Novel MPGD based Detectors of Single Photons for COMPASS RICH-1 Upgrade

Outline

- Basics
- Why this upgrade and how
- R&D and Detector commissioning
- Results
- Conclusions

Shuddha Shankar Dasgupta

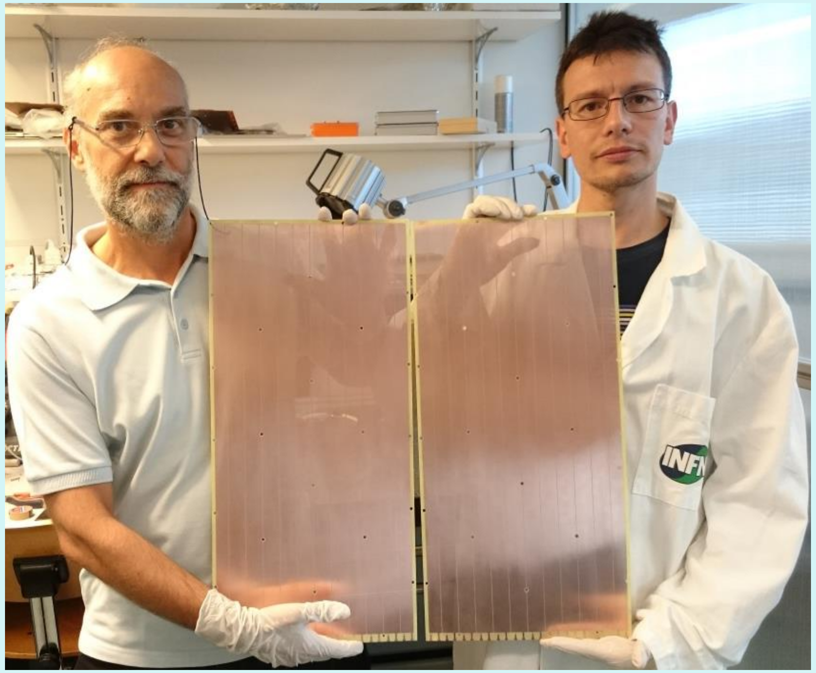
INFN Sezzione di Trieste

On behalf of

COMPASS THGEM Group

Alessandria, Aveiro, Freiburg, Kolkata, Liberec, Prague, Torino

NDIP2017



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COMPASS Experiment @ CERN

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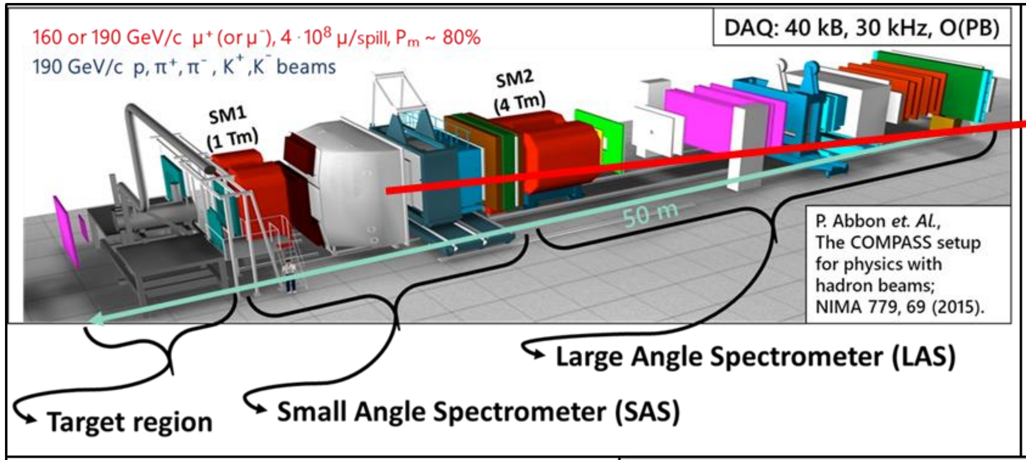
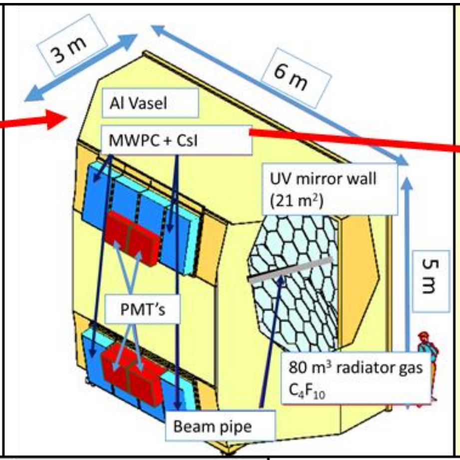
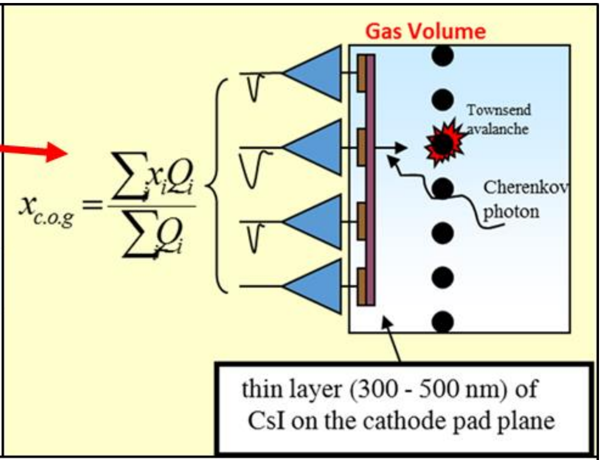
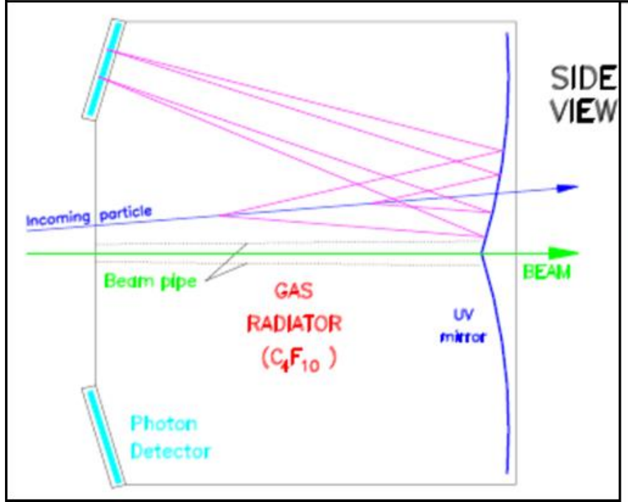
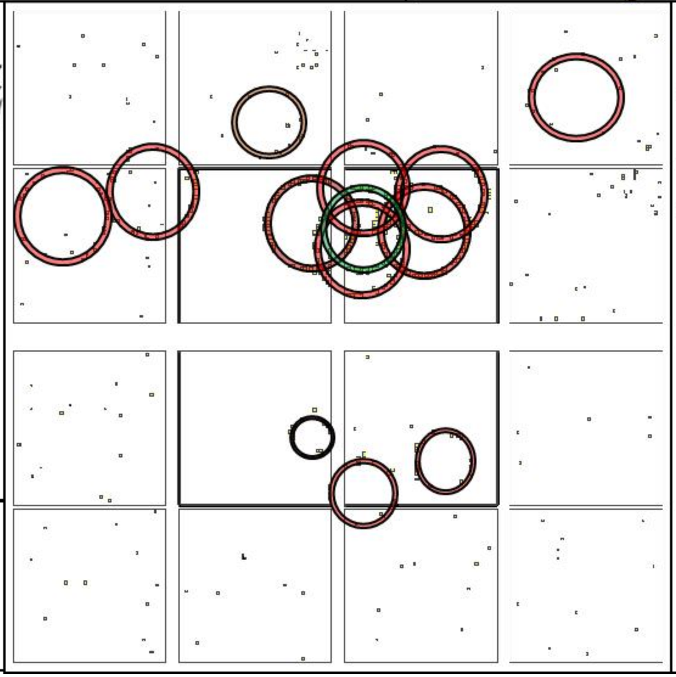


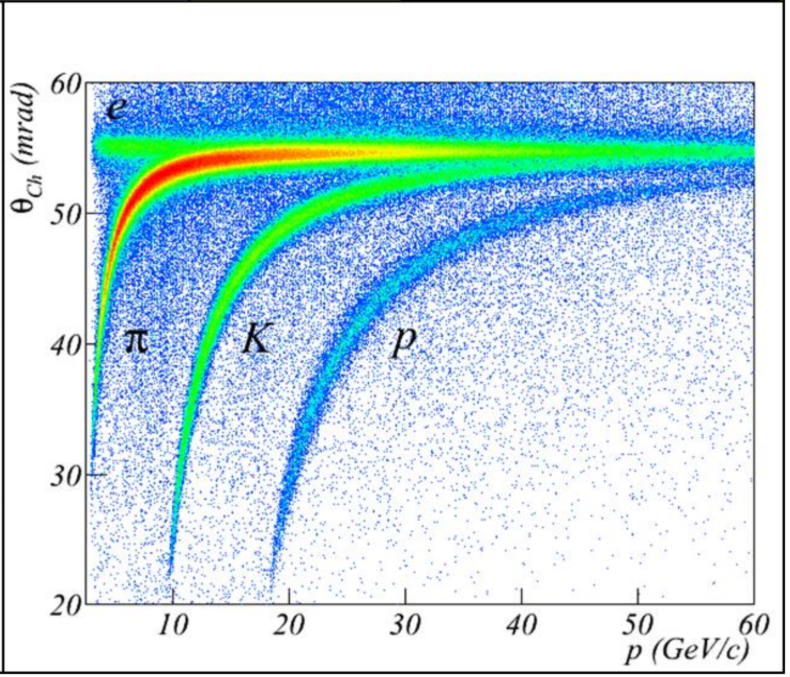






$$\cos\theta_C = \frac{1}{n\beta}$$





COMPASS Experiment @ CERN

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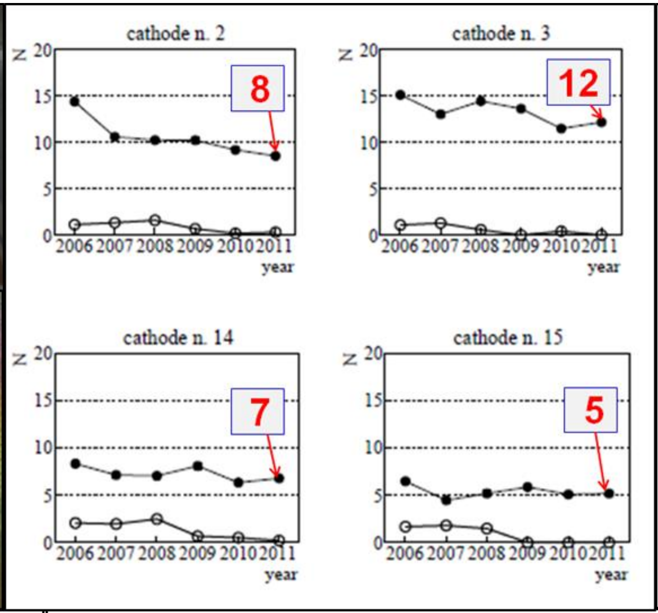
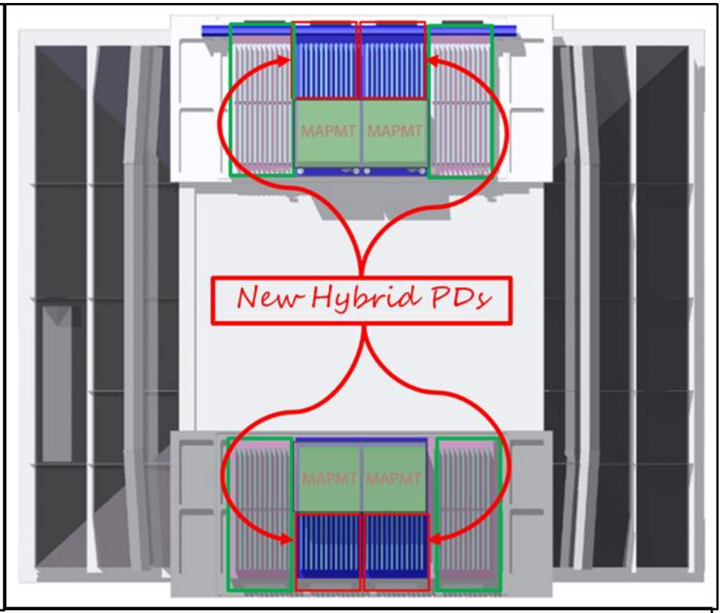


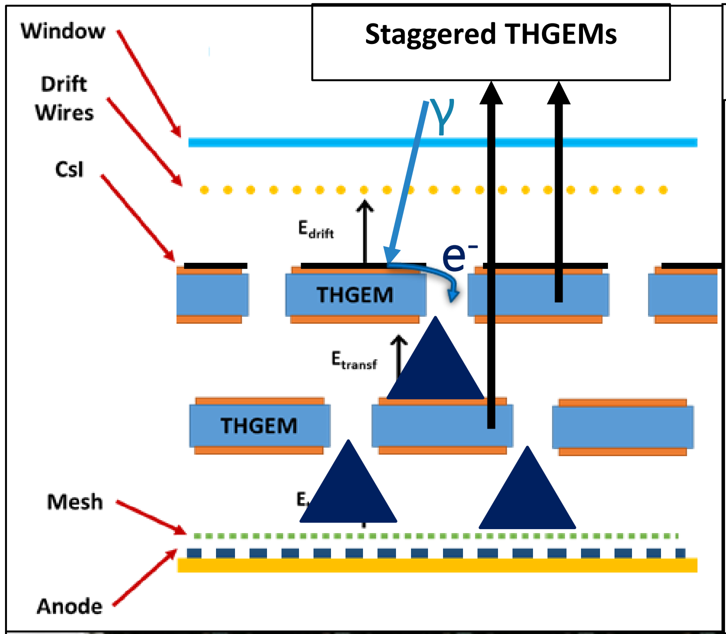


For MWPCs limitations are

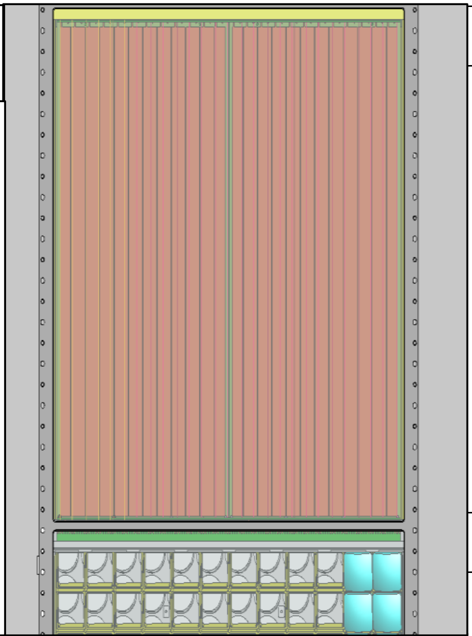
- Low gain, long recovery time after a discharge…
- Slow time response.
- Photon and ion feed back to the photocathode -> Open geometry

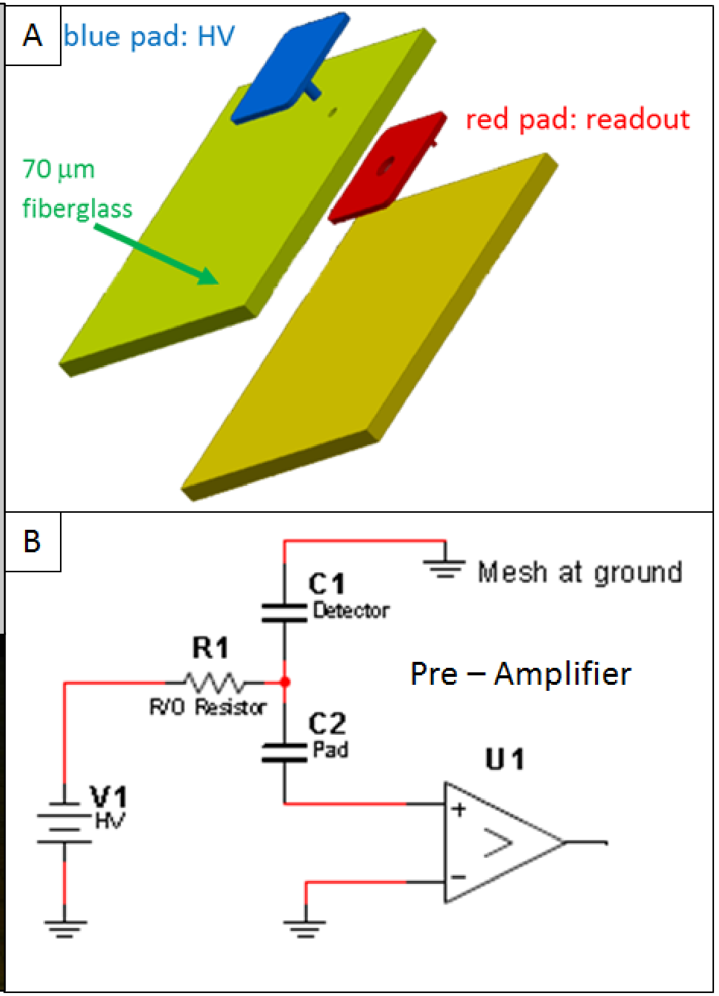
- In order to cope with the challenging requests posed by the future physics program of COMPASS a set of new generation, high performing photon detectors with an active area of 576X576 mm^2 will be installed. The characteristics of the new detectors are:
  1. A small time resolution $\leq 10\ ns$.
  2. A closed geometry to avoid photon feedback.
  3. A large gain ($\geq 10^5$).
  4. A reduced Ion Back – Flow (IBF) to the CsI photocathode ($\leq few\ \%$).

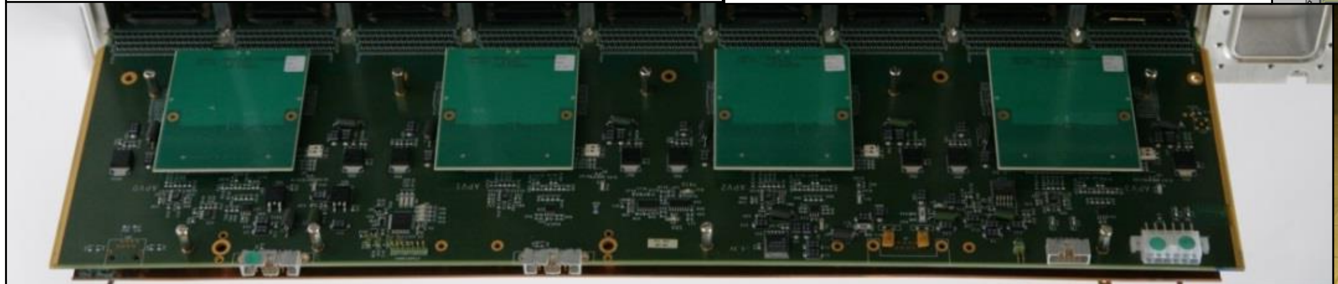
The final photon detectors



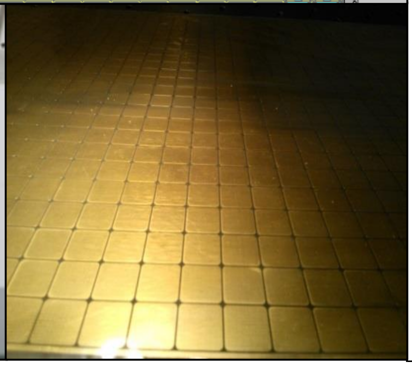
each detectors consists of two modules having 600 x 300 mm²



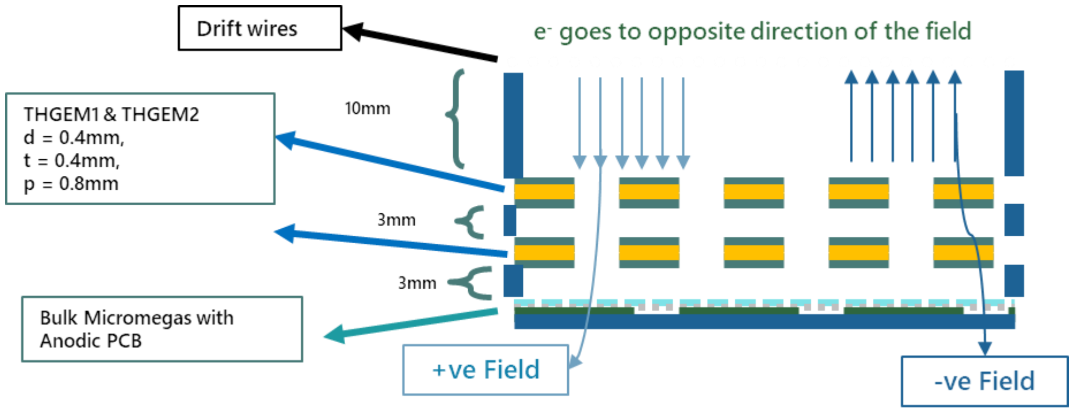




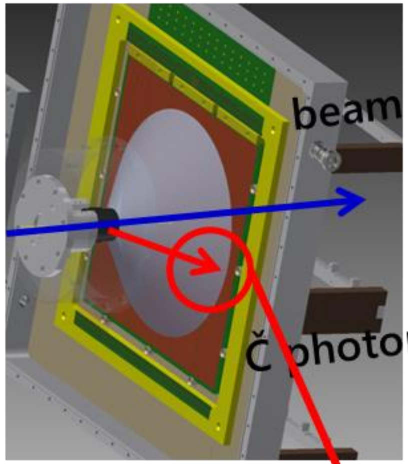
Signal read out via capacitive coupling pad readout and APV25 F/E boards

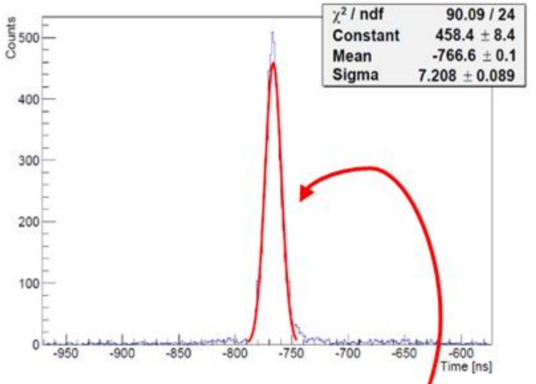


The hybrid detector concept, a change in technology the proof of the choice

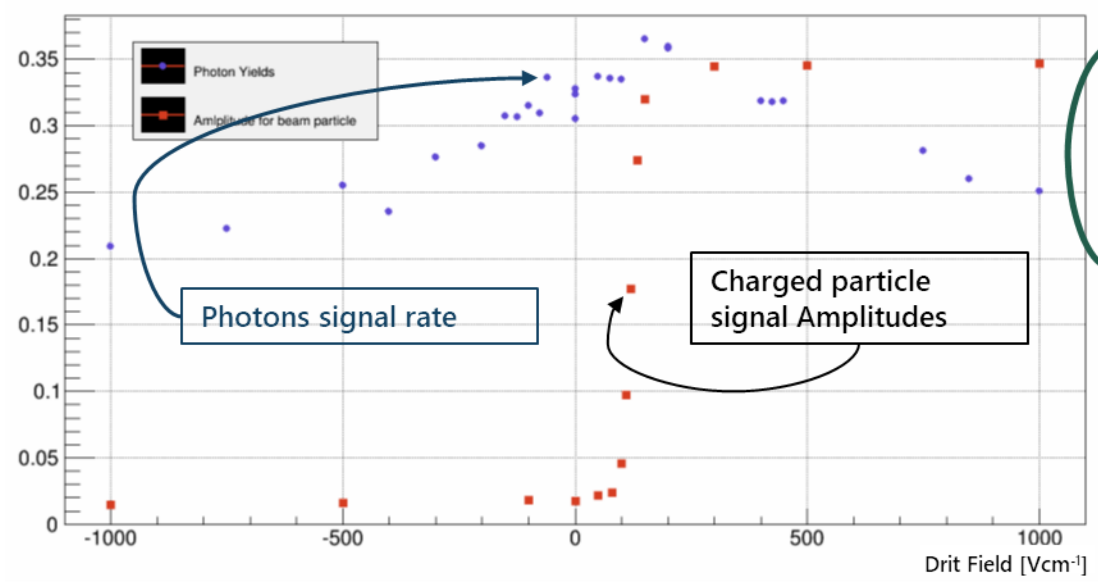


- The 1st THGEM forms the PC
- The 2nd THGEM (staggered) forces the electron diffusion
- The MM provides large gain, made larger by the diffusing the impinging electron cloud

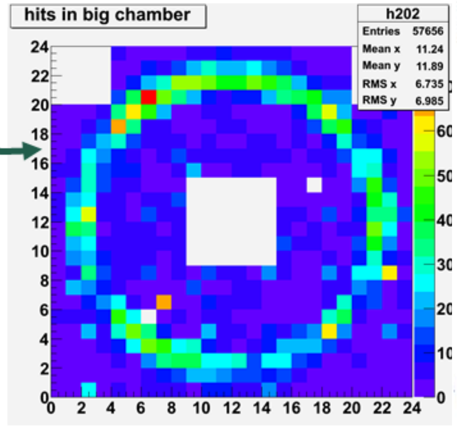




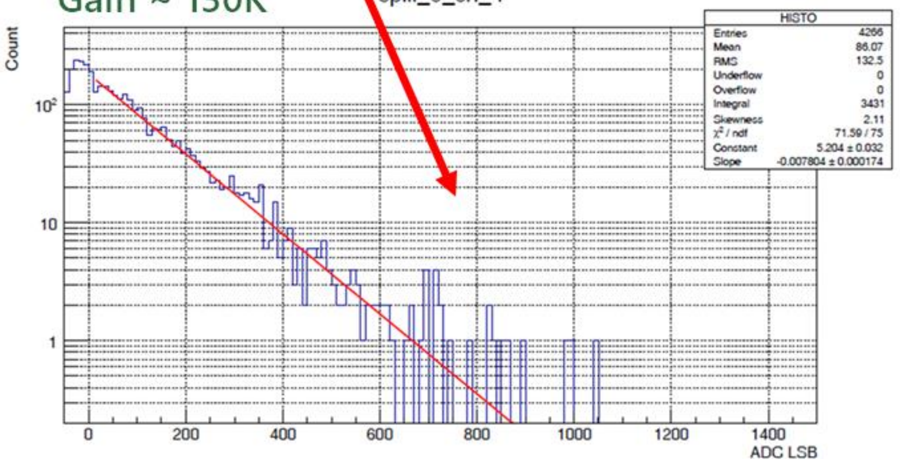
7 ns



Čerenkov RING



Single photon spectra
Gain ~ 130K



Pre production quality control

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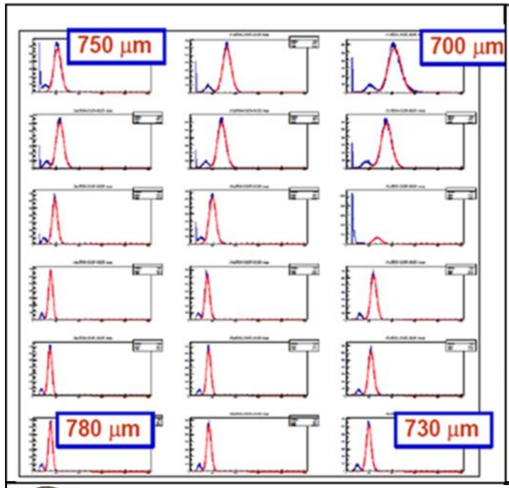
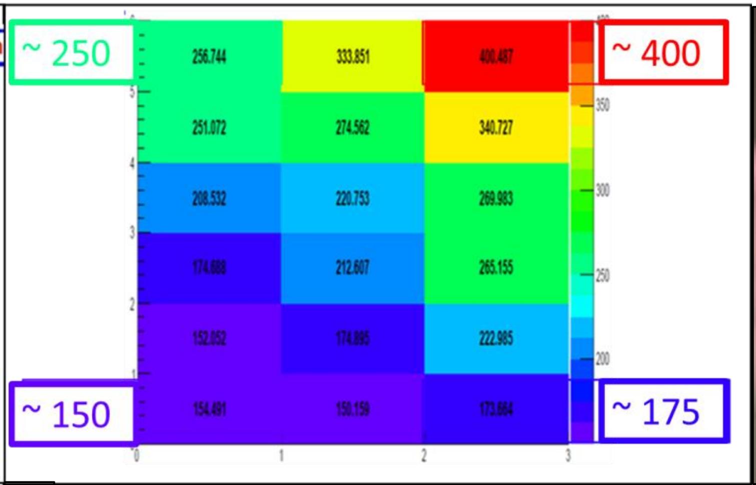
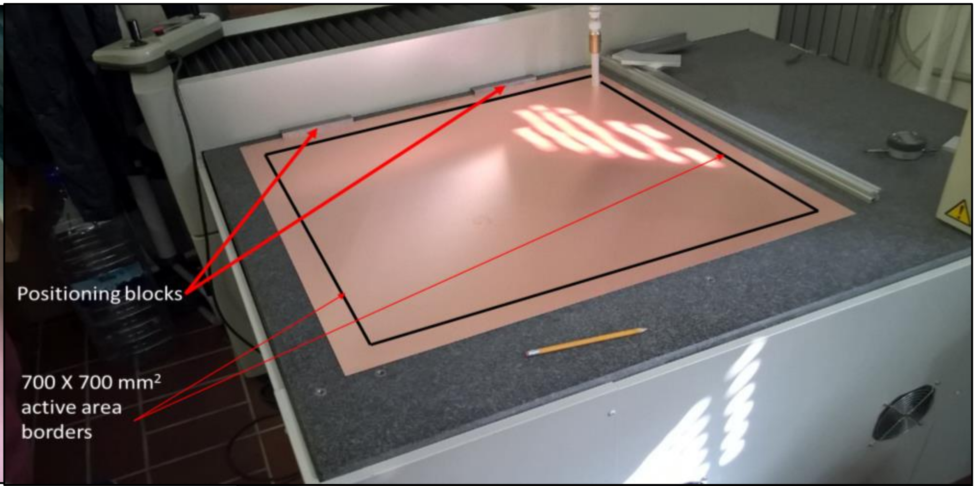






Elite Material Co., Ltd. — Technical Data
http:\\www.emctw.com

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
Permittivity (RC 50%) 1 GHz	2.5.5.9	C-24/23/50	–	4.3
Volume resistivity	2.5.17.1	C-96/35/90	MΩ-cm	>10¹⁰
Surface resistivity	2.5.17.1	C-96/35/90	MΩ	>10⁹

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

50 foils of 1245 mm x 1092 mm

→ cut out borders

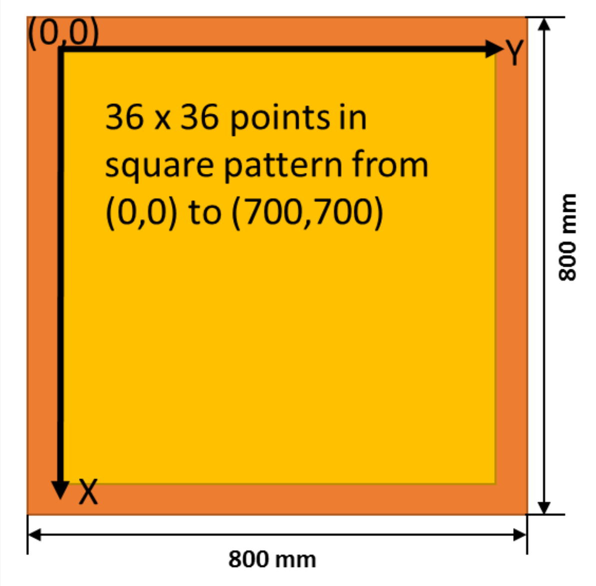
→ 800 mm x 800 mm

→ thickness measurement

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

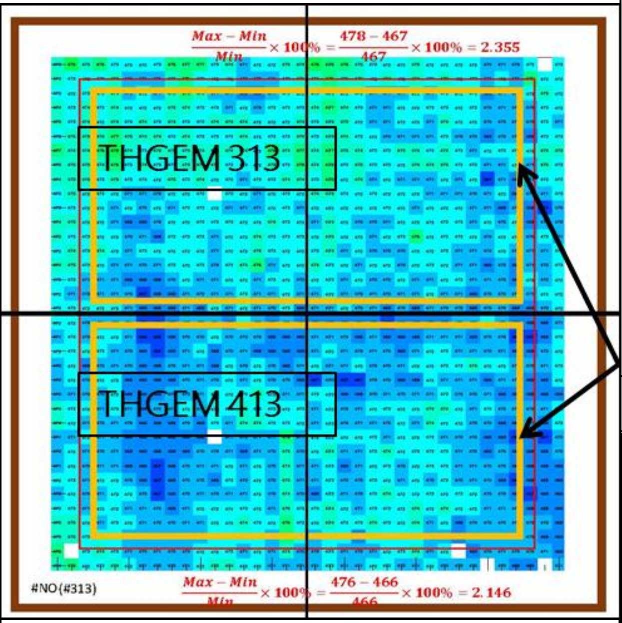
under pressure to induced flatness

Pre production quality control



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

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



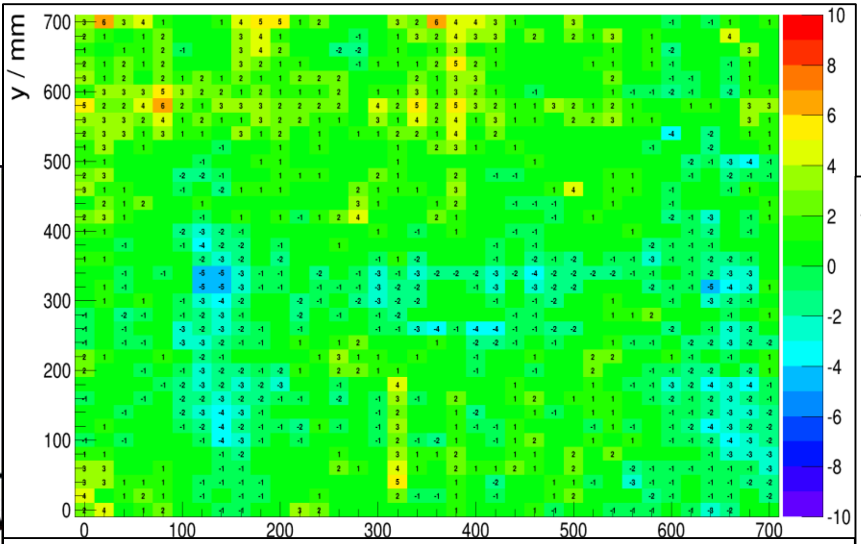
about half of the foils sent to ELTOS for THGEM production

from each foil two THGEMS can be produced:

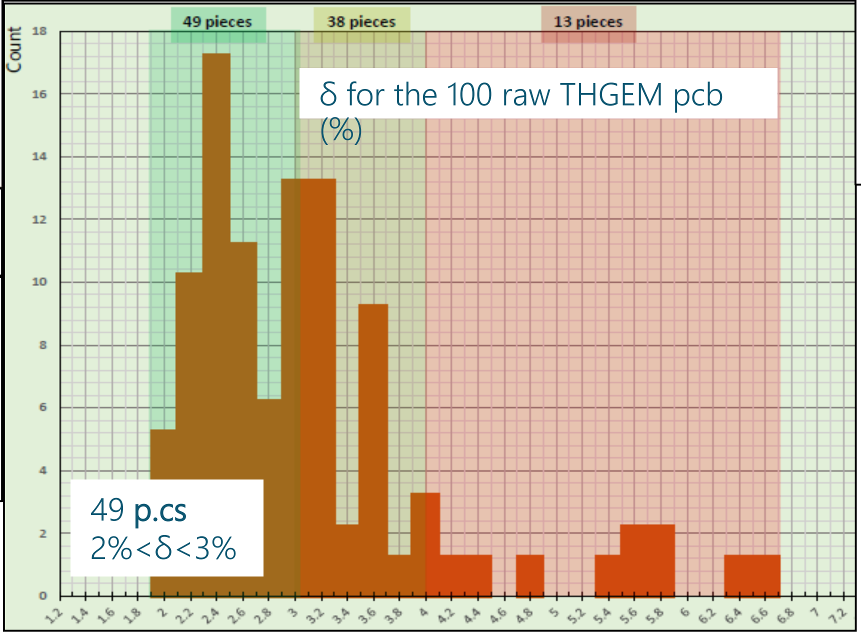
50 foils → 100 raw THGEM pcb

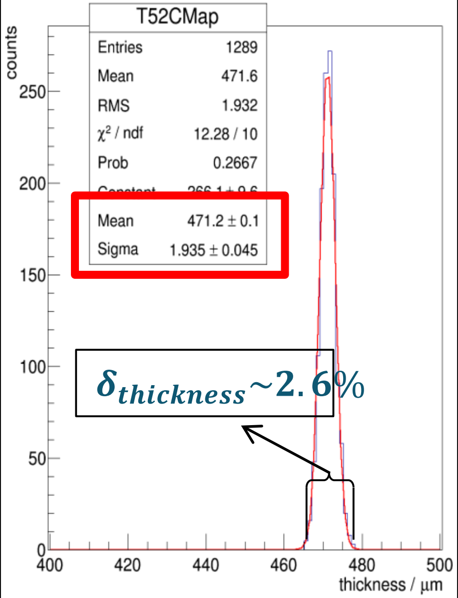
THGEM pcb size = 620 mm x 320 mm,

active area = 581 mm x 287 mm

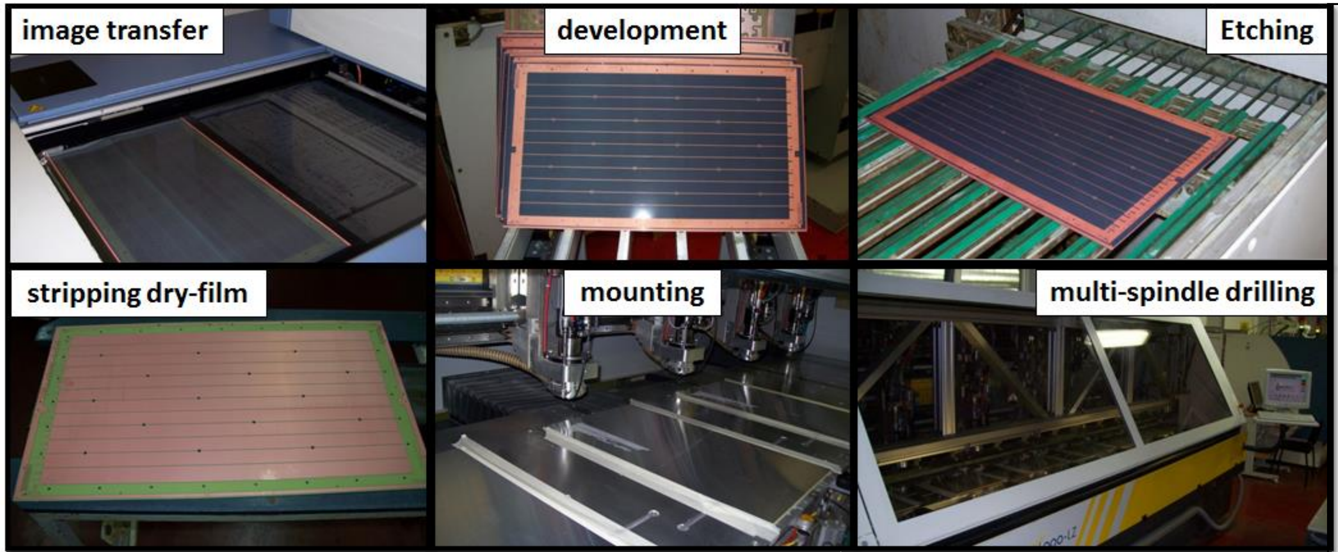


typical result for a good piece.

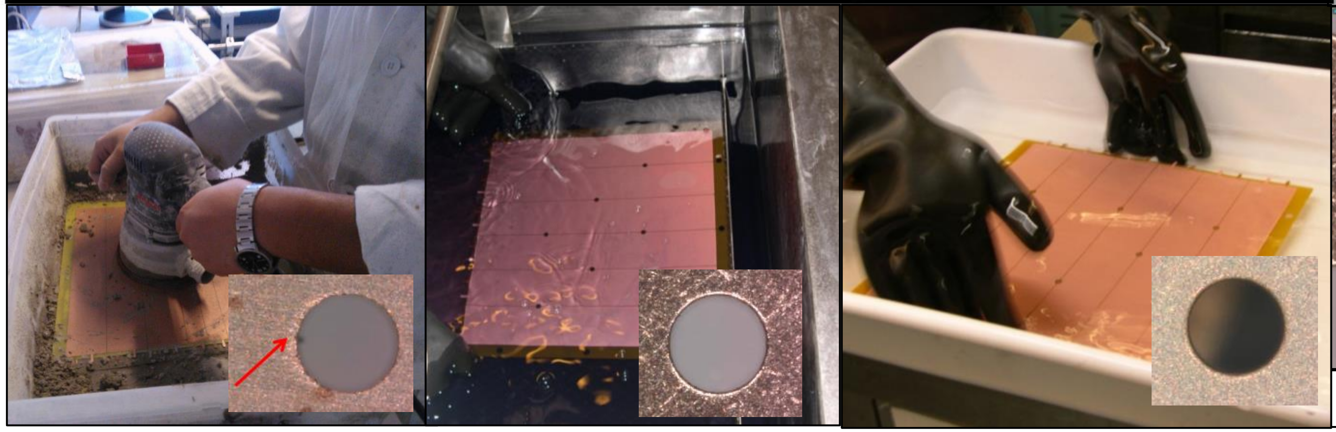


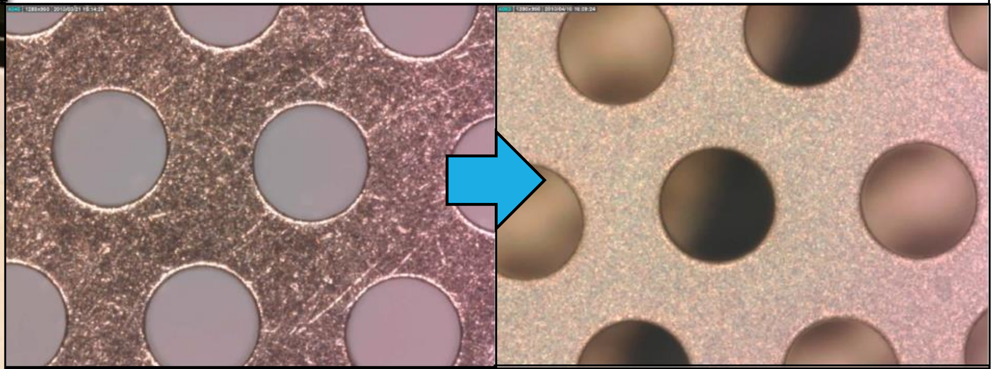


THGEM post production treatment



- To drill 300K holes, it takes ~ 14 hrs
- The cost is 1 Euro for 1000 holes…
- We (at ELTOS spa, Italy) produced ~ 12 m^2





Before treatment | After treatment

THGEM post production treatment

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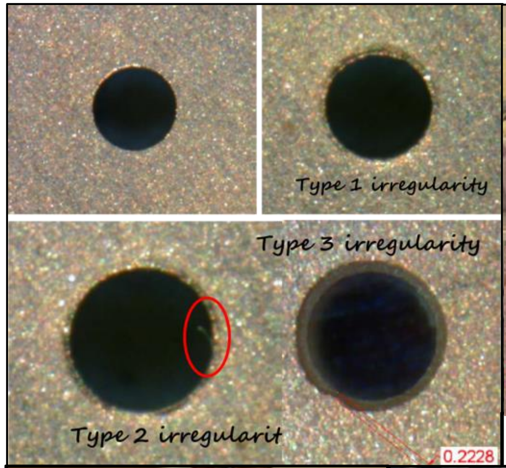
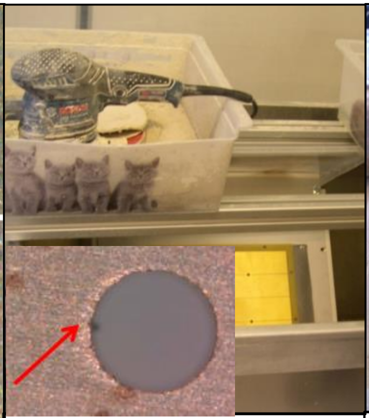
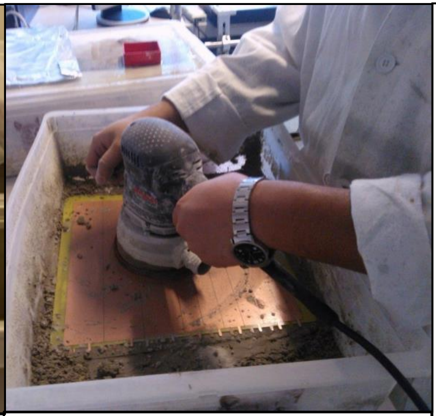


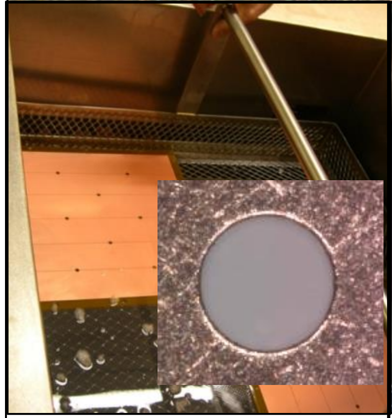


Polishing machine

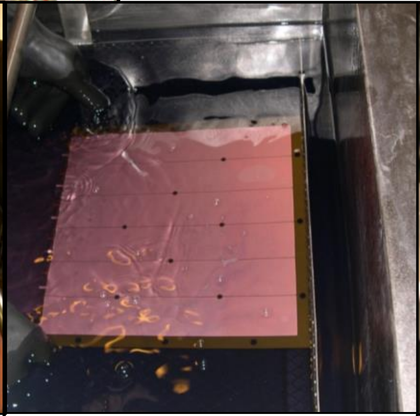


The way we polish

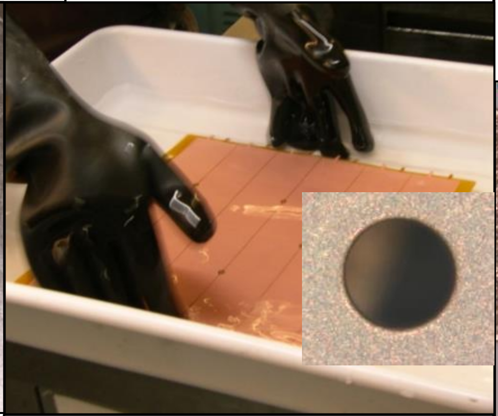
- Polishing (Hinrichs Pumice Powder)
- Cleaning with high pressure water to remove all pumice residuals
- Ultrasonic bath (~1 h) @ 50-60 °C in Sonica PCB solution (pH11)
- Washing with demineralized water + oven at 180 °C for 24 h



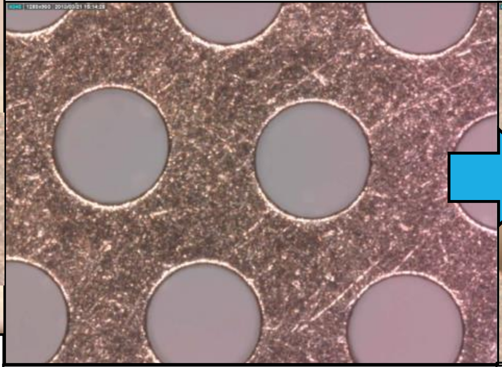
Pieces inside Ultrasonic bath



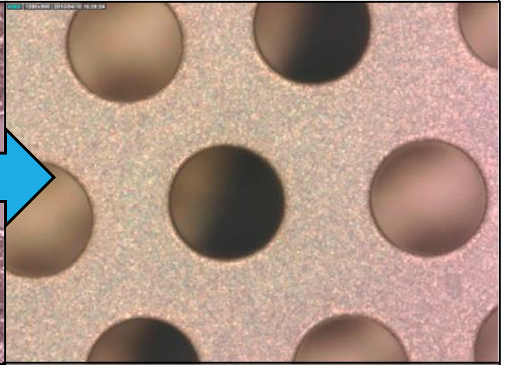
Cleaned piece in the bath



Cleaning of the piece in de – minarilized water



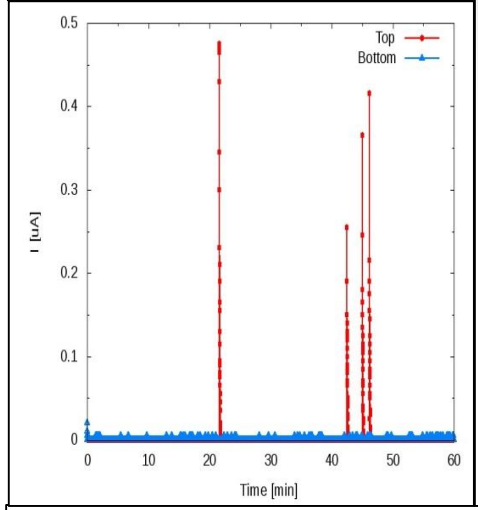
Before treatment



After treatment

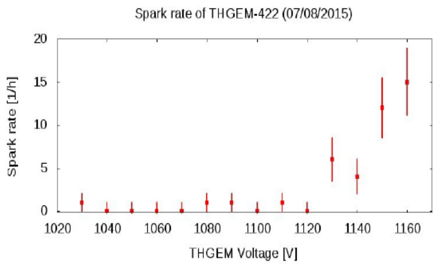
THGEM Quality Assessment

current monitor recording, discharge counting



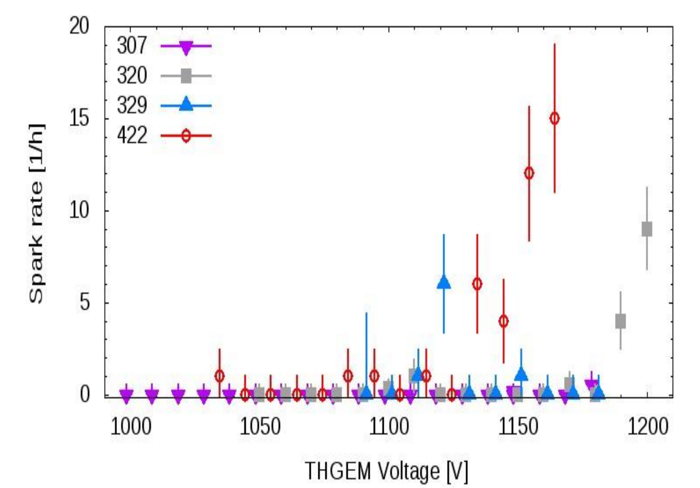
THGEM : 422

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



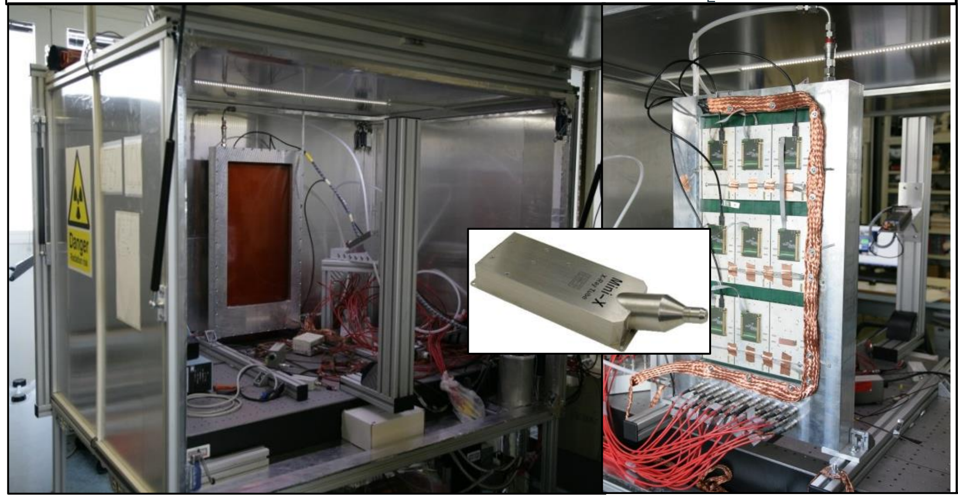
THGEM : 307

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

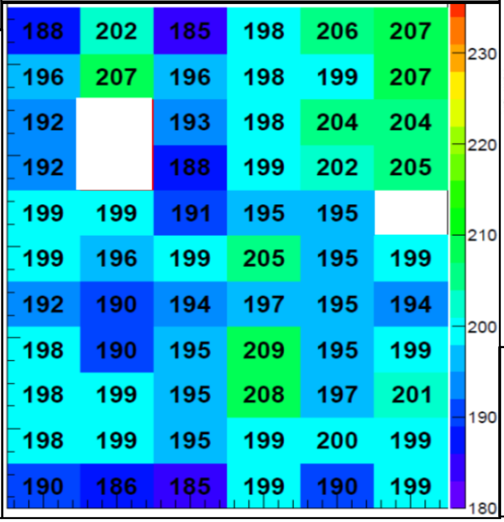


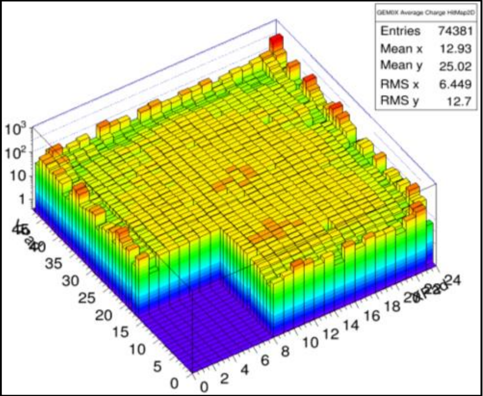
first 4 pieces: 1 rejected. Possibly recovered by repeating the cleaning treatment

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)



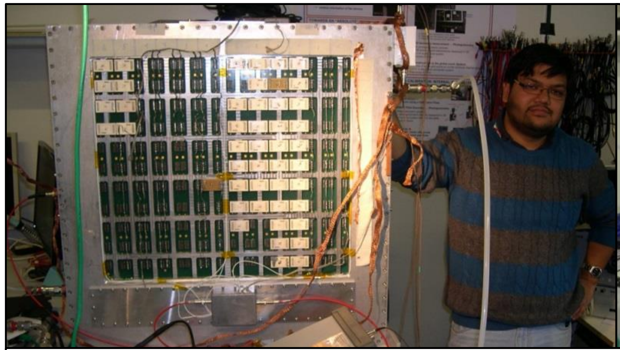
Gain uniformity measurement

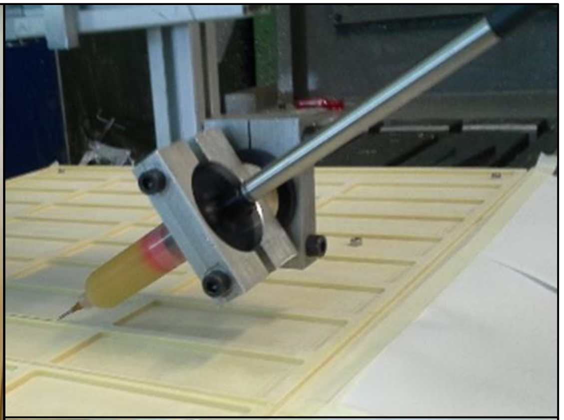


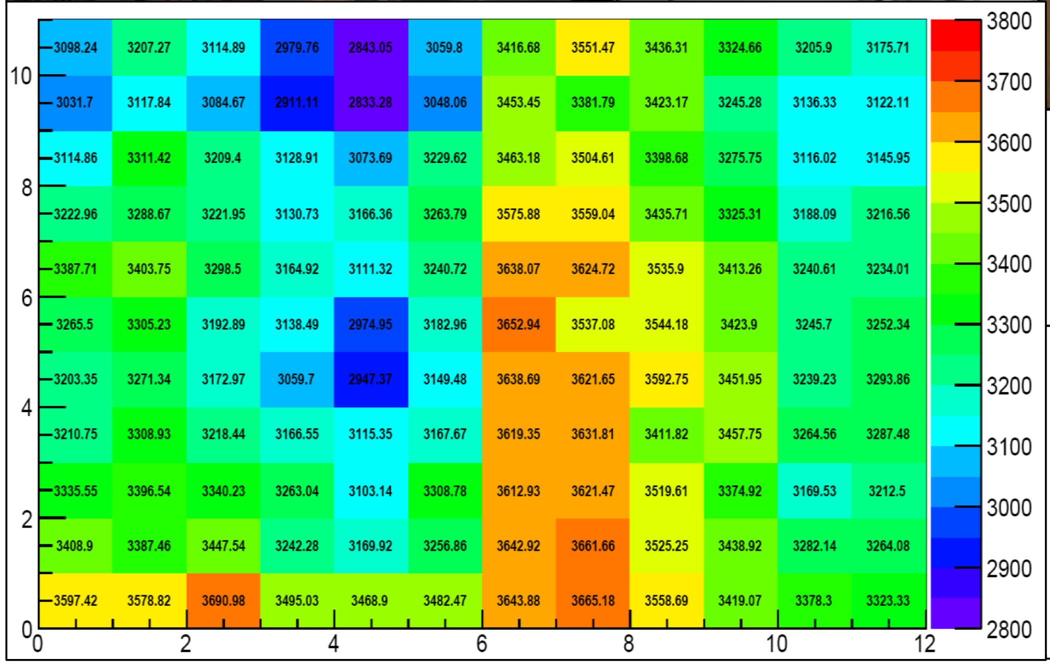


Gain Uniformity using APV – 25 based R/O
Uniformity ~ 10%

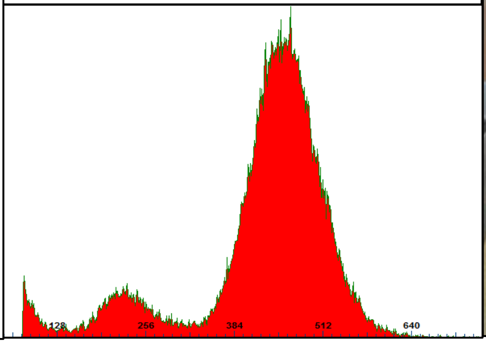
Micromegas

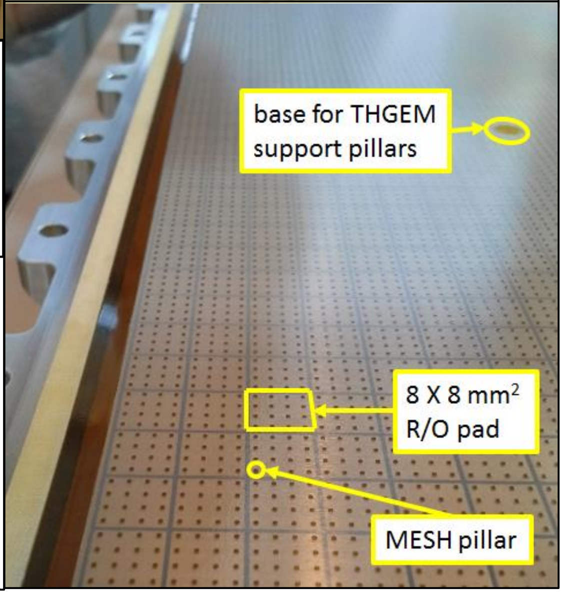






s/<G> = 5% for each of the two Micromegas





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Assembling new PDs

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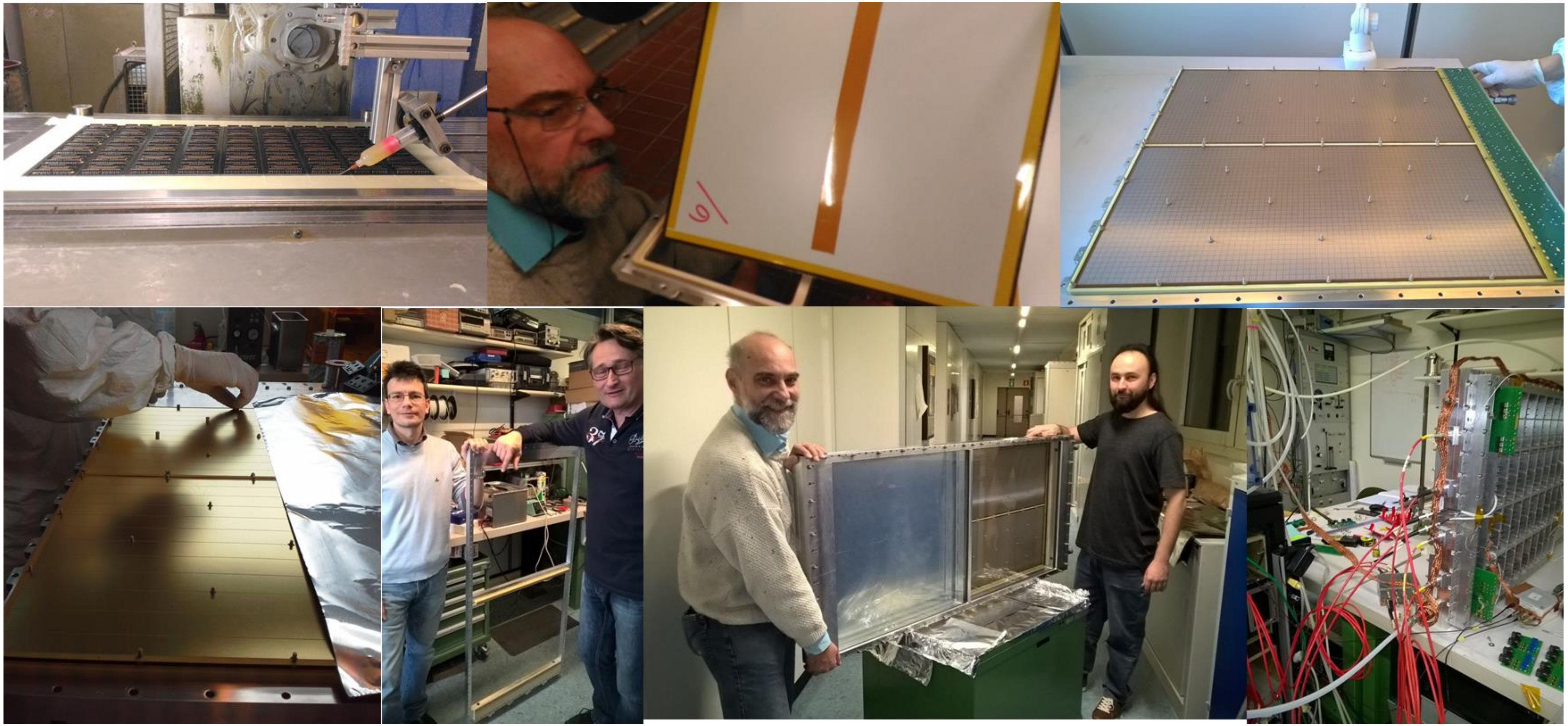
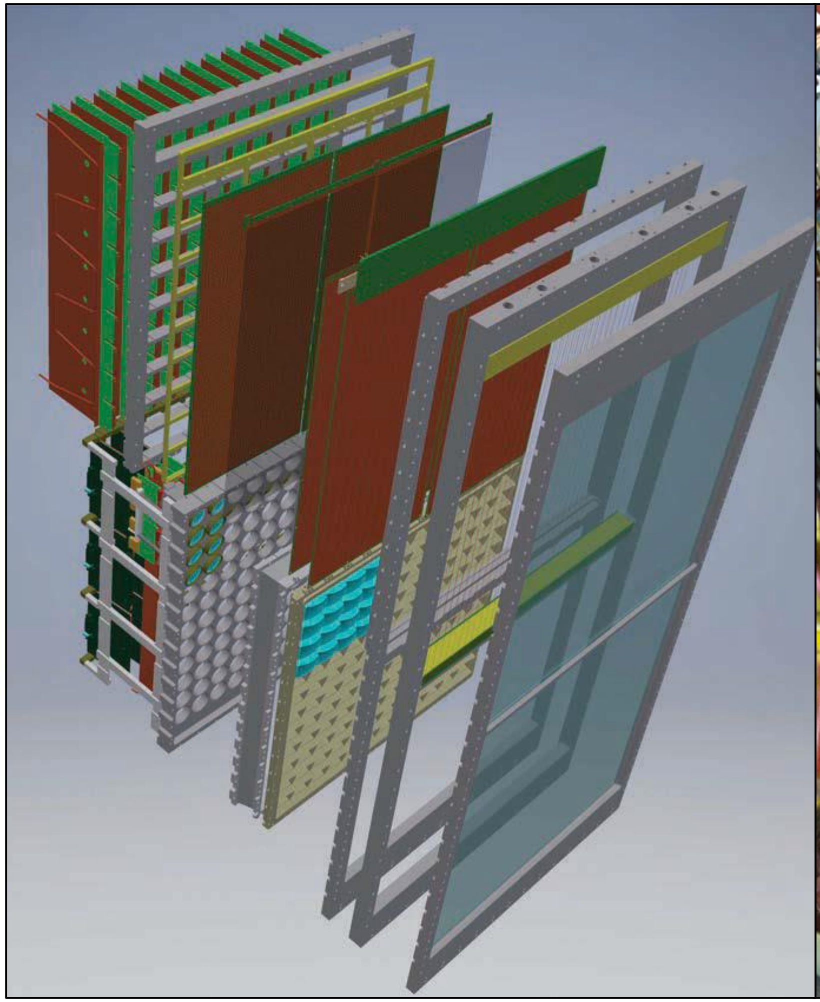
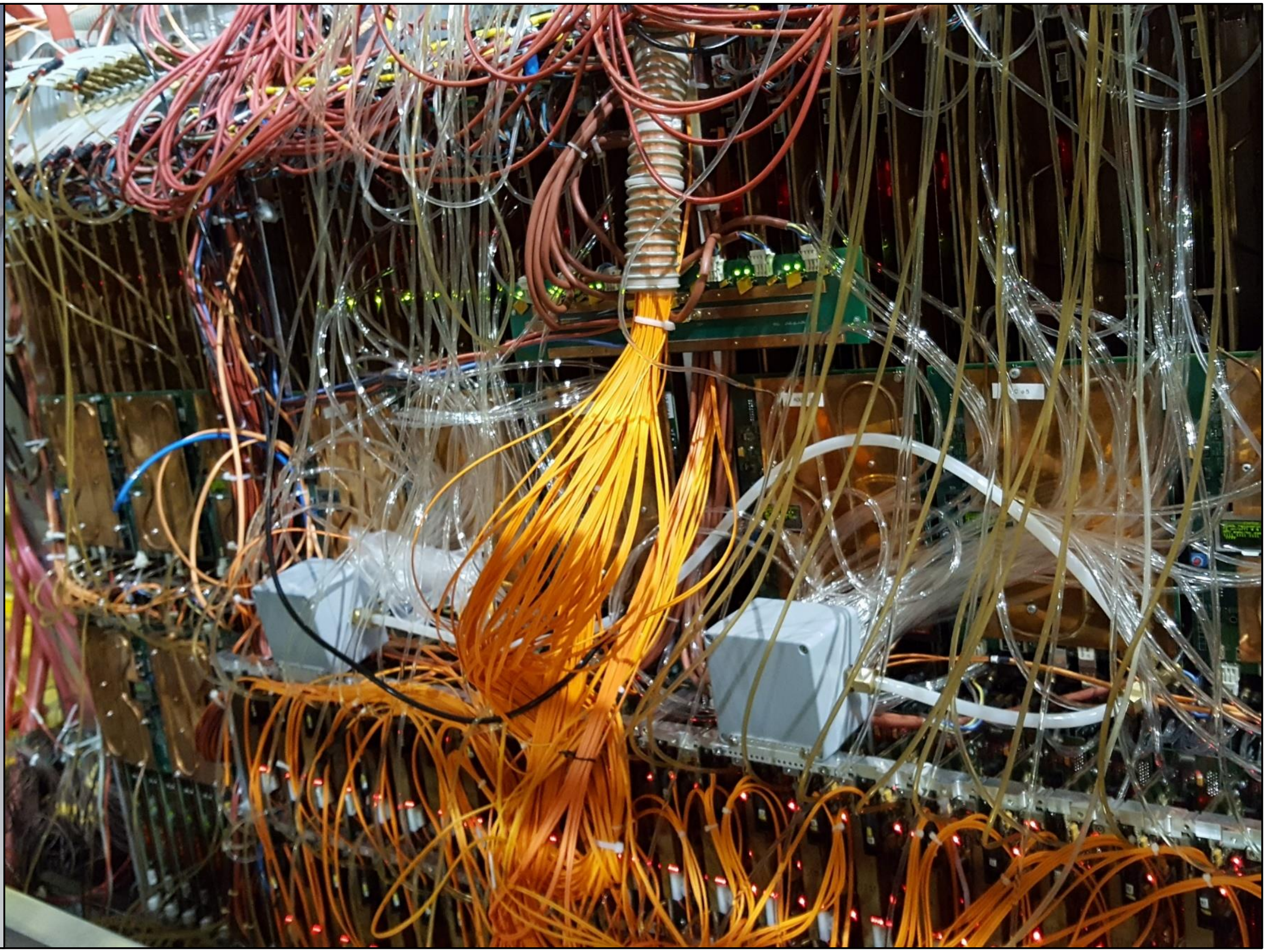


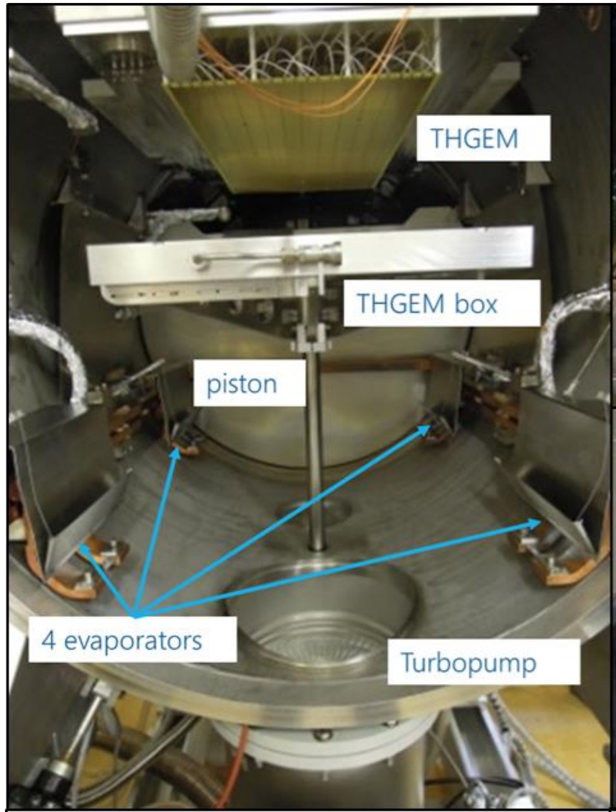
Complexity of the upgrade



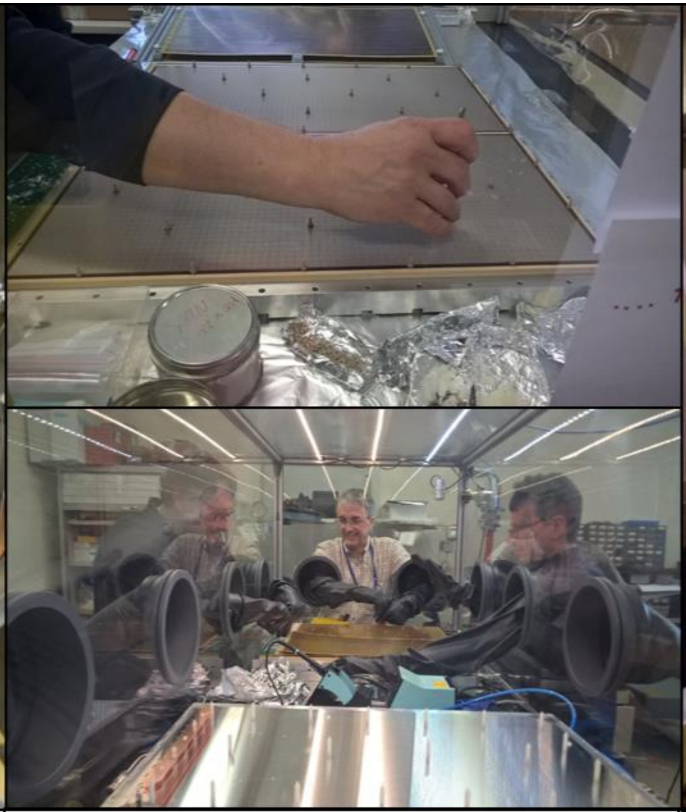


Installation of the new PDs

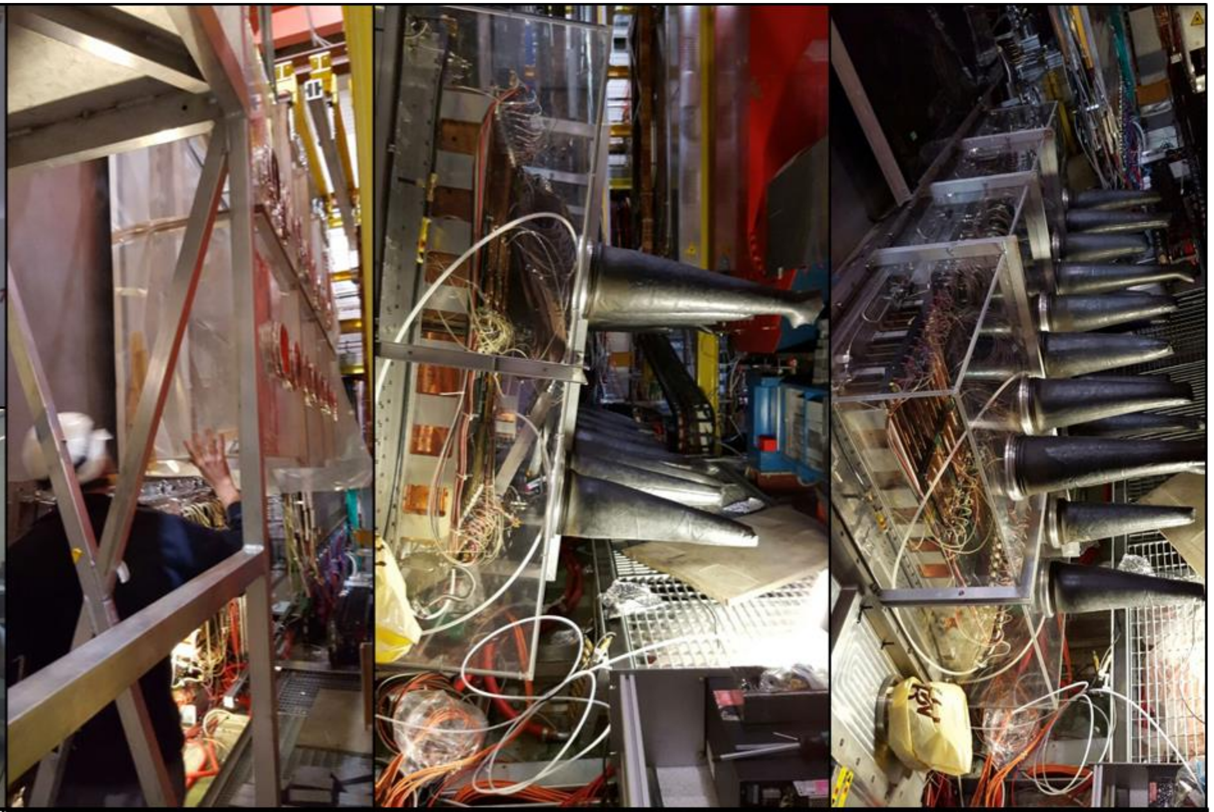
CsI Photo-cathode preparation



CsI evaporation plant



Mounting of CsI PC in lab



Mounting of Hybrid modules with CsI PC on to the RICH

HV control system with p, T correction

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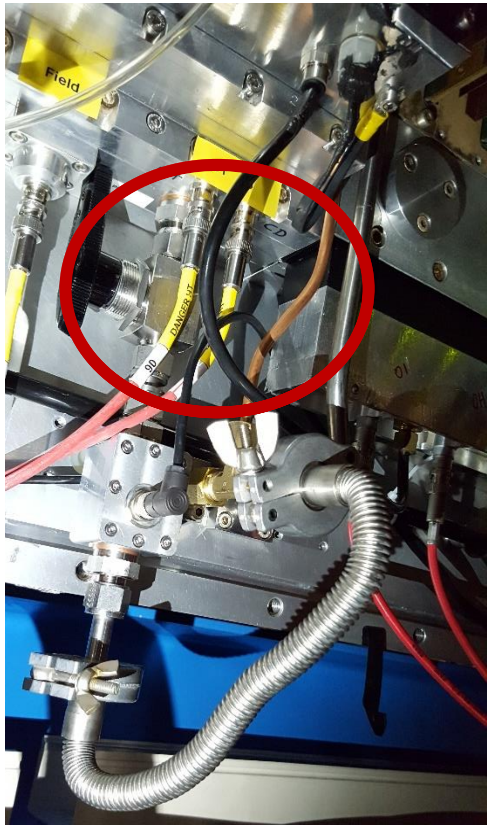
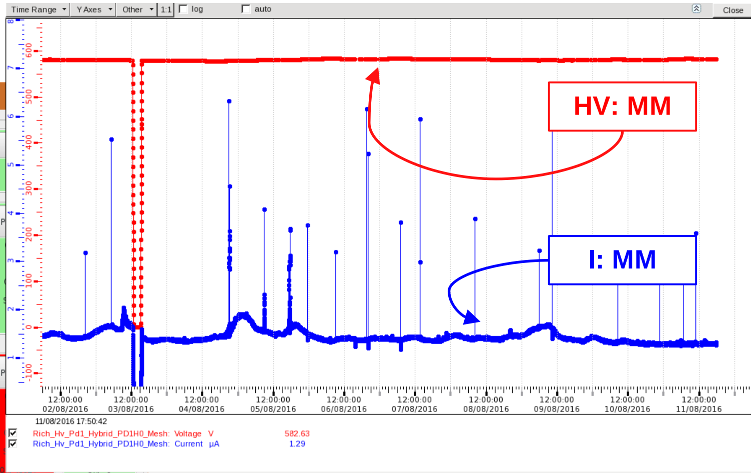
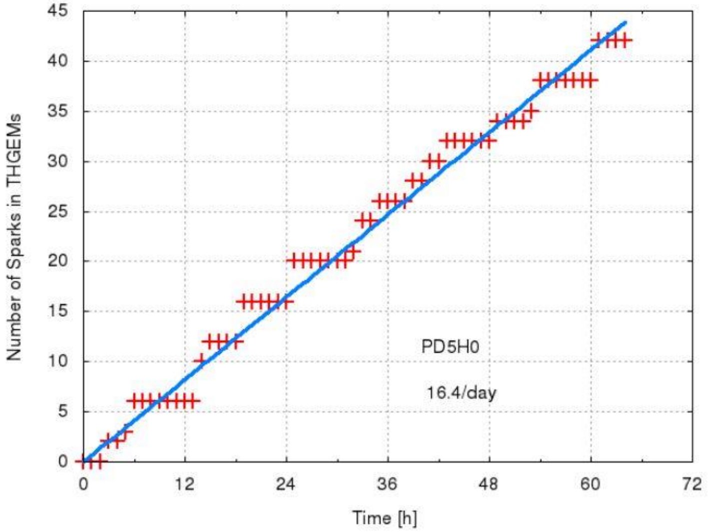
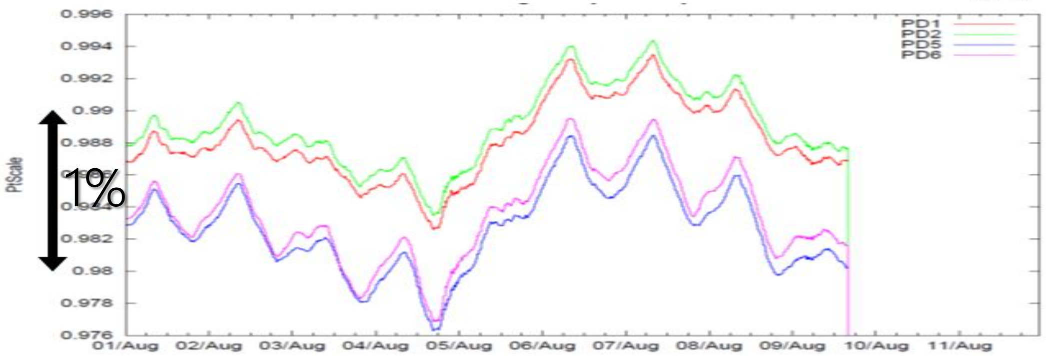
A dedicated HV control system has been designed programmed and tested to control and monitor new Hybrid Detectors: 104 HV channels in 9 different electrode types with diversified function in 16 sectors







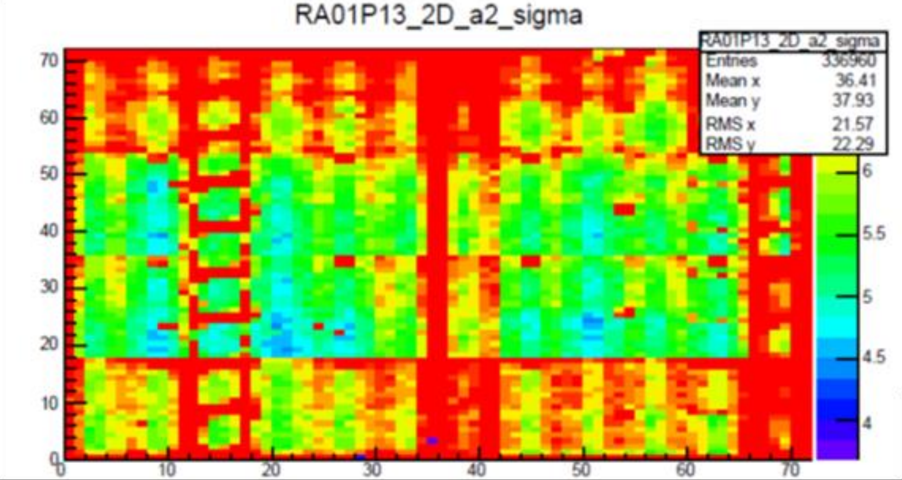


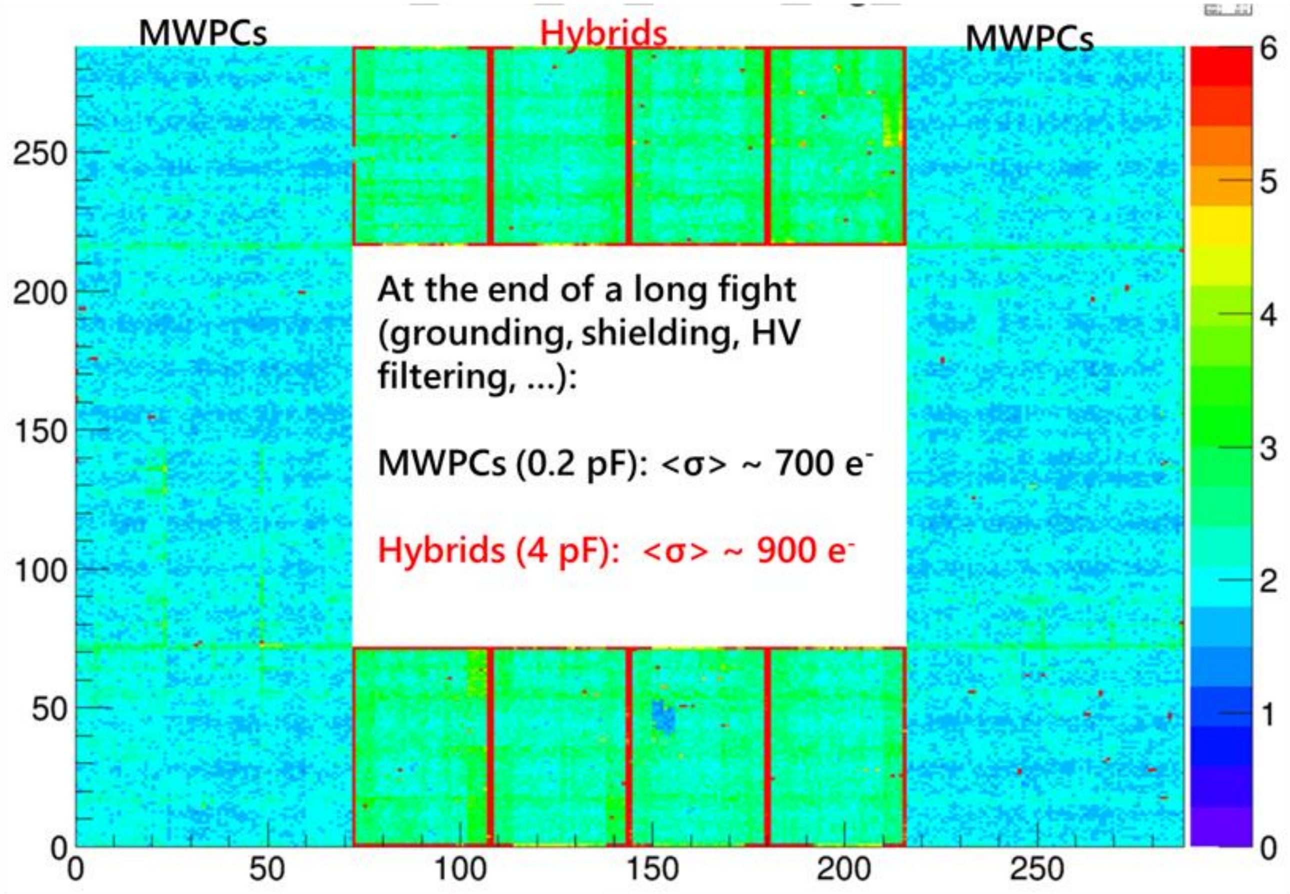
P, T sensors inserted in the gas lines at gas in/out

Commissioning

- Detectors successfully installed in April 2016
- Operated and commissioned during the entire 2016 COMPASS run

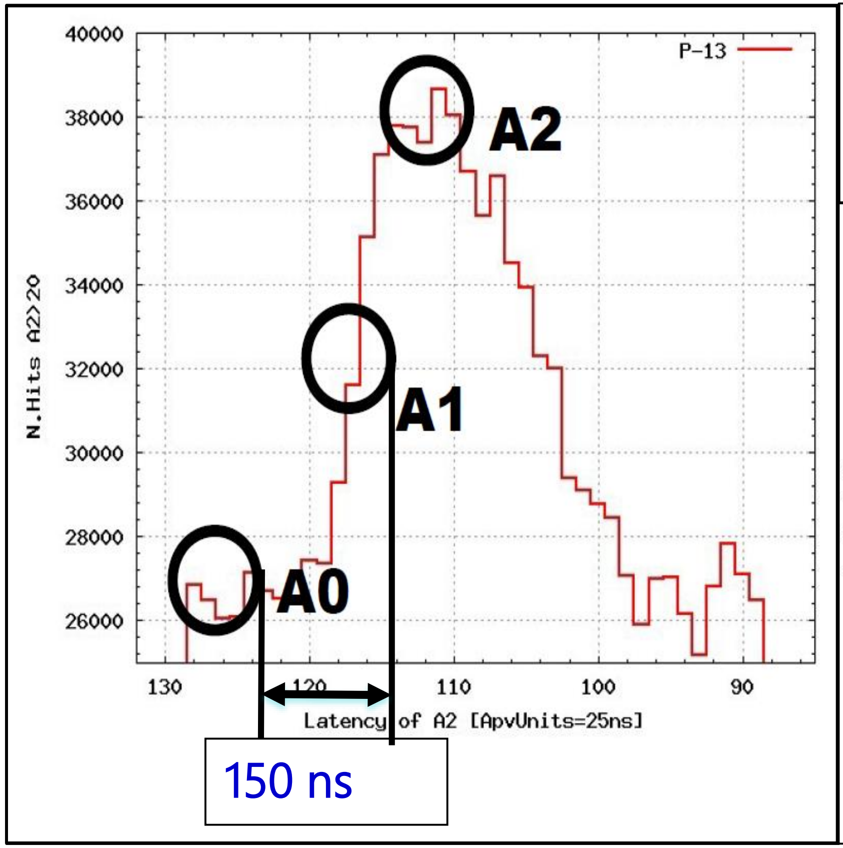
- Some preliminary issues
  - Noise issues
  - HV tuning and monitoring
  - Timing of the signal sampling
  - Gain response stability
  - APV readout errors



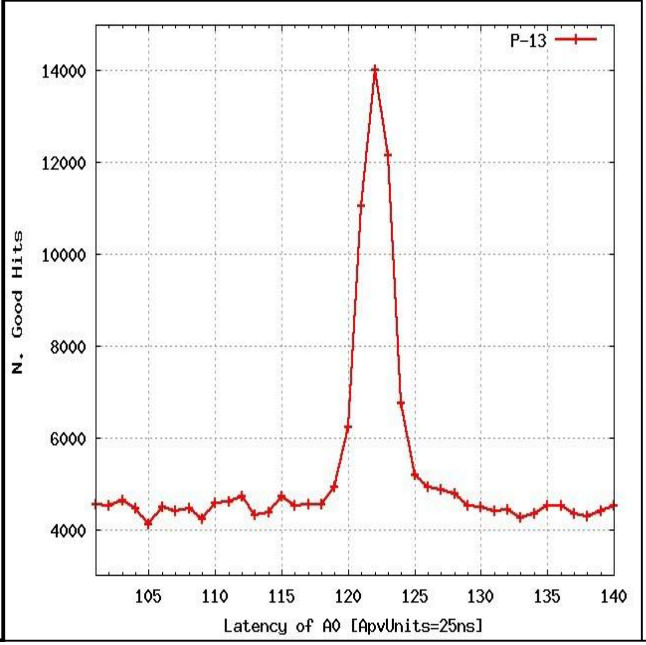


Noise figure for the 62208 ch.

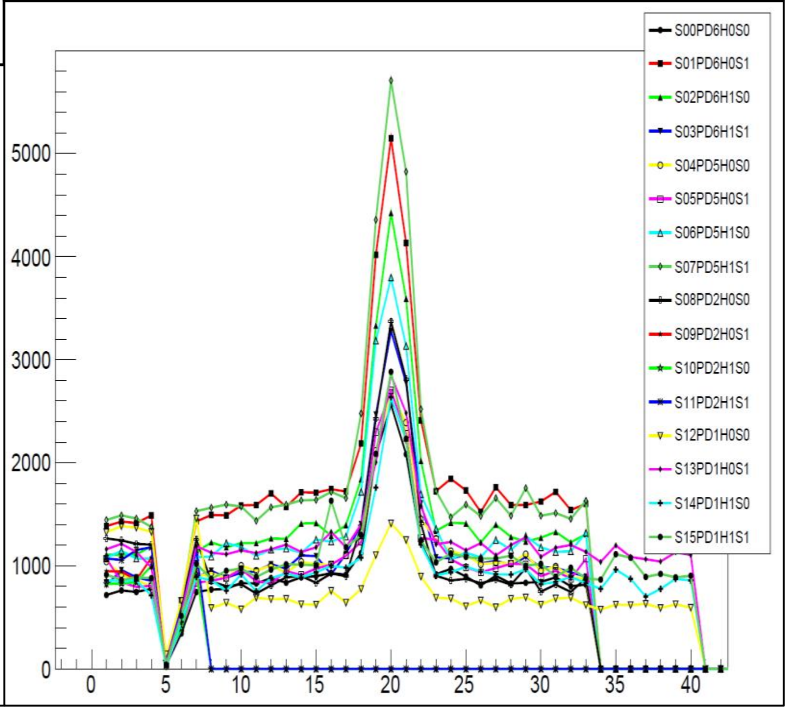
Timing



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



All sectors provide the same time response



Photon Signal

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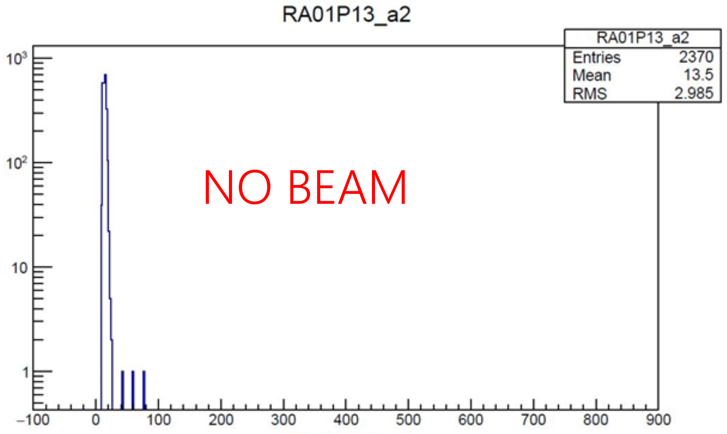
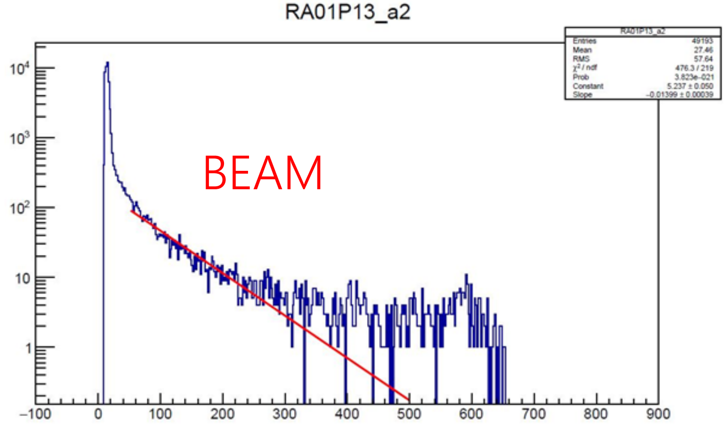
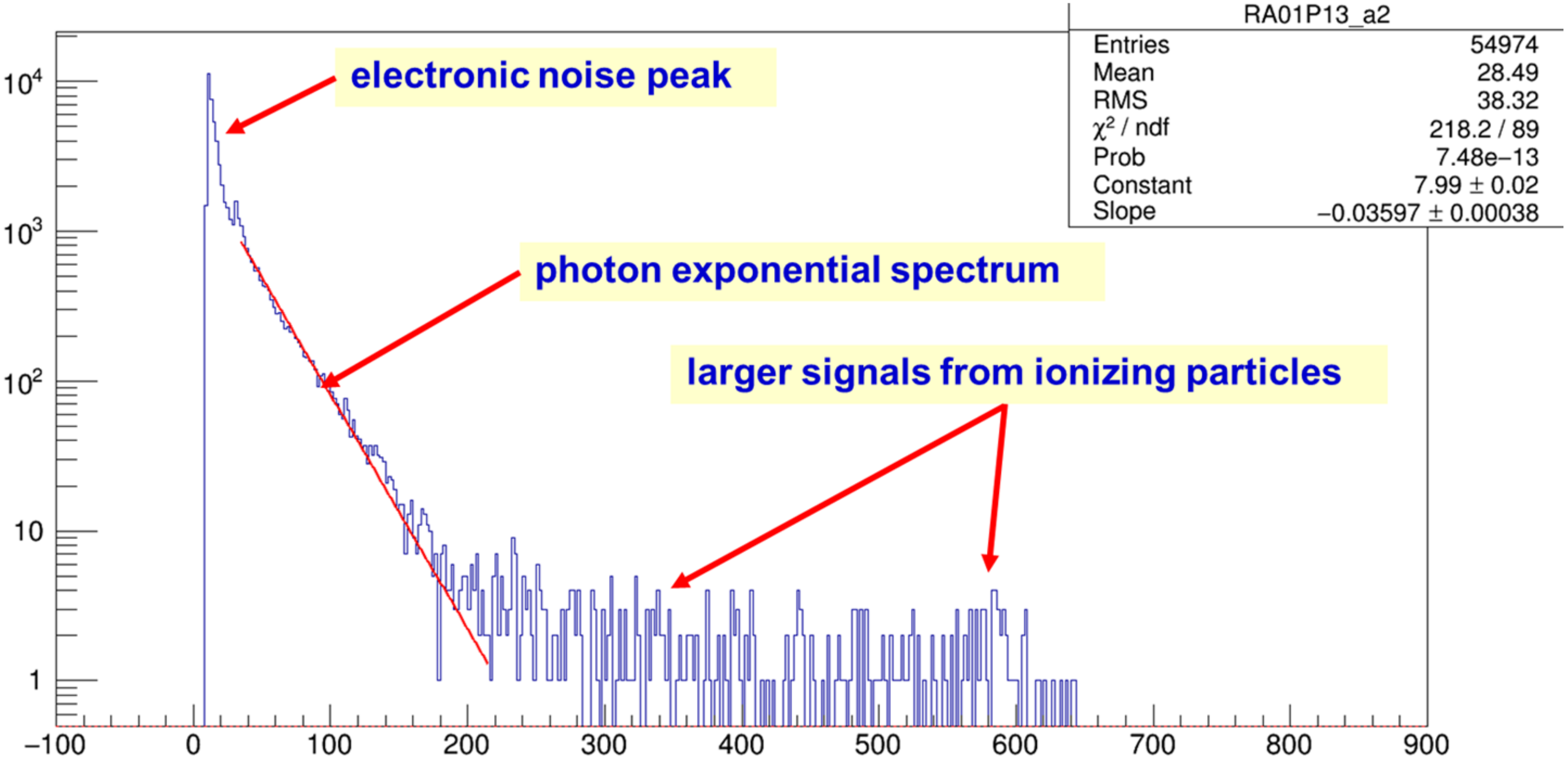
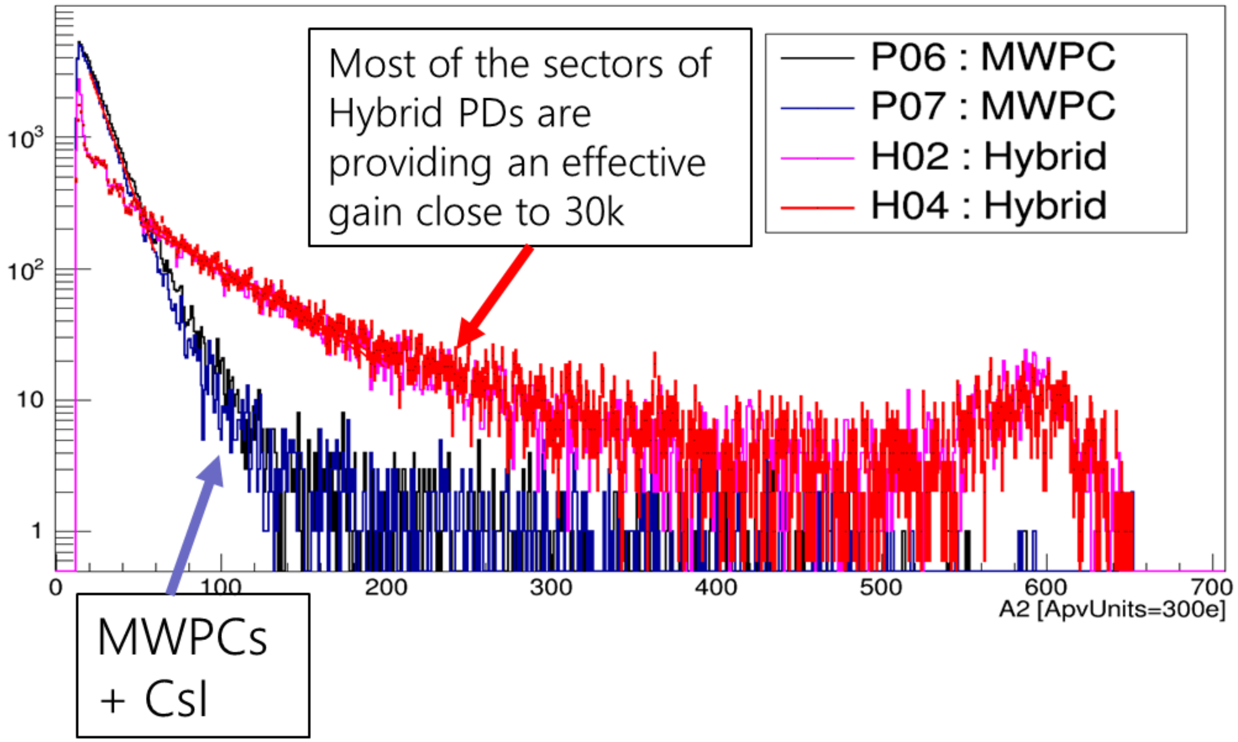
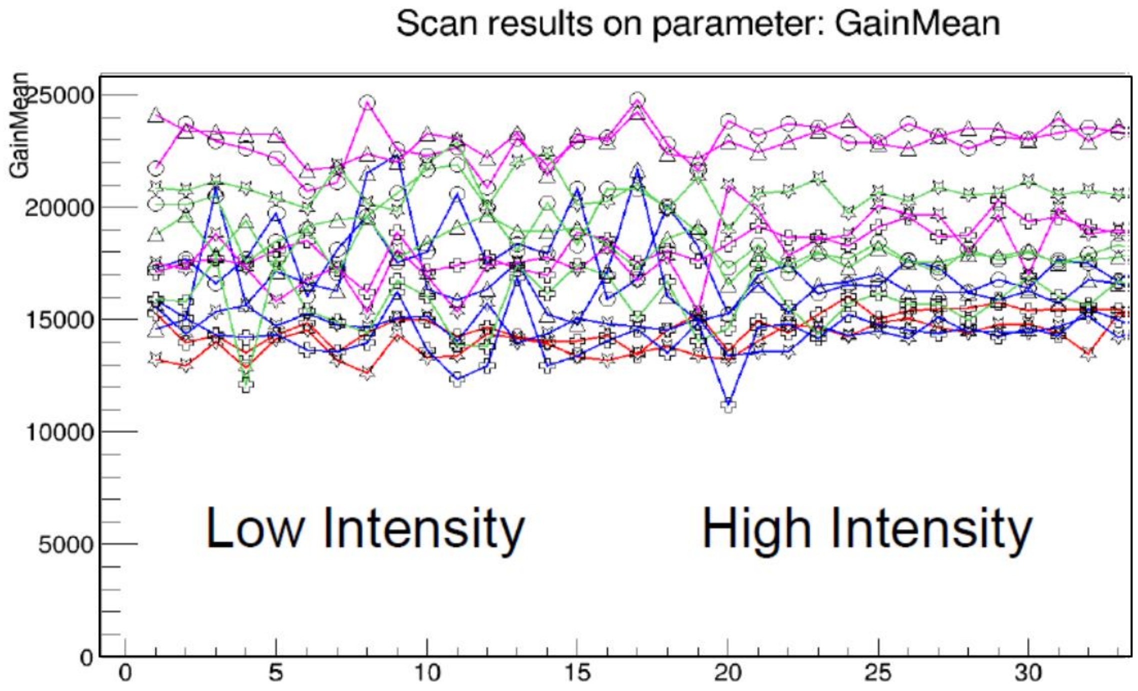






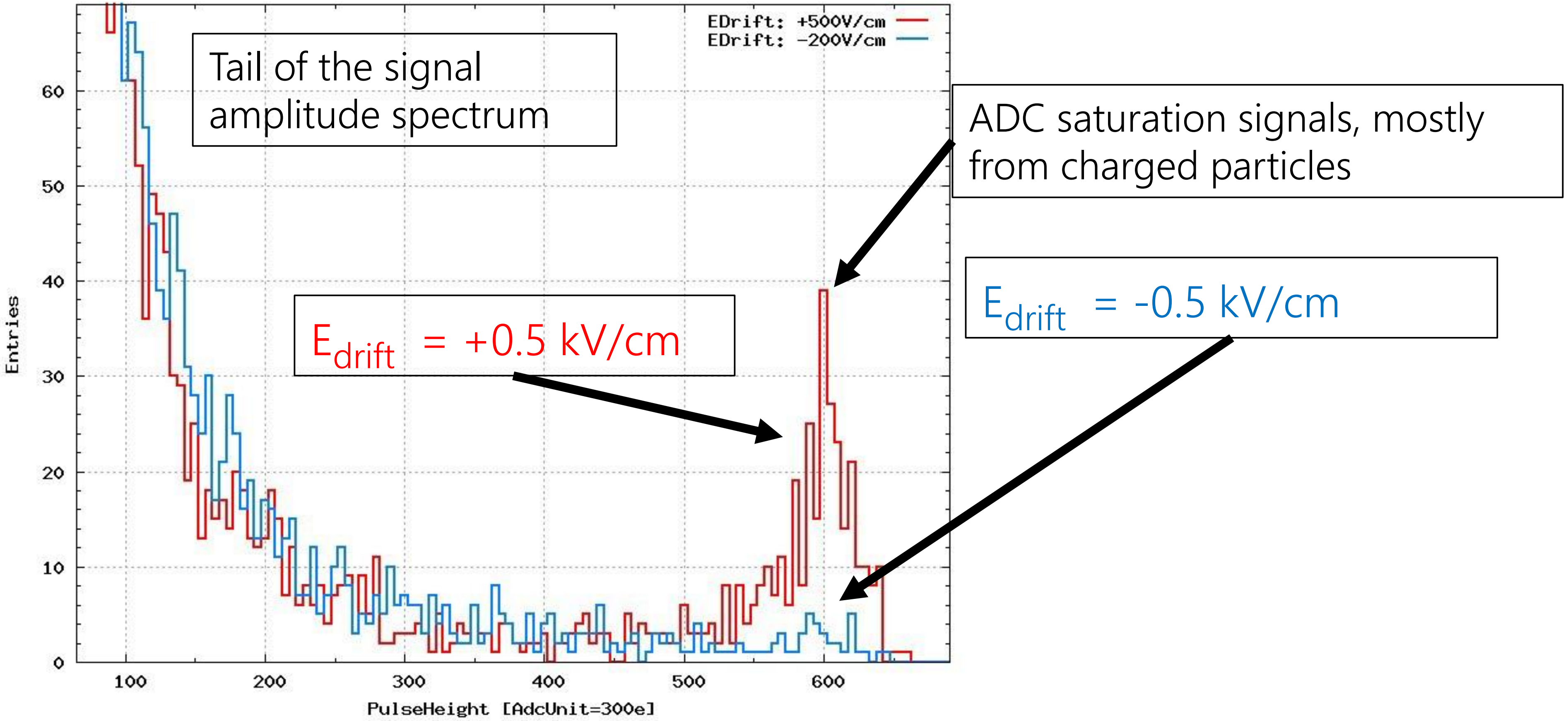


No such a gain in any MPGD in a running experiment.



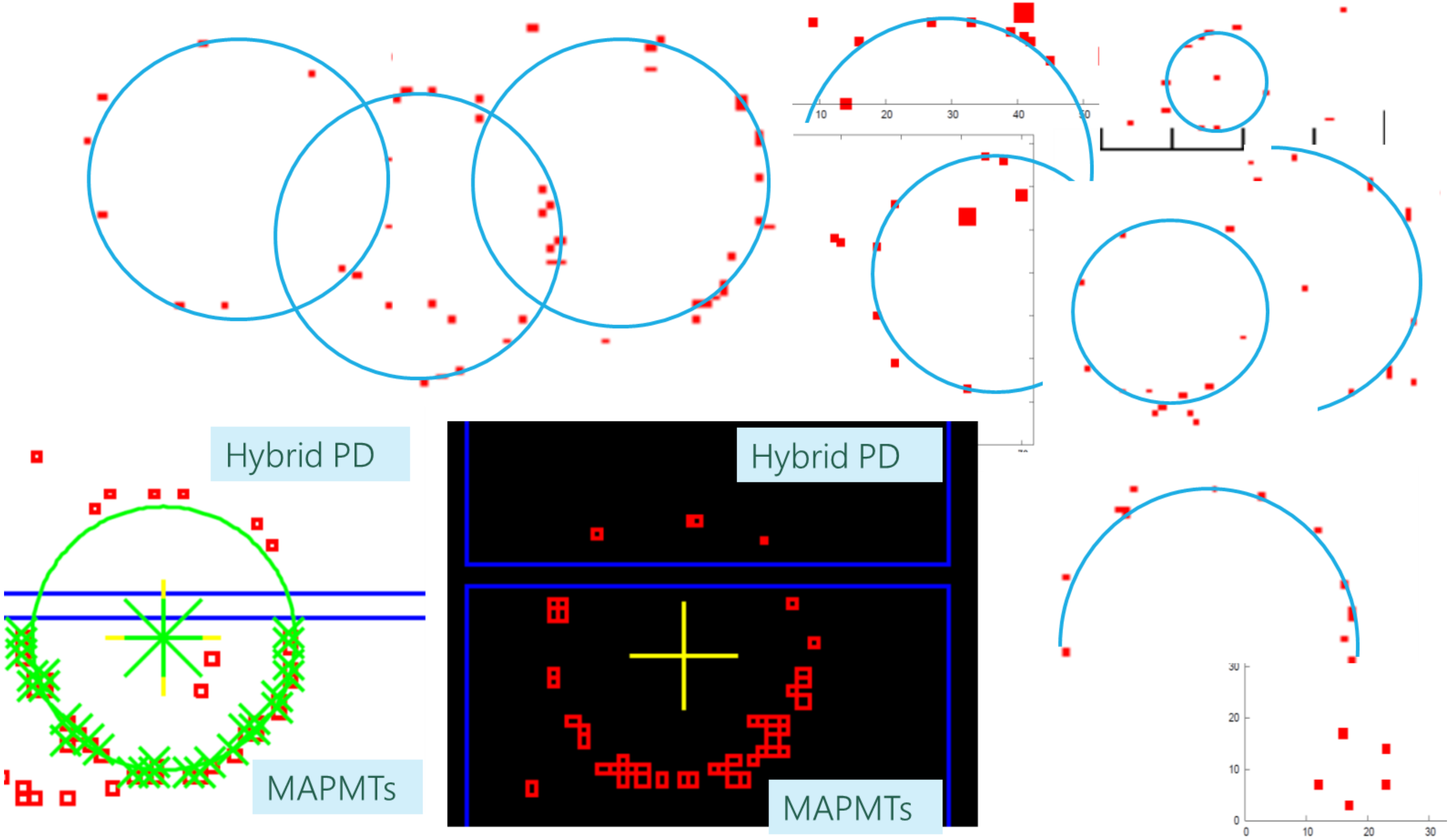
The effective gain does not vary when changing the COMPASS beam intensity by a factor of 2

Charged Particle Signal Suppression



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

Rings



Conclusion

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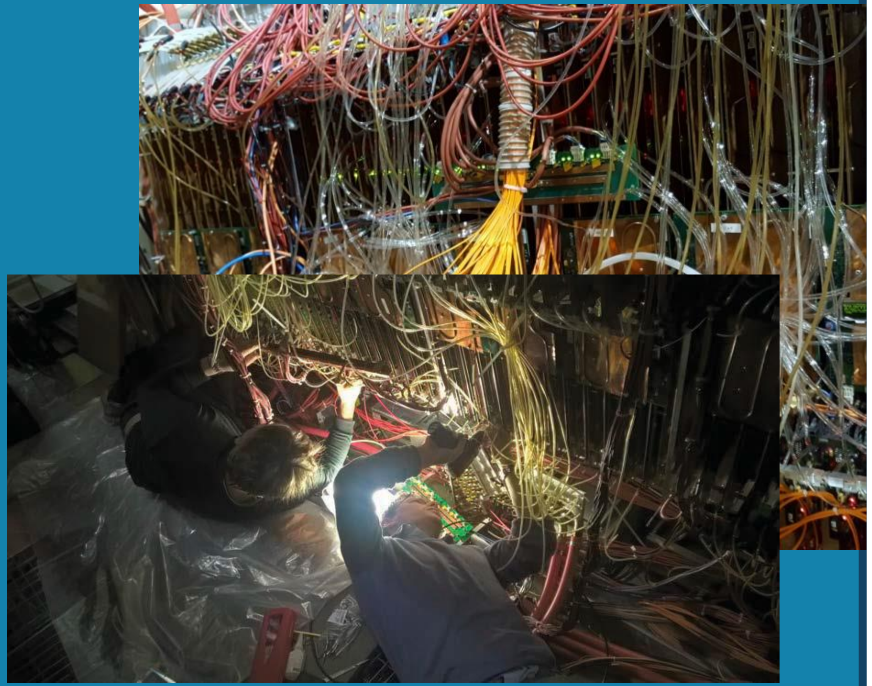
- Four PDs covering 1.4 m^2 were built, tested and mounted on COMPASS RICH and successfully operated during 2016 run for the **first time in the world!**
- Preliminary results are very promising, Detailed analysis is going on …
- Cerenkov rings have been observed …
- Large area MPGD based single photon detectors are not dream but reality.

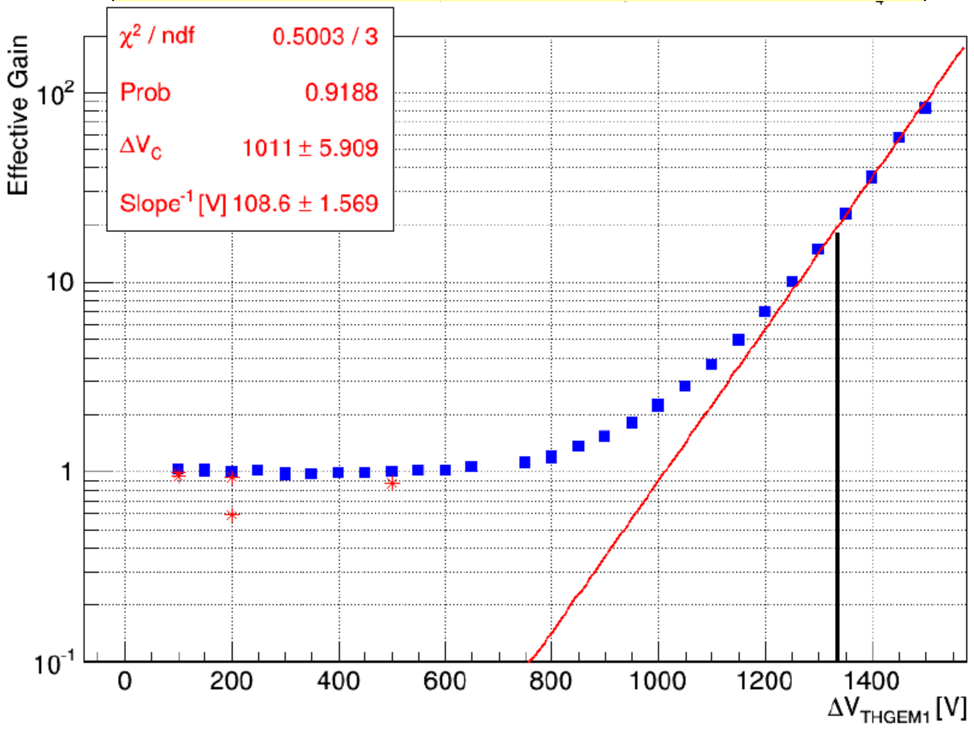
THANK YOU



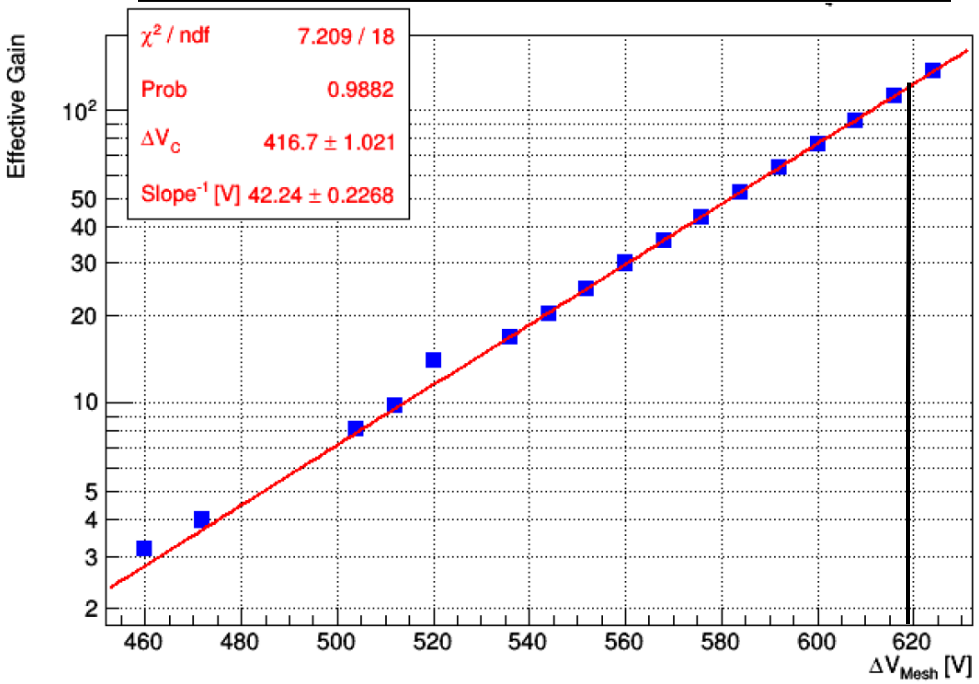
Questions?

Backup: Gain Sharing

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



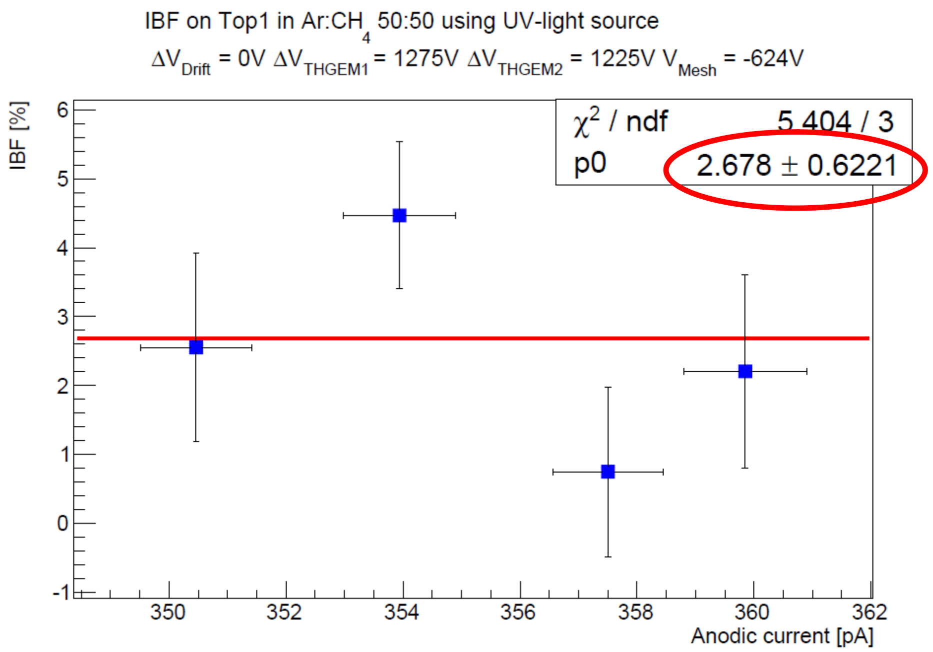
Nominal gain: ~30000 with:

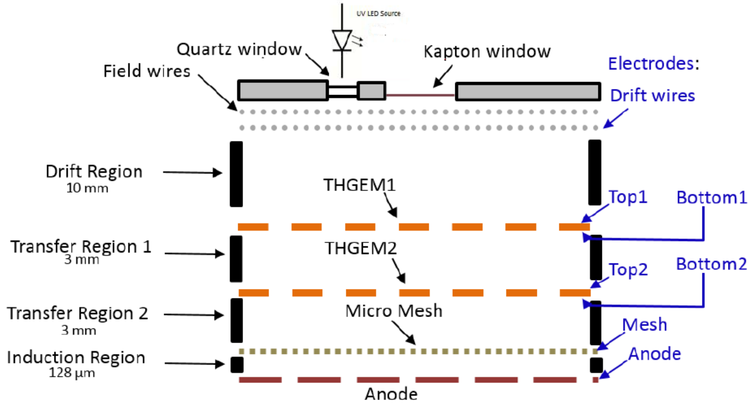
THGEM1 gain* transfer1: ~ 20

THGEM2 gain*transfer2 ~ 15

Micromegas gain ~100

BACKUP: IBF





Trieste home-built picoammeters

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

BACKUP: p, T control

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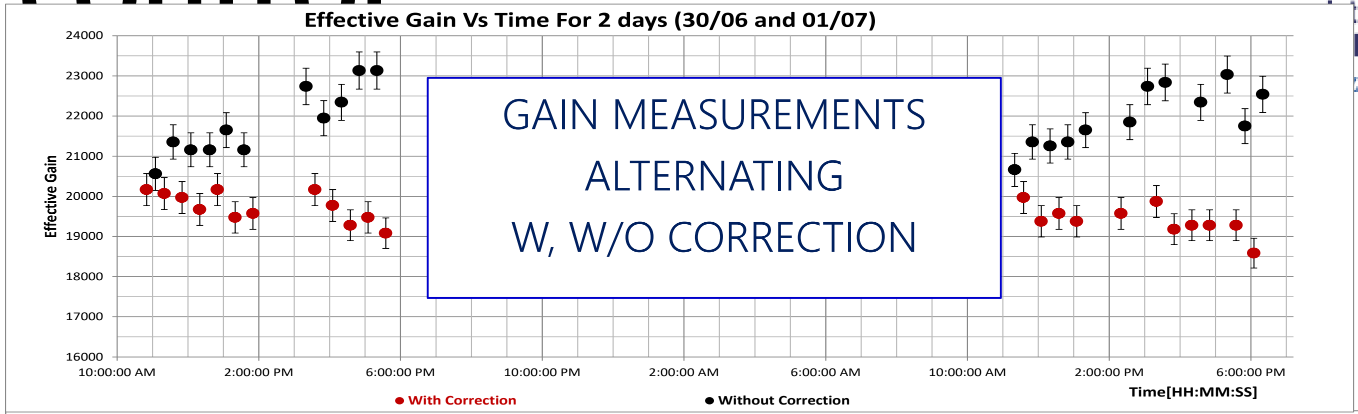
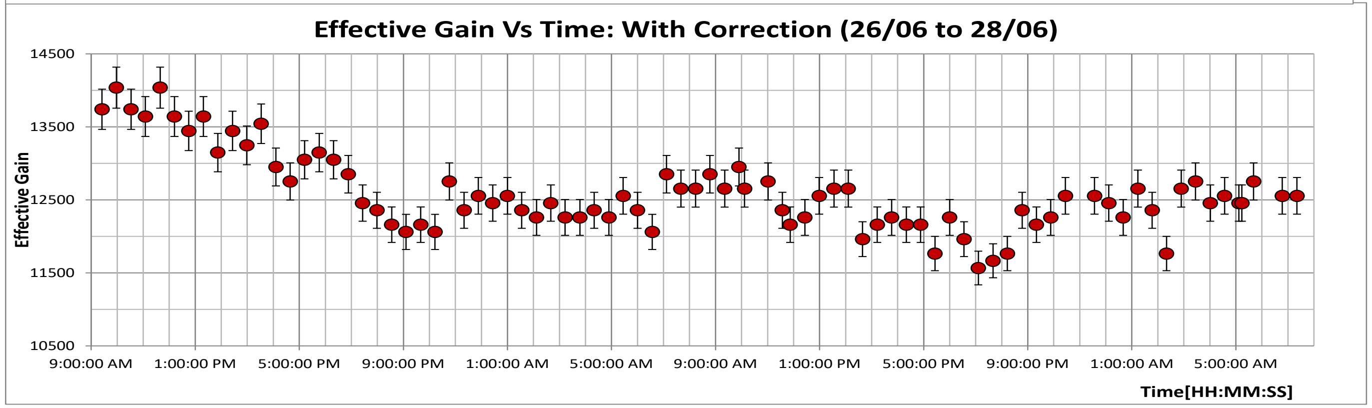
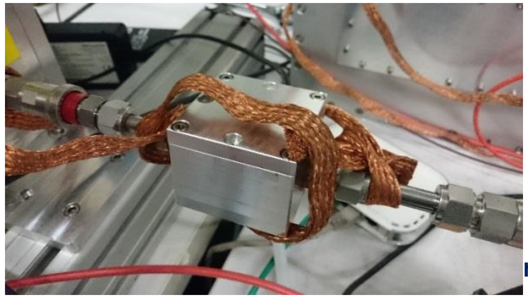




applying voltage compensation: gain evolution ~ 40% → ~ 10 %

p, T sensor at gas input and output



Correction of Voltage $f(P,T)$ LabVIEW based system fully automated + logging

Final co relation coefficient achieved

$$V_{calc} = V_0\left(1 + \alpha\frac{P - P_0}{P_0} - \beta\frac{T - T_0}{T_0}\right)$$

Backup: CsI coating of THGEMs

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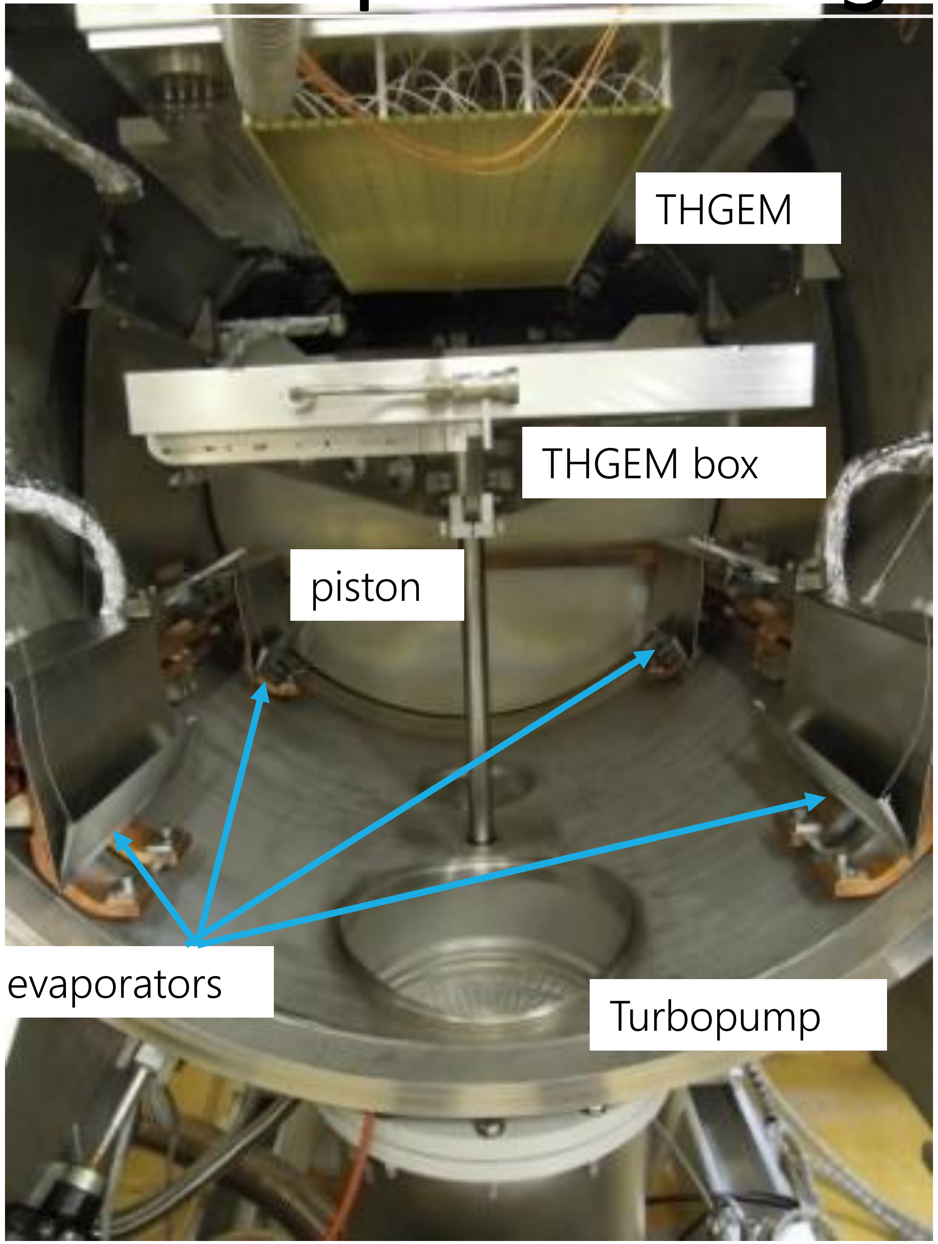

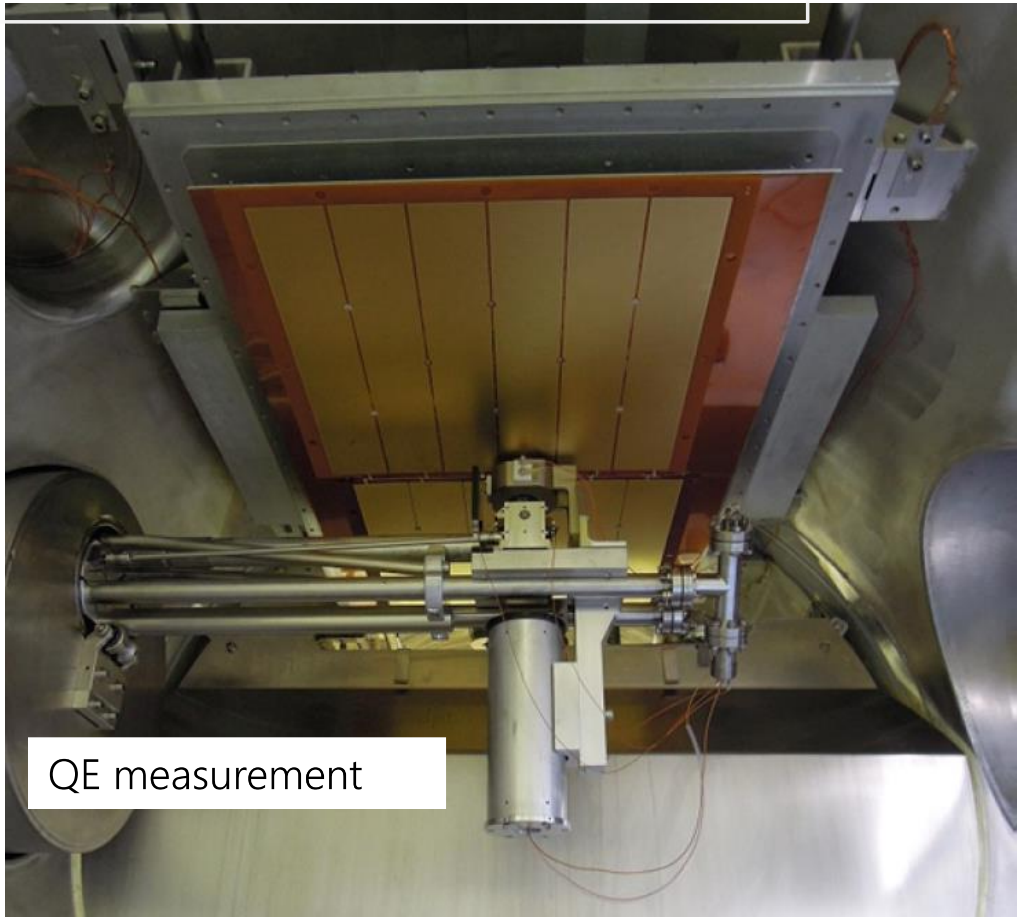

Backup: CsI QE measurement

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

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

11 coated THGEMs available, 8 used + 3 spares

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

Backup: The COMPASS THGEM design

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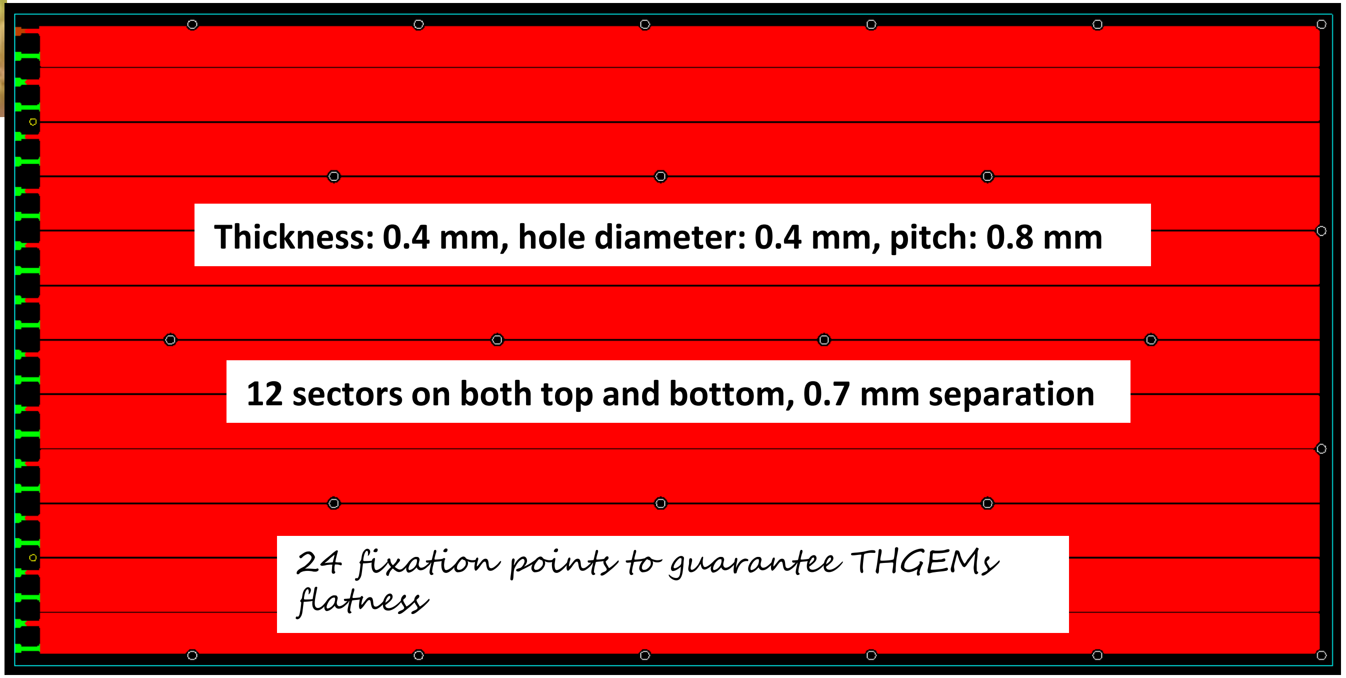

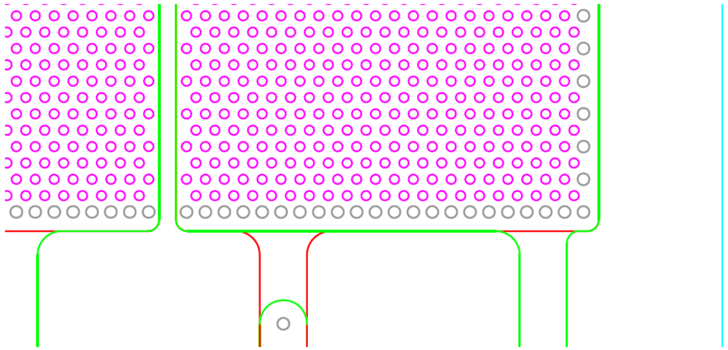

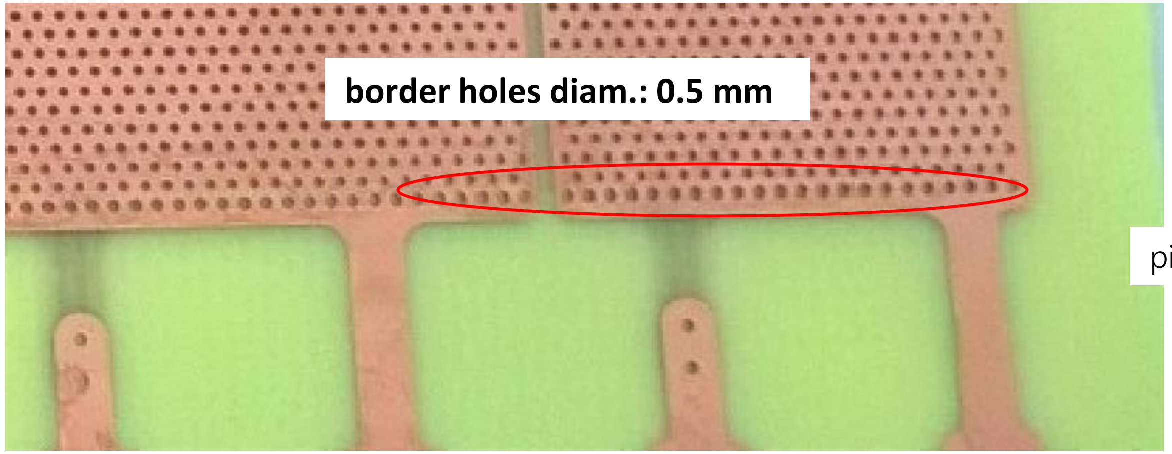

Backup: mechanical frames and wires

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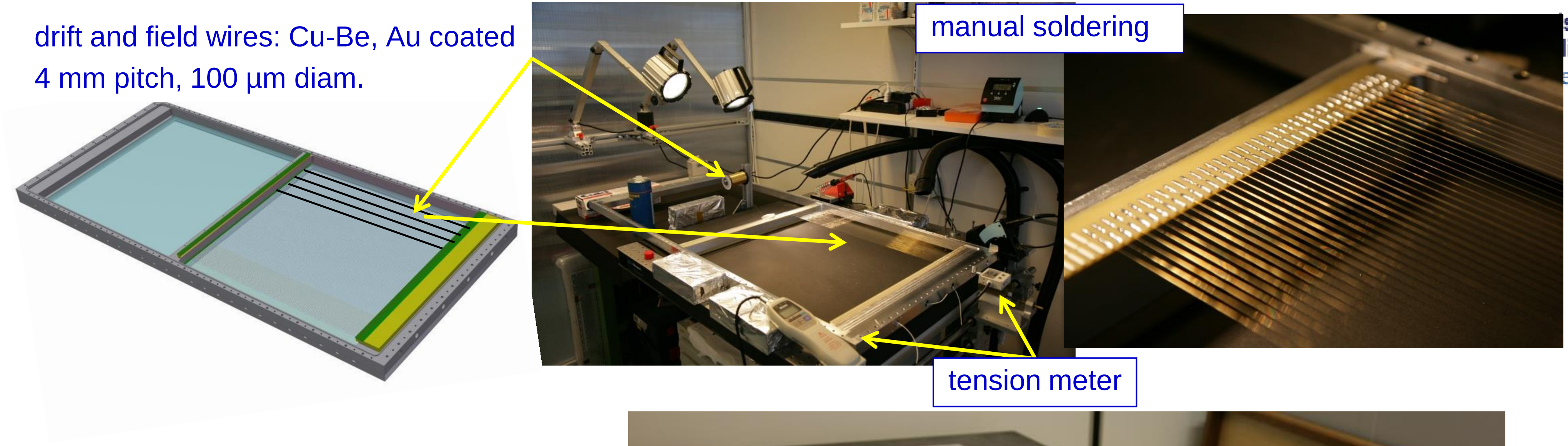
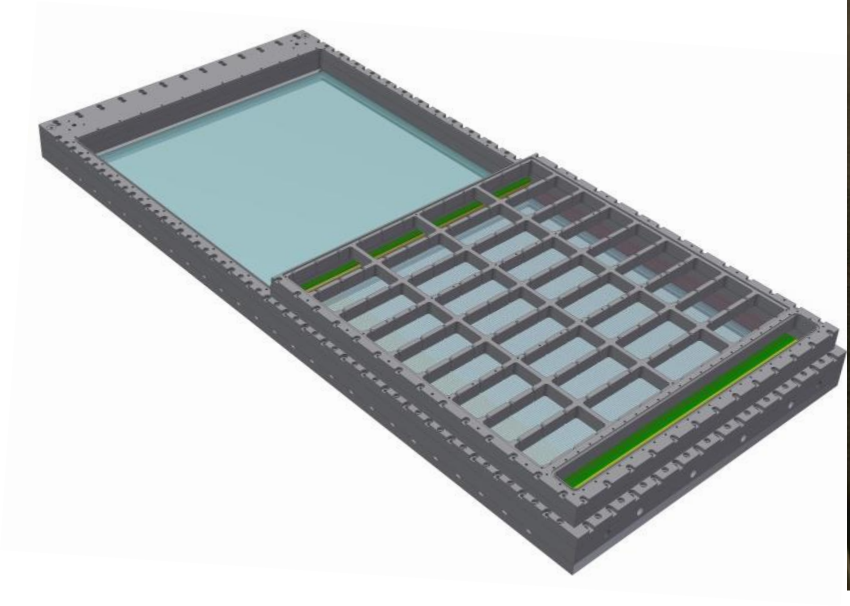
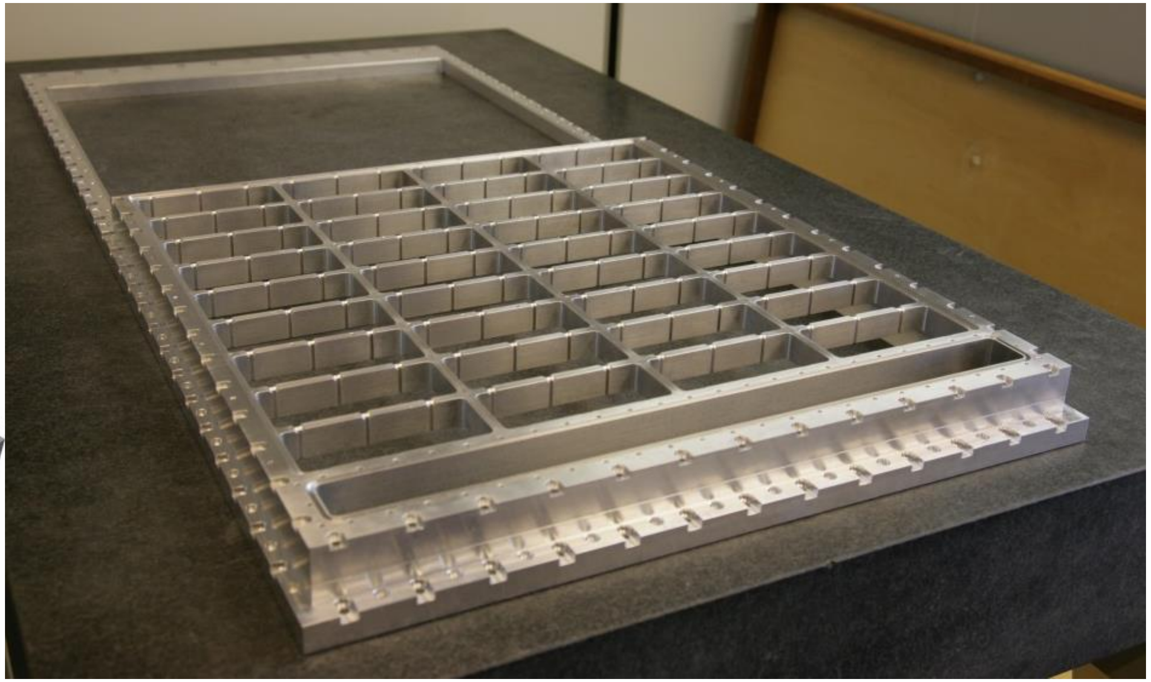
drift and field wires: Cu-Be, Au coated
4 mm pitch, 100 µm diam.

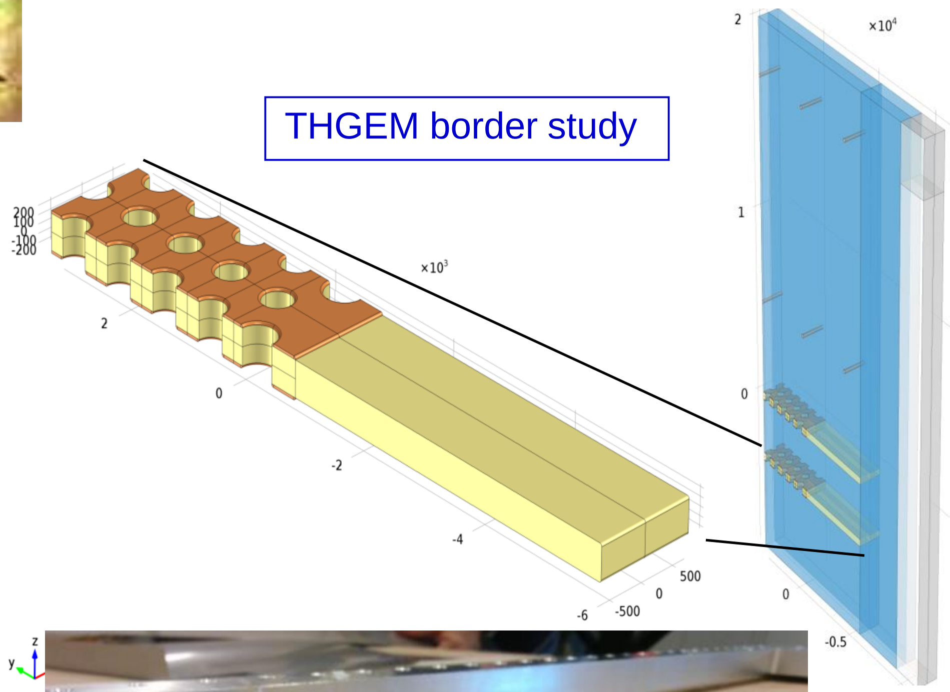


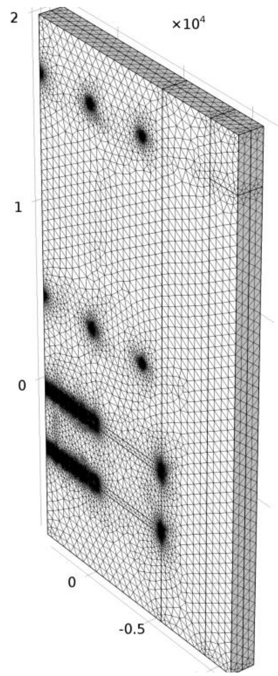


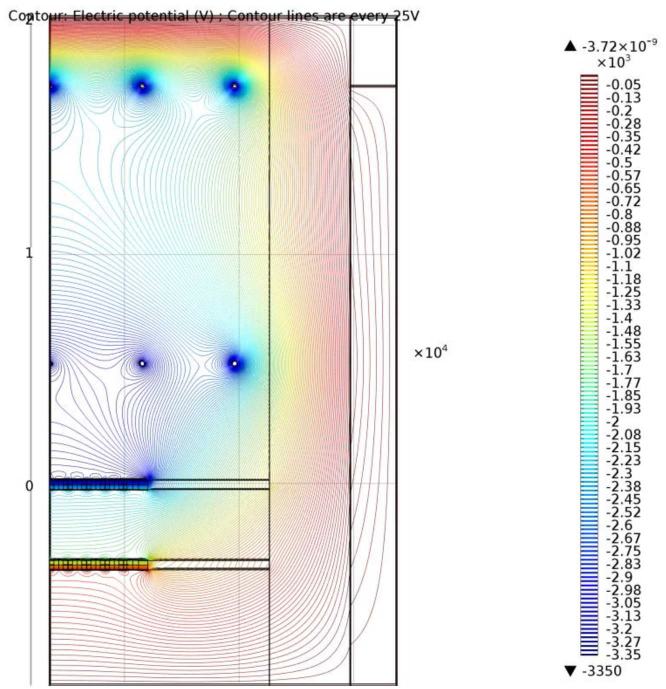


Backup: field shaping electrodes

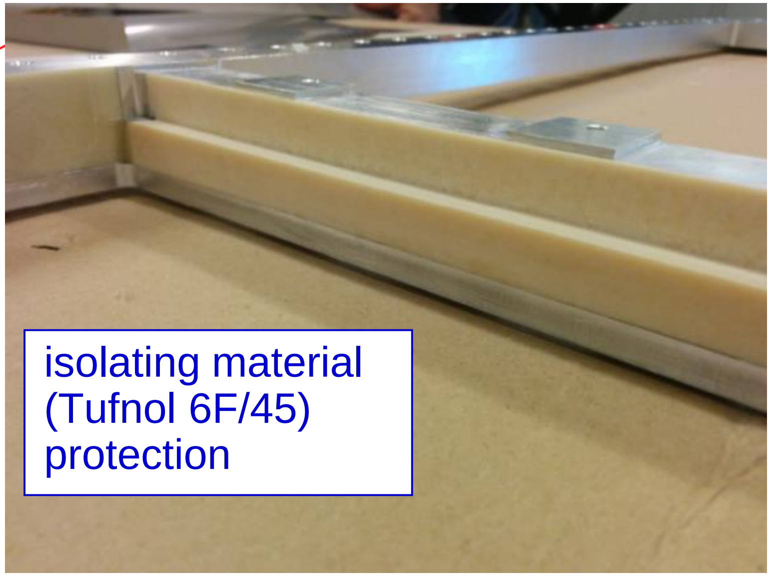
THGEM border study







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