CDCTRG 3D fitter

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Review

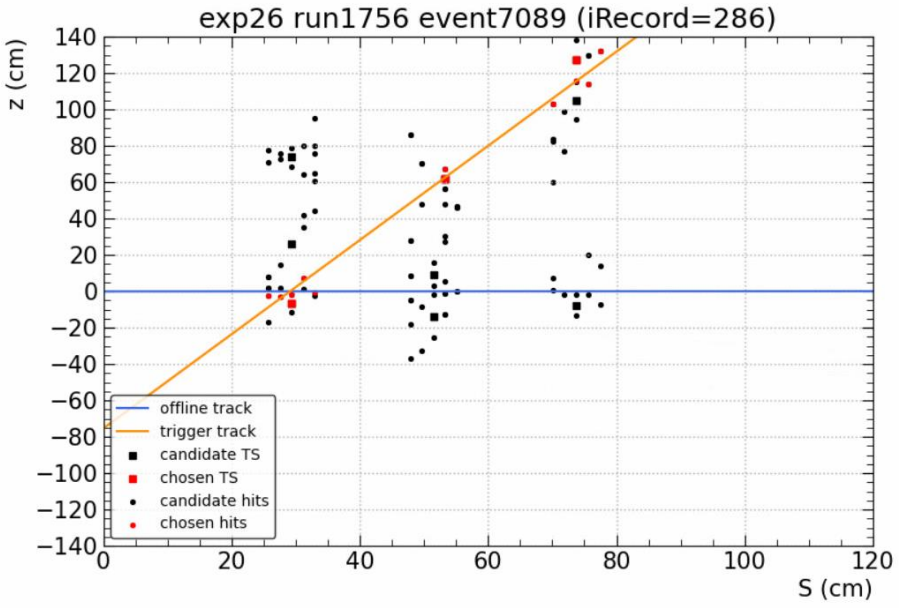
- Motivation
  - To reduce trigger rate, I want to **improve BG rejection rate** while **keeping efficiency.**
- So far I tried
  - Drift correction, ADC, hit selecting
  - Full hit (use all wires, not only priority wire)
- Now I’m trying
  - Voting (like 2D Hough voting)

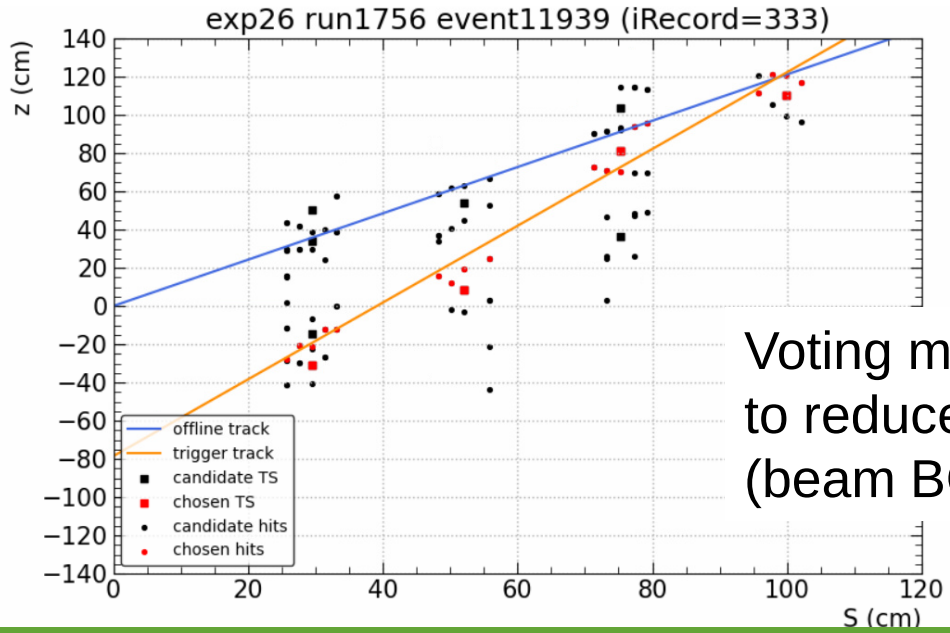
Fitter (Full hit)

- **Problem: Low efficiency** due to wrong selecting
  - Current selecting method
    - Fit using all TSs
    - Repeat “removing farthest TS -> fit” until 4 TS are selected
    - Fit using hits in selected TS
- Bad examples

3D efficiency = 85.90 %
BG rejection rate = 46.30 %
Fake track rejection rate = 85.77 %

Fitter (full hit)		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	5836	745	213
	$\lvert z_0 \rvert > 1$ (BG)	2265	1859	94
	no track	535	2781	443

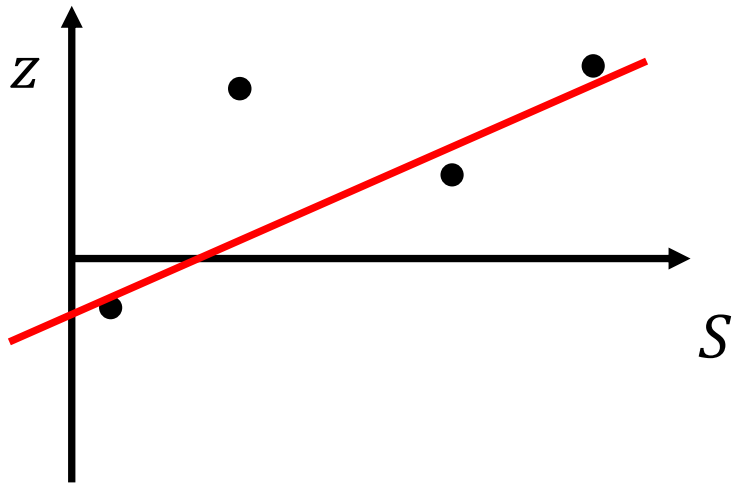




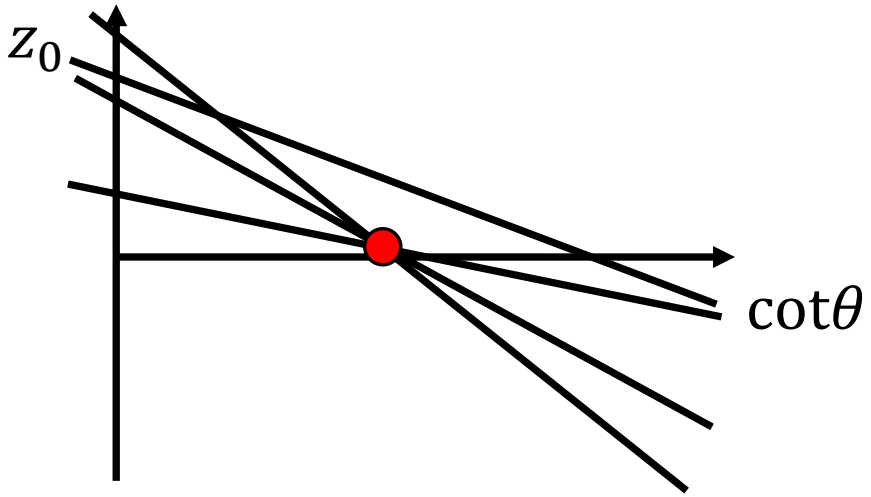
Voting method would be useful to reduce noise hits (beam BG, hits of nearby track)

Voting

Fitting



Voting



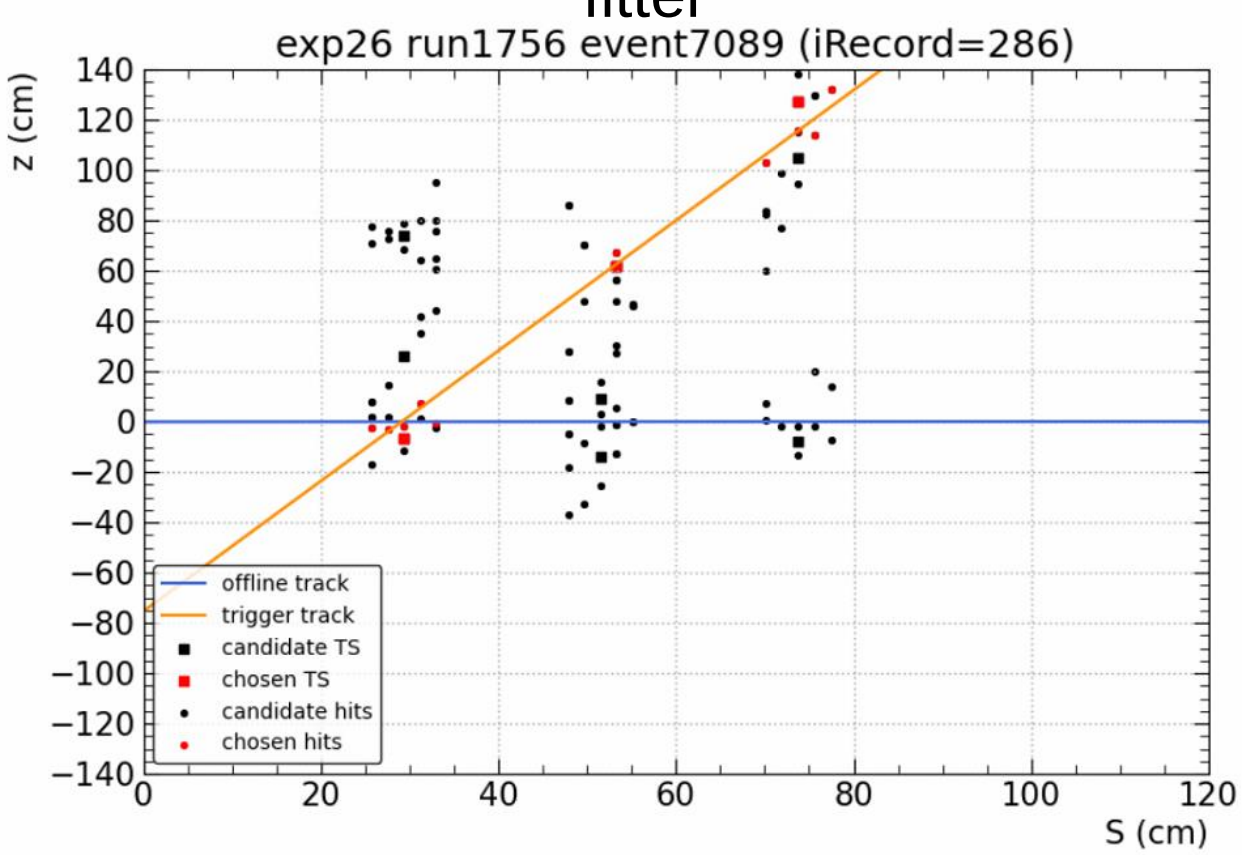
$$z_{hit} = +\cot\theta \cdot S_{hit} + z_0$$

$$z_0 = -S_{hit} \cdot \cot\theta + z_{hit}$$

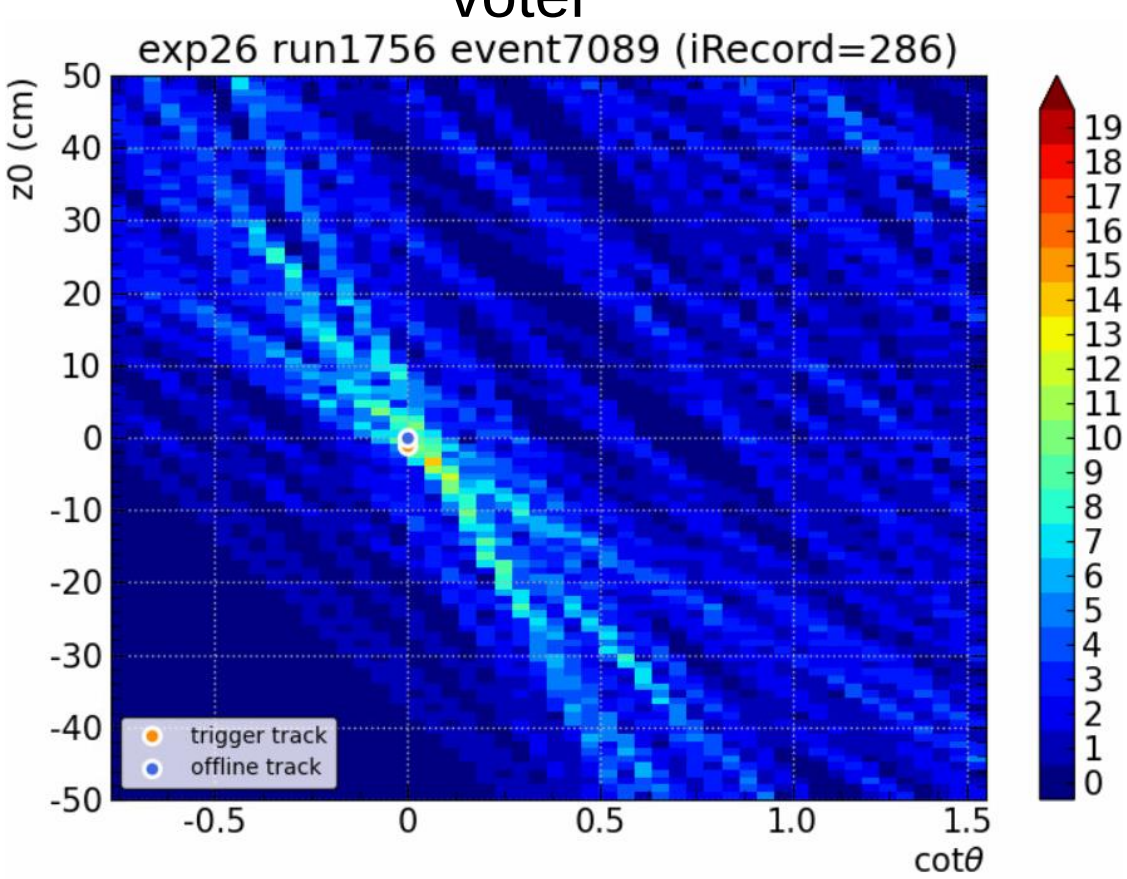
Merit: Noise doesn't affect the correct point

Voting

fitter

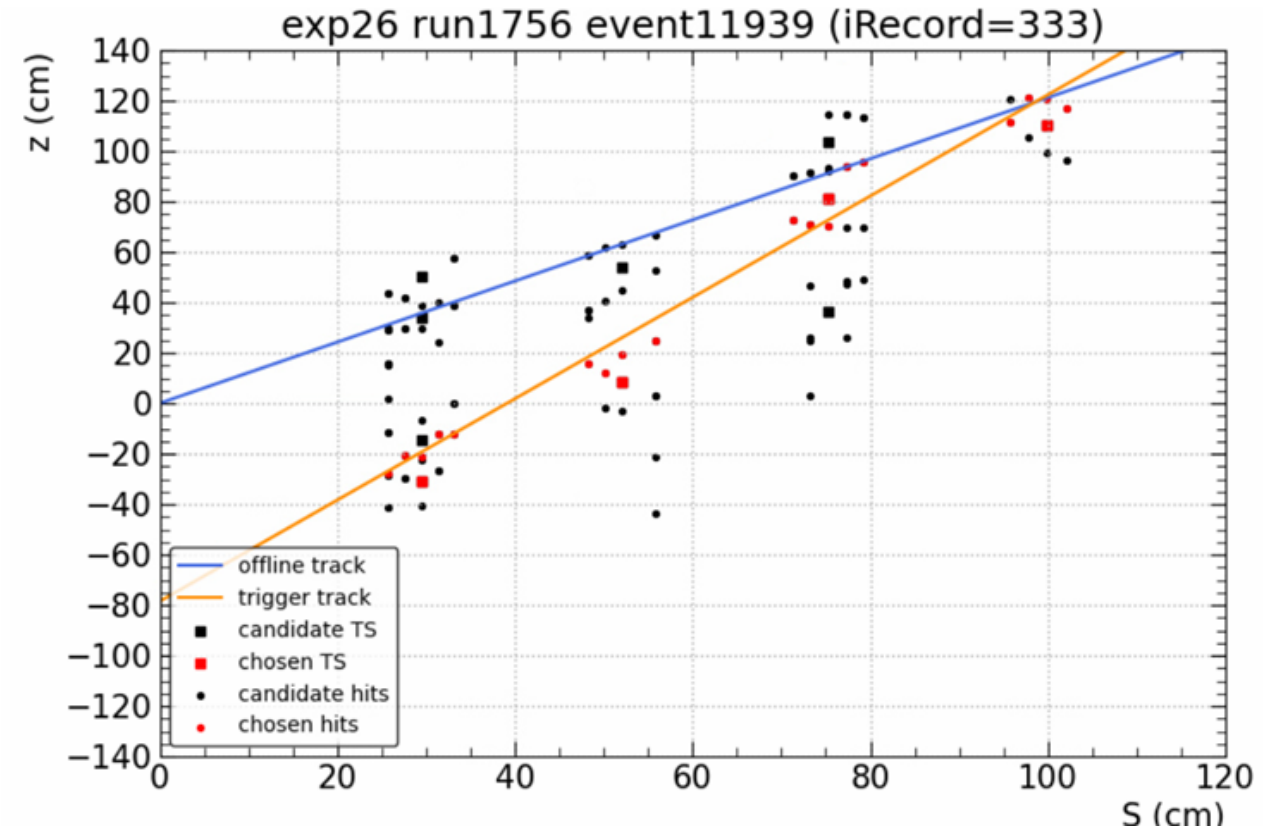


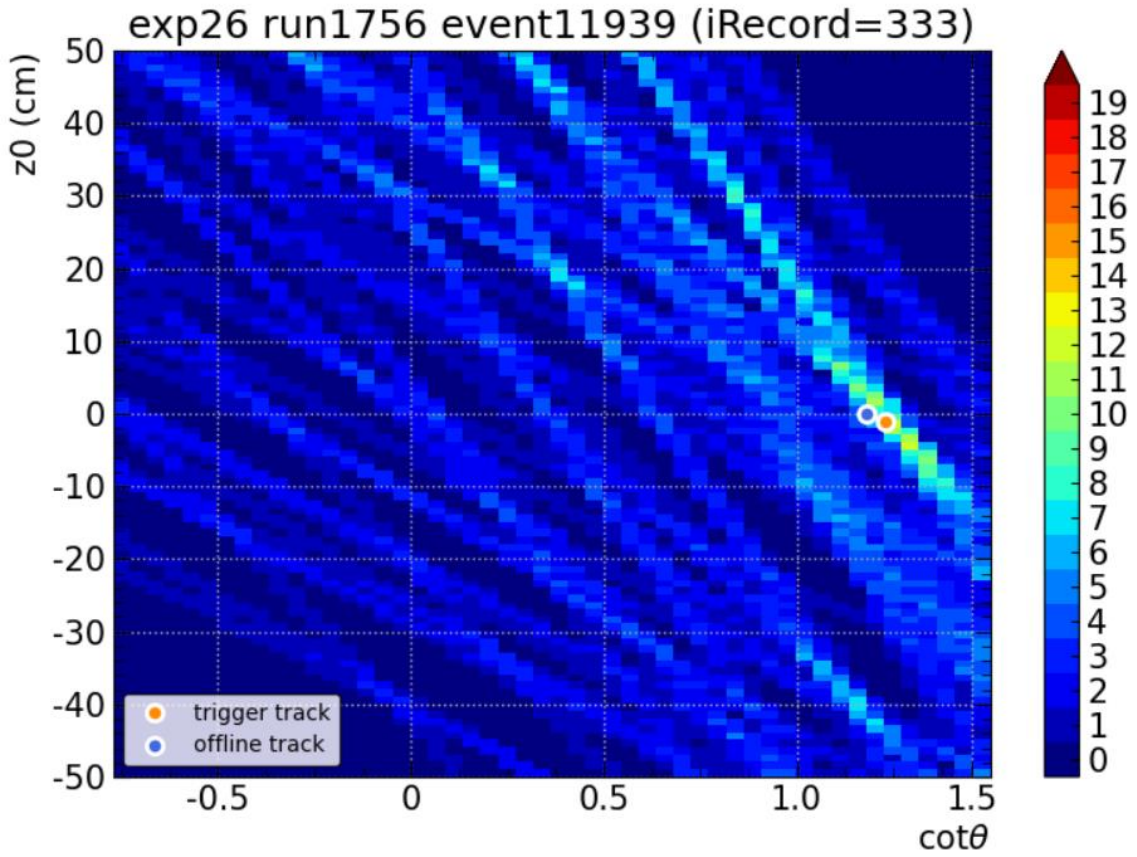
voter



Voter is better at choosing hits

Voting

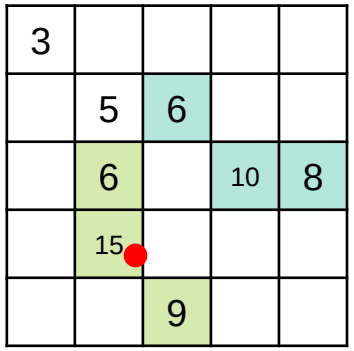

exp26 run1756 event11939 (iRecord=333)
z (cm)
S (cm)
offline track
trigger track
candidate TS
chosen TS
candidate hits
chosen hits


exp26 run1756 event11939 (iRecord=333)
z0 (cm)
cotθ
trigger track
offline track

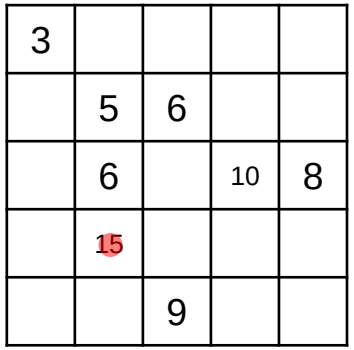
Voting

- Cell size = 100 x 50 ($z_0 \in [-50, 50]\mathrm{cm},\ \cot\theta \in [-0.8, 1.5]$)
  - 5000 is same order as 2D Hough
  - Optimization is not done yet

- Peak finding
  - **A) clustering**
    - Threshold for peak candidate = 6
    - Assume ↘ shaped cluster
    - No cluster size limit
    - Result is center of mass of the most voted cluster
  - **B) Maximum**
    - Result is most voted cell
  - **C) Voting(clustering) + fitter**
    - Select hits near voter's result and fit
  - **D) Voting(maximum) + fitter**

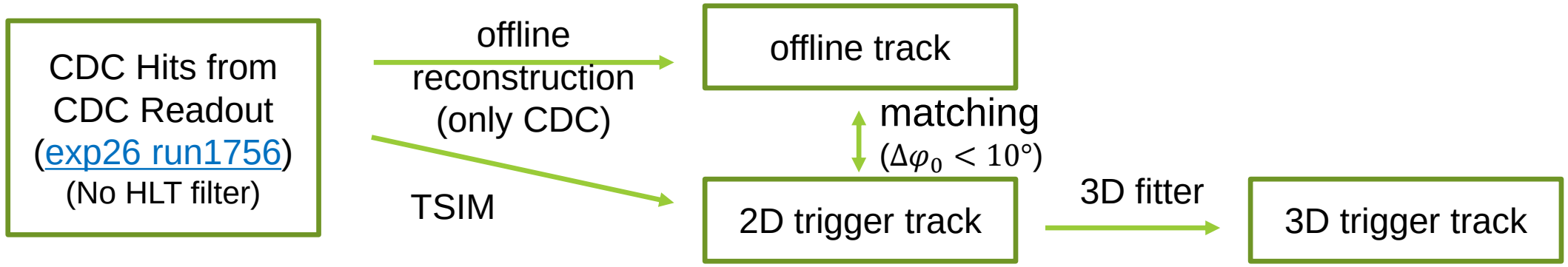


clustering

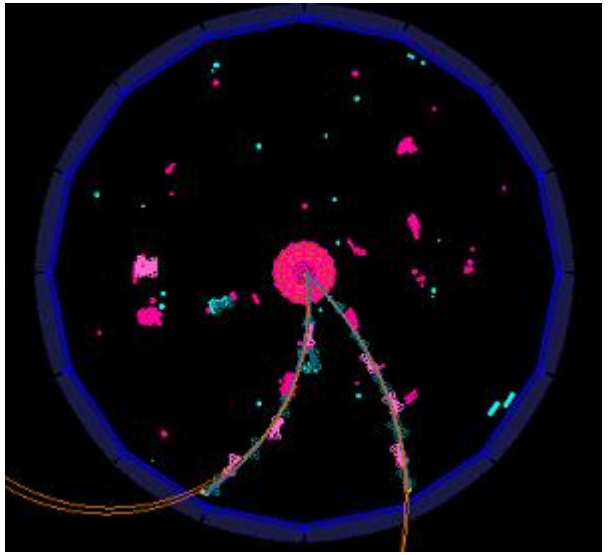


maximum

Reconstruction and Selection



- Track Level Selection (after matching):
  - Exclude unreconstructed offline tracks(no 2D case)
  - Exclude short tracks (2D and offline)
    - short track := !(offlineTrack.getTransverseMomentum() > 0.3
      && offlineTrack.getHitPatternCDC().getLastLayer() > 50
      && offlineTrack.getHitPatternCDC().getFirstLayer() < 5)
  - Exclude overcounting 2D tracks



Performance index

Categorization for matched tracks

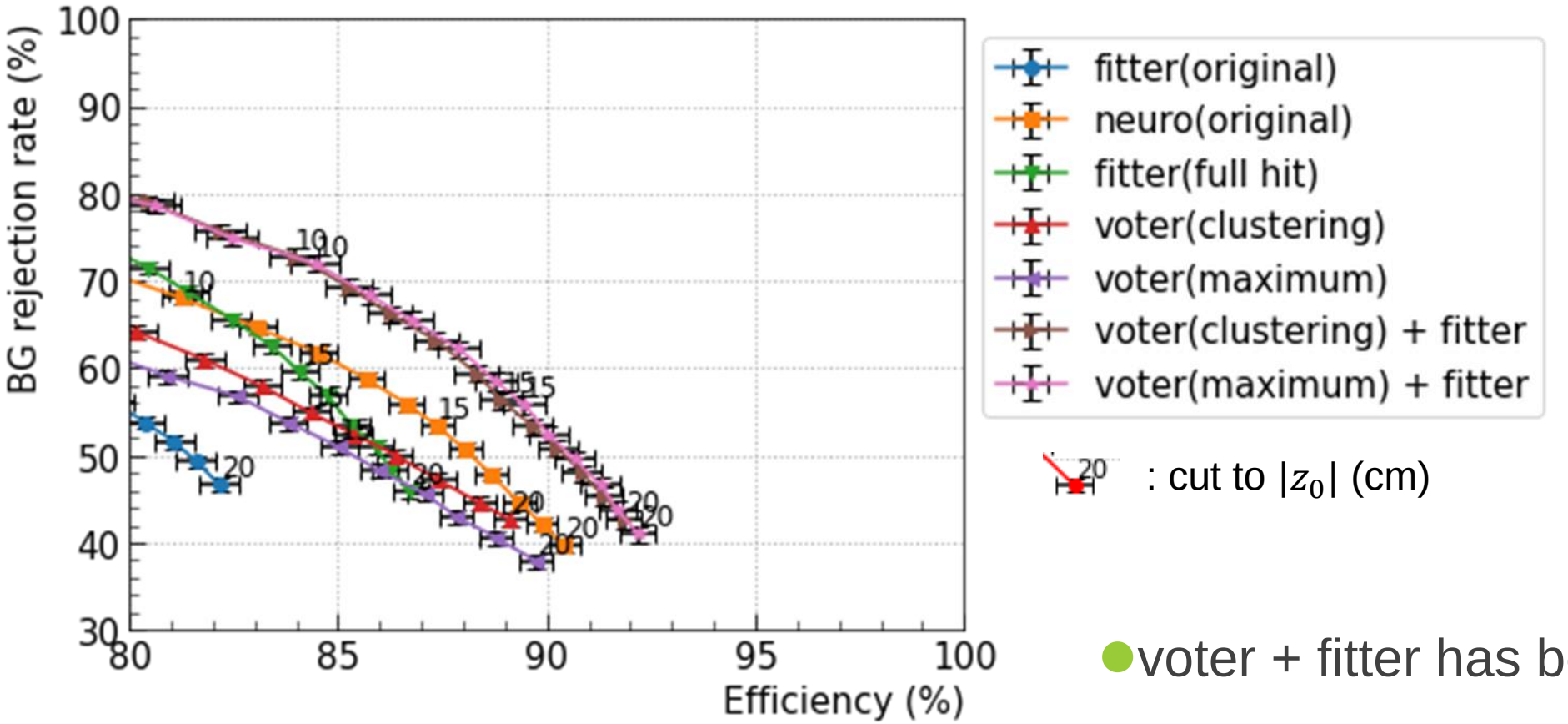
		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (failed 3D tracking)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	signal	loss	loss
	$\lvert z_0 \rvert > 1$ (BG)	BG	rejected BG	rejected BG
	no track	fake	rejected fake	rejected fake

Performance index

3D efficiency := #(signal) / #(signal offline track)

BG rejection rate := #(rejected BG) / #(BG offline track)

Performance

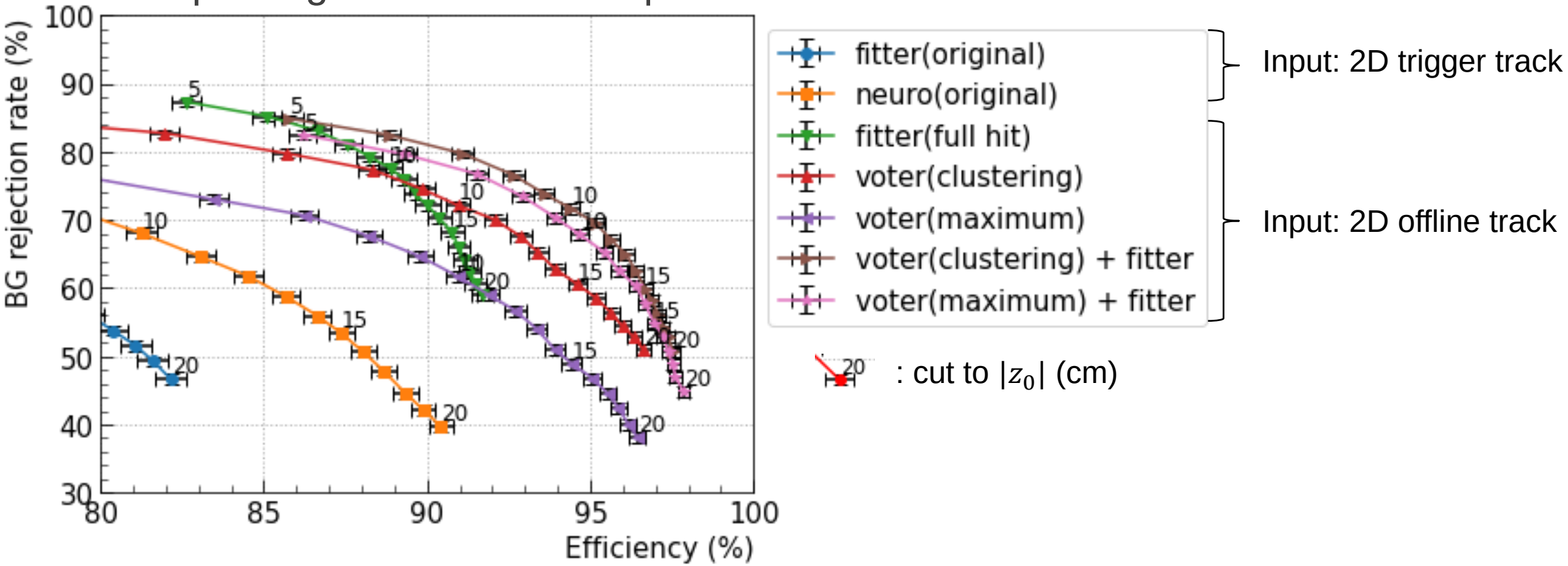


- voter + fitter has best performance

(error bar is based on 68% Clopper-Pearson confidence interval)

Performance

- If input 2D track becomes more accurate, performance becomes better.
  -> Improving 2D fitter is one option.



(error bar is based on 68% Clopper-Pearson confidence interval)

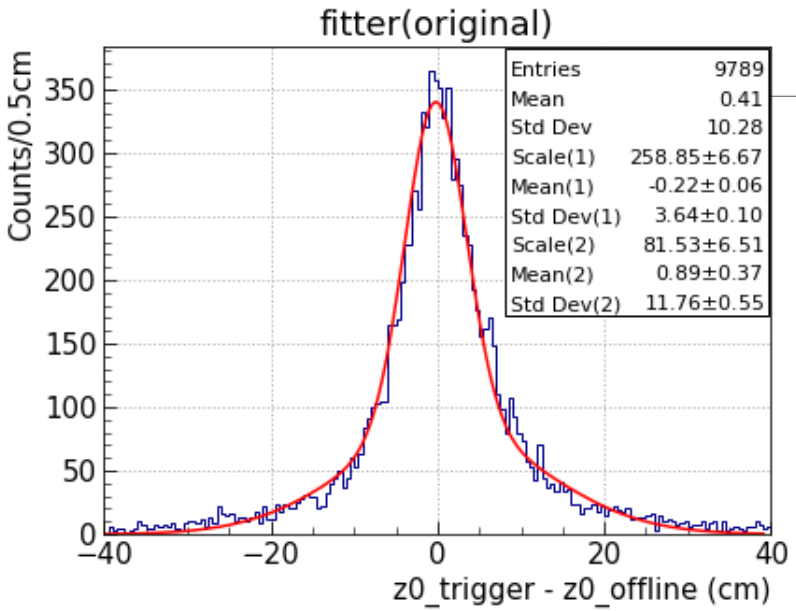
Summary

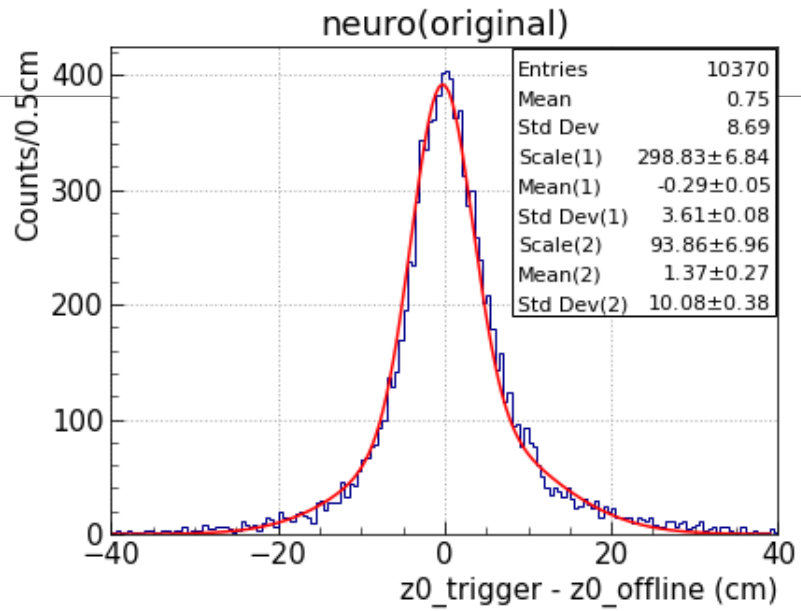
- I tried some voting methods to reduce noise hits.
- **voter + fitter** has best performance

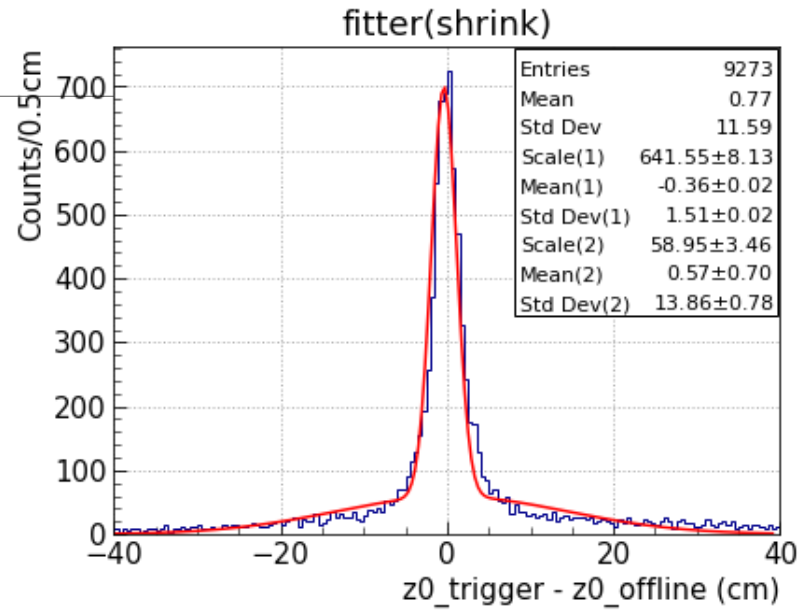
- I can do
  - ☐ cell size optimization
  - ☐ improving 2D fitter

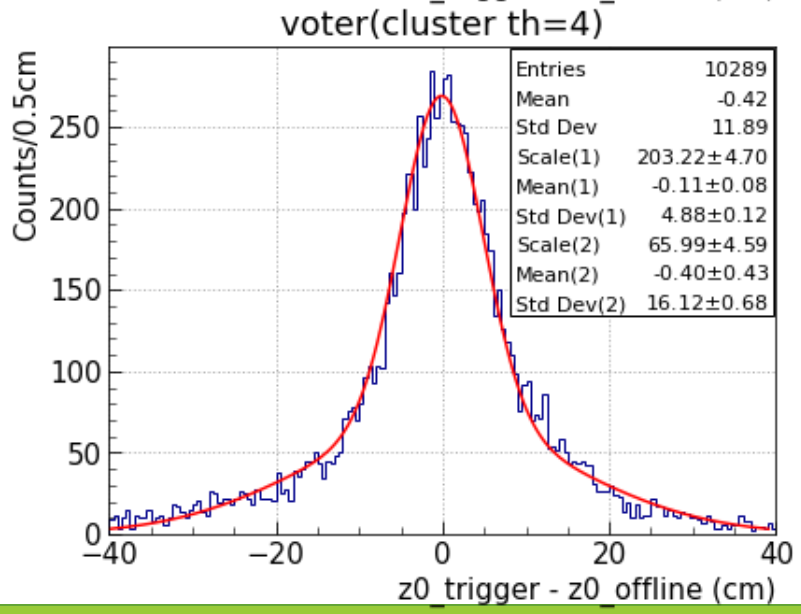
Backup

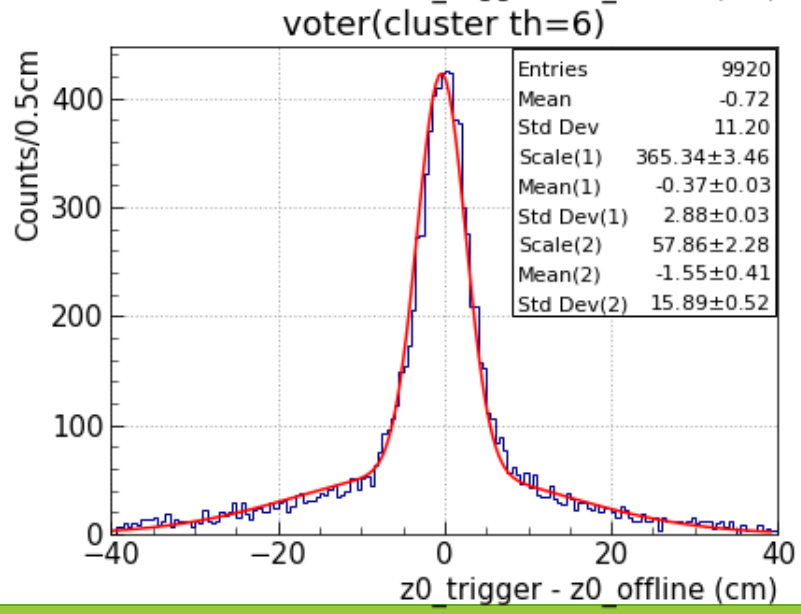
z_0 resolution (input: offline2D)

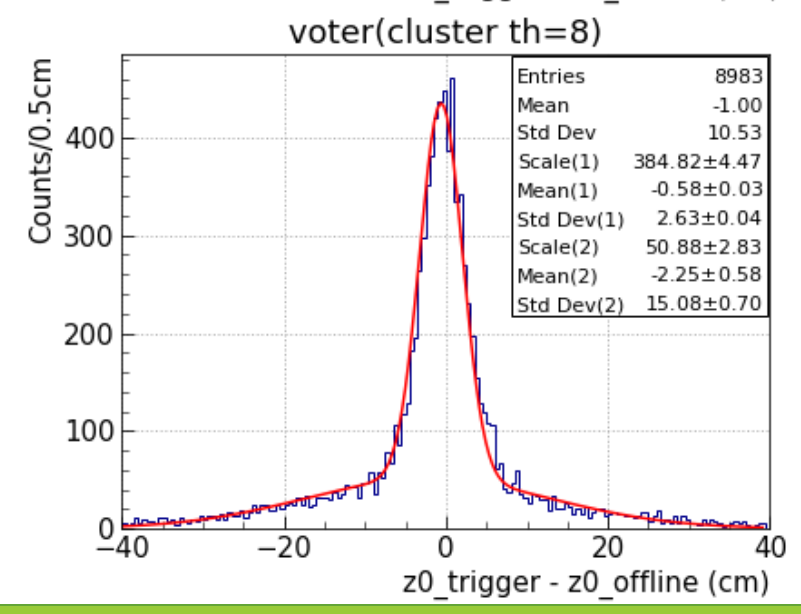




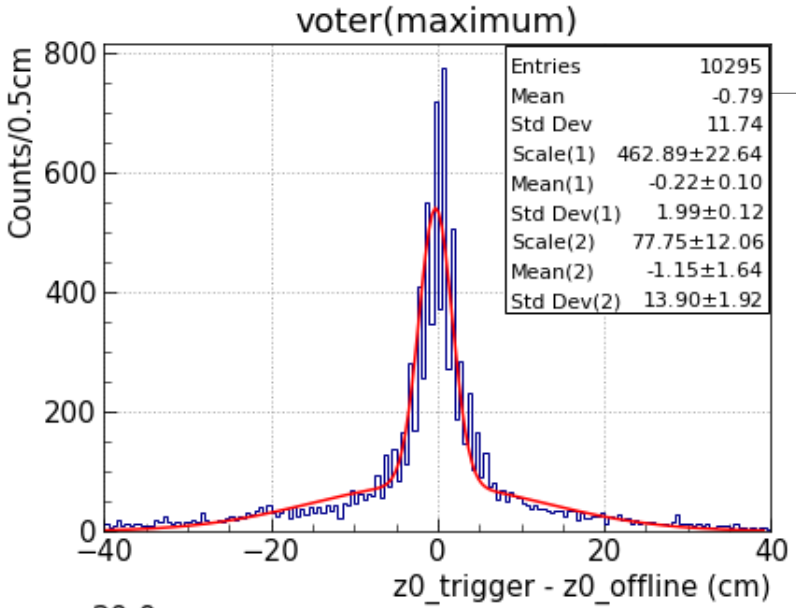


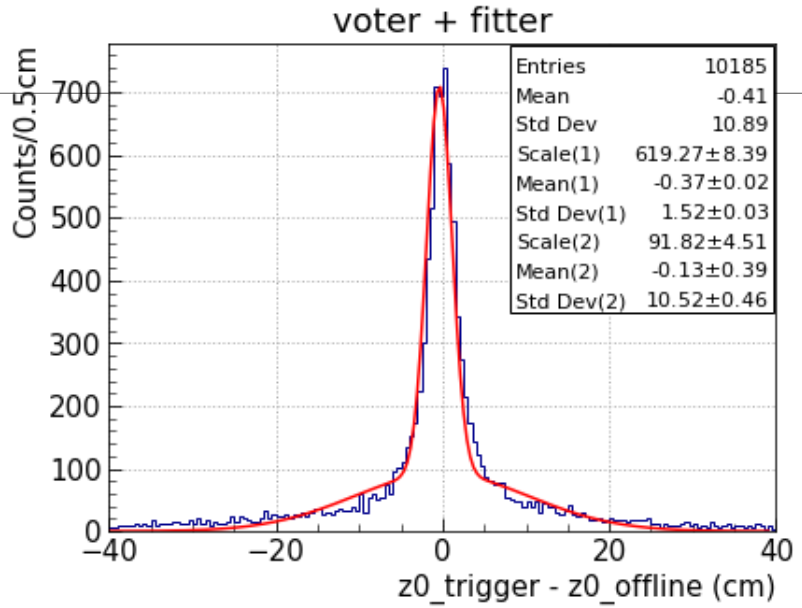


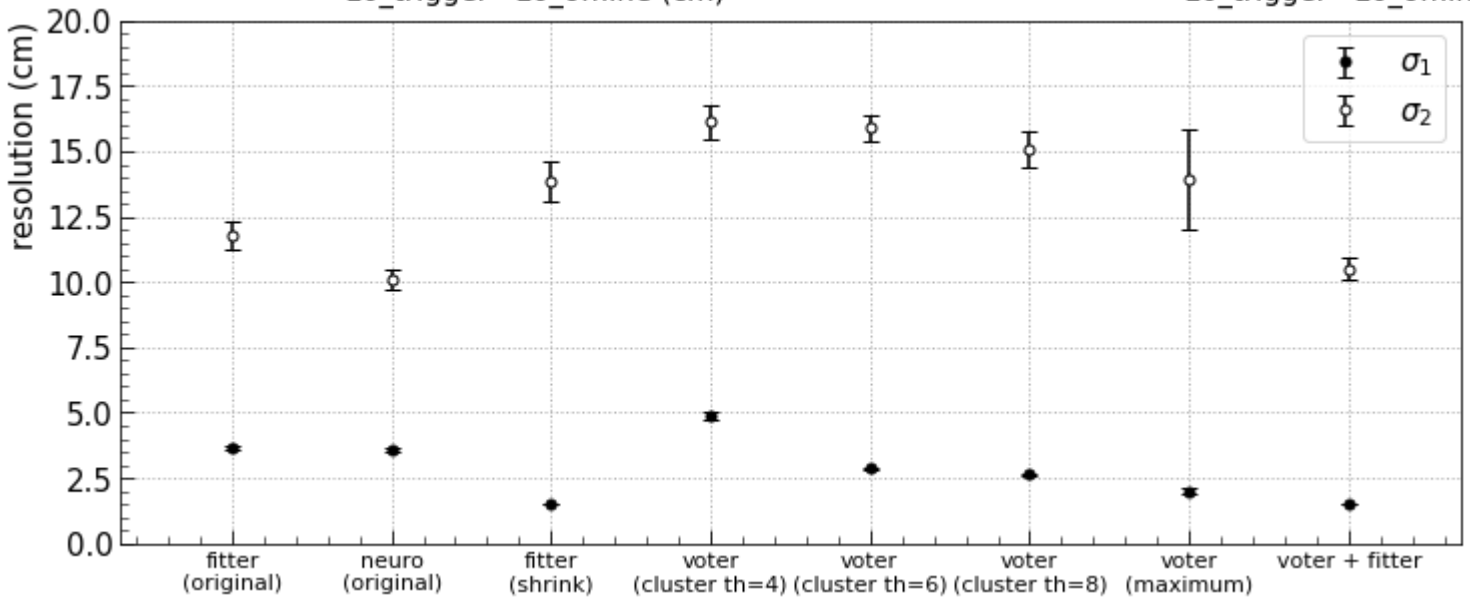




z_0 resolution (input: offline2D)

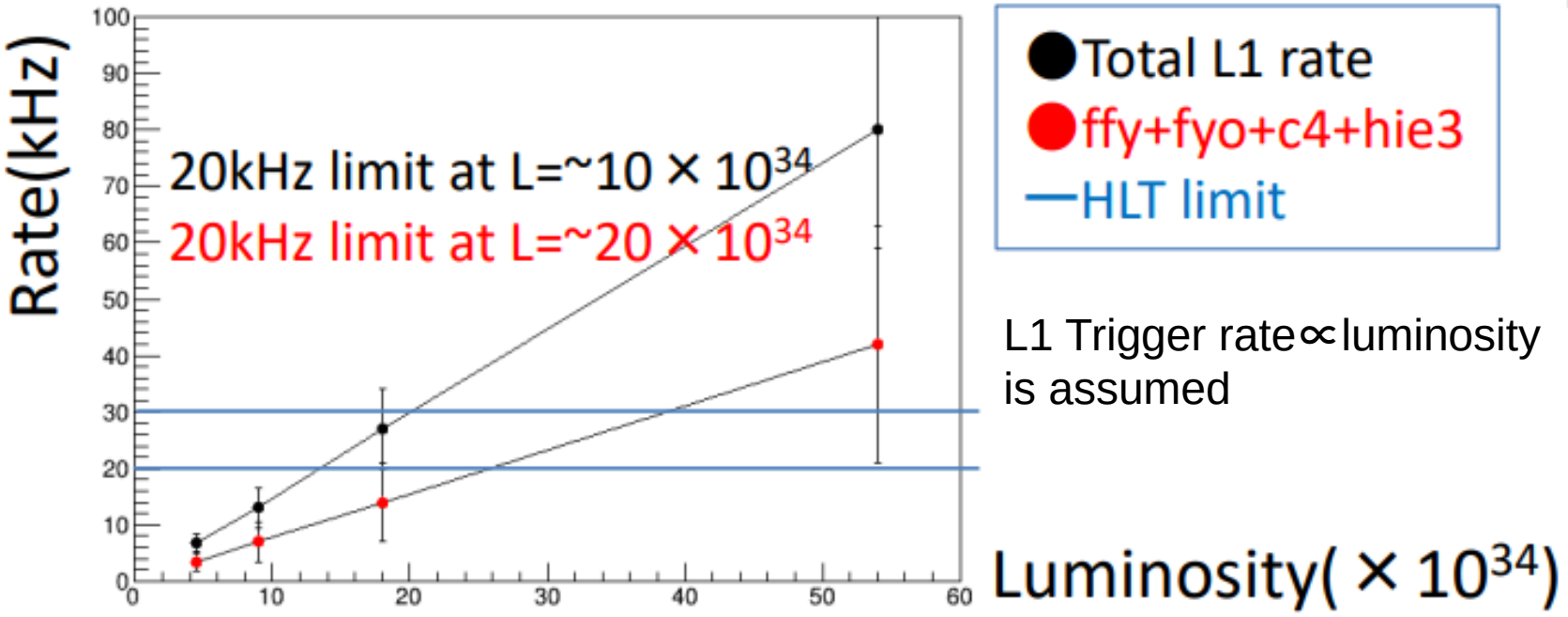






Trigger Rate

- このままのパフォーマンスだと、L1 Trigger Rateはtarget luminosityに到達する前にDAQの処理速度の上限(30 kHz)に達してしまう



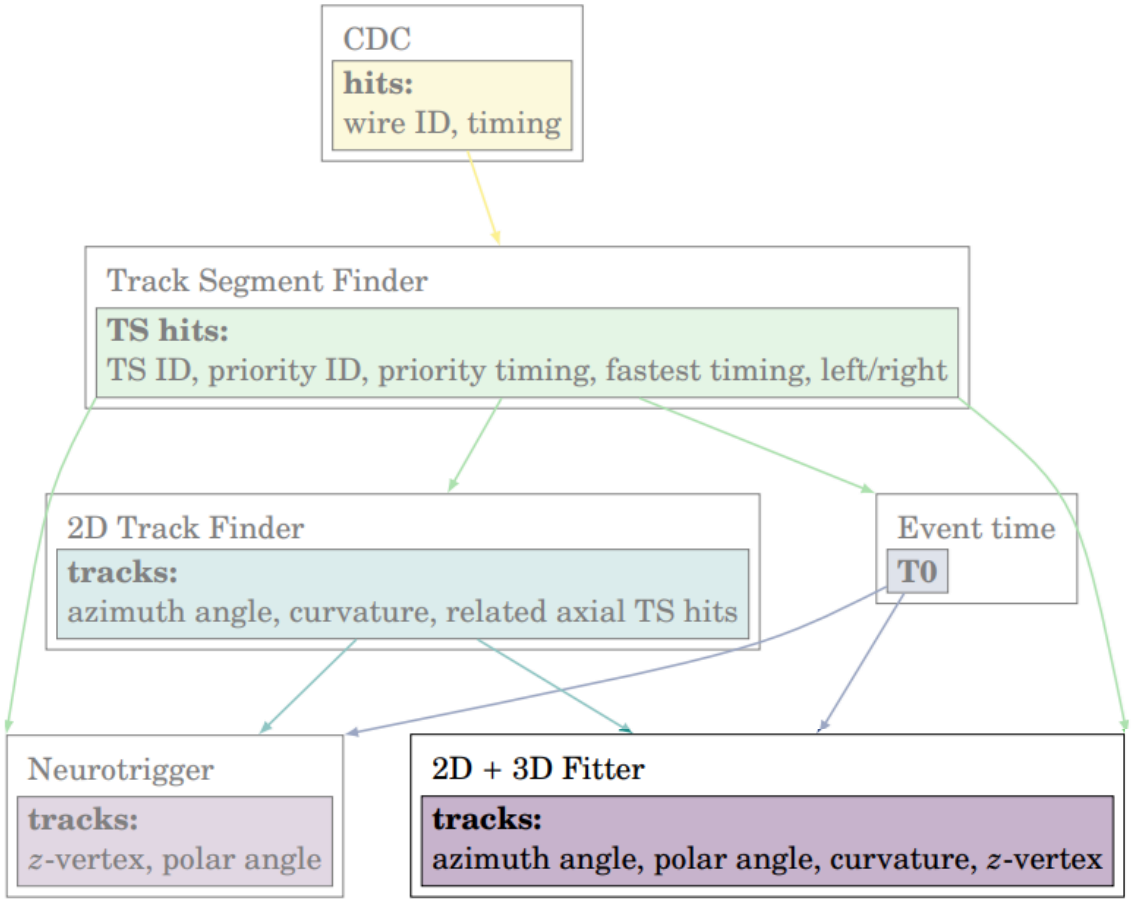
T.Koga
TRG/DAQ Workshop

Event categorization

			Exp26 Run1756 @peak luminosity $=2.3\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$			Exp26 Run1261 @peak luminosity $=4.6\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	
		Definition	Ratio (%)	Trigger Rate (kHz)		Ratio (%)	Trigger Rate (kHz)
Triggered by CDC trigger (ffy OR fyo OR stt)	1. Signal	Not BG, fake track	15.2%	0.61		18.7%	2.13
	2. BG from large z	#(offline with |z0|>1cm) > 0 AND #(offline with |z0|<1cm) == 0	4.3%	0.17		8.3%	0.95
	3. Fake track	#(offline) == 0	1.8%	0.07		14.7%	1.67
Triggered by other trigger			78.7%	3.18		58.4%	6.66
	total		100%	4.04		100%	11.4

※ # of sampled events = 10000
※ HLT filtering is OFF in both runs.

CDC Triggerでできること

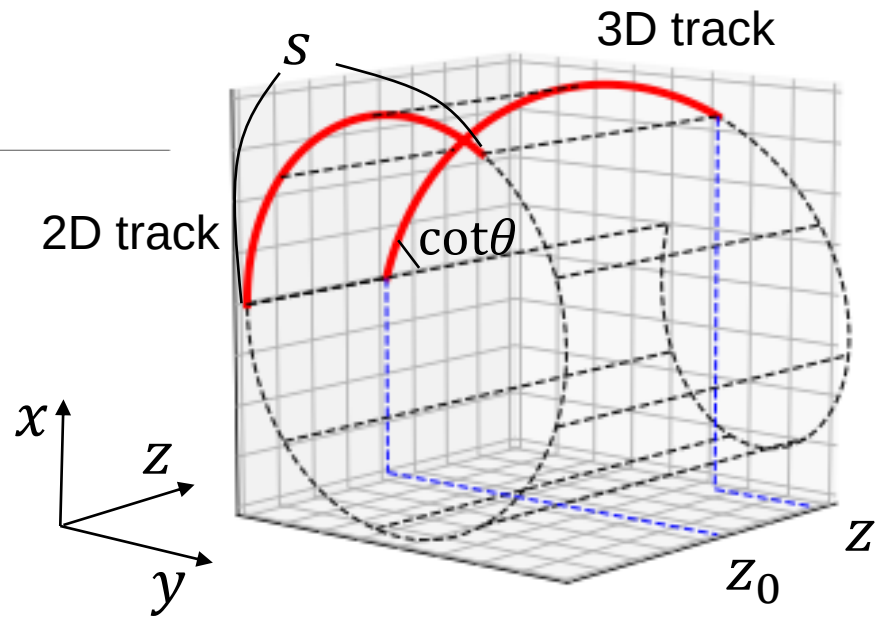


1. BG from large zを減らす
2. fake trackを減らす
3. z resolutionを良くする
   - 既存のアルゴリズムの改良
   - UT4への移行に伴うADC、full hitの活用

- 3D fitterに取り組む理由
  - Neuroよりも原理が単純なので問題点を見つけたりテストしたりしやすい

Algorithm

- As a property of a helix, $z(s) = \boldsymbol{\cot\theta} \cdot s + \boldsymbol{z_0}$



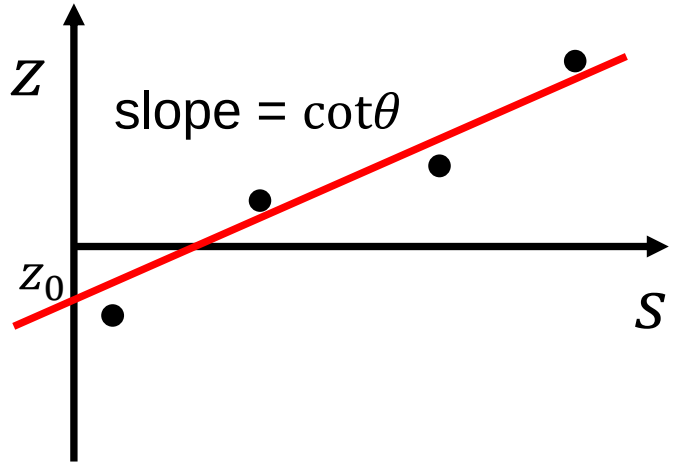
- Determine $\boldsymbol{z_0}$ and $\boldsymbol{\cot\theta}$ by minimizing χ^2.

$$\chi^2 = \sum_{i=1}^{4} \frac{(z_i - z(s_i))^2}{\sigma_i^2}$$

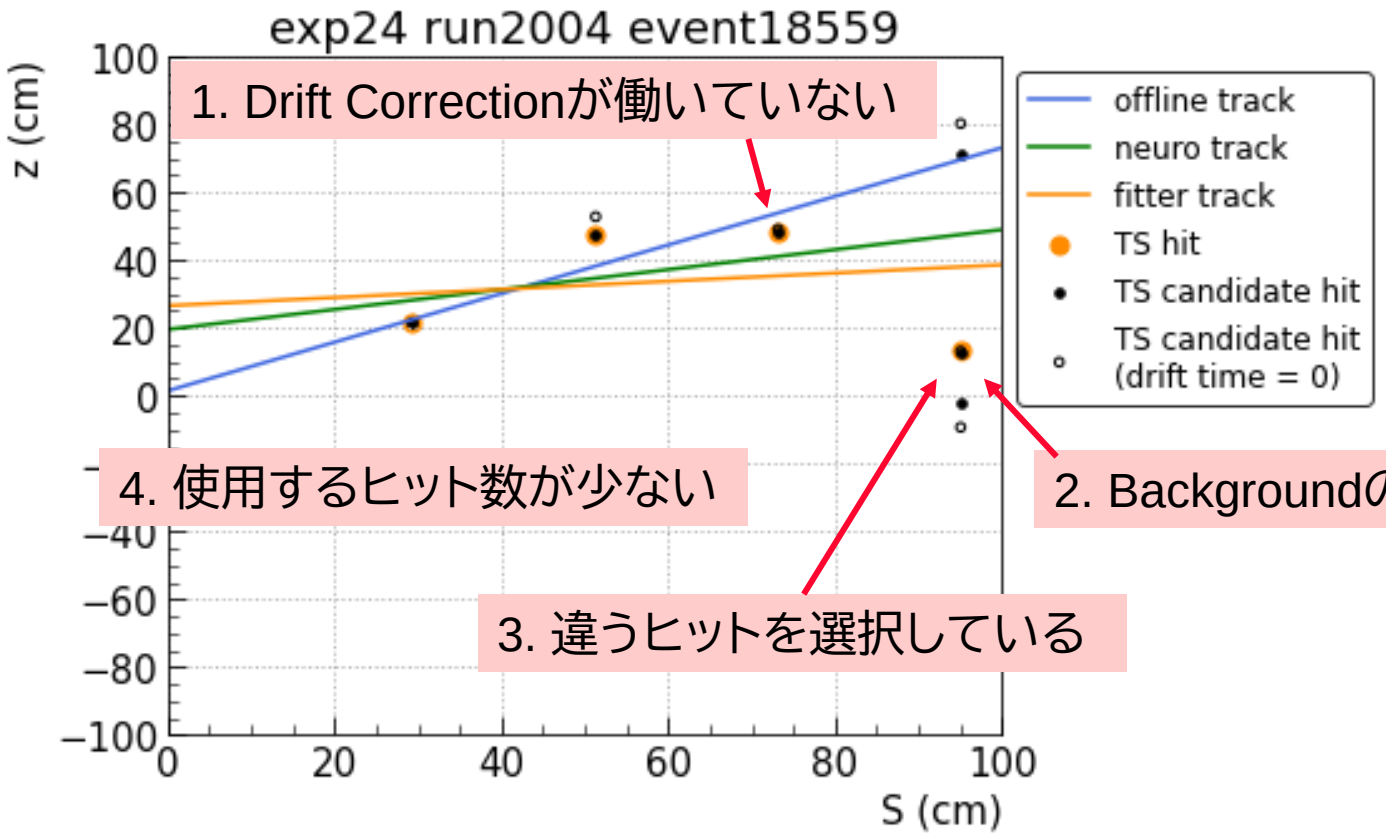
z_i: z position

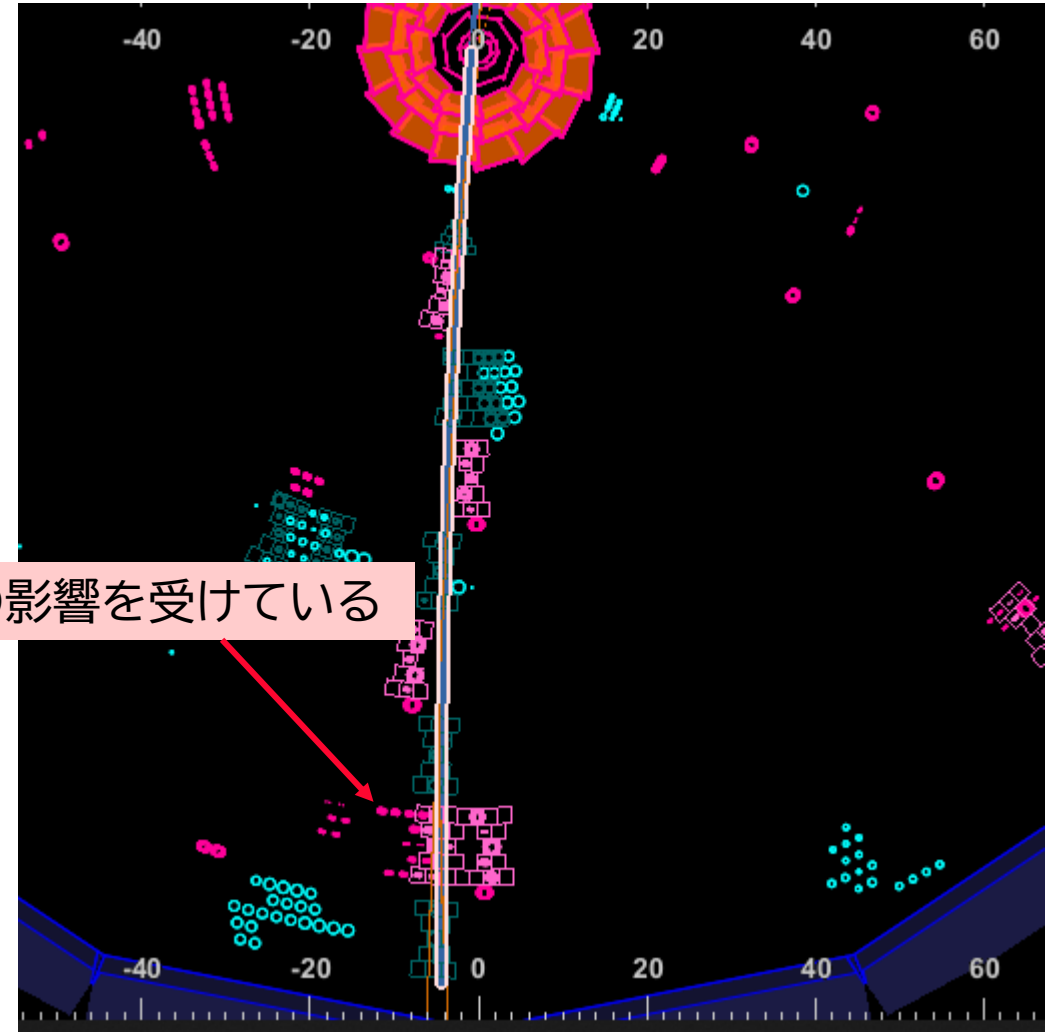
s_i: arc length of 2D track

σ_i : constant. standard deviation of $\Delta z_i (= z_i - z(s_i))$



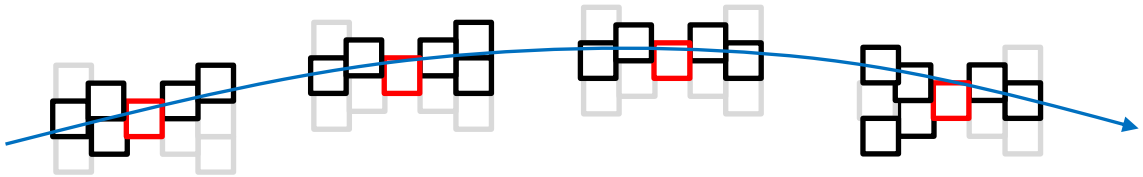
問題点

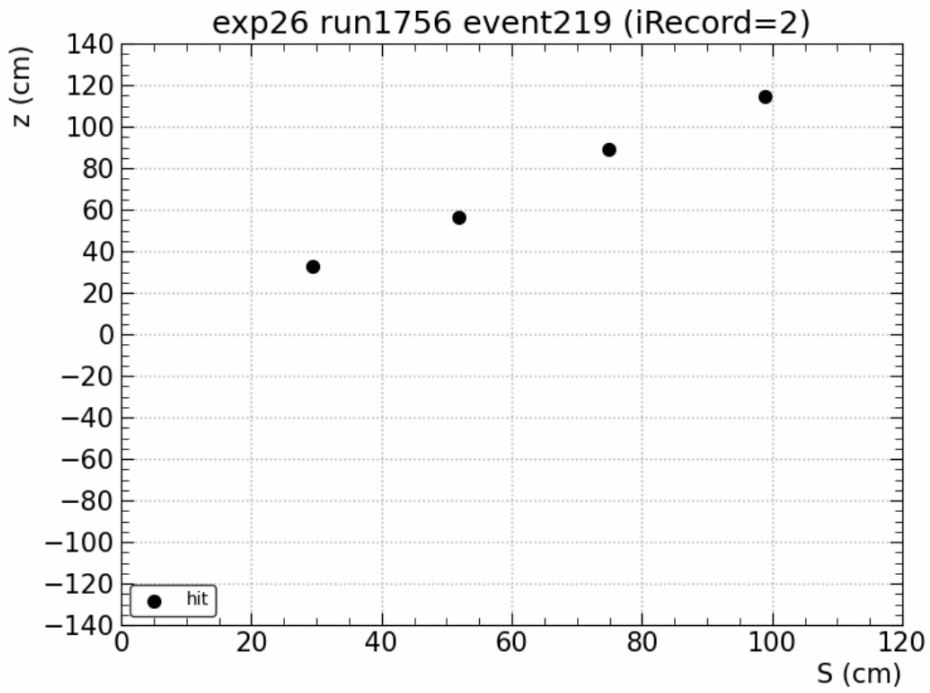

exp24 run2004 event18559
1. Drift Correctionが働いていない
4. 使用するヒット数が少ない
3. 違うヒットを選択している
offline track
neuro track
fitter track
TS hit
TS candidate hit
TS candidate hit
(drift time = 0)
z (cm)
S (cm)


2. Backgroundの影響を受けている

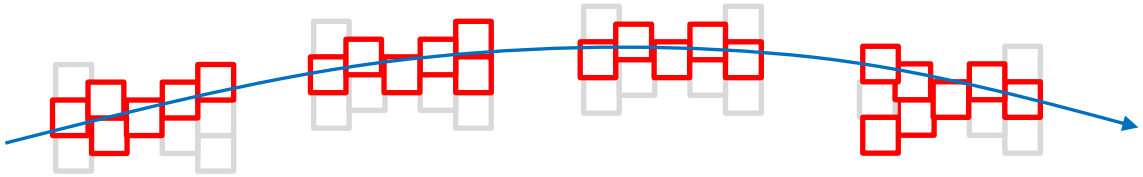
Full hit

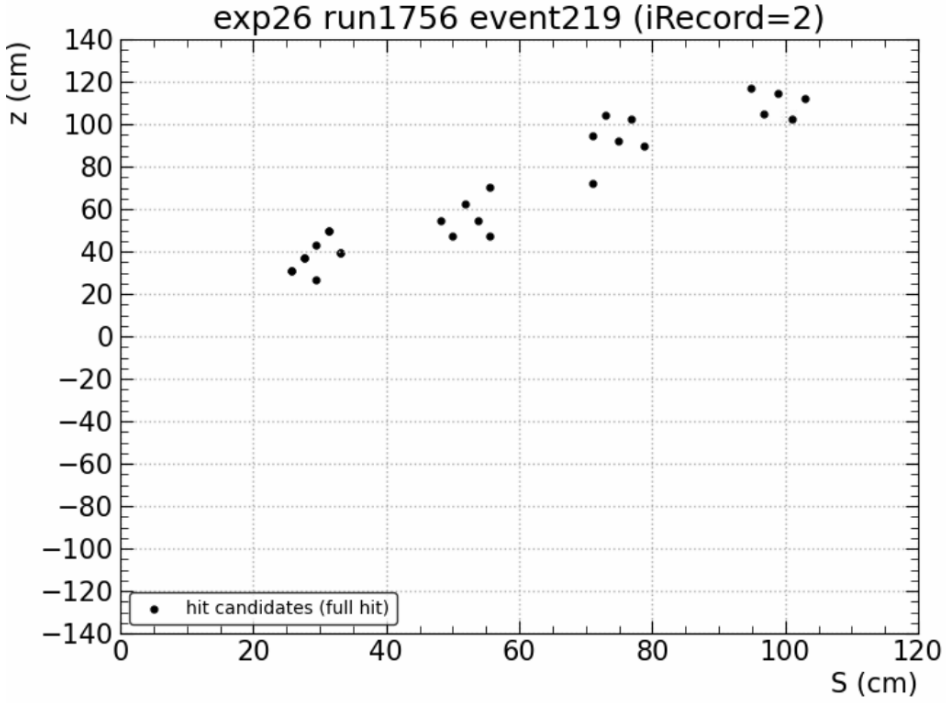
Only priority hit





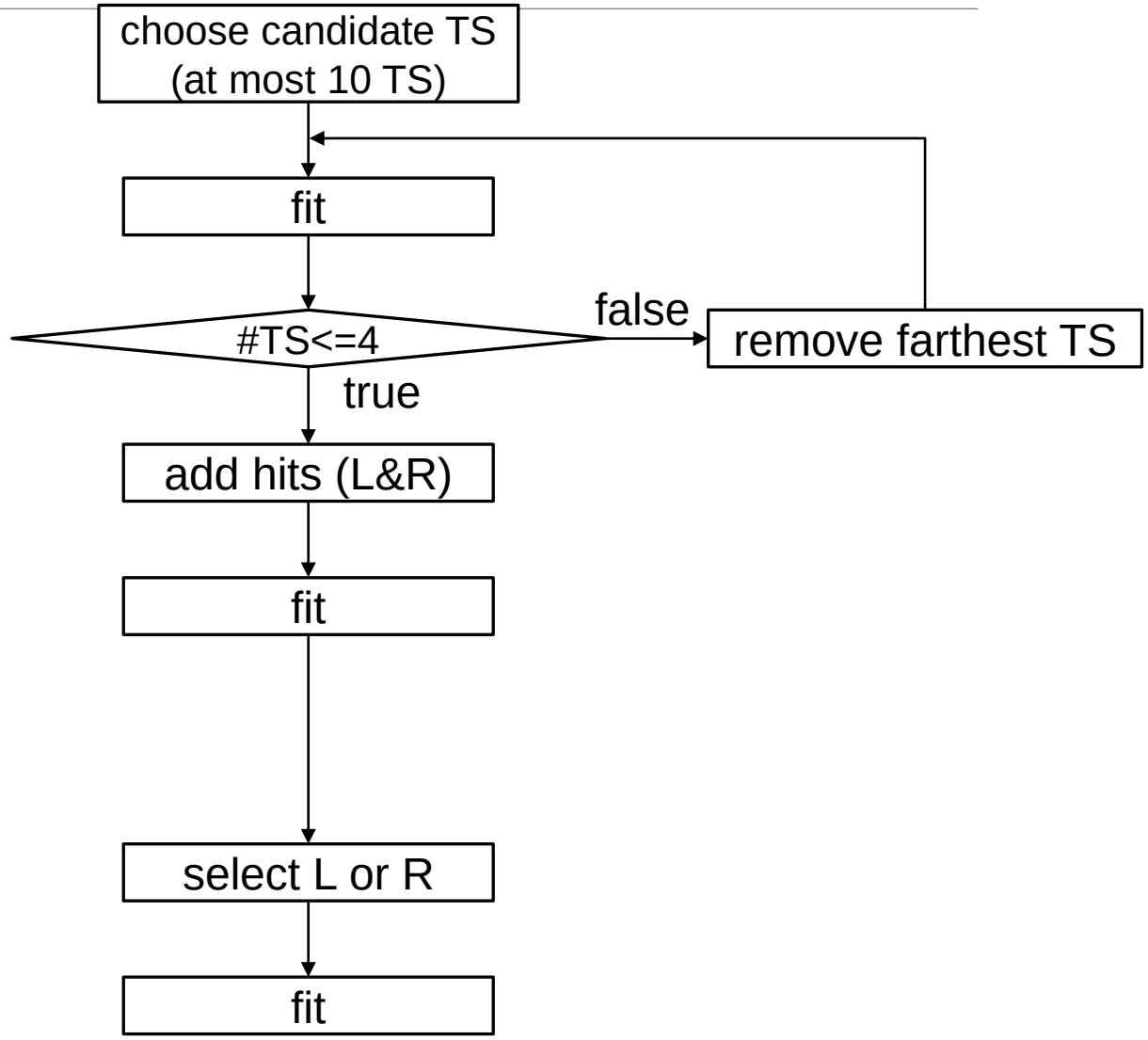
Full hit





“shrink method”

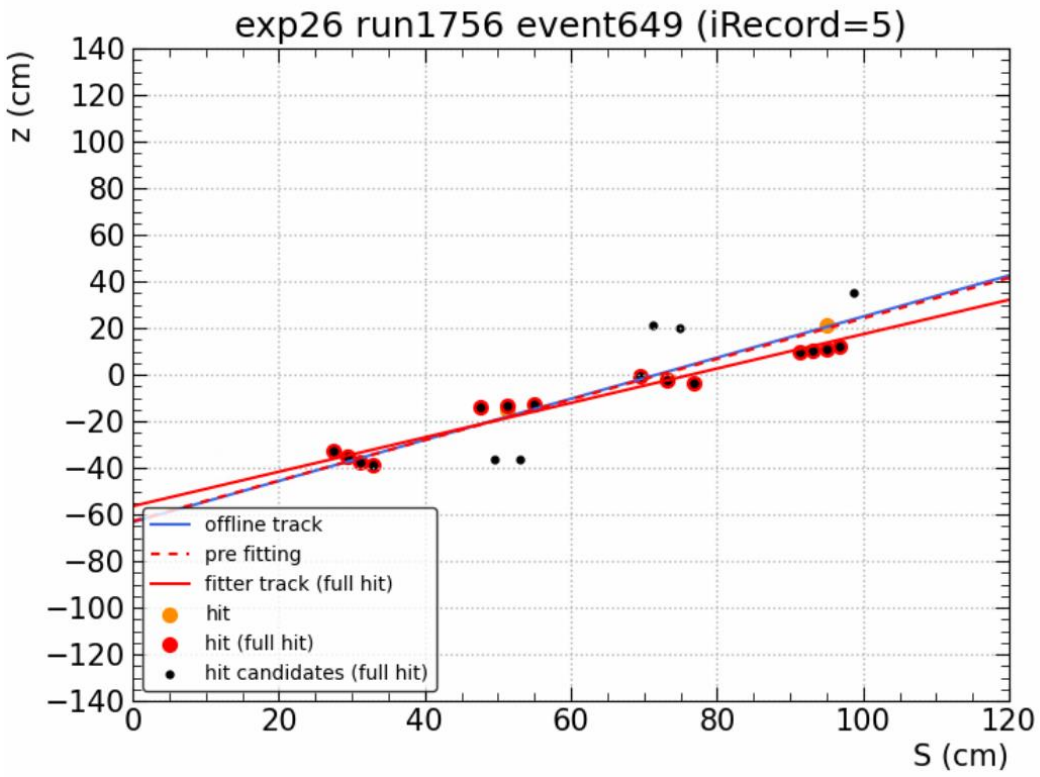
1. Select 4 TSs(for 4 Super Layers)
   - Repeat “Fit -> Removing the farthest TS”
     ※farthest := |z_hit – z_fit| is the largest
2. Apply drift correction to selected hits(in selected TS)
   - Drift direction is both Left & Right (add 2 hits)
3. Fit and select either Left or Right
   - Select nearest one
4. Final fit



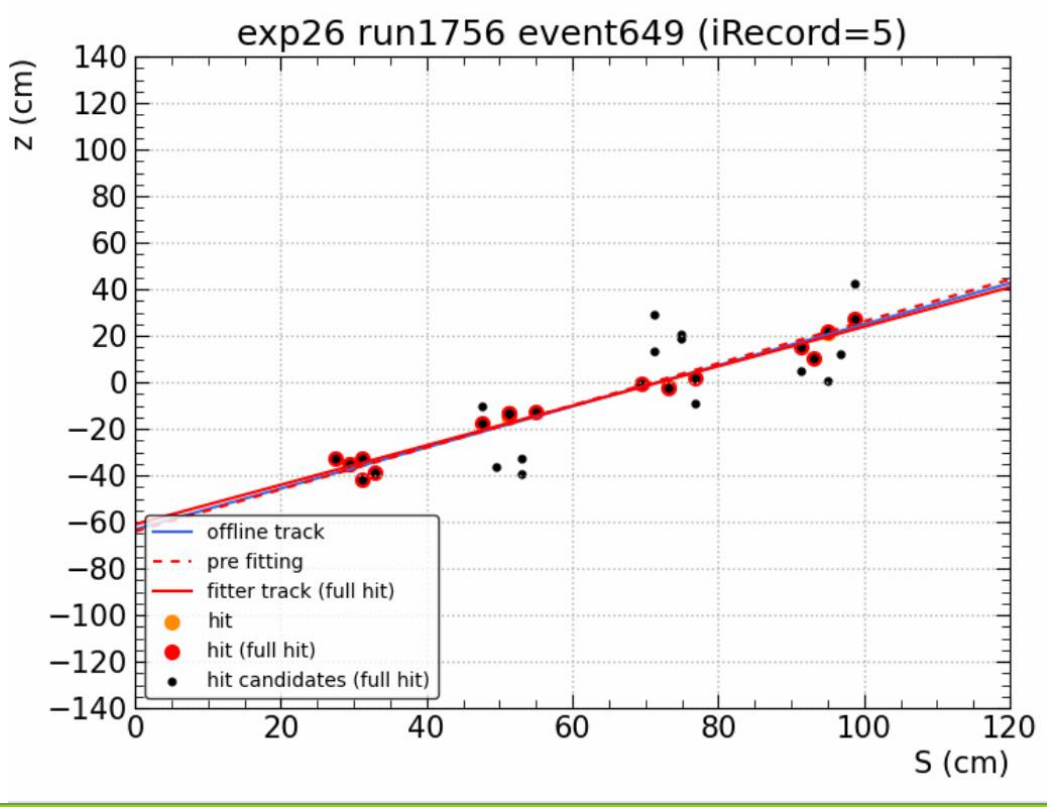
Drift correction

- Priority wire以外のwireに対してLeft/Rightを定めていないので、Leftの場合とRightの場合の2つのヒットを候補として加えた

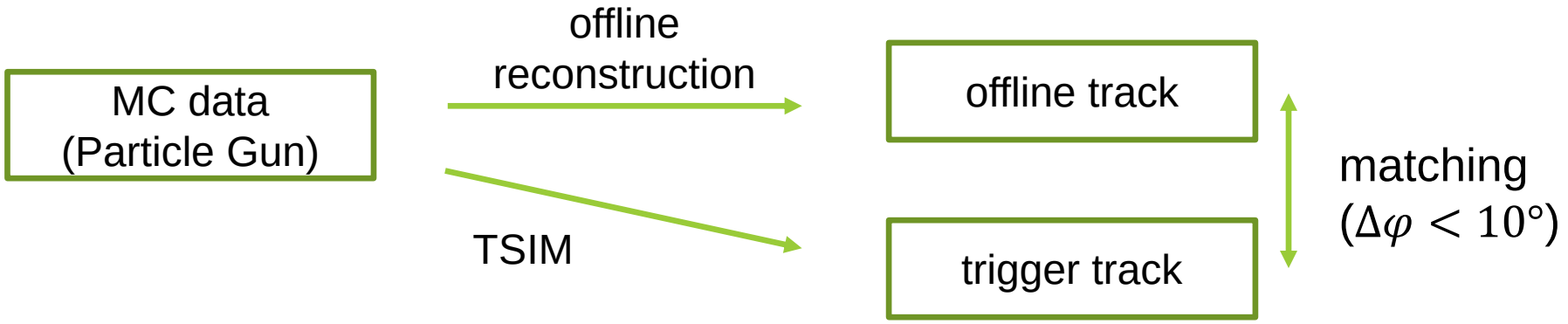
Without drift correction



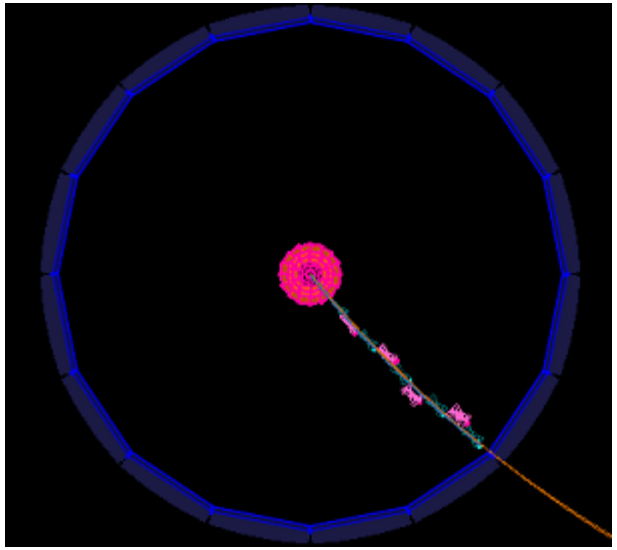
With drift correction



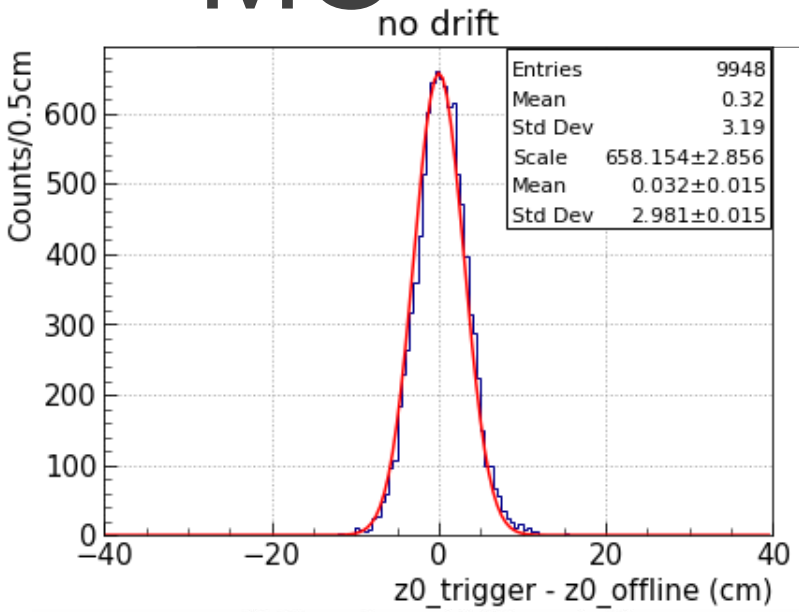
MC: Reconstruction and Selection

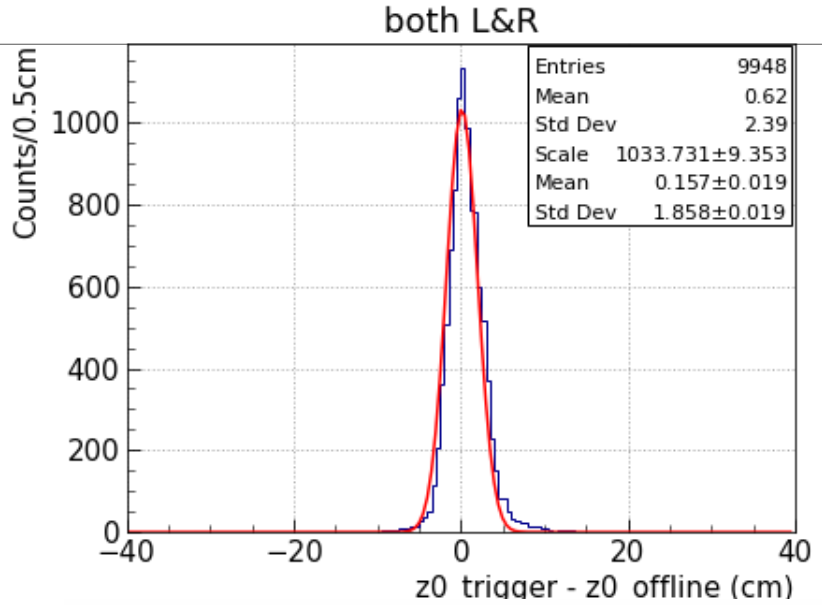


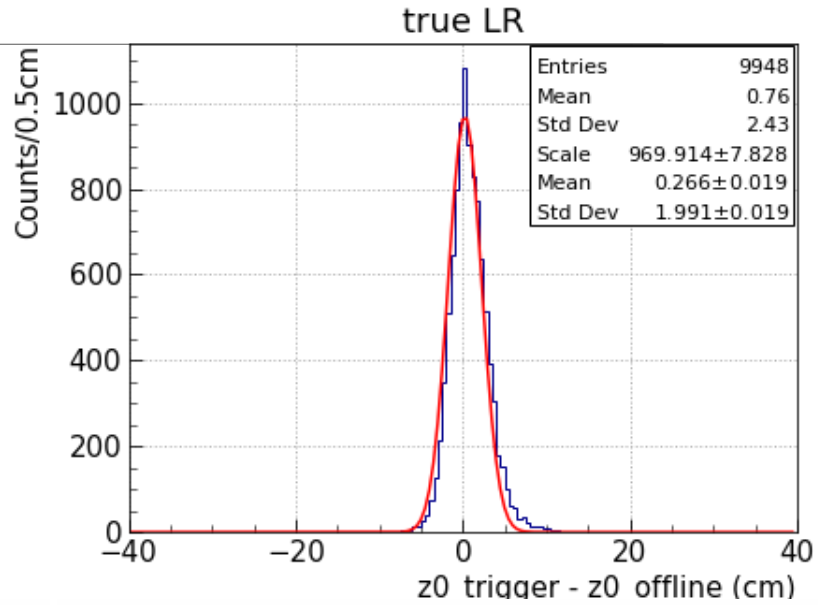
- MC condition:
  - Single muon without BG
  - Momentum : [0.5 GeV, 3.0 GeV] uniform distribution
  - Phi : [0°, 360°] uniform distribution
  - Theta : [60°, 120°] uniform distribution
  - POCA : origin

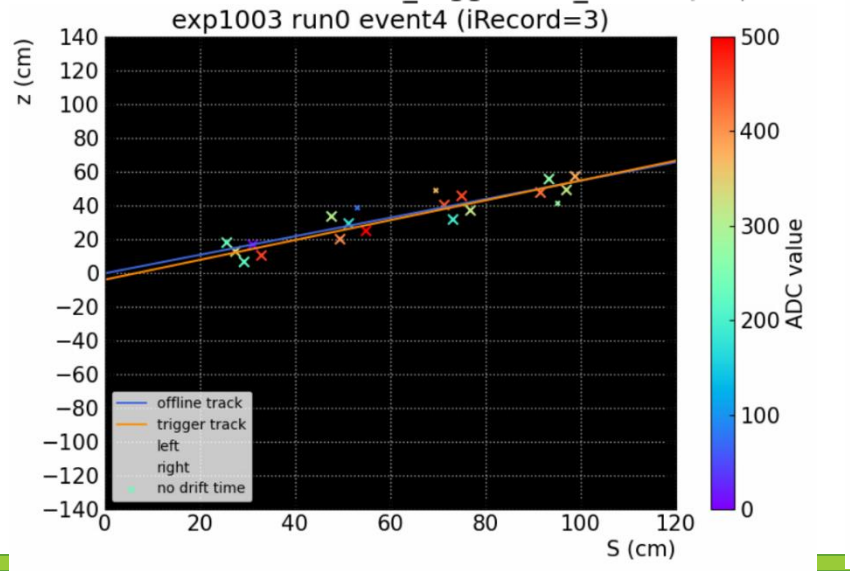


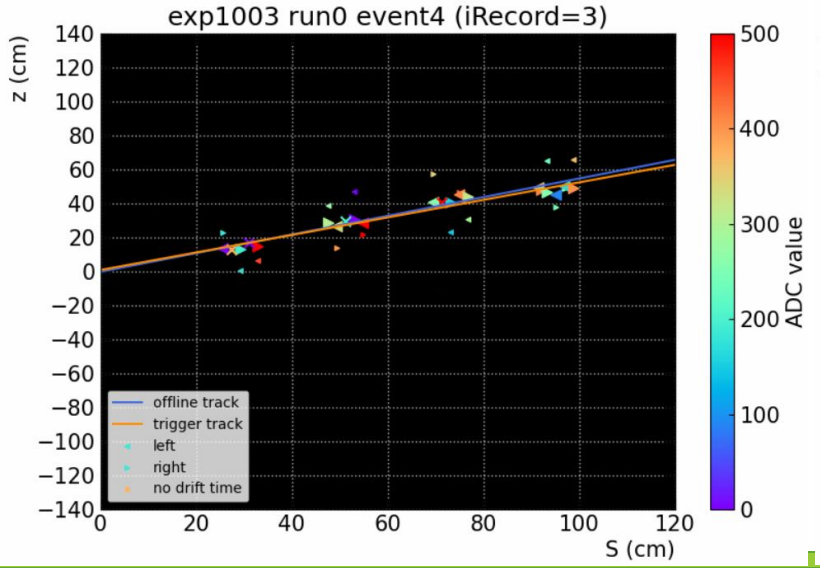
MC

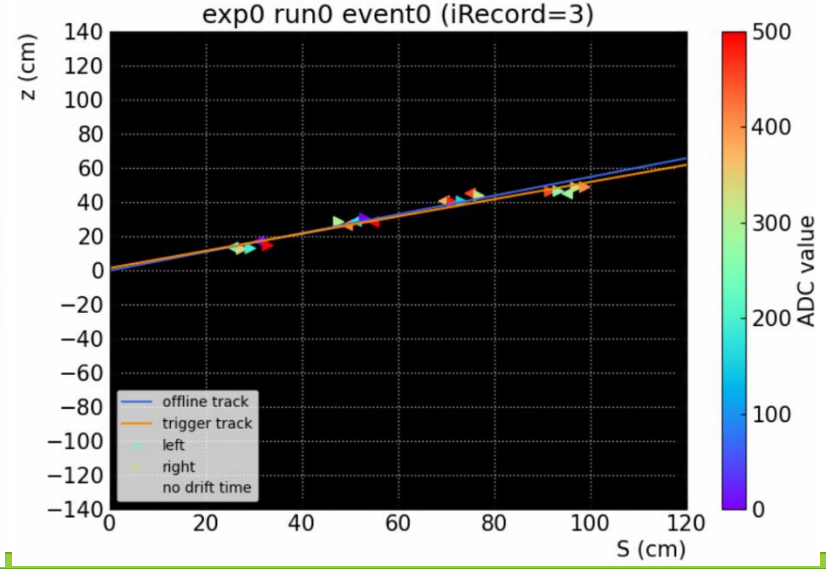

no drift
Entries 9948
Mean 0.32
Std Dev 3.19
Scale 658.154±2.856
Mean 0.032±0.015
Std Dev 2.981±0.015
Counts/0.5cm
z0_trigger - z0_offline (cm)


both L&R
Entries 9948
Mean 0.62
Std Dev 2.39
Scale 1033.731±9.353
Mean 0.157±0.019
Std Dev 1.858±0.019
Counts/0.5cm
z0_trigger - z0_offline (cm)

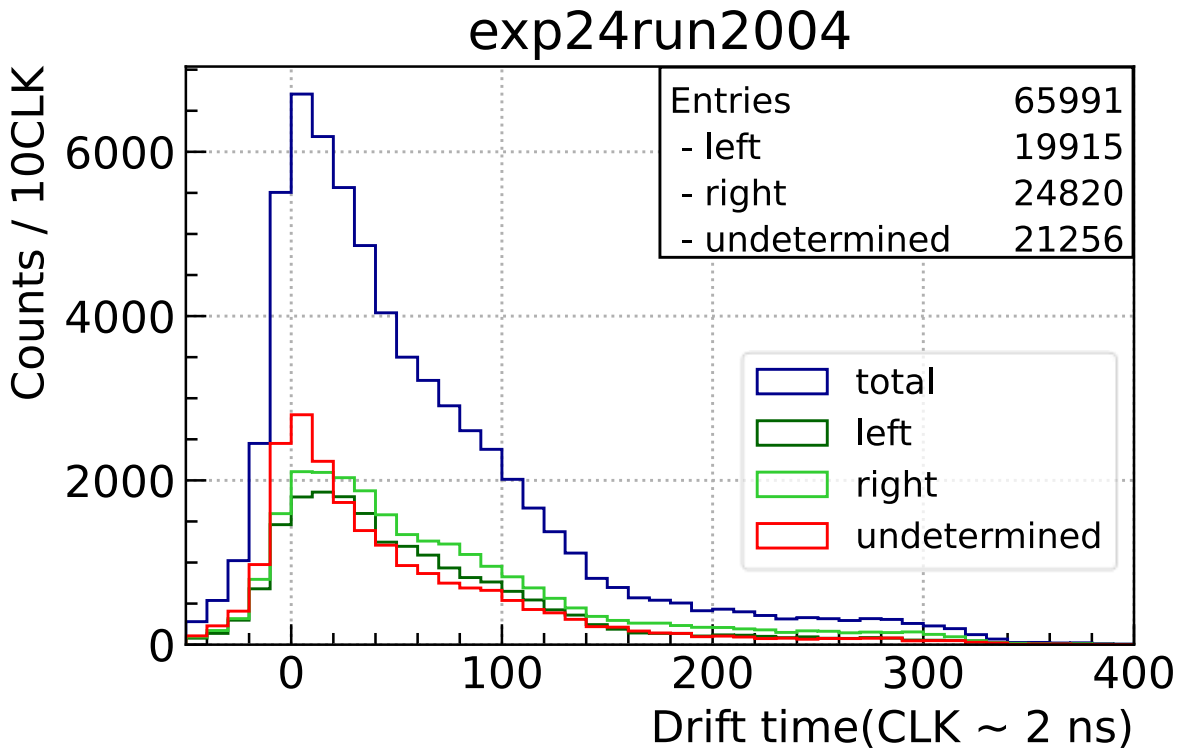

true LR
Entries 9948
Mean 0.76
Std Dev 2.43
Scale 969.914±7.828
Mean 0.266±0.019
Std Dev 1.991±0.019
Counts/0.5cm
z0_trigger - z0_offline (cm)

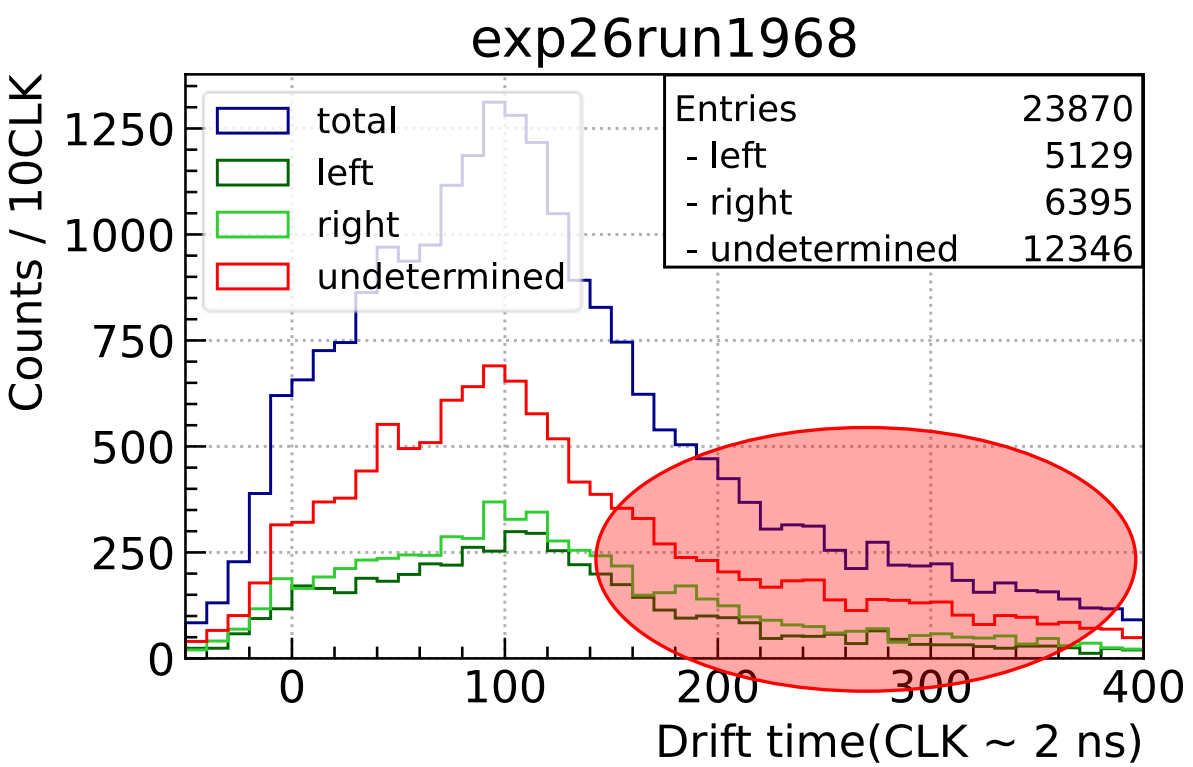

exp1003 run0 event4 (iRecord=3)
offline track
trigger track
left
right
no drift time
z (cm)
S (cm)
ADC value


exp1003 run0 event4 (iRecord=3)
offline track
trigger track
left
right
no drift time
z (cm)
S (cm)
ADC value


exp0 run0 event0 (iRecord=3)
offline track
trigger track
left
right
no drift time
z (cm)
S (cm)
ADC value

Drift correction: Problem



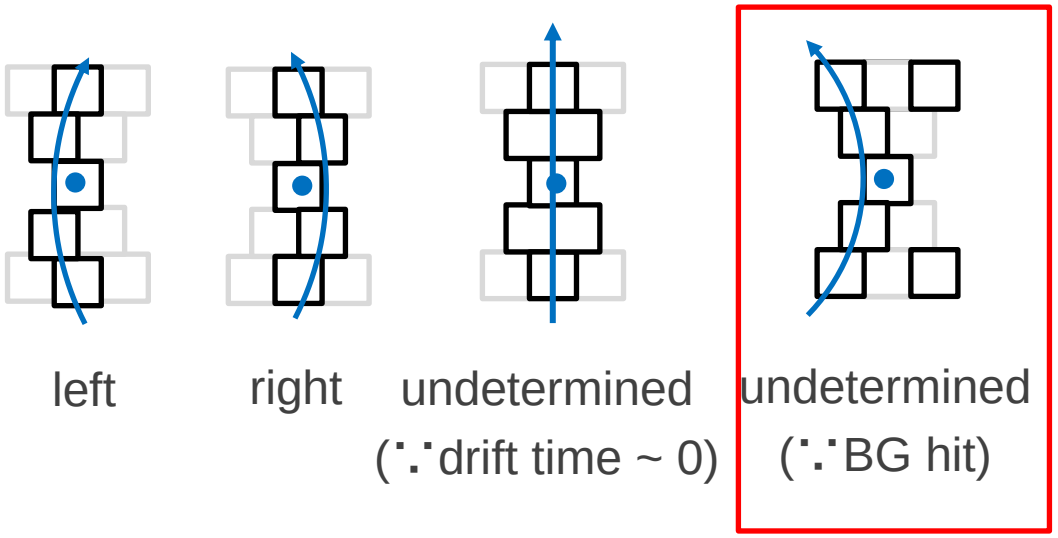


- There are many undetermined hits with large drift time.

※TS hits used by fitter track were counted.

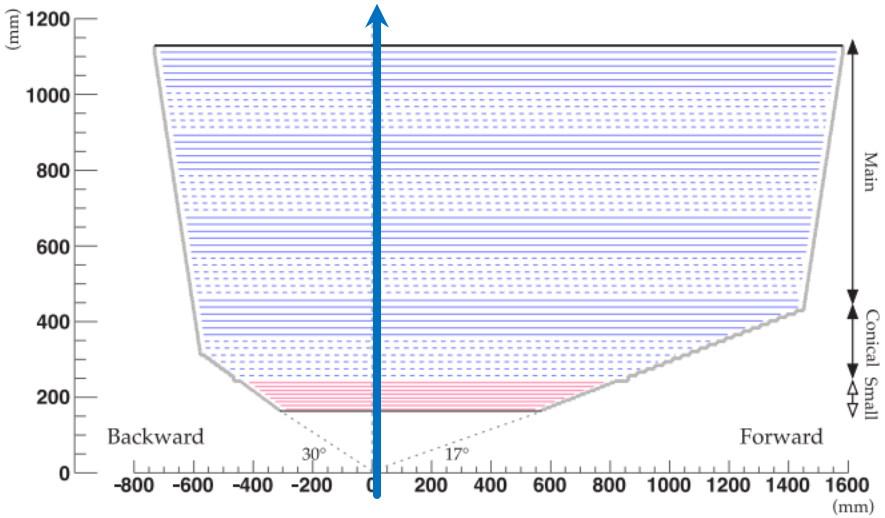
Drift correction: Left/Right

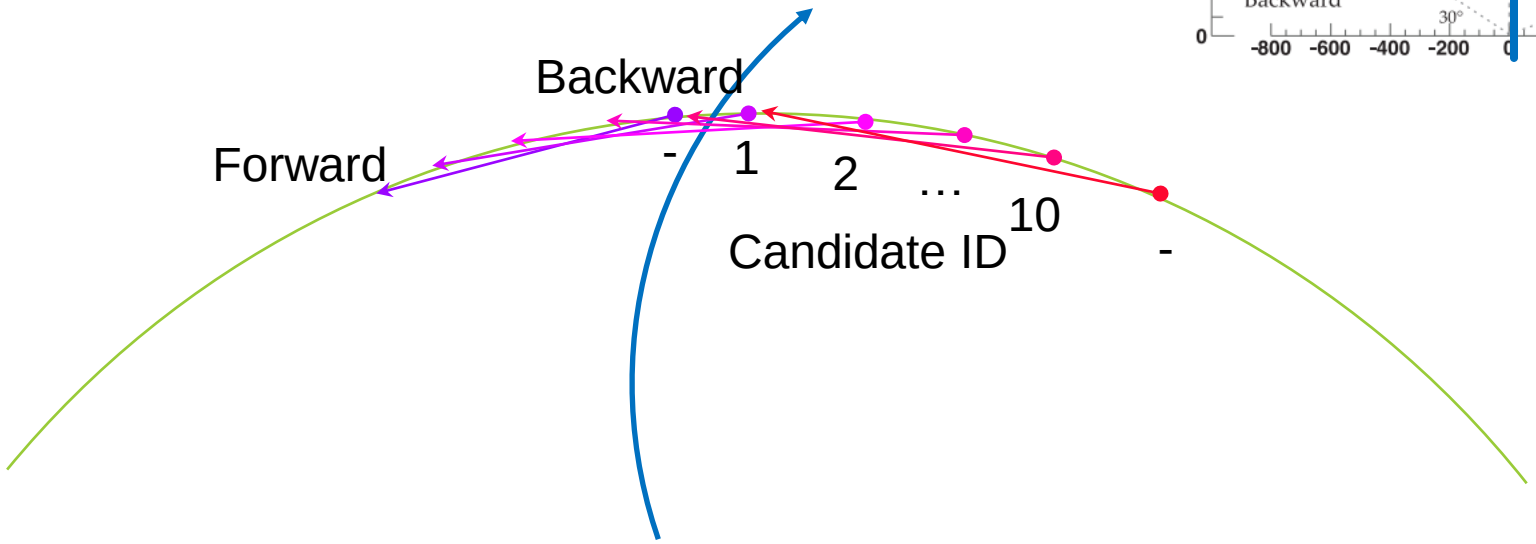
Pattern matching



Hit choice: Candidates

- Stereo wire is shown as a line in r-phi plane.
- 9 ~10 wires are possible to intersect with one
- Fitter choose the hit nearest to Candidate ID
  - This corresponds to choosing hit near z~0.





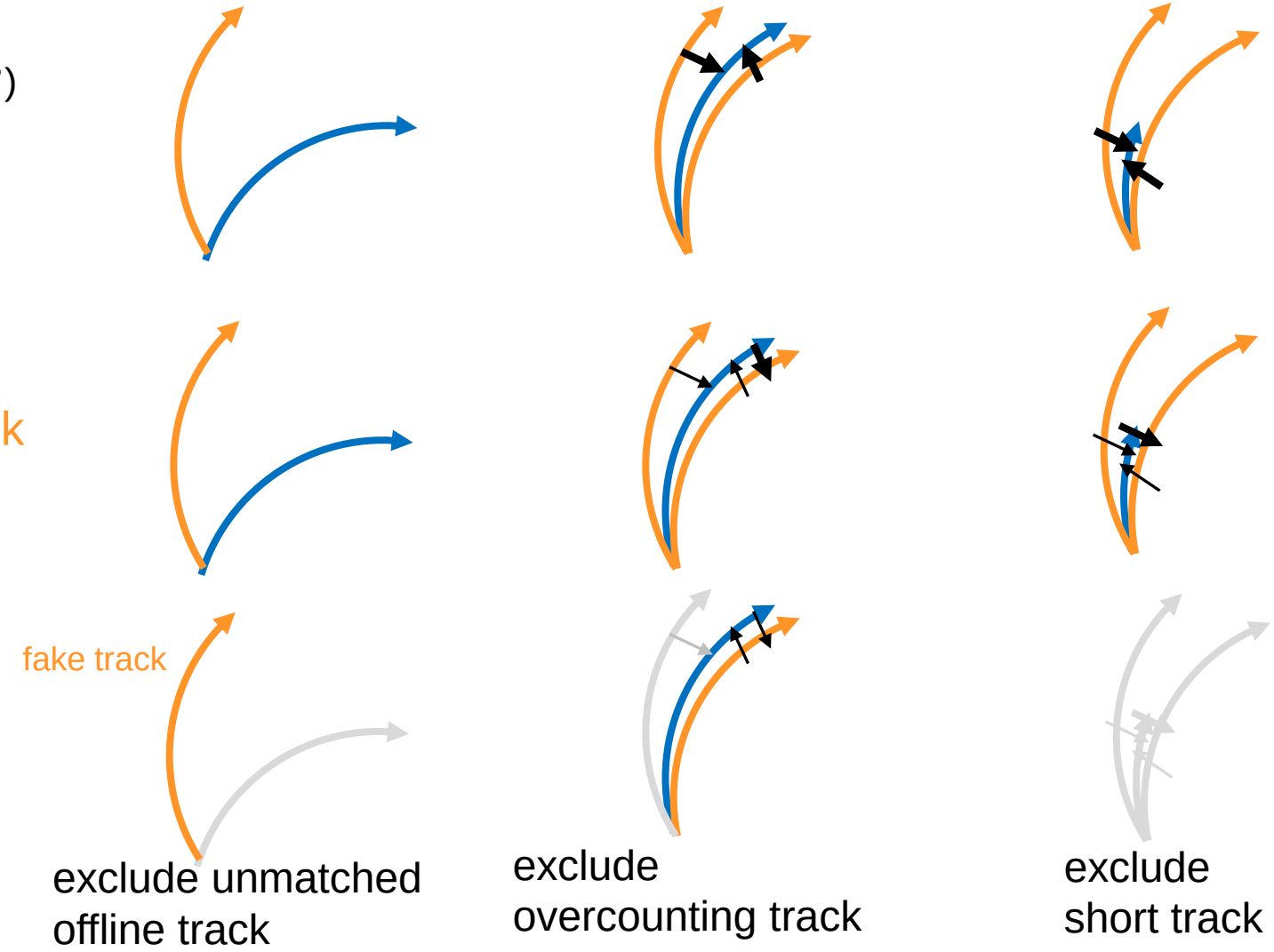
Matching based on 2D track

1. matching from trigger track
to nearest offline track ($\Delta\varphi_0 < 10°$)

※"nearest" means $\Delta\varphi_0$ is the smallest.

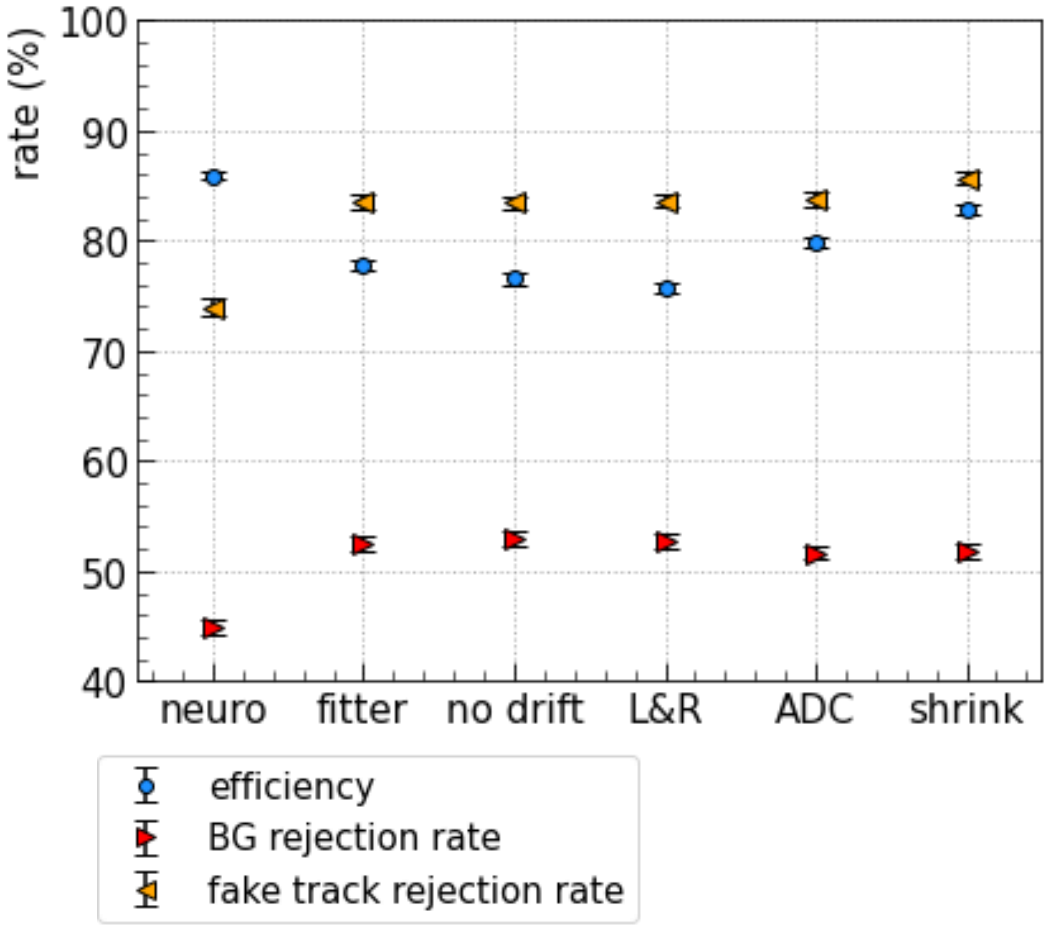
2. matching from offline track
to nearest matched trigger track

3. selection

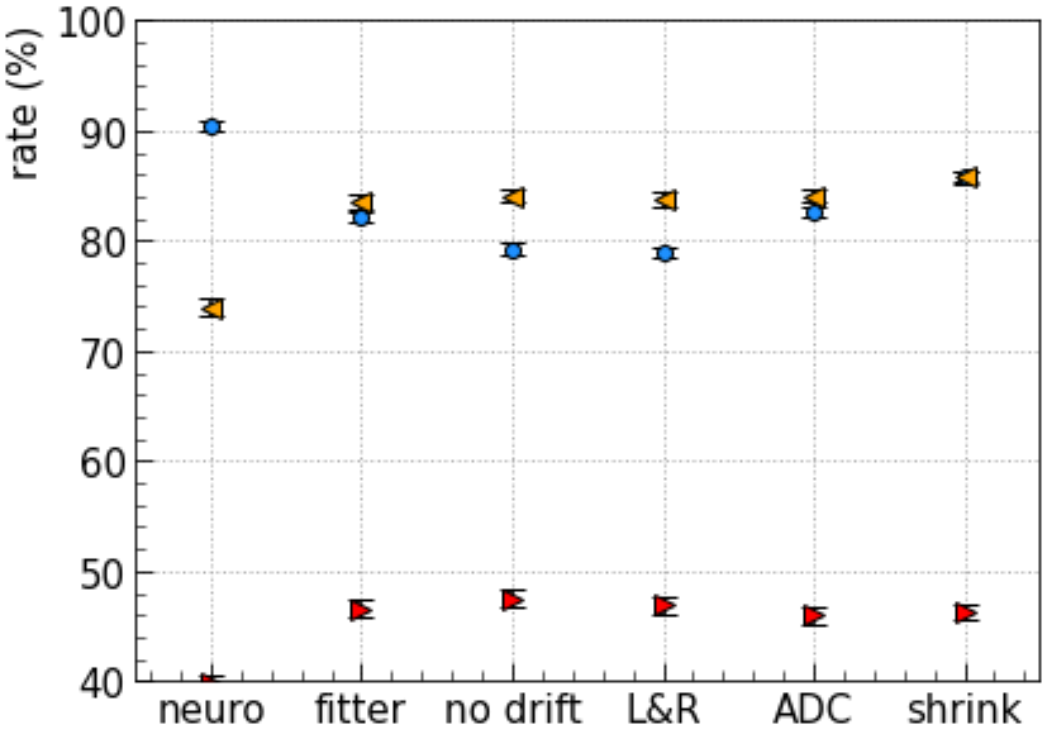


Performance

Before bug fix
(including short track)

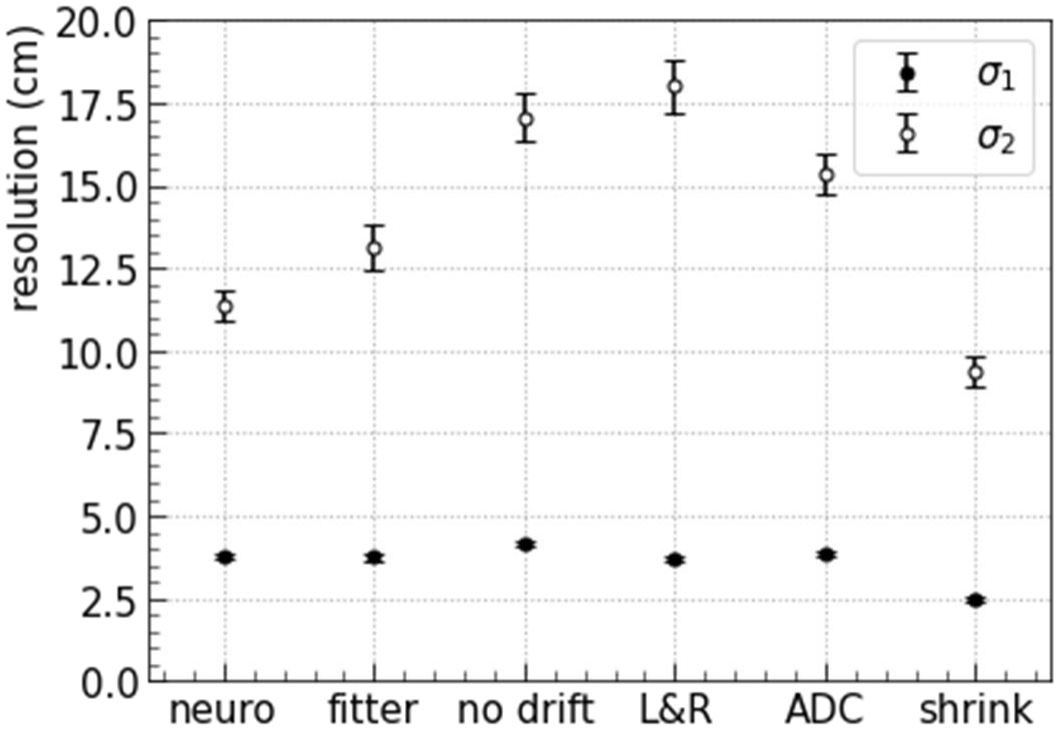


After bug fix
(excluding short track)

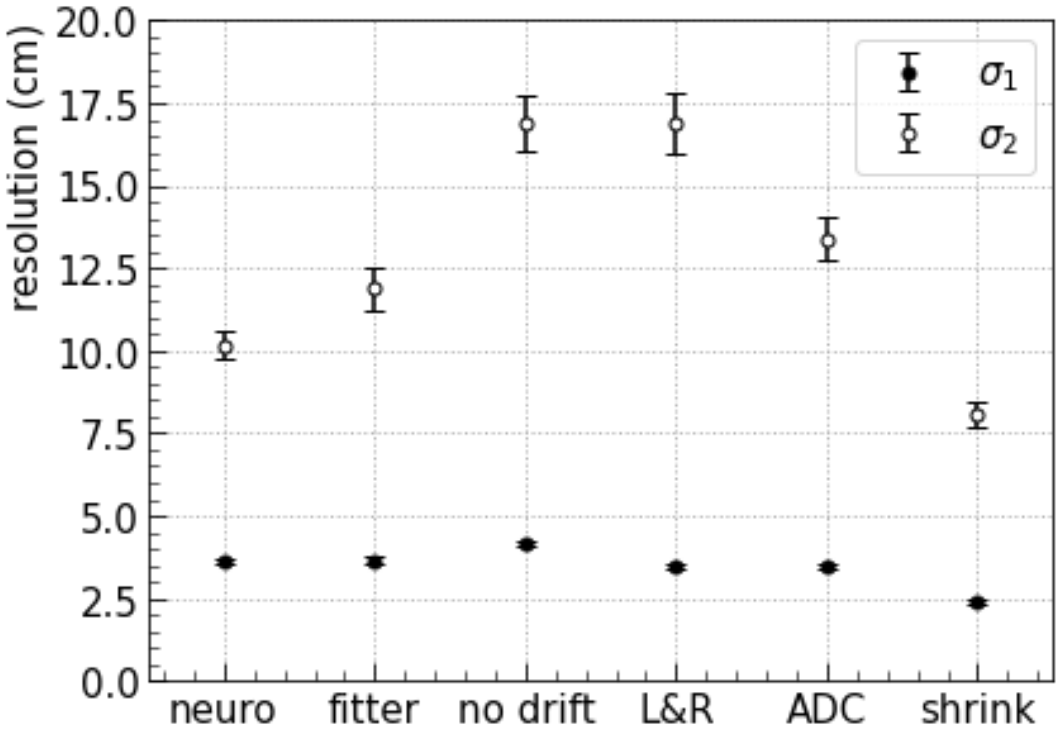


z_0 resolution

Before bug fix
(including short track)



After bug fix
(excluding short track)



Δz_0 distribution was fitted with
double gaussian
σ_1, σ_2: std dev. of each gaussian

Track categorization

Fitter (Shrink) Before bug fix		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	6960	1012	426
	$\lvert z_0 \rvert > 1$ (BG)	2760	2729	230
	no track	540	2776	443

3D efficiency = 82.88 %
BG rejection rate = 51.74 %
Fake track rejection rate = 85.63 %

Fitter (Shrink) After bug fix		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	5836	745	213
	$\lvert z_0 \rvert > 1$ (BG)	2265	1859	94
	no track	535	2781	443

3D efficiency = 85.90 %
BG rejection rate = 46.30 %
Fake track rejection rate = 85.77 %

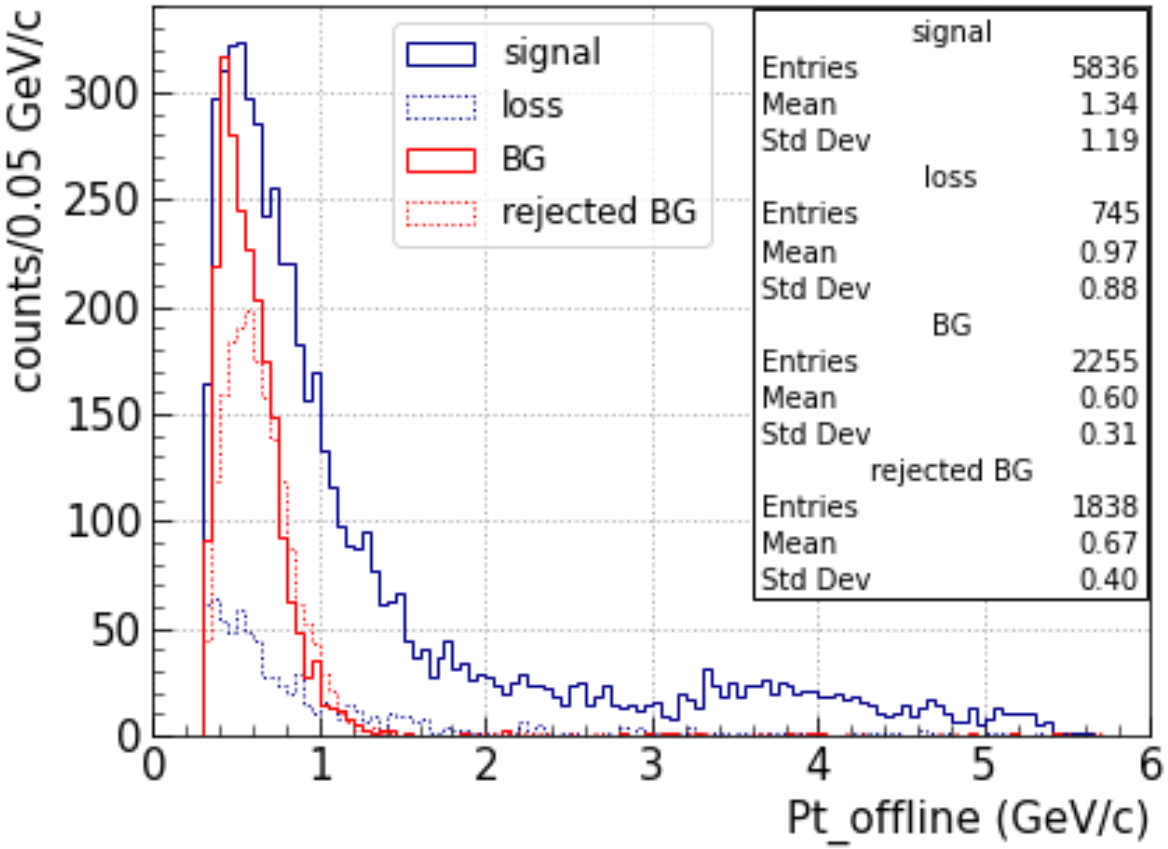
Countermeasures

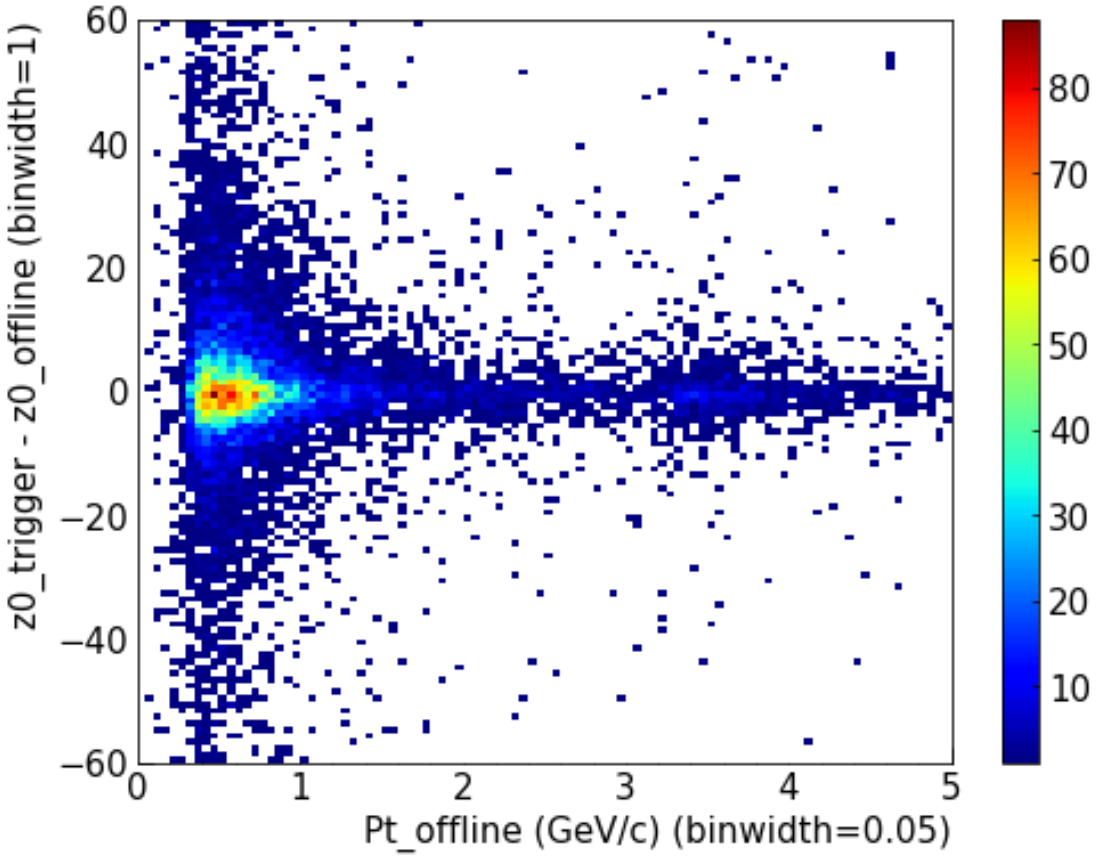
#	Category	#	Subcategory
15	wrong 3D fitter	9	Multiple TS are selected in 1 Super Layer
		1	TS of adjacent track are selected
		5	No idea
12	wrong 2D input		
3	wrong matching	1	Overcounting track is selected
		2	Counterpart of pair-created track is selected

-> 1 TS in 1 Super Layer
efficiency +1.5%
BG rejection -0.1%

-> temporarily ignore these effects by using offline 2D tracks

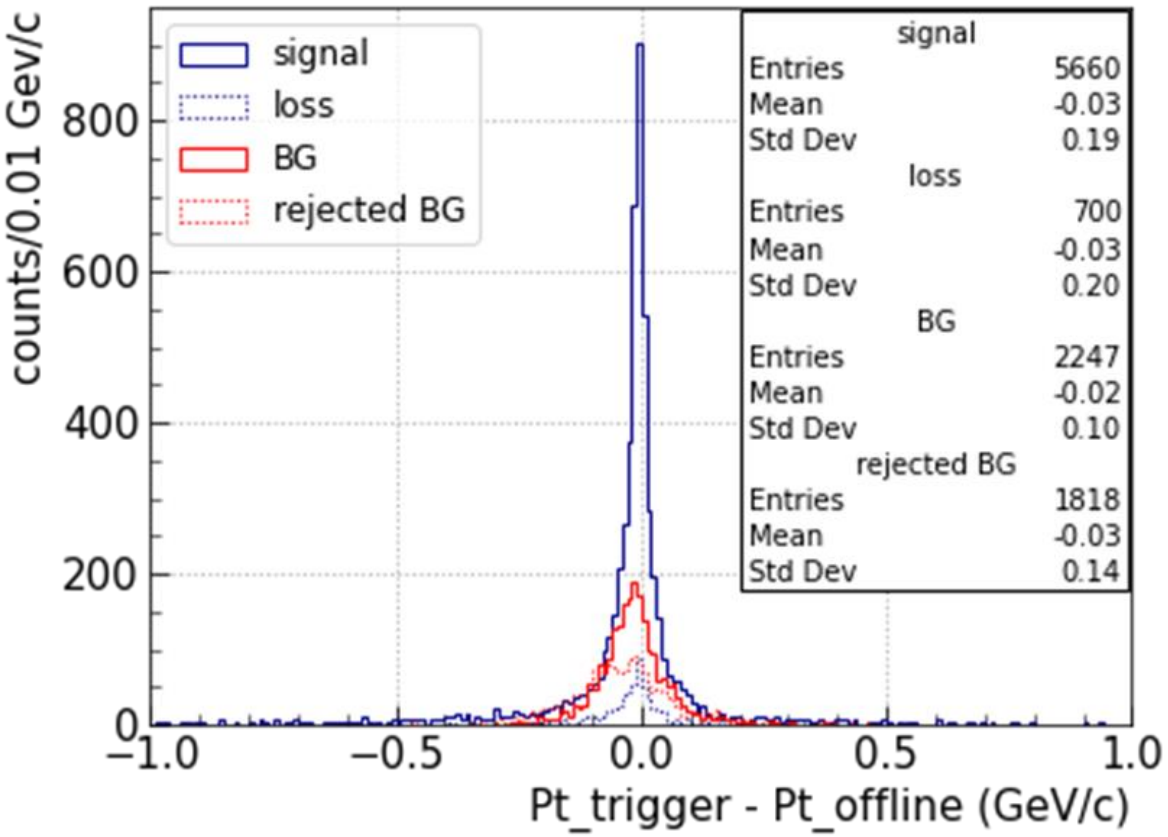
P_t dependency

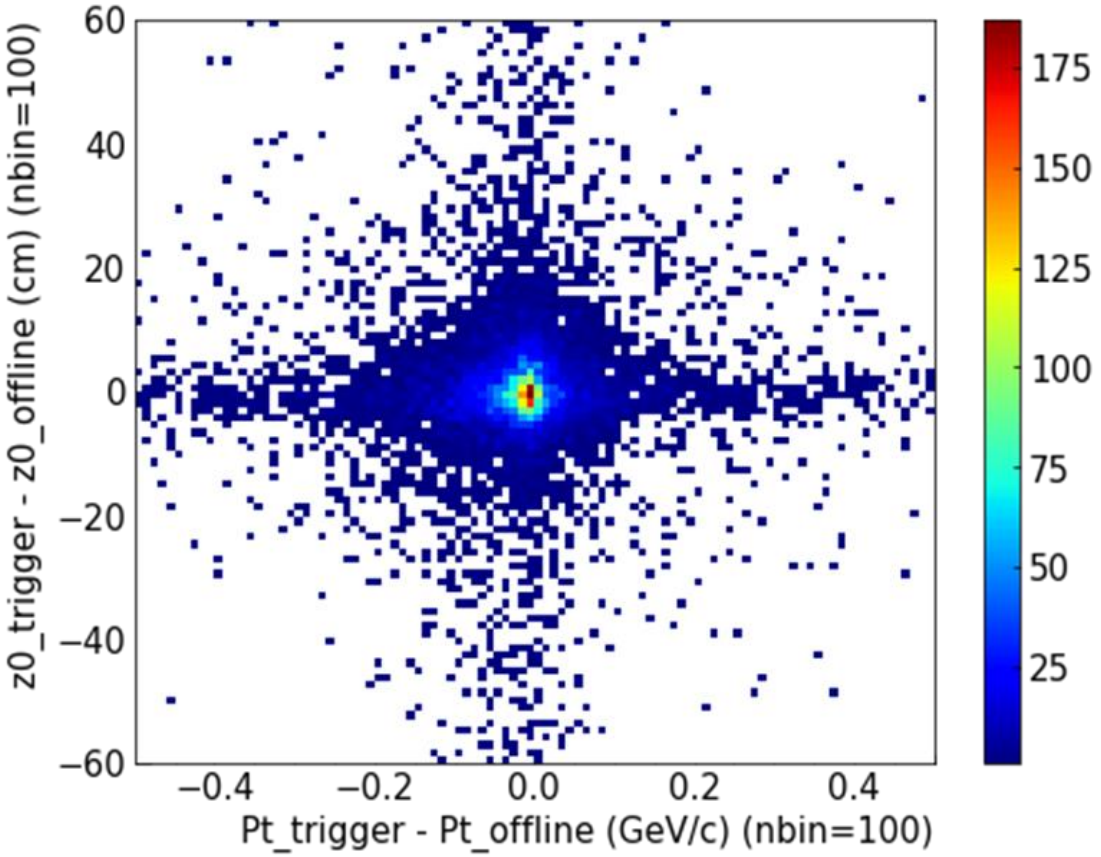




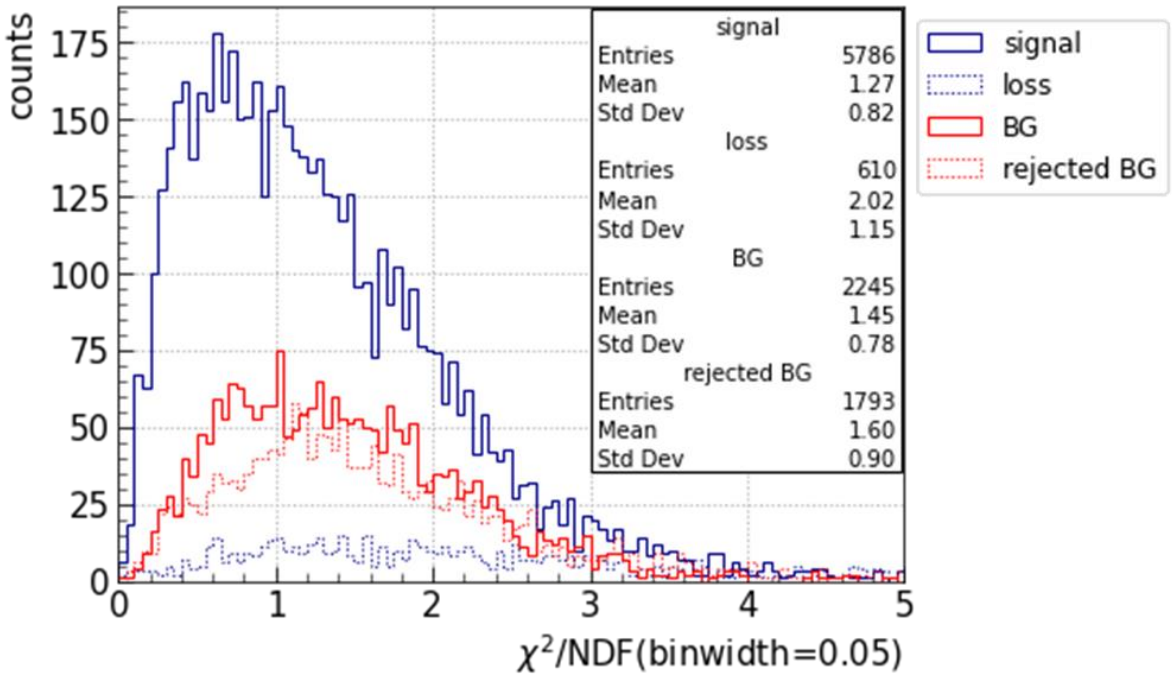
71% of the loss tracks has low momentum(<1 GeV/c).

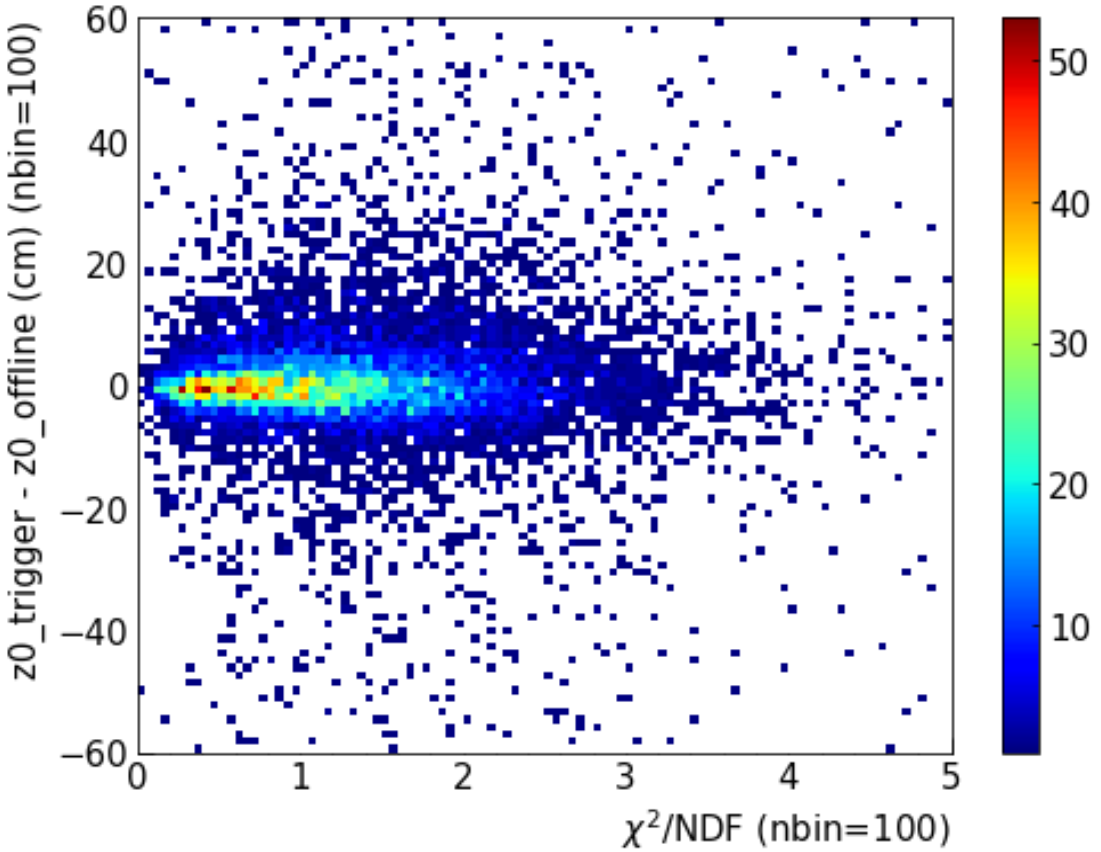
ΔP_t dependency



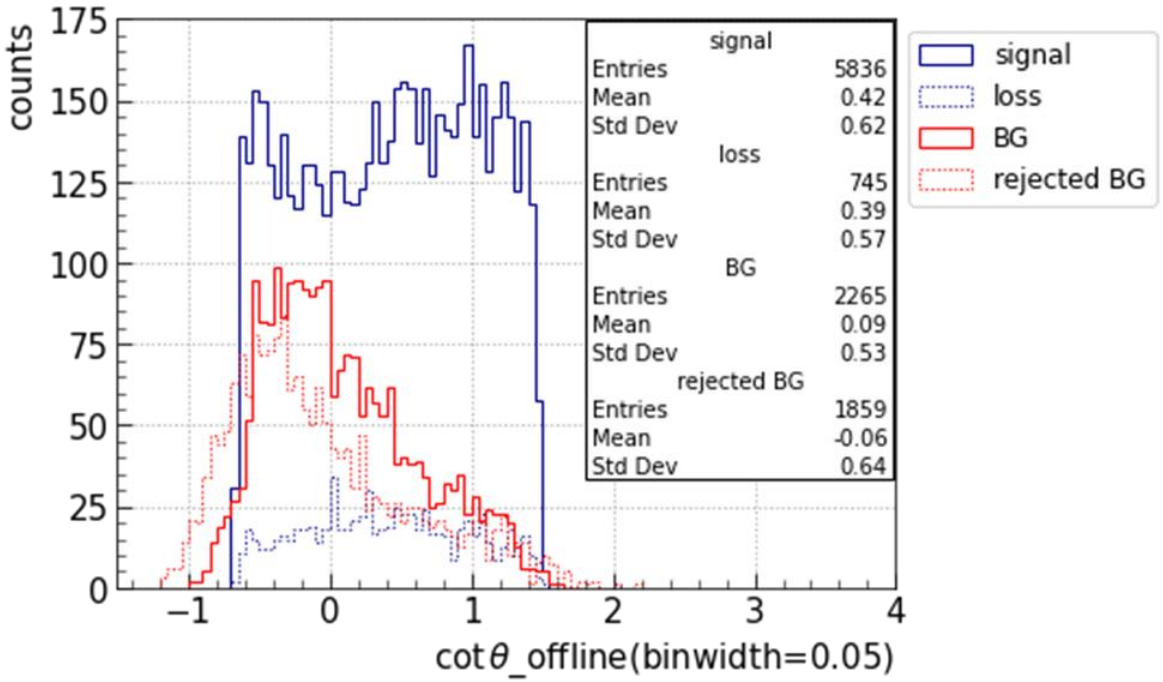


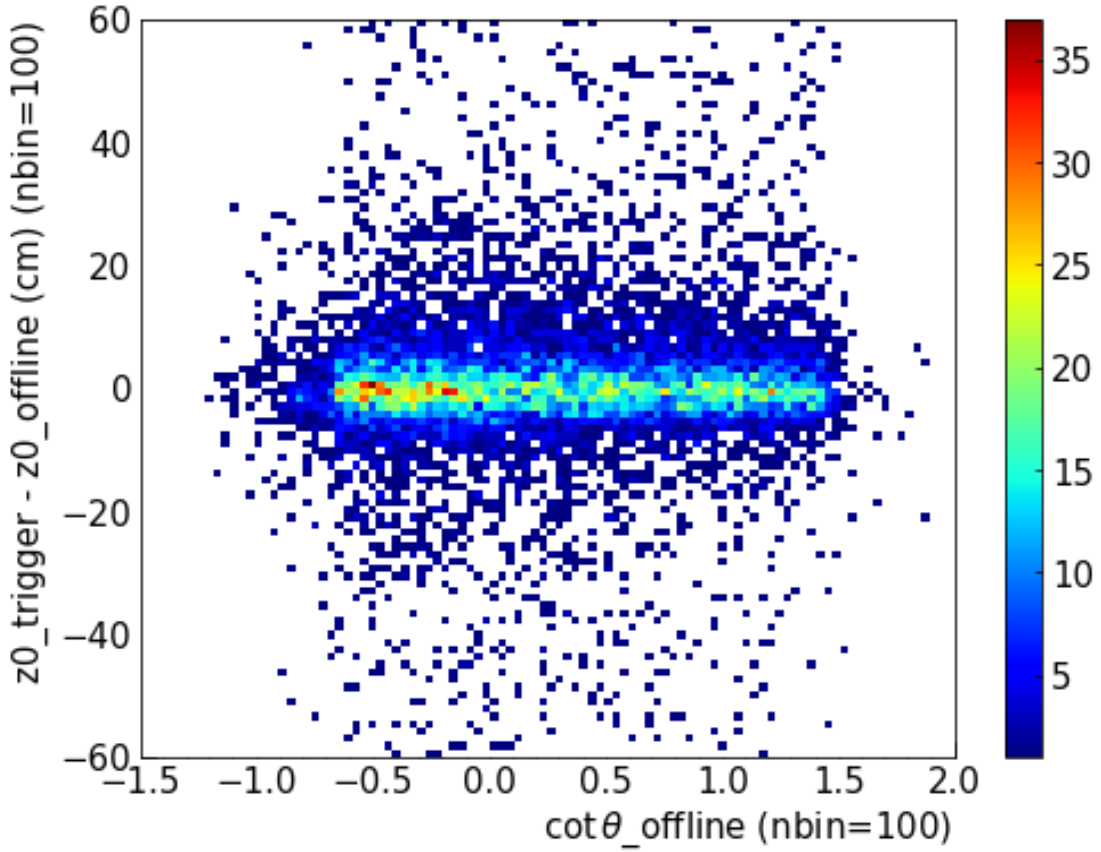
χ^2/NDF dependency





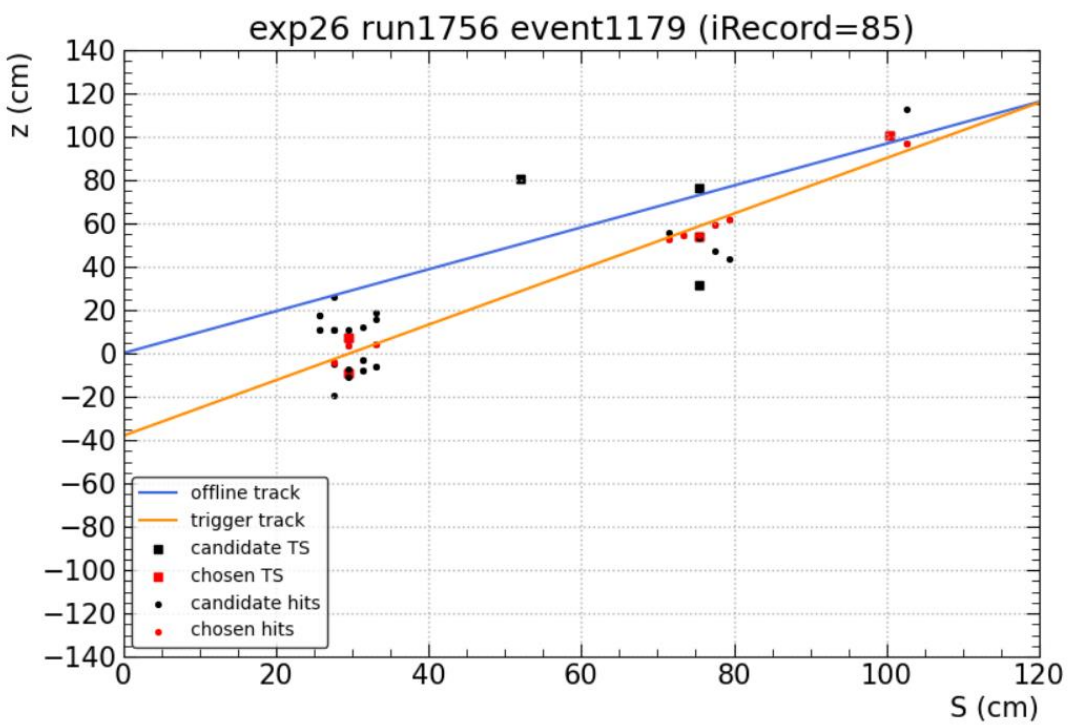
$cot\theta$ dependency

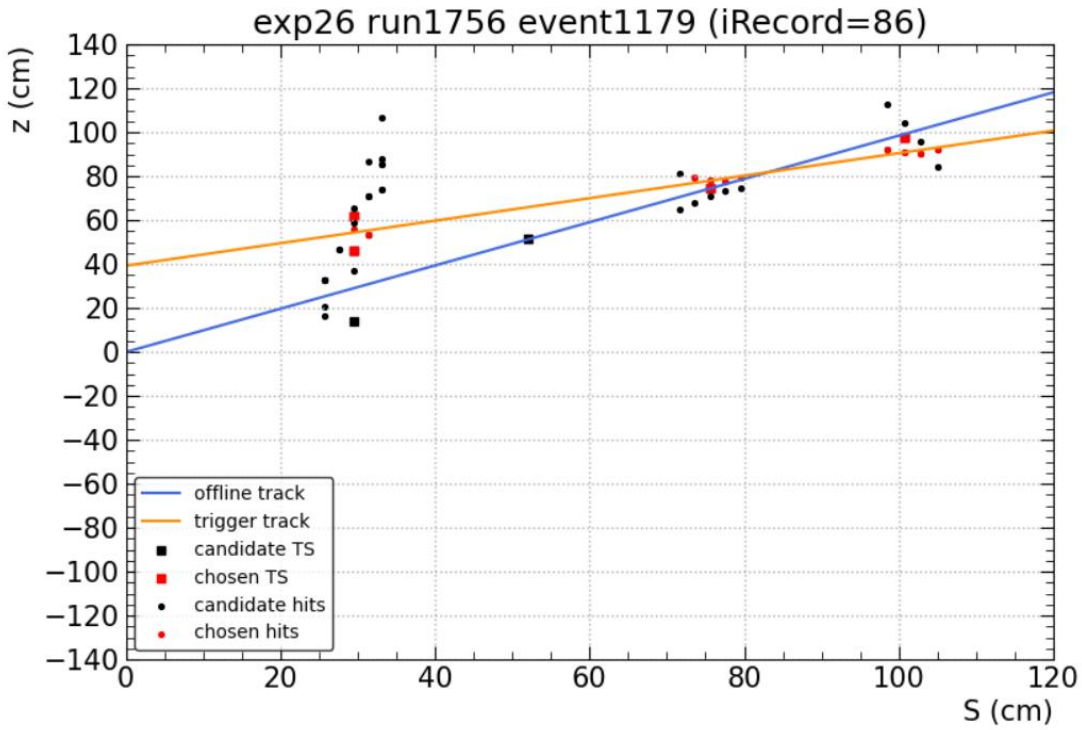




Cause of loss track

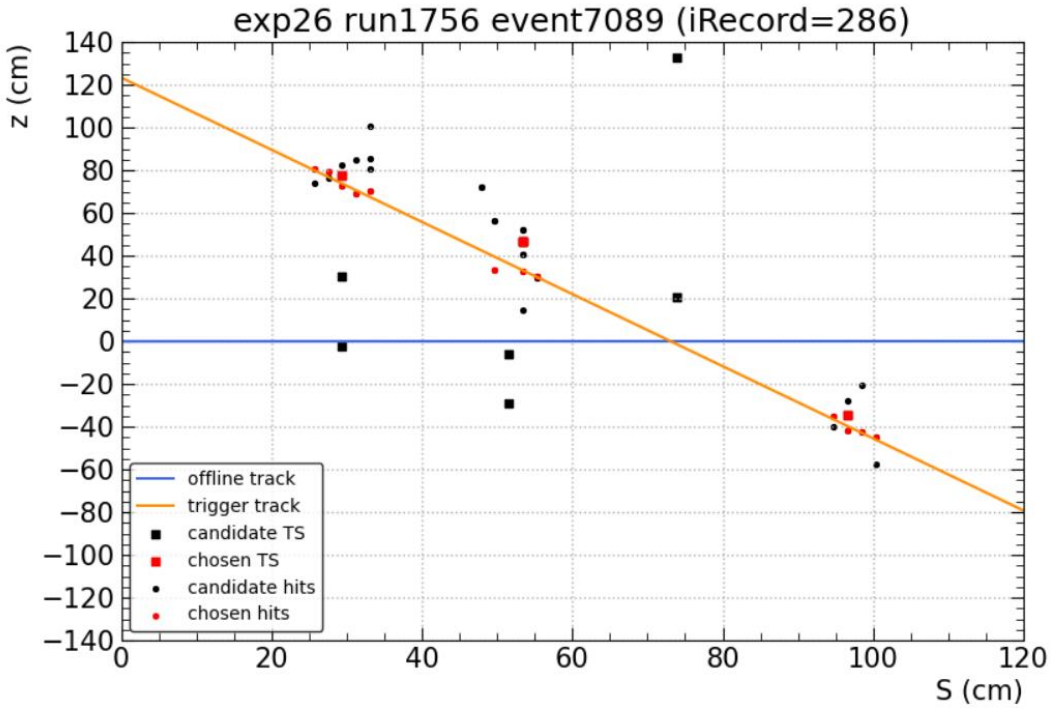
#	Category	#	Subcategory
15	wrong 3D fitter	9	Multiple TS are selected in 1 Super Layer
		1	TS of adjacent track are selected
		5	No idea

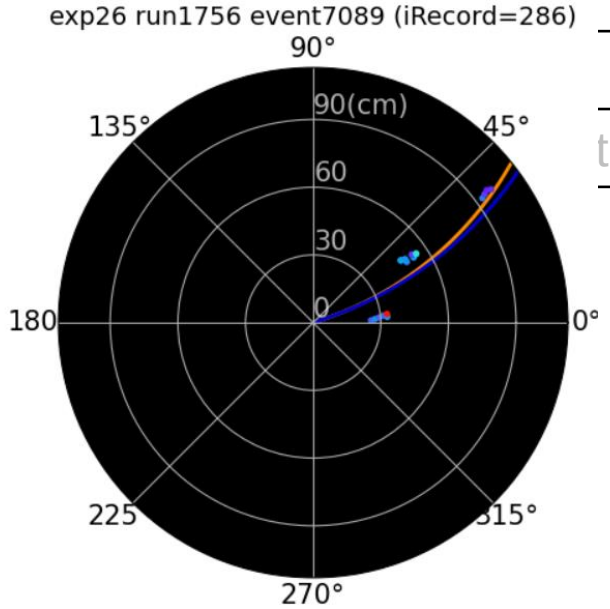


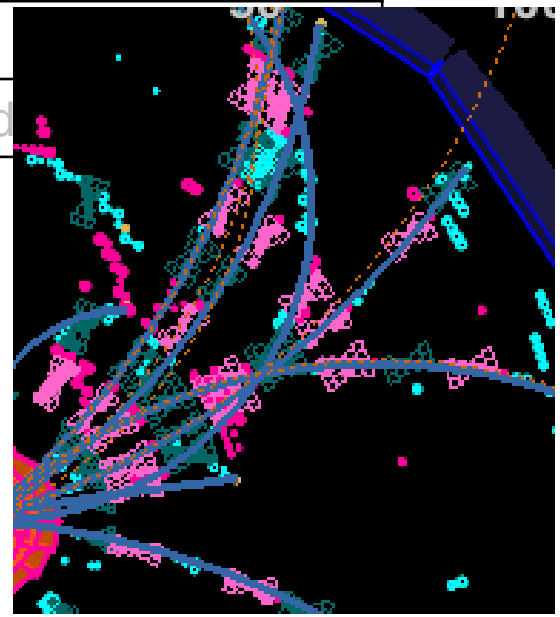


Cause of loss track

#	Category	#	Subcategory
15	wrong 3D fitter	9	Multiple TS are selected in 1 Super Layer
		1	TS of adjacent track are selected
		5	No idea

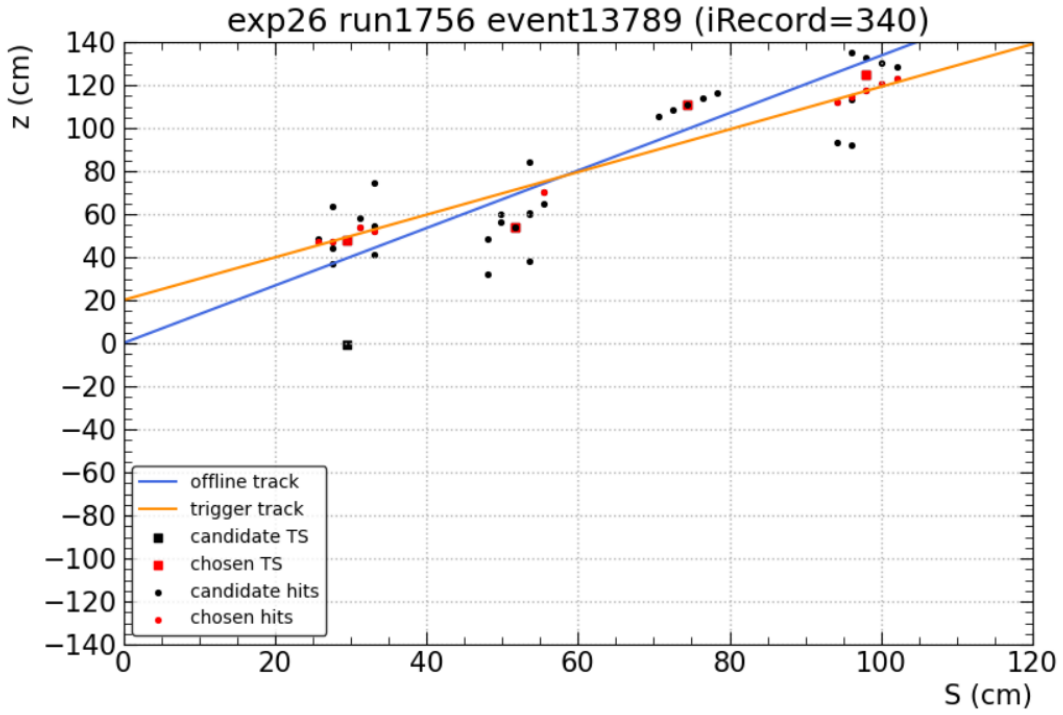


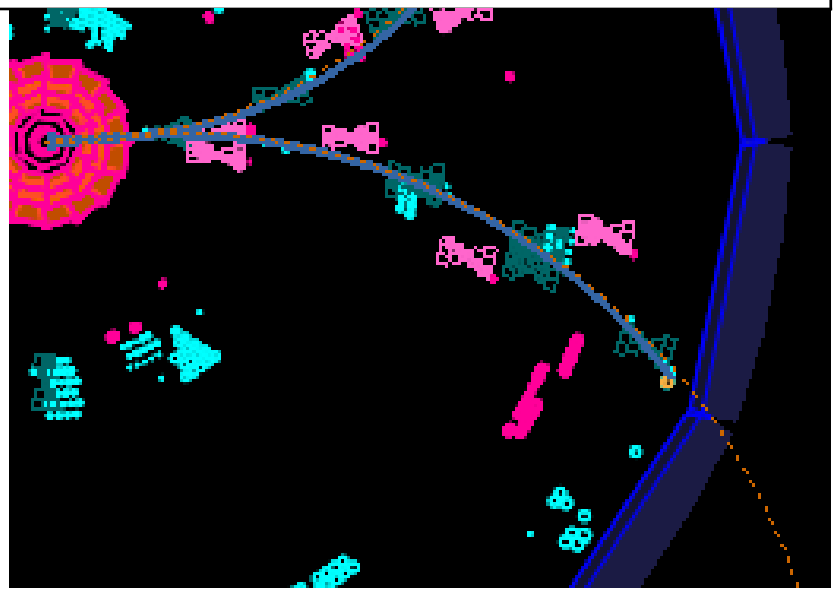




Cause of loss track

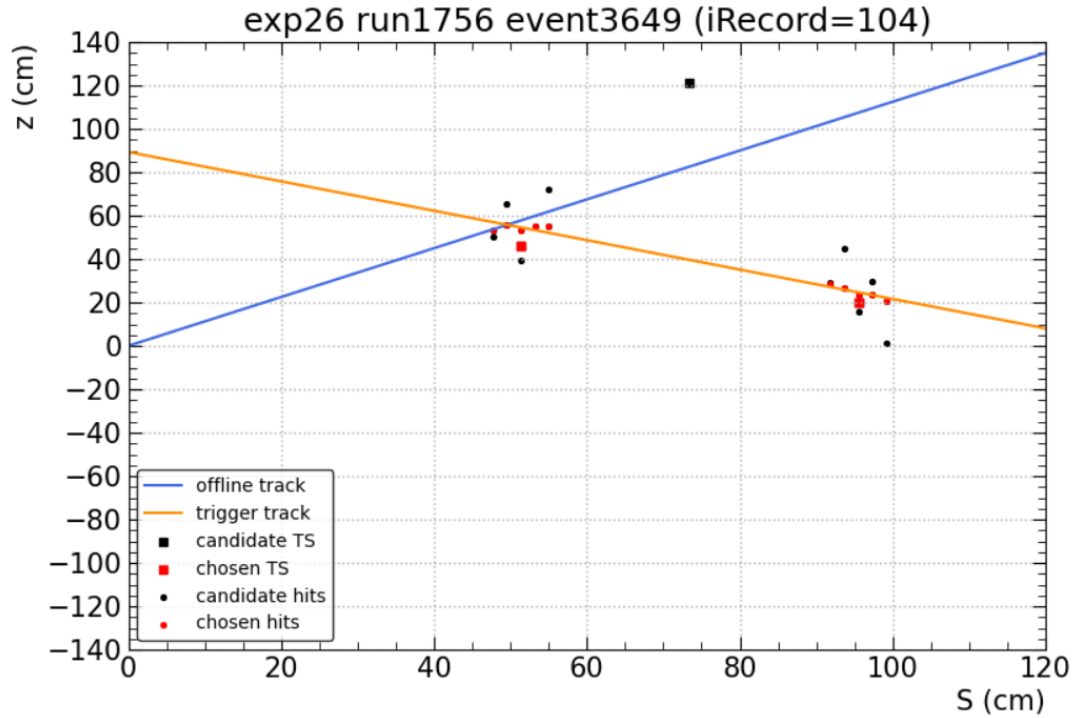
		9	Multiple TS are selected in 1 Super Layer
15	wrong 3D fitter	1	TS of adjacent track are selected
		5	No idea
12	wrong 2D input		
		1	Overcounting track is selected
			r-created track is selected

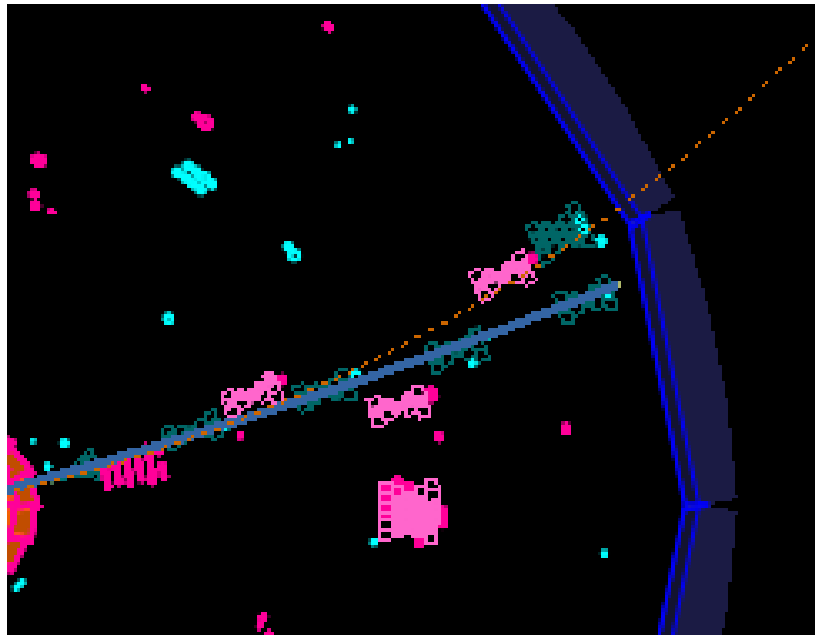




Cause of loss track

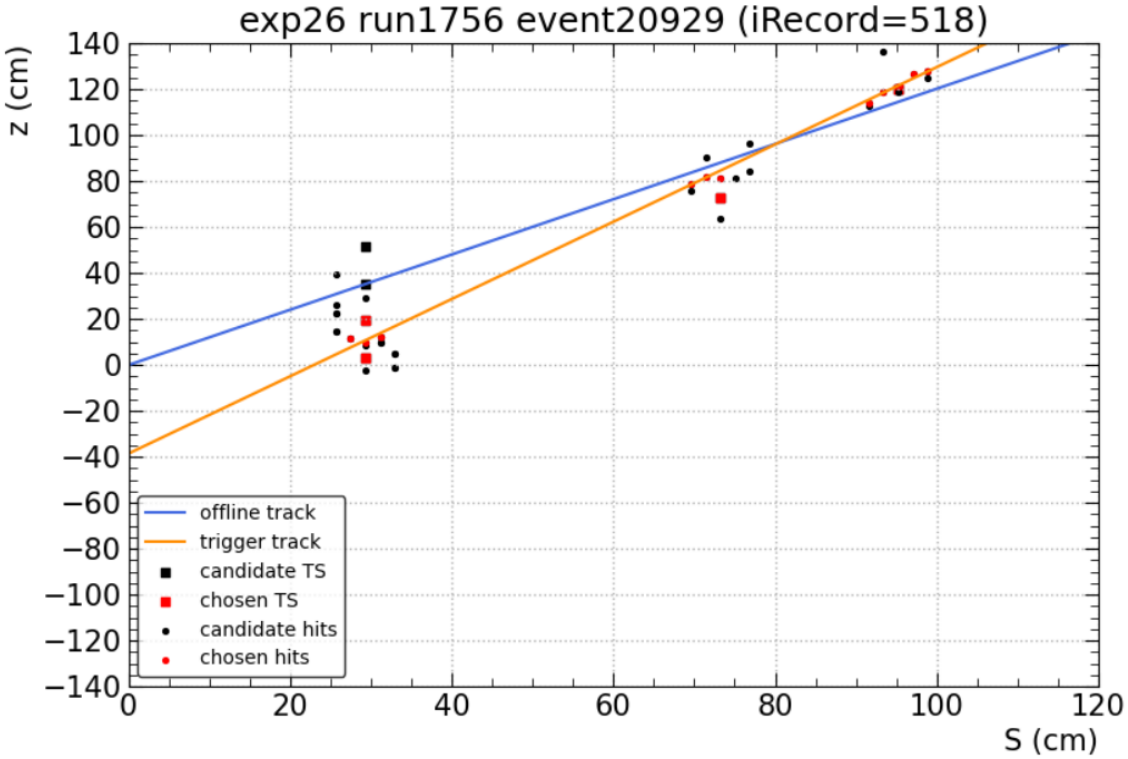
15	wrong 3D fitter	1	TS of adjacent track are selected
		5	No idea
12	wrong 2D input		
3	wrong matching	1	Overcounting track is selected
			-created track is selected

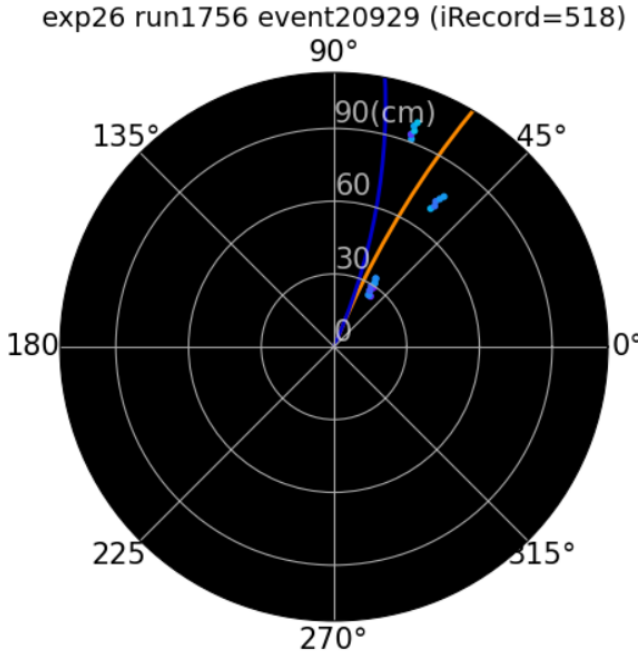


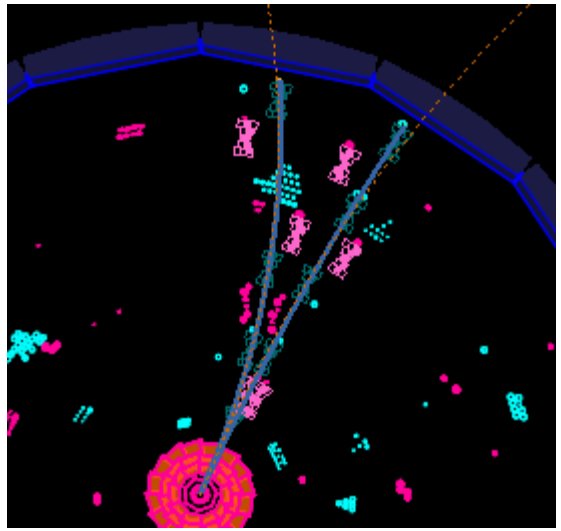


Cause of loss track

12	wrong 2D input		
3	wrong matching	1	Overcounting track is selected
		2	Counterpart of pair-created track is selected







Performance indices

Original fitter		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	5582	683	529
	$\lvert z_0 \rvert > 1$ (BG)	2252	1727	239
	no track	620	2268	871

3D efficiency = 82.16 %

BG rejection rate = 46.61 %

Fake track rejection rate = 83.51 %

Fitter (shrink)		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	6231	364	199
	$\lvert z_0 \rvert > 1$ (BG)	1726	2025	467
	no track	0	0	3759

3D efficiency = 91.71 %

BG rejection rate = 59.08 %

Fake track rejection rate = 100 %

Performance indices

Voter (cluster)		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	5983	239	571
	$\lvert z_0 \rvert > 1$ (BG)	1699	1109	1408
	no track	0	0	3759

3D efficiency = 88.06 %

BG rejection rate = 59.72 %

Fake track rejection rate = 100 %

Voter (maximum)		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	6552	241	1
	$\lvert z_0 \rvert > 1$ (BG)	2609	1543	66
	no track	0	0	3759

Good point
Basically this method never fails
(except for no hit case)

3D efficiency = 96.44 %

BG rejection rate = 38.15 %

Fake track rejection rate = 100 %

Performance index

voter(maximum) +fitter		Trigger Track		
		2D + 3D $\lvert z_0 \rvert < 20$	2D + 3D $\lvert z_0 \rvert > 20$	Only 2D (3D tracking failed)
Offline track	$\lvert z_0 \rvert < 1$ (signal)	6648	145	1
	$\lvert z_0 \rvert > 1$ (BG)	2326	1825	67
	no track	0	0	3759

3D efficiency	= 97.85	%
BG rejection rate	= 44.86	%
Fake track rejection rate	= 100	%