ORAnGE High sensitivity particle tracker based on Optically ReAdout GEM

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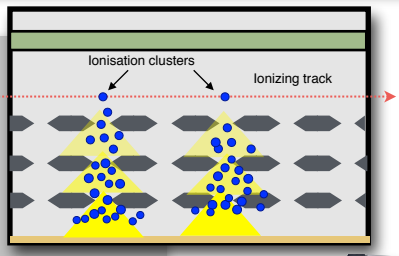
GEM-based detectors have had a noticeable development in last years and have successfully been employed in different fields from High Energy Physics to imaging applications. Light production associated to the electron multiplication allows to perform an optical readout of these devices. The big progress achieved in CMOS-based photosensors make possible to develop a high sensitivity, high granularity and low noise readout. In this work we present the results obtained by reading out the light produced by a triple-GEM structure by means of a 4 mega-pixel CMOS sensor with noise level lesser than 2 photons per pixel. The choice of a CF_4 rich gas mixture (He/CF_4 60/40) and a detailed optimisation of the electric fields allow to reach a light-yield enough high to obtain, for the first time, very visible signals from minimum ionizing particles. Results of a test beam with 470 MeV electrons are presented.

Operation Principle

In gas detectors, during the multiplication process, along with electrons, a lot of photons are produced in de-excitation of gas molecules.

The light produced in a Triple-GEM structure can be acquired to determine the position of primary ionization and reconstruct an ionizing track.



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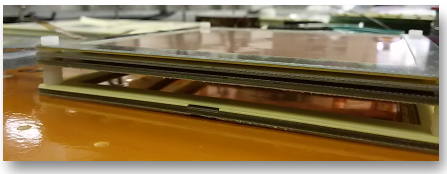
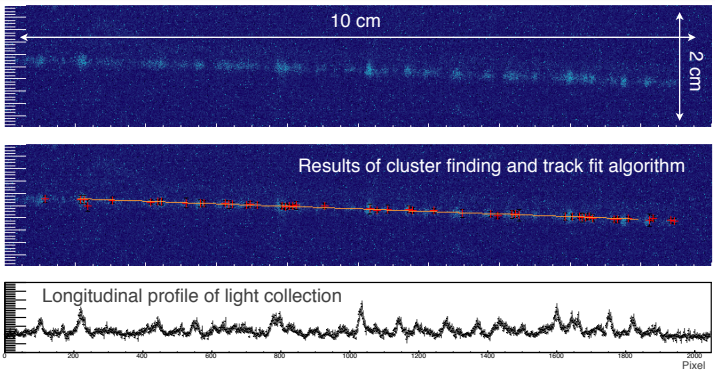
Detector and Optical readout system

The Triple-GEM with **2 mm** transfer gaps, a **10 mm** wide drift gap and an active area of 10x10 cm².

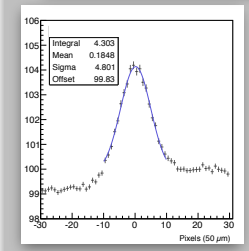


A high sensitivity (**70% quantum efficiency, 2 photon noise**) and high granularity (4 Mega Pixels) CMOS Camera (Hamamatsu ORCA 4.0) instrumented with a high aperture lens (Schneider 25mm FL, **f/0.95**) allowed a very efficient and precise track reconstruction.

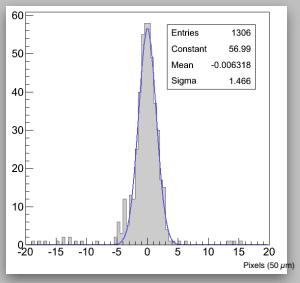
Example of a reconstructed 470 MeV electron track



Transversal profile and space resolution

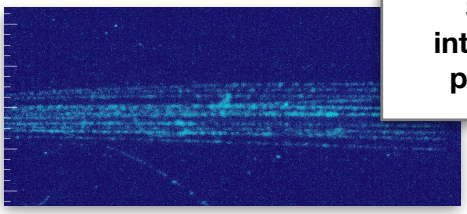


The average transversal profiles of the track shows a gauss shaped light distribution with a sigma of about **5 pixels** (i.e. **250 μm**).



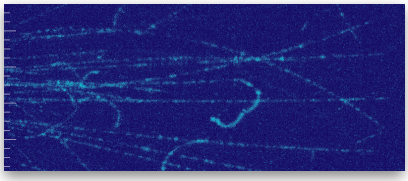
The distribution of the residuals of the reconstructed cluster positions from the fitted tracks has a sigma of **about 75 μm**.

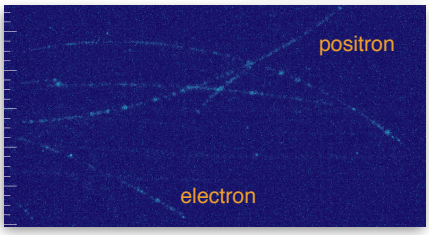
Some interesting pictures



Electron beam passing though the detector;

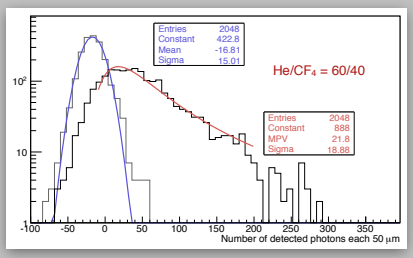
Tail of electromagnetic shower in presence of a 0.2 T magnetic field. Electrons are bent downward and positrons upward.





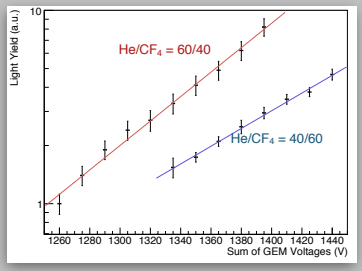
Detail: an **electron-positron pair** emerging from an electromagnetic shower and separated by a 0.2 T magnetic field

Light Collection



The amount of collected light was measured along the tracks. **Each 50 μm, at a voltage of 470 V per GEM, about 40 photons are detected** by the CMOS sensor. Since from simulation about 10 electrons are expected per track millimetre, about **80 photons are collected per primary electrons**.

The system light collection was measured for two gas mixture. While a 60% of CF_4 allowed to reach higher voltages, **the mixture with 40% CF_4 showed a total light collection more than two times larger** in the whole studied range. The amount of collected photons of a **factor 10** was found for an increase of the total GEM voltage of **about 160 V**.



[1] Marafini et al., *High granularity tracker based on a Triple-GEM optically read by a CMOS-based camera,* JINST **10** (2015) 12, P12010 doi:10.1088/1748-0221/10/12/P12010
[2] Marafini et al., *MONDO: a neutron tracker for particle therapy secondary emission fluxes measurements,* NIM A 58300 doi:10.1016/j.nima.2015.10.109
[3] Marafini et al., *Optical readout of a Triple-GEM detector by means of a CMOS sensor,* NIM A 58300 doi: 10.1016/j.nima.2015.11.058

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