Hyperon Reconstruction with Realistic Track Finders

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Outline

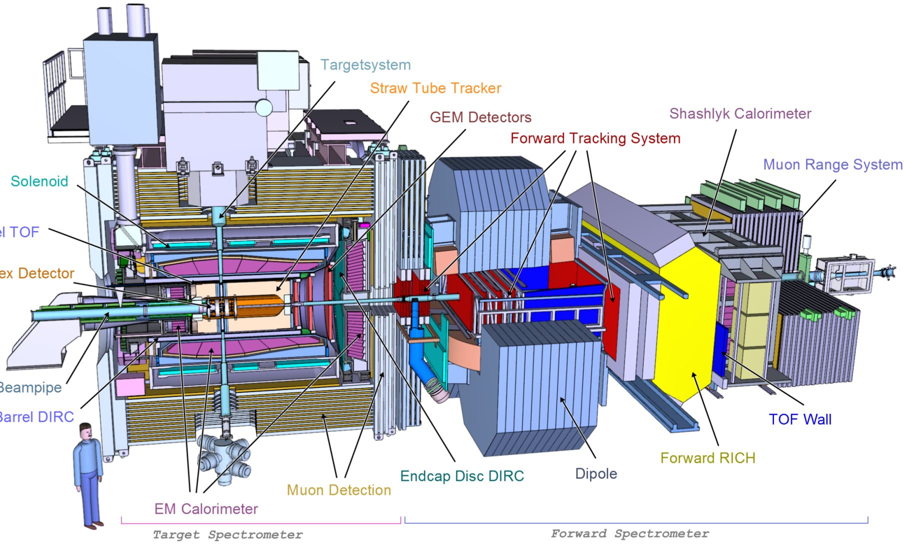
- Motivation
- The PANDA Experiment at FAIR
- Hyperon reconstruction ($\bar{p}p \to \Lambda\bar{\Lambda} \to \bar{p}\pi^+ p\pi^-$) with IdealTrackFinder
- Hyperon reconstruction with realistic trackers (BarrelTrackFinder, SttCellTrackFinder)
- Summary
- Outlook

Motivation

- Assessing the current state of realistic trackers.
- How effective these logarithms are with hyperon reconstruction?

$\Rightarrow$ hyperon reconstruction with IdealTrackFinder as benchmark

PANDA Detector



Benchmark Analysis

Exclusive Reconstruction:

- Signal: $\bar{p}p \to \Lambda\bar{\Lambda} \to \bar{p}\pi^+ p\pi^-$
- Background: $\bar{p}p \to \bar{p}\pi^+ p\pi^-$ (non-resonant)

Simulation conditions:

- 10^6 events at 1.642 GeV/c
- EvtGen as event generator for signal and non-resonant bkg. channels
- The point-like target (Ideal)
- Ideal Reco (IdealTrackFinder) and Ideal PID algorithms

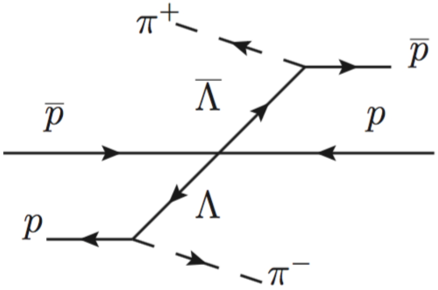


Figure of Merit (FoM)

Our figure-of-merit (FoM) is the expected ratio of events from the signal and the non-resonant background weighted with ratios of respective cross-sections:

Figure-of-Merit

$$FoM = \frac{\epsilon(p\bar{p} \to \Lambda\bar{\Lambda})}{\epsilon(p\bar{p} \to \bar{p}\pi^{+}p\pi^{-})} \cdot \frac{\sigma(p\bar{p} \to \Lambda\bar{\Lambda}) \cdot BR(\Lambda \to p\pi^{-})^{2}}{\sigma(p\bar{p} \to \bar{p}\pi^{+}p\pi^{-})}$$

- ϵ is the reconstruction efficiency of either signal or background
- $\sigma(p\bar{p} \to \Lambda\bar{\Lambda}) = 64.1 \pm 0.4 \pm 1.6\ \mu b$, $BR(\Lambda \to p\pi^{-}) = 63.9 \pm 0.5\%$
- $\sigma(p\bar{p} \to \bar{p}\pi^{+}p\pi^{-}) = 15.4 \pm 5.2\ \mu b$

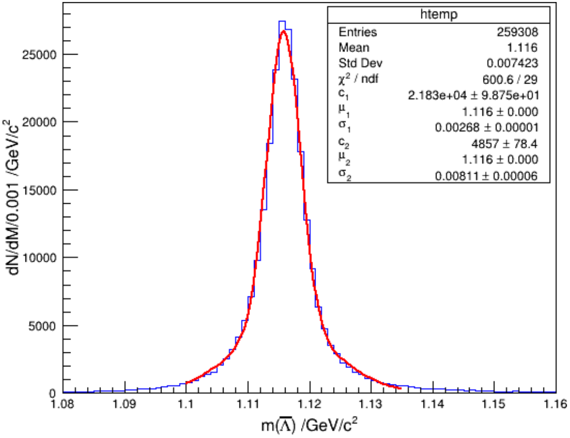
Event Reconstruction

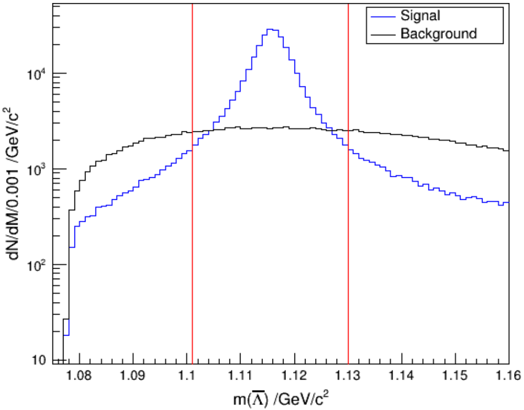
The following event selection criteria are used [1]:

- Final state contains $\bar{p}, \pi^+, p$ and π^-
- **The $\bar{p}\pi^+$ and $p\pi^-$ combinations have invariant masses near m_Λ.**
- Four-momentum is conserved between initial and final state (4C fit)
- **$z-$ position of decay vertex is displaced *w.r.t.* the interaction point: $z_{fit}(\Lambda) + z_{fit}(\bar{\Lambda}) > 2$ cm**

[1] W. I. Andersson, *Exploring the Merits and Challenges of Hyperon Physics: with $\bar{P}$ANDA at FAIR*, Dissertation (2020)

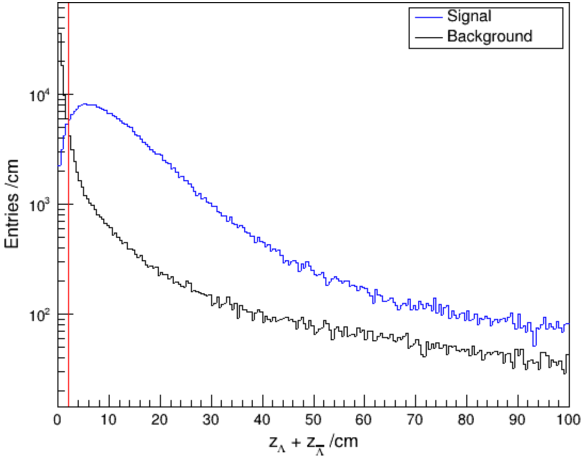
Invariant Mass Criterion





Mass Resolution: $\sigma_{m_{fit}}(\bar{p}\pi^+) = 2.680 \cdot 10^{-3}\ \mathrm{GeV/c^2}$,
Mass Window: $|m_{\mathrm{fit}}(\bar{p}\pi^+) - m_{\mathrm{PDG}}(\bar{\Lambda})| < 5 \cdot \sigma_{m_{fit}}(\bar{p}\pi^+)$

The $z_{\bar{\Lambda}} + z_{\Lambda} > 2$ cm Criterion



Final Reconstruction Efficiencies & FoM

Channel	$p\bar{p} \to \bar{\Lambda}\Lambda \to \bar{p}\pi^+ p\pi^-$	$p\bar{p} \to \bar{p}\pi^+ p\pi^-$
Generated	10^6	10^6
Rest of Cuts	222344	28787
$z_{\bar{\Lambda}} + z_{\Lambda} > 2$ cm	200772	3443
Reconstruction Efficiency %	20.08 ± 0.05	0.344 ± 0.006

$$FoM = \frac{\epsilon(p\bar{p} \to \Lambda\bar{\Lambda})}{\epsilon(p\bar{p} \to \bar{p}\pi^+ p\pi^-)} \cdot \frac{\sigma(p\bar{p} \to \Lambda\bar{\Lambda}) \cdot BR(\Lambda \to p\pi^-)^2}{\sigma(p\bar{p} \to \bar{p}\pi^+ p\pi^-)}$$

$$FoM_{\text{Ideal}} = 99$$

Realistic Tracking Algorithms

The track building algorithm can be categorized as primary *vs.* secondary, online *vs.* offline, global *vs.* local tracking algorithms.

- **Primary/Secondary:** A primary algorithm builds tracks originating from IP. This constraint greatly simplifies track build. On the other hand, IP agnostic algorithms are known as secondary algorithms.
- **Local/Global:** A local tracking algorithm builds tracks in a single sub-detector while global tracking algorithm using all sub-detectors at once to build tracks.

Two algorithms, **BarrelTrackFinder** (primary, global) & **SttCellTrackFinder** (secondary, local), are studied.

BarrelTrackFinder (I)

The 9.8×10^5 signal events, and 9.9×10^5 non-resonant background events at a beam momentum of $p_{beam} = 1.642$ GeV/c. The reconstructed final states are:

Channel	$p\bar{p} \to \bar{\Lambda}\Lambda \to \bar{p}\pi^+ p\pi^-$	$p\bar{p} \to \bar{p}\pi^+ p\pi^-$
Generated	984000	988000
$\bar{p}$	918686 (93.36%)	1051642 (106.4%)
p	849874 (86.37%)	1114149 (112.77%)
π^+	505284 (51.35%)	683009 (69.13%)
π^-	450620 (45.79%)	691406 (69.98%)

When comparing to **single track efficiencies** with **IdealTrackFinder**, they are close for the $\bar{p}/p$, but about 20% lower for the pions (π^+, π^-).

BarrelTrackFinder (II)

Final selection efficiencies are given as follows:

Channel	$p\bar{p} \to \bar{\Lambda}\Lambda \to \bar{p}\pi^+ p\pi^-$	$p\bar{p} \to \bar{p}\pi^+ p\pi^-$
Generated	984000	988000
Rest of Cuts	14731	19460
$z_{\bar{\Lambda}} + z_{\Lambda} > 2$ cm	9268	4011
Final Efficiency %	0.94 ± 0.01	0.406 ± 0.006

$$FoM_{\text{Barrel}} = 3.9$$
$$FoM_{\text{Ideal}} = 99$$

The final efficiencies for **IdealTrackFinder** are $20.08 \pm 0.04\%$ and $0.344 \pm 0.005\%$ for signal and background, respectively.

SttCellTrackFinder (I)

The 736500 events are generated for the signal sample whereas 738000 events for the non-resonant background channel at beam momentum of $p_{beam} = 1.642$ GeV/c.

Channel	$p\bar{p} \to \bar{\Lambda}\Lambda \to \bar{p}\pi^{+}p\pi^{-}$	$p\bar{p} \to \bar{p}\pi^{+}p\pi^{-}$
Generated	736500	738000
$\bar{p}$	309528 (42.03 %)	308643 (41.82 %)
p	306227 (41.58 %)	335680 (45.49 %)
π^{+}	263354 (35.76 %)	273059 (37.00 %)
π^{-}	225525 (30.62 %)	268071 (36.32 %)

As expected, signal and background efficiencies are similar. Overall the reconstruction efficiencies are roughly 30% less when compared to the IdealTrackFinder.

SttCellTrackFinder (II)

Final selection efficiencies are given as follows:

Channel	$p\bar{p} \to \bar{\Lambda}\Lambda \to \bar{p}\pi^+ p\pi^-$	$p\bar{p} \to \bar{p}\pi^+ p\pi^-$
Generated	736500	738000
Rest of Cuts	652	200
$z_{\bar{\Lambda}} + z_{\Lambda} > 2$ cm	472	90
Final Efficiency %	0.064 ± 0.003	0.012 ± 0.001

$$FoM_{\text{Cell}} = 8.9$$
$$FoM_{\text{Ideal}} = 99$$

The final efficiencies for IdealTrackFinder are $20.08 \pm 0.04\%$ and $0.344 \pm 0.005\%$ for signal and background, respectively.

Summary

The study with **realistic** tracking was intended to examine the current state of these algorithm. In case of SttCellTrackFinder, one can conclude that

- algorithm needs further improvements
- gives poor momentum resolution → poor reconstruction efficiency
- including MVD & GEM detectors will improve the momentum resolution
- In addition, using primary track finder before SttCellTrackFinder reduces ghost tracks

The BarrelTrackFinder is mature algorithm which is not intended to study hyperon physics. However, it still performed better compared to the SttCellTrackFinder but with poor FoM (3.9 compared to 8.9)

Outlook

- SttCellTrackFinder, inclusion of MVD and GEM detectors
- Both SttCellTrackFinder & HoughTrackFinder didn't work properly with PzFinder
  - Probable cause is with `-nan` values of track parameters (present in the issue tracker)
  - Partial fix was applied inside PzFinder (not tested with HoughTrackFinder yet)
- Developer should test HoughTrackFinder & SttCellTrackFinder with PzFinder for STT.

Thank you for your attention.
Questions?