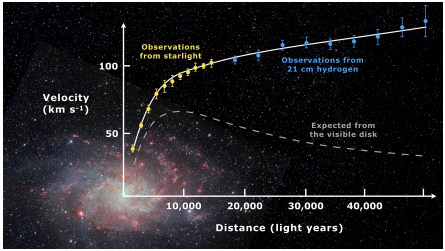
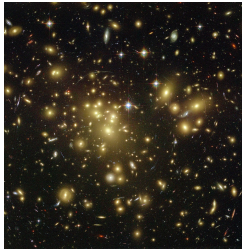
Searching for Light Dark Matter with NEWS-G

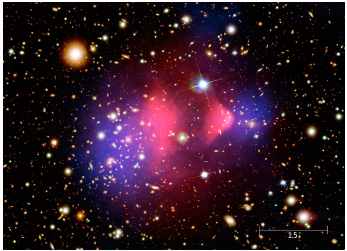
Tom Neep, University of Birmingham, on behalf of the NEWS-G Collaboration

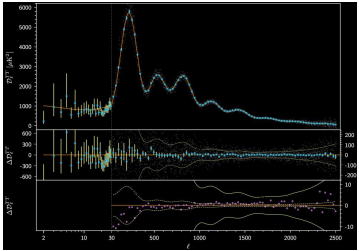
April 13, 2021

Evidence for Dark matter







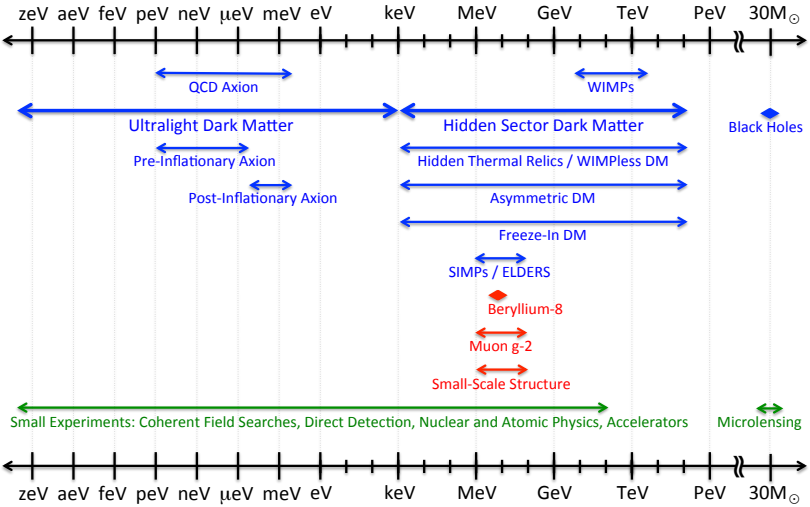


- Galactic rotation curves
- Lensing
- Bullet cluster
- ΛCDM

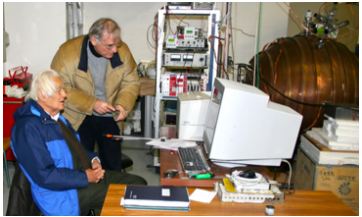
Dark Matter Landscape

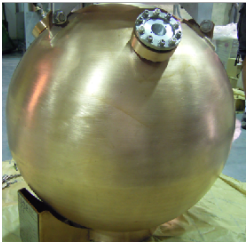
arXiv:1707.04591

Dark Sector Candidates, Anomalies, and Search Techniques



The NEWS-G Collaboration



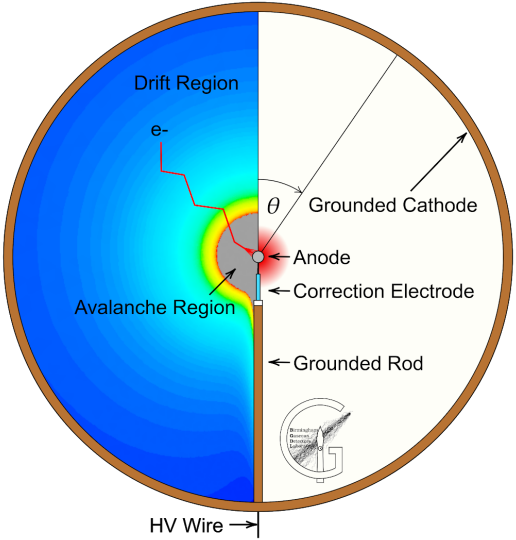


Spherical Proportional Counters (SPCs)

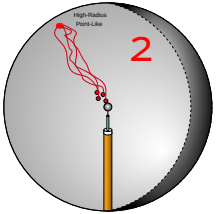
- SPCs consist of a grounded metalic shell, which acts as a cathode, a gas volume and a central anode sensor
- The anode is kept at a high voltage and supported by a grounded metallic rod
- A dark matter candidate will interact in the gas volume causing ionisation. Electrons will drift towards the anode in a radial electric field, before avalanching close to the anode, inducing a signal

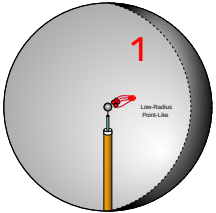
Advantages

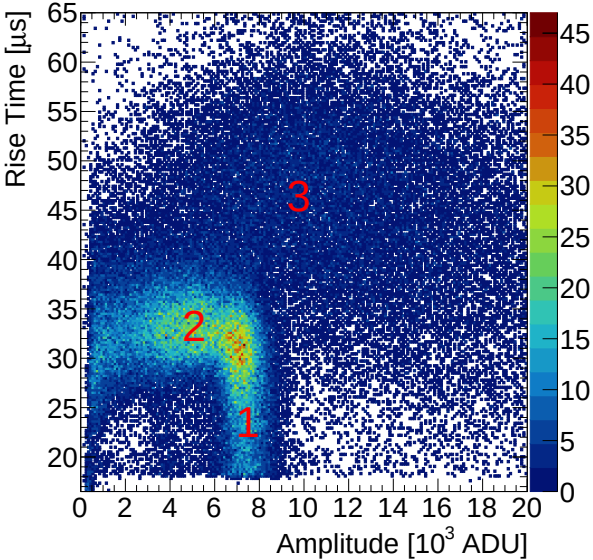
- Low capacitance
- High-pressure operation
- Optimal volume-to-surface ratio
- Easy to switch target gas

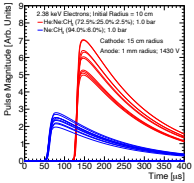


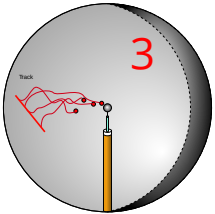
Pulse shape discrimination











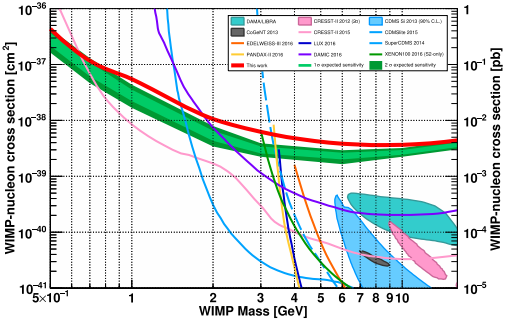
SEDINE @ LSM

Astropart. Phys. 97, 54 (2018)

- The first NEWS-G detector was called SEDINE and operated at LSM
- 60 cm diameter copper SPC filled with Ne+CH_4 (0.7%) at 3.1 bar [9.6 kg · days]
- Set world leading limits on "WIMP-like" dark matter with $m_{\chi^0} < 650$ MeV
- Limits have since been surpassed
- Main background from decays in the copper sphere

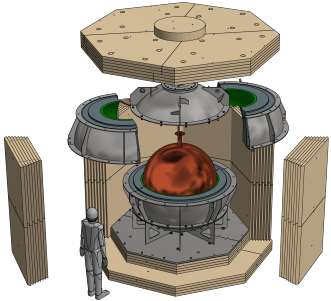
How to improve?

- Longer exposure and larger mass
- Lower backgrounds
- Better signal/background discrimination
- Lighter targets



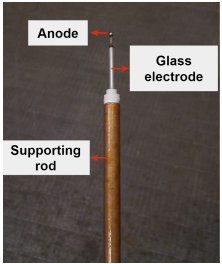
SNOGLOBE @ SNOLAB

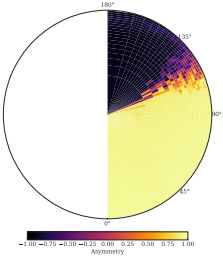
- The current NEWS-G SPC is called SNOGLOBE. This will operate at SNOLAB in Canada having previously operated at LSM.
- Several improvements over SEDINE
- 140 cm diameter $\rightarrow$ **New technology needed to collect charge at edge of detector**
- 4N Aurubius Copper (99.99% pure) **with 500μm electroplated copper** inner surface

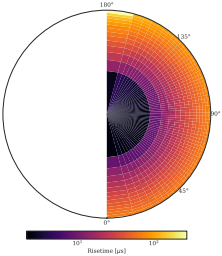


ACHINOS

- One challenge of a larger detector is ensuring that the electric field is strong enough at the edges of the detector to collect all charge deposited
- Using a single anode sensor, the electric field strength is coupled to the gain of the detector
- To overcome this limitation, the ACHINOS was developed
- An additional advantage of such an sensor it is allows coarse directional readout







Electroplating

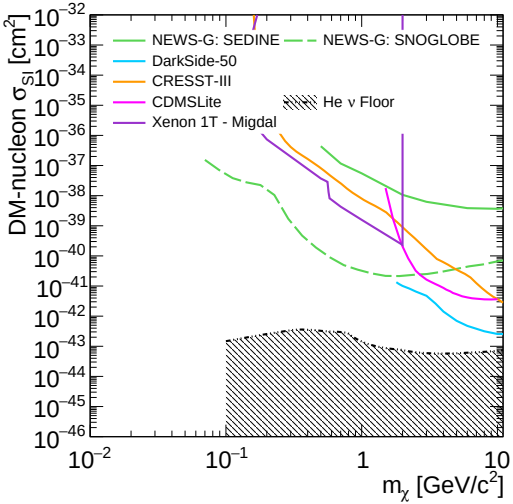
NIM A 988 (2021) 164844

- The largest background in the previous iteration of the analysis was from 210Pb decays in the copper sphere
- In addition to using 99.99% pure copper, the inner surface of the sphere has been **electroplated**
- A 500 μm layer of pure copper has been plated on the inner surface of SNOGLOBE
- Rate of copper $\approx$ 36 μm per day
- Expect to reduce background rate by more than a factor of 2

SNOGLOBE projection

SNOGLOBE

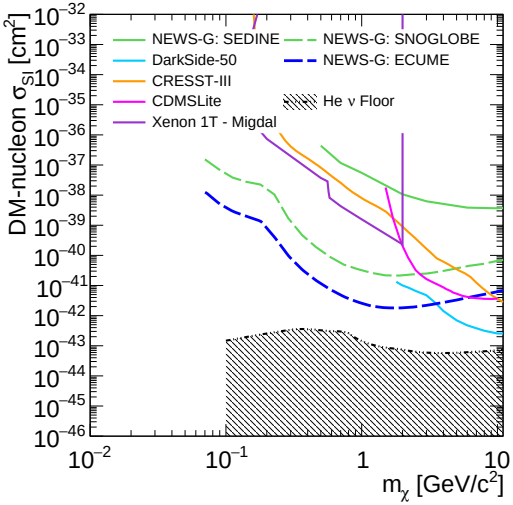
- Expect to improve sensitivity by several orders of magnitude and set limits down to 100 MeV
- The detector is now in position at SNOLAB
- Commissioning and data taking to start this year (delayed due to COVID)



The Future: ECUME & DarkSPHERE

ECUME

- Despite the electroplating, we still expect the largest background with SNOGLOBE to come from decays in the copper sphere
- The ECUME project aims to build a fully electroformed detector underground



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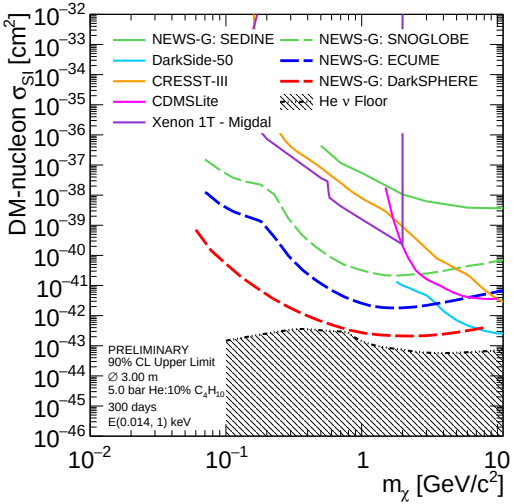
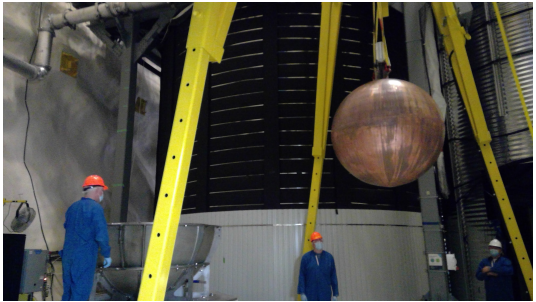
DarkSPHERE

- Proposal to build a 3m diameter fully-electroformed detector
- Will operate with He and isobutane
- We hope to build and operate this detector at Boulby Underground Lab.
- An opportunity for world leading dark-matter experiment in the UK!!



Summary

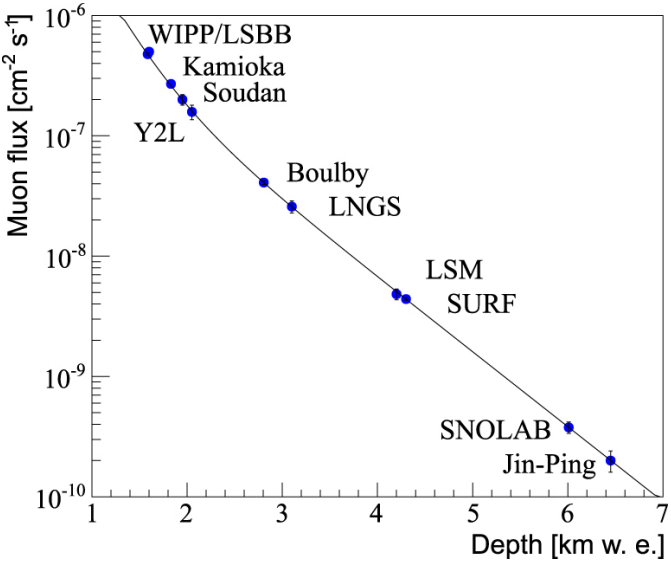
- The NEWS-G Collaboration is searching for light dark matter using spherical proportional counters
- SNOGLOBE currently being commissioned in SNOLAB
- Aiming to set world leading limits on masses below 1 GeV
- An exciting year ahead!



Back-up

Labs

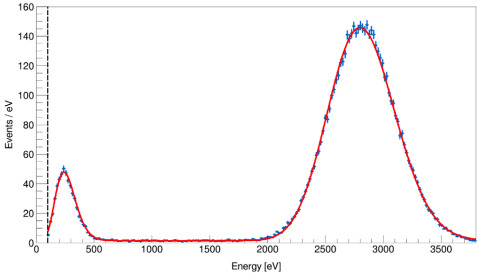
J.Phys. G43 (2016) 013001

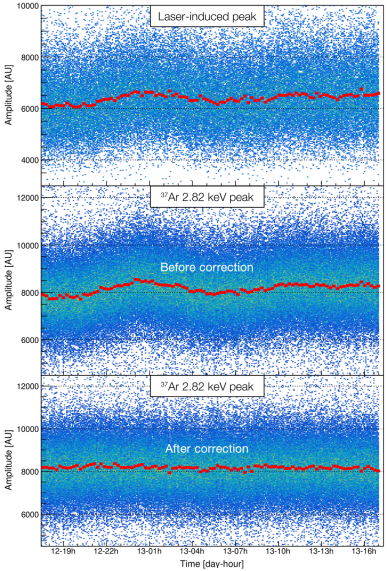


Monitoring & Calibration

Phys. Rev. D 99, 102003

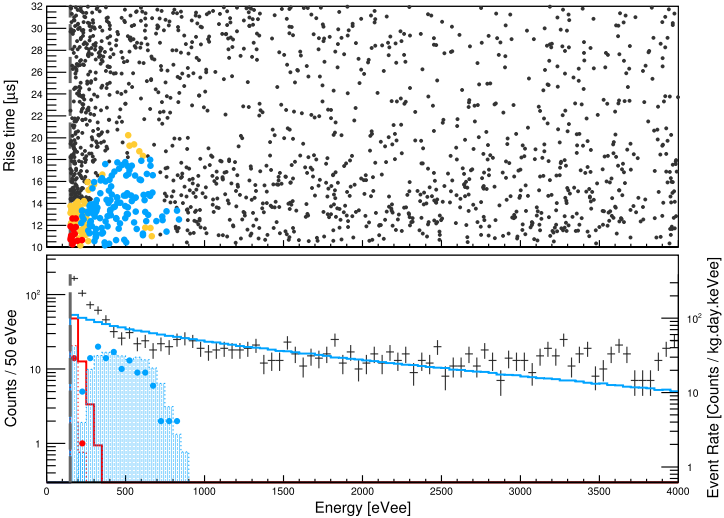
- Detector stability is monitored using a laser system
- Can be used to calibrate the detector
- ^{37}Ar calibrations are performed at the end of runs





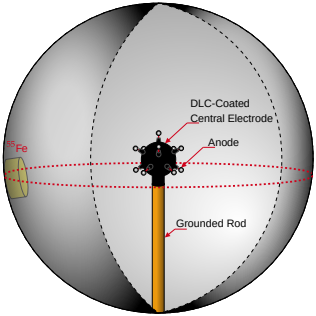
SEDINE analysis

Astropart. Phys. 97, 54 (2018)



DLC ACHINOS

JINST 15 (2020) 11, P11023



- Studied achinos ϕ dependence for **JINST 15 (2020) 11, P11023**
- 3D printed DLC sensor, 11 1mm diameter anodes in 30cm diameter SPC
- Here an ^{55}Fe source has been moved around the detector (at the same latitude)

- Gain changes versus ϕ
- Lines up with which anode the source is closest too
- Gain variation is well reproduced by the simulation!
- We can show with simulation this can be corrected by applying different voltages to each side of the achinos
- **See P. Knights talk for more about simulating SPCs!**