Update status for 3D trigger

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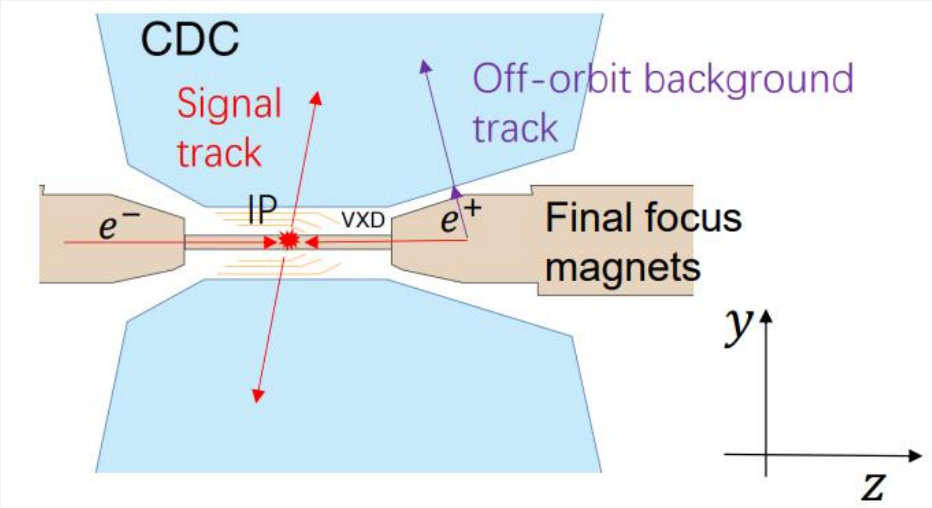
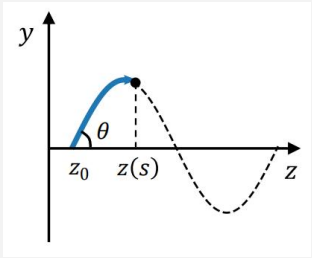
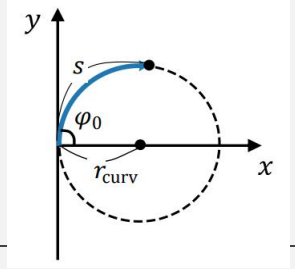
Motivation

New 3D algorithm to reduce more background while keeping the same efficiency
Evaluate performance of the new 3D algorithm with real data

- The results of the offline tracking(more precise) could be used as reference
- Evaluate the Z0 resolution, also θ and ϕ resolution
- Evaluate the efficiency: = number of triggered signal tracks/ number of signal tracks
- Evaluate the background rejection rate := number of NOT triggered BG tracks/ number of BG tracks







Definition of Z0, θ and ϕ

Dataset

Previous dataset used to test : exp34run142(cosmic run)

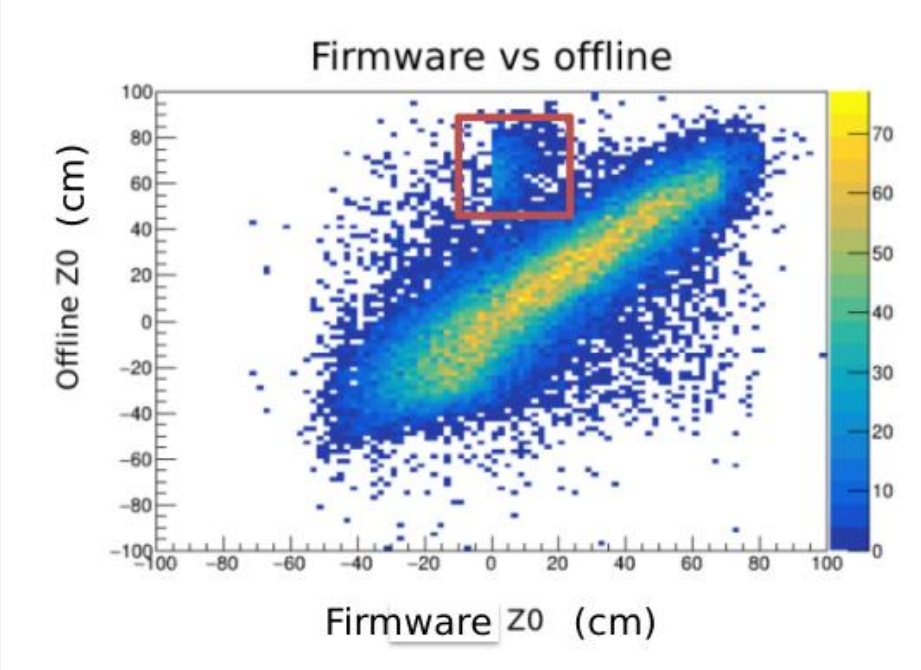
Dataset after modification : exp35run2816 ~ run2897(physics run)

Dataset after modification : exp35run2908 ~ run2909(cosmic run)

Review

Previously there are some events showing the red box are beyond expectation during the comparison between the firmware result and the offline result in (Z0, Cotθ).

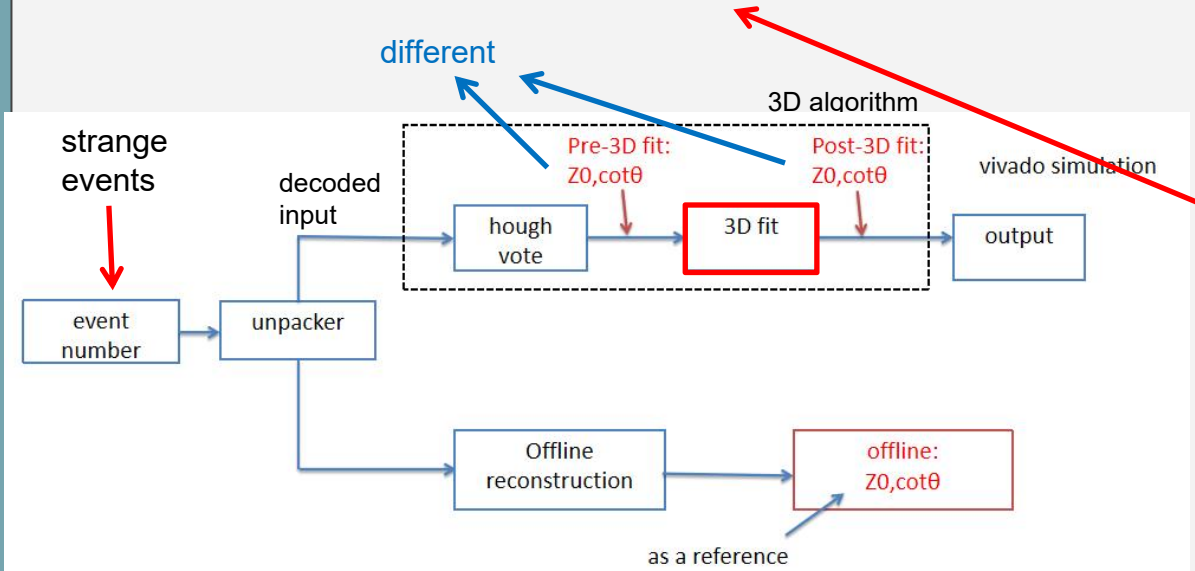
- Check all the process: Use specific events
- Avoid statistical error: At least 10 events



exp34run142
cosmic run

Comparison

(Z0, cot) of pre-3d fit and post-3d fit are different, “3D fit” need to be checked



example of one event

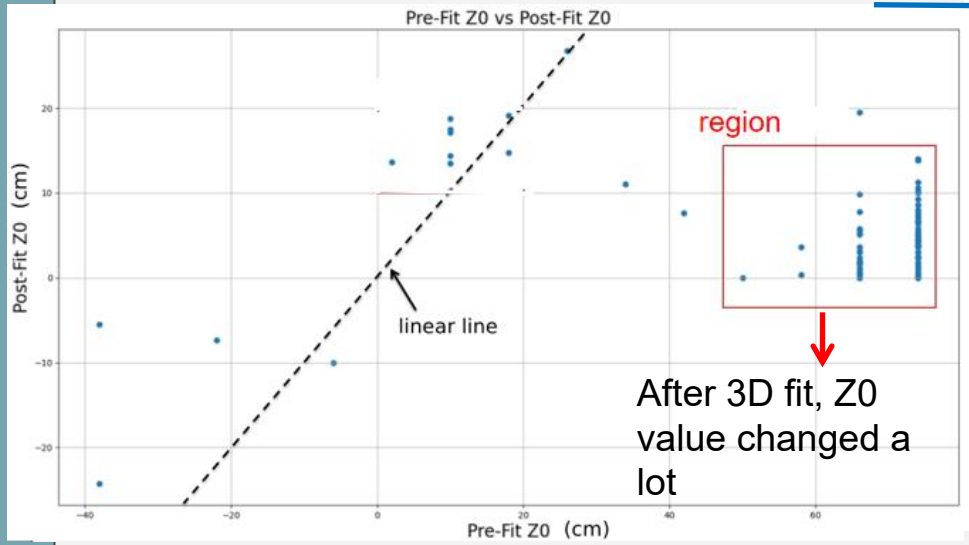
	Z0(cm)	Cotθ	ϕ
Pre-3d fit	74	-0.304	1.374
post-3d fit	1.125	-0.21	1.374
Offline	59.56	0.04	1.380

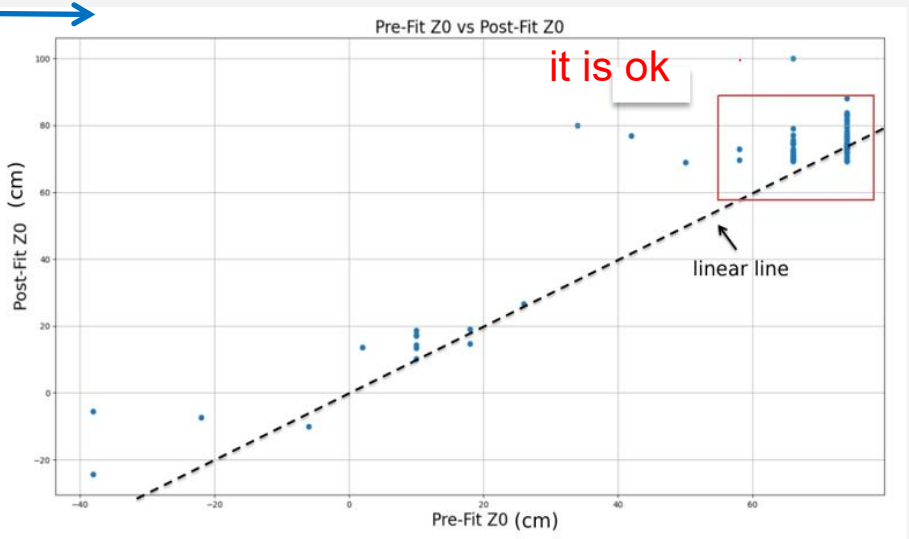
- pre-3d fit and post-3d fit: (Z0,cotθ,ϕ) ,before and after 3d fit module
- offline track: (Z0,cotθ,ϕ) from offline track

2D plot of pre-3d fit Z0 and post-3d fit Z0

Large difference of Z0 is seen between pre-3d fit Z0 and post-3d fit Z0 on the left figure, after modification , it is ok. The reason is overflow showing at next page.

modification





Pre-3d fit Z0 → 3D fit → post-3d fit Z0

need to be checked

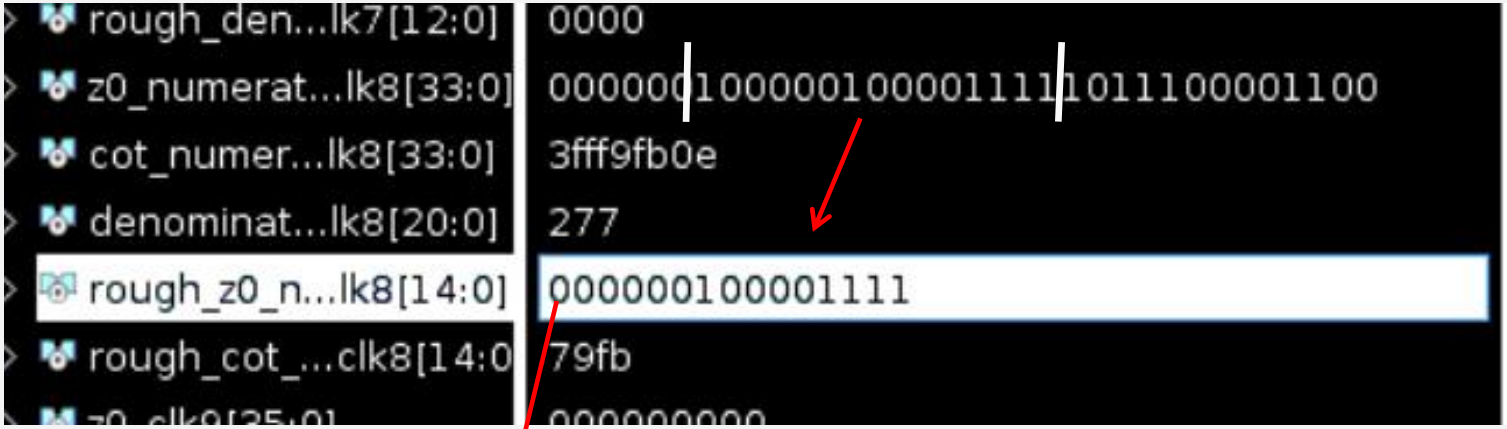
pre-3d fit, post-3d fit mean results before and after the 3D fit respectively

Reason

Overflow results in the strange event in the previous data checking

overflow: signed bit “0” overlap the first bit “1”
One of calculation process is wrong

vivado simulation

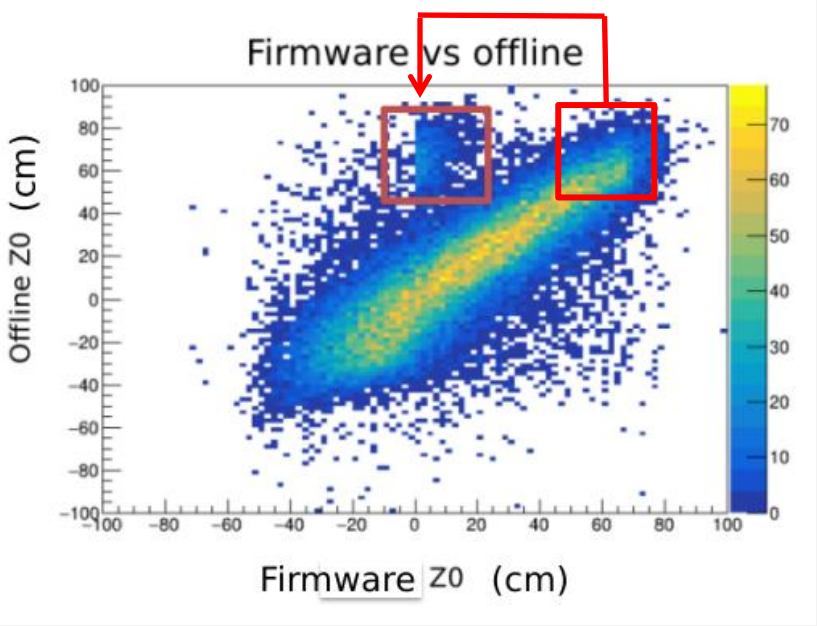


It should be 1, but it is overlaped by 0 (signed number, 0: positive, 1: negative)
It is required as a positive number

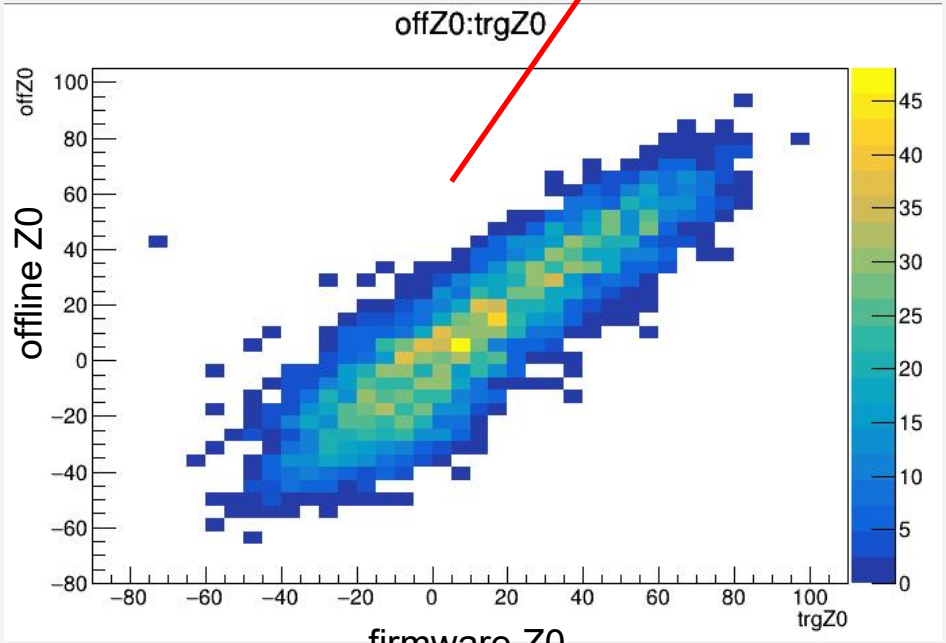
Result check after modification

- After modification , problem is solved
- Data sample is exp35run2908-exp35run2909, cosmic run

overflow



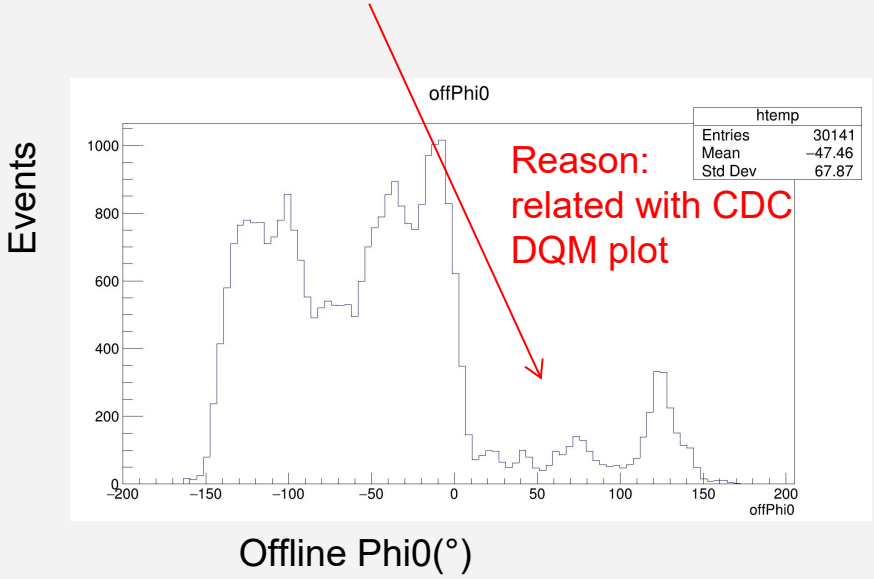
Now there is no strange event caused by overflow

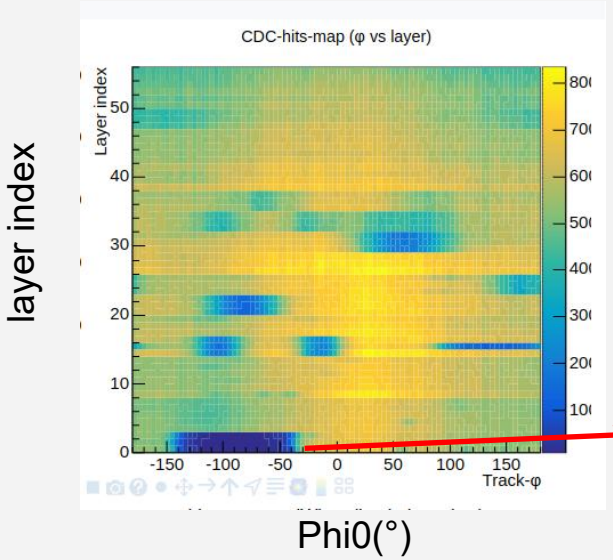


Phi angle check

Just a few events around [10,100](°) are caused by firstlayer cut, showing at the CDC DQM plot, we changed condition to firstlayer<20

Selection requirement:
long track: firstlayer<5 and lastlayer>50

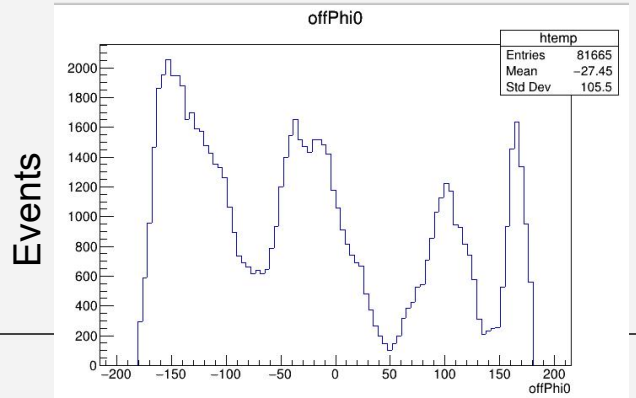




CDC DQM plot

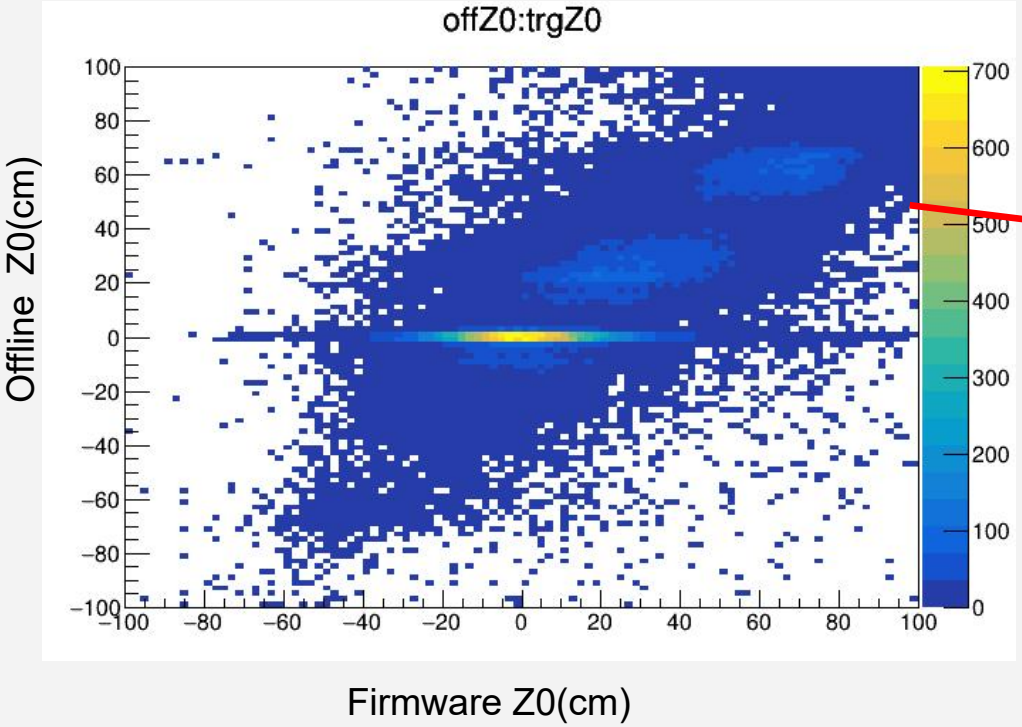
many dead CDCFE, firstlayer<5 (phi angle is refined)

When firstlayer<20



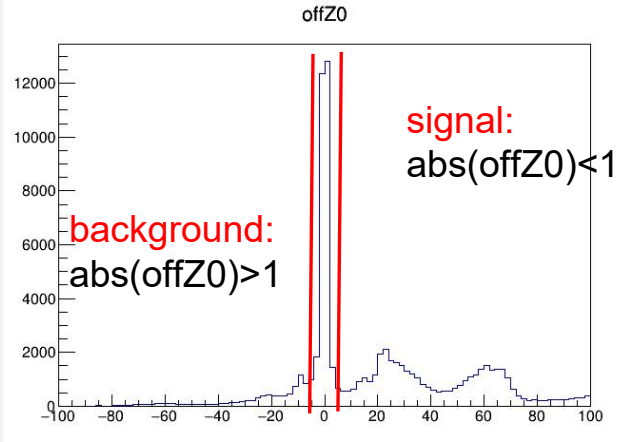
Dataset

I used the physics run data after new 3D firmware installed
exp35run2816 ~ exp35run2897



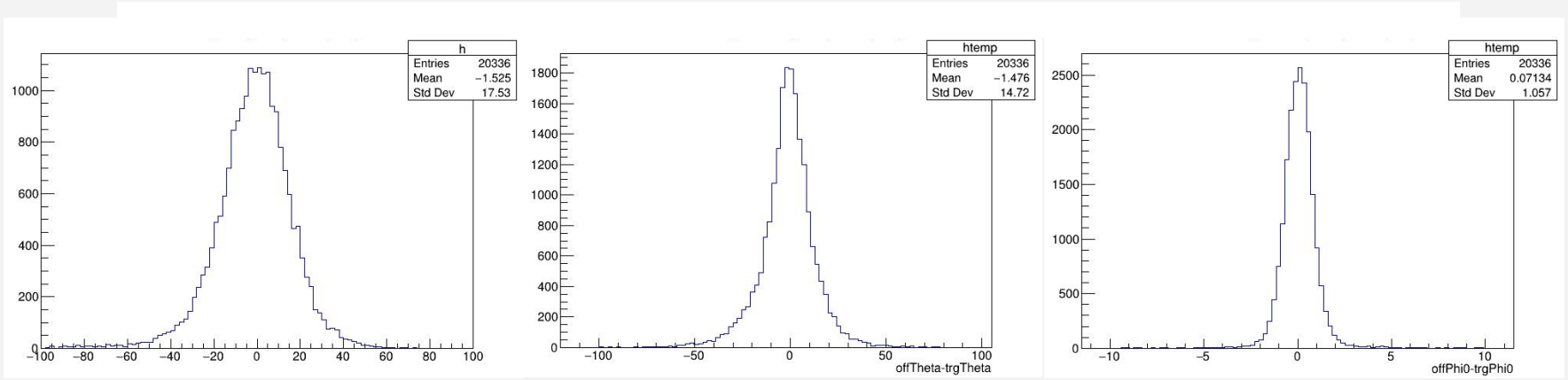
require the offZ0 and trgZ0 range in [-100cm,100cm]

Now there is no strange event caused by overfow



Resolution Check

Requirement: abs(offline Z0) < 1, select signal part
Check the Z0, Theta, Phi resolution
Z0 resolution is around17cm, which is larger than Neural network



Z0 resolution(cm)

Offline Z0 - firmware Z0

Theta resolution(°)

Offline Theta - firmware Theta

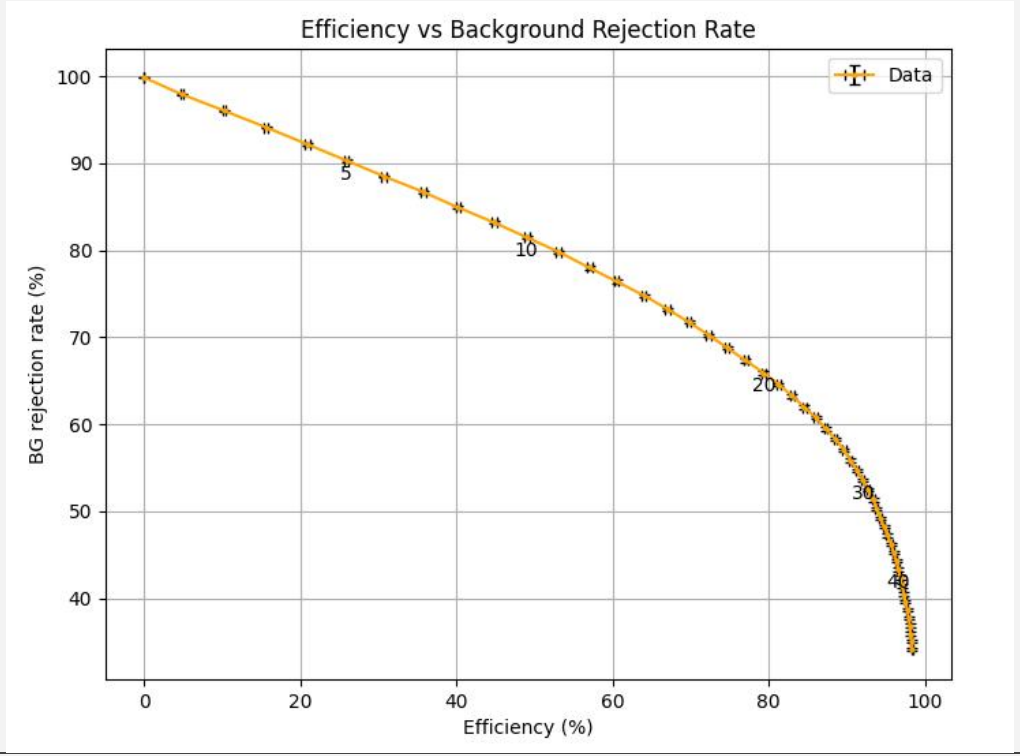
Phi0 resolution(°)

Offline Phi0 - firmware Phi0

Efficiency vs BKG rejection rate

Z0 cut is 30 cm:

Efficiency: 92.09% ± 0.19% Background rejection rate: 53.58% ± 0.20%



- Efficiency: = number of triggered signal tracks/ number of signal tracks
- Background rejection rate := number of NOT triggered BG tracks/ number of BG tracks

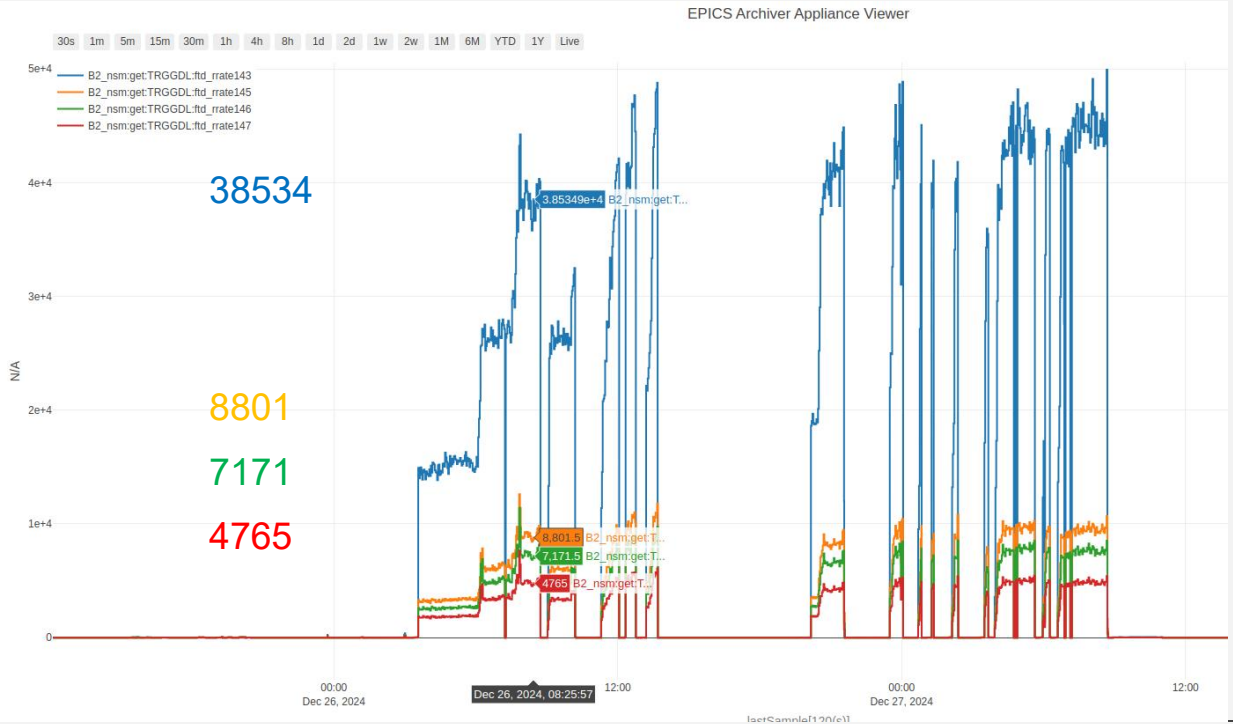
Binomial Error:

eff (p) = # of triggered signal/ # of signal

$\sigma = \sqrt{\frac{p(1-p)}{N}}$

Trigger rate

Around 33% reduction of trigger rate by comparing NN and NN&3D
Some background not rejected by NN is vetoed by 3D trigger

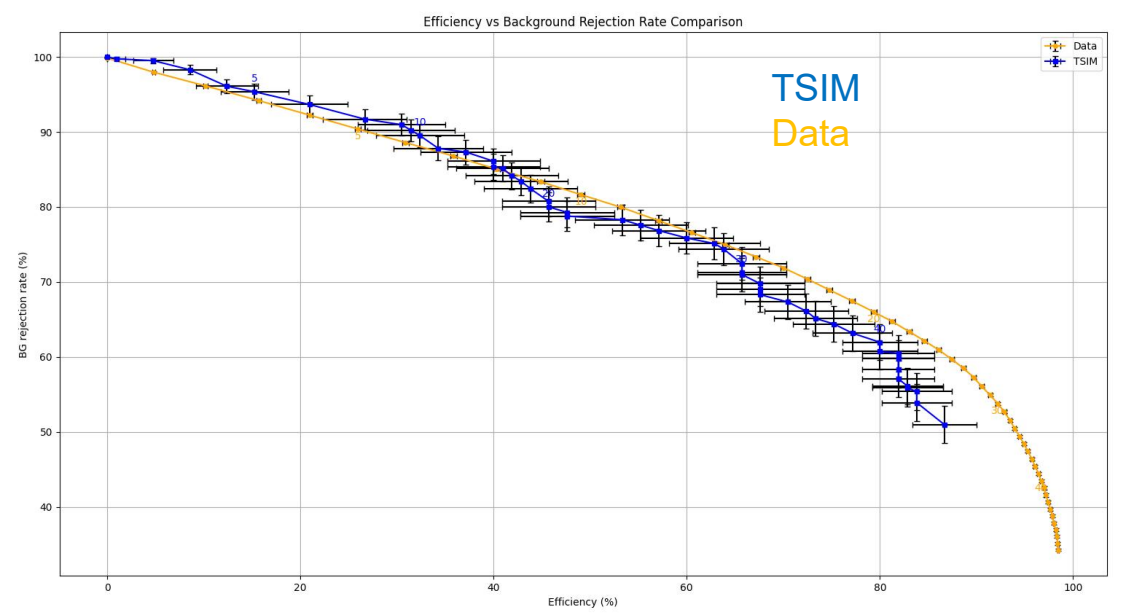


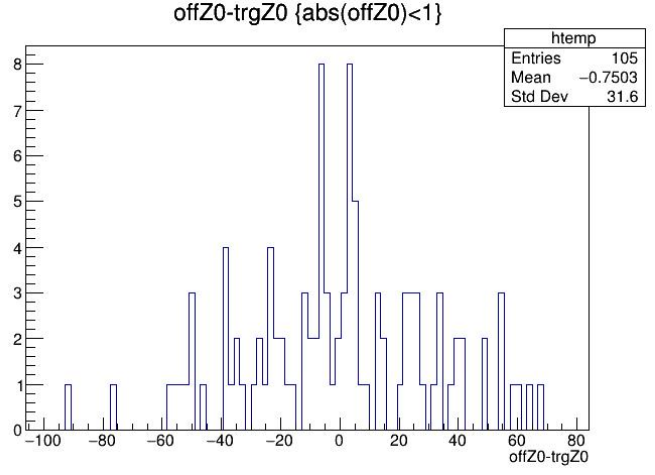
2D
3D
NN
NN&3D

TSIM result

3D TSIM is implemented by software algorithm, not firmware algorithm
Only a few events could be got, it maybe is not accurate
Still there is a problem for physics run, for cosmic run, the number of events is much more,maybe there is something different,which result in this

Efficiency: 65.71% ± 4.63%
Background rejection rate:
71.22% ± 2.24%





Background rejection rate(%)

Efficiency(%)

Z0 resolution(cm)

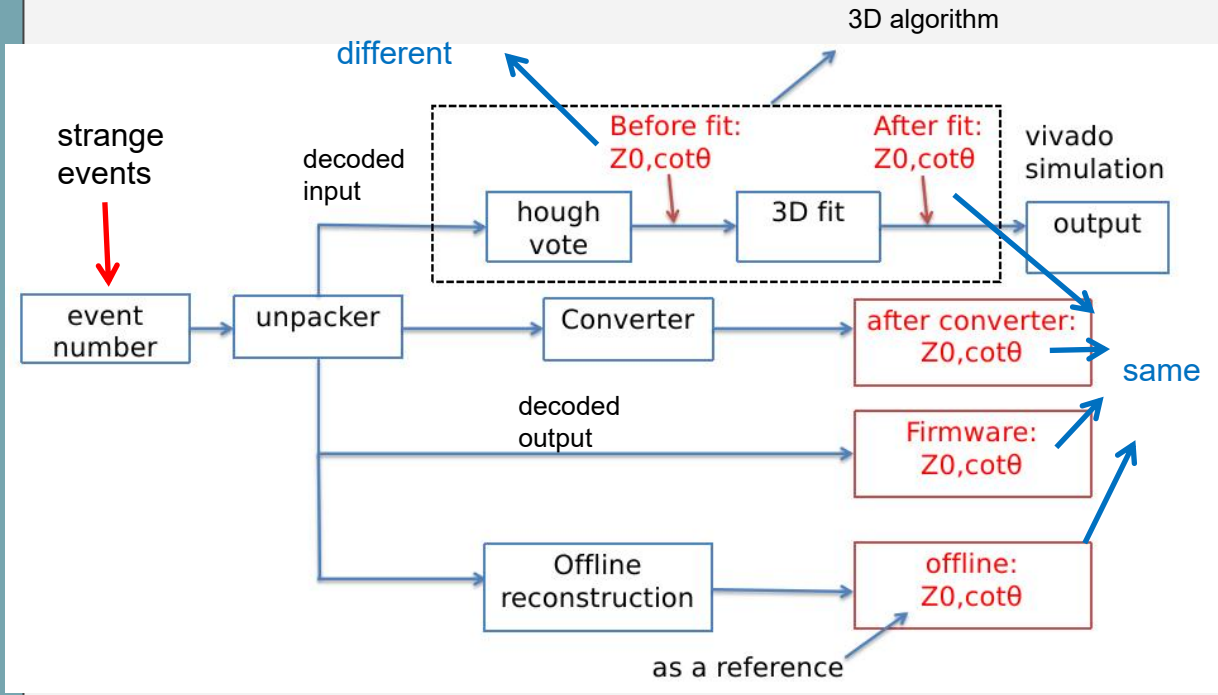
Summary

Summary
1. Overflow and phi angle problem have been fixed
2. Trigger rate of NN could be reduced by adding new 3D
3. Z0 resolution is worse than NN, maybe because drift time is calculated wrong, which will have large effect to 3D algorithm, after DNN modification for drift time, 3D will apply it

back up

Comparison

(Z0, cot) before 3D fit is different with others, 3D fit module need to be checked



example of one event

	Z0(cm)	Cotθ	ϕ
Before fit	74	-0.304	1.374
After fit	1.125	-0.21	1.374
After converter	1.125	-0.204	1.374
Firmware	1.125	-0.21	1.374
Offline	59.56	0.04	1.380

- Firmware: directly obtained from firmware data
- before and after 3d fit: (Z0,cotθ,ϕ) before and after 3d fit module
- offline track: (Z0,cotθ,ϕ) from offline track
- after converter:(Z0,cotθ,ϕ) after converter

event1

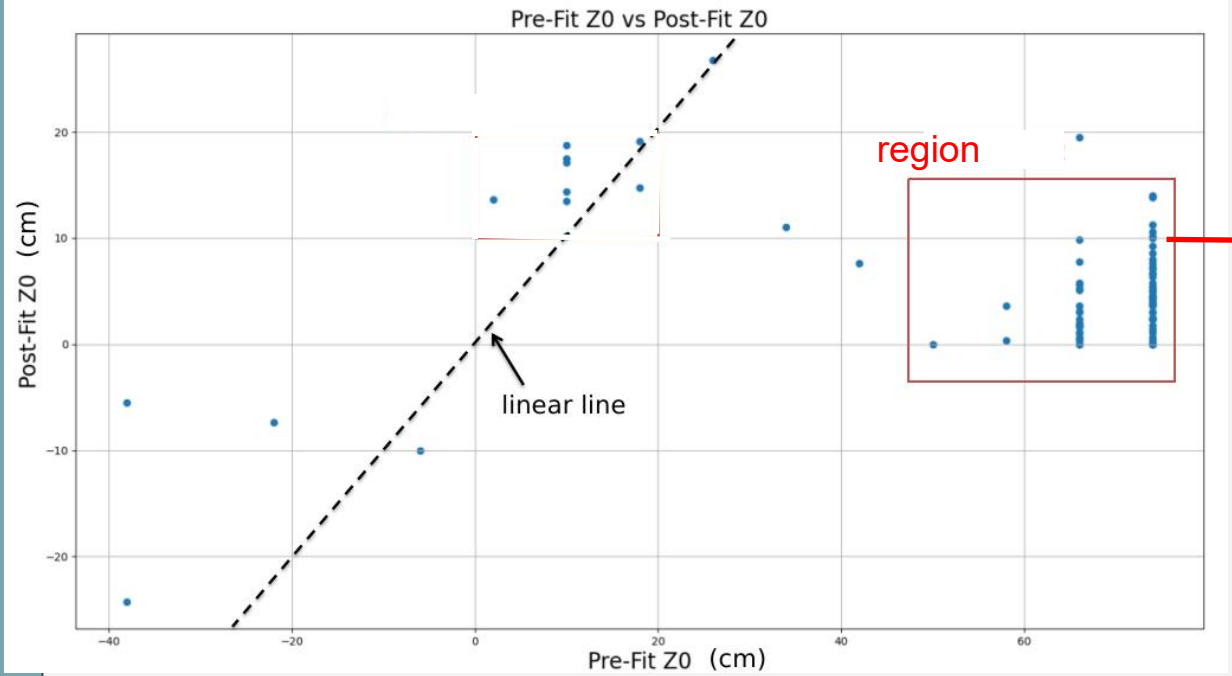
event: exp34run142(cosmic)

A little difference in ϕ result between firmware and during converter table, because the phi bit value multiply 0.002(precision,9bits) in firmware table, but multiply 0.00195(precision) in converter.

	Z0(cm)	Cotθ	φ
Firmware	1.125	-0.21	1.374
Before fit	74	-0.304	1.374
After fit	1.125	-0.21	1.374
After converter	1.125	-0.204	1.374
Offline	59.56	0.04	1.380

2D plot of before and after fit

Large difference of z0 is seen between post-3d fit and pre-3d fit



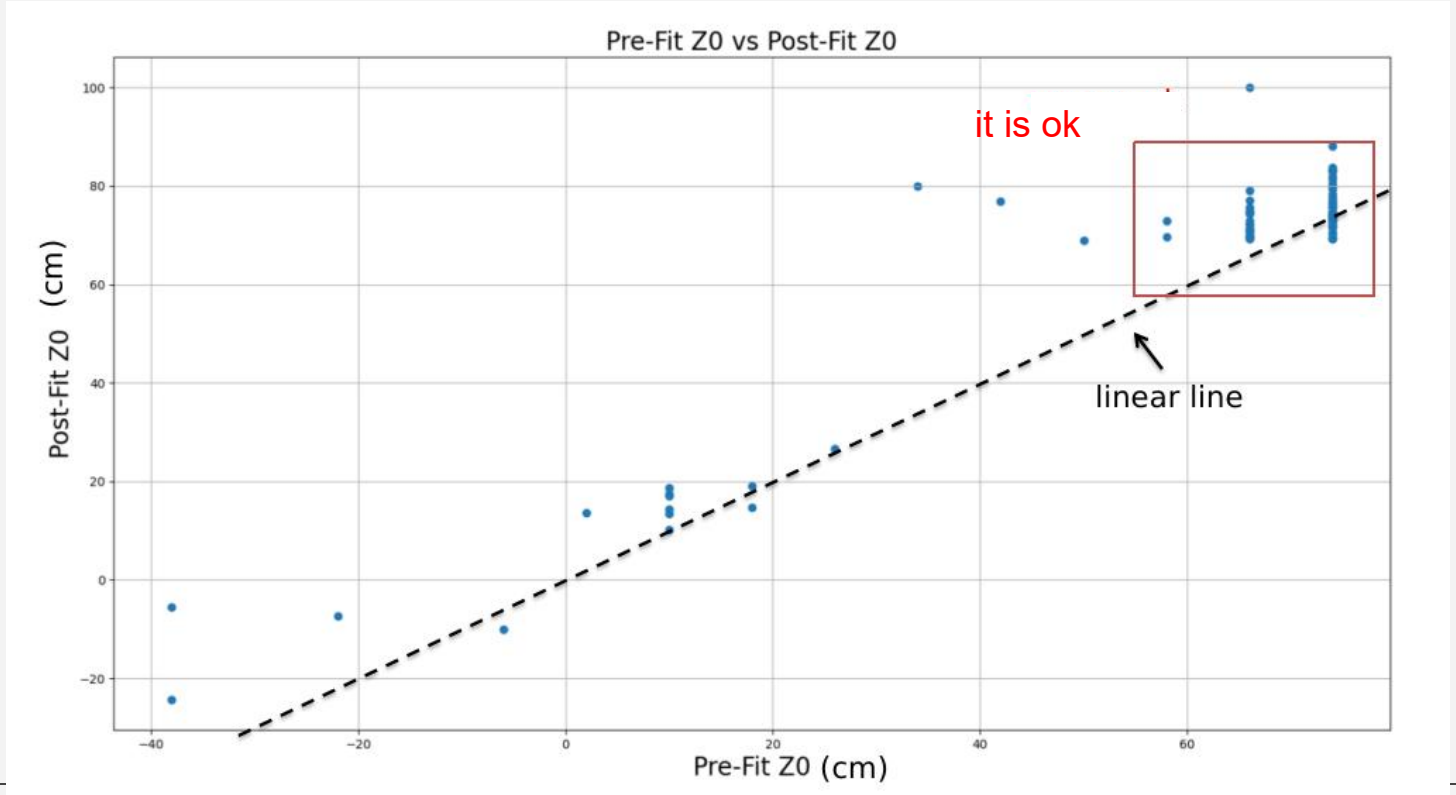
After 3D fit, Z0 value changed a lot

need to be checked

pre-3d fit, post-3d fit mean results before and after the 3D fit module respectively

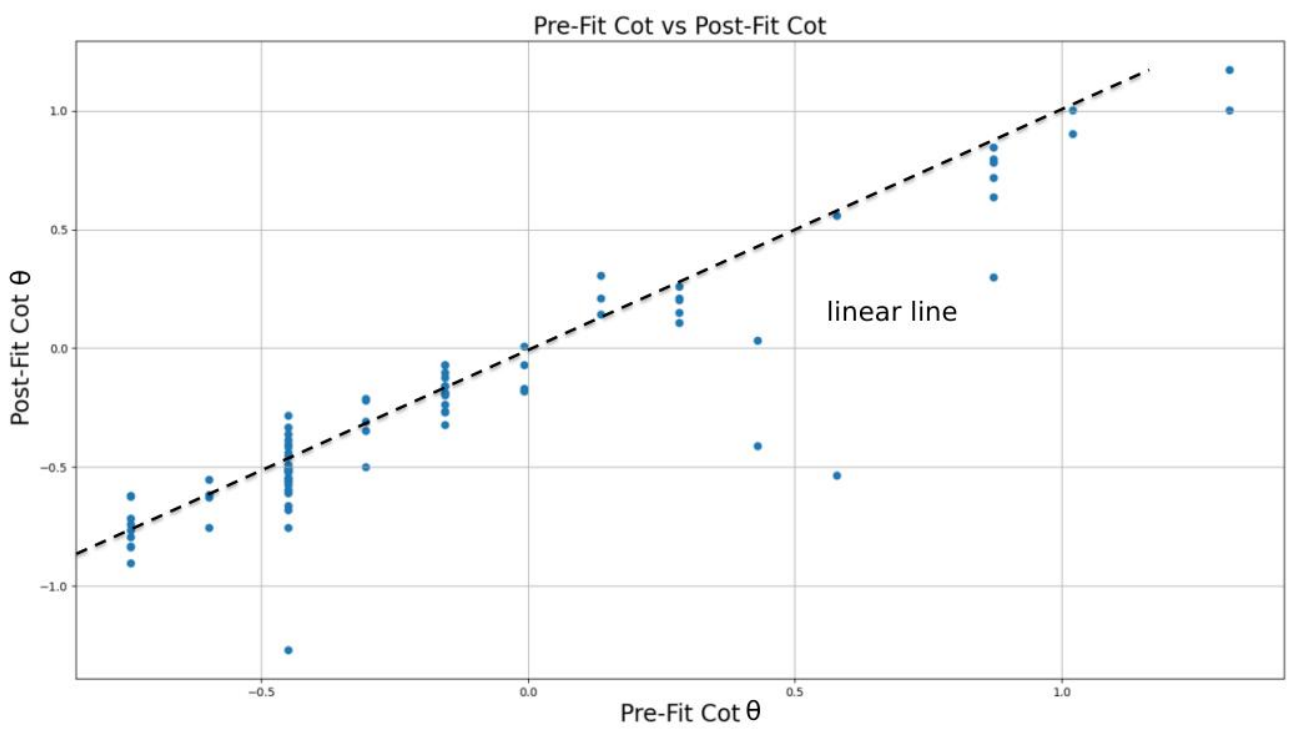
2D plot of before and after fit

- After modification , it is ok. (Linear relationship is expected)



2D plot of before and after 3D fit

- This is ”pre-3d fit Cotθ” vs ”post-3d fit Cotθ” plot, it is normal, Cotθ calculation don’t have problem.



Only the process of calculating Z0 has some problems

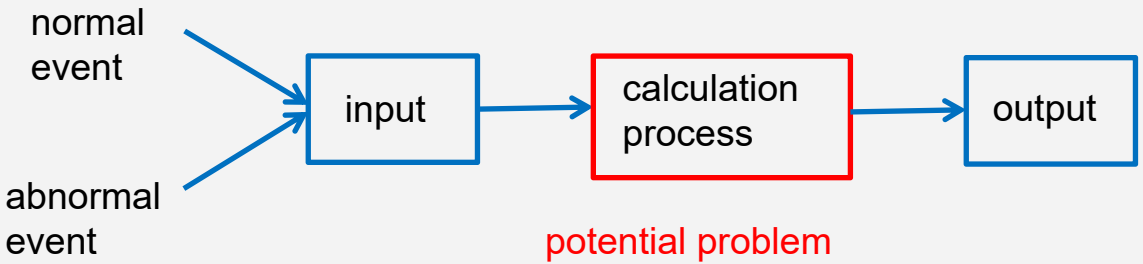
Checking flow of the 3d fitter module

3d fitter module is to deal with these two equation

- $$z_0 = \frac{-\left(\sum_i \frac{s_i}{\sigma_i^2}\right)\left(\sum_i \frac{s_i z_i}{\sigma_i^2}\right)+\left(\sum_i \frac{s_i^2}{\sigma_i^2}\right)\left(\sum_i \frac{z_i}{\sigma_i^2}\right)}{\left(\sum_i \frac{1}{\sigma_i^2}\right)\left(\sum_i \frac{s_i^2}{\sigma_i^2}\right)-\left(\sum_i \frac{s_i}{\sigma_i^2}\right)\left(\sum_i \frac{s_i}{\sigma_i^2}\right)}$$

$$\cot\theta = \frac{\left(\sum_i \frac{1}{\sigma_i^2}\right)\left(\sum_i \frac{s_i z_i}{\sigma_i^2}\right)-\left(\sum_i \frac{s_i}{\sigma_i^2}\right)\left(\sum_i \frac{z_i}{\sigma_i^2}\right)}{\left(\sum_i \frac{1}{\sigma_i^2}\right)\left(\sum_i \frac{s_i^2}{\sigma_i^2}\right)-\left(\sum_i \frac{s_i}{\sigma_i^2}\right)\left(\sum_i \frac{s_i}{\sigma_i^2}\right)}$$

1. Confirm the formual of Z0 and cot is correct ✔
2. Use same input to check calculation process and output
3. Check normal and abnormal event respectively



Result of comparison

The steps of calculation in vivado simulation have problem
Same input, but there are different outputs, calculation process is wrong

	Z0(cm)	Cotθ
vivado simulation	57.84	0.01
python	57.84	0.01

Output of normal event

	Z0(cm)	Cotθ
vivado simulation	1.125	-0.21
python	70.51	-0.203

Input Z0: 74 cm

Output of abnormal event

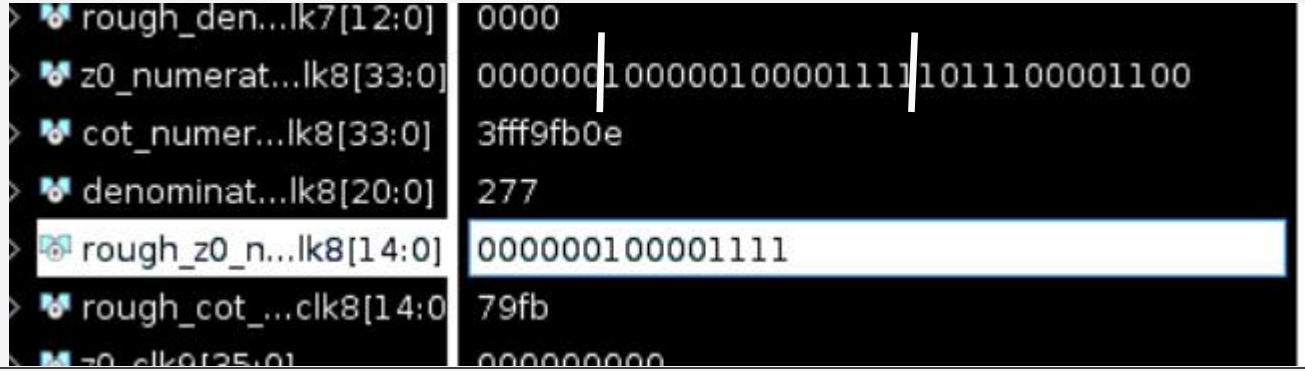
Reason

steps:

1. signed (signed number), 0: positive, 1:negative
2. right shift 13
   (00100010 -> 00000100) right shift 3 bits

   Precision will decrease (1.23 -> 1.2) decimal number as an example
3. resize 15(resize the representation of bit to a specific width)
   as an example: resize 6 to 0011010 -> 011010

overflow: maybe signed bit “0” overlap the first bit “1”



Two methods to modify

A. shift bit method
1. right shift one more bit (maybe precision will decrease)
2. right shift one less bit to the final Z0 result(left shift one more bit than before), for offsetting the impact of shifting right by one more bit

B. Digital Signal Processing method
Modify the dsp module, change dsp for fitter 21x15 to dsp for fitter 21x16

in my case, dsp for 21x15 is a 21-bits number multiply a 15-bits number

Comparsion result

• I compare some results of two method, the results keep consistent. Still a little difference in some events, but it is small.

Shift Bit Z0(cm)	Shift Bit Cot(θ)	DSP Z0(cm)	DSP Cot(θ)
70.3800	-0.2100	70.3800	-0.2100
76.5000	-0.8300	76.5000	-0.8300
70.8750	-0.4900	71.0000	-0.4900
71.6300	-0.0700	71.6300	-0.0700
69.2500	-0.0700	69.2500	-0.0700
73.2500	-0.7100	73.2500	-0.7100
14.7500	0.8500	14.7500	0.8500
78.3750	-0.6200	78.5000	-0.6200
73.0000	-0.3100	73.0000	-0.3100
71.2500	-0.5200	71.2500	-0.5200
73.6300	-0.7700	73.6300	-0.7700
79.1250	-0.6000	79.1250	-0.6000
26.6250	0.5600	26.7500	0.5600
80.0000	-0.5360	80.0000	-0.5360

Dataset

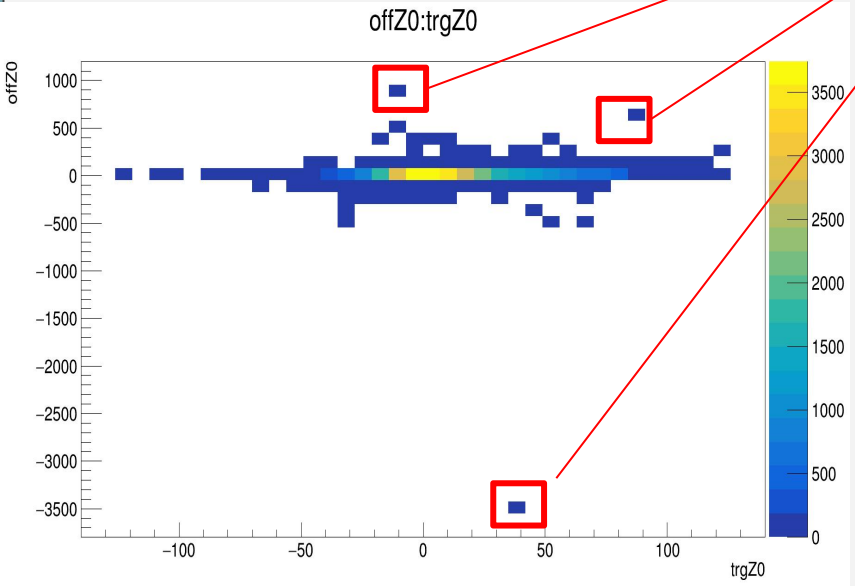
I used all the physics run data after new 3D firmware installed
exp35run2816 ~ exp35run2897

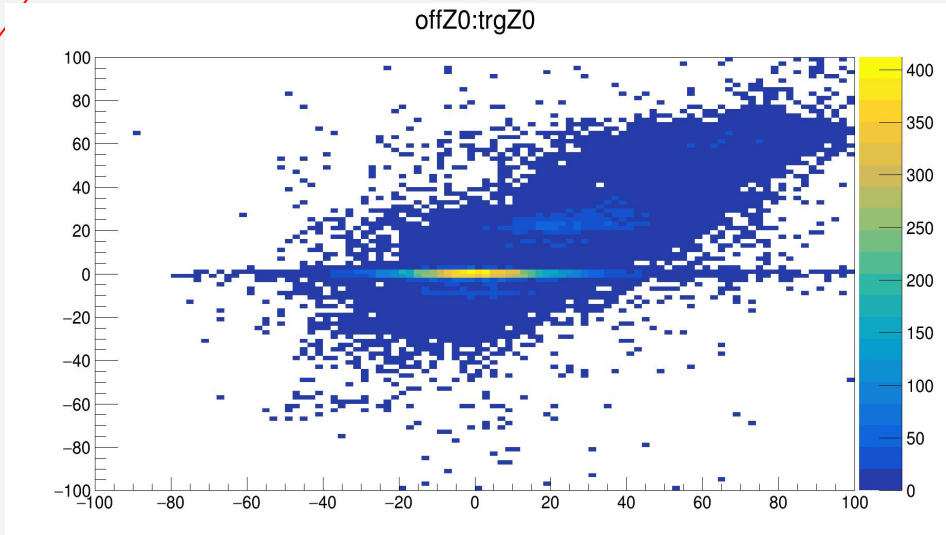
Firstlayer<5

only one event,maybe because sometimes offline track is reconstructed incorrectly

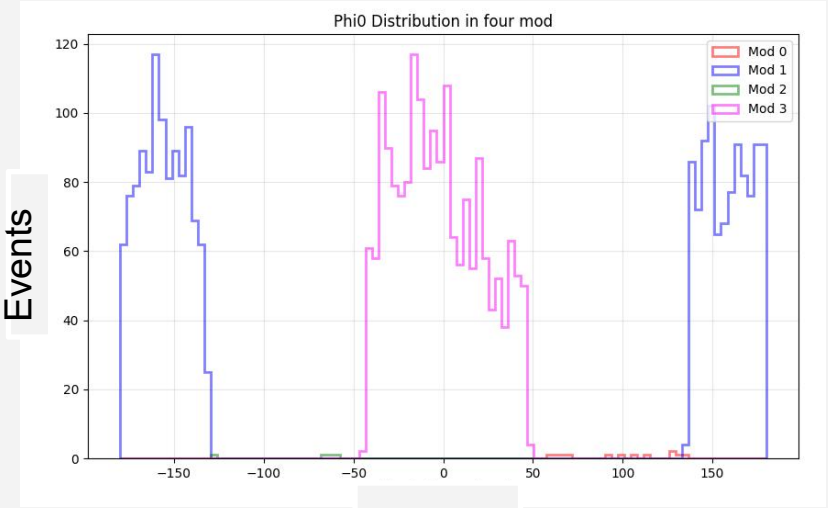
directly draw the 2D plot

require the offZ0 and trgZ0 range in [-100cm,100cm]





Phi angle check



Phi angle[-180, 180](°)

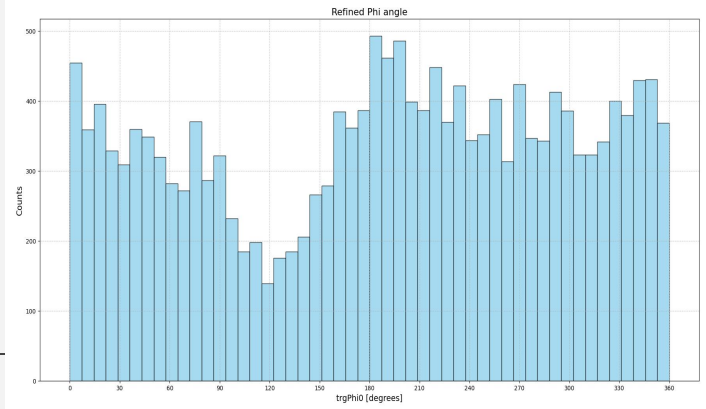
After modification, empty of phi angle is fixed

There are 4 mods covering 360 degree phi angle.
Previously there are almostly no events in mod0 and mod2.

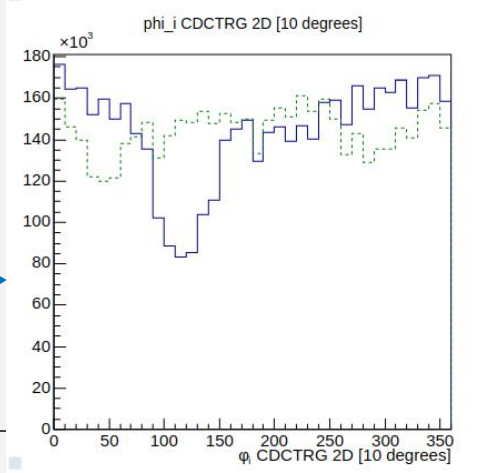
This is because the setting of clock difference between 2D module and 3D module is wrong

Fixed phi angle

Phi angle range: [0, 360](°), refined



similiar



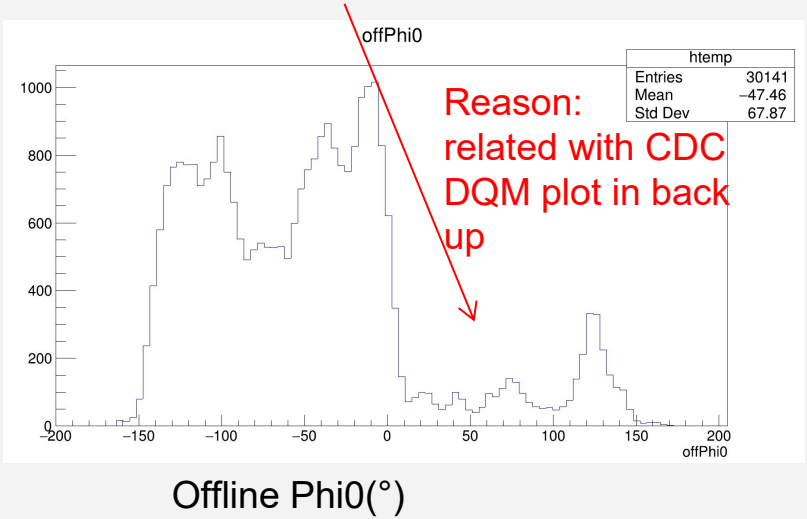
DQM plot, as a reference

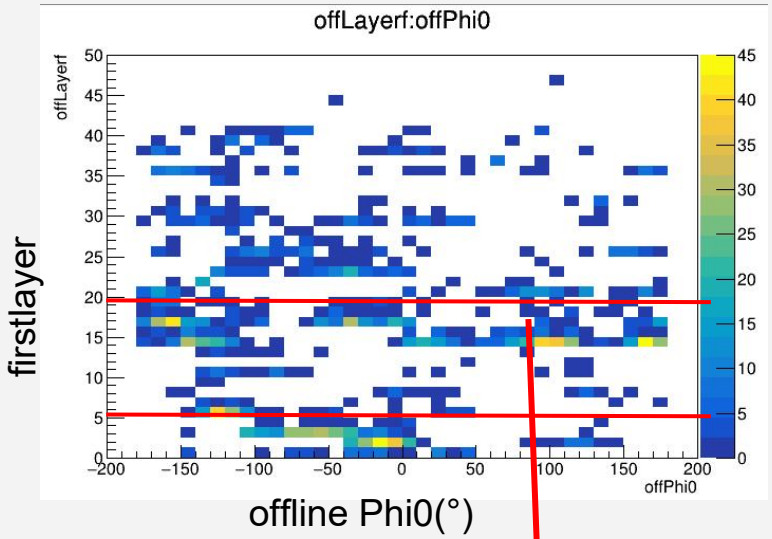
Phi angle range: [0, 360](°)

Phi angle check

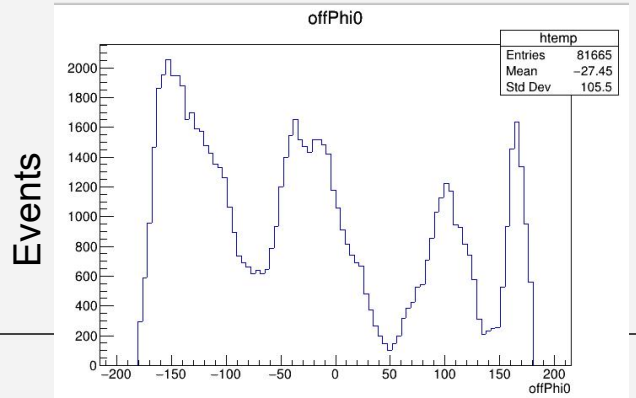
Just a few events around [10,100](°) are caused by firstlayer cut

Selection requirement:
1. offline track
2. Pt>0.3Gev
3. long track: firstlayer<5 and lastlayer>50

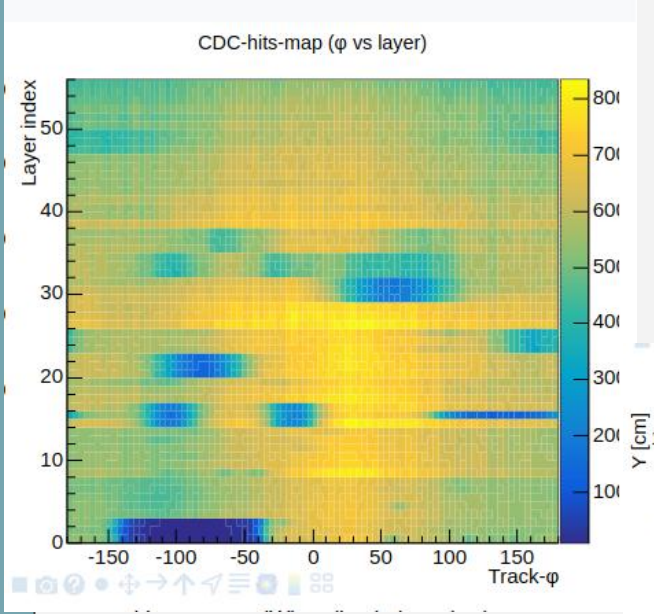


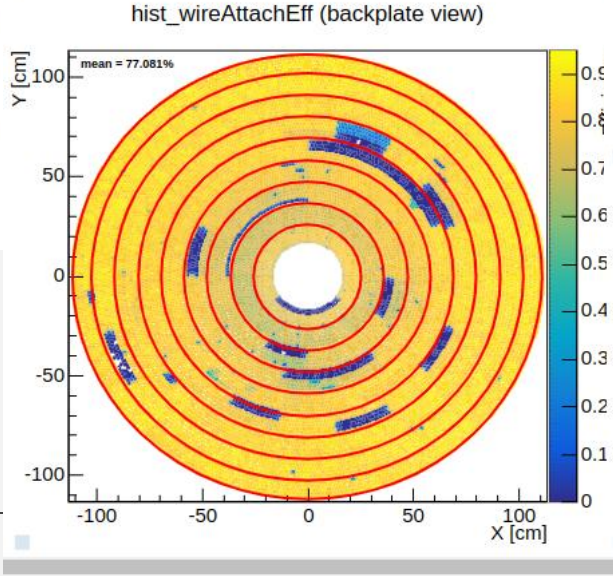


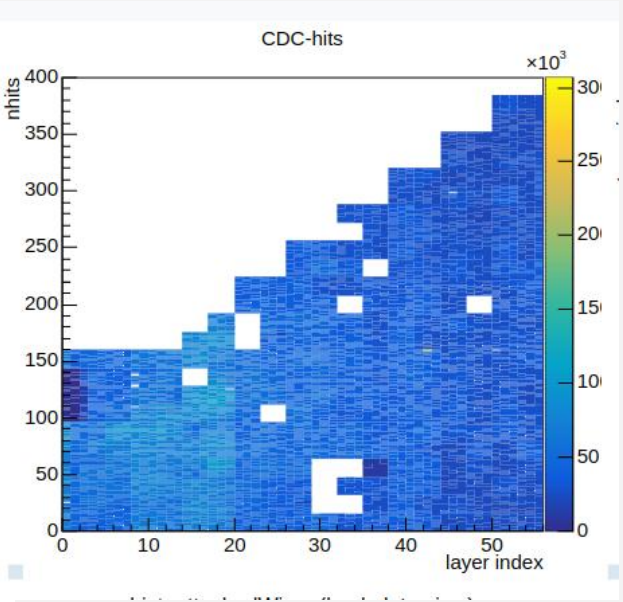
Change firstlayer from 5 to 20



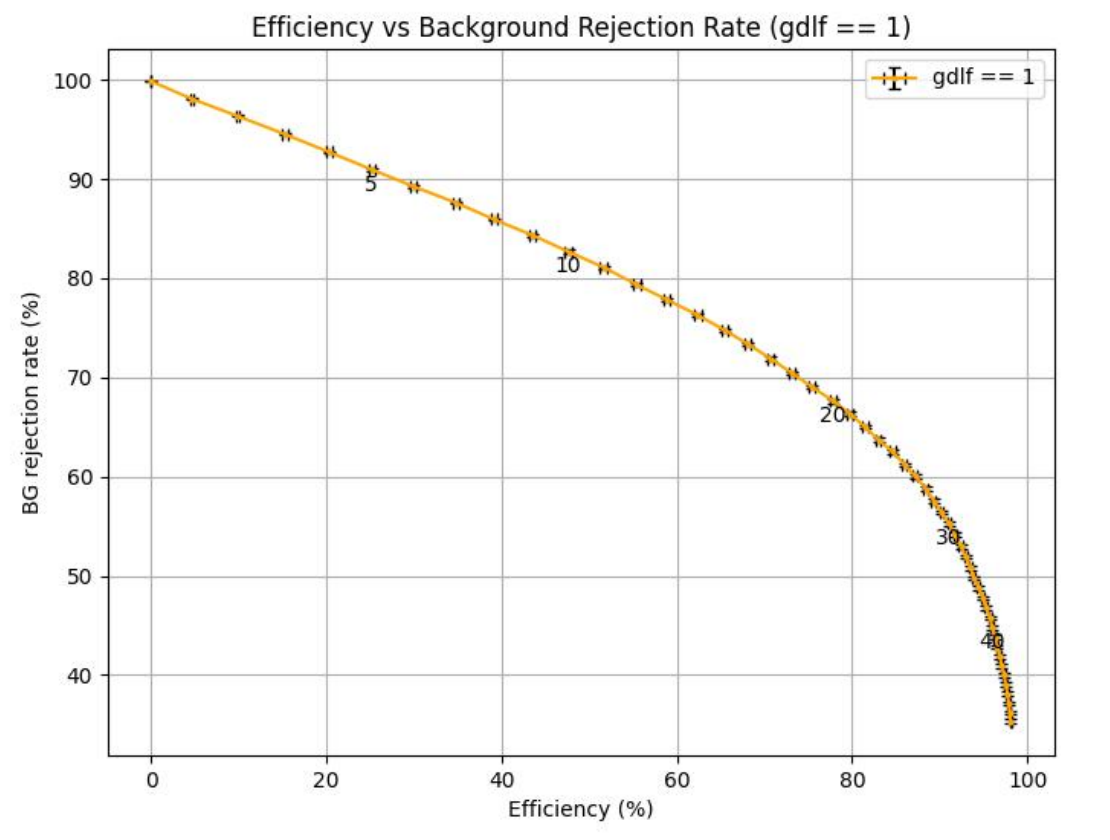
DQM plot of CDC







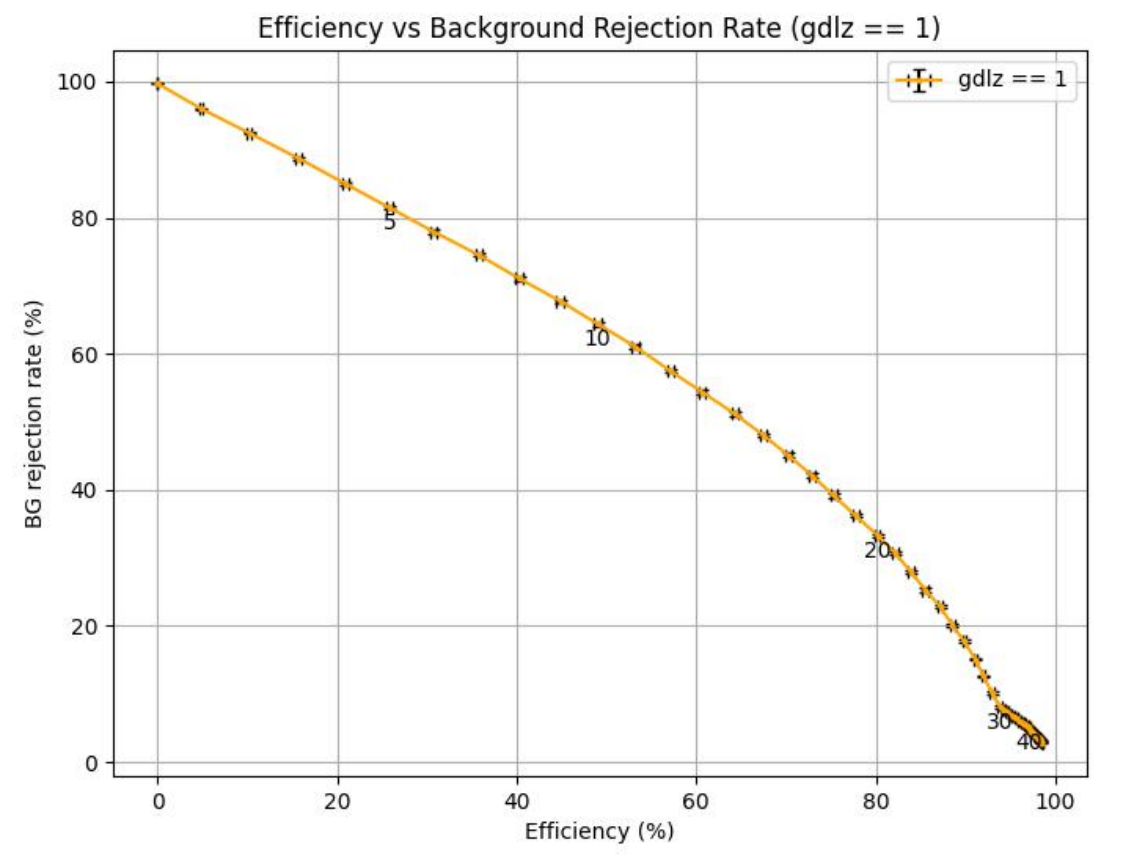
Efficiency vs BKG rejection rate



I will add the explaination of each bit later

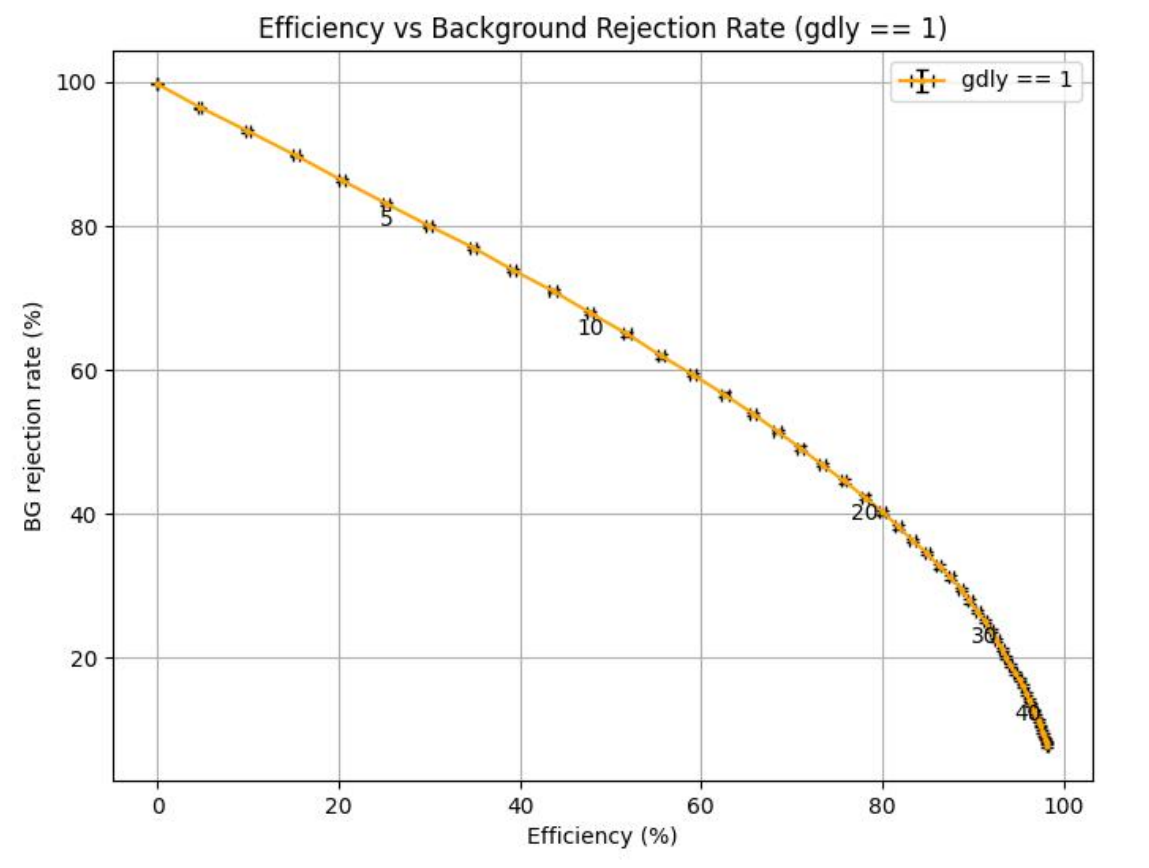
condition gdlf == 1 and trgZ0 cut = 30 cm:
Efficiency: 91.06% ± 0.23%
Background rejection rate: 55.27% ± 0.20%

Efficiency vs BKG rejection rate



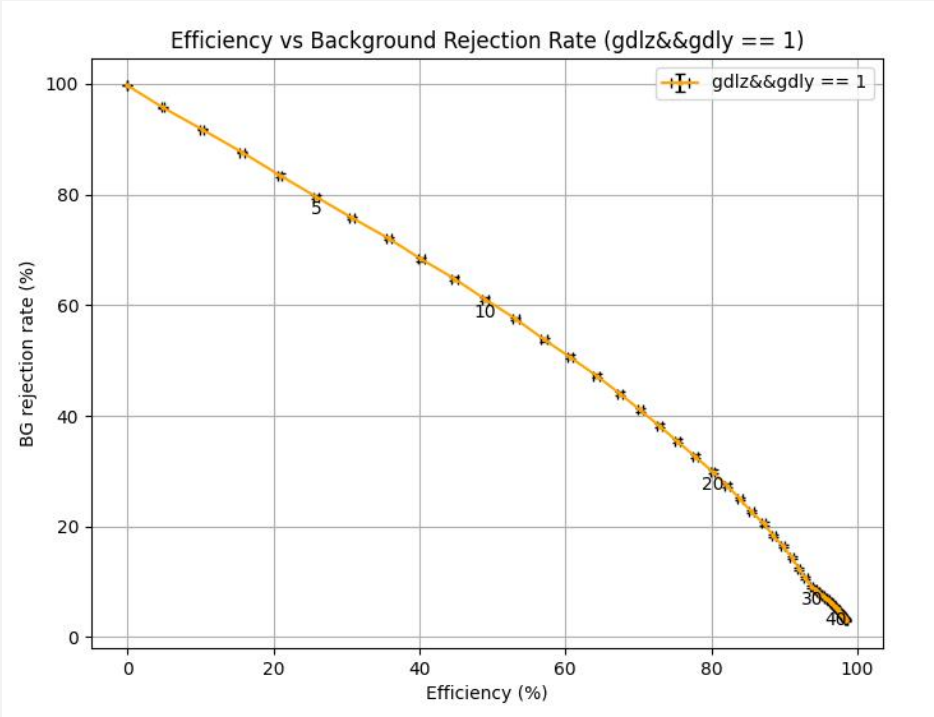
condition gdlz == 1 and trgZ0 cut = 30 cm:
Efficiency: 93.82% ± 0.19%
Background rejection rate: 8.10% ± 0.16%

Efficiency vs BKG rejection rate



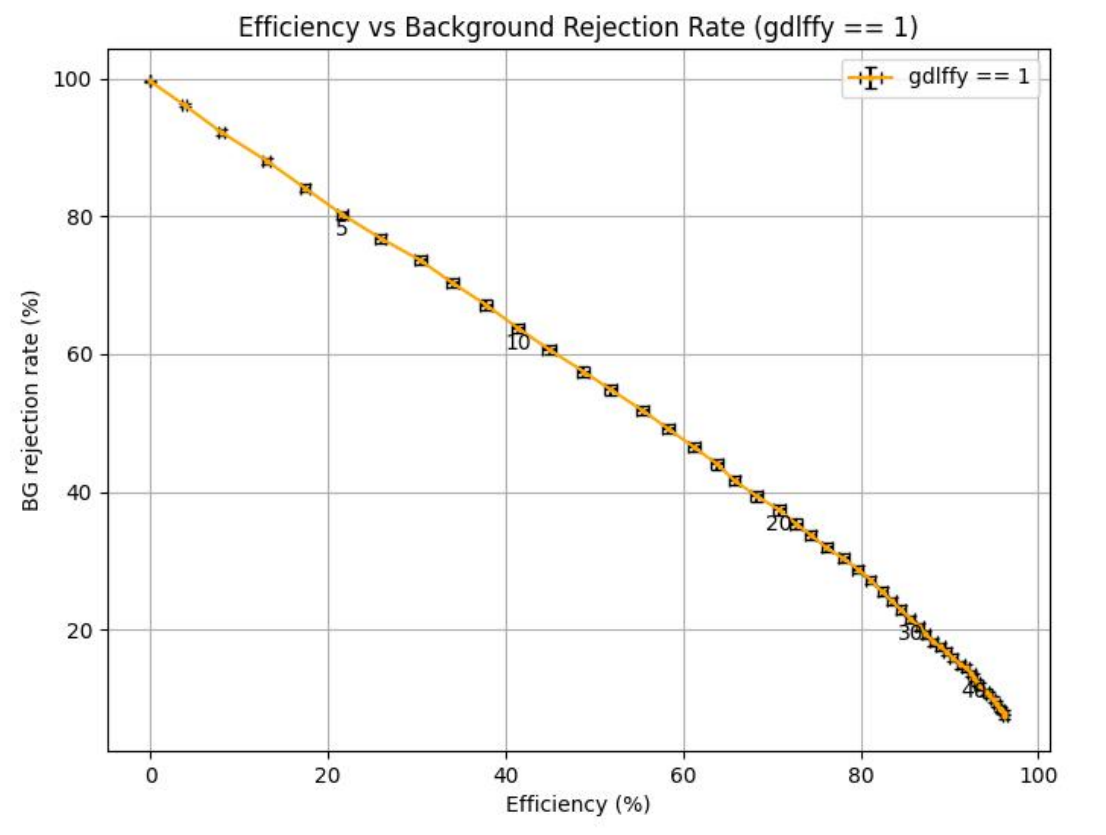
condition gdly == 1 and trgZ0 cut = 30 cm:
Efficiency: 91.33% ± 0.22%
Background rejection rate: 25.10% ± 0.27%

Efficiency vs BKG rejection rate



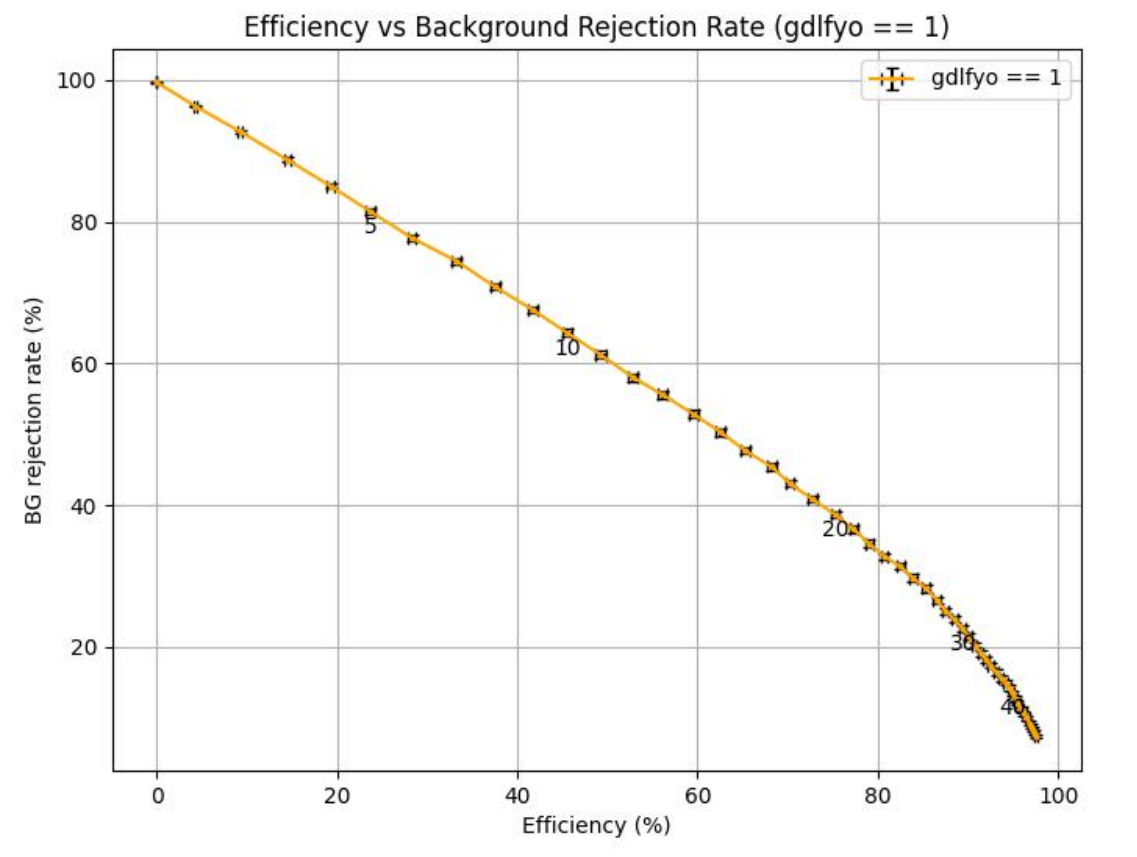
condition gdlz&&gdly == 1 and trgZ0 cut = 30 cm:
Efficiency: 93.75% ± 0.20%
Background rejection rate: 9.16% ± 0.20%

Efficiency vs BKG rejection rate



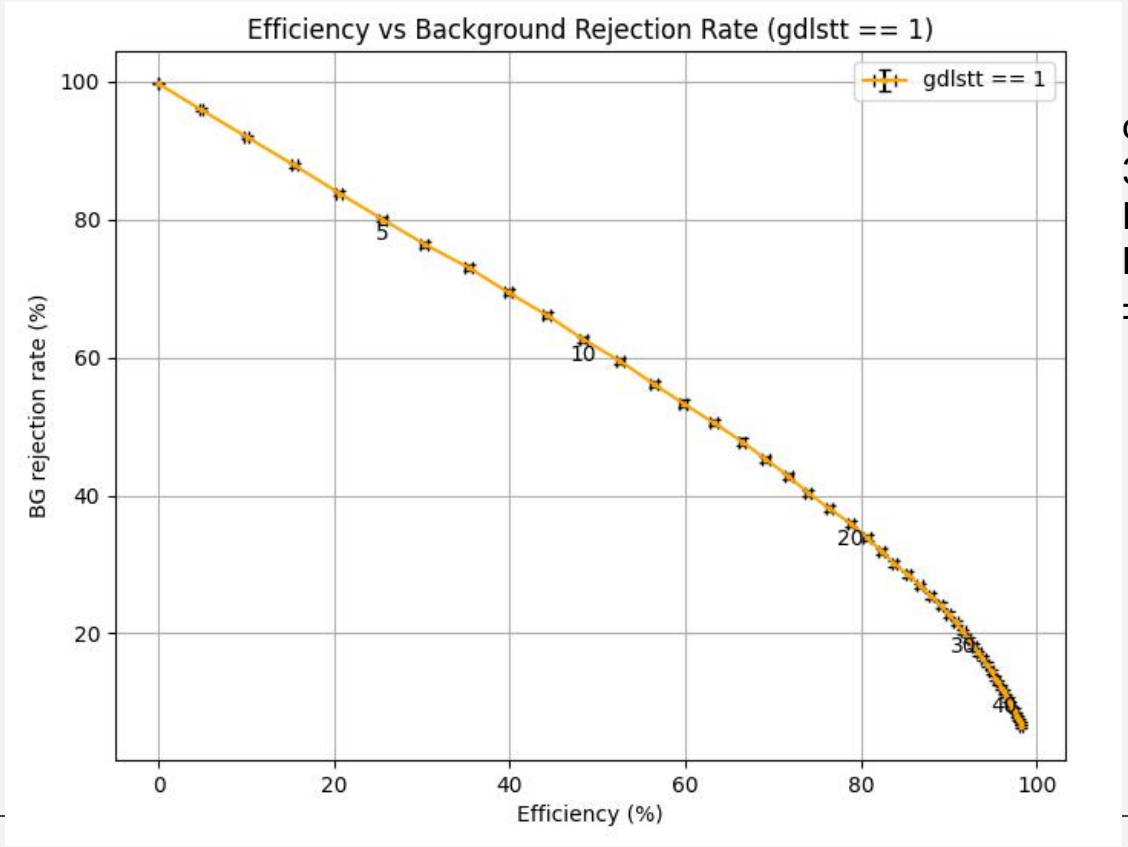
condition gdlfy == 1 and trgZ0 cut = 30 cm:
Efficiency: 85.60% ± 0.50%
Background rejection rate: 21.52% ± 0.59%

Efficiency vs BKG rejection rate



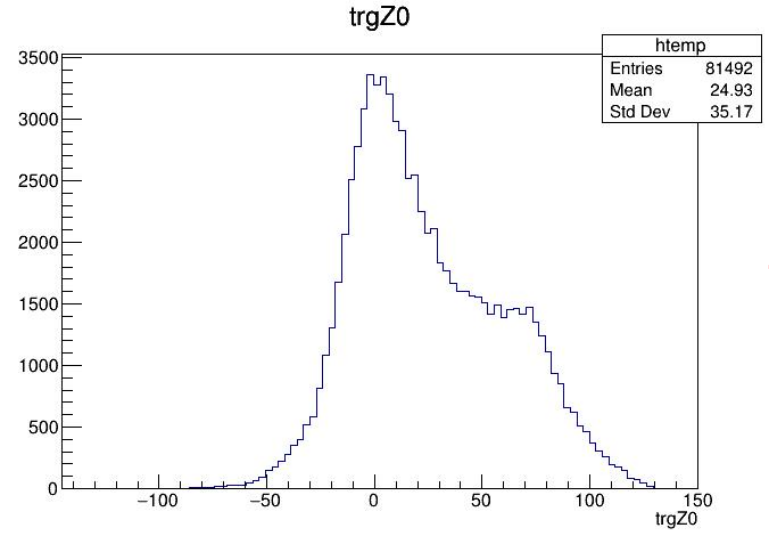
condition gdlfyo == 1 and trgZ0 cut = 30 cm:
Efficiency: 89.46% ± 0.34%
Background rejection rate: 22.54% ± 0.43%

Efficiency vs BKG rejection rate

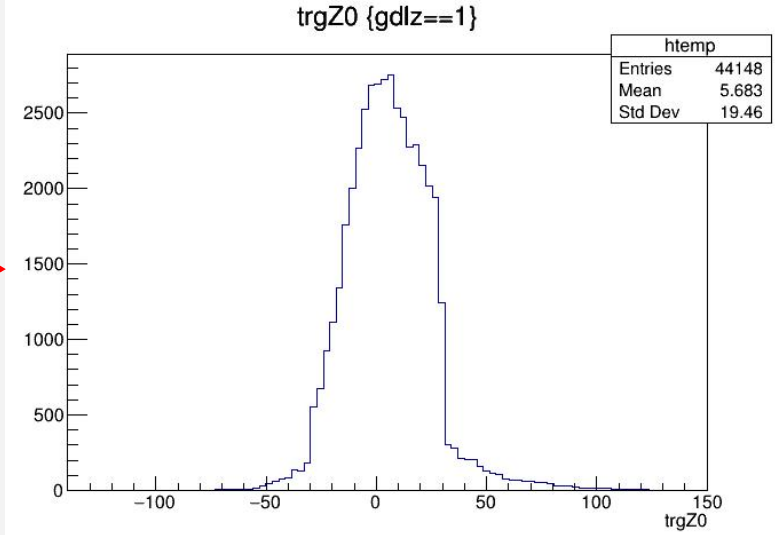


condition gdlstt == 1 and trgZ0 cut = 30 cm:
Efficiency: 91.66% ± 0.25%
Background rejection rate: 20.26% ± 0.37%

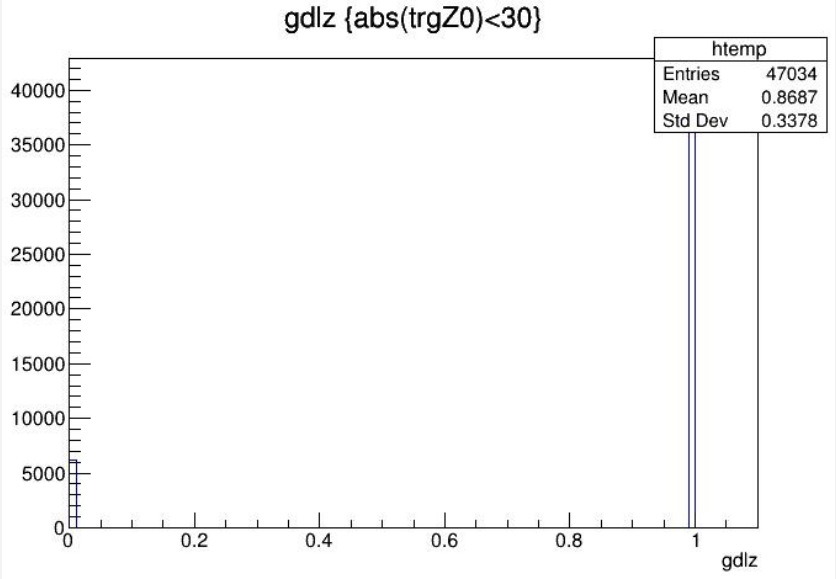
Check for trigger bit Z(3D, Z0 < 30 cm)

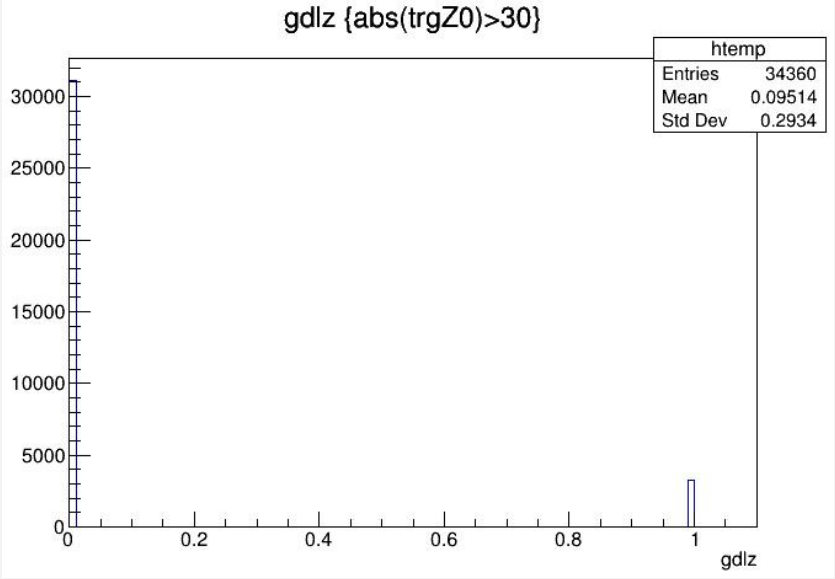


require
gdlz=1



Check for trigger bit Z(3D, Z0 < 30 cm)

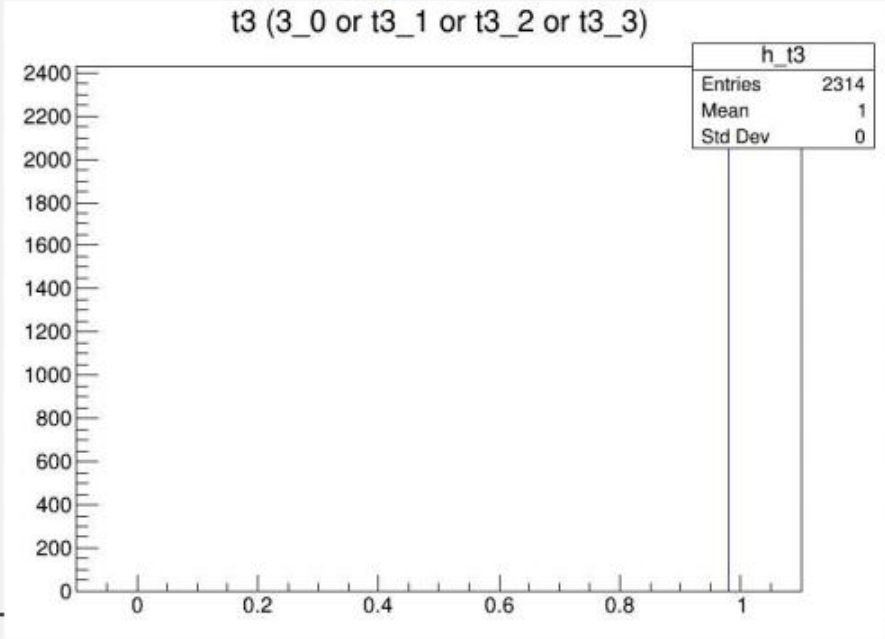




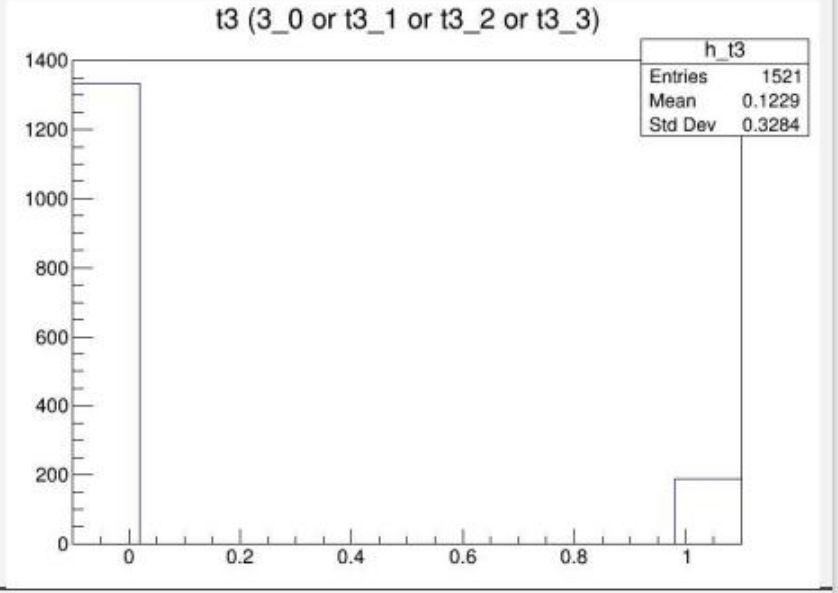
trigger bit t3(t3_0 or t3_1 or t3_2 or t3_3)

when abs(trgZ0)<30, all of them are 1, it is correct

abs(trgZ0)<30



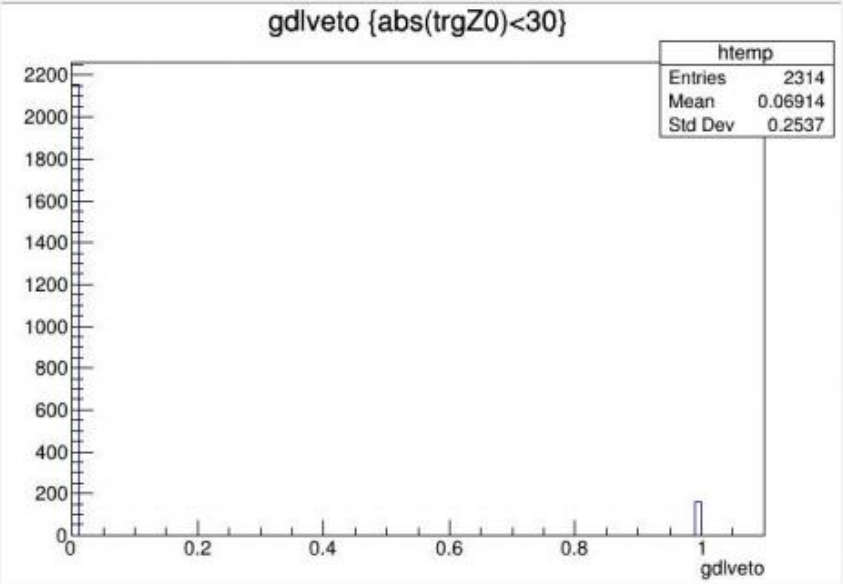
abs(trgZ0)>30



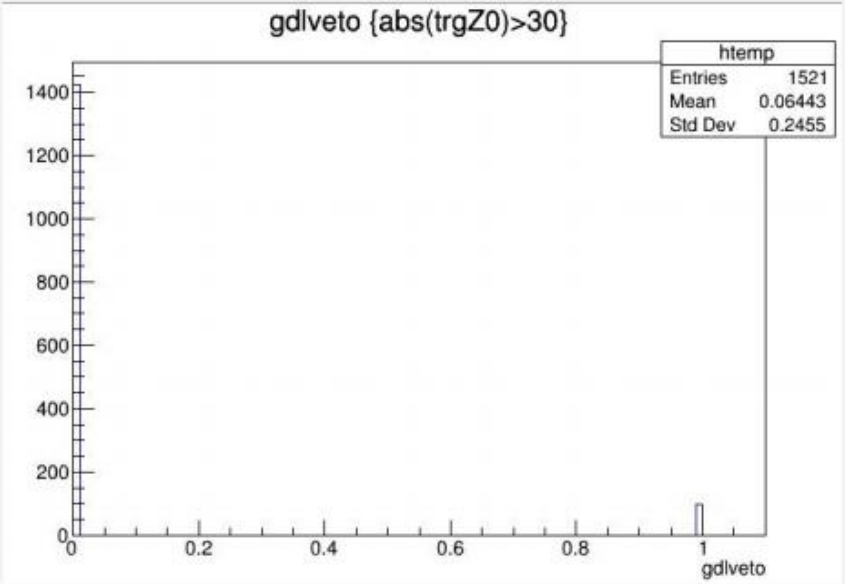
trigger bit veto

cannot get pure 0 or 1, z =()&!veto, so when z =1, veto should be 0

abs(trgZ0)<30



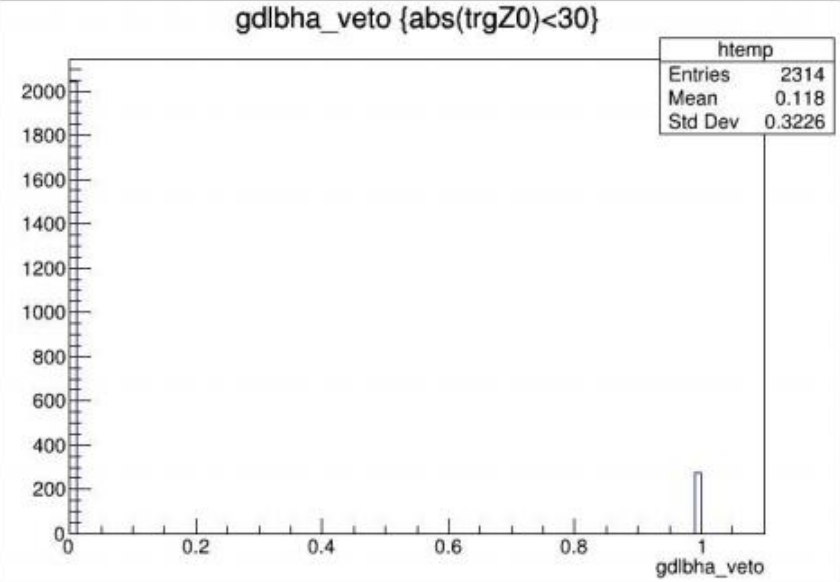
abs(trgZ0)>30



trigger bit bha_veto

cannot get pure 0 or 1,becasue z =()&!bha_veto, so when z =1, bha_veto should be 0

abs(trgZ0)<30



abs(trgZ0)>30