Spin Observable Measurements in $\overline{Y}Y$ Reactions

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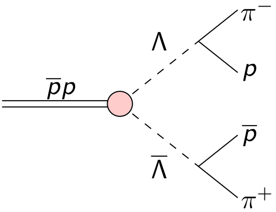
Outline

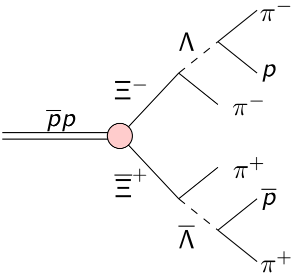
- Spin observables
  - Channels to be studied
  - Accessible observables
  - Analysis methods
- $\overline{\Lambda}\Lambda$ @ 1.642 GeV/c
  - Efficiencies
  - Acceptance functions
- Outlook

Hyperon channels accessible with $\overline{\text{P}}$ANDA

Why antihyperon-hyperon production?

- $\bar{p}p \to \bar{\Lambda}\Lambda$
  - Measured before @ LEAR
  - Comparison of polarisation & spin correlation
- $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$
  - Scarce data
  - Potential to measure @ 7.0 GeV/c
- $\text{BR}(\Lambda \to p\pi^{-}) = 64\%$
- $\text{BR}(\Xi^{-} \to \Lambda\pi) \approx 100\ \%$





Spin observables in $\bar{p}p \rightarrow \overline{Y}Y$

Spin observables can be used to test theoretical model. Angular distribution related to

$$I \propto \sum_{\mu,\nu=0}^{3} \sum_{k,l=0}^{3} \overline{\alpha}\alpha\chi_{kl\mu\nu} P_k^B P_l^T \overline{k}_\mu k_\nu$$

With unpolarised beam and unpolarised target, differential cross section χ_{0000}, polarisation $\chi_{00\mu 0} = P_{\bar{i}}$, $\chi_{000\nu} = P_i$ and the spin correlations $\chi_{00\mu\nu} = C_{ij}$ are accessible.

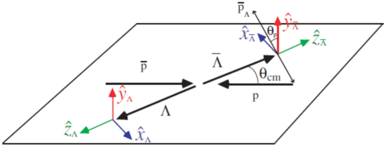
Polarisation

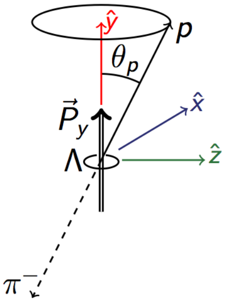
- 3 polarisation parameters for spin-$\frac{1}{2}$ hyperons: P_x, P_y, P_z
- $P_x = P_z = 0$ due to strong production
- $P_y = P_{\overline{y}}$ due to rotational invariance

Spin correlation

- 9 spin correlation parameters for spin-$\frac{1}{2}$ hyperons: $C_{i,j}$
- $C_{xy} = C_{yx} = C_{yz} = C_{zy} = 0$ due to strong production
- $C_{xz} = C_{zx}$ due to rotational invariance

Spin observables in $\bar{p}p \to \overline{Y}Y$





$$\hat{z} = \frac{\vec{p}_\Lambda}{|\vec{p}_\Lambda|}, \hat{y} = \frac{\vec{p}_i \times \vec{p}_f}{|\vec{p}_i \times \vec{p}_f|}, \hat{x} = \hat{y} \times \hat{z}$$

Polarisation

Proton angular distribution:

$$I(\theta_p) \propto \frac{1}{4\pi}(1 + \alpha P_Y \cos\theta_p)$$

$\overline{\alpha}, \alpha$ - decay asymmetry parameter

Spin correlation

Nucleon angular distribution:

$$I(\theta_i, \theta_j) \propto \frac{1}{16\pi^2}(1 + \overline{\alpha}\alpha \sum_{i,j} C_{ij} \cos\theta_i \cos\theta_j)$$

Reconstructing the Spin Observables

Spin observables can be extracted using Method of Moments:

$$\langle \cos\theta_y \rangle = \langle k_y \rangle = \int_{-1}^{1}\int_{-1}^{1} I(k_y, k_{\overline{y}}) \times k_y \, dk_y \, dk_{\overline{y}}$$

Polarisation and Spin Correlation is given by:

$$P_y = \frac{3}{\alpha}\langle k_y \rangle = \frac{3}{\alpha}\frac{\sum_{m=1}^{N} \frac{k_{y,m}}{A(k_{y,m})}}{\sum_{m=1}^{N} \frac{1}{A(k_{y,m})}}$$

$$C_{ij} = \frac{9}{\overline{\alpha}\alpha}\langle \overline{k}_i k_j \rangle = \frac{9}{\alpha\overline{\alpha}}\frac{\sum_{m=1}^{N} \frac{\overline{k}_{i,m} k_{j,m}}{A(\overline{k}_{i,m}, k_{j,m})}}{\sum_{m=1}^{N} \frac{1}{A(\overline{k}_{i,m}, k_{j,m})}}$$

Reconstructing the Spin Observables

If $\cos\theta_y$ is symmetric around 0 i.e.

$$A_Y(\cos\theta_y) = A_Y(-\cos\theta_y)$$

$$A_{\overline{Y}}(\cos\theta_{\overline{y}}) = A_Y(-\cos\theta_{\overline{y}}),$$

the spin observables are obtainable without acceptance correction:

$$P = \frac{1}{\alpha}\frac{\langle k_y \rangle}{\langle k_y^2 \rangle}$$

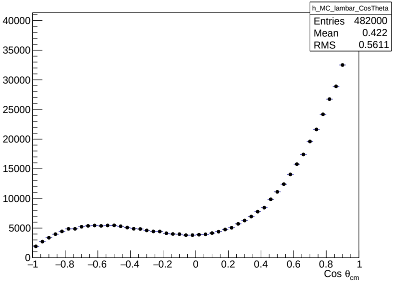
$$C_{ij} = \frac{1}{\alpha\overline{\alpha}}\frac{\langle \overline{k}_i k_j \rangle}{\langle \overline{k}_i^2 \rangle \langle k_j^2 \rangle}, i,j = x,z$$

$$C_{yy} = \frac{1}{\alpha\overline{\alpha}}\frac{\langle \overline{k}_y k_y \rangle - \langle \overline{k}_y \rangle \langle k_y \rangle}{\langle \overline{k}_y^2 \rangle \langle k_y^2 \rangle}$$

Simulation study of $\overline{p}p \rightarrow \overline{\Lambda}\Lambda$

Simulation parameters

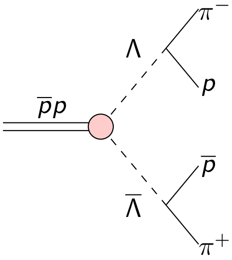
- 482000 $\overline{p}p \rightarrow \overline{\Lambda}\Lambda$ events
- Forward-peaking distribution
- Antiproton beam $p_{\overline{p}} = 1.642$ GeV/c
- Full $\overline{\text{P}}$ANDA Detector setup
- Ideal Pattern Recognition
- Ideal Particle Identification



Event reconstruction

Event selection:

- Combine $p\pi^-$, $\overline{p}\pi^+$
- Select $|m_\Lambda - M(p\pi^-)| < 0.1$ GeV
- Vertex & Mass fit
  Select combination based on χ^2
- Reject candidate if $P(\mathrm{Vtx}) < 0.001$
- Tree fit



Reconstruction Efficiencies

Ideal tracking task: PndSttMvdGemTrackingIdeal.cxx

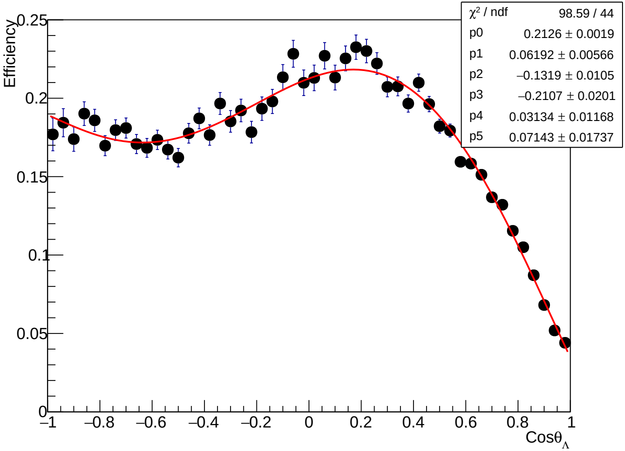
```
for(candit=candlist.begin(); candit!=candlist.end(); ++candit) {
  PndTrackCand* tcand=candit->second;
  trackID=candit->first;
  if(!tcand) {
    if(fVerbose>3) Warning("Exec","Have no candidate at %i",trackID);
    continue;
  }
  if( tcand->GetNHits() < 3 ) continue;
```

Ideal PR requirement for track: 3 hits from any detector

Track	Efficiency (%)
π^+	81.3
π^-	83.4
p	99
$\overline{p}$	75.8

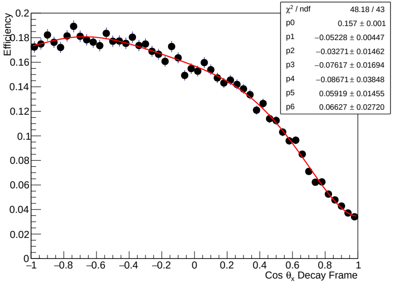
Particle	Efficiency (%)
Λ	54.4
$\overline{\Lambda}$	52.9
$\overline{p}p$	13.4

Reconstruction Efficiencies

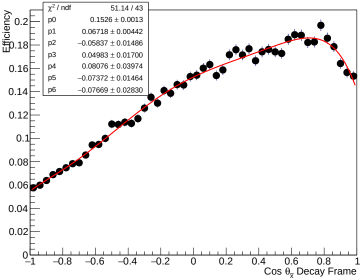


Acceptance Functions

$\cos\theta_x$

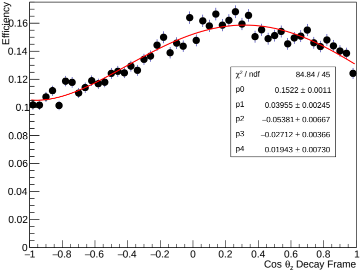


$\cos\theta_{\overline{x}}$

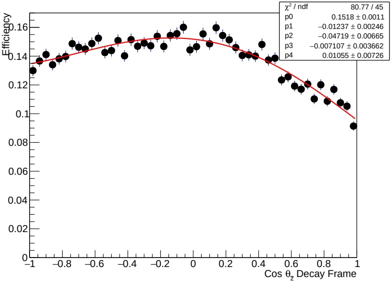


Acceptance Functions

$\cos\theta_z$

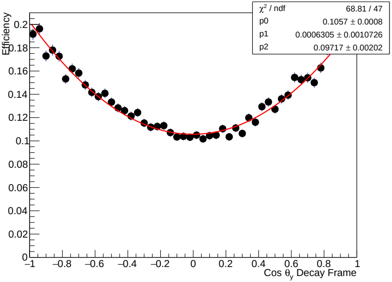


$\cos\theta_{\overline{z}}$

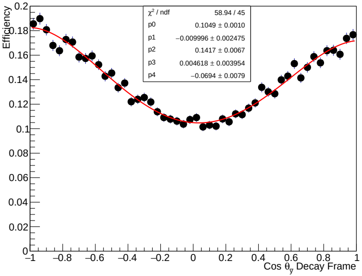


Acceptance Functions

$\cos\theta_y$



$\cos\theta_{\overline{y}}$



Outlook

- Performance check of analysis tools:
  - Benchmarking
  - DecayTreeFitter as alternative?
- Realistic PID
- Background studies
- Analysis of $\overline{p}p \to \overline{\Xi}\Xi$
  - Reproduce Erik Thomé's result @ 4.0 GeV/c
  - Study feasibility @ 7.0 GeV/c (X(3872) threshold)
- Efficiency studies of $\overline{p}p \to \overline{\Omega}\Omega$

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Thank you for your attention!

Backup

Hyperon production $\overline{p}p \to \overline{Y}Y$

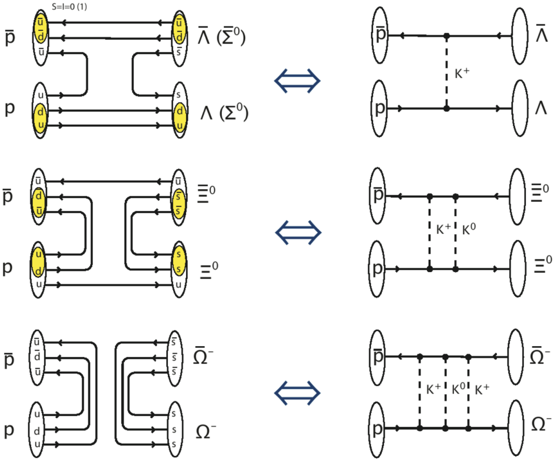

Figure: $\overline{p}p \to \overline{Y}Y$ in quark-gluon picture (left) and in Hadron picture (right).

Hyperons: Spin observables in $\overline{p}p \to \overline{Y}Y$

Polarised Particle	None	Beam	Target	Both
None	I_{0000}	A_{i000}	A_{0j00}	A_{ij00}
Scattered	$P_{00\mu0}$	$D_{i0\mu0}$	$K_{0j\mu0}$	$M_{ij\mu0}$
Recoil	$P_{000\nu}$	$K_{i00\nu}$	$D_{0j0\nu}$	$N_{ij0\nu}$
Both	$C_{00\mu\nu}$	$C_{i0\mu\nu}$	$C_{0j\mu\nu}$	$C_{C_{ij\mu\nu}}$

- In $\overline{p}p \to \overline{Y}Y$ there are 256 spin variables in total

Accessible hyperons at $\overline{\text{P}}$ANDA

$$\bar{p}p \to \bar{\Lambda}\Lambda,\ \bar{\Sigma}^-\Sigma^+,\ \bar{\Sigma}^0\Sigma^0,\ \bar{\Sigma}^-\Sigma^+,\ \bar{\Xi}^0\Xi^0,\ \bar{\Xi}^+\Xi^-,\ \bar{\Omega}^+\Omega^-,\ \bar{\Lambda}_c^-\Lambda_c^+$$

$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$p\pi^-$	$p\pi^0$	$\Lambda\gamma$	$n\pi$	$\Lambda\pi^0$	$\Lambda\pi$	ΛK	$\Lambda\pi$
64%	52%	$\approx$ 100%	$\approx$ 100%	$\approx$ 100%	$\approx$ 100%	68%	$\approx$ 1%