Physics & MC meeting
18 December 2024

Status of track reconstruction for SPD

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Introduction

Track reconstruction is usually divided on two separate sub-tasks:

a) track finding (or pattern recognition);
b) track fitting (in general on the base of Kalman filter method).

Track finding:

a) division set of measurements in the tracking detectors (vertex and tracker) into subsets;
b) each subset contains measurements believed to originate from the same particle.

Track fitting - starts with the measurements inside one subset as was provided by the track finder.

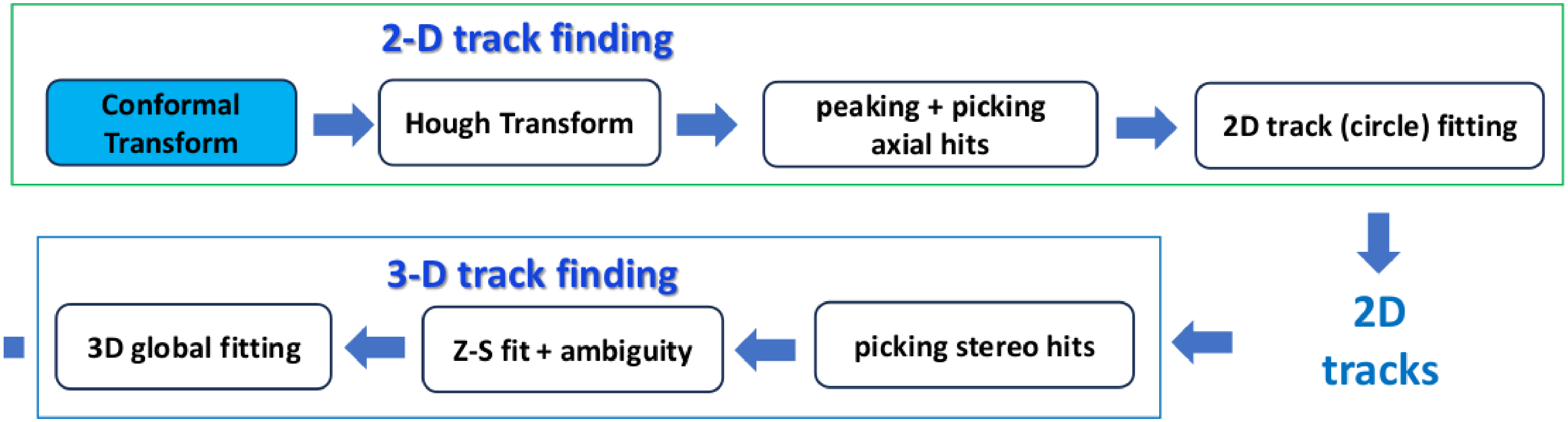
Different techniques can be used for track finding procedure:

a) global method => simultaneous clustering detector hits into track candidates;
b) local method => generate seeds in one detector (usually in vertex) and then use these seeds to complete them by hits from another detector (tracker) and form track candidates.

The local track finding method was realized for SPD track reconstruction procedure with vertex detector.

The track reconstruction procedure for the 1-st stage of SPD experiment with Micro Megas detector will be presented in this talk.

General approach



1. Track finding algorithm starts from 2D (x-y plane) :

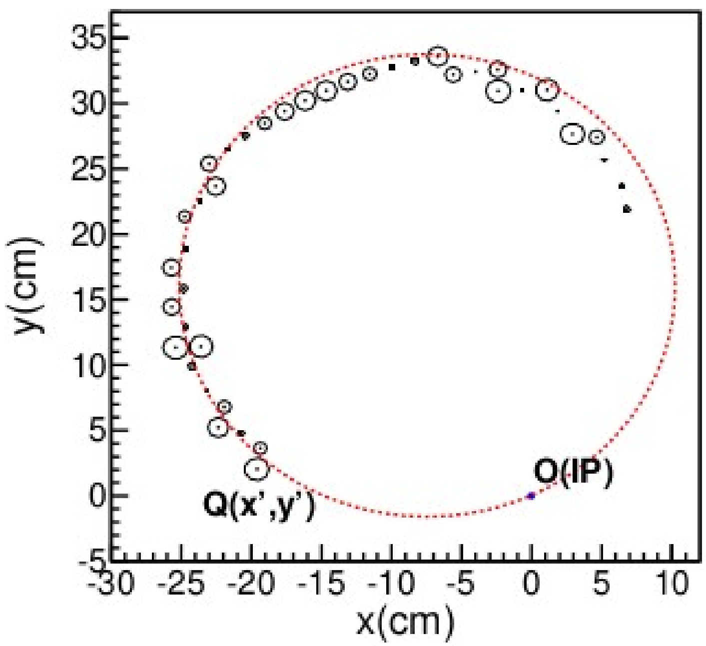
   - use hits in straw trackers as input;
   - conformal transformation;
   - Hough/Legendre transformation (or some another);
   - find peaks and select axial hits (hits from straw tubes which are parallel to the z-axis);
   - 2D circle fitting;
   - picking stereo hits (hits from tilted straw tubes);
   - determine z and phi of track;
   - finally apply 3D Kalman fitting.

Conformal transformation

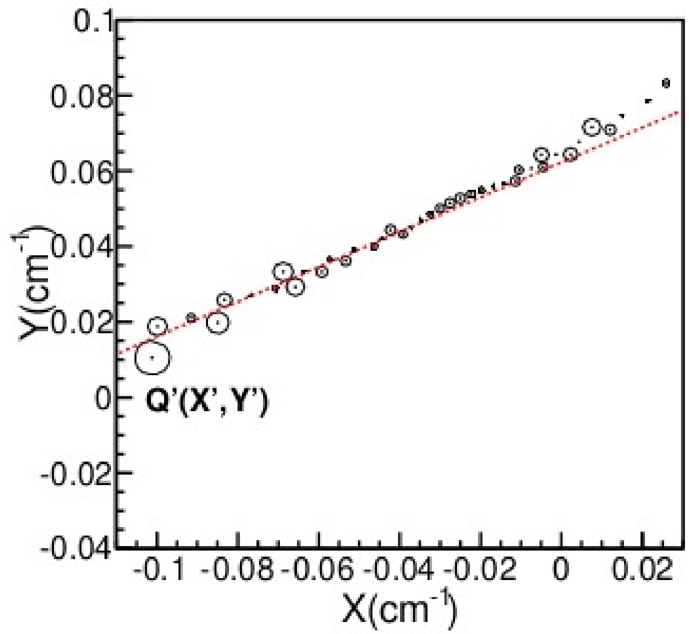
1. Conformal transformation :

- (Track) Circles which is passing the origin point transform into straight lines;

- (Drift circle) Circles not passing the origin point transform into new circles.



$$X = \frac{2x}{x^2 + y^2}, Y = \frac{2y}{x^2 + y^2}$$

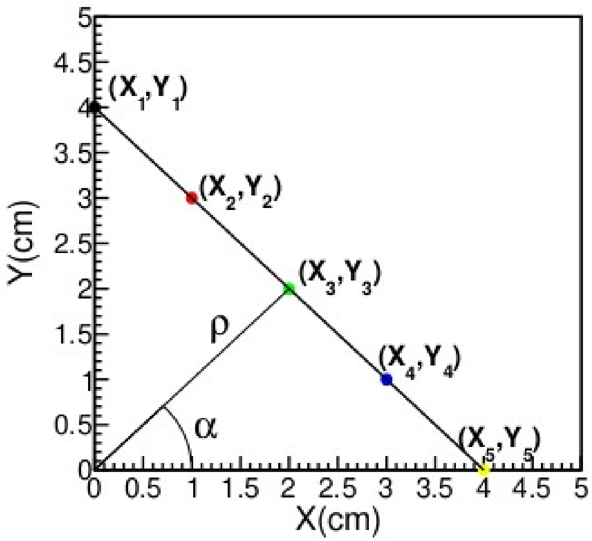


2. Deviation from a straight line is associated with energy losses of particle.

Hough/Legendre transformation

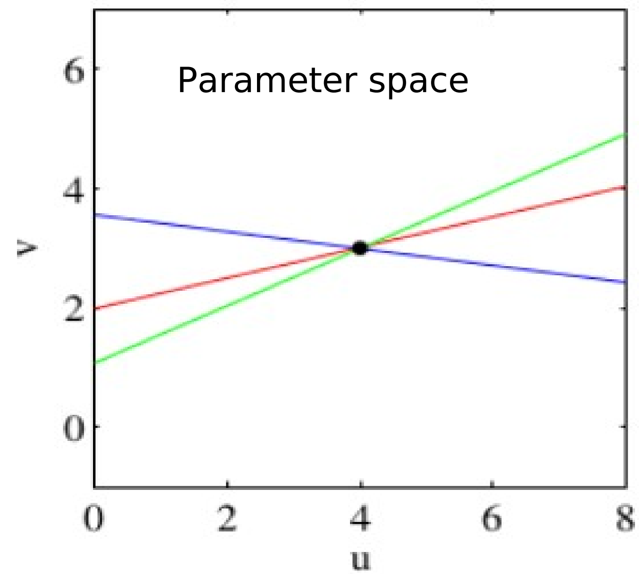
2-D track finding

Conformal Transform → **Hough Transform** → peaking + picking axial hits → 2D track (circle) fitting



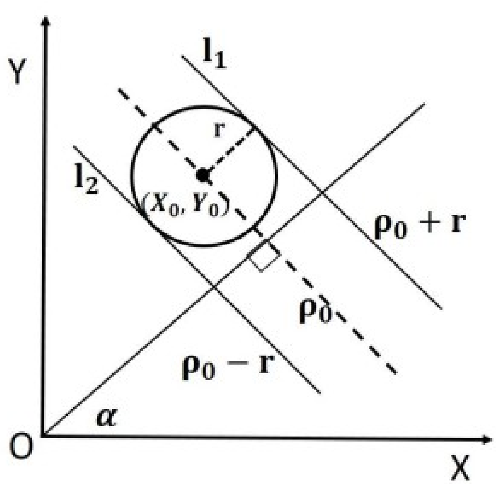
Hough transformation
(each point is line in parameter space)

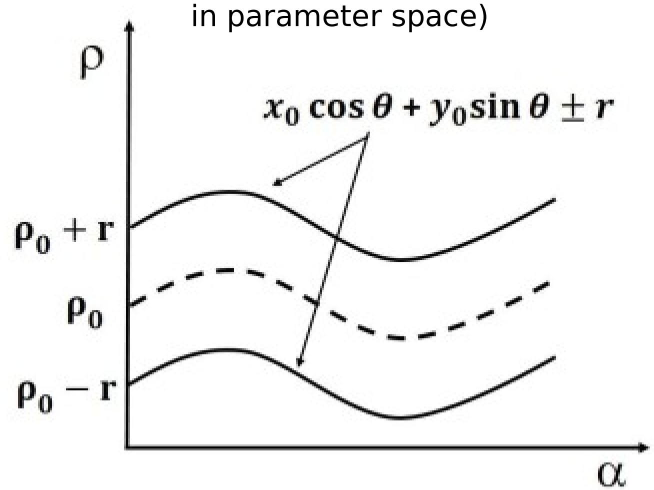
$$v = a * u + b$$

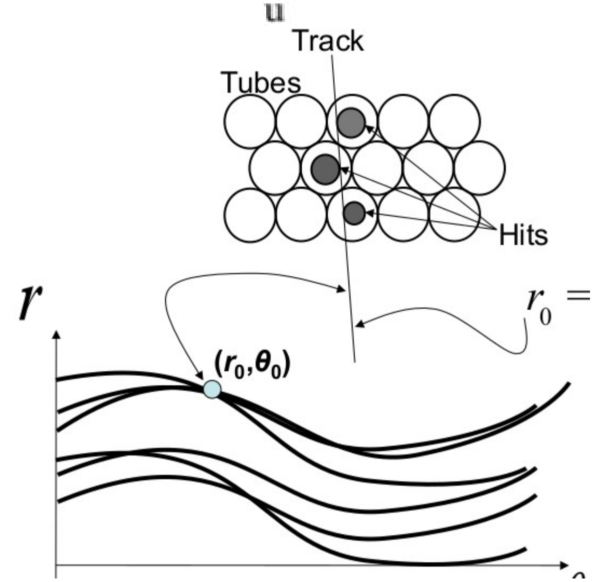


Legendre transformation:
ρ = X cos α + Y sin α + Rd
ρ = X cos α + Y sin α - Rd

(each point is two cosine line
in parameter space)



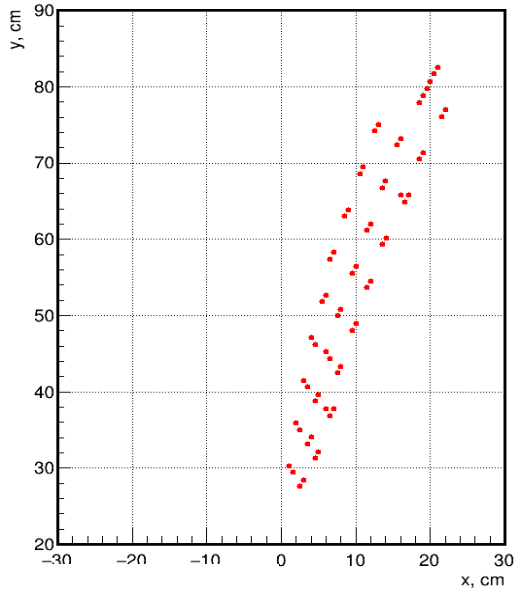


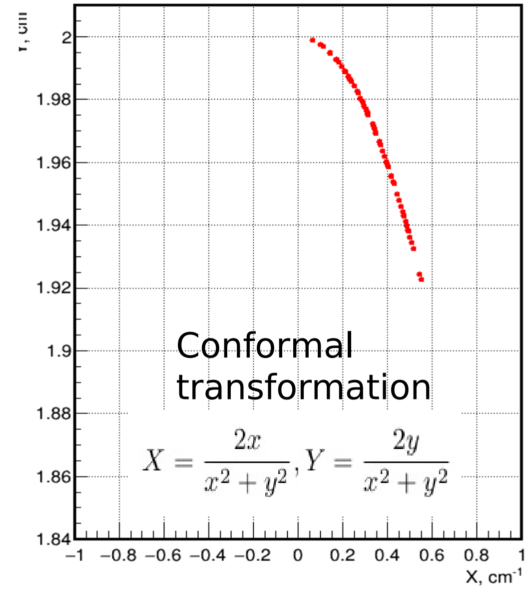


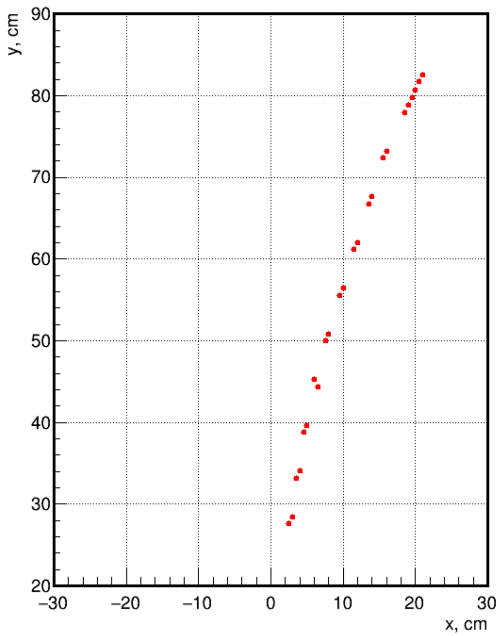
Standard straw tracker geometry

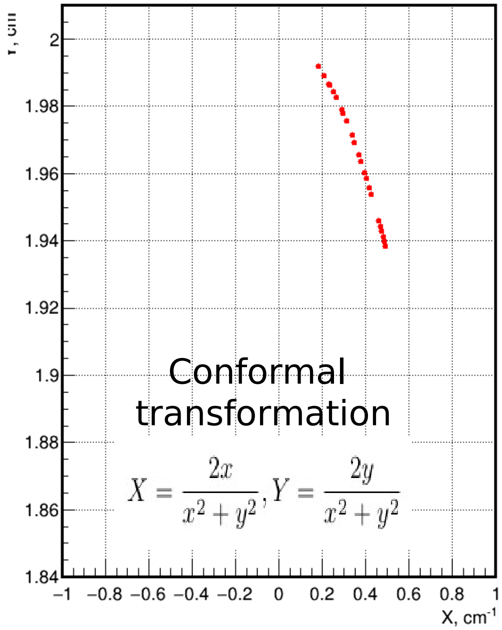
Muon of 1 GeV/c with $\theta = 45^0$, $\varphi \sim 90^0$

All hits (red points – wire position of fired straw tubes)







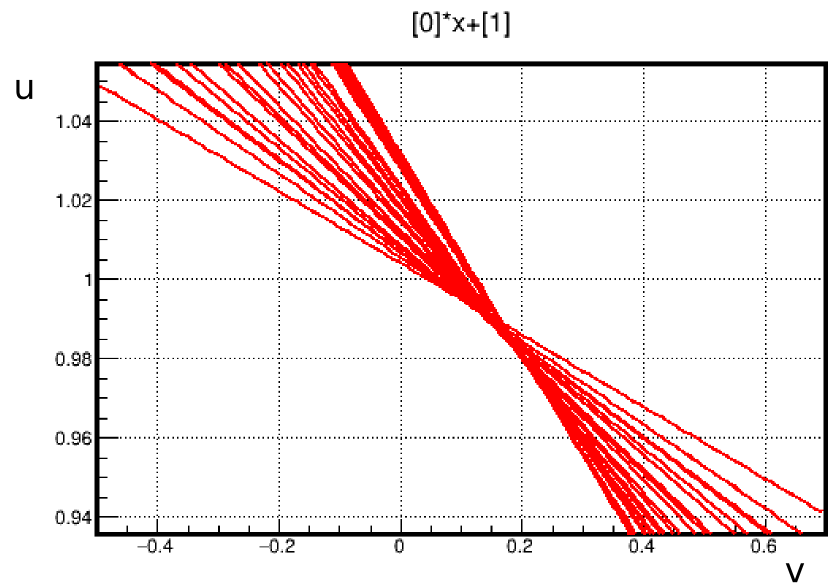


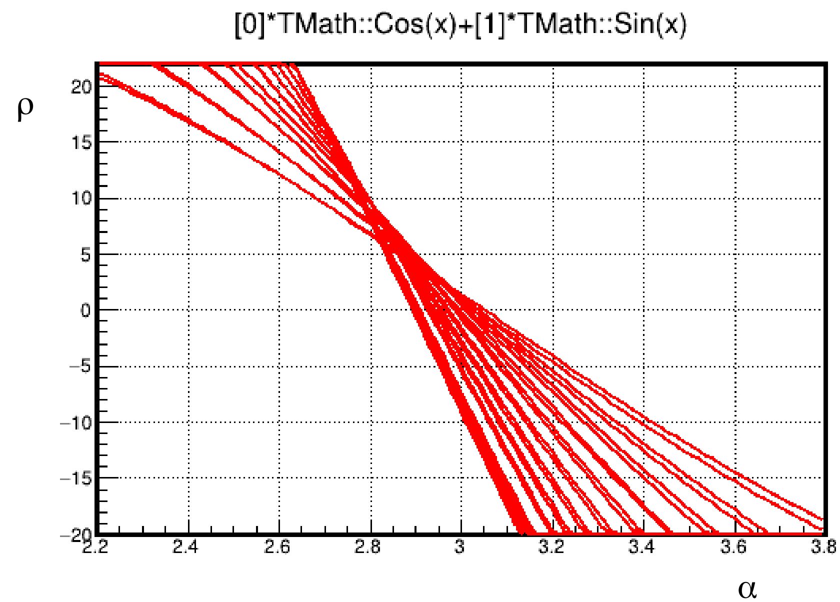
Hits from straw tubes which are parallel z-axis

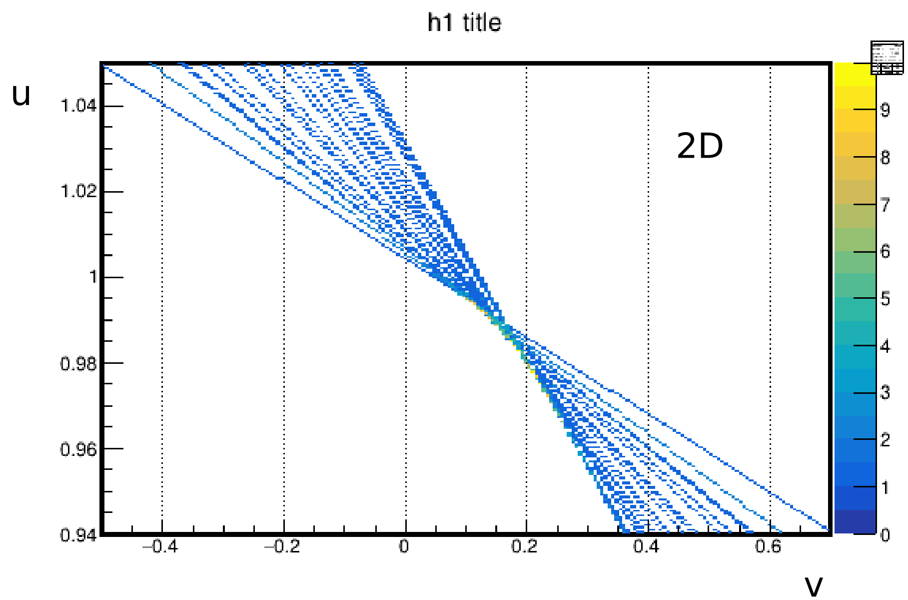
Parameter space

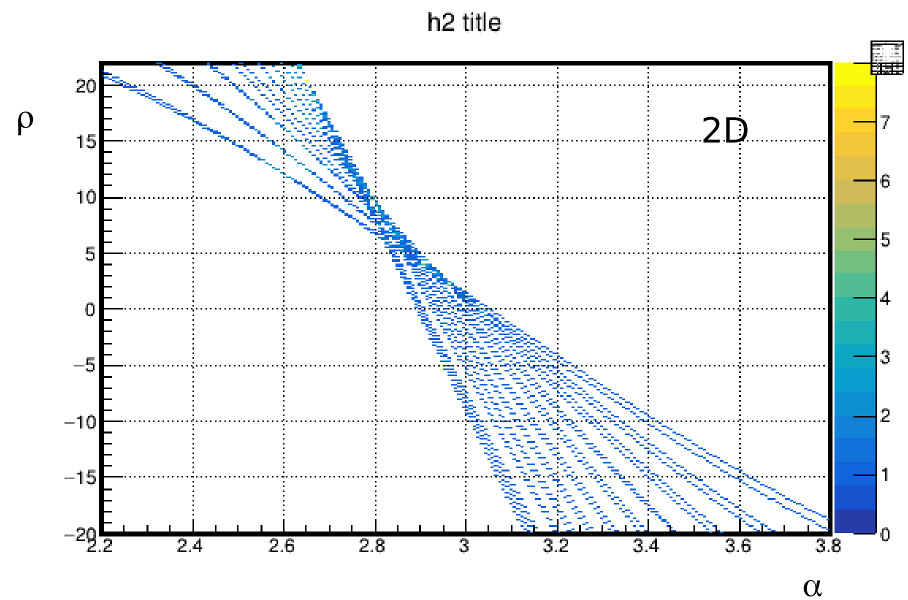
Hough transformation

Legendre transformation



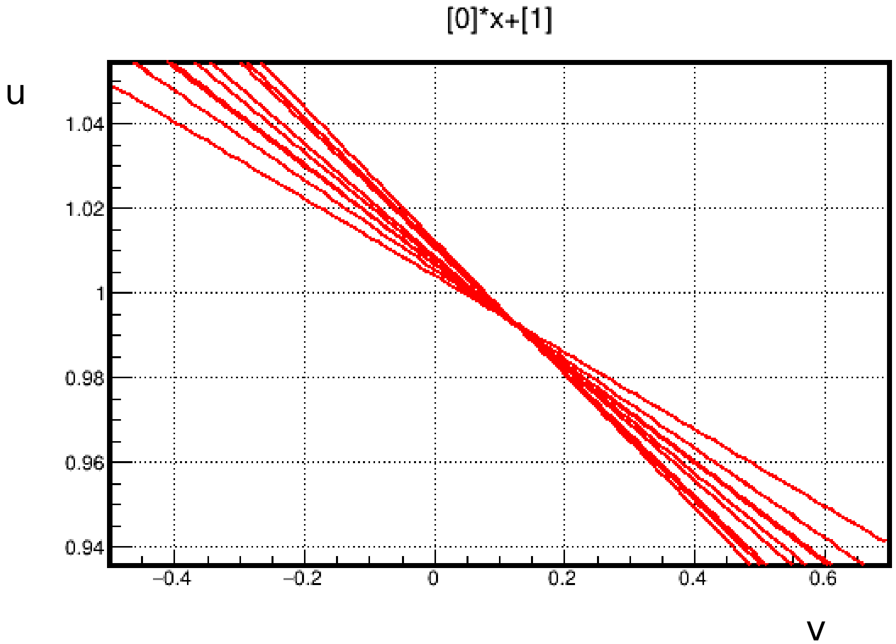




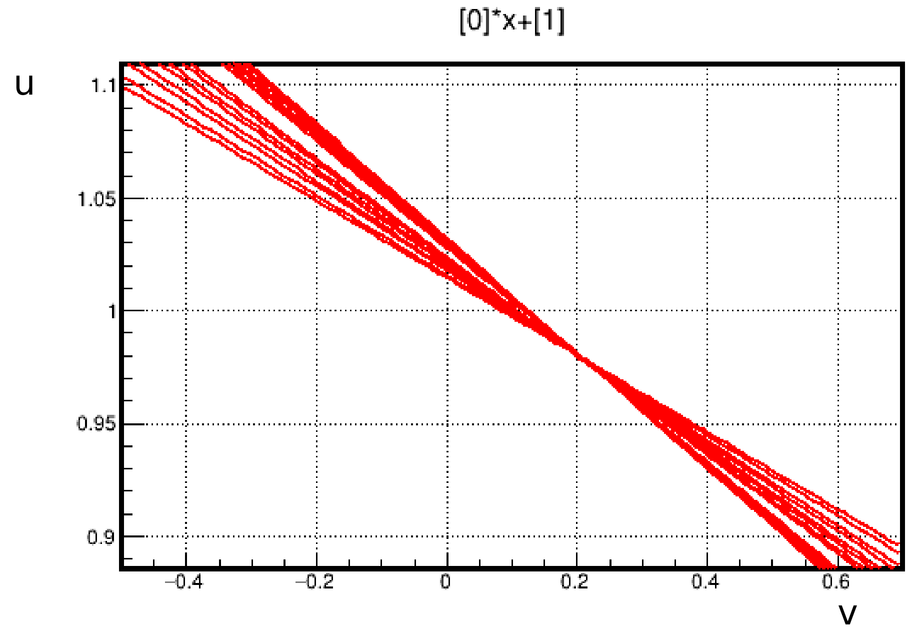


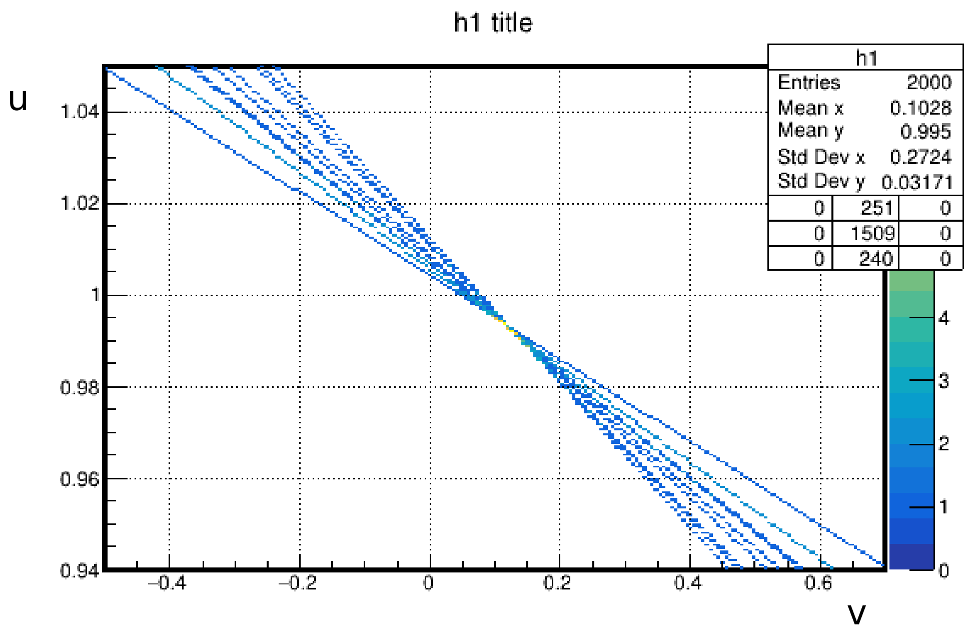
Parameter space (Hough)

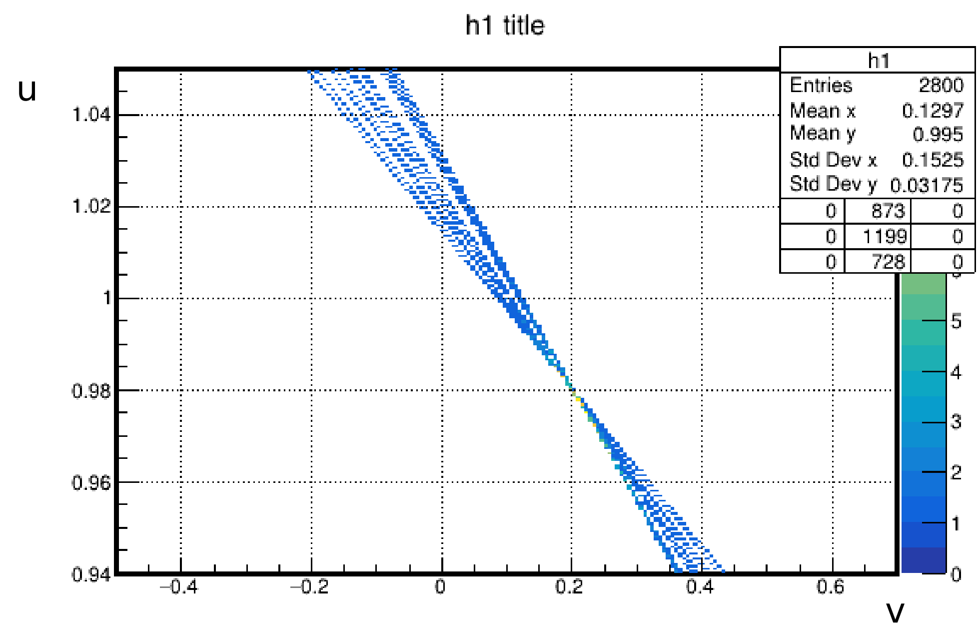
Layer number < 15



Layer number > 15

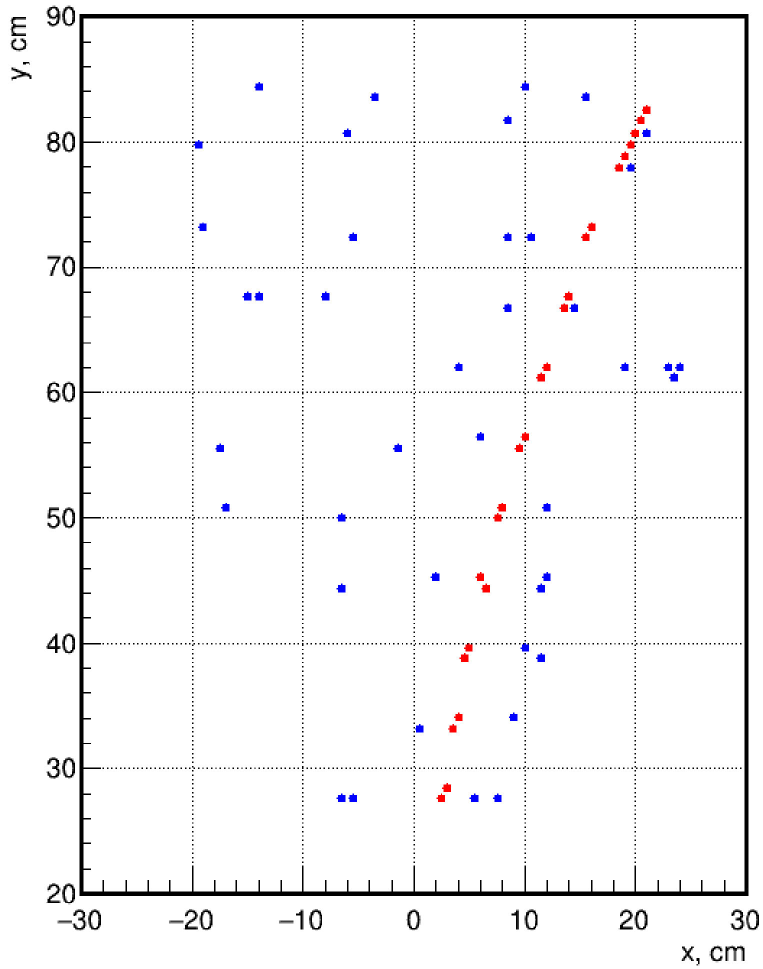


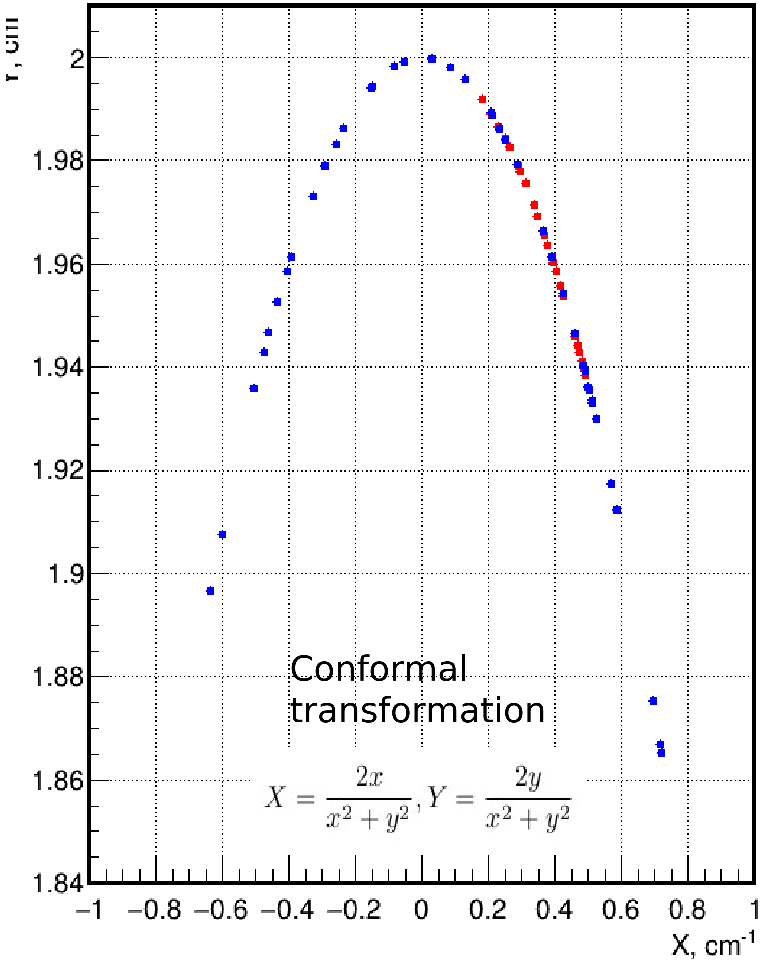




Adding noise to hits

Muon of 1 GeV/c with θ = 45^0, φ ~ 90^0 and adding 200 % random noise hits

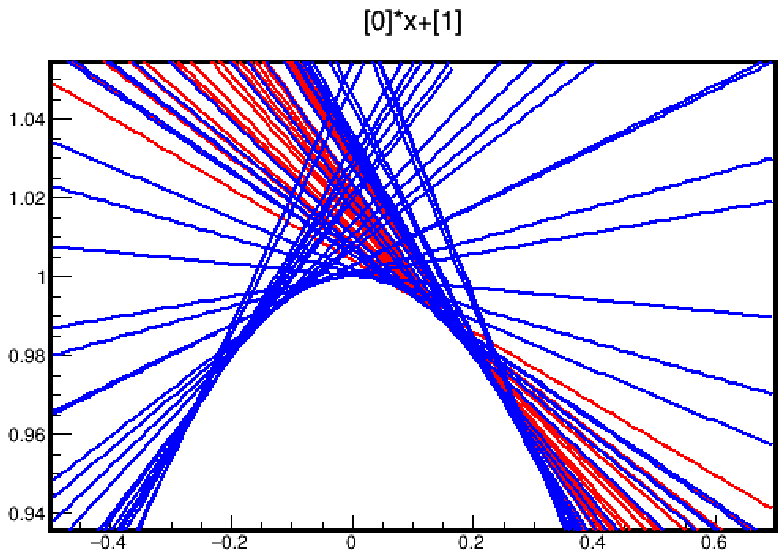


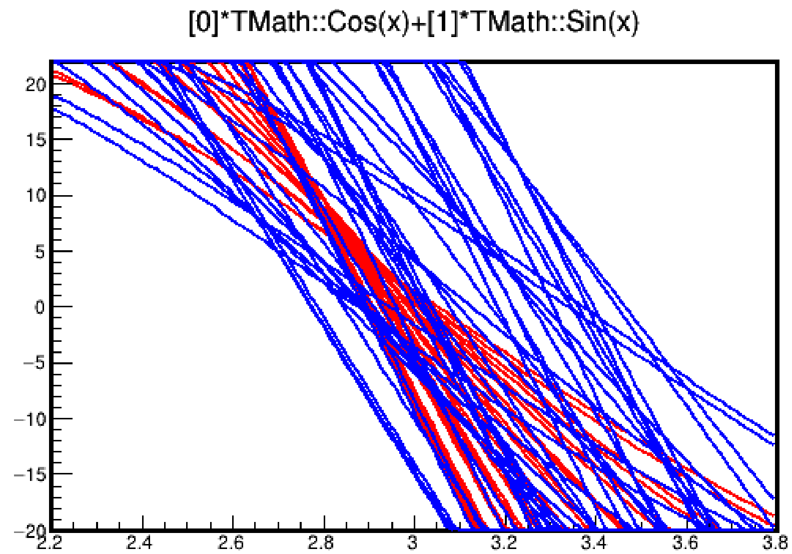


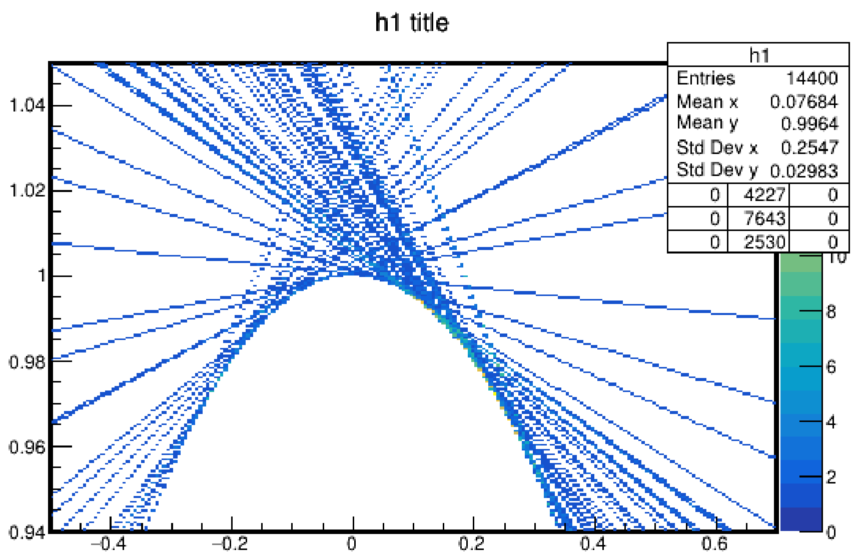
Parameter space with noise

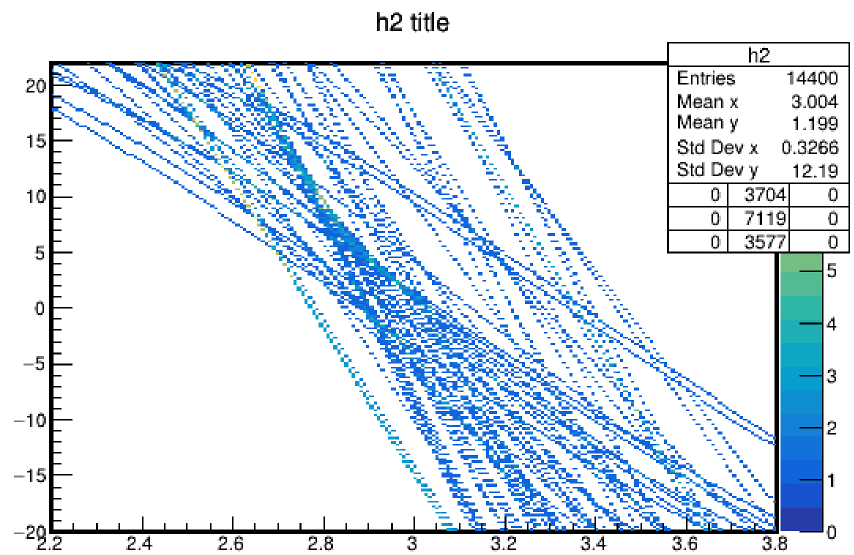
Hough transformation

Legendre transformation

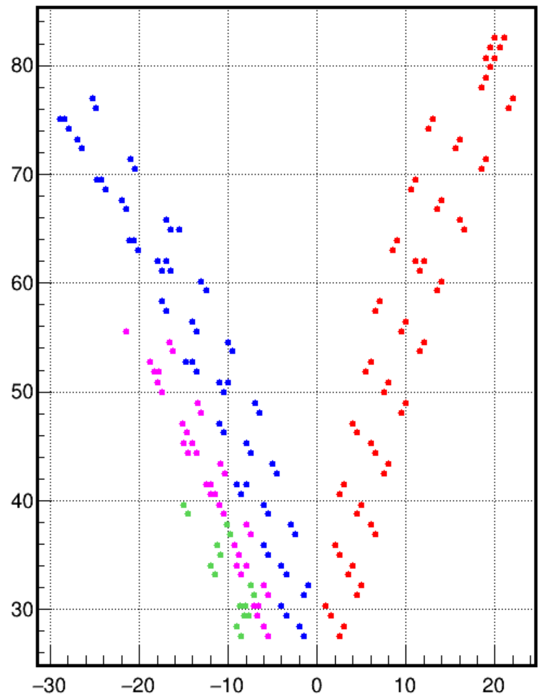








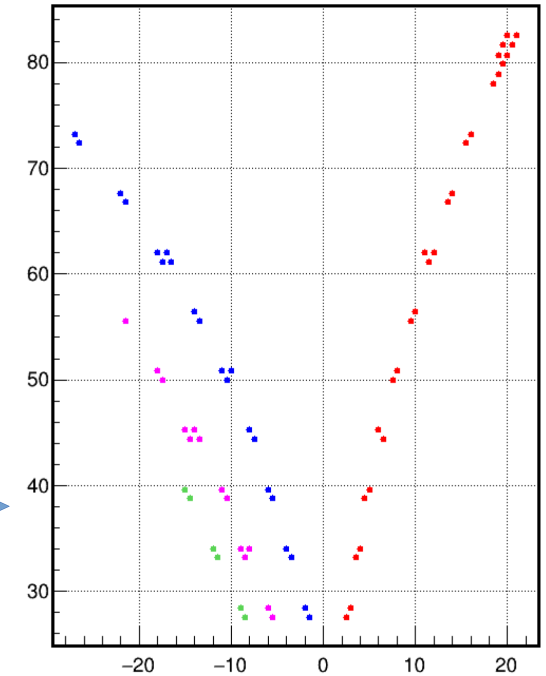
4 particles in straw tracker



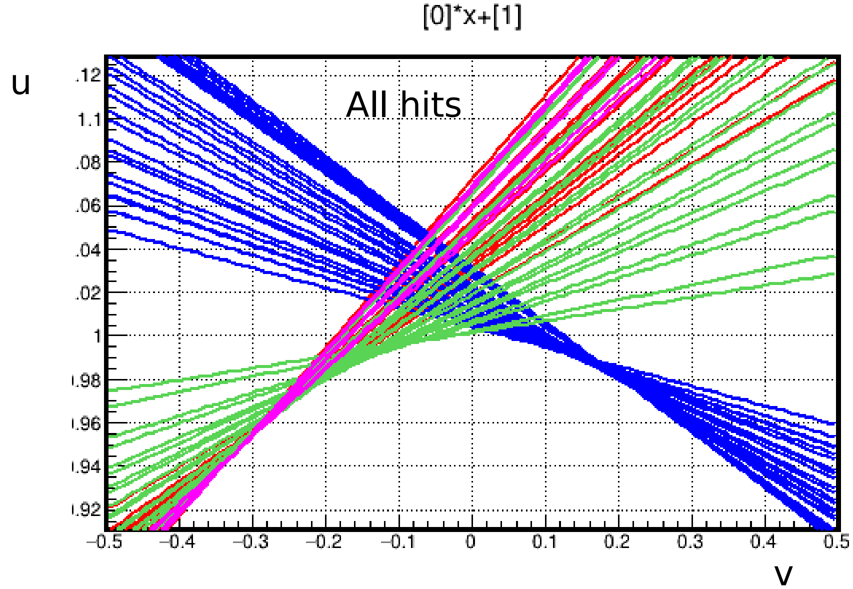
1 muon (+,) of 1 GeV/c and
3 muon (-) of 1.0 and 0.5 GeV/c
with θ = 45⁰, φ ~ 90⁰

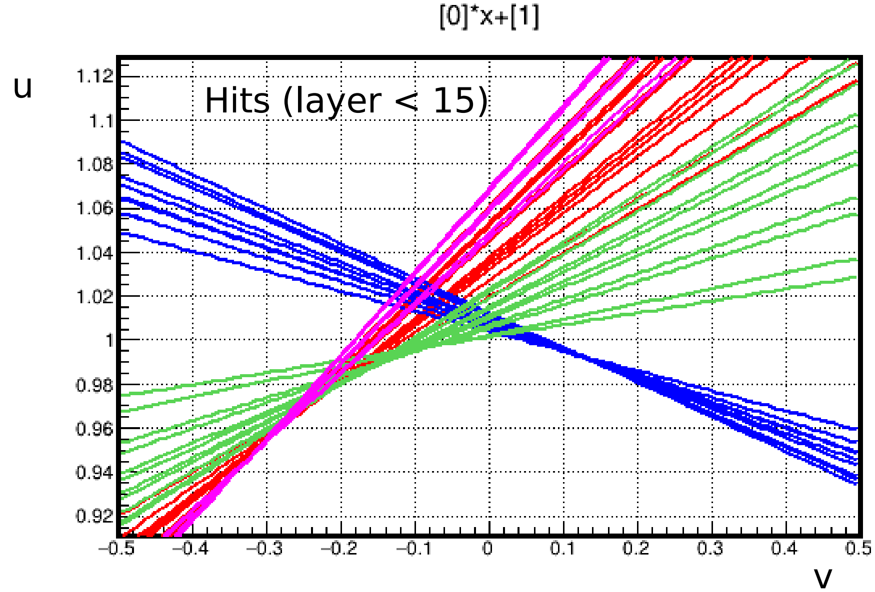
All hits

Hits from straw tubes
which are parallel z-axis



Hough transformation



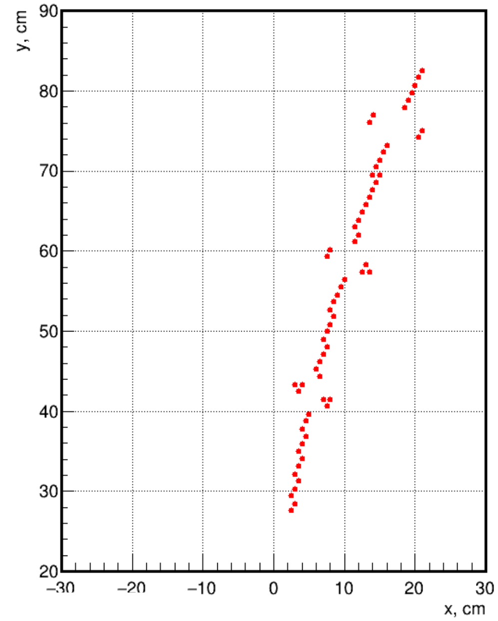


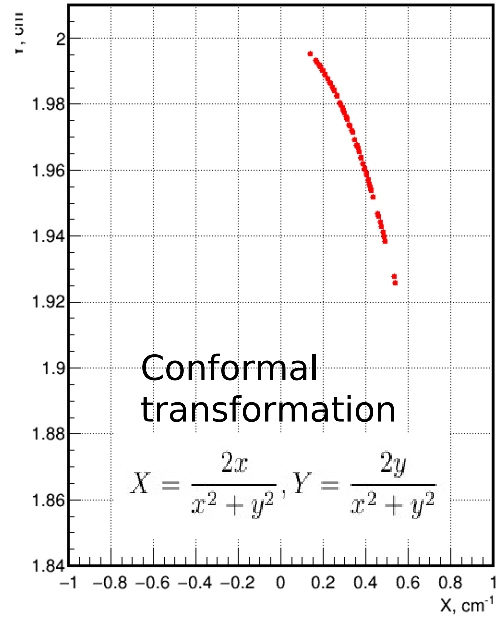
Another tracker geometry

4*(7+1+1) – layer structure

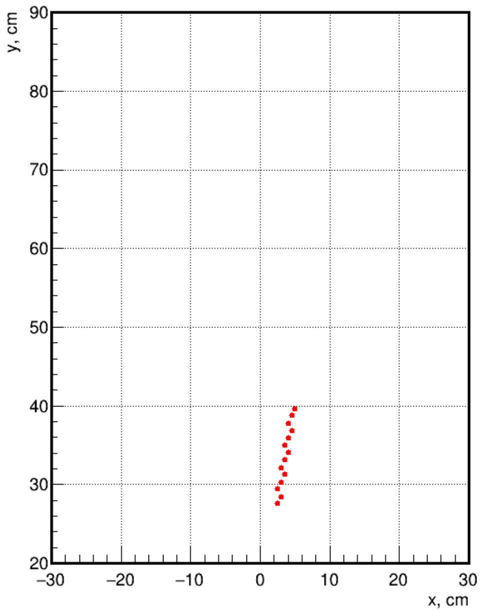
Muon of 1 GeV/c with $\theta = 45^0$, $\varphi \sim 90^0$

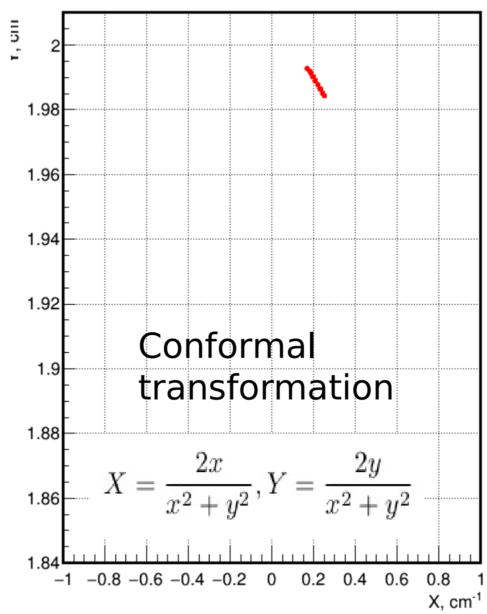
All hits (red point – wire position of fired straw tube)





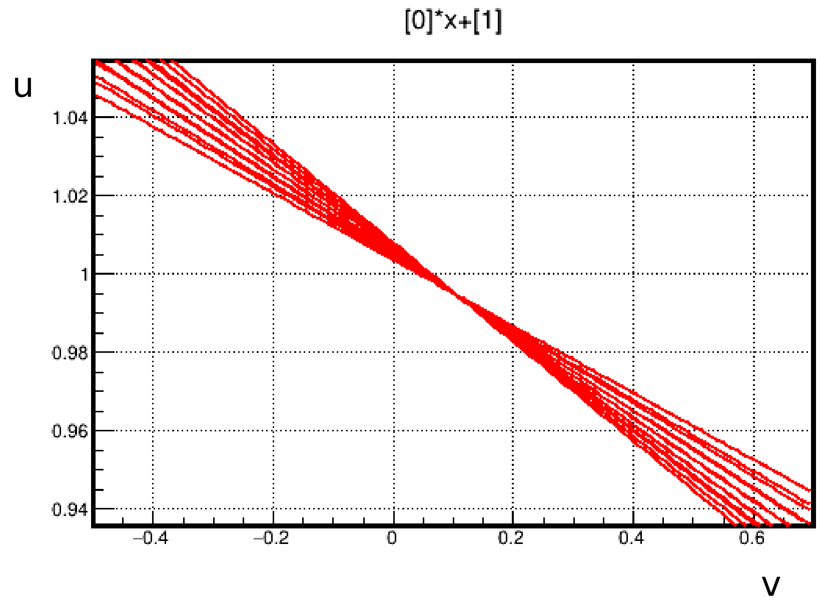
Hits from straw tubes which are parallel z-axis (layer < 8)

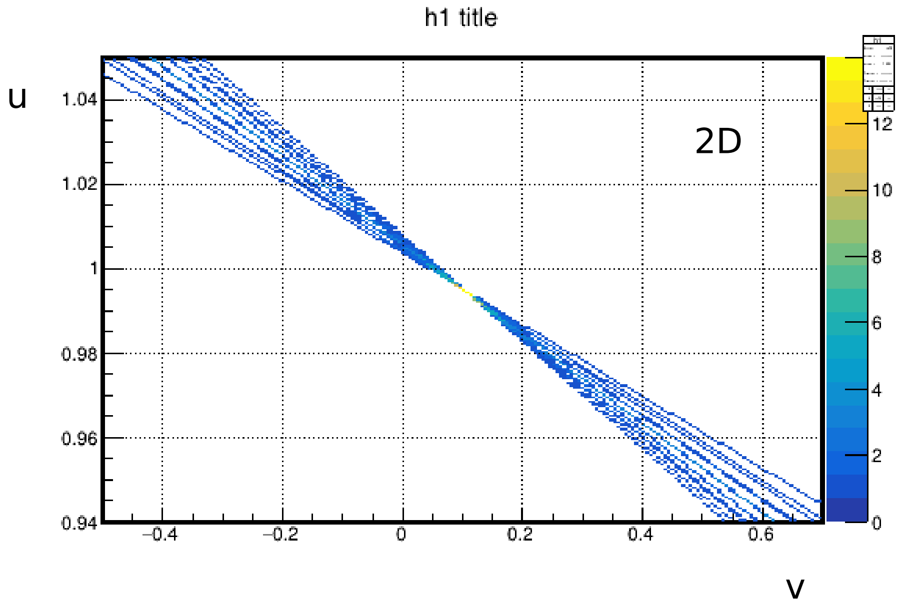




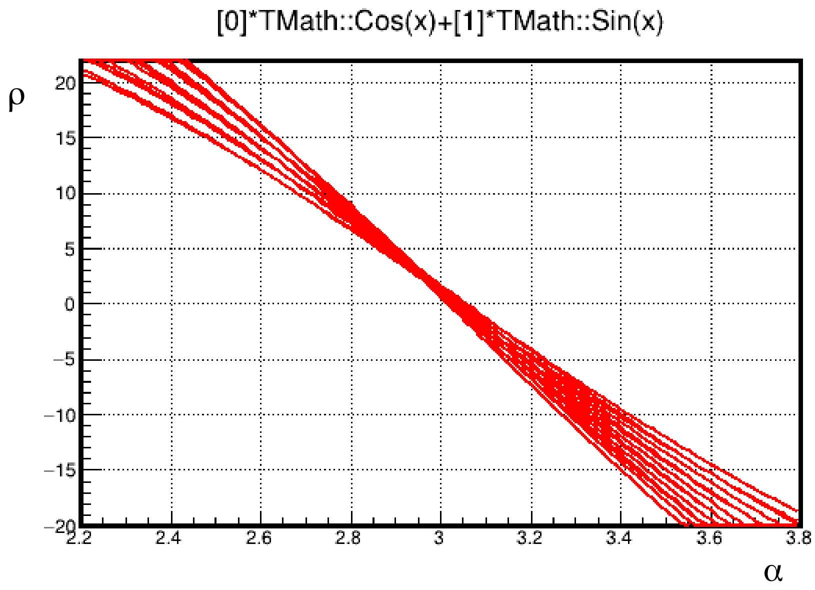
Hough/Legendre transformation

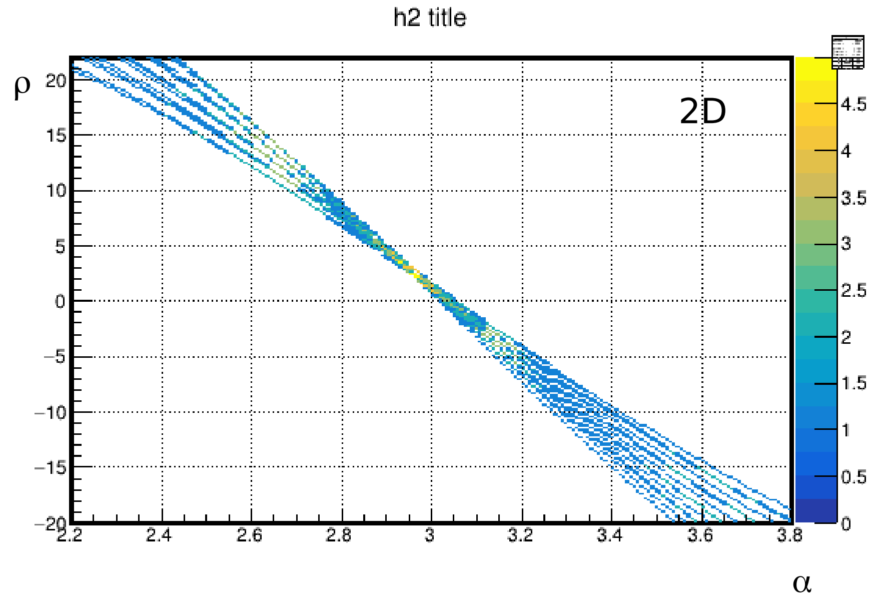
Hough transformation





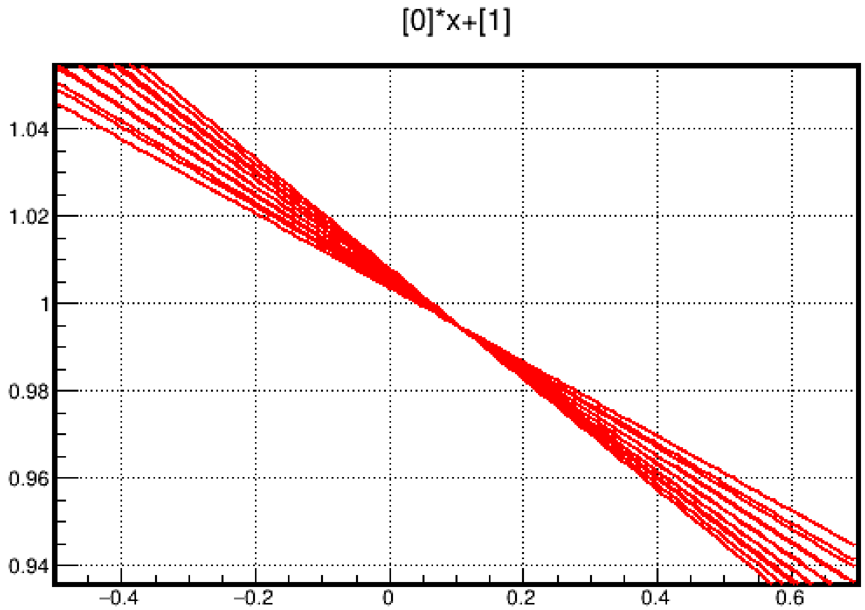
Legendre transformation

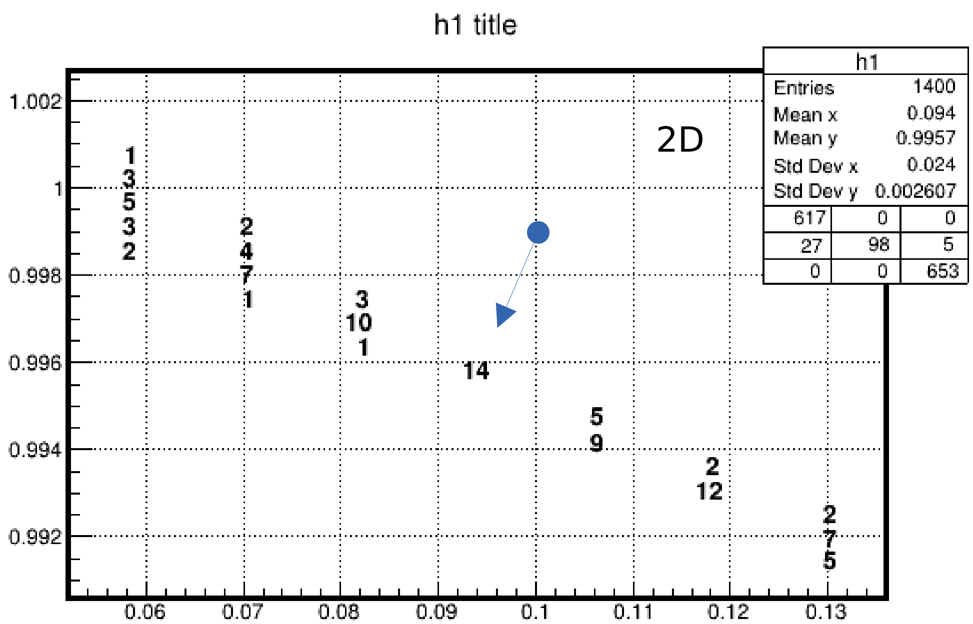




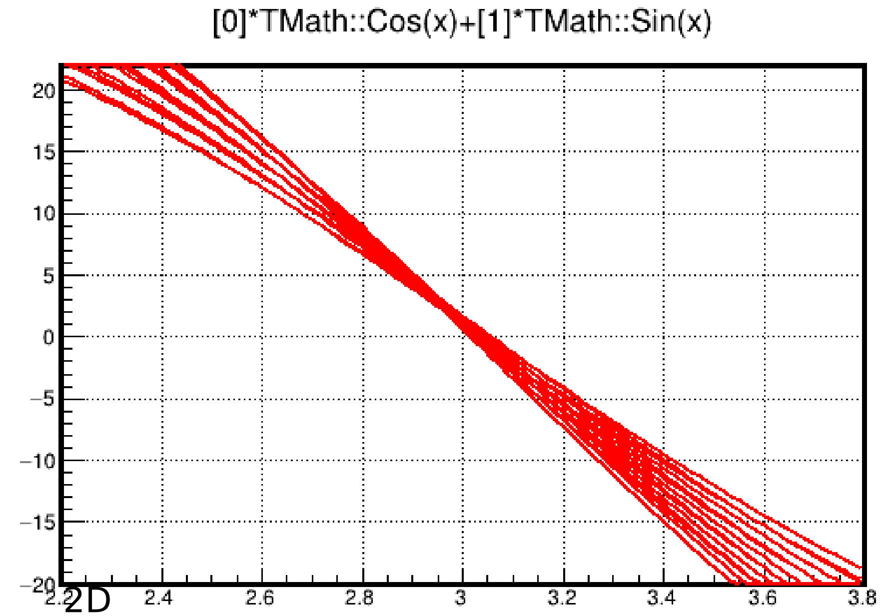
Hough/Legendre transformation (peaking)

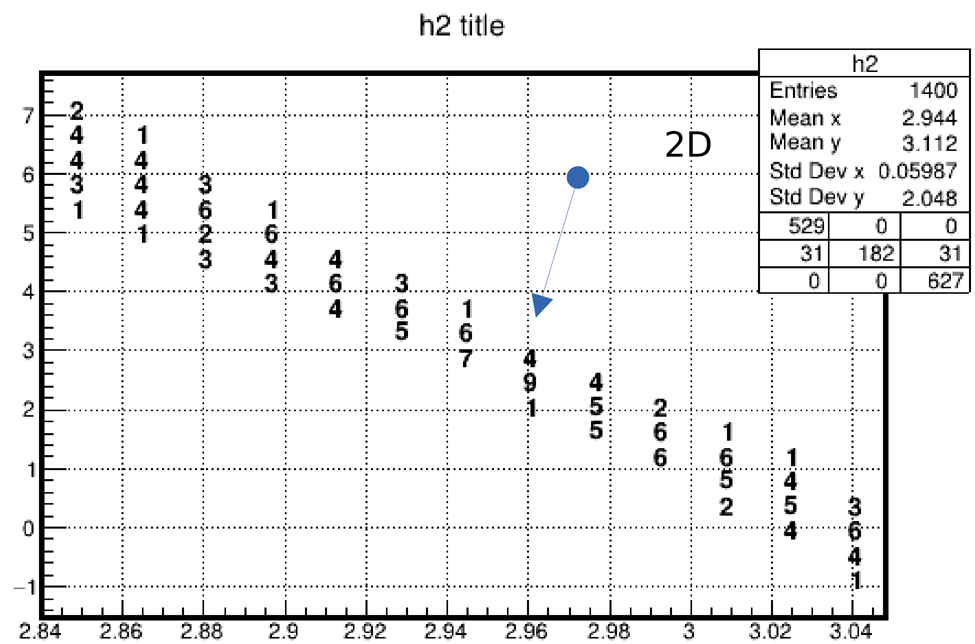
Hough transformation



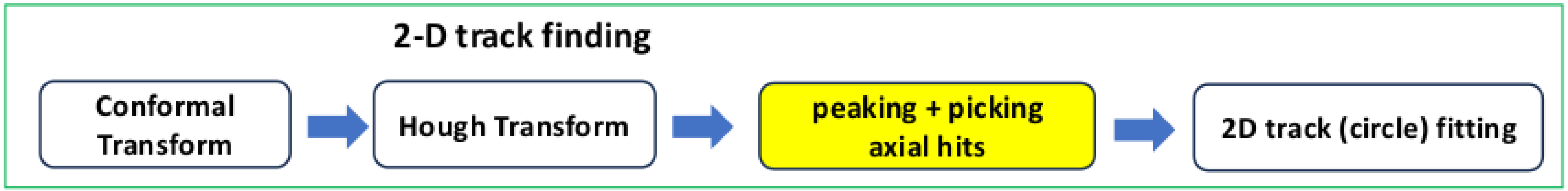


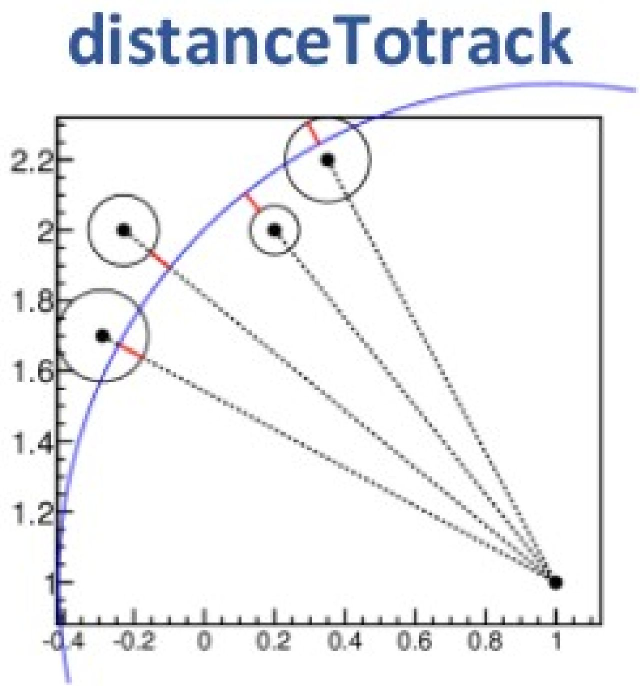
Legendre transformation





2D track (circle) fitting





residual = *drift – doca (red lines)*

doca – is the distance between the circle line and the straw tube center and

drift - is the radius of the drift circle.

The next function can be construct

$$\chi^2 = \sum_{i=1}^{nhits}\left(\frac{drift_i - doca_i}{\sigma_i}\right)^2$$

Where σ is the error of drift radius.

Miinimisation of this χ2 can done with the Newton Method and circle parameters can obtained by iterative calculation as follows:

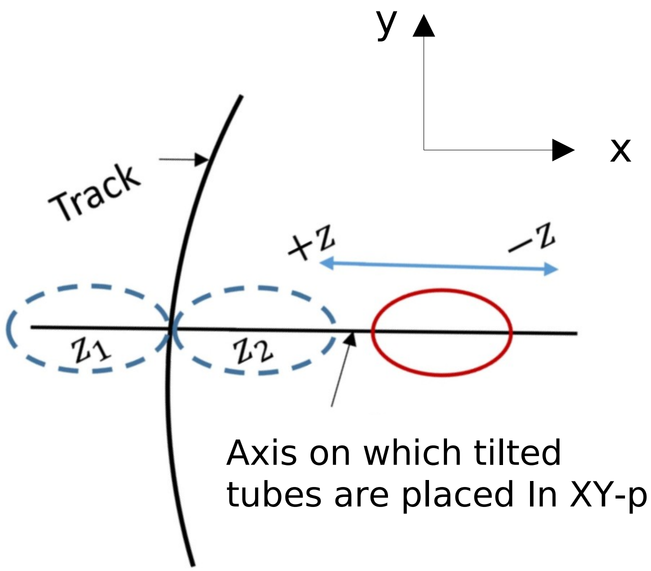
$$a_{(D+1)} = a_{(D)} - \left(\frac{\partial^2 \chi^2}{\partial a^{T} \partial a}\right)^{-1}_{(D)} \left(\frac{\partial \chi^2}{\partial a}\right)_{(D)}$$

Longitudinal track reconstruction

1. Charge particle trajectory in constant magnetic field is helix which can be described:

   a) in XY plane as circle with radius $R = PT / 0.3 \cdot B$;

   b) z-coordinate is the function of arc length (s), $z(s) = z0 + s \cdot \tan\lambda$, where $s = (\Phi - \Phi 0) \cdot R \cdot q$,
   Φ – azimuthal angle, λ – dip angle, z0 and Φ0 – track parameters in starting point or in primary vertex



2. The z-position for each hit in a tilted straw tube is extracted through an alignment procedure as illustrated below. The track radius is determined before by the pattern recognition procedure in XY-plane.

   Since these tubes are tilted, the projection of the drift radius onto the XY-plane becomes an ellipse. The drift ellipse is aligned such way that its center position lies along x-axis of layer and is tangential to the particle trajectory.

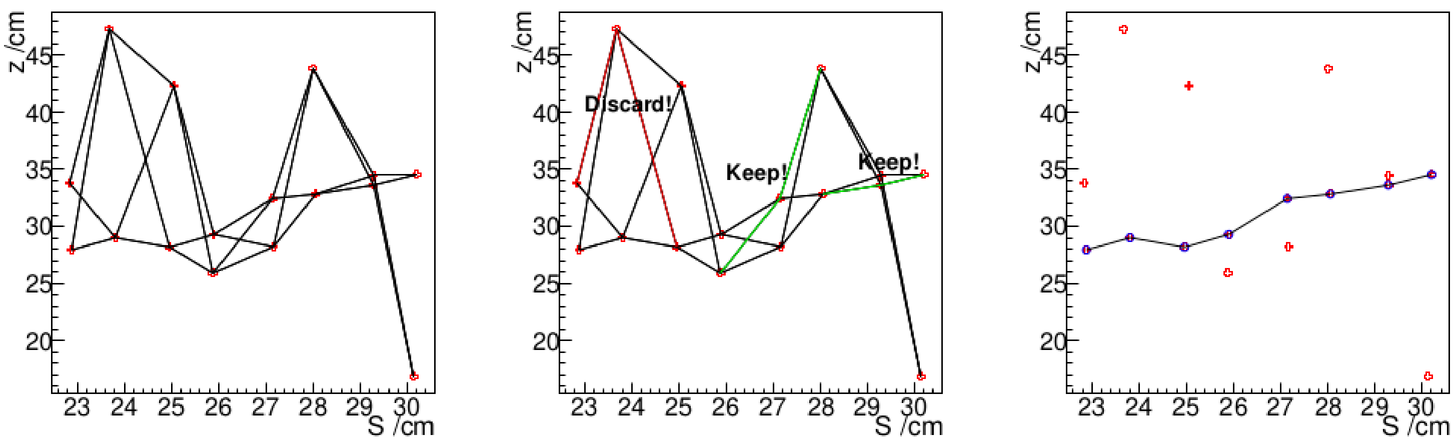
   This alignment provides two solutions, introducing a left/right ambiguity with one solution on each side of the trajectory

Longitudinal track reconstruction

Combinatorial approach:
a) determine all possible connections between layers;
b) calculate angles between neighboring lines;
c) reject paths with θ < 90⁰;
d) select path by minimizing

$$w = \sum_{j}^{N-1} \left(180^\circ - \theta_j\right)^2,$$

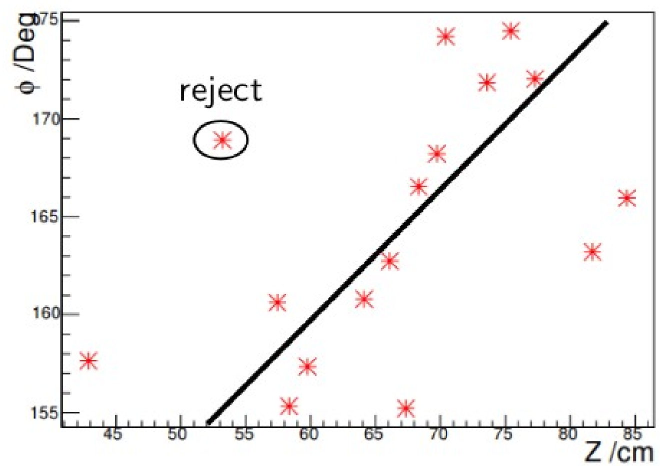
Hough transformation:
a) generate set of lines around point;
b) fill line parameters in accumulator;
c) repeat for all points;
d) select maximum in accumulator.



(a) (b) (c)

Recursive annealing fit:
a) fit by line to all points;
b) remove point with largest residual;
c) calculate new line fit;
d) repeat until one point has been rejected for each straw tube;
e) do final line fit.

$$\chi^2 = \sum_{i}^{n} \frac{\left(z_i - kS_i - z_0\right)}{\sigma_i^2},$$

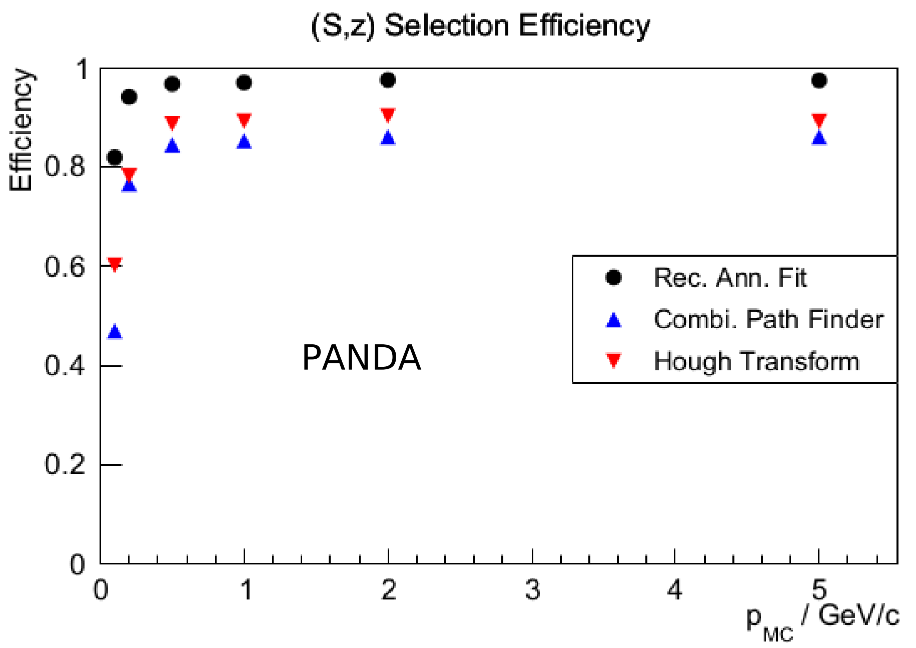


Longitudinal track reconstruction

This procedure provides the next track parameters estimation:

a) theta and phi angles;
b) estimation of primary vertex position.

Last step is applying the fitting procedure the selected straw tubes (Kalman filter).



Results from PANDA estimation (it is shown as example):

a) hits selection efficiency:
- Combinatorial Path Finder reaches up to ≈ 85%.
- Hough transformation achieves efficiencies of ≈ 90%
- Recursive Annealing Fit performs best with efficiency above 95%.

b) hit z-resolution ~3 mm;

c) longitudinal momentum P_l resolution ~2% at P = 1 GeV/c;

Summary

1. General schema for track reconstruction using only hits from straw tracker is clear.
2. Some parts of code are written and under tuning procedure .
3. Needs to determine optimal transformation procedure (Hough, Legendre or something else).
4. Check the longitudinal track reconstruction procedure.
5. Code will be ready till end of March.