Strange Particle Production and Polarization of Λ Hyperons in the HERMES Experiment.

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Semi-inclusive and inclusive reactions with Λ, $\bar{\Lambda}$, and K_s in the final states are studied in the HERMES experiment using unpolarized gas targets and the polarized 27.5 GeV positron beam of the HERA collider. Semi-inclusive DIS kinematics of Λ production in current fragmentation region show a good agreement with LEPTO based Monte Carlo calculations for the accepted by the HERMES spectrometer events. Longitudinal Λ polarization for the semi-inclusive Λ production is measured. The false asymmetry resulting from the spectrometer acceptance is excluded by analyzing two data sets with opposite beam polarizations. Polarization transfer coefficient from the knocked out quark to the Λ is found to be $0.04 \pm 0.17(stat) \pm 0.09(syst)$. In inclusive case transverse polarizations of Λ and $\bar{\Lambda}$ are measured. Averaged over the range of the transverse Λ, $\bar{\Lambda}$ momentum $0 < p_t < 1.7$ GeV/c it is found $P^n = 0.066 \pm 0.011(stat) \pm 0.025(syst)$ for Λ and $P^n = -0.066 \pm 0.037(stat) \pm 0.025(syst)$ for $\bar{\Lambda}$.

The HERMES spectrometer [1] allows to detect the scattered positrons and hadrons produced by the 27.5 GeV polarized positron beam of the HERA collider incident on the the internal polarized/unpolarized gas target. Here we report on experimental study of the the reactions with Λ, $\bar{\Lambda}$, and K_s in the final states.They are detected through their $p\pi^-$, $\bar{p}\pi^+$, and $\pi^+\pi^-$ decays ,respectively. In semi-inclusive case secondary hadrons ($p\pi$, $\pi\pi$) are measured in coincidence with the scattered positron. Recently we have also analyzed the inclusive reactions with same particles in the final states. The positron tagging is no longer required in this case.

The data analyzed were accumulated in two dedicated runs of 1996-1997 years with beam polarizations of the opposite signs ($P_B \simeq \pm 0.52$) and unpolarized H, D, ^{3}He, and ^{14}N targets (unpolarized run). The target density was increased by a factor of $\simeq 10$, being only restricted by the positron beam life time. The number of inclusive DIS positrons detected by the spectrometer in the unpolarized run was $7.24 \cdot 10^6$ at integrated luminosity 163 pb^{-1}.

In semi-inclusive case the Λ ($\bar{\Lambda}$,K_s) events were selected under conditions that at least one of the detected particles has been identified as the scattered positron and two others as the hadrons. Primary and secondary (decay) vertices were reconstructed, hadron pair invariant masses were calculated giving clearly seen Λ, $\bar{\Lambda}$ and K_s peaks even without background suppression. In order to suppress the combinatorial background, vertex separation cut $z2 - z1 > 10$ cm has been mainly used (in combination with some other cuts), where $z1, z2$ are primary and secondary vertex positions along the beam direction. With these cuts the residual background was at the level of $\simeq 10$ % for Λ and K_s and somewhat worse ($\simeq 25$ %) for $\bar{\Lambda}$. In inclusive case event selection was done in a similar way with only difference that the primary vertex was reconstructed by intersection of the reconstructed hadron pair momentum vector and the positron beam line. With all the cuts applied we have obtained in semi-inclusive case

$$N_\Lambda = 2800 \quad N_{\bar{\Lambda}} = 320 \quad N_{K_s} = 8700.$$

In inclusive case the yields are much higher because most of the produced particles are related to the photoproduction peak of positrons scattered at very small angles (photoproduction regime) with $\langle Q^2 \rangle \simeq 0.04$ (GeV/c)^2. In inclusive case we have obtained

$N_\Lambda = 73 \cdot 10^3 \quad N_{\bar{\Lambda}} = 18 \cdot 10^3 \quad N_{K_s} = 110 \cdot 10^3.$

In the HERMES kinematic domain current fragmentation ($x_F > 0$) dominates semi-inclusive production of Λ hyperons with u (d) quarks mostly knocked out from the target and fragmenting to the Λ. As LEPTO based Monte Carlo calculations show, with Λ kinematics restricted by the DIS cuts (Q^2 >1 (GeV/c)^2, y <0.85, 0.02< x_Bj <0.8) 95% of Λ-s are produced via parent u(d) quarks and only 5% via parent s quark. These numbers comprise both Λ-s produced through the string fragmentation directly ($\simeq$ 40%) and also those coming from Σ^0 and $\Sigma(1385)$ resonances.

Kinematic distributions over DIS variables (Q^2, y, x_Bj, z) show a good/qualitative agreement with Monte Carlo calculations not only for Λ, but also for $\bar{\Lambda}$ and K_s.

Note that in case of Λ production fragmentation functions D_d^Λ and D_u^Λ are equal since Λ is isosinglet. Contributions from antiquarks are strongly suppressed in current fragmentation. Thus only one fragmentation function $D_{u,d}^\Lambda(z)$ dominates and it can be directly extracted from the experimentally measured z distribution, the latter being corrected for the spectrometer acceptance and smearing effects.

As has been recently pointed out by Jaffe [2] polarization transfer from the longitudinally polarized lepton beam to the Λ in current fragmentation region is sensitive to the spin-dependent part of the fragmentation function. At relatively high z the ratio $\Delta D_{u,d}^\Lambda / D_{u,d}^\Lambda$ is defined by the spin structure of Λ.

Measured Λ polarization can be written as

$$P_\Lambda = \tau \frac{y(2-y)}{1+(1-y)^2} P_B \tag{1}$$

where P_B is beam polarization. Under assumption of the u(d) dominance polarization transfer coefficient $\tau = \Delta D_{u,d}^\Lambda / D_{u,d}^\Lambda$.

In 'ideal' Λ model $\tau = 0$ is expected , since there is no contribution from u(d) quarks to the Λ spin in this case ($\Delta u = \Delta d = 0, \Delta s = 1$). In more realistic case [2–4] the contribution of u(d) quark is negative ($\Delta u = \Delta d = -0.2, \Delta s = 0.6$) and $\tau = -0.15$ is expected provided s quark contribution taken into account.

In order to measure Λ polarization the 1996-1997 year data sets with opposite beam polarizations were used in such way that the spectrometer acceptance function was ruled out from the analysis. After the background suppression, data quality and DIS cuts 1692 Λ events were selected to extract the Λ polarization and polarization transfer coefficient τ. Moment method has been used to extract Λ polarization. In the kinematic domain with $x_F > 0$ and mean values of Q^2=2.48 (GeV/c)^2, z=0.446, and $D_y = \frac{y(2-y)}{1+(1-y)^2}$=0.694 we have obtained

$$\tau = 0.04 \pm 0.17(stat) \pm 0.09(syst).$$

Because of relatively large statistical error bar this result is compatible both with ideal and realistic model expectations.

Transverse Λ polarization has been intensively studied in hadron collisions using different beams and targets [5]. It has been found that inclusive Λ's are usually strongly polarized with polarization vector P_n directed perpendicular to the Λ production plane. In case of lepto/photo produced Λ's transverse polarization is poorly studied up to now.

In the HERMES experiment we have studied transverse polarization of inclusively produced Λ's (photoproduction regime) with statistics much higher than that for the semi-inclusive case. Due to up/down mirror symmetry of the HERMES spectrometer acceptance correction is negligible.False asymmetry as a function of the transverse momentum p_t has been additionally investigated with the help of K_s and hadron h^+h^- pairs. By our estimations the systematic error in transverse polarization related to this false asymmetry does not exceed 0.025. To extract transverse Λ polarization, the moment method has been used similar to the longitudinal polarization case. The transverse Λ polarization versus p_t is shown in Fig. 1. Statistics is not sufficient For $\bar{\Lambda}$ and only one point is plotted. The result is averaged over p_t range. Finally, for the p_t range up to 1.7 GeV/c it has been found

$$P^n = 0.066 \pm 0.011(stat) \pm 0.025(syst)$$

for inclusive Λ's and

$$P^n = -0.066 \pm 0.037(stat) \pm 0.025(syst)$$

for inclusive $\bar{\Lambda}$'s.

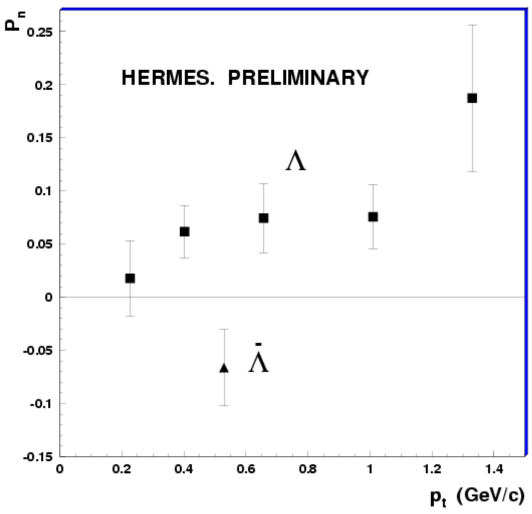

Figure 1. Transverse Λ and $\bar{\Lambda}$ polarizations.

REFERENCES

1. K. Ackerstaff et al., NIM **A417** (1998) 230.
2. R.L. Jaffe, Phys. Rev. **D54** (1996) 6581.
3. M. Burkard and R.L. Jaffe, Phys.Rev.Lett.**70** (1993) 2537.
4. A.A. Anselm, M.G. Ryskin, Z.Phys. **C68** (1995) 297.
5. A.D. Panagiotou, preprint CERN-EP/89-131 (1989).