New Developments in Large Area THGEMs & APV Exercise

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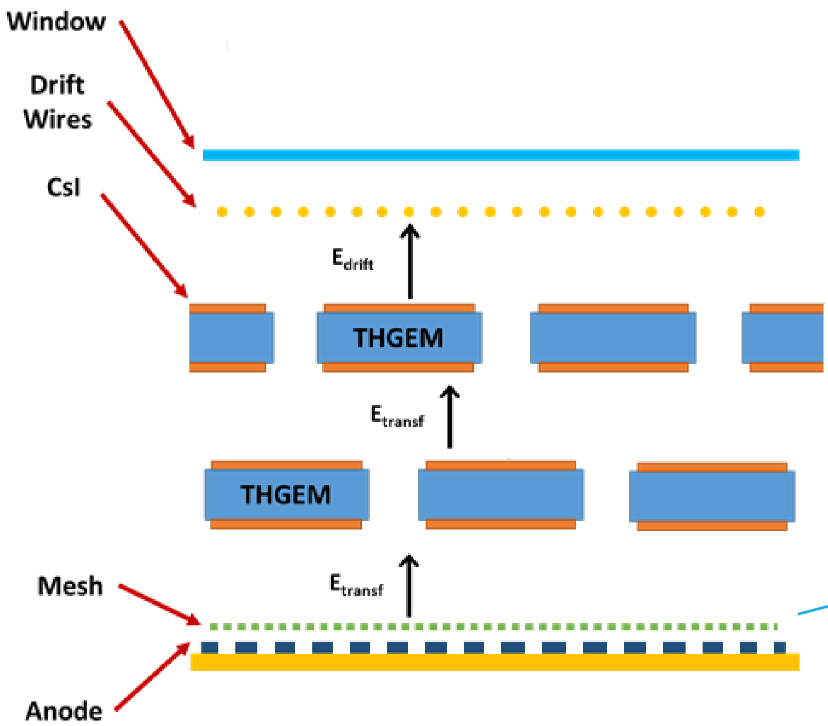
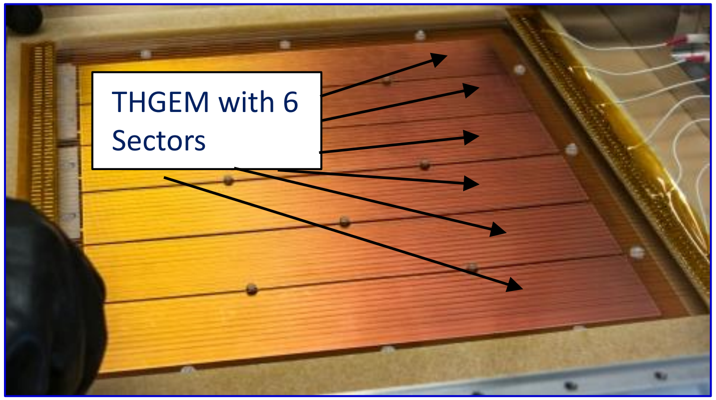
THGEM Hybrid Detector + APV Readout

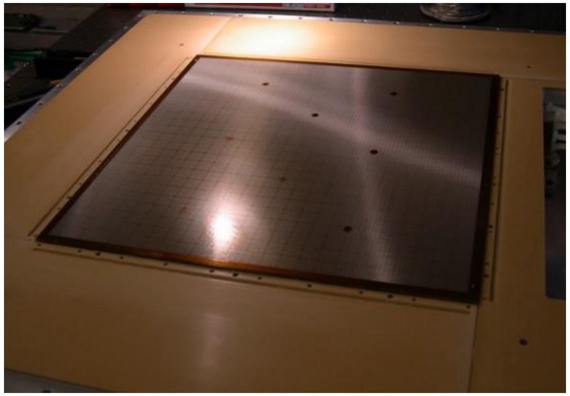
Motivation of the Exercise

Hybrid Detector (2 x THGEM + Micromesh) tested at the 2014 T10 TestBeam



Double THGEM: t = 0.4 mm; p = 0.8 mm; h = 0.4 mm

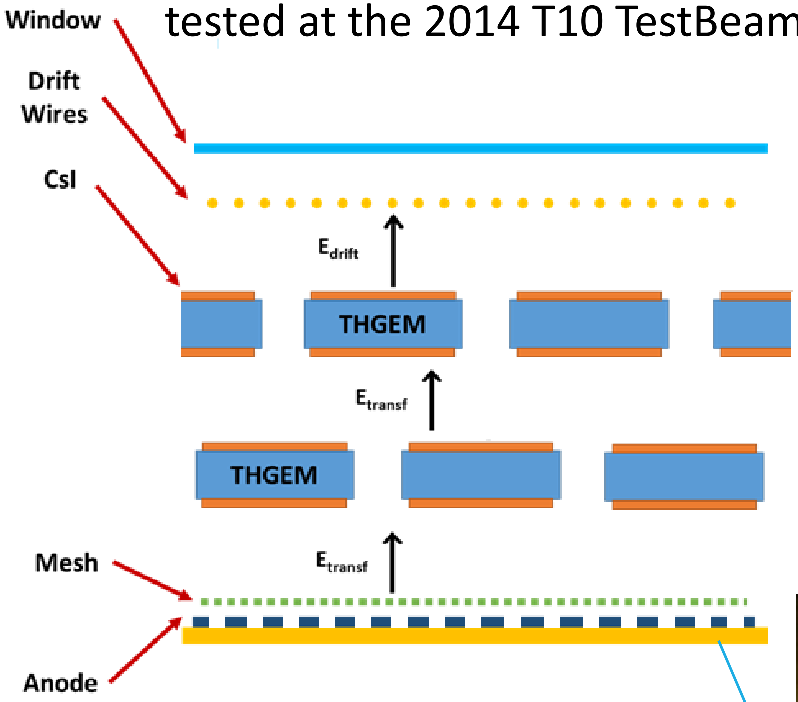


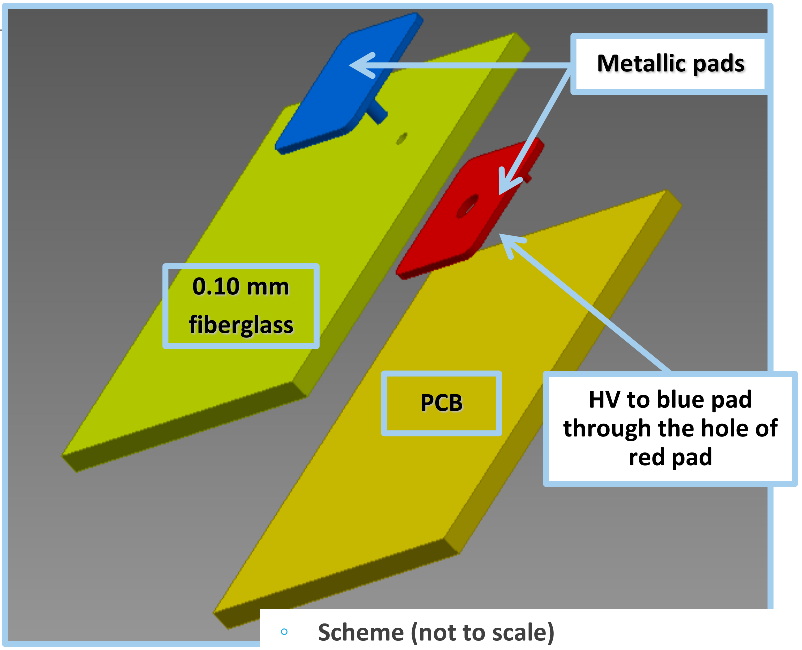


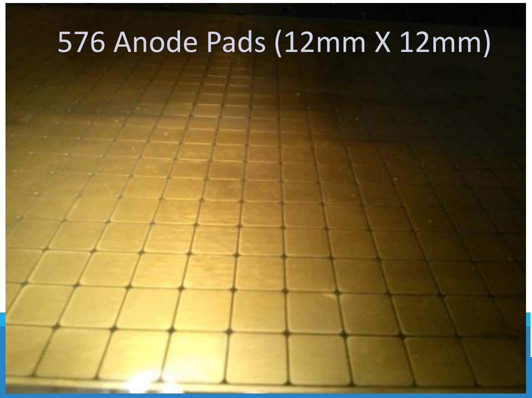
Bulk Micromesh

Motivation of the Exercise

Hybrid Detector (2 x THGEM + Micromesh)
tested at the 2014 T10 TestBeam

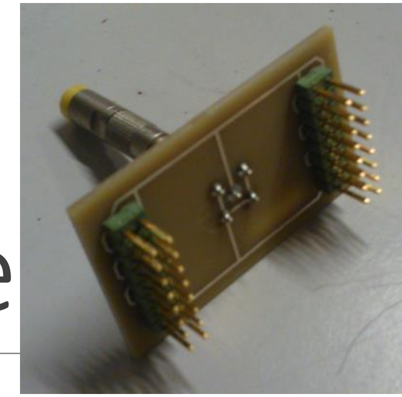






- Scheme (not to scale)
  - Only 1 single pad shown
- Principle
  - Blue pad at HV via internal connection
  - Resistive (individual pad resistor at the PCB rear surface)
  - Red pad: signal induced by RC coupling

Motivation of the Exercise



Analogue Readout:

- Charge Sensitive pre-amplifier Cremat (CR110/111) + Ortec Amplifier + Amptek MCA
- Readout through 16 pads connected together by the connector shown in the picture.
- Gain determination: ≈ 10^5.

Digital Readout:

DREISAM CARD

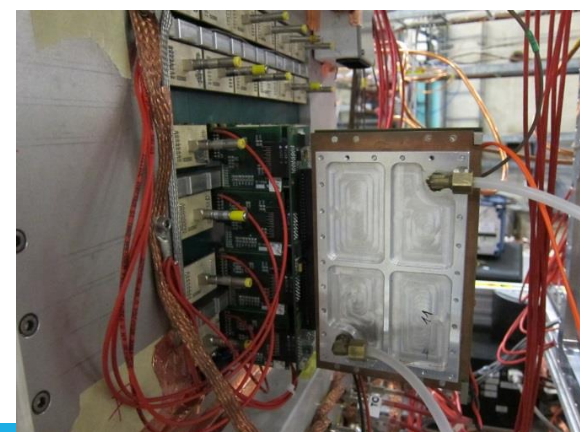
ROOF Board

CMAD Boards

Protection Boards

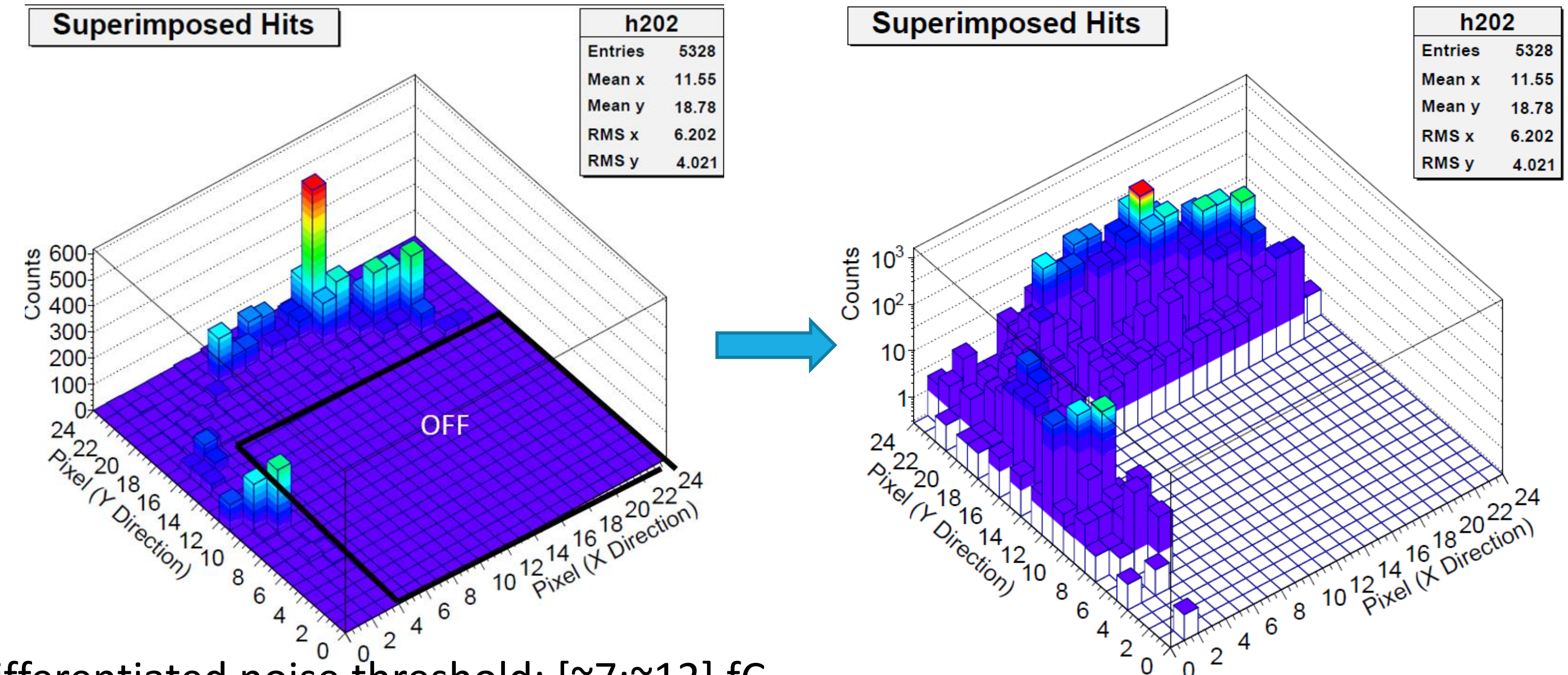
Readout chain: same as RICH-1 – MAPMT

- C-MAD
- Roof
- DREISAM card



Motivation of the Exercise

Digital Readout Data: Cherenkov Ring

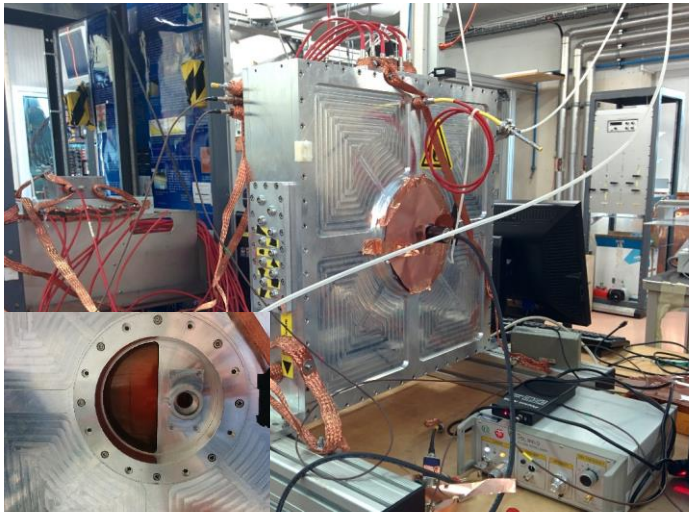
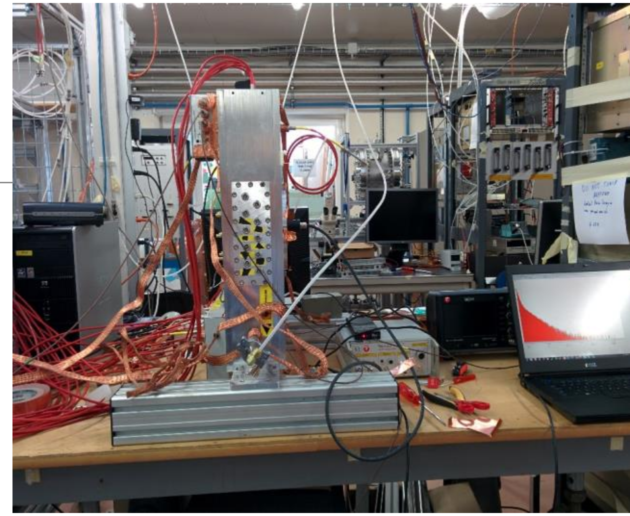
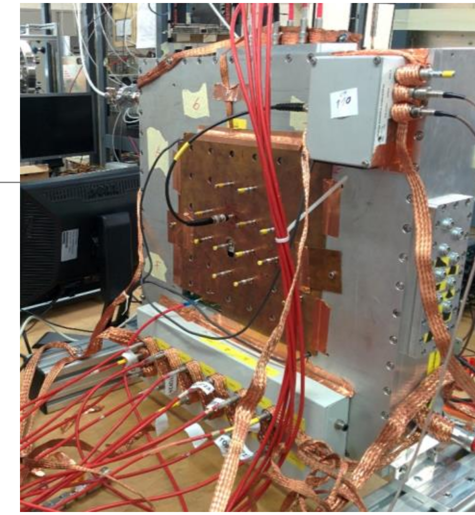


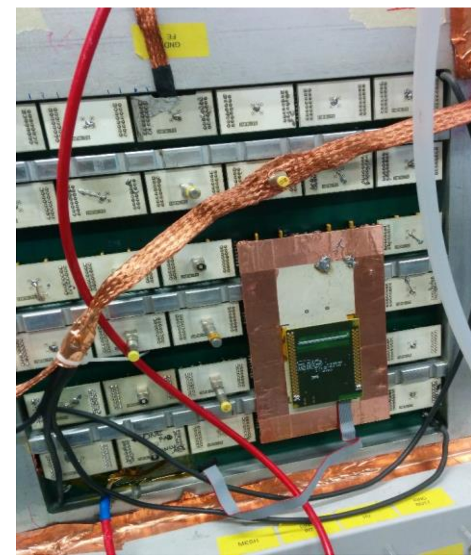
Differentiated noise threshold: [~7;~12] fC

320 pads of 576 switched off because of even higher noise.

What causes such high noise level?! Detector? Electronics?!
Coupling of a hybrid detector to our digital electronics??

→ **APV Test @ RD51 Lab**
(thanks for the help provided)

Exercise Setup

4 (short) days in the RD51 Laboratory

300 x 300 mm^2 double THGEM Hybrid detector in $Ar/C0_2$ (70/30) atmosphere

- It is the detector used at the test beam, no change of THGEM/MM

New double Kapton and Quartz window equipped

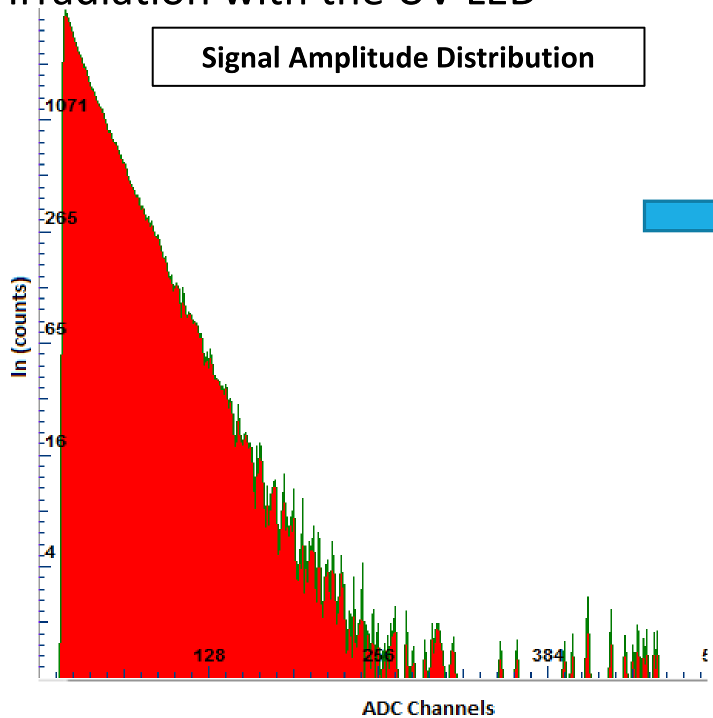
- Iron 55 source
- UV led Sepia LED head @ 245 nm + PLD 800 pulser max pulsing rate 10 MHz

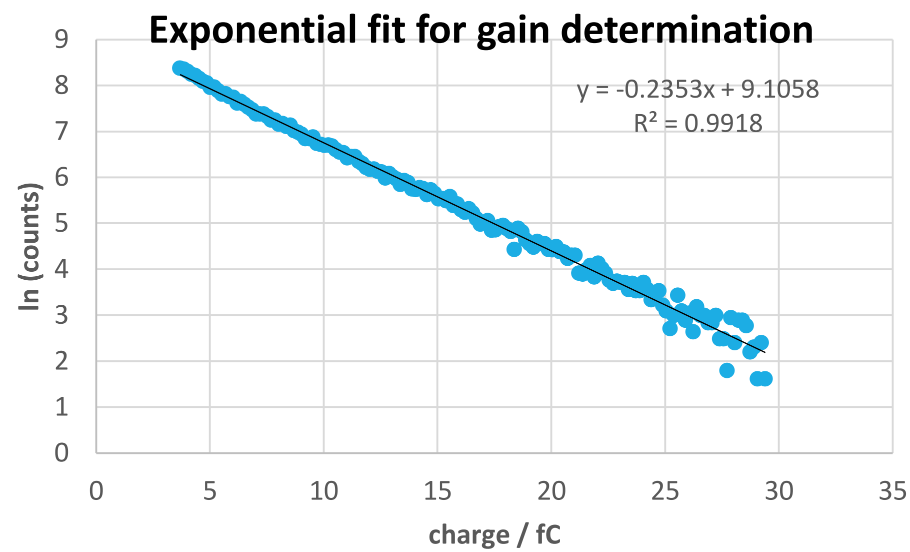
DAQ

- Standard CR110 pre-amplifier + Ortec amplifier + MCA
- DATE based with APV FE cards SRS system and AmoreSRS

Analogue Readout test

- Data acquisition for testing the system
- Gain Determination for comparison with APV
- Irradiation with the UV LED





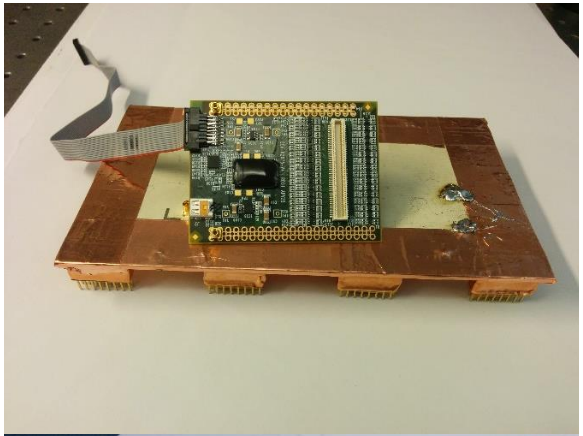
Gain ≈ 27 k
Threshold @ 3 fC

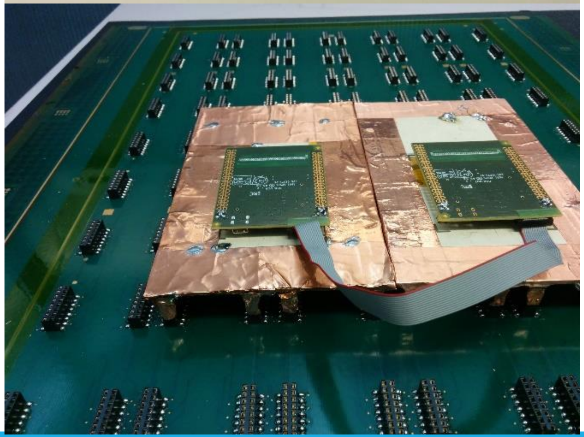
The conditions (Voltages and Gas) used to obtained this gain were kept unchanged during the whole APV exercise.

APV-First tests

Configuration

2 Apv chips 1 master, 1 Slave, Interface board for *our* 2x8 connector to the Panasonic;





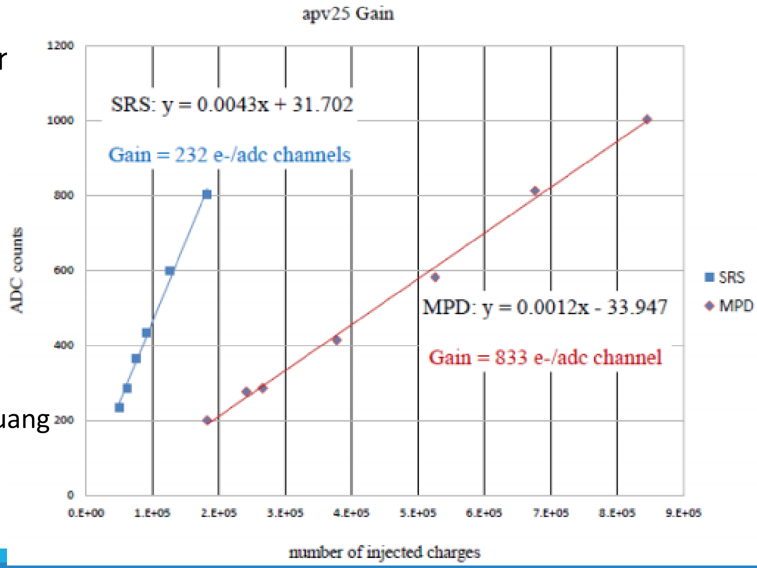
1 chip 128 ch → 16 connectors of 8 pads each

First Issue → Noise of the chip

- when free (intrinsic)
- When coupled to the detector
- Offset from the ideal ADC channel
- rms of the noise for each channel

ADC Channel ←→ Charge calibratior

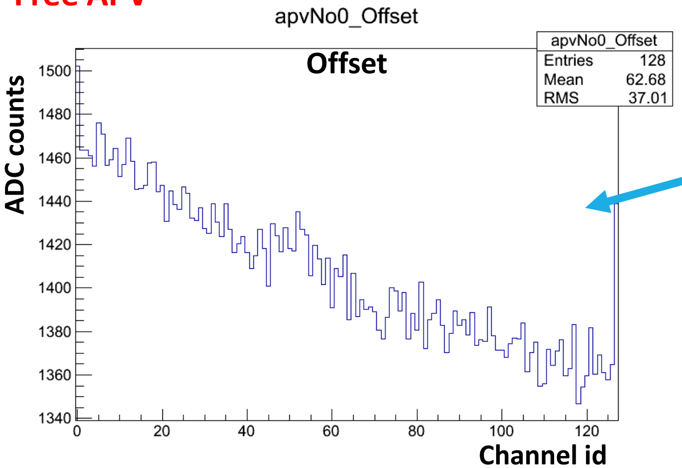
232 electrons per ADC channel



Calibration of the gain and measurement
of the noise for the apv25 electronics
K. Gnanvo, N. Liyanage, C.Gu, K. Saenboonruang
RD51 collaborators

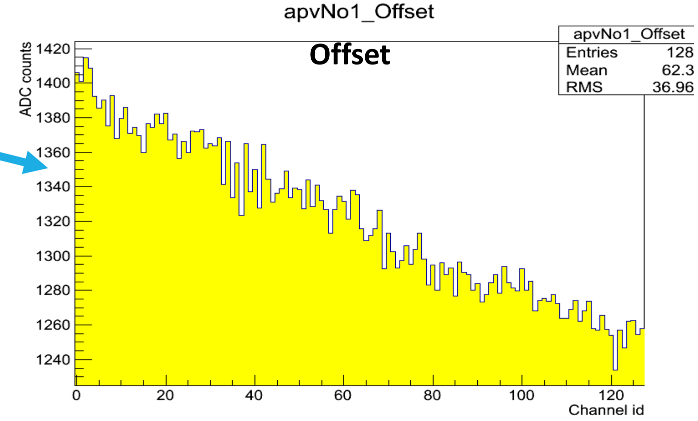
APV-First tests: 1 chip connected to the detector; 1 free; HV OFF

Free APV

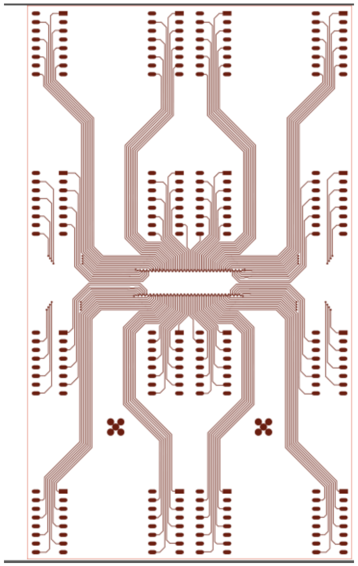


Typical APV offset behavior: related to the chip implementation ok

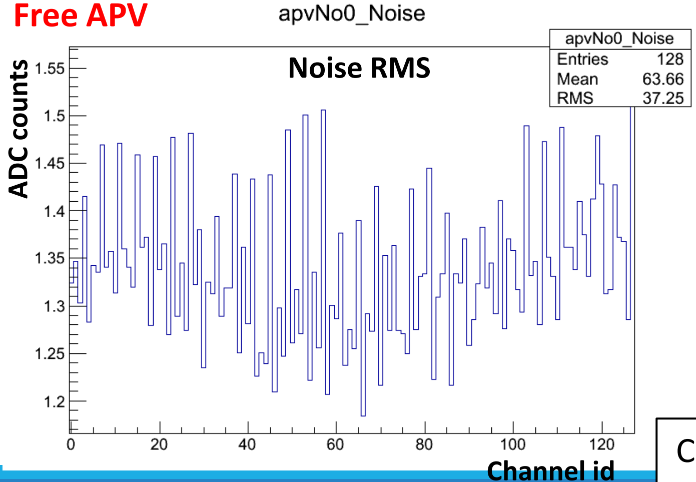
APV Connected to Detector



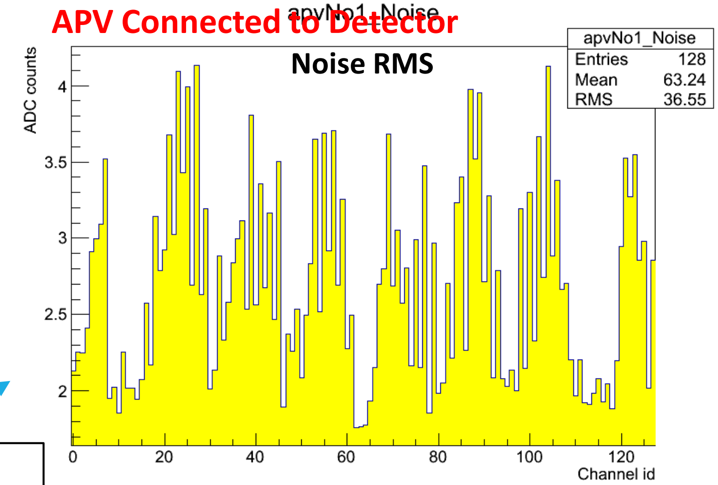
APV Connection board



Free APV



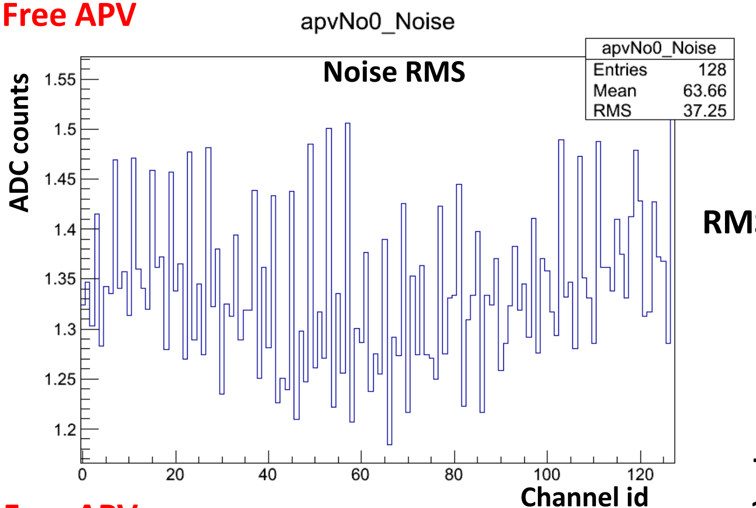
APV Connected to Detector



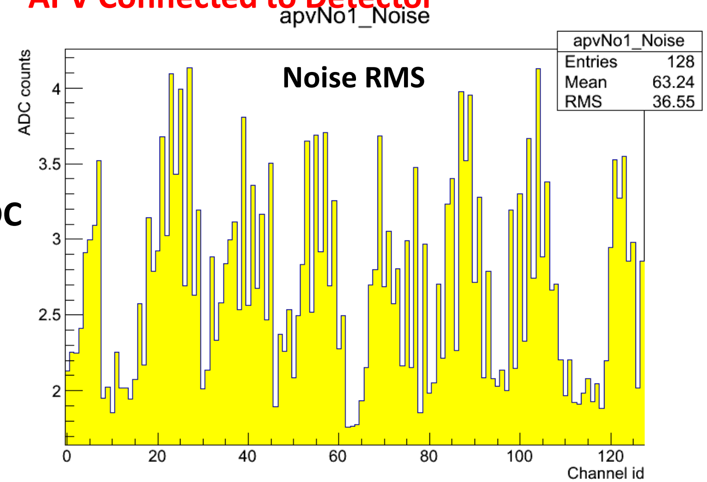
Correlation between noise structure and length of the paths

APV-First tests: 1 chip connected to the detector; 1 free; HV OFF

Free APV



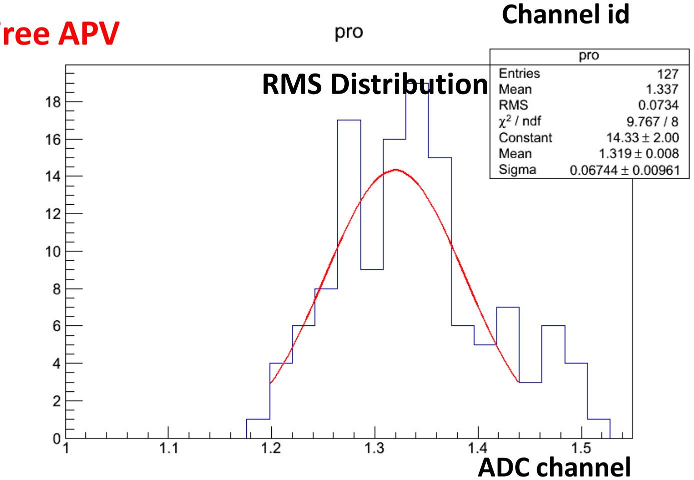
APV Connected to Detector



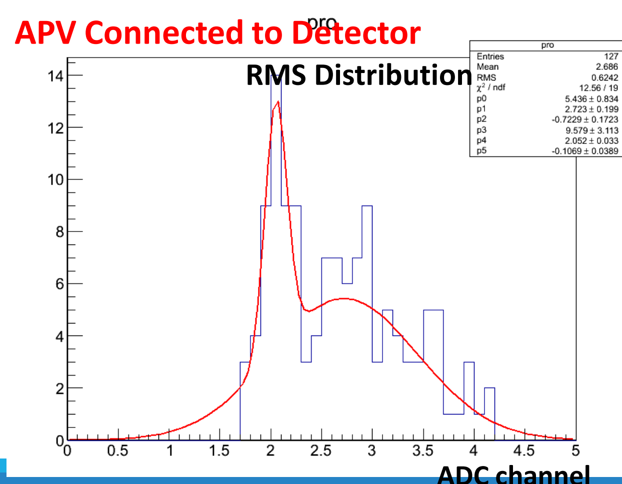
RMS$_{max}$ (connected)= 5 ADC

In the worse case a threshold cut on the amplitude at 5 times the RMS of the channel, corresponds to a cut of only 1 fC.

Free APV



APV Connected to Detector



APV-First tests: Timing issue

- all the events recorded in the 27 x 25 ns memory buffer (675 ns).
- 10 MHz Led pulsing with a photon detection efficiency of 2-3% → expected rate 15%
- Flat time distribution in the time buffer

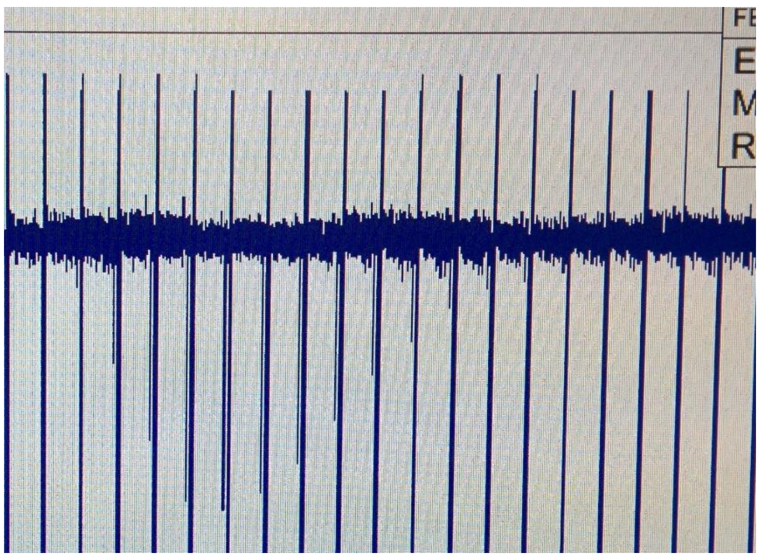
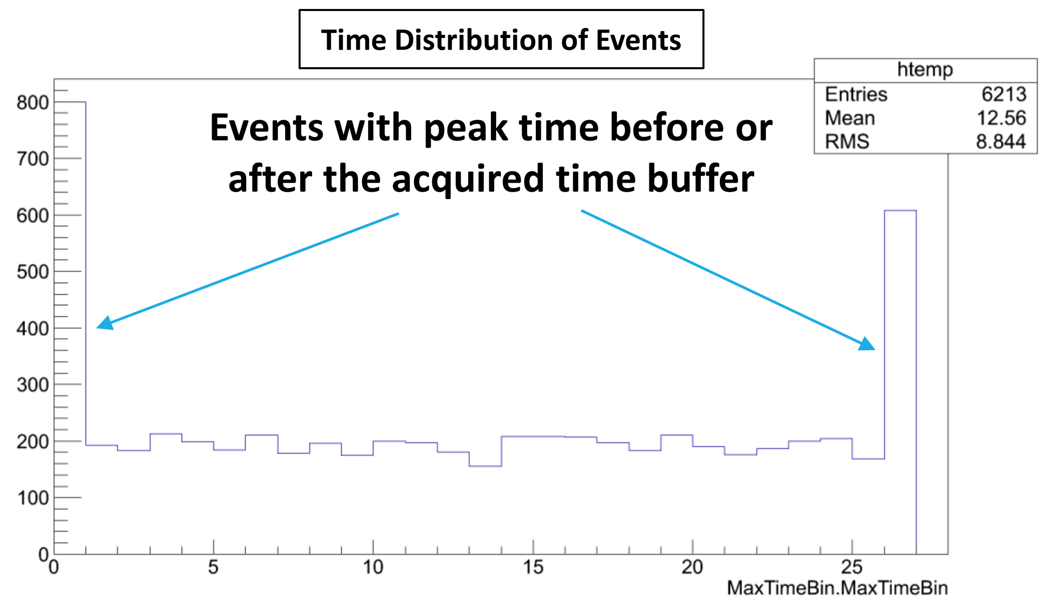


Photo of one the first visualised signals, acquired in the thrill of the moment.

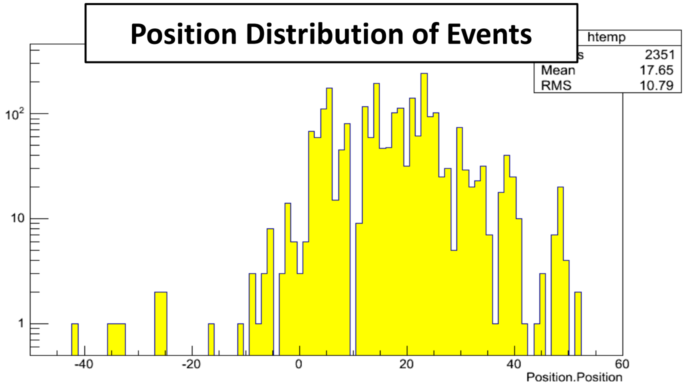


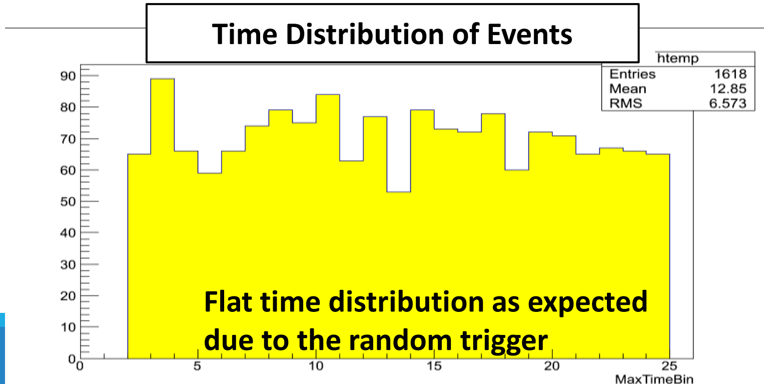
Time / ns

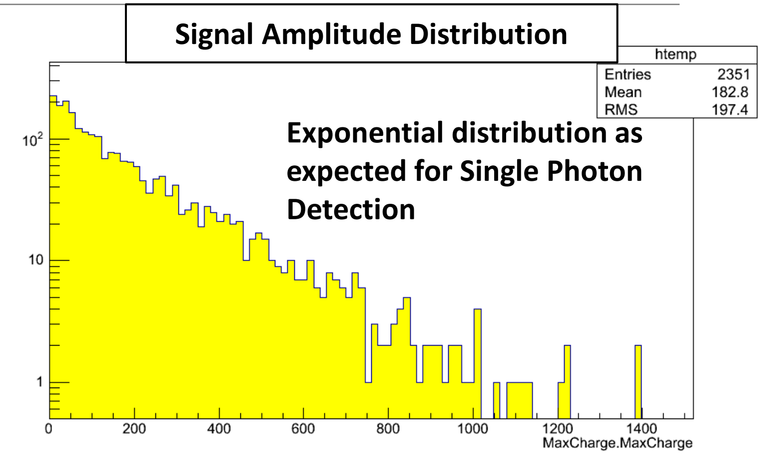
APV-First tests: events

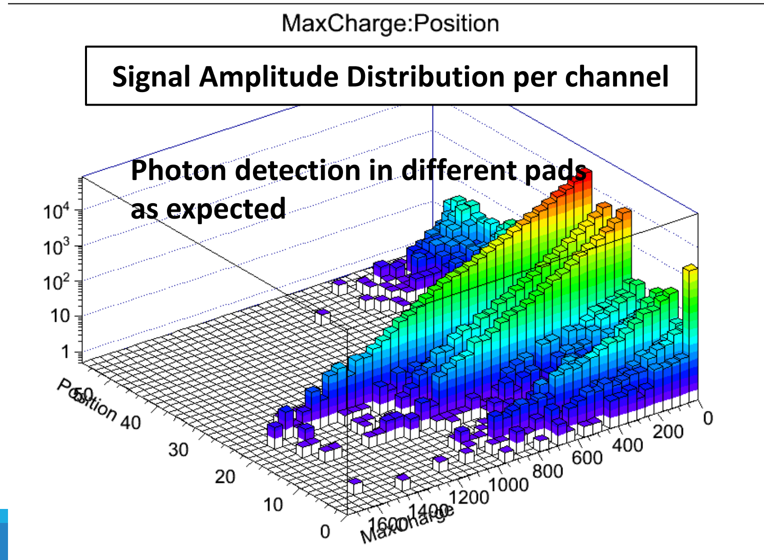
Event Over Threshold, that enters the histogram (AmoreSRS)
From pedestal file:

- -remove the baseline offset
- -compute the RMS after common mode subtraction
- -cut on the amplitude at 5 times the RMS of the channel



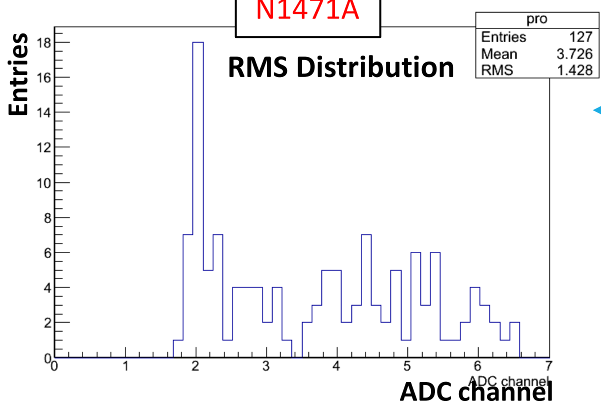




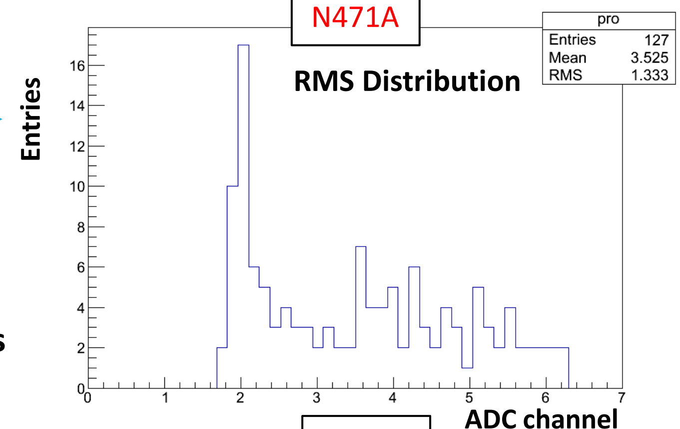


APV-First tests: N1471A vs N471A

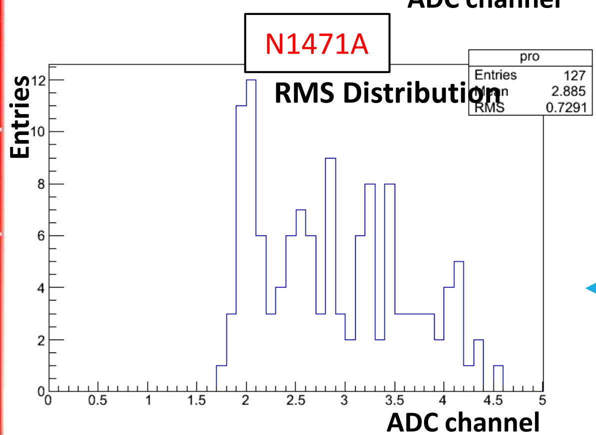
- In the analogue readout, the N1471A unit introduces a modular noise!
- N1471A connected to Drift and to HV pads all the other layers to our standard N471A



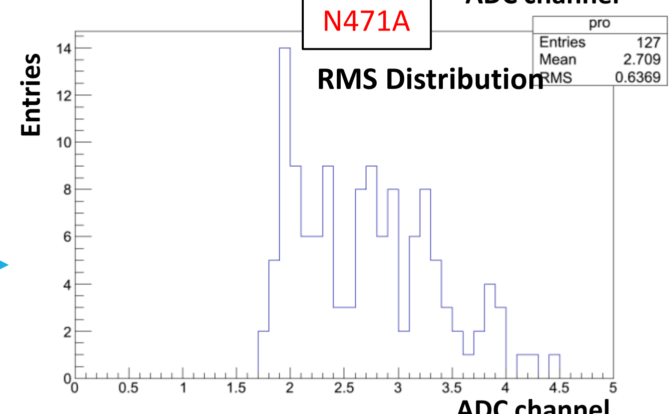
Chip 0



This exercise shows similar results between the two power supplies

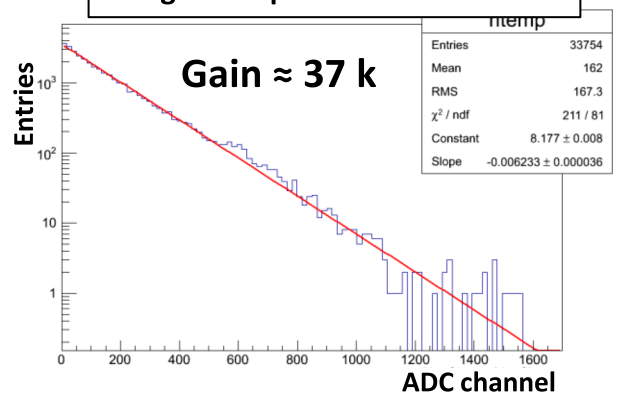


Chip 1

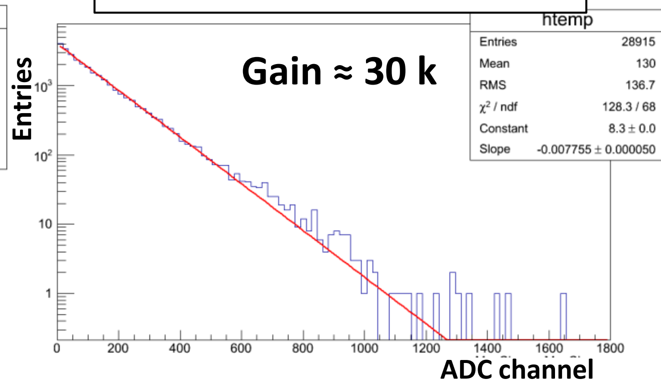


APV-First tests: different shaping time

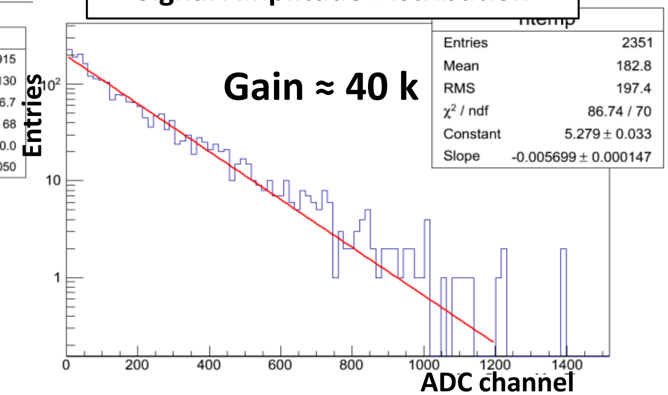
Signal Amplitude Distribution



Signal Amplitude Distribution



Signal Amplitude Distribution

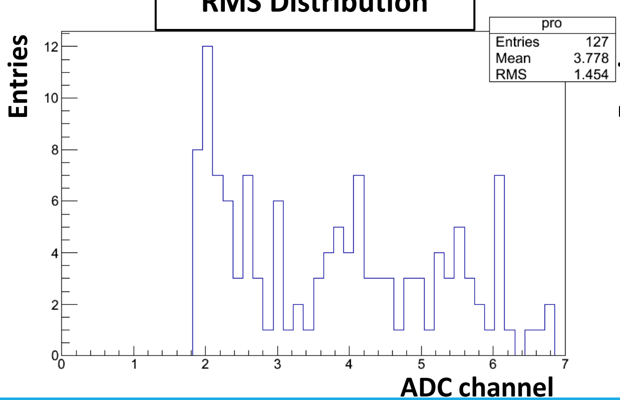


25ns shaping time

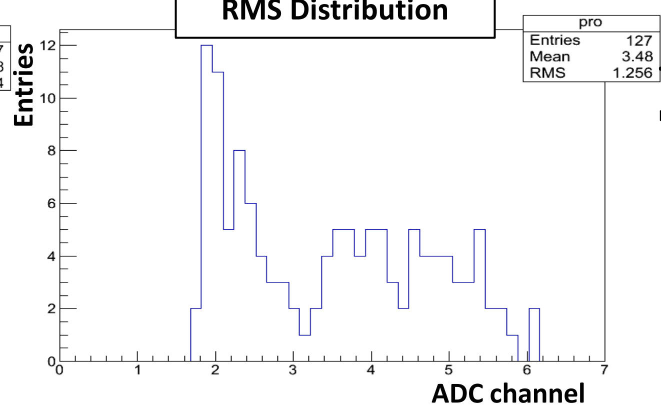
200 ns shaping time

Standard APV setting (100 ns ???)

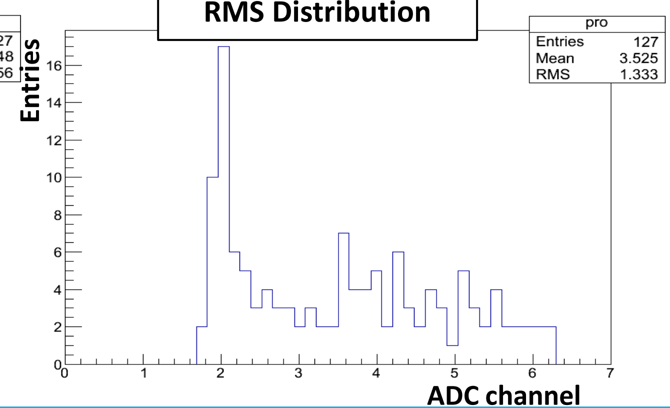
RMS Distribution



RMS Distribution



RMS Distribution



No significant effect of the shaping time in the noise RMS

APV Exercise Conclusions

- The short studies point to low noise (possible to cut at 5 x RMS = 1fC) when coupling the APV chips to the capacitive hybrid detector.
- The HV units N471A and N1471A seem to behave similarly when using the APVs as readout.
- Gain Determination through the APV readout matches the gain determined through the analogue readout (although it depends on the shaping time).
- Shaping time does not influence the RMS Distribution.

Large Area THGEMs (300 mm x 600 mm)

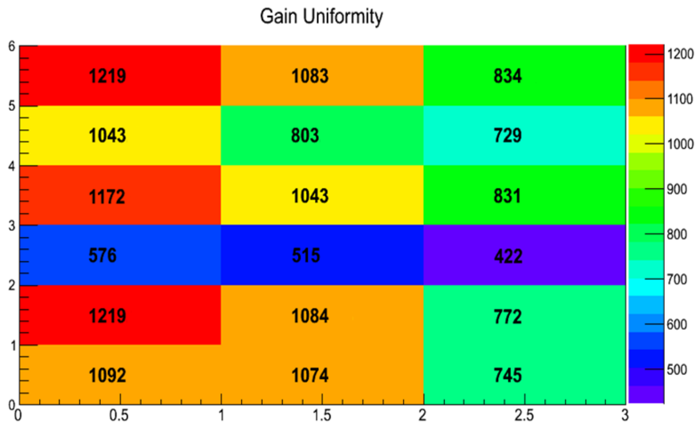
Motivation

Goal: RICH Detector with an active area of 600 x 600 mm².

30 x 30 mm² → 300 x 300 mm² → 300 x 600 mm² → 600 x 600 mm²

Thickness PCB variance as big as 15%

Gain Variance > 40%

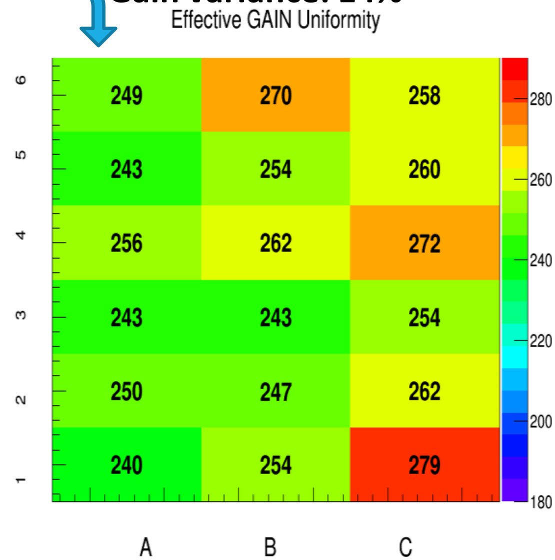


example THGEM: t = 0.8 mm; p = 0.8 mm; h = 0.4 mm

- Measure thickness of raw PCB (< 5%)
- Polish
- Ultrasonic Cleaning
- Distilled Water cleaning
- Oven @ 160 ºC

- **Higher Max ΔV**
- **More uniform gain**

Gain variance: 14%



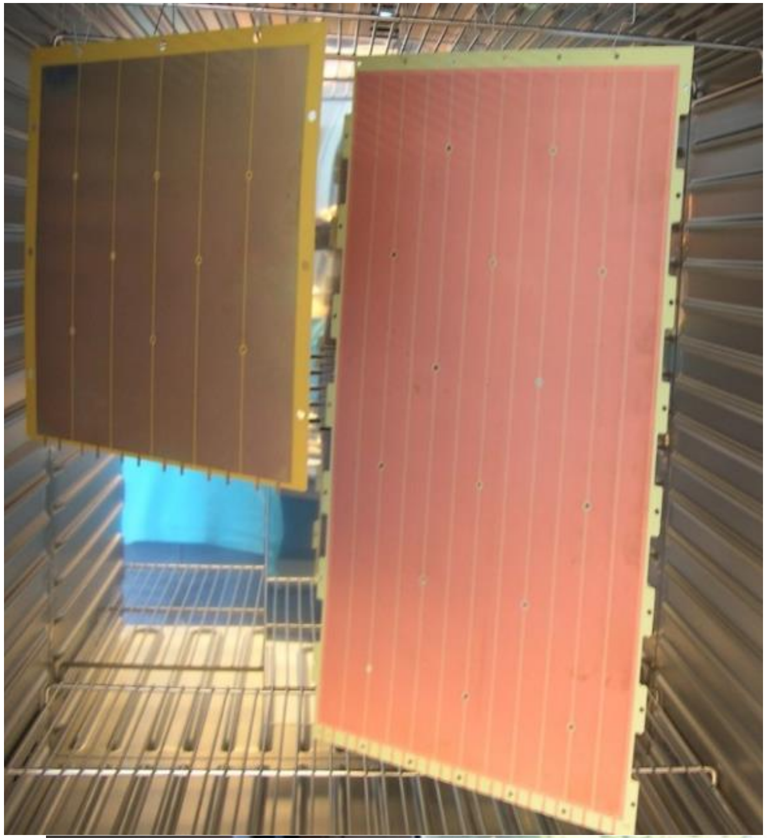
example THGEM: t = 0.4 mm; p = 0.8 mm; h = 0.4 mm

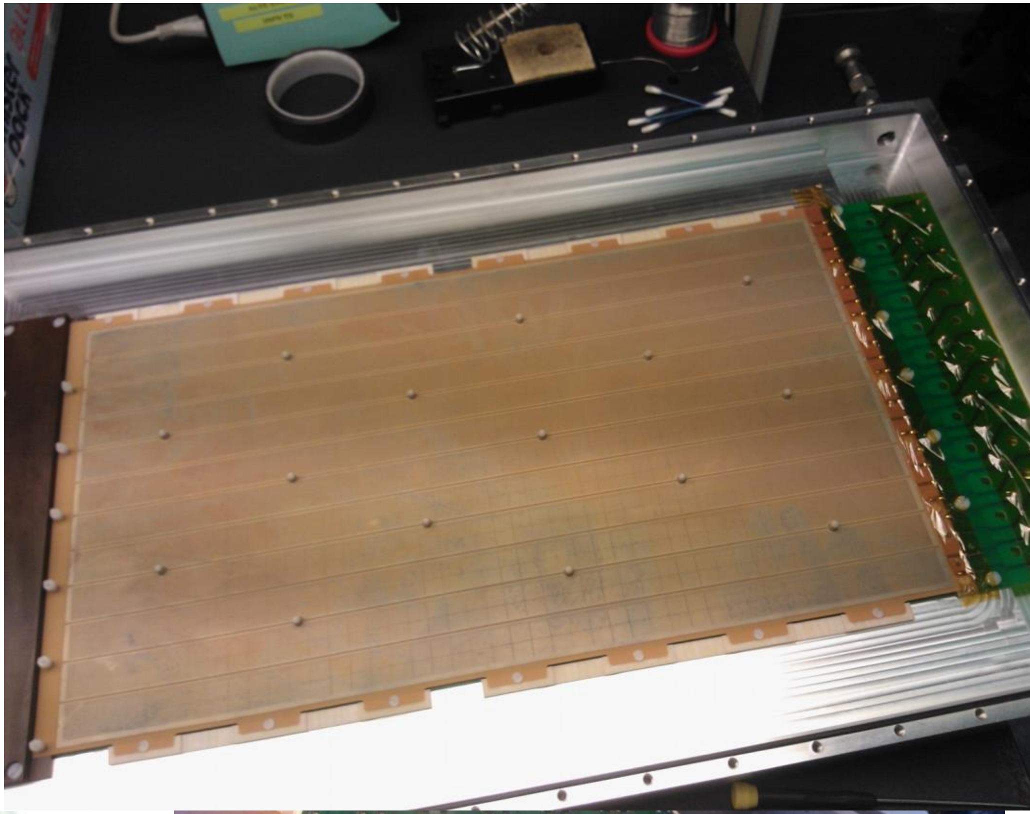
Motivation

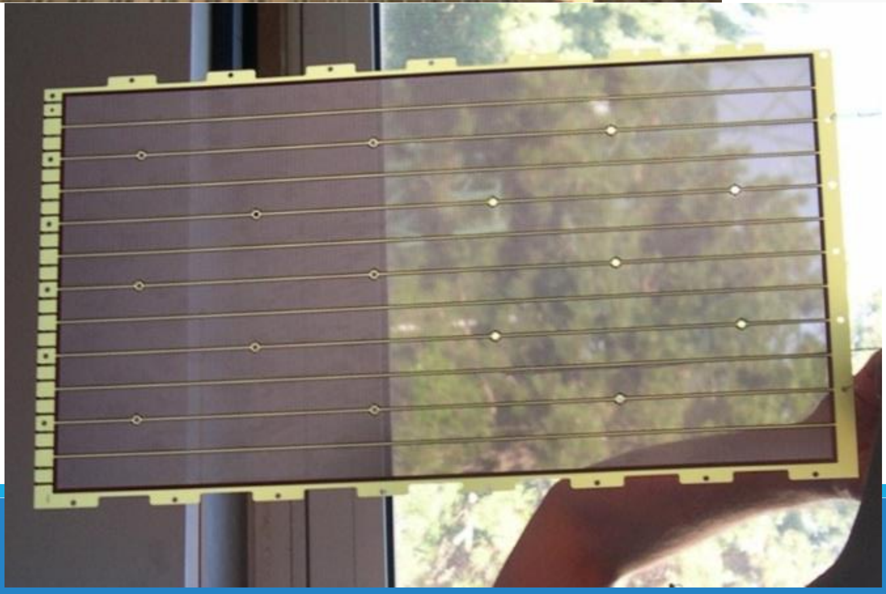
<u>Goal: RICH Detector with an active area of 600 x 600 mm^2.</u>

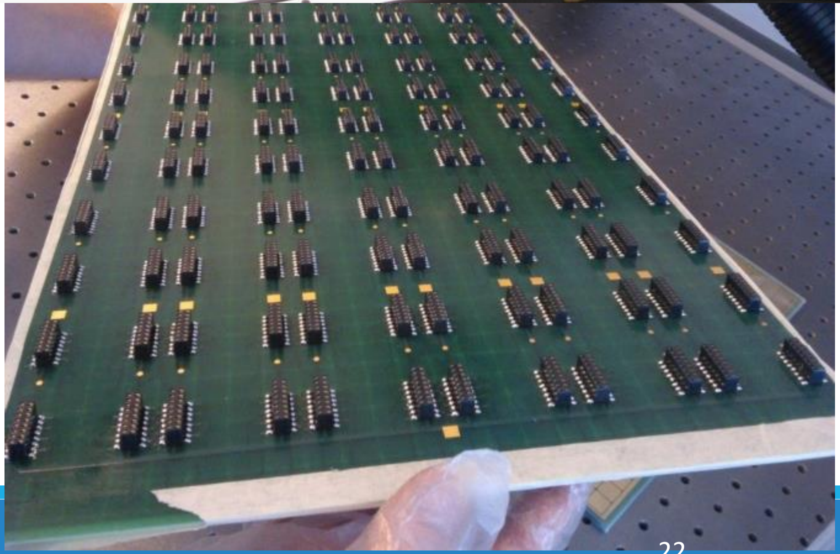
30 x 30 mm^2 → 300 x 300 mm^2 → 300 x 600 mm^2 → 600 x 600 mm^2

- **Measure thickness of raw PCB (< 5%)**
- **Polish**
- **Ultrasonic Cleaning**
- **Distilled Water cleaning**
- **Oven @ 160 ºC**
- **Gain Characterization (4 THGEMs for Characterization)**

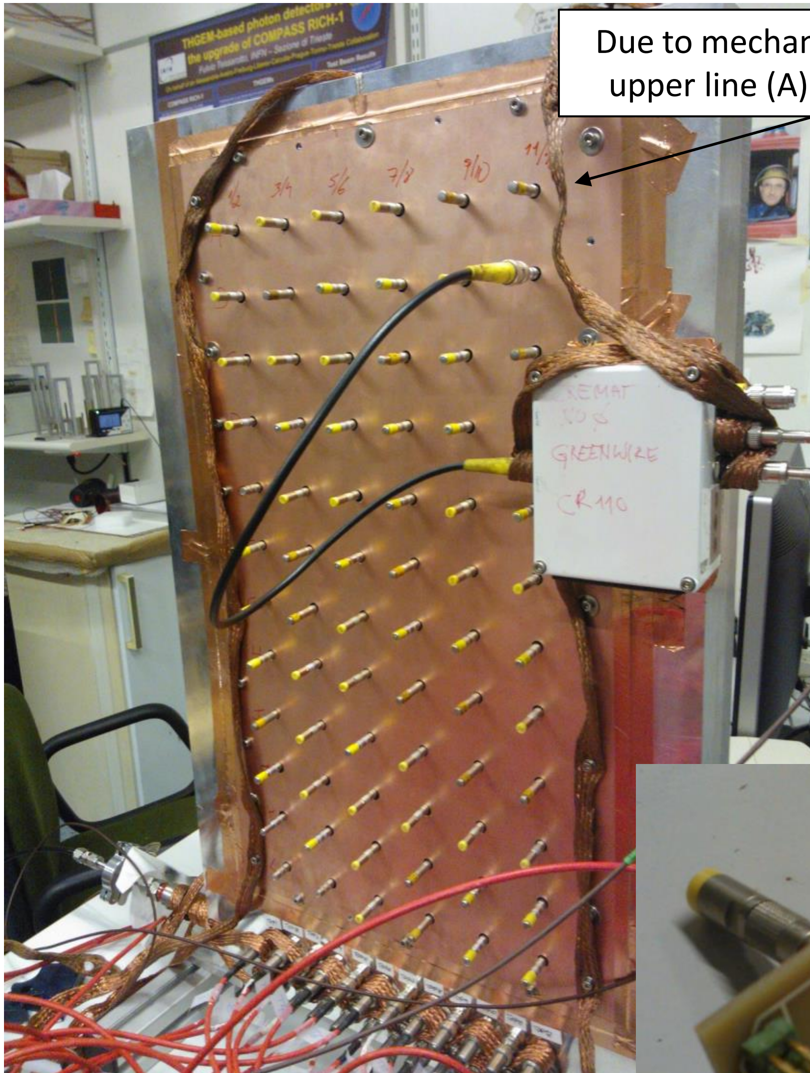


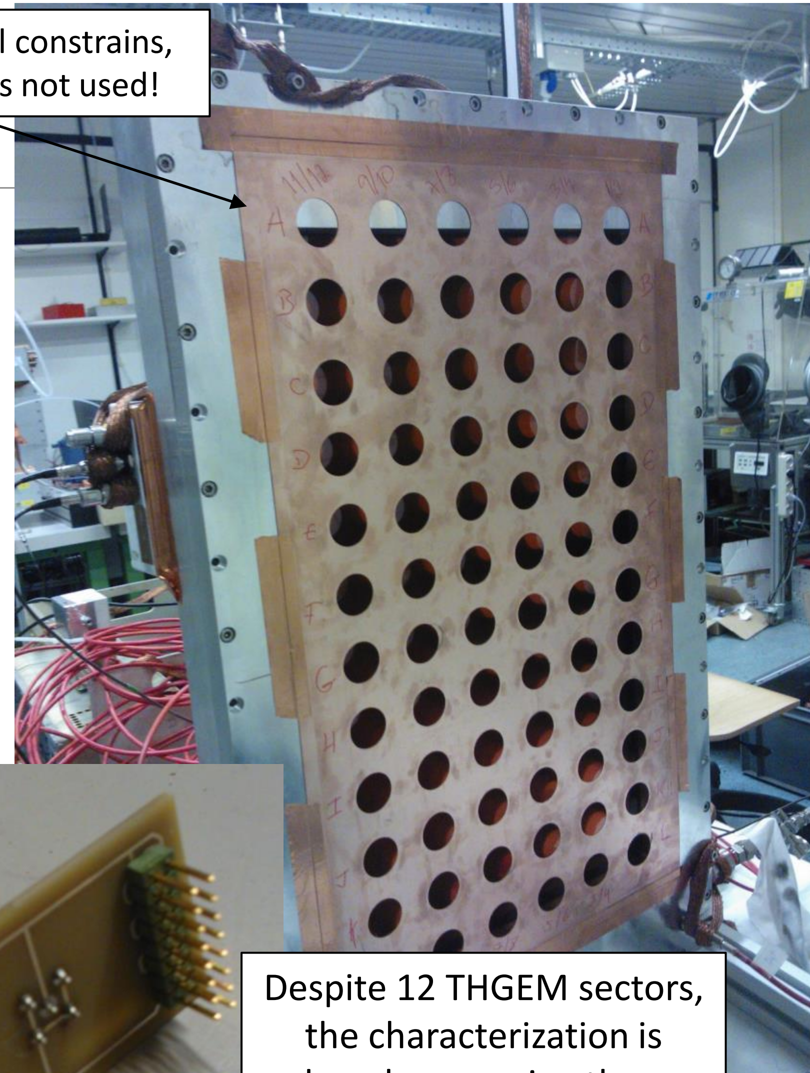


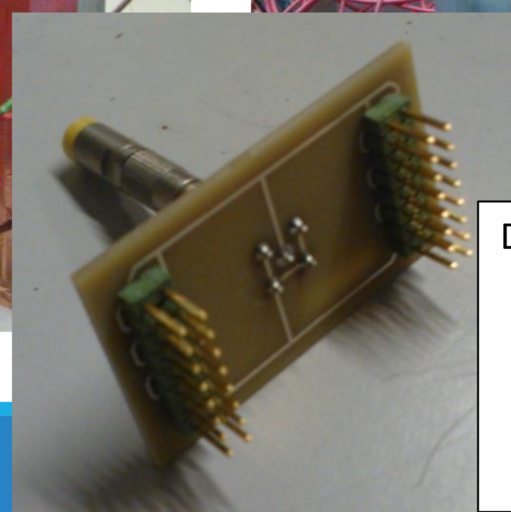




Due to mechanical constrains, upper line (A) was not used!







Despite 12 THGEM sectors, the characterization is done by grouping these sectors in groups of two, due to the design of the readout boards

Thickness #01 & #02 Respectively (units: um)

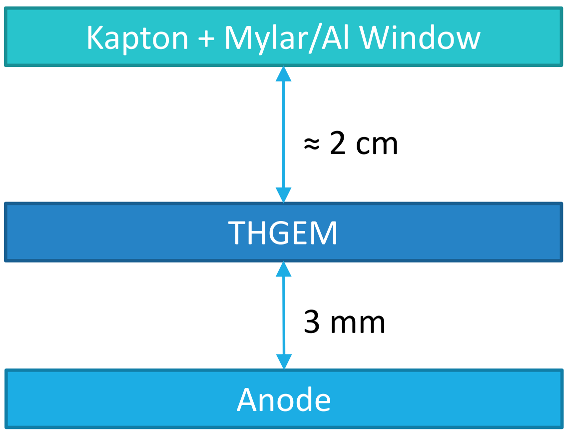
473	472	473	473	473	475	472	474	473	471	471
473	474	473	472	473	474	474	472	471	473	470
471	472	474	473	473	474	474	473	470	473	471
473	472	471	473	472	473	473	471	471	472	471
471	470	470	472	471	472	471	472	471	472	474
471	471	470	471	471	472	473	473	473	472	472
472	472	470	472	473	473	473	474	471	471	473
473	473	471	472	474	478	474	473	472	472	473
474	473	473	473	472	471	471	471	471	471	472

Isola PCB thickness variation of #F01 min 470 max 478 MAX error 1.7%

469	469	470	474	472	473	473	469	469	469
468	469	468	471	471	471	471	468	469	467
468	469	470	473	470	471	470	468	469	467
469	468	470	472	469	470	469	468	469	467
471	470	471	472	469	471	470	470	468	466
470	471	470	471	469	469	470	468	467	467
470	470	471	473	470	471	470	467	468	467
470	468	469	470	471	470	470	468	469	467
469	469	471	469	470	471	470	469	470	470

Isola PCB thickness variation of #F02 min 466 max 474 MAX error 1.7%

Setup



4 THGEM available! (#01 - #04)
Each THGEM tested: ≈ 180 spectra!!

Gas mixture: Ar/CO_2 (70:30)

Analogue readout chain: Cremat pre-amplifier (CR110) + Ortec Amplifier + Amptek MCA

E_{drift} = 1 kV/cm
$E_{induction}$ ≈ 1.5 kV/cm

Irradiation with ^{55}Fe
(Gain determination through the ^{55}Fe main peak)

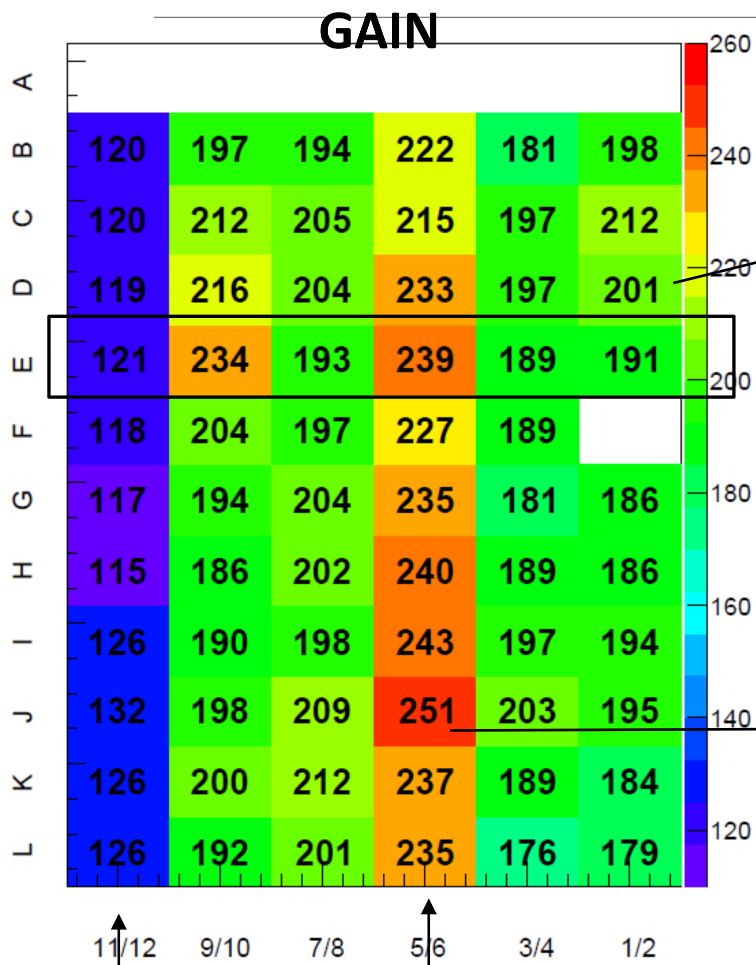
THGEM Max ΔV Summary

	#01	#02	#03	#04
Max ΔV	1310 V	1300 V	1300 V	1330 V

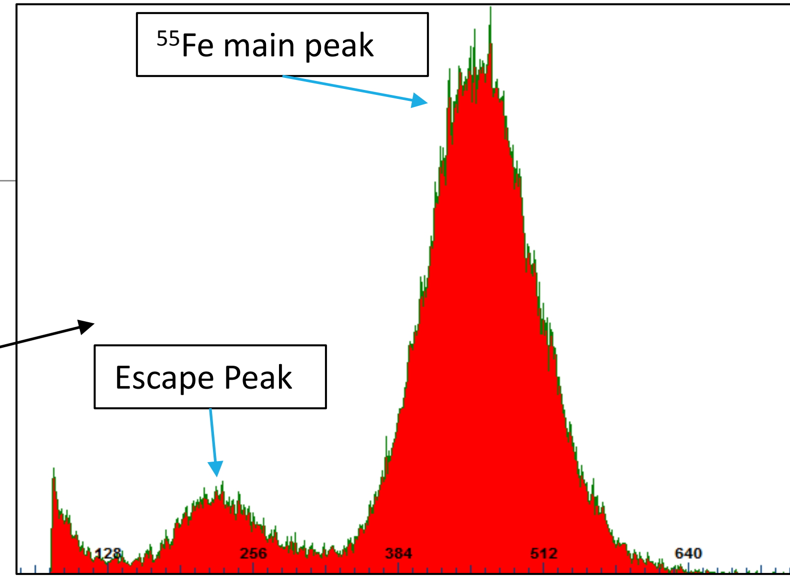
(Maximum ΔV that the THGEM can stand, in the referred gas mixture, with recoverable discharges.)

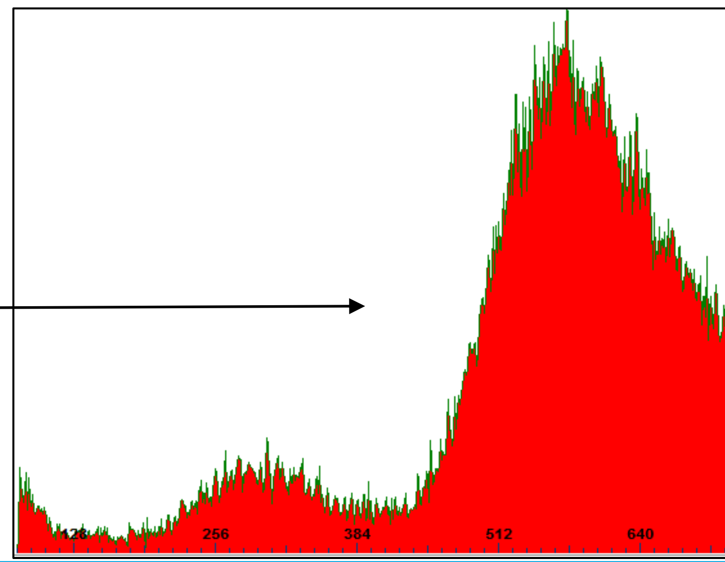
Results are comparable to the ones obtained for 300 x 300 mm^2 pieces under the same circumstances!

THGEM #01



Fixed ΔV=1300V





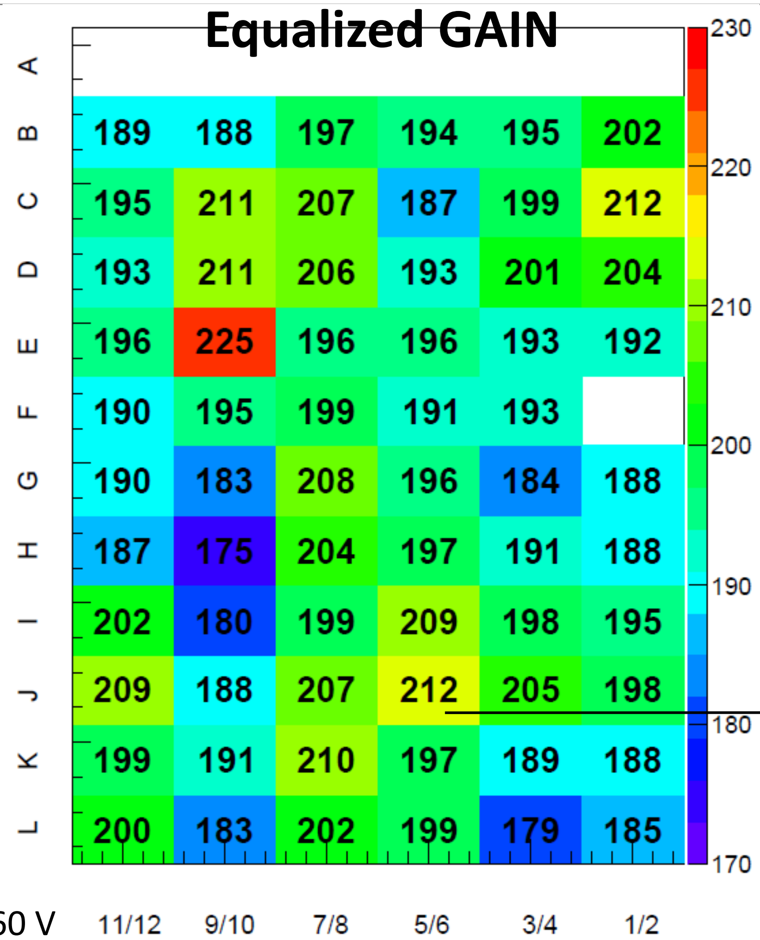
The deformation of the main peak is due to different gains of the two sectors that are measured together

Due to HV offsets → Gain equalization at 1 average sector

Gain equalization for #01

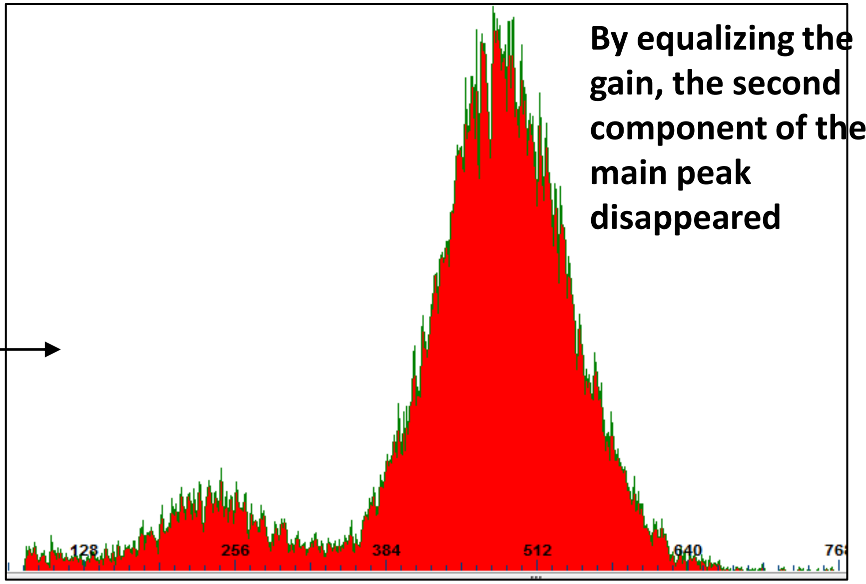
ΔV_{1E} = 1297 V
ΔV_{2E} = 1285 V
ΔV_{3E} = 1296 V
ΔV_{4E} = 1297 V
ΔV_{5E} = 1282 V
ΔV_{6E} = 1272 V
ΔV_{7E} = 1296 V
ΔV_{8E} = 1295 V
ΔV_{9E} = 1297 V
ΔV_{10E} = 1290 V
ΔV_{11E} = 1320 V
ΔV_{12E} = 1332 V

$\Delta V_{max} - \Delta v_{min}$ = 60 V



To eliminate the effect of the HV offset, the HV of each unit is tuned so that the gain along sector E is equalized at 200.

Why sector E?? It corresponds to a sector with an average gain for all vertical sectors



THGEM #01 & #02 Comparison

Equalized GAIN THGEM #01

	11/12	9/10	7/8	5/6	3/4	1/2
A						
B	189	188	197	194	195	202
C	195	211	207	187	199	212
D	193	211	206	193	201	204
E	196	225	196	196	193	192
F	190	195	199	191	193	
G	190	183	208	196	184	188
H	187	175	204	197	191	188
I	202	180	199	209	198	195
J	209	188	207	212	205	198
K	199	191	210	197	189	188
L	200	183	202	199	179	185

Color scale: 170 – 180 – 190 – 200 – 210 – 220 – 230

Gain variation: 22%

ΔV_{1E} = 1297 V
ΔV_{2E} = 1285 V
ΔV_{3E} = 1296 V
ΔV_{4E} = 1297 V
ΔV_{5E} = 1282 V
ΔV_{6E} = 1272 V
ΔV_{7E} = 1296 V
ΔV_{8E} = 1295 V
ΔV_{9E} = 1297 V
ΔV_{10E} = 1290 V
ΔV_{11E} = 1320 V
ΔV_{12E} = 1332 V

$\Delta V_{max} - \Delta v_{min}$ = 60 V

Equalized GAIN THGEM #02

	11/12	9/10	7/8	5/6	3/4	1/2
A						
B	207	215	204	221	193	213
C	205	222	212	203	203	216
D	209	242	204	202	212	203
E	198	238	202	201	208	203
F	190	208	196	193	204	
G	198	203	193	195	198	198
H	189	200	188	195	190	205
I	197	200	188	192	195	203
J	201	208	186	186	195	209
K	193	203	186	190	197	202
L	202	202	186	191	198	211

Color scale: 180 – 190 – 200 – 210 – 220 – 230 – 240 – 250

Gain variation: 23%

ΔV_{1G} = 1307 V
ΔV_{2G} = 1303 V
ΔV_{3G} = 1307 V
ΔV_{4G} = 1310 V
ΔV_{5G} = 1291 V
ΔV_{6G} = 1280 V
ΔV_{7G} = 1307 V
ΔV_{8G} = 1305 V
ΔV_{9G} = 1302 V
ΔV_{10G} = 1306 V
ΔV_{11G} = 1341 V
ΔV_{12G} = 1337 V

$\Delta V_{max} - \Delta v_{min}$ = 61 V

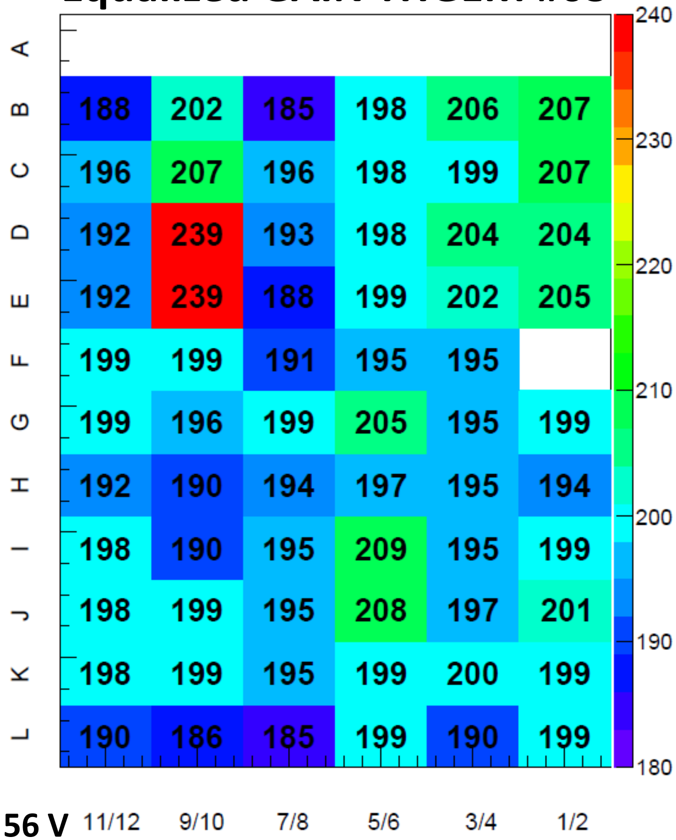
THGEM #03 & #04 Comparison

Gain variation: 23%

ΔV_{1H} = 1308 V
ΔV_{2H} = 1302 V
ΔV_{3H} = 1309 V
ΔV_{4H} = 1310 V
ΔV_{5H} = 1296 V
ΔV_{6H} = 1283 V
ΔV_{7H} = 1306 V
ΔV_{8H} = 1306 V
ΔV_{9H} = 1305 V
ΔV_{10H} = 1306 V
ΔV_{11H} = 1339 V
ΔV_{12H} = 1336 V

$\Delta V_{max} - \Delta v_{min}$ = 56 V

Equalized GAIN THGEM #03

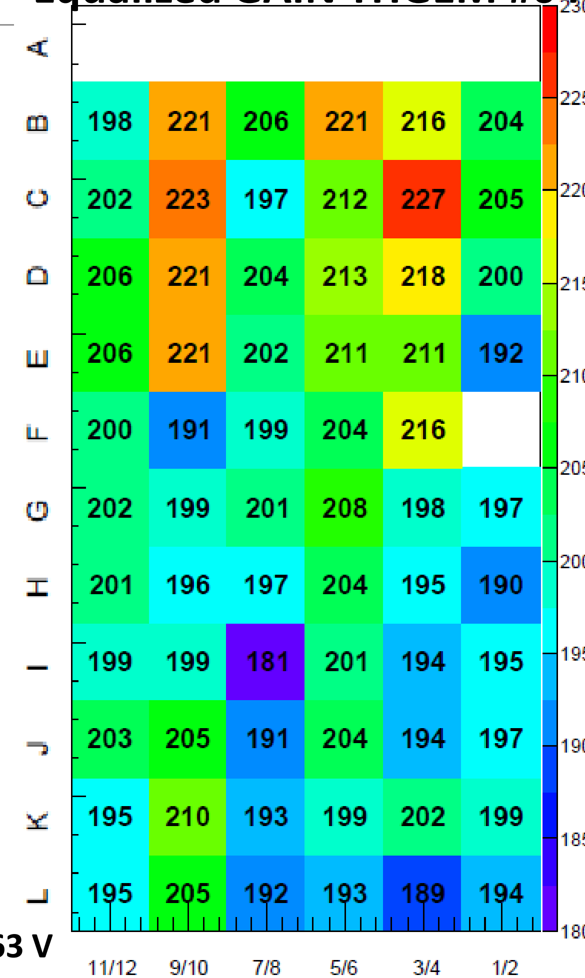


Gain variation: 20%

ΔV_{1G} = 1301 V
ΔV_{2G} = 1293 V
ΔV_{3G} = 1303 V
ΔV_{4G} = 1308 V
ΔV_{5G} = 1291 V
ΔV_{6G} = 1275 V
ΔV_{7G} = 1303 V
ΔV_{8G} = 1301 V
ΔV_{9G} = 1298 V
ΔV_{10G} = 1302 V
ΔV_{11G} = 1338 V
ΔV_{12G} = 1336 V

$\Delta V_{max} - \Delta v_{min}$ = 63 V

Equalized GAIN THGEM #04



Large Area THGEMs Conclusions

- 300 x 600 mm^2 THGEMs present an approximately equal behaviour to its predecessor (300 x 300 mm^2).
- All pieces have maximum gain in the same point → Anode problem?! → gain variance, not taking these points into account, for THGEM #01, #02 and #03 is respectively: 17%; 11%; 16%.
- These Studies show that we are in the right track and further studies can be performed.

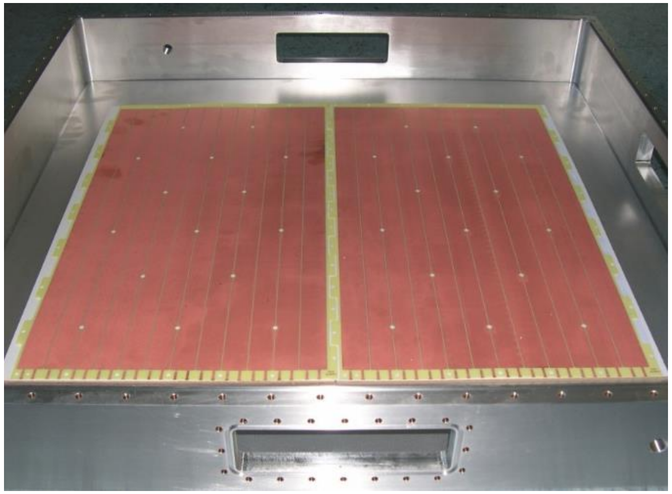
Conclusion and next steps

30 x 30 mm^2 → 300 x 300 mm^2 → 300 x 600 mm^2 → 600 x 600 mm^2

- N raw
  P
- P
- U
- D ng
- C
- G
- **Operation in Hybrid mode with single THGEM**
- **Operation in Hybrid mode with double THGEM**

Future Work

30 x 30 mm^2 → 300 x 300 mm^2 → 300 x 600 mm^2 → 600 x 600 mm^2



example THGEM: t = 0.8 mm; p = 0.8 mm; h = 0.4 mm

End

Thanks for your attention