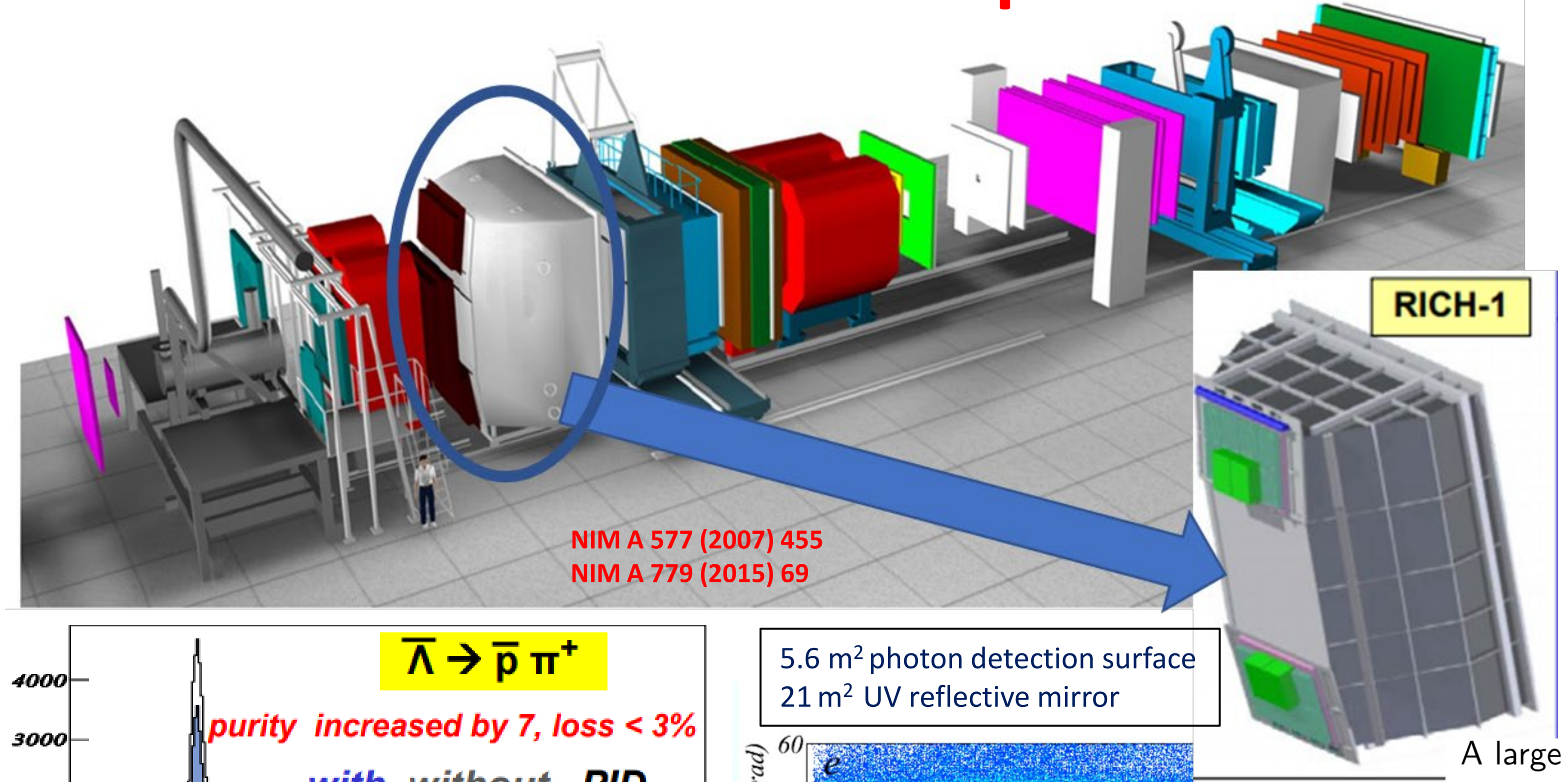
MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond

1. **PID in COMPASS Experiment**
2. **Towards 2016 COMPASS RICH upgrade**
3. **Quality control of hybrid components**
4. **The upgrade**
5. **Detector performance**
6. **Summary of COMPASS RICH upgrade**
7. PID in EIC and its challenges
8. R&D for EIC PID with MPGD technologies
9. Beam test performance
10. Summary of EIC related activities

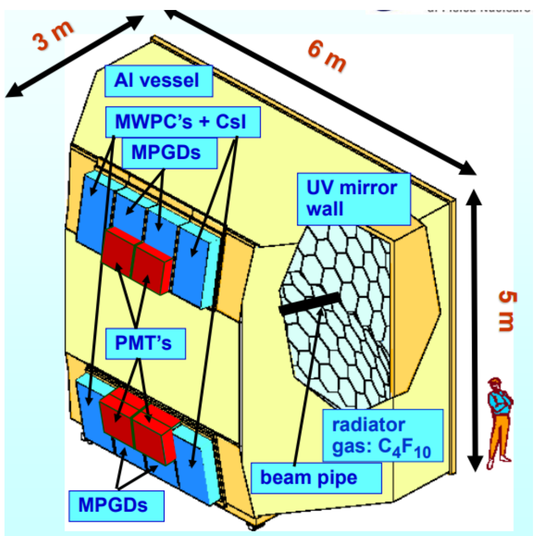
Chandradoy Chatterjee

INFN Trieste

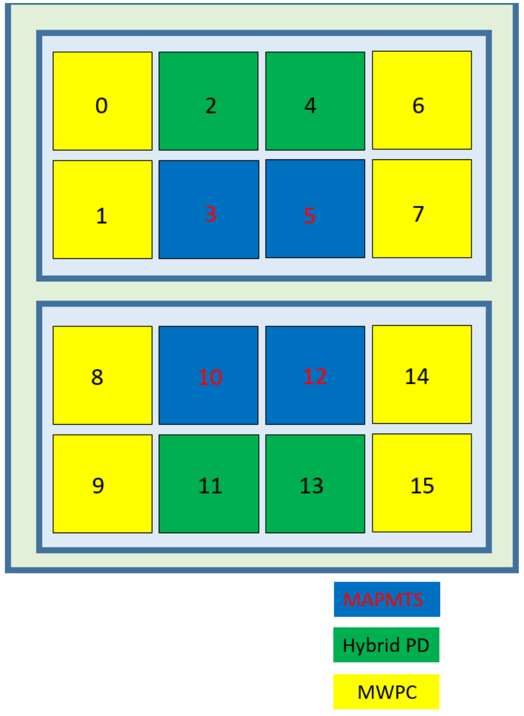
PID in COMPASS Experiment

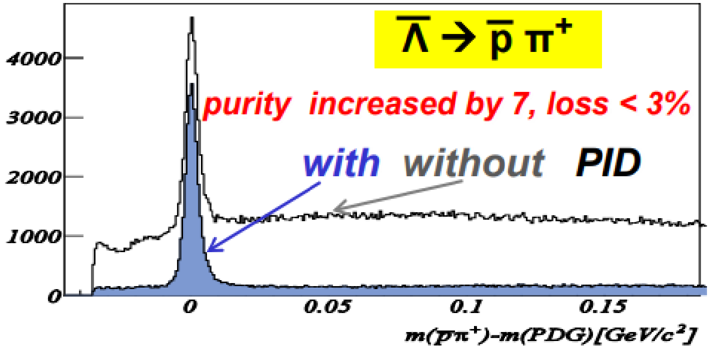


Approved SIDIS data taking in 2021→ RICH is crucial.
Future COMPASS++/AMBER requires efficient RICH for pbar cross-section, spectroscopy measurements.



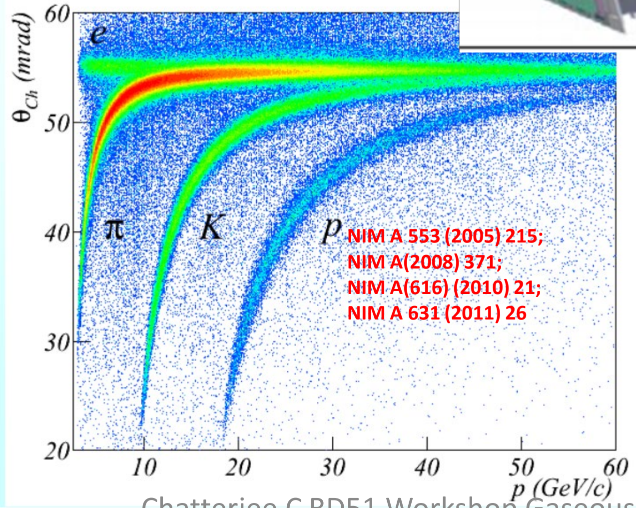
In 2016-2017 data taking COMPASS RICH used three different photon detection technology





Vast number of COMPASS physics analysis require excellent PID.

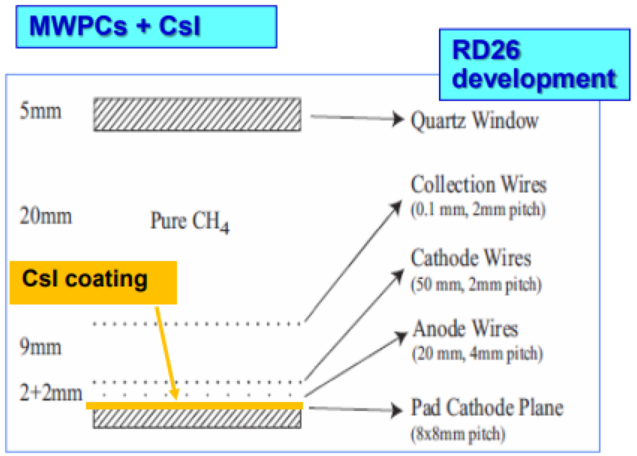
5.6 m^2 photon detection surface
21 m^2 UV reflective mirror



A large gaseous RICH provides:

- hadron identification from $3-60$ GeV/c
- wide angular acceptance (H: 500 $mrad$ V: 400 $mrad$)
- trigger rate ~ 50 KHz and beam rate 10^8 MHz
- material in beam region :$1.2\% X_0$, material in acceptance :$22\% X_0$

2016 COMPASS RICH UPGRADE



MWPCs with CsI photocathode, the limitations

- Severe recovery time (~ 1 d) after a detector discharge
  - Ion accumulation at the photocathode
- Feedback pulses
  - Ion and photons feedback from the multiplication process
- Ageing (QE reduction) after integrating a few mC / cm²
  - Ion bombardment of the photocathode

→ Low gain: a few times 10^4 (effective gain: <1/2)

→ "slow" detector

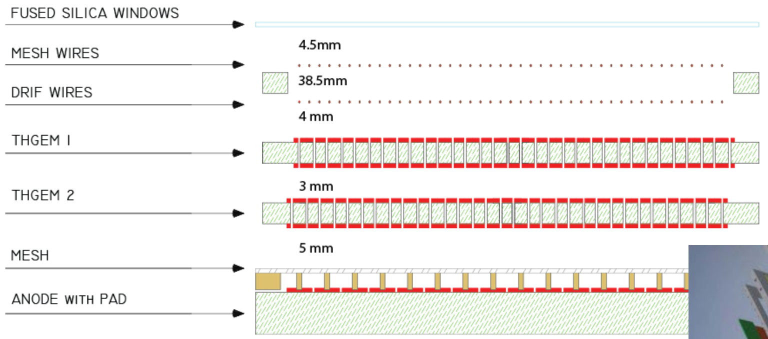
Reduced wire-cathode gap because of :

- **Fast RICH** (fast ion collection)
- **Reduced MIP signal**
- **Reduced cluster size**
- **Control photon feedback spread**

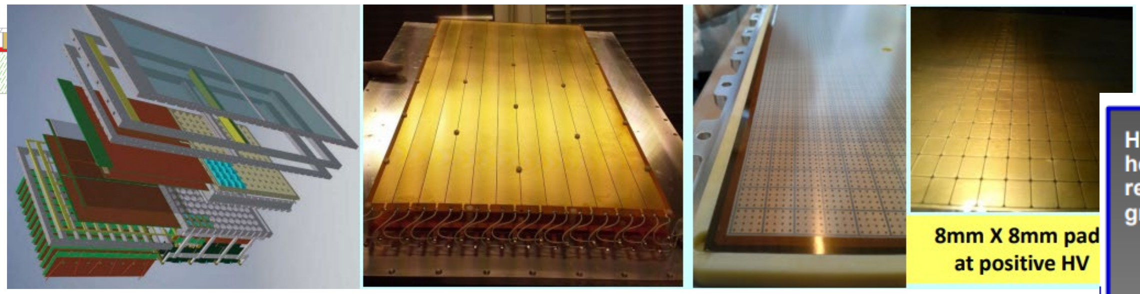
To overcome the limitations:

- Less critical architecture
- suppress the PHOTON & ION feedback
- use intrinsically faster detectors → MPGDs

2016 COMPASS RICH UPGRADE



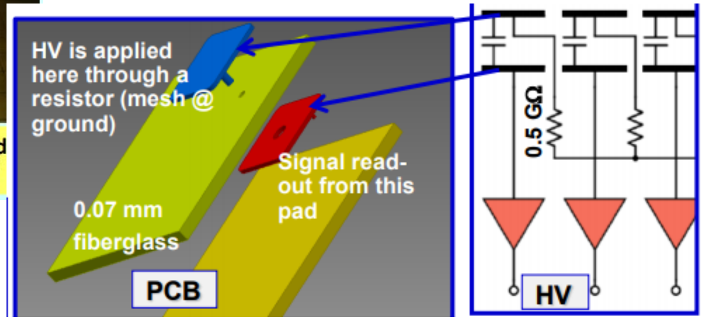
THGEM, detail 77% surface for CsI coating



Resistive MICROMEGAS by bulk technology **NIMA 560 (2006) 405.**

→ traps the ions

→ ~100 ns signal formation



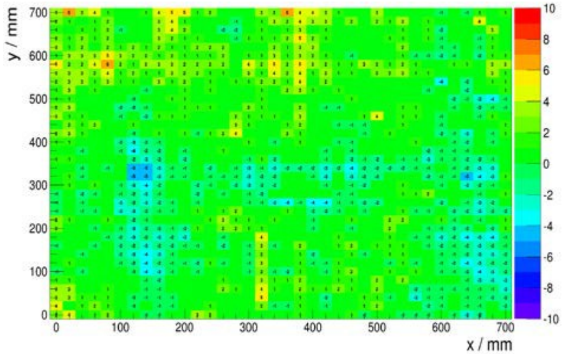
Quality Control of components

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

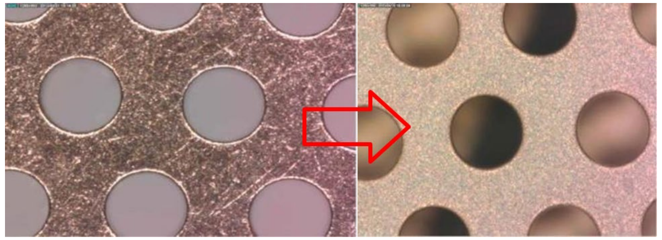
Elite Material Co., Ltd. — Technical Data — http://www.emctw.com

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	$>10^{9}$



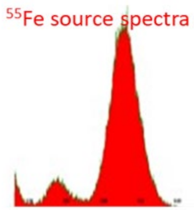
Mitutoyo EURO CA776 coordinate measuring machine with ruby touch probe, hosted in a thermalized room

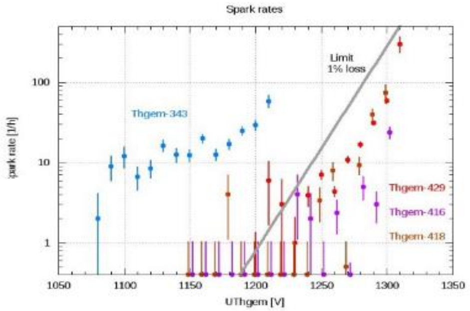


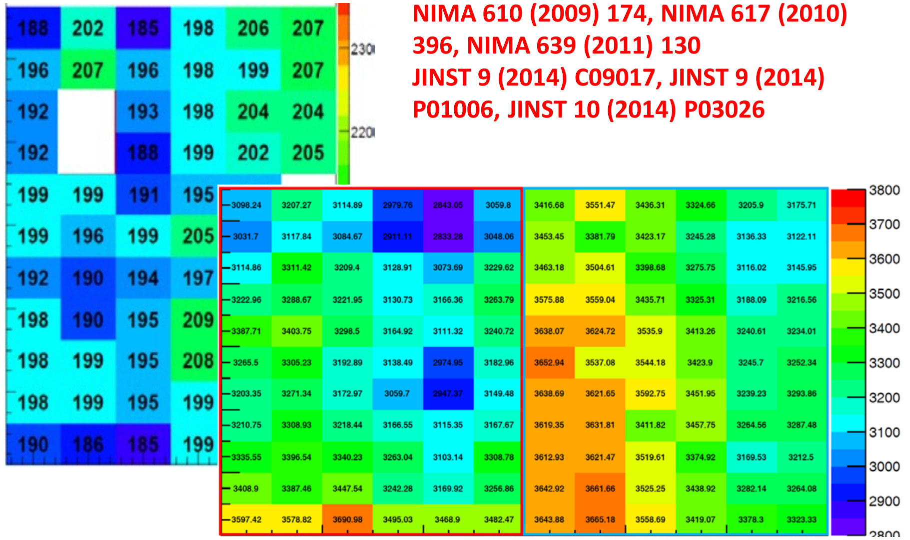
In Trieste a specific cleaning procedure is applied : polish with fine grain pumice powder, pressure water cleaning, ultrasonic bath with Sonica PCB solution (PH11), distilled water rinsing and oven @ 160^{O}C

Measurement of the raw material thickness before the THGEM Production, accepted: $\pm$ 15 µm $\leftrightarrow$ gain uniformity $\sigma \leq 7\%$.

THGEM polishing with an "ad hoc" protocol setup by us: $\geq$ 90% break-down limit obtained.



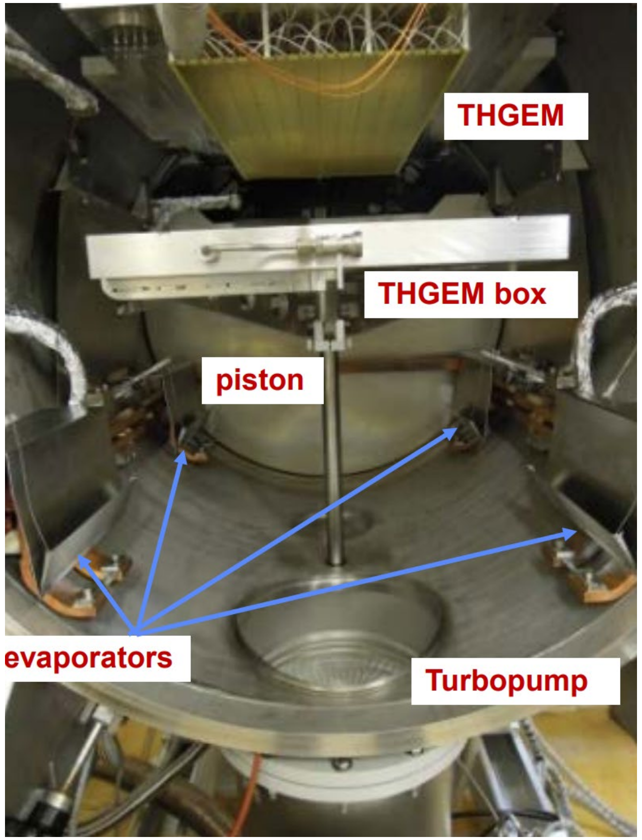


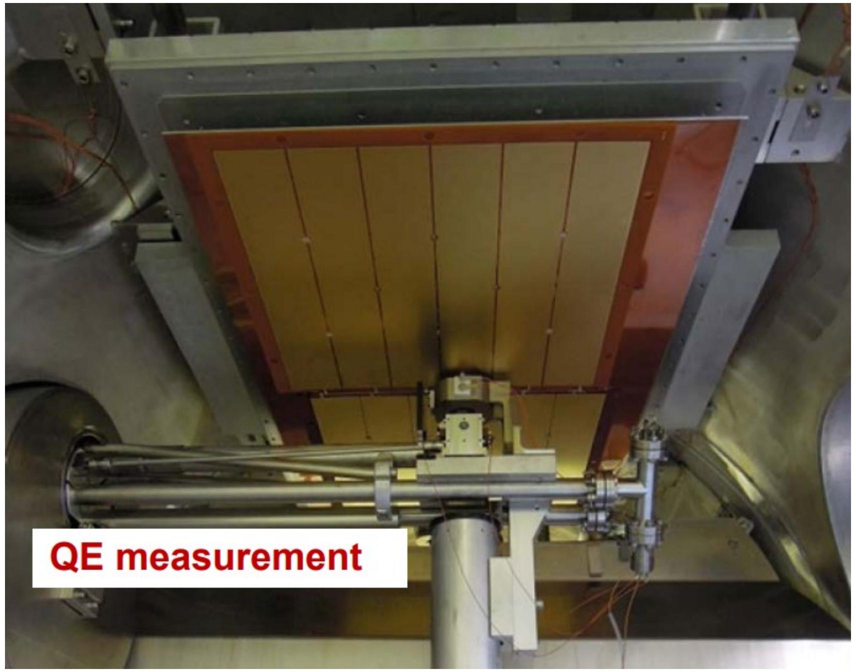


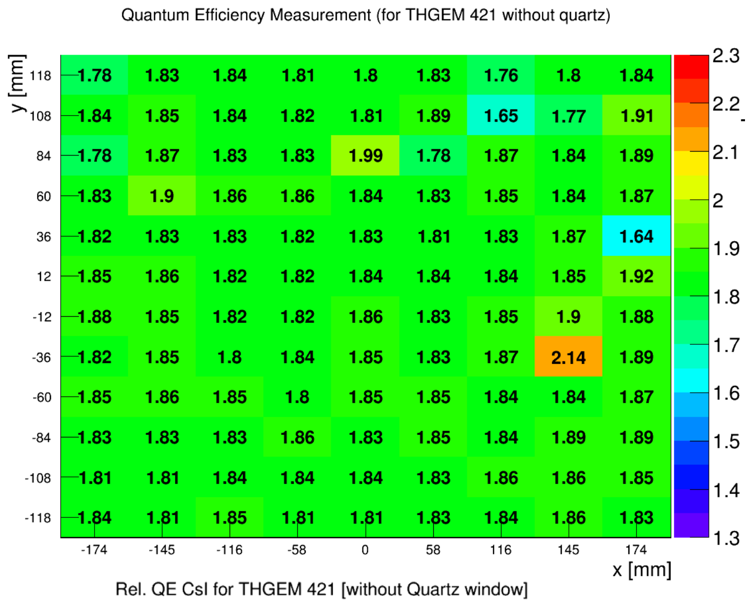
NIMA 610 (2009) 174, NIMA 617 (2010) 396, NIMA 639 (2011) 130
JINST 9 (2014) C09017, JINST 9 (2014) P01006, JINST 10 (2014) P03026

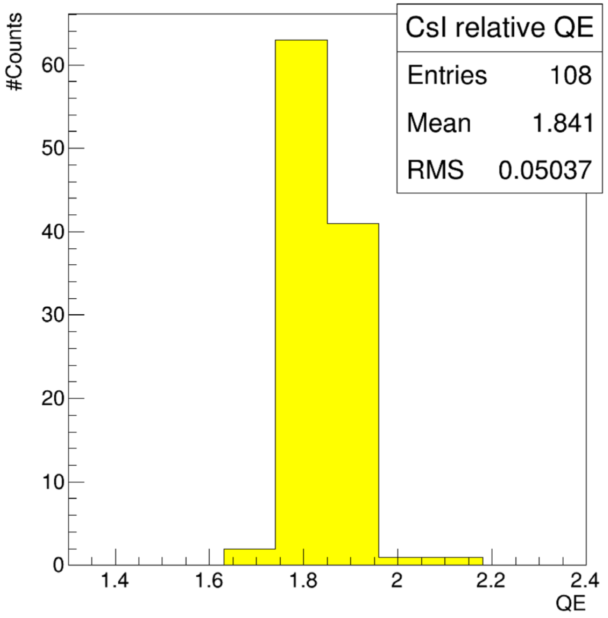
X-ray THGEM test to access gain uniformity ($\leq$ 7%) and spark behaviour, and X-ray MM test to access integrity and gain uniformity ($\leq$ 5%)

CsI coating at CERN





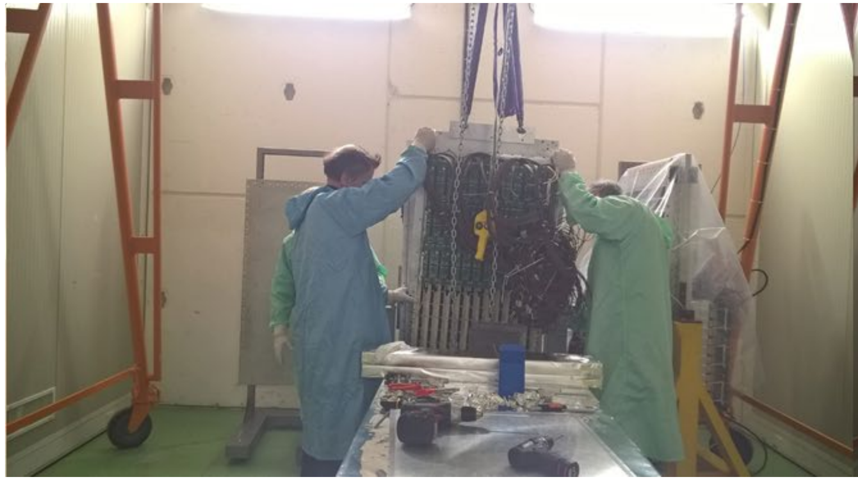




Uniformity:

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

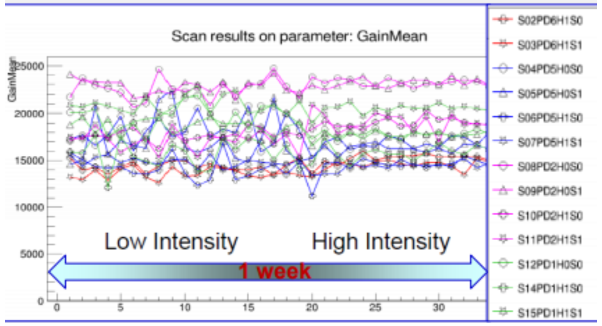
The Upgrade: challenging and acrobatic



More acrobatic images or details of upgrade related adventures?
→ S.S. Dasgupta **CERN-THESIS-2017-069**

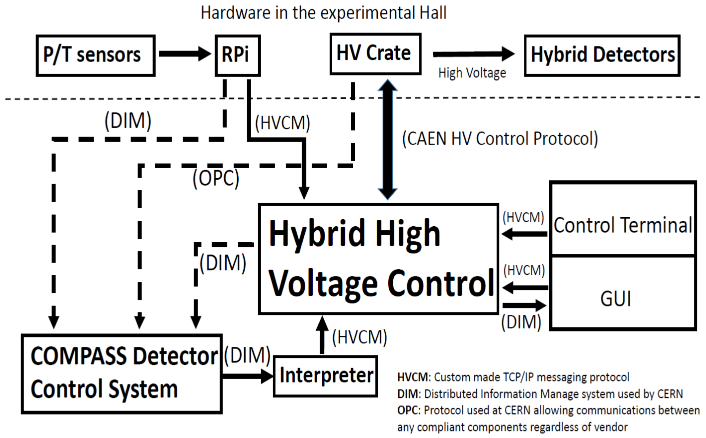
T/P fluctuations and way-out

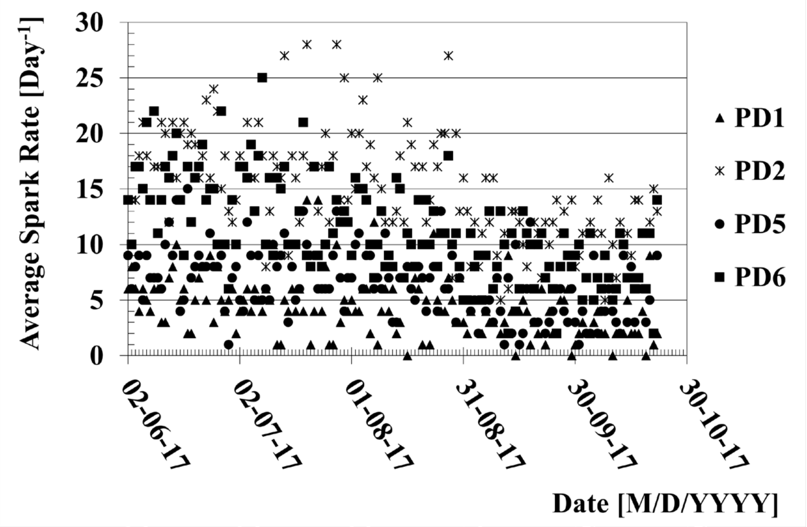
- **Gain stability vs P, T:**
  - G = G(V, T/P)
  - Enhanced in a multistage detector
  - ΔT = 1°C → ΔG ≈ 12 %
  - ΔP = 5 mbar → ΔG ≈ 18 %
- **THE WAY OUT:**
  - Compensate T/P variations by V
  - → Gain stability at 5% level

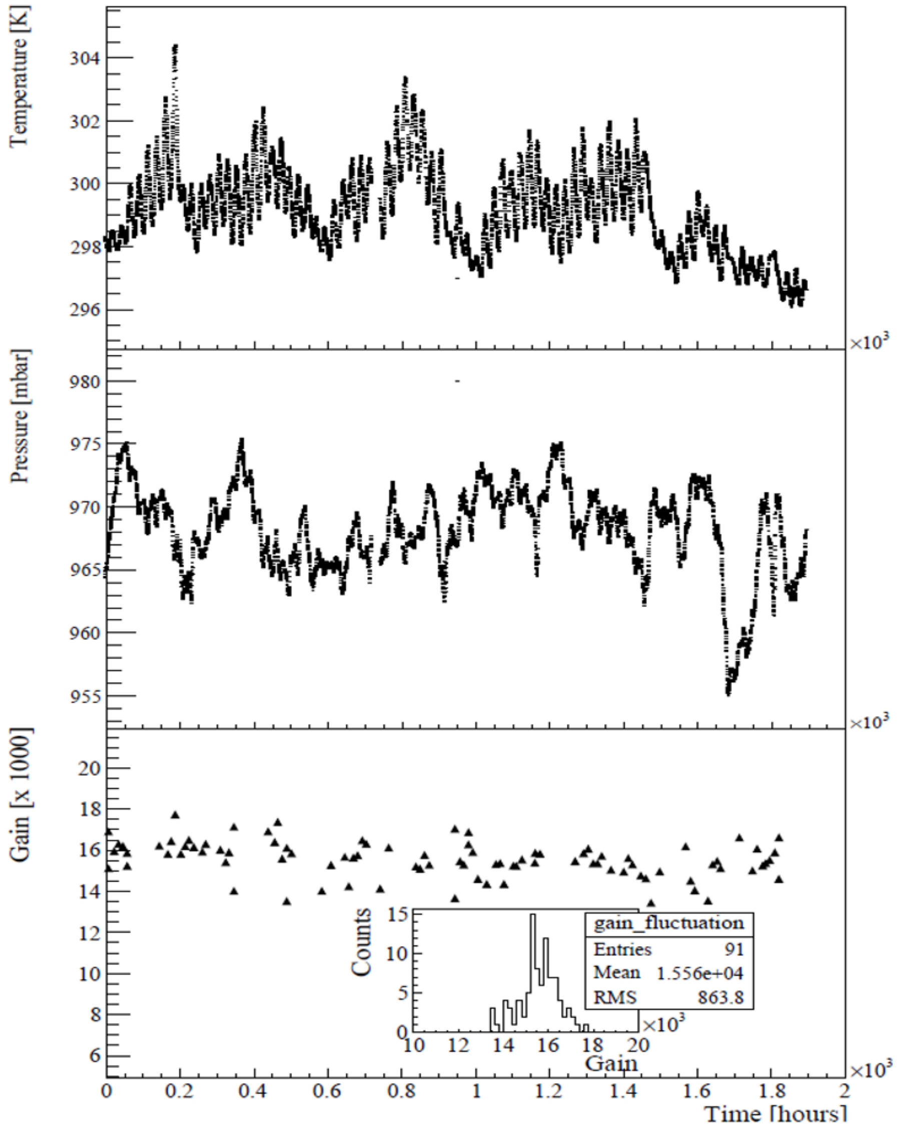


Without correction roughly 25% fluctuation of gain is expected.

NIMA 952(2019)162378



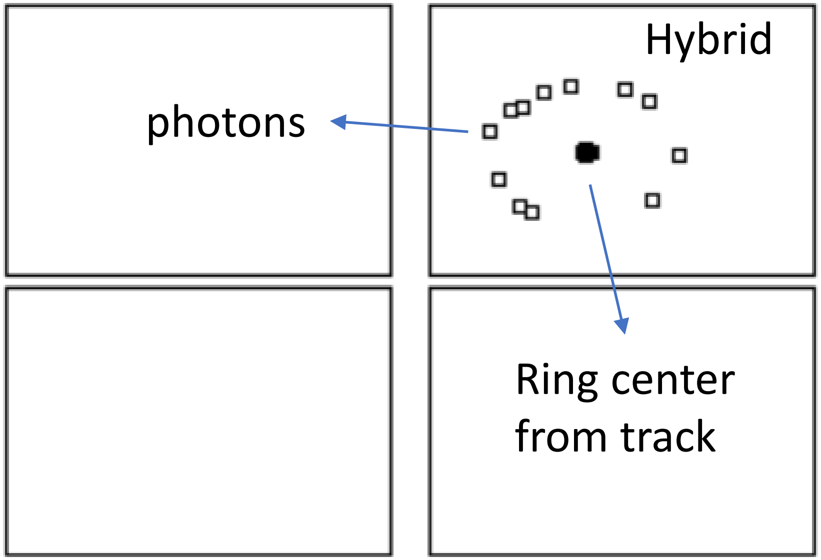




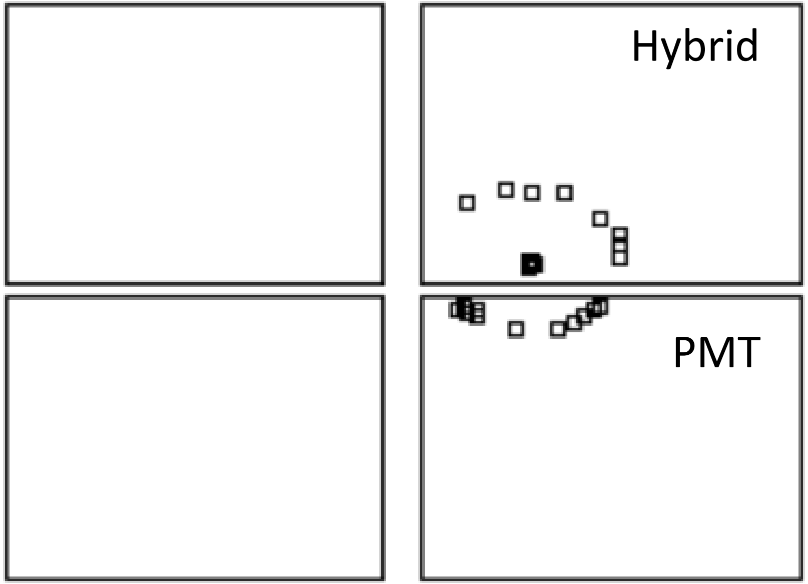
Similar hardware & software have been prepared and tested for MWPCs. Will be used in 2021 data taking!

Event displays

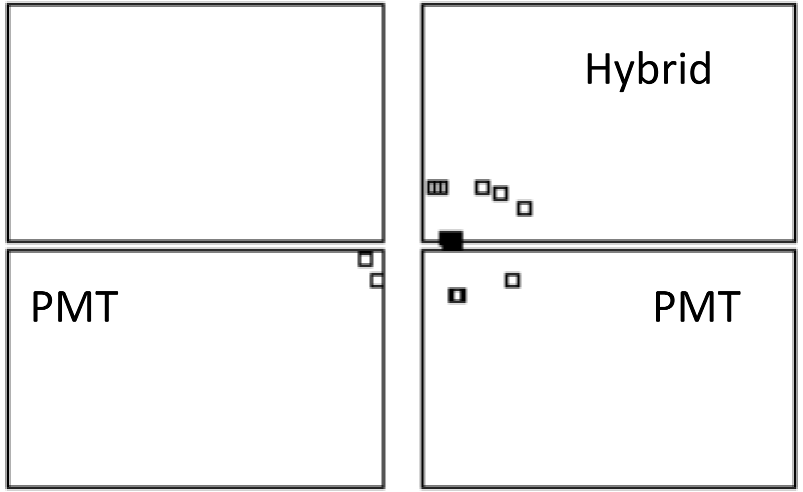
6.36 GeV pion



6.76 GeV pion

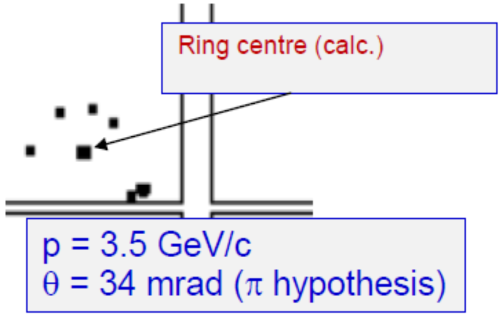


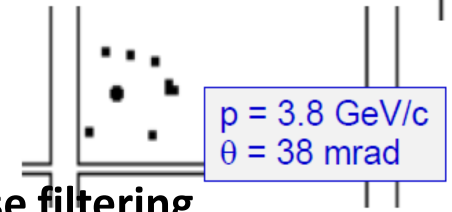
6.4 GeV pion

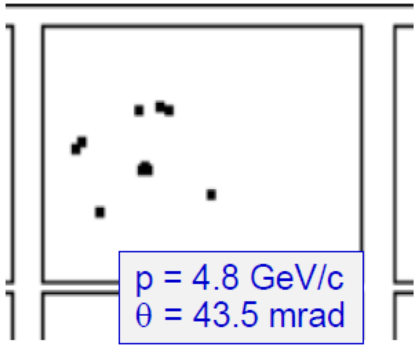


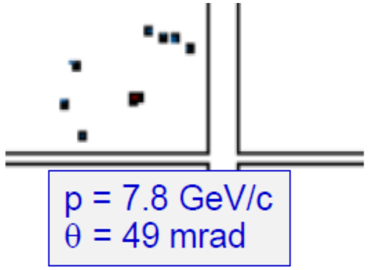
For reference:

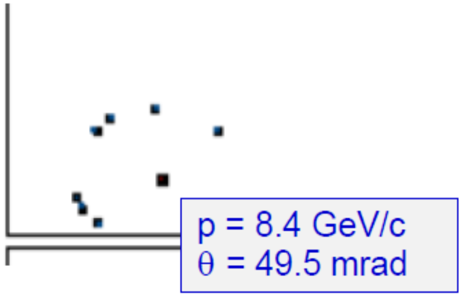
Θ (β = 1) = 52.5 mrad











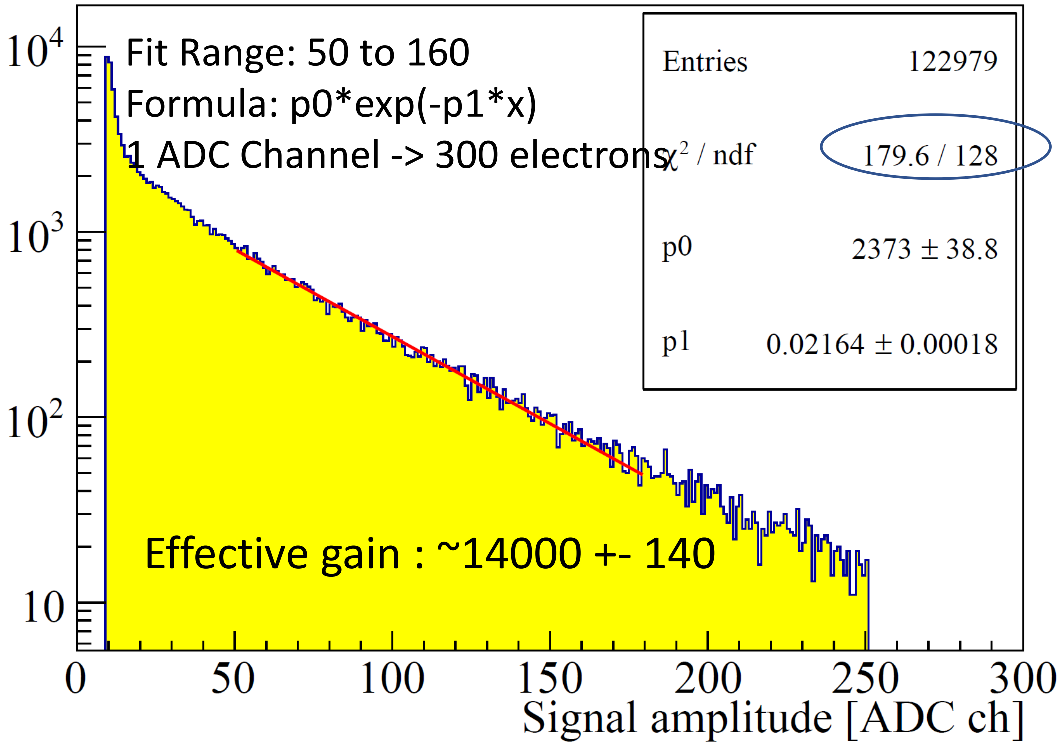
- **Ring center calculated from particle trajectory**
- **Detected photoelectrons : hits on the sensors. No noise filtering**

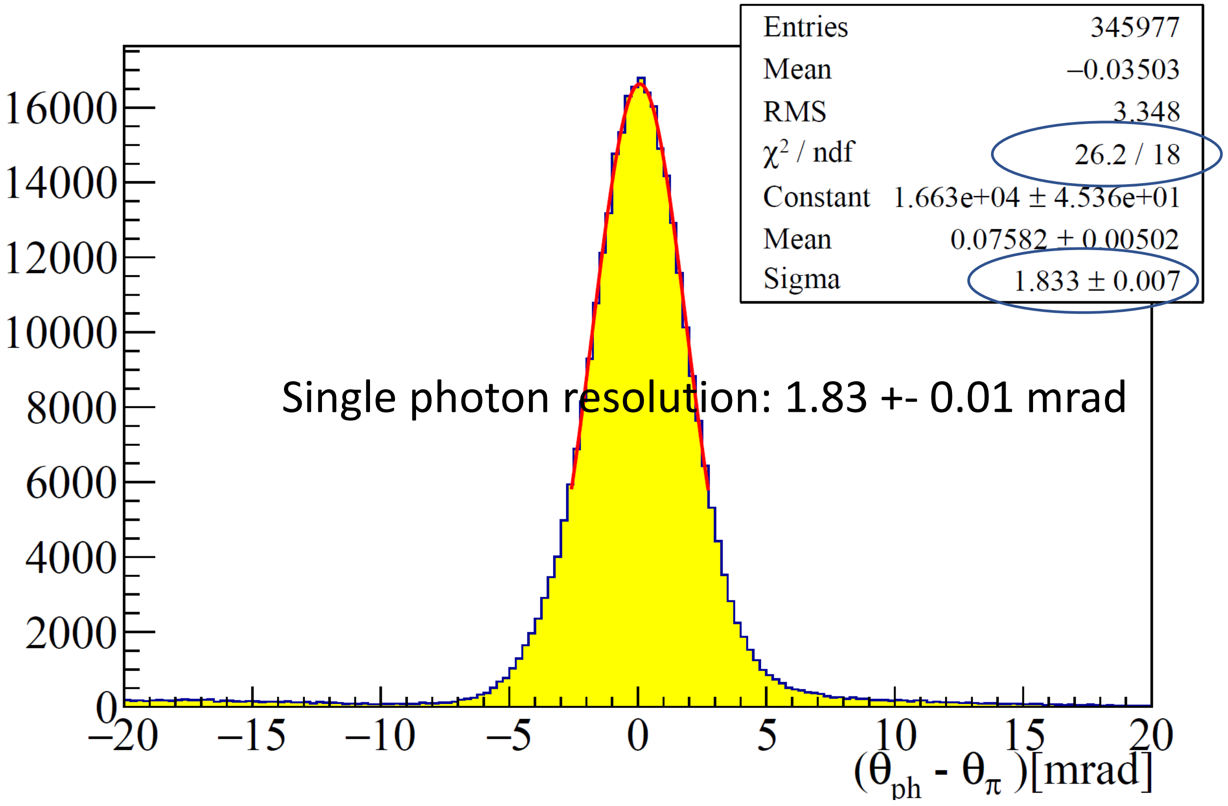
Characterization of the novel Photon detectors

Dedicated pion beam was used to characterize the novel detectors and by extracting the following properties from reconstructed rings

1. Effective Gain
2. Single photon resolution
3. Number of photons per ring at saturation

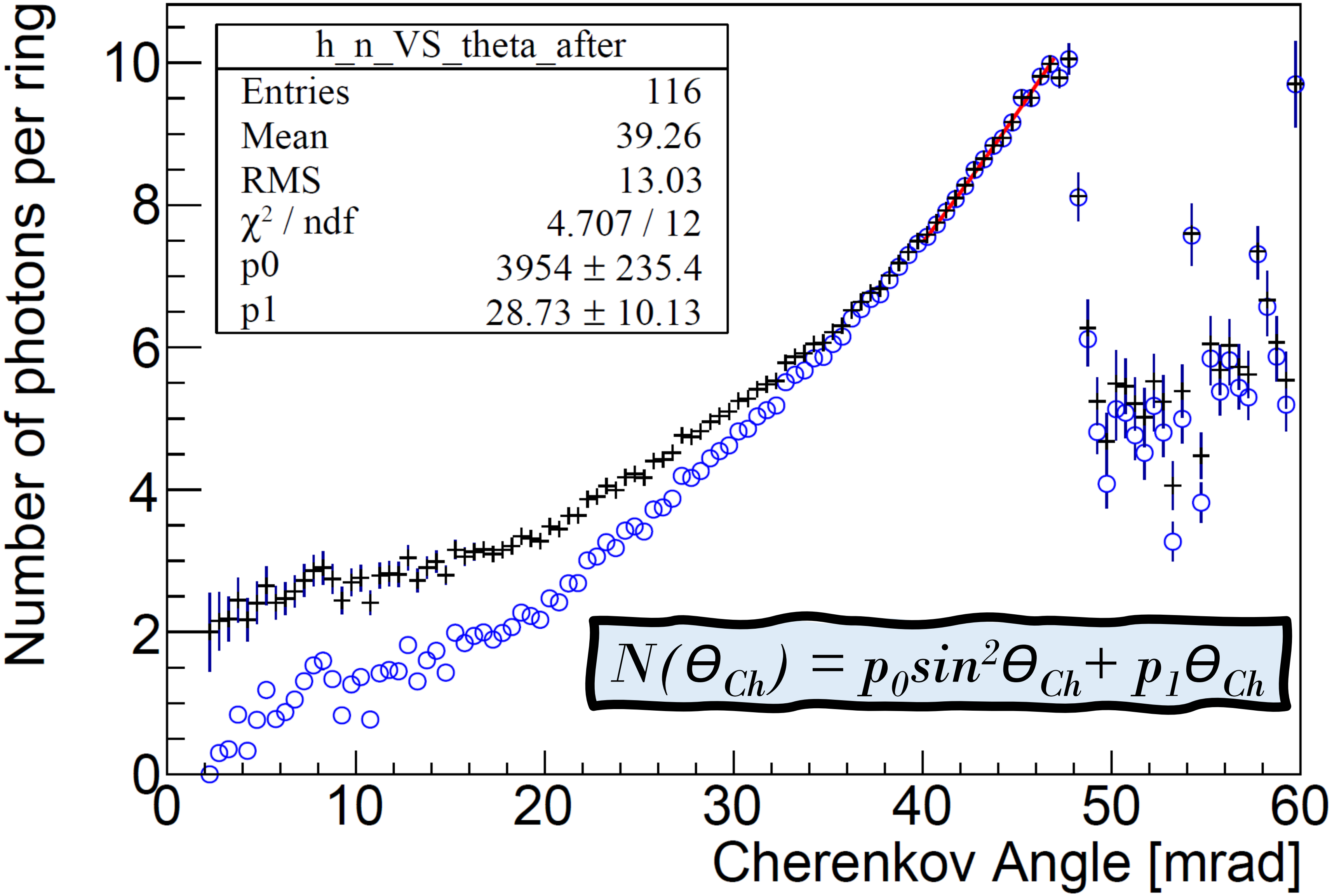
Dedicated pion beam to characterize!





Characterization of the novel Photon detectors …

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

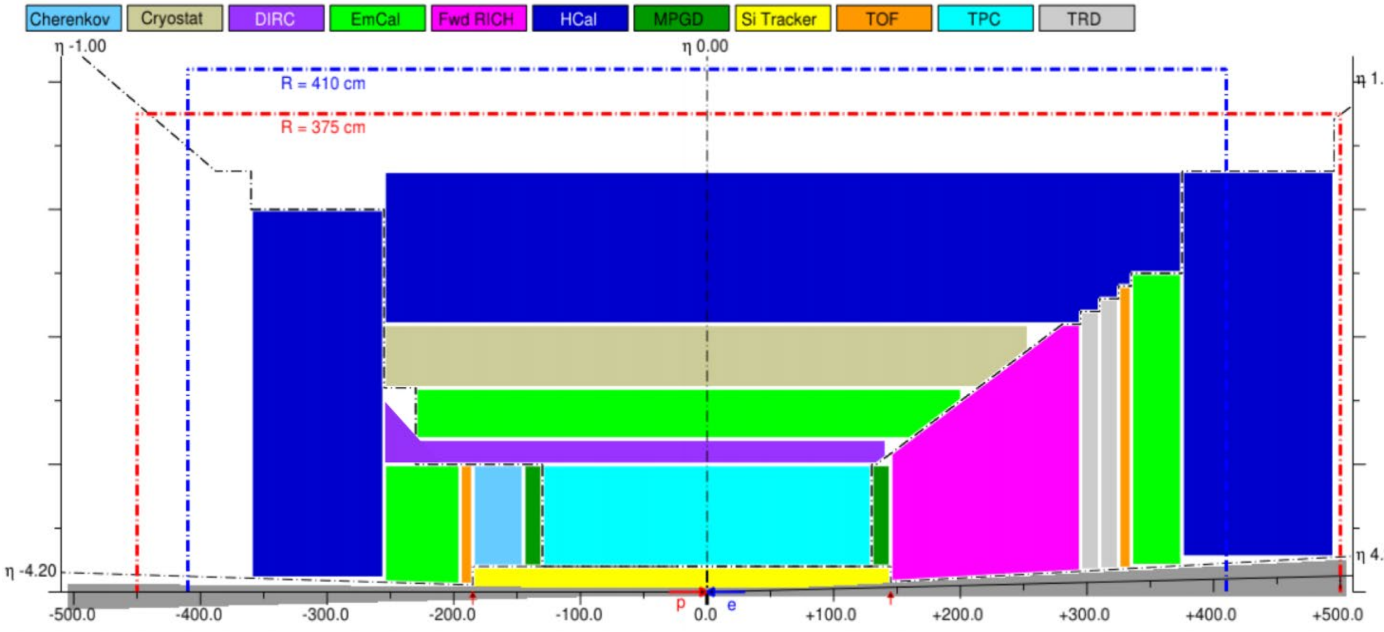


COMPASS 2016 RICH upgrade summary

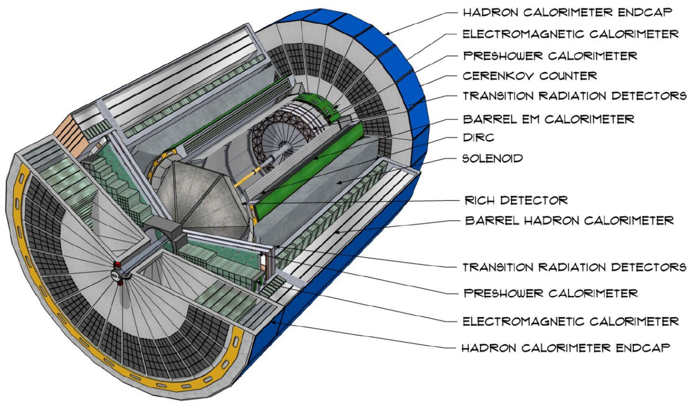
1. A **7 years long R&D program** had been dedicated to upgrade COMPASS RICH with MPGD based single photon detection.
2. **COMPASS has pioneered MPGD based PDs for RICH application in 2016**.
3. The detector performance is **thoroughly studied,** and results are **encouraging** for use of MPGD based single photon detectors for future RICH applications.
4. The hybrid PDs are working at an effective gain of **14k, with a level of 5% stability**. An **IBF below 3%** is achieved (thanks to inclusion of MM and staggered THGEMs).
5. Single photon resolution is **1.83+-0.01 mrad**.
6. In best working condition the detector can detect **~11 signal photons per ring at saturation**.

PID in the EIC at USA

A.Accardi et al., “Electron Ion Collider: The Next QCD Frontier,” Eur. Phys. J., vol. A52, no. 9, p. 268, 2016. National Academies of Sciences, Engineering, and Medicine, “An Assessment of U.S.- Based Electron-Ion Collider Science.” The National Academies Press, Washington DC, 2018. https://doi.org/10.17226/25171.



EIC is Approved!!!



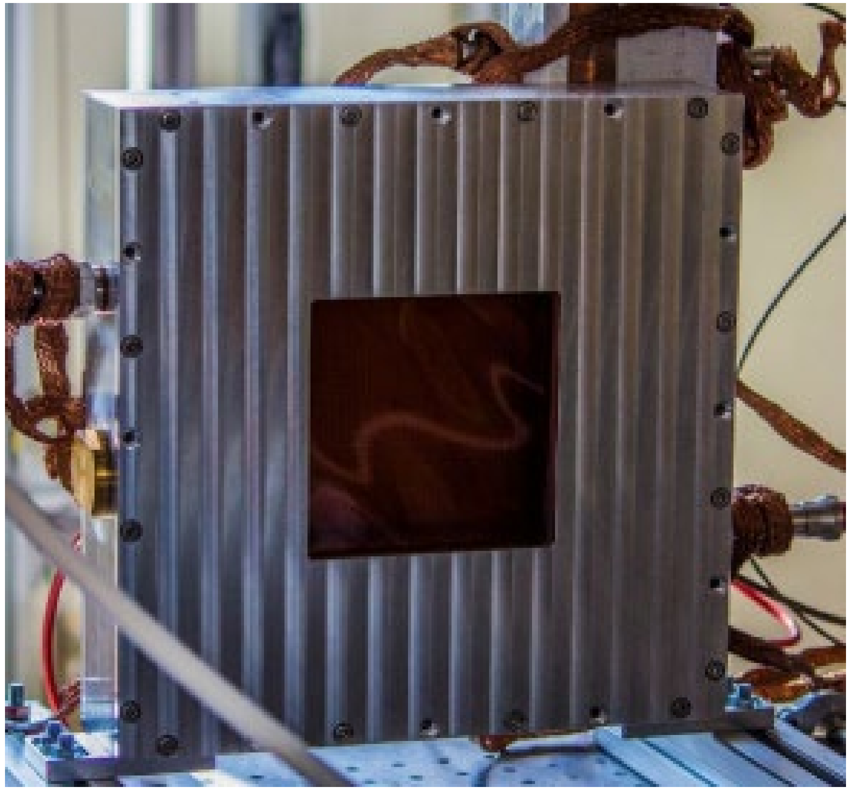
4π detector setup.

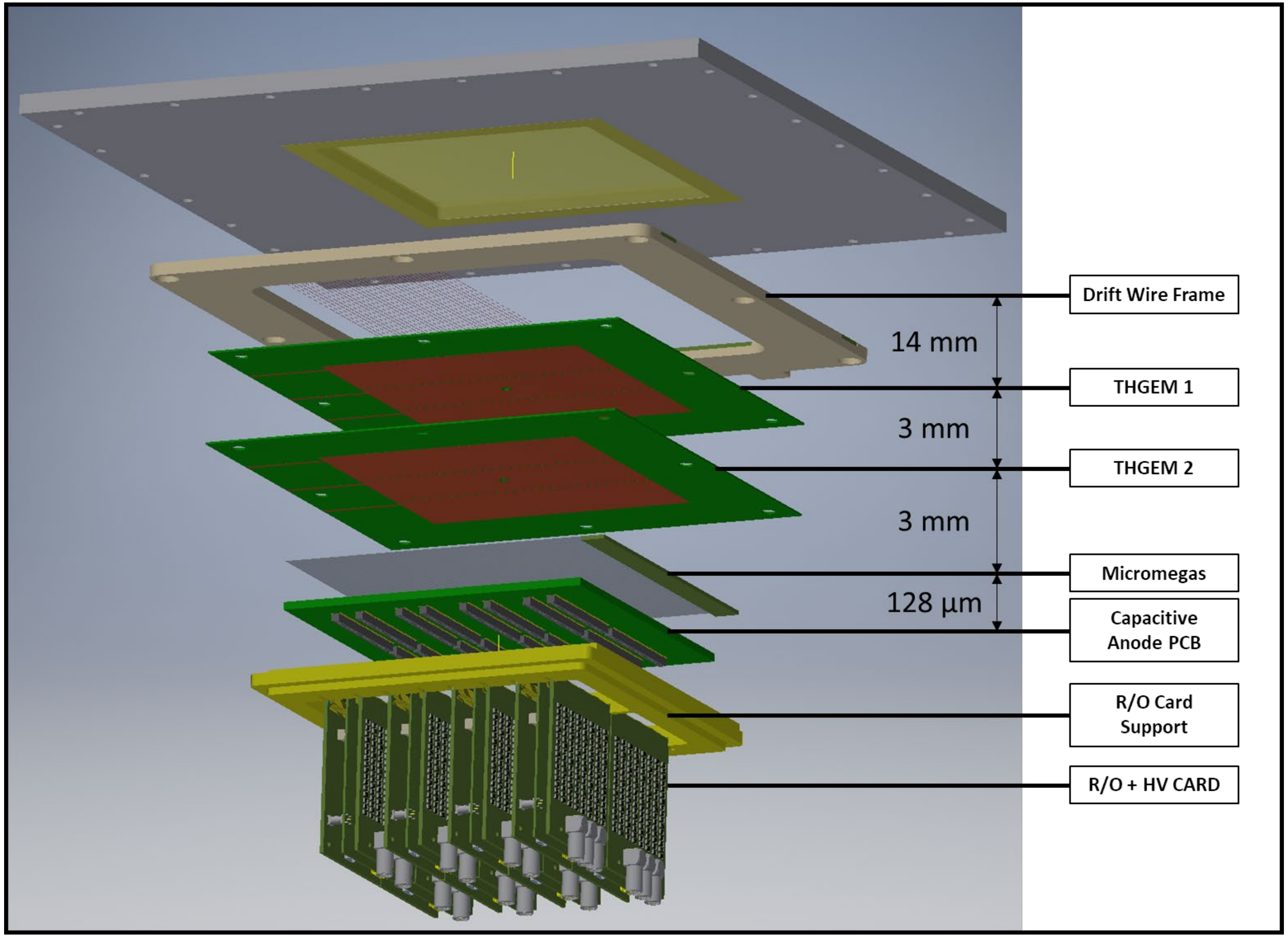
Challenge→ include high momentum PID detectors in hermetic detector!

- Compact collider set-up →short radiator length (around 1m) → Limited number of generated photons
- Standard quartz window opaque λ < 165 nm → possibility **windowless RICH (**M. Blatnik et al., IEEE NS 62 (2015) 3256**)** → Gaseous detectors
- **CsI** most used, however ageing due to **humidity and ion bombardment** → quest for novel PC with sensitivity in the far UV region → H-ND powder as possible alternative photocathode of CsI (Talk by D.D’Ago).
- Improvement of Spatial resolution→ Smaller pad size.
- Operation in intense magnetic field → MPGD based single photon detectors are tested cost effective solution (Thanks to COMPASS 2016 upgrade).

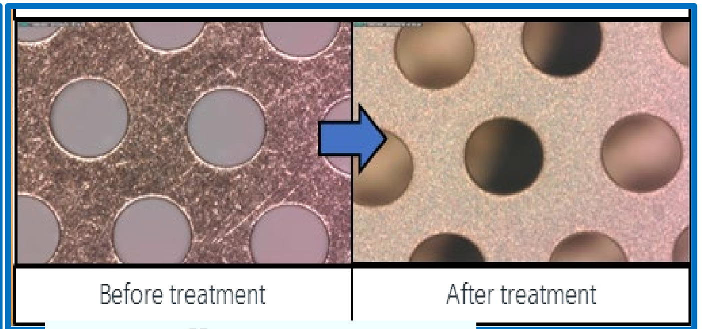
Minipad detector setup

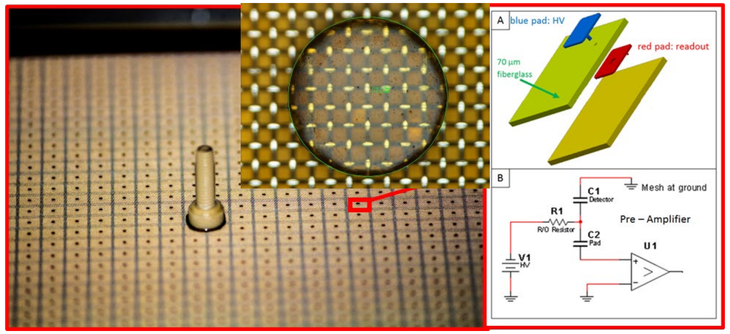
- Modular structure: all components and services within the active area.
- Prototype with 10x10 cm2 active area.
- 1024 square pads of 3x3 mm2 with 0.5 mm inter-pad space



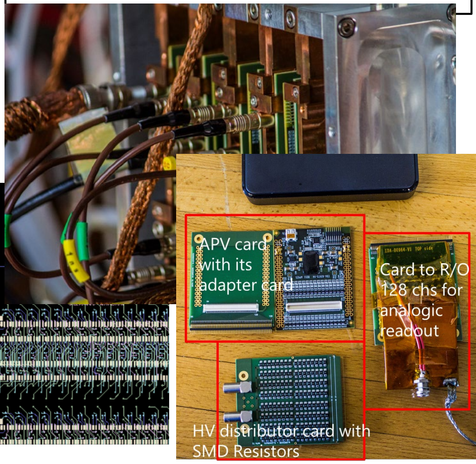


Components: Lab Test and performance

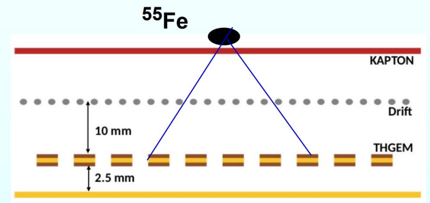




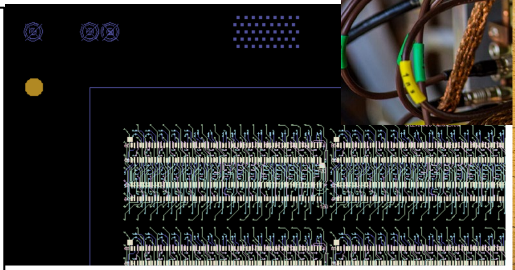
8 x 16 (=128) pads connected via SAMTEK1143 (130 pin) SMD connector Individual 470 MΩ SMD resistor per pad on HV distribution cards (128/card). 8 cards

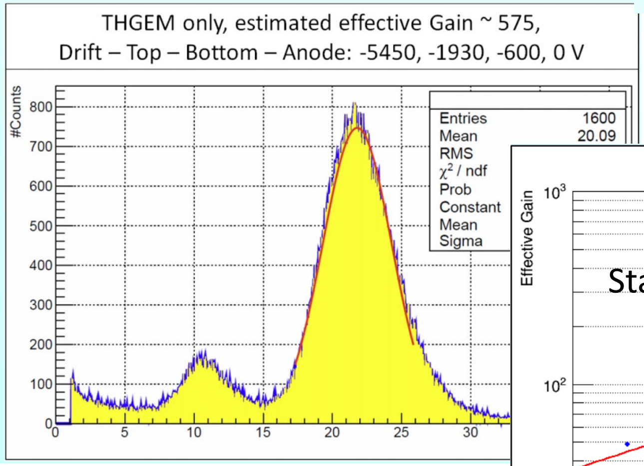


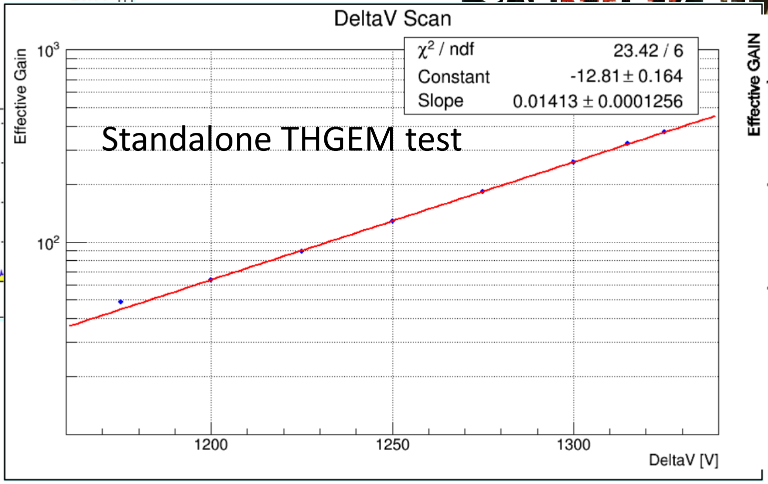
Test performed using Ar:CO2 70:30 gas mixture,
^{55}Fe source, AMPTEK Mini-X, Picoquant PLD 4000B
Ar:CO2 70:30,
CREMAT CR110 + ORTEC + AMPTEK MCA 8000A

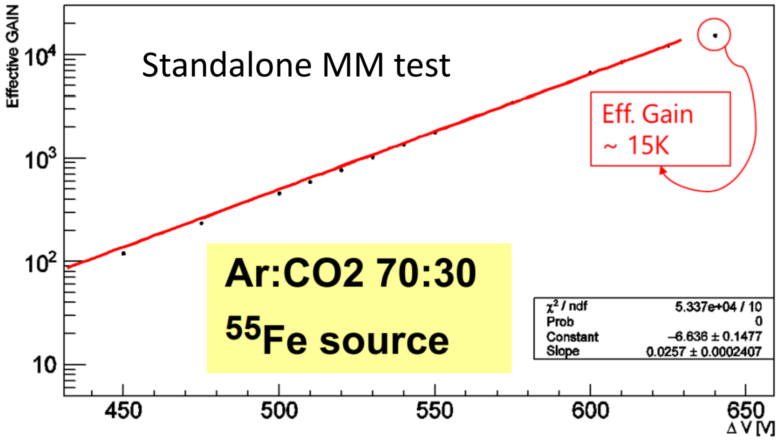


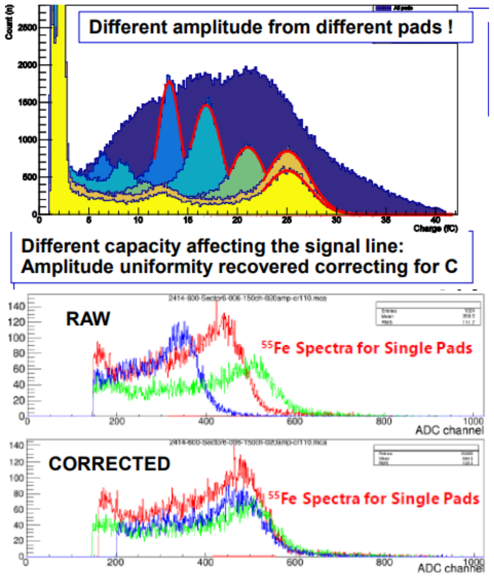
Produced at CERN, standard bulk technology woven stainless steel mesh,18 µm wires, 63 µm pitch One pillar per pad, 500 µm diameter. Gap = 128 µm.







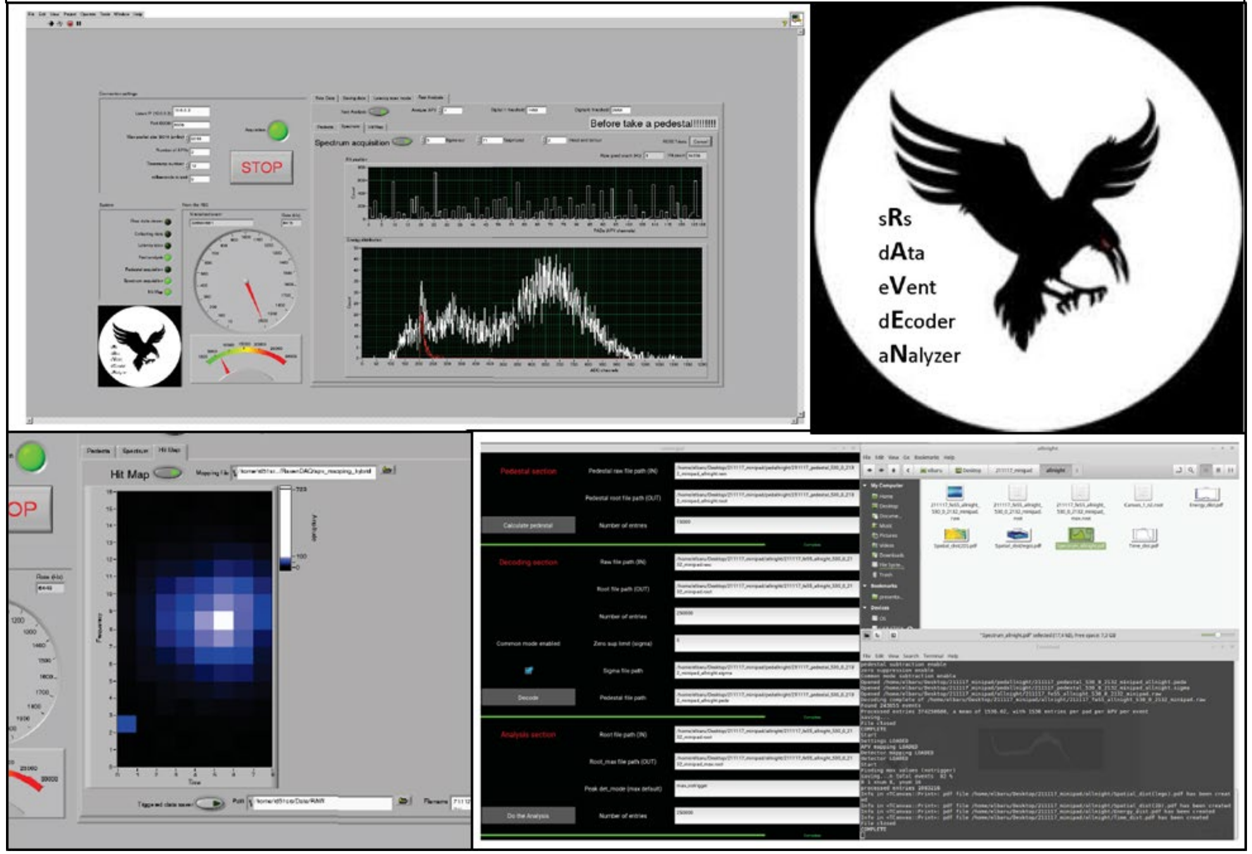




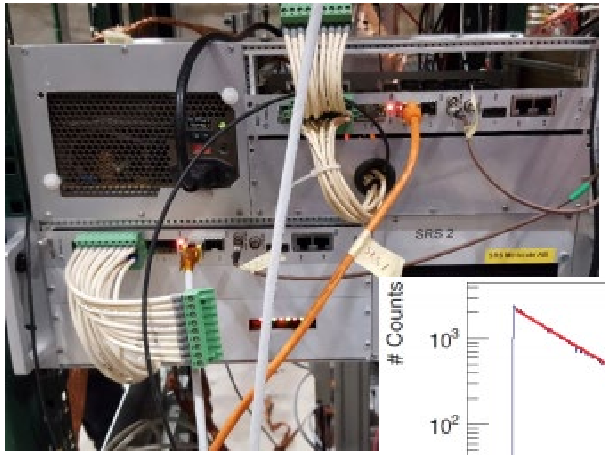
NIMA 936 (2019) 565

DAQ and online analysis: RAVEN

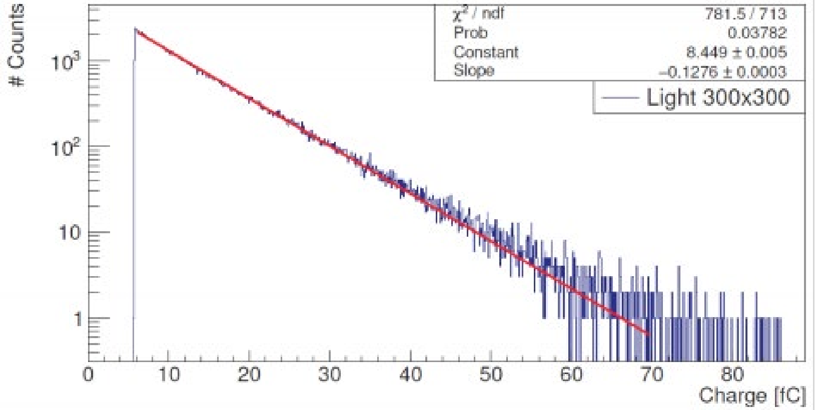
Home made DAQ and Decoder based on LABView and C++



- Read-out system : SRS (from RD51)
- FE chip: APV25
- DAQ: RAVEN, an original system developed for these studies based on LabVIEW.
- Decoding and online analysis included.
- Good rate capability: 10 kHz for single APV.

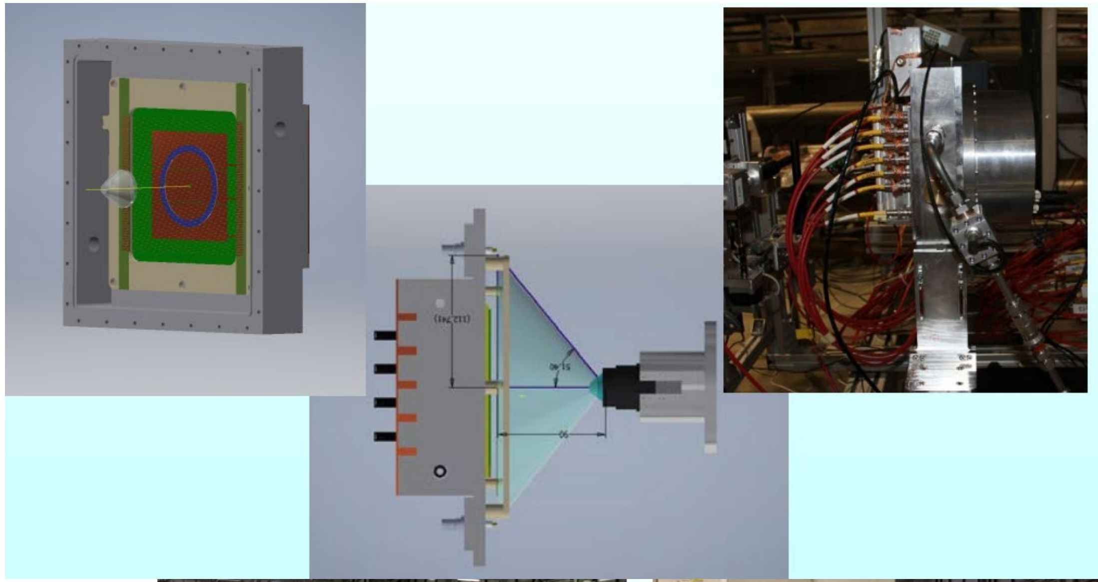


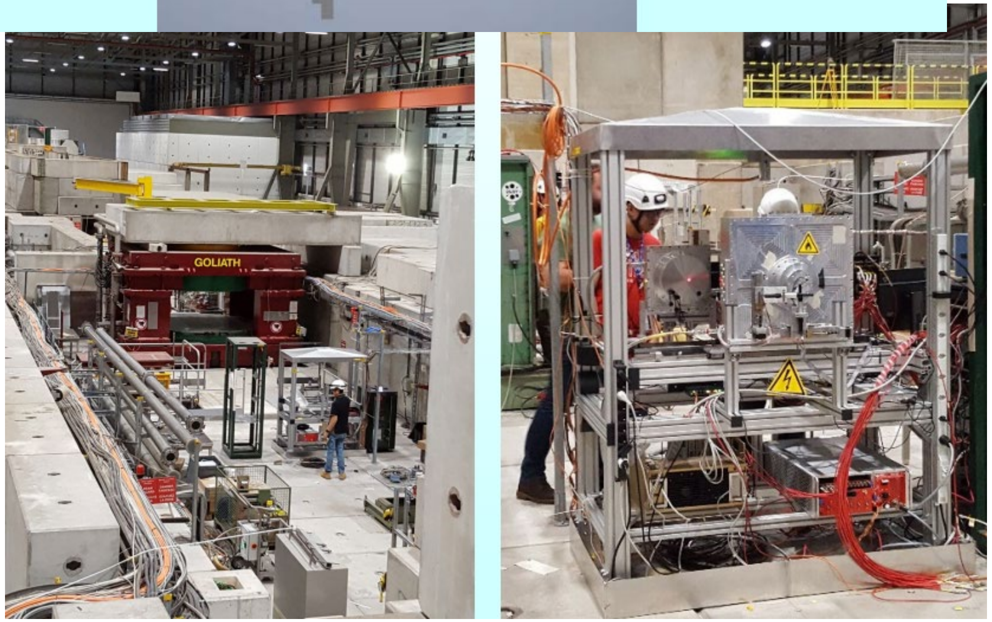
$Ar:CH_4$ 50:50 Picoquant PLD 4000B pulsed UV laser source



Master Thesis: M.Baruzzo, Construction, characterisation and DAQ development of a single photon MicroPattern Gaseuos Detector for the future EIC RICH.

Towards beam test at RD51 beamline

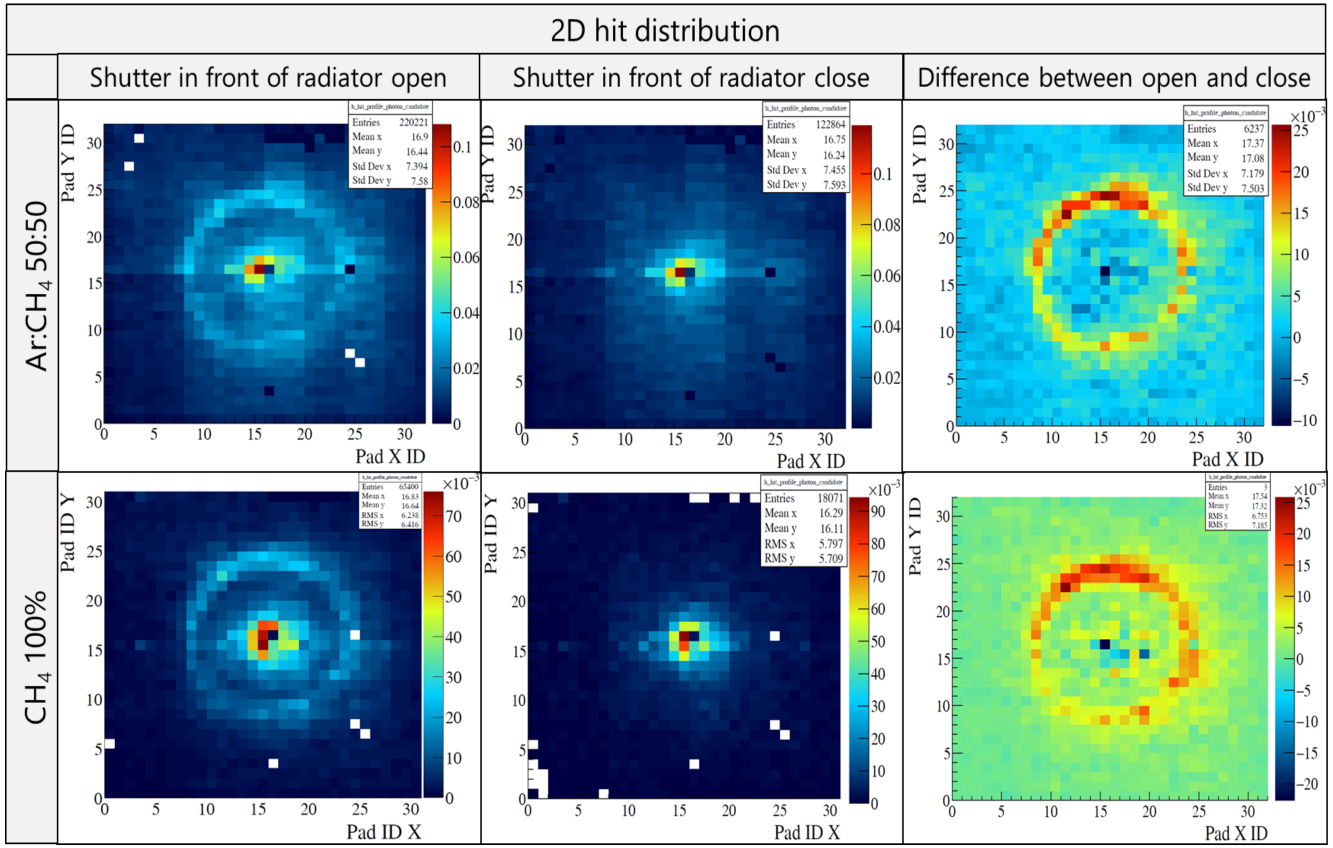




J. Agarwala[4], C.D.R. Azevedo[2], C. Chatterjee[3], A. Cicuttin[4], P. Ciliberti[3], M.L. Crespo[4], S. Dalla Torre[1], S. Dasgupta[1], M. Gregori[1], S. Levorato[1], G. Menon[1], F. Tessarotto[1], Y.X. Zhao[1]

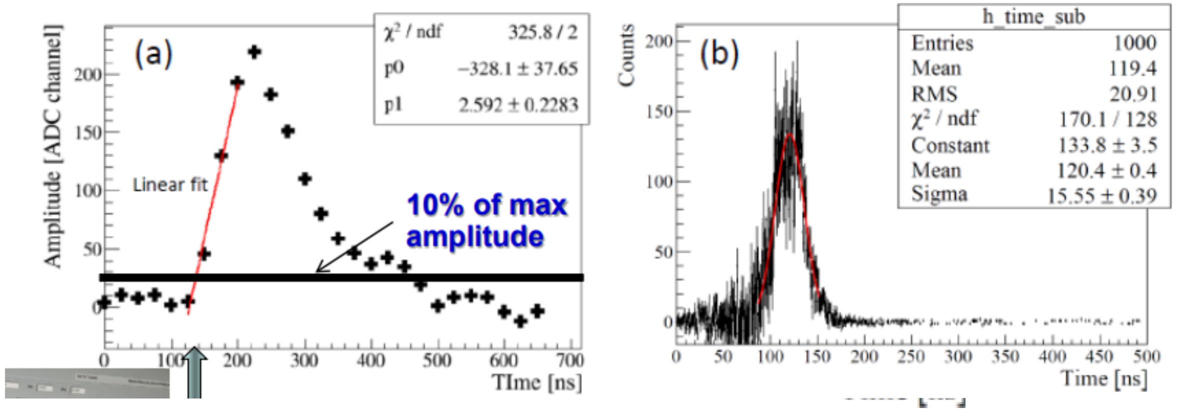
[1]INFN Trieste, Trieste, Italy
[2]University of Aveiro, Aveiro, Portugal
[3]University of Trieste and INFN Trieste, Trieste, Italy
[4] Abdus Salam ICTP, Trieste, Italy and INFN Trieste, Trieste, Italy

Beam test results



- Development of an optimized detector for increased resolution based on the hybrid THGEM + MM and 3mm x 3mm minipad.
- Study the compatibility of these hybrid PDs with CF_4 for a windowless RICH for the future Electron Ion Collider

Timing



Gain from cluster amplitude : 30 K

subtracting the trigger time contribution (random in the 25 ns window):

$$\sigma_t = 14 \text{ ns}$$

Summarizing Minipad activities

1. COMPASS hybrid like PD prototype has been coupled to miniaturized pad size.
2. THGEMs and MMs have been studied in standalone and in hybrid architecture in lab.
3. Dedicated DAQ has been prepared for decoding and online analysis.
4. A beam test had been conducted at CERN H4 beamline.
5. Clean signature of photon is observed.
6. Covid-19 outbreak has been a show-stopper in 2020 activities.
7. Further R&Ds in both activities are foreseen in 2021.

Thanks for your attention