Polarization and asymmetries in neutral strange particle production

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Abstract. Inclusive Λ, $\bar{\Lambda}$ and K_s^0 production in deep inelastic *ep* scattering has been studied with the ZEUS detector at HERA using an integrated luminosity of 120pb^{-1}. Differential cross sections, baryon to antibaryon production asymmetry and baryon to meson production ratios have been measured in the laboratory system for $Q^2 > 25\text{GeV}^2$.

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INTRODUCTION

This paper discusses the production of the neutral strange particles Λ, $\bar{\Lambda}$[1] and K_s^0 in deep inelastic scattering at HERA. As well as measuring differential cross sections for their production, the baryon-antibaryon asymmetry and the baryon to meson ratio are investigated, and a first ZEUS measurement of the transverse and longitudinal Λ polarization is made.

All of these measurements endeavour to clarify in different ways the transition from quark to hadron. For example the Λ to K_s^0 ratio has been measured in e^+e^- colliders [1] and in heavy ion collisions [2]. The ZEUS measurement in *ep* collisions adds more information in trying to understand when a baryon is produced, and when a meson.

Λ transverse polarization also gives information on hadron production. The DeGrand-Miettinen model [3] explains the Λ spin as being carried predominantly by the s quark which picks up polarization via Thomas Precession when it is accelerated. Hence a measurement of the transverse polarization will give information on the initial direction of the s quark that ends up in the Λ.

Observing these particles also allows an investigation into baryon number and how it is transported. Significant baryon number transport over several units of rapdidity has been observed in heavy ion collisions [4]. Various models have been developed to explain this, including associating baryon number with valence quarks and moving it through rapidity by multiple scattering [5] or associating baryon number with a gluonic junction [6]. In HERA *ep* collisions initially a baryon number of +1 exists as the proton moving down the beampipe. The possibility of this baryon number being observed in the Λ system in the central rapidity region is investigated.

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[1] Hereafter,both Λ and $\bar{\Lambda}$ are referred to as Λ, unless explicit comparisons are made.

EVENT SELECTION AND ANALYSIS

This analysis uses an inclusive sample of neutral current deep inelastic scattering (DIS) events collected by ZEUS in the 1996-2000 HERA running period, corresponding to an integrated luminosity of 120 pb^{-1}. The kinematic region was $Q^2 > 25\mathrm{GeV}^2$ and $0.02 < y < 0.95$.

Λ and K_s^0 are detected in the $p\pi$ and $\pi^+\pi^-$ decay channels respectively. A secondary vertex is observed and the mass is reconstructed from the momenta of two oppositely charged tracks coming from the vertex. Both tracks are assumed to have the mass of a π^+ (for K_s^0) or the track with the most momentum has the proton mass and the other the mass of a π^+ (for Λ). Combinatorial background is removed with a bin-by-bin sideband subtraction method.

The Λ polarization is measured via the angular distribution of the decay products:

$$\frac{dN}{d\Omega} \propto \frac{1}{4\pi}(1 \pm \alpha P \cos\theta) \tag{1}$$

in the Λ rest frame, where $\alpha = 0.642 \pm 0.013$[1] is the decay asymmetry parameter and P is the polarization. θ is the angle between the decay proton momentum, $\vec{p}$ and the Λ momentum, $\vec{P}_\Lambda$ (longitudinal polarization) or between $\vec{p}$ and $\mathbf{n} = \vec{P}_{beam} \times \vec{P}_\Lambda$, where $\vec{P}_{beam}$ is the momentum of the electron beam (transverse polarization).

MONTE CARLO SIMULATION

Data were corrected to hadron level by using the ARIADNE 4.08[7] Monte Carlo (MC) interfaced to HERACLES via DJANGOH 1.1[8]. The parton density functions were taken from the CTEQ4D set. The strange suppression factor, λ_s was set to 0.3. ARIADNE is based on the Color Dipole Model and the LUND string model[9] is used to simulate the fragmentation of the partons. The Ariadne prediction of the cross sections is also shown on the results plots.

RESULTS

The results of the $\Lambda/\bar{\Lambda}$ polarization are presented in Fig. 1. Averaged over the full kinematic range, the transverse polarization of Λ and $\bar{\Lambda}$ were observed to be $+1.4 \pm 4.5(\mathrm{stat})^{+4.1}_{-1.9}(\mathrm{syst})\%$ and $-1.8 \pm 4.4(\mathrm{stat})^{+3.1}_{-1.3}(\mathrm{syst})\%$ respectively. The longitudinal polarization of Λ and $\bar{\Lambda}$ was also measured to be consistent with zero within the total uncertainties. The longitudinal polarization was observed to be $+0.3 \pm 10.3(\mathrm{stat})^{+0.1}_{-7.8}(\mathrm{syst})\%$ for Λ and $+19.8 \pm 10.8(\mathrm{stat})^{+4.2}_{-12.6}(\mathrm{syst})\%$ for $\bar{\Lambda}$.

The differential Λ and K_S^0 cross sections, $\frac{\Lambda-\bar{\Lambda}}{\Lambda+\bar{\Lambda}}$ asymmetry and Λ/K_S^0 ratio as a function of p_T, η, x and Q^2 are shown in Fig. 2 and Fig. 3. The MC generally describes the cross sections in the data. However, the MC tends to overestimate the K_s^0 production, particularly at low P_T.

The ratio $\frac{\Lambda-\bar{\Lambda}}{\Lambda+\bar{\Lambda}}$ as a function of all kinematic variables is consistent with zero.

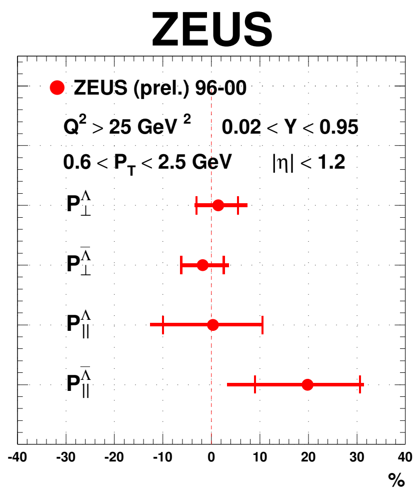

FIGURE 1. Transverse and longitudinal Λ and $\bar{\Lambda}$ polarization.

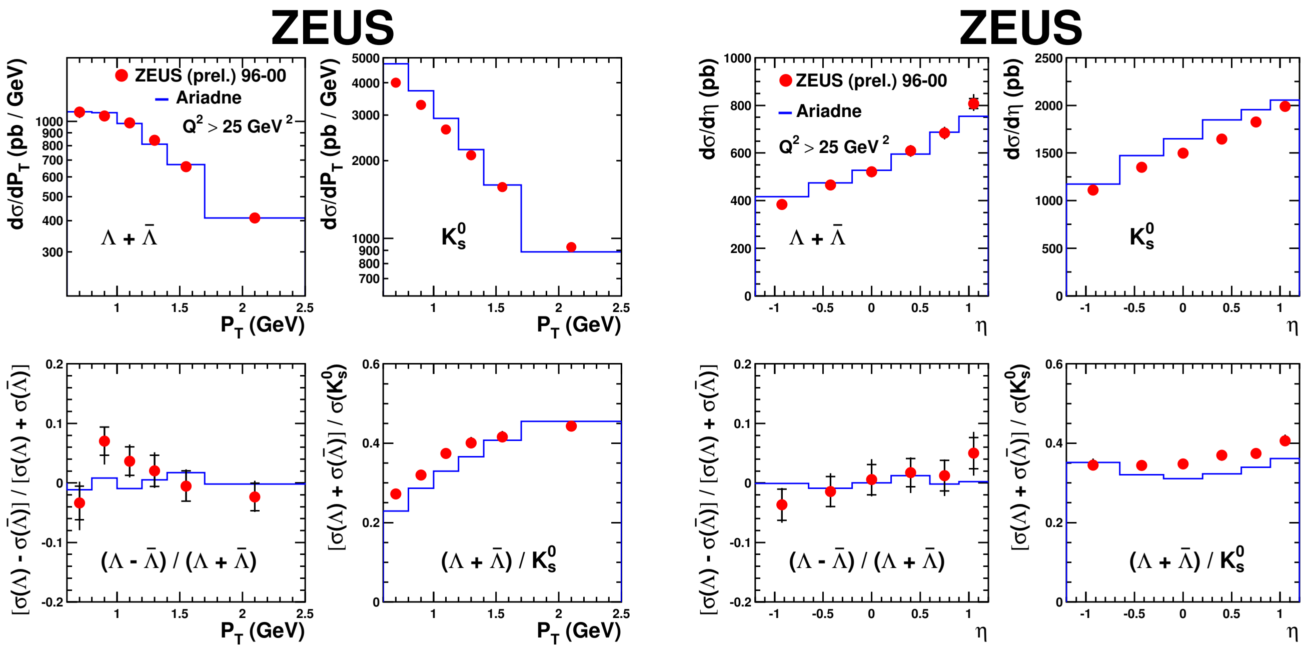

FIGURE 2. Λ and K_s^0 cross sections, $\frac{\Lambda-\bar{\Lambda}}{\Lambda+\bar{\Lambda}}$ ratio and $\frac{\Lambda+\bar{\Lambda}}{K_s^0}$ ratio as a function of P_T and η

The Λ/K_S^0 ratio is generally described by the MC. However, although the steep rise as x decreases is modelled by the MC to some extent, it is not to the same degree. Other differences between the MC and the data can be seen as a function of P_T, where the Λ/K_s^0 ratio is in excess of the MC at low P_T, and as a function of η where the MC is symmetric about $\eta = 0$, whereas the data shows an increase in this ratio as η increases.

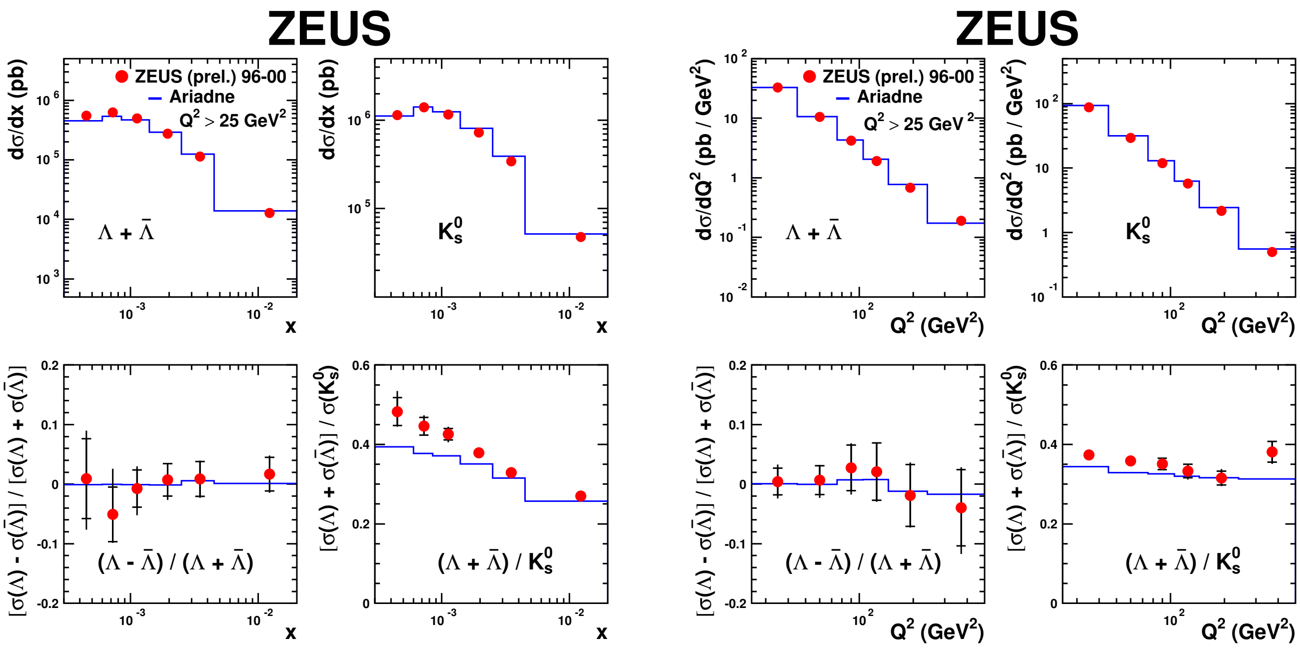

FIGURE 3. Λ and K_s^0 cross sections, $\frac{\Lambda-\bar{\Lambda}}{\Lambda+\bar{\Lambda}}$ ratio and $\frac{\Lambda+\bar{\Lambda}}{K_S^0}$ ratio as a function of x and Q^2

CONCLUSIONS

Using the model of DeGrand and Miettinen [3], the lack of any transverse polarization suggests that the strange quarks in the Λ baryons observed by ZEUS do not come from any particular direction. The longitudinal polarization being consistent with zero is as expected with HERA-I data, but gives a measure of the potential to measure any polarization transfer from the electron beam to the Λ in HERA-II. The Λ/K_S^0 ratio has been measured, and the data is generally described by ARIADNE. Areas of the phase space do exist where the MC is not sufficient to describe the data, particularly at low P_T and low x. No significant $\Lambda - \bar{\Lambda}$ asymmetry is seen.

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