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Directional Detection Research On Dark Matter With MIMAC

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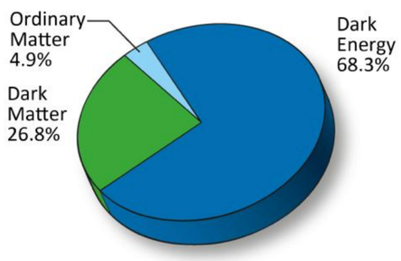
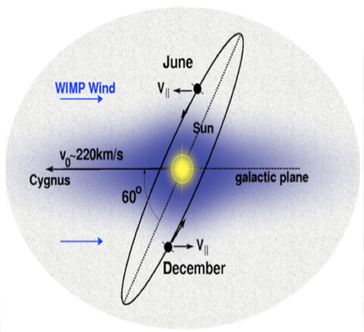
INTRODUCTION

Dark Matter (DM) in the form of Weakly Interacting Massive Particles (WIMPs) has been searched for since the 1980's. WIMPs interact with nuclei of the detectors. If a signal is observed in direct detection experiments, the best signature for its Galactic origin would be with a directional detector. To meet that challenge, directional Dark Matter detectors should be sensitive to low energy recoils in the keV range and have an angular resolution better than 20° . MIMAC (MIcro-TPC MAtrix of Chambers) is a low pressure gas detector which provides both the kinetic energy and three-dimensional track reconstruction of electron and ion tracks. We use specially developed low energy (1-25 keV) ion beam facilities to test the MIMAC response. In this paper we report the first ever observations of ^{19}F ion tracks in this low energy range. We have studied the track lengths (depths), widths and angular spreads with respect to the incoming ion direction. The estimated angular resolution is better than 10° at the measured energies. This is very encouraging for the hope to get a signature of the Galactic origin of a Dark Matter signal.



TODAY: 13.8 billion years old



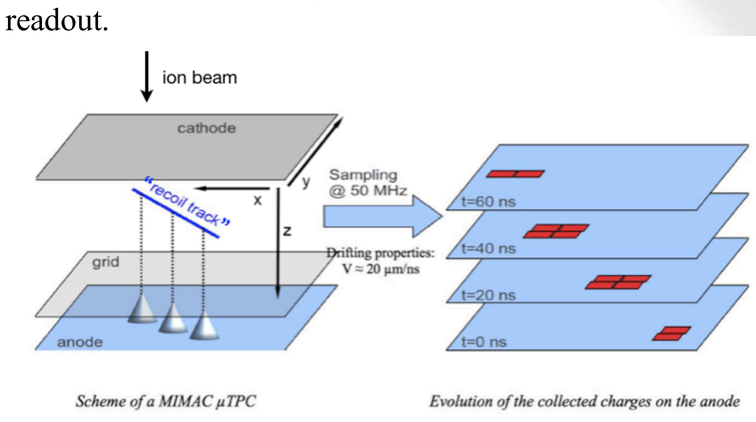
Keywords: Dark Matter, Directional Detection, keV Recoil Track Reconstruction, Angular Resolution

MIMAC DETECTOR

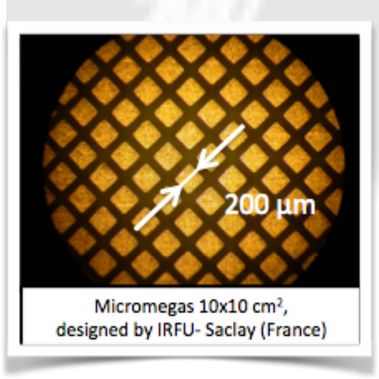
Detector General

The MIMAC detector is a matrix of low pressure micro-Time Projection Chamber (TPC) developed in collaboration between LPSC (Grenoble) and IRFU (Saclay). A chamber of the MIMAC matrix is based on a direct coupling of a pixelated Micromegas with a specially developed fast self-triggered electronics.

The nuclear recoil produced by an elastic WIMP collision, or any ion injected in the detector, releases part of its kinetic energy in the form of ionization. The primary electrons drift under an electric field to the grid of a bulk Micromegas producing avalanches under the influence of a high electric field (> 10 kV/cm) in a thin amplification gap. The secondary electrons are collected by the pixelated Micromegas anode, which contains strips of pixels in the *X* and *Y* directions (pitch of 424 μm) with a total of 512 channels (256 on each axis) over an area of 10.8×10.8 cm^2, providing a 2D readout. And *Z* information is derived from time duration and simulated drift velocity. Energy measured via grid of Micromegas, sampling @50MHz, same as the anode readout.



Scheme of a MIMAC μTPC *Evolution of the collected charges on the anode*



Micromegas 10x10 cm^2, designed by IRFU- Saclay (France)

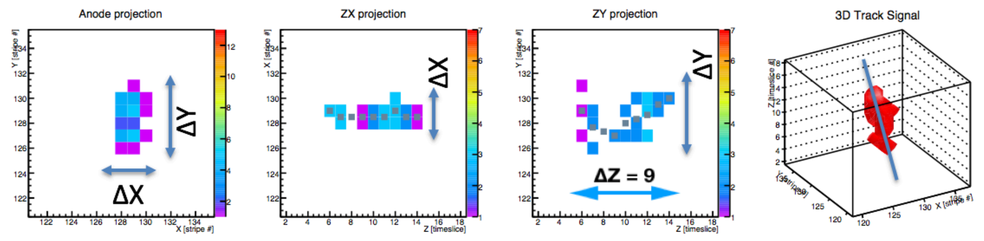
Experiment Set-up & Working Condition

- MIMAC gas mixture: 70% CF_4 + 28% CHF_3 + 2% C_4H_{10} @ 50 mbar.
- Major target: ^{19}F (spin dependent, low pressure Dark Matter gas detectors are competitive) range from 6.3 keV to 26.3 keV.
- Beam line and quenching facility: LHI and COMIMAC.
- Drift field: 150 V/cm. => Drift velocity: 22.9 μm/ns. (MAGBOLTZ)
- Calibration source: ^{55}Fe X-ray (5.9 keV)

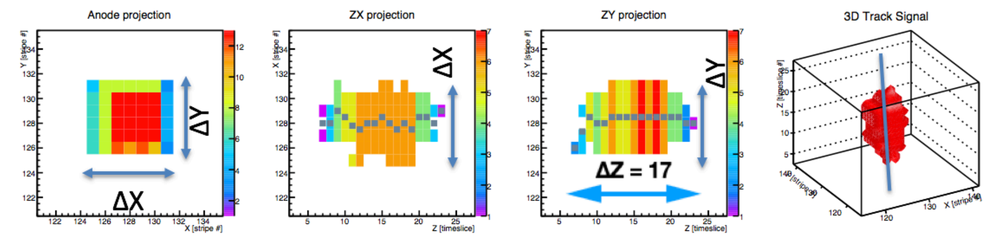
MAIN RESULTS AND DISCUSSIONS

➢ **3D Track Reconstruction in keVee Range**

Fluorine 6.3 keV (~2 keVee)

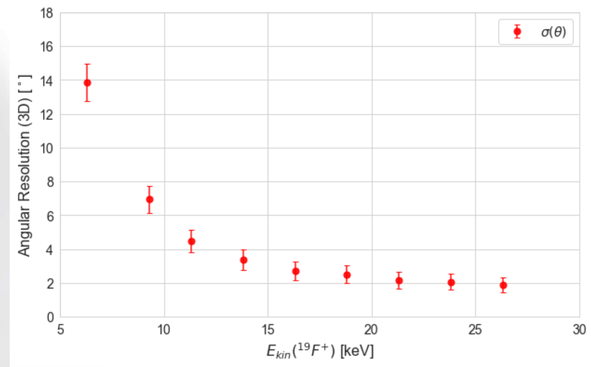


Fluorine 26.3 keV (~9 keVee)

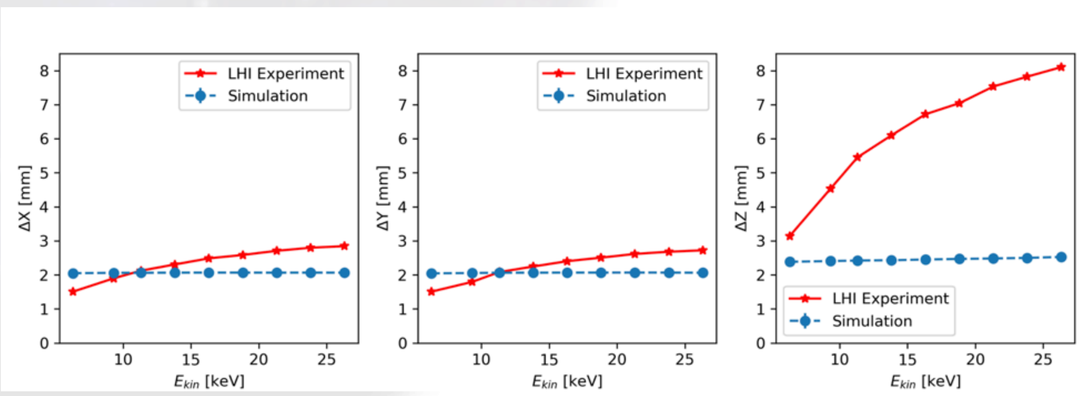


➢ **Angular Resolution < 20°**

- Performed experiment for 3 times, each time improve the design to make the experiment solid.
- Discussed and compared several reconstruction algorithms, concerning the result quality and robustness.
- The exciting results: a reconstructed angular resolution below 8 at an energy as low as 10 keV!



➢ **Large Discrepancy Discovery -- Experiment vs. Simulation**



➢ **Others: energy resolution ~ 15% FWHM; quenching factor ~ 0.3, etc.**

SUMMARY AND FUTURE

- Directional detection is an essential counter part for the major detection projects that are mainly focus on energy channel.
- A new directional detector of nuclear recoils at low energies (E > 100 eV) has been developed giving a lot of flexibility on targets, pressure, energy range… MIMAC is ready!
- Angular resolution and directional studies of 3D tracks have been performed experimentally with LHI facility, showing a promising result for future detection, while large discrepancies with respect to simulations!
- The 1 m^3 will be the validation of a new generation of a large DM high definition detector including directionality (a needed signature for DM discovery).

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