MIGDAL

Migdal In Galactic Dark mAtter expLoration

UNIVERSITY OF BIRMINGHAM

GDD Gas Detectors Development Group

Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG

HELSINKI INSTITUTE OF PHYSICS

IMPERIAL

KING'S College LONDON

LIP

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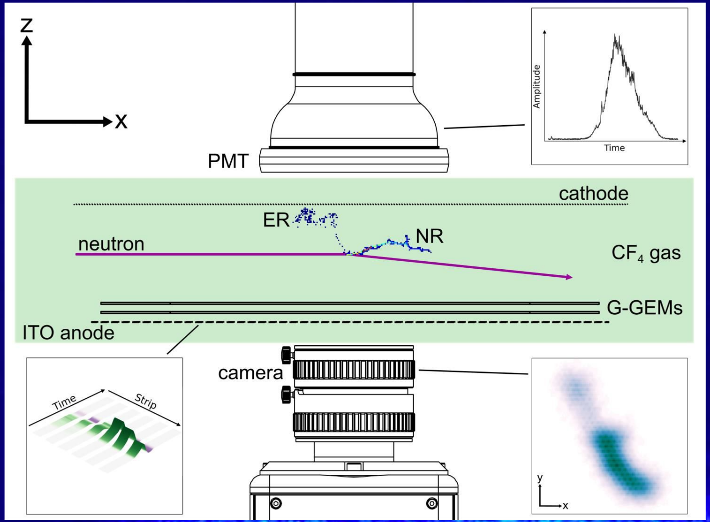
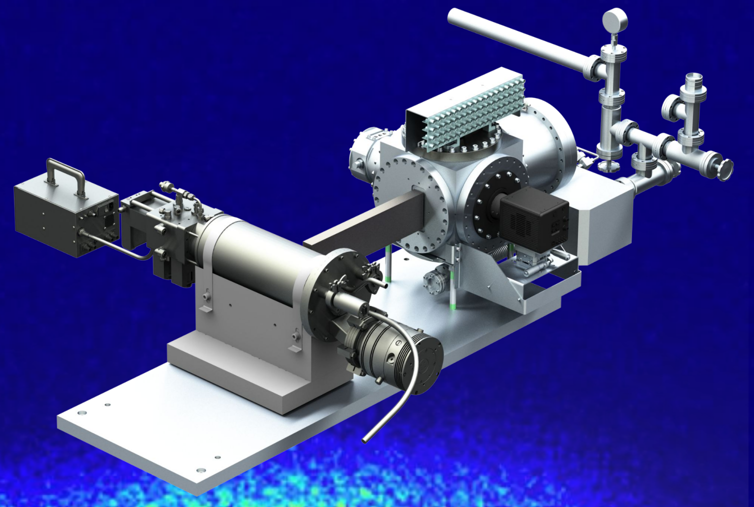
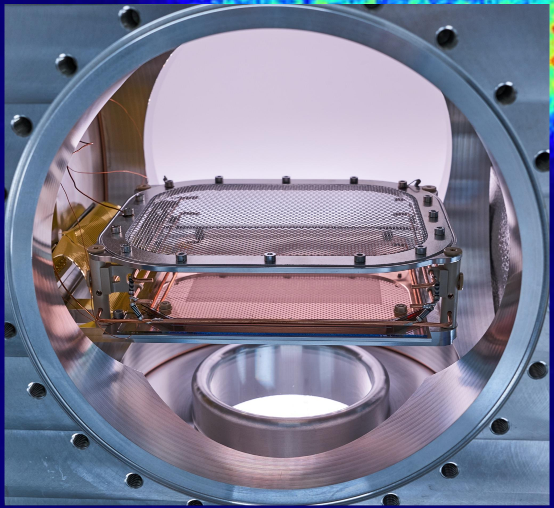
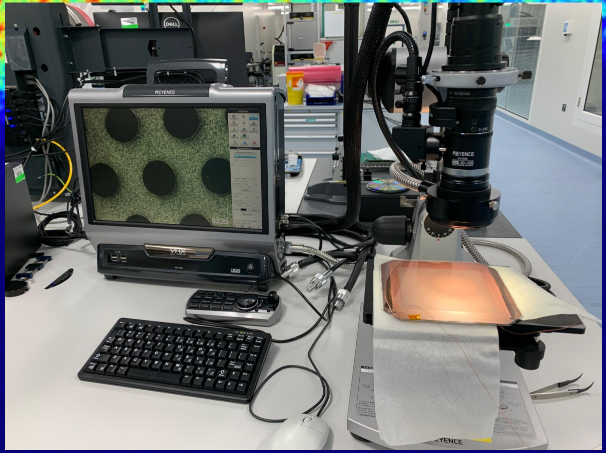
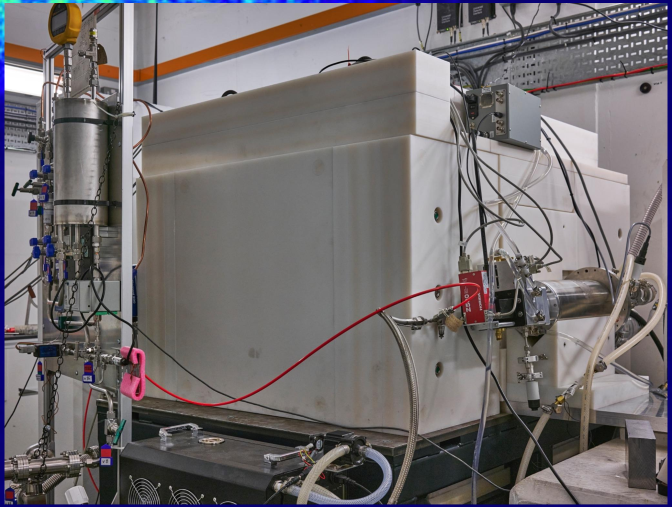

Z
X
PMT
Amplitude
Time
cathode
ER
NR
neutron
CF4 gas
G-GEMs
ITO anode
camera
Time
Strip
y
x

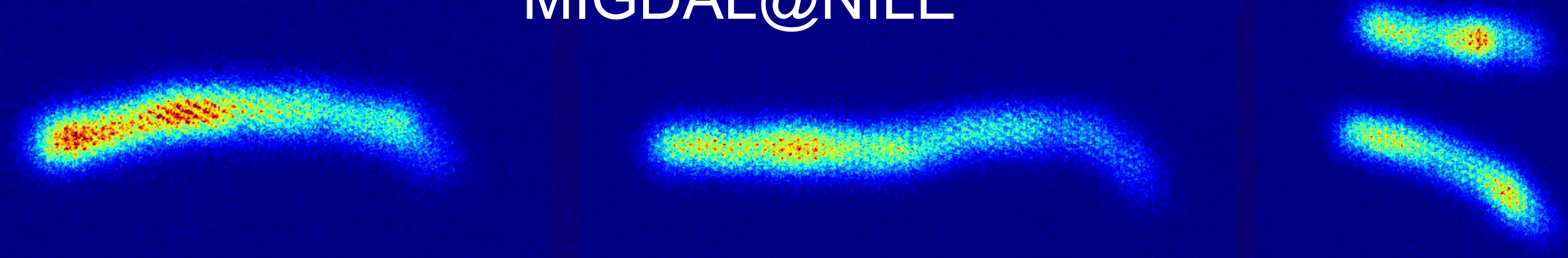


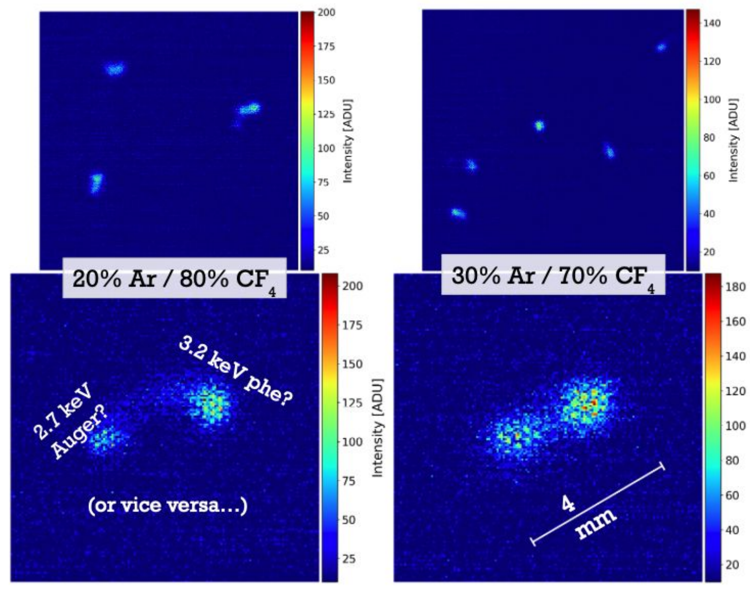


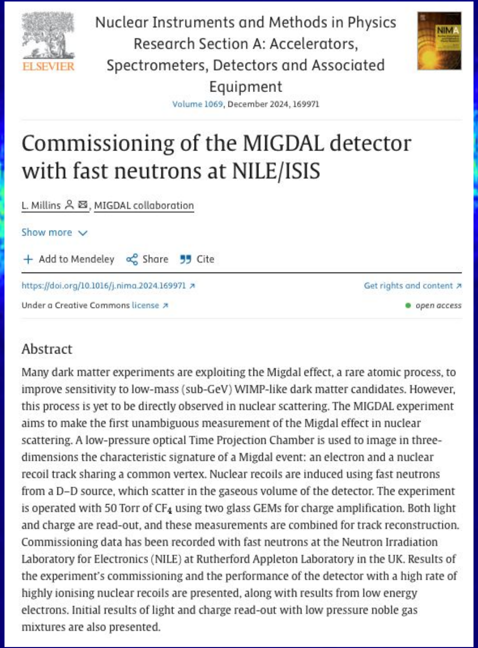

KEYENCE



MIGDAL@NILE







ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 1069, December 2024, 169971

Commissioning of the MIGDAL detector with fast neutrons at NILE/ISIS

L. Millins, MIGDAL collaboration

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Abstract

Many dark matter experiments are exploiting the Migdal effect, a rare atomic process, to improve sensitivity to low-mass (sub-GeV) WIMP-like dark matter candidates. However, this process is yet to be directly observed in nuclear scattering. The MIGDAL experiment aims to make the first unambiguous measurement of the Migdal effect in nuclear scattering. A low-pressure optical Time Projection Chamber is used to image in three-dimensions the characteristic signature of a Migdal event: an electron and a nuclear recoil track sharing a common vertex. Nuclear recoils are induced using fast neutrons from a D–D source, which scatter in the gaseous volume of the detector. The experiment is operated with 50 Torr of CF_4 using two glass GEMs for charge amplification. Both light and charge are read-out, and these measurements are combined for track reconstruction. Commissioning data has been recorded with fast neutrons at the Neutron Irradiation Laboratory for Electronics (NILE) at Rutherford Appleton Laboratory in the UK. Results of the experiment's commissioning and the performance of the detector with a high rate of highly ionising nuclear recoils are presented, along with results from low energy electrons. Initial results of light and charge read-out with low pressure noble gas mixtures are also presented.

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Transforming a rare event search into a not-so-rare event search in real-time with deep learning-based object detection

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Deep learning-based object detection algorithms enable the simultaneous classification and localization of any number of objects in image data. Many of these algorithms are capable of operating in real-time on high resolution images, attributing to their widespread usage across many fields. We present an end-to-end object detection pipeline designed for real-time rare event searches for the Migdal effect, using high-resolution image data from a state-of-the-art scientific CMOS camera in the MIGDAL experiment. The Migdal effect in nuclear scattering, crucial for sub-GeV dark matter searches, has yet to be experimentally confirmed, making its detection a primary goal of the MIGDAL experiment. Our pipeline employs the YOLOv8 object detection algorithm and is trained on real data to enhance the detection efficiency of nuclear and electronic recoils, particularly those exhibiting overlapping tracks that are indicative of the Migdal effect. When deployed online on the MIGDAL readout PC, we demonstrate our pipeline to process and perform the rare event search on 2D image data faster than the peak 120 frame per second acquisition rate of the CMOS camera. Applying these same steps offline, we demonstrate that we can reduce a sample of 20 million camera frames to around 1000 frames while maintaining nearly all signal that YOLOv8 is able to detect, thereby transforming a rare search into a much more manageable search. Our studies highlight the potential of pipelines similar to ours significantly improving the detection capabilities of experiments requiring rapid and precise object identification in high-throughput data environments.

I. INTRODUCTION

Convolutional neural networks (CNNs) as backbones for computer vision systems have found remarkable success in extracting meaningful information from image and video data. AlexNet [1] was one of the first major breakthroughs in CNN-based computer vision, where it achieved a Top-5 image classification error rate that was more than 10 percentage points lower than its closest competition in the ImageNet [2] 2012 contest. This result brought deep learning and CNNs to the forefront of modern computer vision research. Since then, CNNs have enabled a host of other computer vision applications including regression predictions of image inputs, object detection, key point detection, and instance segmentation as exemplified with the image data from our experiment shown in Fig. 1.

Image classification and regression are among the simplest computer vision applications, where images are passed through an algorithm (often a CNN) and mapped to discrete and continuous sets of outputs, respectively. Common examples of classification and regression tasks

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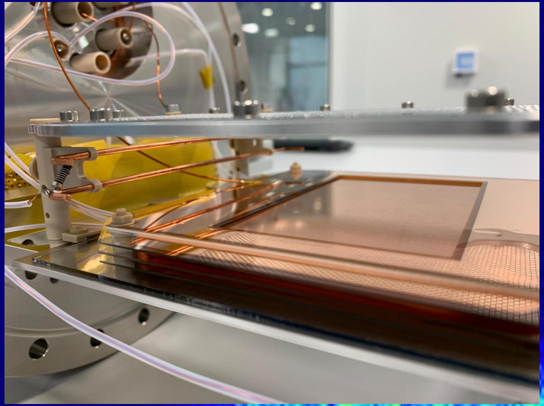
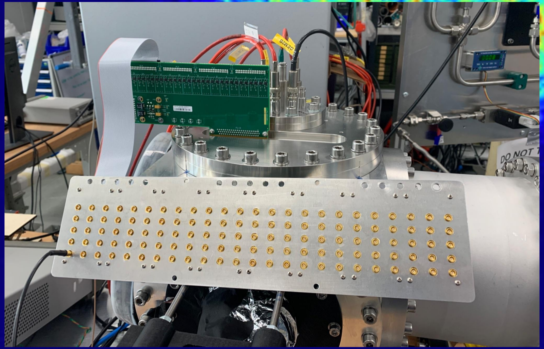
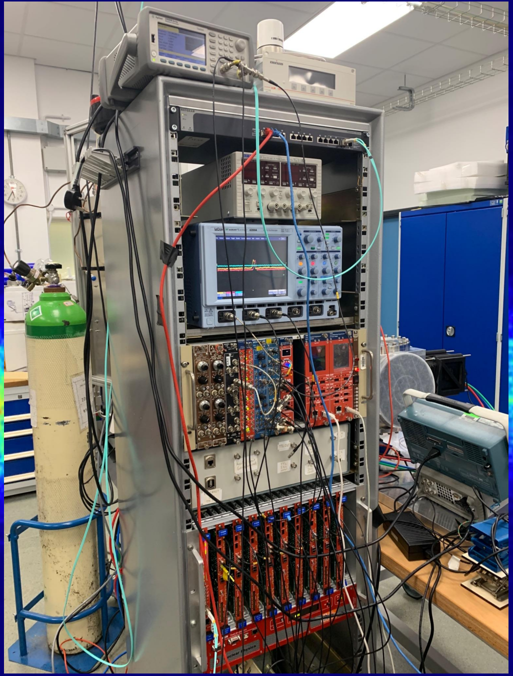
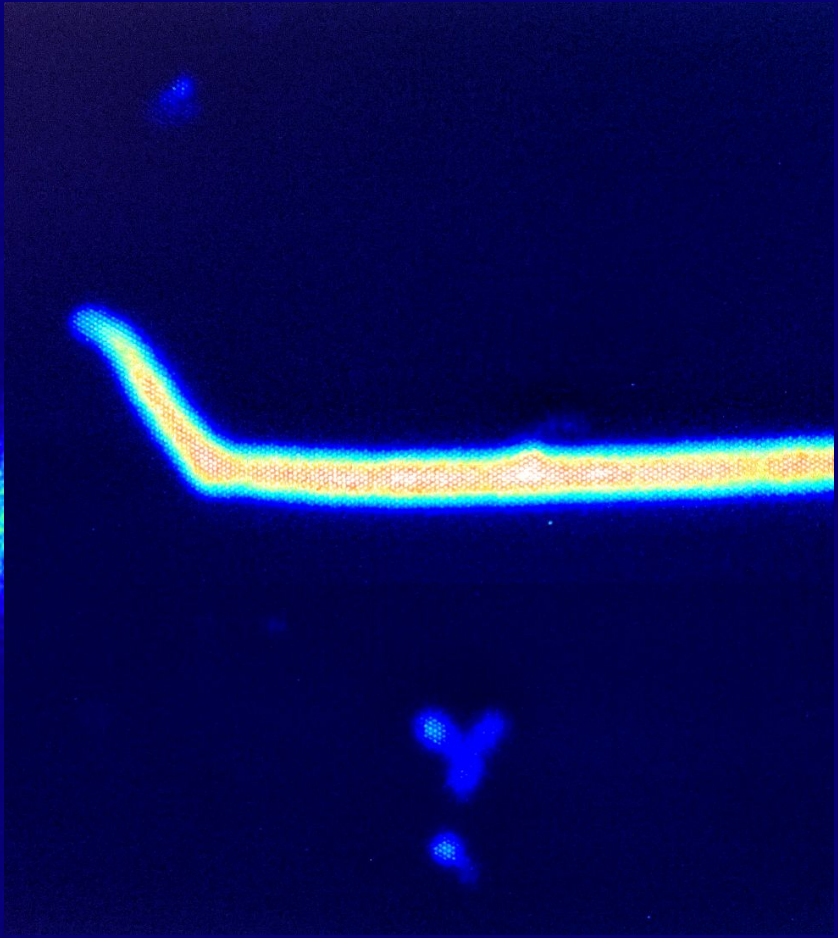
R&D and UPGRADE










Season's Greetings
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