Test beam of STT prototype

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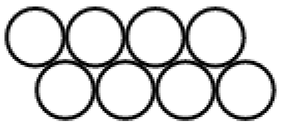
Straw tube tracker prototype

2 layers with 32 straws each

- **DUT** : a **straw chamber** (~20x20 cm2) read out with a mu2e **VMM3**-based board



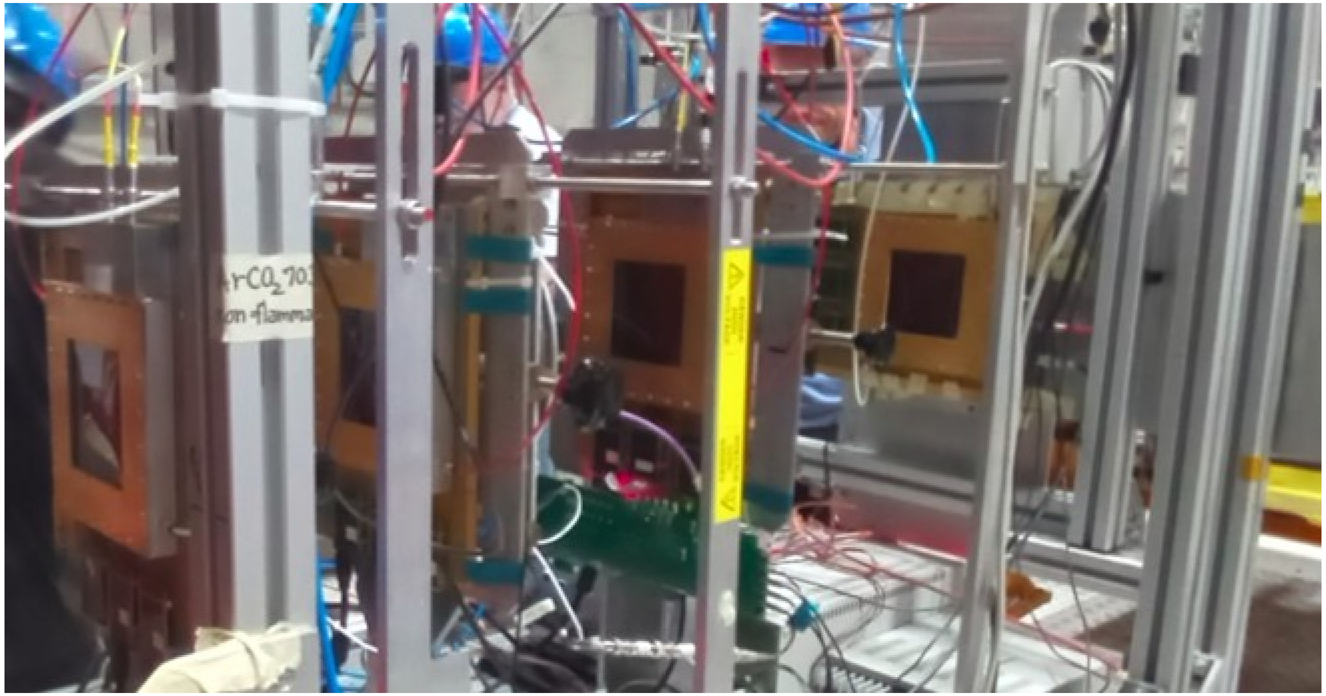
Dstraw = 6 mm, Dwire =30 um, gas Ar(70%)+CO2(30%), 2 layers of 32 straws

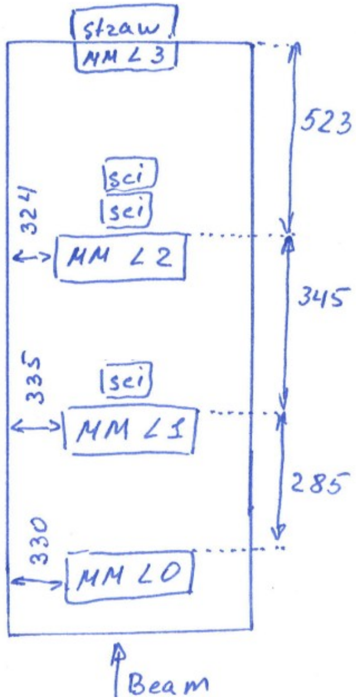
time-at-threshold mode

Test beam setup (June)

D. Sosnov

BEAM

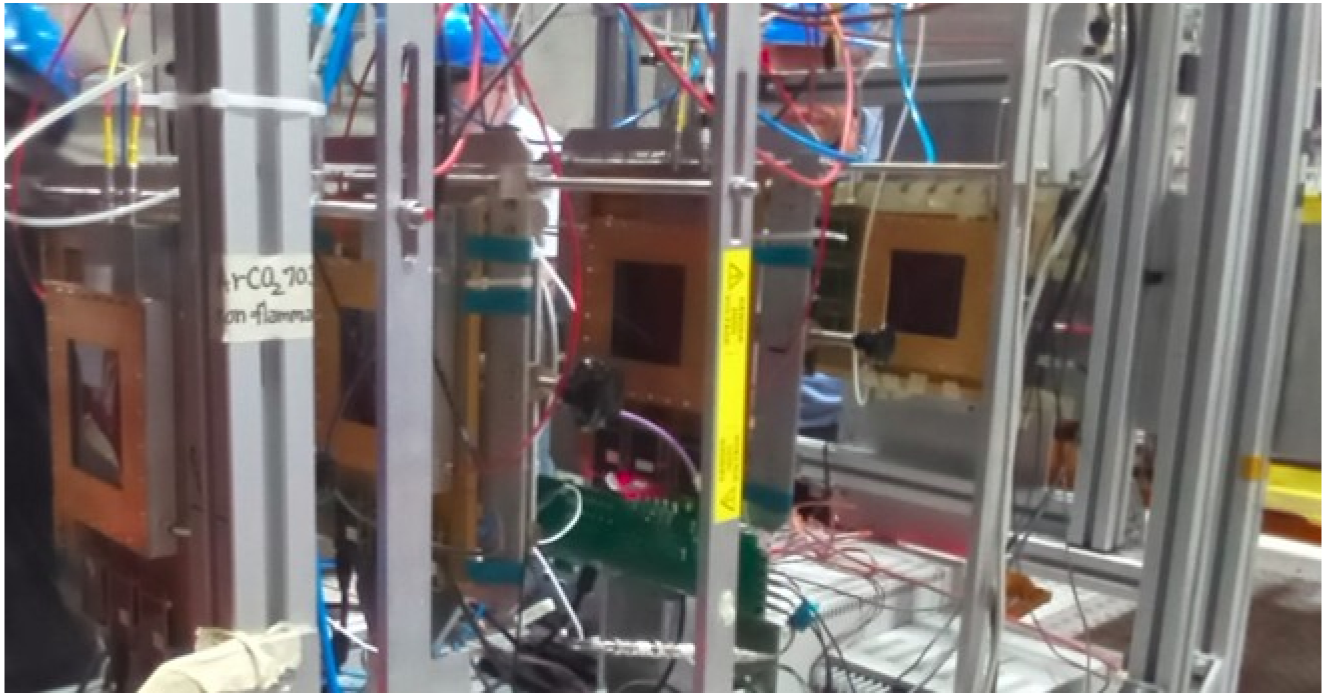


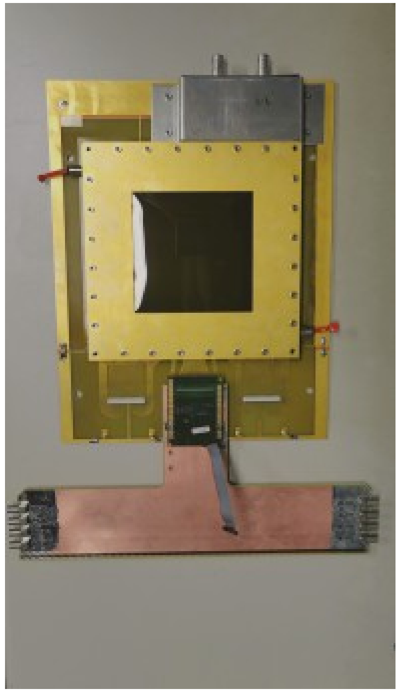


4 MicroMega layers (first 3 with vertical strips, last with horizontal strips)
3 scintillators used for trigger
Straw tube prototype

The DAQ issue

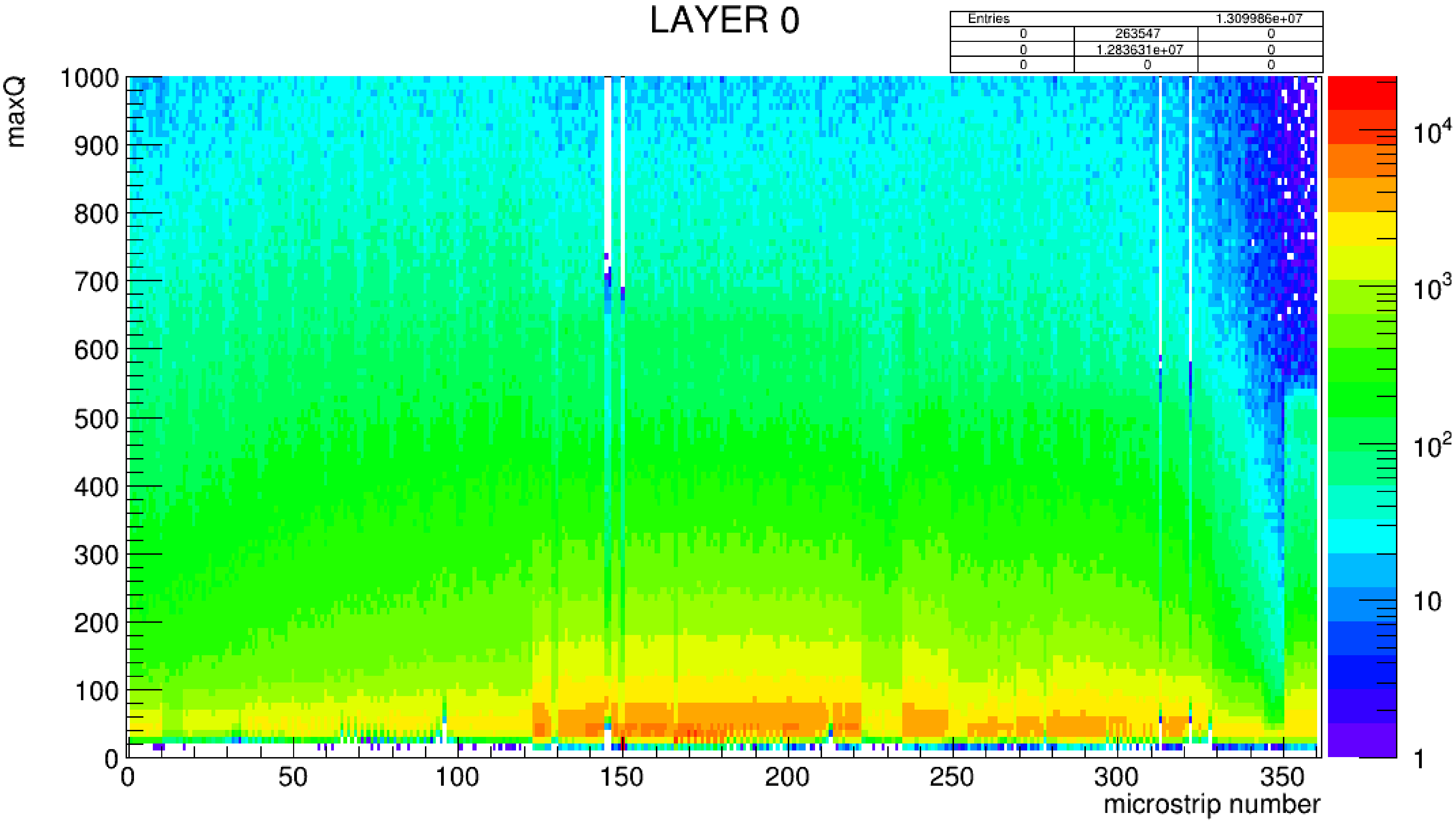
BEAM





4 MicroMegas with APV-based readout
5 straws, 3 scintillators and 56 strips from Layer 2 were read by a Mu2e Board (VMM3 chip) hoping to find a way to synchronize the 2 readouts

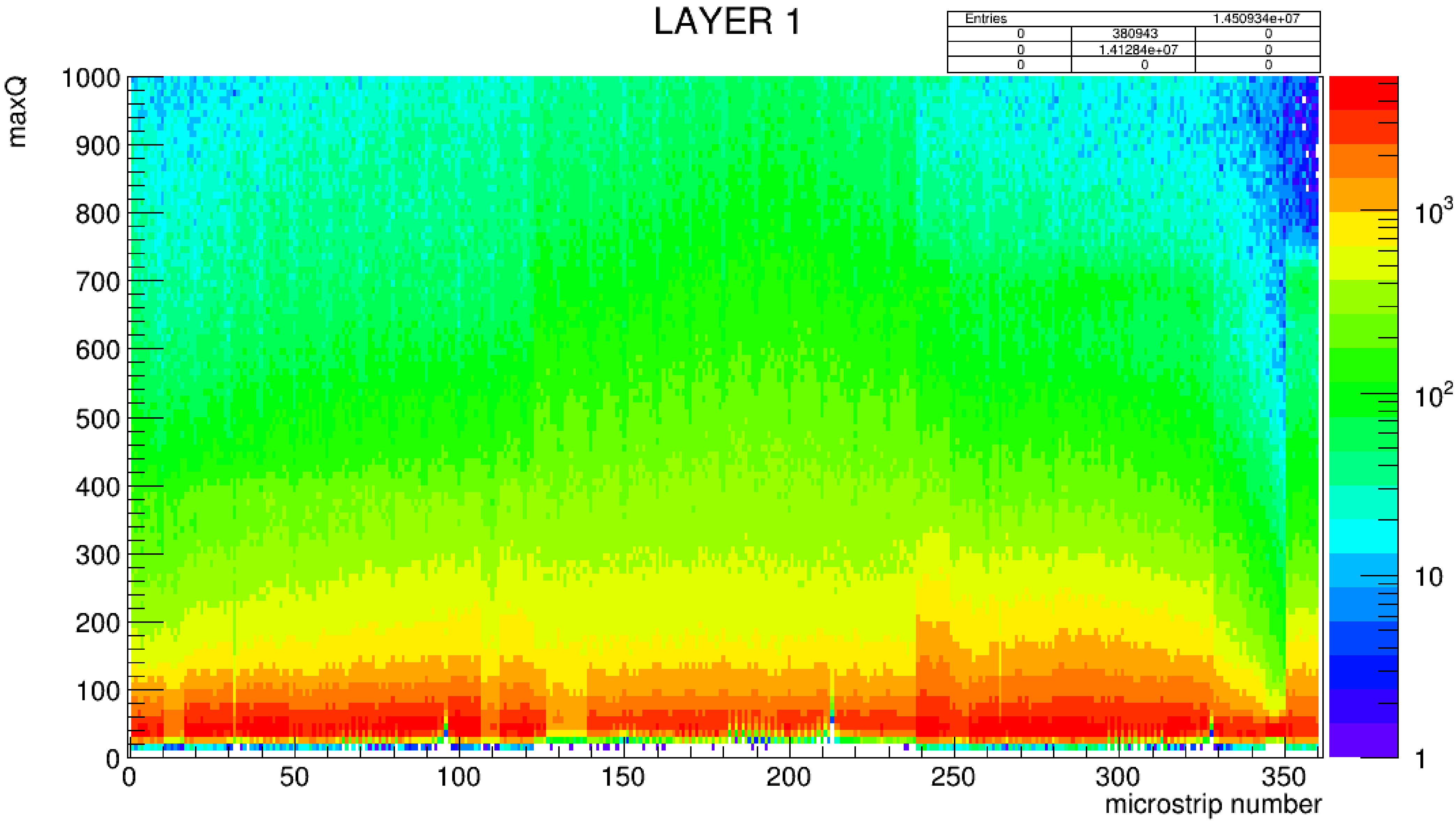
APV RUN 331: LAYER 0 microstrips pulse hight



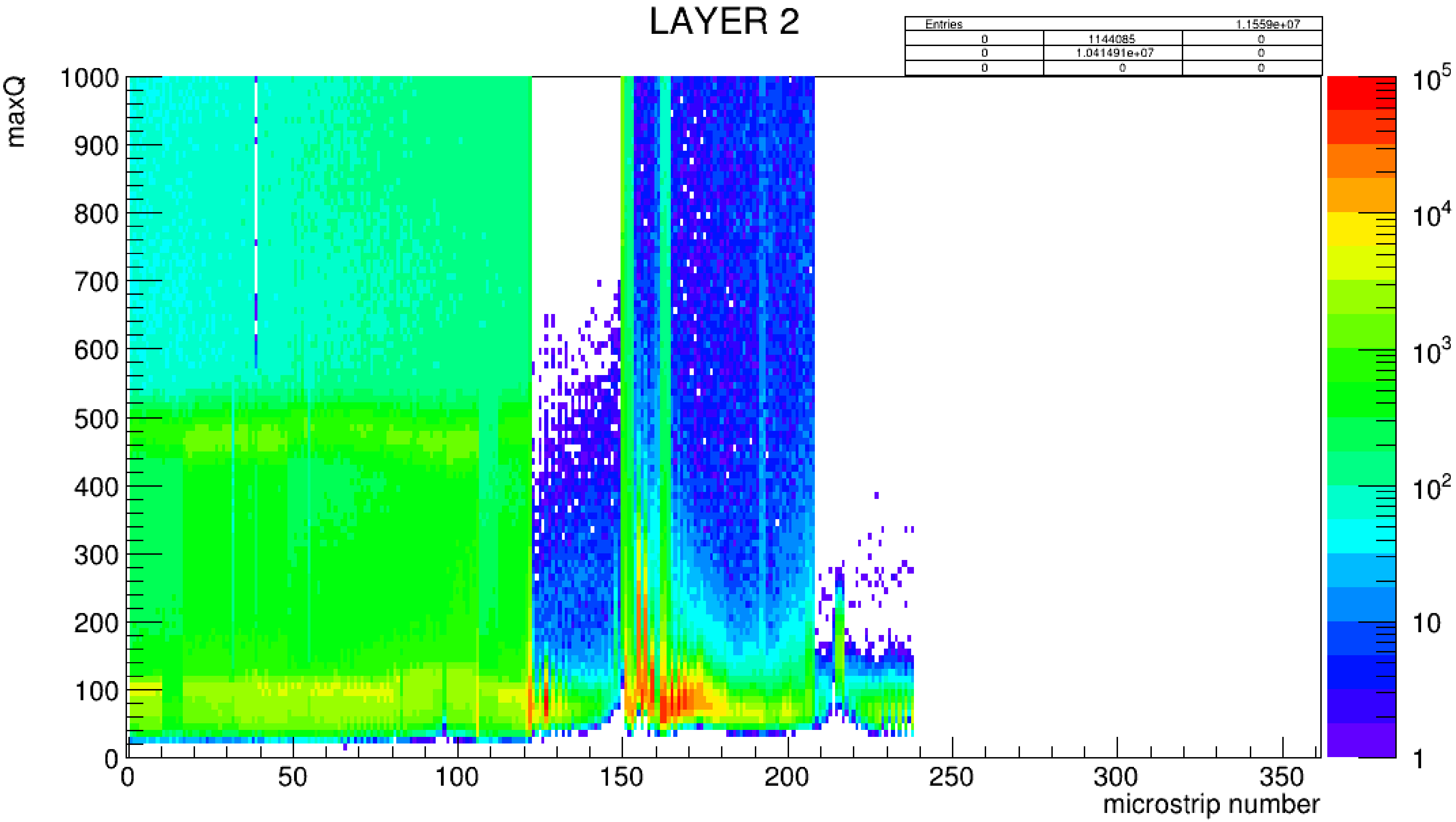
The microtrip **pitch is 250 μm**

Higher occupancy in the central part but some dead or inefficient strip also there

APV RUN 331: LAYER 1 microstrips pulse hight

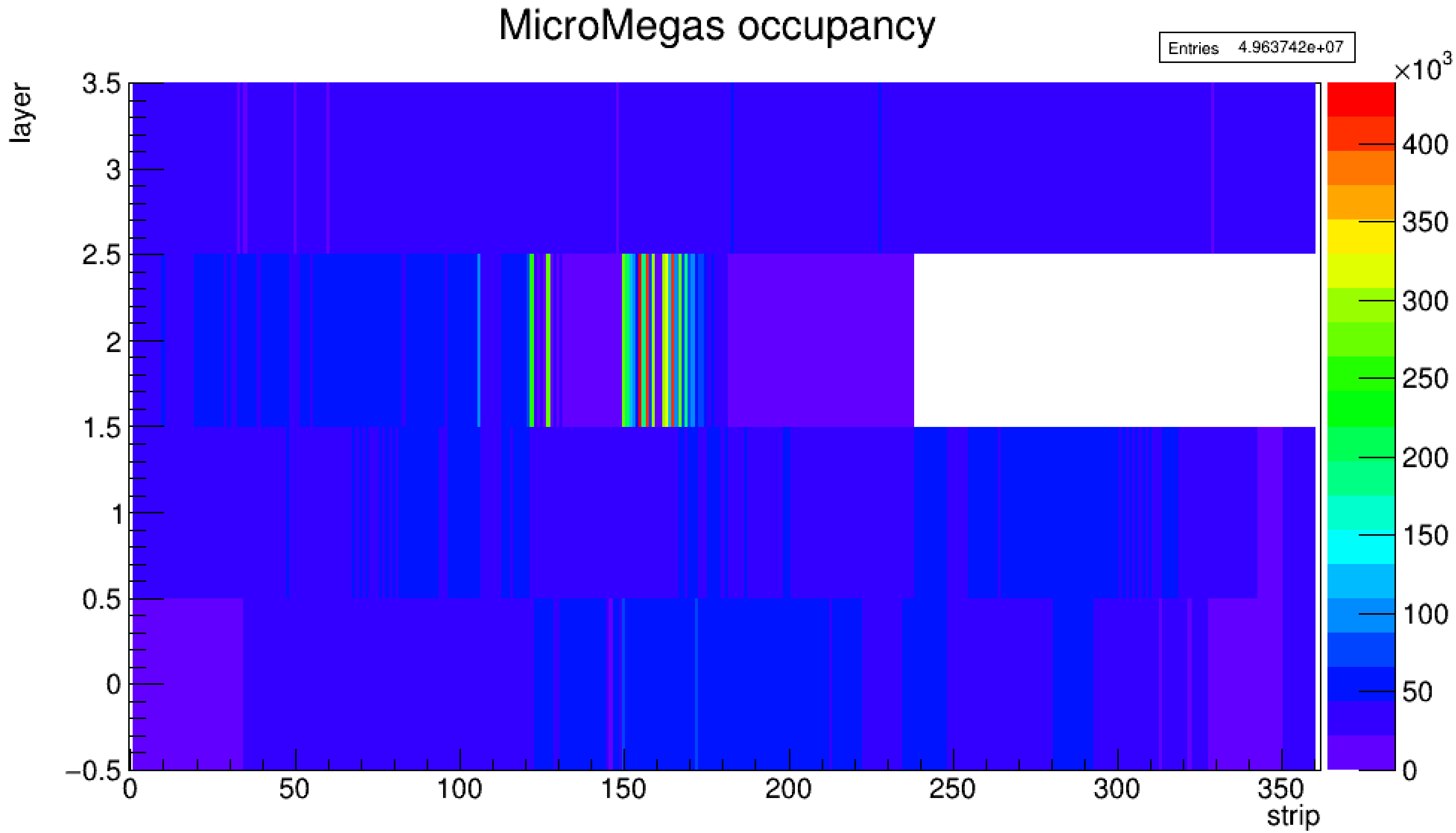


APV RUN 331: LAYER 2 microstrips pulse hight



Strips from **154** to **209** are read also by the Mu2e board
Some of them are noisy, some are inefficient, the ones above 240 are disconnected

APV RUN 331: microstrip occupancy

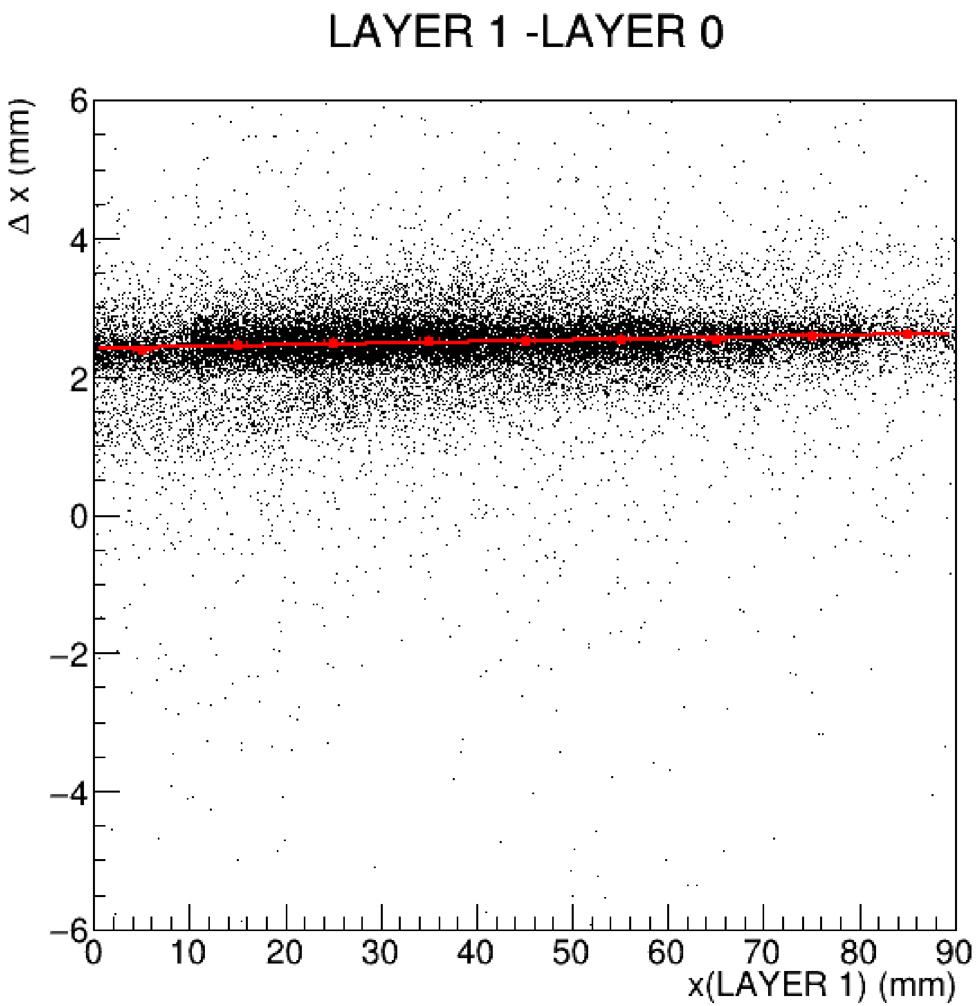


LAYER 2, that is the one read by both Mu2e and APV board, shows problematic strips: noisy or low (100 to 180), low (180 to 240), dead (>240)
In LAYER 3 the strips are horizontal (not the same illumination from beam)

Microstrip clustering

- Create group of ‘adiacent’ hits allowing for gaps of 2 strips to consider the strip connected to the cluster
- Reject noise (clusters with < 3 strips but not for LAYER 2, maximum strip charge <300 (<100 for LAYER 2))
- Reject cross talk or splashes (cluster with >90 strips)
- Calculate the **cluster center** as average strip number weighted with pulse height

LAYER 1 -LAYER 0 alignment



The coordinate x is given by the strip number multiplied by the 250 μm pitch.

Look at the difference (Δx) between cluster centers in layer 1 and 0 versus the cluster center (x) in layer 1.

Gaussian fit of slices of x(LAYER 1)

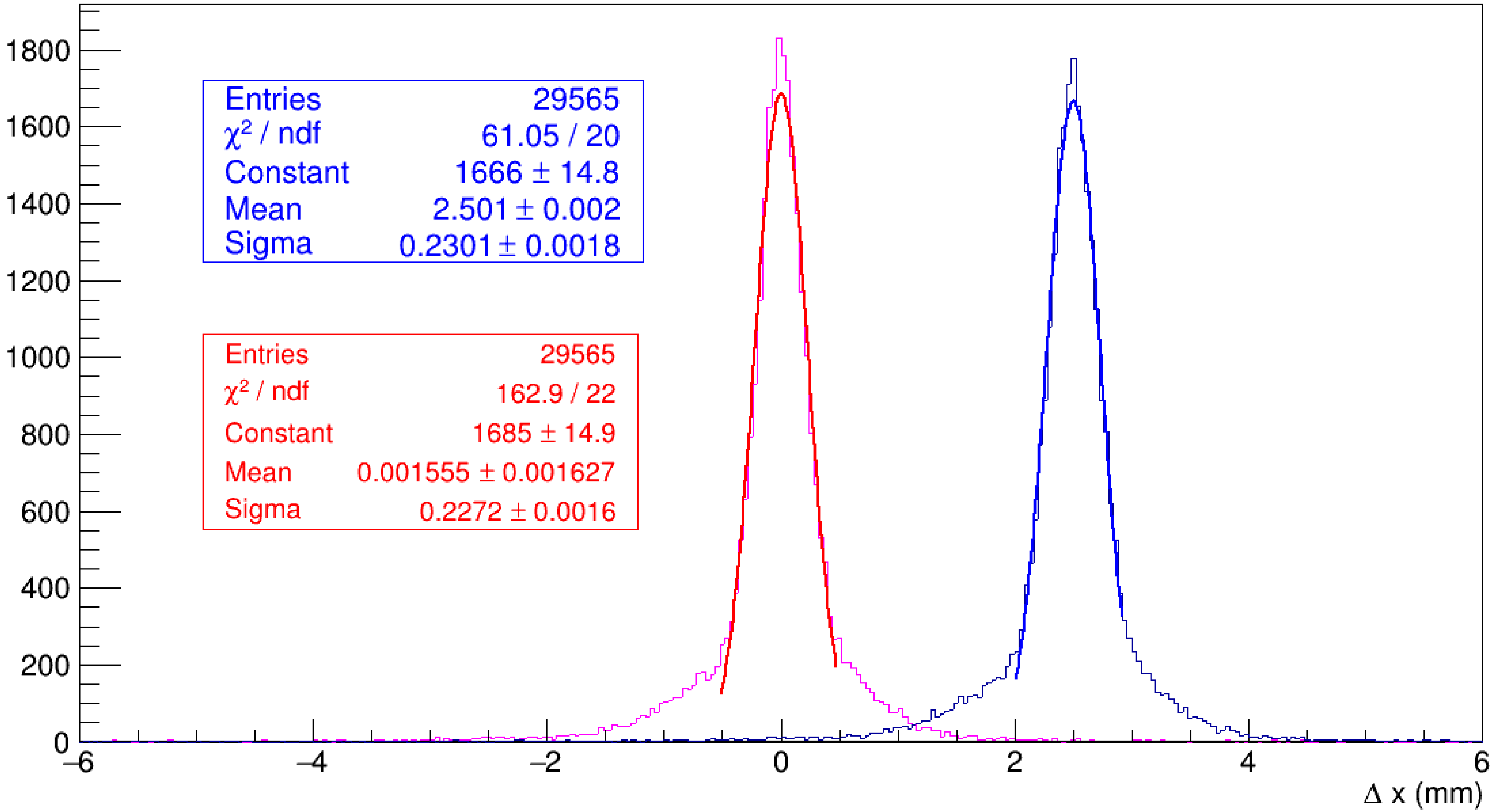
Linear fit of the gaussian means.

LAYER 1 is **shifted** and **rotated** according to:

$x \rightarrow x' = x - a - b*x$ with a= 2.412 b= 2.29e-3

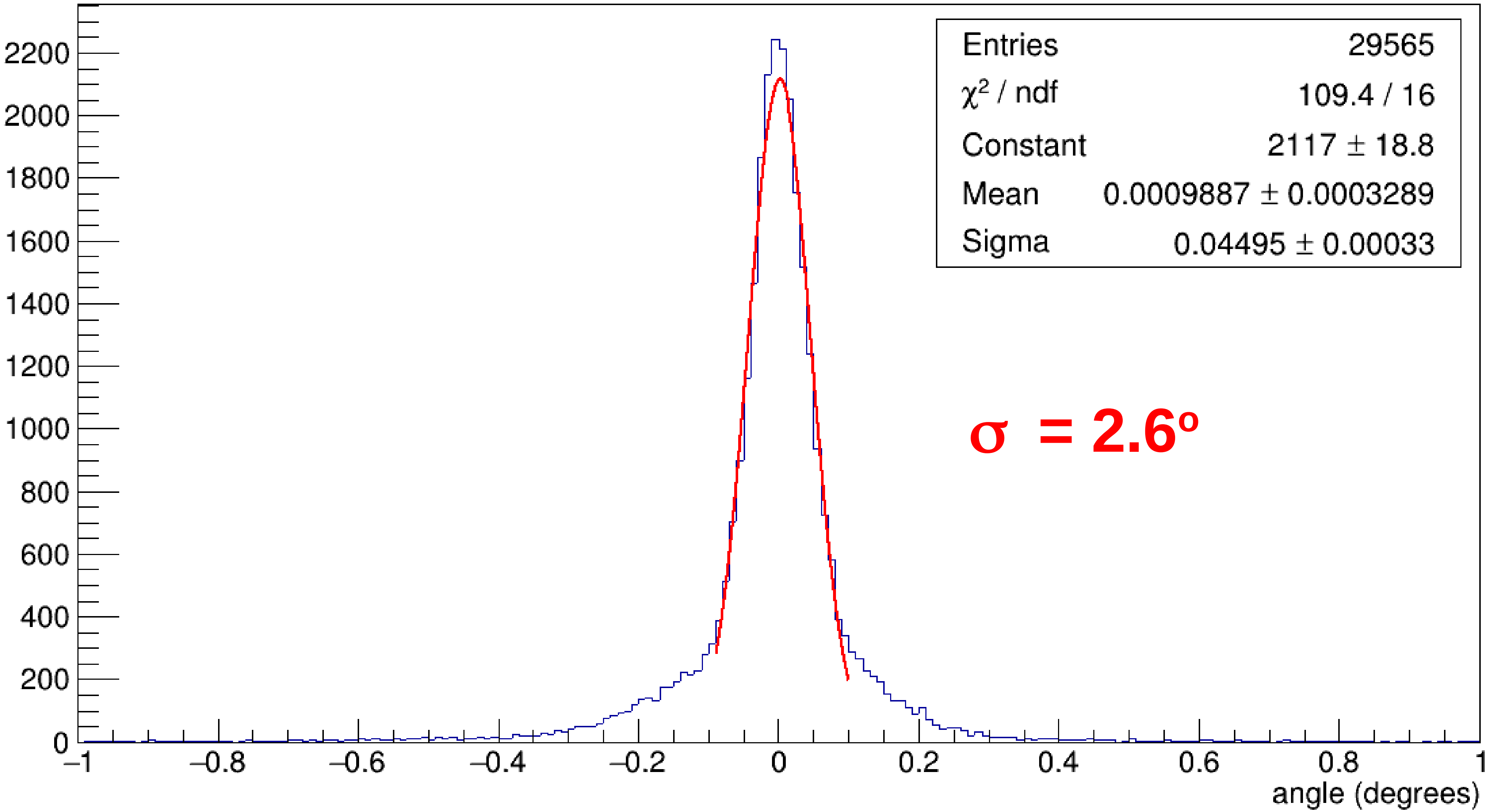
This makes layer 0 and layer 1 parallel in xz but not necessarily perpendicular to the beam

APV RUN 331: LAYER 1 – 0 alignment



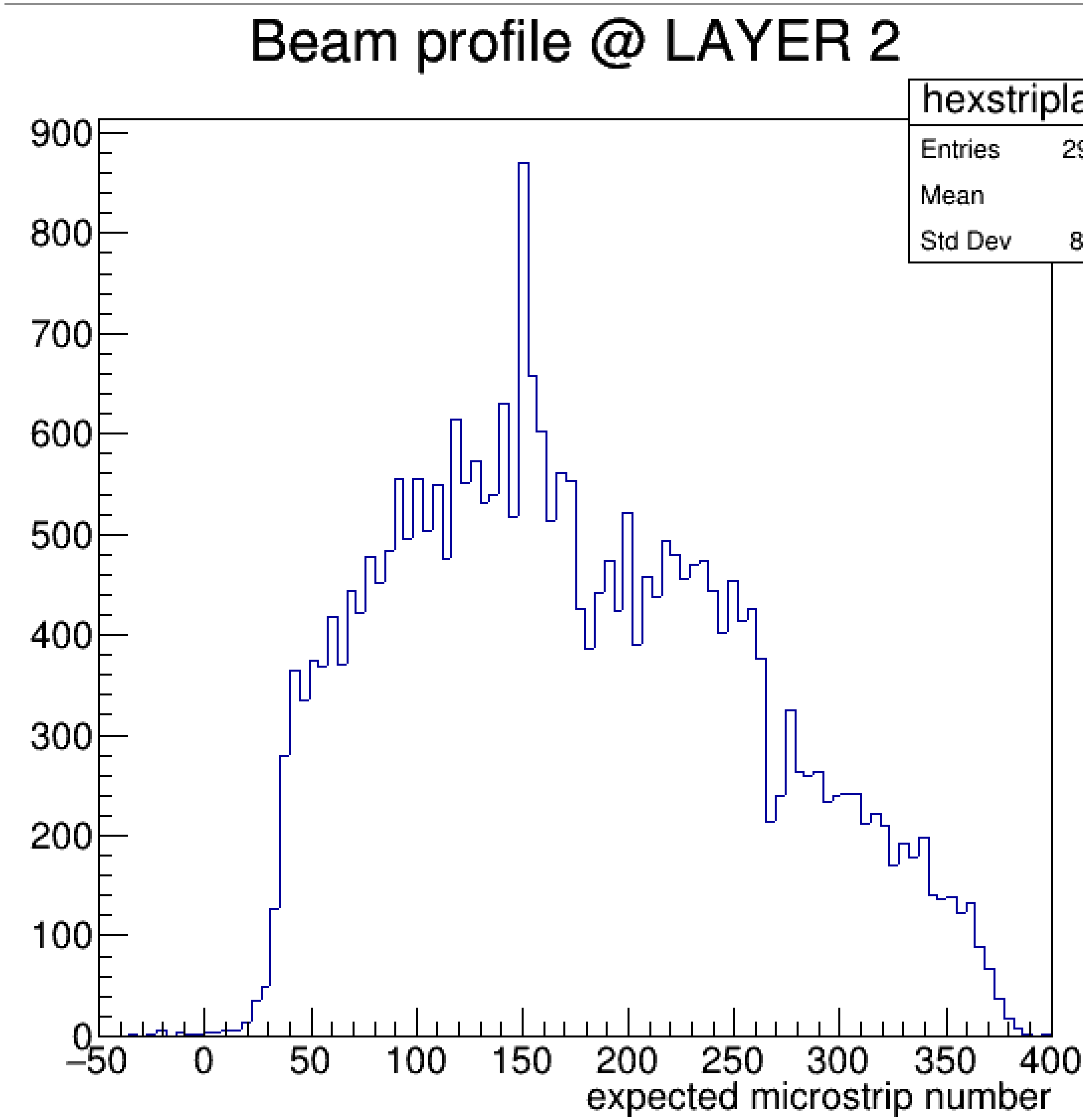
Alignment works: - average difference consistent with 0
- sigma improves

APV RUN 331: beam angular spread



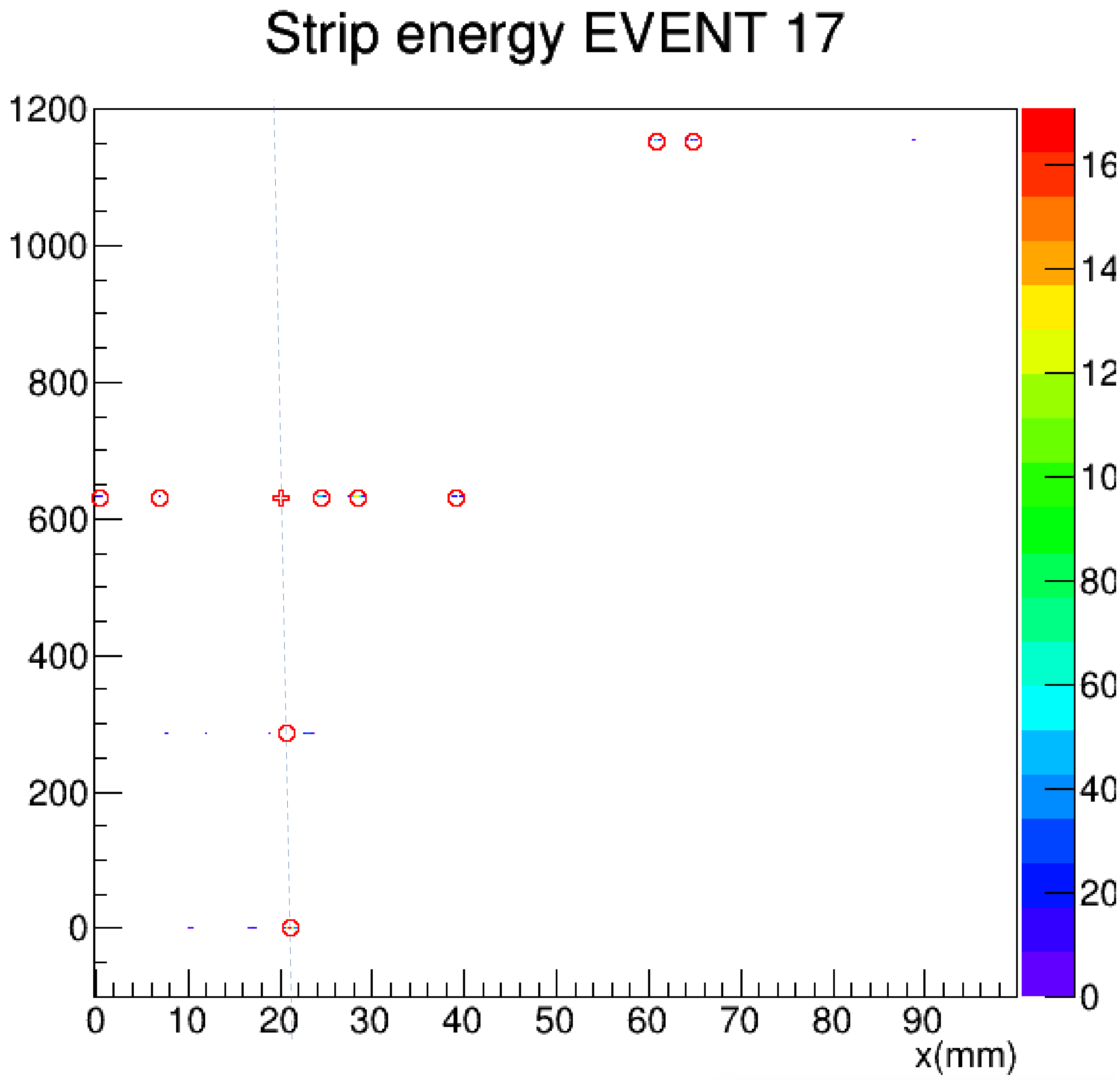
The angular spread is small but not negligible

APV RUN 331: extrapolated strip on LAYER 2



The expected strip obtained by the intersection of the LAYER 1-0 track with LAYER 2 can be used to select he correct cluster on LAYER 2

APV RUN 331: LAYER 2 cluster selection

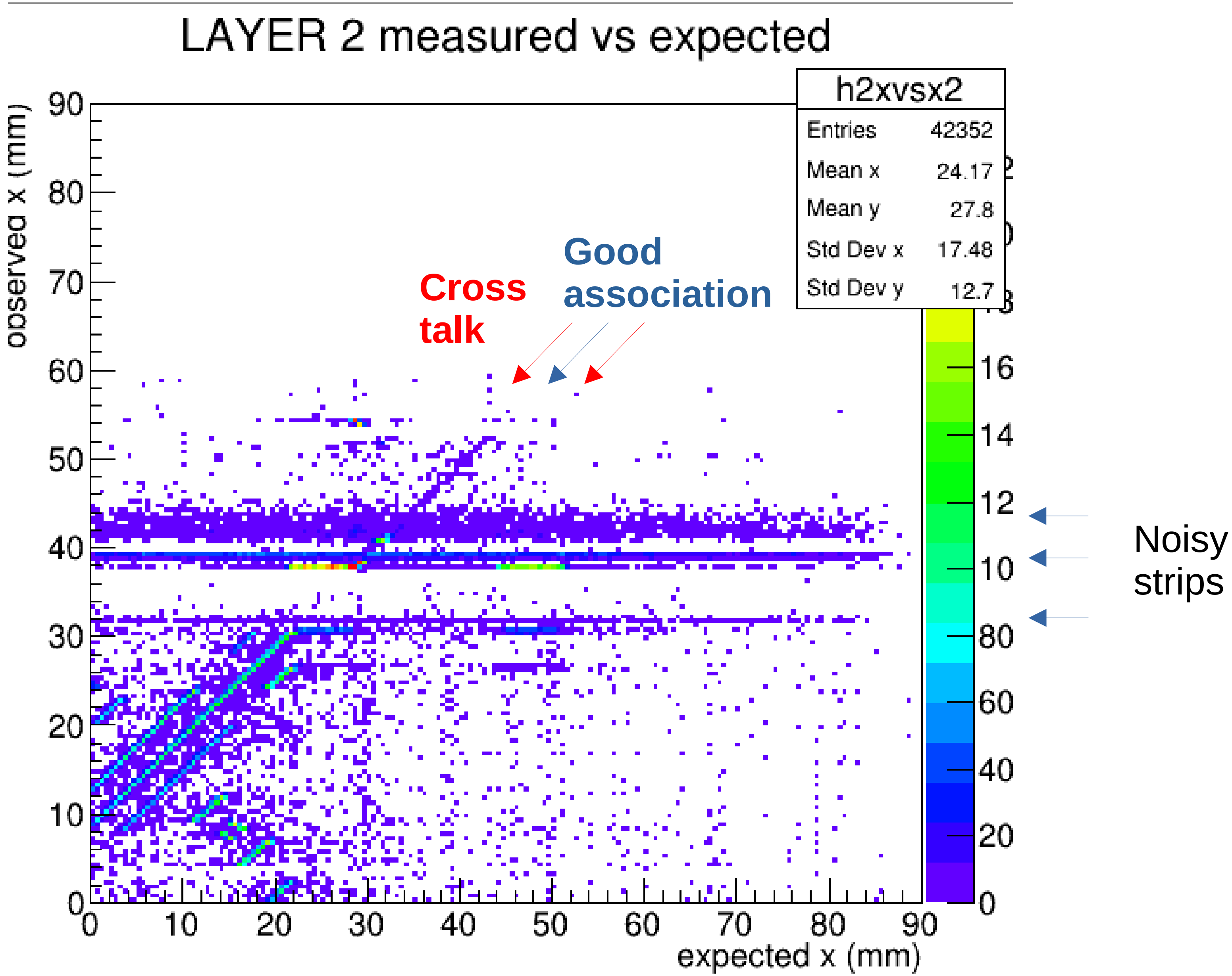


Many noisy strips and clusters in layer 2

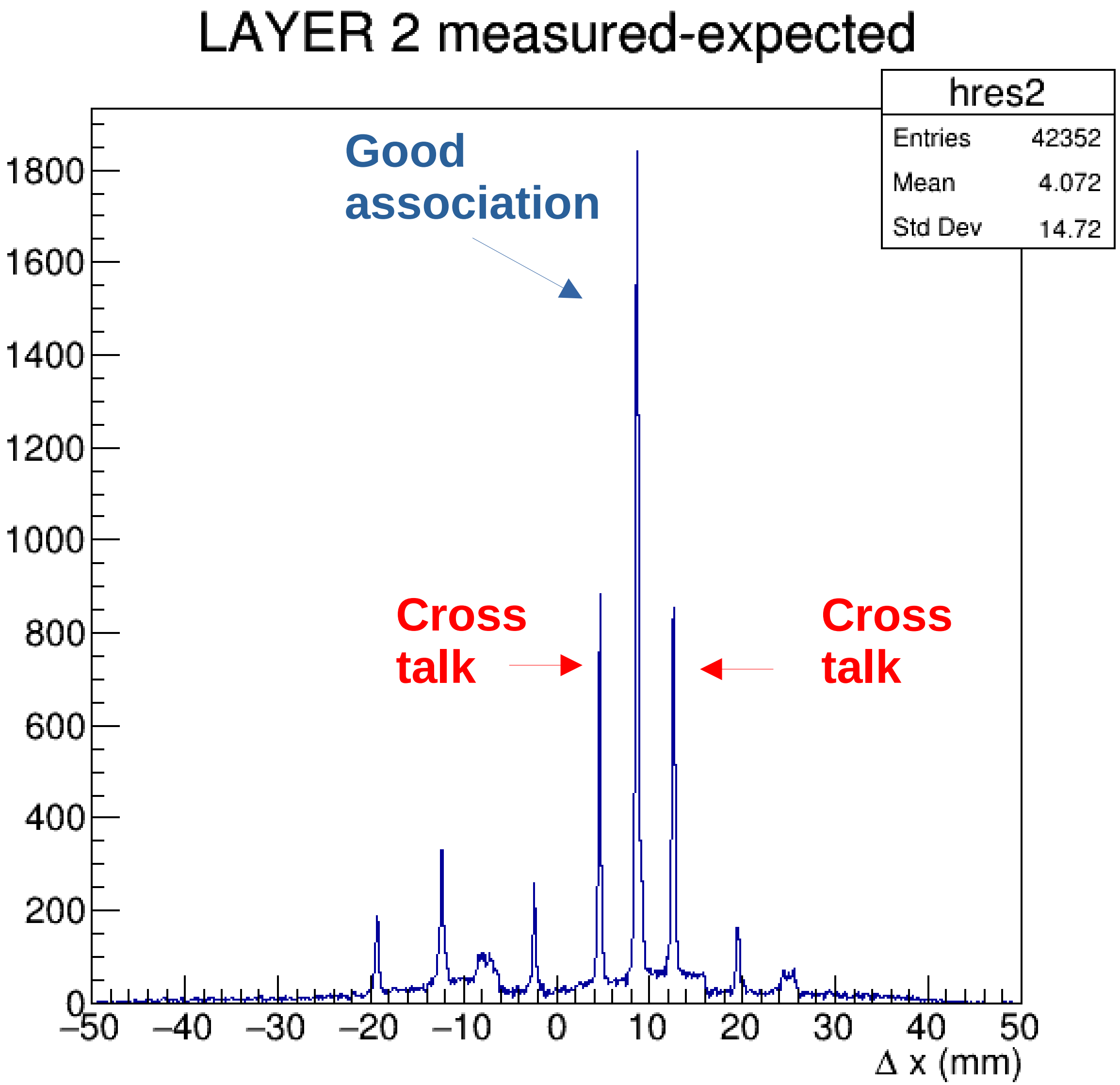
Sometimes the good cluster is missing!

Extrapolated direction from LAYER 0 and 1 (after alignment) is more reliable

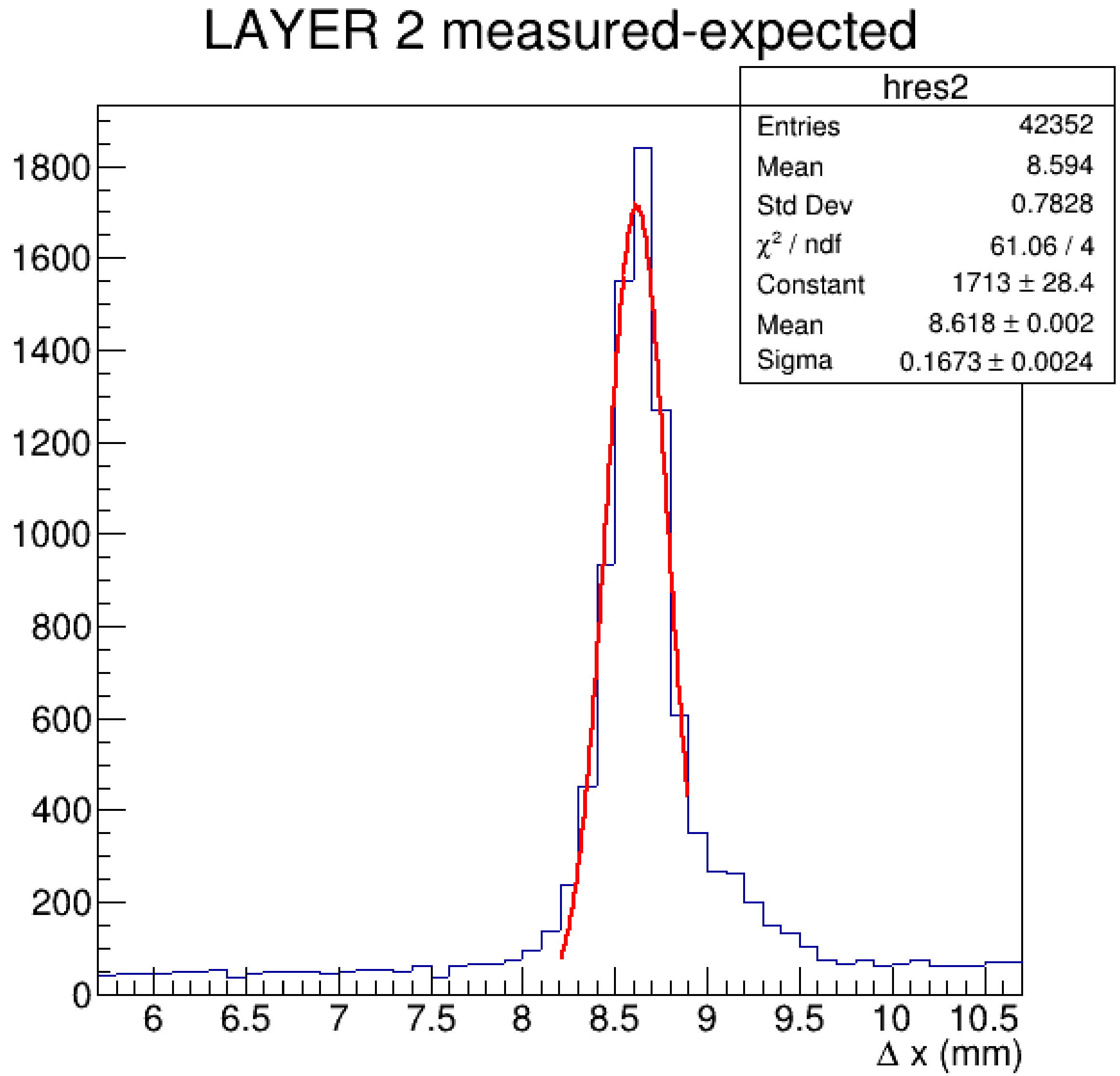
APV RUN 331: expected vs observed cluster center



APV RUN 331: LAYER 2 cluster center residuals



APV RUN 331: LAYER 2 cluster center residuals

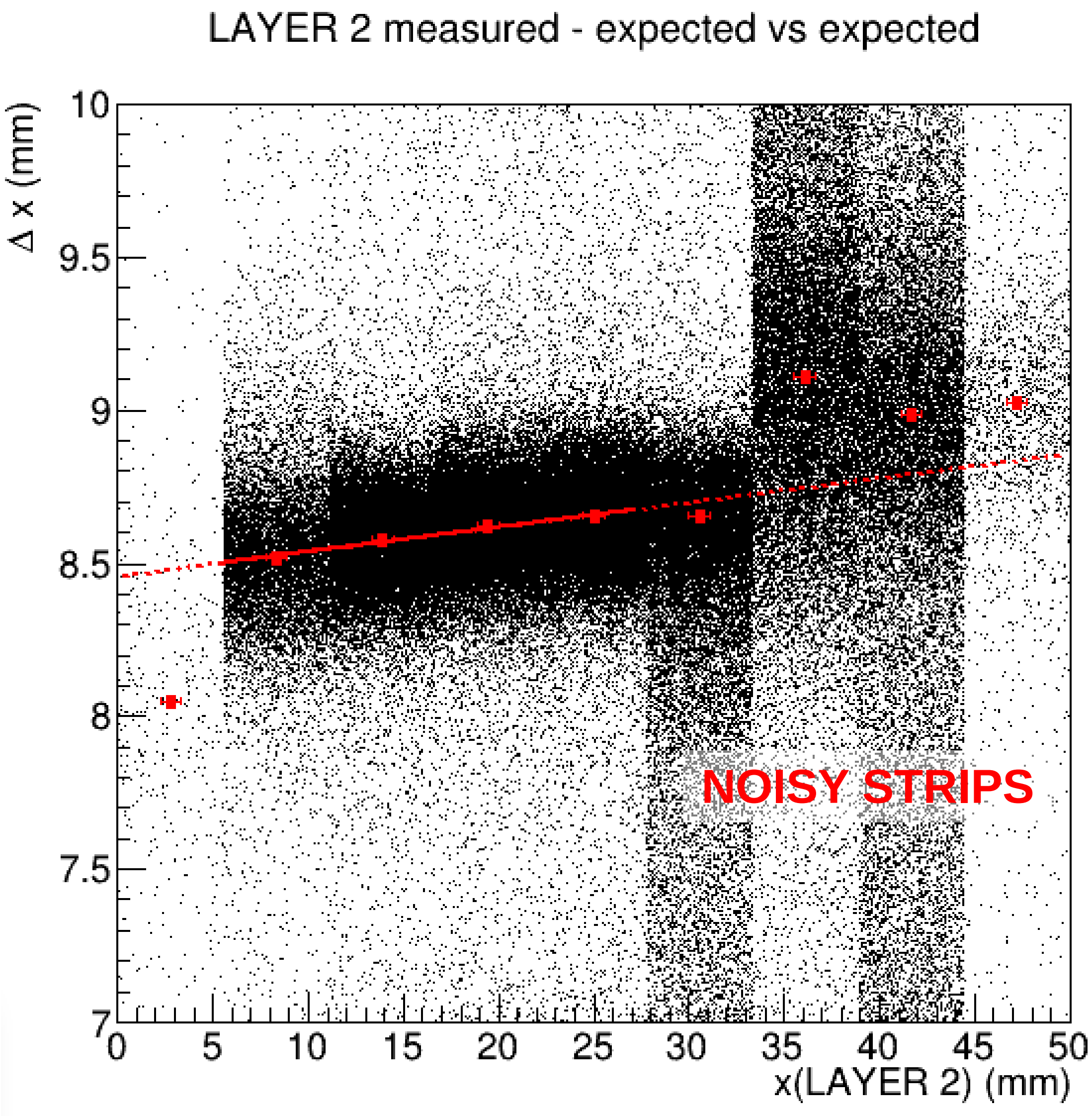


σ = 167 μm
(< 1 strip = 250 μm)

LAYER 1-0 Extrapolation can be used to point to the correct cluster in LAYER 2

If LAYER 2 cluster is missing, is the LAYER 1-0 track accurate enough to get a 1 ns time resolution?

APV RUN 331: alignment of LAYER 2 wrt 0&1



Look at the difference between expected position and observed position in LAYER 2

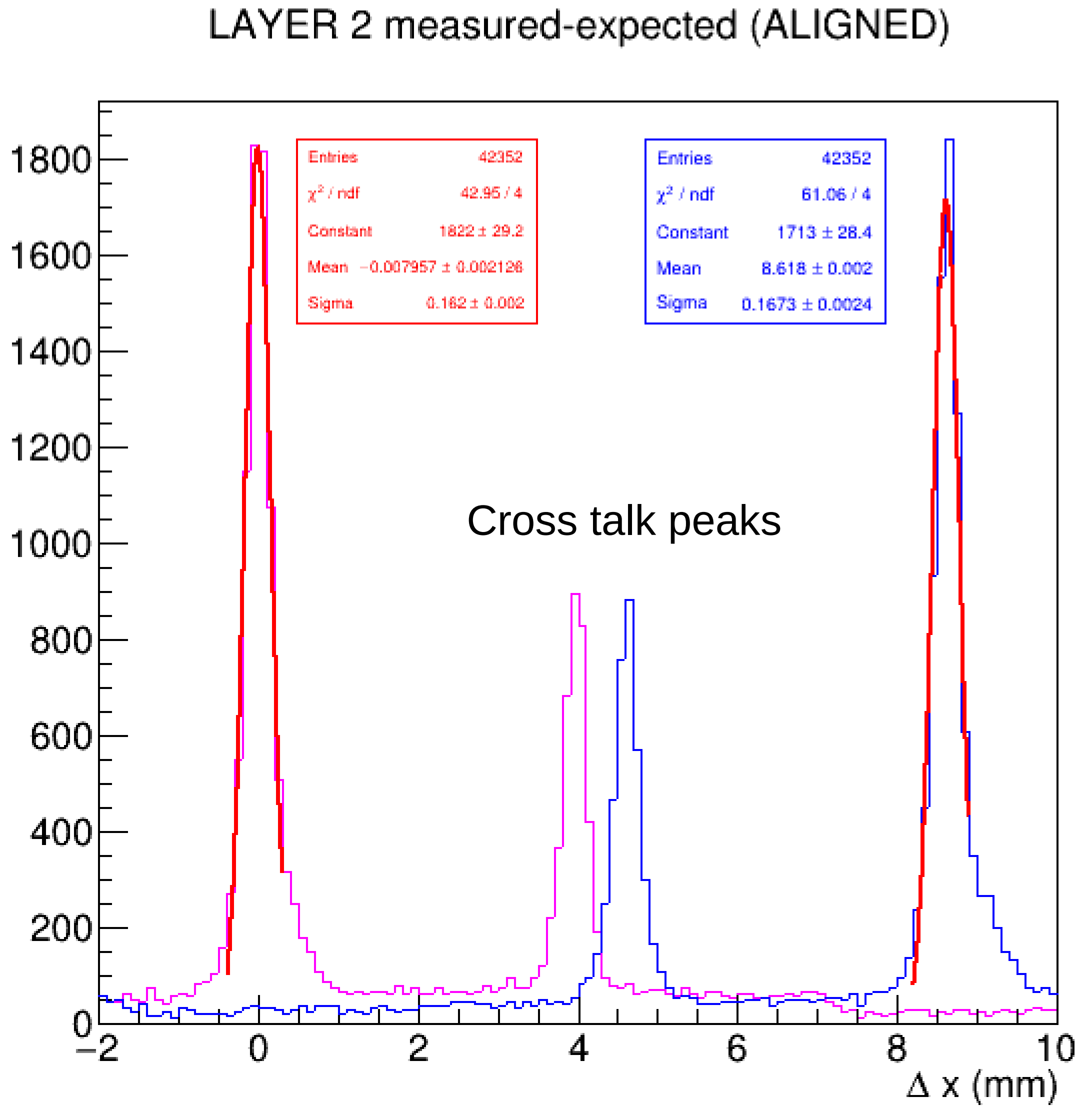
Linear Fit in slices of x

Exclude the points corresponding to **noisy** strips (strips >100)

LAYER 2 correction: $x \rightarrow x' = x - a - b*x$ with a= 8.46 b= 8.e-3

This makes layer 0, 1 and 2 parallel and aligned

RUN 331: alignment of LAYER 2 wrt 0&1



Before the alignment:

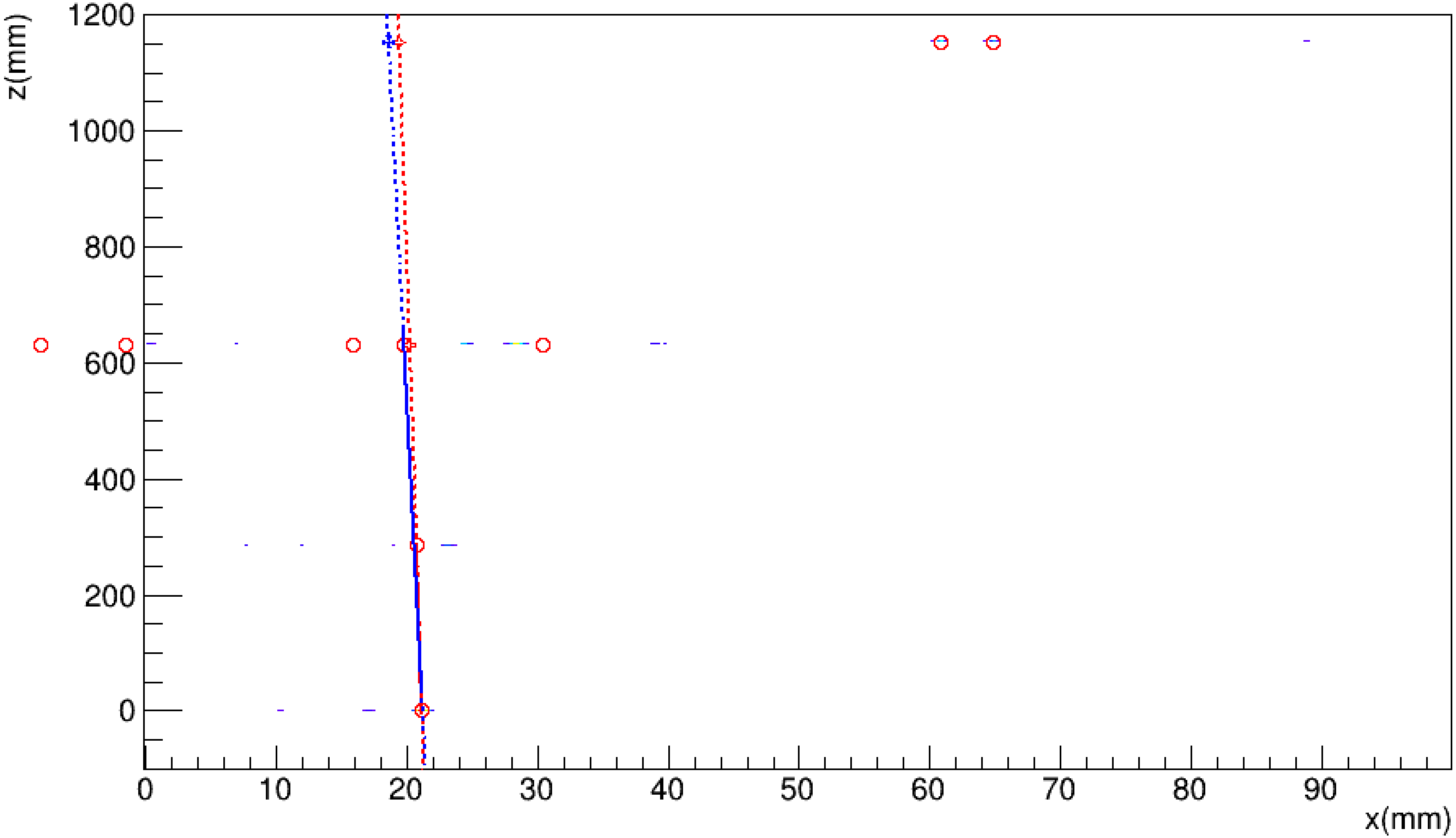
σ = 167 μm

After the alignment:

σ = 162 μm

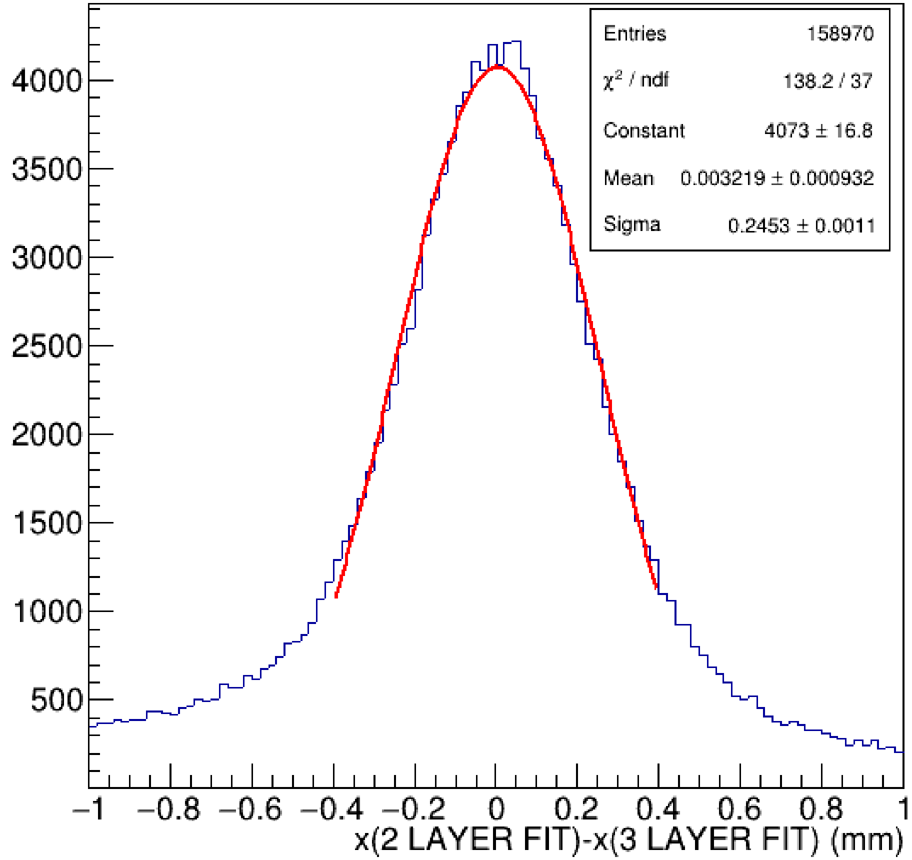
Alignment works: - average difference consistent with 0
- sigma improves

APV RUN 331: error on LAYER 1-0 track extrapolation



Compare the extrapolation to the straw layers using LAYER 0&1 fit with the one obtained fitting LAYER 0&1&2 when LAYER 2 cluster center is within 1 mm from LAYER 1-0 track

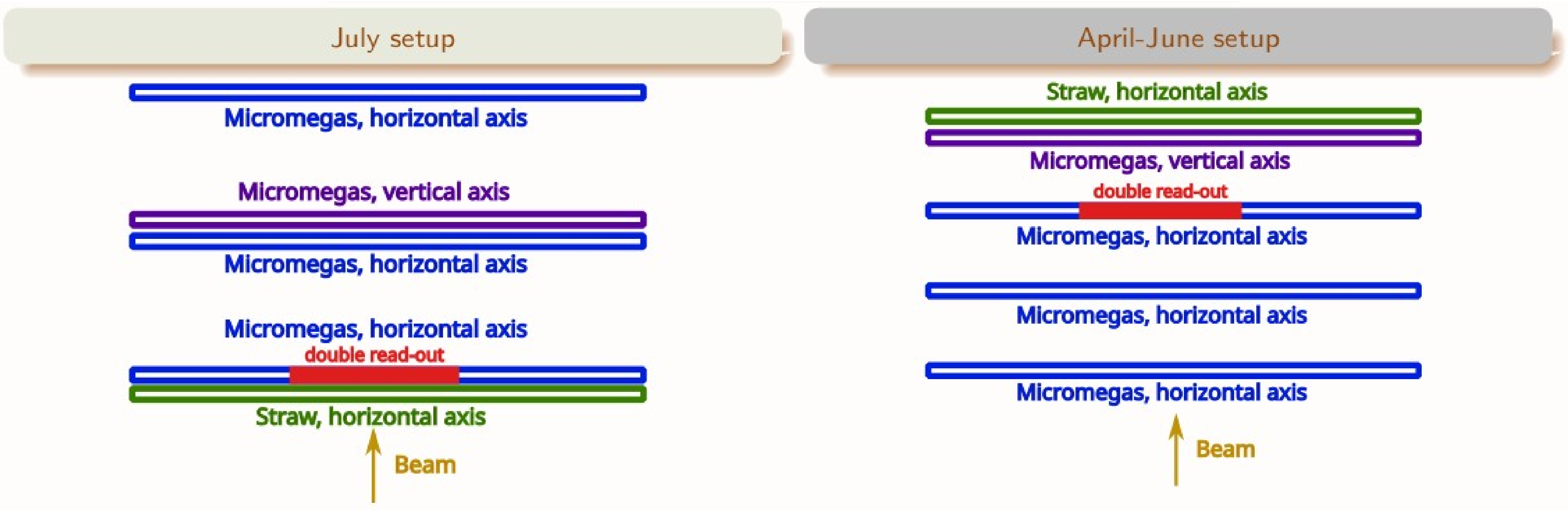
APV RUN 331: straw hit position error using LAYER0&1



The pointing resolution obatined using LAYER 0 and 1 only is ~250 μm
Assuming a 50 μm/ns average drift velocity this corresponds to a **5 ns spread**!
→ LAYER 0&1 cannot be used alone to investigate the straw time resolution

This was mainly due to the extrapolation error: diiferent setup since July!

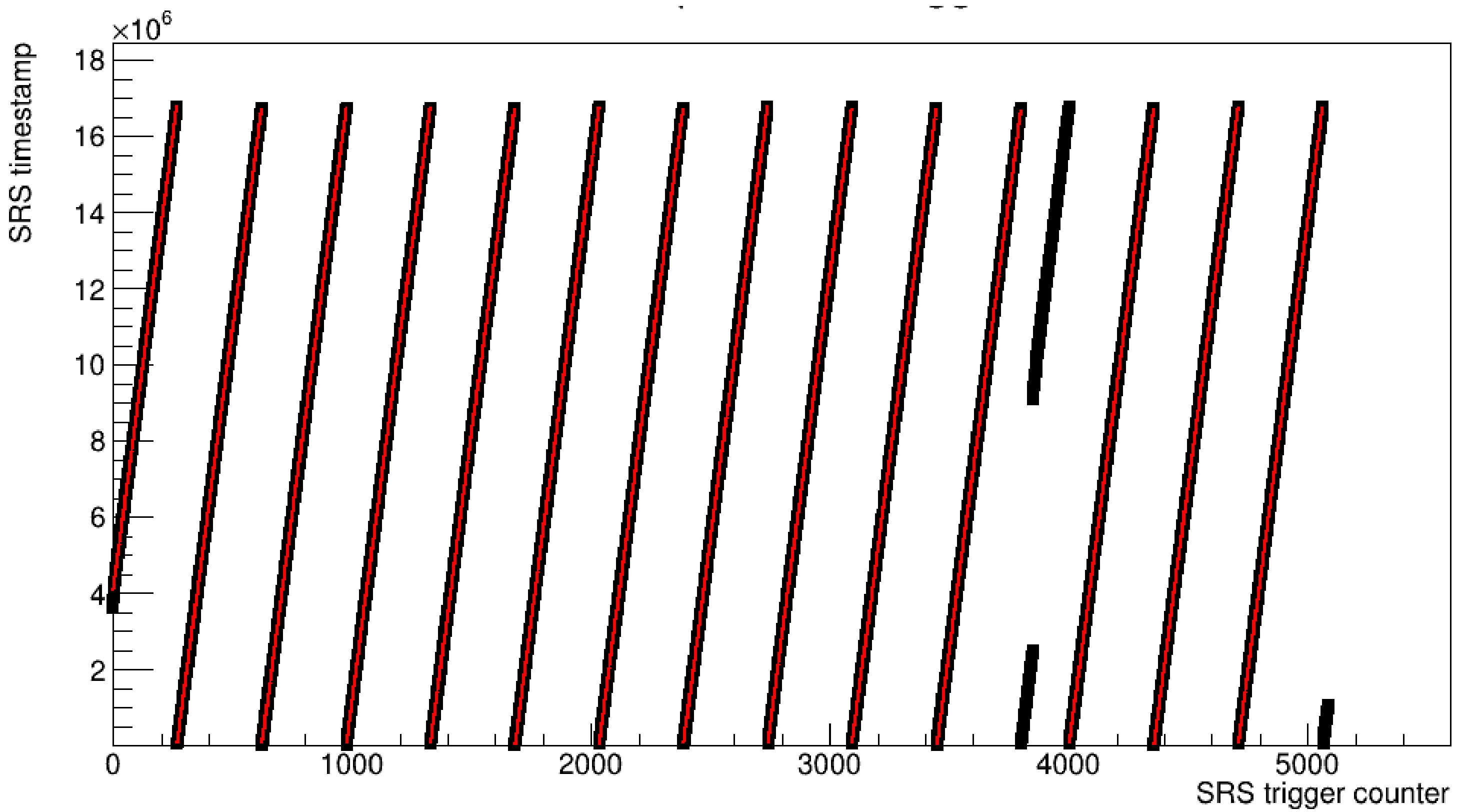
New test beam setup



Now the MicroMega close to the straw can be used to fit the track (no extrapolation errors)

Still it's the noisy one because shares some strip with the Mu2e board

The problem of readout synchronization

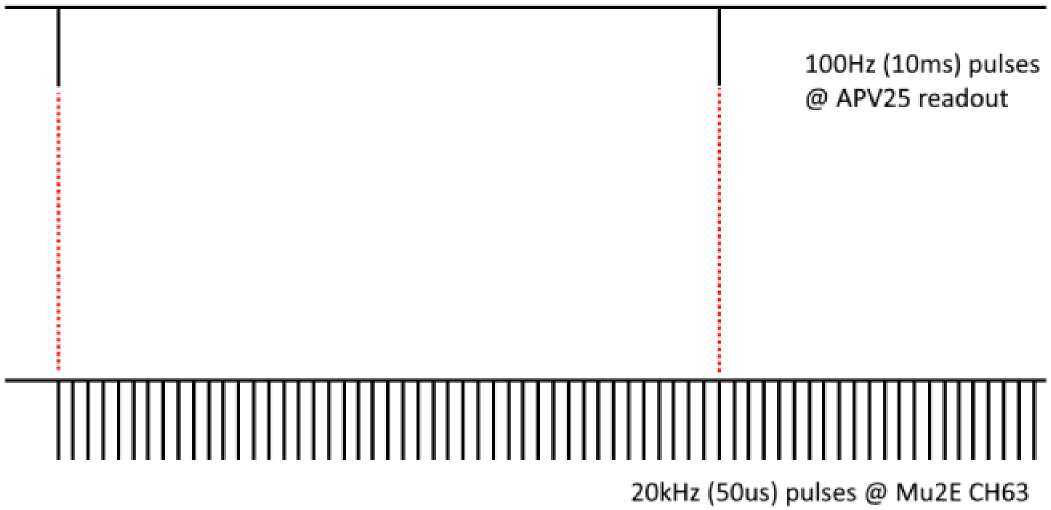


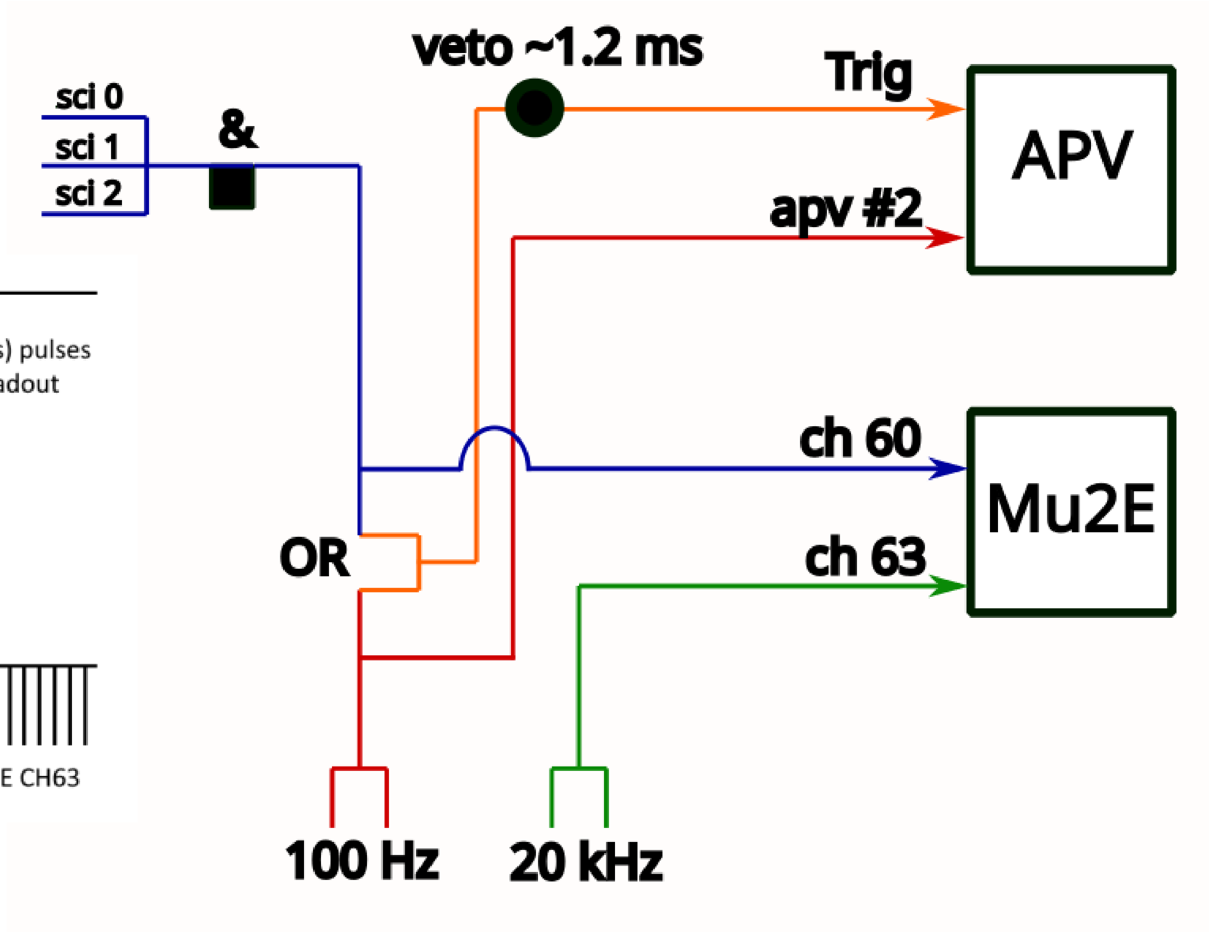
Each event has a DAQ time with a very poor resolution

APV readout is triggered while VMM readout is continous
The SRS board of APV readout provides a timestamp with a tick of 25 ns.
VMM events have a board clock id with a period of 25 ns and the ToT information.

Unfortunately SRS timestamp shows anomalies that cause the misalignment of the two readouts.

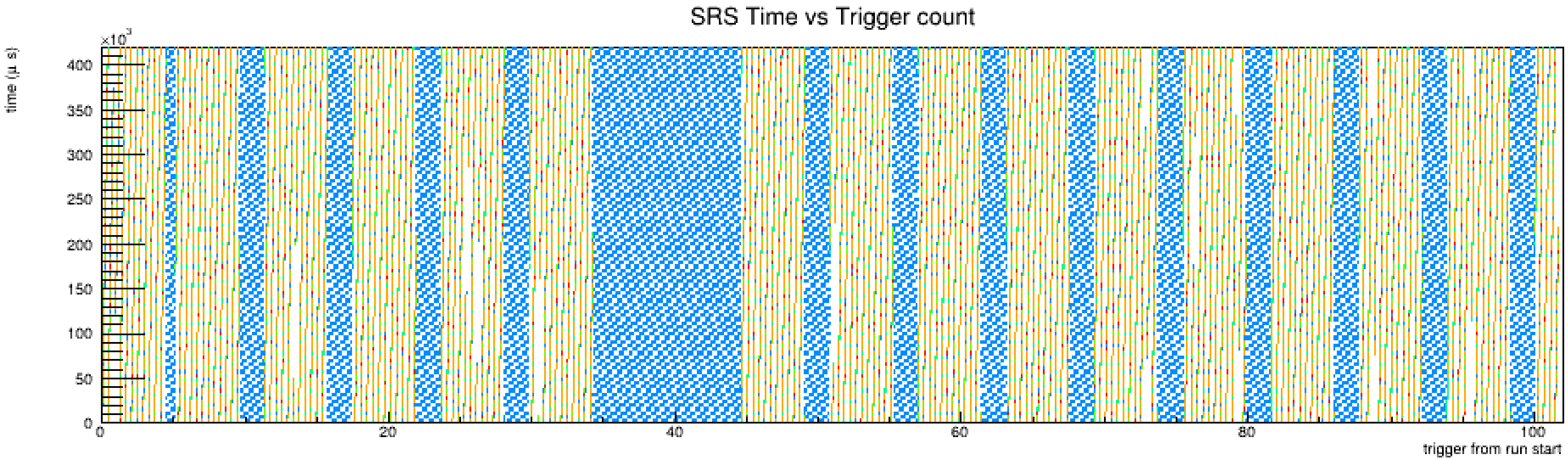
External synchronization (pulse generator)

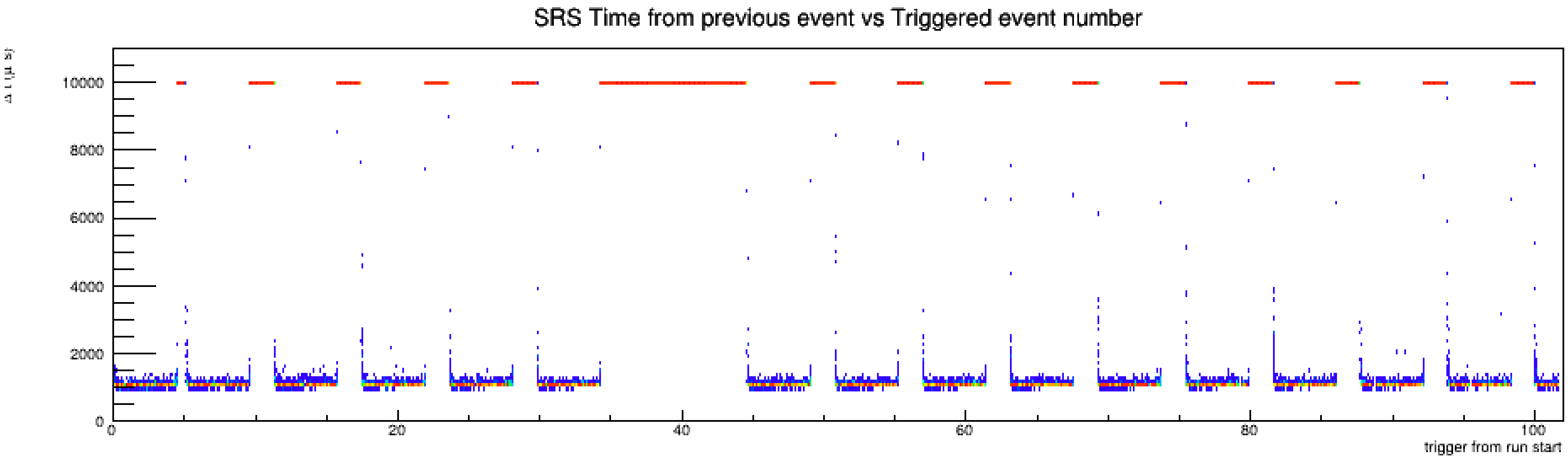




The same pulse generator sends a signal with period 50 μs to the VMM board and 10 ms to the APV boards.
The signal to APV is used as trigger but is vetoed during the spill

Pulser signals in APV

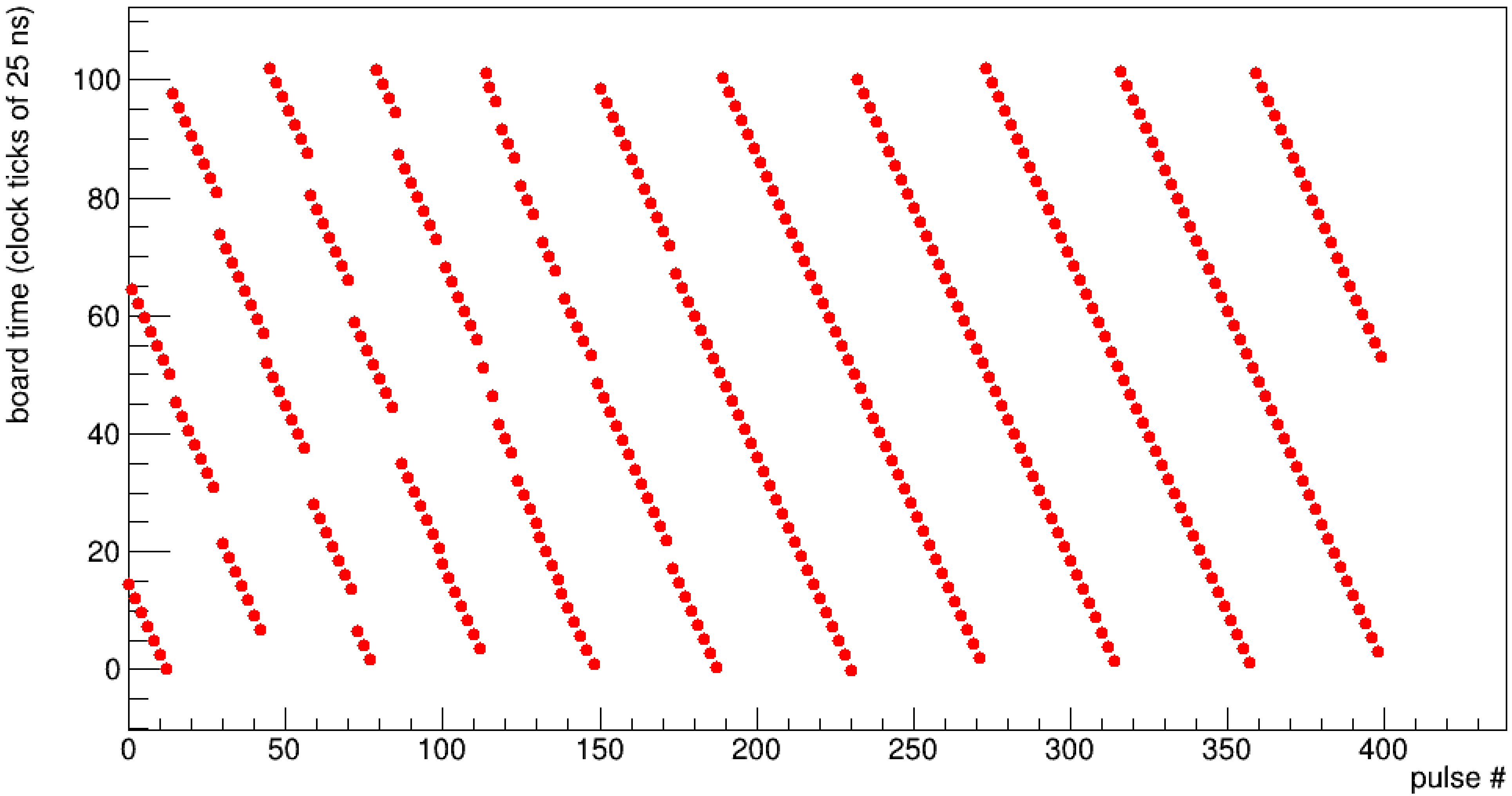




The distance between to pulses is 10 ms as expected

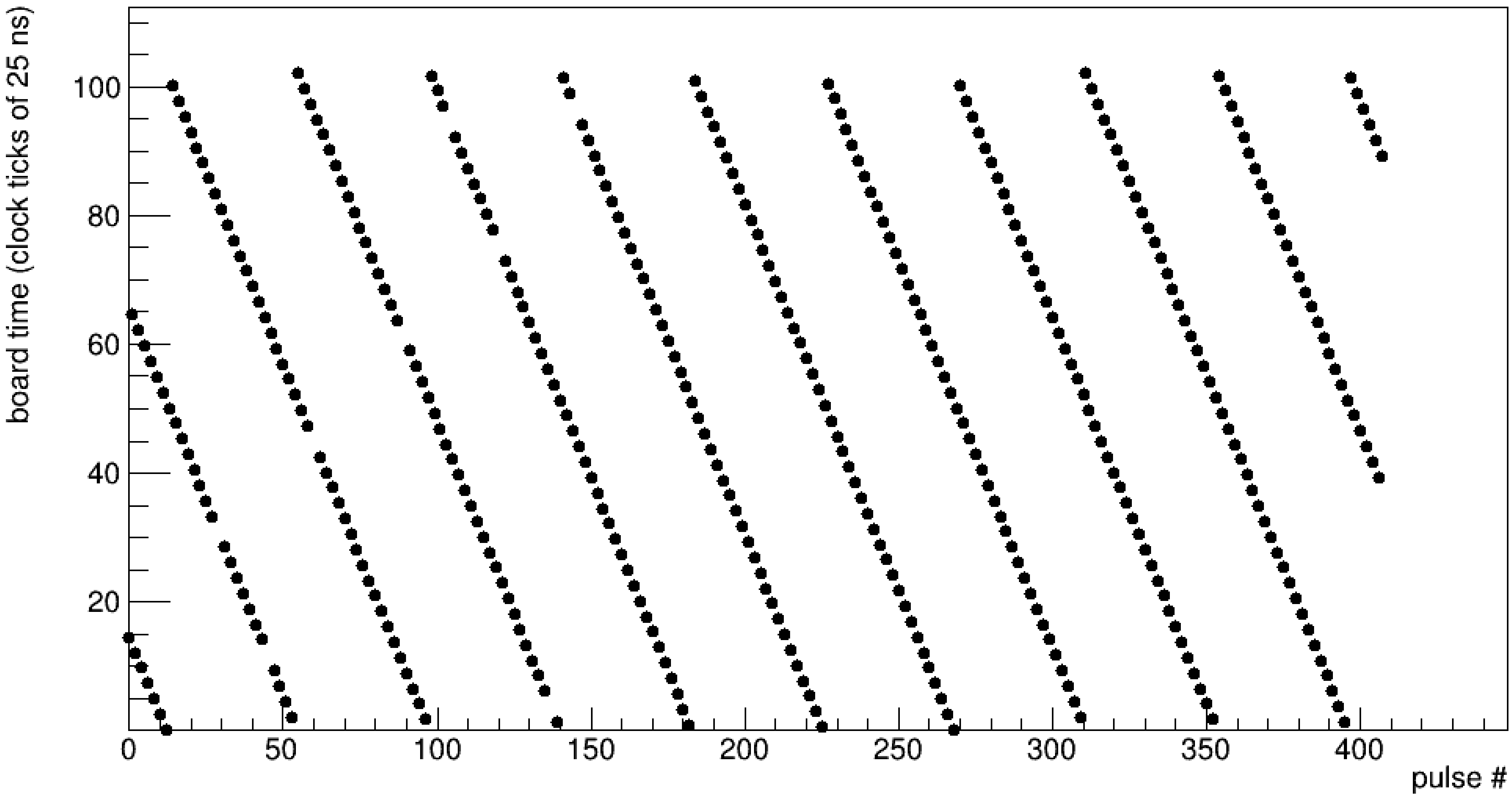
The spill structure is clearly visble

Pulser signals in VMM



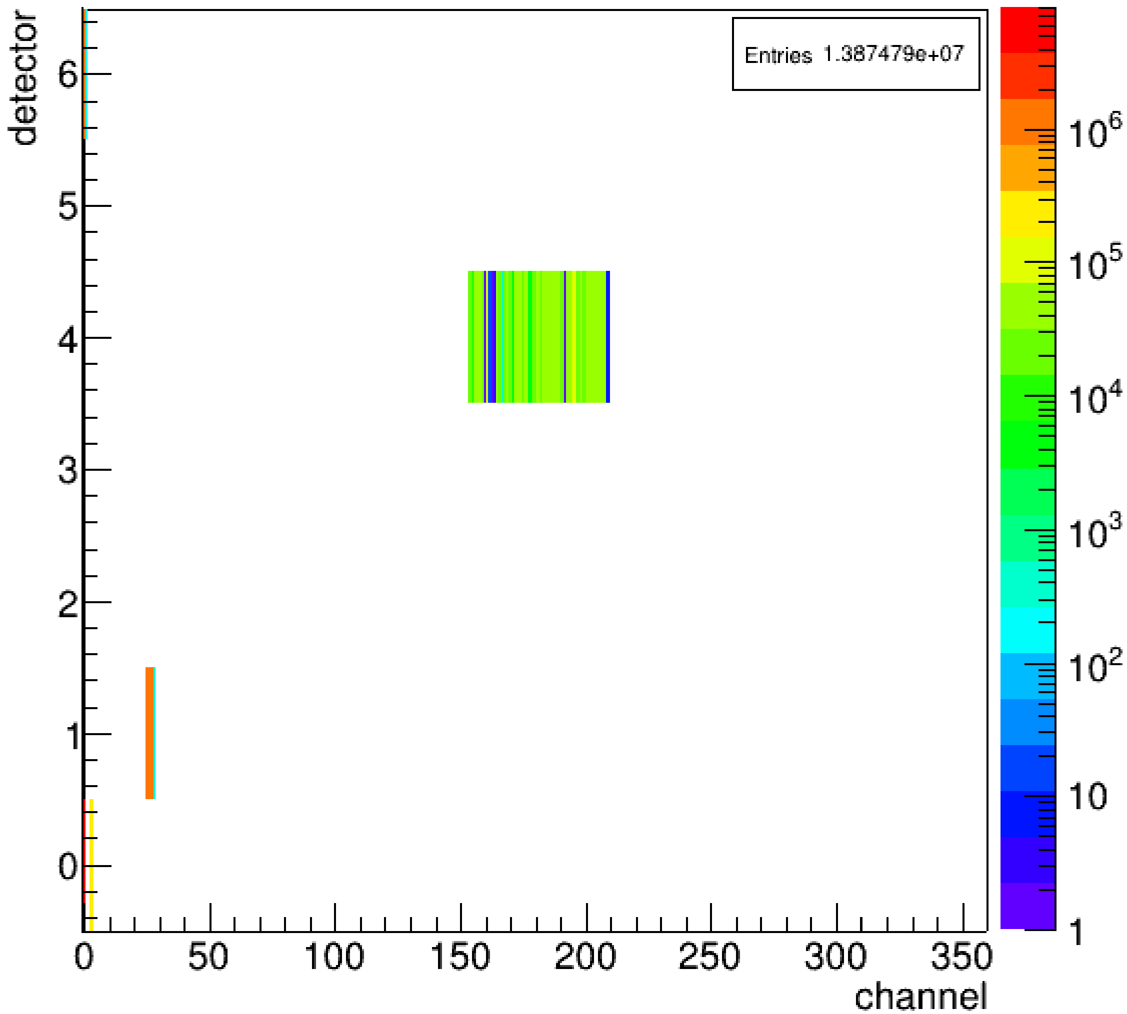
Also in this case we observe missing pulses and time shifts

Pulser signals in VMM (recovering time shifts)



Accumulate a time offset correction when the time distance is not 50 μs. Is this enough? Work in progress...

VMM standalone analysis

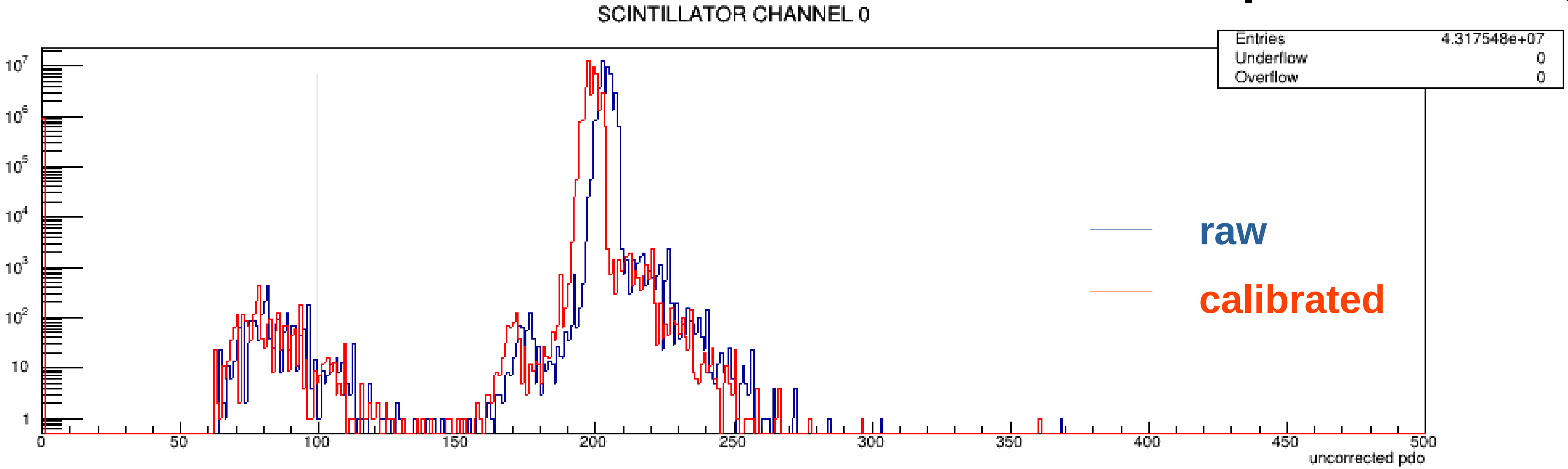


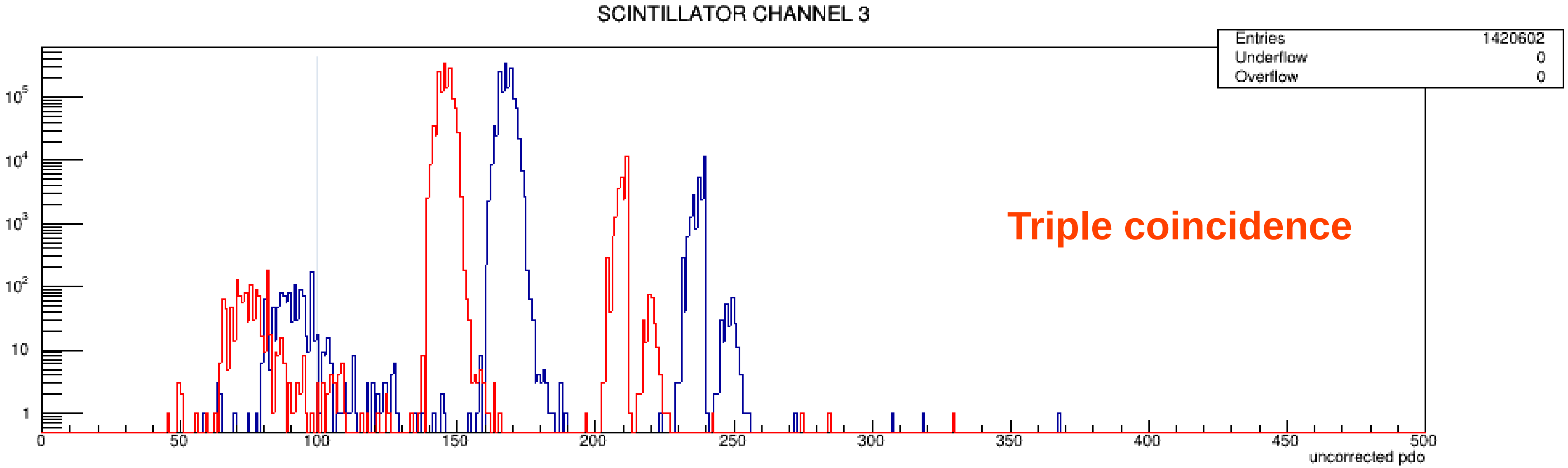
MicroMega LAYER 2:
strips from 154 to 209

Straws:
From 24 to 28

Scintillators:
channels 0, 1 and 3 (triple coinc.)

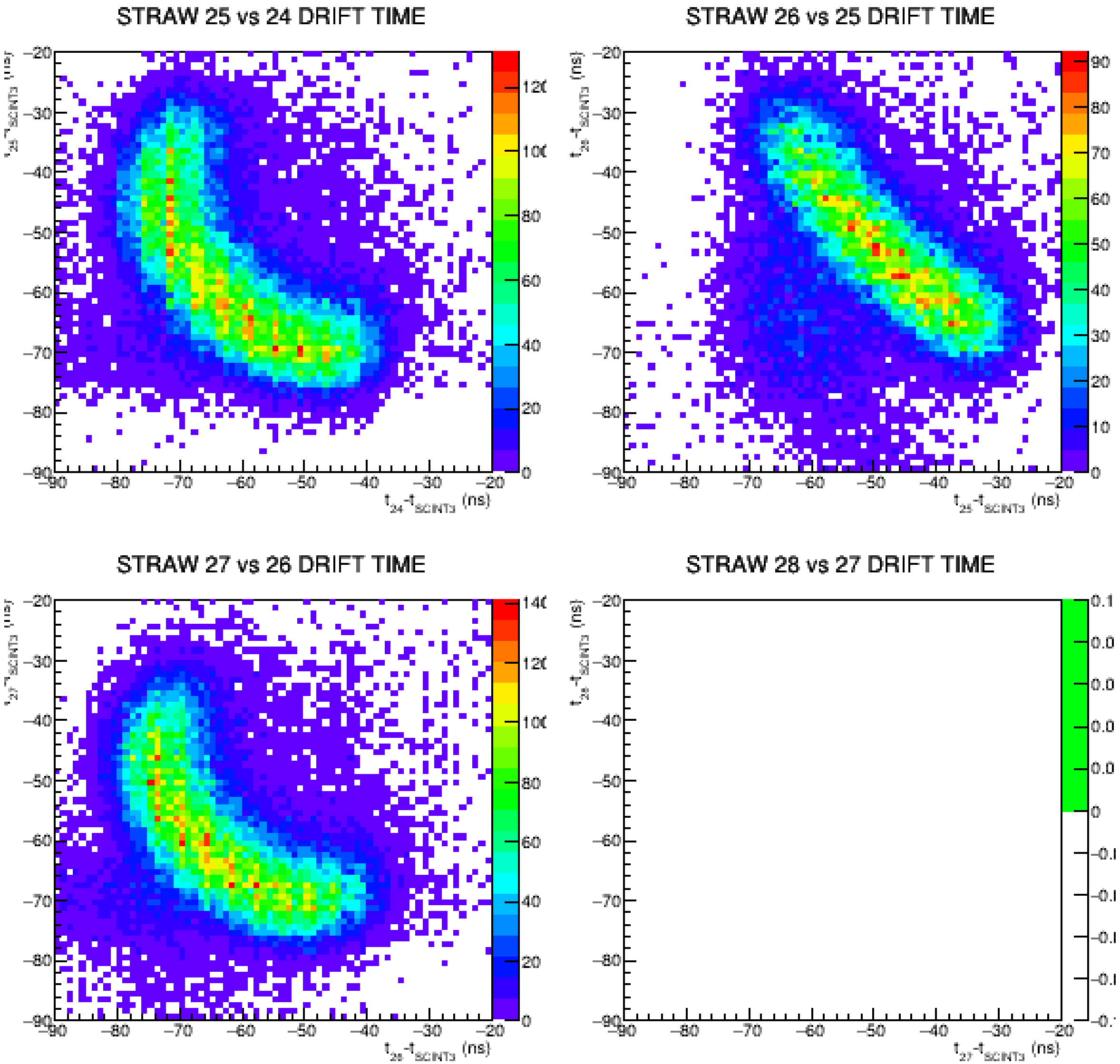
VMM RUN 665: Scintillator channels pulse height





Calibration function is a first order polynomial using the ADC observed range
A cut on calibrated pulse height is used to suppress the noise

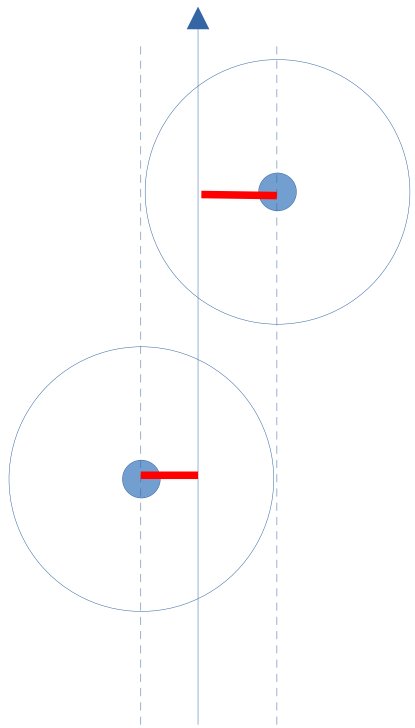
VMM RUN 665: drift time of adiacent straws



Drift time is obtained by subtracting the straw calibrated time and the scintillator coincidence calibrated time

Straw 25 and 26 show a linear anticorrelation while the other show a curious ‘banana’ shape

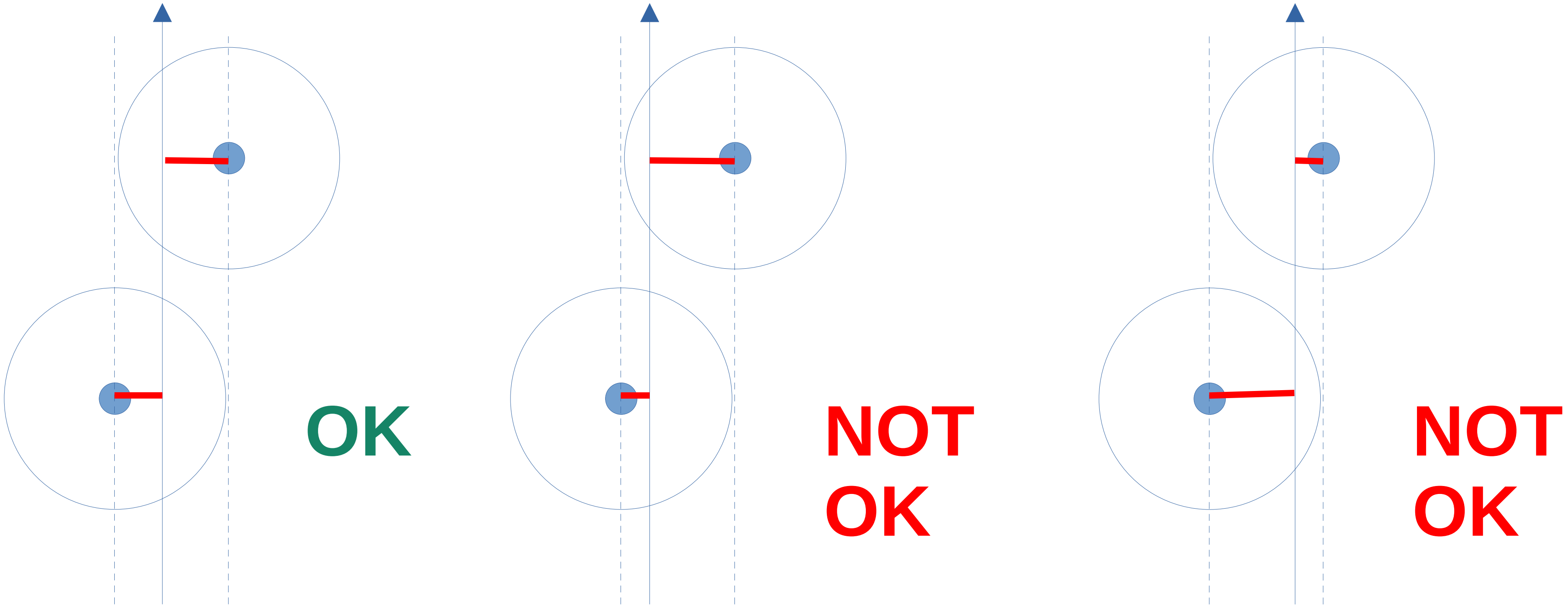
A rough estimate of straw time resolution



I we consider the beam perpendicular (in fact we know it a sigma of ~2.6°) the **sum of the drift distances** is **constant** (= the x distance between the wires)!

If we are in the region far from the wires where the space-time relation is in good approximation linear, the sum of the drift distances is proportional to the sum of the drift times, so also the **sum of the drift times** (or **total drift time**) must be **constant**!

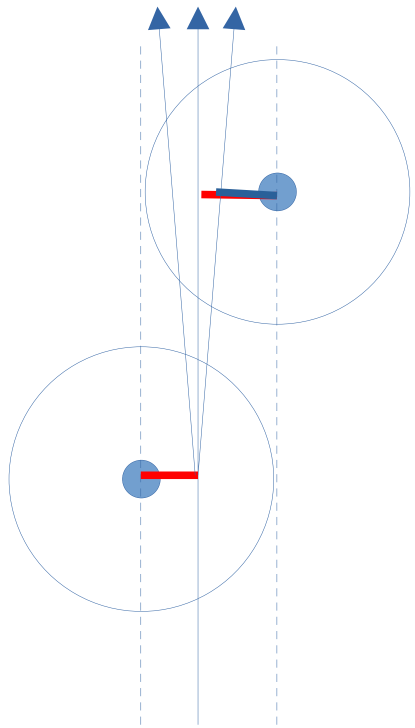
A rough estimate of straw time resolution



The condition to be far from the wires can be checked looking at the "**drift time asymmetry**" between the straws: the difference between their drift times is 0 when we are far from both wires, different from 0 otherwise.

This explains the **banana plot**: the relation is linear until we are far from both wires, otherwise is linear for one but not for the other.
The different behaviour of straw 25,26 is due to lower straw overlap

A rough estimate of straw time resolution

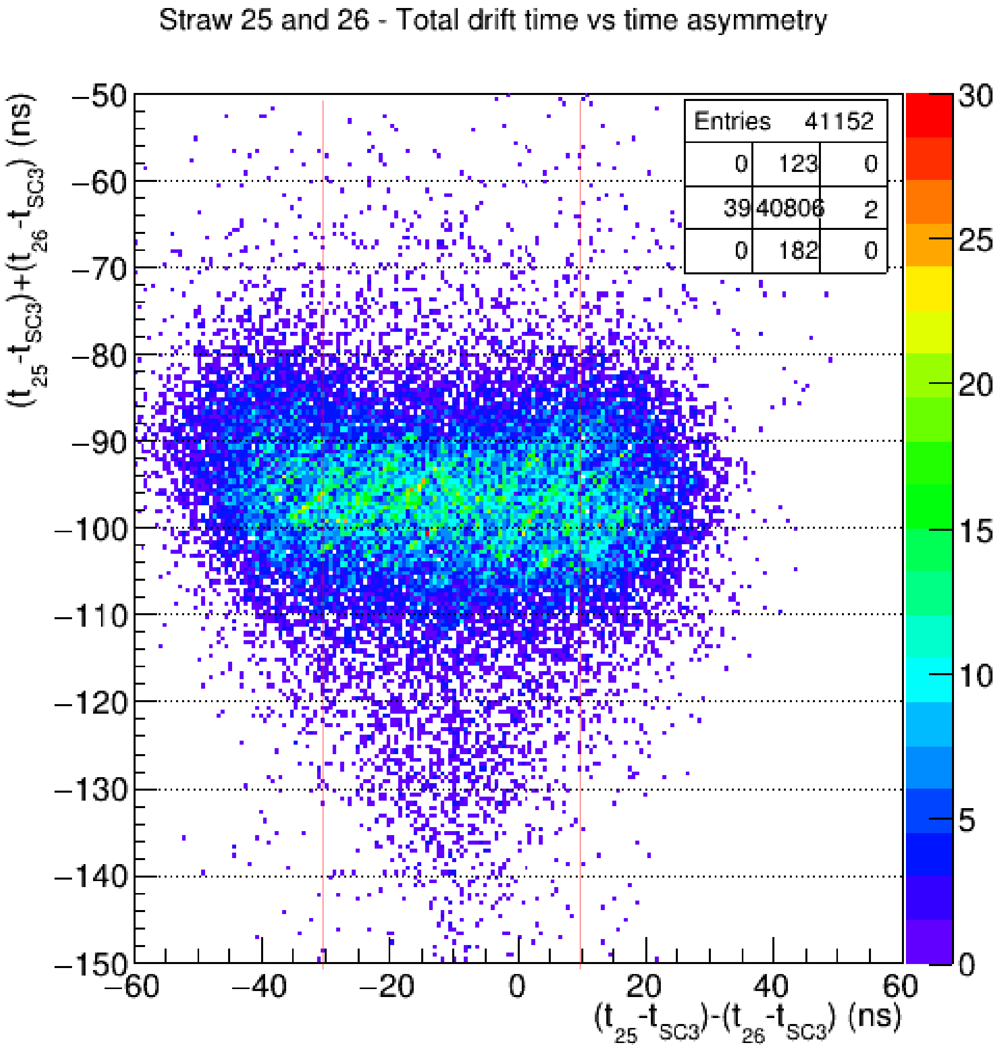


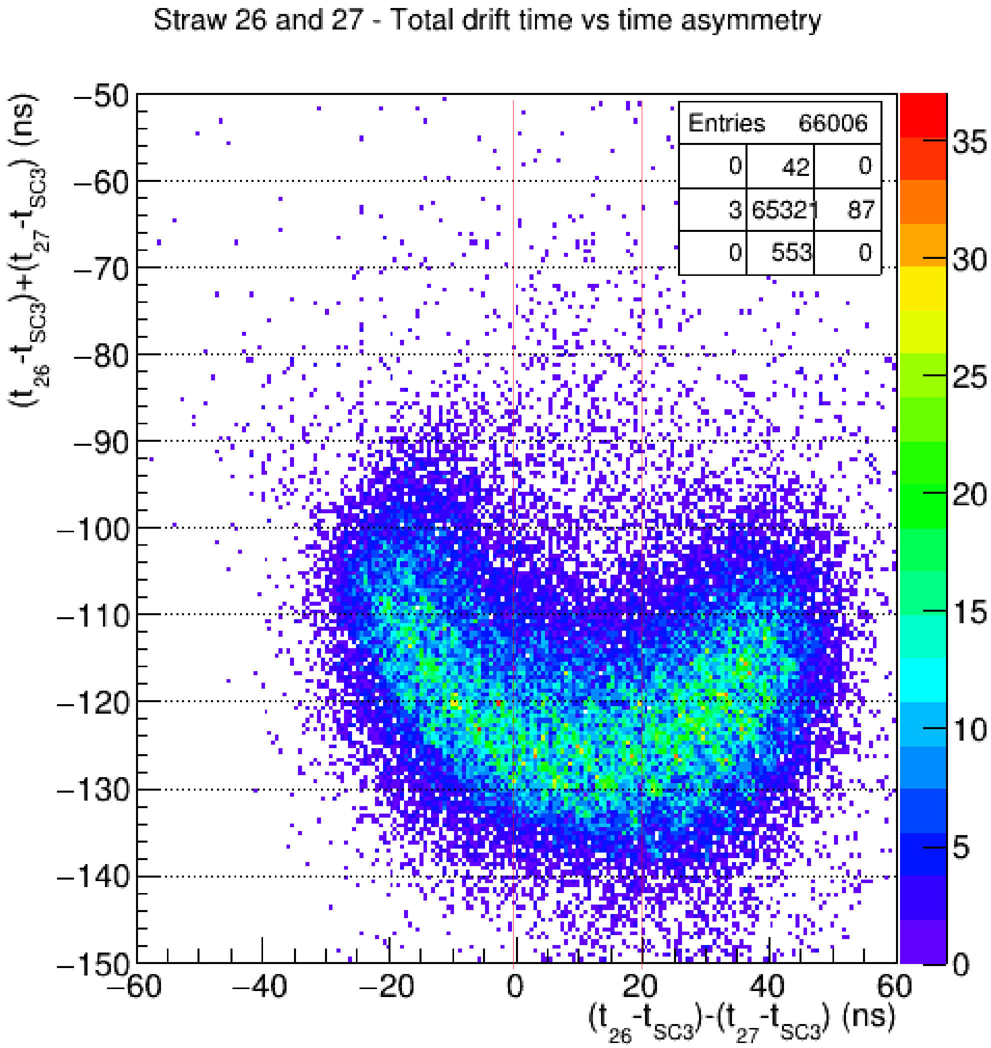
In fact the beam is not exactly perpendicular: there's a sigma of ~2° on the angle that corresponds to **~250 μm** on 7 mm.

So the total drift time is expected to fluctuate with a sigma of 250 μm that for a drift velocity of ~**80 μm/ns** corresponds to ~**3 ns**!!
(for 50 μm/ns becomes 5 ns!)

A more accurate result requires to use the particle direction obtained by the fit of the MicroMega layers

VMM RUN 665: total drift time vs drift time asymmetry

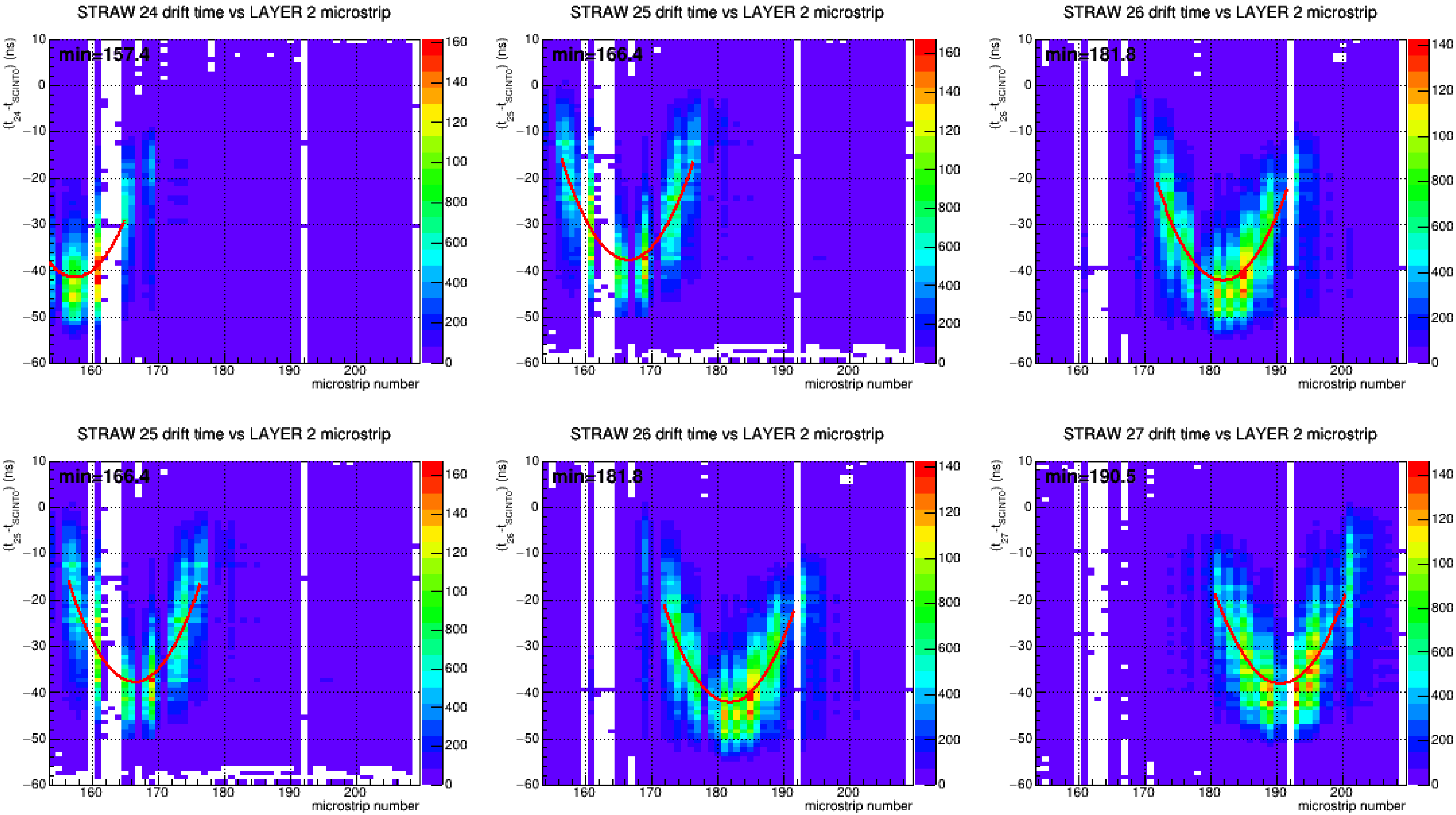




To select the linear region we ask for:

$-30<\Delta t_{25}-\Delta t_{26}<10$ ns and $0<\Delta t_{26}-\Delta t_{27}<20$ ns

VMM RUN 665: straws overlap (microstrip hits)

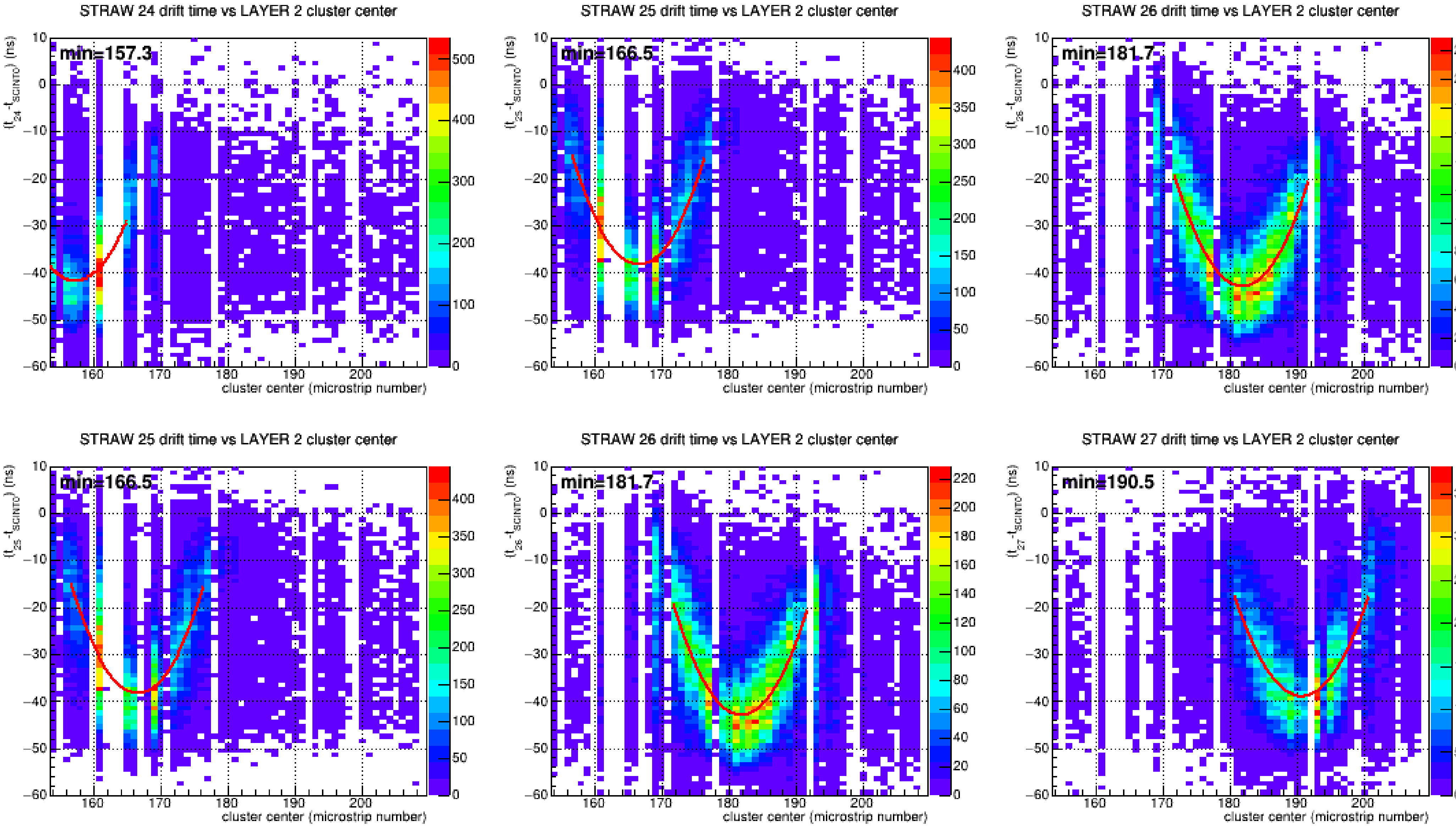


One entry per microstrip hit (not for cluster). Parabolic fit. 1 strip=250 μm

Minima correspond to wire position: 24→25: 2.25 mm, 25→26: 3.85 mm, 26→27: 2.2 mm

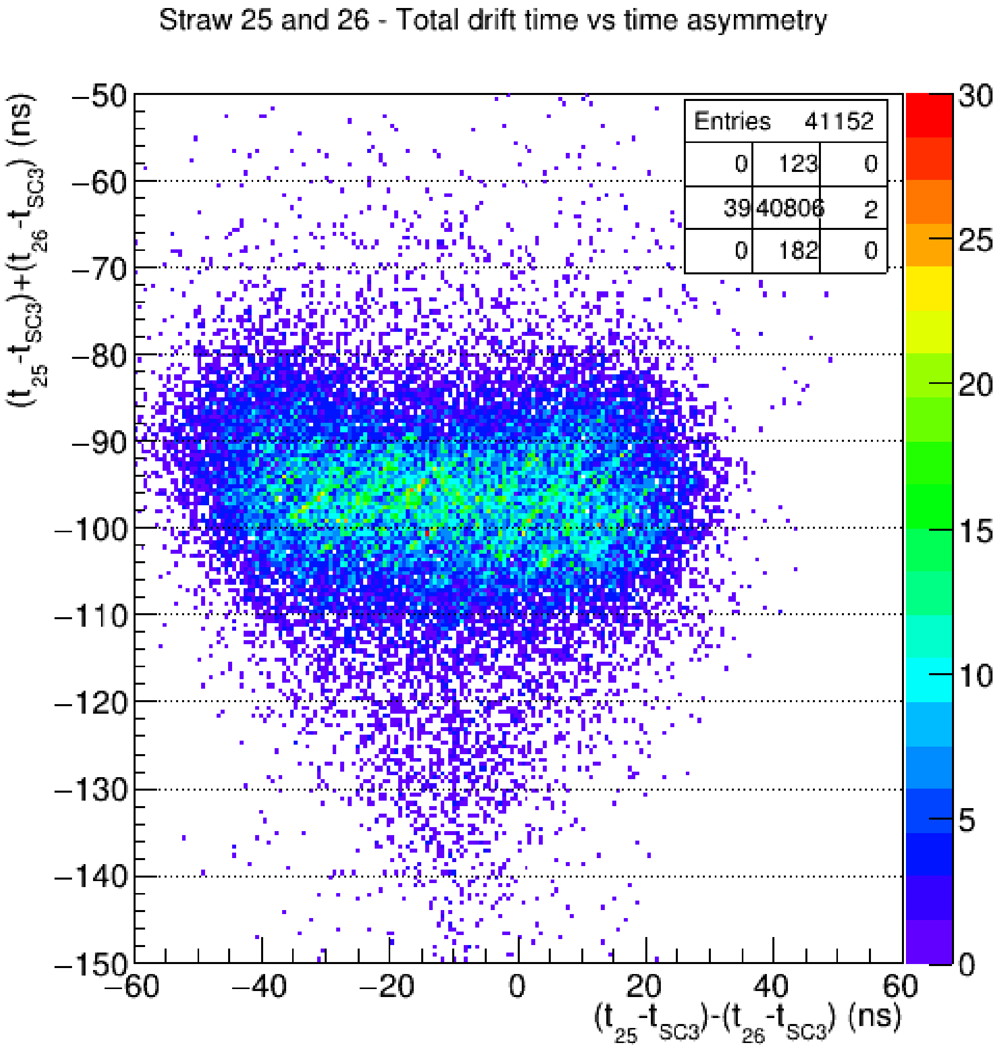
24→26: 6.1 mm, 25→27: 6.0 mm

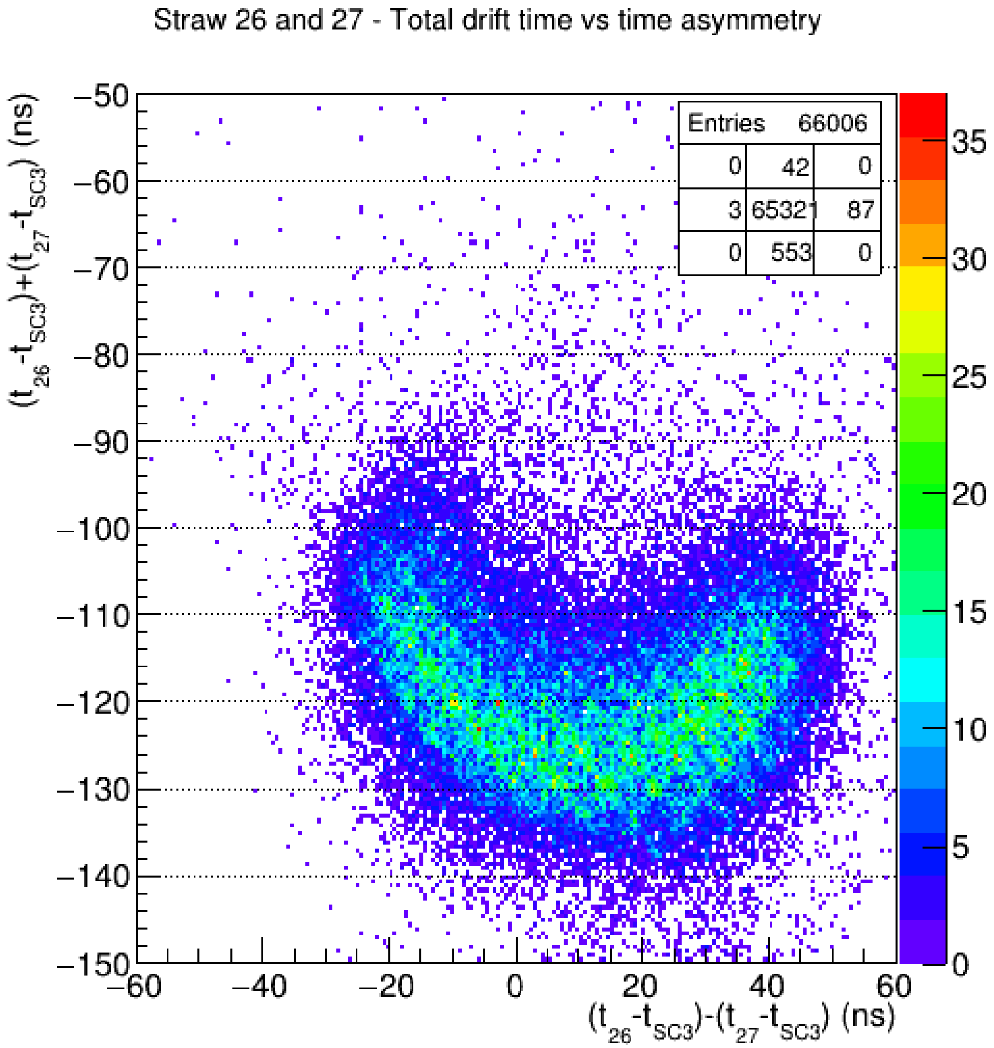
VMM RUN 665: straws overlap (strip clusters)



One entry per cluster center. Parabolic fit. 1 strip=250 μm
Minima correspond to wire position: 24→25: 2.3 mm, 25→26: 3.8 mm, 26→27: 2.2 mm
24→26: 6.1 mm, 25→27: 6.0 mm

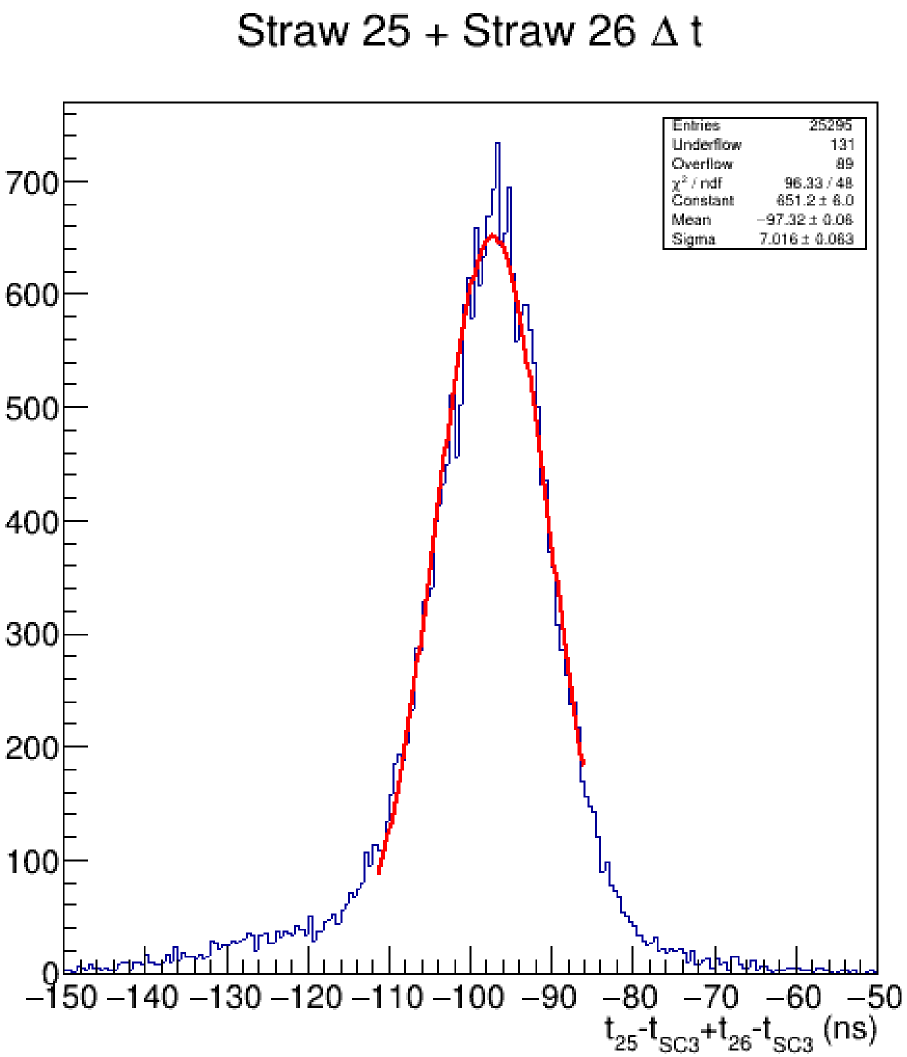
VMM RUN 665: total drift time vs drift time asymmetry

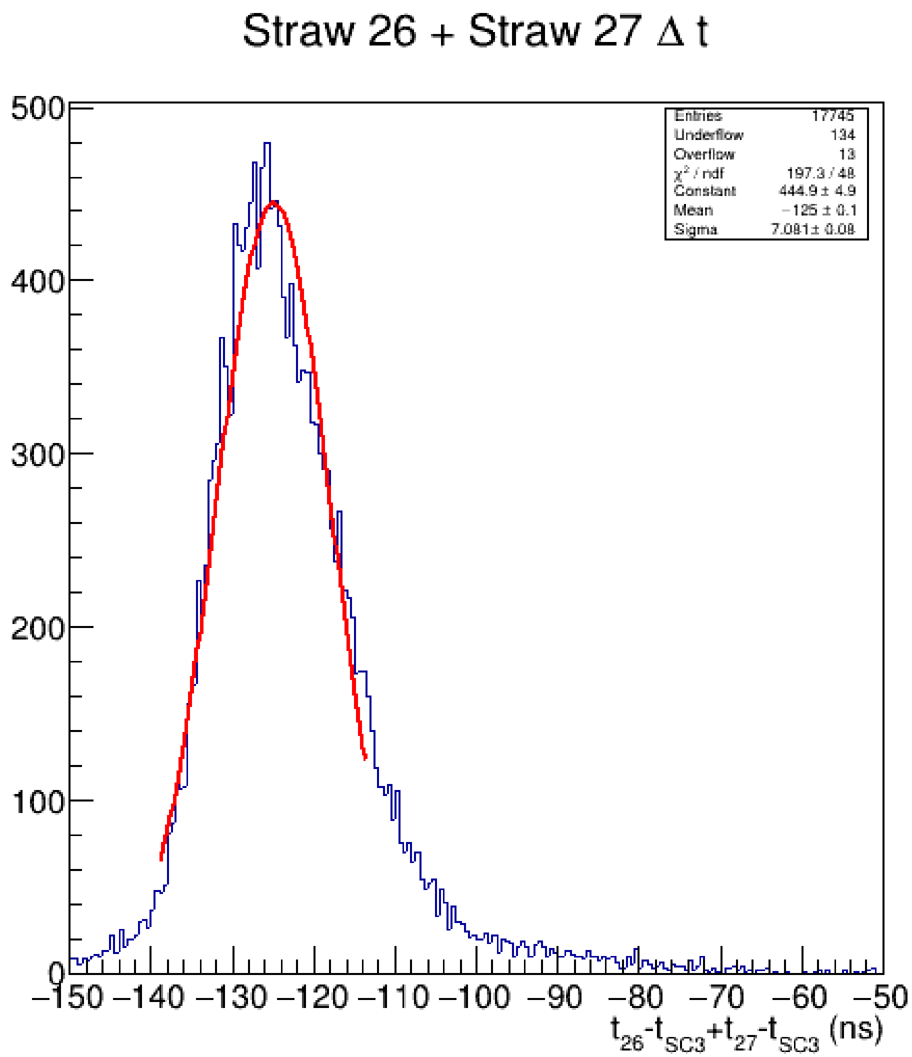




The first is nearly constant!
The second shows the ‘banana’ shape but is nearly constant far from the edges

VMM RUN 665: total drift time after cuts

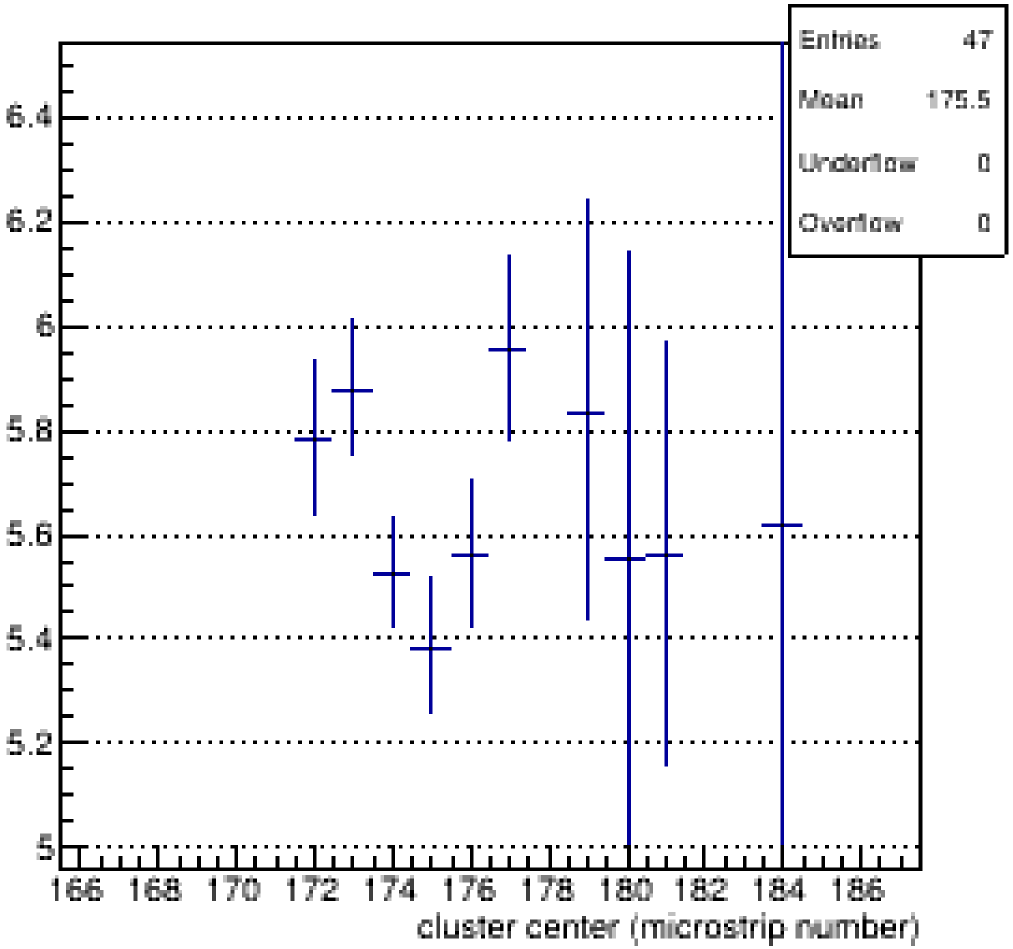




σ~7 ns

For one straw: $\frac{7}{\sqrt{2}} \sim 5\ ns$

VMM RUN 665: total drift time sigma



The result can be improved by considering only the events that cross a given microstrip

$\sigma_{\Delta t}$~5.5 ns

For one straw ~**3.9 ns**

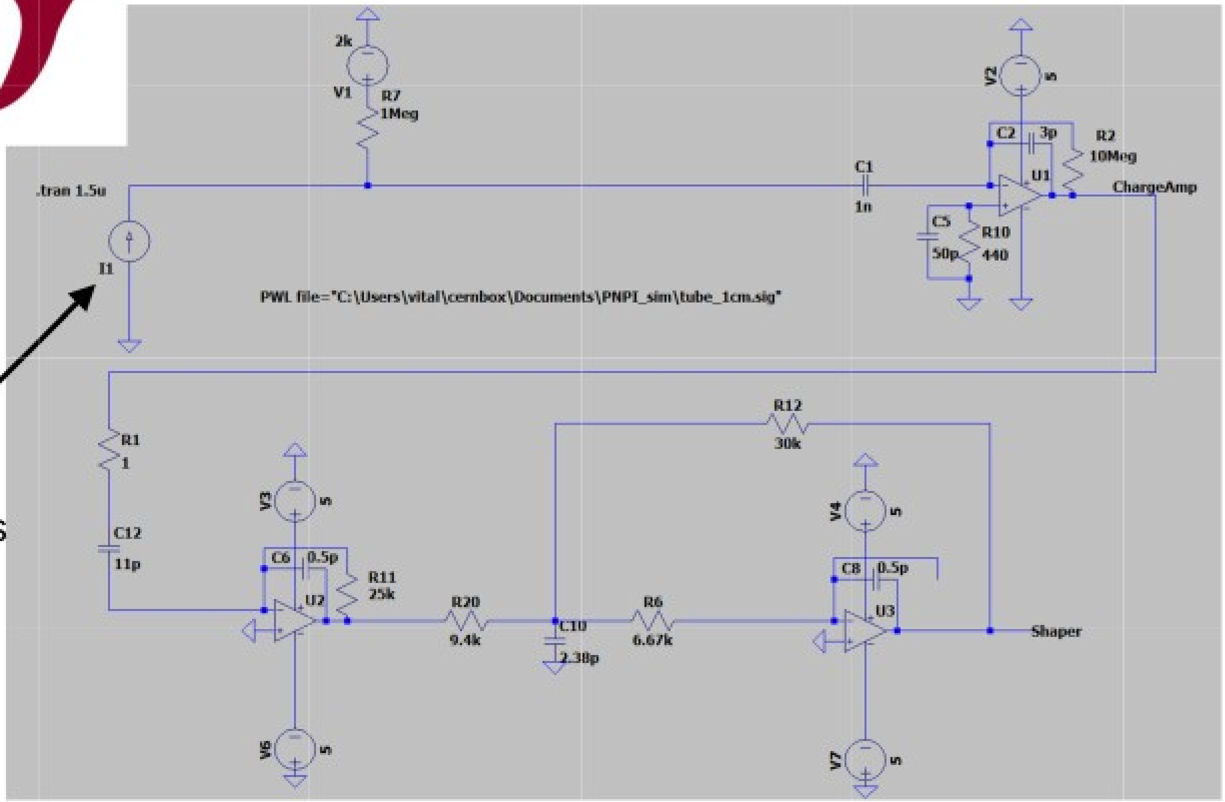
This is patch to reduce the effect of the beam angular spread (~2.6°)

A better correction would come when the readouts syncronization will be ready

Expected time resolution from simulation

LTspice®

VMM3 + Straw Model

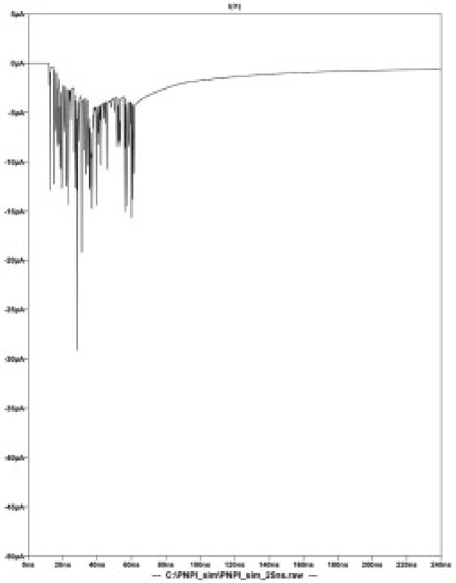


Straw Tube is represented as a current source

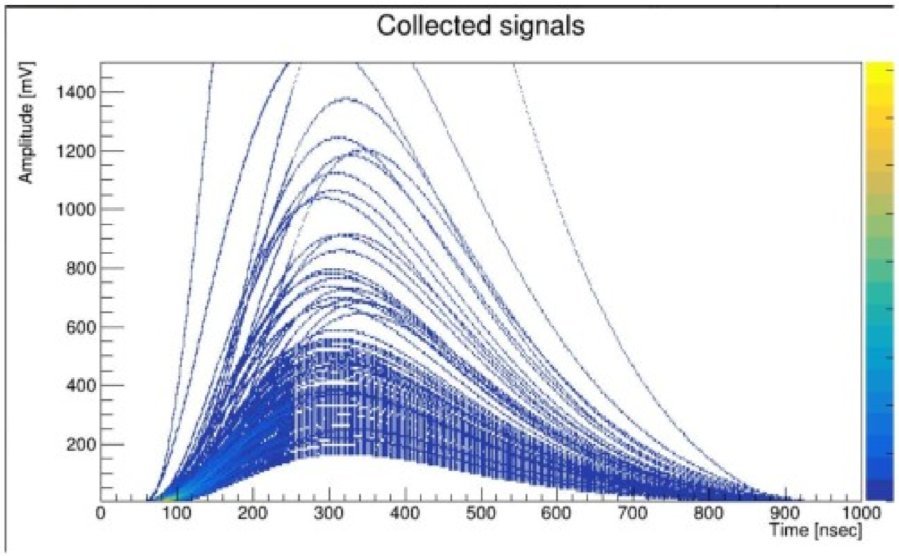
Vitaly Bautin, Aliaksei Paulau (JINR)

Expected time resolution from simulation

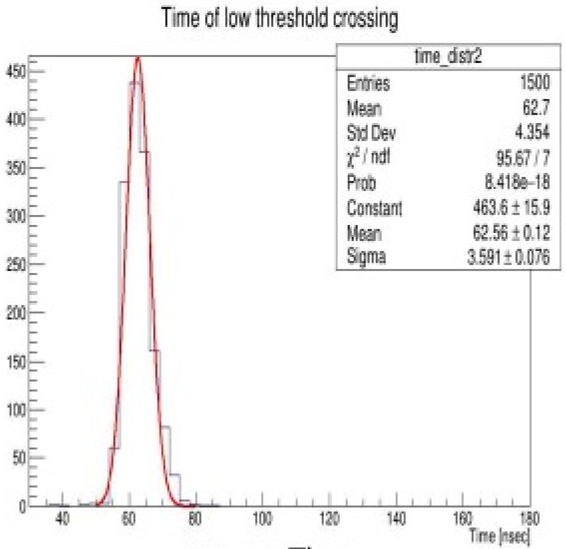
Garfield + LTSpice simulation



Garfield simulated signal
from straw tube



LTSpice amplifier & shaper response
to the signals provided by Garfield

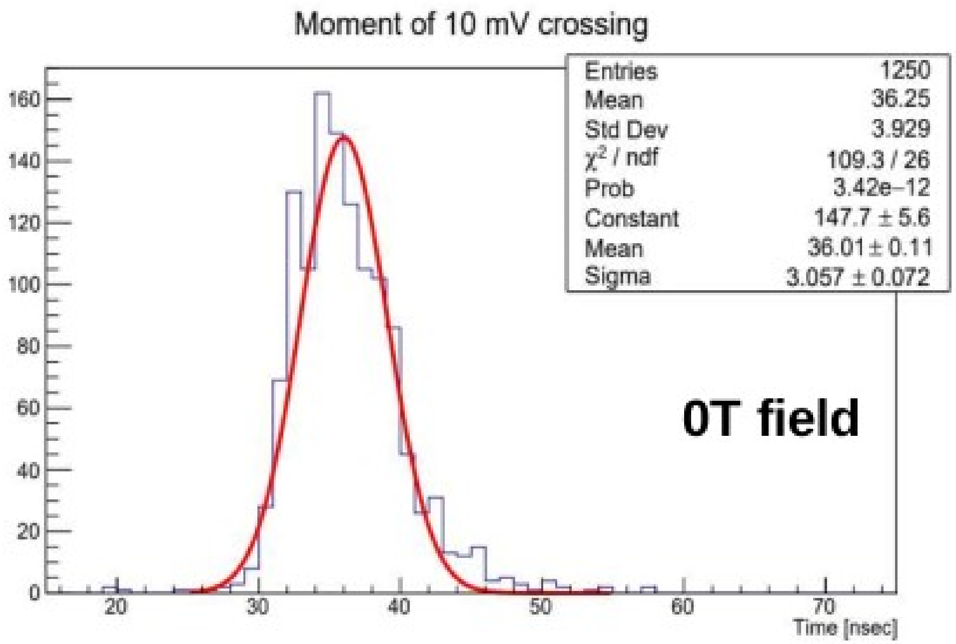


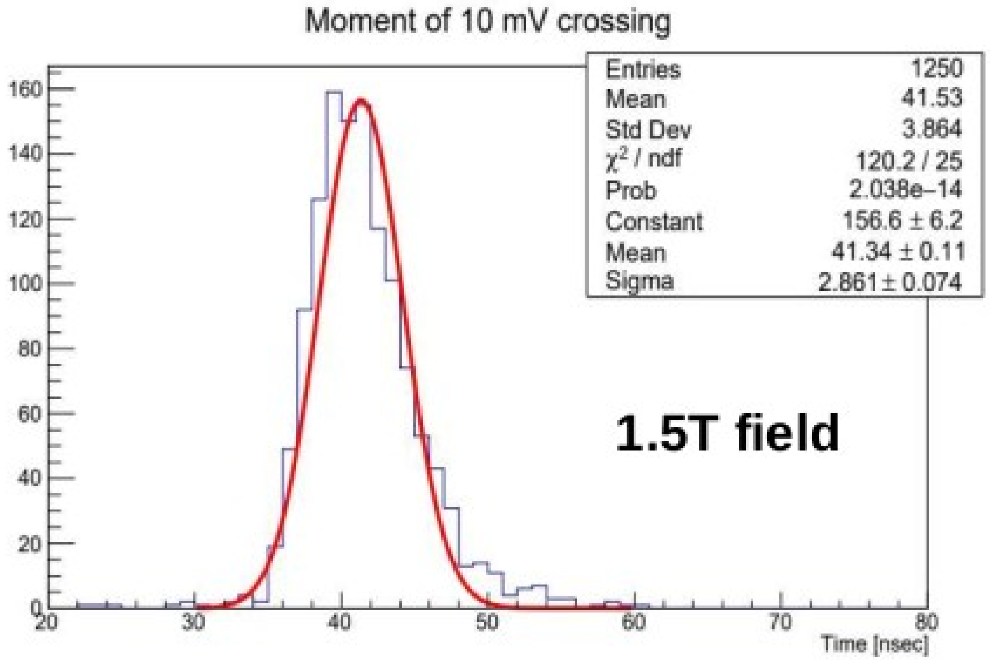
25ns p.Time
10mV THL

Vitaly Bautin, Aliaksei Paulau (JINR)

$\sigma_{\Delta t}$~3 ns!

Effect of magnetic field on time resolution (simul.)



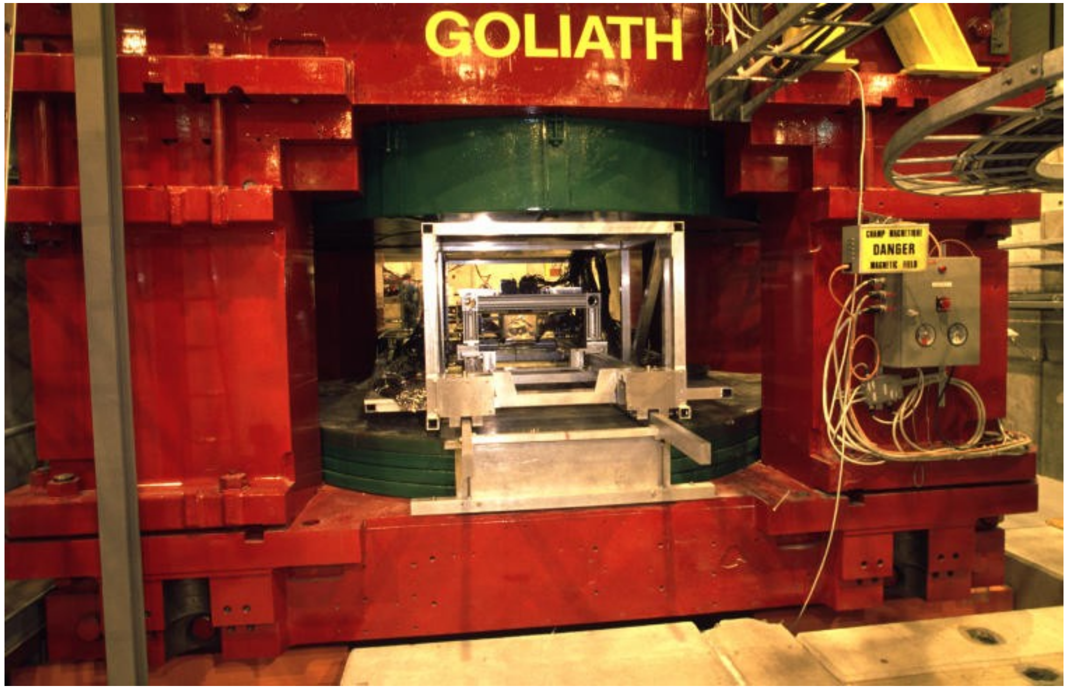


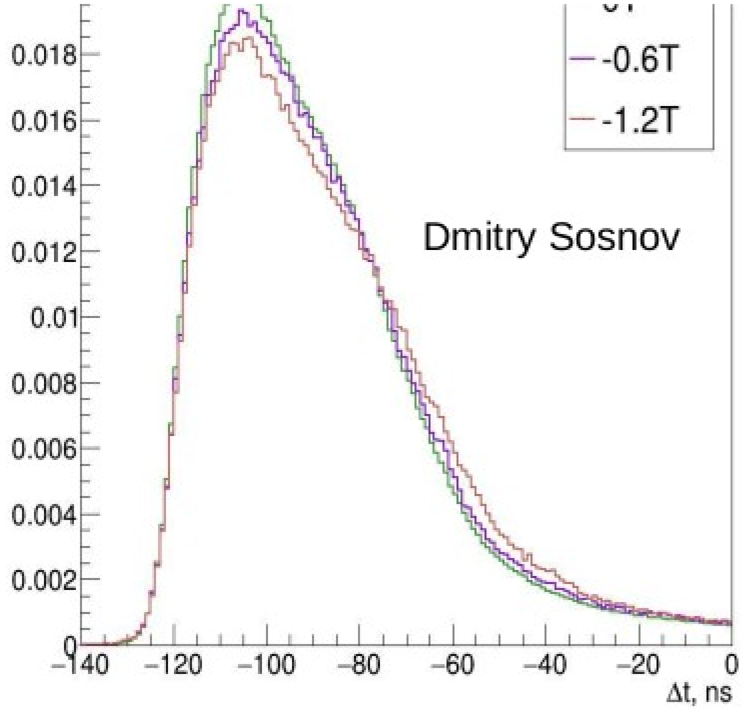
Vitaly Bautin, Aliaksei Paulau (JINR)

5 ns shift of the mean drift time

Effect of magnetic field on time resolution (meas.)

Dmitry Sosnov(JINR)

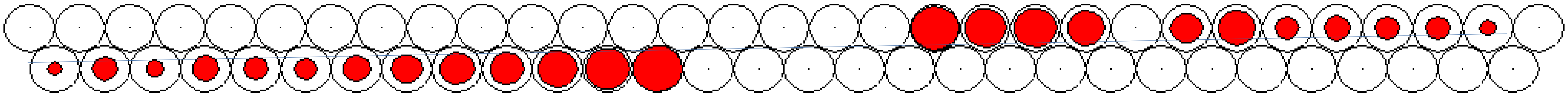




A new readout based on TIGER chip should allow to acquire straw amd microstrips with the same system

Same **5 ns** shift of the mean drift time observed

Another work in progress



Special runs with rotated setup.

Encouraging results using a unique linear drift space-time relation for all the straws

Need more refined space-time relation, changing from straw to straw (iterative procedure)

Summary

Test beam of 6 mm straw tube prototype being performed this year at Cern. Indication for a time resolution of ~3 ns.

Is it enough? No clear requirements from **simulations**.

Tiger chip results should come in few weeks. No problems with readout synchronization.

Both VMM3 and TIGER chip need R&D. Man power (and/or funds) needed.

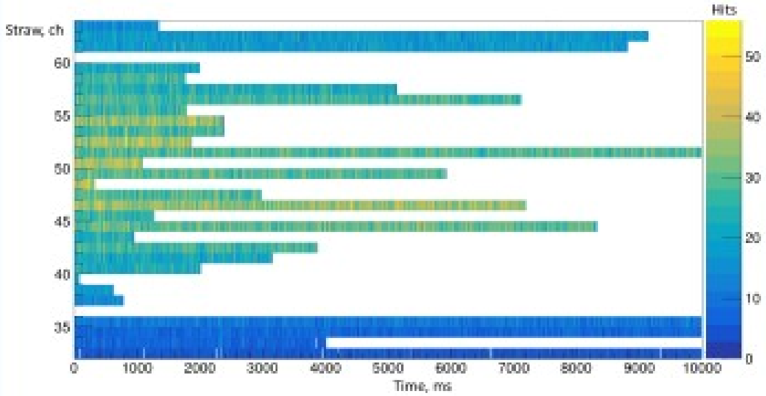
Next test beam will hopefully validate the first prototype built in Italy: a lot of work and opportunities to acquire and share the needed know-how!

BACKUP

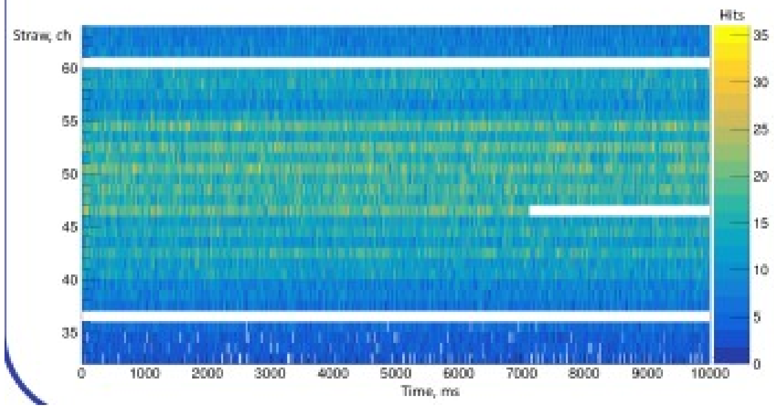
VMM3a bug in time measurement

- VMM3a "latching" in T@T mode was observed. A possible explanation is an algorithmic problem in the cases when the time between the threshold crossing and signal peak is too short (<1 clock cycle).

A comparison of operation stability with 40MHZ and 80MHz clock frequency:

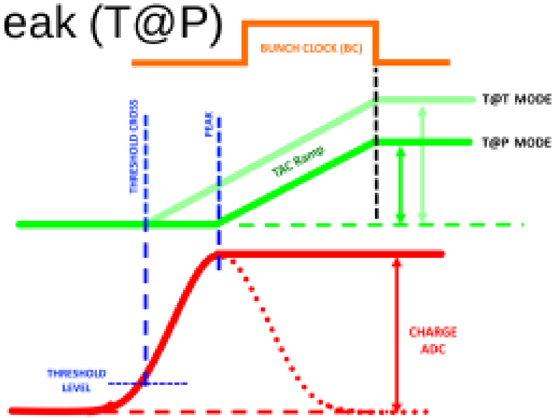


Peaking time 200ns,
BC = 80MHz



Peaking time 200ns,
BC = 40MHz

- time measurements (nominally 8b TDC)
  - time-at-threshold (T@T)
  - time-at-peak (T@P)



Vitaly Bautin (JINR)