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

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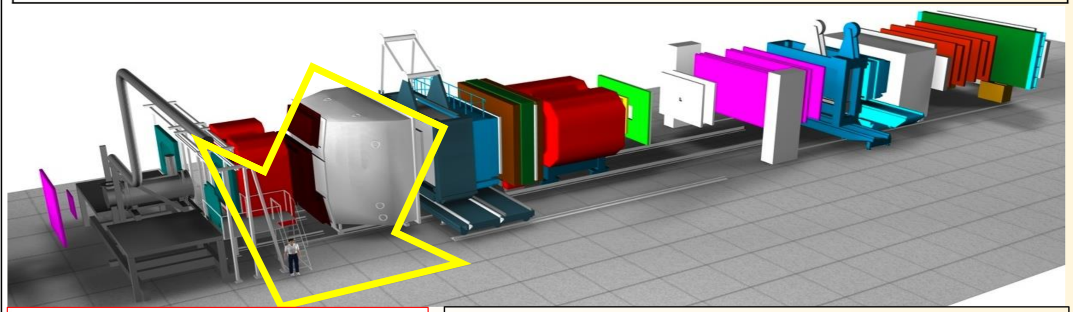
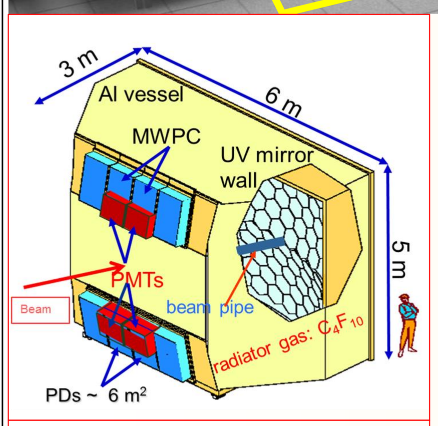
COMPASS RICH-1

Common Muon and Proton Apparatus for Structure and Spectroscopy

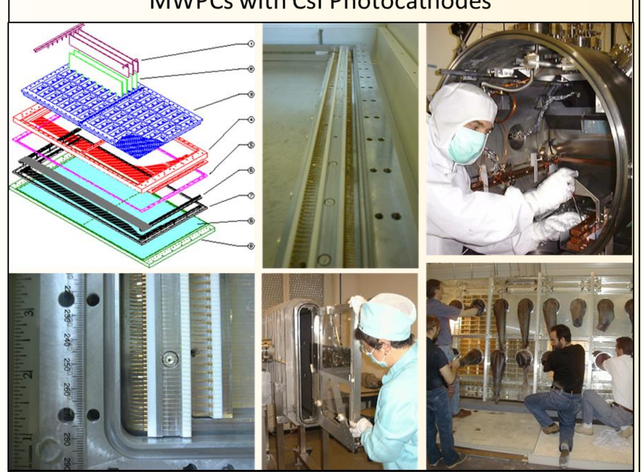
Measurements with muon beam:	Measurements with hadron beams:
COMPASS - I (2002 – 2011)	
Spin Structure, Gluon Polarization	Pion Polarizability
Flavor Decomposition	Diffractive and Central Production
Transversity	Light Meson Spectroscopy
Transverse Momentum Dependent PDFs	Baryon Spectroscopy
COMPASS - II (2012 – 2018)	
DVCS and DVMP	Pion and Kaon Polarizabilities
Unpolarized SIDIS and TMDs	Drell-Yan Studies
LoI in preparation (2020 - …)	





hadron PID from 3 to 60 GeV/c
acceptance: H: 500 mrad V: 400 mrad
trigger rates: up to ~50 KHz, beam rates up to ~10^8 Hz,
Detector designed in 1996 In operation since 2002
MAPMT based upgrade in 2006 A new upgrade with Hybrid MPGD is done in 2016

MWPCs with CsI Photocathodes

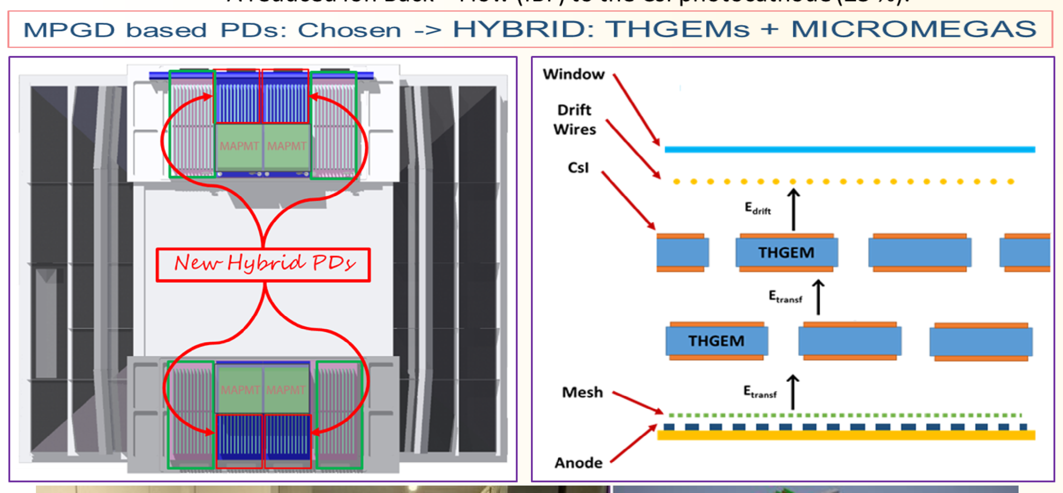


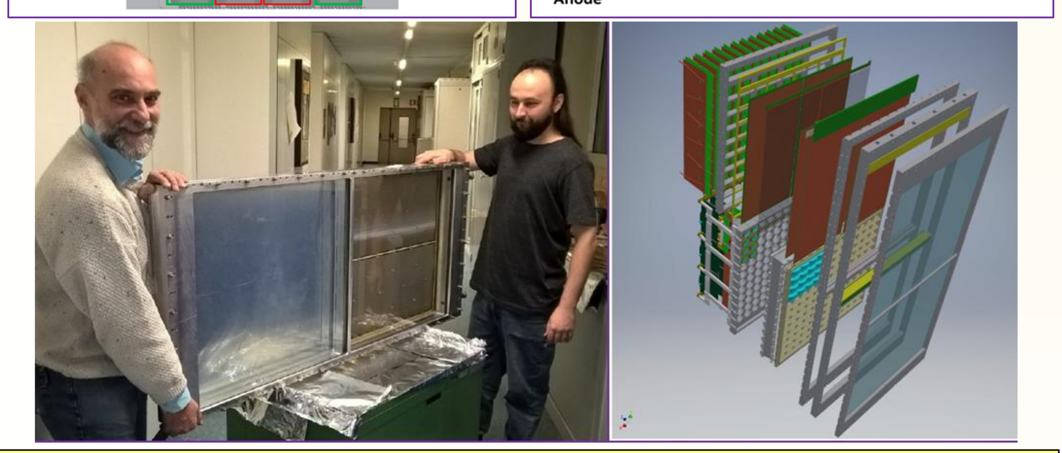
- Low gain, long recovery time after a discharge.
- Slow time response.
- Large photon and ion feed back to the photocathode.

RICH-1 UPGRADE

The new PDs have to be capable of :
A small time resolution ≤**10 *ns***.
A closed geometry to avoid photon feedback.
A large gain (~10^5).
A reduced Ion Back – Flow (IBF) to the CsI photocathode (≤3 %).

MPGD based PDs: Chosen -> HYBRID: THGEMs + MICROMEGAS





THGEM

THGEMs are Electron Multipliers derived from the GEMs concept with larger geometrical dimensions and produced by *standard PCB drilling technology.*

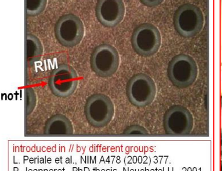
PCB technology, thus:
- robust
- mechanically self supporting
- industrial production of large size boards
- economic

Comparing to GEMs
- Geometrical dimensions X ~10
  - But e⁻ motion/multiplic. properties do not!
  - Larger holes: dipole fields and external fields are strongly coupled

About gain:
- Large gains are easily obtained (rim !)

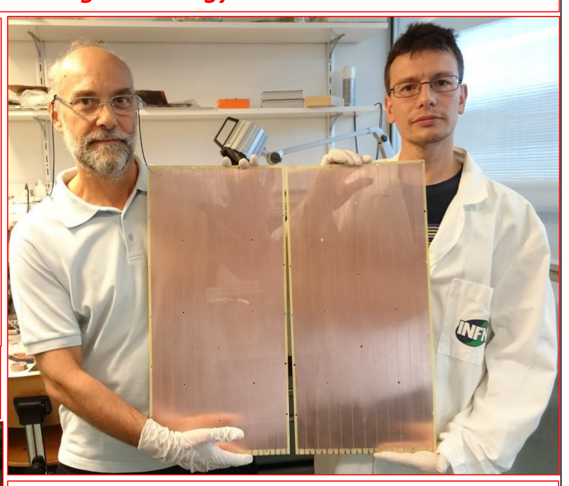
About PCB geometrical dimensions:

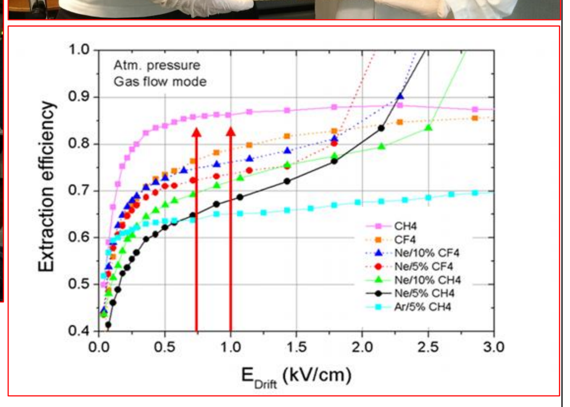
Hole diameter :	0.2 - 1 mm
Pitch :	0.5 - 5 mm
Thickness :	0.2 - 3 mm



introduced in // by different groups:
L. Periale et al., NIM A478 (2002) 377.
P. Jeanneret, PhD thesis, Neuchatel U., 2001.
P.S. Barbeau et al, IEEE NS50 (2003) 1285
R. Chechik et al, .NIMA 535 (2004) 303

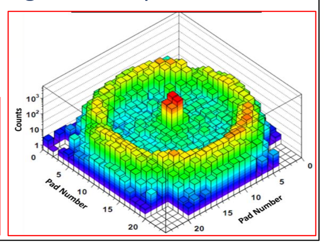
200,000 turns/min 20,000 holes/h storage: 840 tools, controlled diameter depth, run-out.





Efficient photo detection demands the optimization of several parameters:
- Choice of Gas: affects Photoelectron Extraction Efficiency.
- Choice of Drift field: Affects Photoelectron Collection Efficiency.
- Choice of Hole diameter, Pitch and Thickness: Affect the orthogonal component of the field over the CsI surface, hence affect the photoelectron extraction efficiency.

Optimized parameters:
Hole diameter = 400µm **Thickness = 400µm**
Pitch = 800µm **Rim=0µm**



THGEM for Upgrade

Thickness uniformity plays an essential role in defining the maximum achievable gain.
Observed Thickness variation up to 50 µm for 400 µm thick PCBs. Maximum gain is limited by the thinner area.
The raw PCB for THGEM production have been selected among those presenting thickness variation smaller than ±6µm

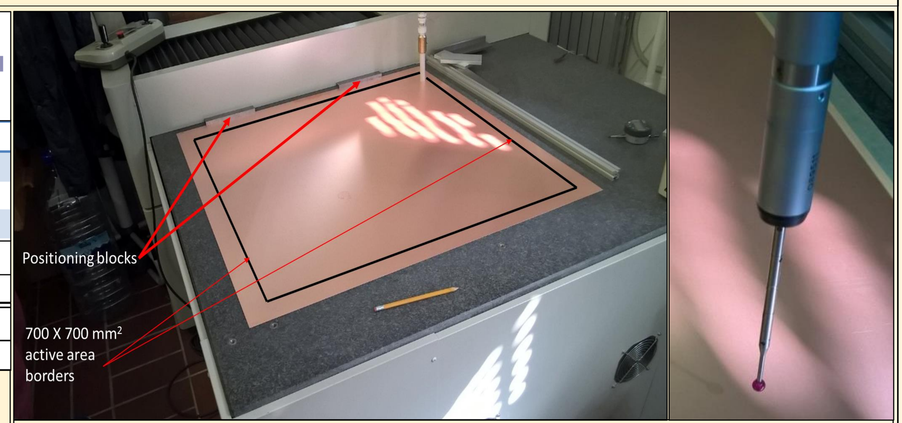
Elite Material Co., Ltd. http:\\www.emctw.com Technical Data

Lead-free , Halogen-free Material

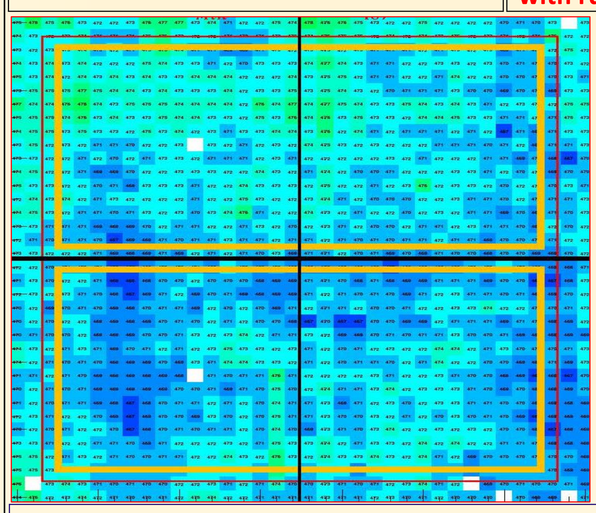
PRODUCT	EM 370-5
Thickness	0.407 mm
Copper	35µ / 35µ
Sheet Size	1 245 x 1 092 mm

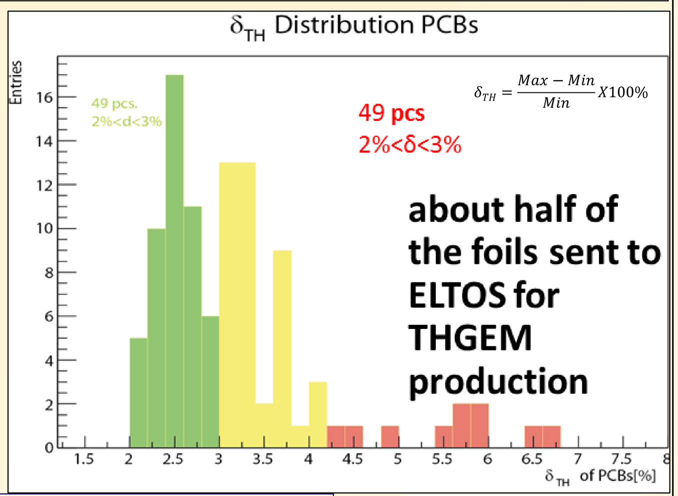
Permittivity (RC 50%)	1 MHz	2.5.5.9	C-24/23/50	–	4.8
	1 GHz			–	4.3
Volume resistivity		2.5.17.1	C-96/35/90	MΩ-cm	>10^{10}
Surface resistivity		2.5.17.1	C-96/35/90	MΩ	>10^9

- **For each foil 36 x 36 points in square pattern are measured 3 times.**
- **Total 50 foils were treated.**
- **To allow consistency checks both sides of the foils are measured.**



The foil is made coplanar to the marble via applying vacuum with a dedicated system. Mitutoyo EURO CA776 coordinate measuring machine with ruby touch probe, hosted in a thermalized room.

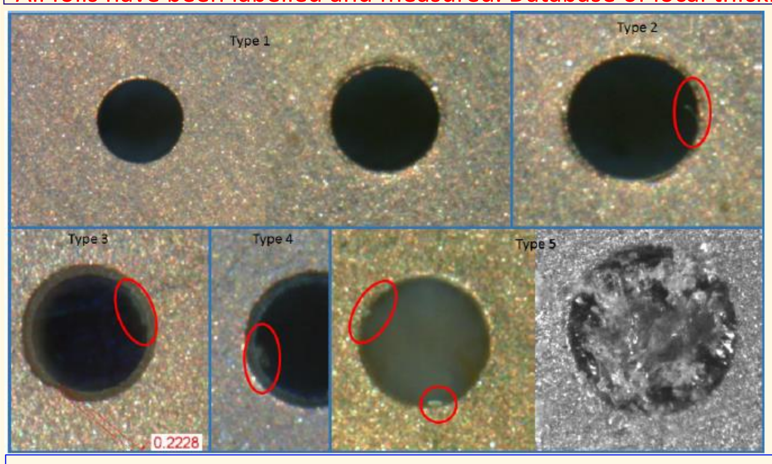




about half of the foils sent to ELTOS for THGEM production

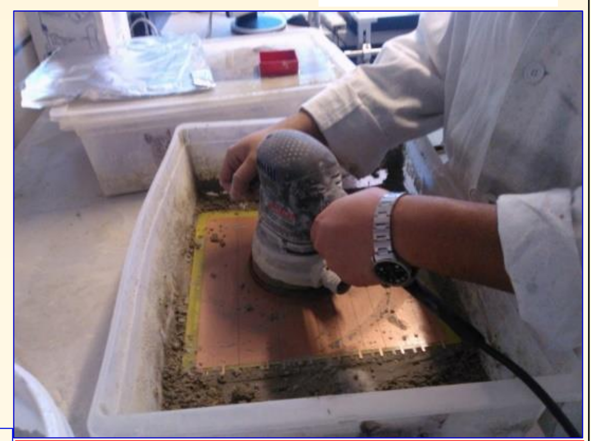
from each foil two THGEMS can be produced 50 foils → 100 raw THGEM pcb .
THGEM pcb size = 620 mm x 320 mm, active area = 581 mm x 287 mm.
All foils have been labelled and measured. Database of local thickness of all THGEMs

Tolerance inch (mm)
± 0.0030" (0.076)

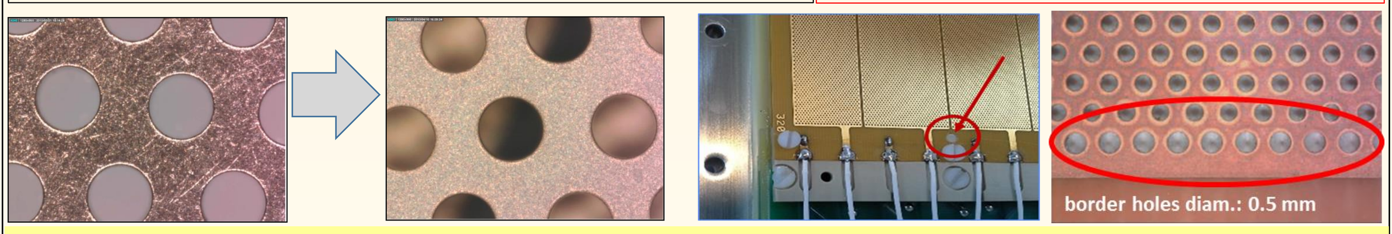


Holes after drilling may have Cu foil remnant and PCB remnant inside it. Dedicated post production treatment is performed to ensure better hole quality.

Ultrasonic bath with pH 11 pcb cleaner; washing with demineralized water eventually heated inside oven at 180 °C for ~ 24 hours



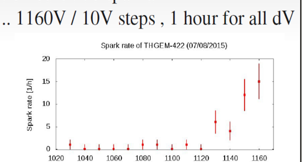
Mechanical brushing using pumice stone plus water: long process fine grain size pumice stone. pressurized water cleaning to remove pumice residuals



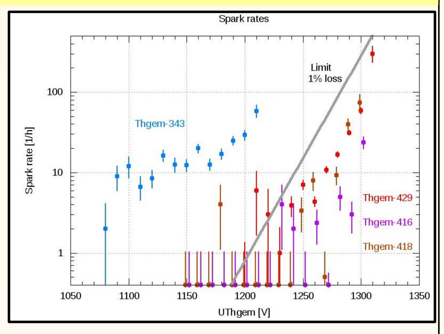
Quality Assessment Stage 1 : Test for breakdown Voltage (in N_2) and discharge counting (in Ar/CO_2 70/30)

Threshold for selection.
All THGEMs beyond the limit are rejected because of high spark rate at lower field.

THGEM : 422
- dV=1000V : 4 hours : 0 sparks/h
- dV=1150V : 6 hours : 70 sparks/h
- dV=1030V .. 1160V / 10V steps , 1 hour for all dV

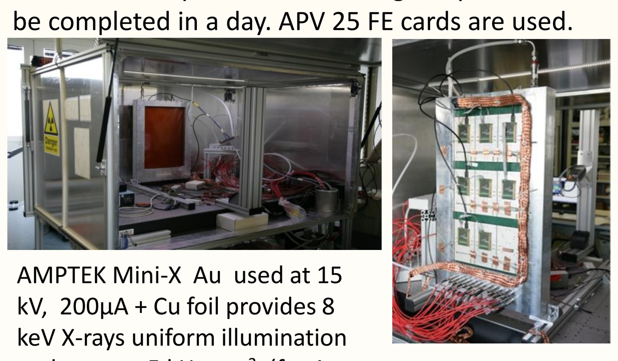


THGEM : 307
- dV=1100V : 74 hours : 0.27 sparks/h
- dV=1150V : 14 hours : 0.29 sparks/h



Quality Assessment Stage 2: Gain uniformity measurements

Gain uniformity is measured using X ray Source. For different sectors the gains are measured. The manual task can't be completed in a day. APV 25 FE cards are used.



AMPTEK Mini-X Au used at 15 kV, 200µA + Cu foil provides 8 keV X-rays uniform illumination and a rate > 5 kHz cm⁻² (for 1 cm Ar/CO_2 70/30).

Satisfactory gain uniformity has been reached.

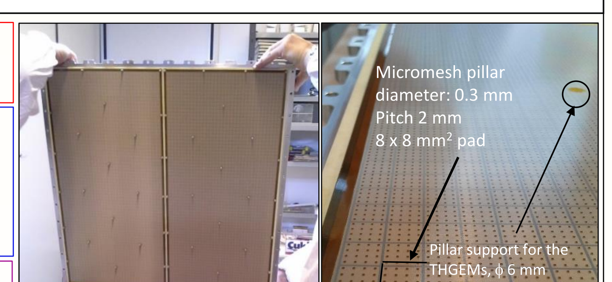
$$\delta_G = \frac{G_{max} - G_{min}}{G_{min}}$$

$$\delta_G < 10\ \%$$

188	202	185	198	206	207
196	207	196	198	199	207
192		193	198	204	204
192		188	199	202	205
199	199	191	195	195	
199	196	199	205	195	199
192	190	194	197	195	194
198	190	195	209	195	199
198	199	195	208	197	201
198	199	195	199	200	199
190	186	185	199	190	199

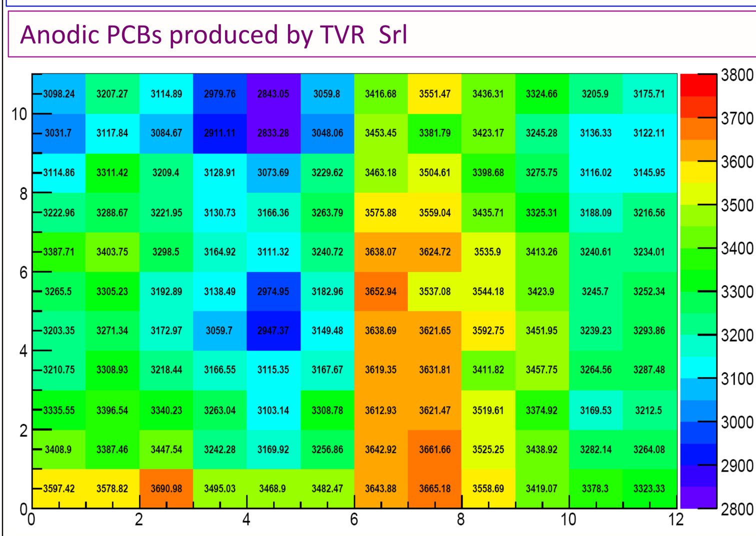
Micromegas

Micromegas have intrinsic ion trapping property. COMPASS RICH-1 requires Photon detectors with Low Ion Back Flow (IBF).



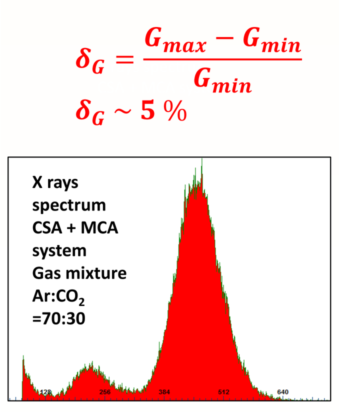
Bulk Micromegas (CERN) active area: 581 mm x 287 mm
- 128 µm mesh gap
- 18µm woven wires with 45 µm pitch
- Anodic plane segmented into 8x8 mm² pads. ~20K pads.

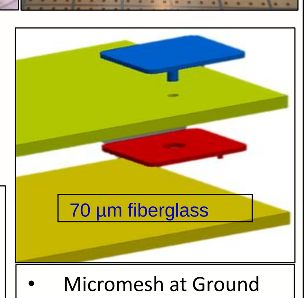
Anodic PCBs produced by TVR Srl



$$\delta_G = \frac{G_{max} - G_{min}}{G_{min}}$$

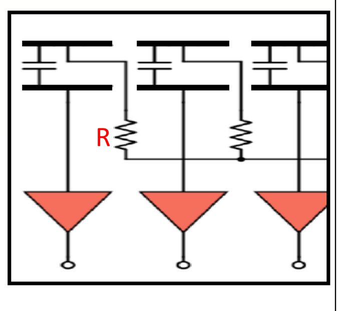
$$\delta_G \sim 5\ \%$$





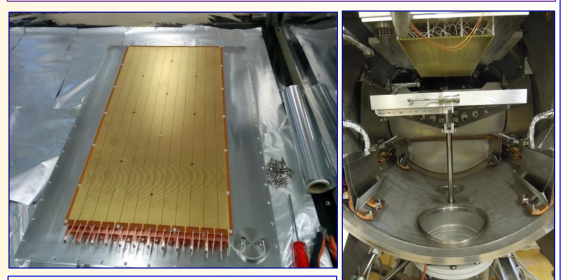
- Micromesh at Ground
- Anodic (Blue) pad at HV via ~ 0.5 GΩ resistor
- Readout (Red) pad at 70 µm from anodic one (capacitive coupling).

In case of a discharge the HV of the non tripping pad is almost unaffected: 2V drop ~4% drop in gain. R ~ 0.5 GΩ is preserving the non-tripping pads efficient all the time !



CsI coating

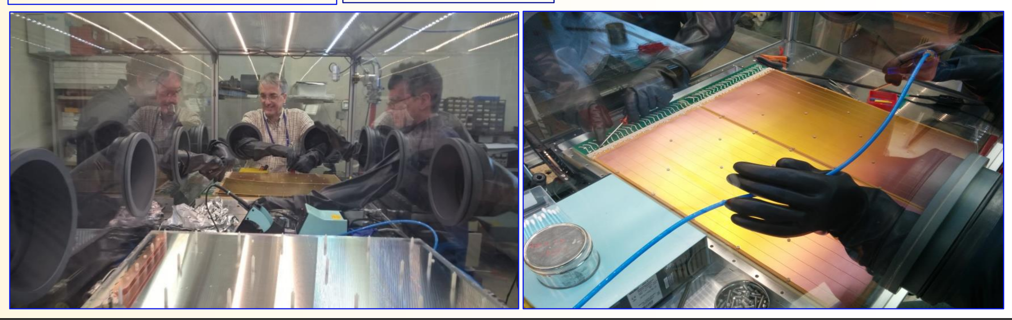
CsI coating on the top of the THGEM is done at CERN measured QE as expected.



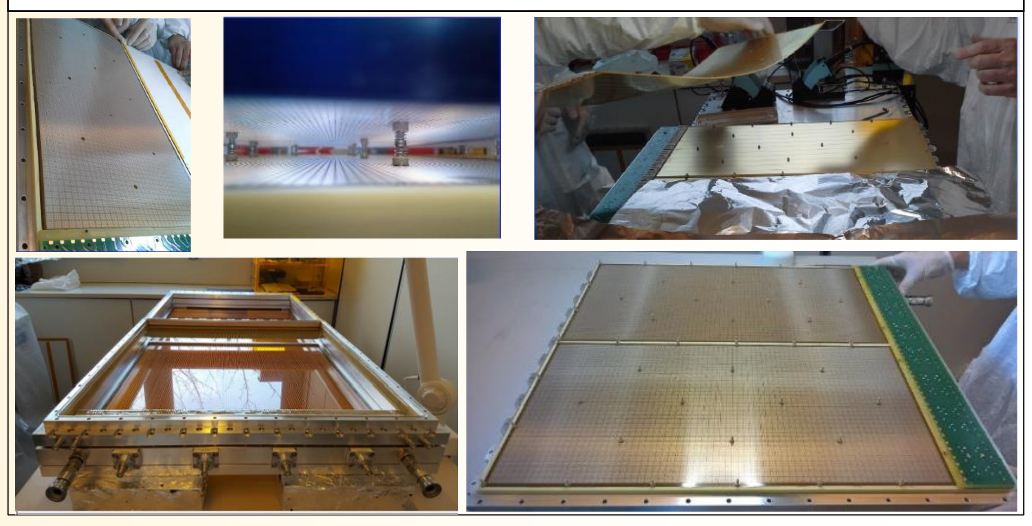
Selected THGEMs after QA Are sent for CsI coating at CERN

CsI plant at CERN

CsI Coating Procedure:
- Installation of substrate inside evaporation plant together with gas tight chamber.
- Evacuation of evaporation plant for two days to assure ~10^{-7} hPa.
- Slow deposition (~1 nm.s⁻¹) of a 300 nm thick CsI layer.
- Thermal treatment (8h at 60°C) to optimize photocathode response.
- Measurement of CsI at 60 and 20 degrees.
- Extraction after closing gas tight chamber (1 bar).
- Storage and handlings are done in boxes with continuous flow of low contamination gas.



Assembly

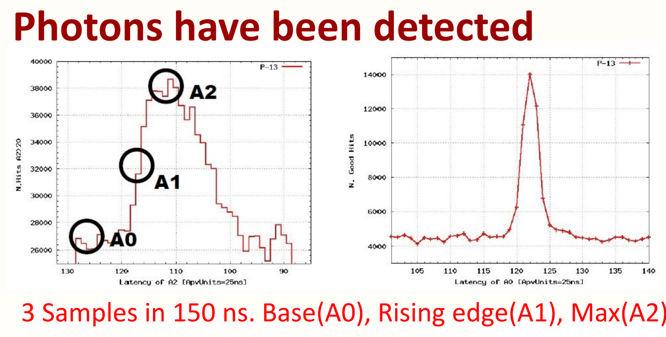


Installation of Hybrid on RICH

In Spring 2016, four MPGD based Hybrid photon detectors have been installed on COMPASS RICH-1.
Extremely delicate installation!

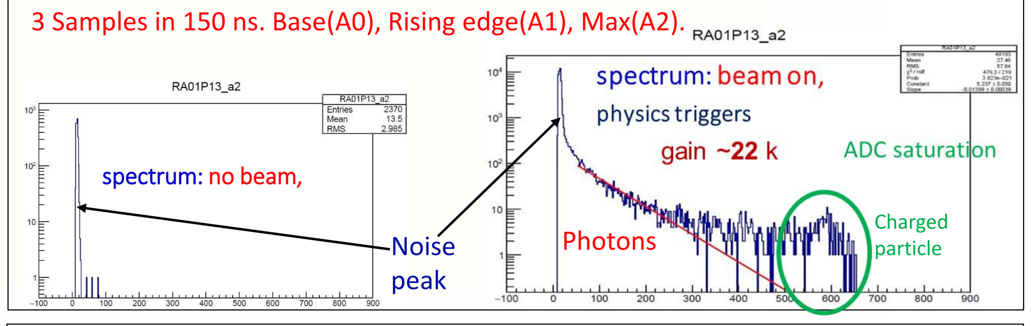
Preliminary Results

Photons have been detected



RICH FEE: APV25+ DAQ:
Latency Scan in steps of 25 ns.
Fast Rising of Signal, crucial parameter
Clear Indication of Photon Signal at proper latency value in beam on condition.

3 Samples in 150 ns. Base(A0), Rising edge(A1), Max(A2).



Summary

- COMPASS requires excellent hadron identification in challenging conditions,
  ->RICH1 has been upgraded with MPGD based hybrid detectors of single photons.
- 1.4 m² of double THGEM and Micromegas based detector have been produced and installed on COMPASS RICH-1.
- The Preliminary results show that the Hybrid detector sees Cherenkov photons, efficiently!
- This novel technology is paving the way for future developments.

Reference: http://doi.org/10.1016/j.nima.2017.02.013