# Optical readout of a Triple-GEM detector by means of a CMOS sensor

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**Abstract**

In last years, the development of optical sensors has produced objects 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 two or three photons per pixel are commercially available and can be used to read-out the optical signals provided by tracking particle detectors. In this work the results obtained by optically reading-out a triple-GEM detector by a commercial CMOS sensor will be presented. A standard 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 wavelenght photons matching the maximum quantum efficiency of the sensor.

*Keywords:* Tracking detectors, GEM, Micro-pattern Gas Detectors
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## 1. Introduction

Micro-pattern gas detectors have proven to be versatile devices for high resolution particle tracking. One of the most successful micro-pattern technologies is the Gas Electron Multiplier (GEM), introduced in 1996 at CERN [? ]. During the electron multiplication process, photons coming from atomic and molecular de-exitation are produced. Given the impressive development of light sensors based on CMOS technology it is really promising to explore the possibility of detecting this light by means of such a high granularity and low noise device.

## 2. The triple-GEM structure

The electron multiplication structure was obtained by stacking three standard GEM's (70 $\mu$m diameter with 140 $\mu$m pitch). A planar cathode was placed above the first GEM to create a 3 mm wide drift gap and two 2 mm wide transfer gaps were left between the three GEM foils. The electrons created in the multiplication were collected on the bottom of the third GEM. The readout plane was replaced by a transparent plastic foil window in order to readout the photons created in the last GEM channels.

## 3. The gas mixture

The measurements were performed by using a binary gas mixture Ar/$CF_4$ (95/5). It is expected to have an emission spectrum with a main contribution around 600 nm [? ].

A Garfield simulation was performed to evaluate the main characteristics of the gas mixture. A shown in Fig. **??** the drift velocity has its maximum for low fields and thus decreases and saturates.

It was calculated that a minimum ionizing particle has the capability of creating about 12 clusters in the 3 mm wide drift gap that means an average distance of 250 $\mu$m. About 2.5 electrons per cluster in average are expected for a total of about 28 primary electrons.

## 4. Test set-up

The light produced the the GEM stack was readout by means of a R9800 photo-multiplier. The system was tested by means of cosmic rays. Two NaI scintillators, one above and one below the GEM were used to trigger the muons.

The waveforms of the signals provided by the two PMT reading the NaI and the GEM PMT were acquired by a 10 GS/s oscilloscope.

## 5. Optimization of electric fields

The electric fields between the GEM were optimised in order to maximise the light yield. The results of the field scans are shown in Figs. **??** and **??**. The amount of light is almost stable for drift fields in the range $0.5 \div 1.5$ kV/cm while a transfer field around 1.5 kV/cm maximises the light production.

The GEM-PMT response to a single photo-electron was measured by using a calibrated light source. By means of this calibration it was calculated that in the optimised field configuraiton about 170 p.e. were collected in average for a minimum ionizing particle crossing.

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vdrift.pdf

Figure 1: Drift velocity as a function of the electric field.

ly_Ed.pdf

Figure 2: Light yield as a function of the drift field.

ly_Et.pdf

Figure 3: Light yield as a function of the transfer field.

t_Ed.pdf

Figure 4: Channel levels.

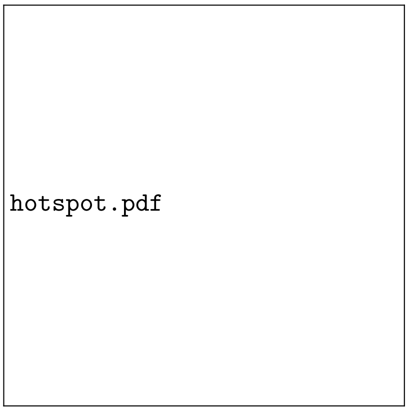


Figure 5: Hot spot in the GEM system. The fine structure of the GEM holes is visible.

## 6. Measurements with a CMOS-based camera

After the light yield was optimised we started measurements with a high sensitivity low noise Hamamatsu CMOS-based camera [1]. 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 was of the order of few nanoamperes these spots appear when the high voltage reaches the operating values and their intensity increases with the gain.

## 7. Conclusion

The light yield of a triple-GEM stack in a Ar/$CF_4$ gas mixture was studied. After a suitable optimization of the electric fields a total amount of about 170 photo-electrons was found. The light emission was also revealed by a CMOS based camera. It was possible to detect hot spots appearing in the GEM very likely due to continuos micro-discharges in the channels.

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