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FIFRELIN, a fission code very useful for neutrinos and dark matter experiments

FIFRELIN is a fission fragment de-excitation Monte Carlo code that has been developed for more than a decade at CEA-Cadarache [1]. Its accurate predictions using up-to-date nuclear models and databases, regarding neutron/γ/electron emissions, are now at the state-of-the-art in the fission community [2]. Recently this code has started to become more than a fifrelin[1] for the neutrino and dark matter communities.

Up to now, most of electronic antineutrino ($\bar{\nu}_e$) detectors rely on the inverse beta-decay reaction, where a $\bar{\nu}_e$ interacts with a proton and produces a positron and a neutron. The emitted neutron is thermalized in the detector volume, until it is captured by a nucleus, producing a compound nucleus which de-excitates by γ emission. Loading the detector with gadolinium (Gd) increases the neutron sensitivity of the setup, but demands a precise knowledge of the Gd de-excitation to understand its response. In the context of the STEREO experiment searching for sterile neutrinos, an unprecedented agreement between the STEREO data and the GEANT4 simulation has been achieved thanks to the FIFRELIN de-excitation cascades of Gd [3,4].

Recently, these developments have found original applications in the searches for Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) at reactors and for light dark matter (DM). The signature of these processes are sub-keV nuclear recoils detected in cryogenic detectors. However, calibration for nuclear recoils at this energy scale remains a challenge. A novel idea based on FIFRELIN γ de-excitation predictions of a nucleus after thermal neutron capture has been proposed by the CRAB collaboration [5]. In particular, single-γ cascade of several MeV induce nuclear recoil peaks in the 100 eV−1 keV range. A first measurement with a $CaWO_4$ cryogenic detector of the NUCLEUS experiment [6] showed a nuclear recoil peak at around 112 eV (^{182}W(n,γ)^{183}W) with a 3σ significance and evidence at the 6σ level of the nuclear recoil spectrum, in very good agreement with FIFRELIN-GEANT4 simulations [7]. This has been recently confirmed by the DM experiment, CRESST, [8] demonstrating the feasibility of this method as an in-situ non-intrusive calibration of cryogenic detectors.

With an upcoming high-precision measurement campaign, CRAB could set constraints on the nuclear models used by FIFRELIN, using the interplay between the γ-cascade timing and the timing of the nuclear recoil in matter.

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[1] fifrelin: something of little value

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