Excited Nucleons Study at BESIII

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With the 106 million ψ' events collected at BESIII in 2009, the decay of $\psi' \to p\overline{p}\eta$ is studied. Partial wave analysis shows that N(1535) contributes a lot in the mass spectrum of $p\eta(\overline{p}\eta)$. The mass, width and spin-parity of N(1535) are determined to be $1.524^{+0.005+0.010}_{-0.005-0.005} GeV/c^2$, $0.130^{+0.027+0.061}_{-0.027-0.014} GeV/c^2$ and $\frac{1}{2}^-$. The decay of $\psi' \to p\overline{p}\pi^0$ is also studied.

1 Introduction

Although symmetric non-relativistic three-quark models of baryons are quite successful in interpreting low-lying excited baryon resonances, they tend to predict far more excited states than are found experimentally (missing resonance problem) [1, 2]. From the theoretical point of view, this could be due to a wrong choice of the degrees of freedom and models considering di-quarks have been proposed [3]. Experimentally, the situation is very complicated due to the large number of broad and overlapping states that are observed. Moreover, in traditional studies using tagged photons or pion beams, both isospin 1/2 and isospin 3/2 resonances are excited, further complicating the analysis.

An alternative method to investigate nucleon resonances is via decays of charmonium states such as J/ψ and ψ'. By selecting specific decay channels, such as $\psi' \to p\overline{p}\pi^0$, the N* intermediate resonance coupling to $p\pi^0$ or $\overline{p}\pi^0$ can be studied. Here, Δ resonances are excluded due to isospin conservation. As a consequence, the reduced number of states greatly facilitates the analysis [4].

N* production in $J/\psi \to p\overline{p}\eta$ was studied using partial wave analysis at BESI [5], in which two N* resonances were observed. In a recent analysis of $J/\psi \to p\overline{n}\pi^- + c.c.$ [6], a new N* resonance around $2GeV/c^2$ named $N_x(2065)$ was observed. This $N_x(2065)$ was also observed in the decay of $J/\psi \to p\overline{p}\pi^0$ [7]. The production of N(2065) in J/ψ decay is close to the edge of the phase space. Thus, a similar search for this resonance in the ψ' decays might be helpful. Here we report a study of N* resonances from $\psi' \to p\overline{p}\eta$ and $\psi' \to p\overline{p}\pi^0$ based on the 106M ψ' sample collected by the upgraded Beijing Spectrometer (BESIII), located at the Beijing Electron-Positron Collider(BEPCII) [8].

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2 Partial wave analysis of $\psi' \rightarrow p\overline{p}\eta$

In this analysis, only $\eta \rightarrow \gamma\gamma$ is used, which is about 40% [9] of the total statistics. In Figure 1, the left plot shows a clean η peak and the η mass cut(dashed line), and the right plot shows the dalitz plot of $M^2_{p\eta}$ versus $M^2_{\overline{p}\eta}$. The presence of N* resonance in $M_{p\eta}$ and $M_{\overline{p}\eta}$ is obvious.

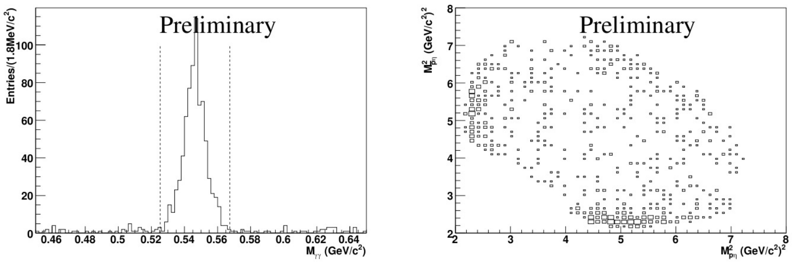

Figure 1: $M_{\gamma\gamma}$(left) and the dalitz plot of $M^2_{p\eta}$ versus $M^2_{\overline{p}\eta}$(right). Dashed lines in the left plot indicate the cut values used.

A partial wave analysis(PWA) has been done, in which the phase space decay, one 1^{--} $p\overline{p}$ resonance, and nine N* intermediate resonances: N(1440), N(1520), N(1535), N(1650), N(1700), N(1710), N(1720), N(1900), N(2080), are considered, and their mass, width, spin-parity and other parameters are taken from PDG [9]. The significance level of each resonance is studied and only N(1535) and the phase space decay are significant. Using N(1535) and the phase space decay, the PWA result agrees with the data well (Figure 2).

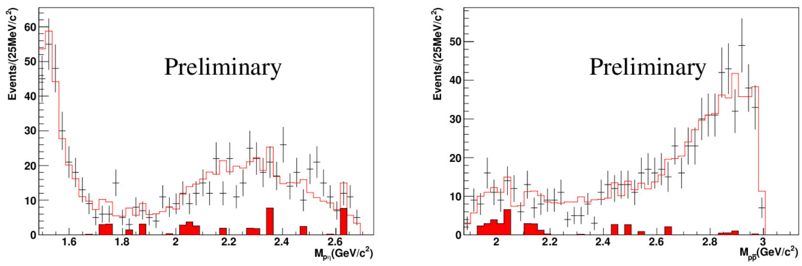

Figure 2: The invariant mass of $p\eta$(left) and $p\overline{p}$(right). The histogram is for PWA result, the error bar corresponds data, and the shaded histogram means the background from η sideband and the continuum data.

From the result of PWA, the mass and width of N(1535) are $1.524^{+0.005+0.010}_{-0.005-0.005} GeV/c^2$ and $0.130^{+0.027+0.061}_{-0.027-0.014} GeV/c^2$, where the first errors are statistical and the second are systematic. And the spin-parity is determined to be $\frac{1}{2}^-$. These are consistent with the PDG values [9]. The branching ratio of $\psi' \rightarrow p\overline{p}\eta$ is measured to be $(6.6 \pm 0.3 \pm 0.6) \times 10^{-5}$. This measurement agrees with PDG value [9], but has a smaller error. The production branching ratio of ψ' to $p\overline{p}\eta$ via N(1535) is $(5.5^{+0.3+7.4}_{-0.3-1.0}) \times 10^{-5}$. This is the first measurement.

3 Study of $\psi' \to p\overline{p}\pi^0$

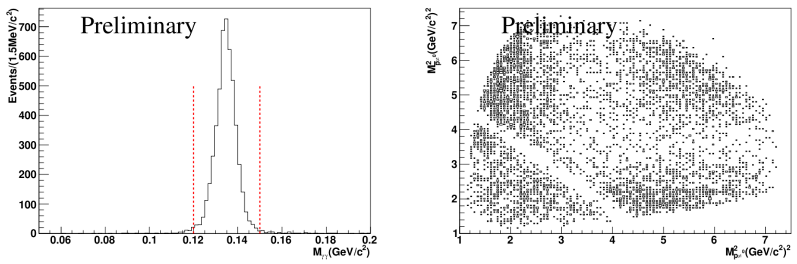

Figure 3: $M_{\gamma\gamma}$(left) and the dalitz plot of $M^2_{p\pi^0}$ versus $M^2_{\overline{p}\pi^0}$(right). Dashed lines in the left plot indicate the cut values used.The gap of the right plot is due to the cut of J/ψ decays.

This analysis has the same final states as the former decay. In Figure 3, the left plot shows the clean π^0 peak and the cut(dashed line) on its mass spectrum, and the right plot shows the dalitz plot of $M^2_{p\pi^0}$ versus $M^2_{\overline{p}\pi^0}$ which is obviously non-uniform. The mass spectra of $p\pi^0$ and $p\overline{p}$ are shown in Figure 4. Several N* peak can be seen below $1.7GeV/c^2$ from the $p\pi^0$ mass spectrum. In this analysis, $p\overline{p}$ production are excluded.

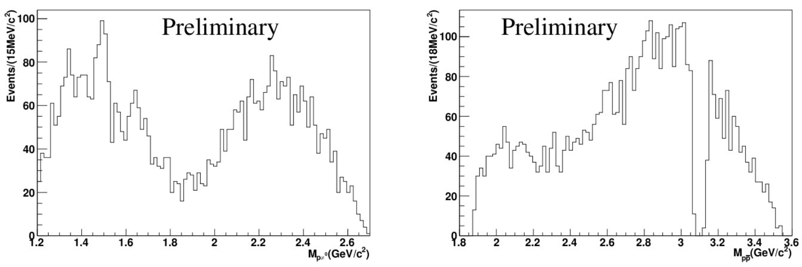

Figure 4: The invariant mass of $p\pi^0$(left) and $p\overline{p}$(right). The gap of the right plot is due to the cut of J/ψ decays.

In a recent analysis of the CLEO-c Collaboration [10], $\psi' \to p\overline{p}\pi^0$ are studied using 24.5×10^6 ψ' events. Without taking account of any possible interferences between resonances, they studied the contibution of two N* resonances N(1440) and N(2300) and two $p\overline{p}$ resonances $R_1(2100)$ and $R_2(2900)$ respect to the structures in $p\pi^0$ and $p\overline{p}$ mass spectra. In our present investigation, with almost four times of statistics than CLEO-c's analysis and also taking account of the interferences, more detailed information about intermediate states are expected. Now, the partial wave analysis of this work is ongoing.

4 Summary

In this analysis, two ψ' decay channels about excited nucleon states are reported. For these channels via charmonium decay, the reduced number of intermediate resonances due to the isospin conservation greatly facilitates the analysis. The purpose of this paper focuses on showing the way of N* study via charmonium decay at BESIII. Using this method, more analysis related to excited nucleon states could be performed with many other decay channels, such as $\psi' \to N\overline{N}$ by $N\pi\pi$(or $\overline{N}\pi\pi$) coupling. Beside of excited baryon study, this method could also be used to study excited hyperons, such as Λ^*, Σ^*, and Ξ^* states. With the accumulating of more charmonium data samples, BESIII will have a bright future at the excited nucleon study.

Acknowledgments

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