COMPASS RICH-1 Upgrade with MPGD-based Photon Detectors (lessons learned, experience, performance)

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

on behalf of the COMPASS RICH Group

The COMPASS RICH-1 upgrade

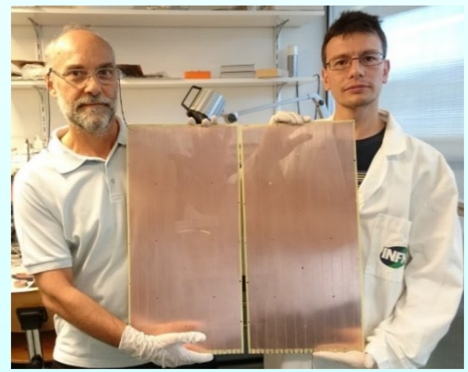
The hybrid PD design and construction

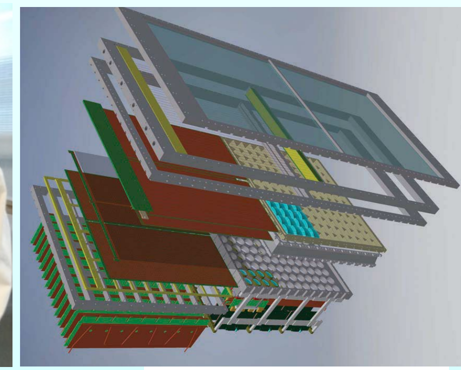
HV control, spark rates, noise level

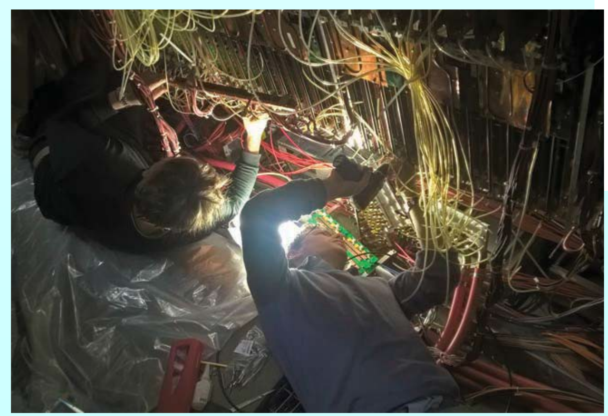
Uniformity and stability

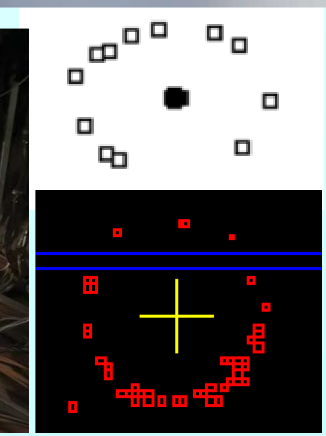
Hybrid PD characterization

Conclusions



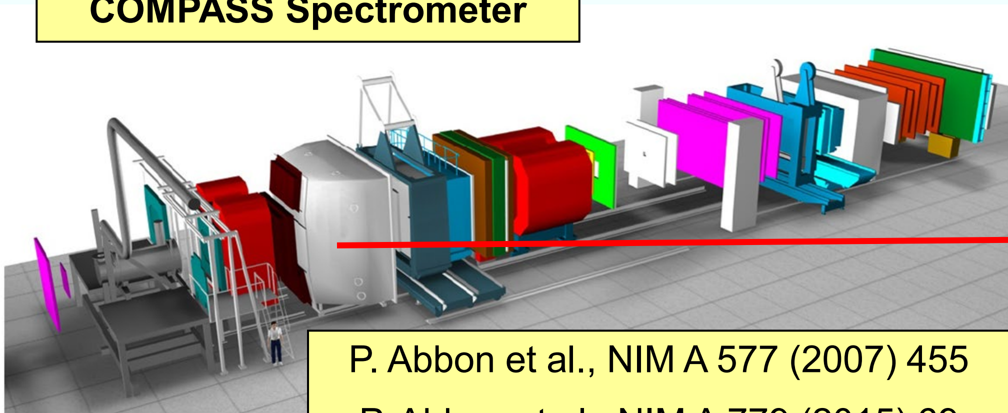






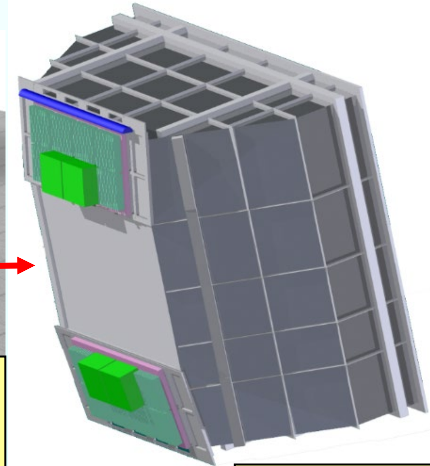
COMPASS RICH-1 upgrade

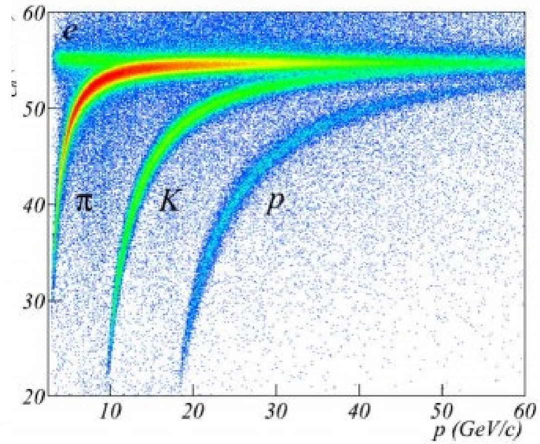
COMPASS Spectrometer



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

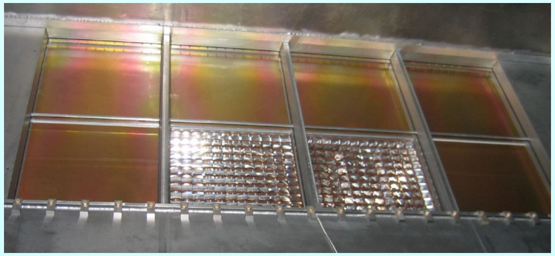
P. Abbon et al., NIM A 779 (2015) 69



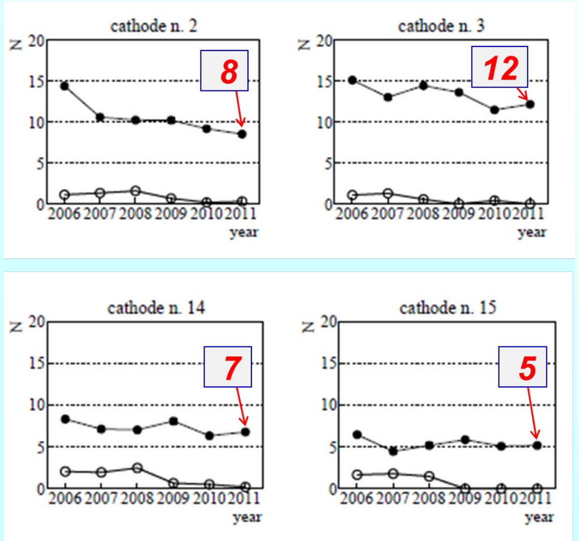


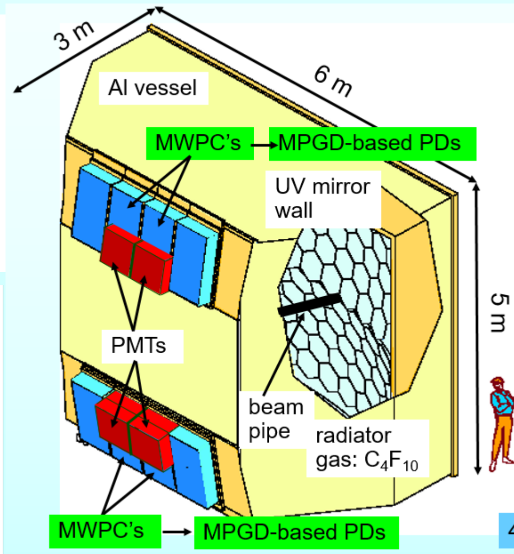
F. Tessarotto et al., JINST 9 (2014) C09011

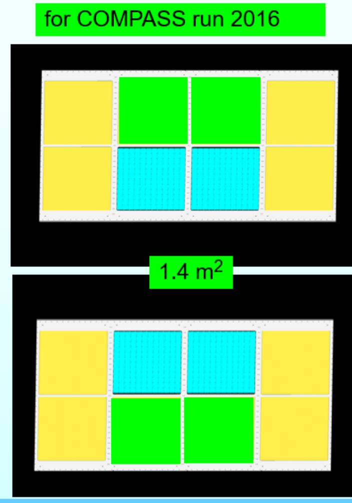
acceptance: H: 500 mrad V: 400 mrad; beam rates up to ~10^8 Hz;
2.4% Xo (beam region), 22% Xo (acceptance) 80 m^3 C_4F_{10}, 21 m^2 UV mirrors, 1.4 m^2 MAPMTs, 4 m^2 gaseous PDs



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



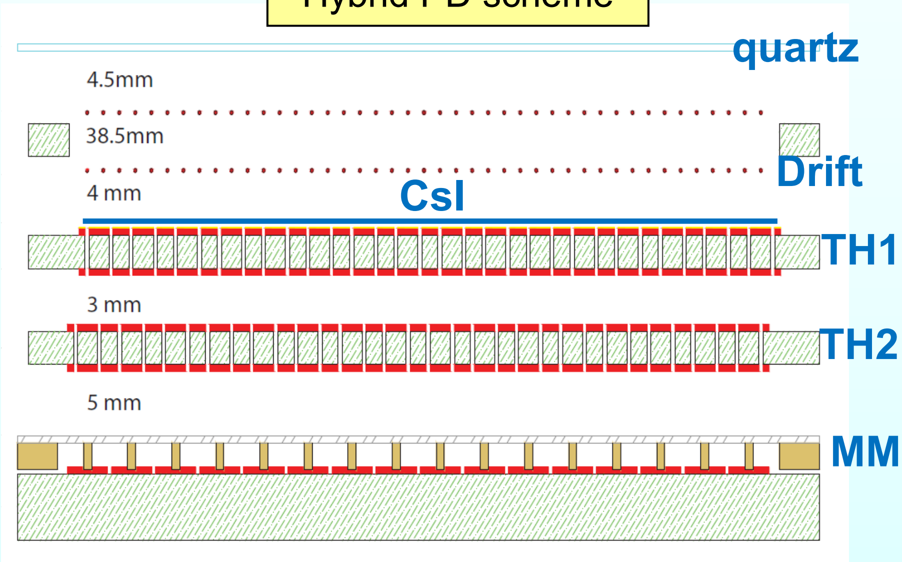




4 new detectors of 600 mm x 600 mm

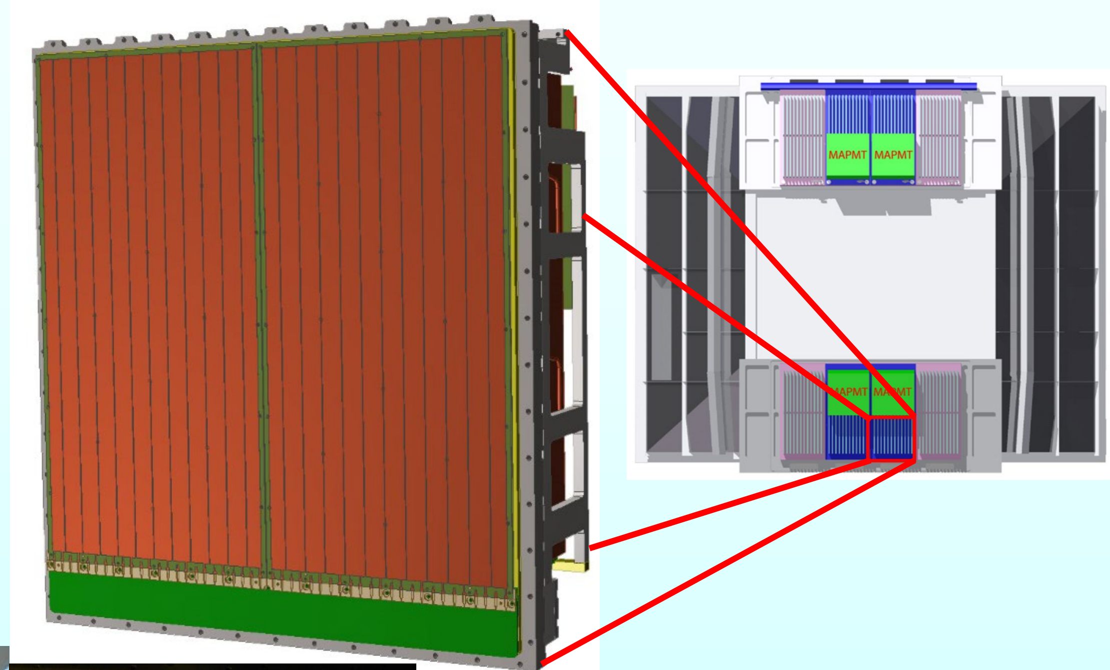
The hybrid THGEM+Micromegas PDs

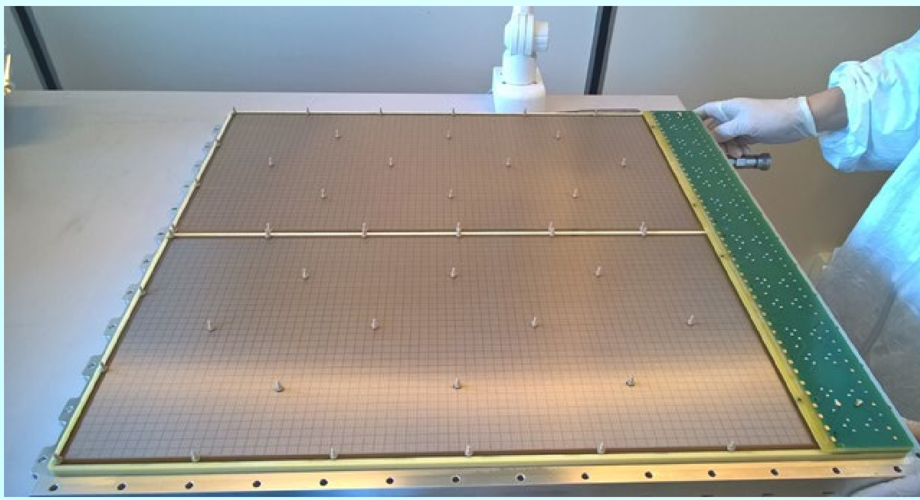
Hybrid PD scheme

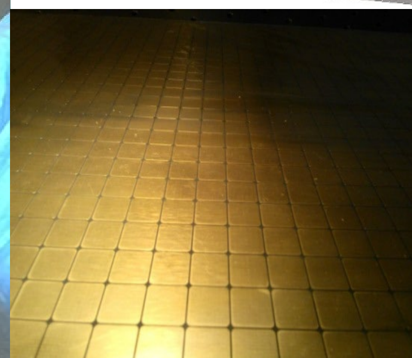


Standard Bulk Micromegas produced at CERN

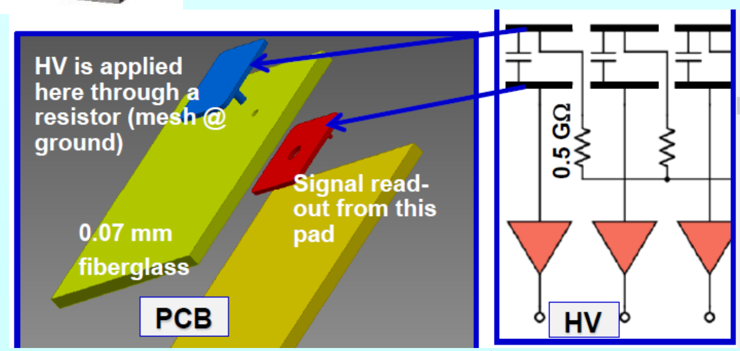
modular structure: one module = 600x300 mm^2





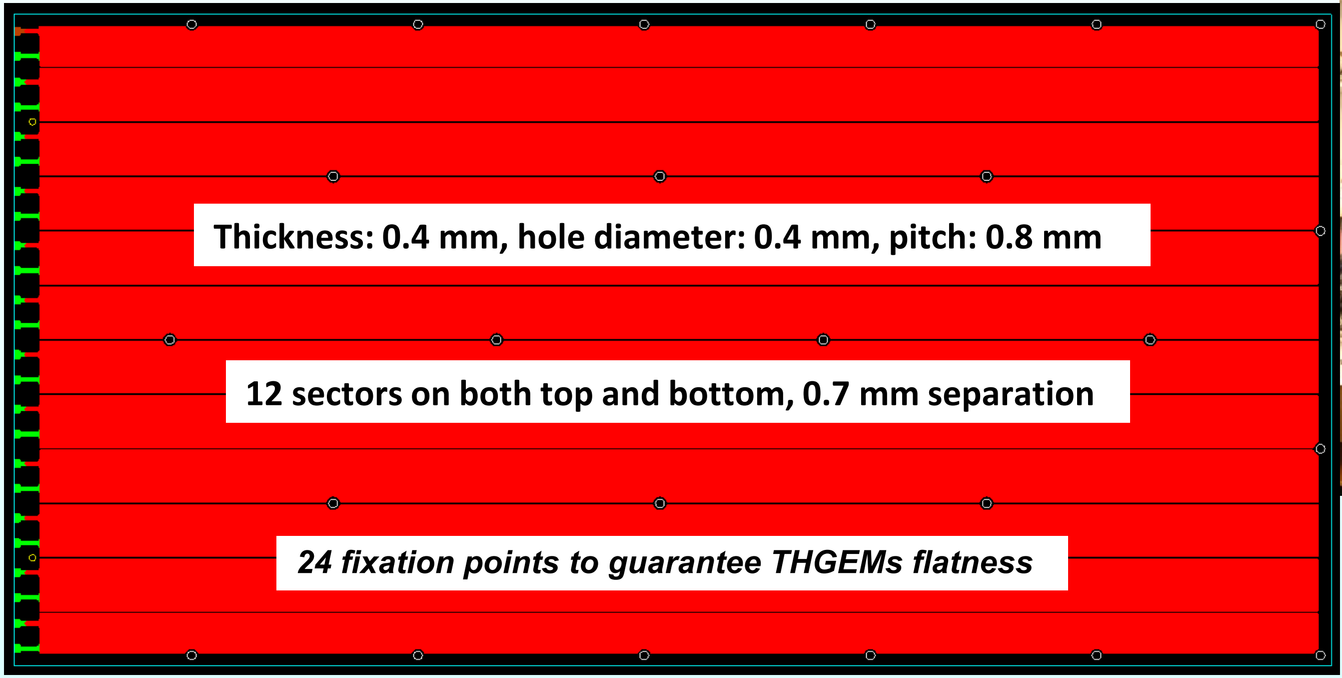


8mm X 8mm pads at positive HV



Capacitive coupling → APV25

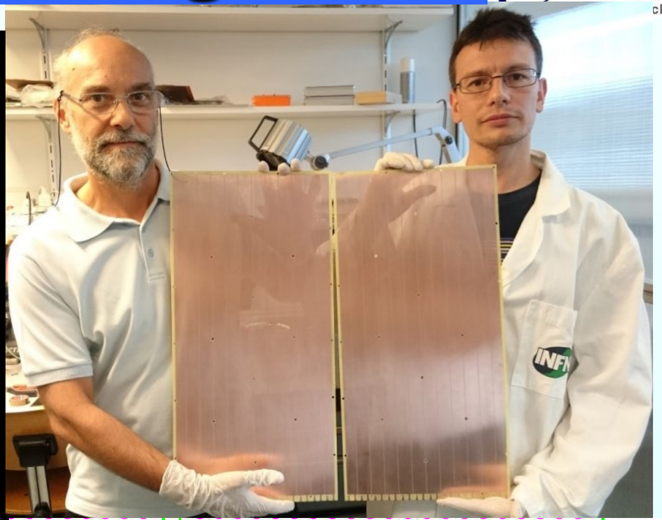
The COMPASS THGEM design

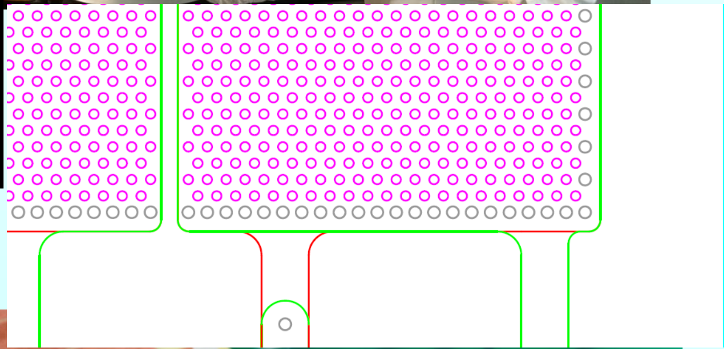


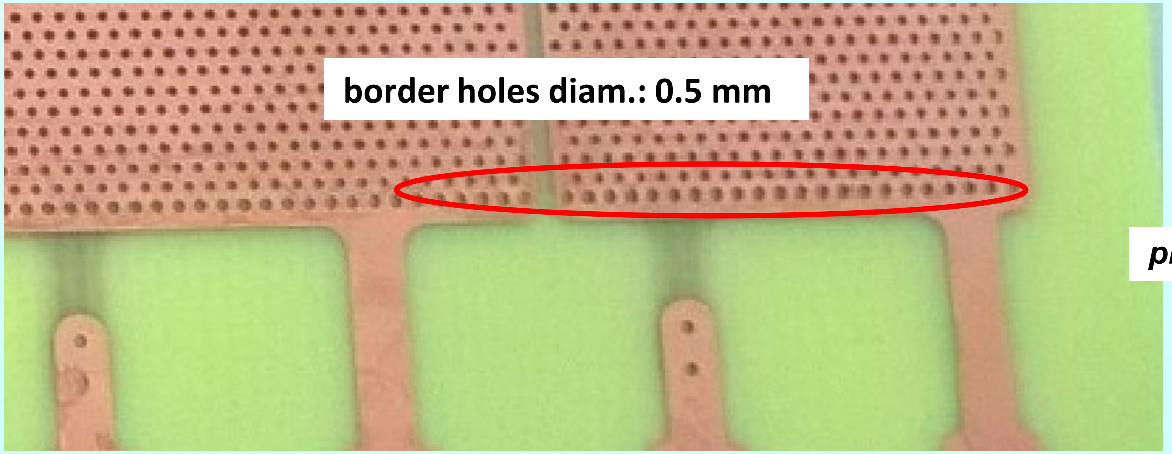
Thickness: 0.4 mm, hole diameter: 0.4 mm, pitch: 0.8 mm

12 sectors on both top and bottom, 0.7 mm separation

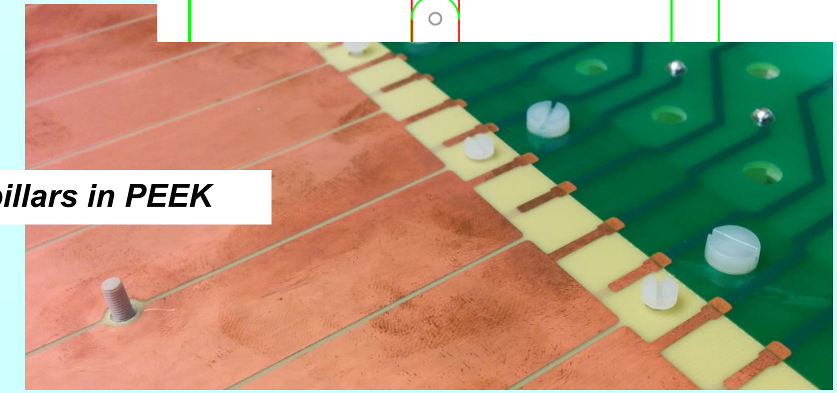
24 fixation points to guarantee THGEMs flatness







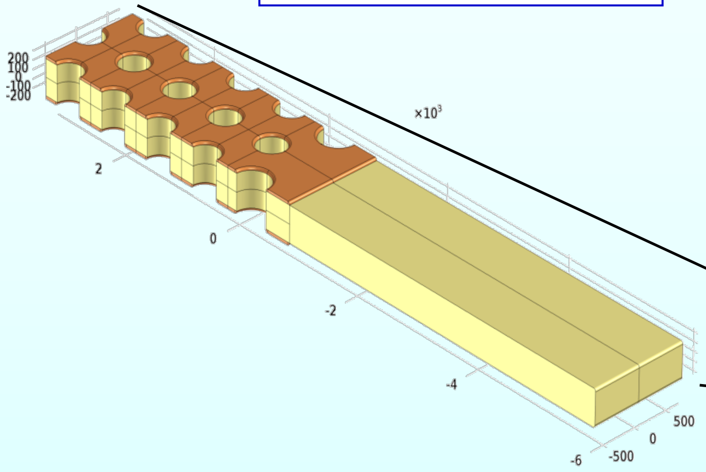
border holes diam.: 0.5 mm

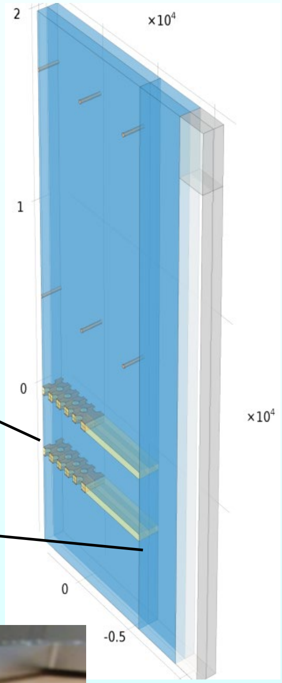


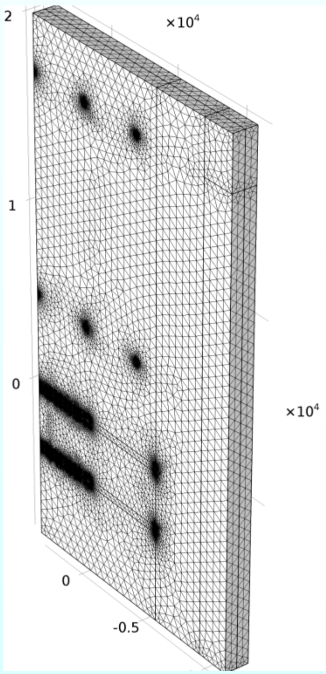
pillars in PEEK

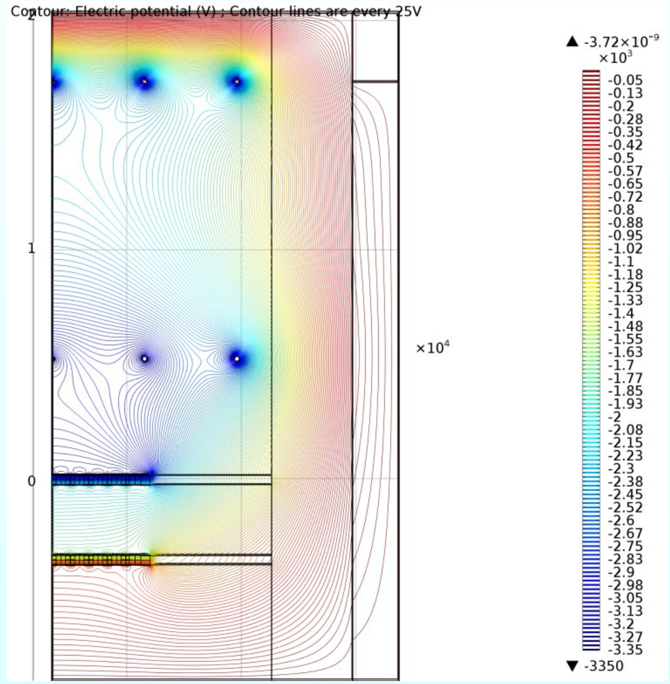
field shaping electrodes

THGEM border study

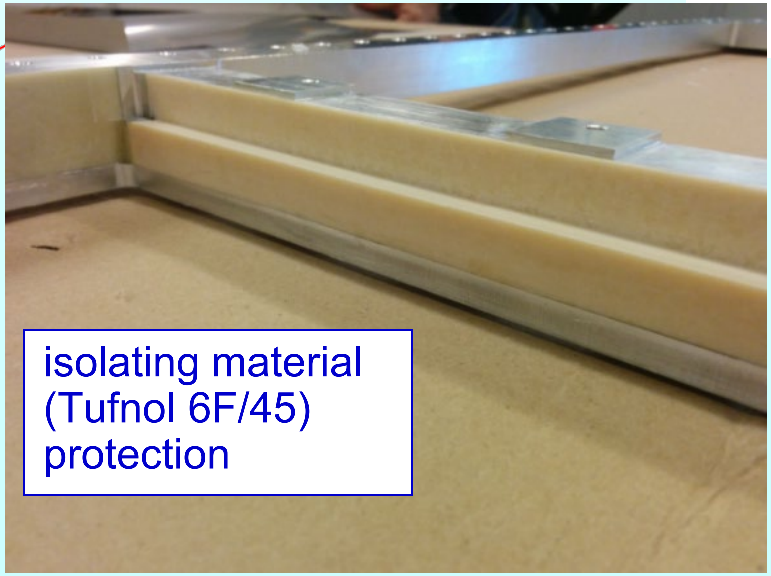






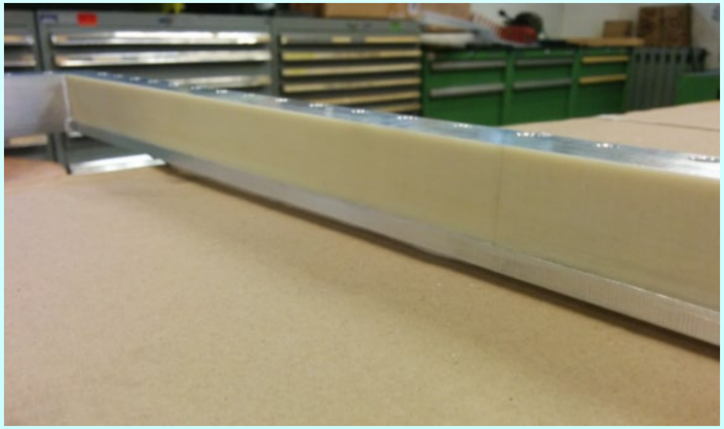


large field values at the chamber edges and on the guard wires



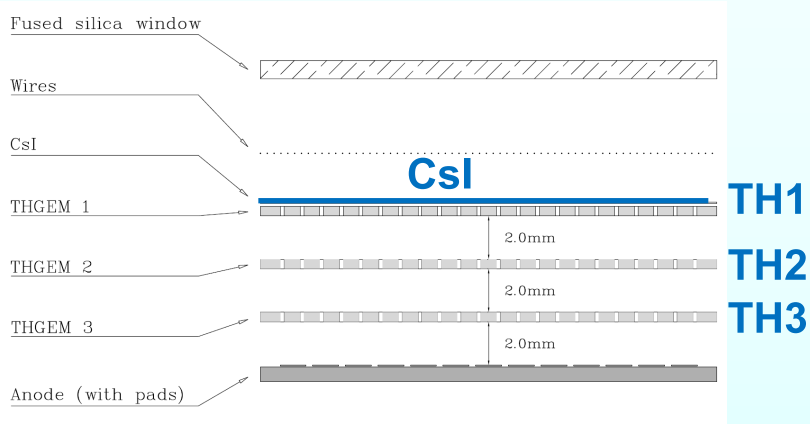
isolating material (Tufnol 6F/45) protection

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

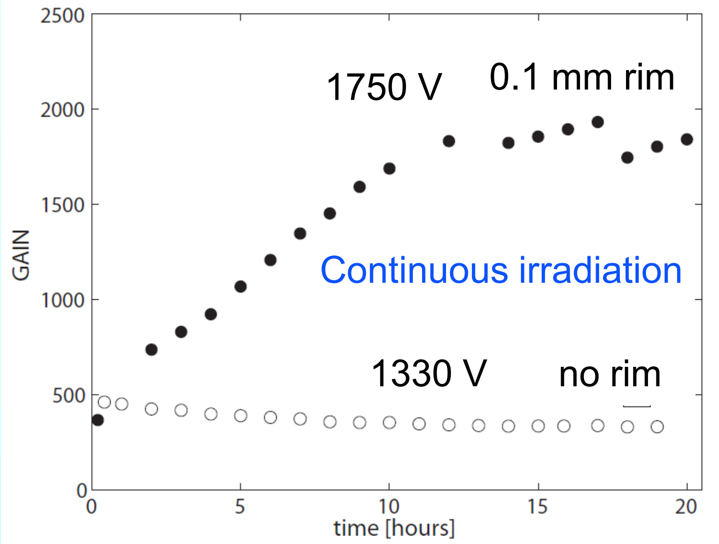


Why THGEMs with no rim

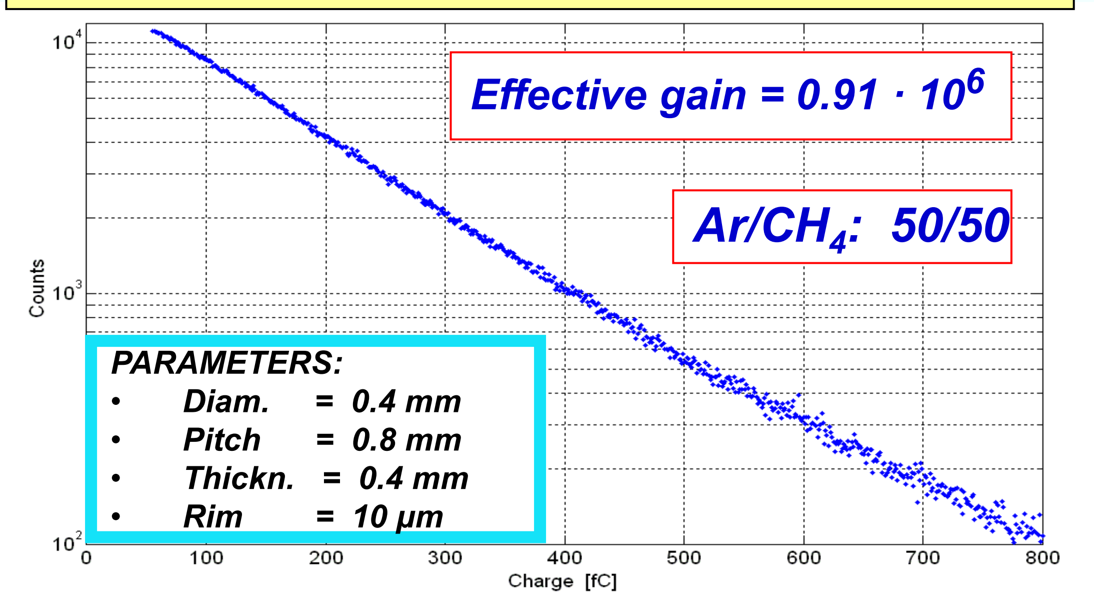
Triple THGEM



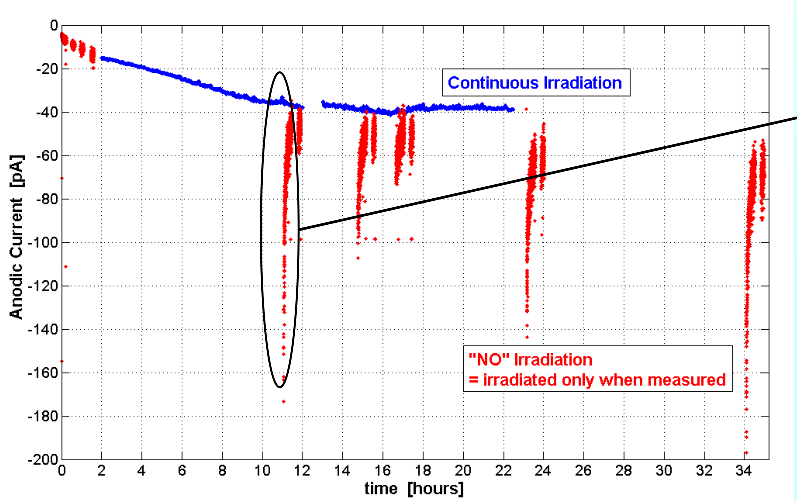
Rim ≠0 → difficult to control the gain

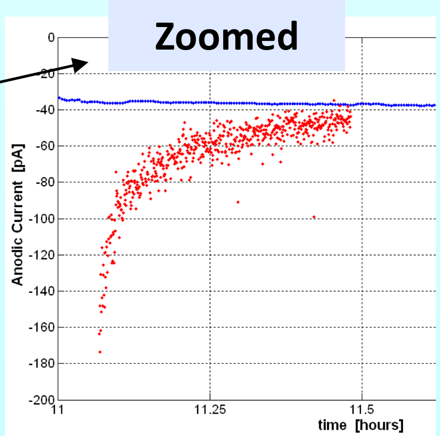


High gain obtained in a 3THGEM with 30x30 mm^2 active area

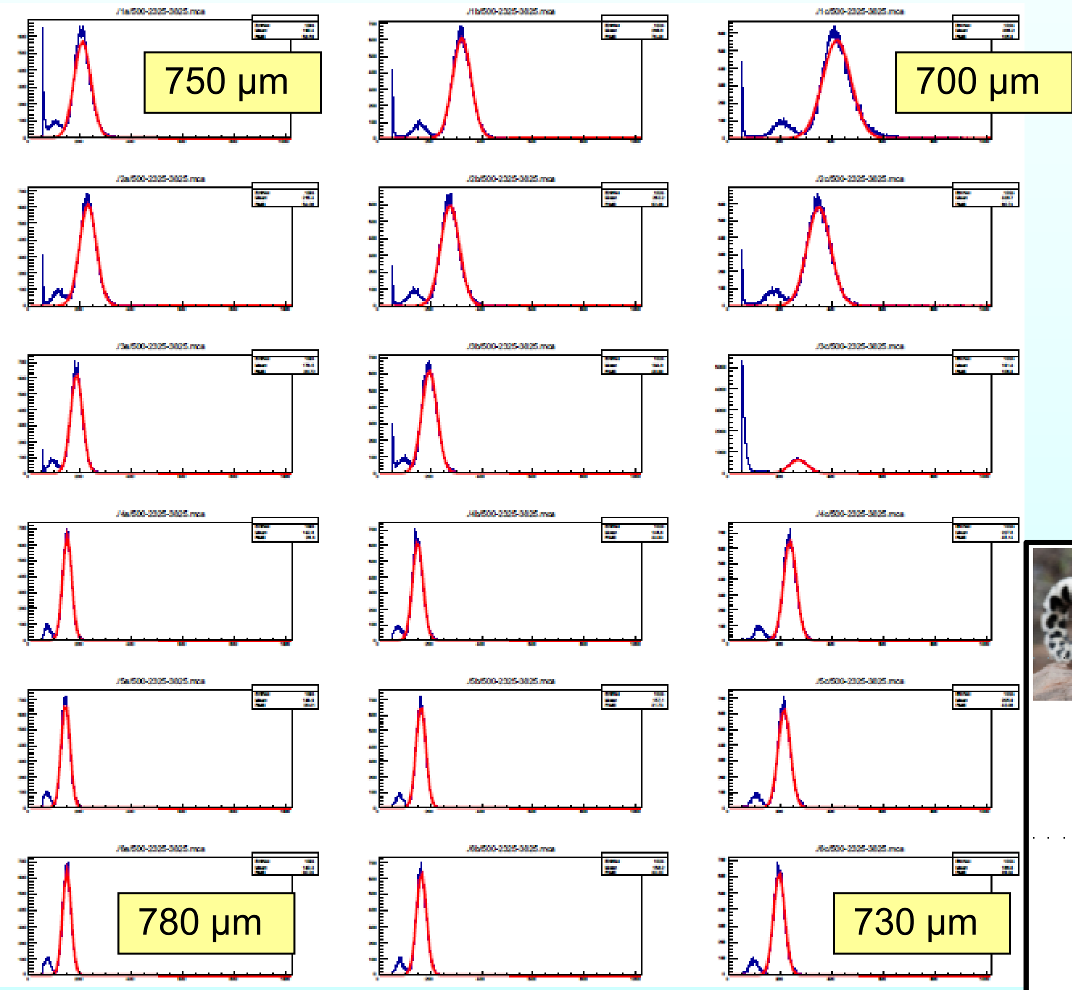


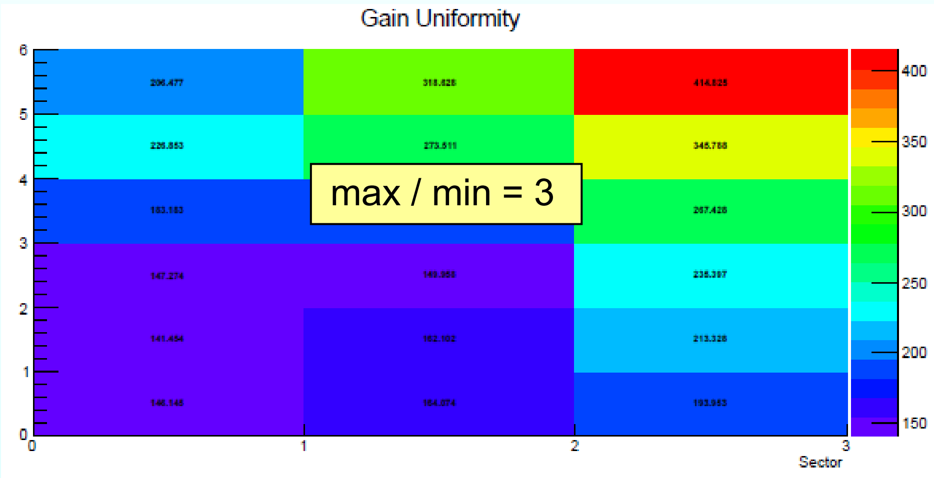
M. Alexeev et al., NIMA 617 (2010) 396



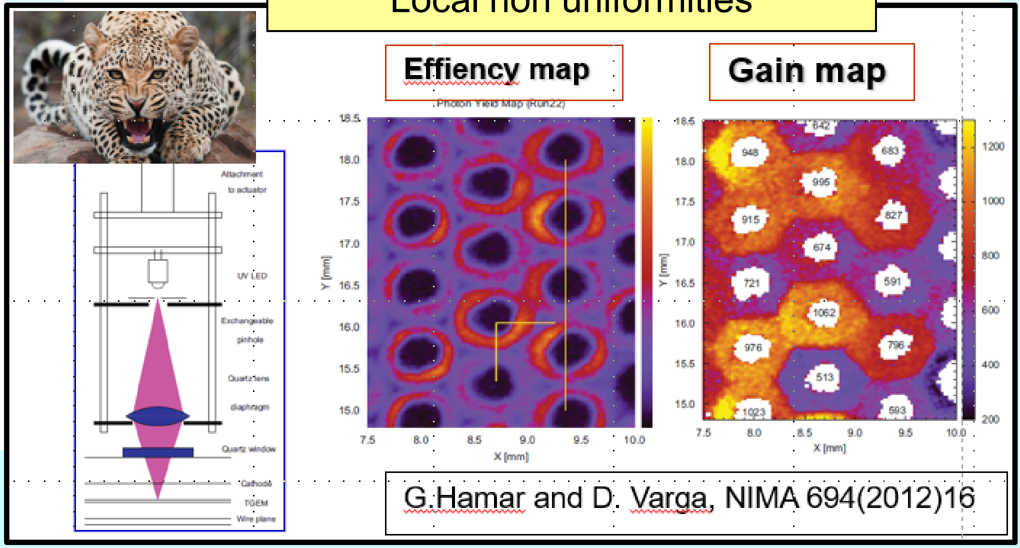


Thickness-related non uniformity





Local non uniformities



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

➔ Strict thickness uniformity requirement

THGEM raw material selection

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

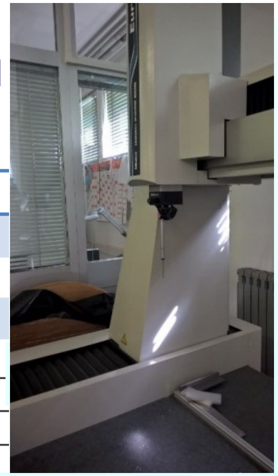
50 foils of 1245 mm x 1092 mm → cut out borders → 800 mm x 800 mm → thickness measurement

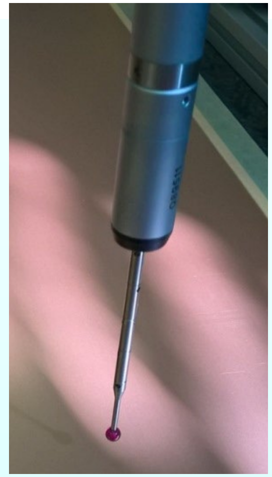
Elite Material Co., Ltd. Technical Data

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	$>10^{9}$

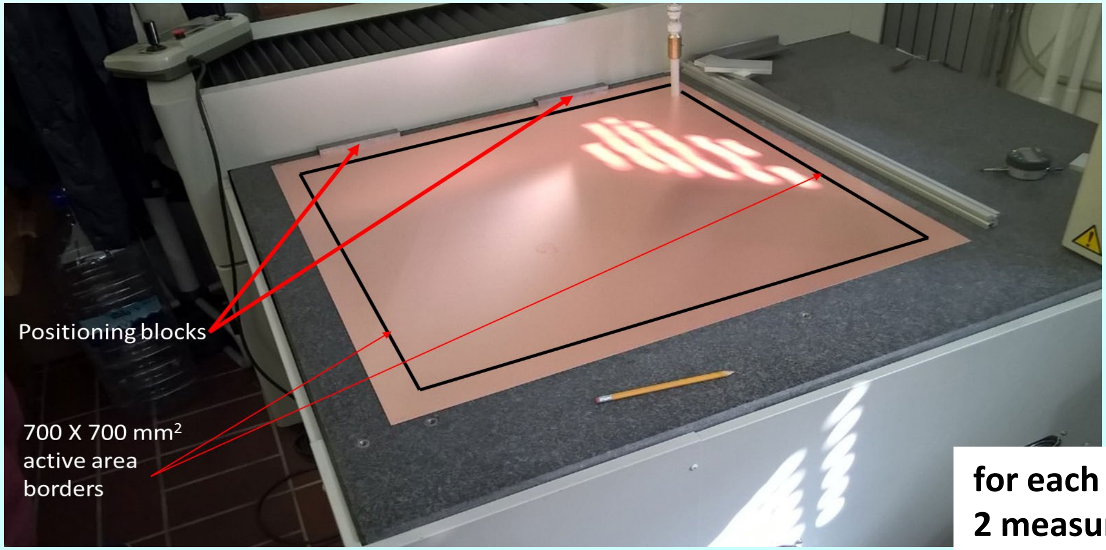


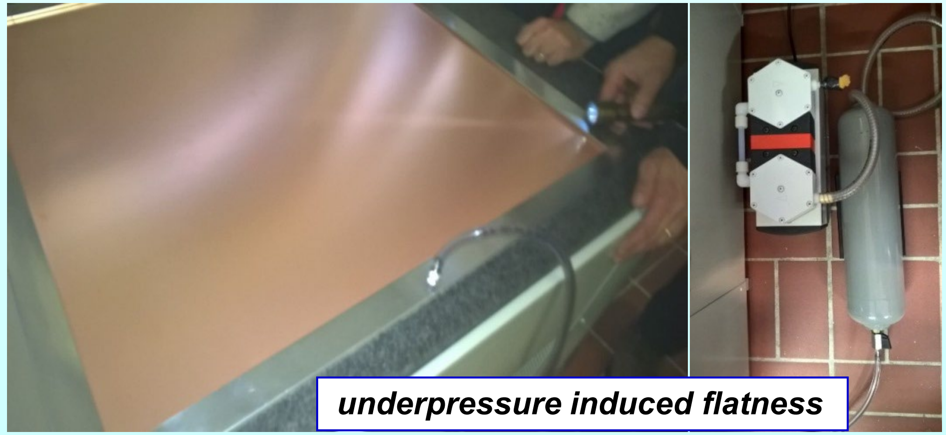


Mitutoyo EURO CA776

coordinate measuring machine with ruby touch probe,

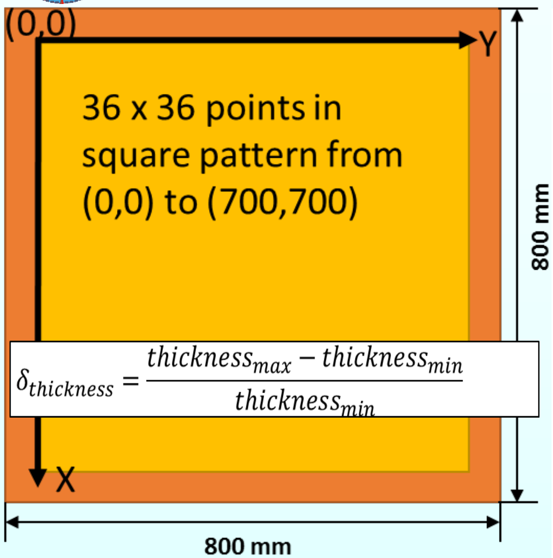
hosted in a thermalized room

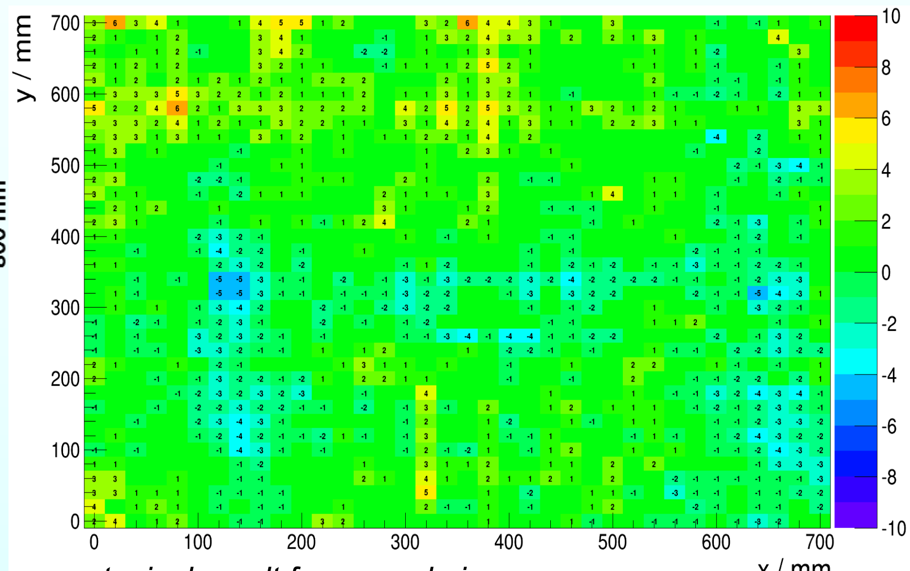




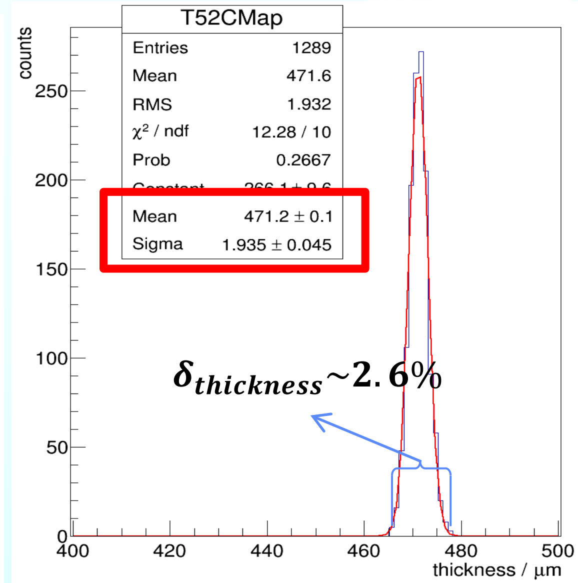
for each foil 36 x 36 points in square pattern are measured
2 measurements (direct and reversed) to allow consistency checks.

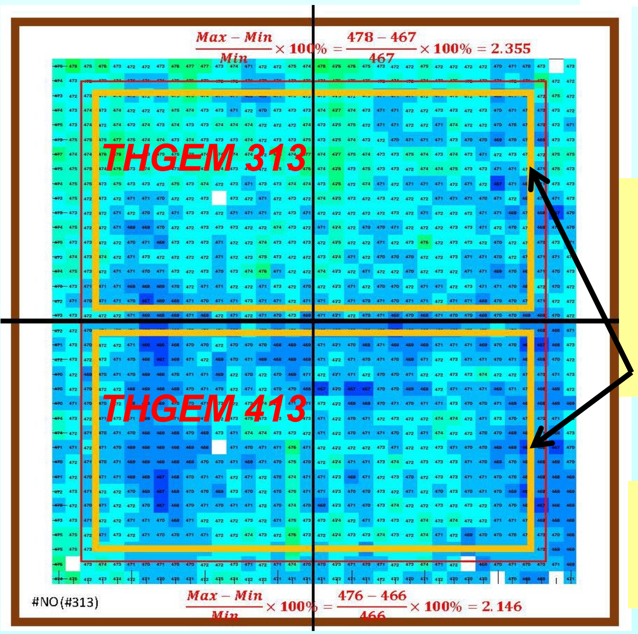
THGEM raw material selection





typical result for a good piece.





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

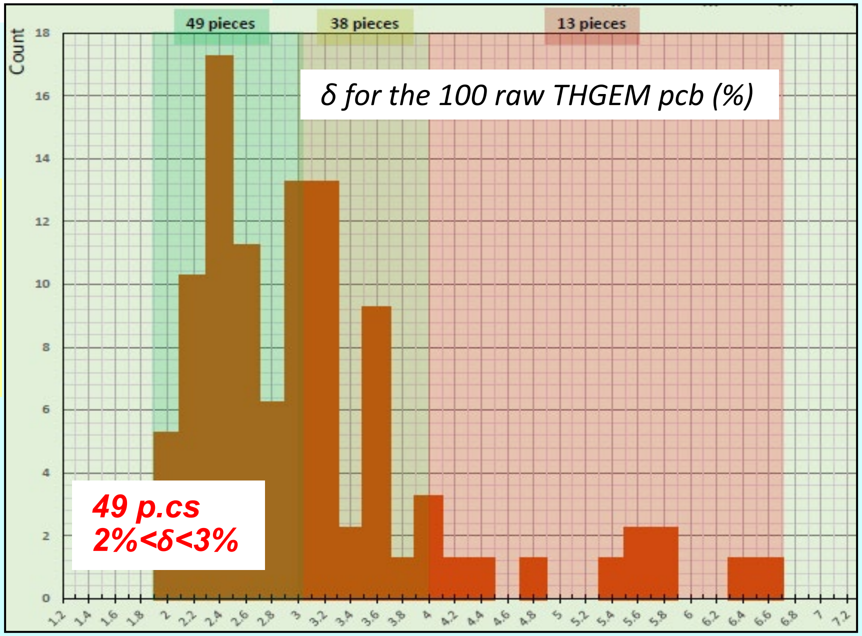
from each foil two THGEMS can be produced:

50 foils → 100 raw THGEM pcb

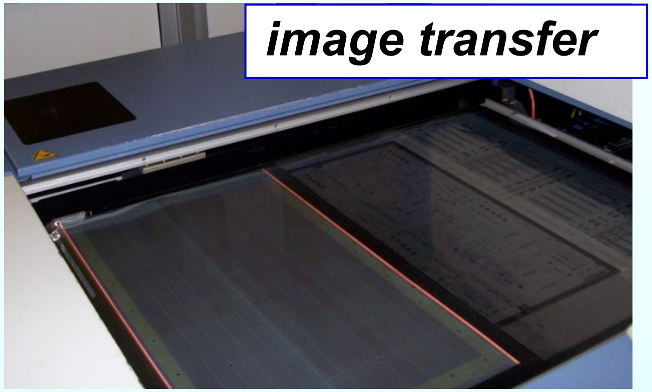
THGEM pcb size = 620 mm x 320 mm,

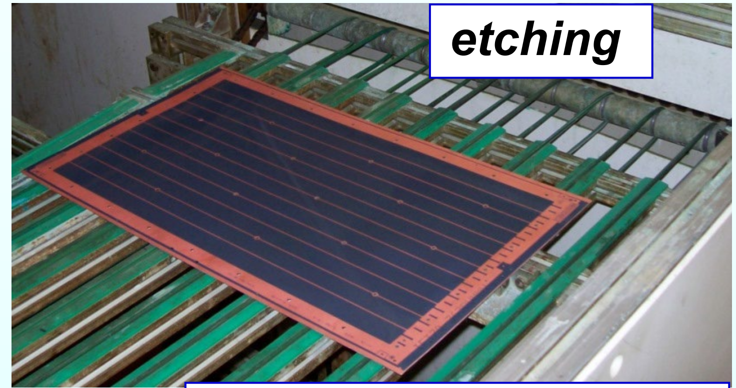
active area = 581 mm x 287 mm

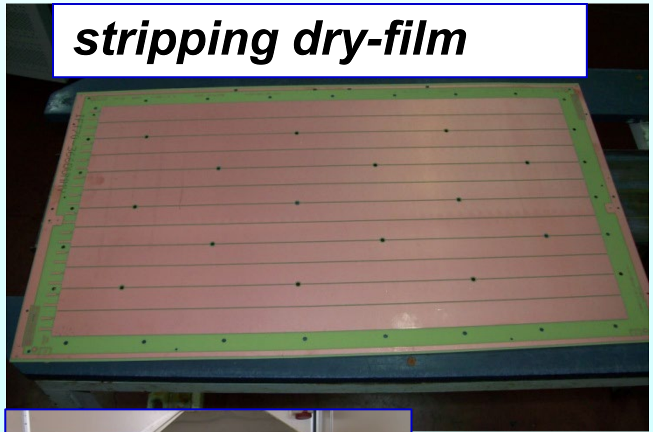
60 THGEMs have been produced by ELTOS

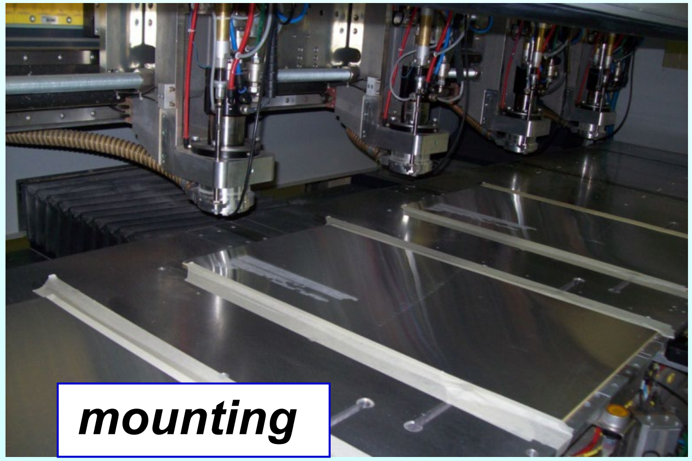


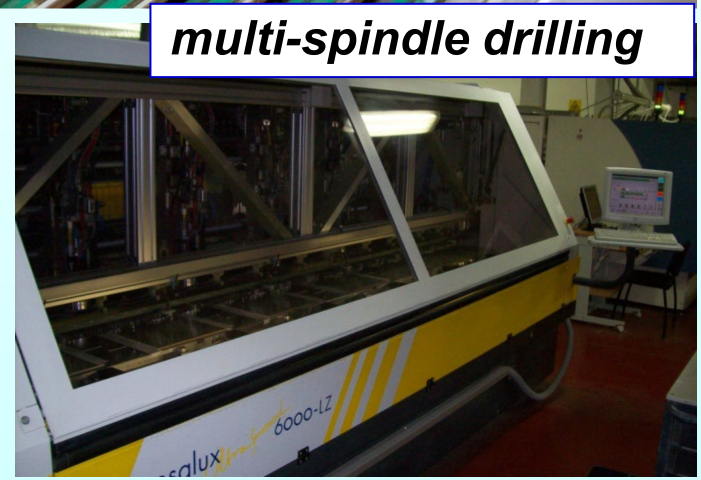
Production of the THGEMs at ELTOS



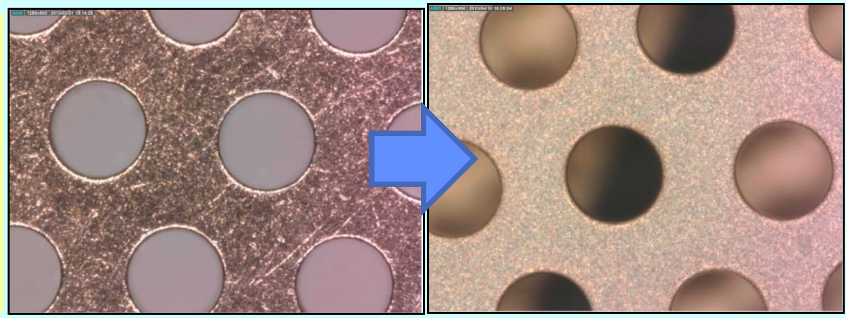




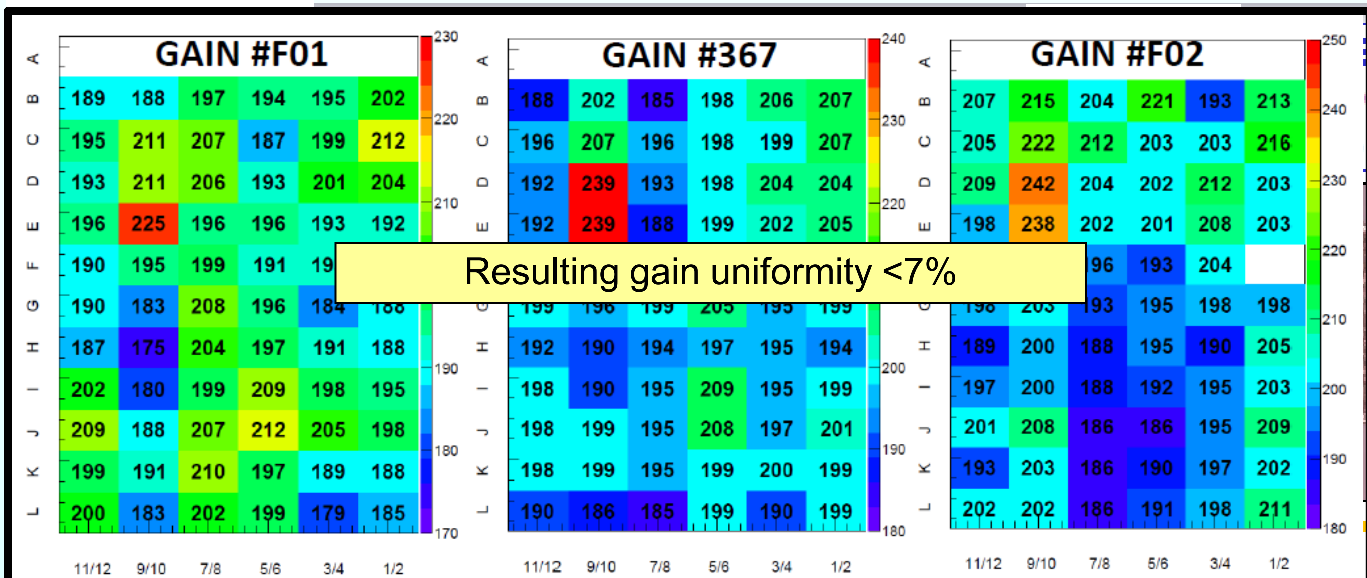




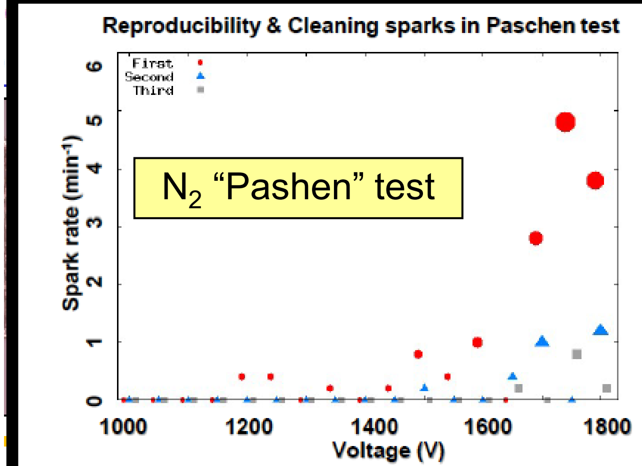
In Trieste a specific cleaning procedure is applied : polish with fine grain pumice powder, pressure water cleaning, ultrasonic Bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160 ºC

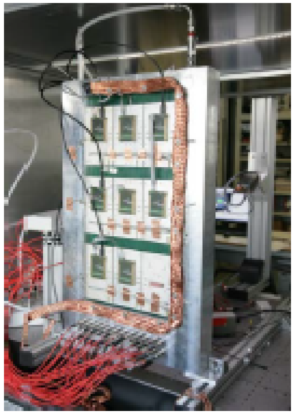


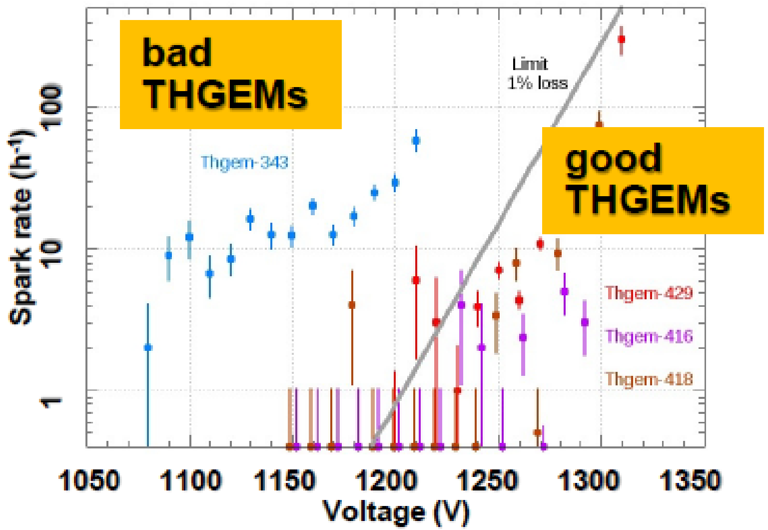
quality control

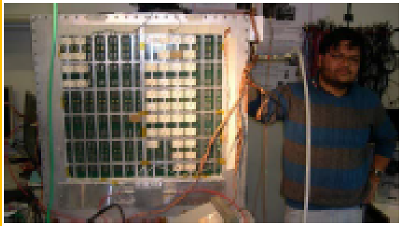


Electrical stability tests

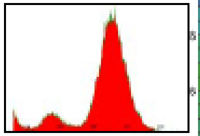


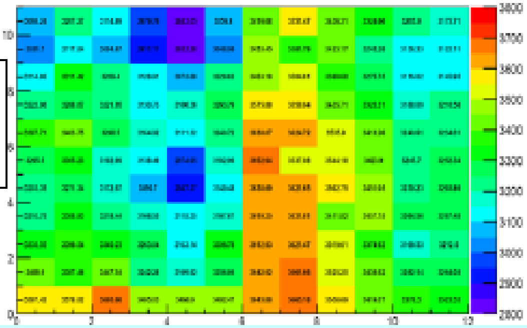




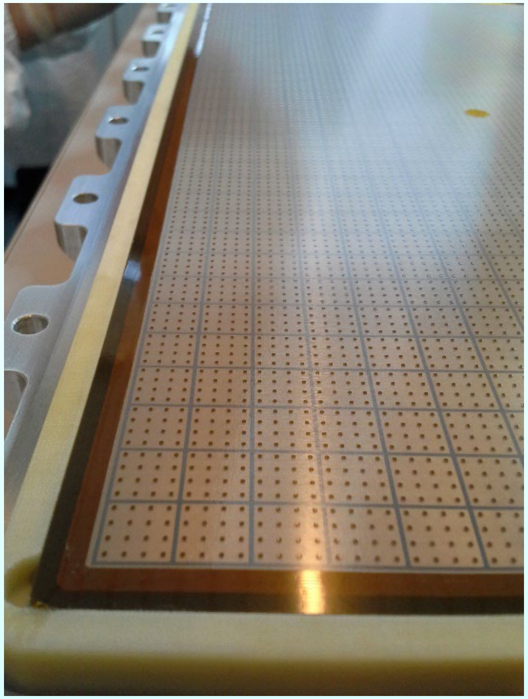


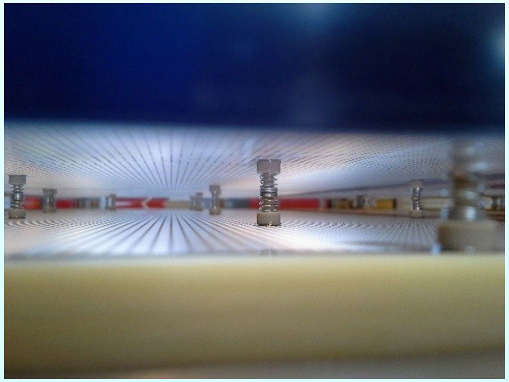
X-ray MM test to access integrity and gain uniformity (<5%)

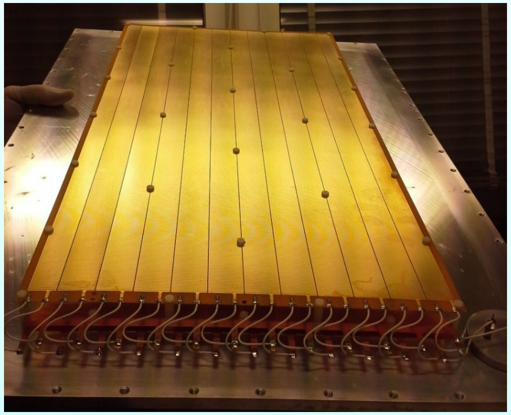


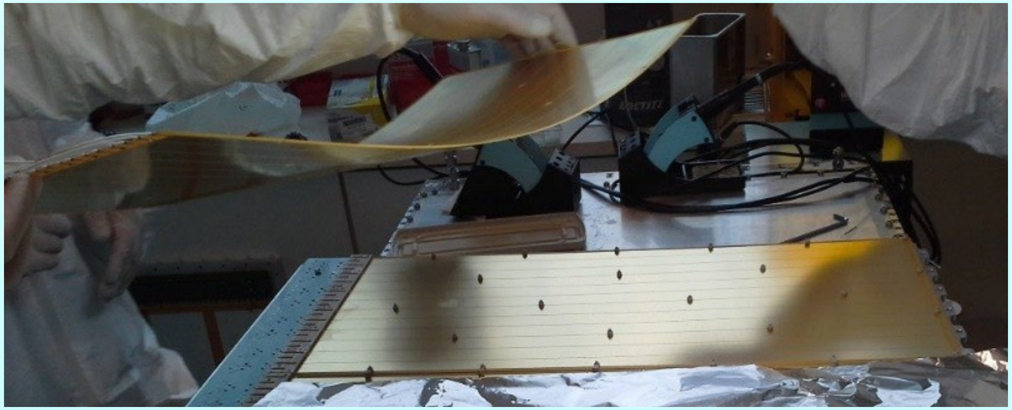


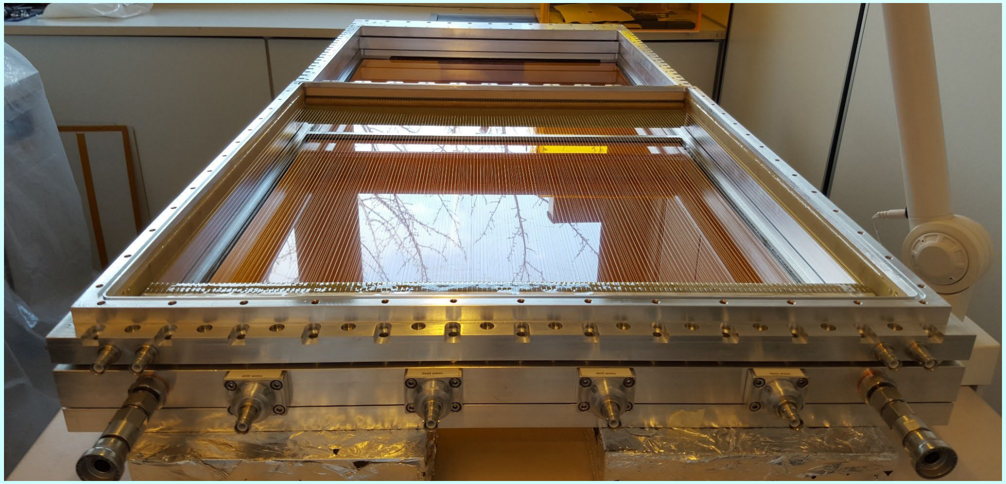
assembling



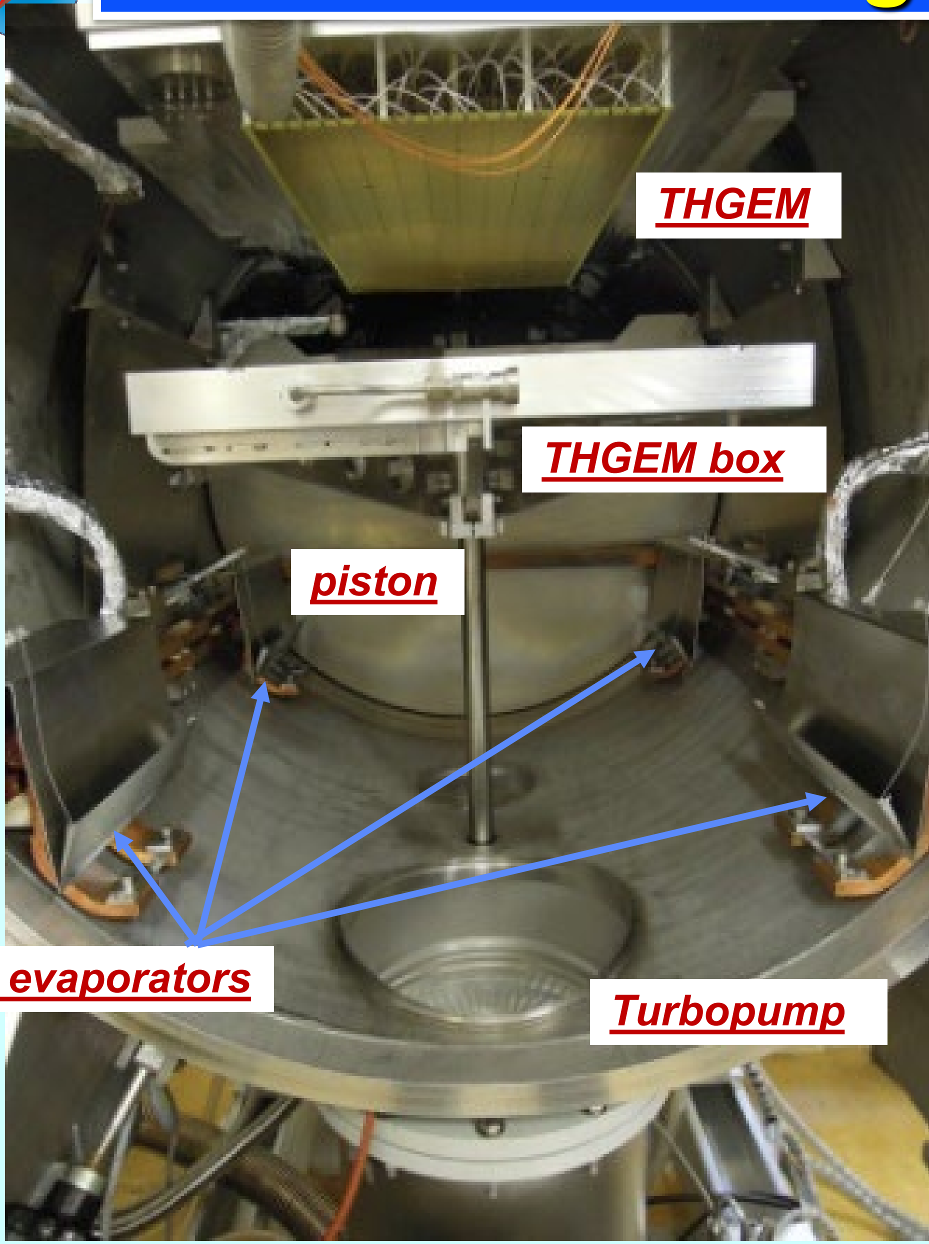


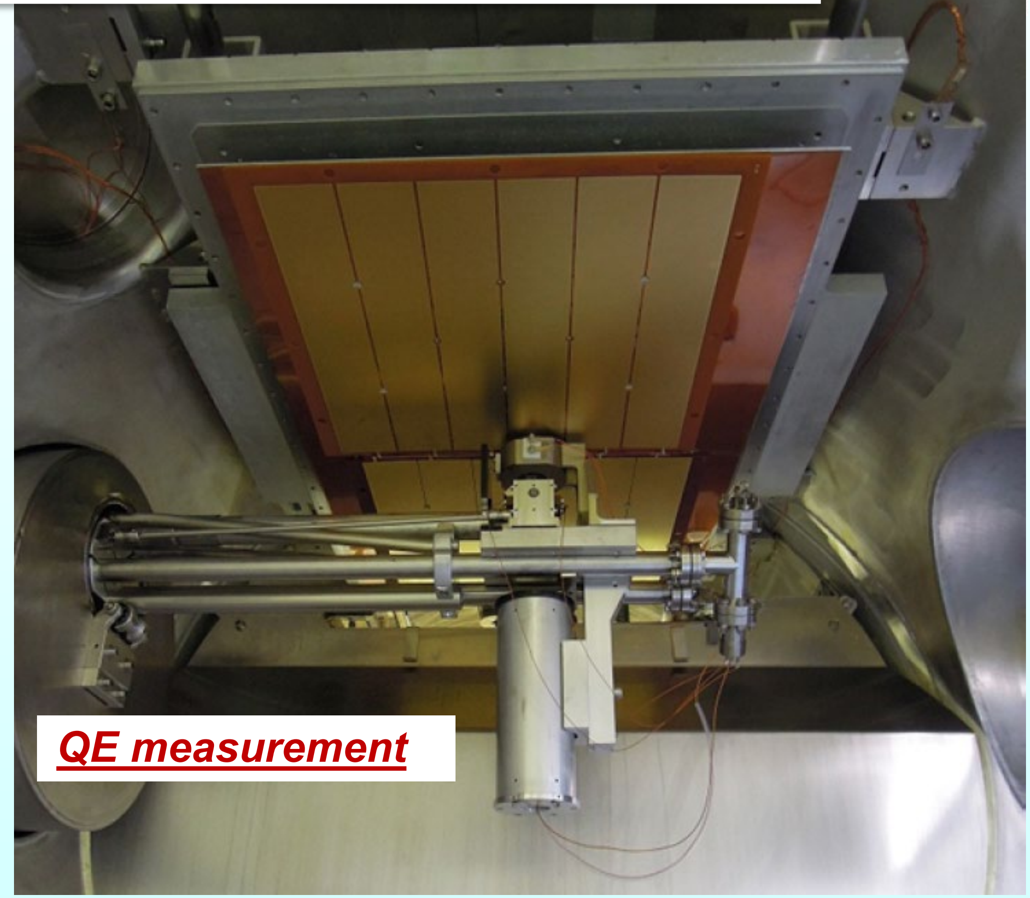


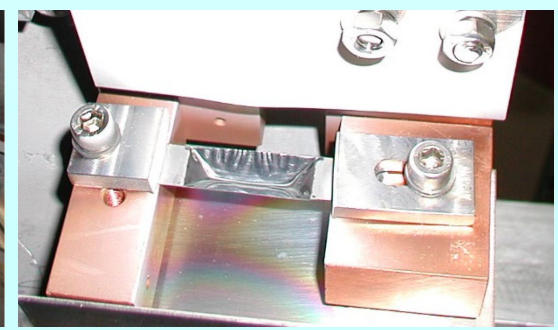




CsI coating of THGEMs





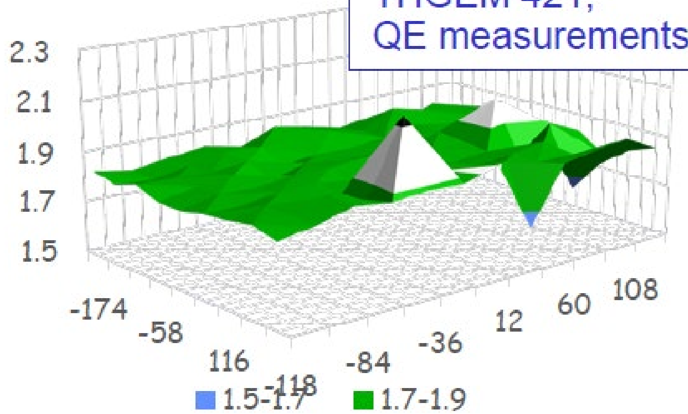


CsI QE measurement

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

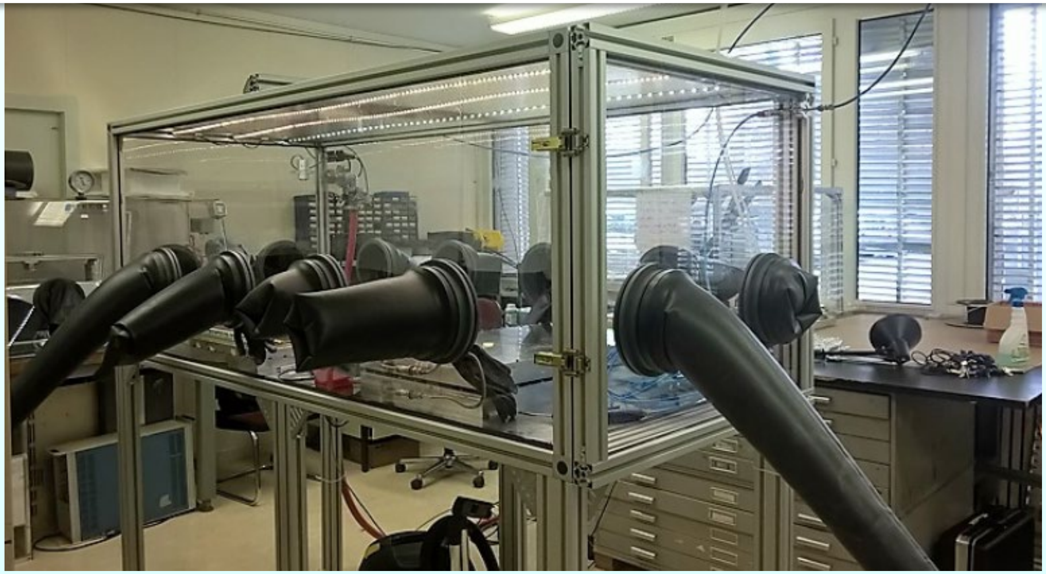
QE uniformity

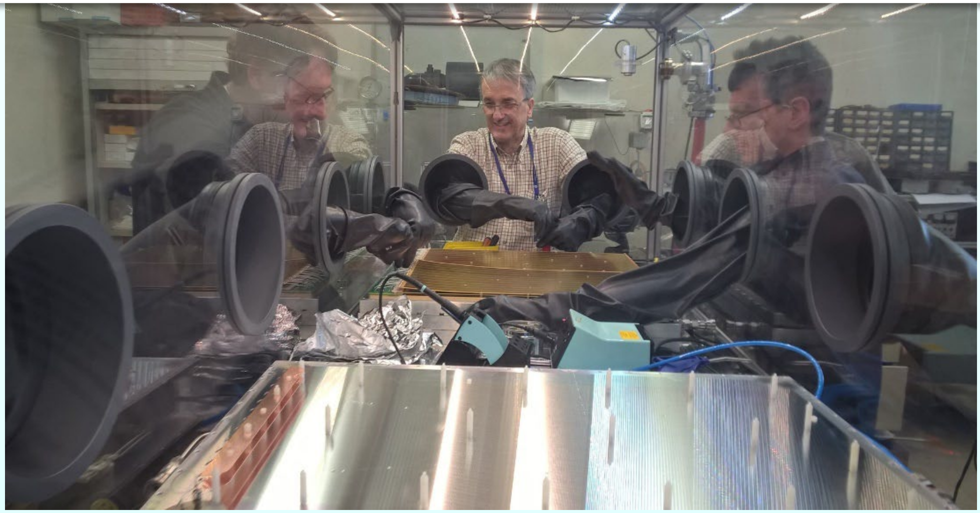
- **3 % r.m.s. within a photocathode**
- **10 % r.m.s. among photocathodes**

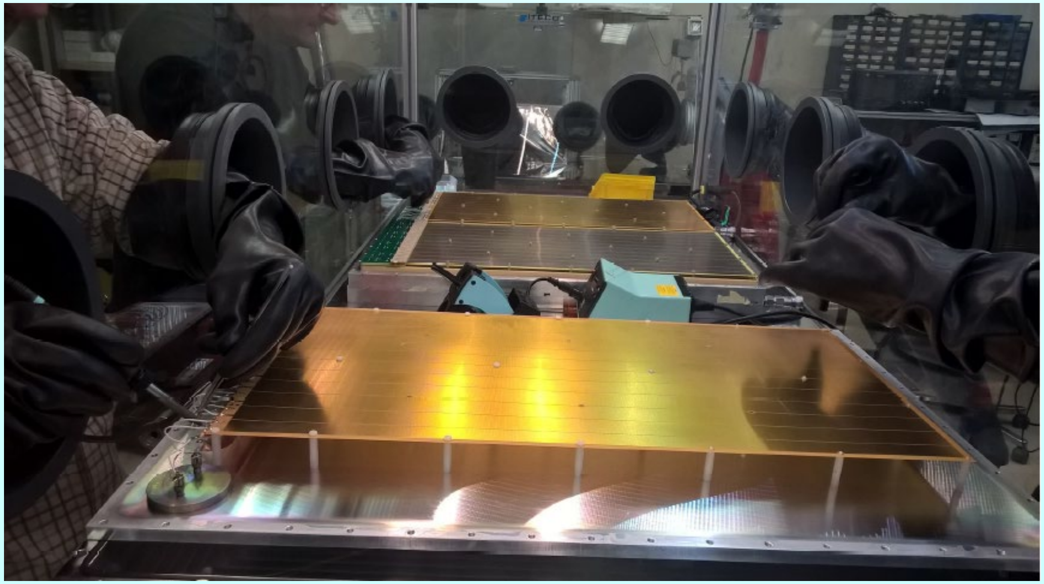
Optical transparency: $\frac{\pi}{2\sqrt{3}}\left(\frac{d}{p}\right)^2$ *~ 0.23* →

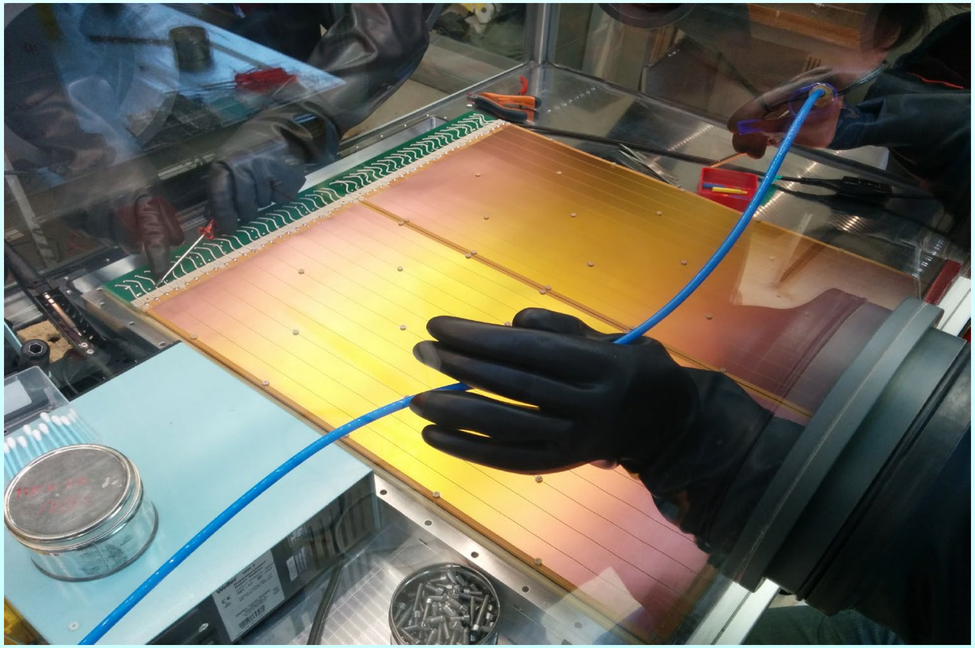
mean THGEM QE: ~ 93% of reference

CsI THGEM mounting

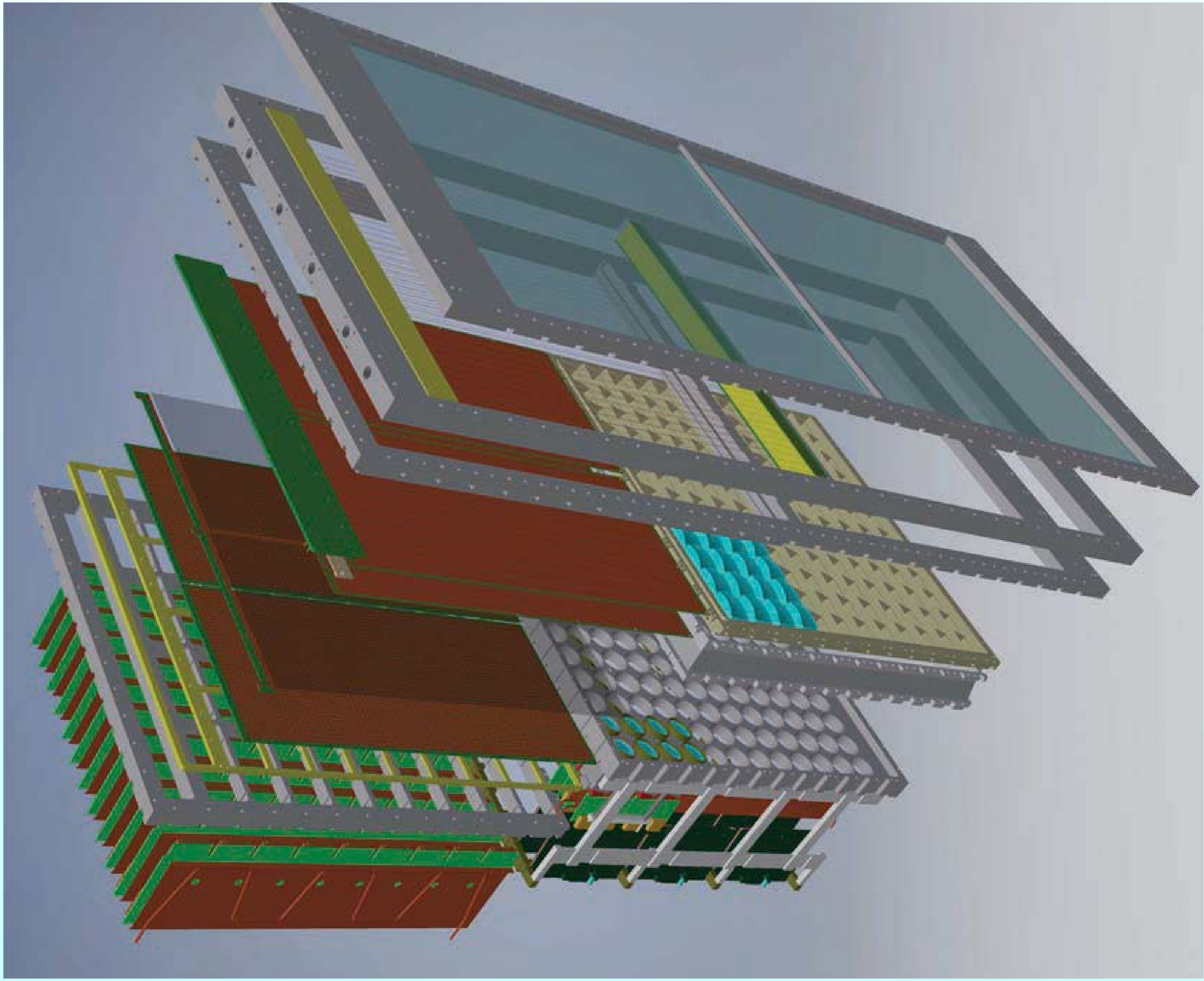






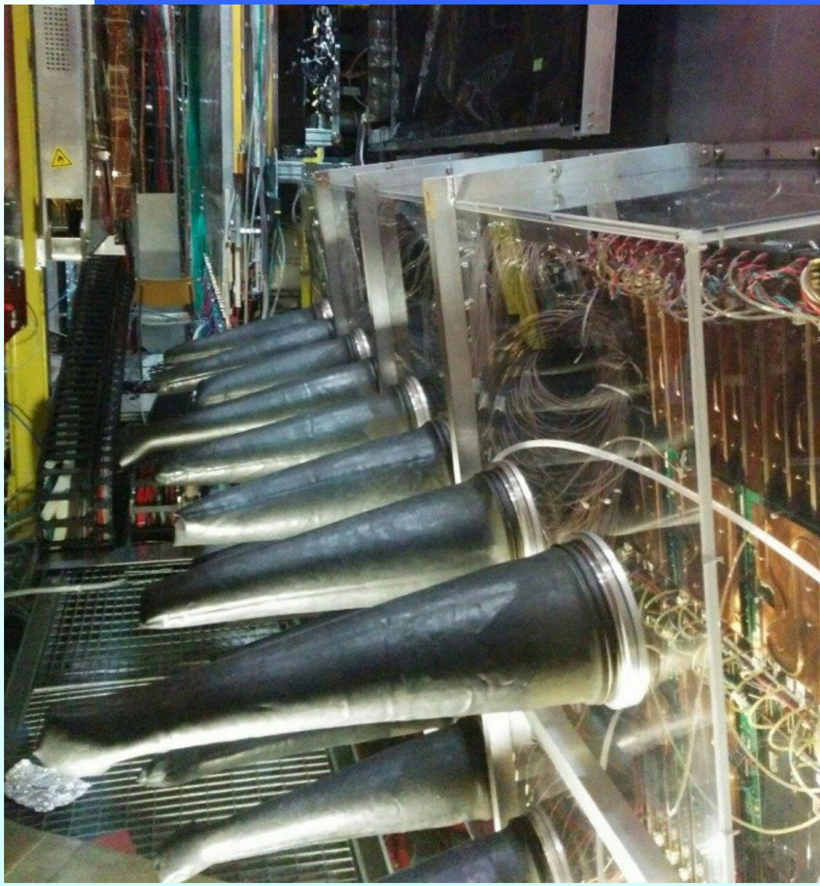


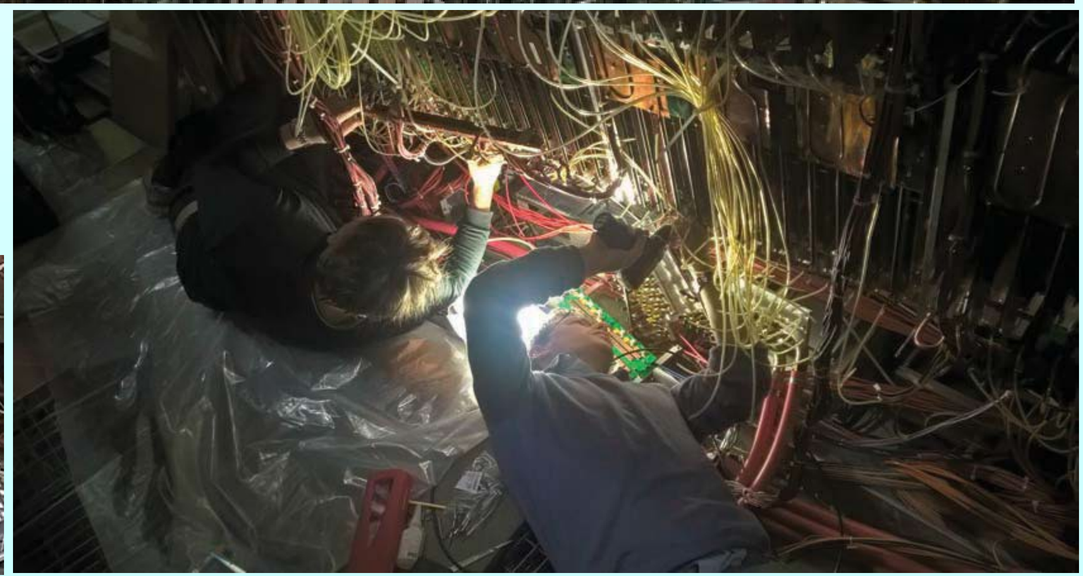
The new COMPASS PDs

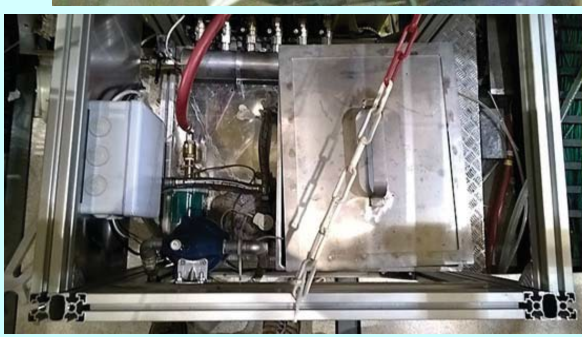


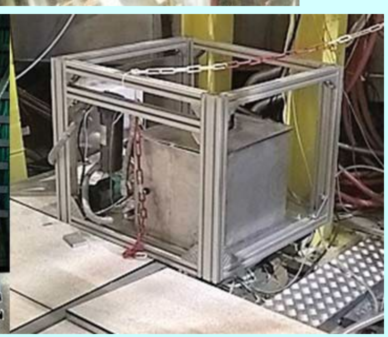
Installation of hybrids on RICH_1

Equipping the hybrids on RICH_1

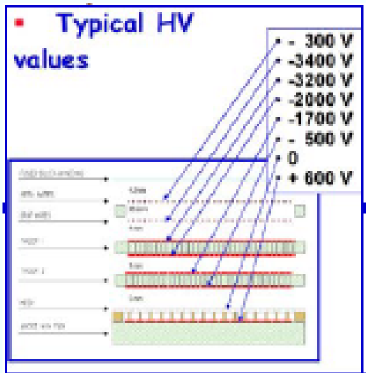


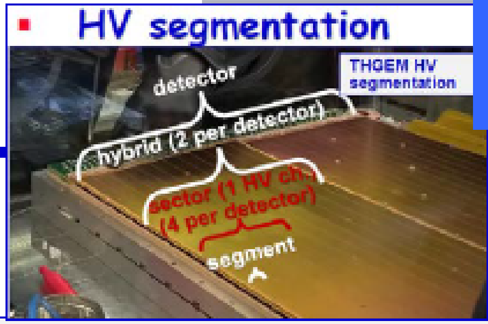






HV CONTROL



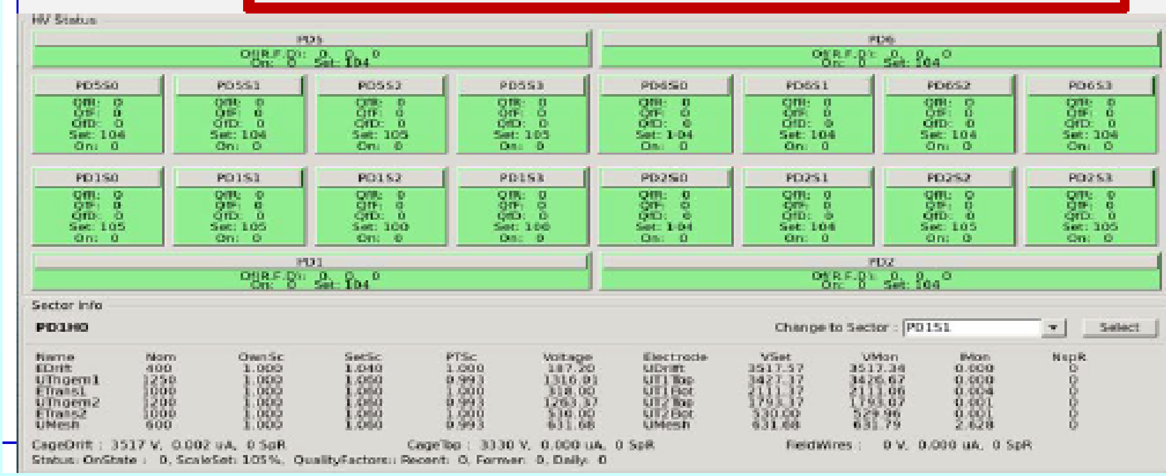


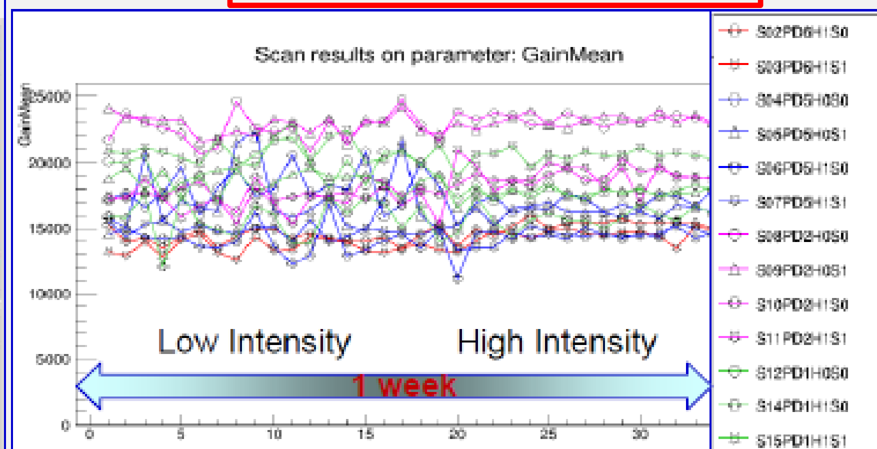
In total 136 HV channels with correlated values

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

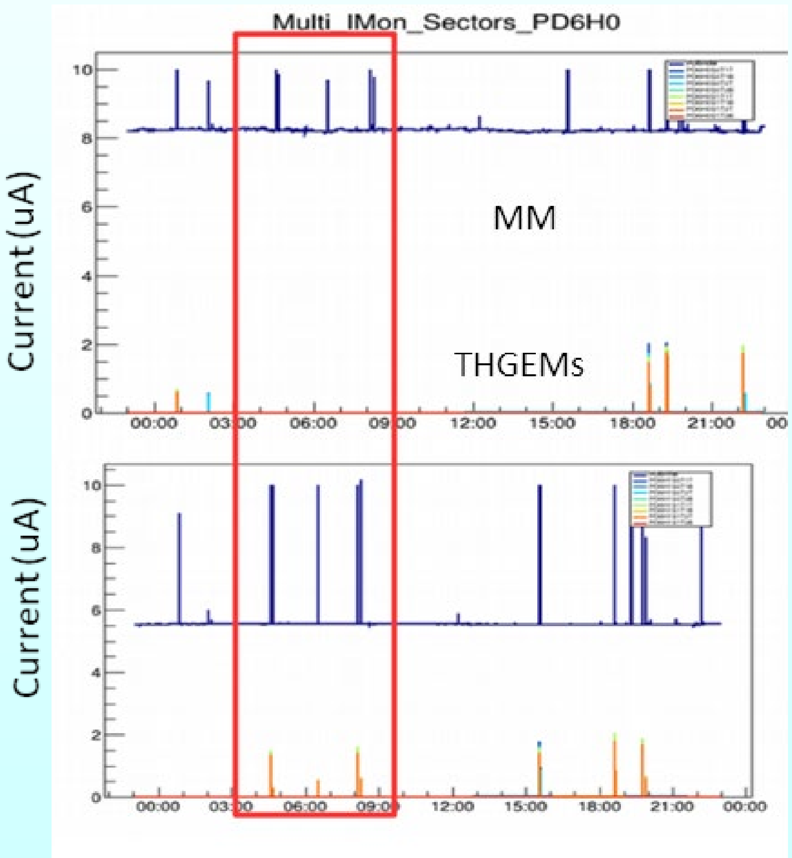
- **Gain stability vs P, T:**
  - G = G(V, T/P)
  - Enhanced in a multistage detector
  - $\Delta T = 1^{o}C \rightarrow \Delta G \approx 12\ \%$
  - $\Delta P = 5\ mbar \rightarrow \Delta G \approx 18\ \%$
- **THE WAY OUT:**
  - Compensate T/P variations by V
  - → Gain stability at 5% level





sparks

Spark: event with I > 23 nA



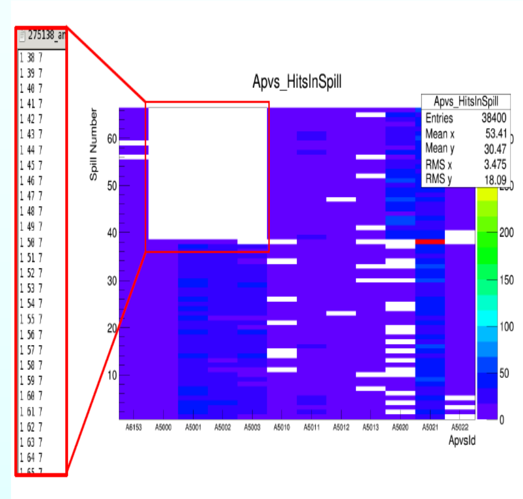
THGEMs induce sparks in MMs

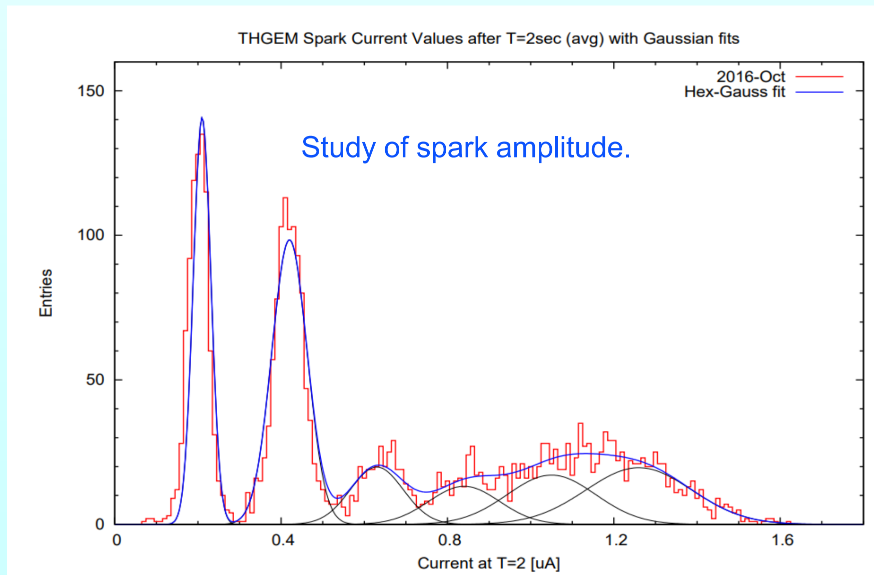
Current sparks in THGEMs

- 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





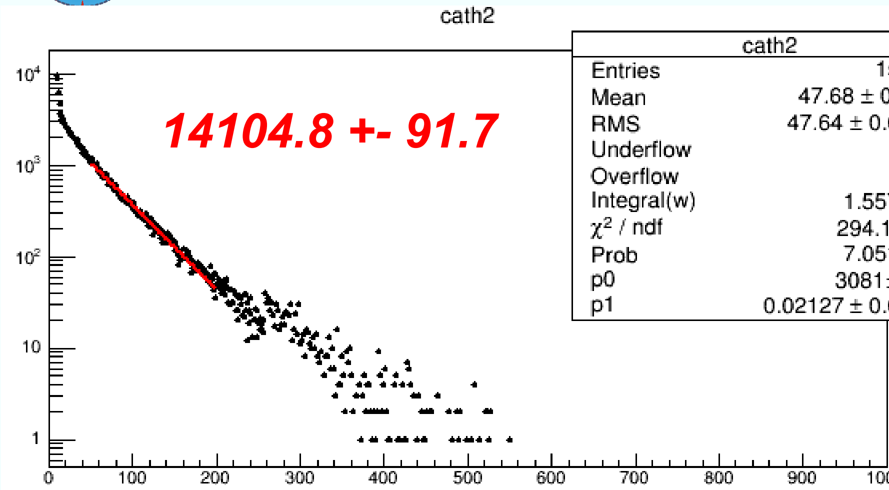
Some sparks produce APV errors.

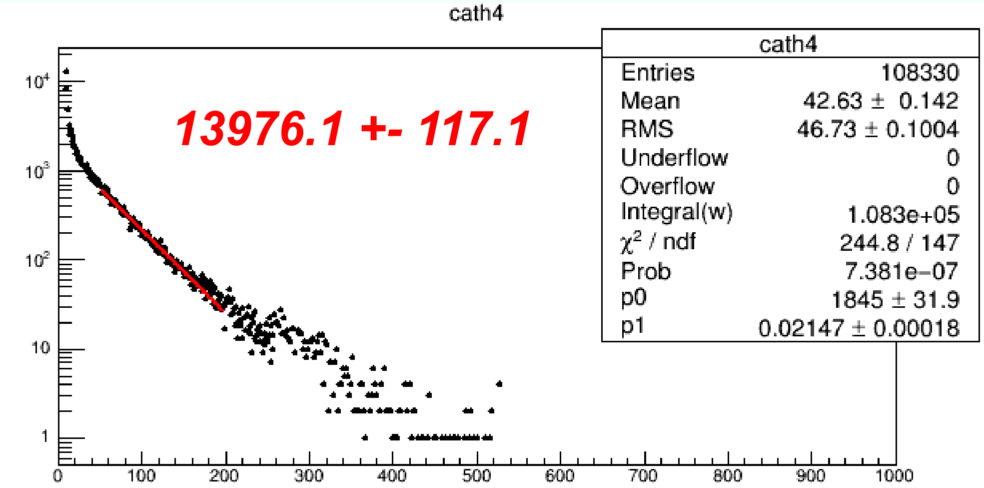
APV header error related to data scrambling.

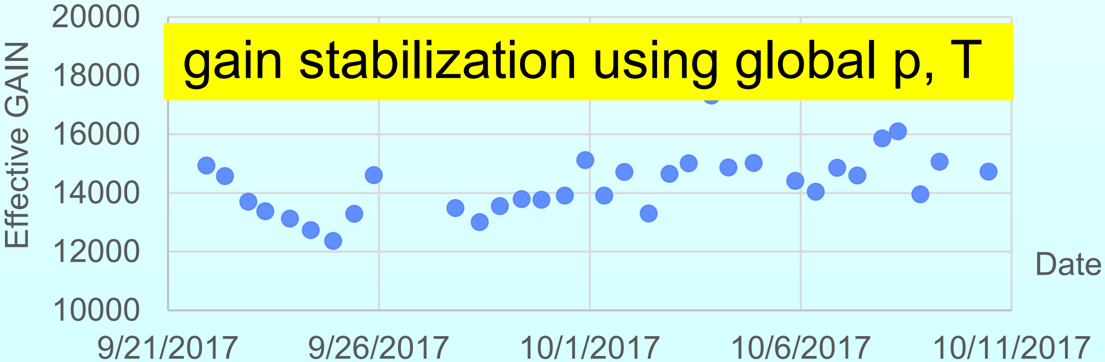
Missing hits and data attributed to different channels.

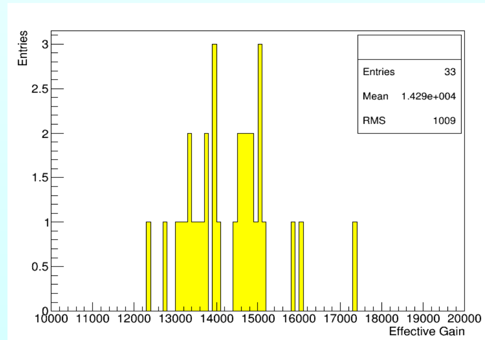
→Automatic APV reload procedure as soon as APV header errors are detected.

Gain stability in time

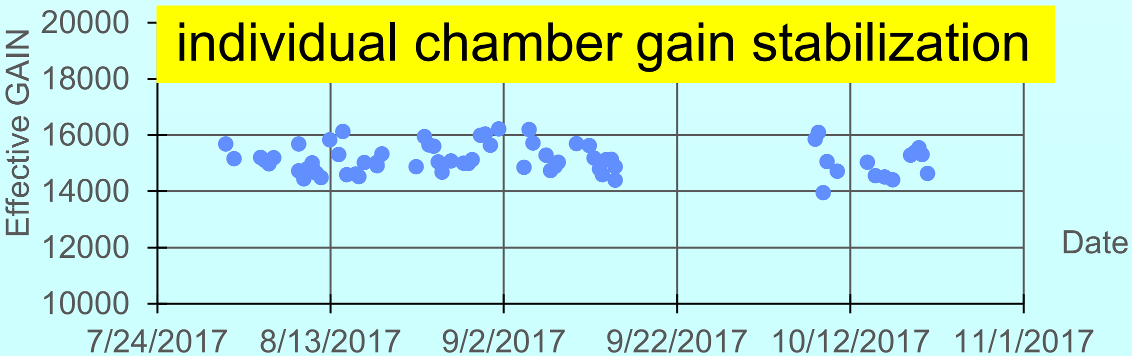


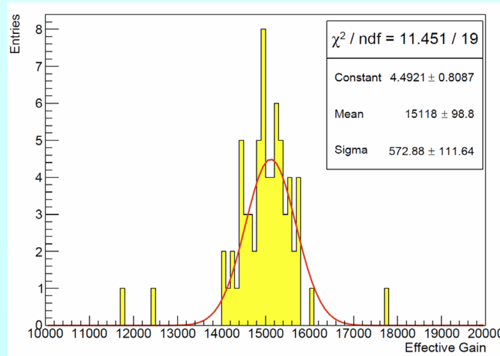






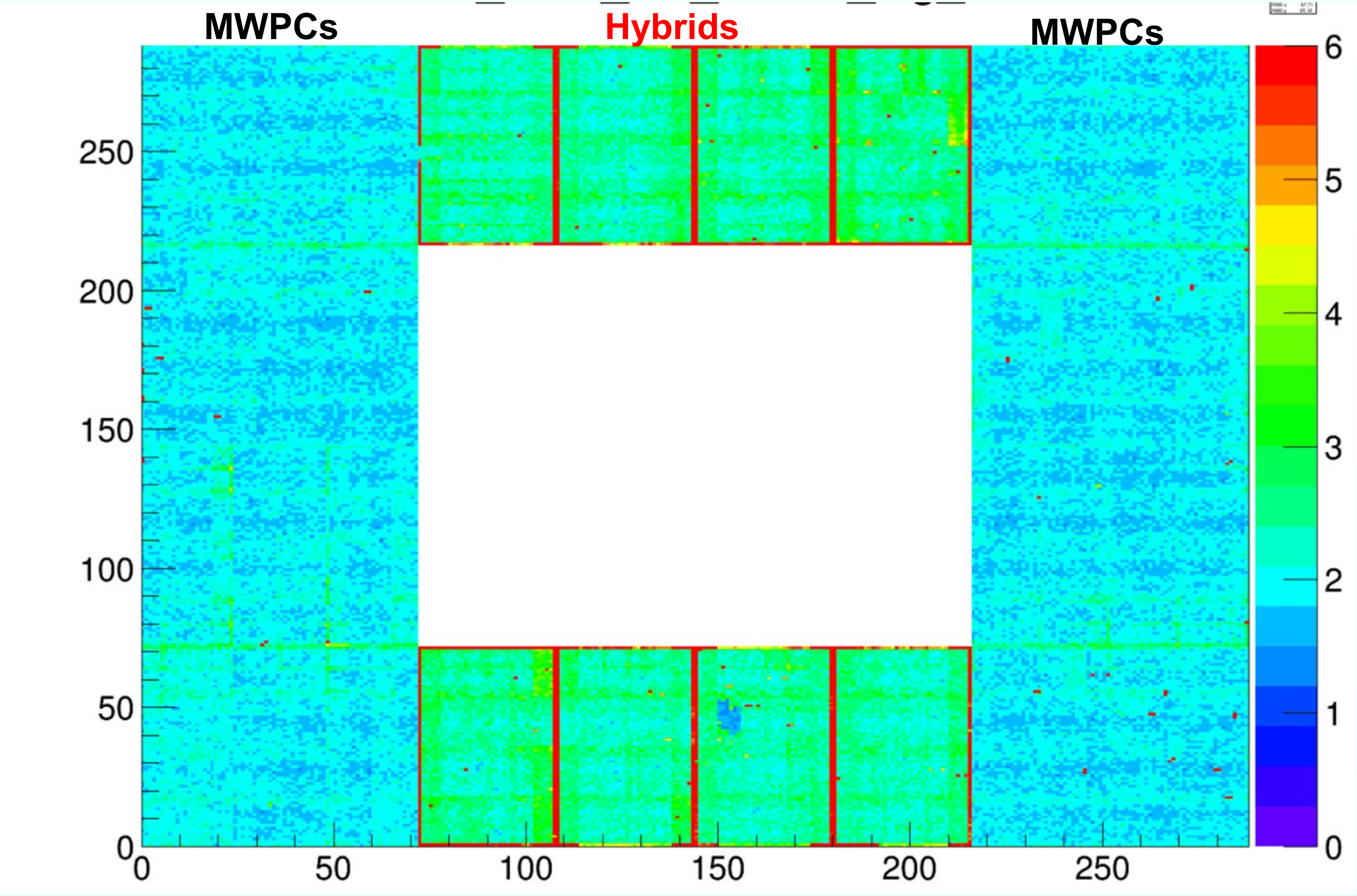
global corrections: **σ/mean ~ 7%**



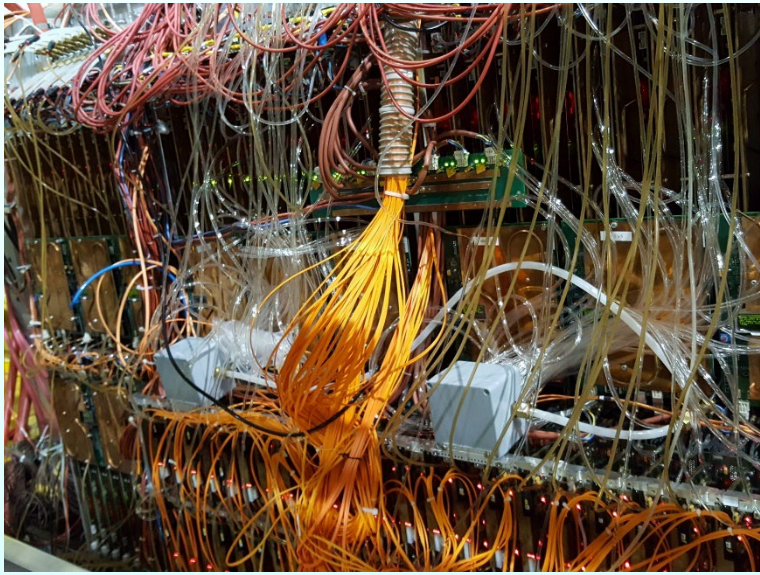


individual corrections: **σ/mean ~ 4%**

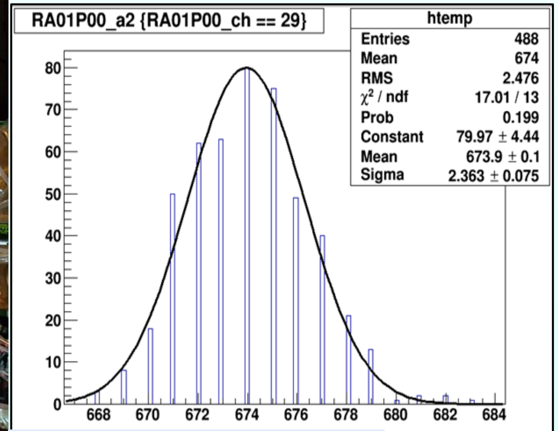
Noise figure for the 62208 ch.



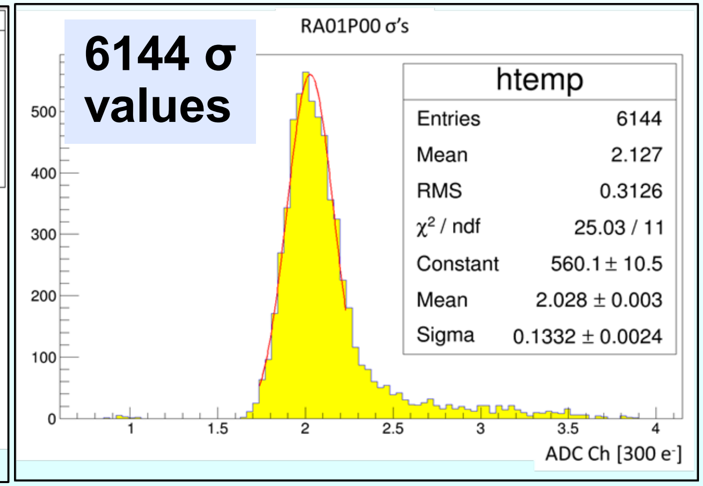
Noise level and pedestal stability



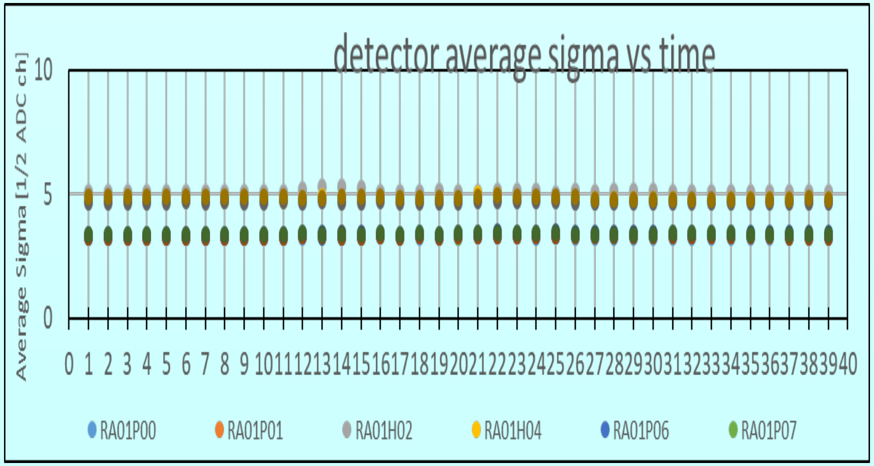
- 12 Detectors, 6144 Ch each.

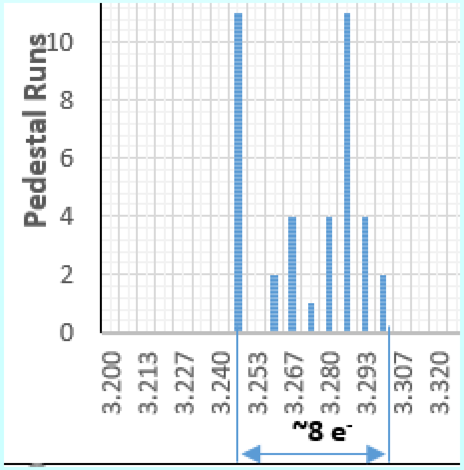


single channel



- 39 APV Pedestal Runs during COMPASS 2017 run.





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

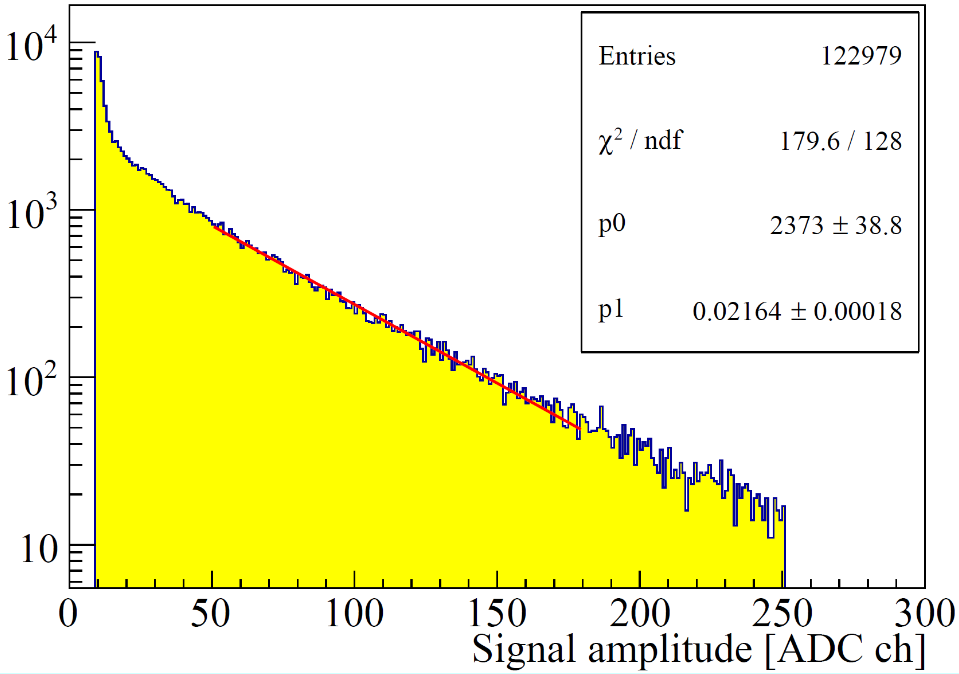
The niose levels are:

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

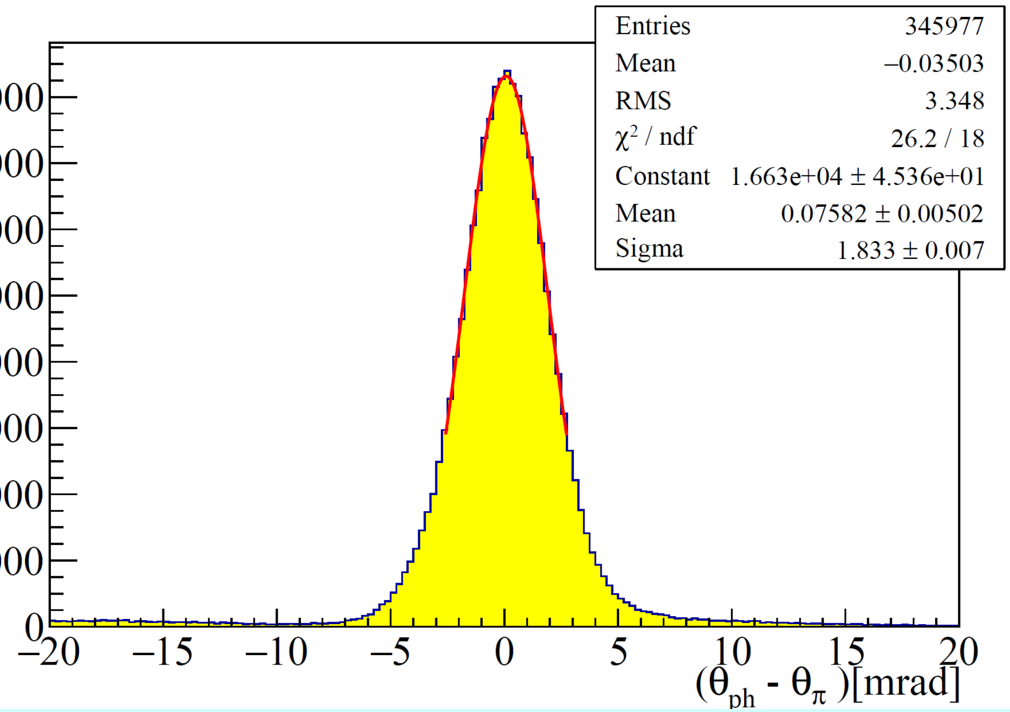
The noise levels are very stable in time

Gain and angular resolution

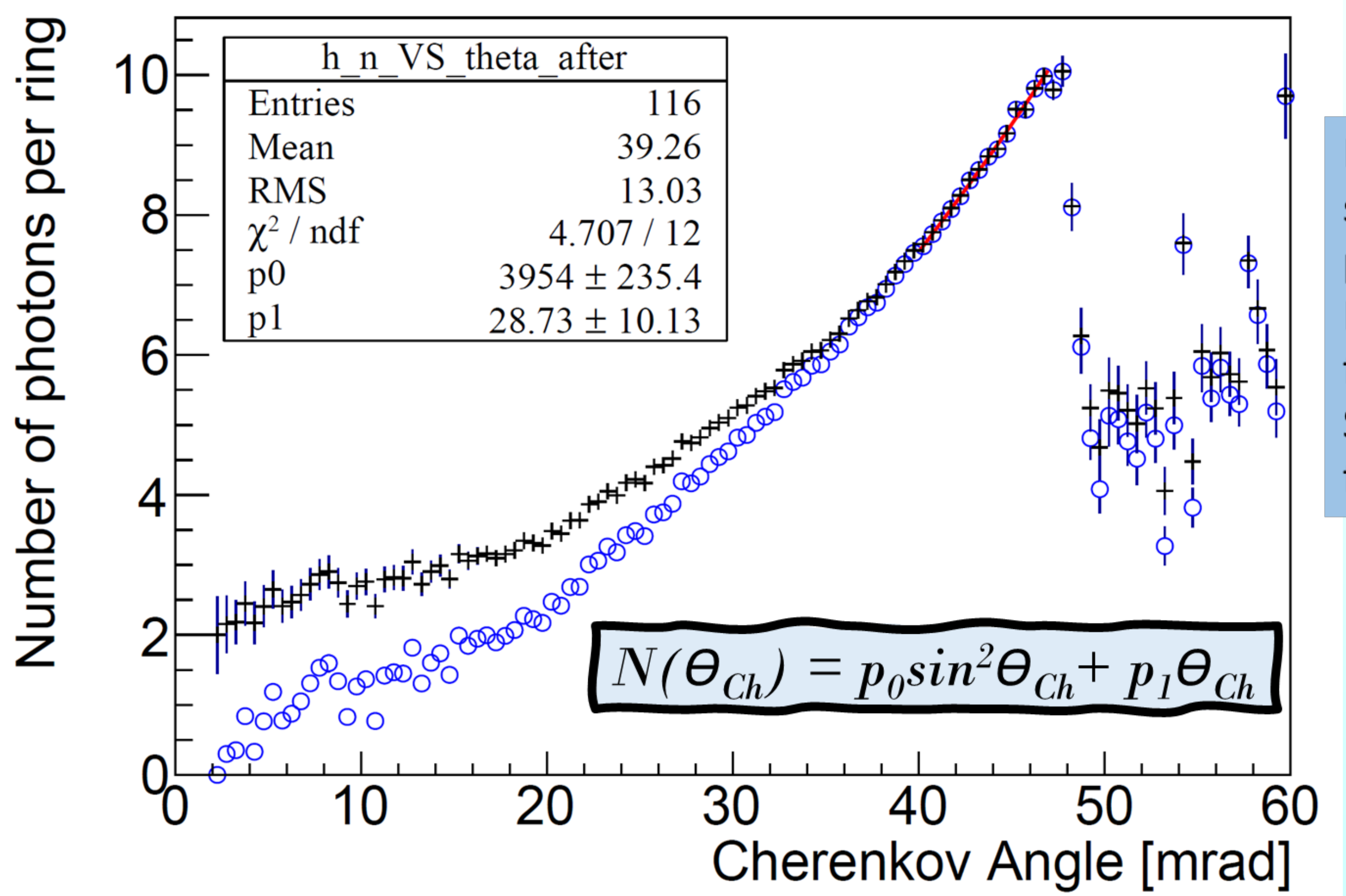
Effective gain : ~14000 +- 140



Single photon resolution: 1.83 +- 0.01 mrad



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

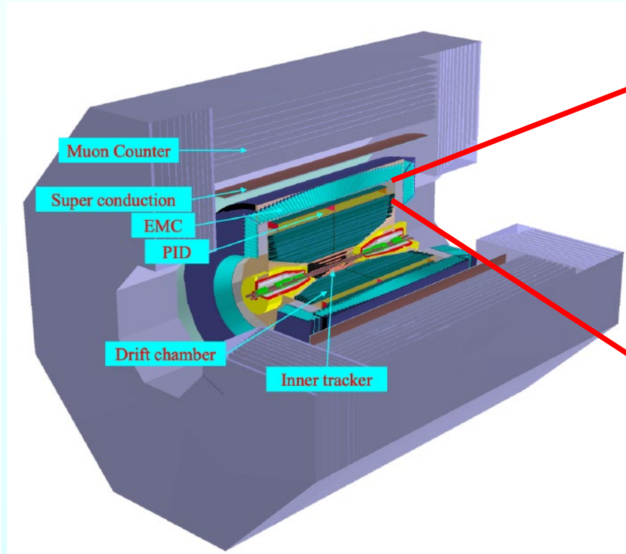
STCF

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



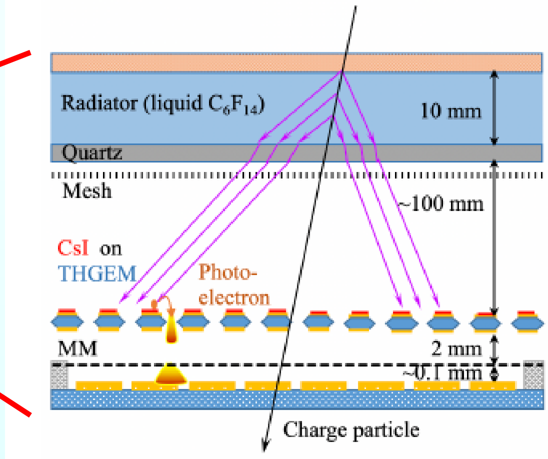


Figure 3.42: The RICH detector structure.

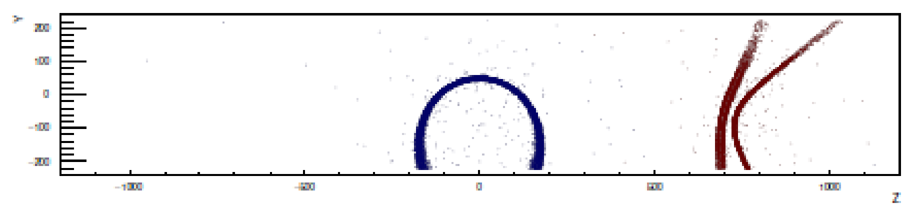


Figure 3.46: Examples of Cherenkov images in a RICH module. The blue image depicts the distribution of hits for 2 GeV/c pion with incident angle $\theta = 0°$, perpendicular to RICH, while the red image depicts $\theta = 40°$.

Hybrid THGEM-Micromegas PD's heve 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.