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

S. Levorato  INFN Trieste,
on behalf of COMPASS THGEM group:

Alessandria, Aveiro, Freiburg, Kolkata, Liberec, Prague, Torino, Trieste.
Outline of the talk

1) The motivation of the upgrade

2) The single photon detector for the upgrade: a “MPGD choice” and its building blocks
   - THGEM
   - MicroMegas

3) Construction and installation

4) The detector preliminary performance
The motivation of the upgrade, the COMPASS II phase

COMPASS RICH-1
Already upgraded in 2006 with MAPMT in the most inner central region

- Generalized parton distribution (GPD)
- Flavour separation and fragmentation in SIDIS
- Transverse momentum dependent distributions (TMD)
- QCD at very low momentum transfers

Improved / challenging performance for the COMPASS spectrometer detectors

- In our case a “improved PID performance”
  - Faster and higher gain

Number of photons for central 60x60 cm² MWPC:

- On average lower than the other PC
- Slow decreasing trend \( N_{\text{ph}} \) vs year

Central Cathodes

- MAPMT in the most inner central region
The Hybrid detector concept and the building blocks: the THGEM, the Bulk MicroMegas and the FE

**Hybrid detector concept**

To simplify the construction requirements a modular architecture has been adopted where one "module" consists of:

- One 300 mm x 600 mm Bulk Micromegas detector
- Two layers of THGEMs (300 mm x 600 mm) in staggered configuration

Two modules are put side by side to build a 600 mm x 600 mm detector

Operational gas mixture: Ar/CH$_4$ 50/50

Signal read out via capacitive coupling pad readout and APV25 F/E boards

Multi-Pad Anode 8mm X 8mm pad size
The Hybrid detector concept and the building blocks: the THGEM, the Bulk MicroMegas and the FE

Two modules are put side by side to build a 600 mm x 600 mm detector

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To simplify the construction requirements a modular architecture has been adopted where one "module" consists of:

THGEM 1
THGEM 2

Two modules are put side by side to build a 600 mm x 600 mm detector.
The Hybrid detector concept a result of 8 years of intense R&D activity: just a glimpse

Effective gain = \(0.91 \cdot 10^6\)

Ar/CH\(_4\): 50/50

Photon yield & Charged Particles vs Drift Field

PARAMETERS:
- Diam. = 0.4 mm
- Pitch = 0.6 mm
- Thckn. = 0.4 mm
- Rim = 10 \(\mu\)m

Preliminary IBF measured <5%
Now with optimized geometry below 2%

See G. Hamar Poster

Cascaded multiplier allows for large gain \(\sim 10^5\)
The hybrid first “ingredient” : the THGEM
The THGEMs design: specifics

- 12 sectors on both top and bottom, 0.7 mm separation
- Thickness: 0.4 mm, hole diameter: 0.4 mm, pitch: 0.8 mm
- 24 fixation points to guarantee THGEMs flatness

THGEM pcb size = 620 mm x 320 mm, active area = 581 mm x 287 mm

Border holes diam.: 0.5 mm

Pillars in PEEK
A uniform response of the detector requires stricter tolerances than those offered by producers

| Tolerance (mm) | \(\pm 0.0030^* (0.076)\) |

Mitutoyo EURO CA776 xyz measuring machine, clean room, thermalize environment

Selection campaign 50 foils of 1245 mm x 1092 mm raw PCB resized into 800 mm x 800 mm and their thickness measured

- The foil thickness is measured in a matrix of 36x36 points.
- Each point is sampled 3 times and the average is computed. (\(~5200\) data entries for each foil).
- Measurements are performed on both sides of the foil for consistency checks.
THGEM quality assessment: material thickness

From each foil two THGEMS can be produced:
50 foils → 100 raw THGEM pcb
THGEM pcb size = 620 mm x 320 mm,
active area = 581 mm x 287 mm

Each foil has been labelled in a unique way.

The δ thickness measurements are stored on a local database

Only the material complying defined criteria is sent to producer (ELTOS Arezzo)

δ_{thickness} = \frac{\text{thickness}_{\text{max}} - \text{thickness}_{\text{min}}}{\text{thickness}_{\text{min}}} 

δ_{TH} Distribution PCBs

Two areas of different thickness

49 pcs
2%<δ<3%
A post production specific surface treating and cleaning procedure developed in Trieste is applied:
- Surface Polishing.
- High pressure water cleaning.
- Ultrasonic Bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160 ºC.
THGEM performance QA in two consecutive steps:

1. Paschen test: discharge counting vs voltage in controlled atmosphere (Ar/CO₂ 70/30) w & w/o irradiation
2. Gain uniformity measurements

AMPTEK Mini-X Au used at 15 kV, 200µA + Cu foil provides 8 keV X-rays uniform illumination at a rate > 5 kHz cm⁻² (for 1 cm Ar/CO₂ 70/30)

\[ \delta_G = \frac{G_{\text{max}} - G_{\text{min}}}{G_{\text{min}}} < 15\% \]

X rays spectrum
CSA + MCA system

APV 25 FE with RD51 SRS system

i.e. accepted piece #307 0.29 d/h @ 1150 ΔV for 14 h
THGEM storage, transport, gold coating and preparation for CsI deposit

THGEM ready for coating

THGEM are coated at CERN and QE measurements indicate for our photocathodes

\[ \text{QE} = 0.7 \div 1 \times (\text{max CsI QE}) \]

with an increasing trend during the production
The hybrid second “ingredient”: the Bulk MicroMegas
Bulk Micromegas (CERN) active area: 581 mm x 287 mm
- 128 μm mesh pad distance
- 18μm woven wires 45 μm pitch
- pad segmented (8x8 mm²) 2380 pads/module

Strong technological effort from TVR company for the PCB (multilayer 3.2 mm thick) to comply with specific requirements of planarity, surface quality, layer thickness uniformity, surface irregularities (E field).

Test of the (4 x 2) 30 x 60 cm² MMs [in total: 1.4 m², 19040 pads]:
- 2 pads with shorts
- 1 pad: no read-out connection
→ 3 bad pads out of 19040 before installation
Bulk Micromegas: production and performance assessment

9th International Workshop on Ring Imaging Cherenkov Detectors RICH 2016 - Bled Slovenia September 5-9, 2016 - Stefano Levorato INFN Trieste

Effective GAIN scan Ar:CH4 40:60

\[ \delta G = \frac{G_{\text{max}} - G_{\text{min}}}{G_{\text{min}}} < 5\% \]

In case of discharge of 1 pad
only effect: 2V drop → ~4% drop in gain for the surrounding pads, S. Dasgupta Poster for details

Resistor arrays
Connector 8+1 pin

APV25 electronic F/E board

1 Single pad scheme:
Blue pad at HV via individual pad resistor at the PCB rear surface
Red pad: signal induced by RC coupling
Assembly and installation in glimpse
The RICH-1 upgrade, the challenge of the integration in the existing mechanical environment
Mounting the detectors on the COMPASS RICH-1
Preliminary results! ...just one moment more
A dedicated HV control system has been designed, programmed, and tested to control and monitor new Hybrid Detectors: 104 HV channels in 9 different electrode types with diversified function in 16 sectors.

- HV and I is monitored at the nA level, non expected detector behaviour triggers HV reduction following dedicated set of rules (under study).
- Performs HV corrections due to temperature and pressure changes.
- Communicates with the existing COMPASS DCS (too slow for our needs).

In multilayer structure a 1% of P/T variation corresponds to 40% total gain variation: THGEM 15% (x 2) and MM 12%.

Need for P/T correction; residual variation ~10%.

P, T sensors inserted in the gas lines at gas in/out.

See Shuddha Dasgupta Poster.
The Hybrid detector signals from one chamber!

The detector commissioning is ongoing! Signal seen!

Apv25 sampling mode of the pre amplified and shaped signal, a reminder
Photon signals? Yes for sure!!!

Data taken in the same conditions, w/o and w beam

The peak from the electronic noise is the same

a2 spectrum: beam on, physics triggers

gain $\sim 22 \text{ k}$

ADC saturation

a2 spectrum: no beam, random triggers

a2 spectrum: beam on, physics triggers

gain $\sim 15 \text{ k}$

Another example
The hybrid detector: the first results from systematic tests on the COMPASS experiment!

ΔV
588
600
612
624

MM scan

ΔV
1250
1275
1300

THGEM scan

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Stefano Levorato INFN Trieste
A very (very) preliminary estimate of the number of photons

Comparing the number of detected photons in the present status:

from the same data, the number of “signal hits” on Hybrids is similar or larger than on MWPCs
A total surface of $1.4 \, m^2$ has been successfully instrumented by large size (60 x 60 cm$^2$) single photon detector based on MPGD in the COMPASS RICH-1 detector:

**FIRST TIME OF MPGD PHOTON DETECTORS EQUIPPING A RICH IN A RUNNING EXPERIMENT!**

These detectors have been installed during Spring 2016.

This technology is the result of several years of R&D activity.

The running in phase and the commissioning of the single photon detector started since one month thanks to a large effort of the whole group

The characterisation of the detector is now ongoing, the preliminary results shown are very promising, and the detector ultimate performance will be explored in the next months

Thank you very much!