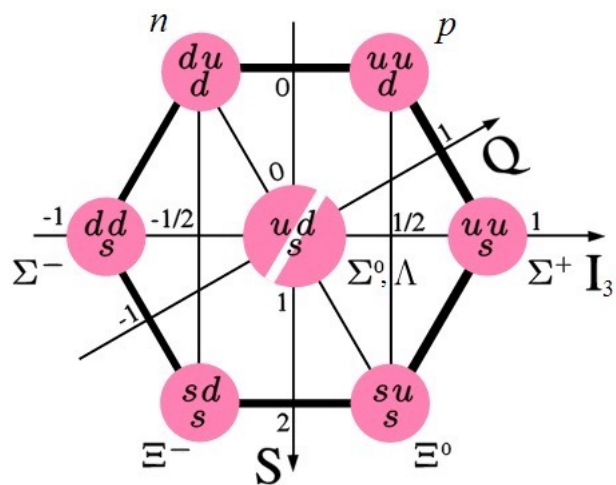# Measurement of
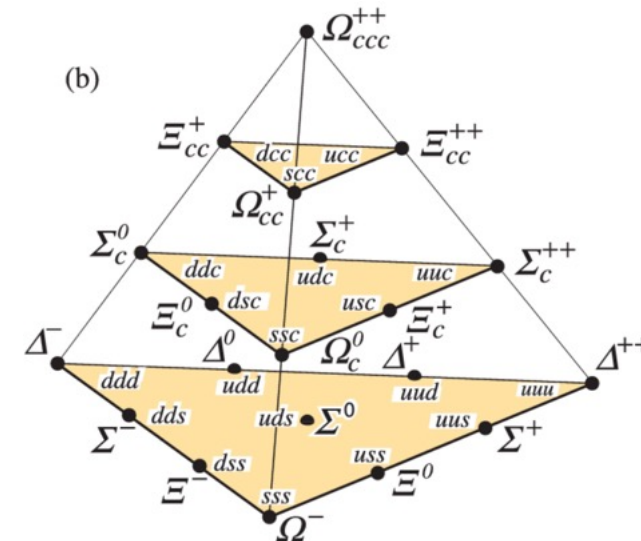# ψ(3686) decays to Baryon pairs

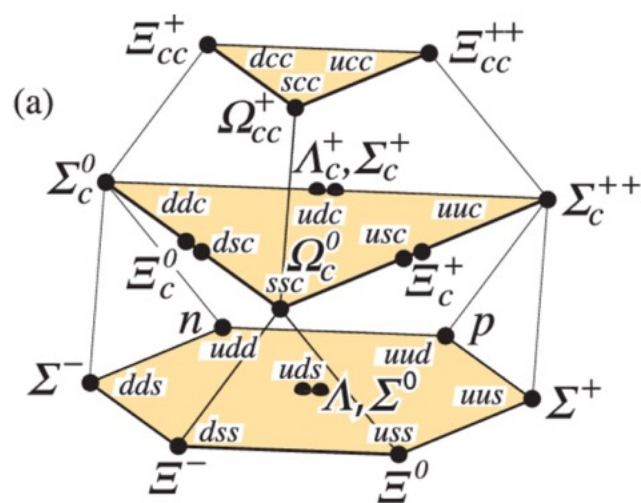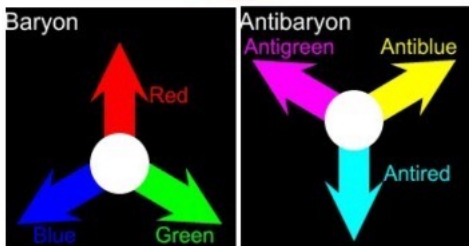**Qingping Ji (Henan Normal University)**
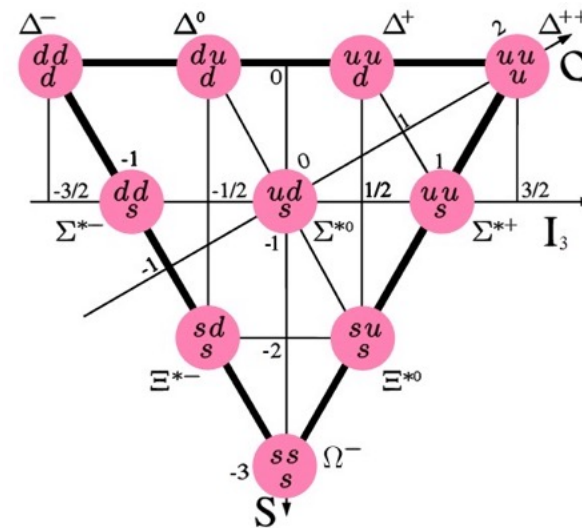
On behalf of BESIII Collaboration

QWG 2022 - The 15th International
Workshop on Heavy Quarkonium

26-30 九月 2022 **GSI Darmstadt**

Baryon States

Baryon Octet

Baryon Decuplet

Outline

Data samples: 448 M ψ(3686)，1310 M J/ψ.

- Measurement of BR. Of J/ψ and ψ(3686) decays to $\Sigma^+\bar{\Sigma}^-$

- Measurement of BR. Of $\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.$

- Observation of $\psi(3686) \to \Xi(1530)^0\bar{\Xi}(1530)^0$ and $\Xi(1530)^0\bar{\Xi}^0$

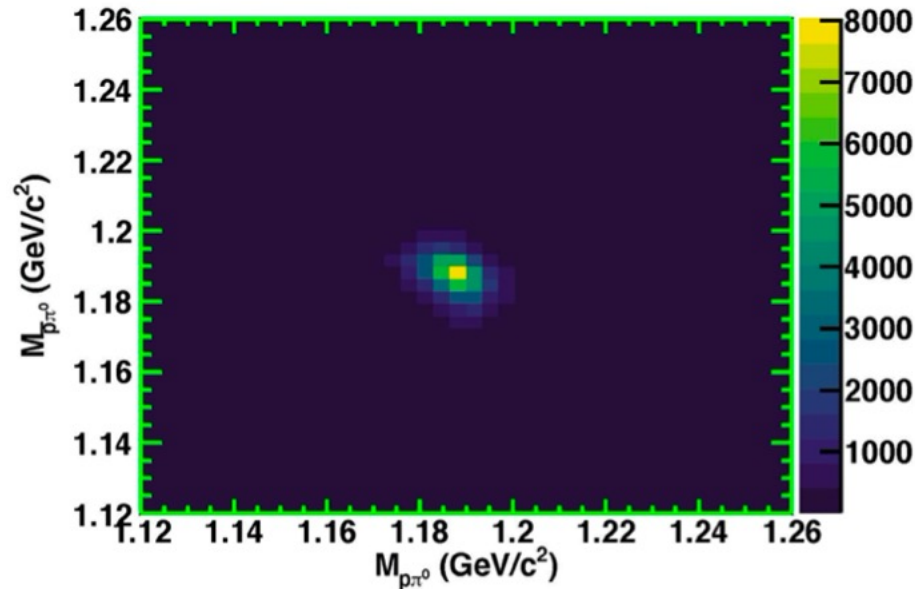- Observation of Ξ^- hyperon Transverse Polarization in $\psi(3686) \to \Sigma^+\bar{\Sigma}^-$

Measurement of BR. Of J/ψ and ψ(3686) decays to $\Sigma^+\bar{\Sigma}^-$

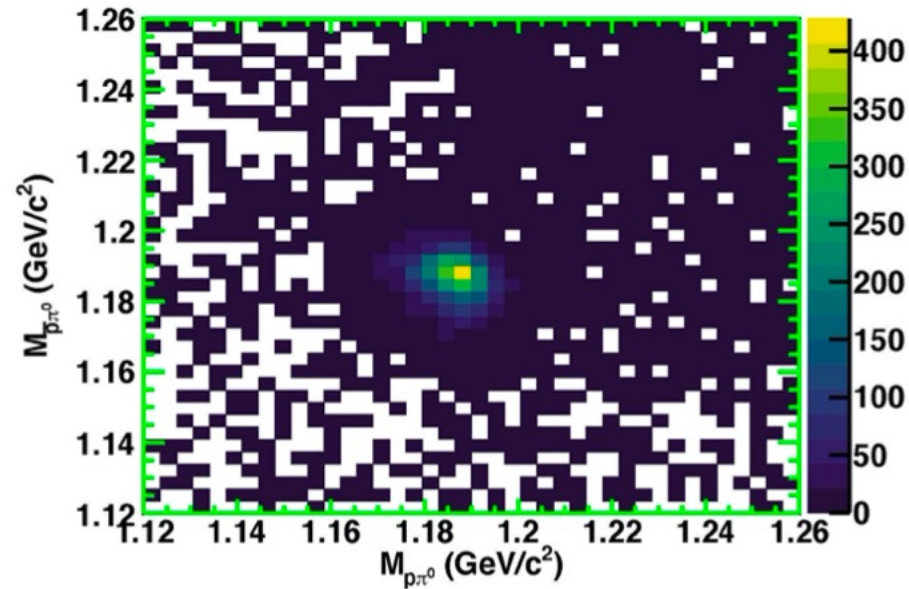- Event selection technique: Full reconstruction

$J/\psi \, / \psi(3686) \rightarrow \Sigma^+\bar{\Sigma}^-$

$\rightarrow \bar{p}\pi^0$

$\rightarrow p\pi^0$

$J/\psi \rightarrow \Sigma^+\bar{\Sigma}^-$

$\psi(3686) \rightarrow \Sigma^+\bar{\Sigma}^-$

4

Measurement of BR. Of J/ψ and ψ(3686) decays to $\Sigma^+\bar{\Sigma}^-$
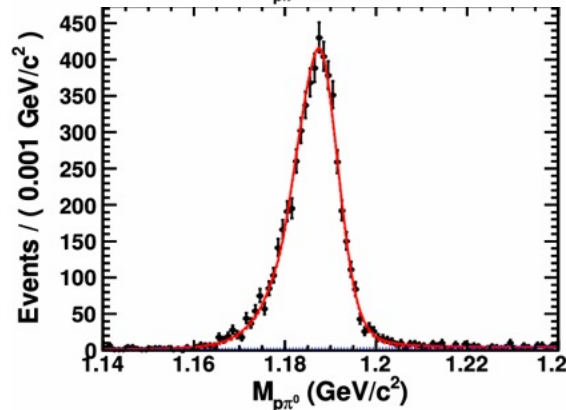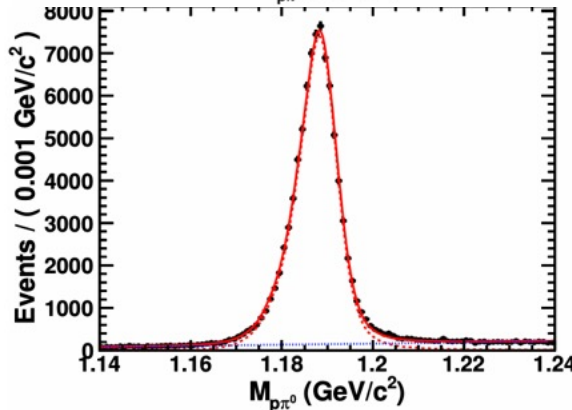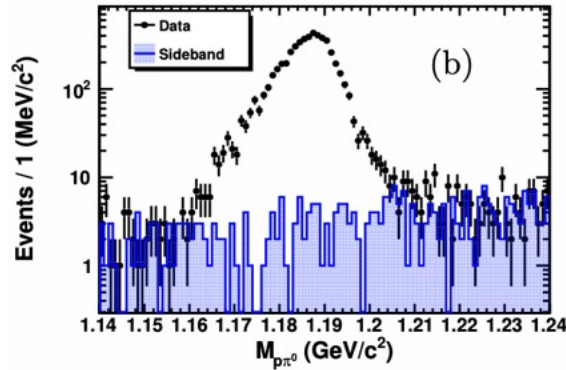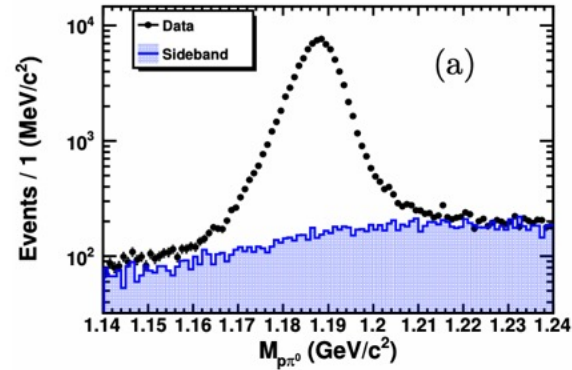
Left column: $J/\psi \to \Sigma^+\bar{\Sigma}^-$
Right column: $\psi(3686) \to \Sigma^+\bar{\Sigma}^-$

No obvious peaking background contribution in the sideband region.

$$\mathcal{Q} = \frac{\mathcal{B}(\psi(3686) \to \Sigma^+\bar{\Sigma}^-)}{\mathcal{B}(J/\psi \to \Sigma^+\bar{\Sigma}^-)} = \frac{(10.61 \pm 0.04 \pm 0.36)\times 10^{-4}}{(2.52 \pm 0.04 \pm 0.09)\times 10^{-4}}$$
$$= (23.8 \pm 1.1)\%$$

- $\mathcal{B}$ agree with the previous measurement (PRD 78,092005 (2008)) within 2σ
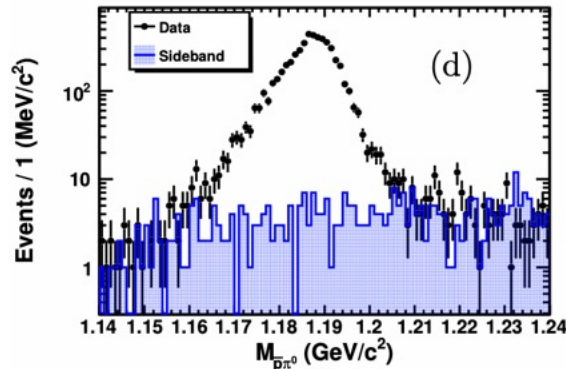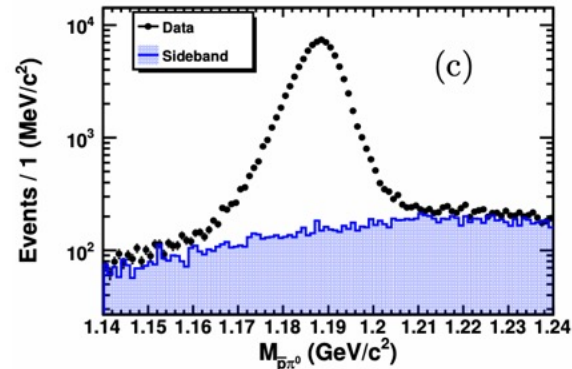- $\mathcal{B}(J/\psi \to \Sigma^+\bar{\Sigma}^-)$: Precision improved by a factor of 6.6 relative best measurement
- $\mathcal{Q}$ agree with the previous measurement in $\Sigma^0\bar{\Sigma}^0$ final states by BESIII (PRD 95, 052003 (2017)).

5

Measurement of BR. Of $\psi(3686) \to \overline{\Sigma}^0 \Lambda + c.c.$

- Event selection technique: Full reconstruction

$$\psi(3686) \to \overline{\Sigma}^0 \Lambda$$

$$\to p\pi^-$$

$$\to \gamma\overline{\Lambda}(\to \bar{p}\pi^+)$$

(a) Data
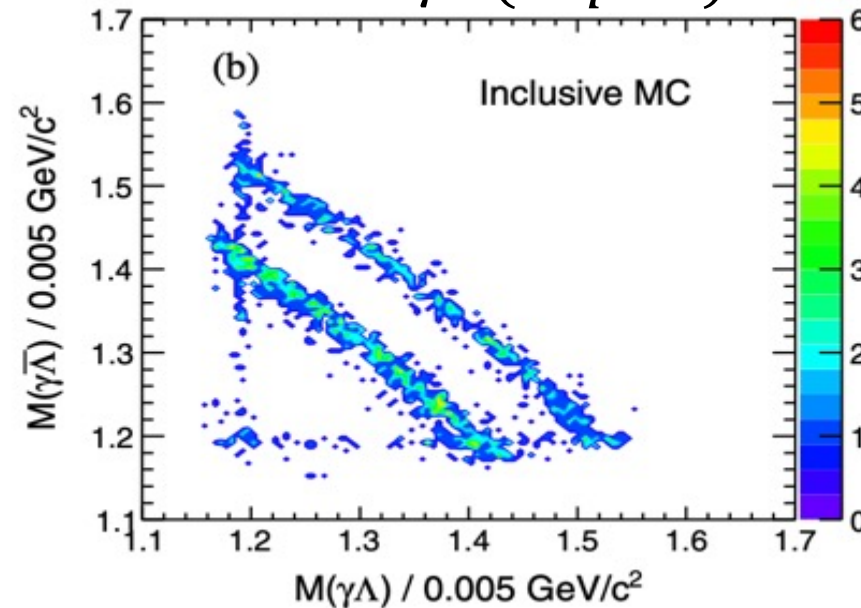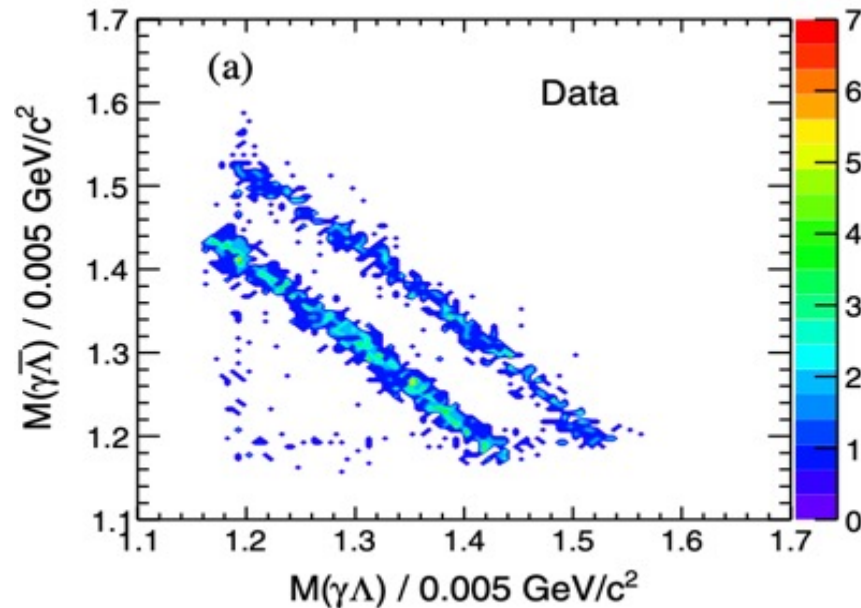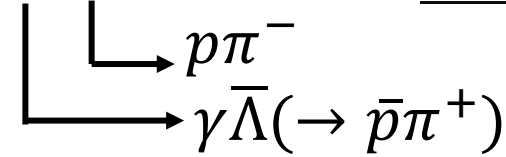
(b) Inclusive MC

- Two sloped bands are backgrounds from $\psi(3686) \to \gamma\chi_{cJ} \to \gamma\Lambda\overline{\Lambda}$, and well Simulated by the inclusive MC samples.
- Improved measurement for $\mathcal{B}(\chi_{cJ} \to \Lambda\overline{\Lambda})$, see Zhiyong's talk.

Measurement of BR. Of $\psi(3686) \rightarrow \overline{\Sigma}^0 \Lambda + c.\,c.$
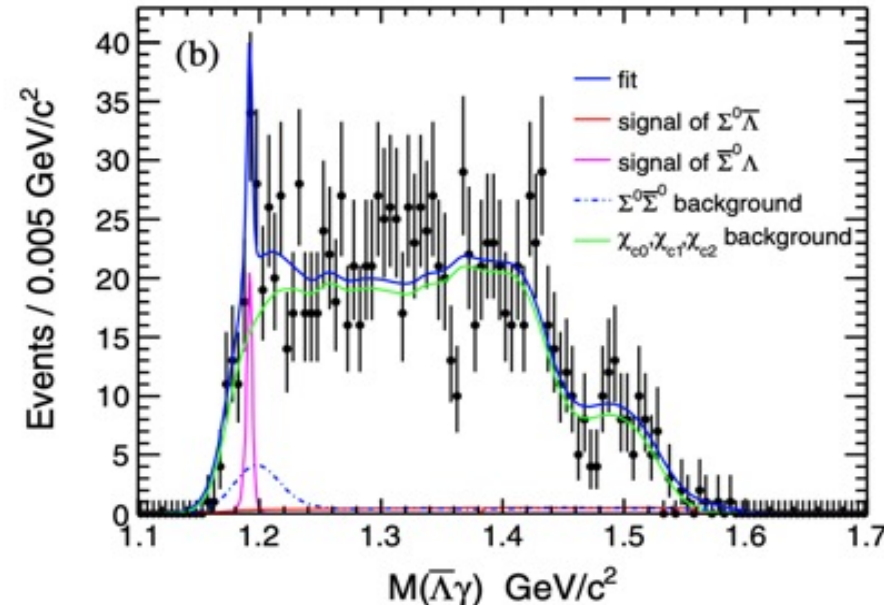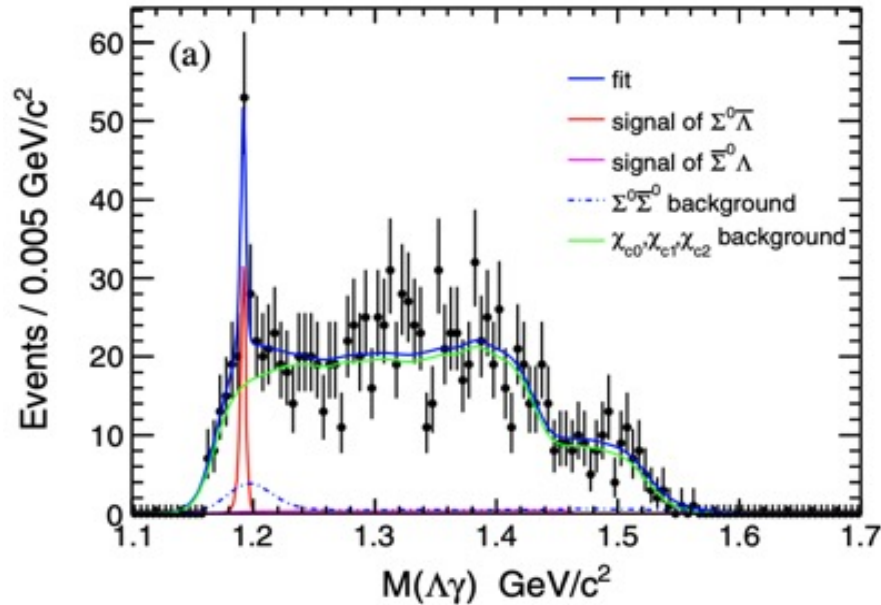
$$\mathcal{B}(\psi(3686) \rightarrow \overline{\Sigma}^0 \Lambda + c.\,c.) = (1.60 \pm 0.31_{\text{stat.}} \pm 0.13_{\text{sys.}} \pm 0.58_{\text{inter.}}) \times 10^{-6}, \theta = 90^{\circ}$$

- Significantly smaller than the CLEO-c's results, ($(12.3 \pm 2.4) \times 10^{-6}$, PRD 96,092004 (2017)).
- Consistent with the theoretical prediction ($(4.0 \pm 2.3) \times 10^{-6}$, IJMP 30,1150148 (2015)).

$$\mathcal{B}(\psi(3686) \rightarrow \overline{\Sigma}^0 \Lambda + c.\,c.) = (1.02 \pm 0.31_{\text{stat.}} \pm 0.13_{\text{sys.}}) \times 10^{-6}, \theta = 0^{\circ}$$

Observation of $\psi(3686) \rightarrow \Xi(1530)^0 \bar{\Xi}(1530)^0$ and $\Xi(1530)^0 \bar{\Xi}^0$

- Event selection technique: $\psi(3686) \rightarrow \Xi(1530)^0 \bar{\Xi}(1530)^0$ **PRD 104, 092012 (2021)**
  Single-baryon tagging

$$\rightarrow \Xi^- \pi^+$$
$$\rightarrow \Lambda \pi^-$$
$$\rightarrow p\pi^-$$
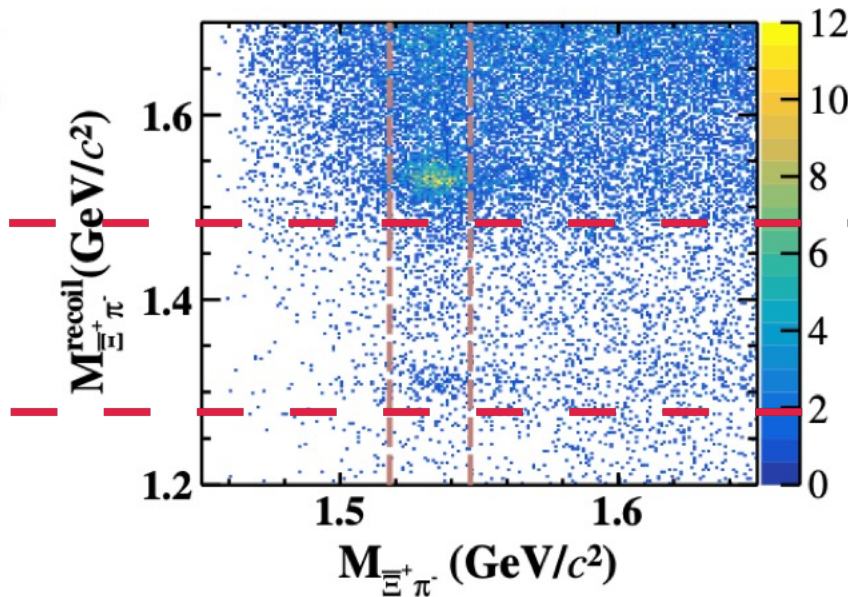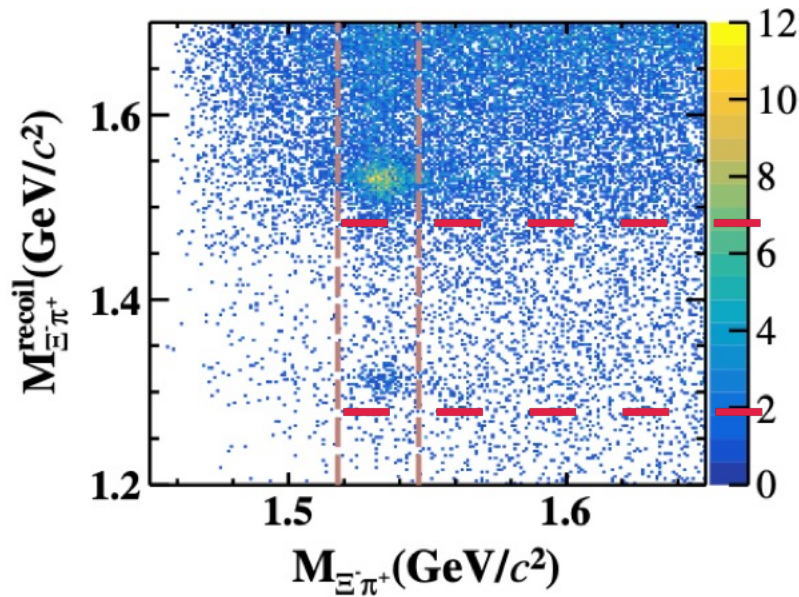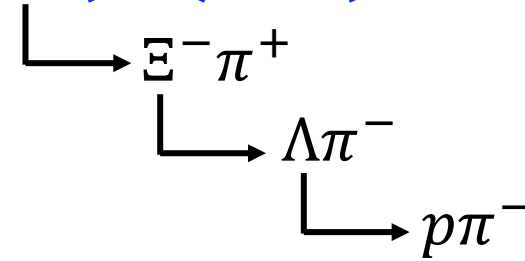
$\rightarrow \psi(3686) \rightarrow \Xi(1530)^0 \bar{\Xi}(1530)^0$

$\rightarrow \psi(3686) \rightarrow \Xi(1530)^0 \bar{\Xi}^0 (c.c.)$

Observation of $\psi(3686) \to \Xi(1530)^0\bar{\Xi}(1530)^0$ and $\Xi(1530)^0\bar{\Xi}^0$
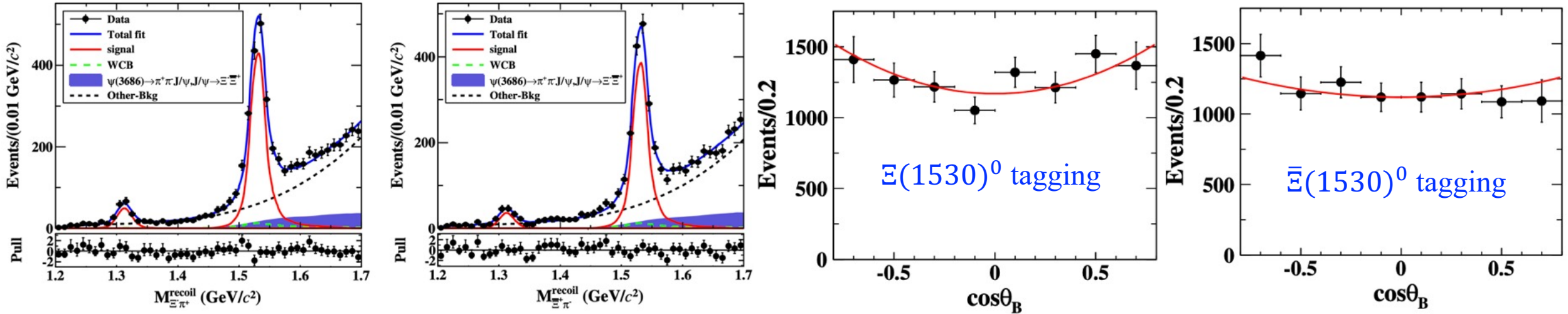
- Observation of SU(3) broken process.
- The measured α value favors the theoretical prediction, consistent with the one measured via the charged mode (PRD100,051101(R) (2019)).

$$\mathcal{R}_1 = \frac{\mathcal{B}(\psi(3686) \to \Xi(1530)^0\bar{\Xi}(1530)^0)}{\mathcal{B}(\psi(3686) \to \Xi(1530)^-\bar{\Xi}(1530)^+)} = 0.59 \pm 0.03 \pm 0.06$$

$$\mathcal{Q}_{\text{neutral}} = \frac{\mathcal{B}(\psi(3686) \to \Xi(1530)^0\bar{\Xi}^0)}{\mathcal{B}(J/\psi(3686) \to \Xi(1530)^0\bar{\Xi}^0)} = (3.31 \pm 1.25 \pm 0.73)\%$$

$$\mathcal{R}_2 = \frac{\mathcal{B}(\psi(3686) \to \Xi(1530)^0\bar{\Xi}^0)}{\mathcal{B}(\psi(3686) \to \Xi(1530)^-\bar{\Xi}^+)} = 0.76 \pm 0.13 \pm 0.06$$

$$\mathcal{Q}_{\text{charged}} = \frac{\mathcal{B}(\psi(3686) \to \Xi(1530)^-\bar{\Xi}^+)}{\mathcal{B}(J/\psi(3686) \to \Xi(1530)^-\bar{\Xi}^+)} = (3.12 \pm 0.49 \pm 0.20)\%$$

Observation of Ξ^- hyperon Transverse Polarization in $\psi(3686) \to \Xi^-\bar{\Xi}^+$

- The effects that Baryon-spin polarization in a vector-charmonium decay into a $B\bar{B}$ pair requires that the decay amplitudes are complex and have non-trivial relative phase $\Delta\Phi$ (PLB 772,16-20(2017)).
- BESIII observed Ξ^- Polarization in $J/\psi \to \Xi^-\bar{\Xi}^+$ for the first time and the process was used for novel CP symmetry tests by measuring the observables $A_{\mathrm{CP}} = (\alpha_{\Xi^-}+\alpha_{\bar{\Xi}^+})/(\alpha_{\Xi^-}-\alpha_{\bar{\Xi}^+})$ and $\Delta\phi_{\mathrm{CP}} = (\phi_{\Xi^-} + \phi_{\bar{\Xi}^+})/2$ (Nature, 606,64-69(2022)).
- CP-violation tests performed with the $\psi(3686) \to \Xi^-\bar{\Xi}^+$ data set have lower precision than those made in J/ψ decays, but the sample can also be exploited for an independent measurement of the strong phase difference, $\delta_p - \delta_s$, for $\Lambda - \pi^-$ scattering.

arXiv:2206.10900, submitted to PRL

10
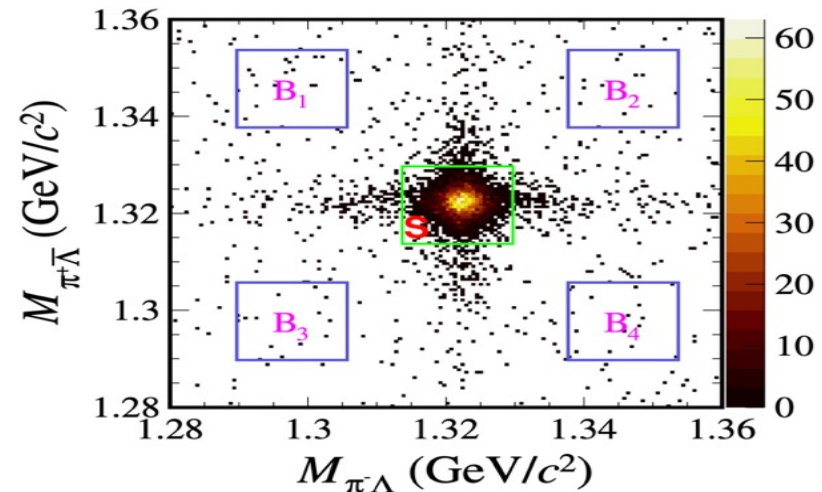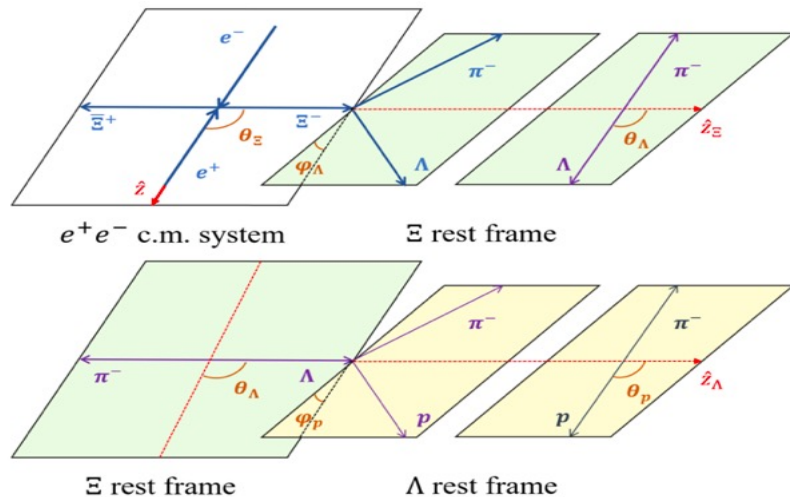
Observation of Ξ^- hyperon Transverse Polarization in $\psi(3686) \to \Xi^- \bar{\Xi}^+$

arXiv:2206.10900, submitted to PRL
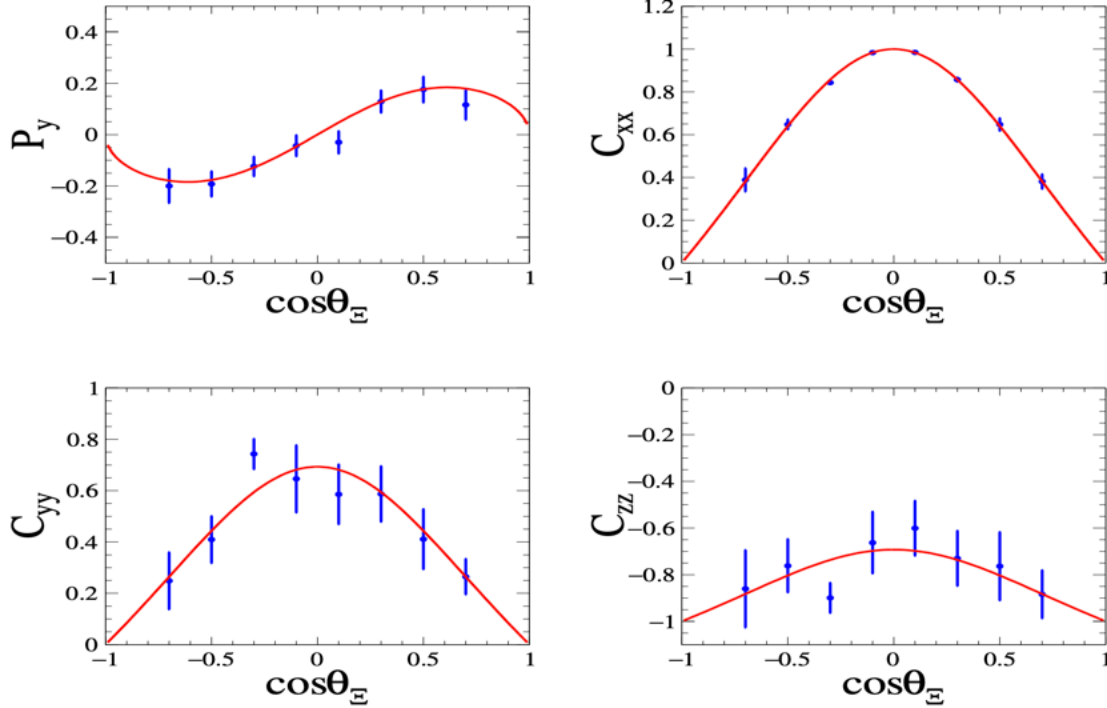
Parameter	$\psi(3686) \to \Xi^- \bar{\Xi}^+$	$J/\psi \to \Xi^- \bar{\Xi}^+$
α_ψ	$0.693 \pm 0.048 \pm 0.049$	$0.586 \pm 0.012 \pm 0.010$
$\Delta\Phi$ (rad)	$0.667 \pm 0.111 \pm 0.058$	$1.213 \pm 0.046 \pm 0.016$
α_{Ξ^-}	$-0.344 \pm 0.025 \pm 0.007$	$-0.376 \pm 0.007 \pm 0.003$
$\alpha_{\bar{\Xi}^+}$	$0.355 \pm 0.025 \pm 0.002$	$0.371 \pm 0.007 \pm 0.002$
ϕ_{Ξ^-} (rad)	$0.023 \pm 0.074 \pm 0.003$	$0.011 \pm 0.019 \pm 0.009$
$\phi_{\bar{\Xi}^+}$ (rad)	$-0.123 \pm 0.073 \pm 0.004$	$-0.021 \pm 0.019 \pm 0.007$
$\delta_p - \delta_s$ (10^{-2} rad)	$-19.5 \pm 13.4 \pm 0.7$	$-4.0 \pm 3.3 \pm 1.7$
$A_{CP,\Xi}$ (10^{-3})	$-14.7 \pm 50.8 \pm 10.3$	$6.0 \pm 13.4 \pm 5.6$
$\Delta\phi_{CP}$ (10^{-3} rad)	$-49.9 \pm 52.1 \pm 2.6$	$-4.8 \pm 13.7 \pm 2.9$

$$\mathrm{P}_y = \sqrt{1 - \alpha_\psi^2}\, \sin\theta_\Xi \cos\theta_\Xi \sin\Delta\Phi / (1 + \alpha_\psi \cos^2\theta_\Xi)$$

$$C_{\mu\nu} = (1 + \alpha_\psi \cos^2\theta_\Xi)\begin{pmatrix} 1 & 0 & P_y & 0 \\ 0 & C_{xx} & 0 & C_{xz} \\ -P_y & 0 & C_{yy} & 0 \\ 0 & -C_{xz} & 0 & C_{zz} \end{pmatrix}$$

- The relative phase $\Delta\Phi$ for $\psi(3686) \to \Xi^- \bar{\Xi}^+$ decay is measured for the first time and differs from zero.

- The decay-asymmetry parameters α_{Ξ^-} and $\alpha_{\bar{\Xi}^+}$ agree within their statistical uncertainties but are lower than the PDG average value ($\alpha_{\Xi^-} = -0.401 \pm 0.010$).

- The strong-phase difference, $\delta_p - \delta_s$, is consistent with the BESIII result measured from the decay of $J/\psi \to \Xi^- \bar{\Xi}^+$.

11

Summary

- ψ(3686) decays to baryon pairs at BESIII provide a large and clean samples to
  - Test '12% rule'
  - Explore hyperon properties, such as their polarization and decay parameters
  - Perform tests of fundamental symmetries

- More new results based on the ~27B ψ(3686) data sample collected at BESIII are on the way !

- The interference effect will be better studied with two continuum data samples collected at BESIII with $\sqrt{s} = 3.650, 3.682$ GeV in 2022.