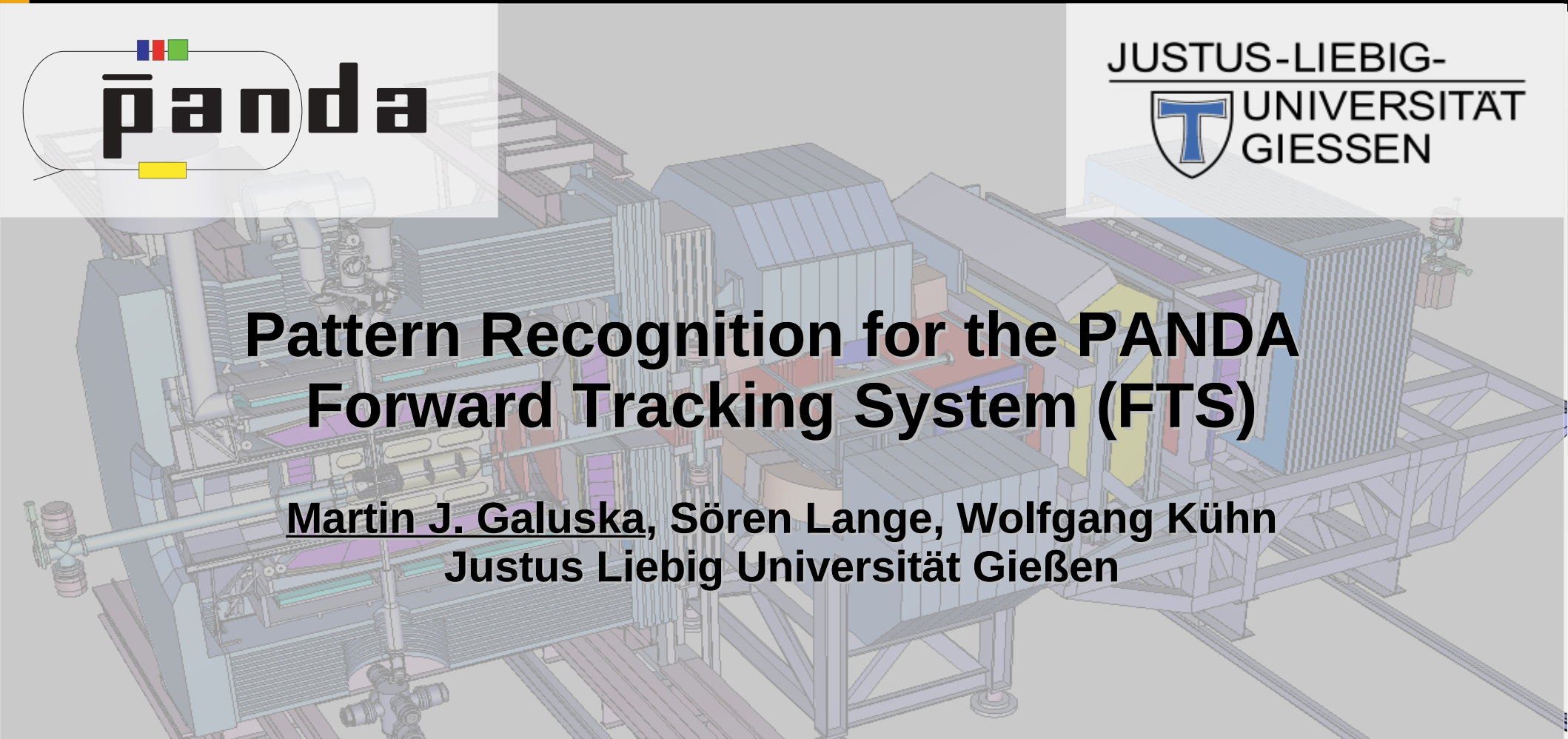


Pattern Recognition for the PANDA Forward Tracking System (FTS)

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

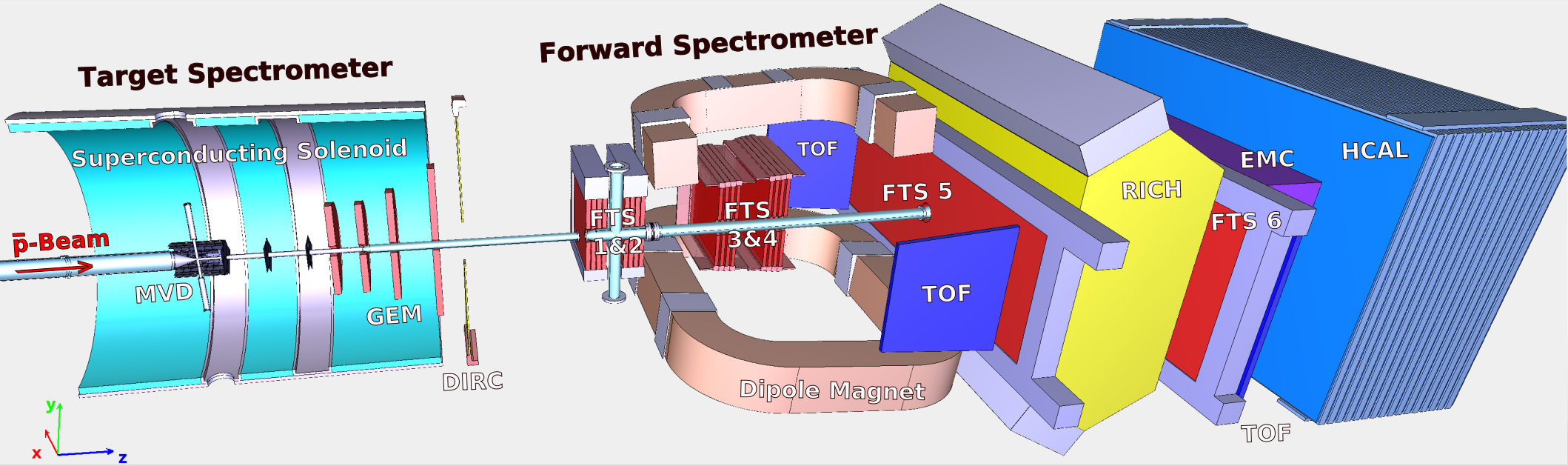
The Forward Tracking System (FTS)

Geometry & Challenges

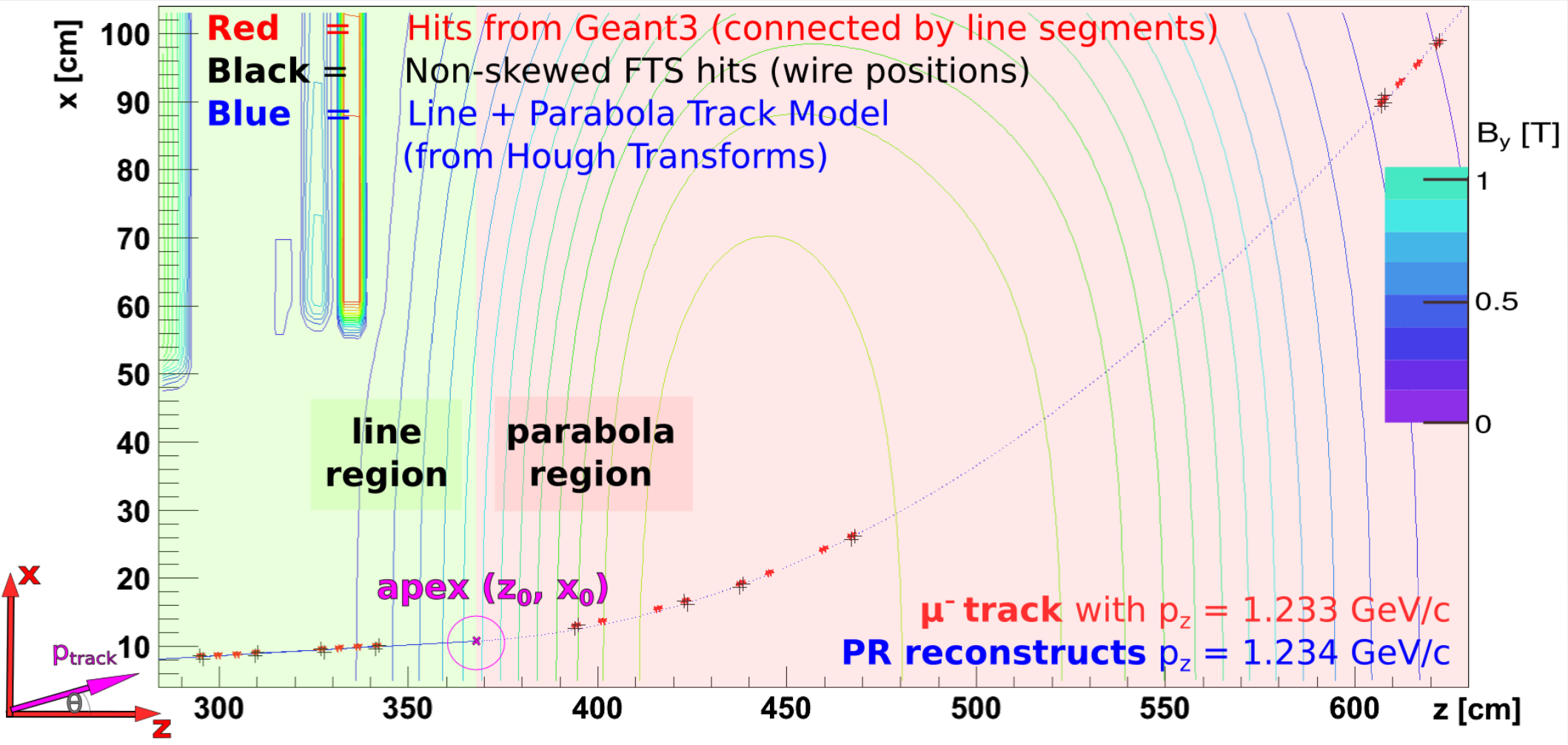
- Measure deflection of charged particles in dipole field
  - 6 straw tube chambers
  - 4 double layers per chamber
  - 13056 straw tubes total
- Momentum acceptance ≥ 3% p_{beam}
- Drift times ≤ 130 / 150 ns (outside / in dipole field)
  - Ar+CO_2 (90 : 10) @ 2 bar, anode wire @ 1.8 kV

Occupancy

- PANDA @ 20 MHz
  - On average: 50 ns between 2 events
  - ≤ 6 overlapping events with prob. ≥ 96.6%
- Up to 8 charged primary tracks in acceptance
- Combinatorial PR:
  - O((6*8)^{6*4}) = O(10^{40}) track candidates

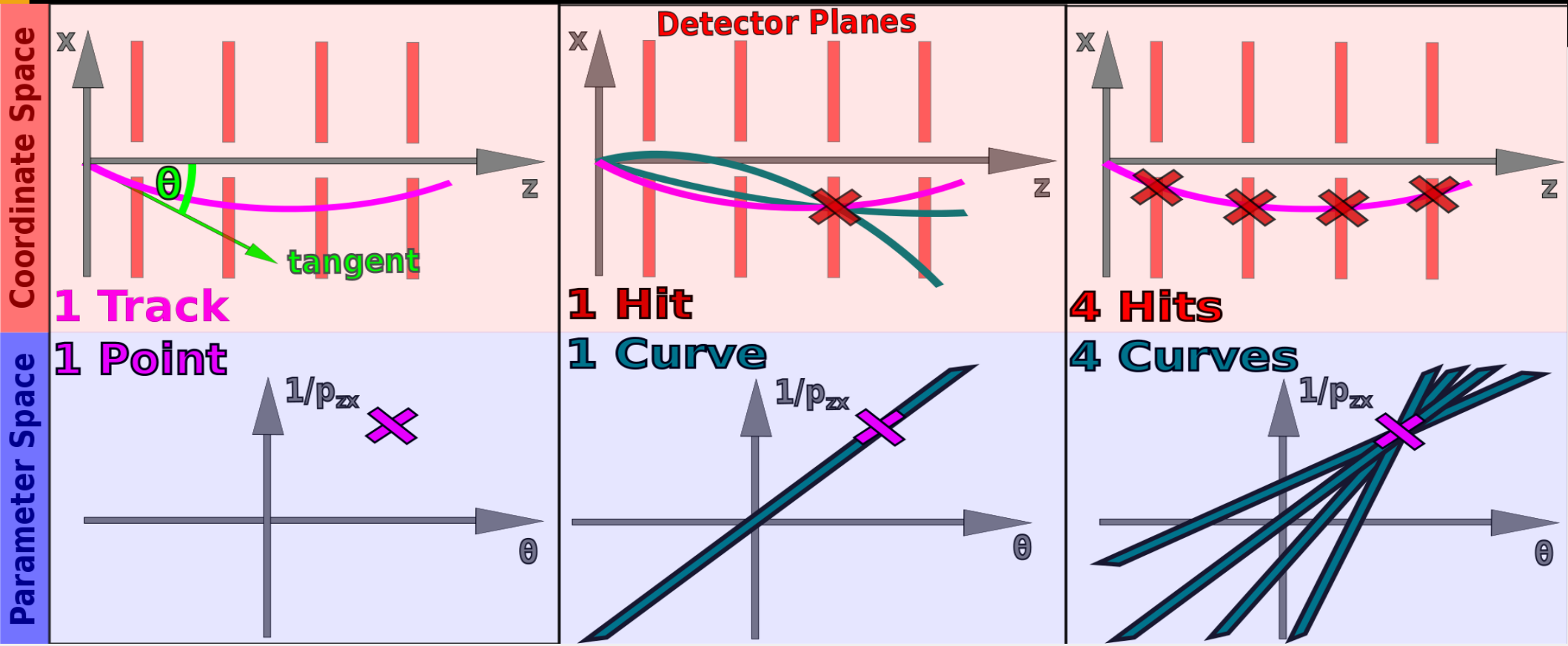


Line+Parabola+Line Track Model for the FTS



- Simulations show that the tracks can be approximated by a line before, a parabola within, and a line behind the dipole field

The Hough Transform for Pattern Recognition



- 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

Equations (x-z-plane)

- Line before and after dipole field:

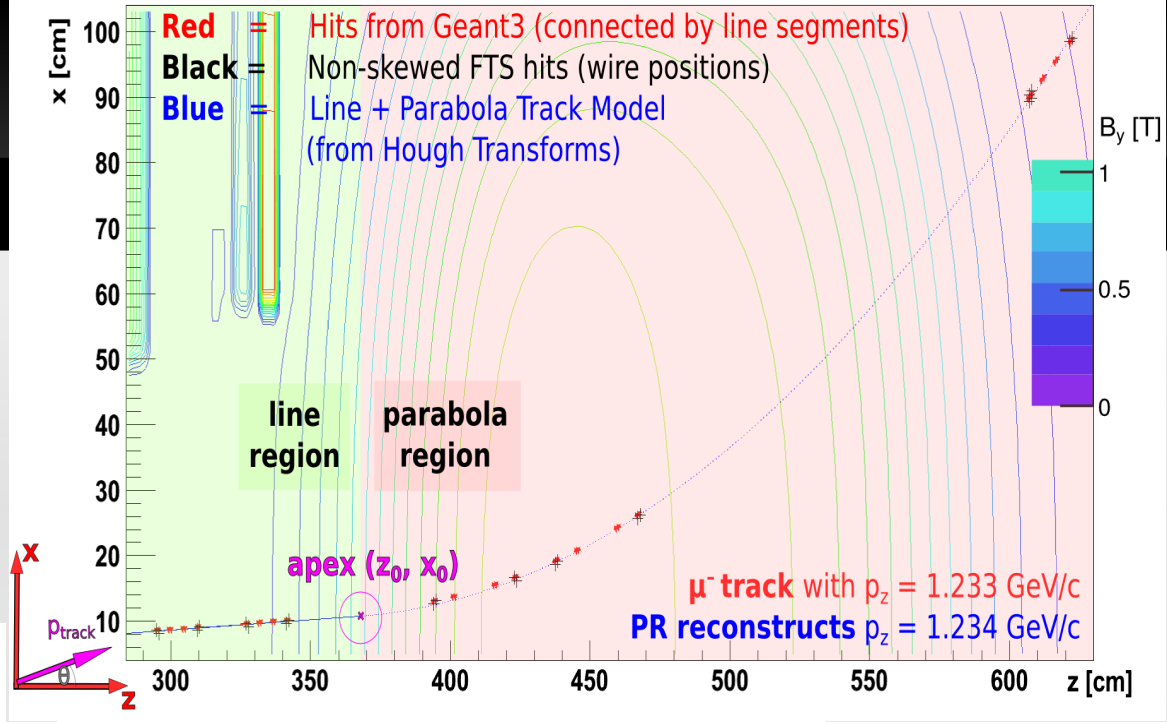
$$x_{\text{hit}} = \tan\theta \cdot (z_{\text{hit}} - z_0) + x_0$$

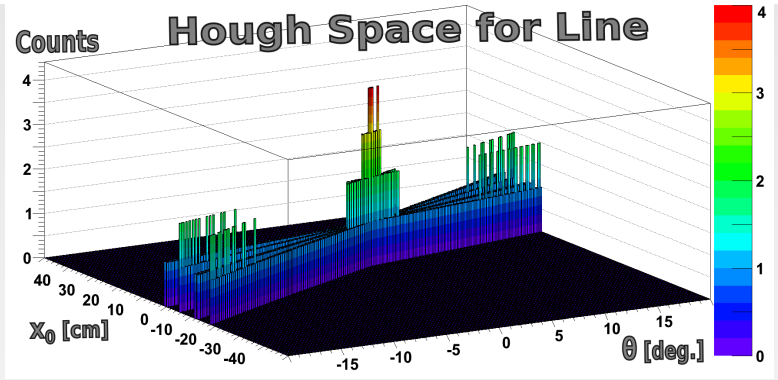
- Parabola within dipole field:

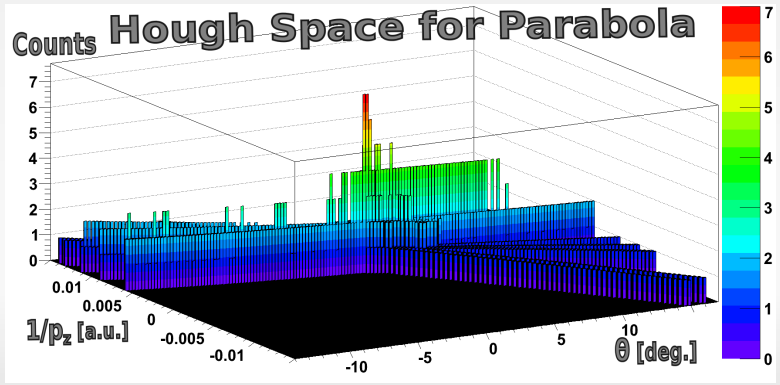
$$\frac{1}{p_{zx}} = \frac{2 \cdot (x \cdot \cos\theta - z \cdot \sin\theta)}{Q \cdot B_y \cdot (z \cdot \cos\theta + x \cdot \sin\theta)^2}$$

with

- (x_{hit}, z_{hit}): Hit coordinates
- (x, z) = ($x_{hit} - x_0$, $z_{hit} - z_0$)
- p_{zx}: Projection of track's momentum in z-x-plane
- Q: Charge of particle
- B_y: Max. y-component of B-field







The Algorithm

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

1. Find **lines in x-z-plane in chamber 1+2 and** in **chamber 5+6 with non-skewed fired straws**

2. **Expand lines to planes in 3D, add** intersecting fired **skewed straws**

3. **Parabola** Hough transform **in x-z-plane on non-skewed straws in chambers 3-5**

4. **Expand parabola to 3D, add** intersecting fired **skewed straws**

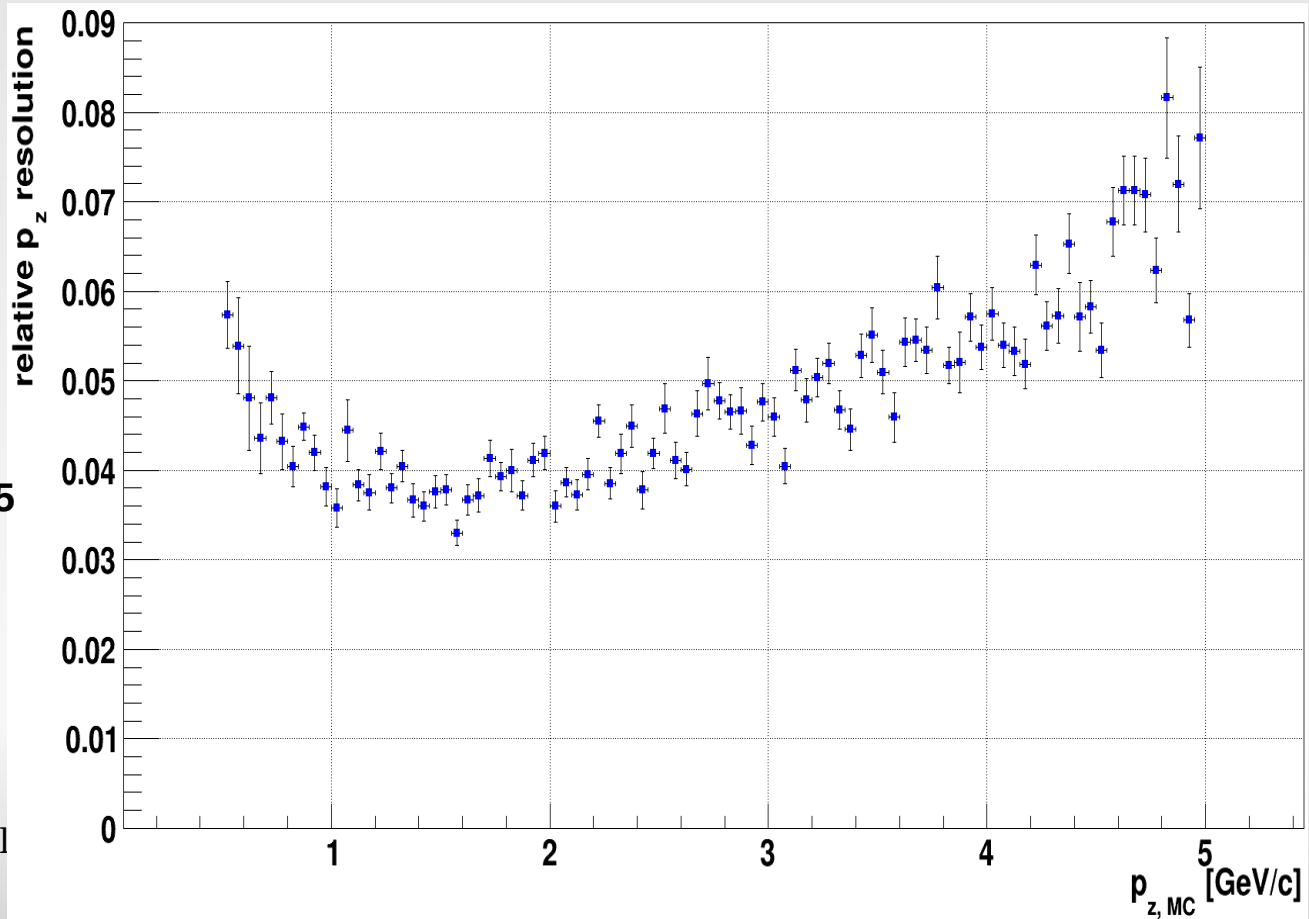
5. Straight **line** Hough transform **in y-z-plane on hits from chamber 1-6**

6. Require all non-skewed hits to lie on line from step 5

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

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

- 50k muons with BoxGenerator (1 muon/event)
- 0.5 GeV/c < p < 5.0 GeV/c, 0.1^0 < theta < 5^0, 0^0 <= phi < 360^0
- Multiple scattering and energy losses included
- All detectors included, dipole field for pbeam = 15 GeV/c
- Full PandaRoot 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!**



Want More Details?

PROCEEDINGS OF SCIENCE

Hough Transform Based Pattern Recognition for the $\overline{\text{P}}$ANDA Forward Tracking System

Martin J. Galuska[*(1)†], Jifeng Hu[(1)], Wolfgang Kühn[(1)], J. Sören Lange[(1)], Yutie Liang[(1)], David Münchow[(1)], Stefano Spataro[(2)], Björn Spruck[(1)] and Milan Wagner[(1)] for the $\overline{\text{P}}$ANDA Collaboration

(1) *Justus-Liebig-Universität Gießen, II. Physikalisches Institut, Heinrich-Buff-Ring 16, D-35392 Gießen*

(2) *Universita' di Torino, Dipartimento di Fisica, Via P. Giuria, 1, I-10125 Torino*

The planned $\overline{\text{P}}$ANDA fixed-target experiment will produce up to $2 \cdot 10^7$ antiproton-proton or antiproton-nucleus collisions per second. Up to 8 primary charged particles per event are expected to reach the acceptance of the $\overline{\text{P}}$ANDA Forward Tracking System (FTS) detector. Due to a drift time of ≤ 150 ns for the FTS straw tubes the signals of on average 3 events will overlap in this layered detector at the peak interaction rate of 20 MHz. The number of overlapping events is ≤ 8 with a probability of $\geq 99.6\%$.

In this paper we describe a Hough transform based charged particle tracking algorithm for the $\overline{\text{P}}$ANDA FTS detector. In the region of the $\overline{\text{P}}$ANDA Forward Spectrometer (290 cm $\leq z \leq$ 780 cm with the z-axis pointing into the beam direction) we use a 3-stages track model of line+parabola+line for the projection of the track into the bending x-z-plane. The projection into the non-bending y-z-plane is approximated by a line for this region.

Preliminary results for single particle momentum resolutions obtained with a proof-of-concept implementation of the described algorithm are presented. Simulations were carried out in PandaRoot, the official framework for simulation, reconstruction and analysis for the $\overline{\text{P}}$ANDA experiment.

This work was supported in part by BMBF (05P12RGFPF), HGS-HIRe for FAIR and the LOEWE-Zentrum HICforFAIR.

51st International Winter Meeting on Nuclear Physics
21-25 January 2013
Bormio (Italy)

*Speaker.
†E-mail: Martin.J.Galuska@physik.uni-giessen.de

PoS(Bormio 2013)023

You can find a published in-detail description of the algorithm here:

http://pos.sissa.it/archive/conferences/184/023/Bormio%202013_023.pdf
(M. Galuska et. al., PoS(Bormio 2013)023)

Thank You!

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

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)