Post-doc position at CEA-Saclay

Département de Recherche sur les Matériaux et la Physico-chimie (DRMP)
Institut de recherche sur les lois fondamentales de l'univers (IRFU)

Solid state physics aspects of cryogenic germanium recoil detectors.

The theme of this postdoctoral work is the precise study of the signals induced by low energy nuclear recoils (few 10 to few 100 eV) in gram-scale cryogenic detectors. Such recoils are of great interest to the fundamental physics community, since they can be induced by coherent scattering of reactor neutrinos on nuclei or by the interaction of nuclei with light dark matter. The project combines the expertise of the IRFU and DRMP teams at CEA Saclay to provide the best possible understanding of all the solid-state physics aspects involved in interpreting the high-precision calibration measurements planned over the next two years in the context of the CRAB project, the principle of which has recently been experimentally validated [1].

Molecular dynamics simulations of small displacement cascades will be carried out at DRMP for crystals of germanium, one of the most widespread material in the cryogenic detector community, using interatomic potentials constructed in a Machine-Learning approach based on the MILADY code developed at DRMP [2]. The quantities of interest for cryogenic detectors will be the energy stored in crystalline defects created by recoil, the sensitivity to recoil direction and the time course of displacement cascades. Comparison with the position and width of measured calibration peaks will provide a unique probe into the underlying solid-state physics. This is thus mainly a numerical simulation project. However, the post-doc will also be involved in the experimental measurement campaigns that will take place in Vienna. This project will therefore enable us to improve the calibration of bolometers for future applications in neutrino and dark matter detection.

This post-doctoral contract, initially proposed for one year, can be extended for a further year to study another problem: all cryogenic detectors with very low thresholds are limited in their sensitivity by a so-called "event-excess" background of unknown origin, whose spectrum increases exponentially at low energies, with a counting rate that slowly decreases with a time constant of a few weeks to a few months. We suspect that interfacial phenomena between the detector crystal (in this case germanium) and the thin-film deposit of the signal sensor (typically aluminum) are at the origin of these excess-events. As the thermal expansions of germanium and aluminum are very different, our hypothesis is that between the synthesis (at least at ambient temperature) and operating (15 mK) temperatures, the mismatch between the lattices changes sufficiently for the number of interfacial dislocations to change. The event-excess would be the sign of the appearance/disappearance of these interface dislocations in very slow kinetics due to the extremely low temperatures. The second year of the post-doc will be devoted to the study of these interface dislocations between germanium and aluminum and their evolution with temperature. The event-excess background is regularly discussed in the community through annual dedicated workshops. This study will be closely connected with the ongoing experimental tests and R&D on cryogenic detectors.

1. Crab-Collaboration, *Observation of a Nuclear Recoil Peak at the 100 eV Scale Induced by Neutron Capture.* Physical Review Letters, 2023. **130**: p. 211802.
2. Goryaeva, A.M., et al., *Efficient and transferable machine learning potentials for the simulation of crystal defects in bcc Fe and W.* Physical Review Materials, 2021. **5**: p. 103803.

Skills: Extended Knowledge of atomic scale simulations, preferably molecular dynamics.

Training required: PhD in Materials science with a specialization in atomic scale simulations

Duration of the project: 1 year, start of the contract on late 2023 or early 2024, with the opportunity to extend for another year.

Contact:

Jean-Paul Crocombette (jpcrocombette@cea.fr) DES/ISAS/DRMP/S2CM/SRMP Tel : (+33) 1 69 08 92 85
David Lhuillier (david.lhuillier@cea.fr) DRF/IRFU/DPhN/LEARN Tel : (+33) 1 69 08 94 97