Measurement of the nuclear-mass dependence of spontaneous (transverse) $\Lambda$ polarisation in quasi-real photoproduction at HERMES

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Introduction

Reaction under study \( \gamma^* + A \Rightarrow \Lambda^+ + X \)

\( A: \; ^1H, ^2H, ^3He, ^4He, ^14N, ^20Ne, ^84Kr, ^132Xe \)

Spontaneous (transverse) \( \Lambda \) polarization does not depend on beam or target polarizations and directed along \( \hat{n} : \)

Polarized \( \Lambda \) decay in \( \Lambda \) rest frame

\[
\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p} (1 + \alpha \; P_\Lambda \cos \Theta_p)
\]

\( \alpha = 0.642 \pm 0.013 \) for \( \Lambda \),

\( \alpha = -0.642 \pm 0.013 \) for \( \bar{\Lambda} \)
A-dependence in pA collisions

Experiment @ FNAL

\[ p \: A \rightarrow \Lambda \: X \]
(targets Cu, Pb, Be)

\[ p_{beam} = 400 \: GeV \]

Experiment @ BNL

\[ p \: A \rightarrow \Lambda \: X \]
(targets H, D, Be)

\[ p_{beam} = 28 \: GeV \]
polarized positron (and electron) beam $E_e = 27.5\, \text{GeV}$,
average beam polarization $P_b \approx \pm 45\%$
polarized and unpolarized internal gas targets:
\( ^1\text{H}, \, ^2\text{H}, \, ^1\text{H}, \, ^2\text{He}, \, ^3\text{He}, \, ^4\text{He}, \, ^{14}\text{N}, \, ^{20}\text{Ne}, \, ^{84}\text{Kr}, \, ^{132}\text{Xe} \)
up/down mirror symmetric (important for extraction of transverse $\Lambda$ polarization)
Extraction of $\Lambda$ polarization

Formalism of $\Lambda$ polarization extraction is based on up/down mirror (geometrical) symmetry of the detector and moment method

$$ P_\Lambda = \frac{\langle \cos \theta_p \rangle_p}{\alpha \langle \cos^2 \theta_p \rangle_p} = \frac{1}{N_\Lambda} \sum_{i=1}^{N_\Lambda} \cos \theta_p $$

No Monte-Carlo simulations of the spectrometer acceptance is involved!
Reconstruction of $\Lambda$ events

Quasi-real photoproduction, $Q^2 < 0.05 \text{ GeV}^2$ for 80% of the events (MC) $\langle E_\gamma \rangle = 15.6 \text{ GeV}$

Background suppression cuts:
- Threshold Cherenkov / Ring imaging Cherenkov detector
- $z_2 - z_1 > 15 \text{ cm}$ for $\Lambda$
- $z_2 - z_1 > 20 \text{ cm}$ for $\bar{\Lambda}$

$N(\Lambda) = 259 \cdot 10^3$, $N(\bar{\Lambda}) = 51 \cdot 10^3$
Kinematic regimes

\[ x_F = \frac{p_\parallel}{p_\parallel^{\text{max}}} \quad \Rightarrow \quad \zeta = \frac{E_\Lambda + p_{\Lambda,z}}{E_e + p_{e,z}} \]

**Light cone variable**

**HERMES data**

\[ \frac{N(\Lambda)}{N(\bar{\Lambda})} \]

\[ \zeta = 0.25 \]

**LUND mechanisms**

\( p \rightarrow (ud)_0 \rightarrow \Lambda \) (current quark fragmentation)

\( \Lambda \rightarrow \bar{u}, \bar{d}, \bar{s} \)

or

\( \Lambda \rightarrow u \) (target diquark fragmentation)
Kinematical dependences of the transverse $\Lambda$ polarization, 1996-2000 data

For $\Lambda$

$$P_{\Lambda} = 0.078 \pm 0.006_{\text{stat.}} \pm 0.012_{\text{syst.}}$$

For $\bar{\Lambda}$

$$P_{\bar{\Lambda}} = -0.025 \pm 0.015_{\text{stat.}} \pm 0.018_{\text{syst.}}$$

False polarization is studied using $h^+h^-$ pairs and $K_s$ data sample

Nuclear effects: $A$, $A/Z$-dependence of $\Lambda$ polarization

\[ N(\Lambda) = 385 \cdot 10^3 \quad (1996 - 2005) \]

\[ \langle p_T \rangle \approx 0.25 \, GeV, \quad \langle \zeta \rangle \approx 0.63 \]
Spontaneous polarization in quasi-real photoproduction regime (Q2 < 0.05 GeV² for 80% and \(\langle E_\gamma \rangle = 15.6 \text{ GeV} \)) obtained mainly on H,D is found to be:

for \(\Lambda\) \(P_n = 0.078 \pm 0.006_{\text{stat.}} \pm 0.012_{\text{syst.}}\)

and \(\bar{\Lambda}\)-bar \(P_n = -0.025 \pm 0.015_{\text{stat.}} \pm 0.018_{\text{syst.}}\).

A (A/Z) - dependence of \(P_n\) is observed. Unlike case of hadron collisions for light nuclei \(P_n\) is positive while for heavy nuclei \(P_n\) is compatible with zero.
Backup slides
A-dependence of the polarization

$0 < \zeta < 1$

$\zeta < 0.25$

$\zeta > 0.25$

HERMES PRELIMINARY

1H, 3He, 4He, 14N, 20Ne, 84Kr, 132Xe
$A/Z$-dependence of the polarization

$0 < \zeta < 1$

$\zeta < 0.25$

$\zeta > 0.25$

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