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Towards efficient neutron spectroscopy with a Nitrogen-filled 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, the detection methods are complex measurements and thus measurements remain elusive.
The use of 3He based detectors –the most widely used technique, to date –is not a viable solution. 3He is scarce and expensive, while the low atomic mass requires large target masses (high pressures/large volumes) that are prohibitive for underground laboratories.

A promising alternative for fast neutron spectroscopy is the use of a Nitrogen filled Spherical Proportional Counter (SPC). The neutron energy is estimated by measuring the products of the 14N(n,a)11B and 14N(n,p)14C reactions. These reactions have comparable cross sections for fast neutrons to the 3He(n,p)3He reaction. Furthermore, the use of a light element such as N2 keeps γ-ray efficiency low and enhances the signal to background ratio in mixed radiation environments. This constitutes a safe, inexpensive, effective and reliable alternative. An initial proof-of-concept [1] suffered from issues such as wall effect, electron attachment and low charge collection efficiency, due to the early stages of the SPC development.

In this work, we tackle these challenges by incorporating the latest SPC instrumentation developments such as resistive multi-anode sensors [2] for high-gain operation with high-charge collection efficiency and gas purifiers that minimize gas contaminants to negligible levels. This allows us to operate with increased pressure up to 1.8 bar, reducing the wall effect and increasing the sensitivity.

Two detectors (30-cm in diameter) 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++ for high energy physics applications [3]. 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.
[1] E. Bougamont et al., Nucl. Instrum. Meth. A 847, 10-14, (2017)
[2] I. Giomataris et al., JINST 15 P11023, (2020)
[3] I. Katsioulas et al., JINST 15 C06013 (2020)

In-person participation

Yes

Primary authors: GIOMATARIS, ioannis (CEA-Saclay); KATSIOULAS, Ioannis (University of Birmingham); KNIGHTS, Patrick (University of Birmingham); MANTHOS, Ioannis (University of Birmingham (GB)); NEEP, Tom (University of Birmingham); NIKOLOPOULOS, Konstantinos (University of Birmingham); PAPAEVANGELOU, Thomas (IRFU - CEA Saclay)

Presenter: MANTHOS, Ioannis (University of Birmingham (GB))

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