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

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The RICH-1 Detector of the COMPASS Experiment at CERN SPS has been upgraded for the physics run 2016: four new Photon Detectors, based on MPGD technology and covering a total active area larger than 1.2 square meters replace the previously used photon detectors, namely MWPCs with CsI photocathodes, in order to cope with the challenging efficiency and stability requirements of the new COMPASS measurements. The new detector architecture consists in a hybrid MPGD combination: two layers of THGEMs, the first of which also acts as a reflective photocathode (its top face is coated with a CsI film) are coupled to a bulk Micromegas on a pad segmented anode; the signals are read-out via capacitive coupling by analog F-E based on the APV25 chip. The related R&D is shortly recalled. All aspects of the COMPASS RICH-1 Photon Detectors upgrade are presented and large emphasis is dedicated to the engineering aspects, the mass production and the quality assessment of the MPGD components. In particular, the design and production of the detector components, the assembling and the validation tests of THGEMs and Micromegas and the engineering challenges of the detector installation are presented. The preliminary performance figures of the upgraded RICH-1 are provided.

Summary

The RICH-1 Detector of the COMPASS Experiment at CERN SPS is undergoing an important upgrade for the physics run 2016: four new Photon Detectors (unit size: 60 x 60 cm2), based on MPGD technology and covering a total active area larger than 1.5 m2 will replace the actual MWPC-based photon detectors in order to cope with the challenging efficiency and stability requirements of the new COMPASS measurements. In COMPASS RICH-1, MPGD photon detectors are used for the first time in a running experiment. This realization does not only represent an important achievement for the COMPASS experiment, but opens the way of a more extended use of novel gaseous photon detectors in the domain of the Cherenkov imaging technique for Particle IDentification (PID), key detectors in several research sectors and, in particular, in hadron physics. The relevance is related to the role of gaseous photon detectors, which are still the only available option to instrument detection surfaces when insensitivity to magnetic field, low material budget, and affordable costs in view of large detection surfaces are required. The MPGD-based photon detectors overcome the limitation of the previous generation of gaseous photon detector thanks to two essential performance characteristics: reduced ion backflow to the photocathode, namely reduced ageing and increased electrical stability, and faster signal development, namely higher rate capabilities.

The new detector architecture consists in a hybrid MPGD combination: two layers of THick GEMs (THGEM), the first of which also acts as a reflective photocathode (its top face is coated with a CsI film) are coupled to a bulk MicroMegas (MM) on a pad segmented anode; the signals are read-out via capacitive coupling. This architecture is the result of an eight-year R&D activity, whose central elements are:

• the exploration of the phase-space of the THGEM geometrical parameters;

• the development of the THGEM production technique;

• the introduction of the resistive MICROMEGAS by discrete elements and the optimization of the parameters of this original MICROMEGAS implementation.

Each of the four large hybrid 600 mm x 600 mm single photon detectors is formed by two identical modules 600 mm x 300 mm, arranged side by side.

The basic structure of the hybrid module consists in two layers of THick Gas Electron Multipliers (THGEM), one MicroMegas (MM), and two planes of wires.

The geometrical parameters of all the THGEM layers are: thickness of 0.47 mm, hole diameter of 0.40mm

and the pitch 0.80 mm. Holes are produced by mechanical drilling and have no rim, namely no uncoated area around the hole edge. The diameter of the holes located along the external borders have been enlarged to 0.5 mm 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 areas separated by 0.7 mm clearance; the segments are group six by six forming two sectors per THGEM. The biasing voltage is individually provided to each sector of the THGEM. A fused silica window separates the radiator gas volume from the detector volume filled with Ar:CH4=50:50 gas mixture. A plane of protection wire plane is positioned 4.5 mm away from the window: they collect ions generated above the THGEMs to prevent their accumulation at the fused silica window. The drift wire plane, formed by wires with diameter 0.1 mm and pitch 0.4 mm, installed at 4mm 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 photo-electron is 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 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, the charge is shared among more holes, typically three, 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. The MMs have a gap of 0.128 mm; they are built using MM bulk technology using 0.3 mm diameter pillars with 2 mm pitch. The intrinsic ion blocking capabilities of the MM as well as the arrangements of the THGEM geometry and fields grants an ion back flow on the photocathode surface lower or equal to 4 %. The charge is collected by the 7.5 mm x 7.5 mm pad segmented anode biased at positive voltage and facing the grounded micromesh. This segmentation results in 4760 readout channels per detector. Each pad is biased trough an independent resistor and the signal, induced on the parallel buried pad, is read out by the Front End APV 25 chip. The 0.5 mm clearance between pads prevents the sparks, when occurring, to propagate towards the surrounding pads: the voltage drop of the anodic pads surrounding a tripping one is about 2 V over the 620 V operation voltage, causing a local gain drop lower than 4 %. The nominal voltage condition of the tripped pad is restored in about 20 micros.
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.
Quality Control (QC) tools, methods and protocol have been developed as well. They include:
• preselection of the row material for the PCB that will form the THGEMs in order to use only foils with homogeneous thickness to guarantee the homogeneity of the gain;
• THGEM control by optical inspection, by collecting and analyzing microscope images scanning the large multiplier surface;
• THGEM validation by gain maps using the multipliers in single layer detectors;
• THGEM validation by measuring the breakdown voltage in nitrogen and comparing it with the phenomenological Paschen limit;
• MICROMEGAS stability and gain maps illuminating the detectors by an X-ray gun station;
• Measurement of the quantum efficiency of the CsI photocathodes;
• Gas leak checks and overall electrical stability checks of the final detectors.
The challenges of the engineering aspects of the project concern both the mass production and the assembly, that requires compatibility with the existing elements of RICH-1. Details about the production yields and the most critical aspects will be provided.
The upgraded RICH-1 has been commissioned during the 2016 COMPASS run: therefore, preliminary performance figures are provided.

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