Measurement of the Transition Form Factor of the η meson with WASA-at-COSY

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Introduction

The issue of confinement and asymptotic freedom in Quantum Chromo Dynamics (QCD) has engaged the attention of physicists for quite some time. One of the basic quests is to understand how quarks and gluons are confined inside the hadrons. The problem can be addressed through the study of hadron structure by measurement of the transition form factor. In this report we investigate the transition form factor of the η meson through its Dalitz decay $\eta \rightarrow e^+e^-\gamma$. This is due to the fact that the invariant mass squared of the leptons is equal to the four momentum transfer squared ($q^2 = m^2_{l^+l^-}$) in such decays. This channel can serve as a probe of the spatial structure of the region of interaction.
Deeper insight into how colored quarks and gluons make colorless hadrons can be gained if we could compare the experimental results on q^2 dependency of the transition form factor with one of the theoretical models such as the Vector Meson Dominance model (VMD). The model is based on the assumption that the interaction of photons with hadrons go through virtual vector mesons. The quantum numbers of the photon are the same as e.g. of ρ, ω, ϕ mesons and the photon can fluctuate for a fraction of time into such mesons. It is possible to determine the transition form factor F(q^2) by comparing the measured mass spectrum of lepton pairs from the decay with the spectrum for the point like meson.

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$$\frac{d\Gamma}{dq^2} = \mid \frac{d\Gamma}{dq^2} \mid_{pointlike} \mid F(q^2) \mid \qquad (1)$$

Usually the form factor is fitted with a single pole type formula:

$$F(q^2) \simeq 1 + \frac{q^2}{\Lambda^2} \qquad (2)$$

Where $1/\Lambda^2$ is the slope. The VMD predicts $\Lambda_\eta = 0.75$ GeV [1]. TABLE I shows the Λ_η values from previous experiments.

TABLE I: Experimental measured Λ_η values.

Experiment	$\Lambda_\eta[GeV]$
CLEO	0.774±0.0011 [2]
IHEP	0.72 ± 0.09 [3]
TPC-2γ	0.70 ± 0.08 [4]
CELLO	0.84 ± 0.06 [5]
OSCE	0.7 ± 1.5 [6]

Experimental Set up

The experiment was done with WASA Detector at COSY in Juelich, Germany. The WASA (Wide Angle Shower Apparatus) provides nearly full solid angle coverage for both neutral and charged particles. COSY is a cooler synchrotron and storage ring which delivers beams of polarized and unpolarized protons and deuteron's in the momentum range between 0.3 GeV/c and 3.7 GeV/c. WASA consists of two part, Forward Detector and Central Detector. The Forward Detector is designed for detection and identification of the scattered projectiles and charged recoil particles like protons. The Central Detector is built around the interaction point and is designed for detection and identification of the decay products of π^0 and η mesons: photons, electrons and charged pions.

Analysis

The data that we are analyzing was taken during April-May, 2007 at a beam energy of 1.4 GeV through $pp \rightarrow pp\eta$ reaction. It has resulted in a total of 10^7 eta mesons. Our signal ($\eta \rightarrow e^+e^-\gamma$) has a very small branching ratio (BR = 4.9 $\times 10^{-3}$). Therefore the list of the eta meson decays considered as a background (TABLE II) include all decays with larger branching ratios. In addition direct production reactions of the charged pions are also considered.

TABLE II: Cross-section for signal and each background reaction.

Channel	Cross-section (mb)
$\eta \rightarrow e^+e^-\gamma$ (Signal)	4.9 $\times 10^{-5}$
$\eta \rightarrow \pi^+\pi^-\gamma$	4.68 $\times 10^{-4}$
$\eta \rightarrow \pi^+\pi^-\pi^0$	2.26 $\times 10^{-3}$
$\eta \rightarrow \gamma\gamma$	3.9 $\times 10^{-3}$
$pp \rightarrow pp\pi^+\pi^-\pi^0$	0.02
$pp \rightarrow pp\pi^+\pi^-$	1

We have simulated 3 million events for each reaction and studied their kinematic behavior. Following criteria are used to select Dalitz events ($\eta \rightarrow e^+e^-\gamma$):

1. E_{dep}/P ratio: Deposited energy and momentum ratio of charged particle has to be greater than 0.75 to suppress the charged pions.

2. MM_η: Missing Mass of η has to be in range 1.75 GeV to 2 GeV to suppress the prompt charged pion background.

3. $\Delta\Phi_{\gamma\gamma^*}$: The phi difference between charged pair and photon has to be in the range 135^0 to 220^0 to suppress the charged pion pair.

4. Φ_V: Angular orientation of decay plane of the electron pair with respect to magnetic field has to be greater than 1.3 rad to suppress the external conversion pair in the beam pipe.

FIG. 1 represent the invariant mass of $e^+e^-\gamma$ meson for experimental data with comparison of Monte Carlo data after applying above mentioned conditions.

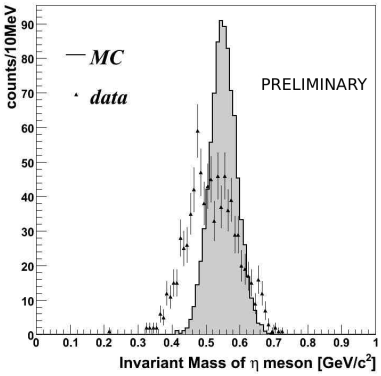

FIG. 1: Invariant Mass of η meson into γe^+e^-.

It is clear from figure that sum of MC data (shaded part) does not describe the experimental data (triangular points) and there is still contribution due to pions. We found that this contribution is coming from the background channel $pp \rightarrow pp\pi^+\pi^-$ because of its large cross section. Our next task is to generate the sufficient amount of MC data for particular this channel to explain the experimental data properly.

References

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