High Resolution Single Photon Scanning Device for ThickGEMs

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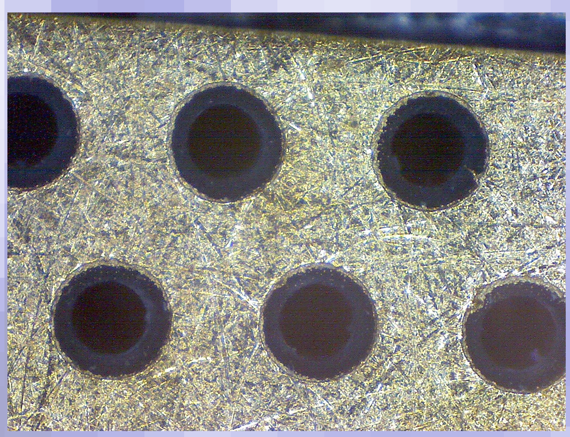
1. Motivation

Micropattern gaseous detector technologies are new promising and rapidly developing ways of upgrades to the standard wire based detectors. One of the most challenging tasks is the detection of UV light in Cherenkov detectors, where only one electron is emitted from a single photon. Gas Electron Multiplier (GEM) or ThickGEM based chambers have several advantages in this field compared to the classical MWPCs. Their geometry abolishes feed-back photons, while reduced ion backflow increases the life of the photosensitive surface.

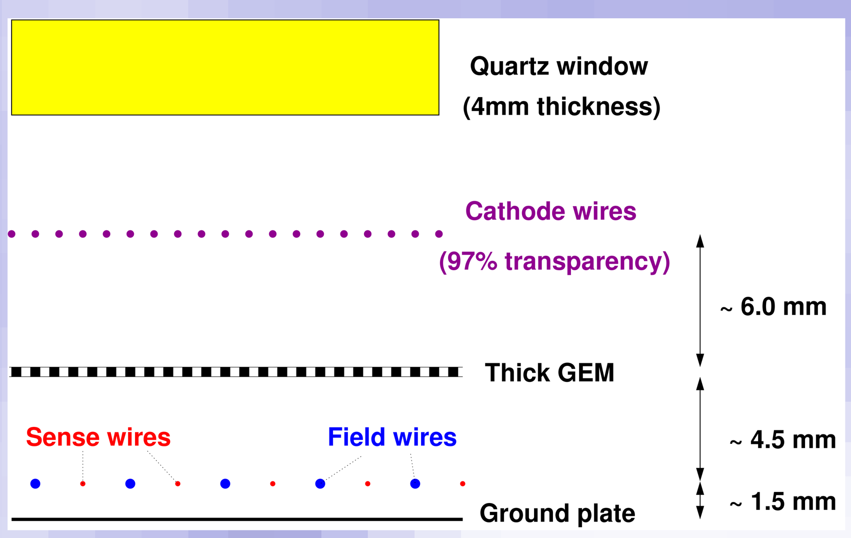
From the top of the TGEM the UV photon induced electron is captured by the closest hole, where the amplification takes place. To reach high enough gain several amplification stages are used eg. GEMs, TGEMs, MM or wire planes.

The hole-type microstructure decreases the effective surface, but this is not the only loss in efficiency. The detection efficiency may depend on the exact position of the emission of the electon, due to extraction in electic field, back-scattering close to the surface, or attachment to molecules.

Precise measurement of the small scale structure of position dependent photon detection may lead to deeper understanding of the microprocesses, and raise possibility to optimize for certain applications, and finetune the present simulation tools.

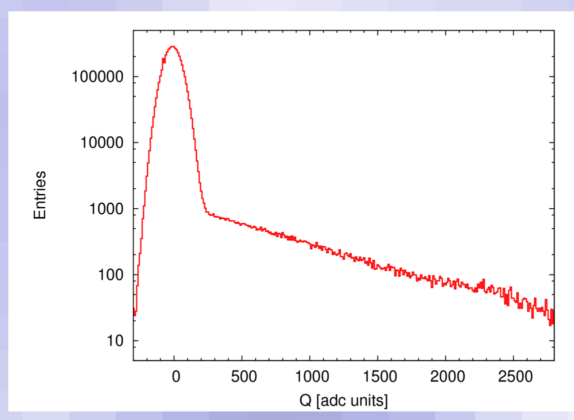


2. Photon Detection



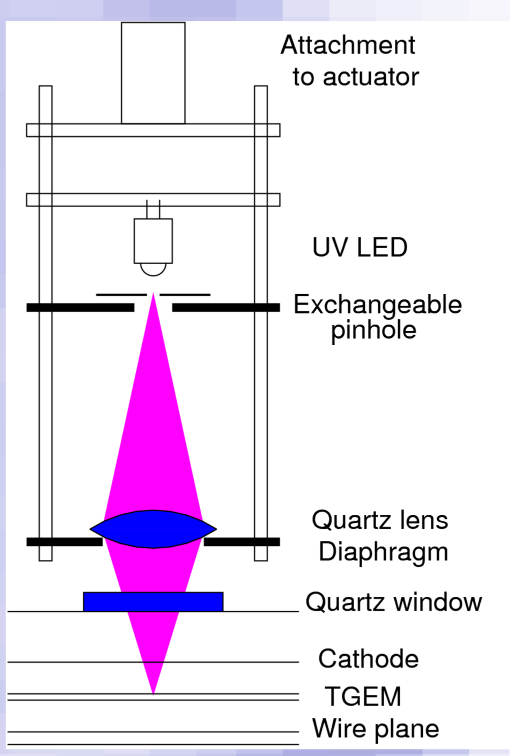
Outline of the ThickGEM+CCC Photon Detector (TCPD)

The measuremts were done with a TCPD chamber (ThickGEM+CCC Photon Detector) , which consists of a wire plane as cathode, a gold plated ThickGEM, and a Close Cathode Chamber[1] as the second amplification stage. UV photons were generated by a SETI UVTOP240 LED, able to produce photo-electron emission from the gold surface. Pulse mode driver was used to get timing informations, and intensity was decreased to have less than 10% event/LED-pulse ratio to produce single photo-electron signals.



Pulse-height spectrum with the Gaussian noise and the exponential PE signal

3. Focusing



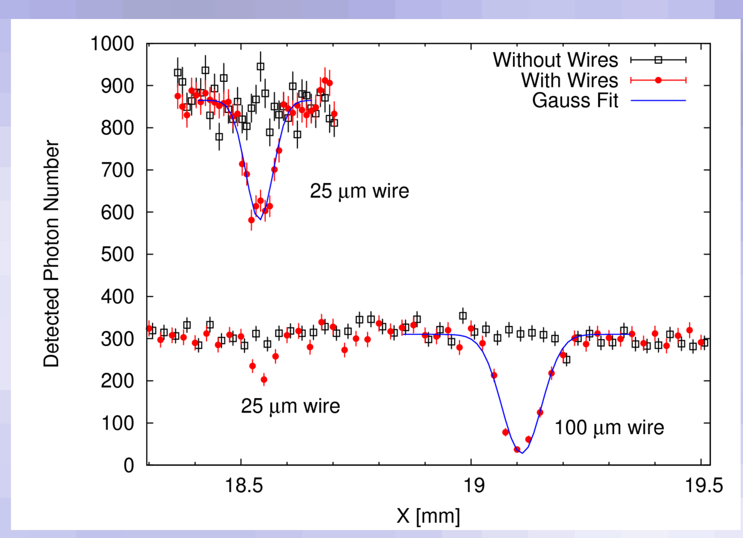
Schematics of the optical setup of the scanning device

To have position information on the emitted photo-electron the UV LED was focused to a small spot onto the upper surface of the TGEM with a pinhole and a quartz lens.

The whole optical setup was fixed to a 3D actuator system, and its movement control was integrated into the DAQ, thus letting us make the high resduolution scans.

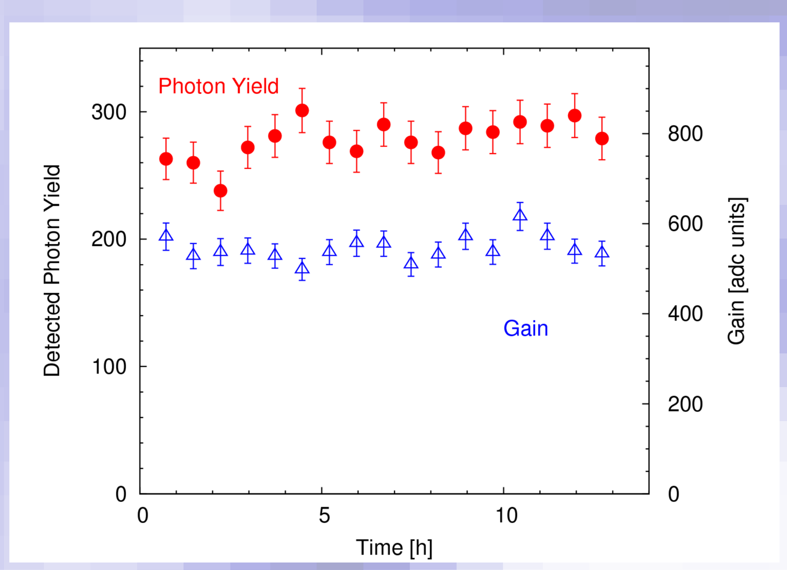
Focusing/resolution was checked with wires placed above the chamber (where the microstructure of the TGEM efficiency is smeared away) and measuring the sharpness of their "shadows". Resolution of 0.07mm was achieved.

During the measurement of TGEMs the precise adjustment of the focal plane was done by measuring the photon efficiency structure in different heights to search for the sharpest map.



Shadows of a 25 and a 100 µm wires

4. Stability

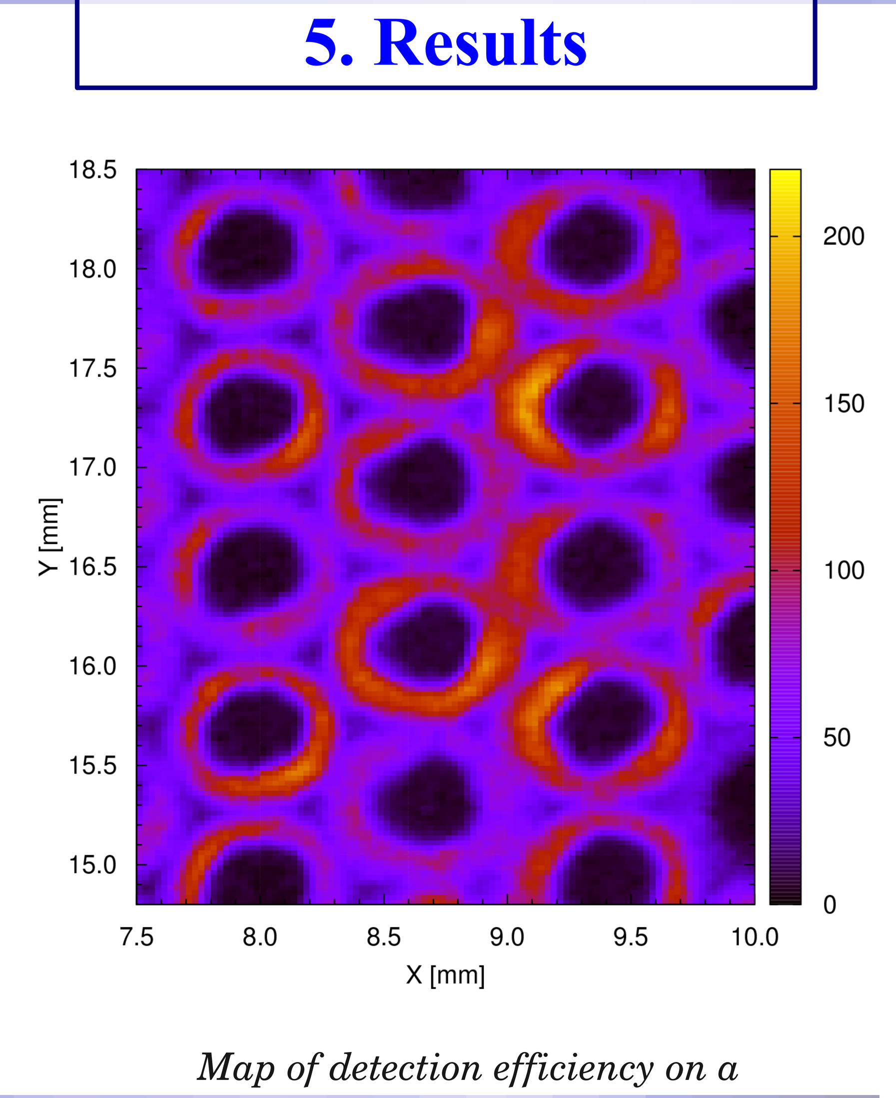


Photon yield and gain variation over time is stabel within errorbars

Measuring maps of efficiecy one has to take thousands of points with good resolution to cover a few holes. Due to the single photo-electron restriction (the 1-10% PE/Event rate) each measuring point should have several thousand individual events. This makes the whole study really time consuming, and raises the question of stability.

A set of points were remeasured several times during the long runs, to have information on slow changes over time in gain and photon yield. The set points were choosen to be on the edge of a hole letting us check the stability of the actuator system as well. Our setup was stable within errorbars in all of our requirements.

5. Results



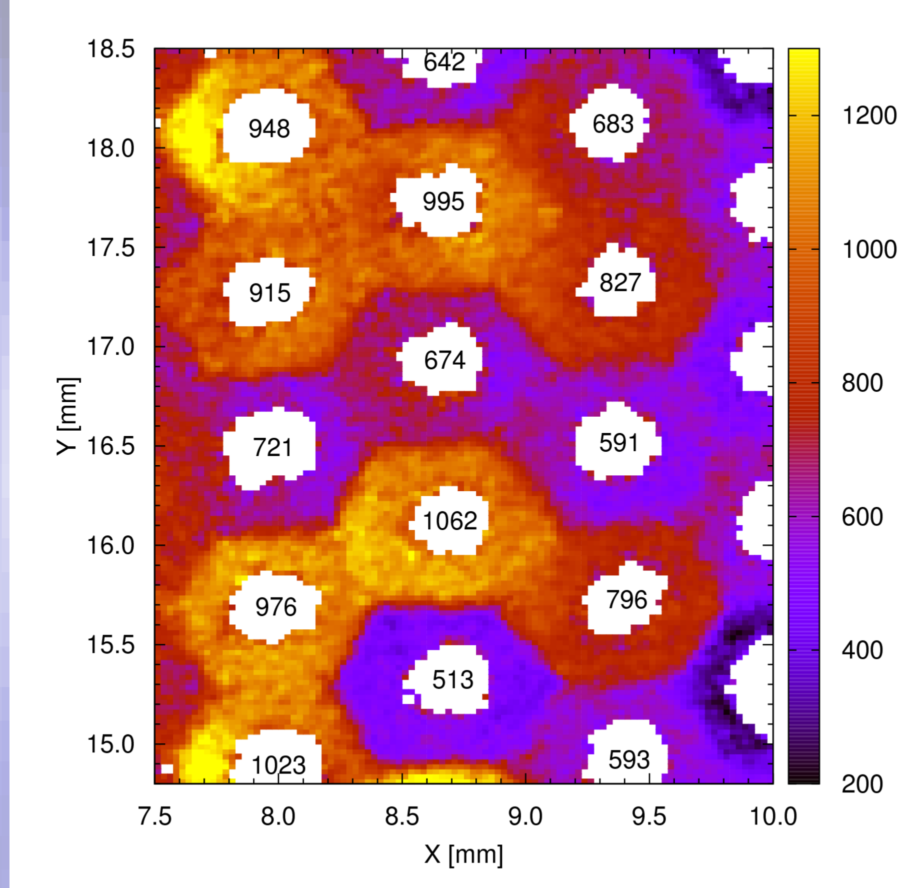
Map of detection efficiency on a TGEM, with pixels of 25x25µm2 (the color code refers to the number of detected photo-electrons)

The detection efficiency is proportional to the integral of the signal from a non-zero pulse height (5 RMS of the noise). The holes of the TGEM are naturally present as dark spots in a hexagonal grid, with practically zero yield.

Additional dark regions appear along the symmetry lines of two holes, and at the symmetry points of three holes, where the field lines cannot go into any of the holes due to symmetry reasons. This results ringlike effective structures around the rim. Note that the total efficiency changes from hole to hole, and not circumlarly symmetric around the hole.

These type of efficiency maps gave the project the nickname: Leopard.

From the single photo-electron spectra the gain can be calculated for each measurement point. One can see, that the gain is locally uniform in the hexagonal collection region of a hole, independently on the emission point; thus let us define the hole-gain abstraction. The hole-gains vary from hole to hole within a factor of two.



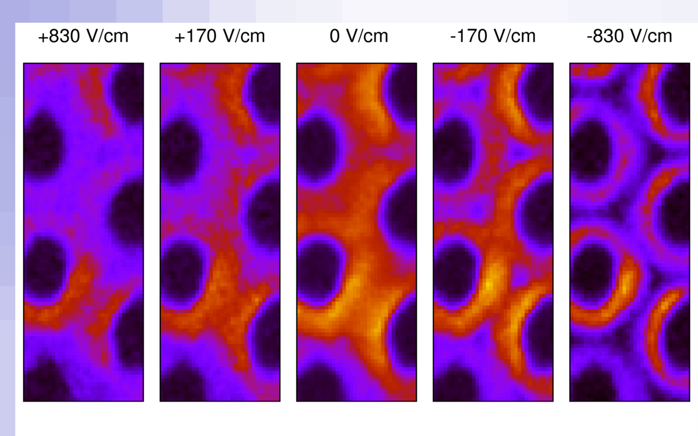
Map of gian on a TGEM, with pixels of 25x25µm2. Color code refers to detected gain in measurement points with non-negligible PE counts. Numbers inside the holes are the averaged hole-gains.

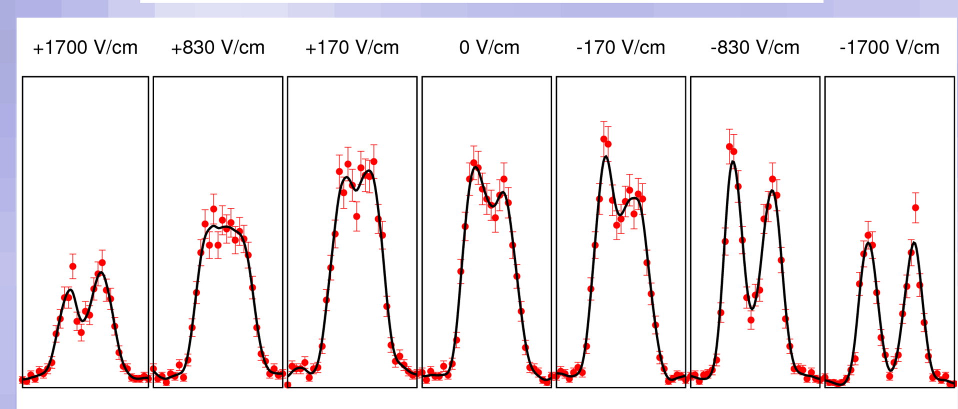
5. Field variations

The former maps were measured with different absolute TGEM gains (5-30) leading to similar results.

In Cherenkov applications the cathode field plays a role in MIP suppression, however it has a primer effect on detection efficiency as well. This change in efficiency is originated mostly from the symmetry regions, therefore its microstructure was measured in a wide field range.

In case of high (normal or reverse) fields the ineffective symmetry region gets wider, making the map even more ring-like. At close to zero cathode field the overall efficiency has its maximum.





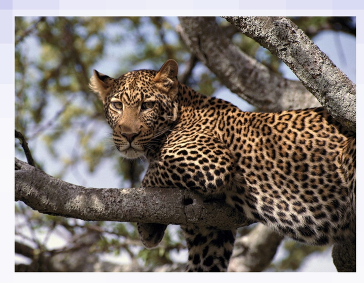
Efficiency map in 2D (upper) and on a line between thow holes (lower) with different cathode fields

7. Summary

We have presented a high resolution scanning device for TGEMs with single photo-electrons, with the basic goal to make a possible way os optimization of TGEM geometries for Cherenkov photon detection.

The measurements proved and quantified the expected dark symmetry points, and showed the real structure of detection efficiency maps. Hole-gains can be defined, and could be baselines for production perfection and quality assurance. These microstructure measurements can give additional input to simulations, and our understanding of elementary processes.

A serious upgrade on data aquisition speed and tuning of the optical system is ongoing to let us look into other MPGD stuctures. Thanks to the RD51 Collaboration this development was highlighted as a Common Project, hosted by Budapest, Triest, and Bari.



References:
CCC : NIM A 648 (2011) 163
Leopard : NIM A 694 (2012) 16