Tracking for the IDEA detector

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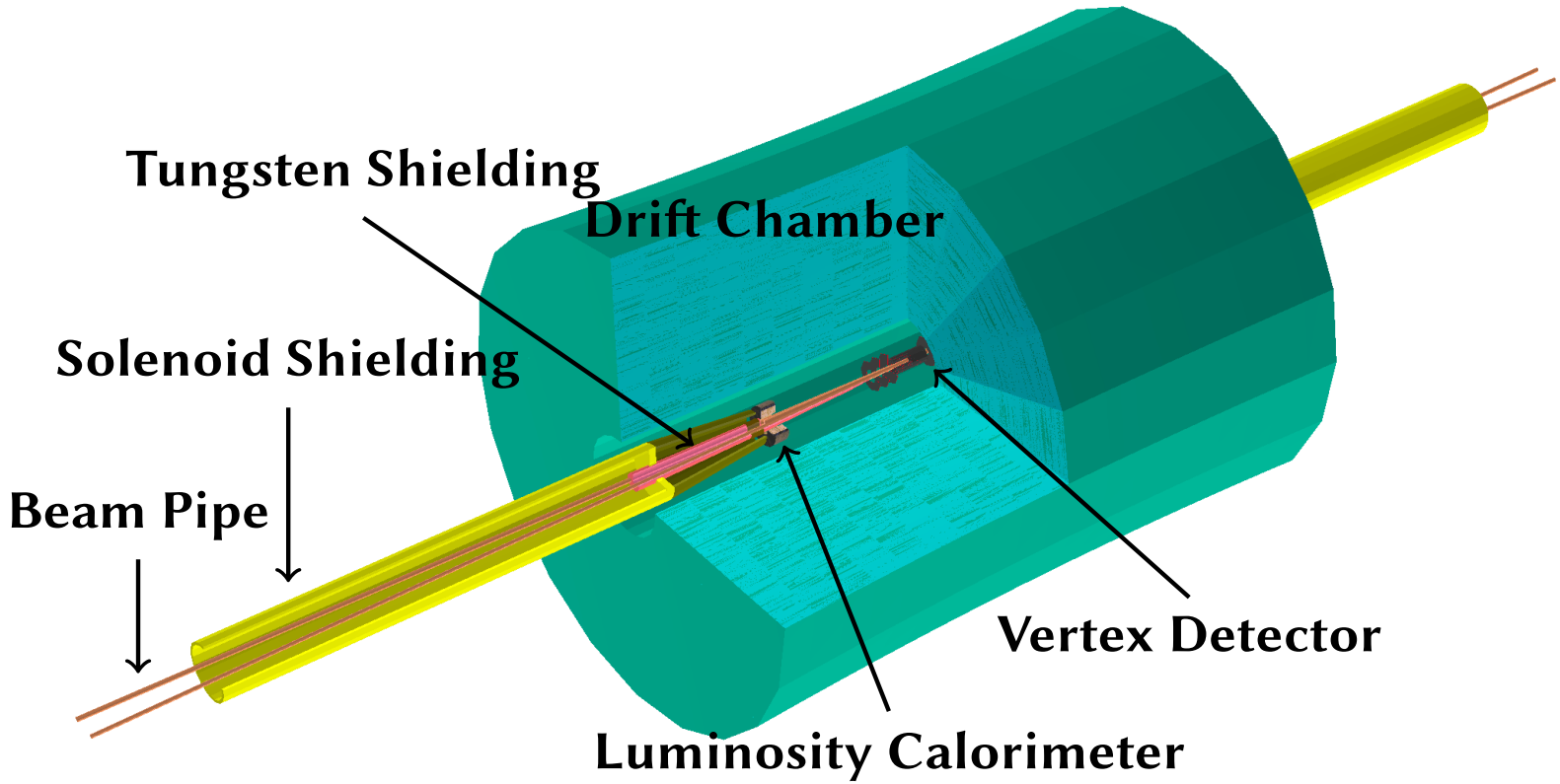
WG11 Detector Design Meeting

CERN
7 March 2019

Introduction

- Hough transform (HT): feature extraction in image analysis, computer vision, ...
  - Identification of lines, ellipses, circles
  - Can be used for the pattern recognition of the tracks in the drift chamber
  - The HT can be combined with Tricktrack (c.f. FCCSW) which is used for seeding in the VXD and limit the search region in the drift chamber.
  - Longer term plan $\Rightarrow$ implementation in ACTS
- In this talk:
  - Detection of single particle tracks using the HT
  - First results of tracking with incoherent pair background

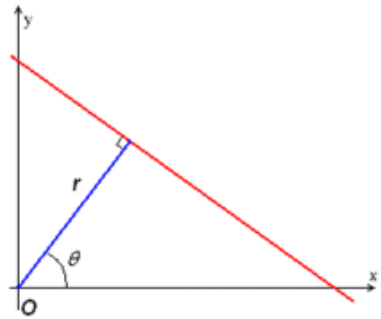
The IDEA detector as simulated & visualized with FCCSW



Hough Transform principle: identification of a simple line

- Represented as a point (b, m) in the parameter space

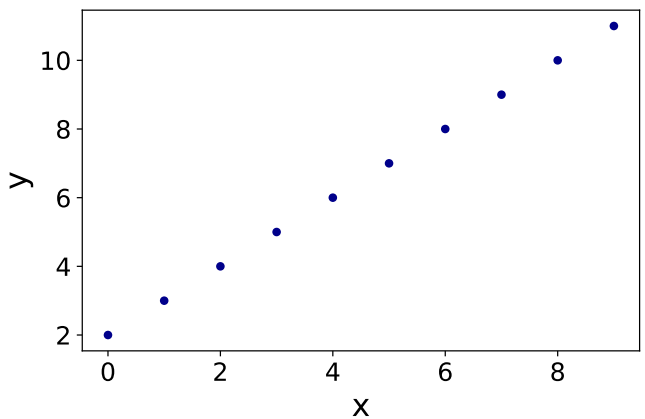
$$y = m \cdot x + b \tag{1}$$

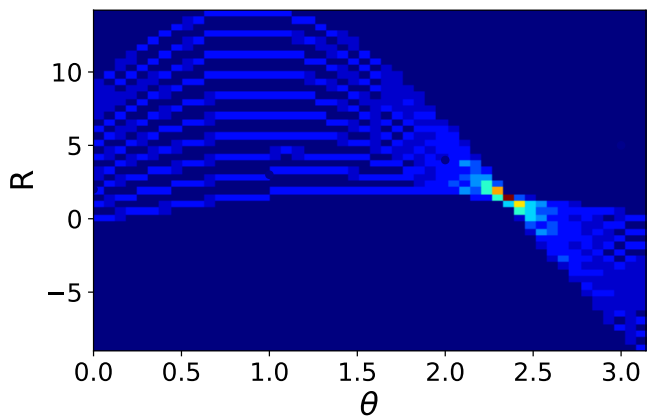


- Hough space: (r, θ)

$$r = x \cdot \cos(\theta) + y \cdot \sin(\theta) \tag{2}$$

  - A line corresponds to local maxima in the Hough space.





HT & Conformal mapping: identification of circles

- A track in B field $\Rightarrow$ helix (circle in (x, y) plane)
- Use conformal mapping to map the circle into line and then apply HT

- Circle equation with center (a, b) and radius R

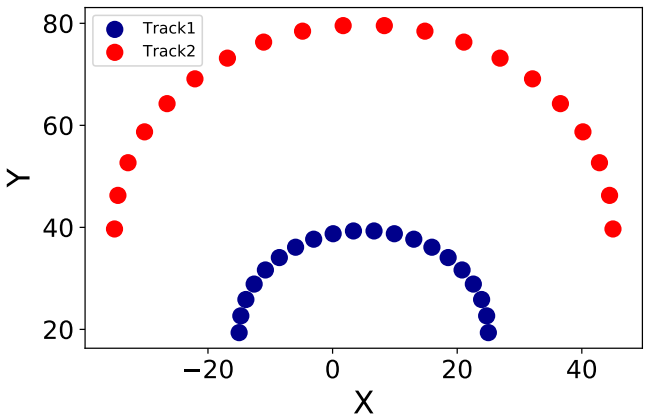
$$(x-a)^2 + (y-b)^2 = R^2 \tag{3}$$

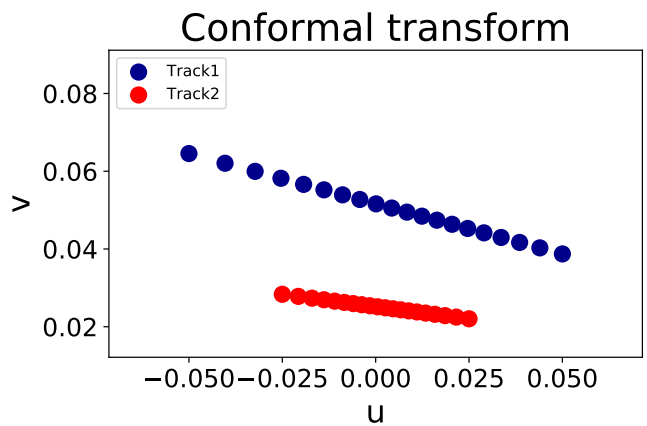
- Conformal mapping: transform the circle into a straight line

$$u = \frac{x}{x^2+y^2}, \quad v = \frac{y}{x^2+y^2} \tag{4}$$

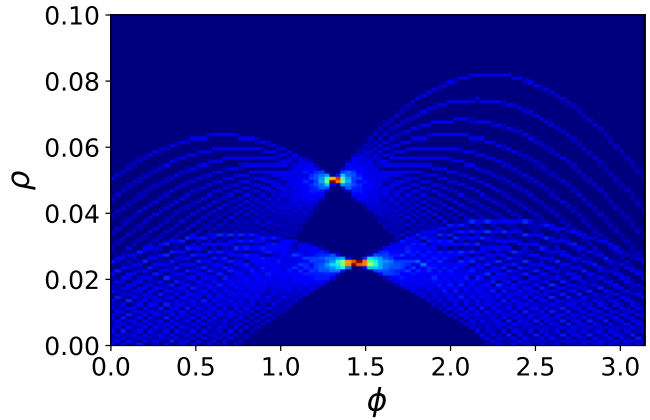
- If $R^2 = a^2 + b^2$, straight lines are of the form:

$$v = \frac{1}{2b} - u\frac{a}{b} \tag{5}$$





Identification of circles (2)



- Hough Transform for a straight line

$$\rho = u \cdot cos(\phi) + v \cdot sin(\phi) \qquad (6)$$

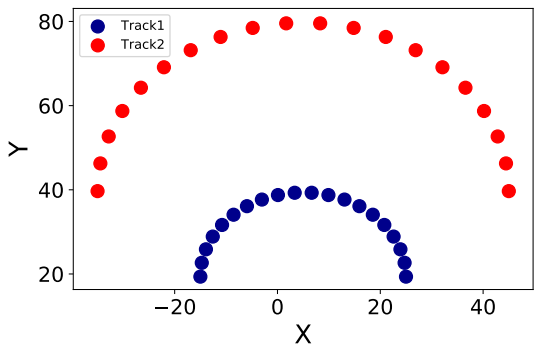
- The bending radius of the tracks: R

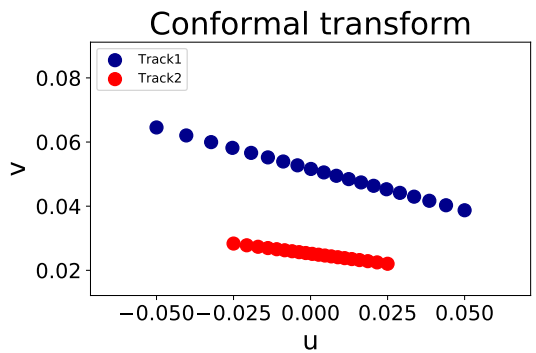
$$R = \frac{1}{2 \cdot \rho} \qquad (7)$$

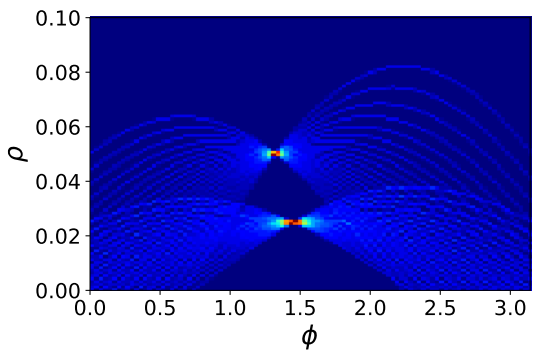
- The center of the circle (a, b)

$$a = \frac{cos(\phi)}{2 \cdot \rho} \qquad (8) \qquad b = \frac{sin(\phi)}{2 \cdot \rho} \qquad (9)$$

Summary

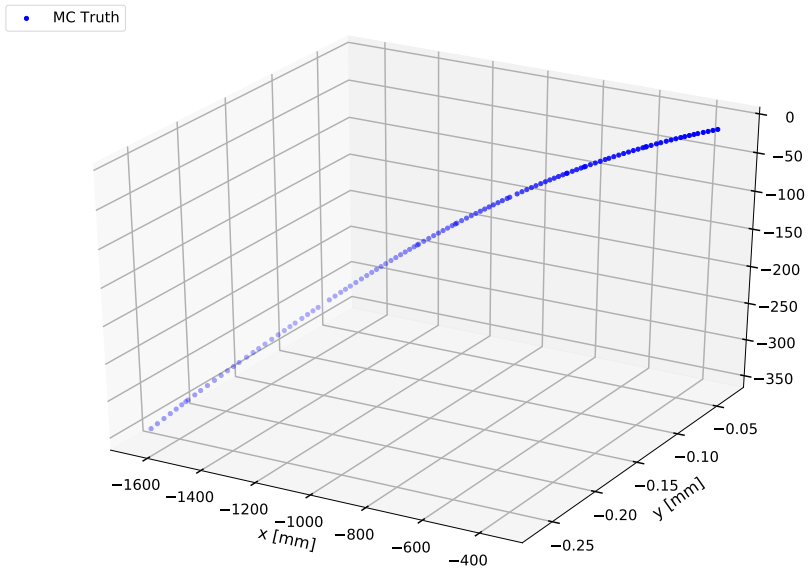


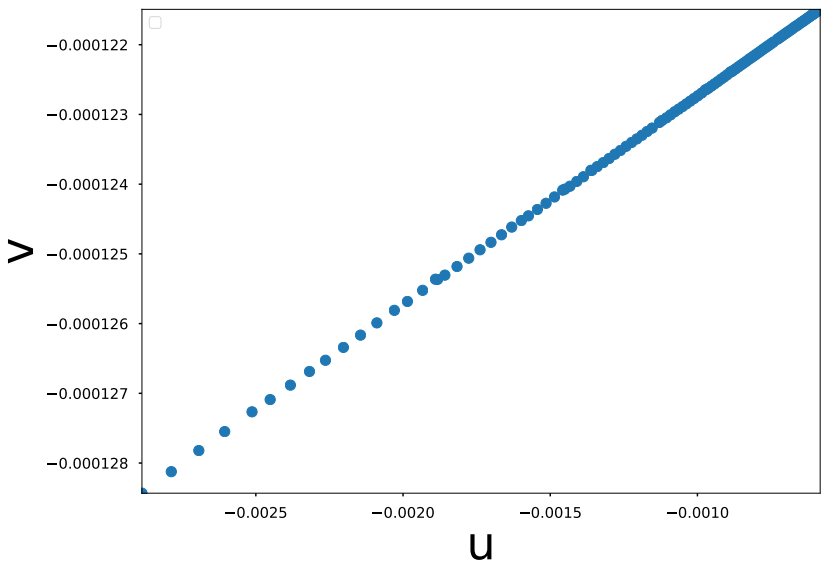


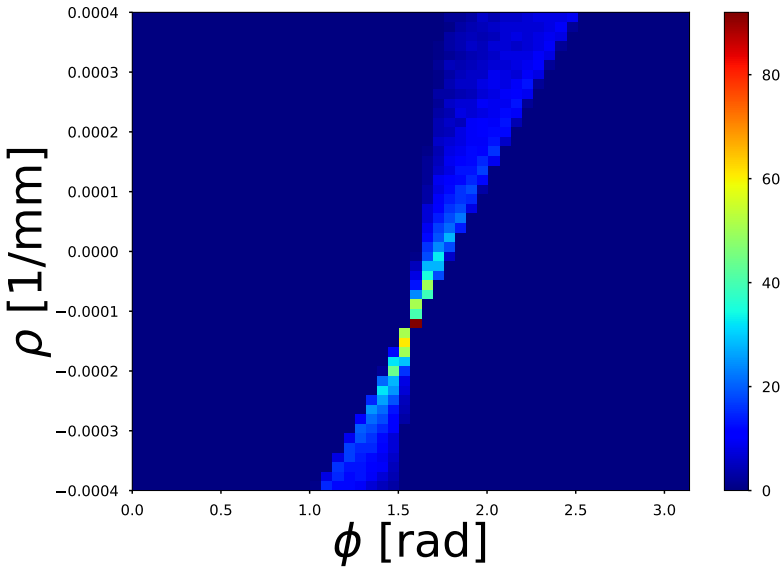


Hough transform: single tracks

- Particle gun: 2.4 GeV muon
- B = 2 T
- Bending radius: 4 m
- MC Truth position corresponds to the intersection of the track with the wire
- Reconstructed hit: MC hit smeared with the single-hit resolution ($\sigma_{x,y}$ = 0.1 mm and σ_z = 1 mm)

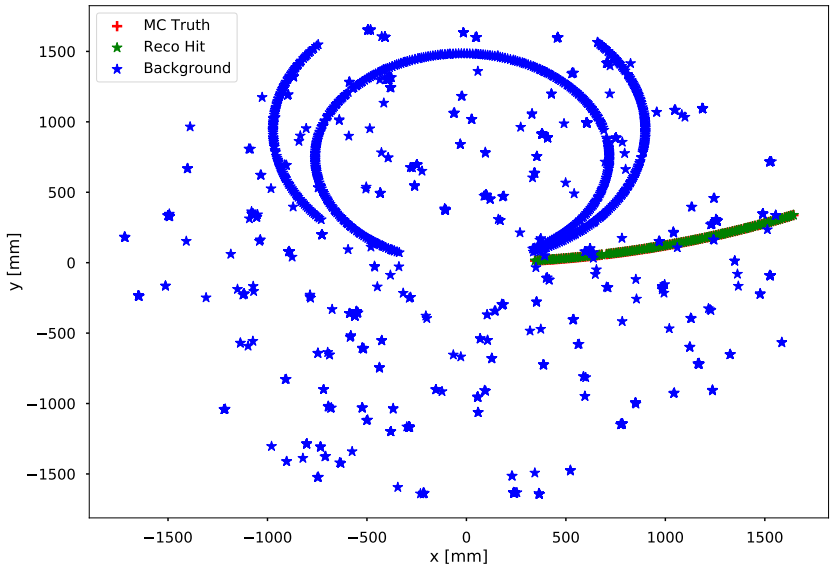


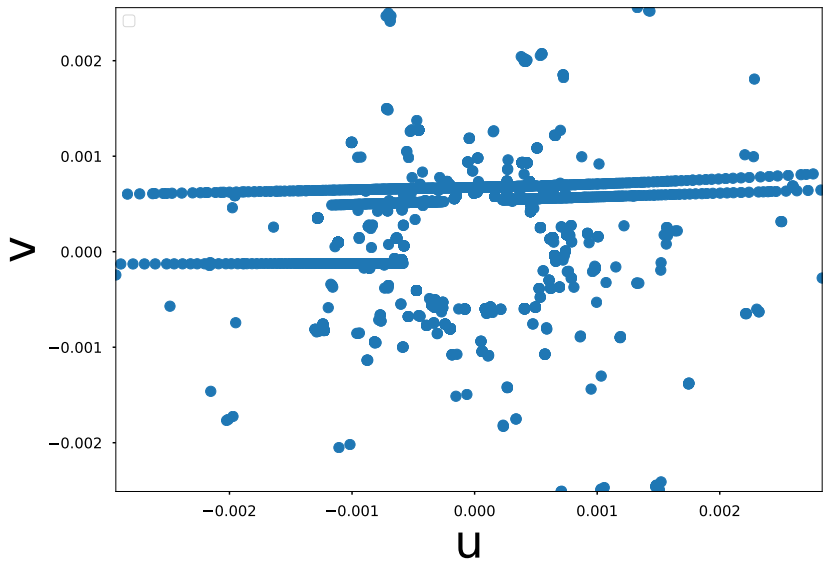


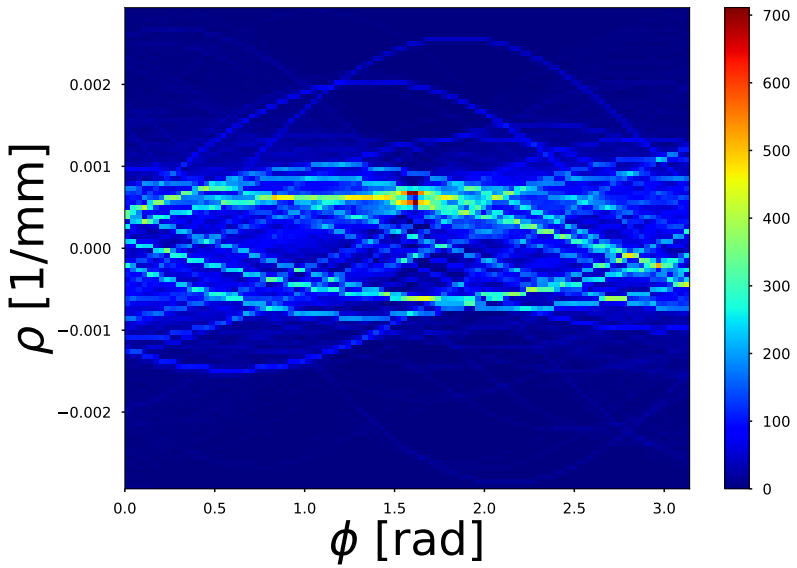


A particle track combined with the background

- Particle gun: 2.4 GeV muon
- 1 BX of incoherent pair background at the top stage





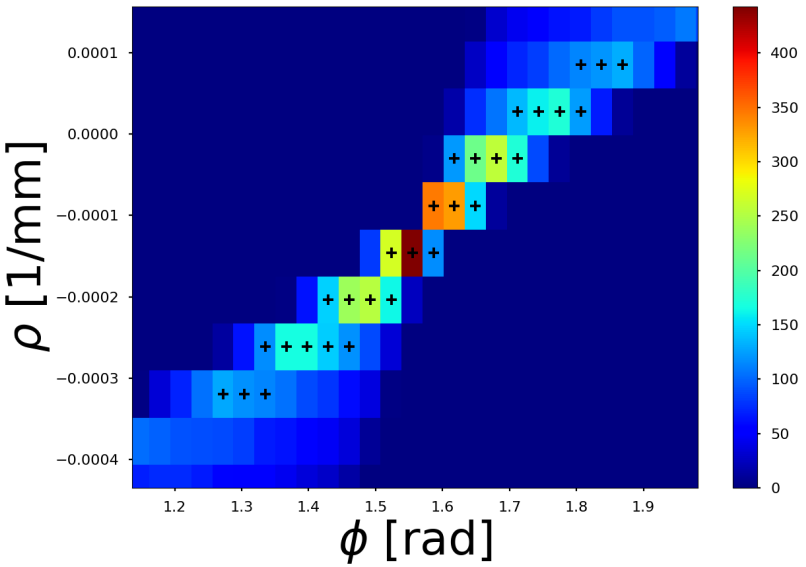


- All the tracks (event & background tracks) are visible in the Hough space.

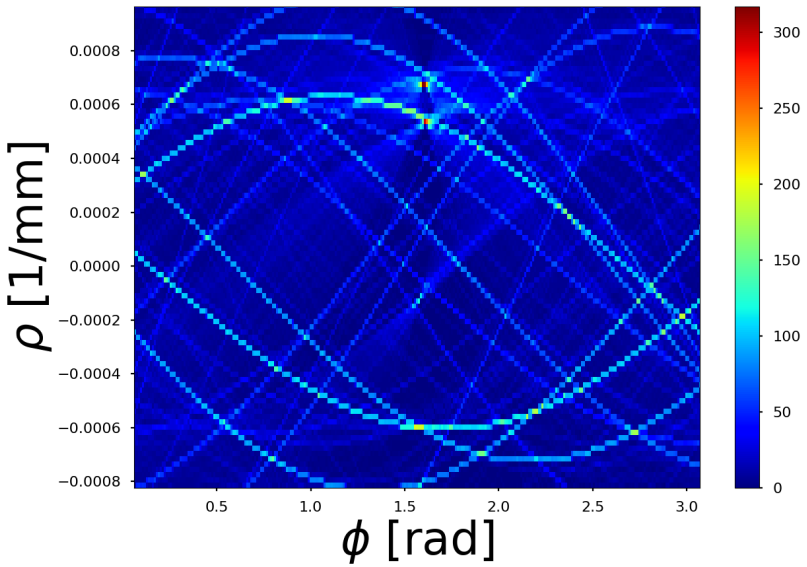
Finding the crossing points in the Hough space

- Visually, the tracks are detected easily in the Hough space
- Automatic detection of the crossing points (or the maxima)
  - The bin size needs to be optimized

- HT without background



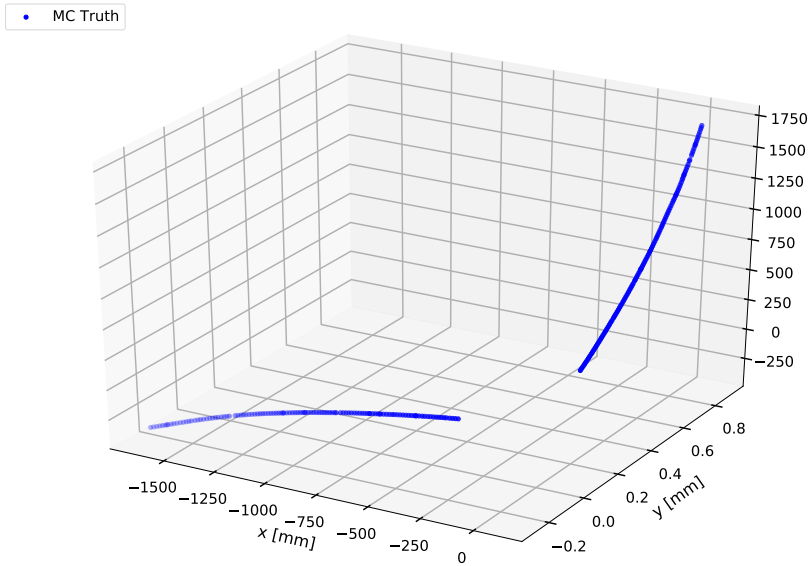
- HT with background

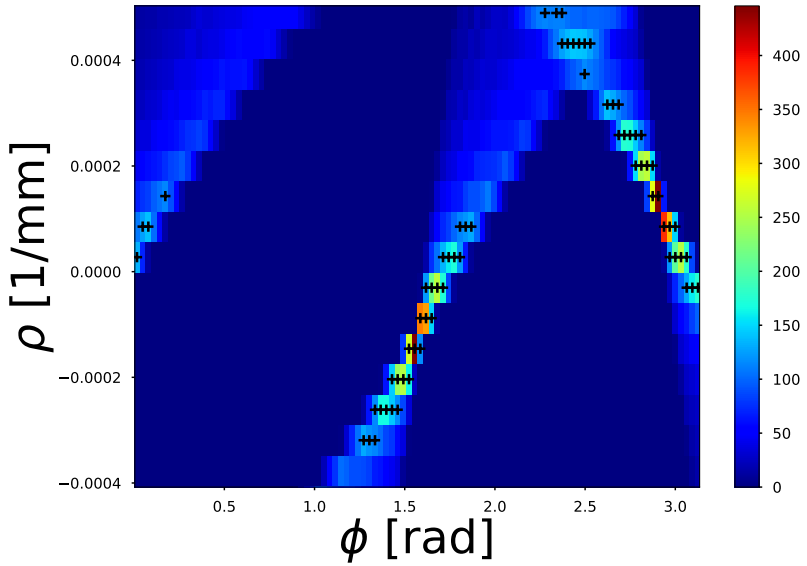


- In the Hough space, select only bins more than 112 hits (total number of layers in the DCH)
- Cluster positions with the highest number of hits $\Rightarrow$ tracks
- The background can be also reduced by a timing cut

Example: 2 particle tracks

- Particle gun: 2.4 GeV muon





- DBSCAN clustering algorithm used with a distance of $\sqrt{2}$ (c.f. scikit-learn)
- 4 clusters detected
- To do: remove the ”ghost” clusters/tracks

Conclusions

- A first implementation of the Hough Transform is available
- Single particles tracks are well detected
  - Visually and also by the detection of the crossing point (maximum) in the Hough space
  - Information on the bending radius of the track is obtained directly
- Parameters to be optimized for finding the maxima in the Hough space
  - Clustering for finding the maxima
  - For the pair background, a timing cut to be applied