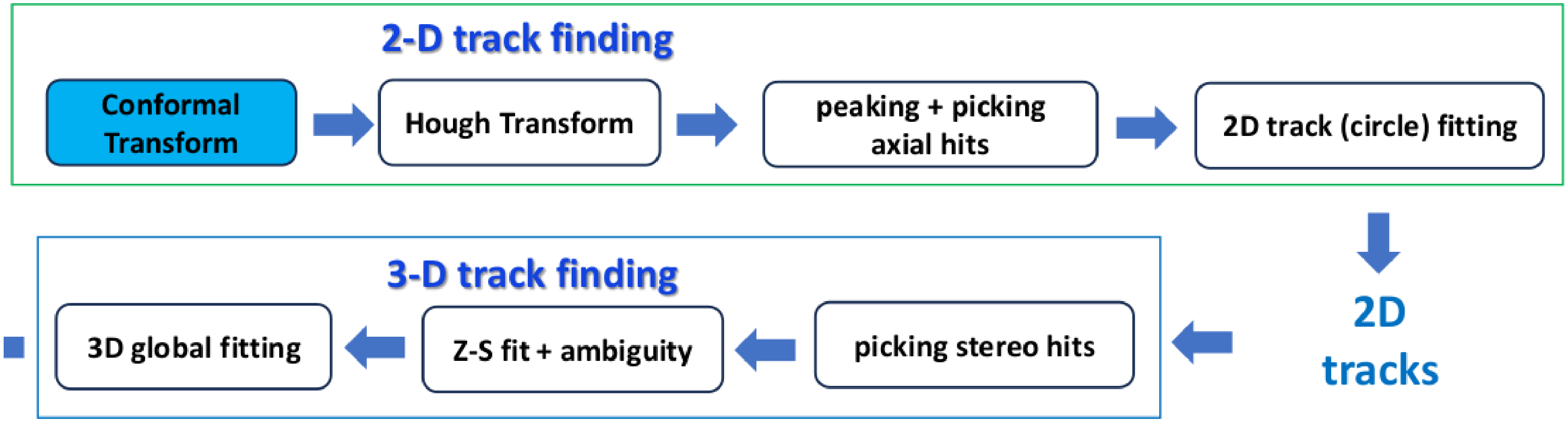
SPD Physics & MC Meeting
24 December 2025

Status of track reconstruction in ST barrel

V. Andreev (LPI, Moscow)

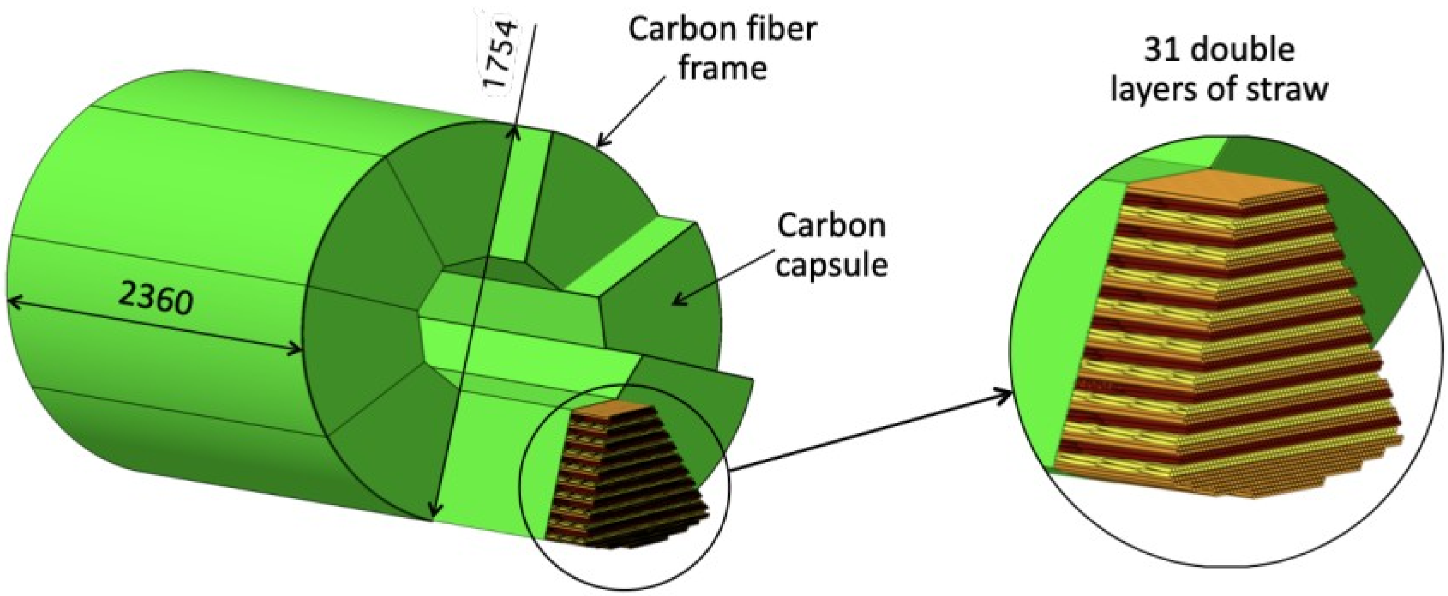
General approach

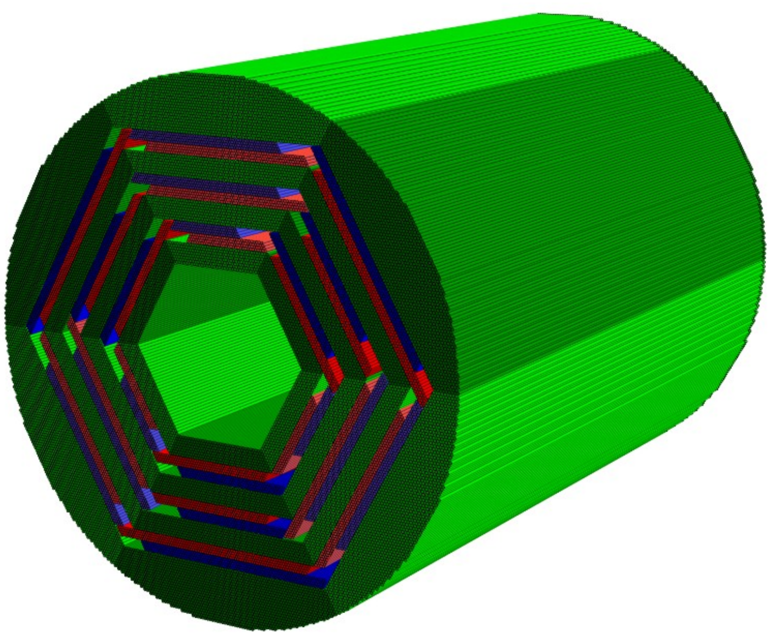


Track finding algorithm starts from 2D finding procedure in XY-plane:

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

Two different tracker geometry





Two different SPD central tracker geometry
were implemented in SPDroot:

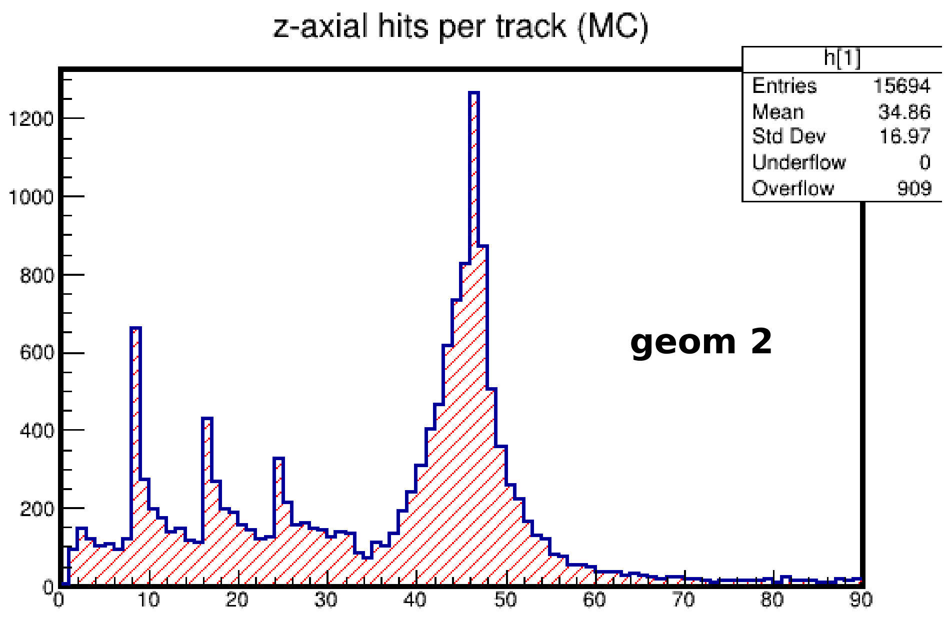
1) octant type geometry (TDR) – top picture;

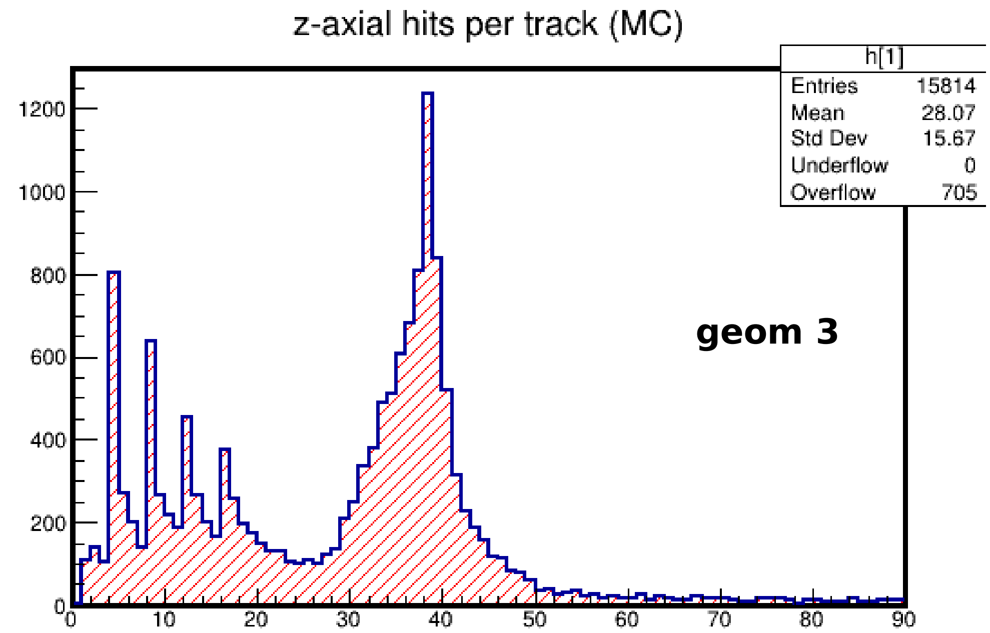
2) sextant type geometry (bottom picture):
- geom 2 => 8+4+4+...
- geom 3 => 4+4+4+...

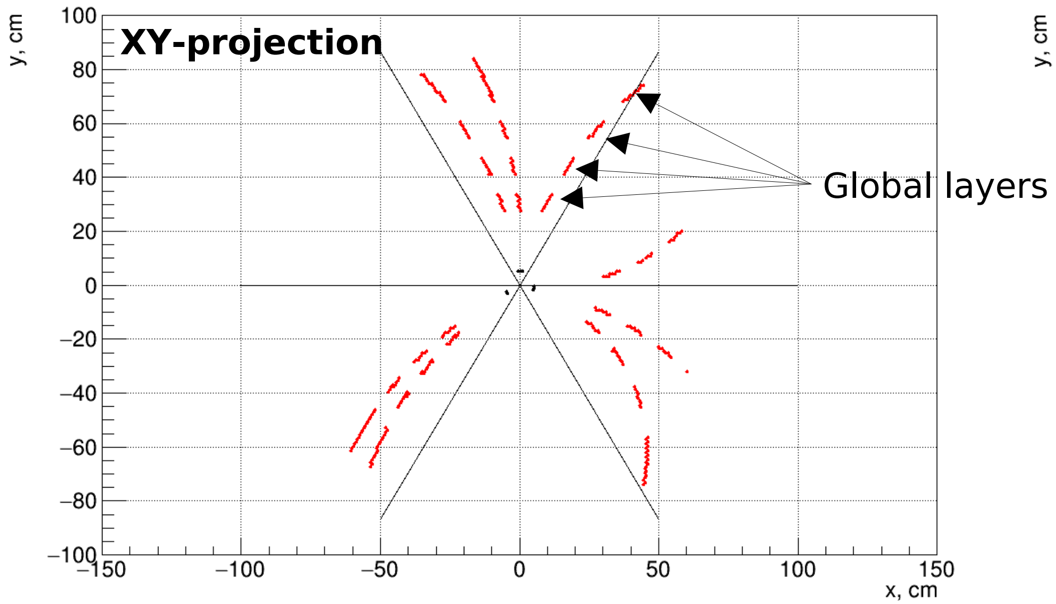
Sextant geometry is now considered as the main option.

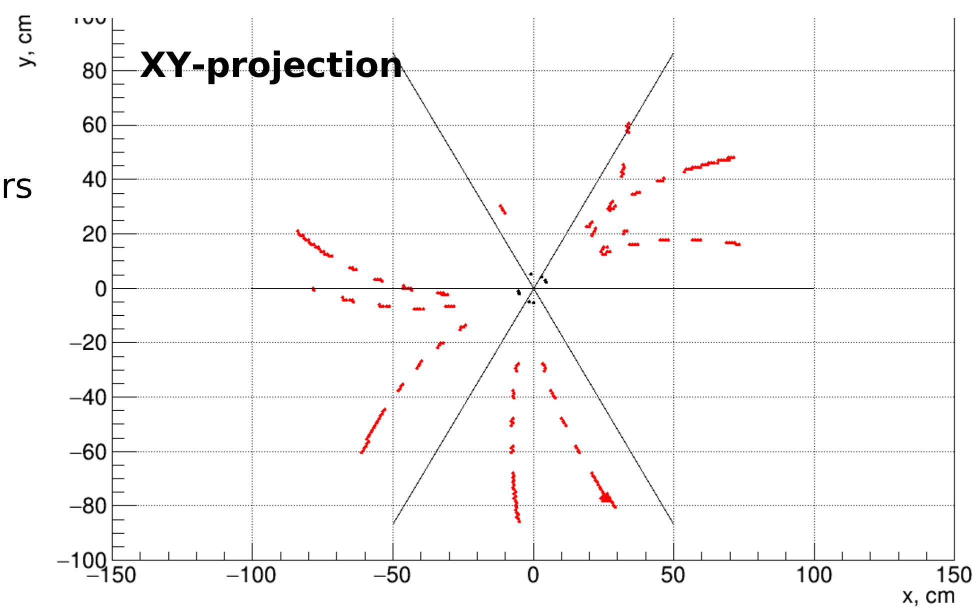
Event sample

1. Use PYTHIA8 generator with Minimum Bias events at $\sqrt{s}$ = 10 GeV as testing sample with sextant tracker geometries and 1 layer of Mvd vertex detector.

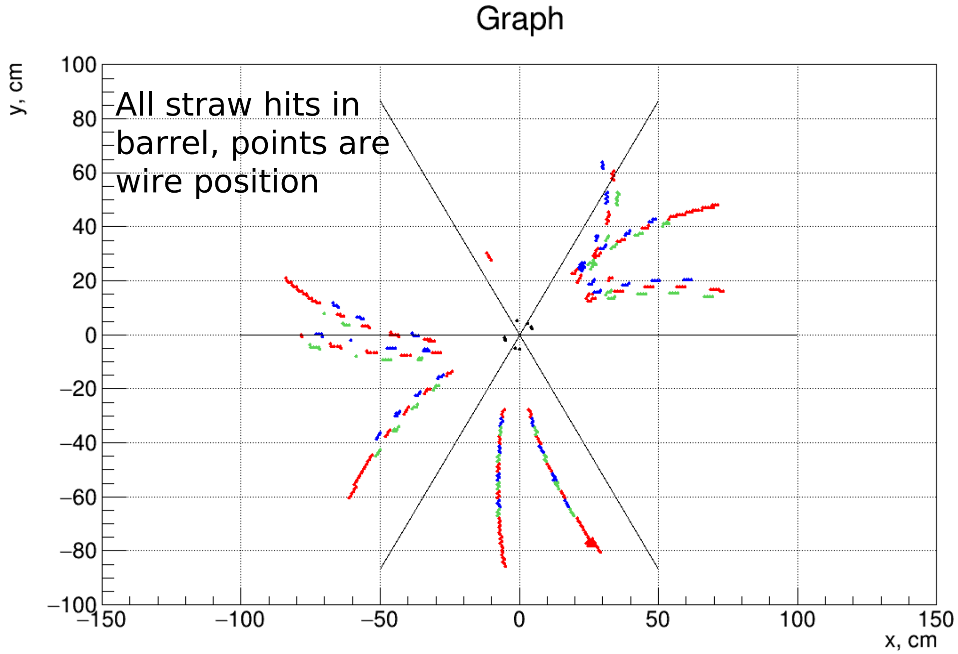


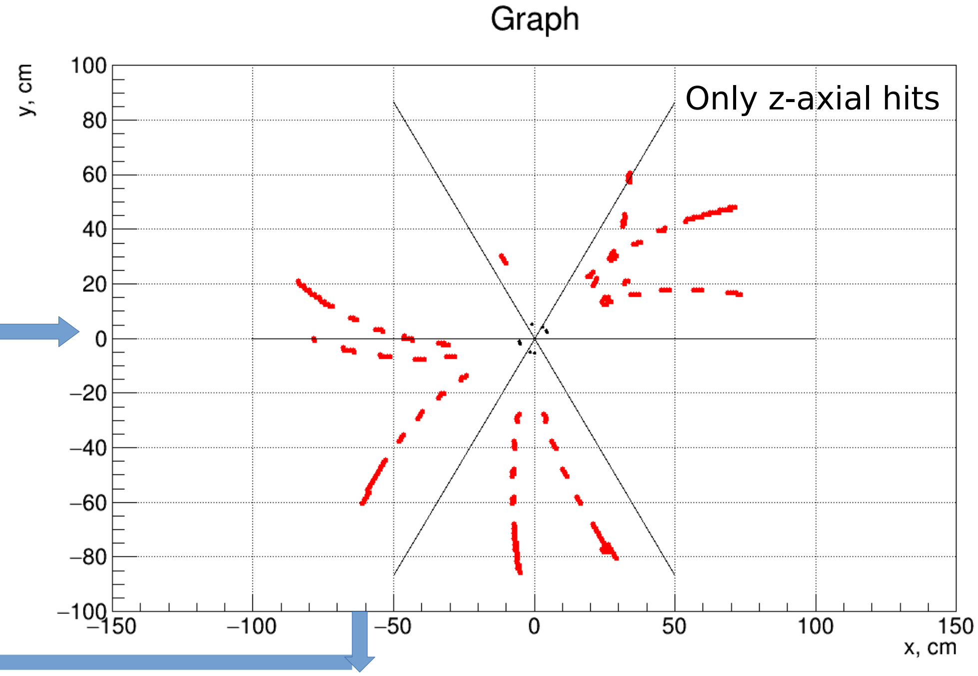


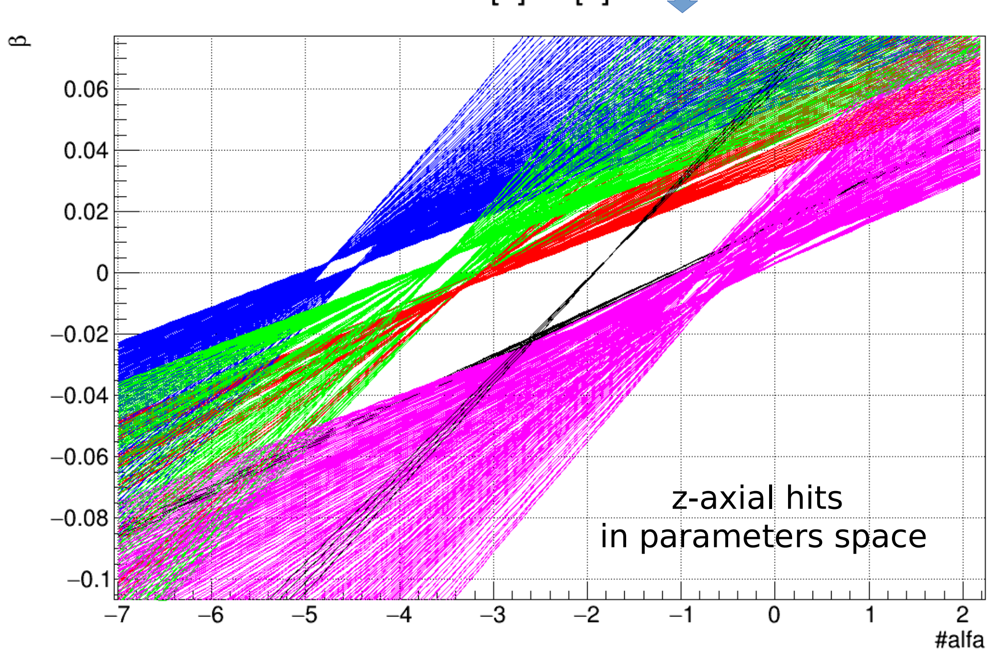


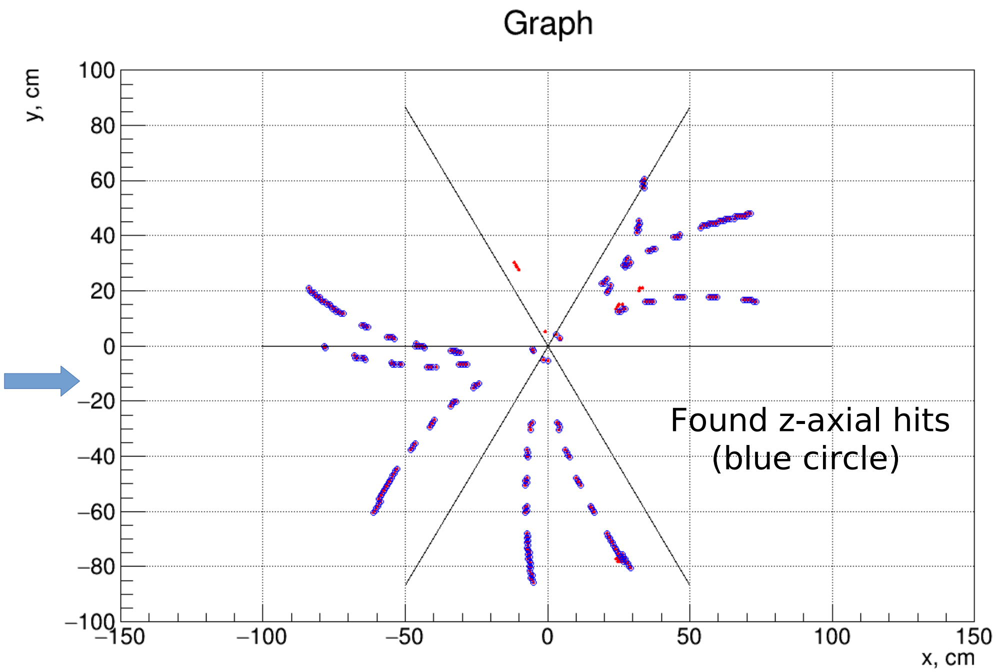


Reconstruction chain (2D)

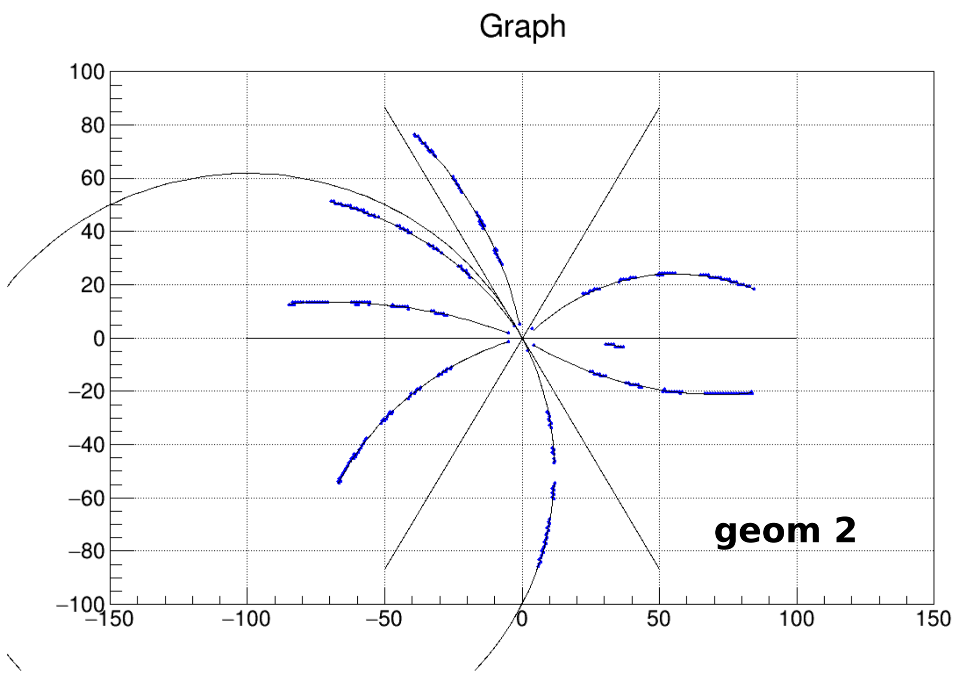


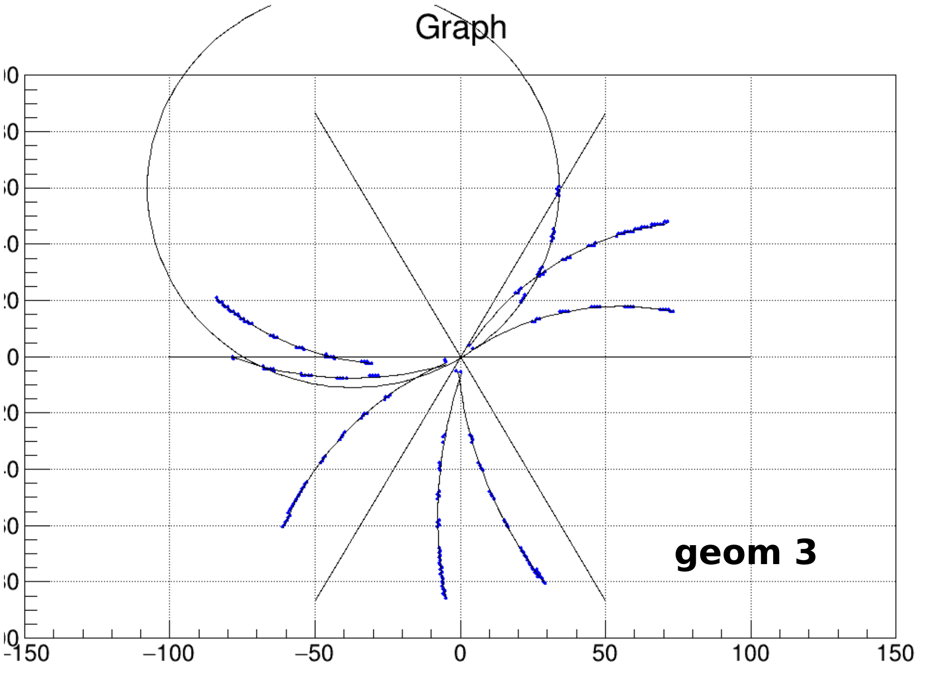






Example of 2D-fitting by circle





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

As you can see for both type tracker geometries this procedure can provide good 2D circle fit.

Geom 2 – two “global” layers are minimum number of layers for track finding

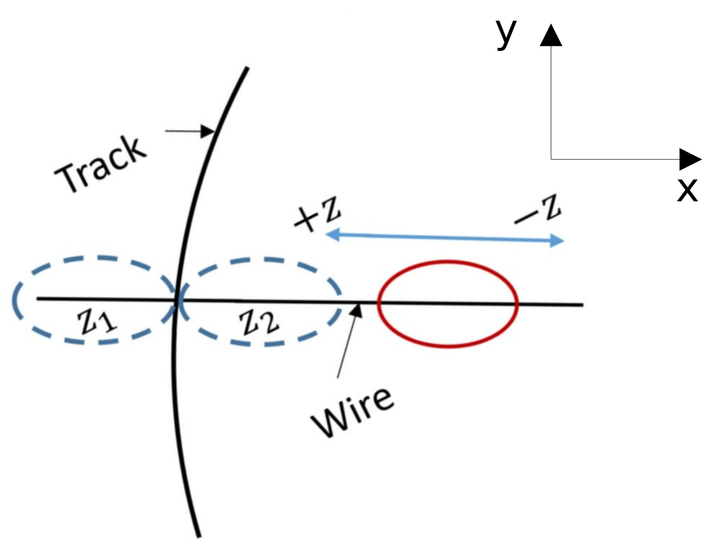
Geom 3 – three “global” layers are minimum number of layers for track finding

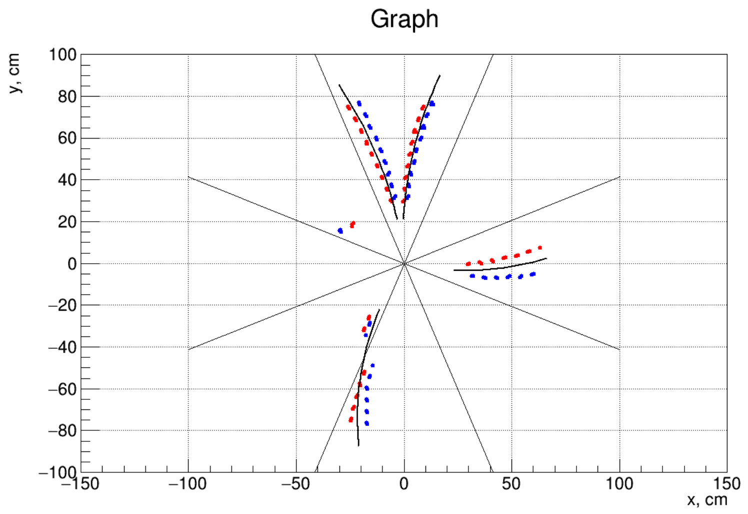
Stereo-hits finding procedure

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 of track 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 red points are straw tubes position of stereo-hits on XY-plane

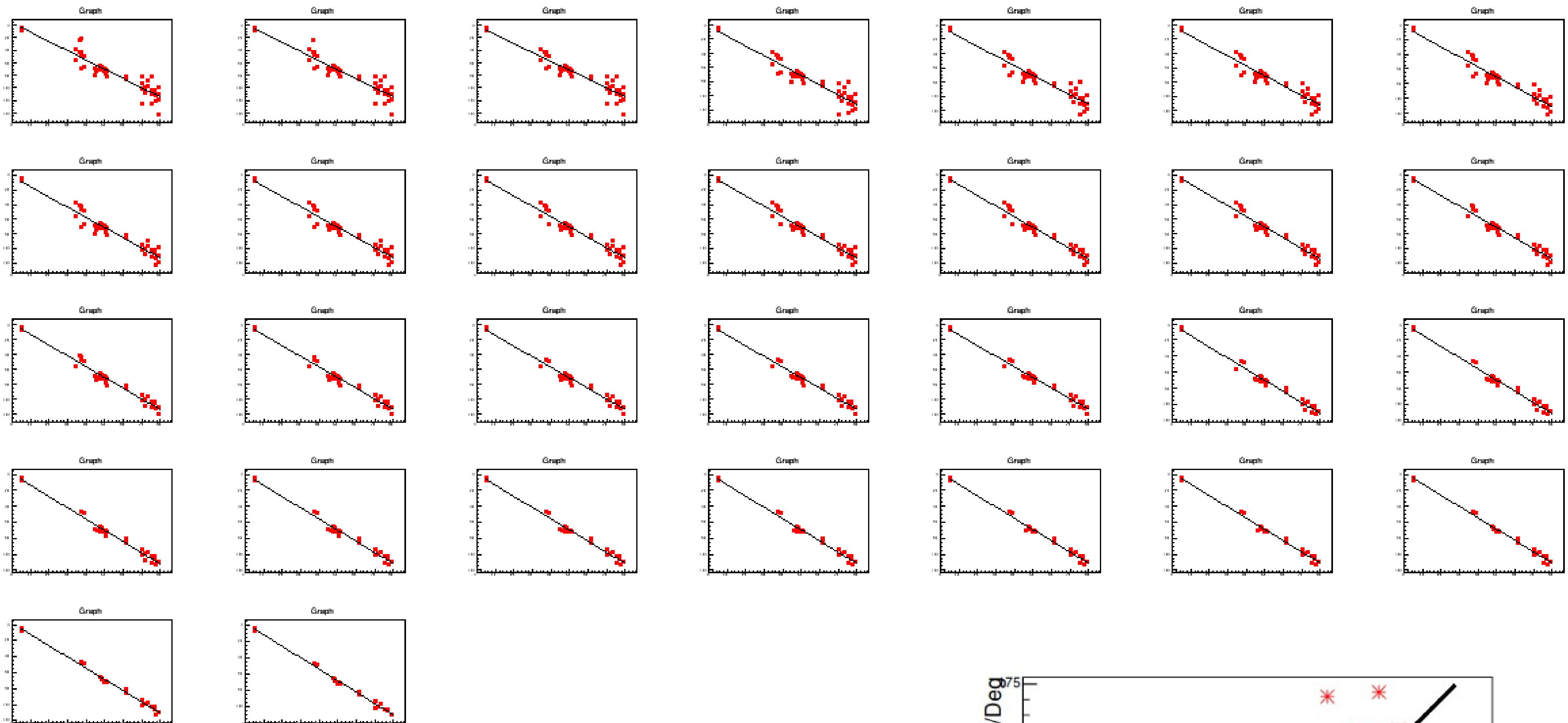
2. The z-position for each stereo-hit (tilted straw tube) is extracted from an alignment procedure as illustrated on the left picture:

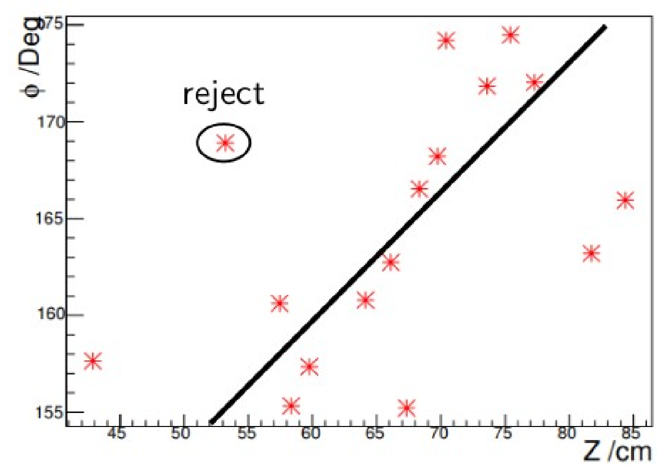
   - the track radius is determined before by the 2D-fitting in XY-plane (black line on the left picture).

   - 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

Stereo-hits finding procedure (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.

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 global fitting procedure of track candidates:

a) there are set of straw tubes (z-axial and stereo) 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.

For estimating track reconstruction quality the comparison with the “ideal” tracks is used.

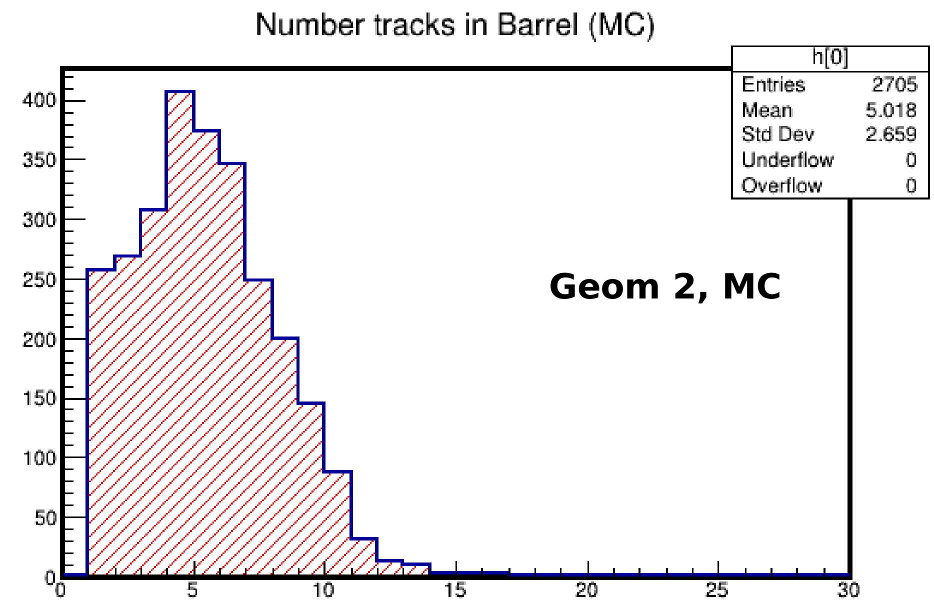
“Ideal” tracks are the tracks fitted by the standard SPDroot Kalman procedure, when all MC hits which belonging to the track are known.

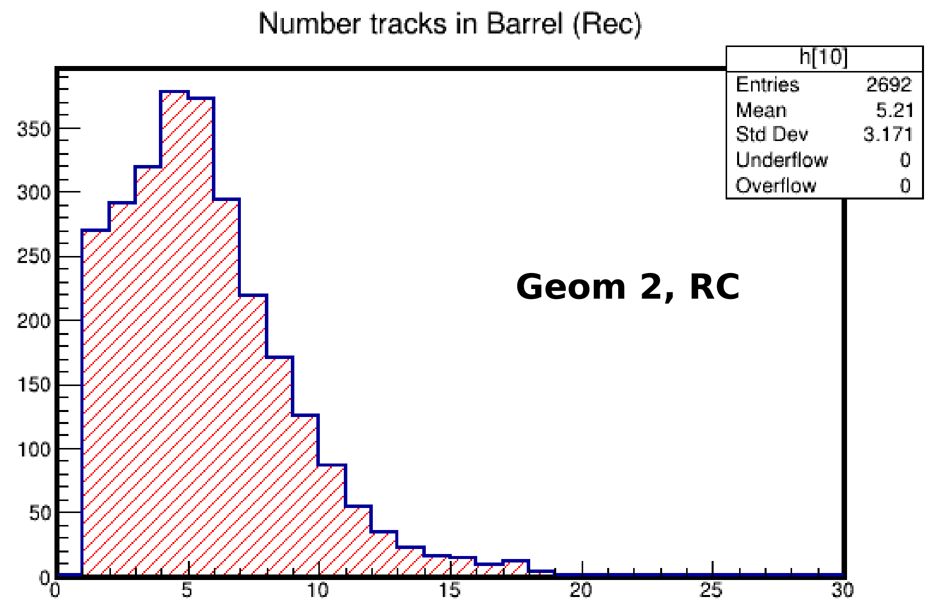
File with Minimum Bias events generated by PYTHIA8 at $\sqrt{s}$ = 10 GeV with sextant tracker geometries and Mvd vertex detector are used as testing samples.

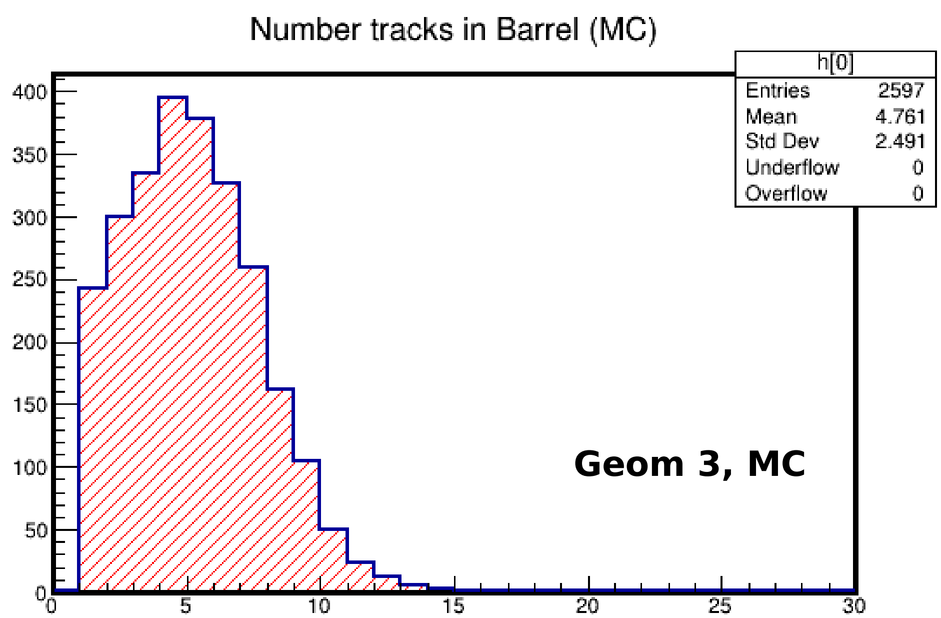
Eff = N^{MC}_{found} / N^{MC}_{total} , where N^{MC}_{total} - total number selected “ideal” MC tracks, and N^{MC}_{found} - number of “ideal” MC tracks for which the reconstruction track was found.
Reconstructed track is considered as identical to “ideal” MC track if number of common Ts hits greater 50 %.

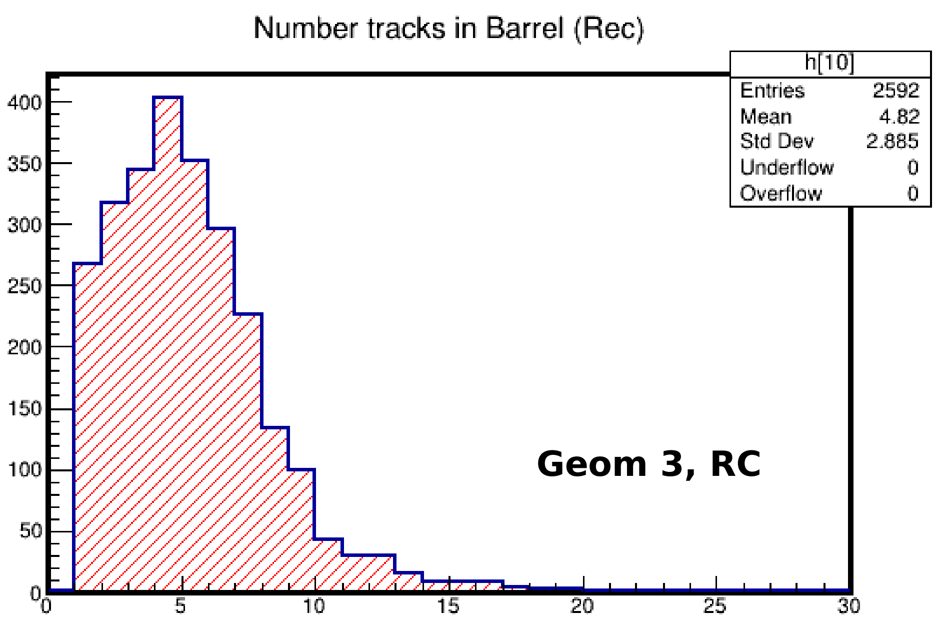
Fake = 1 - N^{RC}_{found} / N^{RC}_{total} , where N^{RC}_{total} total number reconstructed tracks, and N^{RC}_{found} - number of of reconstructed tracks for which the “ideal” MC track was found.

Track multiplicity

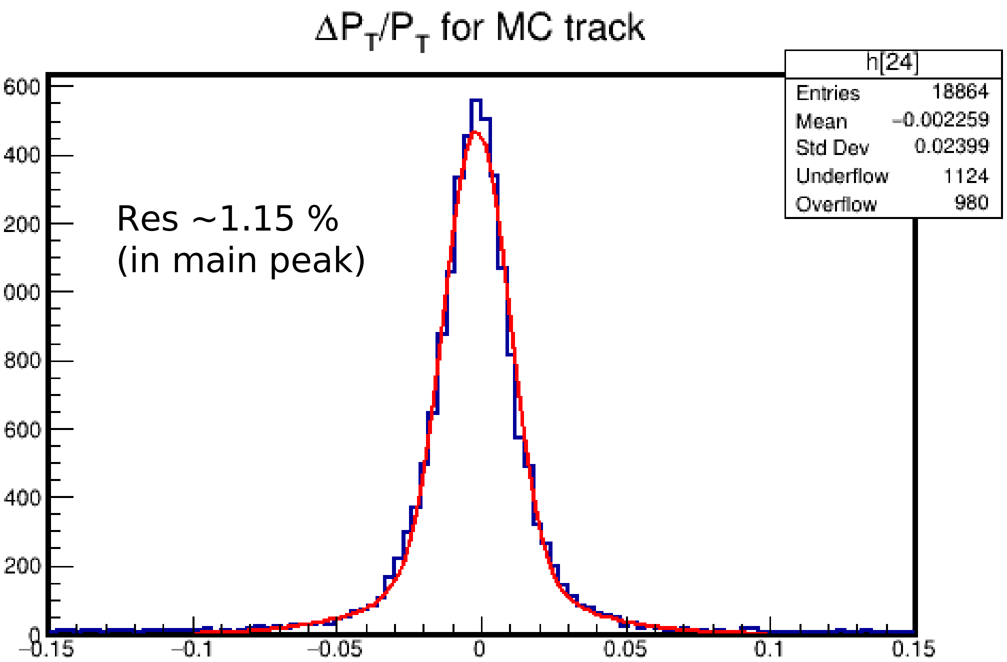


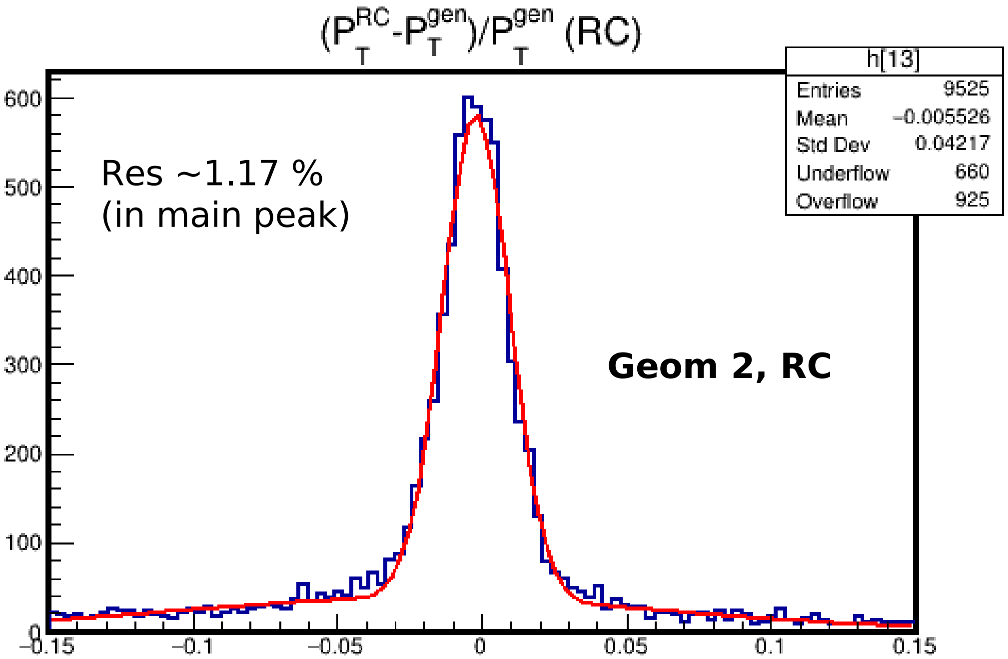






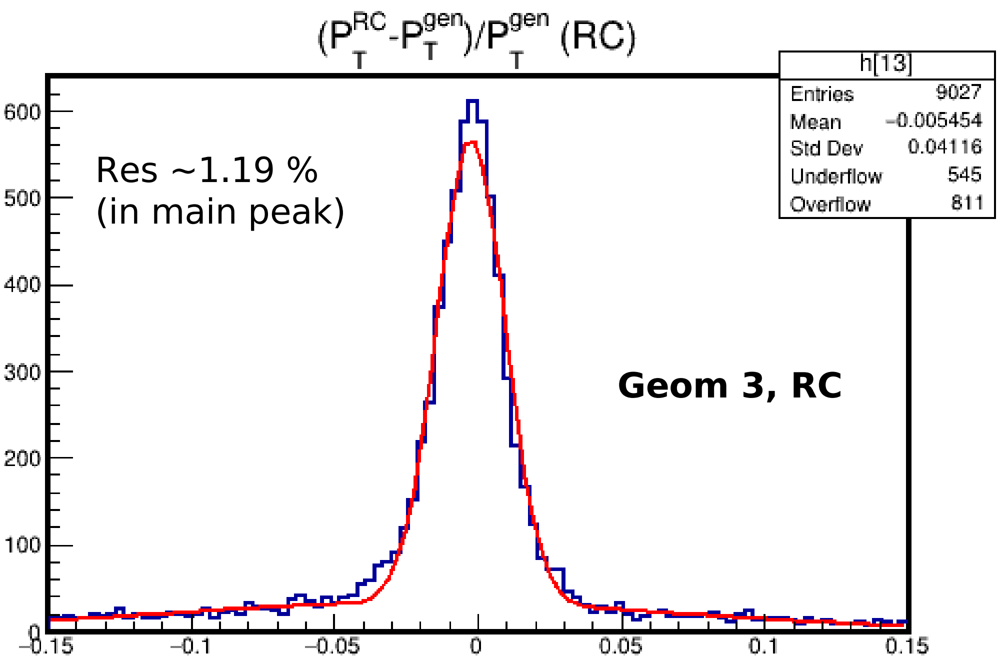
Track Pt resolution



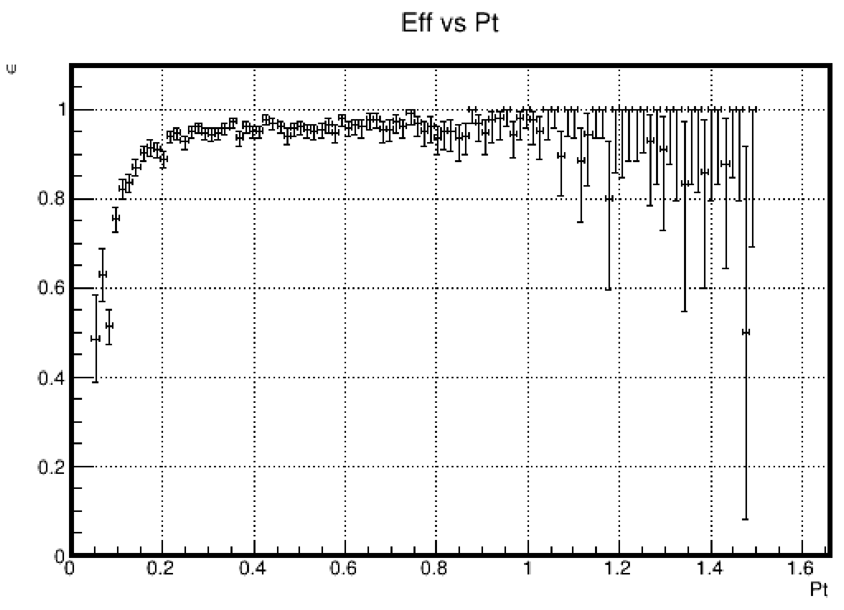


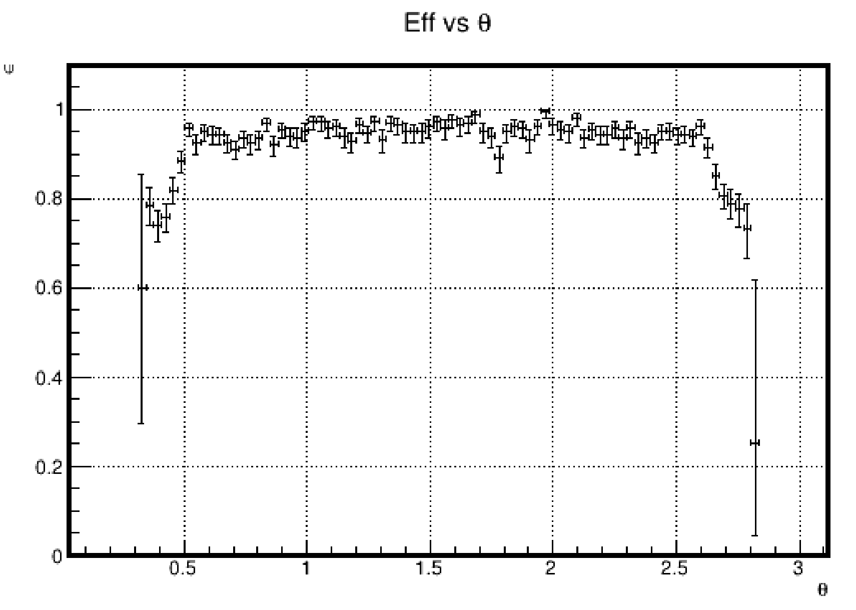
Track Pt resolution is determined by comparison with the generated Pt value:

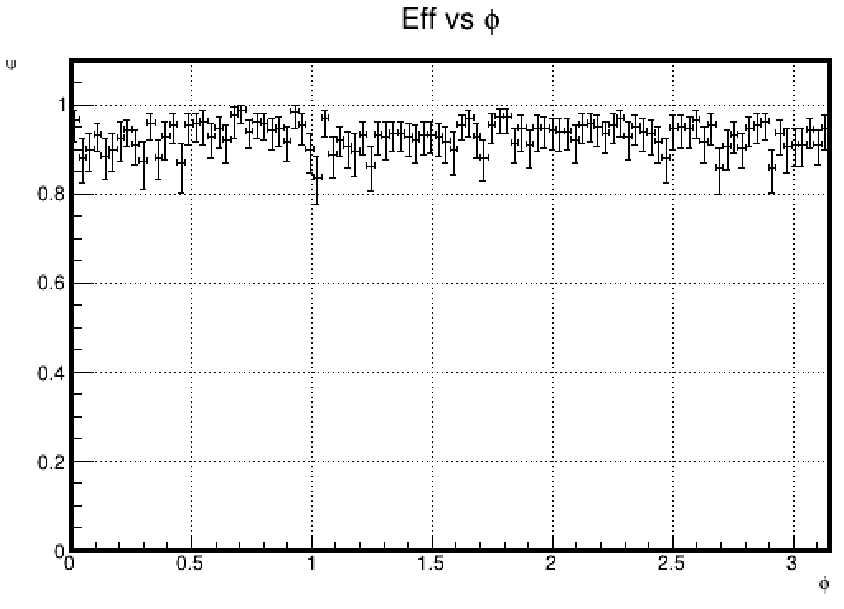
$\Delta Pt = Pt_{fit} - Pt_{gen}$, and $Pt = Pt_{gen}$

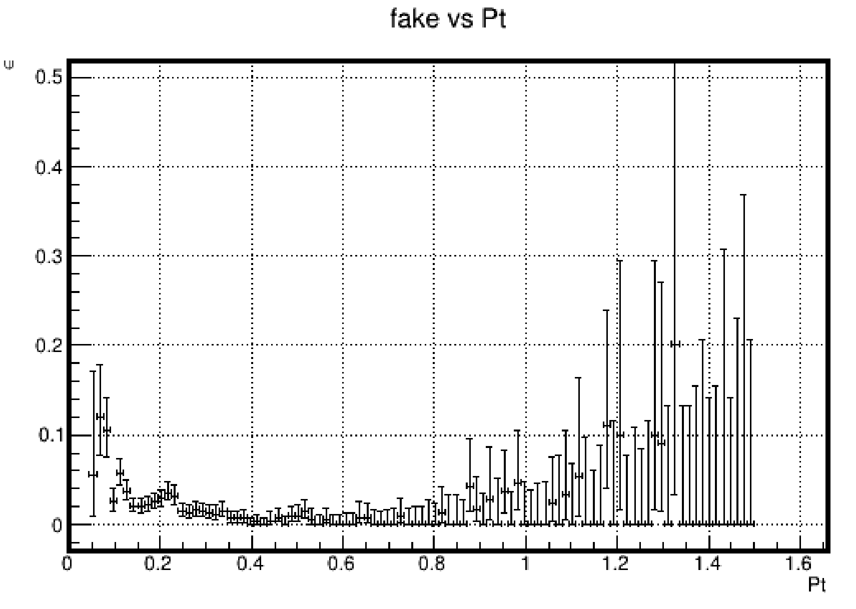


Reconstruction efficiency (geom 2)



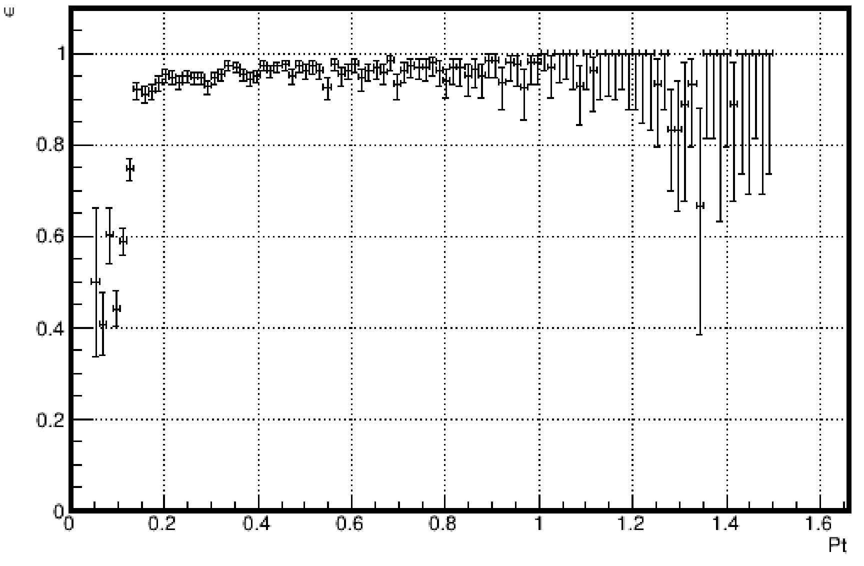




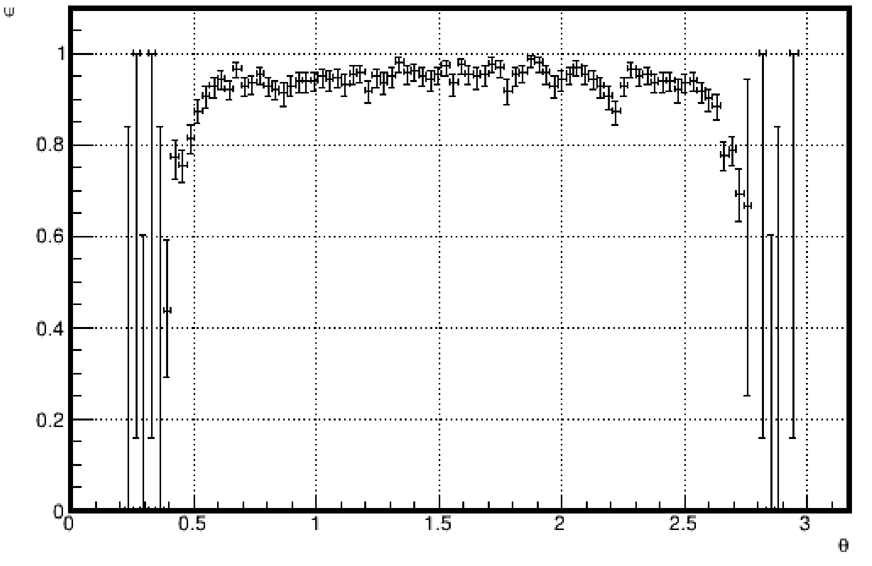


Reconstruction efficiency (geom 3)

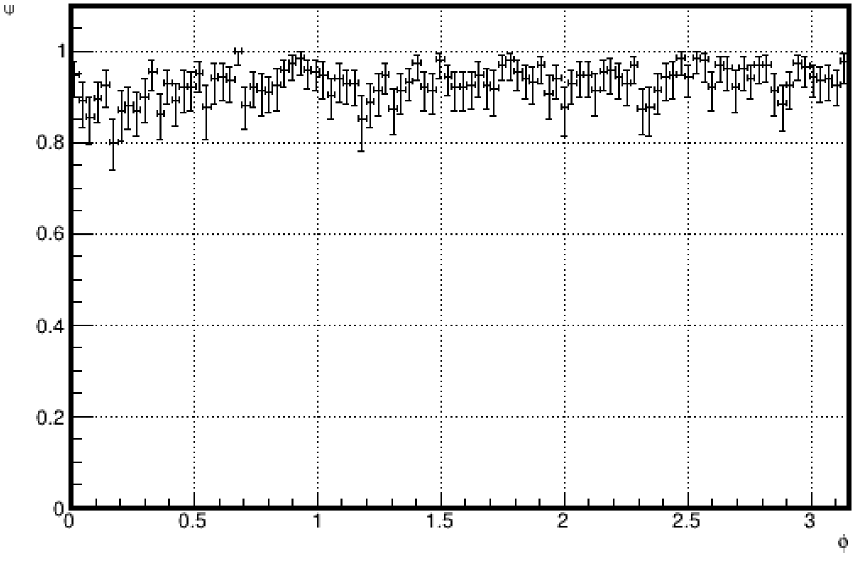
Eff vs Pt



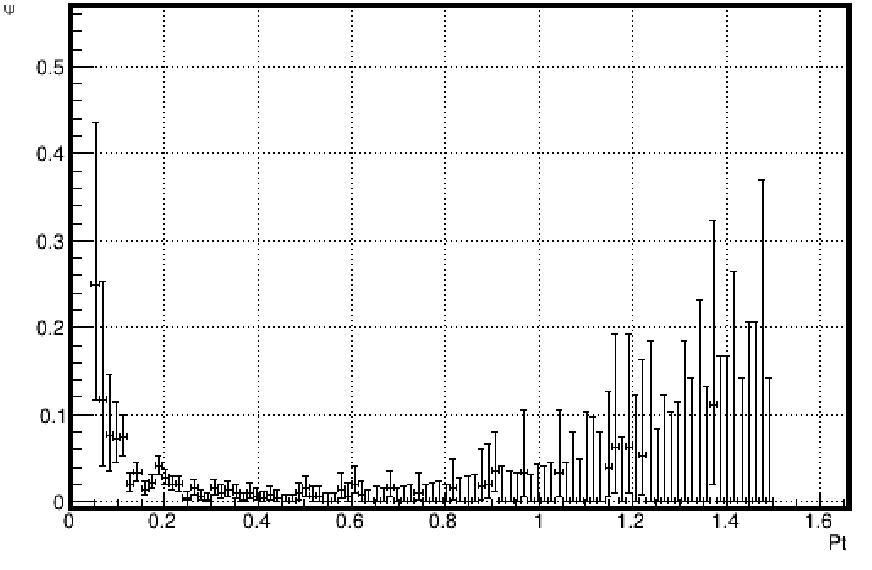
Eff vs θ



Eff vs ϕ



fake vs Pt



How to use the reconstruction program

1. First version of track reconstruction for sextant geometry is available in SPDroot (development branch)

2. Examples in **spdroot/macro/examples/recotrks:**

SimuSextGeomTrack.C – macro for simulation

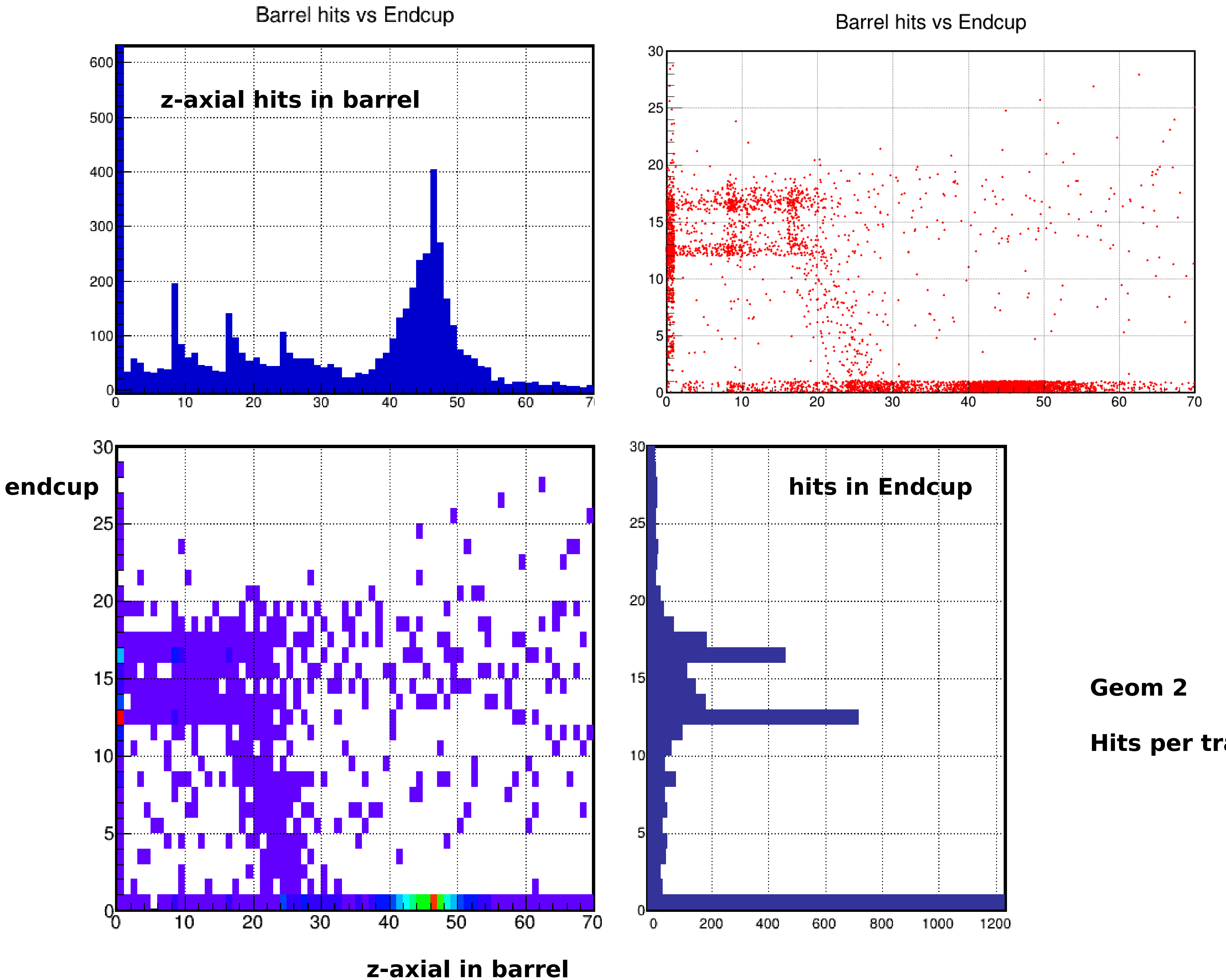
```
// set sextant type geometry
//---------------------------------------
SpdParameter *par;
par = ts_barrel->GetMapper()->AddParameter("TsBGeoType");
if (par) *par = 2;                           // type=2,   => 8+4+4+8+4+4+...
//    if (par) *par = 3;                          // type=3, => 4+4+4+....
```

//---

RecoSextGeomTrack.C – macro for reconstruction

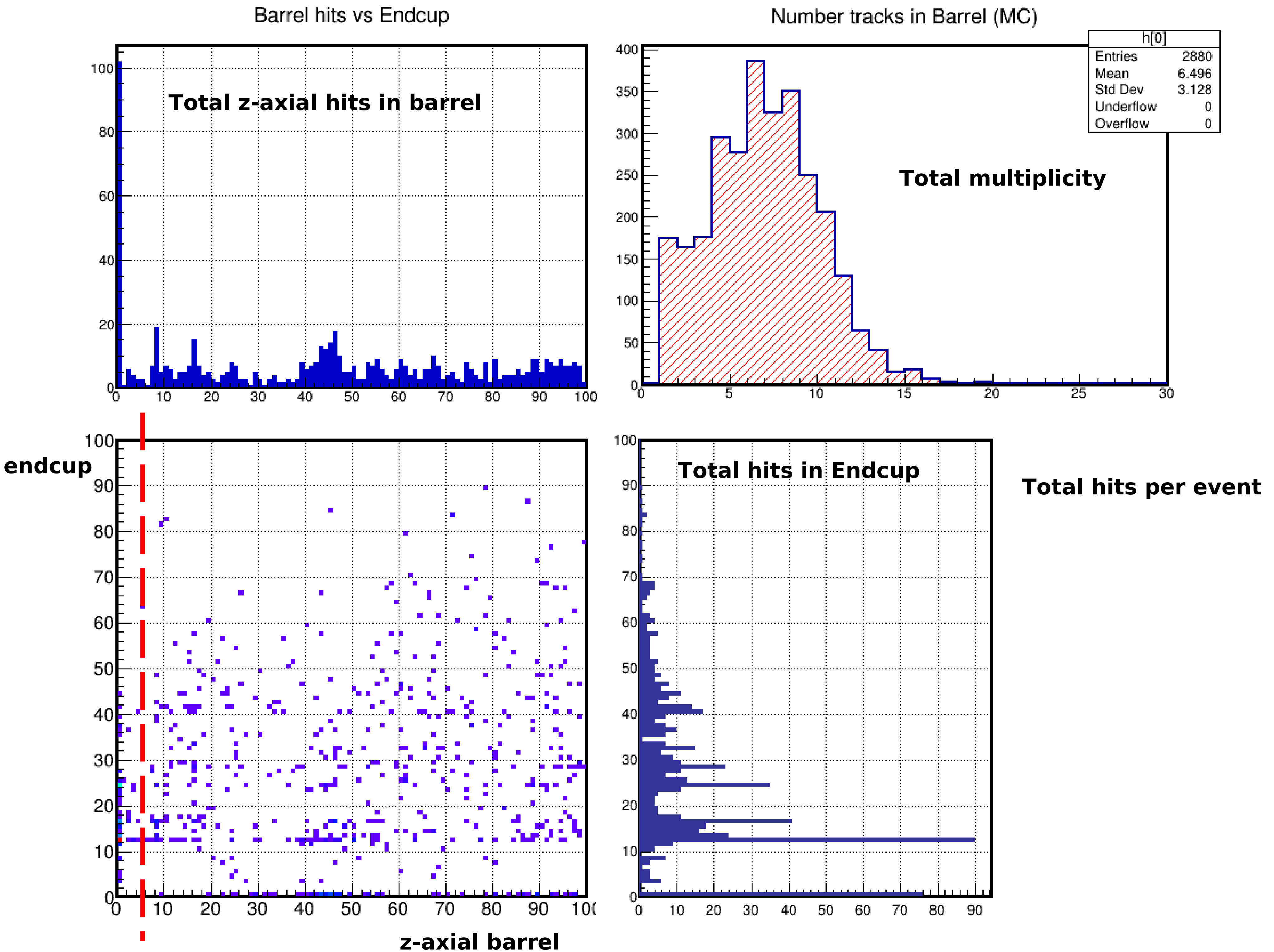
```
SpdRCTracksBarFinder* rc_track_finder = new SpdRCTracksBarFinder();

SpdTrackFitterGF* rc_track_fitter = rc_track_finder->Fitter();

//  set parameters for reco
//-----------------------------------

//rc_track_finder->SetMaxParGeneration(3);        // default = 2
rc_track_finder->SetSkeepHighOccupEvent(false);   // default = true

rc_track_fitter->SetVerboseLevel(0);
rc_track_finder->SetVerboseLevel(1);

Run→AddTask(rc_track_finder);
```

checkSextGeomTrack_v1.C – example for some control plots



Geom 2

Hits per track


Barrel hits vs Endcup
Total z-axial hits in barrel
Number tracks in Barrel (MC)
h[0]
Entries 2880
Mean 6.496
Std Dev 3.128
Underflow 0
Overflow 0
Total multiplicity
endcup
z-axial barrel
Total hits in Endcup
Total hits per event

Summary

1. First version of track reconstruction program for barrel is ready (sextant type geometry).

2. It is included in SPDroot (development branch).

3. It provides good track reconstruction efficiency and low fake rate.

4. Next step – add hits from Endcup for improving the track parameters.

5. Next step – add reconstruction track in Endcup.

Backup slides

Introduction

Track reconstruction is typically divided into two separate sub-tasks:

a) Track finding (or pattern recognition)
b) Track fitting (generally based on the Kalman filter method)

Track finding:

a) Dividing the 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 begins with the measurements within a single subset identified by the track finder.

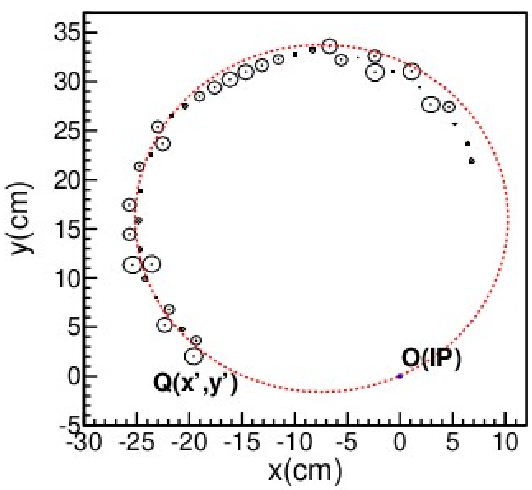
General approach to track finding in major HEP experiments usually starts with constructing track seeds using hits (or space points) in the vertex detector. These seeds are then extrapolated into the main tracker and additional hits are added to the track.

This approach can be implemented in the SPD experiment after installing the MAPS or DSSD vertex detector.

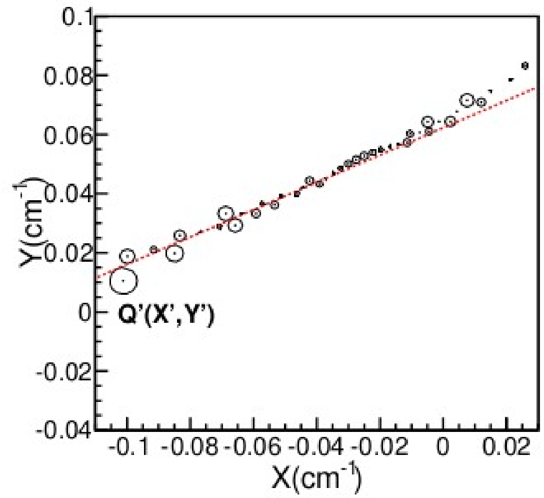
At the first stage, the SPD experiment will operate with only one layer of MicroMegas detector and the standard track reconstruction procedure will not be applicable.

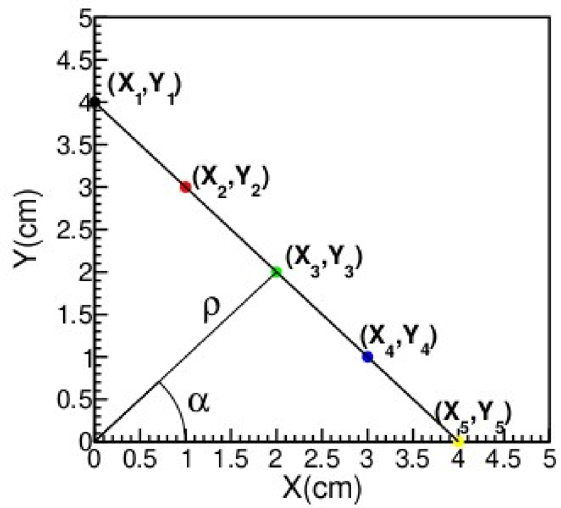
The next track finding procedure is proposed:

Conformal and Hough Transformation



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

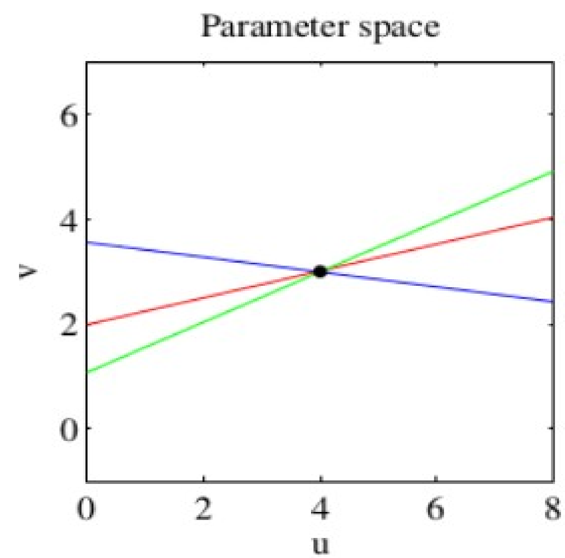




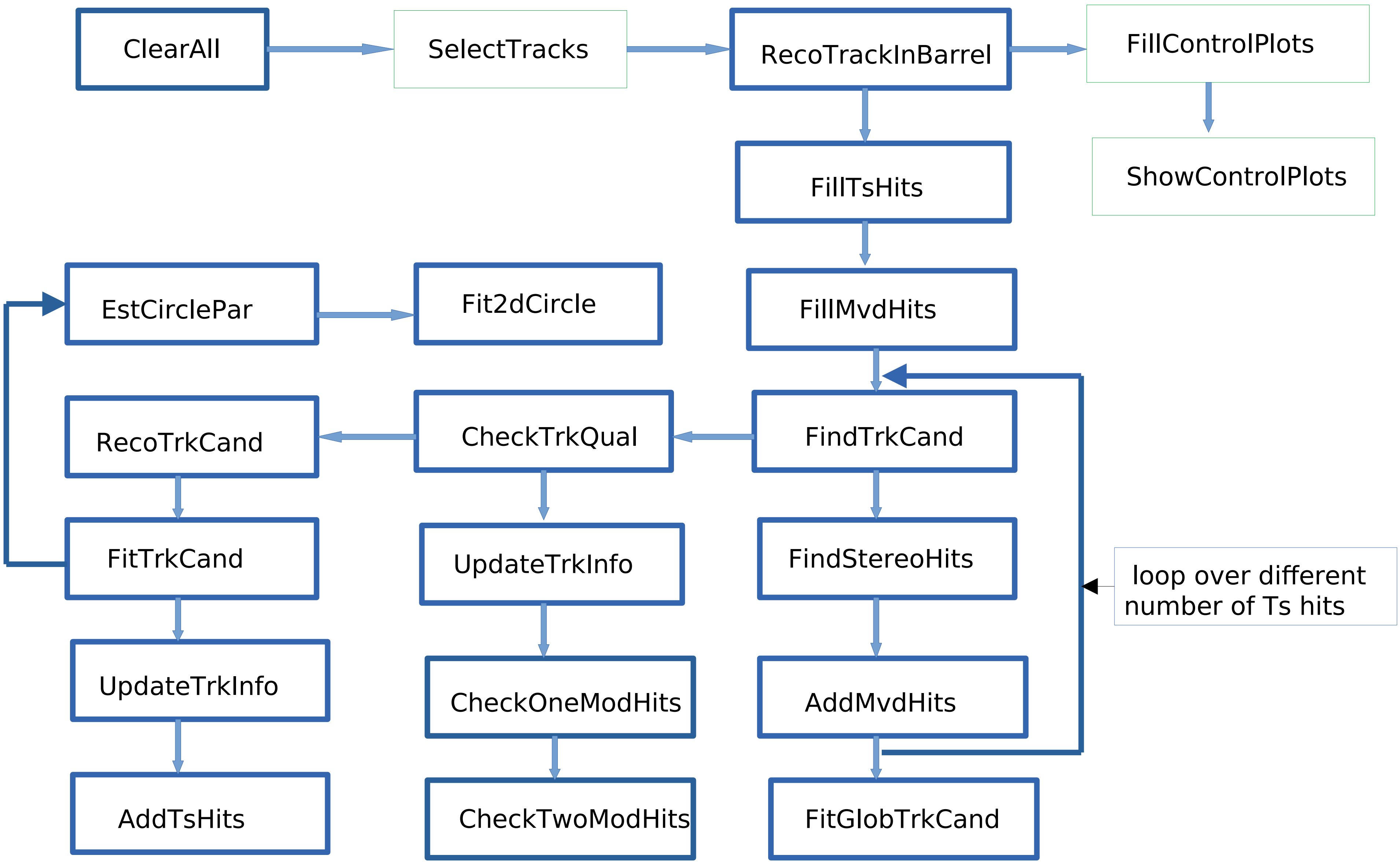
Hough transformation

(each point is line in parameter space)

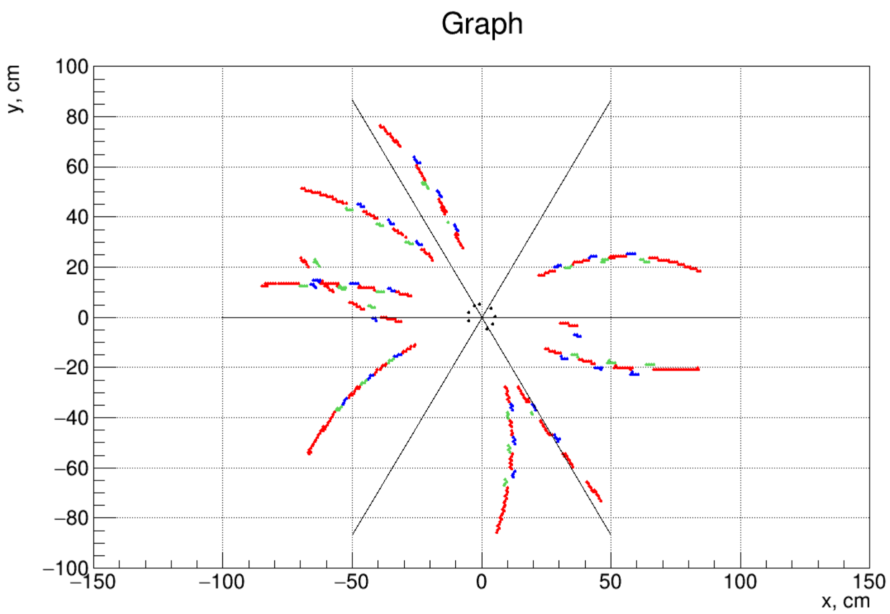
$$v = a * u + b$$

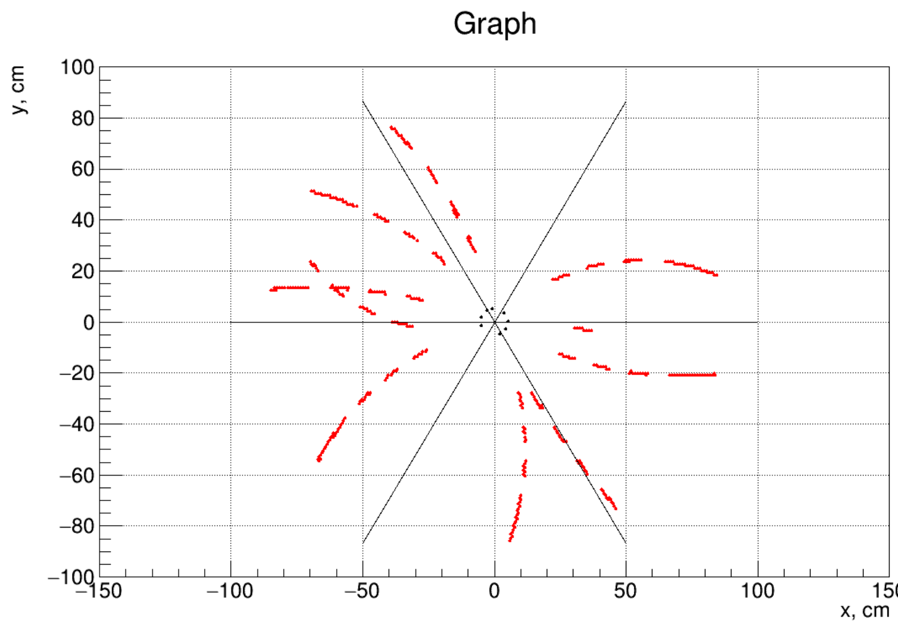


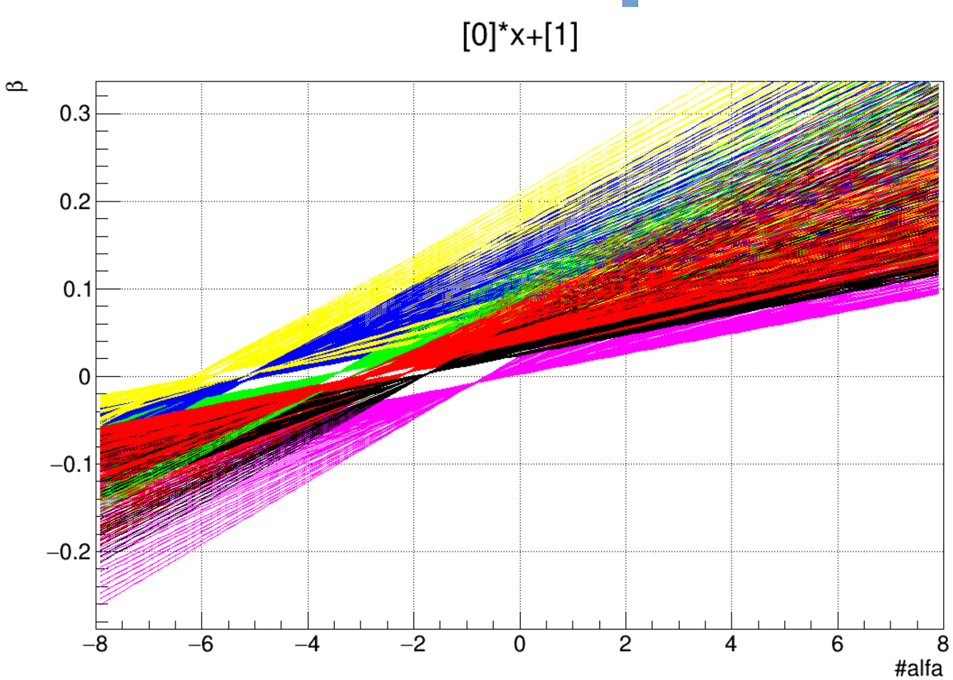
General reconstruction map

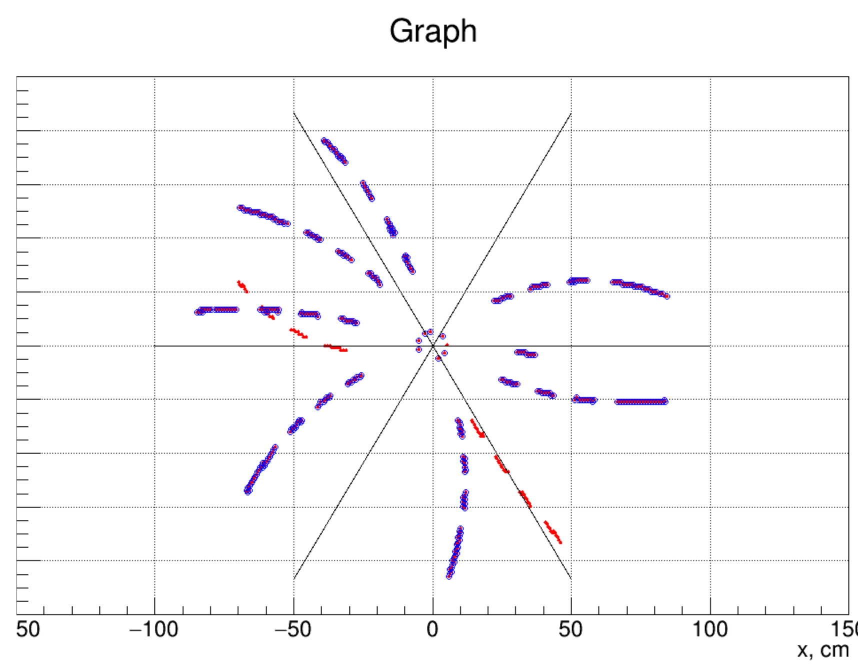


Reconstruction chain (2D)









Influence of dead material