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Shrinkage in Exclusive J/ψ Photoproduction

H1 Collaboration

Abstract

The differential cross sections, $\mathrm{d}\sigma/\mathrm{d}t$, for exclusive J/ψ photoproduction are studied for $|t| \leq 1$ GeV^2 at different values of the γp centre of mass energy, W. The exchanged Regge trajectory is found to have a slope which is indicative of a possible shrinkage of the diffraction peak. However, the present measurements are also compatible with the no shrinkage scenario.

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1 Introduction

The production mechanism for the exclusive photoproduction of light quark vector mesons at high energies is dominated by soft pomeron exchange. It is possible that the exclusive photoproduction of heavy quark vector mesons could be different since the mass of the heavy quarks introduces an energy scale which could allow hard processes to become more important.

Processes which are dominated by soft pomeron exchange show a dependence of the differential cross section on the centre of mass energy, W, of the form

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t} \propto W^{4\alpha(t)-4} \tag{1}$$

where $\alpha(t)$ is the Regge trajectory. For such processes the Regge trajectory will have the form $\alpha(t) = \alpha_0 + \alpha' t$ with α_0 close to unity and show shrinkage of the width of the diffraction peak with energy indicated by a value of the slope, α', of about 0.25 GeV^{-2} [1]. If the cross section follows such behaviour and if the t dependence follows an exponential of the form e^{bt} then b should vary with W as

$$b(W) = b_0 + 4\alpha' \log W. \tag{2}$$

In this paper we study the energy dependence of the values of b in exclusive J/ψ photoproduction to look for evidence of shrinkage. If such shrinkage is found to be abnormal it could be a further indication that hard processes play a part in the production mechanism. Such an indication would add to the observation that the dependence of the cross section on W for exclusive J/ψ production is steeper than that observed for light quark vector meson production [2, 3].

2 The Data Analysis

The H1 collaboration has presented data taken in 1994 on exclusive J/ψ photoproduction [2] and has published the p_t^2 dependence. In this energy and photon virtuality range p_t^2 is a good approximation to $-t$. In this paper the H1 preliminary measurements based on the 1994 and 1995 data are used corresponding to an integrated luminosity of 6.6 pb^{-1}. The 1994 data were selected to have $Q^2 \leq 4$ GeV^2 and the 1995 to have $Q^2 \leq 1$ GeV^2 with a mean value of $Q^2 \sim 0.1$ GeV ^{2}. With such a low mean value of Q^2 the data can be regarded as equivalent to photoproduction. Fits of a simple exponential shape of the form $e^{-bp_t^2}$ were made to the p_t^2 dependence in the range $0 \leq p_t^2 \leq 1.0$ GeV^2 in four energy ranges as shown in Table 1. The b values thus obtained are around 10% lower than those that would be obtained by fitting to the t distribution with the form e^{bt}. This difference is mainly caused by the smearing of the virtual photon direction to the beam axis relative to which the p_t^2 of the J/ψ is measured. ZEUS [3] have made an equivalent measurement of b in the energy range $40 \leq W \leq 140$ GeV.

Table 1

W Range (GeV)	$30 \leq W \leq 65$	$65 \leq W \leq 100$	$100 \leq W \leq 150$	$120 \leq W \leq 240$
Slope b (GeV^{-2})	3.4±0.3±0.4	4.1±0.3±0.4	4.8±0.3±0.6	4.1±0.4±0.6

Fig 1 shows the values of the slope parameters, b, plotted as a function of W together with a fit of the form $b_0 + 4\alpha' \log W$ to the HERA data only, where the b values have been extracted from the p_t^2 distributions. The fit gives a slope, α', of 0.21$\pm$0.15 GeV^{-2} with a χ^2 of 1.2 for 3 degrees of freedom (i.e. a confidence level of 75%). If the slope in the fit is constrained to be zero, i.e. no shrinkage, a confidence level of the fit of 54% is obtained.

Several fixed target experiments have measured the t distribution in exclusive J/ψ photoproduction at lower energies [4, 5, 6]. The only experiment which used a free proton target together with kinematic cuts to reduce the background from inelastic processes such as diffractive dissociation is experiment E401 [4] at Fermilab. All the other experiments used nuclear targets which could be affected by nuclear physics effects, or the kinematic event selection allowed the data to be contaminated by these inelastic backgrounds, or both. Hence the only fixed target experiment which is directly comparable to the HERA data is that from experiment E401. The t distribution from hydrogen target data from this photoproduction ($Q^2 = 0$) experiment is shown in Fig 2 together with a fit of the form e^{bt} for $|t| \leq 1$ GeV^2, as with the HERA data. The value obtained is $b = 3.2 \pm 0.5 \pm 0.5$ GeV^{-2} at $W = 17$ GeV with a χ^2 = 7.2 for 11 degrees of freedom. The first error quoted is statistical, the second is systematic and is derived by observing the effect of omitting the lowest $|t|$ point and restricting the fit to the region $|t| \leq 0.8$ GeV^2. H1 and ZEUS similarly included such a systematic uncertainty in their b value determinations. The E401 collaboration published a more complicated parameterisation of the t dependence. However the linear fit in Fig 2, which gives a good χ^2 fit to the data, shows that a simple exponential fits the data well.

In order to draw reliable conclusions about possible shrinkage, the b values compared must be directly equivalent, ie. they must all be obtained from fits of the same form, e^{bt}, to the same distribution, $\mathrm{d}\sigma/\mathrm{d}t$, over the same range, $|t| \leq 1.0$ GeV^2. In order to compare directly equivalent measurements of the b slopes by H1 with that by E401, the H1 b values extracted from the p_t^2 fits have been corrected by 9-13% to account for the smearing from $-t$ to p_t^2 described above. The sizes of these corrections are ascertained using a Monte Carlo program which generates events according to the observed W, Q^2 and p_t^2 distributions. ZEUS have published a b value accounting for the smearing from $-t$ to p_t^2 [3] so that this measurement requires no further correction. The b values obtained from the t distributions from H1, ZEUS and E401 are shown in Fig 3. A fit of the form $b_0 + 4\alpha' \log W$ to the data yields $\alpha' = 0.22 \pm 0.10$ GeV^{-2} with a χ^2 of 1.3 for 4 degrees of freedom (i.e. a confidence level of 86%). If the slope in the fit is constrained to be zero a χ^2 of 6.4 for 5 degrees of freedom is obtained, a confidence level of 27%.

3 Discussion of Results

The value of α' obtained from the HERA data alone and the analysis in which E401 is included are both consistent with 0.25 GeV^{-2}, the value expected from the same shrinkage of the diffraction peak as that due to soft pomeron exchange. However, the confidence levels from the fits constraining α' to zero are also good. Hence the data indicate that shrinkage may be present but are not conclusive.

None of the experiments is yet able to resolve any deviation of the $|t|$ dependence of the cross section from a simple exponential. The possible influence of such a deviation on the above conclusions is contained in the systematic uncertainties derived, as explained in section 2, by varying the fit ranges.

Recently, the published 1994 measurement from H1 [2], together with measurements from ZEUS, E401 and EMC have been used to show evidence for the absence of shrinkage [7]. This analysis is dominated by the data of high statistical precision of the EMC [5] on the cross section measurements. The EMC data were taken with an iron target and it is possible that there could be differences from free proton data due to nuclear effects. Furthermore, the measurements correspond to the kinematic region $z \geq 0.95$, where z is the fraction of the incident photon energy carried by the J/ψ. This signal allows a hadron activity of several GeV to accompany the J/ψ and so includes some inelastic events such as diffractive dissociation as well as the exclusive channel. We consider that it is unsafe to compare these data with HERA and E401 measurements in a search for shrinkage in the exclusive channel [8]. A repetition of the analysis described in [7], excluding the EMC measurement, suggests the presence of shrinkage but is statistically inconclusive.

4 Conclusion

The energy dependence of the slopes of the t variation of the differential cross sections has been examined in exclusive J/ψ photoproduction. The data indicate that there may be shrinkage of the diffractive peak, as is observed in processes dominated by soft pomeron exchange, but are also compatible with no shrinkage. To resolve this question conclusively higher statistics HERA data covering the full range of photon-proton interaction energies, W, are needed.

References

[1] A. Donnachie and P.V Landshoff. Phys.Lett. B348(1995)213 and B296(1992)227.

[2] Hl Collaboration, S.Aid et al Nucl.Phys. B472 (1996) 3.

[3] ZEUS Collaboration, M. Derrick et al., Zeit.Phys. C75 (1997) 215.

[4] E401 Collaboration, M.Binkley et al Phys.Rev.Lett.48 (1982) 73.

[5] EMC, J.J.Aubert et al.,Nucl.Phys. B213 (1983) 1.

[6] U. Camerini et al., Phys.Rev.Lett. 35 (1975) 483.
B.Gittleman et al.,Phys.Rev.Lett.35(1975)1616.
T.Nash et al., Phys.Rev.Lett. 36(1976)1233.
BFP Collaboration, A.R.Clark et al., Phys.Rev.Lett. 43 (1979)187.
E516 Experiment, B.H.Denby et al.,Phys.Rev.Lett.52(1984)795.
NA14 Collaboration, R.Barate et al., Z.Phys.C33(1987)505.
E687 Experiment, P.L.Frabetti et al.,Phys.Lett.B316(1993)197.
NMC, M.Arneodo et al.,Phys.Lett.B332(1994)195.

[7] A. Levy, Phys. Lett. B424(1998)191.

[8] T. Sloan, *private communication*.

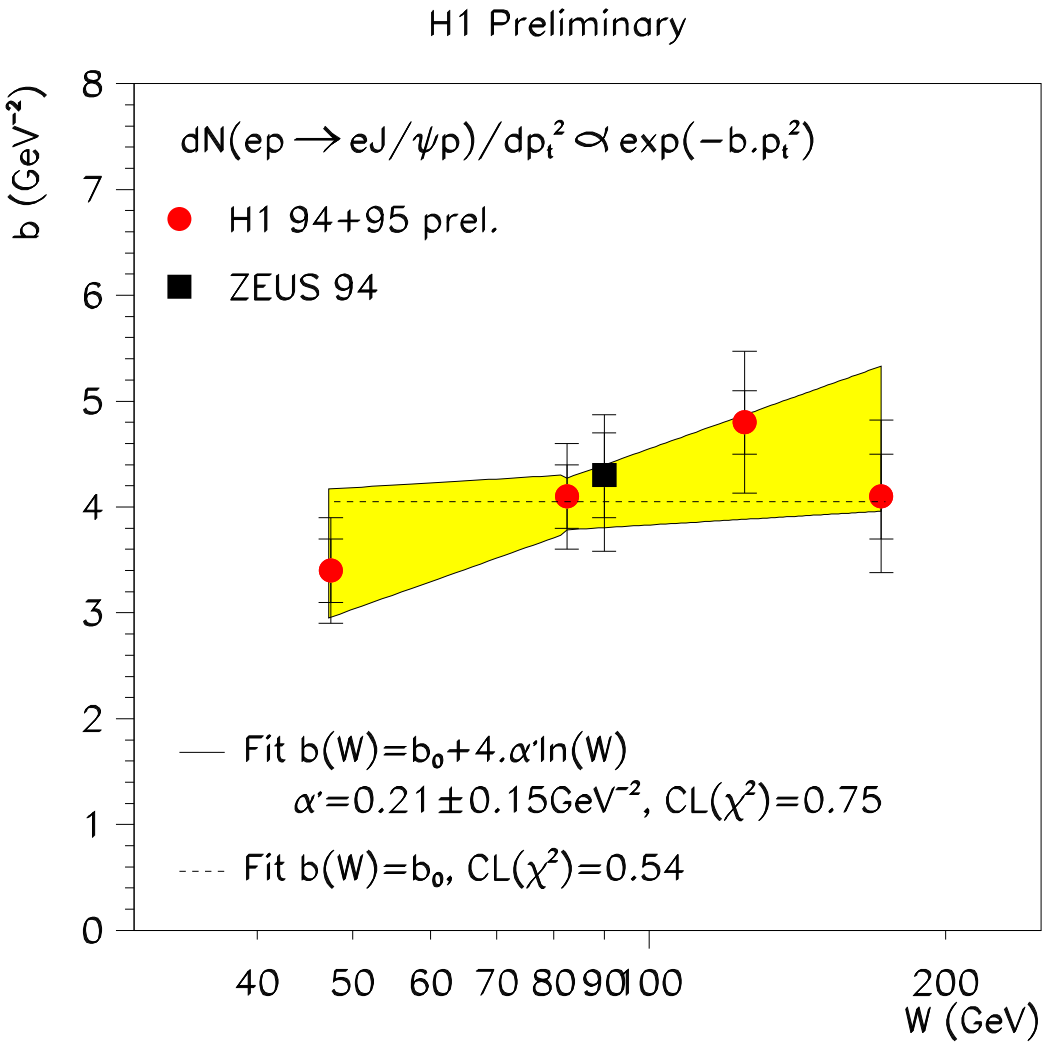

Figure 1: Slopes b from fits to differential distributions $d\sigma(ep \to eJ/\psi p)/dp_t^2$ of the form $e^{-b.p_t^2}$ as measured by the HERA experiments H1 and ZEUS. The band shows a fit with 1σ uncertainties of the form $b(W) = b_O + 4\alpha' \log W$. Also indicated is a fit to a constant value.

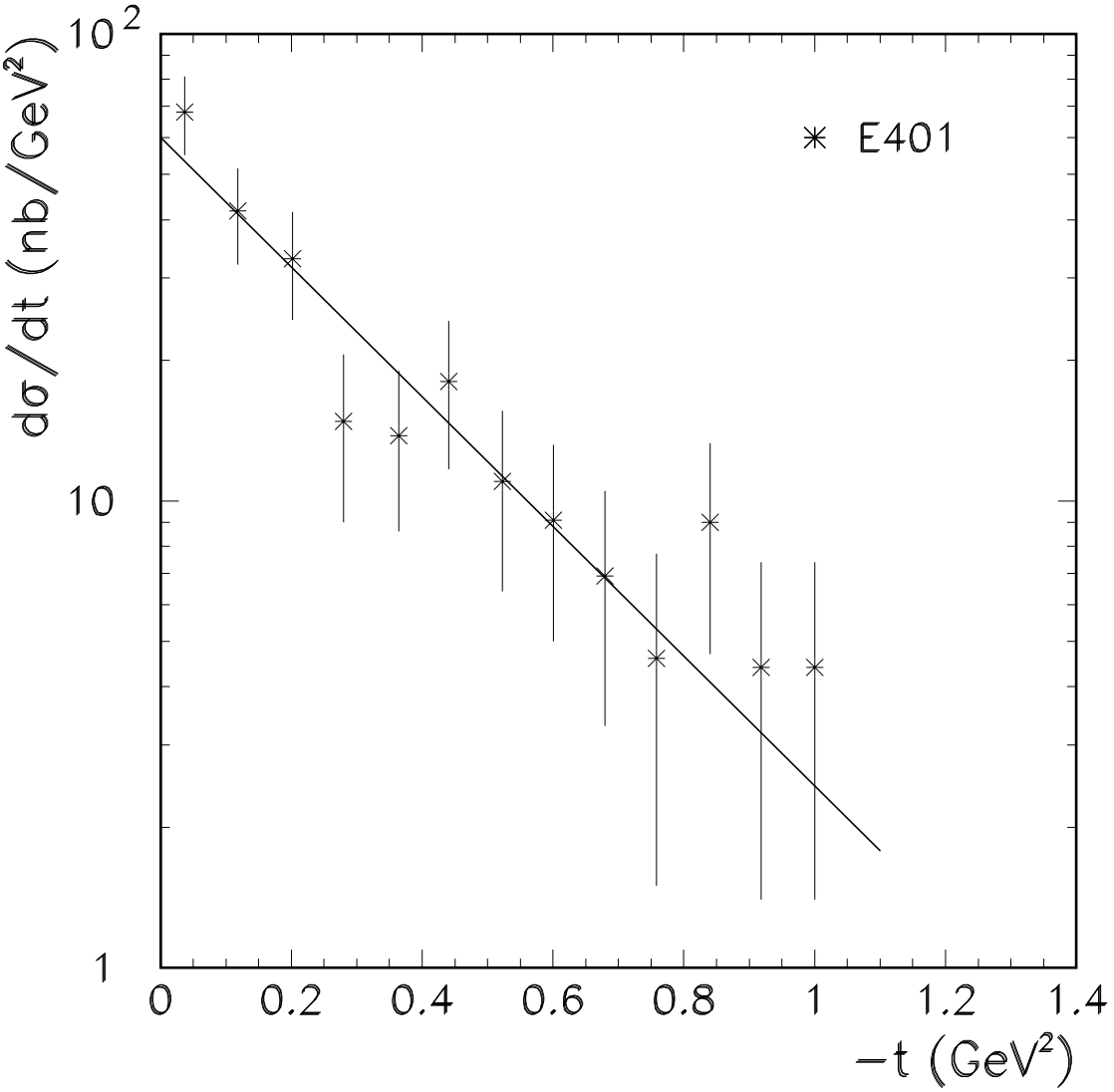

Figure 2: The E401 differential cross section from hydrogen for exclusive J/ψ photoproduction with the simple exponential fit described in the text.

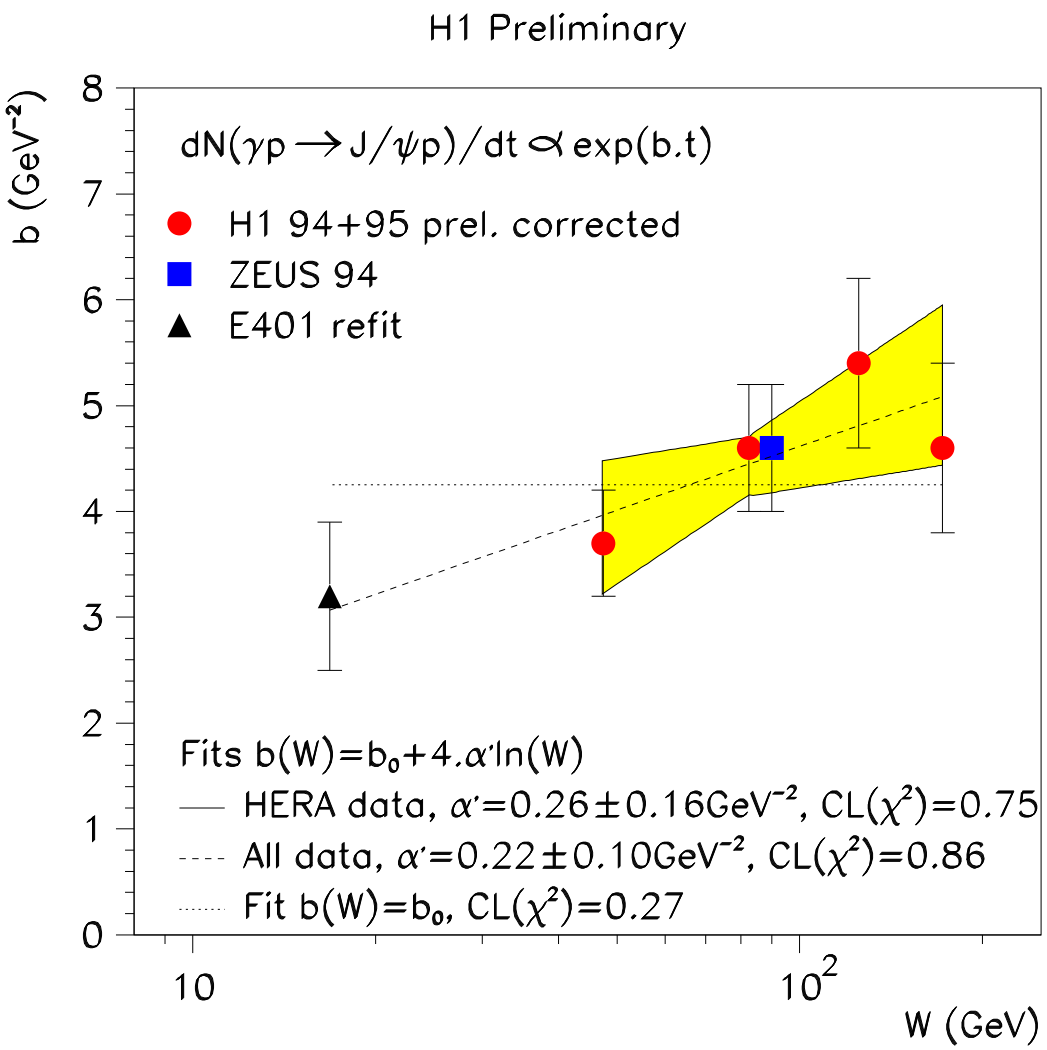

Figure 3: Slopes b from fits to differential distributions $d\sigma(\gamma p \to J/\psi p)/dp_t^2$ of the form $e^{b.t}$ as measured by the HERA experiments H1 and ZEUS, and by E401. The band shows a fit with 1σ uncertainties of the form $b(W) = b_O + 4\alpha' \log W$ to the HERA data alone. The dashed line indicates the best fit including the E401 measurement. Also indicated is a fit to a constant value.