Measurement of the branching ratio of a rare decay $\eta \rightarrow \pi^0\gamma\gamma$ with WASA-at-COSY

Kavita Lalwani for the WASA-at-COSY Collaboration*
* *Department of Physics, Indian Institute of Technology Bombay, INDIA*

Introduction

The branching ratio for the decay $\eta \rightarrow \pi^0\gamma\gamma$ has fundamental implications for intermediate energy physics, where perturbative QCD breaks down. Hence effective field theories are used to describe and reproduce experimental observables. The interest in this decay stems from the fact that it tests one of the most successful field theories, the Chiral Pertubation Theory (χ^{PTh}) to the order O (p^6). Calculations of the decay width using various theoretical models yield values widely different from each other. Similarly the experimental measurements, by different collaborations, on the branching ratio of this channel also do not agree with each other as shown in table 1. This is primarily, because of significant background coming from other decay channels.The tenuous agreement between theory and existing measurements motivated us to measure

TABLE I: Experimental Measurements

Experiments	BR ($\eta \rightarrow \pi^0\gamma\gamma$)
GAMS-2000	$(7.1 \pm 1.4) \times 10^{-4}$ [1]
Crystal Ball	$(2.21 \pm 0.24_{stat} \pm 0.47_{syst}) \times 10^{-4}$ [2]
KLOE	$(8.4 \pm 2.7_{stat} + 1.4_{syst}) \times 10^{-5}$[3]

the branching ratio of this rare decay mode of η, namely $\eta \rightarrow \pi^0\gamma\gamma$ with WASA at COSY.

Experiment

The WASA detector facility is an internal experiment at the COoler SYnchrotron (COSY) in Juelich, Germany. WASA is a 4π multi detector system with capability of detecting both neutral as well as charged particles. It consists of a forward part for the measurement of scattered particles and a central part to measure the decay products of the mesons. COSY delivers phase space cooled protons and deuterons in the momentum range 0.3 to 3.7 GeV/c.

Analysis

Here we present the preliminary results of analysis of decay $\eta \rightarrow \pi^0\gamma\gamma$ with WASA. The data presented here was obtained during the four week production run taken in September-November 2008, where η-meson were produced in the reaction pd $\rightarrow$ ^{3}He η. The ^{3}He in the Forward Detector, formed the zeroth level trigger and the run resulted in approximately 10^7 η's at beam kinetic energy of 1.0 GeV. To select the $\eta \rightarrow \pi^0\gamma\gamma$ events, we demand one charged track in the forward detector and four neutral clusters in the central detector requiring further that energy deposited of each cluster to be more than 20 MeV. In the central detector, to reconstruct π^0-mass from the four reconstructed photons, six possible combinations of photon pairs were made and the χ^2 minimization method was used to choose the best π^0. 3σ cut on the invariant mass of π^0(σ = 11 MeV) has been applied to select the $\pi^0\gamma\gamma$ events. Using these basic conditions signal to background ratio was 5.1×10^{-4}. The major contribution in this decay was from direct $2\pi^0$ production. To reduce this background channel, kinematic fitting has been used to test following two reaction hypotheses:

$$p\ d \rightarrow {}^3He\ \pi^0\ \pi^0 \quad (1)$$

$$p\ d \rightarrow {}^3He\ \pi^0\gamma\gamma \quad (2)$$

Four constraints on the energy and momentum balances have been used. In addition, the invariant masses of the two π^0's have been

*Electronic address: pankavi@gmail.com

used as constraints for hypothesis 1 and constraint on single π^0 mass for hypothesis 2. To enhance signal to background ratio further, following conditions have been used:

- -0.1 < missing energy of the full event pd $\rightarrow$^{3}He $\eta(\rightarrow \pi^0\gamma\gamma) < 0.1$ GeV.
- Cut on the two dimensional distribution obtained by plotting the larger mass of $\pi^0\gamma$ vs mass of $\pi^0\gamma\gamma$ has been applied to reduce contributions from direct pions.
- Events having confidence level of double π^0 greater than 0.00001 have been excluded. This cut reduces the double π^0 events by 94%.
- Selecting CL $(\pi^0\gamma\gamma) > 0.1$ reduces 96 % of $\eta \rightarrow 3\pi^0$ background as well as direct $2\pi^0$ background and 98 % of direct $3\pi^0$ background.
- $m_{\gamma\gamma} > 0.200$ GeV/c^2 and $\theta_{\pi^0\gamma\gamma} < 57^0$ have been applied to reduce remaining background contributions.

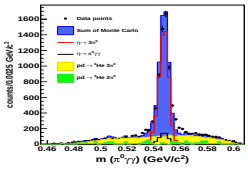

FIG. 1: Invariant mass of $\pi^0\gamma\gamma$. Comparison of data and simulation.

After applying all selection criteria our Monte Carlo reproduces the experimental data. The signal to background ratio is 0.12 as shown in figure 1. To calculate the branching ratio of $\eta \rightarrow \pi^0\gamma\gamma$, we need to have η's from prompt decay channel for example $\eta \rightarrow 3\pi^0$ (32%) and $\eta \rightarrow 2\gamma$ (39%). We have analyzed $\eta \rightarrow 3\pi^0$ for the same data set. The $\eta \rightarrow 3\pi^0$ events were selected by asking one charged track in the forward detector and six neutral clusters in the central detector with $E_{deposited} > 20$ MeV for each cluster. In the central detector, to select $3\pi^0$ candidates from the six reconstructed photons, fifteen possible combinations of two photon pairs were made and the χ^2 minimization method was used to choose the best π^0. The only contributed background was direct production of $3\pi^0$. A cut on χ^2 < 15.0 and missing energy of the full event pd $\rightarrow$ ^{3}He $\eta(\rightarrow 3\pi^0)$ in the range of -0.15 to 0.15 GeV have been applied to reduce direct $3\pi^0$ background. After applying all selection

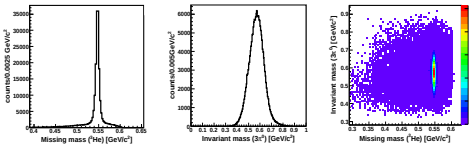

FIG. 2: Missing mass of scattered ^{3}He (left), invariant mass of $3\pi^0$ (center) and Invariant mass of $3\pi^0$ vs missing mass ^{3}He (right) for data.

criteria, remaining contribution of direct $3\pi^0$ has been subtracted using 4th order polynomial as shown in figure 3. We have reconstructed $(3.2\pm0.38_{syst}) \times 10^6$ $\eta \rightarrow 3\pi^0$ events, statistical error is negligible. The extracted $\eta \rightarrow \pi^0\gamma\gamma$ events from the present analysis is 360 $\pm$ 70 (stat) (figure 1). Evaluation of systematical errors inorder to extract the branching ratio are in progress.

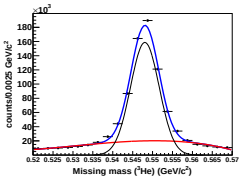

FIG. 3: Missing mass of ^{3}He for data.

Acknowledgments

We acknowledge the financial support given by the DAAD-DST exchange program and support by the technical and administration staff at Forschungszentrum, Juelich.

References

[1] D. Alde et al. Z. Phys. C **25**, 225 (1984).
[2] S. Prakhov et al., Phys. Rev. C **78**, 015206 (2008).
[3] B. Di Micco et al., Acta Phys. Slov. **56**, 403 (2006).