Experimental study of ppη dynamics with WASA-at-COSY

Neha Kiritkumar Shah[1,*]
(for the WASA-at-COSY collaboration)
[1]*Department of Physics, Indian Institute of Technology Bombay, Mumbai - 400076, INDIA*

Introduction

The interaction of the η-meson with nucleons is still not completely understood. The short life time of the η-meson prevents a direct study of the η-nucleon interaction using η-beam. The studies involving the production of η-meson in the nucleon-nucleon interaction close to the kinematical threshold as well as production of η-mesic nuclei will help us to study those interactions. A mutual interaction among the outgoing particles will show up in differential cross-sections and in the magnitude and energy dependence of the total reaction rate. The measurements near the kinematical threshold simplify the interpretation of the data, but still appears challenging because of the three particle final state system. Hence for the complete understanding of the low energy ppη dynamics, determination of the differential observables is necessary. In general, five observables are required to describe the ppη system. In emission plane, the relative movement of the particles is described by the square of the INVARIANT MASS of the proton-proton (M^2_{pp}) and proton-η ($M^2_{p\eta}$) system. The remaining three variables are the polar angle, the azimuthal angle and the angle ψ describing rotation around the direction of η momentum vector. The results available from COSY-11([1]) and COSY-TOF([2]) at excess energy Q = 15 MeV, 15.5 MeV and 41 MeV shows that η-meson is produced in s-wave and the M^2_{pp} and $M^2_{p\eta}$ distributions shows deviation from the pure phase space, which can not be explained by the proton proton final state interactions (FSI). The η-proton FSI can be further studied by investigating Dalitz plot of the η-p invariant mass distributions. With WASA-at-COSY, we have measured the production cross-section of the η-meson and have studied these variables at excess energy Q = 56 MeV.

Experimental setup

The Wide Angle Shower Apparatus (WASA) is installed at the COSY accelerator in Jülich, Germany. The COSY accelerator delivers phase space cooled beam of protons and deuterons in the momentum range between 0.3-3.7 GeV/c. WASA is a fixed target experiment with a pellet target system, which provides the target of hydrogen or deuterium of thickness 35μm. The forward part is designed to measure scattered particles. The central part is designed to measure decay products of the η-meson, like $\pi^{\pm}$, $e^{\pm}$ and photon.

Analysis

The η-meson can be reconstructed in central detector from its decay product or can be identified by using the missing mass of two protons in forward detector. For reconstruction in central detector, we have selected the $\eta \rightarrow 3\pi^0$ channel with the branching ratio (32.51$\pm$0.29)%. The major background contribution is from $pp \rightarrow pp3\pi^0$ (σ = 1.09μb) and $pp \rightarrow pp2\pi^0(\sigma = 250\mu b)$. For selection of events we have applied the following criterion:

- For two protons, select two charged particle in forward detector with energy deposited greater than 40 MeV.
- For six photons, select six neutral clusters in central detector with energy deposited greater than 25 MeV.
- For selection of best three π^0, from 15 possible combination of 2γ-pairs,

*Electronic address: nehashah@phy.iitb.ac.in

the χ^2-method is used and a cut on $\chi^2{}_{combinatorial} < 12$ is applied.

- As the forward detector has mass resolution of 2.6 %, used a condition on missing mass of two protons in the range 0.523-0.571 GeV/c^2 to select six photons in central detector.

Above mentioned criteria reduces the background from pp→pp2π^0, but the background from pp→pp3π^0 cannot be reduced completely. To improve the accuracy of all measured quantities and to constrain events to the allowed phase space, we have applied kinematic fit with the constraints on conservation of energy and momentum for the full event (4C) and π^0 invariant mass of the individual $\gamma\gamma$ pairs (3C).

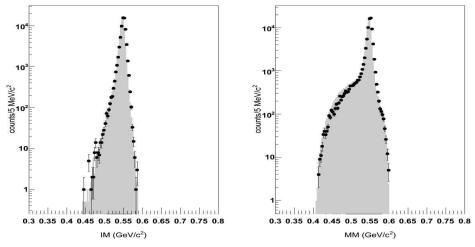

FIG. 1: (a) Invariant mass of $3\pi^0$ and (b) Missing mass of pp after applying all selection criterion, where shaded region is summation of MC for channel and background and solid points are data.

After applying an additional criterion on a confidence level greater than 0.10, the missing mass of two protons in forward detector and invariant mass of $3\pi^0$ in central detector, for data taken in April 2007, are shown in Fig. 1. From 62 hours of data, within three sigma, we have 66258 $\eta \rightarrow 3\pi^0$ events after background subtraction. Now using the time integrated luminosity L = $(2331.61\pm2.36_{stat})$nb^{-1} and overall detection efficiency 1.68%, the total cross-section for η production is $(5.28\pm0.02_{stat})\mu$b. It is shown in Fig. 2 with other data from previous experiments, PINOT([3]) and CELSIUS([4]), at different beam energy. Estimation of the systematic errors are under process.

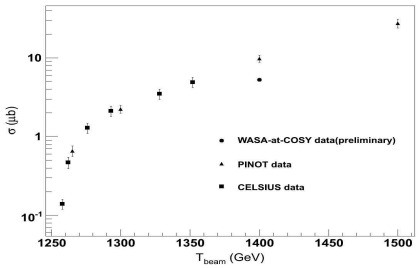

FIG. 2: pp → ppη total cross section versus incident kinetic energy. The circle is WASA-at-COSY data. The triangles are PINOT data([3]) and squares are CELSIUS data([4]).

The acceptance corrected Dalitz plot of the η-p invariant mass distribution is shown in Fig. 3. If there are no interactions involved, the occupation density of the Dalitz plot is expected to be uniform. But we can see some enhancement in the lower part of the η-p Dalitz plot, which is due to the η-p interaction.

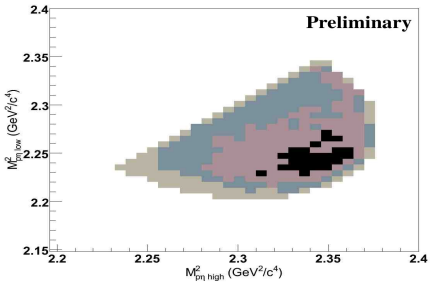

FIG. 3: Acceptance corrected Dalitz plot for η-p invariant mass for data.

References

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