EKLM track-match efficiency study

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Overview

- The Belle *II* detector is a general purpose spectrometer designed to study the decay of BB pairs created via e^+e collisions by the SuperKEKB particle accelerator.
- The detector aims at full reconstruction of all particles and provides an acceptance, in the lab frame, of $\theta = 17^\circ$ to 150° in the polar angle and $\varphi = 0^\circ$ to 360° in the azimuth angle.

SuperKEKB

- The SuperKEKB has a circumference of 3km and is located 10m below the ground
- It is an asymmetric e^+ e collider designed to operate at a center of mass energy of $\sqrt{s} = 10.58 GeV$ with the e^+ and e beams operating at 3.5 GeV and 7 GeV respectively.

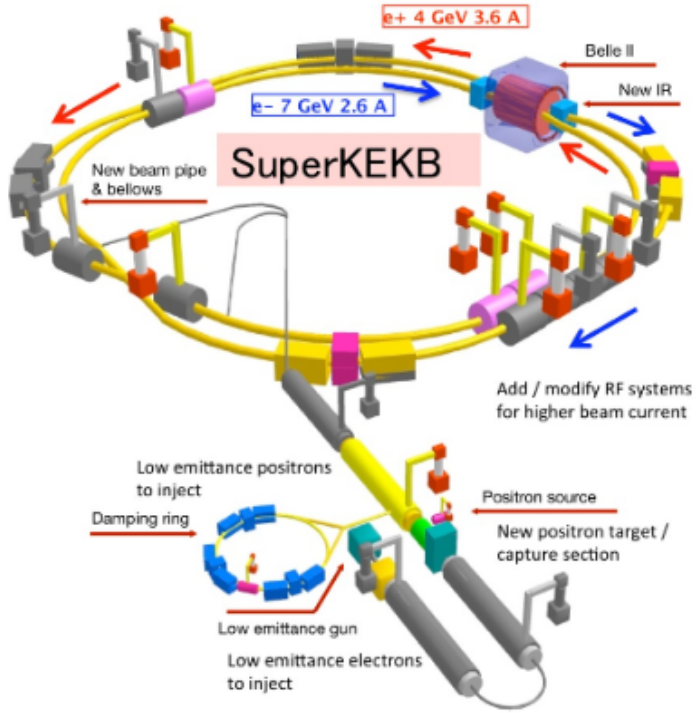
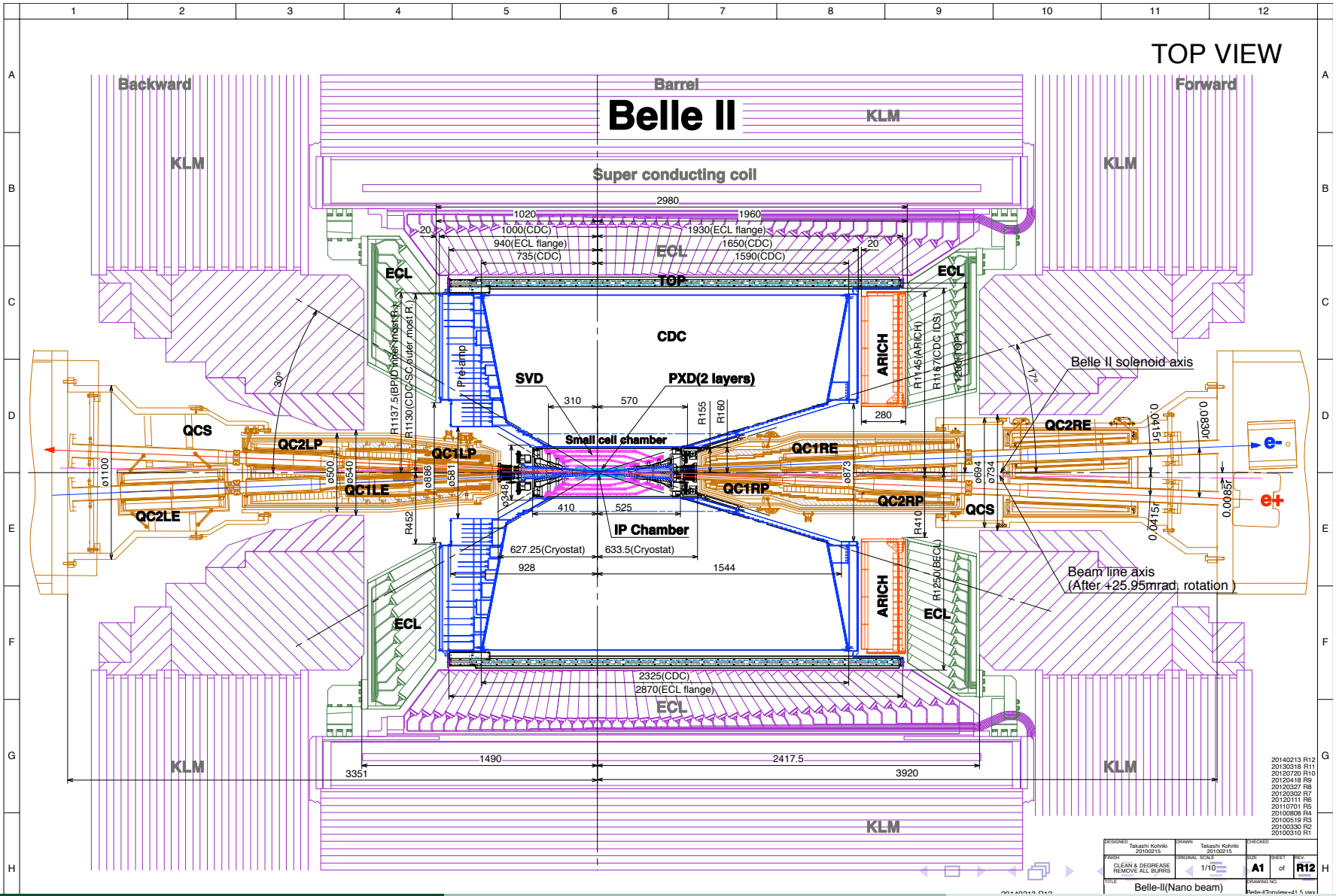


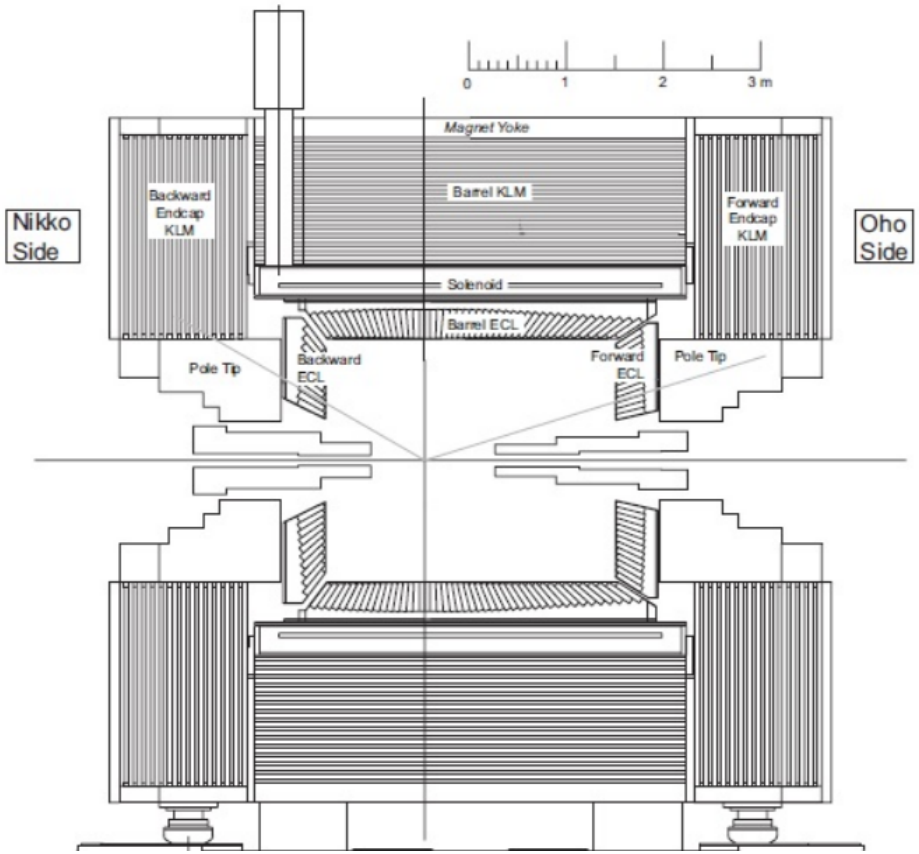
Figure 3.1 – Schematic of the SuperKEKB Accelerator [13].

Belle // detector



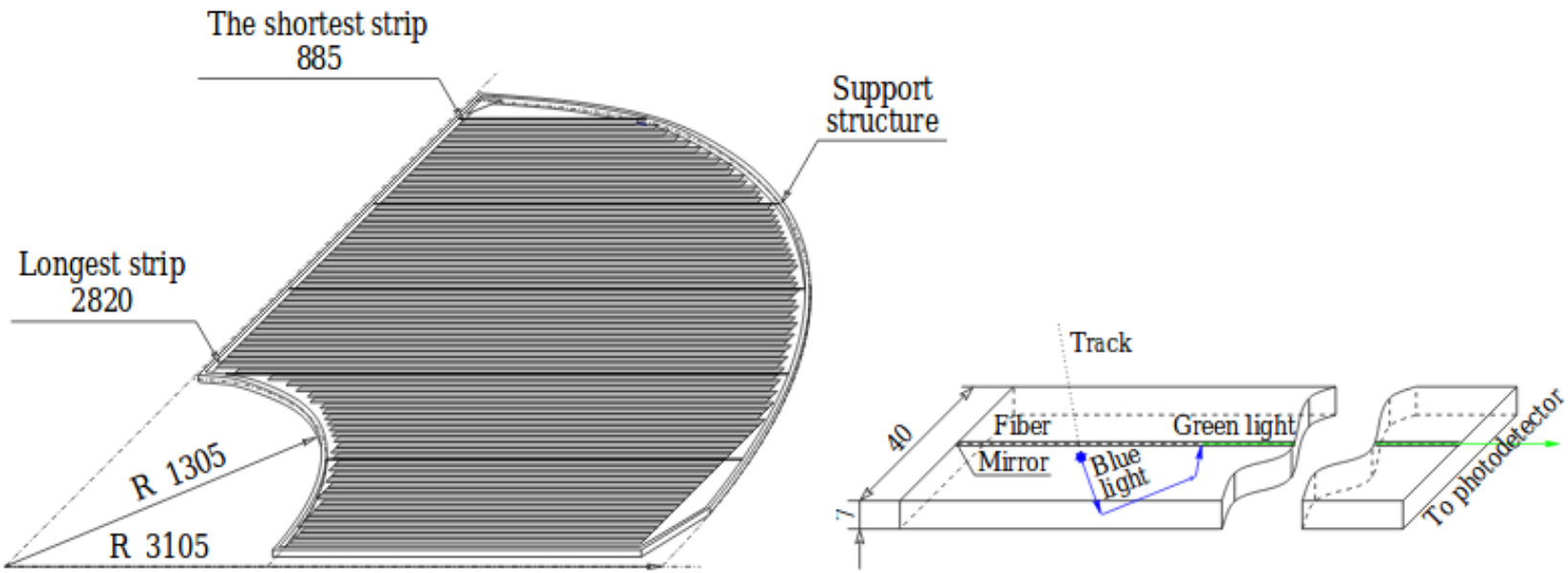
The Belle 2 KLM

- The KLM is designed to detect and distinguish muons from long-lived neutral kaons, K_L^0. It is the outermost subsystem in the detector, located right after the ECL.
- The detector consists of analternating sandwich of 4.7cm thick iron plates and active detector elements.



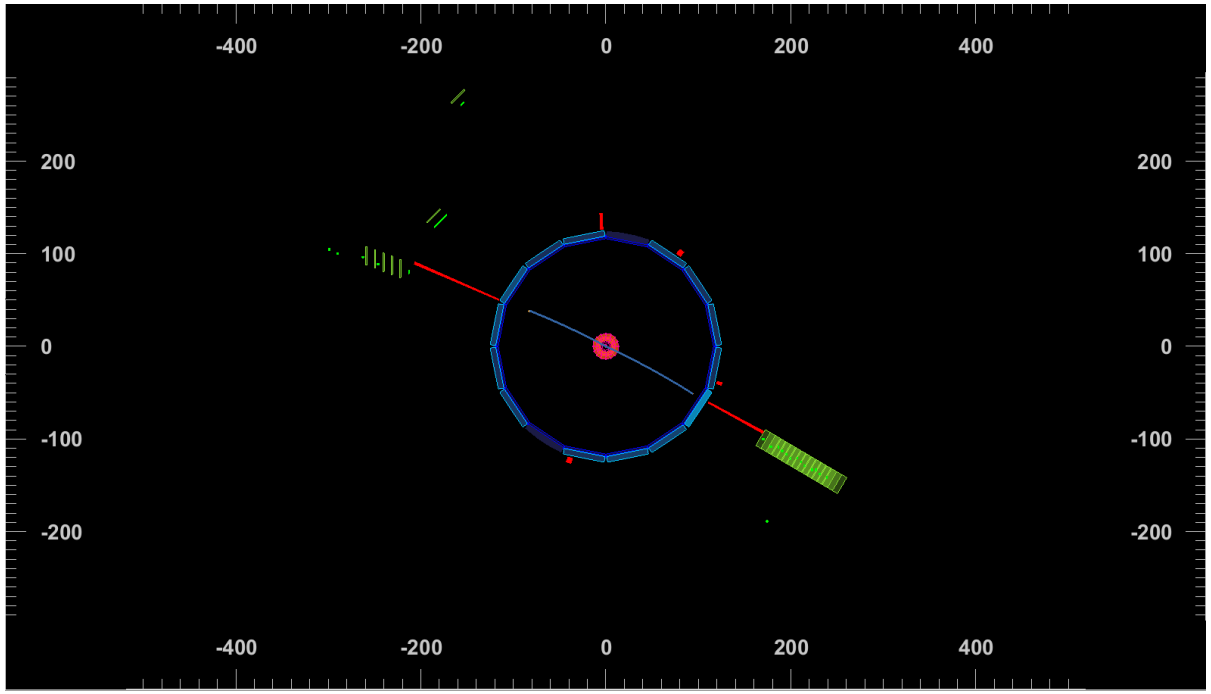
EKLM

There are 2 endcaps, each of them is divided into 4 sectors. There are 14 and 12 layers in forward and backward endcaps, respectively. Each layer consist of 2 planes of scintillator strips, ortogonal to each other



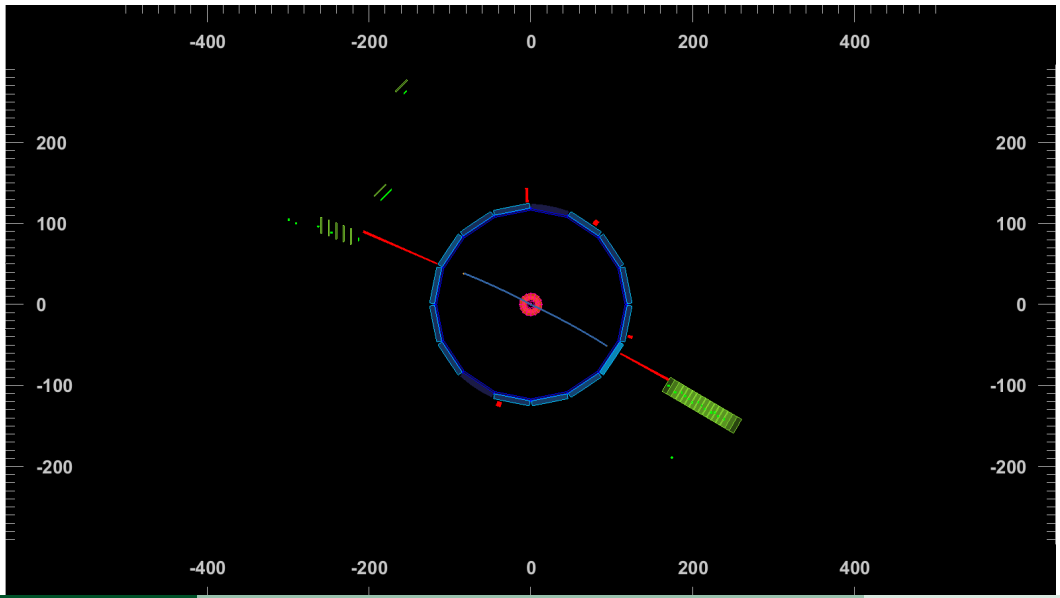
Hits

- Digits (1dhits) - strips that were triggered
- Hit2d - combined from 2 Digits in nearby planes
- ExtHit - hit of extrapolated track in sensetive volume



CDC matching efficiency of EKLM

- Extrapolate CDC tracks into the EKLM volume
- Determine position of extHit in each layer
- Match EKLM hit to extrapolated track hit if $distance < d_{max}$ in same layer and same endcap.
- $N_{extrapolated}$ - number of all ExtHits
- $N_{matched}$ -number of ExtHits matched with Hit2D
- Efficiency defined as $\varepsilon = N_{matched}/N_{extrapolated}$



Data used:

- bucket6 30 runs HLTmumu2trk skims
- $e^+e^- \to \mu^+\mu^-\gamma$ MC sample genereted by Giuseppe Finocchiaro for BKLM study

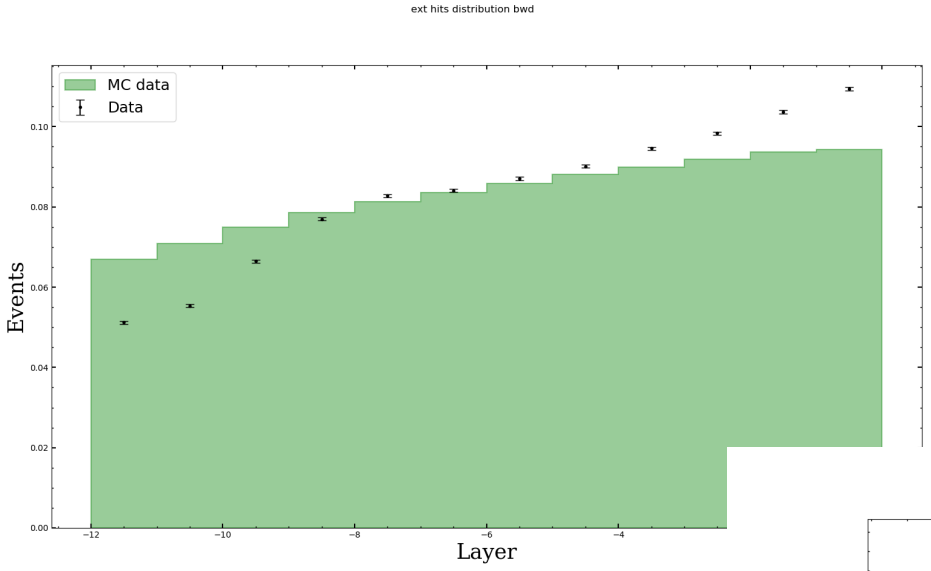
Selection variables

HLTmumu2trk skim requirements and :

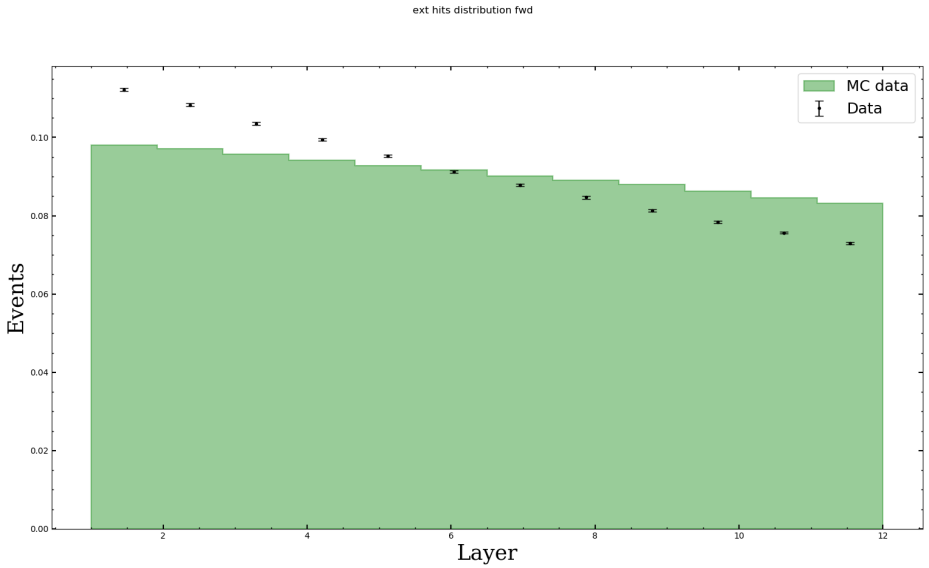
Variable	Restriction	Comment
nTracks	$= 2$	Only 2 tracks required
p	1 GeV / c $<$ p	Track momentum
	p $<$ 11 GeV / c	
My own MuID	5 hits	To find muons events
d_{max}	$<$ 15 cm	Maximal distance to Hit2ds from ExtHit
Z0	$<$ 4 cm	Z Distance from IP
D0	$<$ 2 cm	Distance from IP in x-y plane

Compare Data and MC: ExtHits

Backward



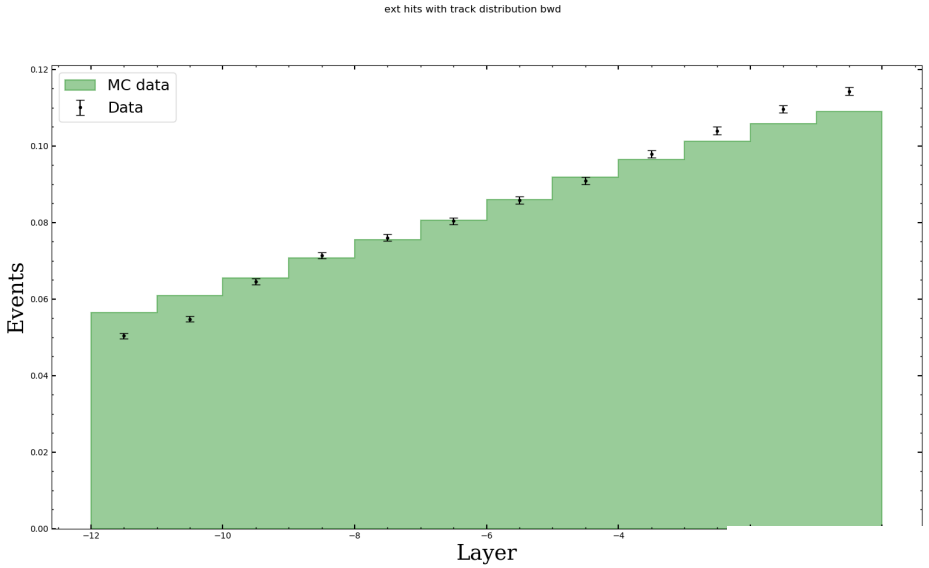
Forward



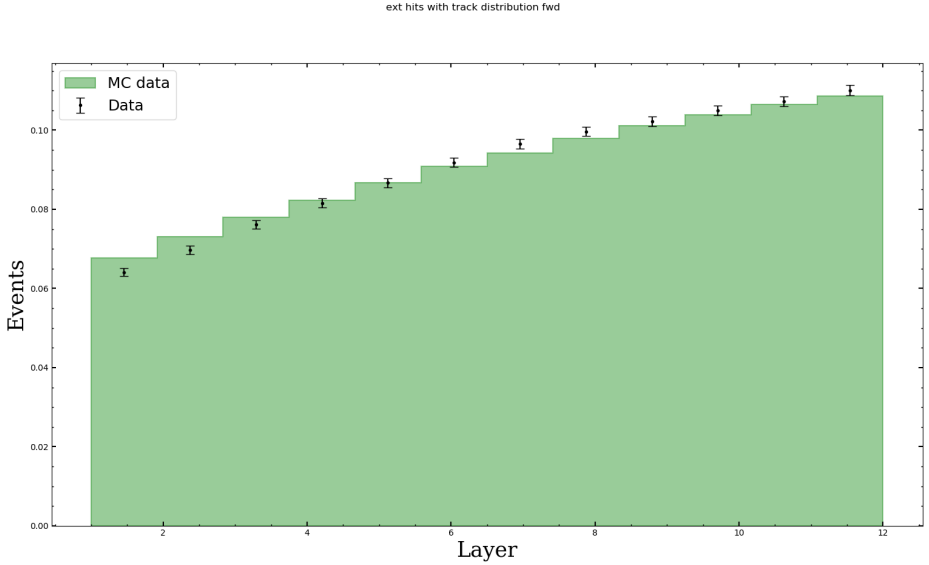
Distributions are quite different

Compare Data and MC: ExtHits after requirements

Backward



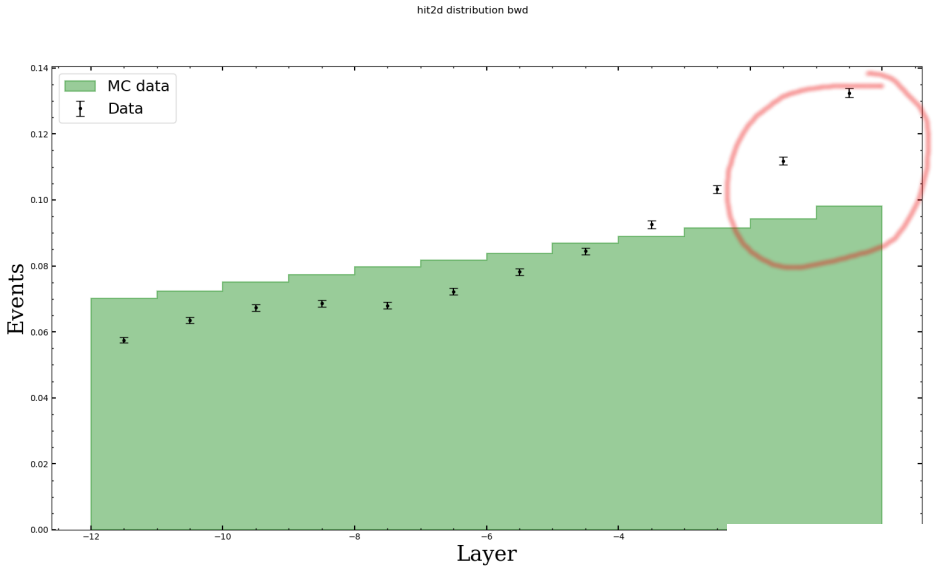
Forward



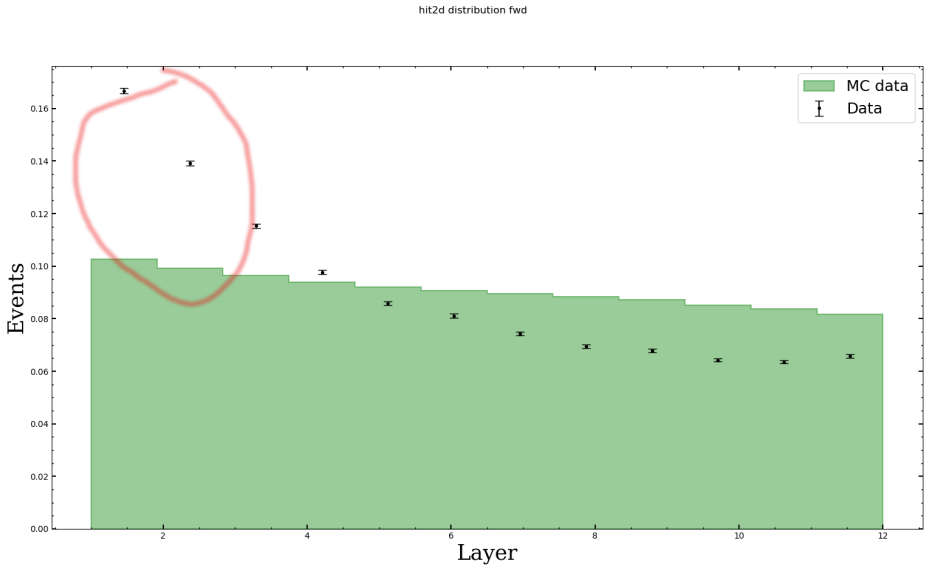
After requirements applied distributions fit much better

Compare Data and MC: Hit2Ds

Backward



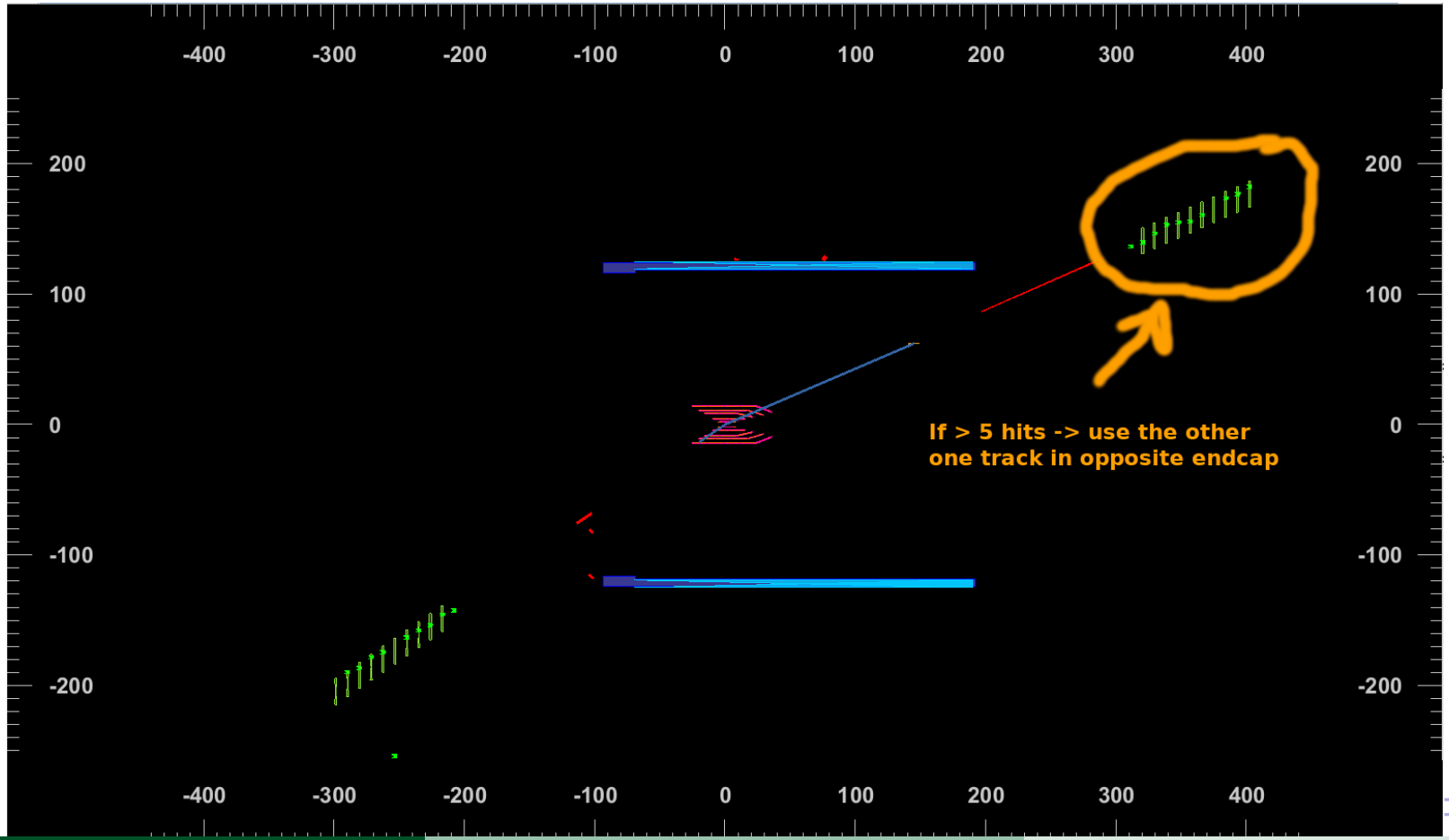
Forward



We consider that these bumps are some background events.

'MuID'

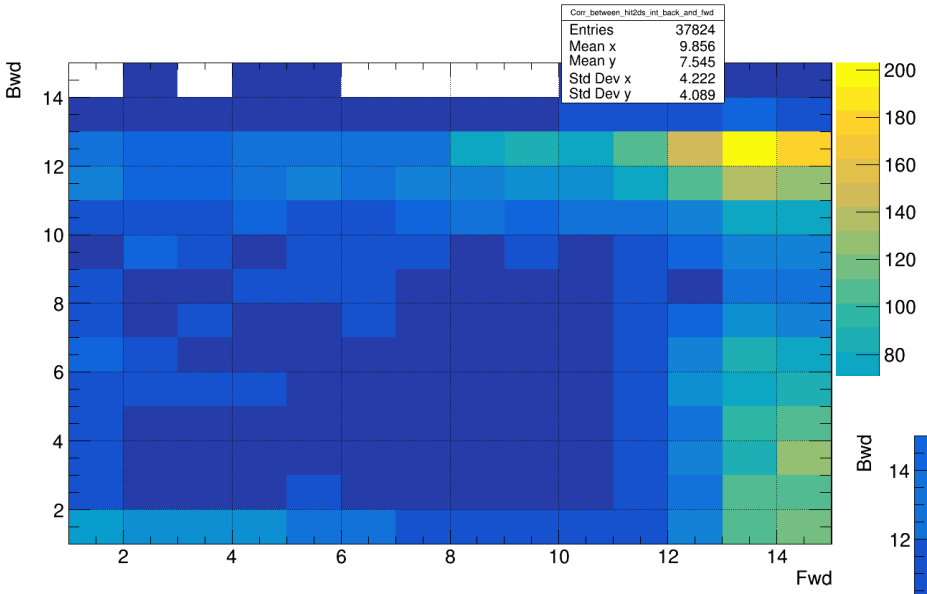
In case of restriction nTracks == 2 trying to find only mumu events. If one of the tracks has more than 5 Hit2Ds in one of the endcaps we use the other one for efficiency estimation.



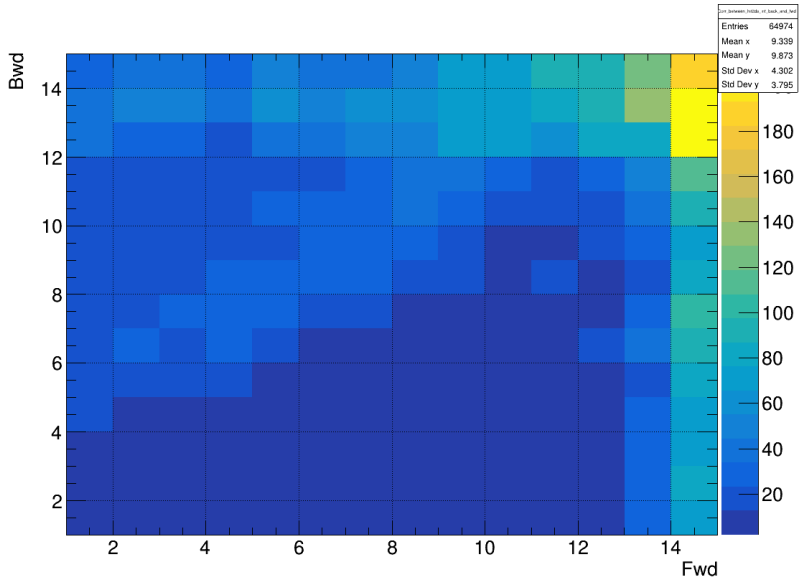
Can we use it?

YES! Because there is no correlation between number of hits in backward and forward. Neither data nor MC.

Data

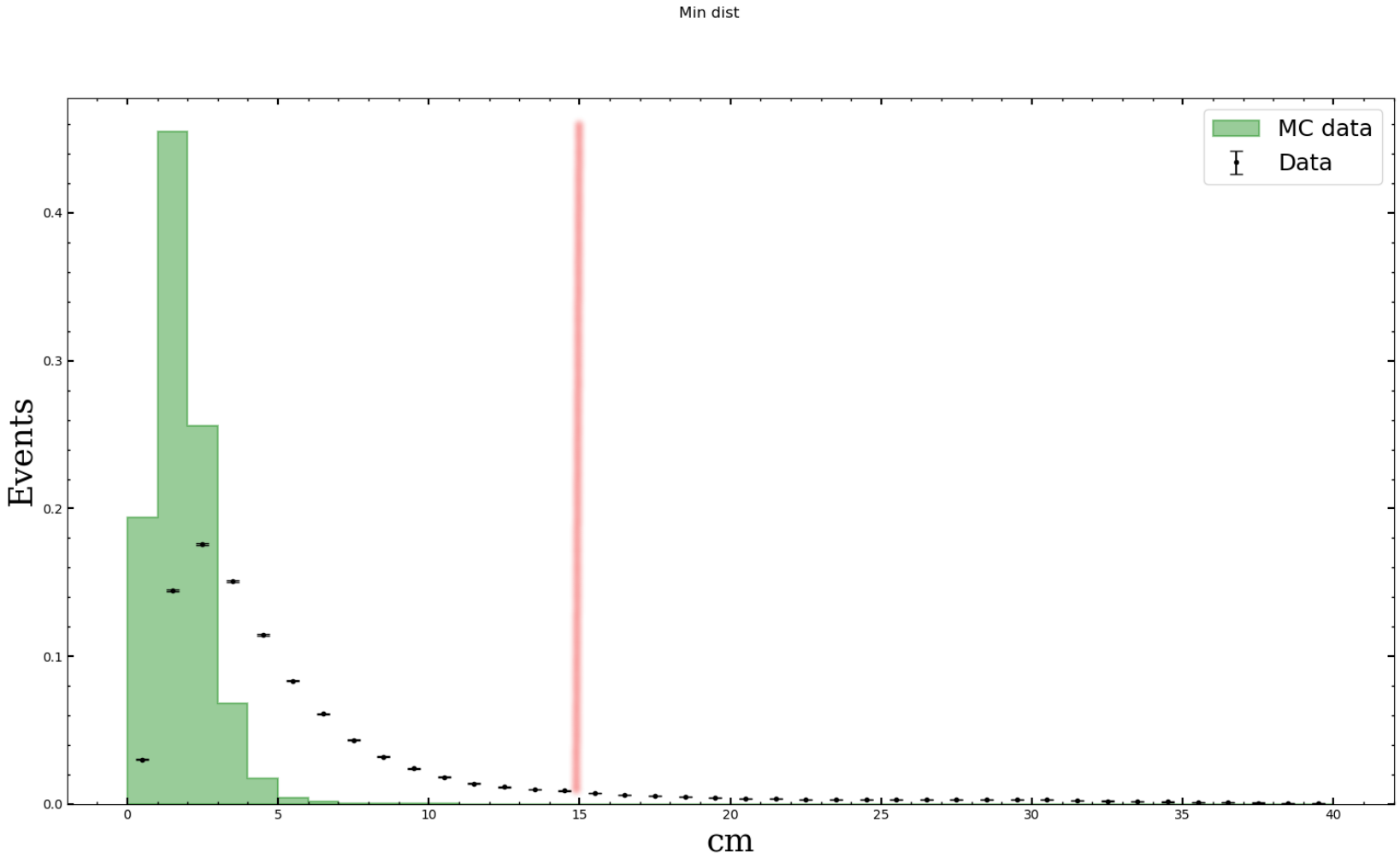


MC

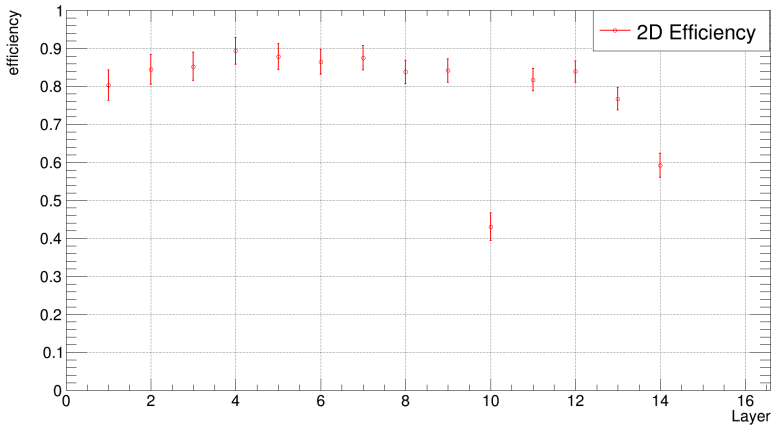


Requirement for d_{max}

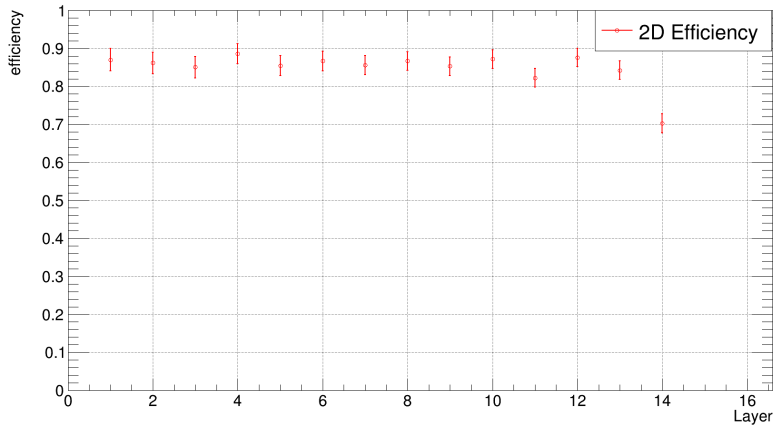
For d_{max} we use requirement $d_{max} < 15$ cm.



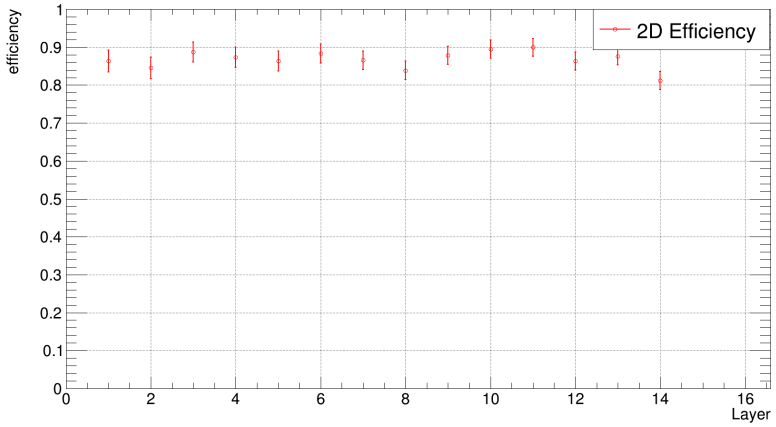
2D Efficiency of each sector in forward endcap



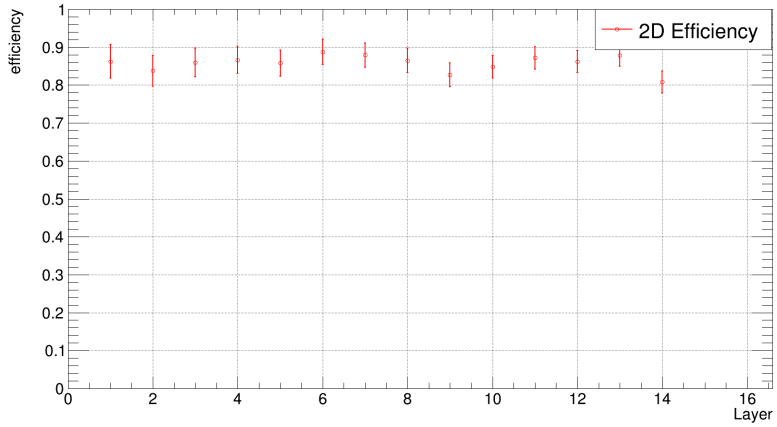
EF0



EF1

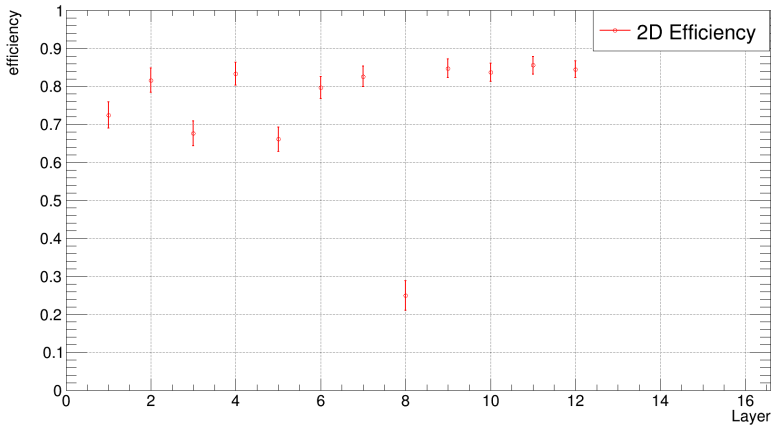


EF2

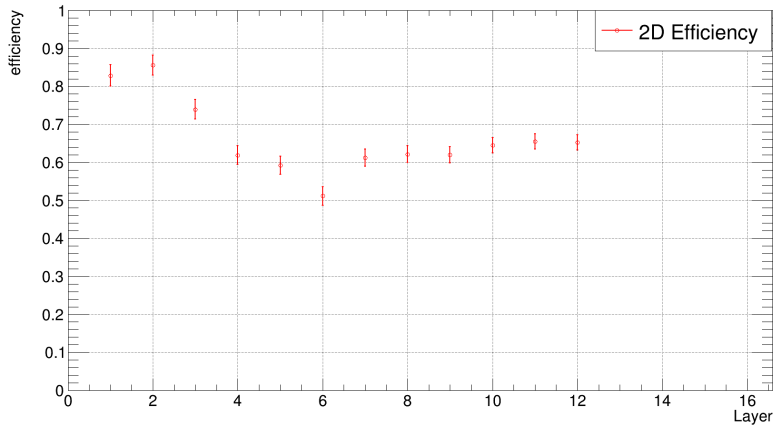


EF3

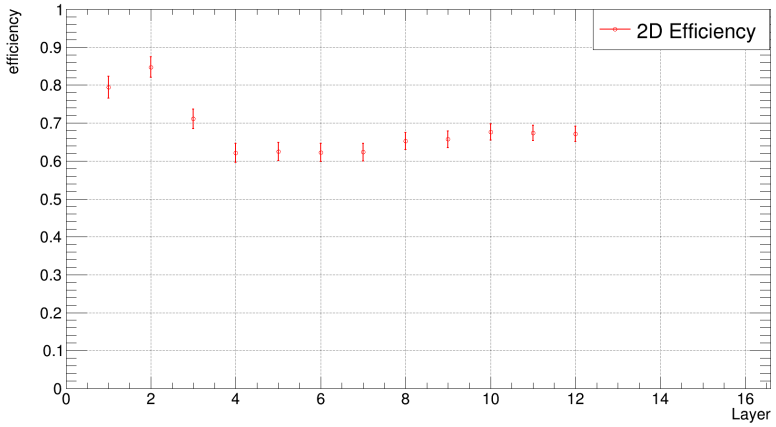
Efficiency of each sector in backward endcap



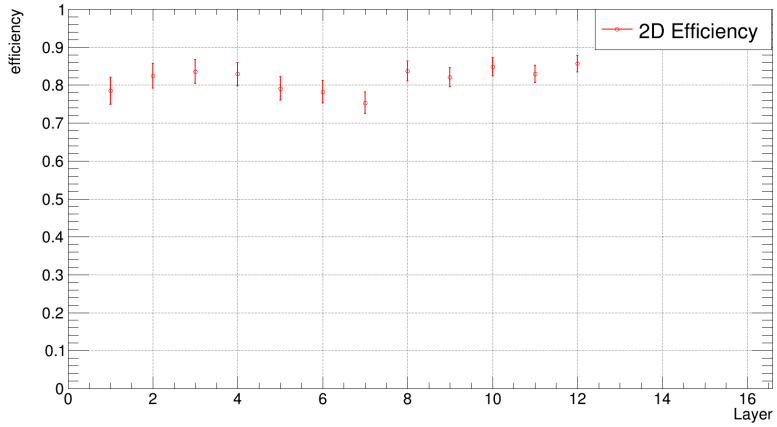
EB0



EB1



EB2



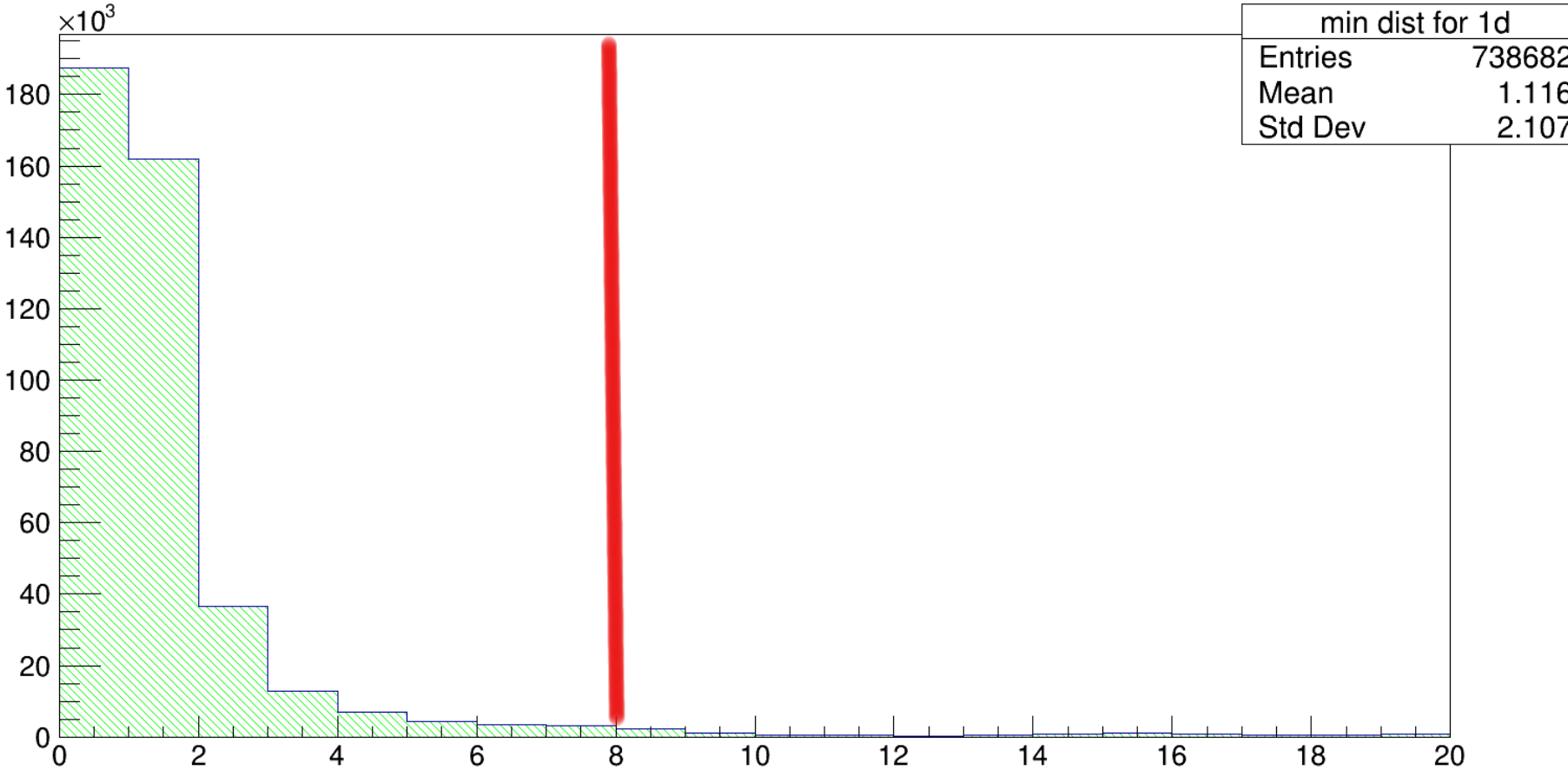
EB3

1D efficiency

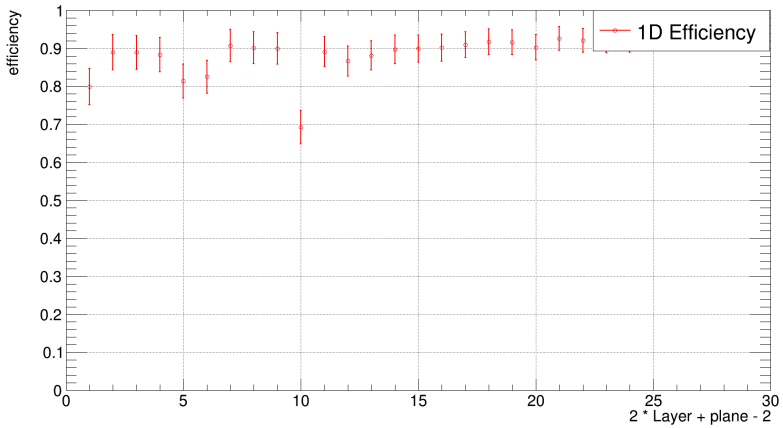
1. Since efficiency may vary inside a sector we should move on to the 1D hits and efficiency of strips
2. Make efficiency estimation for each plane (not layer)
3. Can compare result for layer efficiency by multiplying efficiency of 2 planes that compose layer

1D hits distance

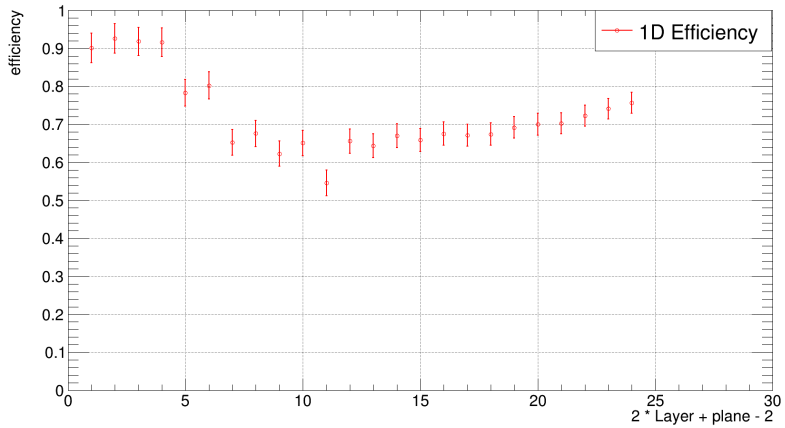
Minimal distance between ExtHit and 1Dhits distribution. Measured in strips numbers. (1 strip width $\approx$ 4cm). To match 1Dhit to ExtHit requirement is set to less than 8 strips.



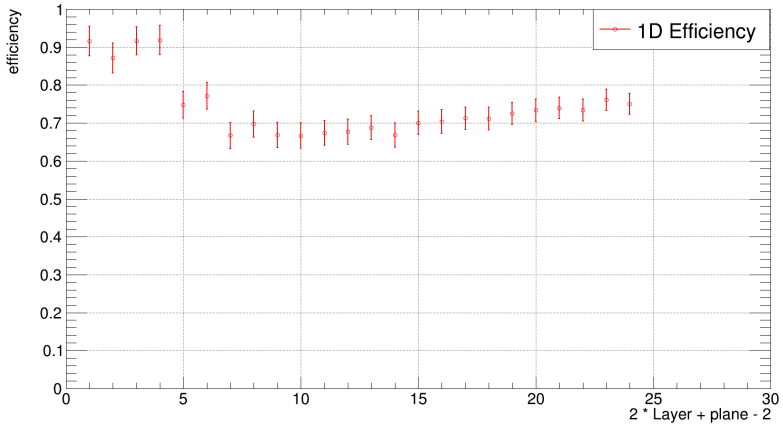
Plane efficiency of each sector in backward endcap



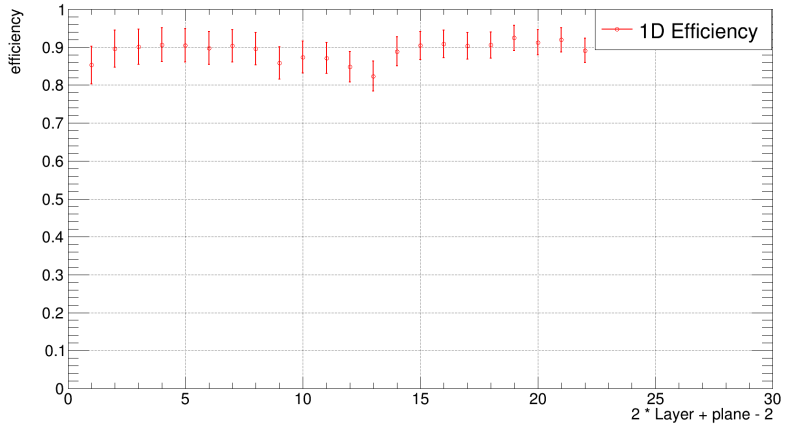
EB0



EB1

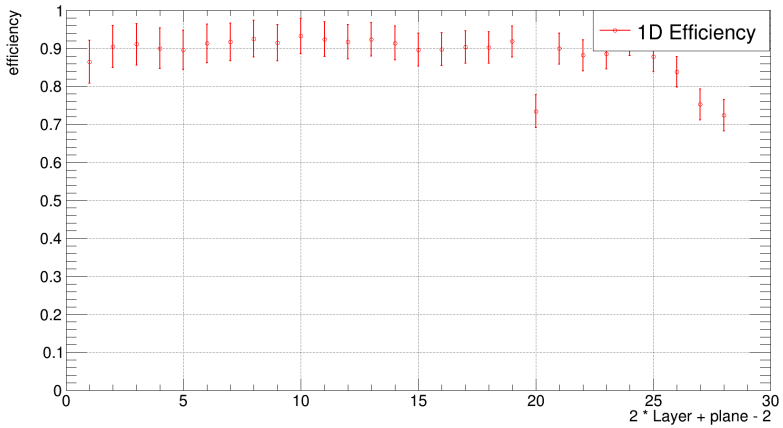


EB2

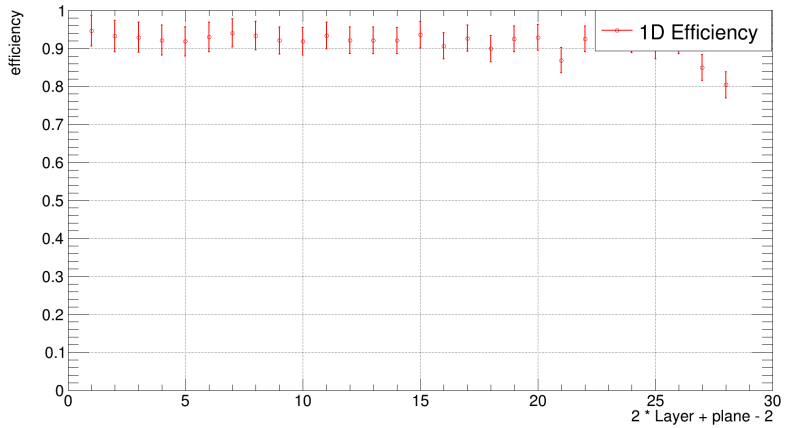


EB3

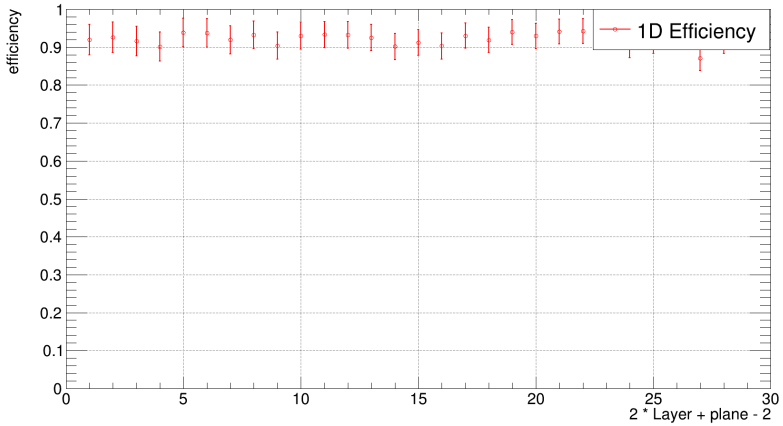
Plane efficiency of each sector in forward endcap



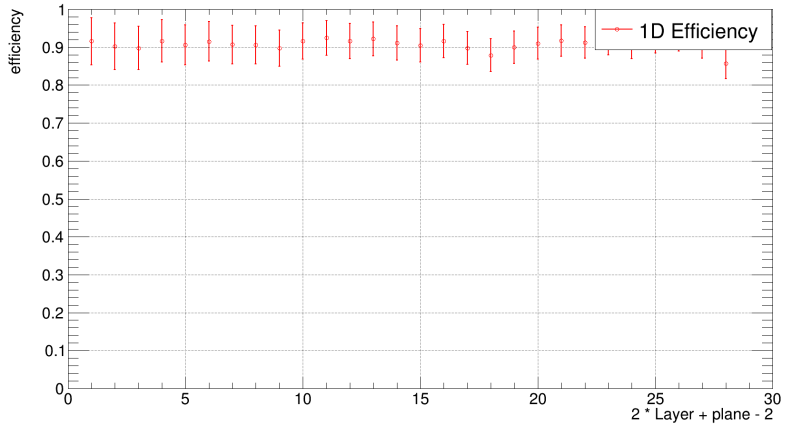
EF0



EF1



EF2



EF3

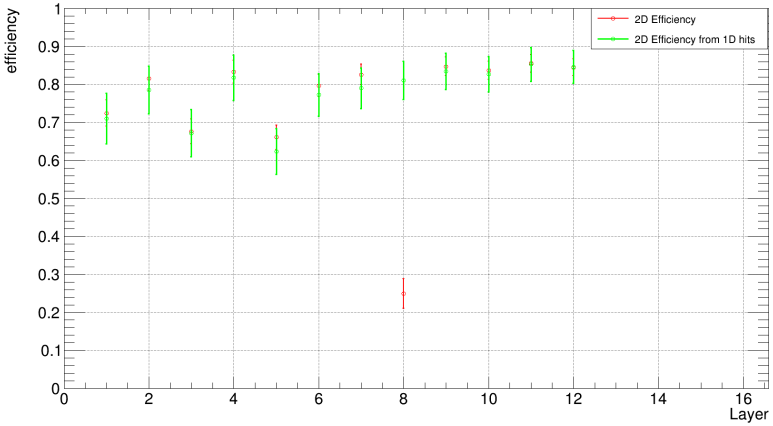
Comparing of effinciency from 1D to 2D

To check correctness of 2D efficiency measurements we can also get it from the following considerations:

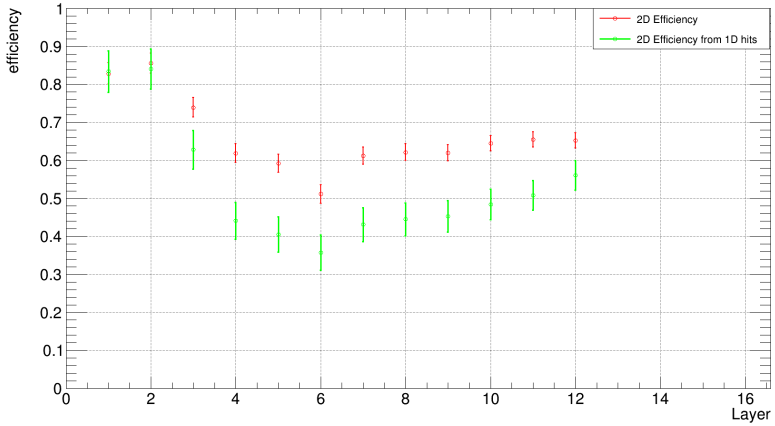
1. There are 2 planes in layer independent from each other
2. 1D efficiency is probability to have 1Dhit in the plane
3. 2D hit is formed from two 1Dhits

2d efficiency can be obtained from 1d efficiency by multiplication of efficiency of 2 nearby planes.

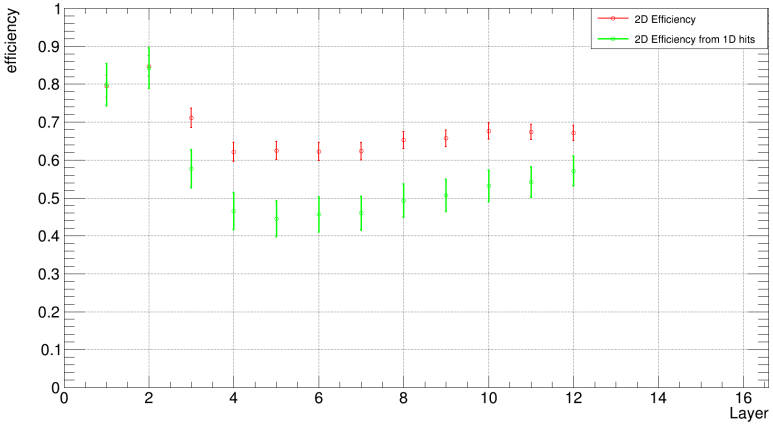
Layer efficiency of each sector in backward endcap



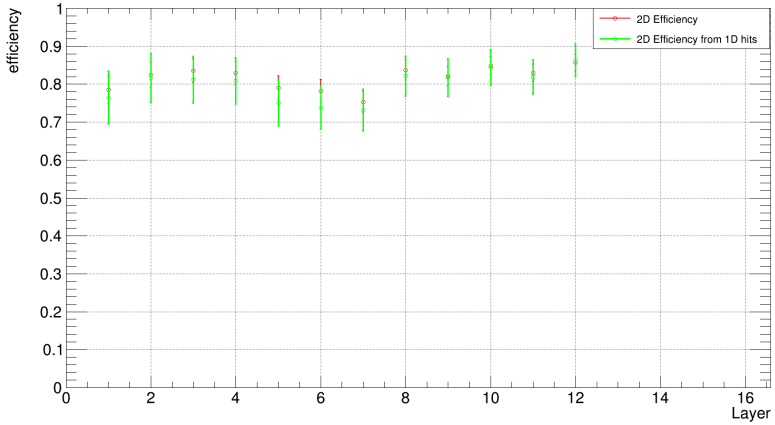
EB0



EB1

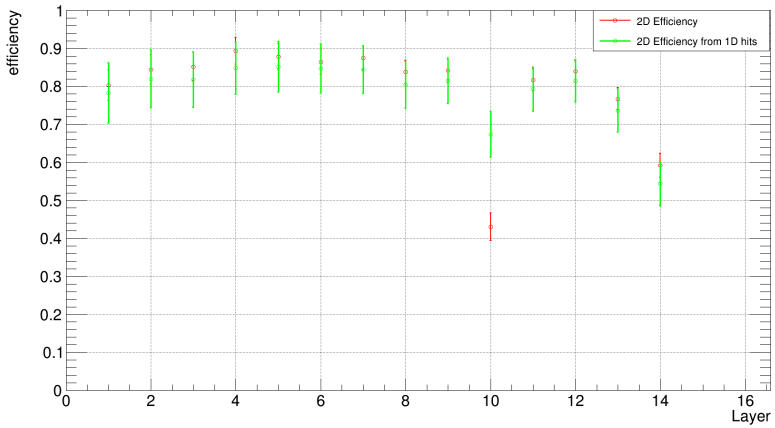


EB2

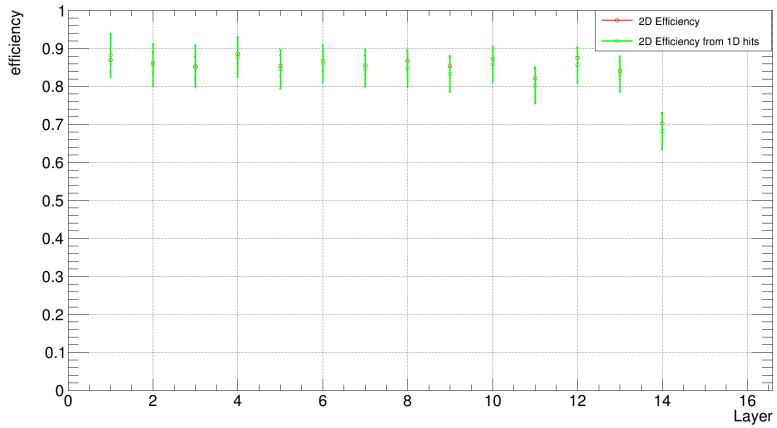


EB3

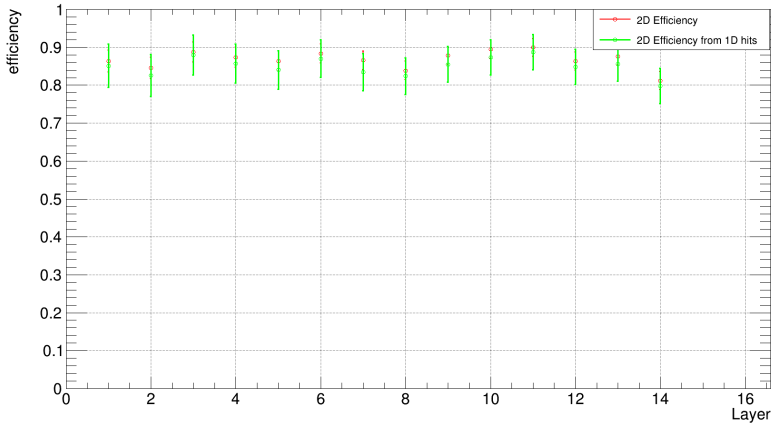
Layer efficiency of each sector in forward endcap



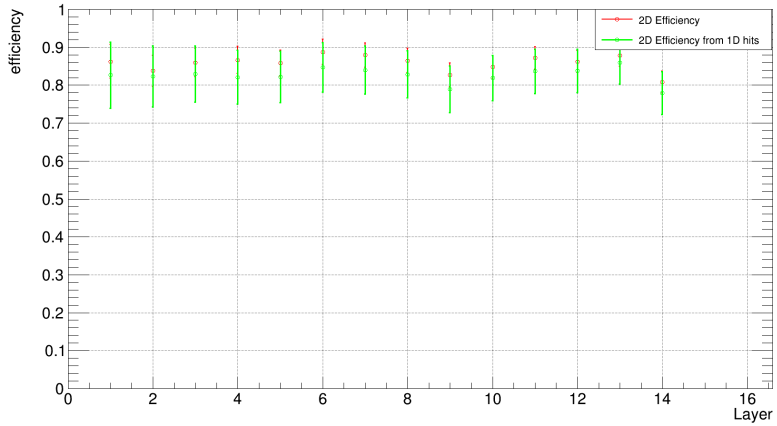
EF0



EF1



EF2



EF3

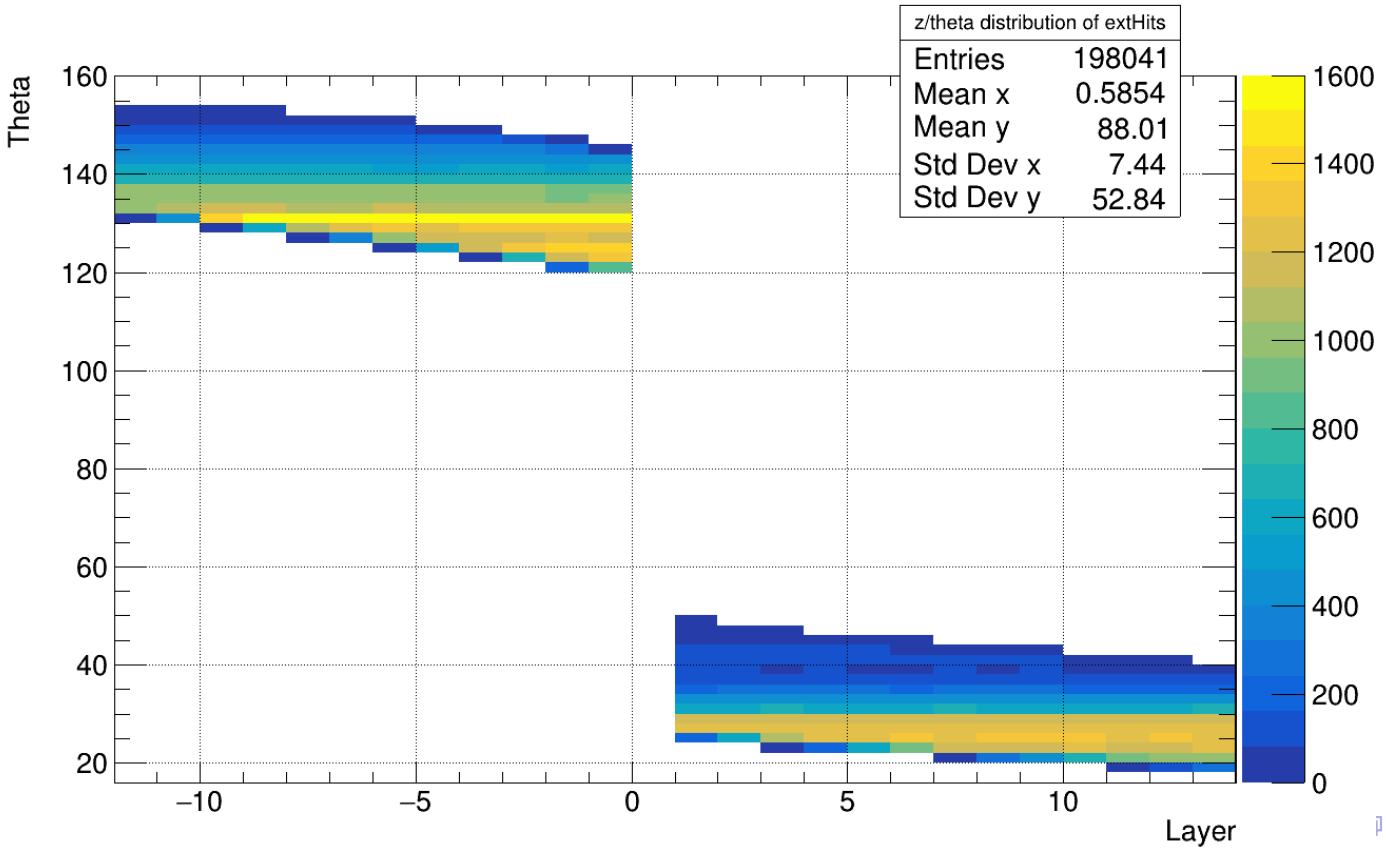
Conclusions

- Was implemented
  - Basf2 module was written and ready to commit
  - Efficiency estimation done
  - Efficiency is not so good (especially in backward), 2D efficiency and 1D efficiency don‘t always match.
- In progress
  - We started investigate dependence of efficiency of theta angle
  - Documentation
- Problems
  - Investigate strange theta distribution. (ask CDC?)
  - Check phi distribution

Next step

Theta z distribution

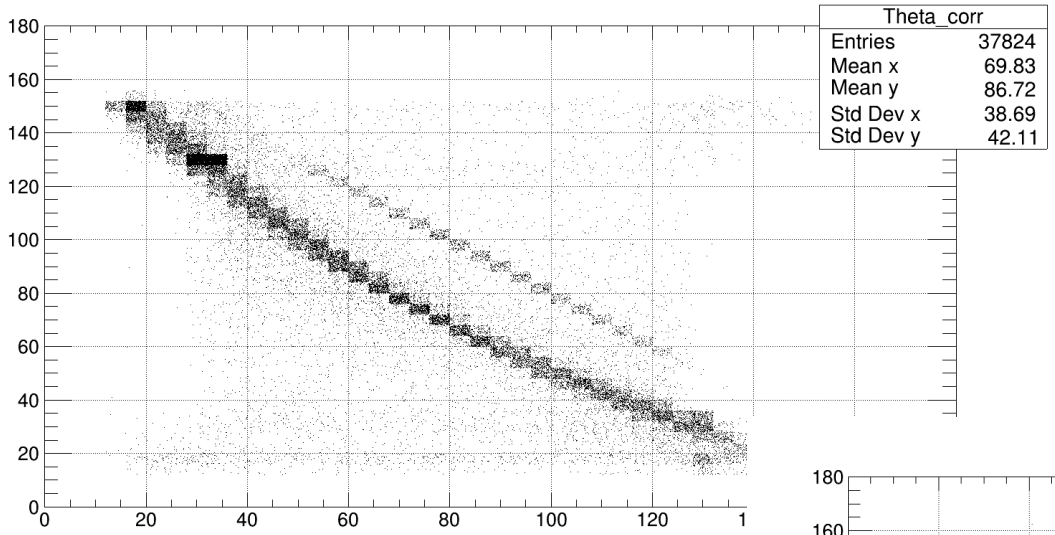
I noticed that there is some selected direction of muons hits. As you can see on this layer-theta distribution there are lines with higher number of events than in the other regions. This can leads to wrong efficiency estimations.



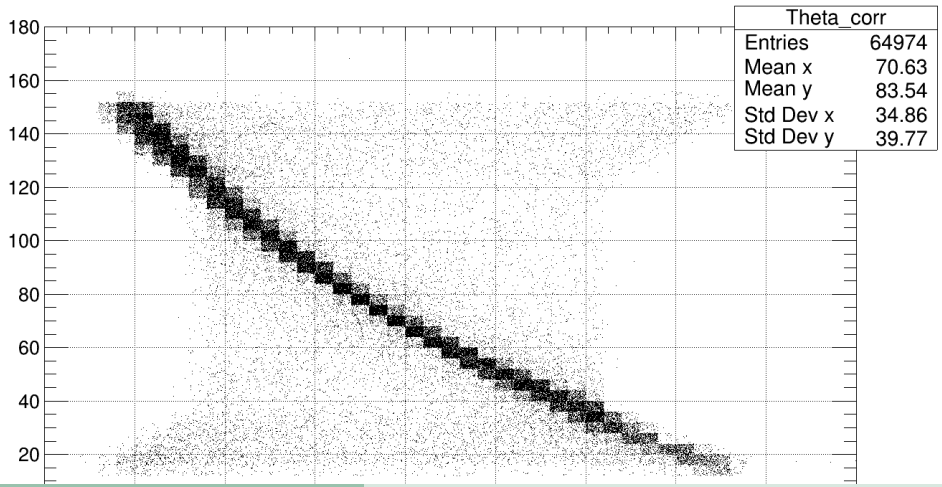
Tracks Theta corr

We can see big correlation of tracks theta on data and same on MC.
But the strange one thing in data!

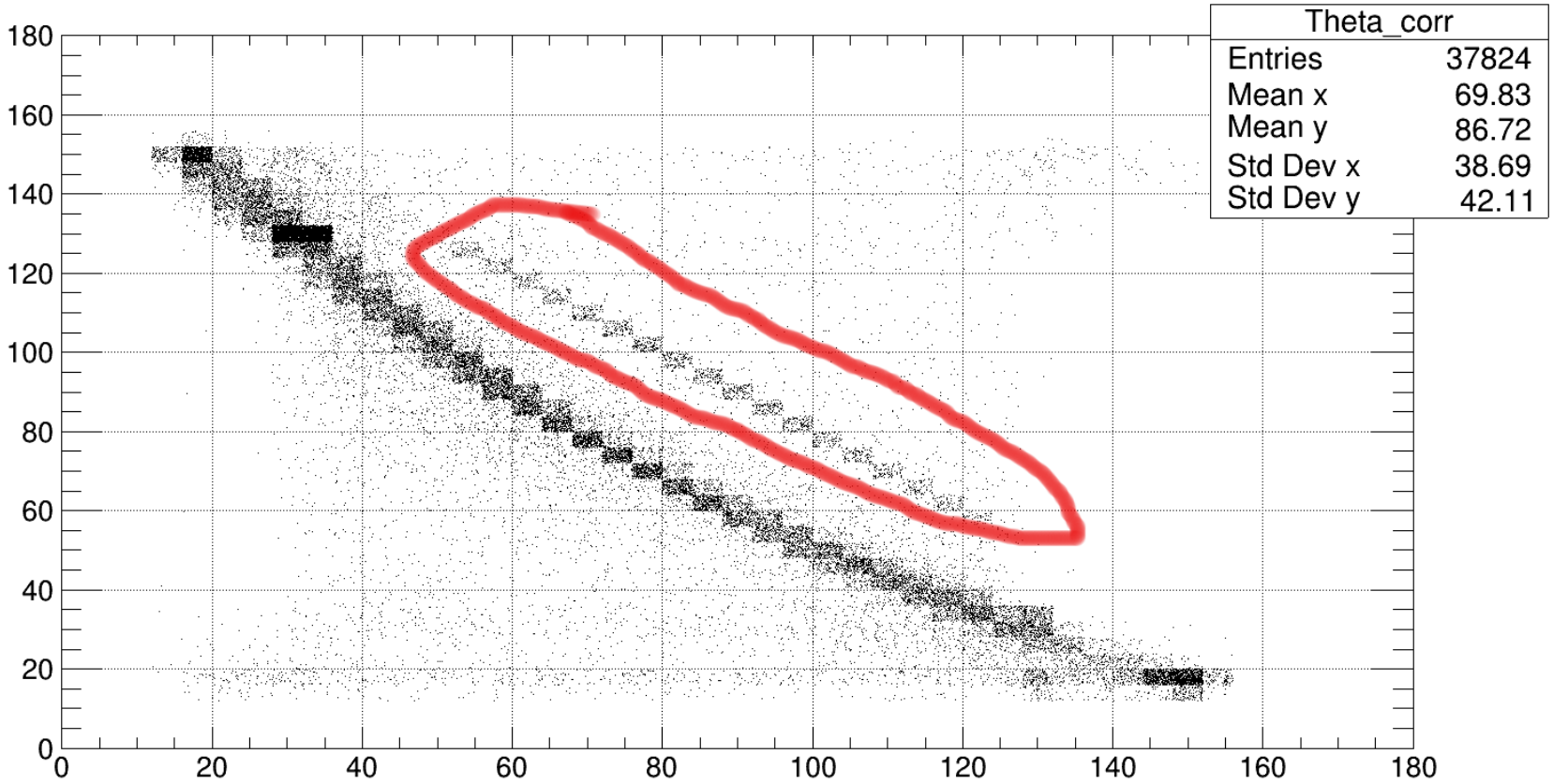
Data



MC

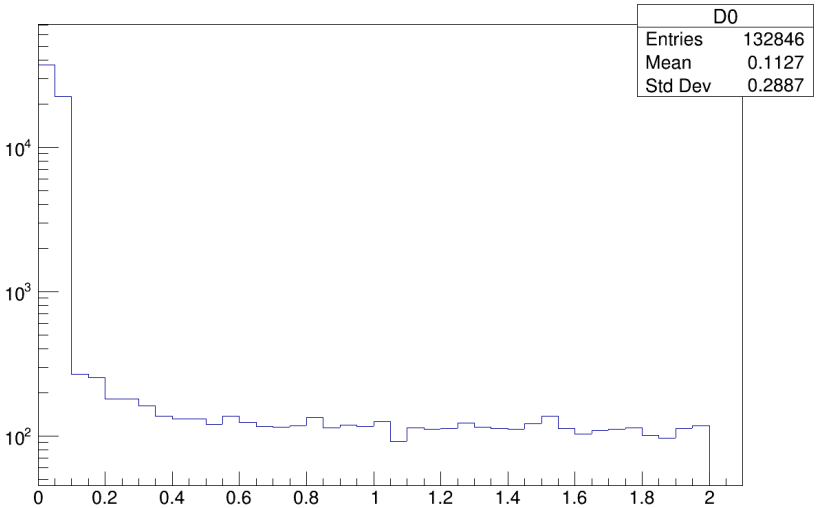


Theta corr

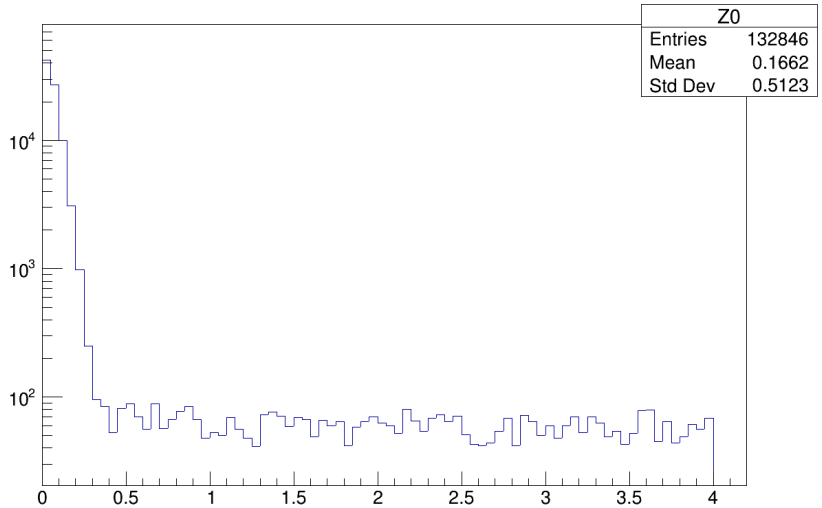

Theta_corr
Entries 37824
Mean x 69.83
Mean y 86.72
Std Dev x 38.69
Std Dev y 42.11
0
20
40
60
80
100
120
140
160
180

D0 and Z0 distributions

There still were a lot of events that probably do not corresponds to IP. So I made a new constraints for D0 and Z0 0.2cm and 0.3 cm respectively.



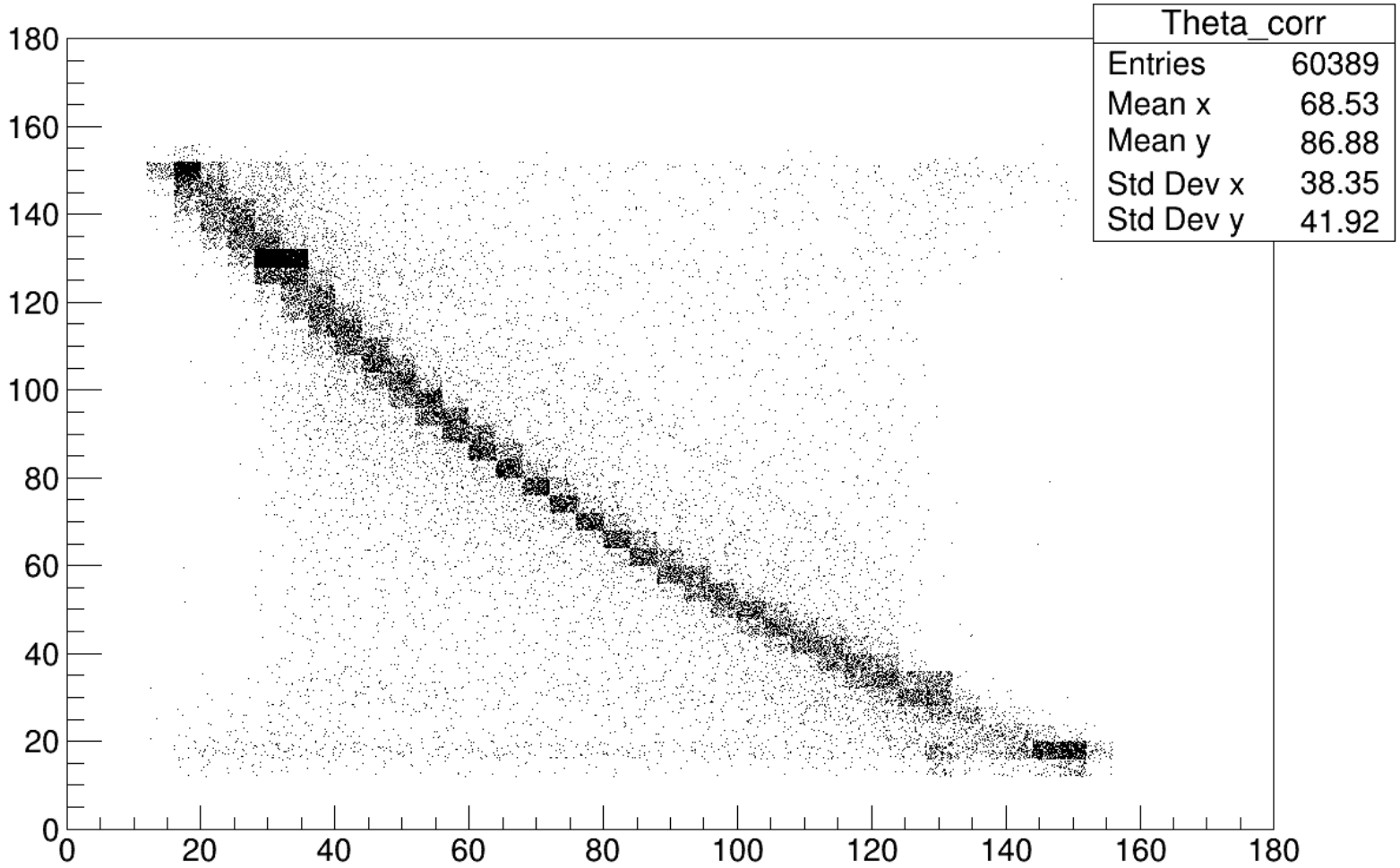
D0



Z0

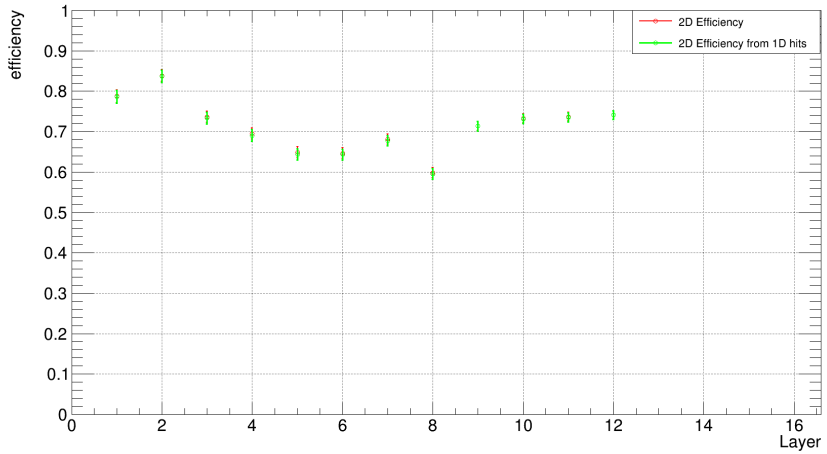
Correlation gone

And after these constraints correlation gone.

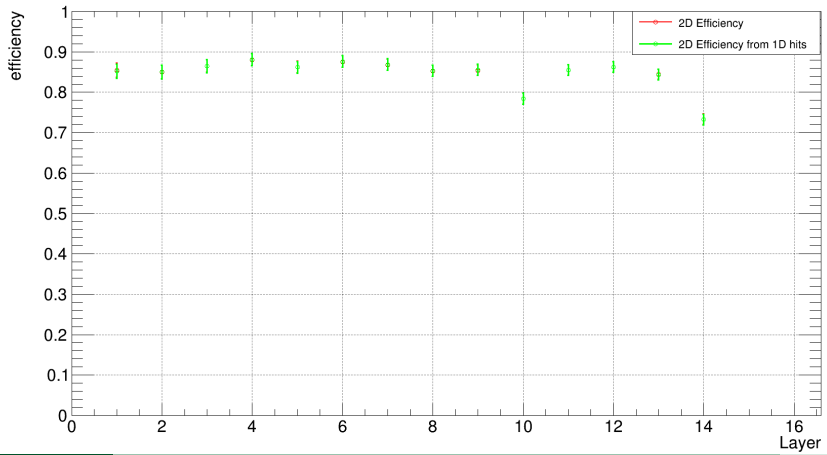


Efficiency without cosmic

Without cosmic events efficiency just the same.

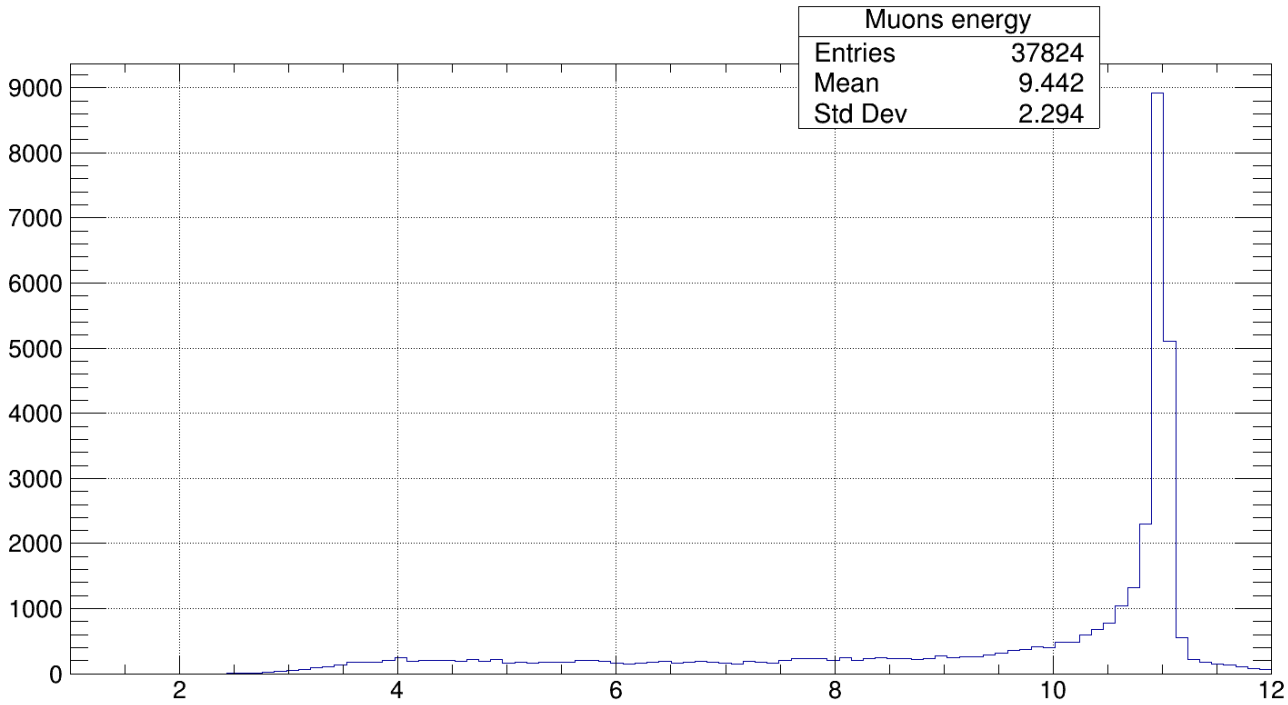


Bwd



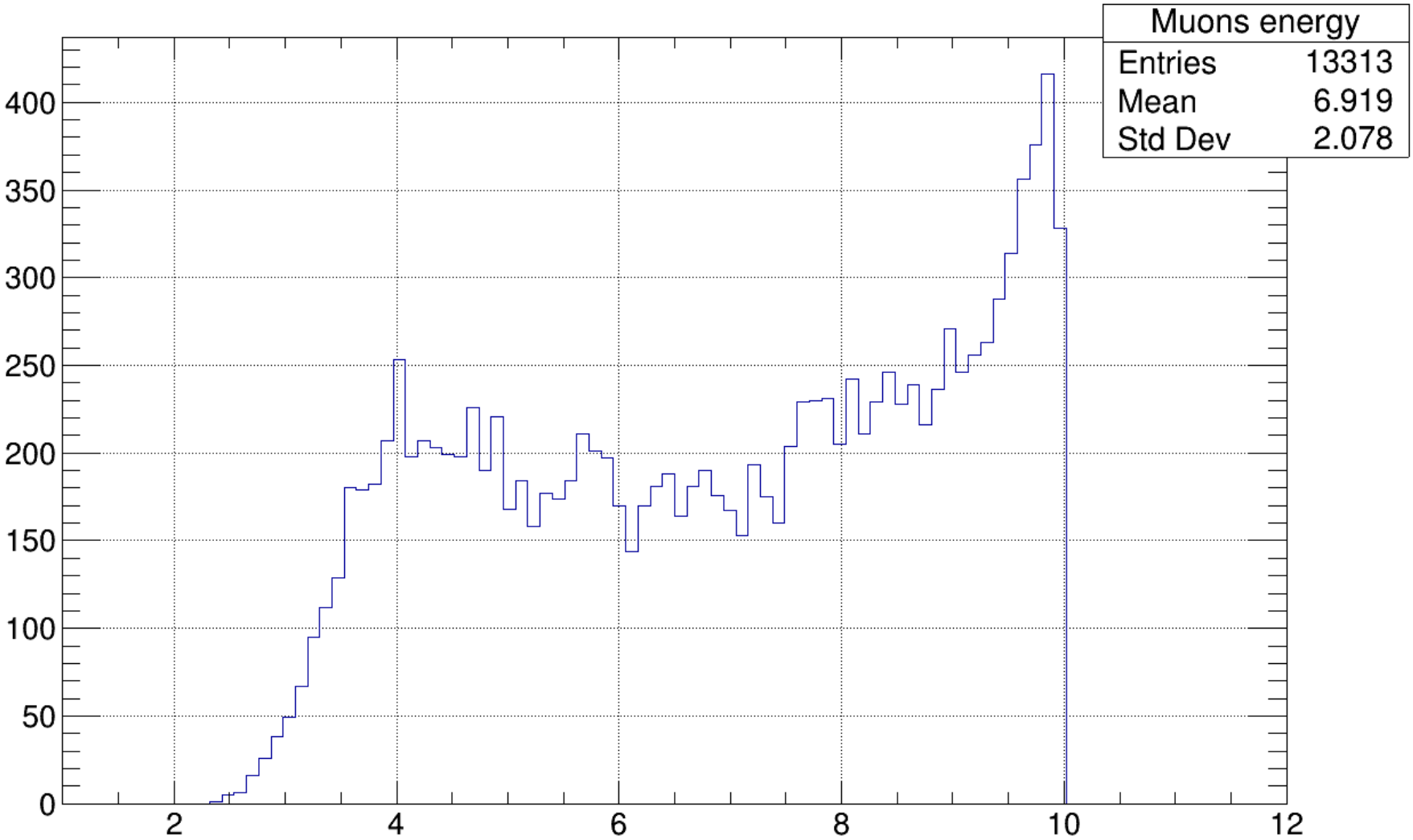
Energy sum distribution

But still there is main line of high correlated tracks. So, I built sum of energies of 2 tracks distribution and noticed that there are many events with energy about beam energy. I wanted to select events with high energy gammas because it can reduce correlation between momentum and direction of two muons.



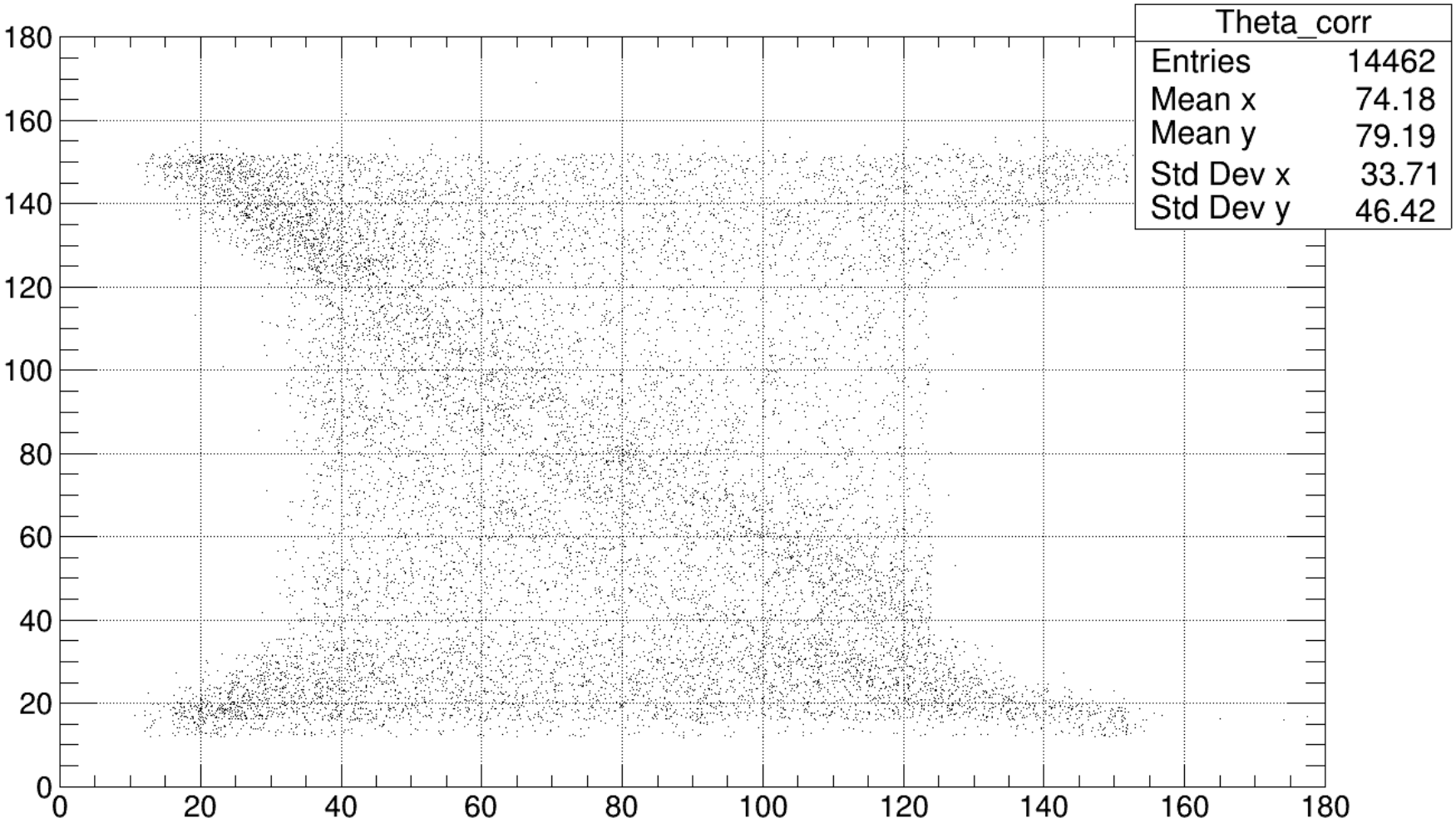
Energy after cut

So after cuts of $2 < E < 10$ GeV

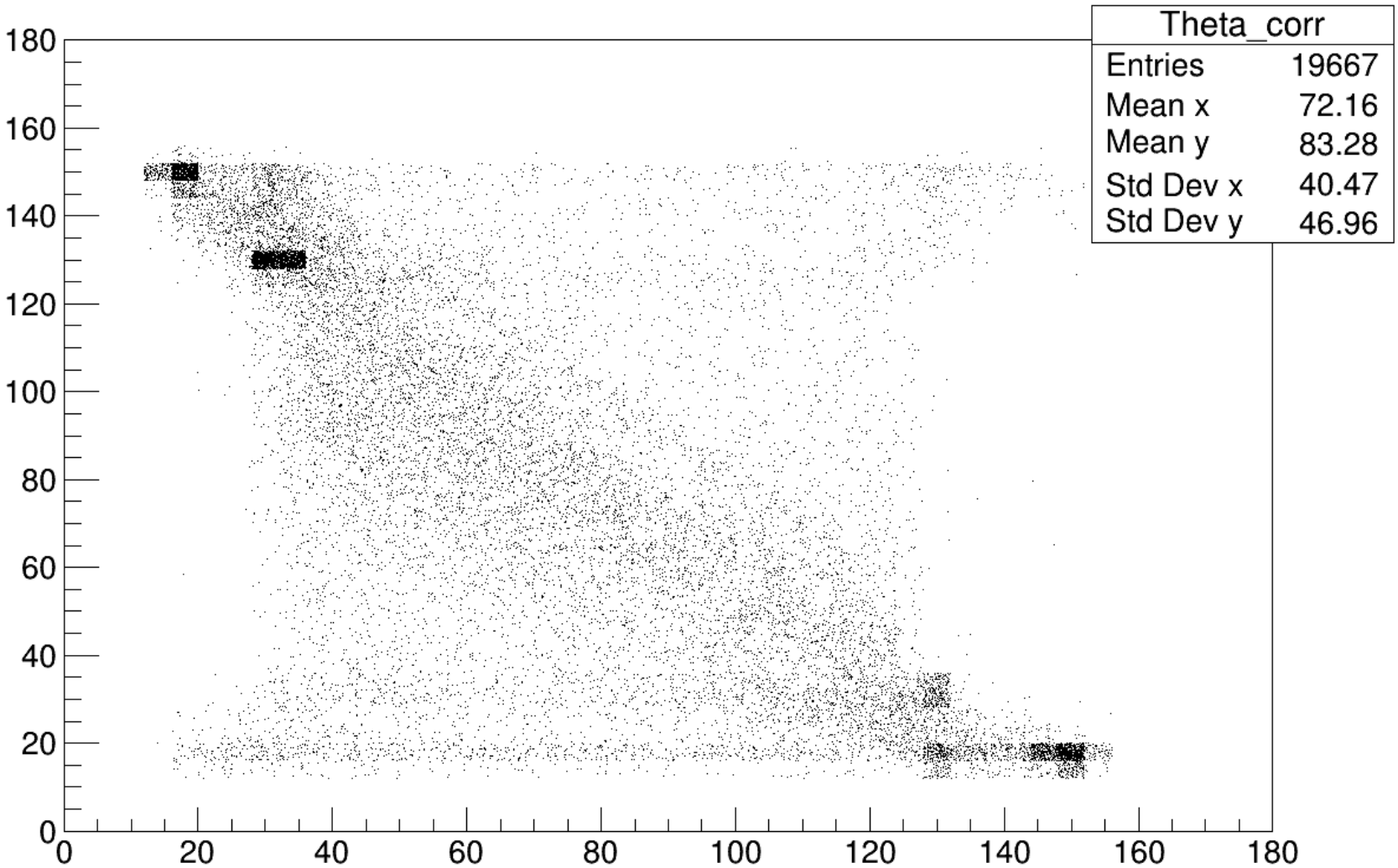


Tracks Theta corr

And theta correlations in MC almost gone!



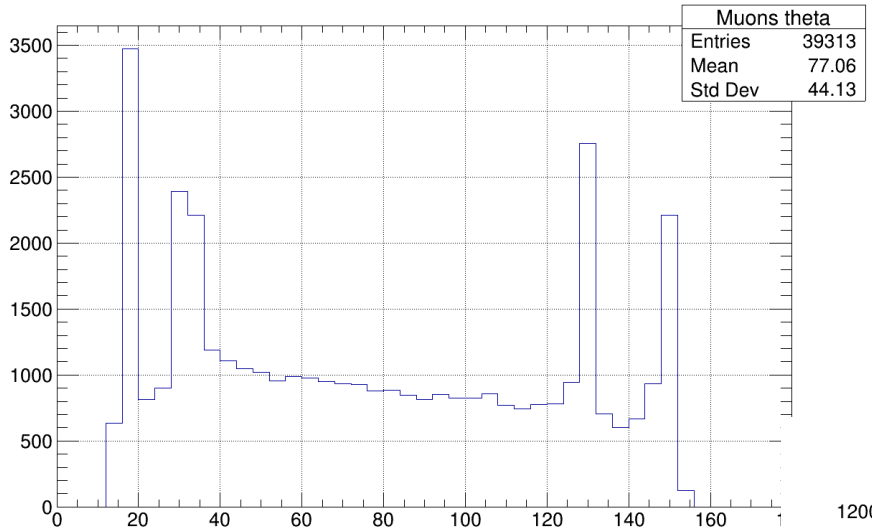
But still there are some strange artifacts in data



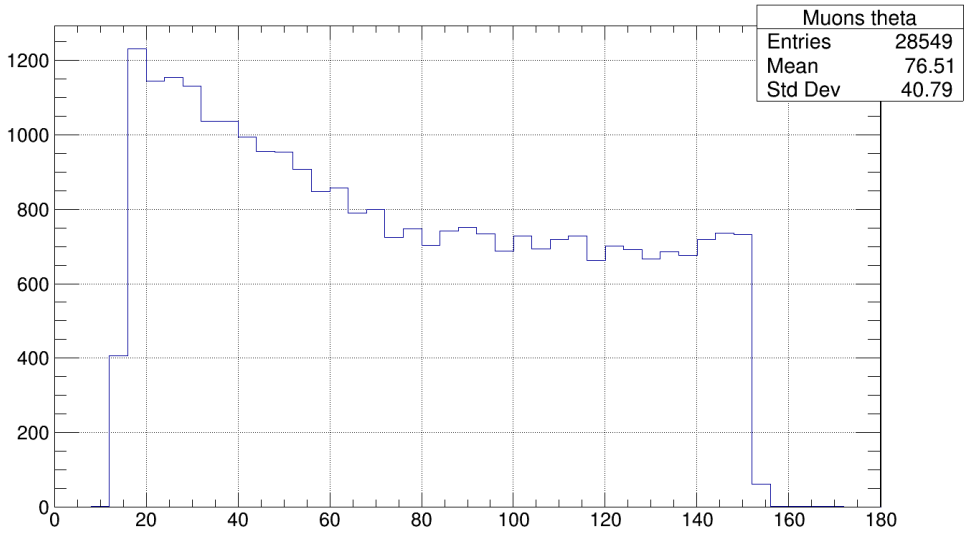
Strange theta distrib

And have some strange theta distribution of tracks in data.

Data

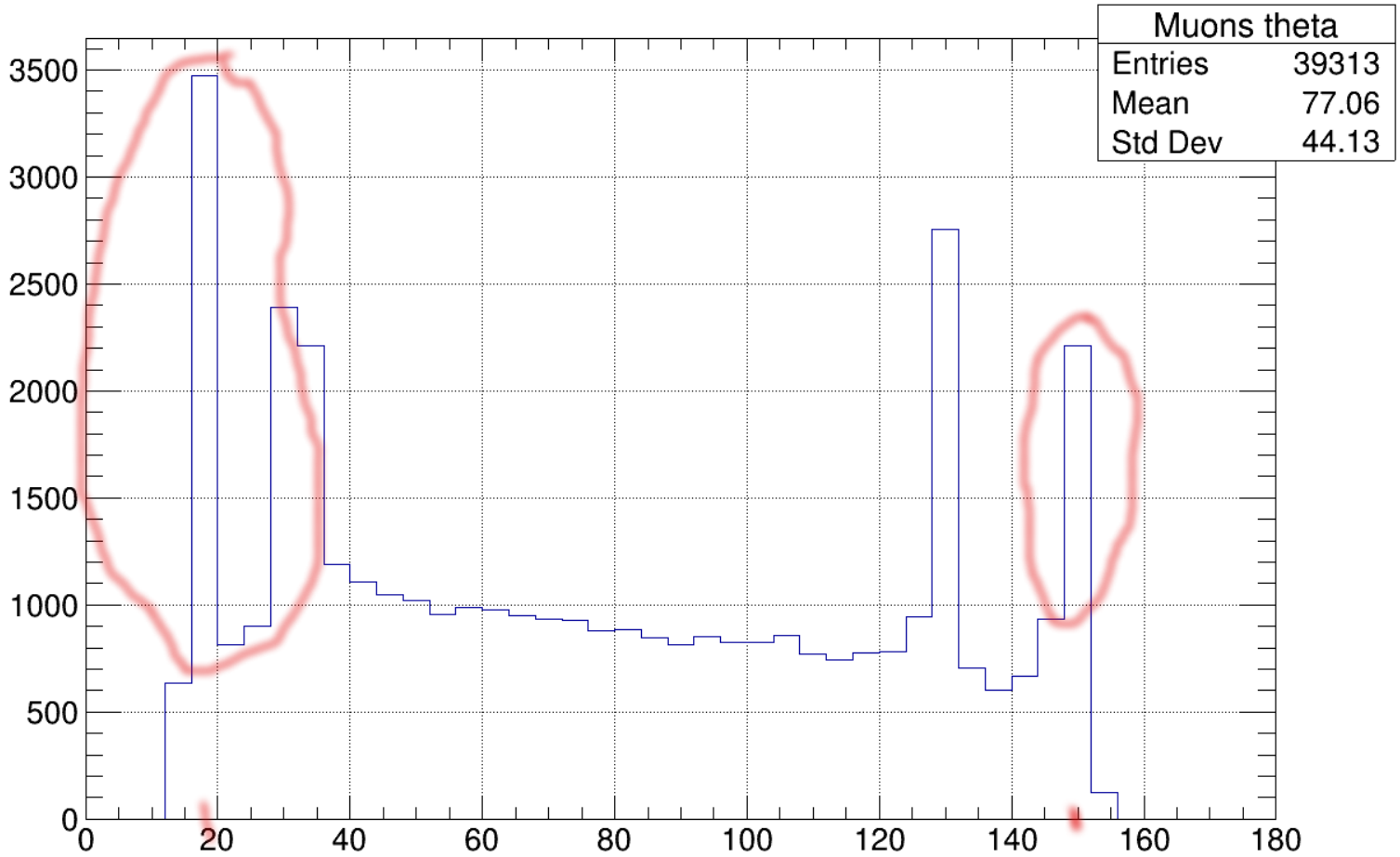


MC



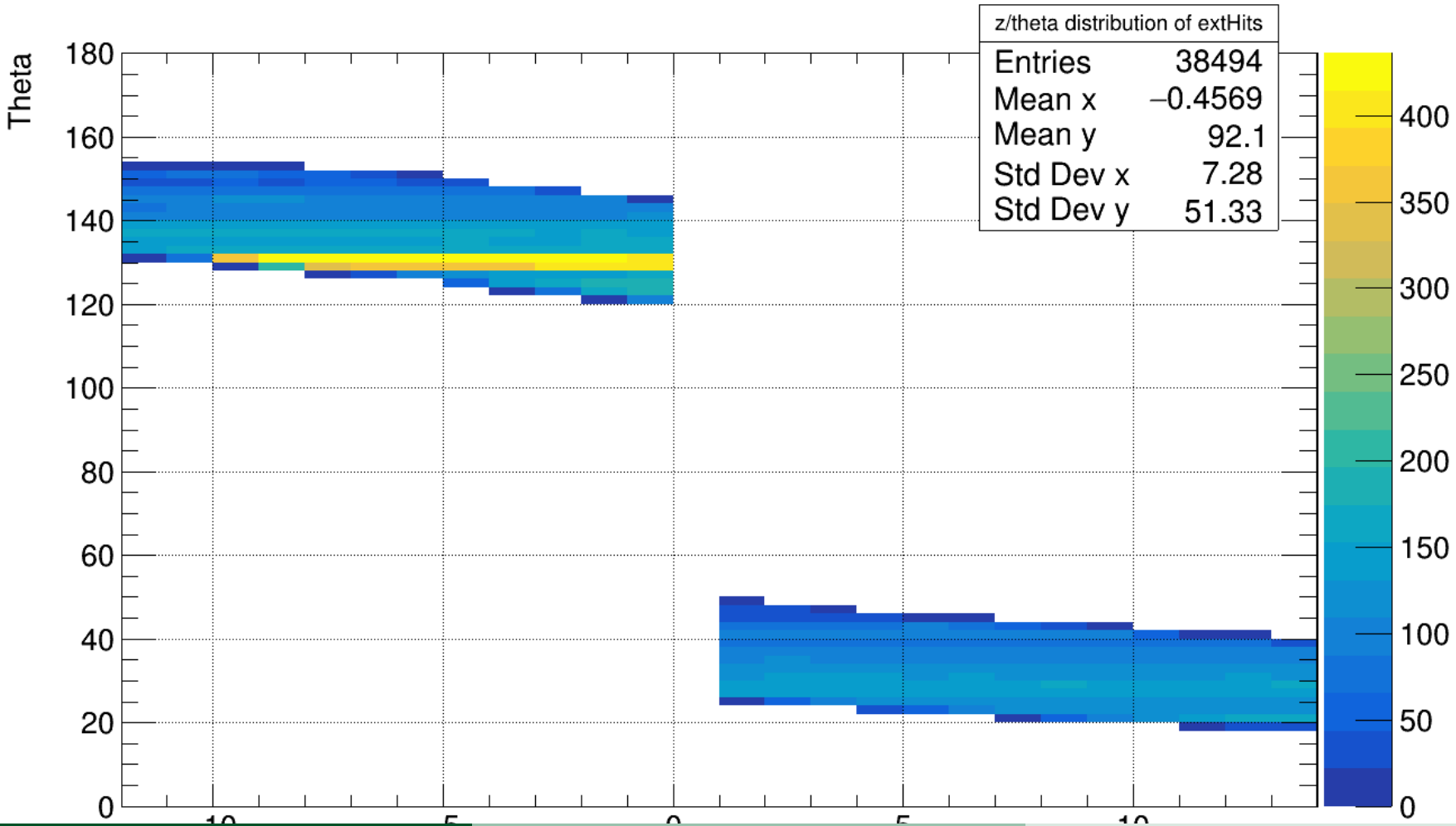
Peaks in theta distribution

My supervisor noticed that they have peaks in the direction of the end of CDC, *e.g.* ≈ 17 and ≈ 150 degrees. Needs investigation.



Theta z distrib

However, when we require $2 < E < 10$ GeV, we get rid of the peaks in forward.



Estimated eff after cut

We can not be sure now about correctness of energy cut and theta distributions. So need to answer the question about theta problems and than move on to the efficiency estimation.