T 103: Search for Dark Matter IV

Time: Friday 9:00–10:15 Location: AM 00.014

T 103.1 Fri 9:00 AM 00.014

Simulations of the MainzTPC2 to observe the Migdal effect
— •Peter Gyorgy, Alexander Deisting, Christopher Hils, Johannes Merz, Uwe Oberlack, and Constantin Szyszka — Johannes Gutenberg-Universität Mainz, Institut für Physik & Exzellenzcluster PRISMA+

The MainzTPC2 is a small-scale dual-phase xenon time projection chamber (TPC), destined to make a measurement that could prove the Migdal effect for Xe atoms. The Migdal effect manifests in the form of an additional electron recoil signature paired with the typical nuclear recoil signal that an elastic scatter e.g. a neutron or WIMP produces. For large dual-phase TPCs — like XENONnT, XLZD — this effect would decrease their detection threshold, extending their sensitivity to lower dark matter masses.

To ensure the success of the experiment, a detailed simulation must be made of the MainzTPC2. This requires extensive modeling and simulations in GEANT4, including neutron scattering, detector effects, optical physics, position reconstruction, and a Migdal signal model.

The measurement itself is expected to take place at the CN facility at LNL, Italy, in the form of neutrons from a beam undergoing an elastic backscatter off the TPC into a secondary scintillator detector. As such, beam characteristics and neutron flight paths must also be modeled. The use of data quality cuts such as time-of-flight and neutron multi-scatter is expected to reduce the background sufficiently to obtain a clear population of Migdal events in their region of interest. This presentation will summarize results from this simulation process.

T 103.2 Fri 9:15 AM 00.014

Results of a Cryogenic Multi-Channel 4π Veto Module in the CRESST Experiment — •Àfrica González Pedraza for the CRESST-Collaboration — Technical University of Munich, Garching

CRESST is a cryogenic experiment searching for sub-GeV dark matter via direct scattering off a target crystal's nucleus. The resulting energy transfer causes a nuclear recoil that increases the target's temperature, measured by a Transition-Edge Sensor (TES) enabling energy thresholds of O(10 eV).

Currently, one of the main sensitivity limitations is an unexpected rise in the event rate below 200 eV, known as the Low-Energy Excess (LEE). One of the leading hypotheses attributes the LEE to mechanical stress stored at material interfaces. To investigate the holder-induced stress component, CRESST employs a dedicated three-channel module that integrates an instrumented holder and a beaker-shaped, large-coverage light detector in addition to the standard CRESST detector configuration.

To precisely characterize the detector response to sub-keV nuclear recoils, the signature of dark matter, CRESST is transitioning to a novel calibration method based on thermal neutron capture, which has the additional advantage of not increasing the backgrounds outside the dedicated calibration campaigns.

This talk presents the latest results from the CRESST beaker module operated at LNGS on the LEE and demonstrates that low-energy nuclear-recoil calibration is achievable in CRESST sapphire detectors.

T 103.3 Fri 9:30 AM 00.014

Fast Template-Based Inference via Conditional Normalizing Flows for XENONnT — •Johannes Merz for the XENON-Collaboration — Institut für Physik & Exzellenzcluster PRISMA^{++}, Johannes Gutenberg-Universität Mainz

Template-based likelihood analysis is a cornerstone of the inference in the XENONnT experiment. It's limited in computational efficiency and flexibility by its reliance on histogram based templates. In this talk, we present a fast inference approach that replaces traditional templates with continuous, differentiable models based on conditional normalizing flows. The models provide an accurate representation of detector response distributions while enabling efficient likelihood evaluation. This significantly accelerates and simplifies parameter inference across the parameter spaces. Our results demonstrate that normalizing flow based templates offer a scalable and efficient alternative to classical template methods for XENONnT.

T 103.4 Fri 9:45 AM 00.014

Status of large-area cryogenic microcalorimeter (LAMCAL) development for DELight — •Lena Hauswald[1], Christian Jeup[1], Friedrich Wagner[1], and Sebastian Kempf[1,2] — [1]Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology (KIT), Germany. — [2]Institute for Data Processing and Electronics, Karlsruhe Institute of Technology (KIT), Germany.

The Direct Search Experiment for Light Dark Matter (DELight) is a pioneering initiative aimed at probing light dark matter (LDM). By utilizing superfluid ^{4}He as target material, DELight will enable the exploration of weakly interacting DM candidates with masses notably below 100 MeV/c^2. To achieve the required detector sensitivity for resolving the various signal channels of the superfluid, both in terms of time and energy resolution, DELight focuses on the development of large-area cryogenic microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology.

In contrast to state-of-the-art MMCs, each LAMCAL will be operated as athermal phonon detector. Here, the energy of athermal phonons generated by a energy deposit and propagating ballistically within the absorber is converted into a temperature rise of the paramagnetic temperature sensor via Al-based superconducting phonon collectors. Consequently, the signal rise time is governed by the phonon collection time, while the absorber heat capacity becomes negligible to first order, enabling excellent energy resolution. This contribution presents the current status of LAMCAL development for DELight, highlighting their potential and the challenges encountered to date.

T 103.5 Fri 10:00 AM 00.014

Signal Processing and Machine Learning for Light Dark Matter Detection in DELight — •Dowling Wong for the DELight-Collaboration — KIT, Karlsruhe, DE

The parameter space for dark matter below a few hundred MeV remains largely unexplored, motivating detectors with ultra-low energy thresholds. The DELight experiment aims to directly detect light dark matter using superfluid helium-4 instrumented with about 60 large-area microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology. Each LAMCAL achieves an eV-scale energy resolution, yielding a nuclear-recoil threshold around 10 eV. To further lower the threshold, robust and noise-aware reconstruction across the multi-channel readout is essential. I present a unified signal-processing and machine-learning framework developed for DELight. At the waveform level, we implement optimal filtering and principal component analysis estimators tuned to measured pulse shapes with noise spectra captured under preliminary operating conditions in the DELight LAMCALs. With physics-informed features, we develop a transformer-based attention architecture that captures inter-channel correlations to improve event reconstruction, while exploring data-driven filters to suppress non-stationary system noise and enhance sensitivity near threshold. I will discuss the architecture of the reconstruction pipeline and its performance on simulated and calibration R&D data, with a focus on trigger efficiency in offline scans. This work is supported by the Heidelberg Karlsruhe Strategic Partnership (HEiKA STAR), with personnel funded by the Alexander von Humboldt Foundation.