Time-based Reconstruction of Hyperons at the PANDA Experiment at FAIR

Jenny Regina

Uppsala University

Department of Physics and Astronomy

21/06-2018
Uppsala

Outline

- Hyperons
- The PANDA Detector
- Investigations of detector signatures
  - $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$
  - $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$
  - $\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$
- SttCellTrackFinder
- Time based simulation
- Summary
- Future Plans

Hyperons

Baryons with at least one light quark replaced by an s or c quark

Hyperon	$c\tau$ $[cm]$	Mass $[GeV/c^2]$	Main decay and branching ratio
Λ (uds)	8.0	1.116	$p\pi^-$ 64%
Ξ^- (dss)	4.9	1.321	$\Lambda\pi^-$ 100%
Ω^- (sss)	2.5	1.672	ΛK^- 68%

- Relatively long lifetime
  $\rightarrow$ **Can travel far before decaying**

- Provide a possibility for testing role of spin in creation of strangeness
- Scarce ammount of data for multi strange hyperons

$\rightarrow$ **Need more data!**

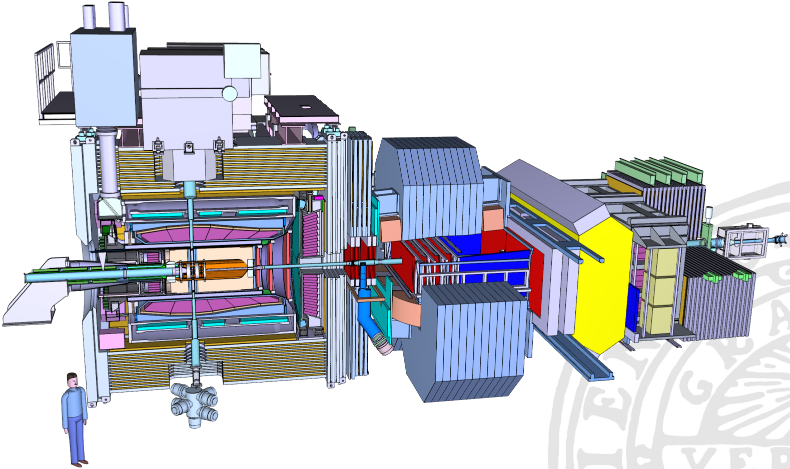
PANDA at FAIR

- **PANDA (anti-Proton ANnihilation at DArmstadt):** multipurpouse detector
  - proton target
  - creation of states with all quantum numbers possible
  - hyperons created in particle-antiparticle pairs
  - reconstruction of both particle and antiparticle possible

Software Trigger

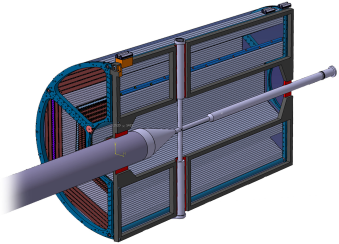
- Signal and background very similar
  - hardware trigger undesirable
- Interaction rate: 20 MHz
  - 200 GB of data/s
- Events filtered using information from tracking, calorimetry and PID

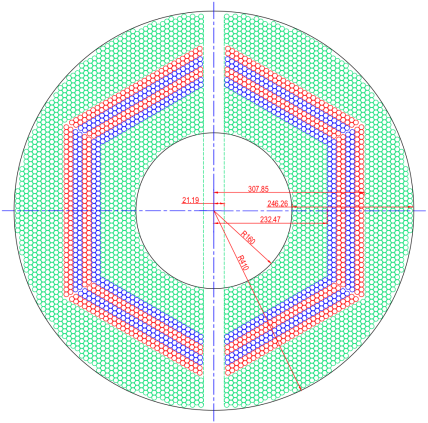
PANDA Detector



Straw Tube Tracker of PANDA

Set of single channel drift tubes

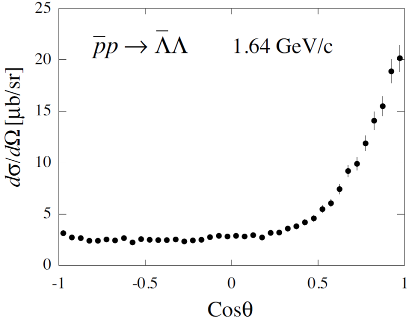


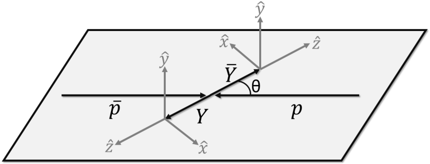


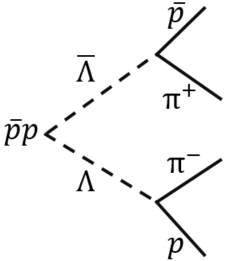
- 4,636 straws planned
- 27 radial layers (green)
- 8 central layers consist of tilted tubes ($\pm 3^{\circ}$) (red and blue) for transversal
- Internal radius: 15 cm
- External radius: 42 cm
- Length of tubes: 150 cm

$\bar{p}p \to \bar{\Lambda}\Lambda$, Previous Measurements

- PS185 at LEAR
- p_{beam}=1.64 GeV

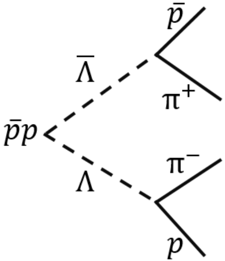


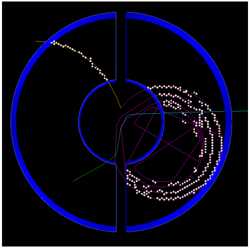




$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$

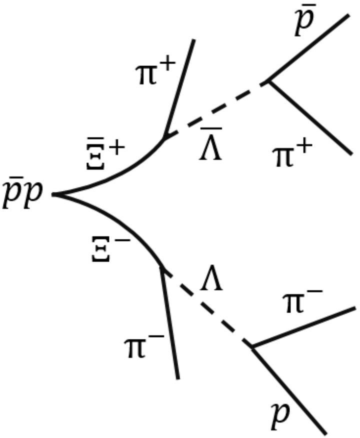
- $\sigma = 64\ \mu b$ at p_{beam}=1.64 GeV
- Studies performed for p_{beam}=1.64 GeV, 7 GeV and 15 GeV
- Λ and $\bar{\Lambda}$ neutral, need to be identified from decay products
- Forward peaking distribution in CM frame
- $\bar{\Lambda}$ forward boosted in lab frame
  - decay products from $\bar{\Lambda}$ can be tracked in forward spectrometer
- Λ decays close to at rest
  - tracking low energy decay products from Λ in target spectrometer - a challenge
- Λ crucial for reconstruction of heavier strange hyperons





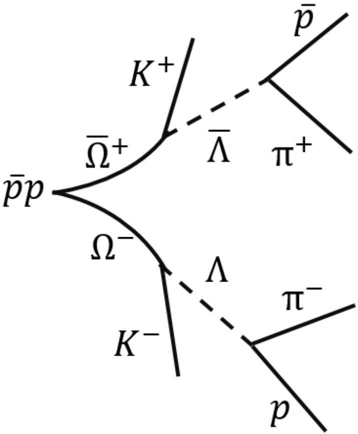
$\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$

- $\sigma \sim 2\ \mu b$ at p_{beam}=4 GeV
- Studies performed for p_{beam}=4.6 GeV
- **PANDA will be first to measure angular distribution**
- Isotropic distribution used for simulations
  - Behaviour of $\bar{\Xi}^{+}$ and Ξ^{-} symmetric
  - Comparison with Λ interesting



$\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$

- No experimentally measured cross section so far
  - $\rightarrow$ **PANDA expected to be first!**
- No good prediction for cross section
- Studies performed for p_{beam} =5 GeV and 15 GeV
- Isotropic distribution used for simulations
  - Behaviour of $\bar{\Omega}^{+}$ and Ω^{-} symmetric



Investigations of Detector Signatures

Motivation:

DyTER (Dynamic Track and Event Reconstruction)

- Modular and dynamic approach
- Needs to be as general as possible but work well for hyperons

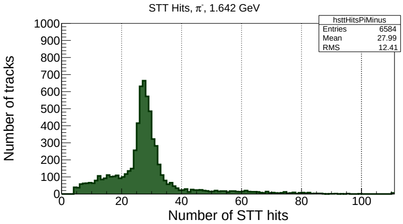
- Usefulness of target spectrometer tracking detectors have been investigated
- $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$, $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$, $\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$
  - Behaviour of decay products in the detector have been investigated

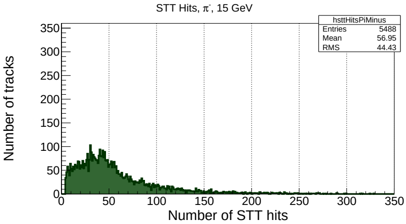
Investigations of Detector Signatures

- Number of hits in tracking detectors
- Reconstructed tracks
  - Need ≥ 4 detector hits for 3D helix fit
- Overlap between different detectors
- Challenging tracks
  - Tracks with too few hits
  - Tracks with many hits
- Number of reconstructed tracks per event
  - How many reconstructible events?
- Possibility of obtaining t_0 from barrel ToF

Investigations of Detector Signatures

- Studies performed for different detector setups
- These studies also guides detector development
- Similar studies have been performed for the forward spectrometer

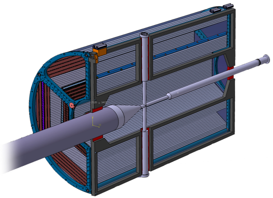


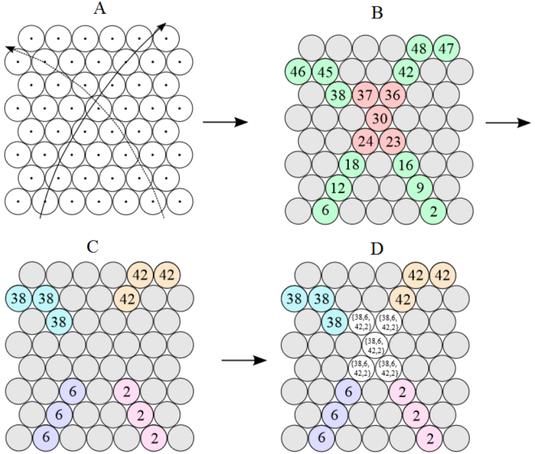


SttCellTrackFinder

J. Schumann

- Cellular Automaton - clustering
- Riemann Fit - track parameters





A Tracks traverse STT

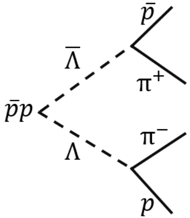
B Hit straws are numbered

C **Unambiguous** hits are iteratively renumbered until hits in one cluster have same number

D **Ambiguous** hits are give all numbers possible

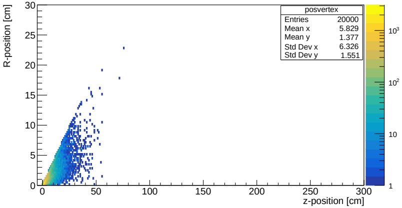
Tracklets need to have at least 3 hits

SttCellTrackFinder for Hyperons

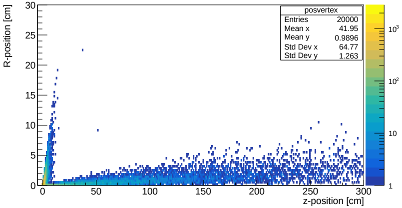


Why?

- Secondary track finder
  - → does not assume track originate from IP
- Hyperon event → displaced vertex
- Most hyperon decay vertices will occur within range of STT
- STT good starting point for tracking
- Efficiency for hyperon events have been evaluated event based and show promising results

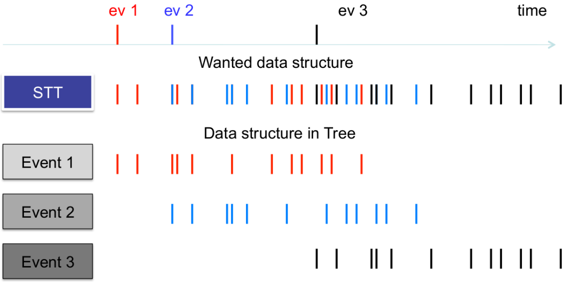


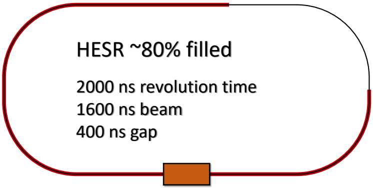
p_{beam}=1.642 GeV



p_{beam}=15 GeV

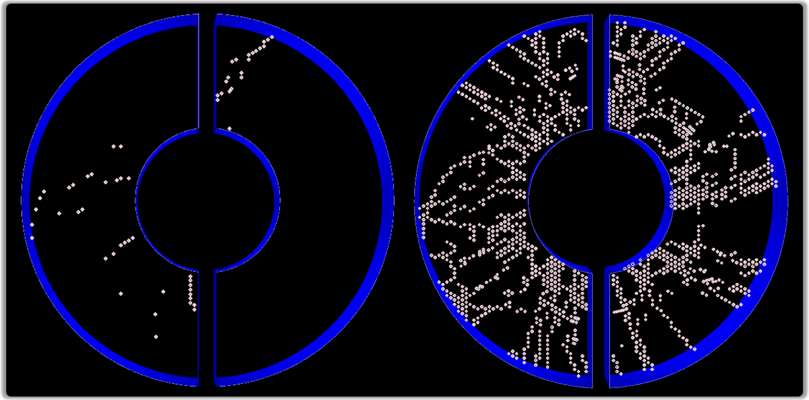
Time Based Reconstruction





- Event mixing at high interaction rates
- HESR: quasi continuous beam
- Time based clustering implemented in SttCellTrackFinder

Time Based Reconstruction, DPM



Left:

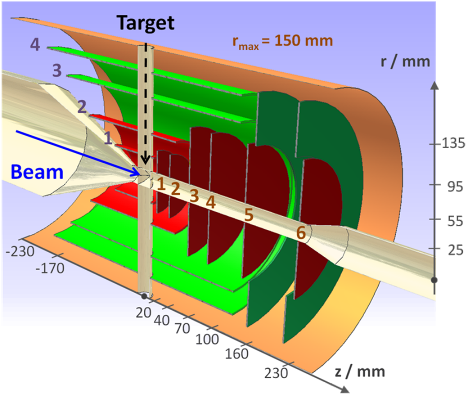
- 200 ns time window
- Tracks well separated

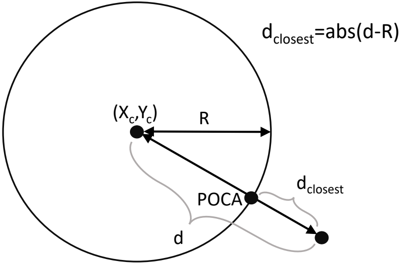
Right:

- 2,000 ns time window
- Event mixing
- Overlap between tracks

MVD

- Include MVD hits in tracking
- Use distance from projections of MVD hits in xy-plane to Riemann track
- Riemann track object: circular at z=0

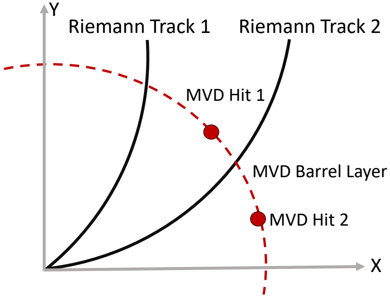




Hit Selection

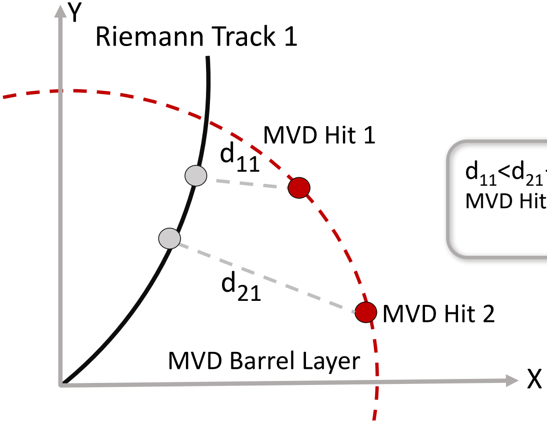
Add best hit from each barrel layer to track

- Disks not taken into account at the moment
- Presently, one hit can be added to several tracks
- One track can at most have 4 hits assigned to it
- Introduce cut on d



Hit Selection

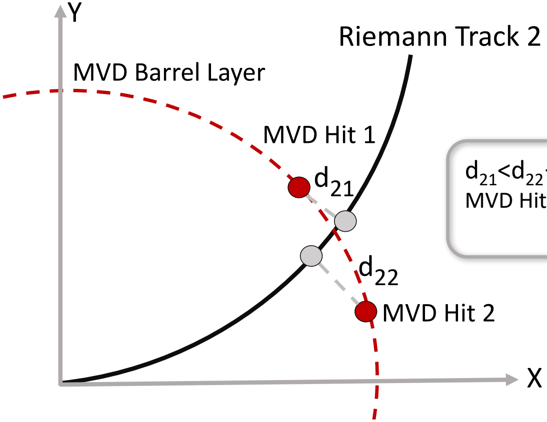
- Distance, d, between MVD hits in one barrel layer and POCA of all tracks calculated
- Hit with smallest d is added to track



$d_{11} < d_{21} \rightarrow$
MVD Hit 1 added to track 1

Hit Selection

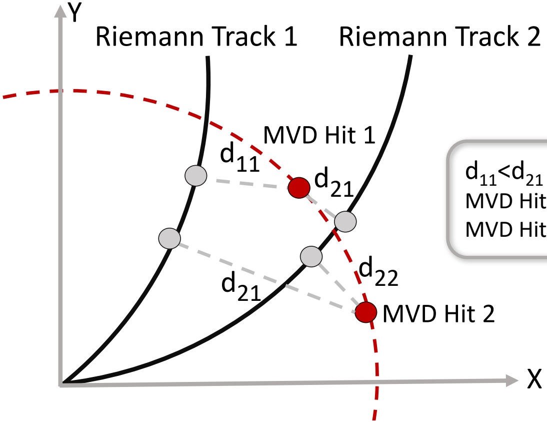
- Distance, d, between MVD hits in one barrel layer and POCA of all tracks calculated
- Hit with smallest d is added to track



$d_{21}<d_{22}\rightarrow$
MVD Hit 1 also added to track 2

Hit Selection

- Distance, *d*, between MVD hits in one barrel layer and POCA of all tracks calculated
- Hit with smallest *d* is added to track



$d_{11}<d_{21}$ and $d_{21}<d_{22}$ →
MVD Hit 1 added to both tracks
MVD Hit 2 not added to a track

Summary

- Hyperons - interesting to study spin observables
  - Could help discriminate between quark-gluon and hadron picture
- PANDA offers unique possibilities for tracking and reconstructing hyperons
- Due to relatively long lifetimes, displaced vertices pose a challenge for reconstructing hyperons
- Detector signatures for hyperon events have been investigated for different detector setups
  - Developed procedure for this using the tools available
  - Internal note on this under correction
- Time clustering have been implemented in the SttCellTrackFinder
- Work on including MVD hits in tracking algorithm ongoing

Future Plans

Near future, 2018-2019

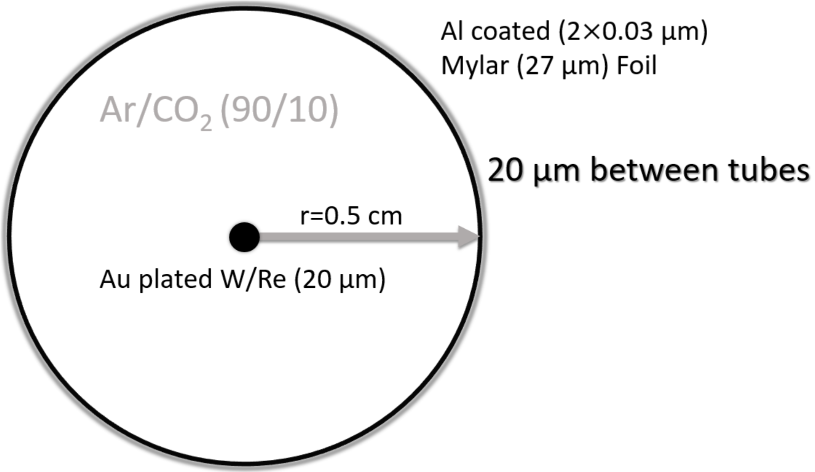
- Look into and test other tracking algorithms and track propagators
- Include barrel ToF hits for event building
- Include GEM hits in tracking
- Evaluate efficiencies at different stages of development
  - Work on standardized tool for evaluating time-based efficiency
- Plans to incorporate machine learning in tracking at PANDA

Long term plans, 2020-2021 (may be subjected to change)

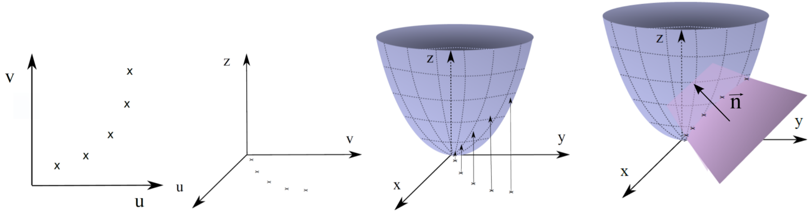
- One or both of following:
  - Test tracking algorithms with PANDA forward trackers at HADES
  - Hyperon analysis with HADES data
- Writing thesis

Thank You!

Straw Tube Tracker of PANDA



SttCellTrackFinder



Points to be fitted

Add z-dimension

Map onto paraboloid

Calculation of plane through 3D points
simple eigenvalue determination