My first look at test beam of STT prototype

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CERN Test beam

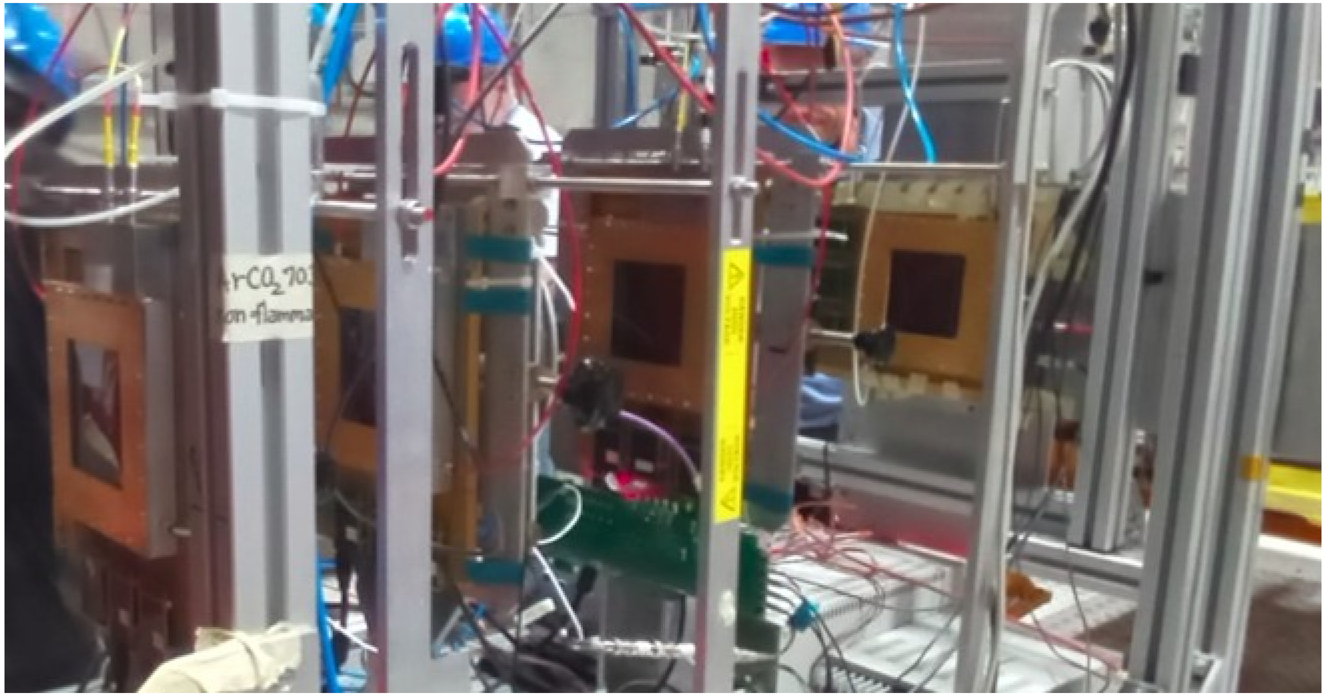
I have been at Cern at beginning of June together with Roberto Petti, Gabriele Sirri and Fabrizio Raffaelli to visit our JINR colleagues at the end of the test beam of the 20x20 cm straw tube prototype. They have been so kind to grant us the access to the data and to share the code to read them.

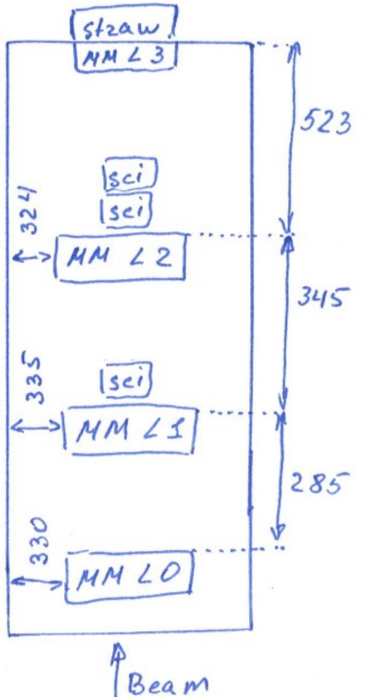
We are still working together to analyze the large amount of data and to get the final answer to the big question:
Is the VMM3 chip able to provide the wanted time resolution for STT?

Test beam setup

D. Sosnov

BEAM

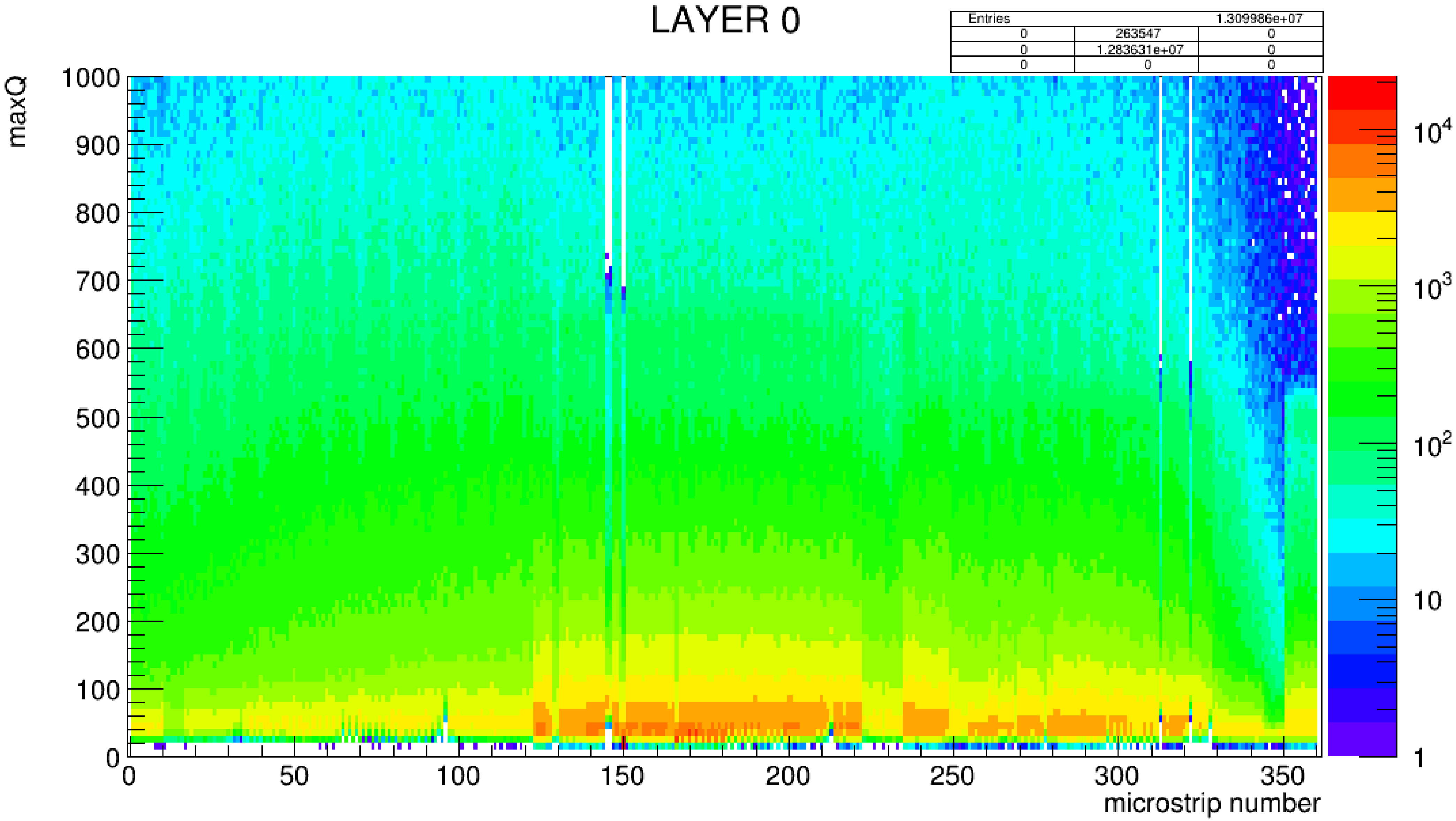




4 MicroMega layers (first 3 with vertical strips, last with horizontal strips)
3 scintillators used for trigger
64 straws with 6 mm diameter disposed on 2 layers

I will consider a specific run where:
All MicroMega strips were read by the APV board (APV RUN 331)
5 straws, 3 scintillators and 56 strips from Layer 2 were read Mu2e Board (VMM RUN 665)

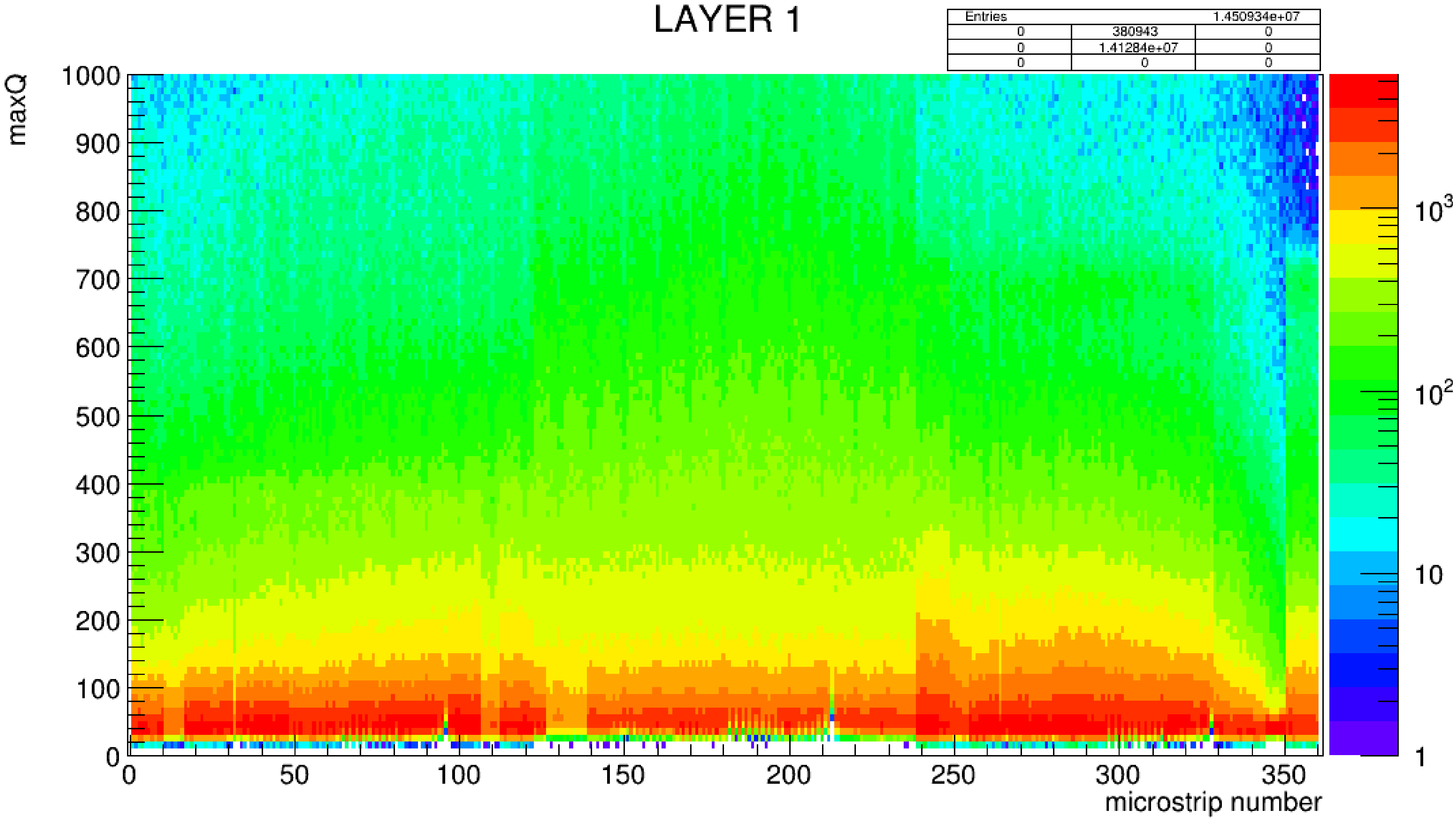
APV RUN 331: LAYER 0 microstrips pulse hight



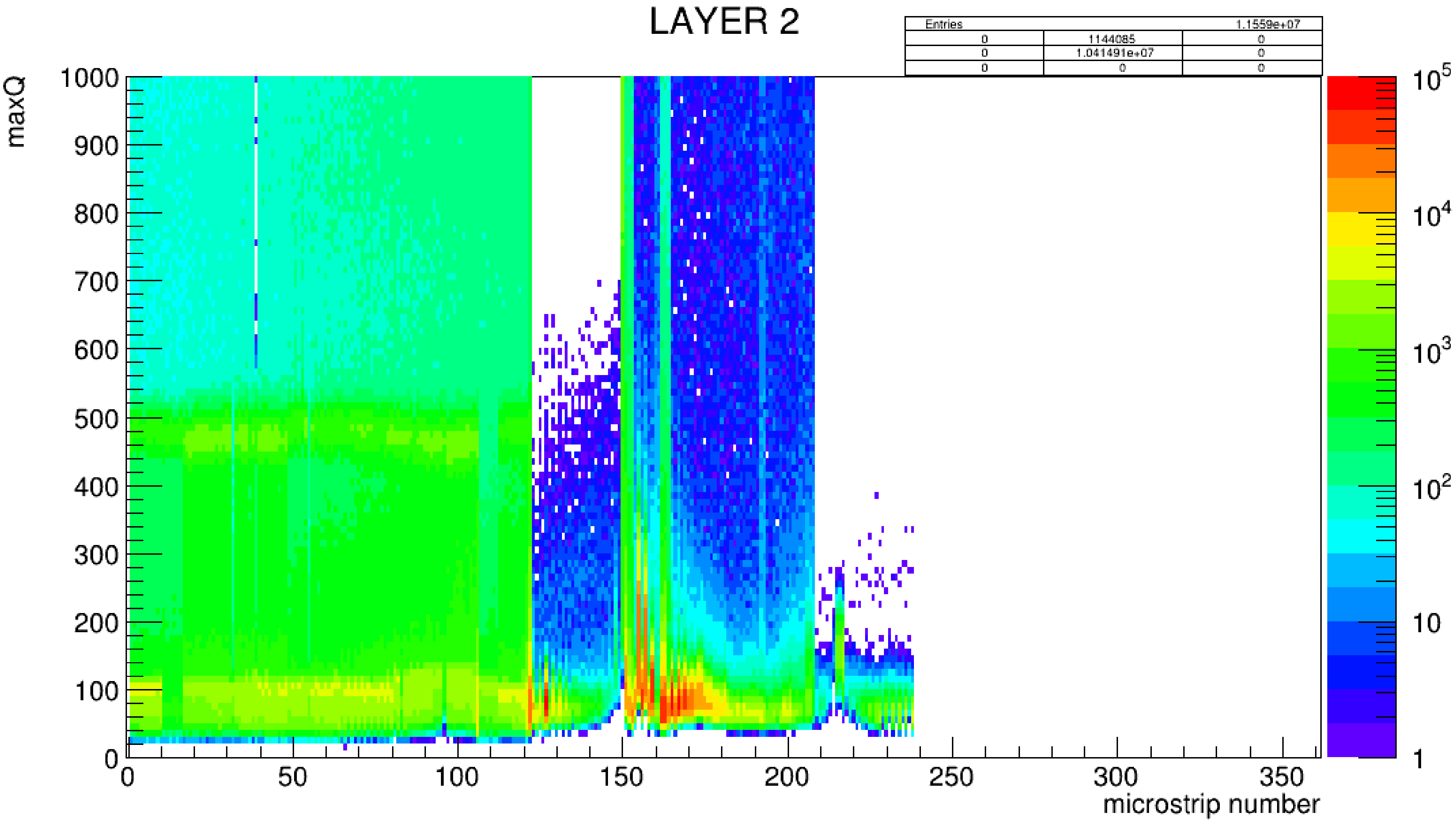
The microtrip **pitch is 250 μm**

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

APV RUN 331: LAYER 1 microstrips pulse hight

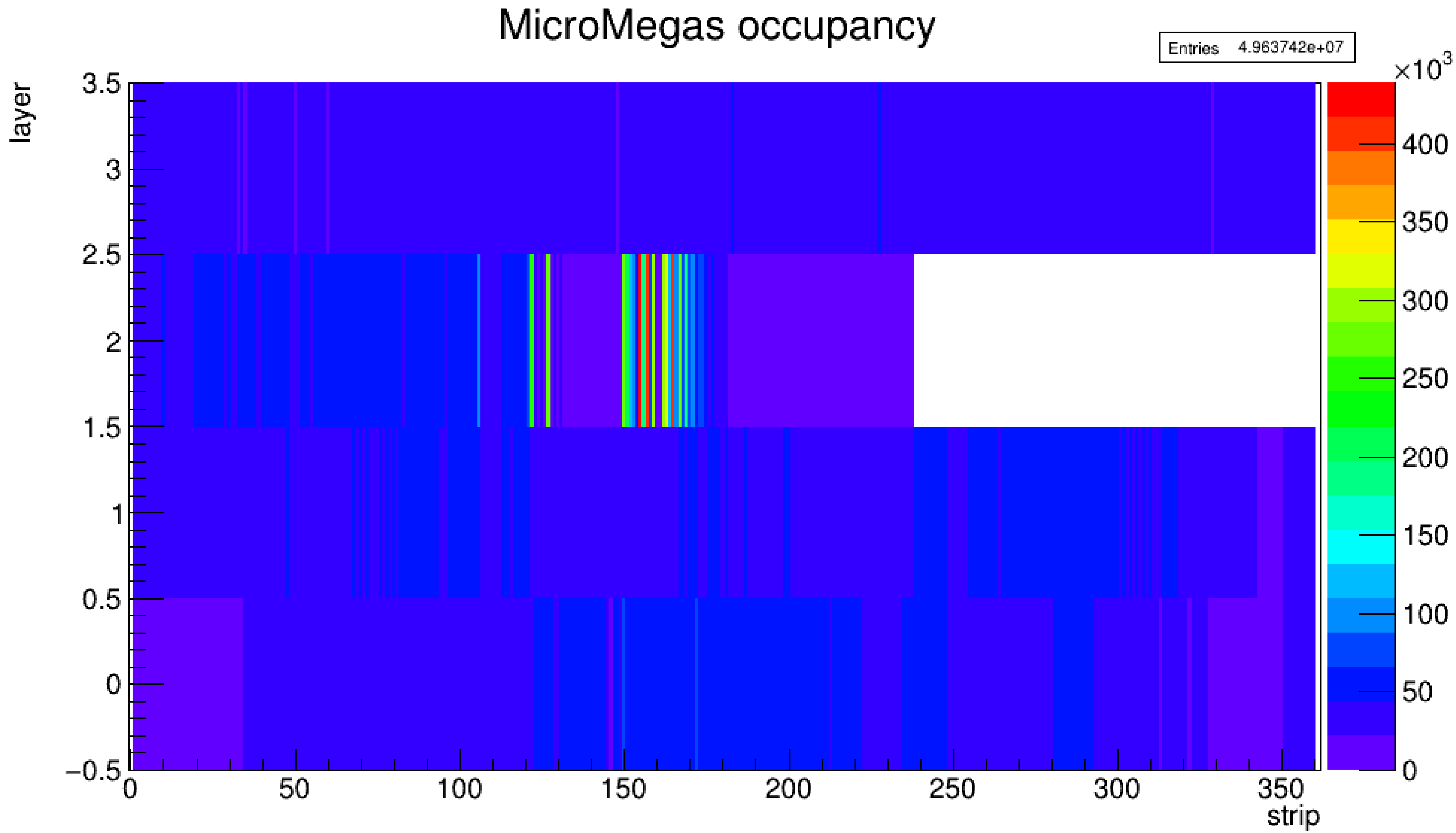


APV RUN 331: LAYER 2 microstrips pulse hight



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



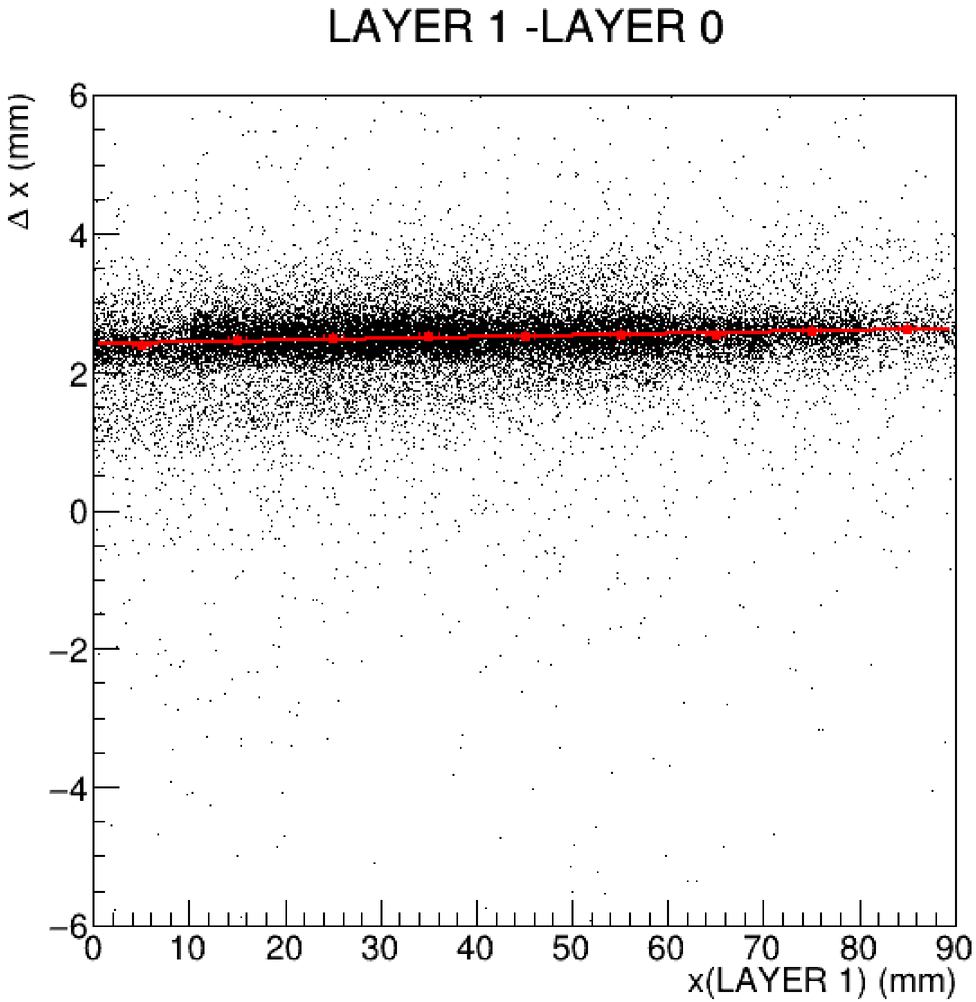
LAYER 2, that is the one read by both Mu2e and APV board, shows problematic strips: noisy or low (100 to 180), low (180 to 240), dead (>240)
In LAYER 3 the strips are horizontal (not the same illumination from beam)

APV RUN 331: microstrip clustering

From **apv.h** and **apv_cluster.h**:

- Create group of ‘adiacent’ hits allowing for gaps of 2 strips to consider the strip connected to the cluster
- Reject clusters with < 3 strips (not for LAYER 2) or >90 strips
- Reject clusters with maximum strip charge < 100 (LAYER 2) or < 300 (other layers)
- Calculate the **cluster center** as the pulse height (maxQ) weighted average of the strip numbers

APV RUN 331: LAYER 1 -LAYER 0 alignment



Look at the difference between cluster centers in layer 1 and 0 versus the cluster center in layer 1.

The position is simply the strip number times the 250 μm pitch.

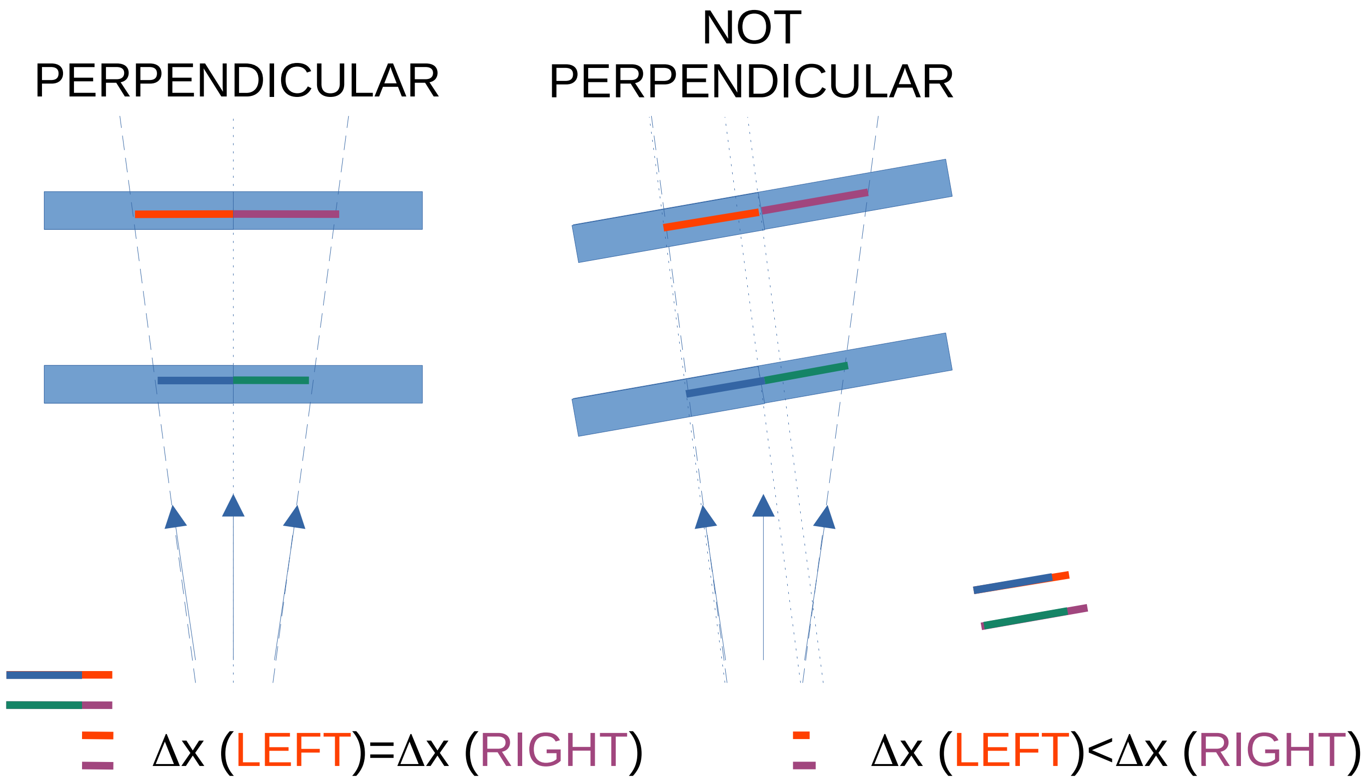
Linear Fit in slices of x(LAYER 1)

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

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

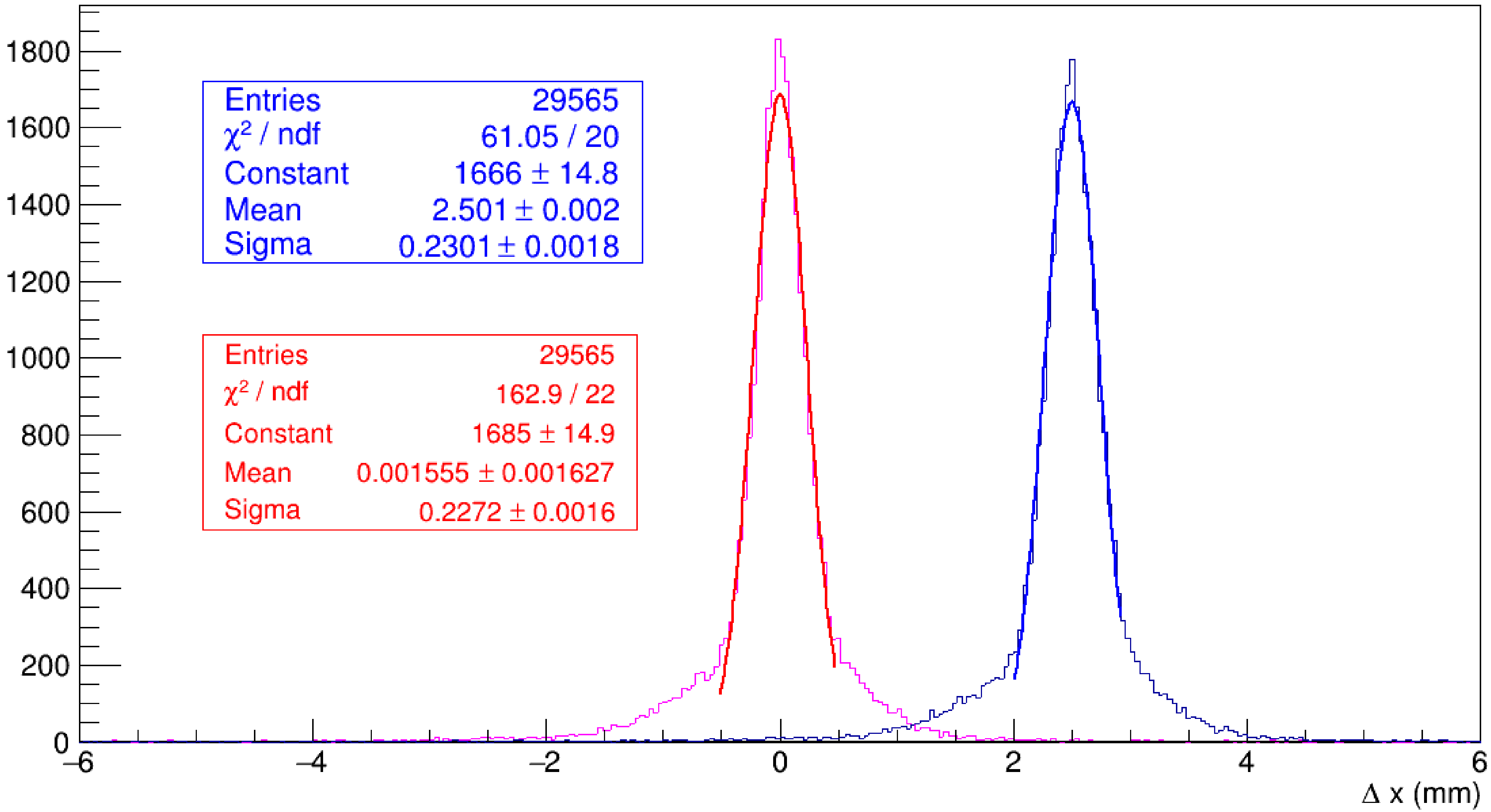
This makes layer 0 and layer 1 parallel in xz but not necessarily perpendicular to the beam

Perpendicularity to the beam



The beam has a certain angular spread (~2°).
In case of non perpendicular planes the x difference is asymmetric.
Trying to rotate the two planes has a rigid body the most symmetric Δx distribution (lowest skewness) corresponds to **no rotation**

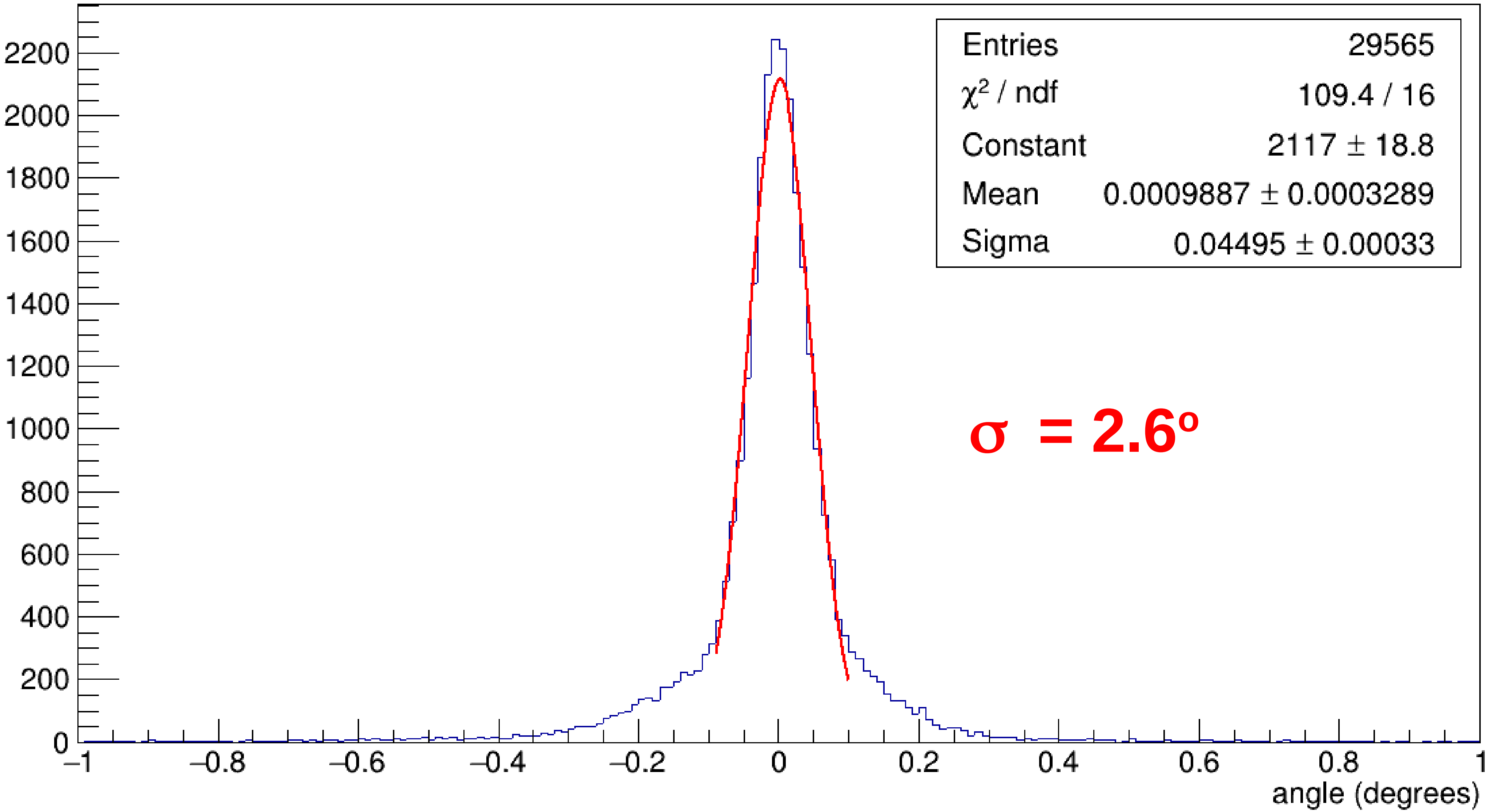
APV RUN 331: LAYER 1 – 0 alignment



Alignment works: - average difference consistent with 0

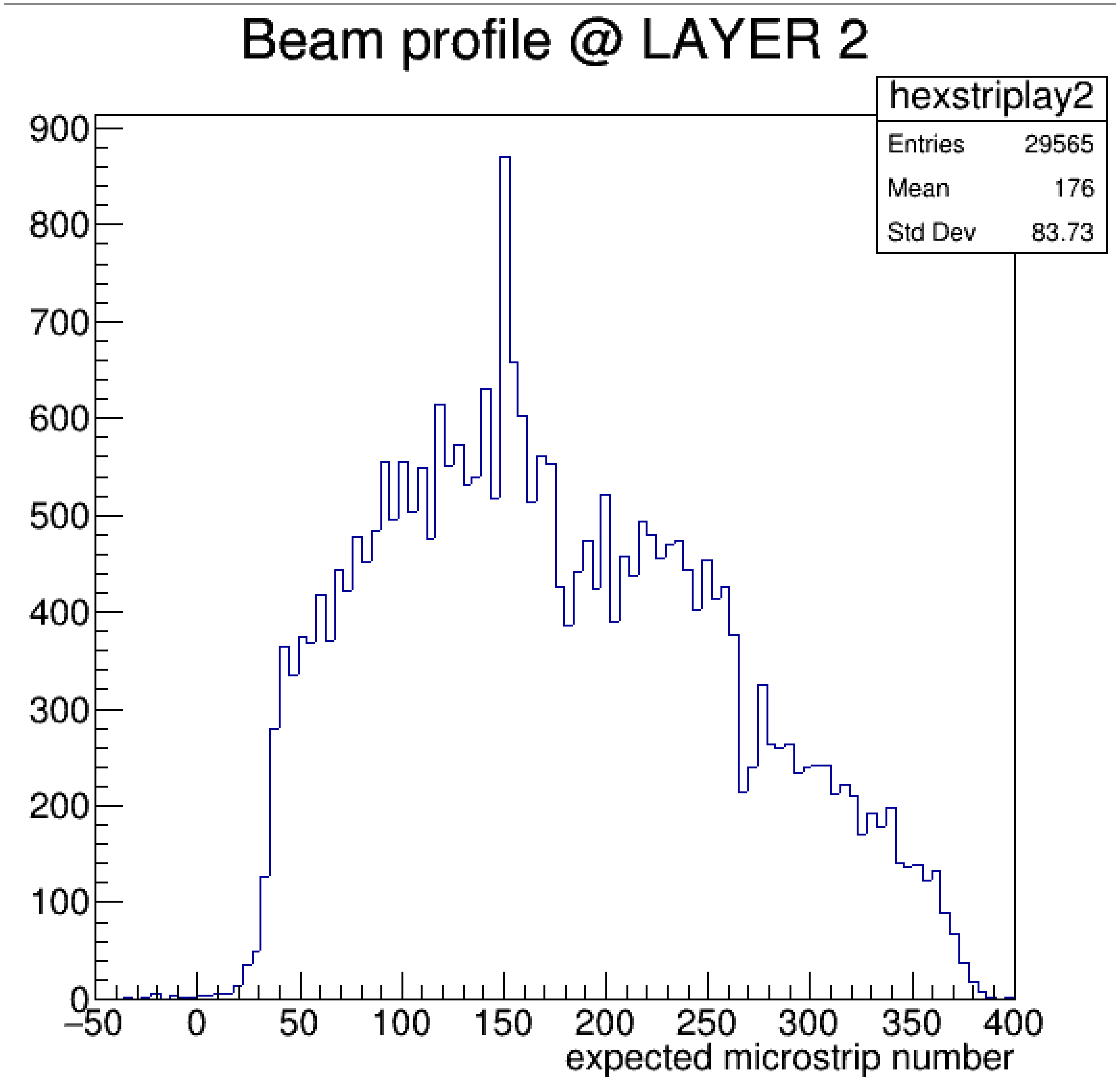
- sigma improves

APV RUN 331: beam angular spread



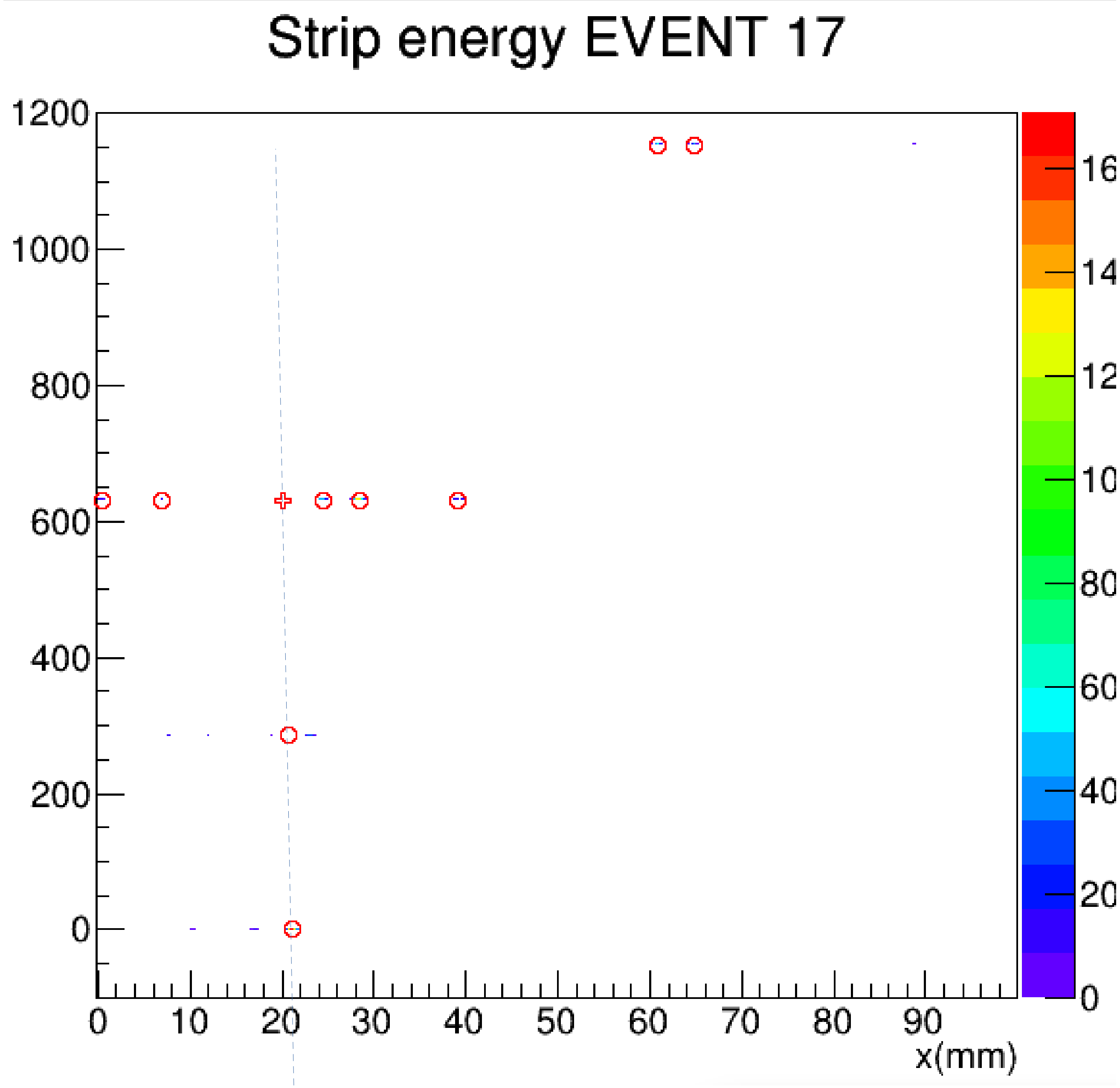
The angular spread is small but not negligible

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

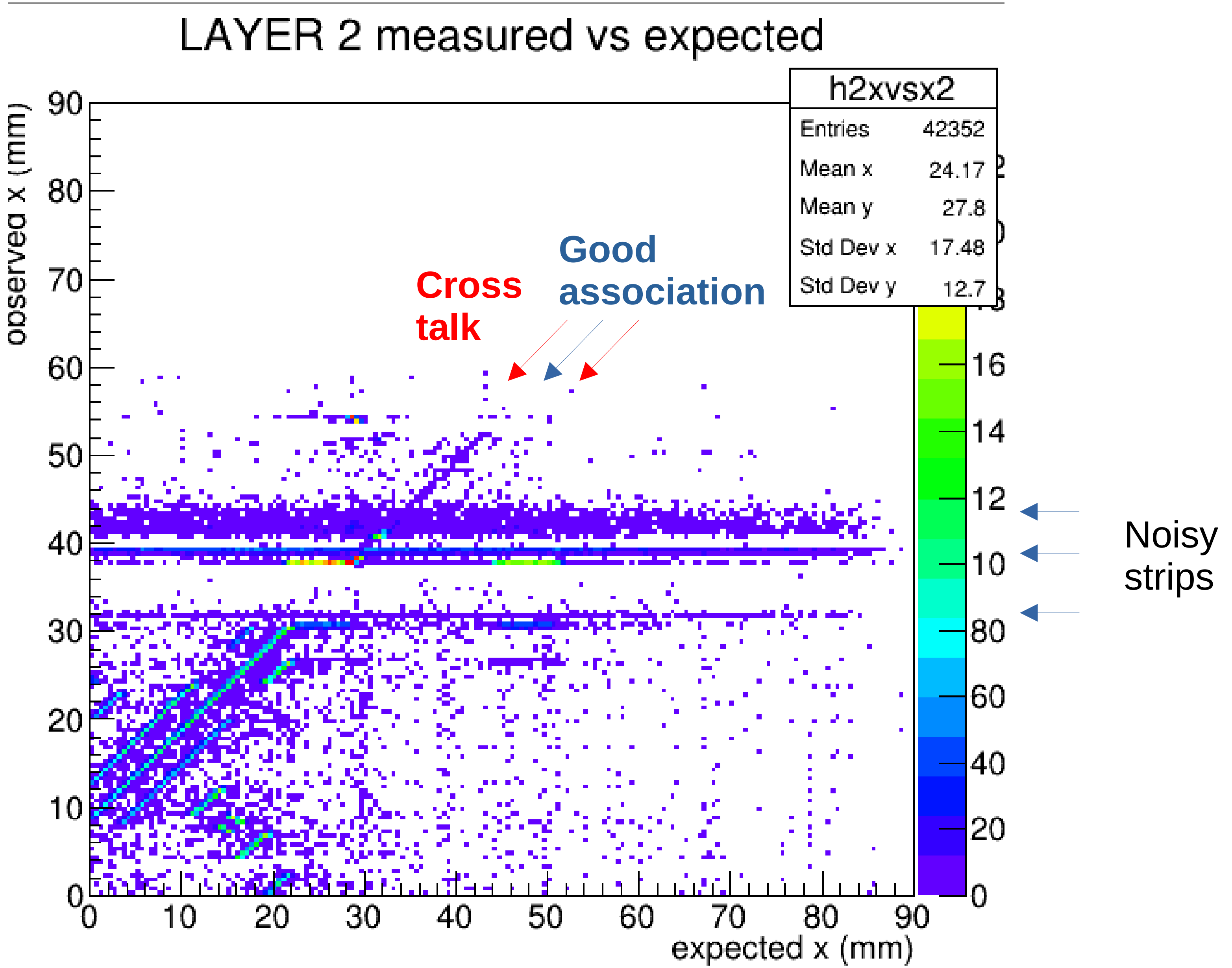


Many noisy strips and clusters in layer 2

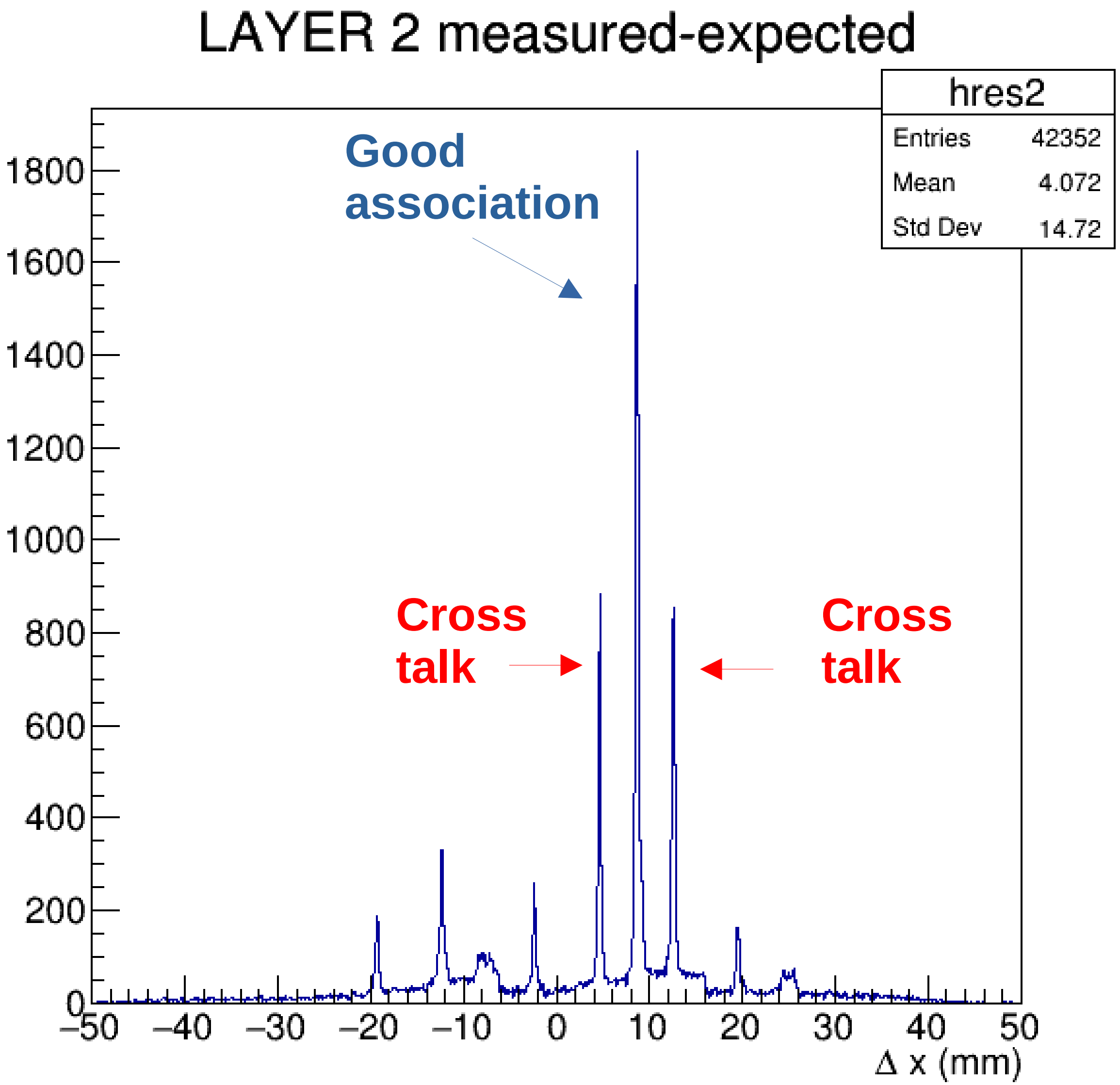
Sometimes the good cluster is missing!

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

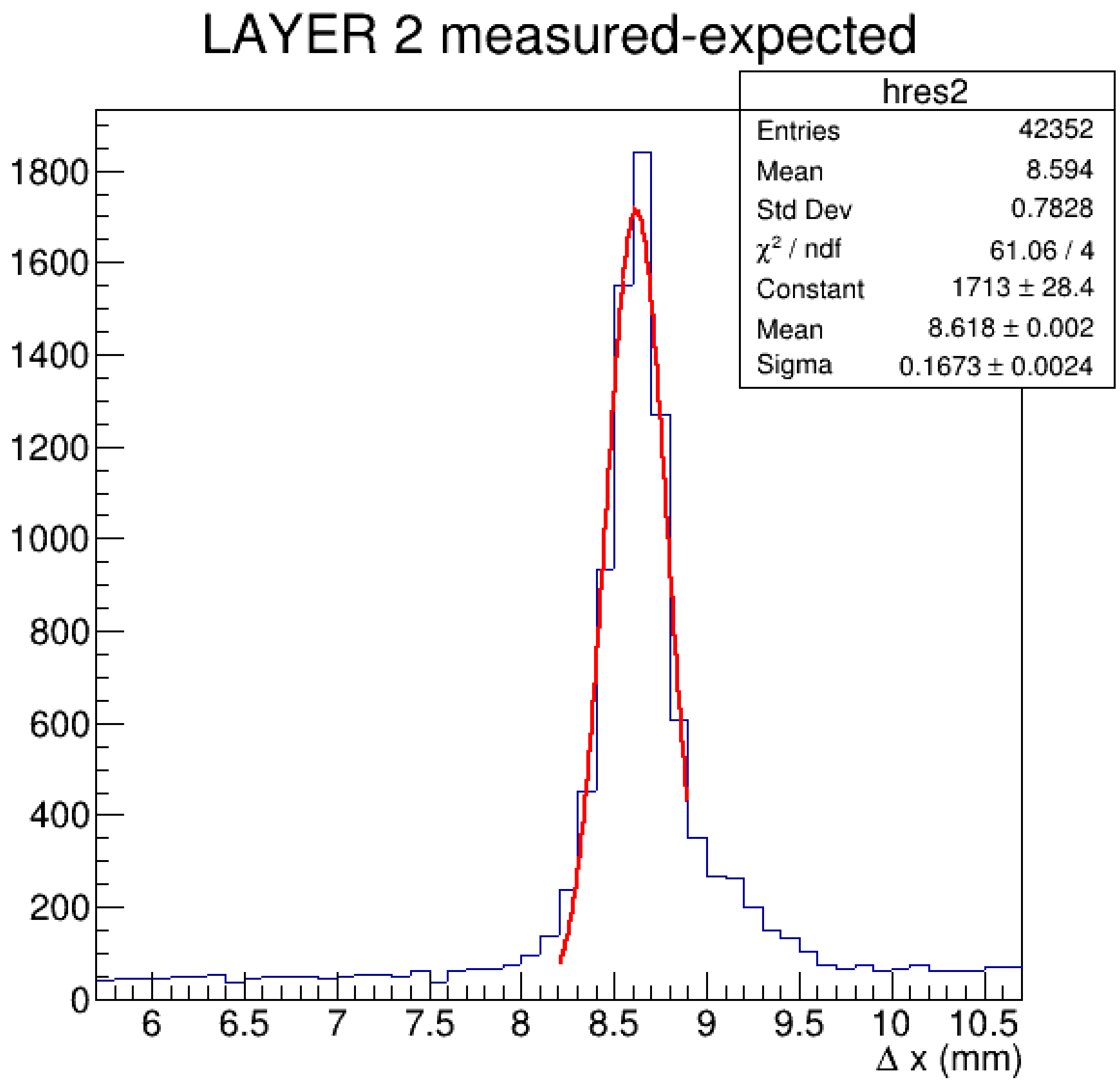
APV RUN 331: expected vs observed cluster center



APV RUN 331: LAYER 2 cluster center residuals



APV RUN 331: LAYER 2 cluster center residuals

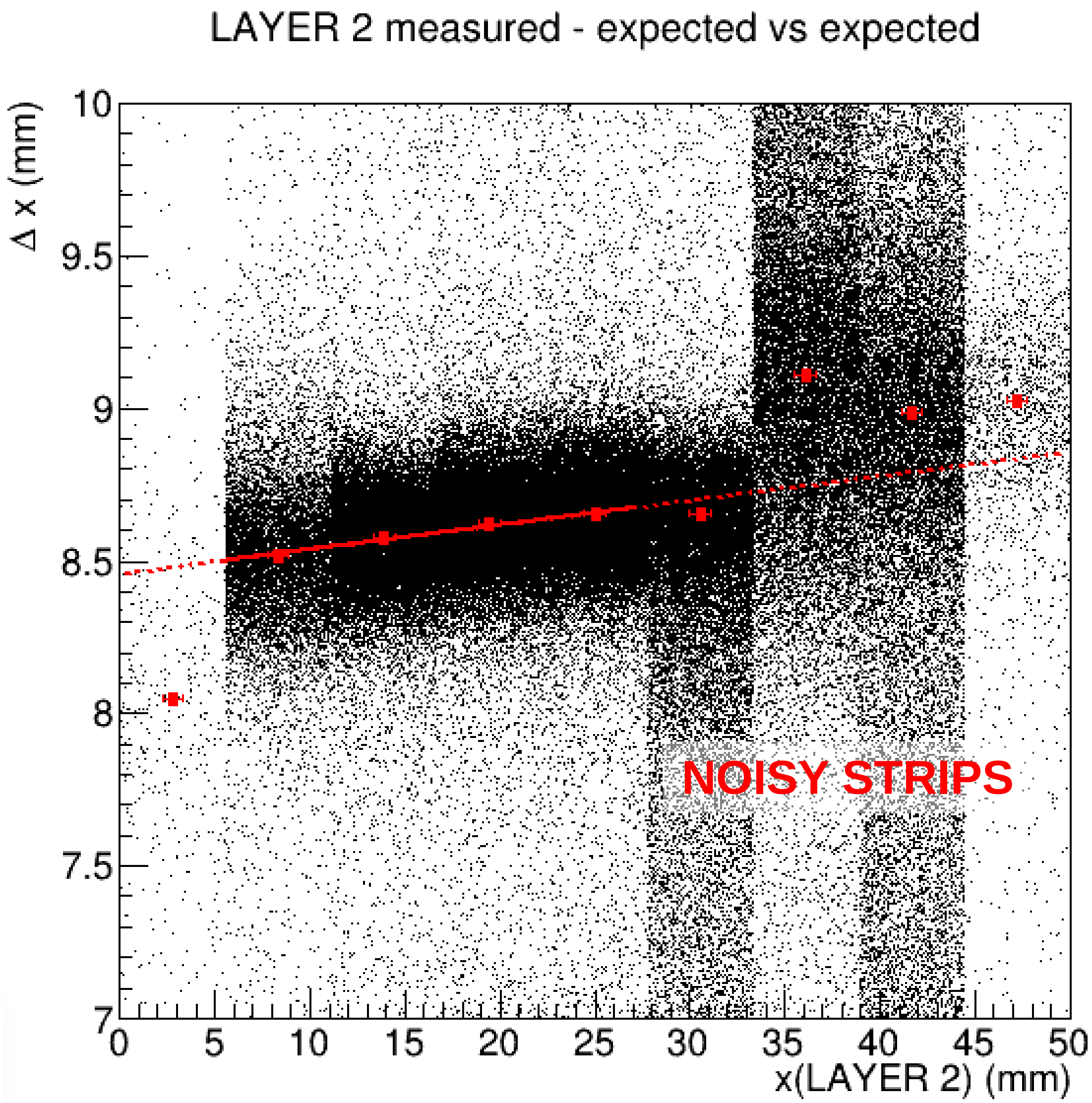


σ = 167 μm
(< 1 strip = 250 μm)

LAYER 1-0
Estrapolation 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

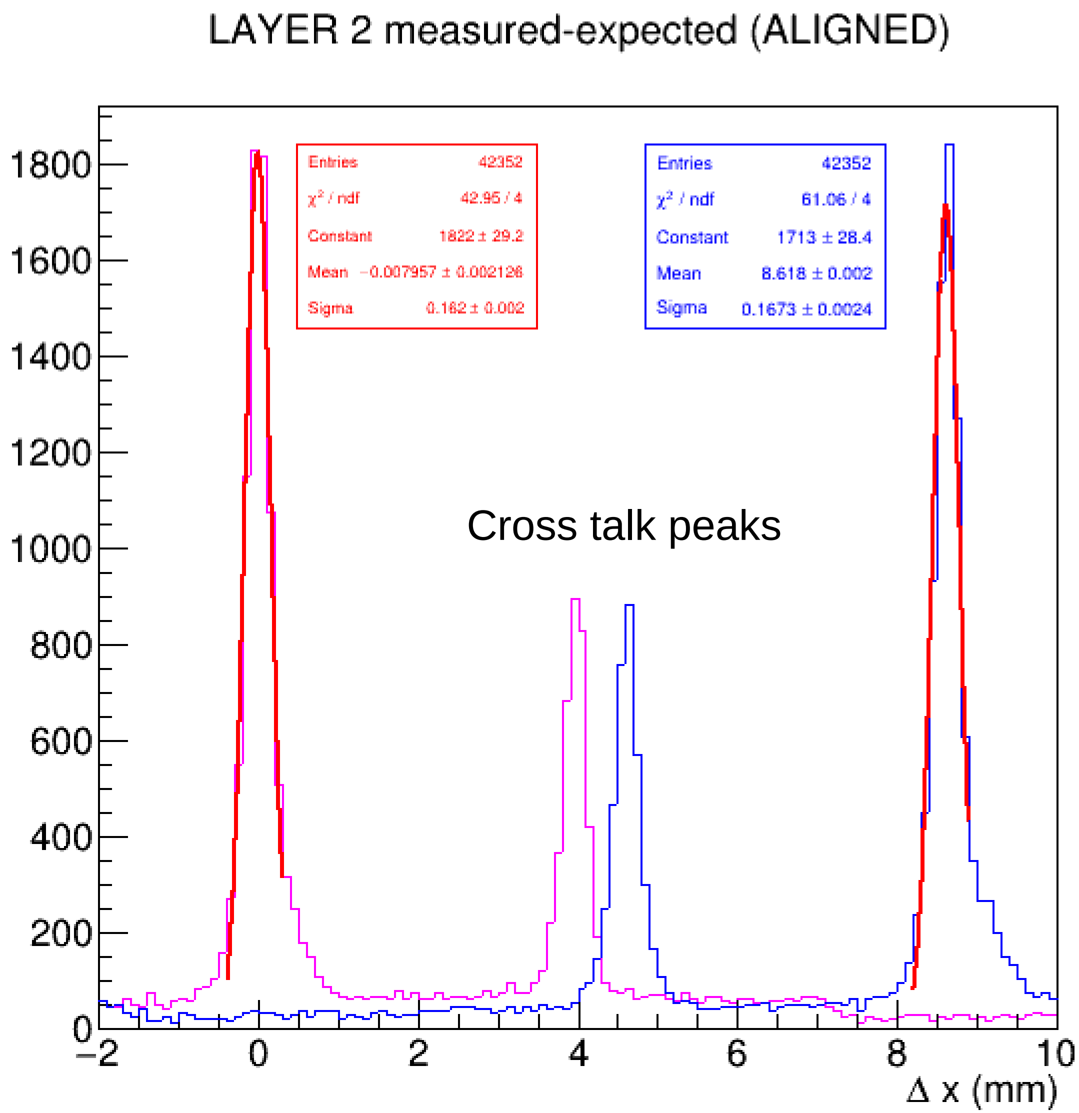
Linear Fit in slices of x

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:

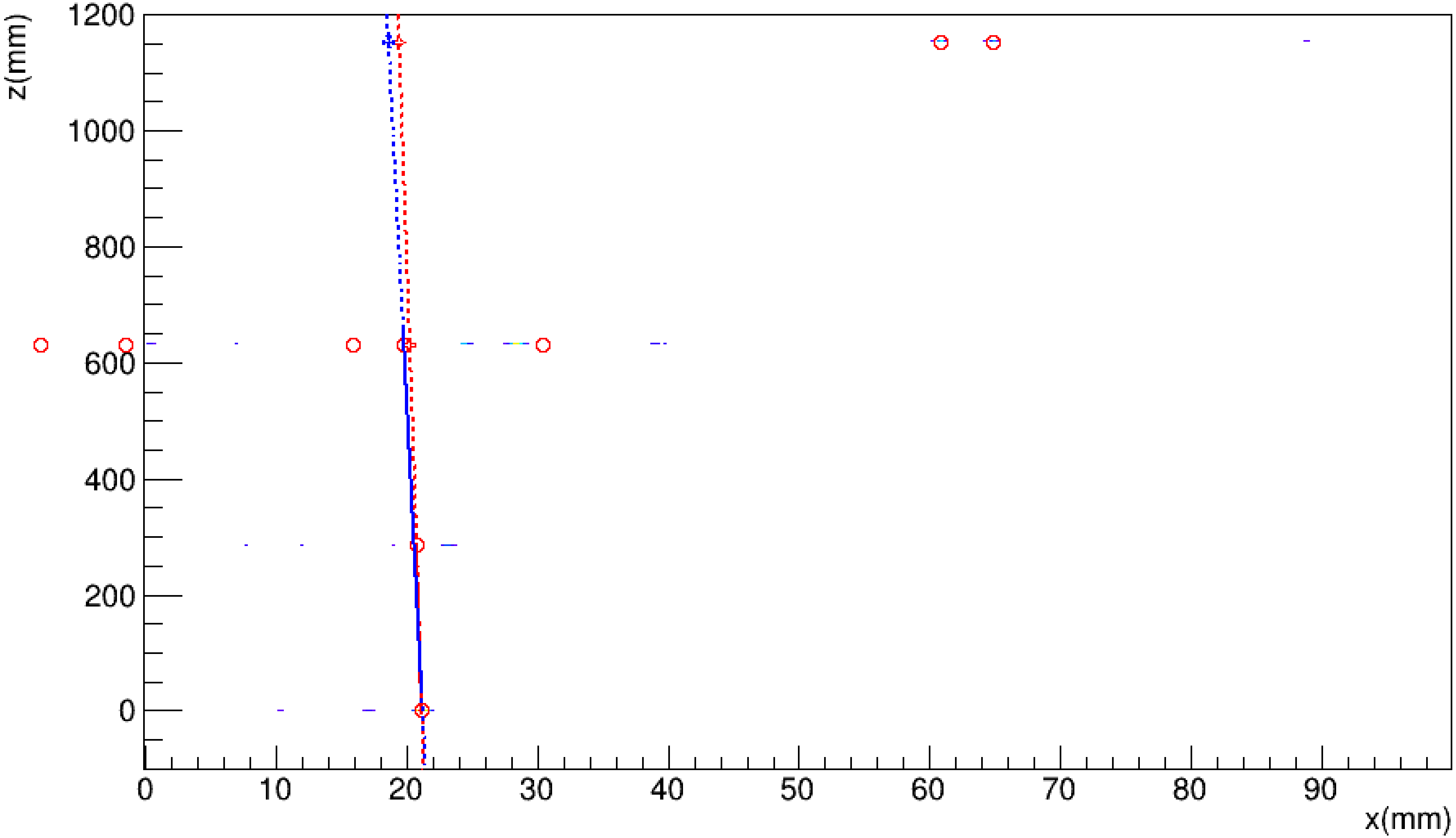
σ = 167 μm

After the alignment:

σ = 162 μm

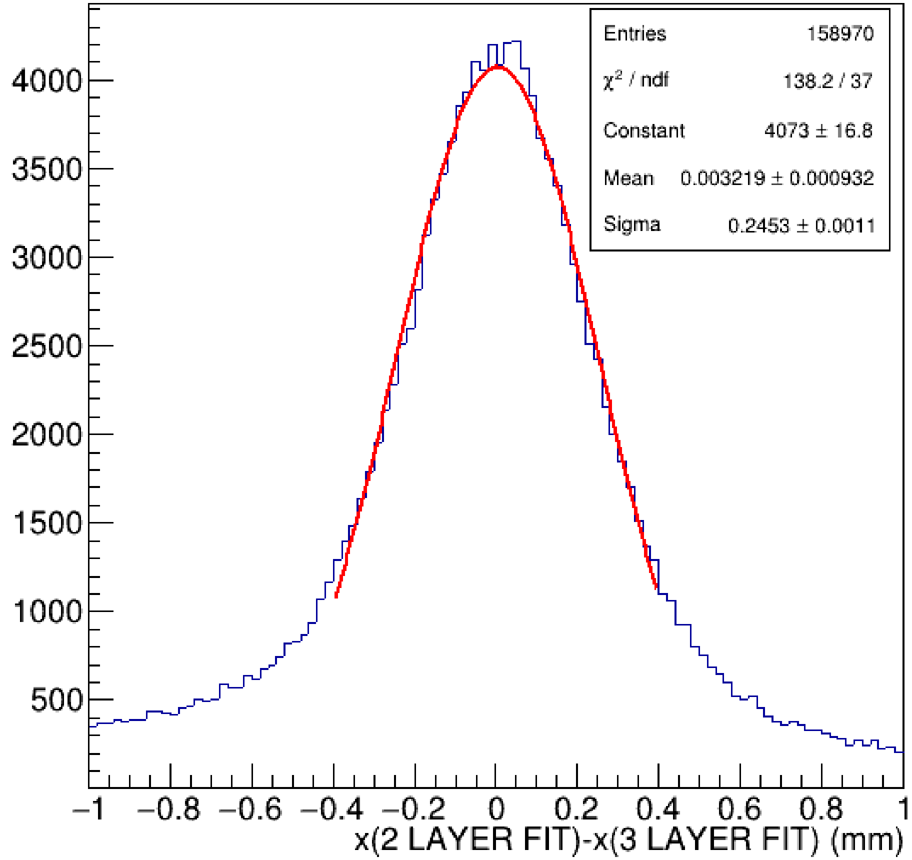
Alignment works: - average difference consistent with 0
- sigma improves

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



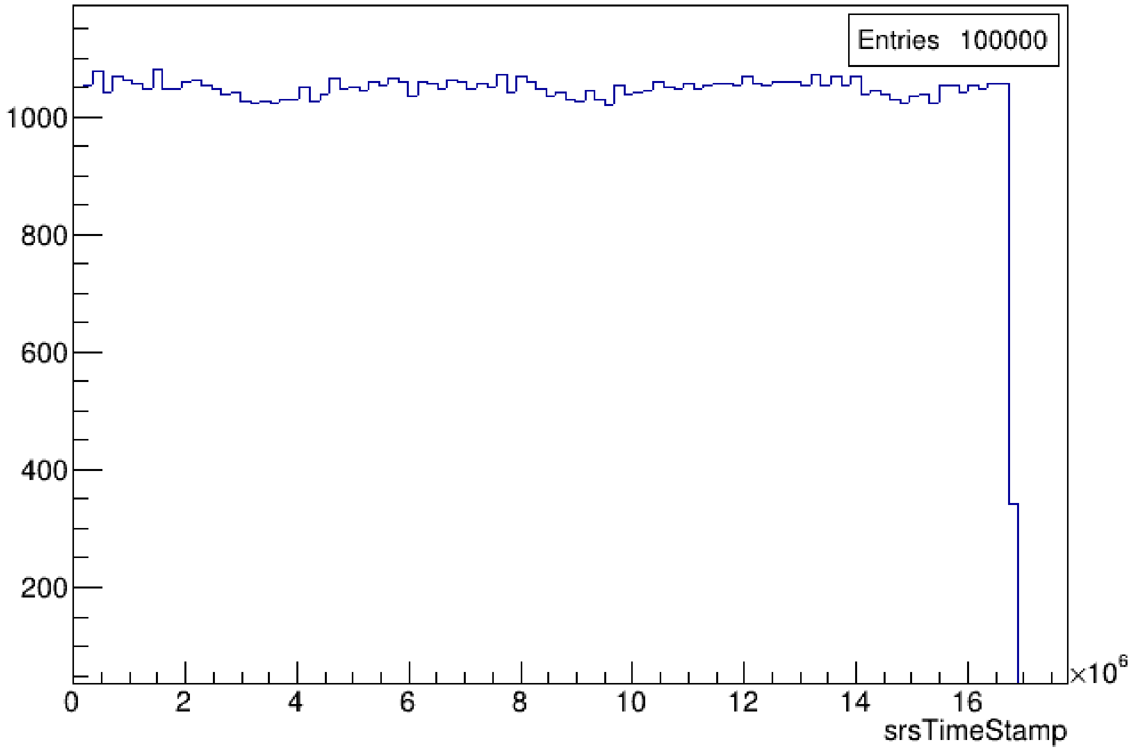
The pointing resolution obatined using LAYER 0 and 1 only is ~250 μm
Assuming a 50 μm/ns average drift velocity this corresponds to a **5 ns spread**!
→ LAYER 0&1 cannot be used alone to investigate the straw time resolution

For the future test beams it's better to put the straw chamber **between** the MicroMega layers to reduce the extrapolation errors

APV RUN 331: SRS Timestamp

To correlate the Mu2e board and the SRS (APV) board a precise and stable timing is needed

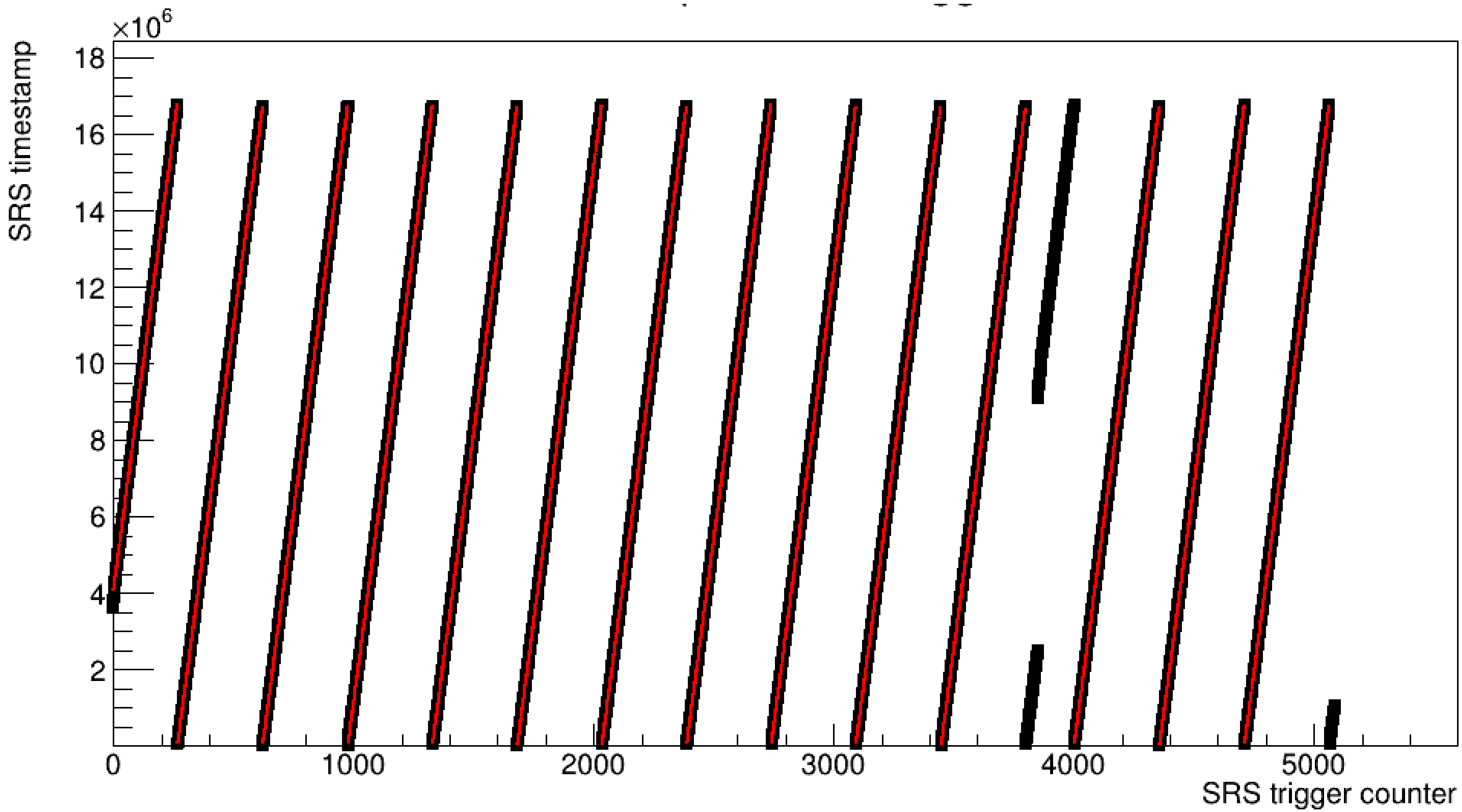
Pulse generator studies have shown that the SRS Timestamp is stable



SRS timestamp saturates at 2^24=16777216

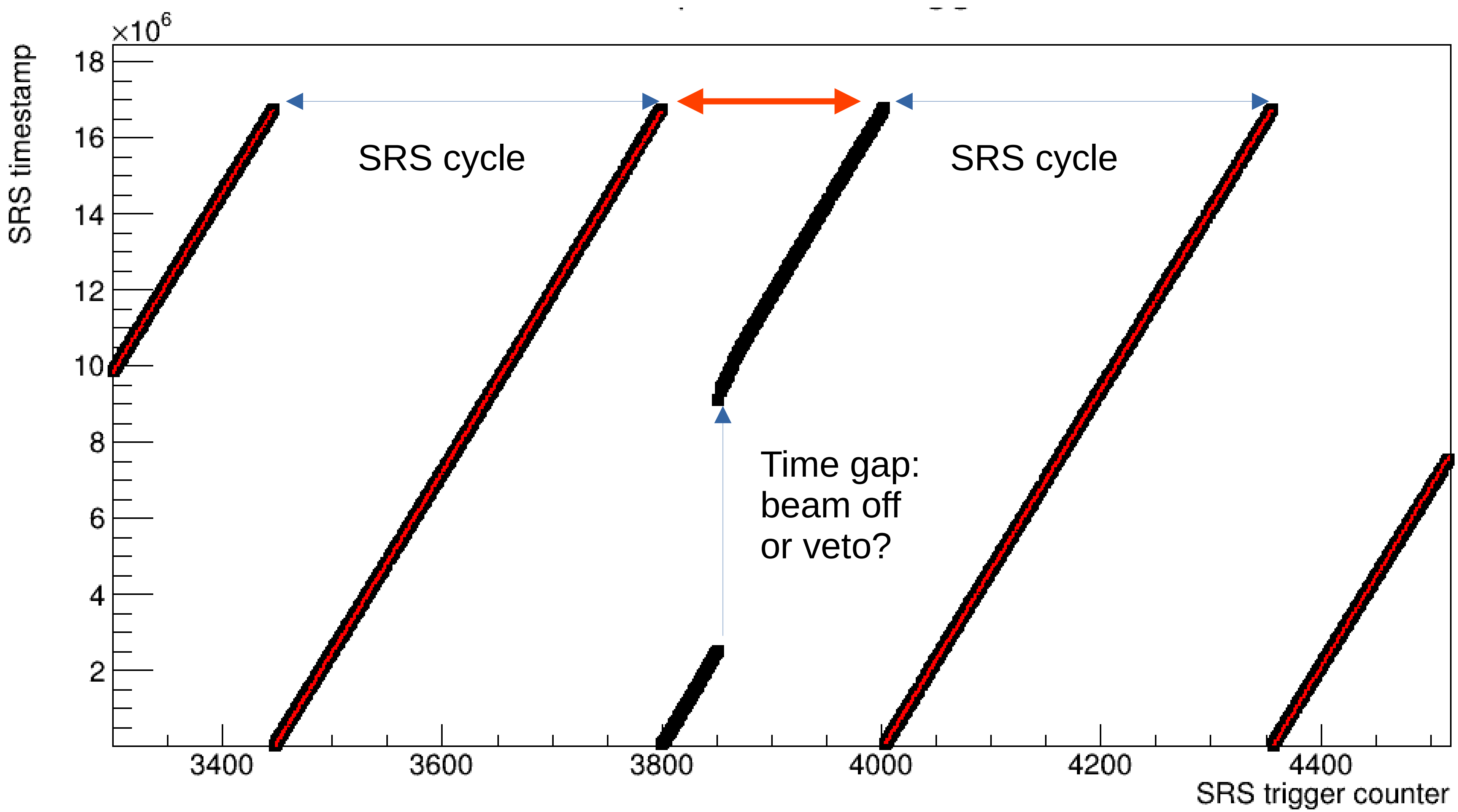
We need the SRS Trigger counter information to convert this in an absolute time

APV RUN 331: SRS Timestamp vs SRS Trigger Counter



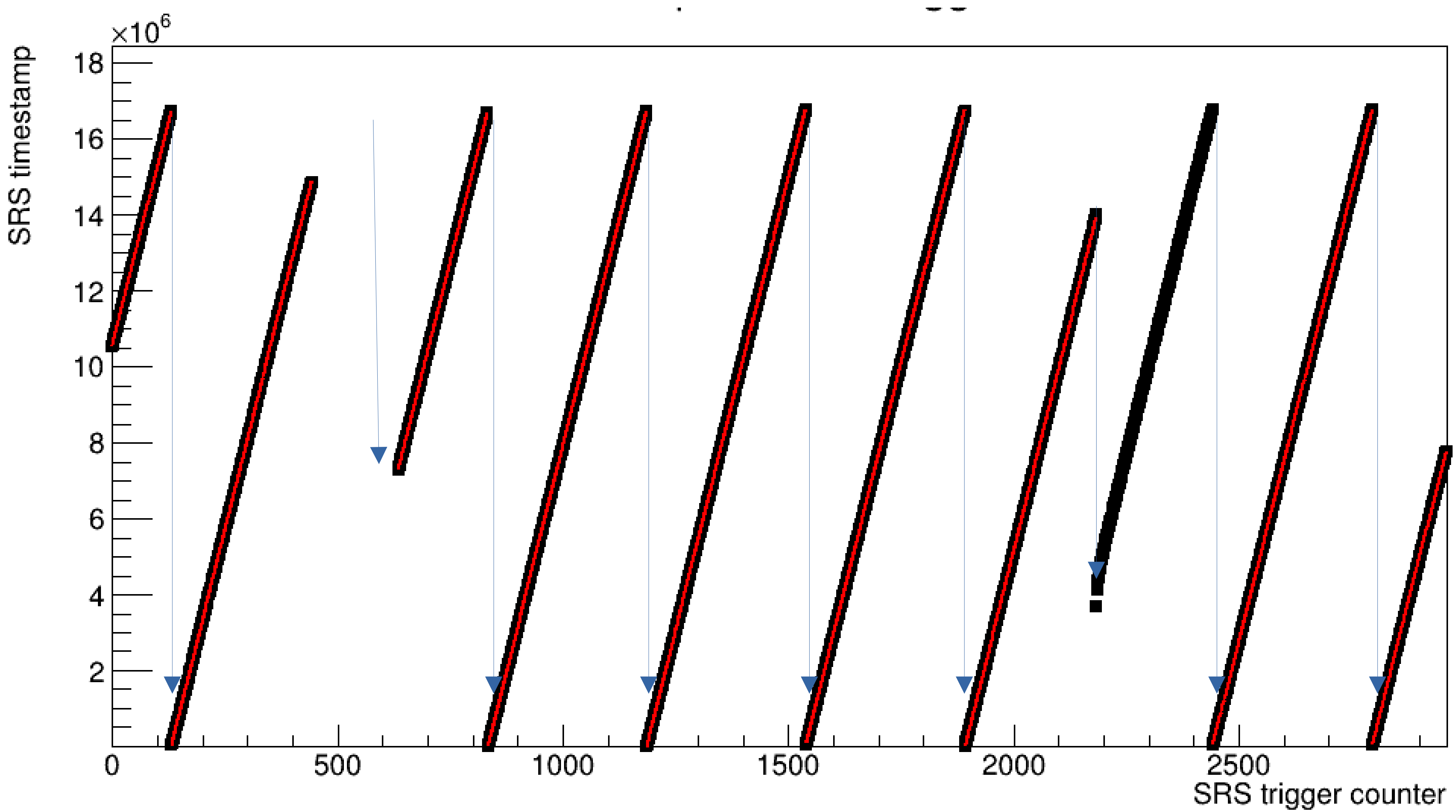
The slope obtained by the fit is not exactly constant: the average is **47480**

APV RUN 331: Time gaps with no SRS triggers



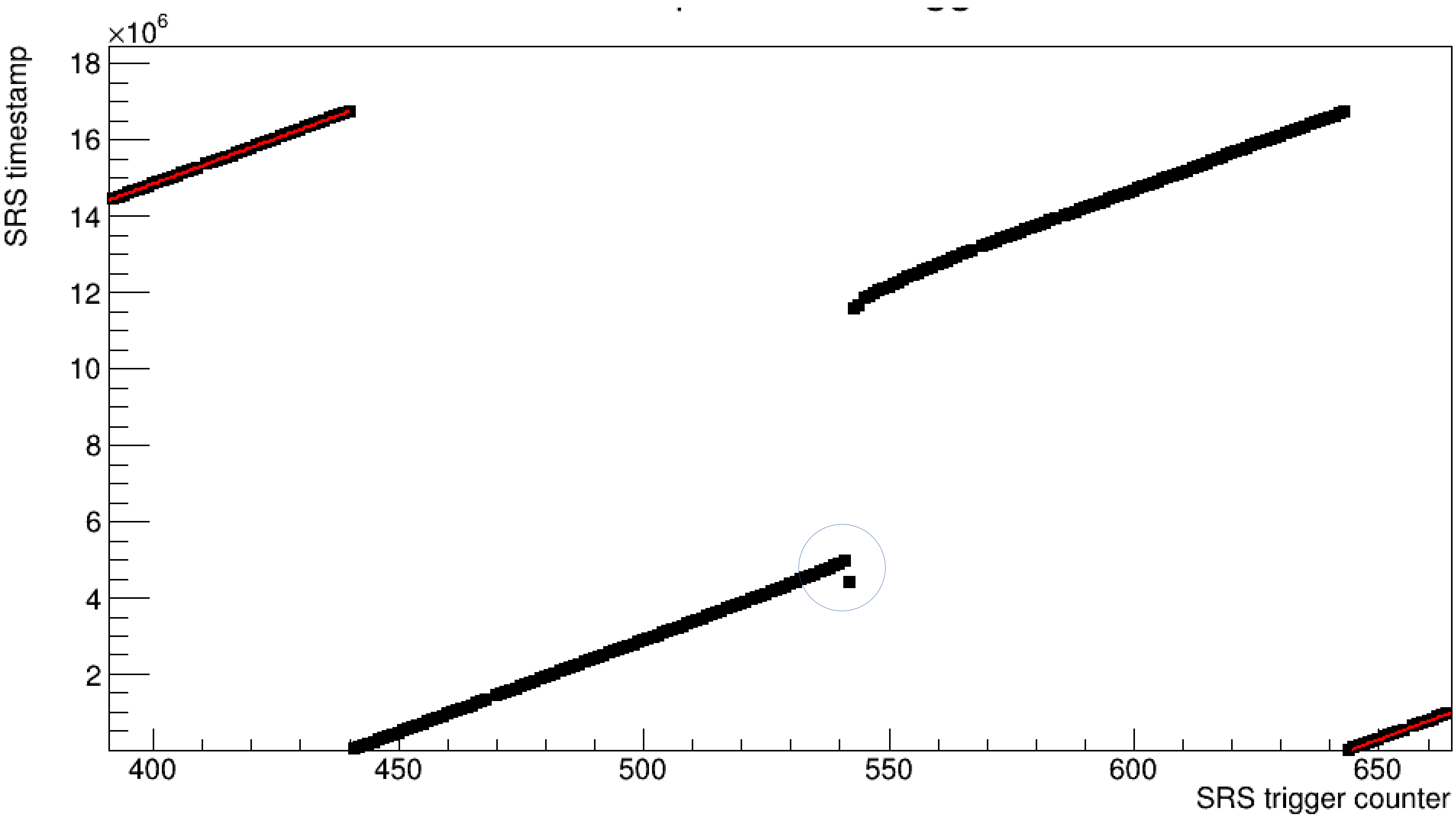
Something strange happens sometimes… sudden increase of timestamp between consecutive trigger counters.
The distance between two timestamp maxima is not respected

APV RUN 331: from SRS Timestamp to absilute time



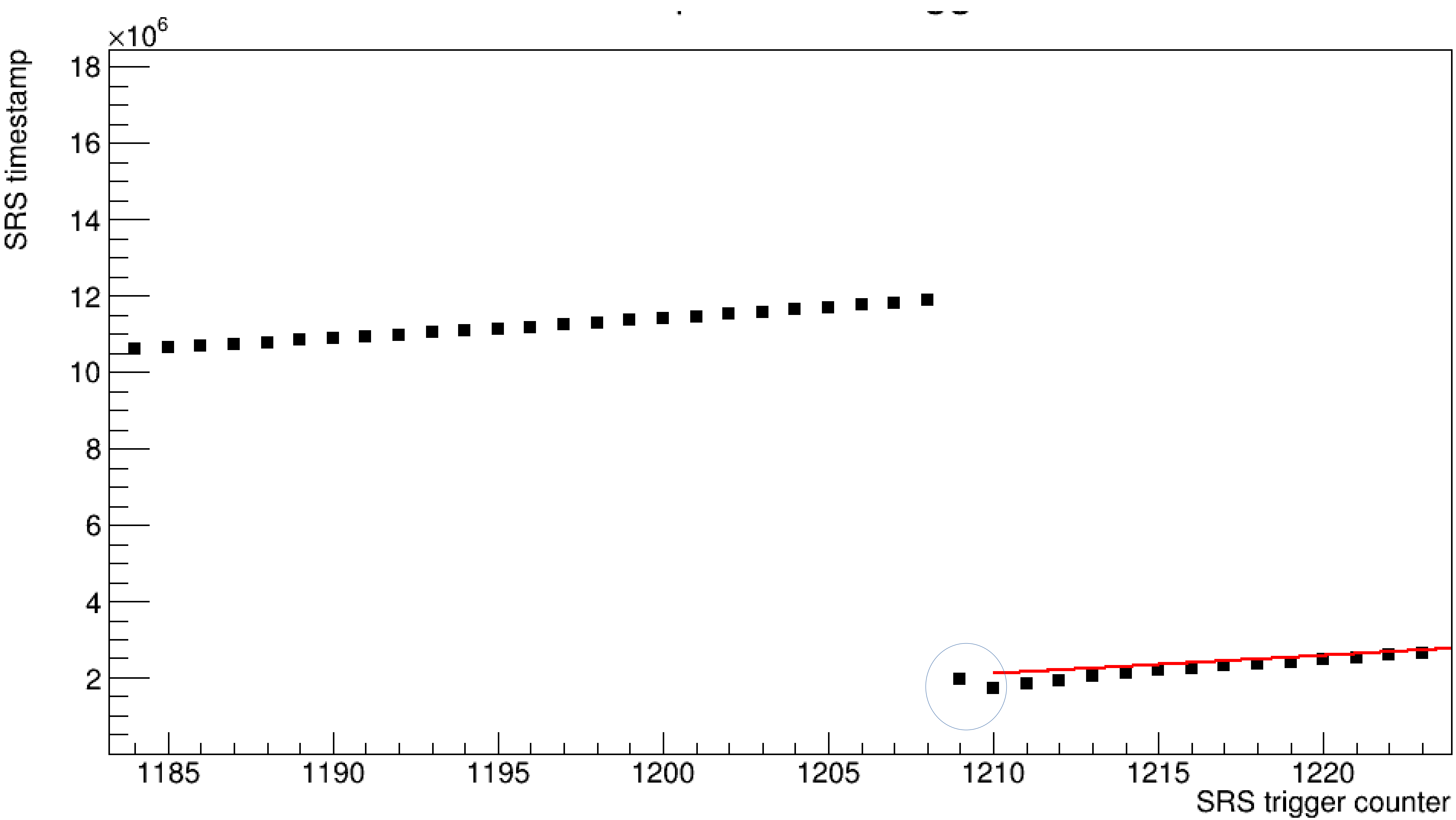
Every time we recognize a new cycle (timeStamp decreases) we add 2^24 to the timestamp offset

APV RUN 331: Pathological cases



This timestamp decreases doesn't indicate a new cycle

APV RUN 331: Fake cycle transition



Also this timestamp decreases doesn’t indicate a new cycle.
We consider a new cycle if at least two consecutive timestamps are lower than the one considered as cycle end

APV RUN 331: outcome of this analysis

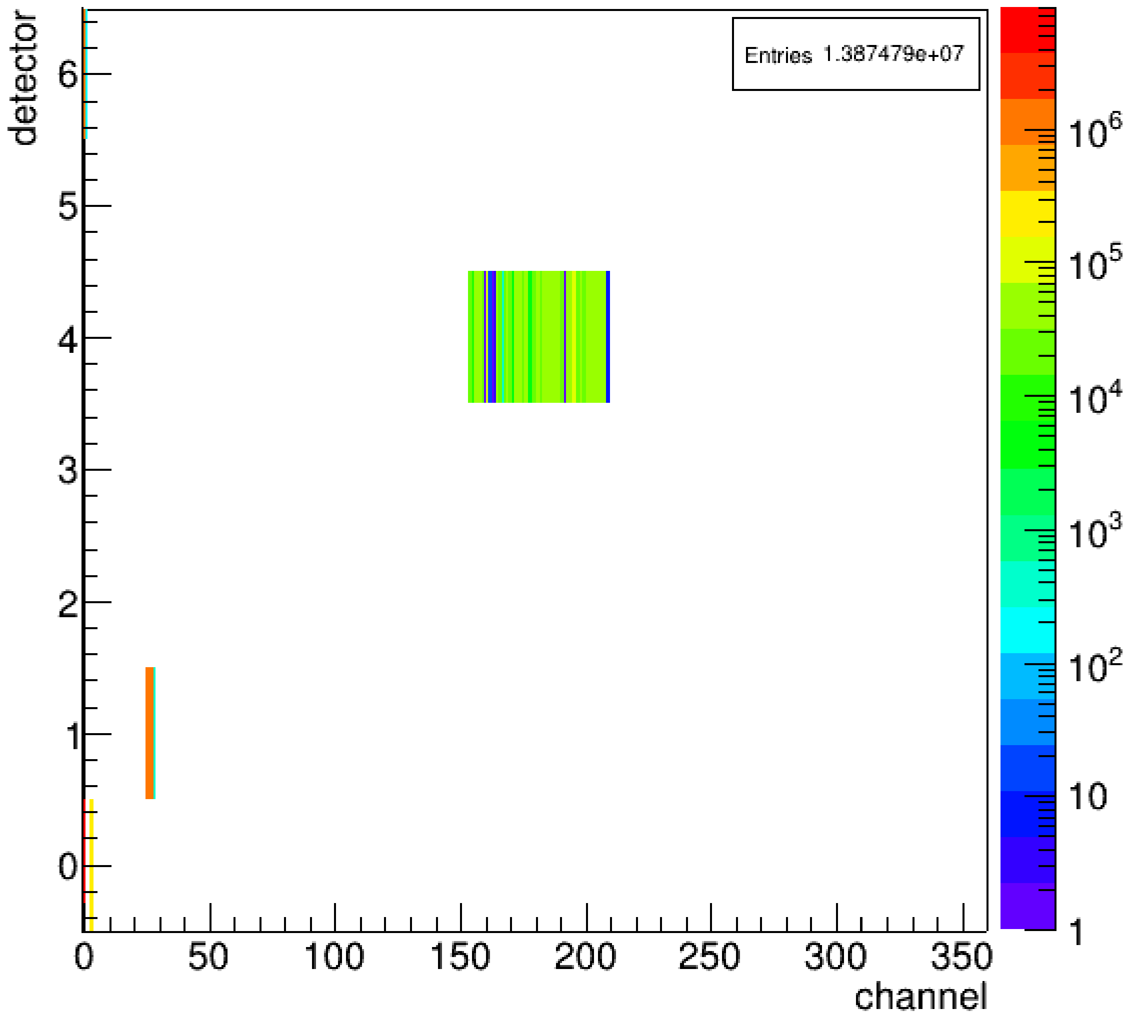
File apv_run331.dat:

- **AbsoluteTime**
- **maxQstrip@L2**
- **maxQ@L2**
- **x@StrawLayer0**
- **x@StrawLayer1**

The last 2 variables are the ones needed to determine the relation bewtween drift distance and drift time and the straw time resolution

The first 3 variables are needed to match the event in the Mu2e board (VMM RUN 665)

VMM RUN 665: detectors occupancy



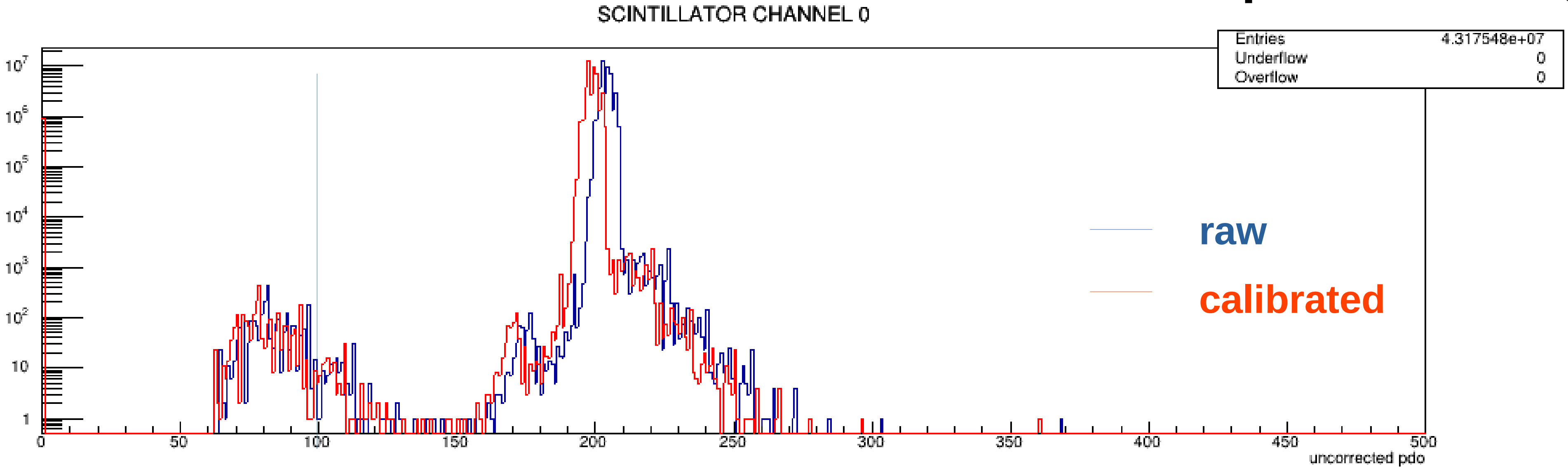
MicroMega LAYER 2:
strips from 154 to 209

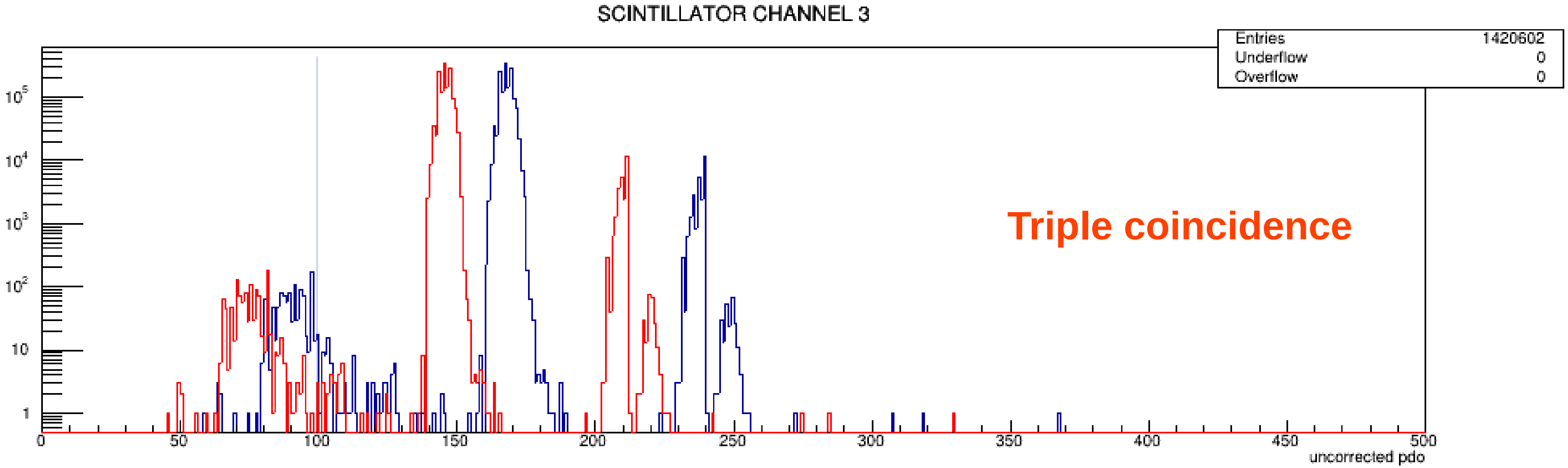
Straws:
From 24 to 28

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

A cut on pulse height (pdo)>100 has been applied to Scintillators and Straws

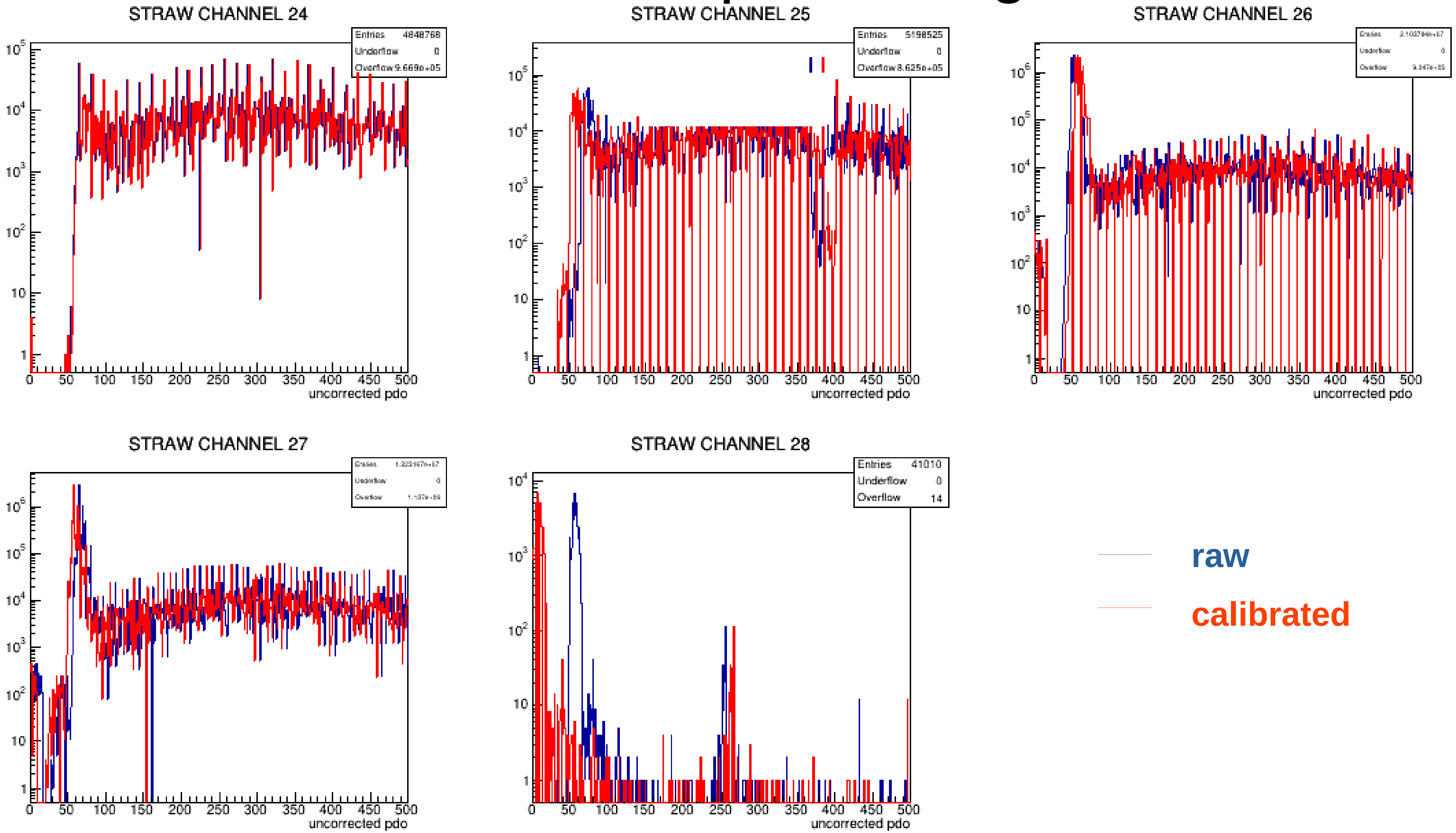
VMM RUN 665: Scintillator channels pulse height





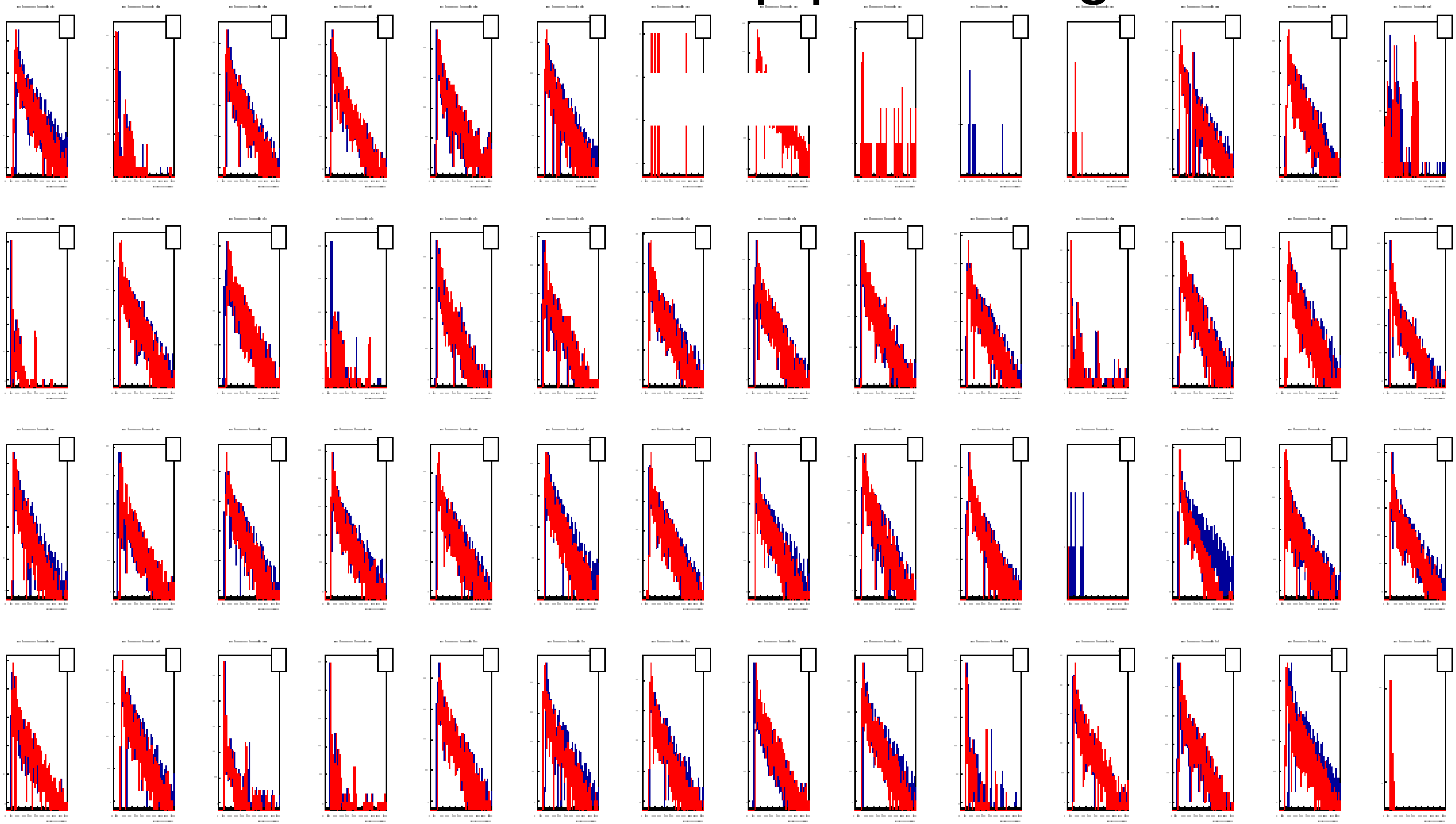
Calibration function is a first order polynomial taken from calibration_pdo_t@t_g1_p25_s100.txt
A cut pdo>100 is applied to calibrated pdo.

VMM RUN 665: Straws pulse height



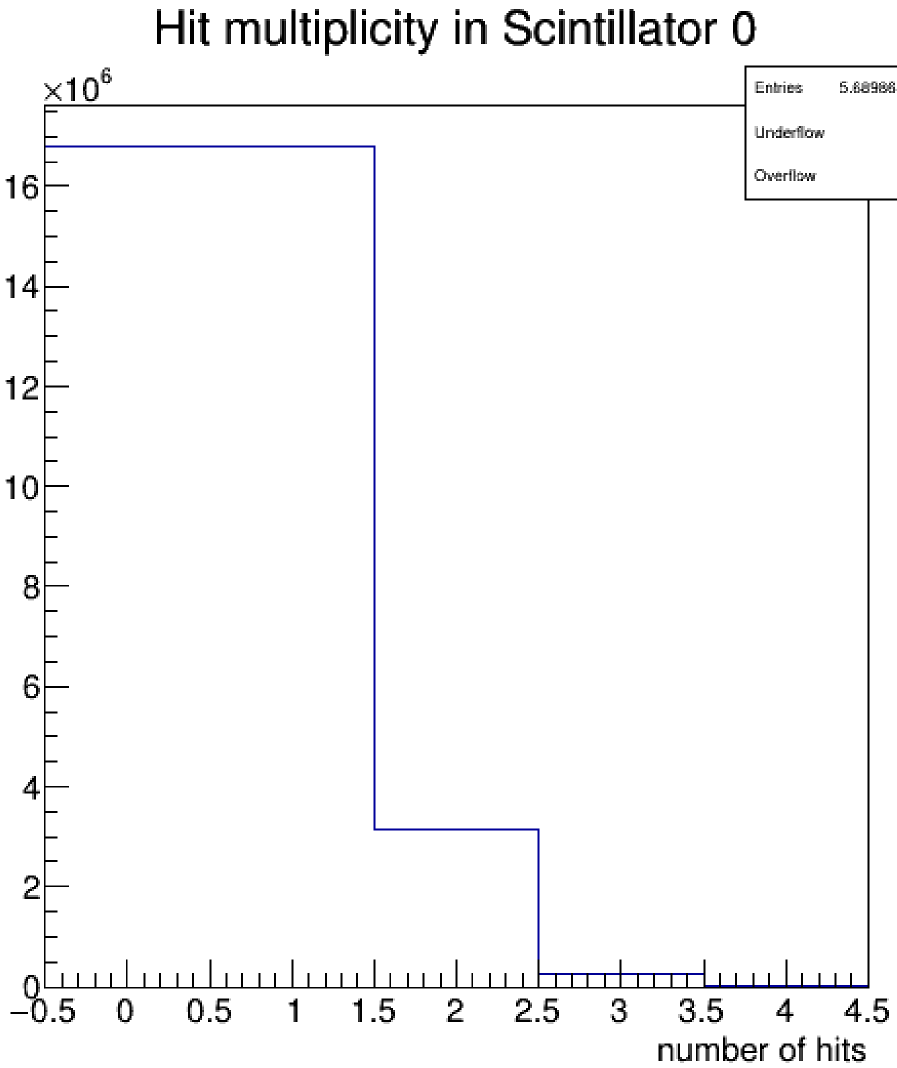
A cut on calibrated pdo>100 has been applied
Straw 28 is very inefficient

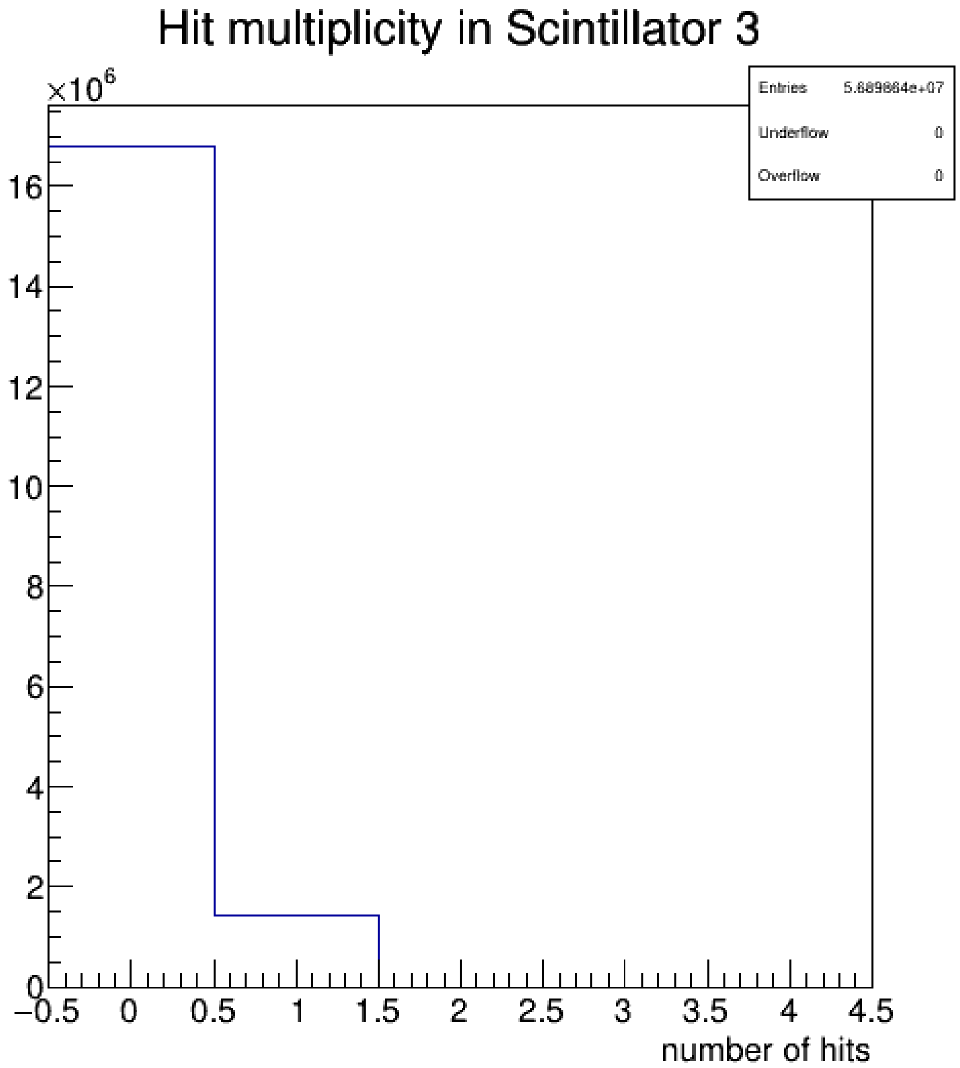
VMM RUN 665: Microstrip pulse height



Some strips are dead or inefficient
No cuts on pdo

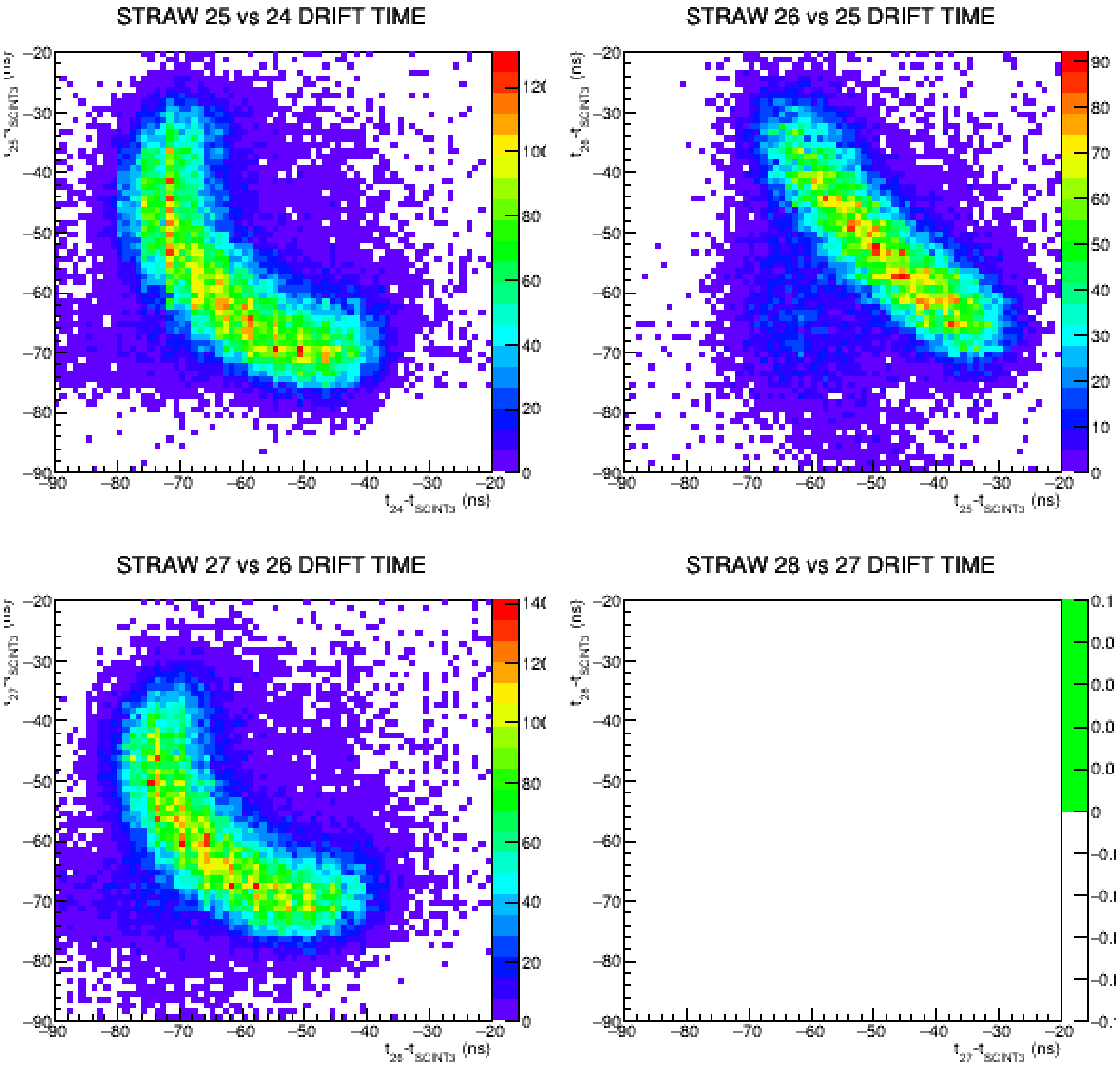
VMM RUN 665: Scintillator channels hit multiplicity





To find the best one look at the number of straws in time with the scintillator hit

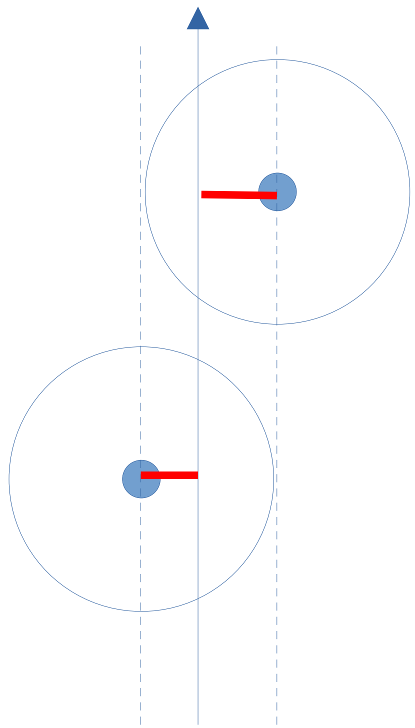
VMM RUN 665: drift time of adiacent straws



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

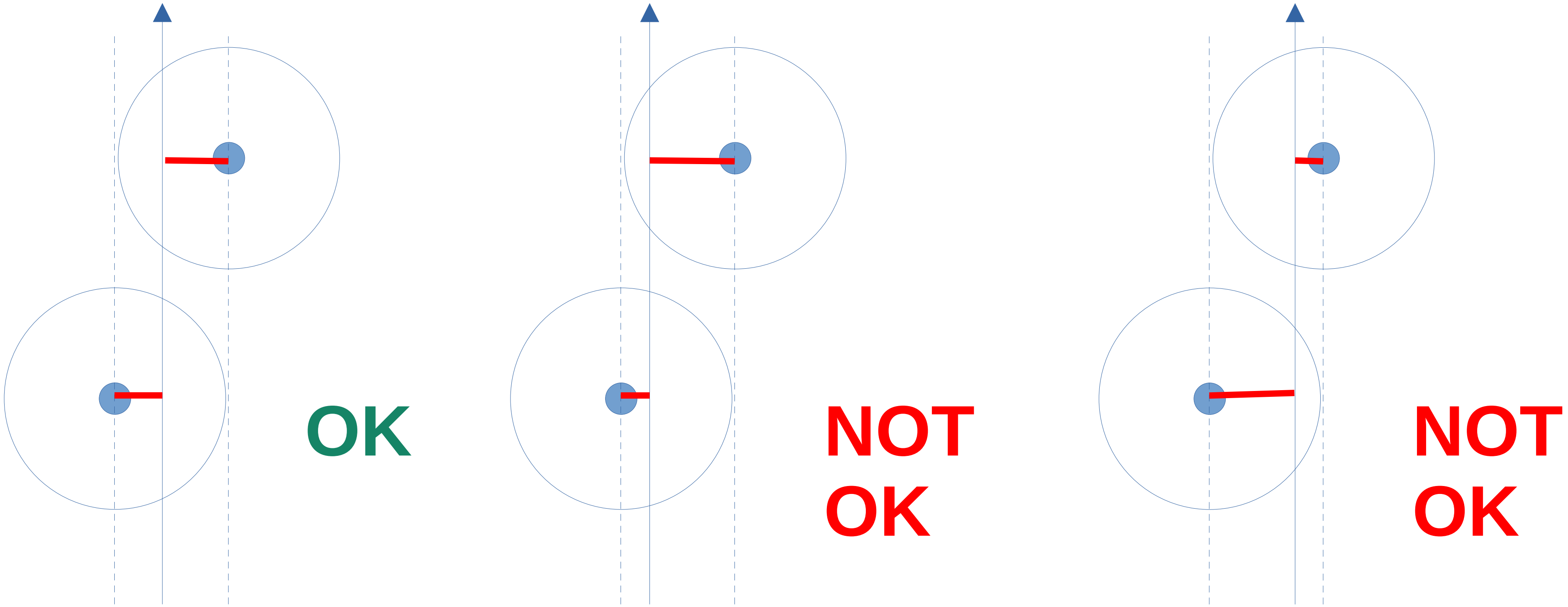
A rough estimate of straw time resolution



I we consider the beam perpendicular (in fact has a sigma of 2°) 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**!

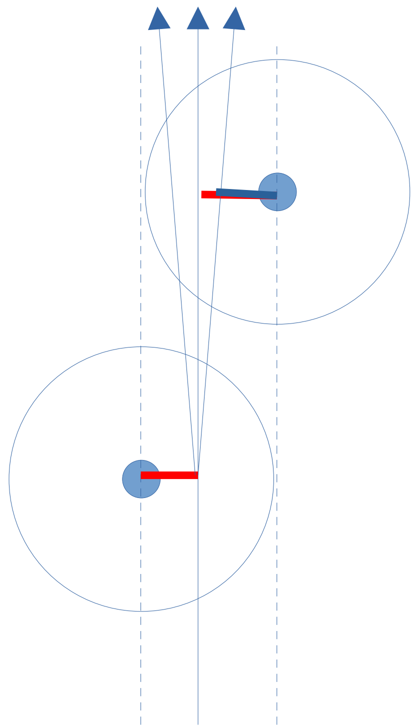
A rough estimate of straw time resolution



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, differnt from 0 otherwise.

This is probably also the explanation of the **banana plot**: the relation is linear until we are far from both wires, otherwise is linear for one but not for the other

A rough estimate of straw time resolution

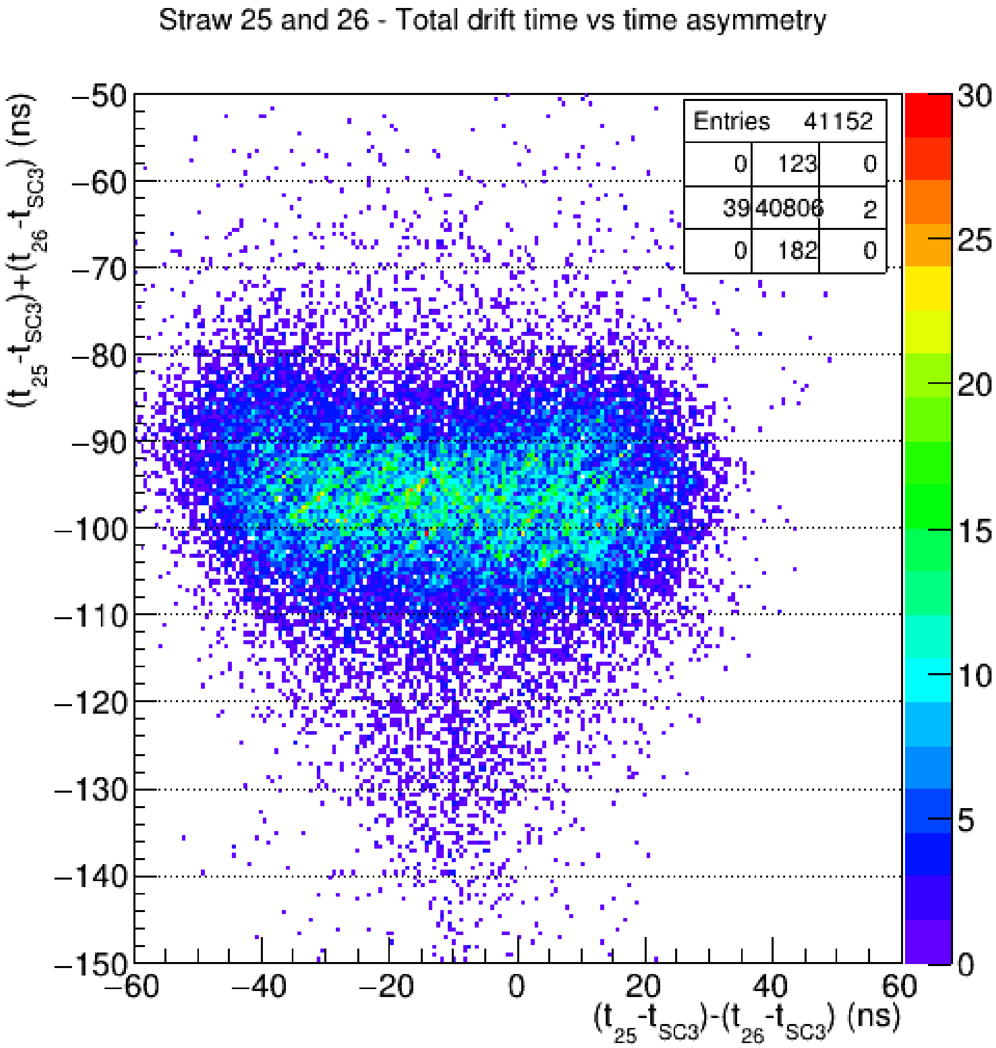


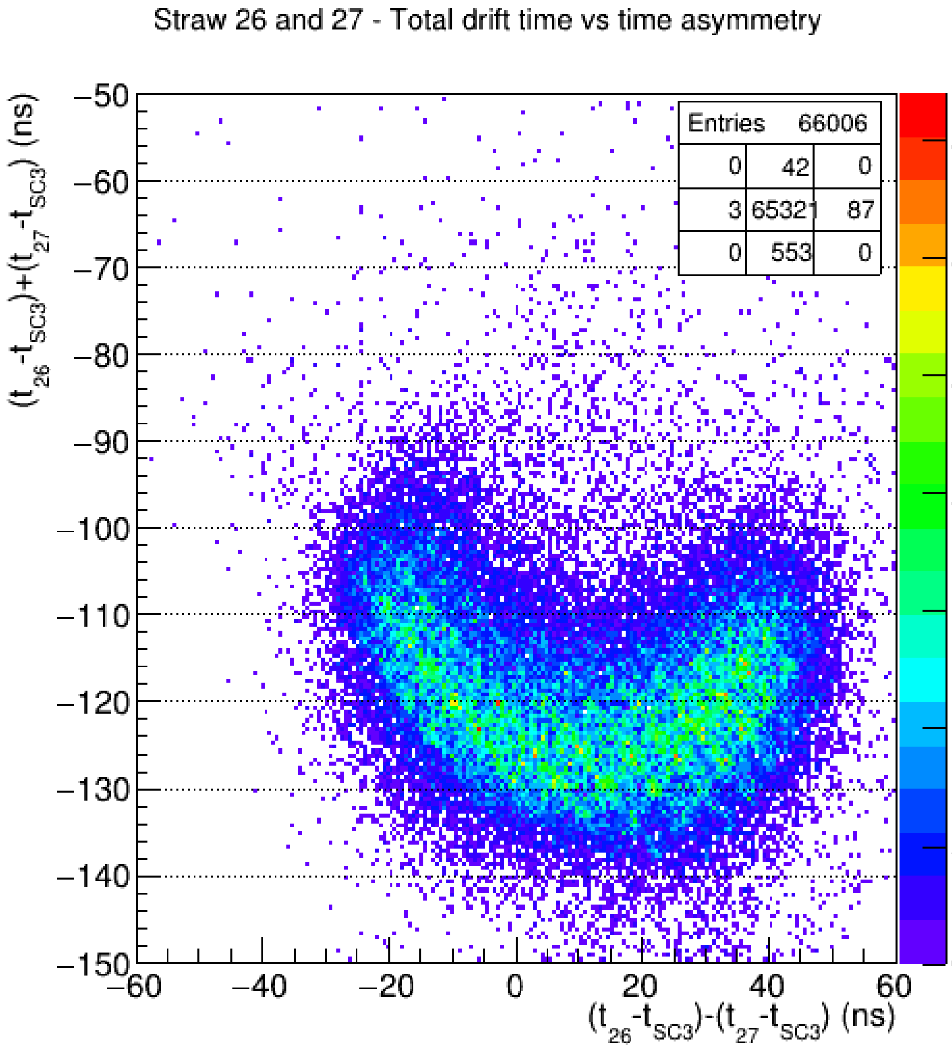
In fact the beam is not exactly perpendicular: there's a sigma of 2^{o} on the angle that corresponds to **~250 μm** on 7 mm.

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

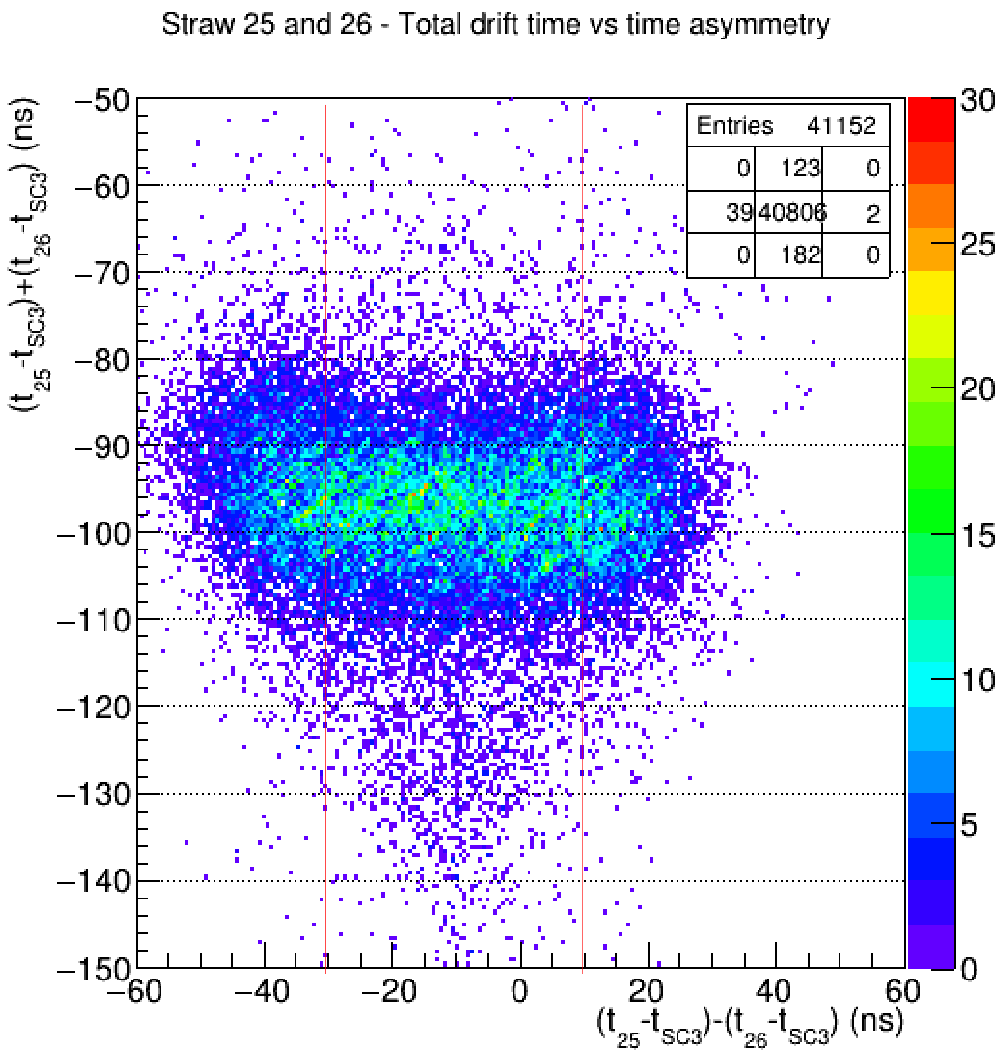
VMM RUN 665: total drift time vs drift time asymmetry

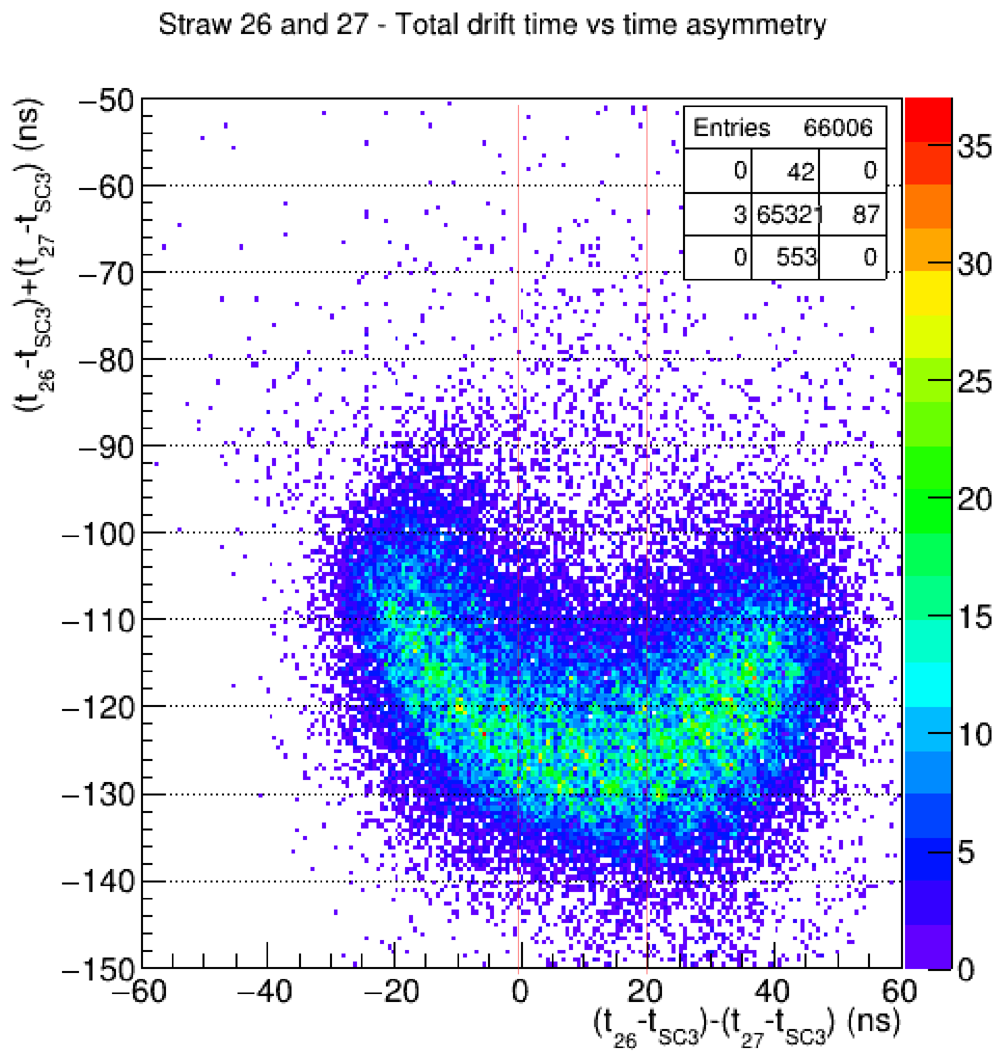




The first is nearly constant!
The second shows the ‘banana’ shape but is nearly constant far from the edges

VMM RUN 665: total drift time vs drift time asymmetry

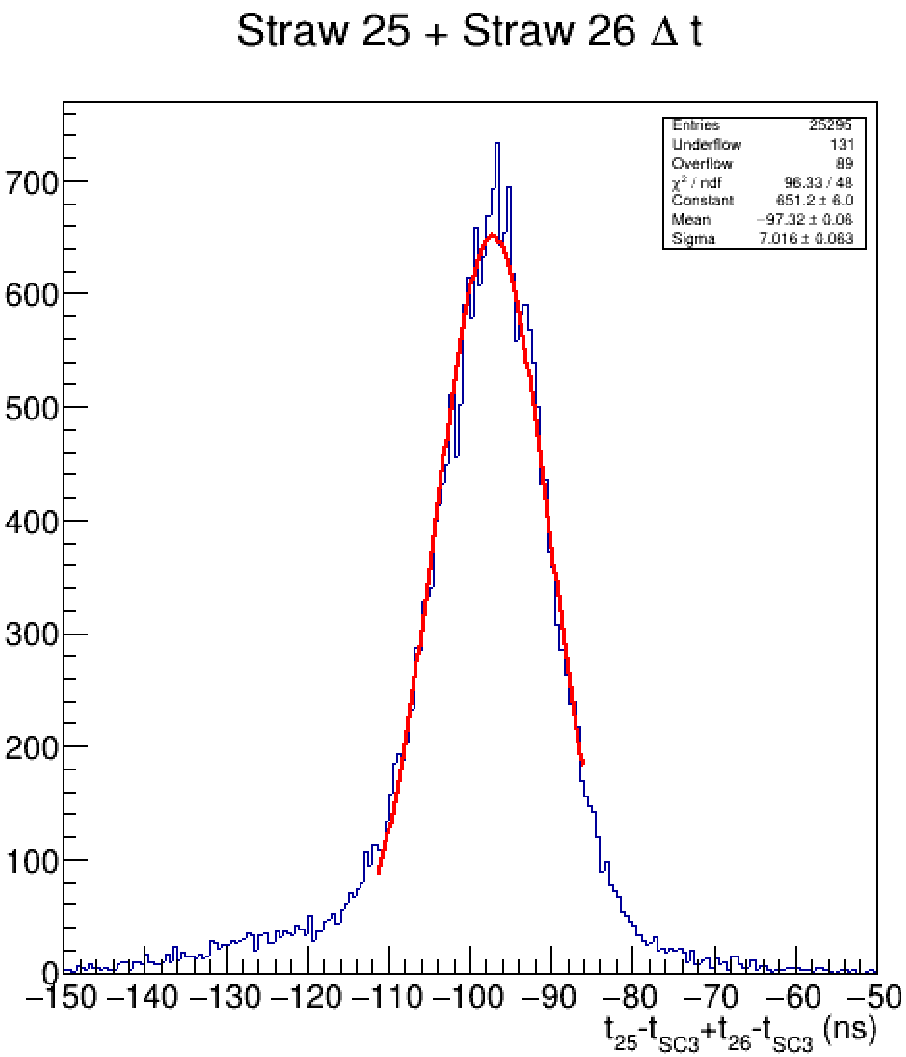


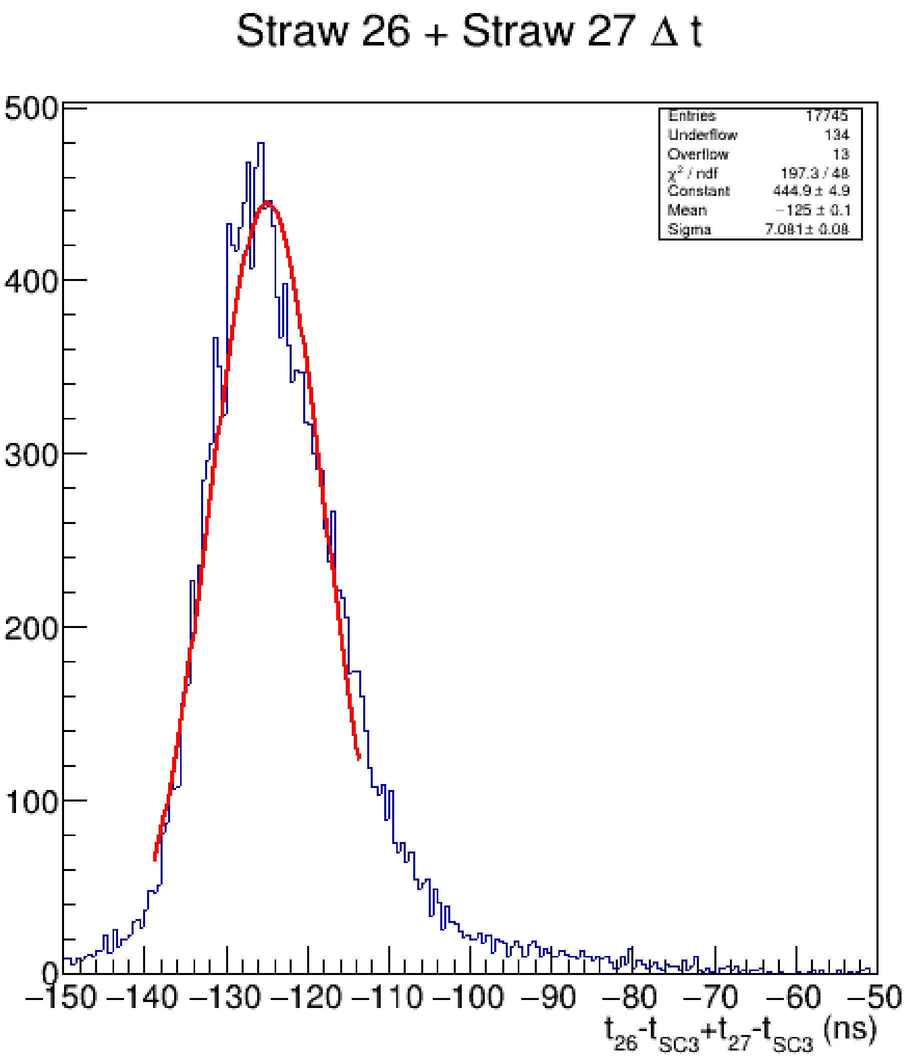


To select the linear region we ask for:

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

VMM RUN 665: total drift time after cuts



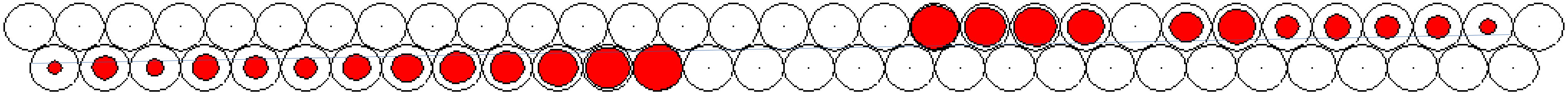


σ~7 ns

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

We need a better alignment to improve this result!

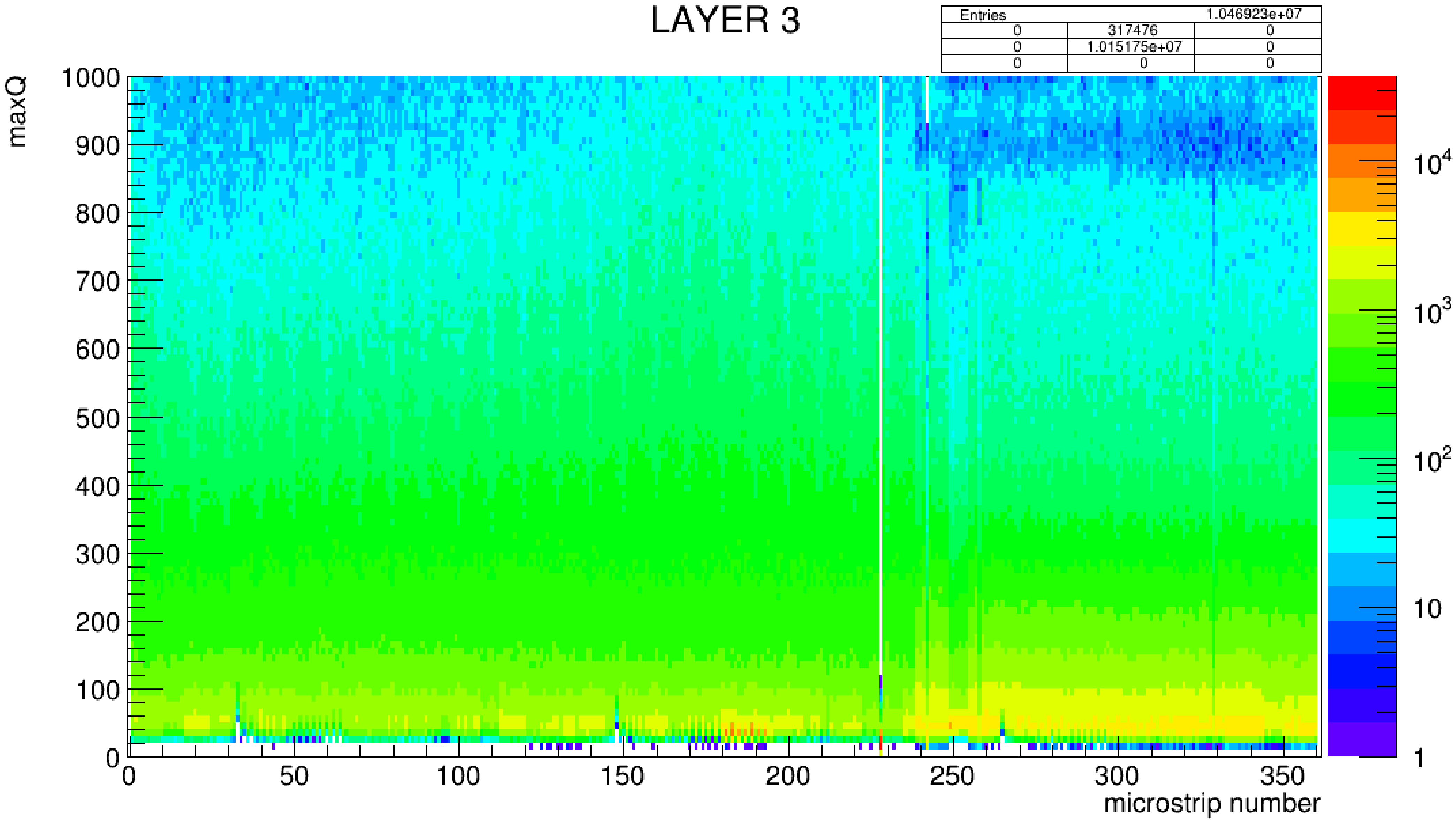
Another work in progress



Special runs with rotated setup.
Need space time relation...

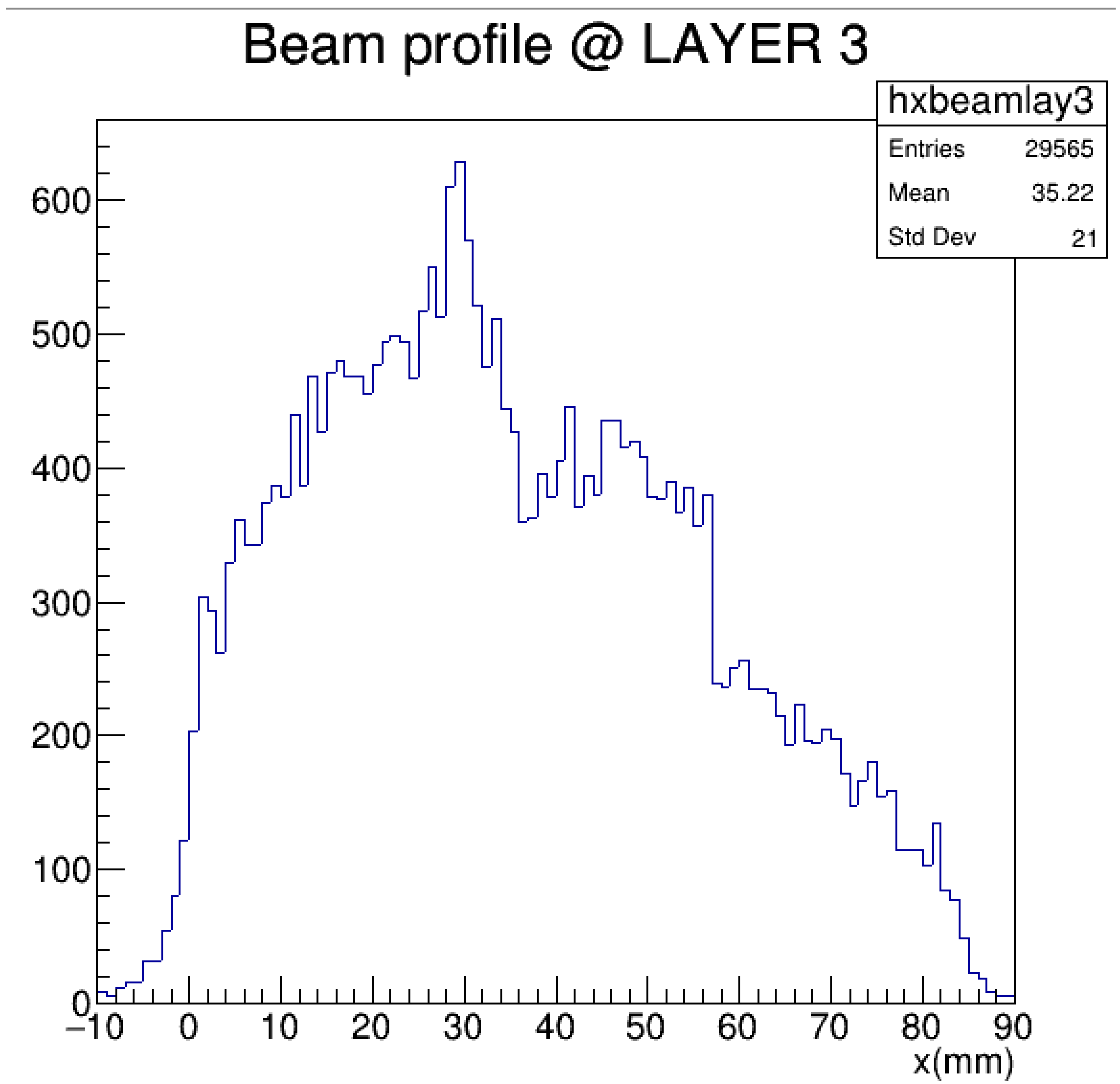
BACKUP

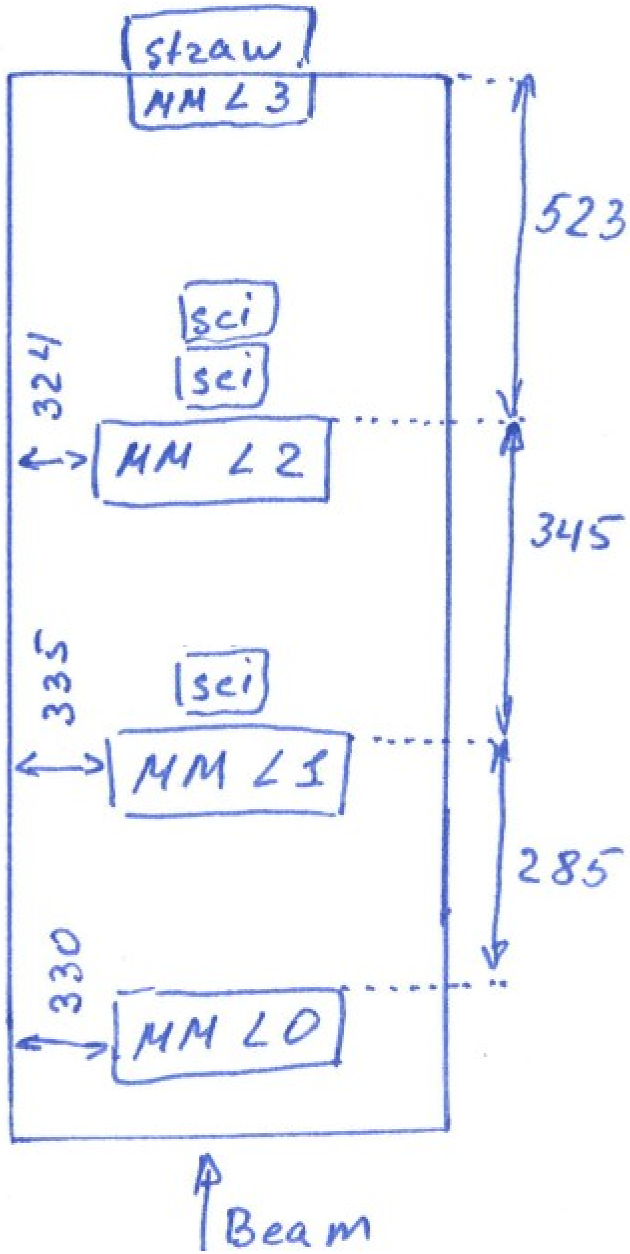
APV RUN 331: LAYER 3 microstrips pulse hight



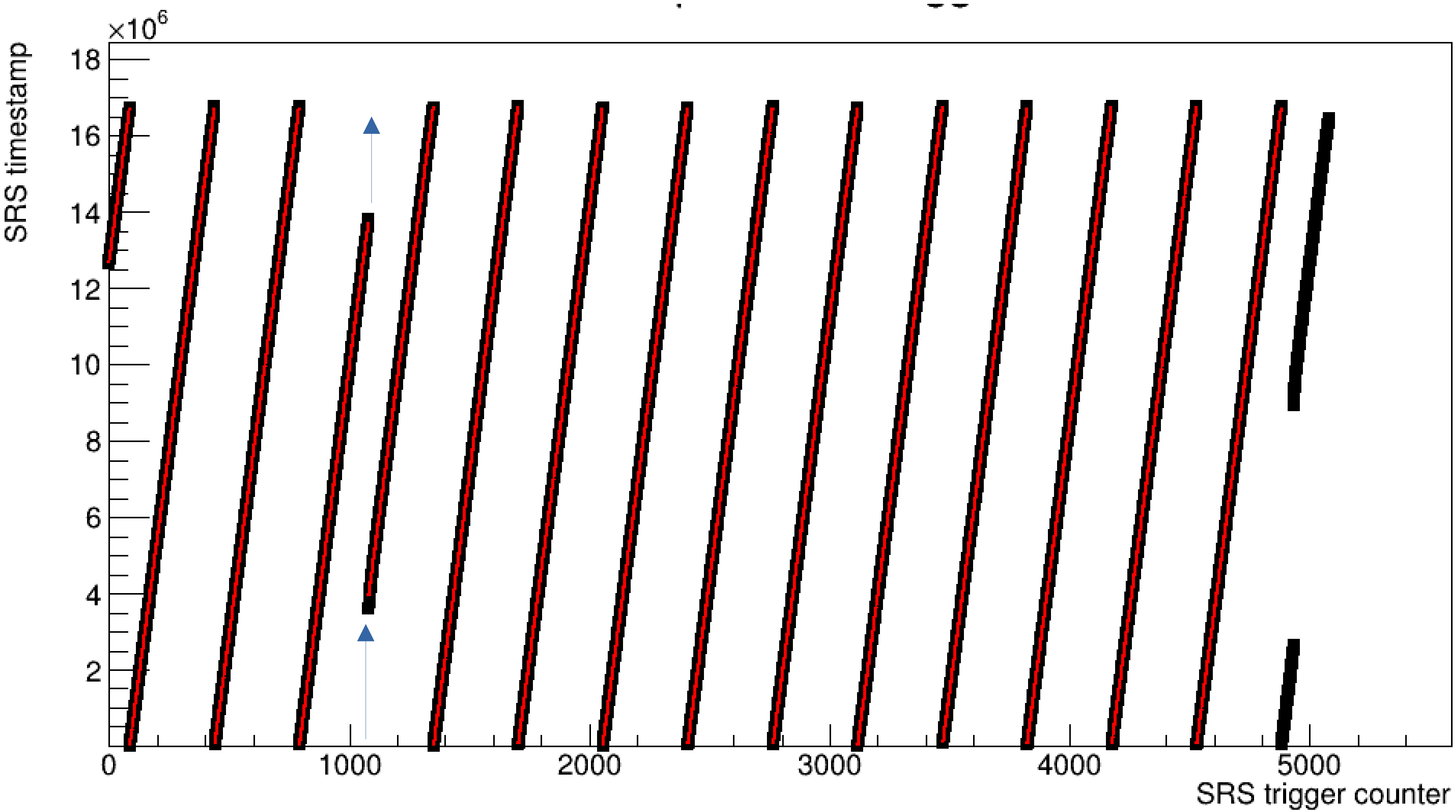
Layer with horizontal strips

RUN 331: extrapolated beam impact on LAYER 3



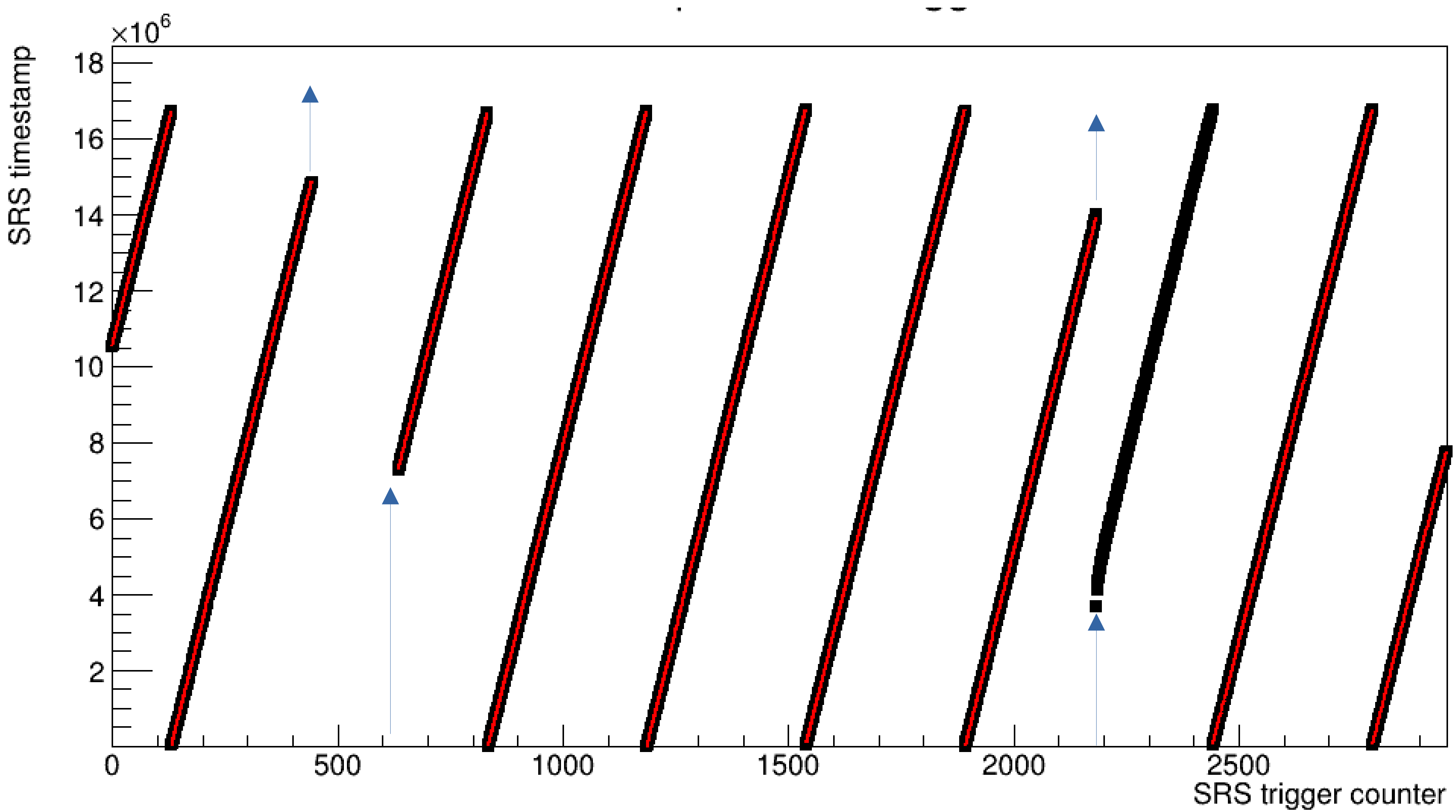


APV RUN 331: no triggers during SRS cycle transition



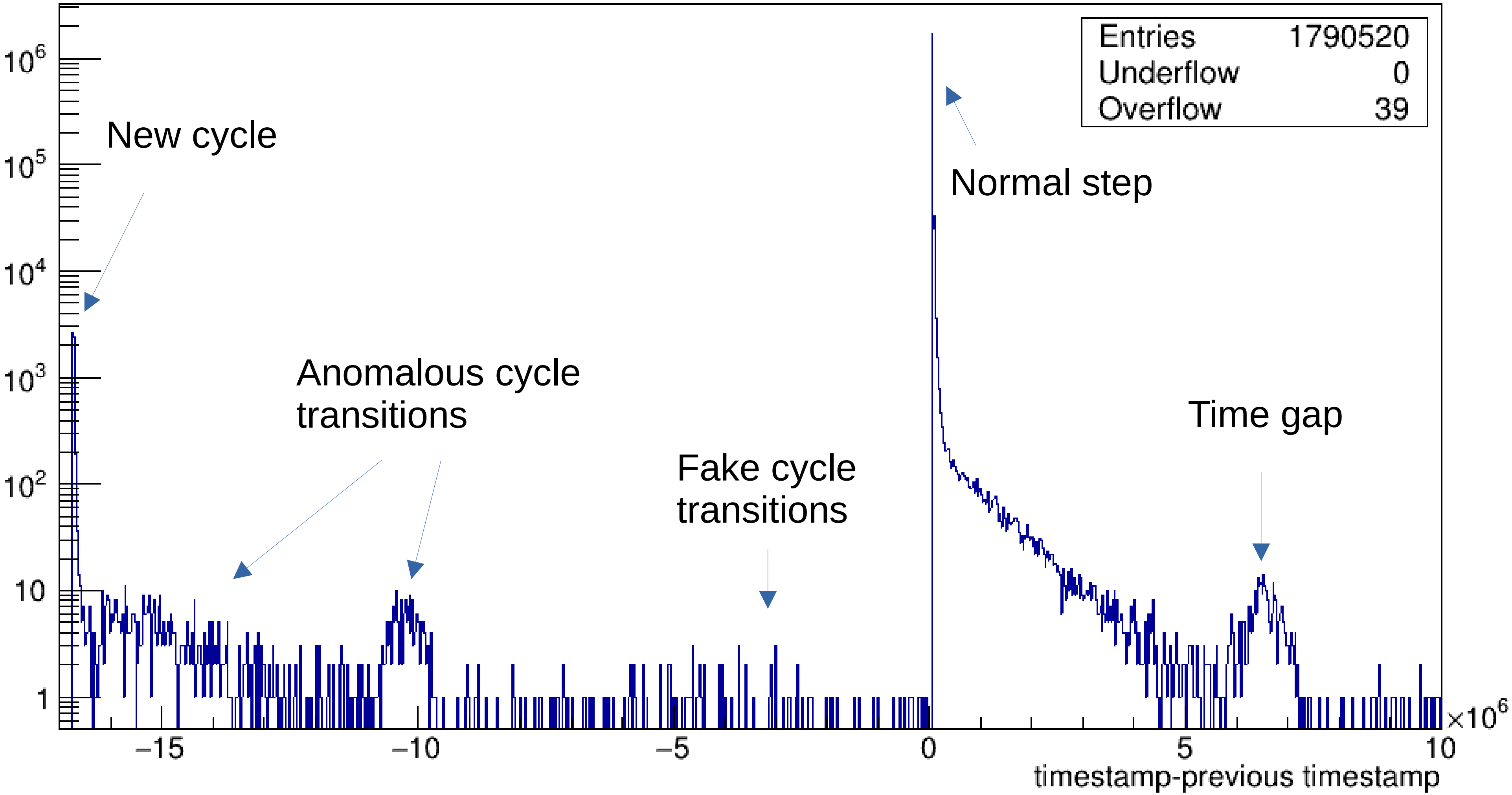
Time gap between cycles

RUN 331: SRS Timestamp vs trigger Counter



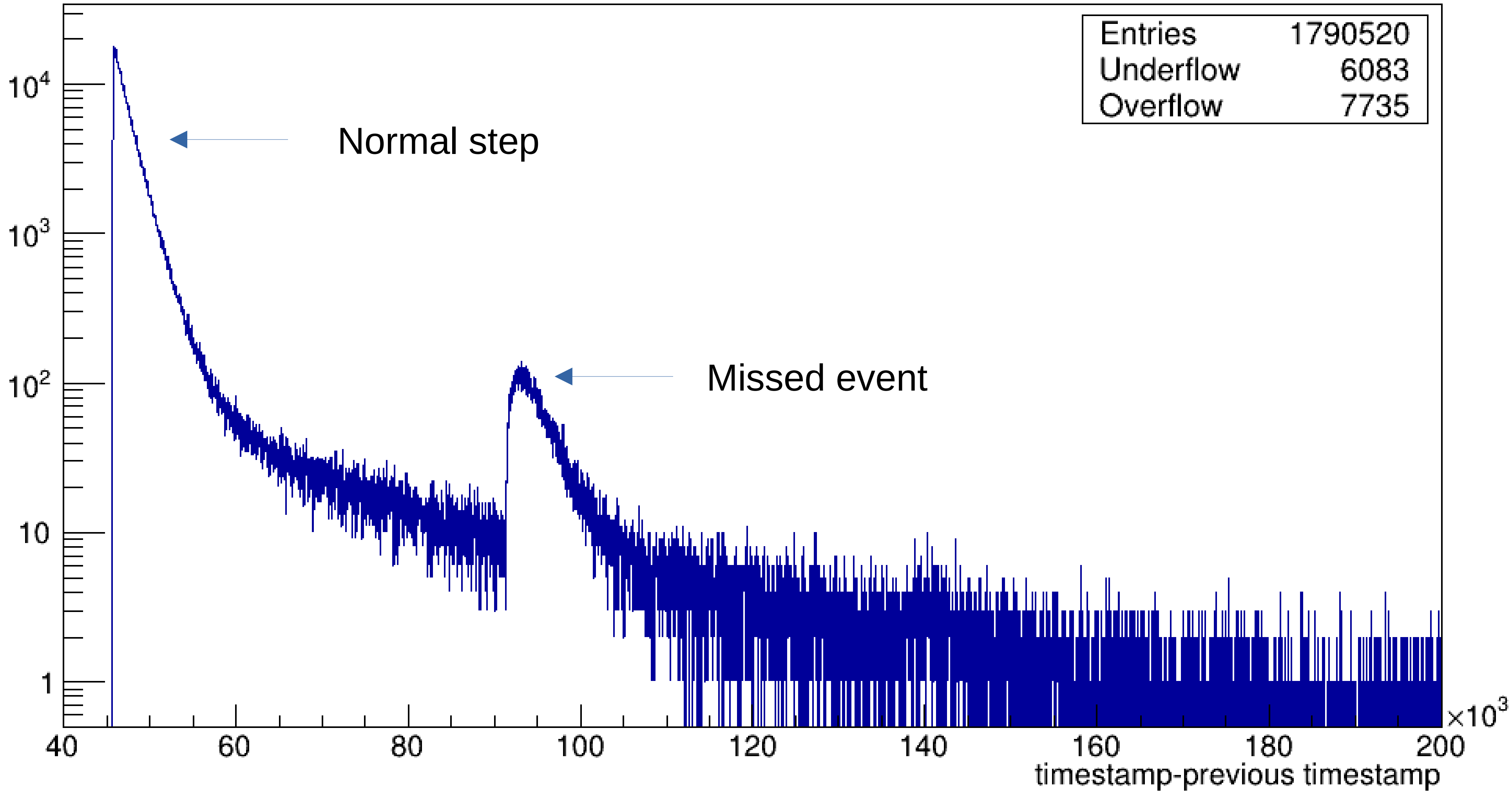
Time gap duration is not constant

RUN 331: SRS Timestamp step



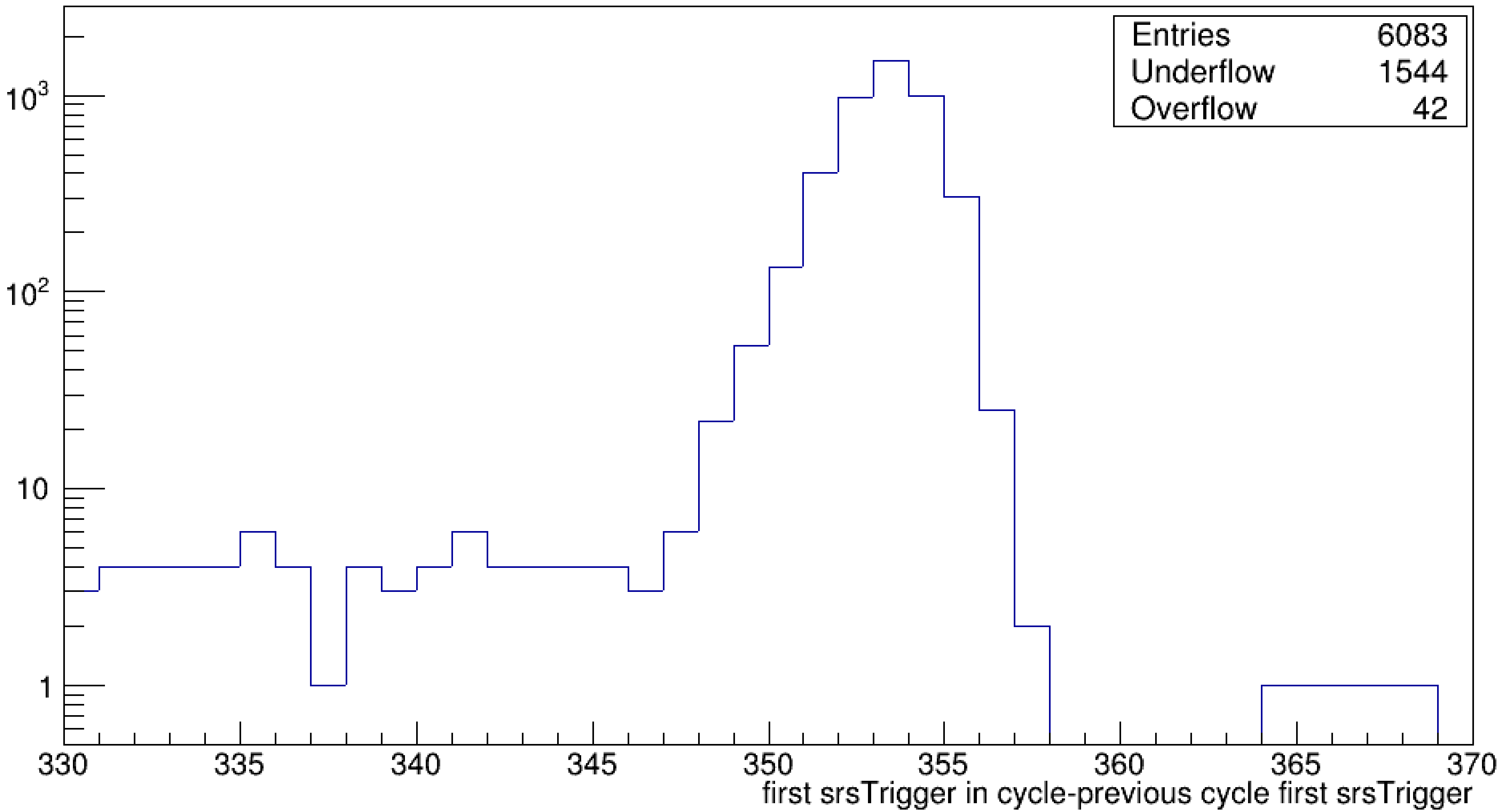
When a new cycle starts the step should be close to -2^24=-16777216
Sometimes it's higher because the cycles are incomplete (at the end or at the beginning)

RUN 331: SRS Timestamp step (zoom)



The normal step between consecutive events is ~45000
Sometimes it's doubled indicating a missing event

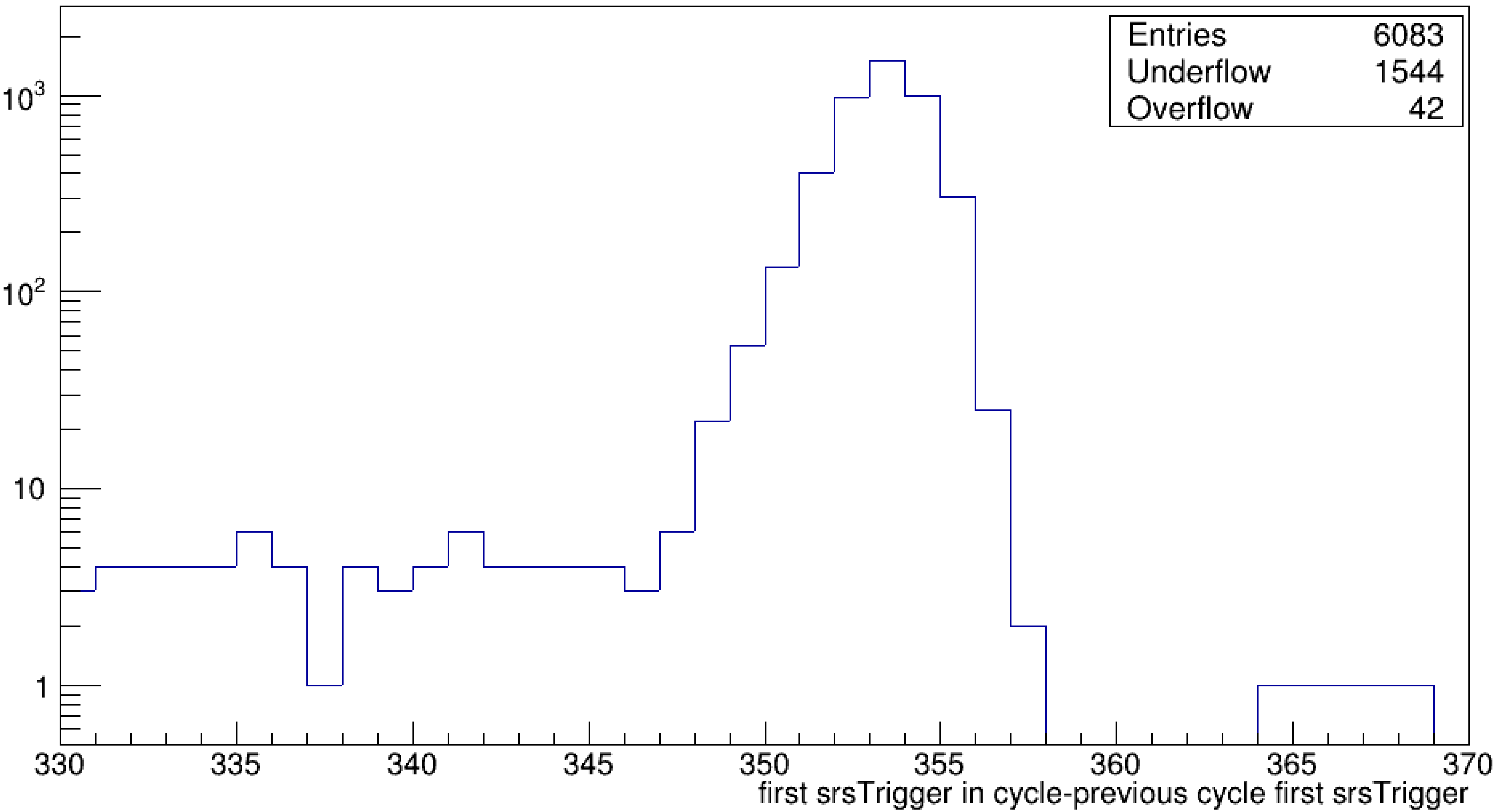
RUN 331: SRS cycle length in srsTriggers



~25% of the cycles have an anomalous length

We cannot use an analytical formula to get an absolute time from srsTimestamp and srsTrigger

RUN 331: SRS cycle length in srsTriggers



Now ~10% of the cycles have an anomalous length
We cannot use an analytical formula to get an absolute time from srsTimestamp and srsTrigger