ω and ϕ mesons absorption in nuclei

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Introduction

The hadron parameters, such as mass and width, are modified in the dense and/or hot nuclear matter [1]. Particularly, the modification of the V (vector) meson (e.g., V ≡ ρ, ω and ϕ) in the normal nucleus has been drawn considerable attention where the chiral symmetry is predicted to be partially conserved [1]. The use of the electro-magnetic tool for the above study is advantageous, since it does not distort the information about the properties of the vector meson produced in the nucleus.

Amongst the low-lying V mesons (i.e., ρ, ω and ϕ), the free-space decay-length of the ρ meson (~1.3 fm) is less than the nuclear dimension (~$A^{1/3}$). Though this decay-length is modified in the nucleus, the calculated results show the ρ meson is dominantly decays inside the nucleus [2]. The measured ρ meson mass distribution spectra in the (γ, $\rho \rightarrow e^+e^-$) reaction on nuclei, as reported from Jlab [3], illustrates the broadening (without mass-shift) of this meson. The calculated results corroborate this finding [2].

The natural decay-widths of the ω and ϕ mesons are 8.5 MeV and 4.3 MeV respectively, i.e., their decay-lengths are much larger than the nuclear dimension. Therefore, both of these mesons dominantly decay outside the nucleus, showing no change in the pole-mass and width in their mass distribution spectra [4]. However, the information about the in-medium widths of the ω and ϕ mesons can be extracted from their absorption in the nucleus. The in-medium width is given by $\Gamma^* = \Gamma_0 + \Gamma_c$. The previous, i.e., Γ_0, denotes the natural width of the vector meson. The latter is its in-medium width which arises because of the interaction of the V meson with the nucleon (N) in the nucleus. $\Gamma_c \alpha \sigma_t^{*VN}$, where σ_t^{VN} is the total VN scattering cross section in the free-space. The starred quantities denote those in the nucleus.

To disentangle the above issue, the nuclear transparencies of the ω and ϕ mesons in the (γ, $\omega/\phi \rightarrow e^+e^-$) reaction on nuclei have been measured in Jlab [5]. The experimental data for ω meson show that they cannot be reproduced by considering the drastic increase of $\sigma_t^{\omega N}$ in the nucleus (i.e., $\sigma_t^{*\omega N}$=150 mb), where as the ϕ meson transparency data are well reproduced considering the drastic increase of $\sigma_t^{\phi N}$ in the nucleus, i.e., $\sigma_t^{*\phi N}$=70 mb.

Description

The formalism of the (γ, $V \rightarrow e^+e^-$) reaction on a nucleus is developed to calculate the nuclear transparencies of the ω and ϕ mesons in the nucleus. The nuclear transparency is defined as

$$T_A = \sigma_t^{\gamma A}(\text{nucleus})/\sigma_t^{\gamma A}(\text{vacuum}), \quad (1)$$

where the total cross section $\sigma_t^{\gamma A}(\text{nucleus}) \equiv \sigma_t(\gamma A \rightarrow VX;\ V \rightarrow e^+e^-)$. In this equation, A denotes the target nucleus. X represents the nucleus in the final state (not measured). Therefore, $\sigma_t^{\gamma A}(\text{nucleus})$ illustrates the cross section of the inclusive vector meson photo-production reaction in the nucleus. The interaction of V meson with the nucleus is described by the optical potential. The measured scattering parameters α_{VN} and σ_t^{VN} are used to evaluate this potential. α_{VN} is the ratio of the real to imaginary part of the V

meson nucleon scattering amplitude. σ_t^{VN} is defined earlier. $\sigma_t^{\gamma A}$(vacuum) represents the cross section of the quoted reaction where the optical potential is taken equal to zero.

Result and discussions

The nuclear transparency with respect to ^{12}C nucleus, i.e., T_A/T_C, for both ω and ϕ mesons have been calculated for the γ beam energy taken upto 4 GeV, as this range is used in the measurements [5]. The calculated result for the ω meson is presented in Fig.1 along with the data [5]. This figure shows that the calculated transparency is close to the measured value.

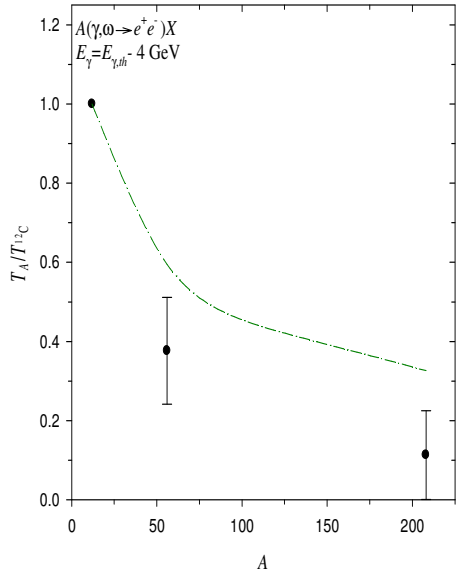

Fig.1 The transparency ratio for the ω meson. *A* is the mass number of the nucleus. $E_{\gamma,th}$ denotes the threshold energy for the ω meson photoproduction in the nucleus.

The calculated transparency ratio for the ϕ meson are compared with the data in Fig.2. It is remarkable that the calculated results reproduce the data very well.

It has been mentioned earlier that the experimentally determined elementary vector meson nucleon scattering cross section, i.e., σ_t^{VN}, has been used instead of considering it as parameter. The calculated results for the nuclear transparency show that the vector meson nucleon scattering cross section in the nucleus is close to that of its free-space value. The incorporation of Fermi motion of the bound nucleon will confirm the above statement.

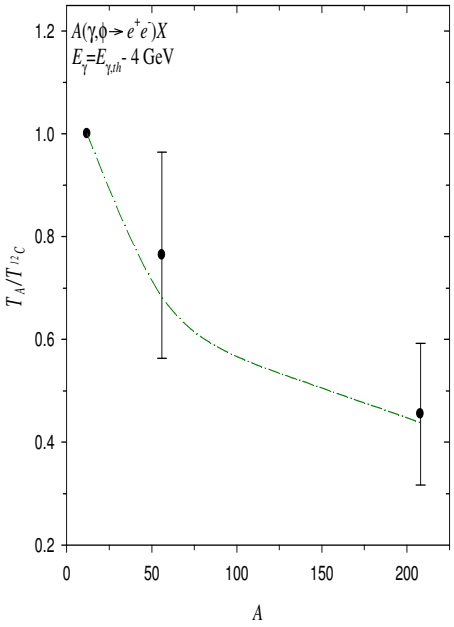

Fig.2 Same as that in Fig.1 but for the ϕ meson.

References

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