SPD Physics Weekly meeting
4 March 2025

Status of track reconstruction for SPD

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Introduction

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

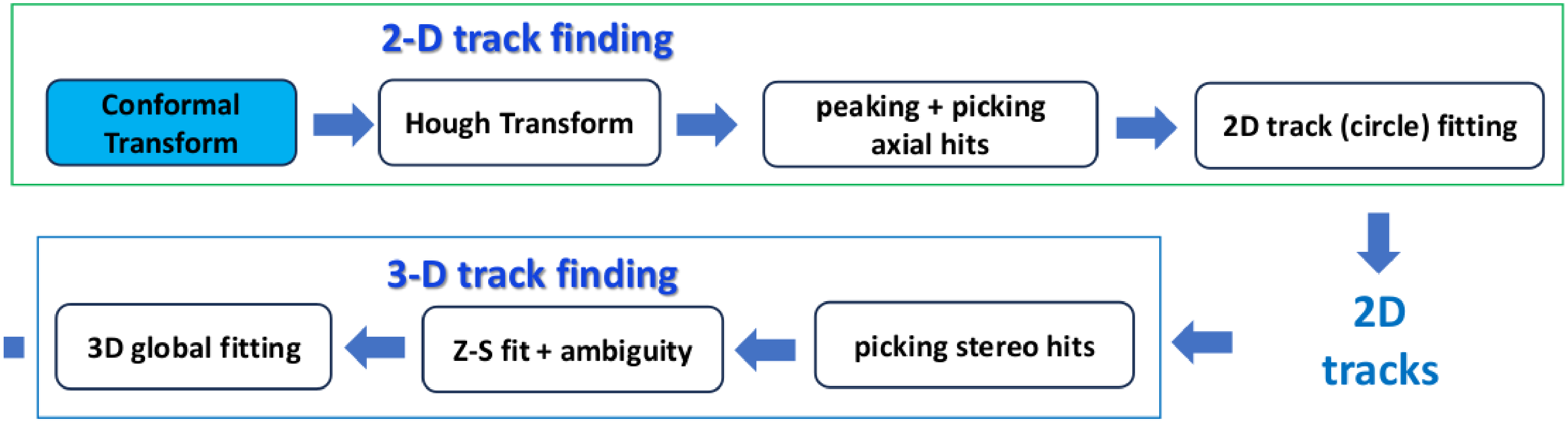
a) track finding (or pattern recognition);
b) track fitting (in general on the base of Kalman filter method).

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.

General approach



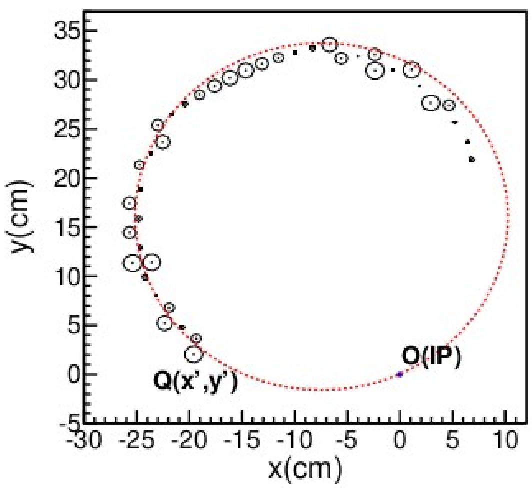
1. Track finding algorithm starts from 2D (x-y plane) :

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

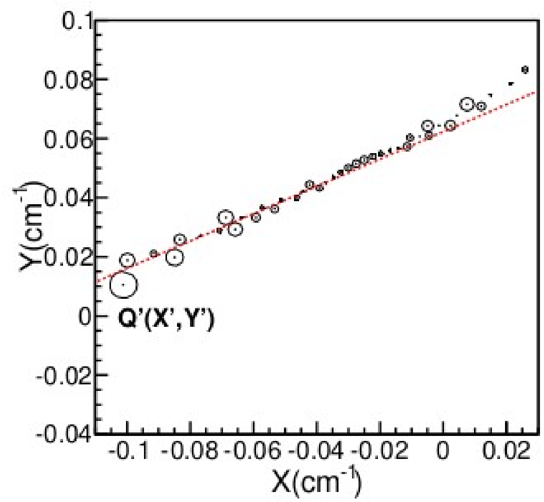
Hough Transformation

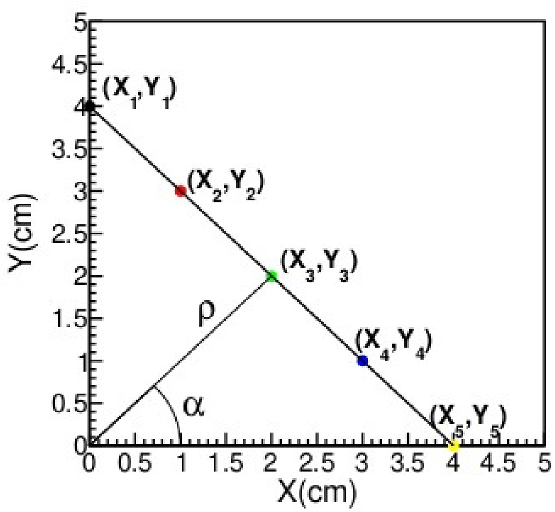
2-D track finding

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



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

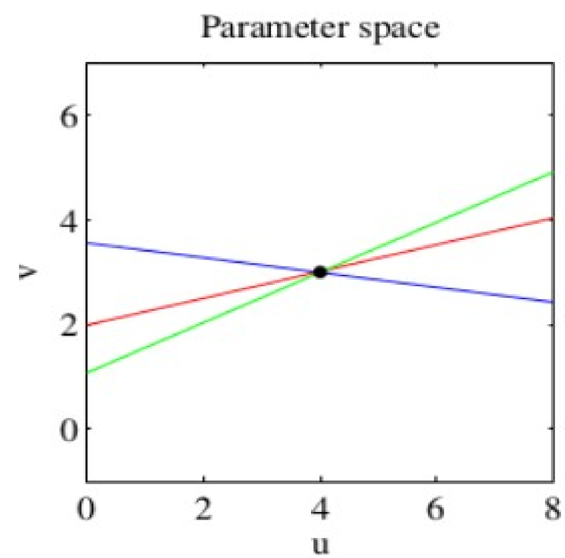




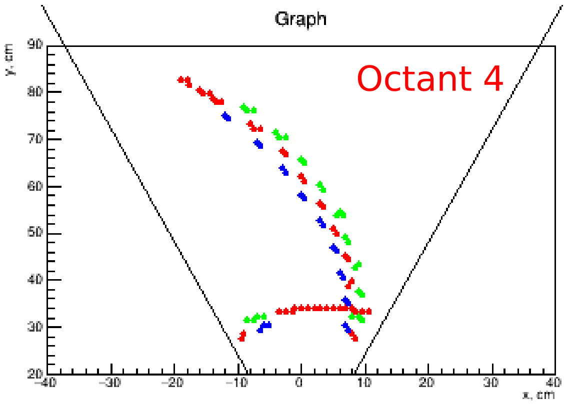
Hough transformation

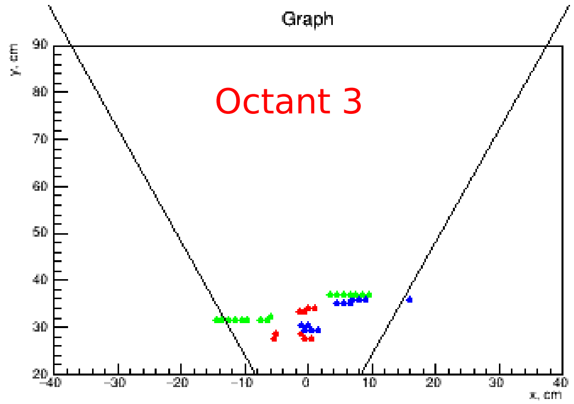
(each point is line in parameter space)

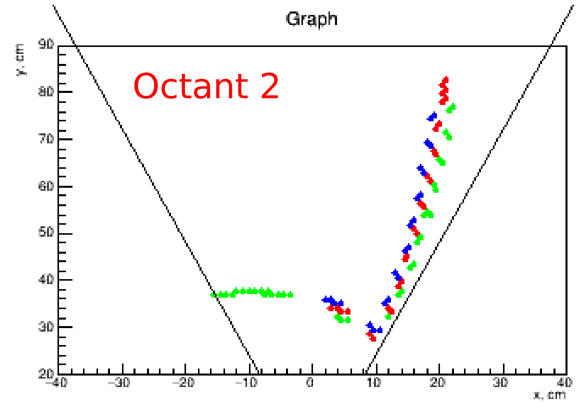
$$v = a * u + b$$



Usual event example



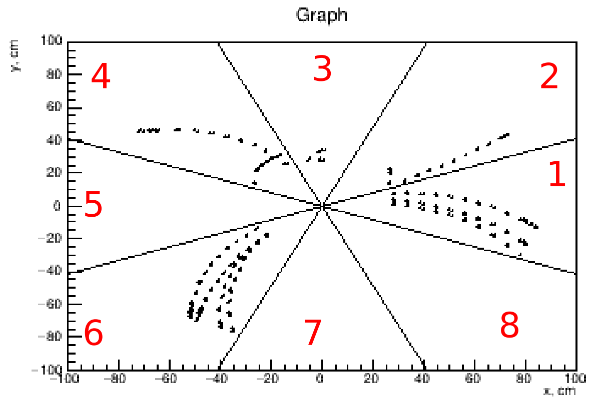


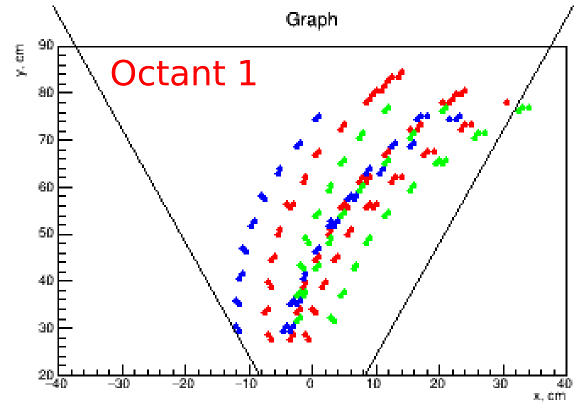


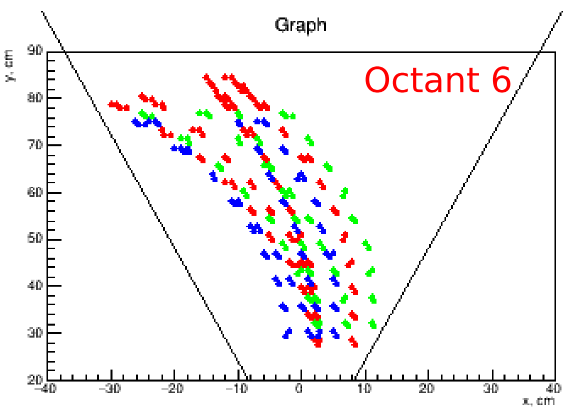
Red points – hits in straw parallel to z-axis

Green points – hits in straw tilted on $+3^0$

Blue points – hits in straw tilted on -3^0

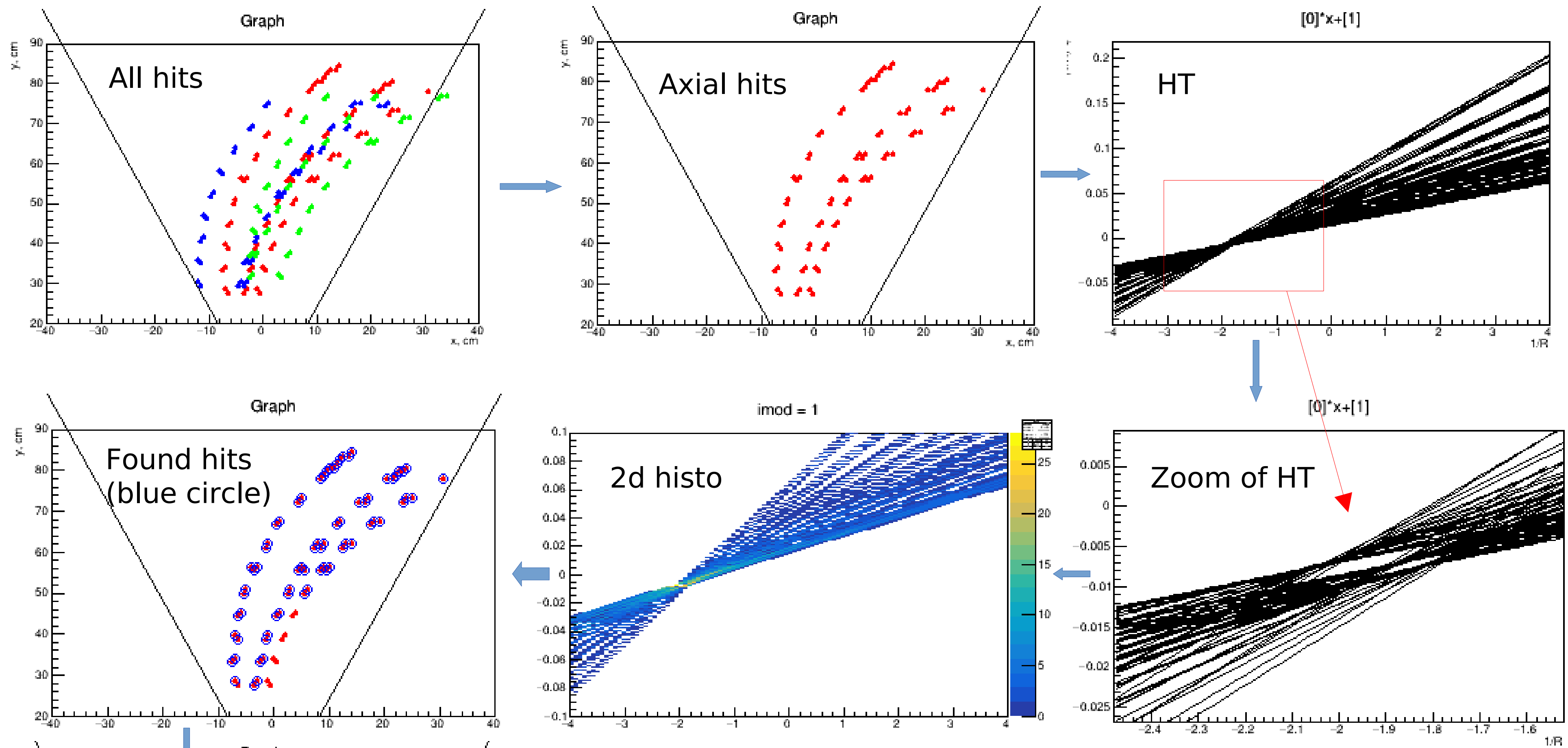


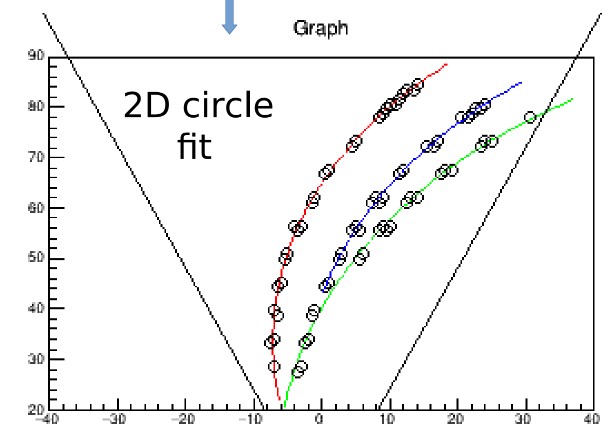




1. Middle plot presents fired axial straw tubes in XY - projection
2. Transform global coordinate of straw tubes to the local coordinates system (or coordinates which coincide with system of Octant 3)
3. All further consideration will be done in local coordinate

2D track finding (Octant 1)

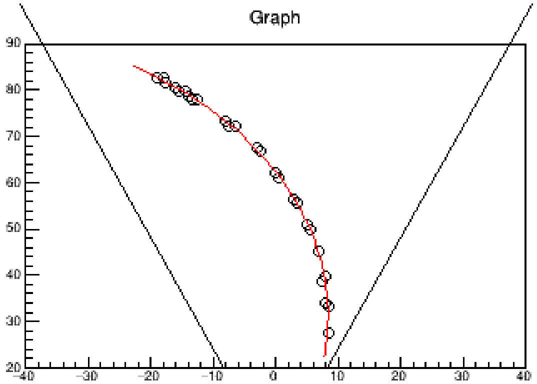


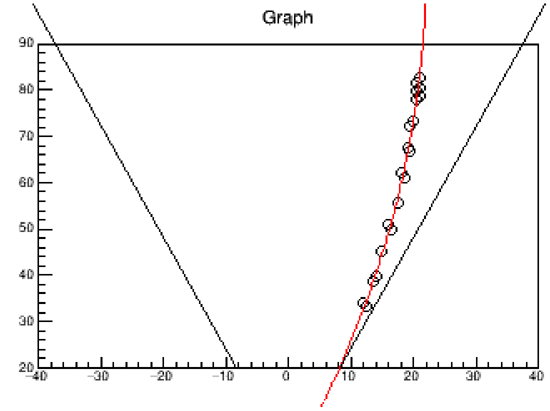


Track finding algorithm starts from 2D (x-y plane) :

1) go from global coordinate system to local system (module = 3);
2) use hits in straw trackers as input (or fired straw tubes);
3) use only axial hits (straw which are parallel to z-axis);
4) apply Hough Transformation;
4) construct 2D histogram
5) find peaks on 2D histogram and select axial hits;
4) 2D circle fitting;

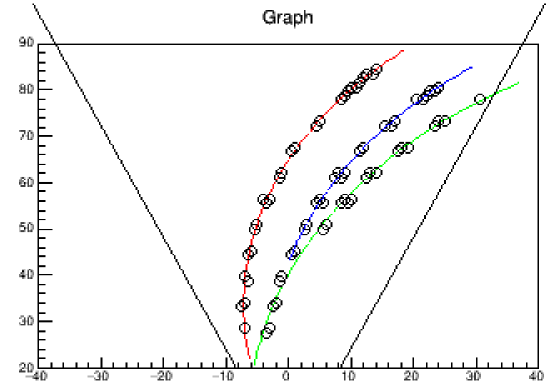
Usual event example (2)

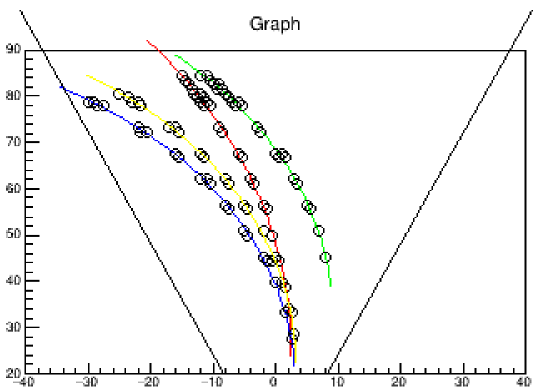




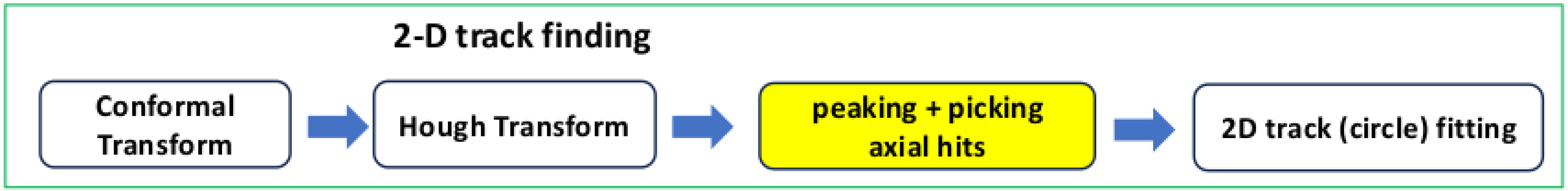
2D found track candidates:

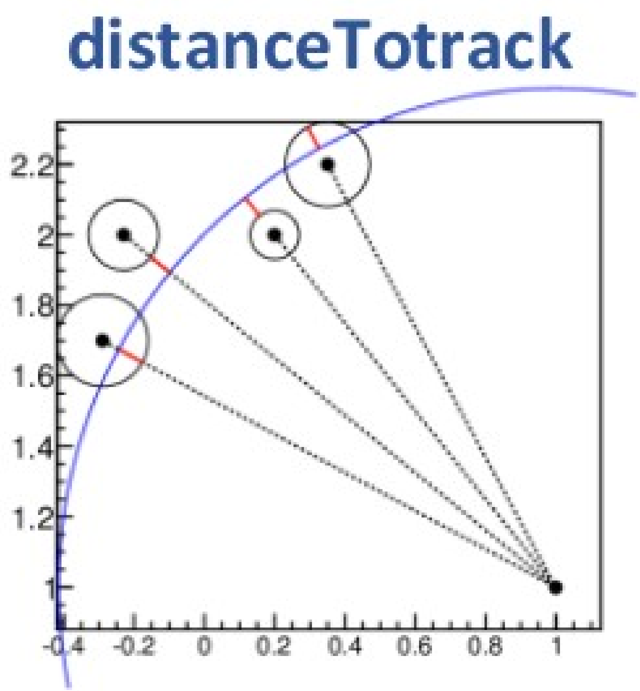
1 octant - 3;
2 octant – 1;
4 octant – 1;
6 octant – 4;





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

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

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:

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

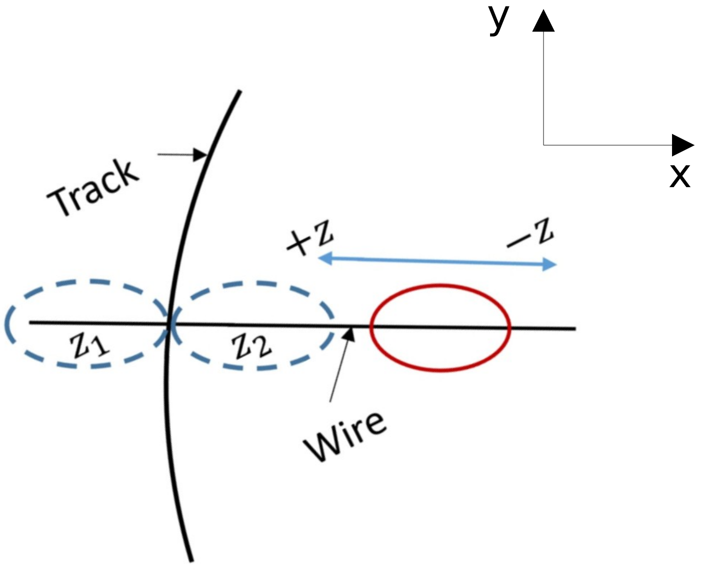
Use only axial wire position for circle fit (at this moment)

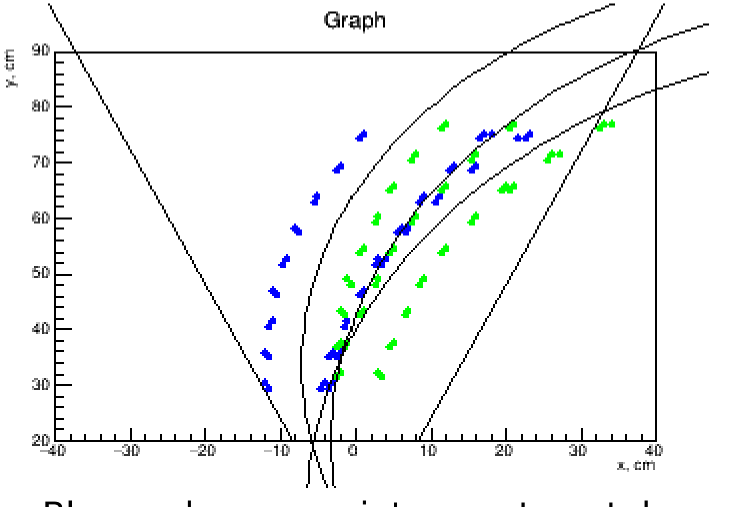
Longitudinal track reconstruction

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 is 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 tilted tubes in XY-plane

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.

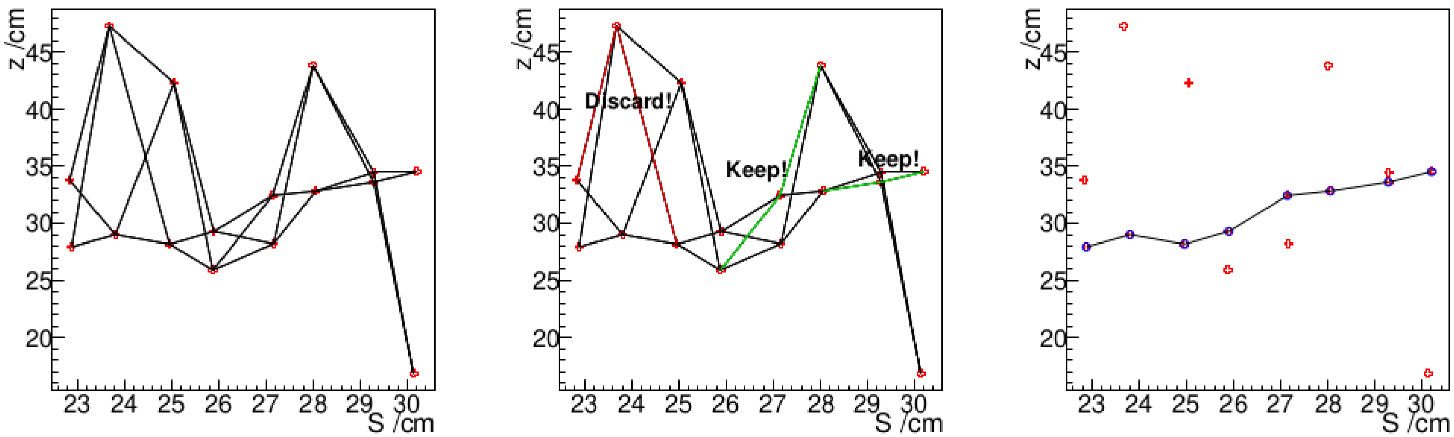
   Since these tubes are tilted, the projection of the drift radius onto the XY-plane becomes an ellipse. The drift ellipse is aligned such way that its center position lies along x-axis of layer and is tangential to the particle trajectory.

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

Longitudinal track reconstruction (2)

Combinatorial approach:
a) determine all possible connections between layers;
b) calculate angles between neighboring lines;
c) reject paths with $\theta < 90^0$;
d) select path by minimizing $w = \sum_j^{N-1} (180^\circ - \theta_j)^2,$

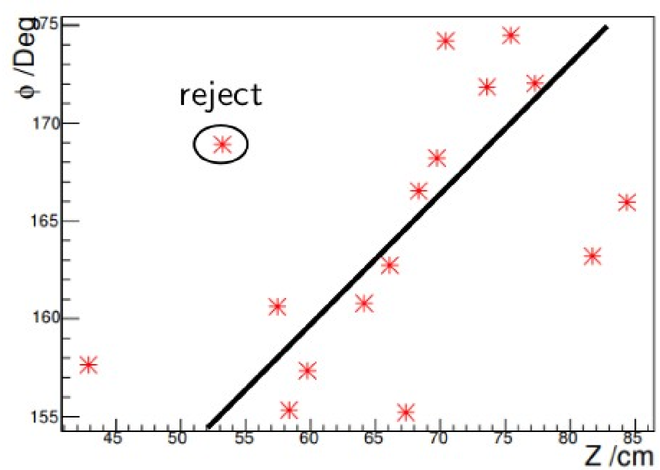
Hough transformation:
a) generate set of lines around point;
b) fill line parameters in accumulator;
c) repeat for all points;
d) select maximum in accumulator.



(a) (b) (c)

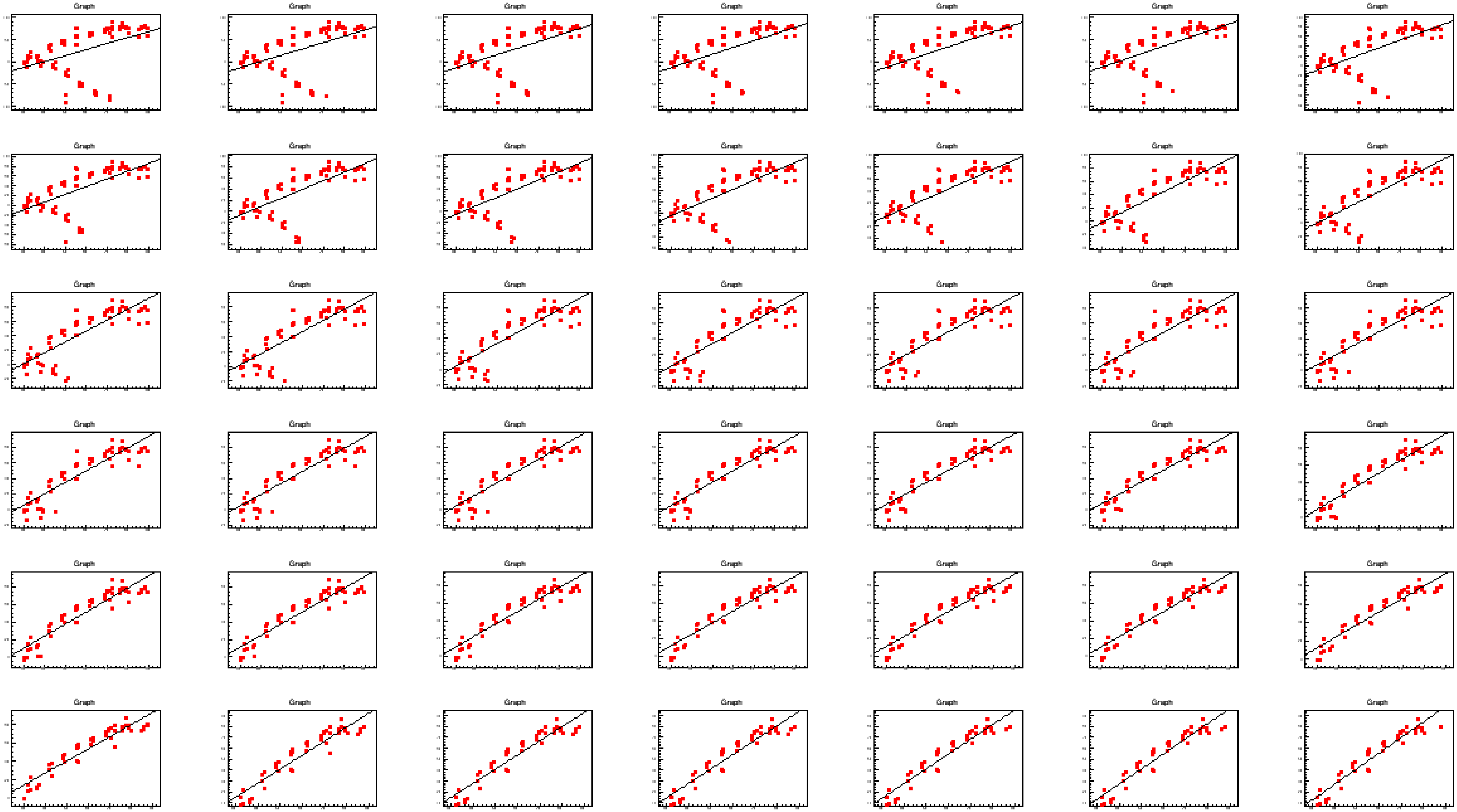
Recursive annealing fit:
a) fit by line to all points;
b) remove point with largest residual;
c) calculate new line fit;
d) repeat until one point has been rejected for each straw tube;
e) do final line fit.

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

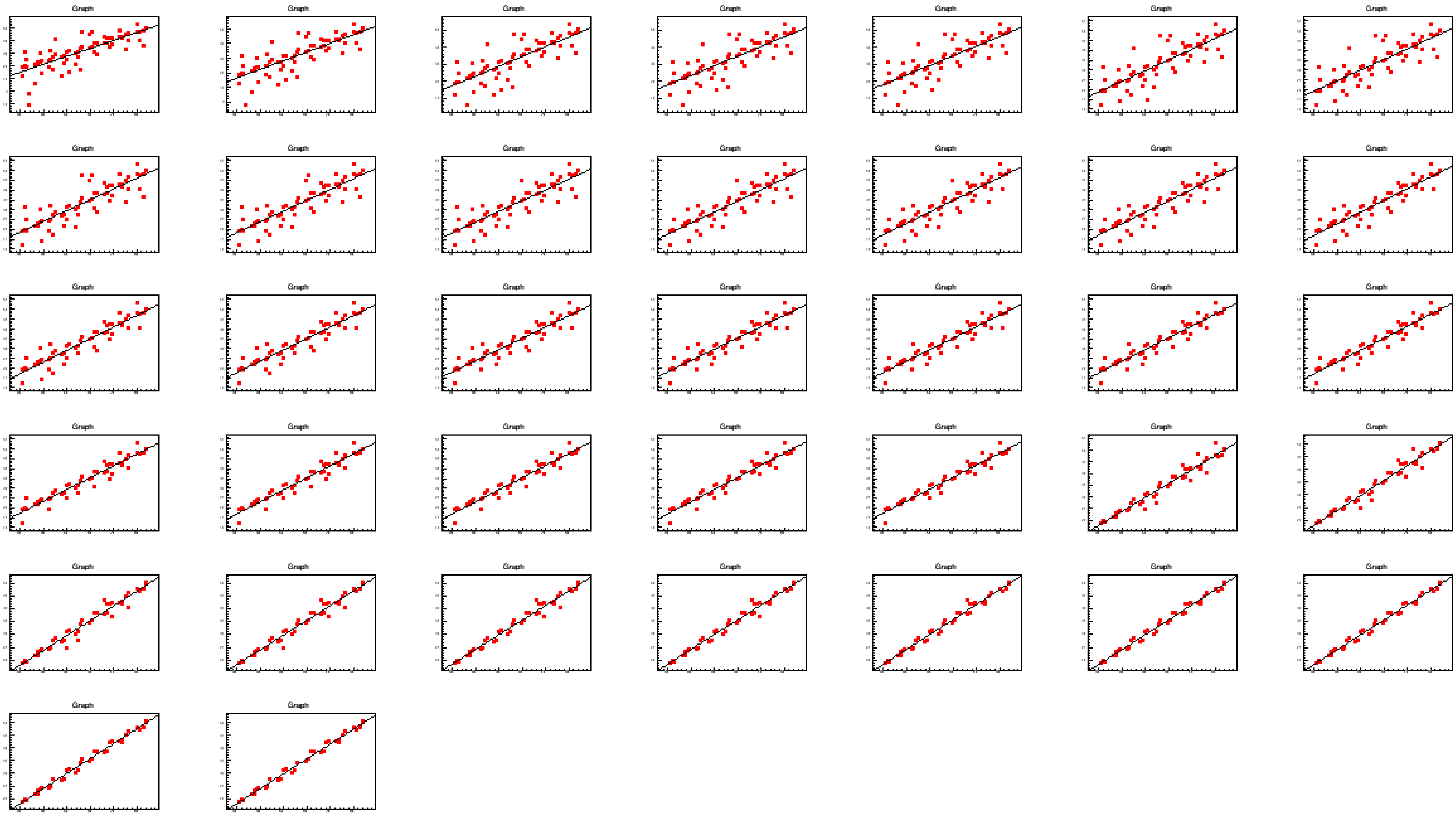


Recursive annealing fit is used in our case.

Example of recursive fit



Example of recursive fit (2)



3D global fitting

This longitudinal hits finding procedure provides the next track candidate parameters estimation:

a) tilted hits which are belong to the considered track candidate;
b) theta and phi angles;
c) estimation of primary vertex position or track position at the first point.

Last step is applying the fitting procedure to the found track candidates:

a) we have set of straw tubes (or hits) which are belonged to the track candidate;
b) estimated position of 1-st track point;
c) estimation of track momentum (Px, Py, Pz) at the 1-st track point (or in the primary vertex);
d) then standard SPD fitting procedure (on the base Kalman filter from Genfit2) can be applied.

Results of reconstruction procedure for considered event example:

a) all track in event – 9:

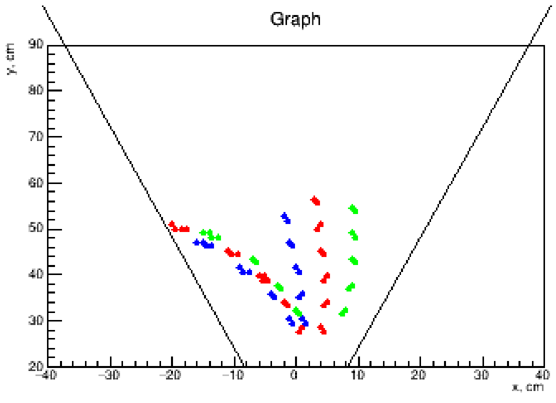
b) 2D found track candidates – 9;

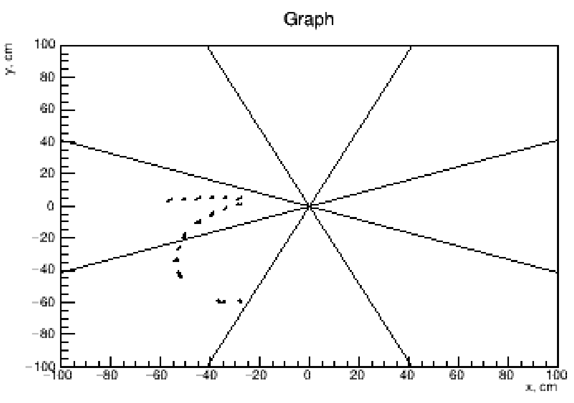
c) longitudinal track candidates – 9;

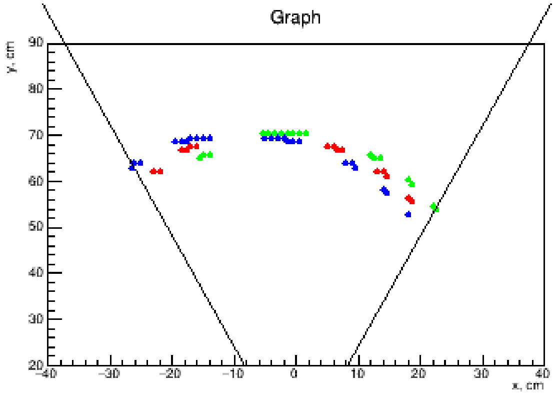
d) global fitting procedure – 9;

Some preliminary conclusion – track reconstruction procedure using only straw detector works.

Another event example
(only 1-st generation tracks)







Another event example (all generation tracks)

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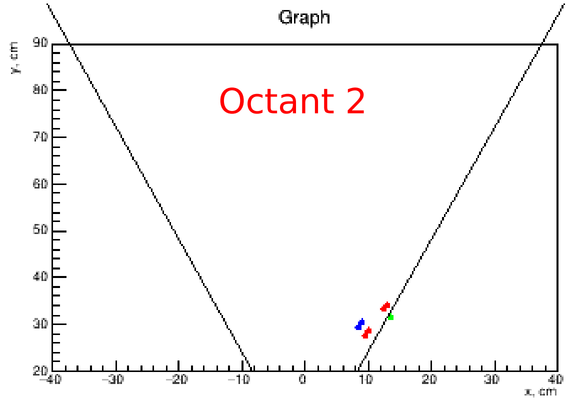
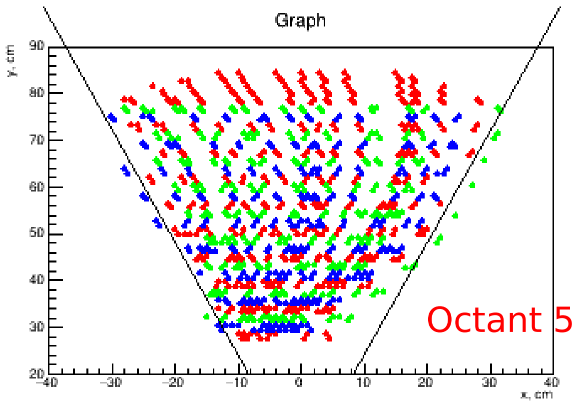
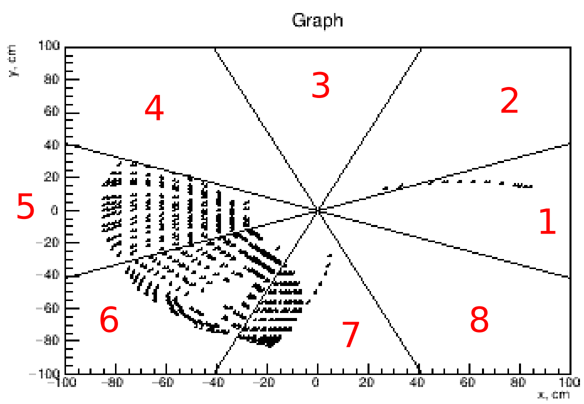
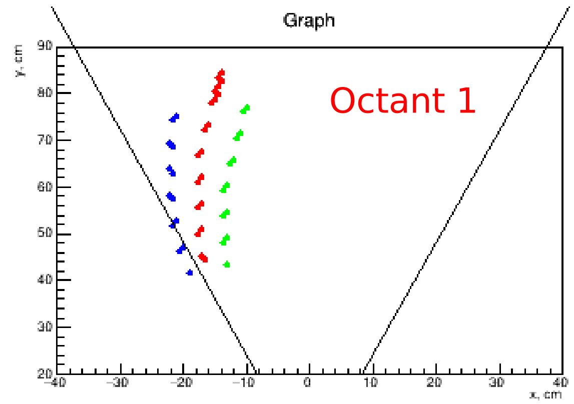
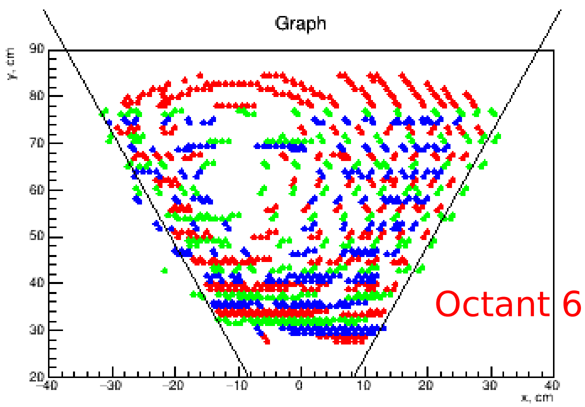
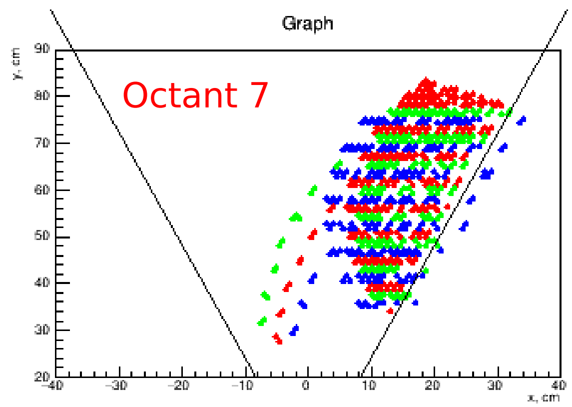






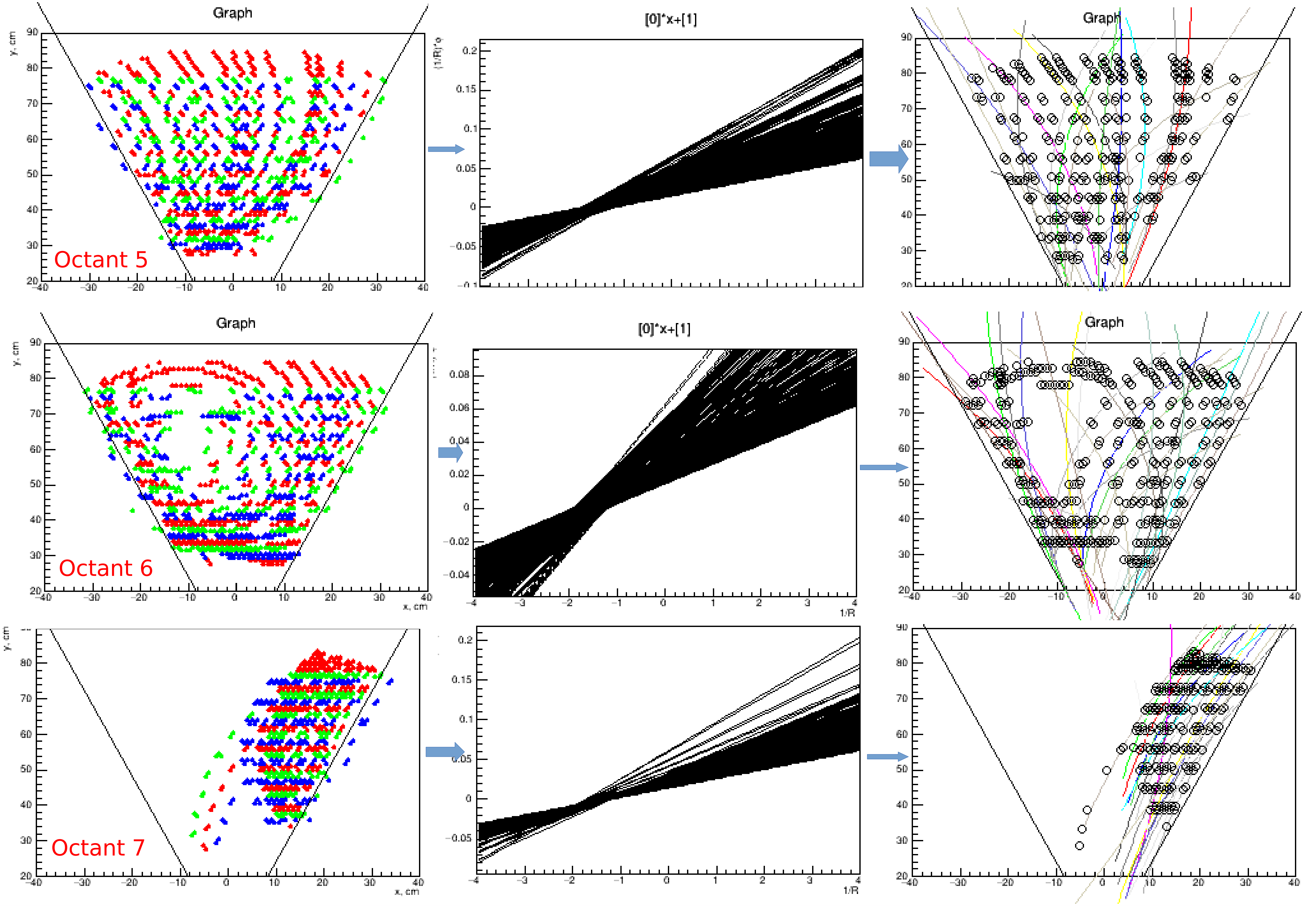




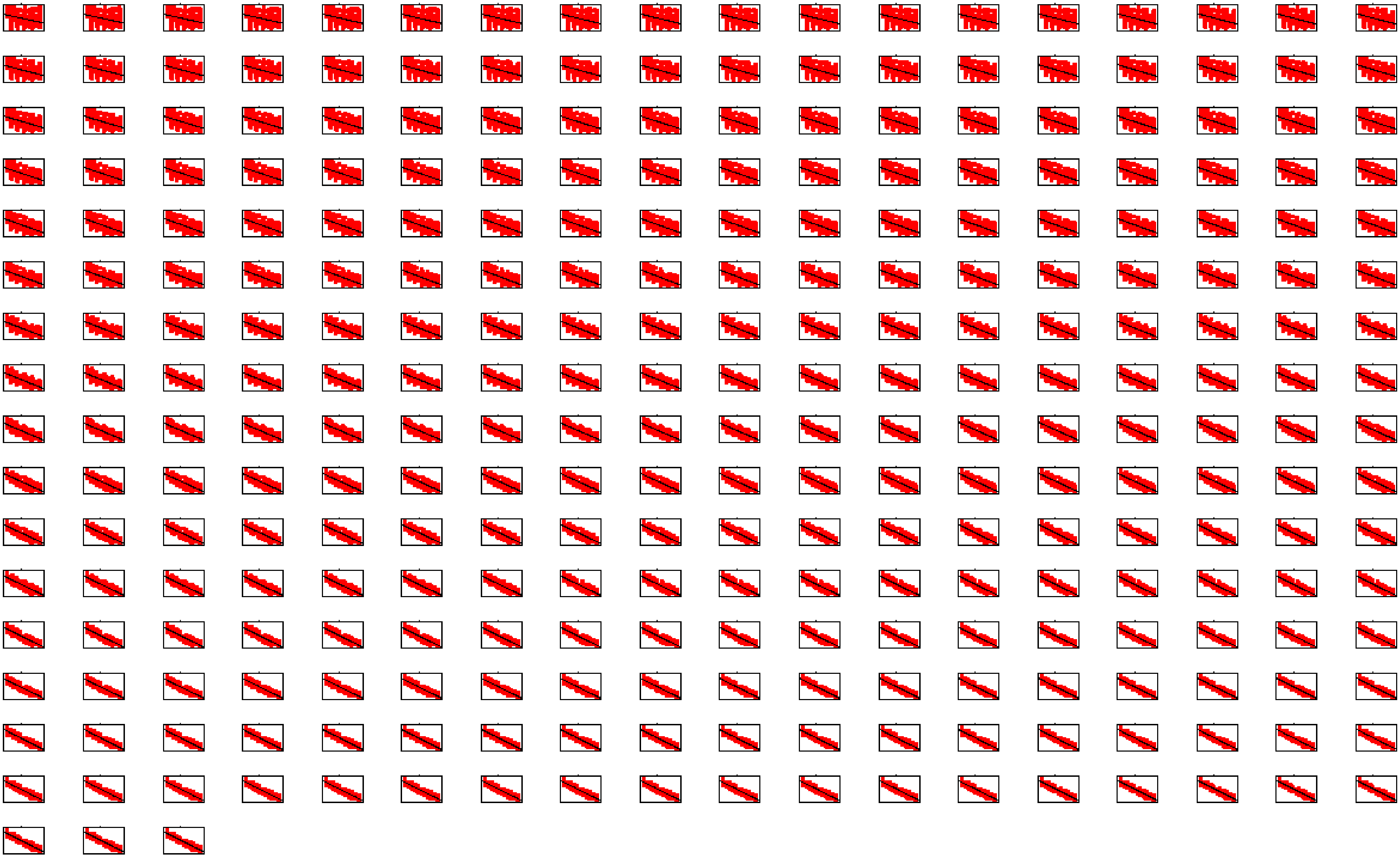


Question – is it possible to reconstruct such type of event ?

Another event example (2)



Another event example
(longitudinal track finding)



Summary

1. General schema for track reconstruction is available and works.

2. It provides good track finding efficiency (evaluate at a glance).

3. Need to check the quality and efficiency of this procedure.

4. Also need to determine the main control event sample (type and energy).

5. Preliminary conclusion - present tracker geometry is “acceptable” for this reconstruction procedure.