

Studies on novel detector concepts

J. Kim (Yonsei Univ., Speaker), Prof. Y. Kwon (Yonsei Univ.), L. Musa (CERN)

12th ALICE ITS upgrade, MFT and O2 Asian Workshop – 2018, 21 Nov. 2018

Contents

- Kalman Tracking
 - Tracking Algorithm
 - Tracking Efficiency
 - Momentum / Angle Resolution
 - Limitations and Future Plan
- Vertex Reconstruction
 - Efficiency for B / D meson
 - Vertex Position Resolution
 - Limitations and Future Plan

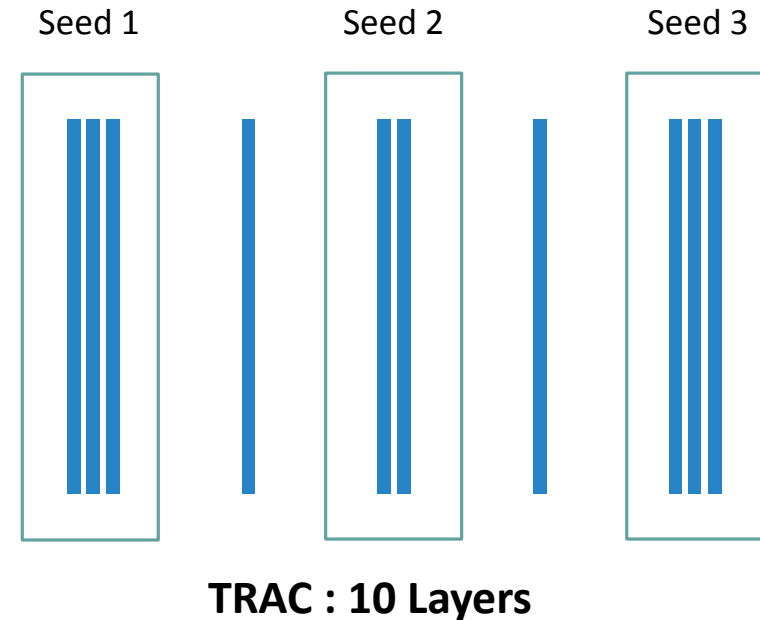
1. Kalman Tracking

Tracking Algorithm

Initial Helix Construction at TRAC

1. Make 3 "Helix Seed" (Tracklet) for 3 Pivot points.
Clustering hits inside of distance cut
(30, 75, 150 μm for each X, 30 μm for Z)
2. Divide "Multiple Hits Seed" into Single one.
Apply Track Slope Criteria
3. Construct Helix for all available combinations

Currently we assumed that Hit efficiency is 100%
→ Efficiency factor should be considered.

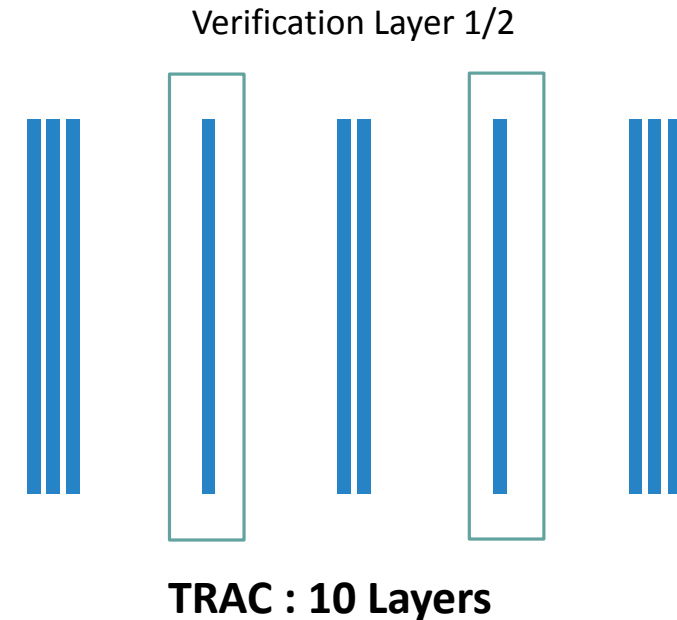


Tracking Algorithm

Verification step for Helix candidates

1. Check hit validity by using verification layer 1 and 2
Real helix can find hits at verification layers,
within (distance cut) = 300 / 400 μm for each.
2. Check linearity of 3 seeds for Z direction
(Parallel to B-field direction)
within (distance error) = 500 μm

After confirmation, Do Kalman Filter for rest detectors
(TRAC/TACT...)



Kalman Tracking Efficiency

We defined the criteria for '**Visible Track**' at Kalman Filtering.

1. Track is Charged Particle (Leave Detector Hits)
2. Initial Momentum is $> 1.5\text{GeV}$ (Lower limits for M.S. effect acceptance)
3. Track is not the 'Out of detector' case at TRAC/TACT

Criteria for matching 'Visible Track' from M.C. Data – Kalman Reconstructed track

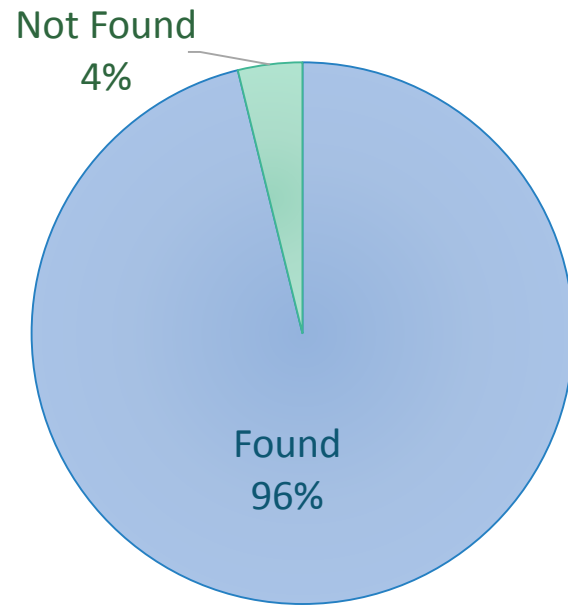
1. Each momentum direction angle (p_T and p_R) is close to MC ($p \cdot d\theta < \sim 0.7\%$ for 10 GeV)
2. Each momentum magnitude is close to MC ($dp/p < \sim 3\%$ for 10 GeV)

Kalman Tracking Efficiency

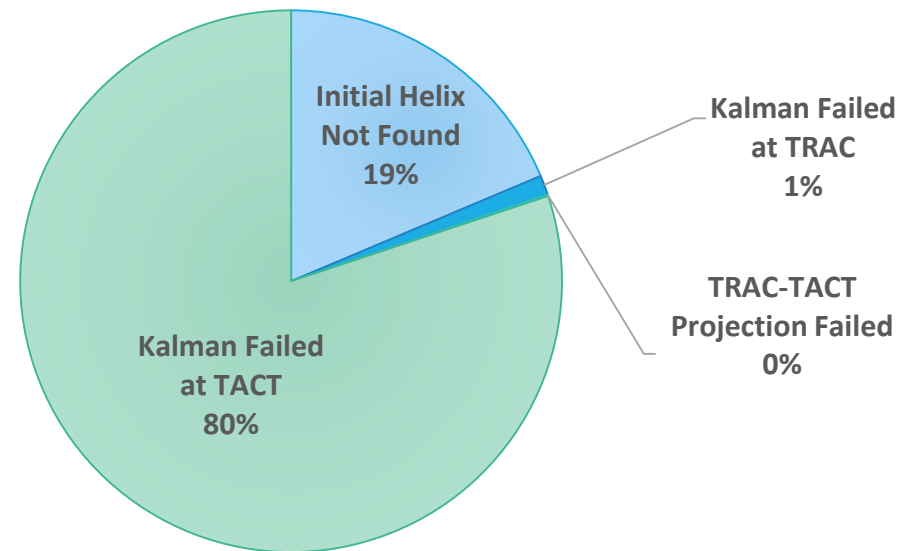
(@ MSEL5 Single p-p Events, Total 2000 Events)

We reconstructed 43785 tracks out of 45533 'Visible Tracks'. (~ 96%)

Total Visible Tracks (45533)



Not Found Tracks (1748)



Kalman Tracking Efficiency – Failed Cases

Specific examples for Kalman tracking failed cases

1. Kink (Momentum Deflection) can cause Kalman failing at TACT.

- 1400 cases (~ 3.1% of total found tracks)

ex)	run002 Event#0 Track#21 :	Delta ray Generation
	run002 Event#1 Track#2 :	Hadron Interaction

2. Initial helix is not constructed.

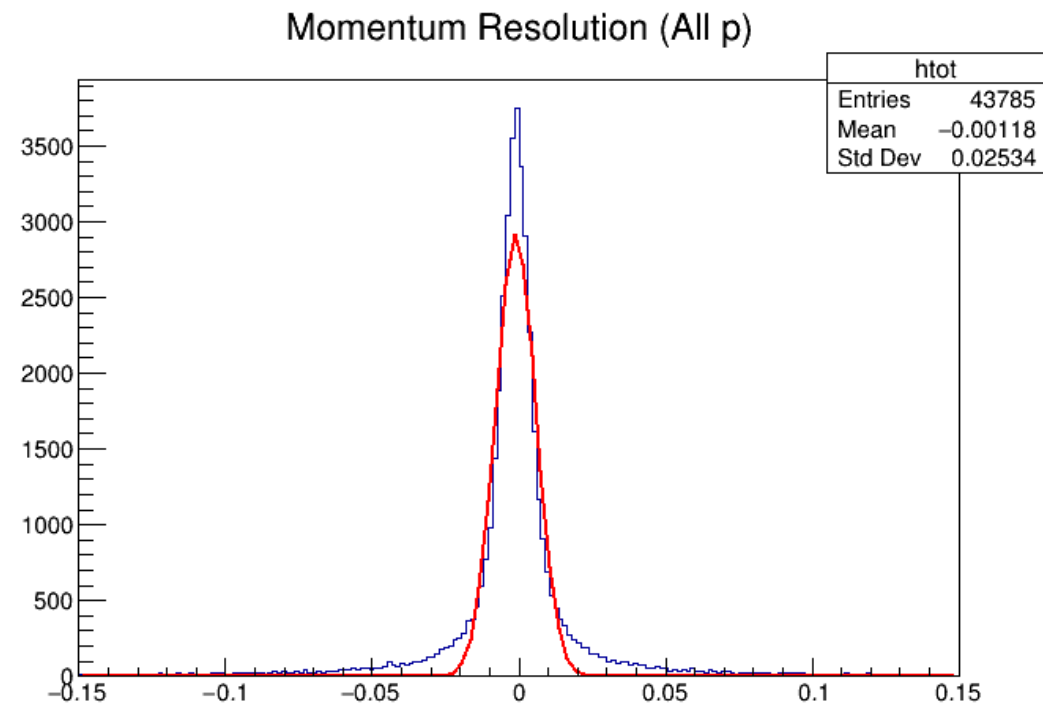
- 326 cases (~ 0.7 % of total found tracks)

→ Refine Helix construction criteria.

Kalman Tracking Resolution

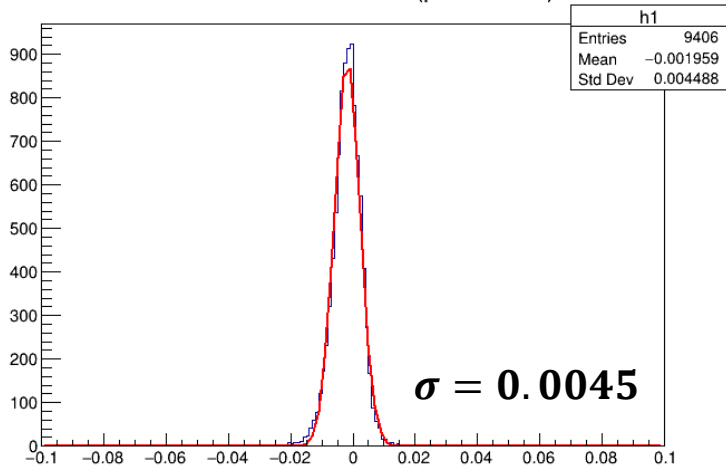
(@ MSEL5 Single p-p Events, Total 2000 Events)

Momentum Resolution ($\delta p/p$): $\sigma = \mathbf{0.025}$ (for All range of p)

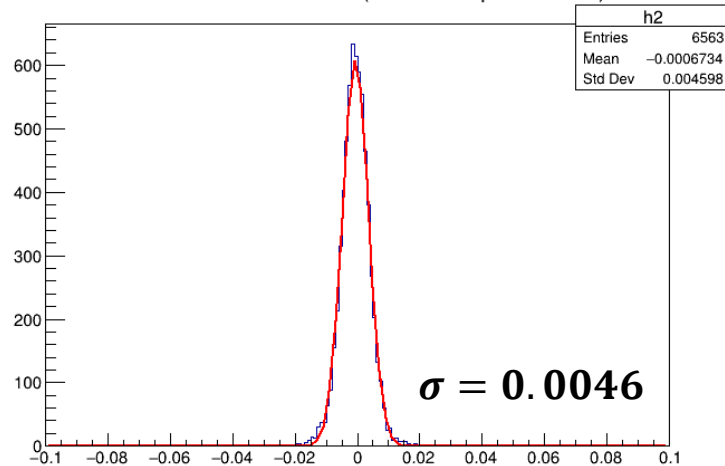


Momentum Resolution ($\delta p/p$)

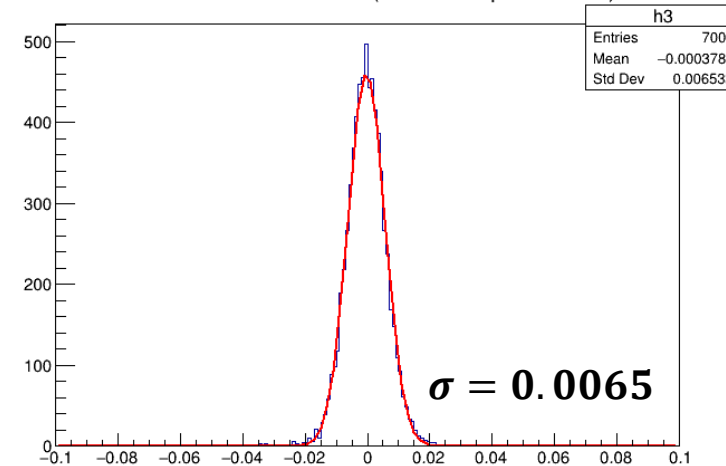
Momentum Resolution ($p < 10\text{GeV}$)



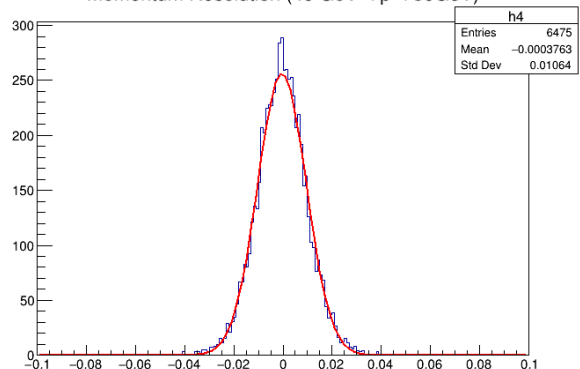
Momentum Resolution ($10\text{ GeV} < p < 20\text{GeV}$)



Momentum Resolution ($20\text{ GeV} < p < 40\text{GeV}$)

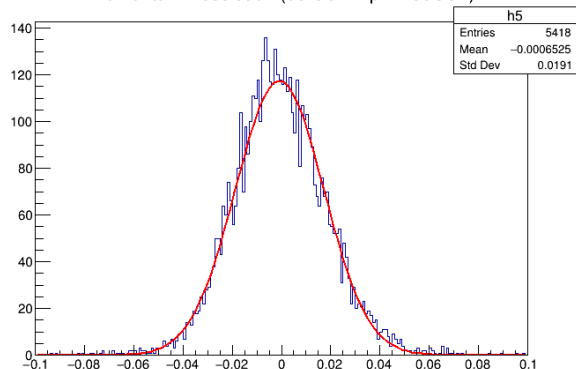


Momentum Resolution ($40\text{ GeV} < p < 80\text{GeV}$)



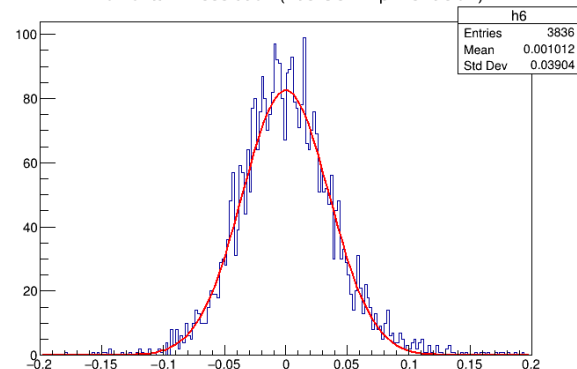
$\sigma = 0.011$

Momentum Resolution ($80\text{ GeV} < p < 160\text{GeV}$)



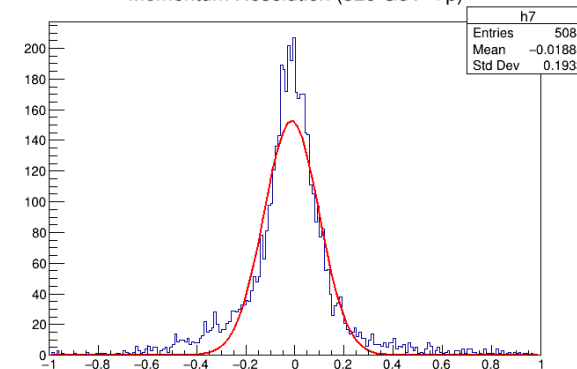
$\sigma = 0.019$

Momentum Resolution ($160\text{ GeV} < p < 320\text{GeV}$)



$\sigma = 0.039$

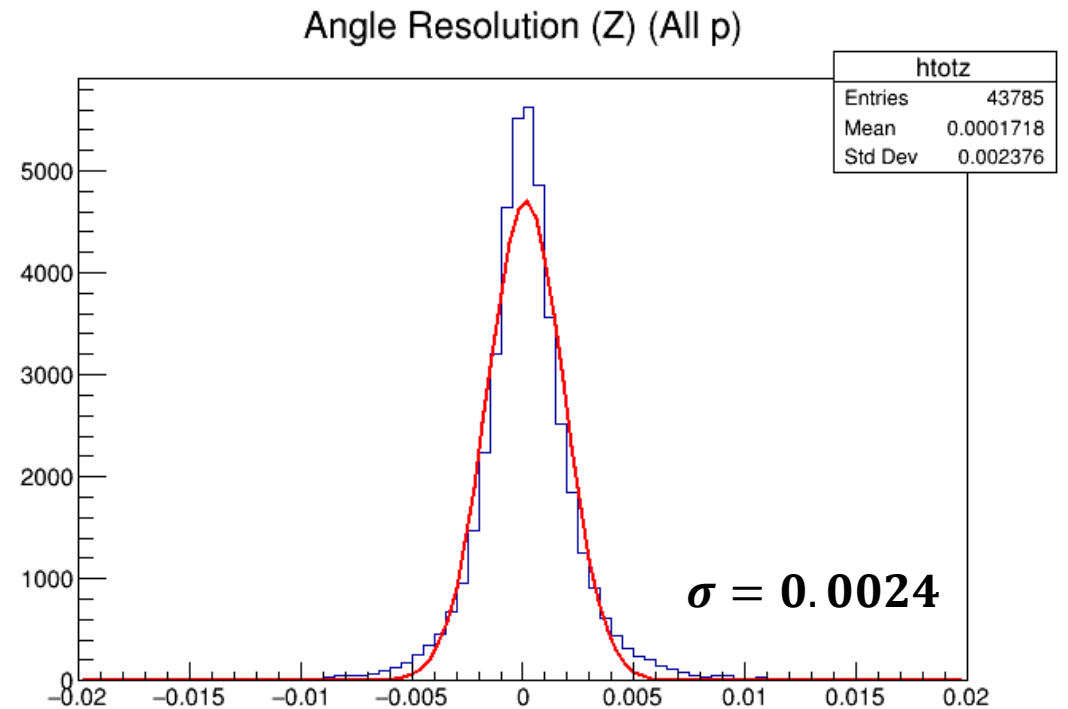
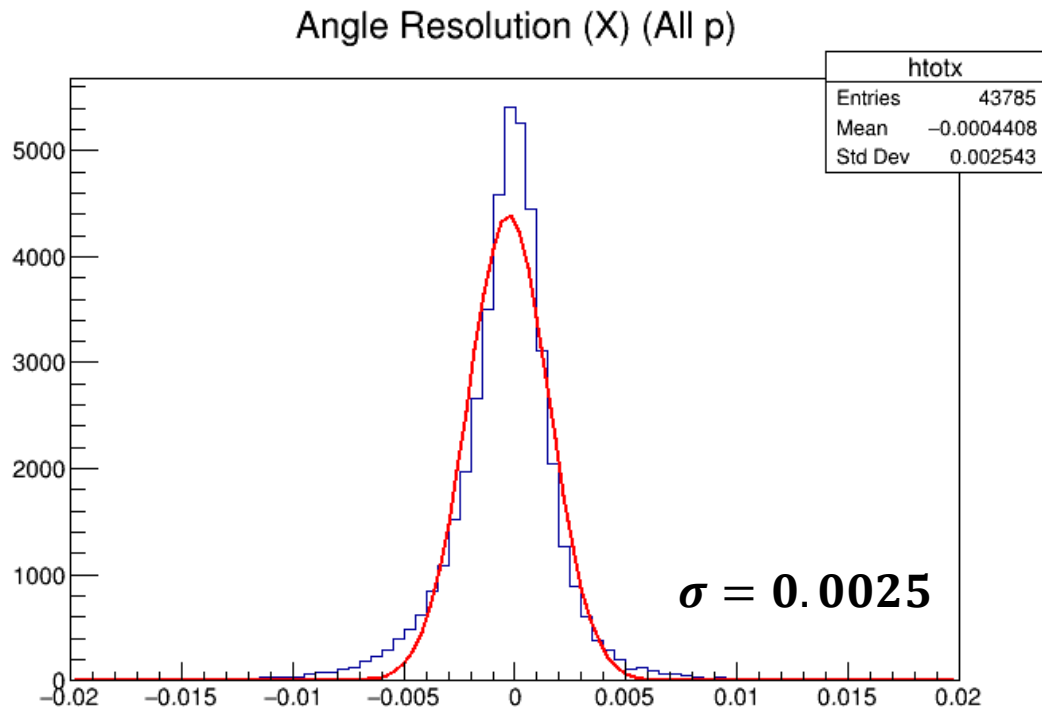
Momentum Resolution ($320\text{ GeV} < p$)



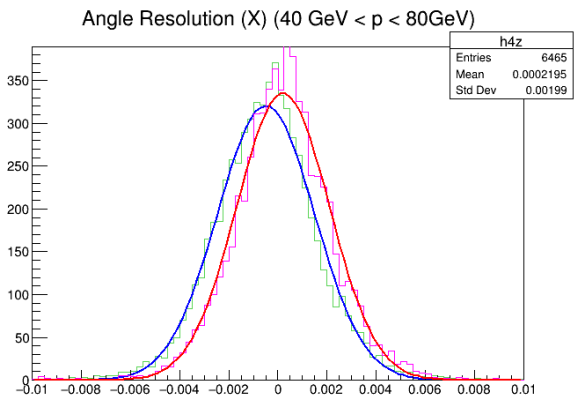
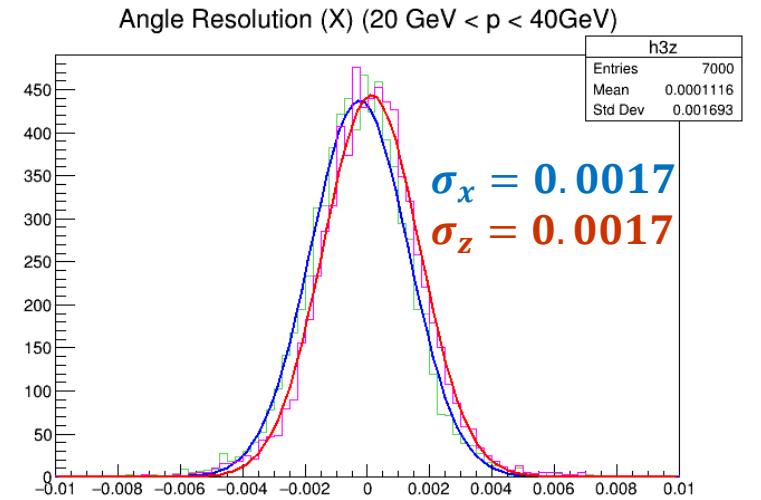
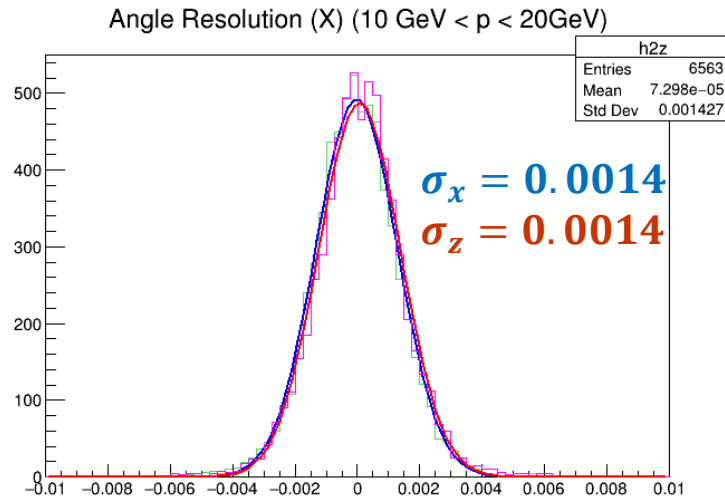
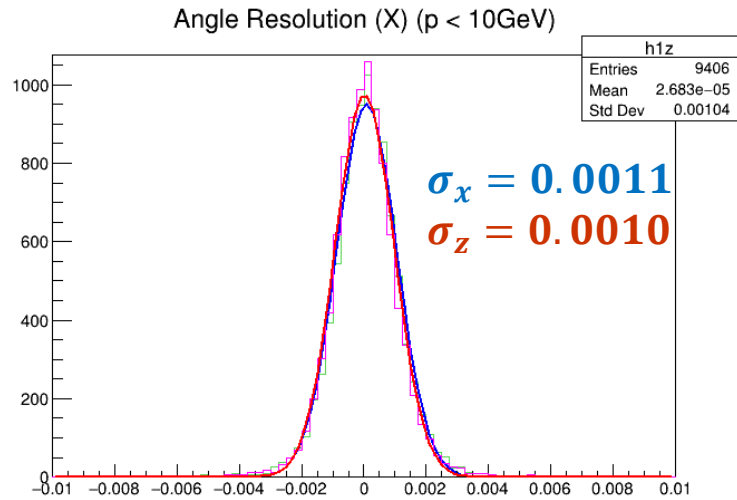
$\sigma = 0.193$

Kalman Tracking Resolution

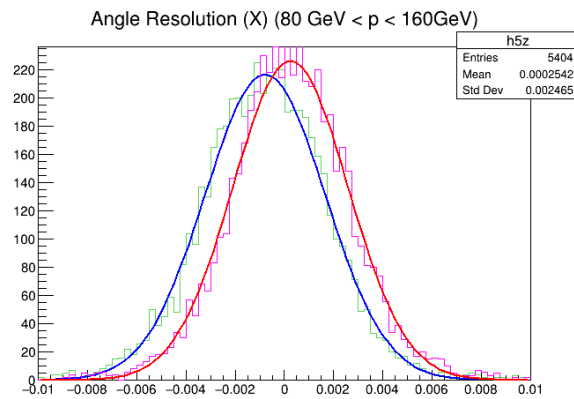
Angle Resolution ($p \cdot \delta\theta$) at Decay Vertex, All range of $p =$ **0.0025** ($rad \cdot GeV$, X direction)
(Beam Direction = Y) **0.0024** ($rad \cdot GeV$, Z direction)



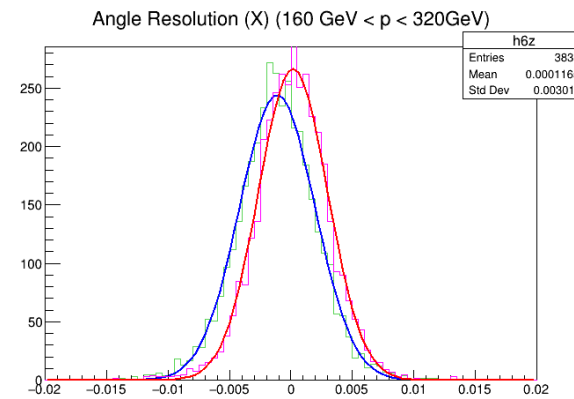
Angle Resolution ($p \cdot \delta\theta$)



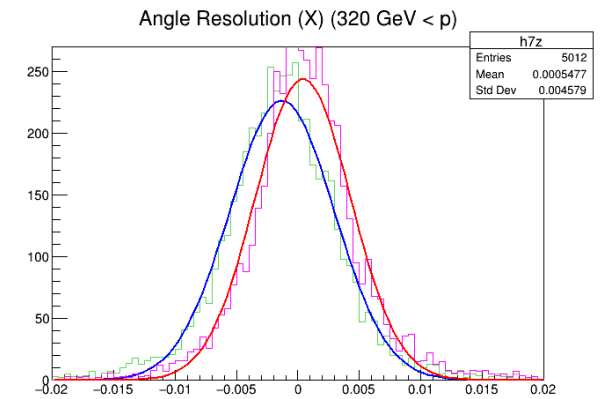
$\sigma_x = 0.0021$
 $\sigma_z = 0.0020$



$\sigma_x = 0.0026$
 $\sigma_z = 0.0025$



$\sigma_x = 0.0033$
 $\sigma_z = 0.0030$



$\sigma_x = 0.0049$
 $\sigma_z = 0.0046$

Kalman Tracking – Limitations&Way to Improvement

We got **96%** Track finding efficiency, **0.025** momentum resolution, **0.0025** angle resolution.

We have following limitations for current algorithm.

1. We can find only tracks which passes all of TACT – TRAC detector.
2. We have some background (ghost) tracks problem, causing confusion when vertex finding

So, we plan to revise them.

1. Apply more precise cut for helix construction&verification to reject background tracks.
2. Apply searching windows when constructing initial 'helix seed'.

2. Decay Vertex Reconstruction

for D / B meson Vertices

Vertex Reconstruction Algorithm

We applied following vertex construction criteria :

1. For all Kalman-success tracks at TACT detector,
2. Scan for all TACT detector layer (with expolation between each layers for 500 um interval)
3. Make vertex suspects for approaching tracks each other (< 15 um latteral distance)
4. Delete duplicated vertices, if exist. (Save most upstream vertex)

and, compare to real vertex information what we have to find.

Vertex Reconstruction – D meson

D decay vertex (@ MSEL5 Single p-p Events, Total 100 Events)

Looking for “D ($D^0 \bar{D}^0 D^+ D^- D_s^+ \dots$) to Charged Particle” Decay Mode

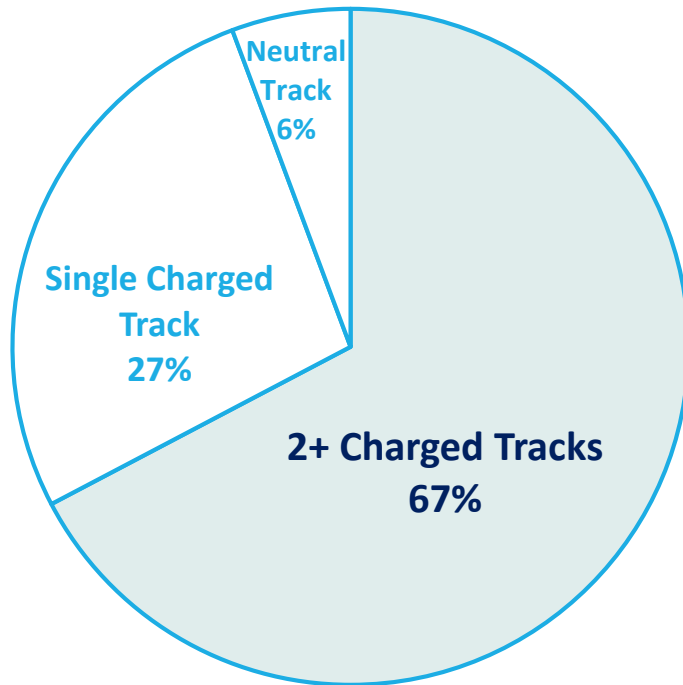
# of Charged Tracks	(Quantity)	# of Trackable Tracks	(Quantity)
0	4	0	4
1	40	0	8
		1	32
2	102	0	4
		1	24
		2	74
3	48	0	0
		1	1
		2	16
		3	31
4+	21	0	0
		1	0
		2	1
		3	2
		4	18

Total Vertex	215
0 Trackable Track	12
1 Trackable Track	57
2+ Trackable Track	142

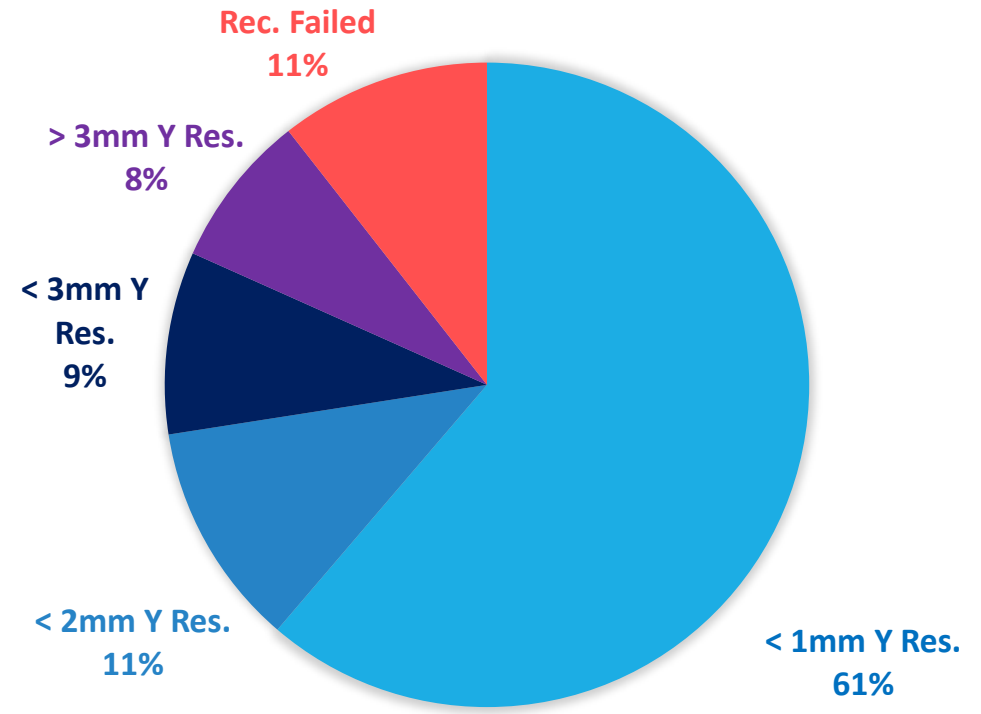
~ 67.0%

Vertex Reconstruction – D meson

D DECAY (TOTAL)

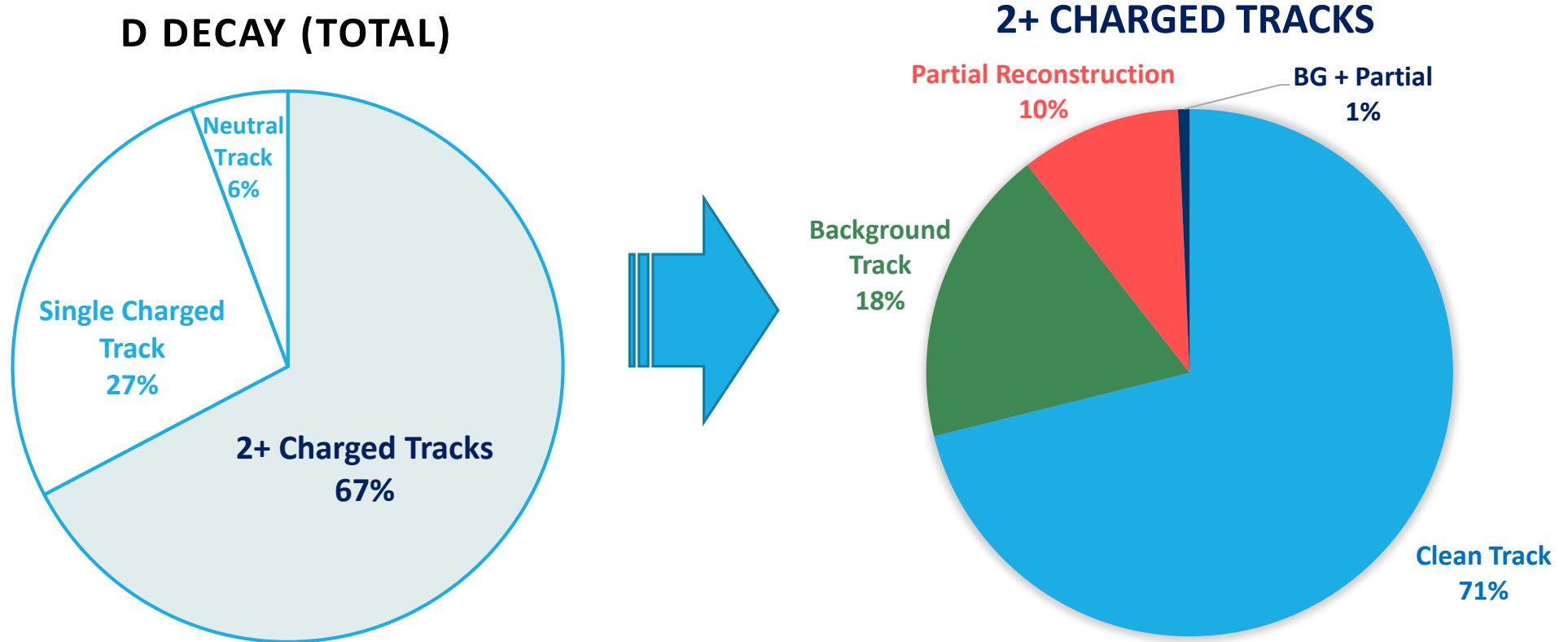


2+ CHARGED TRACKS



Beam Direction = Y

Vertex Reconstruction – D meson



Vertex Reconstruction – B meson

B decay vertex (@ MSEL5 Single p-p Events, Total 100 Events)

Looking for “B ($B^0 \bar{B}^0 B^+ B^- B_s^0$...) to Charged Particle” Decay Mode

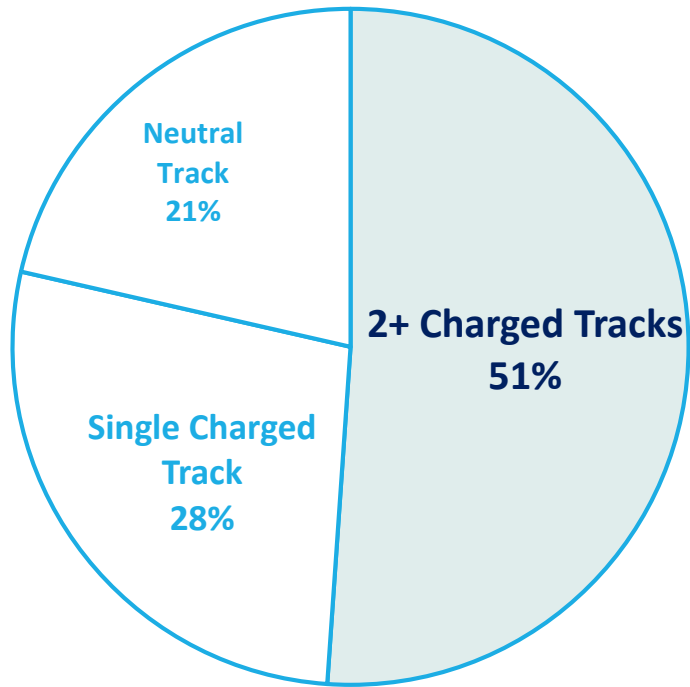
# of Charged Tracks	(Quantity)	# of Trackable Tracks	(Quantity)
2	73	0	38
		1	35
		2	0
3	28	0	1
		1	13
		2	14
		3	0
4+	81	0	0
		1	2
		2	11
		3	30
		4	38

Total Vertex	182
0 Trackable Track	39
1 Trackable Track	50
2+ Trackable Track	93

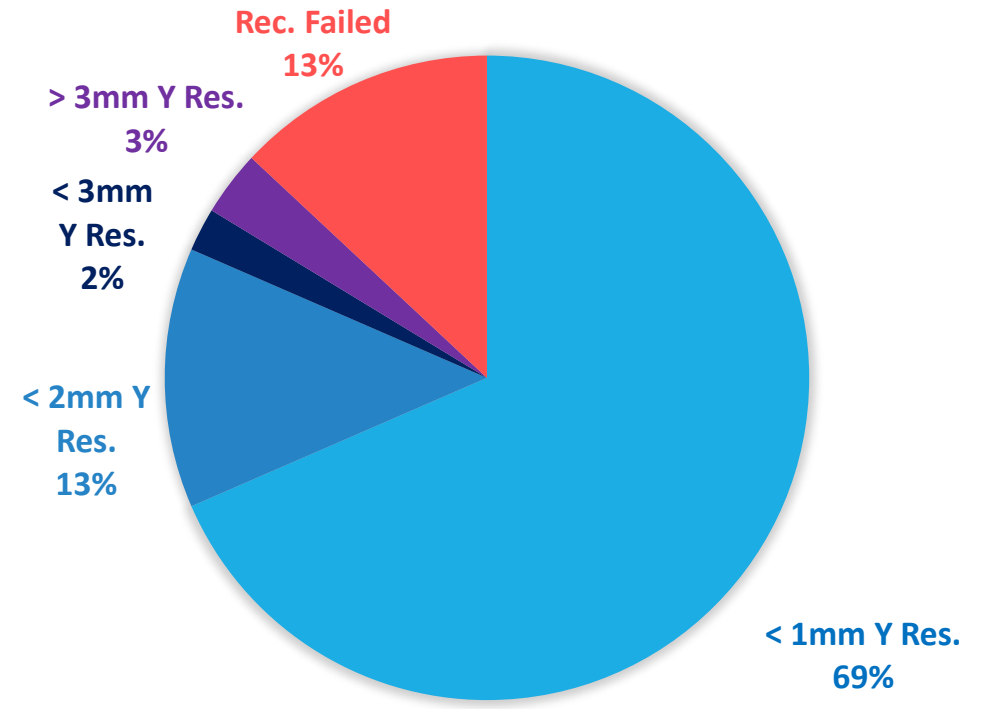
~ 51.1%

Vertex Reconstruction – B meson

B DECAY (TOTAL)



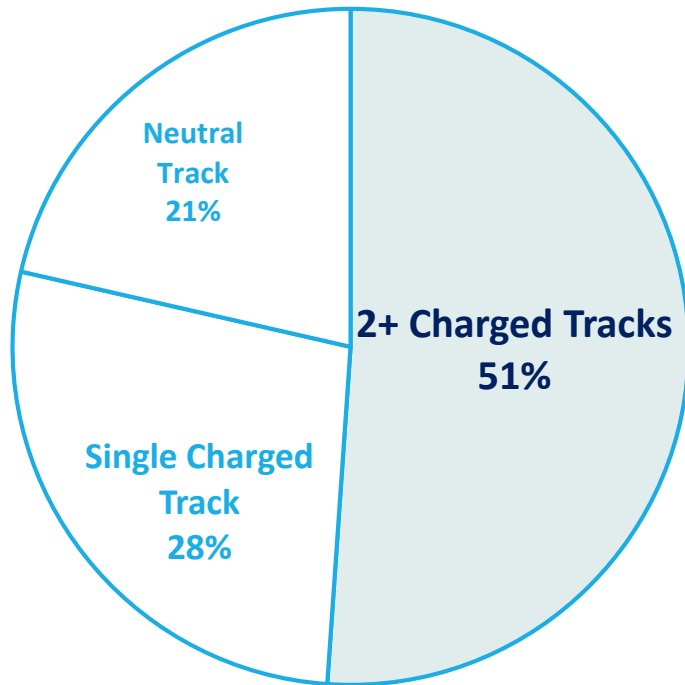
2+ CHARGED TRACKS



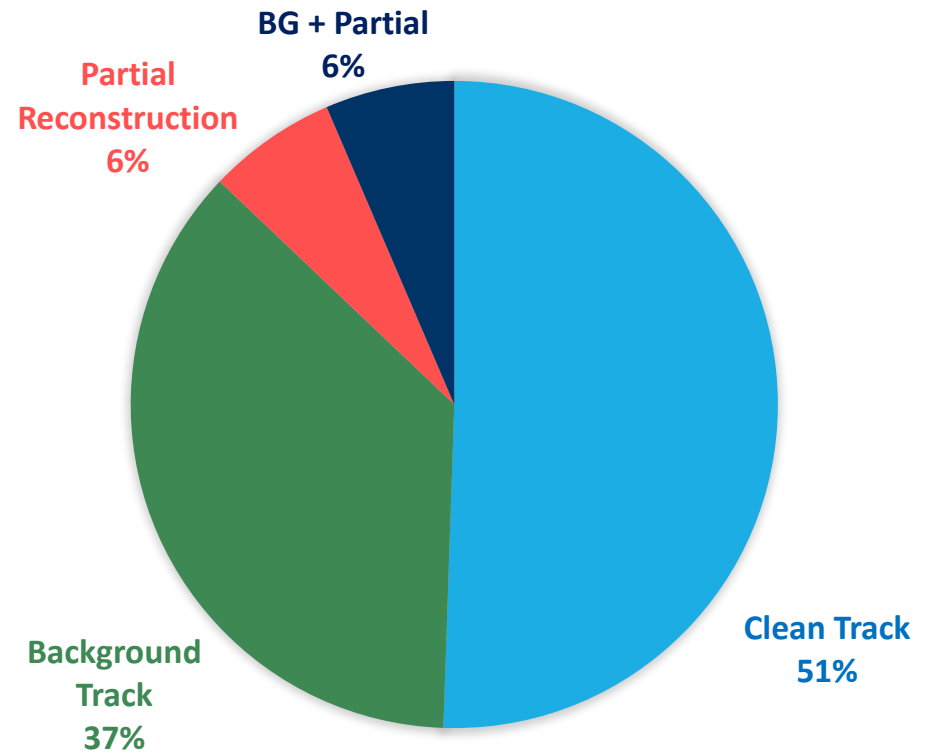
Beam Direction = Y

Vertex Reconstruction – B meson

B DECAY (TOTAL)

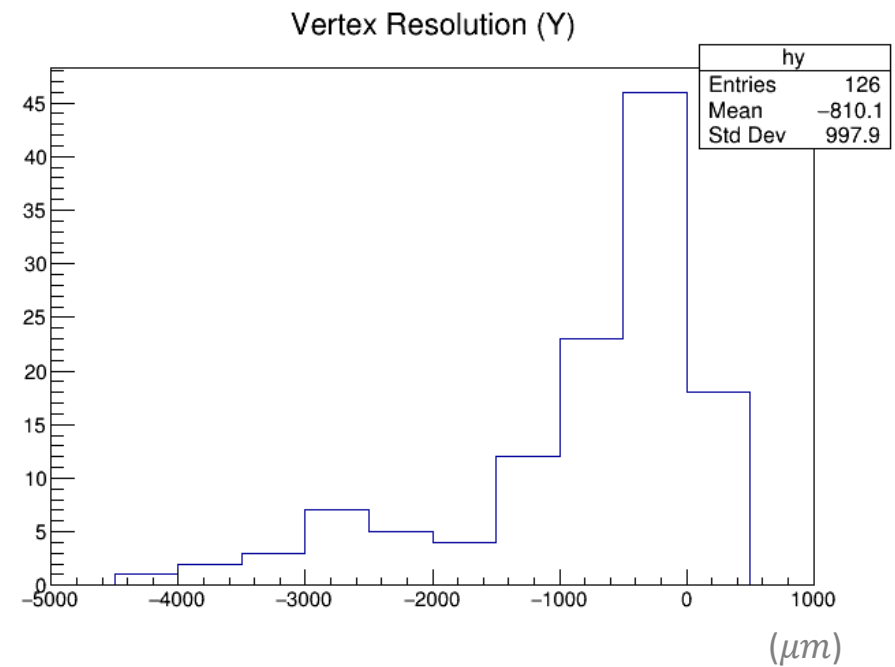
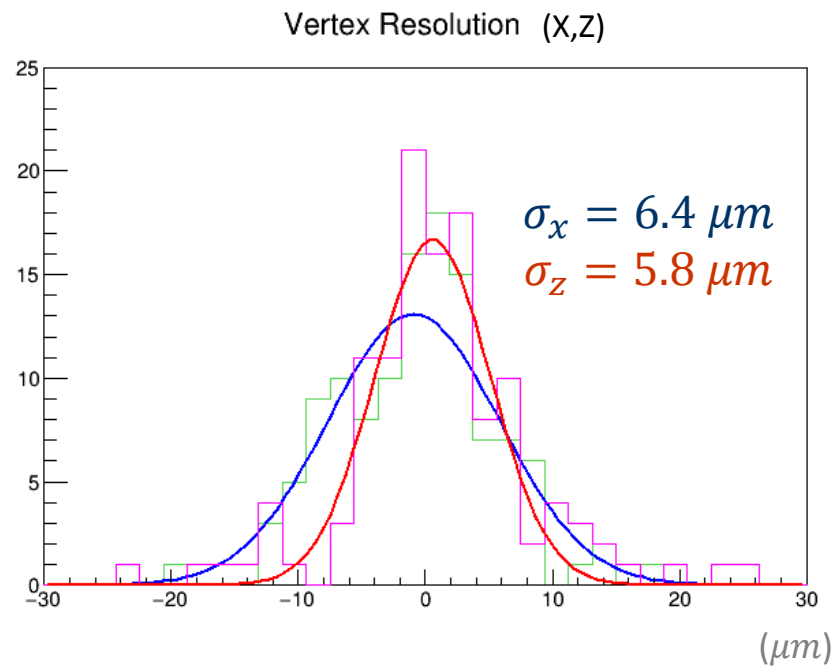


2+ CHARGED TRACKS



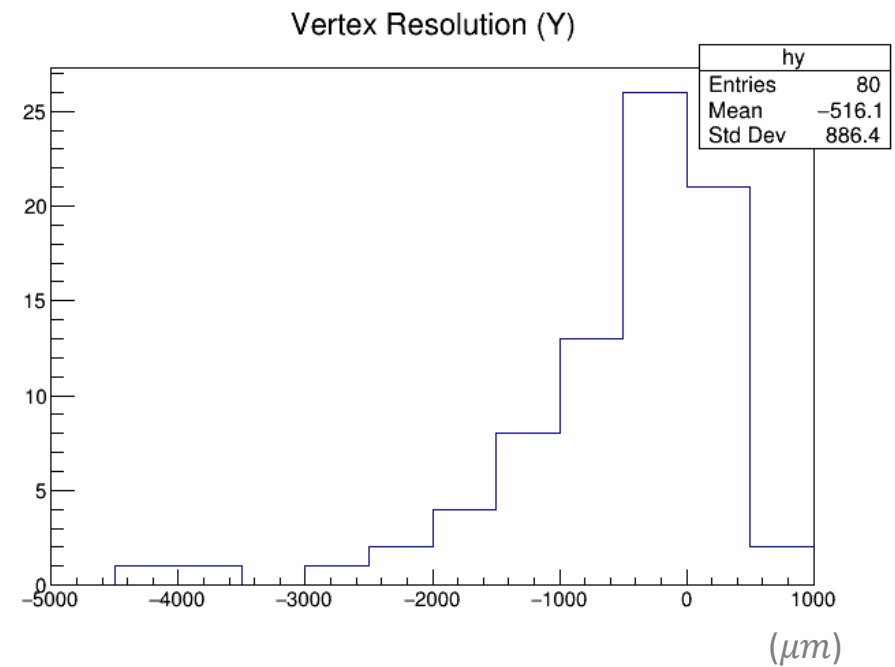
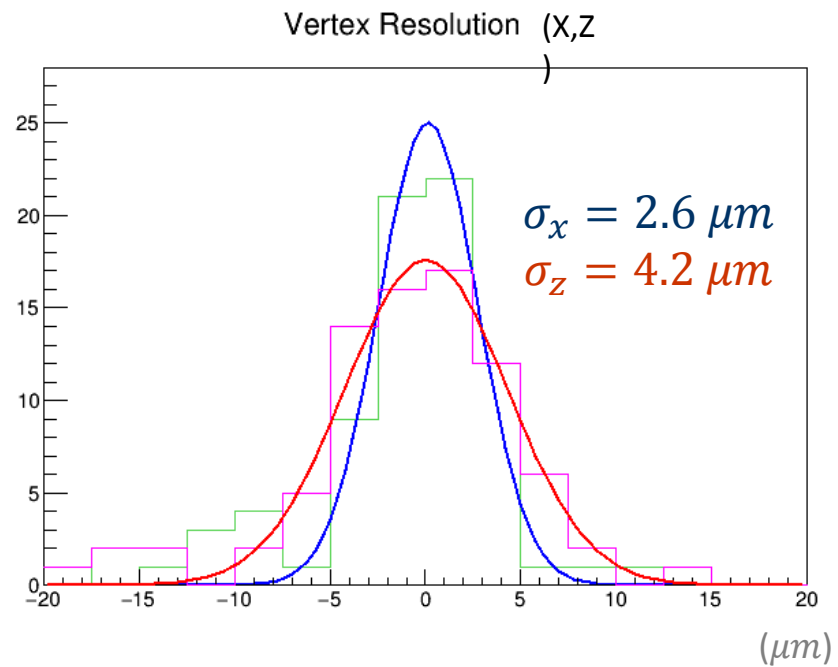
Vertex Resolution

D decay vertex (@ MSEL5 Single p-p Events, Total 100 Events each)



Vertex Resolution

B decay vertex (@ MSEL5 Single p-p Events, Total 100 Events each)



Vertex Finding – Limitations&Way to Improvement

Current Limitations:

1. We cannot find single charged track vertex (1-prong vertex).
2. Lower finding efficiency as vertex lateral position becomes smaller.
3. Track confusion problem when finding vertex.
4. Huge Y position resolution for some bad cases, due to hit confusion at Kalman filter.

Improvement:

1. Advance Kalman algorithm to find vertex using track kink.
2. Advance Kalman algorithm to consider hit density at TACT upstream.
3. Investigate new detector configurations at TACT upstream.