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CRAB : Calibration of nuclear recoils at the 100 eV scale in cryogenic detectors using neutron capture

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Cryogenic detectors have reached extremely low energy thresholds, making them useful tools to detect sub-keV nuclear recoils induced by Coherent Elastic Neutrino-Nucleus Scattering (CEvNS), or interactions with light Dark Matter. However, these detectors lack calibration for nuclear recoils at this energy scale. We propose using nuclear recoils produced by γ de-excitation after thermal neutron capture in the cryogenic detector to provide calibration peaks in the region of interest [1]. In particular, single-γ transitions of several MeV induce well-defined nuclear recoil peaks in the 100eV-1keV range. The suggested method is so far the only calibration method offering pure nuclear recoils in the bulk of the detector, and in this energy range.

Combining GEANT4 Monte-Carlo simulations, and γ de-excitation predictions from the FIFRELIN code, we have studied the expected energy spectrum in various cryogenic detectors widely used in the community. We report the first measurement with a CaWO4 cryogenic detector of the NUCLEUS experiment [2] and a portable thermal neutron source. It shows a nuclear recoil peak at around 112eV with a 3σ significance and evidence at the 6σ level of the full spectrum of nuclear recoils induced by thermal neutron captures, in very good agreement with simulations [3]. To our knowledge, this result constitutes the first direct observation of a nuclear recoil peak at the 100eV scale and demonstrates the feasibility of the CRAB method as an in-situ non-intrusive calibration of cryogenic detectors for CEvNS and Dark Matter experiments.

In a second experimental phase, the CRAB project intends to perform high-precision measurements with a thermal neutron beam at the low-power TRIGA reactor in Vienna. The sensitivity of the CRAB method is significantly increased by the detection of the emitted γ in coincidence with the subsequent nuclear recoil and by the interplay between the γ-cascade timing and the timing of the nuclear recoil in matter. Potential applications for lower recoil energies and to other materials, such as germanium or silicon, will be presented.

[1] L. Thulliez, D. Lhuillier et al., Calibration of nuclear recoils at the 100 eV scale using neutron capture, JINST, 16, 7 (2021)
[2] G. Angloher et al. (NUCLEUS), Exploring CEvNS with NUCLEUS at the Chooz nuclear power plant. Eur. Phys. J. C 79, 1018 (2019)
[3] H. Abele et al. (CRAB and NUCLEUS), Observation of a nuclear recoil peak at the 100 eV scale induced by neutron capture. arXiv:2211.03631 [nucl-ex] (2022)

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