Dalitz plot of the hadronic decay $\eta' \to \eta\pi^+\pi^-$

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Introduction

Strong interaction is the fundamental force which holds together the sub-nuclear objects like the proton inside the nucleus and Quantum Chromodynamics(QCD) is the theory of strong interaction. A lot of progress have been made in high energy perturbative regime, but there is very little work done so far in the low energy regime of QCD, as the coupling strength of the interaction increases at low momentum transfer. Hadrons are the smallest unit in this regime, so the study of hadronic decay of meson like π^0, η, η' is a useful tool to explore the low energy regime.

The aim of the present work is to develop the Dalitz plot of $\eta\prime \to \eta\pi^+\pi^-$ with larger statistics compared to highest statistics collected up to date by the BESIII Collaboration[1]. Dalitz plot is a ternary plot used to represent the relative frequency of various kinematically distinct manners in which the products of certain three-body decays may move apart. It gives information of resonant states as well as short lived intermediate particle mass, lifetime, spin etc[2]. The Continuous Electron Beam Accelerator Facility(CEBAF) Large Acceptance Spectrometer (CLAS) is a fixed target experiment which uses bremsstrahlung photon beam has provided huge data which is suitable to analyze rare decay of the light mesons . The CLAS detector is housed in Hall B at the Thomas Jefferson National Accelerator Facility in Newport News, Virginia.

Experimental Setup

The CLAS experiment uses a 4 GeV electron beam hitting a gold foil(10^{-4} radiation length) produces real photons, via the bremsstrahlung process. The recoiling electrons were then analyzed using a dipole magnet and scintillator hodoscopes to tag the energy of the photons, and Magnetic Spectrometer at Hall B is used to separate electrons from the photon beam. Photons in the energy range from 20% to 95% of the electron beam energy were tagged and thus measured with an energy resolution of 0.1% of the electron beam energy. The physics target, which was filled with liquid hydrogen, was a 40-cm long cylinder with a radius of 2 cm. The 24 start counter scintillators near to interaction region were used in the event trigger and start time. The CLAS detector utilized a non-uniform toroidal magnetic field of peak strength near 1.8 T in conjunction with drift chamber tracking to determine particle momenta. A set of 288 scintillators placed outside of the magnetic field region was used in the event trigger and during off-line analysis in order to determine time of flight (TOF) of charged particles[3].

Data Analysis

The complete channel for the decay of η' meson under study is: $\gamma p \to p\eta'(\pi^+\pi^-\eta)$. In the final state only proton, π^+ and π^- are detected. The CLAS is well optimized for detection of charged particles. Two charged particles and any number of neutral particles along with the proton were added to the selection criteria of data skimming from the huge data set of CLAS. A missing mass technique is used for reconstruction from the kinematical information for the two pions and proton is shown in FIG.1. As seen in the missing mass spectrum in FIG.1, the resolution obtained is sufficient for clear identification of the photoproduced η meson. In FIG.2, γp$\to$pX missing mass was used to identify the photoproduced $\eta\prime$ mesons through detection of the proton. The FIG.2 gives clear identification of

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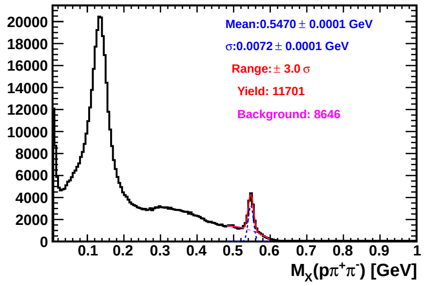

FIG. 1: Missing mass of $p\pi^+\pi^-$ for events where missing mass of the proton is in the range of η', $M_X(p) = 0.958 \pm 0.015$ GeV from subsample of all statistics, showing clear peaks of π^0 and η.

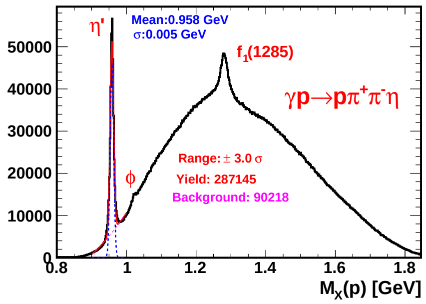

FIG. 2: Missing mass of the proton for events from entire run period, by selecting the missing mass of all detected particles to be in the range of η meson, $M_X(p\pi^+\pi^-) = 0.55 \pm 0.015$ GeV.

$\eta\prime$ mesons coming from the selected η meson region. The η' meson peak fitted with Gaussian and the background with the second order polynomial function contains about 300 K events, which is almost an order of magnitude higher than the highest statistics collected by the BESIII collaboration [1]. For the reconstructed η' mesons FIG.3 shows 2-d Dalitz plot distribution. Here we define the Dalitz plot with the X and Y variables as:

$$X = \frac{\sqrt{3}(T_{\pi^+} - T_{\pi^-})}{Q}, Y = \frac{(m_\eta + 2m_\pi)}{m_\pi} \cdot \frac{T_\eta}{Q} - 1,$$

where T_i $(i = \pi^+, \pi^-, \eta)$ is a kinetic energy of a given particle in the rest frame of η' and

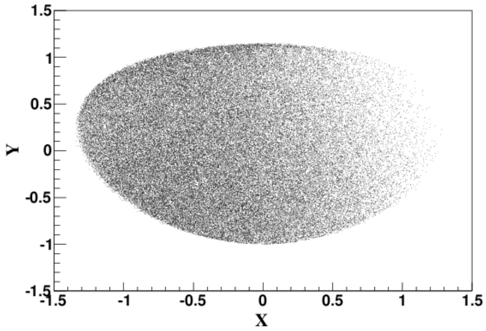

FIG. 3: Dalitz plot distribution for events under the η' peak, $M_X(p) = 0.958 \pm 0.015$ GeV

$Q = T_{\pi^+} + T_{\pi^-} + T_\eta$. The matrix element of the decay can be expanded around the center of the corresponding Dalitz plot in order to obtain the Dalitz slope parameters:

$$M^2 = A(1 + aY + bY^2 + cX + dX^2),$$

where a, b, c and d are real parameters and A is a normalization factor.

In order to perform polynomial fit in X and Y projections one needs first to get acceptance and efficiency corrected Dalitz plot $\eta' \to \pi^+\pi^-\eta$ decay. The Monte Carlo simulation of the CLAS acceptance for this channel through the phase space distribution is in progress.

Outlook

In some decay modes the CLAS has the world's largest dataset for analysis of light pseudo-scalar mesons, in particular it can be used to perform Dalitz plot analyses of $\eta\prime \to \pi^+\pi^-\eta$ of $\eta\prime \to \pi^+\pi^-\pi^0$, which is a rare decay channel. The work can be further extended to get the mixing angle between η and π^0.

References

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