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Status of the development of large area photon detectors based on THGEMs and hybrid MPGD architectures for Cherenkov imaging applications

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ABSTRACT

We report about the development status of large area gaseous single photon detectors based on a novel hybrid concept for RICH applications.

The hybrid concept combines Thick Gaseous Electron Multipliers (THGEMs) coupled to CsI, working as a photon sensitive pre-amplification stage, and Micromegas, as a multiplication stage. The most recent achievements within the research and development programme consist in the assembly and study of $300 \times 300\ mm^2$ hybrid photon detectors, the optimization of front-end electronics, and engineering towards large area detectors. Hybrid detectors with an active area of $300 \times 300\ mm^2$ have been successfully operated in laboratory conditions and at a CERN PS T10 test beam, achieving effective gains in the order of 10^5 and good time resolution ($\sigma = 7$ ns); APV25 front-end chips have been coupled to the detector resulting in noise levels lower than 1000 electrons; the production and characterization of $300 \times 600\ mm^2$ THGEMs is ongoing.

A set of hybrid detectors with $600 \times 600\ mm^2$ active area is envisaged to upgrade COMPASS RICH-1 at CERN in 2016.

1. Introduction

RICH-1 is a Ring Imaging Cherenkov detector [1] within the Large Angle Spectrometer at the COMPASS experiment [2] at CERN. It is based on a mirror focused configuration [3] and comprises, therefore, a gaseous radiator, a mirror system and a photon detection system which consists of 576 Multi Anode Photon Multipliers (MAPMTs) [4], covering the most central area of the detection system (25% of its sensitive area), and 12 MultiWire Proportional Chambers (MWPCs) [5] of $600 \times 600\ mm^2$ each, surrounding the MAPMTs.

The phase II of the COMPASS physics programme [6] foresees the operation under increased rates, which requires the maintenance of the performance of RICH-1 over future years at the present level, in

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more challenging conditions. While MAPMTs can cope with an increased rate, the MWPCs suffer significant ageing under higher photon fluxes and their performance is limited under such conditions. Moreover, MWPCs are intrinsically slow-response detectors and faster ones are needed. In order to enhance the performance of the photon detectors of RICH-1, an upgrade of four of the MWPCs installed in the peripheral area is planned, for early 2016.

The investigation of photon detectors for the aimed RICH-1 upgrade resulted in a novel detector concept that will be presented: the Hybrid detector [7]. It is the outcome of eight years of an extensive research and development programme, consisting of the development and characterization of THGEM structures; study of multi-layer THGEM detectors; evolution from triple-layer THGEM configurations to a hybrid concept that merges two Micro Pattern Gas Detectors (MPGD) architectures; optimization of front-end electronics; and engineering towards large area photon detectors.

2. THGEM based photon detectors

THGEM [8] structures consist of a drilled set of printed circuit board (PCB) that undergoes a chemical etching process. The application of a voltage difference to the two copper sides of the PCB, in a proper gas, allows charge originated from gas ionization to be multiplied through an avalanche process. THGEMs can be arranged in multi-layer configurations and photon sensitivity can be achieved by depositing a CsI reflective photocathode on the upper THGEM layer.

Exhaustive characterization of $30 \times 30\ \text{mm}^2$ single layer THGEM detectors allowed the study and optimization of the THGEM parameters (hole diameter, pitch, thickness and rim) [9], as well as their production procedure. The stacking of these structures in multi-layer detectors permitted the study of the detector's working principles and the effectiveness of THGEM staggering as a solution to suppress the ions, originated by the gas ionization, that reach the CsI layer (IBF – Ion back flow) [10], and that are potentially harmful for its life span and for the performance of the detector [11]. Further, triple-layer THGEM detectors have been successfully operated in laboratory and beam tests [12].

The scaling from small sizes to $300 \times 300\ \text{mm}^2$ active area THGEMs imposed a big challenge in the development of large THGEM-based detectors [13]. The thickness non uniformity observed in some PCB sheets, with thickness variations up to 15% resulted in gain variations throughout the same THGEM of up to 40%. Therefore, in order to assemble a $300 \times 300\ \text{mm}^2$ THGEM detector, the selection of the THGEMs with the best performance and the most uniform gain corresponds to a critical aspect. In this regard, the thickness of tens of PCB sheets was measured to assure thickness variations smaller than 5% for the THGEM production. The produced THGEMs were then subjected to individual characterization through the study of the maximum ΔV applicable throughout the whole THGEM, and the study of the gain uniformity using soft X-rays. Triple-layer THGEM detectors, of the same active area, have then been successfully assembled and operated in laboratory tests. The detector's performance has also been evaluated at test beams, collecting single photon events of Cherenkov light. A pile of events is shown in Fig. 1, where beam particle events are also visible in the center of the Cherenkov corona.

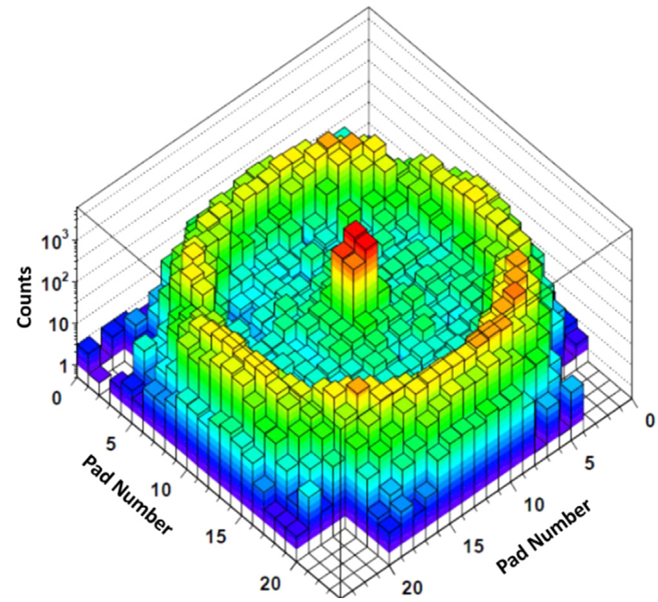

Fig. 1. Cherenkov ring obtained by superimposing events in a $300 \times 300\ \text{mm}^2$ triple-layer THGEM detector [16].

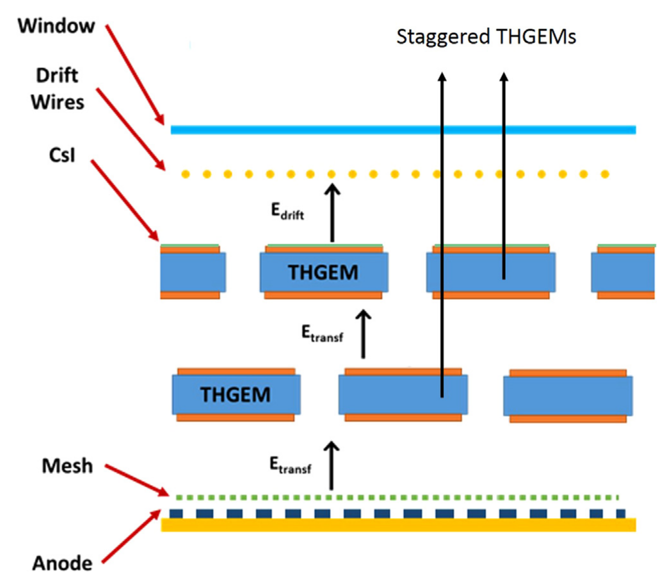

Fig. 2. Scheme of the hybrid detector concept comprising a dual layer THGEM configuration (thickness: 0.4 mm; hole diameter: 0.4 mm; pitch: 0.8 mm), and a Micromegas (128 μm over a multi-pad anode).

3. The hybrid photon detector

The hybrid photon detector concept appears as an evolution of the triple-layer THGEM detectors, resulting in a gaseous detector that merges THGEMs with Micromegas [14]. This MPGD architecture can be coupled with other amplification structures such as GEMs [15] or THGEMs, and has the intrinsic capability of blocking ions while being transparent to electrons [14].

Altogether, the hybrid THGEM – Micromegas detector, schematized in Fig. 2, makes use of a double layer THGEM+CsI configuration (photon sensitive pre-amplification stage), and a bulk Micromegas. The selected THGEM parameters are thickness of 0.4 mm; hole diameter of 0.4 mm; and pitch of 0.8 mm, while the Micromegas has a 128 μm amplification gap. Overall, the hybrid concept results in a robust detector with high photoelectron extraction efficiency, fast signals, high gain, photon feedback suppression, and time stability. Additionally, the misalignment of the holes of the two THGEM layers [10], together with the ion blocking capability of the Micromegas, makes the hybrid detector effective in the IBF suppression.

The hybrid detector also uses a capacitive multi-pad anode, where a set of pads at the surface of the anode is at nominal voltage, and a