IX SPD Collaboration meeting
12-16 May 2025

Track finding status at 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:

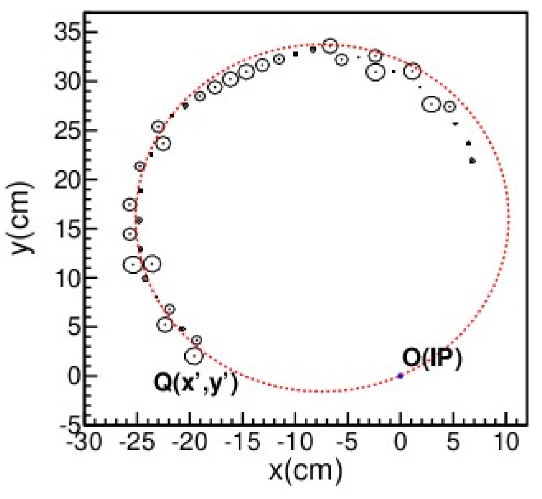
a) division set of measurements in the tracking detectors (vertex and tracker) into subsets;
b) each subset contains measurements believed to originate from the same particle.

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

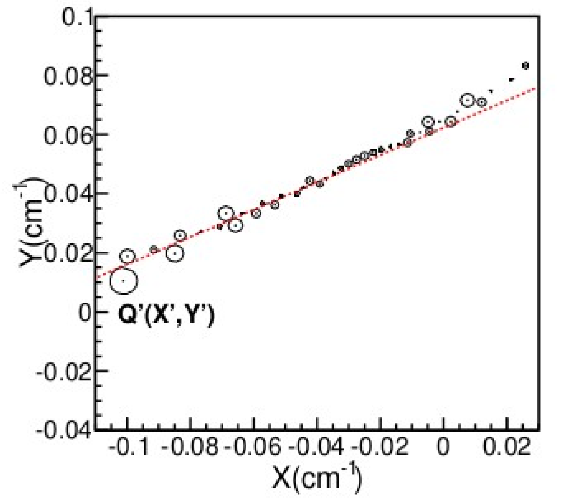
Standard track finding procedure in the main experiments starts from construction of track seeds using hits (or space points) in vertex detector. Then track seed is extrapolated to the main tracker with adding new hits from tracker during this extrapolation. This procedure can be realize for the SPD experiment after installing MAPS or DSSD vertex detector.

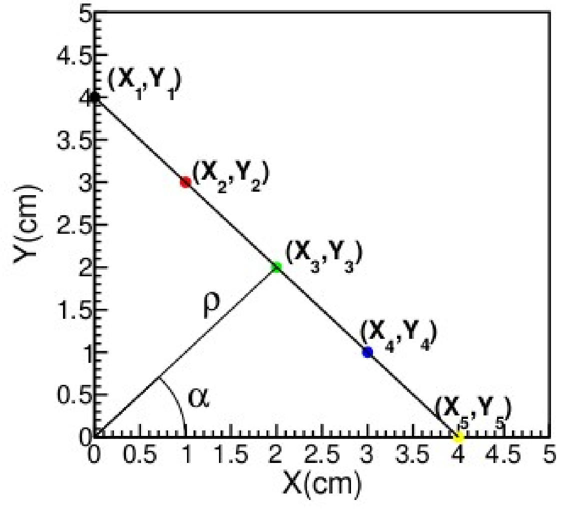
On the 1-st stage of SPD experiment will operate with only 1 layer of MicroMeGas detector and standard procedure is not applicable. The next track finding procedure is propose:

Hough Transformation

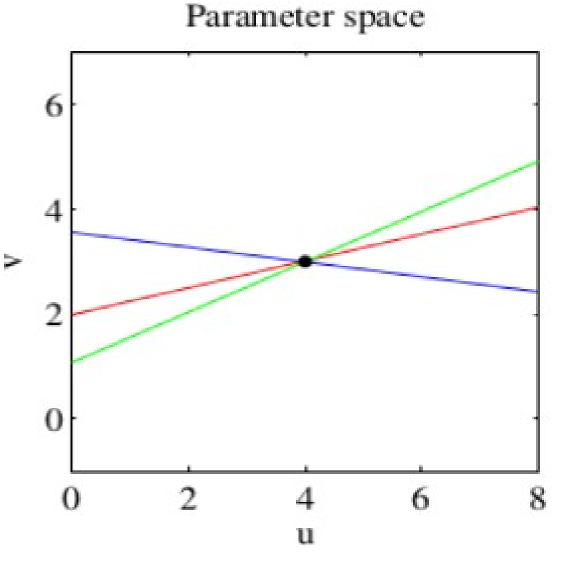


$$X = \frac{2x}{x^2+y^2}, Y = \frac{2y}{x^2+y^2}$$

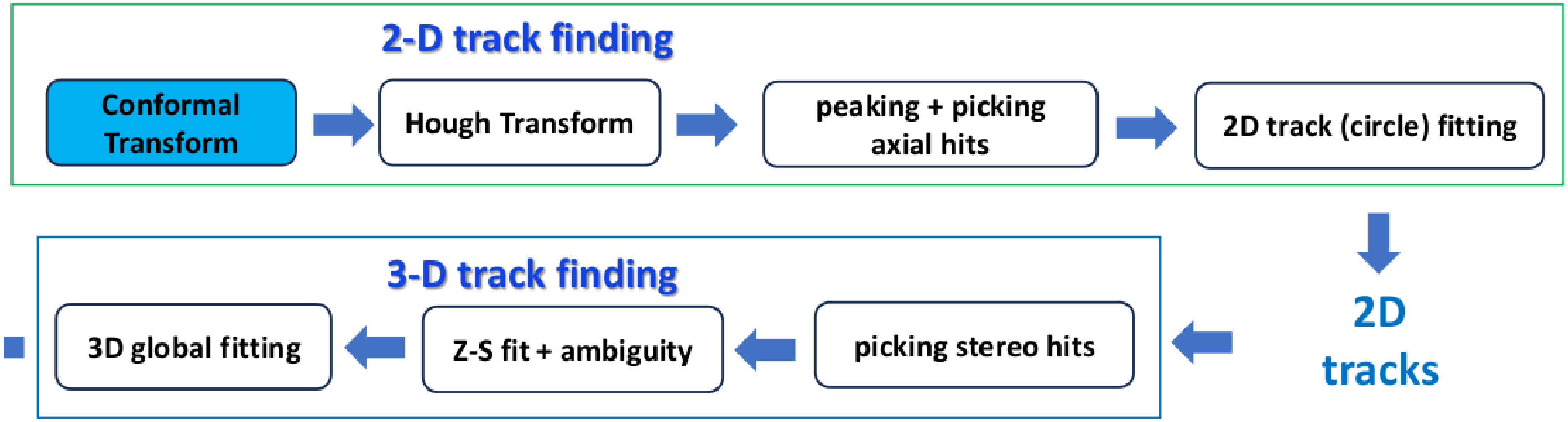




Hough transformation
(each point is line in parameter space)
$v = a * u + b$



General approach



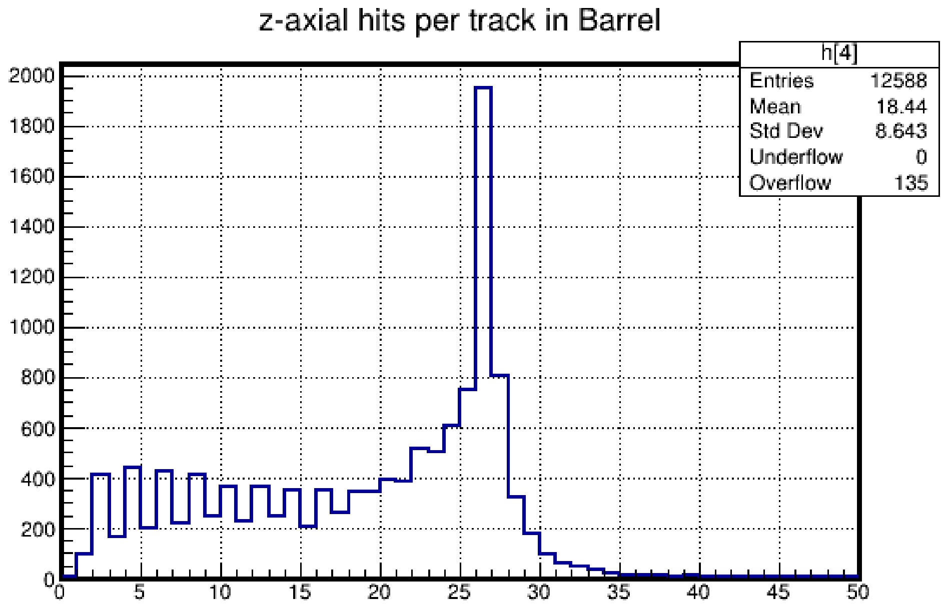
Track finding algorithm starts from 2D finding procedure in XY-plane:

- use the wire position of “fired” straw tubes as input;
- consider z-axial straw tubes;
- apply conformal and Hough transformations;
- find peaks on 2D-histogram;
- provide 2D circle fitting;
- picking stereo-hits (hits from tilted straw tubes);
- estimate the parameters of track candidate at 1-st space point (position and momentum) ;
- finally apply 3D Kalman fitting.

Event example

1. Use PYTHIA8 with open charm production option at $\sqrt{s}$ = 27 GeV as testing event sample.

2. As the reference the track fitted parameters obtained with ideal MC fitting procedure are used.
   The ideal MC fitting procedure means that all hits which are belong to the given track are known.

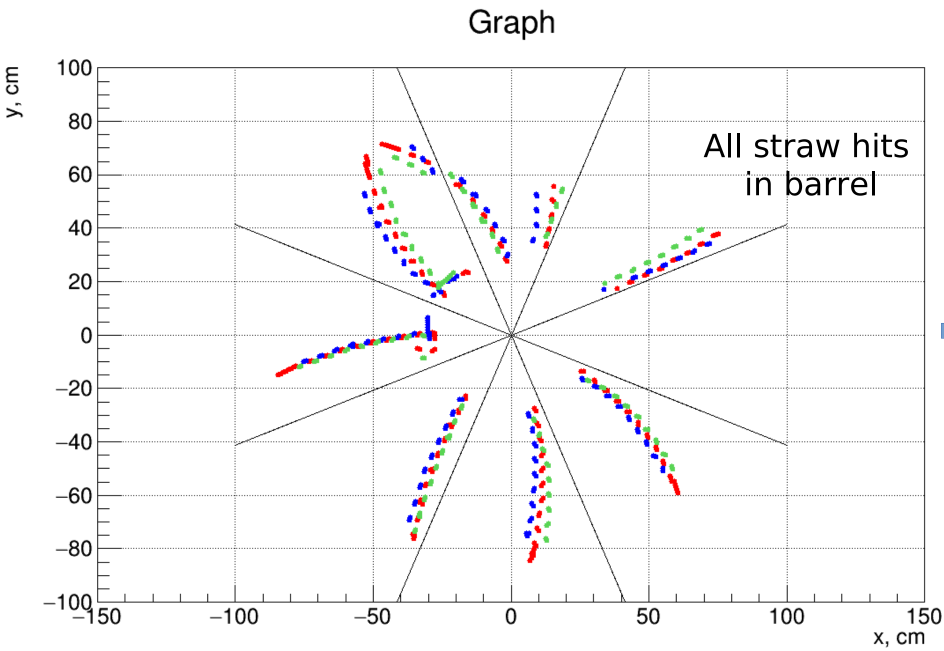


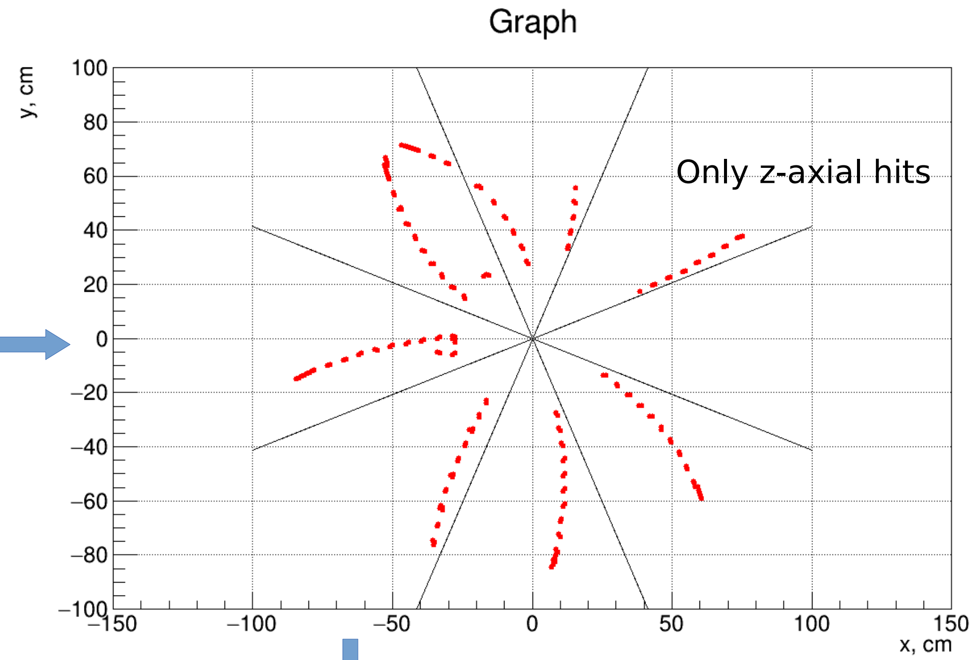
Distribution number of z-axial straw hits in barrel

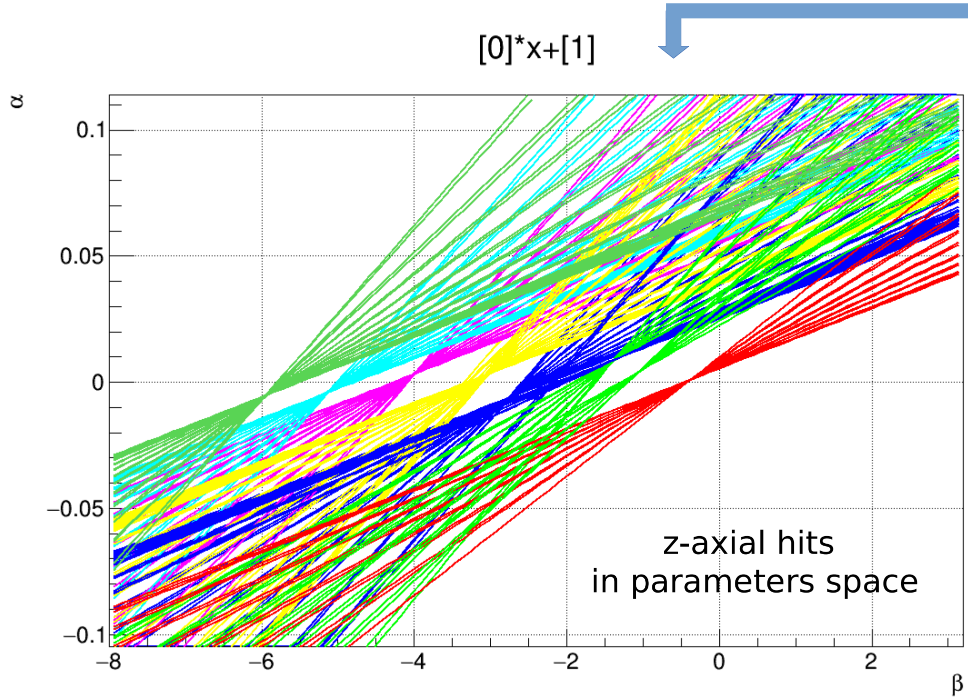
3. Track finding algorithm starts from 2D (x-y plane) procedure:

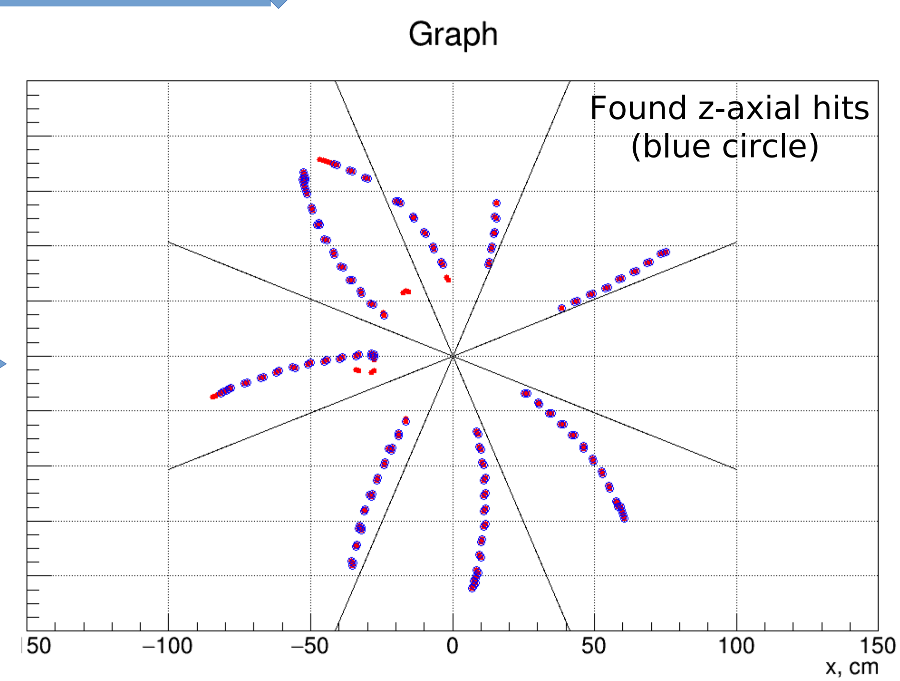
   - use wire position of “fired” straw tubes as input;
   - use only z-axial hits (straw which are parallel to z-axis);
   - apply Hough Transformation;
   - construct 2D histogram;
   - find peaks on 2D histogram and select axial hits which are belong to found peaks;
   - 2D circle fitting.

Event example (2)

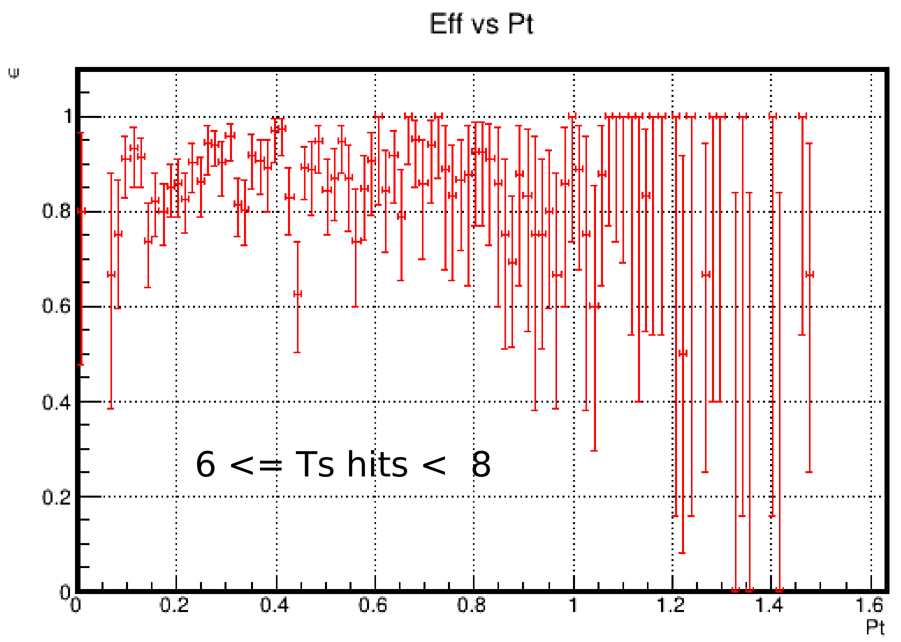


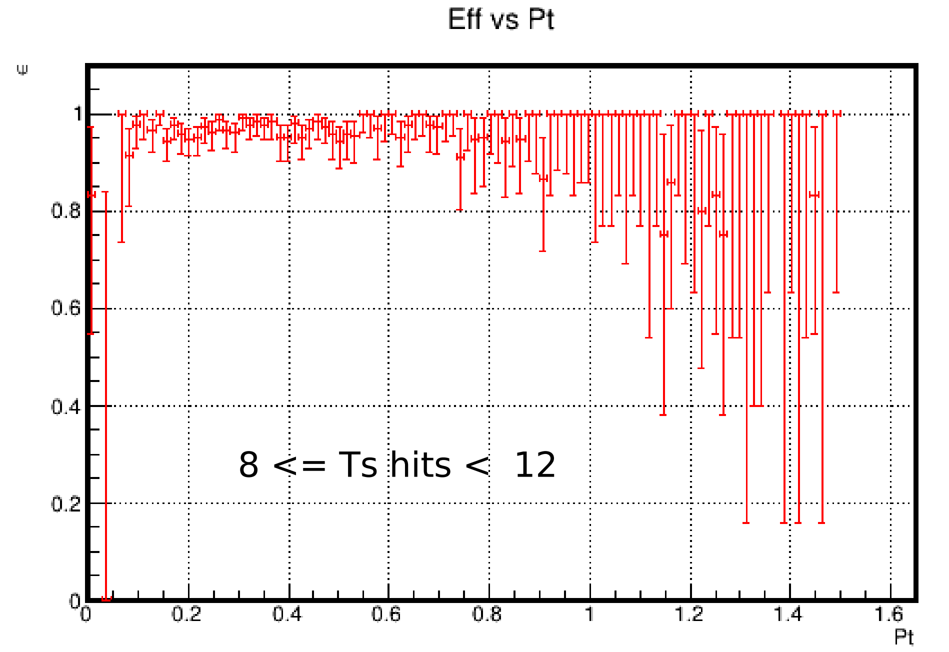


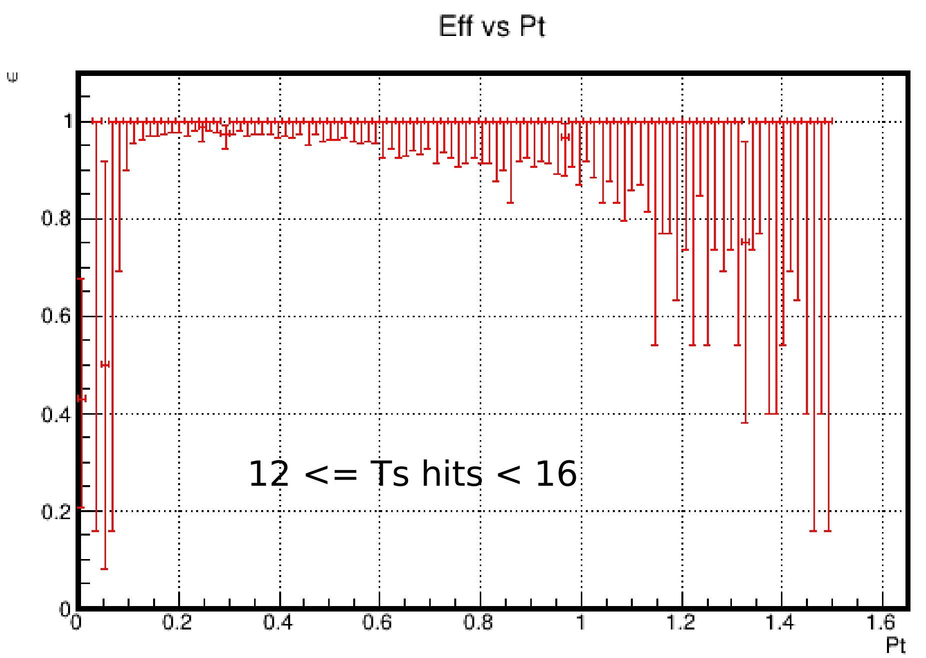


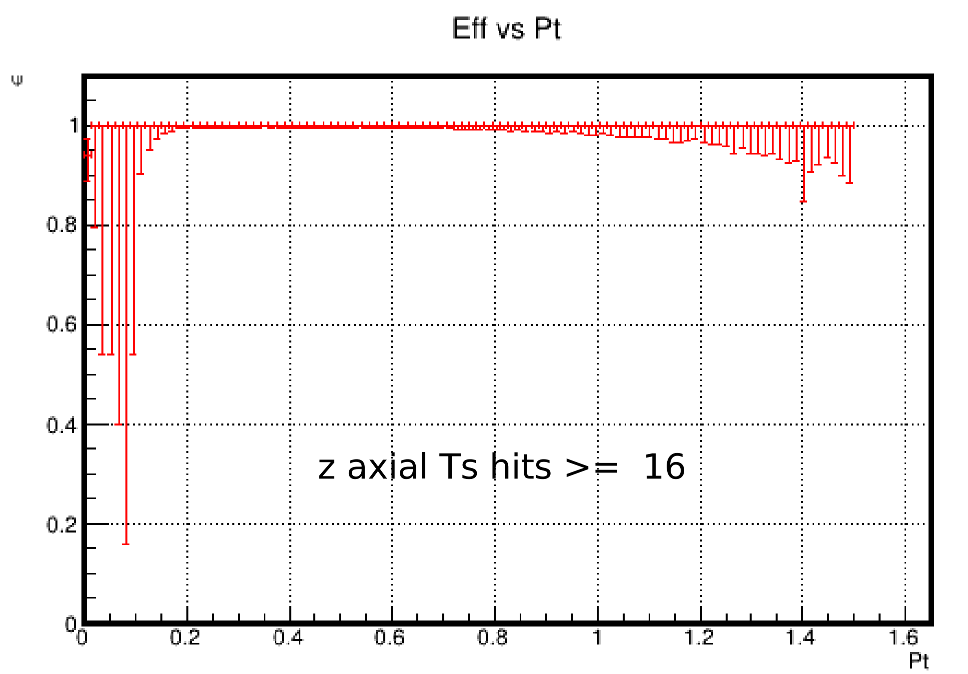


Finding efficiency (primary vertex tracks)

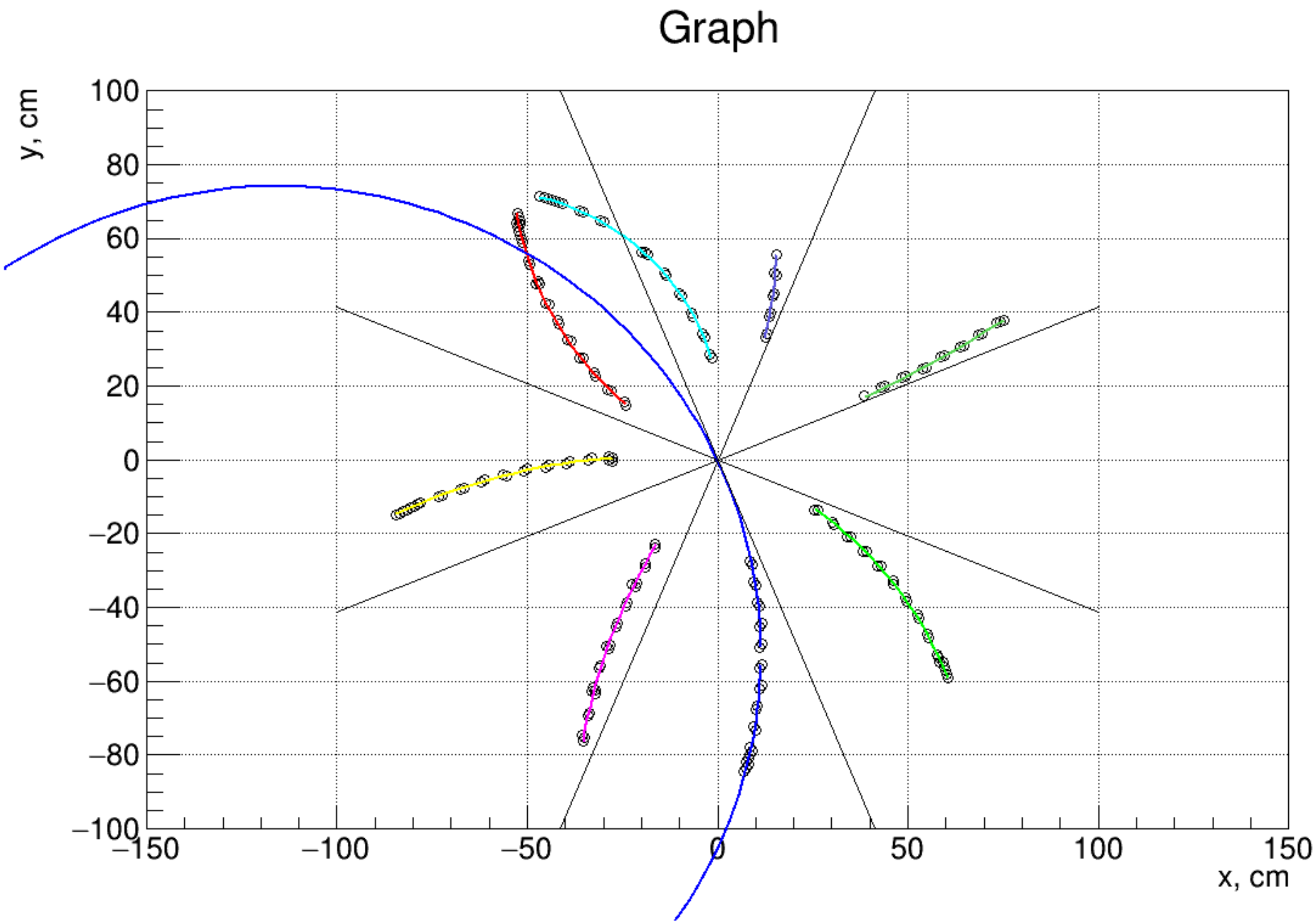






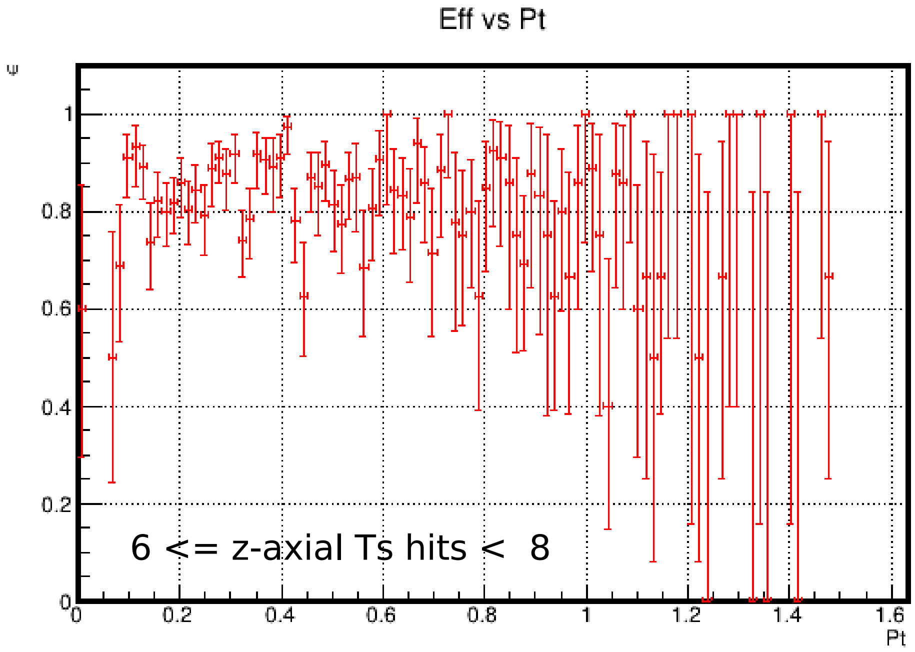


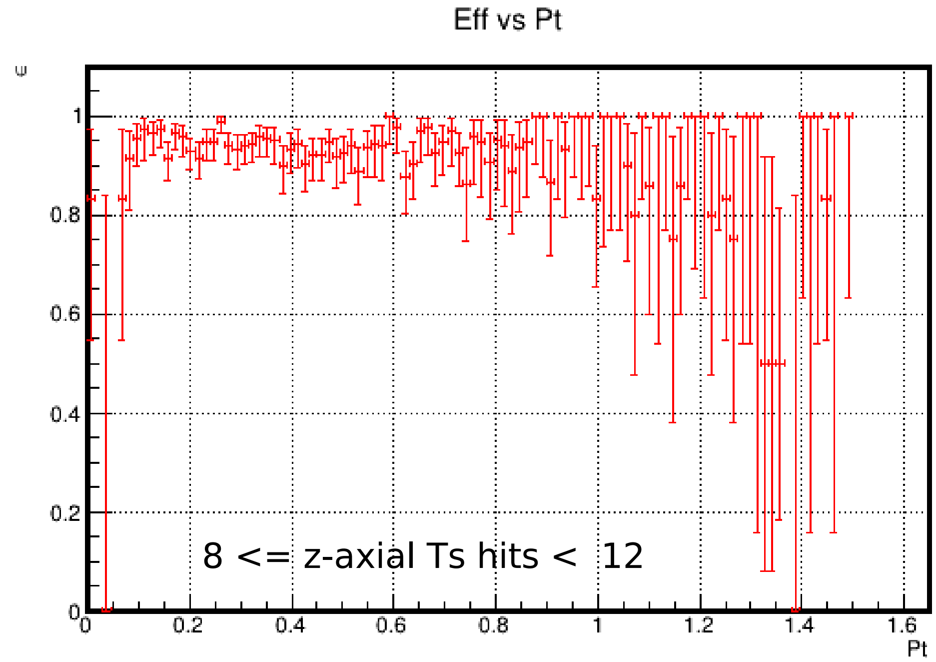
Example of 2D-fitting by circle

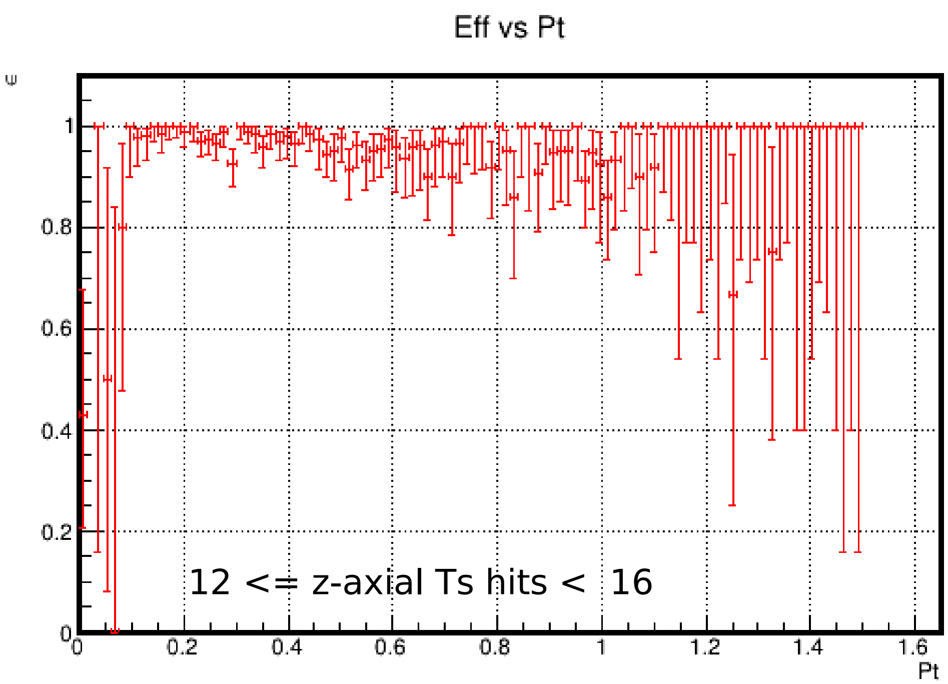


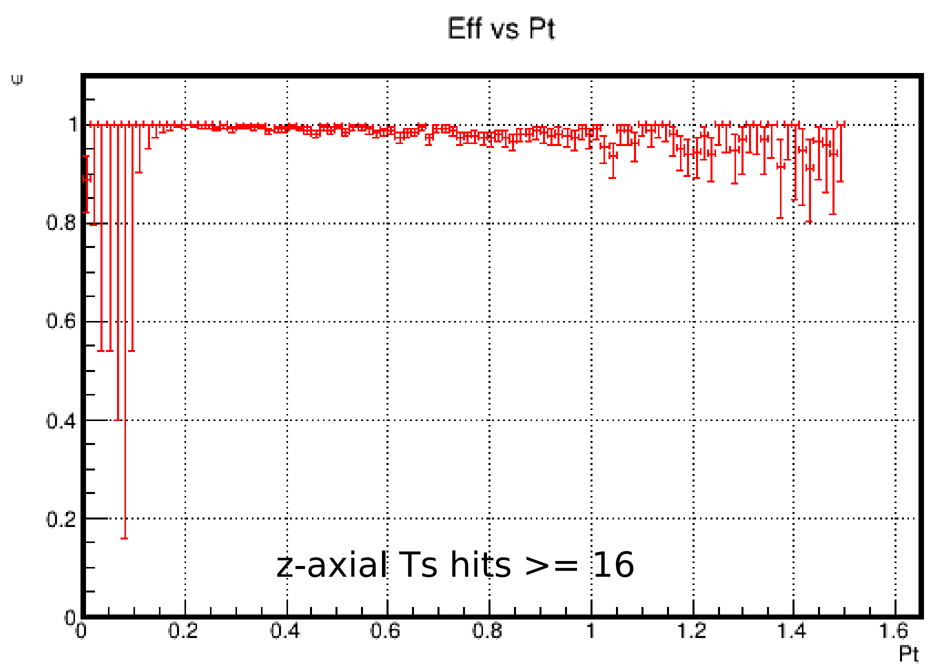
The wire position of found z-axial tubes are used as points for circle fit.

Finding + fitting efficiency







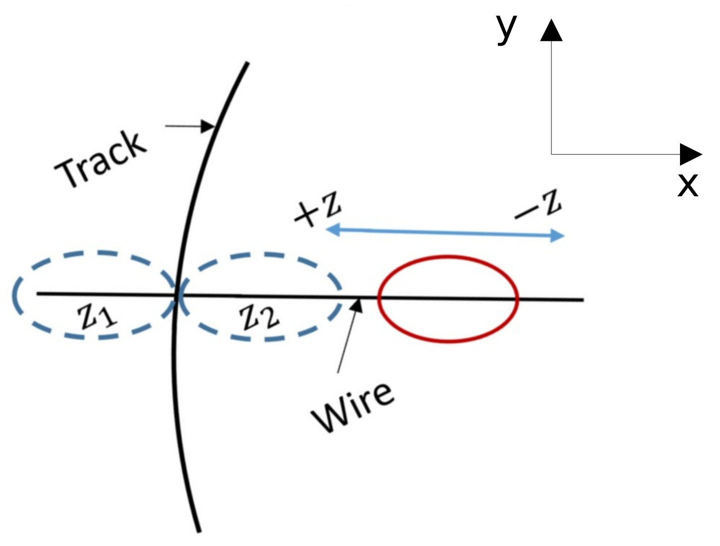


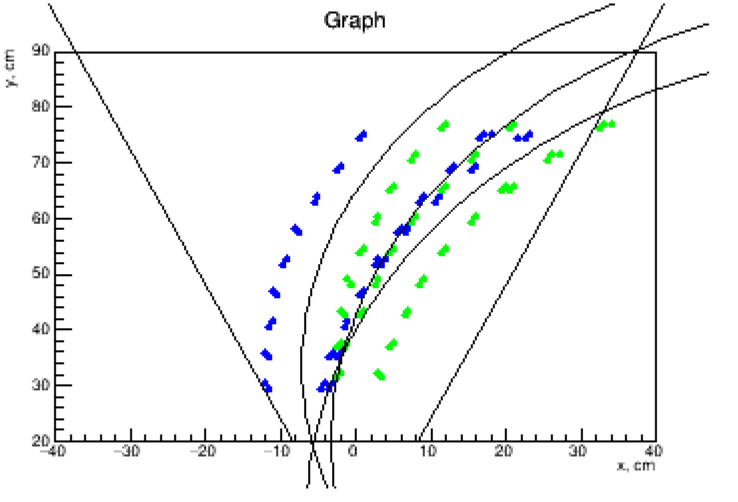
Longitudinal track reconstruction

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•B;

   b) z-coordinate can be considered as the function of arc length (s), z(s) = z0 + s•tanλ,
   where s = (Φ – Φ0)•R•q, Φ – azimuthal angle, λ – dip angle, z0 and Φ0 – track parameters in starting point or in primary vertex





Blue and green points are straw tubes position of stereo-hits in XY-plane

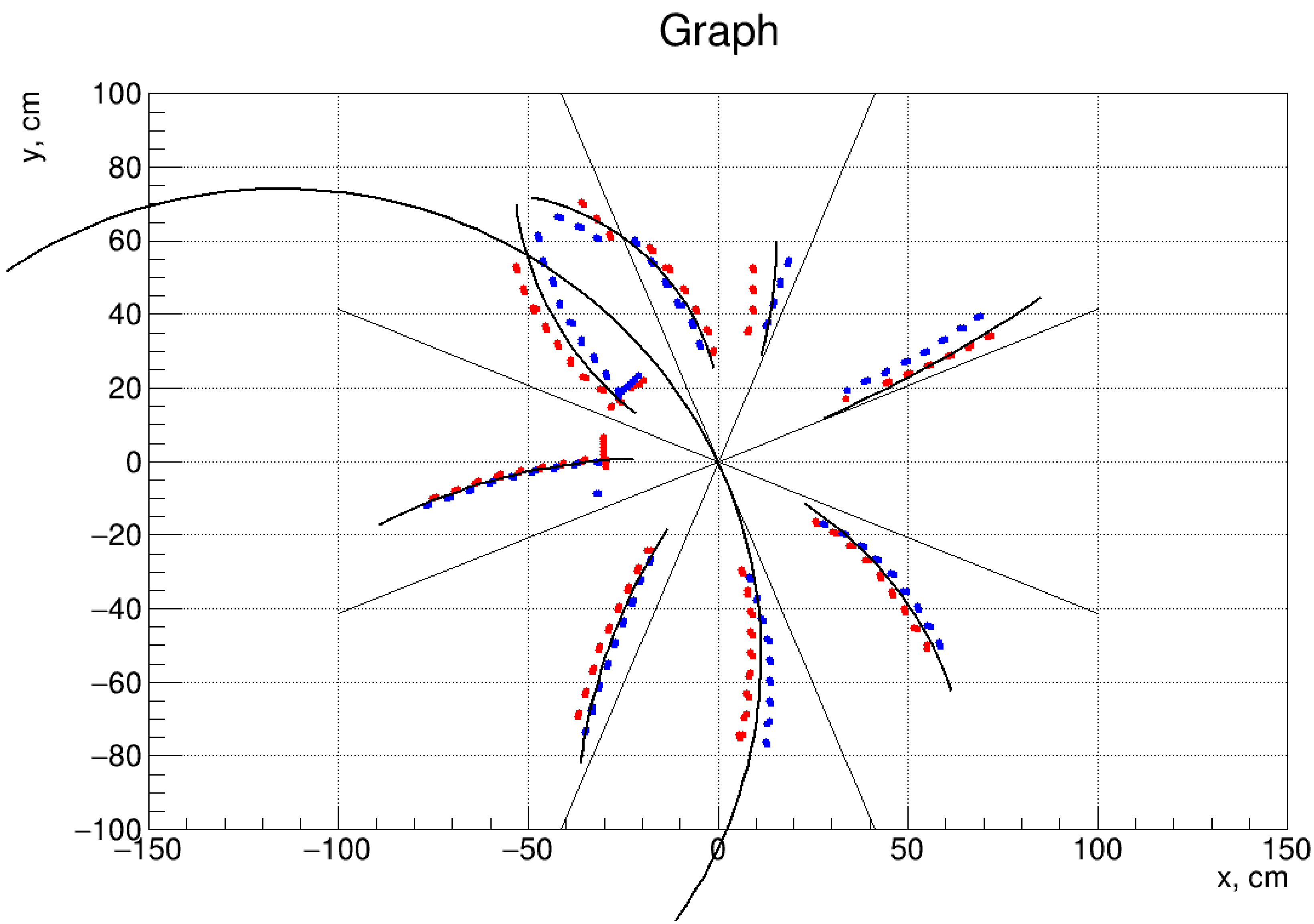
2. The z-position for each stereo-hit (tilted straw tube) is extracted through an alignment procedure as illustrated on the left picture:

   - the track radius is determined before by the 2D-fitting in XY-plane (black line on the picture).

   - red ellipse is projection of drift radius of “fired” tilted tubes on the XY-plane. 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 procedure provides two solutions, introducing a left/right ambiguity with one solution on each side of the track trajectory

Example of stereo-hits



Black lines – circle fit for different track candidates.

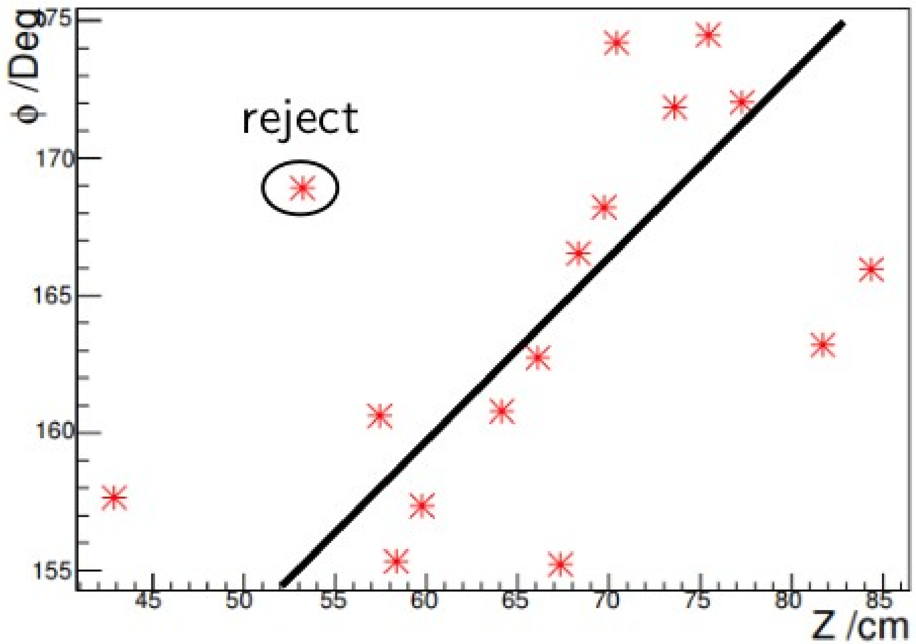
Red and blue points – stereo-hits (or projection of wire of "fired" tilted straw tubes on XY-plane).

Longitudinal track reconstruction (2)

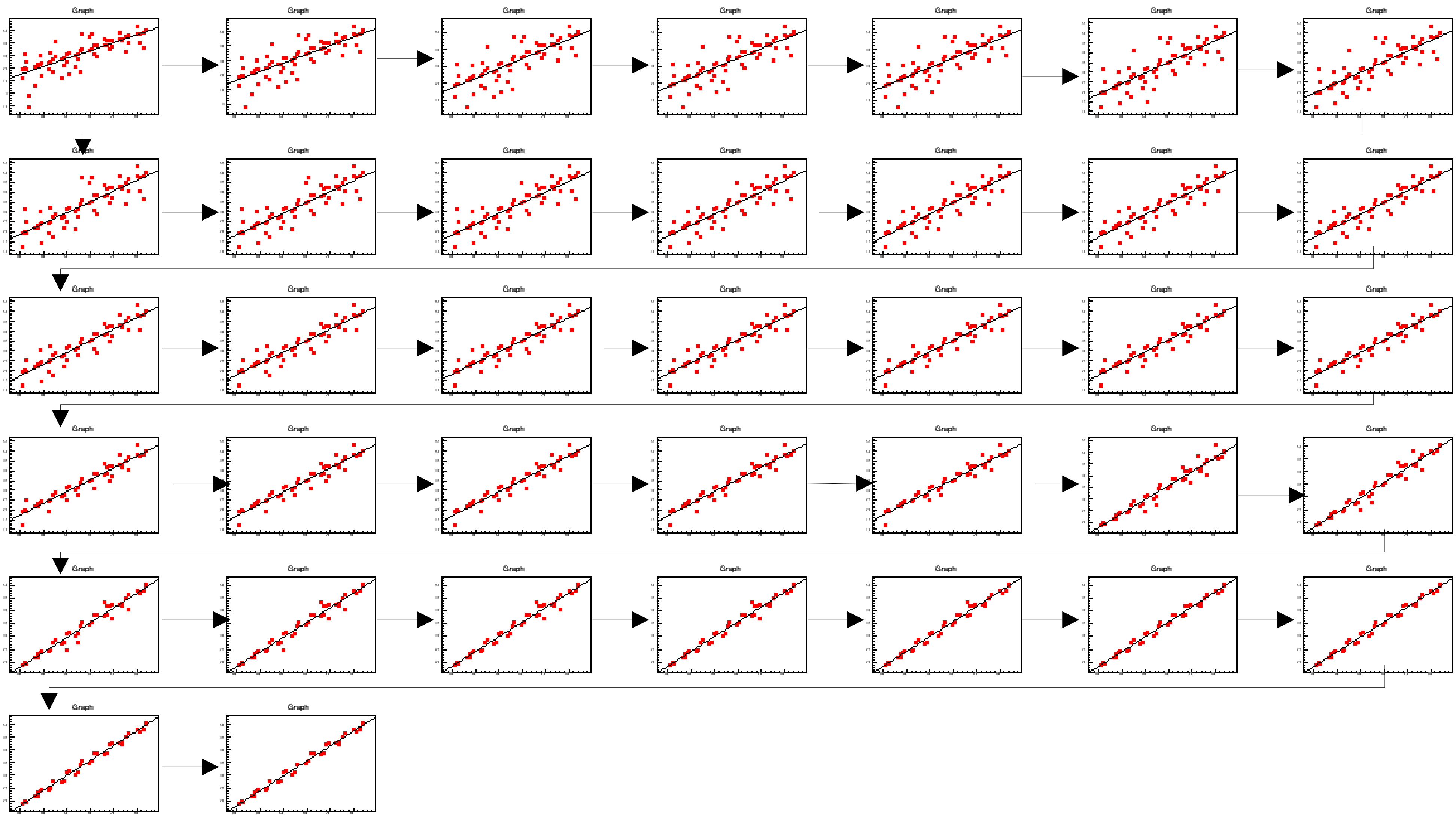
Recursive fit is used for resolving left/right ambiguity:

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

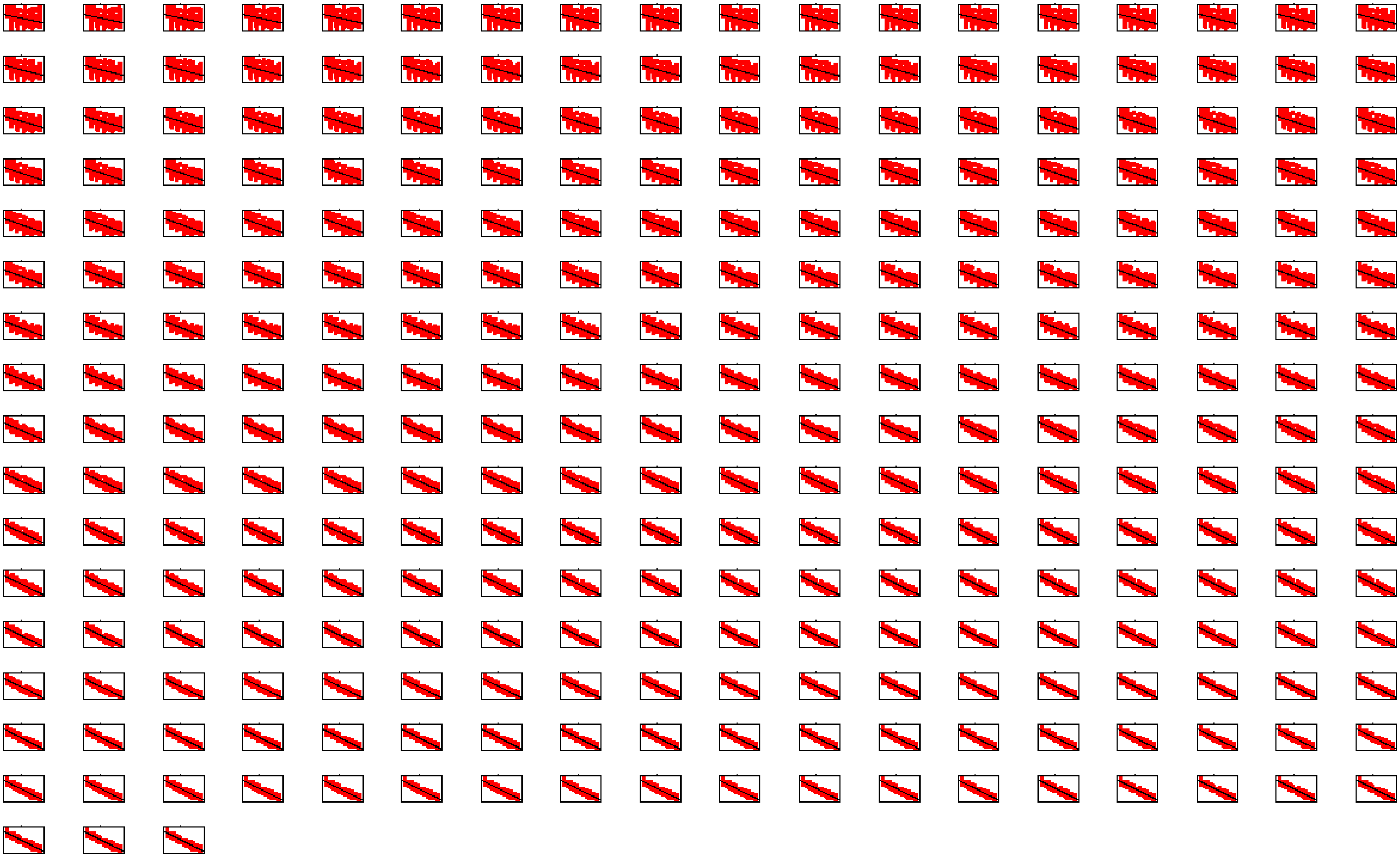
$$\chi^2 = \sum_i^n \frac{\left(z_i - kS_i - z_0\right)}{\sigma_i^2},$$



Example of recursive fit (easy case)



Example of recursive fit (more hard case)



3D global fitting

This stereo-hits finding procedure provides the next parameters of the track candidate:

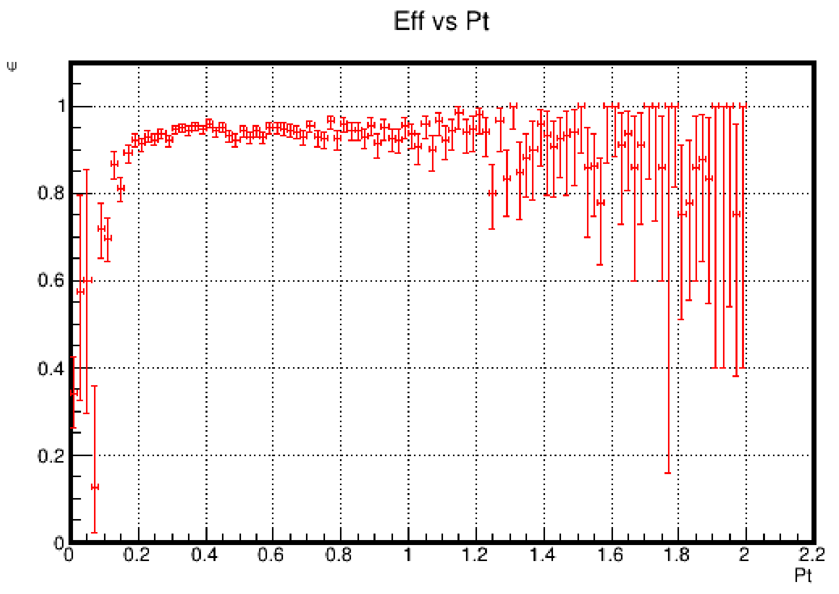
a) set of stereo-hits (or tilted straw tubes) which are belong to the considered track candidate;
b) estimated momentum of track candidate;
b) estimated theta and phi angles;
c) estimated track position at the first measured point.

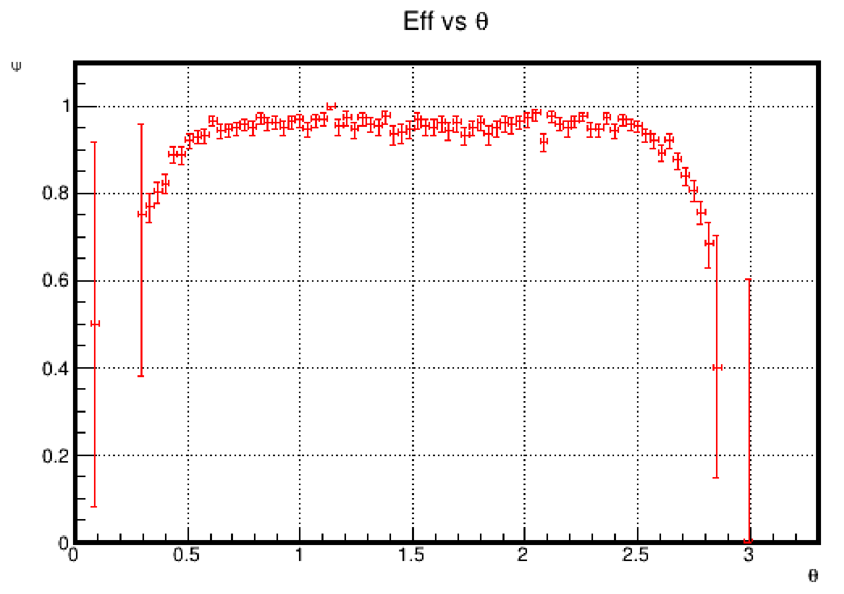
Last step of track reconstruction procedure is the fitting procedure of track candidates:

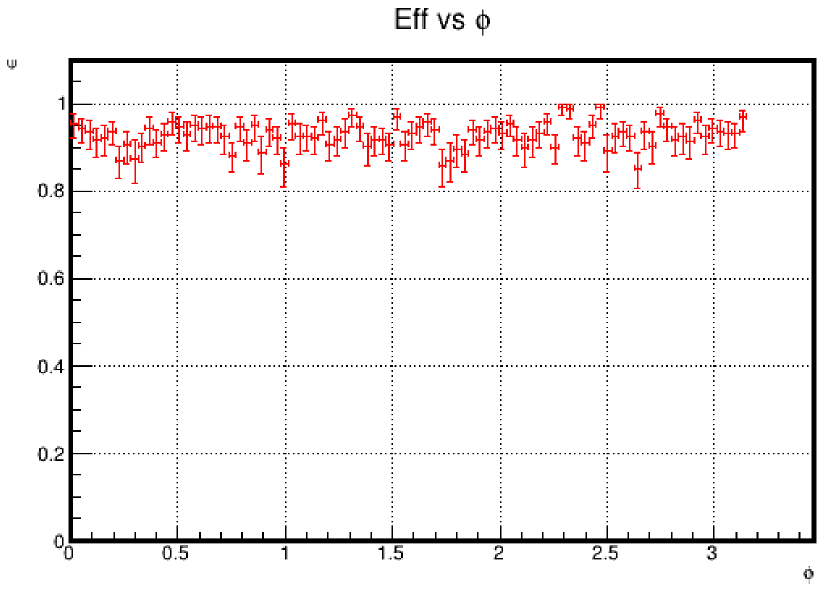
a) there are set of straw tubes (z-axial and tilted) which are belonged to the track candidate;
b) estimated track position at the 1-st measured track point;
c) estimated track momentum (Px, Py, Pz) at the 1-st measured track point;
d) then standard SPD fitting procedure (on the base Kalman filter) can be applied.

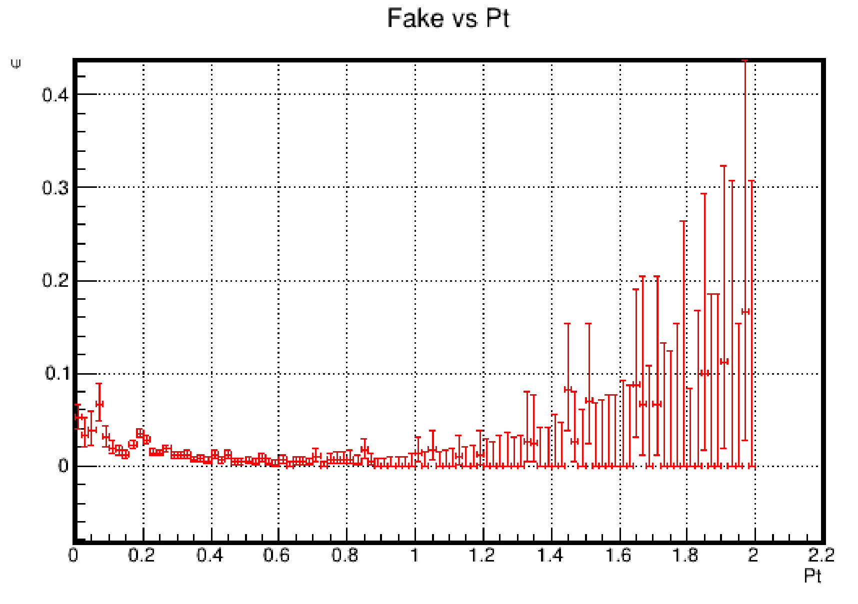
This track reconstruction procedure using only straw detector works !

Reconstruction efficiency
(primary vertex tracks)

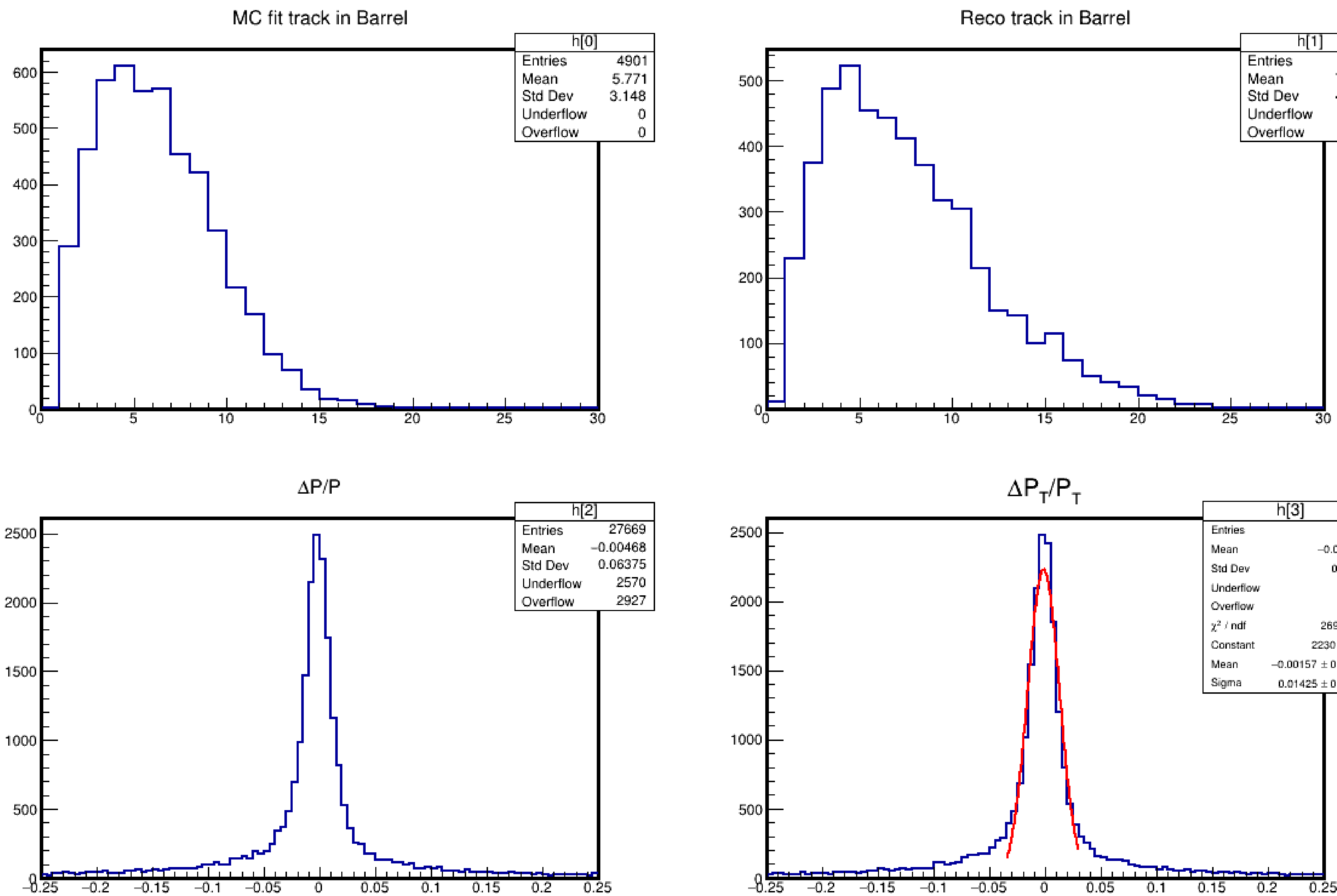






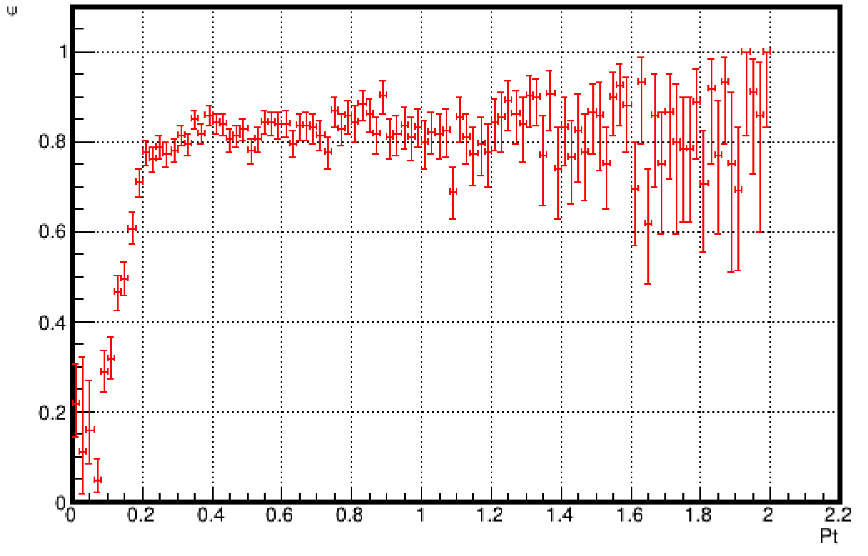


Track reconstruction (primary vertex tracks)

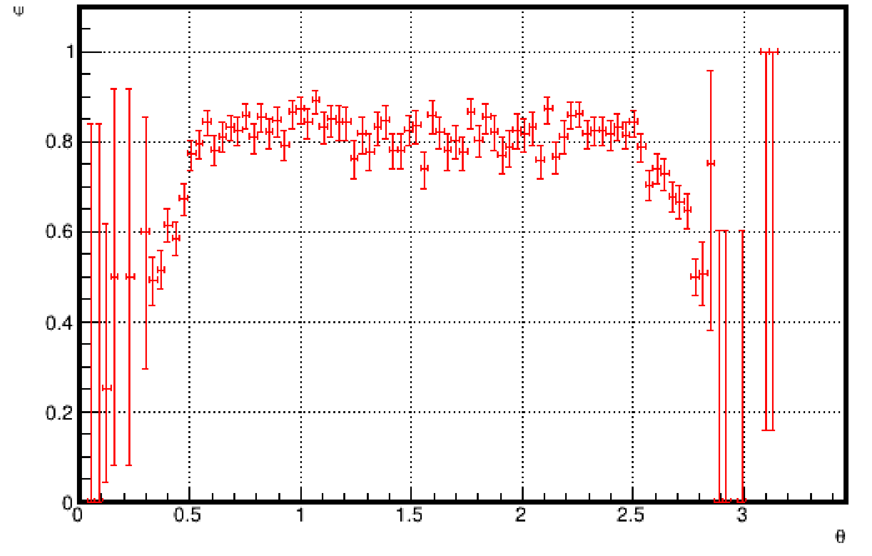


Track reconstruction efficiency (all generations)

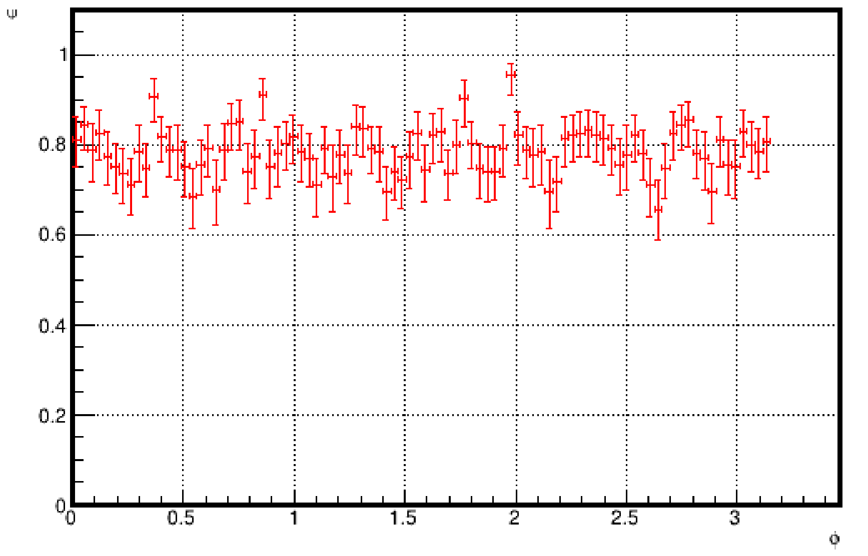
Eff vs Pt



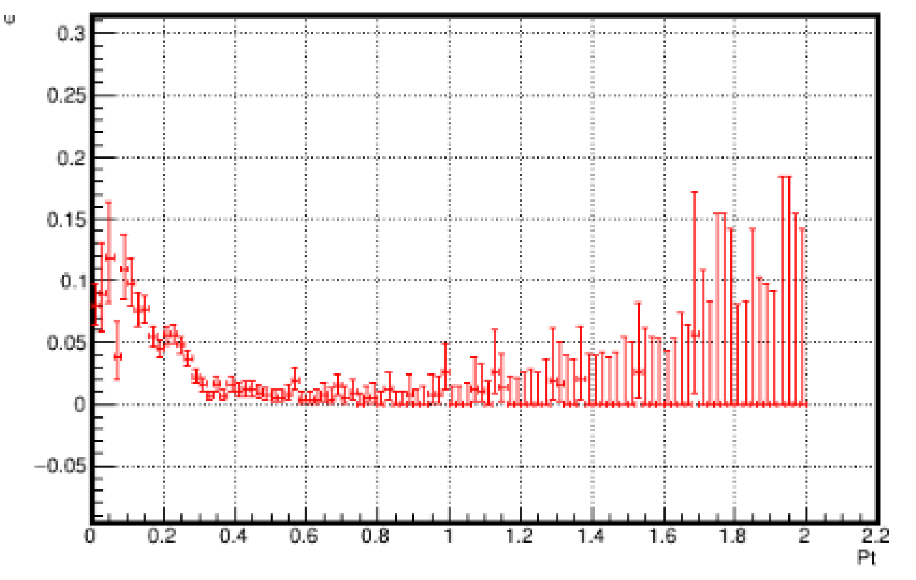
Eff vs θ



Eff vs ϕ



Fake vs Pt



Summary

1. General schema for track reconstruction for barrel straw detector works.

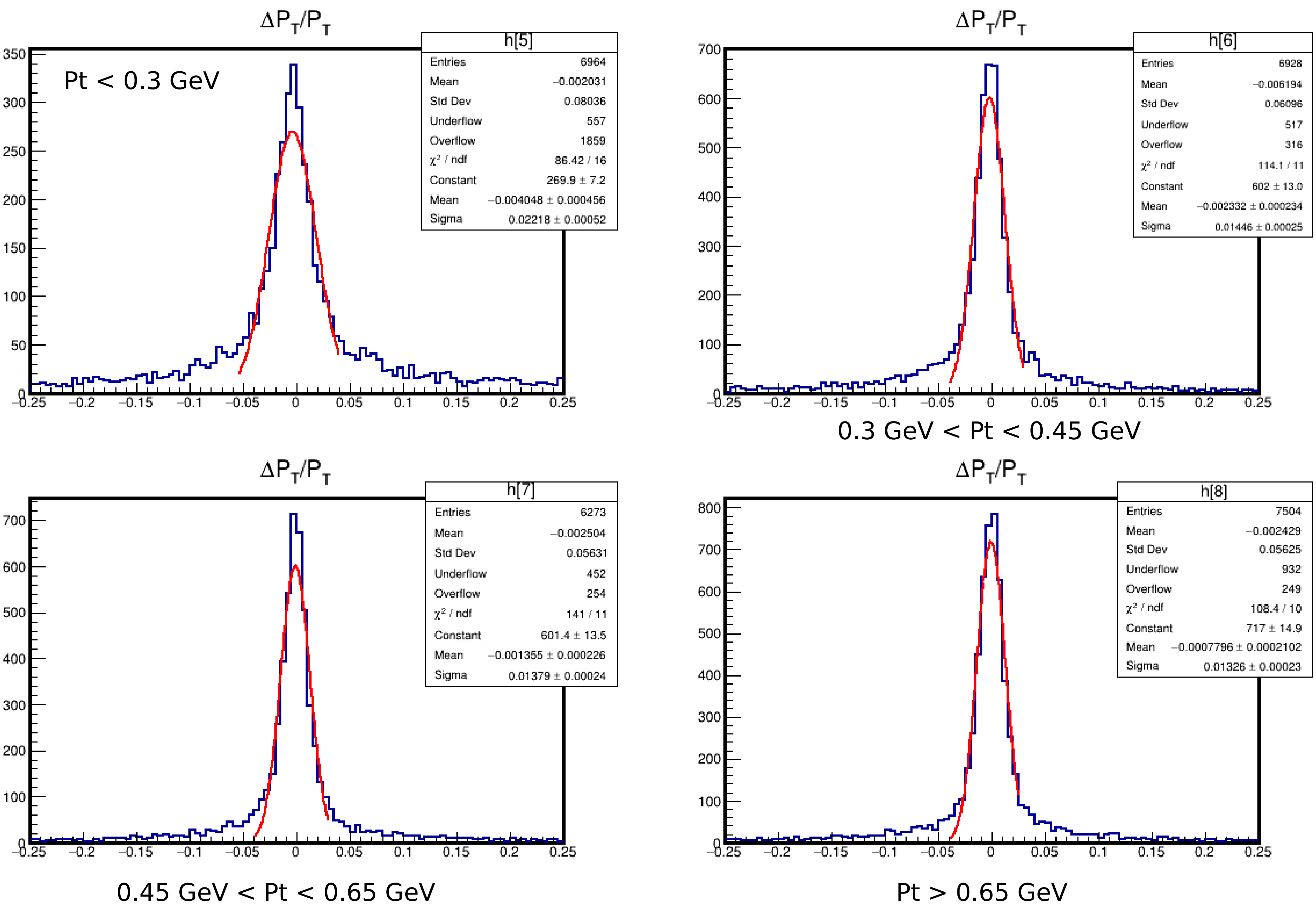
2. It provides relatively good track reconstruction efficiency.

3. Preliminary conclusion - present tracker geometry (with 8 barrel modules) is “acceptable” for the track reconstruction using only straw tracker.

4. Next step is checking this procedure for “new” straw detector geometry (with 6 barrel modules).

5. The possibility to include hits from MicroMeGas and primary vertex reconstruction procedure are also considered.

Track Pt resolution (primary vertex)



3D-fitting efficiency
(all track generations)