Modification of the ρ meson with the size of nucleus

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

The modification of the vector meson in the nuclear medium is a publicized issue at present days. First indication of the modification of ρ meson was seen in the ultra-relativistic heavy-ion collision data [1], which were reproduced by the drastic reduction of the mass of this meson. Later results from the ultra-relativistic heavy-ion collision experiments [2] show the broadening of the ρ meson width without its mass-shift.

The in-medium modification of the vector meson can be studied more judiciously, compared to that in the ultra-relativistic heavy-ion collision, in the hadron and photon (electron) induced nuclear reactions in few GeV region. In fact, various laboratories have already reported their findings about the modification of vector mesons in the normal nucleus. KEK-PS E325 collaboration [3] found the reduction of the ρ meson mass in the proton nucleus reaction. The measurements on the transparency ratio had shown the enhancement in the in-medium widths of ω and φ mesons.

CLAS collaboration [4] reported the broadening (without mass-shift) of the ρ meson in the photonuclear reaction. This measurement was carried out at Jefferson Laboratory where the ρ meson of momentum range: k_ρ(GeV/c) = 0.8 - 3.0 is detected by its decay product e^+e^-. It is produced in the nucleus by the tagged γ beam of energy range: 0.61 - 3.82 GeV.

To investigate the mechanism of the reaction mentioned in the previous paragraph, we calculate the differential cross section for the ρ meson mass m, i.e., e^+e^- invariant mass, distribution spectrum. In addition, the calculated results would be used to analyze the data of this reaction. Therefore, we include in the calculation the kinematical constraints imposed in the measurement done at Jefferson Laboratory.

The modification of the vector meson in a nucleus occurs because of their interaction. We construct this interaction or potential using the proposed in-medium parameters of the ρ meson.

There exist model calculations which envisage the reduction of the ρ meson mass in the nuclear environment. For example, QCD sum rule calculation due to Hatsuda and Lee [5] shows that the in-medium mass m^* of ρ meson decreases linearly with the increase in nuclear density distribution $\varrho(\mathbf{r})$:

$$m^*(\mathbf{r}) = m\,[\,1 - 0.18\,\varrho(\mathbf{r})/\varrho(0)\,]. \qquad (1)$$

Based on CLAS experimental results reported for k_ρ(GeV/c) = 0.8-3.0, the nuclear density dependence of Γ^*(r) follows the form given by

$$\Gamma^*(\mathbf{r}) = \Gamma\,[\,1 + \varrho(\mathbf{r})/\varrho(0)\,]. \qquad (2)$$

The in-medium width $\Gamma^*(\mathbf{r})$ weakly varies with the ρ meson momentum.

As mentioned earlier, the modified

mass $m^*(\mathbf{r})$ and width $\Gamma^*(\mathbf{r})$ of the ρ meson in a nucleus arises because of their interaction or potential $V_{O\rho}(\mathbf{r})$. The relation between them can be expressed as

$$\Delta m(\mathbf{r}) = m^*(\mathbf{r}) - m = \gamma_L (E_\rho/m)\, ReV_{O\rho}(\mathbf{r});$$

$$\Delta\Gamma(\mathbf{r}) = \Gamma^*(\mathbf{r}) - \Gamma = - \gamma_L (2E_\rho/m)\, ImV_{O\rho}(\mathbf{r}), \quad (3)$$

where γ_L is the associated Lorentz factor. m and Γ are the mass and width of the ρ meson in free space. The asterisk stands for the in-medium quantities.

The momentum dependence of the ρ meson potential is incorporated by multiplying a function $f(k_\rho)$ with the mass-shift $\Delta m(\mathbf{r})$ of this meson. This function describes the logarithm dependence of the ρ meson potential:

$$f(k_\rho) = -\frac{1}{2}\left[1 + \log\frac{k_\rho}{k_0}\right], \quad (4)$$

with k_0=1 GeV/c.

Using the ρ meson nucleus potential $V_{O\rho}(\mathbf{r})$ evaluated from Eqs.(1)-(4), we calculate the differential cross section for the ρ meson mass distribution spectra of the considered reaction on ^{12}C, ^{56}Fe, and ^{208}Pb nuclei. The radial density distributions $\varrho(\mathbf{r})$ of these nuclei are taken from those determined by the electron scattering experiments. The calculated results are presented in Fig. 1. This figure distinctly elucidates that the width of the ρ meson mass m distribution spectrum increases with the size of the nucleus where as the shift in the peak position is insignificant [6]. This result corroborates qualitatively the finding reported from Jefferson Laboratory [4]. The calculated ρ meson mass distribution spectrum (not shown) are well accord with the respective measured distribution.

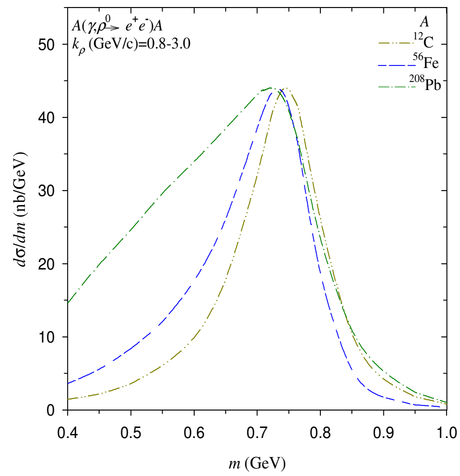

Fig. 1 Broadening of the ρ meson with the size of the nucleus. The short-long-short dash and dot-dash curves are divided by 3.46 and 4.44 respectively.

References

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