

Light Mesons and Strange Particle Production at HERA

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Results on the $\rho^0(770)$, $K^{*0}(892)$, $\phi(1020)$, K_S^0 and Λ production in ep collisions at HERA obtained with H1 and ZEUS detectors are presented. Properties of the light mesons are investigated using photoproduction events and those of the strange particles are studied using the deep-inelastic scattering events. Photoproduction of light mesons, ρ^0 , K^{*0} and ϕ , at the average γp centre-of-mass energy of 210 GeV and in particular the transverse momentum spectra are studied by H1 Collaboration. The K_S^0 and Λ production is evaluated in different regions of the exchanged photon virtuality, Q^2 . Low $2 < Q^2 < 100 \text{ GeV}^2$ and high $145 < Q^2 < 20000 \text{ GeV}^2$ regions are investigated by H1, whereas the $10 < Q^2 < 40000 \text{ GeV}^2$ region by ZEUS experiment. The differential cross sections for K_S^0 and Λ production measured by H1 in the laboratory and Breit frames are compared to the leading order Monte Carlo predictions. Results of the ZEUS Collaboration studies of the scaled momentum distributions of K_S^0 and Λ particles in the Breit frame current fragmentation region in the context of the hadronisation investigation in ep collisions are presented. The data are compared to the leading-logarithm parton-shower Monte Carlo models and next-to-leading order QCD calculations.

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1. Introduction

Particle production at the HERA collider is the effect of a virtual photon and a proton interactions, γ^*p . Depending on the photon virtuality value, Q^2 , the electron-proton interactions can be separated into a quasi-real photon-proton collisions - photoproduction, with $Q^2 \approx 0$, and a deep-inelastic scattering - DIS, where $Q^2 > 0$. Recently, several aspects of the hadronisation process for these types of ep interactions have been investigated by H1 and ZEUS experiments. The transverse momentum, the rapidity and the scaled momentum distributions of ρ^0 , K^{*0} and ϕ mesons (photoproduction) and of strange K_S^0 mesons and Λ baryons (DIS) were measured and compared to the predictions of hadroproduction models or next-to-leading order QCD calculations.

2. Photoproduction of Light Mesons

In this study only one aspect of the light meson photoproduction studied by H1 Collab. is presented. The measured differential cross sections of the ρ^0 , K^{*0} and ϕ mesons as a function of their transverse momentum are compared to analogous distributions for other neutral and charged mesons and hadrons in Figure 1. The measured spectra are well described by a power law. The

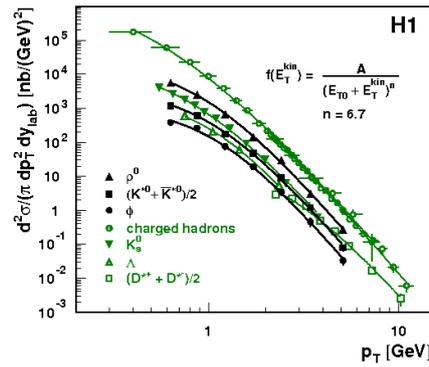


Figure 1: The inclusive cross sections of the light mesons and other particles as a function of the transverse momentum. The curves show the results of fits to a power law cross section parameterisation.

behaviour where particles with different masses, lifetimes and strangeness content are produced with about similar average transverse kinetic energy supports the thermodynamic picture of hadron interactions [1]. Further details of the H1 analysis can be found in [2].

3. K_S^0 and Λ DIS Production at Low and High Q^2

Strange hadron production, particularly that of baryons, has not been understood yet. Recent H1 and ZEUS results obtained for low and high Q^2 values allow to extend our knowledge on the fragmentation and hadronisation processes, including strangeness production. Extensive studies on several aspects of K_S^0 and Λ production were done by H1 Collab. in the laboratory and Breit frames [3]. The differential cross sections as functions of the photon virtuality, Q^2 , the transverse momentum, p_T , the pseudorapidity, η , and Bjorken scaling variable, x , were measured and the

selected results are presented below. The K_S^0 and Λ p_T spectra and the ratio of the differential cross section for Λ production to that of K_S^0 as a function of η measured by H1 Collab. for $2 < Q^2 < 100$ GeV^2 are shown in Figure 2. The distributions were compared to the predictions of the Monte

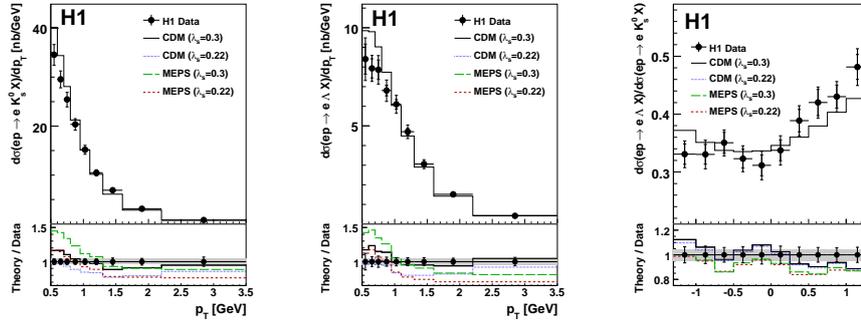


Figure 2: The p_T dependence of the production cross sections for K_S^0 and Λ particles. The rightmost plot shows the ratio of the differential cross sections for Λ baryons and K_S^0 mesons as a function of pseudorapidity.

Carlo models which use different mechanisms for the parton shower development: ARIADNE [4] (referred to as CDM [5]) and LEPTO [6] (referred to as MEPS), but with the same Lund colour string fragmentation model [7] as implemented in the JETSET [8]. For both MC models the strangeness suppression factor λ_s was set to 0.22 or 0.3. Other JETSET parameters relating to the strange quark production were set to the values used by ALEPH Collab. The main idea behind H1 studies was to check if the strange particle production in ep DIS interactions could also be described by the MC models by tuning only the λ_s parameter. The results obtained for K_S^0 and Λ particles indicate that CDM and LEPTO cannot deliver a proper description of the p_T spectra in the whole region via tuning of the λ_s parameter only. The CDM with $\lambda_s = 0.3$ gives a better description for both K_S^0 and Λ data but it overestimates the data in small p_T region. The ratio of the differential cross sections for the Λ and K_S^0 production, the rightmost plot of Fig. 2, for which a reduction of the theoretical uncertainties was expected, is practically insensitive to the λ_s changes. The MEPS and CDM models provide a reasonable description of the data only in selected regions of negative η . For positive η both models underestimate the data. A better description of the data by MC predictions was observed for $145 < Q^2 < 20000$ GeV^2 [9]. The leftmost plot of Fig. 3 shows the laboratory frame distribution of the K_S^0 transverse momentum. The data are compared with predictions of MEPS and CDM models for two values of $\lambda_s = 0.22, 0.286$. The former value was used in studies in low Q^2 region. The latter is identical to the one used by ALEPH in their studies of the strange particles in e^+e^- annihilation at LEP. An agreement between the data and MEPS and CDM predictions was found for $\lambda_s 0.286$. Additional H1 studies of K_S^0 and Λ production performed in the Breit frame allow for a separation of a struck quark (the current hemisphere) from the proton remnant fragments (the target hemisphere). In Figure 3 the p_T distributions are shown separately for the target and current regions (the two right plots). The measured cross section in the target region is about one order of magnitude larger than that measured in the current region. The target hemisphere p_T distribution cannot be described by the MEPS or CDM predictions using only one parameter λ_s . The current region is less sensitive to the λ_s value selection but has much smaller statistics.

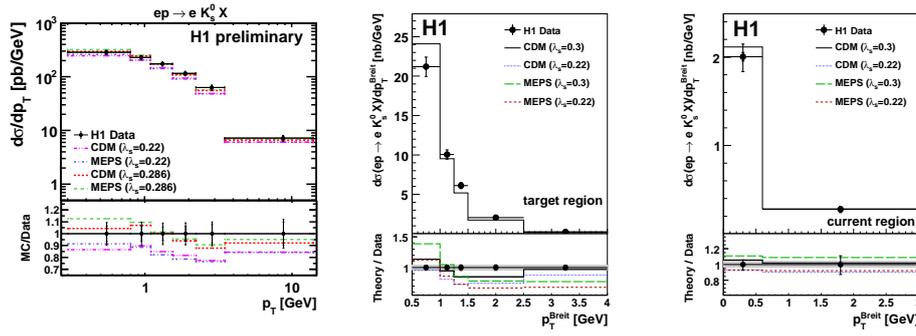


Figure 3: The comparison of the p_T distribution for K_S^0 as measured for $145 < Q^2 < 20000 \text{ GeV}^2$ with the MEPS and CDM predictions for different values of the JETSET λ_s . The last two plots show the p_T distributions obtained in the Breit frame (target and current hemispheres) for $2 < Q^2 < 100 \text{ GeV}^2$.

4. K_S^0 and Λ Scaled Momentum Distributions

ZEUS Collab. investigated production of K_S^0 and Λ in the Breit frame current fragmentation region. The aim was to check the universality of the quark fragmentation function and the factorisation theorem approach used to predict the hadron production in different processes. The scaled momentum distributions were compared with next-to-leading order (NLO) QCD calculations and the leading-log parton-shower MC ARIADNE and LEPTO. Various fragmentation functions (FFs) obtained from fits to e^+e^- data [10, 11], to e^+e^- and $pp/p\bar{p}$ data [12], or to e^+e^- , $p/p\bar{p}$ and ep data [13] were used in the NLO QCD calculations. Figure 4 shows the scaled momentum distributions, $x_p = 2P^{\text{Breit}}/Q$, as a function of Q^2 in different regions of x_p for K_S^0 and Λ particles. With increasing Q value the phase space for a soft gluon radiation gets enlarged. This leads to

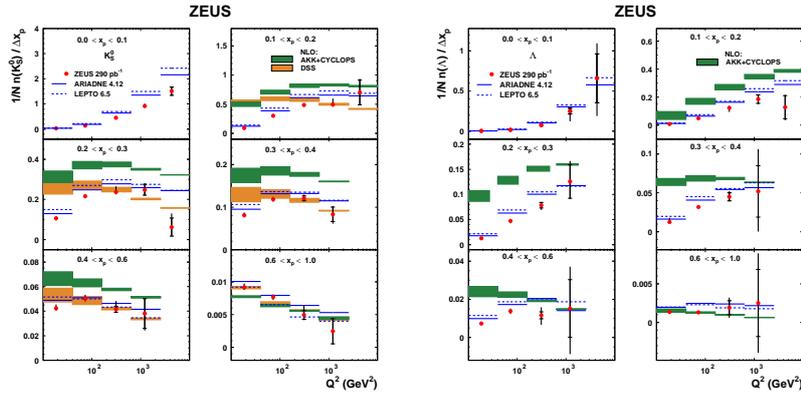


Figure 4: Left: The scaled momentum distributions as function of Q^2 in different regions of x_p for K_S^0 particles together with the predictions of NLO QCD and LO QCD models implemented in MC programs. Right: The corresponding scaled momentum distributions for Λ particles.

the rise in the number of soft particles (small x_p) and to the decrease in the number of those with high x_p . This scaling violation can be seen for K_S^0 and Λ particles in Fig. 4 for large Q^2 values. For K_S^0 the QCD NLO predictions using different FFs describe the data only in certain regions of

the phase space. For the AKK+CYCLOPS calculations it is limited to $0.6 < x_p < 1$, whereas the DSS calculations describe the data adequately, except for low x_p and Q^2 . The ARIADNE 4.12 and LEPTO 6.5 predictions give a good description of the data in almost whole phase space. A similar behaviour is also observed for Λ particles in Fig. 4 (right). The data are reasonably well described by the AKK+CYCLOPS calculations only for $0.6 < x_p < 1$. Again MC codes give a better data description.

5. Summary and Conclusions

Production of the ρ^0 , K^{*0} , ϕ , K_S^0 and Λ particles has been studied in the photoproduction and deep-inelastic scattering processes at HERA. The p_T distributions of the ρ^0 , K^{*0} and ϕ mesons can be described by a power law distribution. These particles are produced with about the same value of the average transverse kinetic energy which supports a thermodynamic picture of hadron interactions. The differential cross sections as a function of p_T and η , for K_S^0 and Λ particles have been measured in low and high Q^2 regions in the laboratory and Breit frames. The predictions based on the CDM or MEPS models with JETSET selected value of $\lambda_s = 0.22$ or 0.30 fail to describe the details of the data for $2 < Q^2 < 100 \text{ GeV}^2$ region. For $145 < Q^2 < 20000 \text{ GeV}^2$ region a reasonable agreement with the data has been found for $\lambda_s = 0.286$. The scaling violation is clearly observed for both K_S^0 and Λ particles. Next-to-leading order QCD calculations based on different fragmentation functions can describe the data only in selected regions of x_p . A better description of the data in most parts of the phase space was supplied by the predictions based on the LO models as implemented into ARIADNE or LEPTO programs.

References

- [1] R. Hagedorn, *Nuovo Cimento Suppl.* **3** (1965) 147.
- [2] H1 Collaboration, F.D. Aaron *et al.*, *Phys. Lett.* **B673** (2009) 119.
- [3] H1 Collaboration, F.D. Aaron *et al.*, *Eur. Phys. J.* **C61** (2009) 185.
- [4] L. Lönnblad, *Comput. Phys. Commun.* **71** (1992) 15.
- [5] B. Andersson *et al.*, *Z. Phys.* **C43** (1989) 625,
L. Lönnblad, *Z. Phys.* **C65** (1995) 285.
- [6] G. Ingelman *et al.*, *Comput. Phys. Commun.* **101** (1997) 108.
- [7] T. Sjöstrand, *Comp. Phys. Commun.* **39** (1986) 347,
T. Sjöstrand, M. Bengtsson, *Comput. Phys. Commun.* **43** (1987) 367,
B Andersson *et al.*, *Phys. Rep.* **97** (1983) 32.
- [8] T. Sjöstrand, *Comput. Phys. Commun.* **bf 82** (994) 74.
- [9] J. R. Tabasco, *Strangeness Production at High Q^2 at H1, presented at DIS 2010*, Florence, Italy.
- [10] B.A Kniehl, G. Kramer and B. Pötter, *Phys. Rev. Lett.* **85** (2000) 5288.
- [11] S. Albino, B.A Kniehl, G.Kramer and C. Sandoval, *Phys. Rev.* **D75** (2007) 034018.
- [12] S. Albino, B.A. Kniehl and G. Kramer, *Nucl. Phys.* **B803** (2008) 42.
- [13] D. de Florian, R. Sassot and M. Stratmann, *Phys. Rev.* **D75** (2007) 114010
D. de Florian, R. Sassot and M. Stratmann, *Phys. Rev.* **D76** (2007) 074033.