The COMPASS RICH-1 MPGD based photon detector performance

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OUTLINE

> Introduction: COMPASS RICH and MWPC

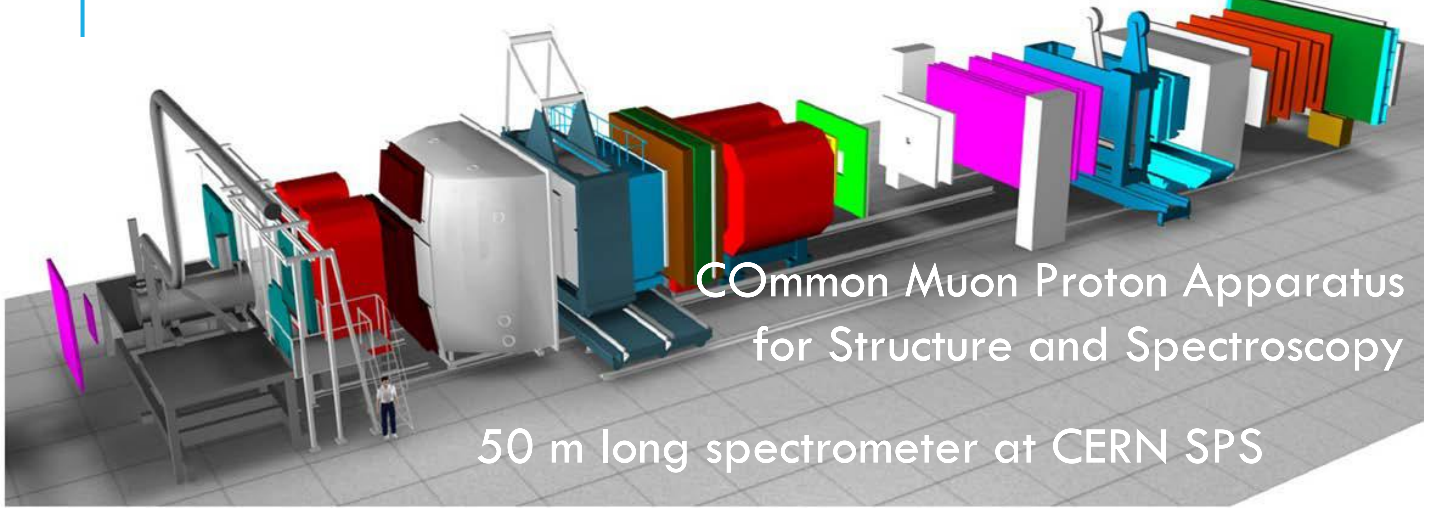
> Hybrid photon detectors - a new approach

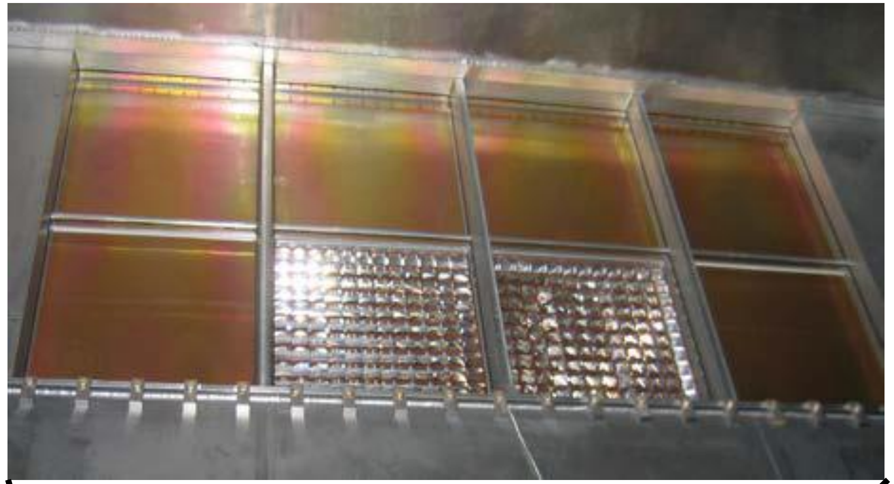
   > Production of the new detectors

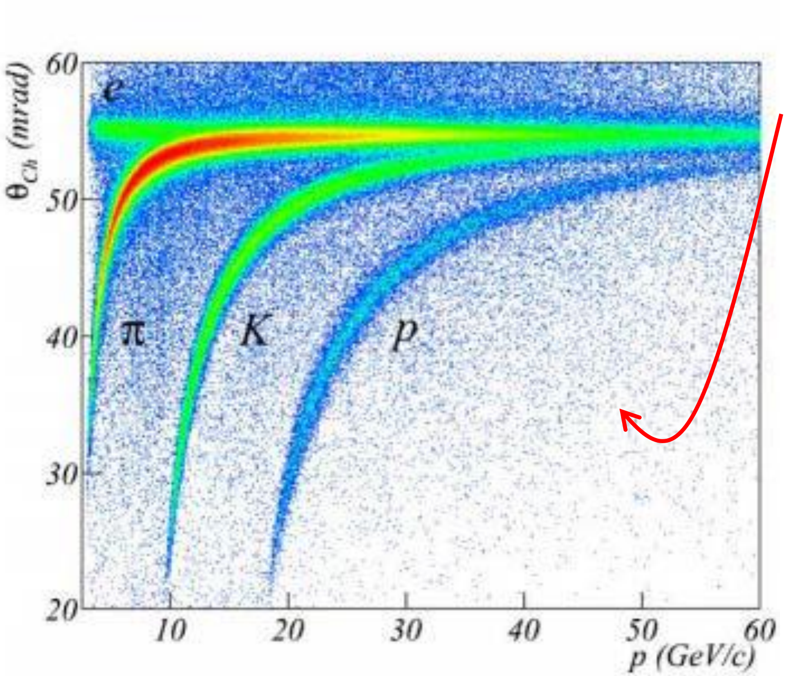
   > Performance of the new detectors

> New perspectives - the mini pad prototype

COMPASS RICH







> large gaseous RICH:

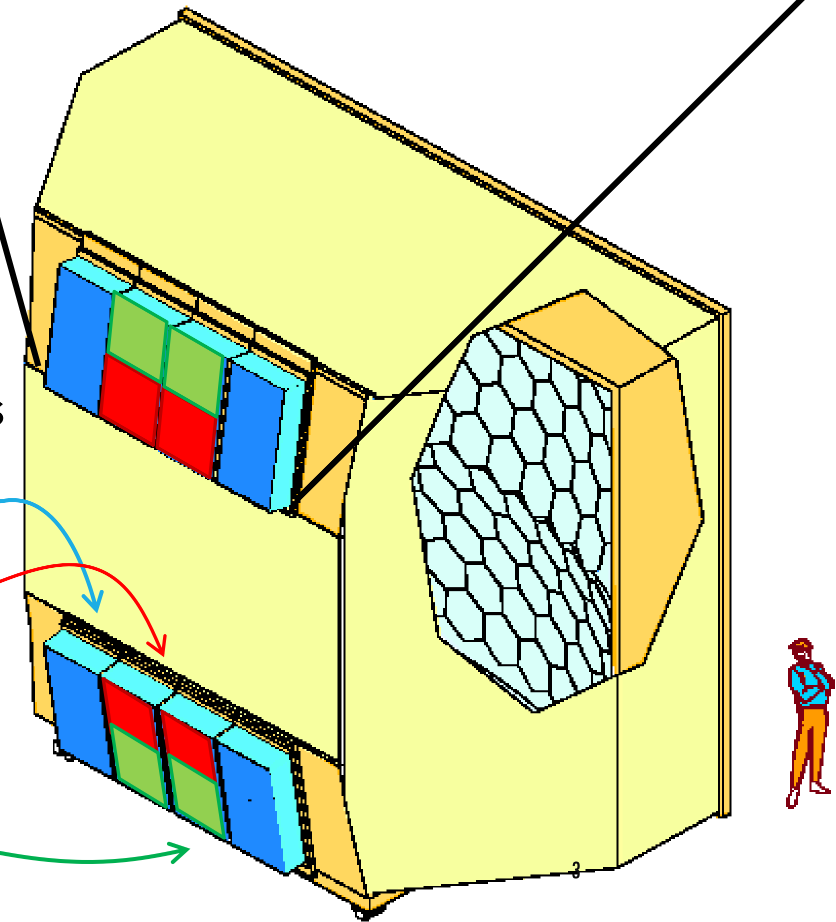
> hadron PID from 3 to 60 GeV/c

> ~ 90 m^3 of C_4F_{10}

> 3 types of different PD technologies

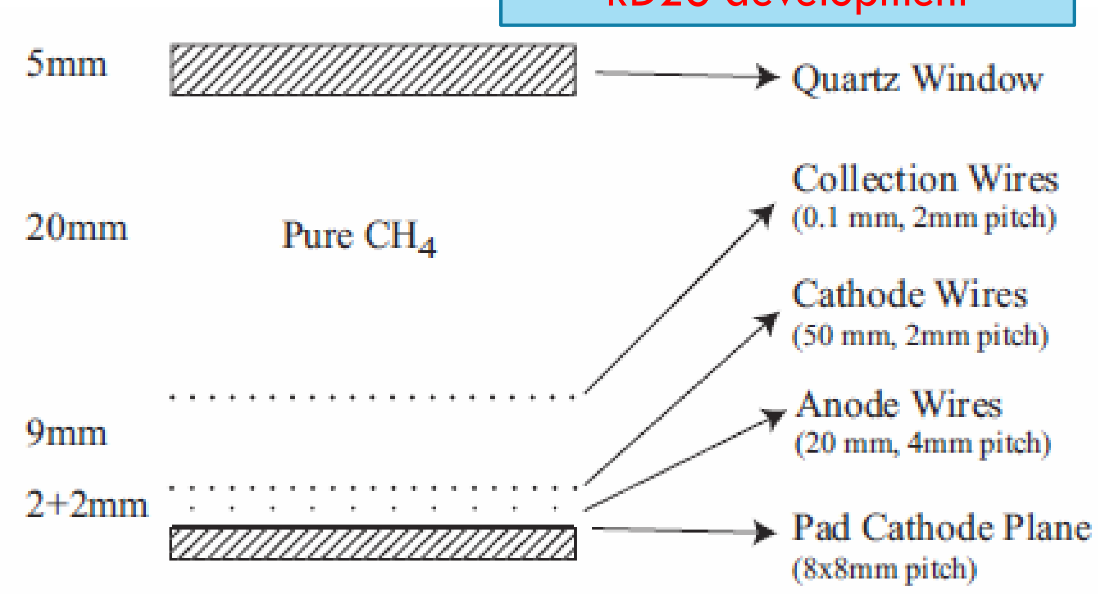
> Photon Detectors timeline:

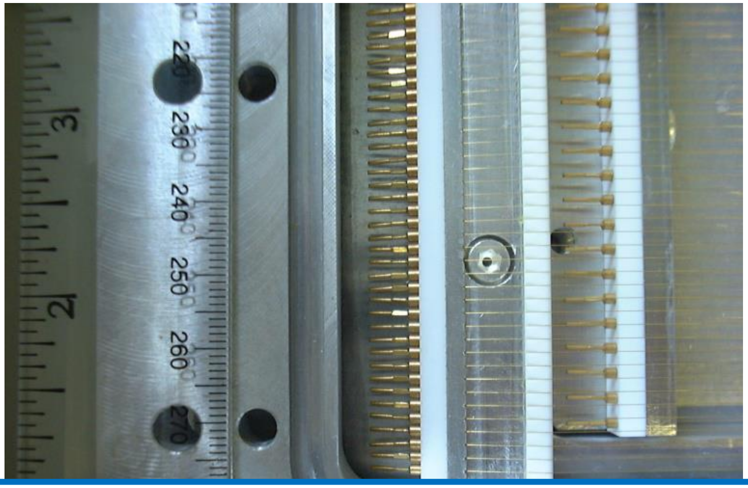
- 1996 MWPCs + CsI
- 2006 MAPMTs upgrade
- 2016 hybrid chamber upgrade (THGEMs + Micromegas)



COMPASS MWPCs

RD26 development

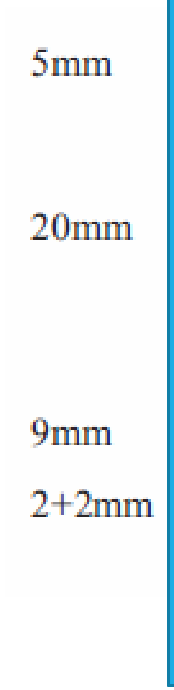




Reduced wire-cathode gap because of :
> Fast RICH (fast ion collection)
> Reduced MIP signal
> Reduced cluster size
> Control photon feedback spread

MWPC + CsI limitations:
> Long 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/cm^2
  Ion bombardment of the photocathode
> Low gain: a few times 10^4 (effective gain: <1/2)
> "slow" detector

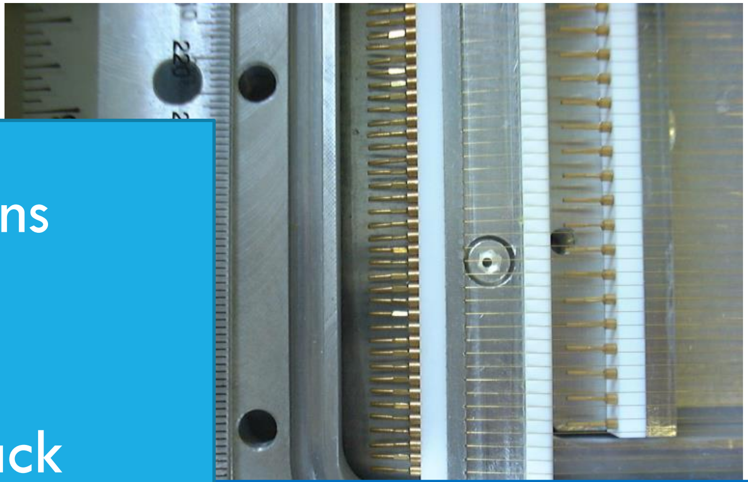
COMPASS MWPCs



Replacement of MWPCs in central regions
To overcome the limitations:

> Suppress the PHOTON & ION feedback
> use intrinsically faster detectors

MPGDs



Reduced wire-cathode gap because of :
> Fast RICH (fast ion collection)
> Reduced MIP signal
> Reduced cluster size
> Control photon feedback spread

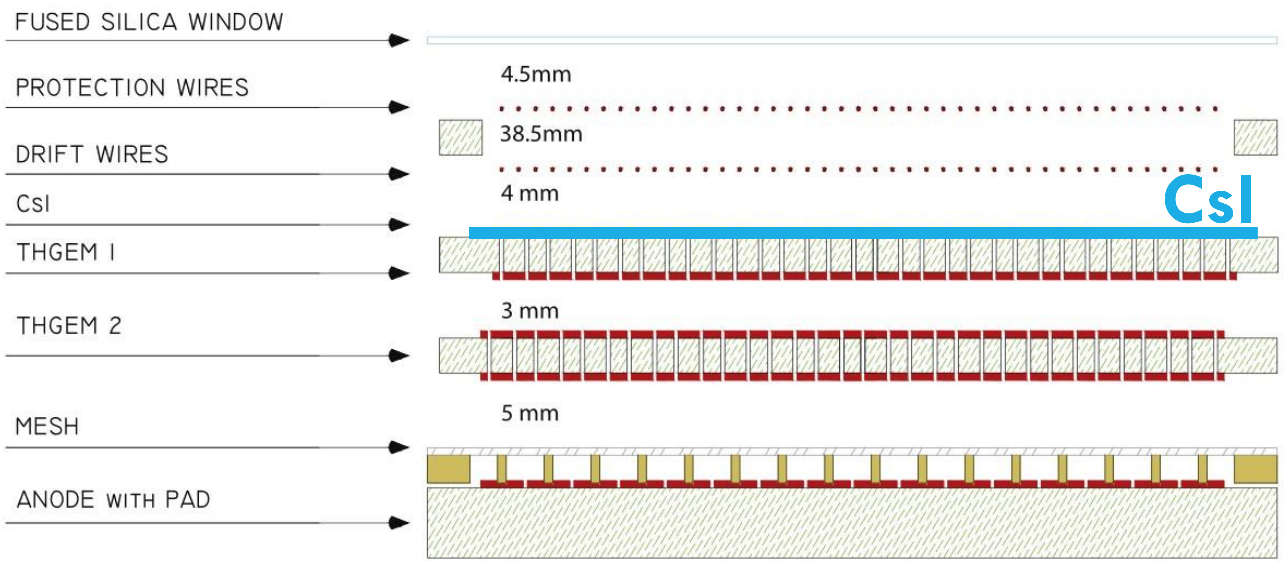
8 MWPCs are still in operation

CsI limitations:
overy time (~ 1 d) after a detector

umulation at the photocathode
k pulses
photons feedback from the

few
mC/cm^2
Ion bombardment of the photocathode
> Low gain: a few times 10^4 (effective gain: <1/2)
> "slow" detector

HYBRID DETECTORS ARCHITECTURE

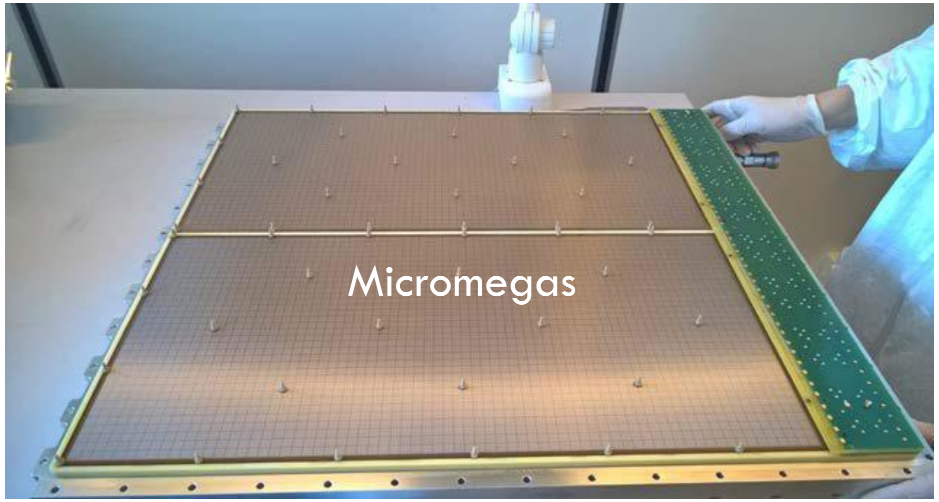


To simplify construction requirements > modular architecture. One module (300 mm x 600 mm) consists of:

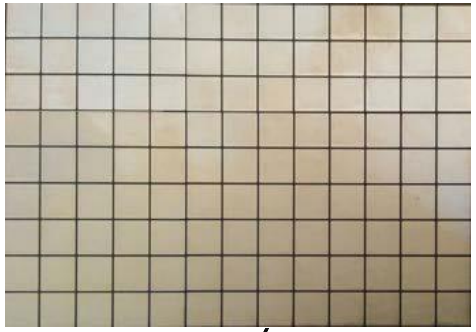
> One Bulk Micromegas detector
> Two layers of THGEMs in staggered configuration

Two modules are put side by side to build a 600 mm x 600 mm detector

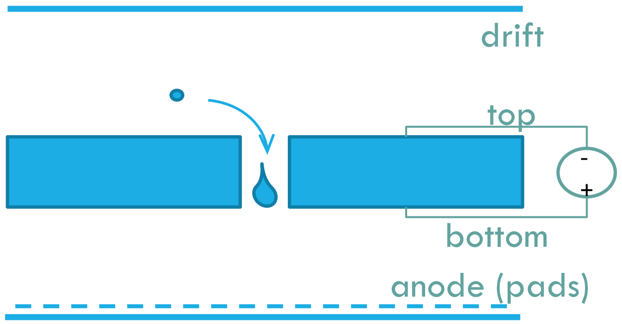
Signal read out via capacitive coupling pad readout and APV25 F/E boards



Pad size: 8 mm x 8 mm
Pad spacing: 0.5 mm



PRODUCTION - THGEMs



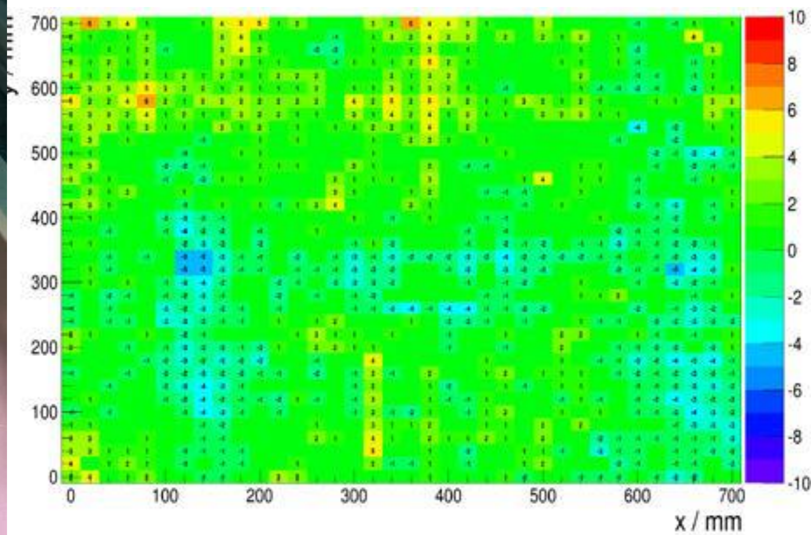
Metal coated PCB with holes drilled

Intense electric field in holes > multiplication

400 µm thickness, 400 µm hole diameter, 800 µm pitch, no rim

Measurement of the raw material thickness before the THGEM production, accepted:
±15 µm ↔ gain uniformity σ< 7%

1



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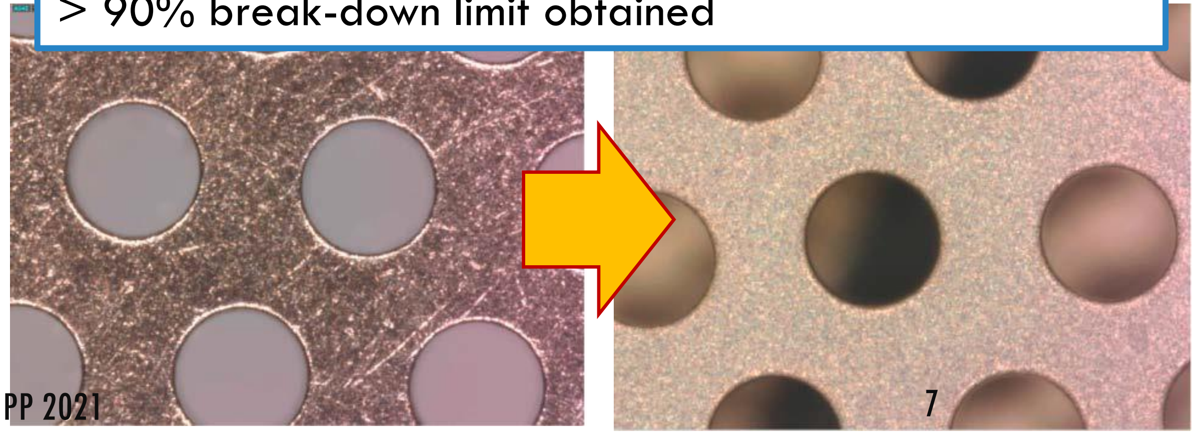
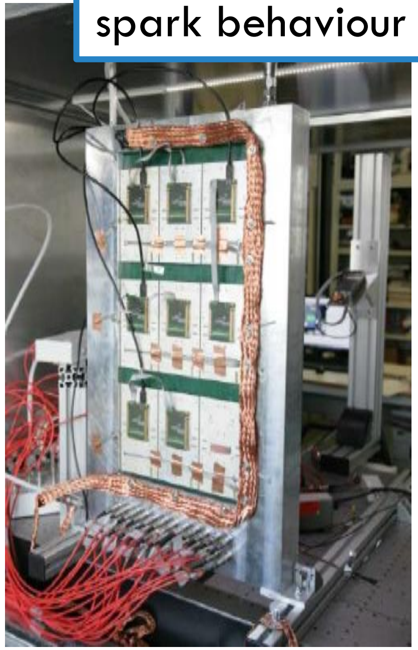
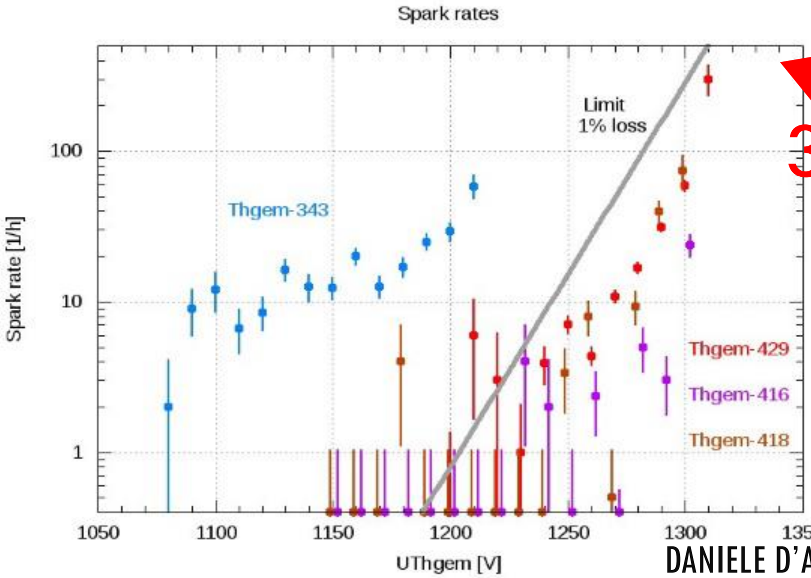
THGEM polishing with an "ad hoc" protocol setup by us:
> 90% break-down limit obtained



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





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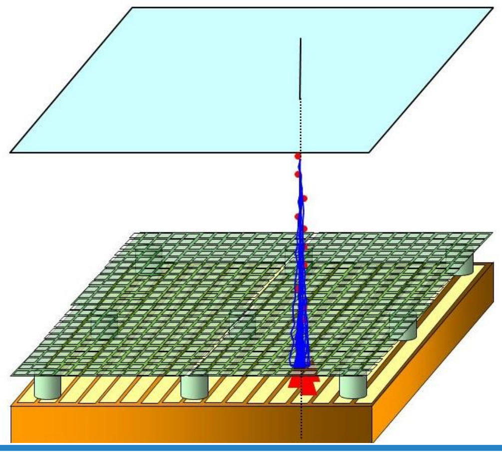
PRODUCTION - MICROMEGAS

Resistive Micromegas (bulk technology)
> Trap ions
> ~100 ns signal formation
> woven stainless steel mesh, 18 µm wires, 63 µm pitch
> One pillar per pad, 500 µm diameter.
> Gap = 128 µm.

Triple THGEM: IBF suppression <5% (staggering plate)

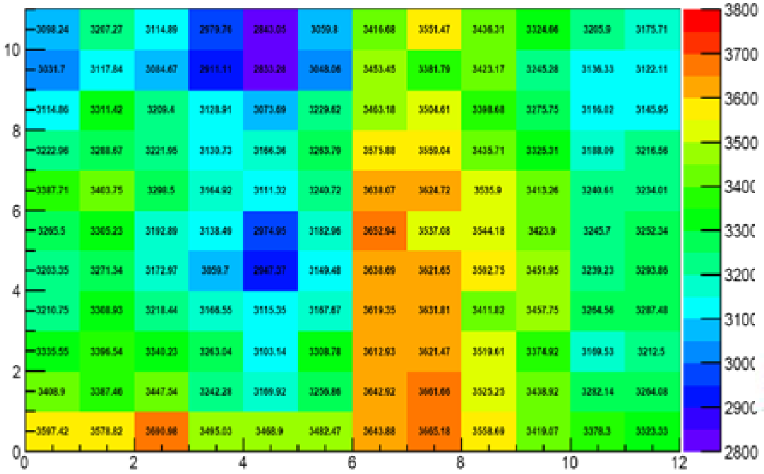
MM: IBF suppression <3%
no need of high Transfer electric field

→ Hybrid architecture

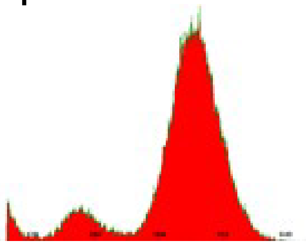


Schematic of a Micromegas detector

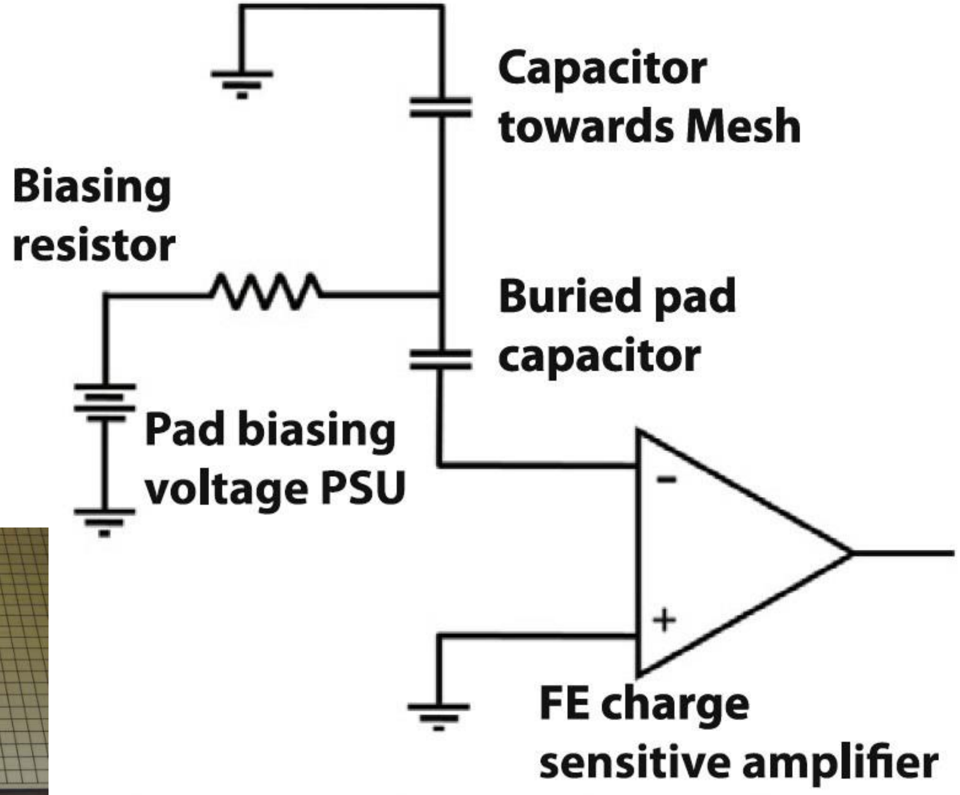
X-ray MM test to access integrity and gain uniformity < 5%



^{55}Fe source spectrum



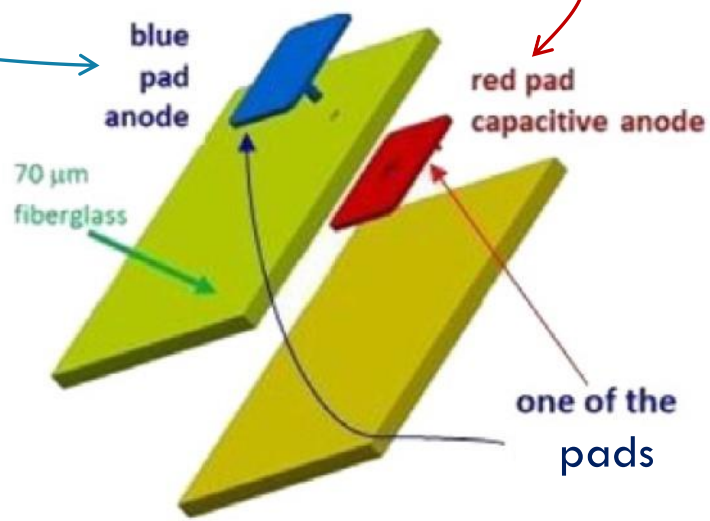
PRODUCTION - PAD DESIGN

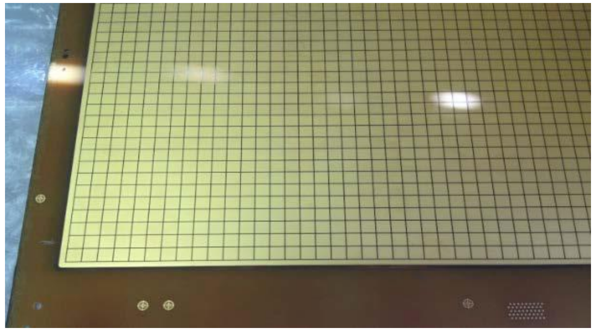


1 Single pad scheme:

Blue pad: at HV via individual pad resistor at the PCB rear surface (mesh is at ground)

Red pad: signal induced by RC



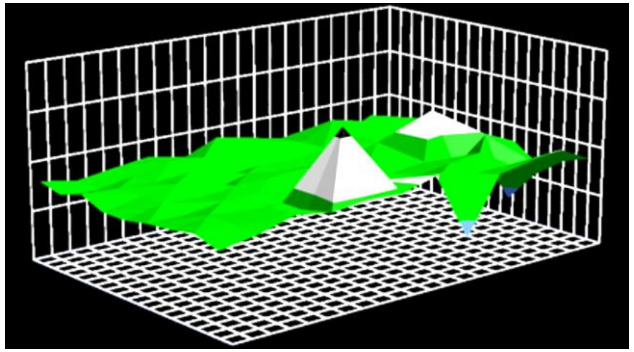


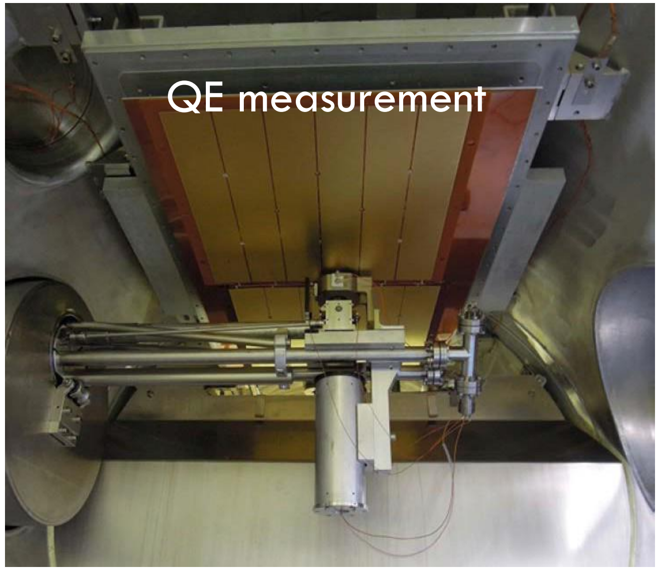
Test of the (4 x 2) 30 x 60 cm^2 MMs
[in total: 1.4 m^2, 19040 pads]:
-2 pads with shorts
-1 pad with no read-out connection
3 bad pads out of 19040 before installation

PRODUCTION - CsI COATING

19 CsI evaporations performed in 2015 - 2016
11 coated THGEMs available, 8 used + 3 spares

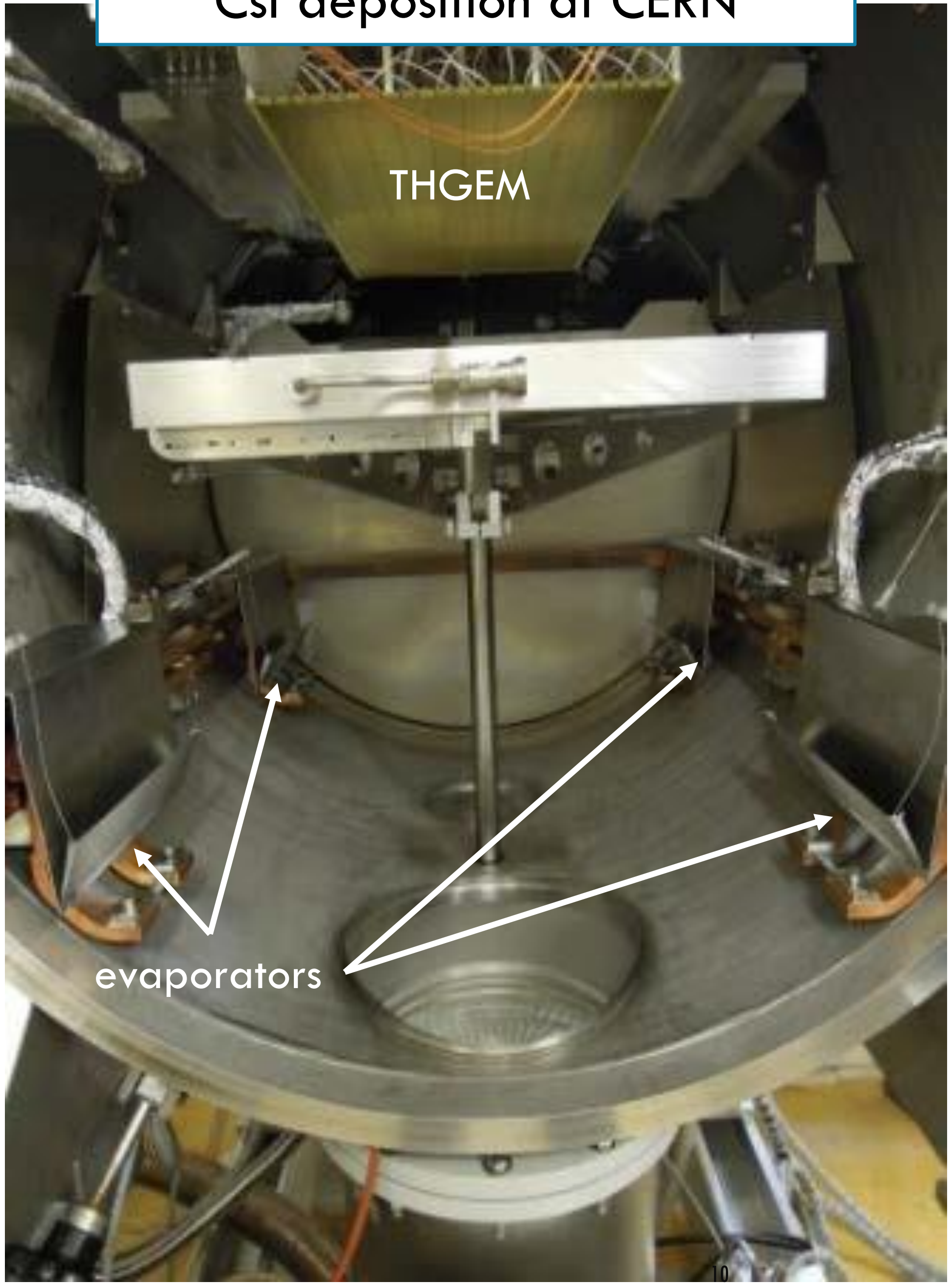
QE is the result of a surface scan
(12 x 9 grid, 108 measurements)
Good uniformity, in the example:
$\sigma_{QE} / < QE > = 3\%$





QE measurements indicate
$< QE > = 0.73\ QE_{ref}$
$r.m.s. = 10\%$
in agreement with expectations
[THGEM optical opacity = 0.77]

CsI deposition at CERN



HV CONTROL

Gain stability vs P, T:

G = G (V, T/P)

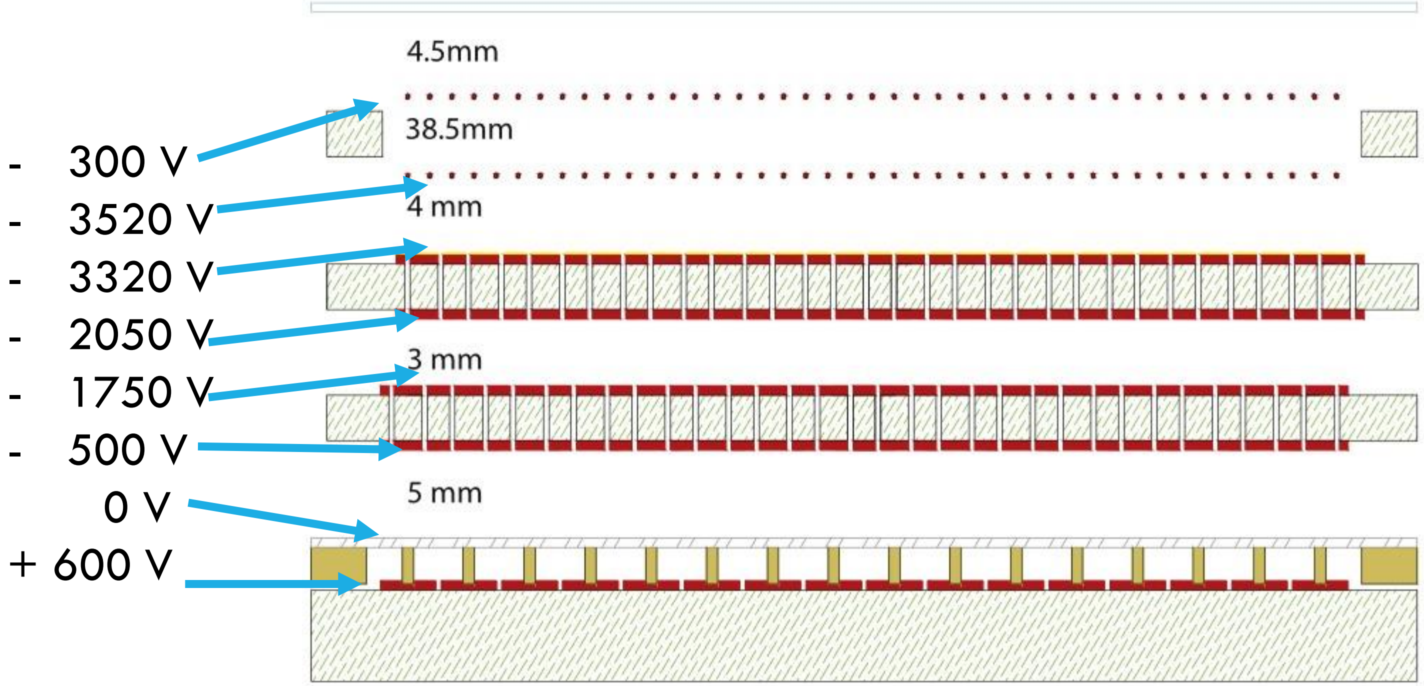
Enhanced in a multistage detector

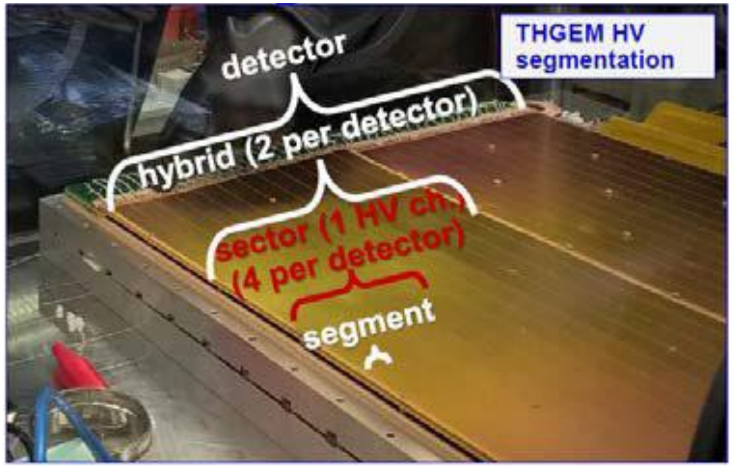
ΔT = 1 degree → $\Delta G \approx$ 12 %

ΔP = 10 mbar → $\Delta G \approx$ 20 %

THE WAY OUT:

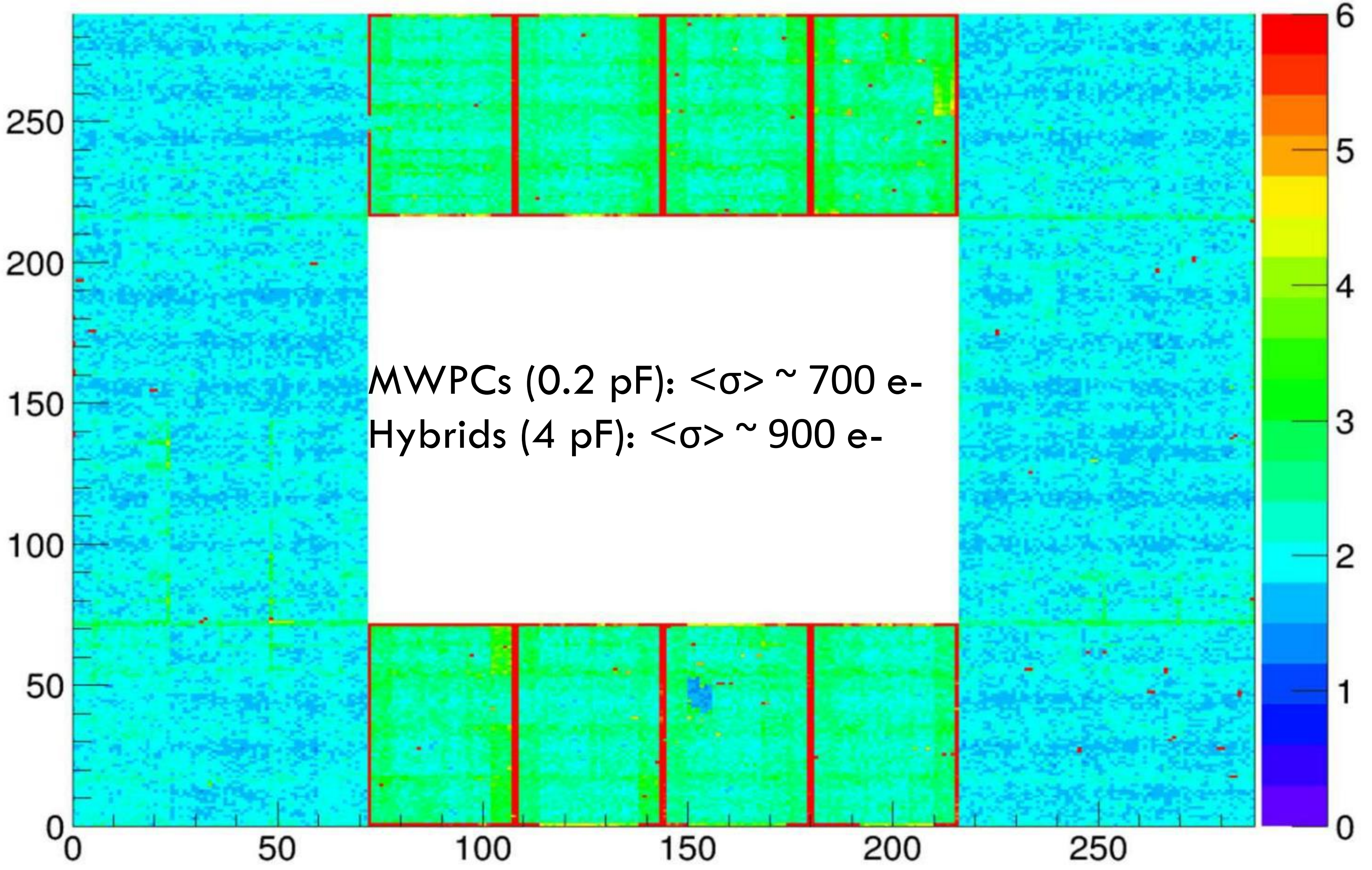
Compensate T/P variations by V





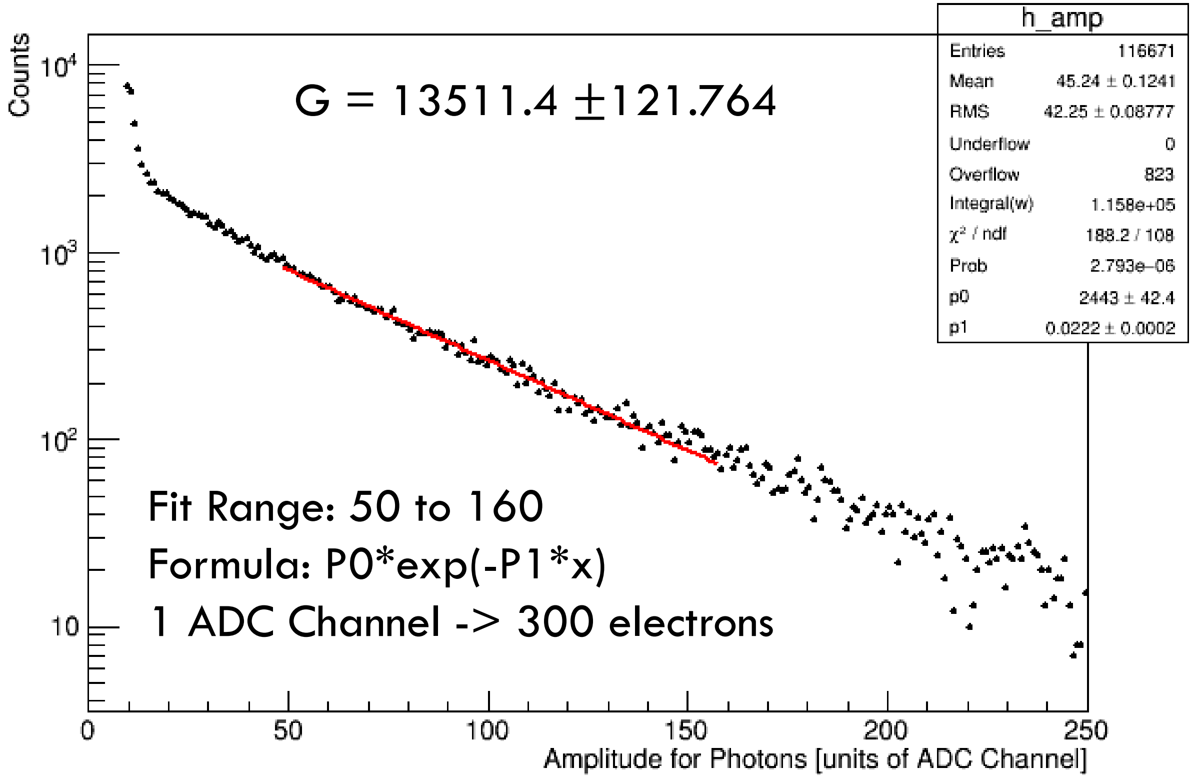
> Custom-made (C++, wxWidgets)
> Compliant with COMPASS DCS (slowcontrol)
> “Own Scale” to fine-tune for gain uniformity
> V, I measured and logged at 1 Hz
> Auto-decrease HV if needed (too high spark-rate)
> User interaction via GUI
> Correction wrt P/T to preserve gain stability

PERFORMANCE - NOISE



MWPCs (0.2 pF): <σ> ~ 700 e-
Hybrids (4 pF): <σ> ~ 900 e-

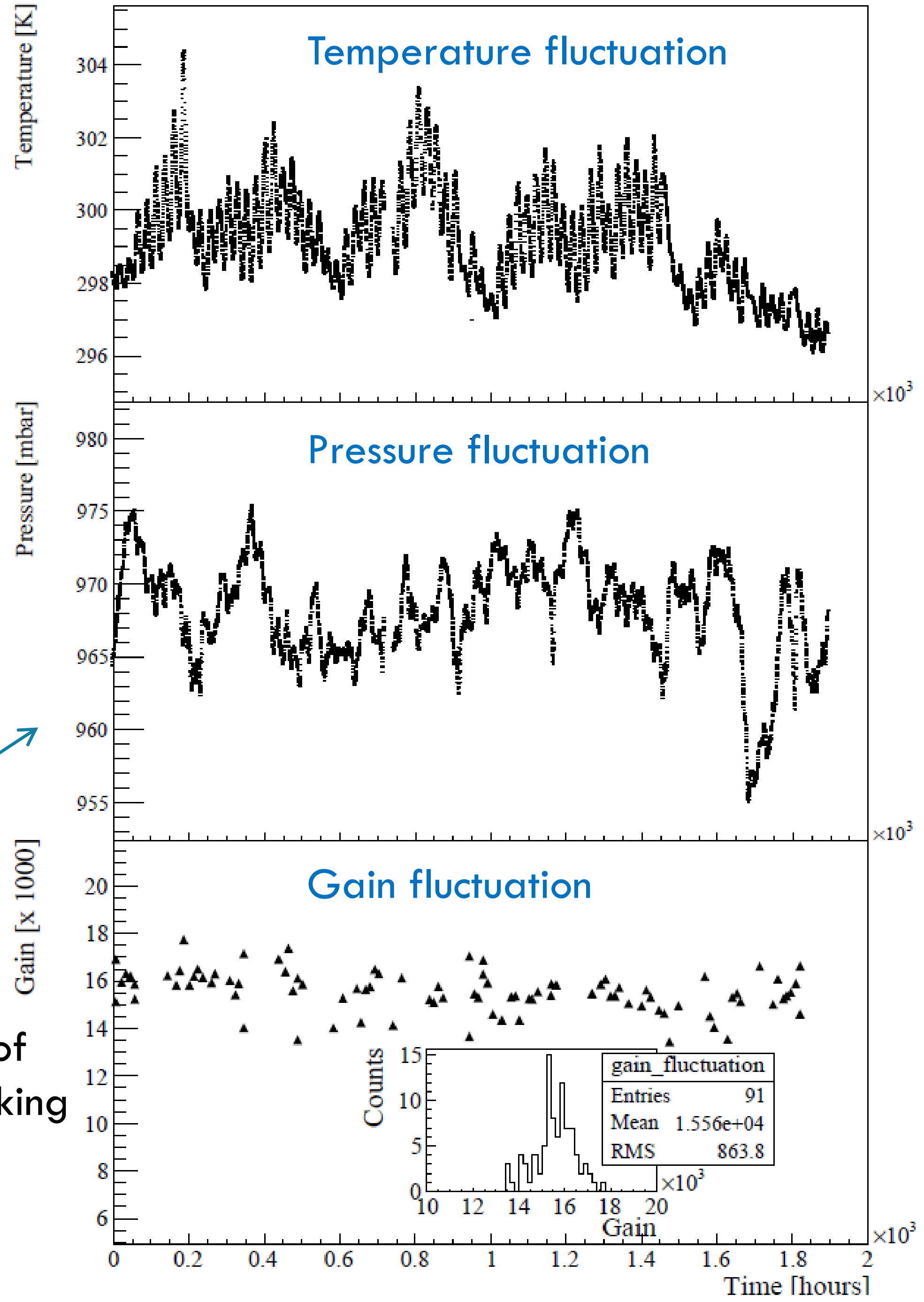
PERFORMANCE - GAIN



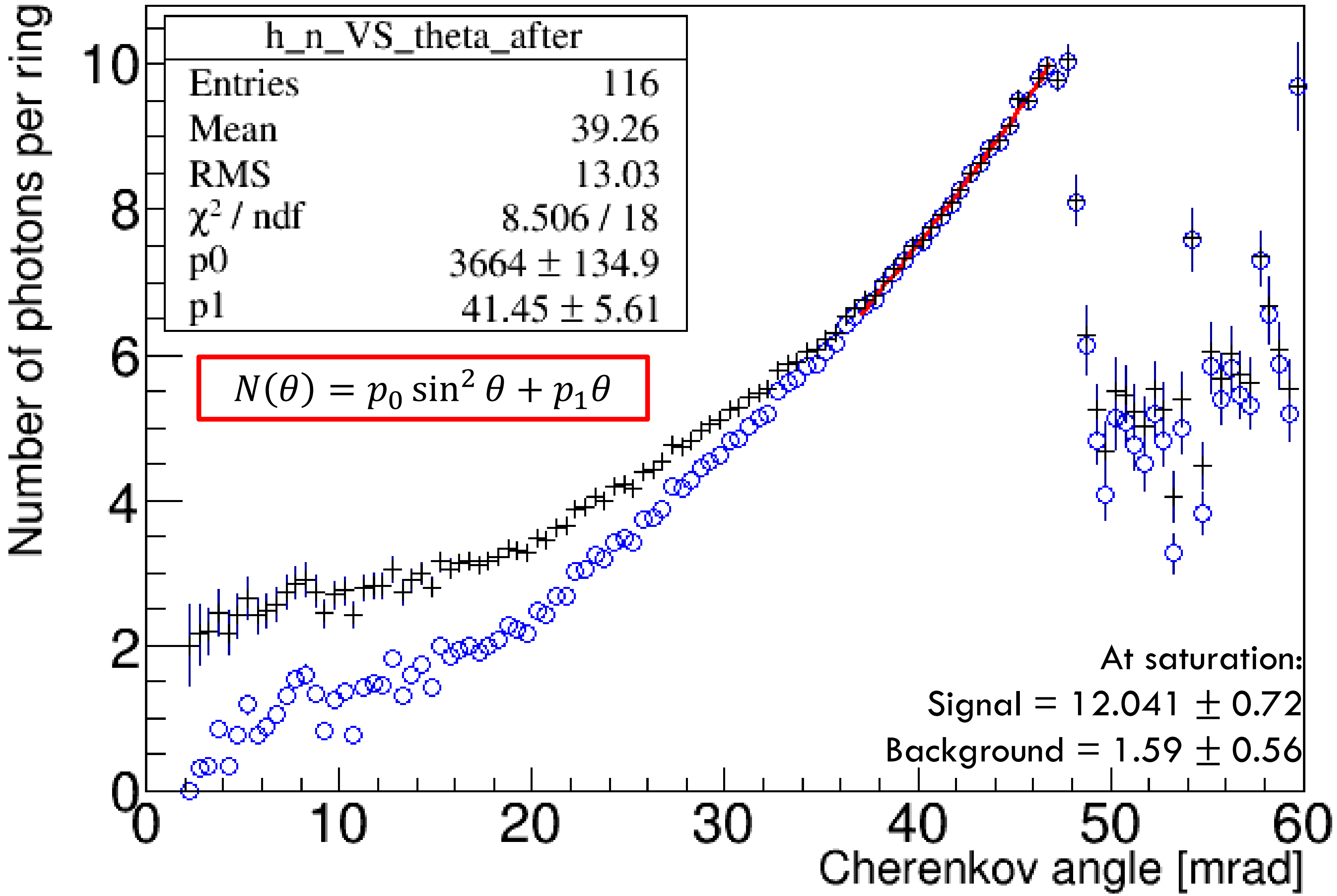
Gain is stable (thanks to pT correction on HV)

$$\frac{\sigma}{<G>} = 6\ \%$$

2000h of data taking



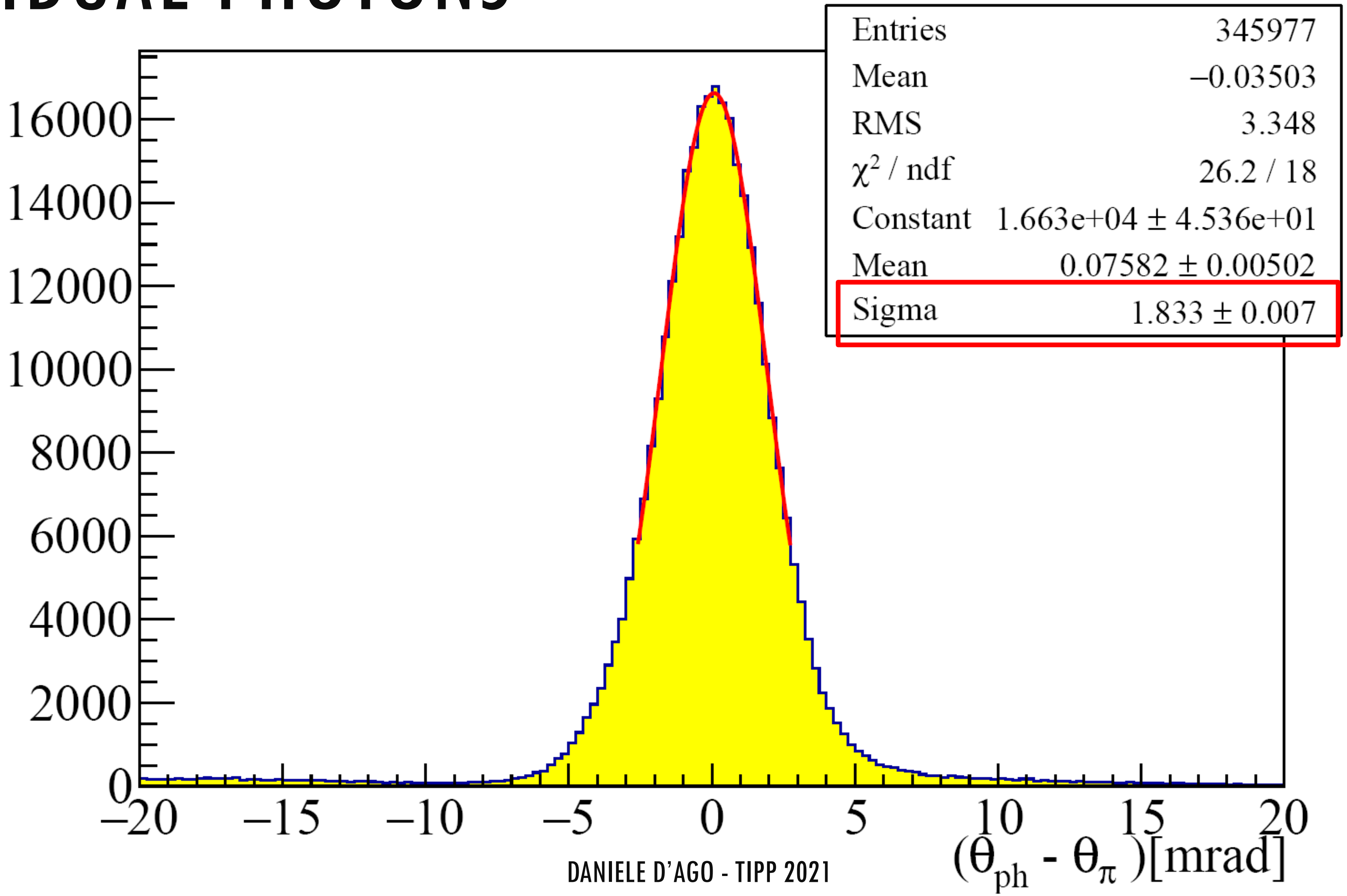
PERFORMANCE - NUMBER OF PHOTONS



+ data points

○ Poissonian correction

PERFORMANCE - RESIDUAL DISTRIBUTIONS FOR INDIVIDUAL PHOTONS



NEW PERSPECTIVES

Reduced pad size

Thin gaseous RICHes would suit also collider experiments
> Higher space resolution is required
> Low number of photons

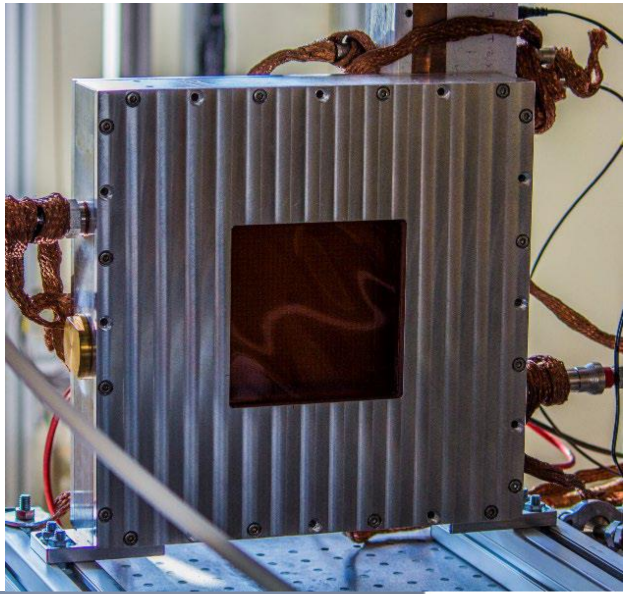
Work at lower λ (higher number of photons, Frank Tamm law)

Windowless RICH [no cut due to quartz window]

Same gas for Cherenkov radiation and multiplication

Suitable photocathode [RD in Trieste presented by Triloki https://indico.cern.ch/event/981823/contributions/4304792/]

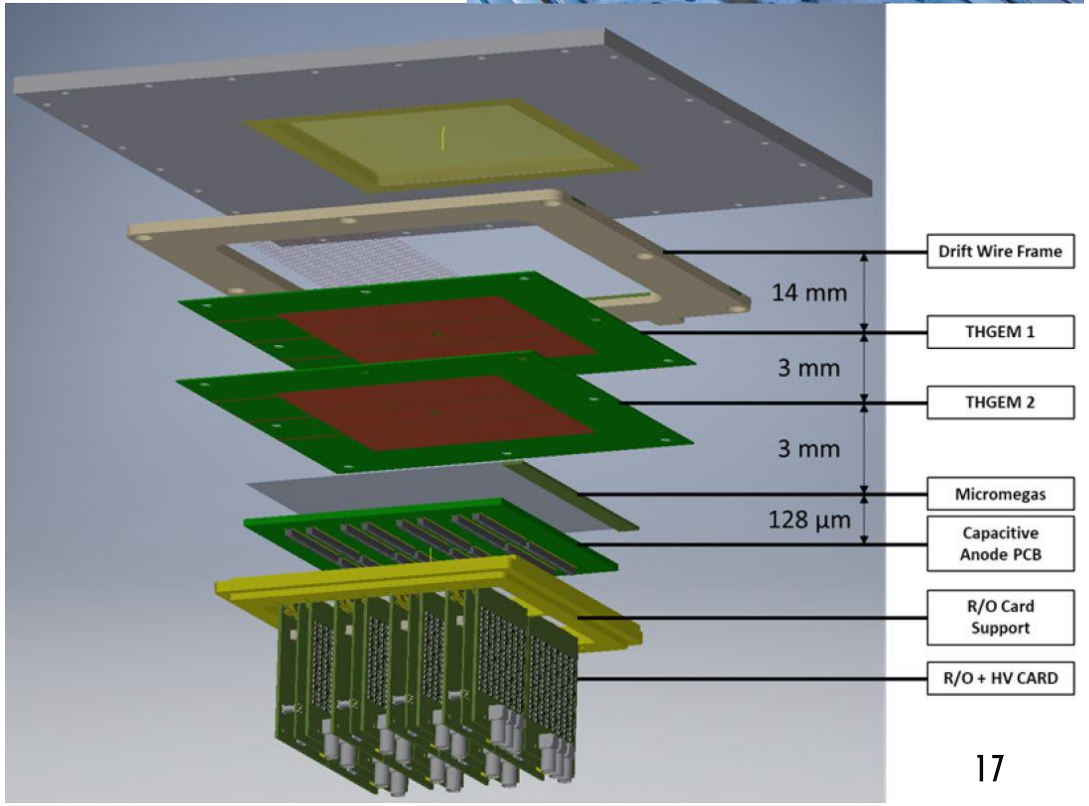
NEW PERSPECTIVES - MINI PAD PROTOTYPE



Hybrid architecture but with reduce pad size
> Pad size: 3x3 mm^2 (0.5 mm inter-pad spacing)
> 10x10 cm^2 active area - 1024 pads

Modular structure: all components and services within active area

Possible extension to larger surfaces with the same design



Single multiplication elements have been tested with ^{55}Fe source, Amptek mini-X and PicoquantPLD 4000B

They show good electrical stability and gain performance

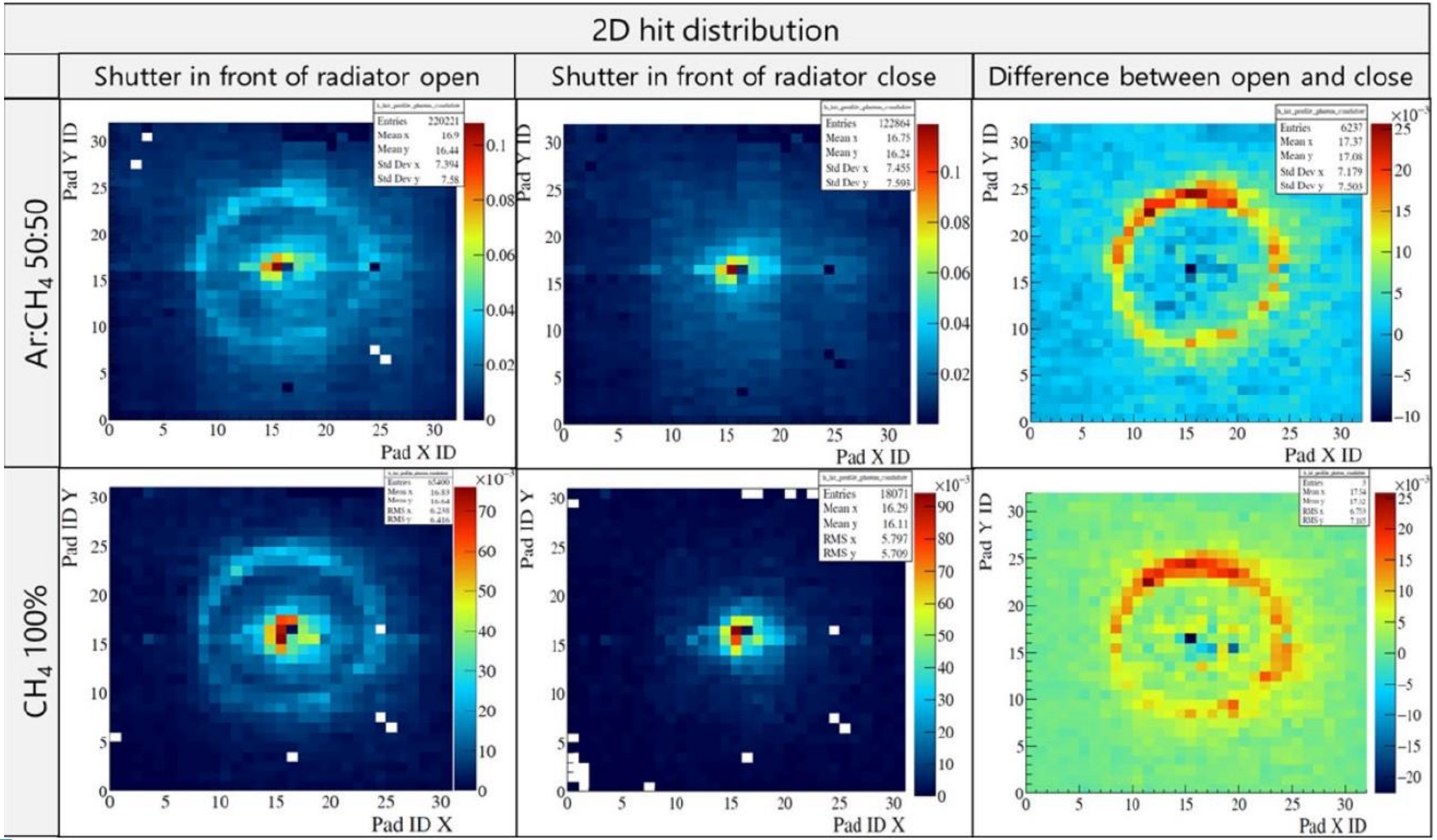
NEW PERSPECTIVES - MINI PAD TEST BEAM

In 2018 test beam at CERN H2 beamline

Fused silica radiator for Cherenkov rings

Different mixtures tested [$Ar:CH_4 = 50:50$ and pure CH_4]

Issue: non uniformity in gain
Will be solved with new anode design



Hit distributions. Left: photons and beams, Centre: beam only, Right: difference of the two

Results are encouraging!

CONCLUSIONS

COMAPSS hybrid detectors are the first application of MPGD based single photon detectors

They showed good performances in dedicated tests and during COMPASS data takings

MPGD technology is being pushed to match more demanding requirements (i.e. EIC)

Results obtained so far are encouraging

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