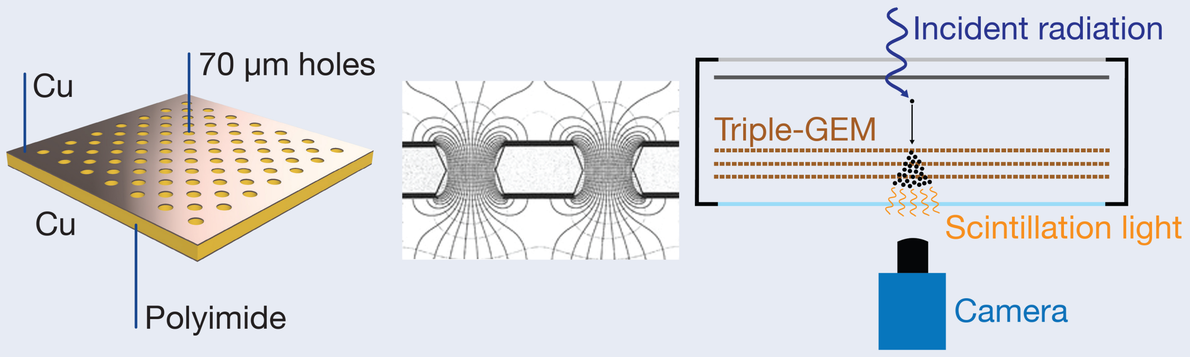
Combined Optical and Electronic Readout for Event Reconstruction in a GEM-based TPC

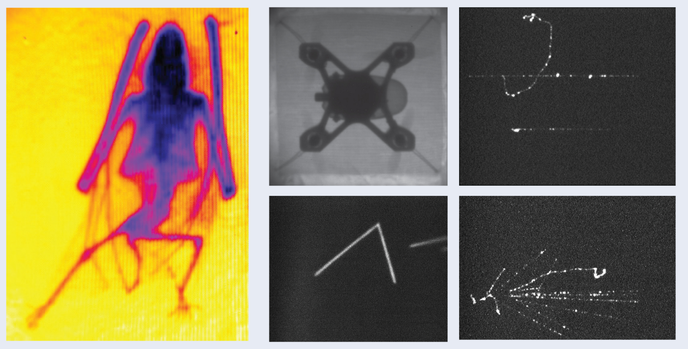
Optically read out detectors based on Gaseous Electron Multipliers (GEMs) can provide 2D projections of particle tracks with high spatial resolution and outstanding sensitivity. Augmenting 2D projections with timing information from a photomultiplier tube, an optically read out Time Projection Chamber (TPC) permitting 3D reconstruction of straight particle tracks was realised. A transparent anode was developed to permit simultaneous optical and electronic readout. Based on a strip anode fabricated from a photolithographically structured ITO layer, arrival times of electronic signals at the transparent strip anode were recorded to obtain relative depth information. Combining optically read out projections with electronically obtained depth information, 3D reconstruction of intricate particle trajectories was achieved.

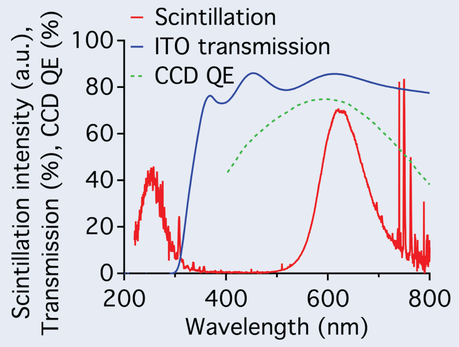
Optical readout of GEM-based detectors



Gaseous Electron Multipliers (GEMs) are a variety of MicroPattern Gaseous Detectors (MPGDs) based on perforated insulating polyimide foils with Cu electrodes on both sides. High electric field regions in the holes of GEM foils result in electron avalanche multiplication and secondary scintillation light emission. Electronic signals induced by secondary electrons can be registered. Alternatively, emitted secondary scintillation light can be optically recorded with imaging sensors.

X-ray radiography and event imaging

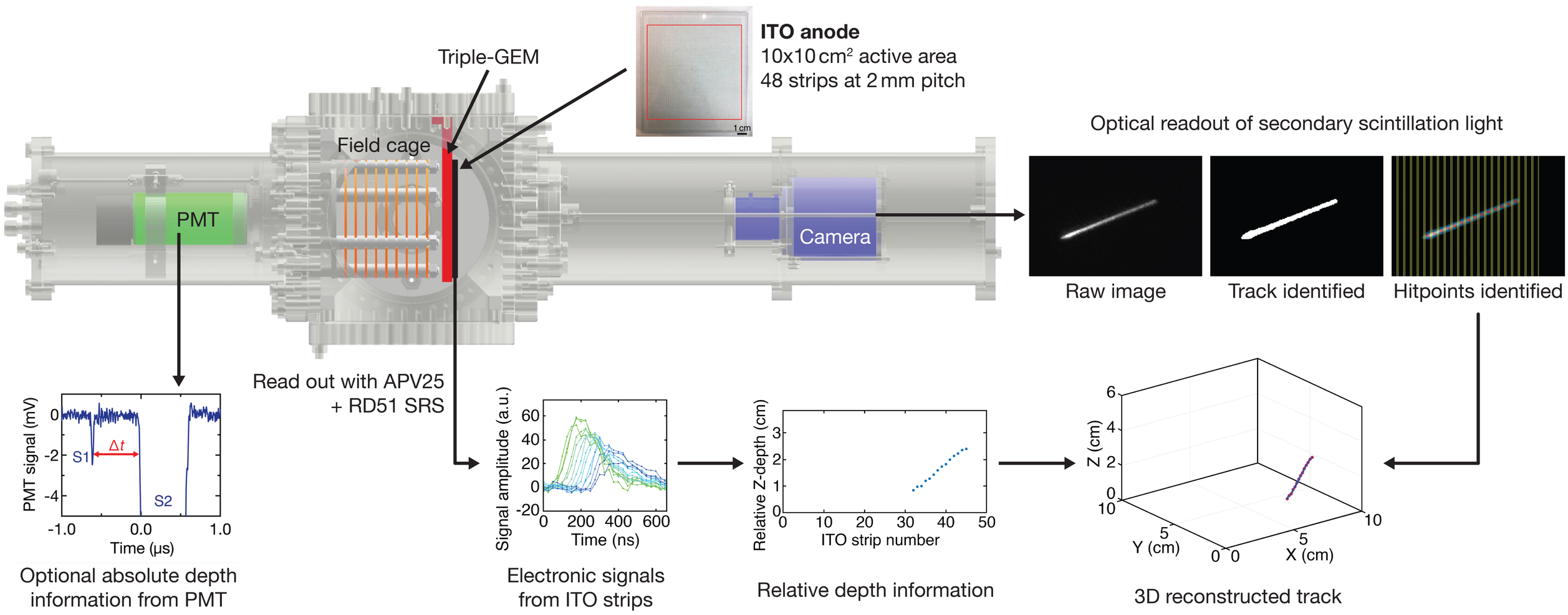




Optical read out of GEM-based detectors can be used for X-ray radiography and fluoroscopy as well as single event imaging. High gain factors permit sensitivity to radiation ranging from MIPs to highly ionising radiation.

Brunbauer et al. JINST (13) 2018.

The emitted secondary scintillation light spectrum of Ar/CF_4 mixtures is compatible with the quantum efficiency (QE) of CCD imaging sensors and the transmission of ITO layers.



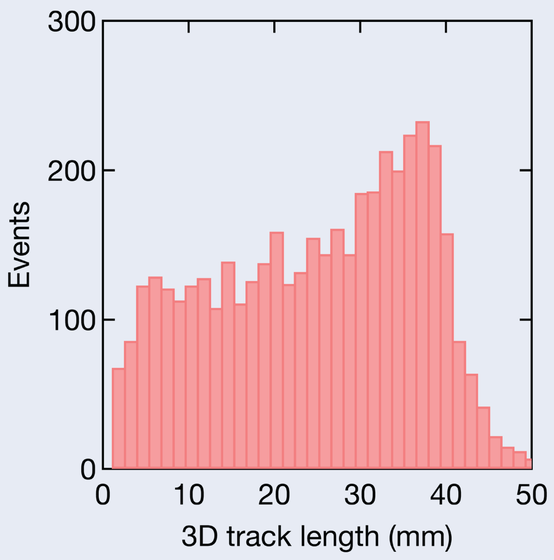
Optional absolute depth information from PMT

Electronic signals from ITO strips

Relative depth information

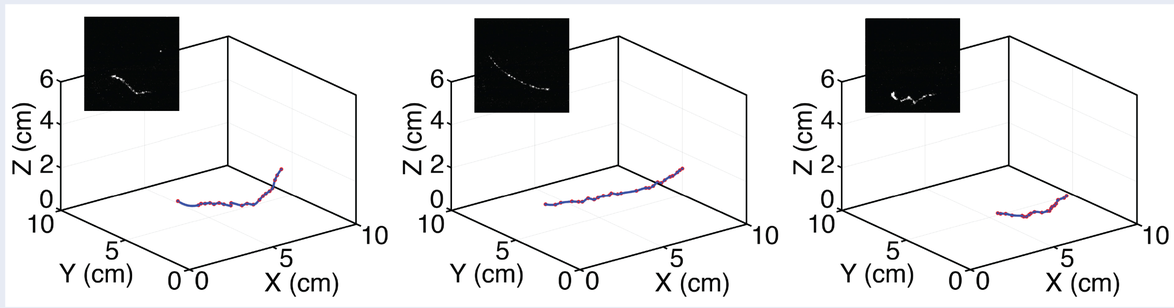
3D reconstructed track

Track length reconstruction



The distribution of the recorded lengths of 3D reconstructed alpha tracks from a ^{220}Rn source was recorded. The determined distribution exhibts a peak around 40 mm length and a large number of tracks with lower lenghts, which is attributed to events partially contained in the active volume of the TPC. The determined track length of fully contained tracks is lower than expected, which might be due to the low granularity of the ITO strip anode and some dead strips, which were not connected to the readout electronics.

Complex track geometry reconstruction



In addition to straight particle tracks like alpha particles, complex track geometries can be reconstructed by combining information from simultaneous electronic and optical readout. This permits the reconstruction of curved tracks as shown for cosmic events, which cannot be unambiguously visualised with timing information from a PMT. The combined readout approach thus extends the reconstruction capabilities of optically read out TPCs.

Brunbauer et al. IEEE TNS (65) 2018.

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Frontier detectors for frontier physics, 14th Pisa meeting on advanced detectors, 2018