IDM 2022
14th International Conference on Identification of Dark Matter
18-22 July 2022
Vienna, Austria

Contribution ID: **71** Type: **Oral presentation (young scientists)**

Directional performances of MIMAC in the keV-range: the reconstruction of 8 keV and 27 keV neutron spectra

Monday 18 July 2022 18:20 (10 minutes)

Directional detection is the only admitted strategy for the unambiguous identification of galactic Dark Matter (DM) even in the presence of an irreducible background as beyond the neutrino floor. The directional detection strategy relies on the simultaneous measurements of the energy and the direction of a DM-induced nuclear recoil for identification of a DM particle without ambiguity. Recoil energies must be searched in the keV-range: a WIMP typically transfers at maximum an energy lower than 10 keV/nucleon. In order to fully describe the nuclear recoil track in this low energy region, directional detectors must be sensitive to any primary charge which requires to operate at high gain (above 10^4). However, at high gain, 3D track reconstruction can be distorted by the influence of the numerous ions produced in the avalanches.

In this talk we present the low-energy performances of MIMAC, a directional detector based on Micromegas. MIMAC is searching simultaneously for ˜GeV WIMPs and for Axion-Like Particles of masses between 200 eV up to 20 keV. We describe the interplay between electrons and ions during signal formation in a Micromegas and we model the response of the detector, at high gain, thanks to a new simulation called SimuMimac that agrees with MIMAC measurements. We will derive a formula for the deconvolution of the signal induced on the Micromegas grid by the motion of the ions, and we will validate it both experimentally and by simulations. The deconvolution enables to extract the time distribution of the primary electrons cloud before the avalanche. The asymmetry of this distribution is related to the stopping power and we show that it can be used to distinguish between the head and the tail of a nuclear recoil track, a key feature of directional detectors.

Finally, we demonstrate the directional performances of the MIMAC detector in the keV-range thanks to the new possibilities offered by the deconvolution of the ionic signal. To do so, we place the detector into mono-energetic neutron fields at 27 keV and 8 keV in order to measure the scattering angle of neutron-proton interactions. We then reconstruct the neutron energy spectra, that depends on the scattering angle, and we obtain a better than 15° angular resolution. As far as we know this is the first time that a directional detector demonstrates such good performances for recoils in the keV-range, achieving the target requirements for the directional strategy of detection.

More details can be found in: https://arxiv.org/abs/2112.12469

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Session Classification: Parallel 1C - Direct detection II