Optical readout of a triple-GEM detector with a CMOS sensor

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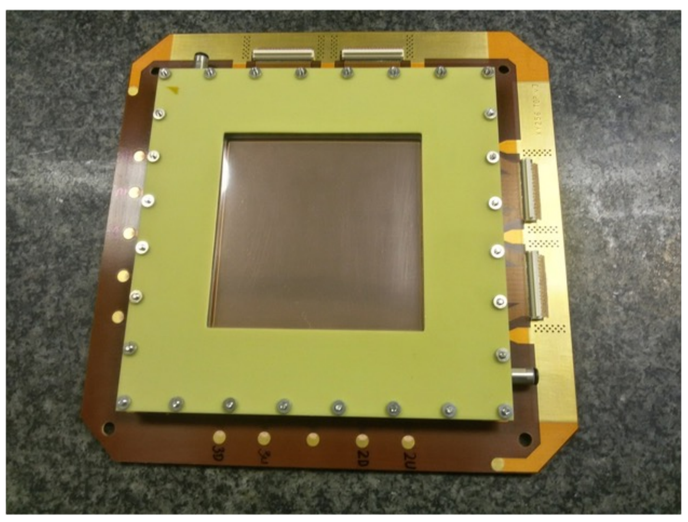
In last years, the development of optical sensors has produced instruments able to provide very interesting performance. Large granularity is offered along with a very high sensitivity. CMOS sensors with millions of pixels able to detect as few as 2 or 3 photons per pixel are commercially available and can be used to read-out the optical signals provided by tracking particle detectors.
A standard GEM detector was assembled with a transparent window below the third GEM allowing the light to get out. The detector is supplied with an Ar/CF_4 based gas mixture producing 650 nm wavelength photons matching the maximum quantum efficiency of the sensor (about 70%). The characteristics of the light yield were studied in details and optimised.

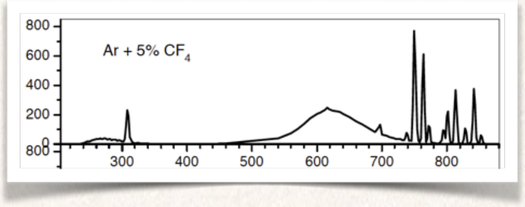
Standard 140/70 GEM;

3 mm wide drift gap and two 2 mm wide transfer gaps;

Electrons are collected on the bottom of the third GEM and only photons are read out;

The readout plane was removed and replaced by a transparent plastic foil window.

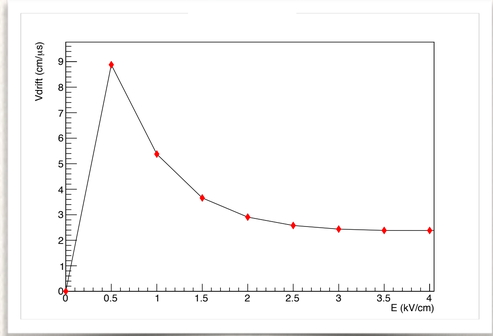


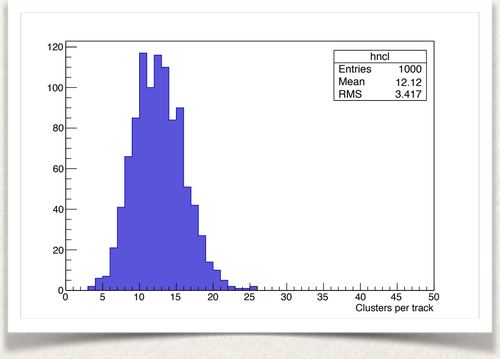


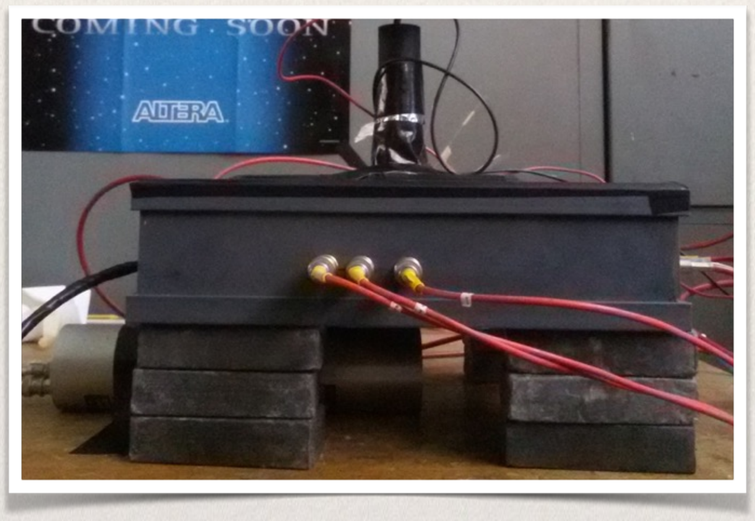
The emission spectrum has the main contribution around 600 nm;

For a minimum ionizing particle about 12 clusters of are evaluated by means of a Garfield simulation in the 3 mm wide drift gap that means an average distance of 250 μm;

2.5 electrons per cluster are expected.

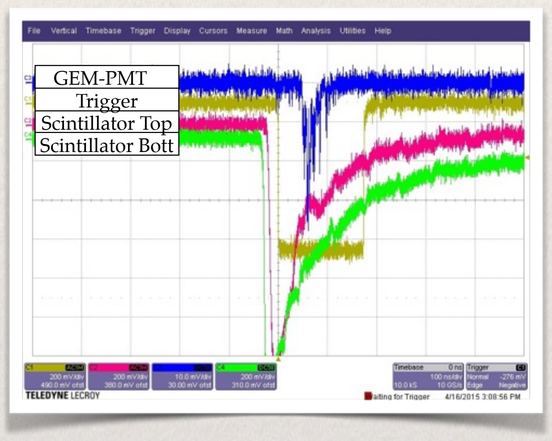






Detector tested with cosmic rays;

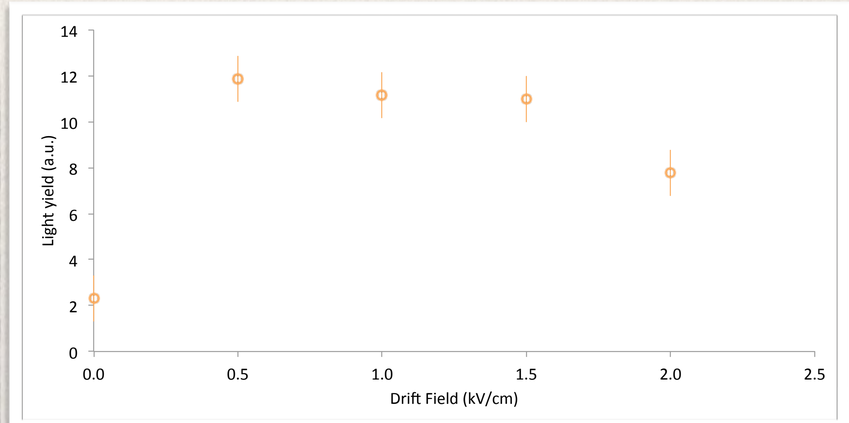
Two NaI scintillators used to trigger the muons.

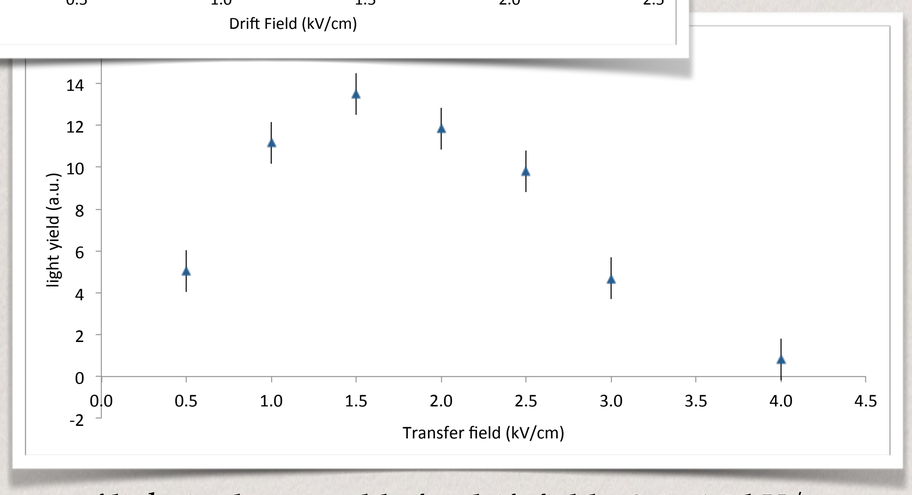


Light collected by a R9800 PMT;

Waveforms were acquired by a 10 GS/s scope;

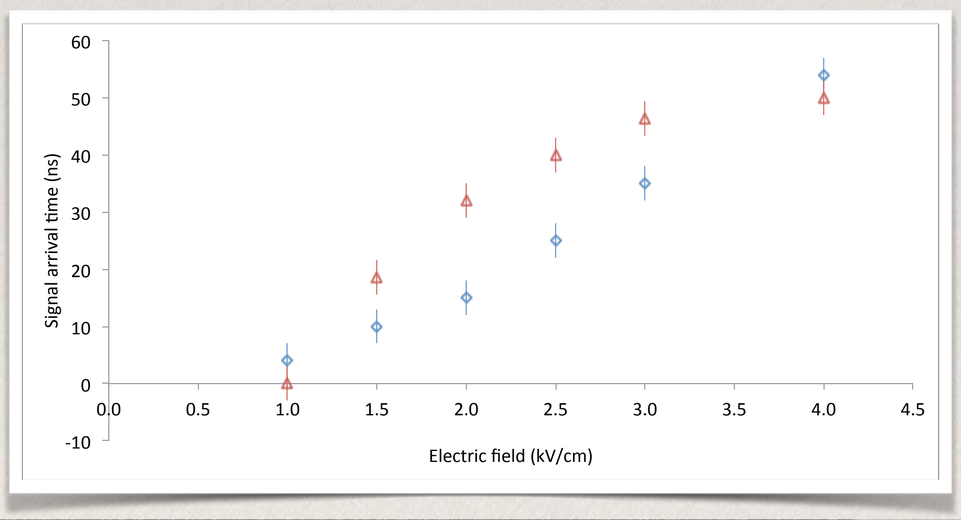
The electric fields were optimised in order to maximise the light yield.





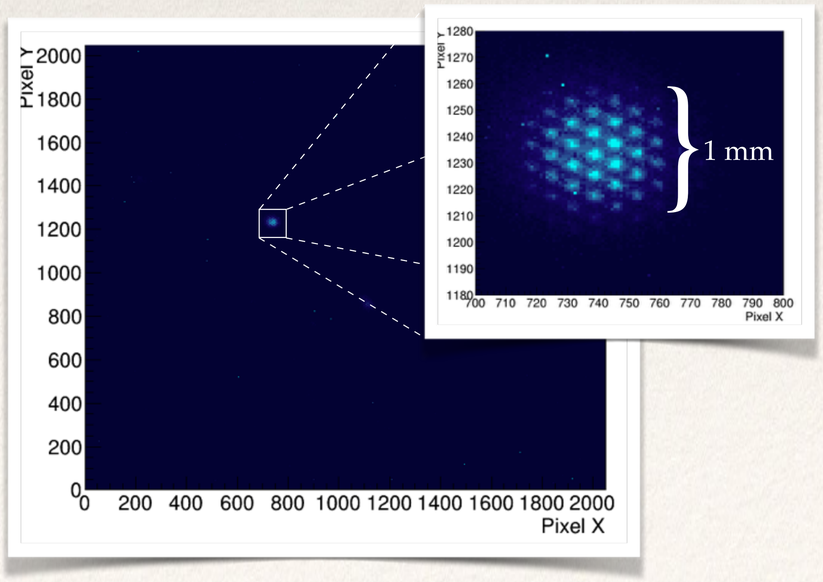
The amount of light is almost stable for drift fields 0.5 - 1.5 kV/cm while a transfer field around 1.5 kV/cm maximises the light production.

At maximum about 150 p.e. were collected in very good agreement with expectations.



The dependence of the arrival time on the transfer field follows the values evaluated from the drift velocity.

After the light yield was optimised we started measurements with a high sensitivity low noise Hamamatsu CMOS-based camera.



Thanks to the possibility of detecting very few photons, by means of this camera, small continuos hot spots were found in the triple-GEM detector.

Even if the leakage current is of the order of few nA these spots appear when the high voltage reaches the operating values and their intensity increases with the gain.