Applying Legendre transformation method for Belle II tracking

DPG Spring Meeting, Particle Physics division

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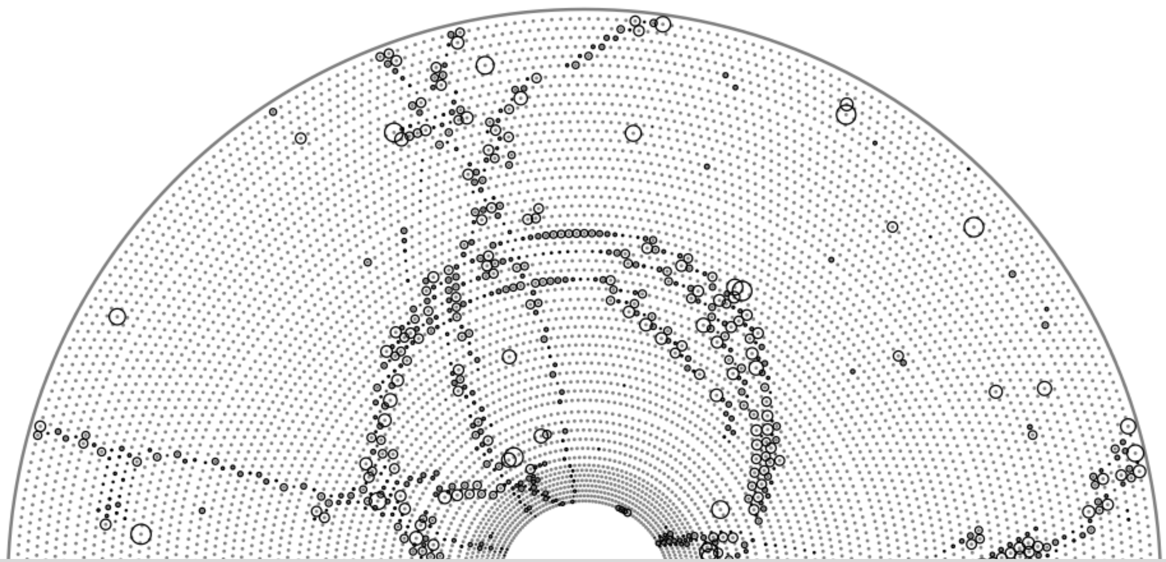
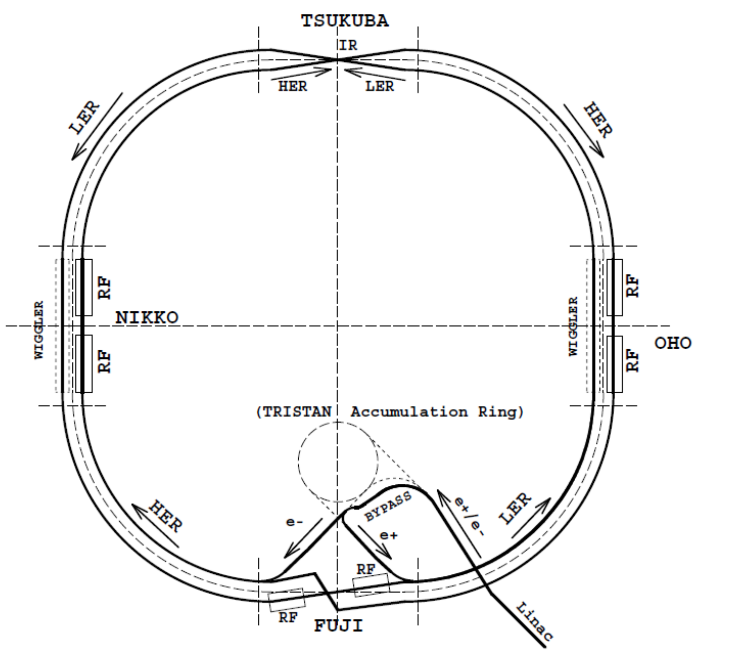
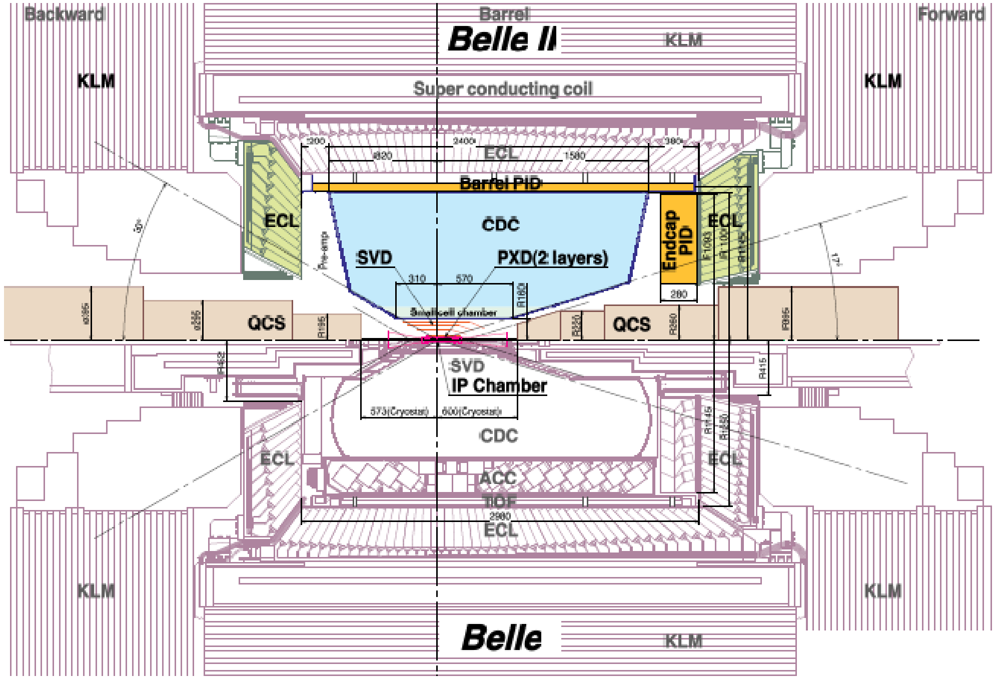


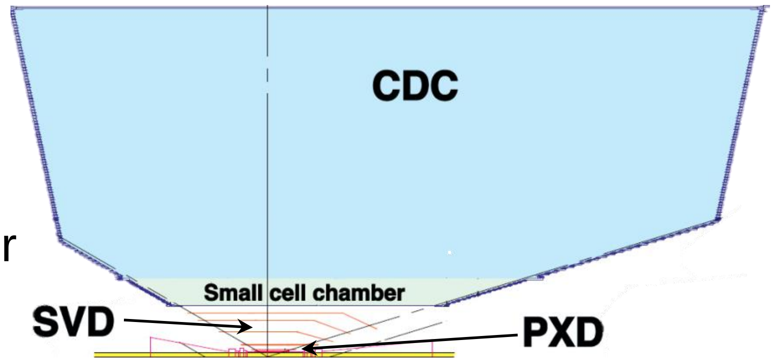
Belle II experiment

- SuperKEKB will be asymmetric electron-positron collider (SuperB-factory)
  - $E(e^-) = 7\ \mathrm{GeV};\ E(e^+) = 4\ \mathrm{GeV}, \sqrt{s} = 10.58\ \mathrm{GeV}$
- Belle II is experiment on SuperKEKB
- Design luminosity: $8 \times 10^{35} cm^{-2} s^{-1}$ (50 times higher than KEKB)





Tracking

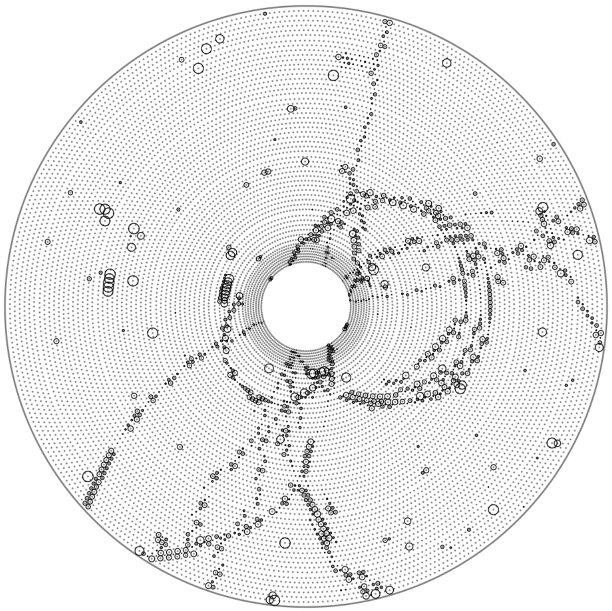


- Belle 2 tracking consist of:
  - PXD – Silicon pixel detector
  - SVD – Double sided silicon strip detector
  - CDC – Small cell central drift chamber

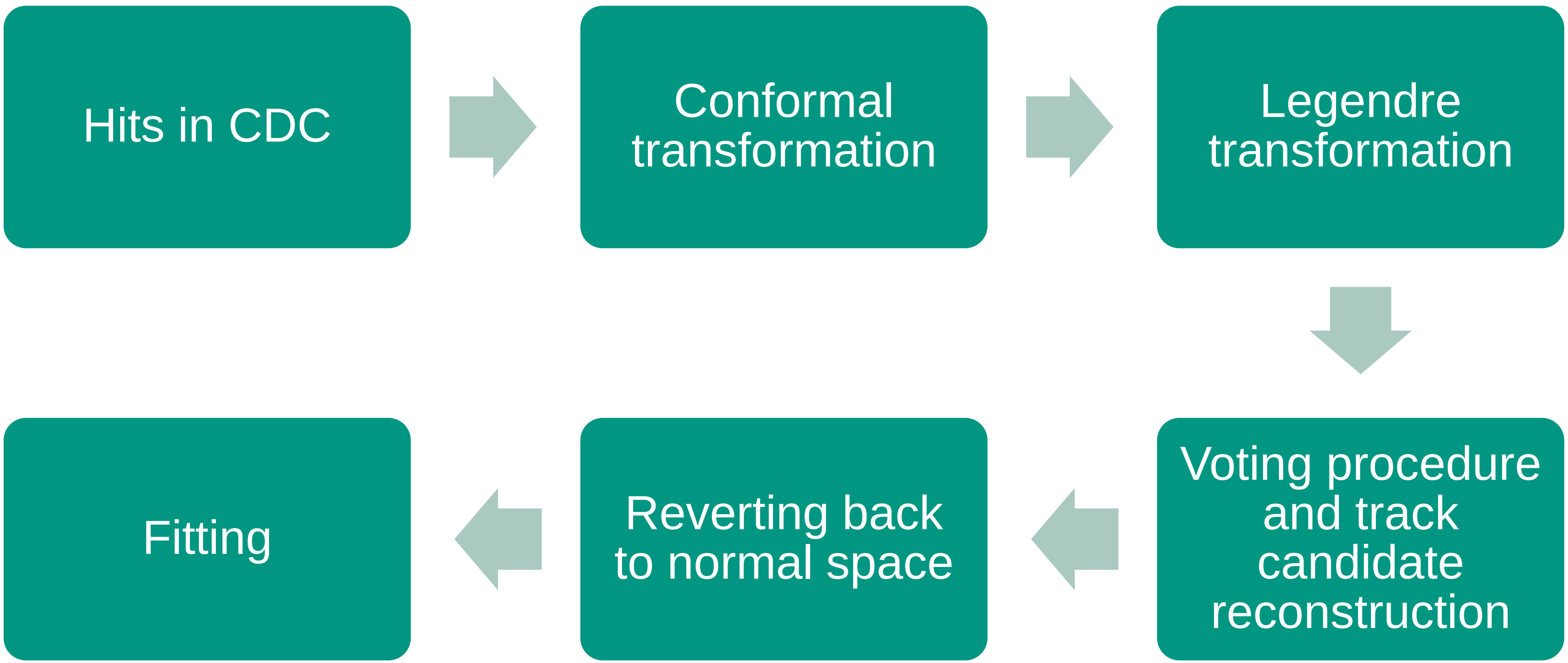
- Main goals of CDC tracking:
  - reconstruct charged tracks and measure their momenta precisely
  - provide particle identification information using measurements of energy loss within its gas volume
  - it provides efficient and reliable trigger signals for charged particles

Tracking

- Charged particles ionize gas in drift chamber, and electrons are drifting in electrical field to sensible wires and produce hits
- Drift distance for each hit can be calculated using the drift time which electrons need to reach the wire
- The task of track finding is to determine which hits belongs to a common track
- There exist few methods for hit pattern recognition
  - We present a method of track finding which based on reconstruction of linear hit patterns in conformal space



Chain of the method

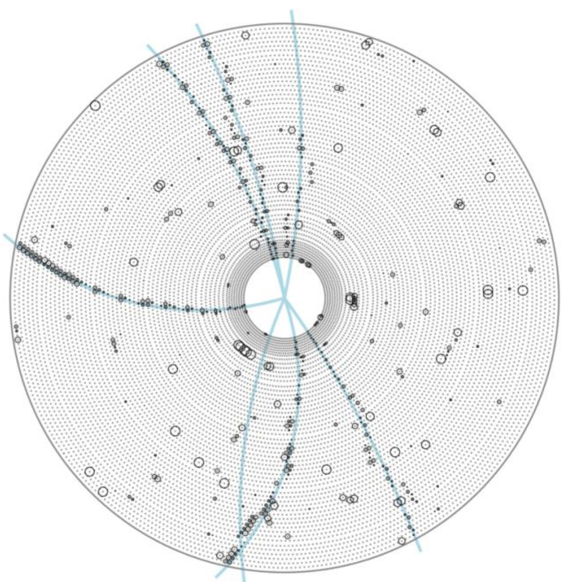


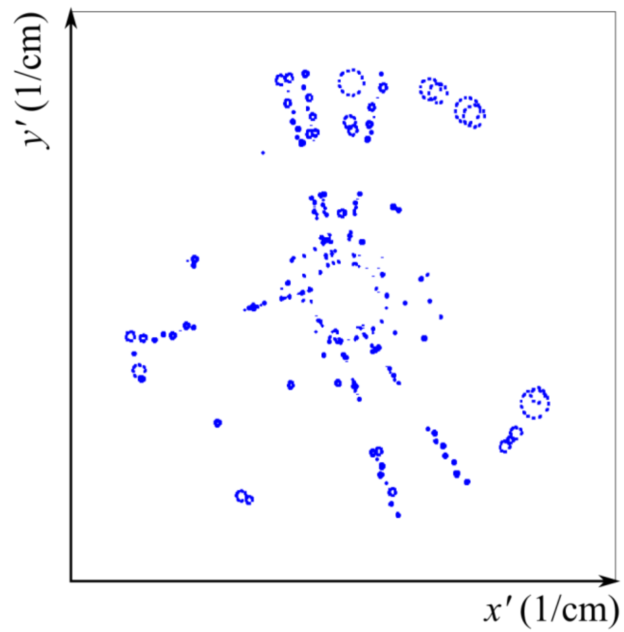
Conformal transformation

- Conformal transformation which transforms circles through origin into lines:

$$x' = \frac{2x}{x^2 + y^2}$$

$$y' = \frac{2y}{x^2 + y^2}$$



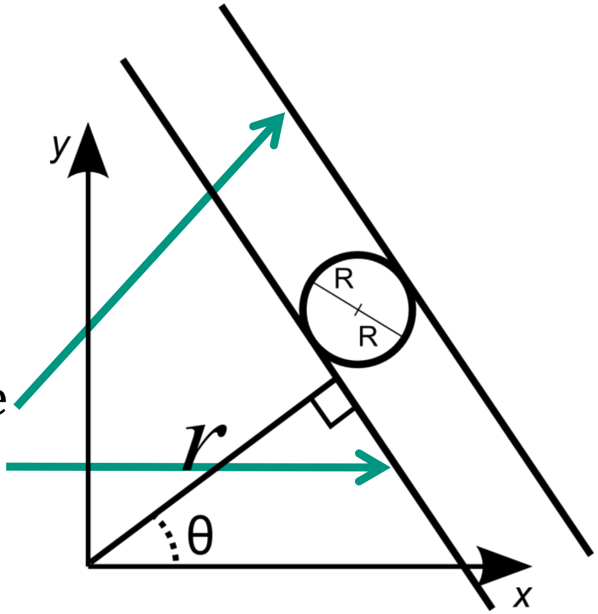


Transformation into Legendre space

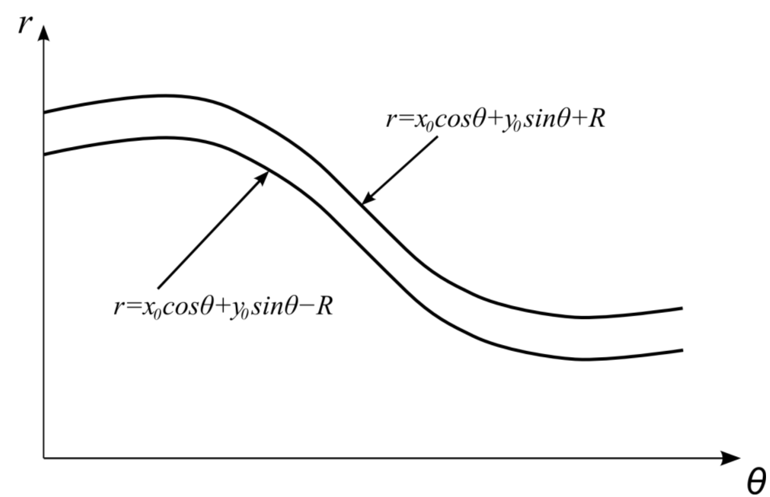
- The method is based on applying Legendre transformation to each drift circle in conformal space
- Legendre transformation of the circle can be written in next form:

$$f(x) \overset{\mathcal{L}}{\leftrightarrow} \begin{cases} r = x_0 + \cos\theta + y_0 \sin\theta + R & \text{for concave} \\ r = x_0 + \cos\theta + y_0 \sin\theta - R & \text{for convex} \end{cases}$$

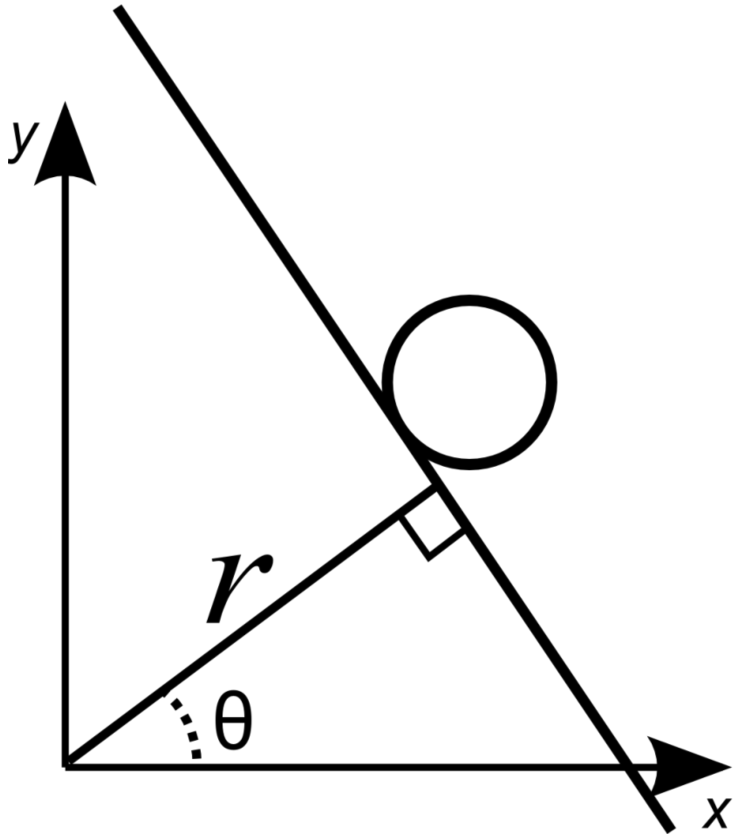
which presents tangents to the circle

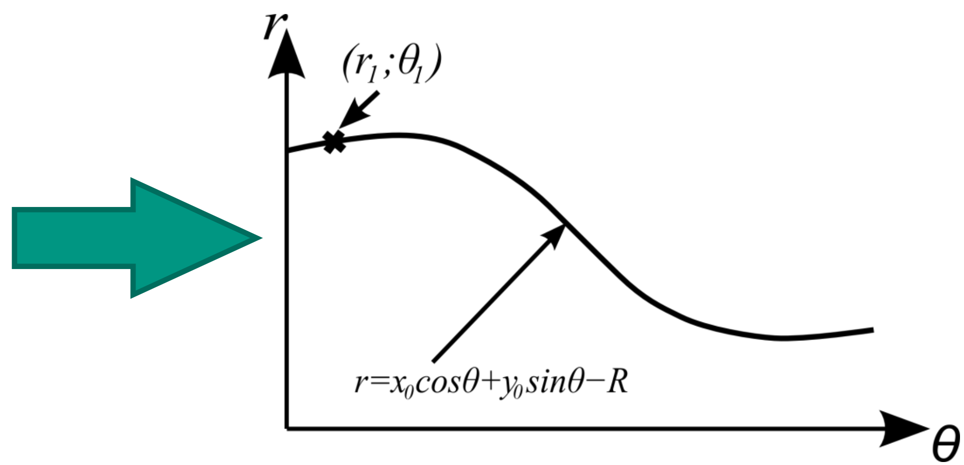


- Representation of the circle in the r, θ Legendre transformation space



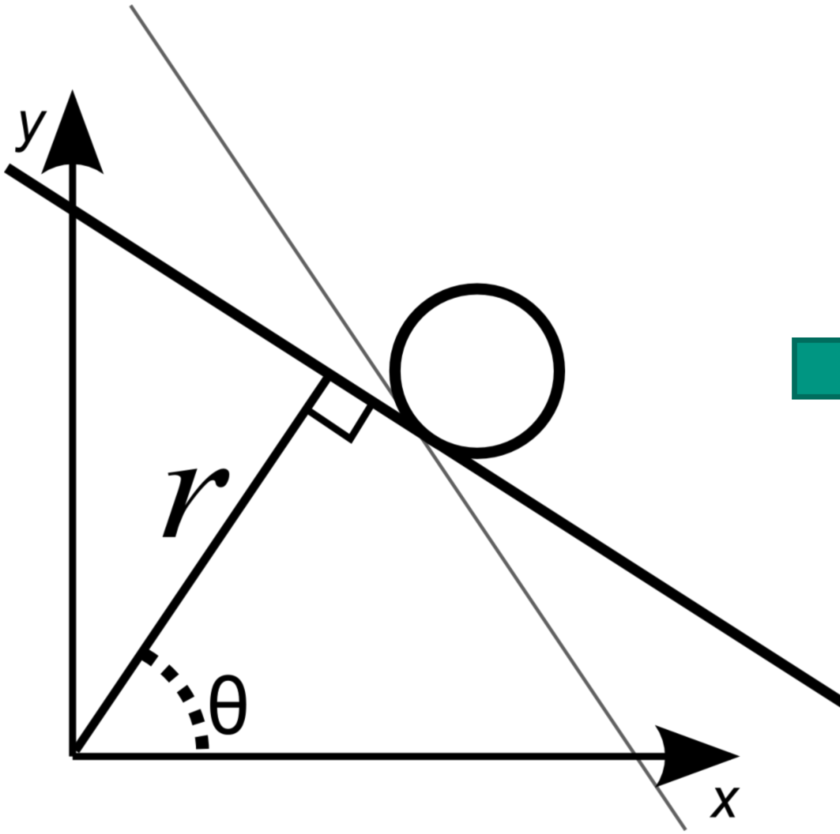
Transformation into Legendre space

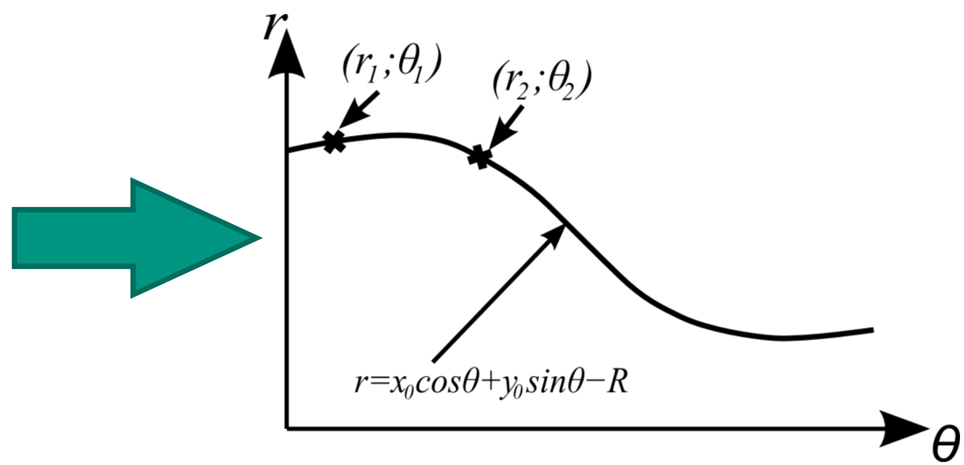




Each tangent has corresponding point in r, θ Legendre transformation space

Transformation into Legendre space





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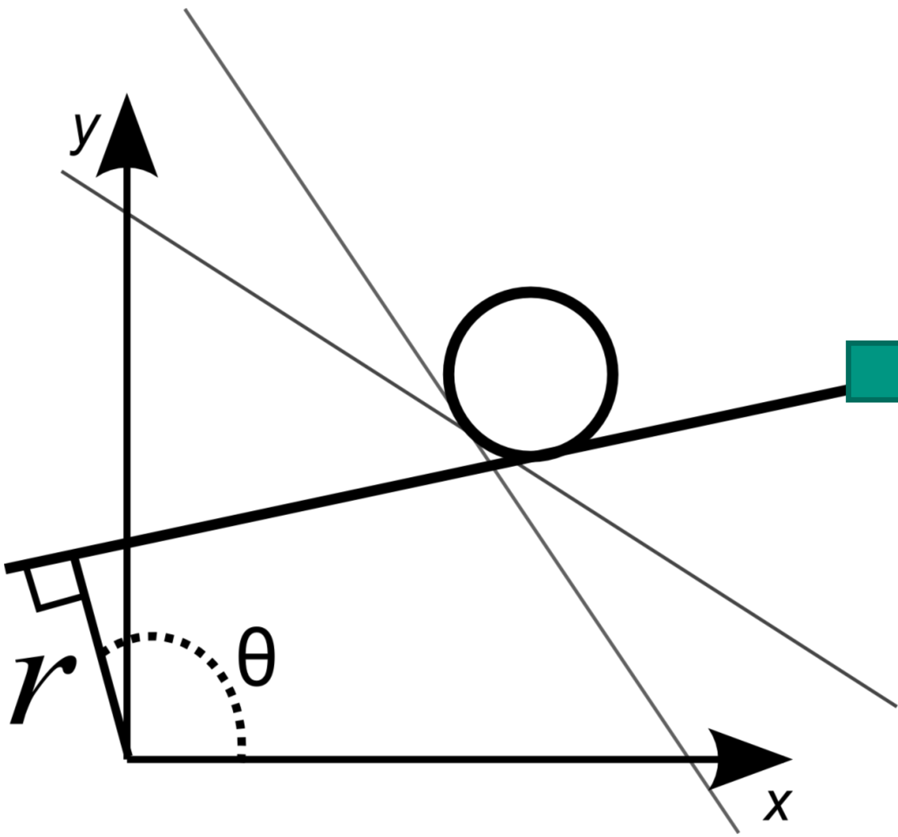
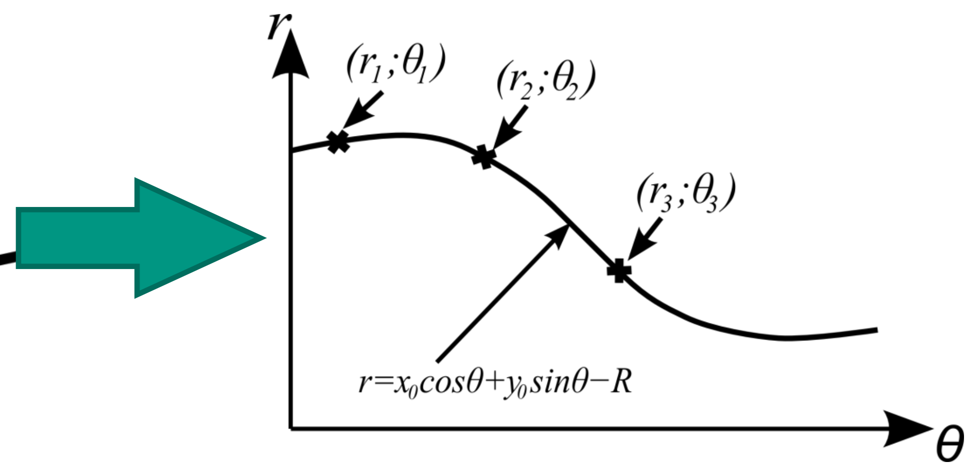
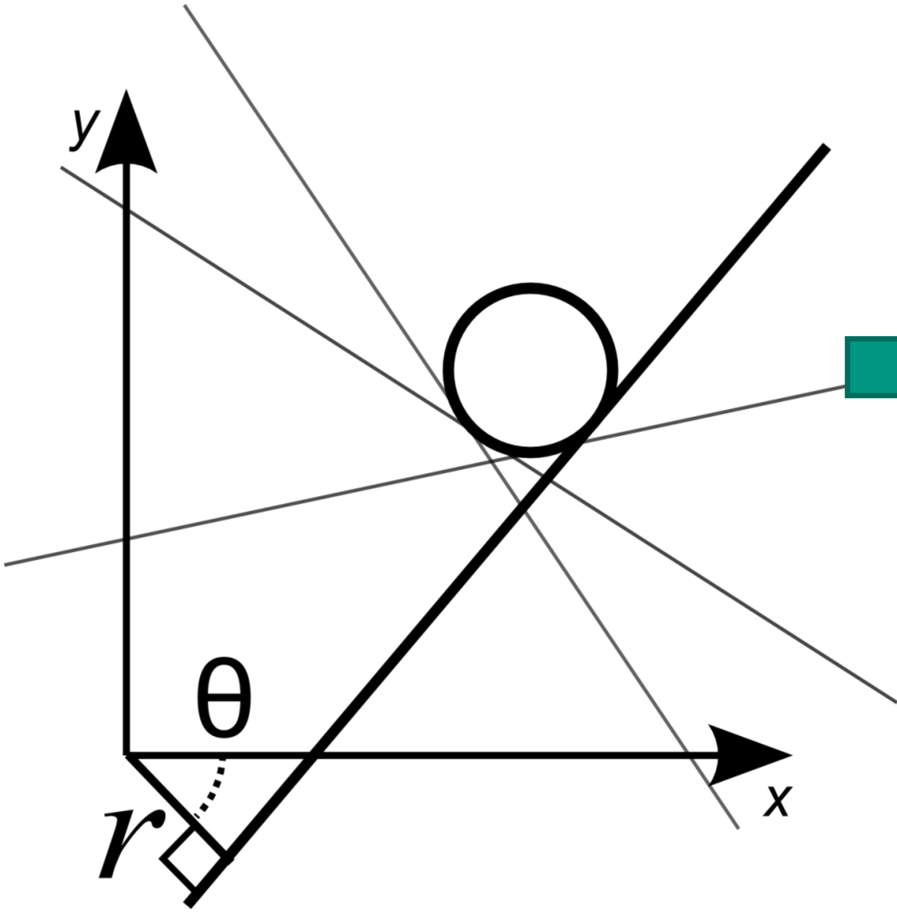
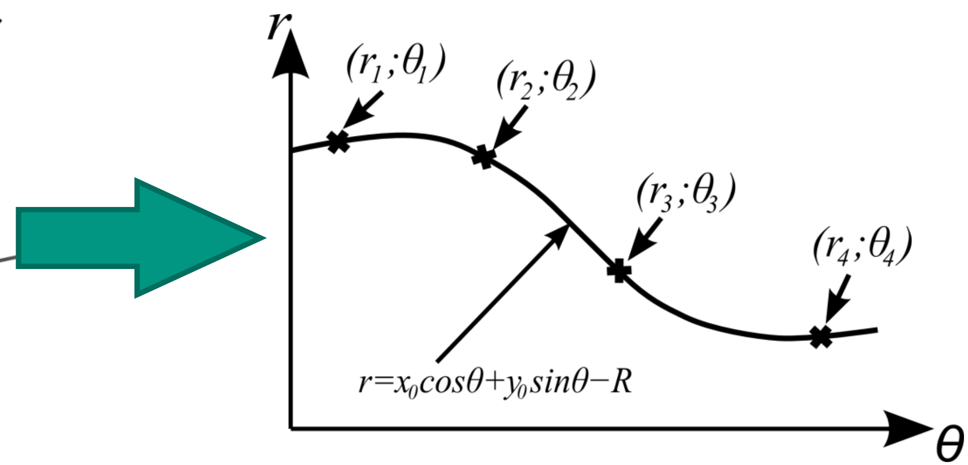




Each tangent has corresponding point in r, θ Legendre transformation space

Transformation into Legendre space

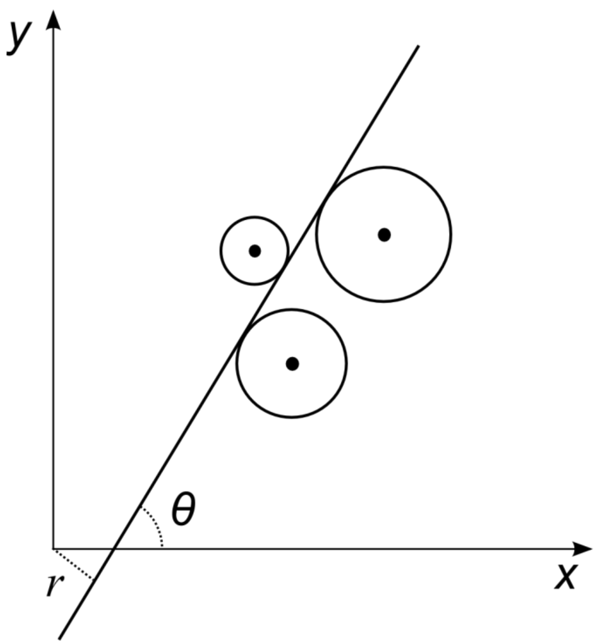


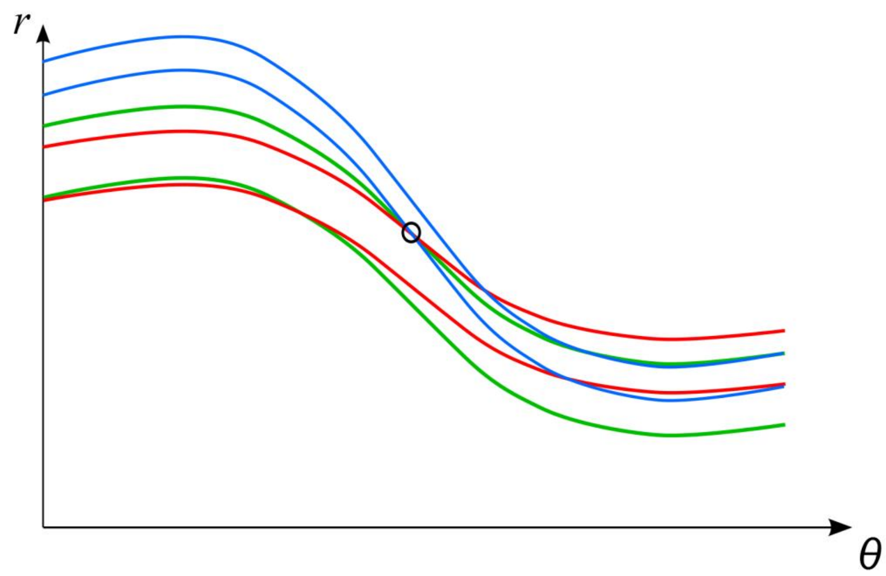


Each tangent has corresponding point in r, θ Legendre transformation space

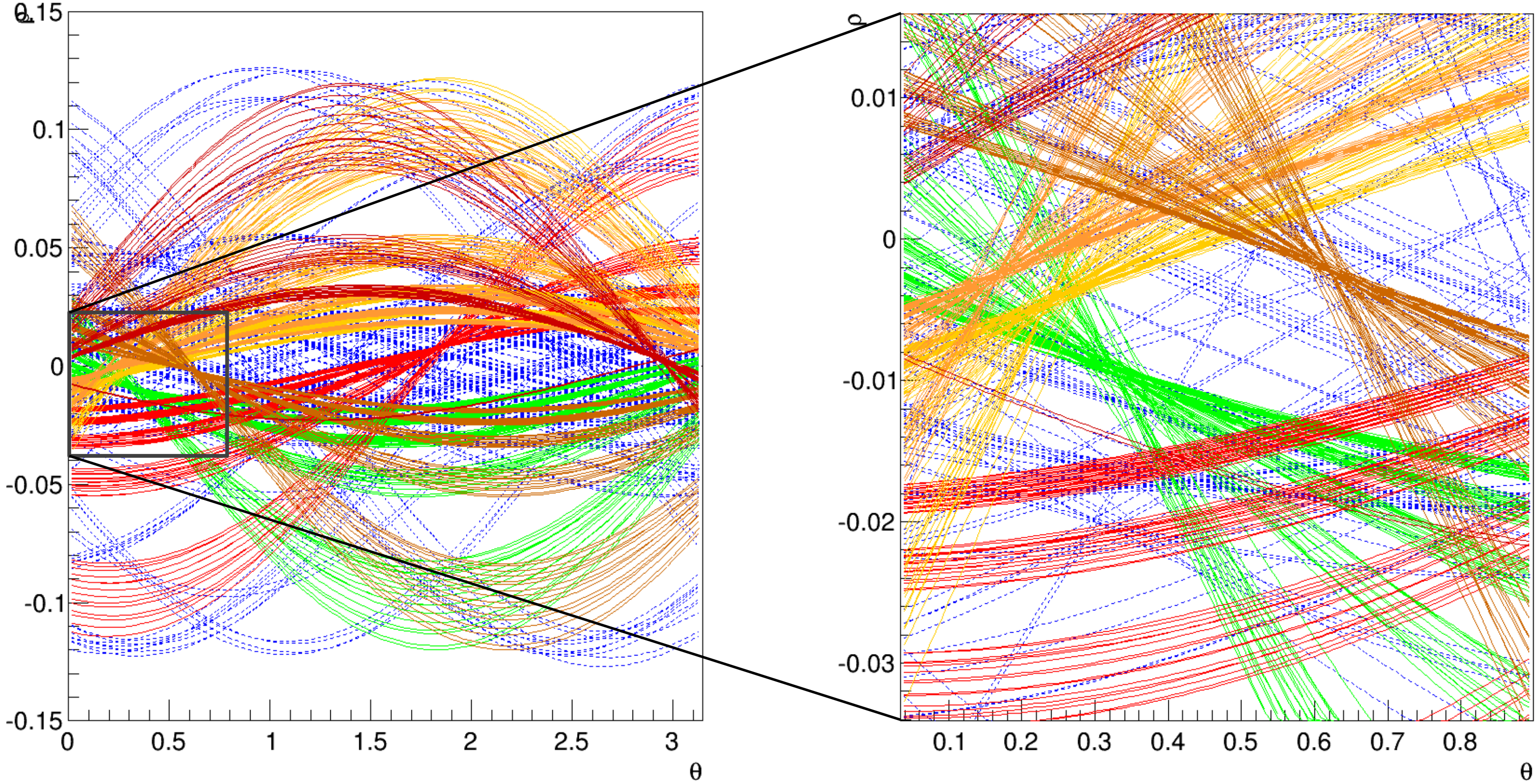
Finding of tracks

- The point of most sinogram intersection in r, θ space represents parameters of the common tangent to each drift circle belonging to the track



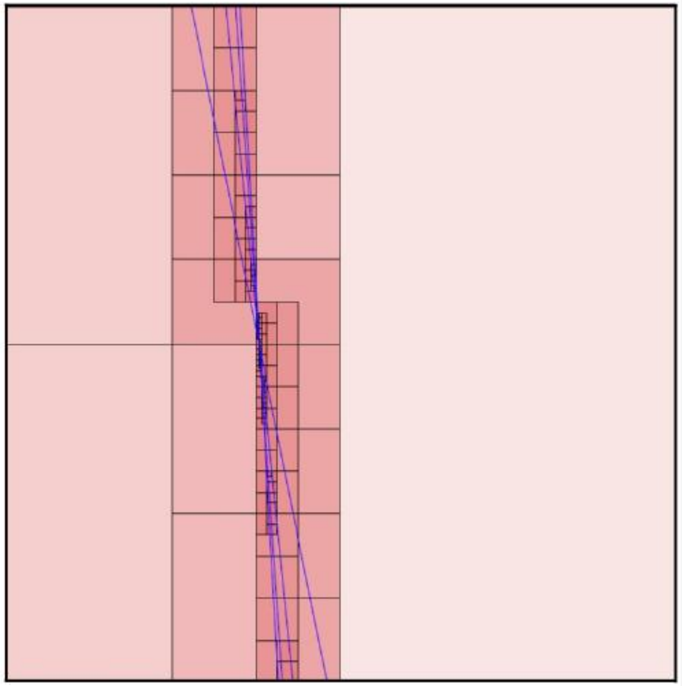


Sinograms of simulated event



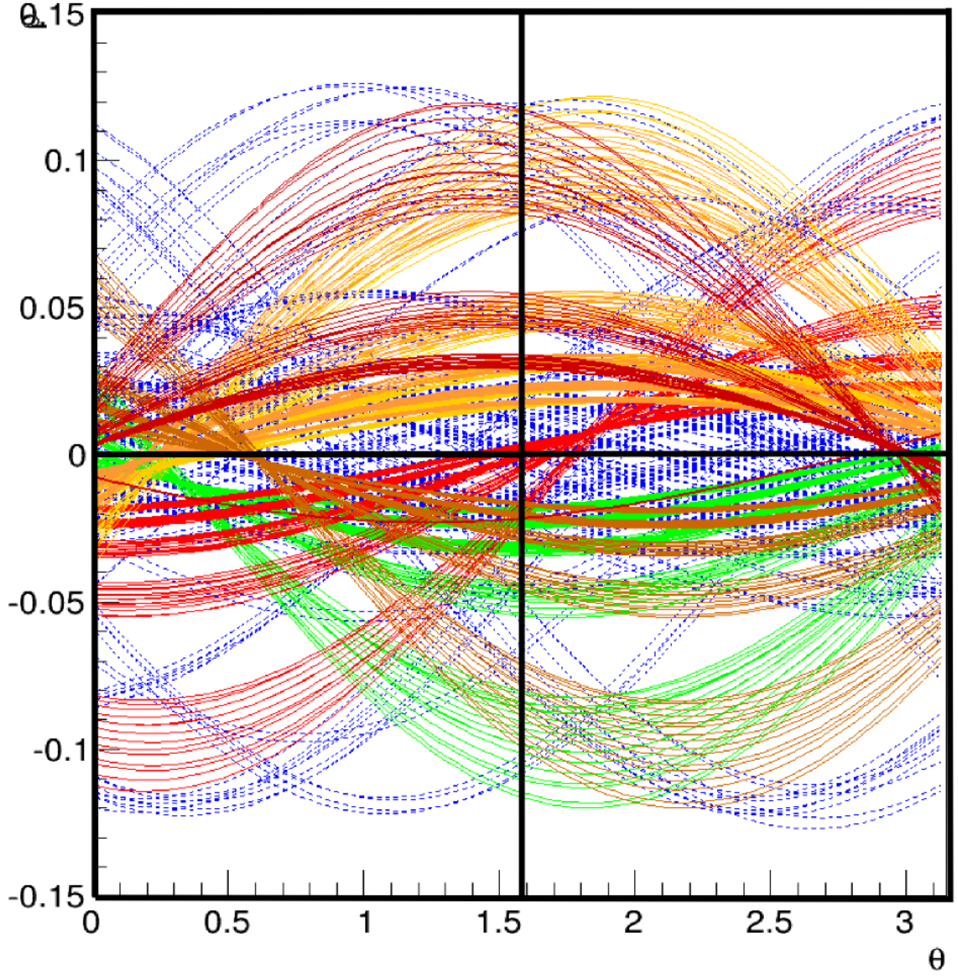
Voting or "How to find the point of most intersections?"

- Let each drift circle *vote* for a set of possible parameters in Legendre space
  - Bin acquires vote if sinogram of drift circle passes through it
- Voting algorithm (based on 2-D binary search):
  - Split (r, θ) space into 4 bins
  - Accumulate votes in each bin
  - Select bins which passes threshold on number of votes
  - Continue bin splitting and voting until desired (r, θ) resolution reached
- Bin with the most of votes (hits) indicates hits pattern of track candidate



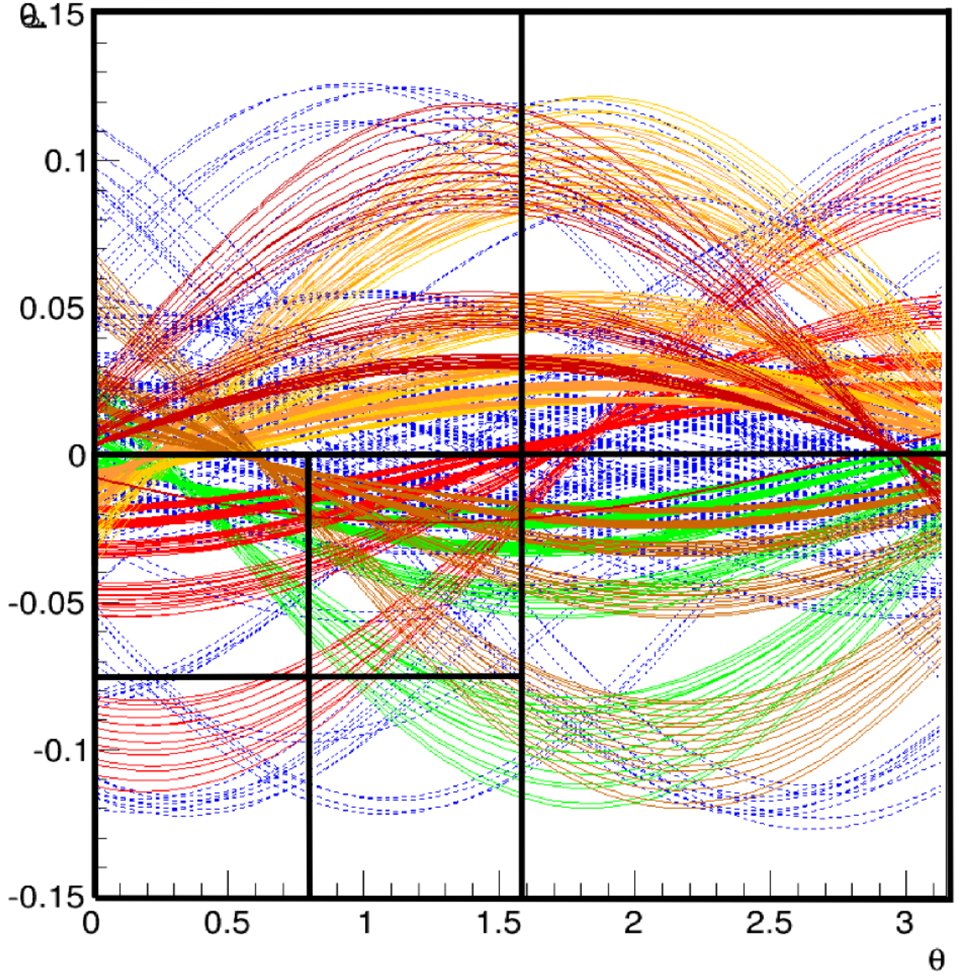
Voting

- **Step 1**



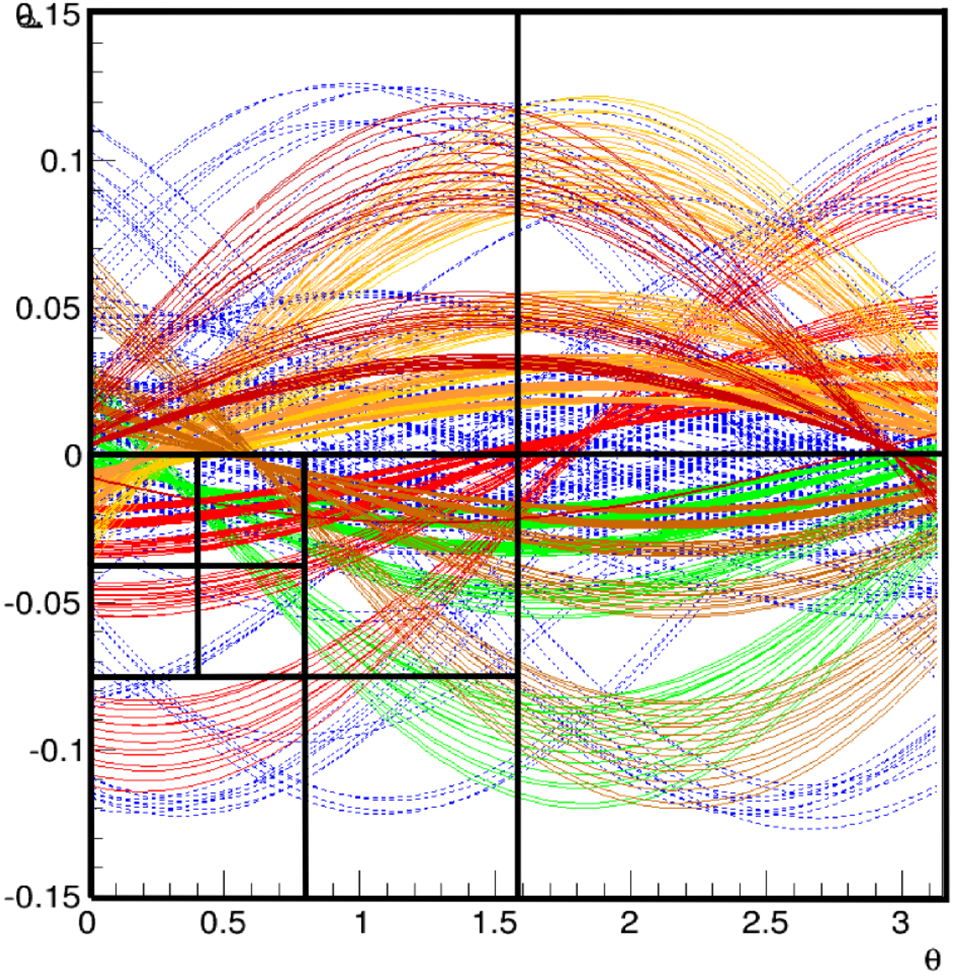
Voting

- **Step 2**



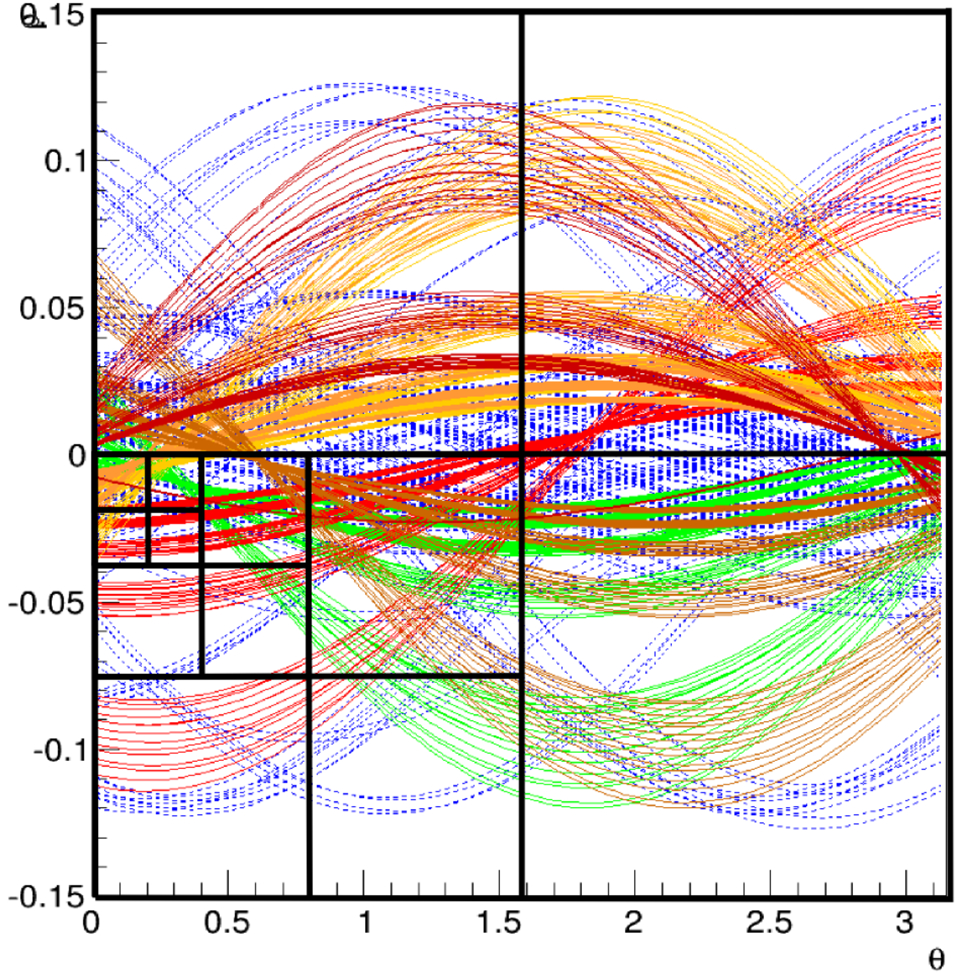
Voting

- **Step 3**



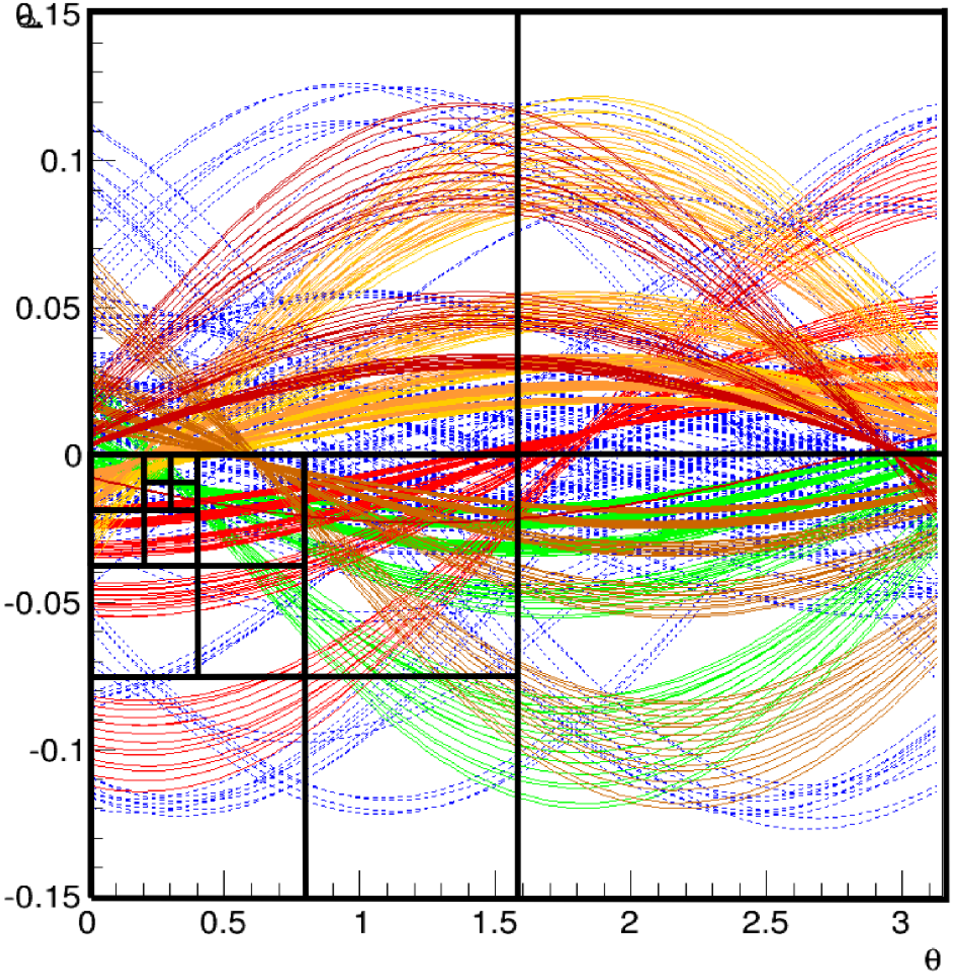
Voting

- **Step 4**



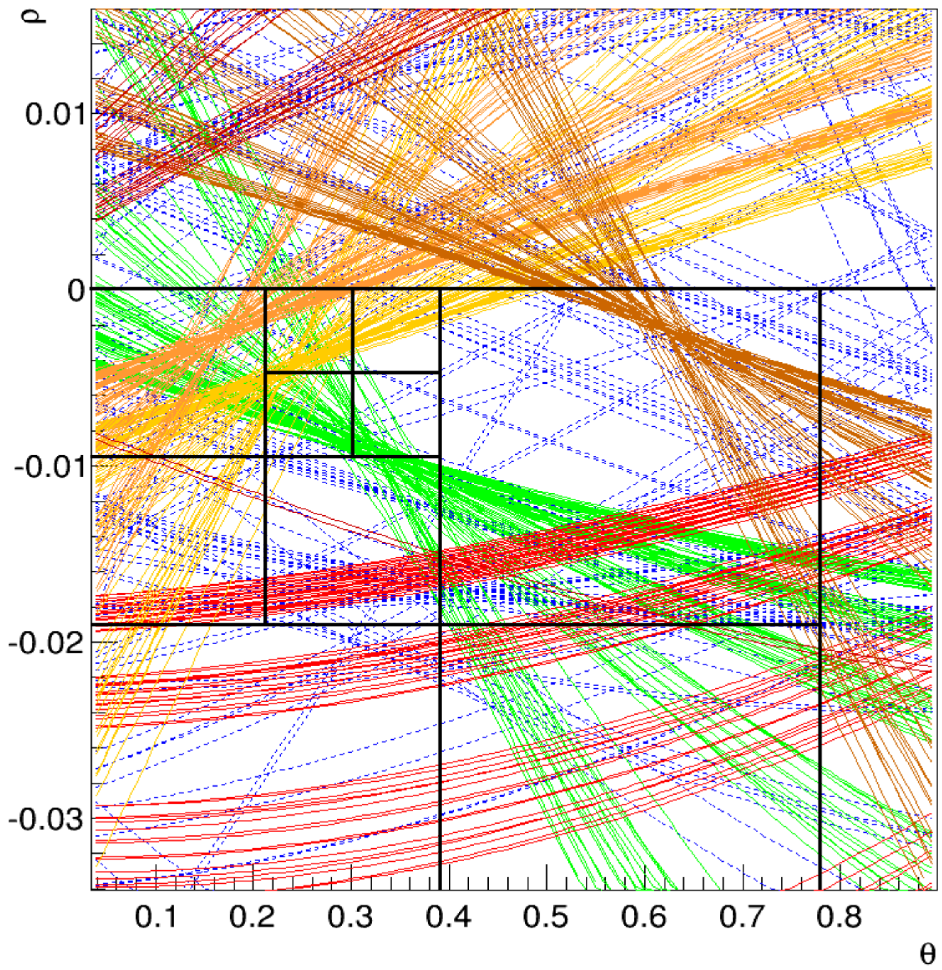
Voting

- **Step 5**



Voting

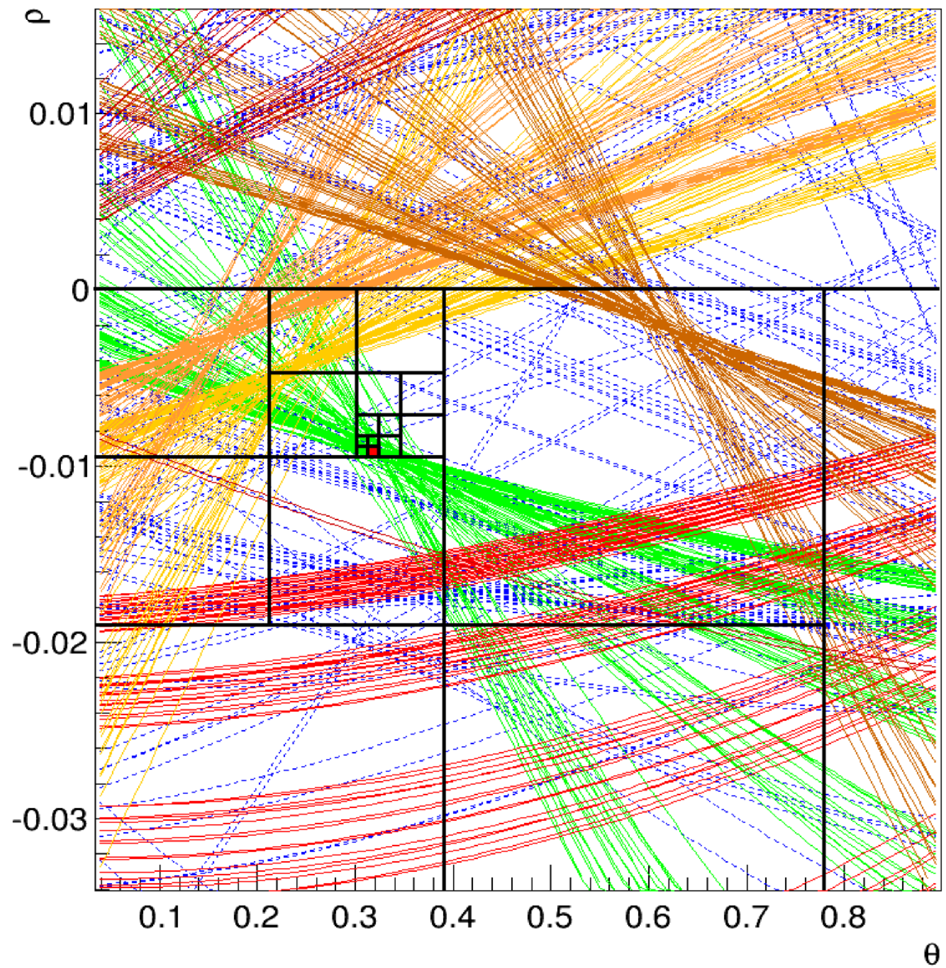
- **Step 6**



Voting

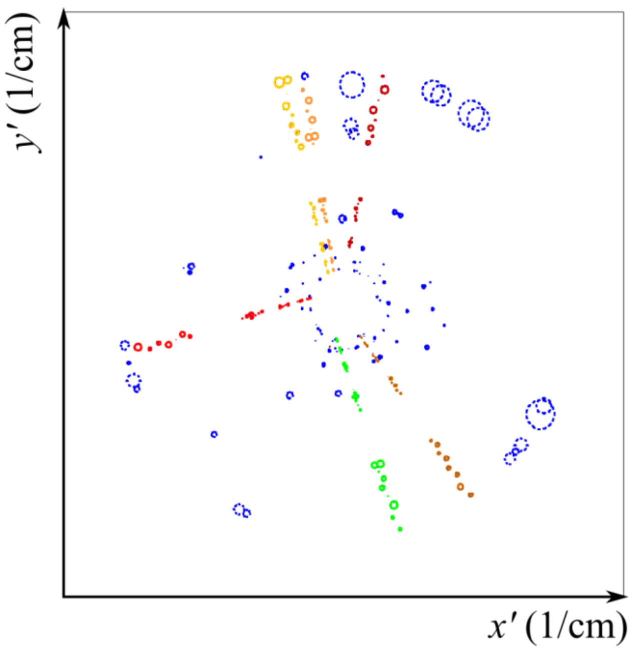
- **Step 10**

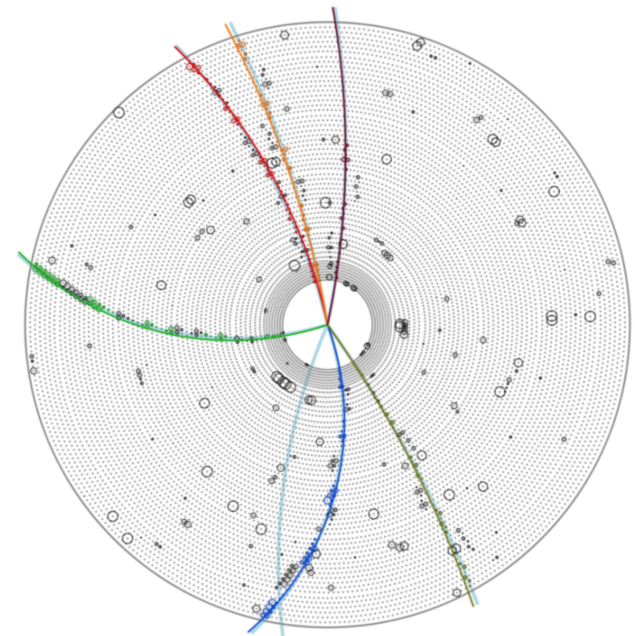
Last step, track candidate parameters are defined



Actual results of algorithm

- Simulated event: $B^- \rightarrow D^0(\rightarrow K^- \pi^+)\,\pi^- + \text{beam background}$



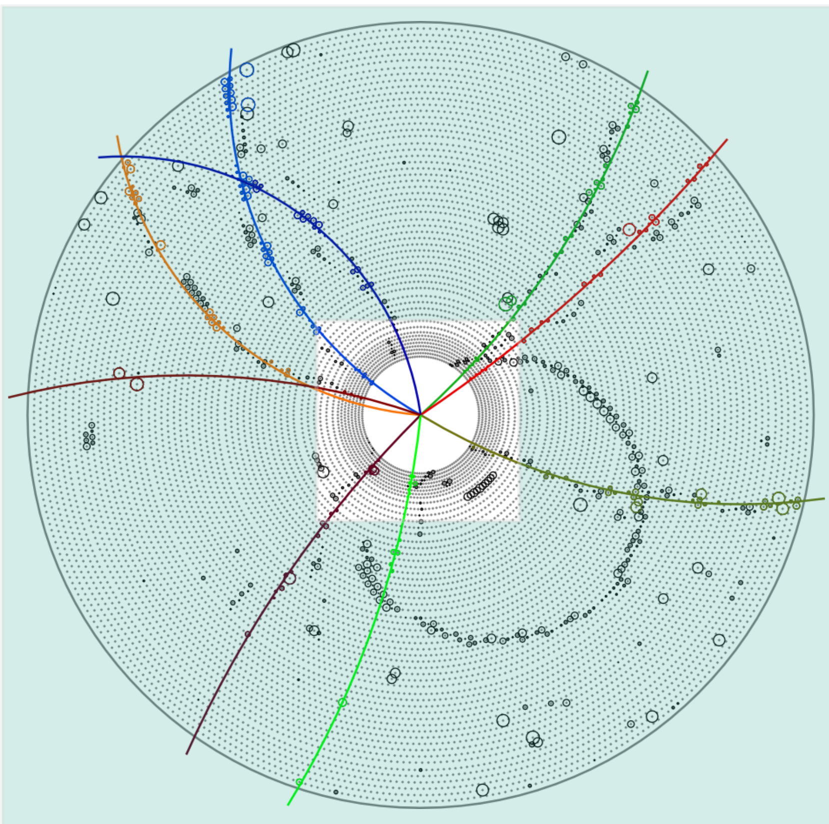


Working only with tracks originating close from IP

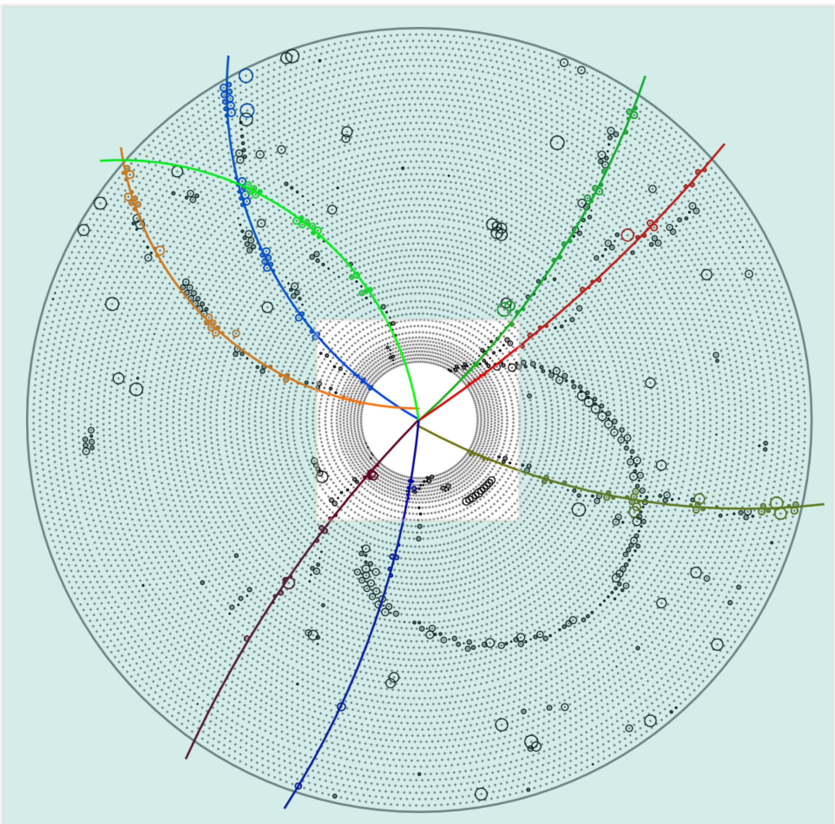
Efficient for finding tracks with high momentum

Track fitting

- Finder uses circular track fitting based on solving system of linear equation



Before



After

Conclusions

- The method can perform fast track finding
- Works quite well with high-p_t tracks
- Limited to tracks originating from IP
- Highly efficient for track finding

Thank you for your attention!