Diffractive Electroproduction of ρ and ϕ Mesons at H1

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These proceedings reports on the H1 analysis at HERA-1 for ρ and ϕ diffractive production, both in the elastic and proton dissociative channel. The total, longitudinal and transverse cross sections are measured as a function of Q^2 and W. The Q^2, t and (for ρ) invariant mass dependences of the s-channel helicity conserving and violating amplitudes are discussed.

1 Introduction

This analysis [1] is devoted to the study of diffractive electroproduction of ρ and ϕ vector mesons (designed in the following as VM), in the elastic and in the proton dissociative channels: $e + p \to e + Y + VM$; $\rho \to \pi^+ + \pi^-$ and $\phi \to K^+ + K^-$, where Y represents the elastically scattered proton or a diffractively excited baryonic system, well separated in rapidity from the vector meson.

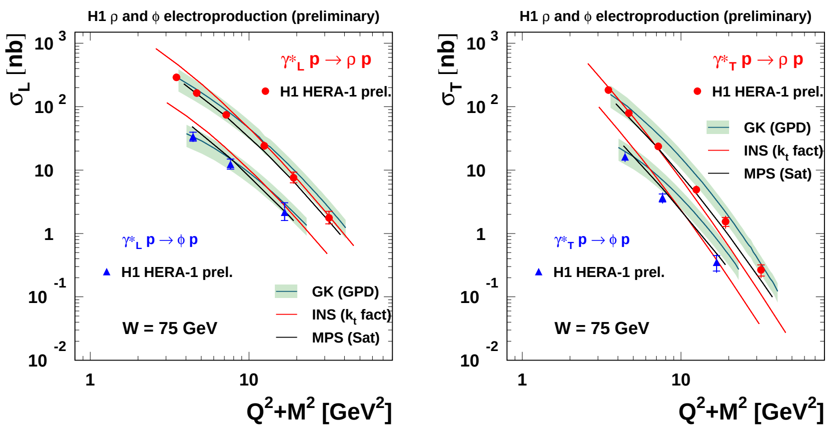

Figure 1: Q^2 dependences of the longitudinal and transverse γ^*p cross sections for elastic ρ and ϕ production for $W = 75$ GeV.

The data analysed here were taken by H1 from 1996 to 2000, i.e. before the luminosity upgrade in 2002 ("HERA-1" data set), corresponding to a total luminosity of 51 pb^{-1}. The interacting particles were electrons or positrons [a] of energy 27.5 GeV, colliding with 820 or 920 GeV protons, which corresponds to electron-proton centre of mass energies of $\sqrt{s} = 300$ and 320 GeV, respectively.

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[a] In the rest of this paper, the word "electron" will be generically used for electron and positron.

The kinematic domain of the measurement is: $2.5 < Q^2 < 60$ GeV^2, $35 < W < 180$ GeV, $|t| < 3$ GeV^2 and $M_Y < 5$ GeV/c^2, where $Q^2 = -q^2$, q being the virtual photon four-momentum, W is the photon-proton centre of mass energy and t is the square of the four-momentum transfer from the incident proton to the scattered system Y, of which the mass is M_Y.

The Q^2 range covers the transition region from soft to hard diffraction. Following a QCD factorisation theorem [2], the longitudinal amplitude [b] for VM production at small x, small $|t|$ and large Q^2 is described in the proton rest frame as the factorisation of three contributions: the fluctuation of the virtual photon into a $q\bar{q}$ colour dipole; the elastic dipole-proton scattering; the $q\bar{q}$ recombination into the final state VM.

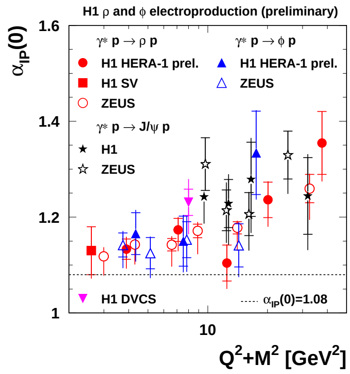

Figure 2: Evolution with $Q^2 + M^2$ of the parameter $\alpha_{I\!P}(0)$.

In view of the large number of models, comparisons will be performed with a limited choice of predictions including: the GPD model of Goloskokov and Kroll (GK [3]), the k_t-unintegrated model presented in the review of Ivanov, Nikolaev and Savin (INS [4]) which is framed into a BFKL approach and the dipole approach of Marquet, Peschanski and Soyez (MPS [5]).

2 Cross section measurements

The Q^2+M^2 dependences of the longitudinal and transverse γ^*p cross sections are presented in Fig. 1 for elastic ρ and ϕ production for $W = 75$ GeV. Overall normalisation errors of 4.7% for ρ and 5.4% for ϕ mesons are not included in the error bars. The GPD model predictions (blue area) are slightly too flat, both for σ_L and for σ_T, but the global normalisations are within the theoretical and experimental errors. The k_t-unintegrated model (red line) gives predictions which are too high and also too steep for σ_T. The dipole saturation model (black line) describes the data relatively well, although the predictions are falling slightly too fast with $Q^2 + M^2$.

The W dependences of the total cross sections for ρ and ϕ production have been extracted for several Q^2 values and are characterised by power laws of the form $\sigma(\gamma * p) \propto W^\delta$. This parameterisation is inspired by the Regge description of soft interactions, with $\delta \simeq 4\ (\alpha_{I\!P}(\langle t \rangle) - 1)$, $\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'\ t$. In soft interactions, typical values for the intercept are $\alpha_{I\!P}(0) \simeq 1.08 - 1.11$ [6]. The W dependences of ρ, ϕ elastic production cross sections are summarised in Fig. 2 in the form of the $Q^2 + M^2$ dependence of $\alpha_{I\!P}(0)$ including earlier measurements from H1 Deeply Virtual Compton Scattering [7] and J/ψ measurements [8] and ZEUS measurements of ρ [9, 10], ϕ [11, 12] and J/ψ measurements [13]. For light vector mesons, W dependences of the elastic cross section are close or slightly harder than the soft behaviour up to $Q^2 + M^2$ values of the order of 10 GeV^2. An increase is then observed, up to values of $\alpha_{I\!P}(0)$ of the order of 1.2-1.3, compatible with J/ψ measurements. This is

[b]Factorisation is proven for longitudinal amplitudes of light VM's and should also apply to heavy VM; its validity is often extended to transverse amplitudes for sufficient Q^2.

related to the hardening of the gluon distribution with the hard scale of the interaction and confirms a transition from soft to hard diffraction.

3 Proton vertex factorisation

Figure 3 presents, as a function of Q^2, the ratios of the elastic and proton dissociative γ^*p cross sections for ρ mesons for $W = 75$ GeV and $M_Y < 5$ GeV/c^2. The overall normalisation error on the ratios, which is not included in the error bars, is 2.4%. No significant dependence with Q^2 of the ratios is observed in the range $2.5 < Q^2 < 60$ GeV^2. These observations support the factorisation of diffractive amplitudes into photon vertex contributions and proton vertex processes.

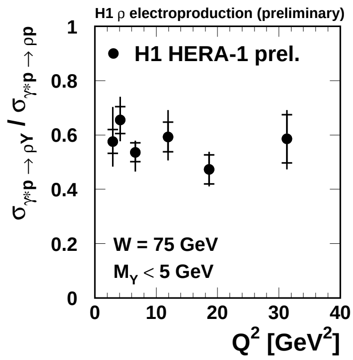

Figure 3: Q^2 dependence of the ratio of proton dissociative ($M_Y < 5$ GeV/c^2) to elastic γ^*p cross sections for ρ meson production, with $W = 75$ GeV.

4 Polarisation measurements

Informations on the spin and parity properties of the exchange and on the contributions of the various polarisation amplitudes are accessed through the distributions of production and decay angles which characterise VM production and two-body decays [14]. These angular distributions allow the measurement at HERA of 15 spin density matrix elements (SDME) given in the form r^i_{jk}, which are normalised bilinear combinations of the complex helicity amplitudes $T_{\lambda_V,\lambda_\gamma}$, λ_γ and λ_V being the helicities of the virtual photon and of the VM.

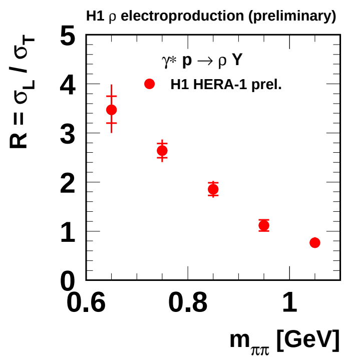

Figure 4: $R = \sigma_L/\sigma_T$ as a function of $m_{\pi\pi}$ for ρ production.

We have measured for ρ and ϕ meson production the Q^2, t and (for ρ only) the invariant mass $m_{\pi\pi}$ dependences of these 15 SDME's from which the ratio between the longitudinal (σ_L) and the transverse (σ_T) γ^*p cross-sections can be extracted. Fig. 4 shows the ratio σ_L/σ_T for ρ meson production as a function of the two pions invariant mass. A striking decrease of the cross section ratio R with the increasing $m_{\pi\pi}$ is observed as already reported by the ZEUS experiment [10]. A simple interpretation of the $m_{\pi\pi}$ dependence follows from the general, "naive" Q^2/M^2 dependence of the cross section ratio, if the mass M is understood as that of the quark pair (i.e. the dipion mass), rather than the nominal resonance mass.

Following the presentation in ref. [15], the amplitude relative strengths, measured with reference to the dominant T_{00} amplitude, are computed from global fits to the 15 SDME measurements, all amplitudes being taken as purely imaginary. Results are shown in Fig. 5 as a function of Q^2 and $|t|$ both for ρ and ϕ production. The strong decrease with Q^2 of the $|T_{11}|$ / $|T_{00}|$ amplitude ratio is related to the usual Q^2 dependence of the cross section ratio $R = \sigma_L/\sigma_T$. For the first time, a Q^2 dependence of the non s-channel helicity conservation (SCHC) $|T_{01}|\ /\ |T_{00}|$ ratio is observed. The normalised T_{01} helicity flip amplitude is increasing with $|t|$ confirming previous SCHC violation observation. Conversely, and for the first time, a decrease with $|t|$ of the $|T_{11}|\ /\ |T_{00}|$ amplitude ratio, for ρ and for ϕ production is observed. The decrease of $|T_{11}|\ /\ |T_{00}|$ with $|t|$, which is not taken into account in perturbative QCD calculations [15], is needed to compensates the increase of $|T_{01}|\ /\ |T_{00}|$ and ensure unitarity.

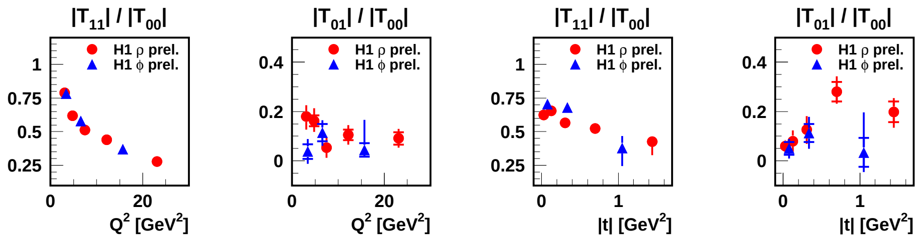

Figure 5: Amplitude ratios as a function of Q^2 and $|t|$ for ρ and ϕ productions.

5 Conclusions

This paper reports on the measurement ρ and ϕ vector meson production at high Q^2. The hardening of the W dependance at high Q^2 indicates a transition from soft to hard diffraction. Proton vertex factorisation is supported by the constancy with Q^2 of the ratio of the proton dissociative to elastic cross sections. Ratio of polarised amplitudes have been extracted confirming SCHC violation.

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