R&D on gas TPCs for the e^+e^- tracker

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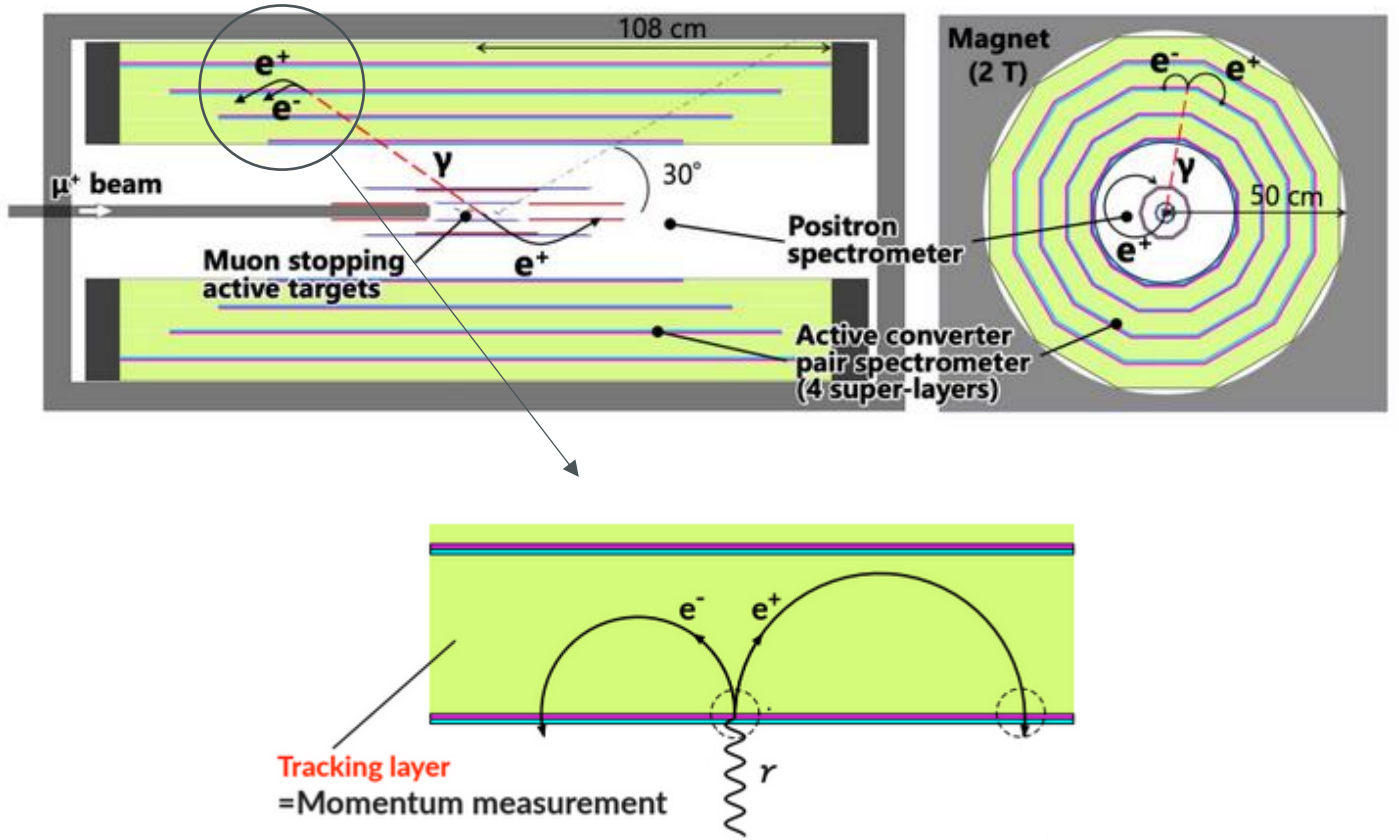
COMPACT LIGHT TRACKER FOR e^+e^- PAIRS

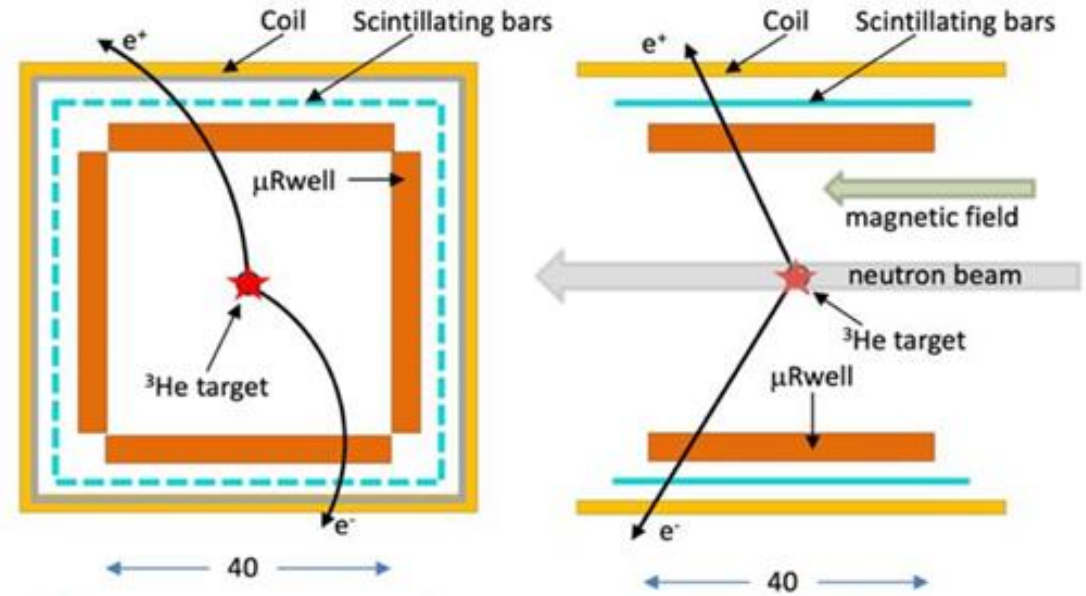
A compact, light tracker could be used in future **μ → e γ experiments**, with **pair conversion approach** to reconstruct the photon



COMPACT LIGHT TRACKER FOR e^+e^- PAIRS

The n_TOF collaboration is developing a tracker that will be used in an experiment to probe the existence of the **X17 boson**

- similar detector features with the one interesting for future μ → e γ experiments. We can:
  - → investigate the readout system
  - → improve the data analysis
  - → use data to tune and validate simulation results



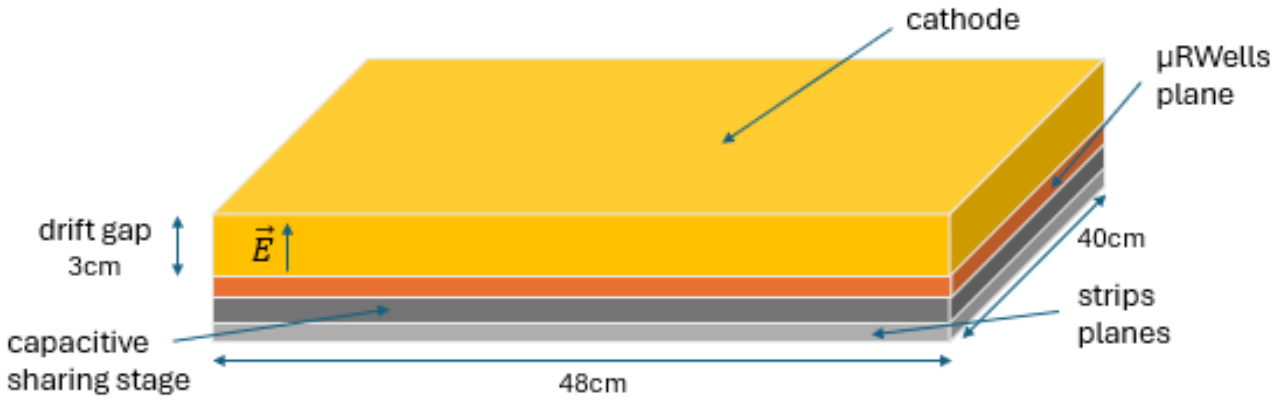
Study of the relative angle of the e^+e^- pairs coming from the nuclear reaction

$$^3He(n, e^+e^-)\,^4He$$

TPC DEMONSTRATOR

TPC demonstrator:

- drift gap = 3cm
- gaseous mixture Ar:CO2 (70:30)
- μRWELLs multiplication stage
- capacitive-sharing stage
- 2 readout planes of orthogonal strips with 1.2mm pitch
- $v_{drift} \sim 6.5 cm/\mu s$

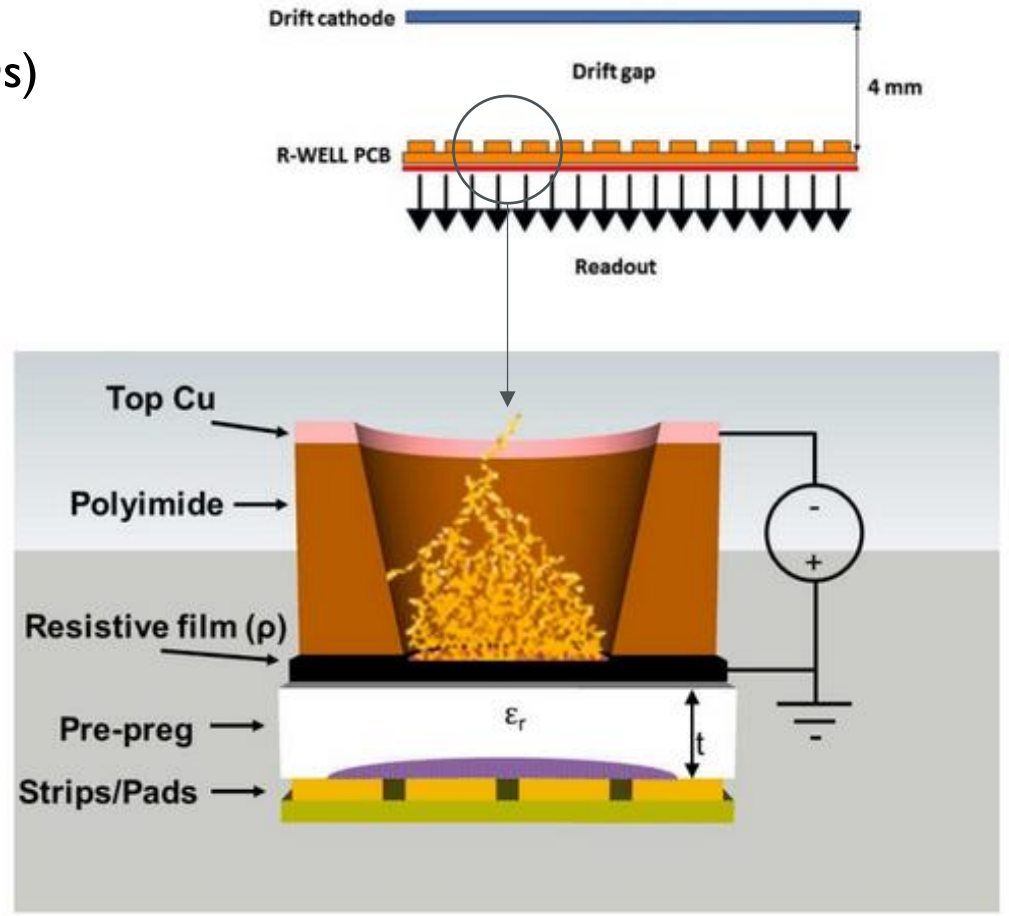


MICRO RESISTIVE WELLS (µRWELLs) readout

µRWells are Micro Pattern Gaseous Detectors (MPGDs) with a resistive anode:

- the multiplication of the drifted electrons takes place in the Well due to the high electric field
- the **resistive layer** locally drops the electric field to prevent breakdowns in high-rate environments
- the signal is capacitively induced on strips or pads for the readout

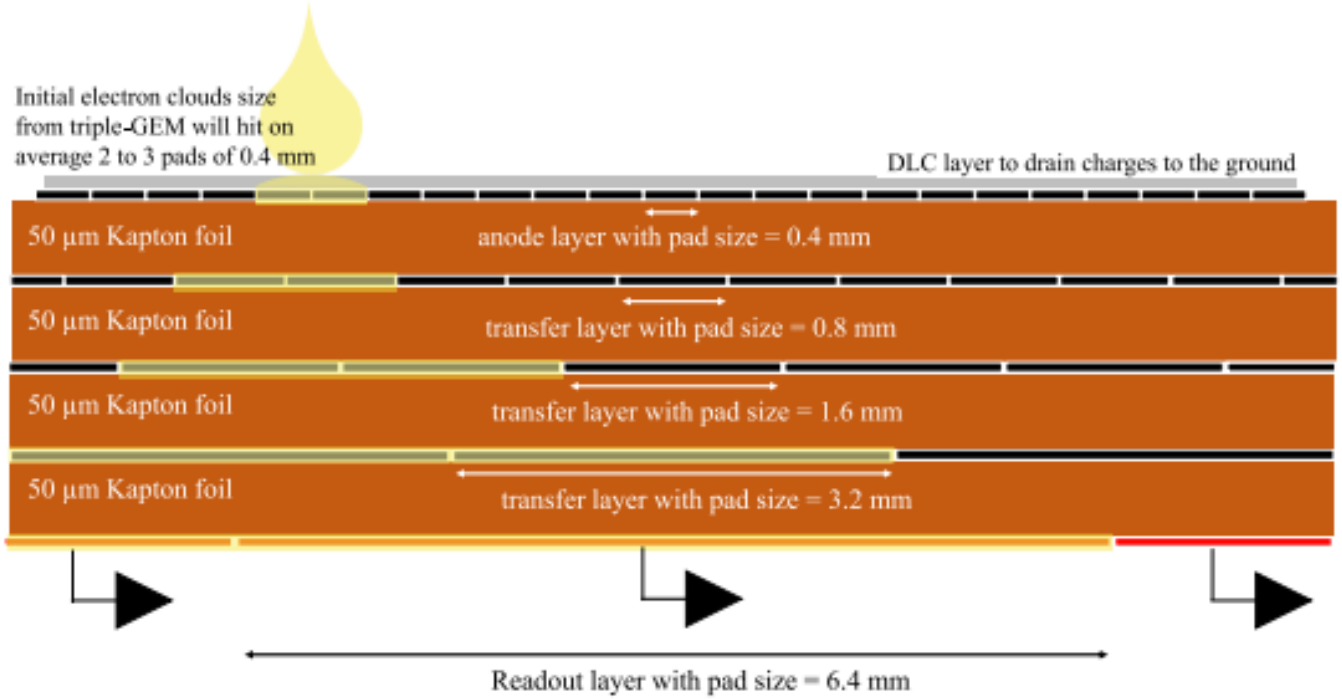
- low material budget detector
- easy assembly procedure and scalability



CAPACITIVE-SHARING STAGE

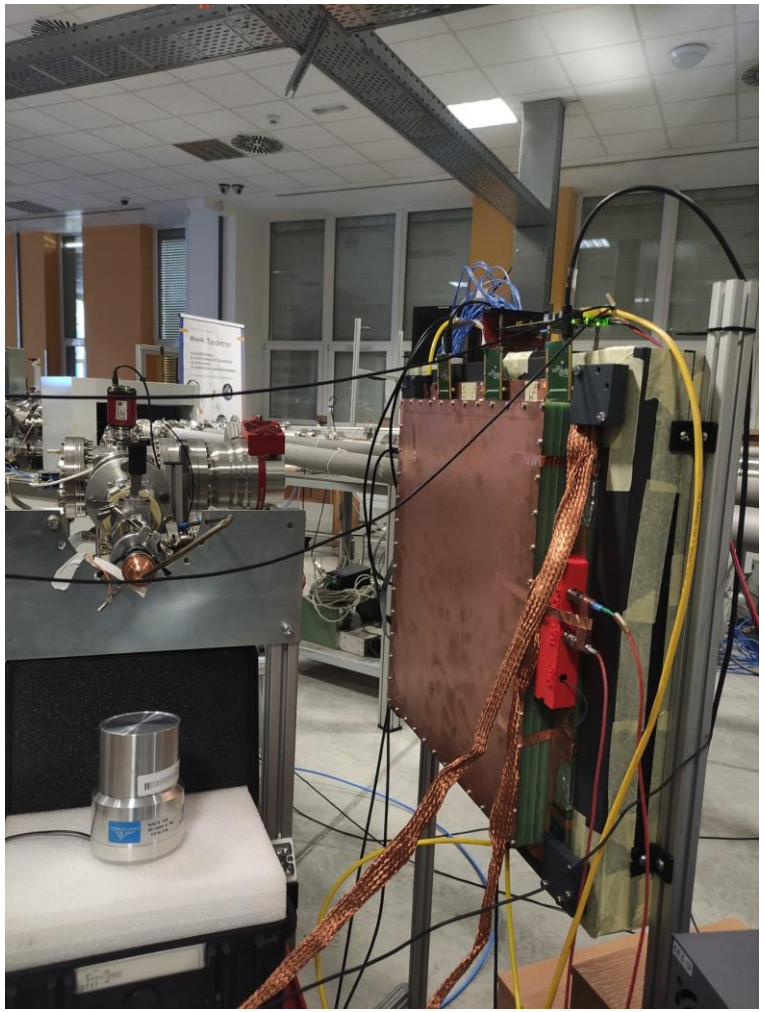
- Several layers, each one composed by copper pads deposited on an insulating material
- The pads' size doubles from one layer to the layer underneath
- The signal propagates vertically at nearly the speed of light via capacitive coupling through the transfer layers

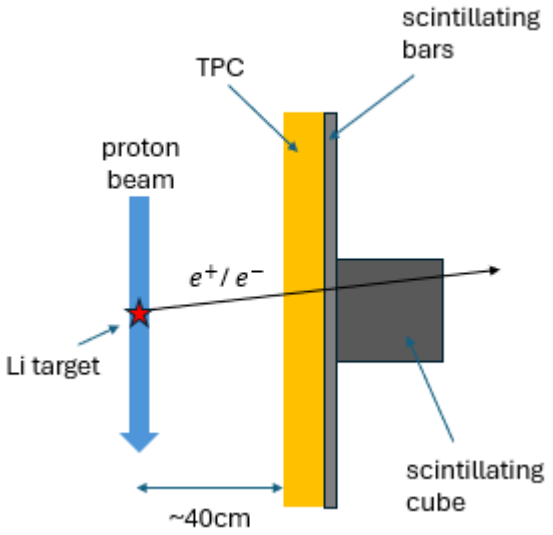
→ spread of the charge on a higher number of readout channels

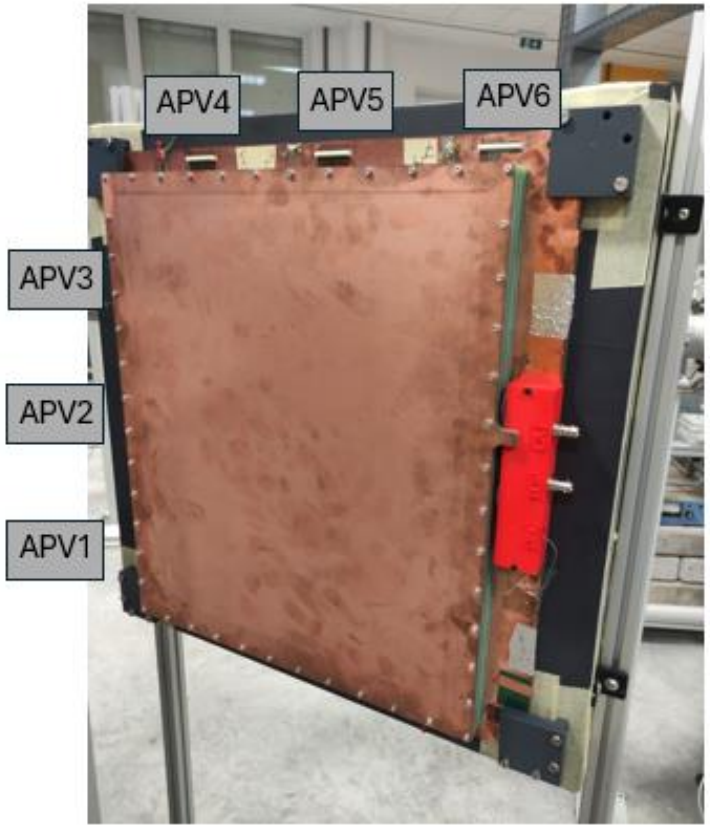


→ **reduction** of number of **readout channels**
→ **improved position resolution**

TEST BEAM @ ATOMKI LAB (DEBRECEN)



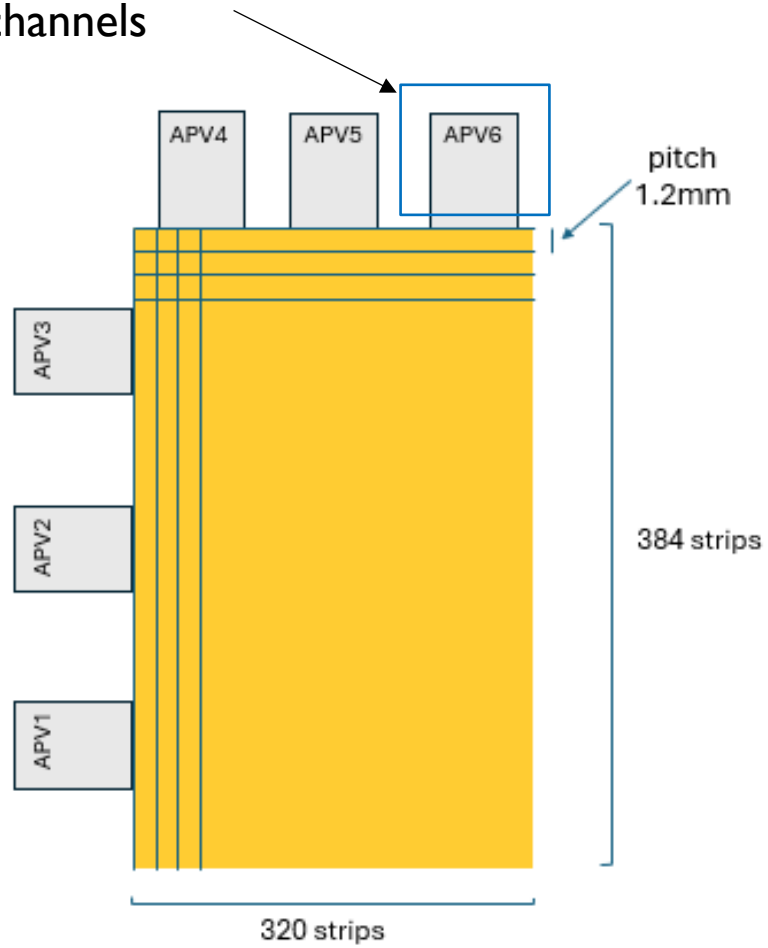


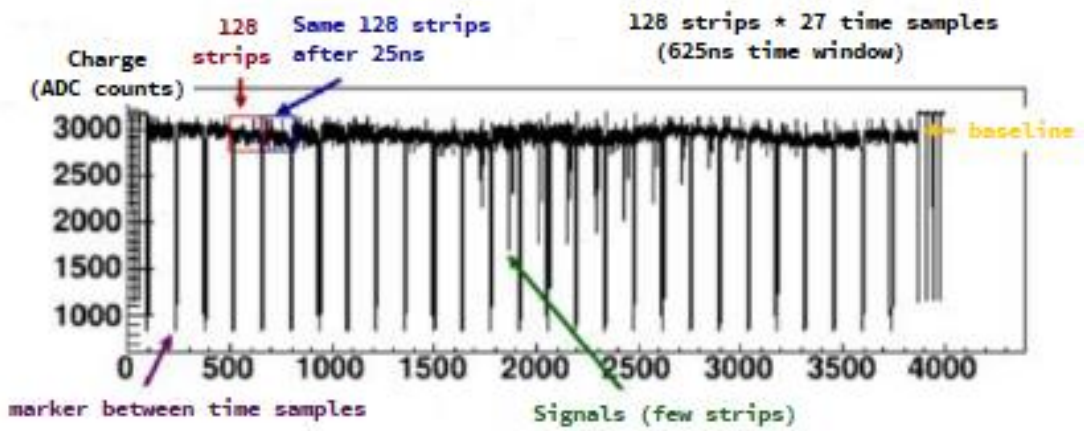


6 APV25s for the readout, each with 128 channels

APV25 CHIPS

APV6 reads only
64 channels





- The charge on each strip is collected by the connected APV channel, amplified and continuously sampled every 25ns
- 27 samples for each channel are acquired for each trigger
- the acquisition window lasts 25ns × 27 = 625ns
- the number of samples can be increased up to 192, to reach an acquisition window of 25ns × 192 = 4800ns

RESULTS OF THE ANALYSIS PERFORMED ON THE TEST BEAM DATA

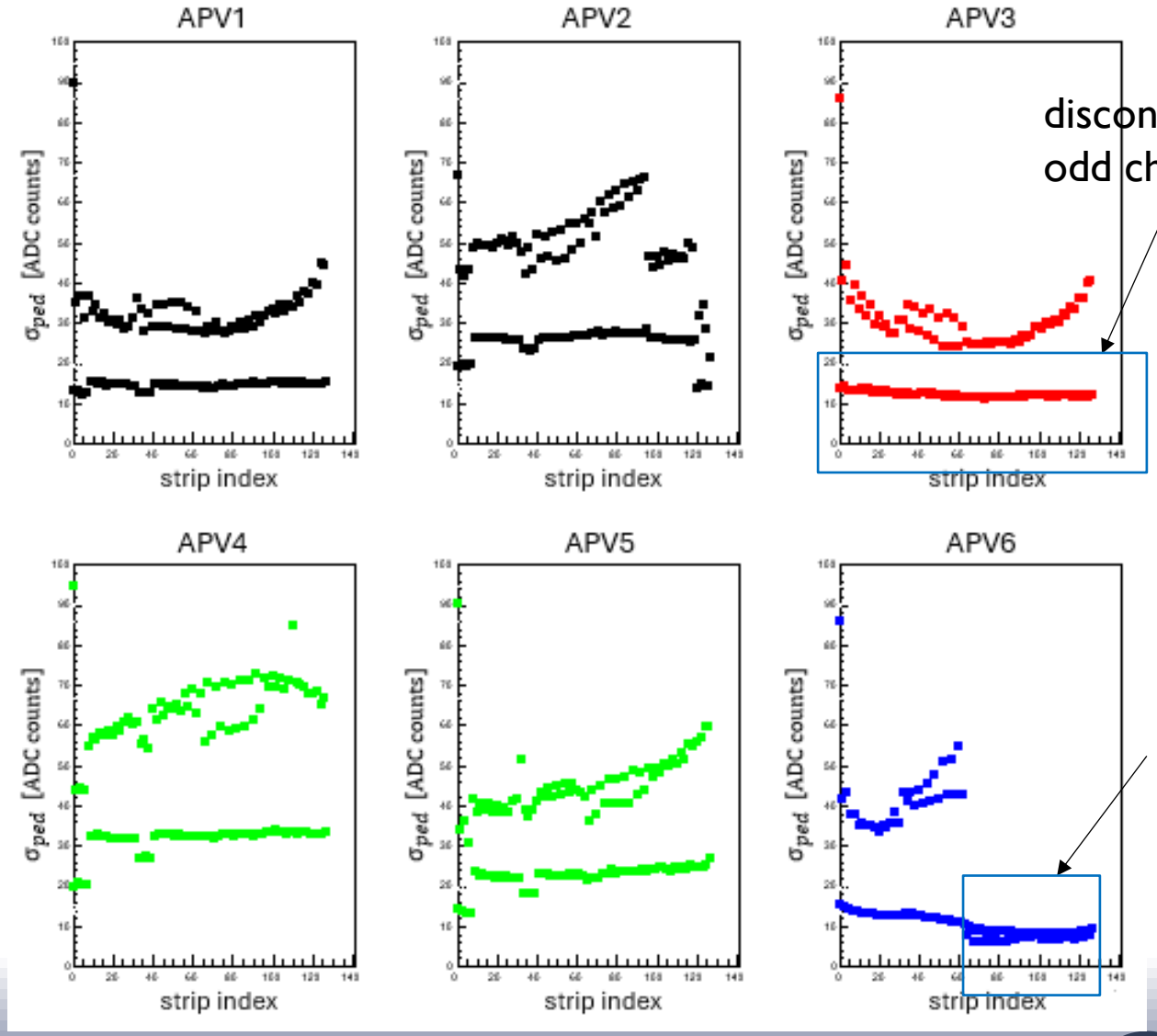
DATA ANALYSIS

From runs without the beam (pedestal runs) the rms σ_{ped} of each channel of each APV are extracted

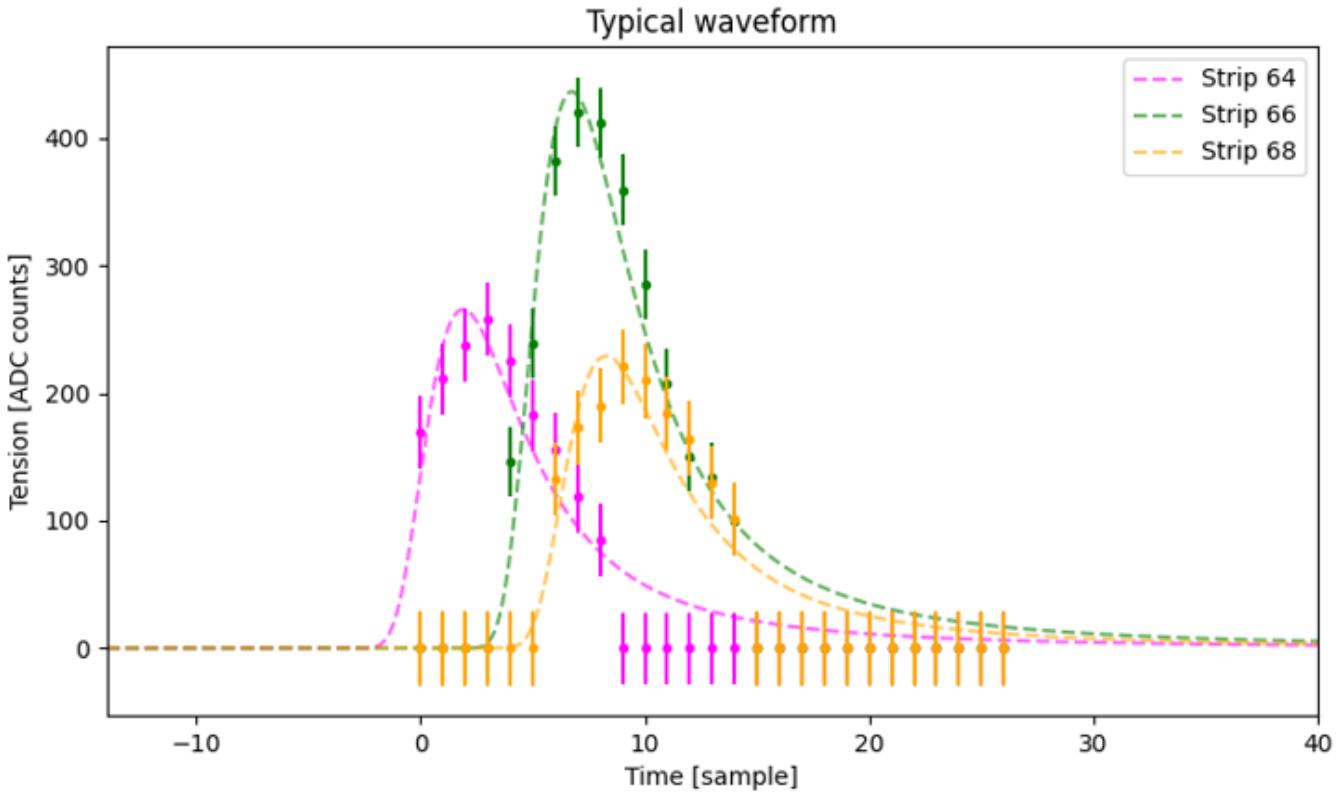
- because of a **manufactory defect**, **half of the strips** (the odd ones) are actually **disconnected** from the readout pins where the APVs are attached, both in the horizontal and vertical directions

→ lower and almost constant σ_{ped}

→ actual **pitch** of **2.4mm**



DATA ANALYSIS



Typical waveforms after noise subtraction and suppression of the noisy channels:

- signals fitted with an empirical function
- from the fit:
  - t_{start} : first time the fitting function crosses half the maximum voltage
  - V_{max} : peak height
- cut on signals with first sample !=0
  $V_0 > 0.8 * V_{max}$
- cut on signals with $\chi^2 > 8.0$

DATA ANALYSIS

Distribution of hit times t_{start}

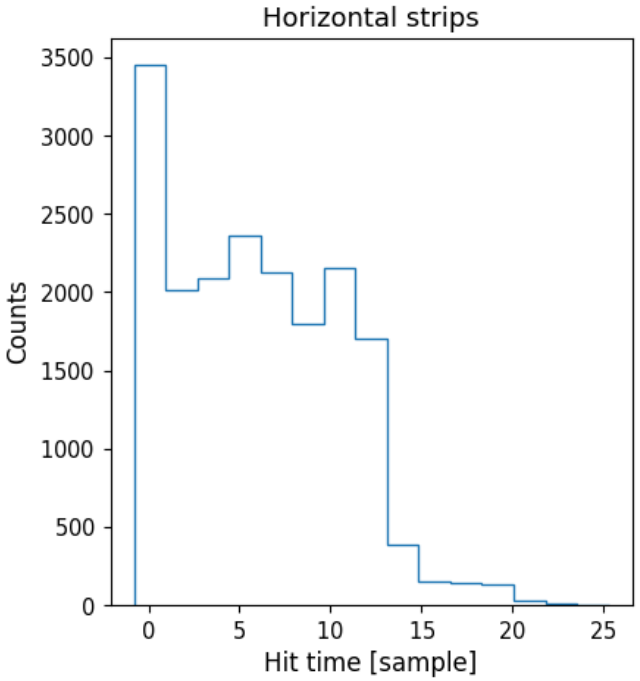
The drift time of electrons ionized near the cathode is:

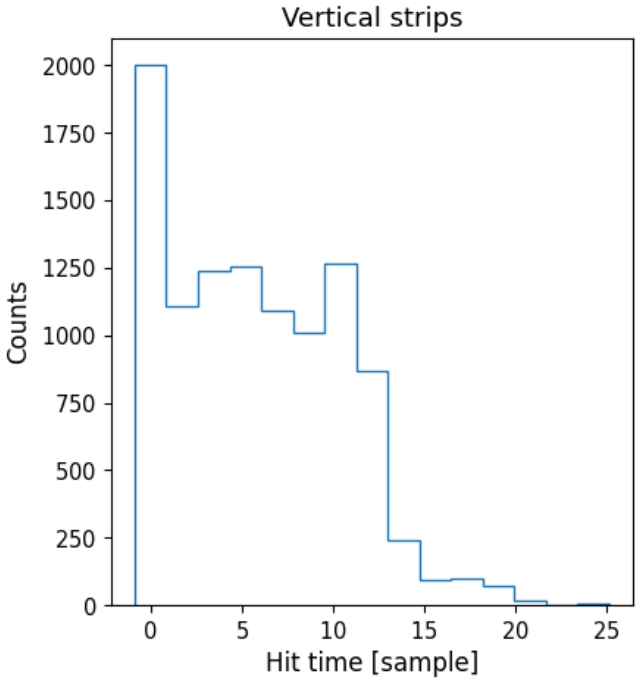
$\Delta t_{drift} \sim 460ns \sim 18$ samples

+ each signal lasts: $\Delta t_{signal} \sim 10$ samples

→ **misplacement** of the **acquisition window:** loss of hits produced within ~ 0.7cm from the readout plane

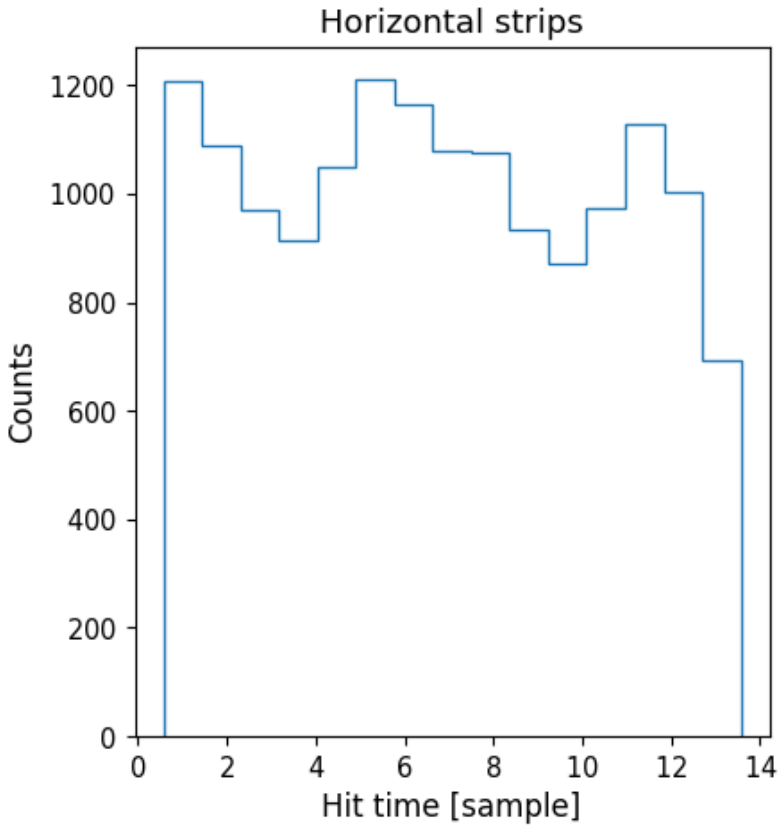
- cut on $t_{start} > 14$: noise or signals not related to the crossing particle of interest
- cut on $t_{start} < 1$: signals in which the first part of the waveform is not recorded

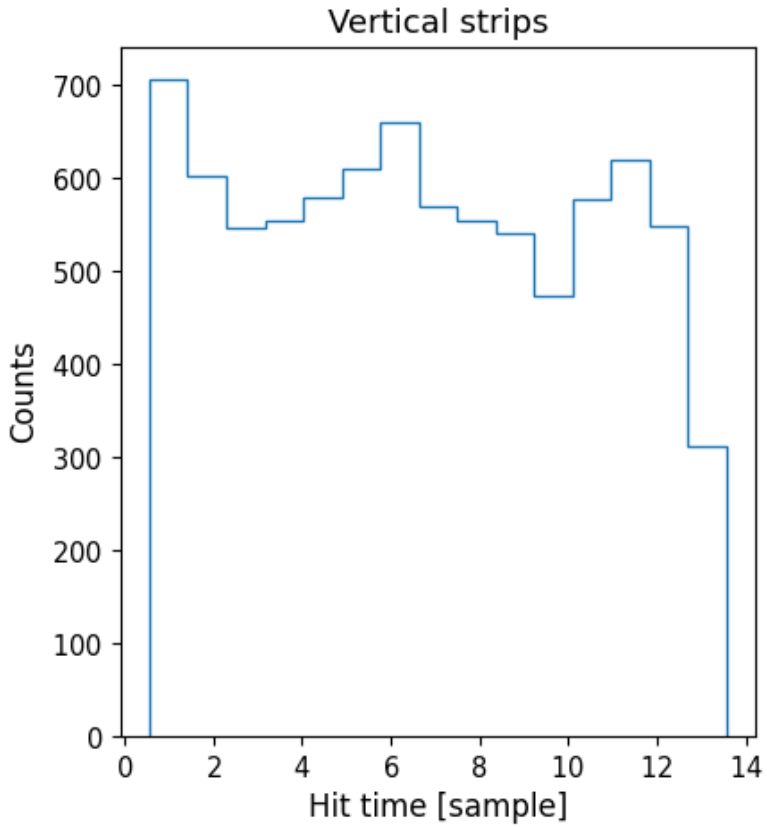




DATA ANALYSIS

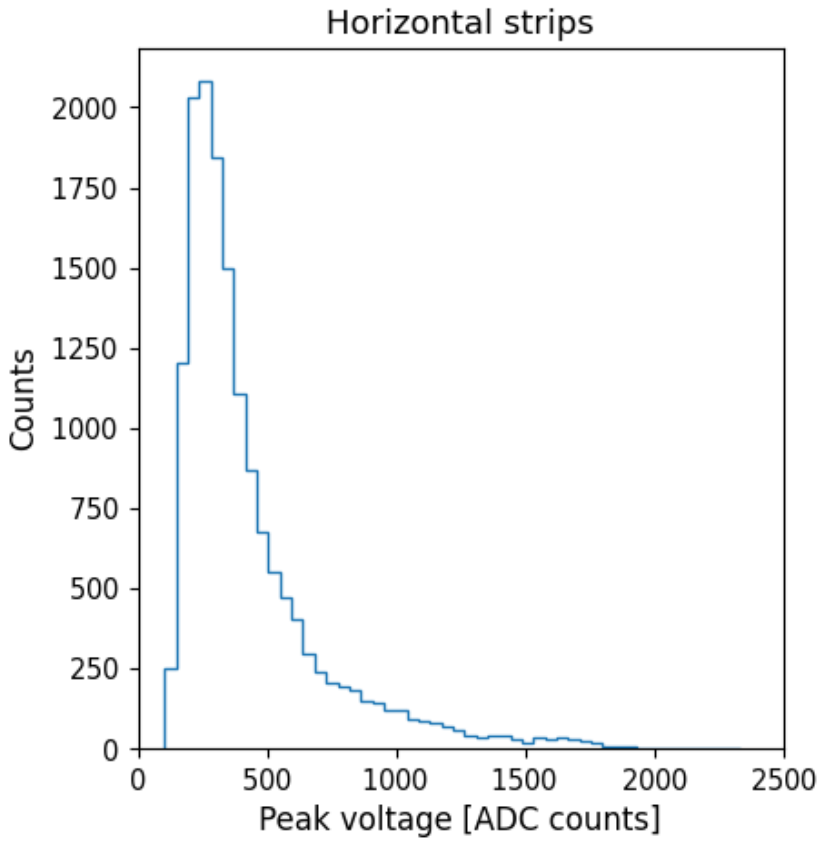
Distribution of hit times t_{start} after final cuts

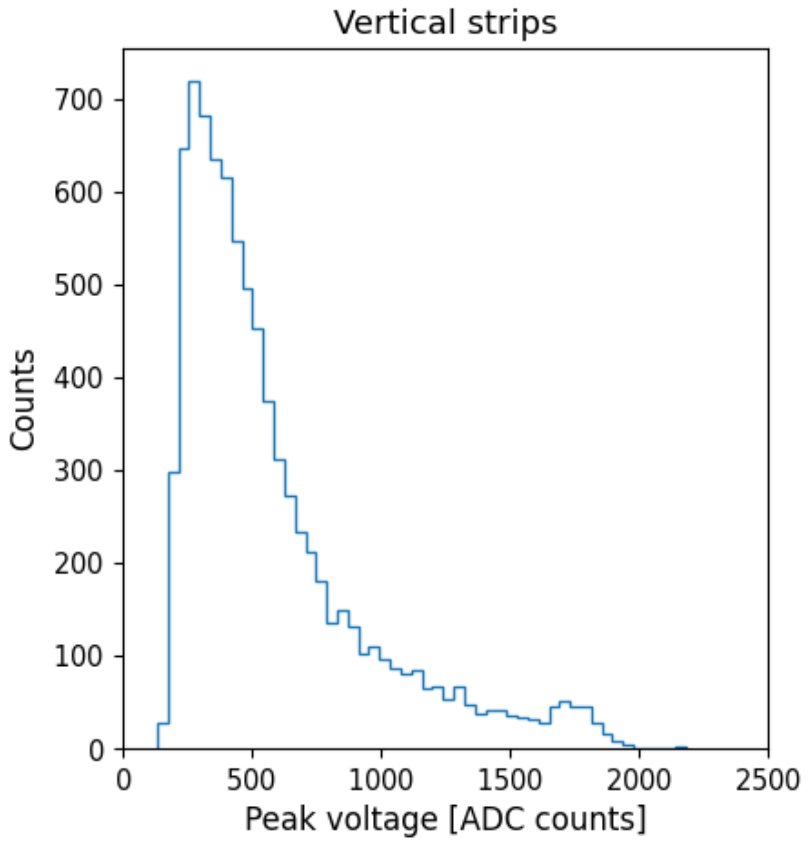




DATA ANALYSIS

Distribution of peak heights V_{max}





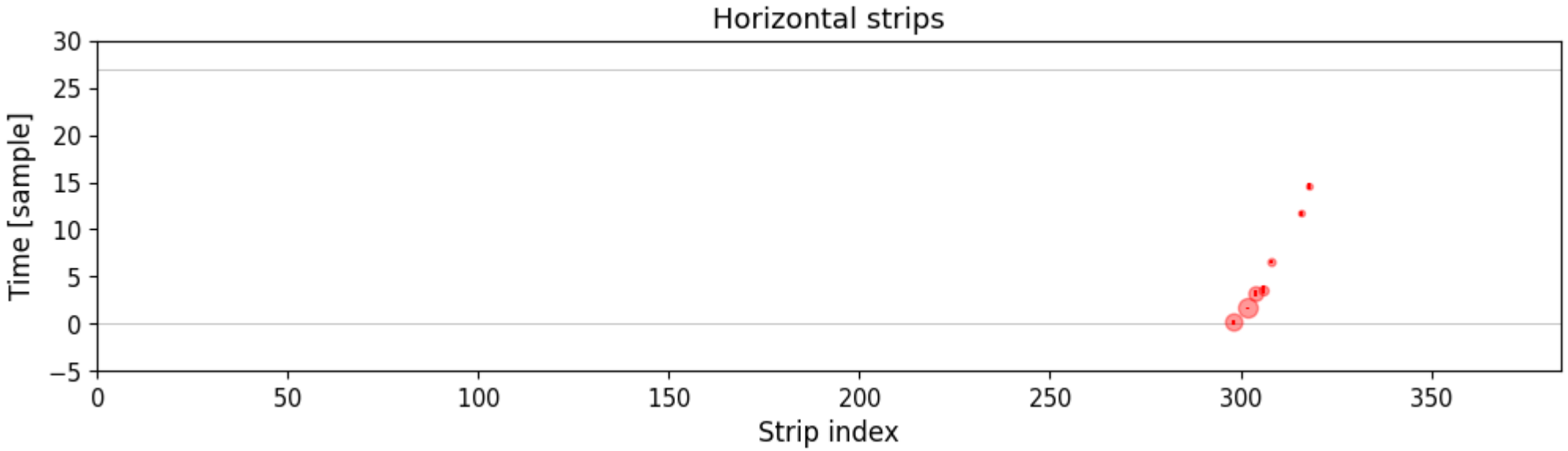
Mean of the peak amplitudes after discarding 30% of the signals in the high voltage tails:

- horizontal:
  V_{max} = 286 ADC counts
- vertical:
  V_{max} = 390 ADC counts

→ **optimizations needed** to achieve a similar response from the two layers

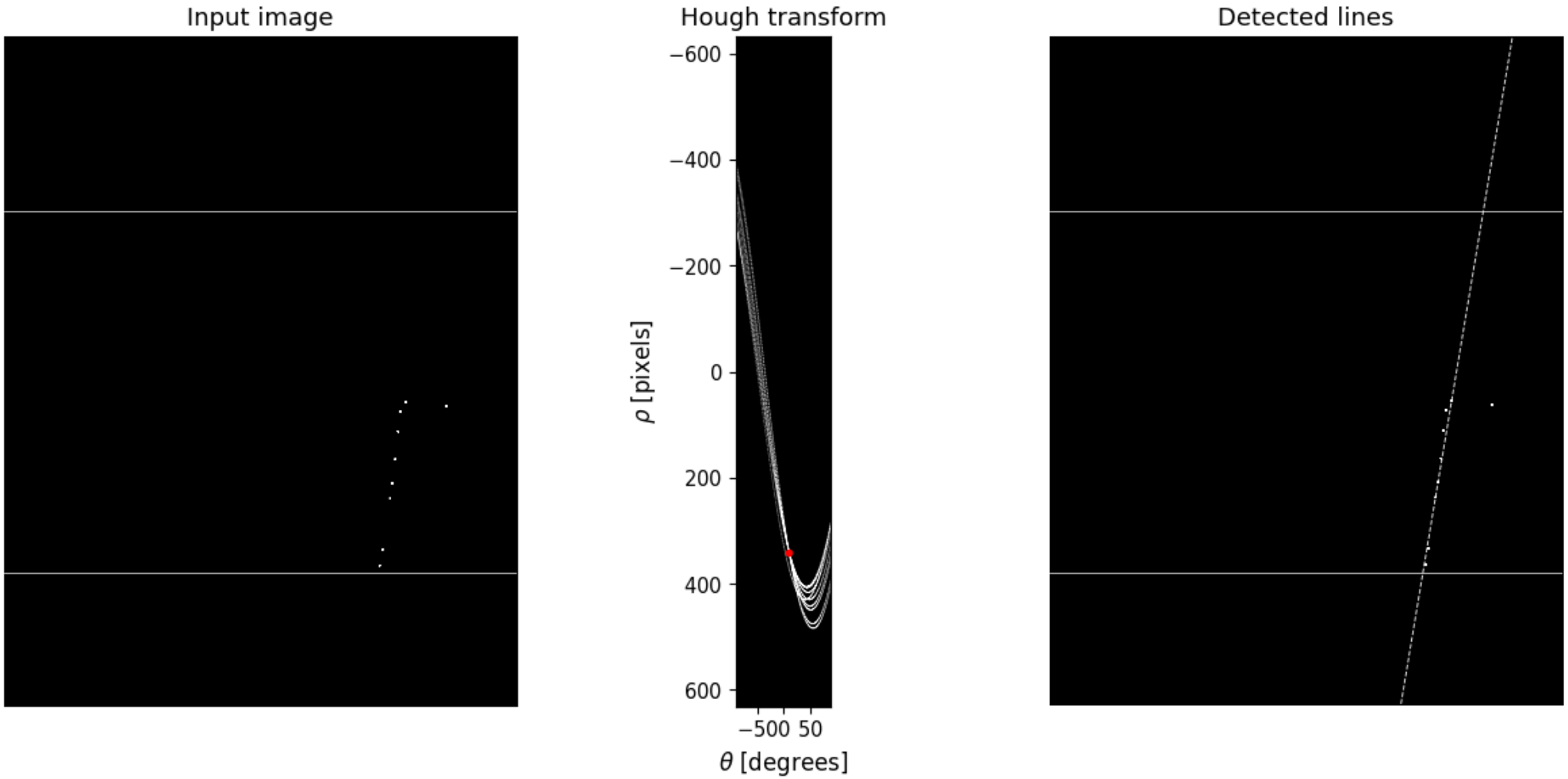
DATA ANALYSIS

Example of reconstructed hits
(size of the dots proportional to V_{max})



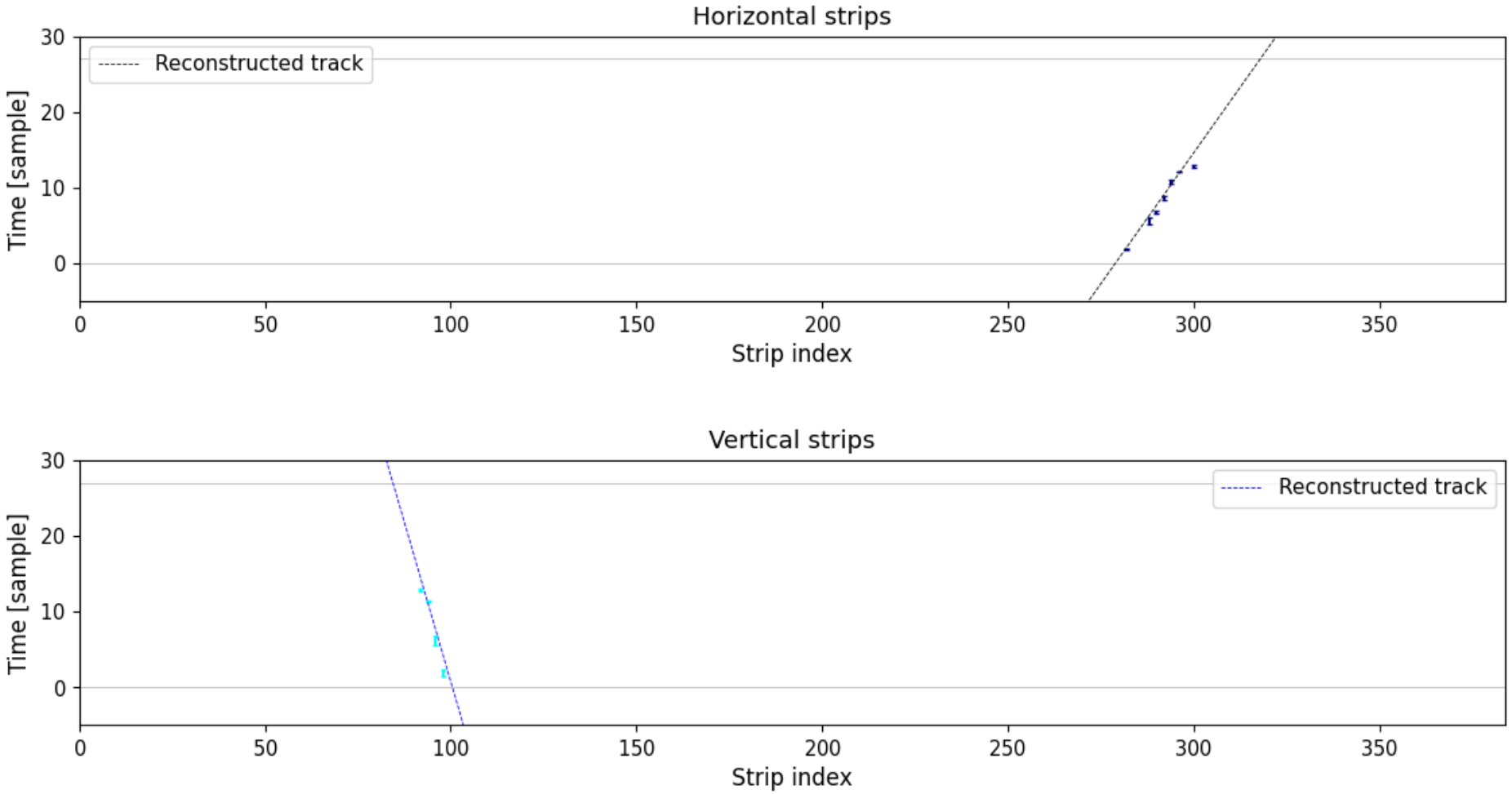
DATA ANALYSIS

Hough transform to clusterize the hits (line parametrization: $\rho = x \cos\theta + y \sin\theta$)



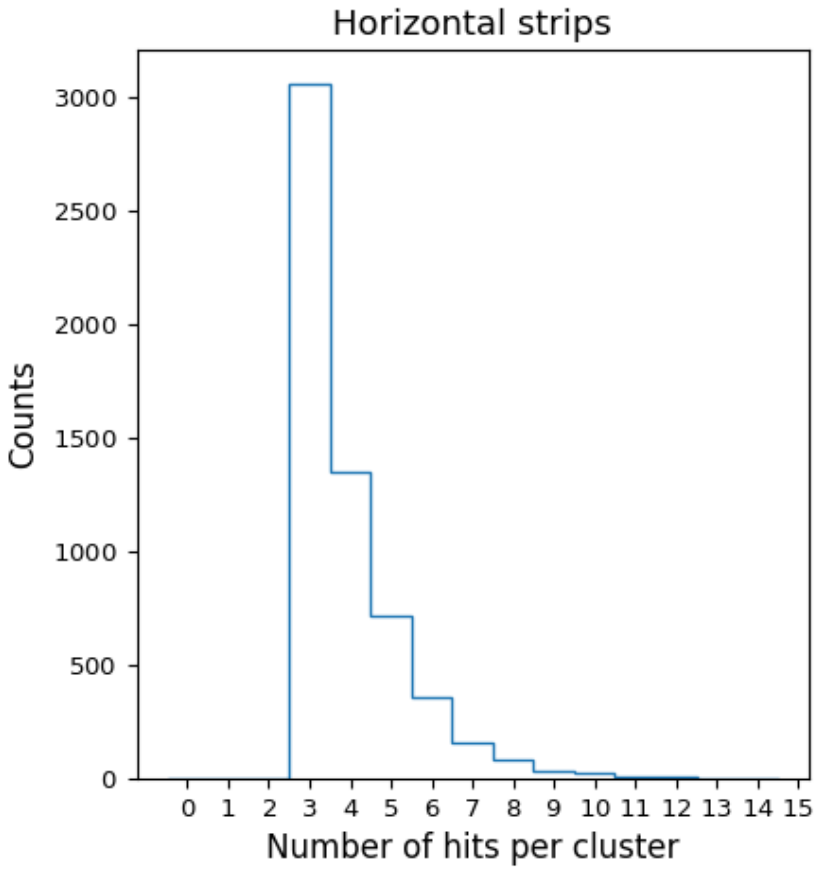
DATA ANALYSIS

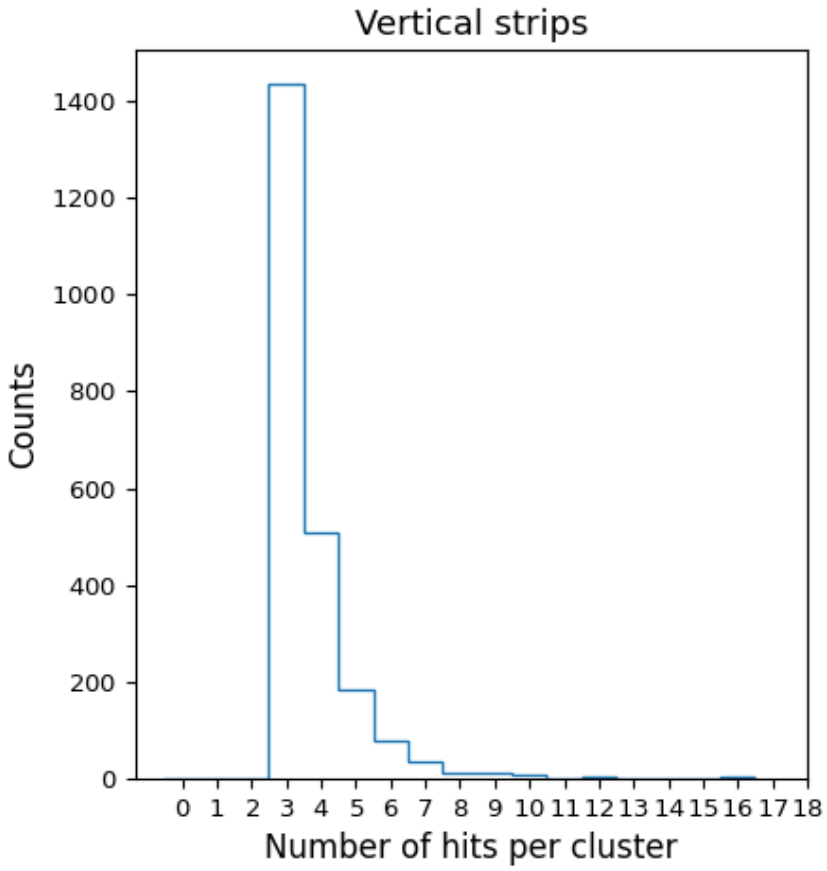
Typical tracks



DATA ANALYSIS

Number of hits per cluster



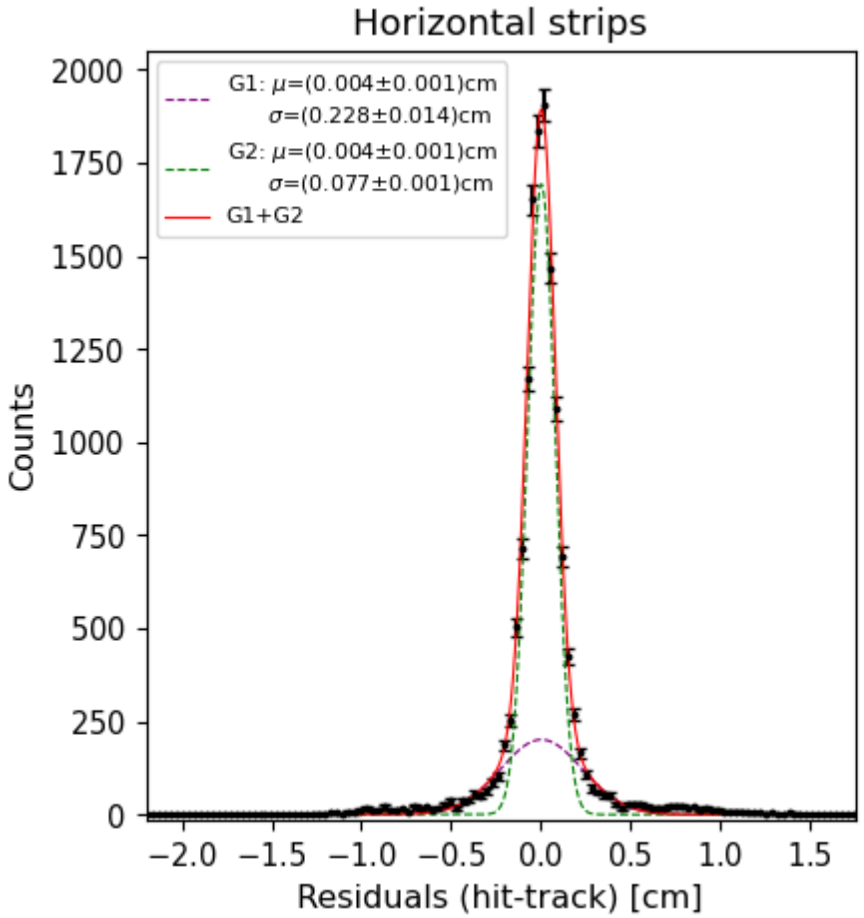


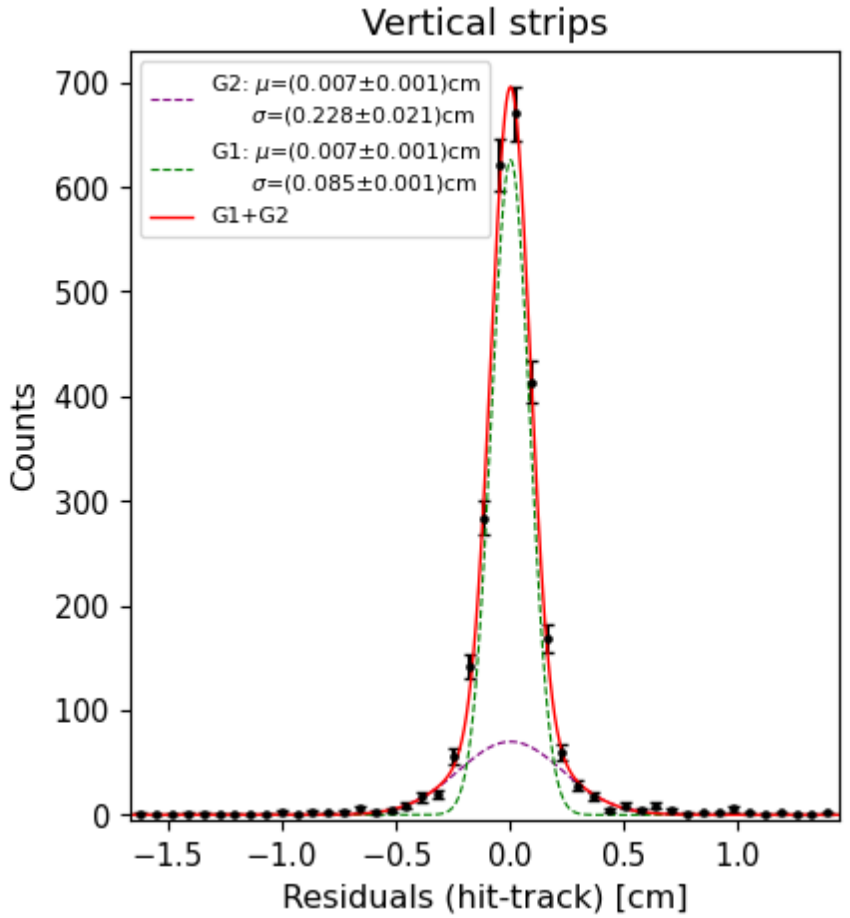
Small number of clusters with more than 6 hits, due to:

- misplacement of the acquisition window
- malfunction of half of the strips

SINGLE-HIT RESOLUTION

Hit-track residuals (from tracks with ≥ 4 hits. The considered hit is removed from the fit, that is performed on the other cluster's hits. The distance between the considered hit and the track is computed)





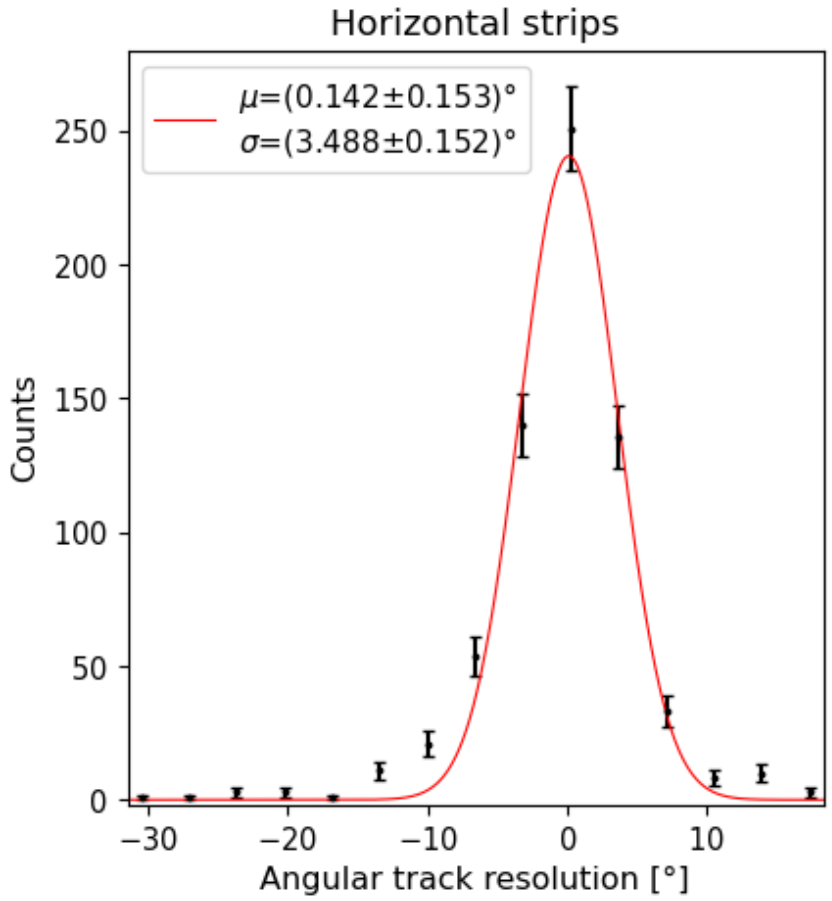
Fit with sum of two gaussians with the same mean, setting $Area_{G1}$:$Area_{G2}$=70:30

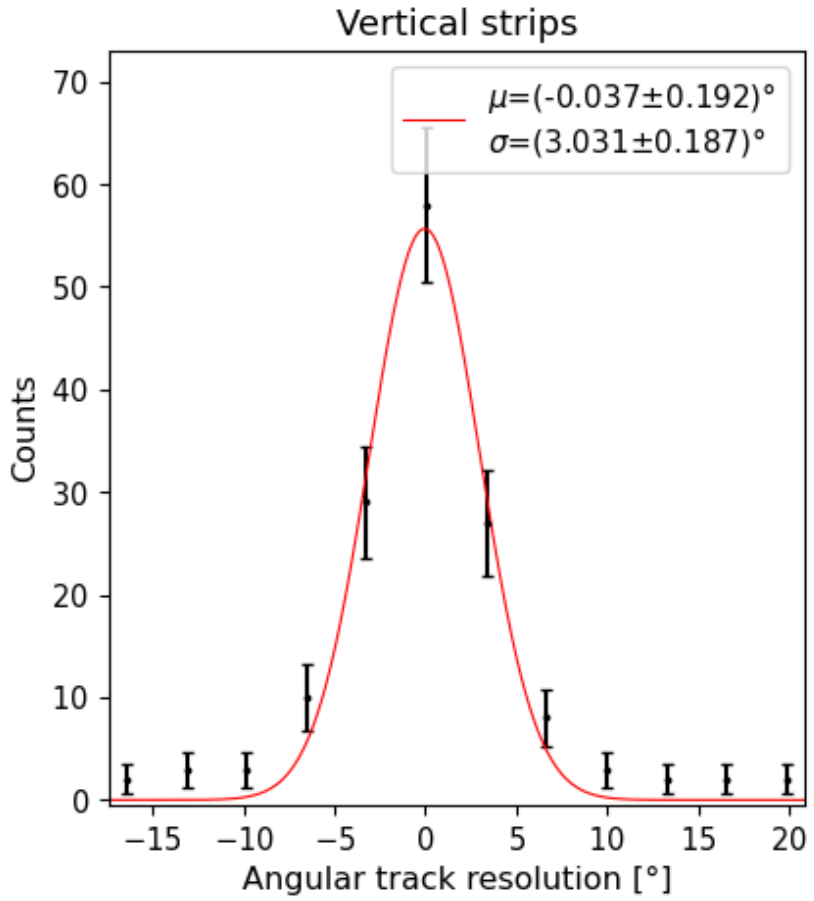
The standard deviations of the core gaussians G1 (green) are:

- horizontal strips: σ_H = (773 ± 9)μm
- vertical strips: σ_V = (848 ± 10)μm

TRACK RESOLUTION

Considering tracks with ≥ 6 strips, the hits are divided into even and odd based on their strip index, and two lines are fitted, one for each group. The distributions of the differences of their angles with the horizontal axes are represented





The track resolutions are derived as the standard deviations divided by $\sqrt{2}$:

- horizontal strips: $\sigma_H = (2.466 \pm 0.107)°$
- vertical strips: $\sigma_V = (2.143 \pm 0.132)°$

CONCLUSIONS AND FUTURE PERSPECTIVES

- **new approach**: 2D-strip readout of a TPC with 3cm (→ O(10cm)) drift length
- test beam @ ATOMKI:
  - position resolution of ~ 800μm
  - track resolution ~ 2°

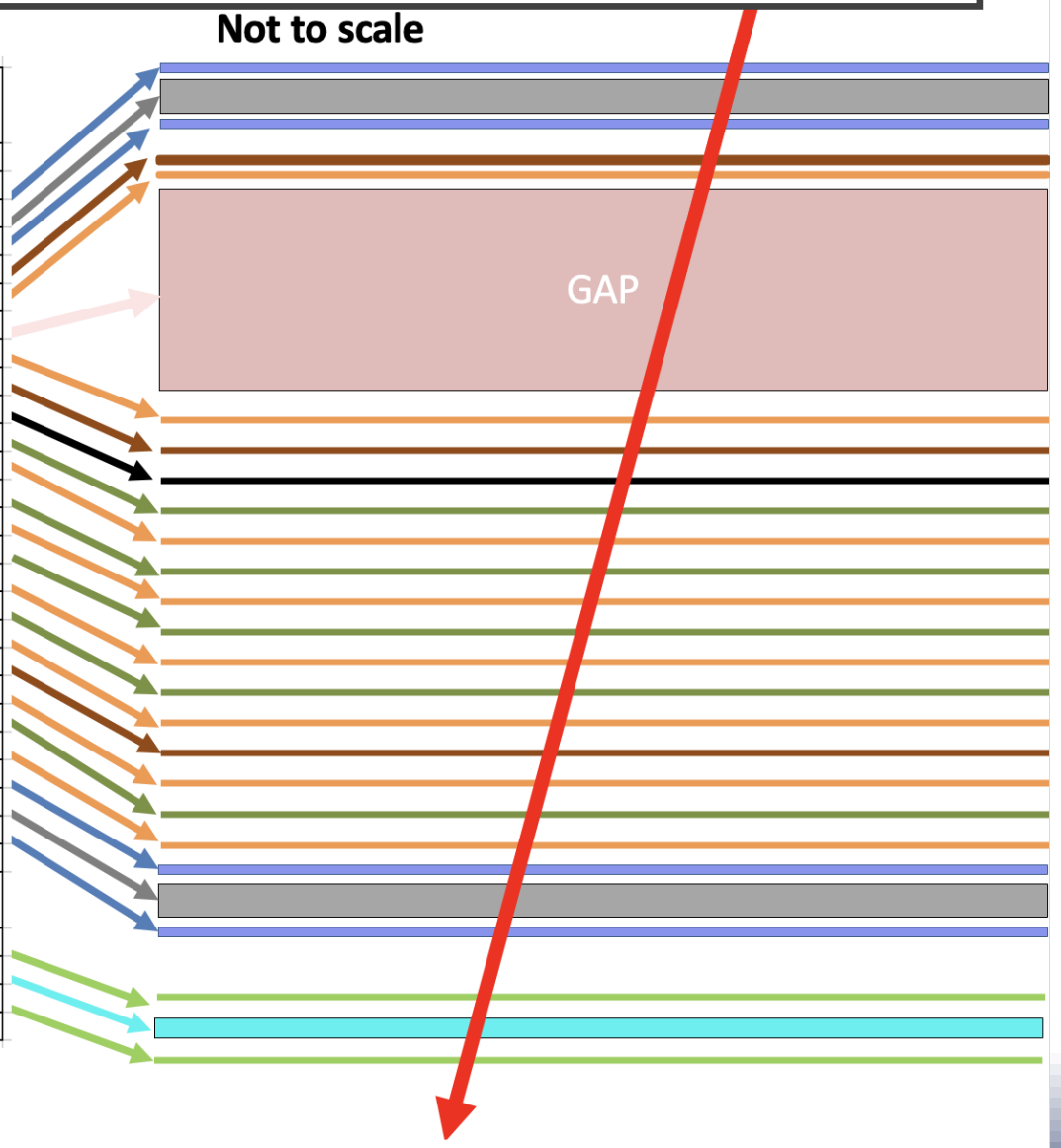
  → not actual detector's performances but **promising results**
- improvement in data analysis and detector design to achieve better results
- possible changes in the detector's features depending on the application
- further studies to understand the advantages and disadvantages of the use of TPCs with μRWells readout in future μ → eγ experiments at high rate

THANKS FOR YOUR ATTENTION!

BACKUP SLIDES

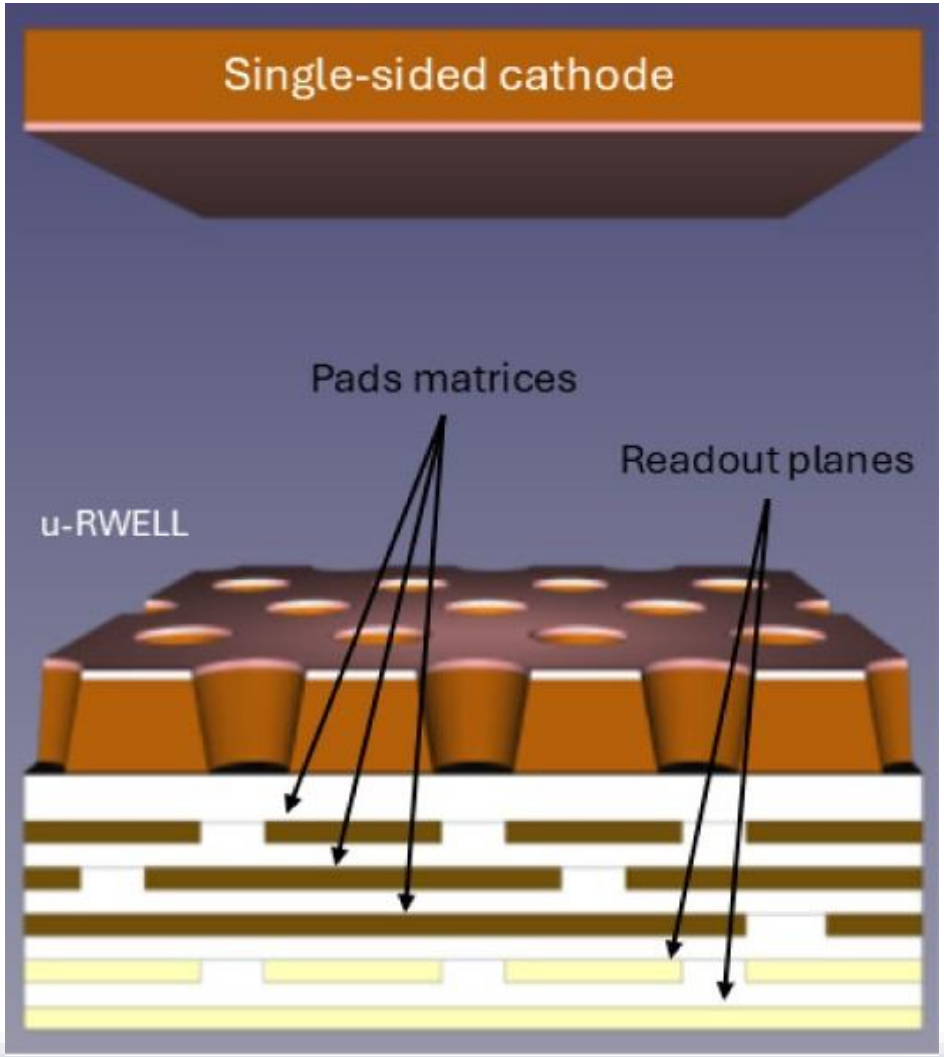
STRATIGRAPHY

uRwell stratigraphy		
DESCRIPTION	**MATERIAL**	**THICKNESS (mm)**
Top honeycomb top skin	glass epoxy	0,2
Aramid Honeycomb	polystyrene	5
Top honeycomb bot skin	glass epoxy	0,2
Cathode KAPTON support	KAPTON	0,05
Cathode electrode	copper	0,005
30mm frame	GAS (Argon)	30
Top urwell	copper	0,01
Kapton	KAPTON	0,05
DLC	carbon	0,00001
Prepreg	vetronite	0,028
Pad sharing 3	copper	0,003
Prepreg	vetronite	0,028
Pad sharing 2	copper	0,003
Prepreg	vetronite	0,2
Pad sharing 1	copper	0,003
Prepreg	vetronite	0,028
X layer	copper	0,005
Kapton	KAPTON	0,05
Y layer	copper	0,005
Prepreg	vetronite	0,125
GND	copper	0,009
Bottom honeycomb top skin	glass epoxy	0,2
Aramid Honeycomb	polystyrene	5
Bottom honey comb top skin	glass epoxy	0,2
TOTAL		**41,40201**
Scintillator stratigraphy		
adesive tape	PET	0,1
ej-200	scintillator	3
adesive tape	PET	0,1
GRAN TOTAL (uRwell + Scint.)		**44,60201**



X layer: strip width = 0.1 mm
Y layer: strip width = 1.1 mm

μRWELL DETECTOR WITH CAPACITIVE-SHARING



TRIGGER SYSTEM

The TPC acquisition is triggered by the coincidence of one of the 12 scintillating bars (read by SiPMs) and a scintillating cube (10cm side, read by a PMT)