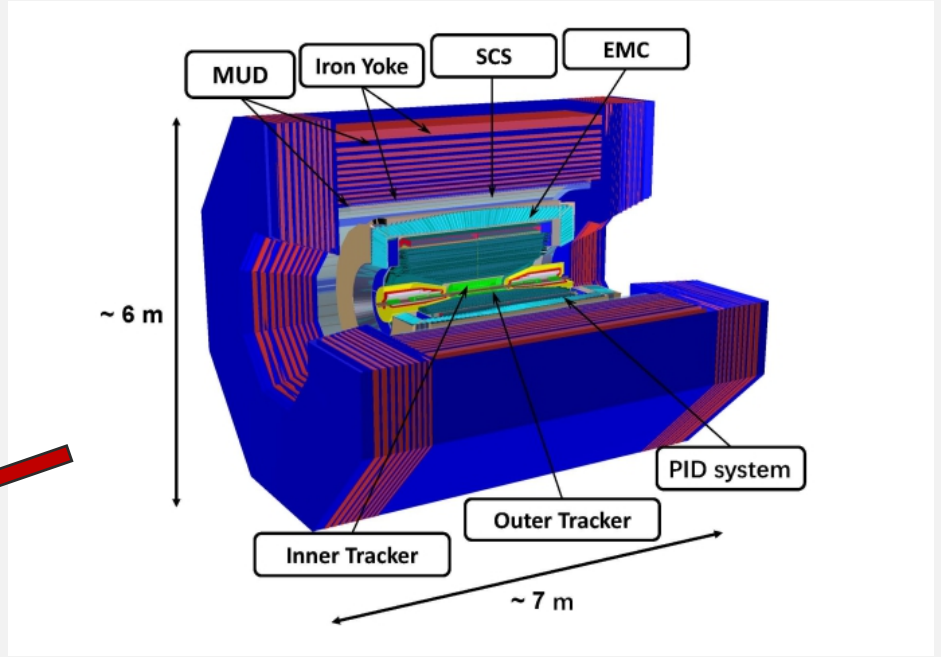
Hough transform based tracking on STCF

Hang Zhou

On behalf of STCF software working group

2023.06.10

The Super τ-Charm Facility (STCF)

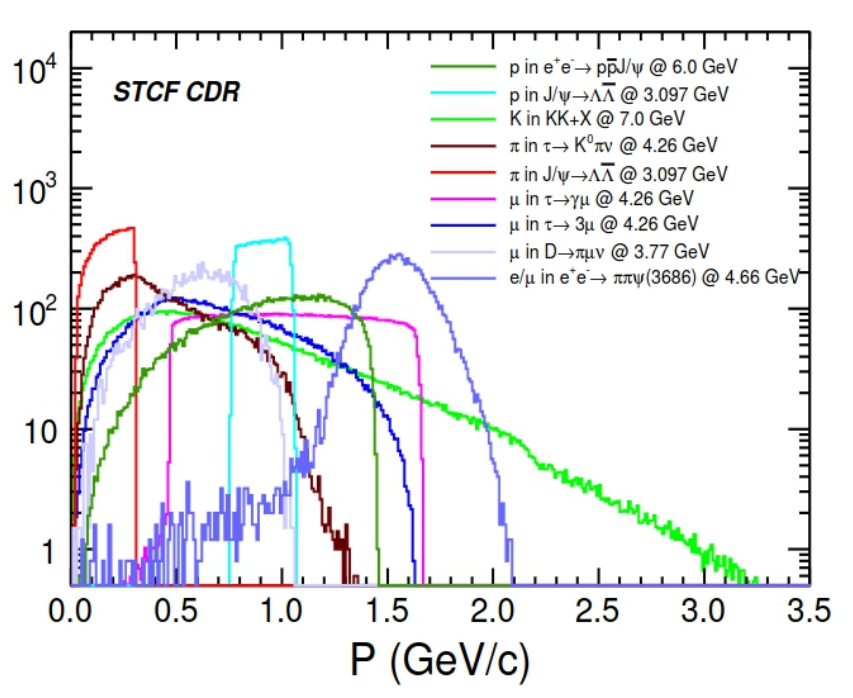


Overview of STCF detectors

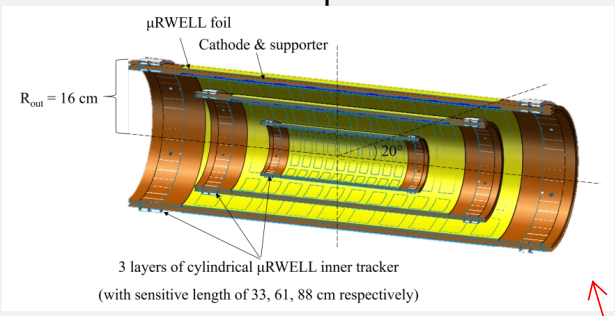
- electron-positron collider
- center-of-mass energy: 2-7GeV
- high luminosity ~ 0.5×10^{35} cm^{-2} s^{-1}

Tracking System of STCF

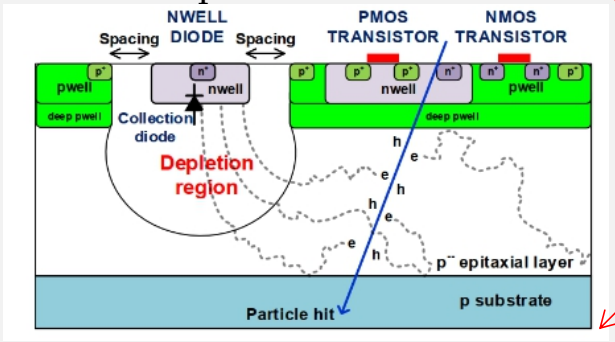
Momentum distributions of charged particles

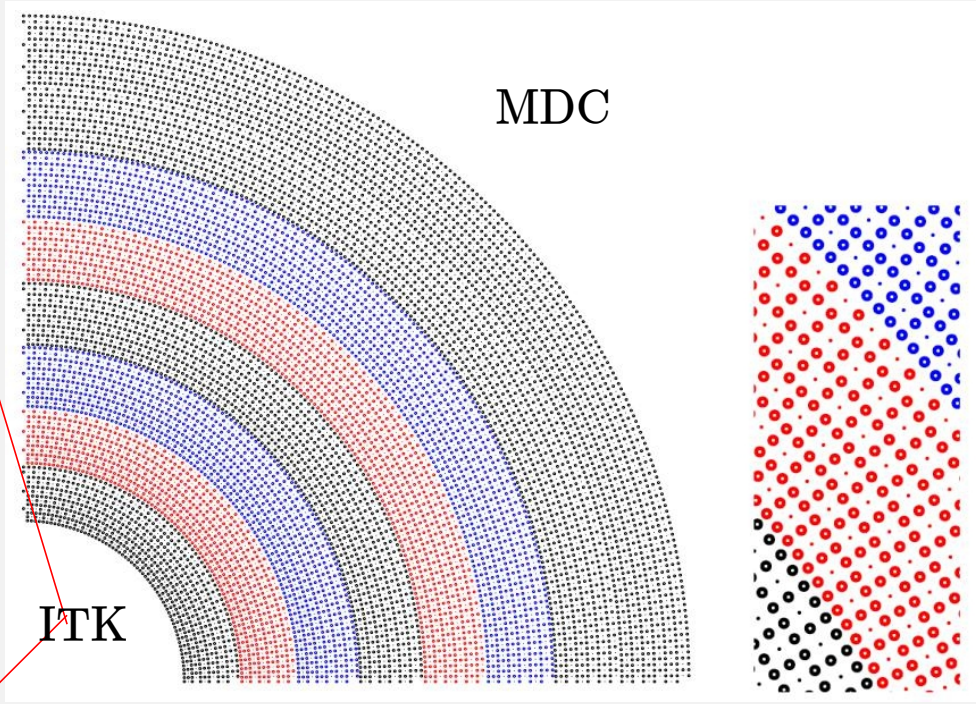


MPGD: μRwell



Silicon pixel: CMOS MAPS





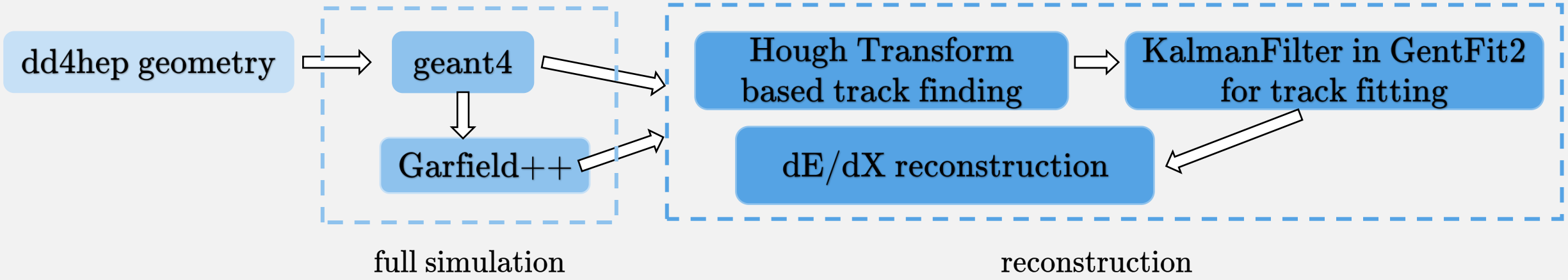
ITK+MDC

Requirements for the tracking system

- Momentum resolution:
  $\sigma p/p = 0.5\%$ at $p = 1GeV$
- Tracking efficiency:
  $> 99\%$ at $p_T > 0.3$ GeV, $> 90\%$ at $pT = 0.1GeV$
- dE/dX resolution: $< 6\%$

- two options of inner tracker(ITK), 3 layers
- 48 layers main drift chamber(MDC), 200-840mm,
  8 super-layers, 4 axial wire super-layers, 4 stereo wire super-layers

Tracking system software(in OSCAR)

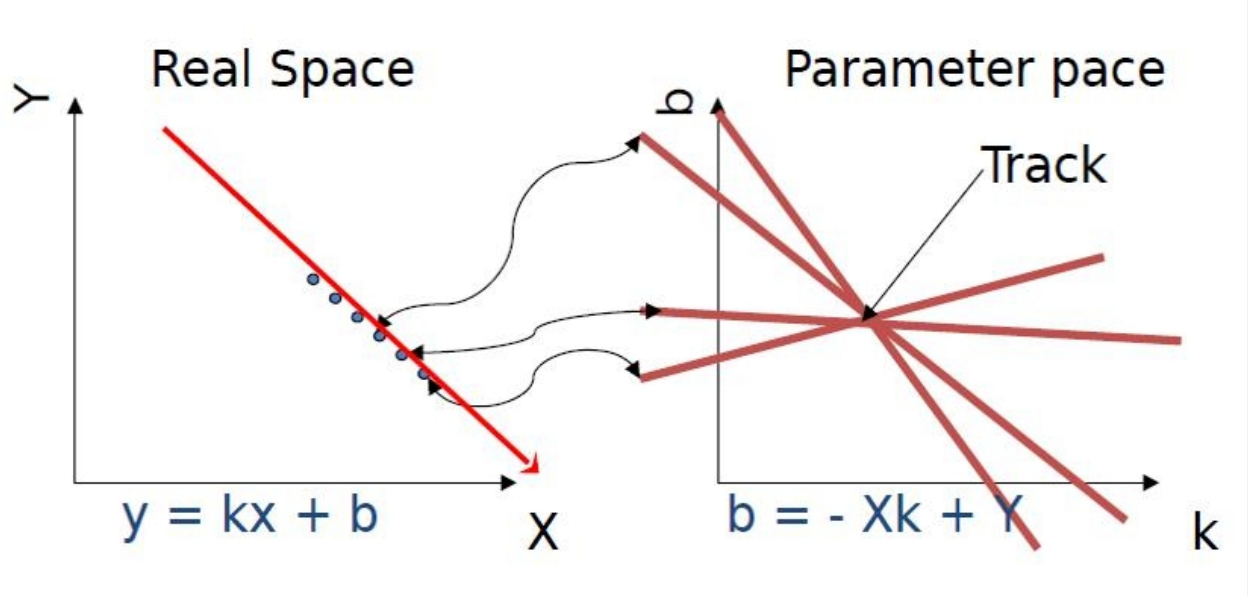


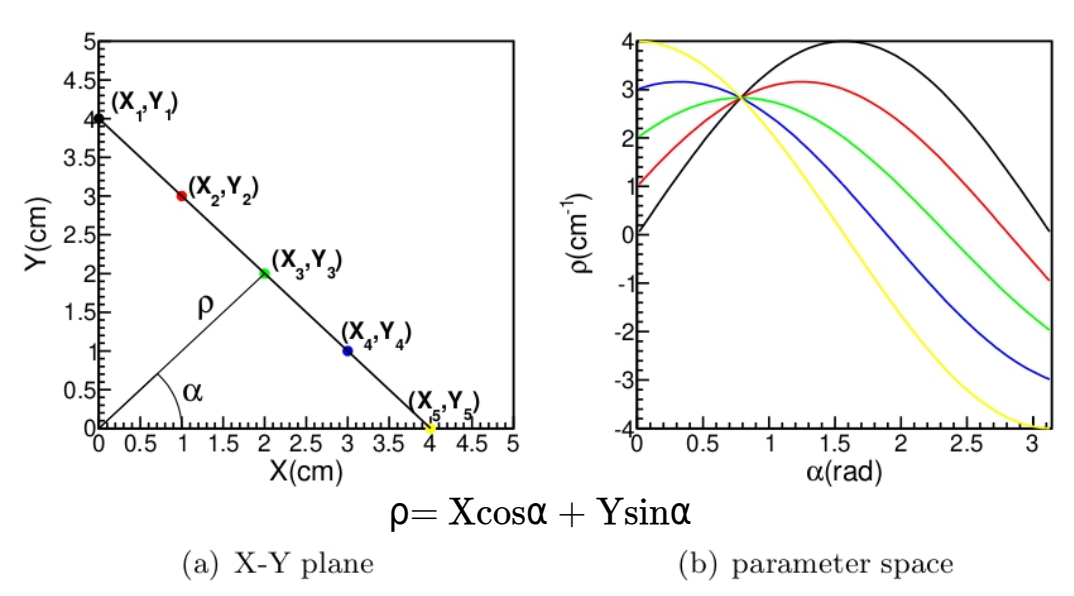
- Current study uses the μRwell based ITK, radii: 6cm 11cm 16cm
- Background mixing, digitization, T0 reconstruction are under investigation
- ITKHit/MDCHit is smeared with detector resolution as input for tracking

  ITK: $\sigma_{r\text{-}\phi} \times \sigma_z$ ~ 100 μm × 400 μm

  MDC: drift distance resolution ~ 120μm
- Axially homogenous 1T magnetic field

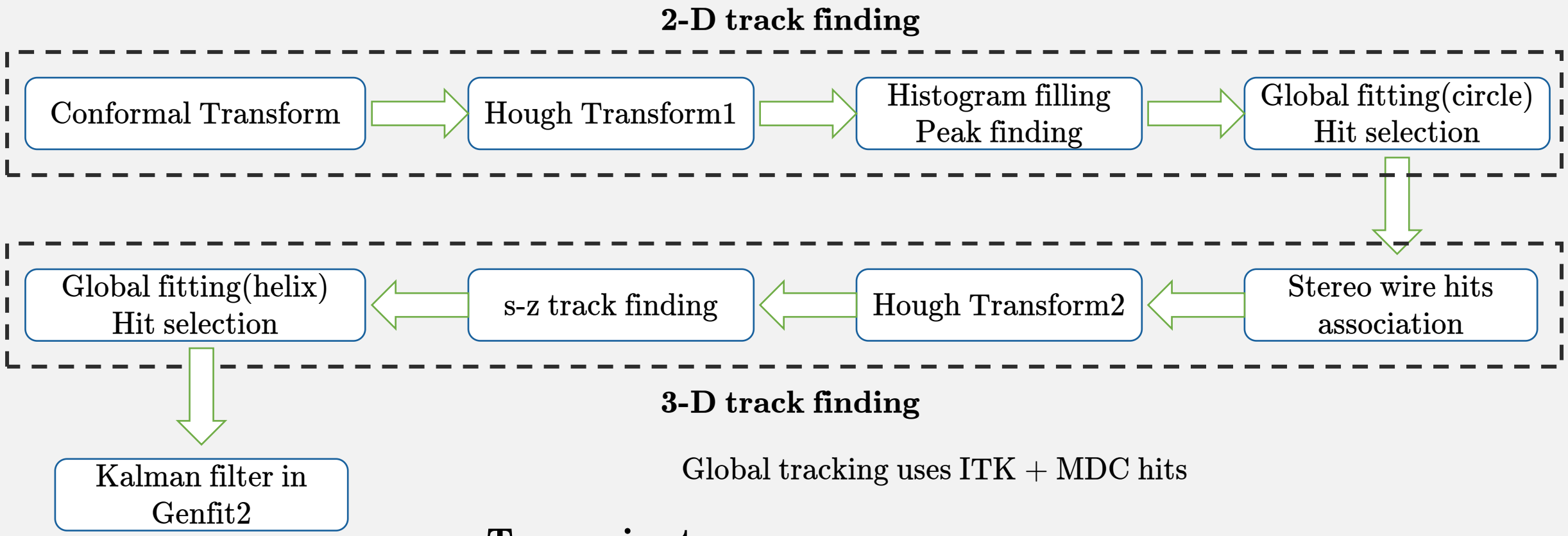
Hough Transform





- a point in the image space -> a line(or a curve) in Hough space
- some points on a line -> lines intersecting at a point in hough space
- The intersection point in the Hough space corresponds to the line in the image space

Procedures of Track Finding based on Hough Transform

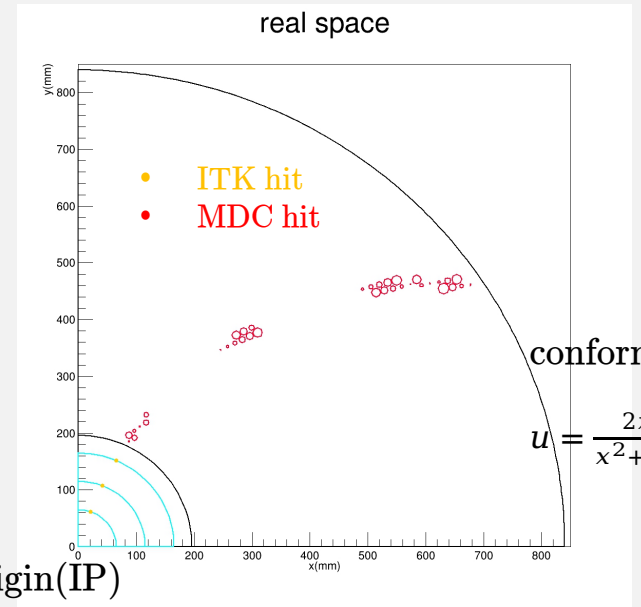


Global tracking uses ITK + MDC hits

Two main steps

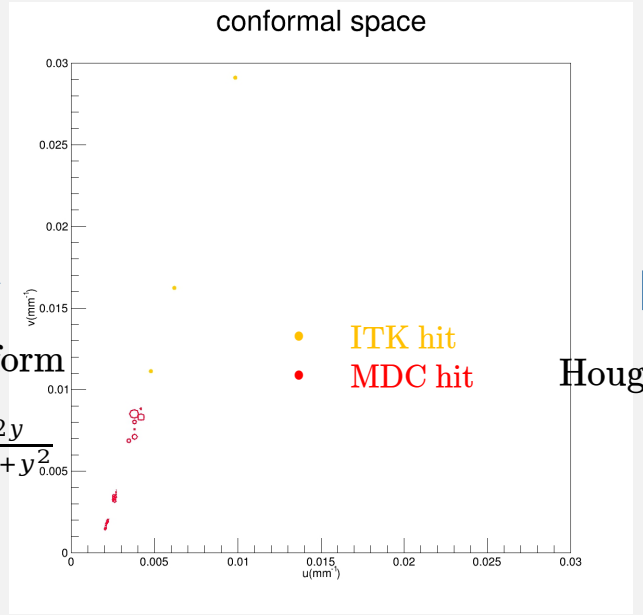
- MDC axial wire hits and ITK hits(x,y) are used to find 2-D track
- MDC stereo wire hits association and 3-D track finding

2-D Track Finding

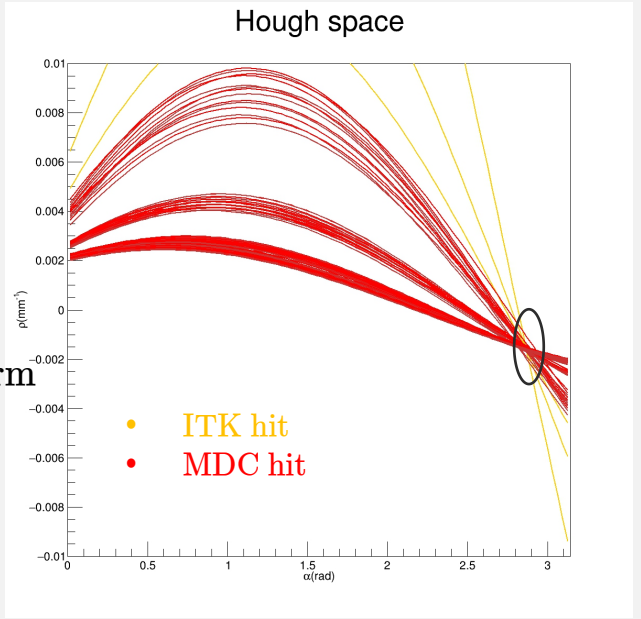


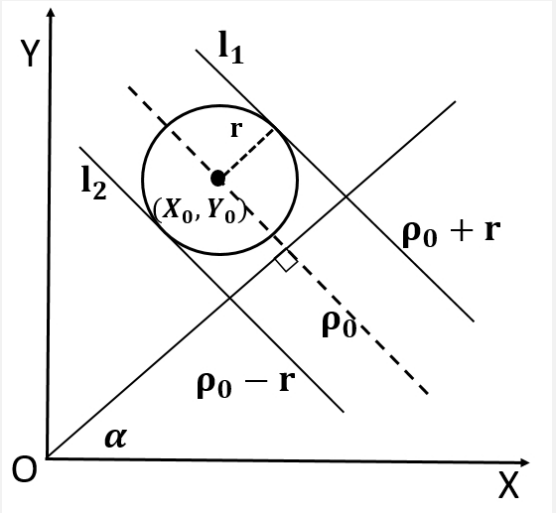
conformal transform

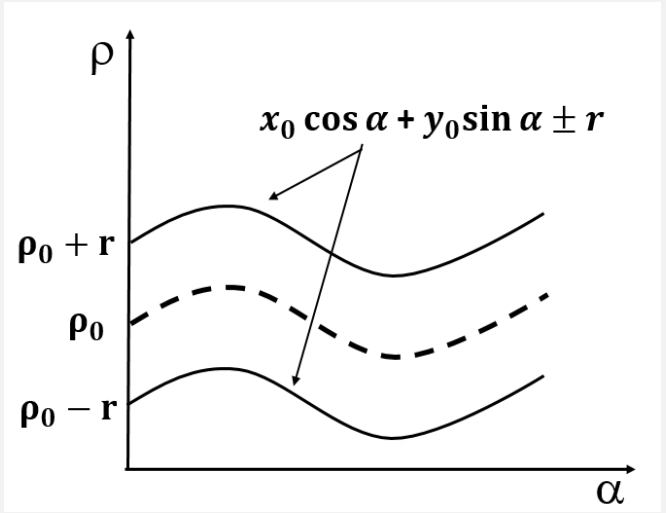
$$u = \frac{2x}{x^2+y^2},\ v = \frac{2y}{x^2+y^2}$$



Hough transform







◆ Conformal transform

Circles passing through the origin -> straight lines

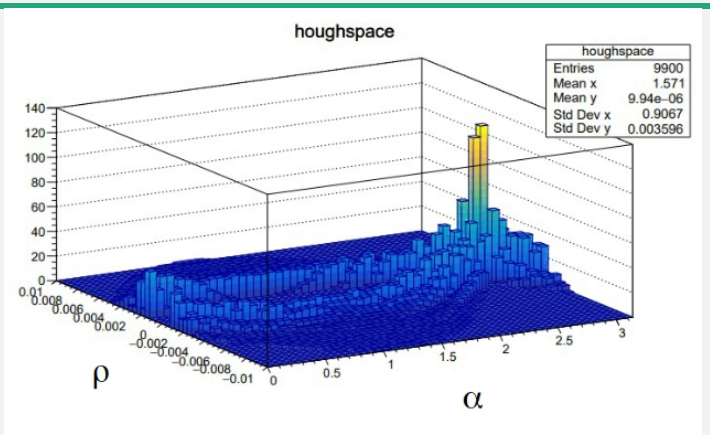
◆ Hough transform with drift distance

(Legendre transform)

one MDC hit -> two curve in Hough space

2-D Track Finding

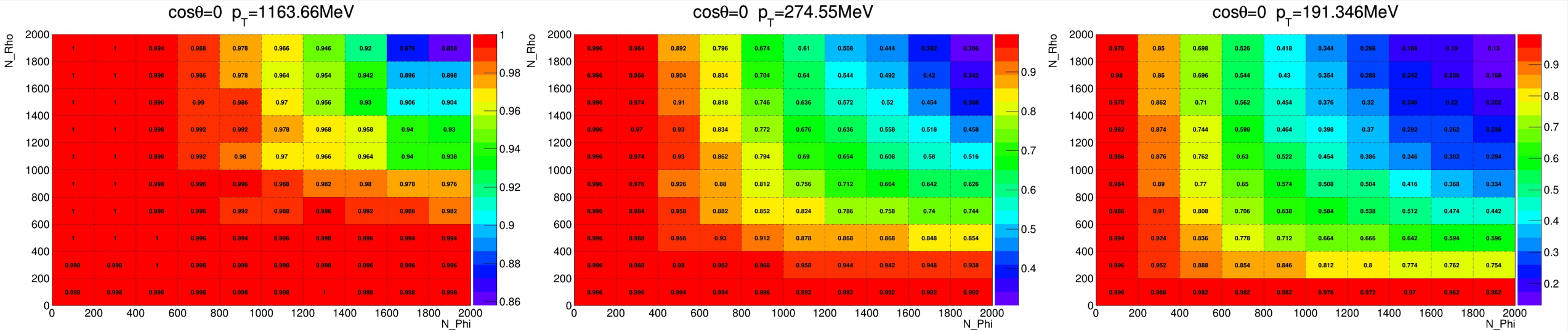
- Use 2-D histogram, counting the lines through each grid cell
- Look for peaks corresponding to potential tracks



->Optimisation of histogram bin size

too small: curves belonging to the same track cannot cross the same bin

too large: more likely to be disturbed by noise



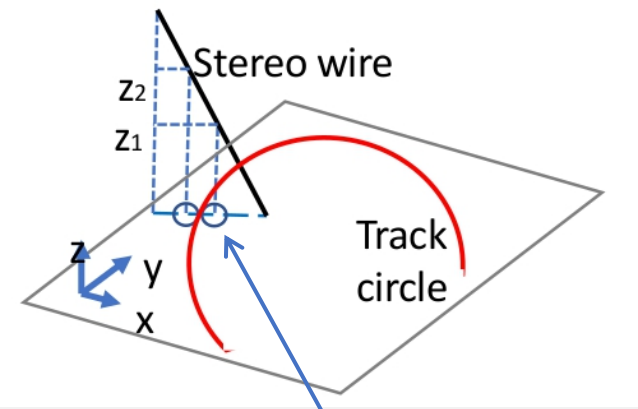
"Good Event" ratio(for single muon track)

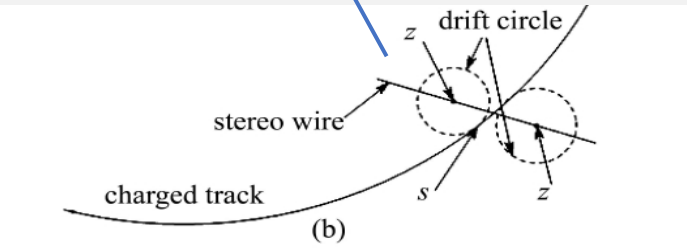
Good event: At least one of the peaks contains most(>95%) of the hits belonging to the same track

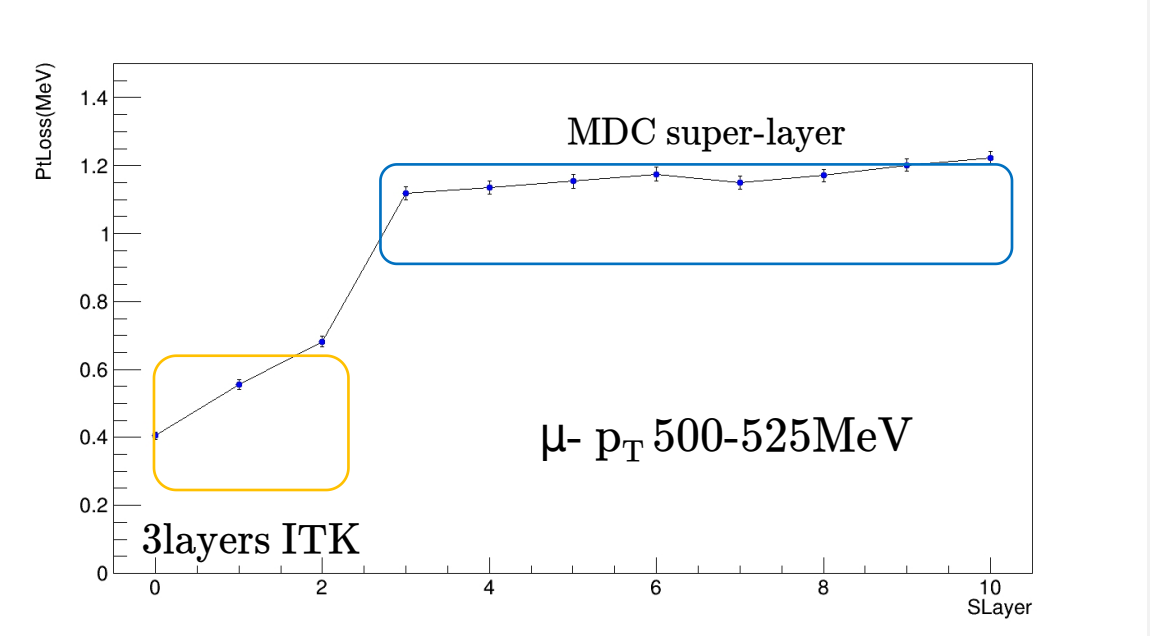
Bin size varies with ρ

3-D Track Finding

- Use the found hits to fit a straight line in the conformal plane, then do 2-D circle fitting(Least Square Method)
- Hits with large residual are discarded
- Stereo wire hits match to get z information







p_T reduction(vs initial value) when the particle enters the detector

Since there is a significant change in momentum before and after the particle enters MDC, only MDC hits are used for the 2D circle fit before calculating z

- Path length on xy(s) and z are linear, Hough tracking agin
- A global fitting is performed to get the parameters of helix track

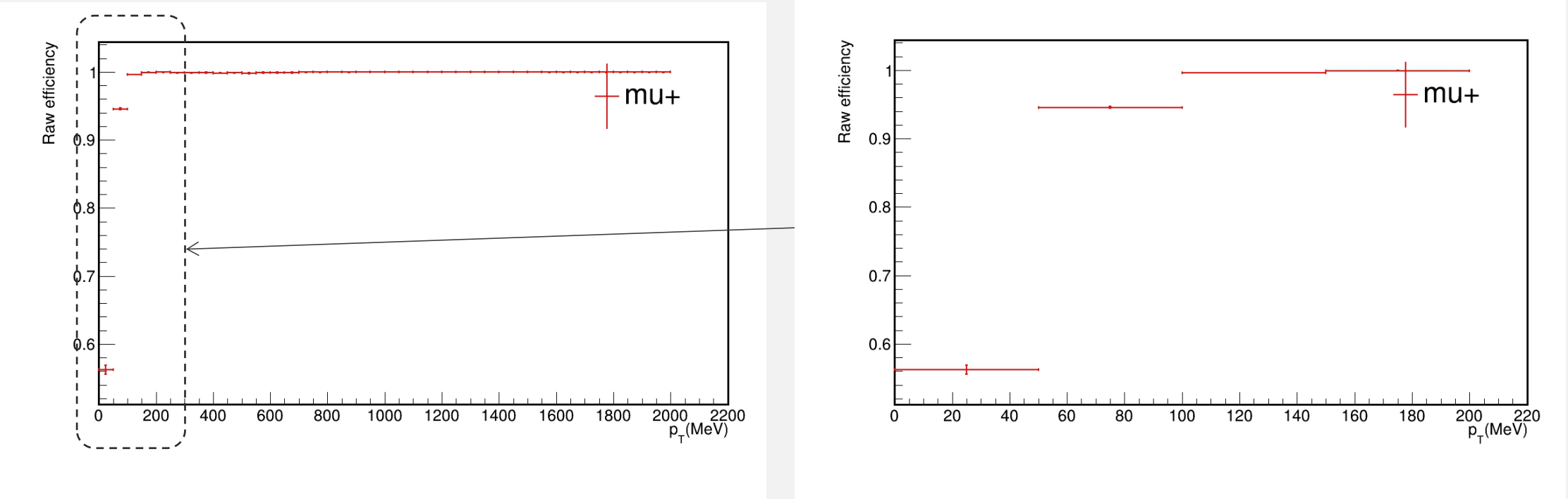
a new fitting method ?

Tracking perfomance

◆Tracking efficiency: N_1/N_{all}

- N_1: number of tracks are successfully reconstructed(At least one found track matches the real track)
- N_{all}: number of all tracks
- |Vr|<1cm && |Vz|<10cm after global fitting, number of hits> 5

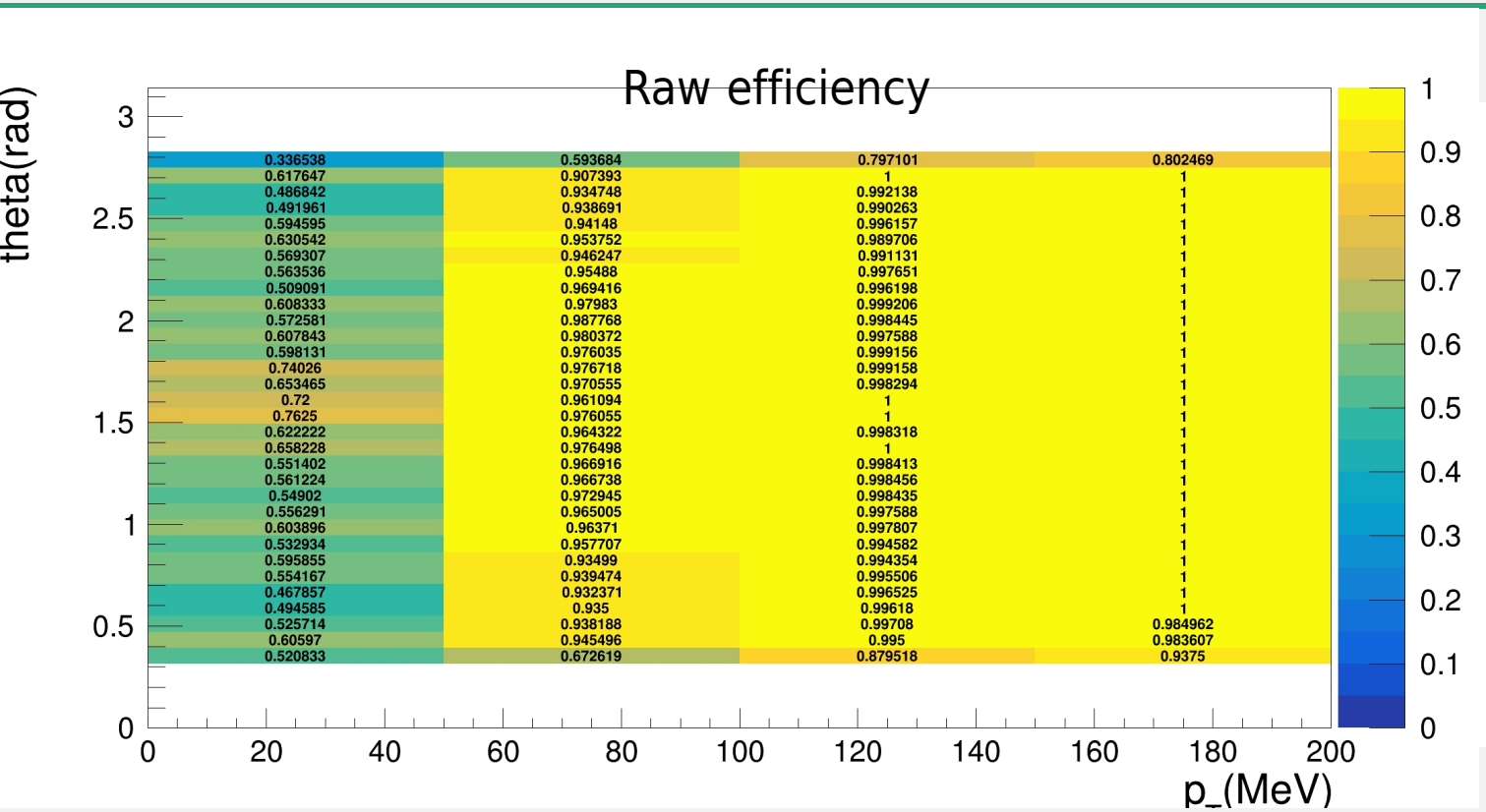
single μ-, random theta and phi, 20°<theta<160°

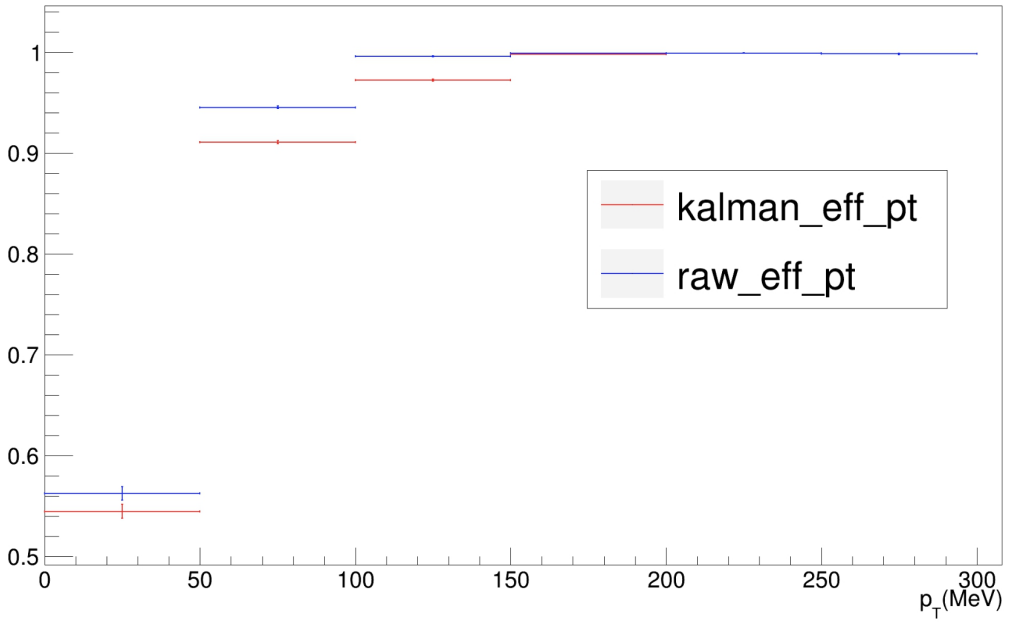


Raw efficiency: tracking efficiency before kalman fitting

$> 99\%$ at $p_T > 0.1$GeV,
$> 90\%$ at $p_T > 0.05$GeV

Tracking perfomance

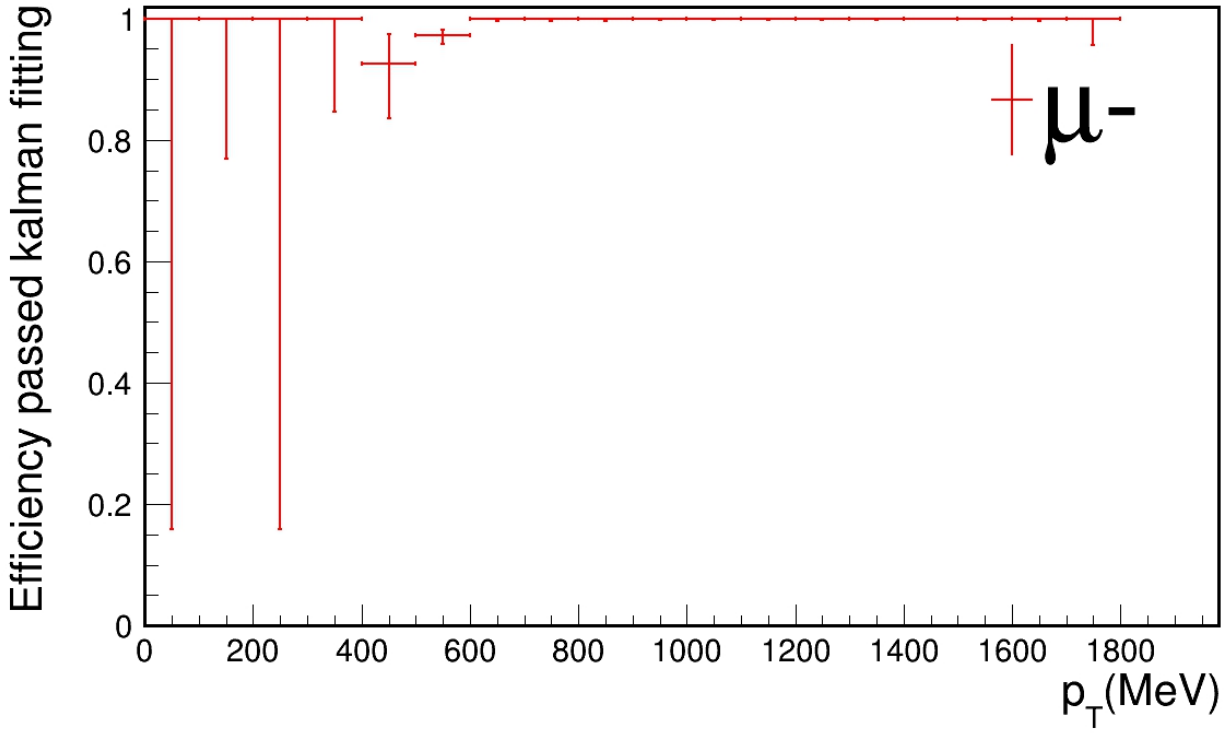


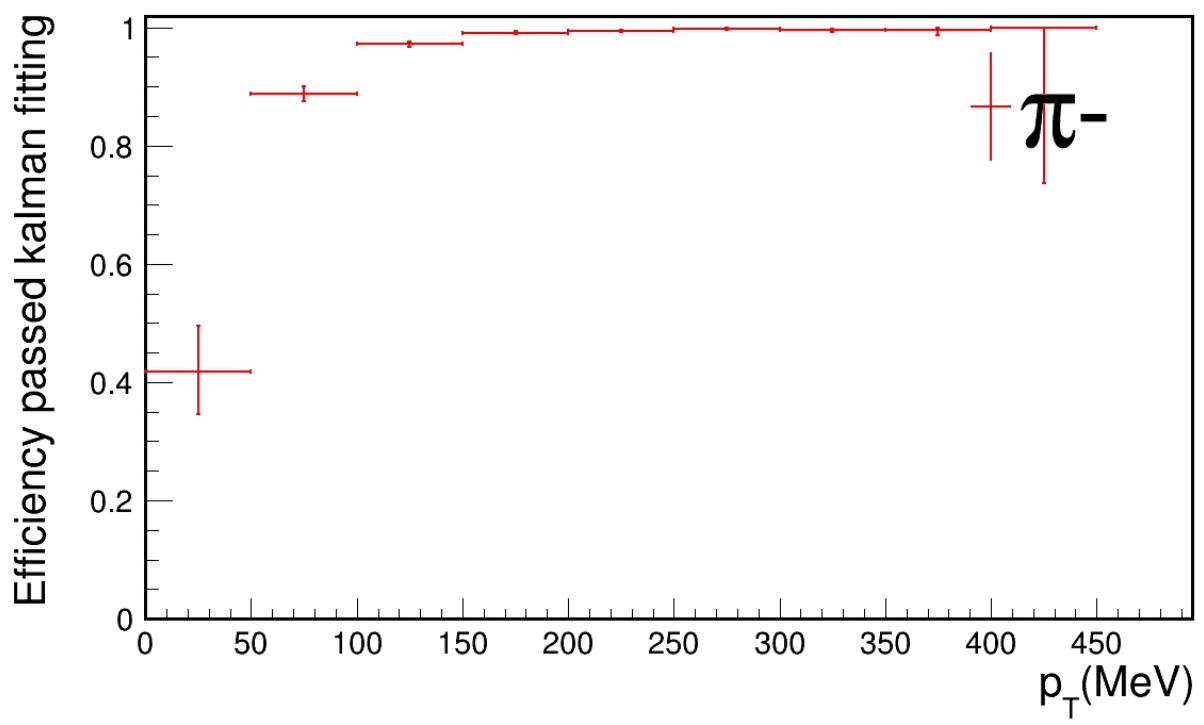


- In some cases, the efficiency and the successful rate of the kalman fitting need to be further optimised
- The quality(e.g. momentum resolution) of the reconstructed tracks needs futher study

Tracking perfomance

$\psi(3686) \rightarrow \pi+\pi- J/\psi(\mu+\mu-)$ $20^\circ < \text{theta} < 160^\circ$ number of hits > 5





Summary&&Discussion

- Simulation and reconstruction of tracking system are implemented in OSCAR
- Tracking efficiency using Hough transform based algorithm looks good
- Needs futher investigation(fitting effciency, resolution, repeat tracks etc.)
- More realistic simulation and reconstruction(background mixing, digitazition etc.)

Thank you