Photoproduction of High Transverse Momentum Charged Particles and a Comparison of Strangeness Production in Photoproduction and Deep Inelastic Scattering

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Photon-proton interactions with $Q^2 < 10^{-2}$ GeV^2 (photoproduction) and deep inelastic scattering (DIS) interactions with photon virtualities $Q^2 > 10$ GeV^2 are studied at the high energy electron-proton collider HERA. Inclusive charged particle spectra in photoproduction are compared to LO QCD calculations and shown to be sensitive to the partonic structure of the photon. K^0 and Λ properties in photoproduction and in DIS are shown and compared with NLO QCD calculations.

1 Introduction

With the ep collider at HERA it is possible to study in the same experiment the hadronic final state of photon-proton interactions for a range of photon virtualities giving an insight into partonic structure of the photon and proton. In photoproduction, the measurement of the high p_T particles can tag hard partonic interactions which can be used to constrain the quark and gluon densities of the photon down to an approximate lower limit of x_γ, the fraction of the photon energy carried by the interacting parton , of $x_\gamma > \frac{p_T e^{-\eta}}{2E_\gamma}$, where p_T and η are the transverse momentum and pseudorapidity of the observed hard particle and E_γ is the exchanged photon energy. The study of strange particle production gives an increased sensitivity at high p_T to charm and gluon interactions while at low p_T a comparison of strangeness production between photoproduction and DIS can test the universality of the fragmentation process.

2 HERA and H1

The results presented in this report are based on data taken in 1994 with the H1 detector at HERA, which collides beams of 27.5 GeV positrons and 820 GeV protons, and corresponds to an integrated luminosity of 1.3 pb^{-1}. A detailed description of the detector can be found elsewhere [1] and only the components relevant to the analyses presented here are described. Photoproduction events are selected by identifying positrons scattered at low angle in the H1 electron tagger, the acceptance of which restricts the kinematic range of y and Q^2, the fractional energy and photon virtuality, to $0.3 < y < 0.7$ and $Q^2 < 0.01$ GeV^2. Positrons scattered at larger angles into the H1 Backward Electromagnetic Calorimeter are used to detect DIS events with Q^2 above several GeV^2. Charged tracks are measured in the central track detector and are used to tag K^0 and Λ [a] particles by reconstructing secondary vertices from the weak decays $K_s^0 \longrightarrow \pi^+\pi^-$ and $\Lambda \longrightarrow p\pi^-$, $\overline{\Lambda} \longrightarrow \overline{p}\pi^+$.

3 Charged Particles in Photoproduction

Figure 1 shows the differential charged particle cross-section in photoproduction [2] as a function of transverse momentum, p_T, compared with a LO QCD calculation. The photoproduction data are defined in the kinematic intervals of $0.3 < y < 0.7$ and $Q^2 < 0.01$ GeV^2.

The cross-section is shown for particles with transverse momenta above 2 GeV and is integrated over the pseudorapidity region $\mid \eta \mid < 1.0$

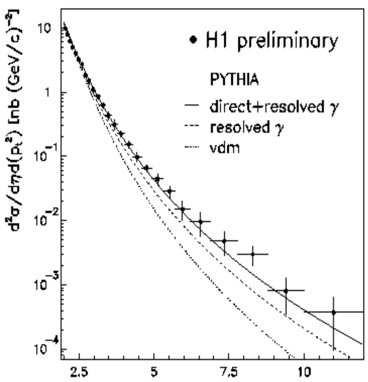

Figure 1: The differential charged particle cross-section $d\sigma/dp_T$ in the interval $\mid \eta \mid < 1$ for charged particles with $p_T > 2$ GeV, compared to PYTHIA using GRV-LO photon and proton parton densities

The QCD calculation was based on the event generator PYTHIA [3] with multiple parton interactions. The GRV-LO parameterisation of the parton distributions for the photon and the proton were used. The data were normalised

[a]Unless otherwise stated, all references in this report to K^0, Λ will implicitly mean $K^0 + \bar{K^0}$, $\Lambda + \bar{\Lambda}$

to the calculation of direct and resolved processes and exceeds the data by 20% at transverse hadron momenta $p_T = 2$ GeV though is consistent with the measurement above $p_T = 2.5$ GeV. Also shown are the relative contributions of the direct, Vector Dominance Model (VDM) and anomalous photon components. The GRV-LO [4] pion parton density parameterisations were used to calculate the VDM component. The VDM contribution was normalised together with the direct photon component to give the total predicted cross-section at $p_T = 2$ GeV and the anomalous contribution then results from the difference between the total calculated cross-section and the VDM plus direct photon components.

With this calculation the anomalous photon component contributes about 50% at transverse momenta above 6 GeV and the direct and anomalous components dominate the cross-section for p_T above 3.5 GeV.

In figure 2, the charged particle differential pseudorapidity cross-section $d\sigma/d\eta$ is shown for particles with transverse momenta above 2 GeV. The corresponding interval of the parton energy fraction can be estimated to be between $x_\gamma(\eta = 1) \approx 0.05$ and $x\gamma(\eta = -1) \approx 0.4$ on average. A comparison is made with PYTHIA with two different parton distribution functions: GRV-LO(figure 2a) and LAC1 [5](figure 2b). The GRV-LO prediction gives a cross-section too large at negative rapidities (high x_γ) but falling short for higher rapidities (low x_γ). The LAC1 prediction shown is seen to substantially exceed the data for $\eta > 0$. The calculated gluon contribution in the photon is shown as a dotted line with LAC1 predicting a steep rise not matched by the data.

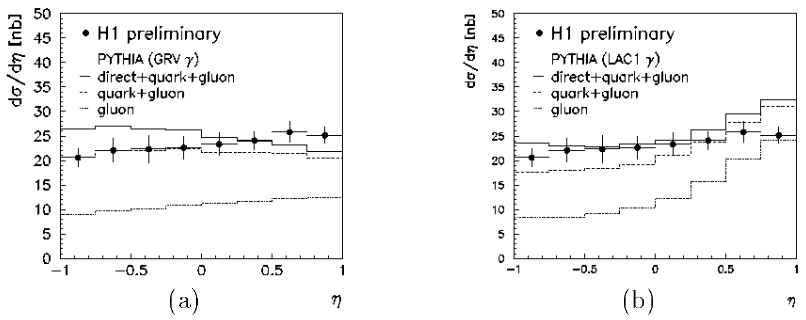

Figure 2: The differential charged particle cross-section $d\sigma/d\eta$ in photoproduction compared to PYTHIA with the GRV-LO(a) and LAC1(b) photon parton parameterisations

4 Strangeness Production

Figure 3 shows the differential K^0 cross-section [7] as a function of p_T in photoproduction in the kinematic range $0.3 < y < 0.6$, $Q^2 < 0.01$ GeV^2 and is shown for the K^0 kinematic interval $0.5 < p_T < 5.0$ GeV and $\mid \eta \mid < 1.3$. A comparison is made to analytical NLO calculations [6] using quark and gluon fragmentation functions from e^+e^- data. The predictions assume that the four scales used in the calculation are equal and are alternatively set to $p_T/2$, p_T and $2p_T$. For p_T above 3 GeV, where the calculation is considered to be reliable, good agreement with the data is observed.

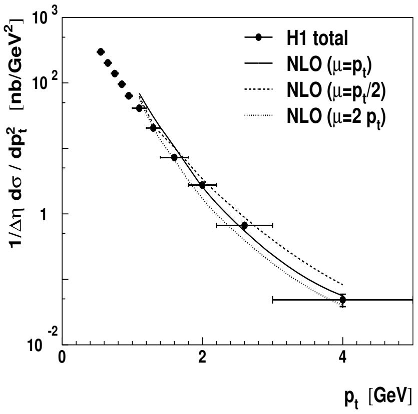

Figure 3: The differential K^0 cross-section as a function of p_T^2 in photoproduction compared to NLO calculations

It is of interest to compare strangeness rates in photoproduction with those in deep inelastic scattering (DIS) processes, where Q^2 is larger than several GeV^2. Though particle rates are expected to be Q^2 independent in the central rapidity region of the photon-proton centre of mass system, differences are expected in the photon fragmentation region [8].

Since the relative contribution of low mass diffractive events in photoproduction and DIS events are very different, these were removed by insisting on a minimum amount of energy in the forward going (proton) region [7]. The remaining sample is termed non-diffractive.

Figure 4 shows the K^0 multiplicity as a function of p_T^* and the K^0 and Λ multiplicity as a function of rapidity, y^*, in non-diffractive photoproduction and DIS interactions [7]. The DIS data lie in the range $10 < Q^2 < 70$ GeV^2,

$0.3 < y < 0.6$, giving an average photon virtuality, $\langle Q^2 \rangle = 23$ GeV^2. These results are presented the photon-proton rest frame, where the exchanged photon defines the longitudinal $+z^*$ axis and are restricted to the region $0.5 < p_T^* < 5$ GeV, $1.3 < y^* < 2.8$ for the K^0 results and $0.6 < p_T^* < 5$ GeV, $1.3 < y^* < 2.8$ for the Λ spectra.

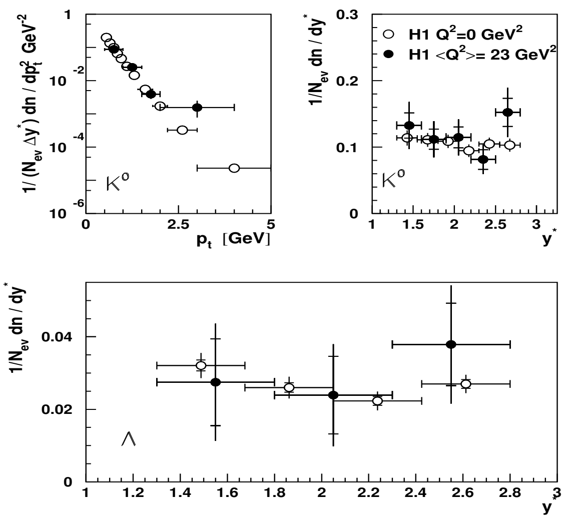

Figure 4: The K^0 and Λ rates in non-diffractive photoproduction and DIS as a function of p_T^{*2} (K^0,top left), y^* (K^0, top right) and y^* (Λ, bottom).

The K^0 rate is seen to be independent of Q^2 in this phase space region though there is a suggestion of a hardening of the K^0 transverse momenta spectra for DIS compared to photoproduction processes. Similarly, the differential multiplicity in η is shown in figure 4 for Λ production in non-diffractive DIS and photoproduction. Within the larger statistical and systematic errors, the rate of Λ production is also seen to be independent of Q^2.

5 Conclusion

Charged particle cross-sections in photoproduction interactions have been presented and compared to QCD LO predictions and have been shown to be sensitive to the partonic structure of the photon and proton. Strangeness production in non-diffractive photoproduction interactions is found to be similar to that in and DIS processes and agree well with QCD NLO calculations.

References

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