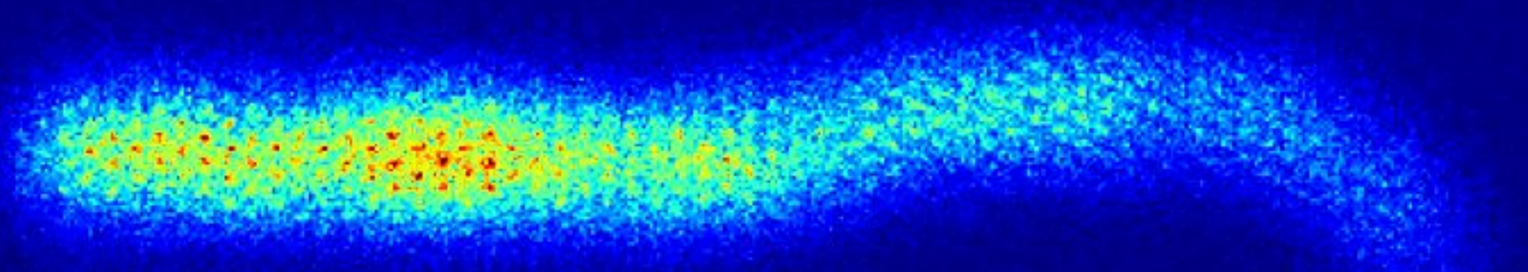
Results from the MIGDAL experiment's commissioning using fast neutrons from a D-D generator



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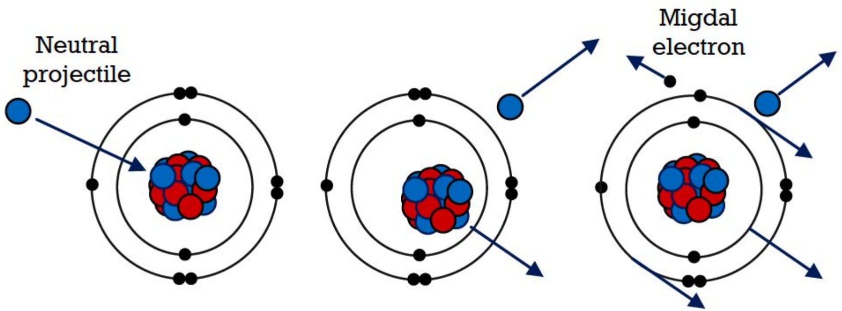
on behalf of the MIGDAL collaboration

XVIII International Conference on Topics in Astroparticle and Underground Physics, TAUP 2023, 28.08-01.09, Vienna

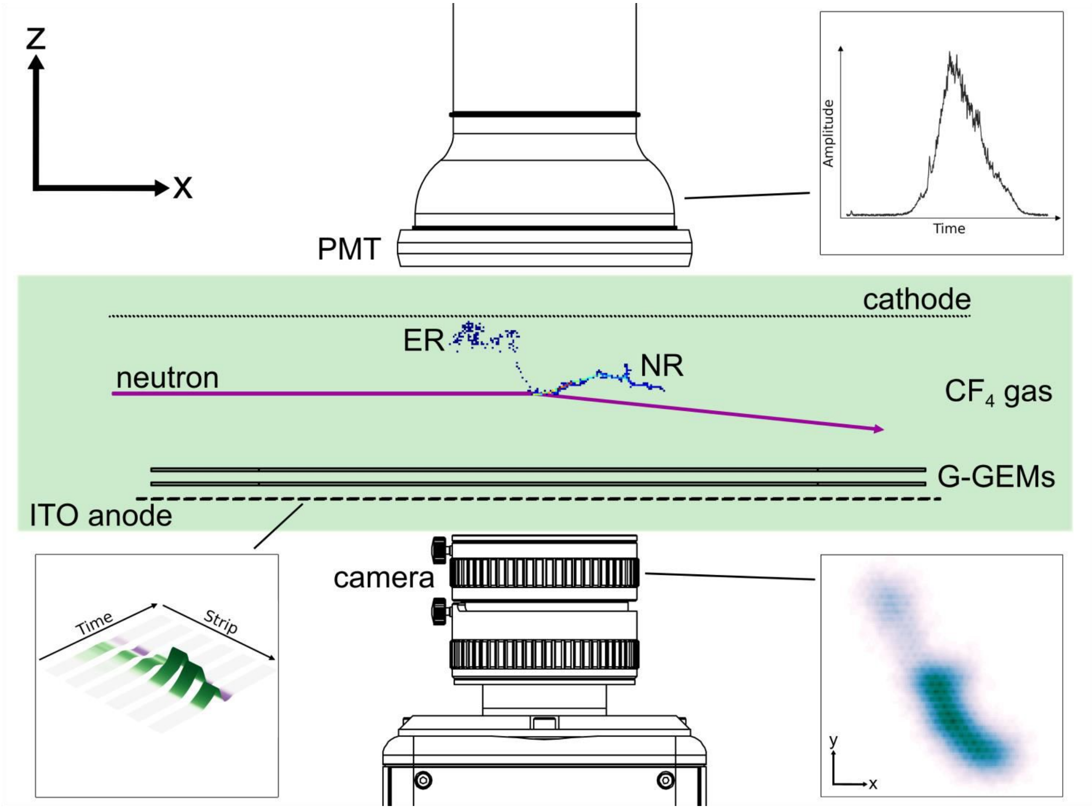
Migdal effect



Migdal event topology involves a nuclear recoil and electron recoil originating from the same vertex.

- Migdal effect increases sensitivity of DM experiments to low mass WIMPs
- Looking for a rare (10^{-5}) atomic phenomenon never before observed in the nuclear scattering
- Aim of the MIGDAL experiment - unambiguous observation and measurement of the Migdal effect using a low pressure Optical TPC
- Signal signature: “V-like” shaped event with two tracks from electron and NR with different dE/dx and sharing the same vertex

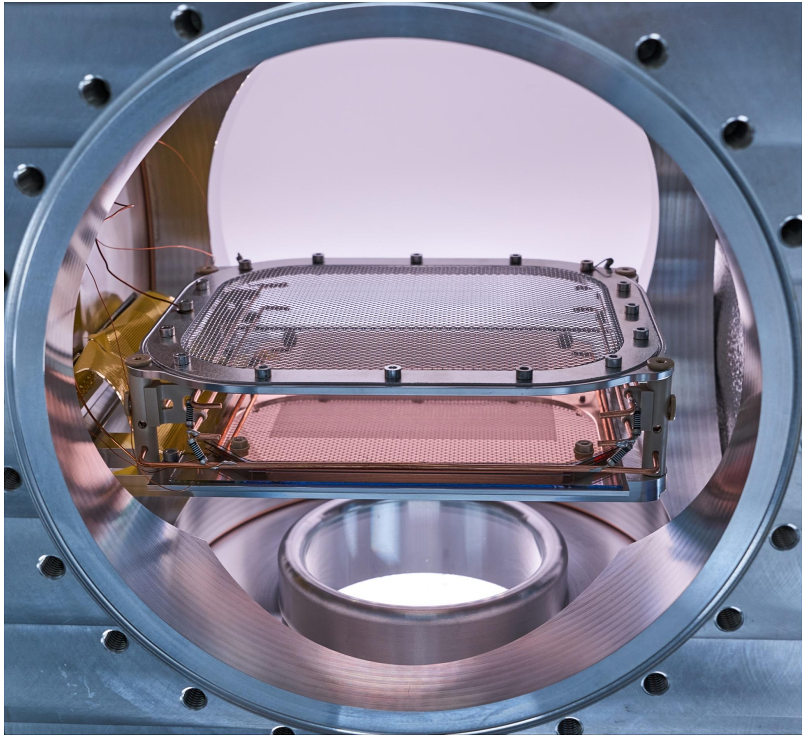
The MIGDAL experiment

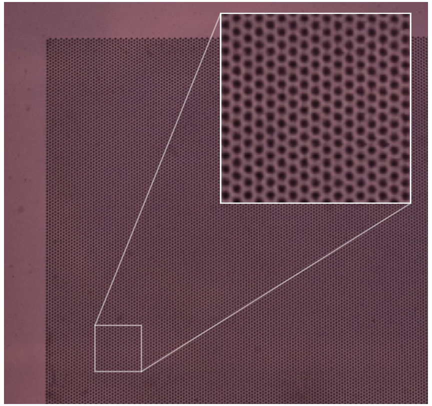


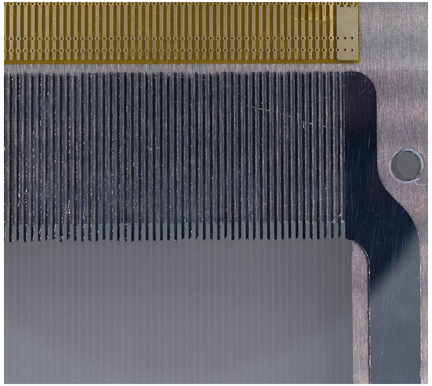
- Low-pressure gas: 50 Torr of CF_4
  - Extended particle tracks
  - Avoid gamma interactions
  - Can stably work with fraction of Ar
- TPC Signal amplification
  - 2 x glass-GEMs (Cu + Ni cladded)
- Readout :
  - Optical : Camera + photomultiplier tube
  - Charge: GEMs + 120 ITO anode strips
- High-yield neutron generator
  - D-D: 2.47 MeV (10^9n/s)
  - D-T: 14.7 MeV (10^{10}n/s)
  - Defined beam, "clear" through TPC
- Electron and nuclear recoil tracks
  - Migdal: NR+ER tracks, common vertex
  - NR and ER have very different dE/dx
  - 5 keV electron threshold

    5.9 keV X-rays from Fe-55 induce 5.2 keV photoelectrons from F for calibration at threshold.

The MIGDAL optical-TPC







Two glass GEMs one Cu- and one Ni-cladded :

- thickness: 550 µm

- OD /pitch: 170/280 µm

- active area: 10x10 cm^2

- total gain ~10^5

ITO strips wire bonded to readout

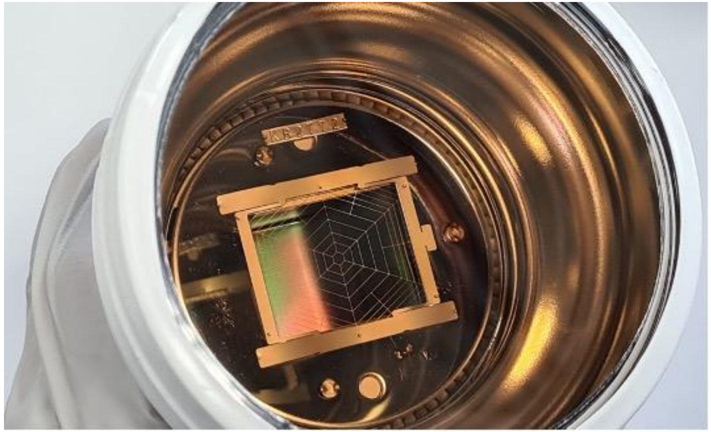
- 120 strips

- width/pitch: 0.65/0.83 mm

Two field shaping copper wires

- TPC inside of the central aluminium cube
- Drift gap: 3 cm between woven mesh and cascade of two glass-GEMs (E_{DRIFT}=200 V/mm for minimum electron diffusion)
- Transfer and signal induction gaps : 2 mm
- Low outgassing materials; vacuum before fill $2*10^{-6}$ mbar; signal unchanged several days after fill

Light and charge readout

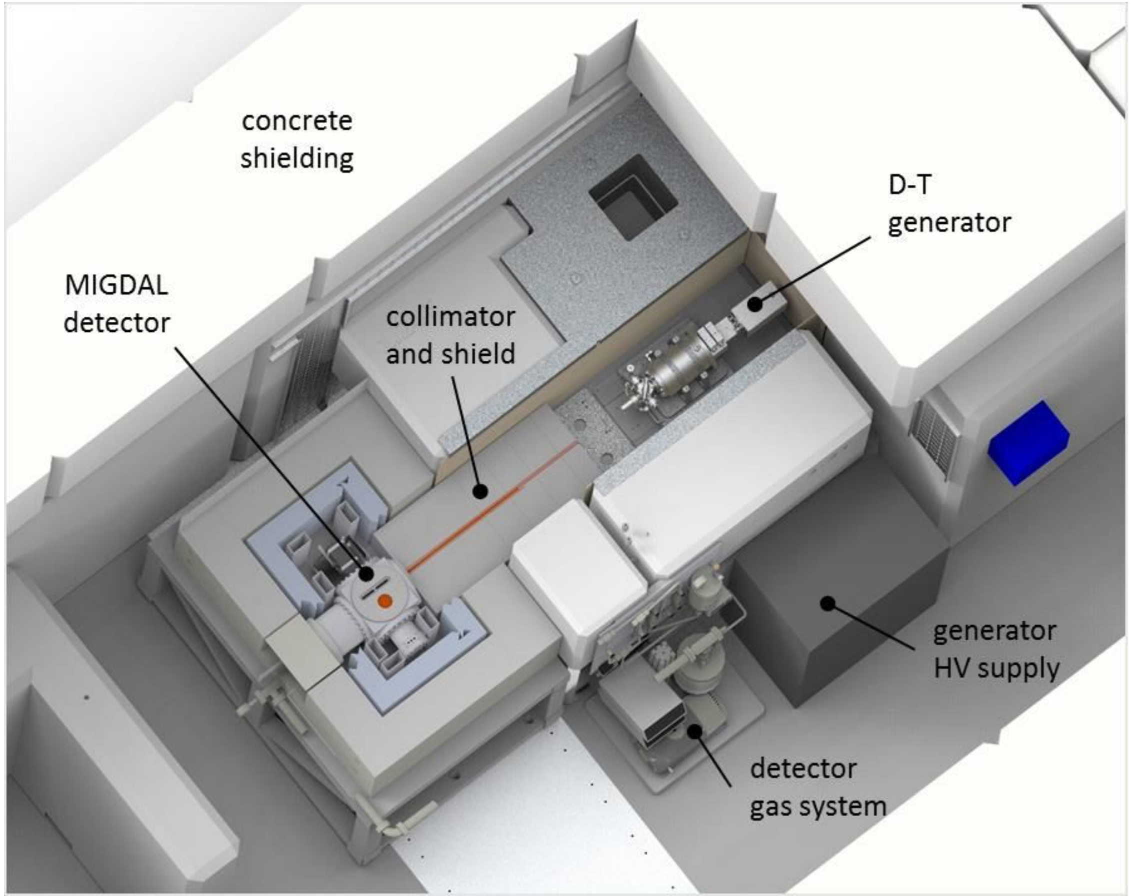


ITO anode strips
Post-GEM ionisation
Readout of (x,z) plane
Pitch: 833 μm
Digitised at 2 ns/sample
(Drift velocity: 130 μm/ns*)*

qCMOS camera
(Hamamatsu ORCA - QUEST)
Detects GEM scintillation through glass viewport behind ITO anode
Readout of (x,y) plane
Exposure: 8.33 ms/frame (continuous)
Px scale: 39 μm (2×2 binning)
Lens: EHD-25085-C; 25mm f/0.85

VUV PMT (Hamamatsu R11410)
Detects primary and secondary (GEM) scintillation
Absolute depth (z) coordinate
Digitised at 2 ns/sample [Trigger]

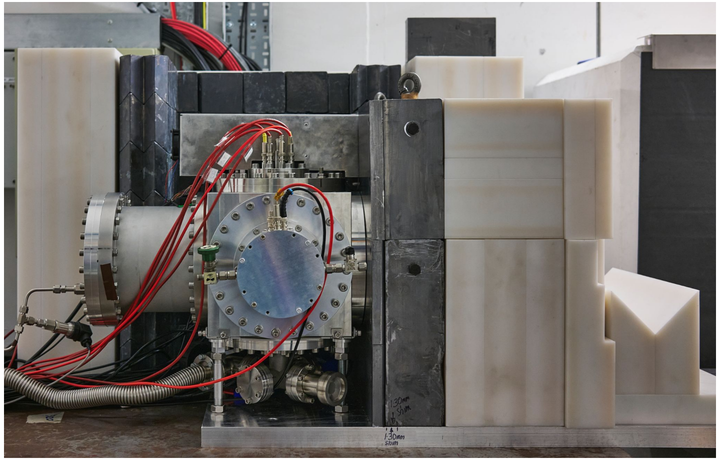
The NILE facility at Rutherford Appleton Laboratory

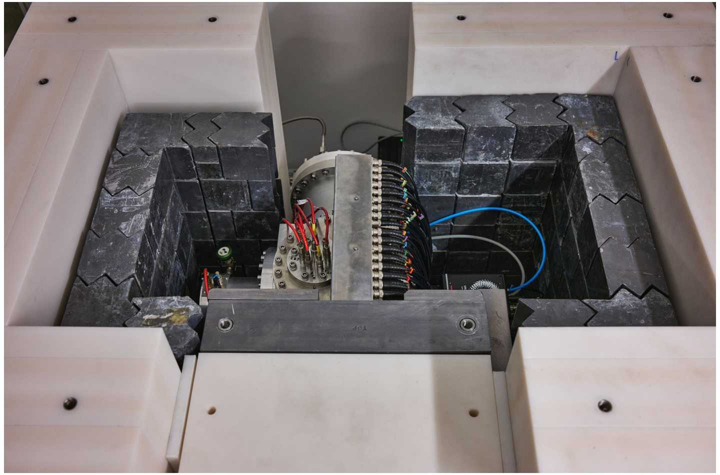


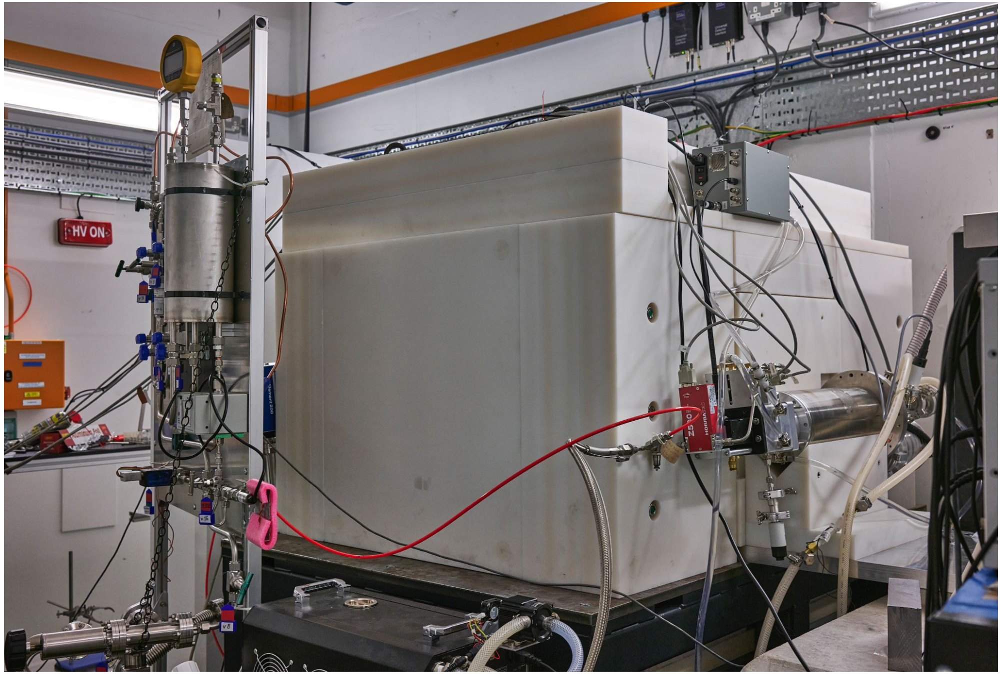
Experiment setup with D-T generator

- D-D and D-T fusion generators installed in “shielding bunker”
- Collimators & additional shielding provide clean beam through OTPC
- D-T collimator 1 m, D-D 30 cm

Experiment installation in the NILE bunker





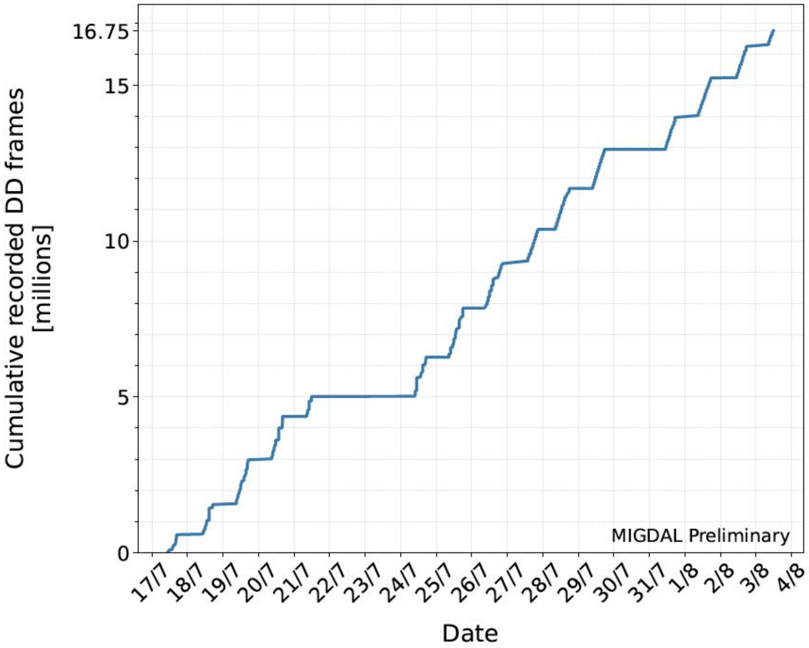


MIGDAL experiment fully assembled at NILE

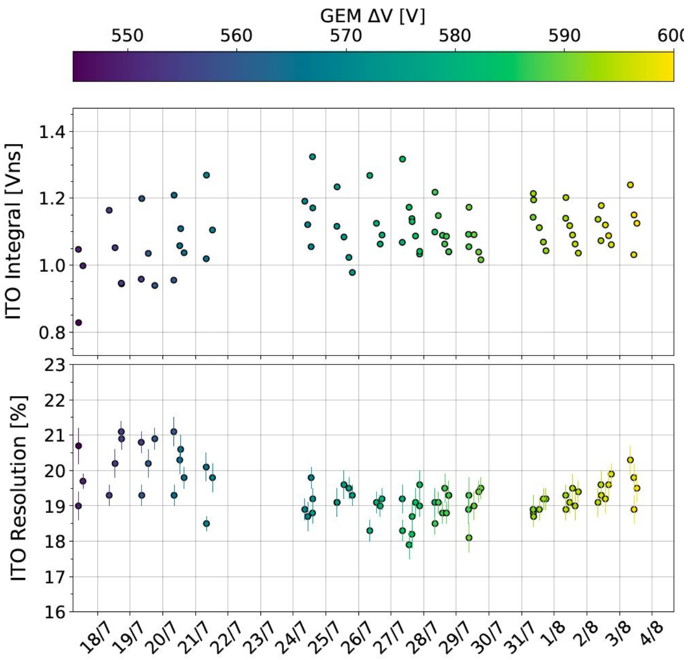
- Lead shield : 10 cm
- Borated HDPE shield : 20 cm
- Collimator HDPE+ lead : 30 cm long

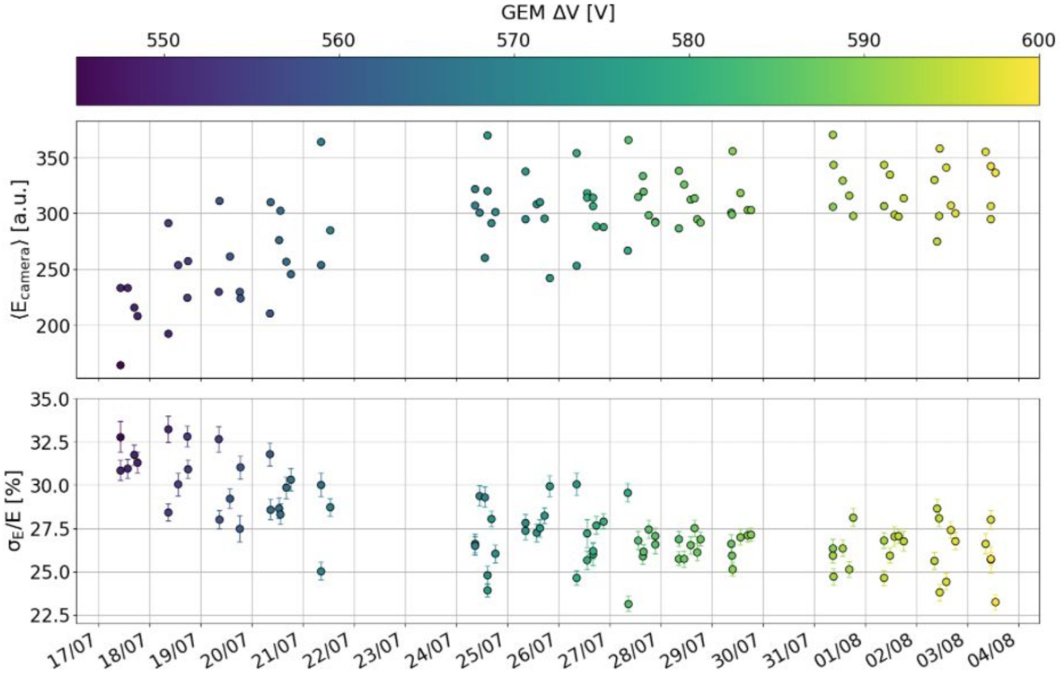
First Science Run (Summary)

- The First Science run took place from the 17th of July to the 3rd of August.
- Data taken using D-D neutron generator, with a lower NR rate than designed, is recorded continuously during 10 hour long shifts, and includes significant fraction of empty frames.
- Frames taken with 20 ms exposure time. Longer than planned due to problems with camera's Linux firmware.
- Data taking interspersed with regular calibration runs (^{55}Fe) to monitor the gain of the detector.
- Voltage across GEMs increased by a small amount each day to keep constant gain.
- Total gain in GEMs tuned to a threshold required to see fully resolved ^{55}Fe peak.
- Average spark rate ~ 7/min due to high dynamic range the detector operates at.
- Half of the data is blinded.



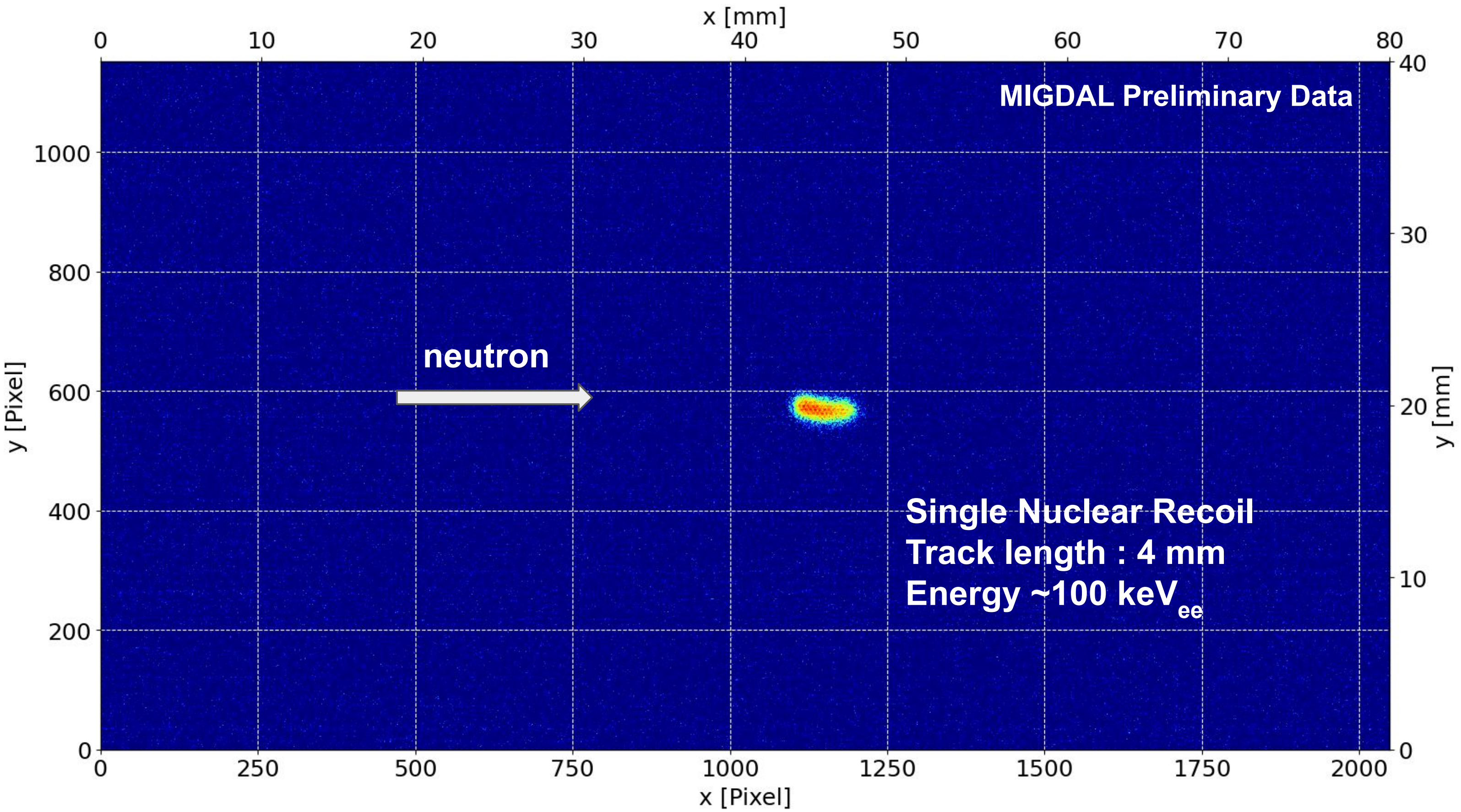
Detector calibration



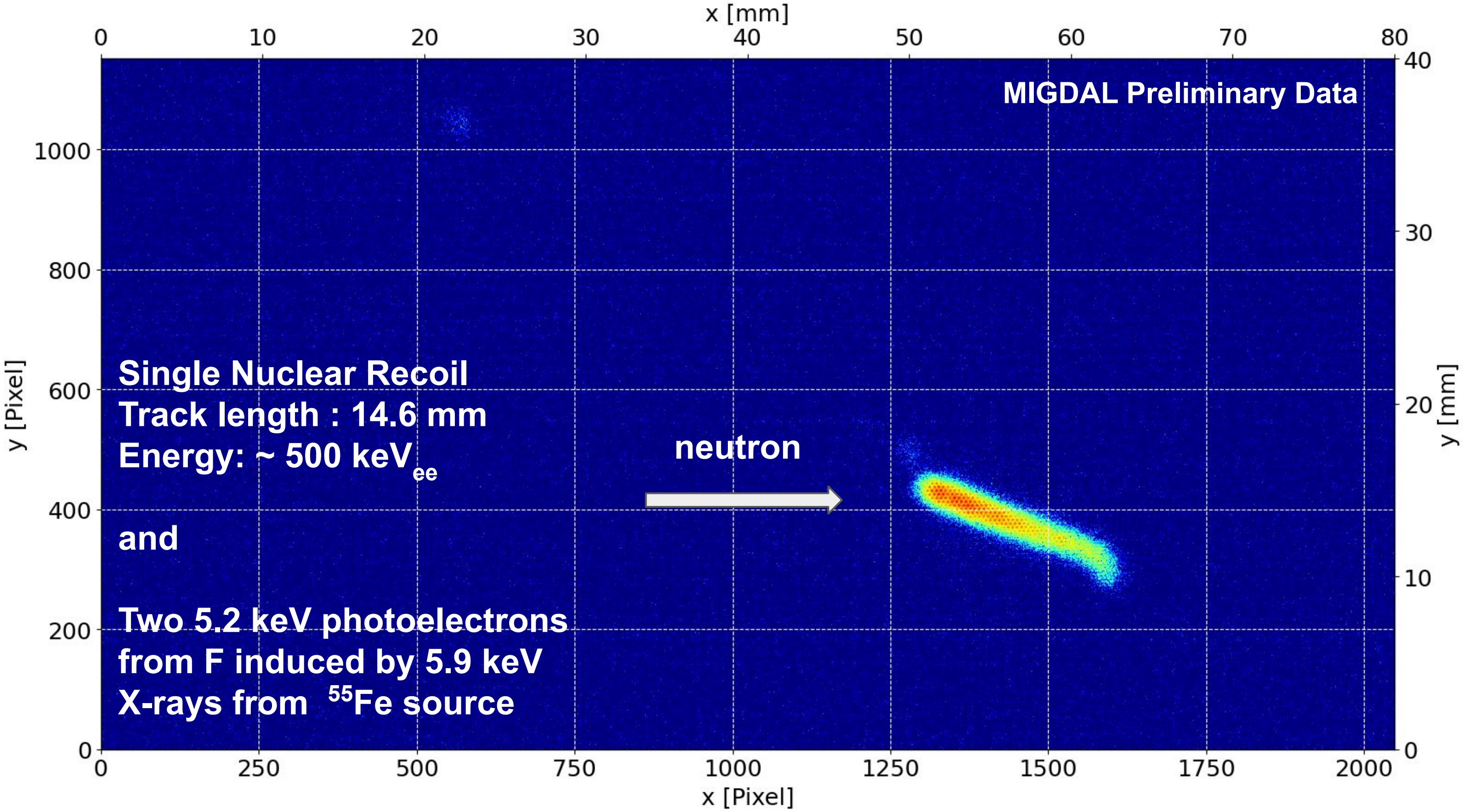


- ^{55}Fe calibration performed several times per day.
- Energy scale is consistent over the course of the science run with ~20% variation.
- Resolution in ITO ~20% and in camera ~ 25 - 32 % camera readout depending on the gain.
- Further improvements are expected with better calibration methods.

Examples of events (Single Nuclear Recoil)



Examples of events (Migdal-like event)



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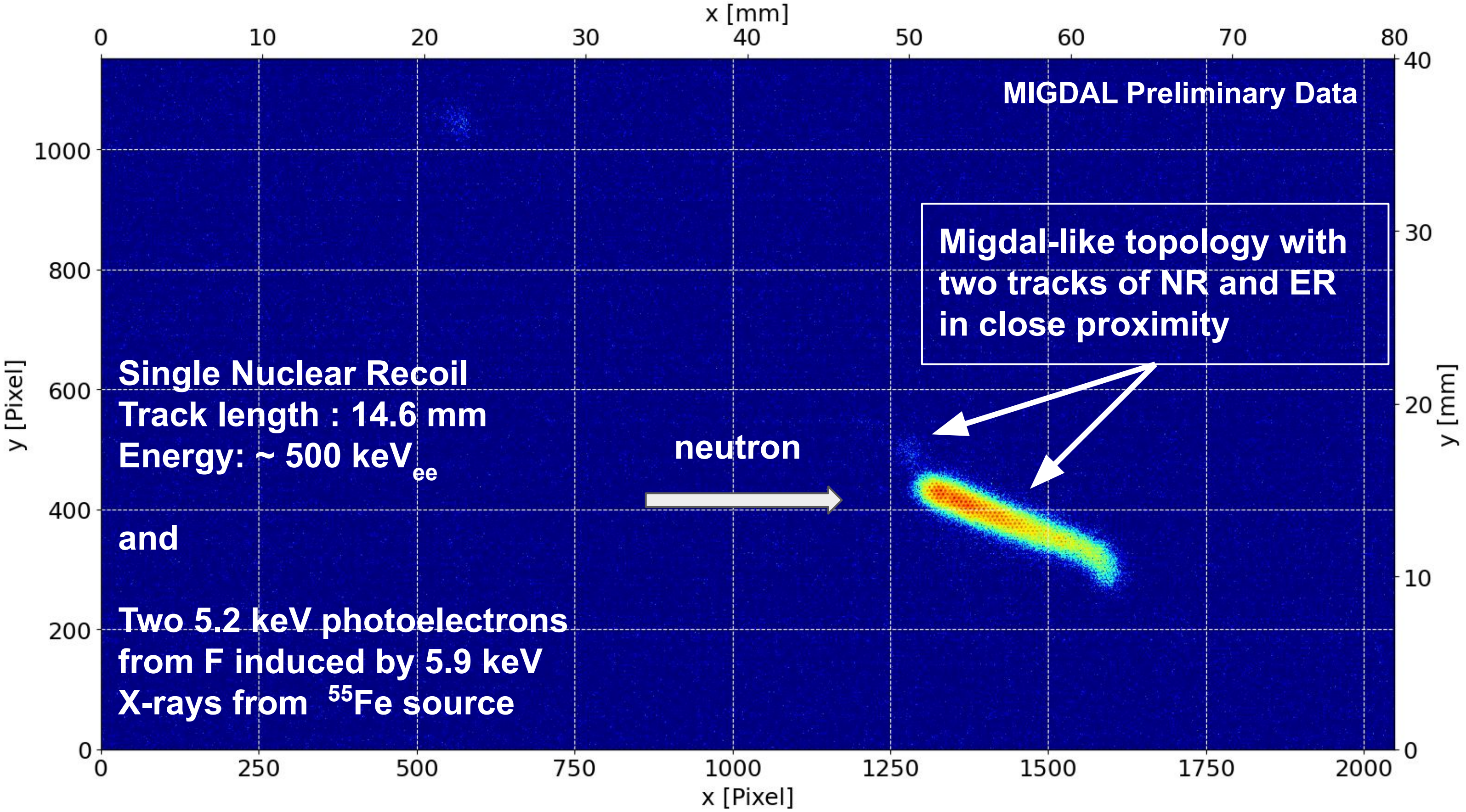

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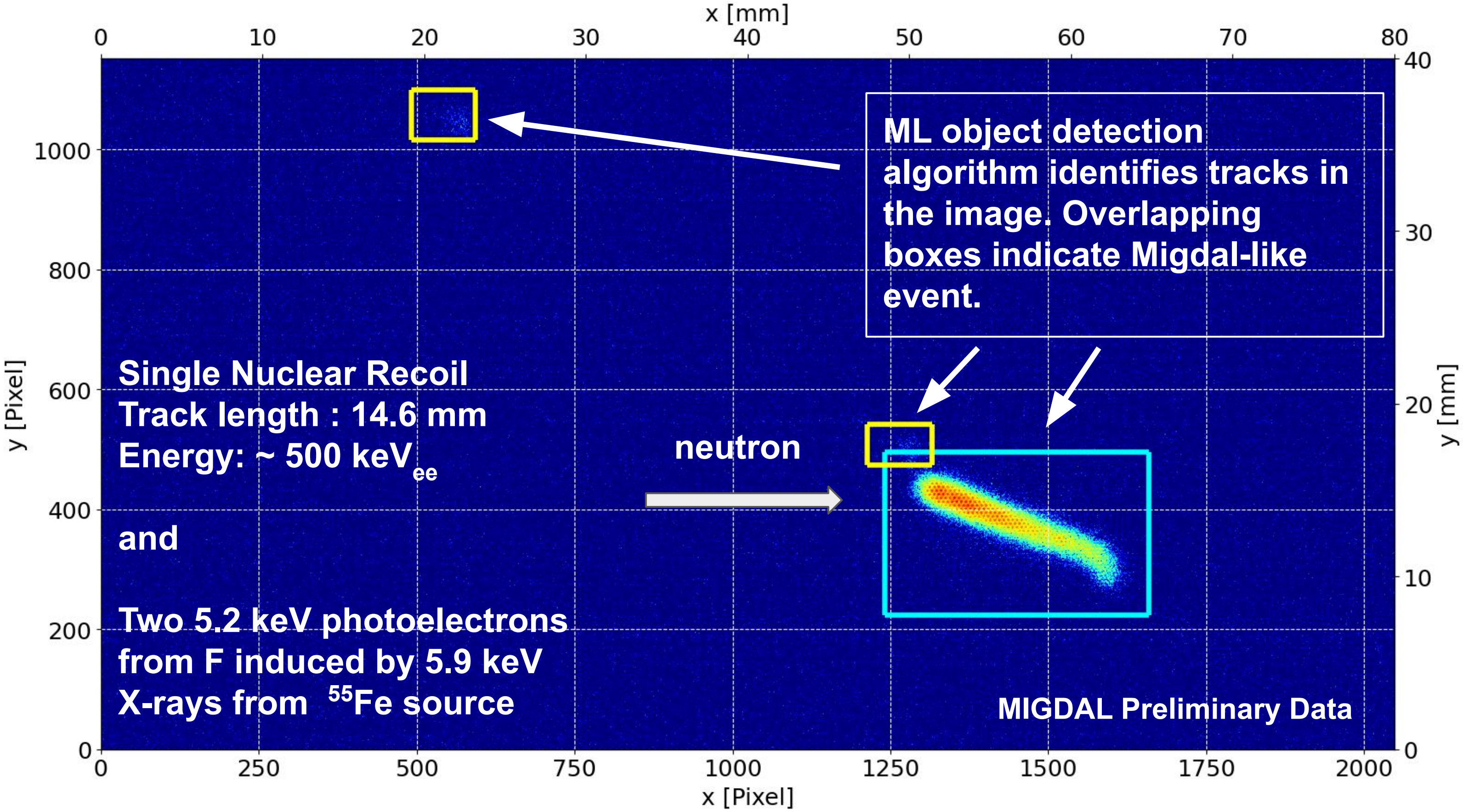

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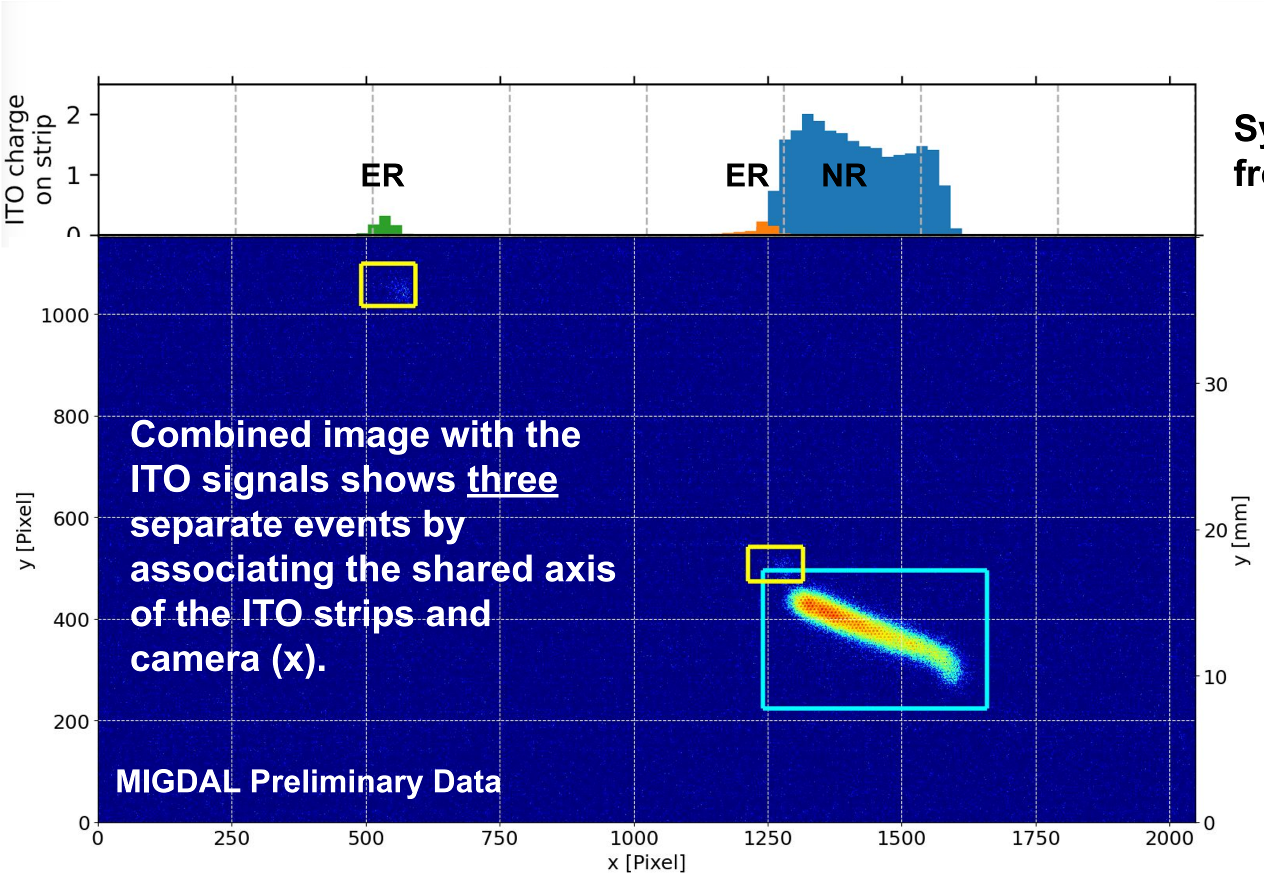
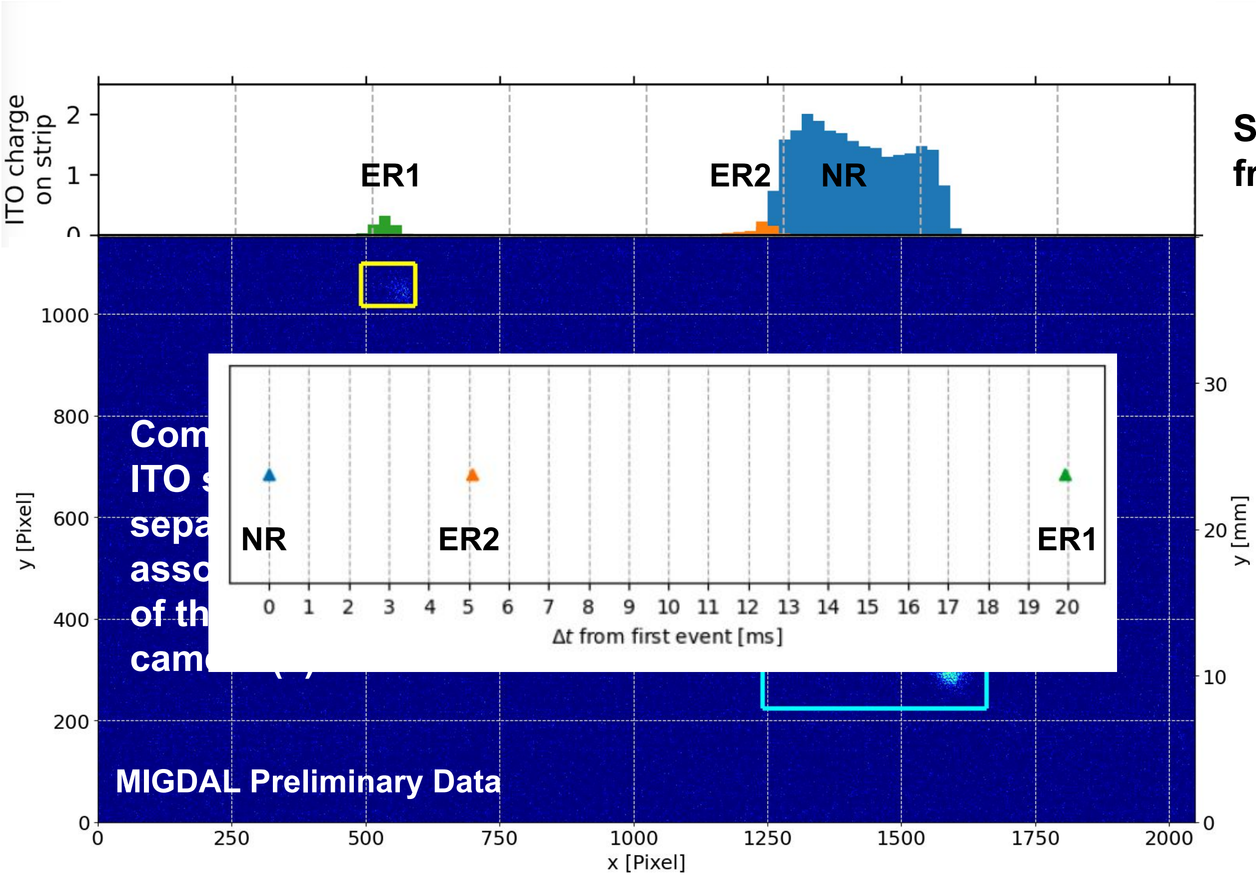


Synchronised signals from ITO strips.

Examples of events (Migdal-like event)



Synchronised signals from ITO strips.

Timing information from ITO strips separates all 3 tracks.

Summary

- The MIGDAL experiment aims to perform an unambiguous observation of the Migdal effect.
- First science run took place with DD neutron source at the NILE facility at RAL.
- The detector performed well through the weeks of operation with highly ionising NRs.
- More data to be taken later in September. Regular calibration runs performed.
- Analysis of recorded data underway.
- 50% of recorded data are blinded.
- Stay tuned for results !

Funding: UKRI Science and Technology Facilities Council; U.S. Department of Energy; FCT Fundação para a Ciência e a Tecnologia; Horizon 2020 European Union Funding for Research & Innovation; National Science Foundation

MIGDAL collaboration: U. Autonoma Madrid, U. Birmingham, GDD Group/CERN, U. Helsinki, Imperial College London, King's College London, LIP-Coimbra, U. New-Mexico, U. Oxford, Royal Holloway, Rutherford Appleton Laboratory, U. Sheffield (https://migdal.pp.rl.ac.uk)