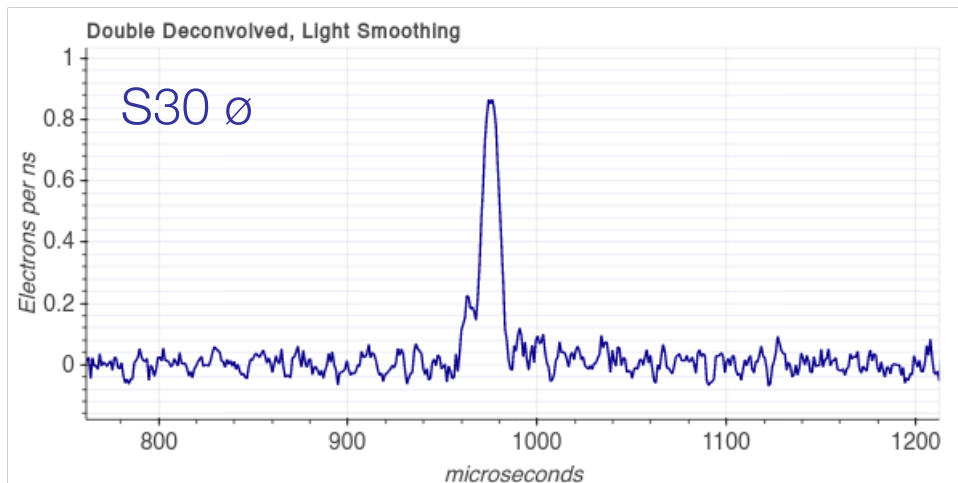
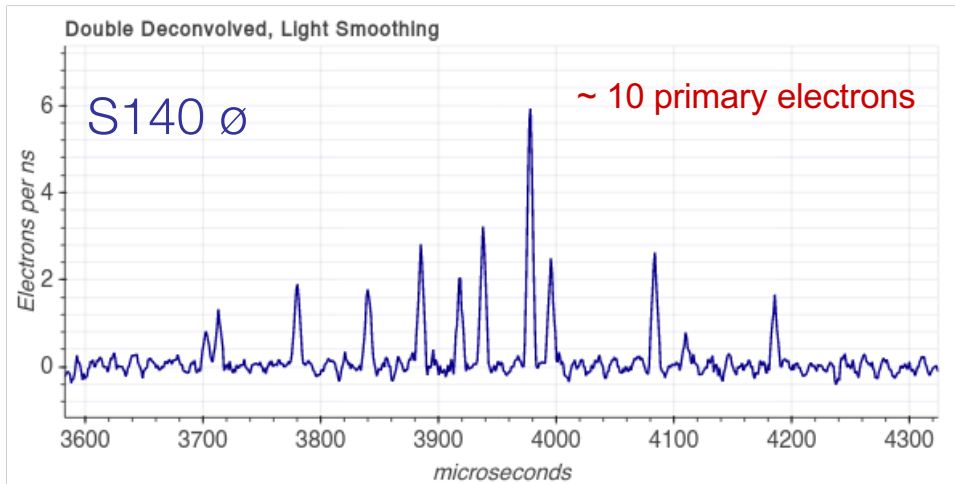
- Temporary lead + water shielding
- ~10 days of physics data
- 135 mbar of pure  $\text{CH}_4$  (114g)
- 500  $\mu\text{m}$  electroplated layer on detector inner surface (*Collab. with PNNL*)  
→ *NIMA 988 (2021) 164844*
- **UV Laser and  $^{37}\text{Ar}$  calibration systems**  
→ *Phys. Rev. D 99, 102003 (2019)*
- **ACHINOS with 2 channels**  
→ *JINST 15 (2020) P11023*





# Electron Peak Finding

The large drift volume allows us to resolve individual primary electrons

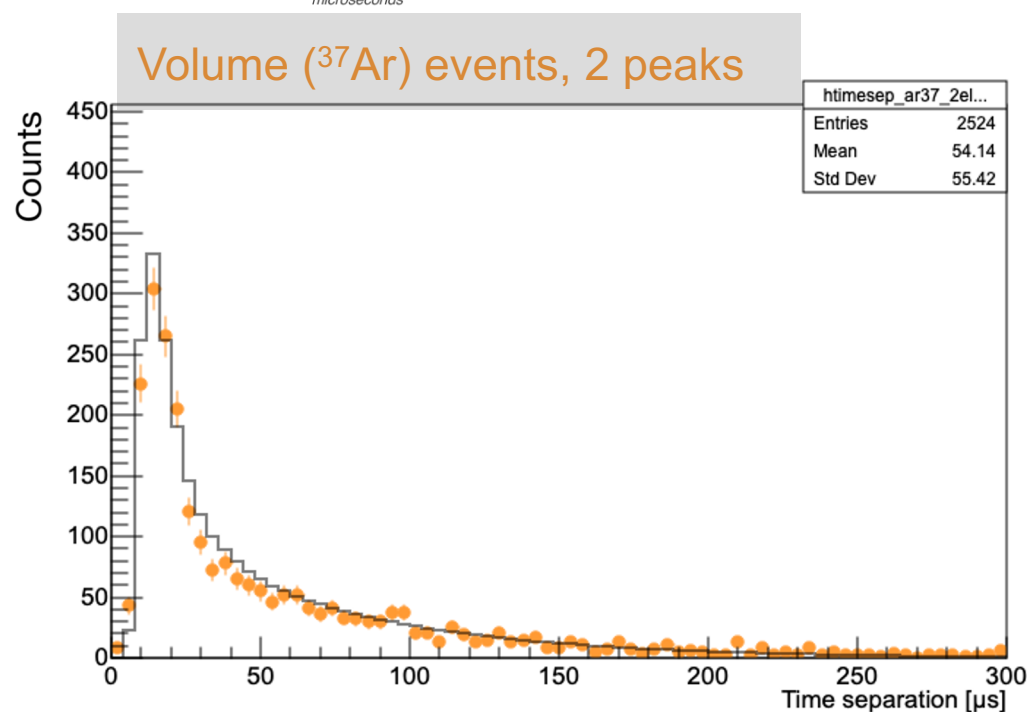
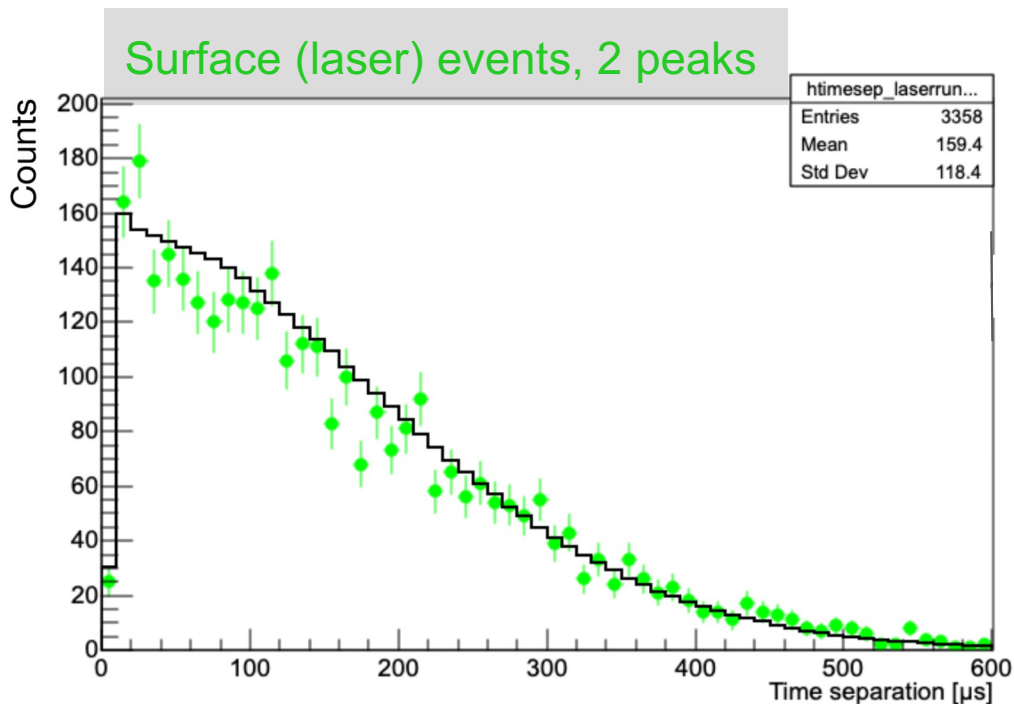
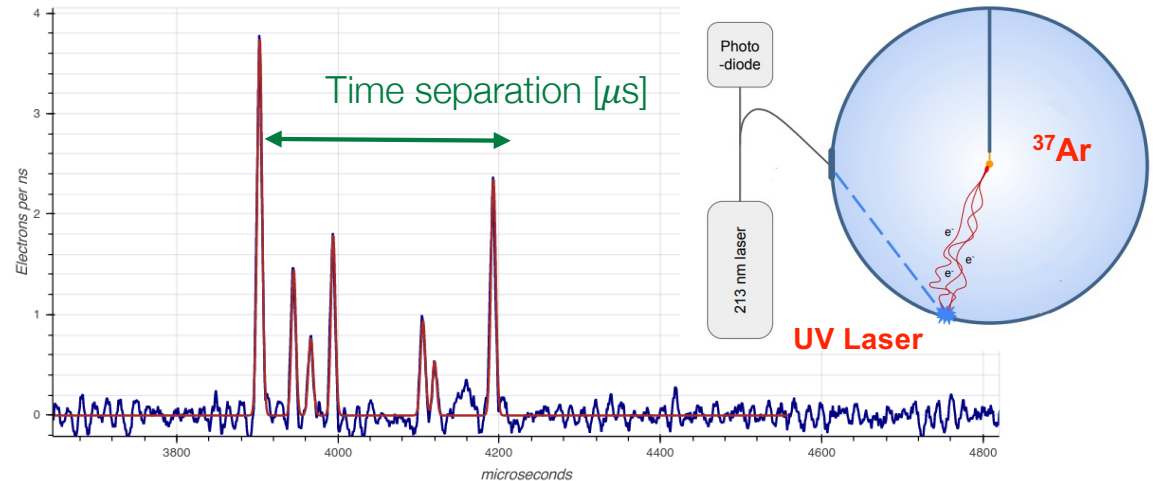


Ability to separate 100% of peaks greater than  $10\mu\text{s}$  apart



# LSM Physics Run

- Time separation allows for discrimination with surface, volume, and pile-up events
- Data divided into 2, 3, or 4 peaks
- Joint profile likelihood ratio fit to 2-, 3-, 4-peak time separation

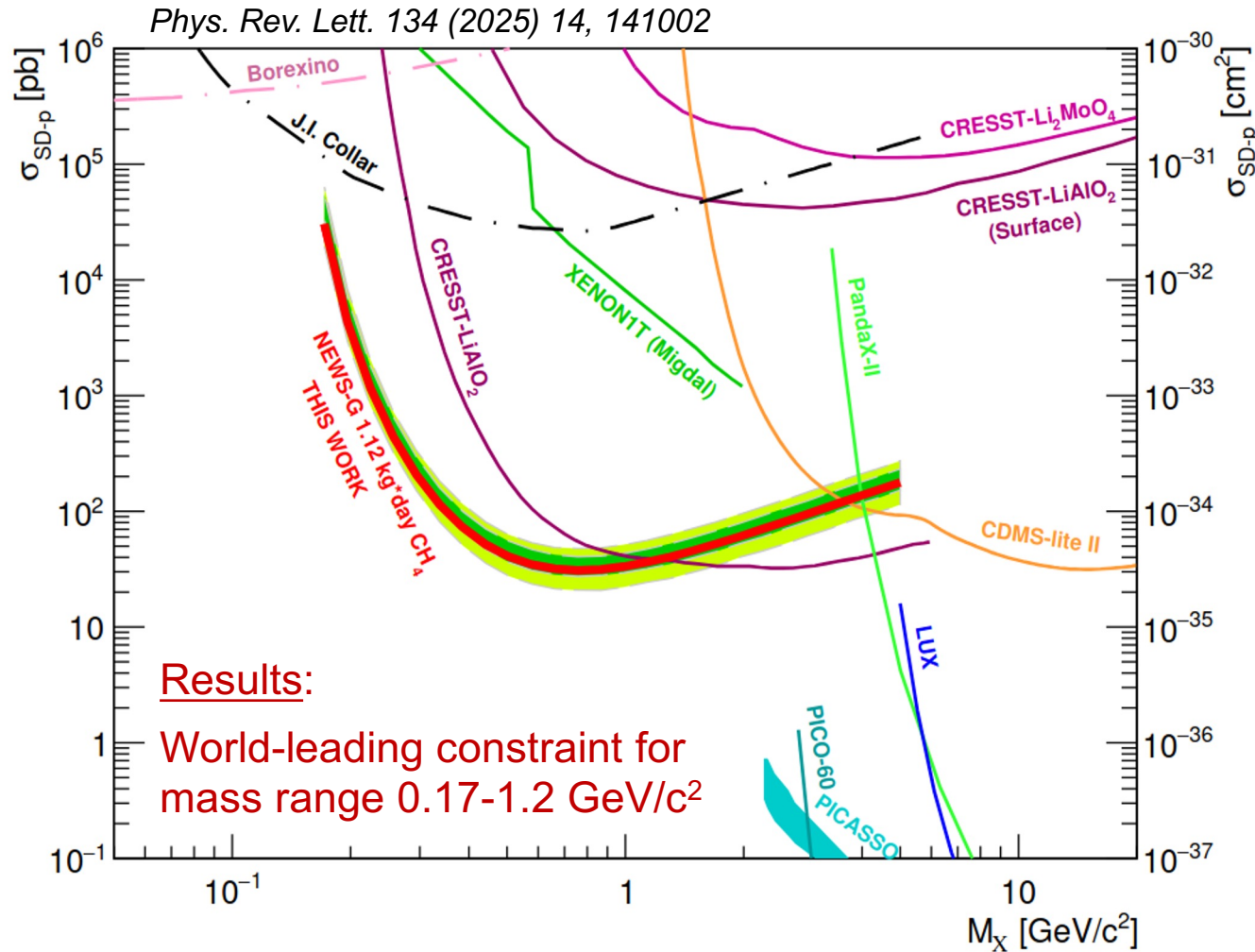






# LSM Physics Results

## S140 SNOLAB



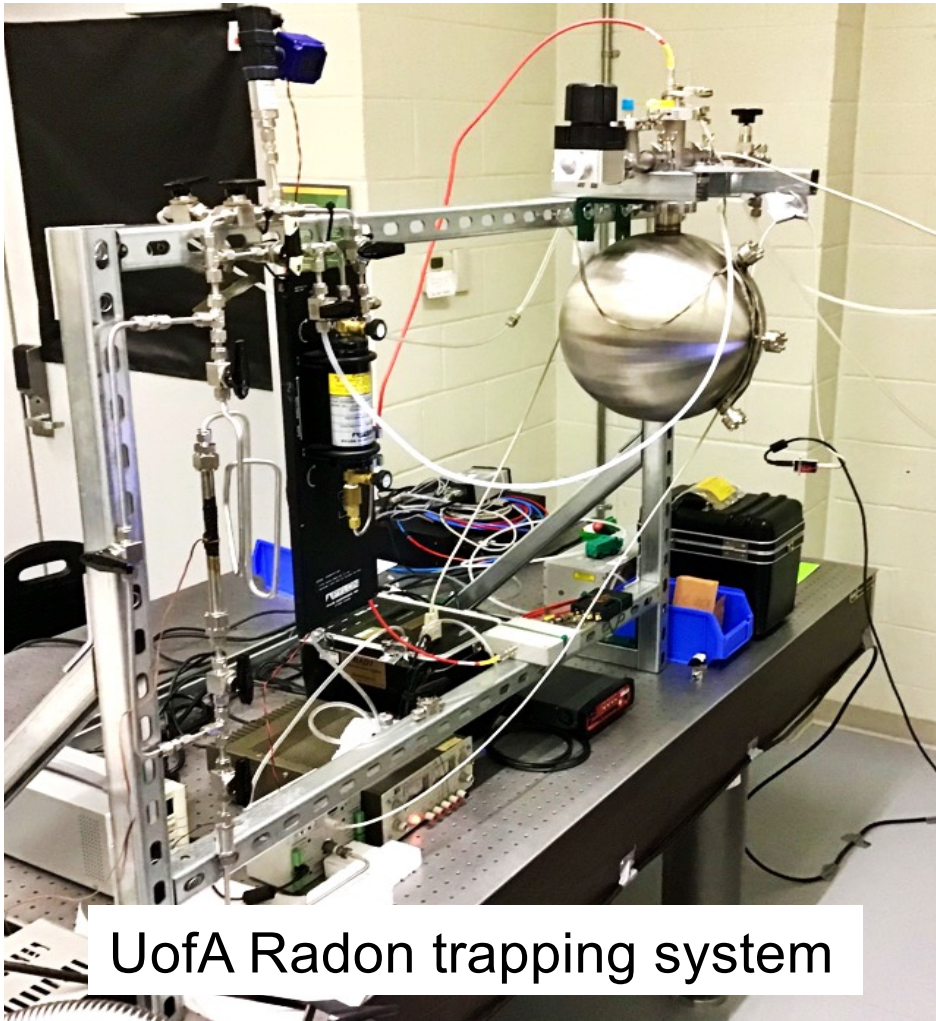
- Detector moved to SNOLAB in 2022 and data taking underway. Stay tuned!





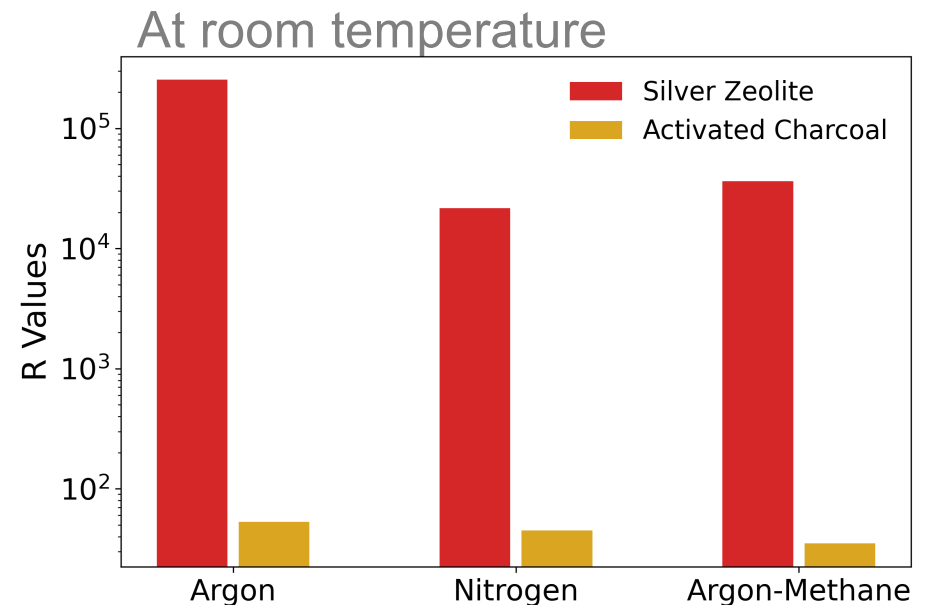
# Radon trapping system

## Towards improving the gas purity



UofA Radon trapping system

- New absorbents tested with a Rad7 and a 30 cm  $\varnothing$  sphere
- Excellent radon reduction ratio obtained at room temperature



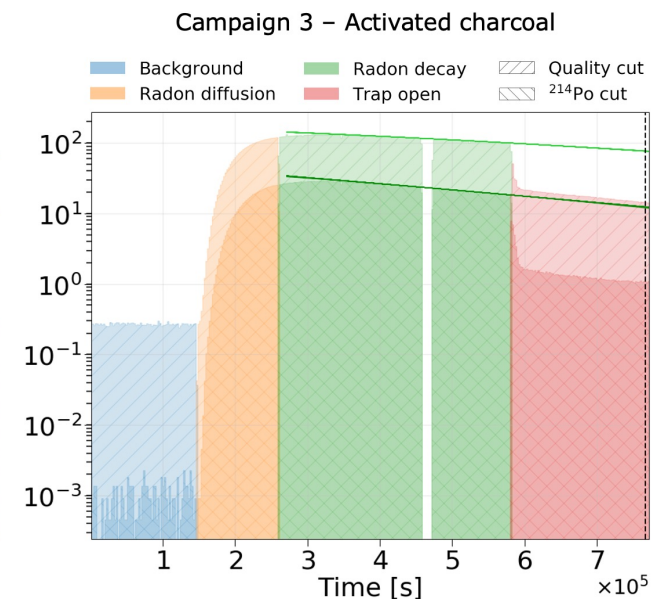
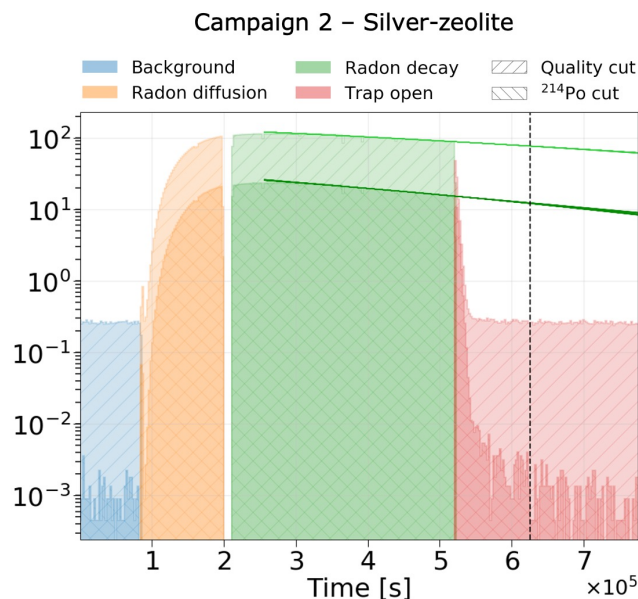
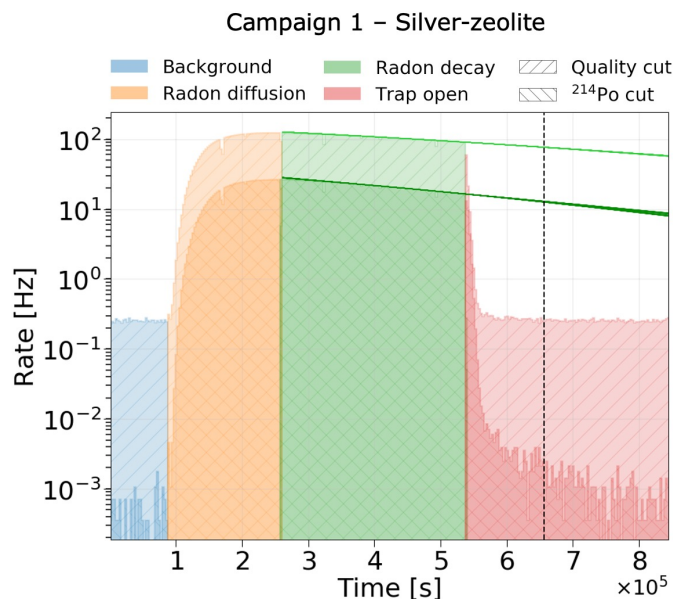
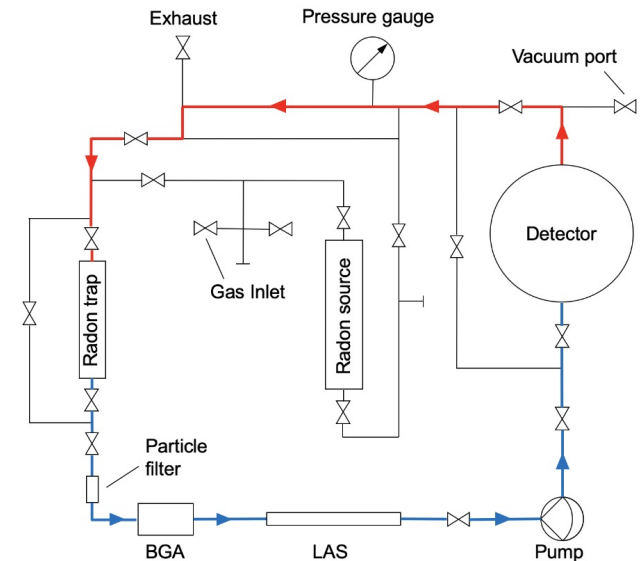




# Radon trapping system

- 30 cm diameter sphere (Ar:CH<sub>4</sub>) 500 mbar
- Close-loop circulation system (1L/min)
- Impressive results at room temperature
- The trap is installed at SNOLAB and data are currently being analyzed

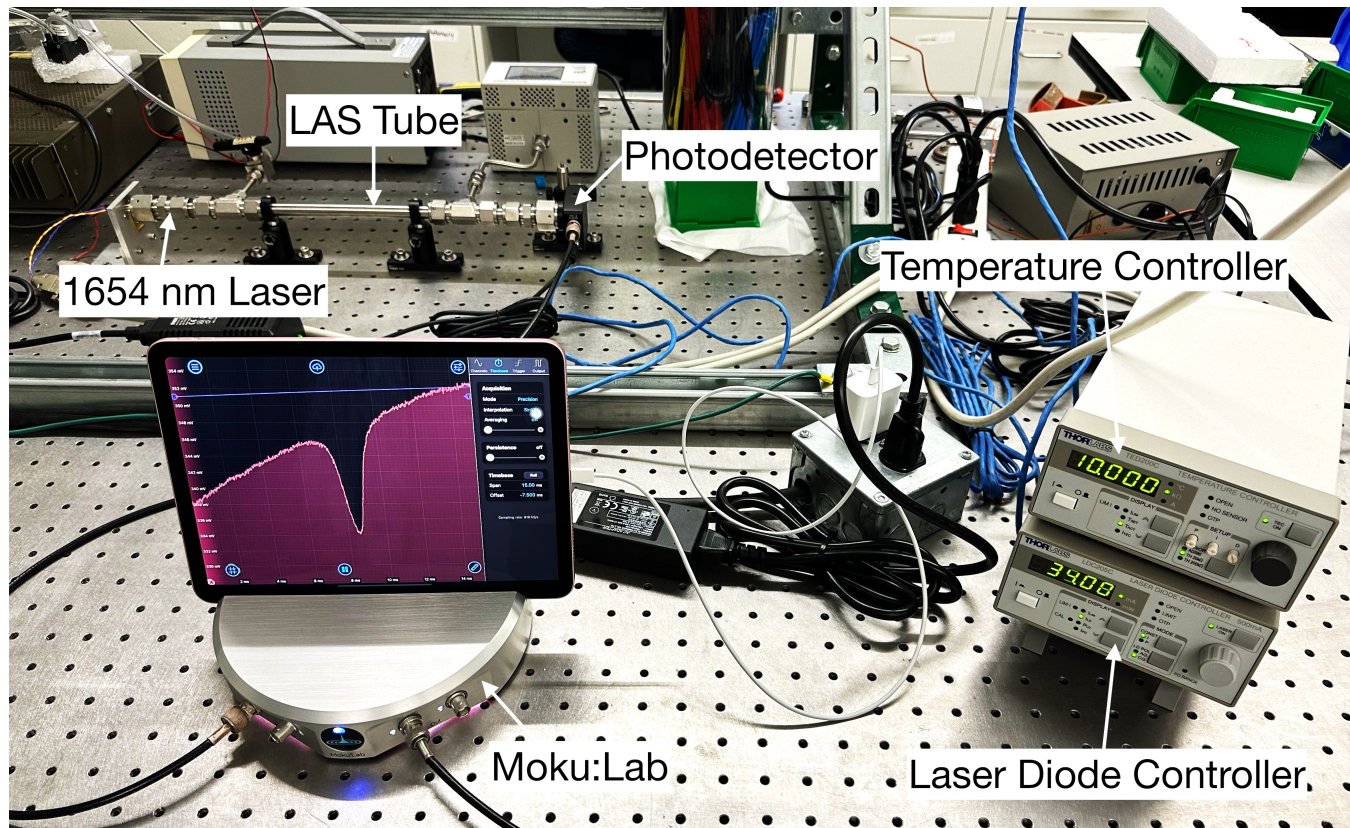
*Submitted arXiv:2505.07979*





# Laser Absorption Spectroscopy (LAS)

- Measure the absolute concentrations of gases with a laser tuned to a wavelength matching the absorption features of the methane gas
- Monitor accurate and absolute methane concentration over time

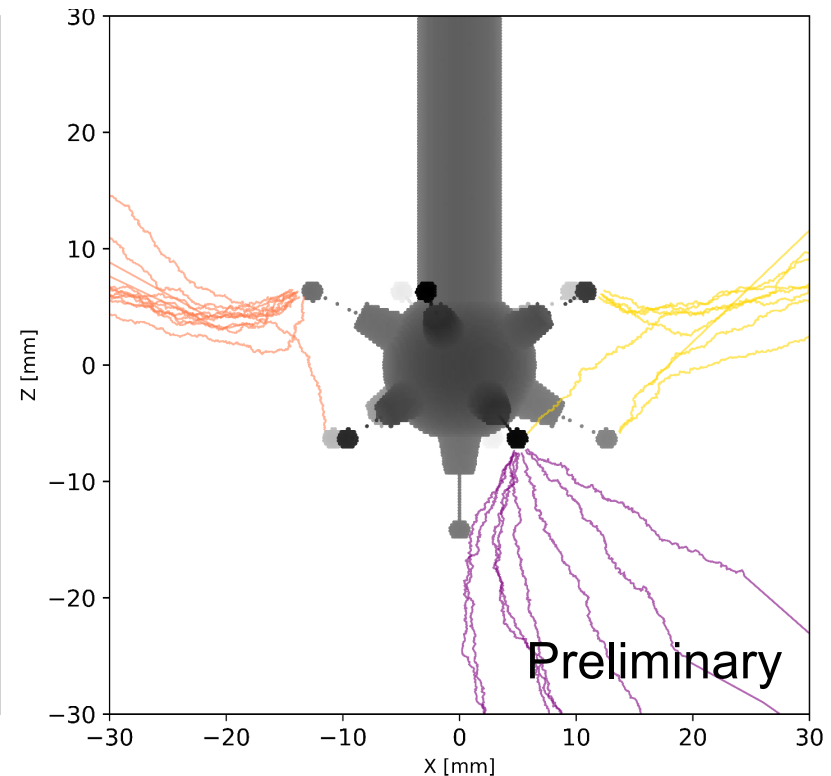
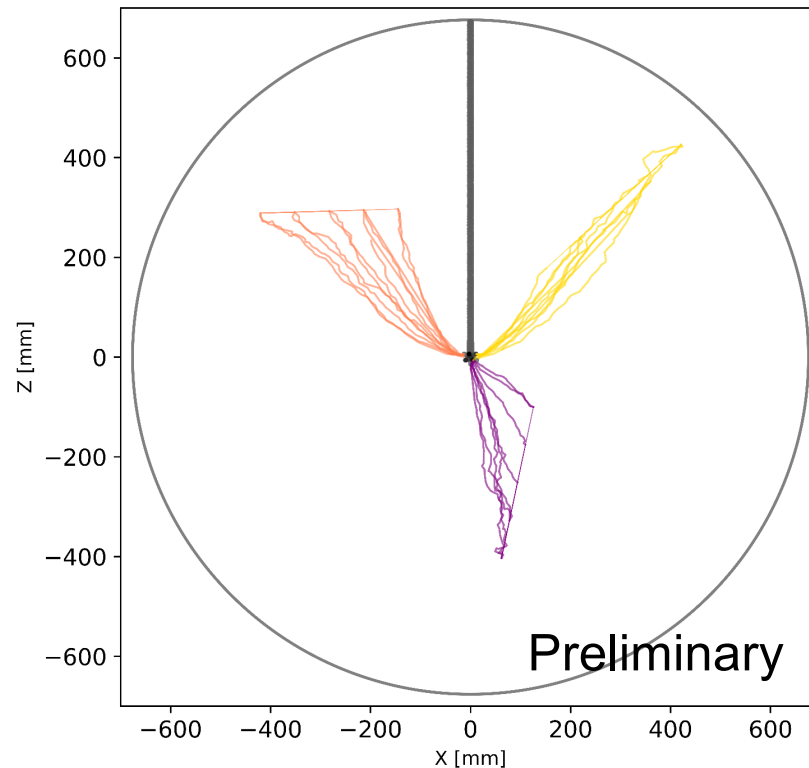






# ACHINOS: Directionality channel

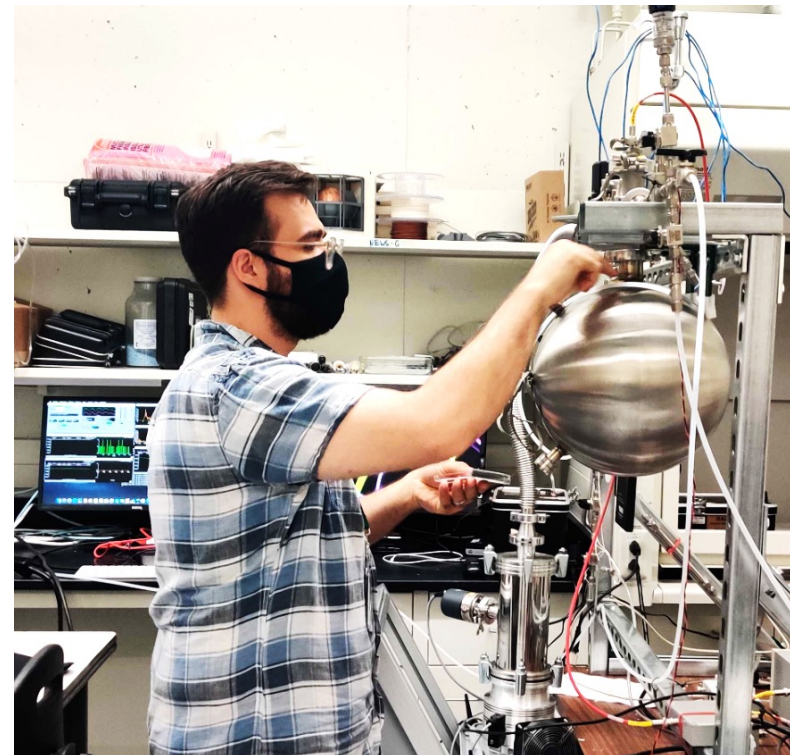
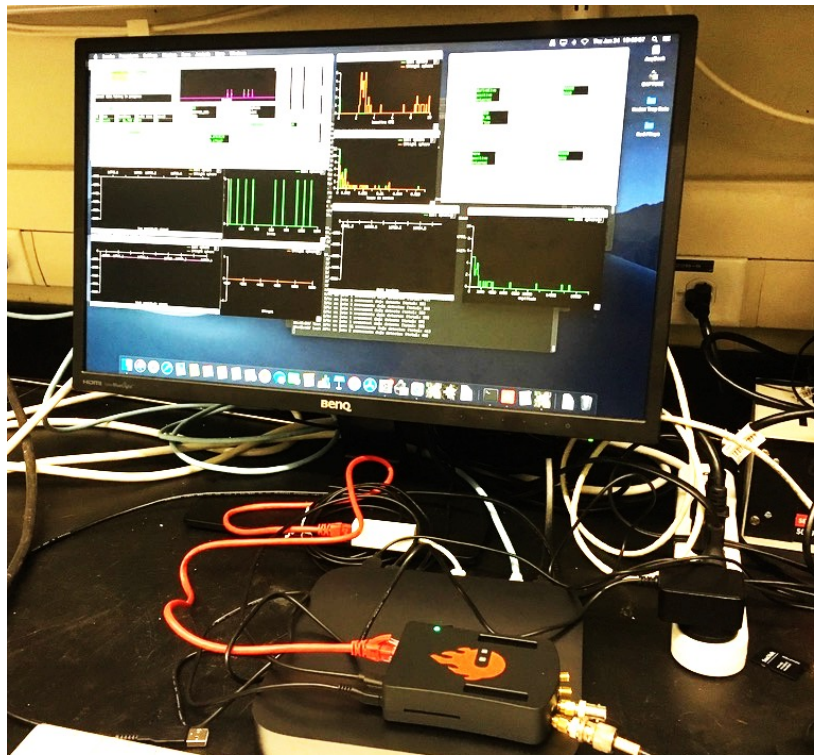
- Adding the directionality channel for the NEWS-G experiment
  - With the new sensor ACHINOS
  - Optimal detector conditions to increase the particle tracks
  - Using pulse parameters to reconstruct the tracks





# ACHINOS: Directionality channel

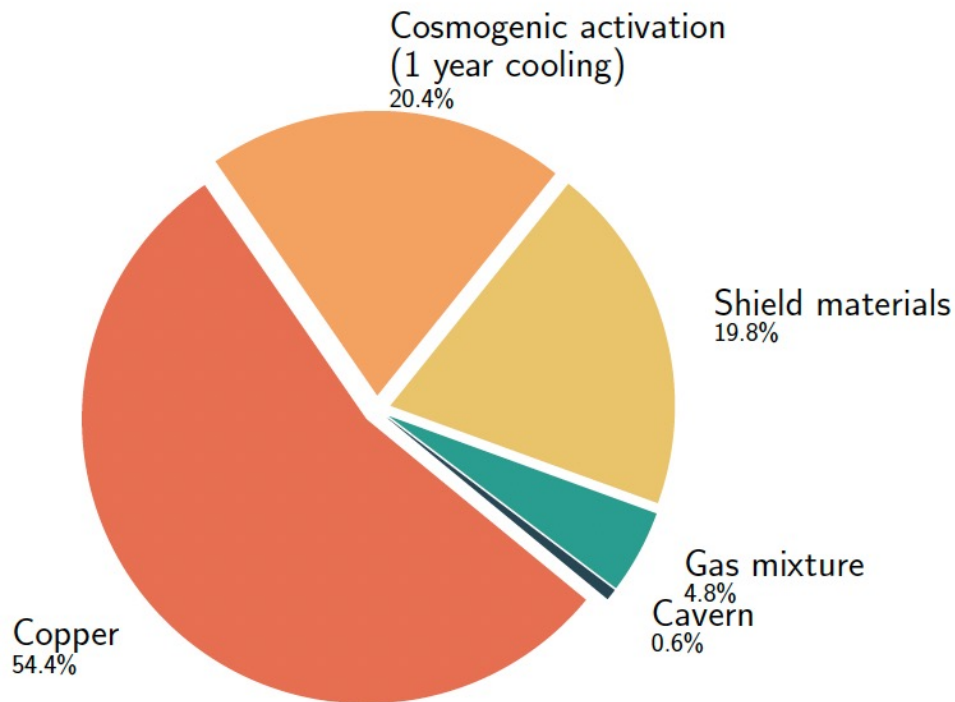
- Adding the directionality channel for the experiment
  - Setup operational to test the directionality
  - Investigate best electronics needed for 11 channels or more





# The Scientific Program

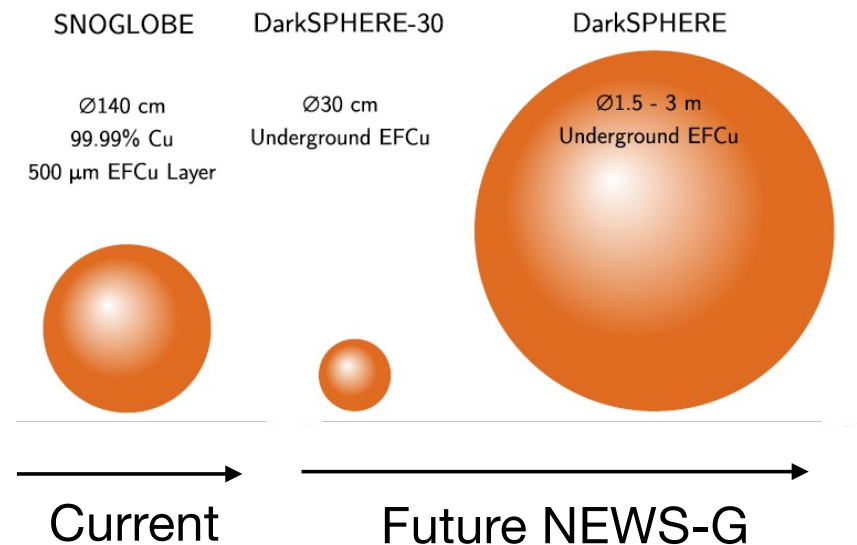
## Expected background S140



Despite efforts **Pb-210 in the copper** remains our largest background with **cosmogenic activation** from surface

## Future and on-going efforts:

- Fully Electroformed copper sphere
- Done underground
- Water-based shield

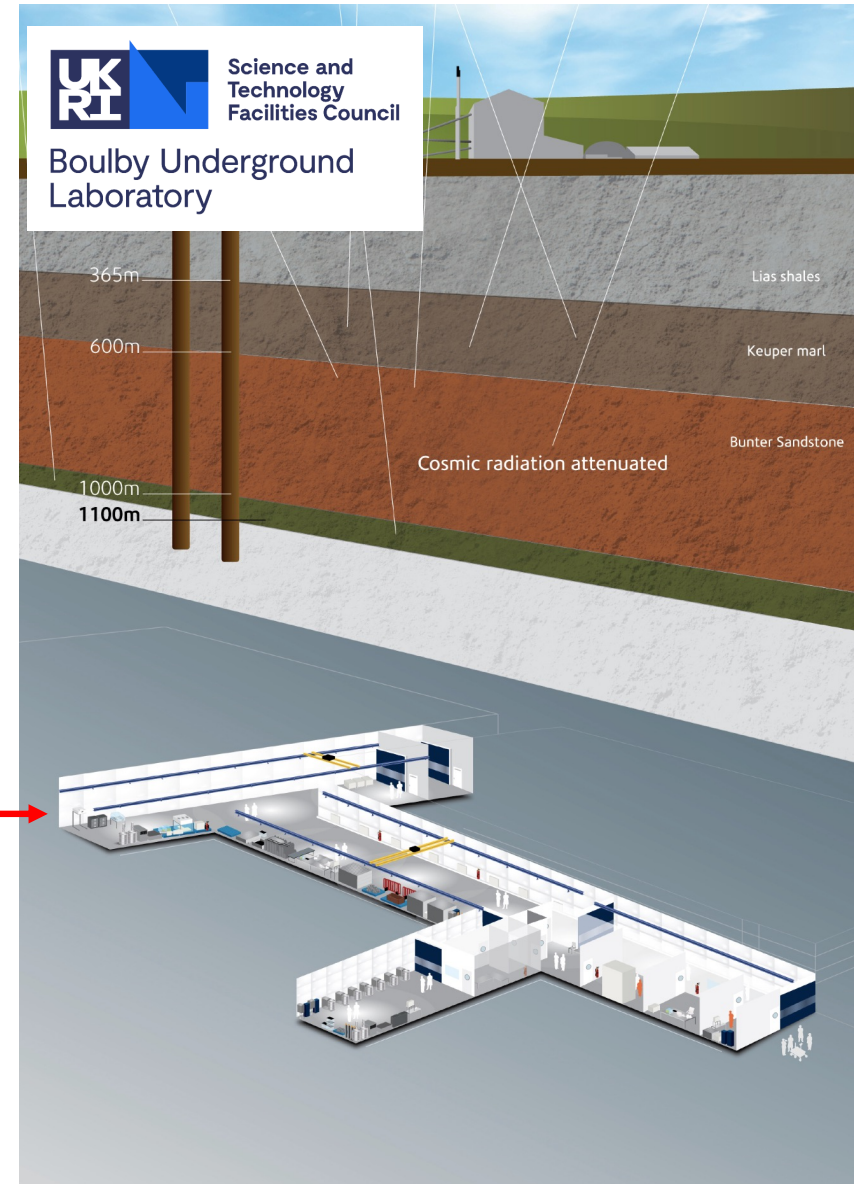
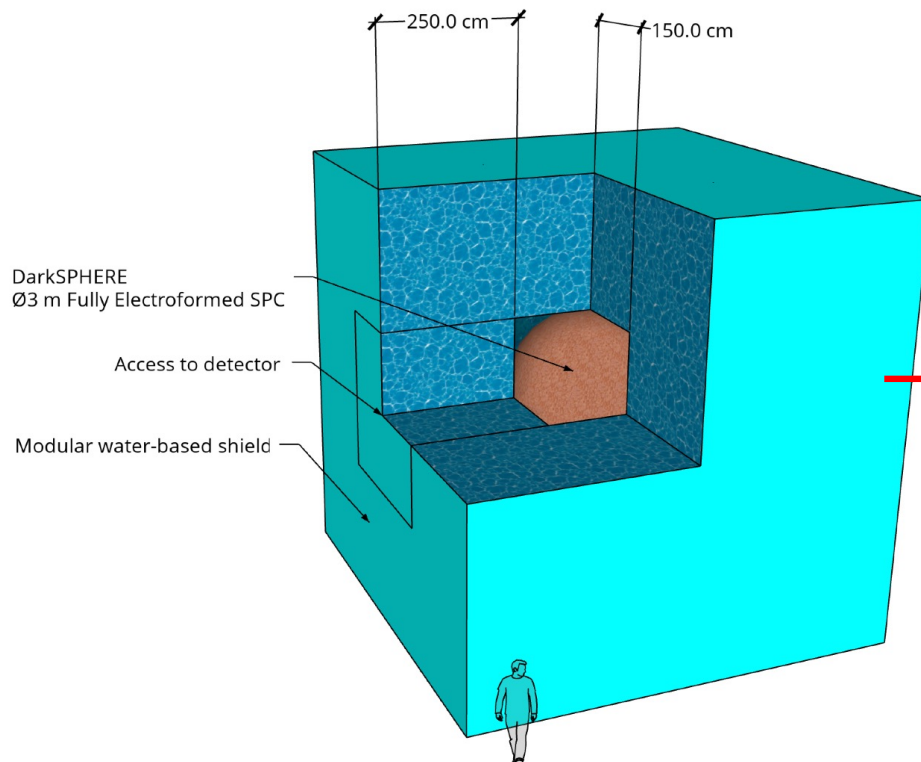






# DARKSphere program

- DarkSPHERE will use a water-based shield
- Pure water shield sufficient for background goal of **0.01 event/keV/kg/day** in ROI
- Boulby potential host for deep-underground science facility





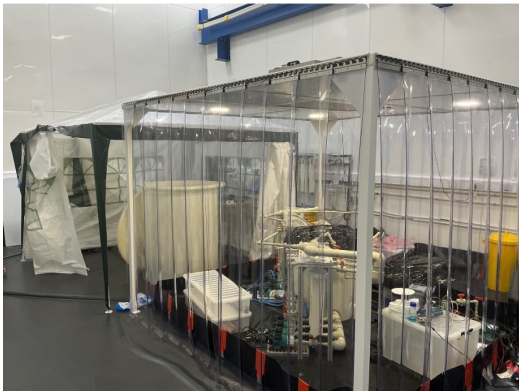
# Electroformed Copper in Boulby

Builds on ECuME (Electroformed Cuprum Manufacturing Experiment) R&D project

**ECuME** At SNOLAB

- Electroformed copper facility underground in Boulby being commissioned
- 30cm diameter sphere prototype to begin construction this year with world-leading physics potential!

ISO-6 clean room tent



Electroforming bath



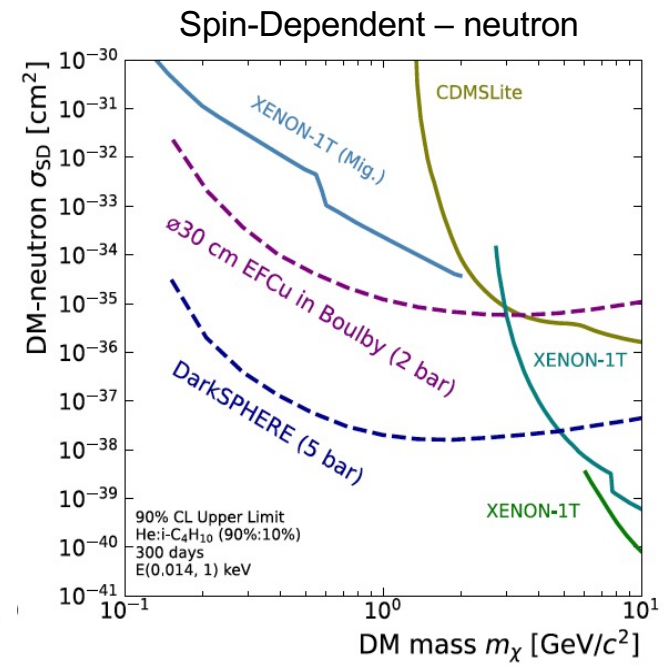
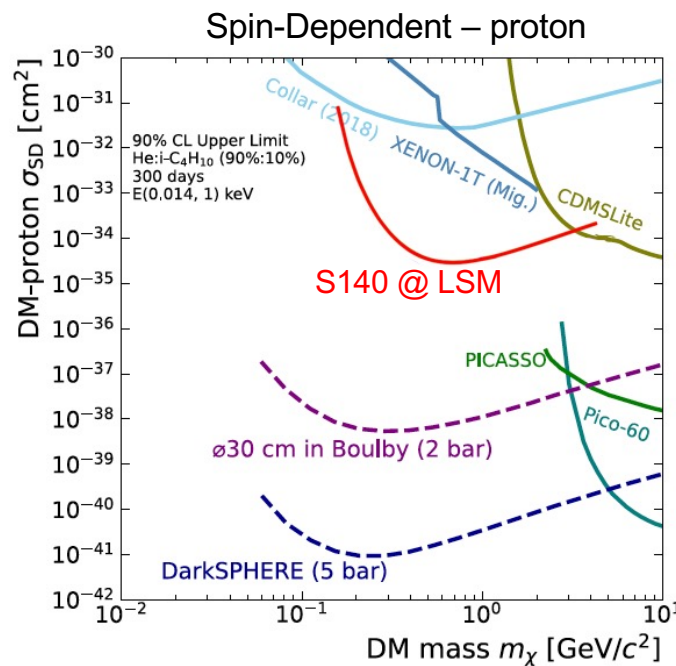
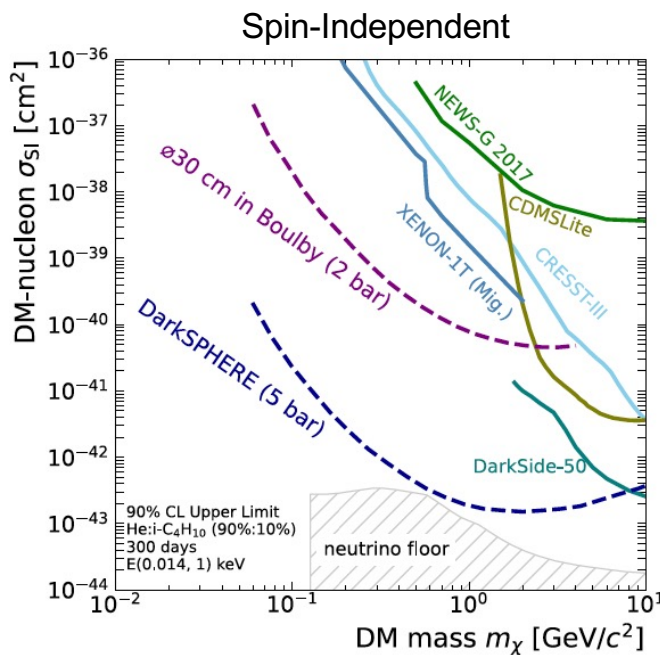




# DARKSphere Physics potential

- Operation with a helium–isobutane gas mixture ( $\text{He}:\text{i-C}_4\text{H}_{10}$ , 90%:10%)
  - 2 bar with 30 cm diameter EFCu sphere
  - 5 bar with DARKSPHERE

Goal: Reaching the neutrino floor in the DM-nucleon scattering cross section

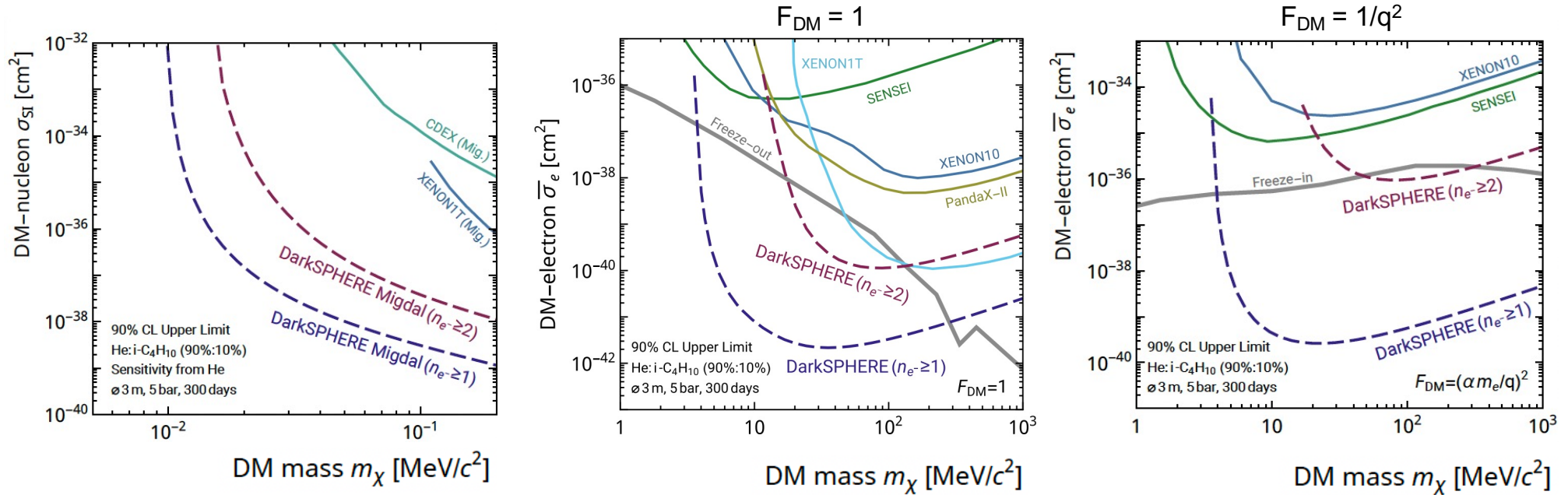






# DARKSphere (3m ø) Physics potential

- Enhanced sensitivity through MIGDAL effect in nuclear scattering
- Sensitivity to electron scattering through low threshold



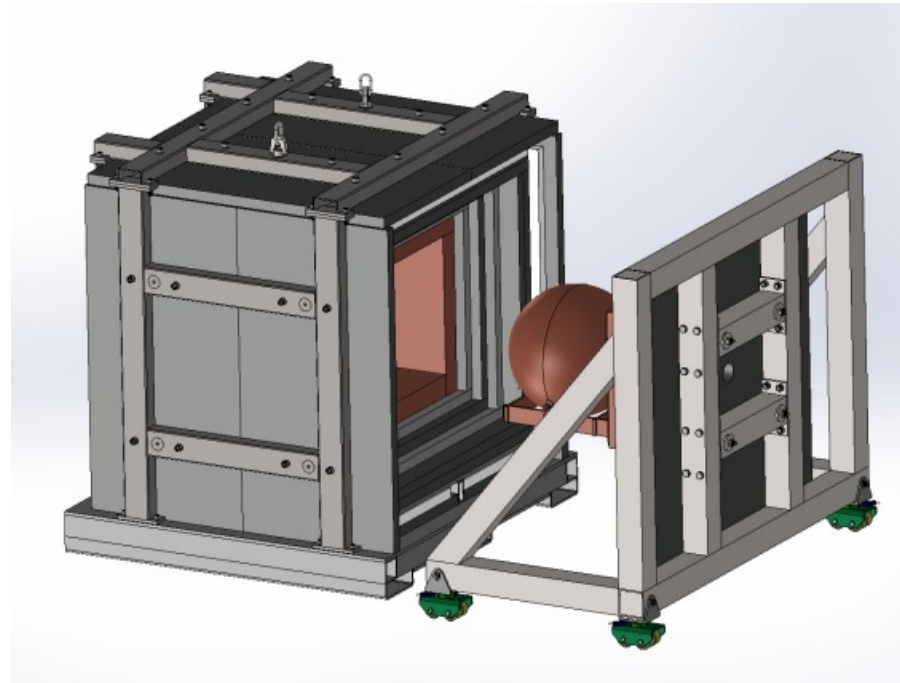
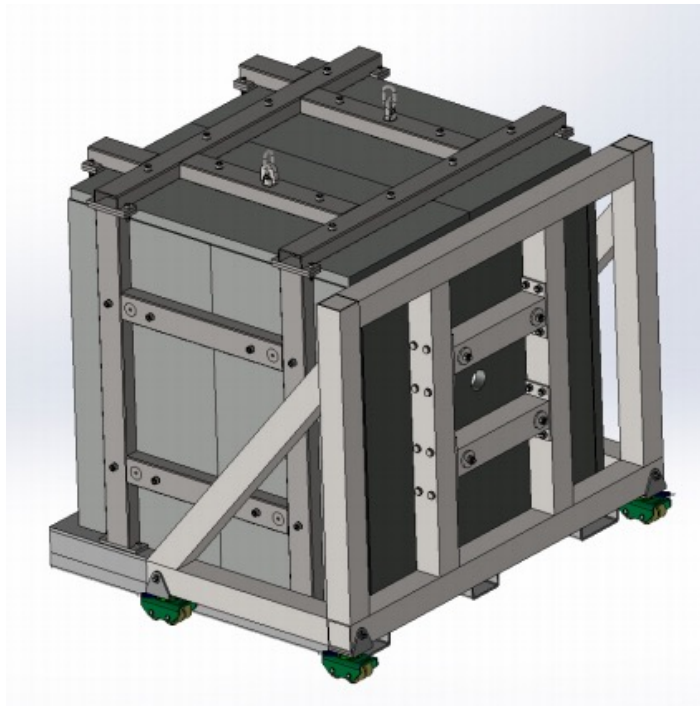


# Study of the $\text{CE}\nu\text{NS}$ with NEWS-G3

## Surface experiment NEWS-G3:

- Unique low-background facility at sea-level lab at Queen's University
- Environmental and cosmogenic backgrounds studies
- Layers of pure copper, polyethylene, and lead with active muon veto

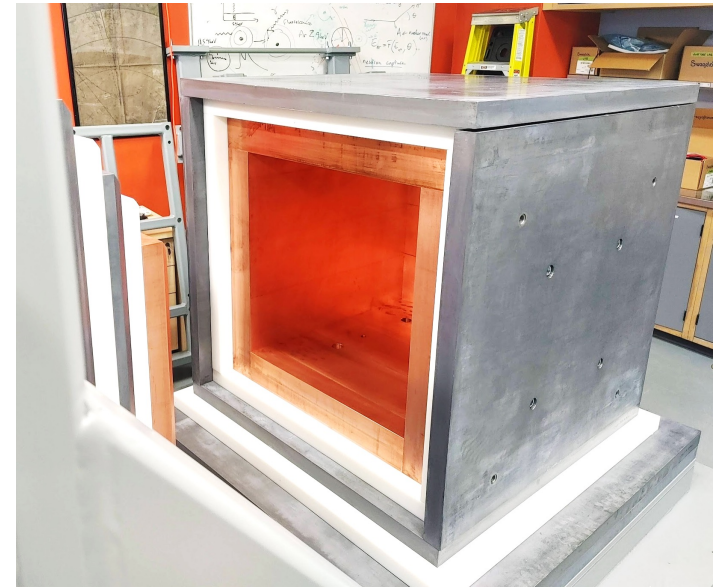
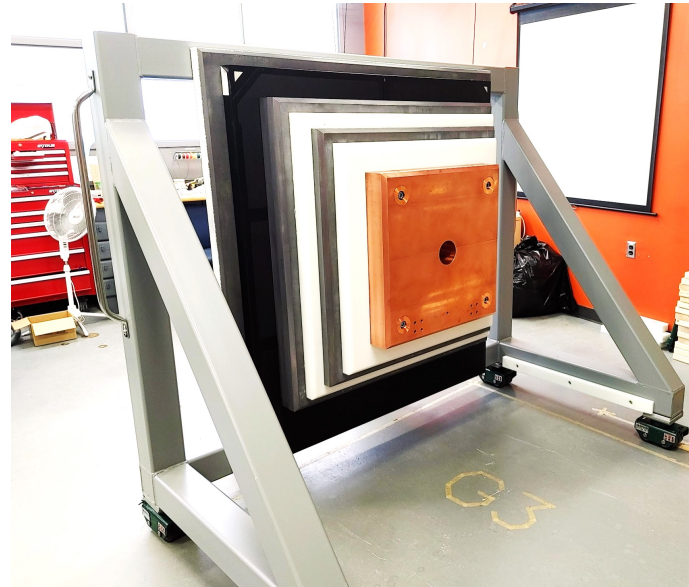
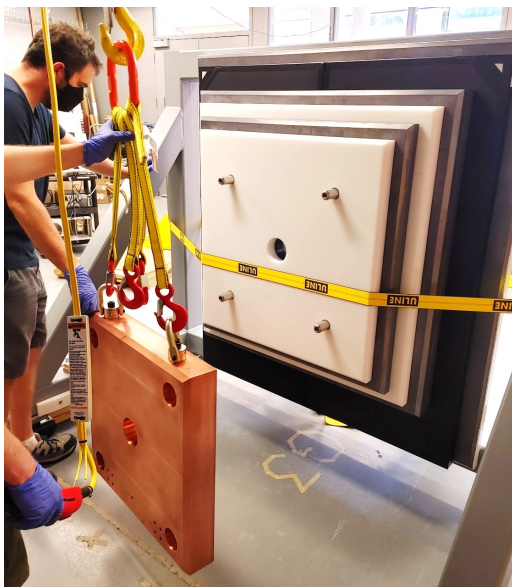
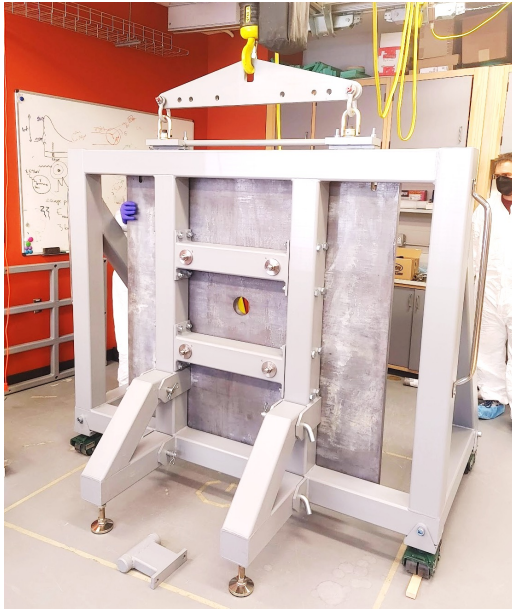
Current Design: (Compact shield + muon veto and fits a 60 cm  $\varnothing$  SPC)







# Study of the $\text{CE}\nu\text{NS}$ with NEWS-G3







# Summary

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Spherical proportional counters have a **number of strengths** in probing light DM and  $\text{CE}\nu\text{NS}$  candidates, enabled by instrumentation advances

- The next phases:
  - Upcoming **physics results** for SNOGLOBE at SNOLAB
  - Gas handling system with **radon trap system** and **LAS**
  - New **electronics for ACHINOS** and **add the directionality channel**
  - Fully **electroformed detector** construction to start this year
- Sensitivity to reach  $\text{CE}\nu\text{NS}$  floor and for many physics opportunities
- NEWS-G3 calibration setup to study the  $\text{CE}\nu\text{NS}$  at nuclear reactor
- Exciting physics programme ahead!