Simulation of $f_0(1710)$ state using PANDARoot

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Introduction

The future experiment $\overline{\mathsf{P}}\mathsf{ANDA}$ (AntiProton Annihilations at Darmstadt) is a fixed target experiment positioned in a High Energy Storage Ring (HESR). The whole experiment would be situated under the boundary of FAIR (Facility for Anti-Proton and Ion Research) at Darmstadt, Germany. A flux of antiproton beam is generated by an inelastic collision of accelerated protons with either copper, nickel or iridium metal target. Such an anti-proton beam revolving in HESR and getting a momentum up to 15 GeV/c strike on a fixed proton target [1–4]. Depending upon the center-of-mass energy of the antiproton-proton annihilation will produce a large number of massive particles.

The main aim of this experiment is to study strong interaction in the low energy Quantum Chromodynamics (QCD) regime [5]. The particle responsible for the strong interaction is called glueball and is the bound state of charge coloured gluons. $\overline{\mathsf{P}}\mathsf{ANDA}$ is designed to detect these glueball resonances and to measure their masses and other properties. These resonances have short life times. However, the particles into which they decay can be identified and their energies and momenta can be measured. This information then allows us to reconstruct the glueball properties [6–8].

In this paper, our aim is to study feasibility of $f_0(1710)$ glueball resonance state in the PANDARoot simulation package. The simulation of $f_0(1710)$ through the channel $\bar{p}p \to f_0(1710)\gamma \to \pi^+\pi^-$; we have to set input antiproton beam momentum, $P_{\bar{p}} = 3.5$ GeV/c and fit 10000 events of antiproton proton collission. Using the Einstein mass-energy relation $E_{\bar{p}} = \sqrt{m_{\bar{p}}^2 + P_{\bar{p}^2}^2}$, we obtained the antiproton beam energy $E_{\bar{p}} = 3.62$ GeV; with an antiproton mass $M_{\bar{p}} = 0.938$ GeV.

The center-of-mass energy denoted by $\sqrt{s}$, gives the total energy available in the laboratory frame and is must be greater than the sum of the masses of the particles being produced. For the reaction $\bar{p}p \to f_0(1710)+\gamma$, the center-of-mass energy is $\sqrt{s} > m_{f_0(1710)} + m_\gamma$. The square of the center-of-mass energy gives the Lorentz invariant quantity s. We write the expression of s, for the two initial state particles as

$$s = \left(\sum_{i=1}^{2} E_i\right)^2 - \left(\sum_{i=1}^{2} p_i\right)^2 . \qquad (1)$$

In $\overline{\mathsf{P}}\mathsf{ANDA}$ the proton target is at rest, so it's momentum P_p is zero. For antiproton proton annihilation, $s = m_{\bar{p}}^2 + 2E_{\bar{p}}m_p + m_p^2$. Hence, we have Lorentz invariant quantity $s = 8.56$ GeV^2 and the center-of-mass energy is $\sqrt{s} =$ 2.92 GeV. This is the energy now present in the system at $P_{\bar{p}} = 3.5$ GeV/c and is enough for the production of $f_0(1710)$.

The Lorentz invariant flux in the laboratory

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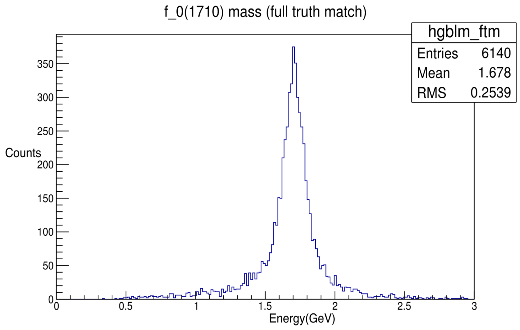

FIG. 1: Full truth match energy curve of $f_0(1500)$ glueball resonance state identified by PANDA-Root simulation for 10000 events.

frame is [9],

$$F_{\bar{p}p} = 4m_p P_{\bar{p}}. \tag{2}$$

It is purely dependent on input momentum of antiproton beam and the rest mass of proton. In our case, $F_{\bar{p}p}$ =13.13 GeV^2/c.

Glueball Resonance in PANDA-Root

The decay channel $\bar{p}p \rightarrow f_0(1710)\gamma \rightarrow \pi^+\pi^-$; contains our interested glueball candidate as an intermediate state. We define the glueball state with its properties like particle code, mass, width, spin, charge etc. in the PANDARoot simulation package. We set the value antiproton momentum and the number of simulated events for the antiproton-proton collision. These events are generated using Monte Carlo simulation GEANT3 under PANDARoot framework. The process followed to study a particular channel is shown in ref. [6]. The energies and momenta of end product particles $\pi^+\pi^-$ are reconstruct the state at vertex which is the intermediate glueball state $f_0(1710)$. The full truth match energy curves for the 10000 simulated events are identified glueball resonance state $f_0(1710)$ is shown given in Fig. 1.

Results and Discussion

Using the PANDARoot simulation package we identified the glueball resonance state $f_0(1710)$. The end state particles $\pi^+\pi^-$ reconstruct the state $f_0(1710)$ with a mean mass 1678 MeV and is agreement with 1723 MeV of PDG [10]. We have to set some input parameter in a simulation package in such a way that the center-of-mass energy ($\sqrt{s}$) must be larger than the energy of the particles are need to be produce; here $\sqrt{s} > m_{f_0(1710)} + m_\gamma$. We fit the antiproton beam momentum $P_{\bar{p}} = 3.5$ GeV/c, it gives the antiproton beam energy $E_{\bar{p}} = 3.62$ GeV and the center-of-mass energy $\sqrt{s} = 2.92$ GeV; and is enough energy for the production of $f_0(1710)$. We also set the antiproton proton collision events, here we set 10000 events; from which 6140 entries recognize the state $f_0(1710)$ with a mean value of mass 1678 MeV.

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