The MIGDAL experiment

Measuring a rare atomic process to help search for dark matter

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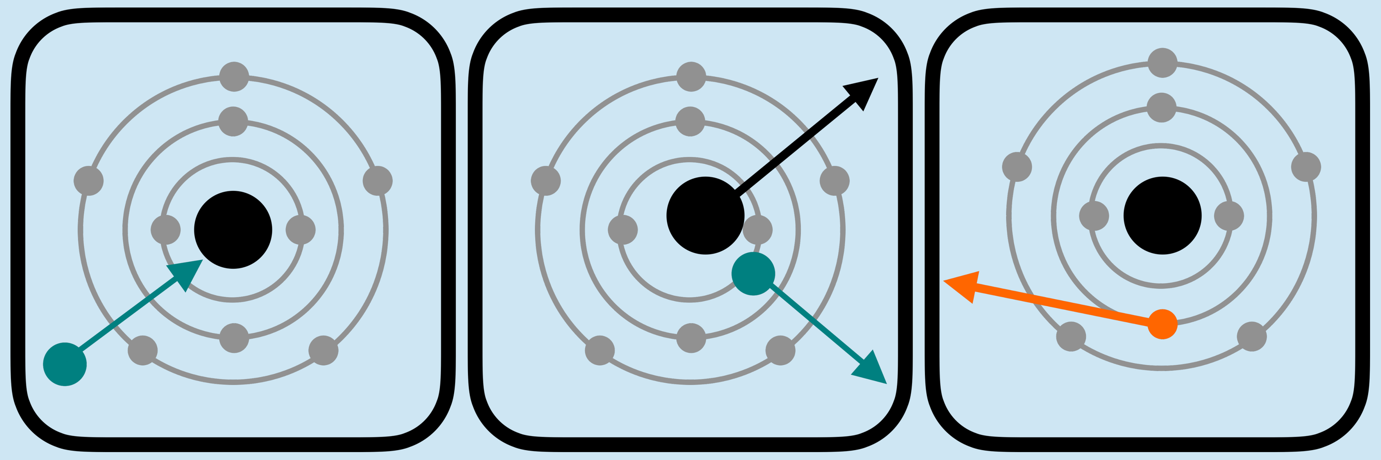
1. The Migdal effect

- Elusive atomic process [1, 2]
- Has been observed in nuclear α, β^- and β^+ decays [3, 4] but lacks experimental confirmation in nuclear scattering
- However, following [5], it is being exploited by Dark Matter experiments such as LUX [6] and XENON [7] to search for low-mass (sub GeV) dark matter

When a **neutral projectile (e.g. neutron or dark matter candidate)** scatters off a **nucleus** the **nucleus** can move relative to its **electron cloud**. This can lead to **ionisation** of the recoiling atom that can be detected as an electronic recoil. The signature of a Migdal event is two tracks originating from the same vertex, one from the nuclear recoil and the other from the electronic recoil.



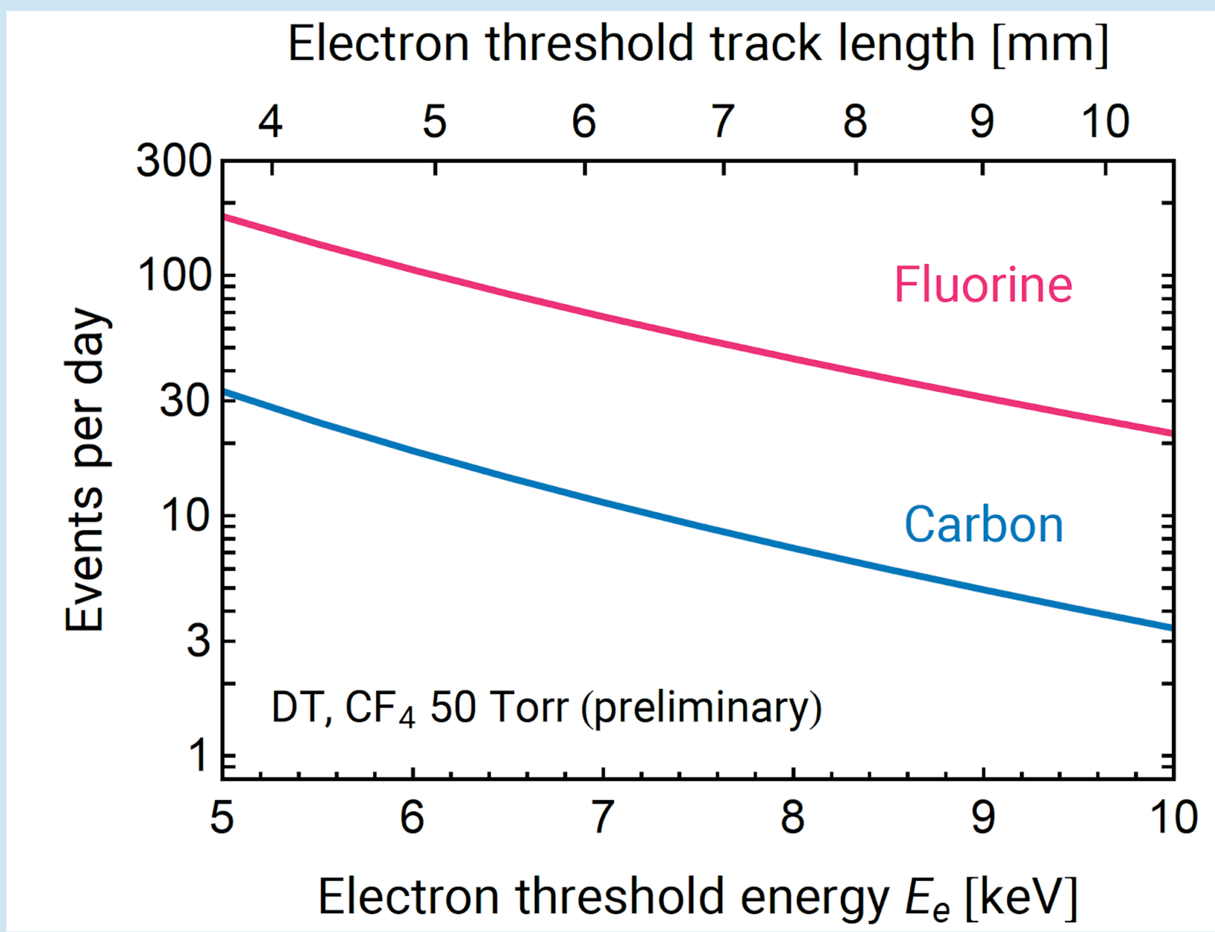
2. The MIGDAL Experiment: Migdal In Galactic Dark mAtter expLoration

- Aims to make **first observation** of Migdal effect in fast-neutron scattering
- Collimated, mono-energetic neutrons from DD and DT generators will be used
- Search will be performed using an optical time projection chamber, initially filled with CF_4 at 50 Torr, known for its good light-emission properties
- Charge and light signals amplified by two glass GEMs
- High-resolution track images will be combined with ionisation and scintillation information to reconstruct tracks in **3D** using fast CMOS camera imaging and induced signal readout with 120 ITO strips connected to 60 channel Acqiris digitiser

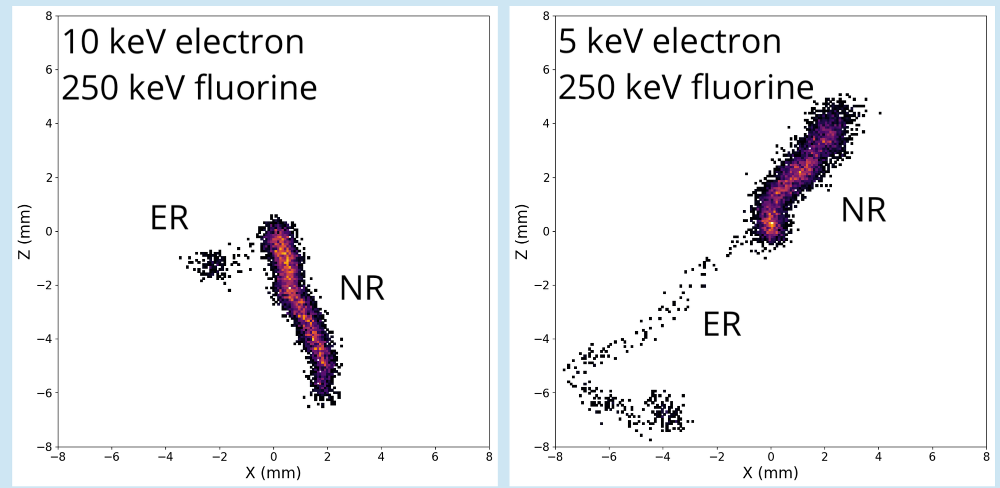
3. Simulation

- A simulation framework has been produced using:
  - DEGRAD [8] to produce electron tracks
  - SRIM [9] for nuclear recoil track production
  - Magboltz [10] for diffusion
  - ANSYS [11],GMSH [12]/ELMER [13],COMSOL [14] to produce electrostatic field maps
  - Garfield++ [15] for the electron avalanche and signal readout
- Allows us to easily study different gases and pressures, and develop reconstruction algorithms

4. Expected Migdal events per day

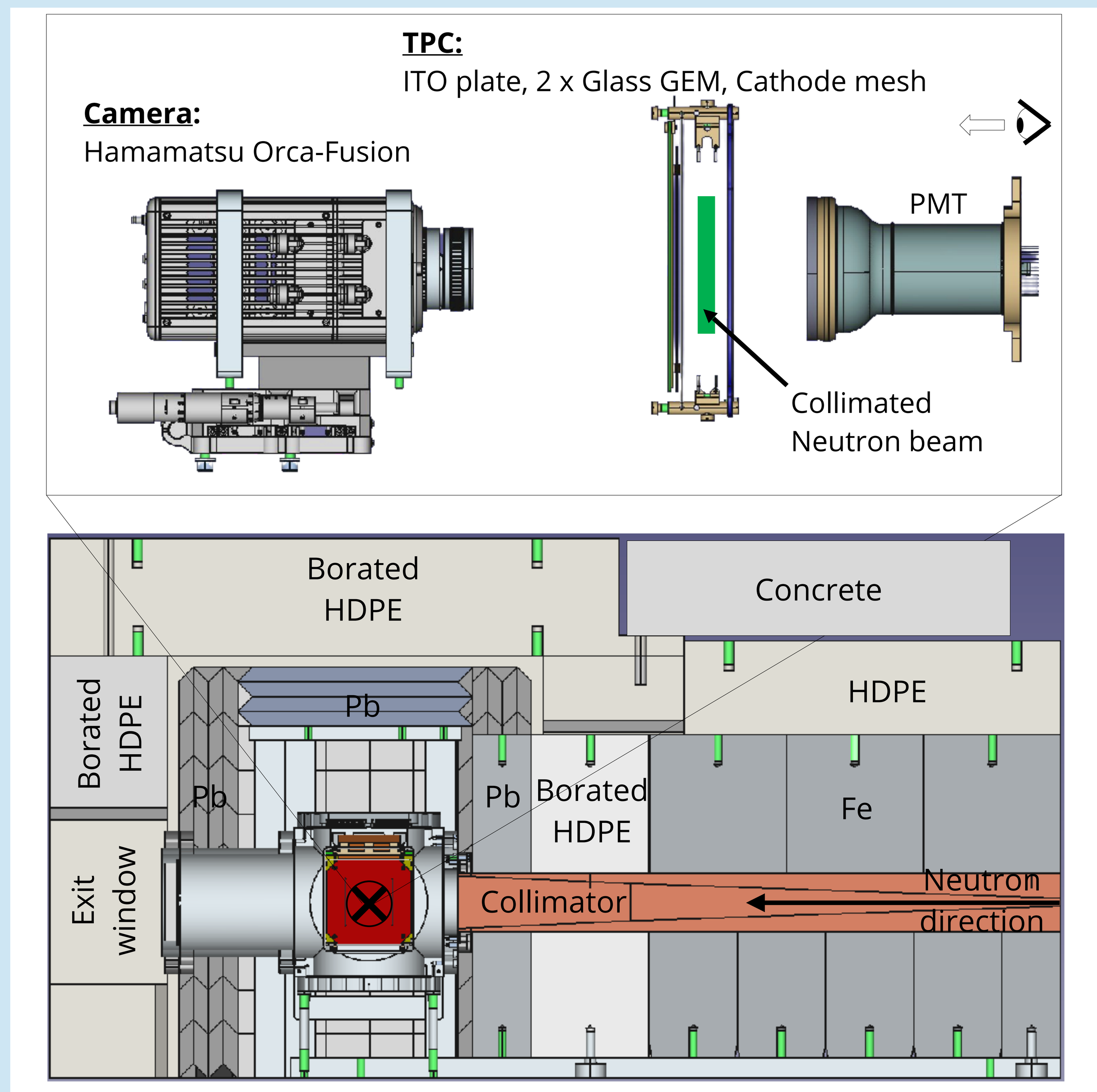


5. Simulated tracks

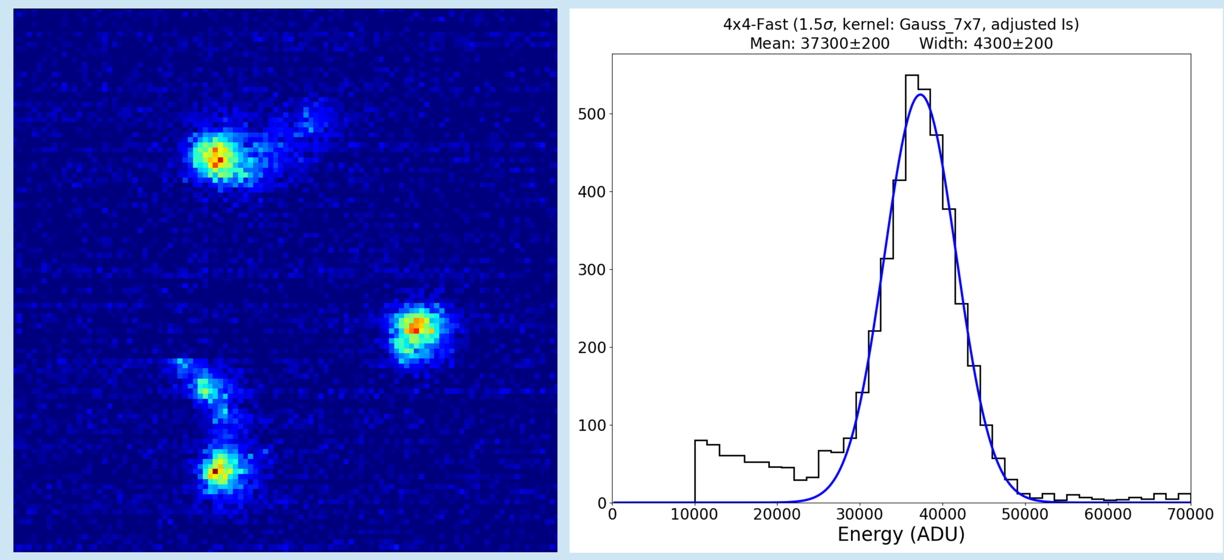


- Two examples of Migdal events after 10 mm of drifting in CF_4
- Each event contains two tracks, one from electronic recoil and one from nuclear recoil
- The two tracks share the same vertex, a characteristic feature of Migdal events
- Different dE/dx along the two tracks will be used to discriminate background events

6. Experiment setup



7. Preliminary glass GEM tests



- Successful tests have been performed using glass-GEMs by the GDD group at CERN with CF_4 at 50 Torr
- (Left) typical ^{55}Fe tracks, (right) energy resolution
- Tracks from 5.9 keV ^{55}Fe decays are well resolved, energy resolution is 27%
- Track head and tail clearly resolved for low energy electrons

8. Outlook

- The experiment will be installed and commissioned at the **NILE facility at ISIS (RAL)**
- Data taking will begin using a DT neutron source (14.1 MeV)
- Expect to be able to **observe** the Migdal effect **quickly**
- A program of mixing the CF_4 with other gases used in dark matter experiments, e.g. argon and xenon, will follow

9. References

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