PROCEEDINGS OF SCIENCE

Inelastic J/ψ production at HERA

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This article reviews the recent experimental results obtained by the ZEUS Collaboration at HERA in the study of the inelastic J/ψ electroproduction. The measured cross sections are compared to theoretical predictions within the non-relativistic QCD framework including colour-singlet and colour-octet contributions, as well as to predictions based on the k_T–factorisation approach.

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1. Introduction

The production of heavy quarkonium in high energy *ep* collisions provides an important tool to study the interplay between perturbative and non-perturbative dynamics. In the following, firstly we give a brief summary of the status of the theory, then we show ZEUS measurements[1] obtained in the kinematic range $2 < Q^2 < 80$ GeV^2, $50 < W < 250$ GeV, $0.2 < z < 0.9$ and $-1.6 < Y_{lab} < 1.3$, where Q^2 is the virtuality of the exchanged photon, W is the photon-proton centre-of-mass-energy, z is the fraction of the photon energy carried by the J/ψ meson in the proton rest frame and Y_{lab} is the rapidity of the J/ψ in the laboratory frame. The measured cross sections are then compared to various theoretical models.

2. The theoretical framework

A recent and exhaustive review of the theoretical situation regarding quarkonium production at high-energy colliders and in fixed target experiments can be found in [2]. In *ep* collisions charmonium can be produced inelastically both through direct photon and resolved photon processes. In direct photon processes the photon couples directly to a parton in the proton, in resolved photon processes the photon acts as a source of partons, one of which participates in the hard interaction. The charmonium can emerge from the hard interaction either immediately with the right values of spin, angular momentum and colour, **colour singlet (CS) model**, or in a coloured $c\bar{c}$ state, **colour octet (CO) model**, which is followed by a long-distance transition to charmonium and light hadrons. This transition is parameterized through process-independent matrix elements, whose values are extracted from experimental data. The theory, incorporating in a coherent manner CS and CO terms, is called Non-Relativistic QCD (NRQCD). The direct photon CS process will dominate at medium z values, while resolved photon CS is present only at low z values. CO contributions will give sizable contributions in the high z (direct photon CO) and in the low z region (resolved photon CO) of the $d\sigma/dz$ distribution. Models in the framework of the semi–hard or k_T–factorisation approach are also available. In these models, based on non–collinear parton dynamics governed by the BFKL or CCFM evolution equations, effects of non–zero gluon transverse momentum are taken into account. Cross sections are then calculated as the convolution of unintegrated (transverse–momentum dependent) gluon densities and LO off–shell matrix elements. These models succeed in describing the p_T spectra of different quarkonium states at Fermilab and J/ψ meson production at HERA, as well as the quarkonium polarisation properties measured both at Fermilab and HERA.

3. Inelastic J/ψ Electroproduction

Inelastic J/ψ production at large Q^2 has a smaller cross section than in photoproduction but presents several interesting aspects. The contribution from the CO model is expected to be more significant; both the CO and the CS predictions should be more accurate due to the higher scale in the interaction. Also, backgrounds from diffractive processes are reduced at high Q^2. The measurements presented here are in a larger kinematic range than those previously published [3]. A measurement of the hadronic final state, X, is presented for the first time. In Figs. 1 - 3 the differential cross sections as function of z, Q^2, the J/ψ transverse momentum squared in the γp centre-of-mass frame, p_T^{*2}, the logarithm of the invariant mass squared of the hadronic system, $\log M_X^2$,

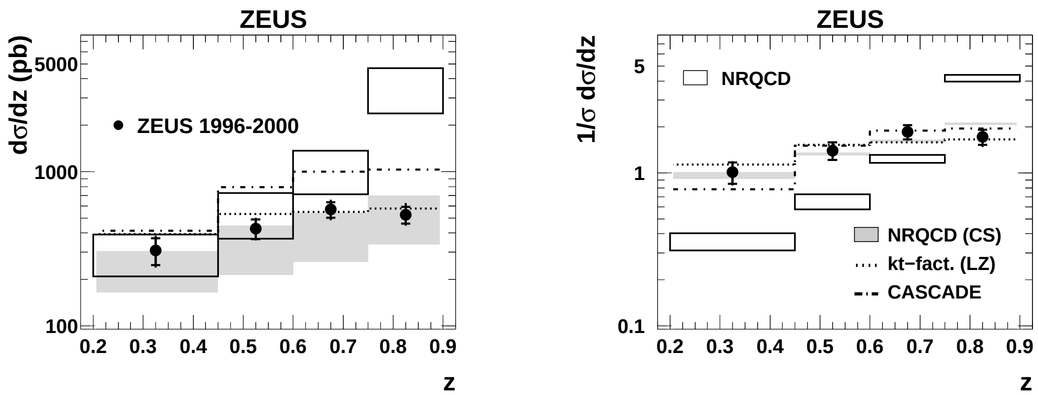

Figure 1: The left plot shows the differential cross section for the reaction $ep \rightarrow eJ/\psi X$ in the kinematic region described in the text as a function of z. The inner error bars of the data points show the statistical uncertainty; the outer bars show statistical and systematic uncertainties added in quadrature. The data are compared to LO NRQCD predictions, a LO CS calculation, a prediction in the k_T–factorisation approach within the CSM and the CASCADE Monte Carlo predictions. The right plot shows the data and the theoretical predictions normalised to unit area.

and its rapidity, Y_X, are shown. They are compared to the predictions of a NRQCD model [4], a CS model with k_T–factorisation (LZ) [5]. The uncertainties for the CS and CO NRQCD predictions correspond to variations of the charm–quark mass and of the renormalisation and factorisation scales. The uncertainty on the long–distance matrix elements and the effect of different choices of parton distribution functions are also taken into account. The bands in the figures show all these uncertainties added in quadrature. In general, the CSM is consistent with the data. The predictions including both CS and CO contributions are higher than the data, especially at high z and low p_T^{*2}. At high values of p_T^{*2} the agreement with the data is reasonable. The prediction does not describe the shapes of the z (see the right plot of Fig. 1), $\log M_X^2$ and Y_X distributions. Previous photoproduction results [6, 7] showed that the agreement between data and theory at high z can be improved using resummed LO NRQCD predictions [8]. It should be noted that, in photoproduction, inclusion of the NLO corrections to the CSM, not available for DIS, significantly improved the description of the data. Calculations based on the k_T–factorisation approach give a reasonable description of the data both in shape and normalisation. The ZEUS data are in agreement with the H1 results in the kinematic region $2 < Q^2 < 100$ GeV^2, $50 < W < 225$ GeV, $0.3 < z < 0.9$ and $p_T^{*2} > 1$ GeV^2 (plots not shown here).

4. Conclusions

Inelastic J/ψ production in DIS has been measured in the kinematic region $2 < Q^2 < 80$ GeV^2, $50 < W < 250$ GeV, $0.2 < z < 0.9$ and $-1.6 < Y_{lab} < 1.3$. The data are compared with LO NRQCD predictions, including both CS and CO contributions, and k_T–factorisation calculations. Calculations of the CS process generally agree with the data, whereas inclusion of CO terms spoils this agreement.

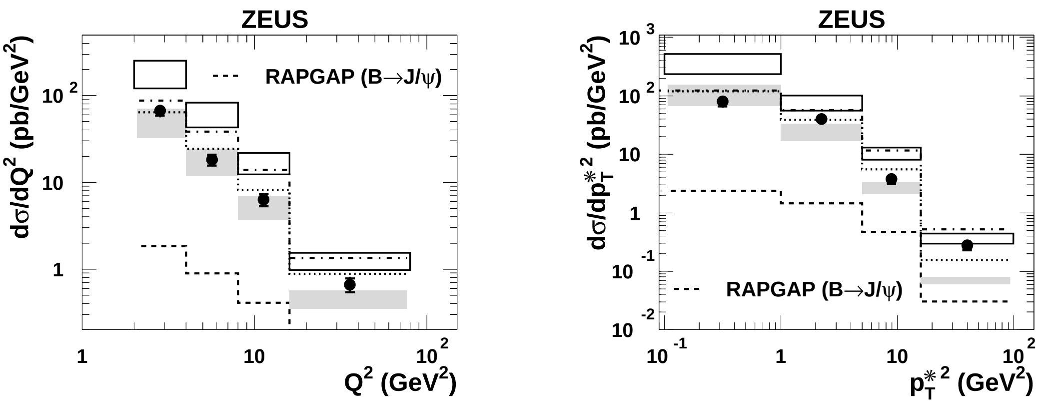

Figure 2: On the left the differential cross section for the reaction $ep \to eJ/\psi X$ as a function of Q^2 and on the right as function of p_T^{*2}. For further details see Fig. 1.

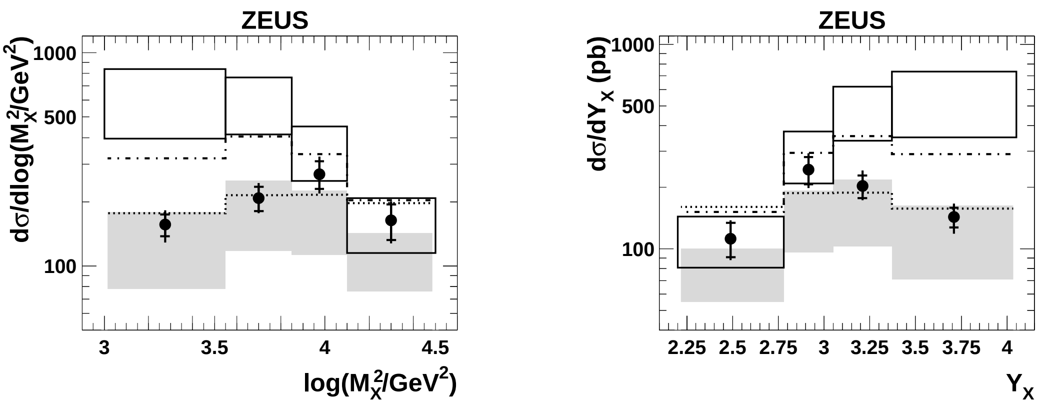

Figure 3: On the left the differential cross section for the reaction $ep \to eJ/\psi X$ as a function of $\log M_X^2$ and on the right as function of Y_X. For further details see Fig. 1.

References

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