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The MPGD-based photon detectors for the upgrade of COMPASS RICH-1

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ABSTRACT

The RICH-1 Detector of the COMPASS experiment at CERN SPS has undergone an important upgrade for the 2016 physics run. Four new photon detectors, based on Micro Pattern Gaseous Detector technology and covering a total active area larger than 1.2 m^2 have replaced the previously used MWPC-based photon detectors. The upgrade answers the challenging efficiency and stability quest for the new phase of the COMPASS spectrometer physics programme. The new detector architecture consists in a hybrid MPGD combination of two Thick Gas Electron Multipliers and a MicroMegas stage. Signals, extracted from the anode pad by capacitive coupling, are read-out by analog F-E based on the APV25 chip. The main aspects of the COMPASS RICH-1 photon detectors upgrade are presented focussing on detector design, engineering aspects, mass production, the quality assessment and assembly challenges of the MPGD components. The status of the detector commissioning is also presented.

1. Introduction

The COMPASS experiment [1] at CERN SPS has recently started a new phase in its physics programme where the new Generalized Parton Distributions and polarized Drell–Yan set of measurements require an improved rate capability, efficiency and stability of the spectrometer detectors [2]. To cope with these challenging requirements several upgrades of the COMPASS spectrometer have been planned, among those the upgrade of COMPASS RICH-1, which provides π–K separation from 3 to 55 GeV/c over ±200 mrad angular acceptance.

COMPASS RICH-1 [3] is a Ring Imaging Cherenkov counter with a 3 m long gaseous C_4F_{10} radiator, 21 m^2 large focusing VUV mirror surface and Photon Detectors (PDs) covering a total active area of 5.5 m^2: Multi-Anode PMTs coupled to individual fused silica lens telescopes in the central region (25% of the surface) and MWPCs equipped with CsI-coated photocathodes in the peripheral area.

In spite of their good performance, MWPC-based PDs present intrinsic limitations: ageing after a few mC/cm^2 charge collection, feedback pulses with a rate increasing at large gain values, long recovery time ($\sim 1d$) after occasional discharge in the detector volume and long signal formation time. The MWPCs have to be operated at low gain and present a non-negligible detector memory and dead time. Among the eight MWPCs of COMPASS RICH-1, four located above and below the center of the detector have shown critical performance; the reader is referred to the articles in [4] for a detailed discussion. For this reason they have been replaced with novel MPGD-based PDs, devel-

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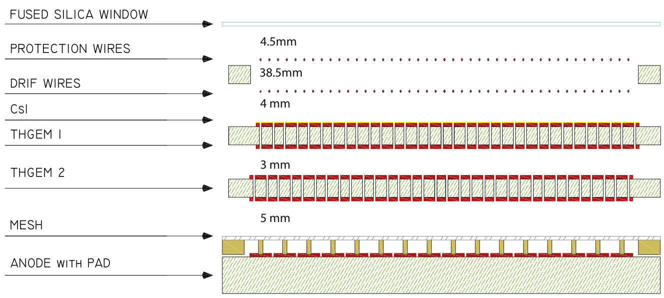

Fig. 1. Sketch of the hybrid single photon detector: two staggered THGEM layers are coupled to a bulk MicroMegas. The drift wire and the protection plane are visible. Distances between the quartz window and between the electrodes are indicated too. Image not to scale.

oped during a seven year-long dedicated R & D programme [5] and installed during the 2015–2016 winter shut-down. They are in commissioning phase during the 2016 data taking run.

2. The hybrid detector architecture

Each of the four large hybrid 600×600 mm^2 single photon detectors is built using a modular architecture and consists of two identical modules 600×300 mm^2, arranged side by side. The basic structure of the hybrid module (Fig. 1) consists in two layers of THick Gas Electron Multipliers (THGEM) [7], one MicroMegas (MM) [8], and two planes of wires. UV light sensitivity is obtained via the deposit of a thin (few hundred nm) CsI layer on the first THGEM electrode which acts as a reflective photocathode for VUV photons. The geometrical parameters of all the THGEM layers are thickness of 470 μm, total length of 581 mm and width of 287 mm. The hole diameter is 400 μm and the pitch 800 μm. Holes are produced by mechanical drilling and have no rim, i.e. there is no metallic clearance area around the hole. The diameter of the holes located along the external borders have been enlarged to 500 μm in order to avoid an increased electric field in the peripheral THGEM holes. The top and bottom electrodes of each THGEM are segmented in 12 parallel sectors separated by 0.7 mm clearance area. Each sector of the THGEMs is electrically decoupled from the others by 1 GΩ resistors. Six consecutive sectors are then grouped together and fed by independent high voltage power supply channels. The protection wire plane is positioned 4.5 mm away from the quartz window which separates the radiator gas volume from the detector volume filled with Ar/CH_4 50/50 gas mixture: it collects ions generated above the THGEMs to prevent their accumulation at the fused silica window. It is made of 100 μm ∅ wires with 4 mm pitch 600 mm long and is set at ground potential guaranteeing the correct closure of the drift field lines. The Drift wire plane (100 μm ∅ 4 mm pitch, 600 mm long), installed 4 mm from the CsI coated THGEM, is biased to a suitable voltage in order to maximize the extraction and collection of the converted photo-electron: the vertical component of the electric field at the CsI deposit layer must be larger than 1 kV cm [6]. The photo-electron is then guided into one of the first THGEM hole where the avalanche process is started due to the electric field generated by the biasing voltage applied between the top and bottom THGEM electrodes. The electron cloud generated in the first multiplication stage is then driven by the 1.5 kV/cm electric field across the 3 mm transfer region to the second THGEM, where thanks to the complete misalignment of the holes with respect to the first THGEM layer (≈462 μm displacement along the THGEM length coordinate), the charge is separated and undergoes a second independent multiplication process. Finally the charge is guided by the 0.8 kV/cm field across the 5 mm gap to the bulk MM where the last multiplication occurs. 300 μm diameter pillars, at 2 mm distance each keep the micromesh (18 μm woven stainless steel wires, 63 μm pitch) at 128 μm distance from the anodic plane. The intrinsic ion blocking capabilities of the

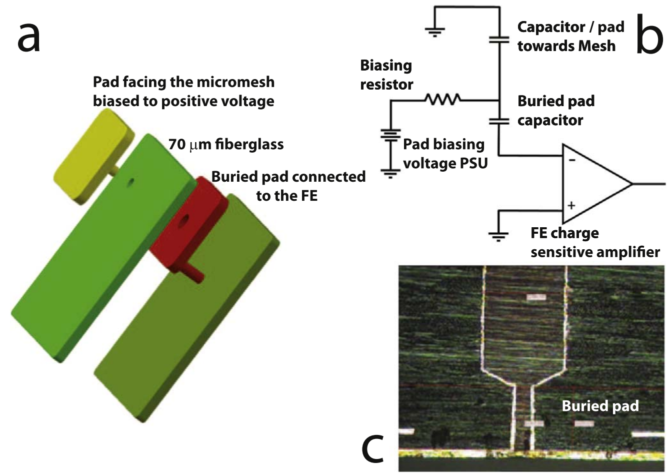

Fig. 2. (a) Sketch of the capacitive coupled readout pad. The biasing voltage is distributed via independent 470 MΩ resistor to the pad facing the micromesh structure (buried pad on the figure). The buried pad is isolated via 70 μm thick fibreglass and connected to the front end chip. (b) Schematic of the capacitive coupled pad principle illustrated via discrete elements blocks, the pad facing the micromesh is indicated as *capacitor/pad towards mesh* while the buried pad is indicated as *buried pad capacitor*. (c) Metallography section of the PCB: detail of the through-via contacting the external pad via the hole of the buried pad.

MicroMegas as well as the arrangements of the THGEM geometry and fields grant an ion back flow on the photocathode surface lower or equal to 4% [5]. The charge is collected by the 7.5×7.5 mm^2 pad segmented anode biased at positive voltage and facing the grounded micromesh. This segmentation results in 4760 readout channels for detector. Each pad is biased through a independent resistor and the signal, induced on the parallel buried pad (Fig. 2a, b), is read out by the Front End APV 25 chip [9]. The signal attenuation caused by the capacitor charge divider (Fig. 2b) results in a signal amplitude reduction of ≈10%. The 500 μm clearance between pads prevents the discharge, when occurring, to propagate towards the surrounding pads. Each of the 2 groups of 2380 biased pads, hosted by a hybrid module, is powered by an independent high voltage power supply channel. The pads of each group are electrically decoupled among them via resistors. The value of the resistance has been chosen as compromise between the need to limit the voltage drop that affects the pads on the same high voltage line after a discharge occurs and the recharge time to recover the operating voltage. The 470 MΩ value adopted allows to limit the voltage drop of the anodic pads next to a tripping one to be below 2 V over the 620 V operational voltage resulting in a local gain drop lower than 4% and a restoring time of the nominal voltage of ≈20 μs. The solution adopted grants no damage to the F.E. electronics when an occasional discharge occurs as verified during the operation of the detector in laboratory and in test beam exercises. The THGEM correct position and planarity is guaranteed by 12 pillars by Peek glued onto corresponding pillars by photosensitive material present in the MM layer.

3. The production and the quality assessments of the hybrid photon detector components

Quality assessment protocols have been implemented for both the THGEMs and the MMs.

3.1. The THGEM production and quality assessment

The THGEMS are produced from halogen-free EM 370-5 by Elite Material Co, Ltd. raw PCB foils. The raw foils have been resized to a square foil (800 × 800 mm^2) side length by cutting out the external parts affected by larger local thickness variations due to the pressing