Simulation studies for the novel charmonium like state Y(4140) with PANDAROOT

Rajeshkumar Dudhat[1], V. Jha[2],* B. J. Roy[2], A. K. Rai[1], S. S. Godre[3], A. Chatterjee[2], and S. Kailas[2]
[1] Sardar Vallabhbhai National Institute of Technology, Surat - 395007, INDIA
[2] Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and
[3] Veer Narmad South Gujarat University, Surat - 395007, INDIA

Introduction

A number of charmonium like mesonic states such as X(3872), Y(3940) and Y(4260), collectively known as the so-called XYZ states (see Ref. [1] for a review) have been discovered in recent years. These are associated with charmonium because they decay predominantly into charmonium like states such as the J/ψ, but their interpretation is far from obvious. Most of the XYZ candidate states do not match with any of the remaining unassigned charmonium levels. As a result, at least some of these states have been touted as candidates for exotic mesons, i.e. mesons with a more complex substructure than the simple quark-antiquark configuration.

The CDF Collaboration observed a narrow near-threshold structure, termed as the Y(4140) meson, in the $J/\psi\phi$ mass spectrum in the exclusive $B^+ \to J/\psi\phi K^+$ decays with the mass $M_{Y(4140)} = 4143.0\pm2.9$(stat) MeV and natural width $\Gamma_{Y(4140)} = 11.7\pm8.3$(stat)MeV [2]. The structure Y(4140), which decays to $J/\psi\phi$ just above the $J/\psi\phi$ threshold, shows a similar decay and production pattern to the previously discovered Y(3940), which is also produced in B-decays and was found in the $J/\psi\omega$ decay channel near its respective threshold.

The measured decay widths of Y(4140) and Y(3940) from the present data imply that these widths are much larger than what is expected if it is a pure charmonium ($c\bar{c}$) state. This could be signals for nonconventional structures of the Y(3940) and the Y(4140). Many possible alternative interpretations such as hadronic molecules, tetraquark states or even hybrid configurations have been proposed for structures of these states. Moreover, the Y(4140) state is the first particle found to decay into two heavy quarkonia ($c\bar{c}$ and $s\bar{s}$), with a hidden flavor decay as is expected for glueballs. For the proper understanding the Y(4140), it would be necessary to study other possible decay modes and determine its properties in detail. The PANDA detector with good lepton-pair identification by means of an electromagnetic calorimeter or by means of muon detectors and kaon identification based on the Cherenkov counters, is well equipped to detect such decays with good signal to background ratio.

Simulation and Results

We have performed the simulation of the Y(4140) in the $Y(4140) \to J/\psi\phi$ and subsequent decays in $J/\psi \to e^+e^-$ and $\phi \to K^+K^-$ decay channels. The Monte Carlo simulation is performed with the PANDAROOT software framework. The events are generated using the EVTGEN event generator, in the $\bar{p}p$ collisions at the centre of mass energy corresponding to Y(4140) resonance. The particles in the generated events are tracked inside the complete PANDA detector using the transport code GEANT3/GEANT4. Subsquently, in the digitization step the response of the individual detectors, signals generation and processing in the front end elctronics is modelled. The reconstruction and identification of the particle candidates for the physics analysis is performed in the final step. The reconstruction of primary daughters J/ψ and ϕ

*Electronic address: vjha@barc.gov.in

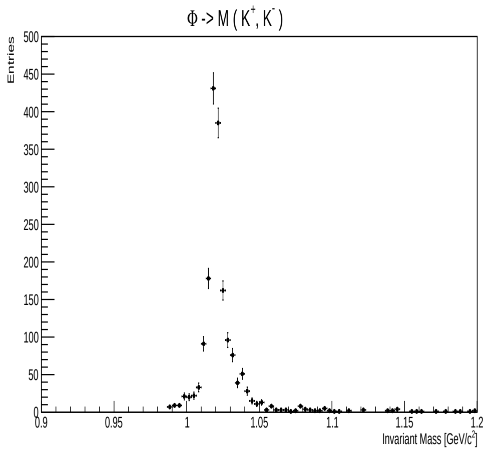

FIG. 1: Invariant Mass $\phi \to K^+K^-$ from the reconstruction.

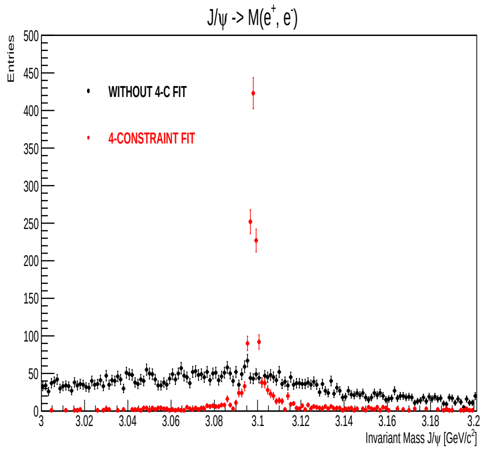

FIG. 2: Invariant Mass of $J/\psi \to e^+e^-$ with and without the kinematic fitting.

is performed through the $J/\psi \to e^+e^-$ and $\phi \to K^+K^-$ decay channels, respectively. The mass spectrum of the reconstructed daughter particles ϕ and J/ψ are presented in Fig. 1 and Fig. 2 respectively.

A 4-momentum kinematic fit using the energy momentum of the initial $\bar{p}p$ system has been performed. The kinematic fitting leads to improved track parameters for the daughter particles and a better resolution of the mass for the J/ψ resonance as shown in Fig. 2. In addition the probability cuts based on the vertex fits are also applied. The final reconstructed resonance mass spectrum in terms of missing mass of kaon pair (as also plotted in Ref. [2]) is shown in Fig. 3.

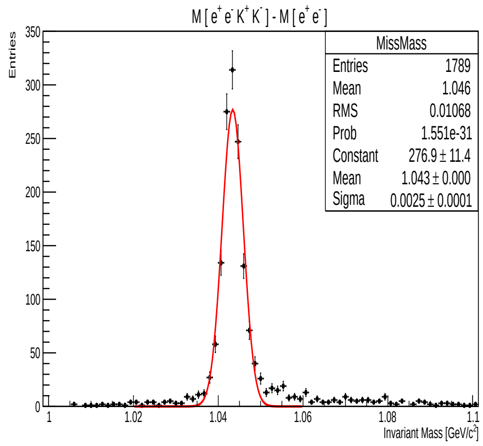

FIG. 3: Mass spectrum of signal corresponding to the Y(4140) resonance obtained from full reconstruction.

It is observed, that the resonance can be well reconstructed by the PANDA experiment with a FWHM $= 5.88$ MeV, which is less than the measured width. The efficiency obtained from the present simulation is $\sim$10% which is mainly due to low momentum of kaons at present energy of formation.

Summary

In summary, we have performed simulations for the resconstruction of Y(4140) with the PANDAROOT simulation framework. The feasibility studies for the detection of this resonance along with the background studies are in progress.

References

[1] S. Godfrey and S. L. Olsen Annu. Rev. Nucl. Part. Sci., **58** 51 (2008)

[2] T. Aaltonen et al. (2009) Physical Review Letters **102**, 242002 (2009)