$(\gamma, \omega p)$ reaction in the nucleus

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The study of the vector meson dynamics in the nuclear reaction has drawn considerable attention at present days. Large medium modification of the ρ meson was indicated first in the enhanced dilepton yield (between 300 and 700 MeV) in CERES and HELIOS ultra-relativistic heavy ion collision data taken sometime around 1995 in CERN-SPS [1]. Almost after a decade, the STAR experiment at RHIC, BNL [2] found a decrease in ρ meson mass in the analysis of the $\pi^+\pi^-$ production data from the peripheral Au+Au collisions. However, the upgraded CERES experiment [3] as well as the dimuon measurements (in the In-In collision) in the NA60 experiment at CERN [4] showed considerable broadening in the ρ meson mass distribution spectrum with no change in the peak position.

The modification of the ρ meson in the normal nucleus also has been reported by various measurements. For example, the KEK-PS E325 collaboration at KEK [5] found enhancement in the e^+e^- yield (in the p+A reaction at 12 GeV) in the low-mass side of the vector meson resonant peak. This enhancement is understood due to the reduction of ρ meson mass in the nucleus. The TAGX collaboration [6] did an experiment on ^{3}He$(\gamma, \pi^+\pi^-)$X reaction in the sub-threshold ρ meson production region, and they reported large decrease in the ρ meson mass. The ρ meson polarization experiment in this collaboration [7] corroborates this finding. The recent results from TJNAF on the (γ, e^+e^-) reaction show the broadening of ρ meson width in the nucleus. The status of this topic is summerized in Ref. [8].

Sometime back, the CBELSA/TAPS collaboration reported ω meson mass modification in the $(\gamma, \pi^0\gamma)$ reaction on the Nb nucleus [9] for $0.2 < k_\omega(\mathrm{GeV/c}) < 0.4$. However, this claim is no longer valid, as the reanalysis of the data could not reproduce the shape reported in [9]. According to them, the exclusive process, i.e., $\gamma A \to \pi^0\gamma p B$, would be better to investigate the ω meson dynamics in the nucleus, since the background problem could be minimize in this reaction.

We have started developing the formalism for the exclusive reaction: $\gamma A \to \pi^0\gamma p B$. In the photonuclear reaction in GeV region, the $\pi^0\gamma$ event in the final state, as we have shown in Ref. [10], occurs dominantly due to $\omega \to \pi^0\gamma$. Therefore, we envisage the mechanism for this reaction as $\gamma A \to \omega p B$; $\omega \to \pi^0\gamma$.

The T-matrix for the exclusive ω meson photoproduction reaction, as mentioned above, can be written as

$$T_{fi} = \Gamma_{\pi^0\gamma} S_\omega(\mathbf{r}' - \mathbf{r}) < \omega p B|\Pi(\mathbf{r})|\gamma A >, \quad (1)$$

where $\Gamma_{\pi^0\gamma}$ describes the ω meson decay: $\omega \to \pi^0\gamma$. It is governed by the $\mathcal{L}_{\omega\pi\gamma}$ Lagrangian density. $\Pi(\mathbf{r})$ is the generalised potential for the $\gamma A \to \omega p B$ process. The ω meson propagator $S_\omega(\mathbf{r}' - \mathbf{r})$ is represented by the eikonal form [11]:

$$G_\omega(\mathbf{r}' - \mathbf{r}) = \delta(\mathbf{b}' - \mathbf{b})\Theta(z' - z) e^{i\mathbf{k}_\omega \cdot (\mathbf{r}' - \mathbf{r})} D_{\mathbf{k}_\omega}(\mathbf{b}, z', z), \quad (2)$$

where $D_{\mathbf{k}_\omega}(\mathbf{b}, z', z)$ describes the nuclear medium effect on the properties of ω meson during its passage through the nucleus. The form for it is given by

$$D_{\mathbf{k}_\omega}(\mathbf{b}, z', z) = \frac{-i}{2k_{\omega\|}} e^{\left[\frac{i}{2k_{\omega\|}} \int_z^{z'} dz'' \tilde{G}_\omega^{-1}(m; \mathbf{r}'')\right]}, \quad (3)$$

with $\tilde{G}_\omega^{-1}(m; \mathbf{b}, z'') = m^2 - m_\omega^2 + i m_\omega \Gamma_\omega(m) - 2E_\omega V_{O\omega}(\mathbf{b}, z'')$. $V_{O\omega}(\mathbf{b}, z'')$ represents the ω meson nucleus optical potential. In fact, this potential accounts for the modification of ω

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meson in the nuclear medium. m_ω and $\Gamma_\omega(m)$ represent the resonant mass and total free space decay width for the ω meson, discussed in Ref. [10].

The wave function for photon is described by the plane wave. The distorted wave function $\chi^{(-)}(\mathbf{k}_{\pi^0}, \mathbf{r}')$ for the π^0 meson in the final state is represented by the eikonal form [11, 12]:

$$\chi^{(-)*}(\mathbf{k}_{\pi^0}, \mathbf{r}') = e^{-i\mathbf{k}_{\pi^0}\cdot\mathbf{r}'} D^{(-)*}_{\mathbf{k}_{\pi^0}}(\mathbf{b}, z'). \quad (4)$$

The factor $D^{(-)*}_{\mathbf{k}_{\pi^0}}(\mathbf{b}, z')$ accounts for the distortion arising due to the π^0 meson scattering on the recoil nucleus. The form for it is

$$D^{(-)*}_{\mathbf{k}_{\pi^0}}(\mathbf{b}, z') = e^{\left[\frac{-i}{v_{\pi^0\parallel}} \int_{z'}^{\infty} dz_1 V_{O\pi^0}(\mathbf{b}, z_1)\right]}, \quad (5)$$

where v_{π^0} is the velocity of pion. $V_{O\pi^0}(\mathbf{b}, z_1)$ denotes the optical potential for the pion nucleus scattering in the final state.

Further developement of this work will be continued.

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