Eur. Phys. J. Plus (2023) 138:609
https://doi.org/10.1140/epjp/s13360-023-04239-z

THE EUROPEAN
PHYSICAL JOURNAL PLUS

Editorial

Advances in cryogenic detectors for dark matter, neutrino physics and astrophysics

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In recent years, the study of neutrinos and Dark Matter (DM) properties has raised much interest in the Particle and Astroparticle physics communities. The current instrumental and computational advancements made possible the discovery of some fundamental properties of these key constituents of our Universe. In the next 5–10 years, the most important open questions on neutrino and DM physics will be addressed, such as which is the mass and nature of neutrinos or what DM is made of.

There have been enormous technological advancements since the proposition of low-temperature detectors for Astroparticle physics applications in the early 80 s. This experimental technique led to the realization of ultra-low threshold detectors, reaching eV-scales[1, 2], and the flawless operation of low-background large arrays of ton-scale size [3]. Nowadays, cryogenic detectors are considered a key technology for next-generation neutrino and DM experiments [4, 5], given their advanced experimental performance over a broad energy range.

The current DM surveys have spanned over four orders of magnitude of DM masses, from hundreds of MeV to few TeV [6], and still awaiting discovery. Neutrinoless double-beta decay investigations have set limits on this process at the level of 10^{25-26} y and limits on the neutrino mass at the 100 meV scale [7, 8].

The flexibility in the fine-tuning of the different experimental parameters allows also for investigating other fundamental neutrino properties (e.g., magnetic moment) [9], search for sterile neutrinos [10], the detection of astrophysical neutrino sources [11], the search of solar axions [12, 13], and ultimately for the detection of the primordial neutrino background [14].

In this Focus Point, we highlight this experimental technique's great potential. In particular, it will be shown how flexible cryogenic detectors are in operating different kinds of absorber materials to realize multi-purpose experiments searching for signals at very different energy scales, like direct DM investigations at few eV and nuclear decays at some MeV. The impact and broad range of applications of this experimental technique are outlined in [15], where the potential of Metallic Magnetic Calorimeter thermal sensors allows the operation of detectors that can be simultaneously highly sensitive to DM particle interactions at the keV scale and neutrinoless double-beta decay at several MeV.

The work of [16] demonstrates the flexibility of this experimental technique through the operation of an Indium Iodine (InI) crystal to study the spectral shape of β-decays. The high-energy resolution and low-energy threshold of cryogenic detectors can provide valuable information to the so-called g_A*-quenching problem* [17].

Innovative materials for suppressing the background level of rare event searches are discussed in [18, 19], where two different approaches are presented. The first one concerns the potential of liquid He for investigating the fundamental properties of light DM with sub-GeV masses. This material's advantages are unique: light target (kinematically favorable), easy to purify, high Quenching Factor, and outstanding electron/nuclear recoils discrimination. The second work presents preliminary results on the mechanical properties of scintillating plastics at mK temperatures. This material can offer significant leverage for suppressing radioactive background sources near the active detector components (e.g., crystals).

Finally, the advanced performance of machine learning techniques developed for high-energy physics are now implemented in the astroparticle physics sector, and they are offering powerful and efficient analysis methods for the searches of light DM particles, as demonstrated in [20].

Funding Open Access funding enabled and organized by Projekt DEAL.

Data availability Data are available upon reasonable request to the author.

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