A FPGA helix tracking algorithm for PANDA

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15. März 2010

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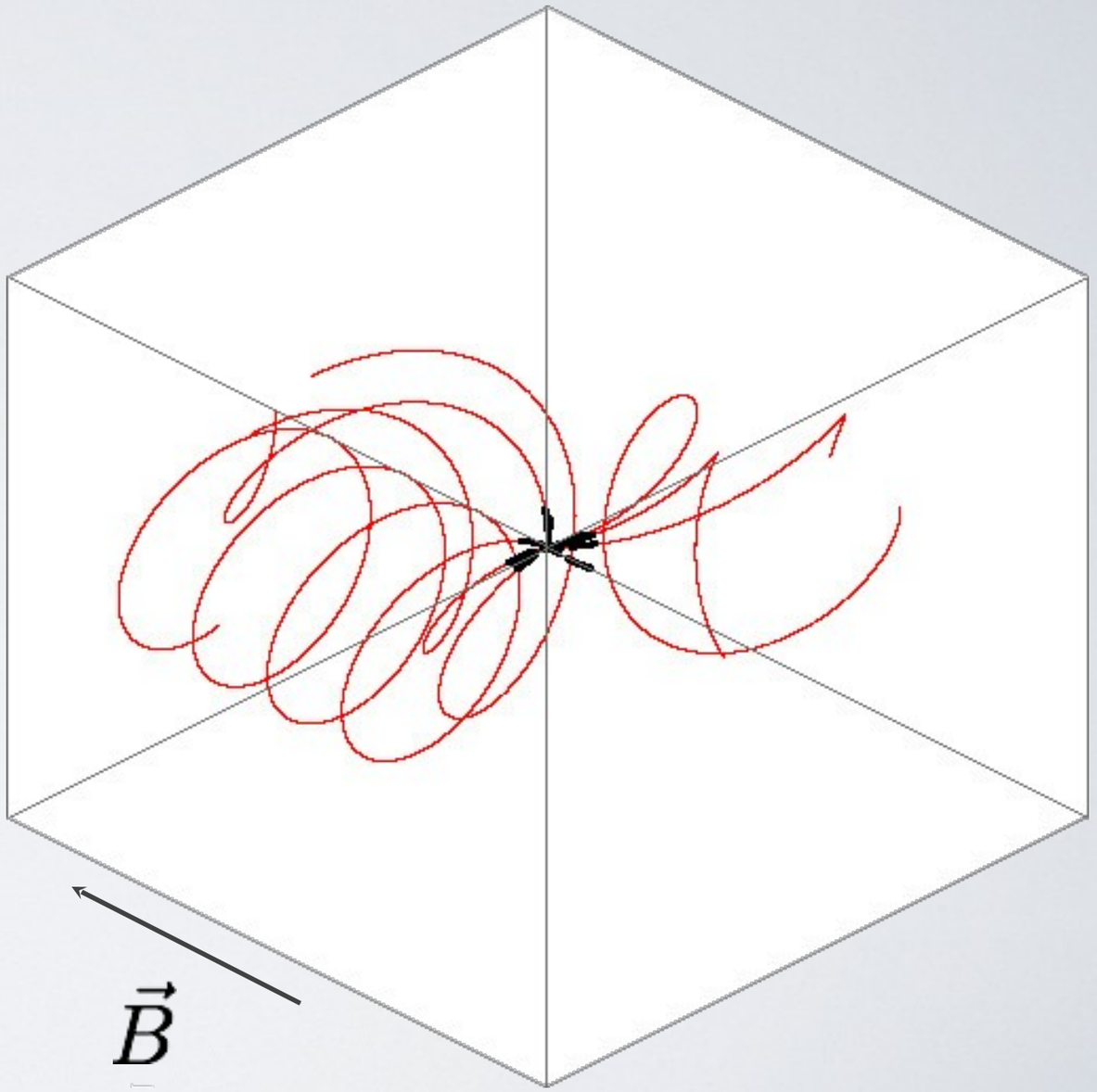
Motivation

- Finding helix shaped tracks in beam direction
- Design an algorithm as online trigger for PANDA
- Portability to FPGA
- Reducing calculation time on FPGA by parallelization
- Problem:
  Complex definition of a helix
- Ansatz:
  Employ transformations to simplify calculations



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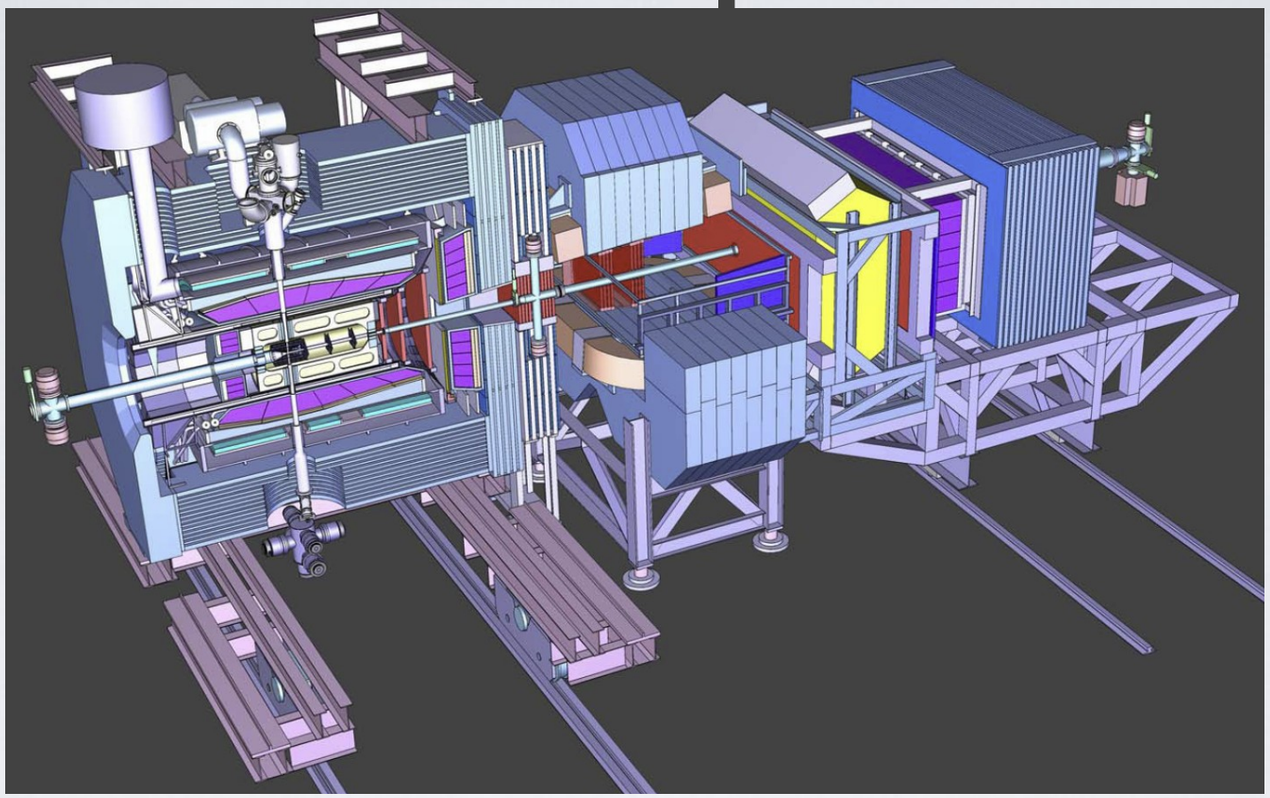
PANDA Experiment



- Fixed target experiment at the future Facility for Antiproton and Ion Research (FAIR) at GSI
- Magnetic field in target region parallel to beam direction
- Used data from inner detectors

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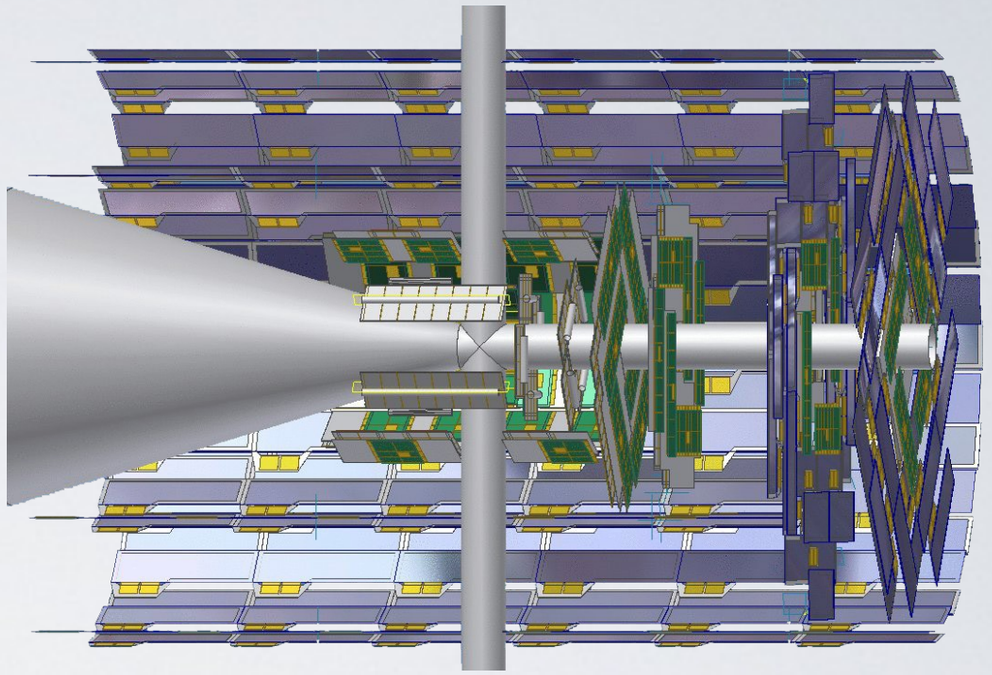
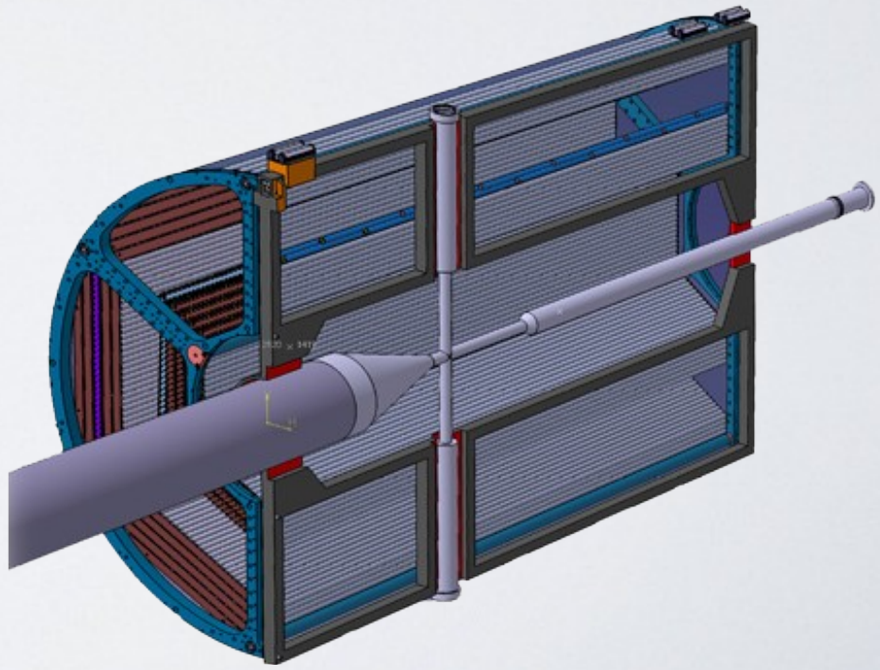
Central Detectors

Used for the Simulation with PandaRoot:

- Micro Vertex Detector (MVD)
  - 5 cylindrical layers of 1-6 cm radius
  - Inner 3 layer as silicon pixel detector
  - Outer 2 layer as silicon strip detector
  - 5 discs in forward direction
- Straw Tube Tracker (STT)
  - Hexagonal structure
  - Straws in beam direction
  - 15 double layers





Not used for the Simulation:

- Time Projection Chamber (TPC)
  - Optional instead of STT
  - Not suitable for online helix tracking

Particles in magnetic Field

- Perpendicular to magnetic field circle shaped

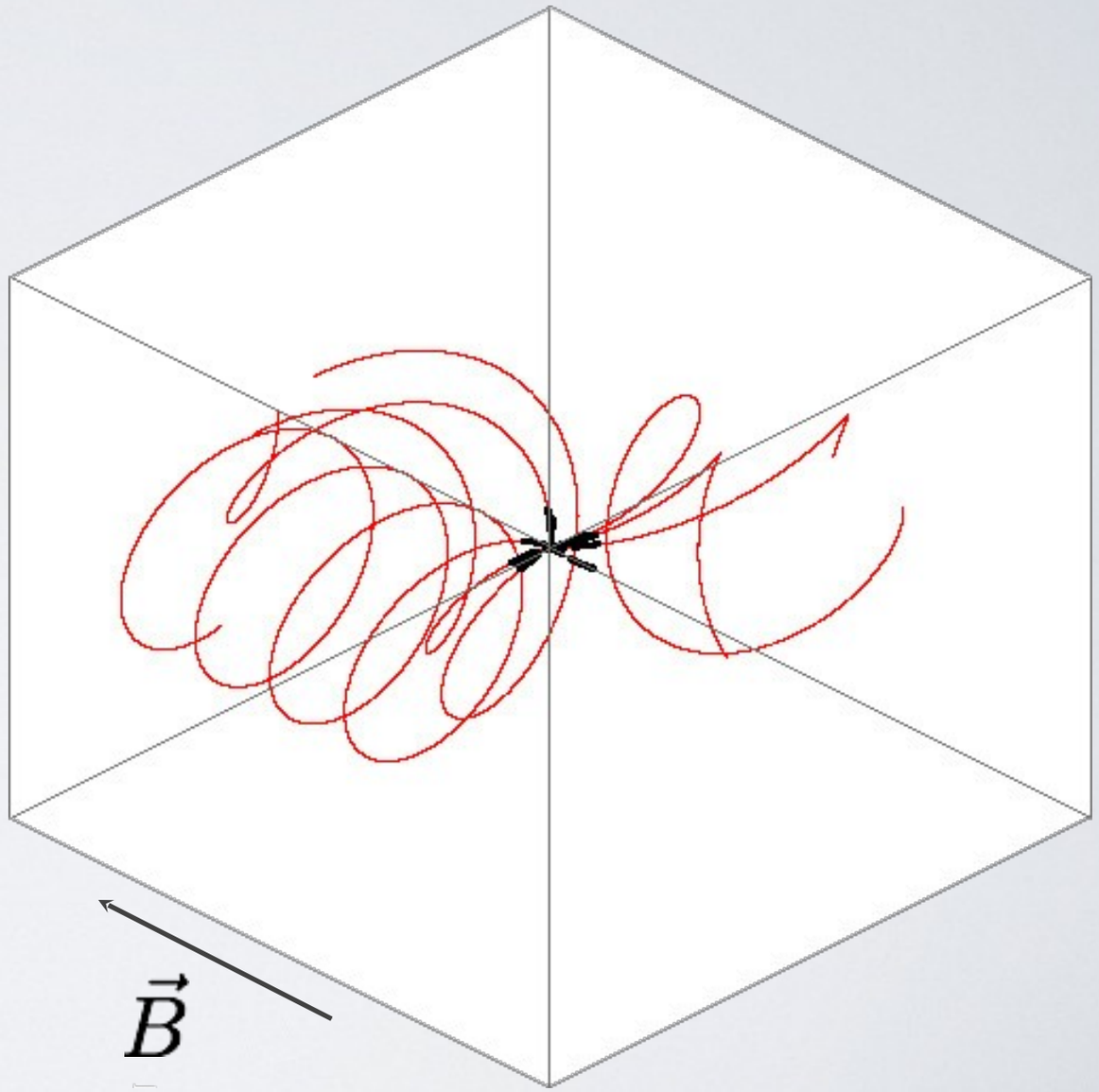
- Helix shaped tracks

- Momentum in eV:

$$p \approx \frac{0.3 \cdot R \cdot B}{\cos \vartheta}$$

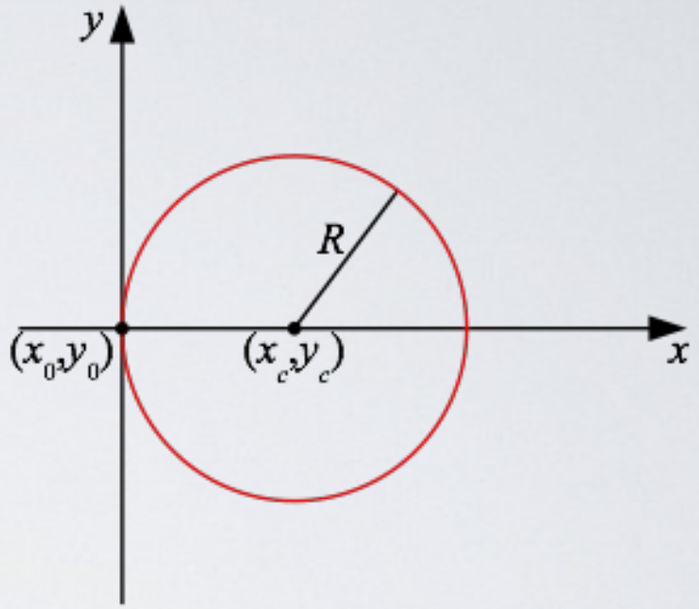
R in m and B in T

- Difficult for online tracking



Conformal Transformation

- Used for projection perpendicular to beam direction

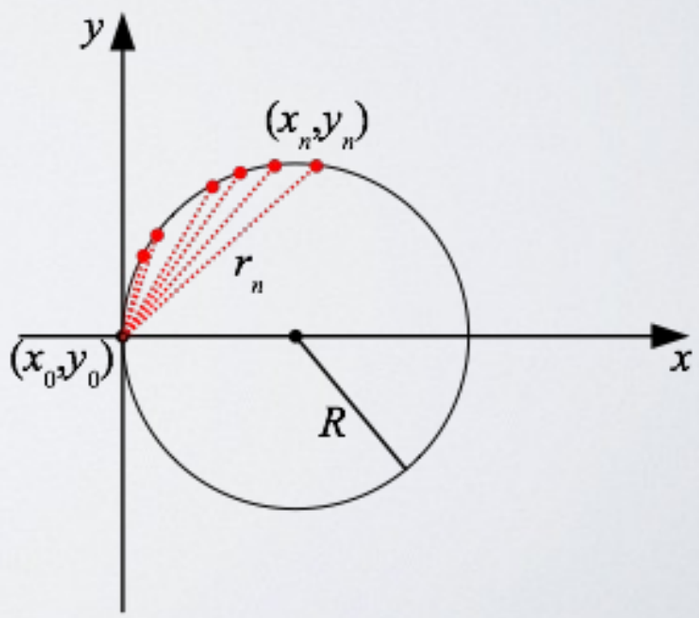


- Finding straight lines is less complex than circles

- Transform circles to straight lines

$$x' = \frac{x - x_0}{r^2} \qquad y' = \frac{y - y_0}{r^2}$$

$$r^2 = (x - x_0)^2 + (y - y_0)^2$$



- Vertex constrained

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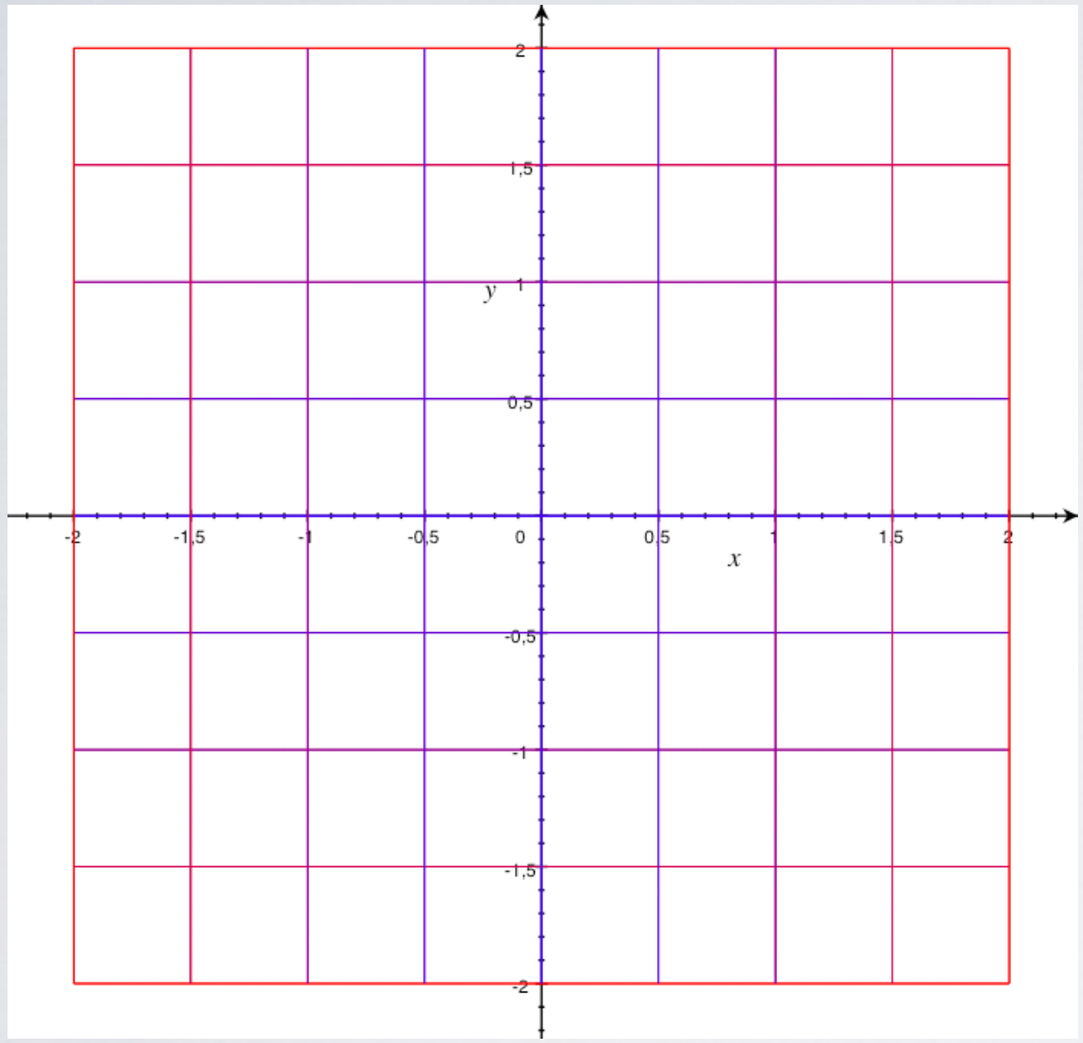
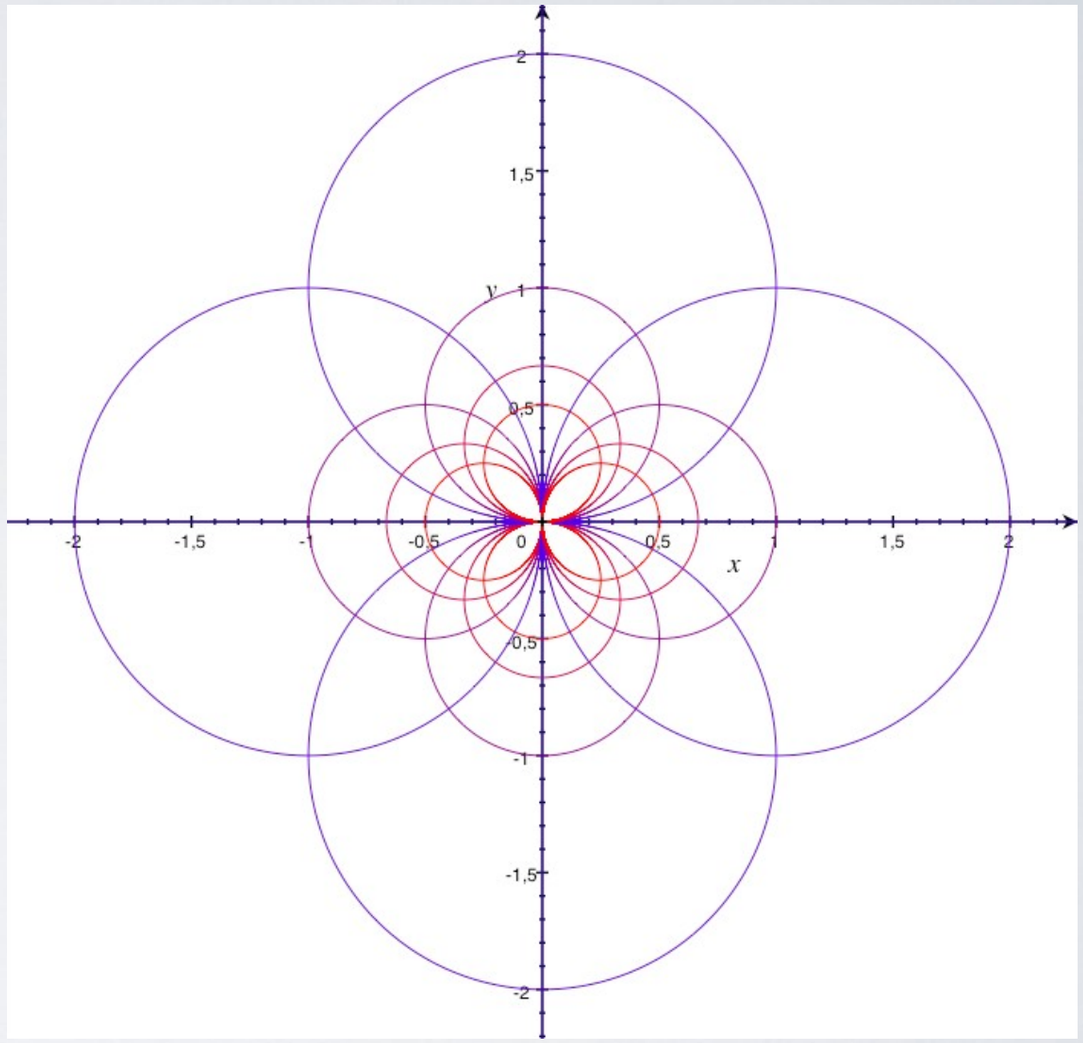
Conformal Transformation



grid in real space



grid transformed to conformal space

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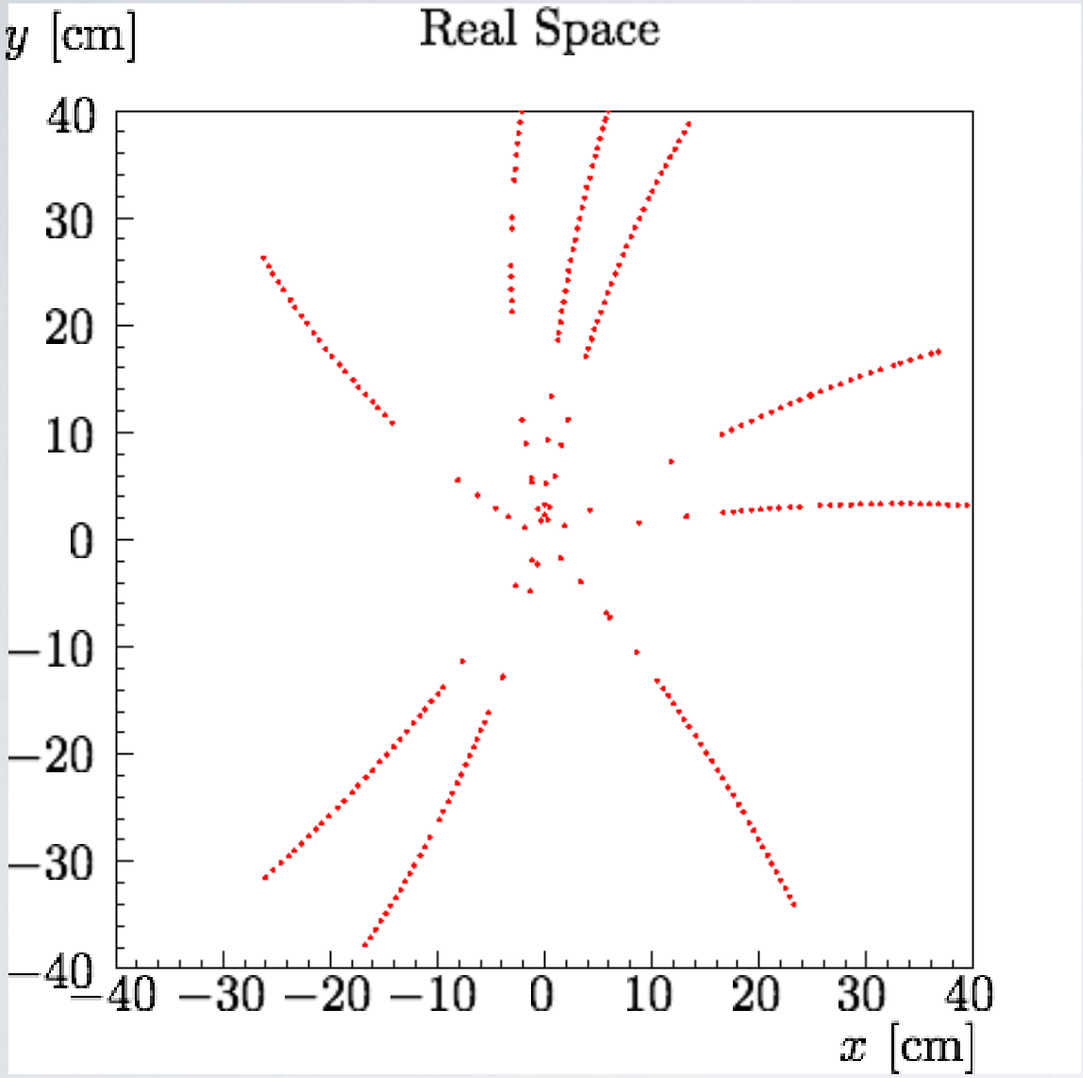
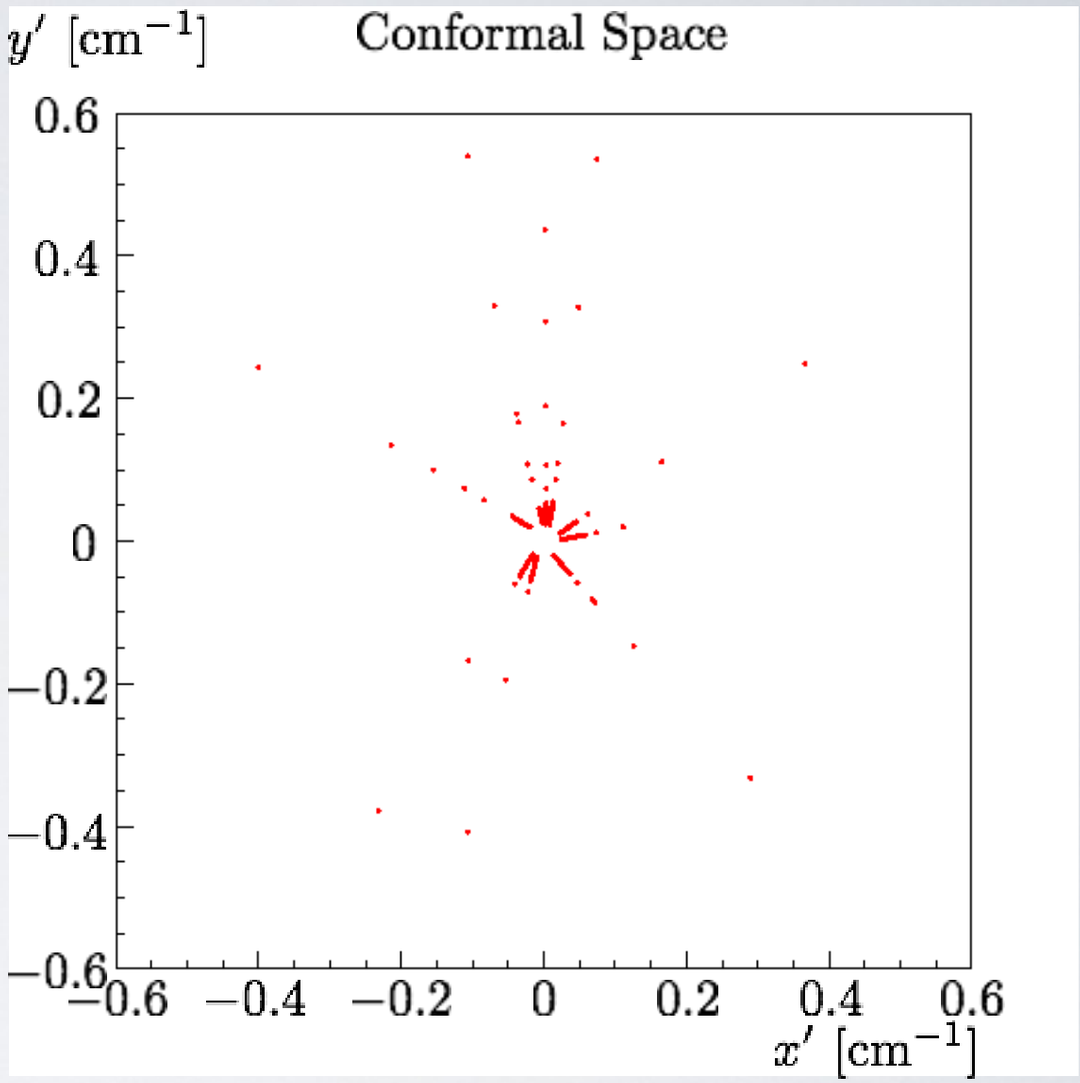
Conformal Transformation





reference point in vertex

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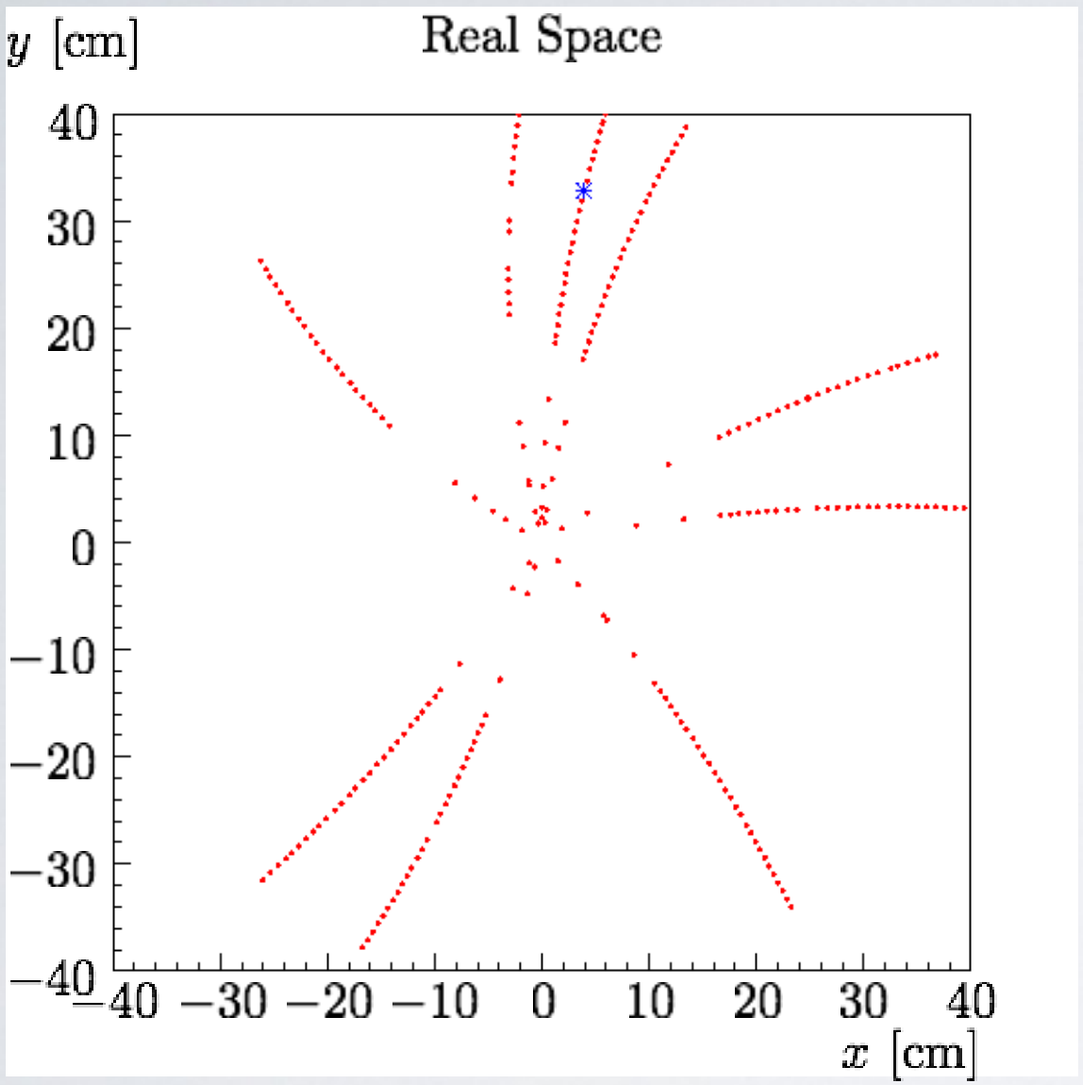
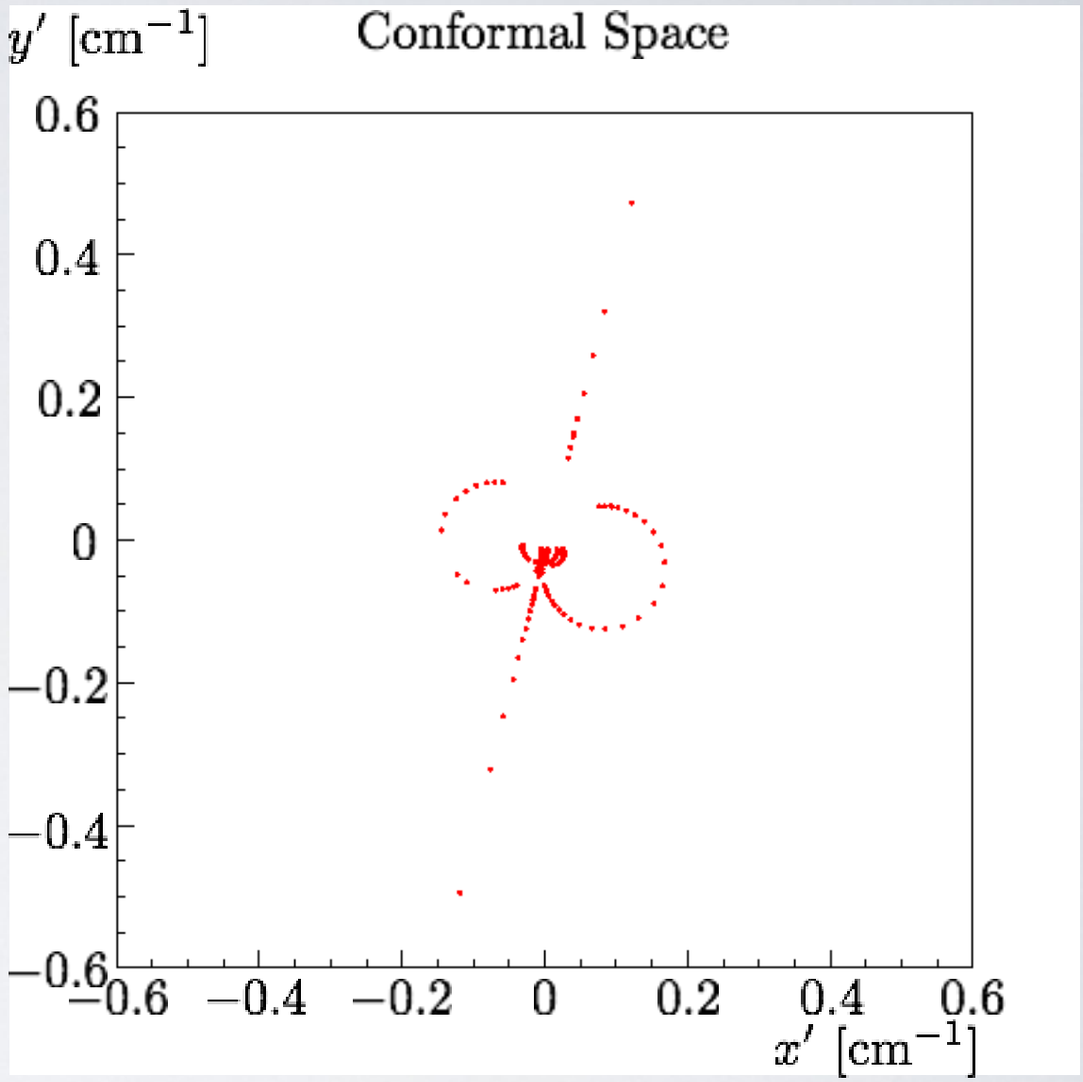
Conformal Transformation

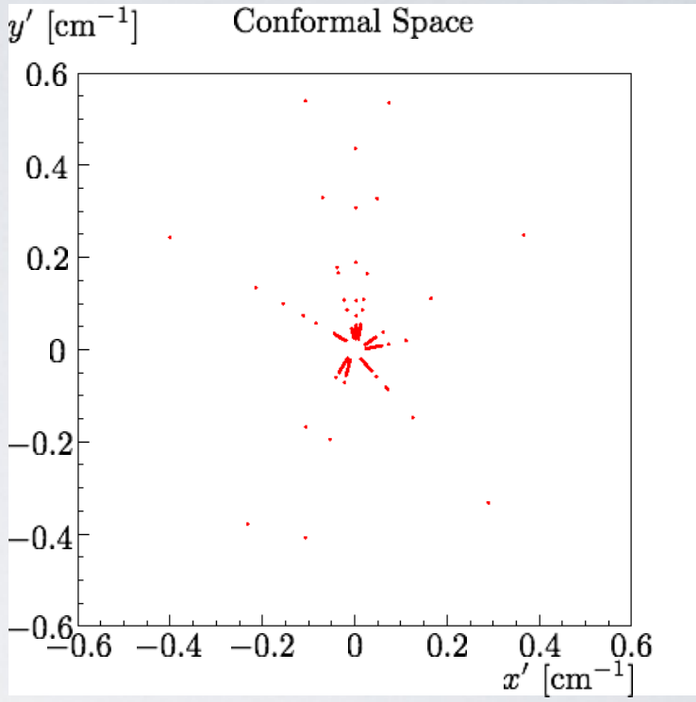




reference point on hitpoint outside of vertex

Hough Transformation

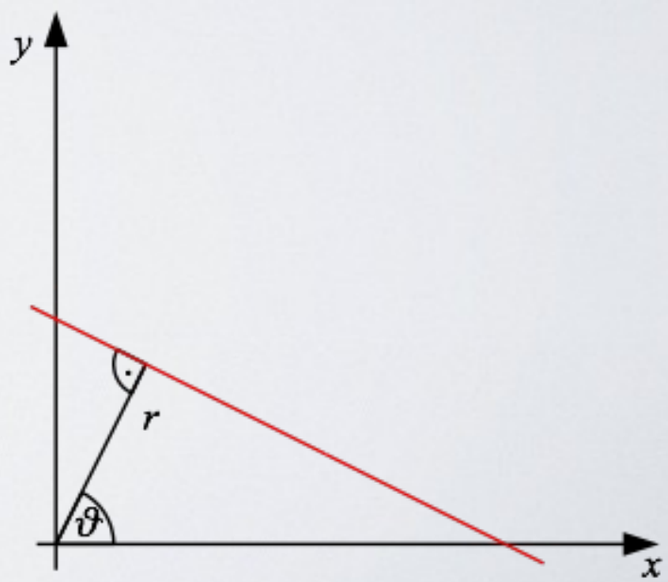
- In general: use a function which describes the pattern searched pattern in a point set (e.g.: lines, circles ...)



- Here: describing lines with r and ϑ

- Calculate for all angles the needed r to get a line through the point

$$r = x \cdot \cos\vartheta + y \cdot \sin\vartheta$$



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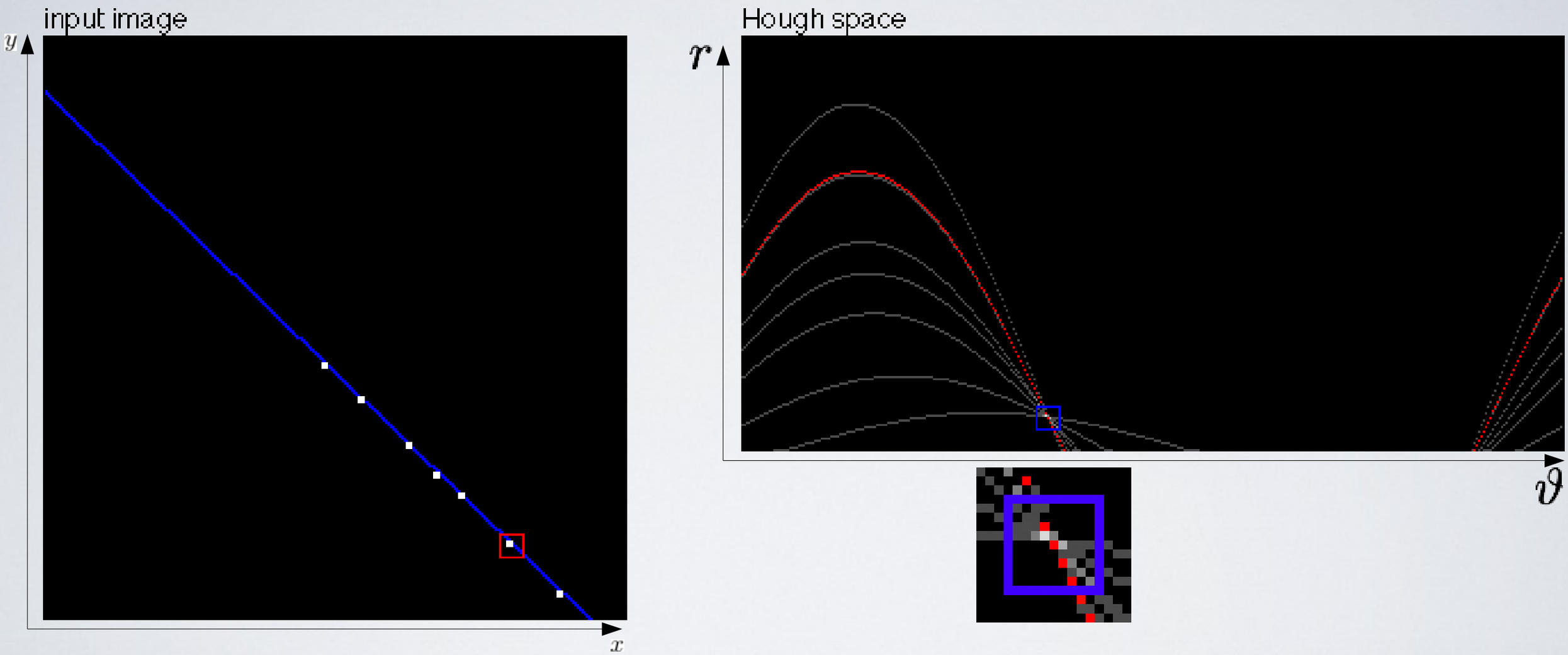
Hough Transformation



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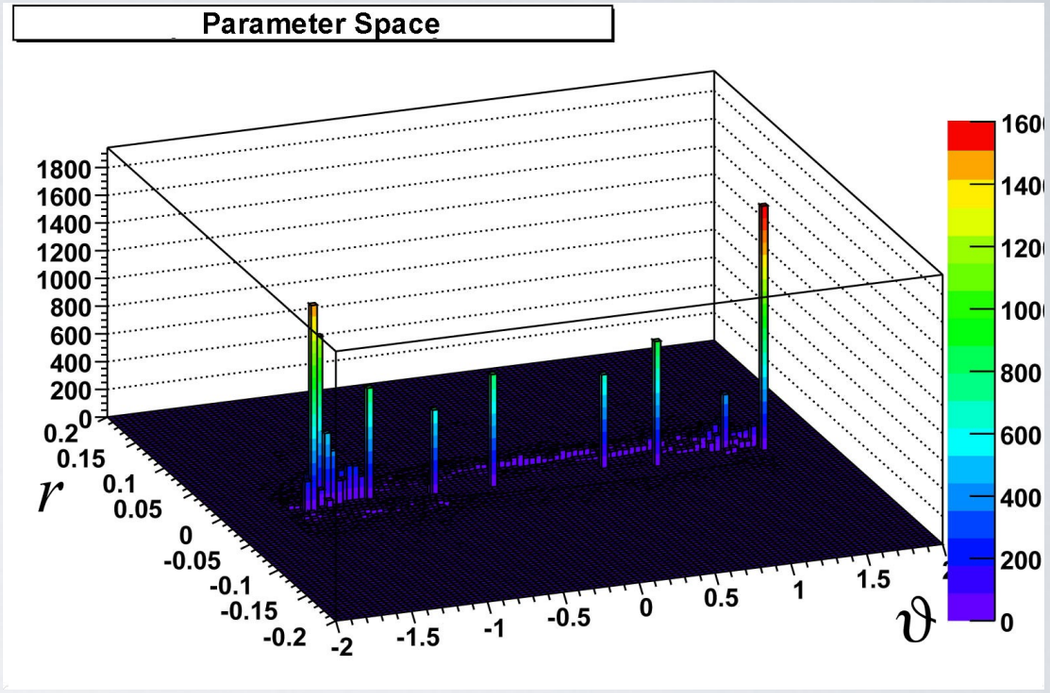
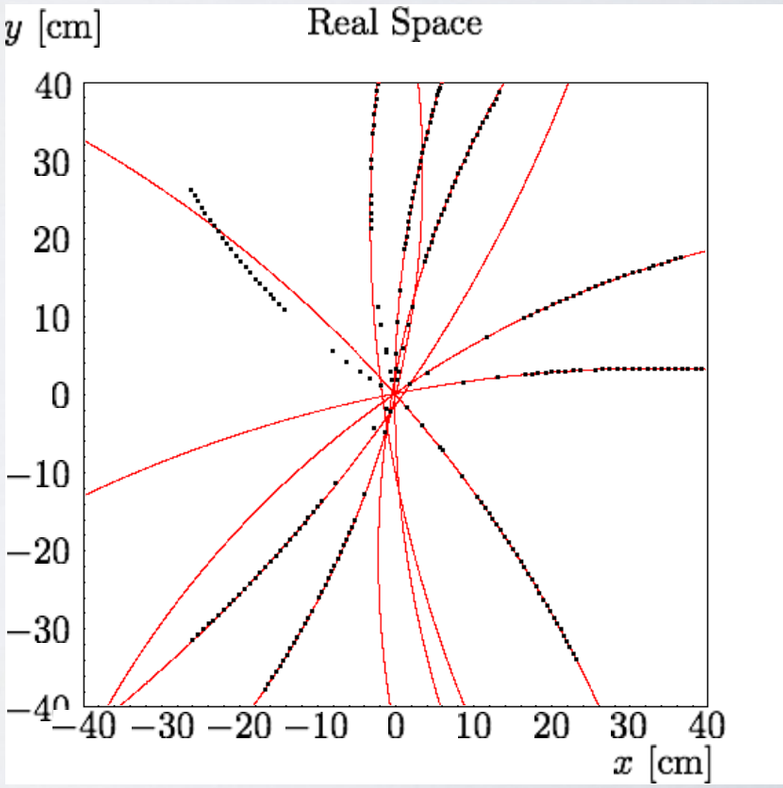
Hough Transformation

- Fill the histogram with data from the calculation
- Peaks in the histogram represent possible line candidates in conformal space
- Calculating back to real space
- Information about direction got lost during this process
- Parameter for beam direction with different Hough transformation





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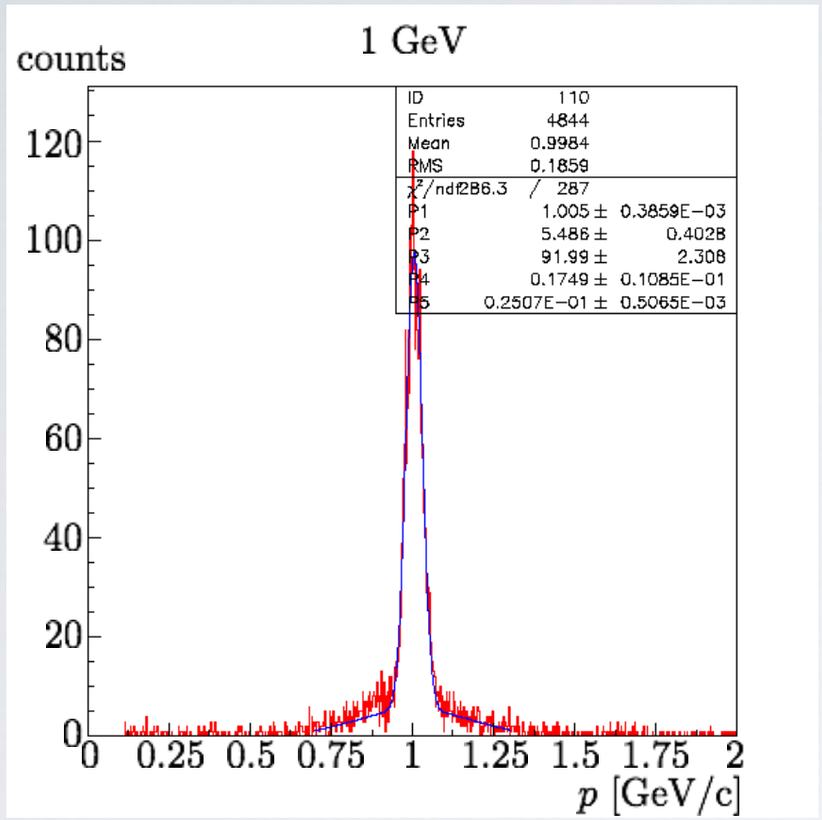
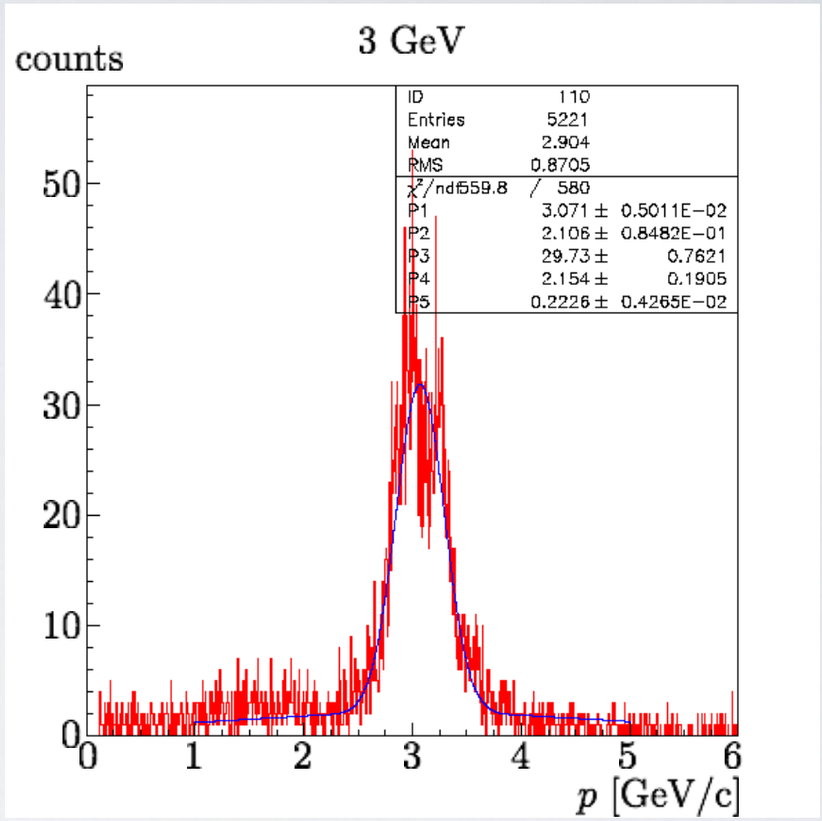
Momentum Resolution





- Simulation with 10 monoenergetic tracks per event (generated with PandaRoot)
- Tested range 0.3 - 5.0 GeV/c
- Only center peak considered to calculate efficiency

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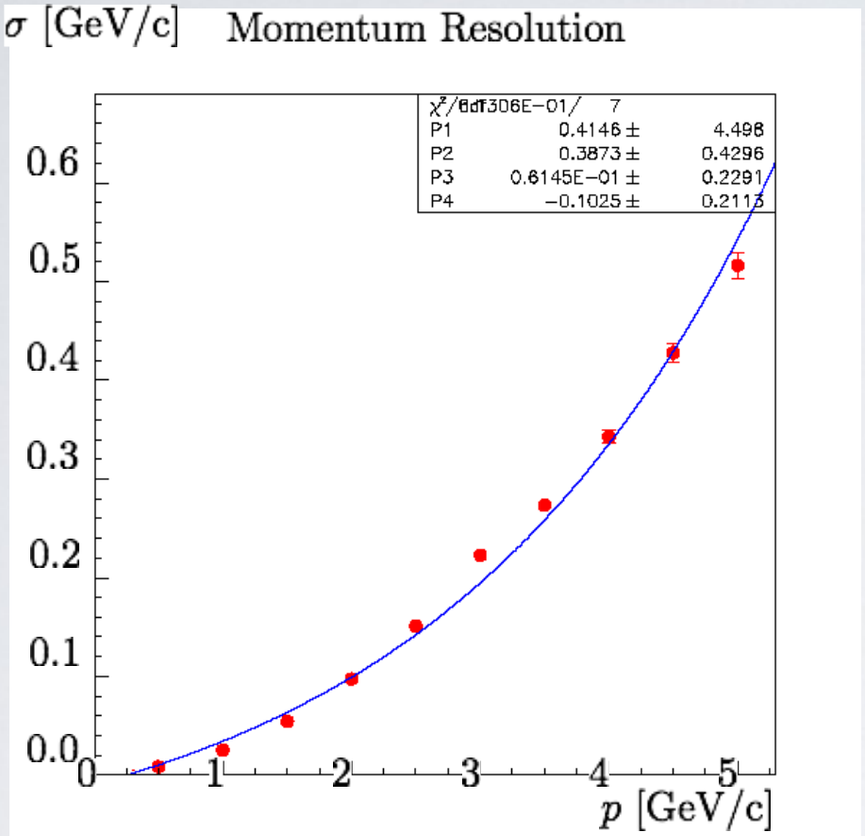
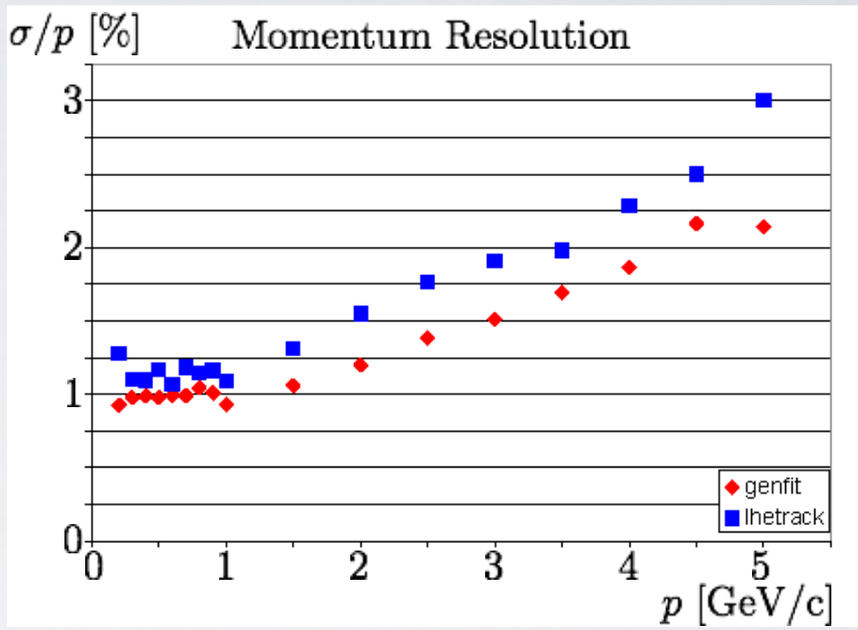
Momentum Resolution





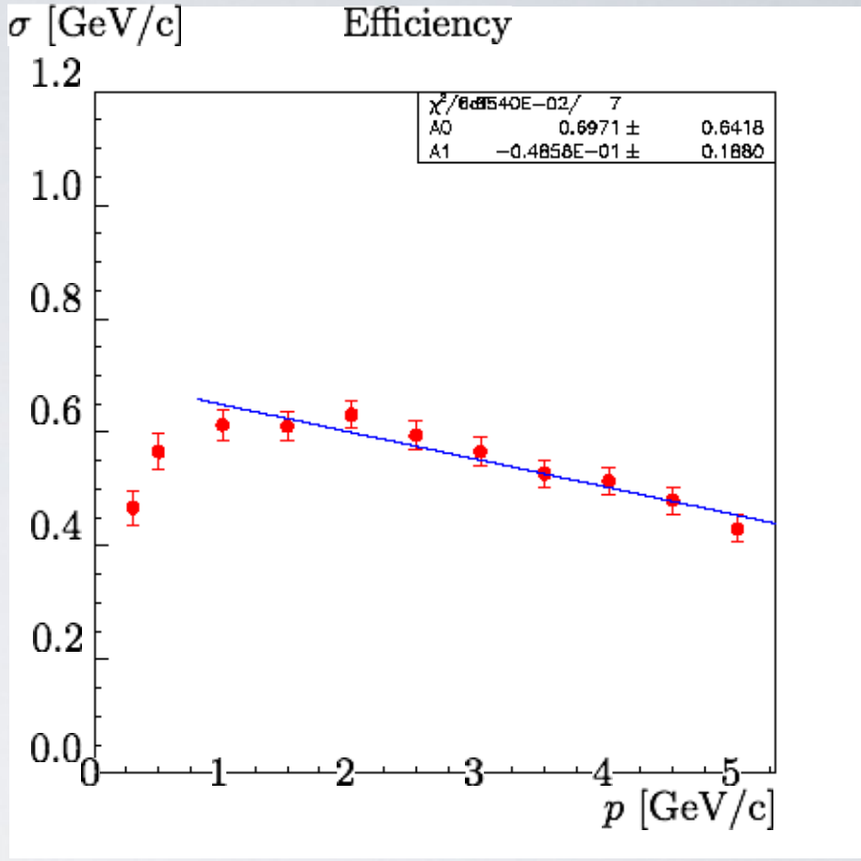
Stefano Spataro

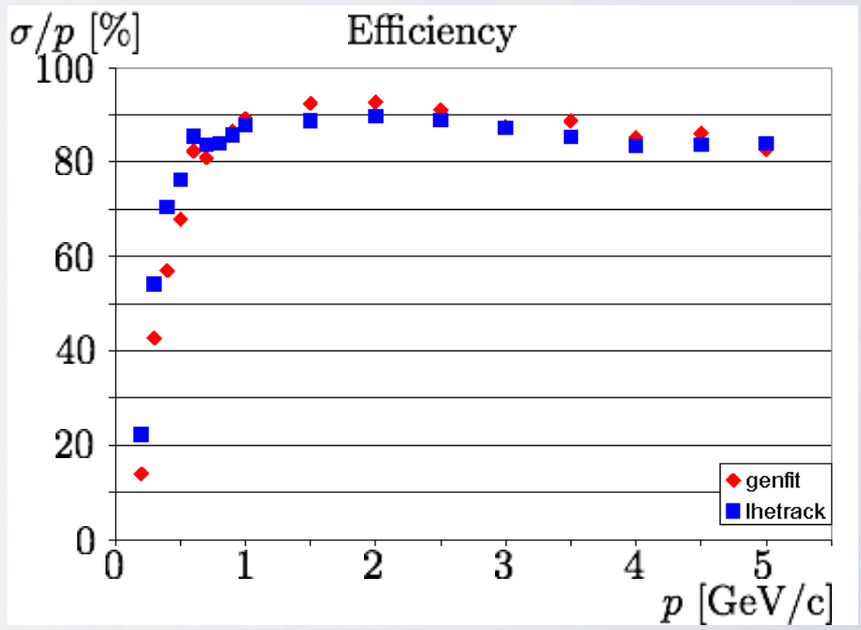
- With online algorithm between 3% (1 GeV/c) and 14% (5 GeV/c)

- With offline analysis framework (PandaRoot) between 1% (1 GeV/c) and 3% (5 GeV)

Efficiency

- Linear decreasing for Momentum over 1 GeV/c
- With online algorithm between
  61% (1 GeV/c) and 43% (5 GeV/c)
  → further work required
- With PandaRoot between
  90% (1 GeV/c) and 85% (5 GeV)
- Efficiency loss for momentum smaller 1 GeV/c
  - 46% at 0.3 GeV/c (online algorithm)
  - 20% at 0.3 GeV/c (PandaRoot)





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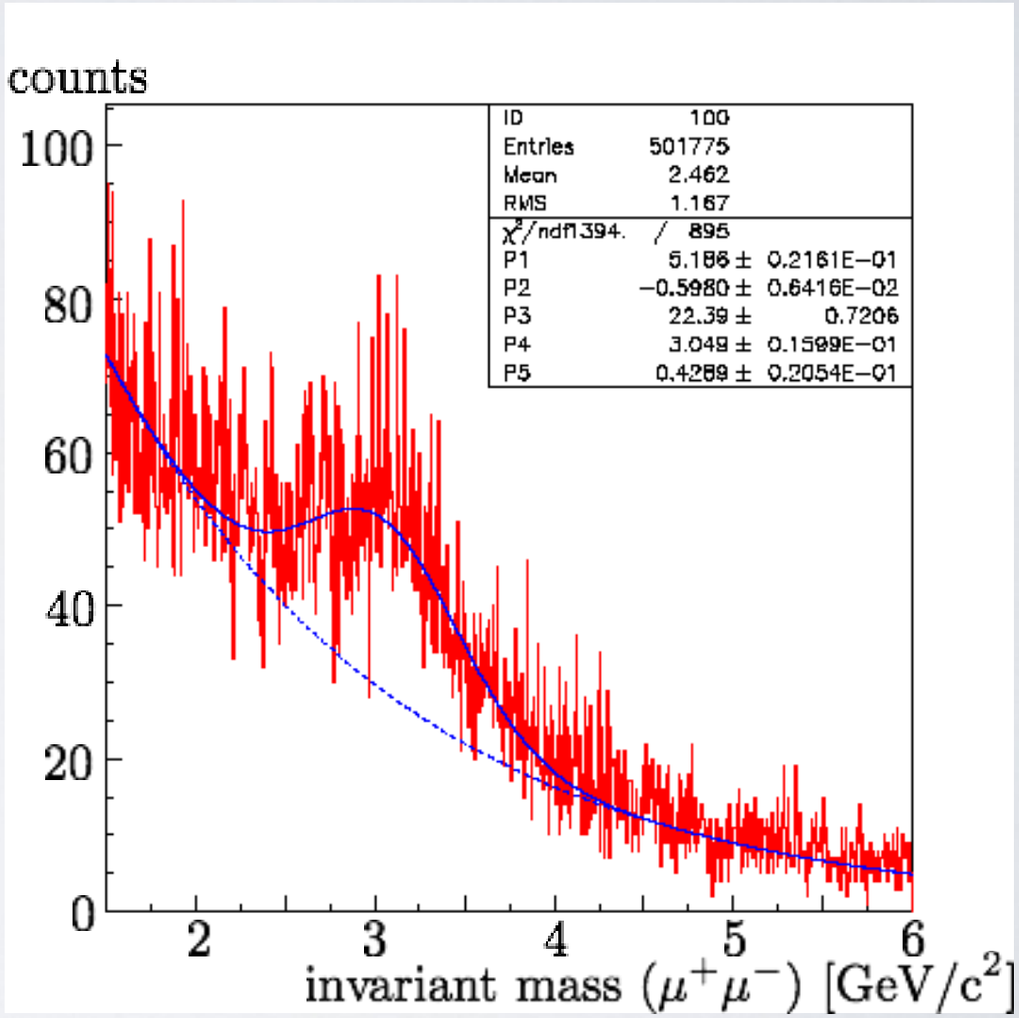
Simulated J/Ψ-decays

- J/Ψ-decay modes from PDG
- Assume all tracks are muons
- Analyzing the invariant mass for $\mu^+\mu^-$-decays
- Calculated J/Ψ-mass approx. 3.1 GeV/c^2
- Efficiency approx. 37%
  → further work required
- no seperation of $\mu^+\mu^-$ and e^+e^--decays possible



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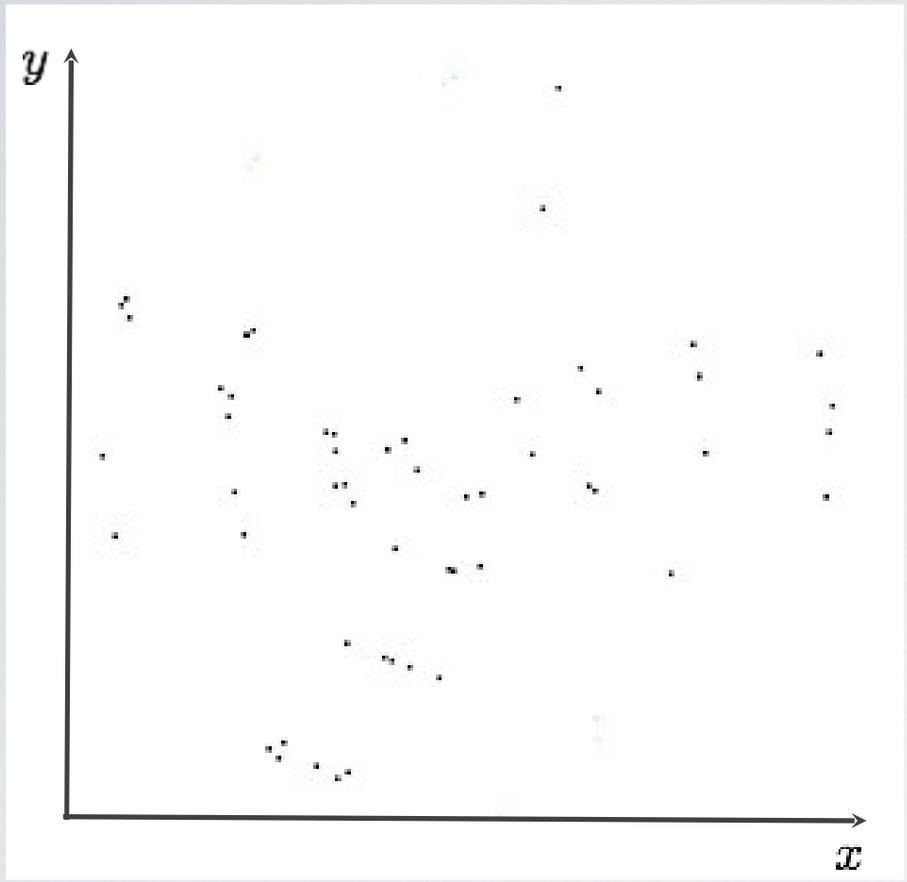
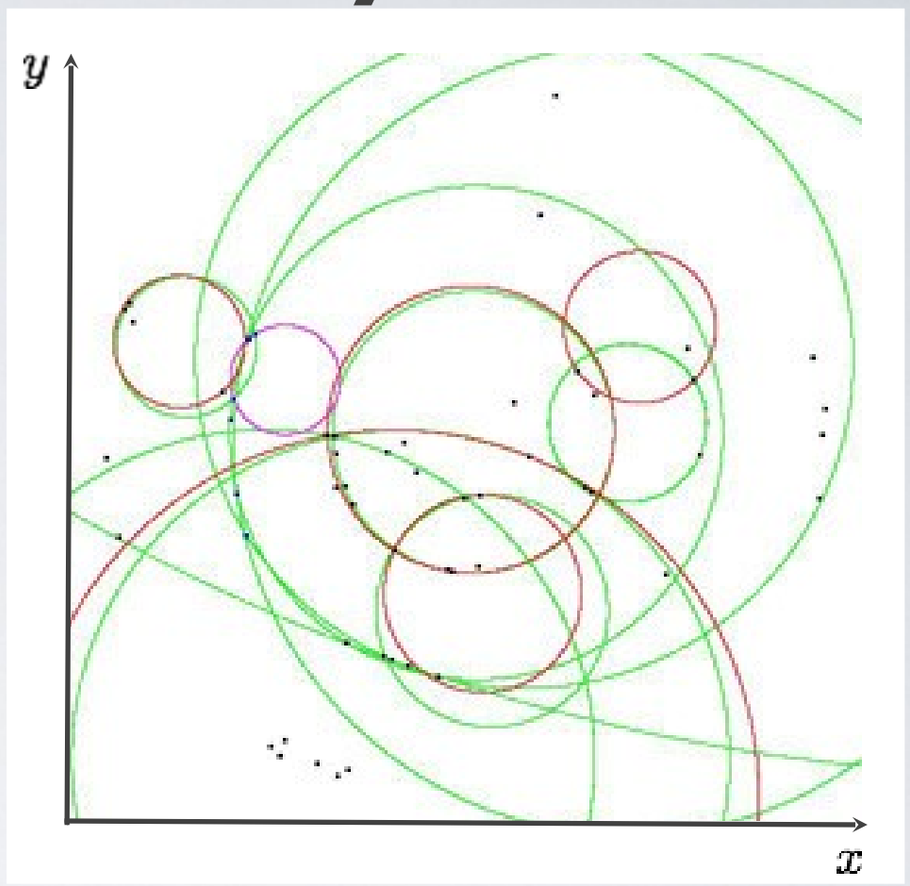
MVD Data Only





- Motivation: Possible central detector with TPC instead of STT
- Less hits per track than hits per detector layer
- Detector geometry identified as tracks

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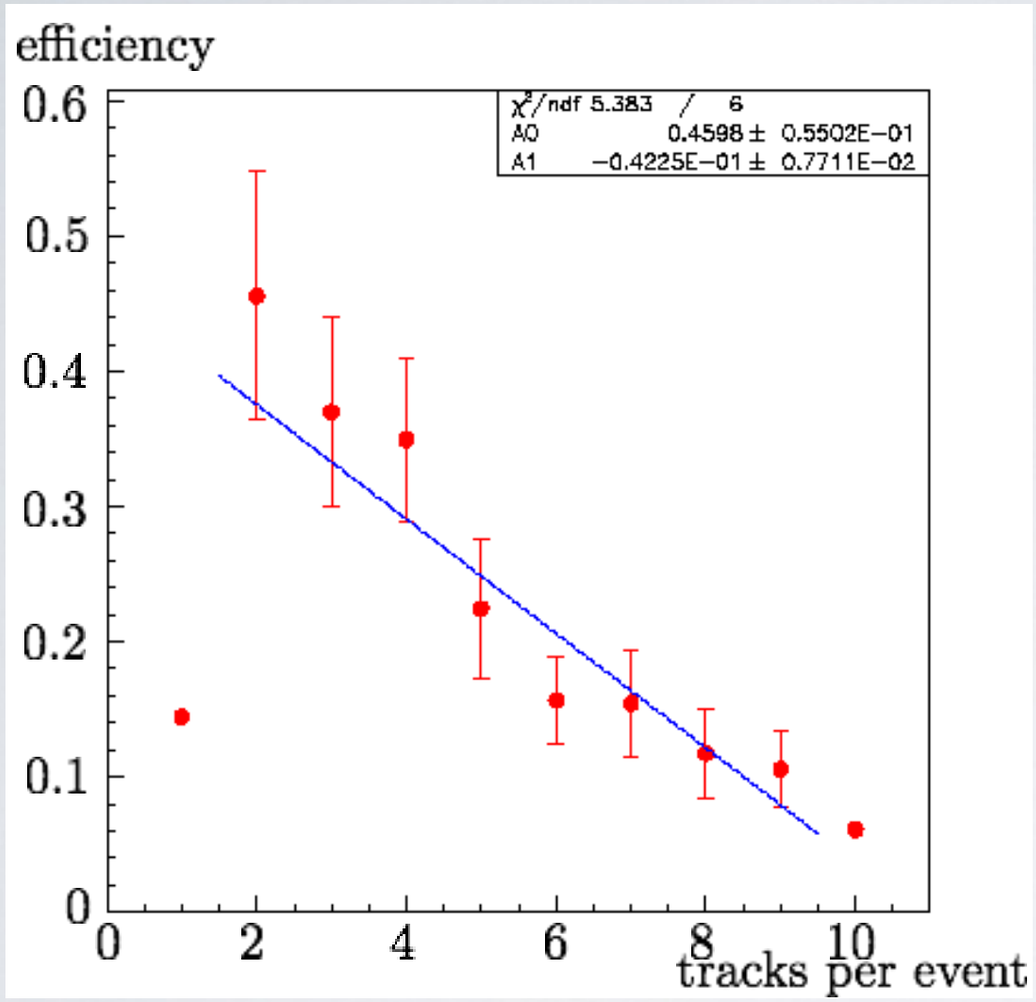
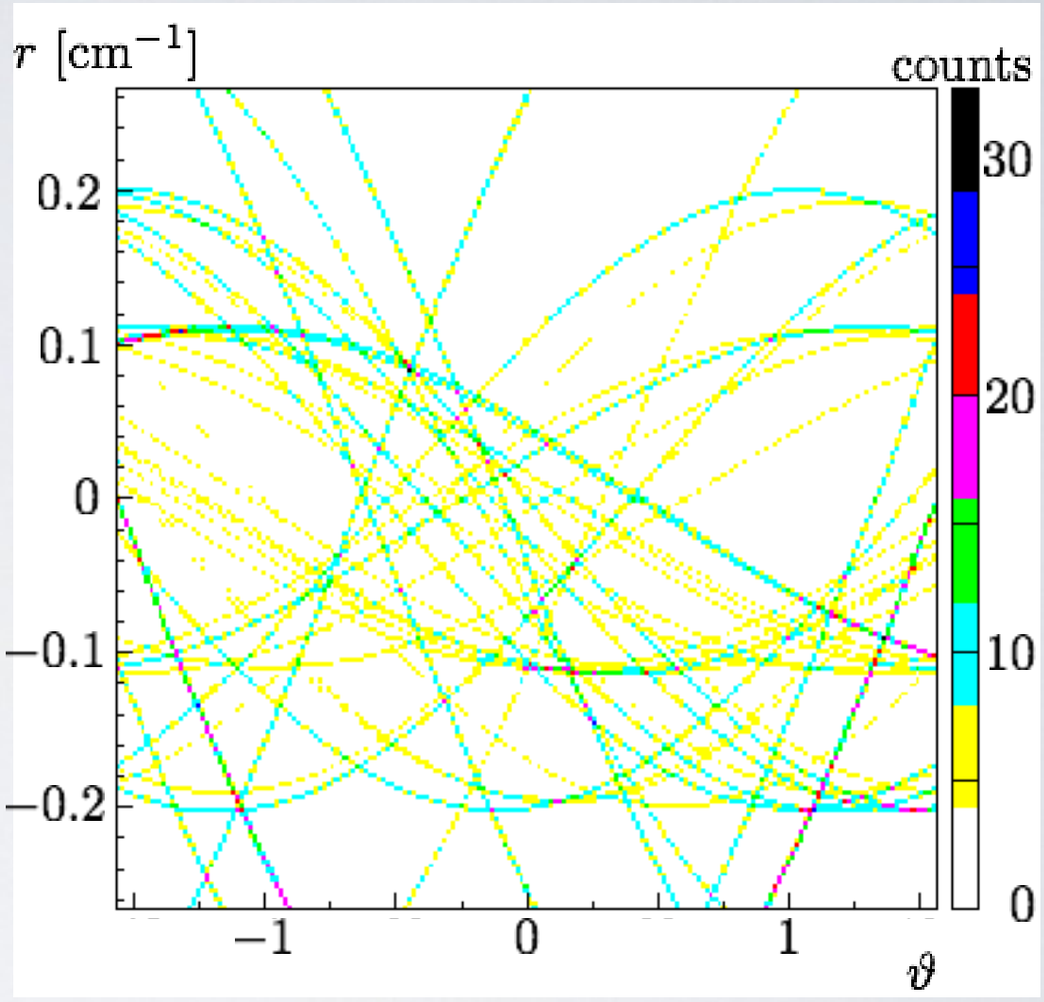
MVD Data Only





- Efficiency loss with rising track number
- Peaks in Hough space which represent real tracks too small to detect

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Summary and Outlook

Summary

- Simplification of complex helix tracking by transformation
- Tracking efficiency of 43%-61%
  efficiency too low, further work required
  - Algorithm with high potential for parallelisation

Outlook

- Porting to VHDL in progress
- FPGA implementation
- Running algorithm on a compute node