

Measurement of the transition form factor of the η meson with WASA-at-COSY

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Abstract

The reaction of $\eta \rightarrow e^+e^-\gamma$ has been used to investigate the transition form factor of the η meson with WASA detector at COSY. The η mesons are produced in fixed target pp collisions at 1.4 GeV beam energy. The analysis techniques and preliminary results of η Dalitz decays are presented in this article.

Key words:

Transition Form Factor, Dalitz decay

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1. Introduction

The issue of confinement in Quantum Chromo Dynamics (QCD) has engaged the attention of physicists for a very long time. One of the ways to gain further insight into how colored quarks and gluons make colorless hadrons, is to study the phenomenological characteristics such as the the magnetic moments, form factors, polarizability of the meson. In this paper, we report on a measurement of the transition form factor of the η meson through its Dalitz decay $\eta \rightarrow e^+e^-\gamma$. As the invariant mass squared of the leptons pairs is equal to the four momentum transfer squared ($q^2 = m_{l^+l^-}^2$), one can probe the spatial structure as a function of momentum transfer using the above decay mode of the eta meson.

One can investigate the agreement between theory and experiment by comparing the experimental results on the q^2 dependency of the transition form factor with theoretical models such as Vector Meson Dominance (VMD)[1]. It is possible to experimentally determine the transition form factor $F(q^2)$ by comparing the experimentally measured dilepton mass spectrum with the point like QED prediction.

$$\frac{d\Gamma}{dq^2} = \left| \frac{d\Gamma}{dq^2} \right|_{pointlike} |F(q^2)|^2 \quad (1)$$

The form factor mentioned in Eq.(1) is fitted with a simple pole type formula:

$$F(q^2) \simeq 1 + b_\eta q^2 \quad (2)$$

b_η in Eq.(2) is the slope of the transition form factor and the value is 1.8 GeV^{-2} predicted by the VMD model [1]. The b_η values obtained from previous experiments are given in TABLE 1.

Experiment	$b_\eta [\text{GeV}^{-2}]$	Reference
Lepton-G	1.9 ± 0.4	[2]
NA60	$1.95 \pm 0.17 \pm 0.05$	[3]
SND	1.6 ± 2.0	[4]

Table 1

Experimentally measured b_η values.

2. Experimental Setup

The experiment was carried out with the WASA (Wide Angle Shower Apparatus) detector at COSY Forschungszentrum, Germany [5]. The WASA detector provides nearly full solid angle coverage for both neutral and charged particles. It consists of two parts: the forward detector (FD) part which is designed for detection and identification of the scattered particles like protons, deuterons and ^3He and the central detector (CD) part which detects and identifies the decay products of mesons, namely, photons, electrons and charged pions.

3. Analysis of $\eta \rightarrow e^+e^-\gamma$

We are interested to study the transition form factor of η mesons through its decay into the $e^+e^-\gamma$ channel. This channel has a branching ratio of ($\text{BR} = 6.9 \times 10^{-3}$). Other more abundant decay channels, i.e. $\eta \rightarrow \pi^+\pi^-\gamma$, $\eta \rightarrow \pi^+\pi^-\pi^0$, $\eta \rightarrow \gamma\gamma$, $pp \rightarrow pp\pi^+\pi^-\pi^0$ and $pp \rightarrow pp\pi^+\pi^-$, contribute background. Hence, a careful systematic monte carlo (MC) study is required to obtain the kinematic conditions for the optimum value of the signal to background ratio. We have simulated 10 million events for each reaction and 22 million events for the $pp \rightarrow pp\pi^+\pi^-$ reaction. In the analysis, events with two oppositely charged tracks and one neutral track in the central detector (CD) and two charged tracks in forward detector (FD) have been selected.

The following criteria obtained from the monte carlo study have been used to suppress the background :

- (i) E_γ , photon energy: The photon energy $E_\gamma > 180 \text{ MeV}$ (Figure 1(a)).
- (ii) MM_{pp} , Missing Mass of two scattered protons: The Missing Mass of two scattered protons, detected in the forward detector is defined as

$$MM_{pp}^2 = (E_{beam} - E_{p_1} - E_{p_2})^2 - (\vec{p}_{beam} - \vec{p}_{p_1} - \vec{p}_{p_2})^2 \quad (3)$$

where E_p and \vec{p}_p are the energy and momentum of two scattered protons. It is clear from figure 1(b) that a condition on MM_{pp} , i.e. $0.530 < MM_{pp} < 0.570$, will reduce the background.

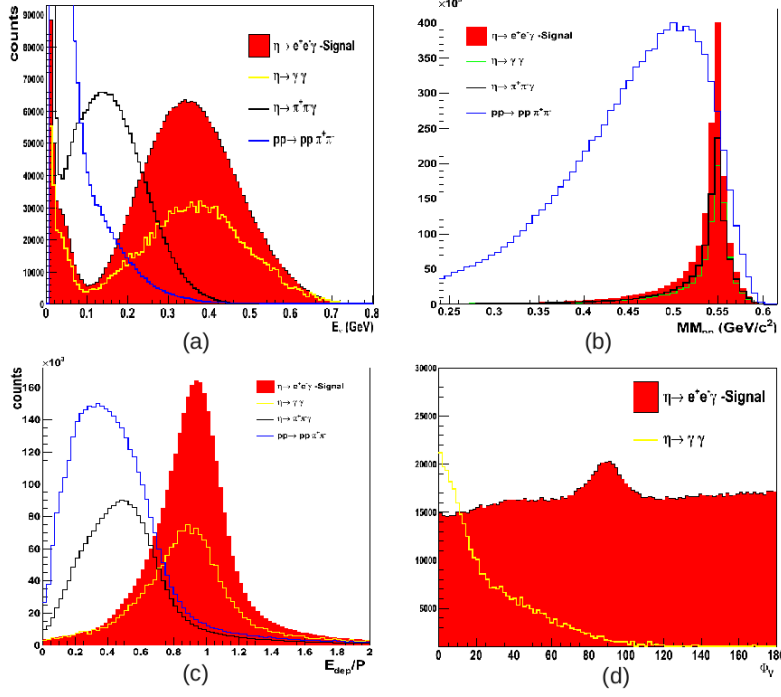


Fig. 1. (a) Photon Energy (b) Missing Mass of two scattered proton (c) Ratio of deposited energy and momentum (d) Orientation angle ϕ_V , for signal and background reactions.

- (iii) E_{dep}/P ratio: The ratio of the total energy deposited and momentum of the electron in the central detector is more than 0.55. The value of E_{dep}/P , i.e. ratio of energy to momentum of the electron in central detector, greater than 0.55 also reduces the background contribution. This is also clear from the figure 1(c).
- (iv) ϕ_V , Angular orientation of electron pair: To separate the external conversion from the Dalitz decay the angular orientation, ϕ_V of the e^+e^- pair plane with respect to the magnetic field has been calculated [6]. Figure 1(d) shows the distribution of ϕ_V for both $\eta \rightarrow e^+e^-\gamma$ and $\eta \rightarrow \gamma\gamma$ reactions. Selecting the condition $\phi_V > 1.0$ radians, suppresses the contribution from $\eta \rightarrow \gamma\gamma$ to a large extent.

A kinematic fit to each event is carried out to further improve the signal to background ratio. The kinematic fitting routine estimates the χ^2_{kf} and its probability $P(\chi^2_{kf})$ and a condition ($P(\chi^2) > 0.2$) on the probability distribution will reduce the background substantially.

Based on the monte carlo study, a set of selection criteria has been used while analysing the data. The invariant mass distribution of the η meson and the lepton pair are shown in figure 2(a) and (b), respectively. Figure 2(b) is obtained by constraining the invariant mass of the η meson within the 3σ of the mean mass of η .

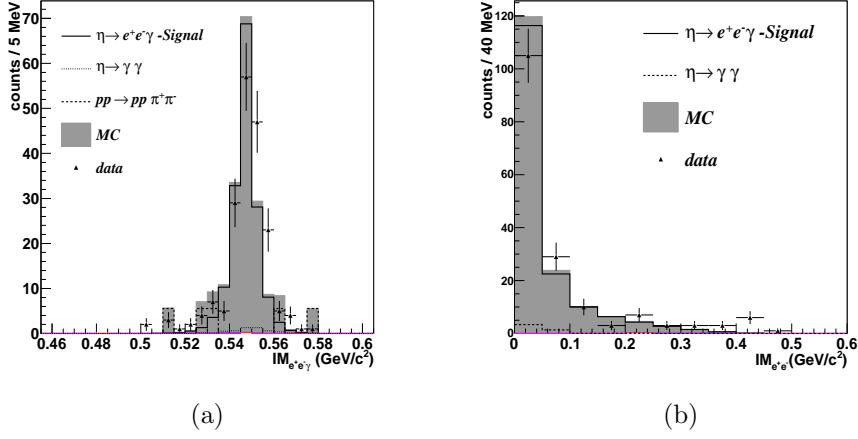


Fig. 2. (a) Invariant Mass of η meson (b) Invariant Mass of lepton pair (e^+e^-).

3.1. Preliminary Results

We have reconstructed 160 ± 13 Dalitz events ($\eta \rightarrow e^+e^-\gamma$). It has been further estimated that the contribution from the reaction $\eta \rightarrow \gamma\gamma$ is $\sim 3\%$, while $\sim 6\%$ of the events are from the reaction $pp \rightarrow pp\pi^+\pi^-$. The extraction of the transition form factor from the data is in progress.

References

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