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Vector mesons polarization versus color transparency

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Abstract. Vector mesons $V = \rho, \omega, \varphi$ can be transversely (helicity $\lambda = \pm 1$) or longitudinally ($\lambda = 0$) polarized. Can vector mesons polarization influence on their interaction with nucleons and nuclei?
The meson-nucleon total cross sections can be extracted by measuring the absorption of mesons in production off nuclei as the nuclear absorption depends on the meson-nucleon total cross section and consequently on the vector meson polarization. Latter on I will discuss the possibility of difference in interaction of transverse and longitudinally polarized vector mesons with nucleons and experiments in which such difference can be detected.

1 Introduction

For many years the vector mesons $V(\rho, \omega, \varphi)$ electroproduction off nuclei has been considered as an effective tool to study the effect of color transparency (CT) (see e.g. [1]). The idea of CT is that hadron produced in certain hard-scattering processes will have a reduced probability of interaction in nuclear matter due to his smaller size compared with the physical hadron. Manifestation of the CT would be an increase in the value of the nuclear transparency defined as $Tr = \frac{d\sigma_A}{Ad\sigma_N}$, where $d\sigma_A(d\sigma_N)$ is the cross section for the process from nuclei target (free nucleon) in production. The CT effect can be understood within the dipole approach [2, 3] , where it is a result of small quark-antiquark dipole interaction with matter. In the hadronic basis this effect is the consequence of Gribov inelastic screening leading to weakening of interaction in nuclei [4].
On the other hand there is another mechanism of weakening of strong interaction as a result of its possible dependence on the polarization of vector meson. The vector meson scattering amplitude off nucleon at zero angle averaged over nucleon spin is determined by two quantities: $\sigma'_T = \sigma_T(1 - i\alpha_T)$ and $\sigma'_L = \sigma_T(1 - i\alpha_L)$, where $\sigma_{T(L)}$ is the total cross section for interaction of a transversely (longitudinally) polarized vector meson with nucleon and $\alpha_{T(L)} = Ref_{T(L)}(0)/Imf_{T(L)}(0)$ is the ratio of the real to imaginary part of the corresponding amplitudes at zero angle. The knowledge of these quantities is crucial for different models. For instance the naive quark model predicts $\sigma_T = \sigma_L$, whereas as it has been discussed later there are experimental indications and theoretical calculations which show that strong interaction of longitudinally polarized vector mesons with nucleons is much weaker than interaction of transversely polarized vector mesons.
In the figure 1 the dependence of nuclear transparency on the virtuality of photon Q^2 in ρ mesons electroproduction on two nuclei is depicted. With increasing of Q^2 the mesons absorption in nuclei decreases which usually has been interpreted as manifestation of CT effect.
On the other hand as it is seen from figure 2 with increasing Q^2 the fraction of longitudinally polarized

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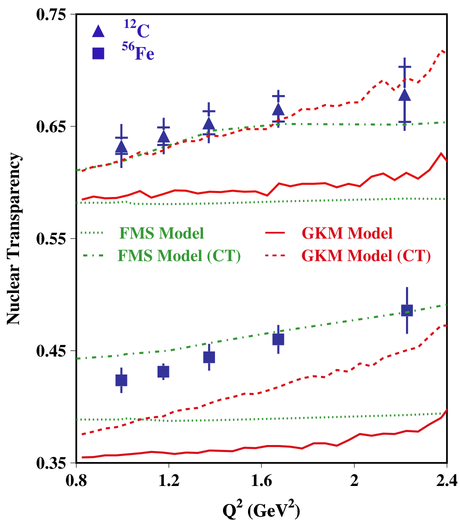

Figure 1. Nuclear transparency as a function of Q^2. Experimental data are from CLAS, JLab [5].

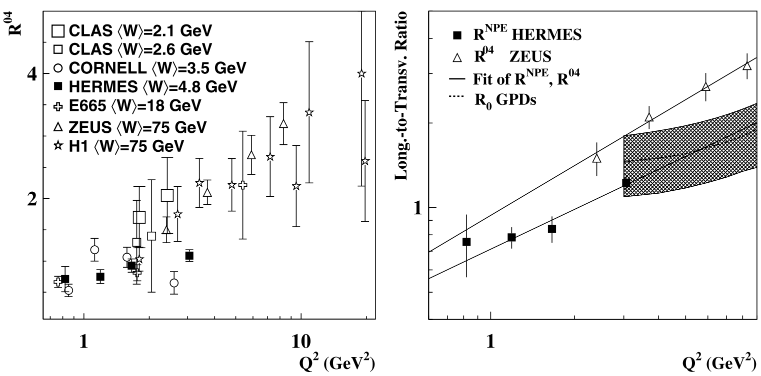

Figure 2. Q^2 dependence of the ratio $R = \sigma_L(\gamma^* p \to \rho p)/\sigma_T(\gamma^* p \to \rho p)$ for exclusive ρ^0 production on proton [6].

vector mesons also grows and if for instance $\sigma_T(VN) \gg \sigma_L(VN)$ the effect of absorption weakening with Q^2 is not a result of CT but at least partially is due to the difference between interaction of longitudinal and transverse vector mesons with nucleons.

2 The vector mesons polarization impact on their interaction with nucleons.

The first indication that interactions of vector mesons with nucleon can depend on its polarization come from the ρ and φ electroproduction on protons [7]. The ratio of the production cross section can be represented as $R = \frac{\sigma(\gamma_L p \to V p)}{\sigma(\gamma_T p \to V p)} = \xi^2 \frac{Q^2}{m_\rho^2}$, where the parameter ξ is the ratio of longitudinal to

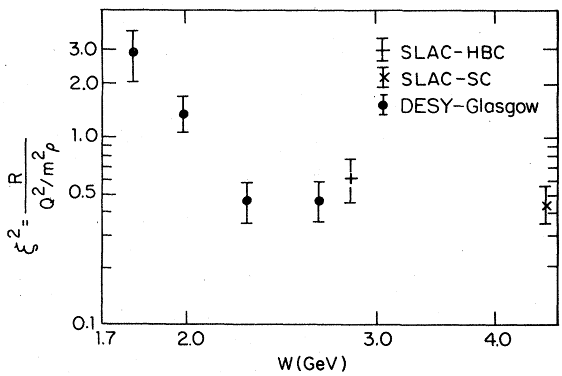

Figure 3. The dependence of the ξ^2 on invariant energy $W = \sqrt{s}$

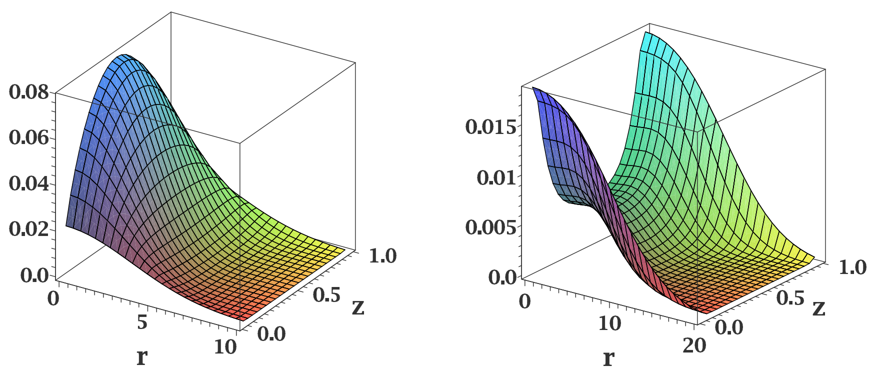

Figure 4. The two dimensional plots in z and r. Quarks distribution in longitudinally polarized ρ^0 meson (left) In transversely polarized one (right).

transverse ρ^0 total cross sections $\xi = \frac{\sigma_L(\rho p)}{\sigma_T(\rho p)}$. In the figure 3 the dependence of this ratio is shown and as it seen above the resonance region $\xi \approx 0.7$. The same quantity for φ meson: $\xi^2 = 0.33 \pm 0.08$. From theoretical point of view the possible difference between transverse and longitudinal cross sections is the result of different distribution of quarks in vector mesons depending on their polarizations. This effect takes place both for valence quarks distribution [8] and the distribution of constituent quarks [9, 10]. The distributions of constituent quarks in ρ^0 mesons for transverse and longitudinal polarizations as a function of transverse distance r between two quarks and z -the share of the vector meson light-cone momentum carried by quark are shown in the figure 4. One can see that quarks distribution in vector meson is very different for different polarizations [9, 10].

3 ω mesons photoproduction of nuclei.

Recently we proposed [11, 12] to measure the ω mesons photoproduction on a set of nuclei at photons energies $5GeV \leq E_\gamma \leq 10GeV$ available at Jefferson Lab. The deal is that incoherent photoproduction

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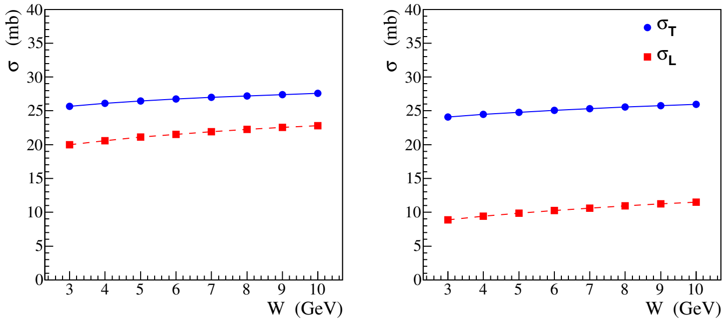

Figure 5. ρ meson total cross section with nucleon in two different parameterizations for vector meson wave function. a) Boosted Gaussian [13] (left) b) Light-cone relativistic model [9](right).

of ω mesons off nuclear targets is a unique way to get information on the possible dependence of strong interaction on the polarization of vector particle.
Unlike the photoproduction of ρ, φ mesons, which at moderate transfer momenta produced mainly transversely polarized (S-channel helicity conservation) the essential part of ω's in photoproduction are longitudinally polarized due to the significant contribution of pion-exchange in considered energy range [7].
From coherent photoproduction one can extract only the transverse cross section $\sigma'_T(\omega N) = \sigma_T(1 - i\alpha_T)$ as the pion exchange contributions from different nucleons cancel each other leading to photoproduction of only transversely polarized mesons. On the other hand in the incoherent photoproduction off nuclei where the ω mesons of both polarizations can be produced one can obtain the important information on longitudinal cross section.
The current quark models [13], [9] predict the considerable difference between total cross sections $\sigma_L(VN), \sigma_T(VN)$ whose dependence on invariant energy $W = \sqrt{s}$ is depicted in the figure 5.
As it was mentioned above the decrease of vector mesons absorption with rising Q^2 in electroproduction off nuclei is commonly interpreted as CT manifestation [5] can be a result of diminished cross section for longitudinally polarized vector mesons as their yield grows with photon virtuality Q^2. On the other hand the effect of color transparency is absent in vector mesons photoproduction at moderate transfer momenta. As a result the vector mesons production by real photons has an essential advantage compared to production by virtual photons.
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