HOUGH TRANSFORMATION ALGORITHM FOR THE TRACKING IN THE CGEM-IT

I. Garzia, G. Mezzadri
INFN - Sezione di Ferrara

4th Workshop on Cylindrical GEM Detectors
INFN Laboratori Nazionali di Frascati, 16-18 November 2015

OUTLINE

Introduction

- CGEM-IT software
- Hough transformation

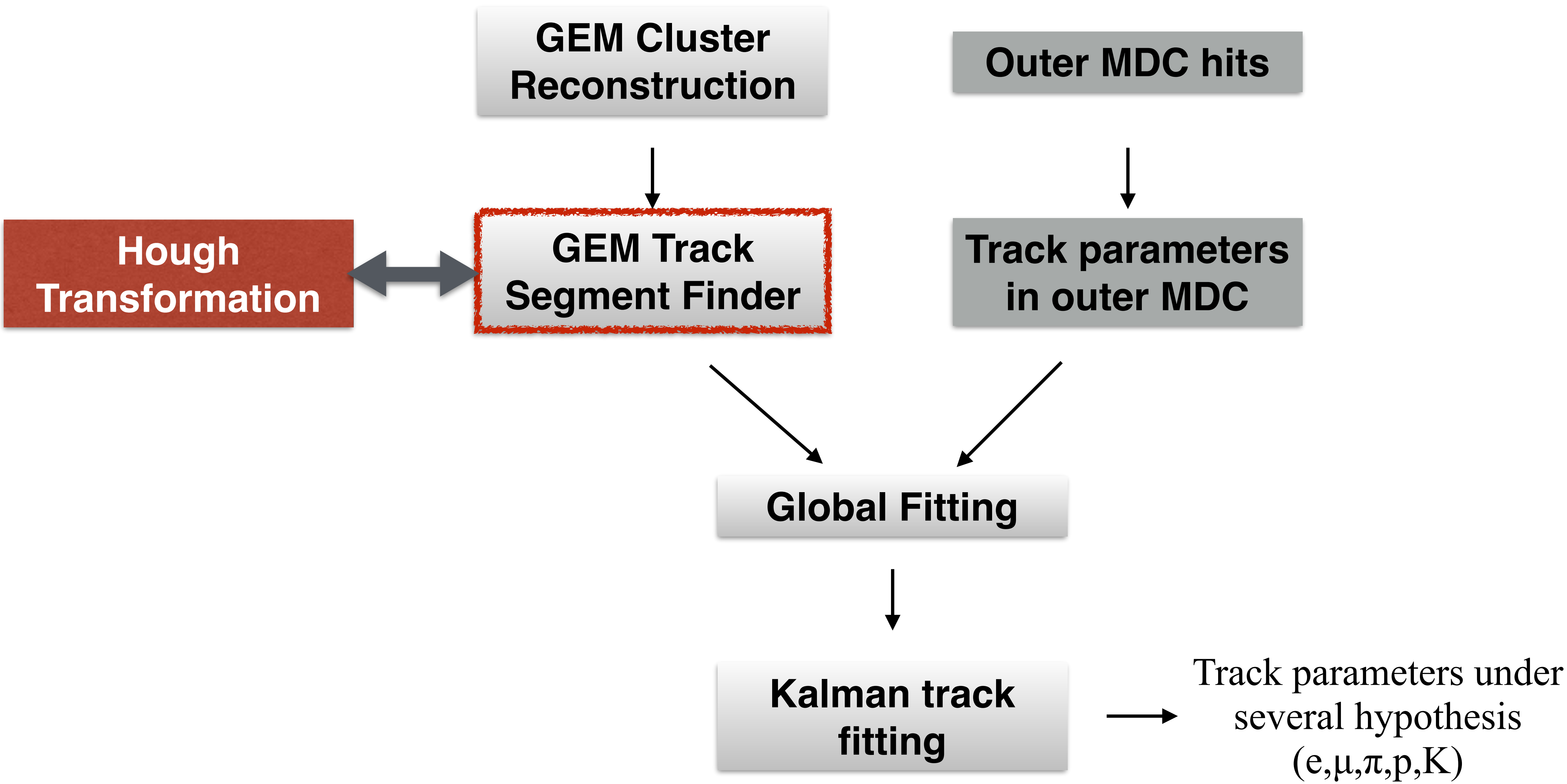
The Hough algorithm

- how to find a track

Summary and conclusions

- status of the code and plans

Reconstruction with CGEM-IT



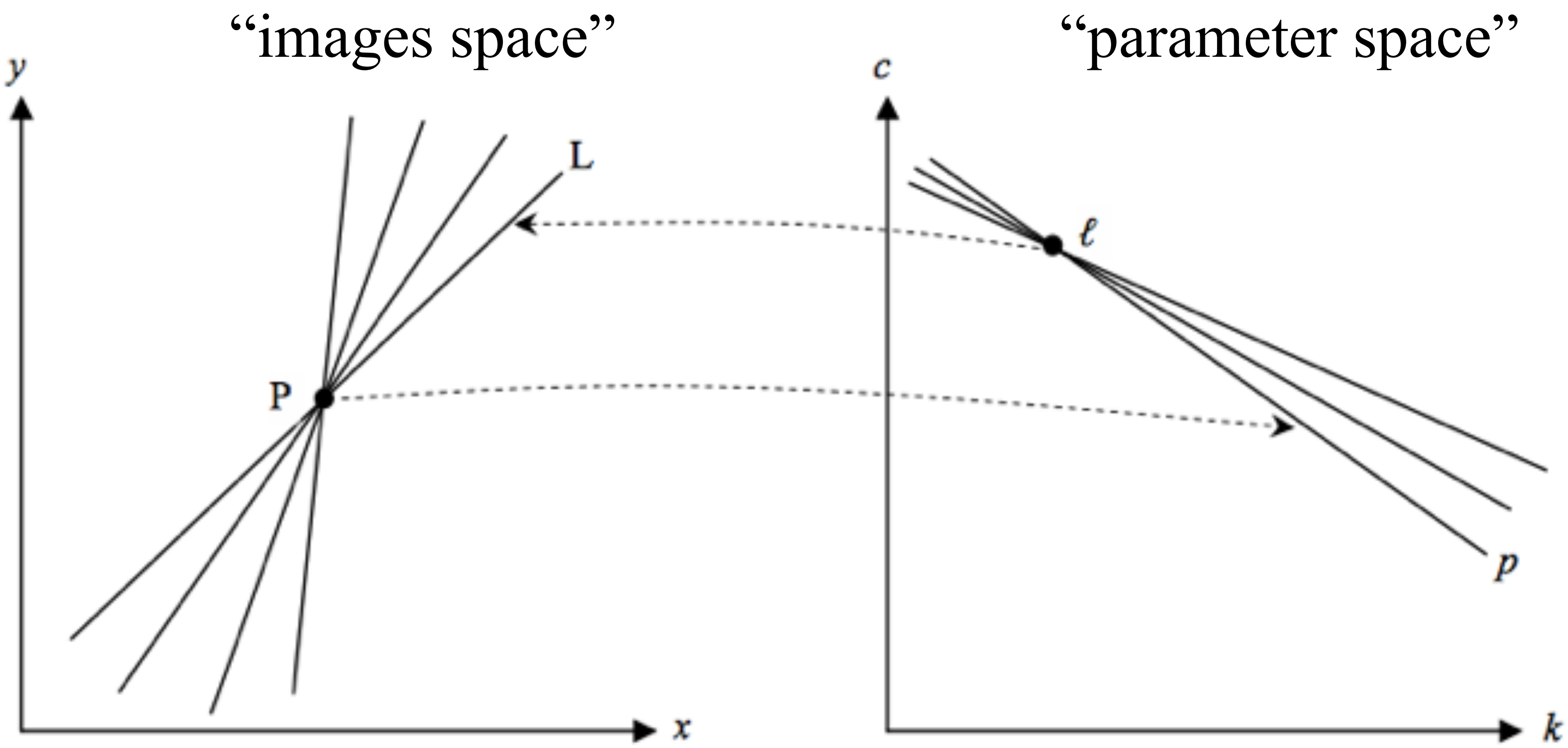
Introduction: the HOUGH transformation

- The Hough transformation (HT) can be used to detect lines, circles or other parametric curves
- It was introduced in the 1962, and first used one decade later to find lines in an image
- It can detect lines, circles, and other structures if their parametric equation is known
- HT can be used as track finder method
  - global tracking method: all hits enter into the algorithm at the same time and in the same way
  - also used in many experiments: ATLAS, PANDA, …
  - first version developed for the MDC tracking in BESIII (Zhang Jin, Zhang Yao,Liu Huaimin) to improve the tracking for low momentum particles (pt<120 MeV)

ADVANTAGES:
- global method (in a local method the pattern recognition starts with a seed of track consisting of a few hits, then more hits are added step by step)
- noise resistant
- resistant to the hits inefficiency

Principle of the Hough transformation

LINE/POINT DUALITY



The line in the "images space" is defined by points whose coordinate satisfy the equation: **y=*k*x+*c***

- A point P in the "images space" defines a lines (*p*) in the "parameters space"

Each point in the "parameter space" can be defined by the bundle of lines passing through it

- each point (*l*) on the line *p* defines a line L in the "image space" in the bundle of lines passing through P

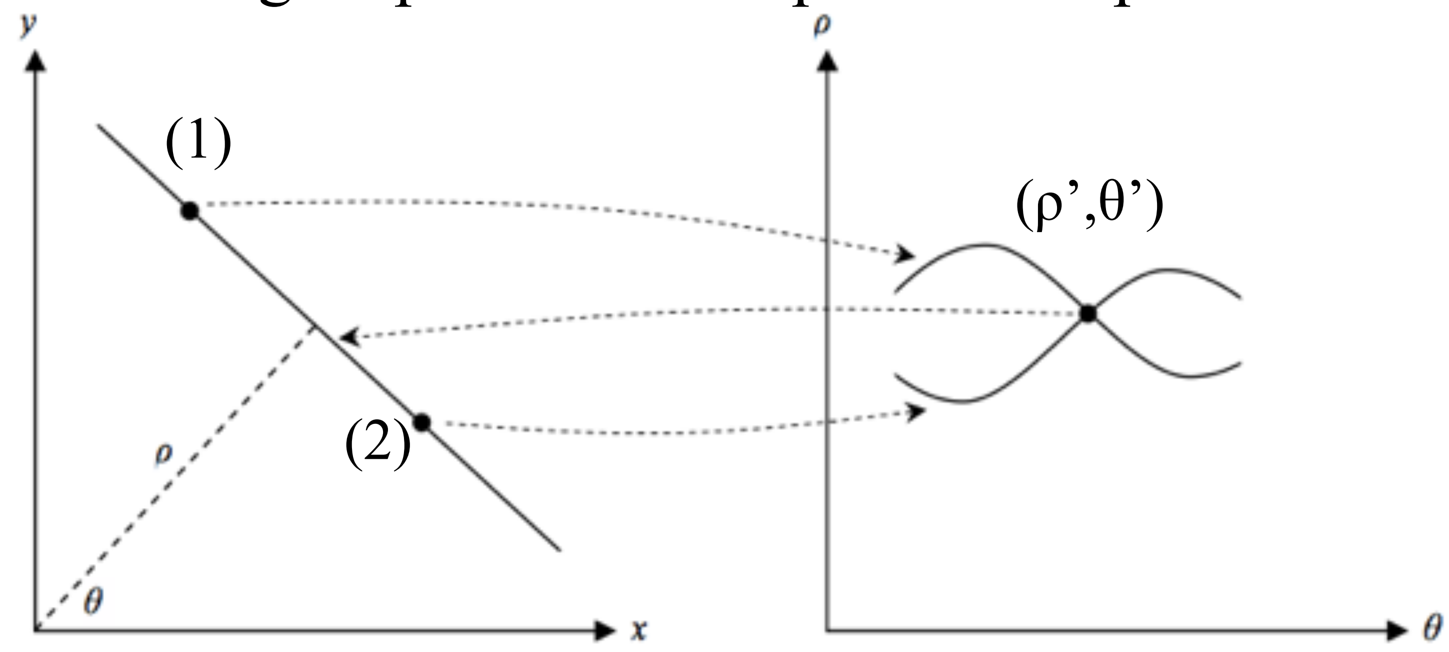
1. Coordinates of *l* are the parameters of line L ==> this method can be thought as a transform between "images space" and "parameters space".
2. **If the hits are on a straight line, the lines in the "parameters space" intersect in one point , and the intersection gives the parameters of the line the hits are on.**

Polar parameterization of lines

To avoid singularities arising from the infine slope for vertical lines, Duda and Hart (Comm. ACM 15, pp.11-15, 1972) introduces a singularity free alternative:

$$\boldsymbol{\rho = x \cdot \cos(\theta) + y \cdot \sin(\theta)}$$

“images space” “parameter space” or “H space”



Each point in the yx-plane gives a sinusoid in the “H space” ==> the intersection point (ρ’,θ’) correspond to the line that passes through the two points (1) and (2)

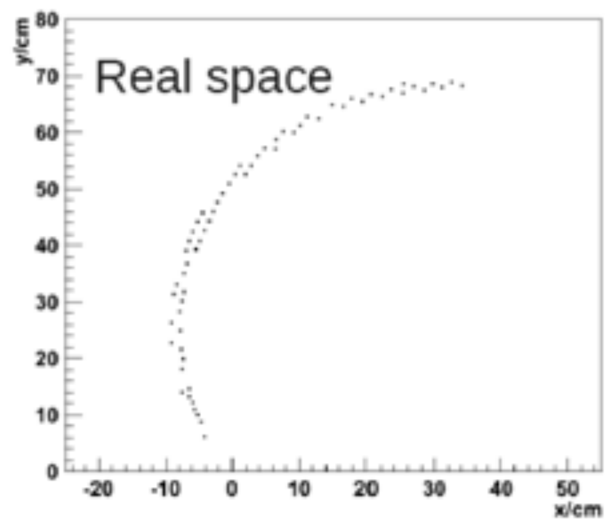
Basic idea of HT: parametric shapes can be detected by looking for accumulation points in the parameter space. If a particular shape is present in the image, then the mapping of all its points into the parameter space must cluster around the parameter values which correspond to that shape (two parameters for a line)

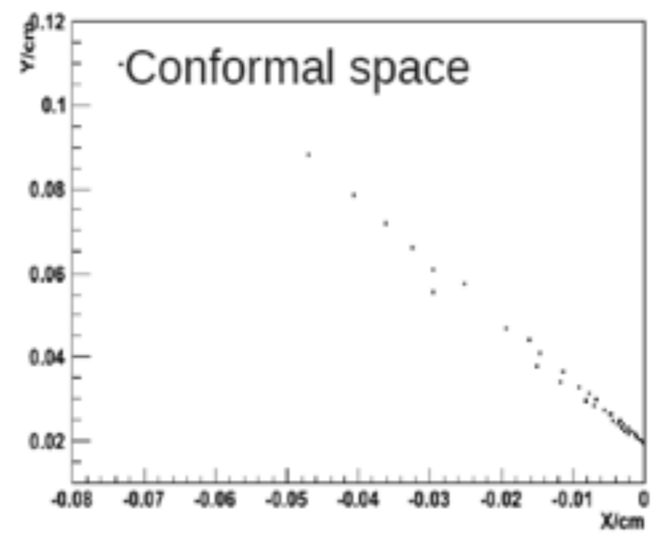
Conformal trasformation

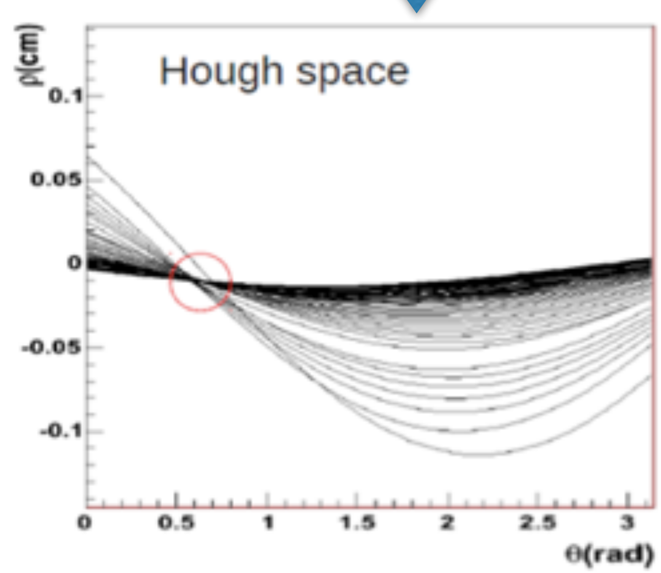
The conformal mapping method (Hansroul *et al.*, 1988) for track finding is based on the fact that circles going **through the origin** of a two-dimensional xy-coordinate system maps onto straight lines in a XY coordinate system by the transformation:

$$(x,y) \rightarrow (X,Y) \quad X=2x/(x^2+y^2) \quad \text{and} \quad Y=2y/(x^2+y^2)$$

Find a straight line is less complicate than find a circle







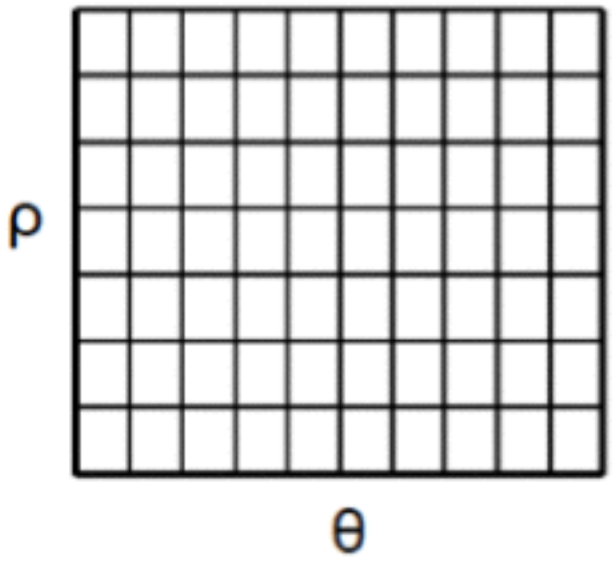
A peak in the 2D histogram corresponds to a track

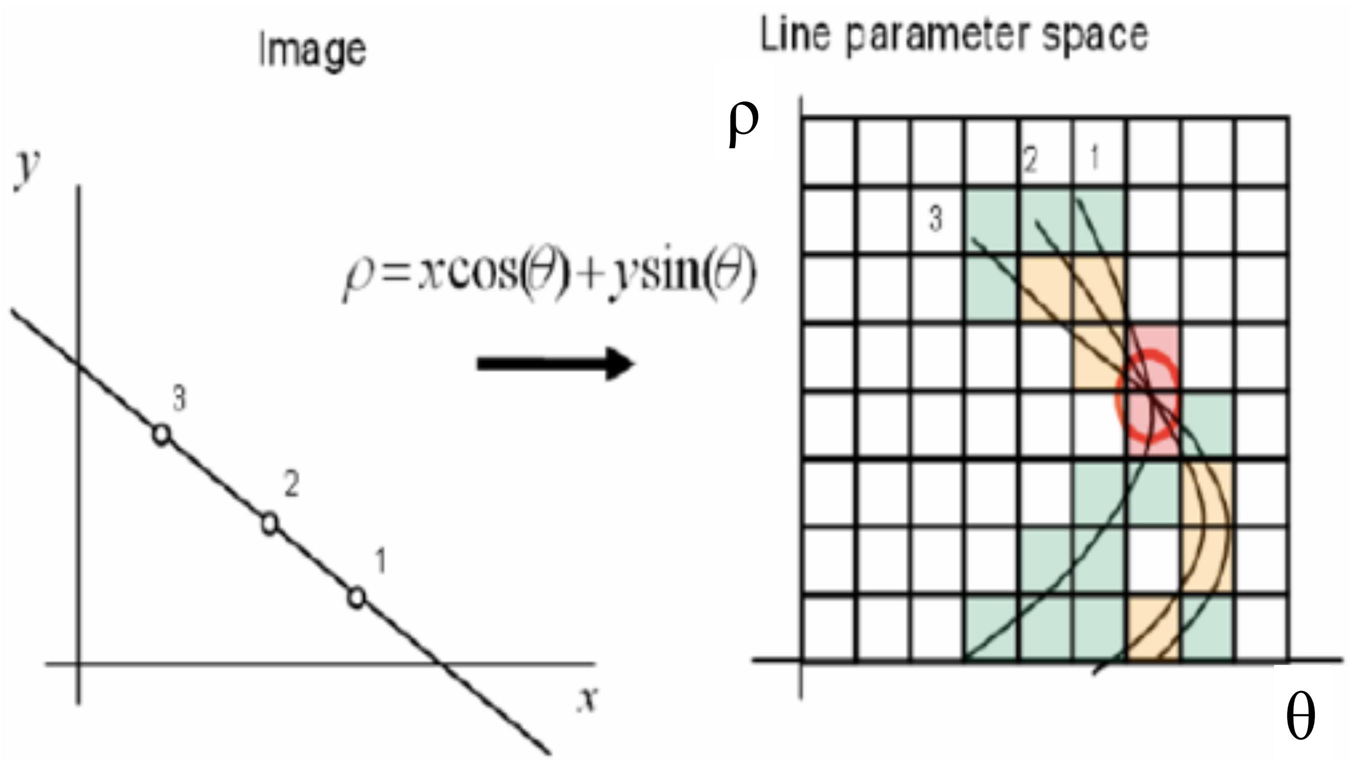
[*MDC-HT, Z. Jin, Z. Yao, L. Huaimin]

HT Algorithm

ALGORITHM STRATEGY:

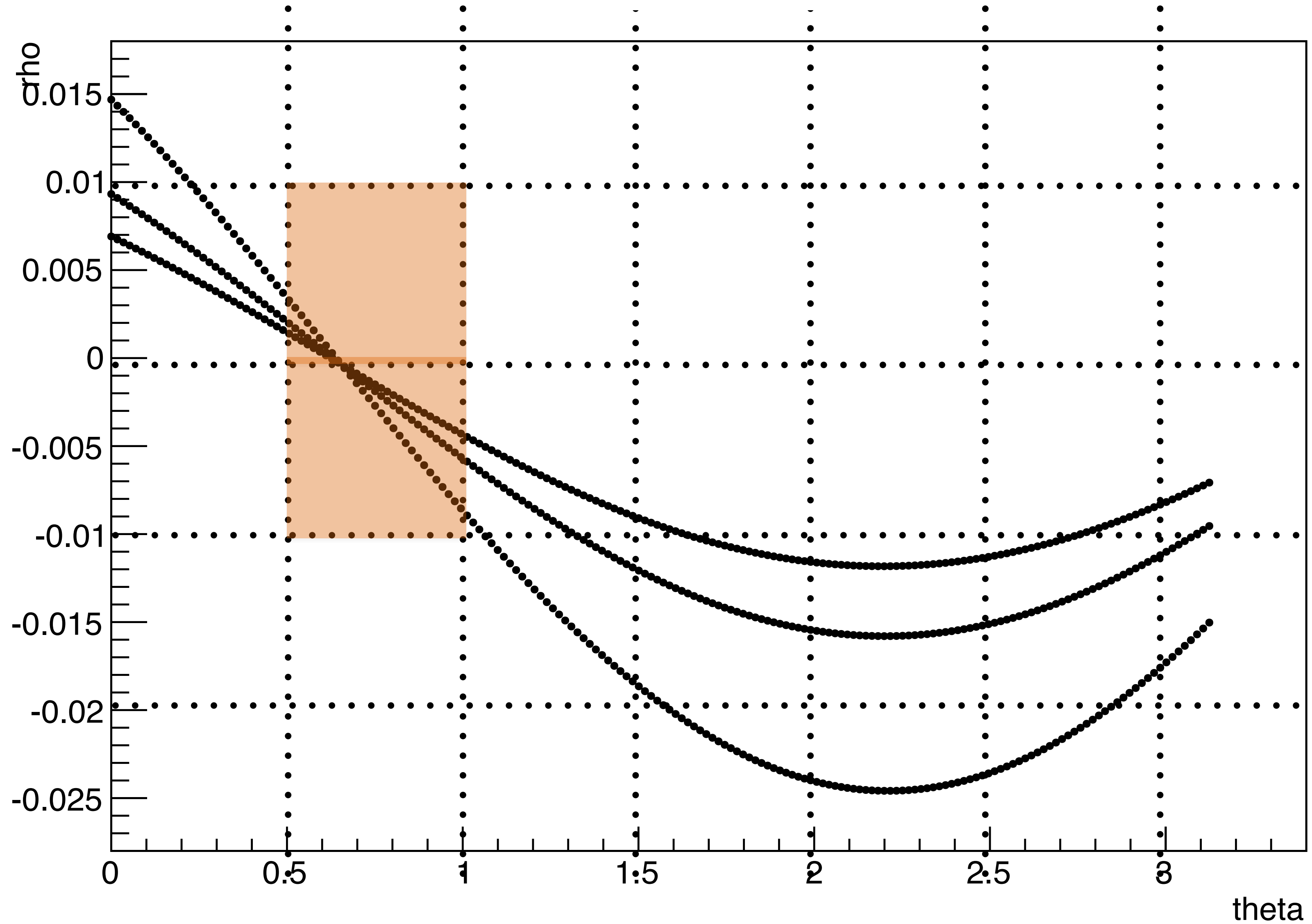
- conformal coordinates: (x,y) ==> (X,Y)
- $0<\theta_i<\pi$
- for each θ_i, we calculate ρ_i: $\rho_i = X\cos\theta_i + Y\sin\theta_i$
- each cell records the number of courses passing through it
    - we find the cells with the largest entries





HT Algorithm: (θ,ρ) discretization (I)

Step1

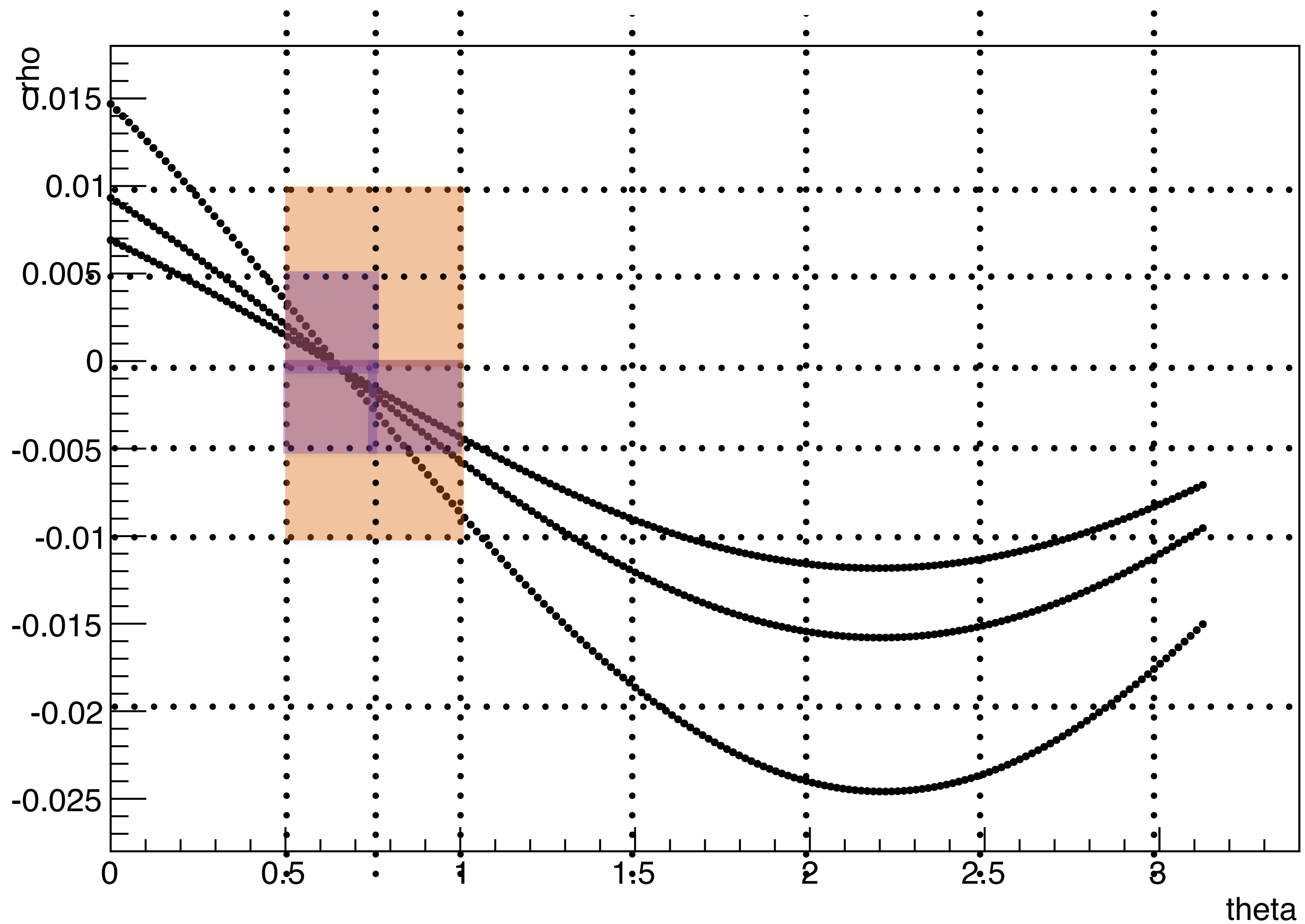


Discretization of the (θ,ρ) space

- efficiency
- resolution
- computing time

HT Algorithm: (θ,ρ) discretization (II)

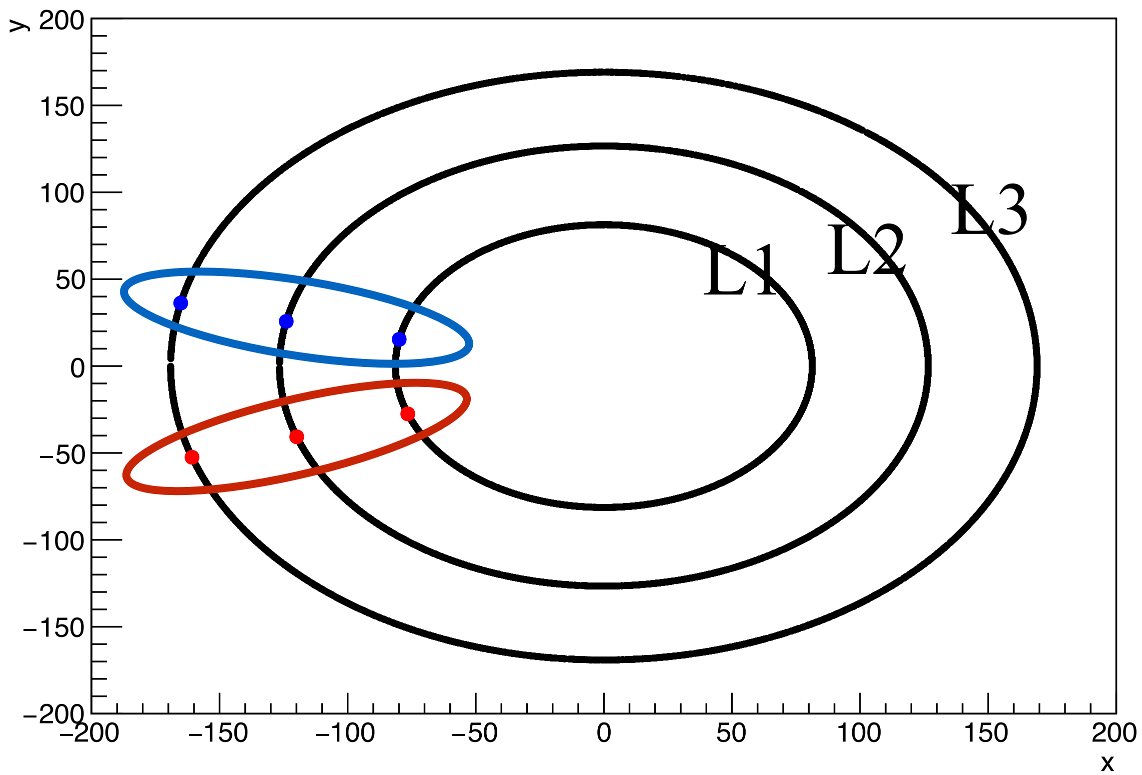
Step2



- Search for the (ρ,θ) intervals with at least 3 hits
- Calculate the average ρ and θ values
- Single decay mode test: excellent results

HT Algorithm for the CGEM-IT

Image space



event 1

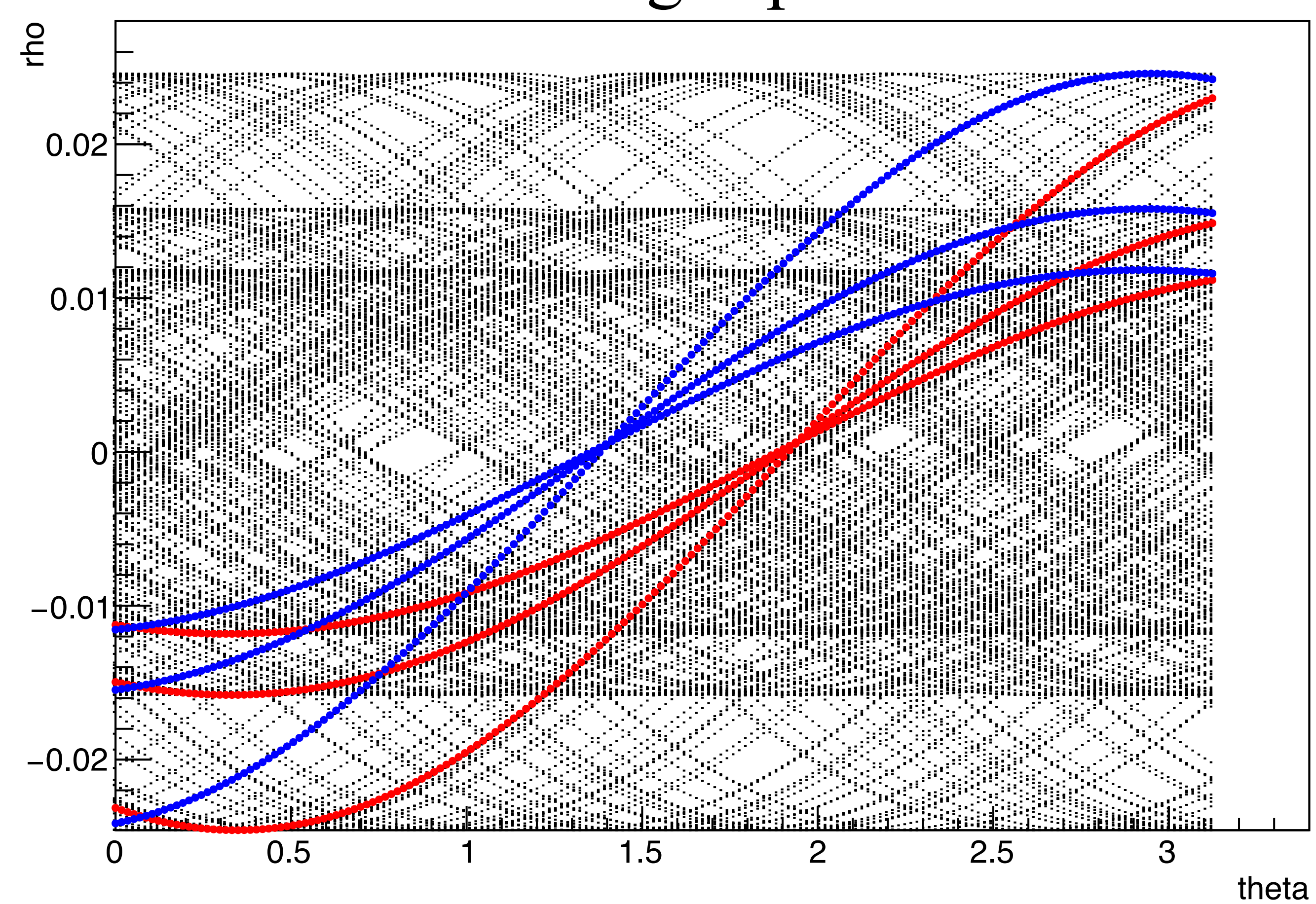
event 2

Simples case: only one track for event and no noise simulated.

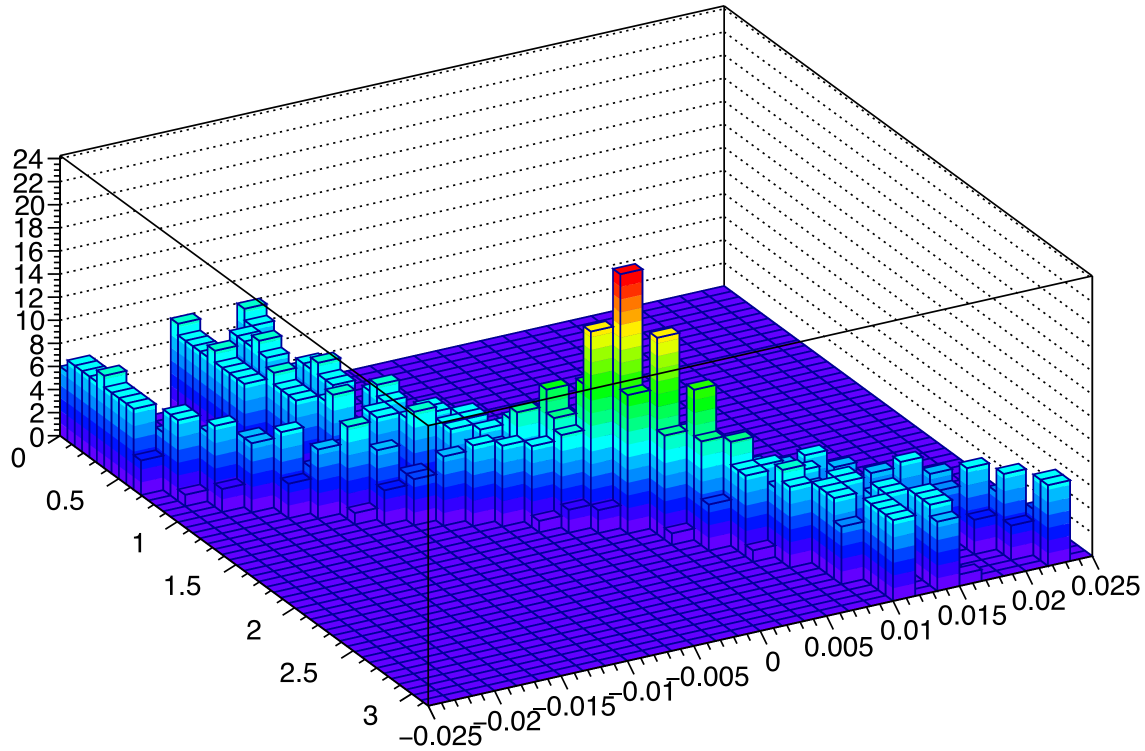
Using the BESIII framework, we simulate muons with p = 1 GeV/c with |cosθ|<0.8

- the intersection point in the H space defines the segment passing through aligned points

Hough space

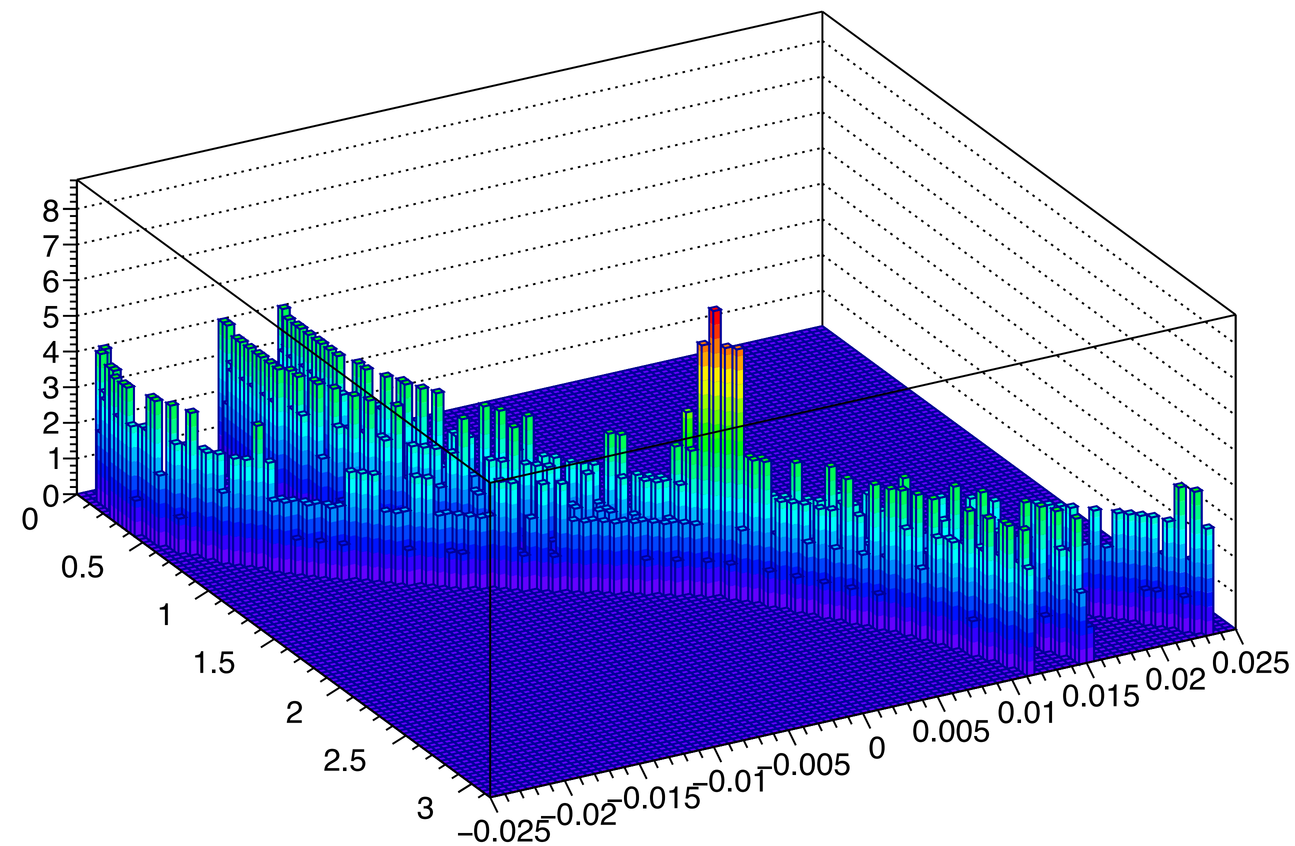


HT Algorithm: binning effect



50 × 30, small bins

- high tracking efficiency
- worse resolution: two neighbor tracks can be mixed in the same peak

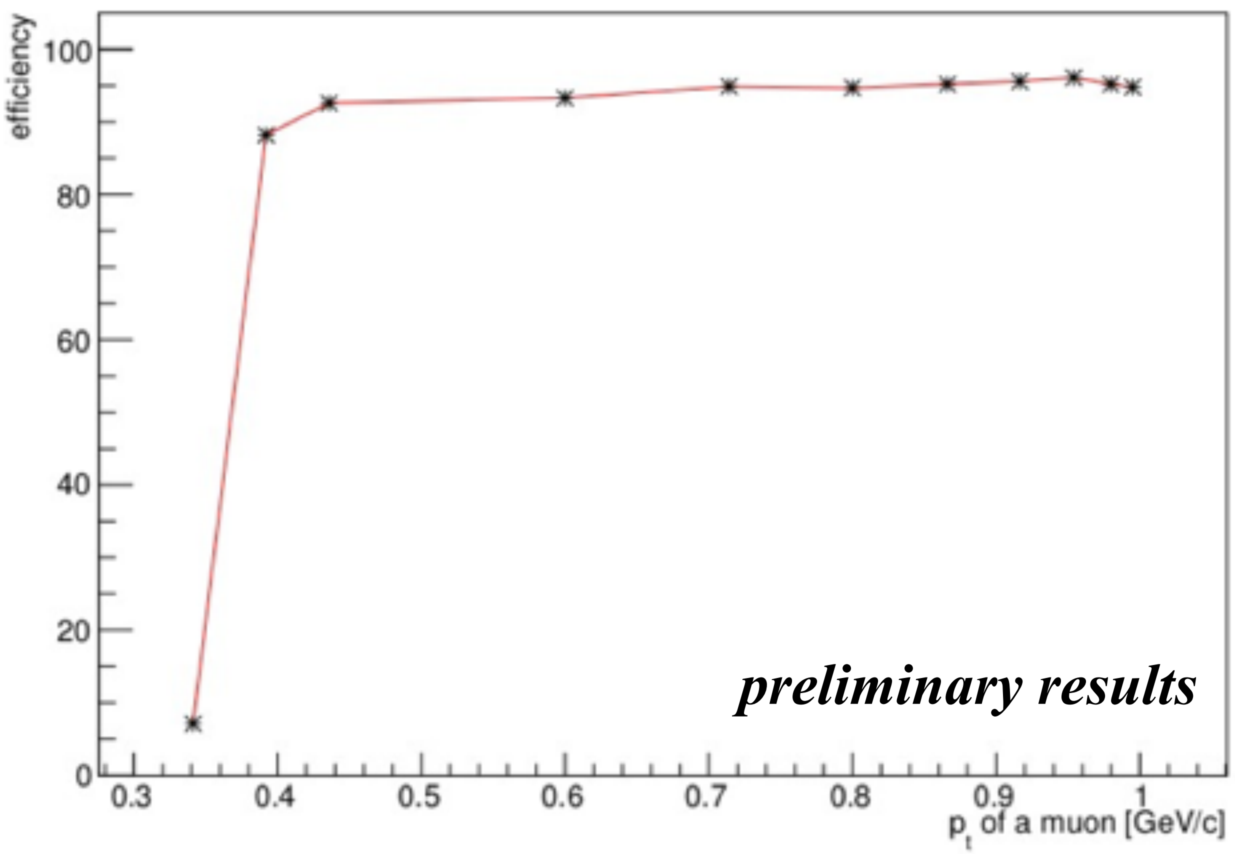


100 × 100, large bins

- the peak should be splitted into many packs
- worsening of the tracking efficiency

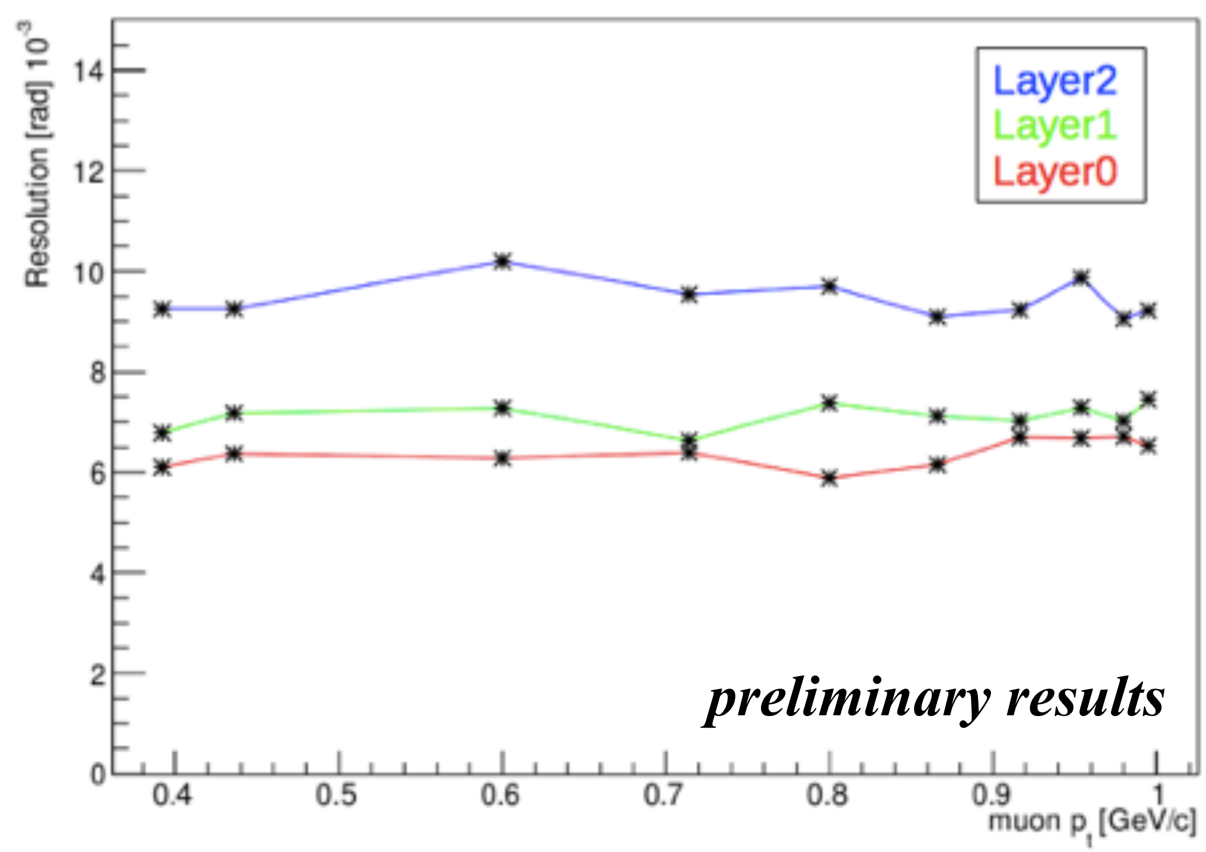
Simulation studies (I)

Efficiency



- 1000 muons with fixed momentum p = 1GeV/*c*
- |cosθ|<0.8
- efficiency: number of tracks surviving the selection / total number of tracks selected

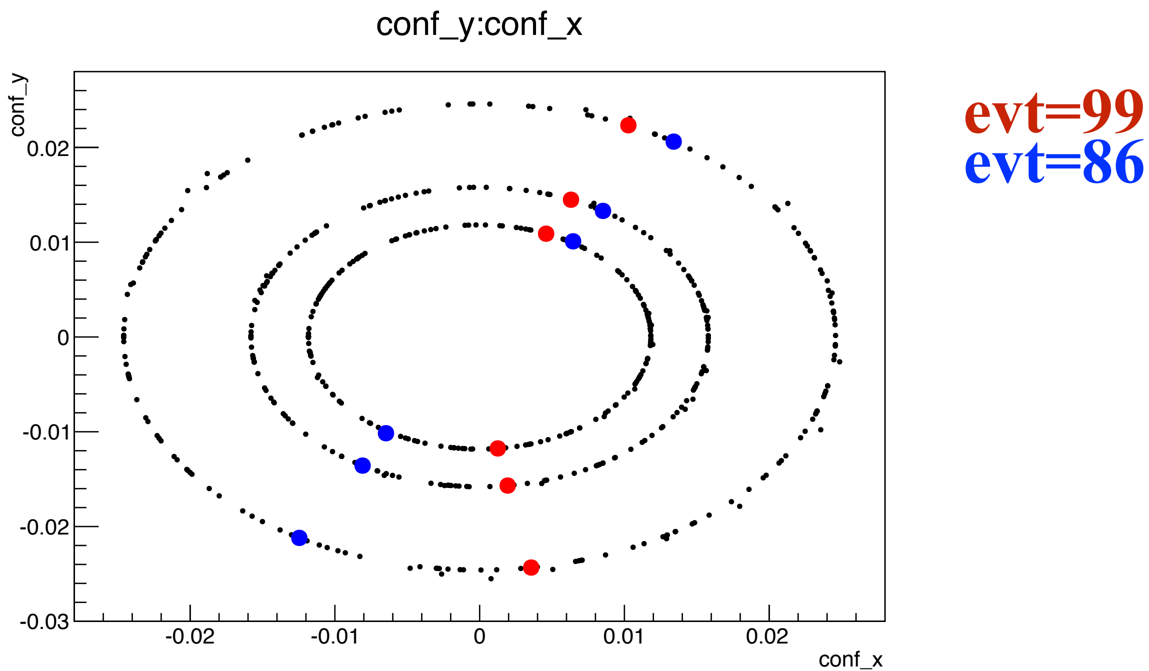
Resolution

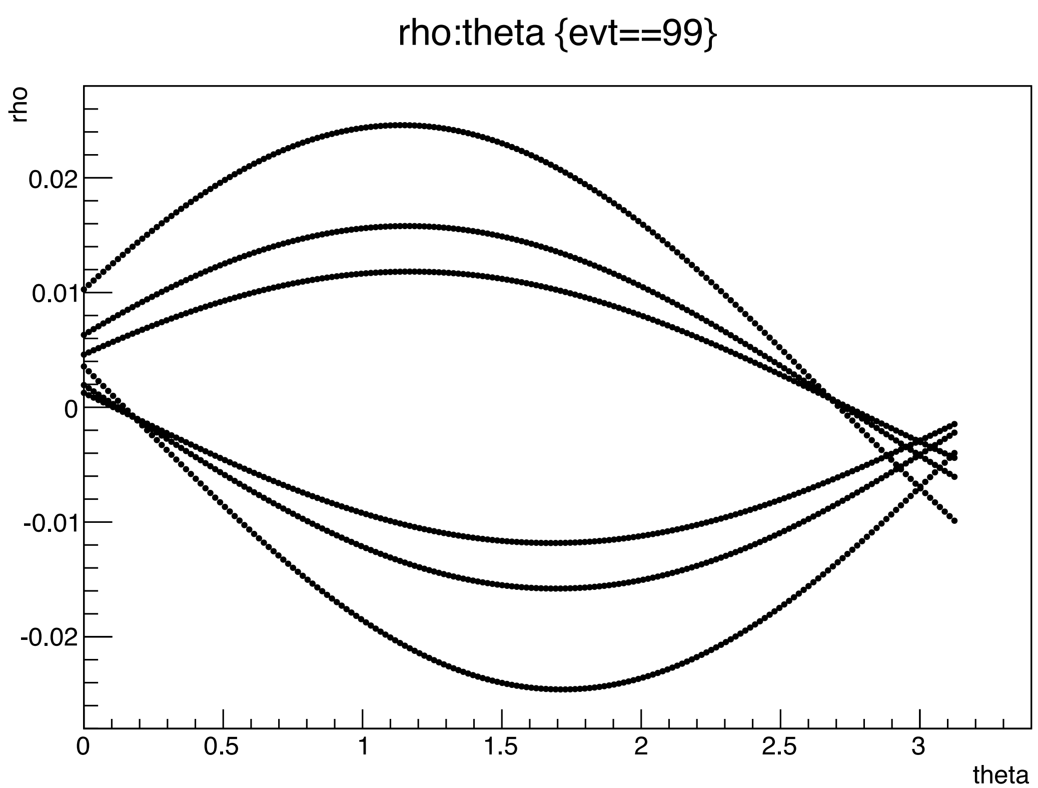


- Resolution: sigma from the gaussian fit to the distribution ($\phi_{\text{MC-truth}}$ - $\phi_{\text{rec-HT}}$)

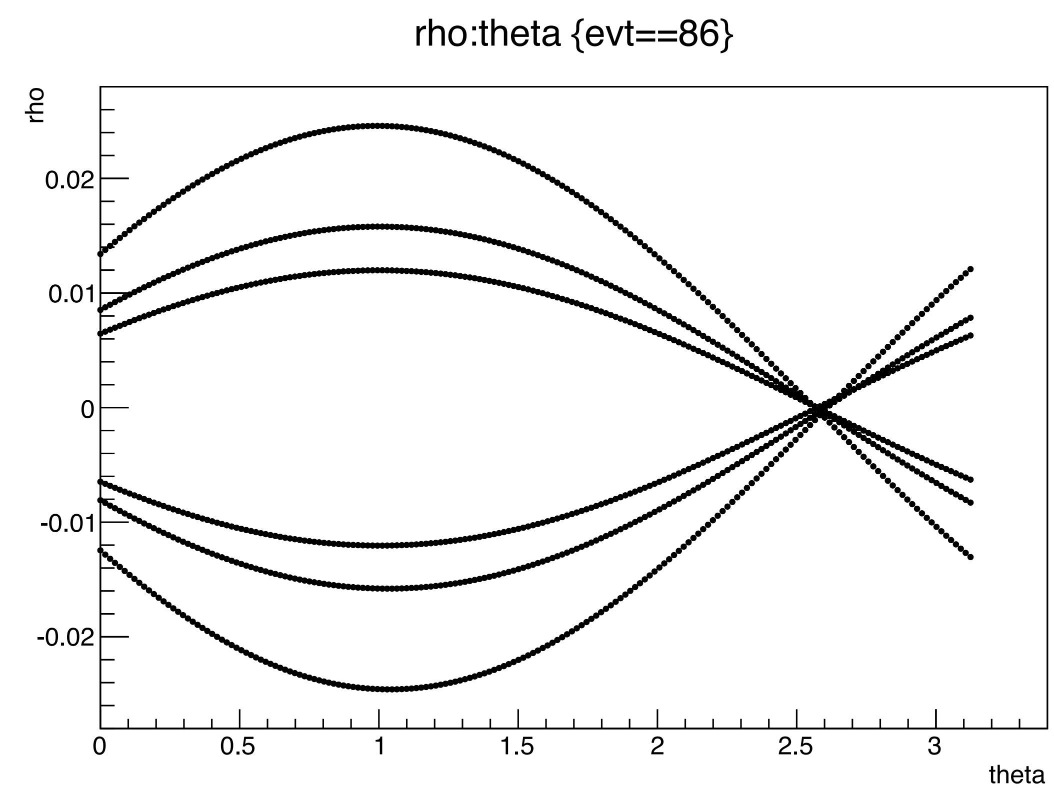
Simulation studies (II)

- We simulate $J/\Psi \rightarrow \rho^{\pm}\pi^{\mp}$





We are able to discriminate the two peaks



We need additional information in order to disentangle the peaks: **slope**

Summary and conclusion

- A first version of the Hough transformation for the CGEM-IT detector is implemented in the BESIII code and is under development
  - works well for single track simulation (no noise included)
  - discrimination of back-to-back tracks by using the slope information

- Efficiency and resolution studies are ongoing

- Future implementation
  - **Hough transformation using outer MCD point in order to increase the performances**
  - Study of physics benchmark channels, like $\Lambda\bar{\Lambda}$ (secondary vertexes)

Thanks for your attention