Resonance scan simulation of X(3872) state using PANDAROOT

Rajeshkumar Dudhat[1],* S. S. Godre[2], and Ajay Kumar Rai[1]
[1]*Sardar Vallabhbhai National Institute of Technology, Surat - 395007, INDIA and*
[2]*Deptartment of Physics, Veer Narmad South Gujarat University, Surat - 395007, INDIA*

Introduction

The X(3872) resonance was first time observed by Belle in study of the $\pi^+\pi^- J/\psi$-invariant mass distribution in exclusive $B^+ \to K^+\pi^+\pi^- J/\psi$ decay channel [1]. It has been confirmed by several experiments like CDF, D0 and BABAR. Recently it was seen in LHCb experiment and determined its quantum numbers $J^{PC} = 1^{++}$. The world average mass of this state is $M_{PDG} = 3.871.68 \pm 0.17$ MeV, that is very close to the $m_{D^0} + m_{\bar{D}^{*0}}$ threshold mass 3871.8 ± 0.3 MeV, which predicts that the X(3872) might be a loosely bound $D^0\bar{D}^{*0}$ molecular state, other possibilities are tetra-quark, a diquark anti-quark bound state, hybrid charmonium or mixtures. The width $\Gamma_{X(3872)}$ is unknown, only an upper limit of 1.2 MeV at 90% C.L. is published.

In the following we studied this state using resonance scan technique for the P̄ANDA experiment (antiProton ANnihilation at DArmstadt), one of the key project under design for the Facility for Antiproton and Ion Research (FAIR) at GSI, Germany [2]. It will be using cooled and highly intense antiproton beam provided by High Energy Storage Ring (HESR) with energy between 1.5 GeV and 15 GeV, interacting with various internal targets. The P̄ANDA detector is multi purpose detector, covering a 4π solid angle. The goal of this experiment covers a wide range of high precision hadron spectroscopy, particular the search for exotic states in charmonium region.

Resonance Scan Technique

The resonance scan technique is used to determine the resonance parameters (mass, width and decay fraction) with high precision. In this method resonance state is studied by changing the center of mass energy $\sqrt{s}$ around the resonance in small steps, here $\sqrt{s}$ is adjusted by the beam momentum p_{beam}. Using Monte-Carlo simulation we simulate signal channel $\bar{p}p \to X(3872) \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$ and background channel $\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$ using PANDAROOT framework based on ROOT and virtual Monte-Carlo [3]. Events are generated using event generator *EvtGen*, generated particles are transported through the P̄ANDA detector geometry using transport model Geant3, after that digitization, reconstruction and particle identification is carried out.

In the present analysis we have applied electron/pion discrimination to classify all $e^\pm$ and $\pi^\pm$ present in the events. All combinations of one electron and one positron candidate in the same event were used to calculate the two particle invariant mass. From $e^\pm$ pair we reconstruct J/ψ mass and apply mass cut from 2.6 GeV to 3.4 GeV to remove the background. We have calculated missing mass for $\pi^\pm$ and if this value falls in J/ψ mass region with mass range from 2.95 GeV to 3.35 GeV. If the event contained one or more suitable J/ψ candidates and at least one possible $\pi^+\pi^-$ pair with a missing mass than this event is used to construct X(3872) candidate. If this mass value falls in the interval from 3.6 GeV to 4.2 GeV, the candidate counter for the scan point is raised by one. The resonance scan technique in detail is described in reference [4], we have used the same methodology and parameters from this reference. The excitation curve is a convolution of resonance cross section (Breit-Wigner) and the beam energy distribution (Gaussian). For constant back-

*Electronic address: raju_dudhat@yahoo.co.in

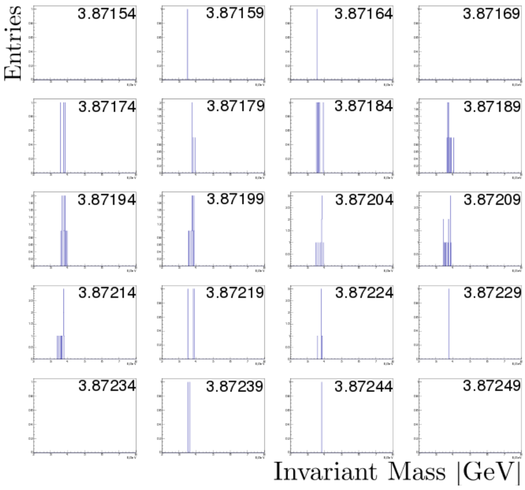

FIG. 1: Invariant mass spectrum for signal channel: $\bar{p}p \to X(3872) \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$.

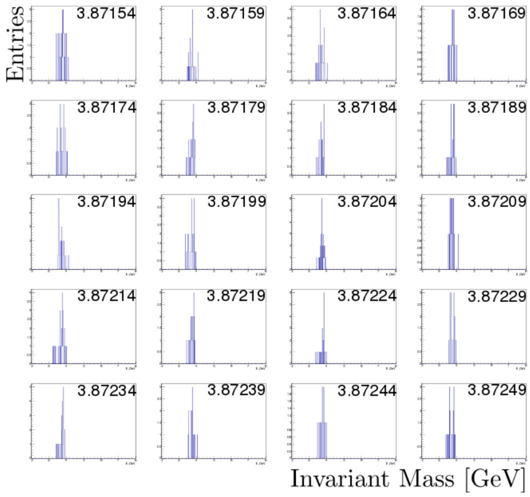

FIG. 2: Invariant mass spectrum for background channel: $\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$.

ground we generate same number of events for each scan points. This simulation is carried out for presumed $\Gamma_{X(3872)} = 200$ KeV and the value of $B(X(3872) \to p\bar{p})$ is taken from reference [5].

Result and Discussion

We perform resonance scan simulation for X(3872) state using 20 scan points with equidistant centre of mass energy between 3.87154 to 3.87249 GeV for signal and background channels, which are shown in Fig.1 and Fig.2 respectively.

The selected candidate counts from the signal and the background are added for each point so that there is no information about how many are due to the signal and how many are for background. We fit these Monte-Carlo points shown in Fig.3 with a convolution of a Breit-Wigner and Gaussian distribution plus a constant background. From this curve we extract the signal after removing the background which is shown as dotted curve in Fig.3. The full width half maximum (FWHM) determined from above is $\Gamma_{X(3872)} = 210$ KeV, which is 5% larger than the input width.

From this we can conclude that the $\bar{\text{P}}$ANDA experiment will be able to measure the width of X(3872) more precisely and it will be most suitable experimental set up for study of different properties of many unexplained resonance states.

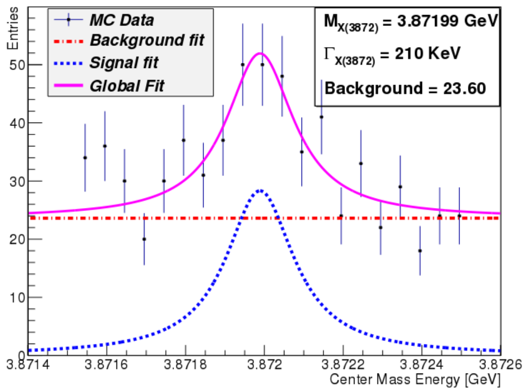

FIG. 3: Resonance Scan Simulation: Monte-Carlo points (signal+background) fitted with a convolution of Breit Wigner and Gaussian function plus a constant background)

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