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

Fulvio Tessarotto (I.N.F.N. – Trieste)

on behalf of the COMPASS RICH Group

The COMPASS RICH-1 PD upgrade R&D

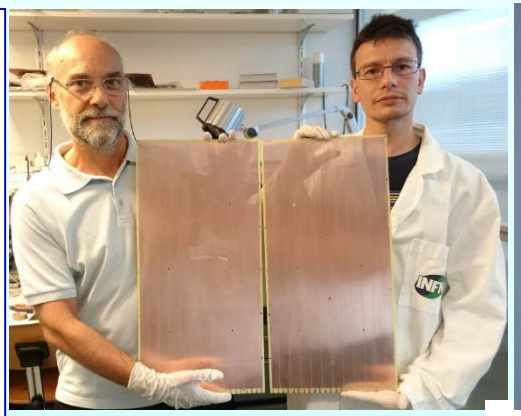
The Hybrid THGEM + MM detector

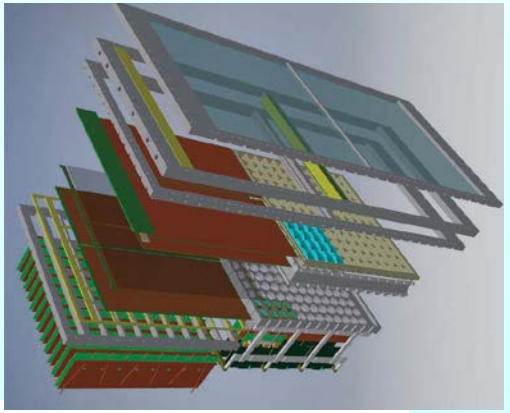
The assembly and installation in 2016

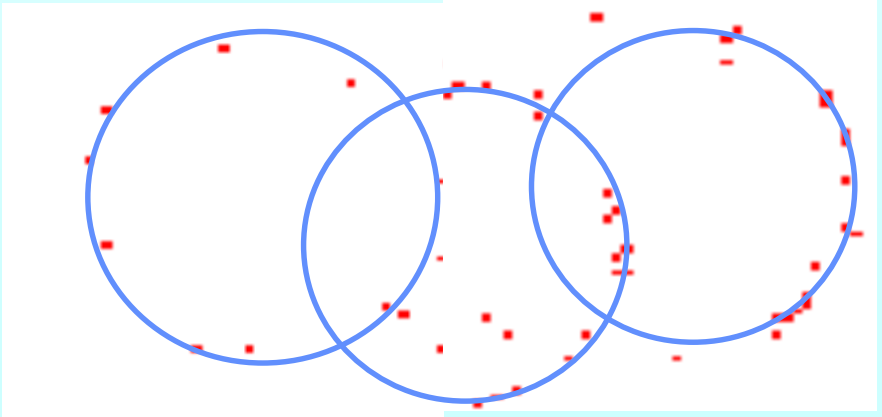
Tuning and commissioning

Promising preliminary results

Conclusions

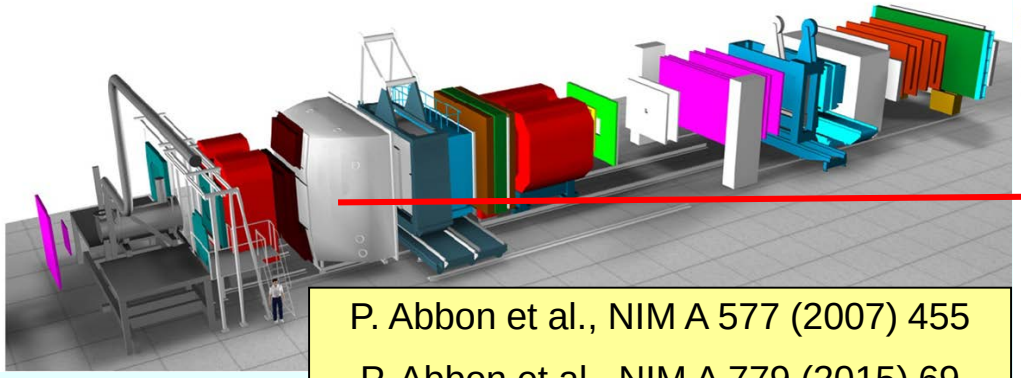






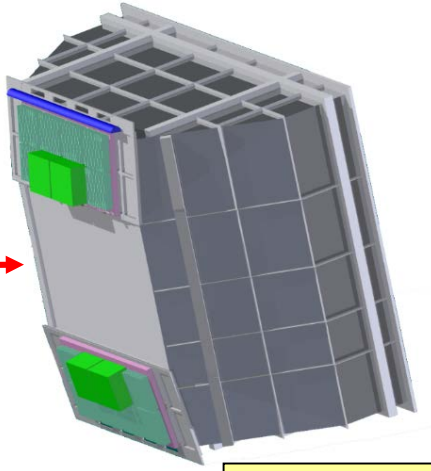
COMPASS RICH-1 upgrade

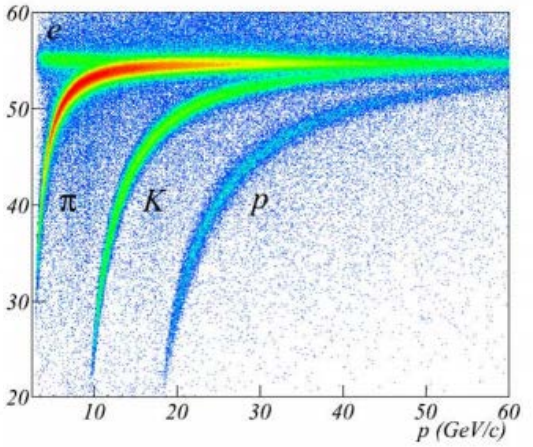
COMPASS Spectrometer



P. Abbon et al., NIM A 577 (2007) 455

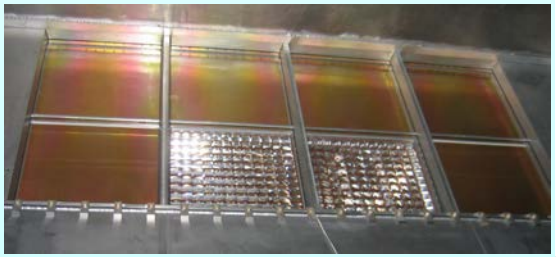
P. Abbon et al., NIM A 779 (2015) 69

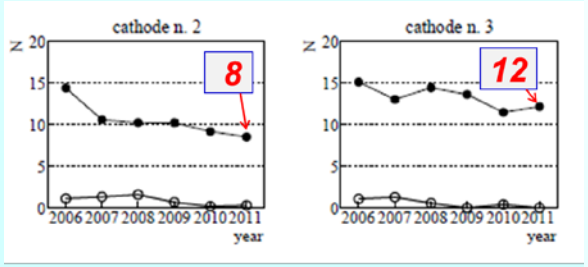


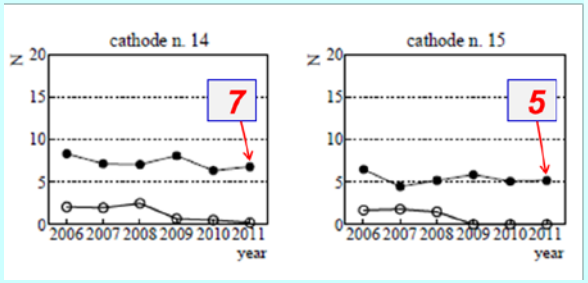


F. Tessarotto et al., JINST 9 (2014) C09011

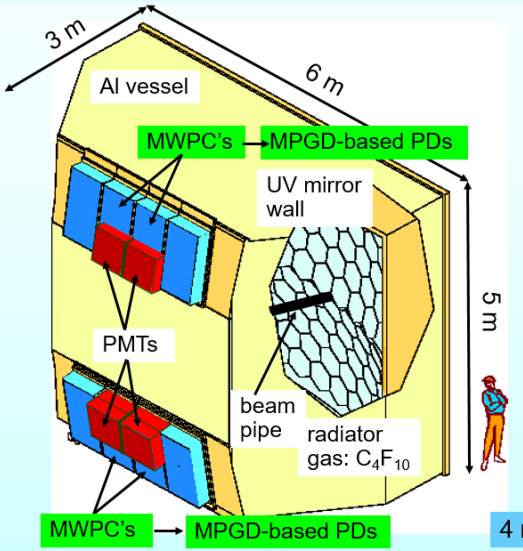
hadron PID from 3 to 60 GeV/c; acceptance: H: 500 mrad V: 400 mrad;
trigger rates: up to ~100 KHz beam rates up to ~10^8 Hz; material: 2.4% Xo (beam region), 22% Xo (acceptance)
80 m^3 C_4F_{10}, 21 m^2 UV mirrors, 1.4 m^2 MAPMTs, 4 m^2 gaseous PDs

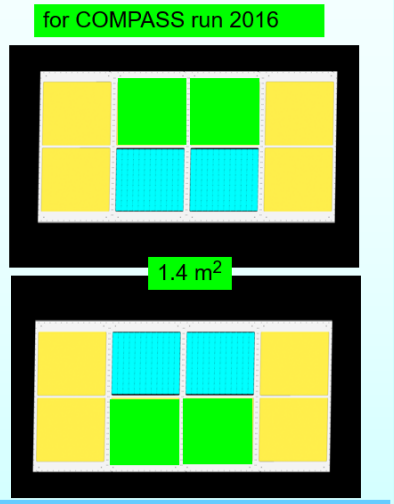






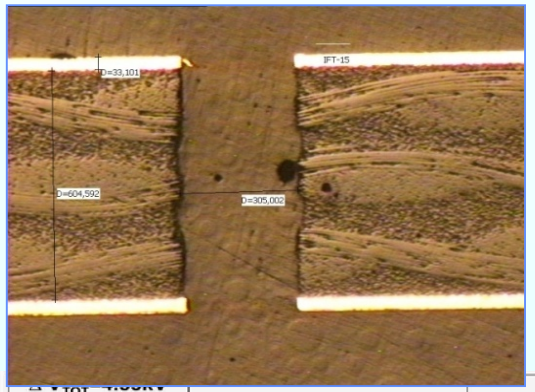
MWPCs+CsI: successful but with important performance limitations, in particular in the case of the 4 central chambers

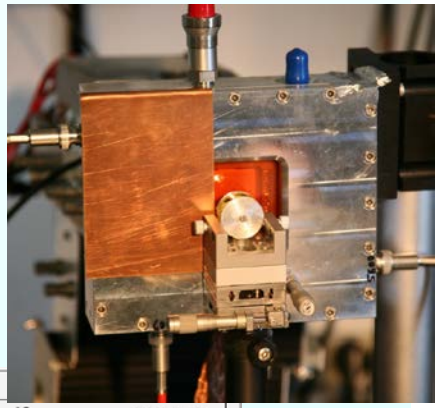


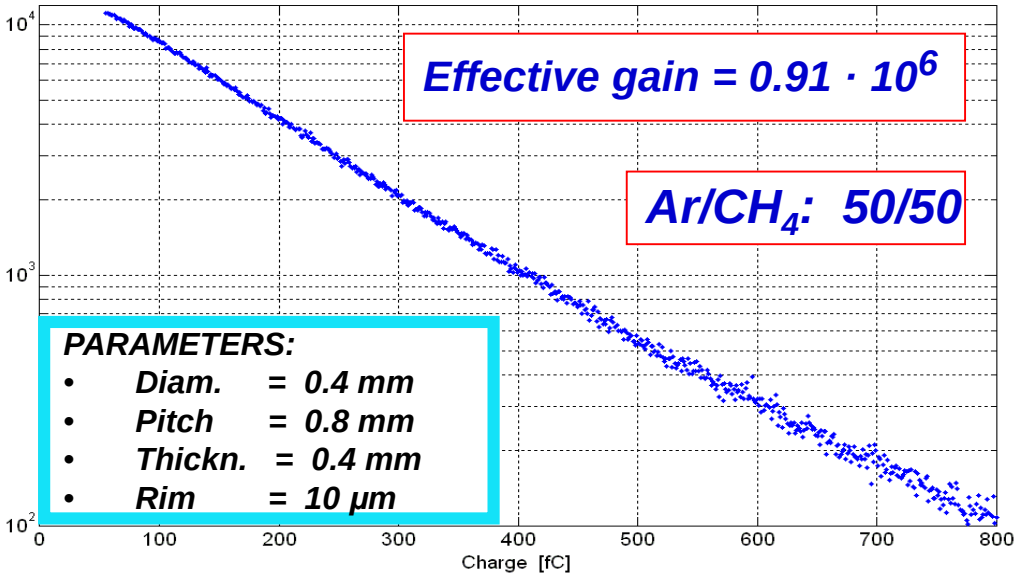


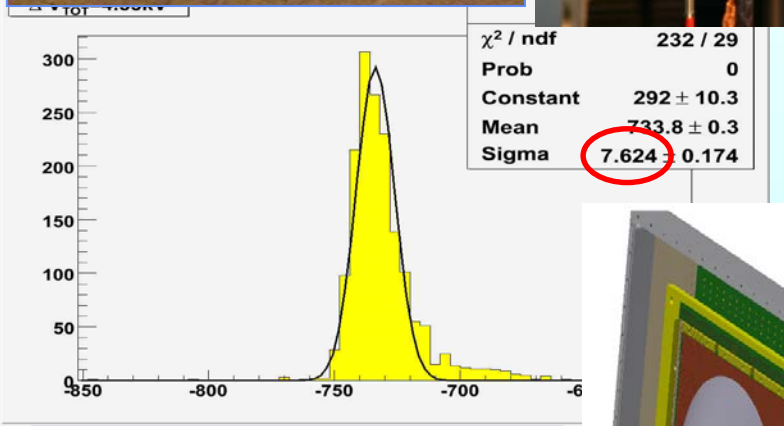
4 new detectors of 600 mm x 600 mm

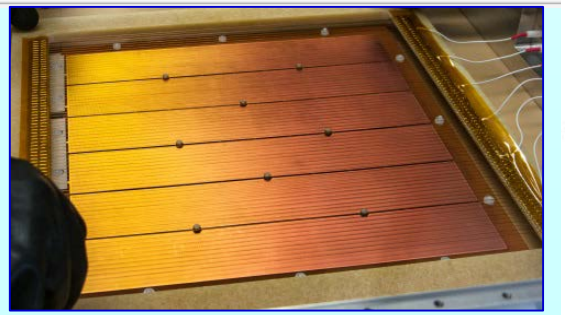
THGEM +CsI: 8 years of dedicated R&D

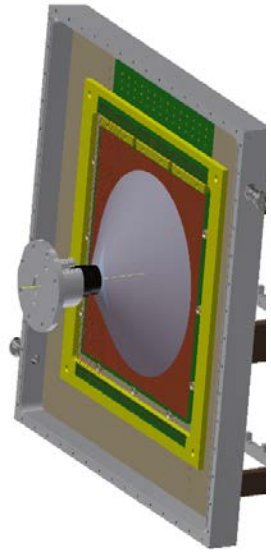


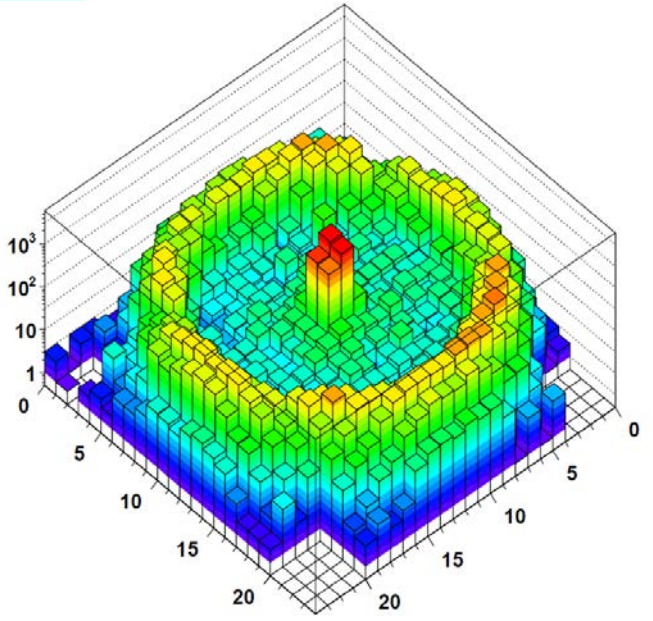




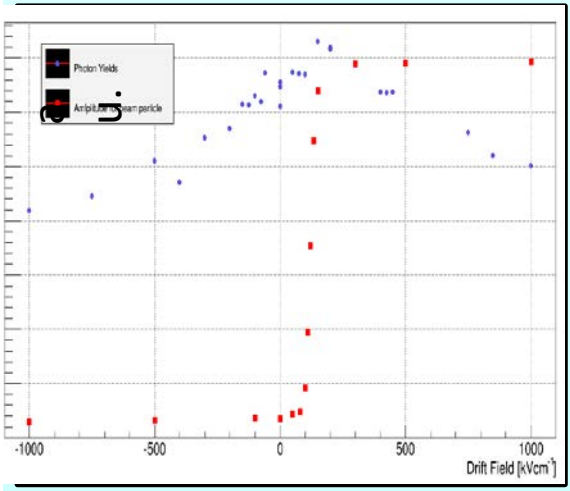






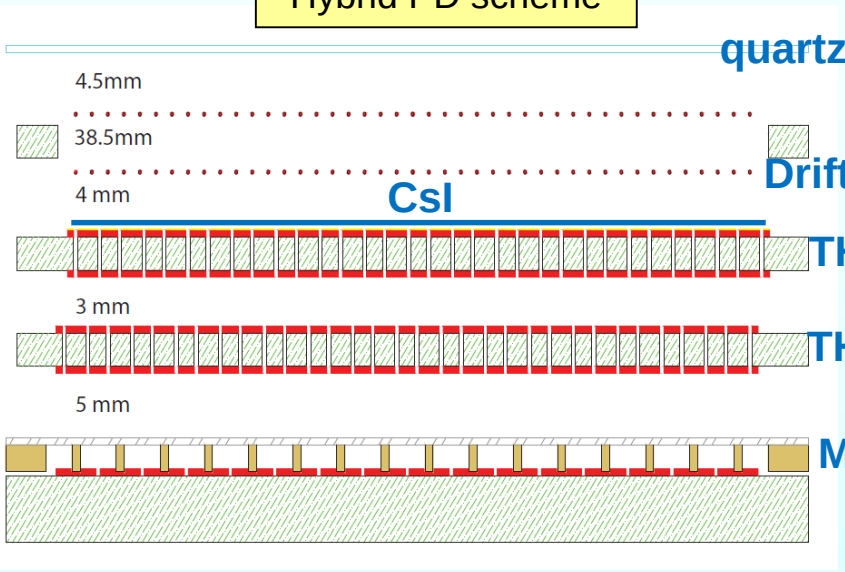


Photon yield & Charged Particles vs Drift Field

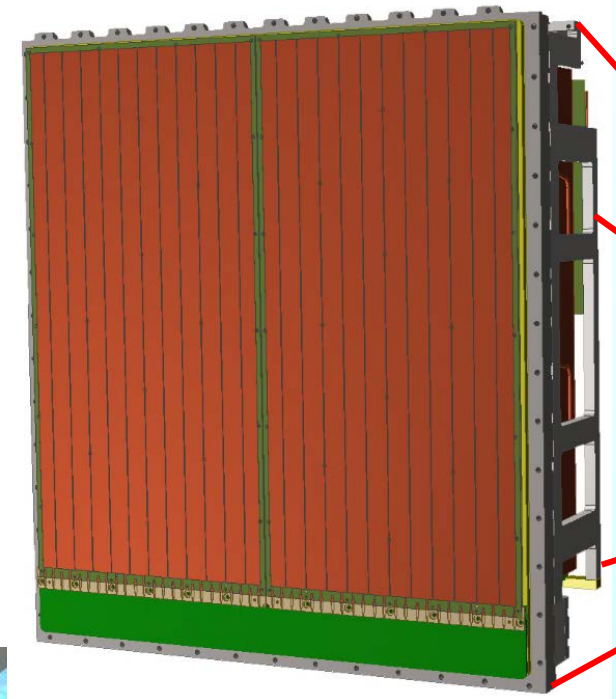


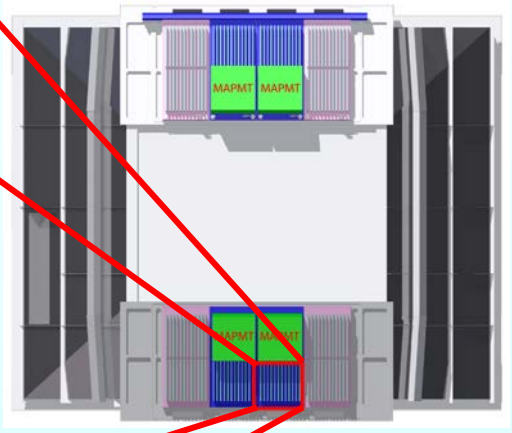
The new hybrid THGEM+Micromegas PDs

Hybrid PD scheme

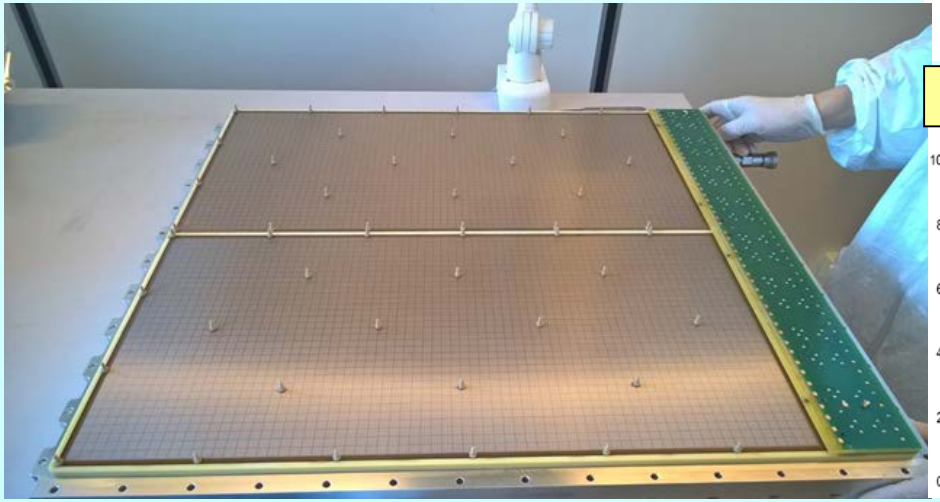


modular structure: one module = 600x300 mm^2

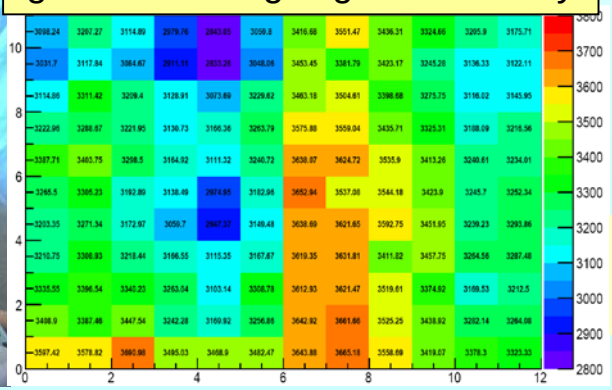


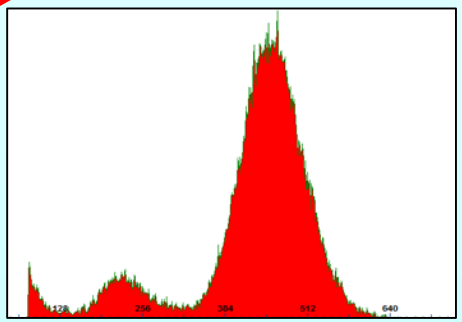


Standard Bulk Micromegas produced at CERN



good Micromegas gain uniformity





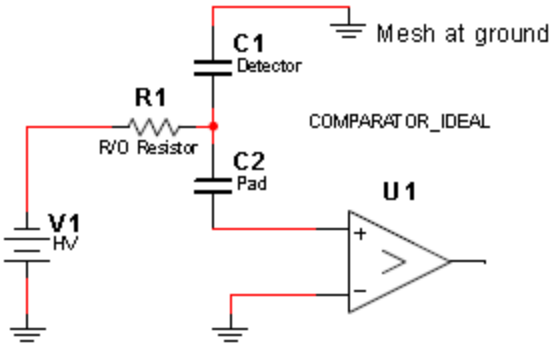
$$\delta_G = \frac{G_{max} - G_{min}}{G_{min}} < 5\ \%$$

The anodic PCB

anodic pad PCB produced by TVR

8mm X 8mm pads at positive HV

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

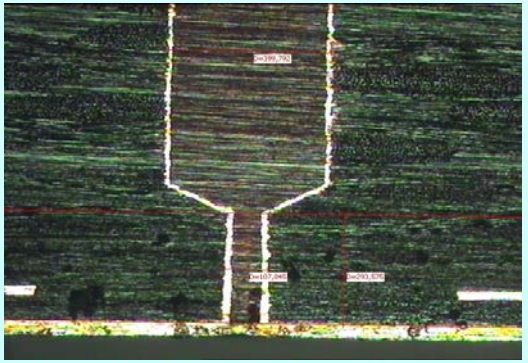


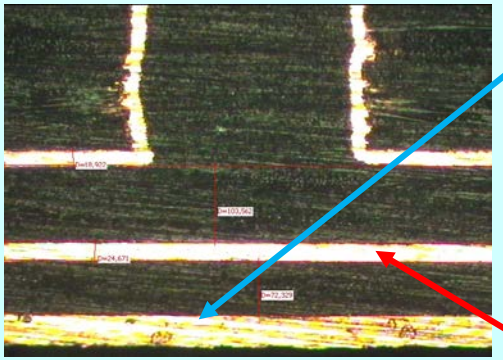
Strong technological effort from TVR Company for the PCB (multilayer 3.2 mm thick) to comply with specific requirements of planarity, surface quality, layer thickness uniformity, surface irregularities (E field).

Tests on 2500 pads: electrical continuity and capacity meas. → 38-42 pF/pad

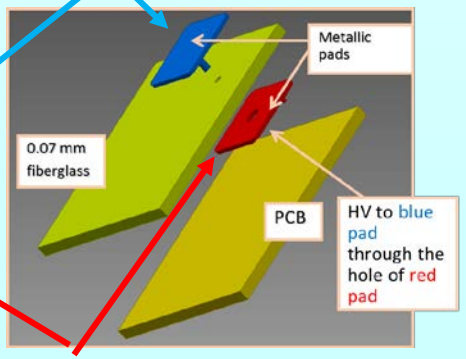
470 MΩ resistor for each anodic pad

"Z drilling controlled via" → planarity issue

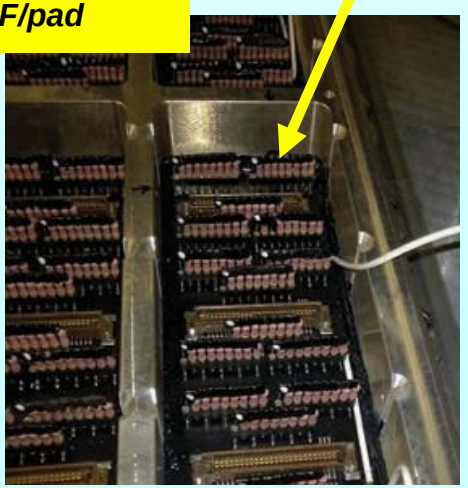




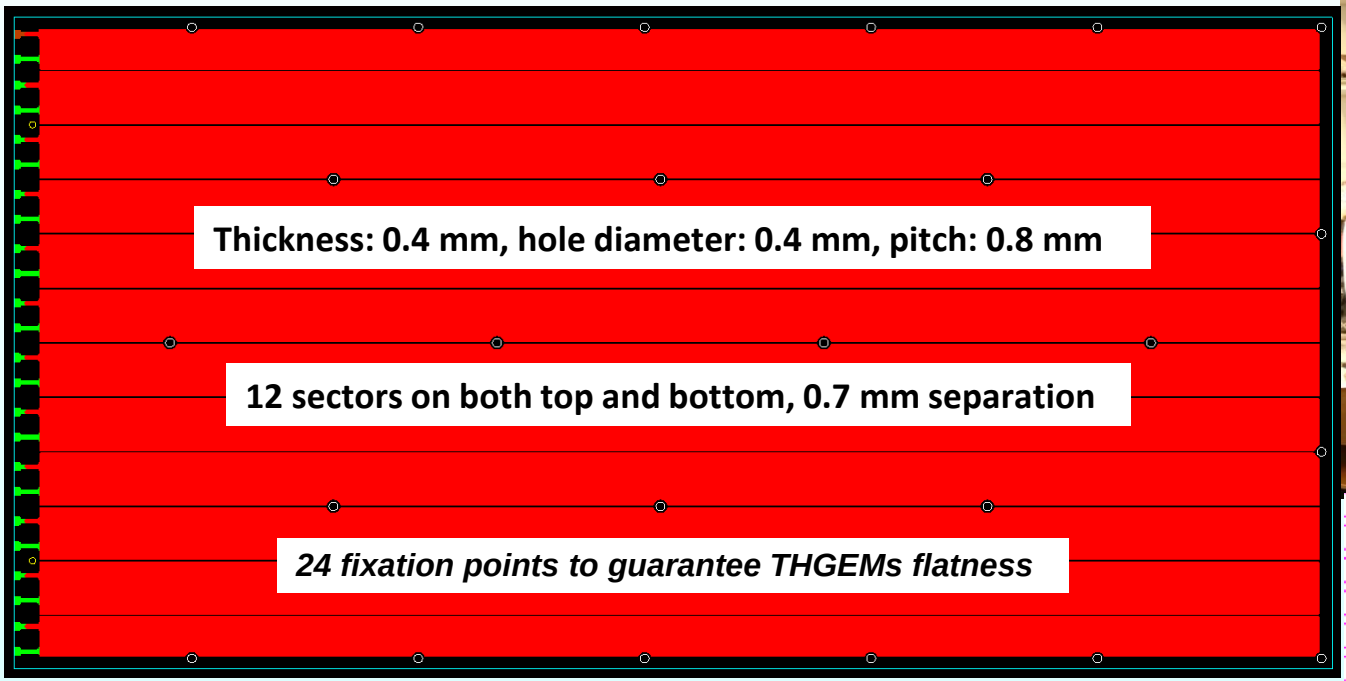
"surface anode" pad

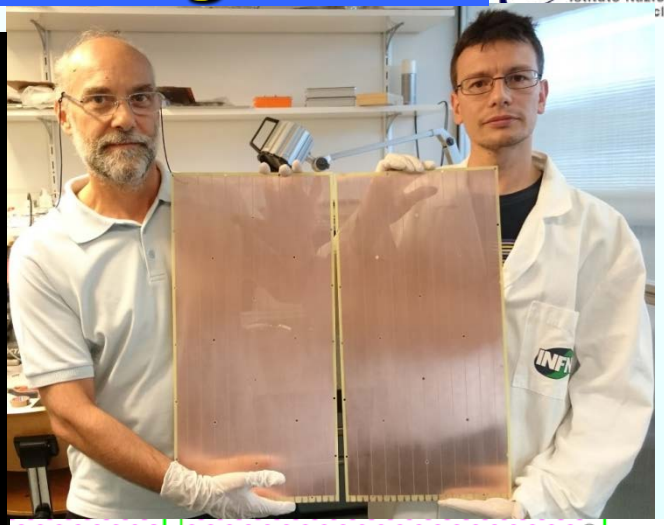


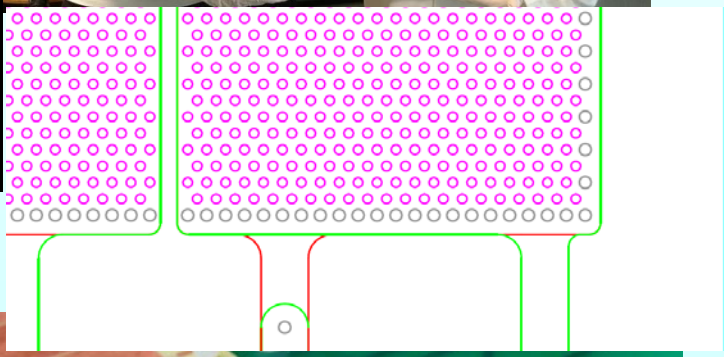
"buried pad"

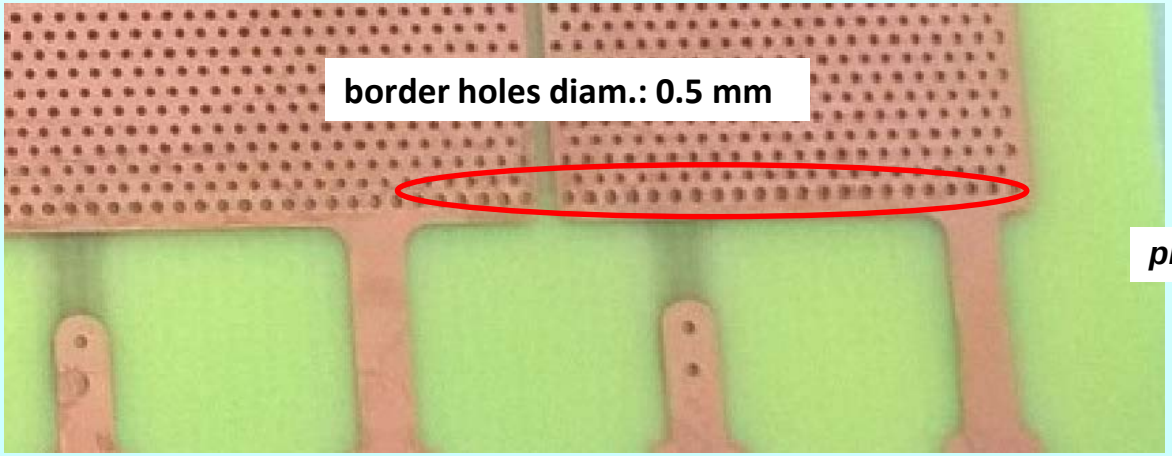


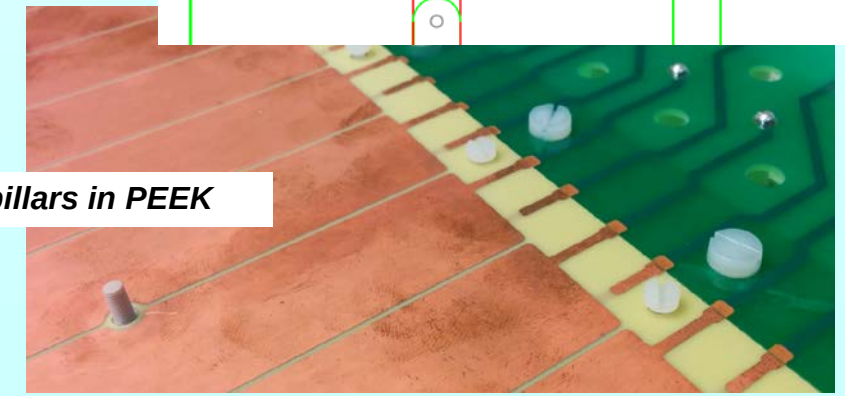
The COMPASS THGEM design











THGEM raw material selection

Our thickness uniformity requirements are stricter than those offered by producers → material selection

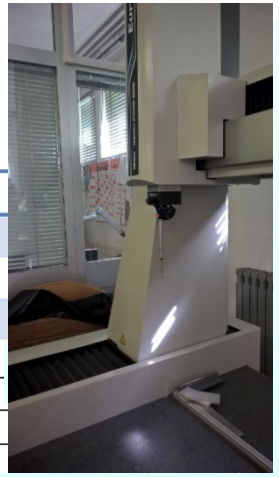
50 foils of 1245 mm x 1092 mm → cut out borders → 800 mm x 800 mm → thickness measurement

Elite Material Co., Ltd. Technical Data

http:\\www.emctw.com

Lead-free , Halogen-free Material

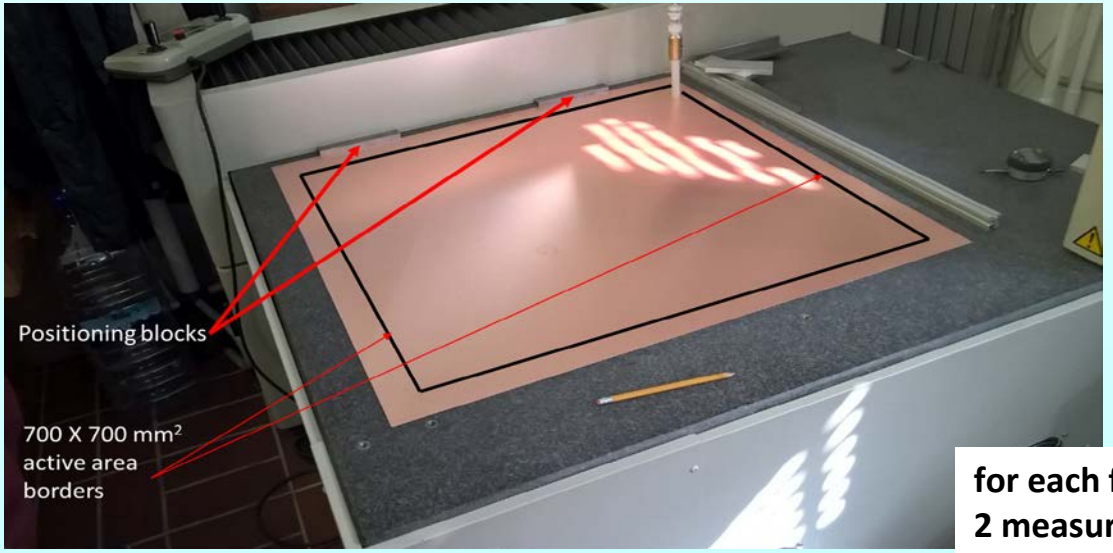
PRODUCT					EM 370-5
Thickness					0.407 mm
Copper					35µ / 35µ
Sheet Size					1 245 x 1 092 mm
Permittivity (RC 50%)	1 MHz	2.5.5.9	C-24/23/50	–	4.8
	1 GHz			–	4.3
Volume resistivity		2.5.17.1	C-96/35/90	MΩ-cm	$>10^{10}$
Surface resistivity		2.5.17.1	C-96/35/90	MΩ	$>10^{9}$



Mitutoyo EURO CA776

coordinate measuring machine with ruby touch probe,

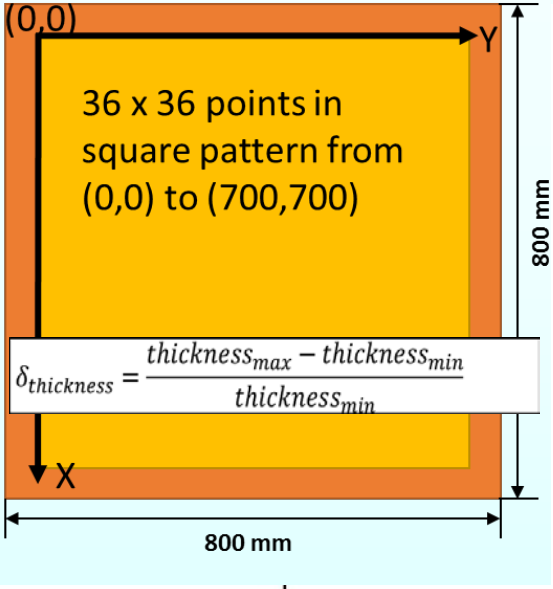
hosted in a thermalized room

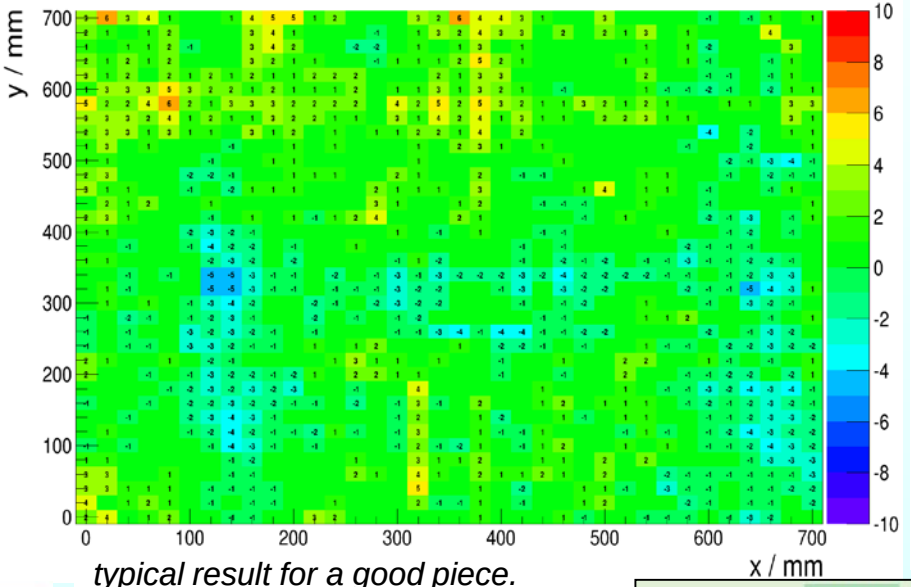


underpressure induced flatness

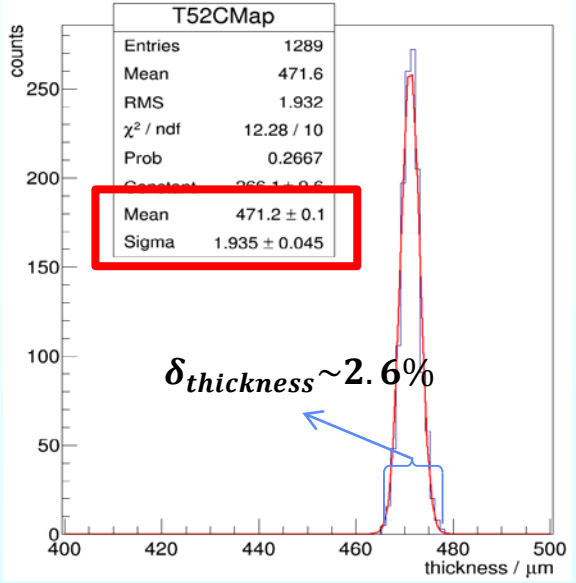
for each foil 36 x 36 points in square pattern are measured
2 measurements (direct and reversed) to allow consistency checks.

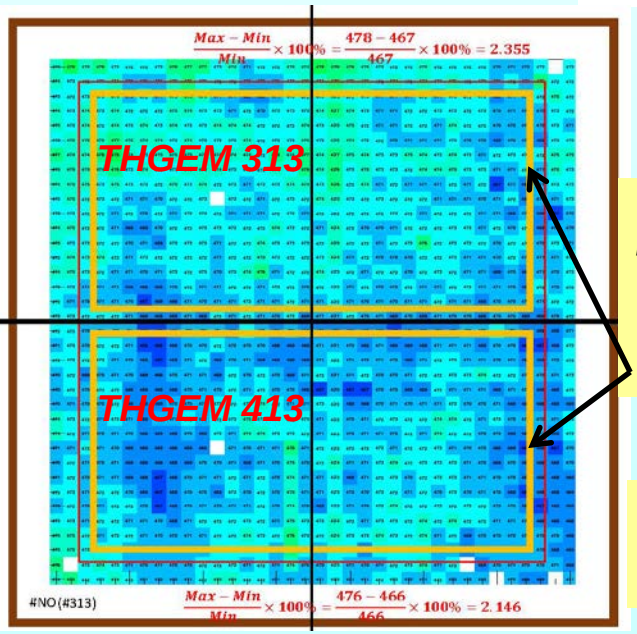
THGEM raw material selection





typical result for a good piece.





all foils have been labelled and measured → database of local thickness of all THGEMS

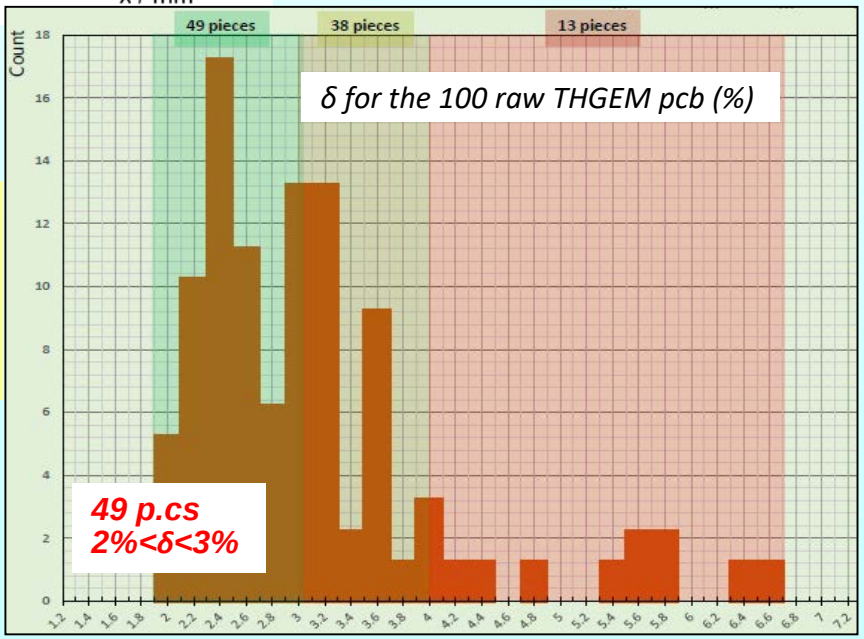
from each foil twoTHGEMS can be produced:

50 foils → 100 raw THGEM pcb

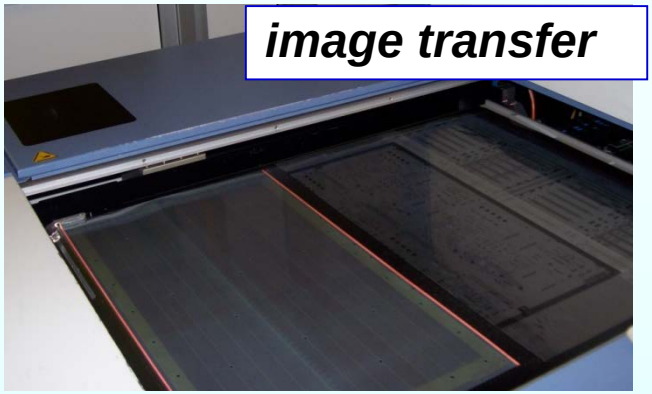
THGEM pcb size = 620 mm x 320 mm,

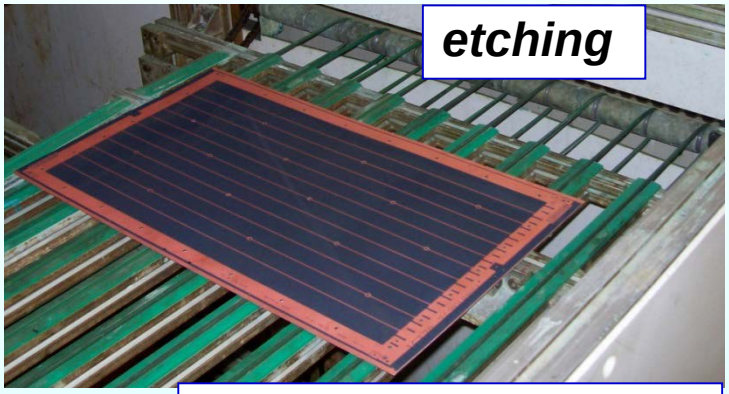
active area = 581 mm x 287 mm

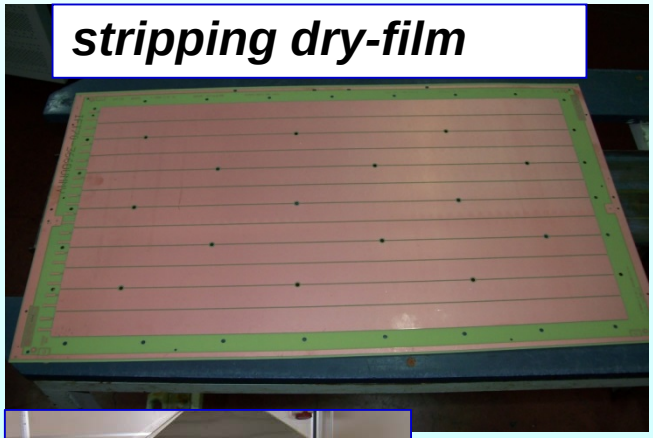
60 THGEMs have been produced by ELTOS

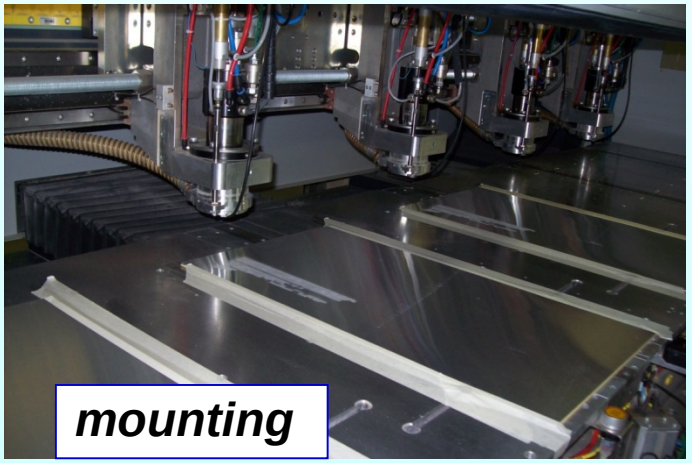


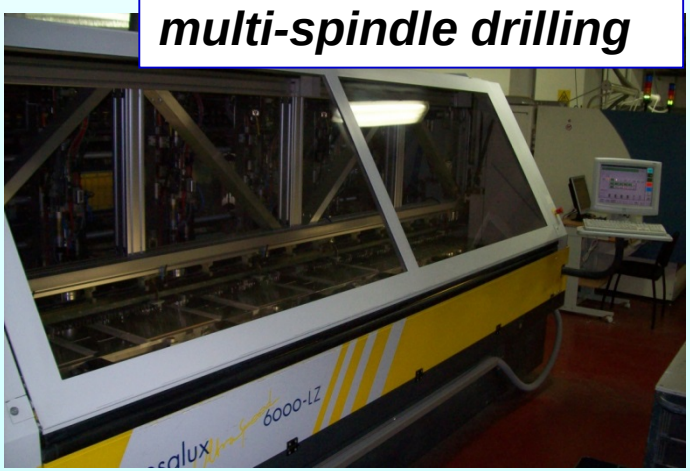
Production of the THGEMs at ELTOS



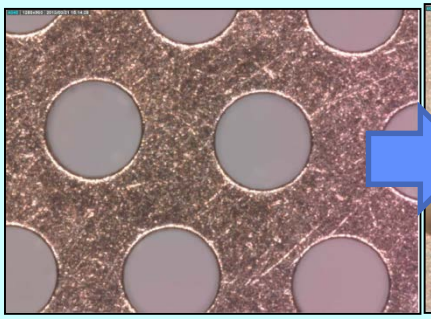


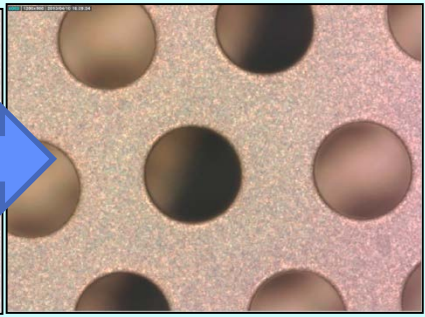






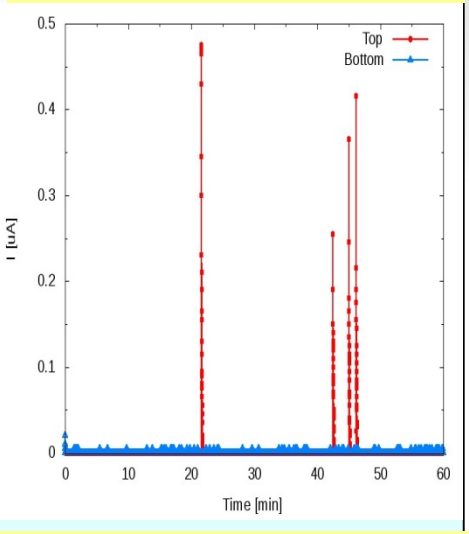
In Trieste a specific cleaning procedure is applied : polish with fine grain pumice powder, pressure water cleaning, ultrasonic Bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160 ºC





THGEM quality assessment

current monitor recording, discharge counting

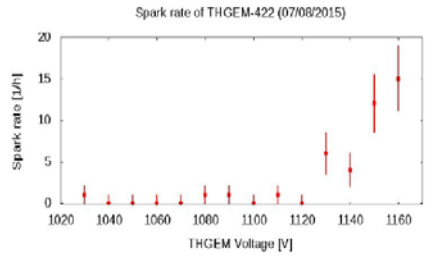


THGEM : 422

- dV=1000V : 4 hours : 0 sparks/h
- dV=1150V : 6 hours : 70 sparks/h

rejected

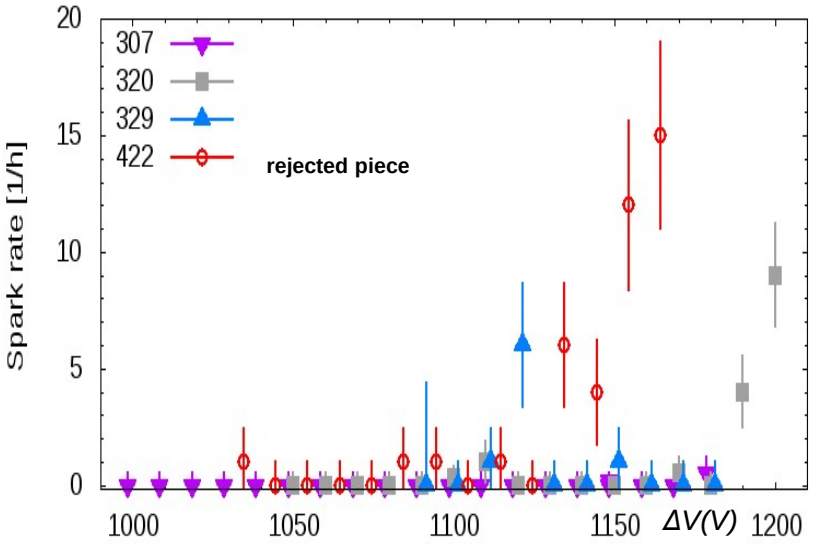
- dV=1030V .. 1160V / 10V steps , 1 hour for all dV



THGEM : 307

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

accepted

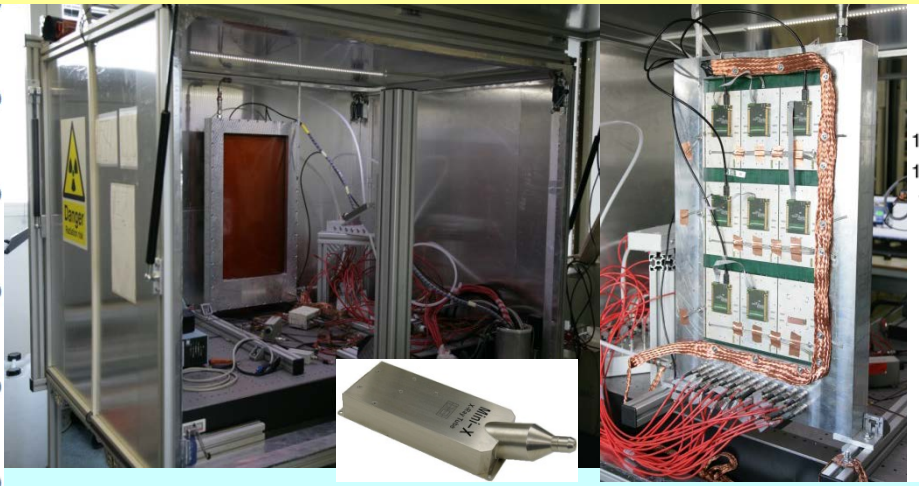


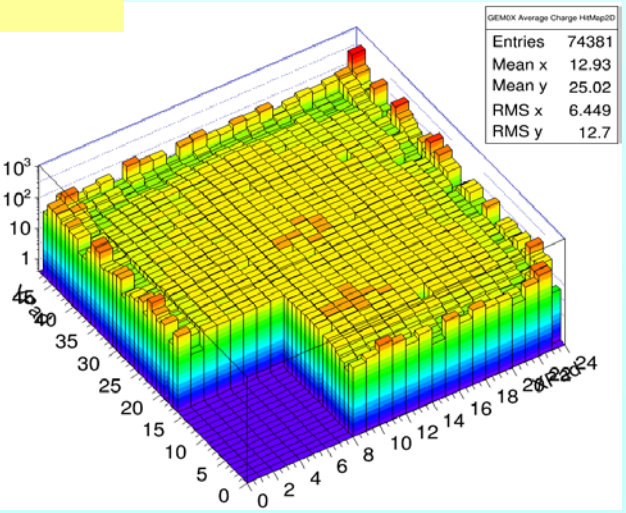
first 4 pieces: 1 rejected. Possibly recovered by repeating the cleaning treatment

Gain uniformity measurement

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

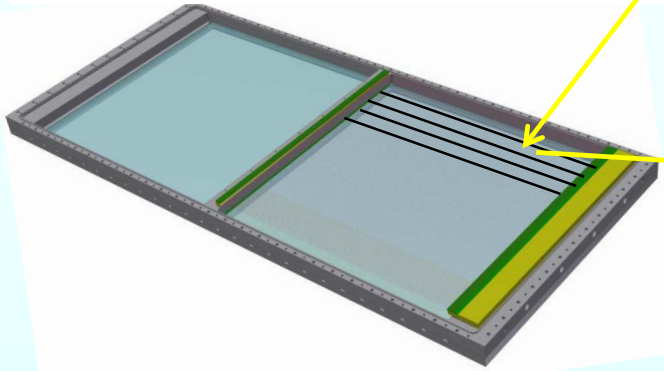
AMPTEK Mini-X Au used at 15 kV, 200μA + Cu foil provides 8 keV X-rays uniform illumination at a rate > 5 kHz cm^{-2} (for 1 cm Ar/CO$_2$ 70/30)

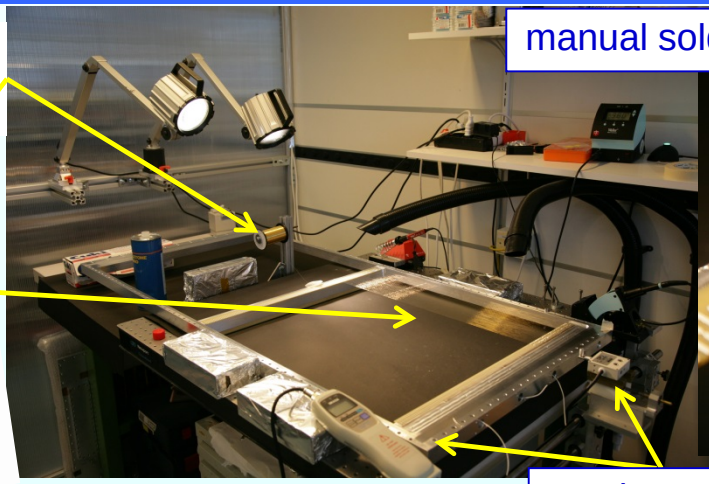




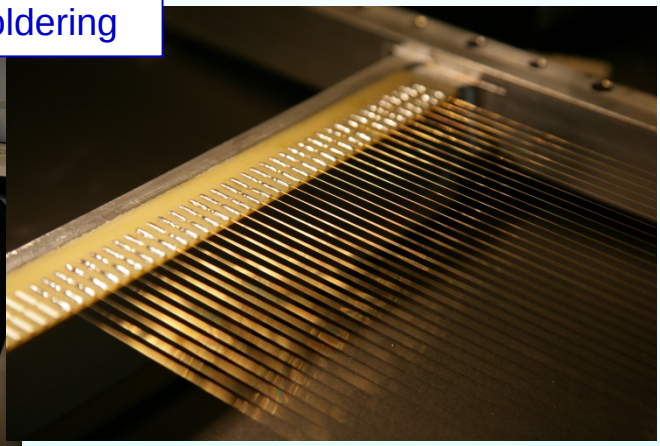
mechanical frames and wires

drift and field wires: Cu-Be, Au coated
4 mm pitch, 100 µm diam.

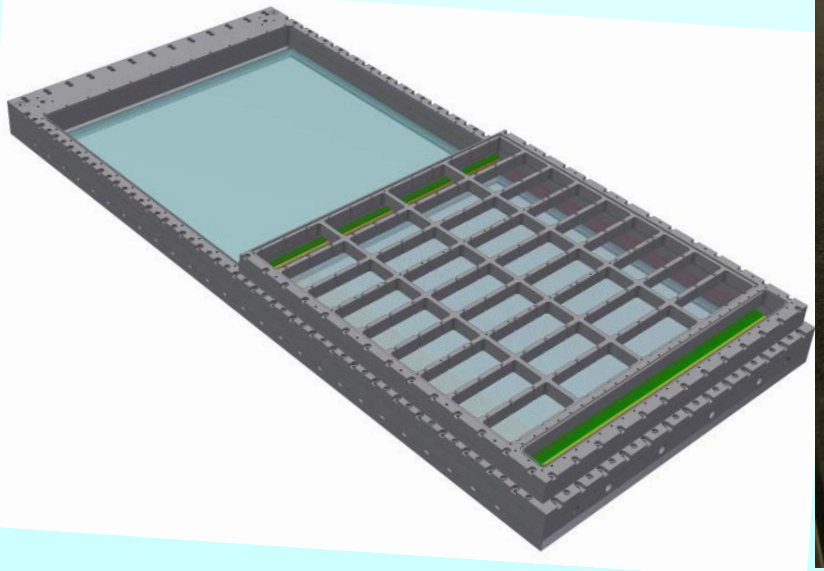


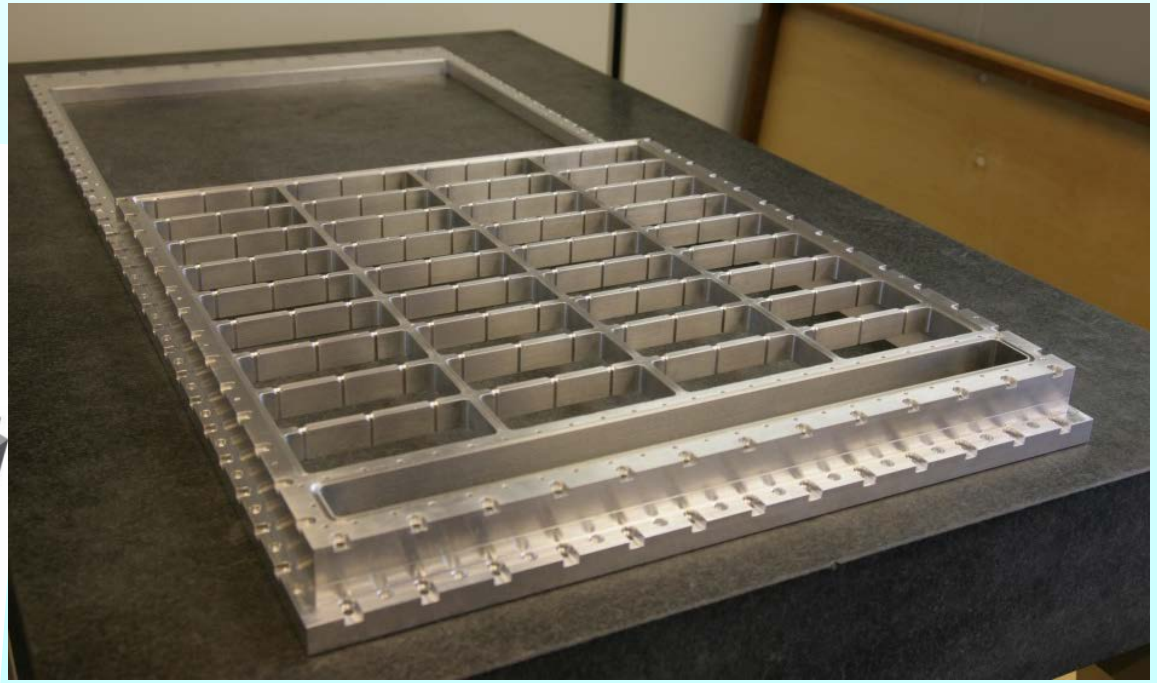


manual soldering



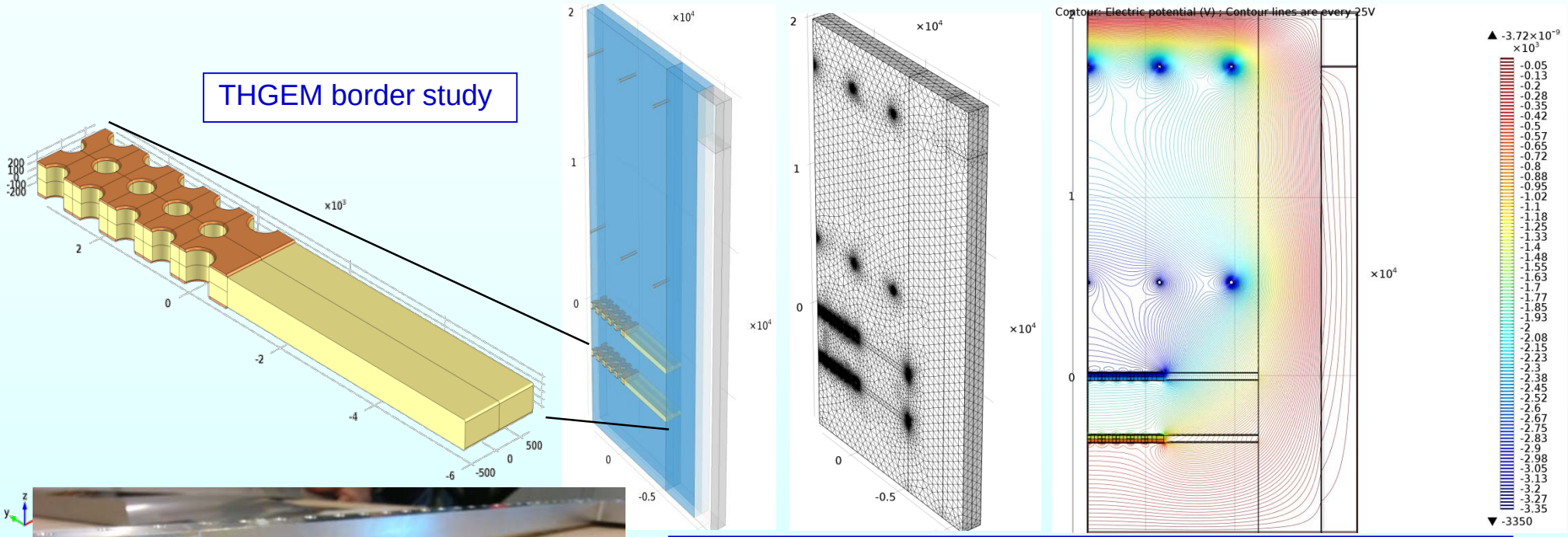
tension meter



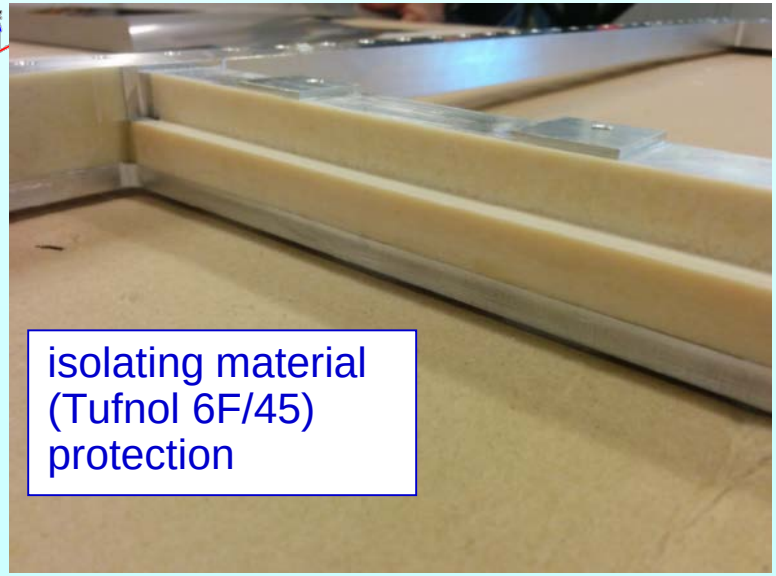


field shaping electrodes

THGEM border study

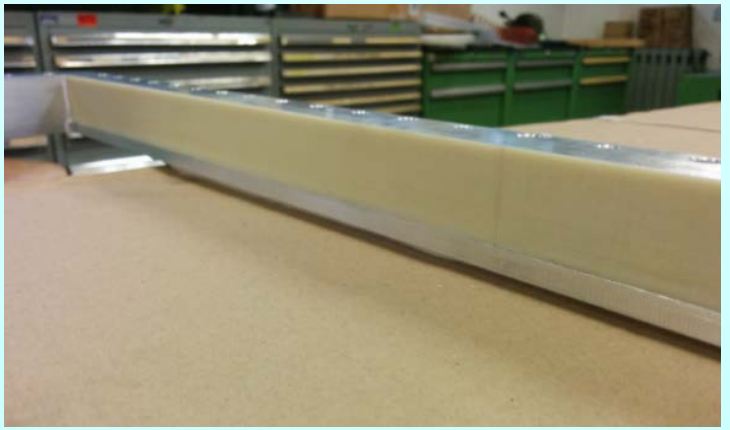


large field values at the chamber edges and on the guard wires

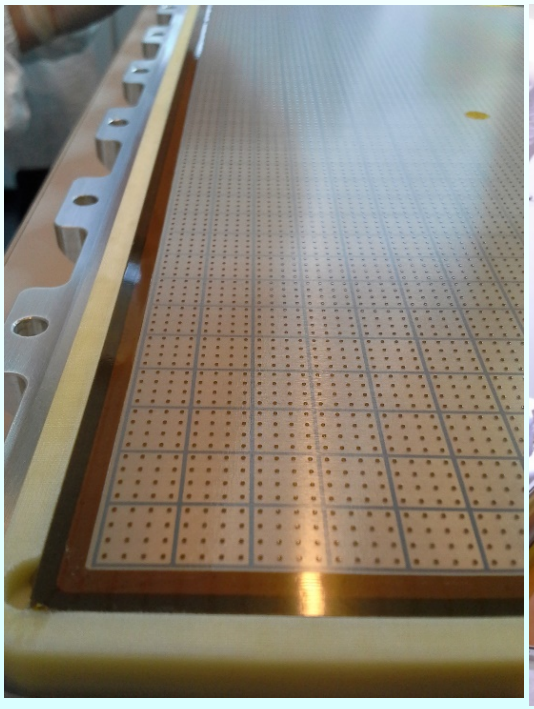


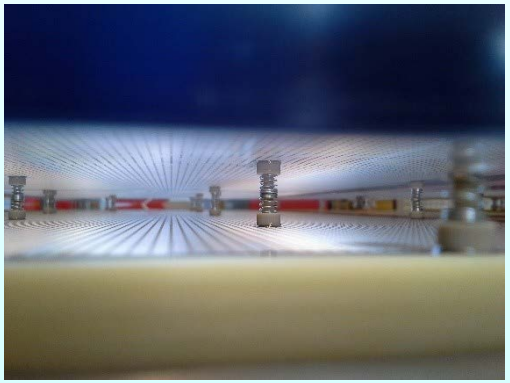
isolating material (Tufnol 6F/45) protection

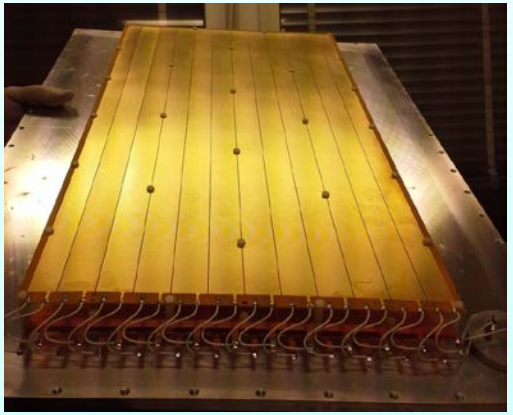
Field shaping electrodes in the isolating material protections of the chamber frames

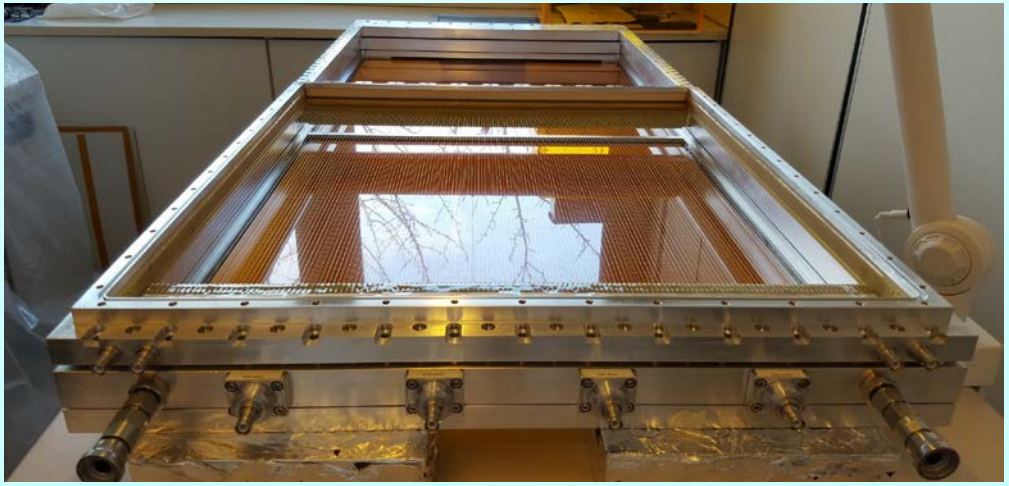


assembling

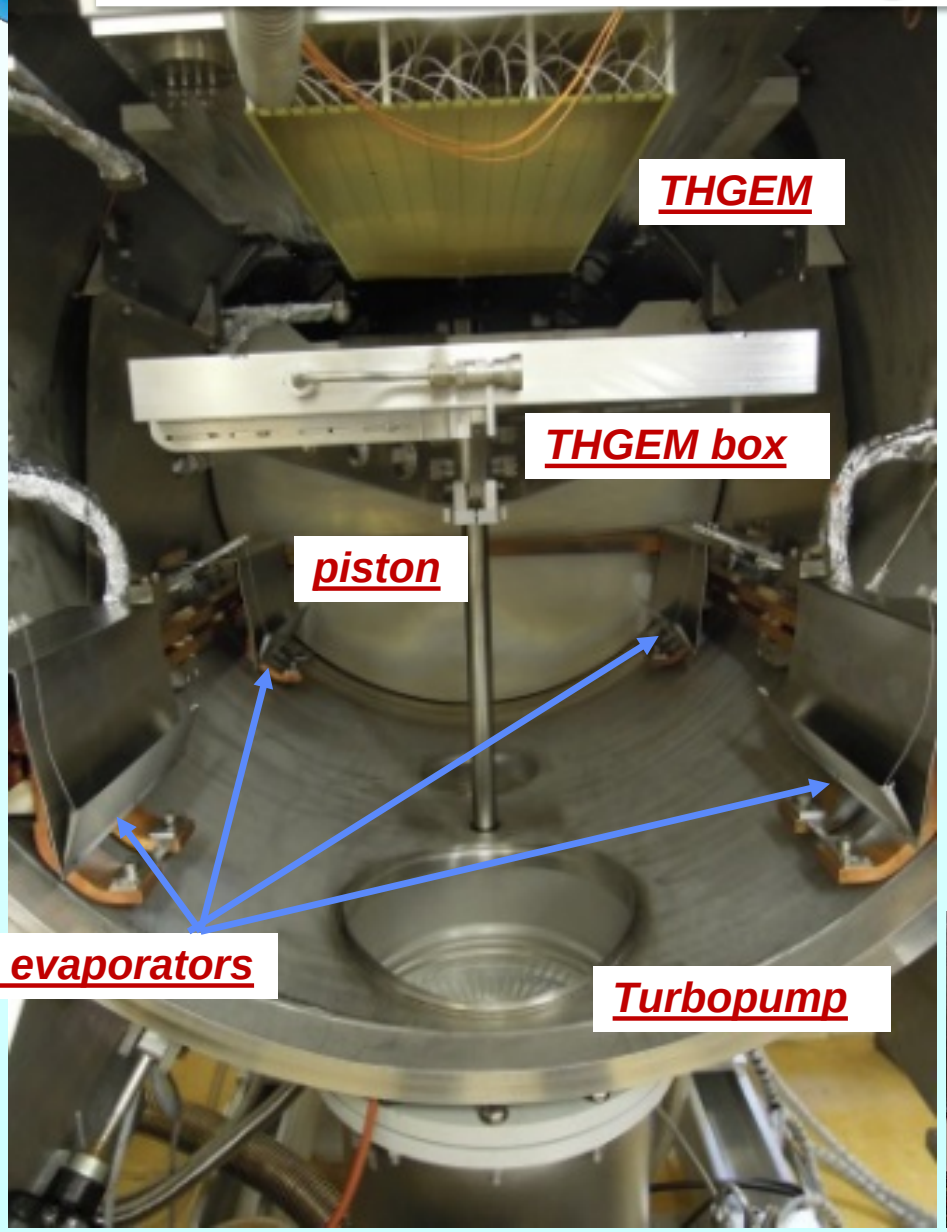


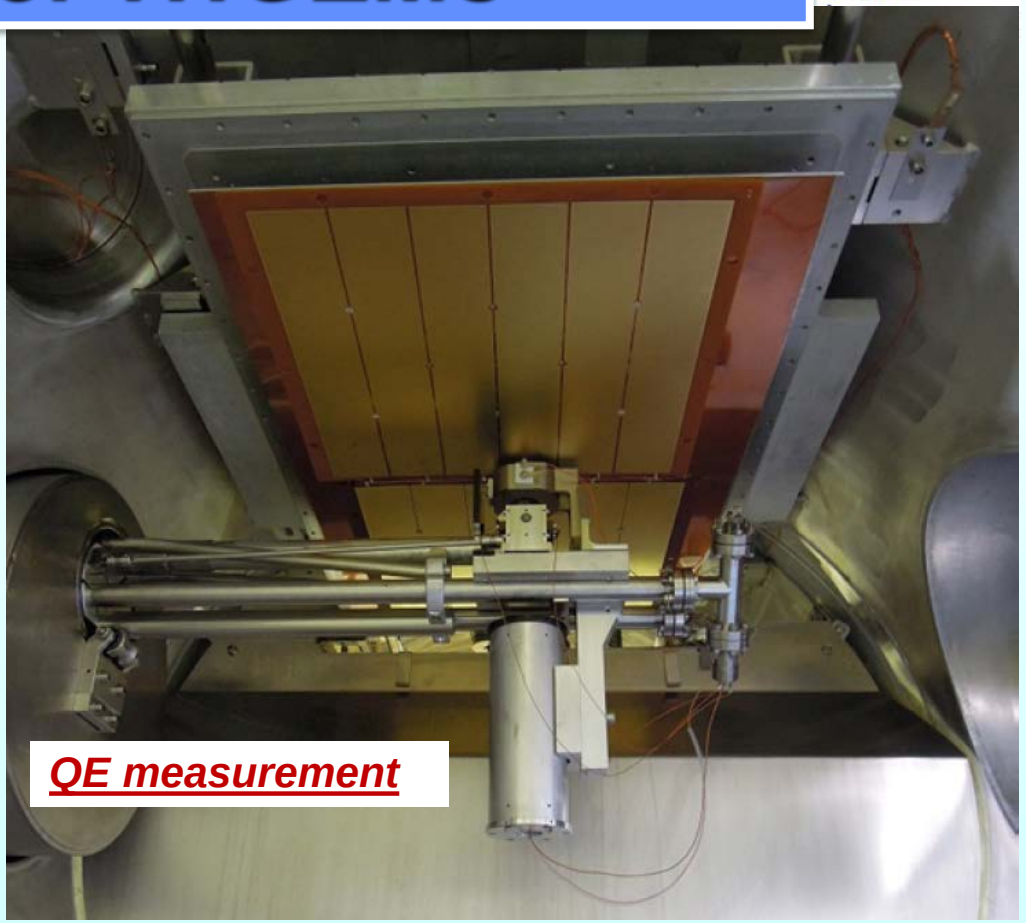


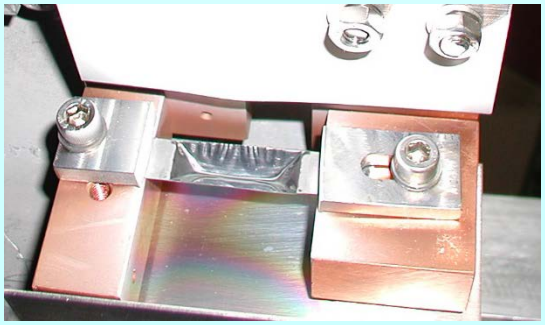




CsI coating of THGEMs







CsI QE measurement

19 CsI evaporations performed in 2015 - 2016 on 15 pieces: 13 THGEMs, 1 dummy THGEM, and 1 reference piece (best from previous coatings)

11 coated THGEMs available, 8 used + 3 spares

$$I_{Normalized} = \frac{I_{CsI} - I_{CsI_{Noise}}}{I_{Ref} - I_{Ref_{Noise}}}$$

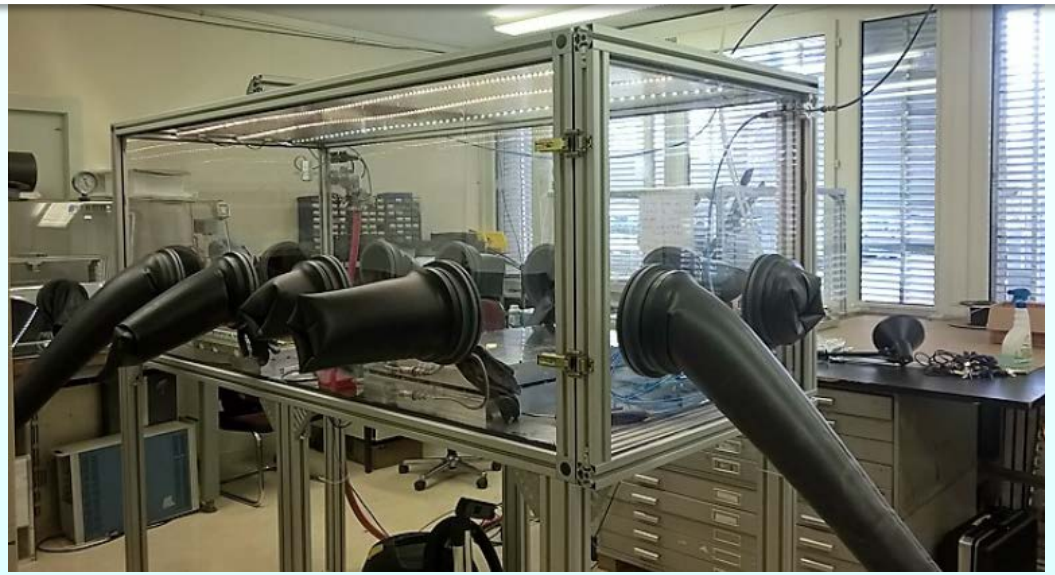
THGEM number	evaporation date	at 60 degrees	at 25 degrees
Thick GEM 319	1/18/2016	2.36	2.44
Thick GEM 307	1/25/2016	2.65	2.47
Thick GEM 407	2/2/2016	2.14	2.47
Thick GEM 418	2/8/2016	2.79	2.98
Thick GEM 410	2/15/2016	2.86	3.14
Thick GEM 429	2/22/2016	2.75	2.74
Thick GEM 334	2/29/2016	2.77	3.00
Thick GEM 421 re-coating	3/10/2016	2.61	2.83
Reference piece	7/4/2016	3.98	3.76

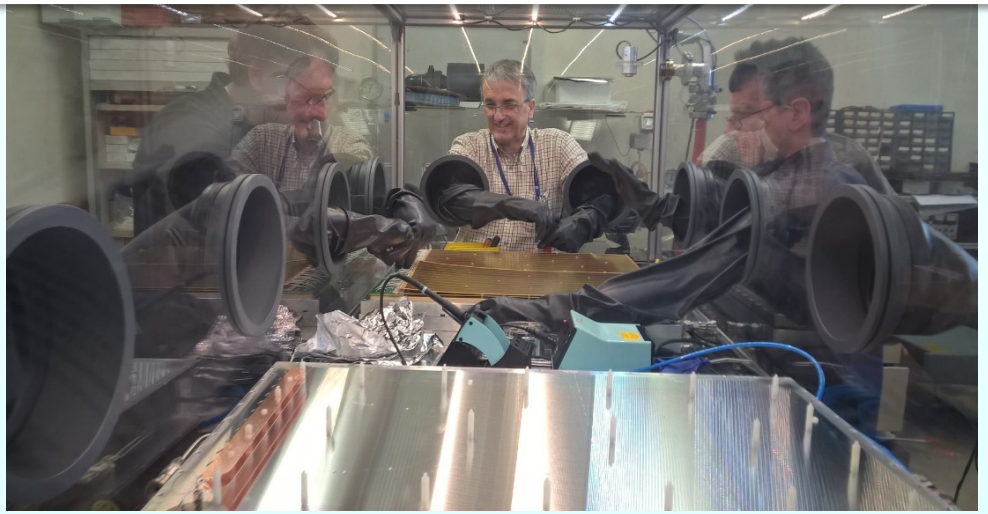
$$\frac{\pi}{2\sqrt{3}}\left(\frac{d}{p}\right)^2$$

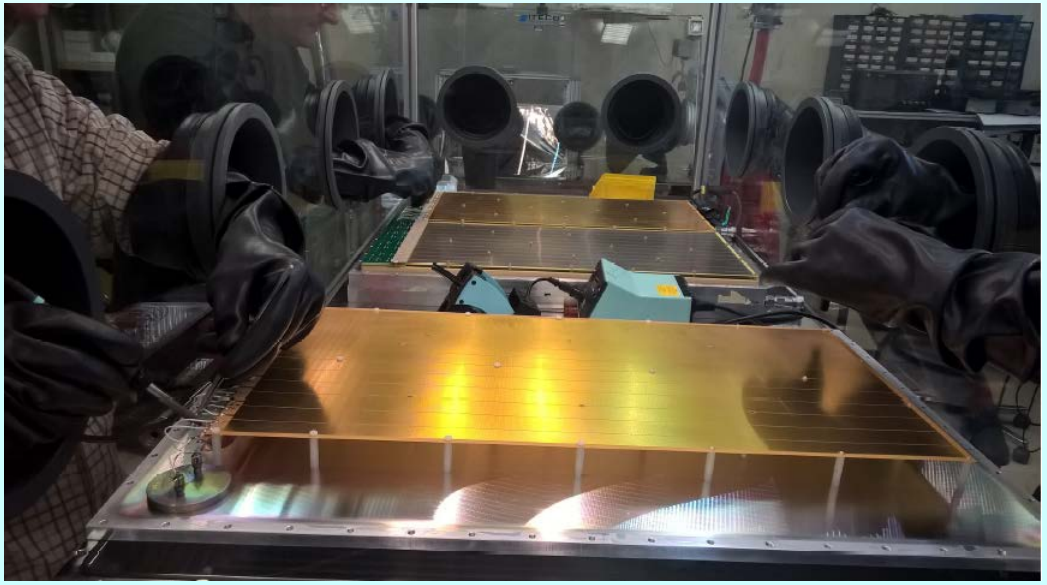
QE measurements indicate an average THGEM QE = 0.73 x Ref. piece QE, in agreement with expectations (THGEM optical transparency = 0.76)

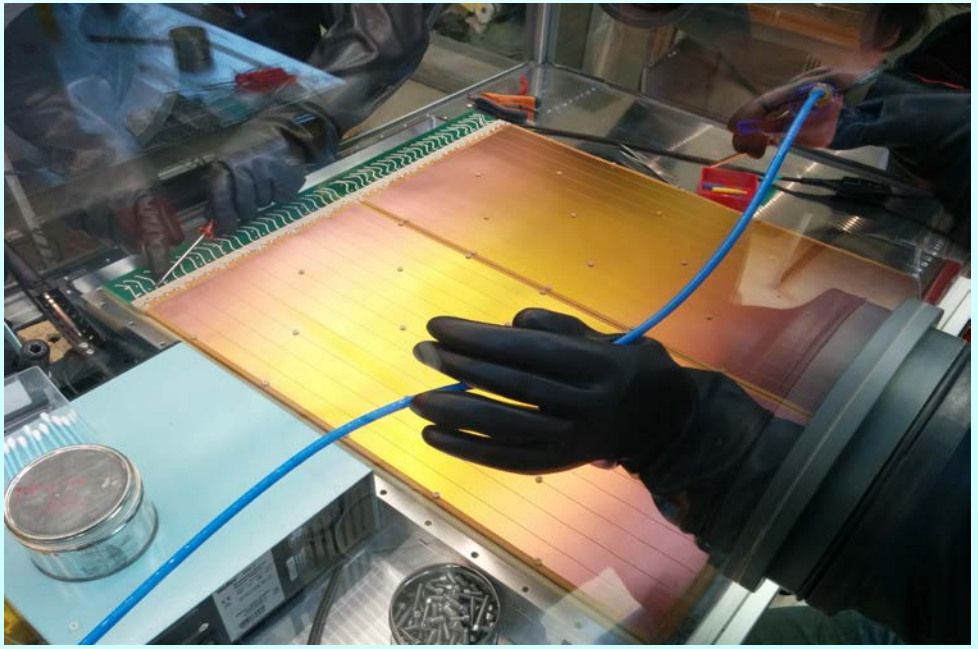
Thanks to Thomas Schnider and Miranda Van Stenis

CsI THGEM mounting

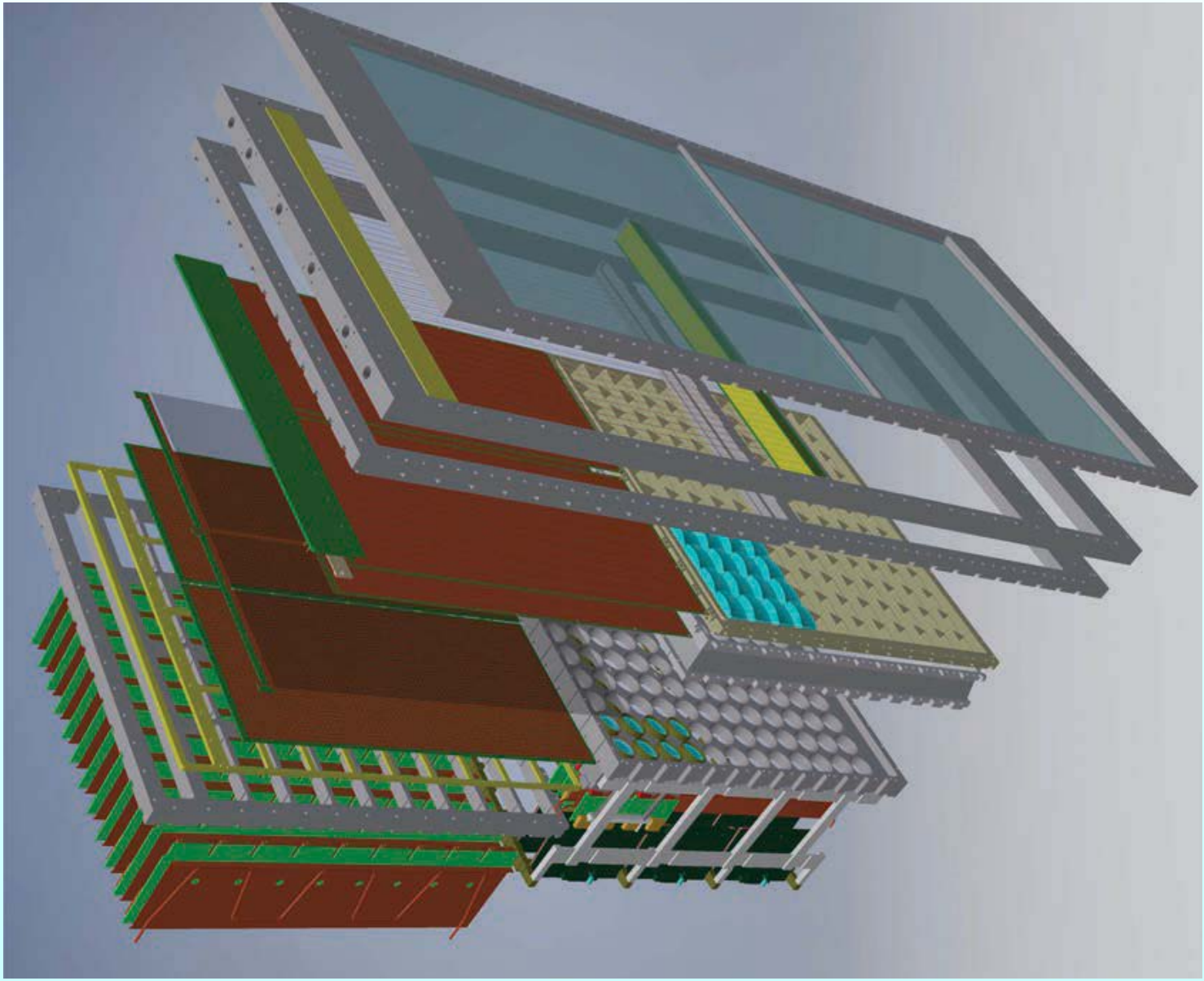




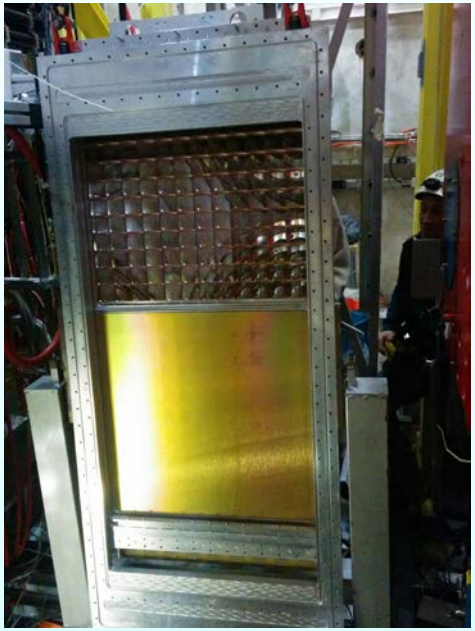


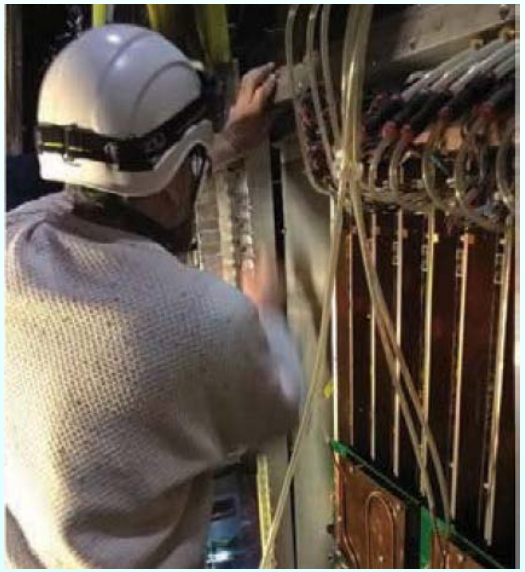


The new COMPASS PDs

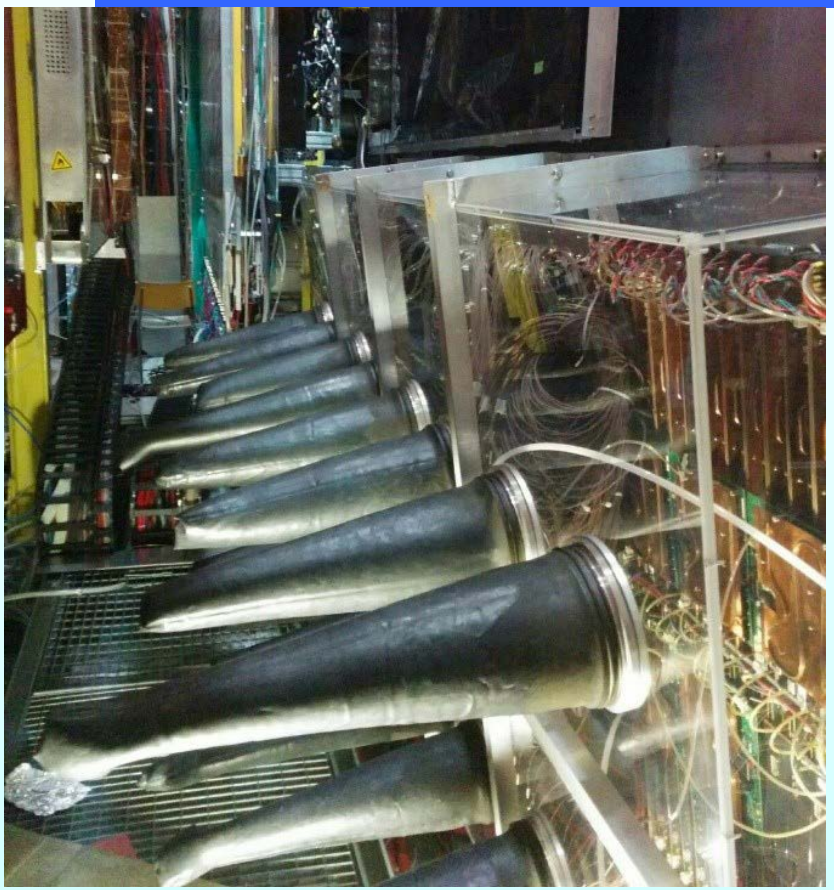


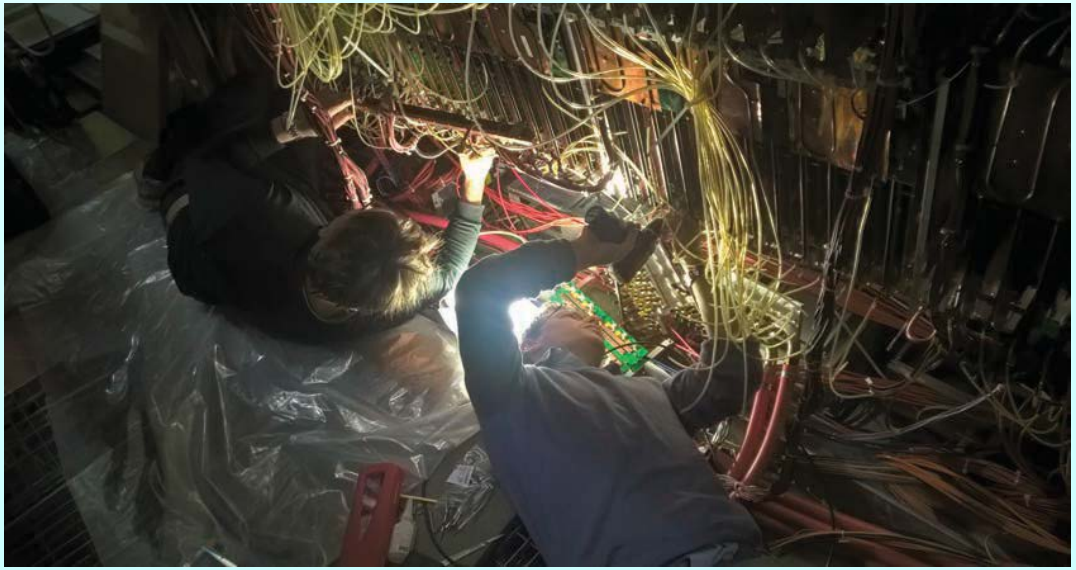
Installation of hybrids on RICH_1

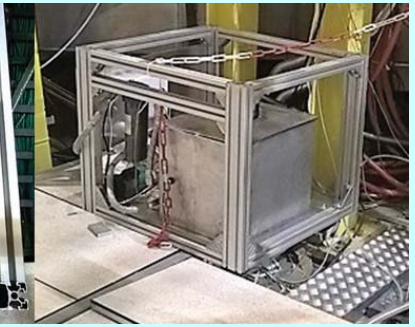





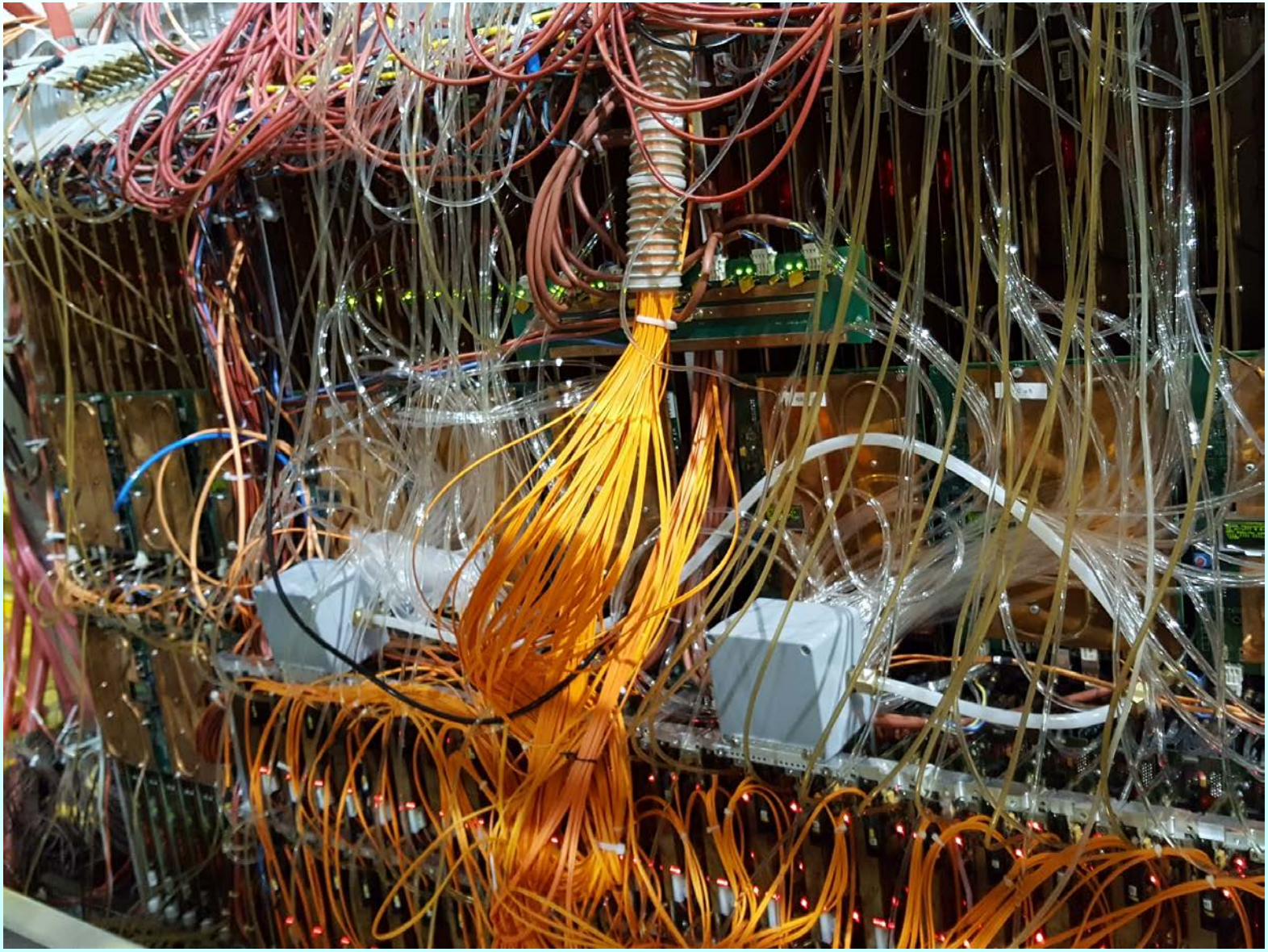

Equipping the hybrids on RICH_1







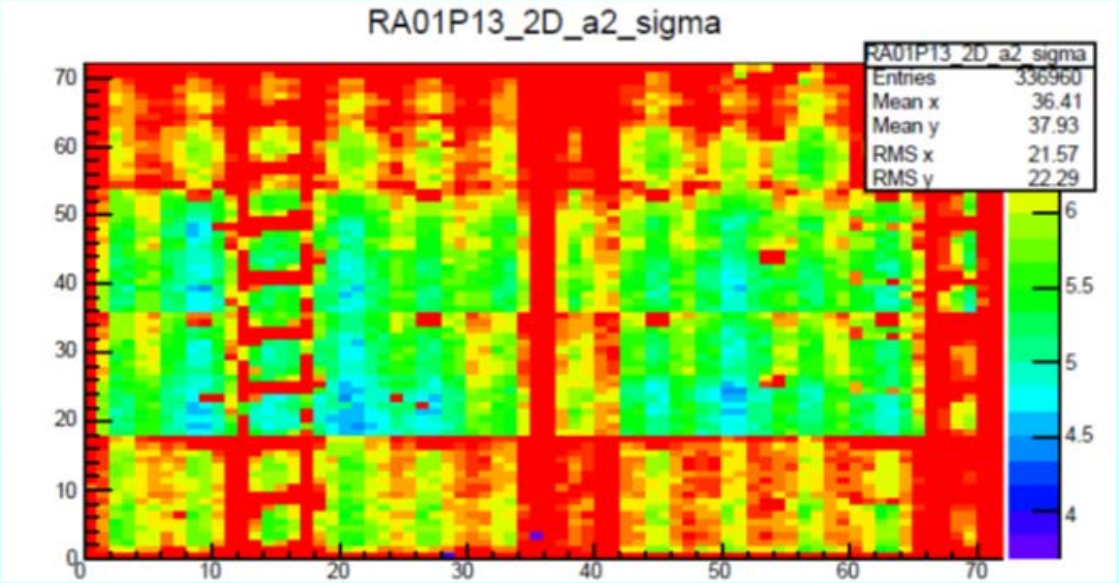
The PD readout and services



commissioning

Detectors successfully installed in April 2016

Operated and commissioned during the entire 2016 COMPASS run



Noise issues

HV tuning and monitoring

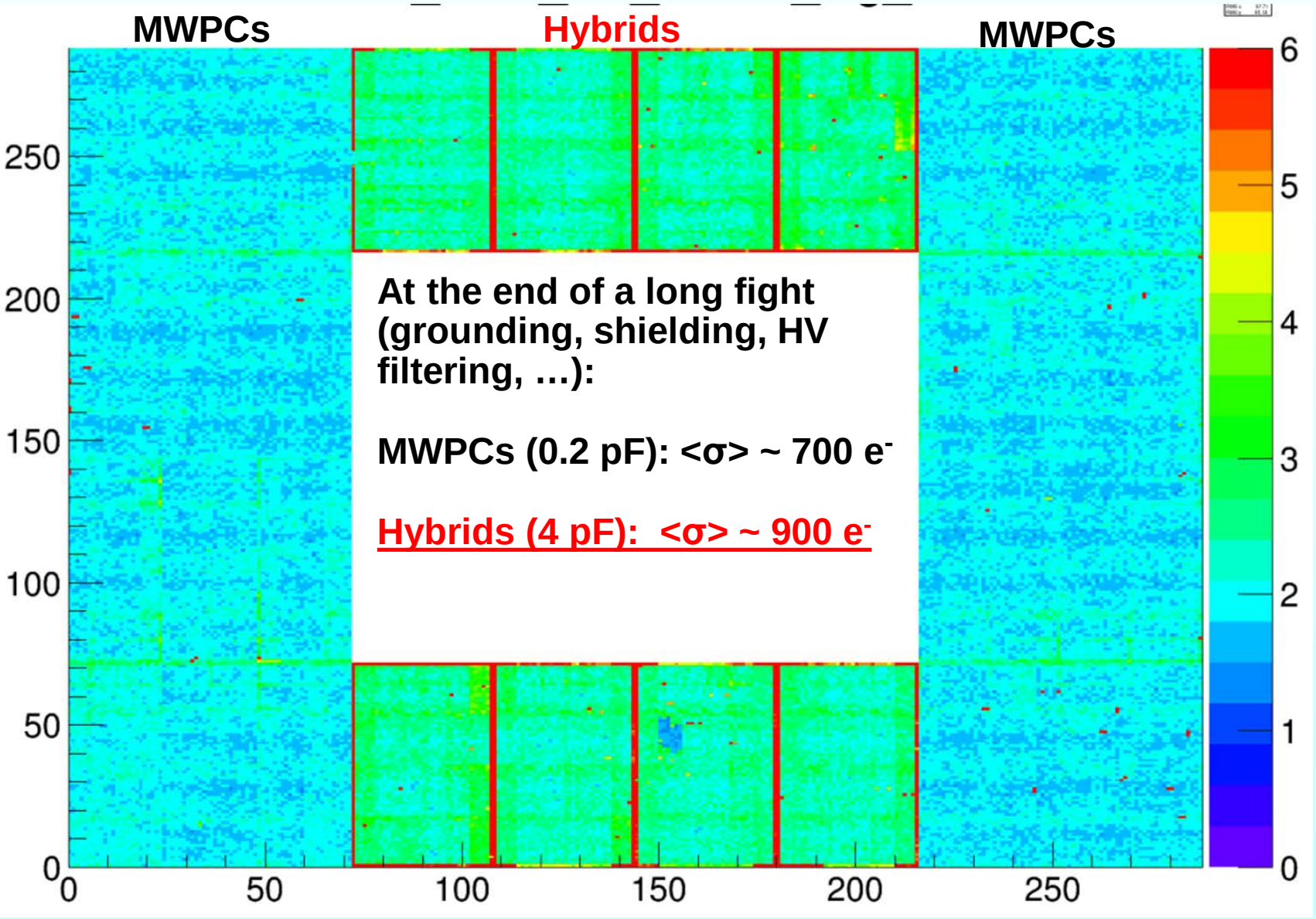
Timing of the signal sampling

Gain response stability

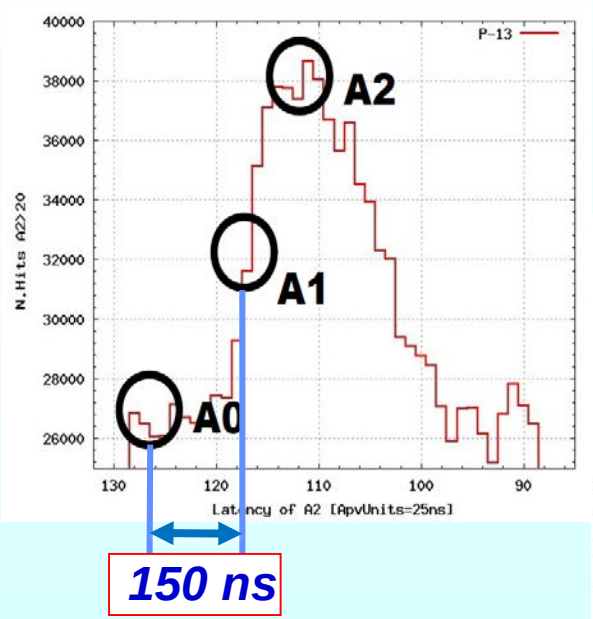
APV readout errors

HV control is discussed in the next talk by Silvia Dalla Torre

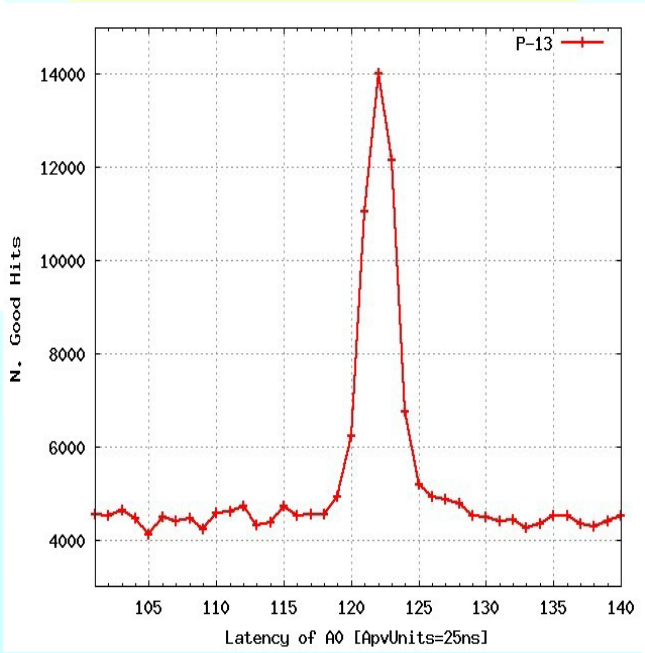
Noise figure for the 62208 ch.



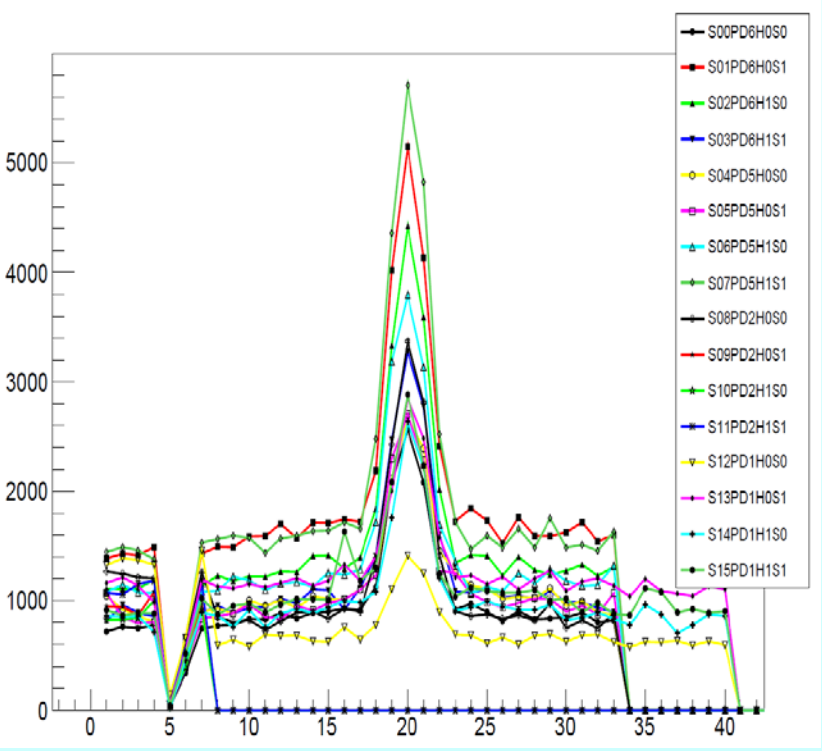
timing and sampling tuning



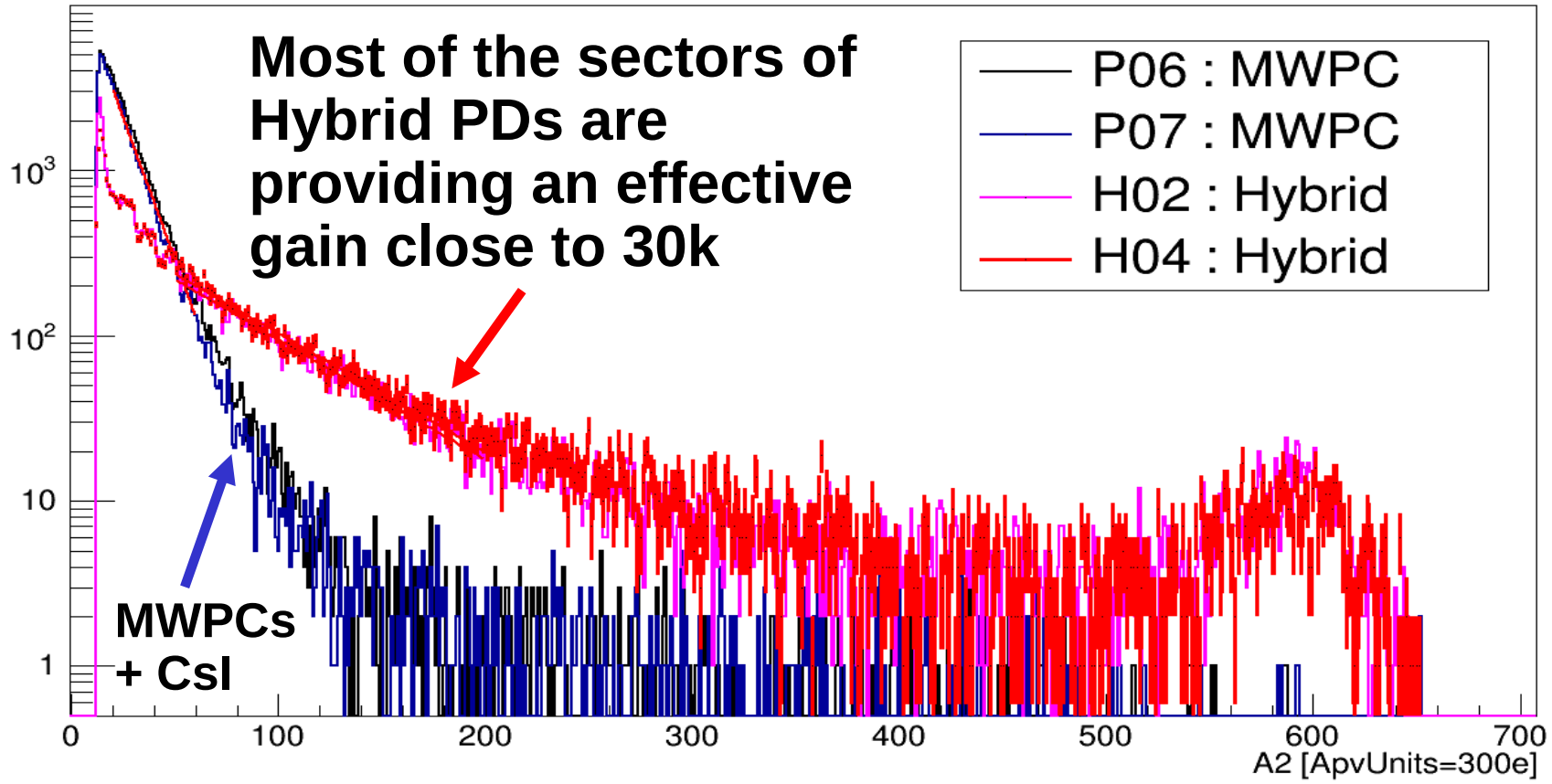
Selecting "good" hits: (A0<5 ADC units, 0.2<A1/A2<0.8)



All sectors provide the same time response

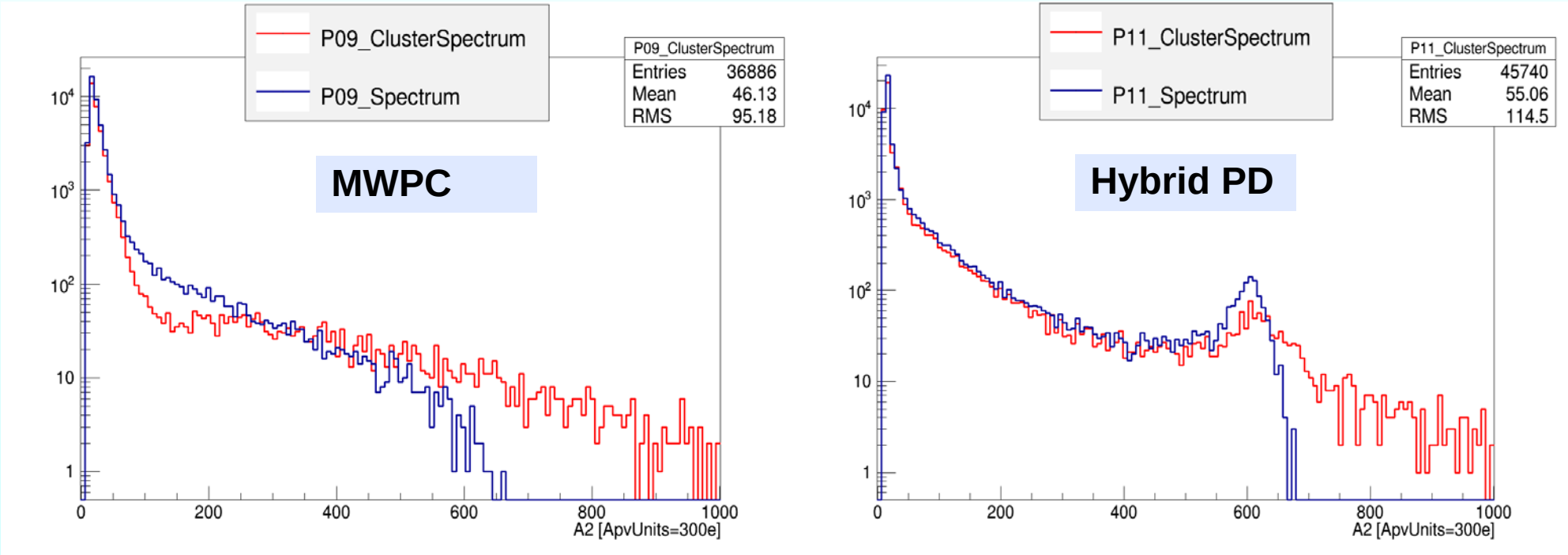


Running at gain of ~30k



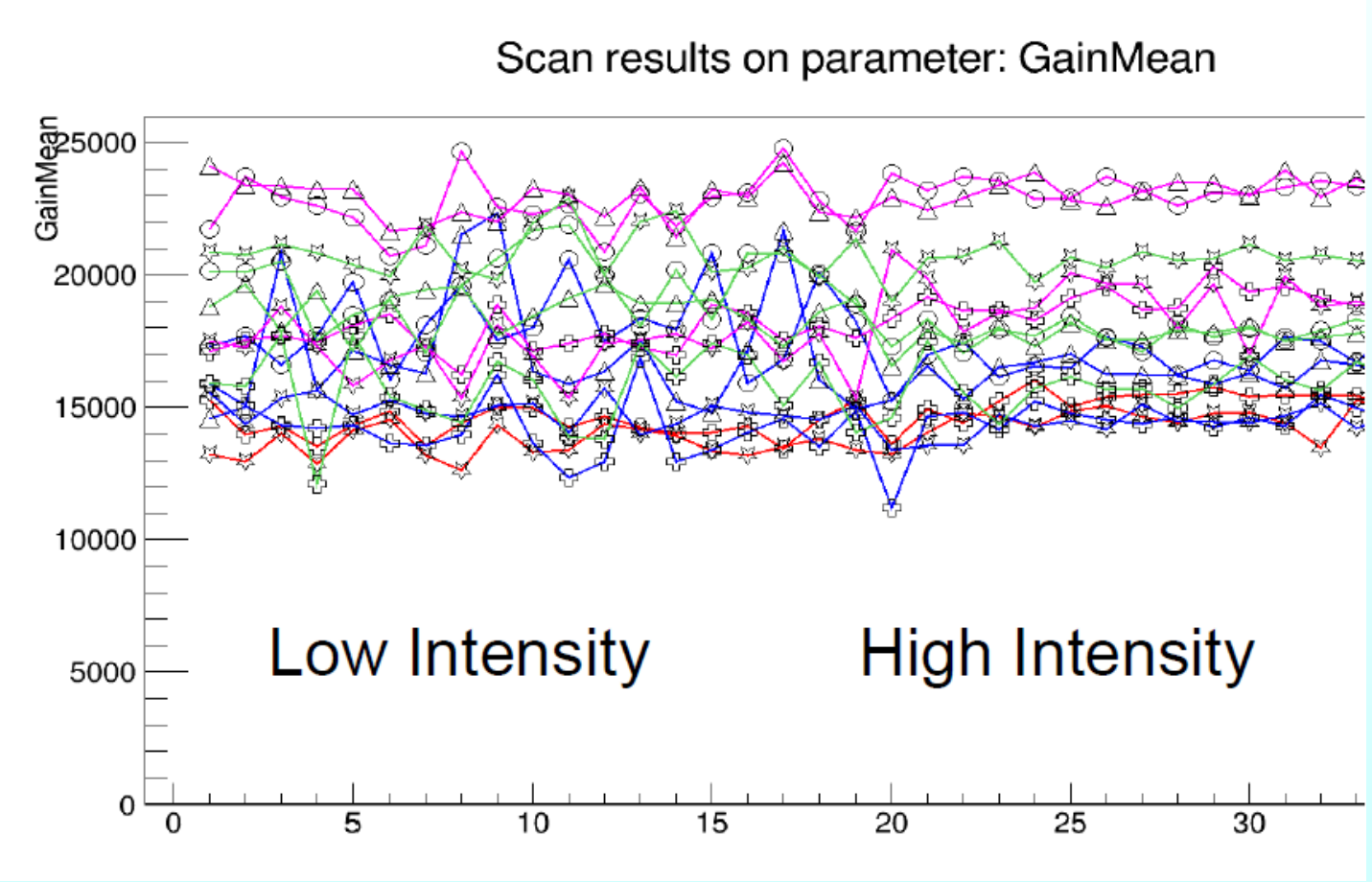
No such a gain in any MPGD in a running experiment.

Amplitude spectra for hits and clusters



The cluster size is larger for signals from charged particles

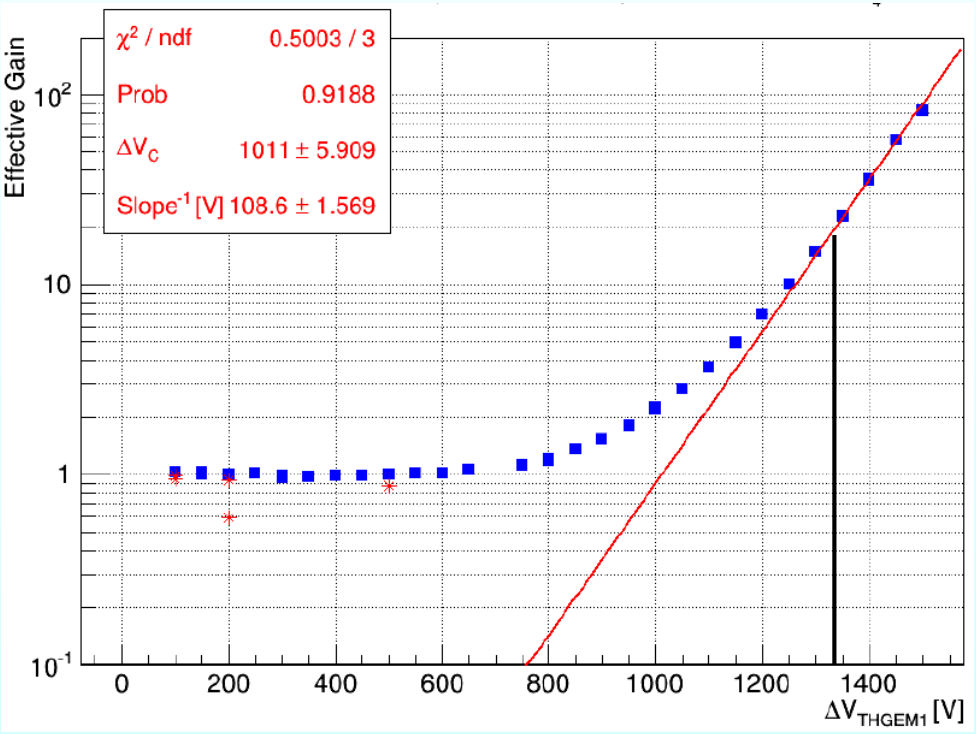
Response dependence on beam intensity



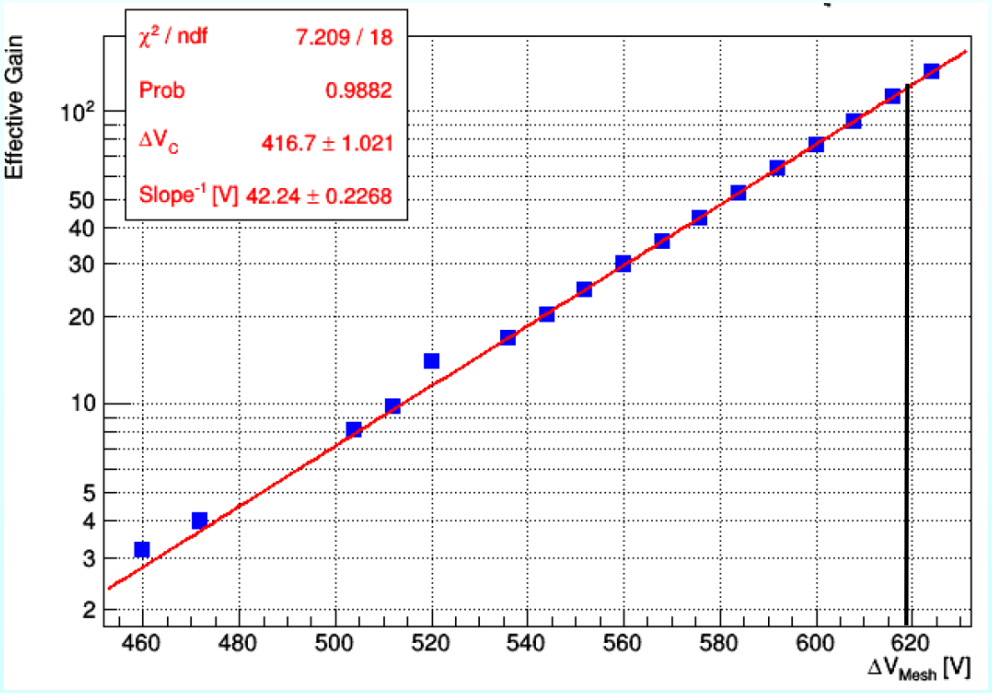
The effective gain does not vary when changing the COMPASS beam intensity by a factor of 2

Gain shearing among multiplication layers

Effective gain*transfer of THGEM1 in Ar/CH4, with THGEM2 and MM at nominal voltages



Effective gain of Mcromegas in Ar/CH4, with THGEM1 and THGEM2 at nominal voltages



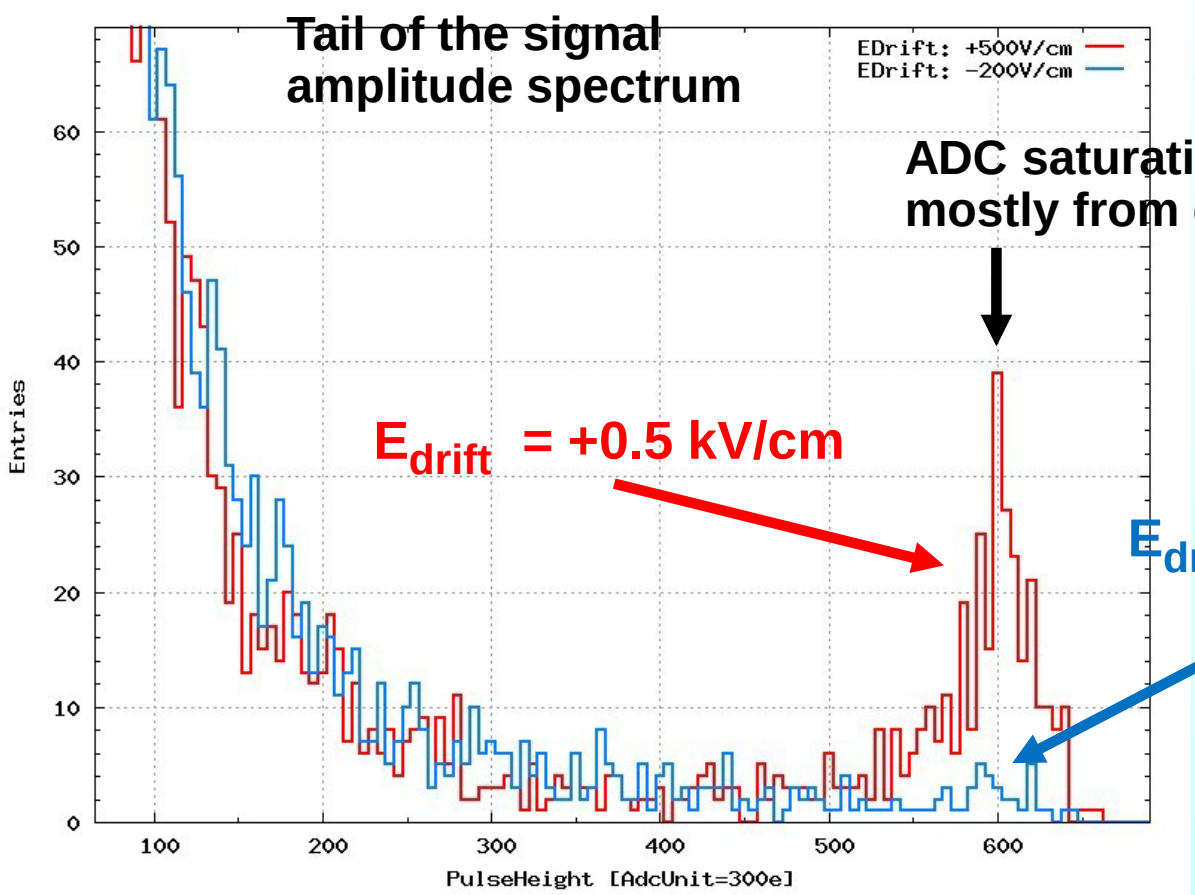
Nominal gain: ~30000 with:

THGEM1 gain* transfer1: ~ 20

THGEM2 gain*transfer2 ~ 15

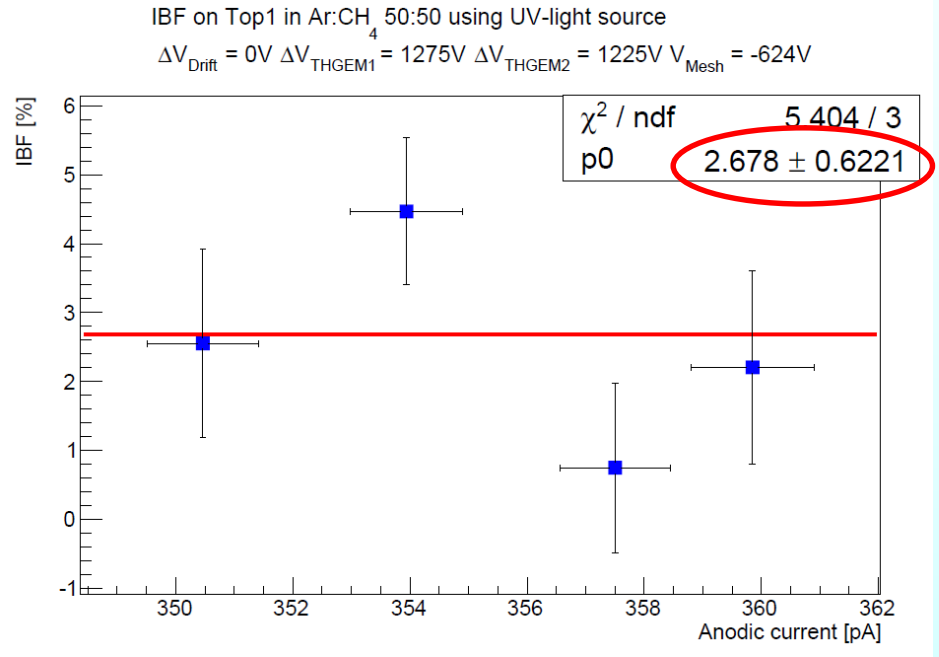
Micromegas gain ~100

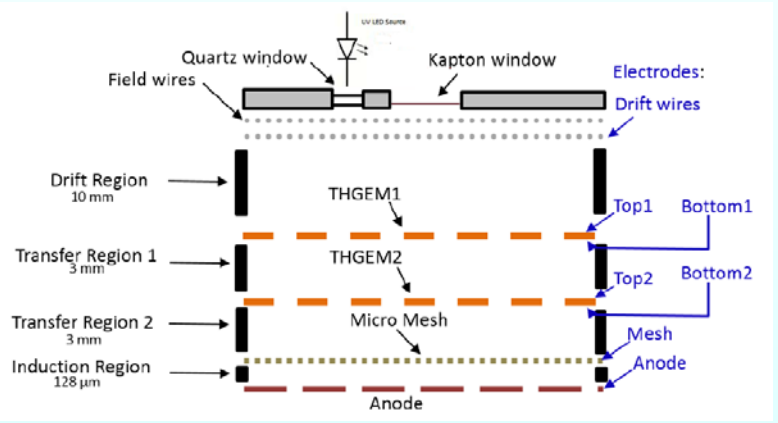
Reverse bias



The results of drift field scans confirm a good suppression of signals from charged particles in the nominal voltage configuration

IBF to photocathode (meas. in lab.)

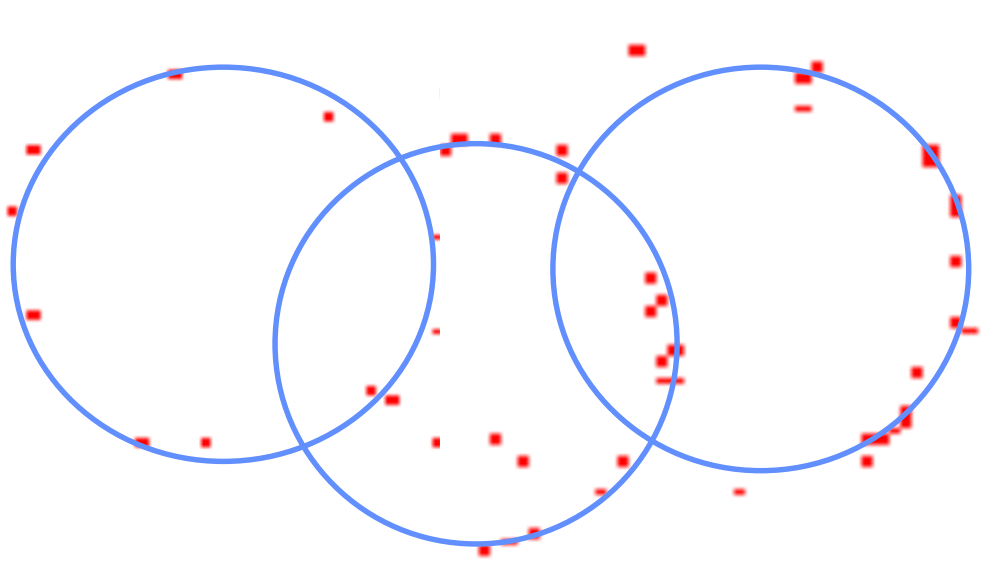


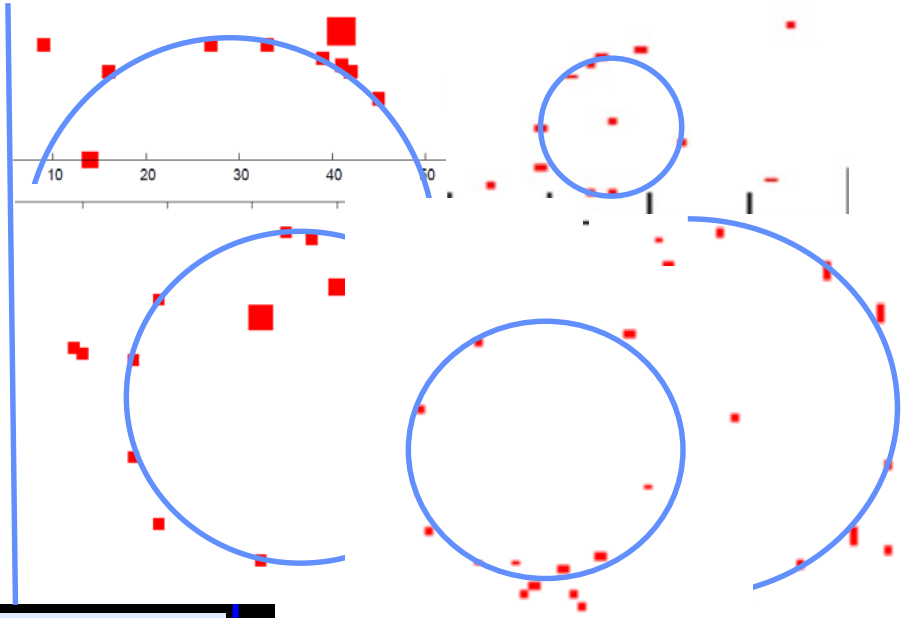


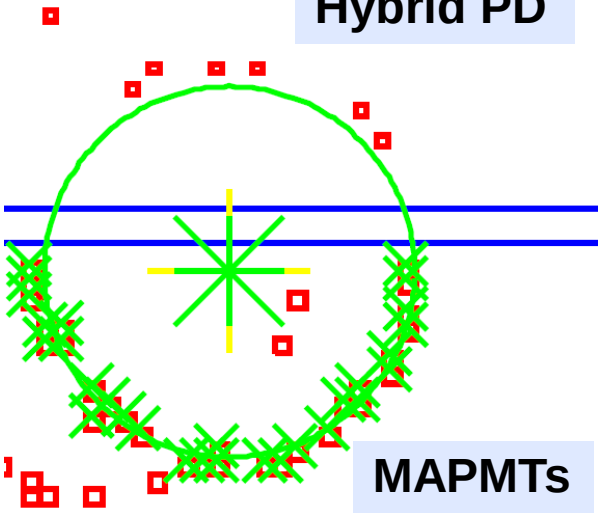
Trieste home-built picoammeters

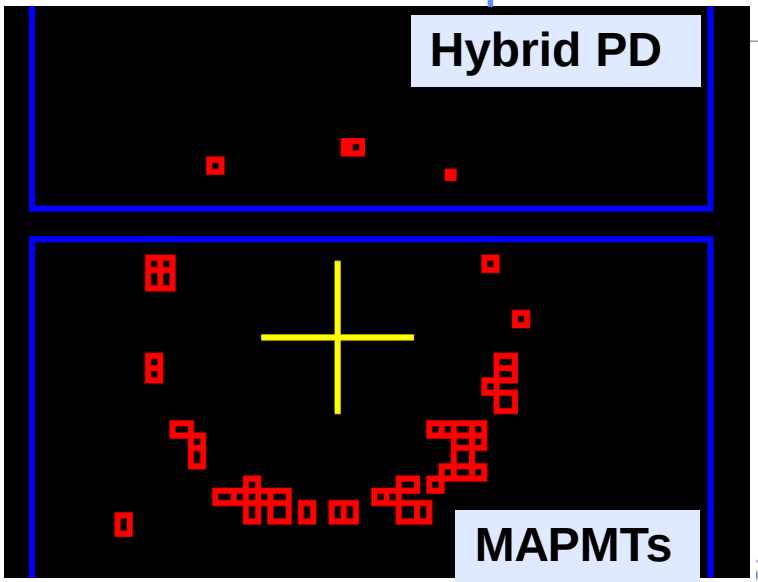
The result of the direct measurement: 3% nicely matches the expectation

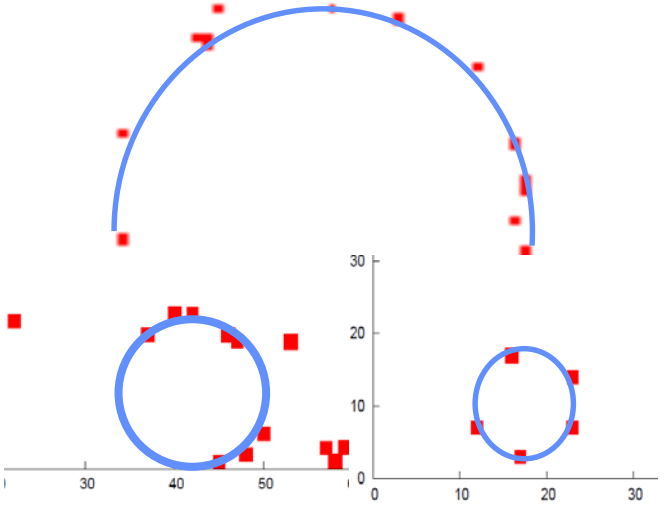
RINGS











CONCLUSIONS

- **COMPASS RICH-1 has been upgraded with 1.4 m^2 of MPGD-based PDs**
- **The Hybrid: 2 THGEMs + Micromegas detectors show good performance**
- **The choices of the 8 year long dedicated R&D program were confirmed**
- **Stable gain ~30k, good uniformity, nice RINGS being collected**
- **A detailed characterization work is ongoing: promising indications**
- **The upgraded RICH-1 is presently running with full efficiency.**