

Construction, operation and performance of the novel MPGD-based photon detectors of COMPASS RICH-1



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Yuxiang Zhao, INFN Trieste

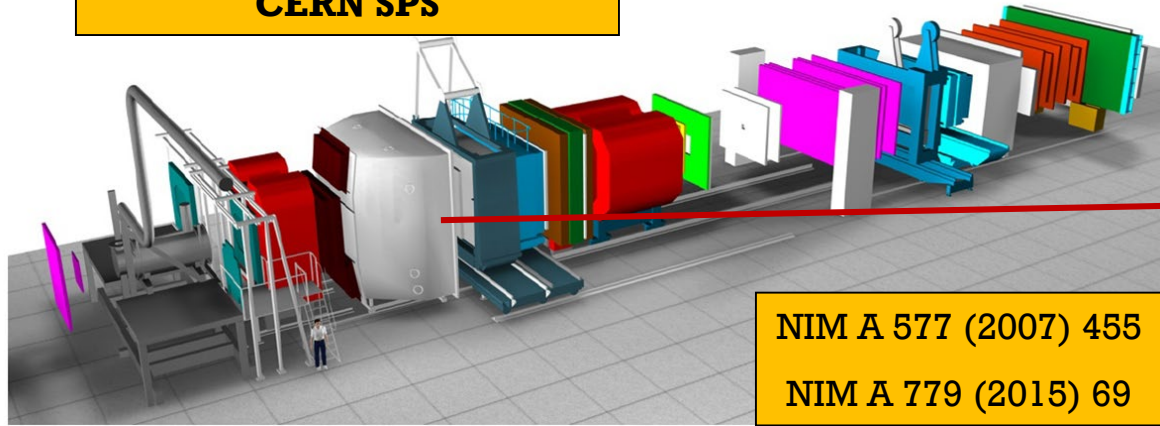
For the COMPASS RICH-1 collaboration

Outline

- Introduction: COMPASS RICH-1 at CERN
- Photon detector upgrade using MPGD based Hybrid detectors
- Detector commissioning and performance
- Ongoing activities and conclusions

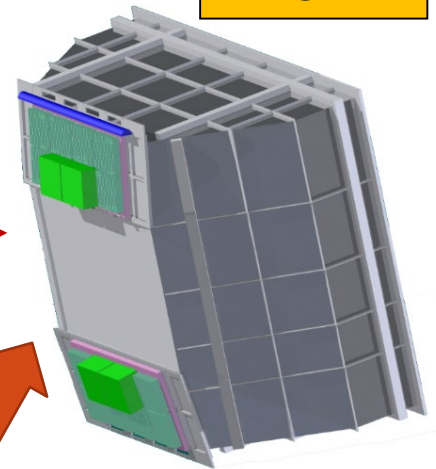
COMPASS RICH-1 at CERN

COMPASS Spectrometer at CERN SPS

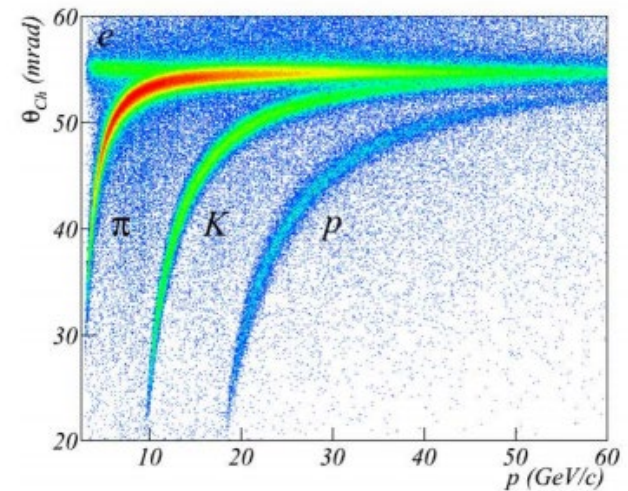


NIM A 577 (2007) 455
NIM A 779 (2015) 69

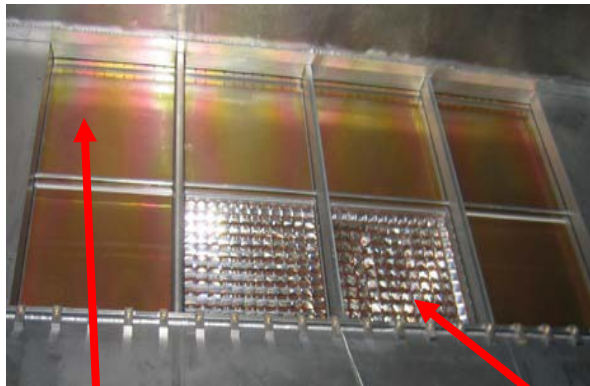
RICH-1



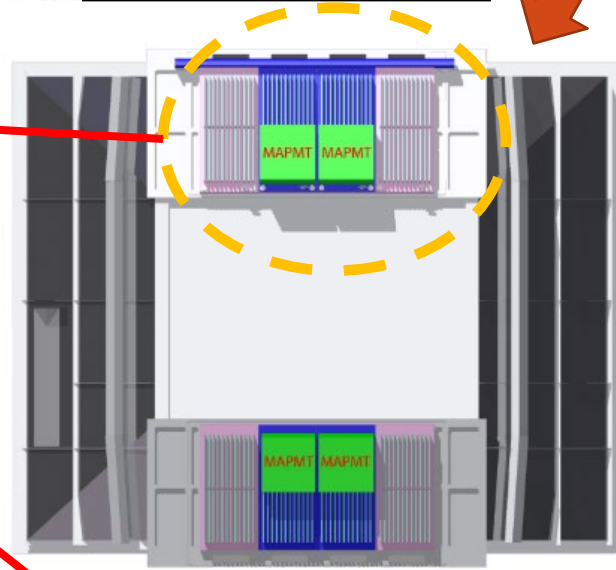
Hadron PID range: 3-60 GeV



Top photon detectors

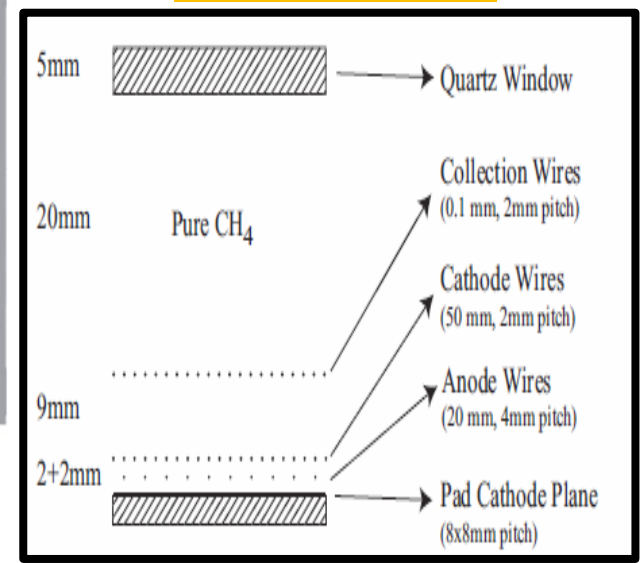


MWPCs+CsI(from RD26): successful but performance limitations, in particular for the 4 central chambers

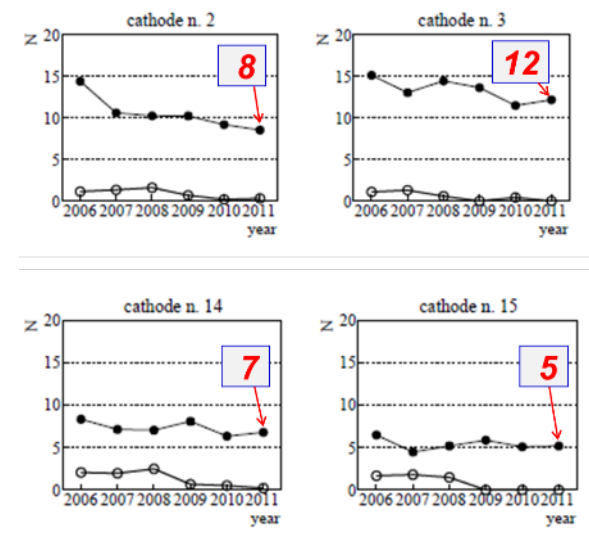


MAPMT's coupled to lens telescope

MWPCs+CsI

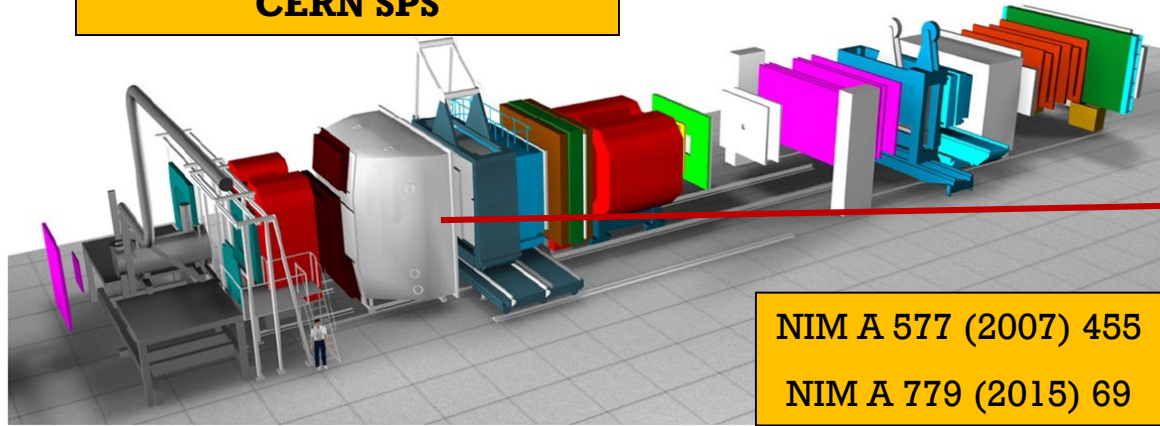


n. of ph.s@ β= 1



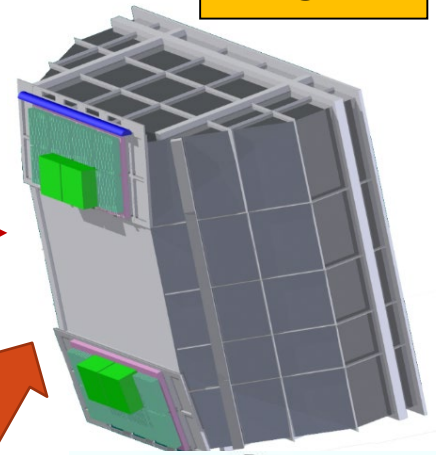
COMPASS RICH-1 at CERN

COMPASS Spectrometer at CERN SPS

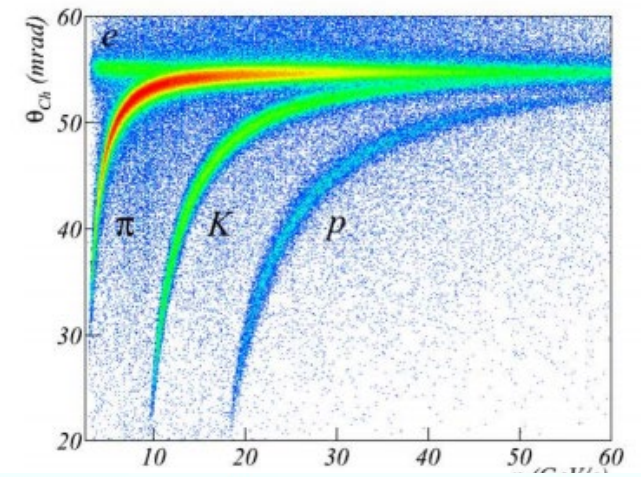


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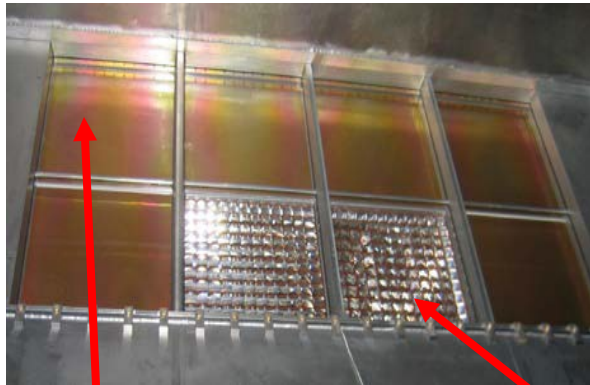
RICH-1



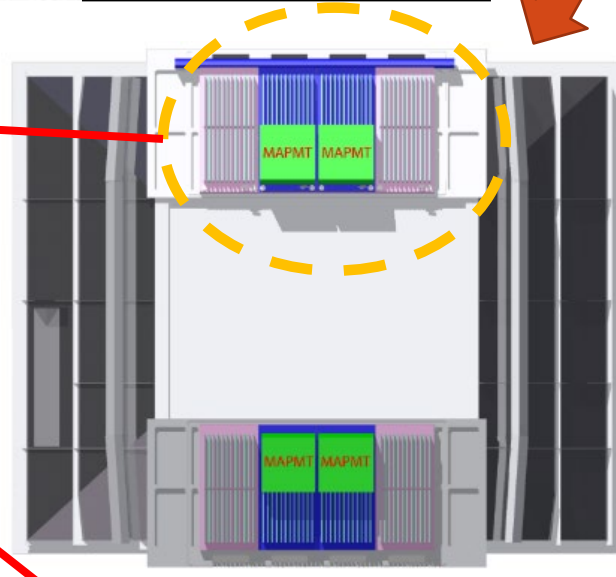
Hadron PID range: 3-60 GeV



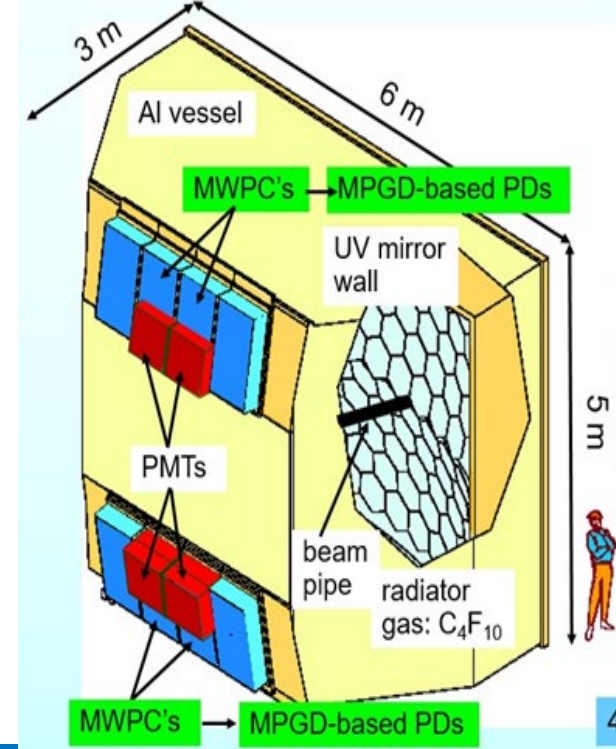
Top photon detectors



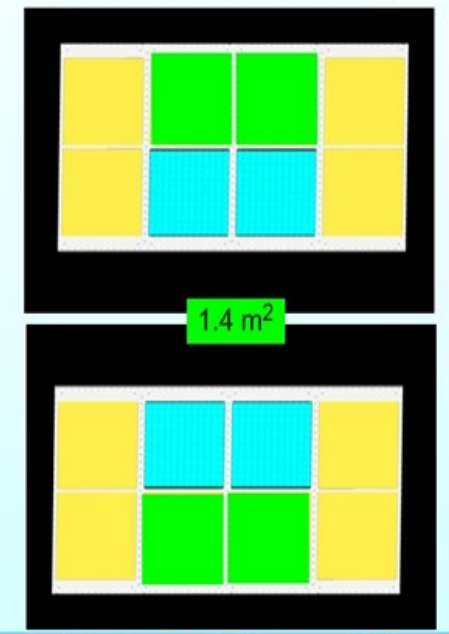
MWPCs+Csl(from RD26):
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MAPMTs coupled to lens telescopes



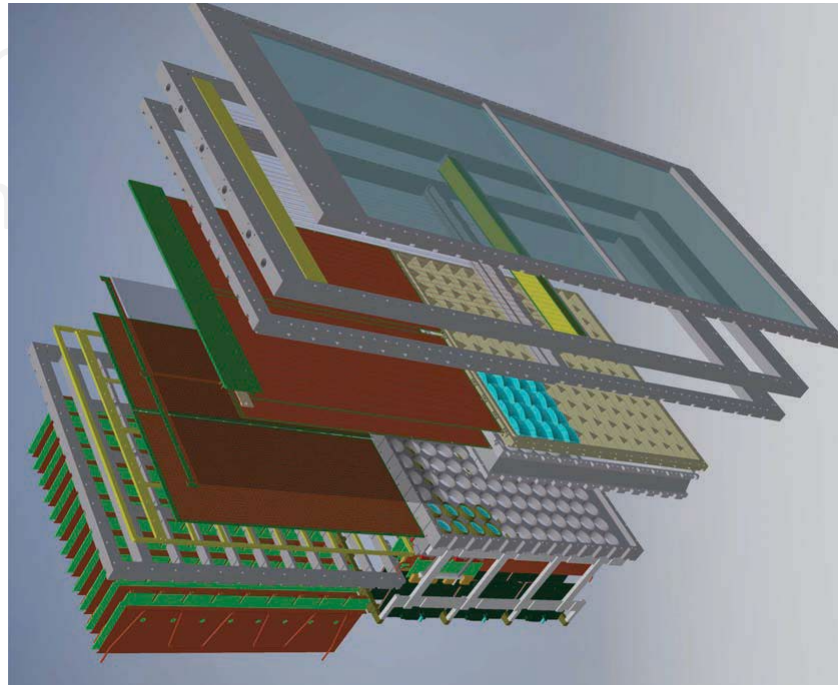
for COMPASS run 2016



4 new detectors of 600 mm x 600 mm

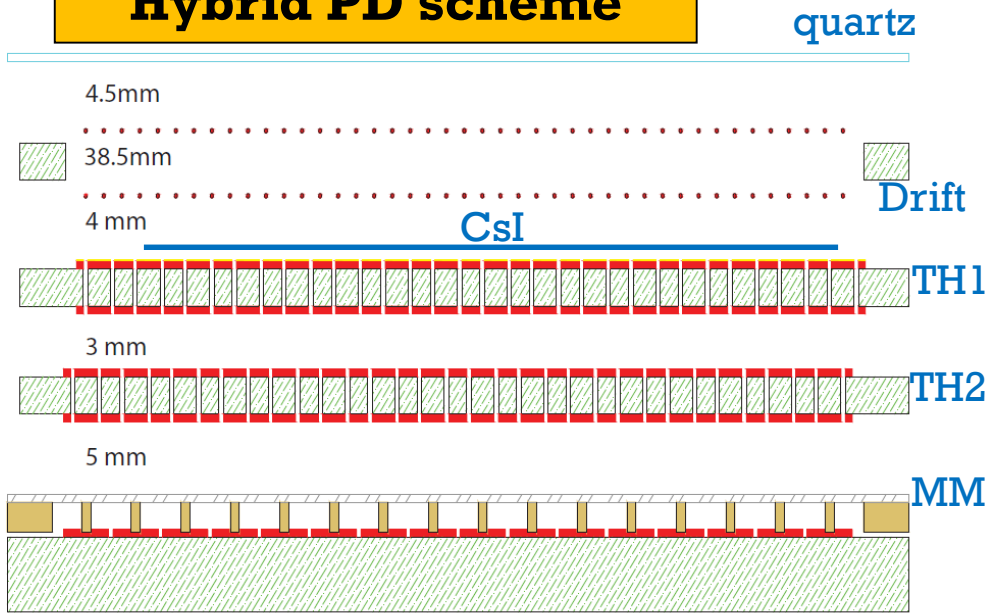
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- Introduction: COMPASS RICH-1 at CERN
- Photon detector upgrade using MPGD based Hybrid detectors
- Detector commissioning
- Ongoing activities and future plans

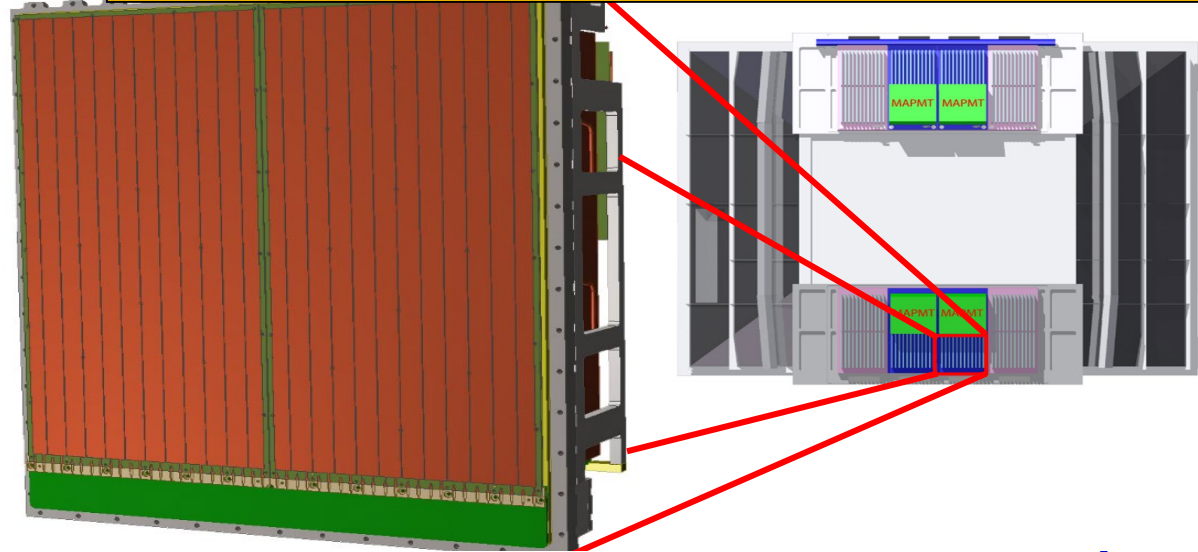


The MPGD-based hybrid photon detector

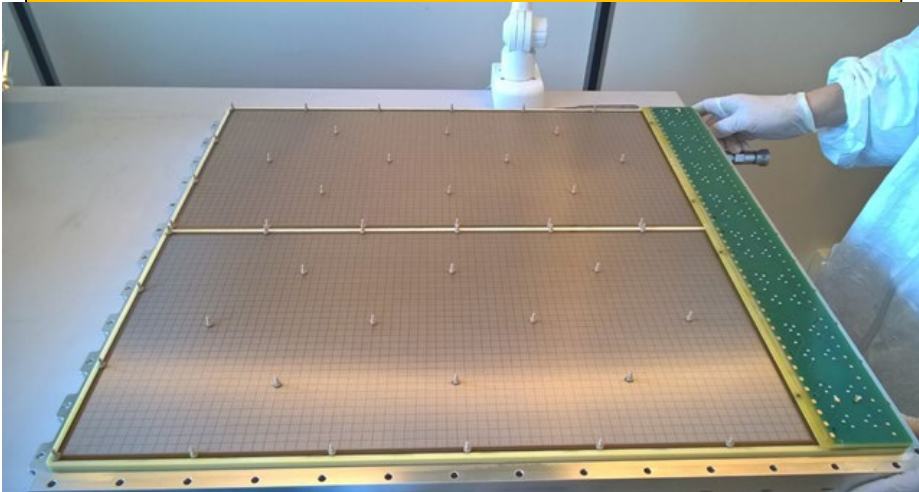
Hybrid PD scheme



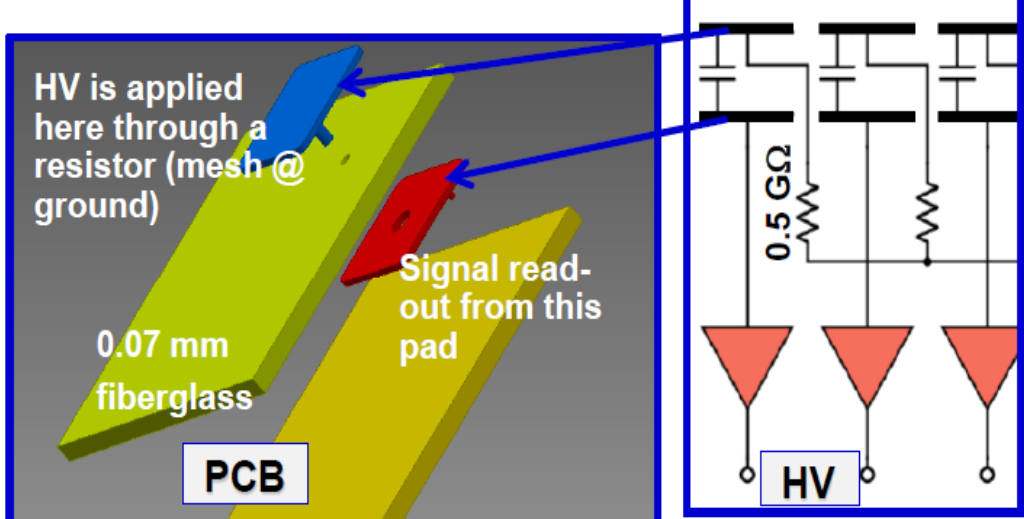
modular structure: one module = 600x300 mm²



Standard Bulk Micromegas produced at CERN



8mm X 8mm pads at positive HV

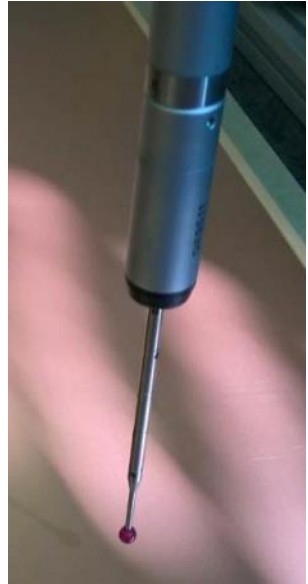


Capacitive coupling → APV25

Component Quality Control

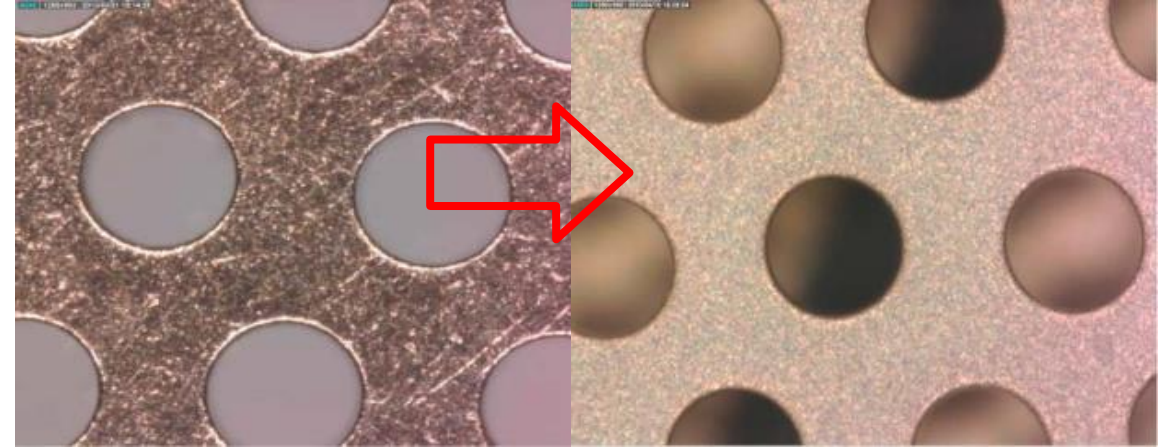
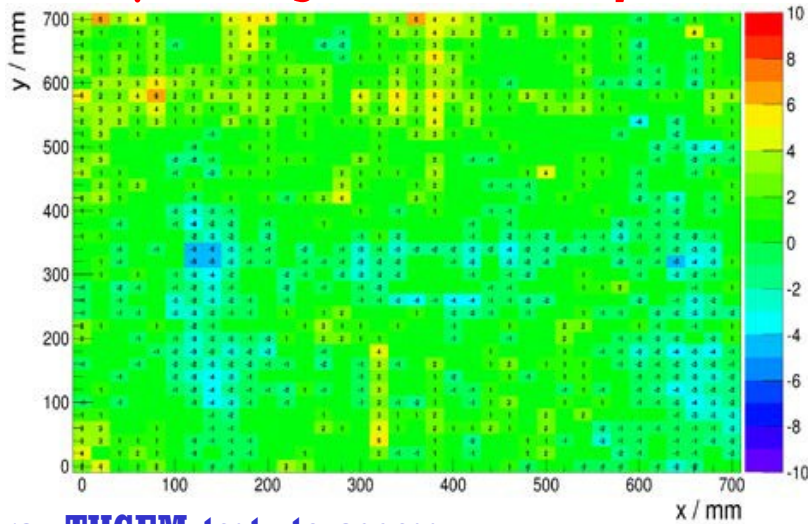
THGEM polishing with an "ad hoc" protocol setup by us including baking:

>90% break-down limit obtained



Measurement of the raw material thickness before the THGEM production, accepted:

$\pm 15 \mu\text{m} \leftrightarrow$ gain uniformity $\sigma < 7\%$



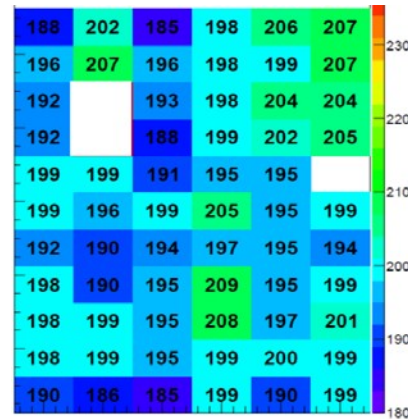
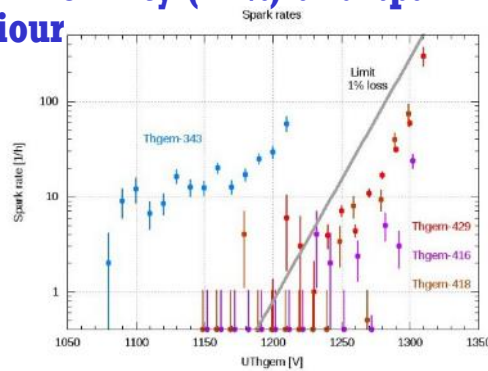
MICROME GAS



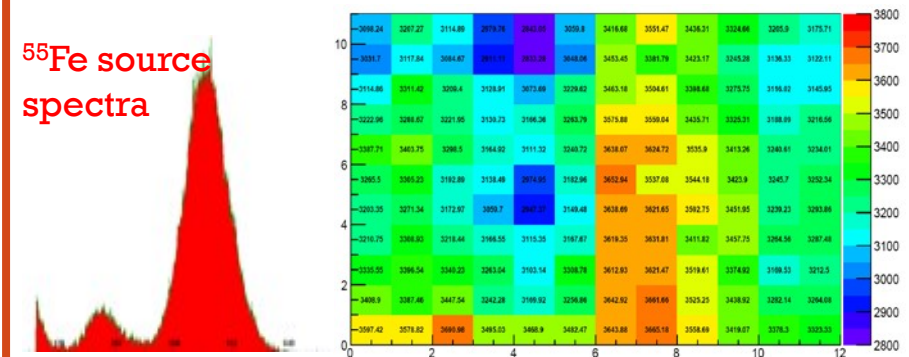
X-ray MM test to access integrity and gain uniformity (<5%)



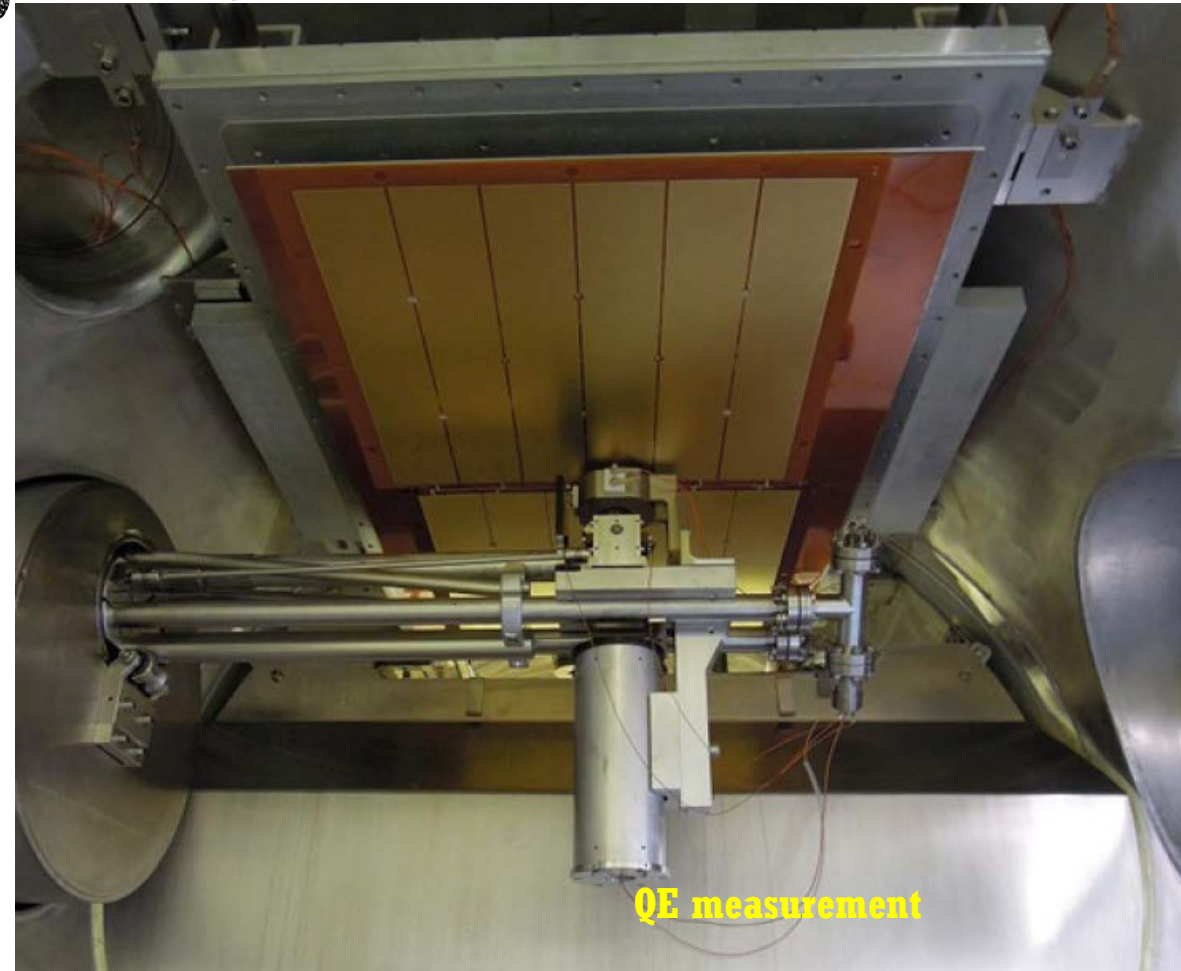
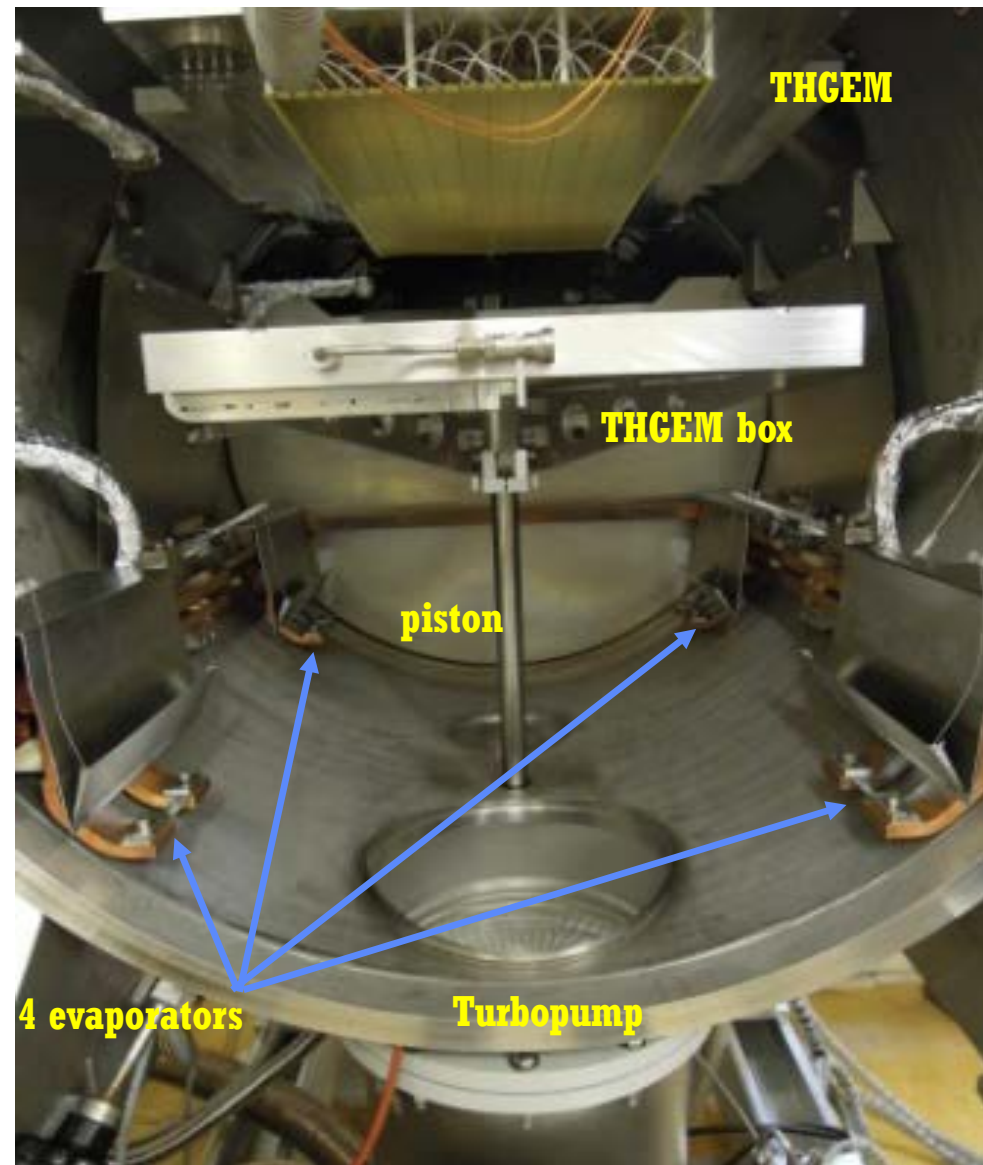
X-ray THGEM test to access gain uniformity (<7%) and spark behaviour



⁵⁵Fe source spectra



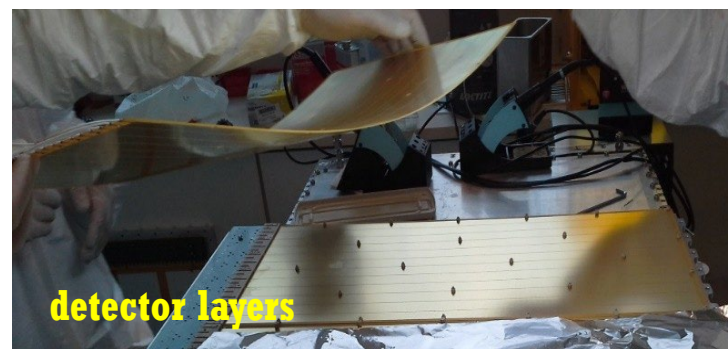
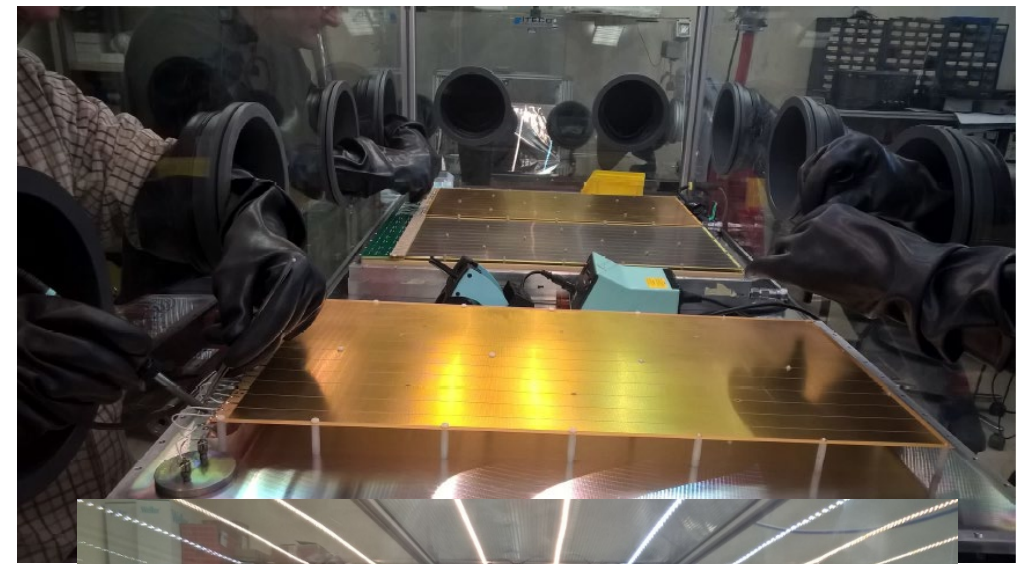
THGEM CsI coating at CERN



QE uniformity

- ✓ 3 % r.m.s. within a photocathode
- ✓ 10 % r.m.s. among photocathodes
- ✓ mean value: 93% of reference

Detector assembling



Assembling CsI coated THGEM in a dedicated Glove box flushing with N₂ gas

HV control for the hybrid detectors

Electrode	Protection wire plane	Drift wire plane	THGEM1 top	THGEM1 bottom	THGEM2 top	THGEM2 bottom	mesh	MM anode
Voltage	-300 V	-3520 V	-3320 V	-2050 V	-1750 V	-500 V	grounded	+620 V
Number of HV channels per detector	1	1	4	4	4	4	0	4

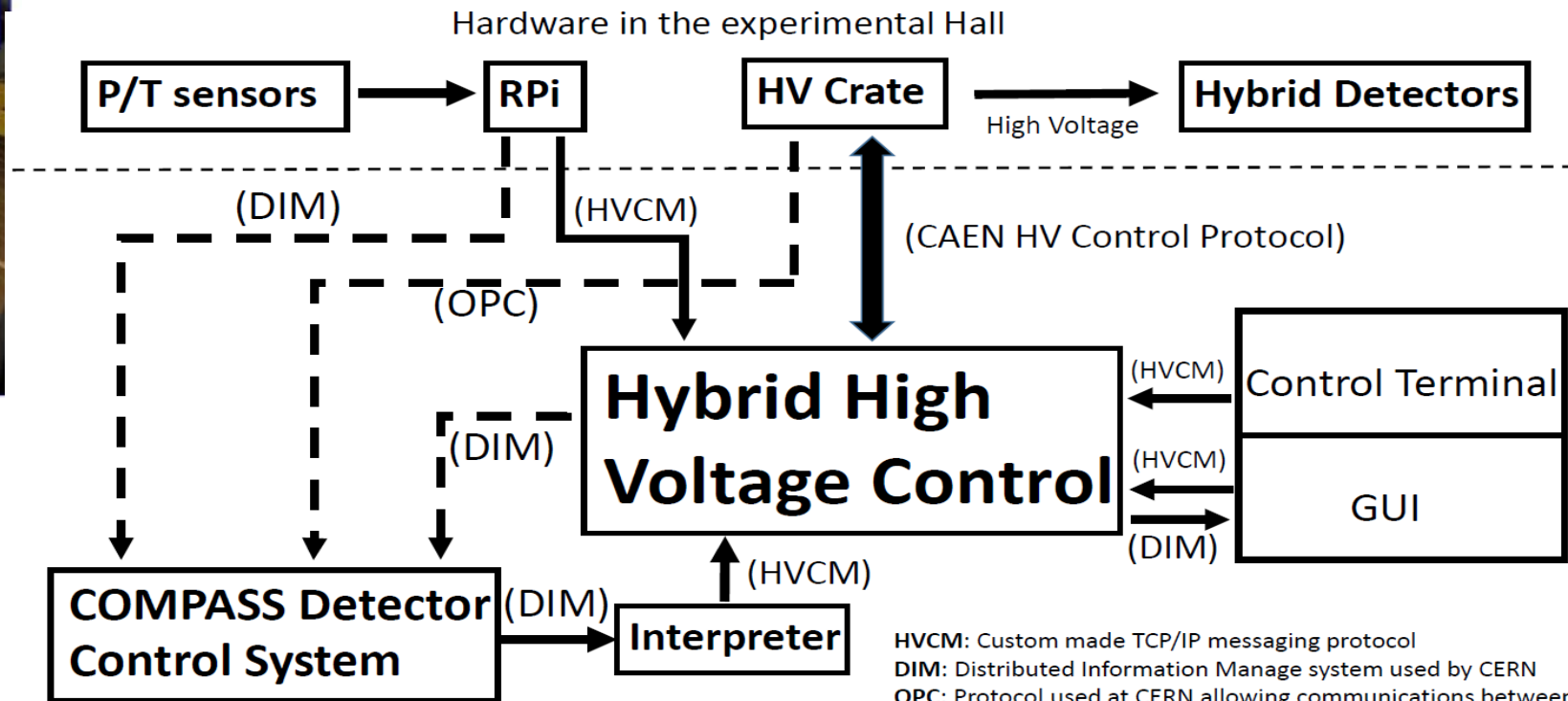
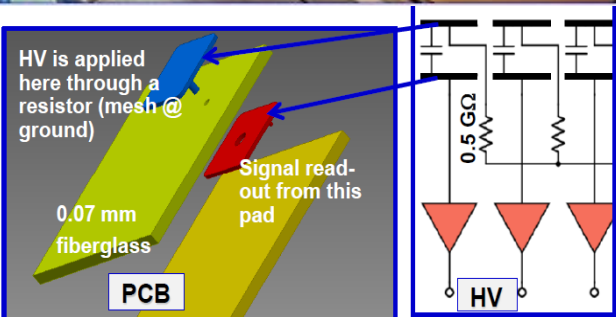
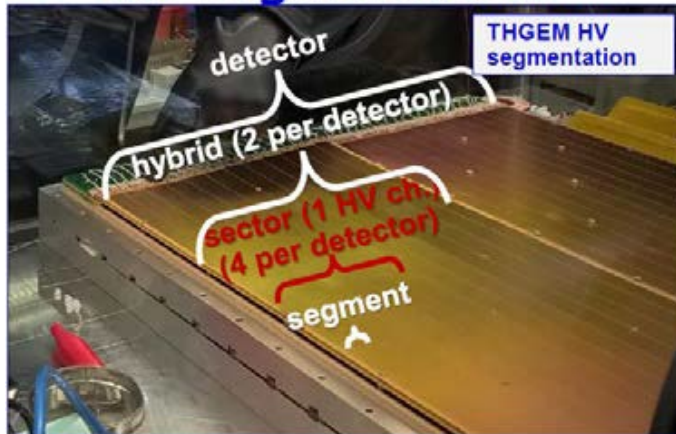
Gain stability vs P, T:

- $G = G(V, T/P)$
- Enhanced in a multistage detector
- $\Delta T = 1 \text{ degree} \rightarrow \Delta G \approx 12 \%$
- $\Delta P = 10 \text{ mbar} \rightarrow \Delta G \approx 20 \%$

THE WAY OUT:

- Compensate T/P variations by V

HV segmentation



HVCM: Custom made TCP/IP messaging protocol
 DIM: Distributed Information Manage system used by CERN
 OPC: Protocol used at CERN allowing communications between any compliant components regardless of vendor

Outline

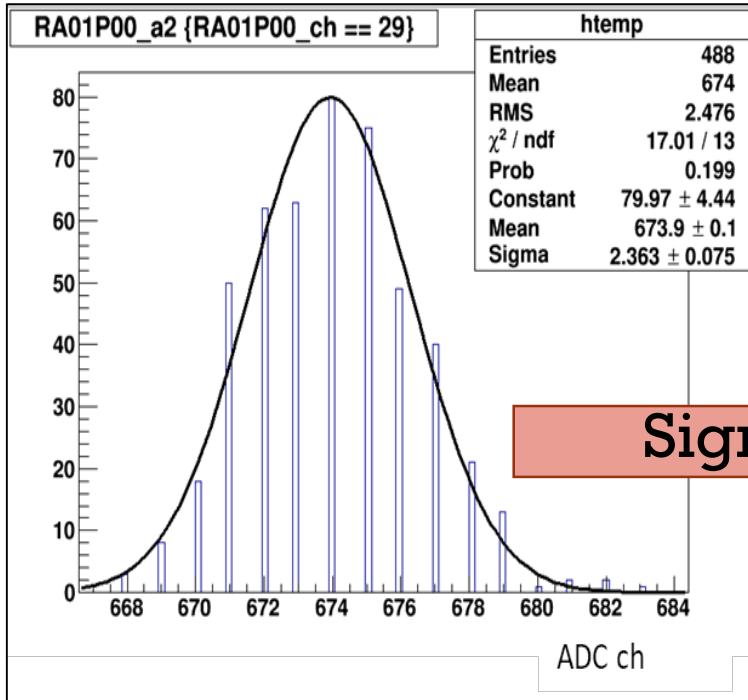
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Noise level for the APV based readout

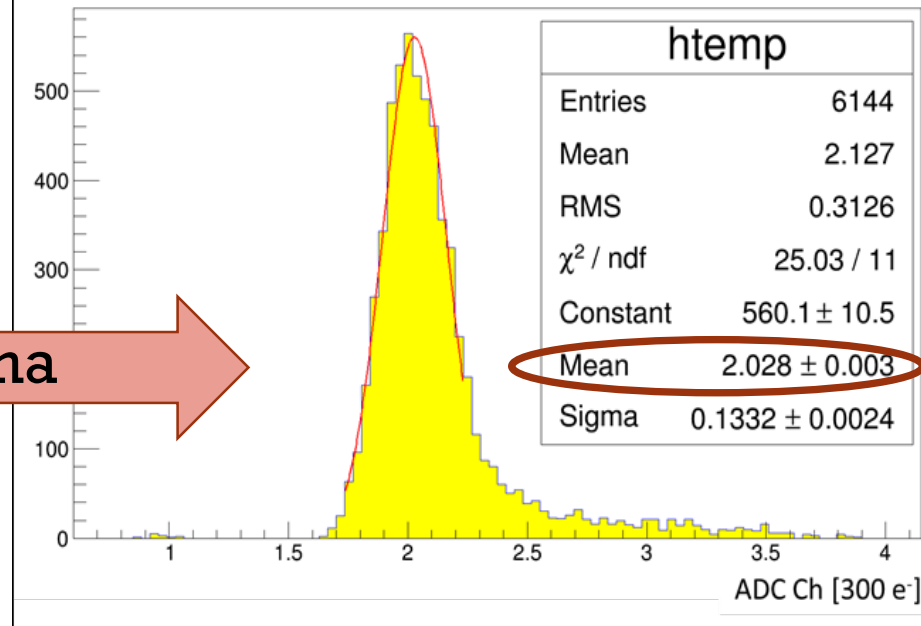
12 Gaseous Photon Detectors using APV based readout
(4 hybrid, 12 MWPC), 6144 Channels/detector

39 pedestal runs in 2017 COMPASS run

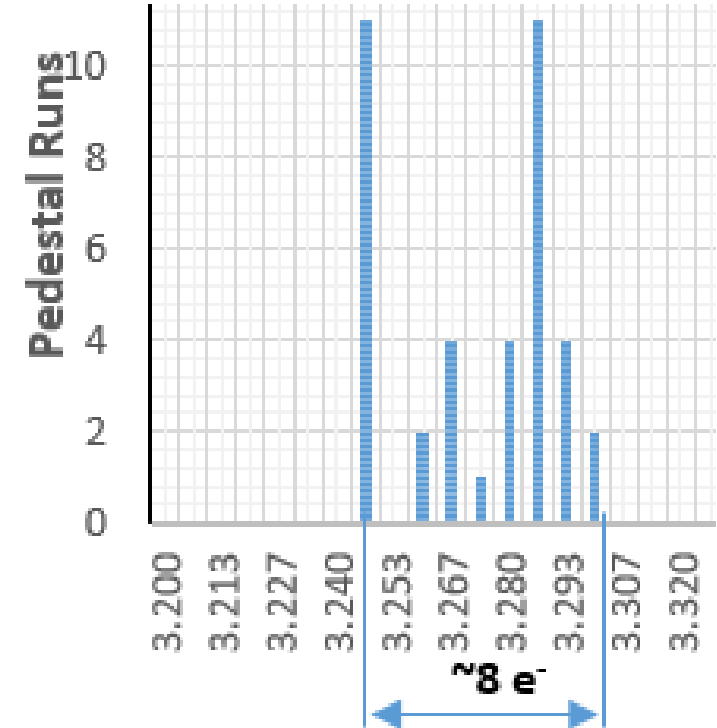
1 channel in a particular pedestal run



6144 channels for 1 detector in a particular pedestal run



Sigma



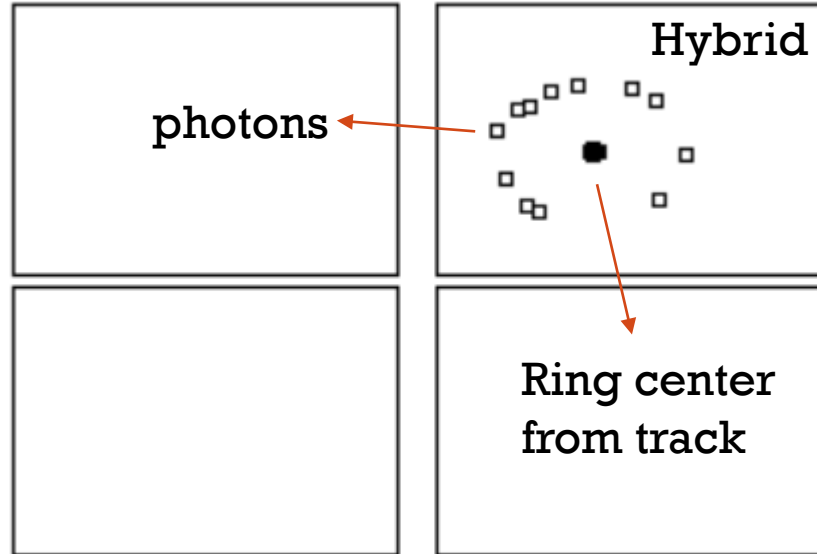
The noise levels are:

- MWPC: $\sim 600 e^-$
- Hybrid: $\sim 900 e^-$

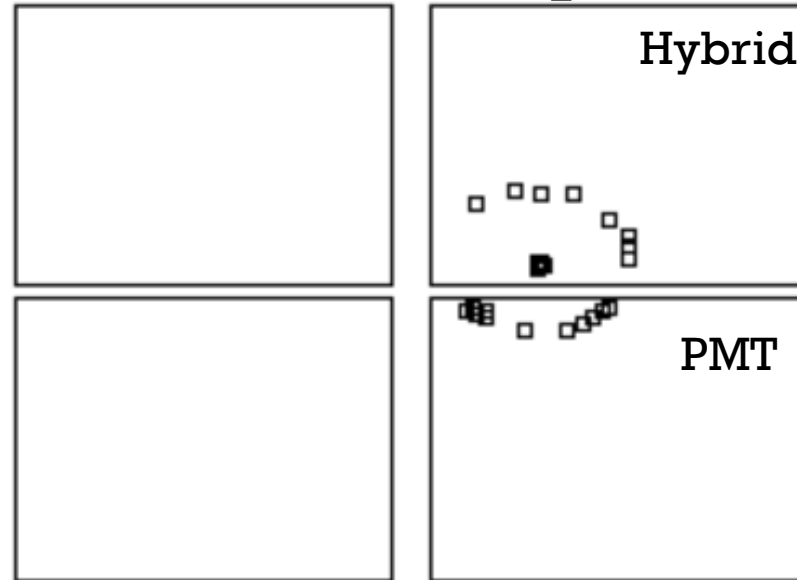
The noise levels are very stable in time

Event displays

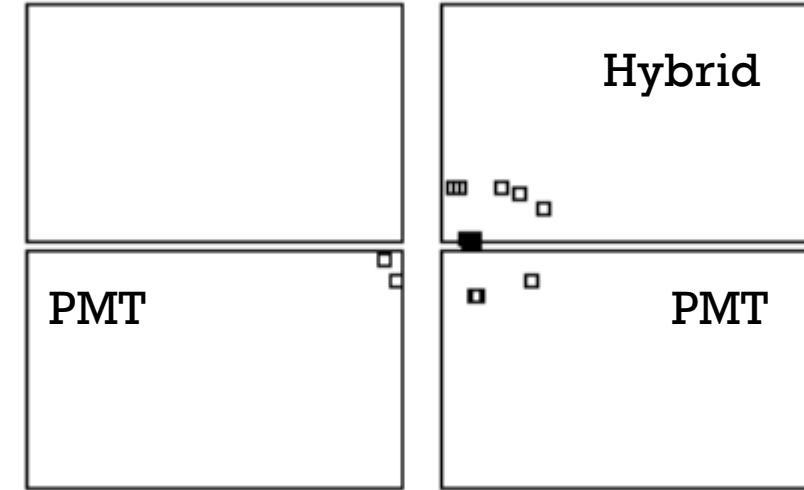
6.36 GeV pion



6.76 GeV pion

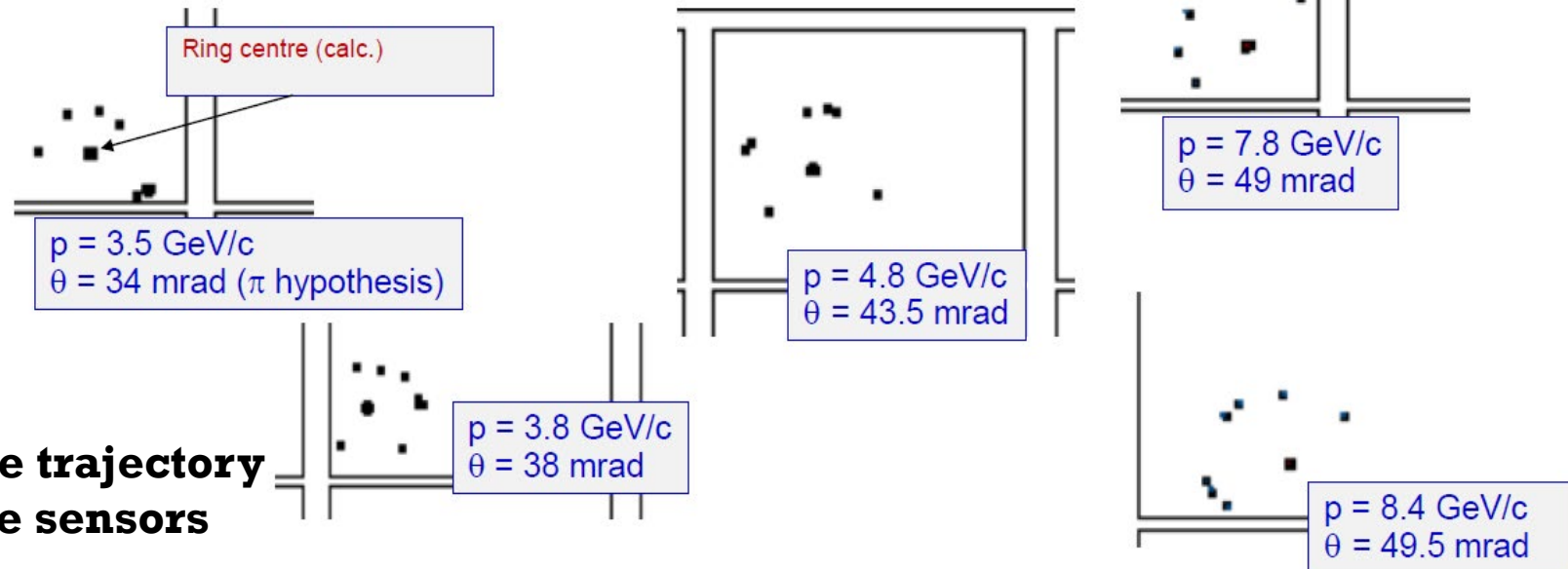


6.4 GeV pion



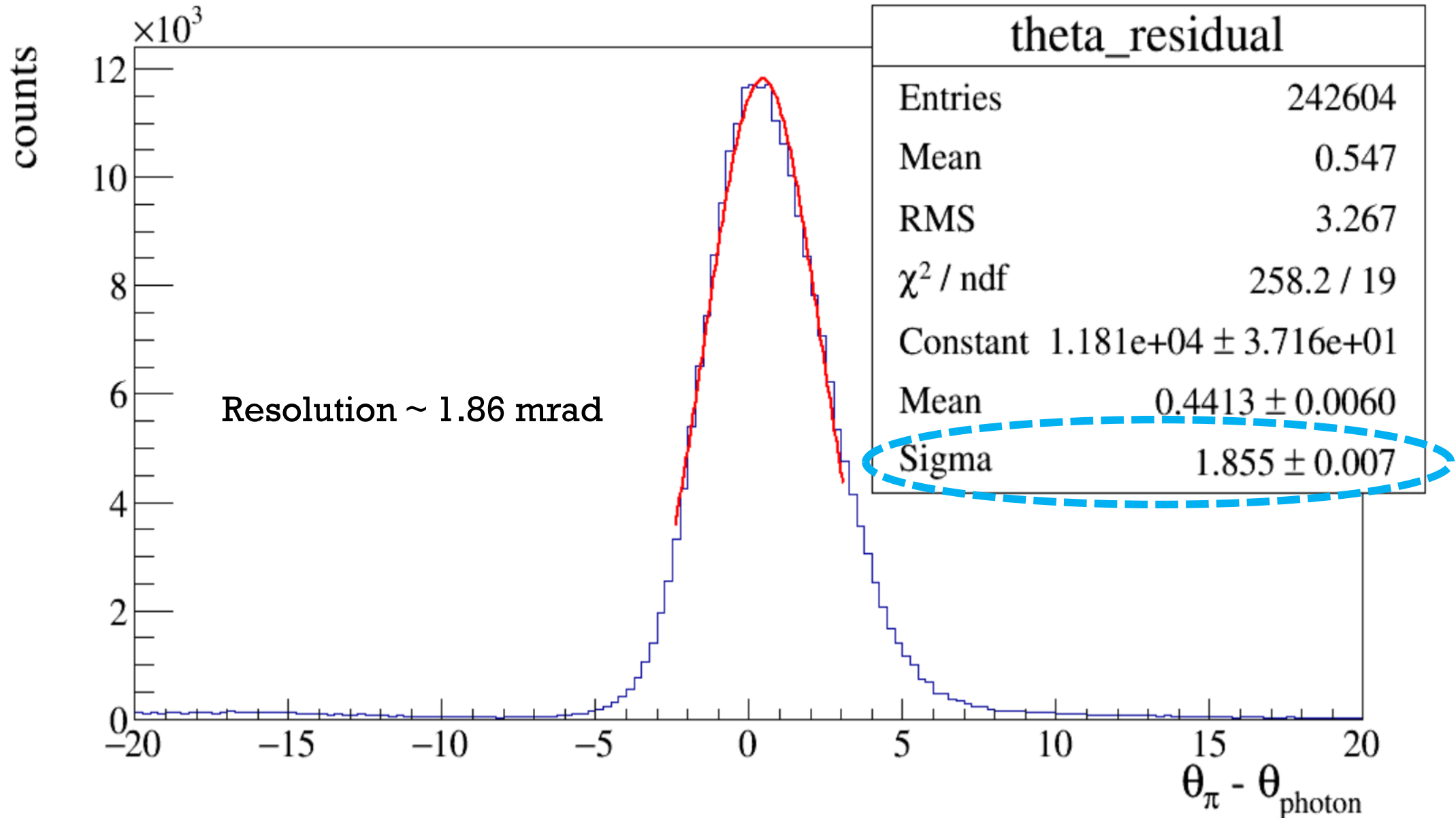
For reference:

$$\theta(\beta=1) = 52.5 \text{ mrad}$$

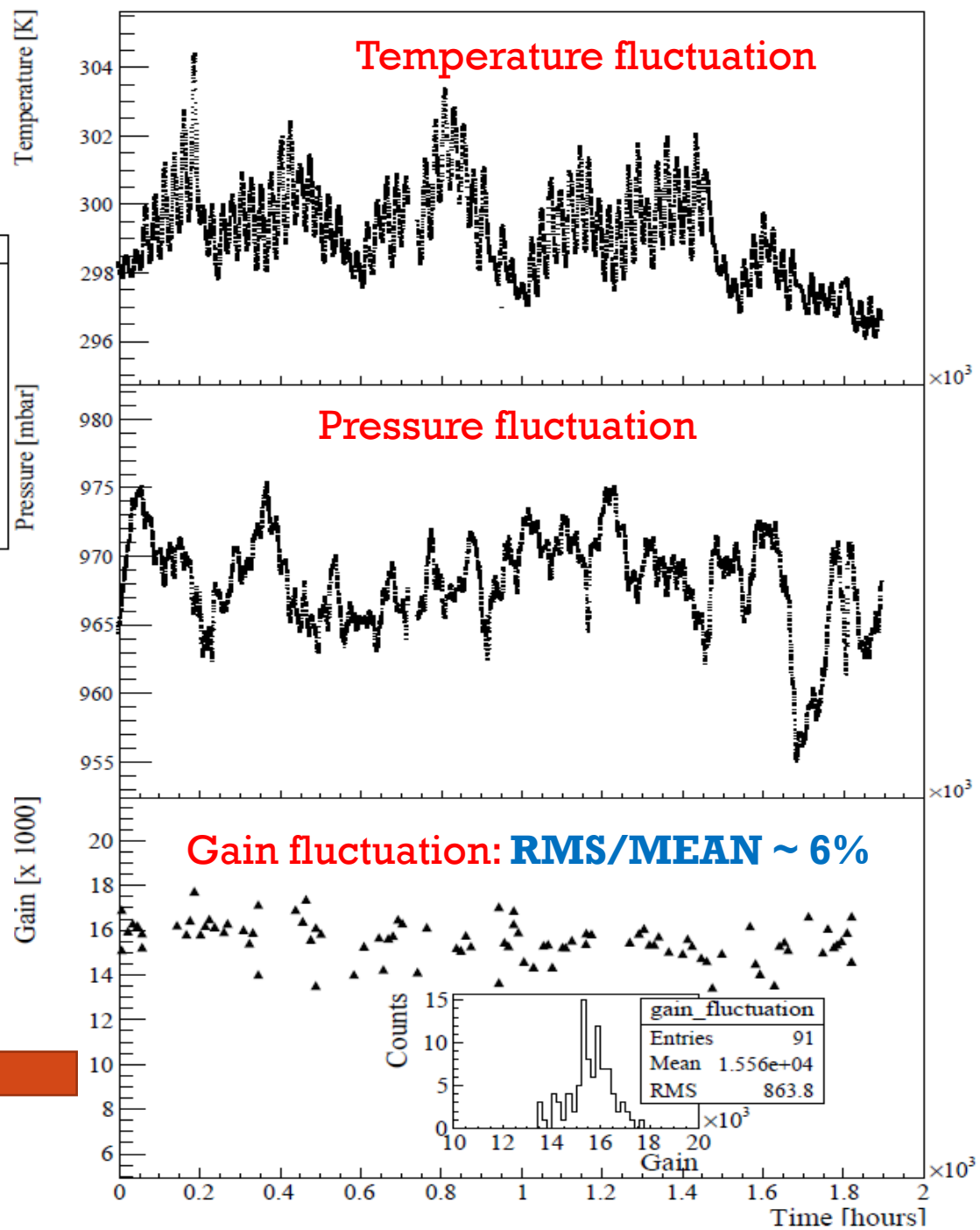
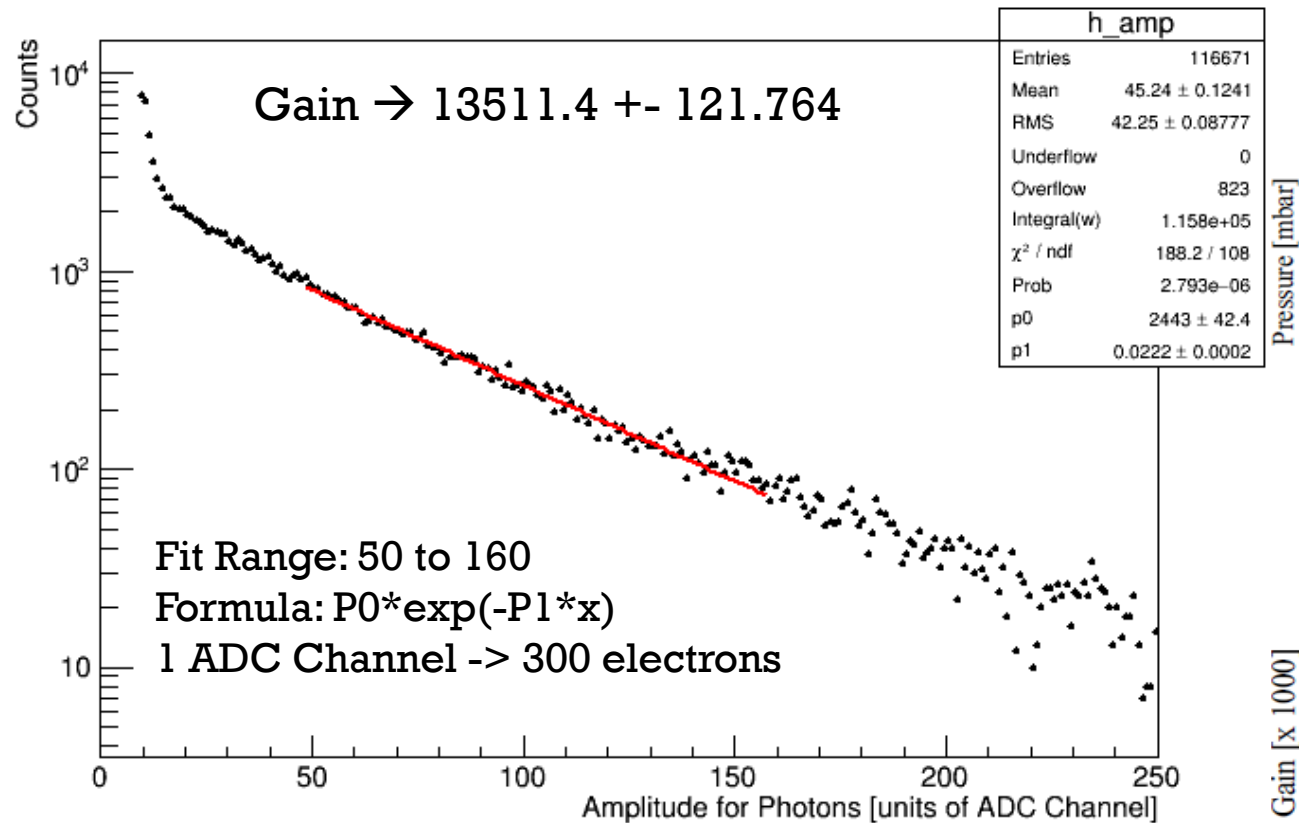


- **Ring center calculated from particle trajectory**
- **Detected photoelectrons : hits on the sensors**

Angular resolution for photon detection



Gain of hybrid detectors

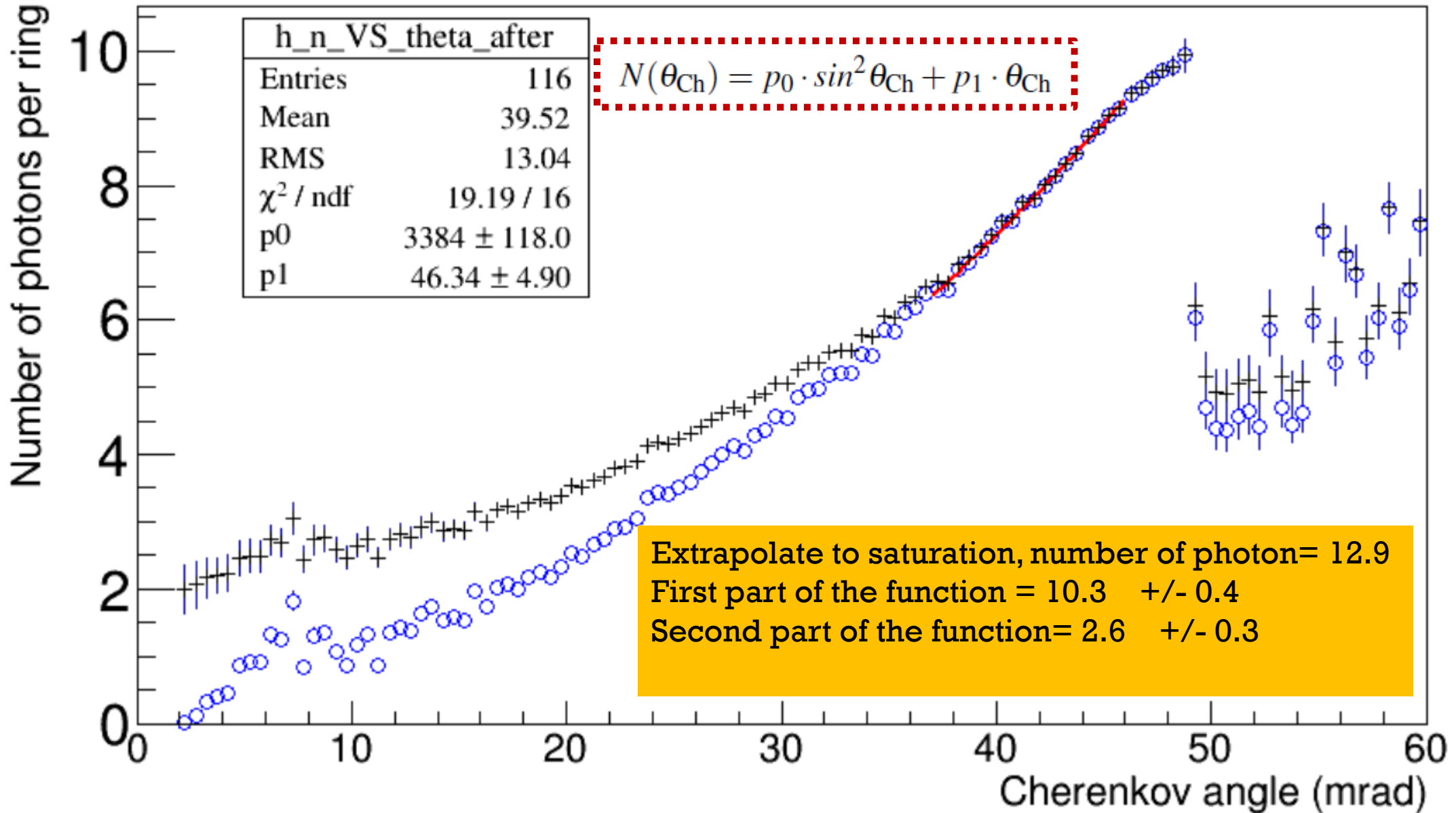


2000 hours of running

A non-negligible achievement due to P, T corrections on HV application



Number of photons



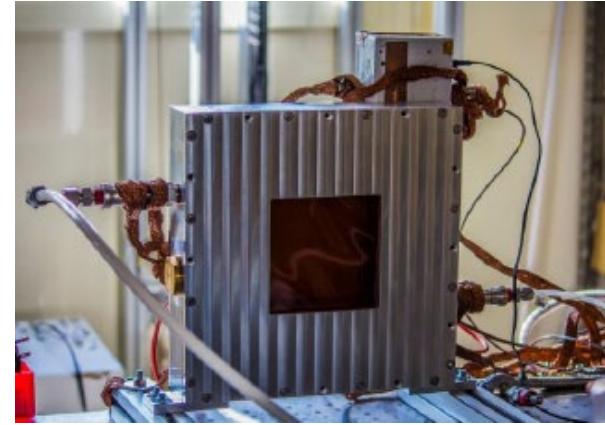
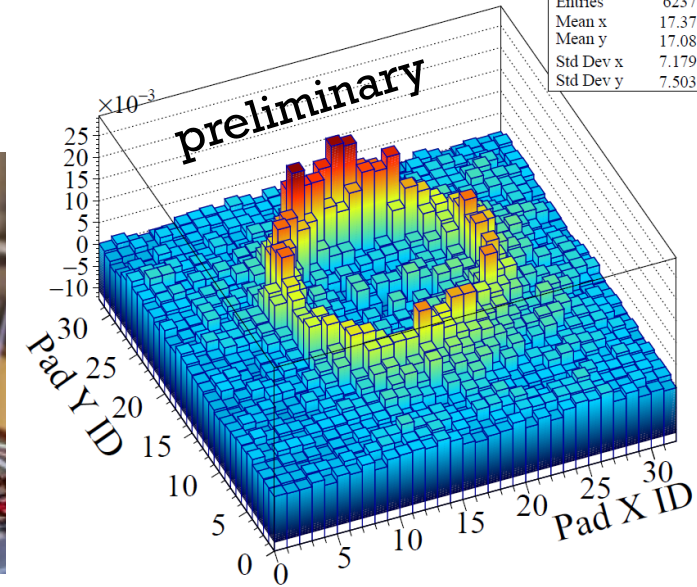
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Ongoing R&D efforts at INFN Trieste

Beam test

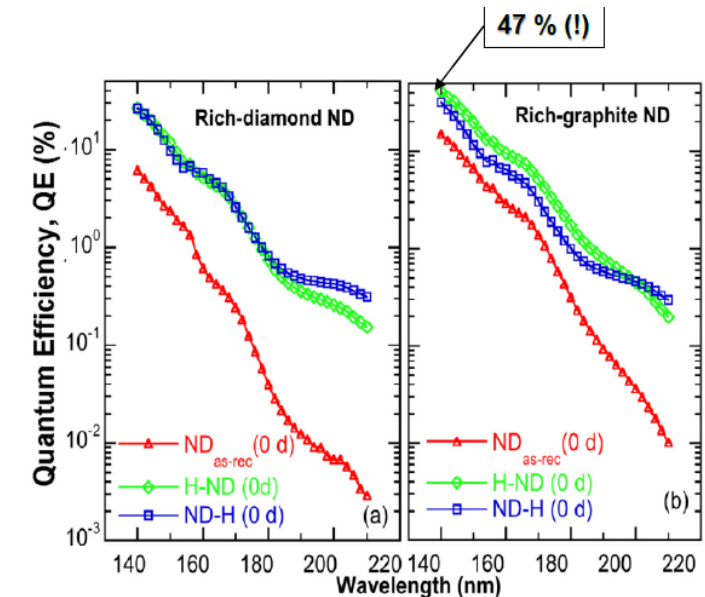
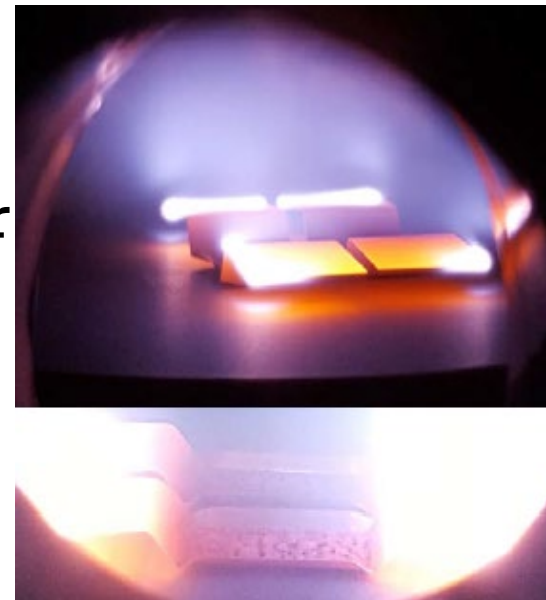
h_hit_profile_photon_candidate	
Entries	6237
Mean x	17.37
Mean y	17.08
Std Dev x	7.179
Std Dev y	7.503



- Development of an optimized detector for finer spatial resolution based on the hybrid THGEM + MM and “mini-pads” of size 3mm x 3mm

- Study the compatibility of these hybrid PDs with CF_4 for a windowless RICH for the future Electron Ion Collider

- Exploring the possibility to use a more robust photocathode in the far UV: hydrogenated nano-diamond crystals



Conclusions

- COMPASS RICH-1 has been upgraded with 1.4 m² of MPGD-based PDs
- The Hybrid PD: 2 THGEMs (1 with CsI) + Micromegas are nicely operating
- They present good gain performance (>10k in a real experiment) and stability, clean rings etc.
- 1.85 mrad single photon angular resolution
- 10 detected photons per ring at saturation
- R&D for future RICH projects are considering the use of this technology

Thanks