

The impact of vector mesons polarization on meson-nucleon interaction.

Sergey Gevorkyan

LHEP, Joint Institute for Nuclear Research

E-mail: gevs@jinr.ru

Abstract. Production of unstable particles off nuclei allows to determine the total cross section of the unstable particle interaction with nucleons. The interaction of vector mesons $V(\rho, \omega, \phi)$ with nucleons are defined by a set of amplitudes corresponding to the transverse polarization of the vector meson (helicity $\lambda = \pm 1$) meson or longitudinal one ($\lambda = 0$). Whereas the total cross section for the interaction of the transversely polarized vector meson with nucleon $\sigma_T = \sigma(V_T N)$ can be extract from the coherent photoproduction, measurements of vector meson photoproduction in the incoherent region provide a unique opportunity to obtain the not-yet-measured total cross section for longitudinally polarized vector meson interaction with nucleon $\sigma_L = \sigma(V_L N)$.

As a good tool for such investigation we proposed the photoproduction of ω mesons on the set of nuclei in the incoherent region. Such experiment can be done using the feasibility of the new experiment GlueX at Jefferson Lab, designed to study the photoproduction of mesons in a large beam energy range up to 12 GeV.

1. Introduction

In the late 60's and early 70's many experiments on vector mesons $V(\rho, \omega, \phi)$ photoproduction off nuclei have been done [1] at SLAC, DESY, Cornell etc., allowed to check the predictions of vector dominance model and quark model, which for instance predict $\sigma(\rho N) = \sigma(\omega N) = \frac{\sigma(\pi^+ N) + \sigma(\pi^- N)}{2}$. At that time the challenge of impact of vector meson polarization on its interaction with nucleons has not been considered as the naive quark model predicts that $\sigma_T(VN) = \sigma_L(VN)$. Moreover in the coherent photoproduction which is huge and has clear and unique theoretical predictions only transverse vector mesons can be produced. As to the incoherent region to extract $\sigma_L(VN)$ one has to pick out the process, where the bulk of longitudinally vector mesons produced, which is not the case for ρ, φ photoproduction where s-channel helicity conservation takes place at moderate momenta transfer.

The first indications that interaction of vector meson with nucleon depends on its polarization come from ρ and φ electroproduction off protons [1]. The ratio of the production cross section can be represented as $R = \frac{\sigma(\gamma_{LP} \rightarrow V_{LP})}{\sigma(\gamma_{TP} \rightarrow V_{TP})} = \xi^2 \frac{Q^2}{m_p^2}$, where the parameter ξ^2 corresponds to the ratio of longitudinal to transverse ρ^0 nucleon total cross sections $\xi^2 = \frac{\sigma_L(\rho p)}{\sigma_T(\rho p)}$. As one can see from Fig.1a this ratio is $\xi \approx 0.5$, whereas for φ meson: $\xi^2 = 0.33 \pm 0.08$



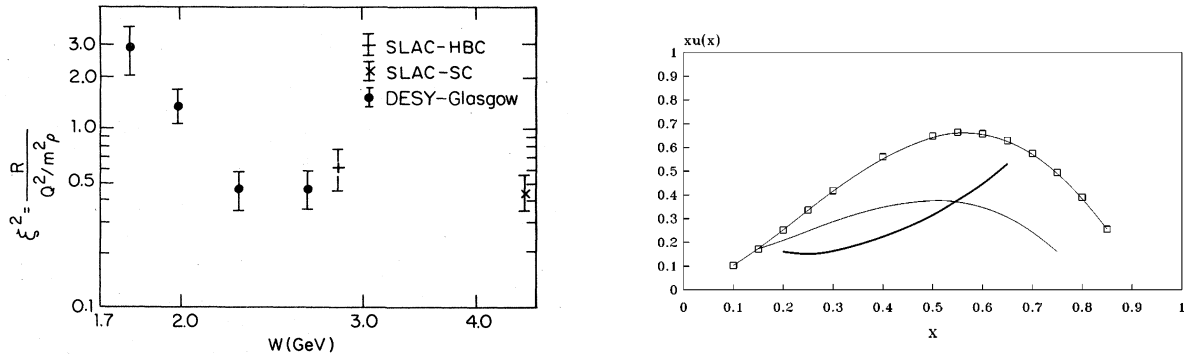


Figure 1. a) The ratio of longitudinal to transverse cross sections as a function of total cms energy; b) The valence quarks distribution in the ρ meson as a fraction of the light-cone momentum: $\square$ - the longitudinally polarized meson, the transversely polarized meson (thick line), the pion (thin line).

At present it is known that valence quarks distribution in the transversely and longitudinally polarized vector mesons are significantly different [2] (see Fig.1b). The same distinction takes place [3] for the distribution of constituent quarks in vector mesons as depicted on the Fig.2. These differences lead to impact of vector mesons polarization on their interaction with matter [4].

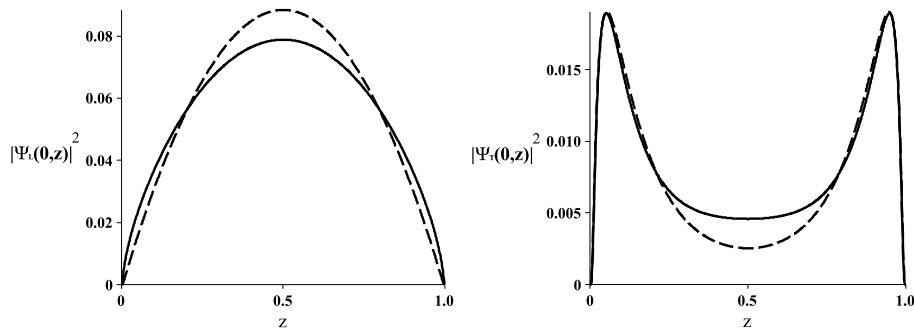


Figure 2. The longitudinal (left) and transverse (right) ρ meson light-cone wavefunctions squared at $r=0$ as a function of light-cone momentum x .

The dependence of the vector particle interaction on its polarization has been known for many years in the case when the constituents of the particle are in the D-wave state. A good example of such effect is the deuteron interaction with matter [5]. The D-wave component in the deuteron wave function leads to different absorption for transversely and longitudinally polarized deuterons. Recently this effect was experimentally measured [6]. There are also predictions that the interaction of mesons with nonzero orbital momentum with nucleons is strongly correlated with the meson polarization [7, 8]. On the other hand for ground-state S-wave vector mesons as ρ, ω, φ the D-wave component in their wave functions can emerge as a result of the Lorentz transformation [9].

As a good tool to obtain the information on the σ_L we propose the measurement of the ω mesons incoherent photoproduction on nuclei [10]. The deal is that in *omega* photoproduction

at photon energies $4\text{GeV} \leq E_\gamma \leq 10\text{GeV}$ due to pion exchange appreciable amount of longitudinally polarized ω 's can be produced. While in coherent photoproduction only transversely polarized mesons can be produced (the pion exchange leads to different signs of the photoproduction amplitudes on protons and neutrons which lead to reduction of pion exchange), the photoproduction in the incoherent region allows one to extract the σ_L from their absorption in the matter.

The photoproduction of ω mesons with different polarizations on nuclei in the reaction

$$\gamma + A \rightarrow \omega + A' \quad (1)$$

where A' denotes the excitation of the target nucleus or its break-up products. Generalizing the Glauber multiple scattering theory for potentially different absorptions of transversely and longitudinally polarized mesons [10] the incoherent cross section reads:

$$\begin{aligned} \frac{d\sigma_A(q)}{dt} &= \frac{d\sigma_0(q)}{dt} (\rho_{00} N(0, \sigma_L) + (1 - \rho_{00}) N(0, \sigma_T)) \\ N(0, \sigma) &= \int \frac{1 - \exp(-\sigma \int \rho(b, z) dz)}{\sigma} d^2b, \end{aligned} \quad (2)$$

where $d\sigma_0(q)/dt$ is the differential cross section of the ω meson photoproduction on nucleon, $\sigma_{T,L}$ is the total ω -nucleon cross section for longitudinally and transversely polarized mesons, and ρ_{00} is the ω meson spin density matrix element defining the fraction of longitudinally polarized ω mesons. If $\sigma_T = \sigma_L$ the nuclear transparency has the well known form $A_{\text{eff}} = \frac{d\sigma_A}{dt} / \frac{d\sigma_0(q)}{dt} = N(0, \sigma)$. Spin density matrix elements for photoproduction on nuclei ρ_{00}^A and nucleons ρ_{00} are related as:

$$\rho_{00}^A = \frac{N(0, \sigma_L)}{\rho_{00} N(0, \sigma_L) + (1 - \rho_{00}) N(0, \sigma_T)} \rho_{00} \quad (3)$$

In the case of $\sigma_T = \sigma_L$ the spin density matrix elements on nuclei and nucleon coincides $\rho_{00}^A = \rho_{00}$. For $\sigma_T \neq \sigma_L$ ρ_{00}^A should depend on the nuclear mass number A .

On Fig.3 the A -dependence of nuclear transparency A_{eff} and spin density matrix element ρ_{00}^A at the value of $\sigma_T = 26\text{mb}$ and two values of σ_L are shown. The calculations have been done in the framework of more elaborated version of multiple scattering theory than considered above which leads to the energy dependence of nuclear transparency and ω meson spin density matrix elements on nuclei (for details see [10]).

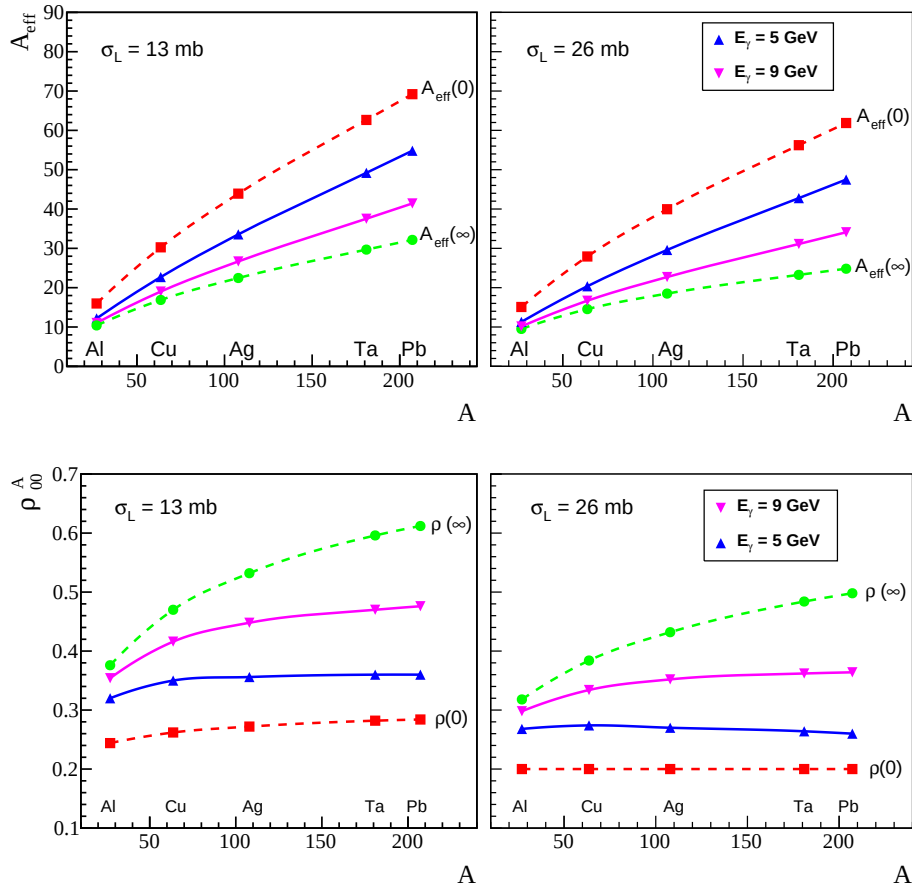


Figure 3. The A-dependence of the nuclear transparency and spin density matrix element.

Thus the measurement of the photoproduction cross section and omega meson spin density matrix elements in the incoherent region ($|t| \geq 0.1$ GeV) will allow to determine the total cross section of longitudinally polarized vector mesons with nucleons $\sigma_L(\omega N)$ and thus shed light on the exciting challenge of impact of vector meson polarization on strong interactions.

Let us note that neither the absorption of longitudinally polarized mesons, nor the spin density matrix elements on nuclei in the photoproduction have been measured so far.

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