Analysis of particles with anomalous momentum detected at COMPASS 2018 experiment

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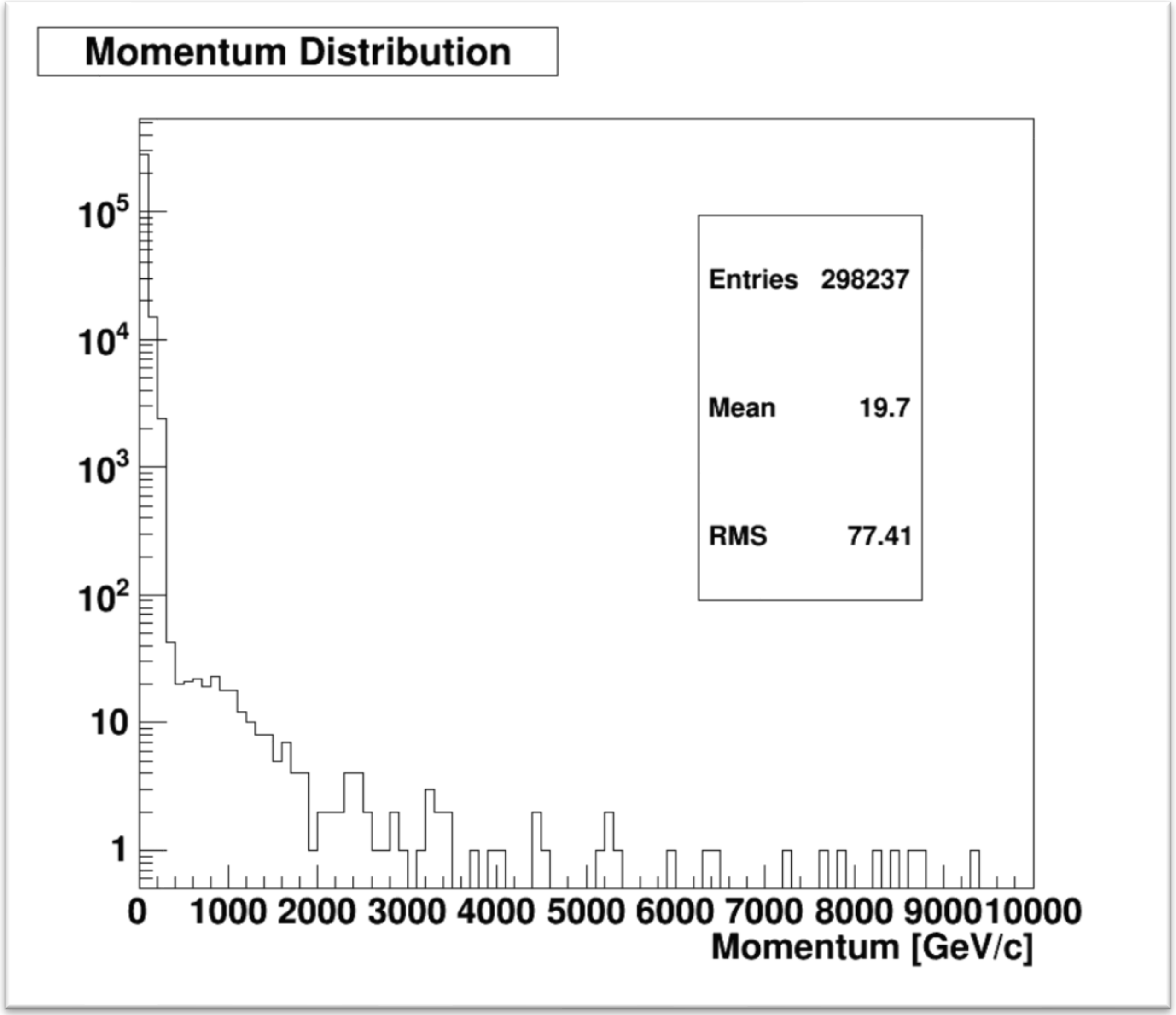
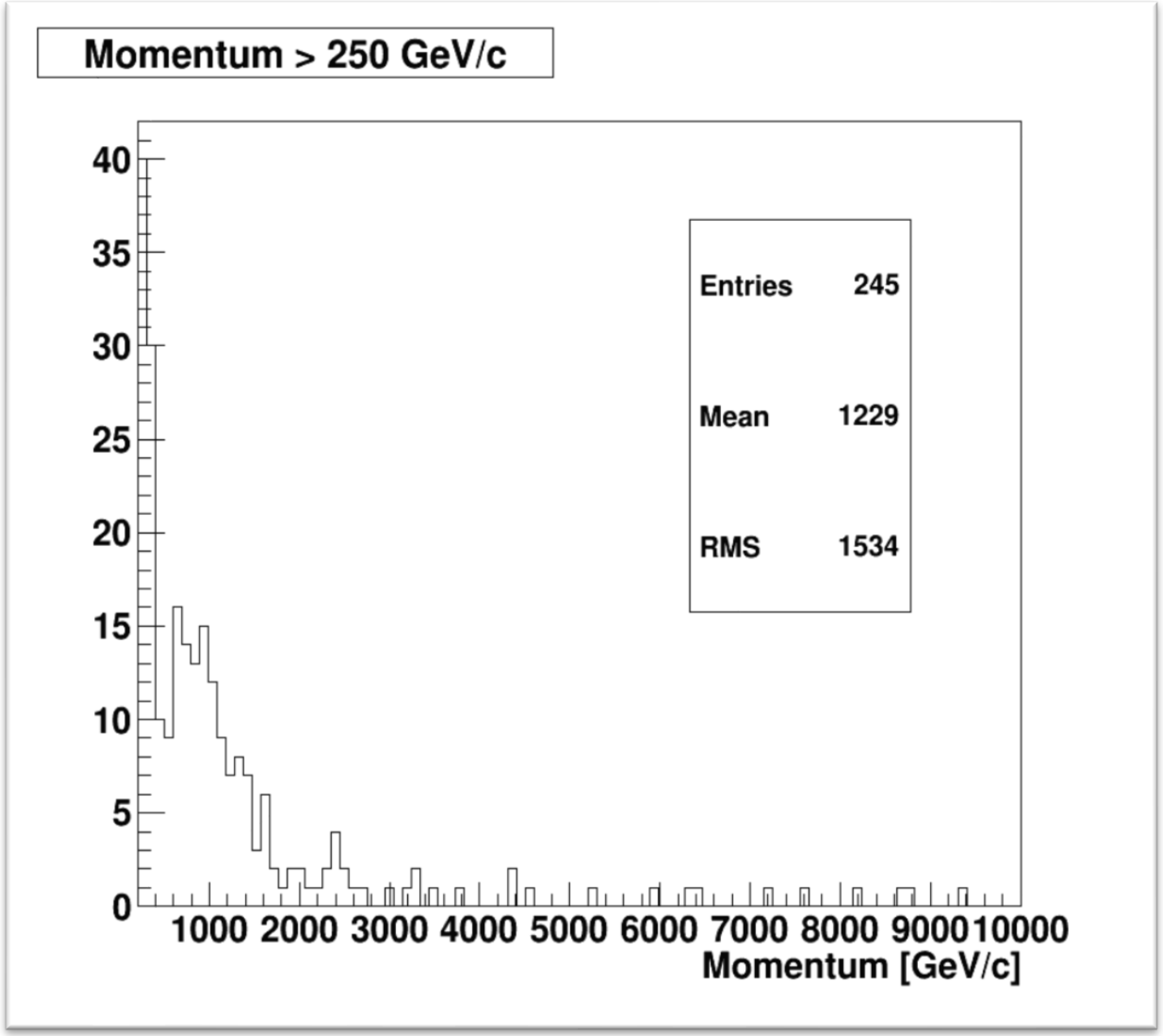
We analysed 10 miniDST files of the 284351 run in the 2018 data.

Momentum Distribution of all particles

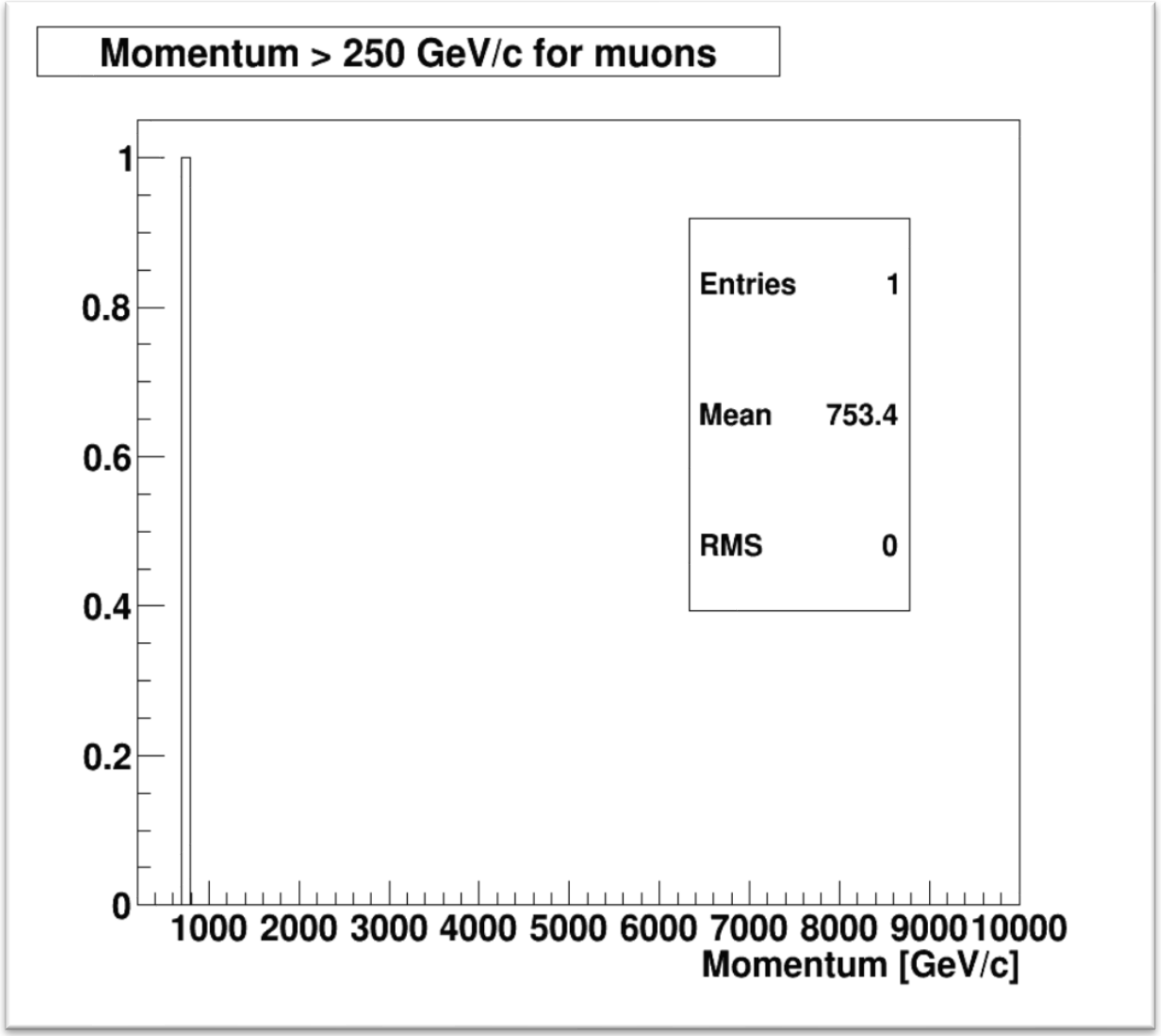


COMPASS is a fixed target experiment. We know that the beam has a momentum of 190 GeV/c. Thus through **conservation of momentum** the product of the collision cannot have momentum over 190 GeV/c.

Considering particles with momentum above $190 + 5\sigma$ with $\sigma = 3.5\ GeV/c$ so we are not considering the tail end of the distribution.

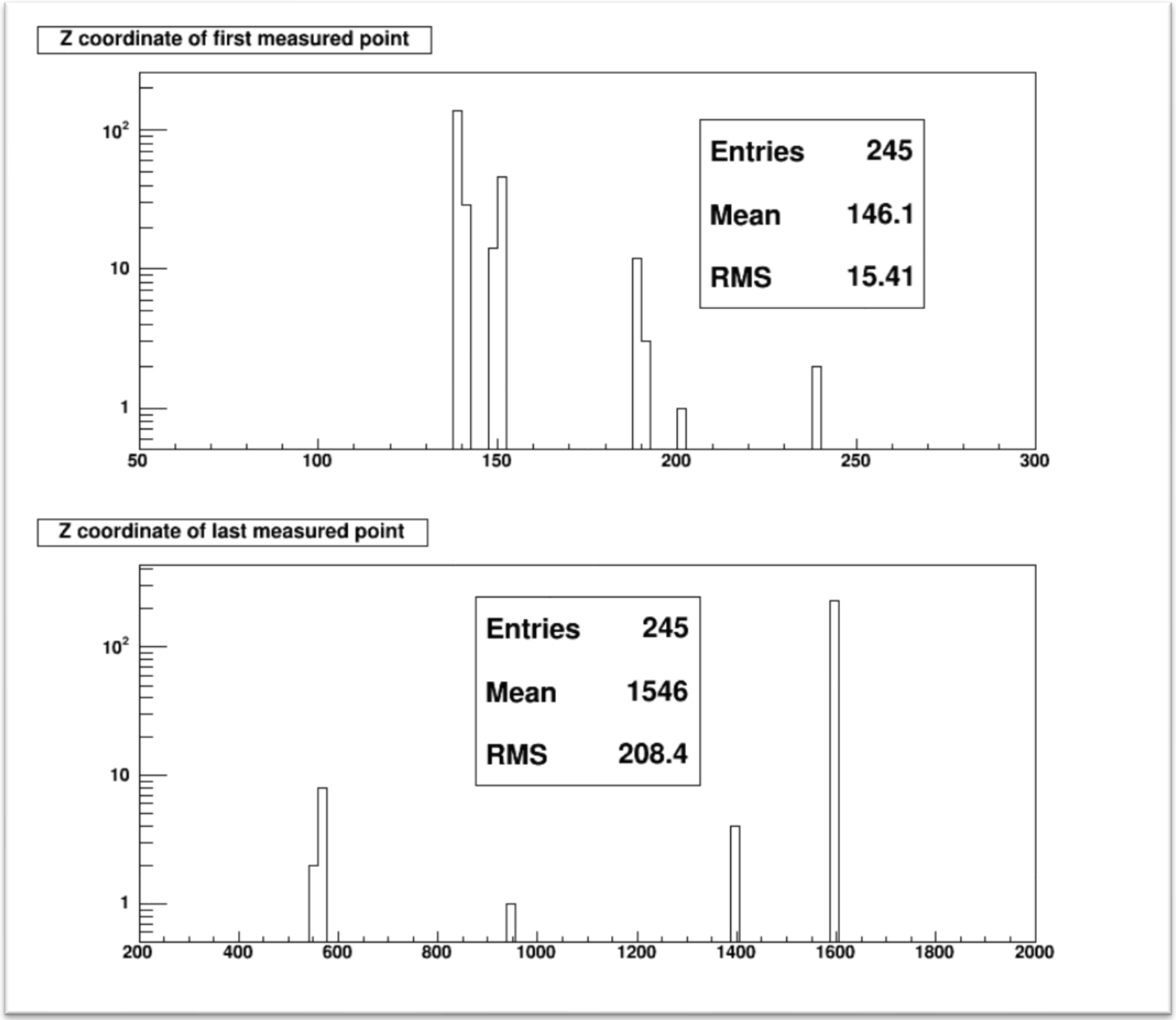


0.085% of particles have momentum above 250 GeV/c.



Only 0.4% of these particles are muons.

Analysis of first and last measured point of outgoing particles with anomalous momentum over 250 GeV/c, at the Z axis.



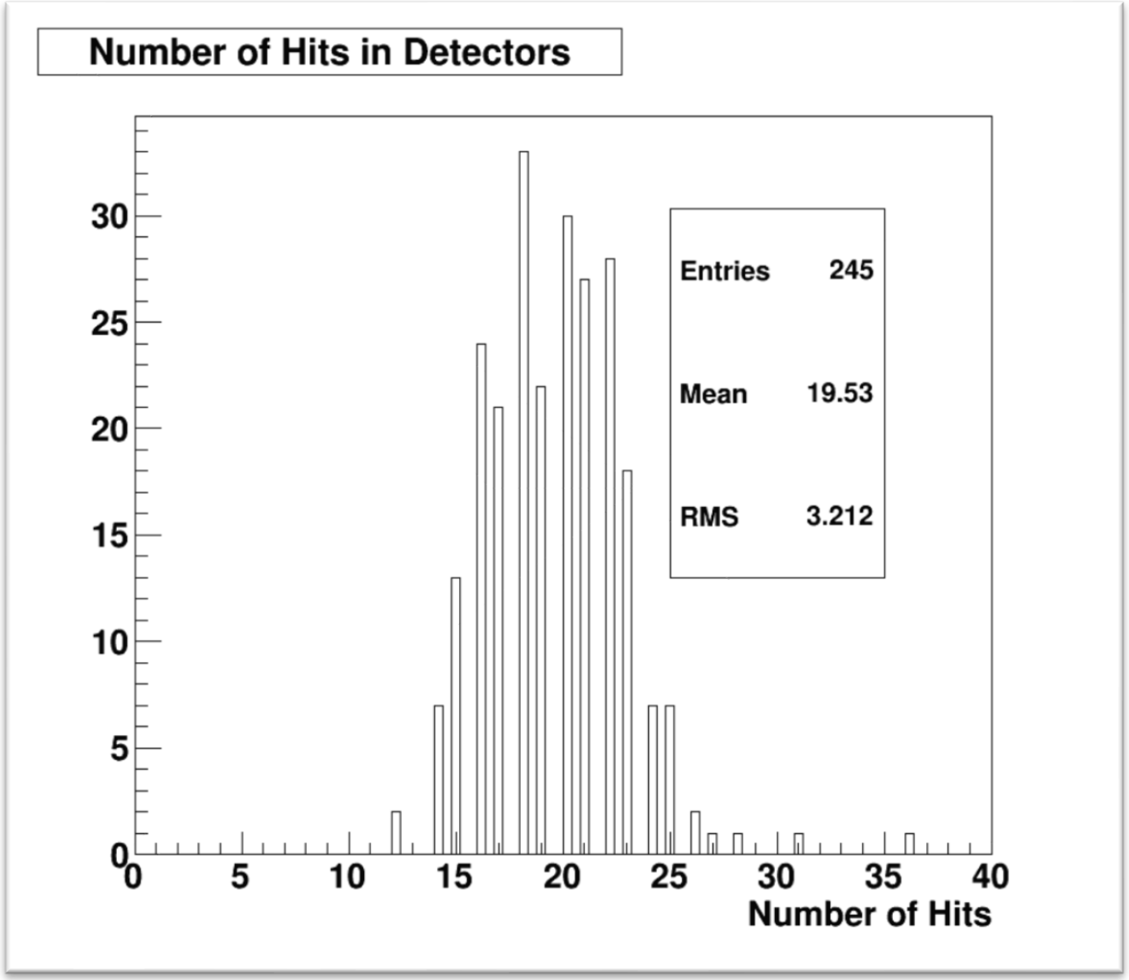
The momentum of outgoing charged particles is measured through the **Lorentz Force** while they pass through the magnetic field of the dipole:

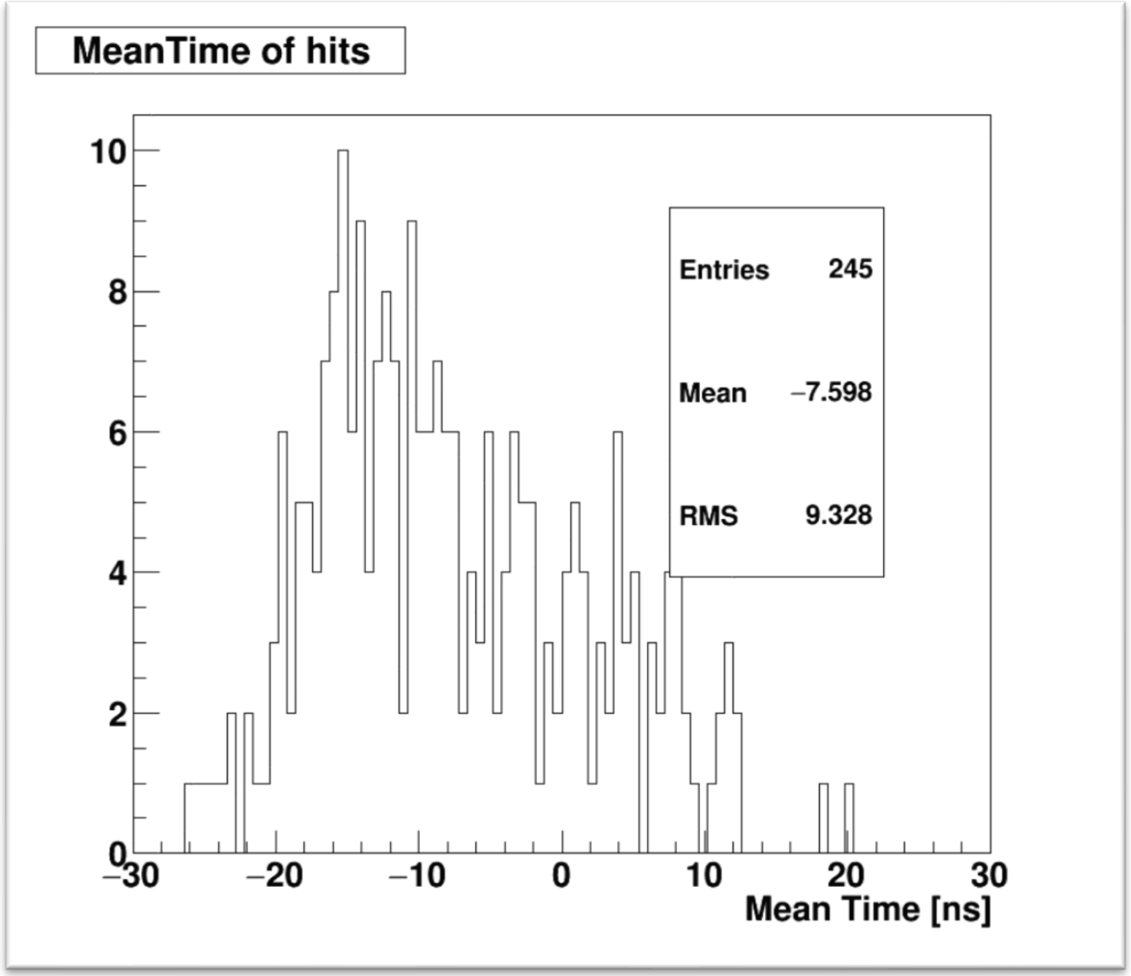
$$\boldsymbol{F} = q\boldsymbol{v} \times \boldsymbol{B}$$

Which means that there needs to be a **track** before and after the dipole in order to determine the angle of the deviated particle due to the magnetic field. Which then is used to determine the momentum.

We know that the first dipole after the target, the SM1, has its centre at 350 cm and the second dipole SM2 at 1825 cm.

These graphs tell us that the first point was measured before the dipole and the last point after the dipole SM1, in which case these data points should have their momentum correctly measured. This is not the case. Why?

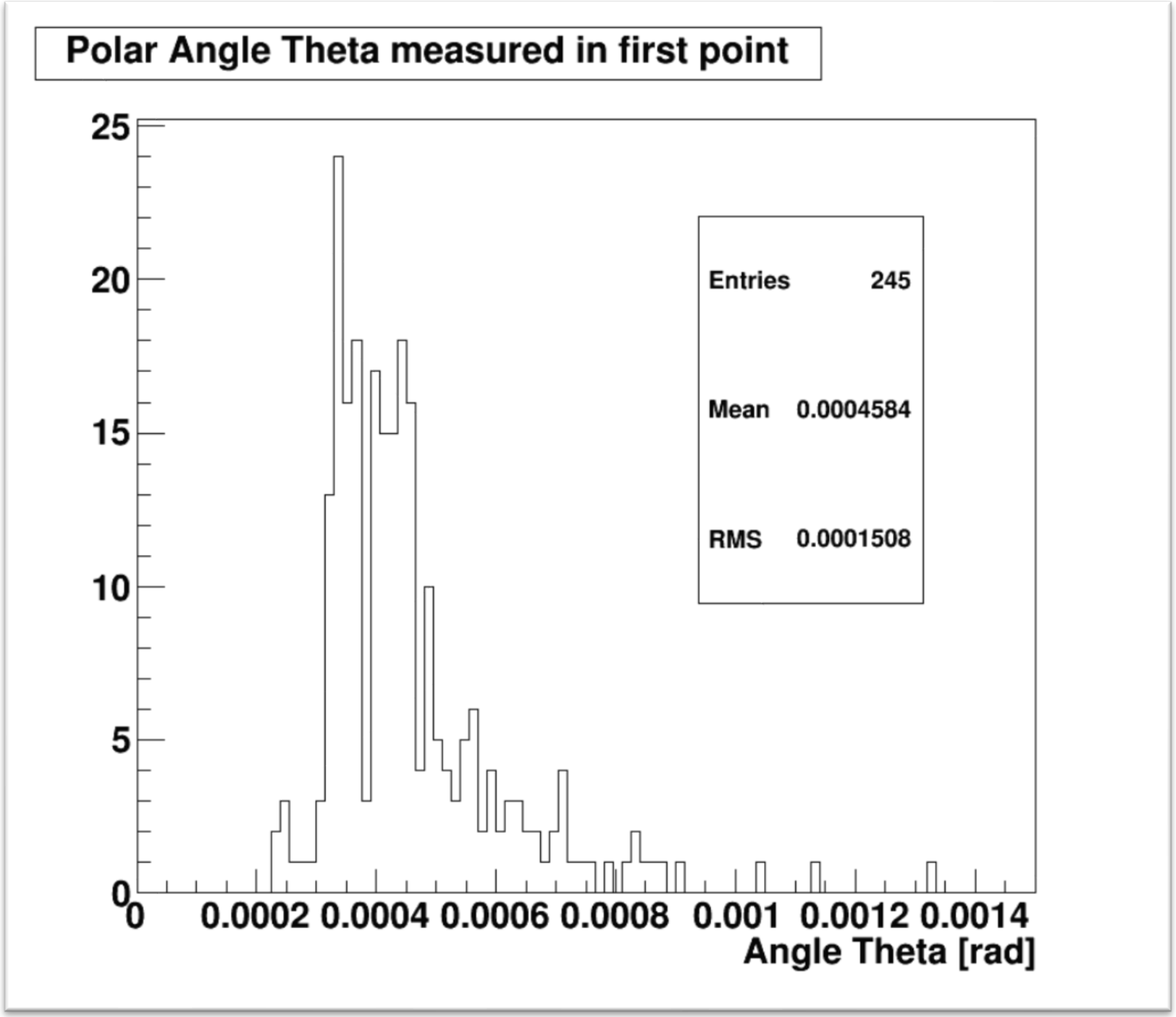




The tracks of these particles were built based on approximately 20 hits, which should have been enough to get an accurate measure of the momentum.

In which detectors do we see these hits?

The mean time of the hits is not centred at zero, which means the calibrations in time are not perfect, but they have been measured as expected.



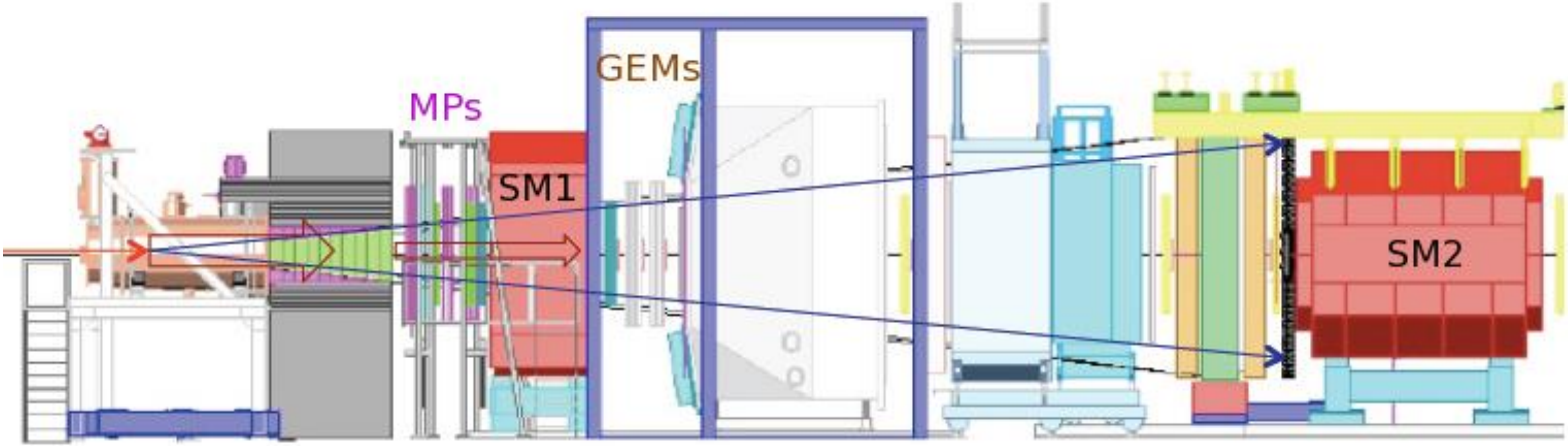
To identify the detectors we need to know the average polar angle; the angle of the trajectory relative to the beam.

Angle theta measured in the first point:

$$\theta_{FP} \approx 0.4\, mrad \approx 0.02°$$

The particles with anomalous momentum have very small polar angles, so small they are not relevant to the COMPASS experiment given that no trigger is covering such small angles. With angles so small these particles cannot be identified as muons.

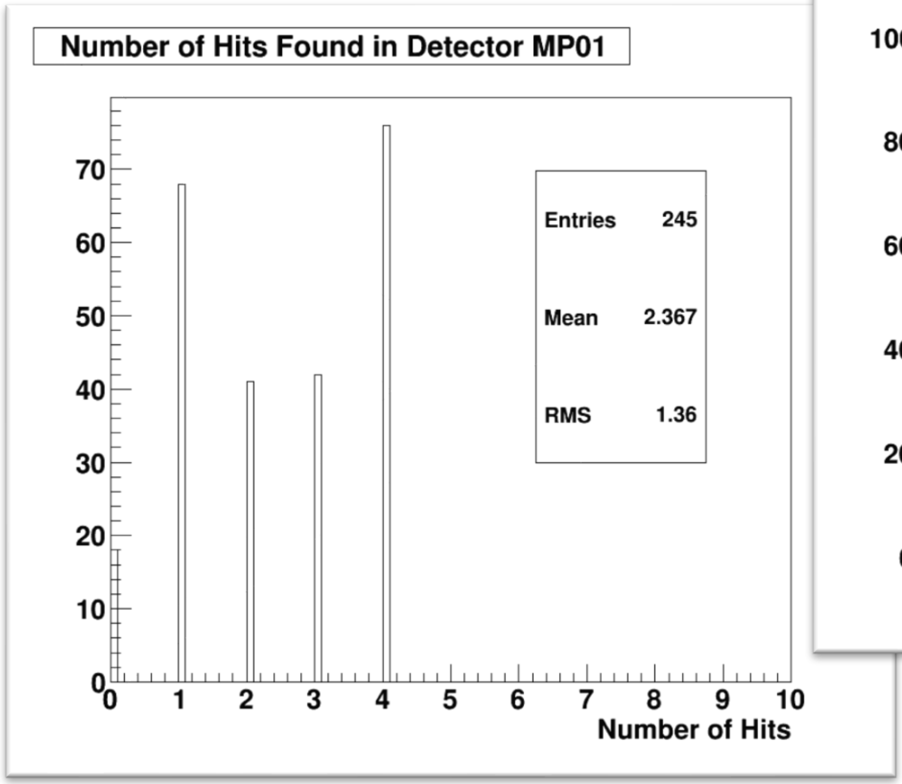
Section of the COMPASS detector layout

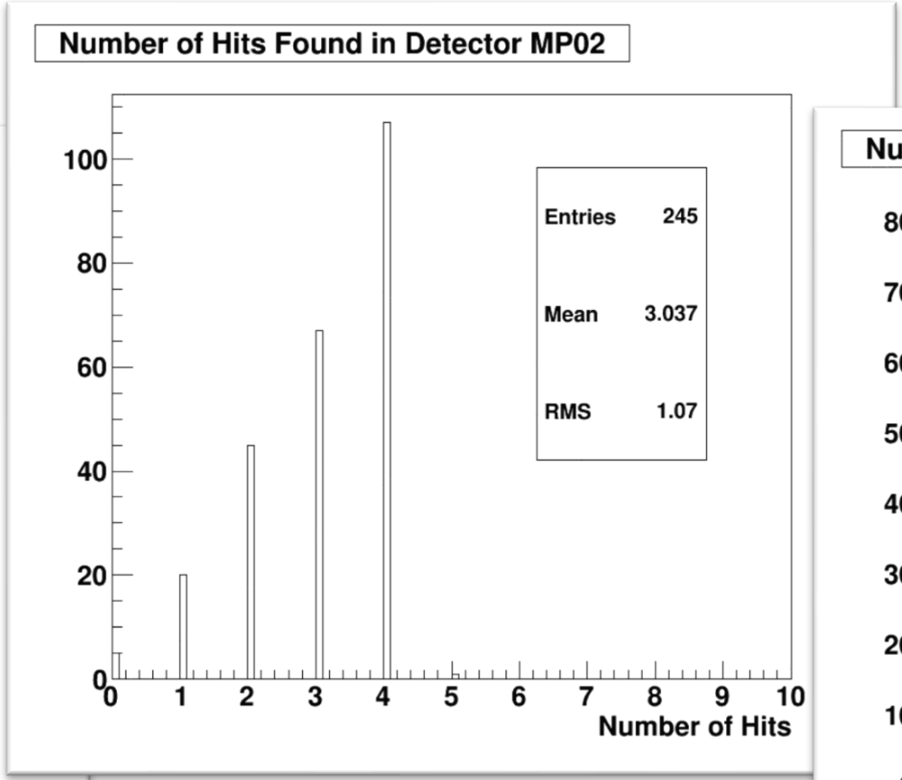


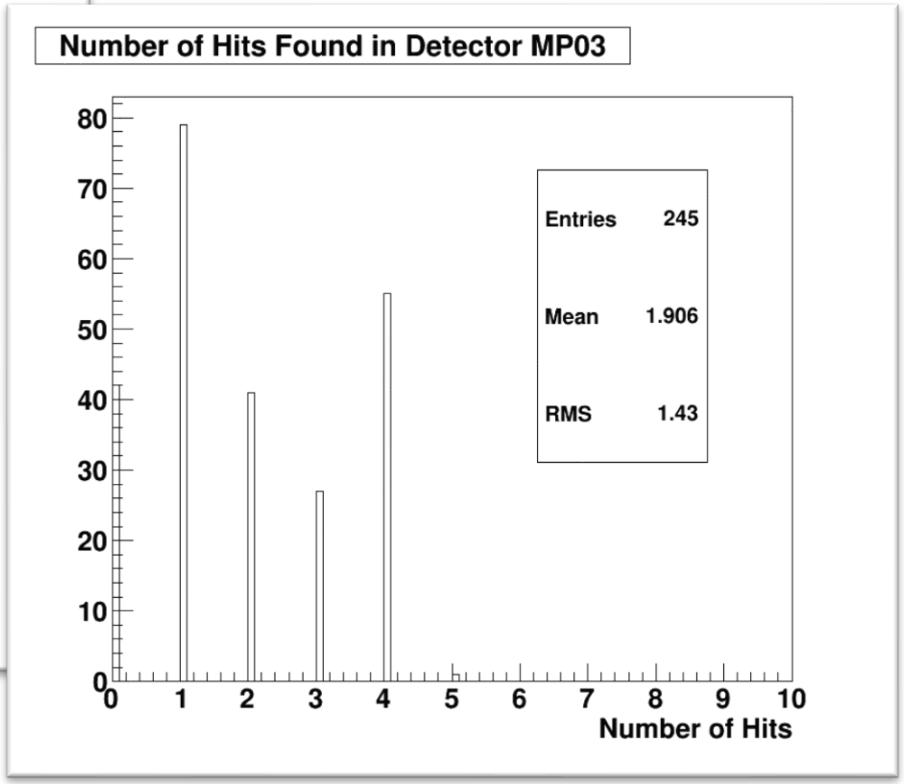
Given that the first point was measured before the SM1 dipole and the last point after the SM1, we’ll be analysing the number of hits in the Pixel Micromegas (MP) detectors and the Gas Electron Multiplier (GEM) detectors.

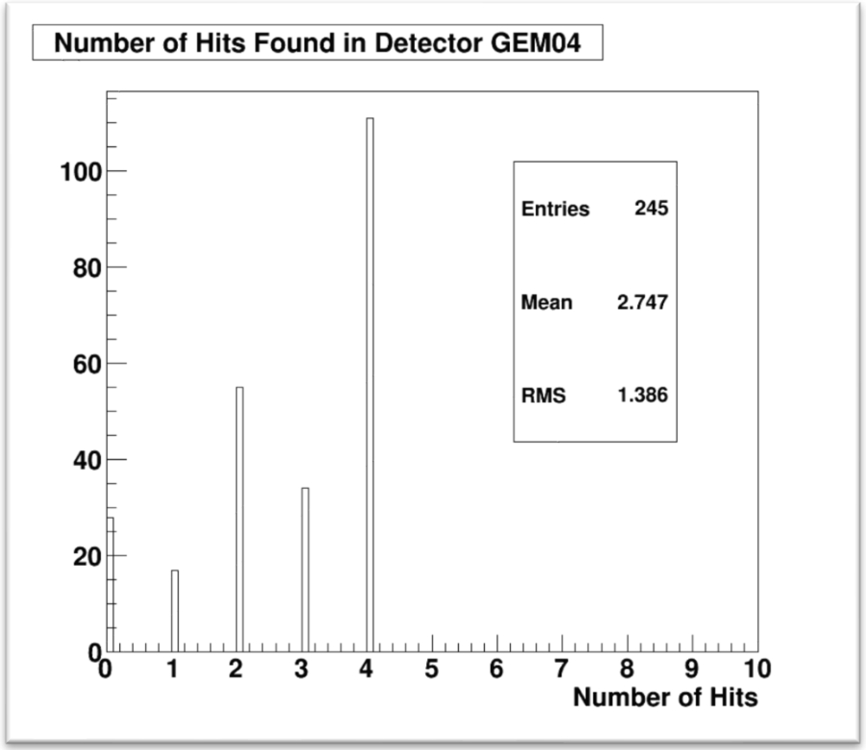
In the Pixel Micromegas we see a significant amount of hits in the MP01, MP02 and MP03 detectors.

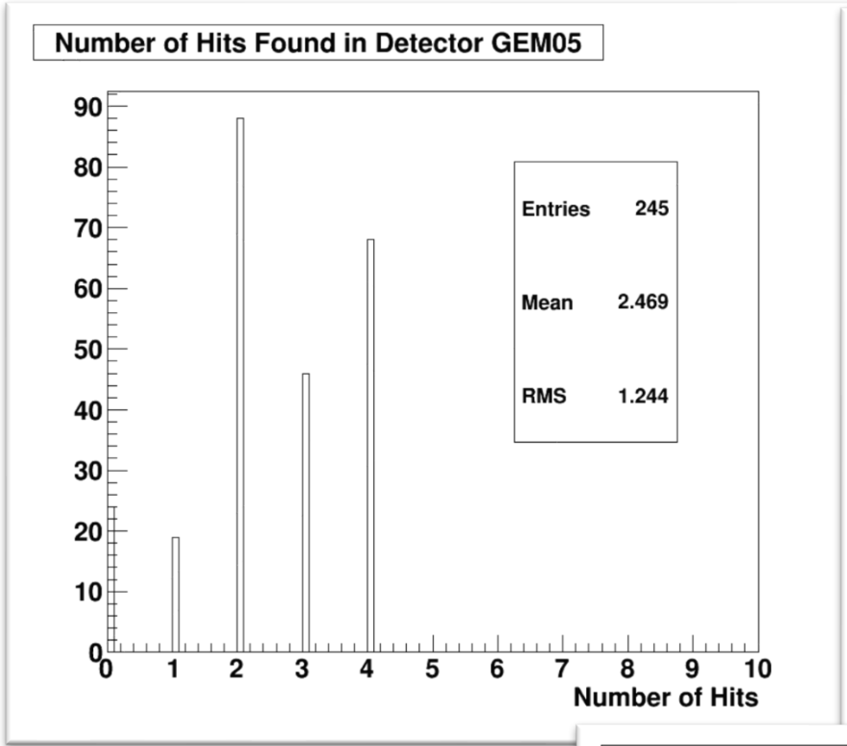
Four is the maximum number of hits associated in each Pixel Micromega, because there are four planes in total in these detectors. These detectors have 4.5x3.75 cm central zones with pixels which are especially suited to detect particles with small polar angles.

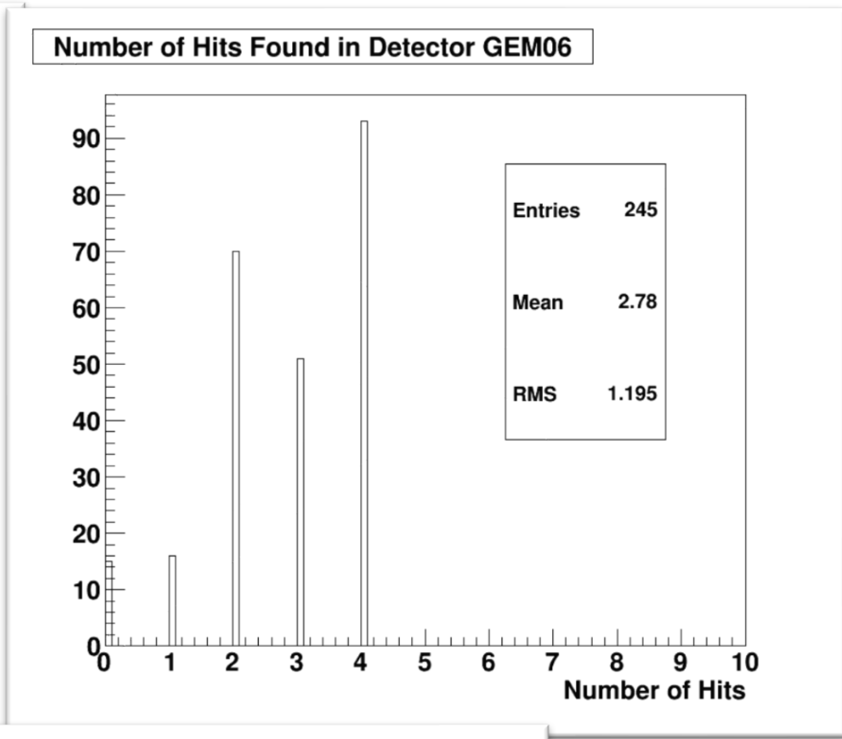






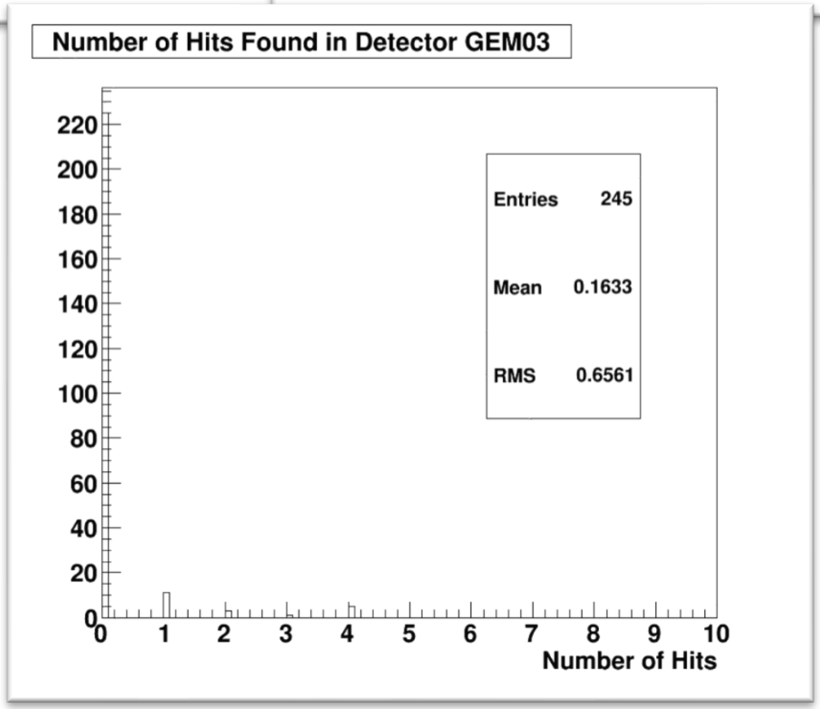






Again, each GEM detector has 4 planes and is used primarily for small angle trajectories. However GEM01, GEM02 and GEM03 did not detect any significant amount of hits, contrary to the GEM04, GEM05 and GEM06 detectors.

To understand why, we did the following calculations:



Using the y plane, because it's not sensitive to the magnetic field, we compare it with the detector centre

Considering that the GEM detectors have circular dead zones with $\mathrm{R} = 2.5\ cm$ radius, and the polar angle determined in Slide 6 is $\theta = 0.4584\ mrad$.

Detector Name	Detector centre relative to the beam axis [cm]
MP01	138
GEM03	565
GEM04	959

As the particles pass from MP01 to GEM03, they go through the dead zone, which is why the GEM03 does not detect hits.

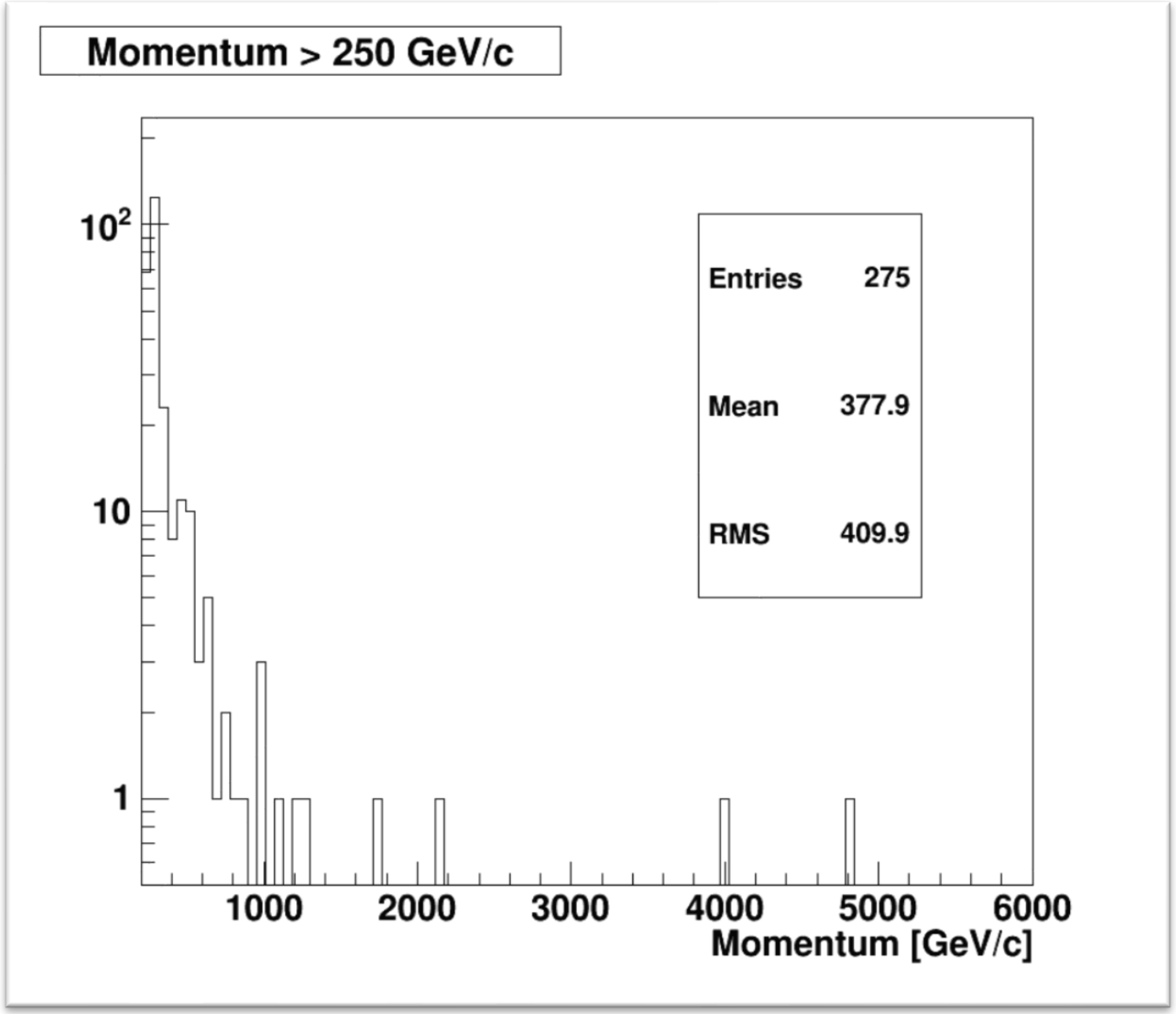
⟹ $y = (565 - 138) * 0.0004584 = 0.196\ cm\ = 1.96\ cm < R$

⟹ $y = (959 - 138) * 0.0004584 = 0.376\ cm = 3.76\ cm > R$

On the other hand, as the particles pass from MP01 to GEM04, they have y values larger than the radius and so they do not pass through the dead zone and the detector is able to register the hit.

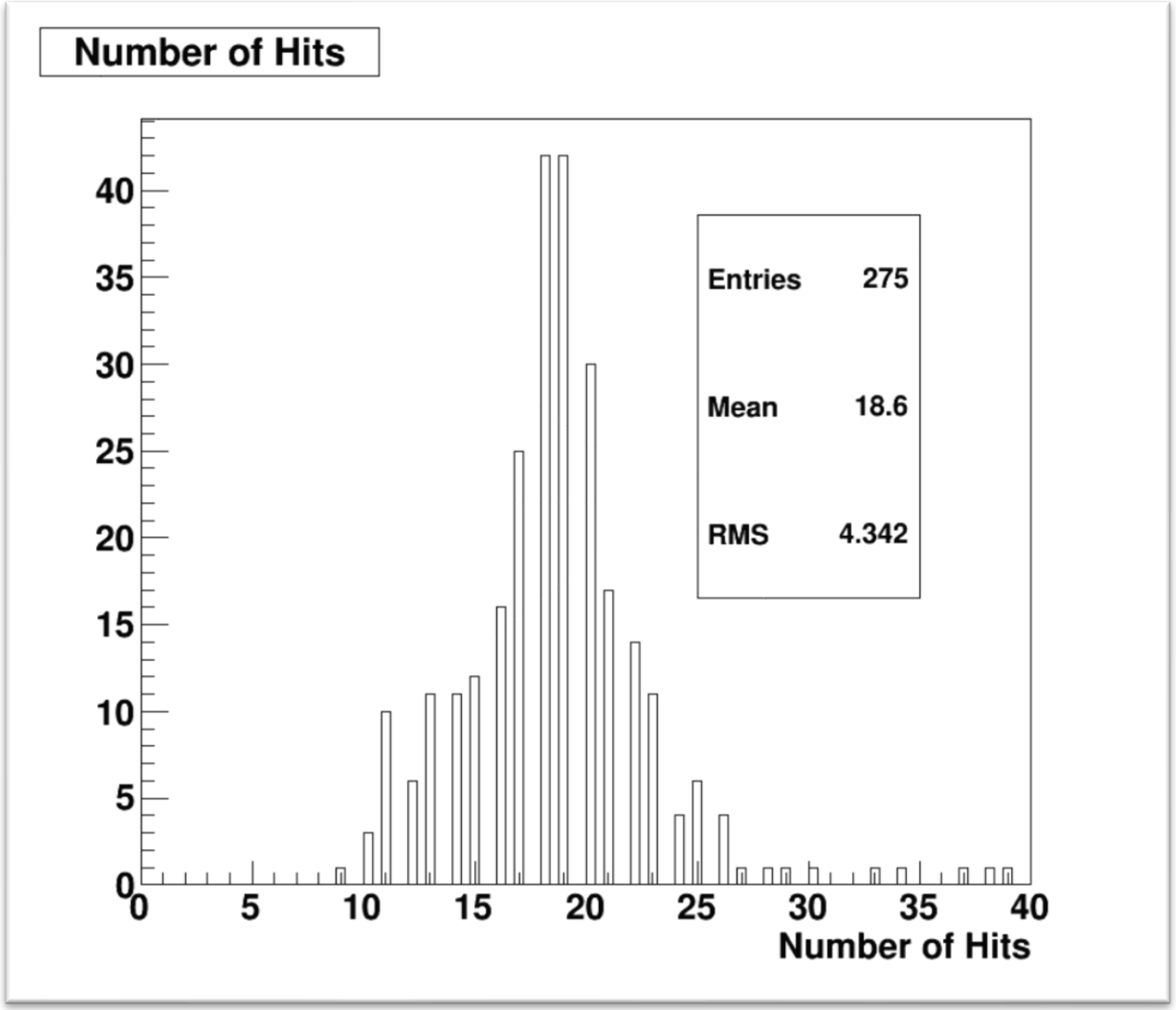
We analysed 5 microDST files of the 15W07t5-259935 run in the 2015 data.

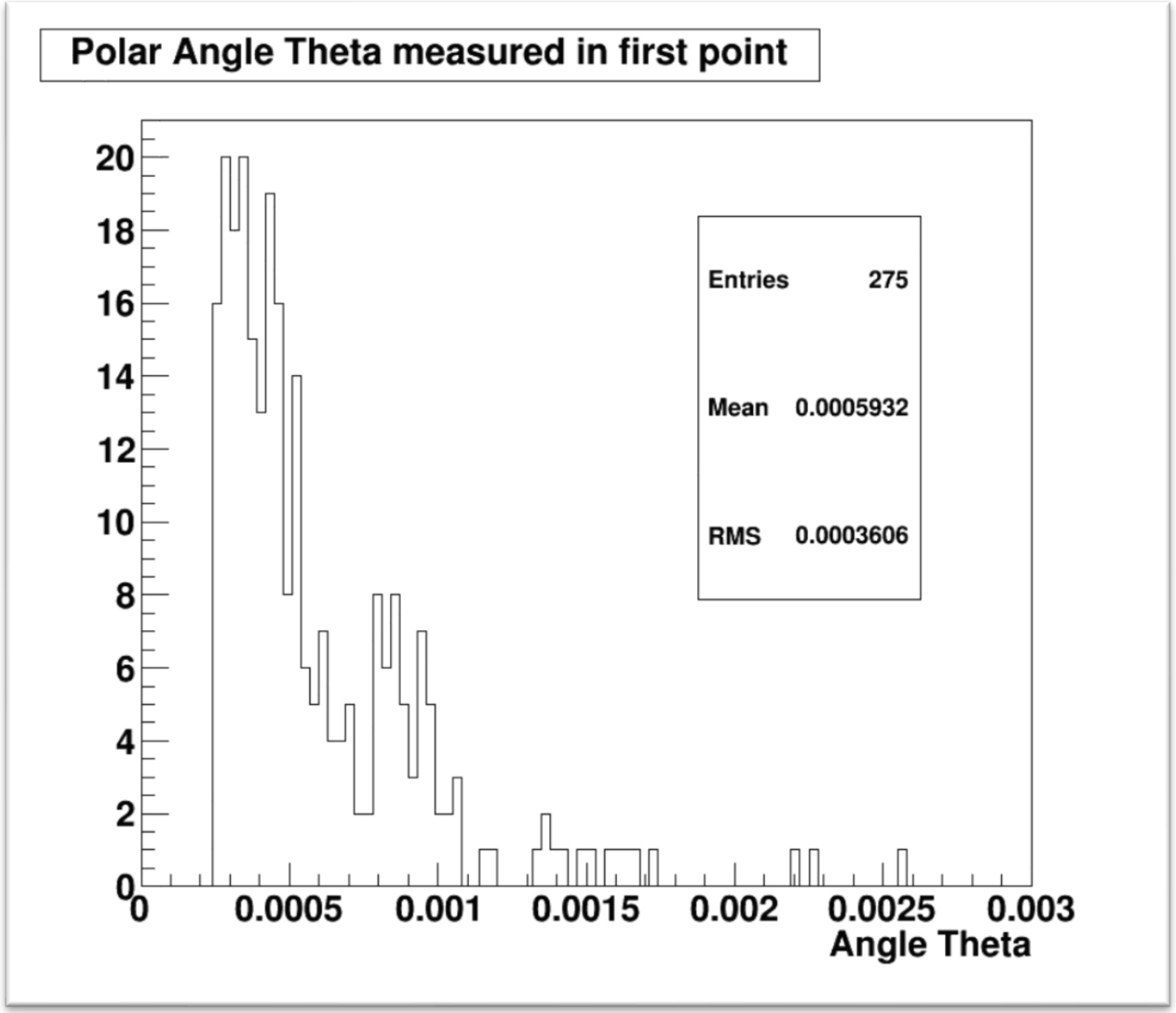
Comparison with 2015 COMPASS data



In 2015, the SciFI04 detector was installed near the Pixel Micromegas, unlike the setup in 2018. This detector is far more precise than the MP detector for particles with associated smaller angles. This may explain why there's less particles with momentum above 250 GeV/c; 0.006% in 2015 compared with 0.085% in 2018.

However, given the extra detector, why is there still anomalous momentum detected?

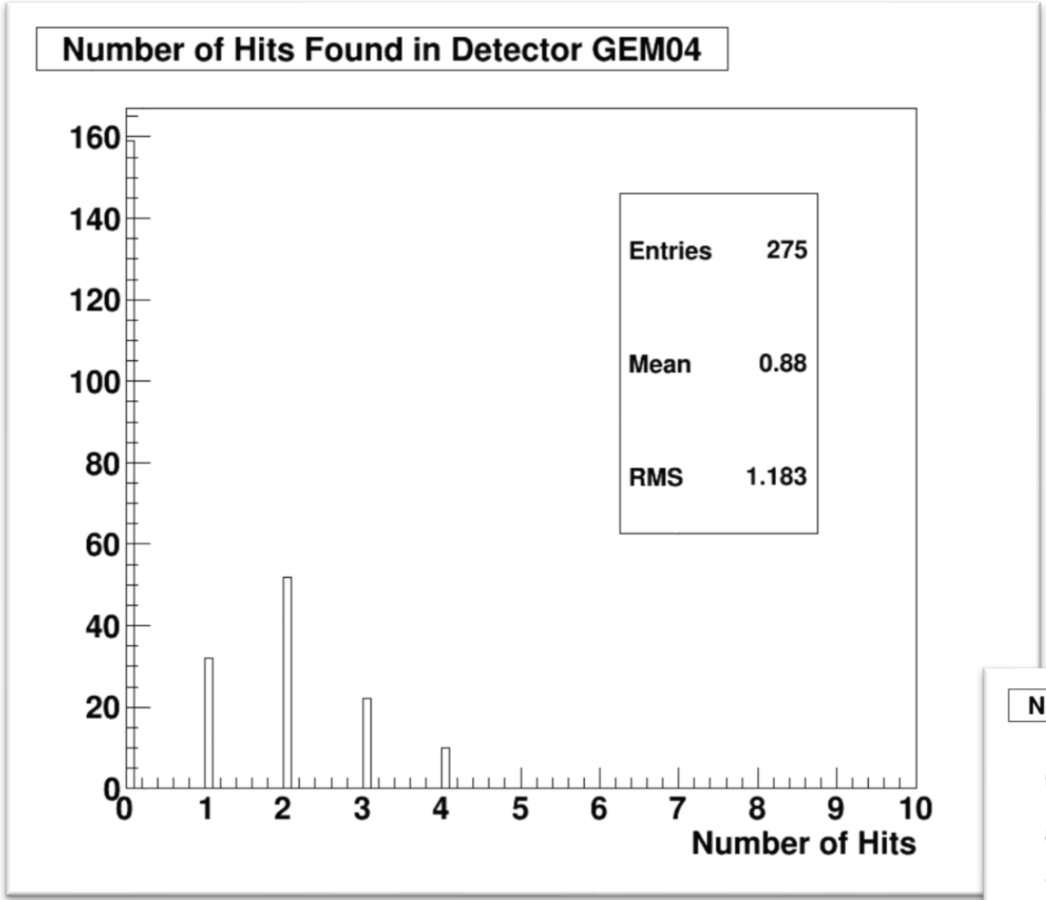




Average number of hits is 18.6. With an extra detector in 2015, meaning with 3 more planes, there should have been 3 more hits detected on average, compared to 2018.

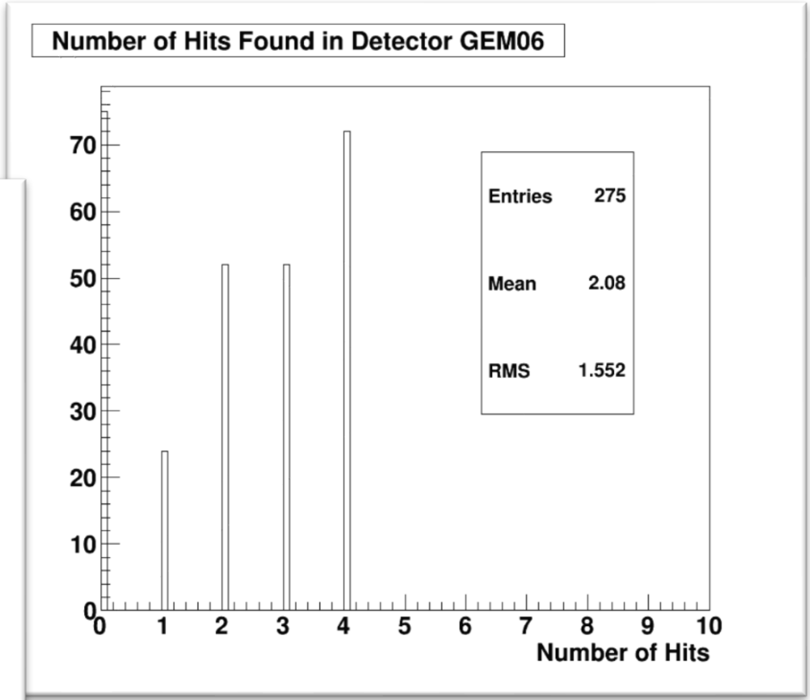
Angle theta measured in the first point is also small:

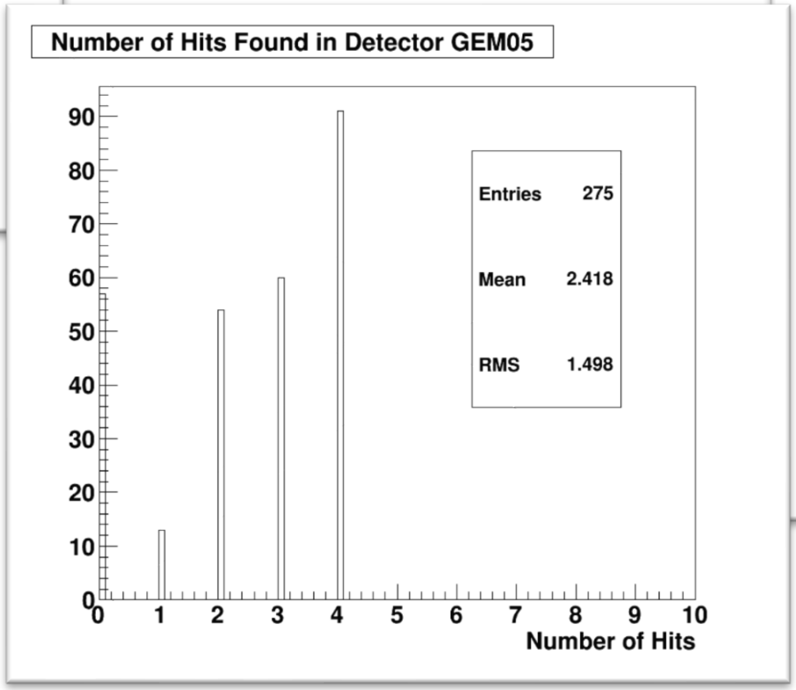
$$\theta_{FP} \approx 0.59\ mrad \approx 0.03°$$



Unlike in 2018, the GEM04 detector doesn't have a significant number of hits despite no alteration to its position in the detector layout.

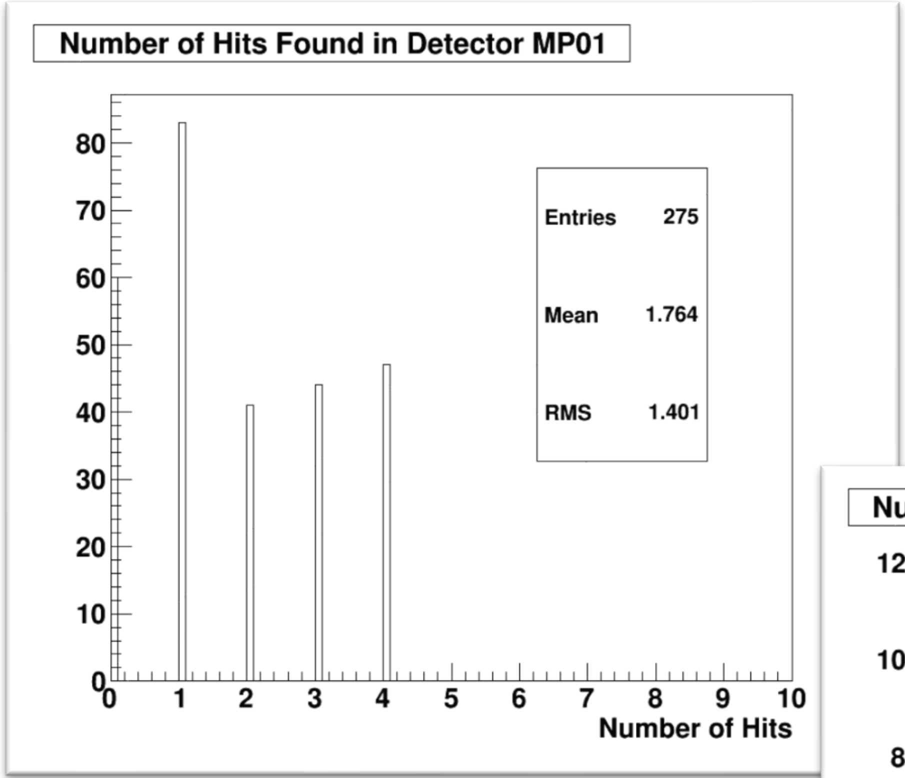
This may explain why we have so few number of hits in 2015, approximately 18.6 on average, despite having an extra detector.

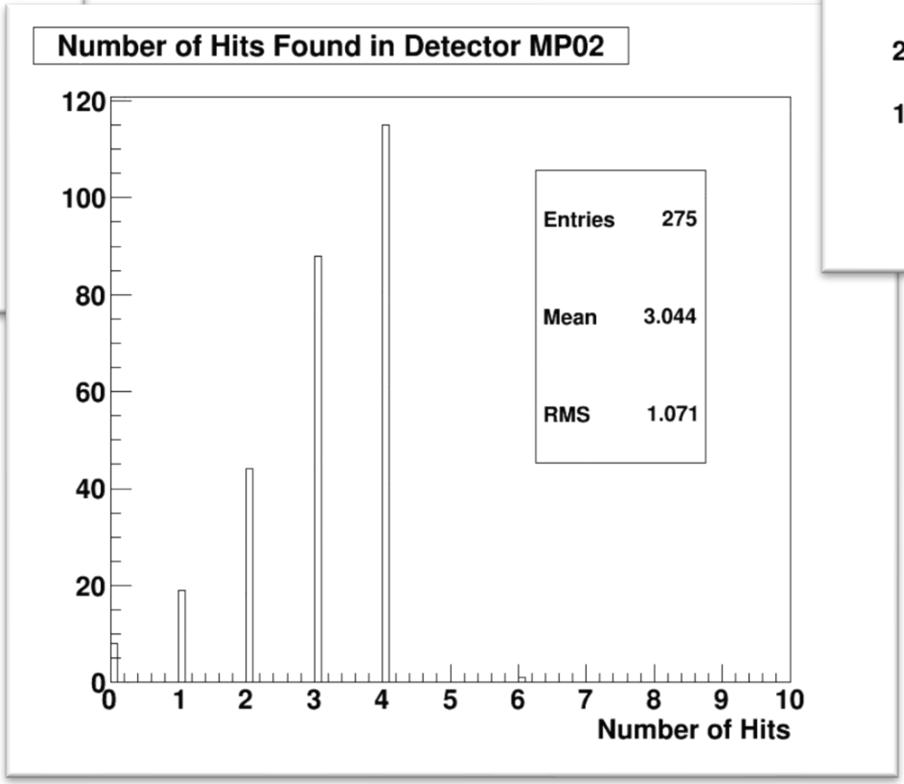


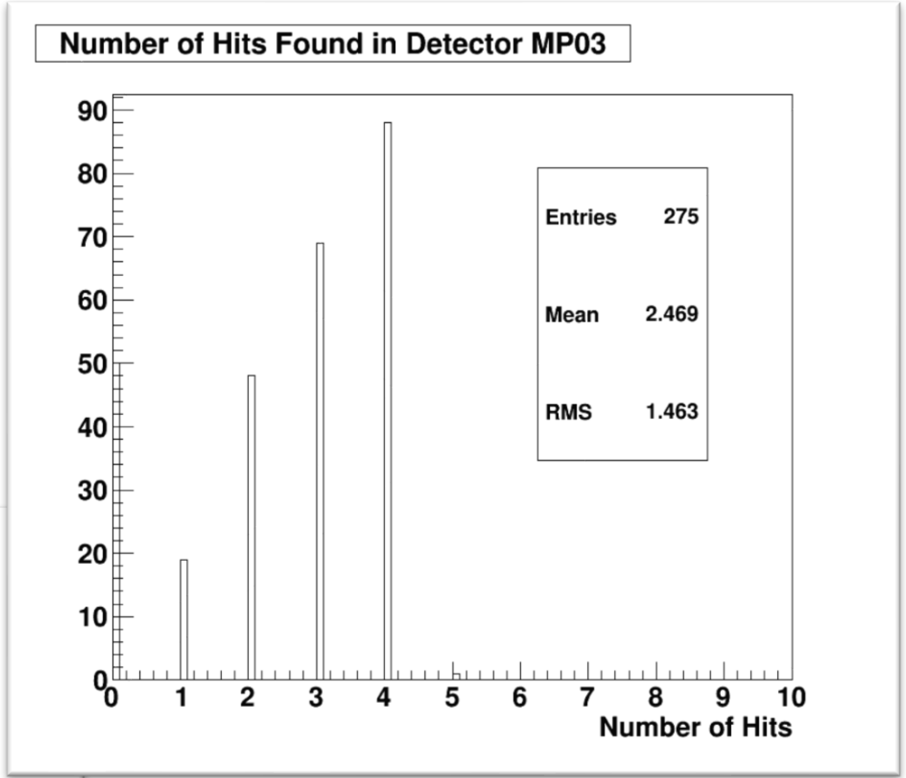


The GEM05 and GEM06 in 2015 had similar performance as in 2018.

The Pixel Micromega detectors in 2015 have a similar number of hits as in 2018.





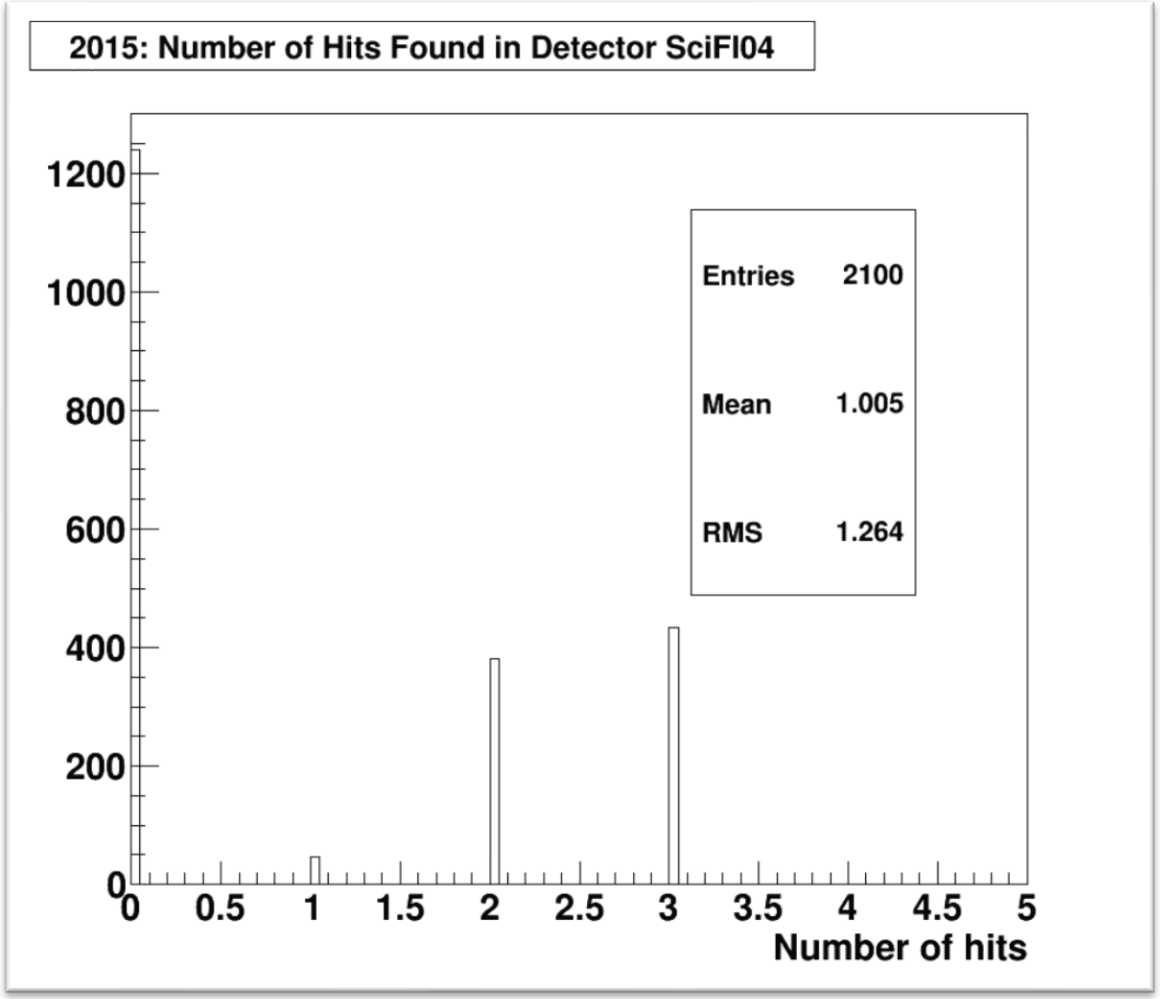


To determine whether or not the SciFI04 detector was the determining factor to having less particles with anomalous momentum in 2015, we need to analyse the sample of particles with momentum below 250 GeV/c but with these same characteristics.

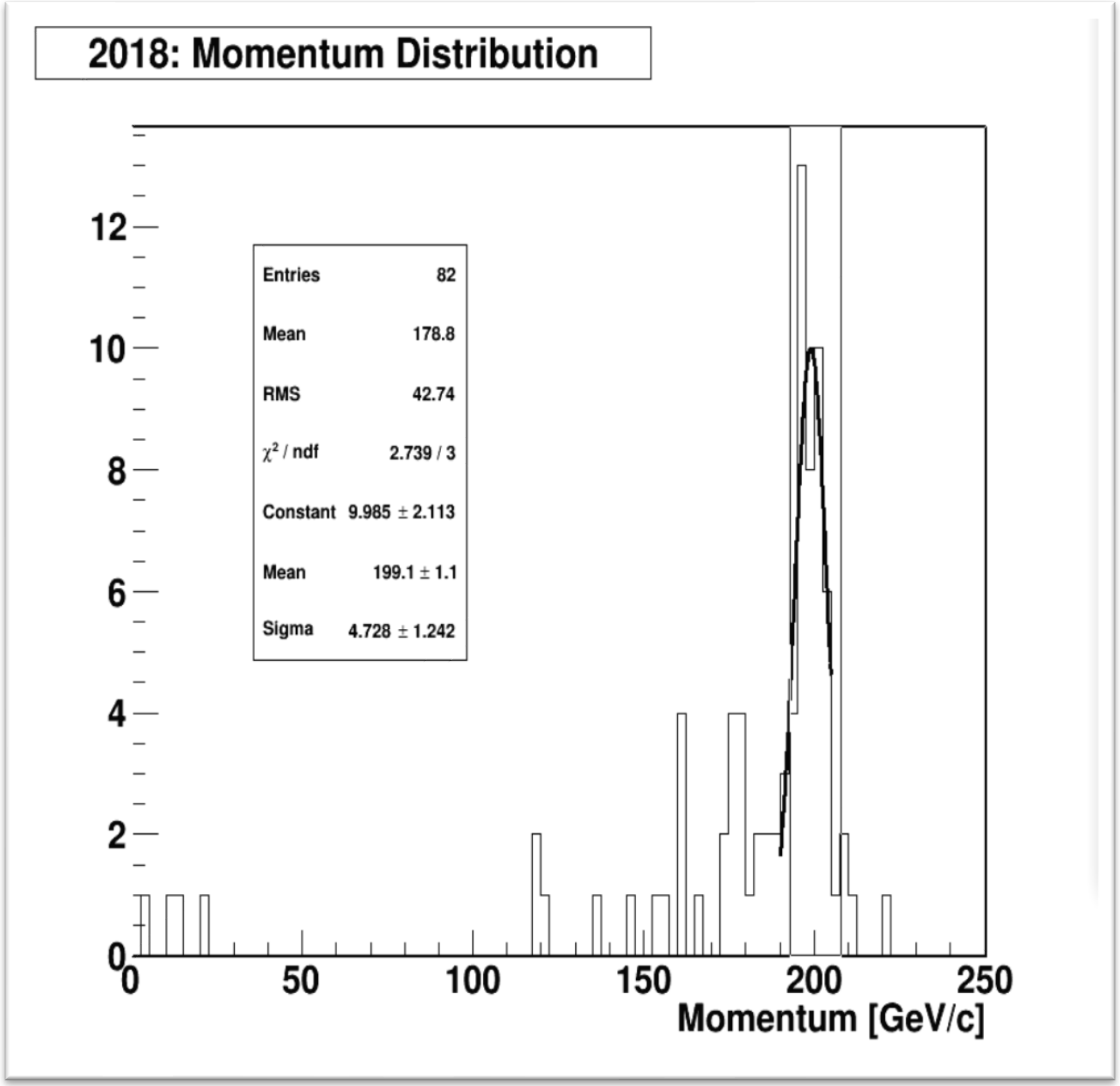
Meaning that if we consider the previous analysis, Slide 12, we know that the vast majority of particles with anomalous momentum have corresponding polar angles less than 0.01 rad and number of hits less than 28.

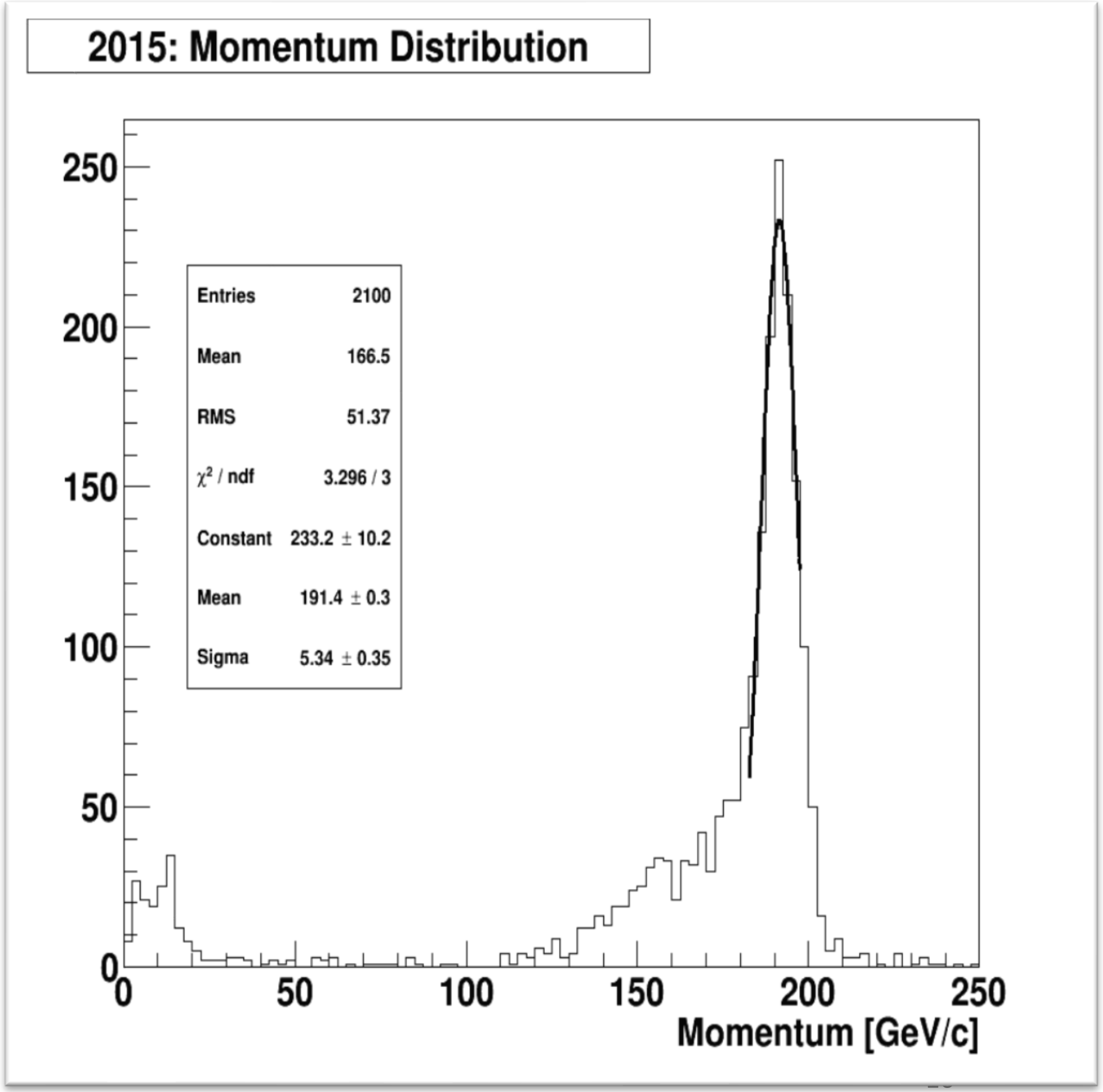
In these conditions, we should see hits in the SciFI04 to justify this hypothesis, but the majority of the hits were not associated to this detector.

However this does not meant that there aren't detectors near the second spectrometer that contributed to the hits and allowed for measurement of momentum.



Comparison between 2018 and 2015 momentum distributions for angles lower than 0.01 rad, momentum less than 250 GeV/c and number of hits less than 28.





Conclusion

- The particles with anomalous momentum have associated small polar angles, they are detected in the first spectrometer with MP and some of the GEM detectors.
- In the overall data of reconstructed particles, this is sample is not very representative, only 0.085% have momentum above 250 GeV/c.
- This is not a new problem, we see it as well in the 2015 data with similar characteristics despite the presence of an extra detector, the SciFI04. The GEM04 detector is not detecting these particles and can be the reason why there are fewer hits in 2015 compared to 2018.

- This analysis, while not particularly useful for the Drell-Yan process given the small theta angles, can be relevant in terms of detector placement in the event of an experiment were the particles have angles of this size.
- Additionally, this analysis was made considering only particles with constructed vertices for the LAS-LAS detector. Without this condition we can have a far more global analysis of the 2018 and 2015 data with anomalous momentum.