Monte Carlo Simulation of X(3872) State Using PANDAROOT

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Introduction

Charmonium Spectroscopy is powerful tool for the understading of strong interaction, Many e^+e^- and p$\bar{\text{p}}$ collider experiments like BABAR, BELLE, CDF, CLEO, D0 etc study different charmonium states like $\eta_c(1S)$, $J/\psi(1S)$, $h_c(1P)$, $\psi(2S)$, $\psi(3770)$, X(3872), Y(4260) [1].

The X(3872) resonance was first observed by the BELLE Collaboration in decay process $B^\pm \to K^\pm\pi^+\pi^- J/\psi$ [2], it was confirmed by CDF, D0, and BABAR. The mass of X(3872) is 3.8715 GeV/c^2 [PDG], which is very close to the $m_{D^0}+m_{\bar{D}^{*0}}$ (3.8718 GeV/c^2), which predicts that X(3872) might be a loosely bound deuteron-like molecule state. Theoritical studies predict a diquark-antiquark, a tetraquark state or a hybrid charmonium. The width of X(3872) is unknown, only an upper limit for $\Gamma_{X(3872)}$ of 2.3 Mev at 90% CL is published, so no satisfactory explanation for the structure of X(3872) is available.

$\bar{\text{P}}$ANDA (antiProton ANnihilation at DArmstadt) is one of the key project at the future Facility for Antiproton and Ion Research (FAIR) at GSI. $\bar{\text{P}}$ANDA will use the $\bar{\text{p}}$ circulating in the High Energy Storage Ring, to study their interactions with protons or nuclei on a fixed target. The $\bar{\text{p}}$ momentum in the range 1.5 - 15 GeV/c corresponds to a center-of-mass energy in p$\bar{\text{p}}$ collisions in the range 2.5 - 5.5 GeV [3] which is suitable for study of charmonium physics.

Charmonium states have been studied mainly in e^+e^- and p$\bar{\text{p}}$ collider experiments. In e^+e^- collisions, only the $J^{pc} = 1^{--}$ states can be directly formed, in p$\bar{\text{p}}$ interactions, direct formation is possible for all the states with different quantum numbers through coherent annihilation of the three quarks of the protons with the three antiquarks of the antiproton. $\bar{\text{P}}$ANDA will be able to obtain high precision data on charmonium states and measure their masses, widths and excitation curves with high precision.

PANDAROOT is an offline framework based on ROOT, GEANT3 and GEANT4 for $\bar{\text{P}}$ANDA Detector [4], which is useful for large scale simulation and analysis. There are also different implemented subdetectors like Time Projection Chamber (TPC), Micro Vertex Detector (MVD), Electromagnetic Calorimeter (EMC) etc. Using these tools we have studied Monte Carlo simulation for X(3872) resonance and preliminary result are presented here.

Calculational Details

We have simulated 15000 events for p$\bar{\text{p}}$ $\to J/\psi\pi^+\pi^-$ with the centre of mass energy corresponding to X(3872) resonance, where J/ψ subsequently decay to e^+e^-. Here, charged $\pi^\pm$ and $e^\pm$ are identified by energy deposited in the EMC and momentum (p) are determined using the track finder and the track fitter from MVD and TPC information.

The cut for $\pi^\pm$ is $0 \le E_{EMC}/p \le 1$ and for $e^\pm$ is $0.8 \le E_{EMC}/p \le 1.2$. Using the above cut we can reduce the background. Here, J/ψ is reconstructed using invariant mass of $e^\pm$ pair. By adding J/ψ and $\pi^\pm$ mass we have reconstructed X(3872) resonance. We have generated another 15000 events using same decay channel for $\psi(2S)$ resonance and reconstracted by method described above.

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Results

The reconstructed $e^+e^-[J/\psi]$ mass is shown in Fig 1. By adding J/ψ mass and $\pi^{\pm}$ mass we get $\psi(2S)$ state mass and X(3872) state mass, which are shown in Fig 2 and Fig 3 respectively. Unfitted data are shown by dashed line and the 4-momentum fitted data are shown by solid line.

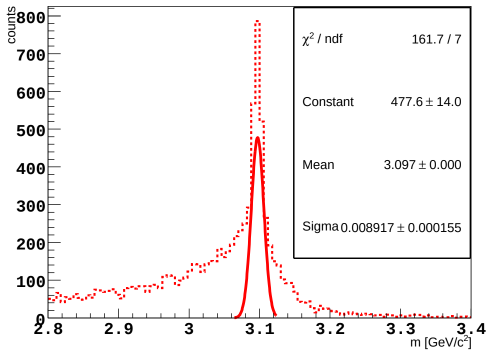

FIG. 1: Invariant mass of J/ψ state.

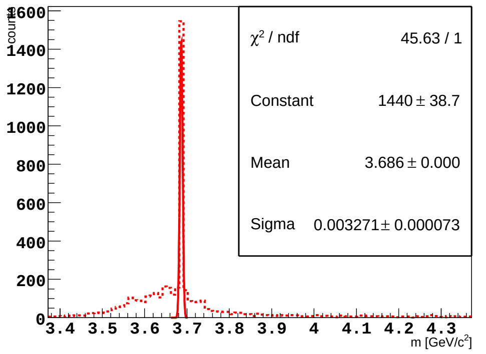

FIG. 2: Invariant mass of ψ(2S) state.

Conclusion

In the PANDAROOT framework we have studied Monte Carlo simulation for different states with corresponding decay channels for PANDA Physics and obtained mass of the three states. The 4 - momentum fit values are shown in Table I.

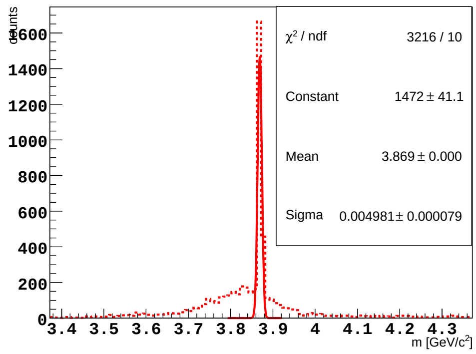

FIG. 3: Invariant mass of X(3872) state.

TABLE I: Mass in Gev/c^2

State	MC Mass	PDG Mass	Exp. Mass
J/ψ(1S)	3.097	3.096	3.09691 [KEDR]
ψ(2S)	3.686	3.68609	3.68598 [E760]
X(3872)	3.869	3.8715	3.87161 [CDF2]

Table I also shows the average PDG values and experimental values. The present Monte Carlo simulation values match well with PDG and experimental values. Similarly, we can also study different properties of states like decay width, branching ratio etc.

References

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