

Toward Realistic Reconstruction of Hyperons in the PANDA Experiment at FAIR

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Realistic Reconstruction

(A) - Realistic Target Conditions

- From a *point-like* target to an *extended* target
- Hyperon reconstruction using $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ channel, comparison both cases using a Figure-of-Merit (FoM)
- Ideal tracking and pid algorithms are used

(B) - Realistic Track Reconstruction

- Graph representation of tracks in the form of nodes/edges
- Perform *Edge Classification* using Interaction GNN
- Track formation by using Connected Components method
- The data include **5 muon pairs** per event, 10^5 events in total

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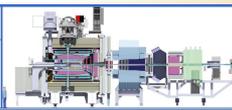
The PANDA experiment will provide unique opportunities to study Quantum Chromodynamics (QCD) in the confined domain. A beam of antiprotons, in the momentum range of 1.5 GeV/c to 15 GeV/c, will impinge on a stationary target (proton or heavy atom). These interaction will allow to study several sub-domains of QCD.

QCD Confinement Domains:

- Nuclear Structure
- Strongly Interacting Physics
- Charm and Exotics
- Hadrons in Nuclei

What is a hyperon?

- A hyperon is a baryon with at least one strange (or charmed or bottom) quark in addition to up and down quarks.
- All ground-state strange hyperons (Λ , Σ , and Ξ), except the Σ^0 hyperon, decay through parity violating weak interactions.
- They are excellent diagnostic tools due to their traceable spin.



1 - Realistic Target Conditions:

Physics simulations are usually performed by assuming a *point-like* target (*IdealIP*). In reality, this assumption is not true as realistic target is an *extended* one. It is observed that residual gas from the *detector-in* target dominates into the beam-pipe. The residual gas is mitigated by using a cryogenic pump, 300 m upstream from the interaction point (IP).

Three vacuum scenarios in PANDA:

- *IdealIP*: A scenario where a residual gas is absent (i.e. the ideal case)
- *NormalIP*: A scenario where residual gas is considered
- *NormalIP+Cryo*: A scenario where a cryogenic pump is used to mitigate residual gas

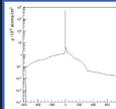
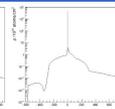



Fig. NormalIP Fig. NormalIP+Cryo

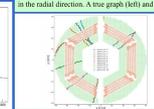
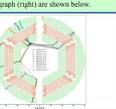
2 - Realistic Reconstruction:

We use geometric deep learning to reconstruct muon tracks in the Straw Tube Tracker. Test tracks as graphs (combination of nodes and edges) and perform edge classification using interaction graph neural networks (Interaction GNN) [arXiv:2103.06995v2].

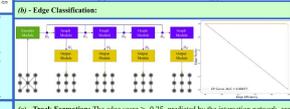
Geometric Deep Learning Pipeline:

Input: Tracks
Graph Construction
Edge Classification
Track Reformation

6a) - **Graph Construction:** A heuristic method is used to build graphs in adjacent layers in the radial direction. A true graph (left) and input graph (right) are shown below.

6b) - **Edge Classification:**



6c) - **Track Reformation:** The edge score > 0.25, predicted by the interaction networks, are used in track building. We use connected component algorithm from graph theory to find weakly connected components, where each component is a track candidate.

Track Evaluation: The final result is a list of track candidates from the deep learning pipeline. We evaluate track reconstruction using the tracking efficiencies given below.

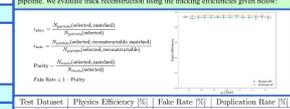


Figure-of-Merit:

$$FoM = \frac{\sigma(\bar{p}p \rightarrow \bar{\Lambda}\Lambda)}{\sigma(\bar{p}p \rightarrow \bar{p}^+\pi^-)} \cdot \frac{\sigma(\bar{p}p \rightarrow \bar{\Lambda}\Lambda) \cdot BR(\Lambda \rightarrow p\pi^-)}{\sigma(\bar{p}p \rightarrow \bar{p}^+\pi^-)}$$

Final Results: Using ideal track finding and particle identification (PID):

Target	$\epsilon_{sig} [\%]$	$\epsilon_{bkg} [\%]$	FoM
IdealIP	20.08 ± 0.05	0.344 ± 0.006	99
NormalIP	15.27 ± 0.004	0.517 ± 0.007	50
NormalIP+Cryo	17.06 ± 0.004	0.558 ± 0.007	52

Conclusion:

The FoM for both realistic scenarios is almost half of the ideal case, however, we can still study hyperons with reasonable accuracy. We expect, FoM will improve in the future.

Test Dataset	Physics Efficiency [%]	False Rate [%]	Duplication Rate [%]
Full	94.6	0.225	16.6
Clean	92.6	0.220	7.92

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Thank you for your attention