

Tracks pattern recognition for the SHiP Spectrometer Tracker



Mikhail Hushchyn^{1,3}, Andrey Ustyuzhanin^{1,2,3}, Oleg Alenkin³, Eric van Herwijnen⁴

- 1) Yandex School of Data Analysis
- 2) Higher School of Economics
- 3) Moscow Institute of Physics and Technology
- 4) CERN

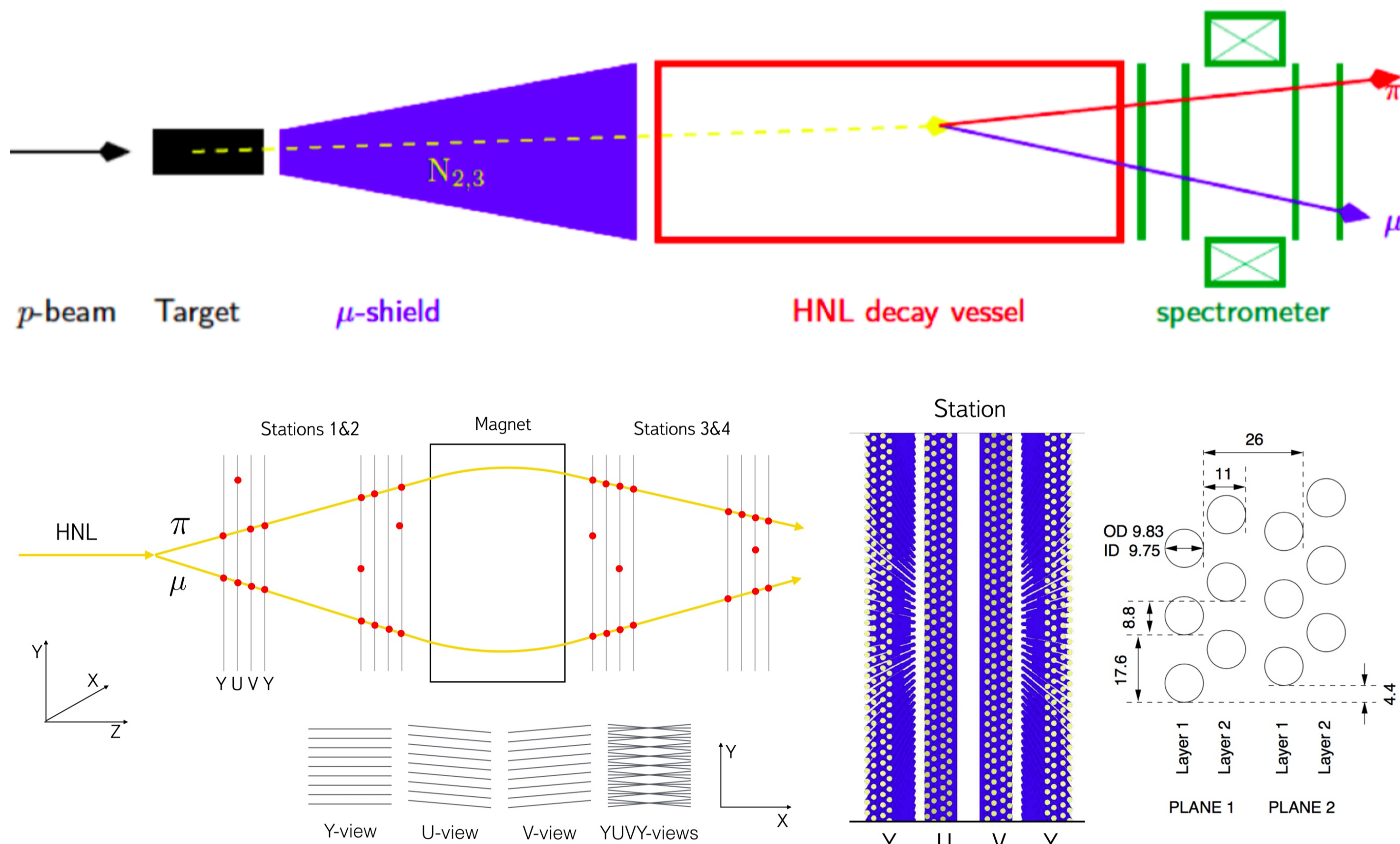
E-mail: mikhail91@yandex-team.ru

22nd International Conference on Computing in High Energy and Nuclear Physics, San Francisco, October 10-14, 2016

Introduction

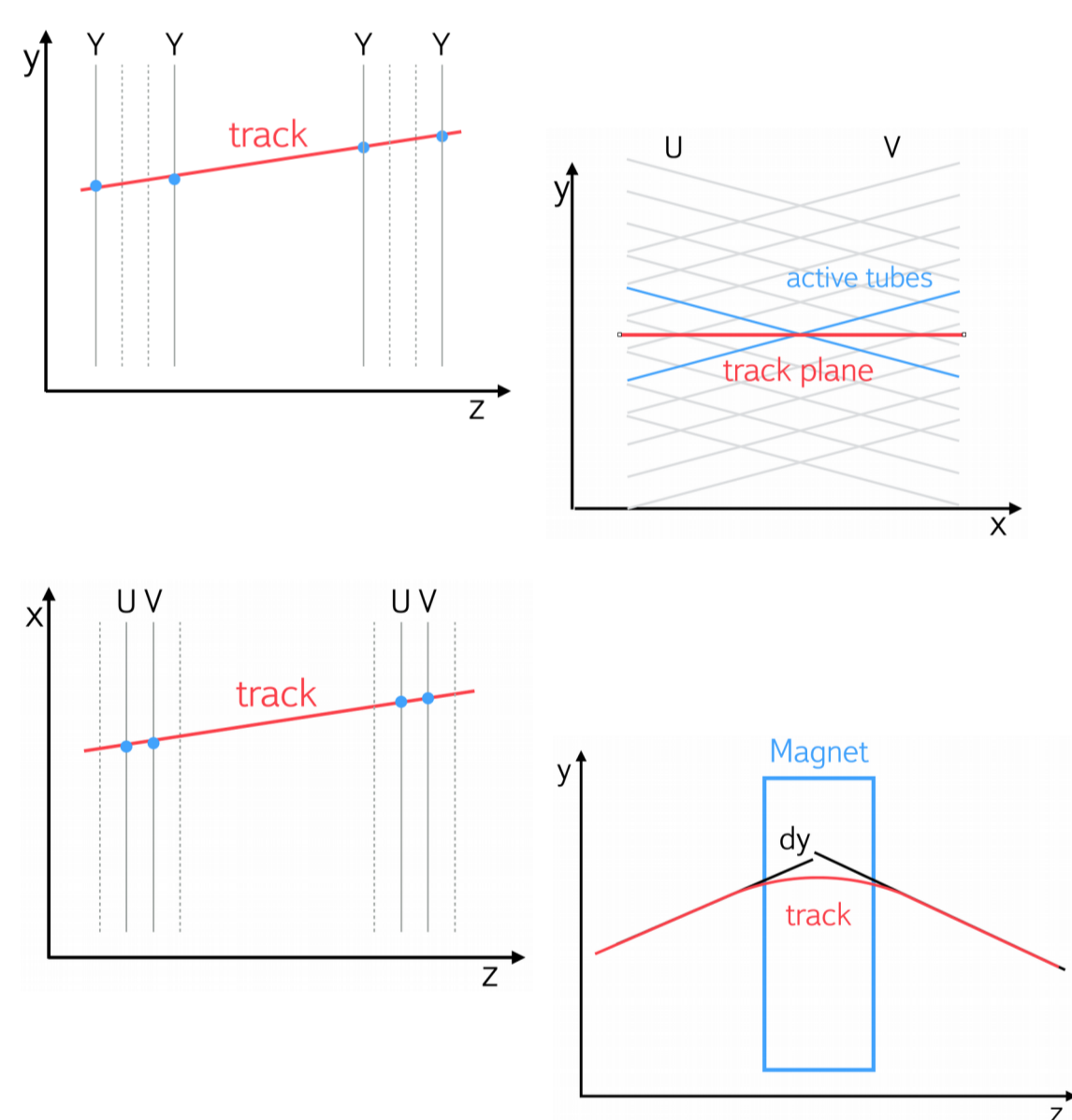
The SHiP is a new proposed fixed-target experiment at the CERN SPS accelerator. The goal of the experiment is searching for hidden particles predicted by the models of Hidden Sectors. The purpose of the SHiP Spectrometer Tracker is to reconstruct tracks of charged particles from the decay of neutral New Physics objects with high efficiency. The problem is to develop a method of pattern recognition based on the SHiP Spectrometer Tracker design. The baseline algorithm gives efficiency of 94.1% [1].

The Spectrometer Tracker Geometry



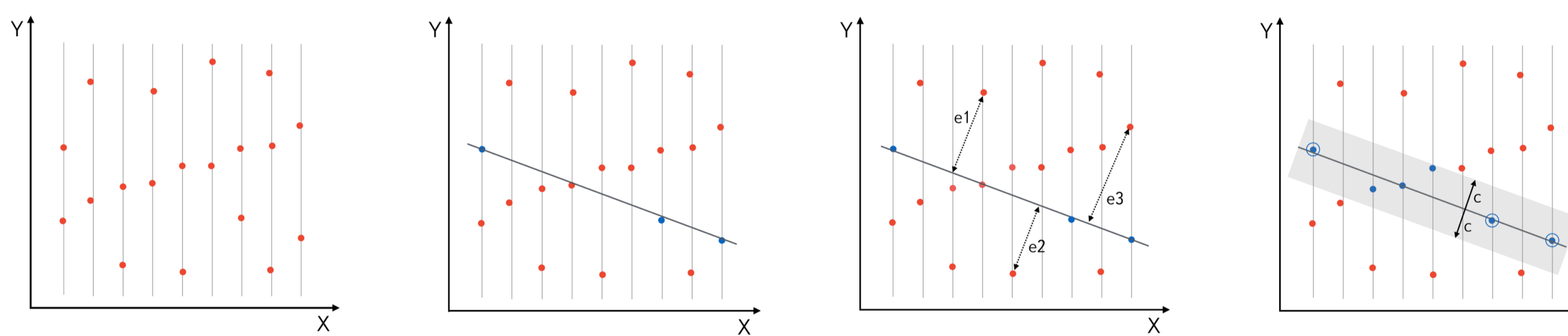
General Scheme of Track Recognition [1]

1. Look for tracks in the 16 layers with horizontal straw tubes (Y-views, y-z plane).
2. For each track found in the Y-view, intersect the plane defined by this track and the x-axis with the stereo (U,V) hits. This gives (z,x) coordinates.
3. Look for tracks in 16 layers of stereo-views in x-z plane using (z, x) coordinates of the intersections.
4. Combine tracks before and after the magnet. Reconstruct a particle momentum and charge.



RANSAC

RANSAC (RANdom SAMple Consensus) is an iterative method for regression problem with samples contaminated with outliers.



Searching for one track:

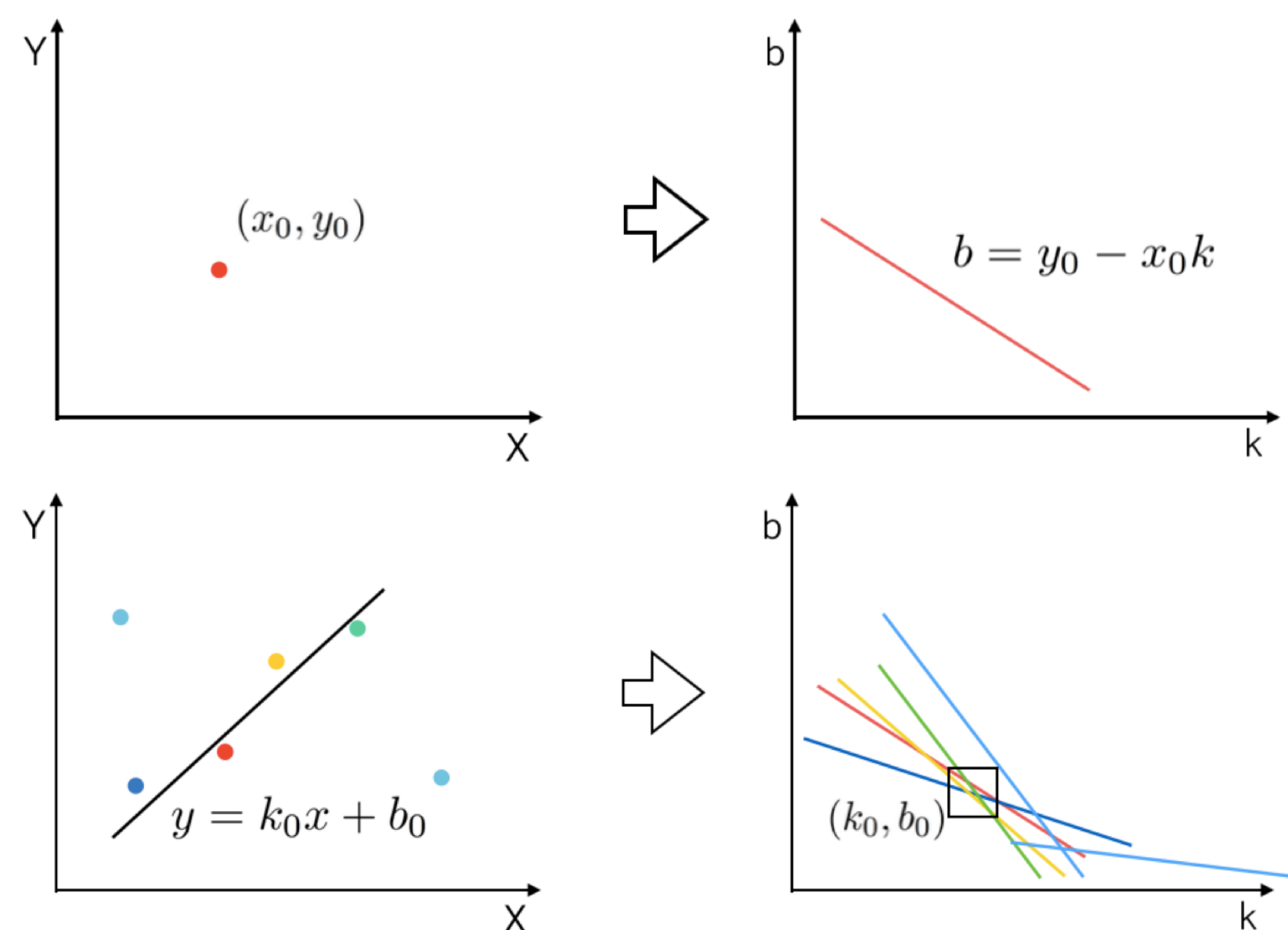
1. The RANSAC selects a random subset of the hits.
2. The linear model is fitted using this subset.
3. The error of the data with respect to the fitted model is calculated.
4. The number of inlier candidates is calculated.
5. Steps 1-4 are repeated until the maximum number of iterations.
6. A model with maximum number of inliers is returned.

Searching for all tracks:

1. Find a track among all unused hits.
2. Mark inlier hits as used.
3. Repeat steps 1-2 until number of hits per track is larger than min, or until desirable number of tracks are not found.

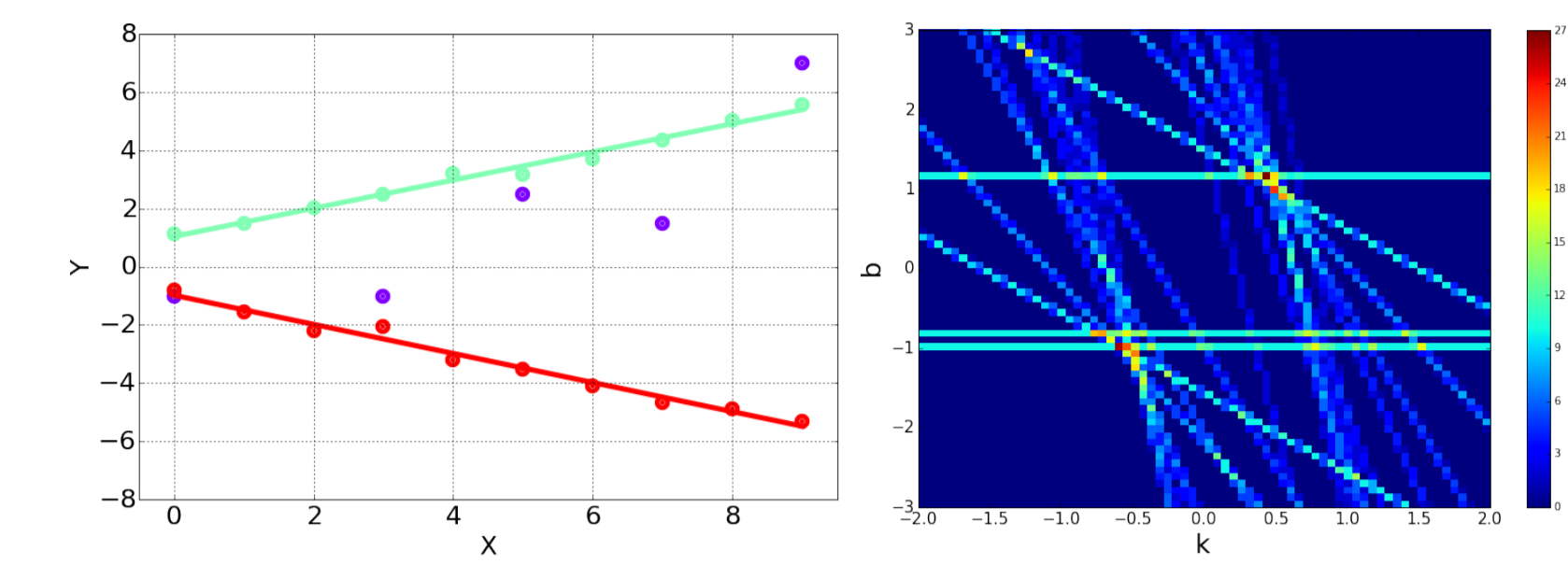
Hough Transform

For the linear model $y = kx + b$:



The tracks are looked for one by one using histogramming technique.

Hits of the found tracks are excluded from the histogram.



Artificial Retina

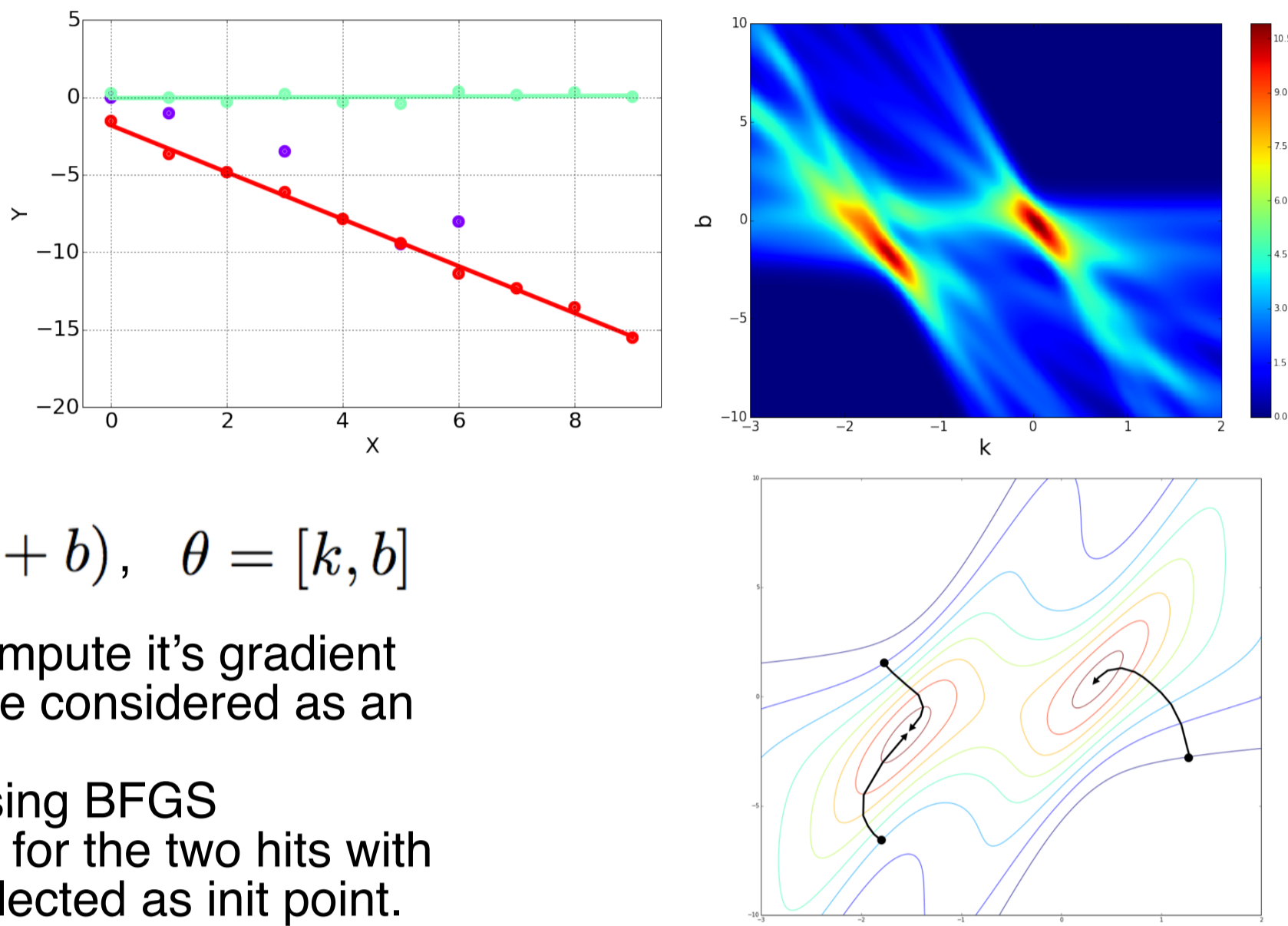
The artificial retina function is defined as:

$$R(\theta) = \sum_i e^{-\frac{\rho^2(\theta, x_i)}{\sigma^2}}$$

where $\rho(\theta, x_i)$ is distance between the i-th hit and a track with parameters θ .

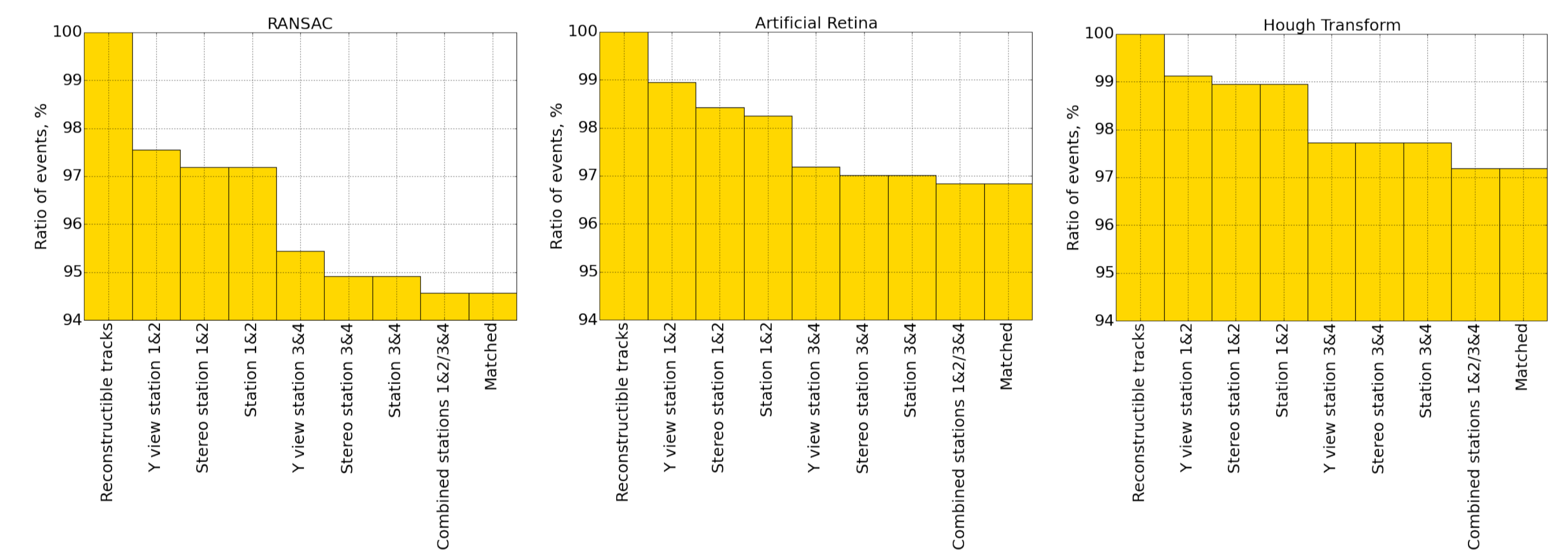
For 2D tracks: $\rho(\theta, x_i) = y_i - (kx_i + b)$, $\theta = [k, b]$

The artificial retina function allows to compute its gradient and hessian. So, the track finding can be considered as an optimization problem. The tracks are looked for one by one using BFGS optimization algorithm. Line parameters for the two hits with the maxima retina function value are selected as init point.

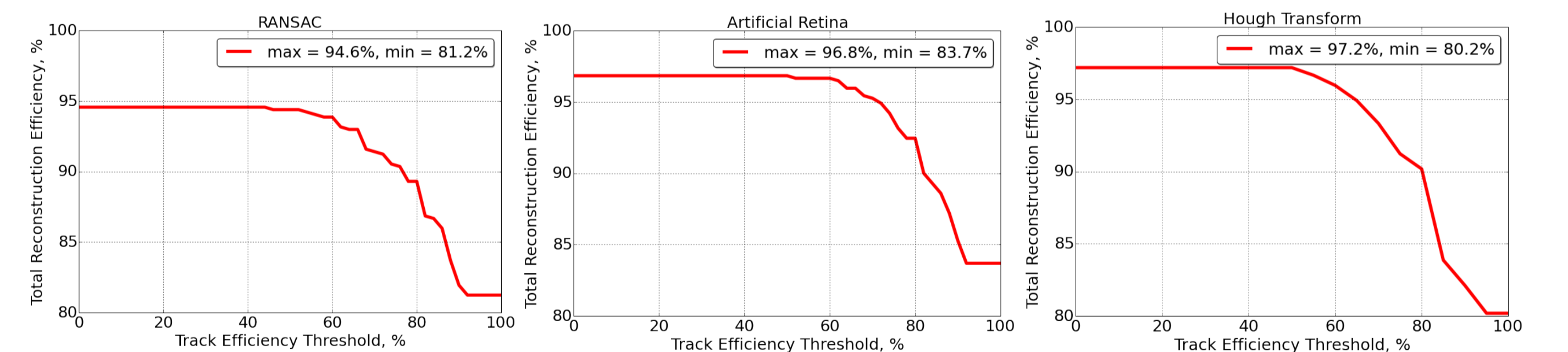


Results

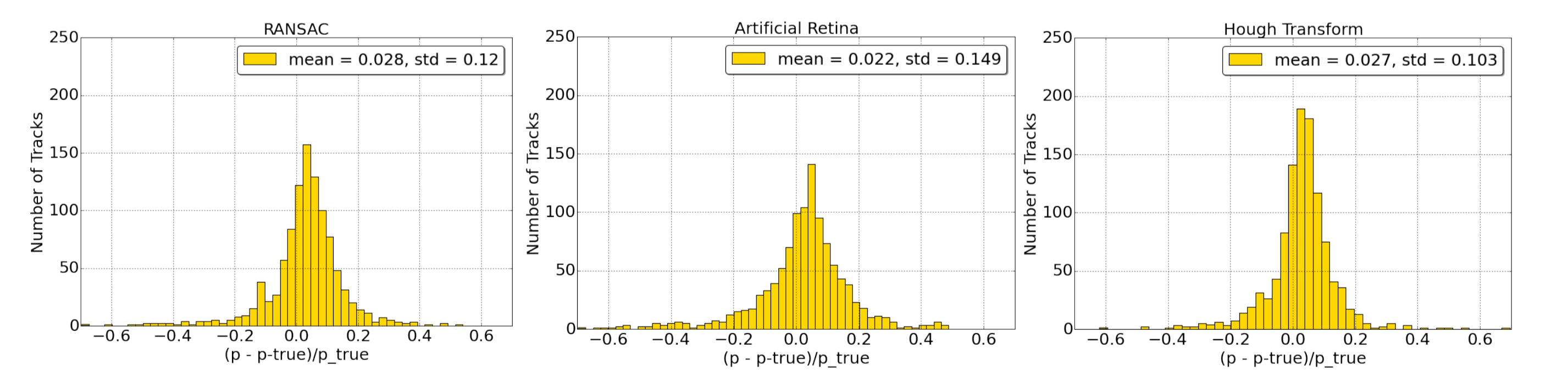
How many events pass through the track finding steps. If the two tracks (for muon and pion) of an event are not recognized, the event will not go to the next step. The last columns on the graphs below show total reconstruction efficiency.



Track efficiency is a criterion which specifies whether a certain particle has been found by the algorithm or not. If the qualified majority of hits, for example at least 70% originates from the same true particle, the track is said to reconstruct this particle. Dependence of total reconstruction efficiency from the track efficiency threshold:



The particles momenta reconstruction accuracy:



Method	Max Total RecoEff., %	Min Total RecoEff., %	Momentum Mean Rel. Error, %	Momentum Std. Rel. Error, %
Baseline[1]	94.1	-	3.2	-
RANSAC	94.6	81.2	2.8	12
Artificial Retina	96.8	83.7	2.2	14.9
Hough Transform	97.2	80.2	2.7	10.3

Conclusion

This study shows that the different track finding methods have the total reconstruction efficiencies larger than 94.1%. The Artificial Retina and Hough Transform methods demonstrates the best results. All methods have mean particles momenta error about 2.5% and its standard deviation about 12%. Thus, decreasing the error needs more investigations.

References

[1] H. Dijkstra, M. Ferro-Luzzi, E. van Herwijnen and T. Ruf Simulation and pattern recognition for the SHiP Spectrometer Tracker, SHiP-PUB-2015-002, March 31, 2015, CERN-SHIP-NOTE-2015-002