First Operation of an ACHINOS-equipped Spherical Proportional Counter with Individual Anode Read-out

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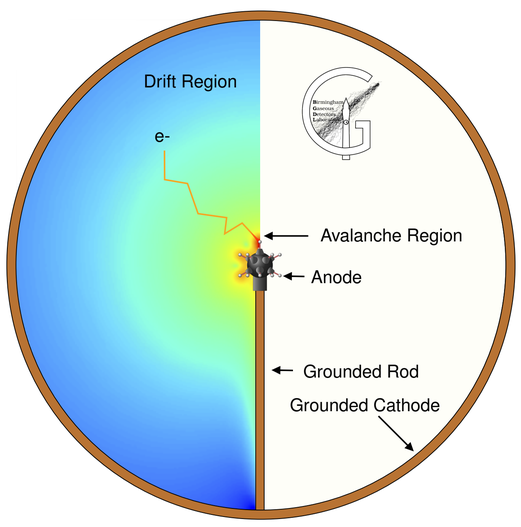
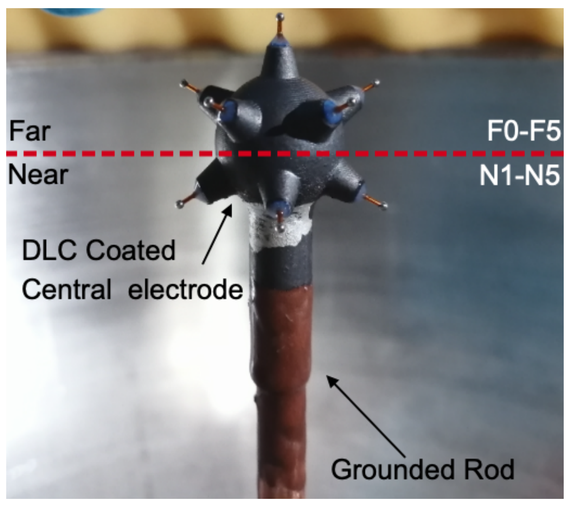
The Spherical Proportional Counter

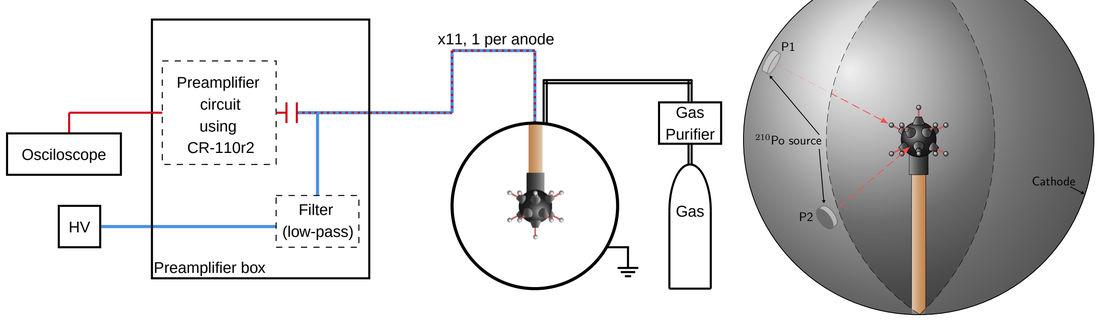
- The Spherical Proportional Counter [1, 2] is a gaseous detector with applications from dark matter [3, 4] to neutron spectroscopy [5].
- Comprises a $\mathcal{O}$(m) grounded shell, with a $\mathcal{O}$(mm) spherical anode at the centre at high voltage, providing charge amplification and signal read-out.
- For large volume, higher pressure operation, an ACHINOS structure was developed over the single anode [6], to decouple the drift and avalanche field, previously read-out in two channels - Near and Far.





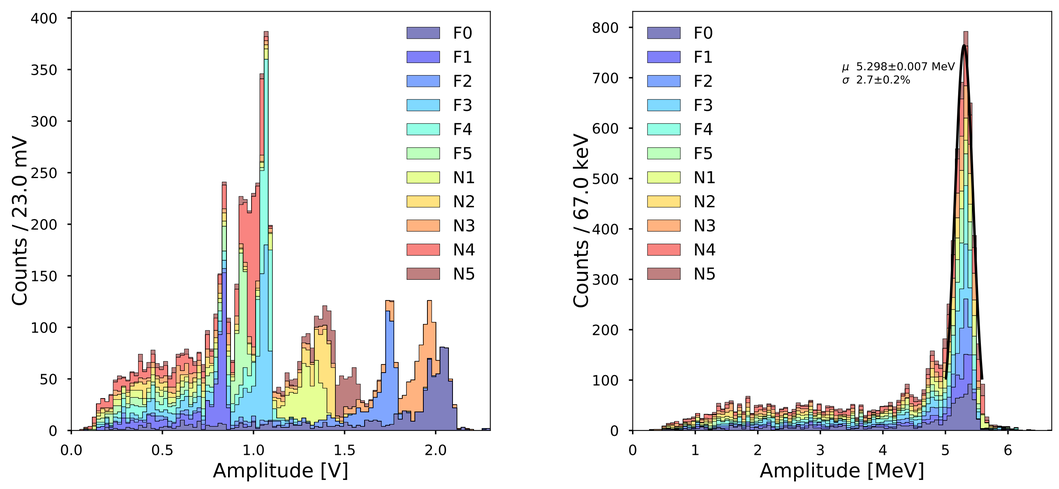
Experimental Set-up

- An individually read-out ACHINOS was operated with 11 anodes of 0.5 mm radius in a 15 cm radius sphere [7].
- Detector operated at 500 mbar of Ar:CH_4 (98%:2%), with each anode biased to 800 V.
- Each anode biased individually and read-out through a purpose built preamplifier board.
- A ^{210}Po source decays via a 5.3 MeV α-particle, the position of which could be manipulated for calibration.

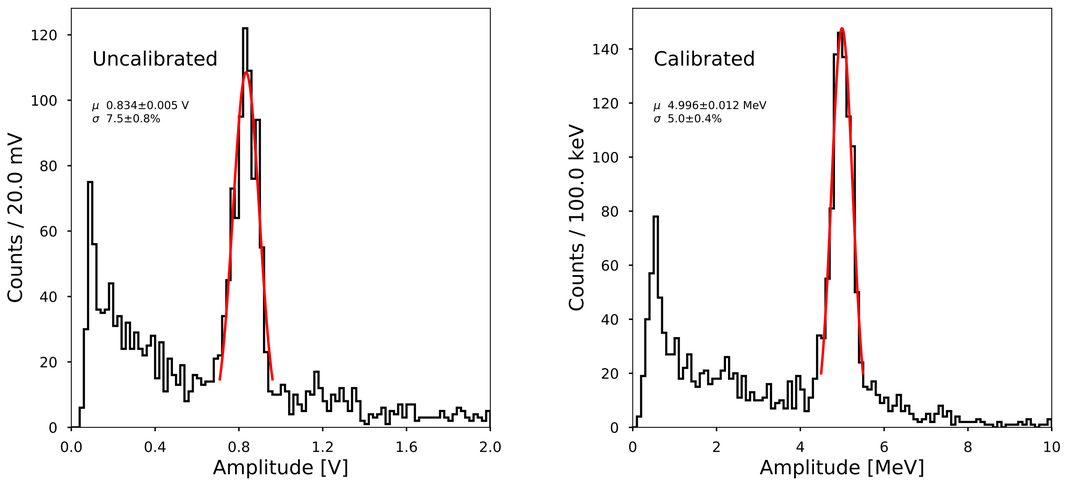


Results

- After individual calibration, data shows an energy resolution of 2.7%, approximate local energy resolution of a single anode.

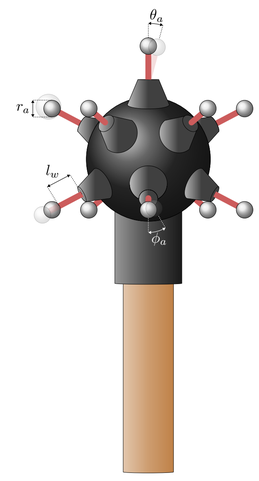


- With source was pointed between two anodes, ionisation charge is shared between anodes.
- A 2.5% improvement in energy resolution when the anodes are calibrated individually.



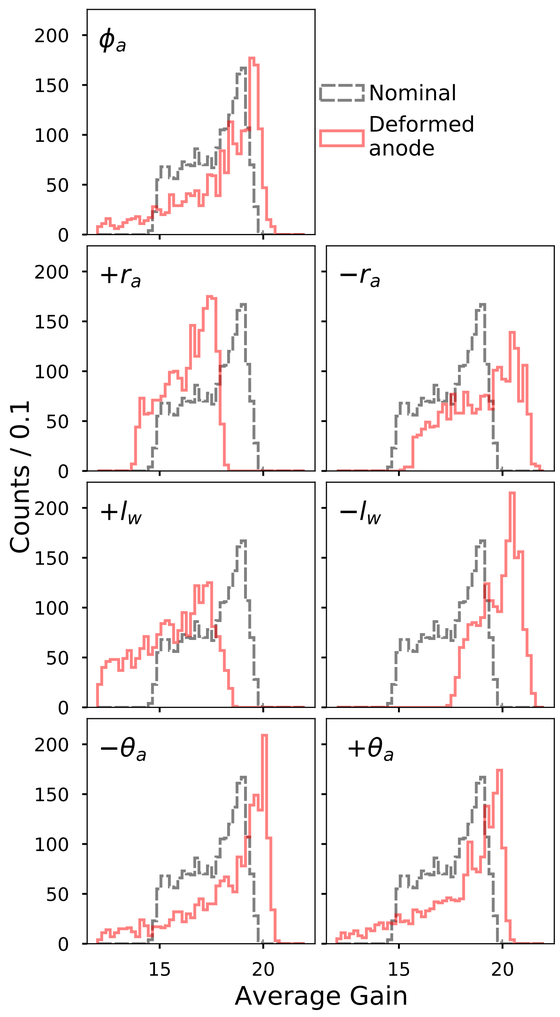
Simulation study

- Main anode to anode variation in gain is die to the grounded rod, which can be corrected [8].
- Additional anode to anode variations studied in simulation.
- Sensor modelled using `Gmsh/Elmer`.
- Simulation framework utilises `Geant4` and `Garfield++` [9].

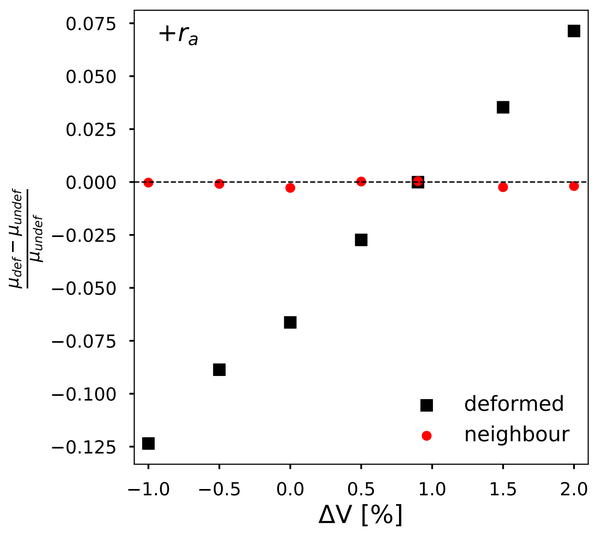


Parameter	Nominal Value	Deformation Magnitude
r_a	0.5 mm	$\pm$0.0125 mm
l_w	2.5 mm	$\pm$0.05 mm
θ_a	0 rad	$\pm$0.5 rad
ϕ_a	0 rad	$\pm$0.5 rad

Construction Imperfections



- For each deformation, the average gas gain was compared to the nominal.
- Gain difference can be corrected, either by individual calibration or by adjusting the voltage applied to the affected anode.
- For l_w and r_a it is possible to recover the energy resolution by adjusting the voltage.
- For larger r_a, the correction voltage to optimise the relative difference in gain on the deformed anode with respect to the nominal is demonstrated.



Summary

- Individual anode read-out has been developed for the ACHINOS sensor.
- Individually read-out ACHINOS shows significant improvements in energy resolution.
- Individual read-out is a key development for the spherical proportional counter, e.g. by allowing for 3D reconstruction of events and fiducialisation/ event localisation, important for applications such as dark matter searches and neutron spectroscopy.
- The sources of differences in gain between anodes has been studied extensively in simulation, and correction voltages studied to recover energy resolution.

References

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