IL NUOVO CIMENTO **41 C** (2018) 74
DOI 10.1393/ncc/i2018-18074-y

Colloquia: IFAE 2017

# The novel photon detectors based on MPGD technologies for COMPASS RICH-1 upgrade

C. Chatterjee(*) on behalf of the COMPASS RICH group
*INFN, Sezione di Trieste and Dipartimento di Fisica, Università di Trieste - Trieste, Italy*

received 21 April 2018

**Summary.** — The RICH-1 detector of the COMPASS experiment at CERN SPS has been upgraded for the 2016 physics run: four MWPC-based photon detectors have been replaced by newly developed detectors based on MPGD technologies, for a total active area of $1.4\,\mathrm{m}^2$. The new detector architecture consists in a hybrid combination of two layers of THGEMs, the first acting as a reflective photocathode, and a Micromegas equipped with a pad segmented anode. The signals are read out via capacitive coupling by an analog F-E based on the APV25 chip. The characteristics and the performance of the new hybrid photon detectors are presented.

## 1. – Description

The COMPASS experiment [1, 2] at CERN SPS performed an important upgrade of its apparatus, to cope with the challenging requirements imposed by the new physics programme. COMPASS RICH-1 [3] provides $\pi$-$K$ separation from 3 to $55\,\mathrm{GeV}/c$ over $\pm 200\,\mathrm{mrad}$ angular acceptance using a $3\,\mathrm{m}$ long gaseous $C_4F_{10}$ radiator, a $21\,\mathrm{m}^2$ large VUV mirror surface and Photon Detectors (PDs) covering a total active area of $5.5\,\mathrm{m}^2$: Multi-Anode PMTs coupled to individual fused silica lens telescopes cover the central region (25% of the surface) and MWPCs with CsI-coated photocathodes equip in the peripheral area.

Despite their good performance, MWPCs have limitations: ageing after few $\mathrm{mC/cm}^2$ 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, low gain and non-negligible dead time. Among the eight MWPCs of COMPASS RICH-1, four, located above and below the centre of the detector, have shown critical performance [4]; hence, they have been replaced with novel Micro Pattern Gaseous Detectors(MPGDs)-based PDs, resulting from an eight year-long dedicated R&D programme [5].

(*) E-mail: chandradoy.chatterjee@ts.infn.it

## 2. – The hybrid detector architecture.

Each photon detector has an active area of $600 \times 600\,\text{mm}^2$ and is formed by two identical modules of $600 \times 300\,\text{mm}^2$, arranged side by side. They consist of two layers of THick Gas Electron Multipliers (THGEM) [6], one bulk MicroMegas (MM) [7], and two planes of wires (fig. 1). A CsI layer of 300 nm thickness on the top of the first THGEM electrode acts as a reflective photocathode for VUV photons. All the THGEMs have identical geometrical parameters: thickness $470\,\mu$m, the hole diameter is $400\,\mu$m and the pitch $800\,\mu$m. Holes are produced by mechanical drilling and have no rim, *viz.* there is no metallic clearance area around the hole. The diameter of holes at external borders is $500\,\mu$m 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. $1\,\text{G}\Omega$ resistor electrically decouples one sector from the other. Six consecutive sectors are grouped together and fed by independent high voltage power supply channels.

A wire plane made of $100\,\mu\text{m}\ \phi$ wires with 4 mm pitch is located 4.5 mm away from the quartz window, which separates the radiator gas volume from the detector volume, collects the ions generated above the THGEMs. A similar wire plane installed 4 mm from the CsI coated THGEM, is biased to a suitable voltage to maximize the extraction and collection of the converted photo-electrons into the THGEM holes where they start avalanche multiplication processes. The electron cloud generated in the first multiplication stage is driven by 1.5 kV/cm electric field across the 3 mm transfer region to the second THGEM, where thanks to the complete misalignment between the two layers, it splits among two or three holes, where a second independent multiplication process takes place. Finally, the 0.8 kV/cm field across the 5 mm gap to the bulk MM guides the charge to the last multiplication in the MM. Pillars with $300\,\mu$m diameter and at 2 mm pitch each keep the micromesh ($18\,\mu$m woven stainless steel wires, $63\,\mu$m pitch) at $128\,\mu$m distance from the anodic plane. The intrinsic ion blocking capabilities of the MM as well as the arrangements of the THGEM geometry and fields grant an ion back flow on the photocathode surface lower than or equal to 3% [5]. The charge is collected by the $7.5 \times 7.5\,\text{mm}^2$ anode pads which are biased at positive voltage and facing the grounded micromesh. This segmentation results in 4760 readout channels for detector. Each anode pad is biased through an independent $470\,\text{M}\Omega$ resistor. The signal is capacitively induced on a parallel buried pad and read out by the front end electronics based on the APV25 chip [8].

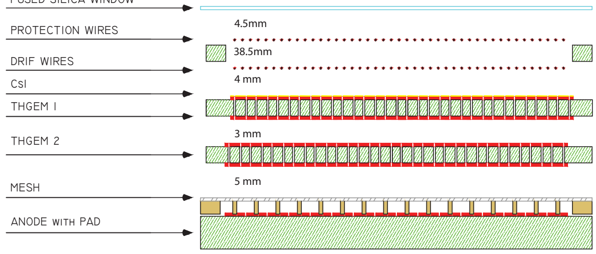


Fig. 1. – Sketch of the hybrid single photon detector. Image not to scale.

## 3. – Production of THGEMs and quality assessments of the hybrid photon detector components.

The THGEMS were produced from halogen-free raw PCB foils (EM 370-5 by Elite Material Co, Ltd.). A selection of the raw material, based on homogeneous thickness, is needed in order to ensure homogeneous gain: a foil is accepted when $(th_{\max} - th_{\min}) \leq 15\,\mu\text{m}$, where $th_{\max}$, $th_{\min}$ are the maximum and minimum of the measured thickness values. The selected foils are mechanically drilled by ELTOS S.p.A. using a multi-spindle machine.

A dedicated polishing method was applied to get rid of drilling residuals in the holes and smoothen the hole edges, and to refine the surface polishing [9].

THGEMs were validated by measuring gain uniformity, breakdown voltage and discharge rates when illuminated by X-ray source.

The quantum efficiency of the CSI photocathodes was measured in the CsI evaporation plant [10]: it is compatible with the maximum Q.E. values expected.

## 4. – Performance

The new hybrid PDs have been installed on COMPASS RICH-1 and commissioned during 2015-16 Physics Run. They operate at a gain of 20–30 K in Ar/$CH_4$ 50/50 gas mixture. The $\sigma_{\text{noise}}$ is $\sim$900$e$ Electron Noise Equivalent, which ensures high efficiency in single photoelectron detection. A detailed characterisation work is ongoing.

REFERENCES


[1] Abbon P. *et al.*, *Nucl. Instrum. Methods A*, **577** (2007) 455; Abbon P. *et al.*, *Nucl. Instrum. Methods A*, **779** (2015) 69.

[2] The COMPASS Collaboration, CERN/SPSC/2010-014, SPSC-P-340, May 17, 2010; CERN/SPSC/2010-022, SPSC-M-772, September 3, 2010.

[3] Alexeev M. *et al.*, *Nucl. Instrum. Methods A*, **639** (2011) 219; Dalla Torre S. *et al.*, *Nucl. Instrum. Methods A*, **639** (2011) 271; Tessarotto F. *et al.*, *JINST*, **9** (2014) C09011; Alexeev M. *et al.*, *Nucl. Instrum. Methods A*, **766** (2014) 208.

[4] Alexeev M. *et al.*, *JINST*, **9** (2014) P01006; Alexeev M. *et al.*, *Nucl. Instrum. Methods A*, **766** (2014) 199.

[5] Alexeev M. *et al.*, *JINST*, **9** (2014) C09017; Alexeev M. *et al.*, *JINST*, **10** (2014) P03026.

[6] Breskin A. *et al.*, *Nucl. Instrum. Methods A*, **598** (2009) 107 and references therein.

[7] Giomataris I. *et al.*, *Nucl. Instrum. Methods A*, **560** (2006) 405.

[8] Abbon P. *et al.*, *Nucl. Instrum. Methods A*, **567** (2006) 104.

[9] Alexeev M. *et al.*, *Nucl. Instrum. Methods A*, **766** (2014) 133.

[10] Braem A. *et al.*, *Nucl. Instrum. Methods A*, **502** (2003) 205.