Implementation of New Track Pattern Recognition Methods into FairShip

Mikhail Hushchyn, Oleg Alenkin, Eric Van Herwijnen, Andrey Ustyuzhanin

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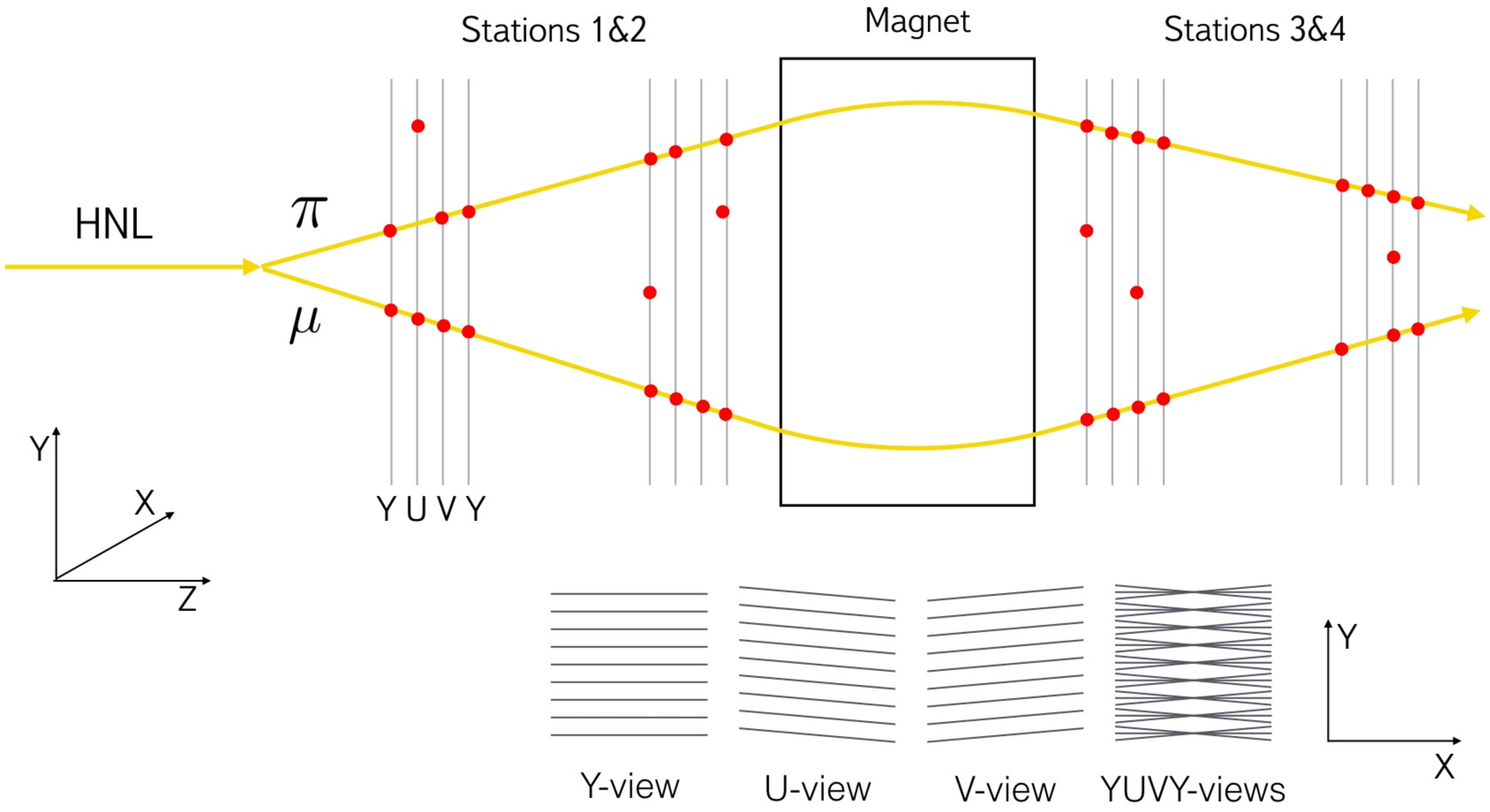
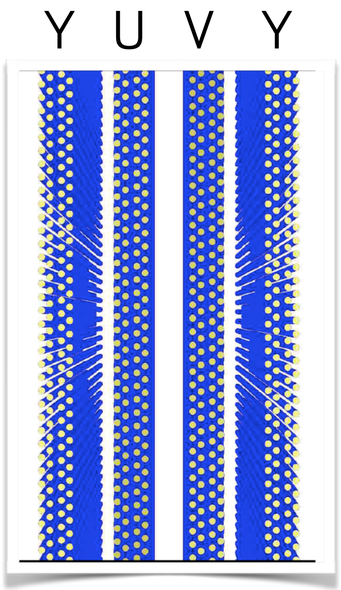
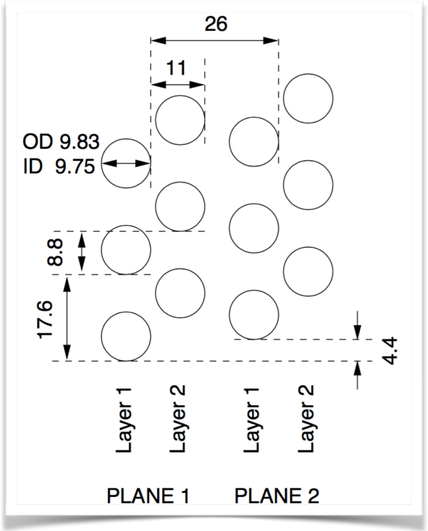
Straw Tracker

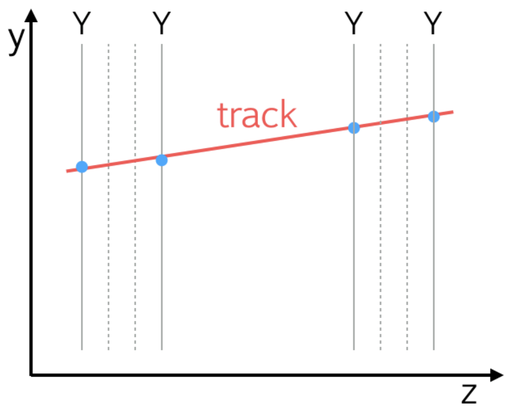






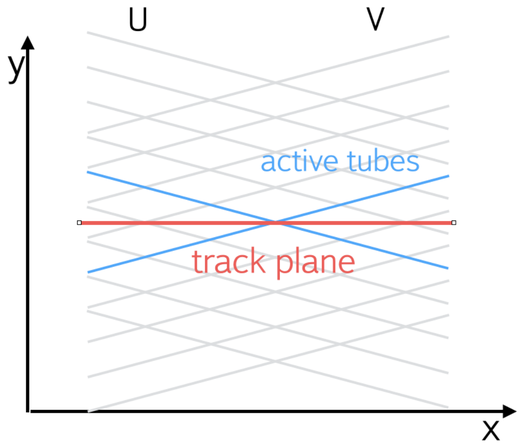
The PR Procedure Overview

1



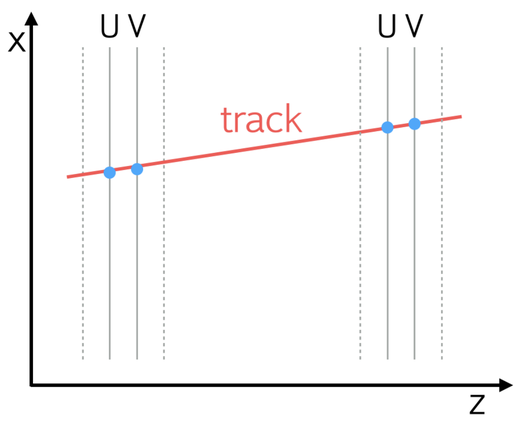
Look for tracks in the 16 layers with horizontal straw tubes (Y-views, y-z plane).

2



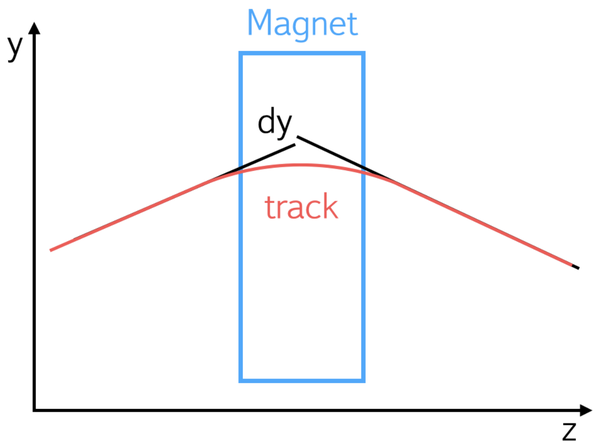
For each track found in the Y-view, intersect the plane defined by this track and the x-axis with the stereo (U,V) hits. This gives (z,x) coordinates.

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.

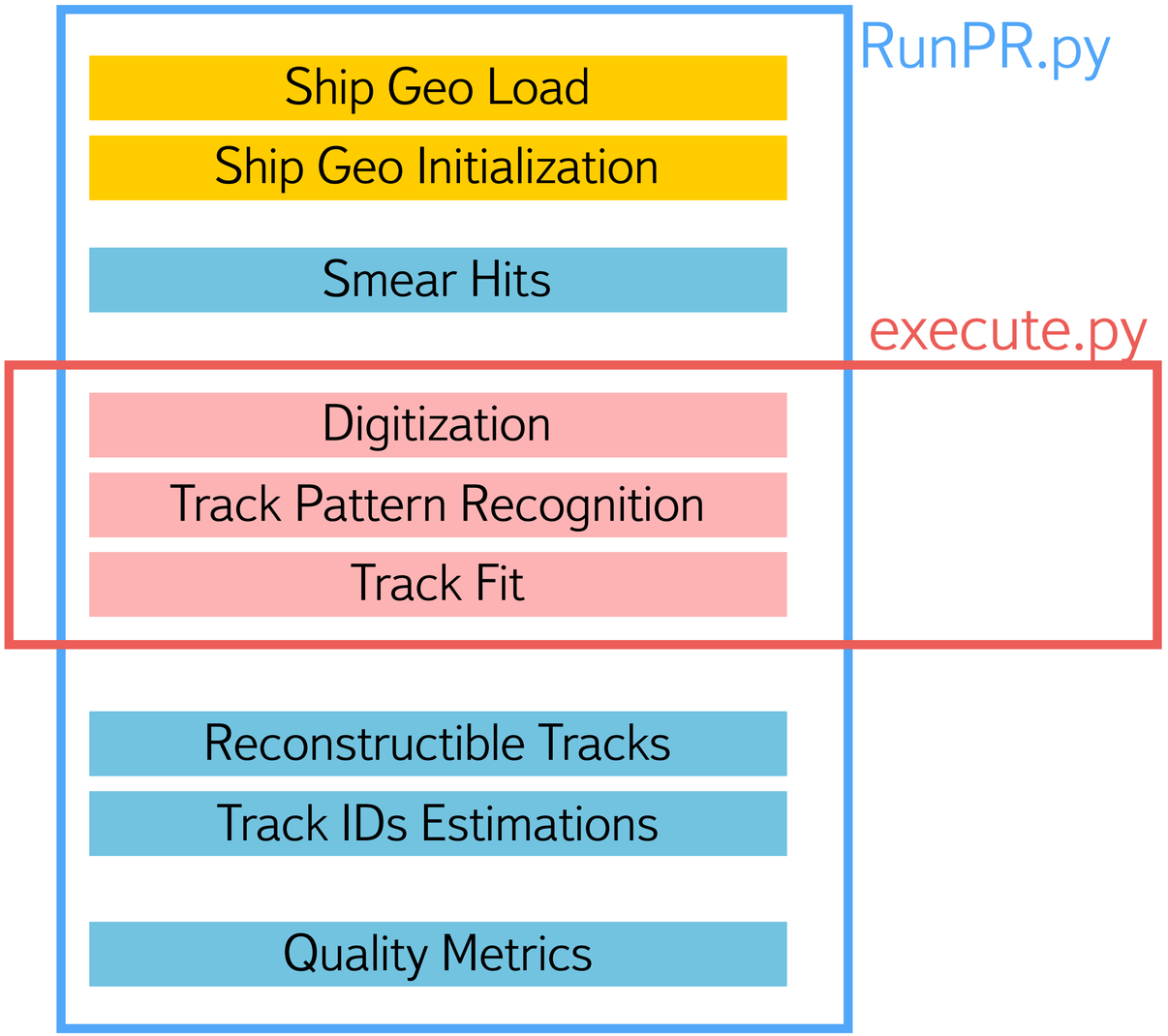
New PR in FairShip

New track pattern recognition methods are implemented into FairShip:

- https://github.com/ShipSoft/FairShip/tree/master/Developments/track_pattern_recognition (follow pull requests)
- The code description and instructions how to run it are provided.
- It have not integrated into **FairShip/macro/ShipReco.py** yet.

Code Architecture

- The PR procedure is divided into separate blocks
- The blocks interconnect with each other using defined APIs
- No global variables
- Changes in one block don't affect the others
- Easy to update/upgrade
- Each function is described



Results

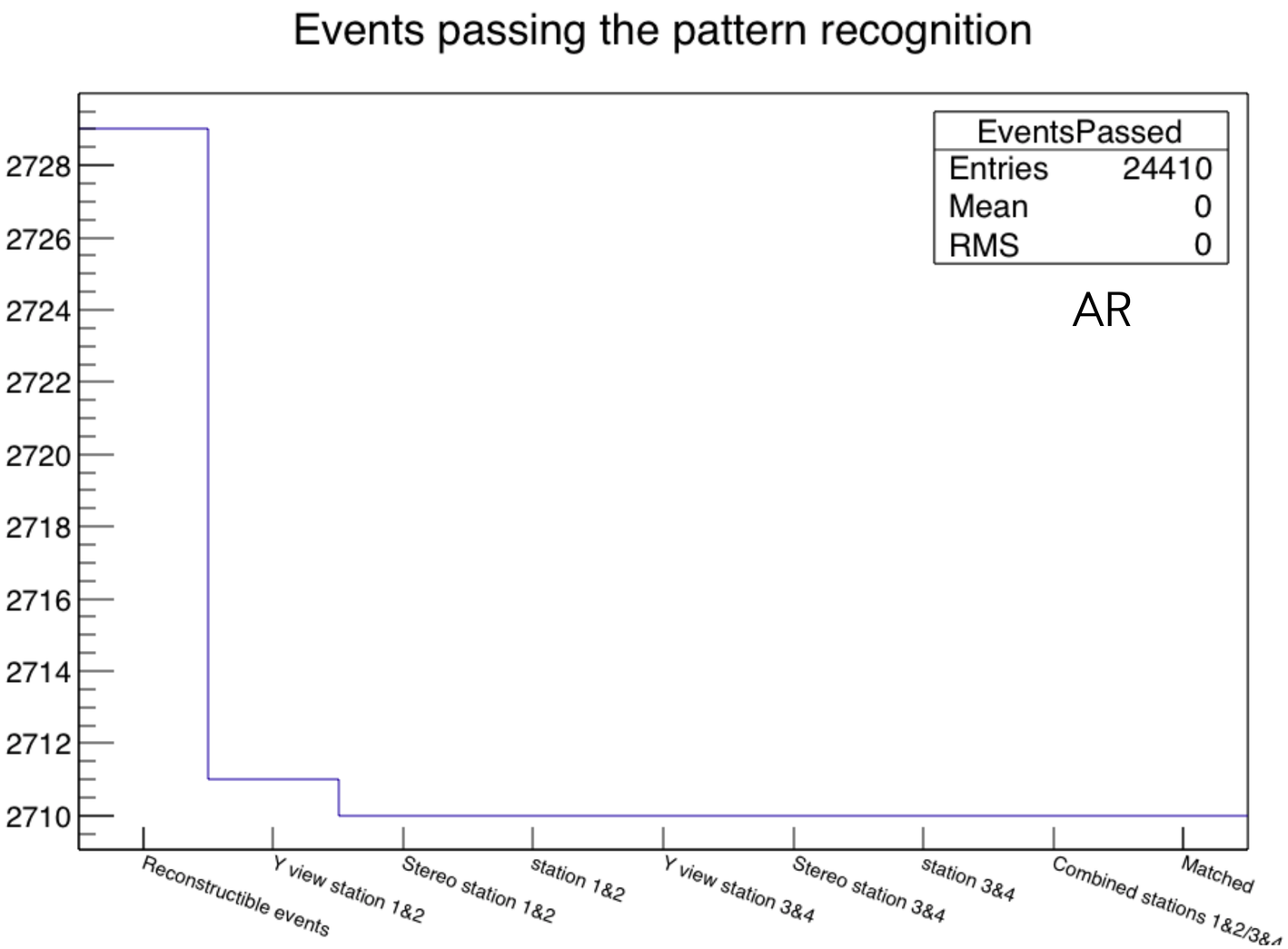
Test sample: 30k events

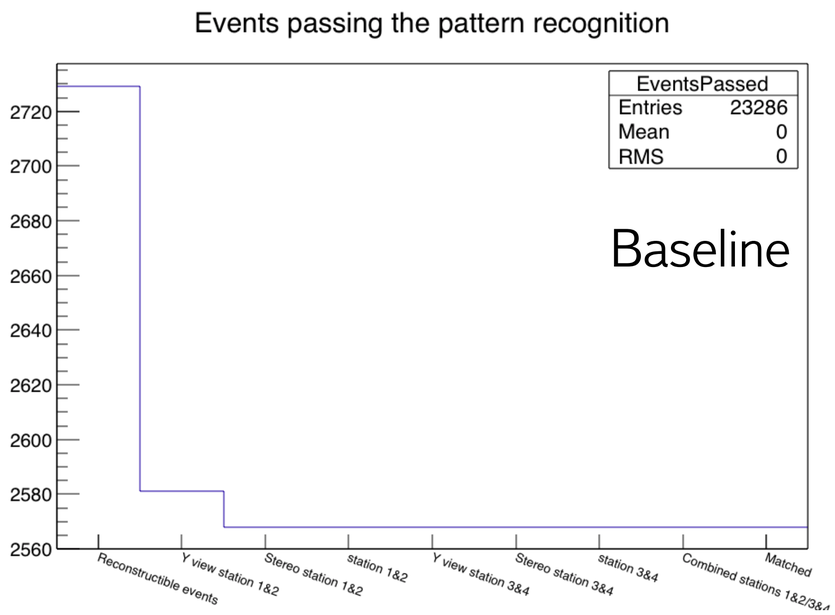
Method**	Events Passed PR, %	Track Efficiency*, %	Left-Right Amb. Res., %	Time, ms/ event
Baseline	94.1	99.2	94.5	18
Hough Transform	98.7	99.3	94.9	34
Artificial Retina	99.3	99.8	98.3	38
Reconstructor	96.8	99.0	82.9	39

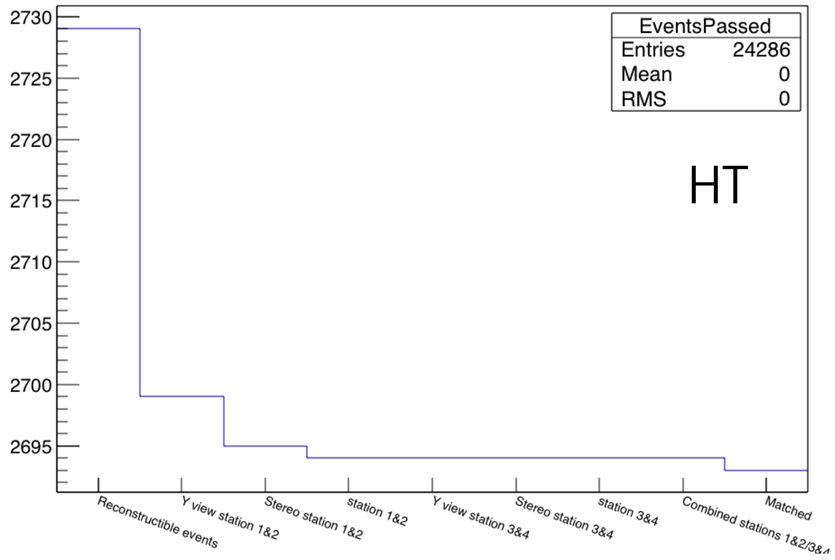
* **Track Efficiency** is N_correct_reco_hits / N_reco_hits

** Description of the methods are in backup slides.

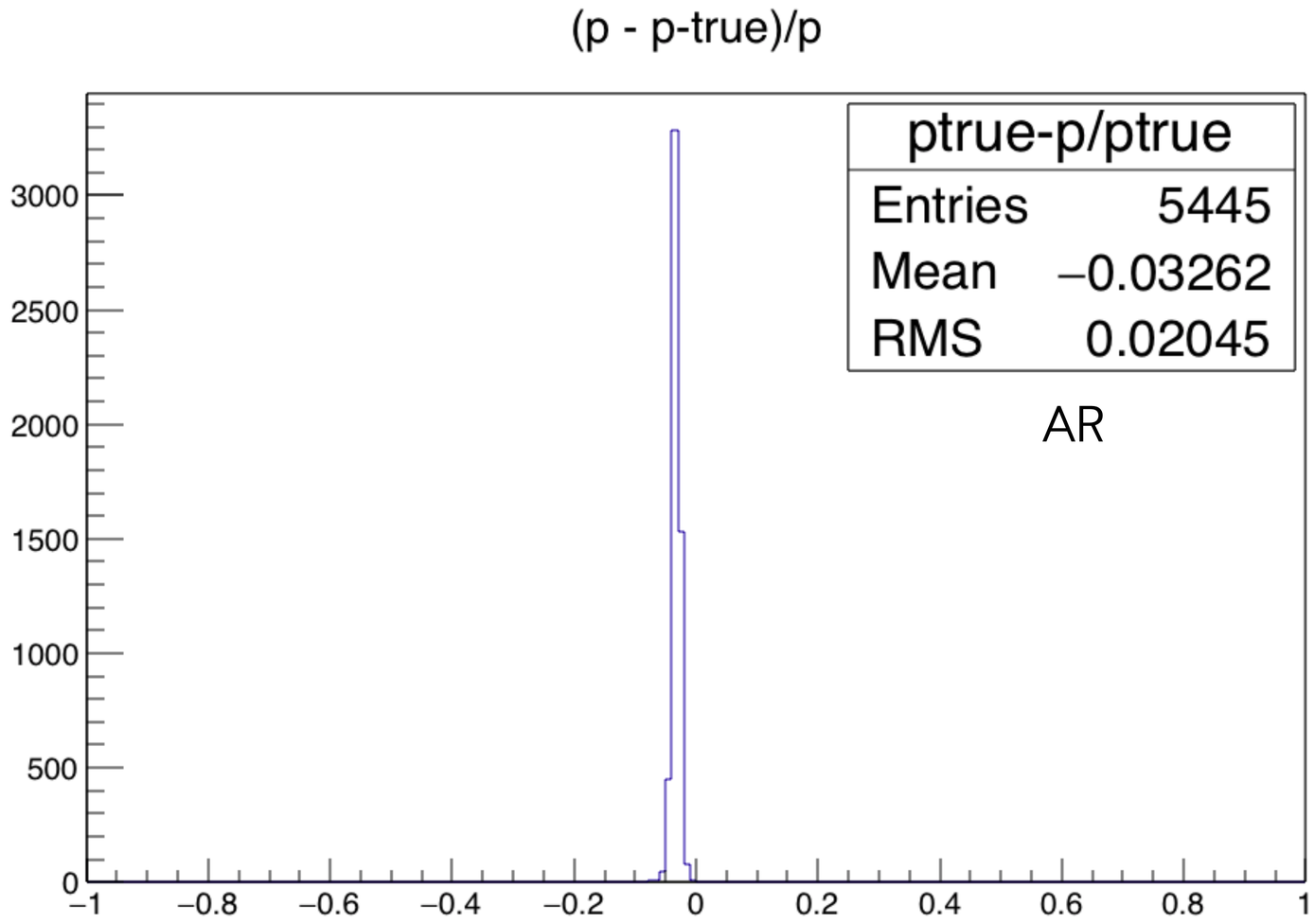
Events Passed the PR

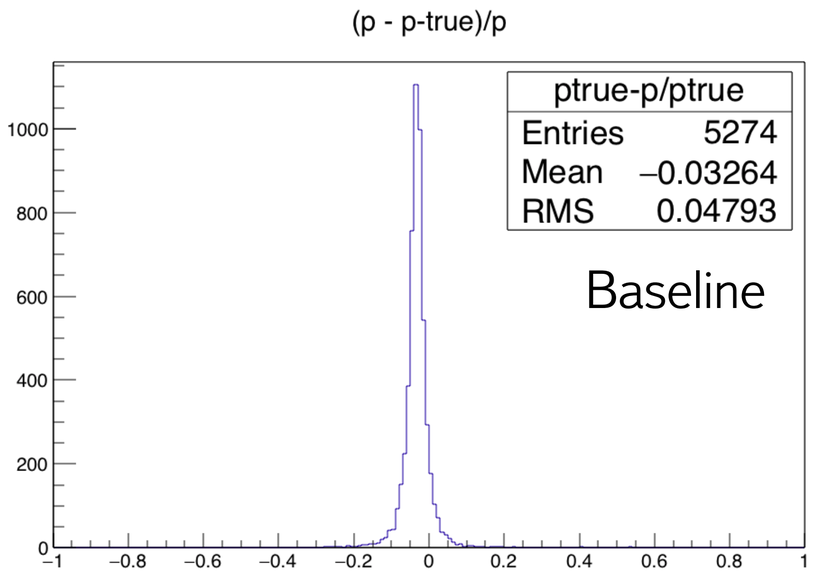


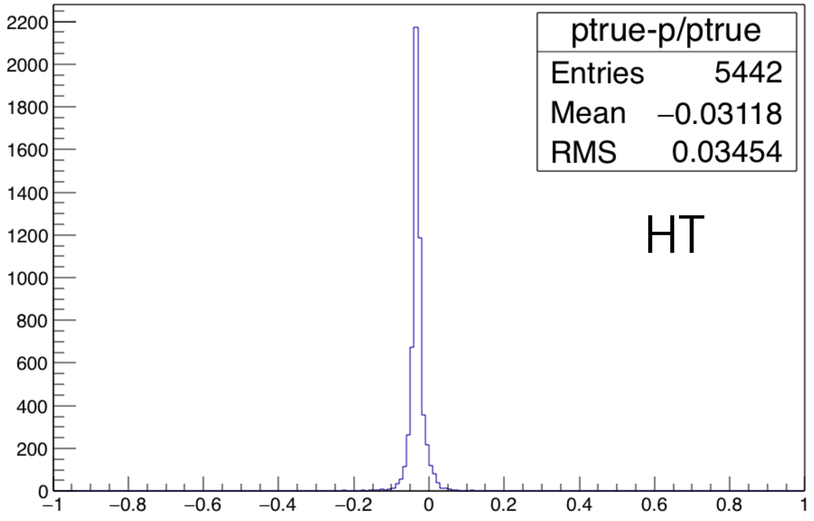




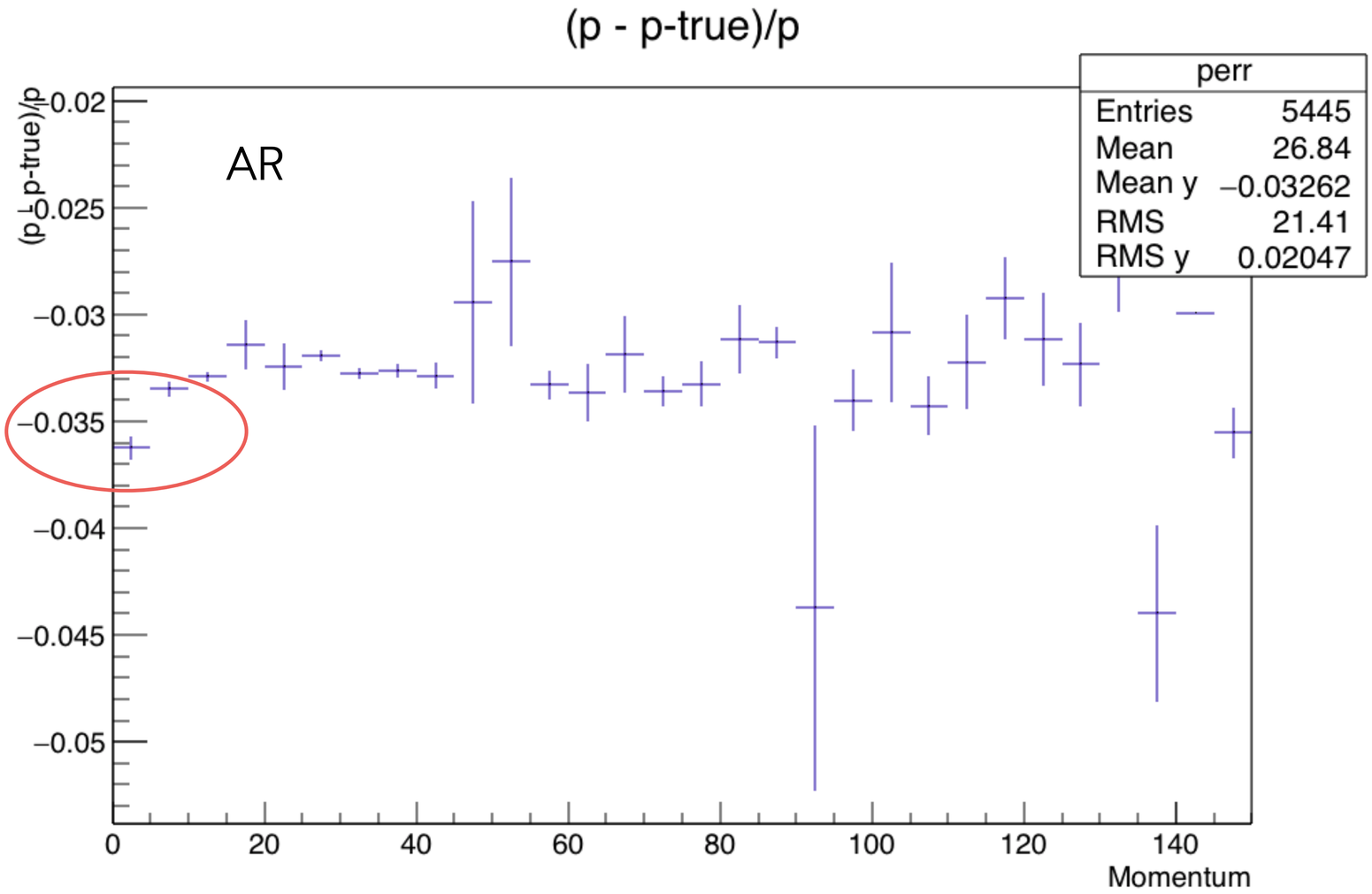
Momentum Reconstruction Accuracy

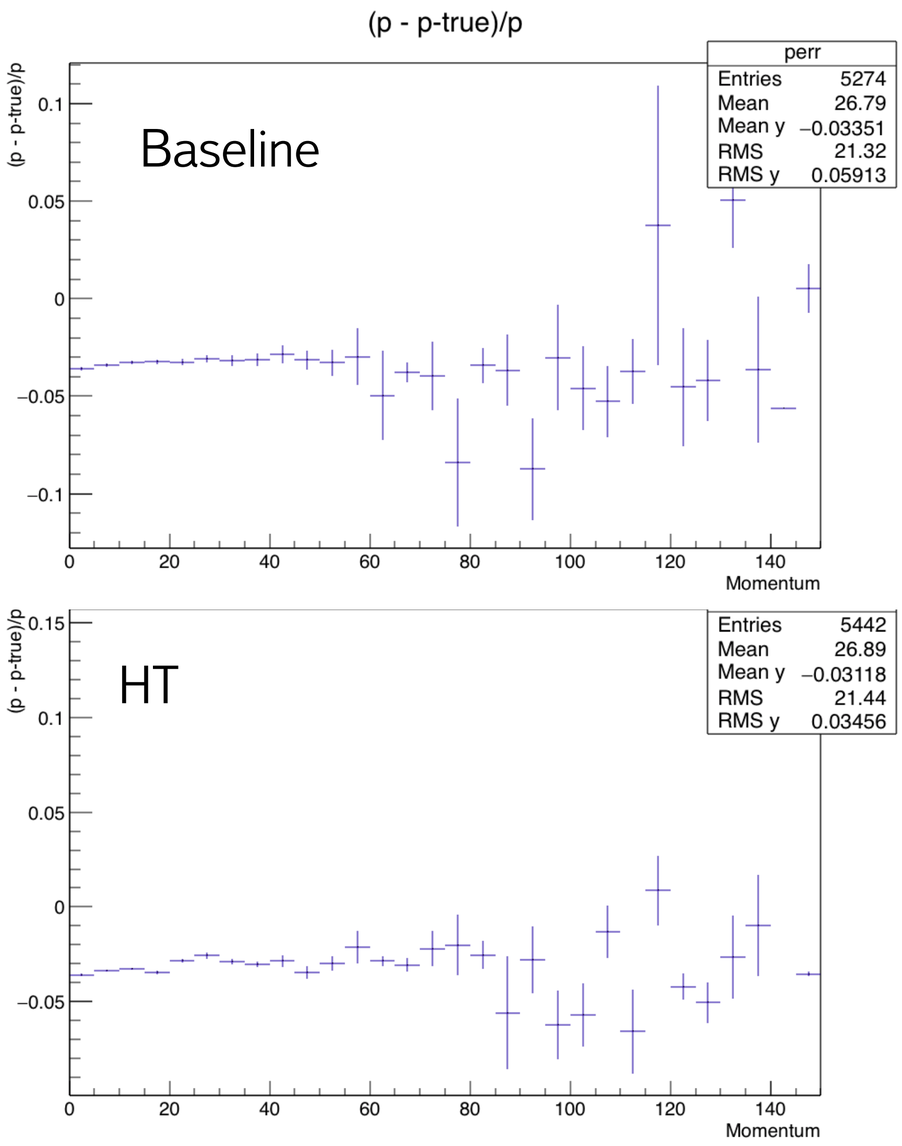




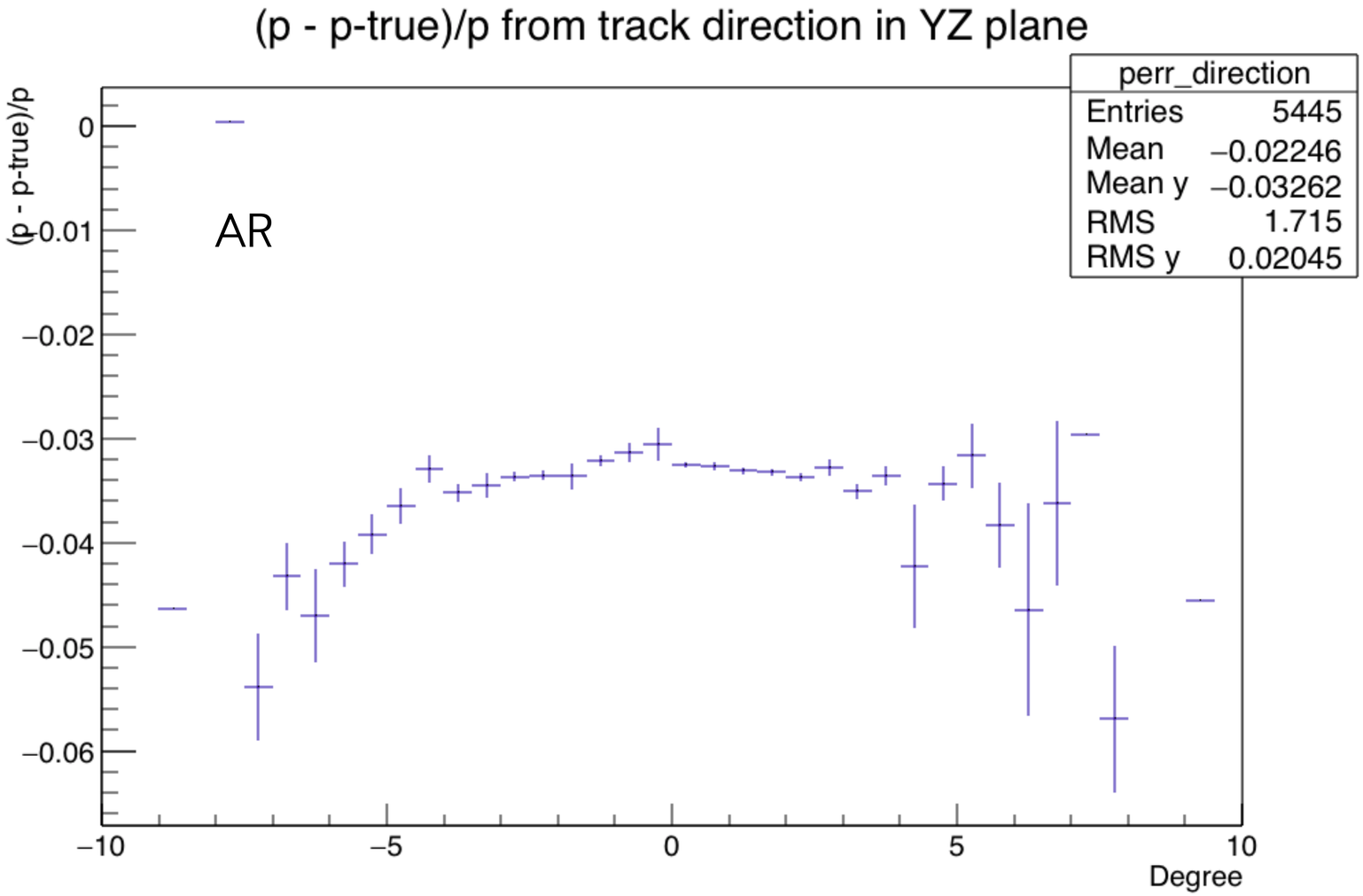


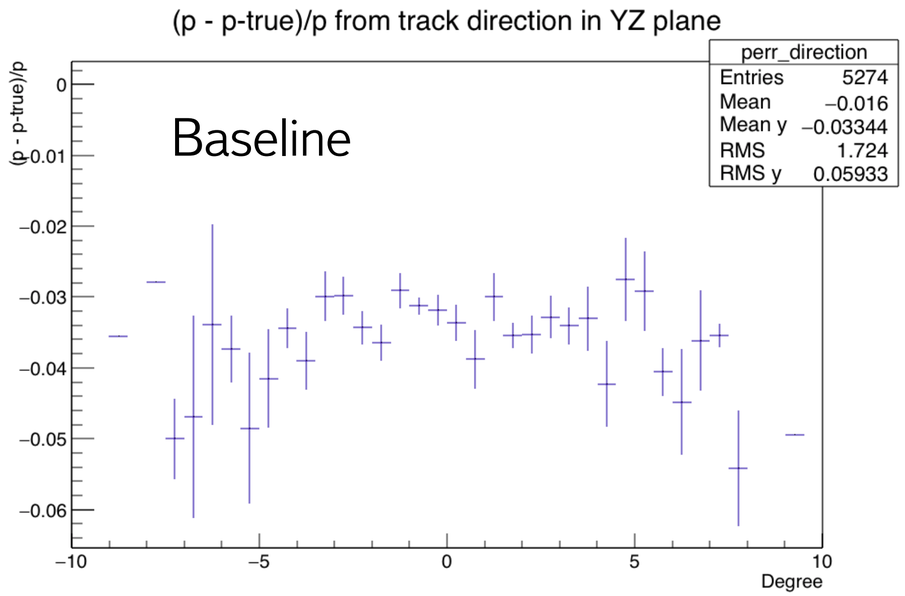
Momentum Reconstruction Accuracy vs Momentum

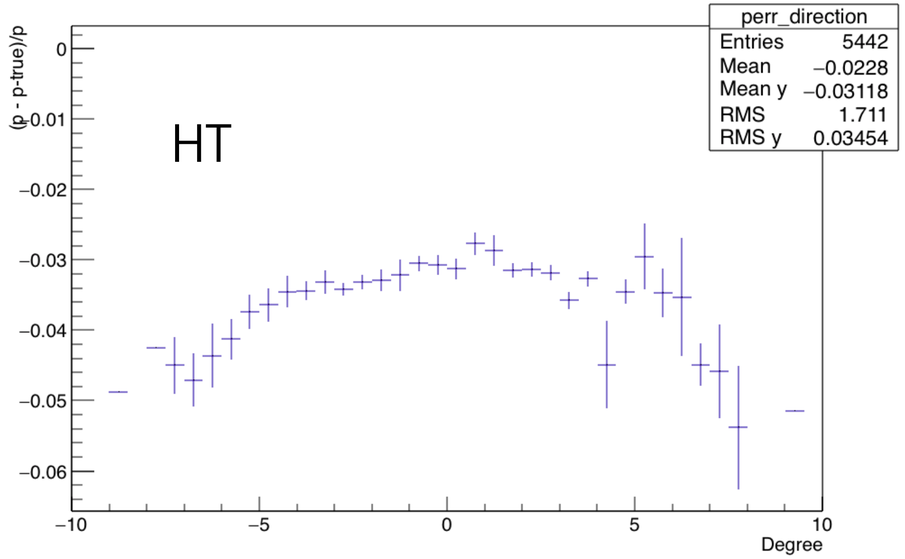




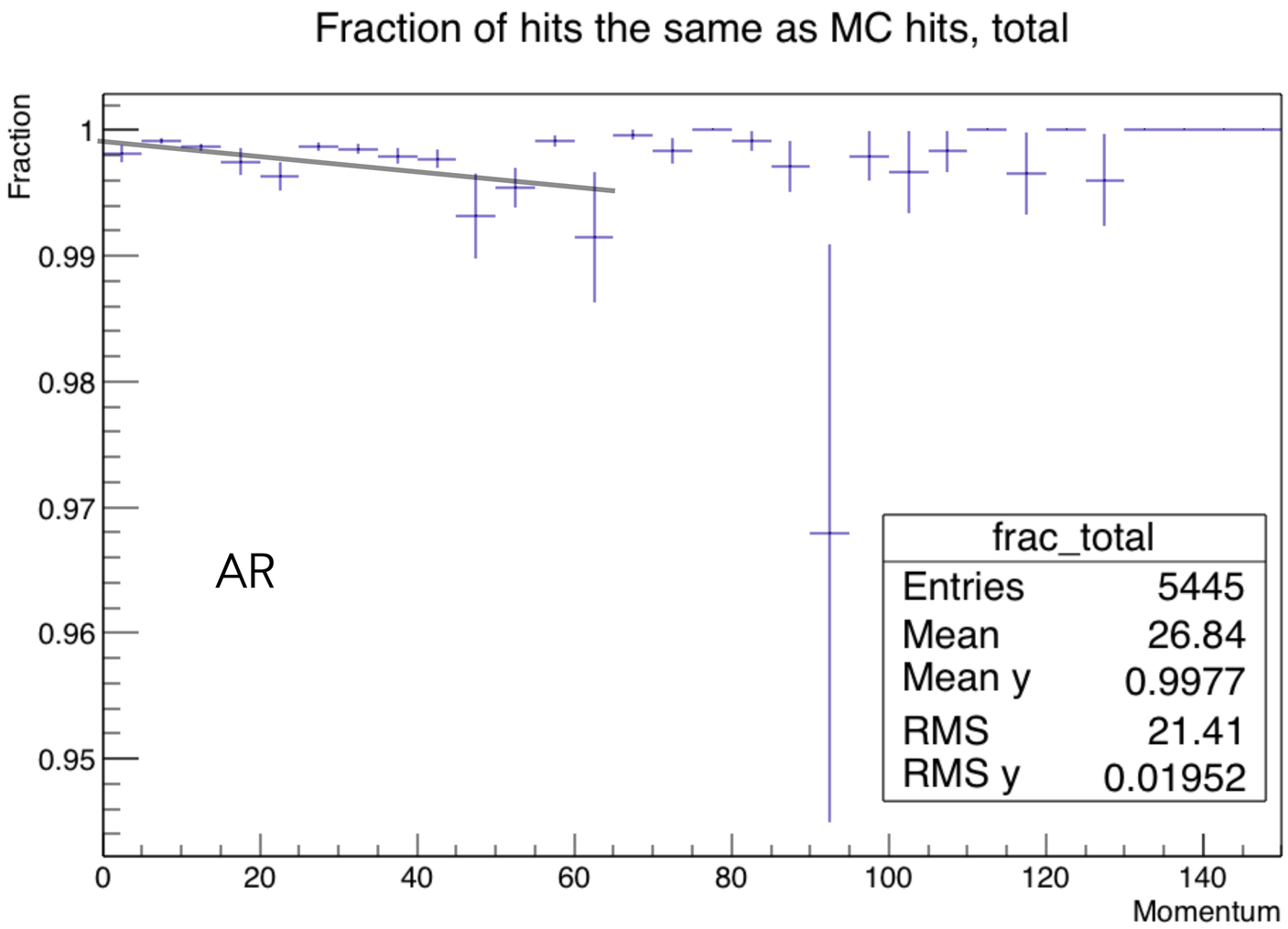
Momentum Rec. Acc. vs Track Slope in YZ

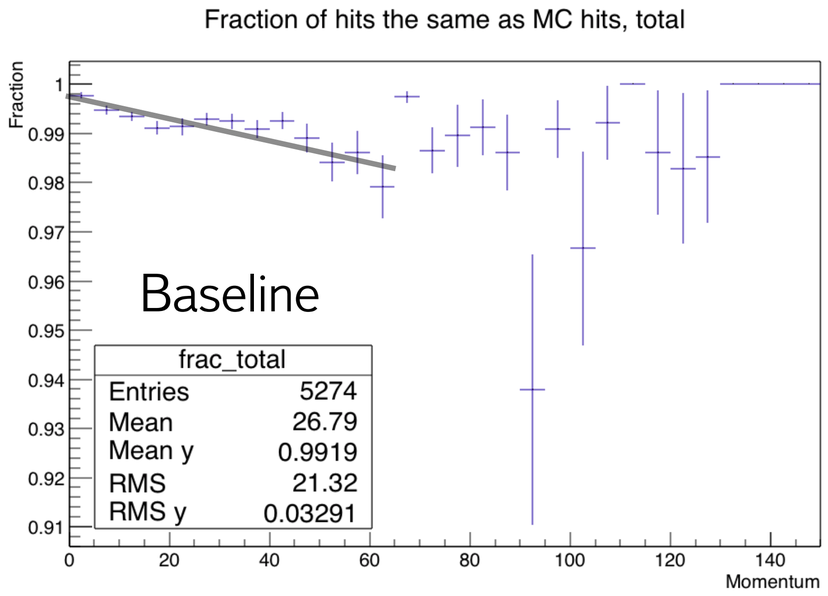


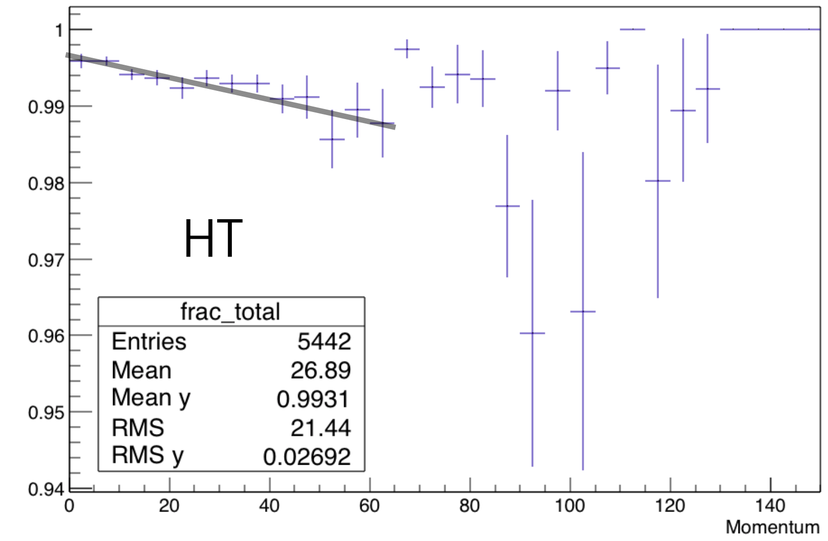




Track Efficiency vs Momentum







RAM Leakage

Track PR methods use ROOT.genfit.DAF() to fit recognized tracks.

Experiments show that the fit is main source of RAM leakage:

- approx. 150 MB per 1k events in new implementation of the PR methods
- approx. 60 MB per 1k events in macro/ShipReco.py (current PR)

Other steps of PR use negligible amount of RAM.

Conclusion

Method**	Events Passed PR, %	Track Efficiency*, %	Left-Right Amb. Res., %	Time, ms/ event
Baseline	94.1	99.2	94.5	18
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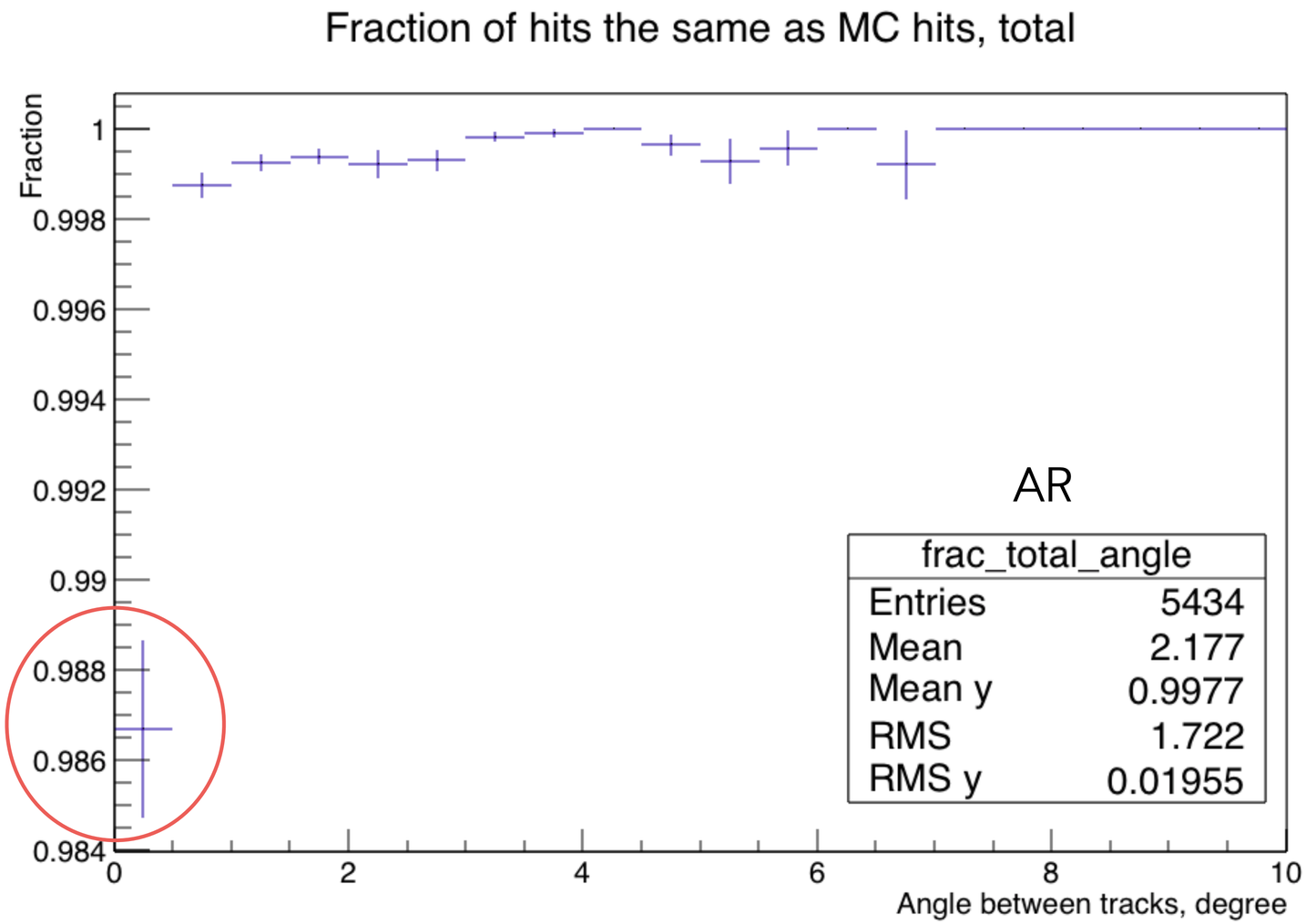
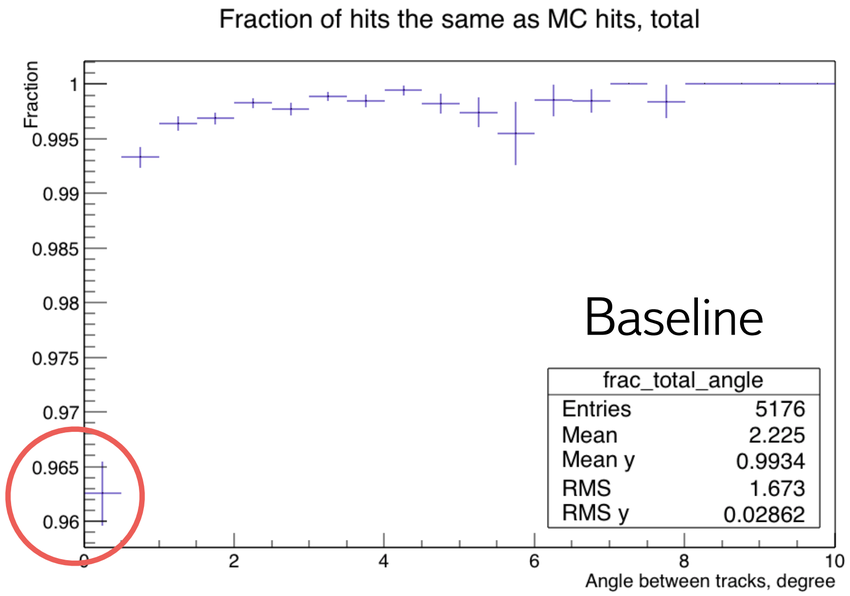
Artificial Retina	99.3	99.8	98.3	38
Reconstructor	96.8	99.0	82.9	39

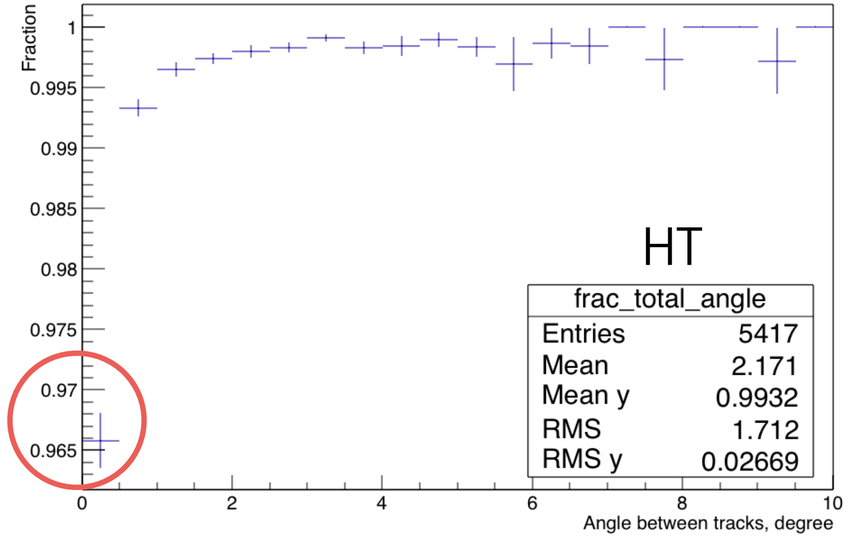
- The best and more accurate PR method is AR
- Speed-Efficiency balance
- The methods are implemented into FairShip

Backup

Track Efficiency vs Angle between Tracks in YZ

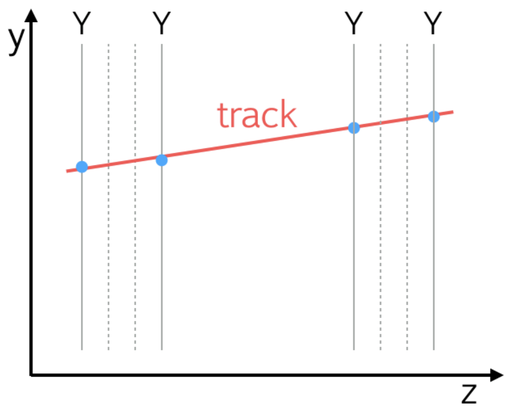






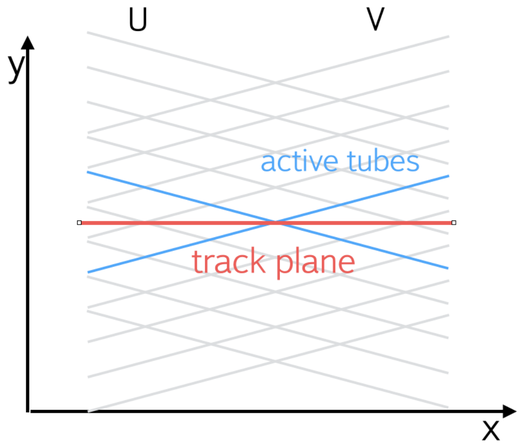
The PR Procedure Overview

1



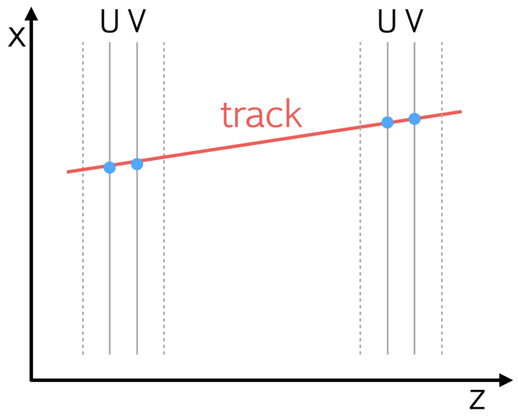
Look for tracks in the 16 layers with horizontal straw tubes (Y-views, y-z plane).

2



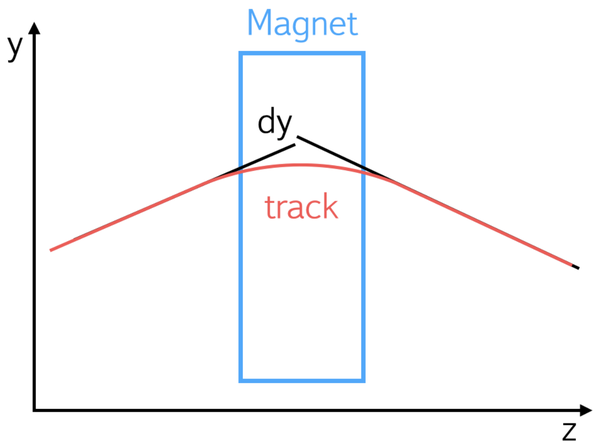
For each track found in the Y-view, intersect the plane defined by this track and the x-axis with the stereo (U,V) hits. This gives (z,x) coordinates.

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.

Baseline [1]

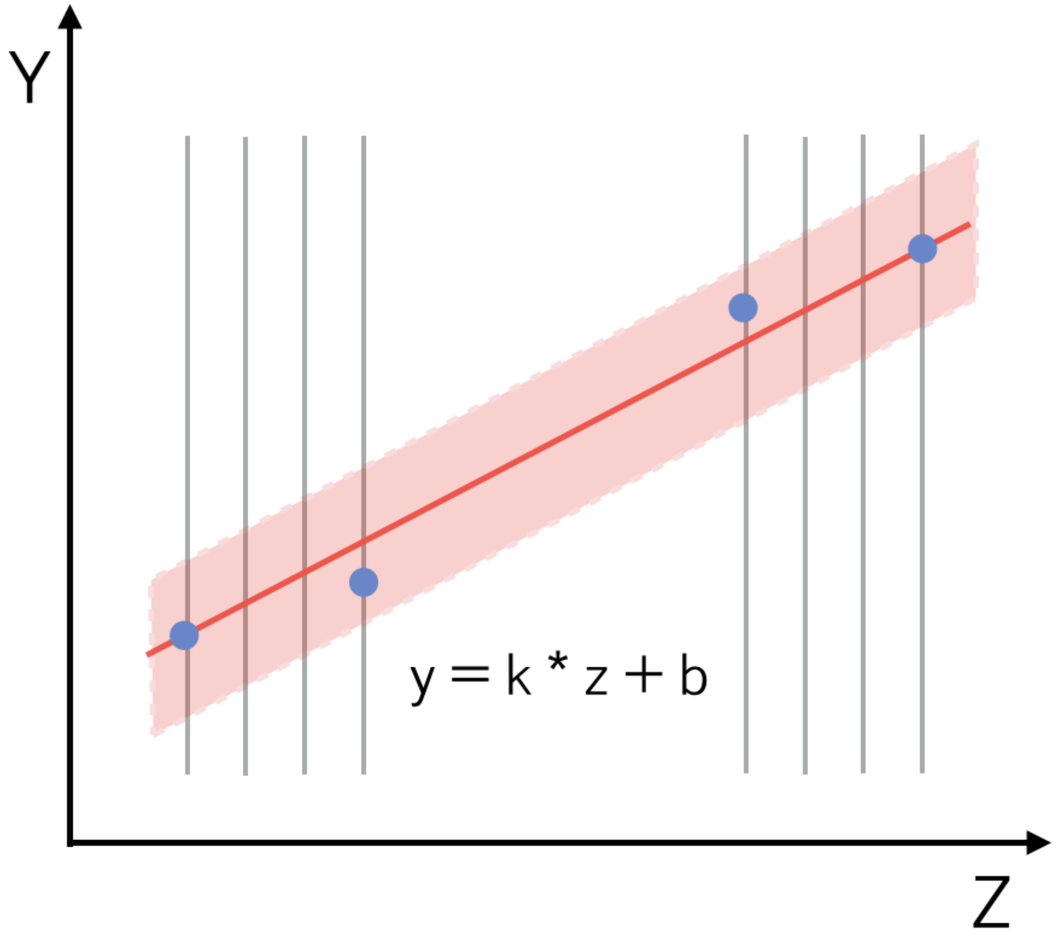
Track PR procedure in a plane:

1. Estimate line parameters (k, b) for two hits.

2. Find track hits within a window width from the line.

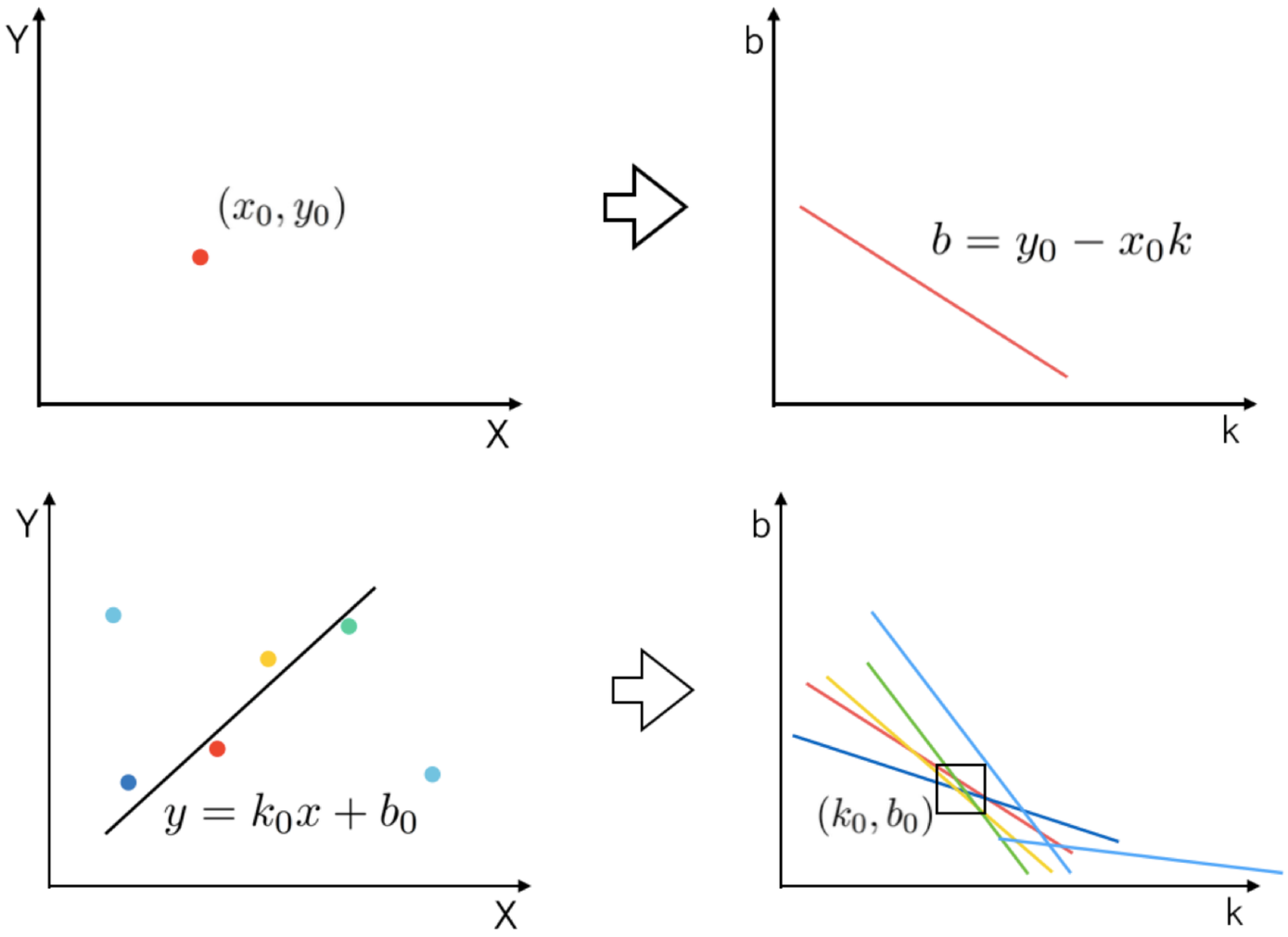
3. Repeat steps 1 and 2 for each pair of hits.

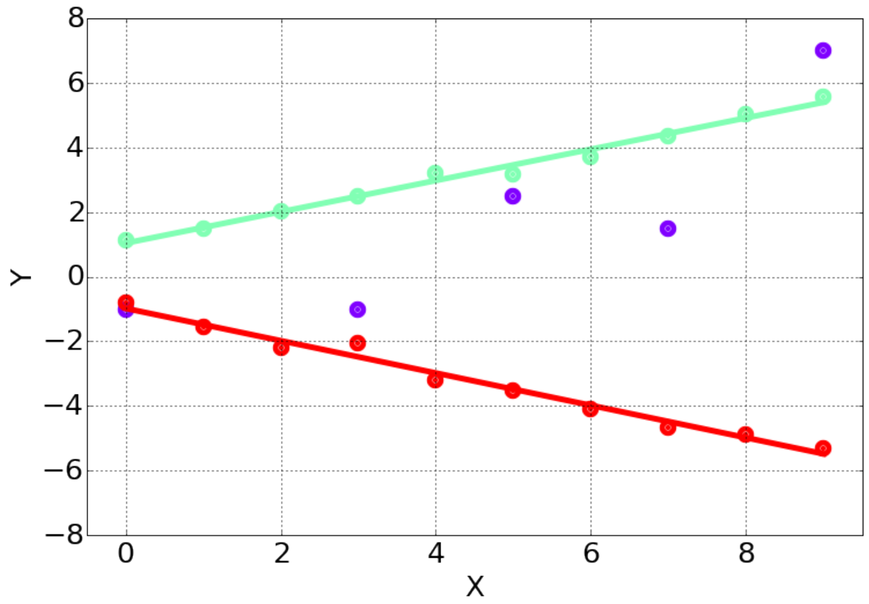
4. Select two tracks with the largest number of unique hits.

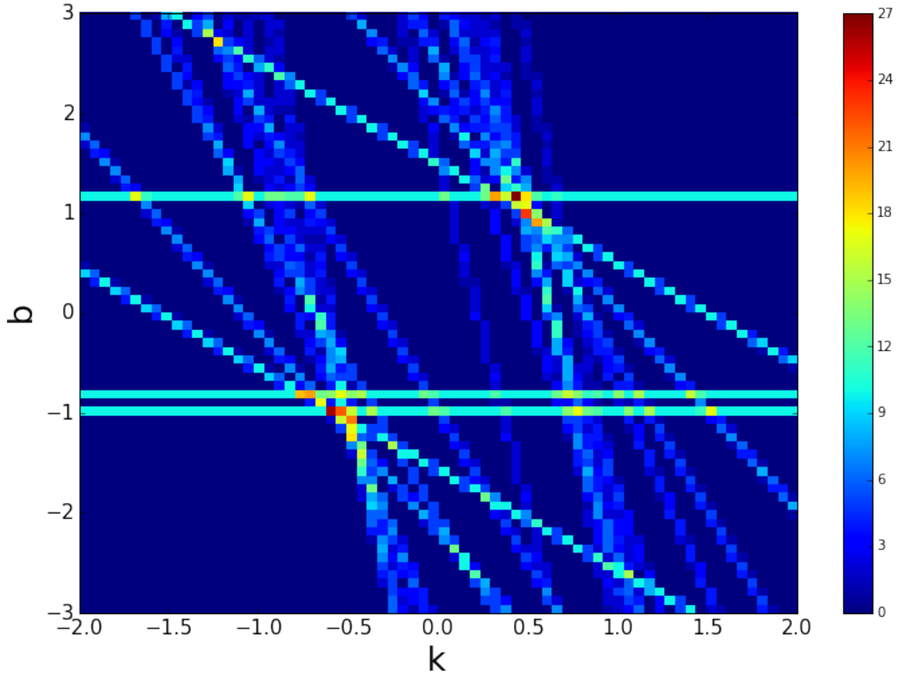


[1] H. Dijkstra, M. Ferro-Luzzi, E. van Herwijnen and T. Ruf Simulation and pattern recognition for the SHiP Spectrometer Tracker, SHiP-PUB-2015-002, March 31, 2015, CERN-SHiP-NOTE-2015-002

Hough Transform







Hough Transform

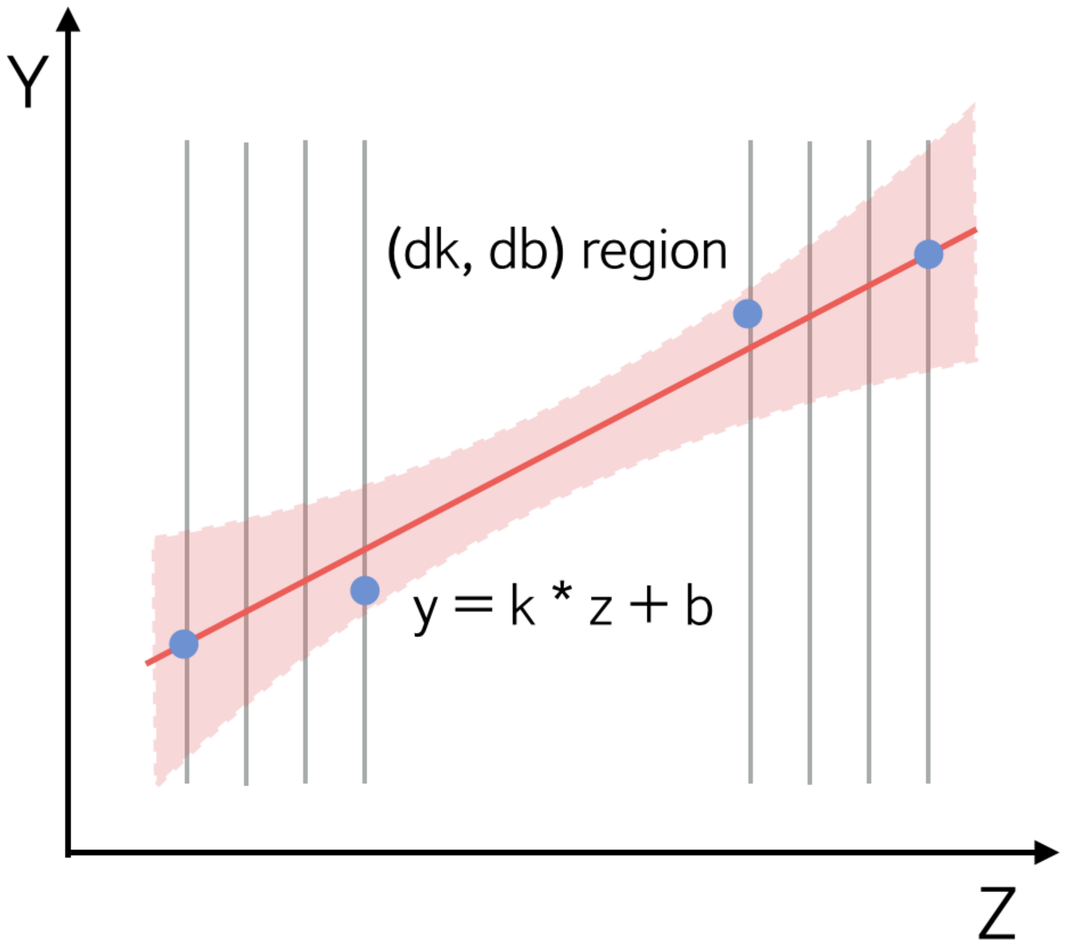
Track PR procedure in a plane:

1. Estimate line parameters (k, b) for two hits.

2. Use Hough Transform to find track hits within (dk, db) parameters region.

3. Repeat steps 1 and 2 for each pair of hits.

4. Select two tracks with the largest number of unique hits.



Artificial Retina

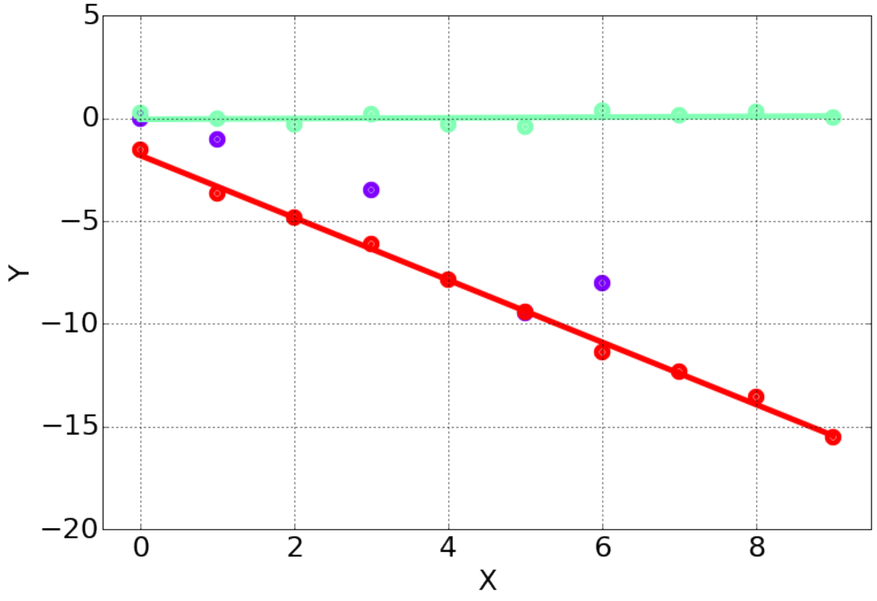
The artificial retina function is defined as:

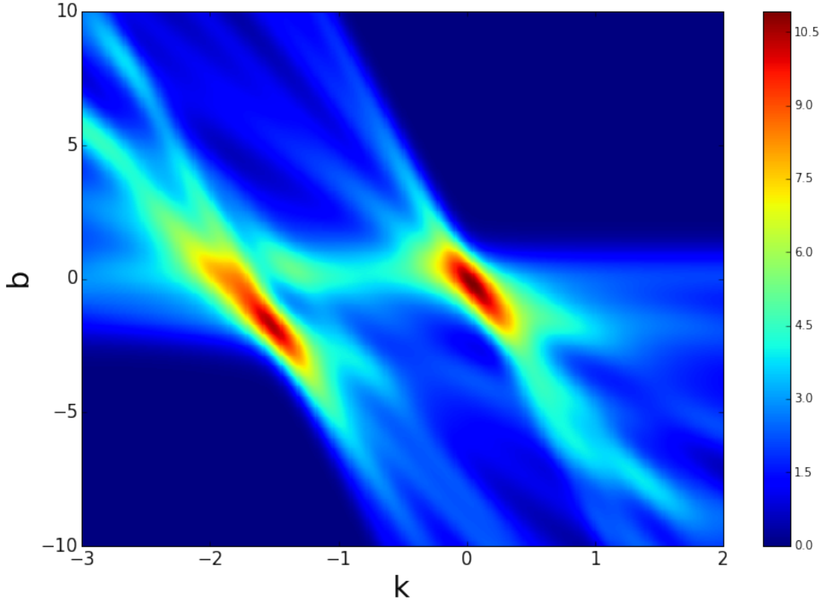
$$R(\theta) = \sum_i e^{-\frac{\rho^2(\theta, x_i)}{\sigma^2}}$$

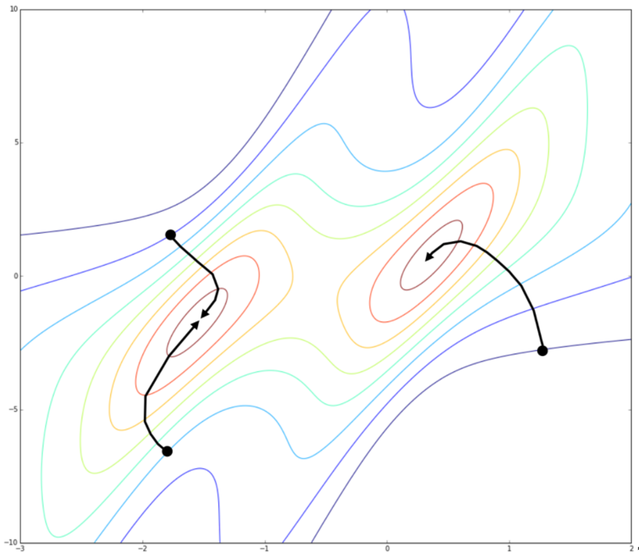
where $\rho(\theta, x_i)$ is distance between the i-th hit and a track with parameters θ .

For 2D tracks:

$$\rho(\theta, x_i) = y_i - (kx_i + b) \qquad \theta = [k, b]$$







Artificial Retina

Track PR procedure in a plane:

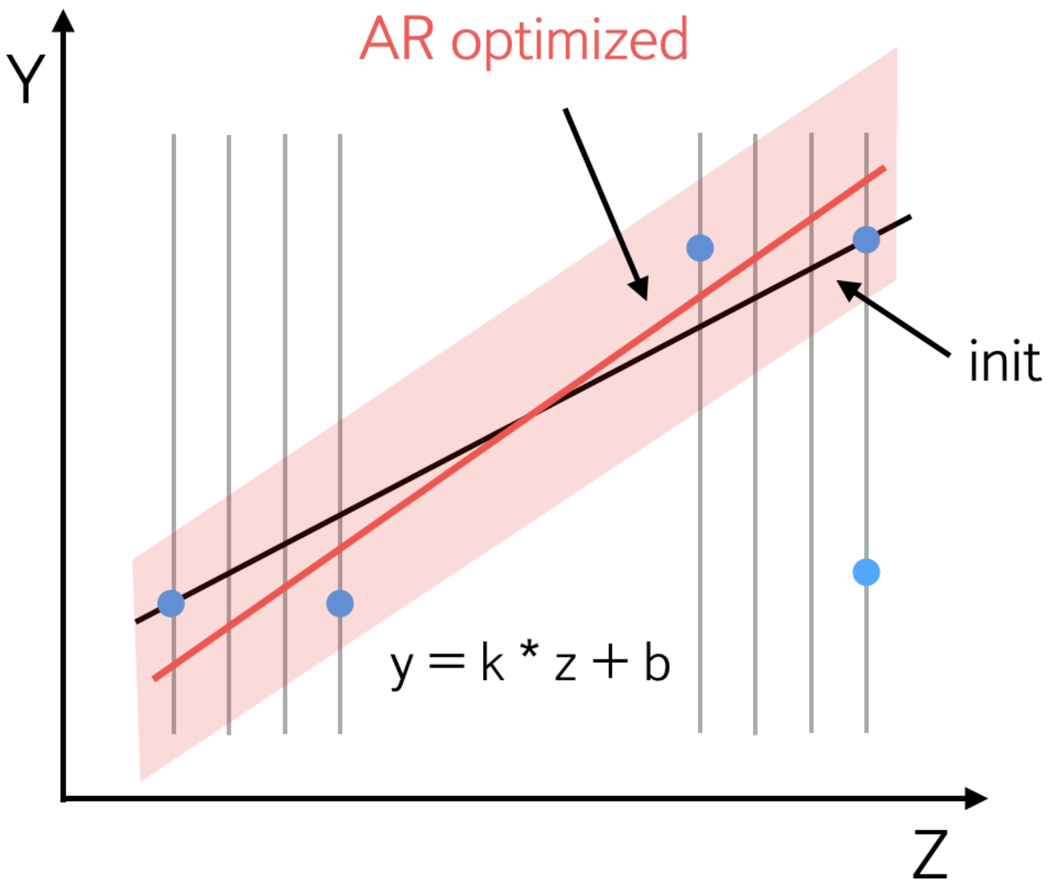
1. For each pair of hits estimate line parameters (k, b) and calculate AR function value.

2. Use pair with the highest value as init point of AR function maximization procedure.

3. Fit track parameters by maximizing AR function value.

4. Select hits within a window width from the fitted track. Exclude the hits from the sample.

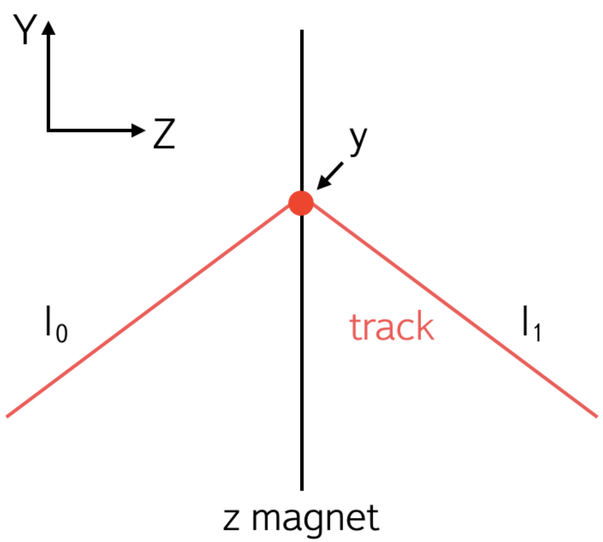
5. Repeat steps 1-4.

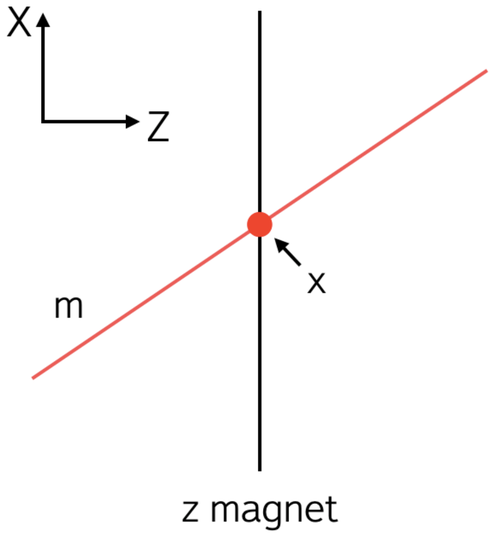


Reconstructor

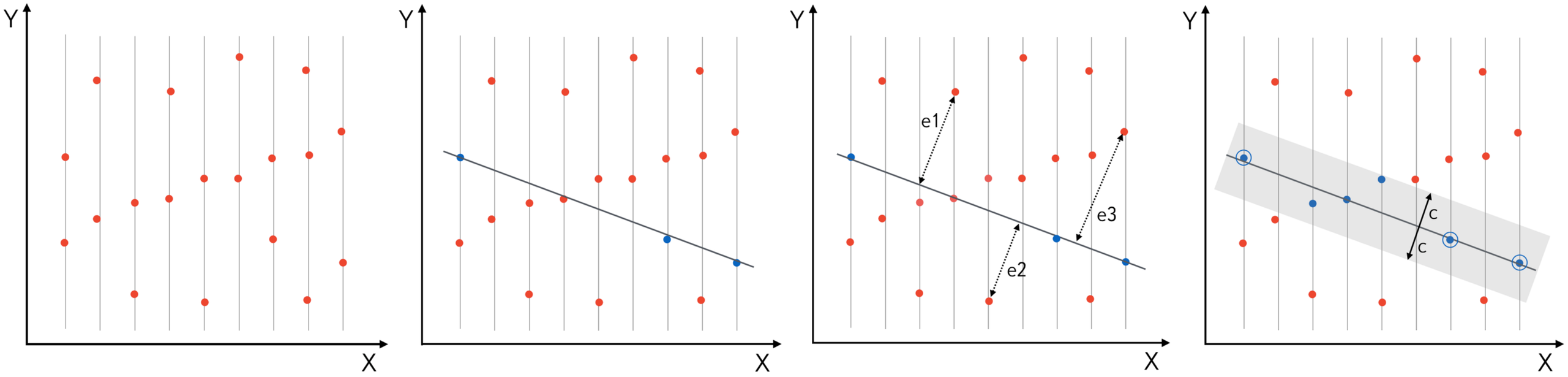
Let's search whole track before and after the magnet simultaneously.

A track parametrization θ: $\theta = (l_0, l_1, y, m, x)$





RANSAC



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.

Reconstructor

Track PR procedure:

1. Project hits to the magnet plane as shown.

2. Estimate the y parameters of tracks.

3. Use RANSAC to estimate track parameters and hits before and after the magnet for Y and Stereo views as described in slide 14.

4. Select two tracks with the largest number of unique hits.