Updates on the SttCellTrackFinder, MvdHitFinder and the Time-based Reconstruction

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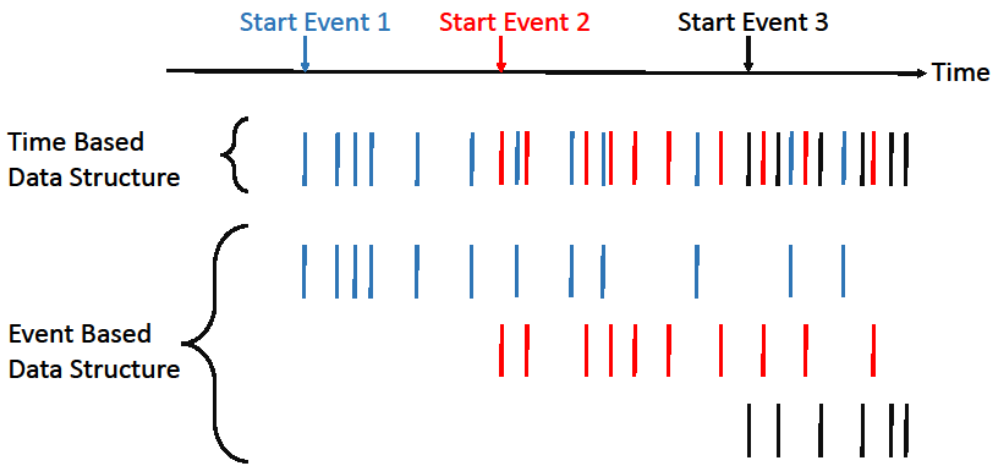
PANDA CM, Computing Session
GSI, 24-28 June

Outline

- Status of time-based tracking
- Current work
- Tests
- Outlook

Time-based Reconstruction



Event-based: data sorted according to events
Time-based: data sorted according to time-stamp

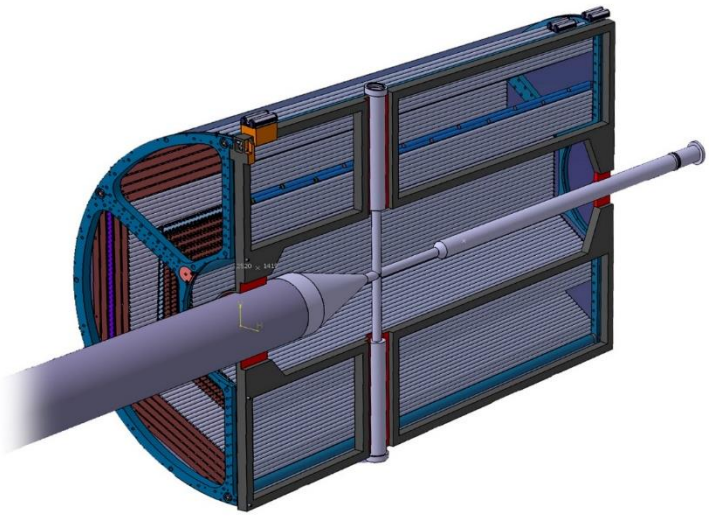
1. Time based digitization works for main barrel tracking detectors [1]
2. Realistic track reconstruction able to handle time-based data; SttCellTrackFinder and MvdHitFinder
3. Need tracking quality assurance which can handle time based data

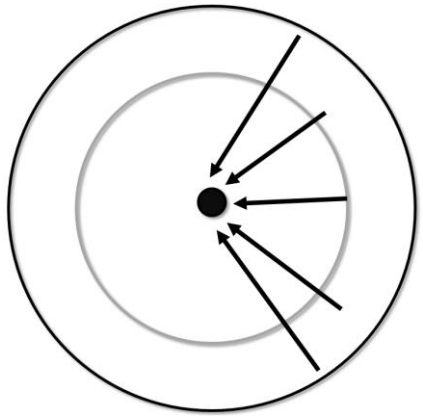
[1] https://indico.gsi.de/event/6354/contribution/7/material/slides/0.pdf

SttCellTrackFinder

Developed by J. Shumann

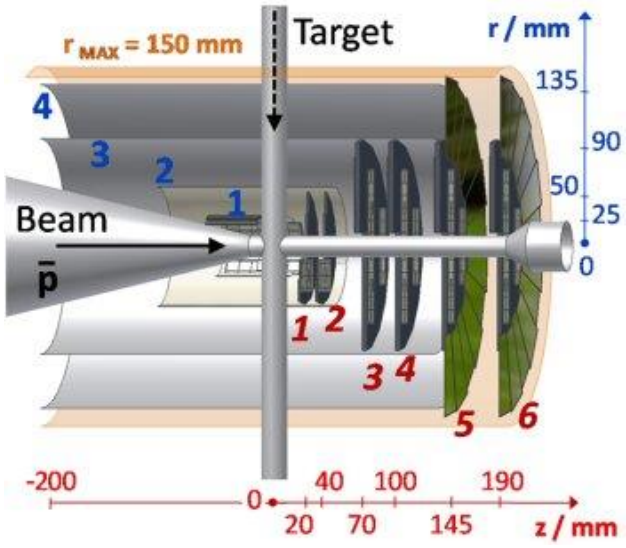
- Cellular Automaton
- Riemann Fit
- Utilizes STT hit information
- Have procedure for utilizing isochrones information
- Parts run on GPU





MvdHitFinder

- Extrapolation of tracks to MVD
- Utilizes MVD hit information

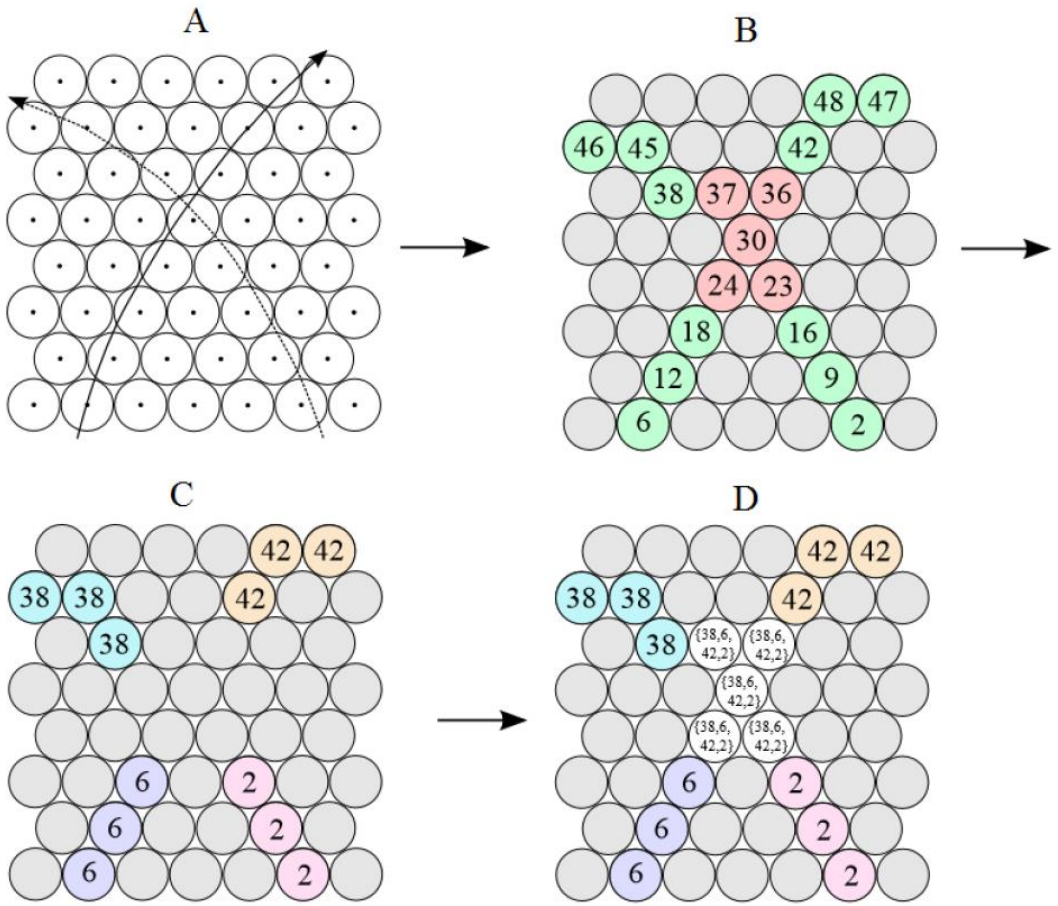


- Mainly use xy-information
- Do not assume tracks originate from interaction point

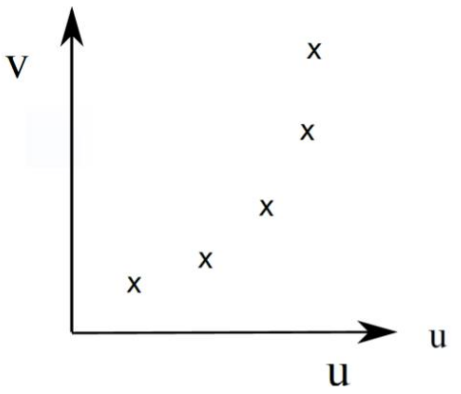
The Cellular Automaton

A. Tracks traverse STT
B. Hit tubes are numbered
C. *Unambiguous* hits are iteratively renumbered until hits in one cluster have same number
D. *Ambiguous* hits are given all numbers possible

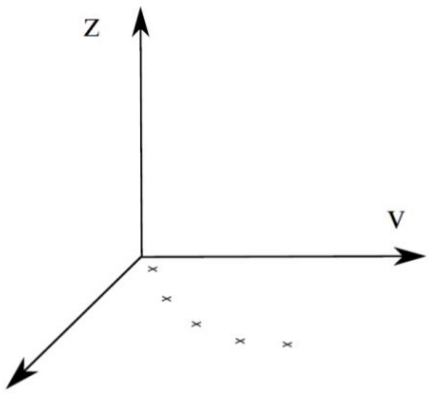
- Time information can be taken into account
- Two separate unambigous hit clusters can only be connected to longer track segment if they are interconnected via ambigous hits



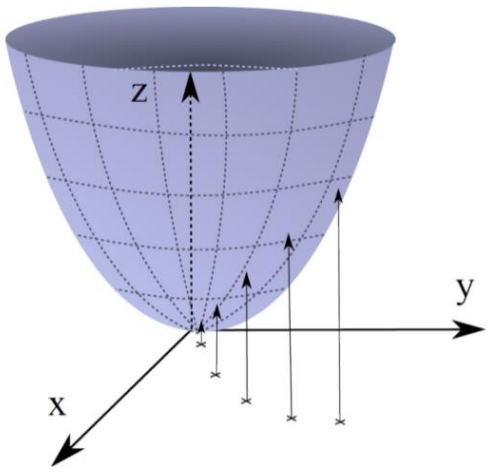
The Riemann Fit



Points to be fitted



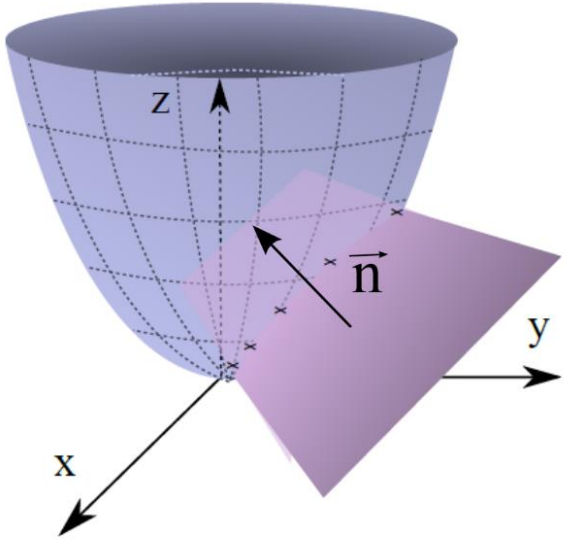
Add z-dimension



Map onto paraboloid

For STT, u=x, v=y

$z=x^2+y^2$



Calculation of plane through 3D points
simple eigenvalue determination

From $\vec{n}$, cirlcle parameters are known:

$$\left.\begin{aligned} u_0 &= -\frac{n_1}{2n_3} \\ v_0 &= -\frac{n_2}{2n_3} \end{aligned}\right\} \text{Circle center}$$

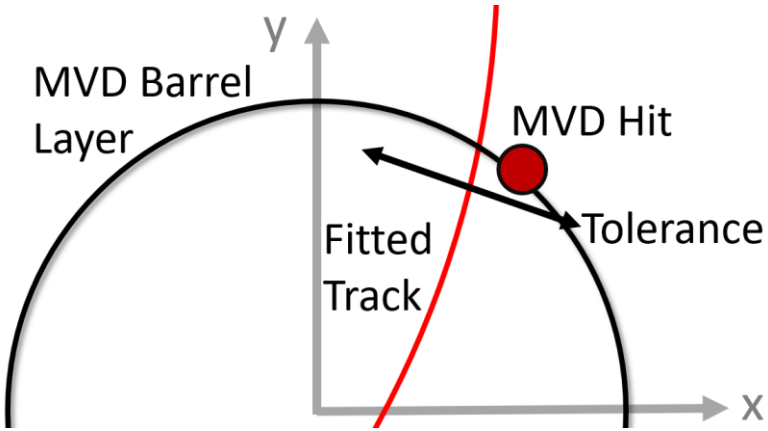
$$\rho^2 = \frac{1 - n_3^2 - 4cn_3}{4n_3^2} \quad \text{Radius}$$

$c+n_1x+n_2y+n_3z=0$

Mvd Hit inclusion

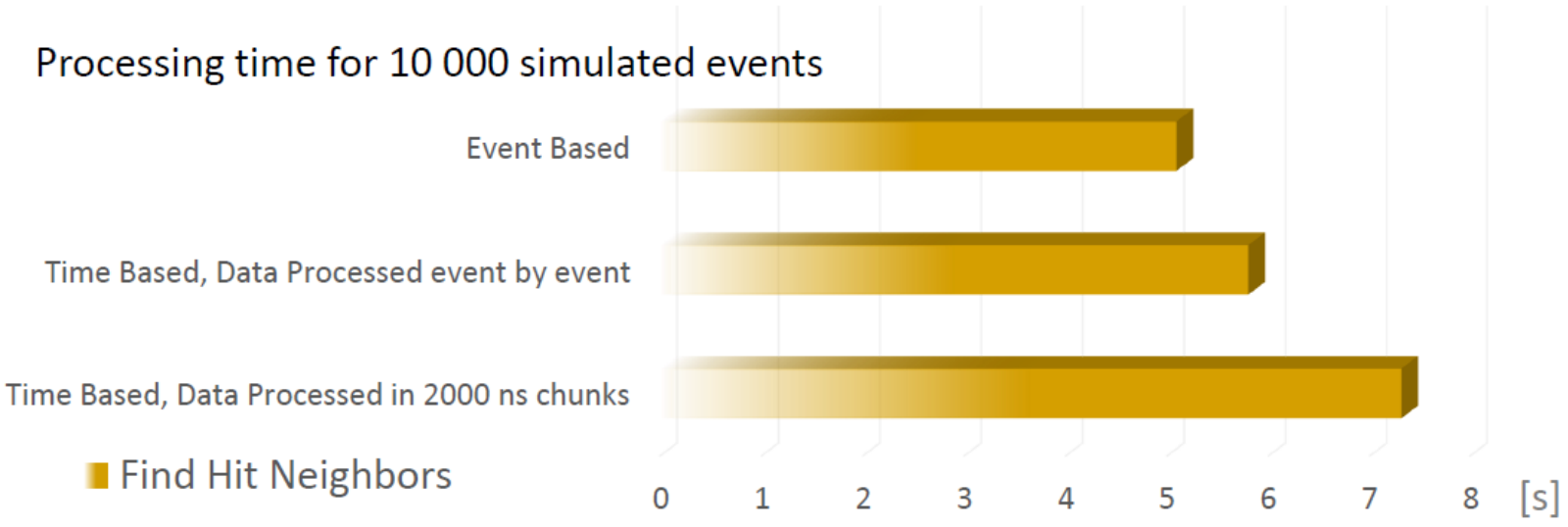
Procedure:

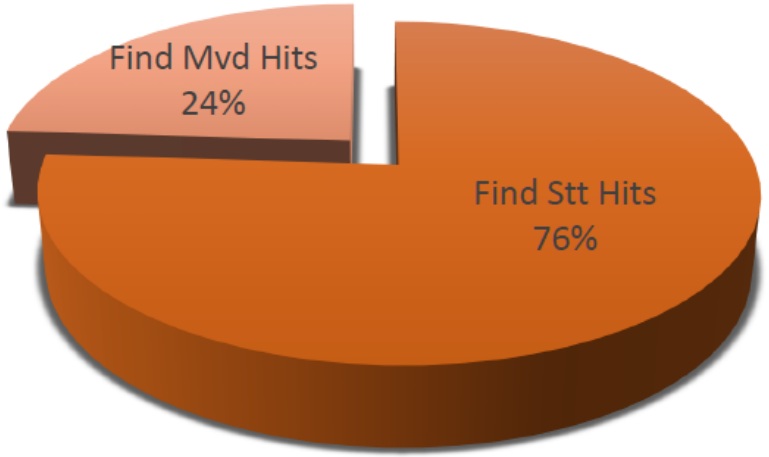
- Take already fitted track
- Add MVD hit to track if hit is within certain tolerance of track
- Add only best (closest) hit from each layer
- Refit track
- Repeat for each layer
- Outermost layer → Innermost layer



- Not sensitive to missing hits in layers
- Currently only handle barrel layers
- One hit can be added to several tracks

Runtime analysis



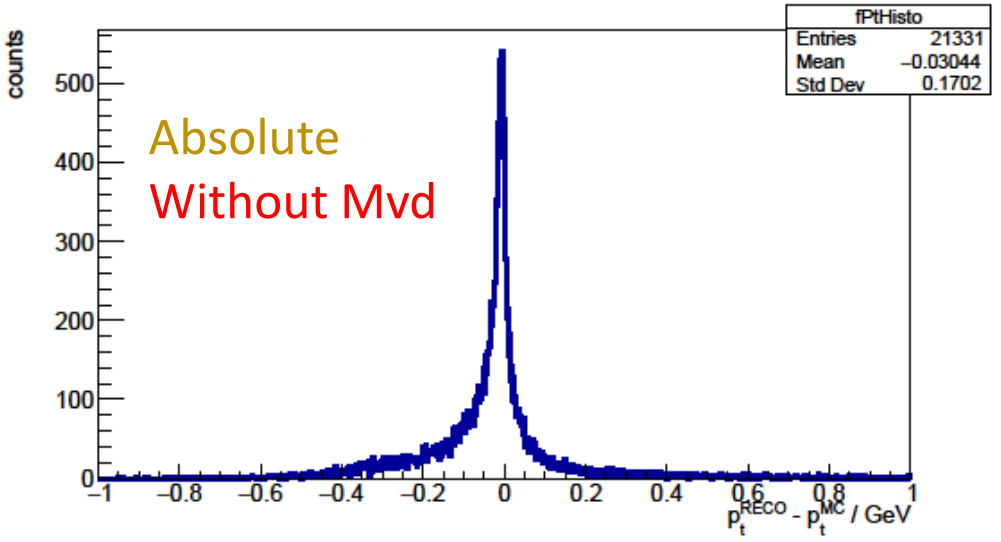


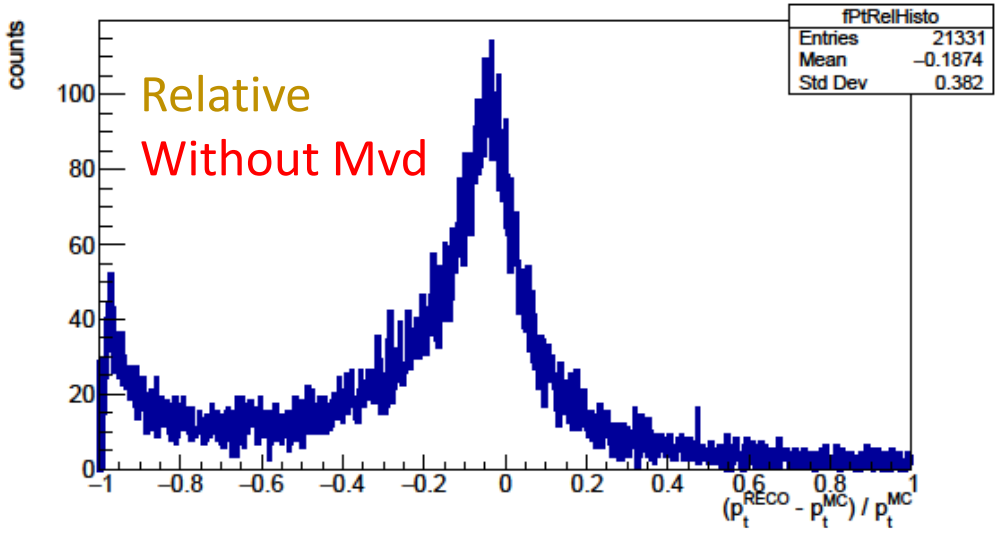
~ 10 ms / event on CPU **On i7 3.4 GHz processor**

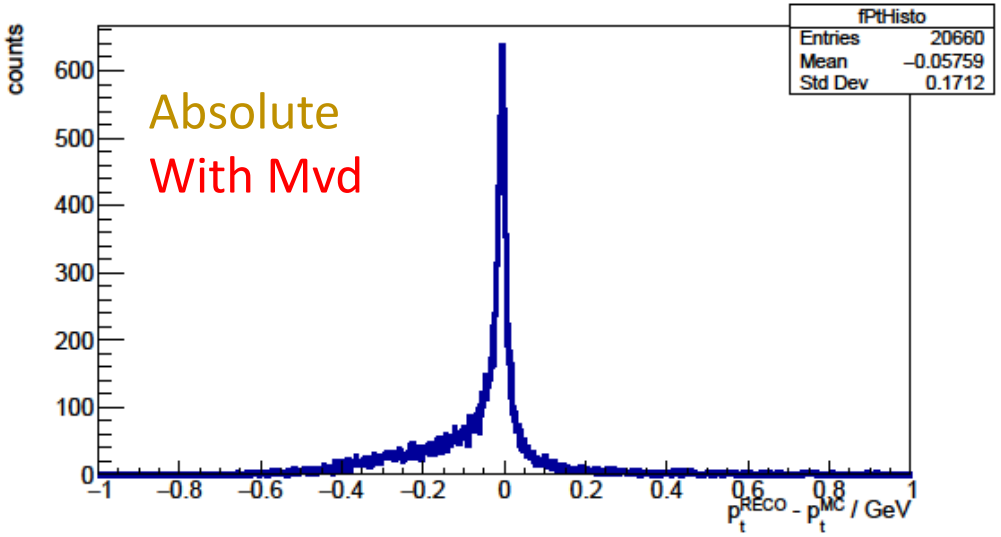
Speedup of factor 100 can be achieved for STT hit finding part on GPU **GeForce GTX 750 Ti GPU**

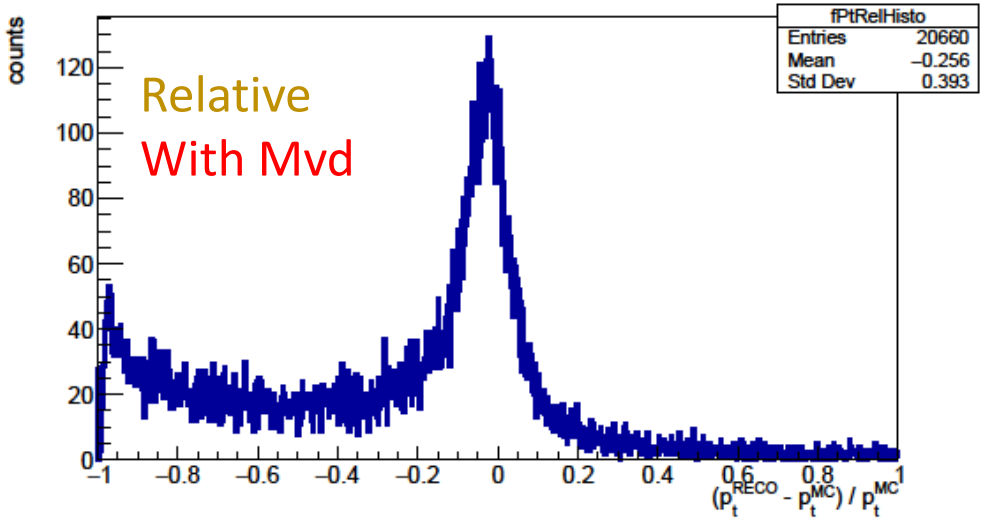
Momentum resolution

- Isochrones included in tracking procedure
- No Kalman filter
- DPM events
- P_{beam}=2 GeV/c



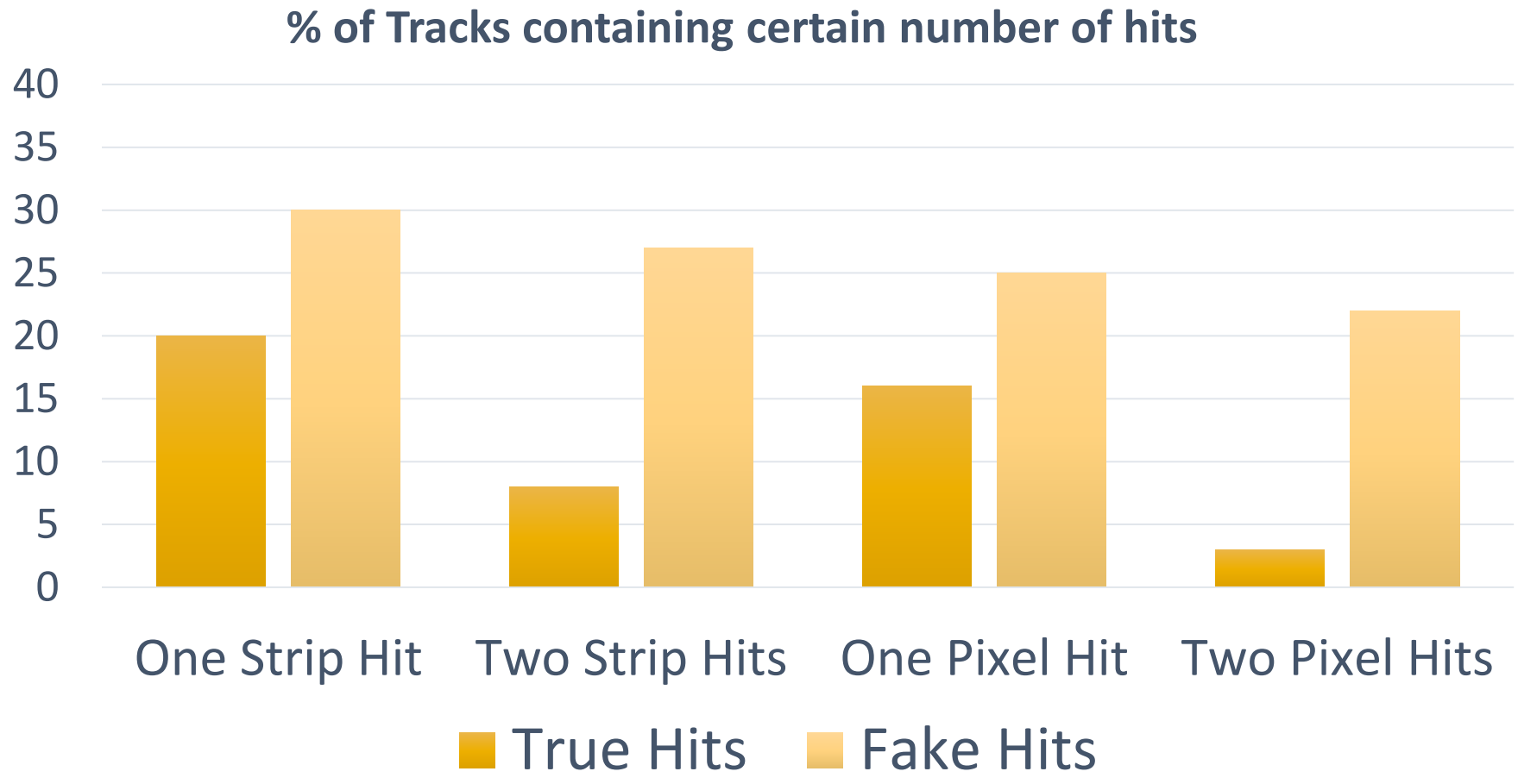




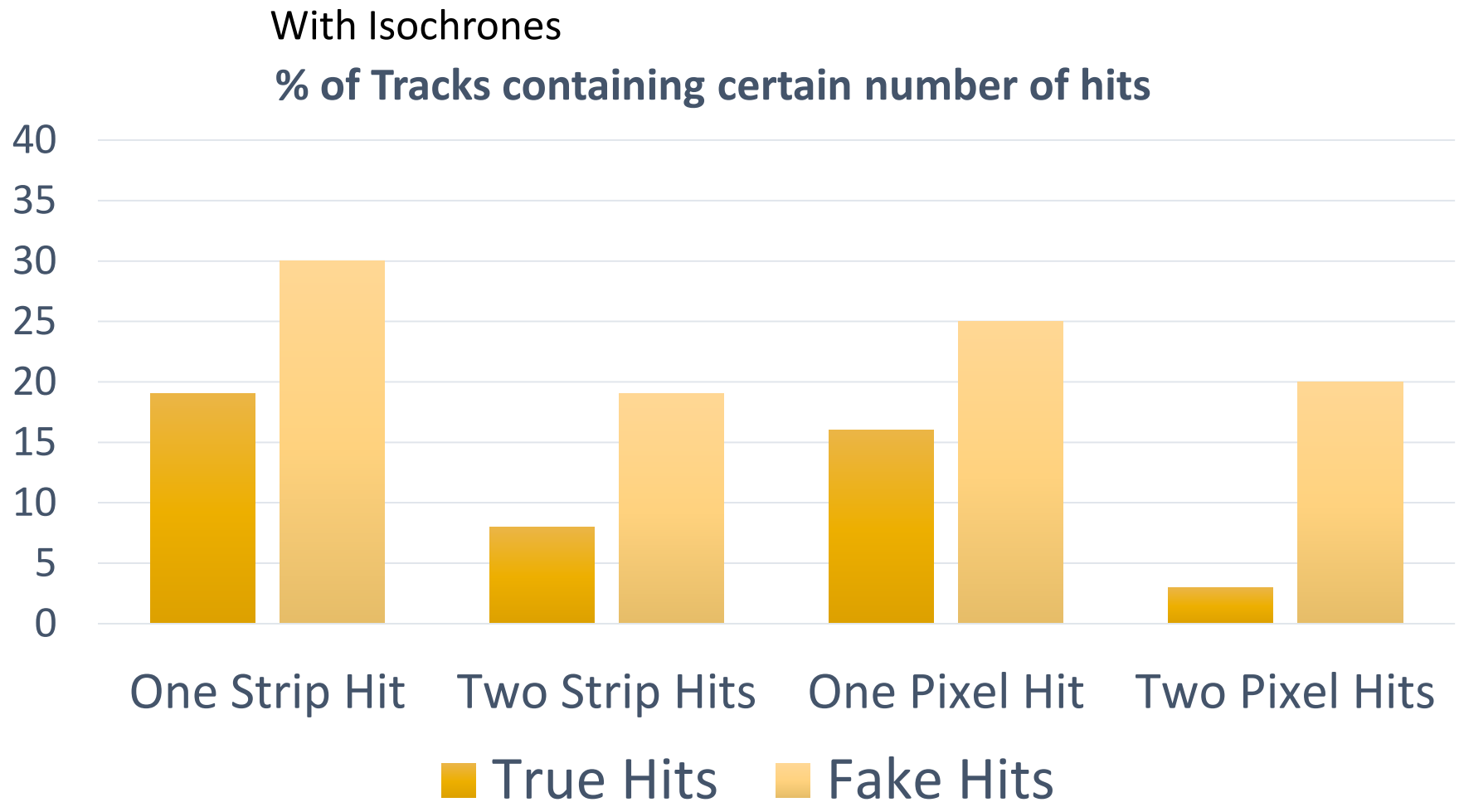


MVD Hits

Without Isochrones

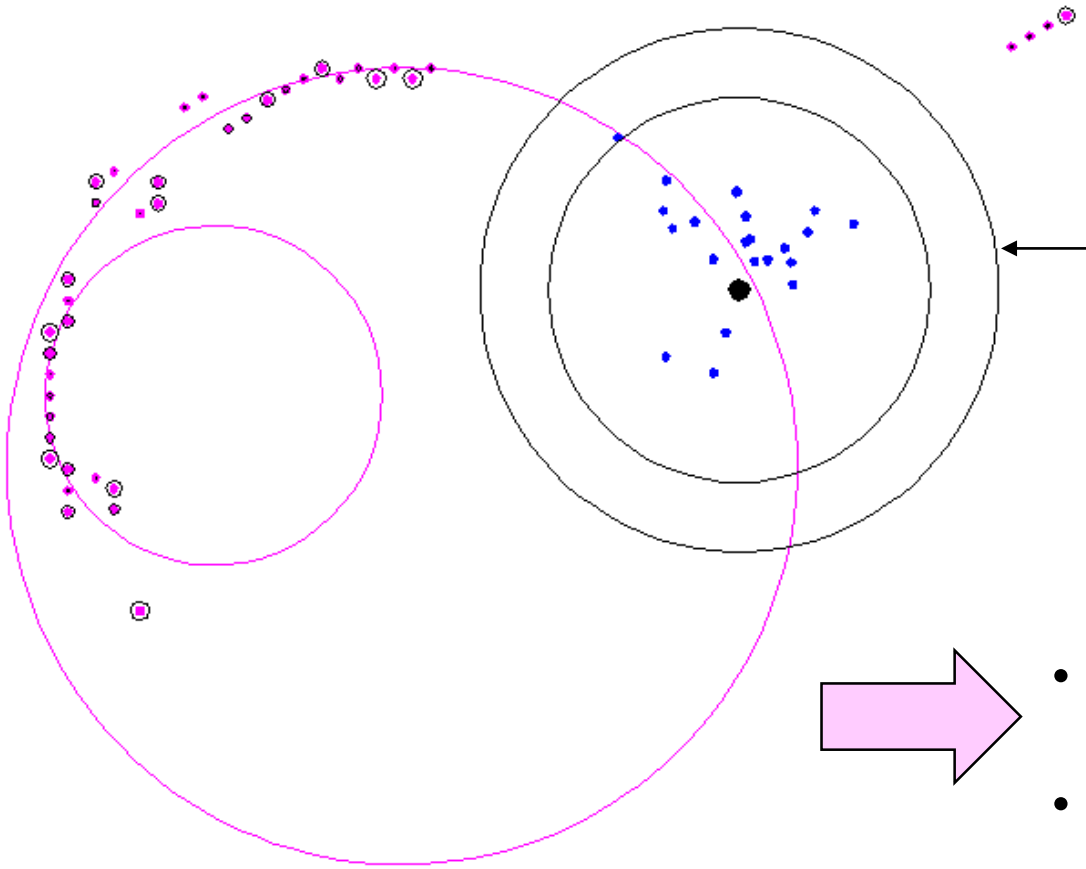


Need to work on fake MVD hit rejection!



Reduces number of fake hits but fake MVD hit reduction still need more work!

One possible reason:
tracks reconstructed in segments but not connected



MVD Strip layers

- Riemann Tracks
- STT Hits
- MVD Hits
- Interaction Point

- Poorly reconstructed radii of tracks reconstructed in segments
- Challenge to connect disconnected track segments using Riemann tracks

Difficulty in assigning MVD hits

Possible solution: Conformal Mapping

$$u = \frac{x}{x^2+y^2} \qquad v = \frac{y}{x^2+y^2} \qquad 1)$$

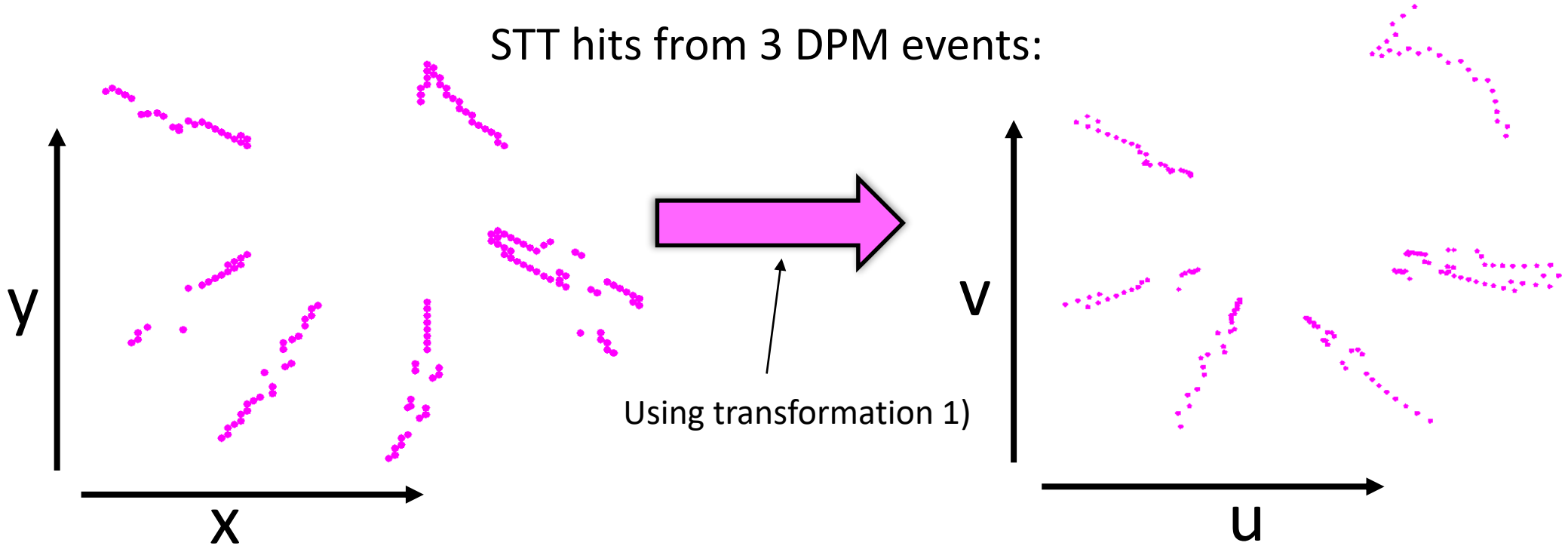
Circular paths *going through the origin* in detector space →
(x,y) space to linear paths (u,v) space

For secondary tracks: $x'=x-x_0$, $y'=y-y_0$, (x_0,y_0) is first hit of track

$$u = \frac{x'}{x'^2+y'^2} \qquad v = \frac{y'}{x'^2+y'^2} \qquad 2)$$

Conformal Mapping

STT hits from 3 DPM events:



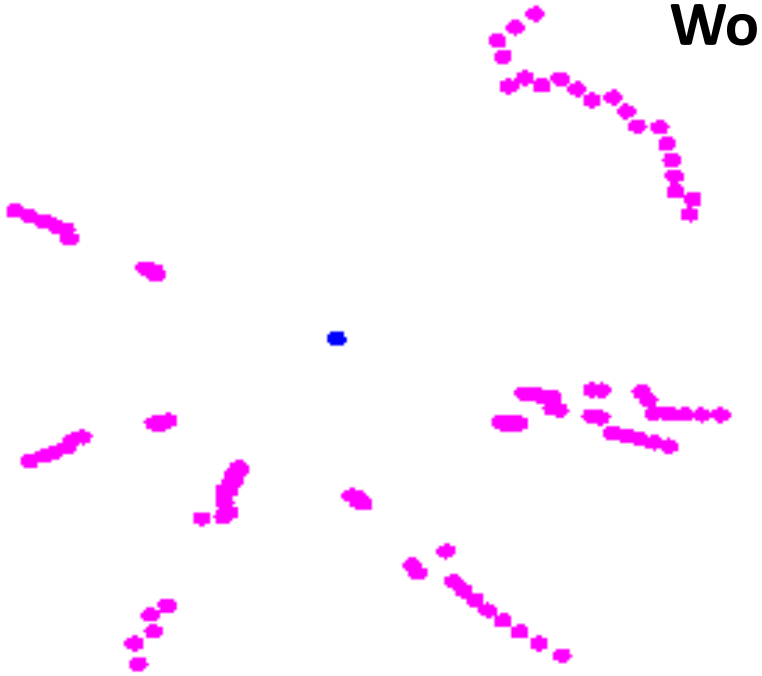
Three effects of transformation present:

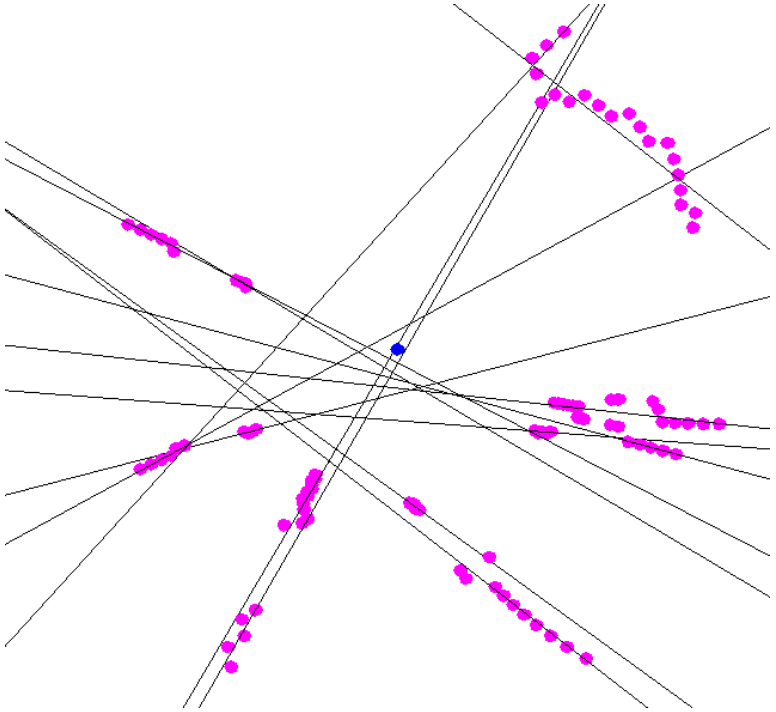
1. rescaling (not visible in example, u,v scale ~10 times smaller than x,y), distance between hits in u,v space not linear
2. inversion, outermost hits end up innermost and vice versa (visible)
3. curved tracks originating from origin becomes linear

Conformal Mapping of Tracks

- Conformal mapping for track segments which have not been combined with another track segment in the SttCellTrackFinder
- N.B. not for track reconstruction itself but for connecting track segments with each other
- Fit **straight lines** with simple linear regression to tracks in conformal space
- Use **line parameters or angles** to connect different track segments with each other

Work in progress!





Tests of SttCellTrackFinder

Definitions:

- **Reference track set:** Tracks with >5 STT Hits
- **Condition for SttCellTrackFinder reconstructibility:** >5 STT Hits
- If a track contains hits from several MC tracks, the one from which the most hits originate is counted as the true one

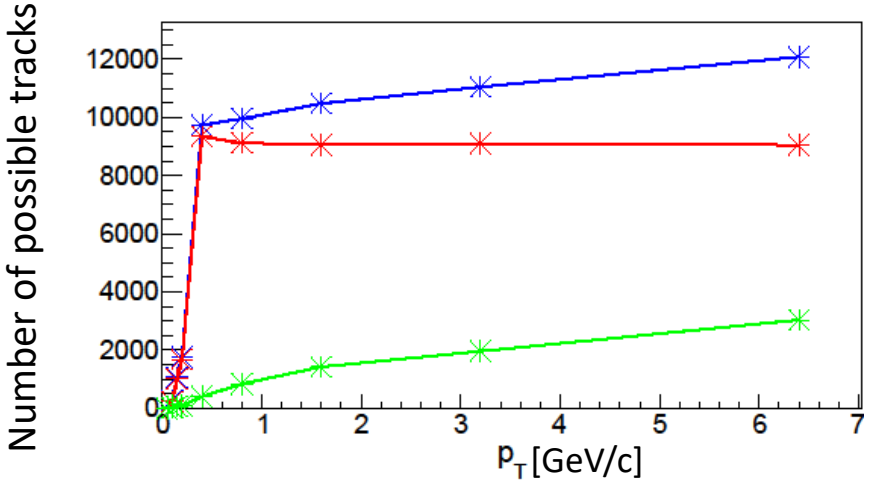
$$\text{Fraction of Reconstructed tracks} = \frac{\#\ Reconstructed\ tracks\ by\ SttCellTrackFinder}{\#\ Tracks\ in\ reference\ track\ set}$$

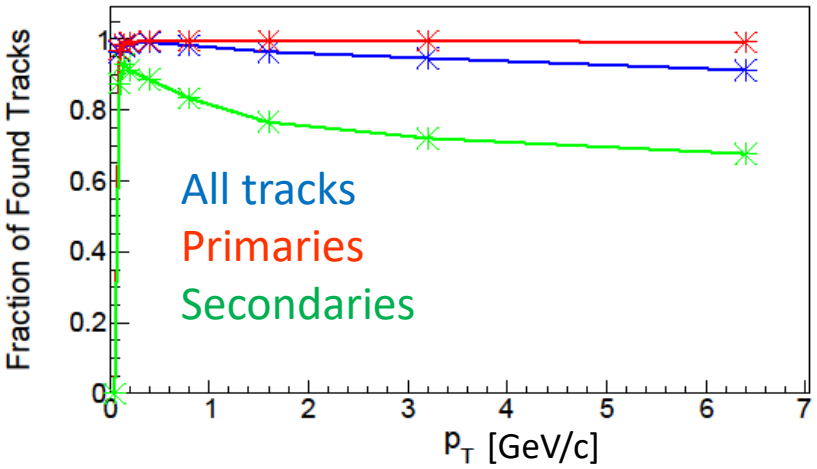
Varying P_t

- Box Generator
- **Varying p_t**
- **Particles originate from (0,0,0)**
- Isotropic $10<\theta<120$, $0<\varphi<360$
- 1 particle per event
- Protons and Pions
- 10,000 primaries/data point

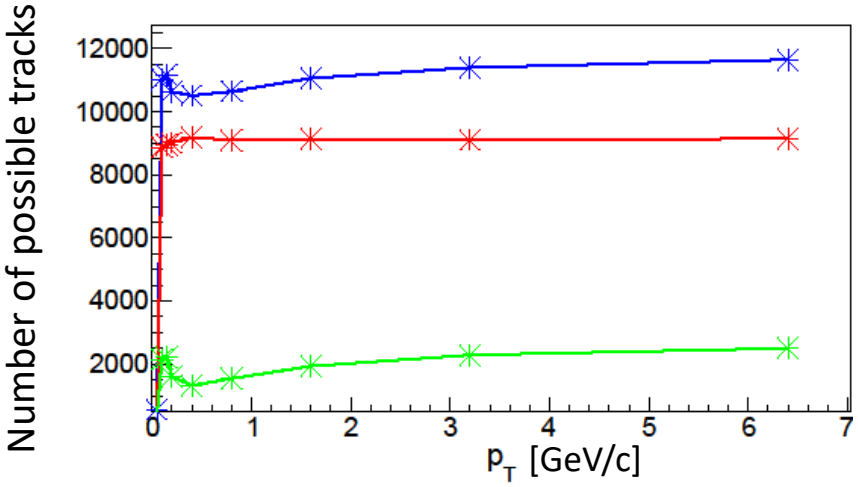
Results

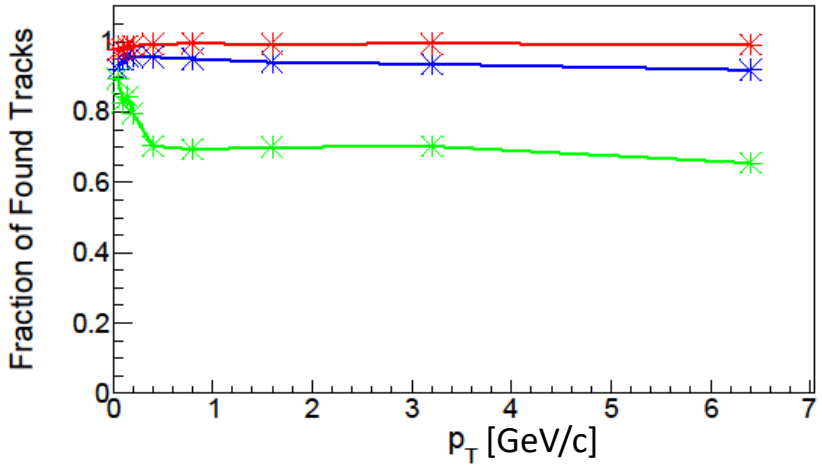
p


Number of possible tracks
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7
p_T [GeV/c]


Fraction of Found Tracks
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7
p_T [GeV/c]
All tracks
Primaries
Secondaries

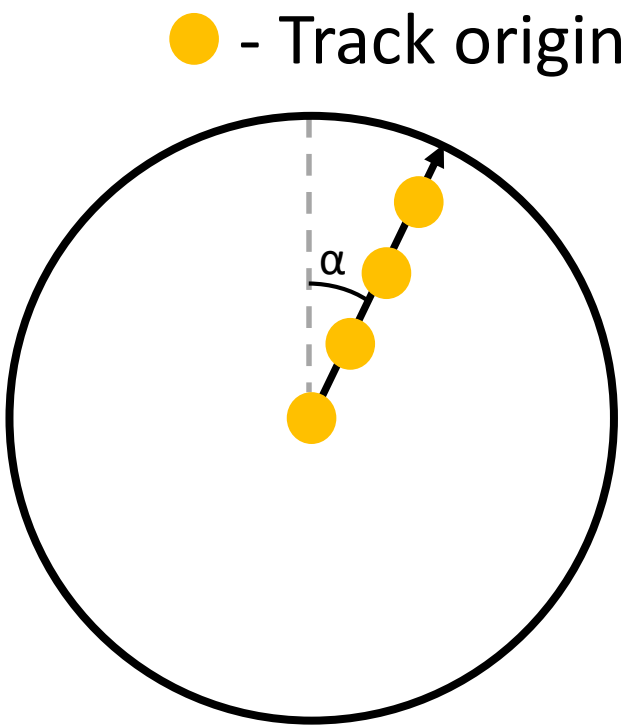
π^-


Number of possible tracks
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7
p_T [GeV/c]


Fraction of Found Tracks
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7
p_T [GeV/c]

Varying radial track origin

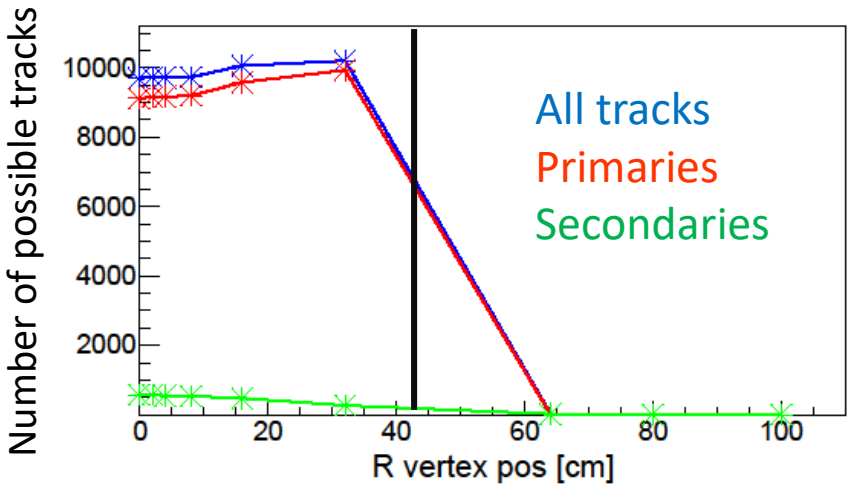
- Box Generator
- **P_t=1 GeV/c**
- **Varying origin, $R=x^2+y^2$**
- **z=0 cm, α=25°**
- Isotropic $10<\theta<120$, $0<\varphi<360$
- 1 particle per event
- Protons and Pions
- 10,000 primaries/data point

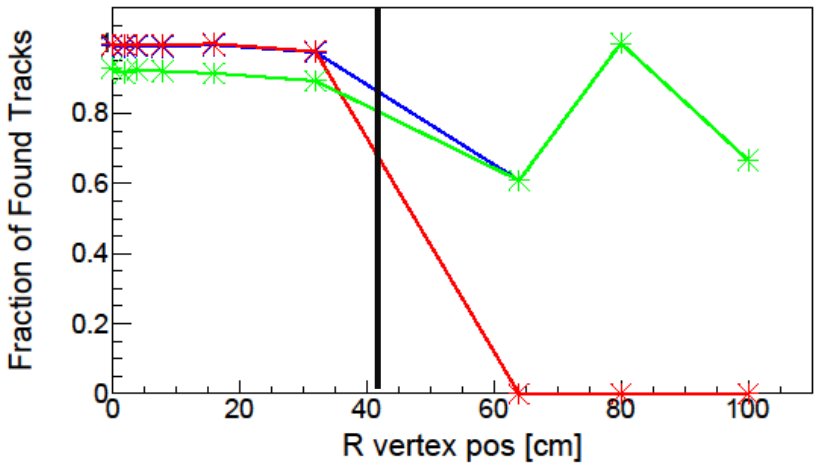


Results of Radial Scan

Vertical lines=STT outer radius

p





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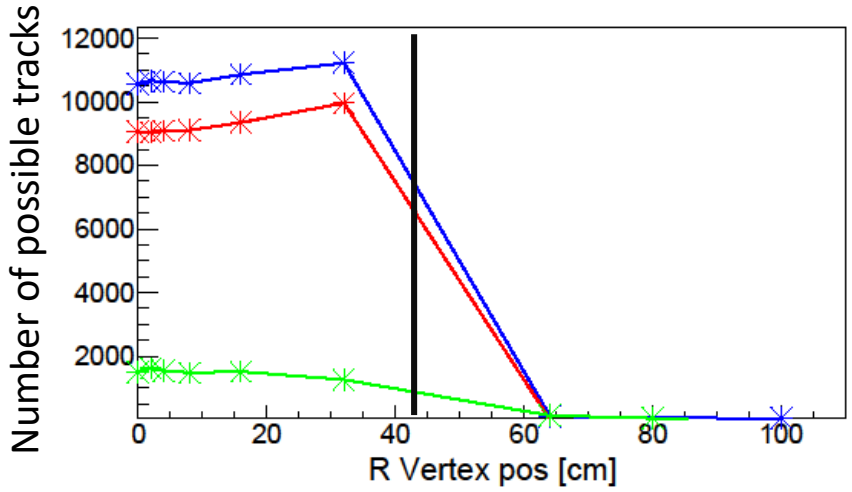
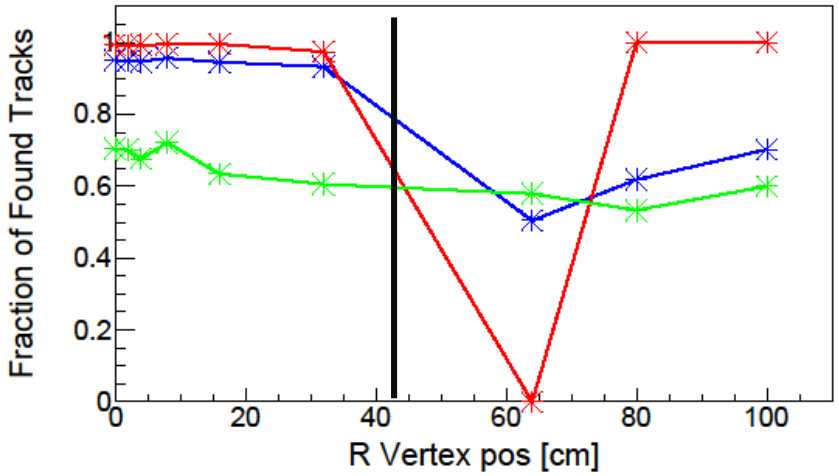
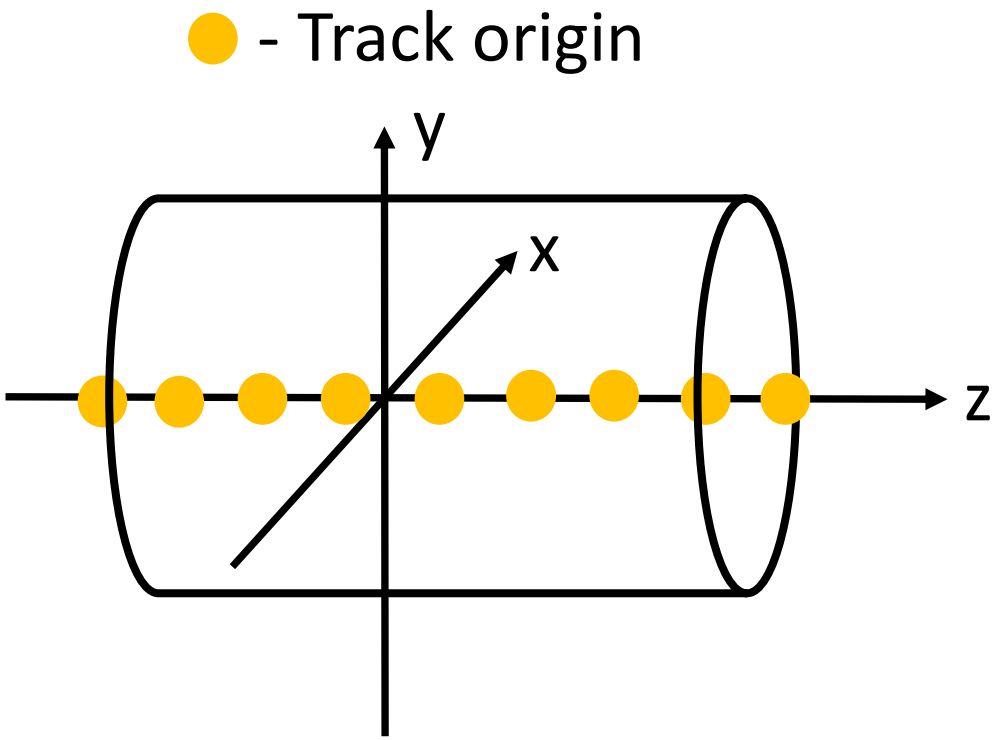




Varying z-position of track origin

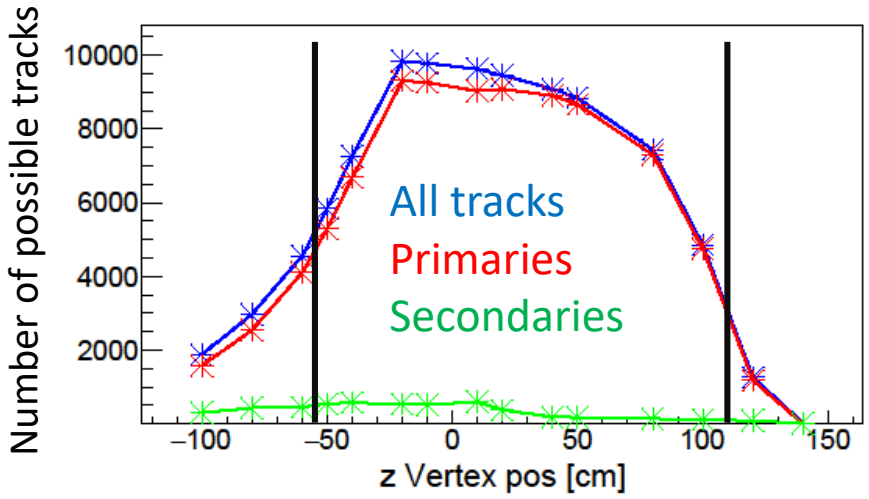
- Box Generator
- **P_t=1 GeV/c**
- **Varying origin, z**
- **x=y=0 cm**
- Isotropic $10<\theta<120$, $0<\varphi<360$
- 1 particle per event
- Protons and Pions
- 10,000 primaries/data point

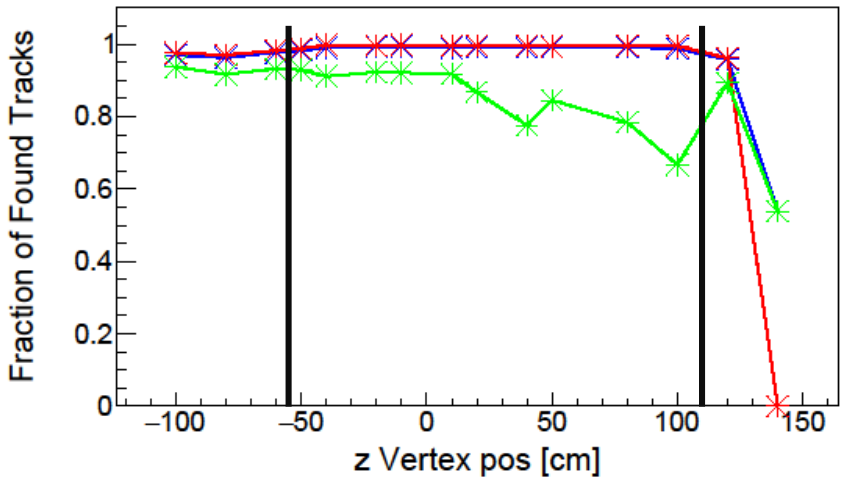


Results of z Scan

Vertical lines=STT outer boundaries

p





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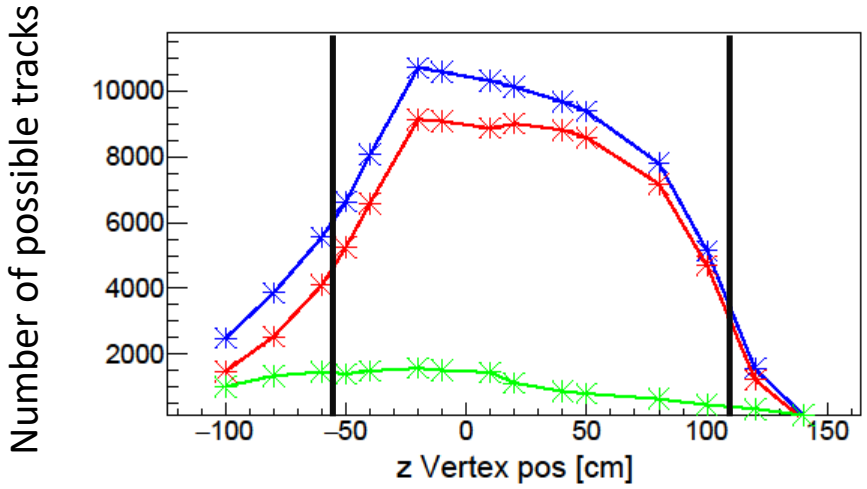
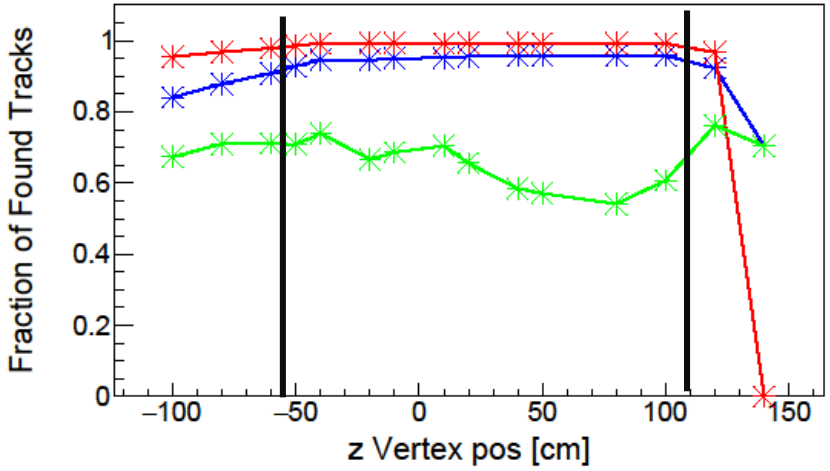




Conclusions

- The SttCellTracFinder is robust over STT acceptance
- It is also robust over relevant P_t range
- Generally high efficiency, > 90 % for single tracks

Summary

- SttCellTrackFinder and MvdHitFinder suitable for track reconstruction with time-based data and for particles from displaced vertices
- Work ongoing on fake MVD hit rejection
- Track finding robust and have high efficiency for single proton and pion tracks over the STT acceptance

Outlook

- Work on time-based tracking QA-task
- Testing algorithms further with time-based data
- Finalizing track cluster merging and fake hit rejection
- Testing with p_z-finder to utilize z-information [2]
- If needed, finalize combinatorial procedure

[2] Reconstruction and benchmarking Pz with the STT by W. Ikegami Andersson, later during this session

Thank You!

MVD Hit Finding

3 possibilities for improvement

- **Conformal mapping** to connect track segments which were not already grouped in the SttCellTrackFinder
- **Combinatorial procedure** to find MVD hits which can be used in a separate Riemann fit
- **Include z-component** to include additional spatial information [2]

[2] Reconstruction and benchmarking Pz with the STT by W. Ikegami Andersson, later during this session

Combinatorial Procedure

- Find compatible combinations of MVD hits between different layers
- Time consuming to test all combinations with new refit
- Need to reduce number of combinations

Example assuming no missing hits in layers:
Number of combinations per event:

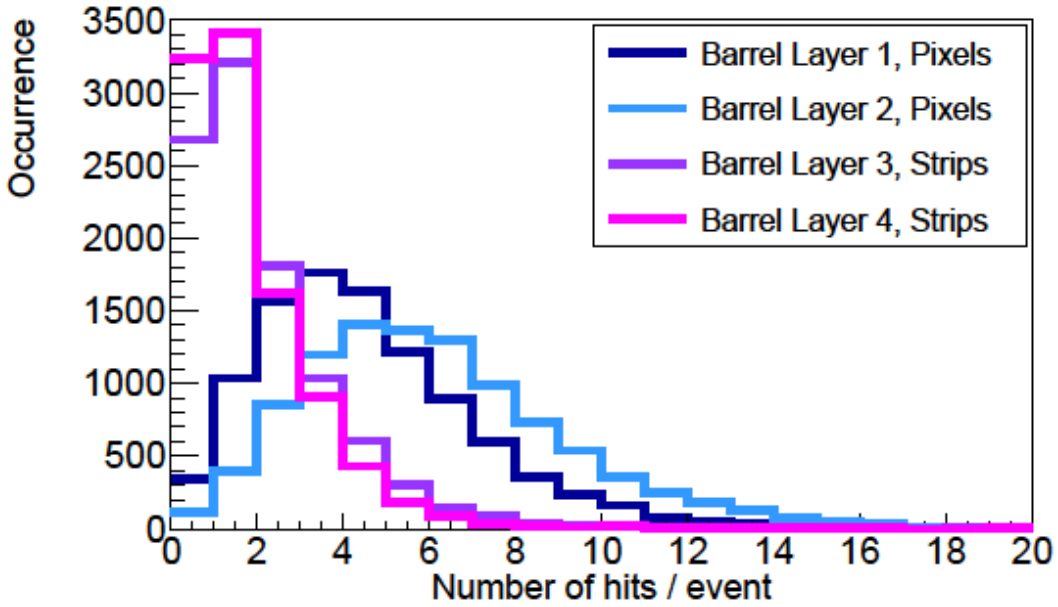
$$n_{p1} \cdot n_{p2} \cdot n_{s1} \cdot n_{s2}$$

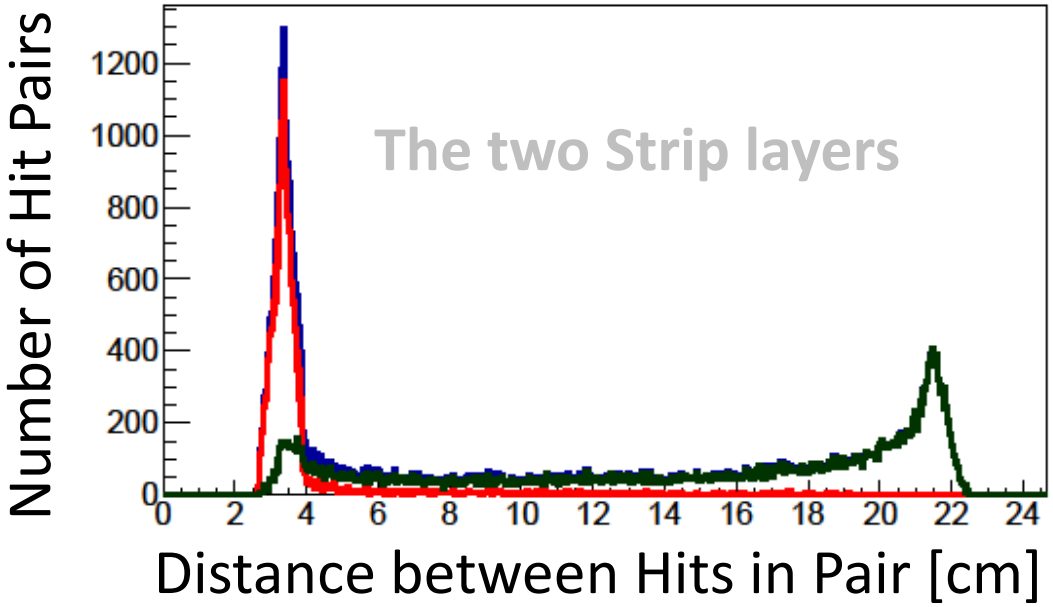
With mean number in each layer:

$$4 \cdot 5 \cdot 1 \cdot 1 = \mathbf{20}$$

With largest number per event:

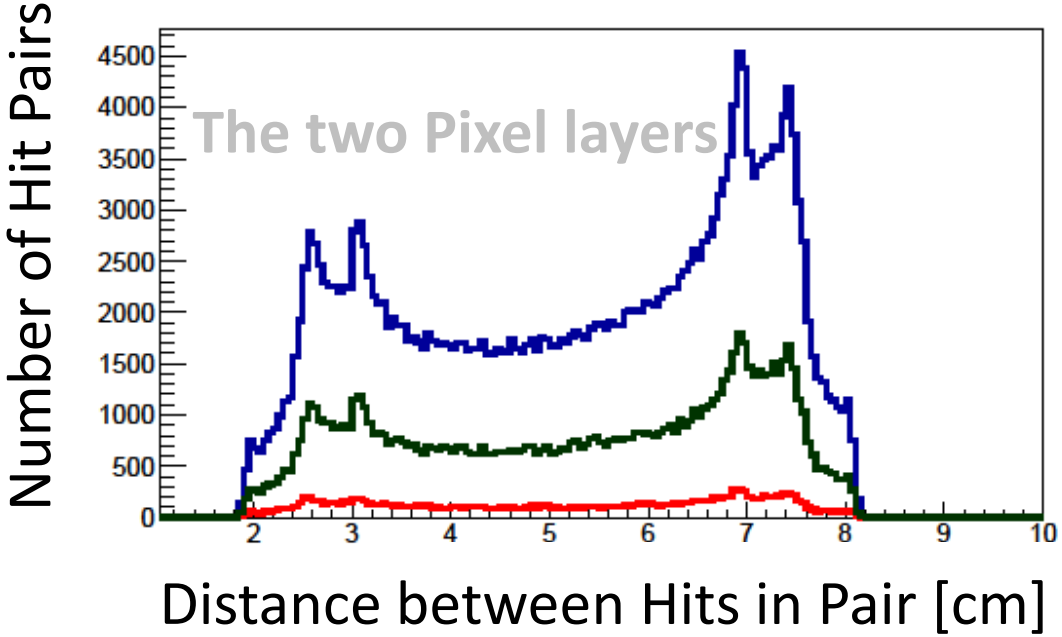
$$16 \cdot 16 \cdot 8 \cdot 8 = \mathbf{16\ 384}$$

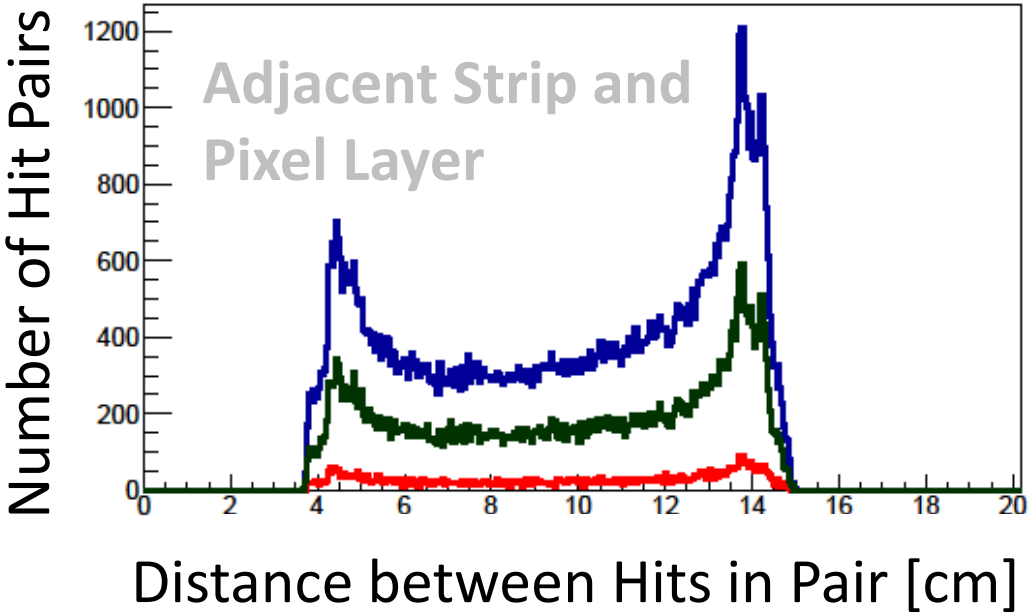


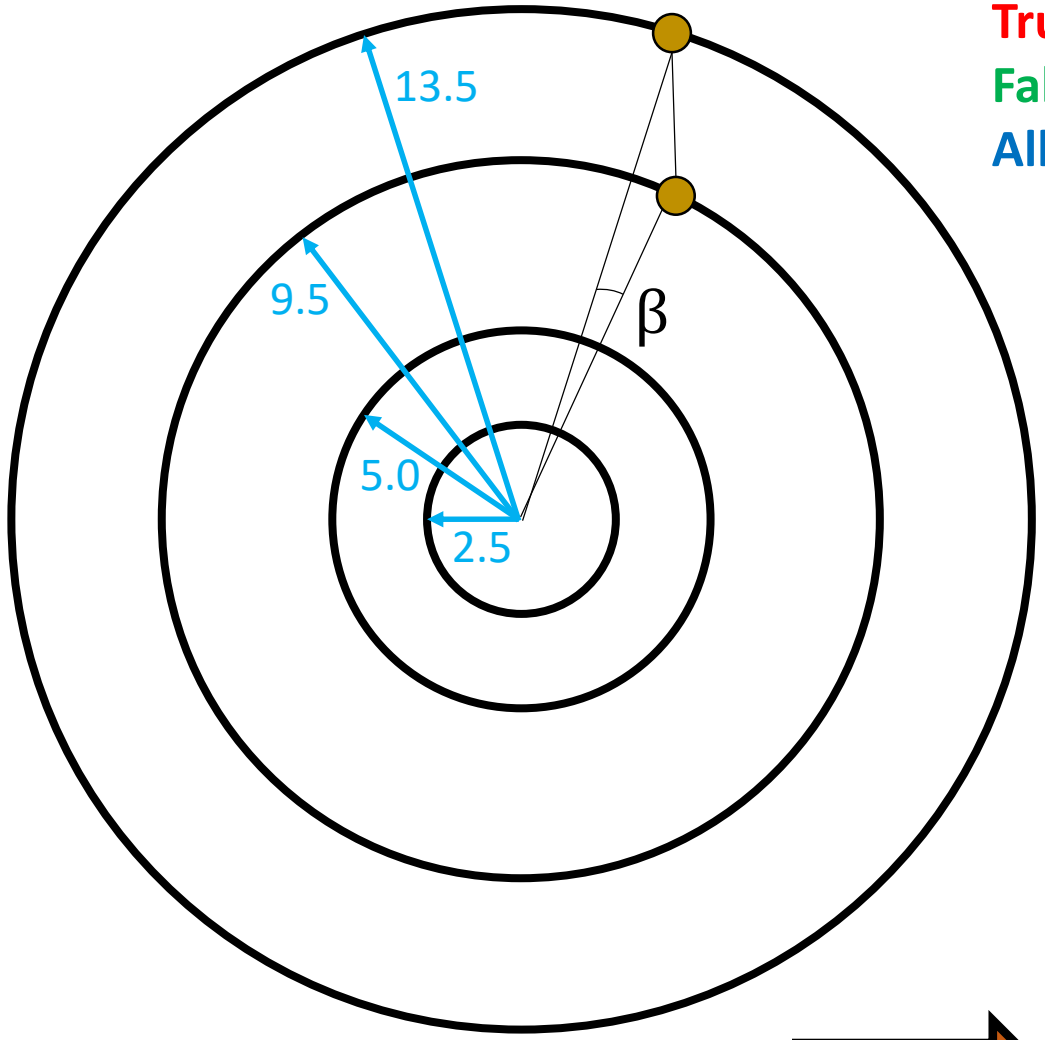


True pair: Hits Belong to Same MC-track
False pair: Hits belong to Different MC-tracks
All Combinations

Strip Hits can be combined using simple distance cut



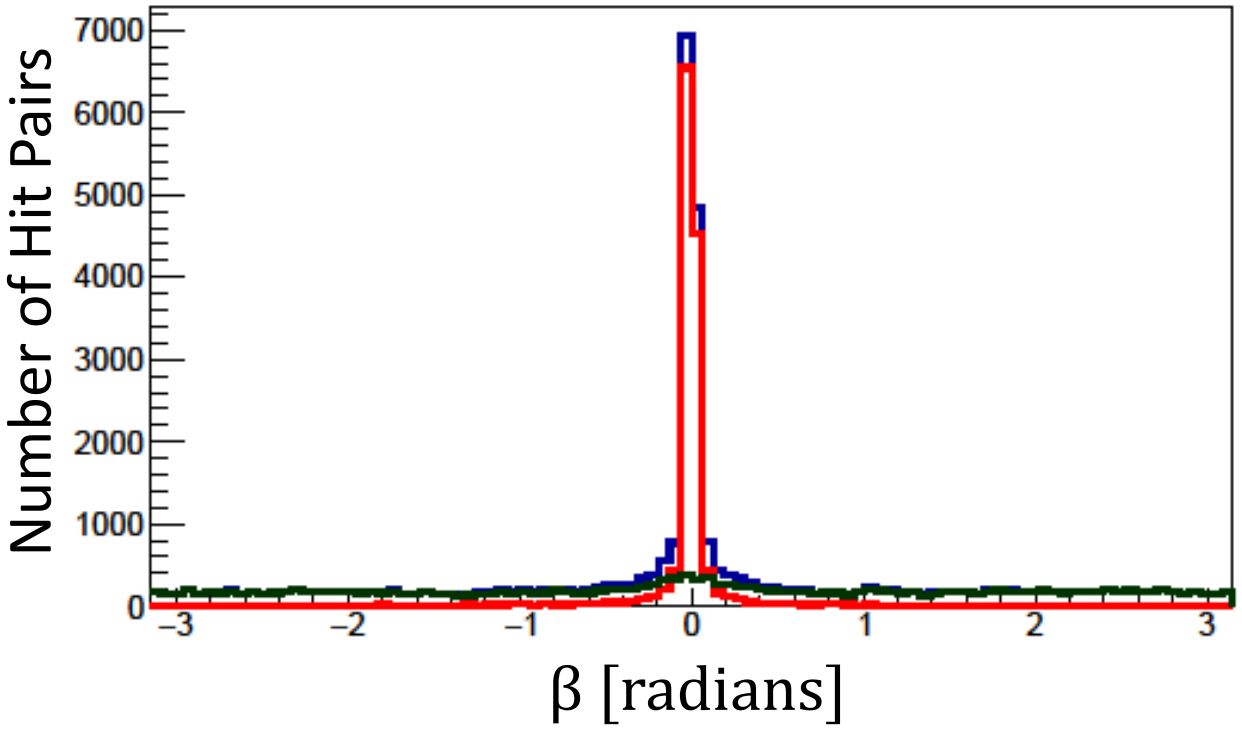




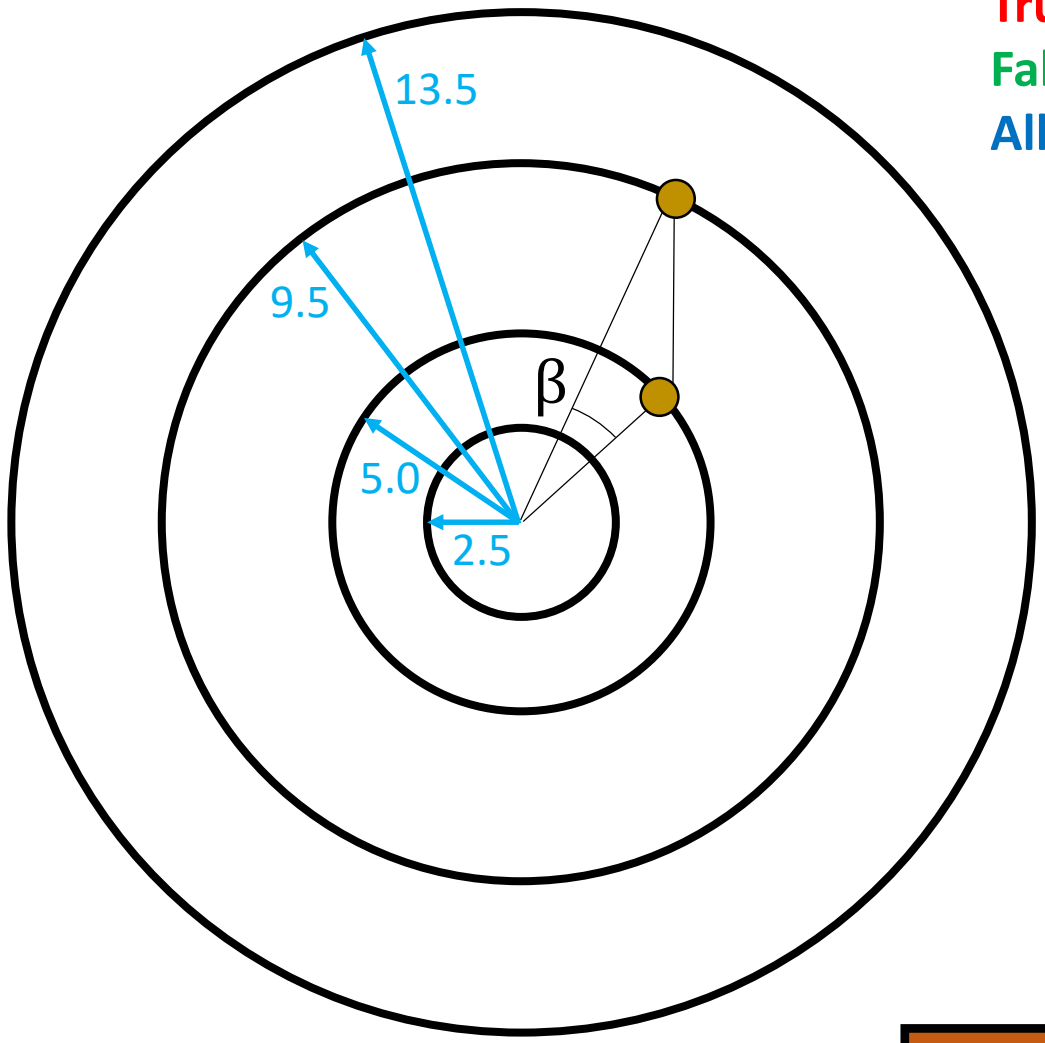
True pair: Combination of Hits Belong to Same MC-track

False pair: Combination of Hits belong to Different MC-tracks

All Combinations



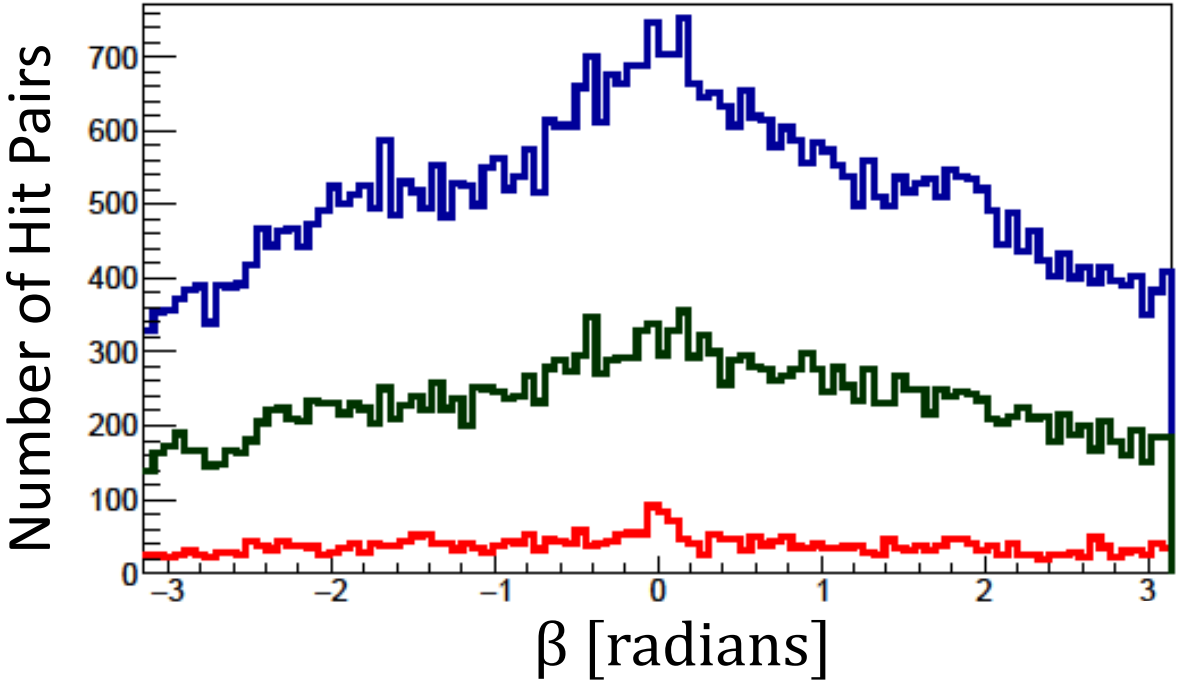
Strip Hits can be combined using cut



True pair: Combination of Hits Belong to Same MC-track

False pair: Combination of Hits belong to Different MC-tracks

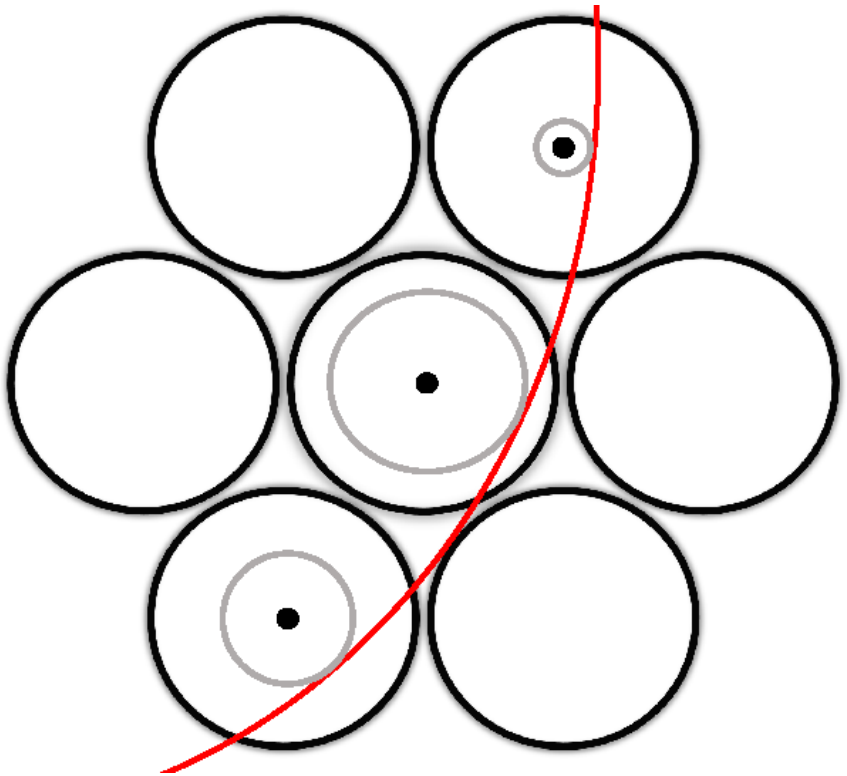
All Combinations



Strip/Pixel Hits can not be combined using cut

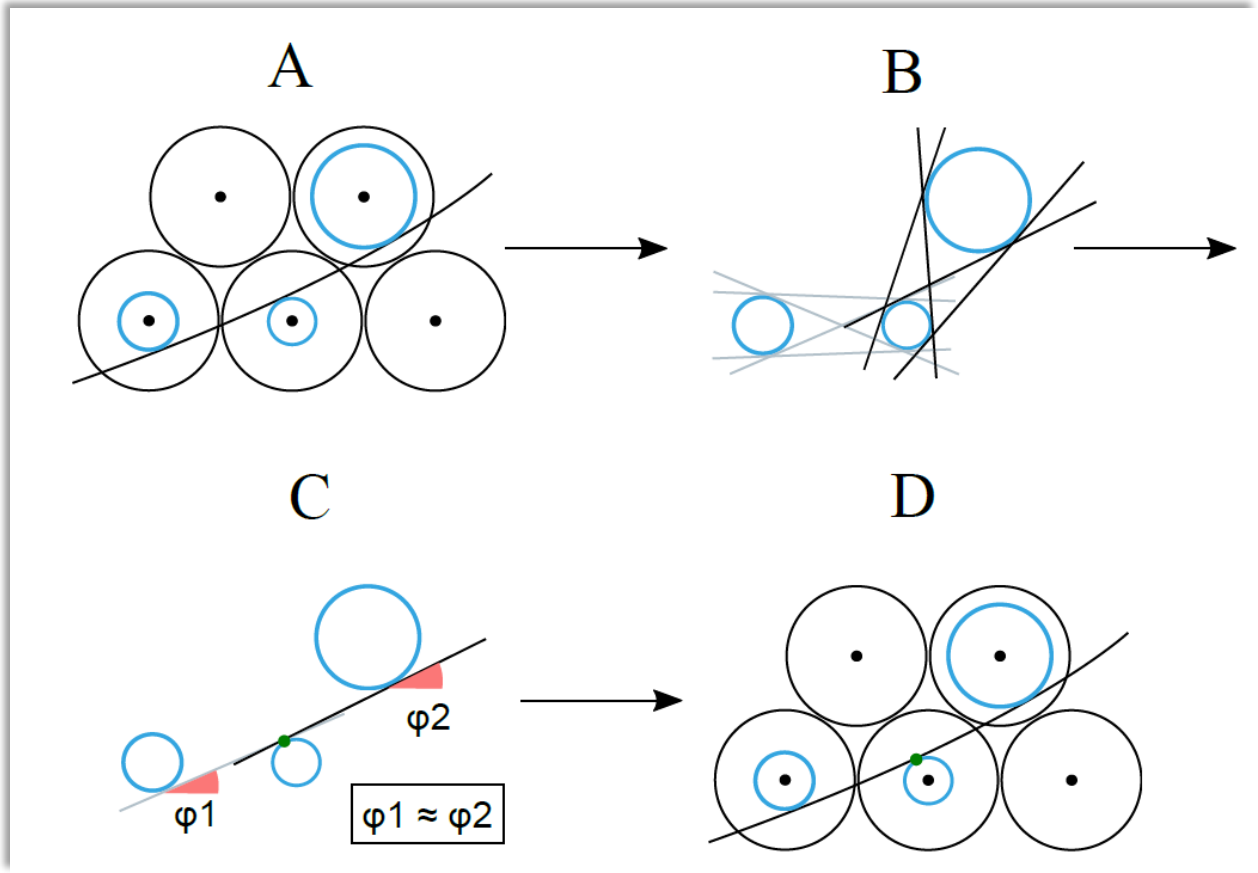
Isochrones – drift circles

Circle with center in wire and going through POCA of track to the wire



- Improve position and momentum resolution
- If not included in tracking, tracks are fitted to center wire

Isochrones in SttCellTrackFinder

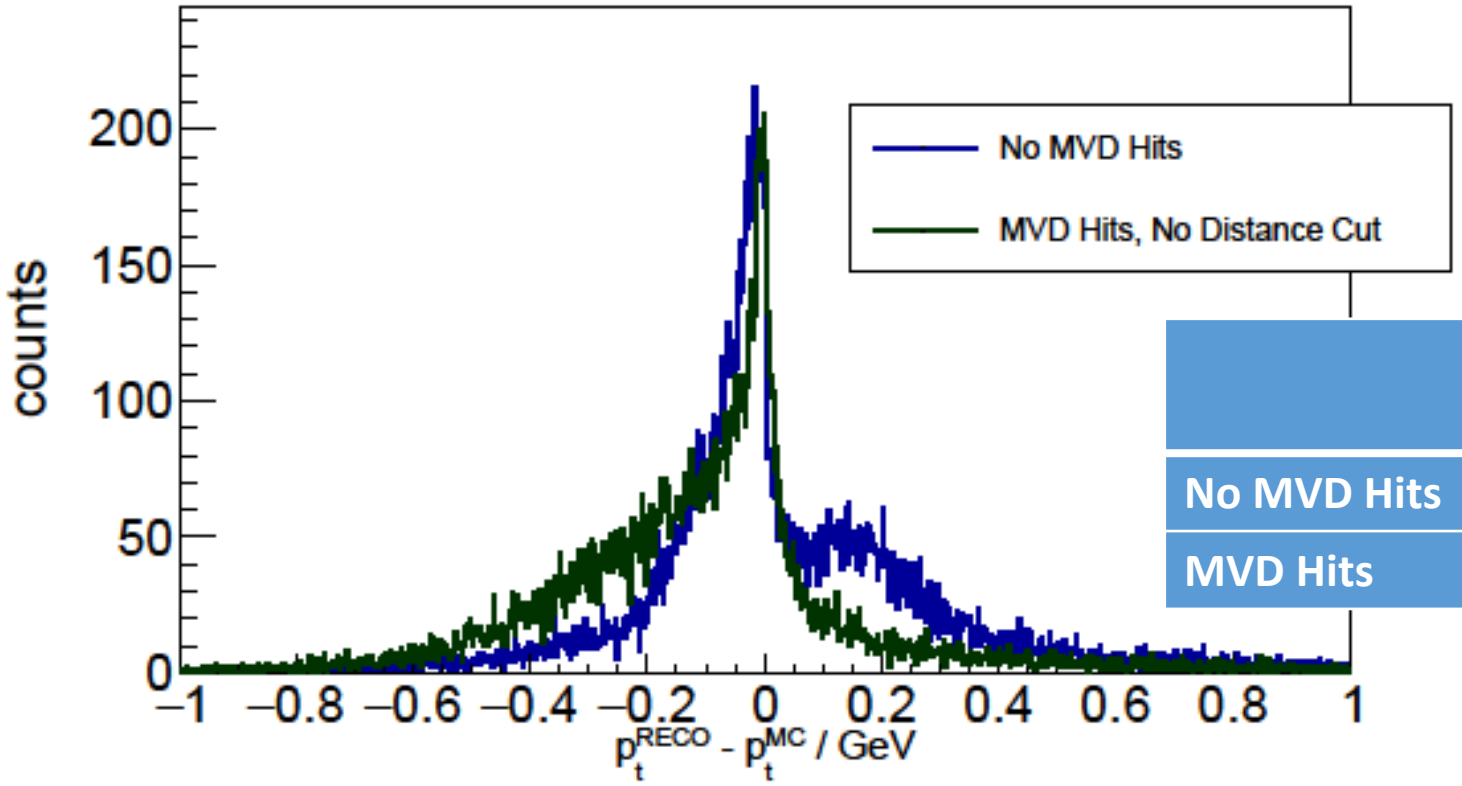


A. Tracks traverse STT
B. Find lines which tangent two adjacent isochrones
C. Obtain angle of all lines. Keep the two lines with smallest difference between angles
D. Position where these lines tangent center isochrone →corrected hit position

Assumption of stright line travel path between two isochrones

Transverse Momentum Resolution

- DPM Sample, P_{beam}=5 GeV/c, 10 000 Events

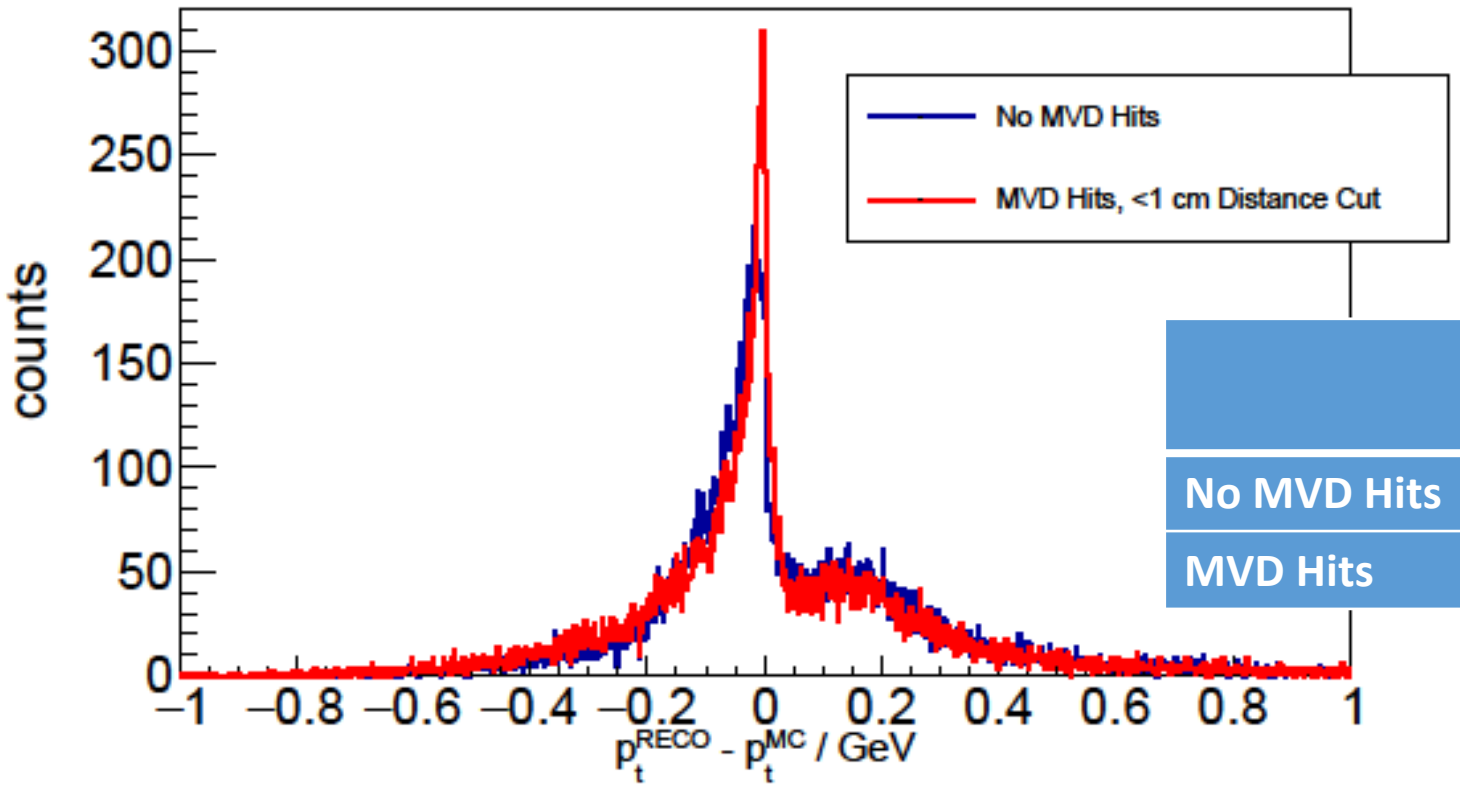


- No isochrones!
- Different qualitative shape of curves
- Peak somewhat narrower but much closer to zero when using MVD hits

	Peak Position (at peak maximum)	FWHM
No MVD Hits	-0.017	0.074
MVD Hits	-0.001	0.060

Transverse Momentum Resolution

- DPM Sample, P_{beam}=5 GeV/c, 10 000 Events



- No isochrones!
- Similar qualitative shape of curves
- Peak narrower and closer to zero when using MVD hits

	Peak Position (at peak maximum)	FWHM
No MVD Hits	-0.017	0.074
MVD Hits	-0.003	0.028