Photoproduction of omega meson in the nucleus

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

To look for the medium effect on the ω meson in a nucleus, CBELSA/TAPS Collaboration had done the experiment on the photoproduction of ω meson in the ^{93}Nb nucleus [1]. In this experiment, the tagged photon of energy range 0.64-2.53 GeV had been used to produce the ω meson and this meson was detected by its decay product $\pi^0\gamma$ in the final state. To observe this meson, the dilepton probe, i.e., $\omega\to l^+l^-$, can be thought better since the distortion due to final state interaction would not occur in this process. It must be emphasized that the dilepton signal for the ω meson would be interrupted by the well known ρ-ω interference effect. This interference occurs since the masses of ρ^0(~770 MeV) and ω(~780 MeV) mesons are nearly equal to each other and the width for $\rho\to l^+l^-$ is either comparable or larger than that of the ω meson. In addition, the change in the hadronic properties of ω meson (free-space width Γ_ω~8.43 MeV) could be immersed in the large decay width (Γ_ρ~151 MeV in the free-space) of the ρ meson. Therefore, the extraction of ω meson signal (through the dilepton emission process) would be difficult.

The $\pi^0\gamma$, as a probe, can provide distinct signal for the ω meson photoproduction. The qualitative discussion on this issue can be seen in Ref. [2]. To minimize the distortion due to π^0 nucleus scattering, the data were taken (by CBELSA/TAPS Collaboration) for T_π > 150 MeV. This restriction on the pion energy reduced the final state interaction drastically [1], since it is above the energy region for the pion nucleon strong coupling to Δ excitation. The medium modification of the ω meson has been shown in this measurement for its momentum range: 0.2 < k_ω(GeV/c) < 0.4.

We study the mechanism for the $\pi^0\gamma$ invariant mass distribution in the γ nucleus reaction to understand the data taken by the CBELSA/TAPS Collaboration [1]. According to our formalism, the elementary reaction for the ω meson production in the nucleus is $\gamma N\to\omega N$. Therefore, the ω meson photoproduction in the nucleus is described by the elementary $\gamma N\to\omega N$ reaction amplitude and the density distribution of the nucleus. These quantities are obtained from the measurements.

The ω meson propagates certain distance and decays into $\pi^0\gamma$. It must be mentioned that the ω meson decays through out its passage including both inside and outside the nucleus. The decay for the ω meson inside a nucleus can be described as

$$Y_\omega^{in} = -\frac{i}{2k_{\omega\|}}\int_z^{z_s} dz' D_\pi(\vec{b},z') D_\omega(\vec{b},z'), \quad (1)$$

with

$$D_\pi(\vec{b},z') = \exp[i\delta_\pi(\vec{b},z')] \text{ and}$$

$$D_\omega(\vec{b},z') = \exp\left[\frac{i}{2k_{\omega\|}}\int_z^{z'} dz'' G_\omega^{-1}(m;\vec{b},z'')\right]. \quad (2)$$

In above equations, (**b**,z) is the production point for the ω meson and the decay point for it is denoted by (**b**,z'). z_s is determined from the extension R_s of the nucleus: $z_s = \sqrt{R_s^2 - b^2}$. δ_π(**b**,z') is the phase-shift function for the π^0 scattering on the nucleus. It can be estimated from the experimentally determined $\pi^\pm N$ scattering parameters. $G_\omega(m;\mathbf{b},z)$ denotes the propagator for the ω meson. It is given by

$$G_\omega^{-1}(m;\vec{r}) = G_{0\omega}^{-1}(m) - 2E_\omega V_{O\omega}(\vec{r}), \quad (3)$$

where $G_{0\omega}(m)$ is the ω meson propagator in the free-space. $V_{O\omega}(\mathbf{r})$ represents the optical potential for the ω meson, which can be expressed by folding the elementary ωN scattering amplitude $f_{\omega N}$ with the nuclear density distribution. The energy dependent values for $f_{\omega N}$ (constrained by the measurements) are used to generate $V_{O\omega}(\mathbf{r})$.

The decay for the ω meson outside a nucleus can be illustrated as

$$Y_\omega^{out} = G_{0\omega}(m)\exp\left[\frac{i}{2k_{\omega\|}}G_{0\omega}^{-1}(m)(z_s - z)\right]. \quad (4)$$

The decay of ω meson through out its passage is described by the addition: $Y_\omega = Y_\omega^{in} + Y_\omega^{out}$.

We have calculated the differential cross section $d\sigma/dm$ of the $\pi^0\gamma$ invariant mass m distribution spectrum due to $\omega\rightarrow\pi^0\gamma$ for k_ω(GeV/c) = 0.21-0.39. We present in Fig.1 the calculated relative cross sections for the decay of ω meson inside and outside the nucleus. The cross section distribution due to coherent addition of both is also presented. The Fig.1 exhibits that the ω meson distinctly decays outside the nucleus. Therefore, the medium modification on this meson is hardly possible.

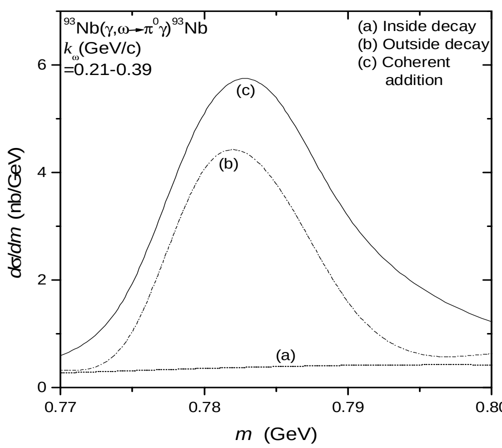

Fig.1 The decay of ω meson inside (a) and outside (b) the ^{93}Nb nucleus. The coherent addition of both (c) is also shown.

It must be mentioned that the detecting system used by CBELSA/TAPS Collaboration [1] had large resolution width (i.e., 55 MeV). It is about 6.5 times larger than the natural width of the ω meson. We incorporate this issue in our calculation by modulating the detector resolution function $R(m,m')$ with the calculated $d\sigma/dm'$, i.e.,

$$\frac{d\sigma}{dm} = \int dm' R(m,m')\frac{d\sigma(m')}{dm'}. \quad (5)$$

$R(m,m')$ is usually expressed by a Gaussian distribution function of width equal to the resolution width of the detector. The form for it is given by

$$R(m,m') = \frac{1}{\varsigma\sqrt{2\pi}}\exp\left[-\frac{(m-m')^2}{2\varsigma^2}\right], \quad (6)$$

with FWHM = 2.35ς = 55 MeV [1].

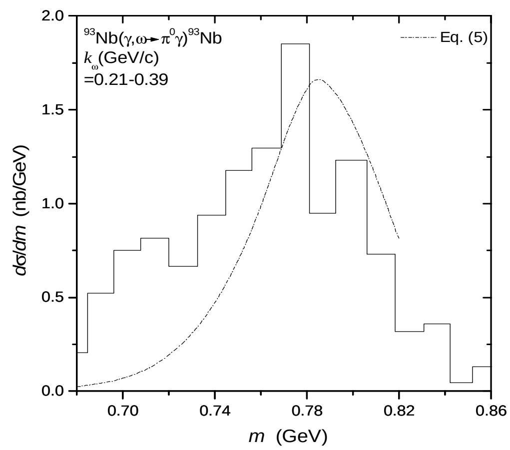

Fig.2 Calculated spectrum (dash dotted line) due to Eq. (5) is compared with the data (histogram).

We compare the calculated cross section due to Eq.(5) with the data in Fig.2 for $0.2 < k_\omega(\text{GeV}) < 0.4$. This figure shows that the calculated results underestimate the cross section in the low mass m region. This is the region where the modification of the omega meson was found in the measurement [1]. The excess in cross section seen in the experiment is unlikely since the omega meson, as shown in Fig.1, dominantly decay outside the nucleus. The reanalysis of the data is going on [3]. Hopefully, this discrepancy will be resolved.

References

[1] D. Trnka et al., (CBELSA/TAPS Collaboration), Phys. Rev. Lett. **94** (2005) 192303.

[2] Swapan Das, Phys. Rev. C **78** (2008) 045210.

[3] V. Metag, private communication.