The $\bar{\text{P}}$ANDA TPC software framework
Reconstruction & Results

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Outline

1. Tracking Overview: The GENFIT generic fitting package
   - Example of working reconstruction: Momentum resolution in the TPC
2. Space-charge Corrections
3. Track Deconvolution
   - Event Time Reconstruction
   - Example of Pattern Recognition in a crowded TPC

Tracking Overview

The GENFIT fitting package

GENFIT is a ”home-made”, generic fitting package for the $\bar{\text{P}}$ANDA experiment

- Written by **Sebastian Neubert** and **Christian Höppner** (TUM, E18)
- Main concept: flexibility

Key features:

- Heart: custom-made Kalman filter, independent of
  - Track representation
  - Hit geometry (detector)
- Versatile
- Default track representation (propagation): GEANE

The GENFIT Kalman filter

- Unlike common fitting packages the Kalman filter is independent of the detector geometry
- Concept: The detector hits know the planes they live in
- Perfect for the TPC: each space-point hit gives back its own virtual detector plane to the Kalman filter

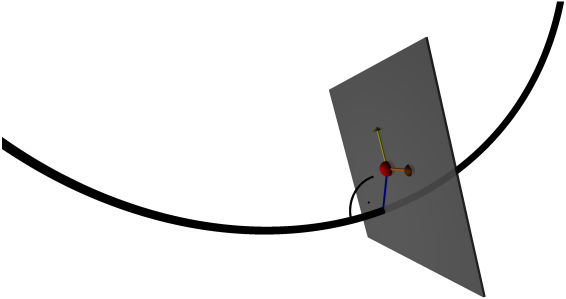

Figure: Schematic of the working principle of GENFIT

TPC Momentum Resolution

- Example of working reconstruction in the TPC: Momentum resolution studies
- Simulation input:
  - For each bin (momentum, angle): 5000 pion events, uniform in ϕ
  - MC modeling: Box Generator, GEANT3 ALICE
  - Full digitization (see talk yesterday)
- Reconstruction using GENFIT and TPC hits only
- Idealized case: No space-charge distortions present!

TPC Momentum Resolution II

- For each bin fit the distribution of reconstructed momenta p_{rec} with Gaussian:

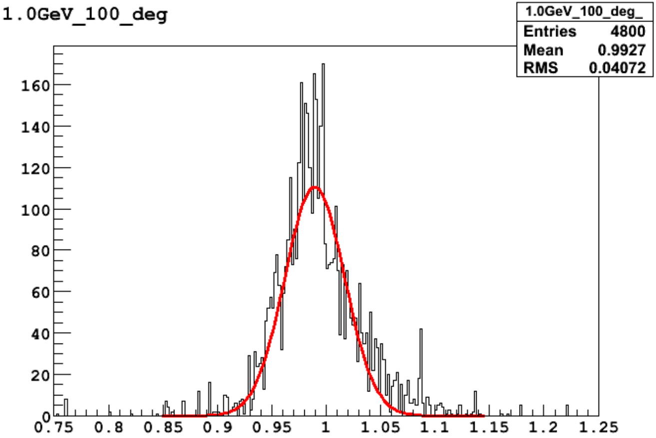

Figure: Methodology of momentum resolution studies

TPC Momentum Resolution III

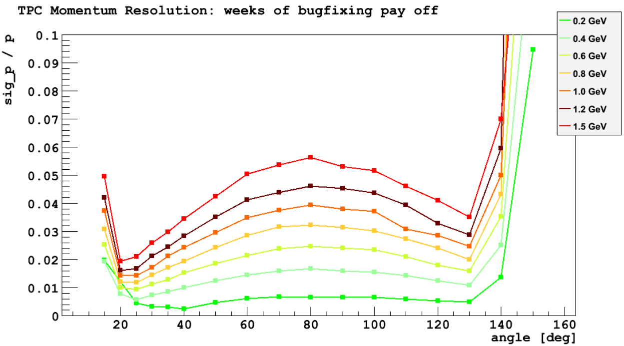

Figure: Momentum Resolution for the TPC alone

- Using the semi-analytical expression for curvature error (see PDG book)

$$\delta k_{res} = \frac{\varepsilon}{L^2}\sqrt{\frac{720}{N+4}}$$

these results correspond to a spatial resolution of $\sim 300\,\mu$m, proving consistency

Space-charge Corrections

- Input quantity for the digitization: Deviation Map

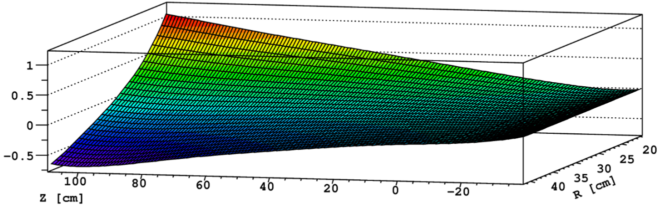

Figure: Final drift distortions (in ϕ) as function of the volume coordinates (cm)

- Read in by the Drifter during digitization

- To be able to correct for this effect, drift distortions have to be measured
- One way to do this (e.g. STAR TPC) are laser tracks in the chamber
- We have implemented a possible mesh of laser tracks on simulation level:

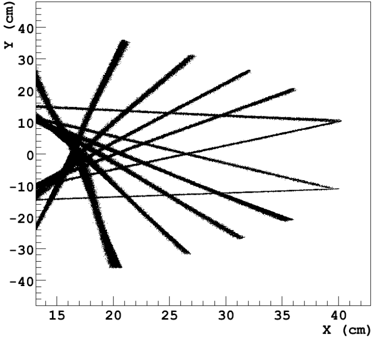

Figure: Top view of laser mesh

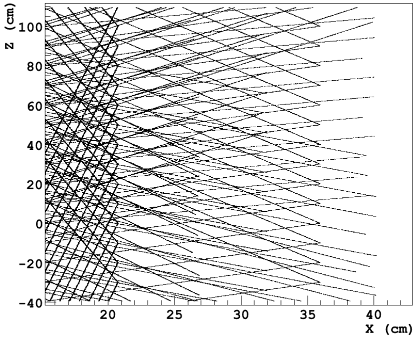

Figure: Side view of laser mesh

Laser-Reconstruction

- A special reconstruction task tries to connect the reconstructed hits on the readout to the known laser-mesh
  $\longrightarrow$ Direct measurement of the drift distortions
- Only very few cuts are applied to reduce the effect of false hit-track matching

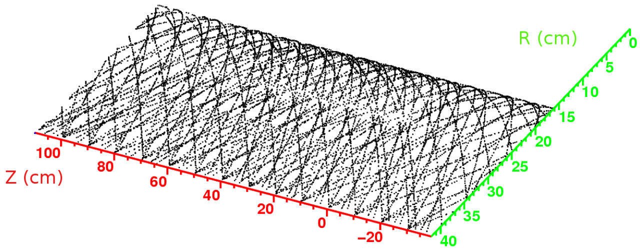

Figure: Top view of reconstructed laser hits in deviation map coordinates

Laser-Reconstruction

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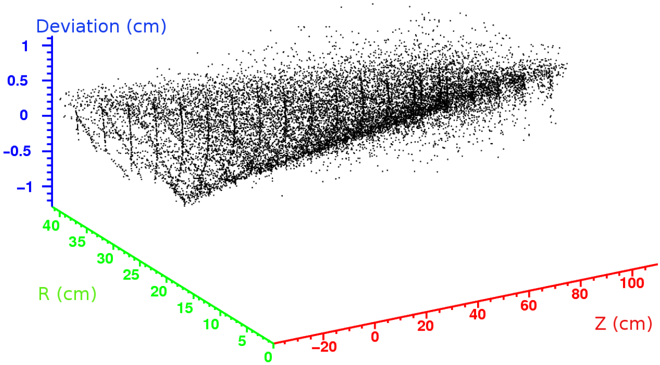
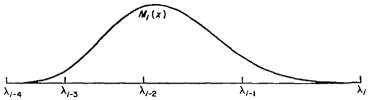


Figure: Side view of reconstructed laser hits in deviation map coordinates

Spline-Fitting I

- The obtained raw results require fitting and smoothing
- For this purpose a least square bi-cubic spline fitting algorithm has been implemented
- Principle:
  - Create mesh λ_i, μ_j of points over the data area
  - At each point elementary B-Splines $M_i(x)$, $N_j(y)$ are attached:



  - The complete spline has the defined representation

$$s(x,y) = \sum_{i=1}^{h+4} \sum_{j=1}^{k+4} \gamma_{ij} \, M_i(x) \, N_j(y) \stackrel{!}{=} f_r$$

  - Fitting problem becomes problem of determining the coefficients γ_{ij} for the data-points f_r ($r = 1...m$)

Spline-Fitting II

- This can be written in matrix form: $\mathbf{A}\,\gamma = \mathbf{f}$
  where **A** is a matrix with m rows and $(h+4)(k+4)$ columns.
- If the data points are sorted in x (y), the matrix **A** has band structure
- The matrix equation can be solved by inverting or (more stably) by using Householder Transformations , which takes advantage of the band structure

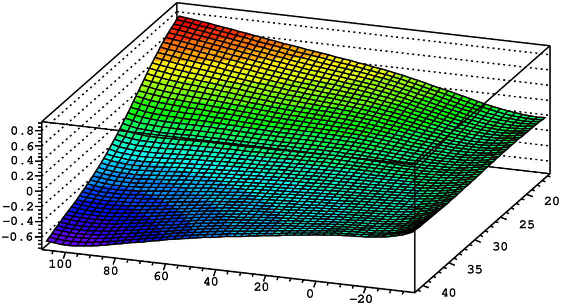


Figure: Spline fit of laser reconstruction data; Knots: 5, 3 on the data area. $\sim$ 22000 data points, fit time $\sim$ 3 seconds

Spline-Fitting Analysis

- Original map implemented as linear interpolation between calculated points
- Either:
  - Compare with this lin. int. at cost of bigger errors between the points
  - Compare with spline fit of orig. DevMap
- Choice: comparison with Spline Fit of orig. map

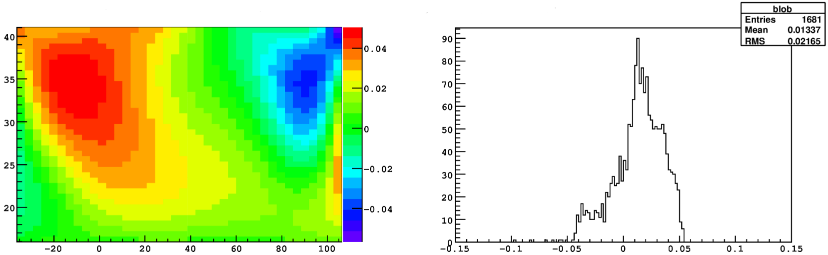


Figure: Absolute difference between reconstructed deviation map (Spline) and original map (Spline)

- Reconstruction of the original map within $\sim 200\mu$m precision

Effects of Correction

- We are able to reproduce the input deviation map
- By shifting the reconstructed data into the coordinates of the measured hits we can immediately correct any reconstructed hit for drift distortions on-line
- Spline objects are small and extremely fast to evaluate and perfect for this purpose

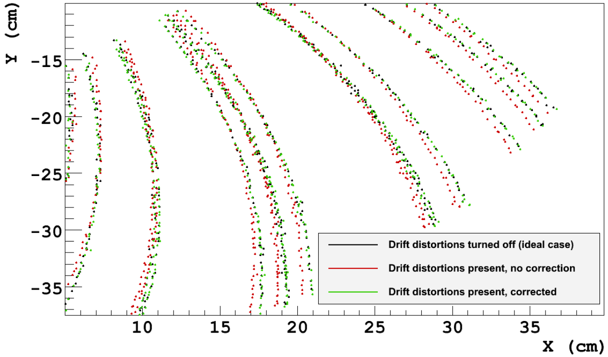


Figure: Effect of drift distortions and laser correction on spatial track measurements

Effects of Correction II

- Uncorrected distortions of $\mathcal{O}$(mm) are immediately visible
- Correction shifts the clusters back well onto the ideal tracks
- Deformation of tracks suggests big impact on momentum resolution

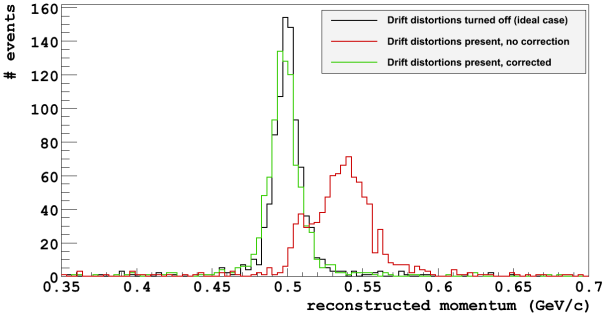


Figure: Effect of drift distortions and laser correction on momentum reconstruction

The corrections restore the ideal momentum reconstruction (mean and sigma) within well below $\mathcal{O}$ (1%)

Event Deconvolution

Event Deconvolution

There were 2 studies on the feasibility of event deconvolution:

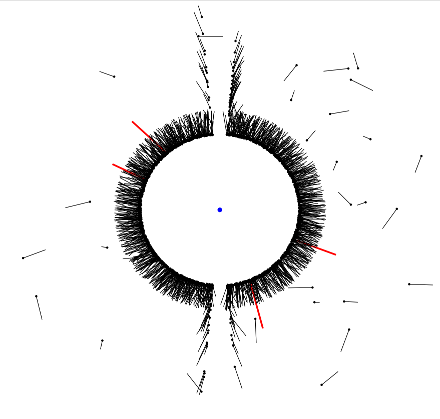
1. Target pointing performed on Monte Carlo data

$$Y(4260) \longrightarrow J/\Psi\,\pi\,\pi$$

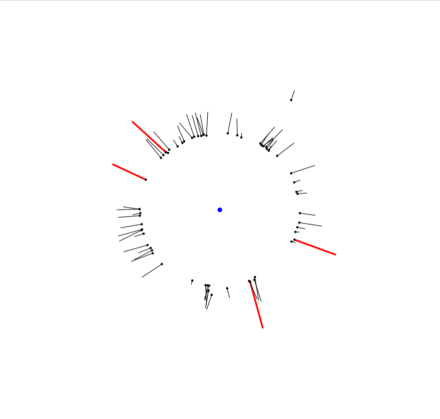
2. Track deconvolution performed on fully reconstructed data...

Monte Carlo data: effect of target pointing:

Event + Background



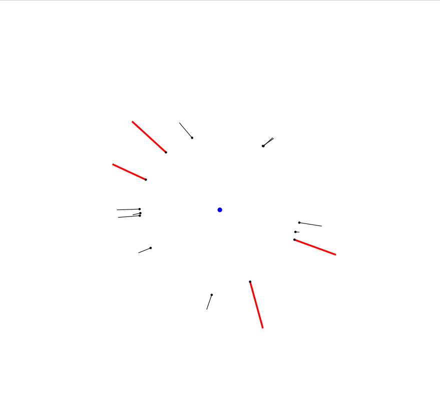
Target pointing $2\mu s$ cut



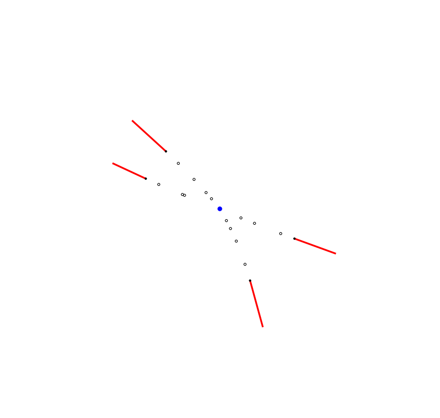
Event Deconvolution - Target Pointing & Cuts

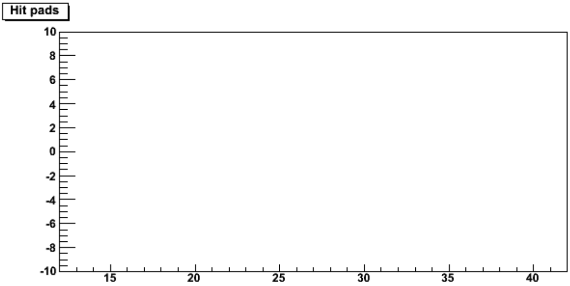
Monte Carlo data: effect of target pointing:

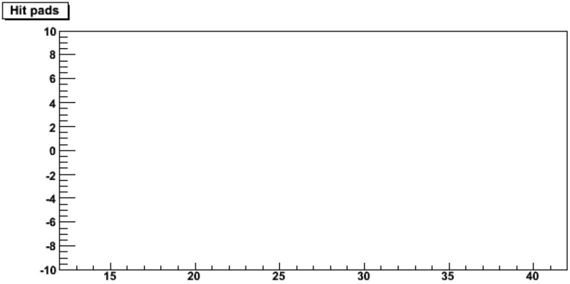
Target pointing 200ns cut



Correlation with MVD




Hit pads
10
8
6
4
2
0
-2
-4
-6
-8
-10
15
20
25
30
35
40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10
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-10
15
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35
40

Conclusion

- Event deconvolution in principle feasible, we reach track purities of $> 90\%$ with target pointing methods
- Under the assumption of azimuthal symmetry it has been shown that field distortions from space-charge effects can be controlled, for example by a system of laser tracks

Backup Slides

Backup slide: TPC geometry

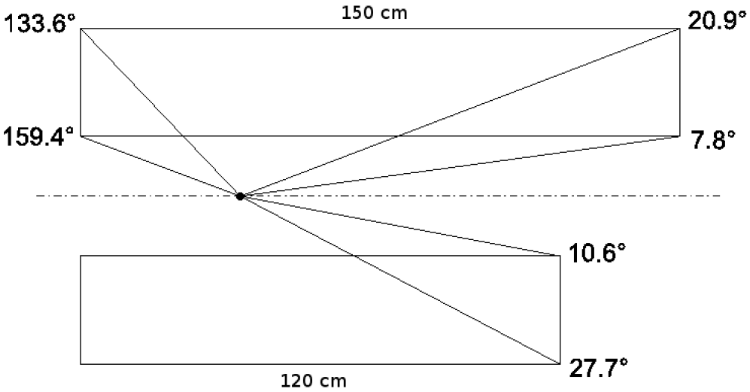

Figure: The two length options and resulting key angles