EXCESS24

sabato 6 luglio 2024 - sabato 6 luglio 2024

Physics Department - Edificio Marconi

Raccolta degli abstract

Contents

2

DoubleTES detectors to investigate the CRESST low energy background: results from above-ground prototypes

Autore: Francesca Pucci[1]

[1] *Max Planck Institute for Physics*

Autore corrispondente: frapucci@mpp.mpg.de

The CRESST experiment utilises advanced cryogenic detectors constructed with different types of crystals equipped with Transition Edge Sensors (TESs) to measure signals of nuclear recoils induced by the scattering of dark matter particles in the detector.
In recent times, the sensitivity of low-mass direct dark matter searches has been limited by unknown low energy backgrounds close to the energy threshold of the experiments known as the low energy excess (LEE). In CRESST, this low energy background manifests itself as a steeply rising population of events below 200 eV.
A novel detector design named doubleTES using two identical TESs on the target crystal was studied to investigate the hypothesis that the events are sensor-related. We present the first results from two such modules, demonstrating their ability to differentiate between events originating from the crystal's bulk and those occurring in the sensor or in its close proximity.

3

Analysis of the CRESST warm-up test data

Autore: Sarah Kuckuk[1]

[1] *Universität Tübingen*

Autore corrispondente: sarah.kuckuk@uni-tuebingen.de

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) is one of the most sensitive experiments for the direct detection of light dark matter via nuclear recoils. At low recoil energies below roughly 200eV, the sensitivity is affected by the presence of an increasing event rate for which dark matter as a major contribution has already been ruled out. Such a low energy excess (LEE) is not only observed in all CRESST detectors but also in other cryogenic experiments, so far without a definitive answer to what the origin is.

Between Oct. 2021 and Feb. 2024, CRESST has performed dedicated studies on the behavior of the excess by warming up the cryostat to different temperatures, alternating with periods of data taking. We will present the current status of the corresponding analysis, which utilizes two-dimensional unbinned fits on time and energy simultaneously. A focus lies on the temporary rises and following decays in the LEE event rate that have been observed to occur after such warm-ups.

4

Estimation of waveform deformation with the matched filter

Autore: Matteo Cappelli[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Autore corrispondente: matteo.cappelli@roma1.infn.it

Pulse shape analysis is a key tool for signal/background discrimination although its effectiveness tends to decrease considerably while approaching the detector's energy threshold. A new pulse shape variable, arising from a mathematical extension of the matched filter, is presented in this work. It is intended to measure the deformation of a waveform with respect to a template signal in order to perform background rejection. Besides the consistency of the mathematical formulation, an application of this new method to simulated data shows a strong discrimination capability that exceeds the one of more common pulse shape parameters both at low and high signal-to-noise ratios.

5

Density-functional theory description of xenon for dark matter-electron scattering in liquid xenon targets

Autore: Einar Urdshals[1]; Luca Marin[2]; Marek Matas[2]; Nicola Spaldin[2]; Riccardo Catena[3]

[1] *Chalmers Technical University*

[2] *ETH Zurich*

[3] *Chalmers University of Technology*

Autore/i corrispondente/i: nicola.spaldin@mat.ethz.ch, matas.marek1@gmail.com, urdshals@chalmers.se, catena@chalmers.se, luca.marin@mat.ethz.ch

We explore the effect of the interatomic interactions in the condensed phases of xenon on the dark matter-electron scattering process, with a focus on applications in liquid xenon detectors. We calculate the electronic structure of atomic, liquid and solid Xe using first-principles density functional theory (DFT), then compute material response functions for the dark matter-electron scattering process within an effective field theory framework. Finally, we use experimental data from XENON10 and XENON1T experiments to compare exclusion limits obtained for isolated atoms and for the condensed phase. Our results allow us to assess the impact of the interatomic interactions on dark matter-electron scattering in liquid xenon.

6

LANTERN: A novel characterization technology for cryogenic detectors

Autore: Giorgio Del Castello[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Autore corrispondente: giorgio.delcastello@roma1.infn.it

Current advancements in low-energy rare-event searches rely on cryogenic calorimeters, commonly used for the direct detection of dark matter or neutrinos. These detectors provide a low-noise environment but face challenges in characterizing responses within the region of interest (ROI). Developed for probing energies from O(10eV) to O(1keV), these detectors encounter issues when calibrating with commonly available radioactive sources since these produce signals at energies above the ROI, affected by non-linearities and saturations, and cannot be removed during data-taking.

To overcome these limitations, a novel calibration procedure is required to better understand detector characteristics. LANTERN is an innovative optical calibration system designed for the characterization of an array of cryogenic calorimiteres. LANTERN exploits the photostatistics generated by the absorption of monochromatic photons produced by a LED, without requiring to know of the total energy deposited. This system is composed by a LED matrix, designed for fast switching times (faster

than the typical response of cryogenic detectors), capable of characterizing up to 64 calorimeters independently.

LANTERN can produce particle-like signals across a wide energy range, from a few eV to several hundreds of keV, allowing for a complete characterization of an array of detectors within the ROI and studies like cross-talk and pixel identification. Furthermore, its minimal electronics and optics contribute to cost-effectiveness and ease of production, with the possibility of customization to meet specific requirements (wavelength, energy range, speed and number of channels). Moreover LANTERN, being electronically activated, can remain present during data-taking, allowing periodic validation of detector performance without introducing unnecessary background.

These features make LANTERN an ideal system to be used with segmented calorimeters operated in low background setups to fully understand their response, thus exploiting their full potential. LANTERN aims to replace the systems employed by the BULLKID and NUCLEUS experiments, that present severe scalability and customization limitations.

7

Towards EXCESS background suppression in the next generation (G3) Noble Liquid detectors

Autore: Sergey Pereverzev[1]

[1] *Lawrence Livermore National Laboratory*

Autore corrispondente: pereverzev1@llnl.gov

A ʻmeta-analysisʼof phenomena reported by the current generation of large dual-phase noble-liquid detectors reveals correlations between barriers for surface charge removal and unextracted electrons dwelling time, mobility, and appearance of E-bursts. An apparent "freezing in place" of unextracted electrons and E-bursts matches the appearance of charged liquid surface hydrodynamic instabilities observed in liquid helium experiments as charge concentration and electric field increase.
Another observation relates to detector designs where the active surface area is surrounded by insulating PTFE. It appears that more trapped charges result in the rate of delayed single-electron emission rising and multi-electron emission decreasing (at least relative to single-electron events). Surface-trapped electrons and impurities can form microscopic clusters (like charged water micro-droplets), and such clusters can leave liquid into gas in a strong electric field. In the gas phase, these clusters can evaporate/ release free electrons- which will look like single-electron events. Having a surface-trapped charge population could be suppressing signal extraction efficiency due to a loss mechanism that transfers signal electron kinetic energy to wave-like perturbations of the charged surface; when signal electron loses kinetic energy near the surface, it will not leave the liquid.
If these assumptions are correct, design changes to suppress charge accumulation at the liquid surface should ensure that low energy signals are extracted with high efficiency broadening the physics reach of G3 experiments. Additionally, a decrease in impurities level from ppb to ppt level should suppress delayed emission events rate in the next (G3) generation of dark matter detectors.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-864739

8

Possibility of detecting low-energy nuclear recoils by nano-explosive detection in NaI(Tl)

Autore: Sergey Pereverzev[1]

[1] *Lawrence Livermore National Laboratory*

Autore corrispondente: pereverzev1@llnl.gov

Detection of low-energy solar and reactor neutrinos (neutrino fog) would be a milestone for direct dark matter searches. Backgrounds in excess of expectations prevent the detection of low-energy neutrino elastic scattering on nuclei in all types of detectors, and evidence is mounting that energy /charge trapping and delayed releases contribute to these phenomena.
Since we have demonstrated that UV light pumps energy into NaI(Tl), causing long-lasting delayed luminescence which can be quenched by red light exposure, the question arises if the production of long-leaving energy-bearing states /electron traps can be used to realize a 'nano-explosive'detection scheme. Here, neutrino coherent scattering or low-mass dark matter particle interactions that have too little energy to directly produce luminescence could instead release greater amounts of stored energy. With a controlled energy pumping scheme, this mechanism might provide a highly sensitive probe for low-energy nuclear recoils. We also describe how such dynamics might help to explain the DAMA-LIBRA observations.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-864740

9

ELOISE –Comparing Geant4 simulations at sub-keV against electron energy loss spectroscopy of $CaWO_4$ and Al_2O_3

Autore: Holger Kluck[1]

Coautore: Jens Burkhart [1]; Michael Stoeger-Pollach [2]

[1] *Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences*

[2] *Technische Universität Wien, University Servicecentre for TEM*

Autore/i corrispondente/i: stoeger@ustem.tuwien.ac.at, holger.kluck@oeaw.ac.at, jens.burkhart@oeaw.ac.at

$CaWO_4$ and Al_2O_3 are well-known target materials for experiments searching for rare events like CEνNS with NUCLEUS or hypothetical dark matter-nucleus scattering with CRESST. In the presence of sub-keV backgrounds of *unknown* origin, like the Low Energy Excess, experiments are also in need for verified and reliable simulations of *known* background components at sub-keV energies, e.g. based on the widely used Geant4 toolkit.
The ELOISE project aims to tackle this issue for electromagnetic particle interactions in both materials. We are currently in the process of evaluating Geant4's accuracy by comparing benchmark simulations with dedicated Electron Energy Loss Spectroscopy (EELS) of $CaWO_4$ and Al_2O_3 at sub-keV energies.
In this contribution, I will briefly describe the problem and outline the scope of ELOISE. Afterwards, I will report the results of ELOISE's EELS measurements. Finally, I will discuss our preliminary comparison with Geant4 simulations of $CaWO_4$ and Al_2O_3 at sub-keV energies.

10

Welcome and Introduction

Autore corrispondente: marco.vignati@roma1.infn.it

11

DAREDEVIL

Autore corrispondente: andrea.melchiorre@lngs.infn.it

12

LEGENDRE: HVeV detectors down at CUTE

Autore corrispondente: emanuelemichielin@gmail.com

13

Below threshold analysis in BULLKID

Autore corrispondente: matteo.folcarelli@roma1.infn.it

14

Discussion

15

Heat Only events in Edelweiss and Ricochet Ge detectors: update

Autore corrispondente: j.gascon@ipnl.in2p3.fr

16

CRESST-III and the quest of the Low Energy Excess

Autore corrispondente: michele.mancuso@mpp.mpg.de

17

New excess measurements from NUCLEUS

Autore corrispondente: margarita.kaznacheeva@tum.de

18

Single and Shared LEE Backgrounds in SPICE Detectors

Autore corrispondente: rkromani@gmail.com

19

Discussion

20

Energy release from recrystallization of amorphous pockets and low-energy excess signals

21

A source of excess quasiparticles in superconducting aluminum that decays over time

Autore corrispondente: elsa.mannila@vtt.fi

22

Investigating Infrared-Induced Excess Quasi-Particles in Superconducting Qubits

Autore corrispondente: michael.kerschbaum@phys.ethz.ch

23

Discussion

24

Poster Slot

25

DAMIC-M

26

SENSEI update on single-electron events

Autore corrispondente: abotti@fnal.gov

27

Low energy ionization signals in DarkSide

Autore corrispondente: sandro.dececco@roma1.infn.it

28

Discussion

29

Observation of a nuclear recoil peak in Sapphire and molecular dynamics simulation of the Al recoil

Autore: Dominik Raphael Fuchs[None]; Holger Kluck[1]; Jens Burkhart[None]

[1] *Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences*

Autore/i corrispondente/i: holger.kluck@oeaw.ac.at, jens.burkhart@oeaw.ac.at, fuchsdom@mpp.mpg.de

The current generation of cryogenic solid state detectors used in direct dark matter and CEνNS searches typically reach energy thresholds of $\mathcal{O}(10\,\mathrm{eV})$ for nuclear recoils. The energy calibration of these detectors is usually done via X-ray sources with energies in the $\mathcal{O}(\mathrm{keV})$ region, requiring an extrapolation to the low-energy regime. Ideally, these detectors should be calibrated via mono-energetic nuclear recoils in the relevant energy range. To achieve this, a new method has been proposed which is based on the radiative capture of thermal neutrons on nuclei, which may be followed by a de-excitation via single γ-emission leading to a low-energetic nuclear recoil. The first experimental observations of this effect were accomplished with $_4$ crystals. In this work we report on the observation of a peak around 1.1 keV in the data of an Al_2O_3 crystal in CRESST-III, which was irradiated with neutrons from an AmBe calibration source. We attribute this mono-energetic peak to the radiative capture of thermal neutrons on ^{27}Al and the subsequent de-excitation via single γ-emission.

To investigate the impact of crystal defect creation on the observable energy, the INCIDENCE project is performing molecular dynamics simulation of the Al recoil within the crystal lattice of Al_2O_3. We will present first results that predict an energy loss of $\mathcal{O}(10\,\mathrm{eV})$ for nuclear recoils at around 1.1 keV.

30

Phonon-only quasiparticle poisoning in superconducting qubits

31

Registration