Studies of charmonium decay from BESIII

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The Beijing Spectrometer III (BESIII) at the electron-positron collider BEPCII is a highly precise general-purpose detector designed for high luminosity e^+e^- collisions in the τ-charm energy region. Since 2009, the BESIII detector has been collecting the largest data sets at the J/ψ, $\psi(3686)$, and $\psi(3770)$ peaks, as well as scan data at $\sqrt{s} = 2.00 - 4.95$ GeV.

Studying the hadronic decays of the $c\bar{c}$ states J/ψ, $\psi(3686)$, and χ_{cJ} (J = 0, 1, 2) provides good opportunities to test theories in the transition region of perturbative and non-perturbative QCD, as well as valuable information on the structure of charmonia.

The first observation of $\psi(3686)$ decays to $\Xi(1530)^0\bar{\Xi}(1530)^0$ and $\Xi(1530)^0\bar{\Xi}^0$

Phys. Rev. D 104, 092012 (2021)

Data: 448M $\psi(3686)$
Channel: $\Xi(1530)^0 \to \Xi^-\pi^+$, $\Xi^- \to \Lambda\pi^-$, $\Lambda \to p\pi^-$

$B(\psi(3686) \to \Xi(1530)^0\bar{\Xi}(1530)^0) = (6.77 \pm 0.14_{stat} \pm 0.39_{syst}) \times 10^{-5}$

- The precision is improved by a factor of 40 [1];
- Isospin symmetry violation.

$B(\psi(3686) \to \Xi(1530)^0\bar{\Xi}^0) = (0.53 \pm 0.04_{stat} \pm 0.03_{syst}) \times 10^{-5}$

- SU(3) flavor symmetry violation;
- Isospin symmetry conservation within 1.5σ of the expectation;
- Violation of the "12% rule" in accordance with the previous measurement for its isospin charged mode $\Xi(1530)^-\bar{\Xi}^+$ [2-4].

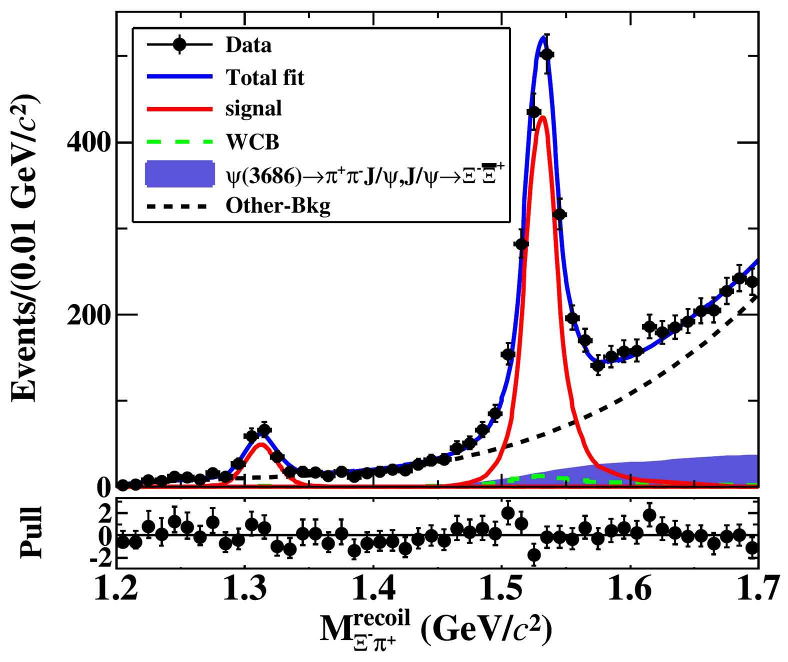

Figure: A simultaneous fit to the recoil mass of $\Xi^-\pi^+$ to determine yields for both decay modes.

The branching fractions of J/ψ and $\psi(3686)$ decays to $\Sigma^+\bar{\Sigma}^-$

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Data: 1.3B J/ψ and 448M $\psi(3686)$
Channel: $\Sigma^+(\bar{\Sigma}^-) \to p\pi^0\ (\bar{p}\pi^0)$, $\pi^0 \to \gamma\gamma$

$B(J/\psi \to \Sigma^+\bar{\Sigma}^-) = (10.61 \pm 0.04 \pm 0.36) \times 10^{-4}$

- The precision is improved by a factor of 7 [11].

$B(\psi(3686) \to \Sigma^+\bar{\Sigma}^-) = (2.52 \pm 0.04 \pm 0.09) \times 10^{-4}$

- In agreement with the PDG value within 2σ[5].

$B(\psi(3686) \to \Sigma^+\bar{\Sigma}^-)/B(J/\psi \to \Sigma^+\bar{\Sigma}^-) = (23.8 \pm 1.1)\%$

- Violation of the "12% rule" in accordance with the previous measurement in the $\Sigma^0\bar{\Sigma}^0$ final states by BESIII [12].

The first observation of the decays $\chi_{cJ} \to nK_s^0\bar{\Lambda}$ + c.c. (J = 0, 1, 2)

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Data: 448M $\psi(3686)$
Channel: $\psi(3686) \to \gamma\chi_{cJ}$ (J = 0, 1, 2), $K_s^0 \to \pi^+\pi^-$, $\bar{\Lambda} \to \bar{p}\pi^+$

$B(\chi_{c0} \to nK_s^0\bar{\Lambda} + c.c.) = (6.65 \pm 0.26_{stat} \pm 0.41_{syst}) \times 10^{-4}$
$B(\chi_{c1} \to nK_s^0\bar{\Lambda} + c.c.) = (1.66 \pm 0.12_{stat} \pm 0.12_{syst}) \times 10^{-4}$
$B(\chi_{c2} \to nK_s^0\bar{\Lambda} + c.c.) = (3.58 \pm 0.16_{stat} \pm 0.23_{syst}) \times 10^{-4}$

- No obvious isospin violation is observed by comparing with the isospin conjugate decays of $\chi_{cJ} \to pK^-\bar{\Lambda}$ + c.c. (J = 0, 1, 2) [8].

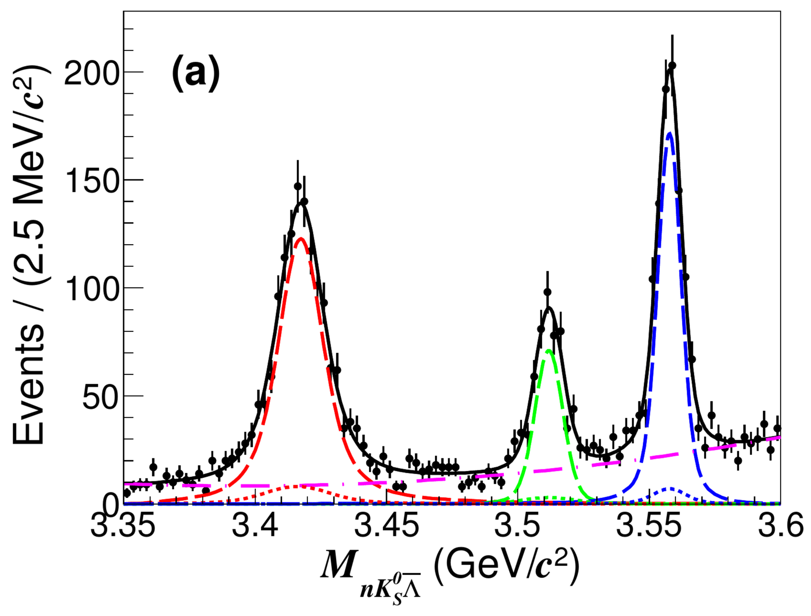

Figure: A simultaneous fit to the invariant mass spectra of $nK_s^0\bar{\Lambda}$ in the signal region.

The first observation of $\psi(3686)$ decay to $\omega K_s^0K_s^0$

Phys. Rev. D 104, 092003 (2021)

Data: 448M $\psi(3686)$
Channel: $\omega \to \pi^+\pi^-\pi^0$, $K_s^0 \to \pi^+\pi^-$

$B(\psi(3686) \to \omega K_s^0K_s^0) = (7.04 \pm 0.39_{stat} \pm 0.36_{syst}) \times 10^{-5}$

- Neither violation of the "12% rule" nor a possible violation of isospin symmetry has been established within the uncertainty [5-6].

The branching fraction of the isospin symmetry breaking decay $\psi(3686) \to \bar{\Sigma}^0\Lambda$ + c.c.

Phys. Rev. D 103, 112004 (2021)

Data: 448M $\psi(3686)$
Channel: $\bar{\Sigma}^0 \to \gamma\bar{\Lambda}$, $\bar{\Lambda}\ (\Lambda) \to \bar{p}\pi^+\ (p\pi^-)$

$B(\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.) = (1.60 \pm 0.31_{stat} \pm 0.13_{syst} \pm 0.58) \times 10^{-6}$ (the third uncertainty due to the $\psi(3686)$-continuum interference);

CLEO-c: $B(\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.) = (12.3 \pm 2.4) \times 10^{-6}$ [9];

Theoretical prediction: $B(\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.) = (4.0 \pm 2.3) \times 10^{-6}$ [10];

- The BESIII result is significantly smaller than the CLEO-c one and consistent with the theoretical prediction.

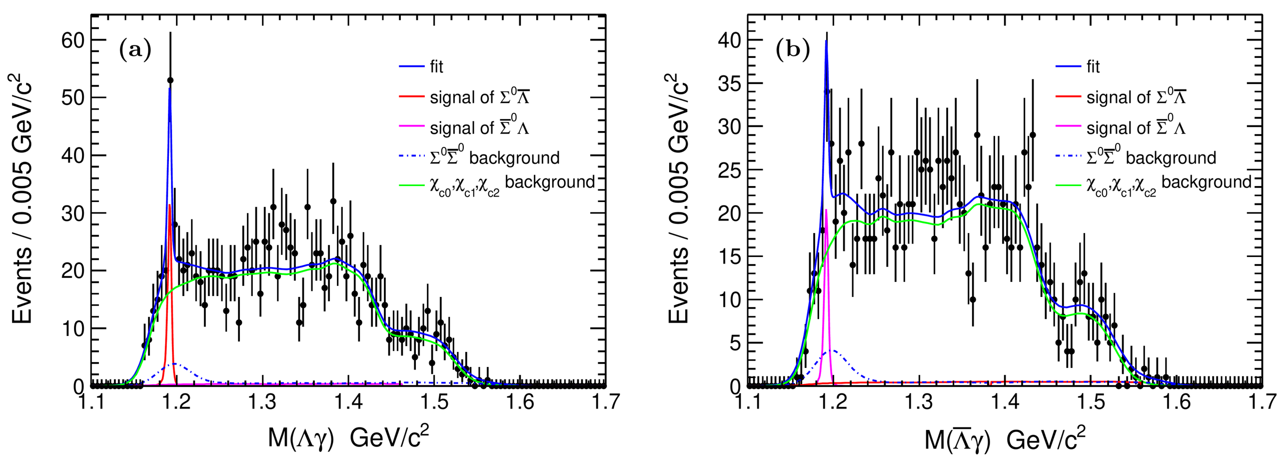

Figure: The projections from the two-dimensional fit to $M_{\gamma\Lambda}$ and $M_{\gamma\bar{\Lambda}}$.

The branching fraction of the inclusive decay $\psi(3686) \to K_s^0$ + anything

Phys. Letts. B 820, 136576 (2021)

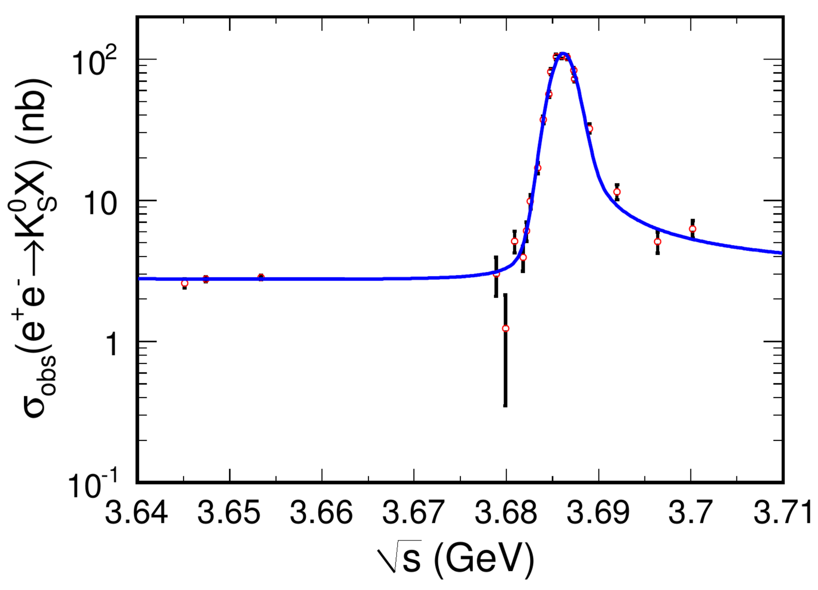

Figure: The best fit to the observed cross sections for $e^+e^- \to K_s^0X$.

Data: $\mathcal{L} = 5.9$ pb^{-1}, $\sqrt{s} = 3.640 - 3.701$ GeV
Channel: $K_s^0 \to \pi^+\pi^-$

$B(\psi(3686) \to K_s^0 + \text{anything}) = (16.04 \pm 0.29_{stat} \pm 0.90_{syst})\%$ is measured for the first time by fitting the observed inclusive K_s^0 cross-section line shape around $\psi(3686)$ peak

- The sum of all the BFs of $\psi(3686)$ decays to exclusive K_s^0 final states including the transitions followed by J/ψ and χ_{cJ} (J = 0, 1, 2) decays is ~ 5.95% [7];
- The BESIII result suggests that there are some undiscovered exclusive channels for $\psi(3686)$ decay to final states containing K_s^0.

Searching for hidden charmonia decays via inclusive prompt J/ψ production

Analysis is ongoing

Data: $\mathcal{L} = 20$ pb^{-1}, $\sqrt{s} = 3.8 - 4.7$ GeV
Channel: $J/\psi \to \mu^+\mu^-$, $\psi(3686) \to J/\psi\ \pi^+\pi^-$, $\chi_{cJ} \to \gamma J/\psi$, (J = 1, 2)

Prompt J/ψ originates from sources other than known decays or initial-state radiation (ISR).
Major background sources:

- inclusive J/ψ decays of $\psi(3686)$ and χ_{cJ}, (J = 1, 2);
- ISR return to the J/ψ and $\psi(3686)$ resonances.

Goal:

- Test if unknown channels/states exist;
- Test the NRQCD factorization hypothesis: the independence of Long Distance Matrix Elements (LDME) that describe the hadronization of the $c\bar{c}$ pair from the process (hadron-hadron collisions, electroproduction, or e^+e^- annihilation).

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