The Contribution of Regge Cuts on π^0 Photoproduction from Complex Nuclei within 4 to 12 GeV

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Abstract. The contribution of Regge cuts on the incoherent π^0 photoproduction cross section from complex nuclei is investigated at forward angles within 4 to 12 GeV. The calculations are performed using two different parameterizations (with and without Regge cuts) for the elementary photoproduction cross section and the multi-collisional intranuclear cascade model (MCMC) to address the nuclear effects. The results indicate that the influence of the Regge cuts is negligible and the nuclear cross section (shape and magnitude) is strongly constrained by short range correlations and meson-nucleus Final State Interactions.

Keywords: Meson photoproduction, intranuclear cascade model, Regge model, nuclear matter, meson-nucleus final state interactions
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THE ELEMENTARY PHOTOPRODUCTION CROSS SECTION

The elementary π^0 photoproduction mechanism ($\gamma + N$ —> $\pi^0 + N$) for low momentum transfer and photon energies typically above 4 GeV can be described in terms of vector meson exchange (VMD) using t-channel helicity amplitudes [1-3]:

$$\frac{d\sigma_n}{d\Omega} = \frac{p_*^2}{\pi}\frac{d\sigma_n}{dt} = \frac{p_*^2}{32\pi^2}\left\{\frac{F_3^2}{2m_N^2} - \left[t + \left(\frac{\mu^2}{2k_*}\right)^2\right]\left[\frac{F_1^2}{4m_N^2} + \frac{F_3^2}{16m_N^4} + \frac{F_1F_3}{2m_N p_*\sqrt{s}}\right]\right\}, \quad (1)$$

where p_* and k_* are the meson and photon momentum, respectively, in the center of mass of the s-channel with m_N and μ representing the nucleon and meson masses. The helicity amplitudes F_1 and F_3 are calculated assuming ρ and ω exchange plus the Reggeon cuts ($F_1 \rightarrow F_1^{\rho} + F_1^{\omega} + F_1^{cut}$; $F_3 \rightarrow F_3^{\rho} + F_3^{\omega} + F_3^{cut}$), as described elsewhere [4]. The corresponding amplitudes are given by:

$$F_1^{\rho,\omega}(s,t) = \frac{\sqrt{2}}{m_N}\gamma_1^{\rho,\omega}\frac{1-e^{-i\pi\alpha(t)}}{\sin[\pi\alpha(t)]}\alpha(t)[1+\alpha(t)][2+\alpha(t)]\left(\frac{s}{s_0}\right)^{\alpha(t)-1}, \quad (2)$$

$$F_1^{\rho,\omega}(s,t) = \frac{\sqrt{2}}{m_N}\gamma_1^{\rho,\omega}\frac{1-e^{-i\pi\alpha(t)}}{\sin[\pi\alpha(t)]}\alpha(t)[1+\alpha(t)][2+\alpha(t)]\left(\frac{s}{s_0}\right)^{\alpha(t)-1}, \quad (3)$$

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$$F_1^{cut}(s,t) = \frac{\sqrt{2}}{m_N}\gamma_1^{cut}\frac{1-e^{-i\pi\alpha(0)}}{\sin[\pi\alpha(0)]}\left(\frac{s}{s_0}\right)^{\alpha(0)-1}\frac{e^{at}}{\ln(s/s_0)}, \tag{4}$$

$$F_3^{\rho,\omega}(s,t) = \frac{2\sqrt{2}}{m_N}t\gamma_3^{\rho,\omega}\frac{1-e^{-i\pi\alpha(t)}}{\sin[\pi\alpha(t)]}\alpha(t)[1+\alpha(t)][2+\alpha(t)]\left(\frac{s}{s_0}\right)^{\alpha(t)-1}, \tag{5}$$

$$F_3^{cut}(s,t) = 2\sqrt{2}\gamma_3^{cut}\frac{1-e^{-i\pi\alpha(0)}}{\sin[\pi\alpha(0)]}\left(\frac{s}{s_0}\right)^{\alpha(0)-1}\frac{e^{at}}{\ln(s/s_0)}. \tag{6}$$

The Regge trajectory was taken as $\alpha_{\rho,\omega}(t) = 0.45+0.9t$, with $s_0 = 1.0$ GeV^2. The parameters $\gamma_1 = \gamma_1^{\rho} + \gamma_1^{\omega} = 127.2(15)\sqrt{\mu b}$, $\gamma_3 = \gamma_3^{\rho} + \gamma_3^{\omega} = 61.6(17)\sqrt{\mu b}$, $\gamma_1^{cut} = 33.88(65)\sqrt{\mu b}$, $\gamma_3^{cut} = 10.23(23)\sqrt{\mu b}$/GeV and $a = 0.668(12)$ GeV^{-2} were obtained by fitting the available data of π^0 photoproduction from the proton. The Coulomb amplitude (added constructively on the spin non-flip F_1 amplitude) was taken from [3] with $\Gamma_{\pi 0 \to \gamma\gamma} = 7.7$ eV [5]. The results of the Regge model including the Reggeon cuts (Model 1) are presented in Fig. 1 and reproduce reasonably well ($\chi^2/n.d.f. = 1.52$) the datasets from DESY [4] and SLAC [6] in the whole range of photon energies and momentum transfer.

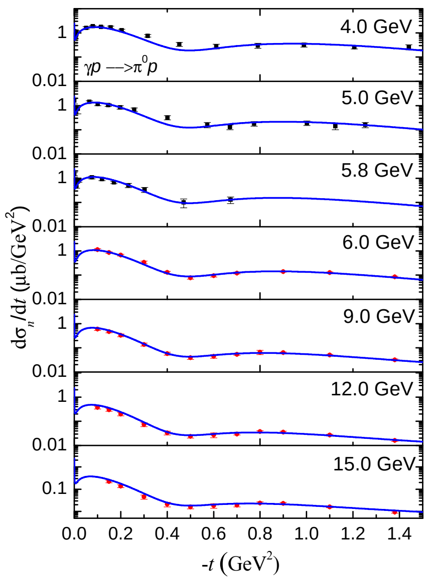

FIGURE 1. Differential cross section for π^0 photoproduction on the proton. The blue lines represent our Regge model including the Reggeon cuts (Model 1). The data points are from DESY [4] (squares) and SLAC [6] (triangles).

However, in order to investigate the influence of the Regge cuts on the complex nuclei cross section, a separate fitting (Model 2) was proposed taking into account only the pole contributions ($F_1 \rightarrow F_1^{\rho} + F_1^{\omega}$; $F_3 \rightarrow F_3^{\rho} + F_3^{\omega}$). With this approach, the F_1 amplitude goes to zero at zero momentum transfer. Fig. 2 presents the results of the Regge model for two different photon energies in comparison with our previous fitting. The data at extreme forward angles $|t| < 0.005$ GeV^2 and at larger momentum transfer $|t| > 0.3$ GeV^2 are omitted in this second fitting.

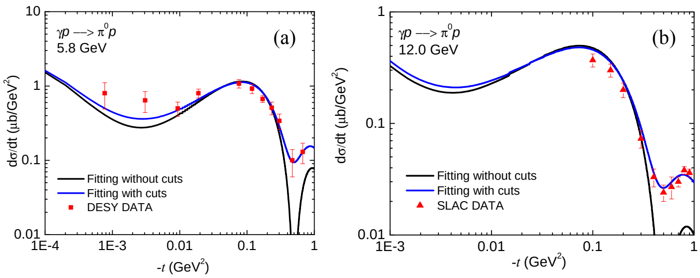

FIGURE 2. Differential cross section (data points) for π^0 photoproduction on the proton from DESY [4] at 5.8 GeV (a) and SLAC [6] at 12 GeV (b). The blue/black lines represent our Regge model with/without the Reggeon cuts. The fitted parameters of Model 2 are $\gamma_1 = 132.7\sqrt{\mu b}$ and $\gamma_3 = 62.65\sqrt{\mu b}$.

INCOHERENT PHOTOPRODUCTION CROSS SECTION FROM COMPLEX NUCLEI: THE CASCADE APPROACH

The incoherent photoproduction cross section from complex nuclei is obtained distributing the neutral pion polar angle in accordance with Models 1 and 2 and running the cascade model MCMC for the evaluation of the nuclear effects. The model consists of a time-dependent multi-collisional algorithm [1-3] that incorporates the following features: i) relativistic kinematics, ii) the inclusion of the meson photoproduction mechanism within 4.0 to 12.0 GeV via two different Regge models (Model 1 and 2), iii) the incorporation of accurate momentum distributions for light nuclei taken from nucleon knock-out reactions, iv) a rigorous non-stochastic Pauli-blocking both for the photoproduction and binary meson-nucleon scatterings, v) photon shadowing effects using a VMD model with vector meson formation time constraint, vi) a consistent analysis of the meson-nucleus FSI via a multiple scattering framework, and vii) the inclusion of realistic (diffractive) angular distributions for the meson-nucleon elastic scattering. A more comprehensive and detailed description of the cascade model both for π^0 and η photoproduction from complex nuclei will be provided shortly [7].

The results for the incoherent π^0 photoproduction cross section from Carbon at 5.2 GeV are presented in Fig. 3 for the two different elementary photoproduction models. It is clearly evident from Fig. 3 (b) that the huge difference between Models 1 and 2 for higher momentum transfer (Fig. 2) does not reflect any substantial change in the shape and magnitude of the nuclear cross section. Such result indicates that the nuclear cross section is highly dependent on the nuclear effects and is not very sensitive to the photoproduction model, provided the structure on the proton data around $|t| \sim 0.1$ GeV^2 is properly described (see Fig. 2). The short range correlations drastically suppress the cross section for low polar angles and dictate its shape, while the effects of FSI and photon shadowing typically govern its magnitude.

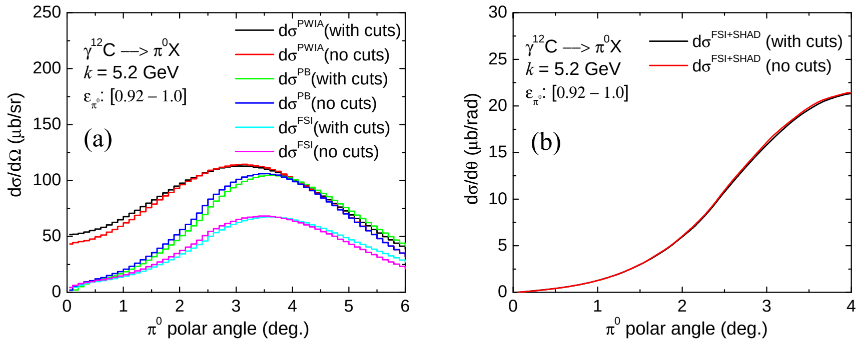

FIGURE 3. Nuclear incoherent π^0 photoproduction cross section from Carbon at 5.2 GeV. The left plot (dσ/dΩ) presents the results of the PWIA (black/red), with Pauli-blocking (green/blue), and with Pauli-blocking and FSI (cyan/magenta) for the corresponding Regge model with/without cuts. The right plot (dσ/dθ) represents the final result from the cascade model also including the photon shadowing with (black) and without (red) the Reggeon cuts. The calculations consider an elasticity cut on the pion energy of 0.92.

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