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Study of Open Charm Production $\Psi(3770) \rightarrow D^+D^-$ at the PANDA Experiment

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The branching fraction of $\Psi(3770) \rightarrow p\bar{p}$ is measured with the BESIII data. With this branching fraction, the cross section of $p\bar{p} \rightarrow \Psi(3770)$, which is important to the PANDA experiment, can be calculated according to the detailed balance. Finally the capability of the current PANDA design to detect the reaction of $p\bar{p} \rightarrow \Psi(3770) \rightarrow D^+D^-$ is studied.

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1. Introduction

The charmonium states above the $D\bar{D}$ breakup threshold could provide rich physics programs in the PANDA experiment, such as the charmonium spectroscopy and the open charm physics. However, the poorly measured charmonium production cross sections are still open questions for these physics programs. Before the operation of the PANDA experiment, an estimation of these cross sections is necessary. One solution is to calculate these charmonium production cross sections using the branching fractions of their reversed processes. This leads us to the measurement of the unknown branching fractions of Ψ(above $D\bar{D}) \to p\bar{p}$. Above the $D\bar{D}$ breakup threshold, the partial width of charmonium to $p\bar{p}$ is expected to be tiny, which indicates large statistic of charmonium is required.

$\Psi(3770)$ is the first charmonium state above the $D\bar{D}$ breakup threshold, and can be produced directly in e^+e^- experiment. With the success of the energy and detector upgrade of Beijing Electro-Positron Collider(BEPC), the BESIII facility has become the high luminosity τ-charm factory. Large amount of J/Ψ, $\Psi(2S)$, $\Psi(3770)$ have been taken and some higher charmonium states, such as $\Psi(4040)$, will also been taken in future. This provides us the chance to measure the branching fraction of Ψ(above $D\bar{D}) \to p\bar{p}$.

Another issue is the capability of the current PANDA design to detect the reaction of $p\bar{p} \to \Psi(3770) \to D^+D^-$. To better show the performance of the current PANDA detector, we implemented the DISC Dirc software in PandaRoot (PANDA simulation and reconstruction software package). This DISC Dirc software provides good particle identification information in the forward direction, which is important for our study. Then we did detailed study of $p\bar{p} \to \Psi(3770) \to D^+D^-$ with the decay channel of $D \to K\pi\pi$.

2. The BESIII experiment and the PANDA experiment

The BESIII detector is a large solid-angle magnetic spectrometer installed at the upgraded Beijing Electron Positron Collider(BEPCII). It is composed of a Helium-gas based drift chamber(MDC), a Time-Of-Flight(TOF) system, a CsI(Tl) Electro-Magnetic Calorimeter(EMC), a superconducting solenoid magnet and a RPC-based muon chamber(MUC). [1]

The PANDA detector will be installed at the High Energy Storage Ring at the future Facility for Antiproton and Ion Research. It is composed of two main parts: a Target Spectrometer (TS) and a Forward Spectrometer (FS). The TS part will be used to measure particles at laboratory angles greater than 5^o and 10^o in vertical and horizontal direction, respectively. It contains a microvertex silicon detector(MVD), a central tracker, a time-of-flight telescope, a barrel DIRC and DISC DIRC for particle identification, an electromagnetic calorimeter, the muon counters and mini drift chambers. The FS part is dedicated to detect particles at forward angles below 5^o and 10^o in vertical and horizontal direction. It contains a dipole magnet, tracking detectors, a gas Cerenkov detector and time-of-flight detectors. [2]

3. The analysis of $\Psi(3770) \to p\bar{p}$ at BESIII

Since 2009, BESIII has taken over 220M J/Ψ, 106M $\Psi(2S)$, about $1 fb^{-1}$ $\Psi(3770)$ events and more charmonium data will be collected in the next few years. With the current $1fb^{-1}$ $\Psi(3770)$ events, we studied the decay of $\Psi(3770) \to p\bar{p}$.

In this analysis, the final states include two charged tracks: one proton and one anti-proton. The charged tracks are reconstructed using MDC. Protons and anti-protons are identified by using barrel TOF information. The following is the selection criteria.

- Good charged track selection
  - Charged tracks are reconstructed from MDC
  - Number of good charged track is 2, net charge is 0;
- PID: $Prob(p) > Prob(\pi)$ and $Prob(p) > Prob(K)$
- $|cos(\theta)| < 0.8$ (momentum of $p, \bar{p}$, to exclude beam related background)
- $\theta(p, \bar{p}) > 170^o$ (Angle between $p\bar{p}$)

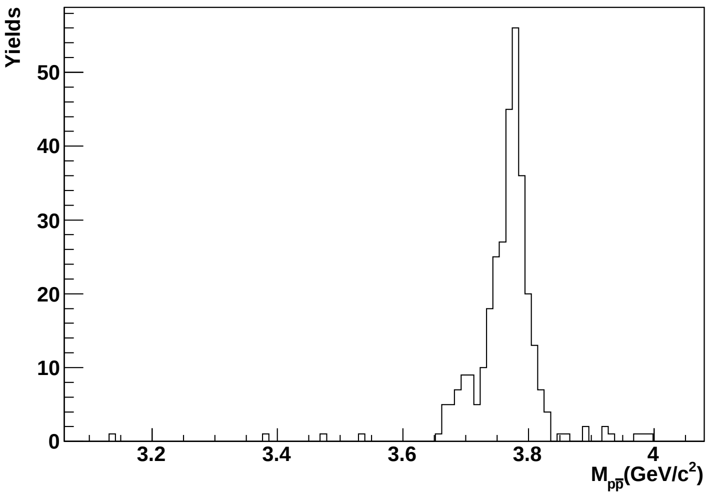

Figure 1: The invariant mass of $p\bar{p}$.

After the event selection, the $p\bar{p}$ mass spectrum of those survived events are shown in Fig.1. With these selected signals, the cross section of $e^+e^- \to p\bar{p}$ can be determined. Fig.2 shows the cross section of e^+e^- versus the center-of-mass energy [1]. The non-resonant contribution is comparable to the cross section of $e^+e^- \to \Psi(3770)$ at the energy point of 3.773GeV. To subtract the non-resonant contribution, about $40pb^{-1}$ continuum data at 3.65GeV is studied. Neglecting the interference between continuum and resonance amplitudes, the difference in the corrections for the ISR and vaccum polarization effect, the cross section of $\Psi(3770) \to p\bar{p}$ can be determined according to the following formula:

$$\sigma_{\Psi(3770)\to p\bar{p}} = [\sigma^{3.773GeV}_{e^+e^-\to p\bar{p}} - f \times \sigma^{3.65GeV}_{e^+e^-\to p\bar{p}}] \pm \sqrt{(\Delta^{3.773GeV}_{stat.})^2 + (f \times \Delta^{3.65GeV}_{stat.})^2}$$

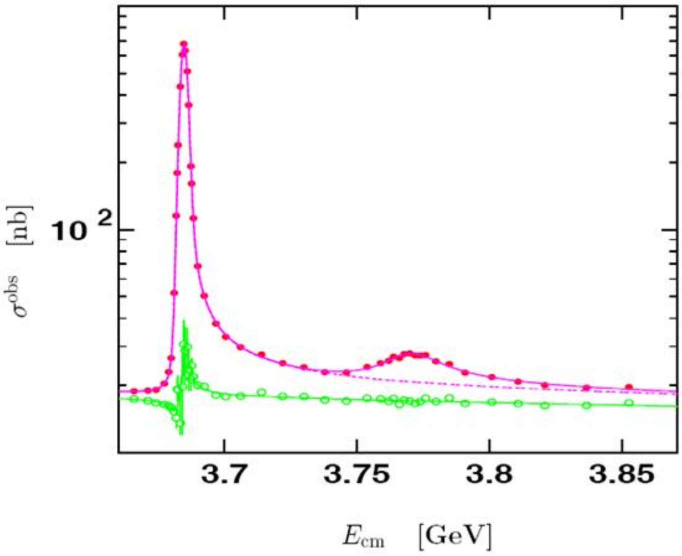

Figure 2: The cross section of e^+e^- versus the center-of-mass energy. Solid dot is the observed hadronic cross section. Blank dot is the non-resonant contribution. [1]

where, $f = 3.65^2/3.773^2$.

With the measured branching ratio of $\Psi(3770) \to p\bar{p}$, the cross section of $p\bar{p} \to \Psi(3770) \to D^+D^-$ can be calculated:

$$\sigma_R(S) \equiv \frac{4\pi(\hbar c)^2}{(s-4m_p^2c^4)} \frac{B_{in}B_{out}}{1+[2(\sqrt{s}-M_Rc^2)/\Gamma_R]^2}$$

here $B_{in} \equiv B(\Psi(3770) \to p\bar{p})$ and $B_{out} \equiv B(\Psi(3770) \to D^+D^-)$.

4. Simulation of $p\bar{p} \to \Psi(3770) \to D^+D^-$ at PANDA

To better show the performance of K/π separation, we implemented the software of DISC Dirc in PandaRoot. The software involves the following four steps: the detector description, the production of DISC hits, the match of DISC hit with inner track, and the implementation of disc particle identification. With this software, the K/π separation in the forward direction is well improved. Then we simulated 100000 $p\bar{p} \to \Psi(3770) \to D^+D^-$ with $D^+ \to K^-\pi^+\pi^+$ and $D^- \to K^+\pi^-\pi^-$. The MVD, TPC(Time Projection Chamber) and GEM are used in the track reconstruction. Kinematic fit is used in this analysis, as shown in Fig.3. With kinematic fit, the mass spectrum of $\Psi(3770)$ is well improved.

The detection efficiency of this channel is very low, due to some reasons, such as the detector acceptance of all 6 final states(only Target Spectrometer used), the tracking efficiency, the efficiency of PID, the efficiency of kinematic fit etc. PandaRoot is at the early stage of development, the detailed study of efficiency at each step is under way.

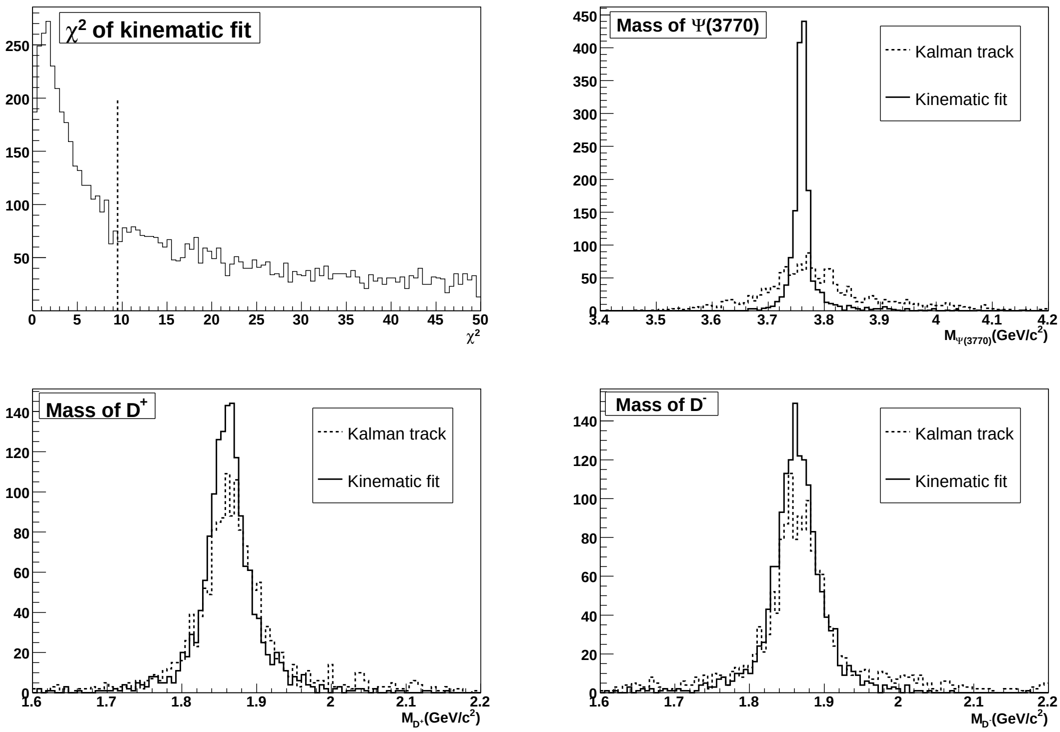

Figure 3: χ^2 of kinematic fit and the invariant mass of $\Psi(3770), D^+, D^-$.

5. Summary

In this paper, the measurement of $\Psi(3770) \to p\bar{p}$ is first presented. With this measurement, the cross section of $p\bar{p} \to \Psi(3770) \to D^+D^-$ can be calculated. Because we have not got the approval of the BESIII collaboration, the final result is not shown in this paper.

Using the current PandaRoot, the detection efficiency of $p\bar{p} \to \Psi(3770) \to D^+D^-$ is also studied. With this detection efficiency and the estimation of charmonium production cross section, we will have a better perspective about the physics potential of the PANDA experiment.

6. Acknowledgements

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References

[1] Preliminary Design Report of the BESIII detector, Jan,2004. IHEP-BEPCII-SB-13

[2] PANDA Collaboratioin, Physics Performance Report for: PANDA, 2009