PROCEEDINGS OF SCIENCE

Exclusive J/Ψ photo- and electroproduction in a dual model

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Exclusive J/Ψ electroproduction is studied in the framework of the analytic $S-$matrix theory. The differential and integrated elastic cross sections are calculated using the Modified Dual Amplitude with Mandelstam Analyticity (M-DAMA) model. The model is applied to the description of the available experimantal data and proves to be valid in a wide region of the kinematical variables s, t and Q^2. Our amplitude can be used also as a universal background parametrization for the extraction of tiny resonance signals

XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects, DIS 2010
April 19-23, 2010
Firenze, Italy

*Speaker.

PoS(DIS 2010)171

1. Introduction

Duality in strong interaction physics is the relationship between the description of hadronic scattering amplitudes in terms of s-channel resonances at low energies, and t-channel Regge poles at high energies, see Fig. 1, for review see Ref. [1]. The Veneziano model [2] embodied duality and correct Regge asymptotic behaviour. The dual model with Mandelstam analyticity (DAMA) [3] appeared as a generalization of Veneziano dual model. Contrary to narrow-resonance dual models, DAMA requires non-linear, complex trajectories. The dual properties of DAMA were studied in Ref. [4]. High-energy exclusive J/Ψ electroproduction was intensively studied in recent years, for a review see Ref. [5]. One of the most interesting properties is the suppression of the so-called secondary reggeon exchanges resulting from the Okubo-Zweig-Iizuka rule [6]. J/Ψ photoproduction is an ideal tool to study the Pomeron exchange. The leading Pomeron exchange can be modelled using DAMA [3] and Modified DAMA [7] amplitudes. The main source of the data at high energies is the HERA collider at DESY [8, 9, 10, 11, 12], while at low energies experimental studies at JLab are promising, see for instance the recent paper of Ref. [13]. In Refs. [14, 15] a model based on DAMA and MDAMA was proposed to describe J/Ψ photo- and electro-production; it resulted in a very good description of the data in the region of s, Q^2 from the threshold to high energy, where pure Pomeron exchange dominates.

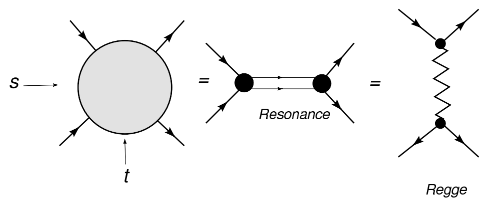

Figure 1: Dual description of hadron scattering amplitude.

2. The model

The DAMA amplitude [3] is given by:

$$D(s,t) = c\int_0^1 dz \left(\frac{z}{g}\right)^{-\alpha(s')-1} \left(\frac{1-z}{g}\right)^{-\alpha_t(t'')}, \tag{2.1}$$

where $\alpha(s)$ and $\alpha(t)$ are Regge trajectories in the s and t channel correspondingly, g and c are parameters, with $g > 1$, $c > 0$, and the notations $x' = x(1-z)$, $x'' = xz$ $(x = s, t, u)$ are used.

To extend the model off-mass shell we need to construct the Q^2-dependent dual amplitude. To this aim we use the so called Modified DAMA (M-DAMA) formalism developed in Ref. [7]. The scattering amplitude is given by

$$D(s,t,Q^2) = c\int_0^1 dz \left(\frac{z}{g}\right)^{-\alpha(s')-\beta(Q^{2''})-1} \left(\frac{1-z}{g}\right)^{-\alpha_t(t'')-\beta(Q^{2'})}, \tag{2.2}$$

where $\beta(Q^2)$ is the following monotonically decreasing dimensionless function of Q^2; $x' = x(1-z)$, $x'' = xz$, where $x \equiv s,\, Q^2,\, t$:

$$\beta(Q^2) = -\frac{\alpha_t(0)}{\ln g}\ln\left(\frac{Q^2+Q_0^2}{Q_0^2}\right). \tag{2.3}$$

Clearly at $Q^2 = 0$ we have $\beta(0) = 0$ so that we reproduce the on-mass shell amplitude of Eq. (2.1).

In Refs. [14, 15] these amplitudes were used to describe J/Ψ photo and electroproduction. Vector meson dominance [16] was employed to relate photon $\gamma^* p \to J/\Psi p$ and hadron amplitudes $J/\Psi p \to J/\Psi p$.

$$A(\gamma^* p \to J/\Psi\, p) = \frac{e}{f_{J/\Psi}} A(J/\Psi\, p \to J/\Psi\, p), \tag{2.4}$$

where $f_{J/\Psi}$ is the decay constant of J/Ψ. $e/f_{J/\Psi}$ is included into the parameter of the model c.

The amplitude reads

$$A(s,t,u,Q^2) = (s-u)(D(s,t,Q^2) - D(u,t,Q^2)). \tag{2.5}$$

Trajectories are chosen in the following way:

$$\alpha(s) = \alpha(0) + \alpha_1(\sqrt{s_0} - \sqrt{s_0 - s}). \tag{2.6}$$

$$\alpha(t) = \alpha^P(t) = \alpha^P(0) + \alpha_1^P(\sqrt{t_1} - \sqrt{t_1 - t}) + 2\alpha_2^P(t_2 - \sqrt{(t_2 - t)t_2}). \tag{2.7}$$

The transverse differential cross section is given by

$$\frac{d\sigma_T}{dt}(s,t,Q^2) = \frac{1}{16\pi\lambda(s, m_{J/\Psi}^2, m_P^2)}|A(s,t,u,Q^2)|^2, \tag{2.8}$$

The total elastic cross section is given by the sum of longitudinal and transverse components:

$$\sigma_{el}(s,Q^2) = (1 + R(Q^2))\sigma_T(s,Q^2), \tag{2.9}$$

where $R = \sigma_L/\sigma_T$ parametrized as in Ref. [17]:

$$R(Q^2) = \left(\frac{a\, m_{J/\Psi}^2 + Q^2}{a\, m_{J/\Psi}^2}\right)^n - 1, \tag{2.10}$$

The results are presented in Table 1 and Figs 2,3 (see [14, 15] for more results). We can conclude that the agreement is rather good and our model has correctly captured the s,t and Q^2 behaviour of J/Ψ meson production.

ON-MASS-SHELL Ref. [14]			
$\alpha^E(0) =$	-1.83	$\alpha_1^E(0) =$	0.01 (GeV^{-1})
$\alpha^P(0) =$	1.2313	$\alpha_1^P(0) =$	0.13498 (GeV^{-1})
$\alpha_2^P(0) =$	0.04 (GeV^{-2})	$t_2 =$	36 (GeV^2)
$g =$	13629	$c =$	0.0025 (GeV^{-2})
$\chi^2/d.o.f. = 0.83$			
OFF-MASS-SHELL Ref. [15]			
$Q_0^2 = 3.464^2$ (GeV^2), $a = 2.164$, $n = 2.131$			
$\chi^2/d.o.f. = 1.2$			

Table 1: Fitted values of the adjustable parameters

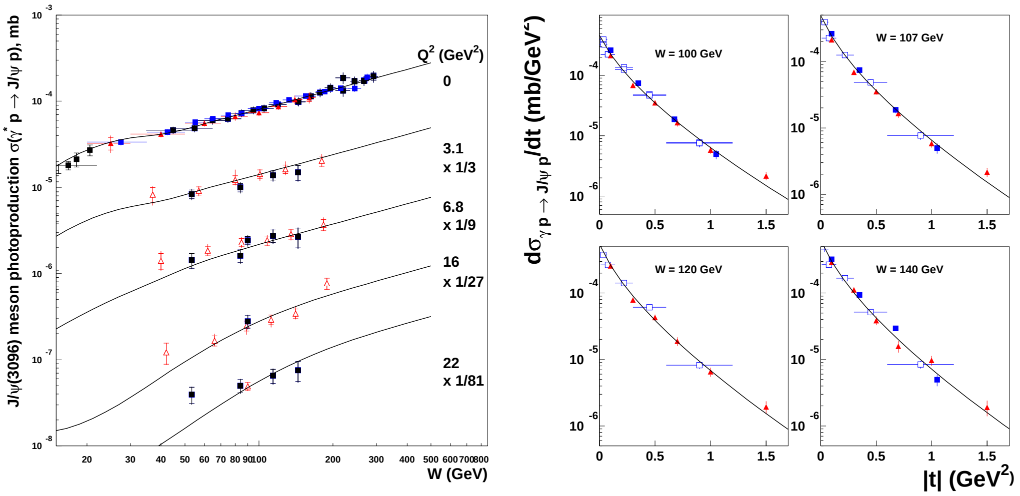

Figure 2: J/Ψ elastic and differential cross sections.

3. Conclusions

A model [14, 15] that describes J/Ψ photo and electroproduction based on DAMA and M-DAMA [3, 7] is constructed. Good fits of the data are achieved in all available regions of the Mandelstam variables and photon virtualities. The model can be used to predict cross sections for J/Ψ photo- and electroproduction for any value of the Mandelstamian variable, and in a wide range of photon virtualities Q^2.

This model can be applied to other vector meson production. Careful study of the influence of the virtuality of the photon and application of VDM is needed to improve the quality of the model.

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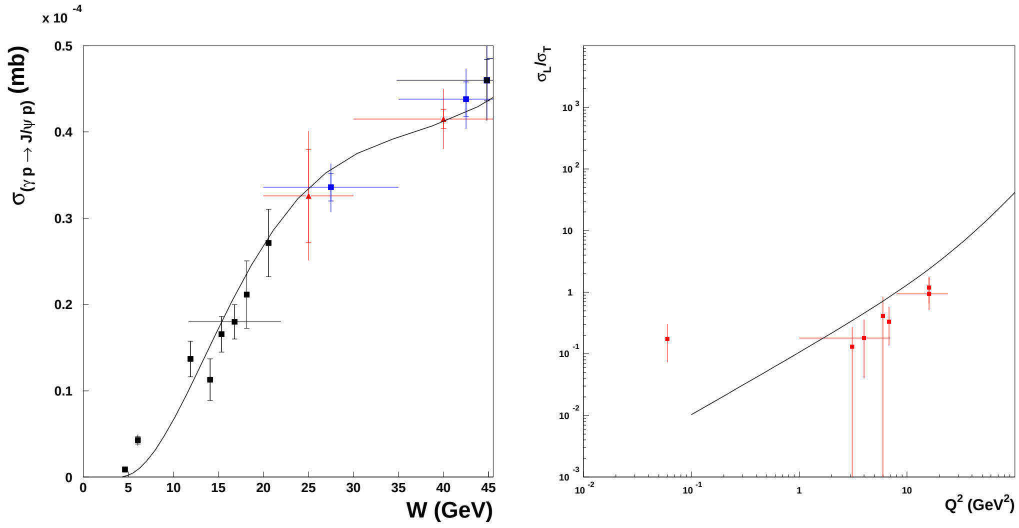

Figure 3: J/Ψ elastic cross section at low W and $R = \sigma_L/\sigma_T$ as a function of Q^2.

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