Study of ρ^0 and ω mesons interference through $\pi^0\gamma$ channel in γ-^{4}He reaction

Swapan Das*
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA
** email:swapand@barc.gov.in*

Photon in the GeV region shows hadronic behavior instead of showing its own electro–magnetic properties. This occurs since the photon possesses the virtual quark-antiquark pair and this pair acts as ρ meson, ω meson … etc. when it interacts with a hadron or nucleus.

The mechanism of the $e^+e^-\to\pi^+\pi^-$ reaction, studied in past, is understood as $e^+e^- \to \gamma \to V(\rho,\omega) \to \pi^+\pi^-$. The symbol V addresses either ρ or ω. The dominant contribution to the cross section of the $e^+e^-\to\pi^+\pi^-$ reaction arises due to the decay of ρ meson. The interference of ρ and ω mesons is needed to consider to reproduce the data. This study describes well the pion form factor. The values of the ρ-ω mixing parameter, the γ-ρ and γ-ω coupling constants, … etc. were extracted from the study of the above reaction.

The signature of the ρ and ω mesons interference is also seen in the dilepton production in the photo-nuclear reaction in the multi-GeV region: $\gamma+A \to V(\rho,\omega)+A$; $V\to e^+e^-$. Various quantities, such as γ-V coupling constants, relative phase of the ρ-ω photo-production amplitude, were also extracted from these reactions. The ρ-ω meson interference was also studied in the double pion ($\pi^+\pi^-$) photo-production reaction on a nucleus.

It should be mentioned that though the ρ and ω mesons interference is studied in the hadronic and leptonic channels, it is not done yet for the semi-hadronic (or semi-leptonic) channel, i.e., $\pi^0\gamma$ for example. Recent past, the mechanism of the correlated $\pi^0\gamma$ emission in the photo-nuclear reactions (in the GeV region) were studied in context to investigate the medium modification of the ω meson in nuclei [1,2]. However, the contribution of the ρ meson to this channel is never considered.

We, therefore, study the ρ-ω meson interference in the photo-nuclear reaction through the $\pi^0\gamma$ channel: $\gamma+A\to V(\rho,\omega)+A$; $V\to \pi^0\gamma$. The formalism of this reaction consists of three parts: (i) the production of the V meson in the nucleus, (ii) the propagation of this meson through the nucleus, and (iii) the decay of V meson either inside or outside the nucleus.

The production of the $V(\rho,\omega)$ meson in the photo-nuclear reaction is described by the measured amplitude of the elementary reaction: $\gamma+p\to V+p$, folded with the measured nuclear density distribution.

The propagation of the V meson is described by the eikonal form. The interaction of this meson with the nucleus is accounted by its optical potential, which is formulated by folding the elementary V-meson nucleon scattering amplitude with the nuclear density distribution. The measured quantities for them are used in the calculation.

The decay of the V meson is addressed by the $V\pi\gamma$ Lagrangian. The π^0 nucleus optical potential is also evaluated as it is done for the V meson. The scattering parameters for the π^0 meson are taken equal to the average of those of π^+ and π^- mesons.

The $\pi^0\gamma$ invariant mass m (i.e., ρ, ω meson mass) distribution spectra have been calculated (in the ϕ=0 plane) at the beam energy E_γ taken equal to 12 GeV. The nucleus considered in the reaction is ^{4}He.

Since we have used light nucleus, the cross section is not expected to be changed much because of the V meson potential V_{OV} and π^0 meson potential $V_{O\pi^0}$. The cross section at the peak is reduced from 25.01 (mb/GeV sr^3) to 23.88 (mb/GeV sr^3) due to V_{OV}. It is further reduced to 21.04 (mb/GeV sr^3) due to $V_{O\pi^0}$. However, there are no change (due to these potentials) in the peak positions which appear at m=0.782 GeV (the mass of ω meson in the free space), see in Fig.1 given below. This occurs since the ω meson (whose natural decay-length is ~23 fm) dominantly decays outside the nucleus.

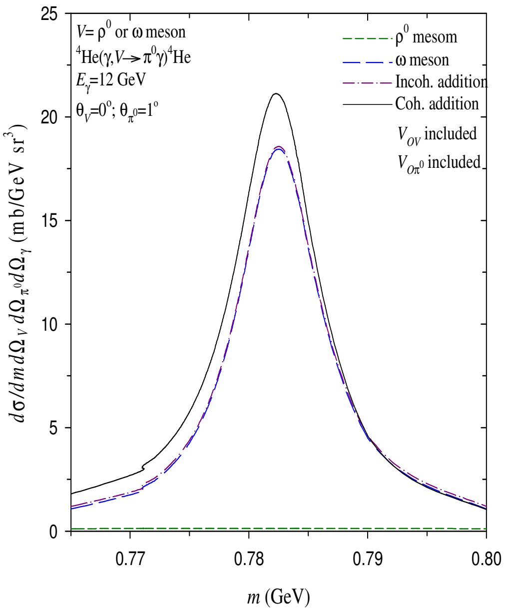

Fig. 1 The $\pi^0\gamma$ invariant mass m distribution spectrum. The V(ρ,ω) meson potential V_{OV} and the π^0 meson potential $V_{O\pi^0}$ are included in the calculated results.

The calculated cross sections for the $\pi^0\gamma$ invariant mass distribution are presented in Fig.1. It shows that the distinctly dominant contribution to the cross section arises due to the ω meson (see long dashed curve). The contribution of the ρ meson to the cross section is negligibly small (short dashed curve) compared to that due to ω meson. Therefore, the incoherent contribution to the cross section (dot-dashed curve) due to these mesons does not show any difference from that due to ω meson only.

The coherently added cross section due to ρ and ω mesons are presented by the solid curve in Fig.1. The enhancement in the cross section due to the ρ-ω meson interference is clearly visible in this figure. It is remarkable that the cross section at the peak (appearing in the figure at m equal to 0.782 GeV) is increased significantly (i.e.,~15%) because of the above mentioned interference, where as it is increased drastically, i.e., 30% to 40%, in the region $m \leq 0.775$ GeV. Further development of this work is in progress [3].

References

[1] M. Nanova et al., (CBELSA/TAPS Collaboration) Eur. Phys. J A 47 **16** (2011); ibid, Phys. Rev. C **82** 035209 (2011).

[2] Swapan Das, Phys. Rev. C **83** 064608 (2011).

[3] Swapan Das, in preparation.