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THGEM-based photon detectors for the upgrade of COMPASS RICH-1

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ABSTRACT

New Cherenkov photon detectors are being developed for the upgrade of COMPASS RICH-1. The detectors are based on THGEMs, arranged in a three layer architecture, with a CsI film on the first layer acting as a reflective photocathode. The response of THGEMs with various geometries under different conditions has been studied and photon detector prototypes have been built, tested in laboratory and operated during test beam runs providing a typical gain of 10^5 and a time resolution of better than 10 ns. A photon detector prototype with 300×300 mm^2 active area, operated at the CERN PS T10 test beam in November 2012, has confirmed the validity of this novel technology and has allowed further studies of the detector response.

1. Introduction

The physics program of the COMPASS Experiment [1] at the CERN SPS has recently been enlarged with the approval of a new series of measurements to be performed with an upgraded version of the apparatus. In the Particle Identification (PID) sector increased rate capability, greater stability and higher efficiency need to be guaranteed.

Present hadron identification requirements (π-K separation from 3 to 55 GeV/c over ± 200 mrad angular acceptance, at beam rates of 40 MHz and trigger rates up to 50 kHz) are fulfilled by the COMPASS RICH-1 detector [2], a Ring Imaging Cherenkov counter with a 3 m long gaseous C_4F_{10} radiator, a 21 m^2 large focusing VUV mirror surface and Photon Detectors (PDs) covering a total surface of 5.5 m^2.

COMPASS RICH-1 is in operation since 2001, and in its original version it used as PDs MWPCs having as a cathode plane a Printed Circuit Board (PCB) segmented in pads and coated with a CsI film. In spite of their good performance, MWPC-based PDs present intrinsic limitations: aging (decrease of quantum efficiency) after a few mC/cm^2 charge collection, feedback pulses with a rate increasing at large gain values, long recovery time after occasional discharge in the detector and long signal formation time (due to the slow ion motion); the MWPCs have to be operated at low gain and present a non-negligible detector memory and dead time.

Since 2006 the central region of the PDs (25% of the surface) is instrumented with matrices of Multi-Anode PMTs coupled to individual fused silica lens telescopes and read out via sensitive front-end digital electronics and high resolution TDCs.

In view of the challenges to be faced by RICH-1 for the future measurements, the COMPASS THGEM R&D project [3] was started, aimed to develop a large size gaseous detector of single photons, able

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to stably operate at large gain and high rate, to provide fast response, good time resolution and insensitivity to the magnetic field.

This article reports on the recent progress of this project.

2. THGEM-based PDs

Among the photon detection technologies (PMTs in standard or hybrid version, Micro Channel Plates, Silicon Photomultipliers, Gaseous PDs) offering interesting perspectives for large scale applications, Gaseous PDs are still the only option for instrumenting large surfaces in Cherenkov Imaging Counters at affordable costs.

Gaseous PDs for future RICH applications should have a small signal formation time, a closed geometry to avoid photon feedback and a reduced ion back-flow to the CsI photocathode: these requirements suggest the use of Micro-Pattern Gaseous Detectors (MPGDs). Gas Electron Multipliers (GEMs) [4] have been successfully used as PD elements in the Hadron Blind Detector [5] of the PHENIX Experiment at RHIC, although not as detectors of single photons. The fine space resolution and the low amount of material offered by GEMs are not essential for RICH applications, while the possibility of higher robustness against electrical discharges and larger operational gains provided by Thick-GEMs (THGEMs) are very appealing.

THGEMs, introduced about 10 years ago [6], are robust gaseous electron multipliers derived from the GEM design, scaling the geometrical parameters and changing the production technology: standard PCBs are used instead of the Cu-coated polyimide foils and the holes are obtained by drilling. Typical values of THGEM geometrical parameters are: PCB thickness from 0.2 to 1 mm, hole diameter from 0.2 to 1 mm and hole pitch from 0.4 to 1.5 mm. A metal-free clearance ring around the hole, the rim, has a width ranging from 0 (no rim) to 0.2 mm.

For the COMPASS THGEM R&D project more than 50 different samples of small ($30 \times 30\ \mathrm{mm}^2$ active area) THGEMs have been characterized using soft X-ray and UV light sources to study the effect of different production procedures, the role of each geometrical parameter, in particular the rim, and to find the optimal configuration for this application. Electrostatic calculations played an essential role for reaching a qualitative understanding of the observed THGEM behavior. Photoelectron extraction and collection efficiencies have been studied under various conditions, together with the gain stability, leading to the choice of the final parameters.

Chambers hosting multilayer THGEM arrangements (Fig. 1) with CsI coating on the top of the first THGEM have been built and operated under various conditions: the signal amplitude distributions have exponential shape and the gain is typically in the range of 10^5–10^6. The measured time resolutions are between 6 and 12 ns.

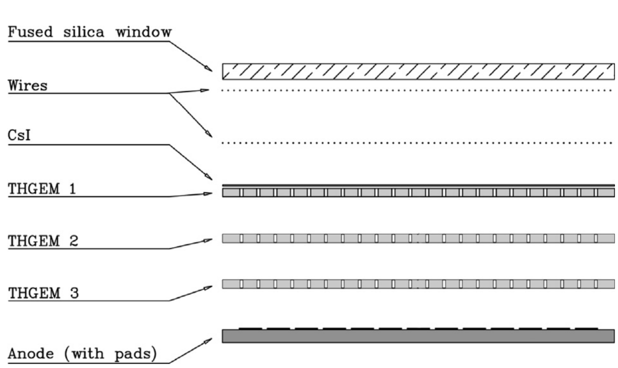

Fig. 1. Scheme of a THGEM-based photon detector.

An extensive study of the Ion Backflow (IBF) ratio [7] has been performed and geometrical arrangements providing reduced IBF have been found: they consist in mounting three THGEMs (having the same hole array) in a staggered hole alignment configuration [8] and in operating the PD with a large difference in the field values of the regions above and below the middle THGEM (for instance 1 kV/cm and 4 kV/cm, respectively), in order to direct most of the positive ions to the intermediate electrodes. This solution can guarantee that the new PDs provide a significantly lower ion bombardment rate at the photocathode with respect to the presently used MWPC-based ones, despite of the increase in the electron multiplication gain.

3. The $300 \times 300\ \mathrm{mm}^2$ active area PD Prototype

The production of large area THGEMs of high quality and uniformity of response is challenging: a strict quality control procedure has been defined, including systematic optical inspection, electrostatic tests and validation in stand-alone configuration inside a detector. Specific treatments (polishing, micro-etching or polyurethane coating) have sometimes been applied after the industrial production to achieve the desired result. Large area samples of good quality provide the same response as the small size THGEMs.

Several THGEMs with $300 \times 300\ \mathrm{mm}^2$ active area have been produced for COMPASS by an industrial PCB producer[2] using standard FR-4 Halogen-free Glass Epoxy Laminate[3] with 35 μm thick Cu on both sides. The raw material is cut and selected on the basis of thickness uniformity with strict tolerances ($\pm$ 3%) to guarantee gain uniformity.

All electrodes are segmented into 6 parallel sectors of 48 mm width and a 0.8 mm spacing is left between sectors to minimize their coupling and the discharge propagation probability. A set of holes placed between sectors and on the PCB border are used for precise and stable positioning. The high voltage is individually provided to each sector.

The PD Prototype (Figs. 2 and 3) consists of a chamber hosting two planes of wires (needed to define a uniform electric field in the region above the photocathode) and of three THGEMs, all having a hole diameter = 0.40 mm, hole pitch = 0.80 mm and a rim of ≤ 5 μm; the CsI coated THGEM has a thickness of 0.40 mm, the other two are 0.80 mm thick.

Precise positioning is provided by a set of inner columns, border blocks and spacers, made of PEEK (Polyether-ether-ketone) and fixed by screws to guarantee the THGEM planarity and to allow easy mounting (and dismounting) operations.

The anode plane is provided by a PCB segmented into a square array of 576 pads, each with an area of $12 \times 12\ \mathrm{mm}^2$. The spacings between the electrodes are: 2.50 mm between the anode and THGEM3, 3.00 mm between THGEMs, 5.20 mm between CsI and the drift wire plane, 30.0 mm between wire planes.

In November 2012 the $300 \times 300\ \mathrm{mm}^2$ PD prototype has been operated at the CERN PS T10 test beam of 6 Gev/c π^+.

A truncated cone fused silica radiator (Fig. 4) was placed on the beam axis and equipped with a cylindrical interceptor having a remotely controlled movement. A trigger system based on a 5-fold scintillator coincidence allowed selecting beam particles traveling along the radiator axis.

An Ar/CH_4 (60/40) gas mixture was used, and the high voltage was provided to each sector via individual resistive dividers

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[3] R-1566W by Panasonic Corporation or DURAVER-E-Cu 156 ML by Isola GmbH.