XLIII PANDA Collaboration Meeting (GSI, Darmstadt)

Status of Pattern Recognition for the PANDA Forward Tracking System

Martin J. Galuska, Sören Lange, Wolfgang Kühn
Justus Liebig Universität Gießen

This work was supported in part by BMBF (06GI9107I), HGS-HIRe for FAIR and the LOEWE-Zentrum HICforFAIR.

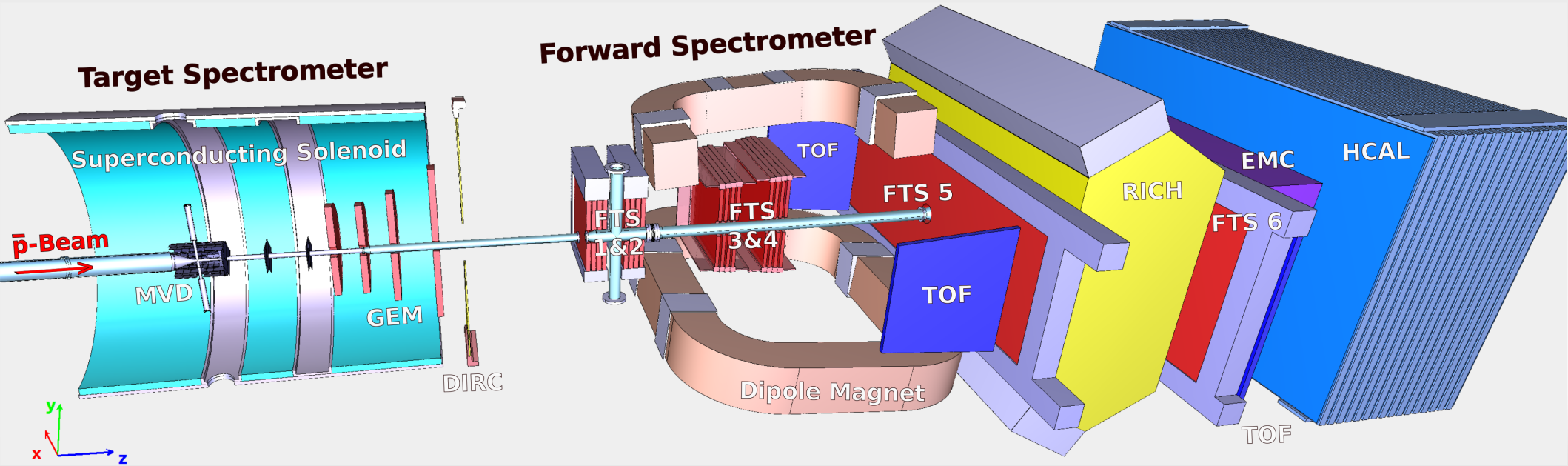
HIC for FAIR
Helmholtz International Center

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

Bundesministerium für Bildung und Forschung

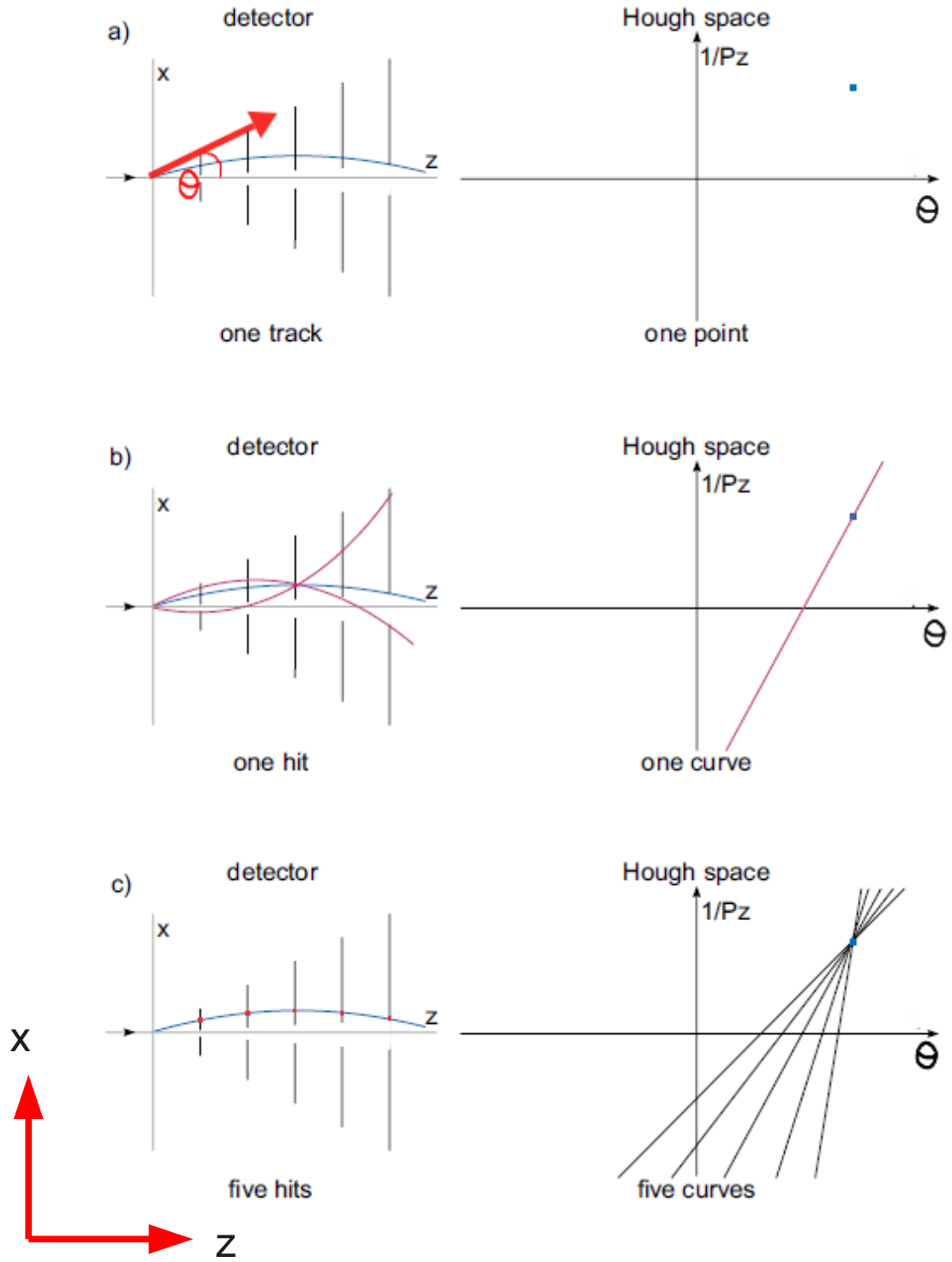
Outline

- Pattern Recognition Algorithm / Parabola Hough Transform
- Current Implementation / Single Muon Test Events
- Preliminary Results for p_z Momentum Resolution / Algorithm Optimization
- Summary / Outlook



Parabola Hough Transform

- In x-z-plane particle is bent due to the dipole magnet.
- Parabola is used as track model within dipole field (FTS 3-5).
- Before (FTS 1+2) and after (FTS 5+6) dipole field, track is approximated by straight line.
- Apex for parabola is found by a line Hough Transform on FTS 1+2.



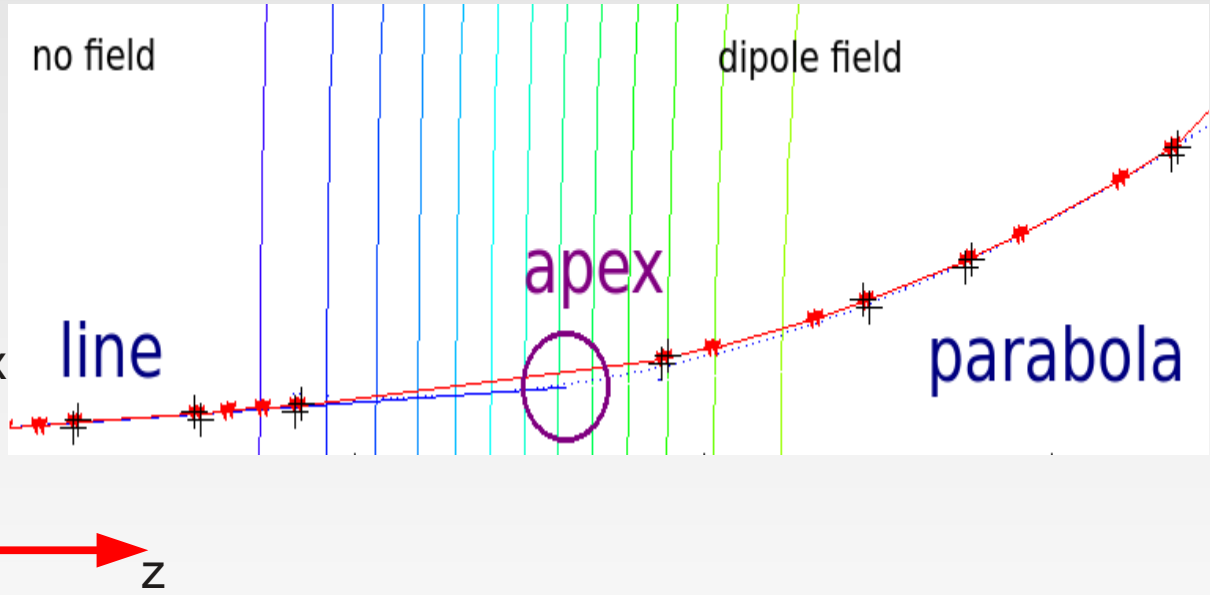
Parabola
Hough Transform

- In x-z-plane particle is bent due to the dipole magnet.
- Parabola is used as track model within dipole field (FTS 3-5).
- Before (FTS 1+2) and after (FTS 5+6) dipole field, track is approximated by straight line.
- Apex for parabola is found by a line Hough Transform on FTS 1+2.

Black = Non-Skewed FTS hits (wire positions)

Red = MC Points (connected by line segments)

Blue = Line + Parabola Track Model



Parabola Equation for PANDA FTS Pattern Recognition

In the x-z plane the approximated parabola is:

$$x = \frac{n\ e\ B_y}{2\ p_z} z^2 \qquad (1)$$

where n is the number of elementary charges e, p_z the z component of the momentum and B_y the y component of the magnetic field. In case of an inhomogenous magnetic field B_y may be any function of the hit coordinates x and z. For tracks starting with an angle $\theta = \arctan p_x/p_z$, $x \rightarrow z\sin\theta - x\cos\theta$ and $z \rightarrow z\cos\theta + x\sin\theta$ and thus

Rotation of axis

$$\frac{1}{p_z} = \frac{2\ (z sin\theta - x cos\theta)}{ne\ B_y\ (z cos\theta + x sin\theta)^2} \qquad (2)$$

Pattern Recognition Algorithm Requirements

Geometry: 6 Chambers of 4 double layers each (0º, +5º,-5º, 0º)

1. Start with (x, y-range, z) for non-skewed (0^o), (x-range, y-range, z) for skewed (+/-5^o) straws in chambers 1-6 (wire positions) and drift circles for all straws

2. ***Run some algorithm which ***

- Determines which hits belong to the same track → Track candidates
- Determines charge, (p_x,p_y,p_z) at some (x,y,z) for all track candidates

3. Match track candidates with other subdetectors → Run Kalman filter

Next slide: The algorithm

The Algorithm (For the Expert's Consideration)

Geometry: Chambers 1+2 before, 3+4 inside, 5+6 after dipole field

1. Use non-skewed straws to find **lines in x-z-plane in chamber 1+2 and** in **chamber 5+6** taking drift circles into account → (x,z) available for hits from non-skewed straws in chambers 1+2+5+6

2. **Expand lines to planes in 3D** and **add hits from** intersections with fired **skewed straws**
→ (x,z) available for all chamber 1+2+5+6 hits, additionally y for hits from skewed straws

3. Perform **parabola** Hough transform **in x-z-plane on** x-shifted hits from **non-skewed straws in chambers 3-5** taking drift circles into account for each line from ch. 1+2 found in step 1
→ charge+p_x+p_z (at entrance to FTS)

4. **Expand parabola to 3D** and **add hits from** intersections with fired **skewed straws**
→ (x,y,z) available for skewed hits in chambers 3-5

5. Perform straight **line** Hough transform **in y-z-plane on hits from chamber 1-6**
→ y available for all hits in chambers 1-6, p_y (at entrance to FTS)

6. Require all non-skewed hits to lie on line from step 5
→ y available for all hits in chambers 1-6

→ (x,y,z) available for all FTS hits, charge, (p_x,p_y,p_z) available for track candidates at specified (x,y,z)

Implemented So Far

Geometry: Chambers 1+2 before, 3+4 inside, 5+6 after dipole field

1. Use non-skewed straws to find **lines in x-z-plane in chamber 1+2 and** in **chamber 5+6** taking drift circles into account → (x,z) available for hits from non-skewed straws in chambers 1+2+5+6

2. **Expand lines to planes in 3D** and **add hits from** intersections with fired **skewed straws**
→ (x,z) available for all chamber 1+2+5+6 hits, additionally y for hits from skewed straws

3. Perform **parabola** Hough transform **in x-z-plane on** x-shifted hits from **non-skewed straws in chambers 3-5** taking drift circles into account for each line from ch. 1+2 found in step 1
→ charge+p_x+p_z (at entrance to FTS)

4. **Expand parabola to 3D** and **add hits from** intersections with fired **skewed straws**
→ (x,y,z) available for skewed hits in chambers 3-5

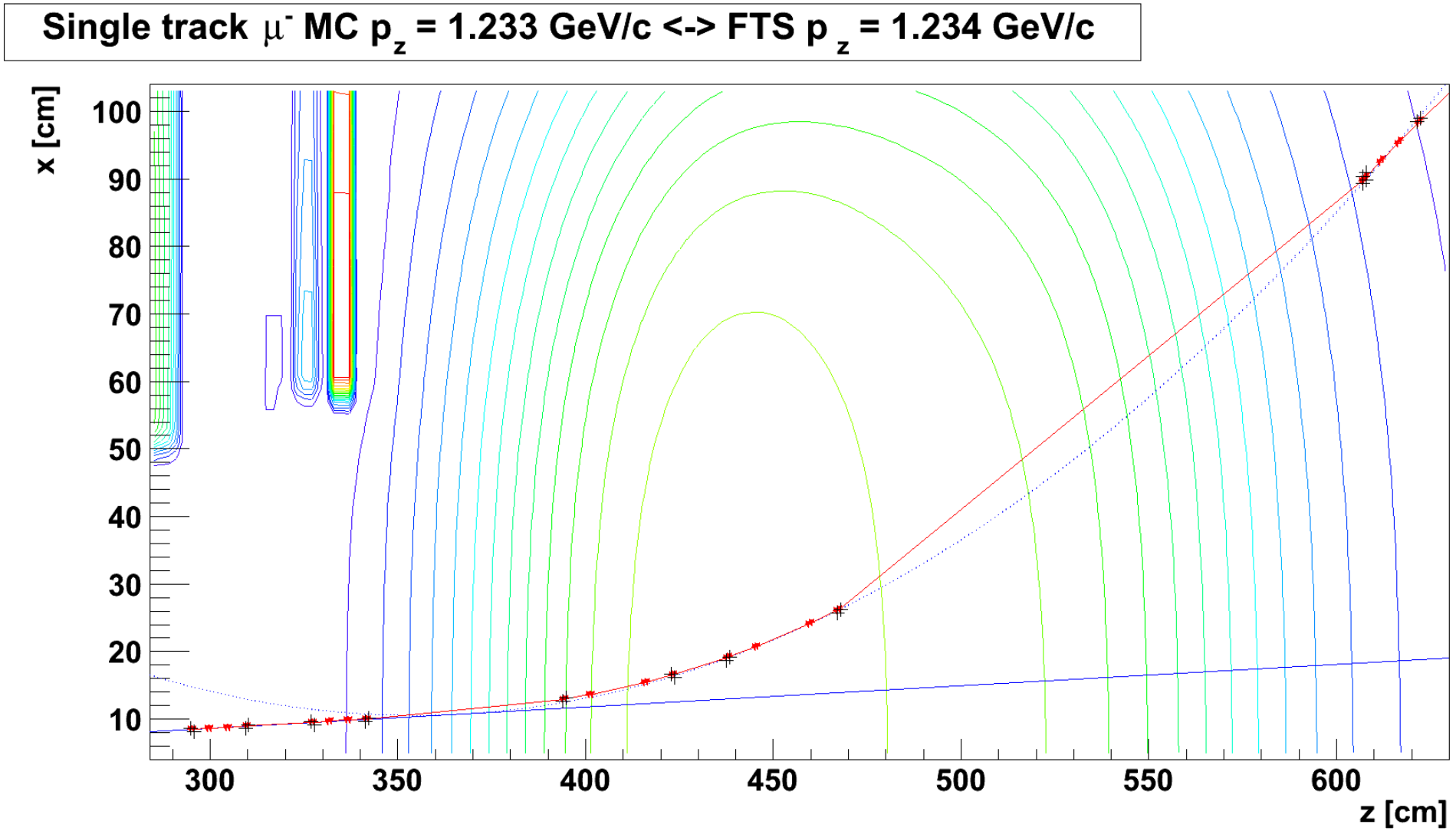
5. Perform straight **line** Hough transform **in y-z-plane on hits from chamber 1-6**
→ y available for all hits in chambers 1-6, p_y (at entrance to FTS)

6. Require all non-skewed hits to lie on line from step 5
→ y available for all hits in chambers 1-6

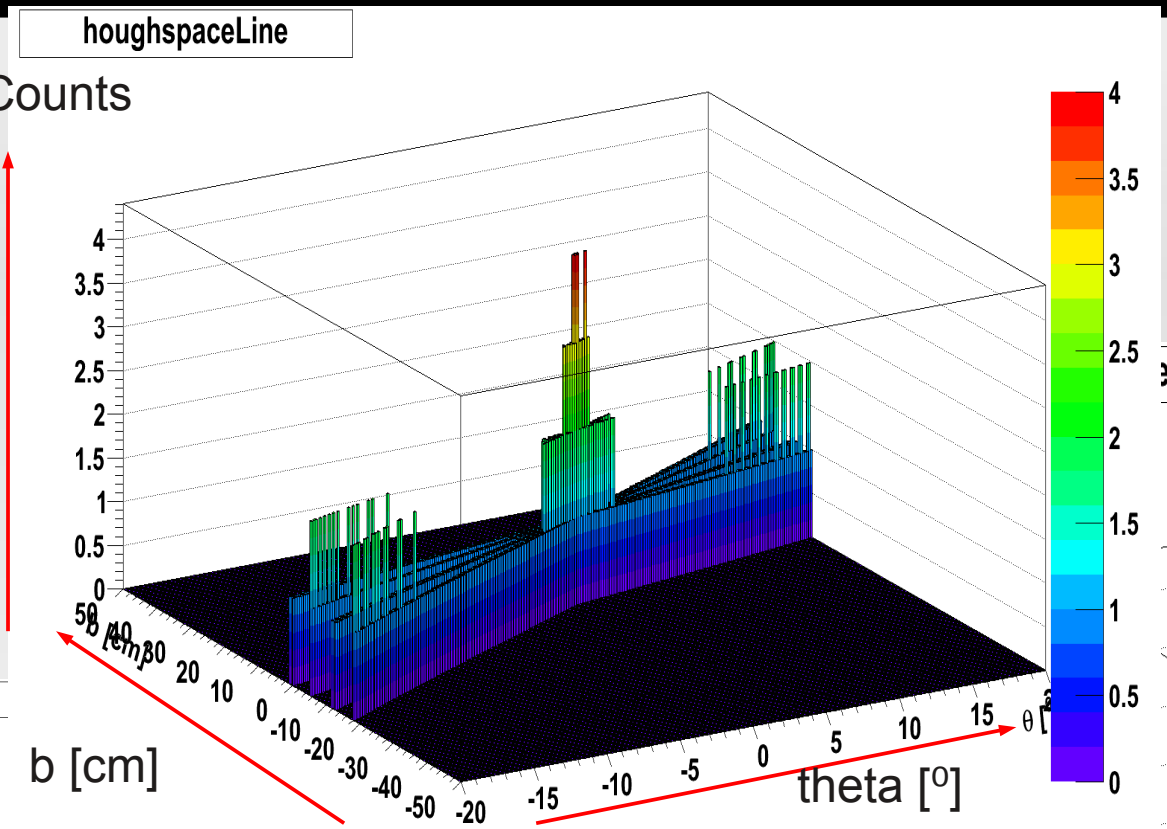
→ (x,y,z) available for all FTS hits, charge, (p_x,p_y,p_z) available for track candidates at specified (x,y,z)

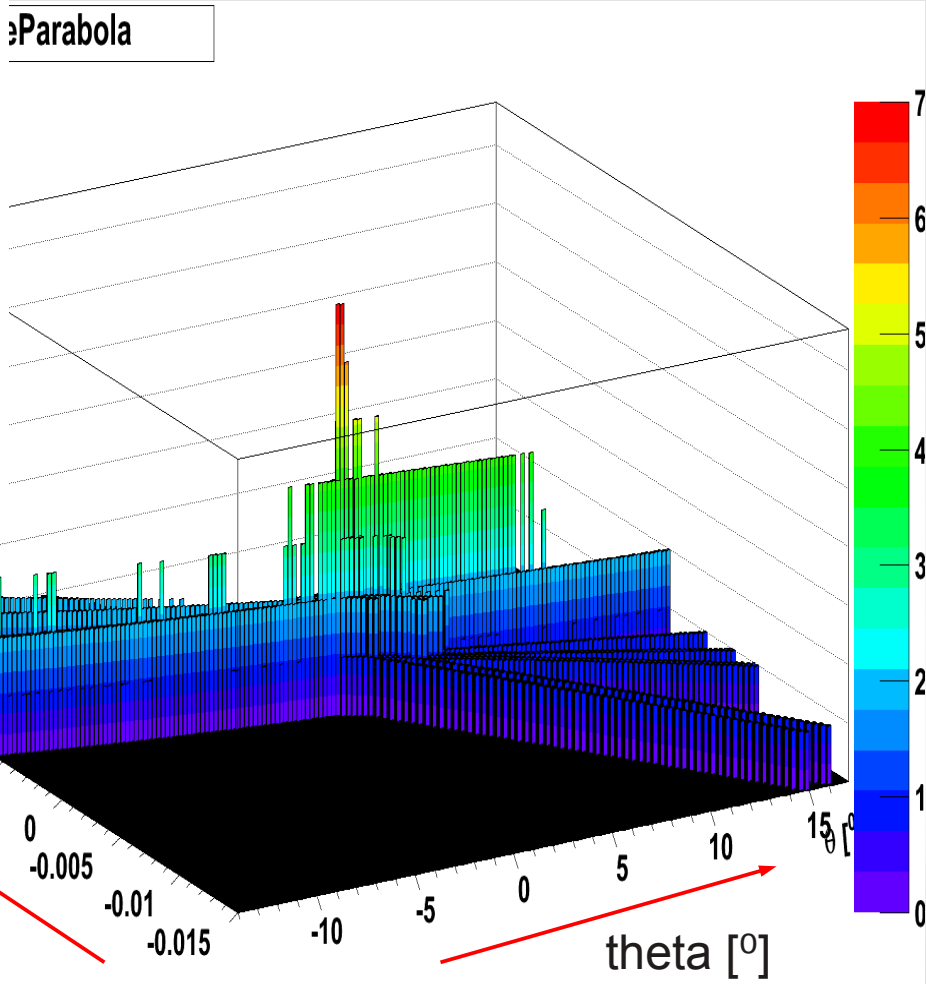
Line+Parabola in x-z For Non-Skewed FTS 1-5 Hits

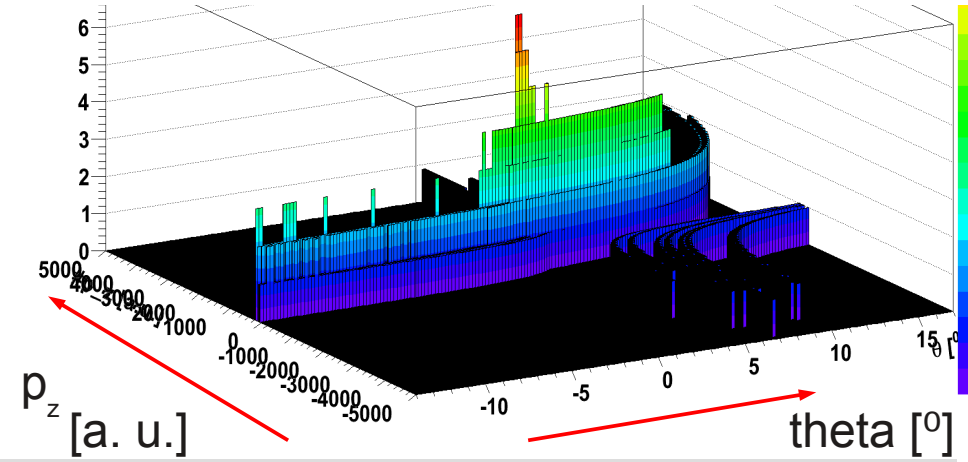
- Apex for parabola Hough Transform is determined by result of straight line Hough Transform
- Black = Non-Skewed FTS hits, red = MC Points (from all detectors)



Hough Spaces for Line, Parabola With p_z and $1/p_z$







Study of Preliminary Momentum Resolution for p_z from FTS Pattern Recognition Only

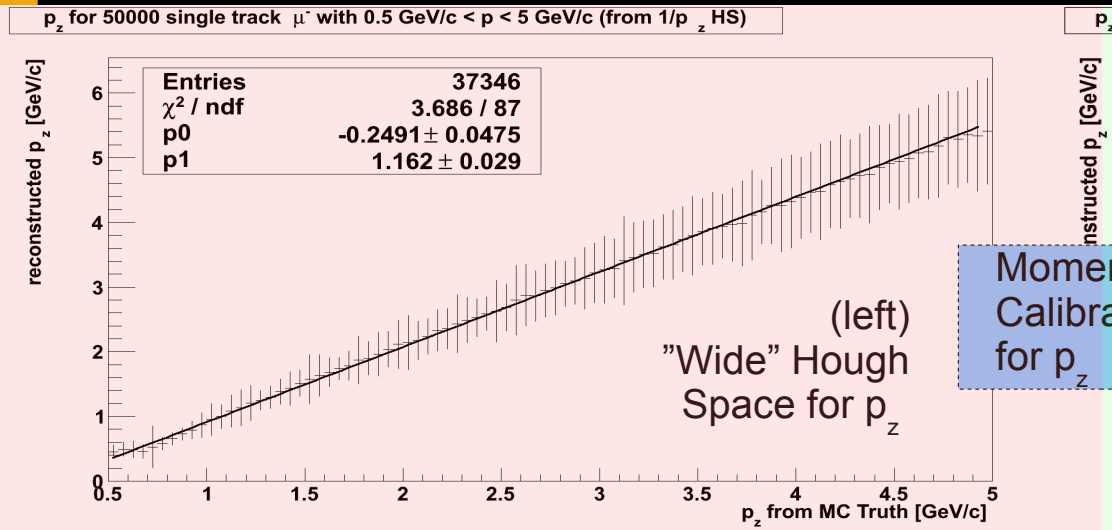
- 50 000 muons with BoxGenerator (1 muon/event)
- 0.5 GeV/c < p < 5.0 GeV/c, 0.1^o < theta < 5^o, 0^o <= phi < 360^o
- Multiple scattering and energy losses included

- All detectors included, dipole field for pbeam = 15 GeV/c
- Full PandaRoot (rev. 17875) simulation

- For reconstruction of p_z **line+parabola Hough Transform in x-z-plane** is performed
- **Only hits from non-skewed FTS 1-5 straws** are used, **no drift circles**!
  - Require **at least 2 non-skewed hits in FTS 1+2 and 4 in FTS 3-5**
- **No matching with other detectors, no Kalman filter!**

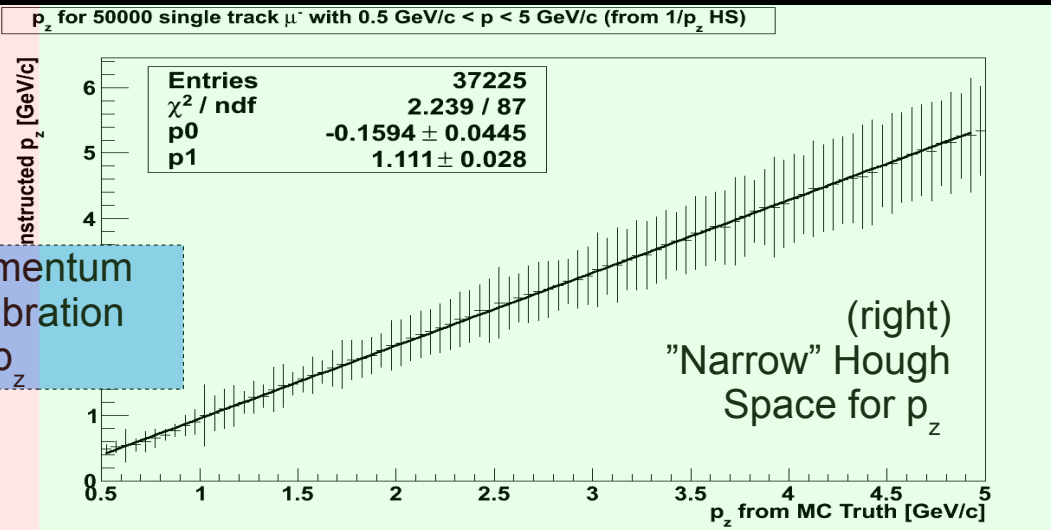
p_z Resolution Study

(Hough Transform on Non-Skewed FTS 1-5 Hits Only)

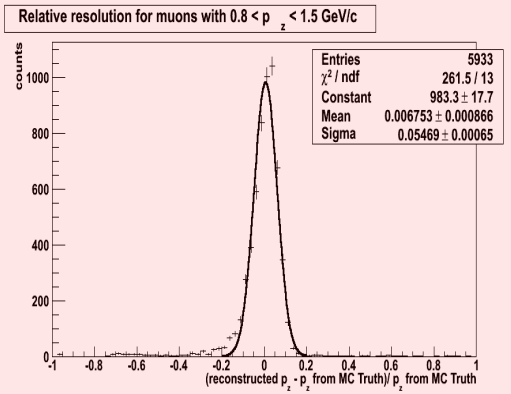


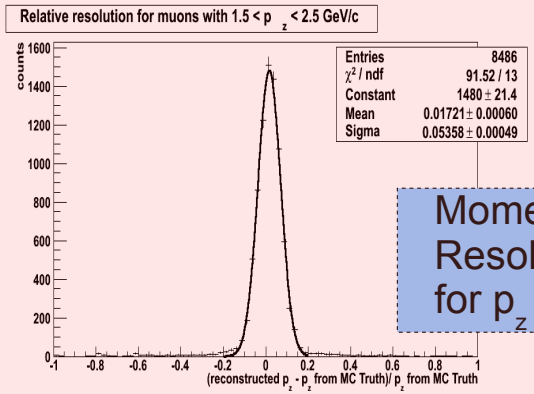
(left)
"Wide" Hough
Space for p_z

Momentum
Calibration
for p_z

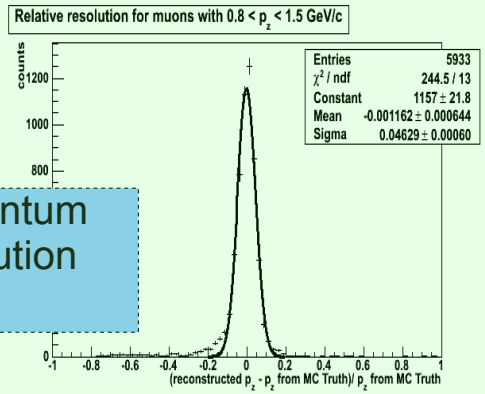


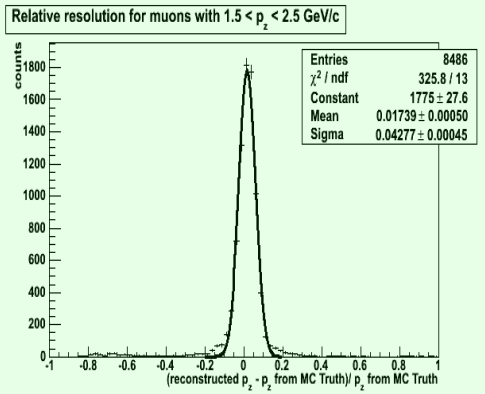
(right)
"Narrow" Hough
Space for p_z

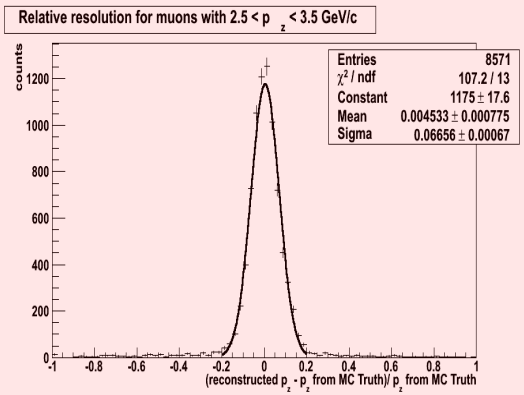


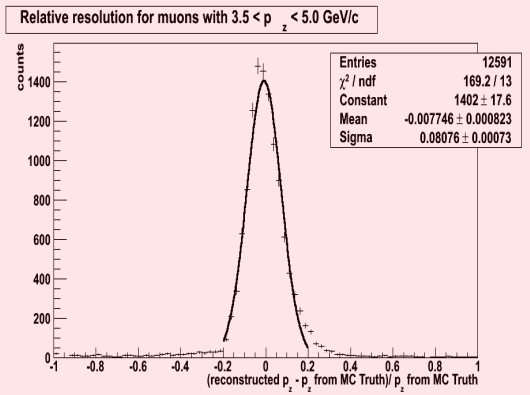


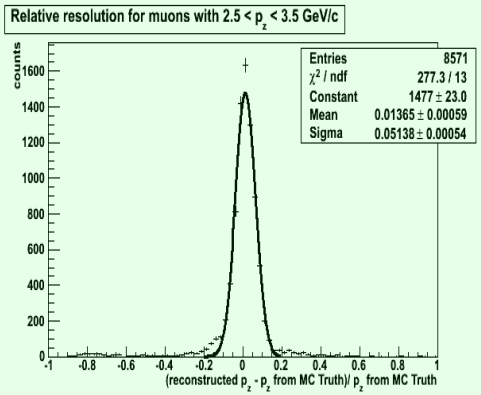
Momentum
Resolution
for p_z

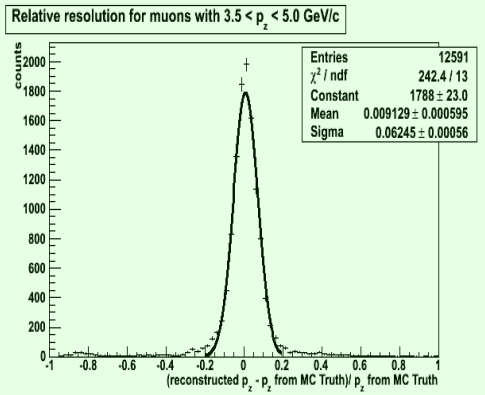












Summary

- Hough transform for parabola and straight line in x-z-plane implemented
  - Algorithm can be run on alll hits or non-skewed hits exclusively
  - Matching between parabola and straight line is done, but needs to be optimized
  - Magnetic field maps can optionally be included in algorithm
- Peak finder implemented
- Parameter optimization started
- p_z momentum resolution study performed for single track events with full detector
  - 50k muons with BoxGenerator (1 muon/event)
  - Momenta 0.5 to 5.0 GeV/c
  - Phi in $[0^o, 360^o)$
  - Theta in $(0.1^o, 5^o)$

Outlook

- Implement full algorithm for line+parabola+line
  - Implement hit candidate construction from skewed straws
  - Include drift circles in Hough transforms
  - Implement straight line Hough Transform for y-z-plane
  - Test algorithm with time-based hit information
- Optimization
  - More sophisticated peak finder
  - Parameters (for matching between line and parabola in x-z-plane, ...)
- Explore alternative algorithms and geometries
  - Line before and after dipole field → kickplane (in x-z)
  - 3 part Hough transform (straight line, circle, straight line)
  - One equation for tracks' shapes in x-z-plane
  - Spline instead of parabola
  - Include parametrization for magnetic field in Parabola Hough transform
- Study single- and multi-particle efficiency, momentum resolution, etc. for all alternatives

Thank You!

And many thanks for help to S. Spataro, S. Lange, D. Münchow, M. Wagner, J. Hu, Y. Liang, M. Al-Turany, W. Kühn and B. Spruck

Backup Slides

Parabola Hough Transform

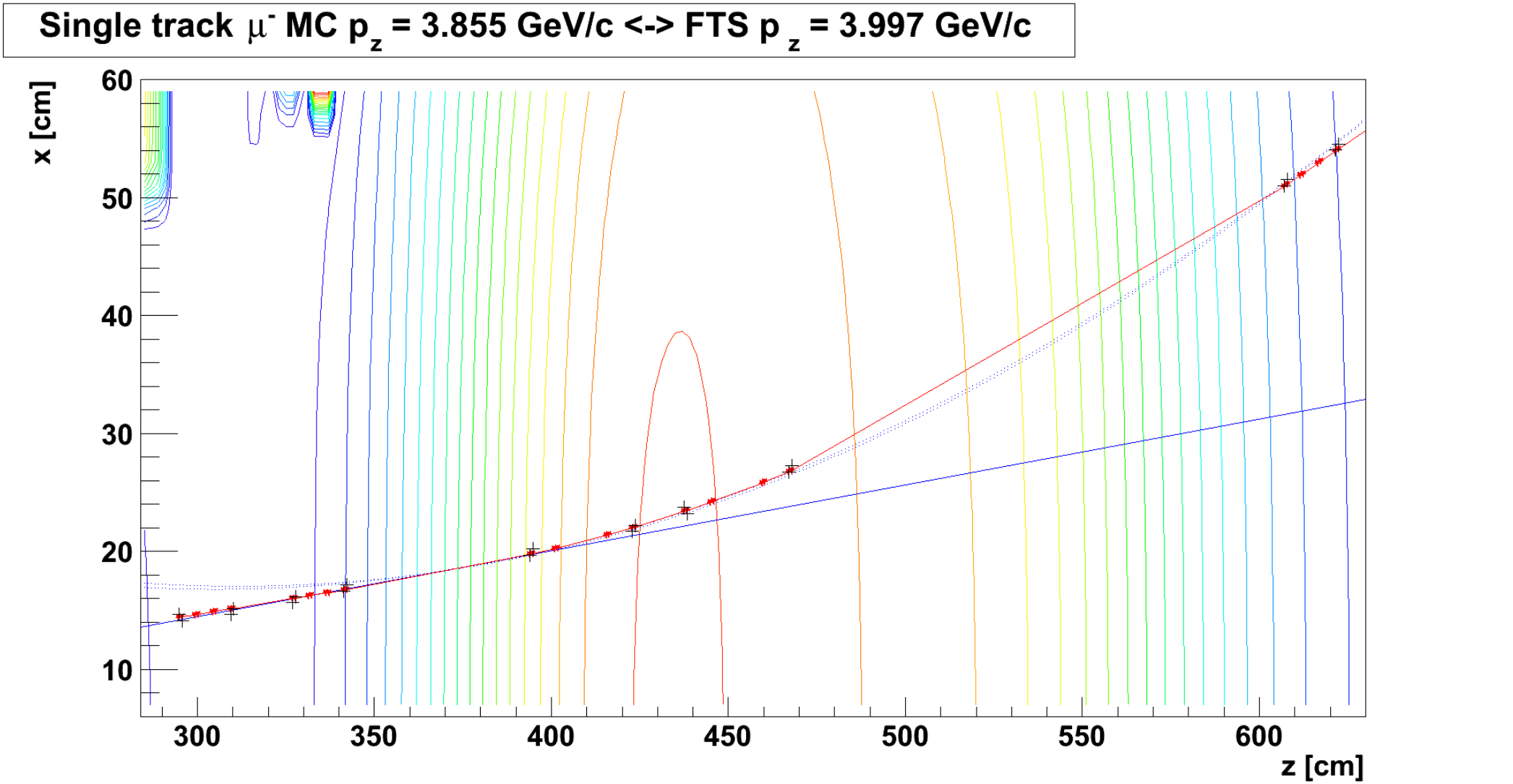
- Idea: Hough Transform of parabola (as in ”Tracking in the Silicon Tracker System of the CBM Experiment using Hough Transform” by Gläß, Steinle, Männer, Univ. of Mannheim)
- Algorithm assumes parabola shape of charged particle tracks in dipole field in x-z-plane with fixed apex
- Simulation showed that particles arrive at dipole field with varying axial distance to z-axis
- Idea: Use straight line Hough transform in x-z on chambers before dipole field to find the distance and correct it in parabola algorithm
- Line+parabola is approximation to track

Hough Transform for Pattern Recognition

- Advantages
  - Can be used for wide variety of approximated analytical track shapes
  - Robust against noisy, missing or additional detector hits
  - Operations per event proportional to number of detector hits
  - Suited for implementation on FPGA

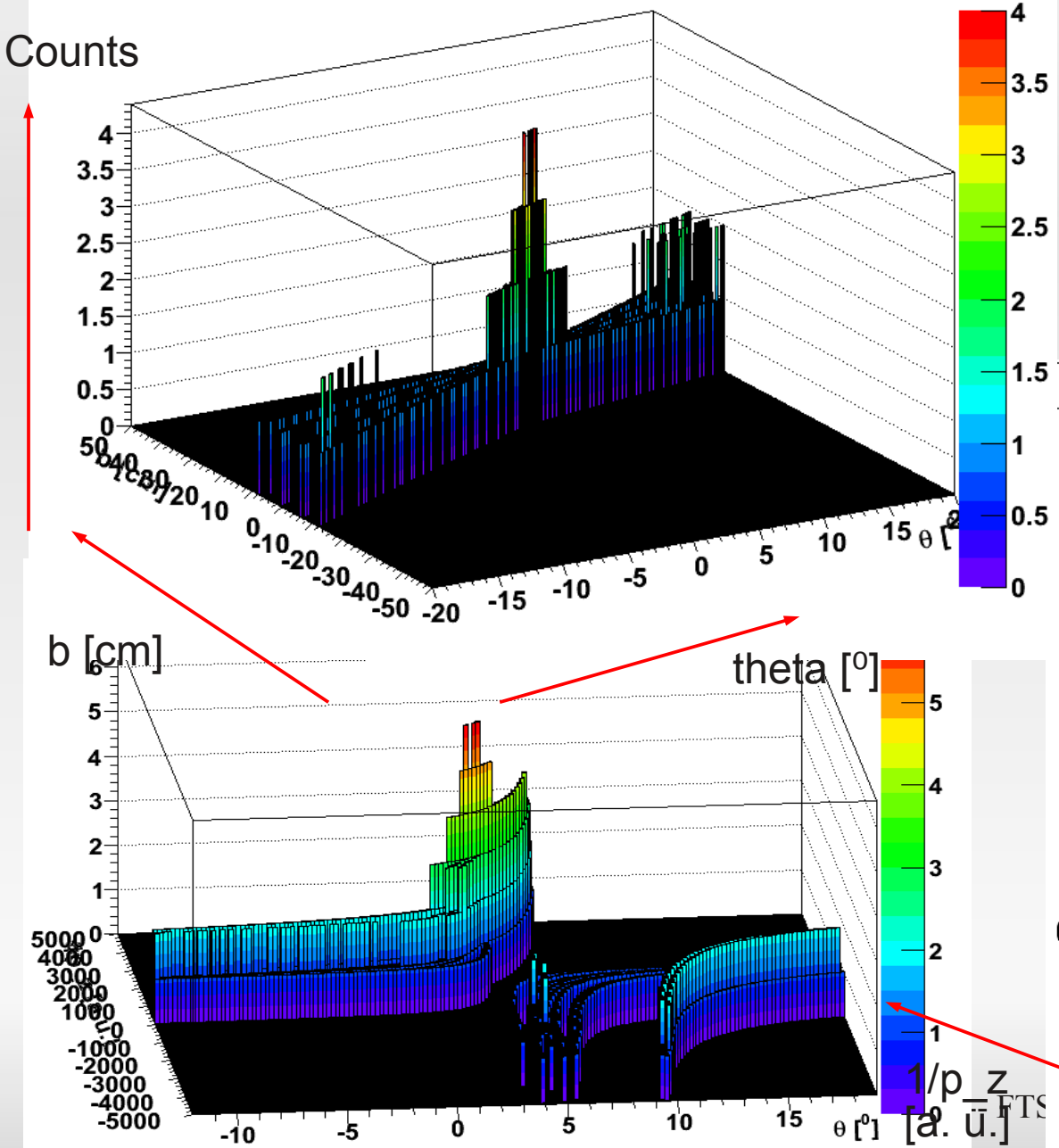
Line+Parabola in x-z

- Hits for parabola Hough Transform are shifted based on result of straight line Hough Transform
- Black = FTS hits, red = MC Points (from all detectors)



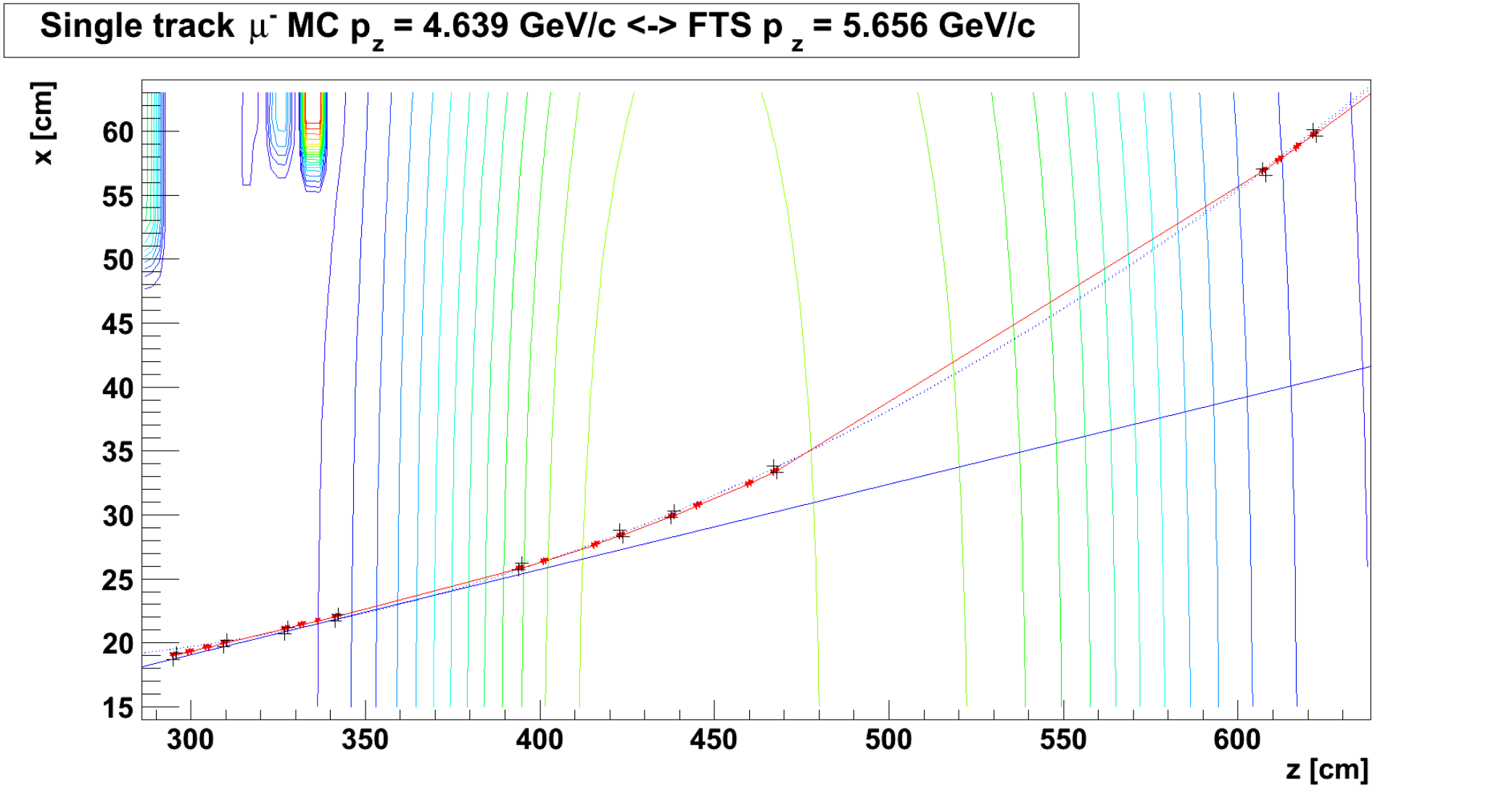
Hough Spaces

houghspaceLine



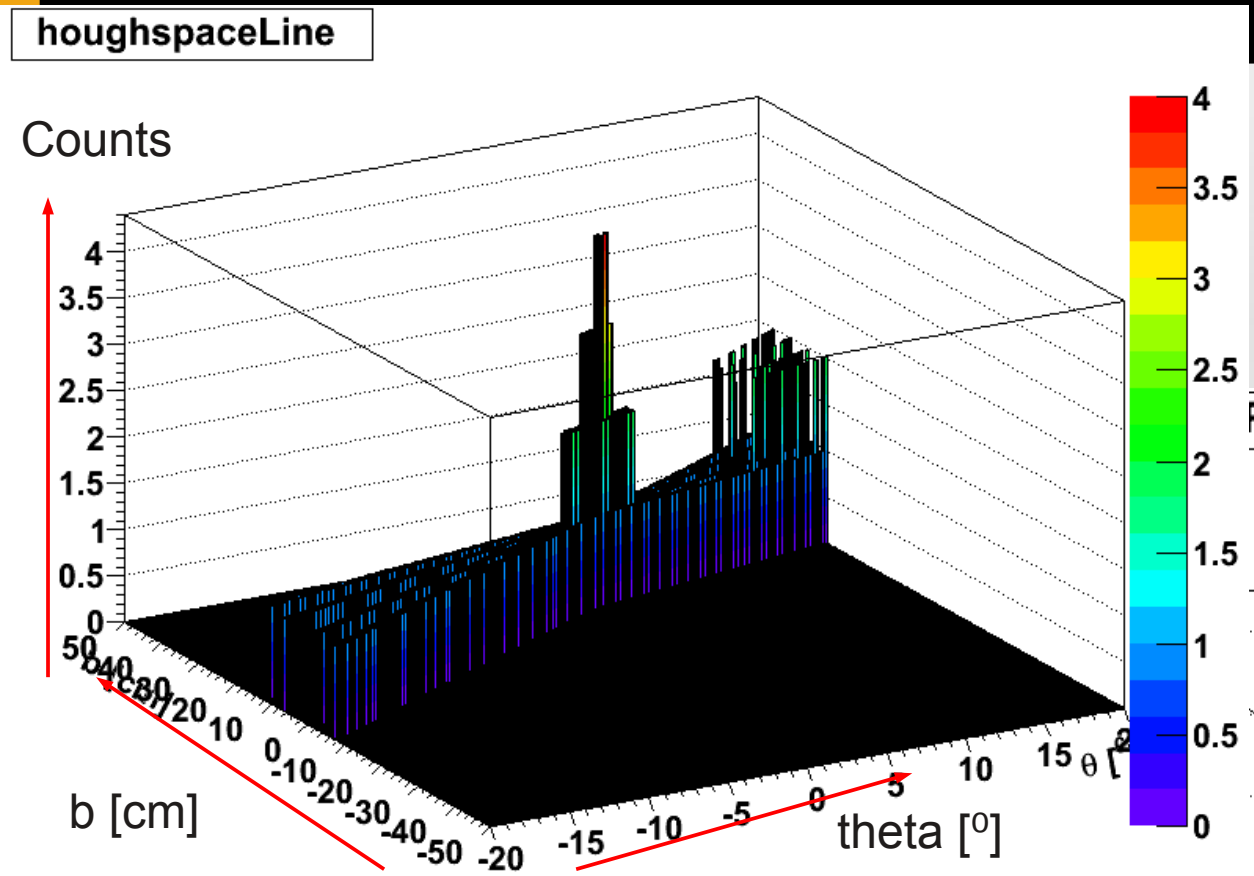
Line+Parabola in x-z

- Hits for parabola Hough Transform are shifted based on result of straight line Hough Transform
- Black = FTS hits, red = MC Points (from all detectors)



Hough Spaces

houghspaceLine



Parabola