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Development of a THGEM-based photon detector for RICH applications

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Summary. — THGEMs (THick GEMs) are electron multipliers derived from the GEM design, with scaled geometrical parameters and manufactured using standard PCB production technology. Coupled to Cesium Iodide photo converting layer they are promising candidates as detectors for future Cherenkov Imaging Counters. More than 30 THGEMs, different in geometry and production process, have been characterized in order to optimize their performance for RICH applications. The photoelectron extraction and collection efficiencies have been studied for several gas mixtures. Encouraging results have also been obtained from the tests with

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multilayer THGEMs used either for ionizing particles or UV light detection. This paper presents the recent developments of these studies.

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1. – Introduction

At present, the only available option for covering with photon detectors very large surfaces at affordable costs is the use of gaseous photon detectors. The most common solution is the use of MWPC coupled with Cesium Iodide photon-converter [1] which is successfully implemented in several experiments. Nevertheless these detectors are suffering from some performance limitations because they have to be operated at moderate gain to avoid electrical instabilities accompanied by long recovery time (about 1 day) [2] resulting in a limited single photoelectron detection efficiency. Aging effects decrease the quantum efficiency when the collected charge is in the order of a few mC/mm^2 [3]. These limitations are due to the ions bombardment of the CsI photocathode and can be overcome with new detector architectures as in a multilayer structure of electron multipliers, where a good fraction of the ions is trapped in the intermediate layers and does not reach the photocathode. This idea is exploited by the Threshold Cherenkov Counter Hadron Blind Detector (HBD) [4] in the PHENIX experiment where a triple GEM is operated at low gain (5000). For imaging counters, high efficiency in the detection of single photon is required and larger gains are needed.

We report here about the progress of the development of a large-gain gaseous photon detector based on THGEM electron multiplier.

2. – The THGEM and its characterization

THGEMs [5, 6] are electron multipliers derived from the GEM design, scaling the geometrical parameters and changing the production technology. The Cu-coated kapton foil of the GEM multipliers is replaced by standard PCBs and the holes are produced by mechanical drilling. A clearance ring, the rim, surrounding the hole, is obtained by Cu etching. PCB thickness of 0.4–1 mm, hole diameter ranging between 0.3 and 1 mm, hole pitch of 0.7–1.2 mm and rim width between 0 and 0.1 mm are typically used. THGEMs can be produced in large series and large size; they have intrinsic mechanical stiffness and are robust against the damages produced by electrical discharges. Thanks to the reduced gaps between the multiplication stages, THGEM-based detectors can be successfully used in magnetic field.

More than 30 different THGEM prototypes have been characterized to understand the role of the various geometrical and production parameters. The THGEMs were arranged in single layer detectors, see fig. 1, tested using X-ray sources and a standard gas mixture (Ar-CO_2 70:30). Amplitude spectra of the anode signals were collected and the currents absorbed by each electrodes in the detector were measured [7].

Large gain can be obtained multiplying electrons by THGEMs with large rim (about 0.1 mm); these detectors exhibit however large gain variation (more than a factor of three)

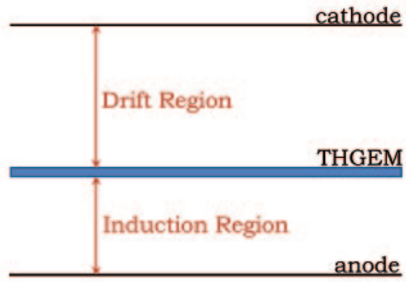

Fig. 1. – Scheme of single layer THGEM; the Drift and Induction regions are indicated in the sketch.

over time depending on the detector irradiation history: stable gain is reached after one or more days of stable electrical bias and irradiation conditions. Detectors formed using THGEM without rim present a stable gain *versus* time and irradiation conditions, but the maximal gains are about one order of magnitude smaller. Using heavily ionizing X-rays (about 300 ionization pairs event), no rate dependence of the gain up to rates above 100 kHz/mm^2 is observed for THGEMs without rim; on the contrary, gain variations *versus* rate are present with a large rim. In spite of the enhanced gain performance, we prefer not to use large rim THGEMs in order to guarantee a stable detector gain. Nevertheless, the etching procedure applied to produce a rim is beneficial, as the hole edges are smoothed and the THGEM can stand higher bias voltages: we used THGEMs with small rim ($\sim 10\,\mu$m) obtainig gain variations in the different conditions below 20%.

3. – Detection of single photons

Our THGEM-based photon detectors consist of multiple THGEM layers where the first layer is coated with CsI film and acts as a reflective photocathode. This configuration is preferred to architectures with semitransparent photocathode, as it results in a larger photon conversion rate.

The photoelectron extraction yield of this detector has been studied measuring the photocurrent dependence on the applied electric field in various gases and at different gas pressures. Some results are presented in fig. 2 where it can be noticed that for gases

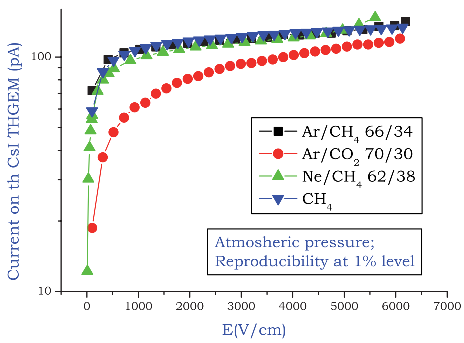

Fig. 2. – CsI photocurrent *vs.* applied field in various gas and gas mixtures at atmospheric pressure.

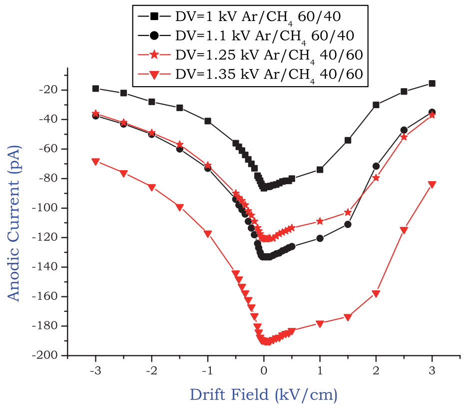

Fig. 3. – Anodic current measured in a single THGEM detector with CsI reflective photocathode *vs.* drift electric field applied; the different point sets have been obtained for different values of the potential applied between the THGEM faces.

and gas mixtures with the best performance, the backscattering phenomenon limiting the extraction yield is overcome only for electric field values above about 1000 V/cm. In our detector, the field at the photocathode surface is the combination of the electric field due to the potential difference across the THGEM and the drift field, generated by the potential difference between the cathode wires and the THGEM. Electron trajectory simulations indicate that the drift field strongly affects the photoelectron collection: when the drift field is zero all photoelectrons enter into the THGEM holes; when it is oriented towards the photocathode, part of the electrons is collected by the cathode wires; instead, when the drift field points towards the cathode wires and is large enough the total field is too feeble to extract and guide the photoelectrons into the holes.

The behavior predicted by the simulations is confirmed by the measurements obtained using a single THGEM layer with CsI coating, a UV lamp and measuring the current collected at the detector anode, see fig. 3.

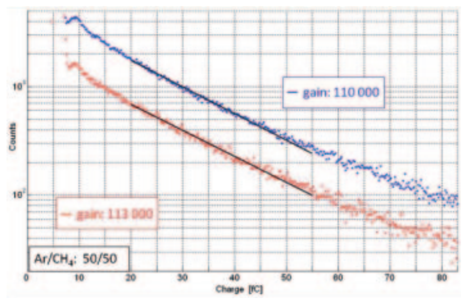

Fig. 4. – Amplitude spectra obtained with the four-layer THGEM detector with CsI photocathode described in the text, illuminating the detector with continuous and pulsed UV light sources in single photoelectron mode.

Tests with multilayer THGEMs in single photon mode have been performed using mainly two tagged UV light sources: a UV LED-255(1) with wavelength 255 ± 10 nm and a Pulse Light Source(2) with 265 ± 10 nm.

A single photoelectron spectrum measured with a four-layer THGEM detector (diameter 0.4 mm, pitch 0.8 mm, thickness 0.4 mm and rim 10 μm) is shown in fig. 4. Gains larger than 10^5 have been measured. Using the electronic chain described in [8] a time resolution of 7.5 ns r.m.s. has been measured.

4. – Outlook and conclusions

More than 30 THGEMs with different geometrical and production parameters have been characterized and the photoelectron extraction efficiency has been studied gaining insight in the parameters relevant to optimize it. We confirm that THGEM photon detectors are promising candidates for single photon detection for RICH applications.

The outcome of our investigation can be beneficial also to THGEM applications in different fields.

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(1) By Seoul Optodevice Co., Ltd, Seoul, South Korea.
(2) The PLS is driven by PDL 800-B by PicoQuant GmbH, Berlin, Germany, obtaining 600 ps long light pulses.