# Spherical Proportional Counters for low mass rare events detection

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On behalf of the NEWS-G Collaboration

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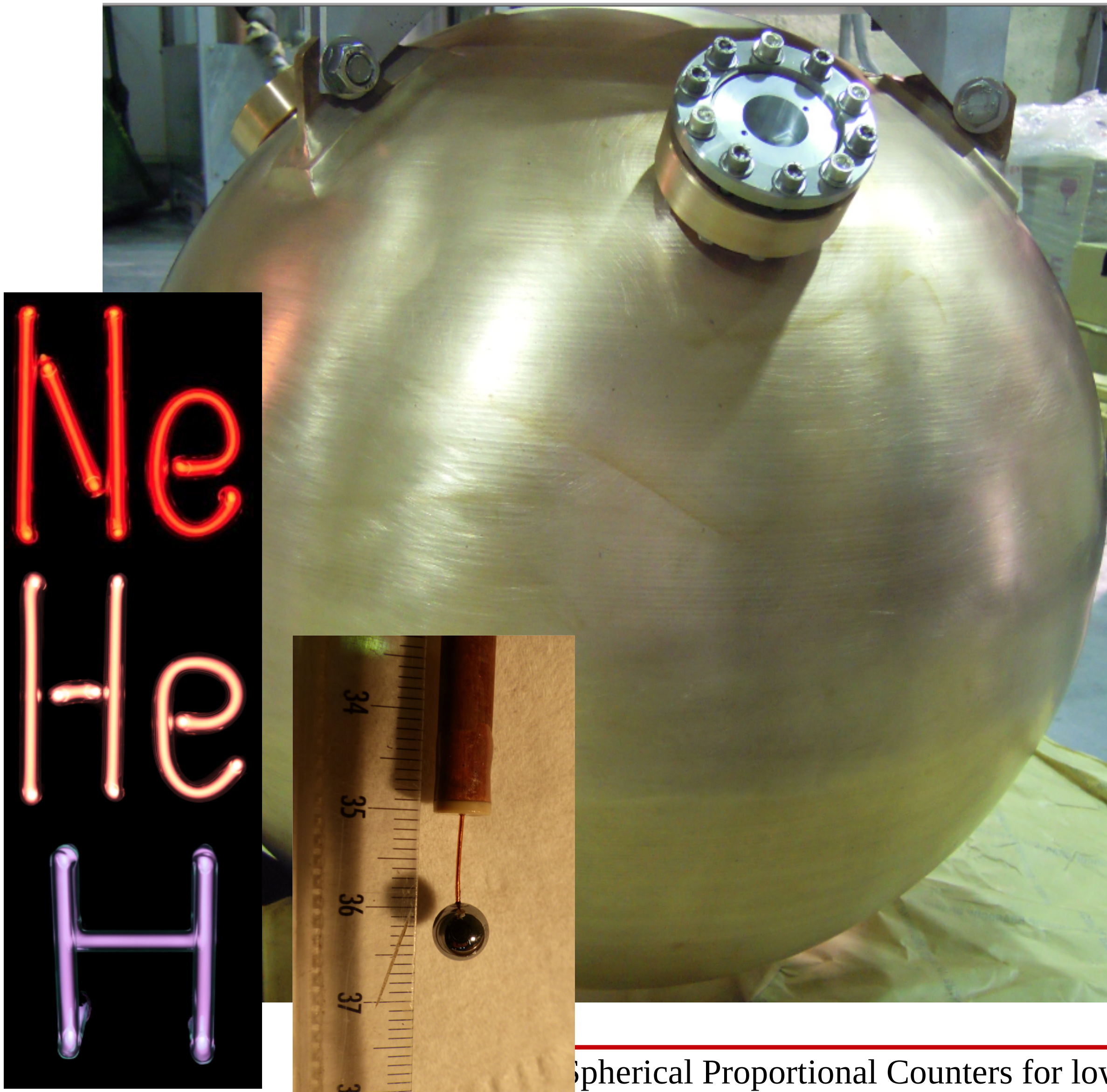
# Outline

- SPCs and NEWS-G
- Calibration tools
- Characterisation of the detector underground
- Results and future plans

# Spherical Proportional Counters

# Spherical Proportional Counters (SPCs)




Metallic vessel filled with a noble gas mixture, with a single high voltage anode/sensor

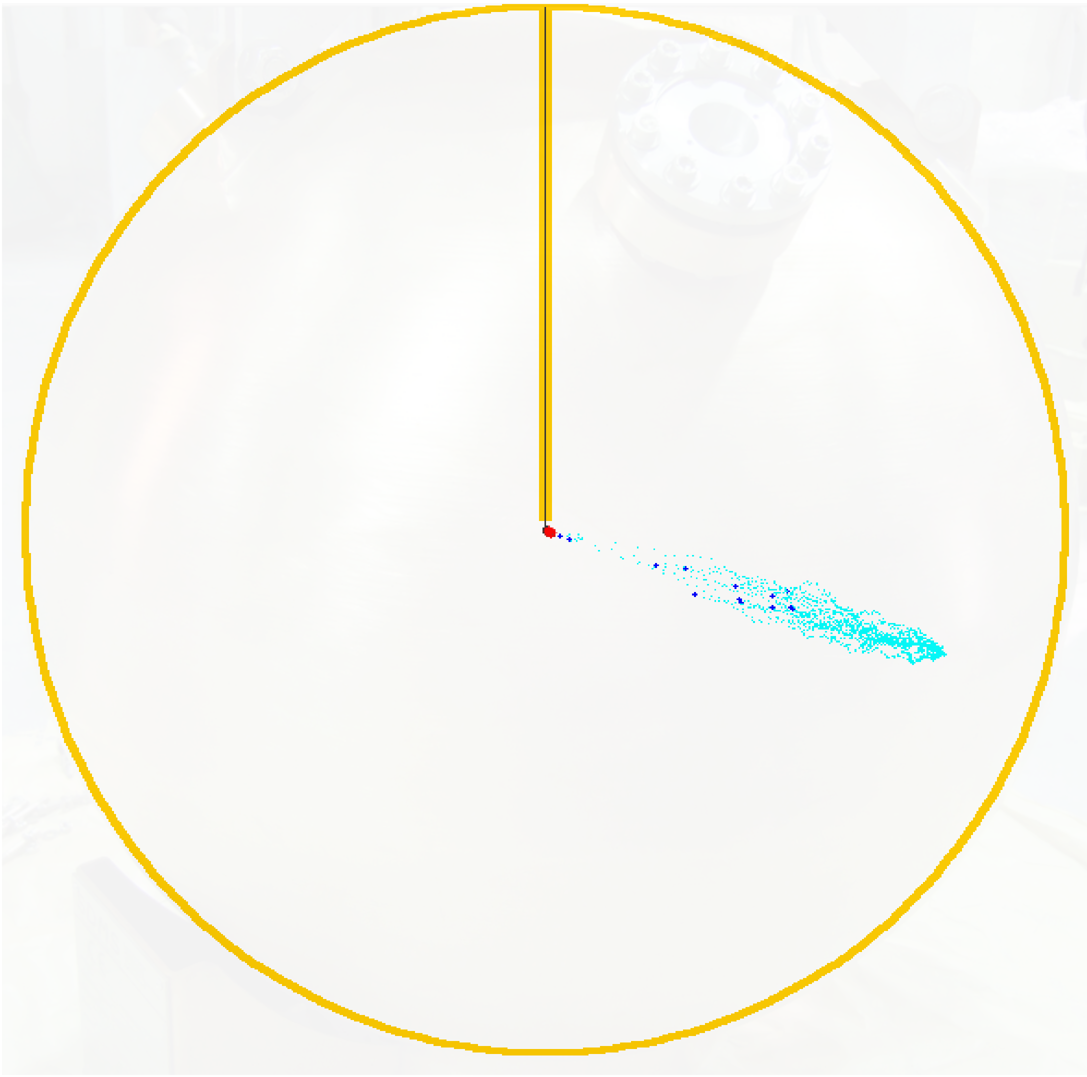
Low-A target atoms increases sensitivity to low-mass WIMPs

Easily exchanged target gas allows BG characterisation

Low capacitance and high gain provide excellent signal/noise

**Single ionization detection threshold!**

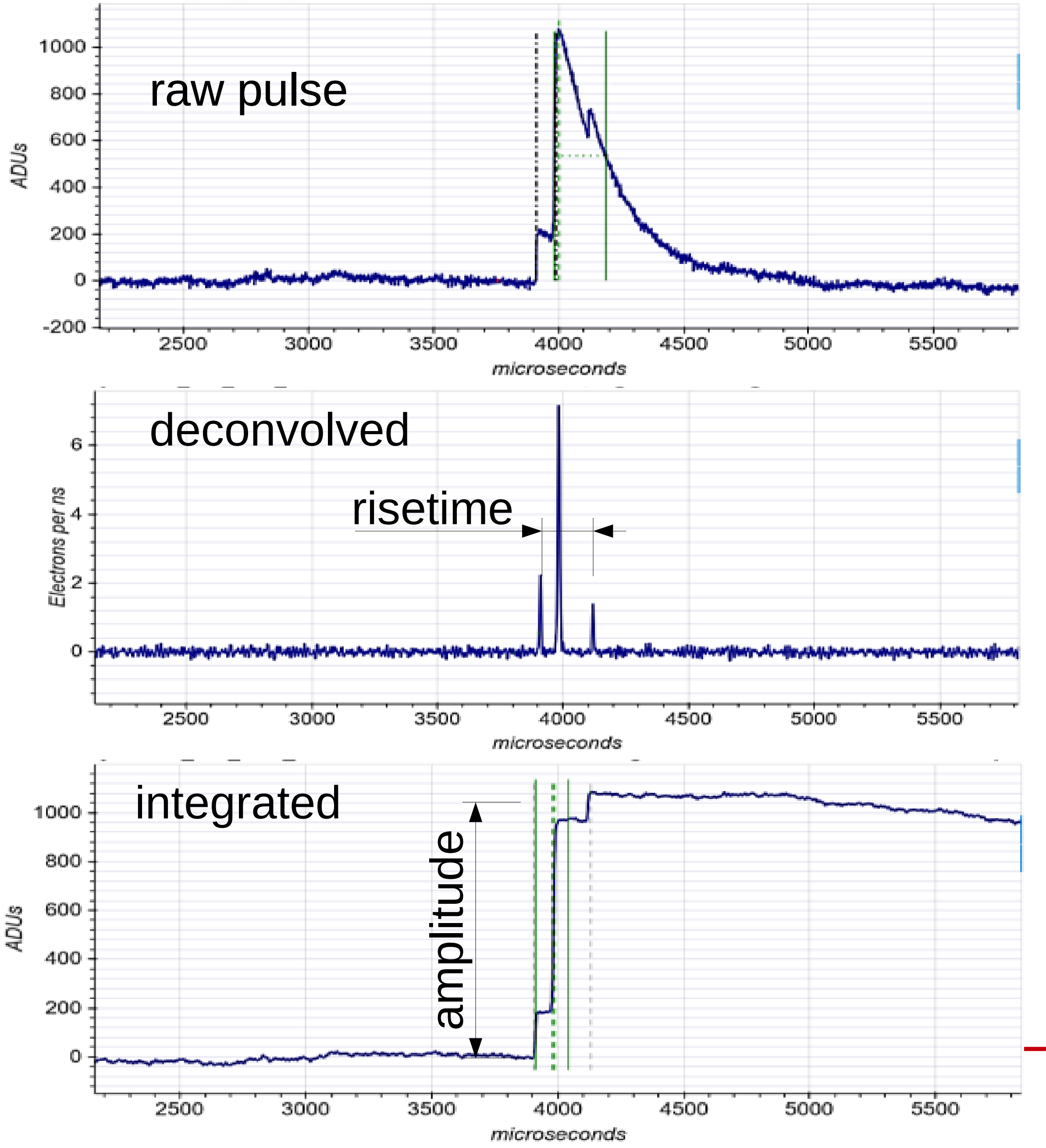
# Principle of Operation



- *Primary ionisation*:
  - nuclear recoils, point-like
- *Drift*:
  - $E \propto V/r^2$
  - r calculated "globally"
- *Avalanche*:
  - $E \propto V/r^2$
  - r calculated "locally"
- *Signal from positive ion drift*
  - time response related to field
- *Signal readout*:
  - charge amplifier
  - digitizer

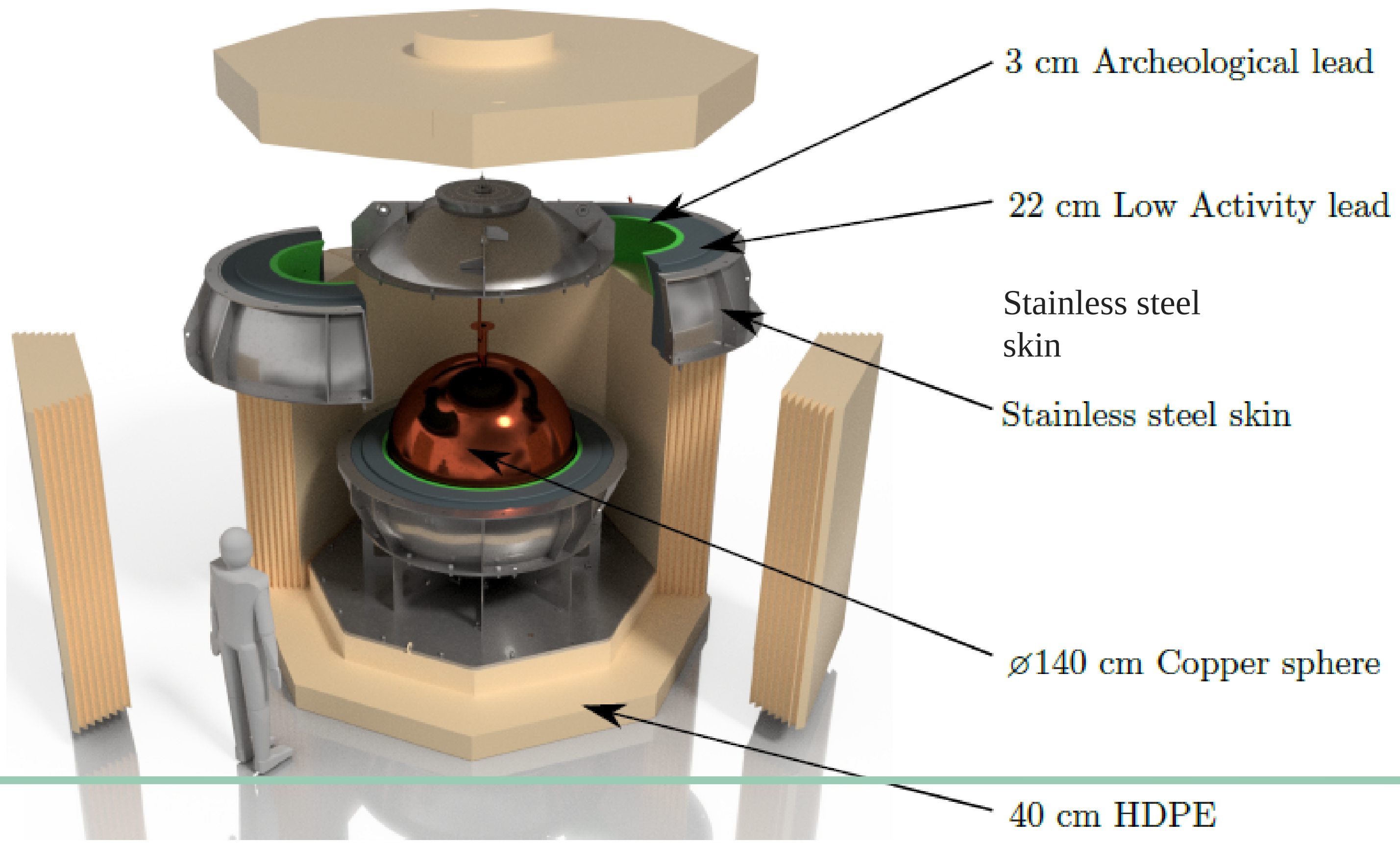
# Signal

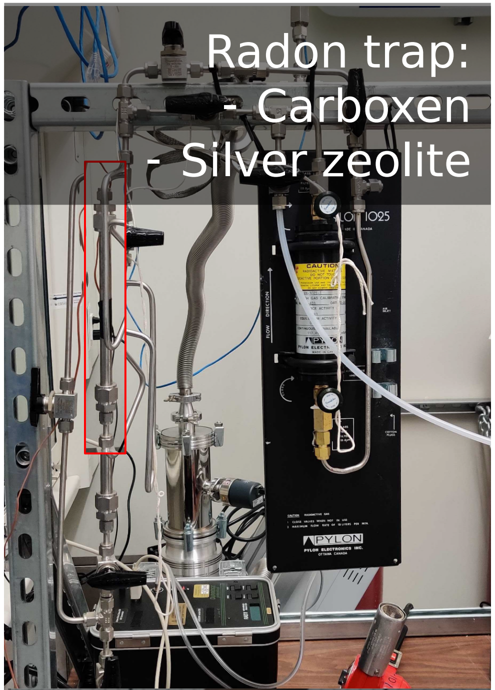
- Double deconvolution
  - amplifier response
  - ion drift
- Measurements
  - amplitude → Energy
  - risetime → diffusion/space distribution
  - electron counting (possible if high diffusion)



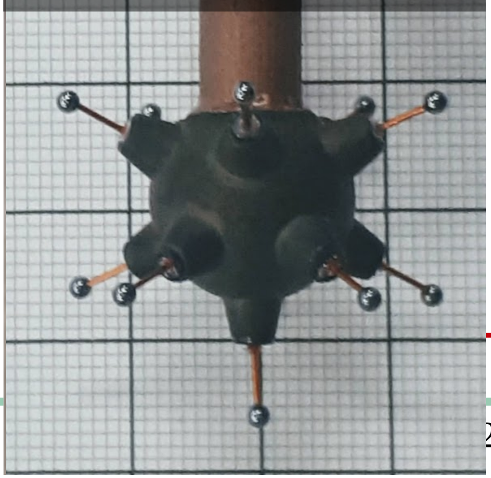
# SNOGLOBE at SNOLAB

- Radio-pure construction, multi-layered compact shield system
- Gas quality: contamination filter and radon removal, precise measurement of methane
- Multi-anode sensor for improved field more isotropic response




I. Katsioulas, Journal of Physics: Conference Series 1468 (2020) 0122058



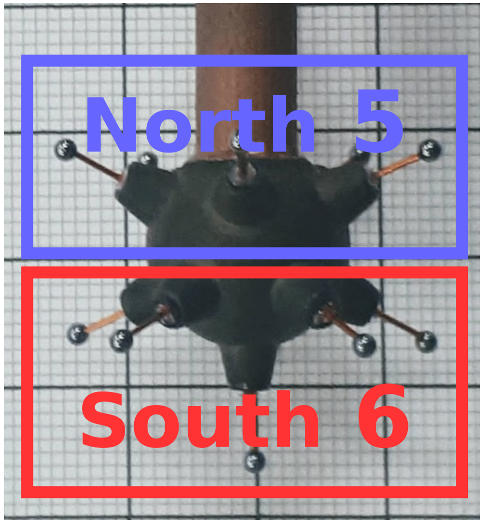
# Sensor readout

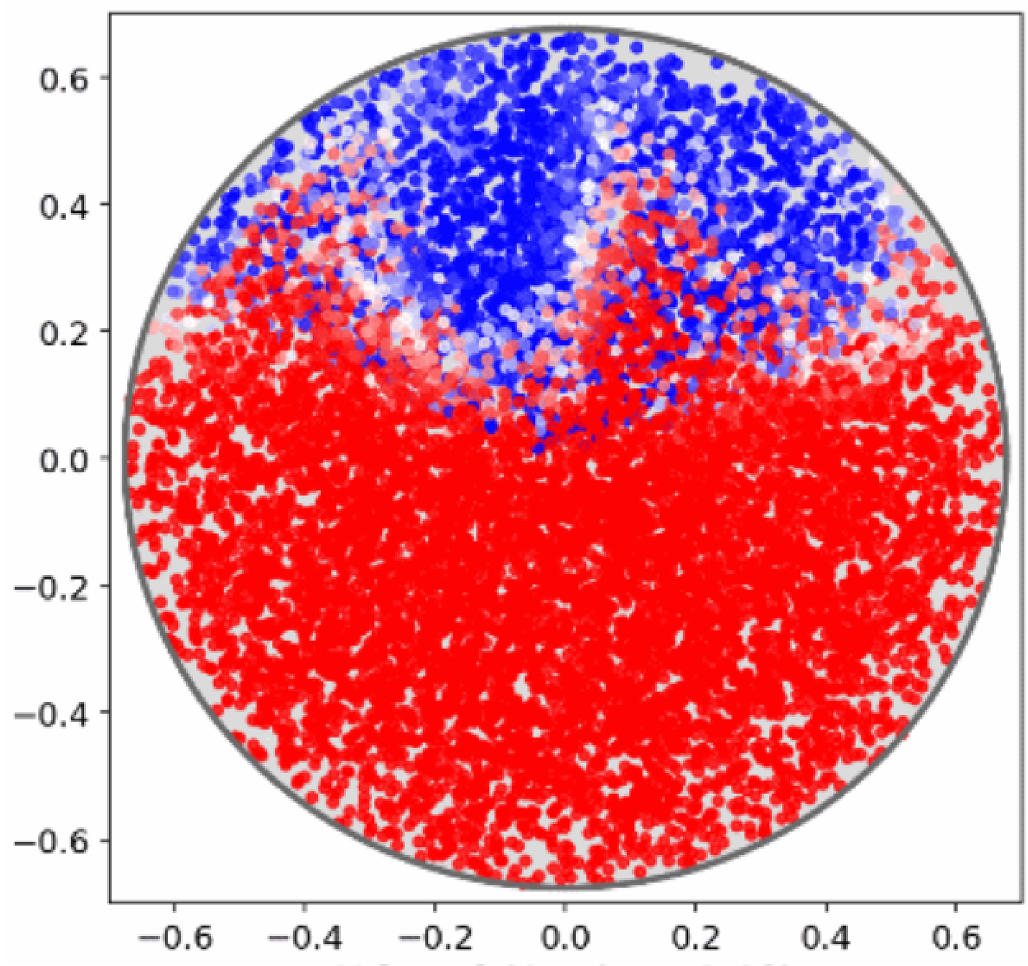
The 11-anode sensor is read out in two channels (north and south)

11-anode “achinos” structure allows better drift field at large radius, with similar gain (high field near anode)

The 11 anodes are bundled into 2 channels:
- “North” (rod side)
- “South” (away side)

The fiducial volume covered by the southern 6 anodes is approximately 70%



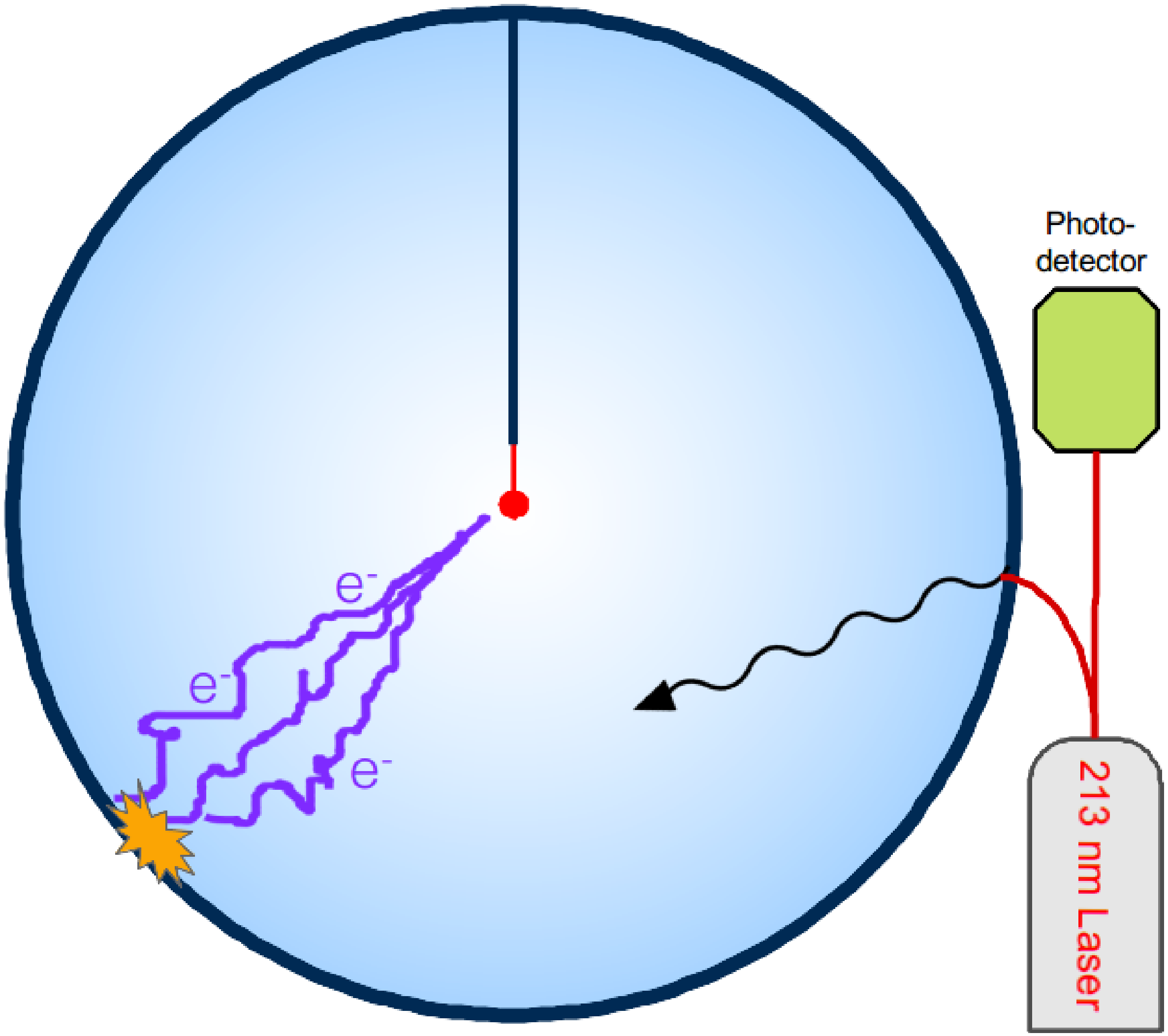



# Calibration tools

# Radioactive sources

- Fe55
  - 5.9keV peak
  - source windows on prototype spheres
  - not possible on high purity copper sphere
- Ar37
  - 2.8keV and 270eV
  - gaseous, uniformly distributed
  - cannot be removed/ cannot be used during rare event search
- AmBe
  - MeV neutrons
  - elastic nuclear recoils (same as WIMP)
  - possible tagging with liquid scintillator

# UV laser calibration




A **213 nm** laser shines into the sphere extracts photo-electrons from the inner surface of the vessel [1]:

Laser-induced calibration events are tagged with a photodiode
Does not create BG (only minor dead time)

Continuous operation during physics runs allows for monitoring of the detector response, changes in detector gain over time

Low intensity laser data also allows for measurement of the hardware trigger efficiency


[1] Q. Arnaud et al, Phys. Rev. D 99, 102003 (2019)

# Nuclear recoils from neutrons

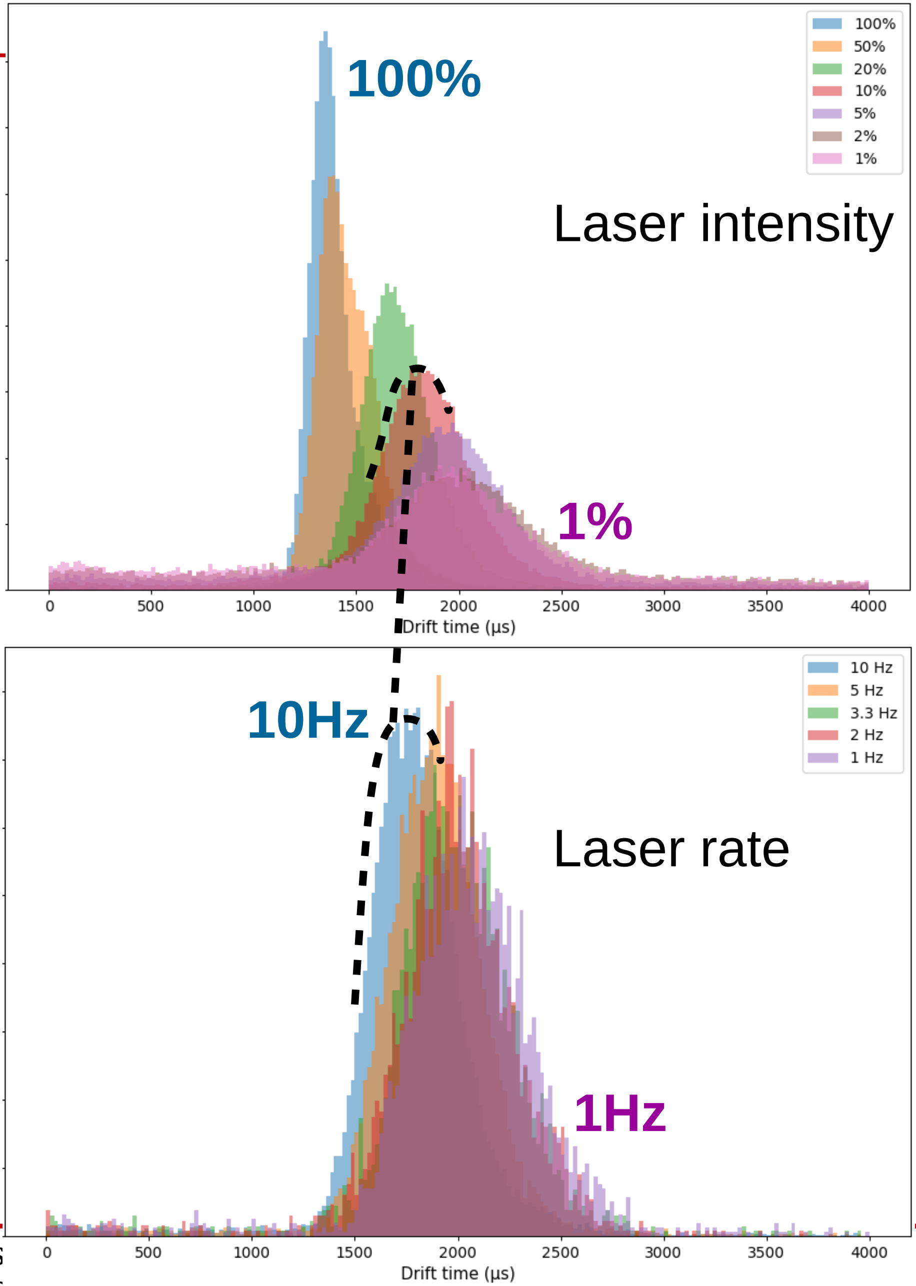
- Nuclear recoils are important calibration
  - WIMP like signal
  - different ionisation yield from gamma & electrons

    ***critical calibration for WIMP search ("Quenching Factor")***
  - point-like, even at higher energies
- Hard to calibrate
  - neutron scattering
  - low cross-section
  - wide energy distributions
  - tagging difficult at low energy
- **See following presentation by Neha Panchal**

# Characterisation underground

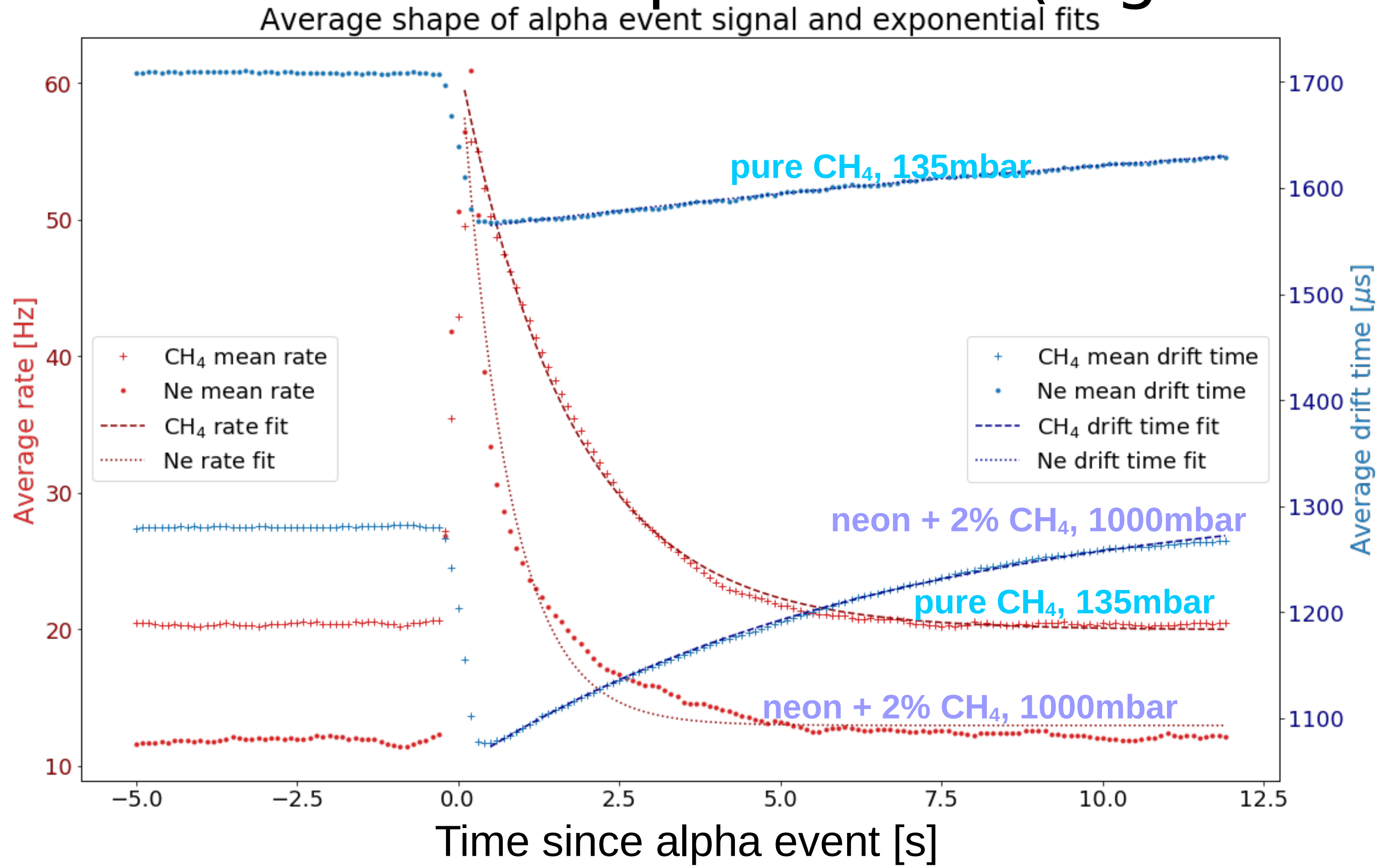
# Small charge dependence

- Drift velocity sensitive to small space charge
- Effect visible with changing laser intensity or repetition rate
- Number of primary electrons O(1-100)



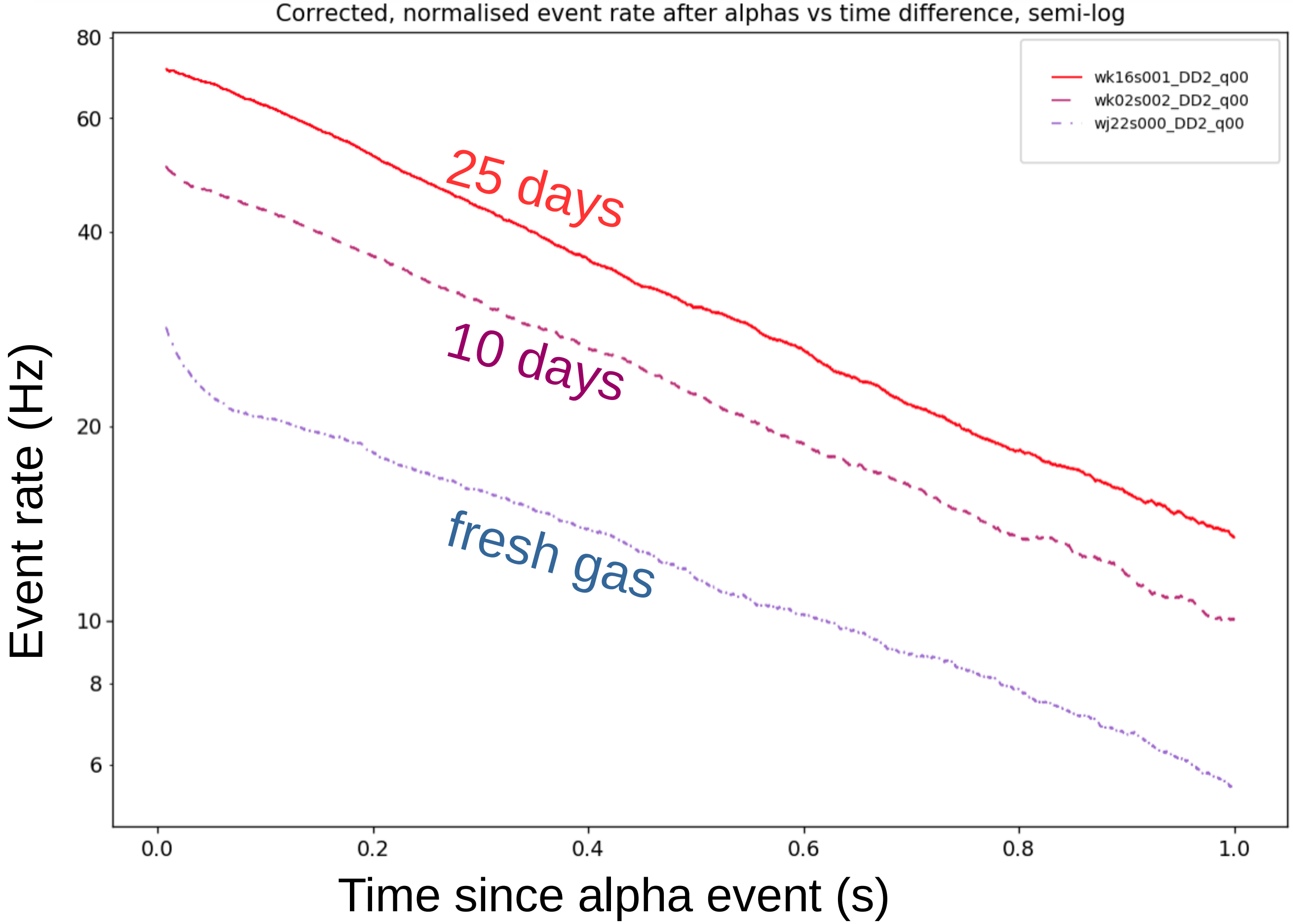
# Drift velocity vs space charge

- The drift time is strongly correlated to the time since the last alpha event (high energy)



# “Alpha tail”

- Alpha events are also followed by a trail of low amplitude (~1electron) events




<u>Likely explanation:</u>
Negative ions from electron capture
- rate of event increases with gas degradation.
- time scale consistent with ion drift time

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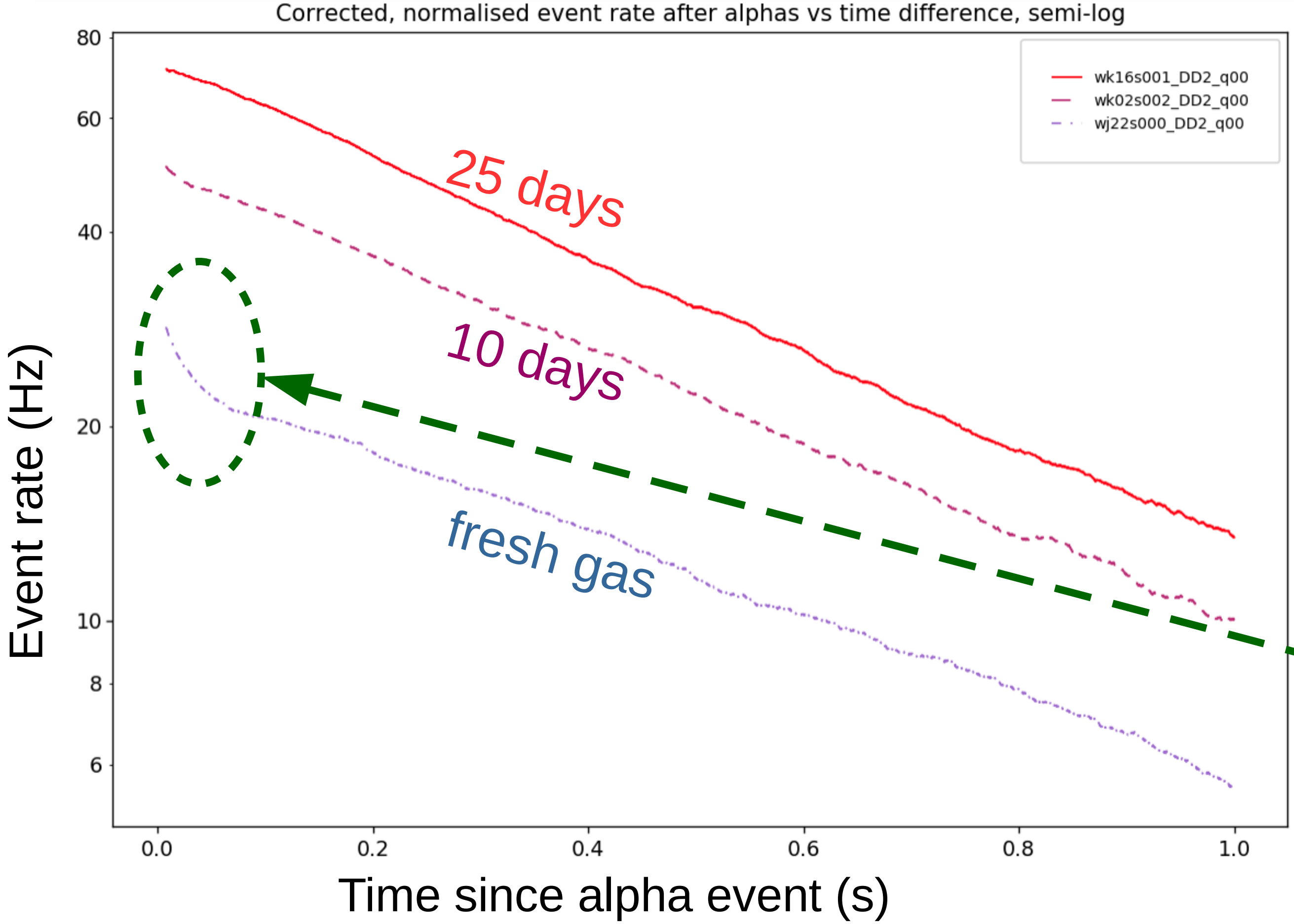



<u>Likely explanation:</u>
Negative ions from electron capture

- rate of event increases with gas degradation (air leak)
- time scale consistent with ion drift time

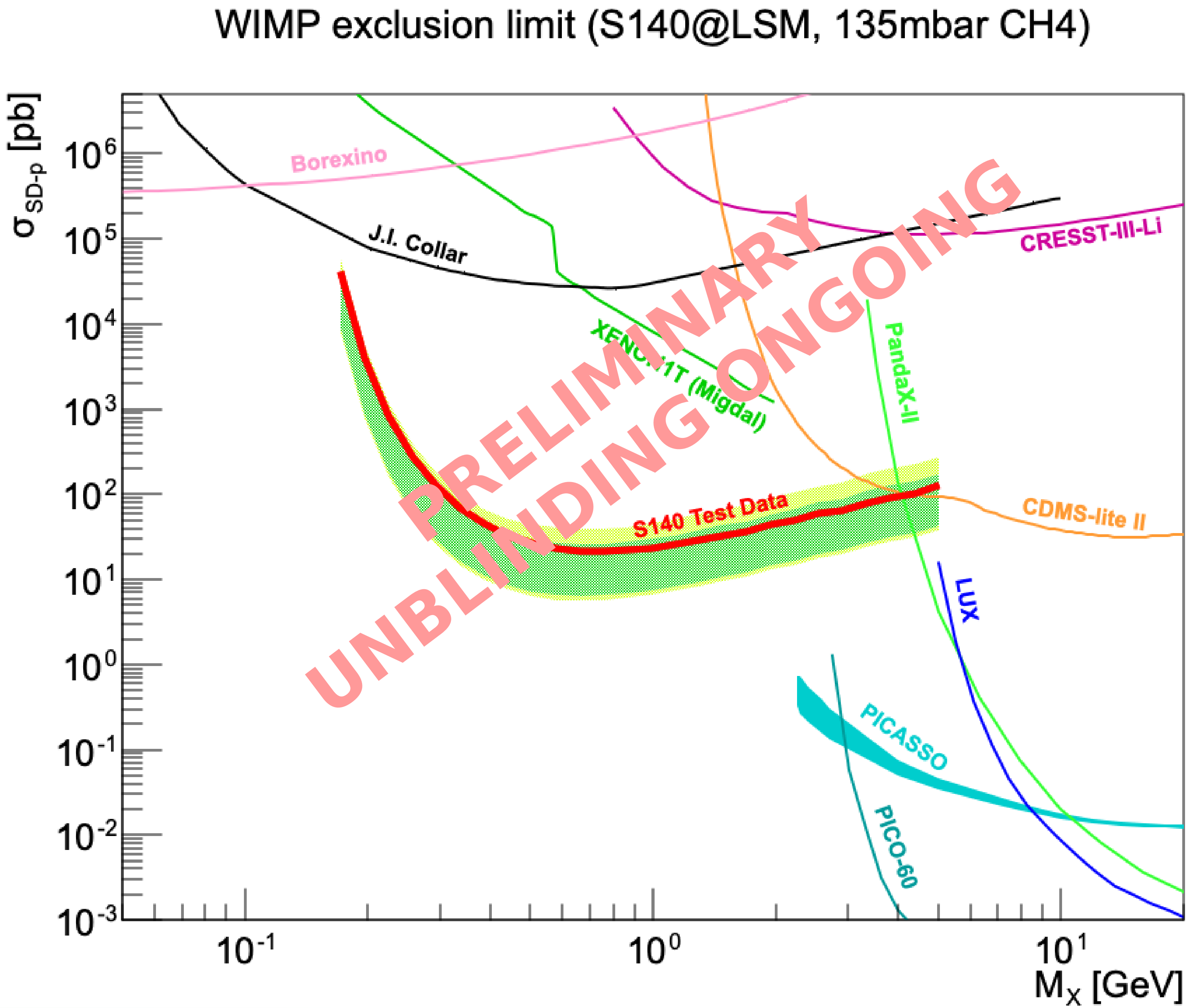
*Unexplained prompt correlation*
*Under investigation*

# Results and perspectives

# Preliminary results in pure CH4

Results with test data (~0.12 kg.days)

Profile likelihood ratio method used to calculate 90% exclusion limit on the existence of WIMPs



# Ongoing development

- Data taking at SNOLAB
  - improved noise and background
  - planned campaign with different target gases (methane, neon, helium)
  - improved gas purification
- G3: active shield for low BG measurements on surface
  - feasibility of coherent neutrino-nucleus elastic scattering (CEvNS) at nuclear reactor
- Improved sensor studies
  - multi-channel readouts
  - 3D printing with resistive material
- Improved gas conditions
  - higher pressure
  - ionisation yield studies for various gas mixtures

# Conclusion

- NEWS-G is operating an SPC at SNOLAB to search for light WIMPs
  - ***low mass WIMP limit in CH4 coming soon!***
  - *newer, cleaner data taking ongoing with other gases*
- Very simple detector, but careful characterisation is needed
  - Combination of UV laser, X-ray sources allow monitoring and calibration in situ
  - extra studies with smaller spheres
- Ongoing work to improve performance and expand applications

# Thank you for your attention

SNOLAB

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Subatech

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