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

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–SPSC–2010–014
SPSC-P-340
May 17, 2010

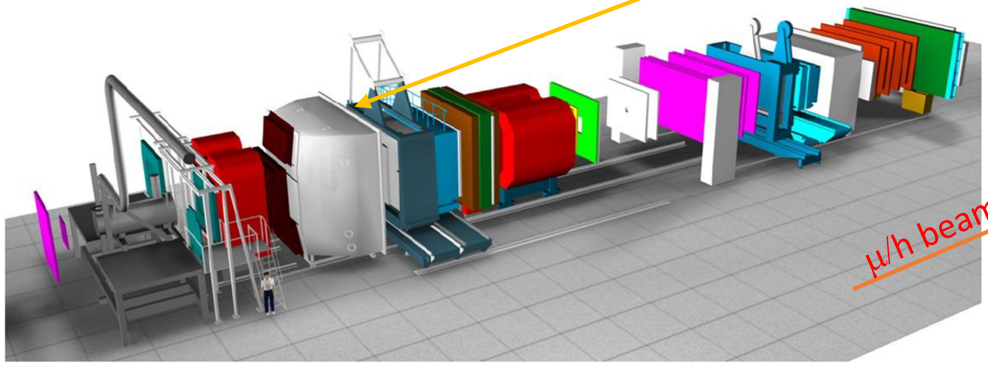
COMPASS-II Proposal

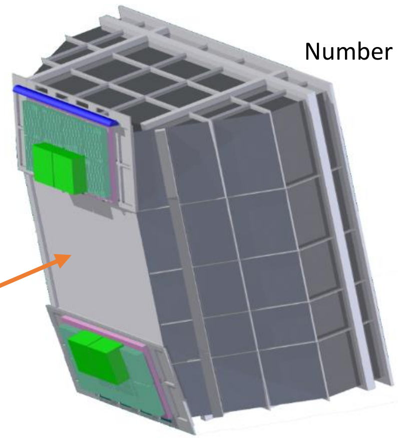
The COMPASS Collaboration

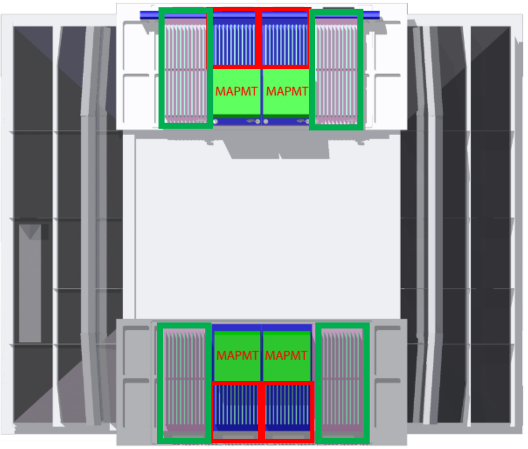
Submitted in May 2010 for 5 yeas data taking (2020) approved in December 2010 for initially 3 years of data taking in 2015-2017

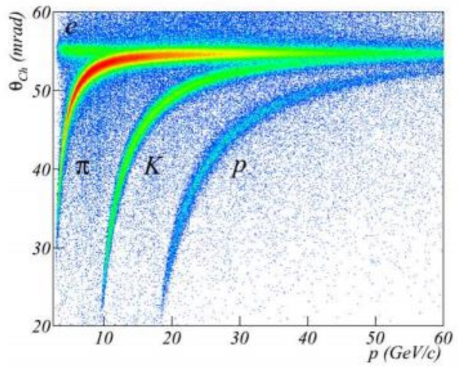
COMPASS RICH-1

Already upgraded in **2006** with **MAPMT** in the most inner central region



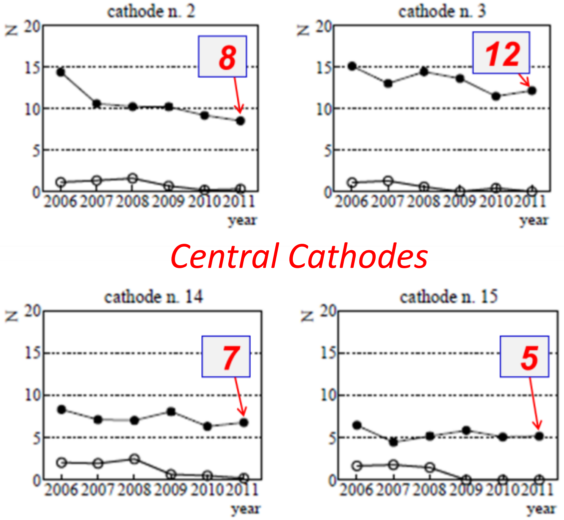






Number of photons for central 60x60 cm ^{2}MWPC:

- On average lower than the other PC $\langle N_{ph} \rangle = 13$
- Slow decreasing trend $\langle N_{ph} \rangle$ vs year

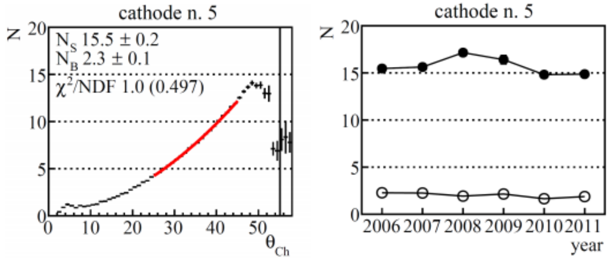


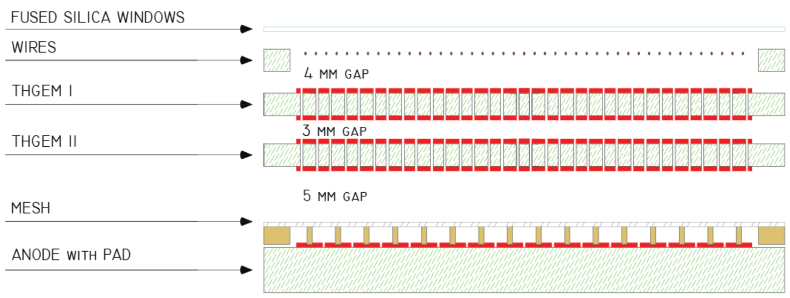
Central Cathodes

- ✓ 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***





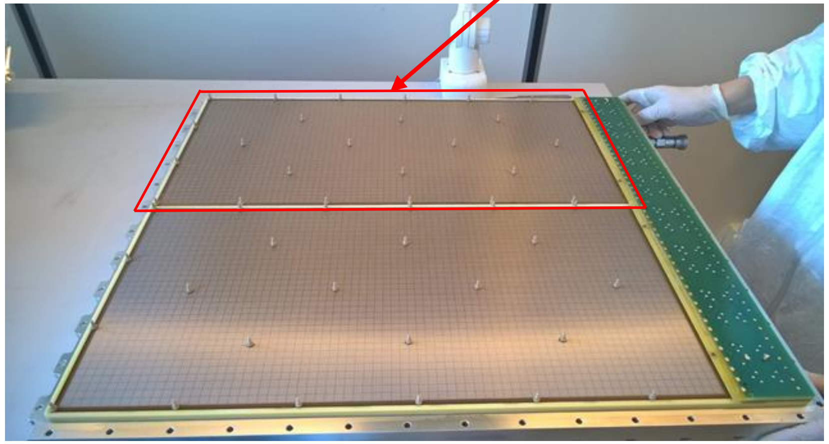
Operational gas mixture : Ar/CH_4 50/50

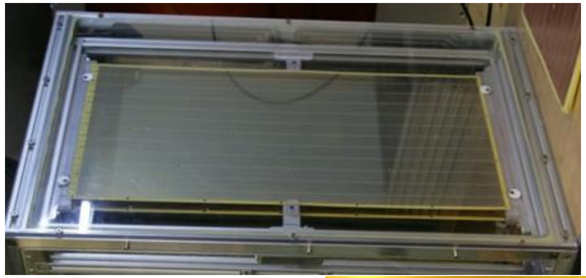
Hybrid detector concept

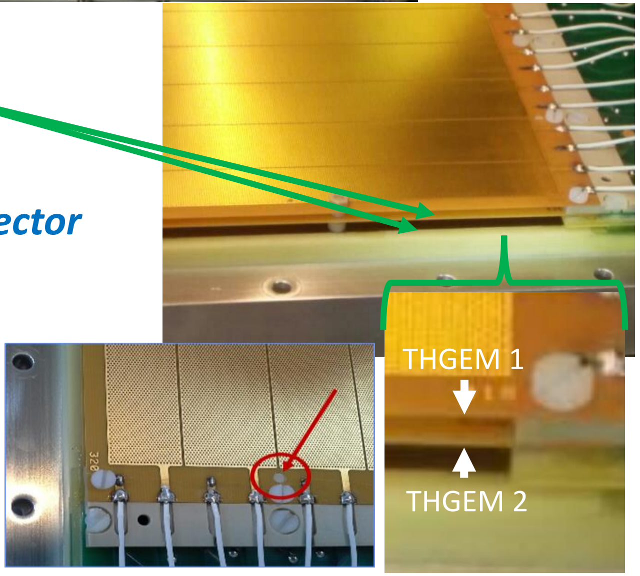
To simplify the construction requirements a modular architecture has been adopted where one "*module*" consists of:

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

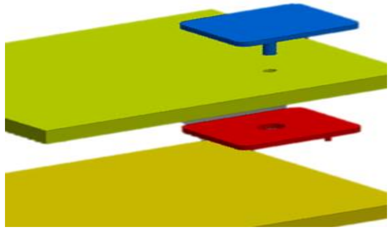
Two modules are put side by side to build a 600 mm x 600 mm detector

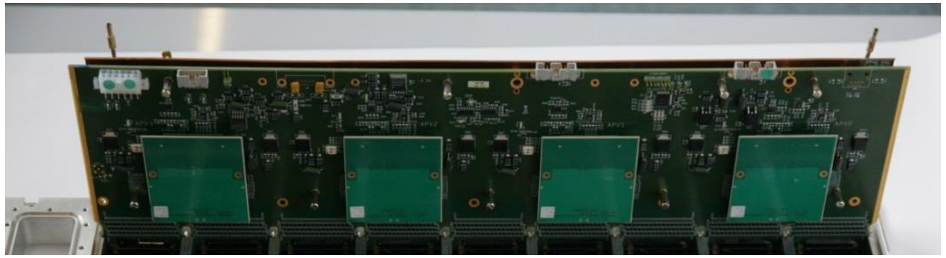






Signal read out via capacitive coupling pad readout and APV25 F/E boards



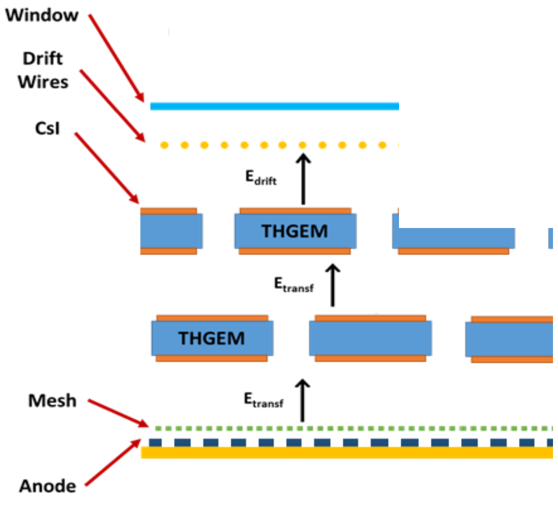


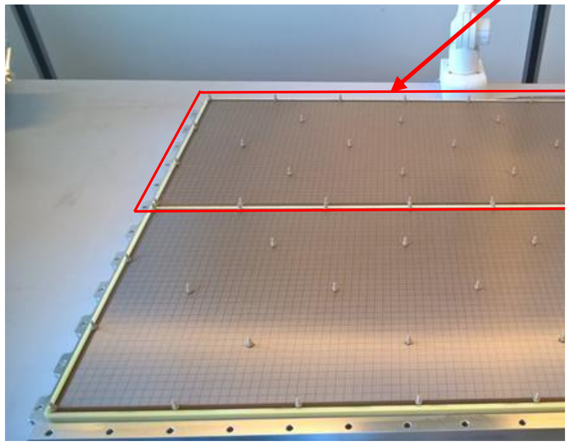
Multi-Pad Anode 8mm X 8mm pad size

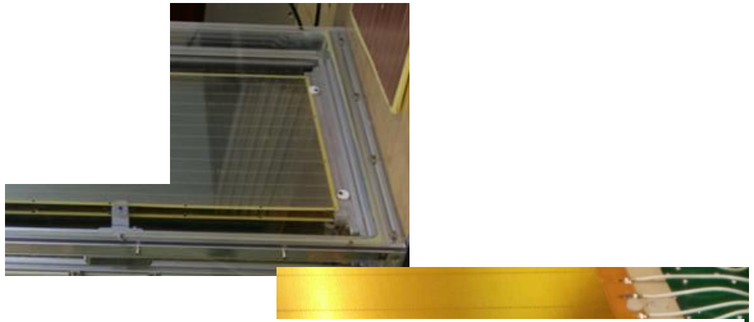
The Hybrid detector concept and the building blocks: the THGEM the Bulk MicroMegas and the FE

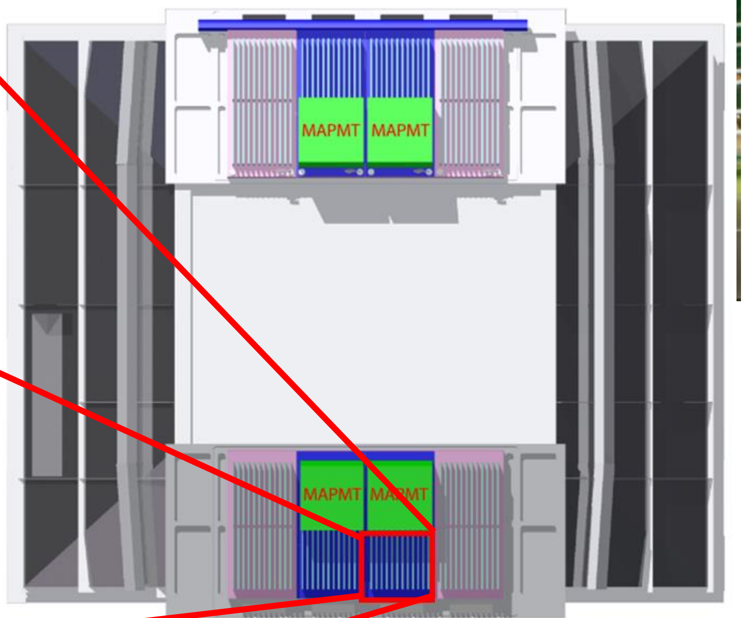
Two modules are put side by side to build a 600 mm x 600 mm detector

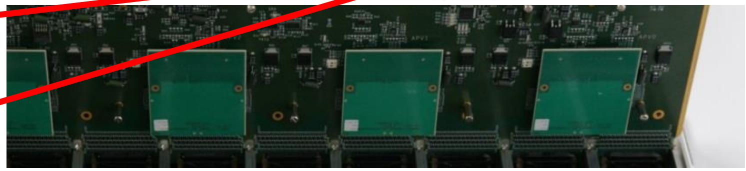
:hitecture has been



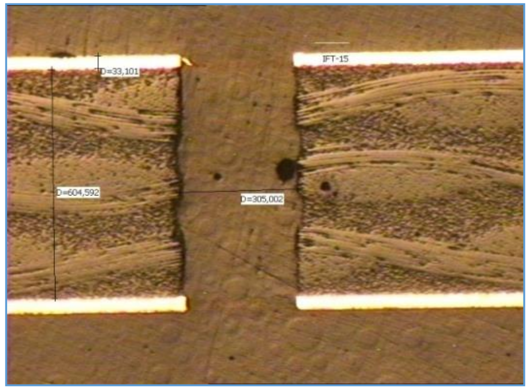


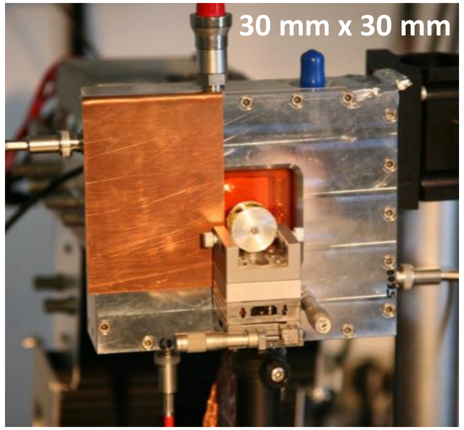


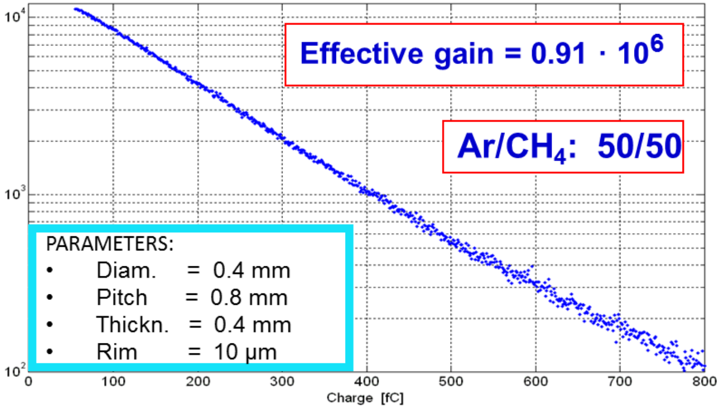




The Hybrid detector concept a result of 8 years of intense R&D activity: just a glimpse

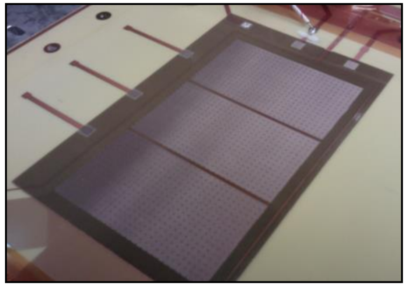


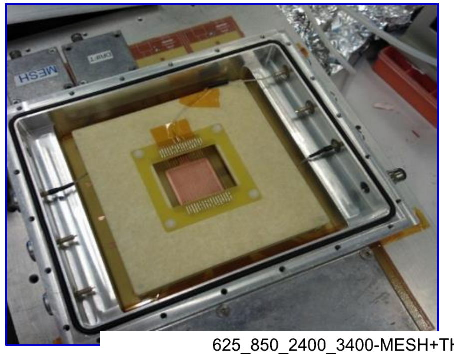


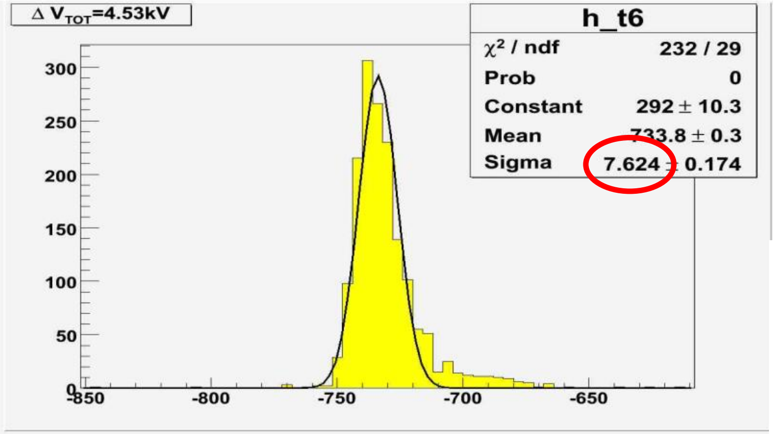


Preliminary IBF measured <5%

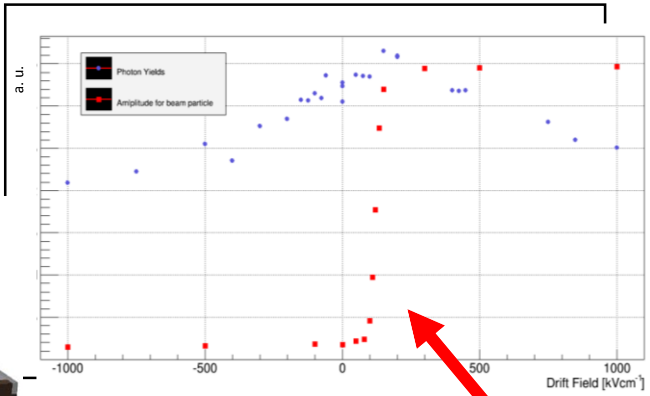
Now with optimized geometry below 2%



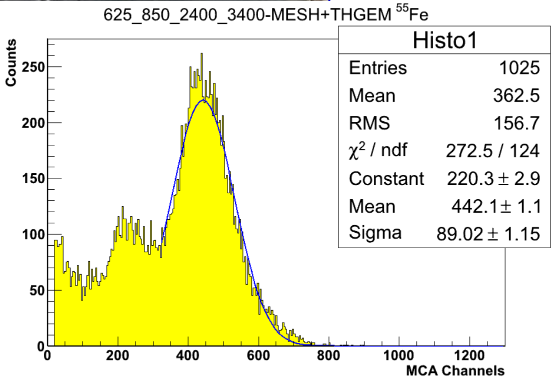


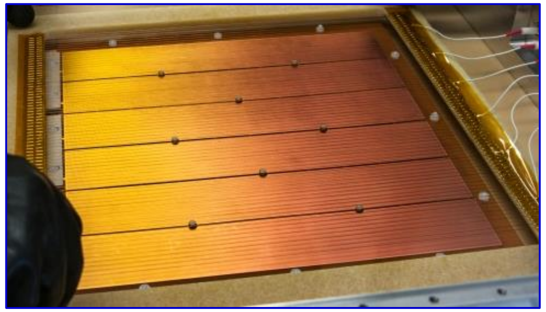


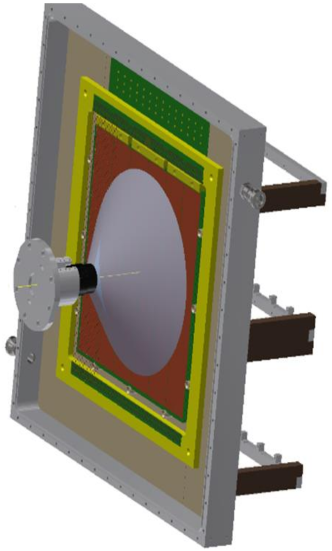
Photon yield & Charged Particles vs Drift Field

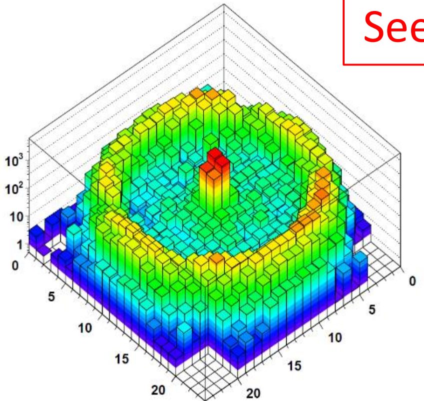


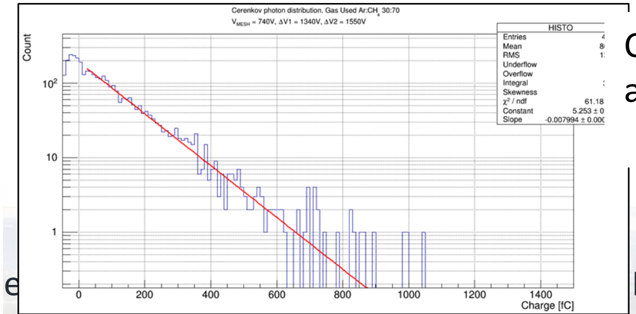
See G. Hamar Poster







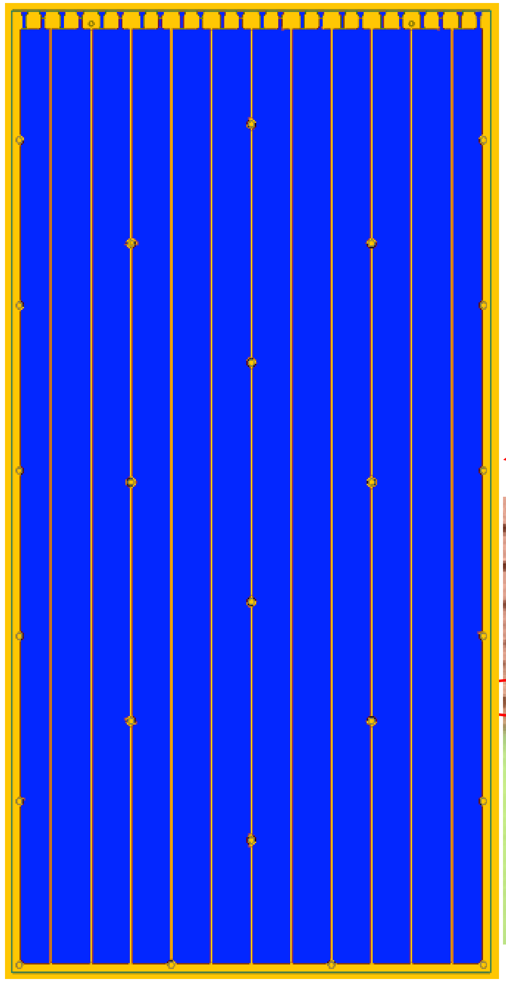




Cascaded multiplier allows for large gain ~ 10^5

The hybrid first “ingredient” : the THGEM

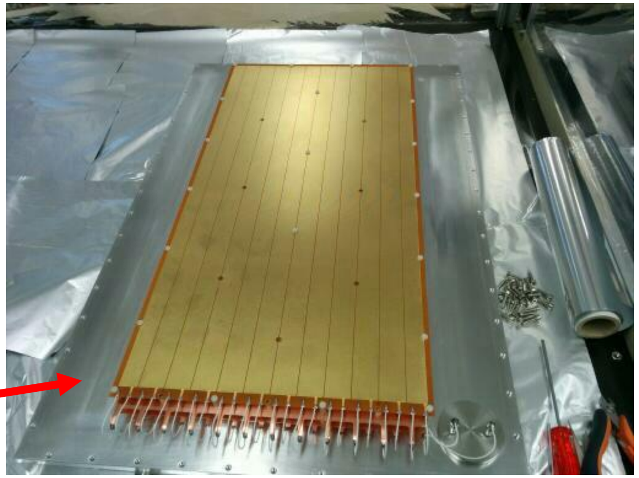
The THGEMs design: specifics

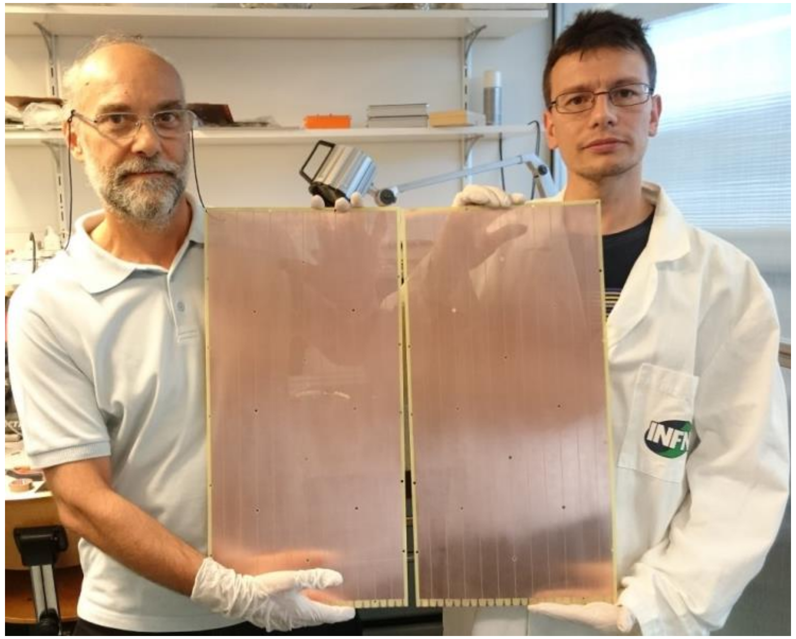


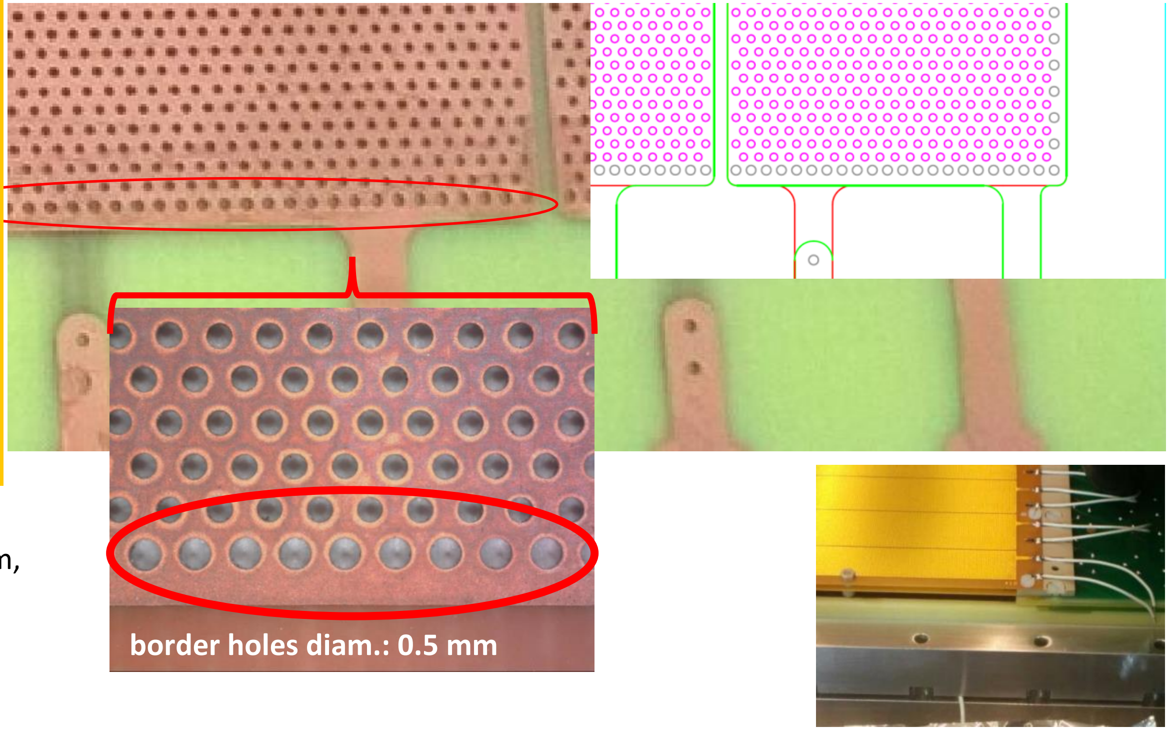
12 sectors on both top and bottom, 0.7 mm separation

Thickness: 0.4 mm, hole diameter: 0.4 mm, pitch: 0.8 mm

24 fixation points to guarantee THGEMs flatness

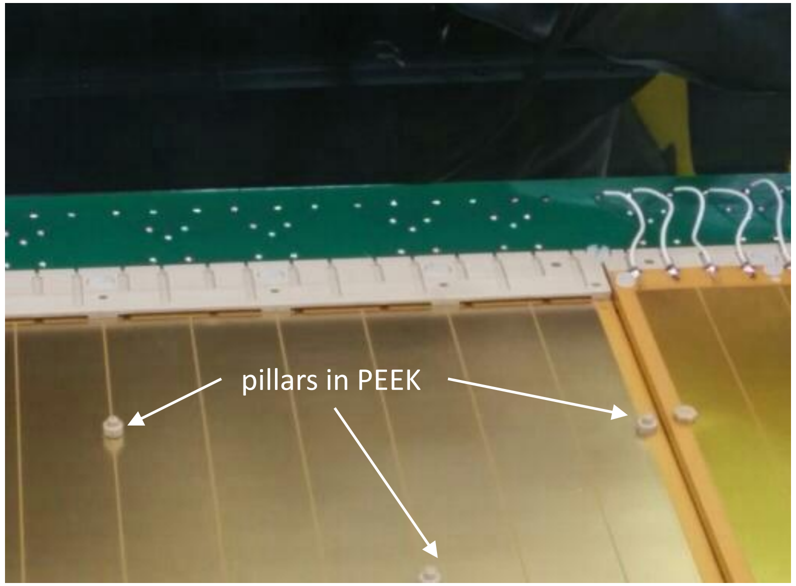






border holes diam.: 0.5 mm

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



THGEM quality assessment: material selection

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

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	$>10^{9}$

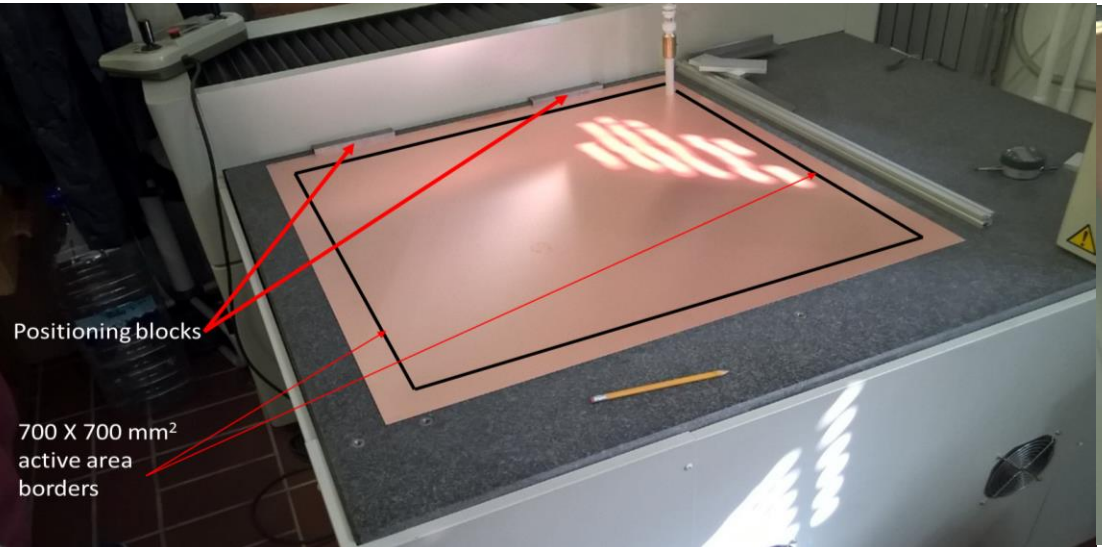
A uniform response of the detector requires stricter tolerances than those offered by producers

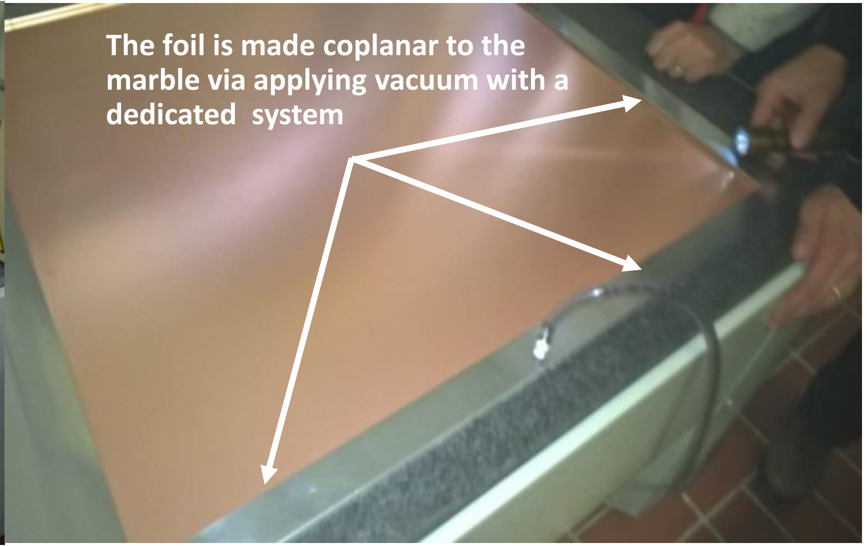
Tolerance inch (mm)
± 0.0030" (0.076)

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



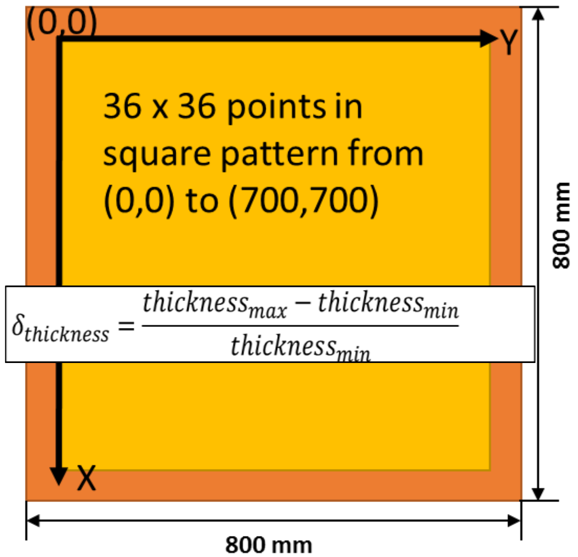
Selection campaign 50 foils of 1245 mm x 1092 mm raw PCB resized into 800 mm x 800 mm and their thickness measured





- 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

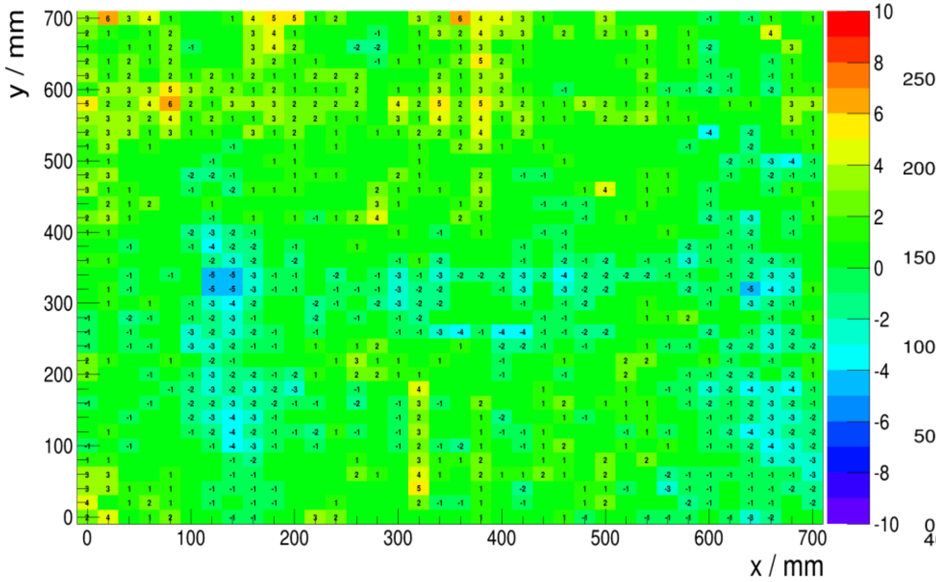


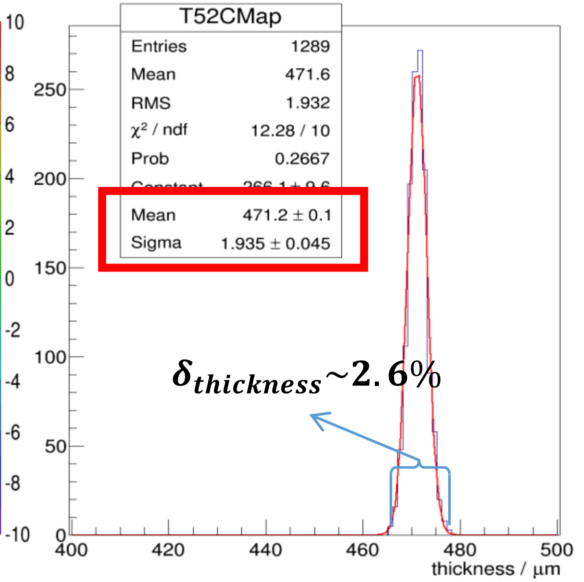
$$\delta_{thickness} = \frac{thickness_{max} - thickness_{min}}{thickness_{min}}$$

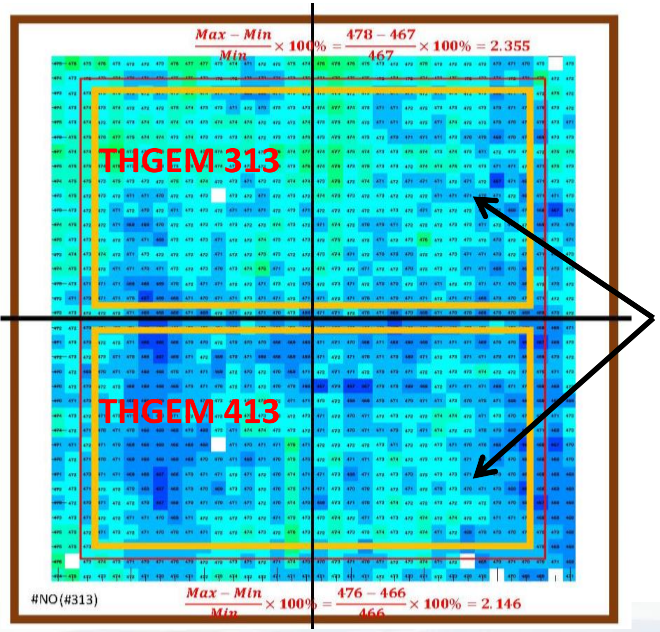
Each foil has been labelled in a unique way.

The δ thickness measurements are stored on a local database

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





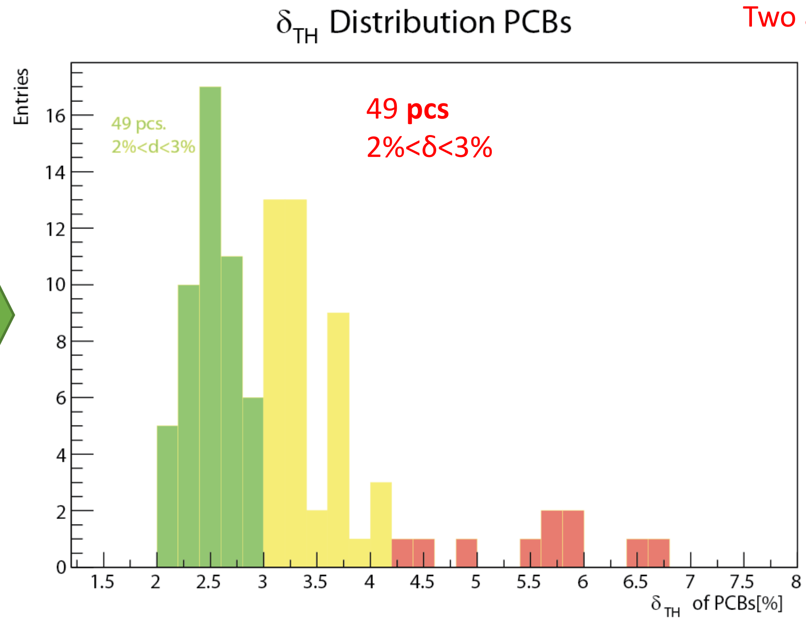


From each foil two THGEMS can be produced:

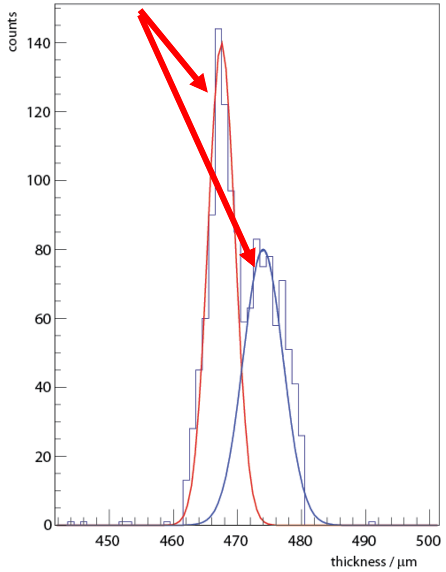
50 foils → 100 raw THGEM pcb

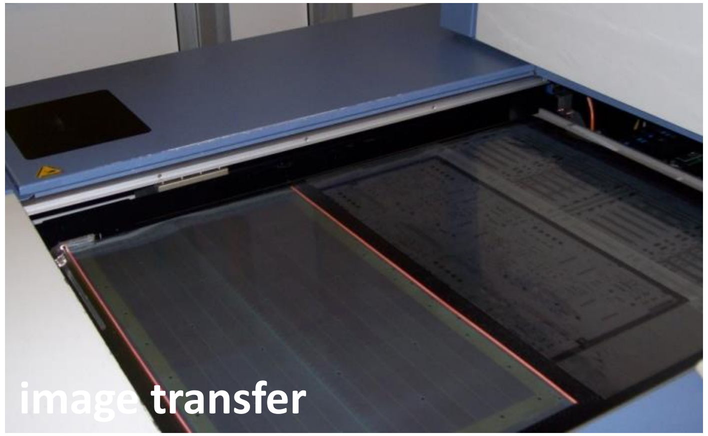
THGEM pcb size = 620 mm x 320 mm,

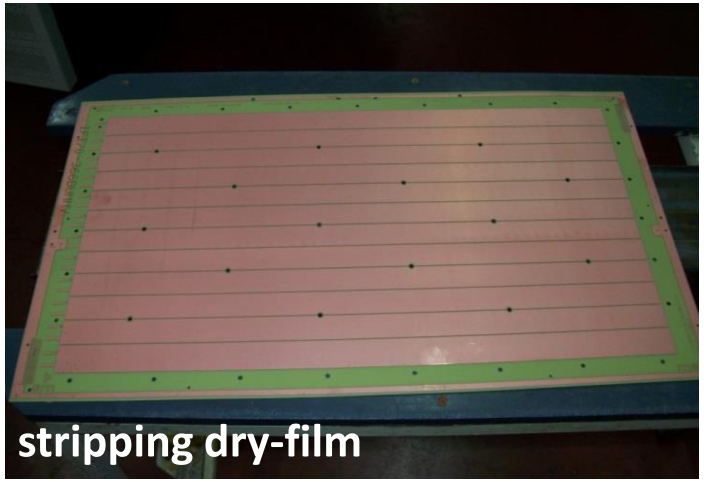
active area = 581 mm x 287 mm

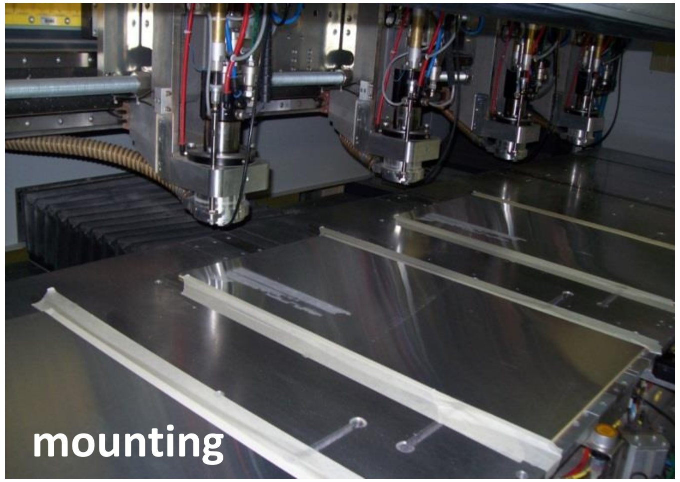


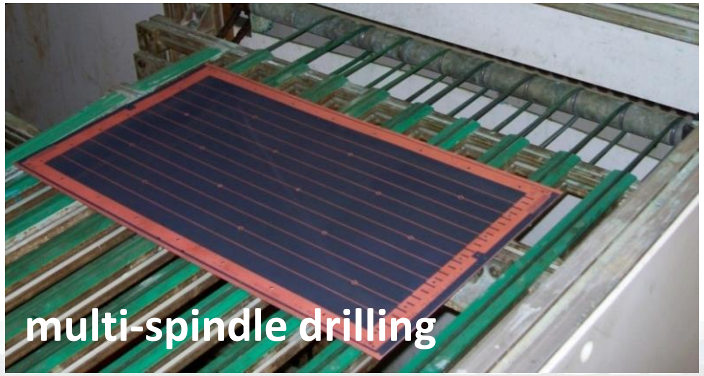
Two areas of different thickness





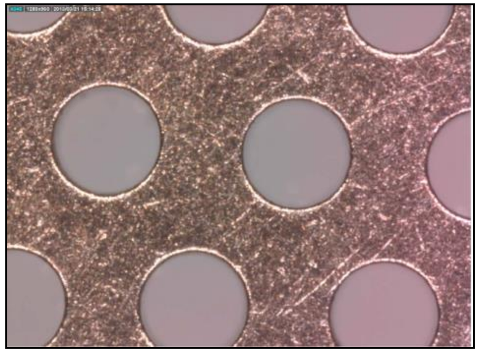


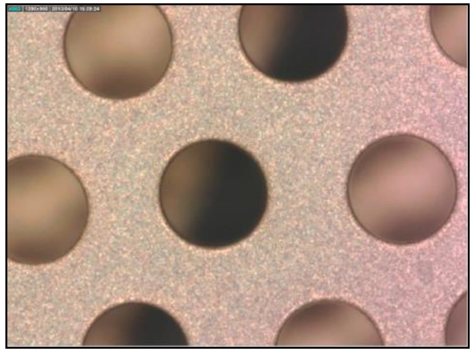


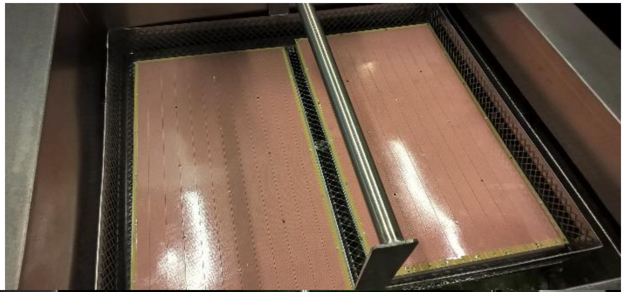


A post production specific surface treating and cleaning procedure developed in Trieste is applied:

- Surface Polishing.
- High pressure water cleaning.
- Ultrasonic Bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160 ºC



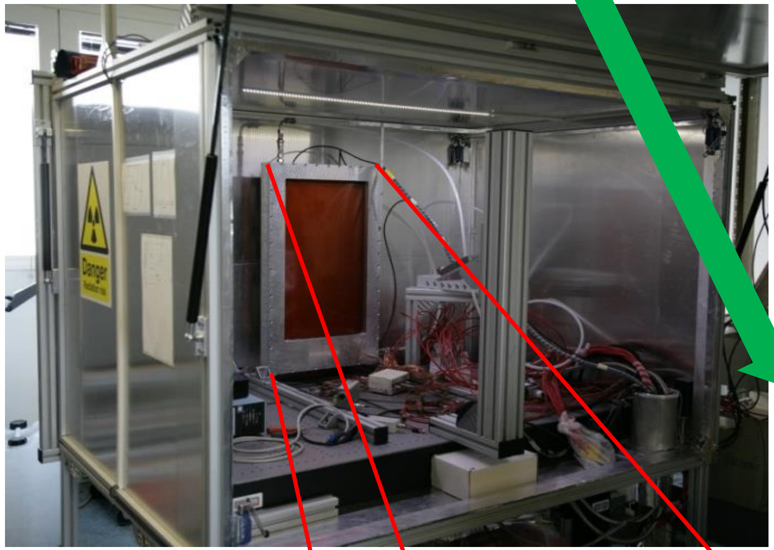




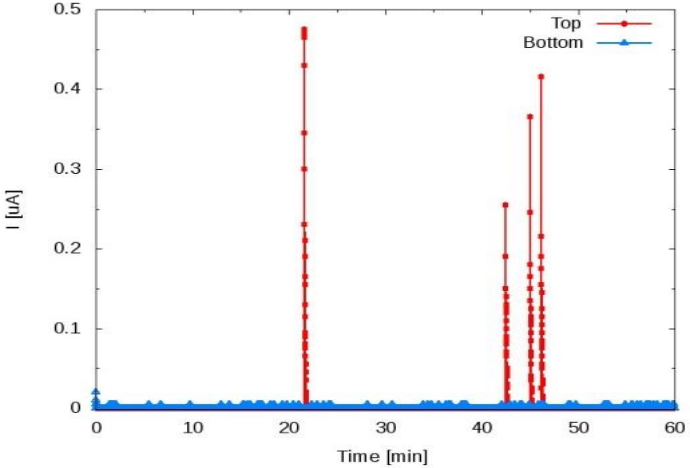
THGEM quality assessment: THGEM performance

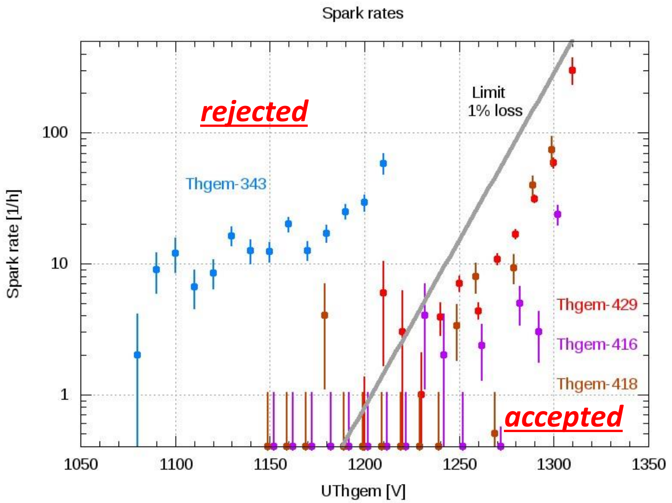
THGEM performance QA in two consecutive steps:

1. Paschen test: discharge counting vs voltage in controlled atmosphere (Ar/CO_2 70/30) w & w/o irradiation
2. Gain uniformity measurements



Current monitor recording, discharge counting at different voltage steps (10 Volts), each voltage step is kept for several hours





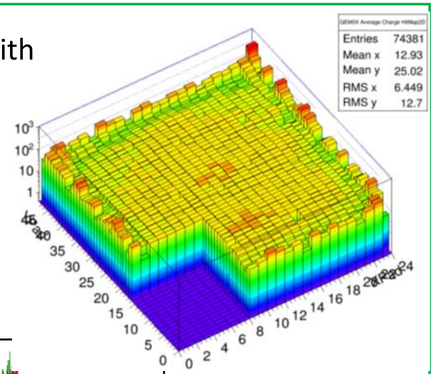
i.e. accepted piece #307 0.29 d/h @ 1150 ΔV for 14 h

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/CO_2 70/30)

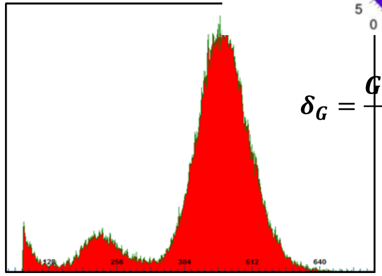
188	202	185	198	206	207
196	207	196	198	199	207
192		193	198	204	204
192		188	199	202	205
199	199	191	195	195	
199	196	199	205	195	199
192	190	194	197	195	194
198	190	195	209	195	199
198	199	195	208	197	201
198	199	195	199	200	199
190	186	185	199	190	199

Colour scale: 230, 220, 210, 200, 190, 180

APV 25 FE with RD51 SRS system

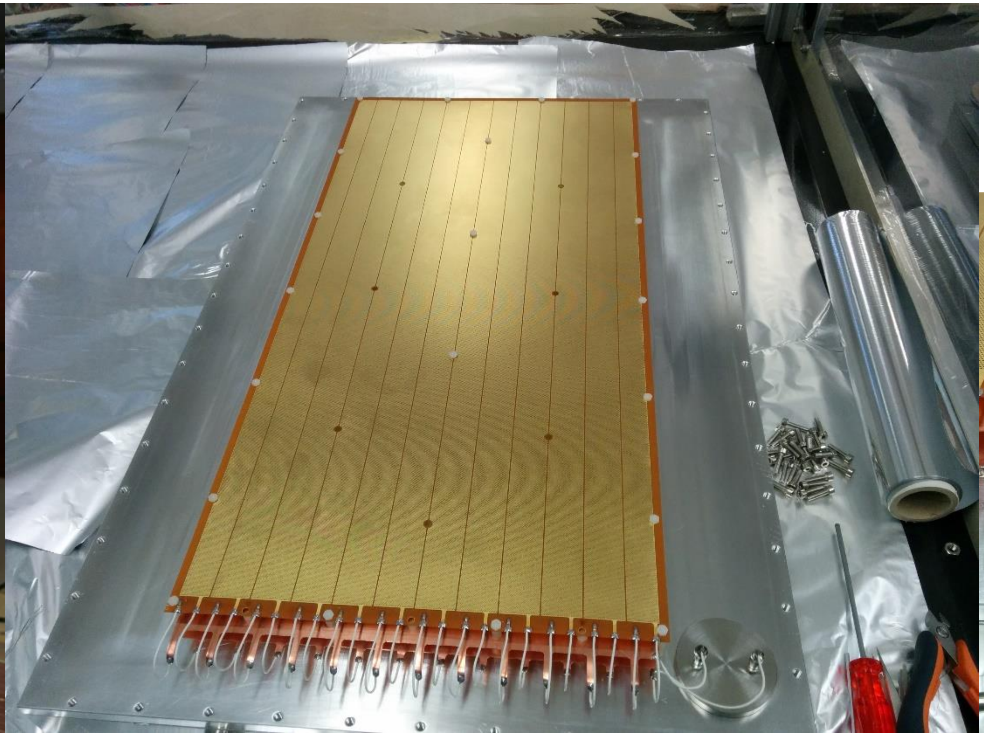


X rays spectrum CSA + MCA system

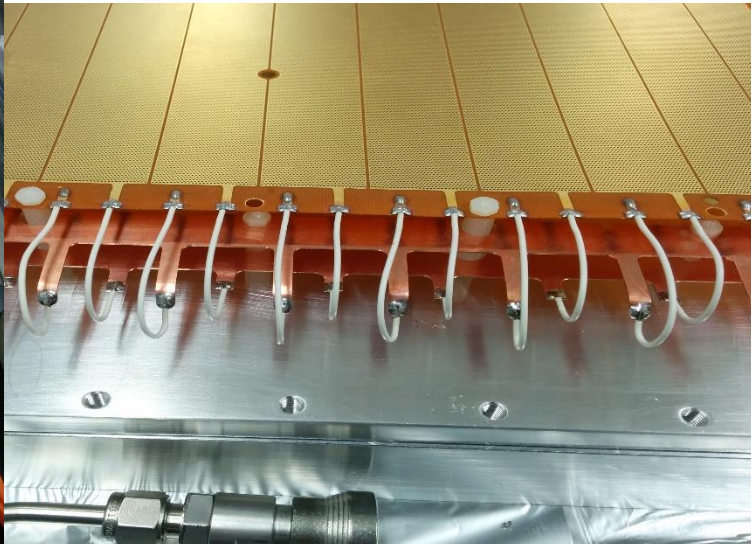


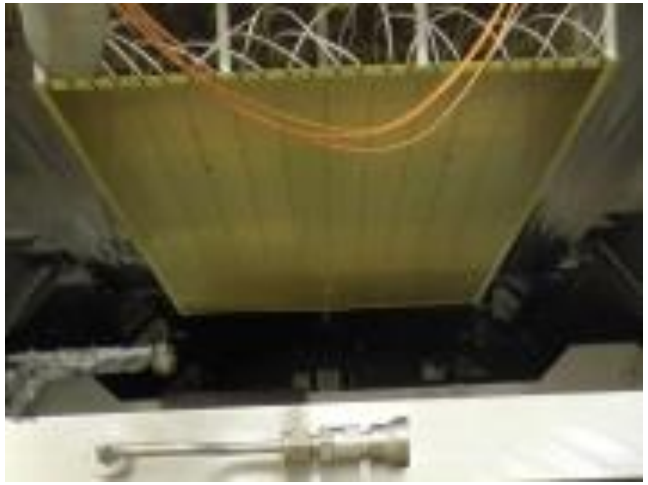
$$\delta_G = \frac{G_{max} - G_{min}}{G_{min}} < 15\ \%$$

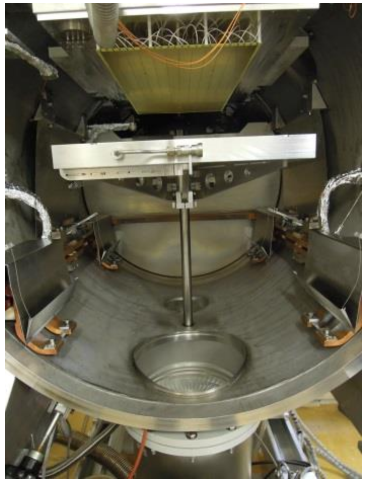
THGEM storage, transport, gold coating and preparation for CsI deposit



THGEM ready for coating





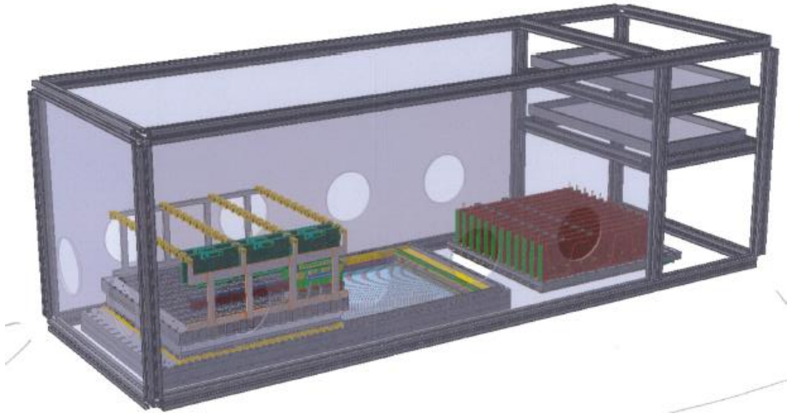


THGEM are coated at CERN and
QE measurements indicate
for our photocathodes

preliminary

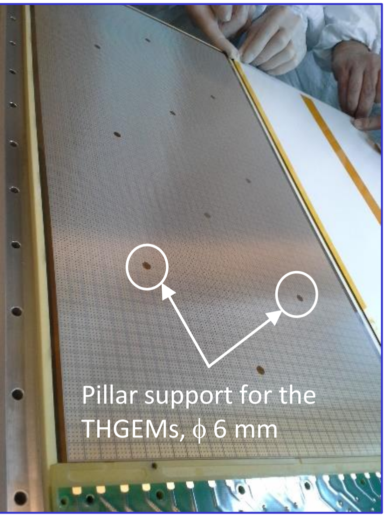
QE = 0.7 ÷ 1 x (max CsI QE)

with an increasing trend during the
production



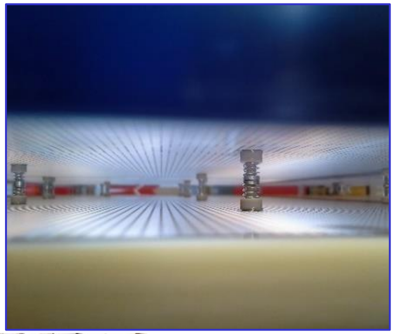
The hybrid second "ingredient" : the Bulk MicroMegas

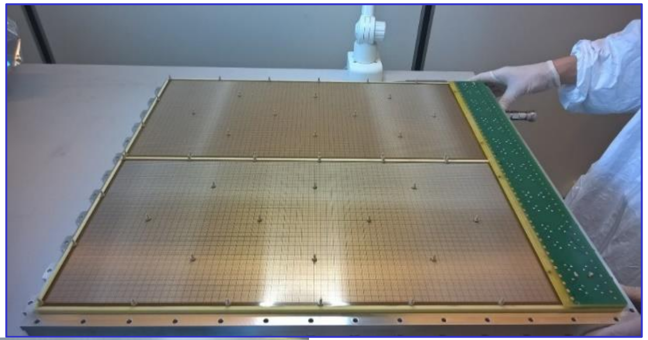
Bulk Micromegas: production and performance assessment



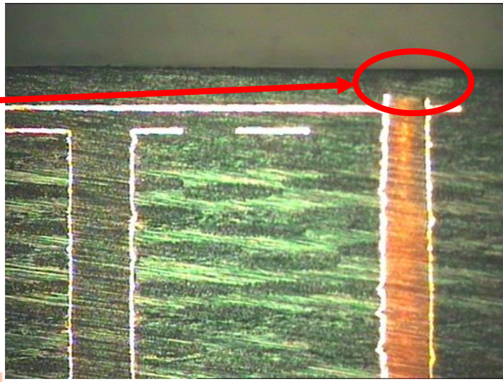
Bulk Micromegas (CERN) active area: 581 mm x 287 mm
- 128 μm mesh pad distance
- 18μm woven wires 45 μm pitch
- pad segmented (8x8 mm^2) 2380 pads/module

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).

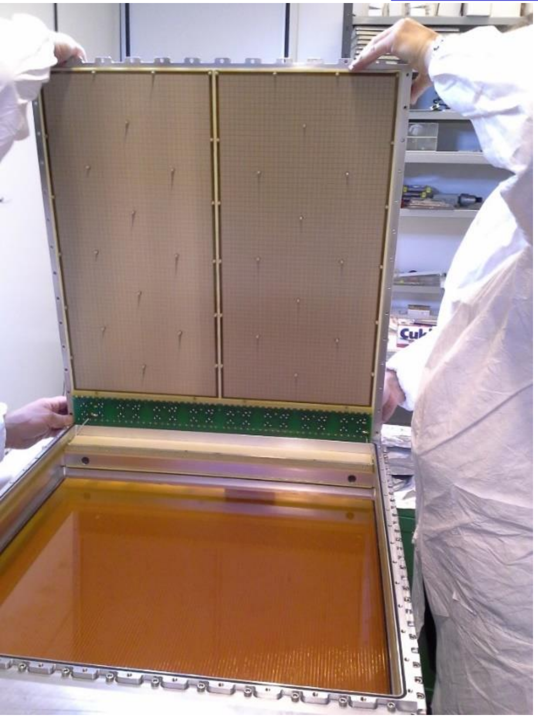


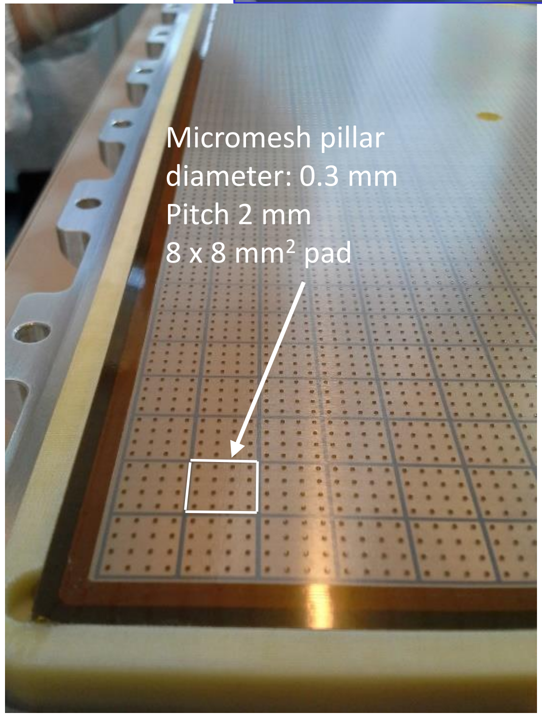


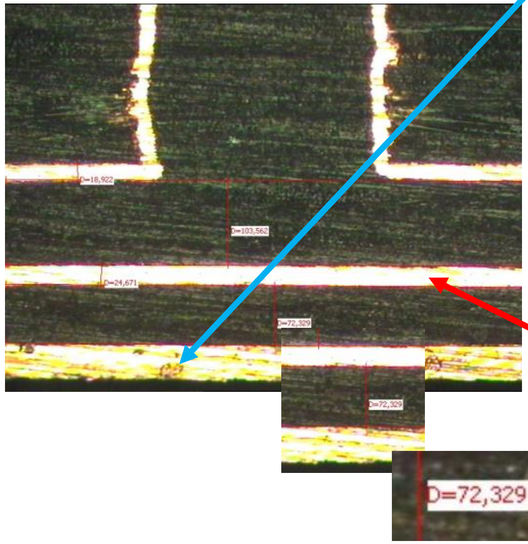
"Via closure" → leakage issue

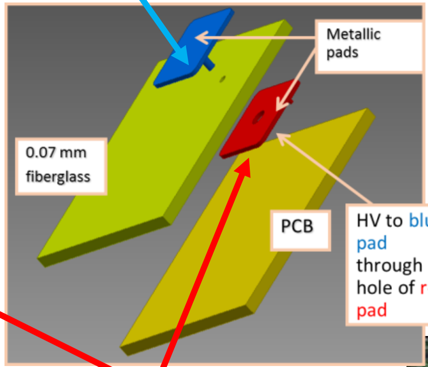


"surface anode" pad



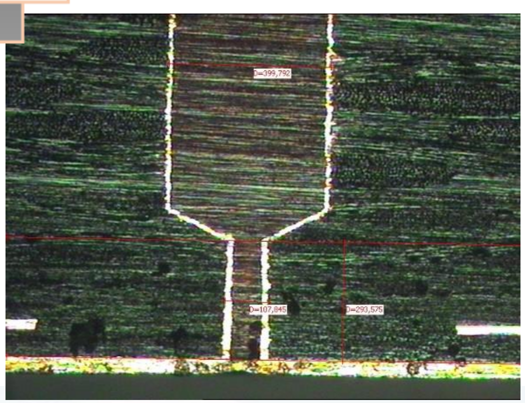






"Z drilling controlled via" → planarity issue

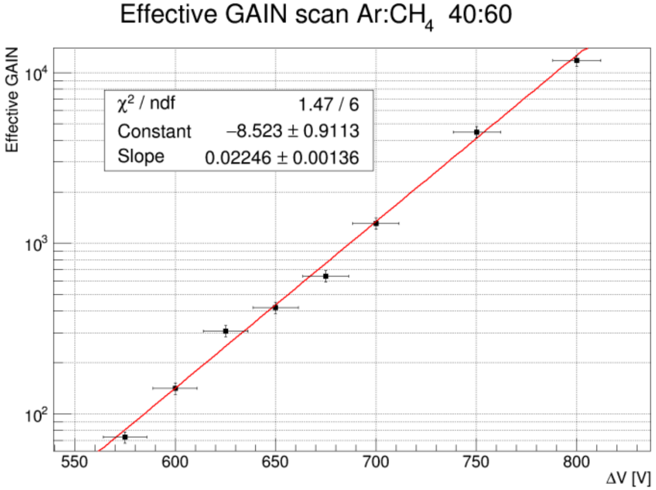
"buried pad"

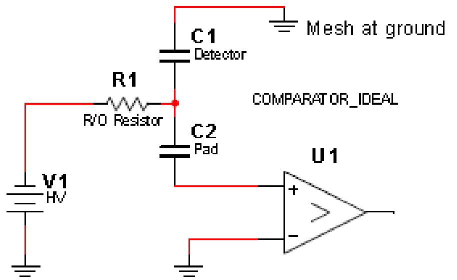


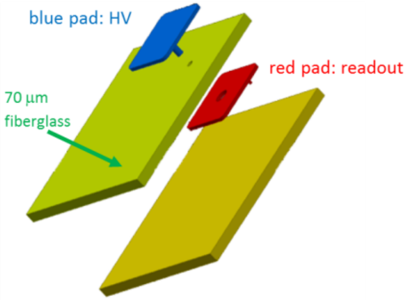
Test of the (4 x 2) 30 x 60 cm^2 MMs
[in total: 1.4 m^2, 19040 pads]:
- -2 pads with shorts
- -1 pad: no read-out connection

→ 3 bad pads out of 19040 before installation

Bulk Micromegas: production and performance assessment



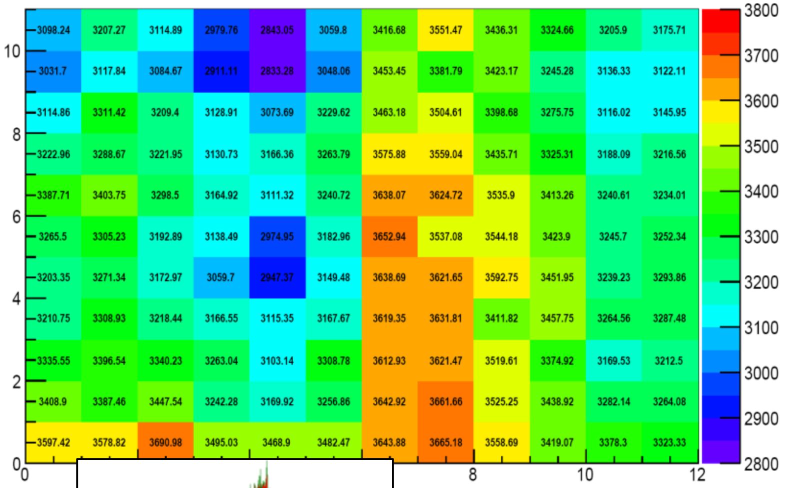


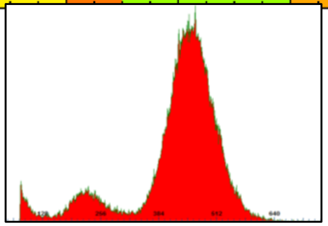


1 Single pad scheme:

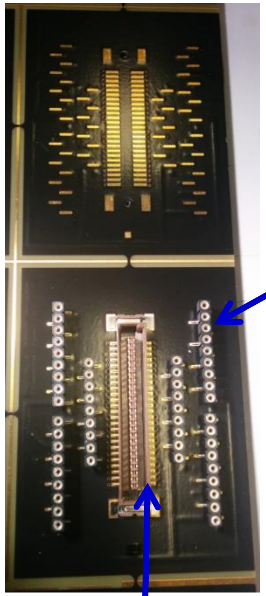
Blue pad at HV via individual pad resistor at the PCB rear surface

Red pad: signal induced by RC coupling

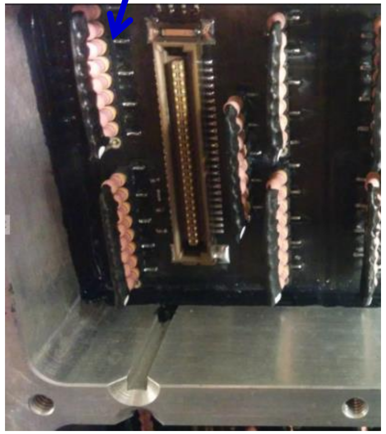




$$\delta_G = \frac{G_{max} - G_{min}}{G_{min}} < 5\ \%$$



Resistor arrays
Connector 8+1 pin



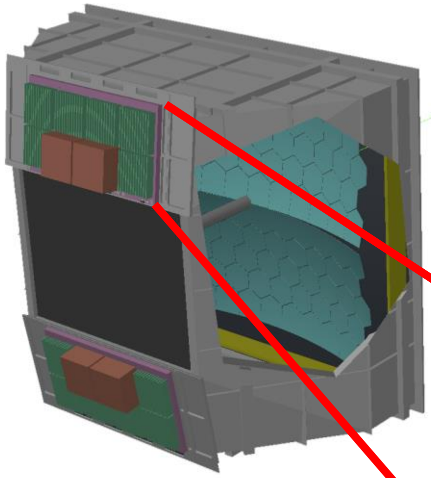
Connector for FE motherboard : 48 ch.

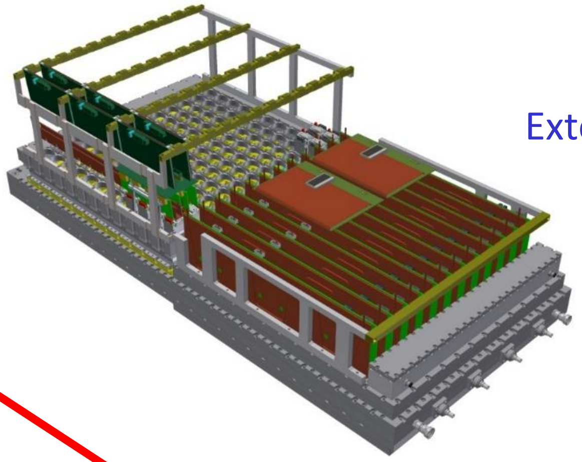
APV25 electronic F/E board

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

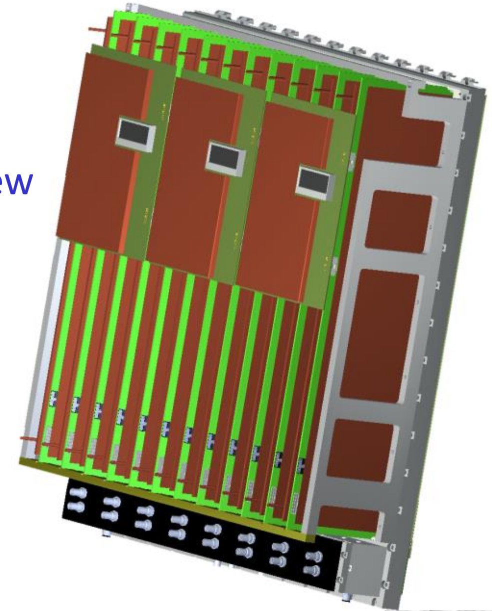
Assembly and installation in glimpse

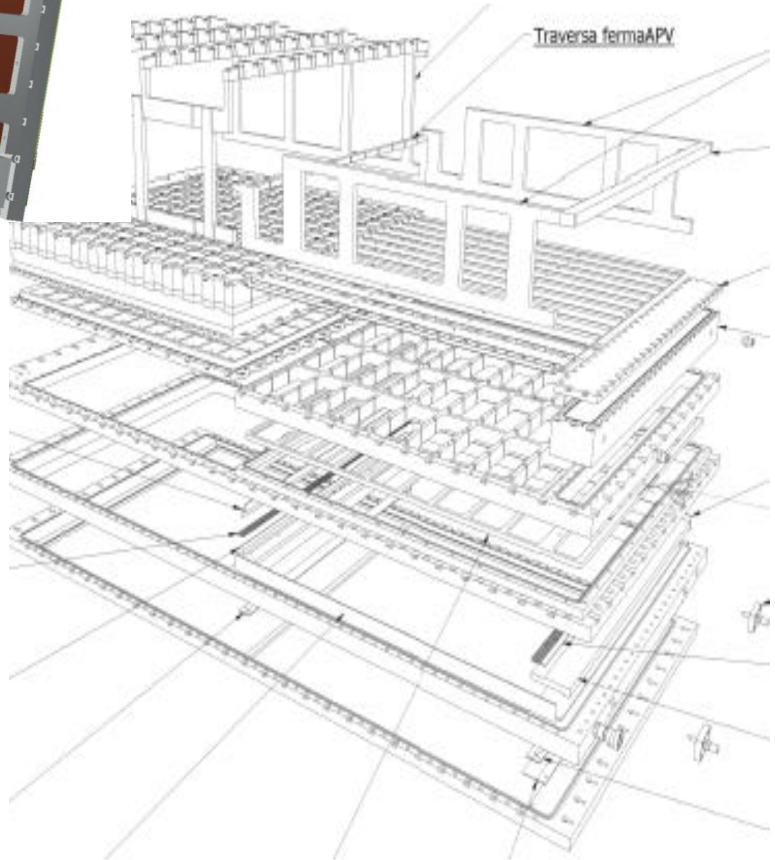
The RICH-1 upgrade, the challenge of the integration in the existing mechanical environment

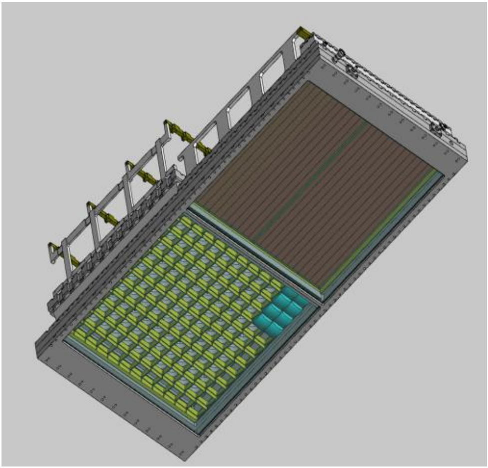


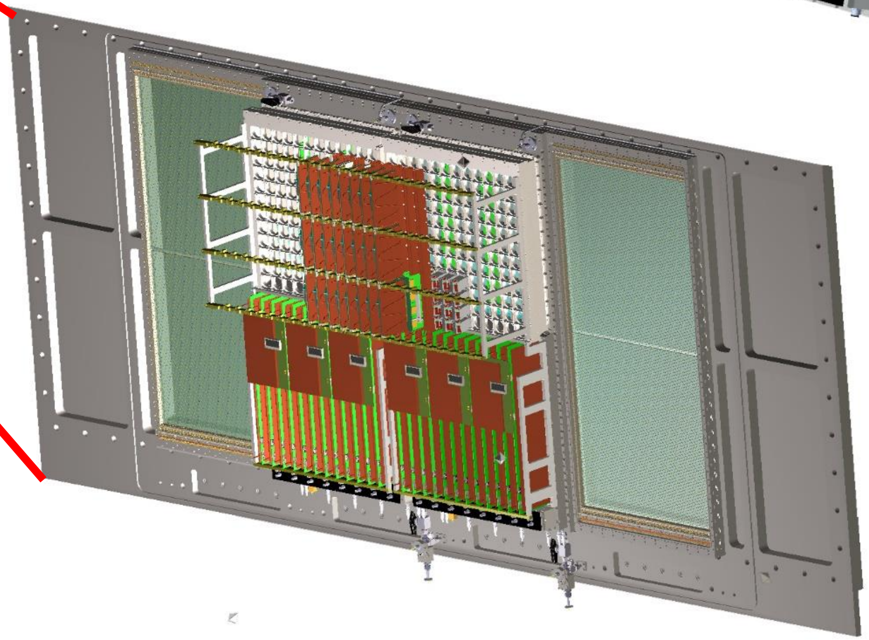


External view



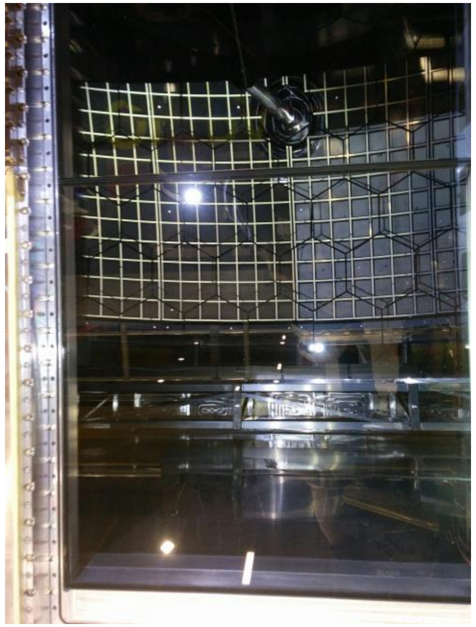




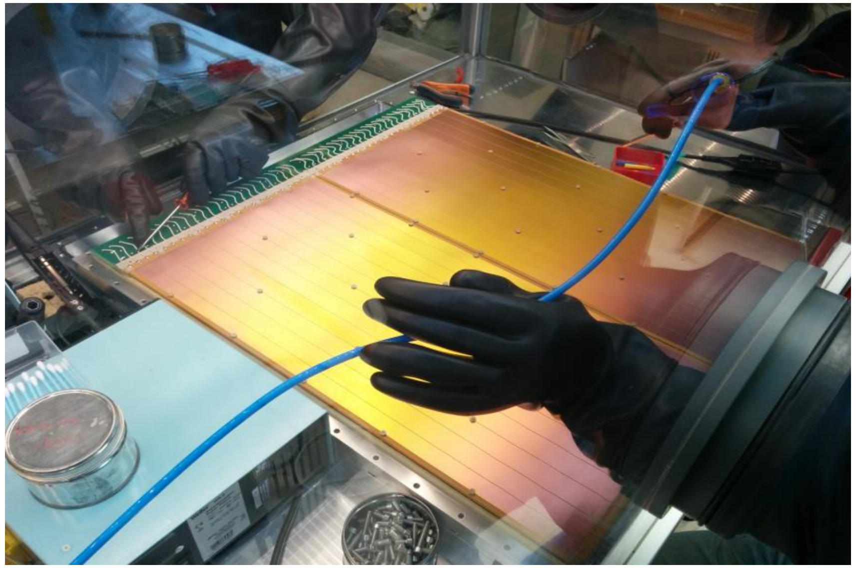


“Photon” view

Mounting the detectors on the COMPASS RICH-1





Preliminary results! …just one moment more

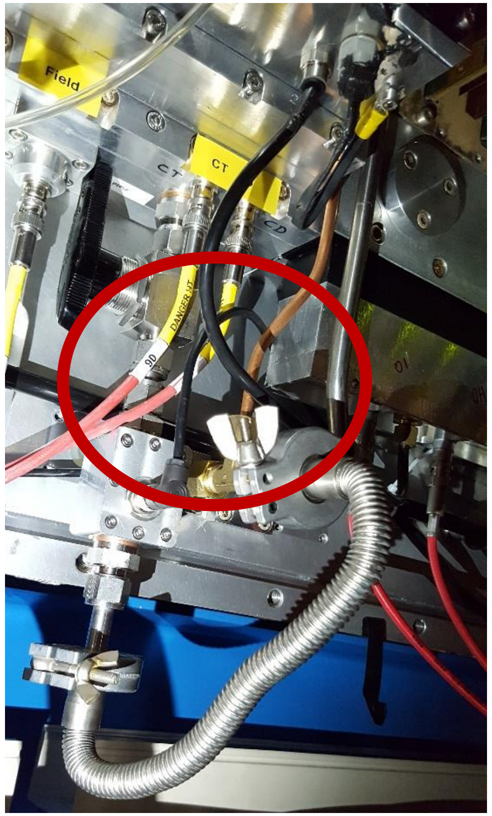
The Hybrid detector controls: the delicate issue of HV powering

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).

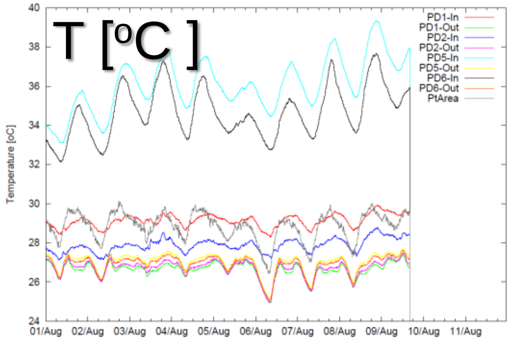
In multilayer structure a 1% of P/T variation corresponds to 40% total gain variation: THGEM 15% (x 2) and MM 12%

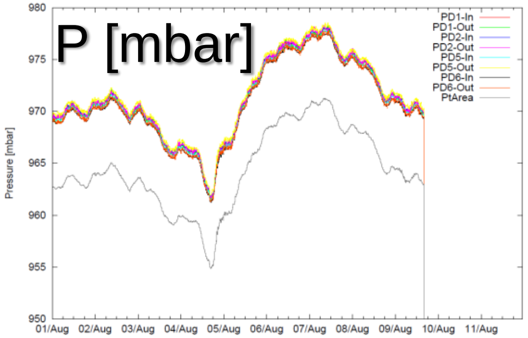
Need for P/T correction; residual variation ~10 %

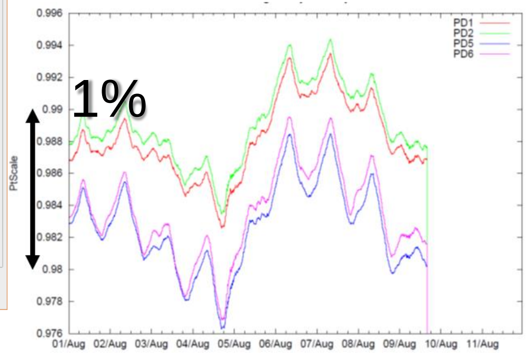


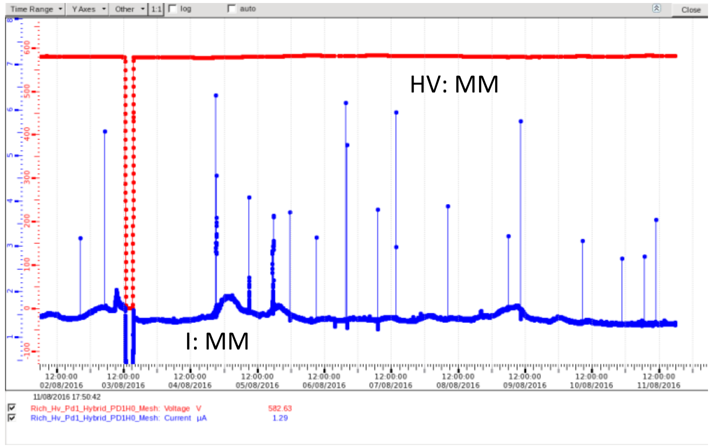
P, T sensors inserted in the gas lines at gas in/out

Name	Nom	OwnSc	SetSc	PTSc	Voltage	Electrode	VSet	VMon	IMon	NspR
EDrift	200	1.000	0.960	1.000	211.20	UDrift	3239.51	3239.39	0.000	0
UThgem1	1250	1.000	1.000	0.991	1238.93	UT1Top	3028.31	3027.85	0.000	0
ETrans1	1000	1.000	1.000	1.000	300.00	UT1Bot	1789.38	1789.17	0.007	0
UThgem2	1200	1.000	1.000	0.991	1189.38	UT2Top	1489.38	1489.33	0.001	0
ETrans2	1000	1.000	1.000	1.000	300.00	UT2Bot	300.00	300.03	0.003	0
UMesh	600	1.000	0.960	0.991	570.90	UMesh	570.90	570.97	1.298	0

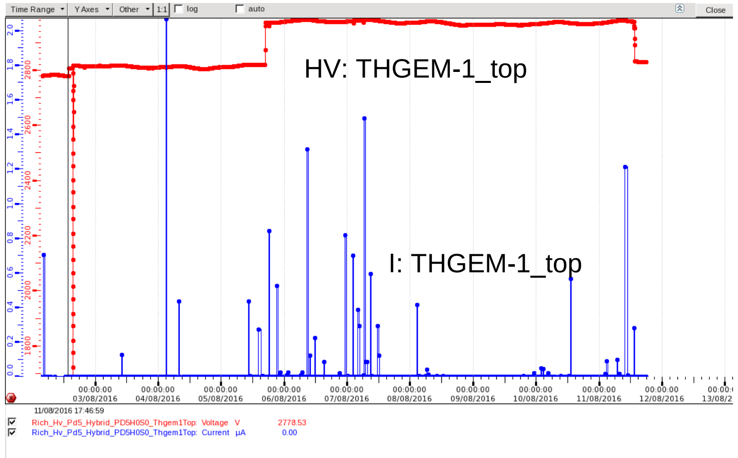








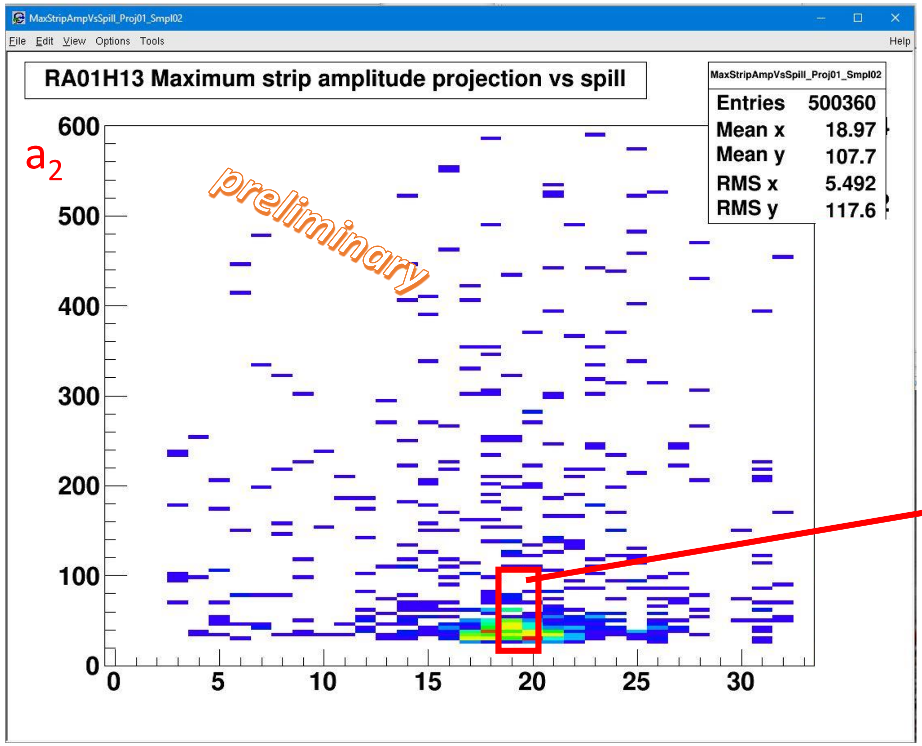
10 days

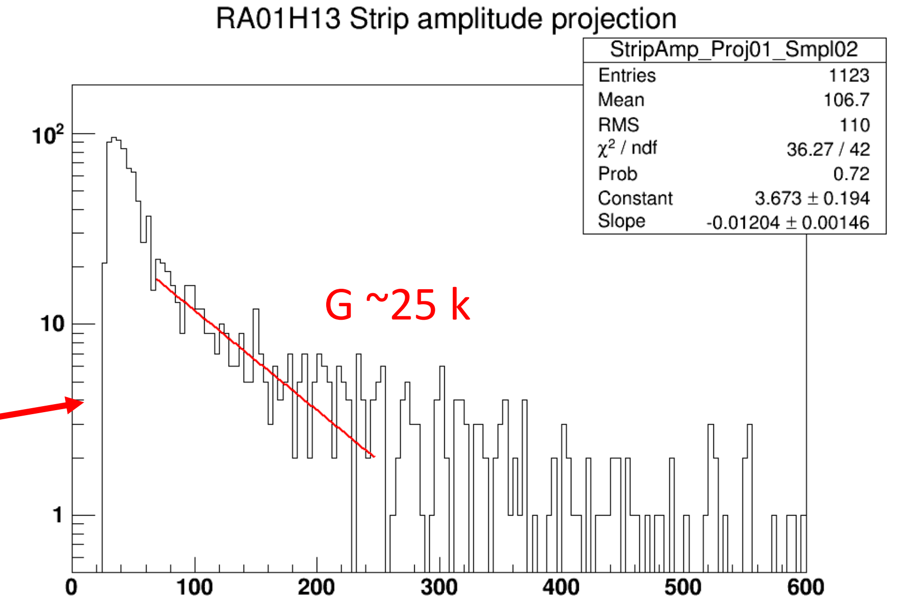


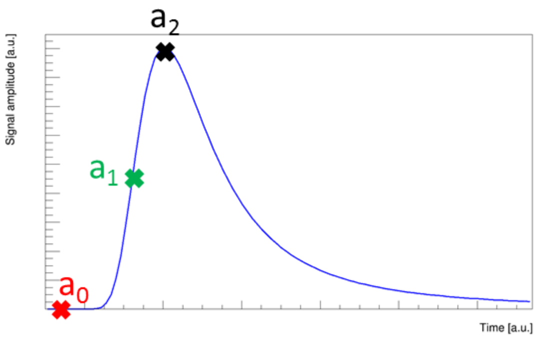
See Shuddha Dasgupta Poster

The Hybrid detector signals from one chamber!

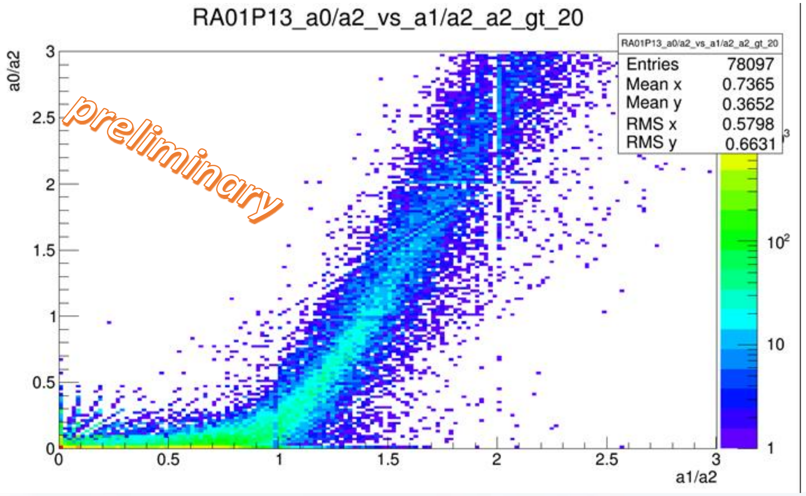
The detector commissioning is ongoing! Signal seen!





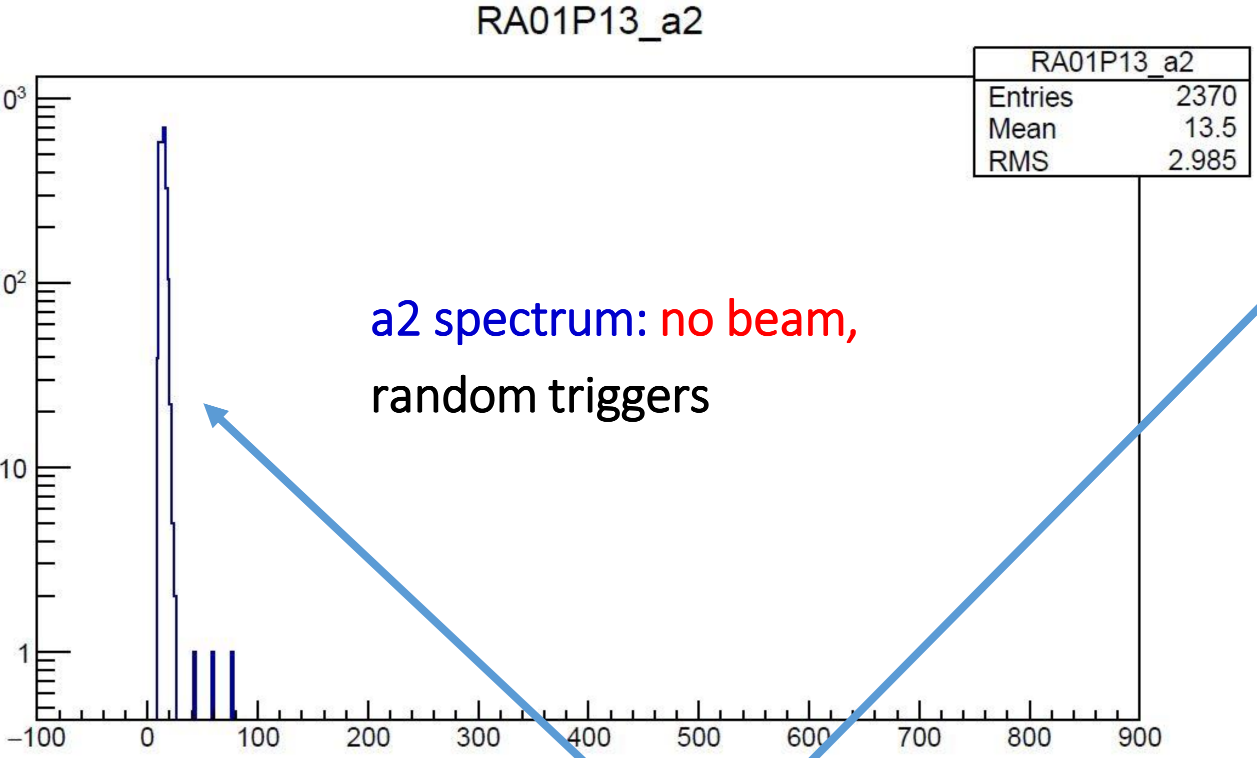


Apv25 sampling mode of the
pre amplified and shaped signal, a reminder

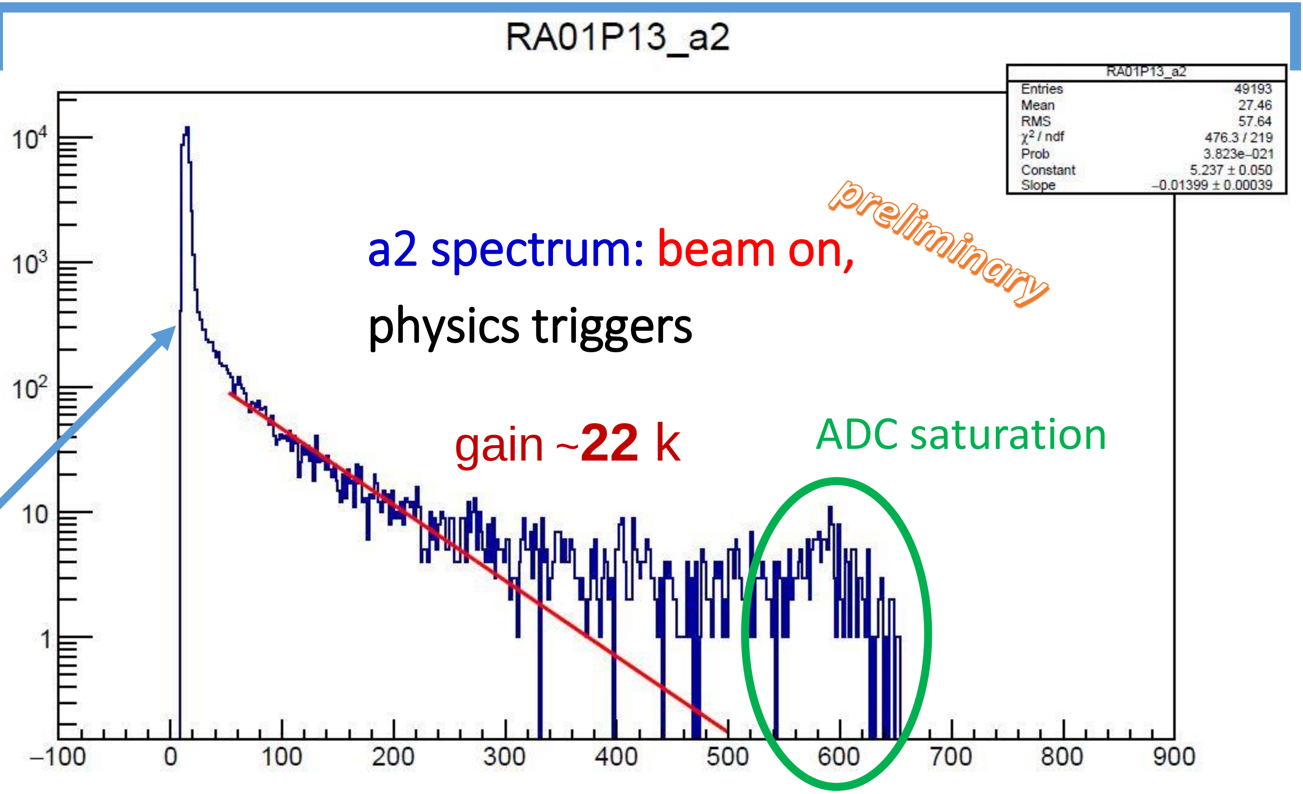


Photon signals ? Yes for sure!!!

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



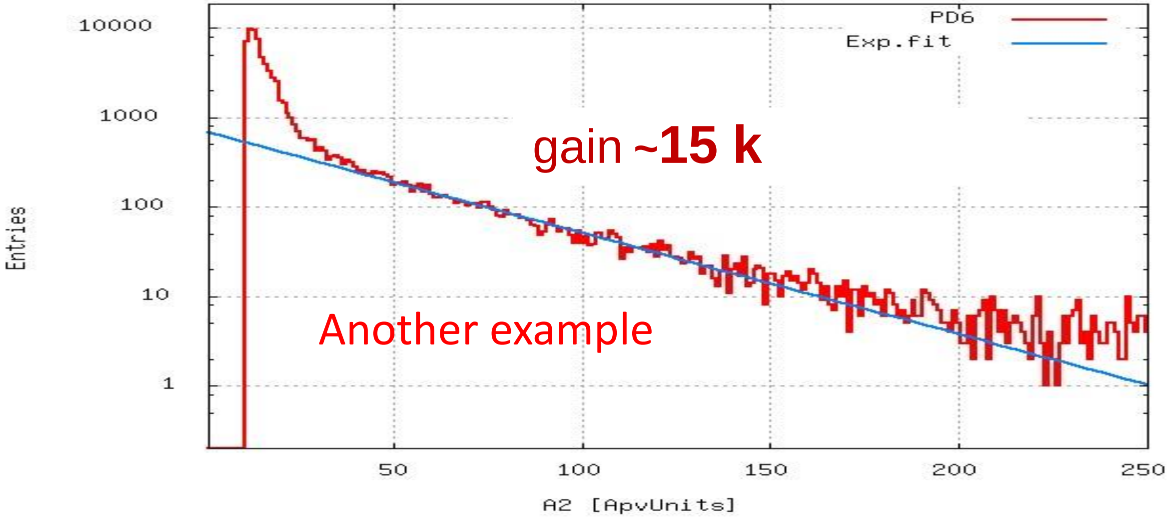
a2 spectrum: no beam,
random triggers



a2 spectrum: beam on,
physics triggers

gain ~**22** k

ADC saturation

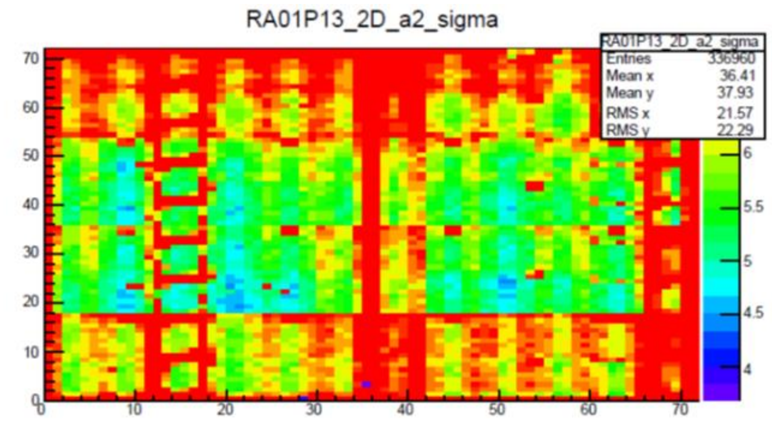


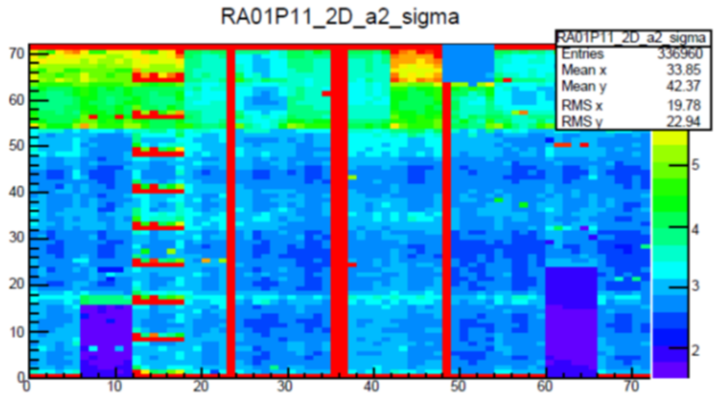
gain ~**15 k**

Another example

The peak from the electronic noise is the same

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

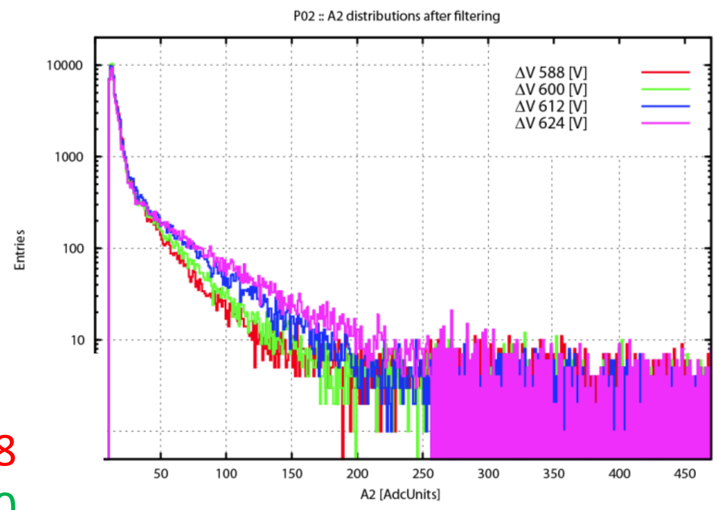




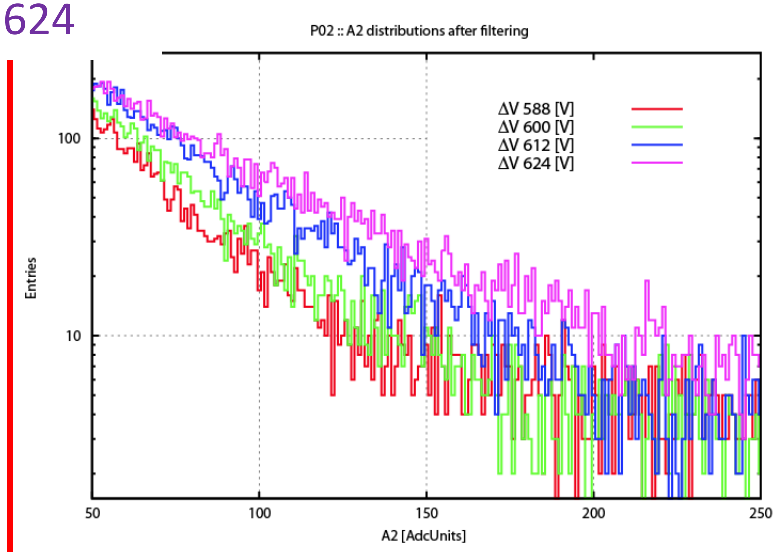
	active pads % (sigma noise </= 6)	<noise> in active pads	<noise> in e-
P02	78.07	3.21	964
P04	71.93	3.14	942
P11	98.99	2.51	754
P13	95.57	3.07	920

preliminary

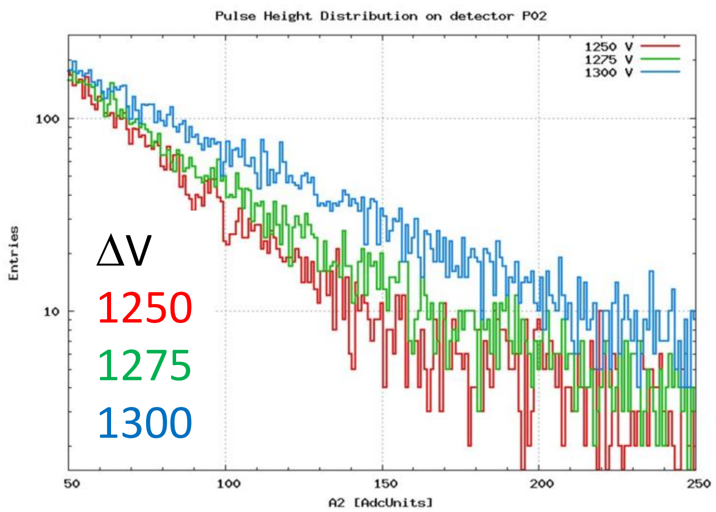
ΔV
588
600
612
624



MM scan

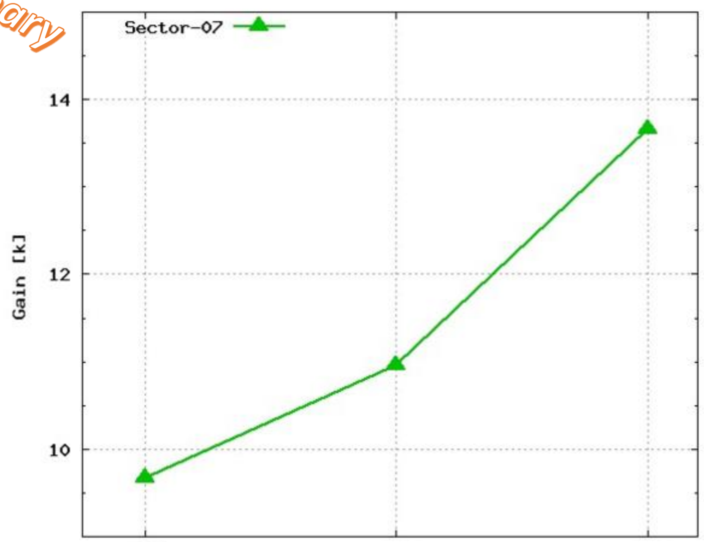


preliminary



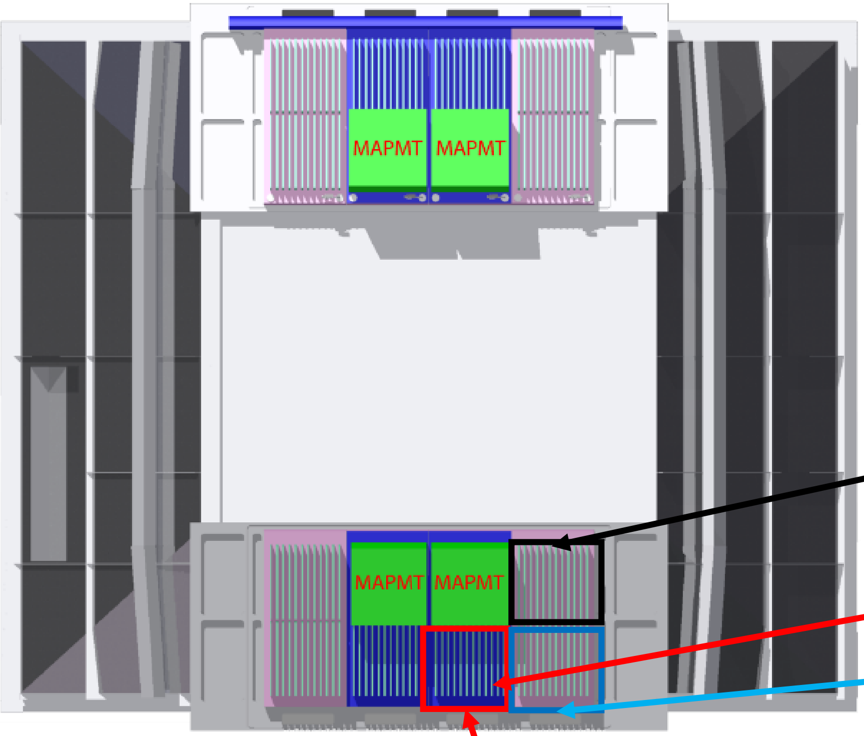
ΔV
1250
1275
1300

THGEM scan

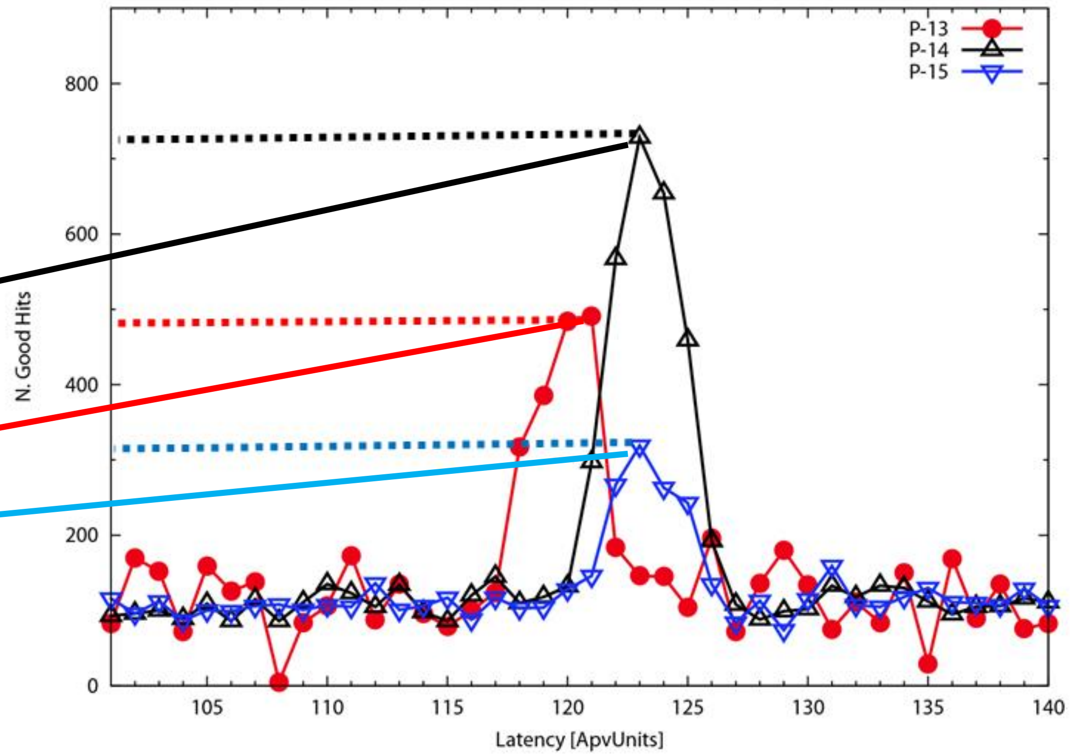


1250 1275 1300 ΔV

A very (very) preliminary estimate of the number of photons



Comparing the number of detected photons in the present status:



Active surface of the detector (HV) 50%

from the same data, the number of “signal hits” on Hybrids is similar or larger than on MWPCs

Conclusion and perspectives

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!