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Comparison of Elastic and Proton Dissociative ρ Meson Electroproduction from H1.

H1 Collaboration

Abstract

Proton dissociative and elastic ρ meson production are compared in the region $Q^2 > 1.5\ \mathrm{GeV}^2$ using H1 detector at the e^+p HERA collider. The slopes of the P_t^2 distributions are measured as a function of Q^2. An indication is observed of an increase in the ratio of proton dissociative to elastic cross sections in the region $Q^2 < 3\ \mathrm{GeV}^2$. A significant deviation from the prediction of S-channel helicity conservation is observed for proton dissociative ρ meson electroproduction process.

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1 Introduction

Precise measurements of vector meson production parameters are important for the understanding of the mechanism of diffractive processes. The data sample collected in 1996 by the H1 collaboration at HERA allows the study of many details of these processes in the intermediate Q^2 region of a few GeV^2 with W ranging from 20 to 150 GeV. The obtained results are compared with the recent H1 measurement of the elastic ρ meson electroproduction [1].

1.1 Phenomenology

In a naive additive quark model the proton dissociative process is treated as a quasi-elastic scattering off the constituent quark in the proton, while the elastic process is treated as a coherent scattering off the proton. The slope of the P_t^2 distribution is assumed to reflect the spatial dimensions of the interacting objects. This approach predicts a considerable difference between b-slopes for the elastic and proton dissociative and for photo ($Q^2 \approx 0$) and electroproduction ($Q^2 > 1.\,\mathrm{GeV}^2$) of ρ mesons.

The proton dissociative and elastic processes can be also compared in the framework of the hypothesis of factorisation of the diffractive vertex [2], which naturally appears in models based on Regge theory assuming a single pomeron exchange. In this approach each amplitude is proportional to the product of two vertex functions. Hence at fixed P_t^2, the ratio of the elastic and proton dissociative cross sections, after an integration over the proton dissociative mass M_Y, should be independent of Q^2.

1.2 Event selection

The data were collected in 1996, when the HERA collider was operated with positrons of 27.5 GeV interacting with protons of 820 GeV. The H1 detector is described in detail in [3] .

The selected event topology consists of a positron recorded in the backward lead-scintillating-fibre calorimeter and two oppositely charged particles, originating from a vertex situated in the nominal e^+p interaction region which are detected in the tracking system. The fragments of the proton dissociative system can be registered in subdetectors installed in forward part of the H1 detector. For the following analysis, two data samples with and without signals in the forward subdetectors were selected, which correspond respectively to elastic and proton dissociative ρ meson production processes.

The kinematic region in this analysis is restricted to $1.5 < Q^2 < 30\ \mathrm{GeV}^2$ and $20 < W < 150$ GeV. The DIFFVM Monte Carlo (MC) generator [4], together with a detailed simulation of the H1 detector, is used to study efficiencies and backgrounds. The proton dissociative ρ meson production cross section is corrected using the MC to the region $(M_Y/W)^2 < 0.1$. All background contributions are determined and subtracted.

2 Results

2.1 $\pi^+\pi^-$ mass spectrum

The invariant $\pi^+\pi^-$ mass spectra of the proton dissociative data sample is shown in Fig. 1. A prominent peak is observed at the nominal ρ meson mass position. The $\pi^+\pi^-$ mass spectrum is fitted with a relativistic Breit-Wigner function with a P-wave energy dependent width to describe the ρ meson signal and an exponential with $\pi^+\pi^-$ mass threshold suppression to describe the non-resonant background. The shape of the ϕ and ω signals is parameterised using corresponding MC data and their contribution is taken into account in the fit procedure. A fit with free mass and width of the ρ signal gives $M_\rho = 770 \pm 6\,\mathrm{MeV}/c^2$ and $\Gamma_\rho = 159 \pm 8\,\mathrm{MeV}/c^2$ in very good agreement with the expected values. The fit is of good quality ($\chi^2/n = 1.03$). The number of events in the ρ peak is 3037 ± 186.

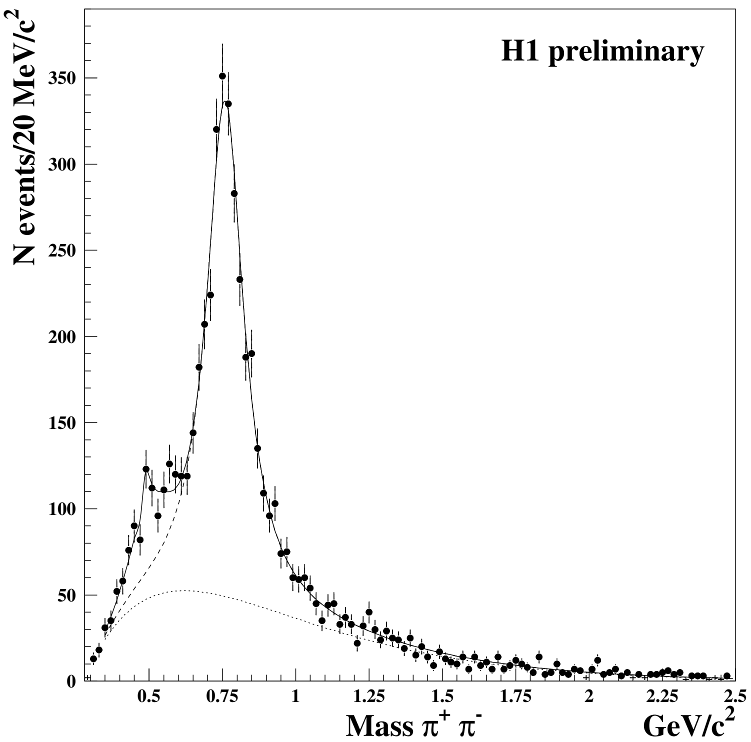

Figure 1: The invariant $\pi^+\pi^-$ mass spectrum for the proton dissociative data sample. The fit results are presented for the nonresonant background (dotted line), the ω and ϕ backgrounds (together, dashed line) and the resonant ρ signal (all together, solid line).

2.2 P_t^2 distribution and its Q^2 dependence

The acceptance corrected P_t^2 distribution is shown in Fig. 2 for the proton dissociative process. For that measurement the $\pi^+\pi^-$ mass distribution is fitted separately in every bin of the P_t^2

distribution. The slope is measured to be $b_{pd} = 2.99 \pm 0.19^{+0.30}_{-0.15}\,\mathrm{GeV}^{-2}$, where the fit interval of $P_t^2 < 0.8\,\mathrm{GeV}^2$ is chosen. The obtained proton dissociative b-slope is approximately two times smaller than elastic one [1].

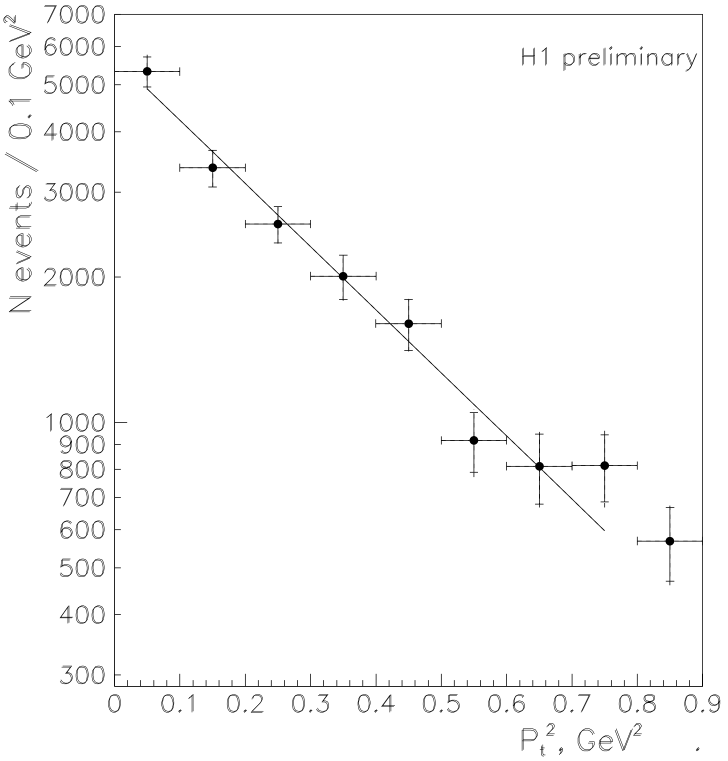

Figure 2: The P_t^2 distribution for the proton dissociative ρ meson electroproduction data sample. The result of the single exponential fit is shown.

The Fig. 3 demonstrates the Q^2 dependence of the b_{pd}-slopes. A sharp transition from the photoproduction to the electroproduction regime is seen in the Q^2 region of few GeV^2.

The ratio of the differential cross sections for the proton dissociative and elastic ρ meson electroproduction is shown in Fig.4. An increase in the ratio is found in the region $Q^2 < 3\,\mathrm{GeV}^2$, in contrast with the approximately flat behaviour of this ratio in the region $Q^2 > 3$ GeV^2.

2.3 Angle Φ dependence

The angle Φ distribution characterising the ρ meson production is measured in intervals of P_t^2. The definitions of the variables used to describe the angular distributions and the interpretations of the various distributions can be found in the previous H1 publication on elastic ρ production [1].

The combination of the matrix elements $r^5_{00} + 2r^5_{11}$ is extracted from the angle Φ distribution fit and is presented as the function of P_t^2 for the proton dissociative ρ meson electroproduction

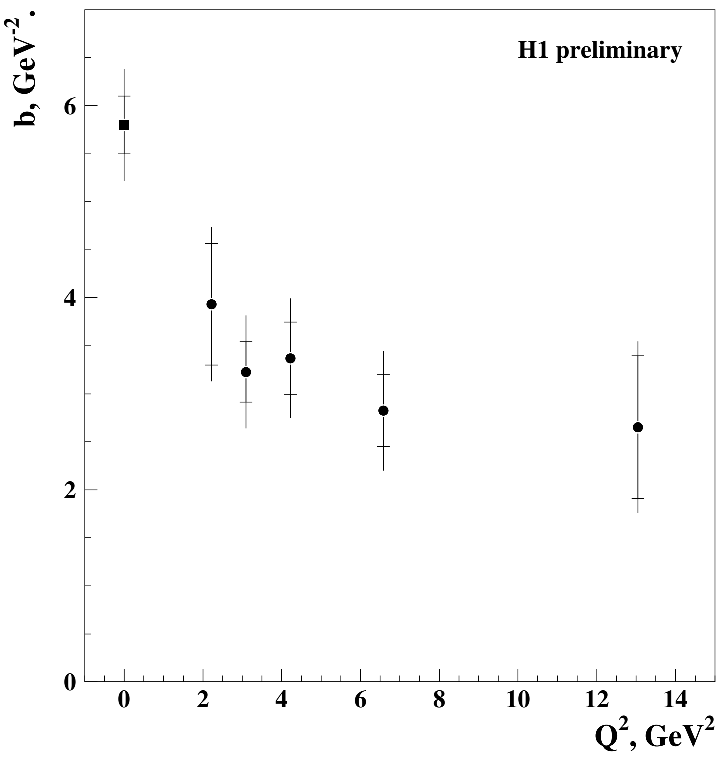

Figure 3: The b-slope as the function of Q^2 for the proton dissociative ρ meson electroproduction (full circles, this analysis) and photoproduction (full square, ZEUS 1997 [5]).

in Fig.5. This matrix elements combination has to be zero in the case of a S-channel helicity conservation. A significant deviation from the S-channel helicity conservation hypothesis is observed. This deviation can be attributed to a spin-flip (from the initial photon to the final ρ meson) amplitude T(0,1), which is theoretically expected to be non-negligible when comparing with non-flip amplitudes [6].

References

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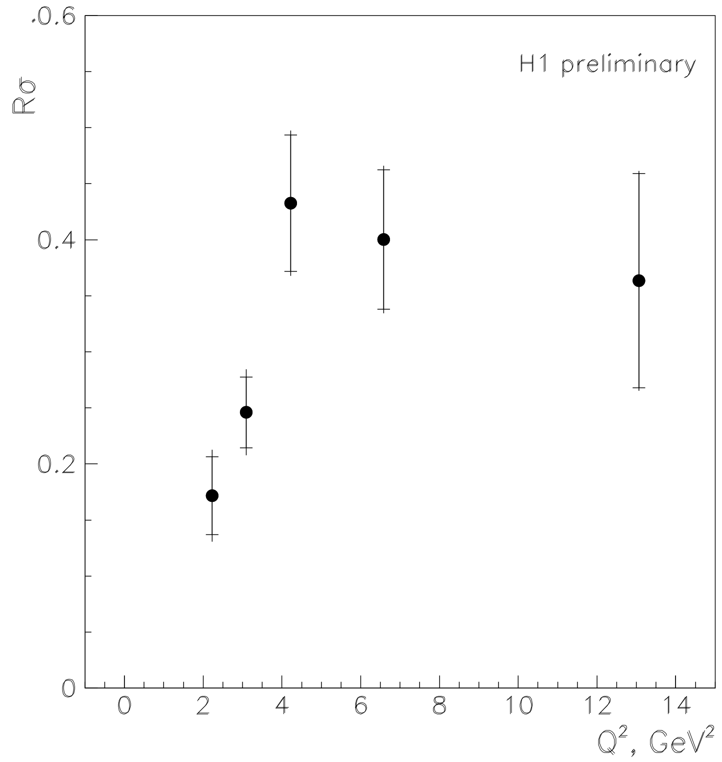

Figure 4: The ratio R_σ of the differential cross sections for the proton dissociative and elastic processes at $P_t^2 = 0$: $\mathrm{R}_\sigma = \frac{\mathrm{d}\sigma_{pdis}/\mathrm{d}P_t^2(P_t^2=0)}{\mathrm{d}\sigma_{el}/\mathrm{d}P_t^2(P_t^2=0)}$ as the function of Q^2. The ratio is extracted from a fit of the elastic and proton dissociative differential P_t^2 distributions by the single exponential.

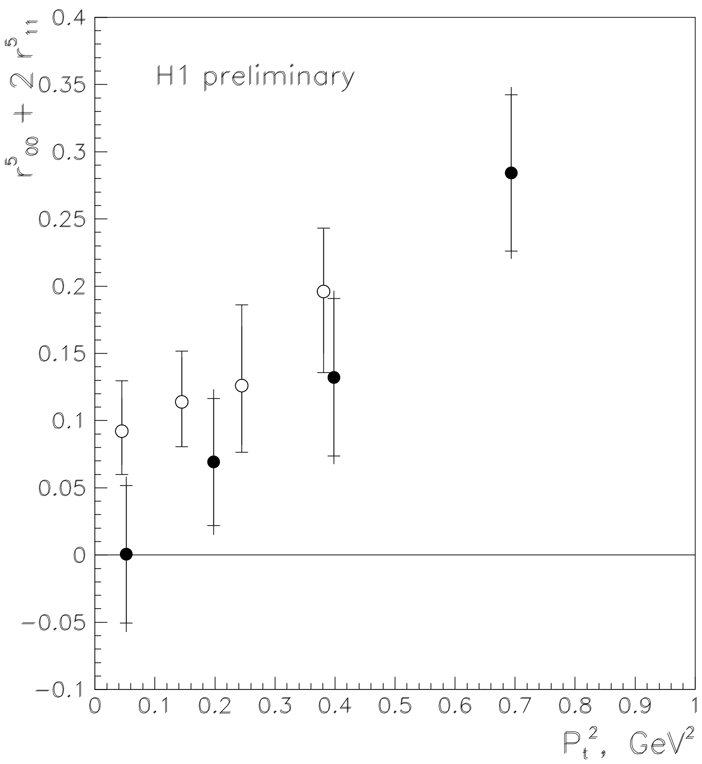

Figure 5: The matrix elements sum $r^5_{00} + 2r^5_{11}$ as the function of P_t^2 for the proton dissociative (full circles, this analysis) and elastic (empty circles, H1 1999) ρ meson electroproduction.