Recent Results From BESII

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We present recent results from the BES experiment on the observation of the $Y(2175)$ in $J/\psi \to \phi f_0(980)\eta$, and $\eta(2225)$ in $J/\psi \to \gamma\phi\phi$, and $X(1440)$ in J/ψ hadronic decays, together with the new observation of $\psi(2S)$ radiative decays and hadronic decays into $nK^0_S\bar{\Lambda}+c.c.$, $\Lambda\bar{\Lambda}\pi^0$, $\Lambda\bar{\Lambda}\eta$. The effort to search for J/ψ decays into $\gamma\gamma$ and invisible decays are also reported.

I. INTRODUCTION

The analyses reported in this talk were performed using either a sample of 58×10^6 J/ψ events or a sample of 14×10^6 $\psi(2S)$ events collected with the upgraded Beijing Spectrometer (BESII) detector [1] at the Beijing Electron-Positron Collider (BEPC).

II. LIGHT HADRON SPECTROSCOPY

A. The $Y(2175)$ in $J/\psi \to \phi f_0(980)\eta$ [2]

A new structure, denoted as $Y(2175)$ and with mass $m = 2.175 \pm 0.010 \pm 0.015$ GeV/c^2 and width $\Gamma = 58 \pm 16 \pm 20$ MeV/c^2, was observed by the BaBar experiment in the $e^+e^- \to \gamma_{ISR}\phi f_0(980)$ initial-state radiation process [3, 4]. This observation stimulated some theoretical speculation that this $J^{PC} = 1^{--}$ state may be an s-quark version of the $Y(4260)$ since both of them are produced in e^+e^- annihilation and exhibit similar decay patterns [5, 6].

Here we report the observation of the $Y(2175)$ in the decays of $J/\psi \to \eta\phi f_0(980)$, with $\eta \to \gamma\gamma$, $\phi \to K^+K^-$, $f_0(980) \to \pi^+\pi^-$. A four-constraint energy-momentum conservation kinematic fit is performed to the $K^+K^-\pi^+\pi^-\gamma\gamma$ hypothesis for the selected four charged tracks and two photons. $\eta \to \gamma\gamma$ candidates are defined as γ-pairs with $|M_{\gamma\gamma} - 0.547| < 0.037$ GeV/c^2, a ϕ signal is defined as $|m_{K^+K^-} - 1.02| < 0.019$ GeV/c^2, and in the $\pi^+\pi^-$ invariant mass spectrum, candidate $f_0(980)$ mesons are defined by $|m_{\pi^+\pi^-} - 0.980| < 0.060$ GeV/c^2. The $\phi f_0(980)$ invariant mass spectrum for the selected events is shown in Fig. 1, where a clear enhancement is seen around 2.18 GeV/c^2. Fit with a Breit-Wigner and a polynomial background yields 52 ± 12 signal events and the statistical significance is found to be 5.5σ for the signal. The mass of the structure is determined to be $M = 2.186 \pm 0.010$ $(stat) \pm 0.006$ $(syst)$ GeV/c^2, the width is $\Gamma = 0.065 \pm 0.023$ $(stat) \pm 0.017$ $(syst)$ GeV/c^2, and the product branching ratio is $\mathcal{B}(J/\psi \to \eta Y(2175)) \cdot \mathcal{B}(Y(2175) \to \phi f_0(980)) \cdot \mathcal{B}(f_0(980) \to \pi^+\pi^-) = (3.23 \pm 0.75\ (stat) \pm 0.73\ (syst)) \times 10^{-4}$. The mass and width are consistent with BaBar's results.

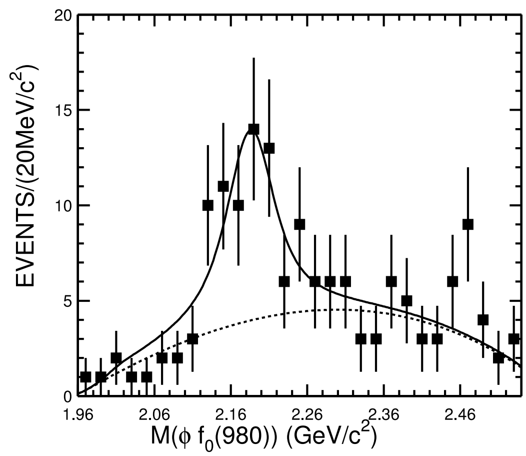

FIG. 1: The $\phi f_0(980)$ invariant mass distribution of the data (points with error bars) and the fit (solid curve) with a Breit-Wigner function and polynomial background; the dashed curve indicates the background function.

B. The $\eta(2225)$ in $J/\psi \to \gamma\phi\phi$ [7]

Structures in the $\phi\phi$ invariant-mass spectrum have been observed by several experiments both in the reaction $\pi^-p \to \phi\phi n$ [8] and in radiative J/ψ decays [9–11]. The $\eta(2225)$ was first observed by the MARK-III collaboration in J/ψ radiative decays $J/\psi \to \gamma\phi\phi$. A fit to the $\phi\phi$ invariant-mass spectrum gave a mass of 2.22 GeV/c^2 and a width of 150 MeV/c^2 [9]. An angular analysis of the structure found it to be consistent with a 0^{-+} assignment. It was subsequently observed by the DM2 collaboration, also in $J/\psi \to \gamma\phi\phi$ decays [10, 11].

We present results from a high statistics study of $J/\psi \to \gamma\phi\phi$ in the $\gamma K^+K^-K^0_SK^0_L$ final state, with the K^0_L missing and reconstructed with a one-constraint kinematic fit. After kinematic fit, we require both the K^+K^- and $K^0_SK^0_L$ invariant masses lie within the ϕ mass region ($|M(K^+K^-) - m_\phi| < 12.5$ MeV/c^2 and $|M(K^0_SK^0_L) - m_\phi| < 25$ MeV/c^2). The $\phi\phi$ invariant mass distribution is shown in Fig. 2. There are a total of 508 events with a prominent structure around 2.24 GeV/c^2.

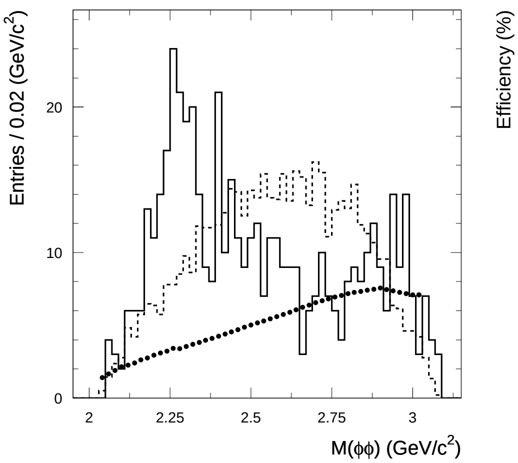

FIG. 2: The $K^+K^-K^0_SK^0_L$ invariant mass distribution for $J/\psi \to \gamma\phi\phi$ candidate events. The dashed histogram is the phase space invariant mass distribution, and the dotted curve indicates how the acceptance varies with the $\phi\phi$ invariant mass.

A partial wave analysis of the events with $M(\phi\phi) <$ 2.7 GeV/c^2 was performed. The two-body decay amplitudes in the sequential decay process $J/\psi \to \gamma X, X \to \phi\phi$, $\phi \to K^+K^-$ and $\phi \to K^0_SK^0_L$ are constructed using the covariant helicity coupling amplitude method. The intermediate resonance X is described with the normal Breit-Wigner propagator $BW = 1/(M^2 - s - iM\Gamma)$, where s is the $\phi\phi$ invariant mass-squared and M and Γ are the resonance's mass and width. When $J/\psi \to \gamma X$, $X \to \phi\phi$ is fitted with both the $\phi\phi$ and γX systems in a P-wave, which corresponds to a pseudoscalar X state, the fit gives 196 ± 19 events with mass $M = 2.24^{+0.03+0.03}_{-0.02-0.02}$ GeV/c^2, width $\Gamma = 0.19 \pm 0.03^{+0.04}_{-0.06}$ GeV/c^2, and a statistical significance larger than 10σ, and a product branching fraction of: $\mathcal{B}(J/\psi \to \gamma\eta(2225)) \cdot \mathcal{B}(\eta(2225) \to \phi\phi) = (4.4 \pm 0.4 \pm 0.8) \times 10^{-4}$.

The presence of a signal around 2.24 GeV/c^2 and its pseudoscalar character are confirmed, and the mass, width, and branching fraction are in good agreement with previous experiments.

C. The $X(1440)$ in J/ψ hadronic decays [12]

A pseudoscalar gluonium candidate, the so-called $E/\iota(1440)$, was observed in $p\bar{p}$ annihilation in 1967 [13] and in J/ψ radiative decays in the 1980's [14–16]. The study of the decays $J/\psi \to \{\omega, \phi\}K\bar{K}\pi$ is a useful tool in the investigation of quark and possible gluonium content of the states around 1.44 GeV/c^2. Here we investigate the possible structure in the $K\bar{K}\pi$ final state in J/ψ hadronic decays at around 1.44 GeV/c^2.

In this analysis, ω mesons are observed in the $\omega \to \pi^+\pi^-\pi^0$ decay, ϕ mesons in the $\phi \to K^+K^-$ decay, and other mesons are detected in the decays: $K^0_S \to \pi^+\pi^-$, $\pi^0 \to \gamma\gamma$. $K\bar{K}\pi$ could be $K^0_SK^\pm\pi^\mp$ or $K^+K^-\pi^0$.

Figures 3 and 4 show the $K^0_SK^\pm\pi^\mp$ and $K^+K^-\pi^0$ invariant mass spectra after ω selection ($|m_{\pi^+\pi^-\gamma\gamma} - m_\omega| < 0.04$ GeV/c^2) or ϕ signal selection ($|m_{K^+K^-} - m_\phi| < 0.015$ GeV/c^2). Clear $X(1440)$ signal is observed recoiling against the ω, and there is no significant signal recoiling against a ϕ.

The $K^0_SK^\pm\pi^\mp$ invariant mass distribution in $J/\psi \to \omega K^0_SK^\pm\pi^\mp$ (Fig. 3(b)) is fitted with a BW function convoluted with a Gaussian mass resolution function ($\sigma = 7.44$ MeV/c^2) to represent the $X(1440)$ signal and a third-order polynomial background function. The mass and width obtained from the fit are $M = 1437.6 \pm 3.2$ MeV/c^2 and $\Gamma = 48.9 \pm 9.0$ MeV/c^2, and the fit yields 249 ± 35 events. Using the efficiency of 1.45% determined from a uniform phase space MC simulation, we obtain the branching fraction to be $\mathcal{B}(J/\psi \to \omega X(1440)) \cdot \mathcal{B}(X(1440) \to K^0_SK^+\pi^- + c.c.) = (4.86 \pm 0.69 \pm 0.81) \times 10^{-4}$, where the first error is statistical and the second one systematic.

For $J/\psi \to \omega K^+K^-\pi^0$ mode, by fitting the $K^+K^-\pi^0$ mass spectrum in Fig. 3(c) with same functions, we obtain the mass and width of $M = 1445.9 \pm 5.7$ MeV/c^2 and $\Gamma = 34.2 \pm 18.5$ MeV/c^2, and the number of events from the fit is 62 ± 18. The efficiency is determined to be 0.64% from a phase space MC simulation, and the branching fraction is $\mathcal{B}(J/\psi \to \omega X(1440)) \cdot \mathcal{B}(X(1440) \to K^+K^-\pi^0) = (1.92 \pm 0.57 \pm 0.38) \times 10^{-4}$, in good agreement with the isospin symmetry expectation from $J/\psi \to \omega K^0_SK^\pm\pi^\mp$ mode.

The distribution of $K^0_SK^\pm\pi^\mp$ and $K^+K^-\pi^0$ invariant mass spectra recoiling against the ϕ signal are shown in Fig. 4, and there is no evidence for $X(1440)$. The upper limits on the branching fractions at the 90% C.L. are $\mathcal{B}(J/\psi \to \phi X(1440) \to \phi K^0_SK^+\pi^- + c.c.) < 1.93 \times 10^{-5}$ and $\mathcal{B}(J/\psi \to \phi X(1440) \to \phi K^+K^-\pi^0) < 1.71 \times 10^{-5}$.

In conclusion, the mass and width of the $X(1440)$ are measured, which are in agreement with previous measurements; the branching fractions we measured are also in agreement with the DM2 and MARK-III results. The significant signal in $J/\psi \to \omega K\bar{K}\pi$ mode and the missing signal in $J/\psi \to \phi X$ mode may indicate the $s\bar{s}$ component in the $X(1440)$ is not significant.

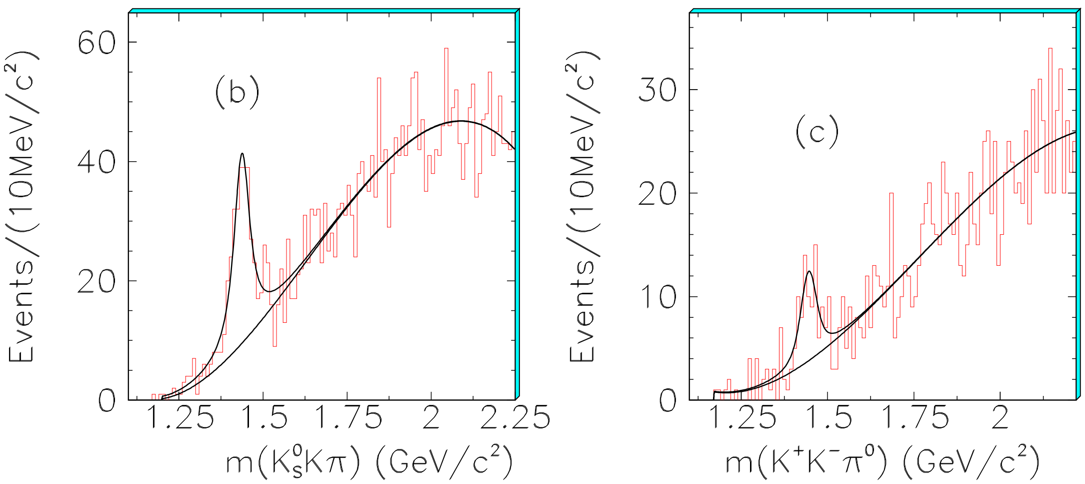

FIG. 3: The $K\bar{K}\pi$ invariant mass distribution for $J/\psi \to \omega K^0_S K^\pm \pi^\mp$ (b) and $\omega K^+K^-\pi^0$ (c) candidate events. The curves are the best fit.

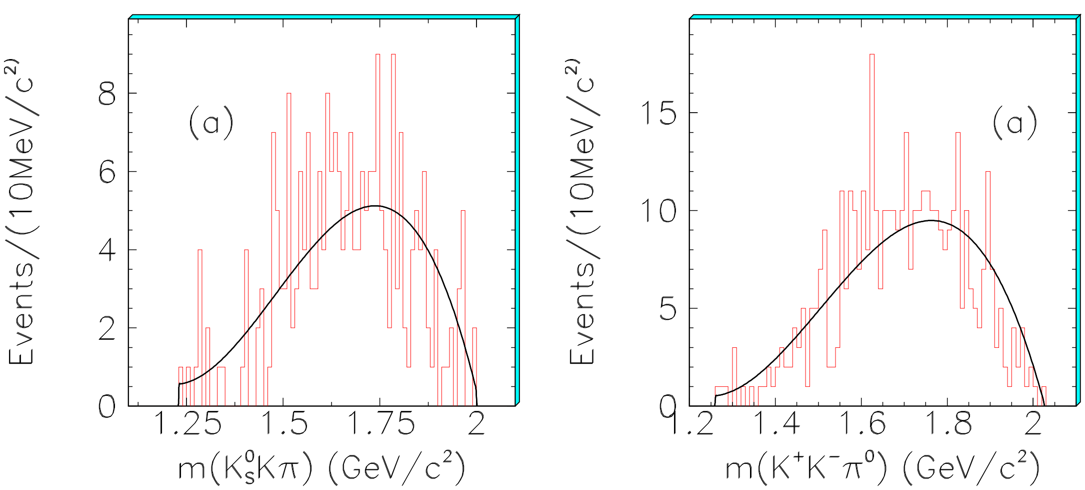

FIG. 4: The $K^0_S K^\pm \pi^\mp$ (left) and $K^+K^-\pi^0$ (right) invariant mass recoiling against the ϕ in $J/\psi \to \phi K\bar{K}\pi$ mode.

III. NEW OBSERVATIONS IN J/ψ AND $\psi(2S)$ DECAYS

A. $\psi(2S)$ radiative decays

Besides conventional meson and baryon states, QCD also predicts a rich spectrum of glueballs, hybrids, and multi-quark states in the 1.0 to 2.5 GeV/c^2 mass region. Therefore, searches for the evidence of these exotic states play an important role in testing QCD. The radiative decays of $\psi(2S)$ to hadrons are expected to contribute about 1% to the total $\psi(2S)$ decay width [17]. However, the measured channels only sum up to about 0.05% [18].

We measured the decays of $\psi(2S)$ into $\gamma p\overline{p}$, $\gamma 2(\pi^+\pi^-)$, $\gamma K^0_S K^+\pi^- + c.c.$, $\gamma K^+K^-\pi^+\pi^-$, $\gamma K^{*0}K^-\pi^+ + c.c.$, $\gamma K^{*0}\bar{K}^{*0}$, $\gamma\pi^+\pi^- p\overline{p}$, $\gamma 2(K^+K^-)$, $\gamma 3(\pi^+\pi^-)$, and $\gamma 2(\pi^+\pi^-)K^+K^-$, with the invariant mass of the hadrons (m_{hs}) less than 2.9 GeV/c^2 for each decay mode [19]. The differential branching fractions are shown in Fig. 5. The branching fractions below $m_{hs} < 2.9$ GeV/c^2 are given in Table I, which sum up to 0.26% of the total $\psi(2S)$ decay width. We also analyzed $\psi(2S) \to \gamma\pi^+\pi^-$ and γK^+K^- modes to study the resonances in $\pi^+\pi^-$ and K^+K^- invariant mass spectrum. Significant signals for $f_2(1270)$ and $f_0(1710)$ were observed, but the low

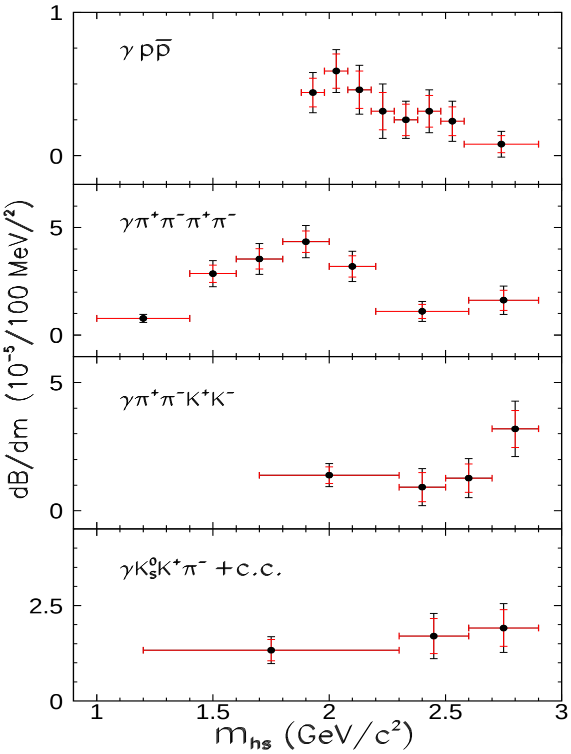

FIG. 5: Differential branching fractions for $\psi(2S) \to \gamma p\overline{p}$, $\gamma 2(\pi^+\pi^-)$, $\gamma K^+K^-\pi^+\pi^-$, and $\gamma K^0_S K^+\pi^- + c.c.$. Here m_{hs} is the invariant mass of the hadrons. For each point, the smaller longitudinal error is the statistical error, while the bigger one is the total error.

statistics prevent us from drawing solid conclusion on the other resonances [20].

B. J/ψ, $\psi(2S) \to nK^0_S\bar{\Lambda} + c.c.$, $\Lambda\bar{\Lambda}\pi^0$, $\Lambda\bar{\Lambda}\eta$

The $X(2075)$ was first reported by BESII near the threshold of the invariant mass spectrum of $p\bar{\Lambda}$ in $J/\psi \to pK^-\bar{\Lambda}$ decays. The mass, width, and product branching fraction of this enhancement are $M = 2075 \pm 12$ (stat.) ± 5 (syst.) MeV/c^2, $\Gamma = 90 \pm 35$ (stat.) ± 9 (syst.) MeV/c^2 [21], and $B(J/\psi \to K^-X)B(X \to p\bar{\Lambda} + c.c.) = (5.9 \pm 1.4 \pm 2.0) \times 10^{-5}$, respectively. The study of the isospin conjugate channel $J/\psi \to nK^0_S\bar{\Lambda}$ is therefore important not only in exploring new decay modes of J/ψ but also in understanding the $X(2075)$.

The invariant mass spectra of ΛK^0_S, nK^0_S, and $\bar{\Lambda}n(\Lambda\bar{n})$, as well as the Dalitz plot for all selection requirements are shown in Fig. 6. In the ΛK^0_S invariant mass spectrum, an enhancement near ΛK^0_S threshold is evident, as is found in the ΛK mass spectrum in $J/\psi \to pK^-\bar{\Lambda}$ [22]. If the enhancement is fitted with an acceptance weighted S-wave Breit-Wigner function and a function $f_{bg}(\delta)$ describing the phase space "background" contribution, the fit leads to M=1.648±0.006GeV/c^2 and $\Gamma = 61 \pm 21$MeV/c^2, respectively. Here the errors are only statistical. The systematic uncertainties are not included since more accurate measurements of the mass and width should come from a full PWA involving interferences among N^* and Λ^* states. The fitted mass and width are consistent with those obtained from a partial wave analysis of $J/\psi \to pK^-\bar{\Lambda}$ [22]. The $X(2075)$ signal which was seen in the $p\bar{\Lambda}$ invariant mass spectrum in $J/\psi \to pK^-\bar{\Lambda}$ is not significant here. Using a Bayesian approach [23] and fixing the mass and width of $X(2075)$ to 2075 MeV/c^2 and 90 MeV/c^2 respectively, the upper limit on the number of events observed N^{UL}_{obs} is 54 events at the 90% C.L.

TABLE I: Branching fractions for $\psi(2S) \to \gamma + hadrons$ with $m_{hs} < 2.9$ GeV/c^2, where the upper limits are determined at the 90% C.L.

Mode	$\mathcal{B}(\times 10^{-5})$
$\gamma p\bar{p}$	2.9±0.4±0.4
$\gamma 2(\pi^+\pi^-)$	39.6±2.8±5.0
$\gamma K^0_S K^+\pi^- + c.c.$	25.6±3.6±3.6
$\gamma K^+K^-\pi^+\pi^-$	19.1±2.7±4.3
$\gamma K^{*0}K^+\pi^- + c.c.$	37.0±6.1±7.2
$\gamma K^{*0}\bar{K}^{*0}$	$24.0 \pm 4.5 \pm 5.0$
$\gamma\pi^+\pi^- p\bar{p}$	2.8±1.2±0.7
$\gamma K^+K^-K^+K^-$	< 4
$\gamma 3(\pi^+\pi^-)$	< 17
$\gamma 2(\pi^+\pi^-)K^+K^-$	< 22

The decays of J/ψ and $\psi(2S)$ to $nK^0_S\bar{\Lambda}+c.c.$ are observed for the first time, and their branching fractions are:

$$B(J/\psi \to nK^0_S\bar{\Lambda} + c.c.) = (6.46 \pm 0.20 \pm 1.07) \times 10^{-4},$$
$$B(J/\psi \to nK^0_S\bar{\Lambda}) = (3.09 \pm 0.14 \pm 0.58) \times 10^{-4},$$
$$B(J/\psi \to \bar{n}K^0_S\Lambda) = (3.39 \pm 0.15 \pm 0.48) \times 10^{-4},$$
$$B(\psi(2S) \to nK^0_S\bar{\Lambda}+c.c.) = (0.81 \pm 0.11 \pm 0.14) \times 10^{-4}.$$

The isospin violating process $J/\psi \to \Lambda\bar{\Lambda}\pi^0$ has been studied by DM2 [24] and BESI [25], and its average branching fraction is determined to be $\mathcal{B}(J/\psi \to \Lambda\bar{\Lambda}\pi^0) = (2.2 \pm 0.6) \times 10^{-4}$ [26]. However, the isospin conserving process $J/\psi \to \Lambda\bar{\Lambda}\eta$ has not been reported, and there are no measurements for $\Lambda\bar{\Lambda}\pi^0$ and $\Lambda\bar{\Lambda}\eta$ decays of $\psi(2S)$.

Table II lists the results for J/ψ and $\psi(2S)$ decay into $\Lambda\bar{\Lambda}\pi^0$ and $\Lambda\bar{\Lambda}\eta$, as well as $J/\psi \to \Sigma^+\pi^-\bar{\Lambda} + c.c.$. We also list the total branching fraction for the conjugate modes, where the common systematic errors have been taken out. Except for $J/\psi \to \Lambda\bar{\Lambda}\pi^0$ and $J/\psi \to \Sigma^+\pi^-\bar{\Lambda} + c.c.$, the results are first measure-

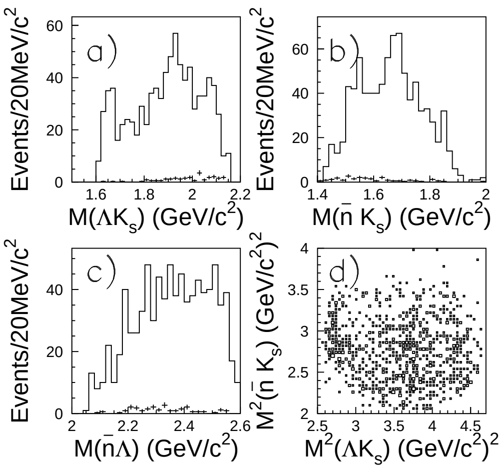

FIG. 6: The invariant mass spectra of (a) ΛK_S^0, (b) $\bar{n}K_S^0$, and (c) $\bar{n}\Lambda$, as well as (d) the Dalitz plot for candidate events after all selection criteria. The crosses show the sideband backgrounds.

ments. Interestingly, the result of $J/\psi \to \Lambda\bar{\Lambda}\pi^0$ presented here is much smaller than those of DM2 and BESI [24, 25]. In previous experiments, the large contaminations from $J/\psi \to \Sigma^0\pi^0\bar{\Lambda} + c.c.$ and $J/\psi \to \Sigma^+\pi^-\bar{\Lambda}+c.c.$ were not considered, resulting in a large value of branching fraction for $J/\psi \to \Lambda\bar{\Lambda}\pi^0$. The small branching fraction of $J/\psi \to \Lambda\bar{\Lambda}\pi^0$ and relatively large branching fraction of $J/\psi \to \Lambda\bar{\Lambda}\eta$ measured here indicate that the isospin violating decay in J/ψ decays is suppressed while isospin conserving decays are favored, which is consistent with expectation.

IV. SEARCH FOR J/ψ RARE DECAYS VIA $\psi(2S) \to \pi^+\pi^- J/\psi$

Search for J/ψ rare decays, e.g. C-parity violation or invisible decays, suffers from removing the QED backgrounds from the direct annihilation of e^+e^-. Using the J/ψ sample produced from $\psi(2S) \to \pi^+\pi^- J/\psi$, the QED background can be strongly suppressed. The direct decay $J/\psi \to \gamma\gamma$ was previously measured to be $Br(J/\psi \to \gamma\gamma) < 5\times10^{-4}$. BES studies the decay $J/\psi \to \gamma\gamma$ using $J/\psi \to \pi^+\pi - J/\psi$, and the upper limit for the branching ratio is measured to be $Br(J/\psi \to \gamma\gamma) < 2.2 \times 10^{-5}$ at 90% confidence level, which is about 20 times lower than previous measurements.

Invisible decays of quarkonium states offer a window into what may lie beyond the standard model. In standard model (SM), the predicted branching fraction for $J/\psi \to \nu\nu$ is $Br(J/\psi \to \nu\nu) = 4.54 \times 10^{-7} \times Br(J/\psi \to e^+e^-)$ with a small uncertainty (2%-3%). However, new physics beyond the SM might enhance the branching fraction of J/ψ invisible decays. One possibility is the decay into light dark matter particles mediated by a new, electrically neutral spin-1 gauge boson U, which could significantly increase the invisible decay rate [27]. It is of interest to search for such light invisible particle in collider experiments. Using $\psi(2S) \to \pi^+\pi^- J/\psi$ decays, a search for the decay of the J/ψ to invisible final states is performed. The J/ψ peak in the distribution of masses recoiling against the $\pi^+\pi^-$ is used to tag J/ψ invisible decays. No signal is found, and an upper limit at the 90% confidence level is determined to be 1.2×10^{-2} for the ratio $\frac{\mathcal{B}(J/\psi\to\text{invisible})}{\mathcal{B}(J/\psi\to\mu^+\mu^-)}$. This is the first search for J/ψ decays to invisible final states.

V. SUMMARY

Using the 58 M J/ψ and 14 M $\psi(2S)$ event samples taken with the BESII detector at the BEPC storage ring, BES experiment provided many interesting results in charmonium decays, including the observation of the $Y(2175)$, $\eta(2225)$, $X(1440)$, and many $\psi(2S)$ radiative decays. The effort to search for rare decays, e.g. J/ψ decays into $\gamma\gamma$ and invisible decays are also reported. These results shed light on the understanding of role played by strong interactions in charmonium decays.

Acknowledgments

This work is supported in part by the National Natural Science Foundation of China under contracts Nos. 10491300, 10225524, 10225525, 10425523,10625524, 10521003.

[1] J. Z. Bai *et al.* [BES Collaboration], Nucl. Instr. Meth. A **458**, 627 (2001).
[2] M. Ablikim *et al.* [BES Collaboration], Phys. Rev. Lett. **100**, 102003 (2008).
[3] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. D **74**, 091103 (2006).
[4] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. D **76**, 012008 (2007).
[5] B. Aubert *et al.* [BaBar Collaboration], Phys. Rev. Lett. **95**, 142001 (2005).
[6] C. Z. Yuan *et al.* [Belle Collaboration], Phys. Rev. Lett. **99**, 182004 (2007).
[7] M. Ablikim *et al.* [BES Collaboration], Phys. Lett. B **662**, 330 (2008).

TABLE II: Measured branching fractions or upper limits at 90% confidence level (C.L.) for all the studied channels. Here, $\mathcal{B}(\Lambda \to \pi^- p) = 63.9\%$, $\mathcal{B}(\Sigma^+ \to \pi^0 p) = 51.6\%$ and $\mathcal{B}(\eta \to \gamma\gamma) = 39.4\%$ are taken from the PDG.

Channels	Number of events	MC efficiency(%)	Branching fraction ($\times 10^{-4}$)
$J/\psi \to \Lambda\bar{\Lambda}\pi^0$	< 11.2	0.75	< 0.64
$J/\psi \to \Lambda\bar{\Lambda}\eta$	44 ± 10	1.8	$2.62 \pm 0.60 \pm 0.44$
$\psi(2S) \to \Lambda\bar{\Lambda}\pi^0$	< 7.0	2.5	< 0.49
$\psi(2S) \to \Lambda\bar{\Lambda}\eta$	< 7.6	2.9	< 1.2
$J/\psi \to \Sigma^+\pi^-\bar{\Lambda}$	335 ± 22	2.3	$7.70 \pm 0.51 \pm 0.83$
$J/\psi \to \bar{\Sigma}^-\pi^+\Lambda$	254 ± 19	1.8	$7.47 \pm 0.56 \pm 0.76$
$J/\psi \to \Sigma^+\pi^-\bar{\Lambda} + c.c.$			$15.17 \pm 0.76 \pm 1.59$

[8] A. Etkin *et al.*, Phys. Lett. B **201**, 568 (1988).
[9] Z. Bai *et al.* [MARK-III Collaboration], Phys. Rev. Lett. **65**, 1309 (1990).
[10] D. Bisello *et al.* [DM2 Collaboration], Phys. Lett. B **179**, 294 (1986).
[11] D. Bisello *et al.* [DM2 Collaboration], Phys. Lett. B **241**, 617 (1990).
[12] M. Ablikim *et al.* [BES Collaboration], Phys. Rev. D **77**, 032005 (2008).
[13] P. H. Baillon *et al.*, NC 50A, 393 (1967).
[14] D. L. Scharre *et al.*, Phys. Lett. B **97**, 329 (1980).
[15] C. Edwards *et al.*, Phys. Rev. Lett. **49**, 259 (1982); Phys. Rev. Lett. **50**, 219 (1982).
[16] J. E. Augustin *et al.* [DM2 Collaboration], Phys. Rev. D **42**, 10 (1990).
[17] P. Wang, C. Z. Yuan, and X. H. Mo, Phys. Rev. D **70**, 114014 (2004).
[18] W.-M. Yao *et al.* [Particle Data Group], J. Phys. G **33**, 1 (2006).
[19] M. Ablikim *et al.* [BES Collaboratio], Phys. Rev. Lett. **99**, 011802 (2007).
[20] M. Ablikim *et al.* [BES Collaboration], arXiv:0710.2324 [hep-ex].
[21] BES collaboration, M. Ablikim, et. al., Phys. Rev. Lett. 93(2004) 112002.
[22] H. X. Yang, for BES Collaboration Int. J. Mod. Phys. A 20(2005) 1985.
[23] G. J. Feldman, R. D. Cousins, Phys. Rev. D57 (1998) 3873.
[24] DM2 Collaboration, P. Henrard *et al.*, Nucl. Phys. B **292**, 670 (1987).
[25] BES Collaboration, J. Z. Bai *et al.*, Phys. Lett. B **424**, 213 (1998).
[26] Particle Physics Group, W. M. Yao *et al.*, J. Phys. G **33**, 1 (2006).
[27] C. Boehm and P. Fayet. Nucl. Phys. **B 683**, 219 (2004); C. Boehm and D. Hooper, J. Silk, M. Casse, and J. Paul, Phys. Rev. Lett. **92**, 101301 (2004); P. Fayet. Phys. Rev. D **70**, 023514 (2004); P. Fayet, Phys. Lett. **B 95**, 285 (1980); P. Fayet, Nucl. Phys. **B 187**, 184 (1981); S. H. Zhu, Phys. Rev. **D 75**, 115004 (2007).