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Investigation of the microstructure of Thick-GEMs with single photo-electrons

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Abstract. Novel Cherenkov detector upgrades favour GEM and ThickGEM based MPGD systems. These detectors have reduced ion backflow, fast signal formation, high gain, and could suppress the MIP signals as well. Their common drawbacks are the inefficiencies of photo-electron collection from the top of the ThickGEM and the local variation of multiplication due to the special geometry.

The developed high resolution scanner using focused UV light gave the possibility to study single photo-electron response of MPGDs in the sub-millimeter scale. Revealing the microstructure of photo-efficiency and local gain provides a new tool to quantitatively compare different ThickGEM geometries and field-configurations, and thus optimize the detector parameters.

The presentation will focus on the key elements of the scanning system; and on the microstructure evolution of different ThickGEM configurations.

1 Introduction

The novel technology of micropattern gaseous detectors (MPGD) opened new promising ways for developing tracking, triggering, and Cherenkov detectors as well [1]. Their complex geometry and the presence of the insulating material makes the optimization of parameters challenging, while the detailed investigation is still an active part of recent R&D.

MPGD-based single photon detection for Cherenkov applications mostly use the first amplification layer as a refractive photocathode, thus using hole-type amplifiers. While in PHENIX HBD [2] GEM [1] foil was used, new RICH upgrades tend to apply ThickGEM [3] technology. The advantages compared to wire chambers have been proven for several aspects [4] by several groups. While the former upgrade plans of ALICE VHMPID [5] considered ThickGEMs, for COMPASS [6] the RICH-1 upgrade [7] will be based on ThickGEM and Micromegas [8] coupled together.

In case of single photon detection, the choice of geometrical parameters as well as electric field configuration are crucial for the high efficiency of the RICH PID. Measuring the behaviour of the detector response in the scale of its micropattern-structure can reveal the inner processes, and could give one a novel way to design the micro-geometry of the detector-elements, and additionally could help in fine-tuning the simulations.

In the Wigner RCP Budapest we have developed a high resolution scanning system [9] to examine the response of MPGDs on single electrons, with the spatial resolution of 30-300um. The system was designed to investigate single ThickGEM layers, and get information on photo-electron detection efficiency and avalanche size, and thus deduce hole-by-hole variations. We have shown that with increased resolution the method can be applied for thin GEM foils as well [10].

Based on the results of the first prototype the idea got supported by the RD51 community and became part of AIDA-2020. The first practical use of the technology was initiated by a common measurement of the Budapest and Trieste groups, with the main aim to compare several different ThickGEM types, that could be used for the mentioned COMPASS RICH Upgrade project.

2 The Leopard System

The high resolution scanner consists of a pulsed UV source, which is focused to a tiny spot (30-300um) onto the surface of the ThickGEM in study. The source is attached to a 3D moving table, to be able to scan the surface and set the proper focal distance. The intensity of the UV light is set to have <<1 photo-electrons (PE) from the surface in average, this way real single electron signals can be measured. To keep the ThickGEM in standard operating condition a postamplification stage is used, this part shall not have its geometrical micro-scale on the same level as the one in study; simple solution can be a wire chamber, or a micromegas. The heart of the system is the combined data acquisition, that takes care of the signal measurement, the moving of the actuator table, setting the

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high voltage, saving the data, and responsible for the communication with the user. Recent version of the DAQ consists of a custom designed board and a RaspberryPi [11] micro-computer (for details see [10]).

High resolution investigation needs the location of the measurement points about an order of magnitude closer to each other than the pitch of the structure, while reasonable statistics is needed for the single electron spectra. To fulfill these requirements billions of events have to be recorded, making the speed of the DAQ a crucial issue. This upgraded version of the system is working with 130kHz of data taking, while being still a tabletop setup (see photo of the setup on figure 1).

Using single PE signals the photo-electron yield and the gain can be decoupled, and can be calculated for all points. The yield image looks like the fur of the leopard, so it brought the nickname "Leopard" for the whole system.

3 Budapest-Trieste Setup

Combining the expertise on ThickGEMs from the INFN Trieste group, and the capabilities of the Leopard setup from the Wigner RCP Budapest group, a common measurement has been initiated.

The aim was to make comparative studies on ThickGEMs from different production technologies, and via this improve the COMPASS RICH-1 Upgrade. A photo of the whole setup, and a short description of the main parts can be seen on figure 1.

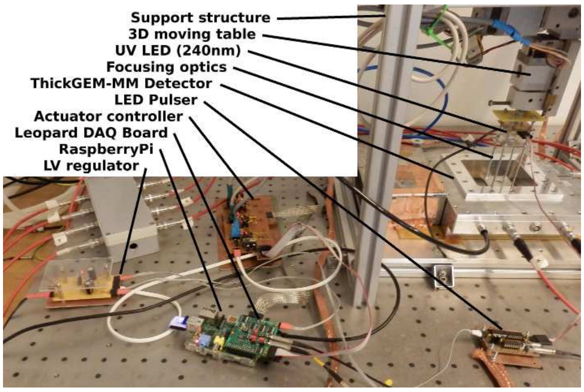

Figure 1. Photo of the Leopard setup in INFN Trieste in 2014. The main components are named and marked on the picture itself.

In case of these measurements the postamplification stage after the ThickGEM was a bulk micromegas (CERN, mesh 45/18, 128um gap), similar as will be used for the upgrade. The list of the ThickGEMs under investigation and their geometrical parameters can be seen in table-1. The chamber was closed with a cathode wireplane and a quartz window.

4 First results

Adjusting the focal distance is necessary to achieve the high resolution information. While rough settings can be done via calculation, the finetuning of the focal distance shall be based on the recorded data itself. In case of ThickGEMs the blur of the image with a 50μm spot size (in focus) is small but not negligible over a 1 mm range, see figure 2.

Table 1. List of the tested ThickGEMs with their main production dimensions.

ThGEM Name	Hole [μm]	Pitch [μm]	Thickness [μm]	Rim [μm]
M1-III	400	800	400	0
DESTRO-I	400	800	400	5
C3HR-II	400	800	400	50
M2.4-G	400	800	600	0
M2.1-II	300	800	400	0

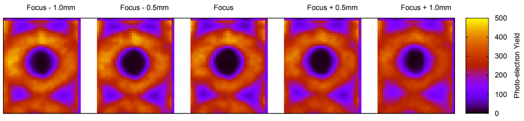

Figure 2. Map of the photo-electron yield with various focal distances. The "sharpest" image corresponds to the best achievable resolution.

One can calculate the photo-electron yield for all points, thus get a map of photo-efficiency; and likewise get map of gain. Within the recorded data the holes can be identified by searching for hole-sized low-yield clusters. Each hole has a well-defined collection area determined by the pattern structure, in our case a hexagon. Gain variation with respect to the entering position of the electron into the hole, can be translated to the emission point of the photo-electron, thus is known in the used Leopard system. Averaging over a large sample of holes we found that the distribution is constant within errorbars for 0.4mm holes, see figure 3 (measured on the ThickGEM : DESTRO-I, see Tab. 1). This is in agreement with the low statistics measurements of the former studies on 0.3mm holes (with large rim) in [9].

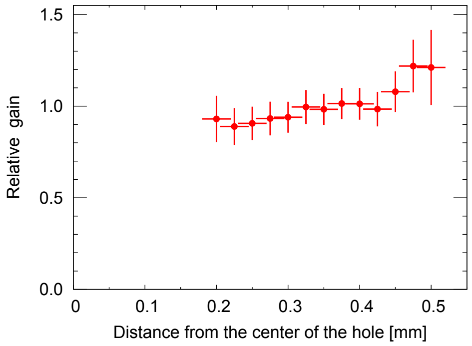

Figure 3. The size of the electron-avalanche as function of the emission point of the photo-electron is consistent with a constant function within the achieved uncertainties.

Based on this information the concept of the hole-gain can be defined. The large number of measured holes in each tested ThickGEMs will make us capable to evaluate the distribution of the hole-gains, and thus compare the different production technologies based on their uniformity in the micro-level.

The displeasing phenomenon of charge-up has non-negligible effect on the measurements: as the scan goes along the line of the tiny points the corresponding holes are charging up slowly, and this can result a slight decrease of gain in each hole towards the direction of the movement. The effect can be overcome via charging up the whole surface beforehand, or during the measurement, or with offline corrections aided by prestudies on the effect.

5 Behaviour of the critical point

An advantage of MPGD-based RICH detectors that with applying a reversed drift field the MIP signals can be suppressed, thus higher gains can be achieved within the range of stability. On the other hand, photo-electrons emitted from the critical/symmetry points and symmery lines are highly sensitive for this parameter [9]. Besides the fact that neither too high normal or reversed fields are good, we have shown that with a small normal field the above effect can be eliminated.

To perform fine scans in voltage within a large range, the time consuming 2D-mapping-measurements has been replaced with single point measurements in the critical/symmetry point; and single-line-measurements connecting hole centers and symmetry points, let us call it the critical-line. On the critical-line-scans one can observe the change of photo-electron yield evolution with various drift fields in the critical points, hole-perimeters, and intermediate regions as well. Sample of the critical-line scan can be seen on figure 4.

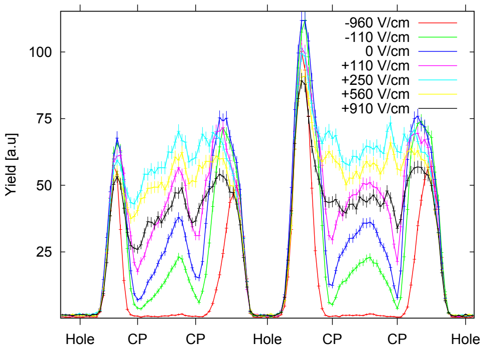

Figure 4. Photo-electron yield along the critical-line scans show the change of the function for several of the applied drift bias. The influence is most crucial at the critical point.

We have shown that PE yield of the critical/symmetry point is extremely sensitive to the applied drift field. It has a well defined maximum at the several hundreds of V/cm normal field, below which the function starts to fall rapidly in a close-to exponential way. For higher fields than the optimum of a small plateau is followed by a slight decrease. This behaviour has been checked for several critical/symmetry points, while the describing parameters seemed to be similar for a given piece of ThickGEM, as shown in figure 5. The plateau for the ThickGEM with 0.3mm holes was significantly smaller.

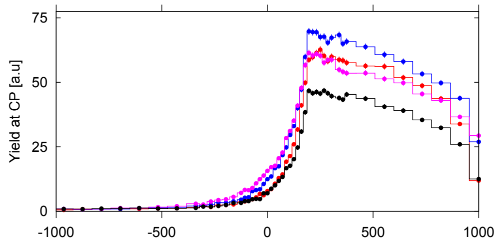

Figure 5. Photo-electron yield of the critical point highly depends on the applied drift field above the ThickGEM (which is responsible for the photoconversion itself).

6 Summary

The Leopard system is designed to investigate the microstructure of MPGD detectors, using single photoelectron response. The combined fast DAQ was developed as an RD51 common project, and was used to check thin GEM foils, and for detailed study of different ThickGEMs. Usability for precise measurements, quality assurance, optimization, and production technology evaluation has been proven. The system could provide even detailed answer on how to set the drift field in case photon-detection is an issue. The evaluation of the performed comparative measurements of the Trieste ThickGEMs are still ongoing, while preliminary results are even now proving the usability of the methods and the system.

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