Track Reconstruction with PANDA at FAIR

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The PANDA detector at FAIR

antiProton ANnihilation in DArmstadt

- Nearly 4\pi coverage
- Event rates up to 20 MHz
- Continuous $\bar{p}$ beam
- Online reconstruction
- Software-based event filtering
Straw Tube Tracker

- 4224 straws
- 19 axial layers (green)
- 8 stereo layers ($\pm 3^\circ$ blue/red) for z-reconstruction
- 10 mm tube diameter
- 150 $\mu m$ isochrone resolution
Event mixing: Low and high intensity

- **Event-based**
  - Event 1
  - Event 2
  - Event 3

- **Low intensity**
  - Event 1
  - Event 2
  - Event 3
  - Events separated in time
  - Similar to event-based processing

- **High intensity**
  - Event 1
  - Event 2
  - Event 3
  - Events start to overlap
  - New reconstruction challenge: Associate data with correct event
Event mixing: Low and high intensity

- Collision rate $\sim 2\text{MHz}$
- Good spatial separation between tracks

- Collision rate $\sim 20\text{MHz}$
- Event mixing becomes more prominent
A Tracks traverse detector
B Hits are marked as active cells
C Active cells are classified as
  - unambiguous: $\leq 2$ active neighbours
  - ambiguous: $> 2$ active neighbours
D Ambiguities are resolved using track fits
  - GPU version has been implemented
Cellular Automaton: Clustering with time information
J. Regina

- Extend spatial clustering to use time information
  → Hits are only combined if $\Delta t < 250\text{ns}$ (based on detector response time)
- Small computational footprint ($\sim 1\%$)

- Full (serial) event reconstruction $\approx 10\text{ms}$ (Intel Core i7 3.4 GHz)
Longitudinal reconstruction with stereo layers
W. Ikegami Andersson

Procedure
- Obtain isochrone from stereo layer
- Align isochrone with track fit by varying $z$-position
- Transform locations to $(z, \phi)$ space
  - Two solutions for each straw

How to solve ambiguity?
Three approaches
- Combinatorial path finder
- Hough transformation
- Recursive annealing fit
Reconstruction of longitudinal track component

Combinatorial approach

- Determine all possible connections between layers
Reconstruction of longitudinal track component

Combinatorial approach

- Determine all possible connections between layers
- Calculate angles between neighboring lines
- Reject paths with $\theta < 90^\circ$
Reconstruction of longitudinal track component
Combinatorial approach

- Determine all possible connections between layers
- Calculate angles between neighboring lines
- Reject paths with $\theta < 90^\circ$
- Select path by minimising $\sum (\theta_i - 180^\circ)^2$
Reconstruction of longitudinal track component

Hough transformation

- Generate set of lines around point
- Fill line parameters in accumulator
- Repeat for all points
- Select maximum in accumulator
  - Maximum selects track parameters
Reconstruction of longitudinal track component

Recursive annealing fit

- Fit line to all points
- Remove point with largest residual
- Calculate new line fit
- Repeat until one point has been rejected for each straw tube
Comparison

- Efficiency = \[ \frac{N_{\text{correctly found hits}}}{N_{\text{all hits}}} \]

- Purity = \[ \frac{N_{\text{correctly found hits}}}{N_{\text{all found hits}}} \]

- Benchmark with reconstructed, prompt muons
- Observables before using Kalman filter
- Recursive annealing fit best in all categories
Summary

- Track and event reconstruction at PANDA challenging task
- Cellular Automaton has been adapted to continuous data stream
- Algorithms for longitudinal parameter extraction have been developed
  - Combinatorial path finding
  - Hough transformation
  - Recursive annealing fit (best performance)

Outlook

- Apply recursive annealing fit to hit rejection in other detectors
- Vectorise/parallelise algorithms
- Port to hardware accelerators
Thank you for your attention!