Analysis of eta photo-production

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Abstract

By using isobar model and the latest data, the structure function of Eta particle is calculated in the process of photo-production. This calculation is carried out for photon energy range of 0.750 – 3.00 GeV. The variations of the structure function are given in terms of scattering angle for different incoming photon energy.


Keywords: Eta meson, Cross-section, Photo-production, Electro-production, Structure function

1. Introduction

In the late sixties many effort was made to investigate the eta photo-production process, however they are so limited due to large error bars in their data [1-4]. In late eighties some measurements were made again with relative improvement but not enough in the reduction of uncertainties to be used in reliable calculations [5, 6].

The most recent data collected in 2003 at experiment BONN-ELSA-CB Detector/Collaboration carry acceptable error bars. Therefore, these experimental data are used here to investigate the total cross section and the structure function of eta particle in the interaction $\gamma p \rightarrow \eta p$.

The variations of the eta structure functions are obtained in terms of the incoming photon energy in the range of 0.75-3.00 GeV. The angular distribution of eta structure function is also studied.

2. Kinematics of eta photo-production

The electromagnetic production of eta is possible via two different interactions, photo- and electro-production, namely:

$$\gamma(q) + N(p_i) \rightarrow \eta(k) + N(p_f)$$

and the four-momentum of the virtual photon exchanged in electro-production (Fig. 1) is given by

$$q = (v, \bar{q}) = e - e'$$

and for photo-production $q^2 = 0$.

In the C. M. system for $\gamma N \rightarrow \eta N$ interaction (Fig. 2), the initial and final momenta of the involved particles can be expressed in terms of the total center of mass energy $W = \sqrt{s}$ and momentum transfer squared $q^2$ as follow:

$$p_f = (E_f, \vec{p}_f): \text{For the recoiled nucleon}$$

$$k = (\omega, \vec{k}) : \text{For the produced eta}$$

where

$$p_i = (E_i, \vec{p}_i): \text{For the incident electron}$$

$$e' = (E', \vec{p}'_i): \text{For the scattered electron}$$

$$p_i = (E_i, \vec{p}_i): \text{For the target nucleon}$$

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$$|\bar{q}| = |\bar{p}| = \frac{1}{2W} \sqrt{[(W + M_f)^2 + Q^2][(W - M_i)^2 + Q^2]},$$

(3)

$$|\bar{k}| = |\bar{p}_f| = \frac{1}{2W} \sqrt{[(W + M_f)^2 - m^2][(W - M_i)^2 + m^2]},$$

(4)

where $Q^2 = -q^2 = \bar{q}^2 - v^2$ and $M_i$ and $M_f$ are initial and final mass of nucleon and $m$ is the mass of eta.

In photo-production, the relation between Lab. photon energy $E_{\gamma}^{lab}$ and the total center of mass energy $W$ is given as:

$$E_{\gamma}^{lab} = \frac{W^2 - M_i^2}{2M_i}. $$

(5)

The five-fold differential cross-section for electro-production is expressed as [7-10]:

$$\frac{d^5\sigma}{d\Omega dE d\Omega_\eta} = \Gamma \frac{d^2\sigma}{d\Omega_\eta},$$

(6)

and the flux of the virtual photon field is given by:
\[ \Gamma = \frac{\alpha}{2\pi^2} \frac{E}{E'} K \frac{1}{1 - \varepsilon} \]  

(7)

where \( K = E'_{\gamma,Y} = \frac{w^2 - M^2}{2M} \) is the photon equivalent energy and \( \varepsilon = \left( 1 + 2 \frac{q^2}{Q^2} \tan^2 \theta \right)^{-1} \) stand for transverse polarization parameter of the virtual photon.

For an un-polarized target without recoil polarization, the virtual photon differential cross-section is:

\[
\frac{d^2\sigma}{d\Omega^\eta} = \frac{d^2\sigma_T}{d\Omega^\eta} + \varepsilon \frac{d^2\sigma_L}{d\Omega^\eta} + \varepsilon (1 + \varepsilon) \frac{d^2\sigma_{LT}}{d\Omega^\eta} \cos \varphi \\
+ \varepsilon \frac{d^2\sigma_{TT}}{d\Omega^\eta} \cos 2\varphi.
\]  

(8)

In contrast to photo-production in which the energy and momentum of the photon is given by \( q^2 = v^2 - \tilde{q}^2 = 0 \), in the case of electro-production, the virtual photon make it possible for the real photon to have an independent energy and momentum variable to provide information about the spatial hadronic structure function.
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In photo-production experiment only two kinematics variables are enough to express the kinematics situation of the system. These two variables are usually chosen to be the scattering angle $\theta$ and the Lab. energy of photon $E_{\gamma}^{Lab}$. Therefore in photo-production process the longitudinal components of the cross-section vanish and the obtained structure function correspond to the transverse component of the cross-section which is determined by considering the polarization observables.

In Fig. 3, the angular distribution of the differential cross section of eta photo-production is shown for different values of incident photon energies. As seen from these plots, the angular distribution of the eta production structure function depends upon incident photon energy and involves three different regions namely, low energy (750-1000 MeV), medium energy (1050-1400 MeV and 1450-1600 MeV) and high energy (1650-2800 MeV). These figures indicate the fact that the change in incident photon energy is a determinant factor in obtaining information about the structural function which is shown in Fig. 4. In Fig. 4, the total cross section is given in terms of photon incident energy expressing that as incident photon lab. energy increases, then the total cross section falls rapidly in the low energy region and then it falls slowly for medium and high energy region indicating more penetration of incident photon and deeper inelastic collision and resulting in better information about the eta structure function.

Fig. 4. Eta photo-production total cross-section as a function of $E_{\gamma}^{Lab}$.

3. Conclusion

The investigation of the electro-production and photo-production of eta meson is increasingly becoming interesting especially in medium energy physics. Since eta is an isospin singlet more complete information about the nucleon structure could be obtained compared to pion production. Therefore doing such experiments is in the list of future experimental performances of many laboratories. In this research by using the latest available data the variation of the total cross-section is obtained in terms of $E_{\gamma}^{Lab}$ and $\theta$ and are in good agreement with the previous performed investigations.

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References