RECENT $J/\psi$ RESULTS FROM BES II

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Multiquark searches have been a hot topic in recent years. Some threshold enhancements were observed during the analysis of 58M $J/\psi$ events collected by BES II detector. These enhancements can’t be explained by the standard model and may be candidates of multiquark. BES also contribute a lot to the study of light scalar mesons, such as $\sigma$, $\kappa$, $f_0(1370)$ and $f_0(1710)$ etc. Study of the excited baryon states and measurements of some $J/\psi$ decays are also done with the $J/\psi$ events of BES.

1 Introduction

58M $J/\psi$ events have been collected by BES II detector. Some analysis based on these data have been done and there are some important results on the multiquark search, light scalar mesons, excited baryon states and measurements of $J/\psi$ decays.

1.1 Multiquark candidates at BES

According to the naive quark Model, hadrons consist of 2 or 3 quarks. However, QCD allows new forms of hadrons, such as multi-quark states, hybrids($q\bar{q}g,qqg$) and glueballs(gg,ggg).

We observe a narrow enhancement near $2m_p$ in the invariant mass spectrum of $p\bar{p}$ pairs from radiative $J/\psi \rightarrow \gamma p\bar{p}$ decays, as shown in Fig. [1]. No similar structure is seen in $J/\psi \rightarrow \pi^0 p\bar{p}$ decays. The enhancement can be fit with either an S- or P-wave Breit-Wigner resonance function. In the case of the S-wave fit, the peak mass is below $2m_p$ at $M = 1859^{+5}_{-10}(\text{stat})^{+5}_{-25}(\text{syst})\text{MeV}/c^2$ and the total width is $\Gamma < 30\text{MeV}/c^2$ at the 90% confidence level. These mass and width values are not consistent with the properties of any known particle.

It is, therefore, of special interest to search for possible resonant structures in other baryon-antibaryon final states. The Belle Collaboration observed a near-threshold enhancement in the $p\Lambda$ mass spectrum from $B \rightarrow p\Lambda\pi$ decays. In the $J/\psi$ data collected by BES II, an enhancement
near the $M_p + M_\Lambda$ mass threshold is observed in the combined $p\bar{\Lambda}$ and $\bar{p}\Lambda$ invariant mass spectrum from $J/\psi \to pK^-\bar{\Lambda} + c.c.$ decays, as shown in Fig. 2. It can be fit with an S-wave Breit-Wigner resonance with a mass $m = 2075 \pm 12 \pm 5$ MeV and a width of $\Gamma = 90 \pm 35 \pm 9$ MeV. It can also be fit with a P-wave Breit-Wigner resonance. Evidence for a similar enhancement is also observed in $\psi' \to pK^-\bar{\Lambda} + c.c.$ decays from BES II data.

During the analysis of $p\bar{\Lambda}$ threshold enhancement in $J/\psi \to pK^-\bar{\Lambda} + c.c.$ decays, we also noticed an extra-ordinary enhancement near the threshold of the invariant mass spectrum of $K^-\bar{\Lambda} + c.c.$ Partial Wave Analysis is carried out to understand its properties. Its mass varies within $1.5 \sim 1.6$ GeV, and its width is about $70 \sim 110$ MeV. The most important is that it has a very large branching ratio of $\sim 2 \times 10^{-4}$, which indicates an extra-ordinary large coupling to $K^-\bar{\Lambda}$ channel.

1.2 Light Scalar Mesons

There have been hot debates on the existence of $\sigma$ and $\kappa$. Using the 58M $J/\psi$ events from BES II, the decay $J/\psi \to \omega \pi^+\pi^-$ is studied. At low $\pi\pi$ mass, a large broad peak due to the $\sigma$ is observed. Two independent analyses are performed, and different parameterizations of the $\sigma$ pole are applied. The mass and width of the $\sigma$ are different when using different parameterizations. However the pole position of $\sigma$ is stable. Different analysis methods and different parameterizations of the $\sigma$ amplitude give consistent results for the $\sigma$ pole. From a simple mean of the six analyses, the pole position of the $\sigma$ is determined to be $541 \pm 39 - i(252 \pm 42)$ MeV.

Based on 58M $J/\psi$ events from BES II, $K^*(892)K^+\pi^-$ channel from $K^+K^-\pi^+\pi^-$ data is studied. A clear low mass enhancement in the invariant mass spectrum of $K^+\pi^-$ is observed. The low mass enhancement does not come from background events of other $J/\psi$ decay channels, nor from phase space effect. The scalar resonance $\kappa$ is highly required in the analysis. Two independent partial wave analyses have been performed in $K^*(892)K^+\pi^-$ channel. Both analyses favor that the low mass enhancement is an isospinor scalar resonant state. The mass and width are $878 \pm 60^{+64}_{-55}$ and $499 \pm 109^{+87}_{-58}$ MeV, respectively in average for results in both analyses.

Lattice QCD predicts the $0^{++}$ scalar glueball mass at $1.5 \sim 1.7$ GeV. $f_0(1500)$ and $f_0(1710)$ are good candidates. We also studied some other light scalar mesons with the BES data, such as $f_0(980)$.

A partial wave analysis is presented of $J/\psi \to \phi\pi^+\pi^-$ and $J/\psi \to \phi K^+K^-$. The $f_0(980)$ is
observed in both sets of data, and parameters of the Flatté formula are determined accurately:

\[ M = 965 \pm 8(\text{stat}) \pm 6(\text{syst})\text{MeV}/c^2, g_1 = 165 \pm 10 \pm 15\text{MeV}/c^2, g_2/g_1 = 4.21 \pm 0.25 \pm 0.21. \]

The \( J/\psi \to \phi\pi^+\pi^- \) data sample also exhibit a strong \( \pi\pi \) peak centered at \( M = 1335\text{MeV}/c^2 \), as shown in Fig. 3. It may be fitted with \( f_2(1270) \) and a dominant \( 0^+ \) signal made from \( f_0(1370) \) interfering with a smaller \( f_0(1500) \) component. There is evidence that the \( f_0(1370) \) is resonant, from interference with \( f_2(1270) \). According to the partial wave analysis, the mass of \( f_0(1370) \) is \( M = 1350 \pm 50\text{MeV}/c^2 \) and width is \( 265 \pm 40\text{MeV}/c^2 \). In the analysis of \( J/\psi \to \phi K^+K^- \), the magnitude of the signal due to \( f_0(1370) \to K^+K^- \) in the PWA fit gives a branching fraction ratio

\[ \frac{Br(f_0(1370) \to K\bar{K})}{Br(f_0(1370) \to \pi\pi)} = 0.08 \pm 0.08. \]

There is no evidence of \( f_0(1370) \) in the \( \pi\pi \) spectrum of \( J/\psi \to \omega\pi^+\pi^- \).

![Figure 3: The invariant mass distribution of \( \pi^+\pi^- \) from Figure 4: The invariant mass distribution of \( K^+K^- \) from \( J/\psi \to \phi\pi^+\pi^- \) decays. The upper histogram shows the \( J/\psi \to \omega K^+K^- \) decays. The histogram shows the mass maximum likelihood fit and the lower one shows back-projection of \( f_0 \) and the dashed curve shows the \( \sigma \to K^+K^- \) S-wave contribution.](image)

In the analysis of \( J/\psi \to \omega K^+K^- \), there is a conspicuous signal for \( f_0(1710) \to K^+K^- \), as shown in Fig. 4. A \( KK \) fit for \( f_0(1710) \) with \( J = 0 \) yields \( M = 1738 \pm 30\text{MeV}/c^2 \) and \( \Gamma = 125 \pm 20\text{MeV}/c^2 \). Earlier BES II data on \( J/\psi \to \gamma K^+K^- \) and \( J/\psi \to \gamma K^0_sK^0_s \) gave \( M = 1740 \pm 4(\text{stat})\pm^{10}_{25}(\text{syst})\text{MeV}/c^2 \) and \( \Gamma = 166^{+5}_{-8}\pm15\text{MeV}/c^2 \). The branching ratio for \( J/\psi \to \omega f_0(1710), f_0(1710) \to K^+K^- \) is \( (6.6 \pm 1.3) \times 10^{-4} \). From a combined analysis with \( \omega\pi^+\pi^- \) data, we find at the 95% confidence level

\[ \frac{Br(f_0(1710) \to \pi\pi)}{Br(f_0(1710) \to KK)} < 0.11. \]

In the analysis of \( J/\psi \to \gamma\pi\pi \), there is a scalar around 1765MeV. It may come from \( f_0(1790), f_0(1710) \) or a mixture of \( f_0(1710) \) and \( f_0(1790) \).

According to the OZI rule, in \( J/\psi \) decays, an \( \omega \) or \( \phi \) signal determines the \( u\bar{u} + d\bar{d} \) or \( s\bar{s} \) component, respectively. However, there are some unusual properties of the \( f_0(1370) \) and \( f_0(1710) \). The \( f_0(1370) \) dominantly decays to \( \pi\pi \)(not to KK) \( \to u\bar{u} + d\bar{d} \), but it is mainly produced together with \( \phi \)(not \( \omega \)). The \( f_0(1710) \) dominantly decays to KK( not to \( \pi\pi \)) \( \to s\bar{s} \), but it is mainly produced together with \( \omega \)(not \( \phi \)).

### 1.3 Excited baryon states

Using the 58M \( J/\psi \) events of BES, more than 100 thousand \( J/\psi \to p\pi^-\bar{n} + \text{c.c.} \) events are obtained. Besides two well known \( N^* \) peaks at 1500MeV and 1670MeV, there are two new,
clear $N^*$ peaks in the $p\pi$ invariant mass spectrum around 1360 MeV and 2030 MeV, as shown in Fig. 5. They are the first direct observation of the $N^*(1440)$ peak and a long-sought "missing" $N^*$ peaks above 2 GeV in the $\pi N$ invariant mass spectrum. A simple Breit-Wigner fit gives the mass and width for the $N^*(1440)$ peak as $1358 \pm 6 \pm 16$ MeV and $179 \pm 26 \pm 50$ MeV, and for the new $N^*$ peaks above 2 GeV as $2068 \pm 3^{+15}_{-40}$ MeV and $165 \pm 14 \pm 40$ MeV.

1.4 Measurement of $J/\psi$ decays

Some branching ratios of $J/\psi$ decays are measured for the first time in BES. The decay $J/\psi \rightarrow \gamma f_2(1270)f_2(1270) \rightarrow \gamma \pi^+\pi^-\pi^+\pi^-$ is observed for the first time and its branching ratio is measured to be $Br(J/\psi \rightarrow \gamma f_2f_2) = (9.5\pm0.7\pm1.6) \times 10^{-4}$. The branching fraction of $J/\psi \rightarrow \gamma\eta_c, \eta_c \rightarrow f_2f_2$ is also measured to be $Br(J/\psi \rightarrow \gamma\eta_c) \cdot Br(\eta_c \rightarrow f_2f_2) = (1.3 \pm 0.3^{+0.3}_{-0.4}) \times 10^{-4}$. The branching fractions of $J/\psi \rightarrow 2(\pi^+\pi^-)\eta$ and $J/\psi \rightarrow 3(\pi^+\pi^-)\eta$ are measured for the first time to be $(2.26 \pm 0.08 \pm 0.27) \times 10^{-4}$ and $(7.24 \pm 0.96 \pm 1.11) \times 10^{-4}$, respectively.

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