



UNIVERSITY OF
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Gas Property Studies for DarkSPHERE at Boulby Underground Laboratory

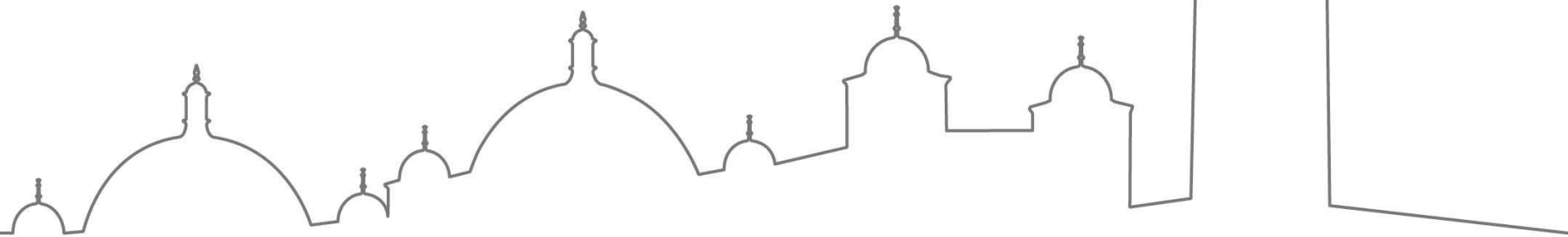
P. Knights, I. Manthos, L. Milligan, L. Millins, K. Nikolopoulos, G. Rogers, P. Walters

21/10/2025

UK HEP Forum

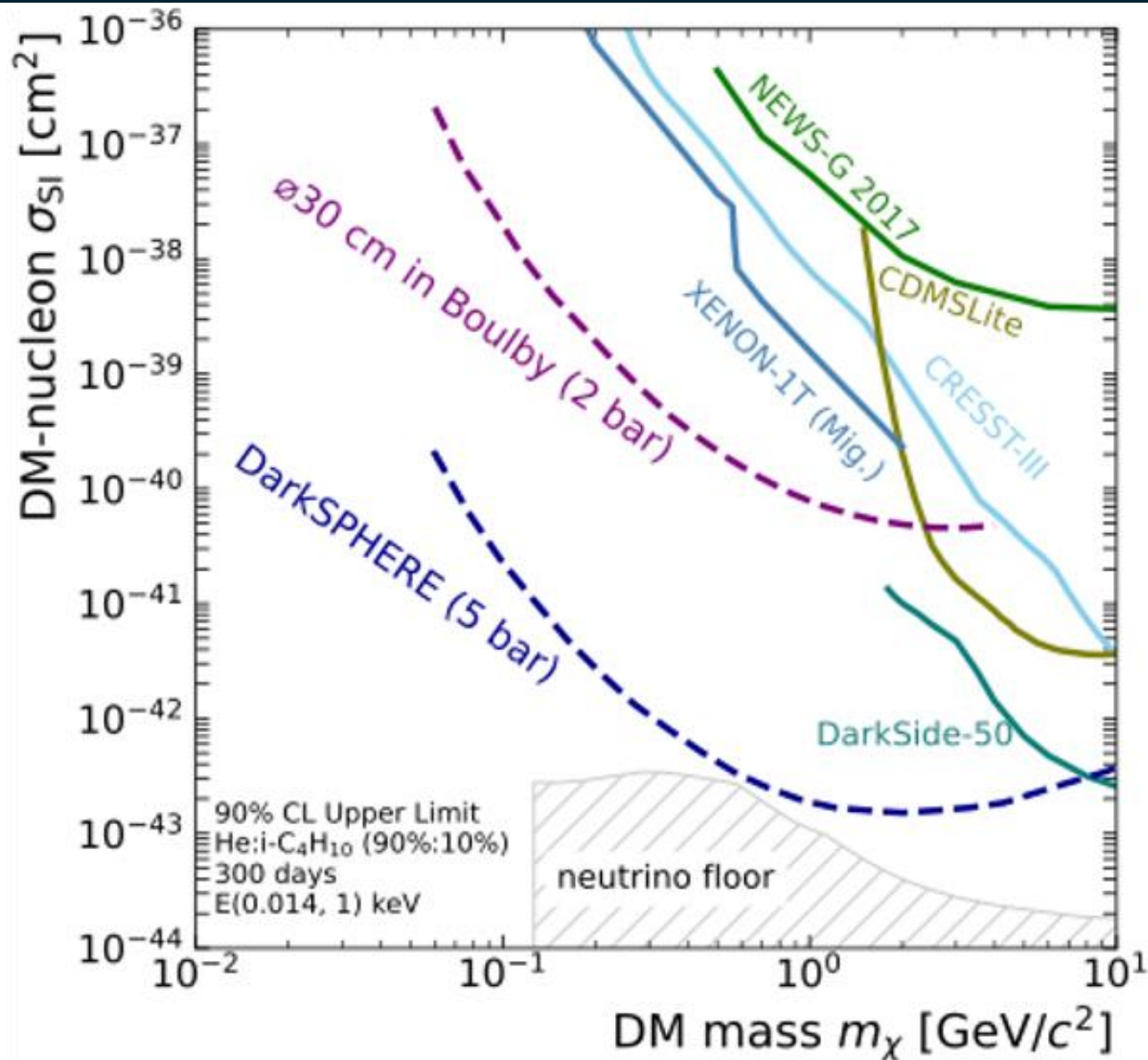
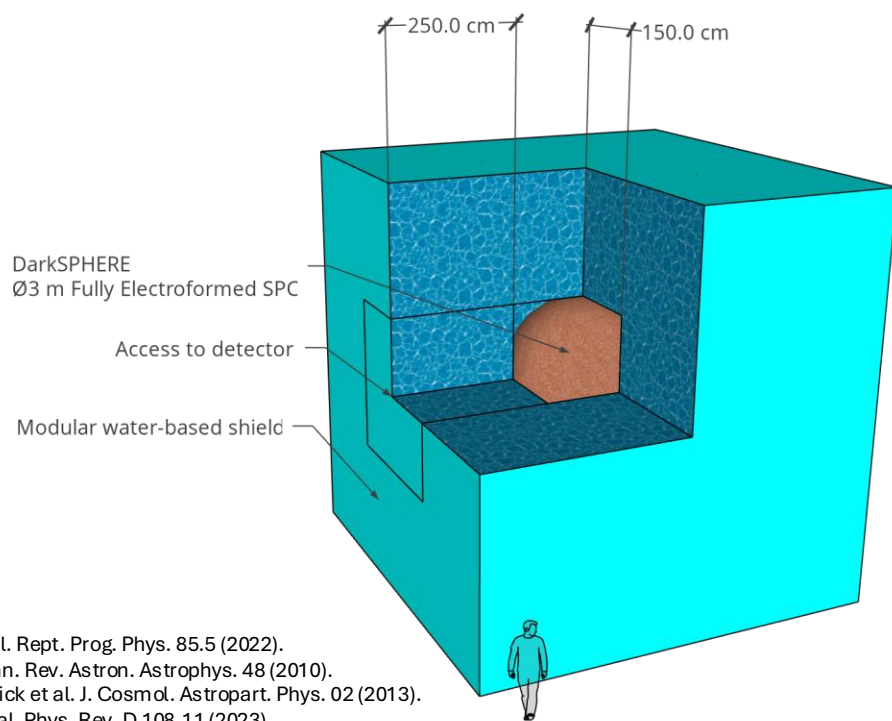
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Background

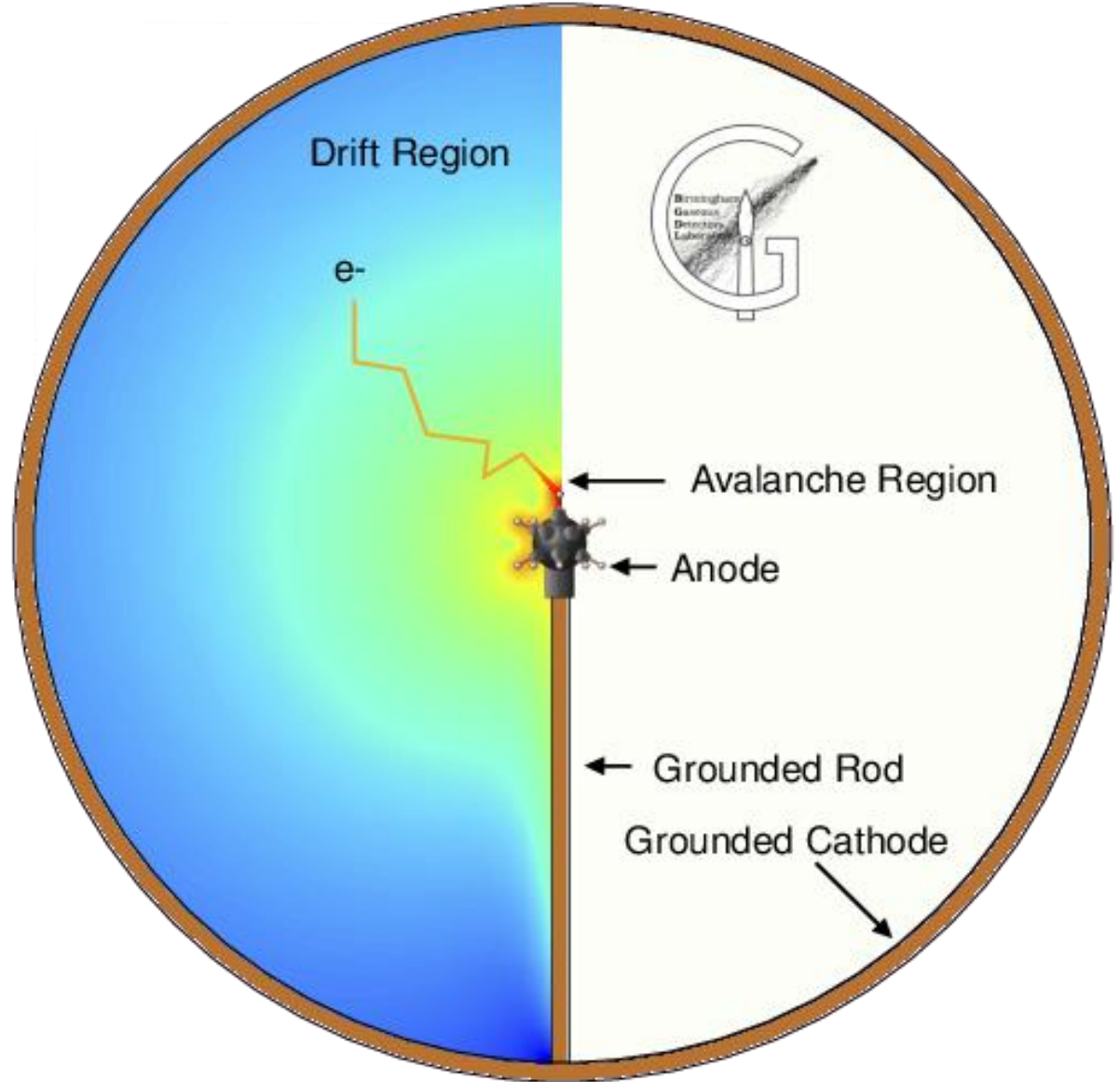
- DM constitutes $\sim 85\%$ of universe's matter [1]
- Direct DM detection efforts exploring theoretically motivated regions of parameter space [2,3]
- Sub-GeV DM less well explored
- DarkSPHERE aims to detect sub-GeV DM using spherical proportional counters (SPCs) [4]



[1] J. Billard et al. Rept. Prog. Phys. 85.5 (2022).
 [2] J. L. Feng. Ann. Rev. Astron. Astrophys. 48 (2010).
 [3] A. L. Fitzpatrick et al. J. Cosmol. Astropart. Phys. 02 (2013).
 [4] L. Balogh et al. Phys. Rev. D 108.11 (2023).

Spherical Proportional Counter

- Energy Threshold: Low capacitance and high gas gain $[O(10^5)]$ give sensitivity to single electron ionisation events.
- ACHINOS [5] readout sensor: High field at large radii
- Flexible gases: kinematic matching to low-mass DM particles
- Ar:CH₄, He:CH₄, and Ne:CH₄ gas mixtures used previously [6]
- DarkSPHERE gas must be characterised, monitor gas quality

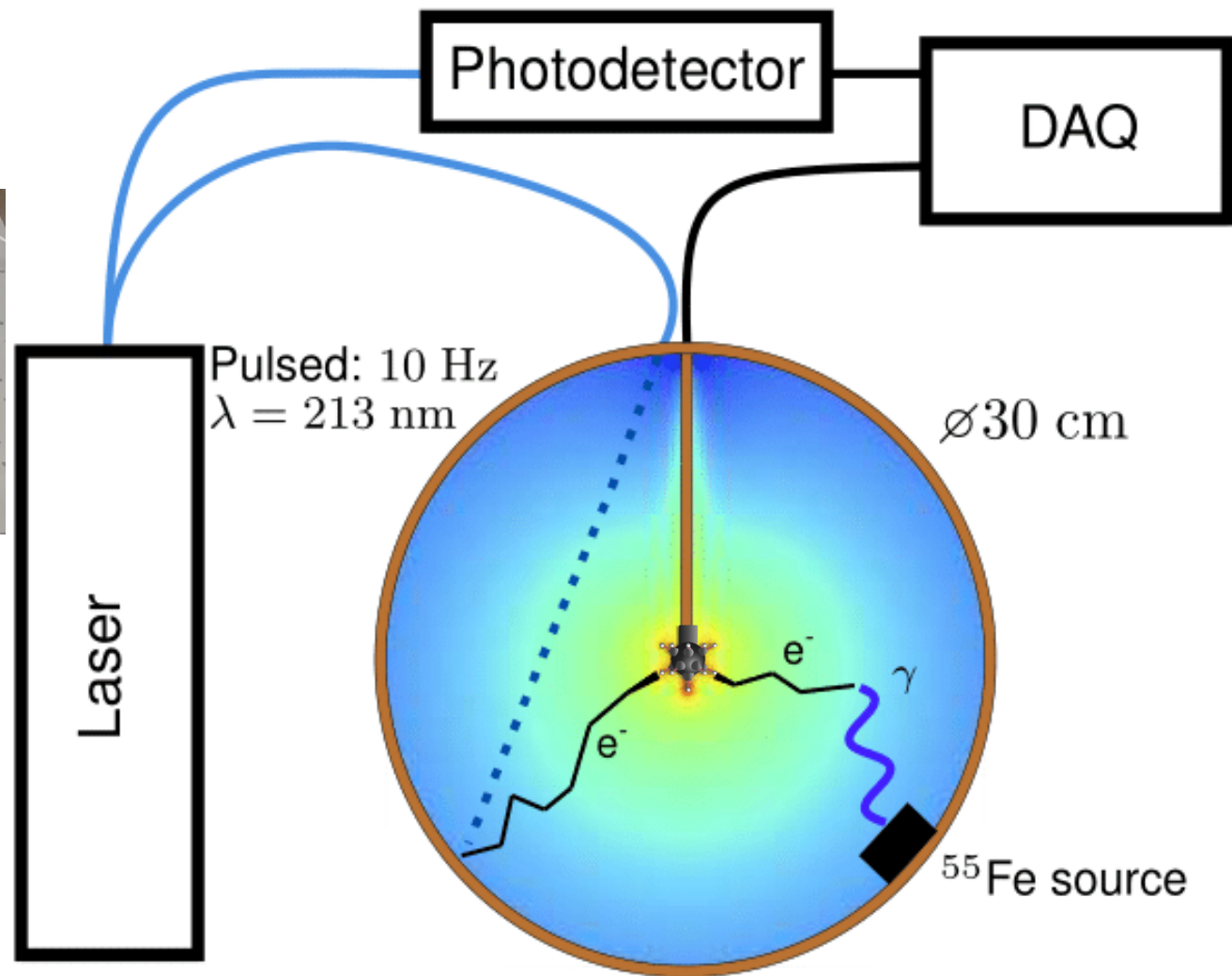


[5] I. Giomataris et al. J. Instrum. 15.11 (2020).

[6] M. M. Arora et al. Phys. Rev. Lett. 134.14 (2025).

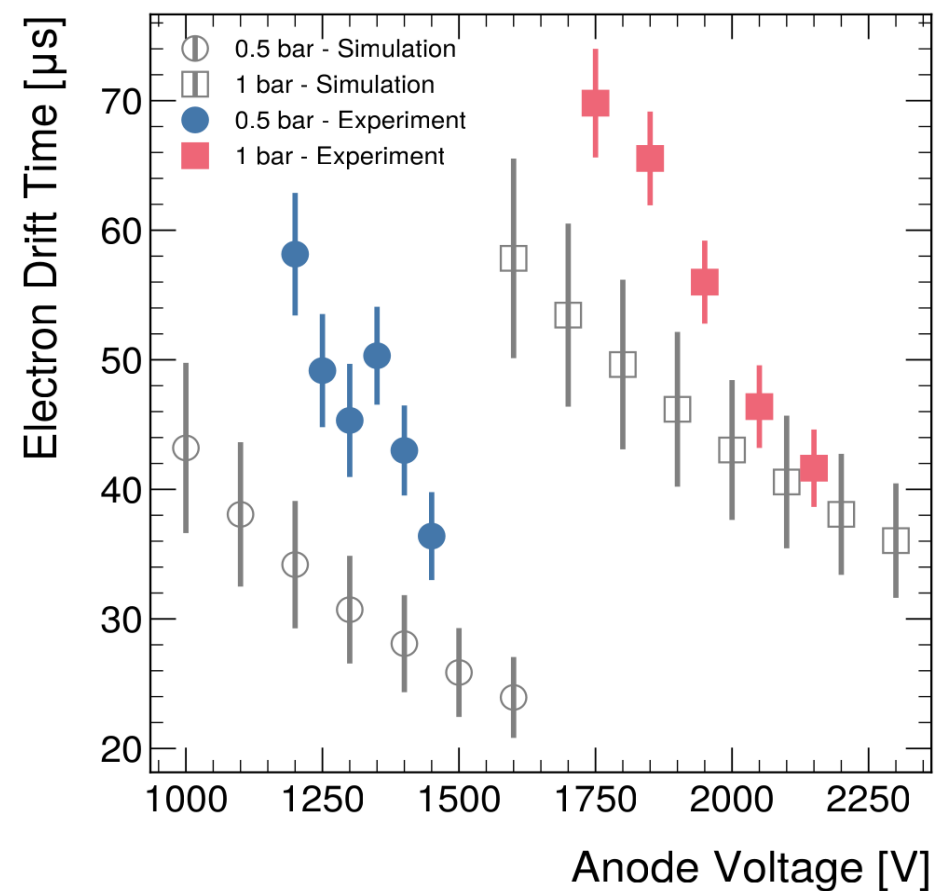
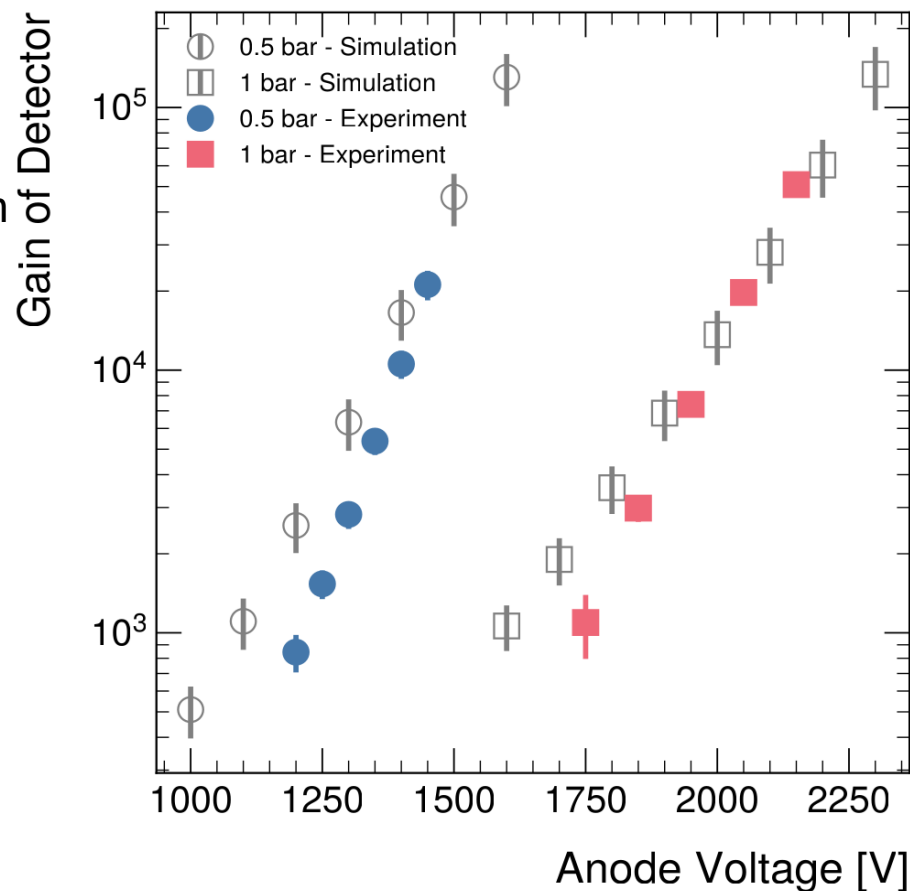
Experimental Method

- Gas properties can be measured from signal analysis (e.g electron drift time)
- Laser tuned to give single electron ionisation events



Results - Field Dependence

- Simulation [7] combining GEANT4 [8], Garfield++ [9] and gas properties from MAGBOLTZ [10]
- Gain of detector and electron drift time measured as a function of anode voltage
- Performed in Ar:CH₄ (98%:2%)



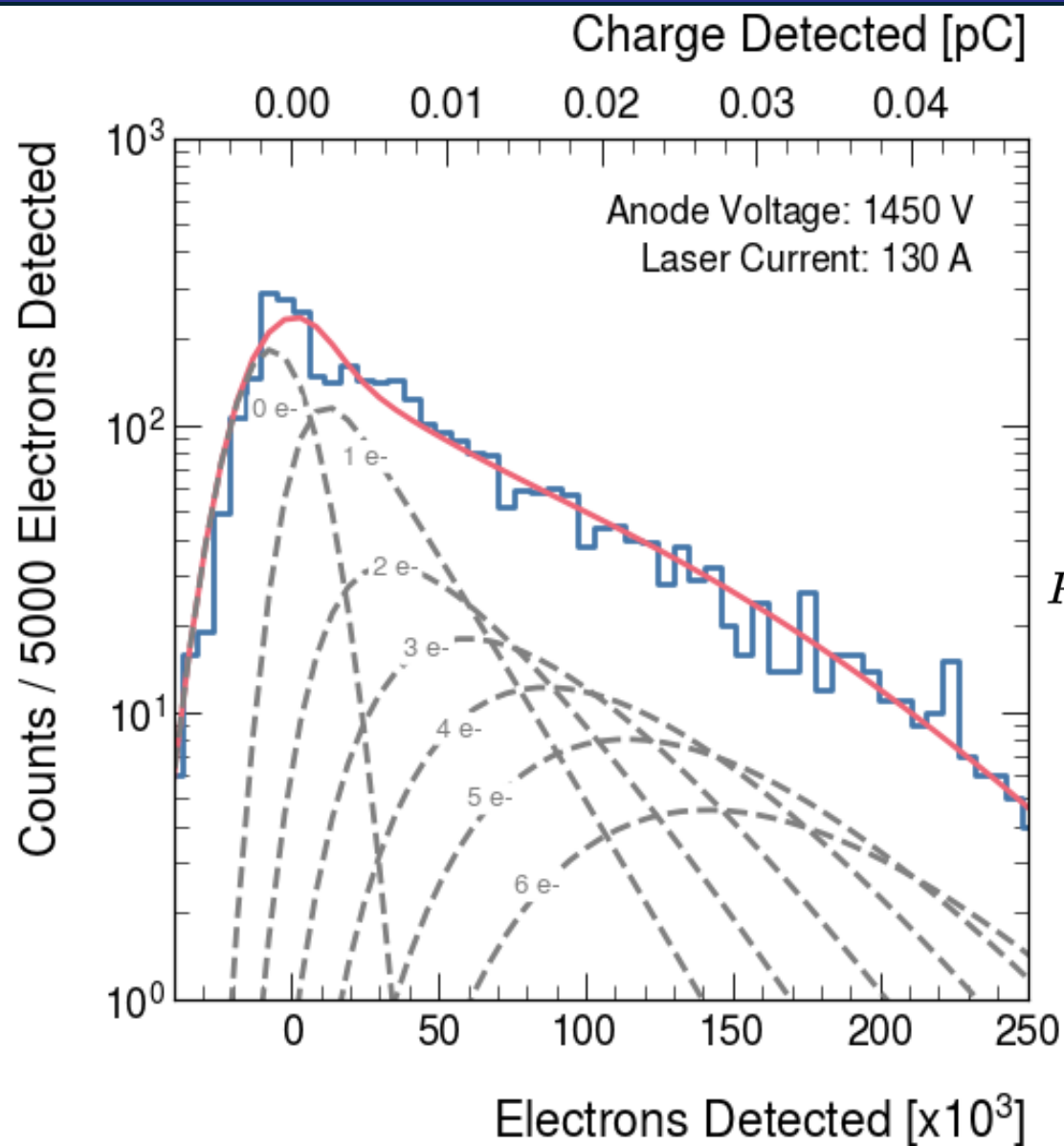
[7] I. Katsioulas et al. J. Instrum. 15.06 (2020).

[8] S. Agostinelli et al. Nucl. Instrum. Meth. A 506 (2003).

[9] H. Schindler and R Veenhof. url: <https://garfieldpp.web.cern.ch/garfieldpp/>.

[10] S. F. Biagi. Nucl. Instrum. Meth. A 421.1-2 (1999).

Results - Single Electron Readout

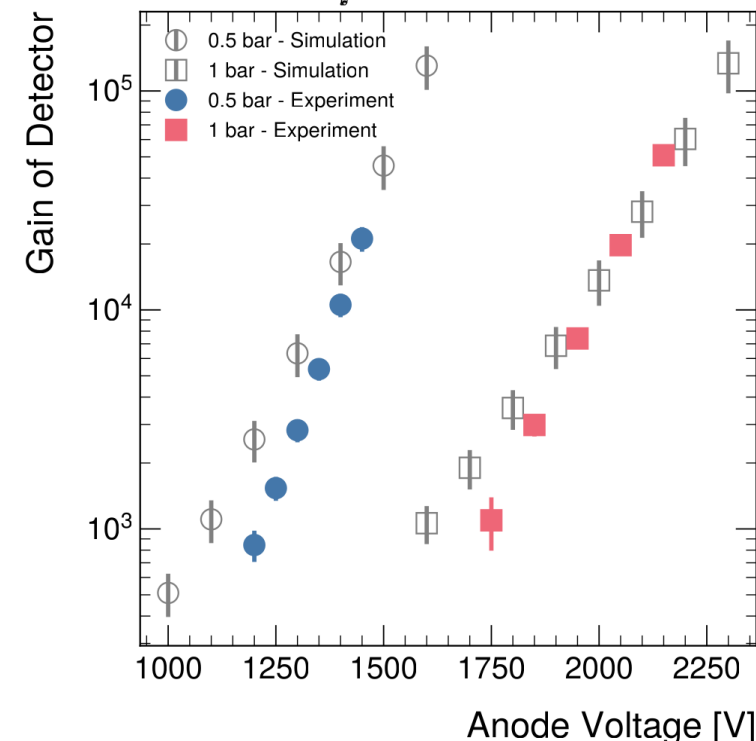
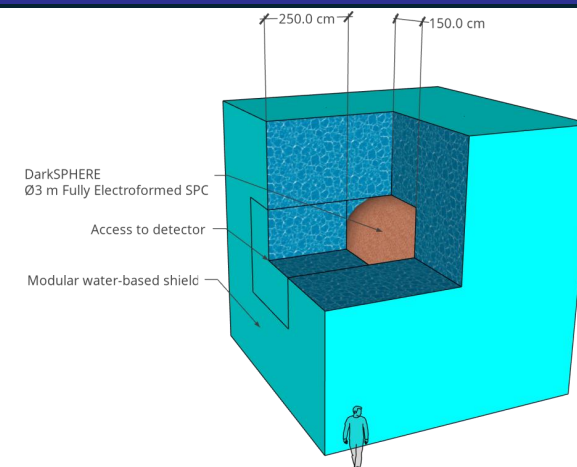
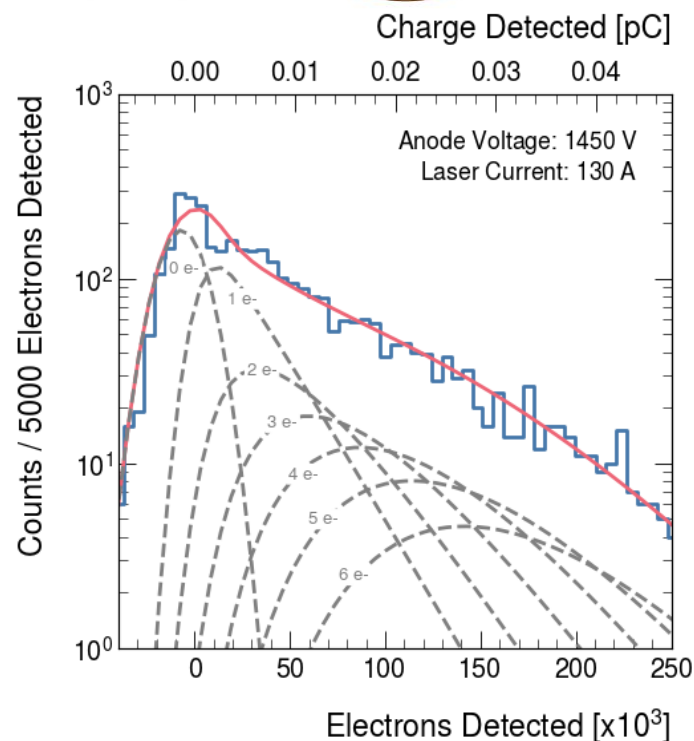
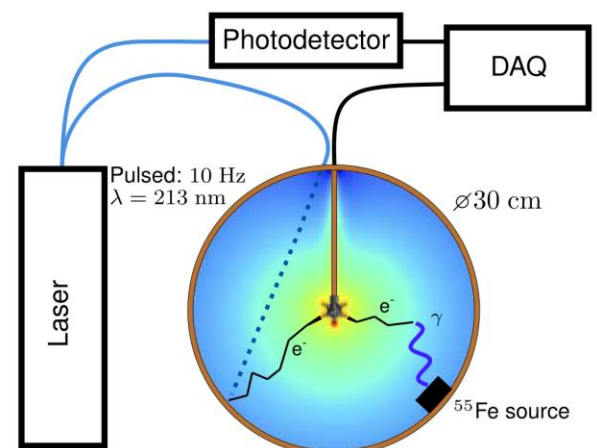
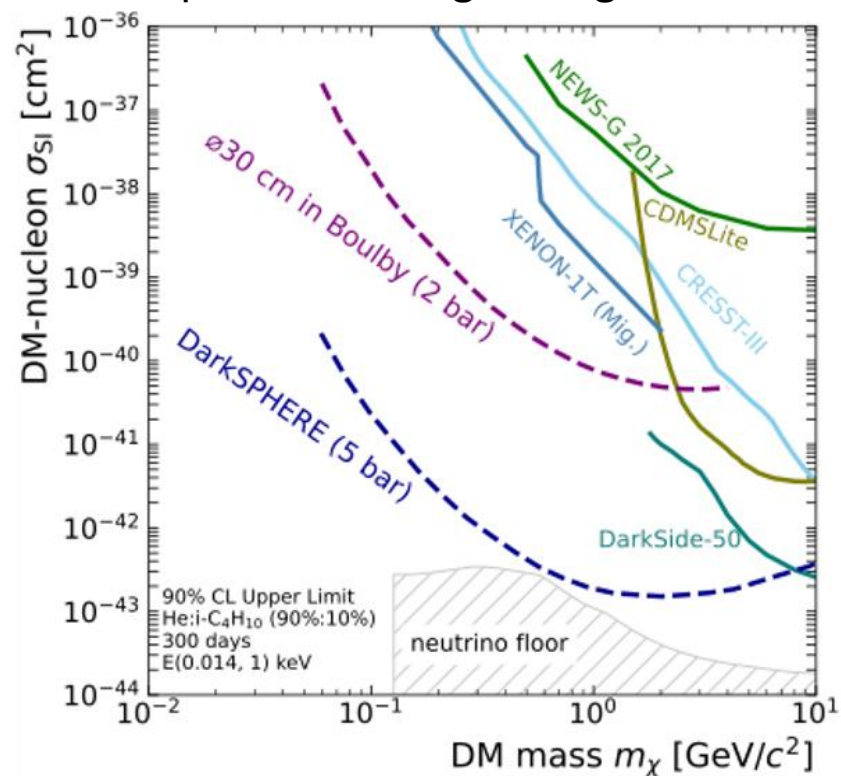


- Laser power reduced
- Fewer photoionisation events
- Statistical fluctuation cause different number of electrons – Polya Distribution, Poisson Statistics
- Fit with a convolution of Polya distributions to show single electron readout capability

$$P(N) = A_{Gauss} \times P_{Gauss} + A_{Polya} \left(\sum_{n=1}^6 (P_{Polya} \circledast P_{Gauss}) \times P_{Poisson} \right)$$

Conclusion

- Gas properties of interest to DarkSPHERE
- Studied using SPC with UV laser setup
- In-situ measurements of gas purity
- Verified single electron readout ability
- Next steps to test using other gas mixtures



Bonus Slide

