MPGD-based RICH at COMPASS

Fulvio Tessarotto (INFN – Trieste)
on behalf of the COMPASS RICH Group

The COMPASS RICH-1 upgrade

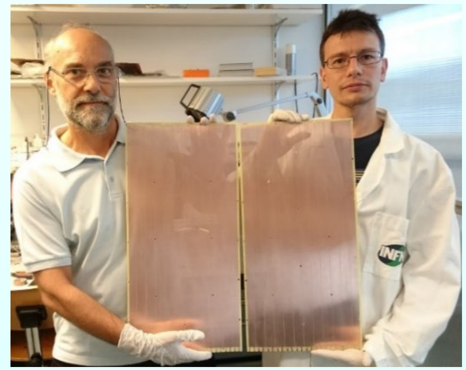
The MPGD-based PD design and construction

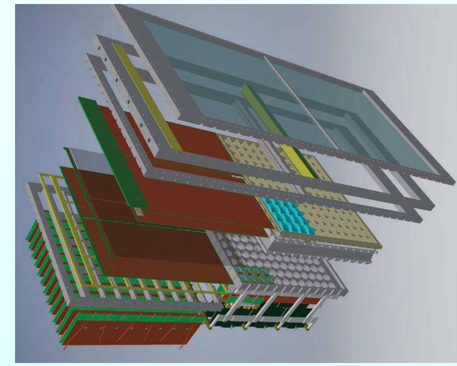
HV control, spark rates, noise level

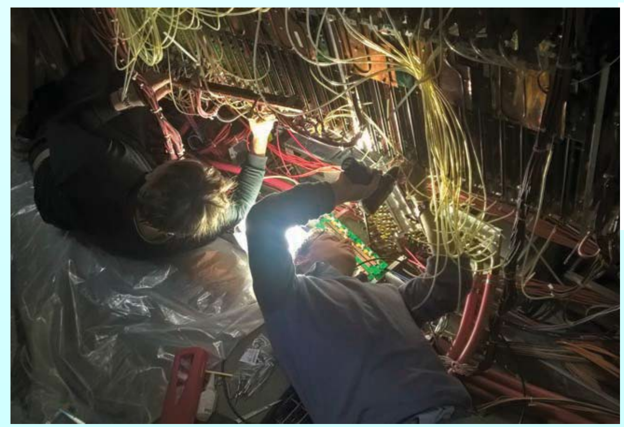
Uniformity and stability

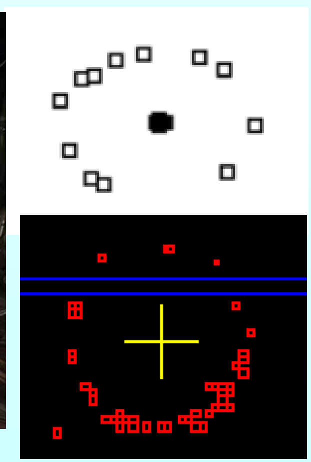
MPGD-based PD characterization

Conclusions





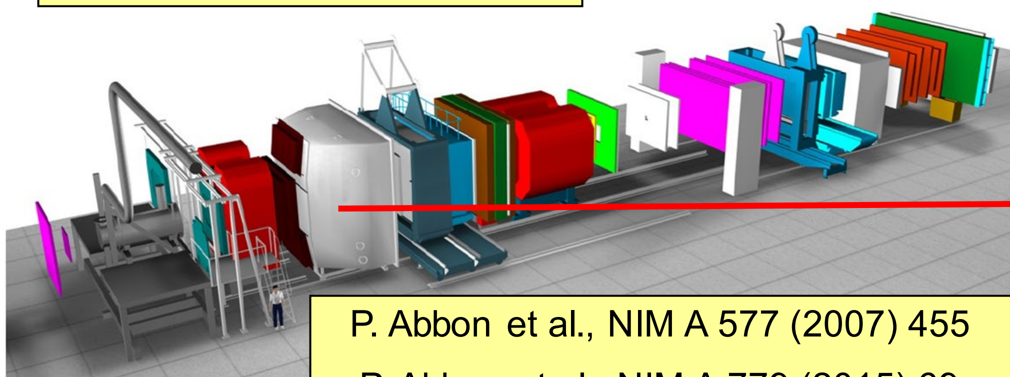




The 2024 International Workshop on Future Tau Charm Facilities

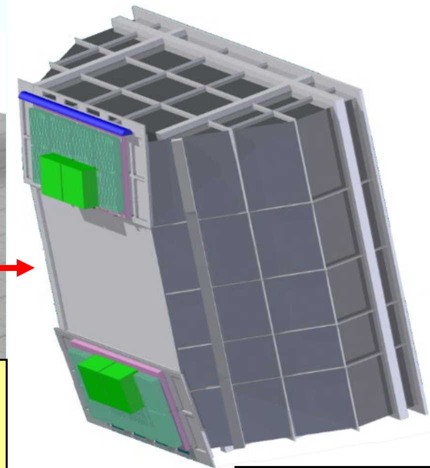
COMPASS RICH-1 upgrade

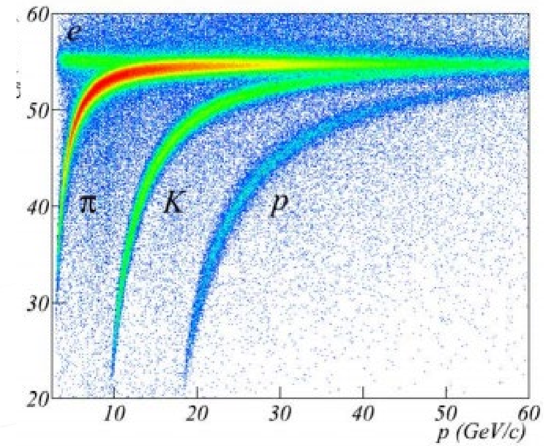
COMPASS Spectrometer



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

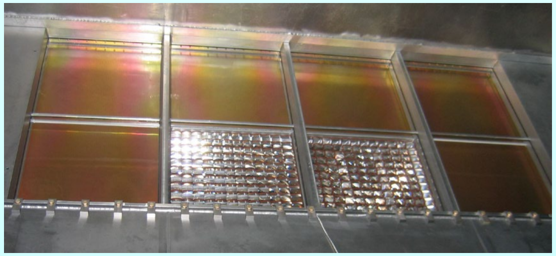
P. Abbon et al., NIM A 779 (2015) 69

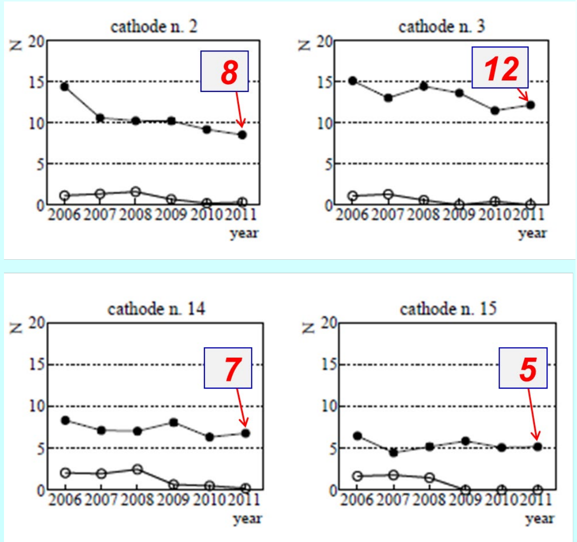




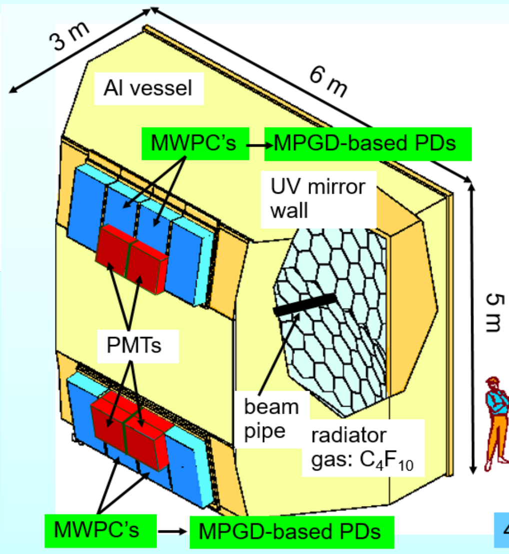
F. Tessarotto et al., JINST 9 (2014) C09011

acceptance: H: 500 mrad V: 400 mrad; beam rates up to ~10^8 Hz;
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

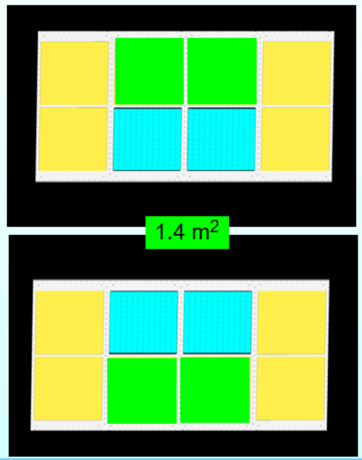




MWPCs+CsI: successful but with important performance limitations, in particular in the case of the 4 central chambers



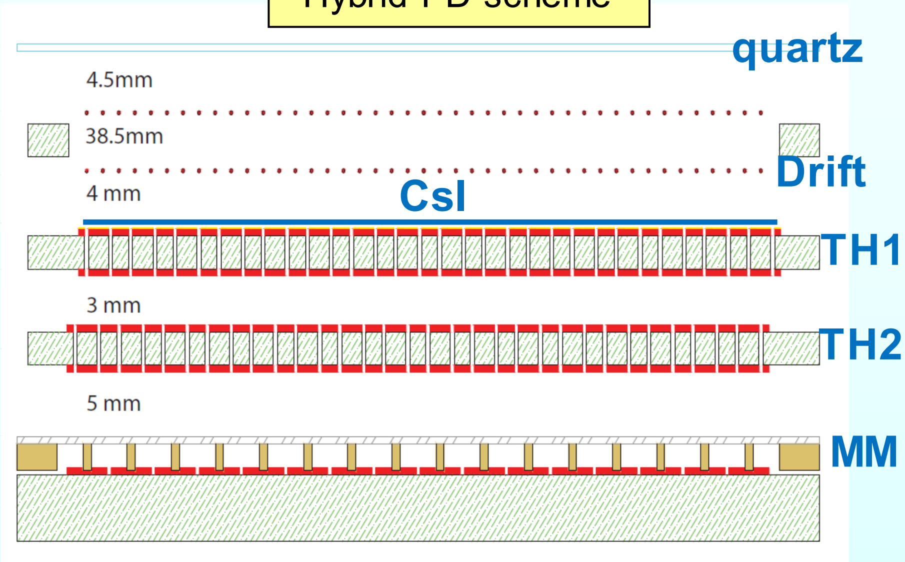
for COMPASS run 2016



4 new detectors of 600 mm x 600 mm

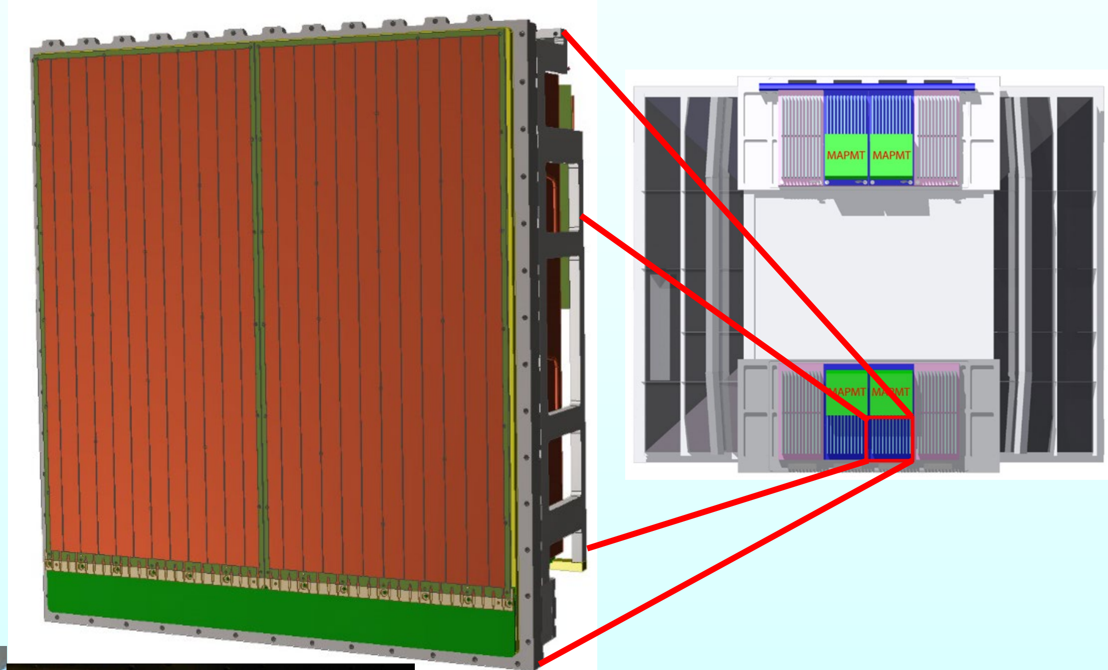
The hybrid THGEM+Micromegas PDs

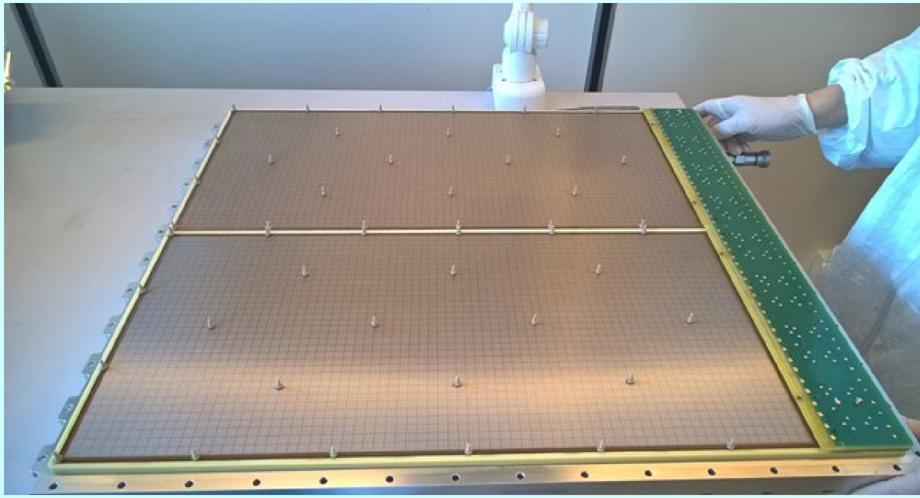
Hybrid PD scheme



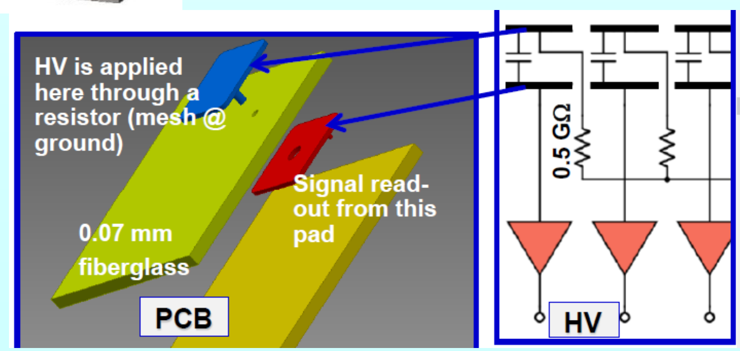
Standard Bulk Micromegas produced at CERN

modular structure: one module = 600x300 mm^2



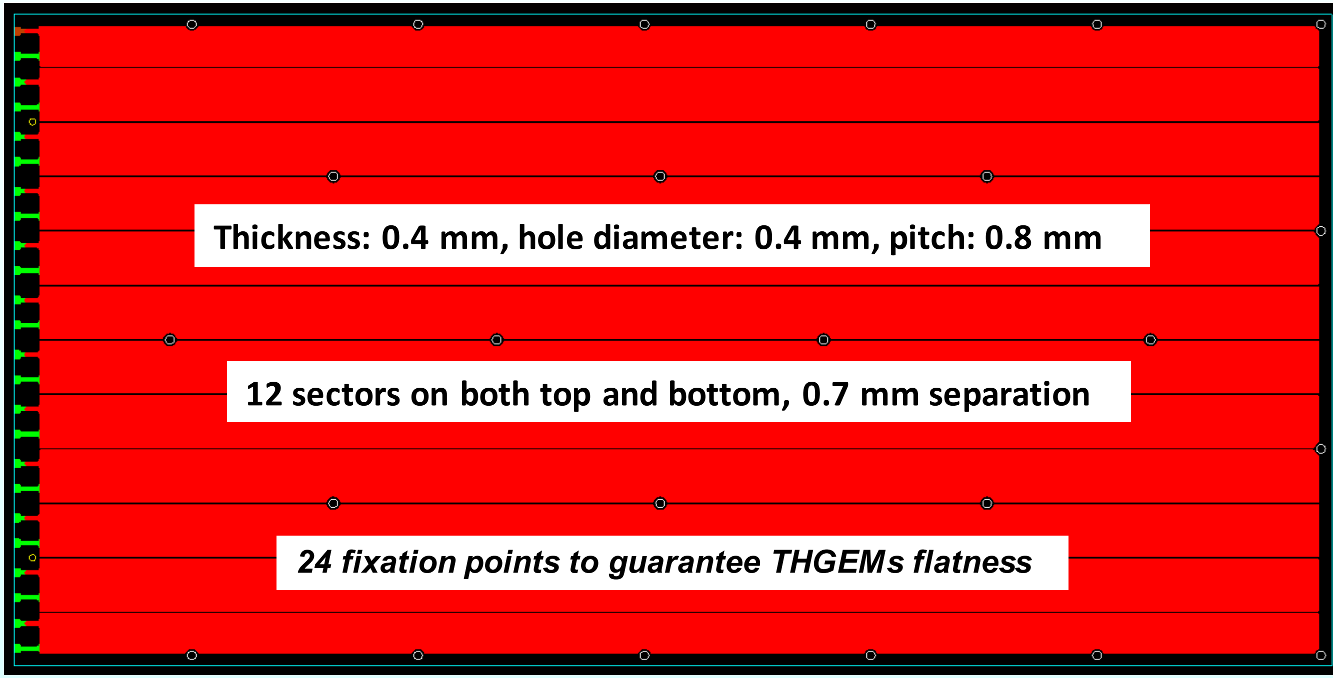


8mm X 8mm pads at positive HV



Capacitive coupling → APV25

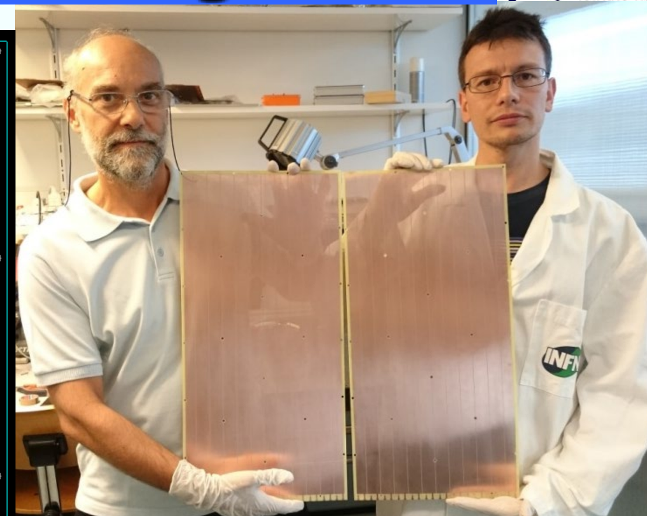
The COMPASS THGEM design

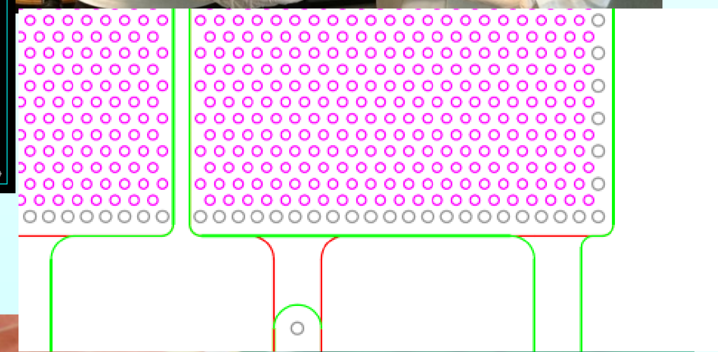


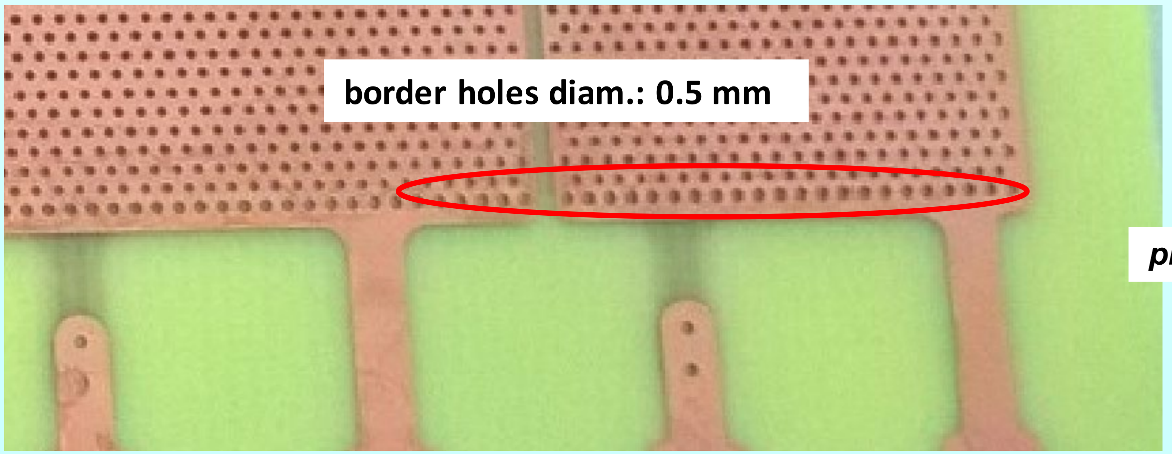
Thickness: 0.4 mm, hole diameter: 0.4 mm, pitch: 0.8 mm

12 sectors on both top and bottom, 0.7 mm separation

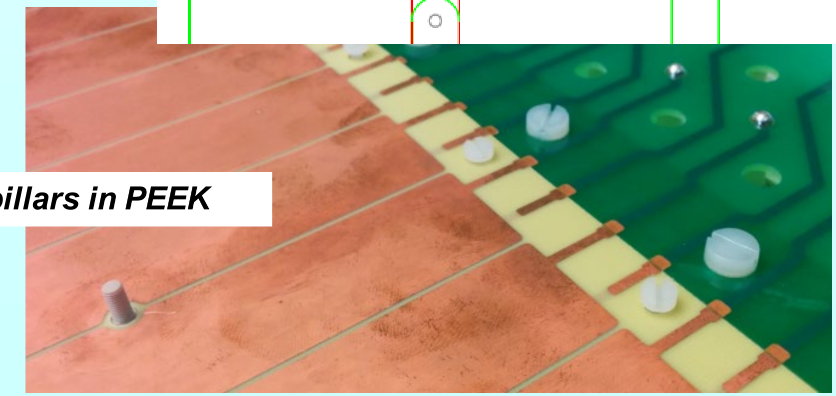
24 fixation points to guarantee THGEMs flatness







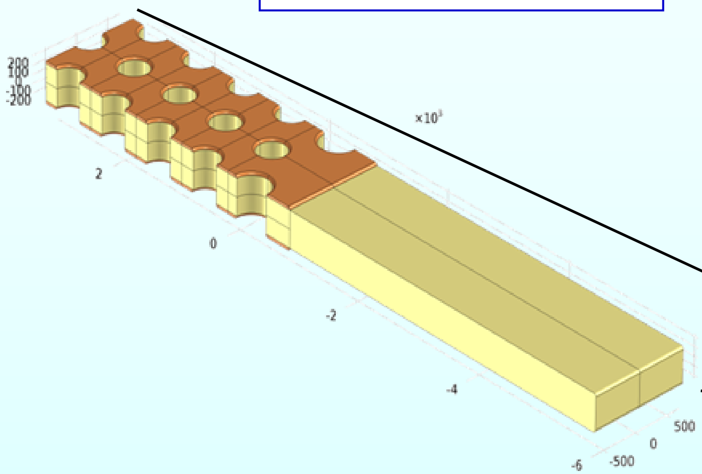
border holes diam.: 0.5 mm

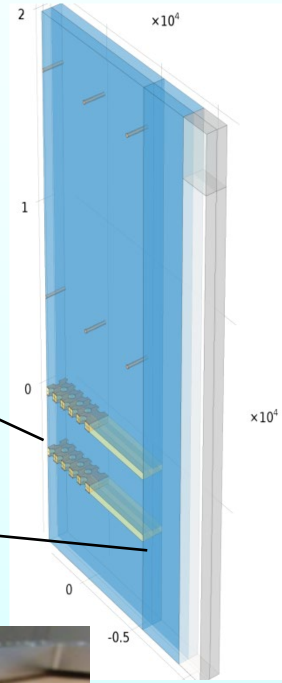


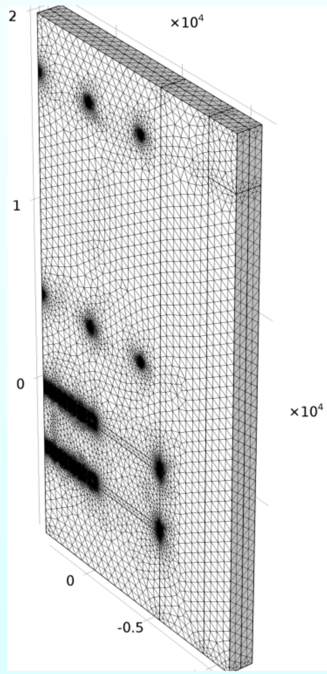
pillars in PEEK

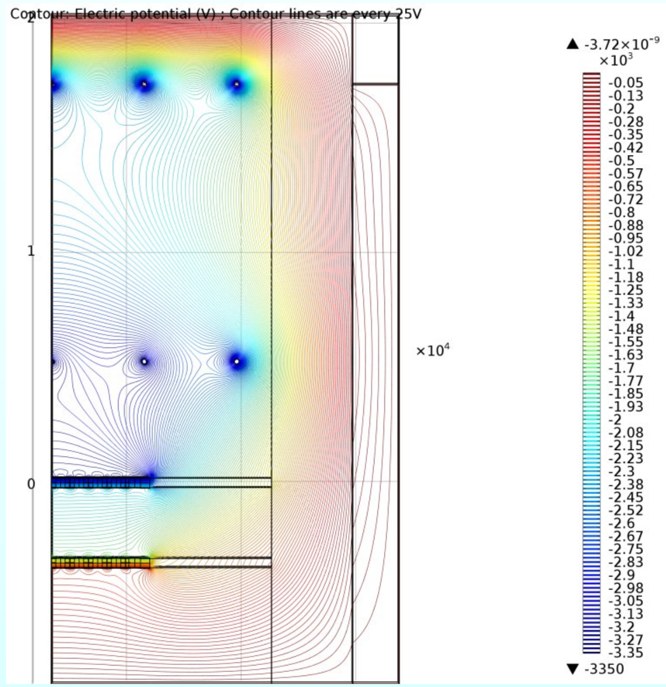
field shaping electrodes

THGEM border study

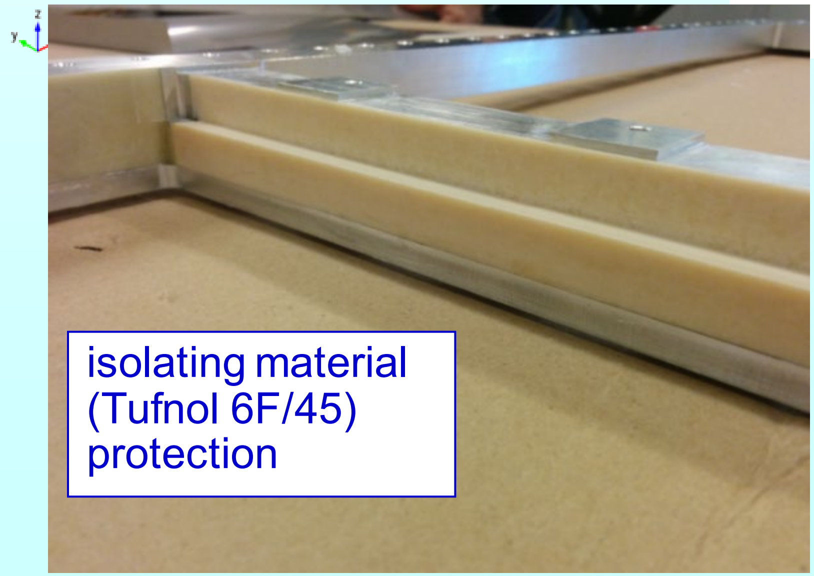






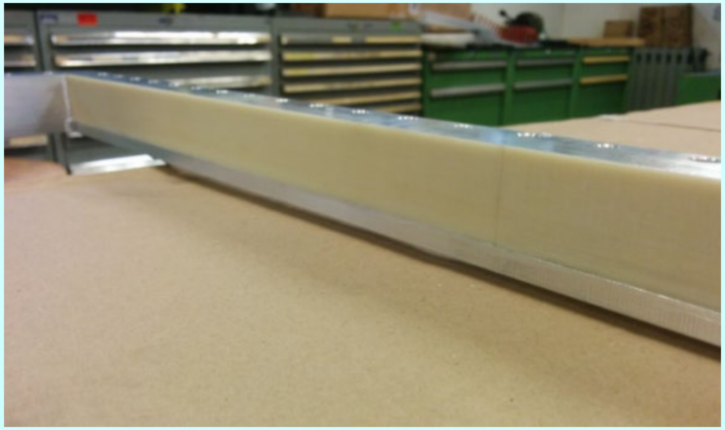


large field values at the chamber edges and on the guard wires



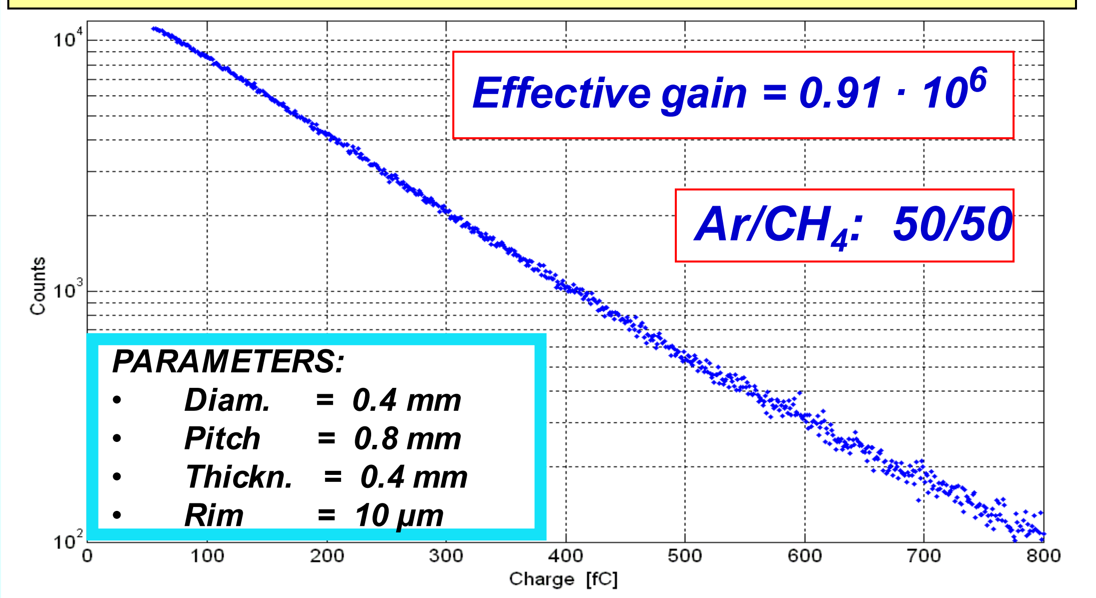
isolating material (Tufnol 6F/45) protection

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

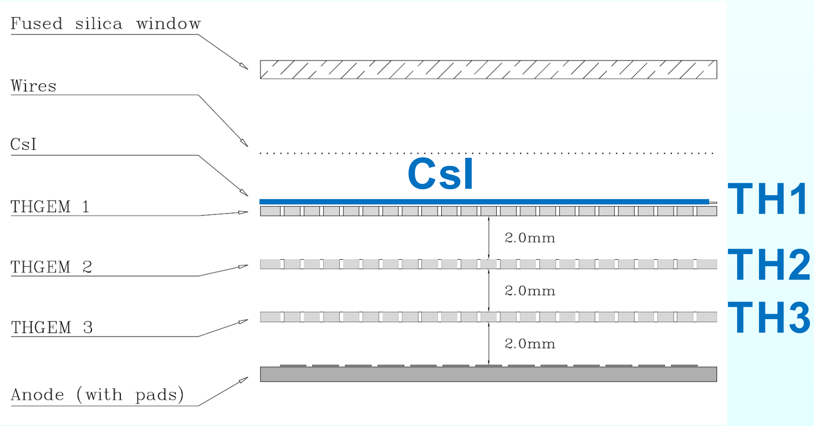


Why THGEMs with no rim

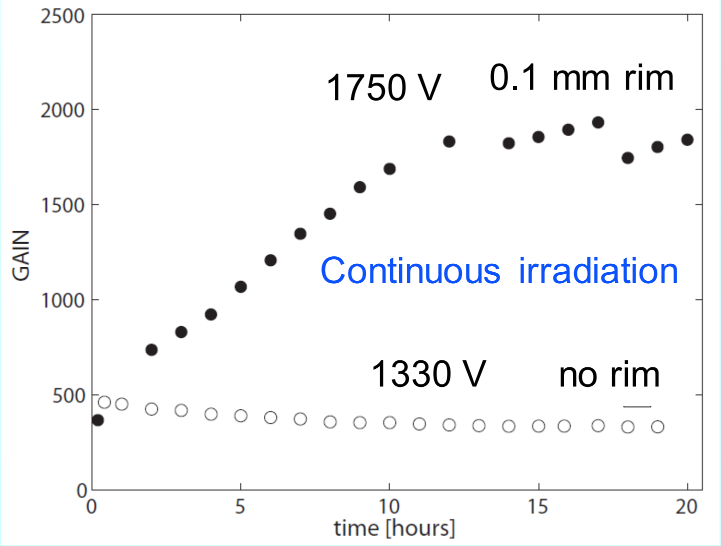
High gain obtained in a 3THGEM with 30x30 mm^2 active area



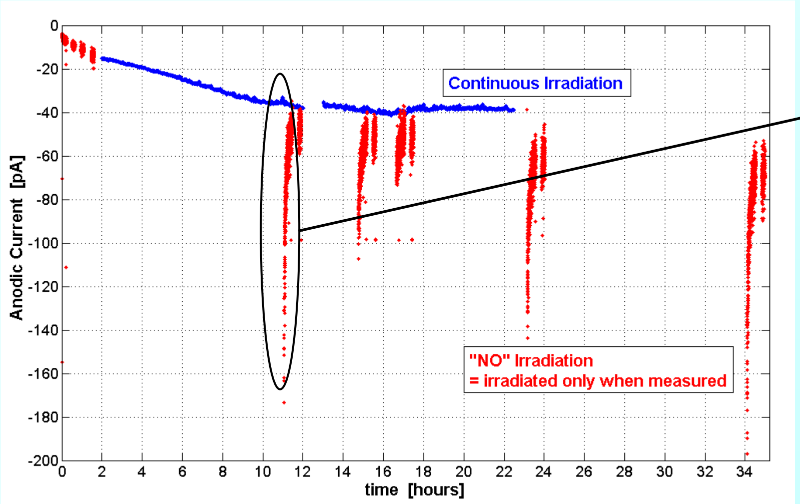
Triple THGEM

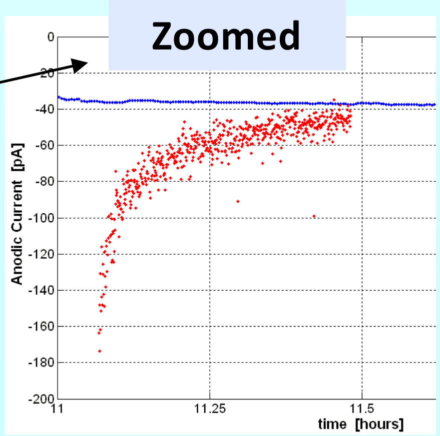


Rim ≠0 → difficult to control the gain

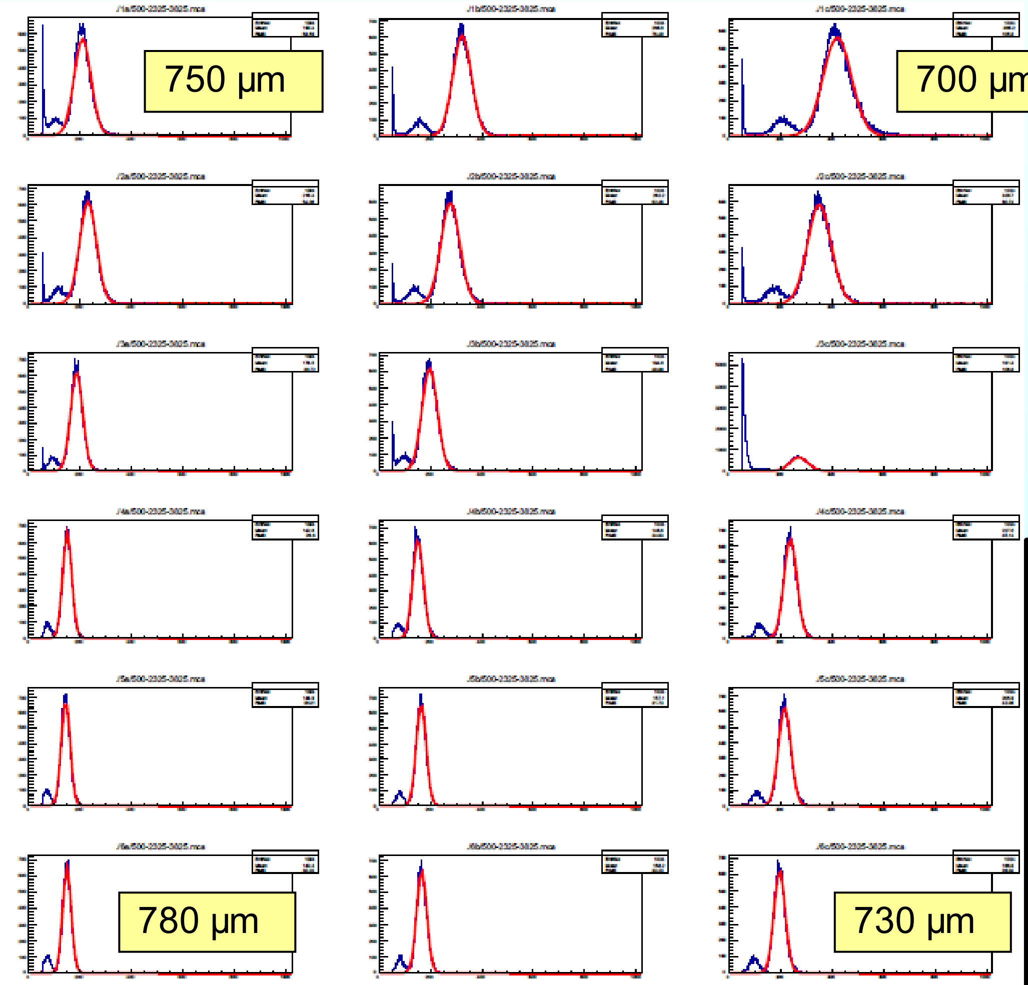


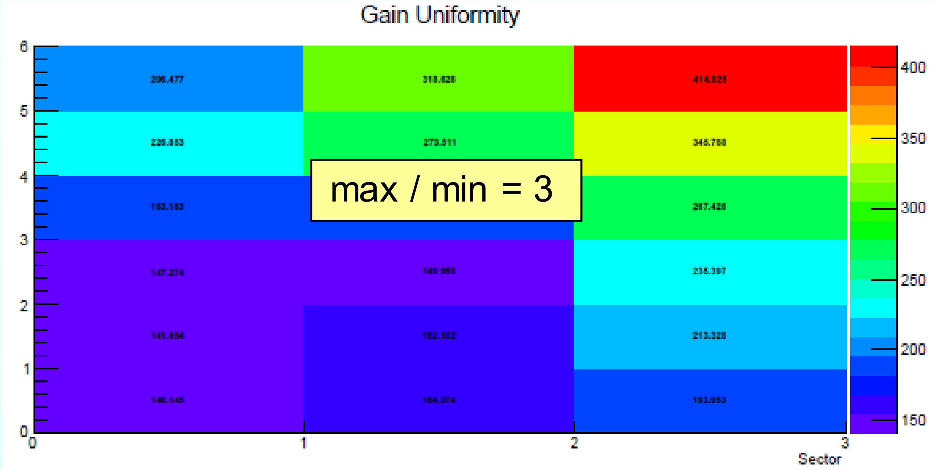
M. Alexeev et al., NIMA 617 (2010) 396





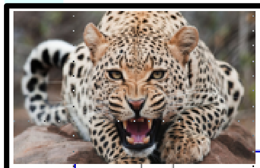
Thickness-related non uniformity

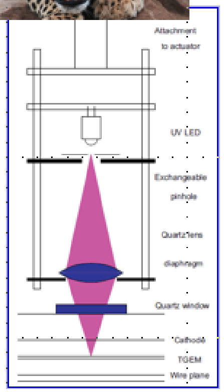




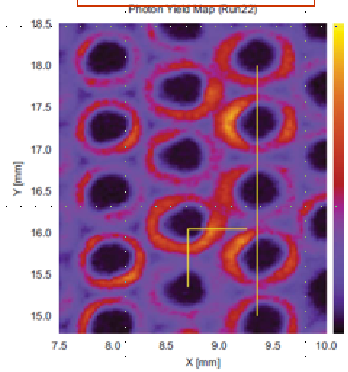
→ Strict thickness uniformity requirement

Local non uniformities

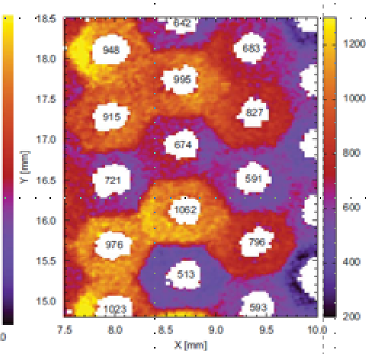




Effiency map



Gain map



G.Hamar and D. Varga, NIMA 694(2012)16

THGEM raw material selection

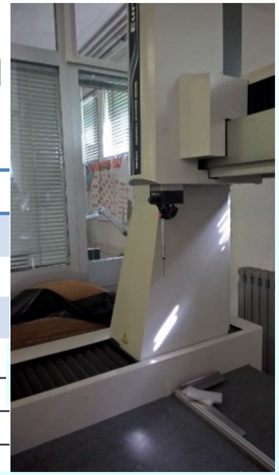
Our thickness uniformity requirements are stricter than those offered by producers → material selection

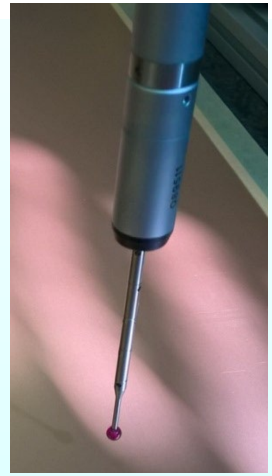
50 foils of 1245 mm x 1092 mm → cut out borders → 800 mm x 800 mm → thickness measurement

EMC **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	$>10^{9}$

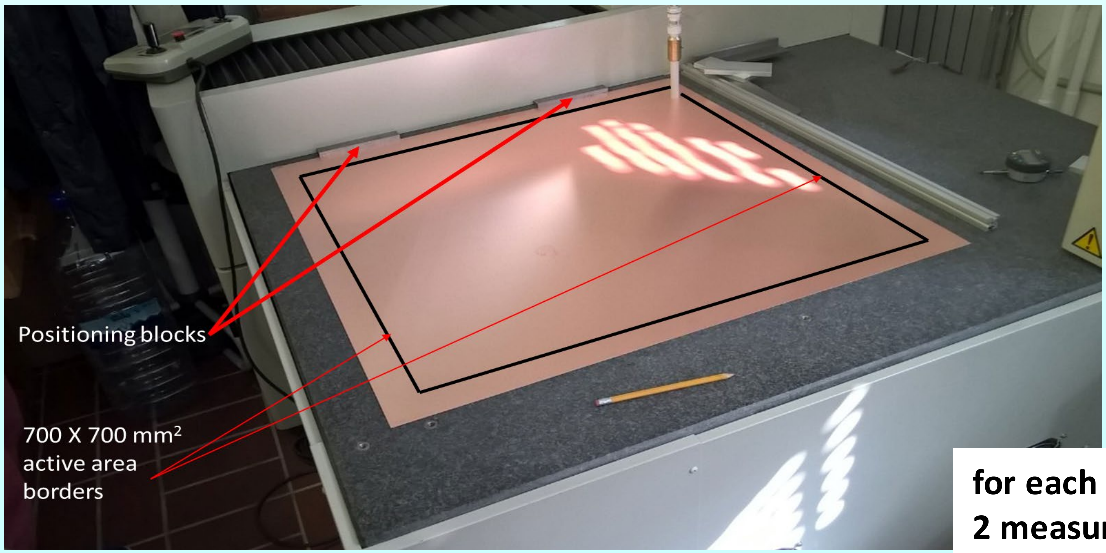


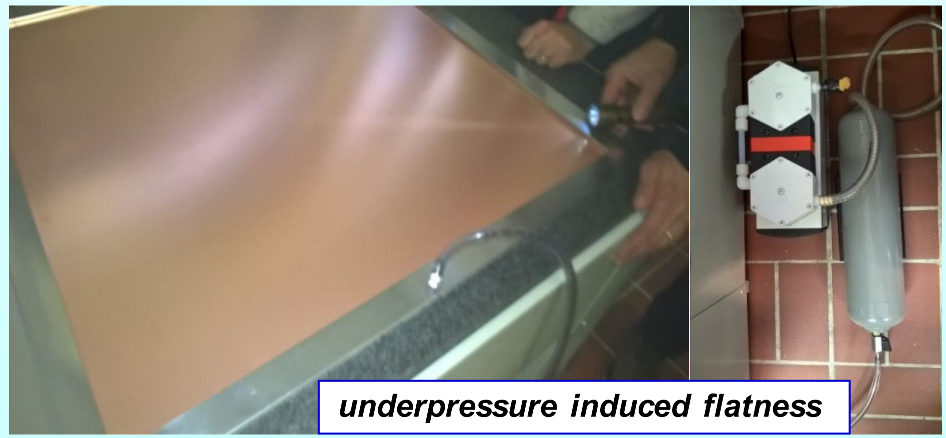


Mitutoyo EURO CA776

coordinate measuring machine with ruby touch probe,

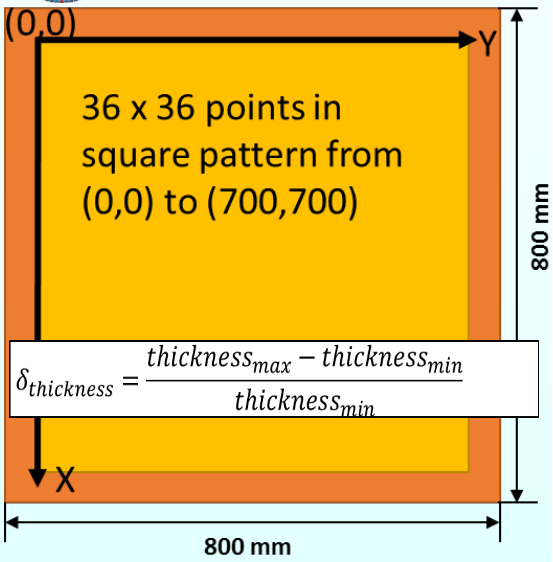
hosted in a thermalized room



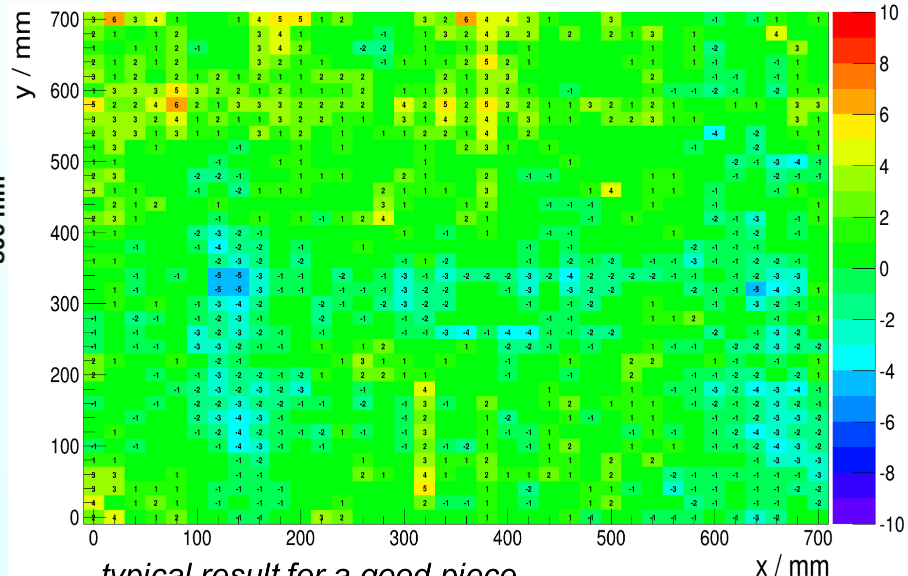


for each foil 36 x 36 points in square pattern are measured
2 measurements (direct and reversed) to allow consistency checks.

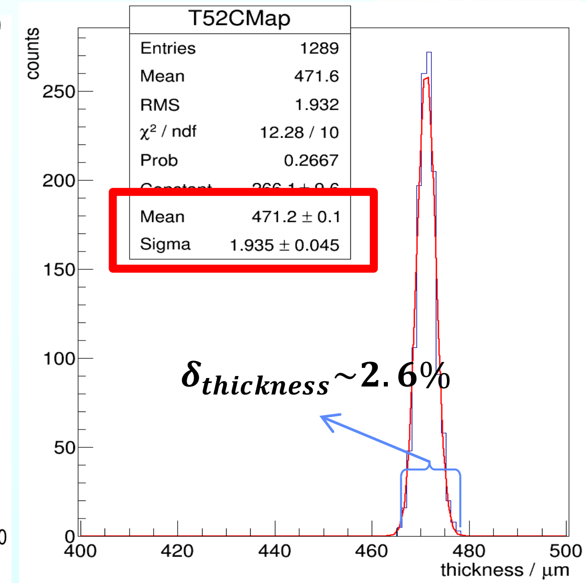
THGEM raw material selection



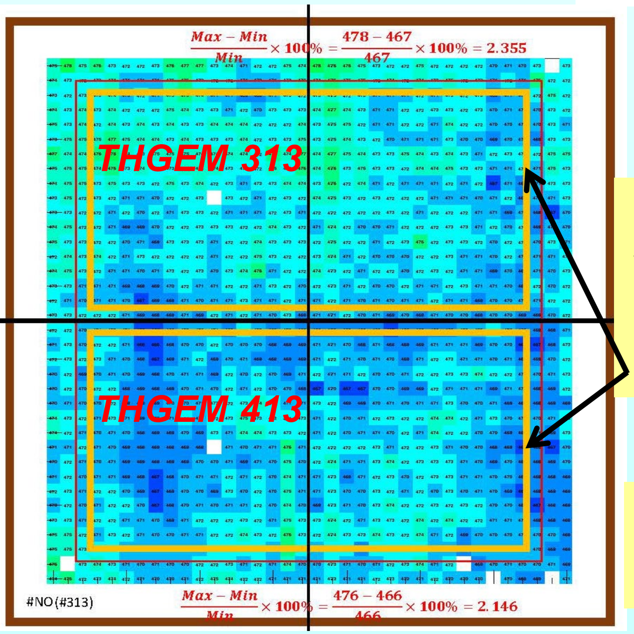
$$\delta_{thickness} = \frac{thickness_{max} - thickness_{min}}{thickness_{min}}$$



typical result for a good piece.



$\delta_{thickness} \sim 2.6\%$



$\frac{Max - Min}{Min} \times 100\% = \frac{478 - 467}{467} \times 100\% = 2.355$

$\frac{Max - Min}{Min} \times 100\% = \frac{476 - 466}{466} \times 100\% = 2.146$

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

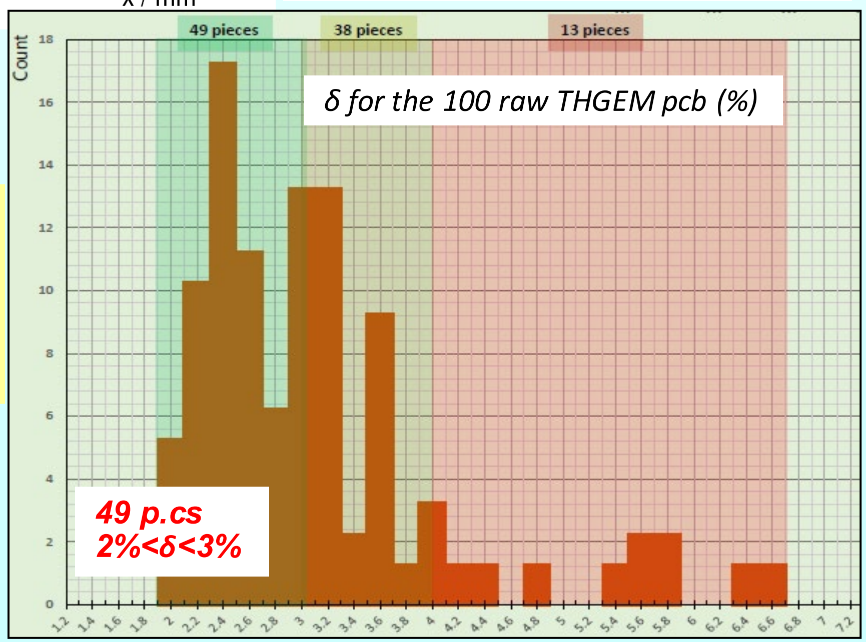
from each foil two THGEMS can be produced:

50 foils → 100 raw THGEM pcb

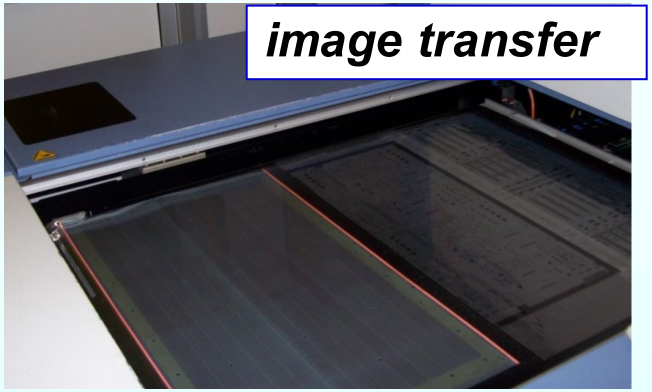
THGEM pcb size = 620 mm x 320 mm,

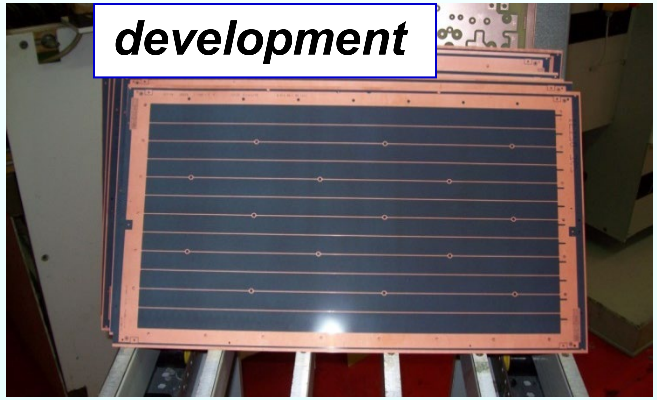
active area = 581 mm x 287 mm

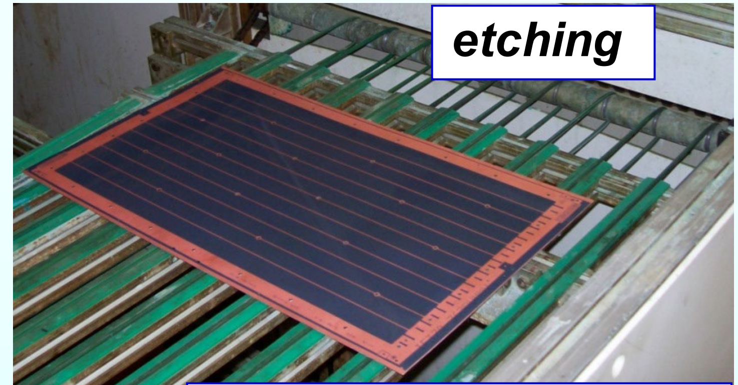
60 THGEMs have been produced by ELTOS

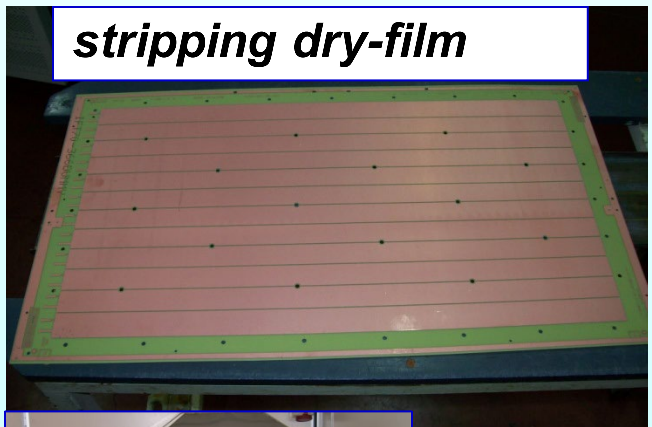


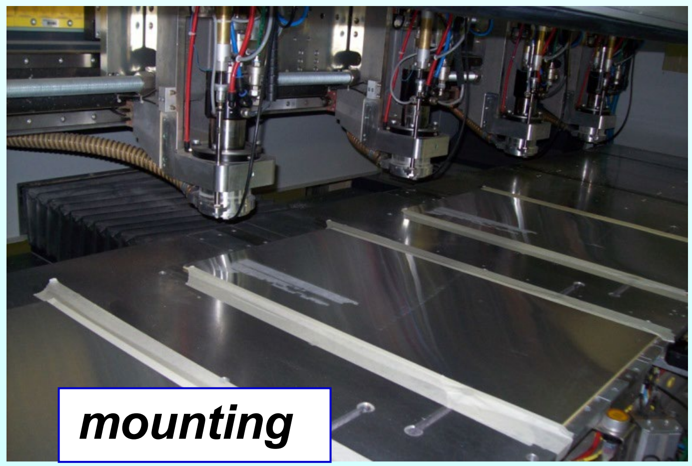
Production of the THGEMs at ELTOS

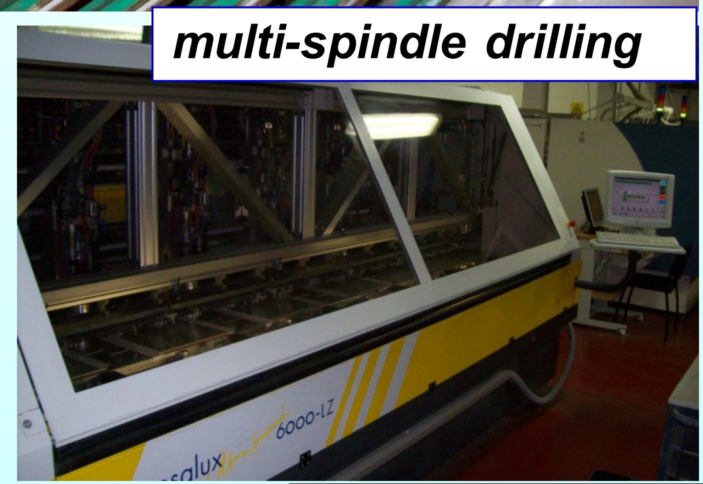




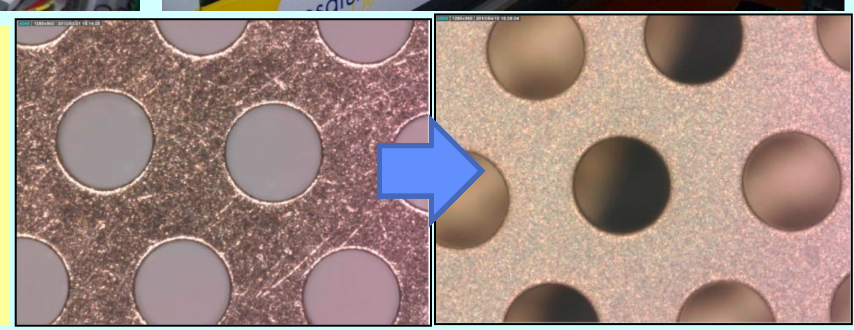




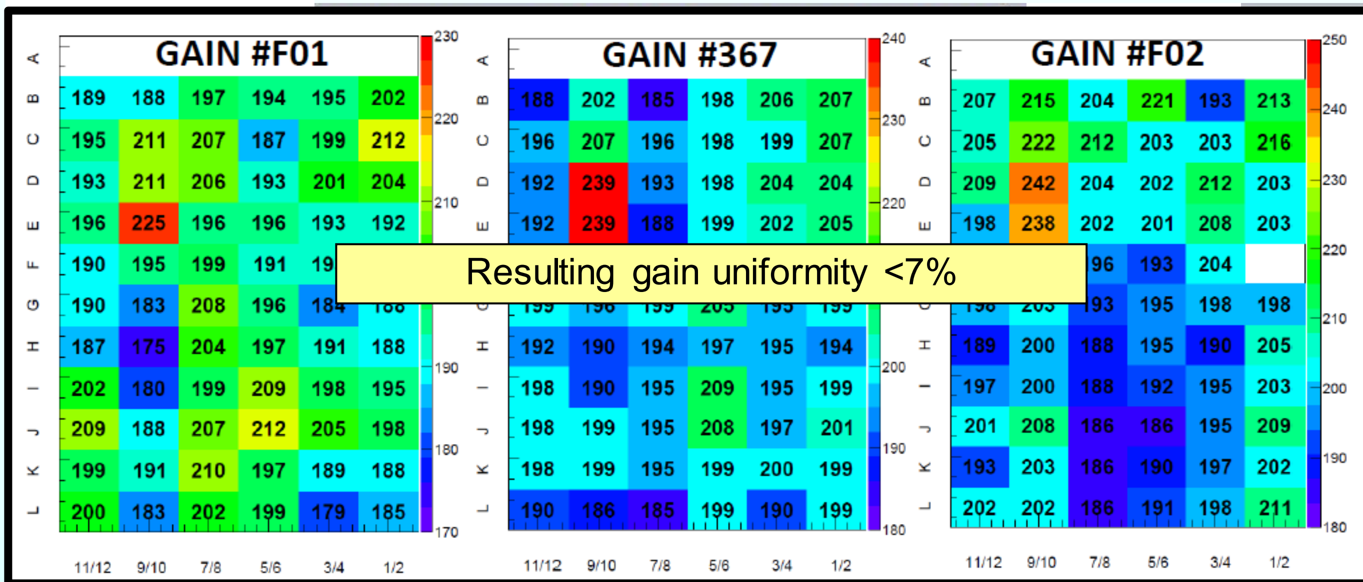




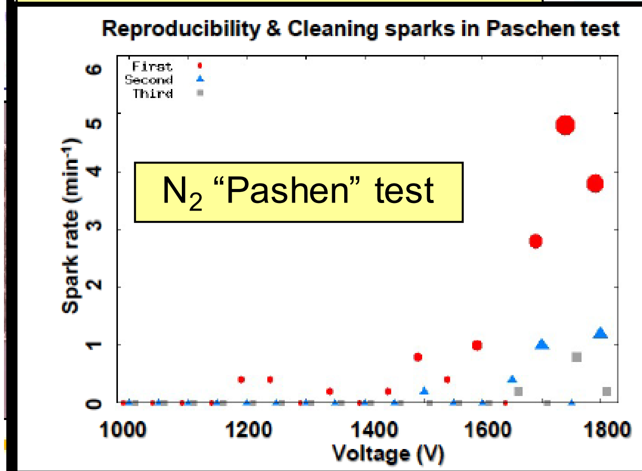
In Trieste a specific cleaning procedure is applied : polish with fine grain pumice powder, pressure water cleaning, ultrasonic Bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160 ºC

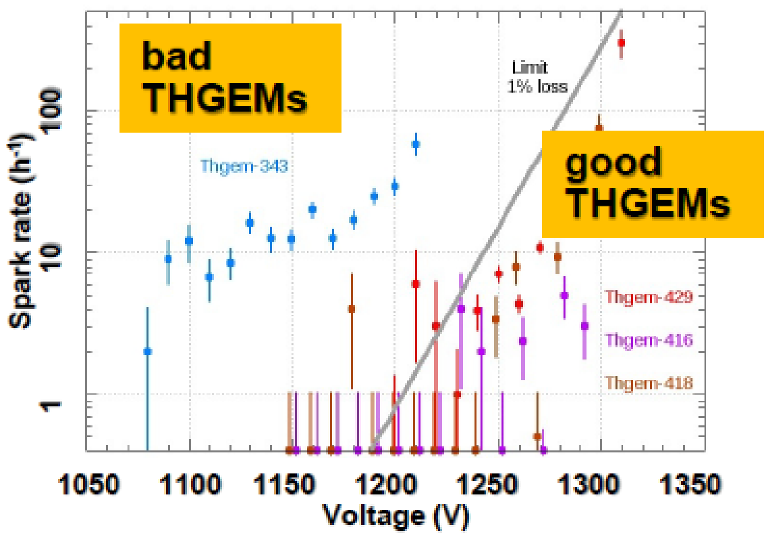


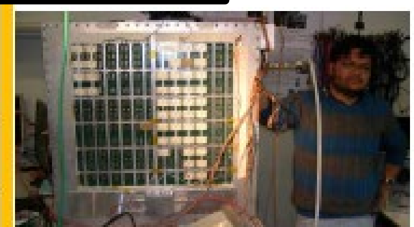
quality control



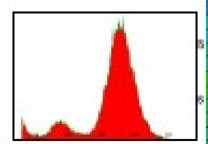
Electrical stability tests

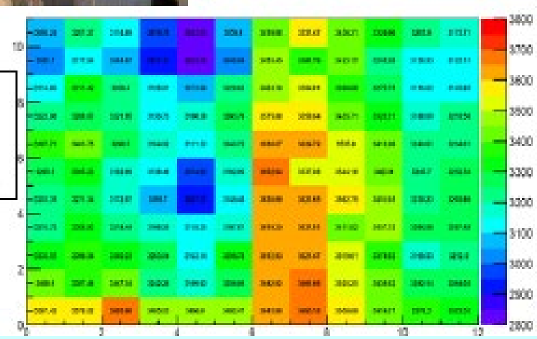




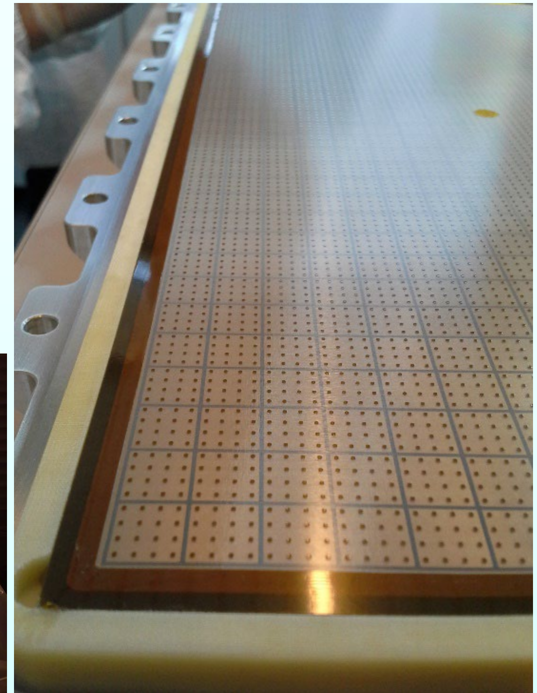


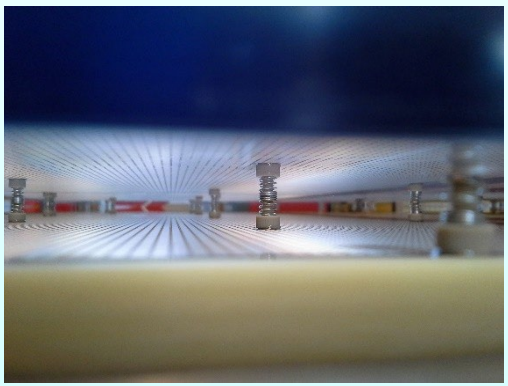
X-ray MM test to access integrity and gain uniformity (<5%)

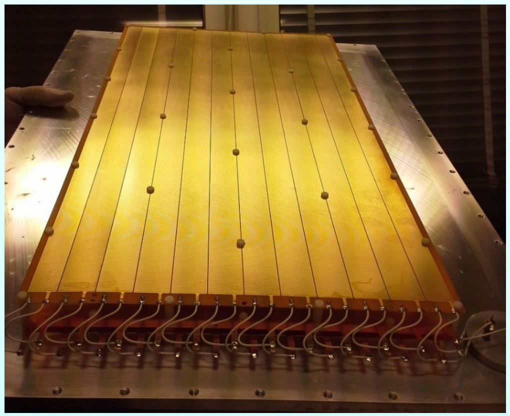


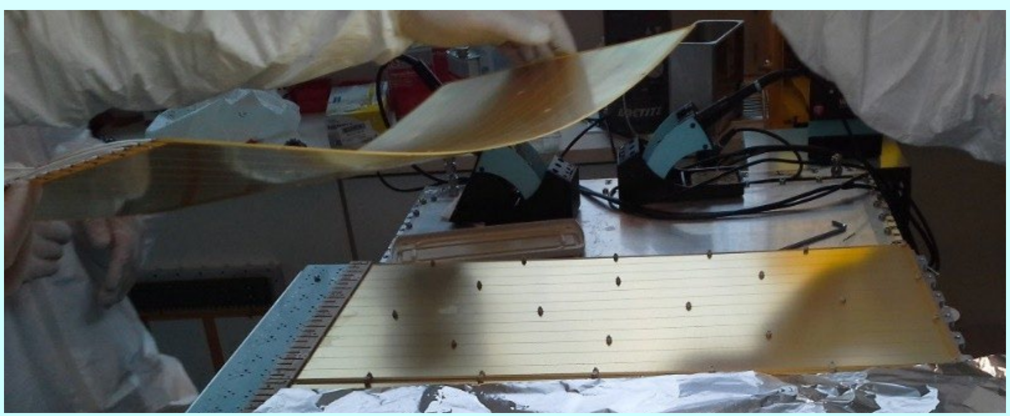


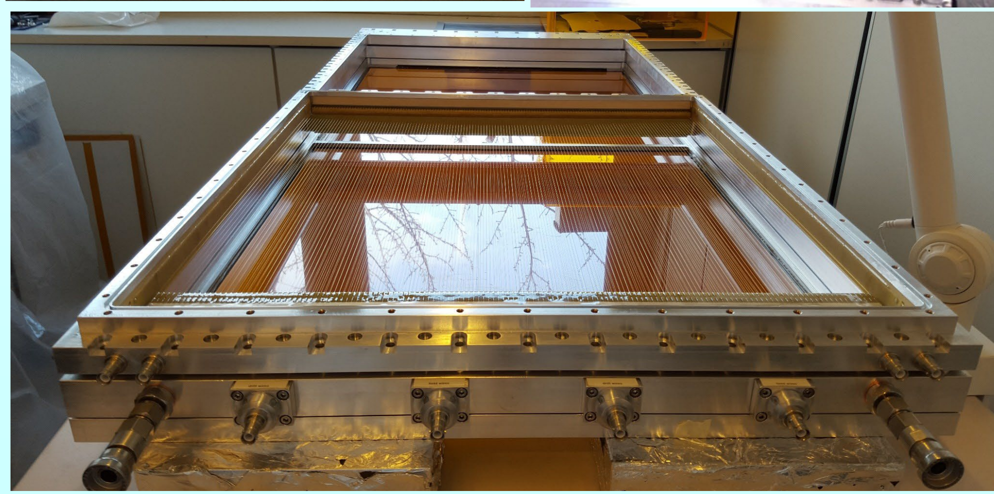
assembling



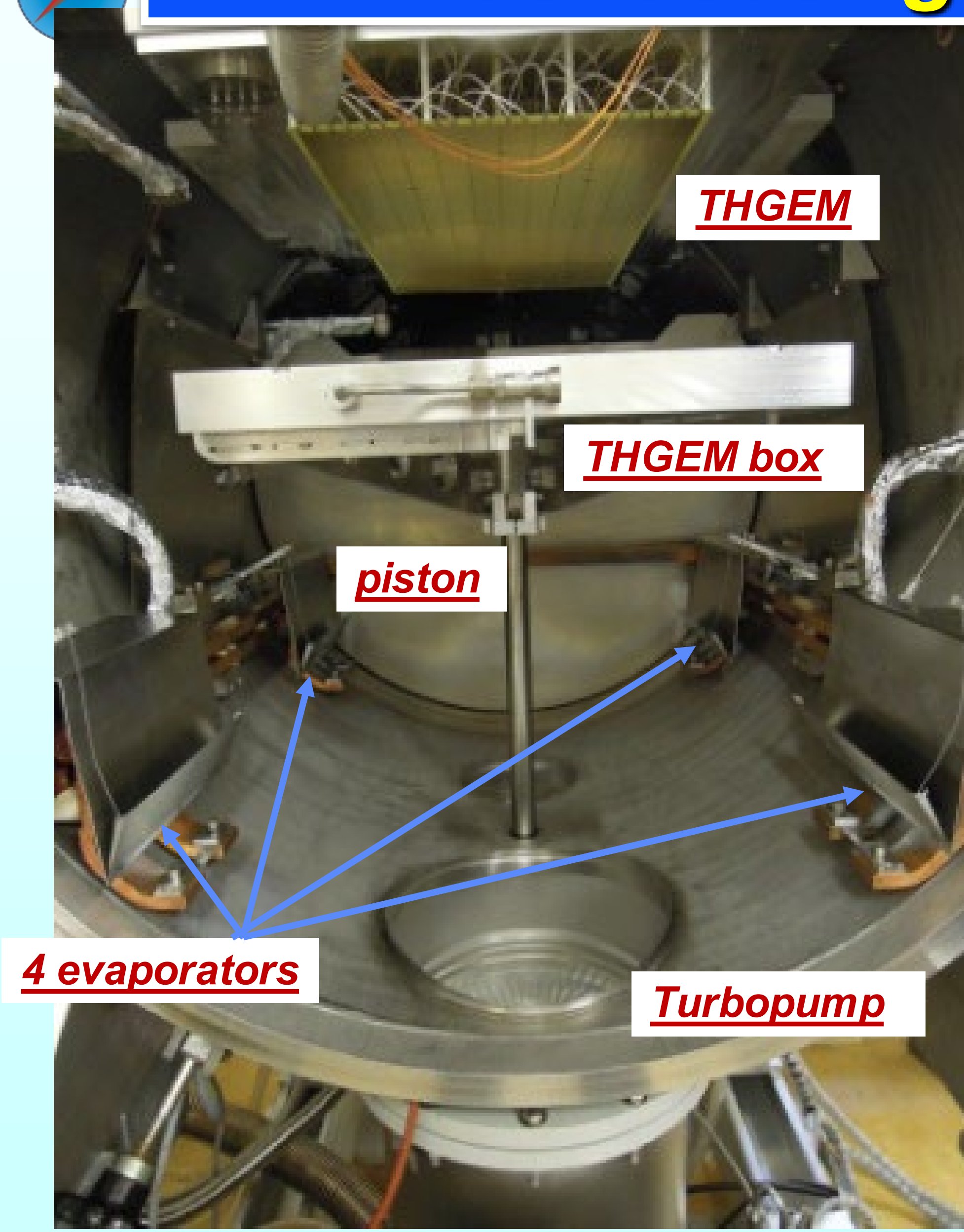


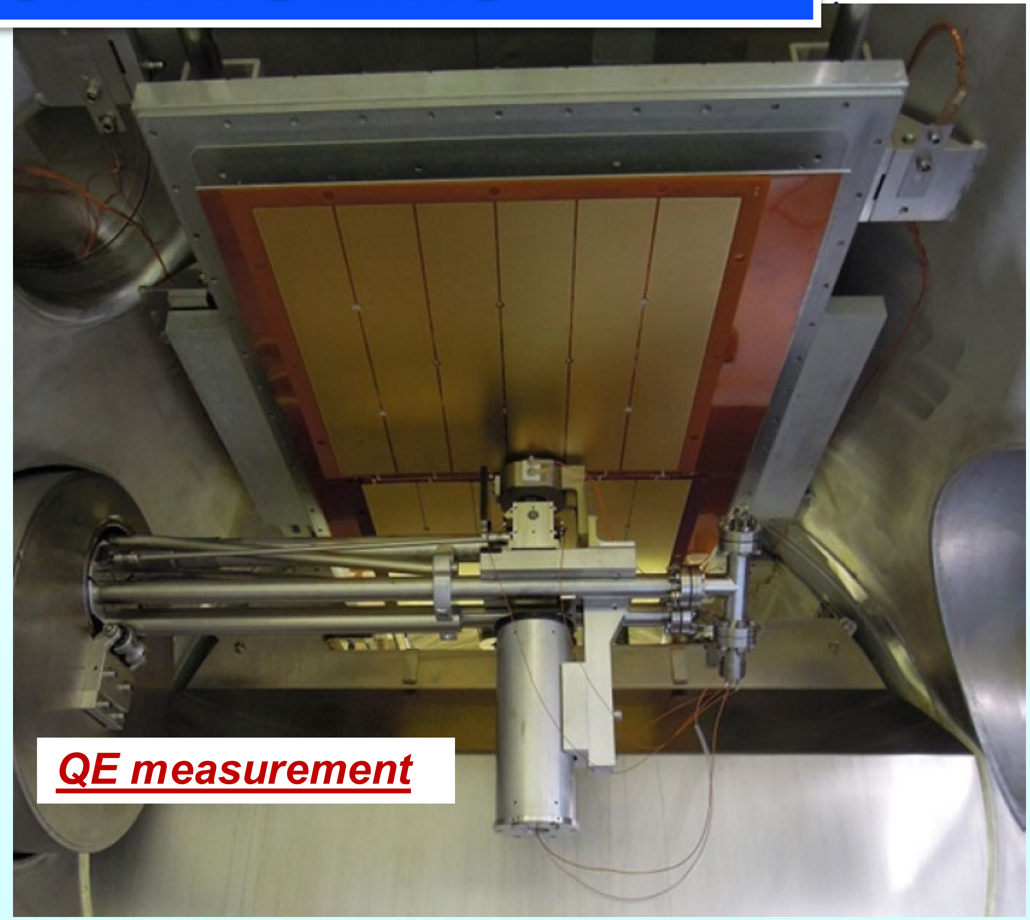


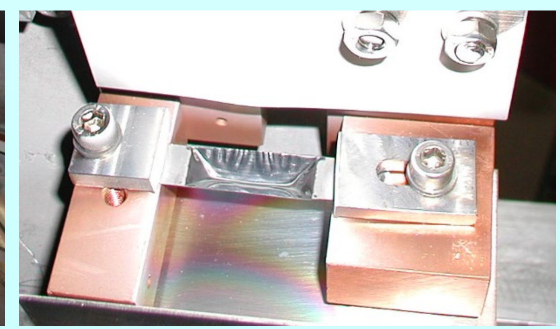




CsI coating of THGEMs





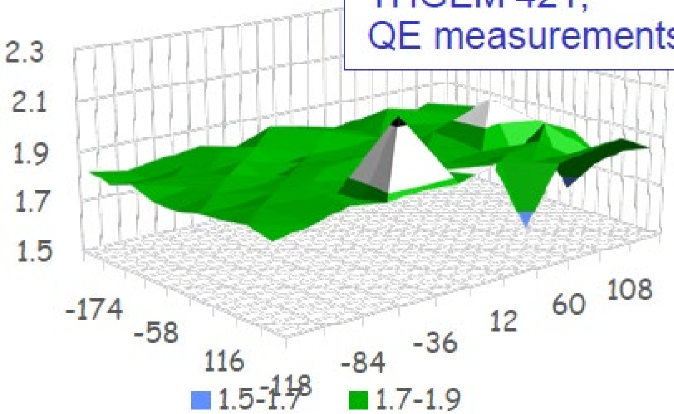


CsI QE measurement

19 CsI evaporations performed at CERN 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 421, QE measurements



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

coated by T. Schnider and M. Van Stenis

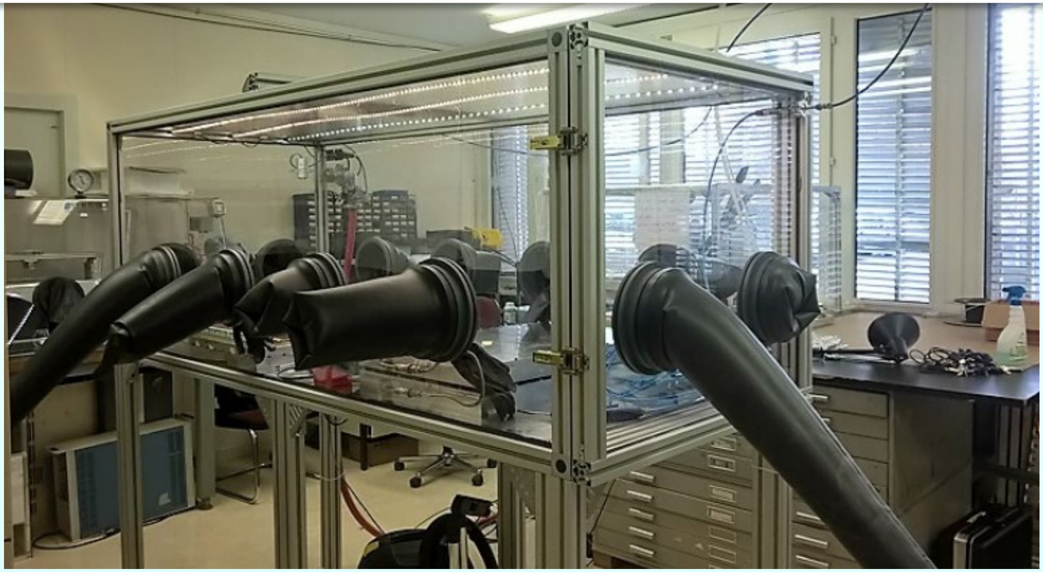
QE uniformity

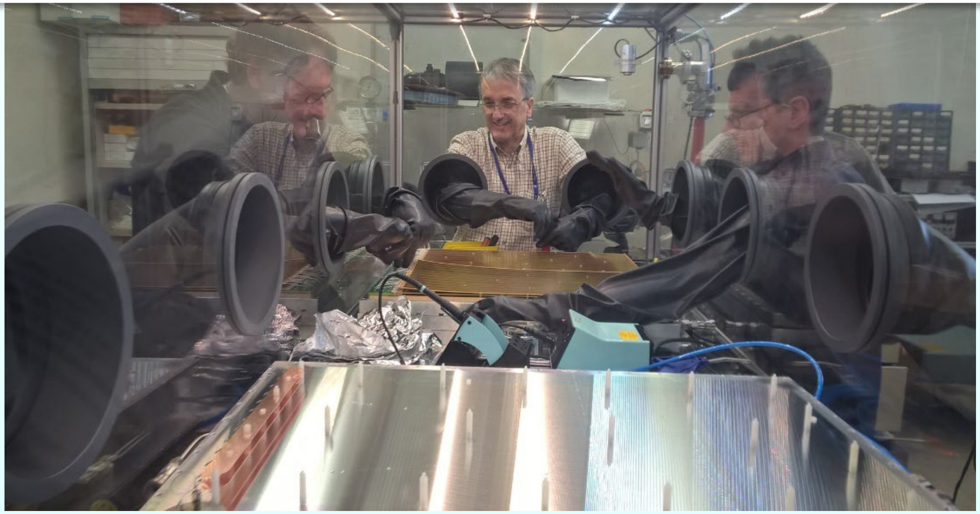
- **3 % r.m.s. within a photocathode**
- **10 % r.m.s. among photocathodes**

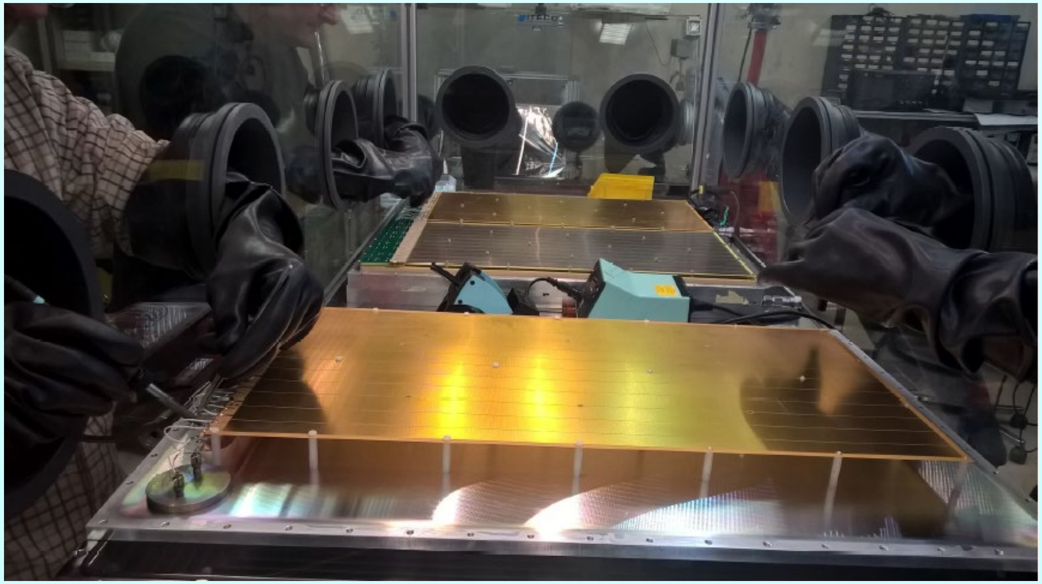
Optical transparency: $\frac{\pi}{2\sqrt{3}}\left(\frac{d}{p}\right)^2$ *~ 0.23* →

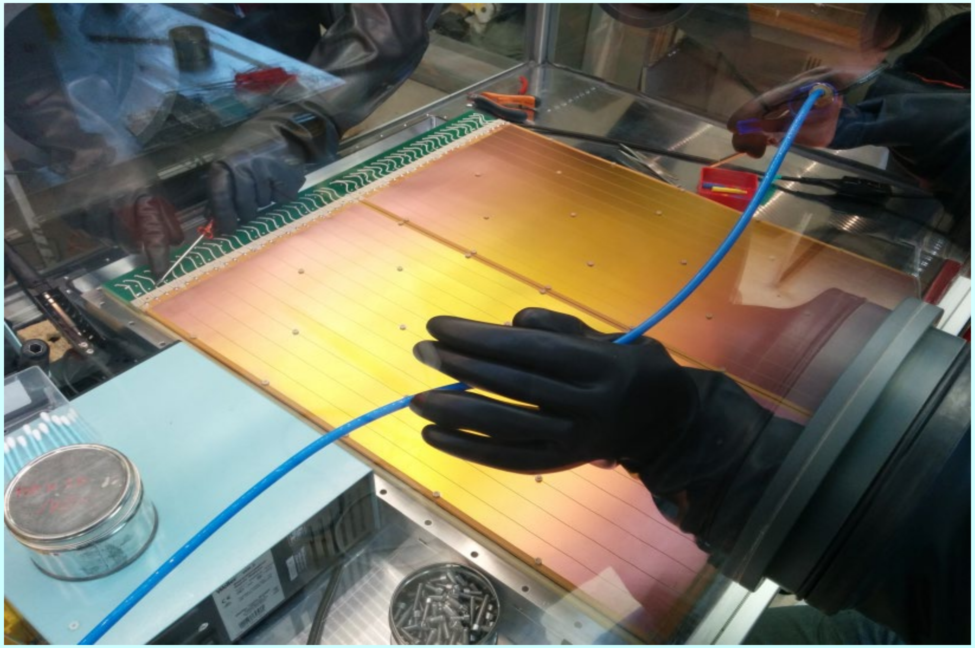
mean THGEM QE: ~ 93% of reference

CsI THGEM mounting

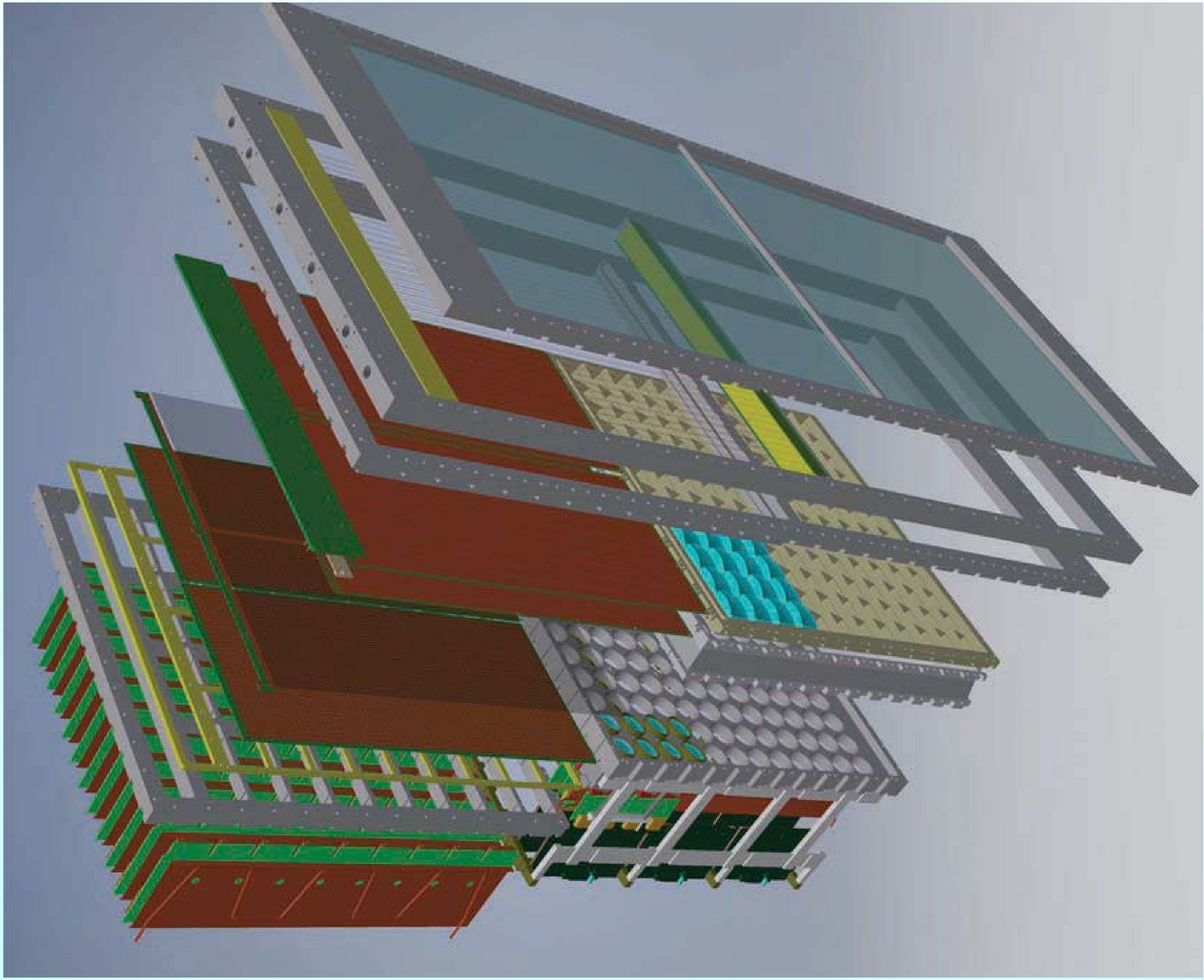




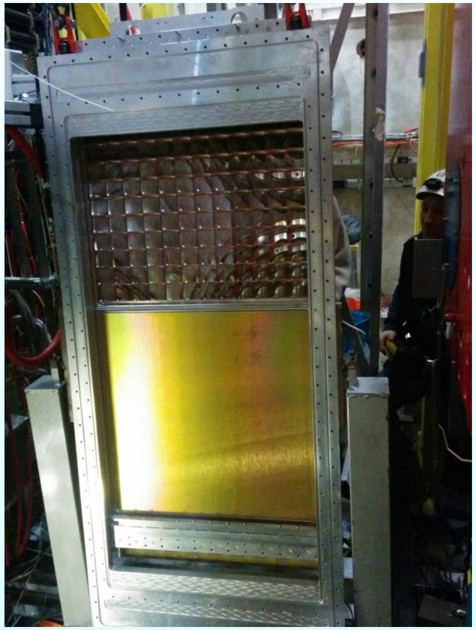




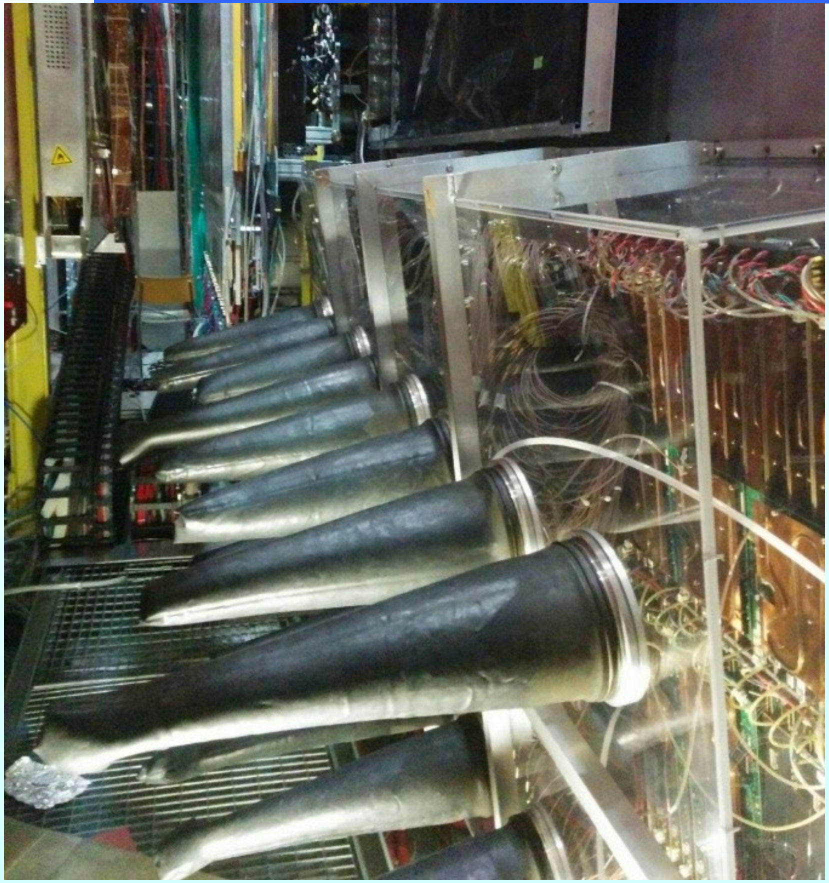
The combined COMPASS PDs

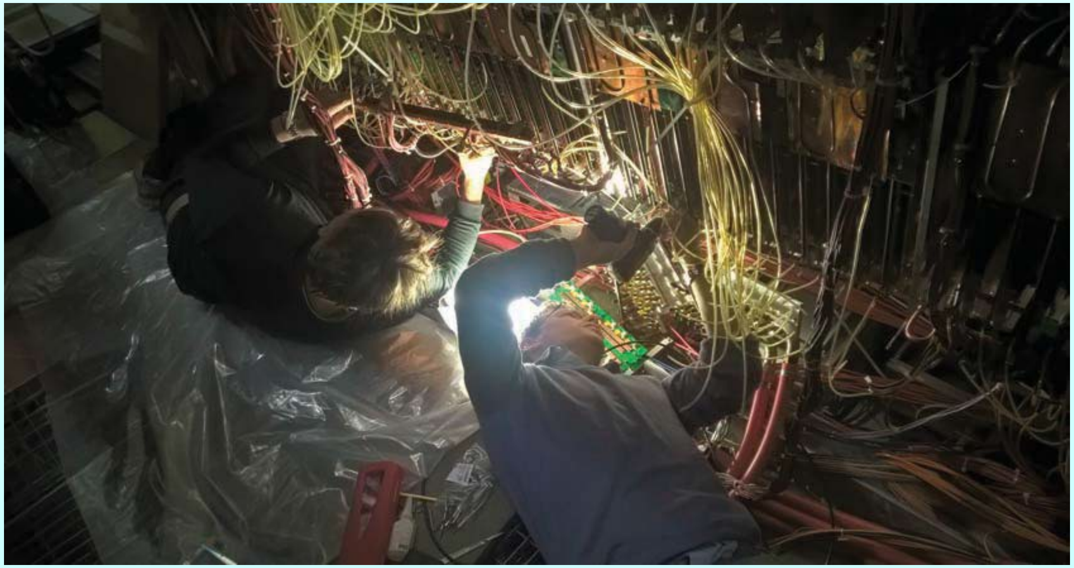


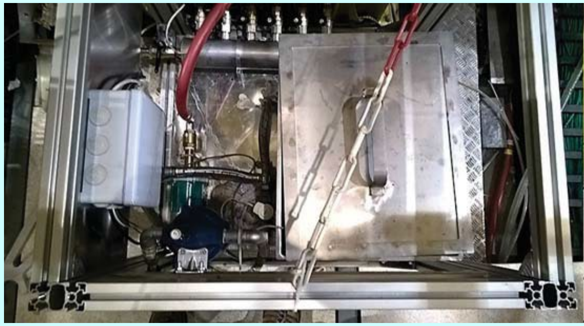
Installation of hybrids on RICH-1

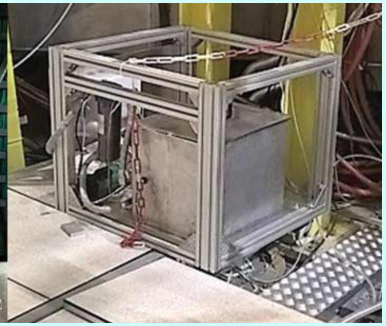


Equipping the hybrids on RICH_1



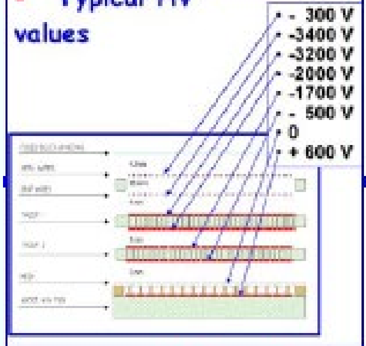




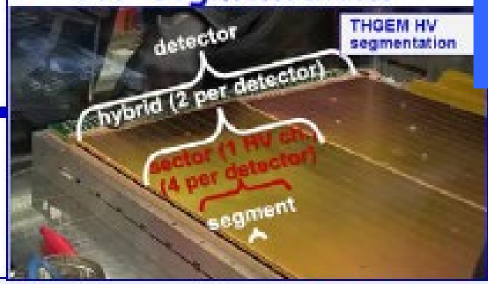


HV CONTROL

- Typical HV values



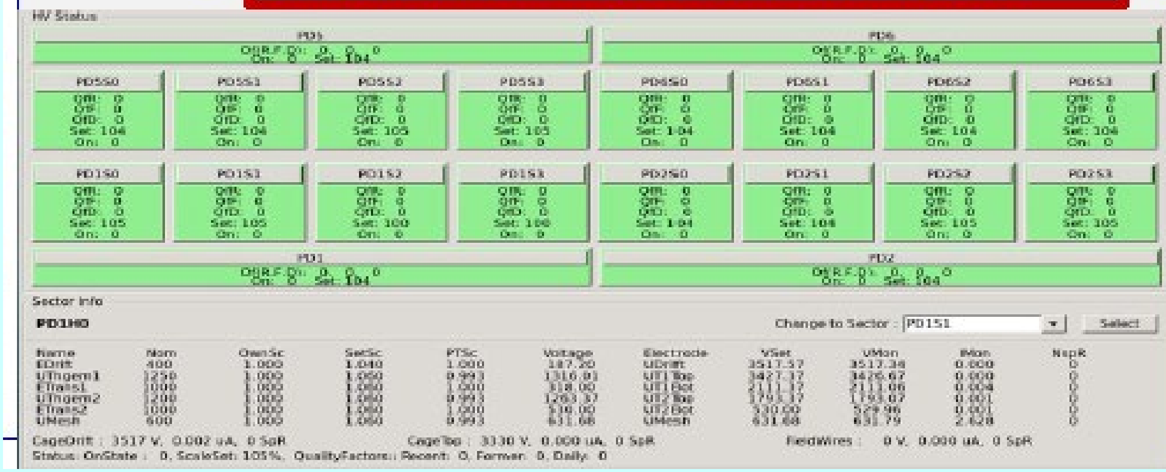
- HV segmentation



In total 136 HV channels with correlated values

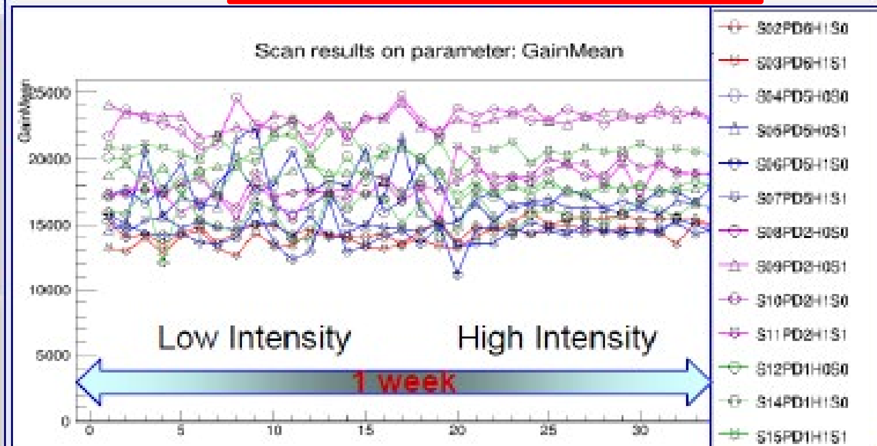
Gain equalization: uniformity at ~1% level

- **Hardware, commercial by CAEN**
- **HV control**
  - Custom-made (C++, wxWidgets)
  - Compliant with COMPASS DCS (slow control)
  - "OwnScale" to fine-tune for gain uniformity
  - V, I measured and logged at 1 Hz
  - Autodecrease HV if needed (too high spark-rate)
  - User interaction via GUI
  - Correction wrt P/T to preserve gain stability



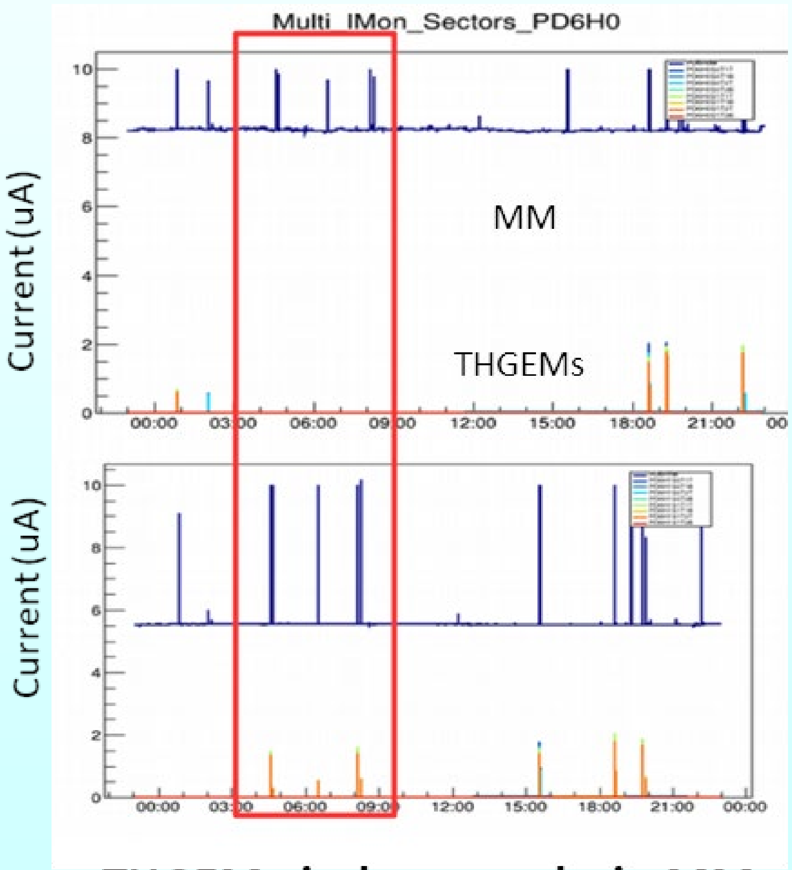
- **Gain stability vs P, T:**
  - G = G(V, T/P)
  - Enhanced in a multistage detector
  - ΔT = 1°C → ΔG ≈ 12 %
  - ΔP = 5 mbar → ΔG ≈ 18 %
- **THE WAY OUT:**
  - Compensate T/P variations by V

    → Gain stability at 5% level



sparks

Spark: event with I > 23 nA



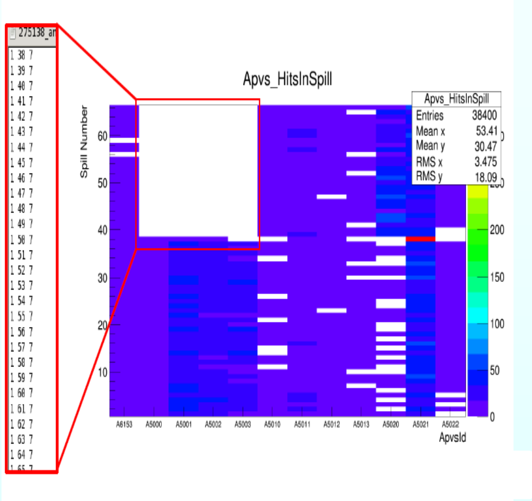
THGEMs induce sparks in MMs

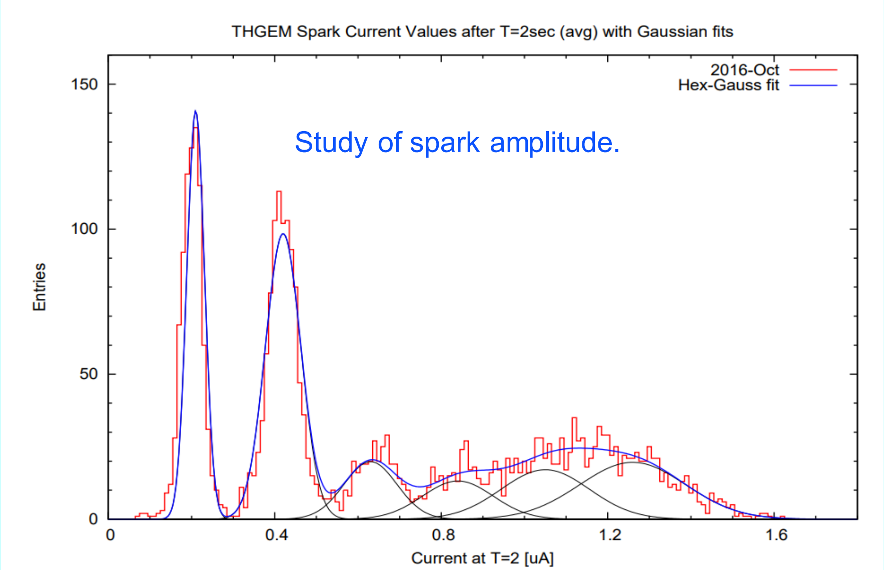
Current sparks in THGEMs

- Rate < 1/h per detector
- Recovery time: ~ 10 s
- Fully correlated between the two layers
- Mild dependence on beam intensity

Current sparks in MICROMEGAS

- Induced by THGEMs
- Recovery time: ~1 s





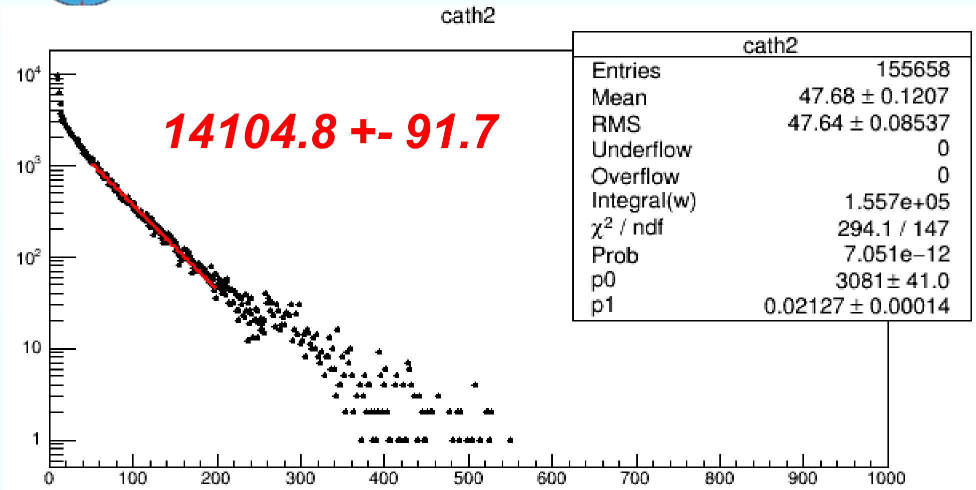
Some sparks produce APV errors.

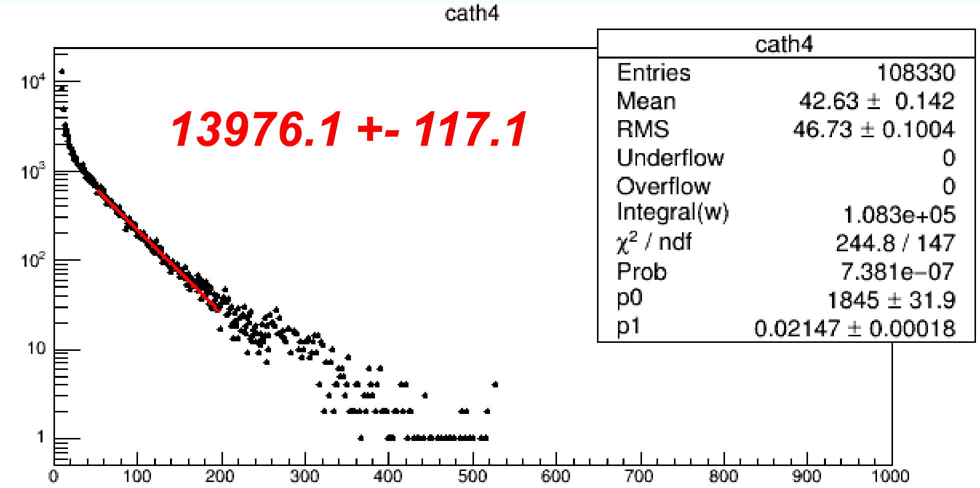
APV header error related to data scrambling.

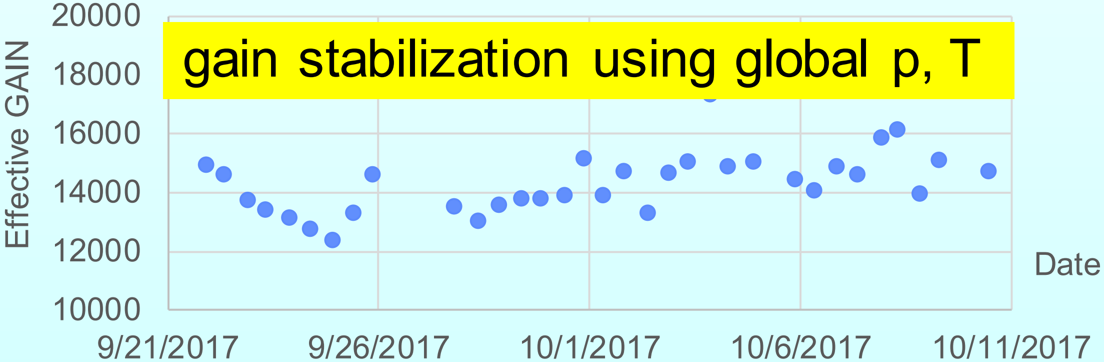
Missing hits and data attributed to different channels.

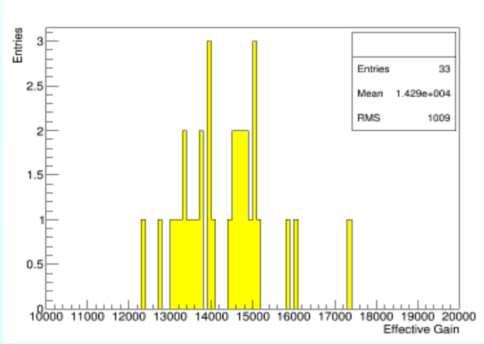
→Automatic APV reload procedure as soon as APV header errors are detected.

Gain stability in time

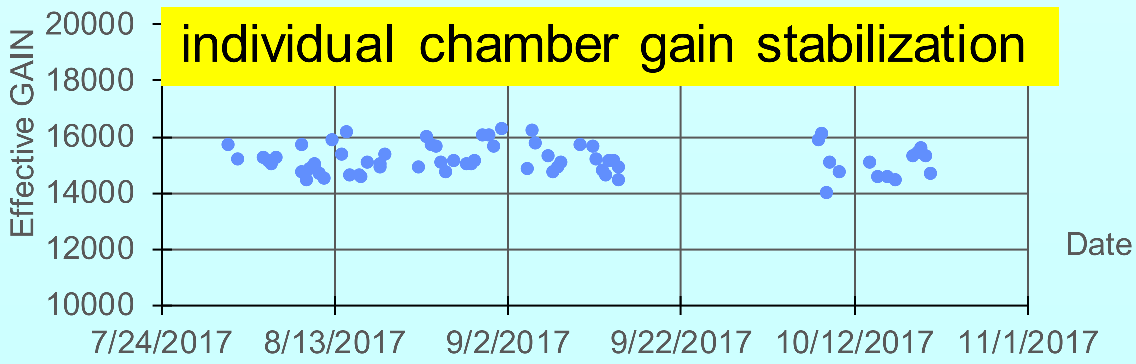


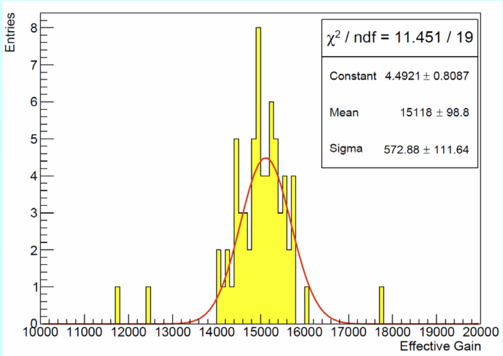






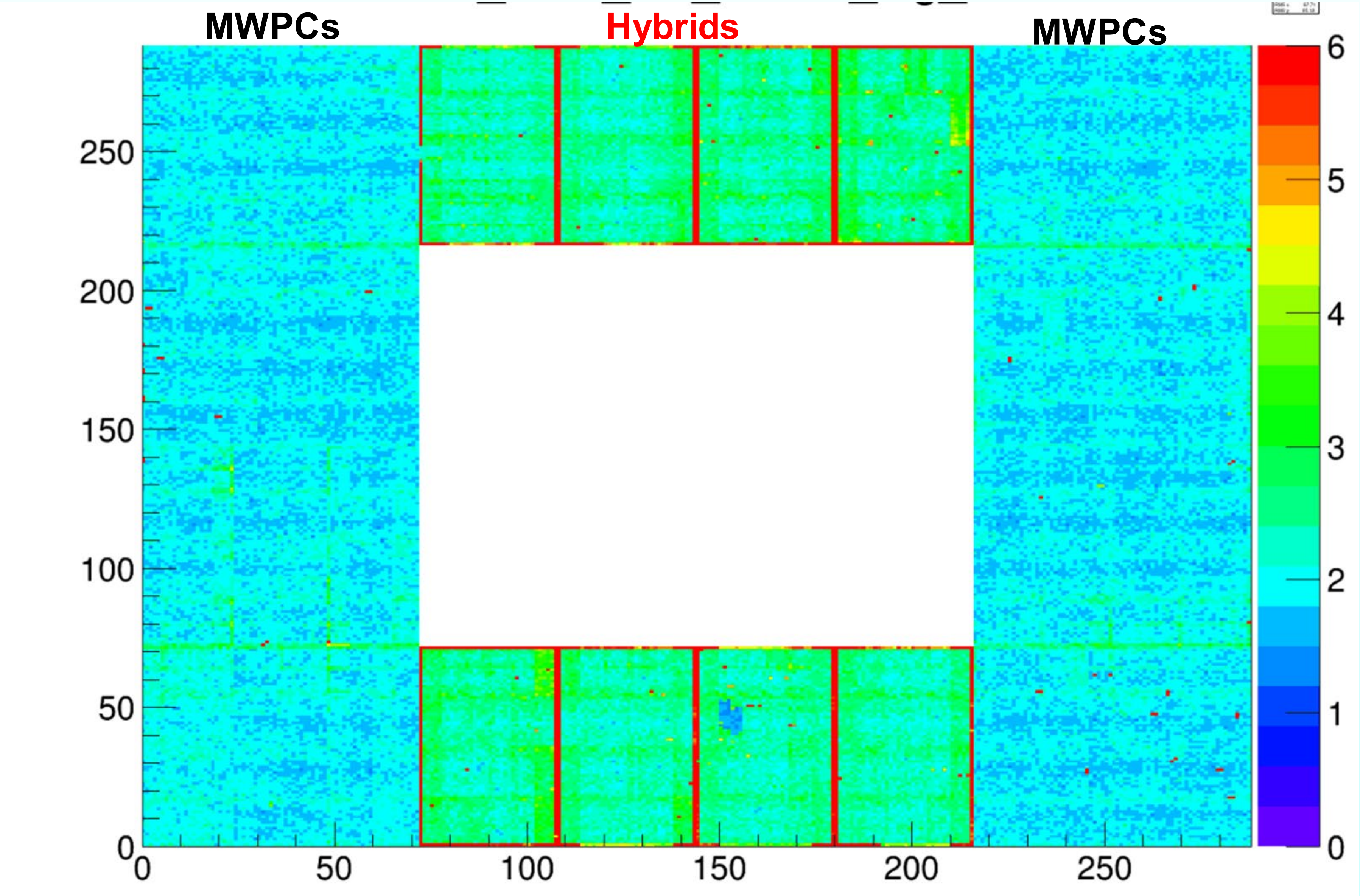
global
corrections:
σ/mean ~ 7%



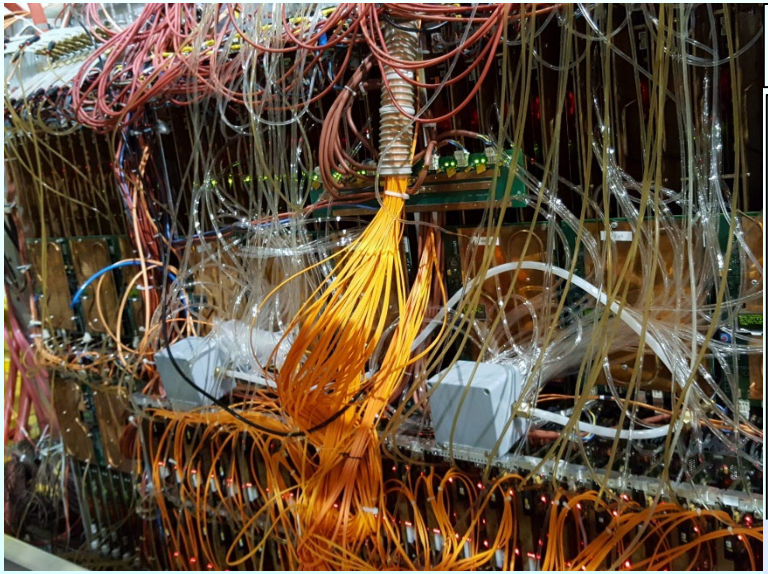


individual
corrections:
σ/mean ~ 4%

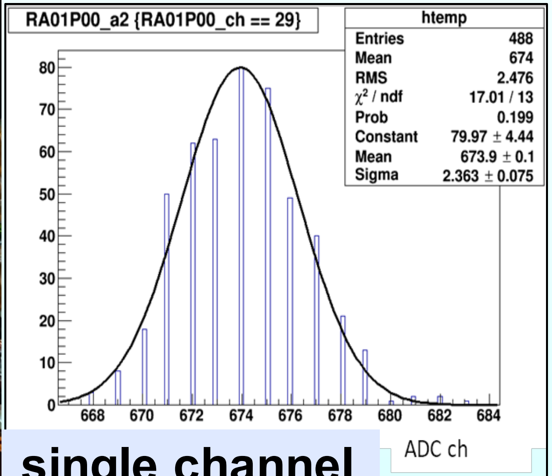
Noise figure for the 62208 ch.



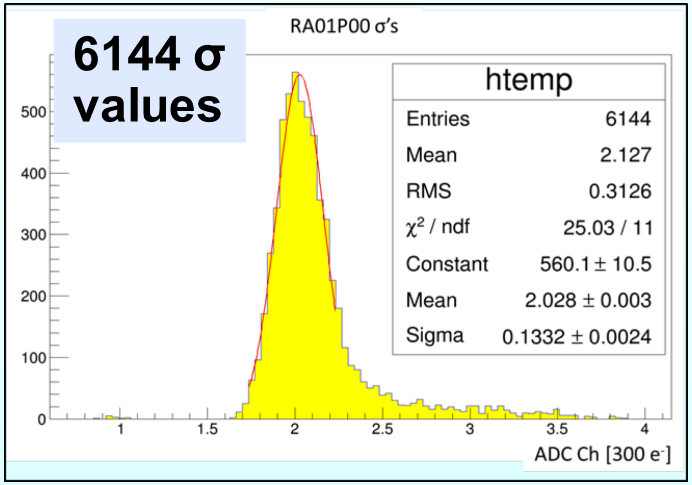
Noise level and pedestal stability



- 12 Detectors, 6144 Ch each.

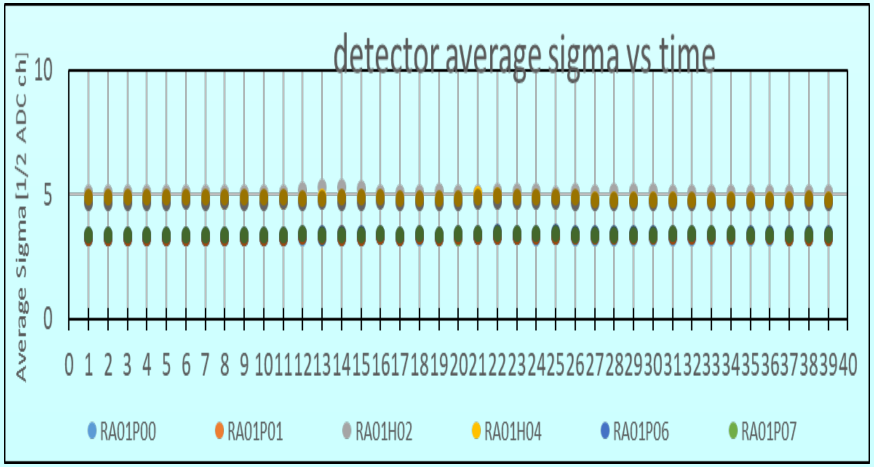


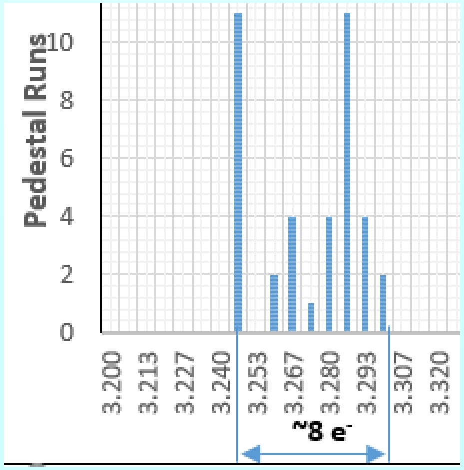
single channel



6144 σ values

- 39 APV Pedestal Runs during COMPASS 2017 run.





The APV25-based F/E is the same for MWPCs +CsI and Hybrid PD's

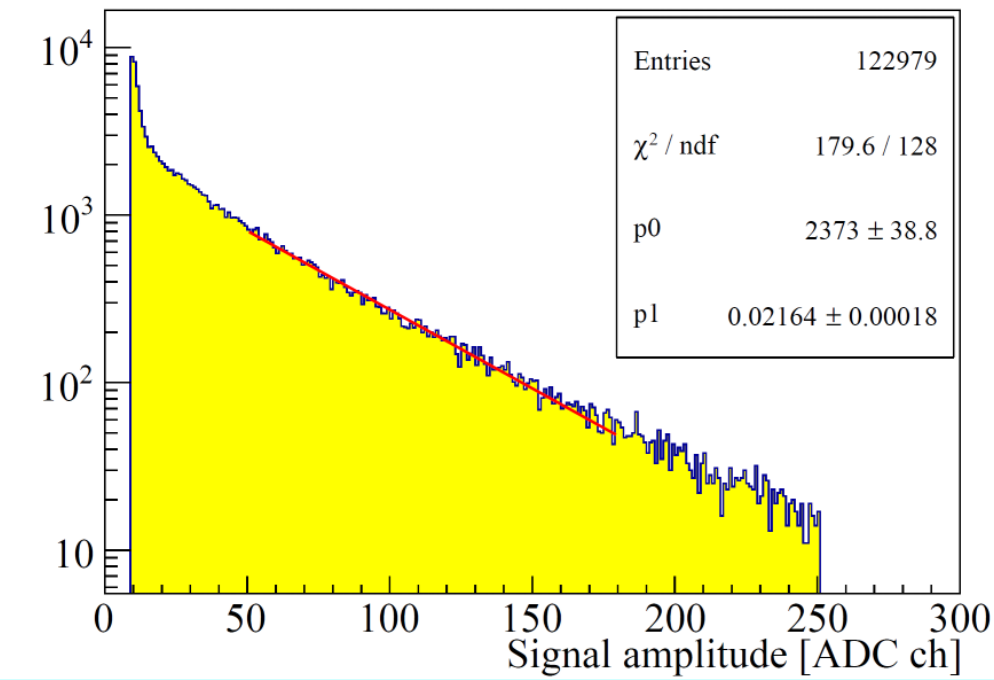
The noise levels are:

- MWPC: ~ 600 e^-
- **Hybrid: ~ 800 e^-**

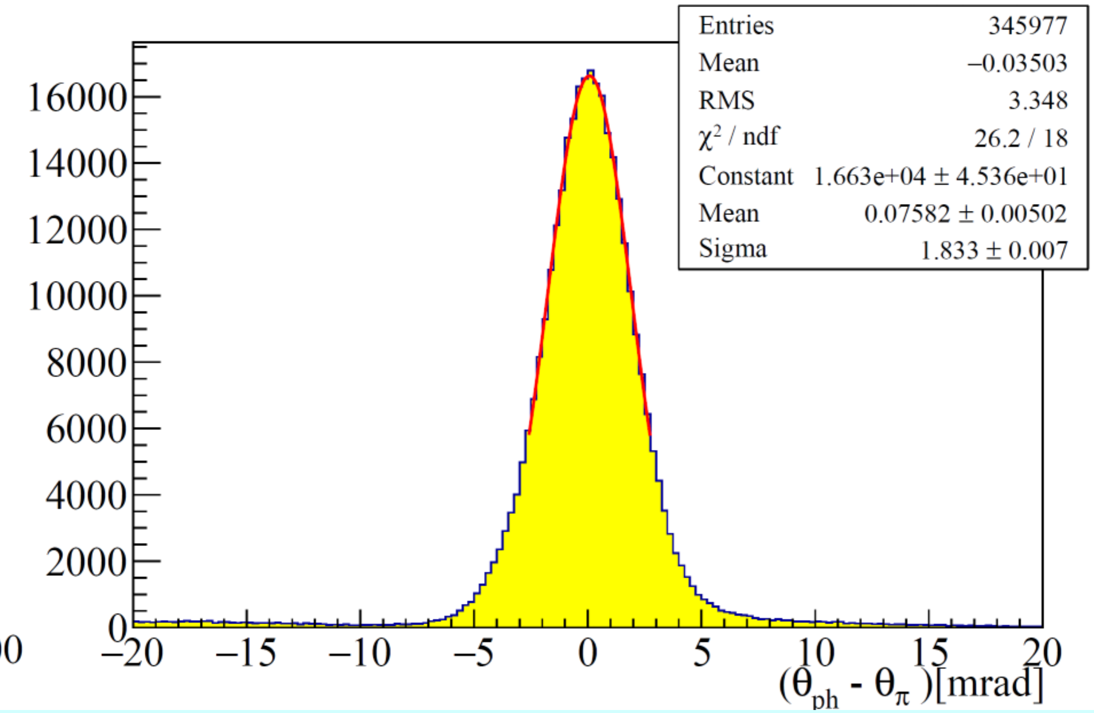
The noise levels are very stable in time

Gain and angular resolution

Effective gain : ~14000 +- 140

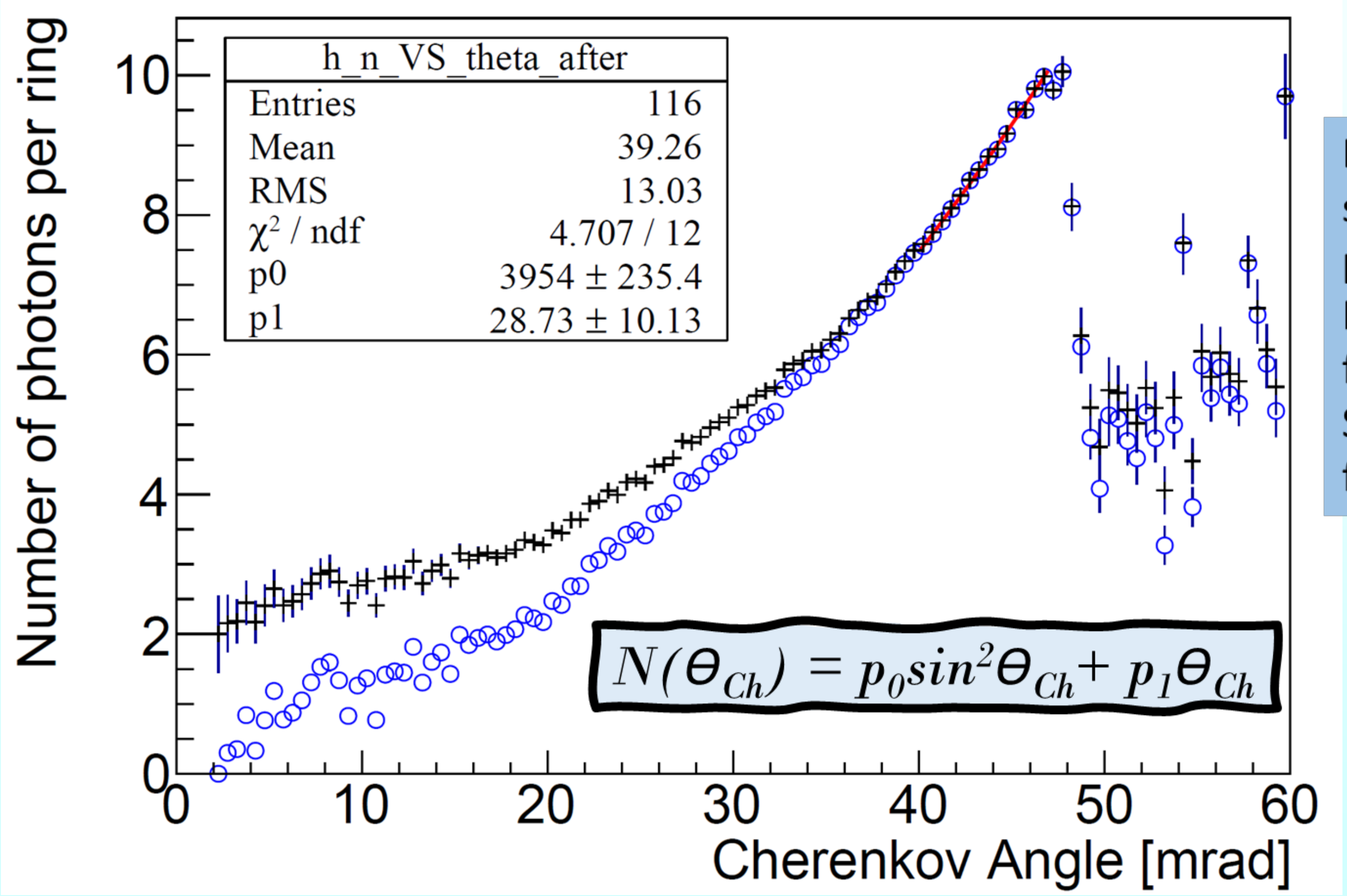


Single photon resolution: 1.83 +- 0.01 mrad



The COMPASS/AMBER MPGD-based PDs have been stably operating since years.

Number of photons per ring



Extrapolate to saturation, number of photon= **12.9**
First part of the function = 11.5 +/- 0.4
Second part of the function= 1.4 +/- 0.3

The COMPASS/AMBER MPGD-based PDs have 11.5 average detected photons per ring at saturation, higher gain and higher stability than the MWPCs +CsI.

STCF RICH

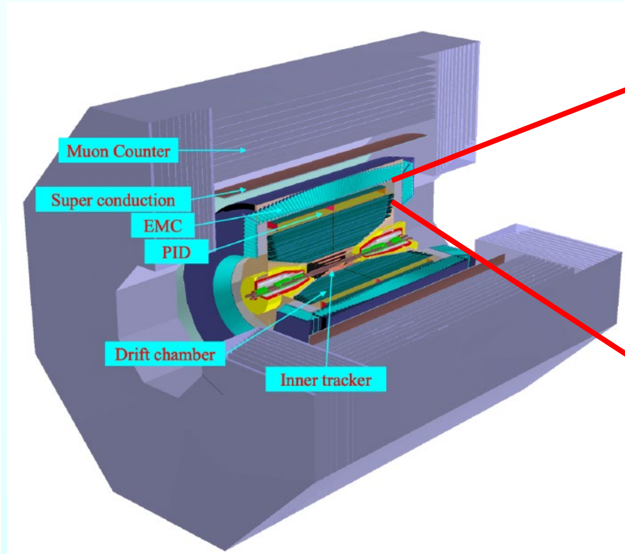
STCF

Conceptual Design Report

Abstract

The Super τ-Charm facility (STCF) is an electron-positron collider proposed by the Chinese particle physics community. It is designed to operate in a center-of-mass energy range from 2 to 7 GeV with a peak luminosity of 0.5×10^{35} $cm^{-2}s^{-1}$ or higher. The STCF will produce a data sample about a factor of 100 larger than that of the present τ-Charm factory — the BEPCII, providing a unique platform for exploring the asymmetry of matter-antimatter (charge-parity violation), in-depth studies of the internal structure of hadrons and the nature of non-perturbative strong interactions, as well as searching for exotic hadrons and physics beyond the Standard Model. The STCF project in China is under development with an extensive R&D program. This document presents the physics opportunities at the STCF, describes conceptual designs of the STCF detector system, and discusses future plans for detector R&D and physics case studies.

arXiv:2303.15790v3 [hep-ex] 5 Oct 2023



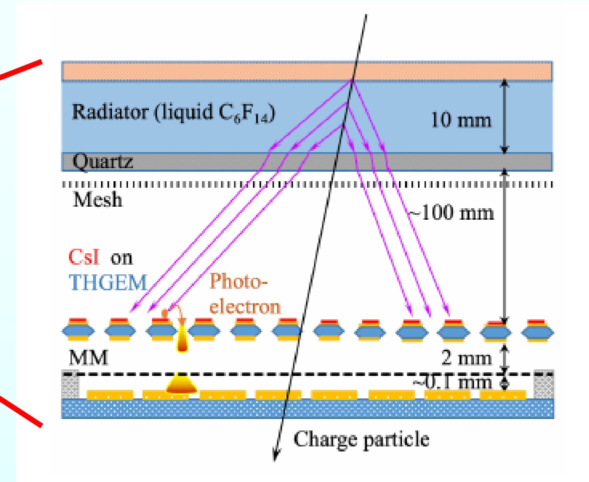


Figure 3.42: The RICH detector structure.

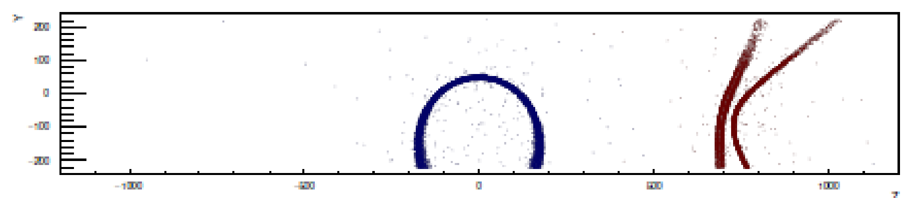


Figure 3.46: Examples of Cherenkov images in a RICH module. The blue image depicts the distribution of hits for 2 GeV/c pion with incident angle $\theta = 0°$, perpendicular to RICH, while the red image depicts $\theta = 40°$.

Hybrid THGEM-Micromegas PD's have recently been proposed for the RICH of the STCF

CONCLUSIONS

- COMPASS RICH-1 has been upgraded with 1.4 m^2 of MPGD-based PDs.
- Specific solutions to achieve control over THGEM gain response.
- The Hybrid PD: 2 THGEMs (1 with CsI) + Micromegas are nicely operating.
- Good stability, low IBF, low spark rate. Spark effects mitigation measures.
- 1.83 mrad single photon angular resolution, 11.5 detected photons per ring.
- Future RICH projects are considering the use of this technology.