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Neutron spectroscopy: The case of the Spherical Proportional Counter

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Fast neutron spectroscopic measurements are an invaluable tool for many scientific and industrial applications, in particular for Dark Matter (DM) searches. In underground DM experiments, neutron-induced background produced by cosmic ray muons and the cavern radioactivity, can mimic the expected DM signal. However, detection methods are complex and measurements remain elusive.
The widely used ^{3}He based detectors are expensive, while the low atomic mass requires large target masses, prohibitive for underground laboratories.

A safe, inexpensive, effective and reliable alternative is the N_2-filled Spherical Proportional Counter (SPC). The neutron energy is estimated by measuring the products of the ^{14}N(n,a)^{11}B and ^{14}N(n,p)^{14}C reactions, which have comparable cross sections to the ^{3}He(n,p)^{3}He reaction. Furthermore, the use of a light element such as N_2 keeps γ-ray efficiency low and enhances the signal to background ratio in mixed radiation environments. Partial proof of principle of this idea suffered from issues such as wall effect, electron attachment and low charge collection efficiency.

In this work, we tackle these challenges by incorporating the latest SPC instrumentation developments such as resistive multi-anode sensors for high-gain operation with high-charge collection efficiency and gas purifiers that minimize gas contaminants to negligible levels. This allows operation with increased target masses, reducing the wall effect and increasing the sensitivity.

Two 30cm diameter detectors are used at the University of Birmingham (UoB) and at the Boulby underground laboratory, operating above atmospheric pressure. We demonstrate spectroscopic measurements of fast and thermalised neutrons from an Am-Be source and from the MC40 cyclotron facility at UoB. Additionally, the response of the detector to neutrons is simulated using a framework developed at UoB, based on GEANT4 and Garfield++. The simulation provides the expected efficiency, the pulse shape characteristics and the means to discriminate the events according to their interaction, providing a good agreement with the measurements.

Collaboration

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