Hyperon Physics at BESIII

Xiongfei Wang (王雄飞)

Lanzhou University

(on behalf of BESIII Collaboration)

The 21st Lomonosov Conference on Elementary Particle Physics

Aug. 24-30, 2023. Moscow, Russia

Outline

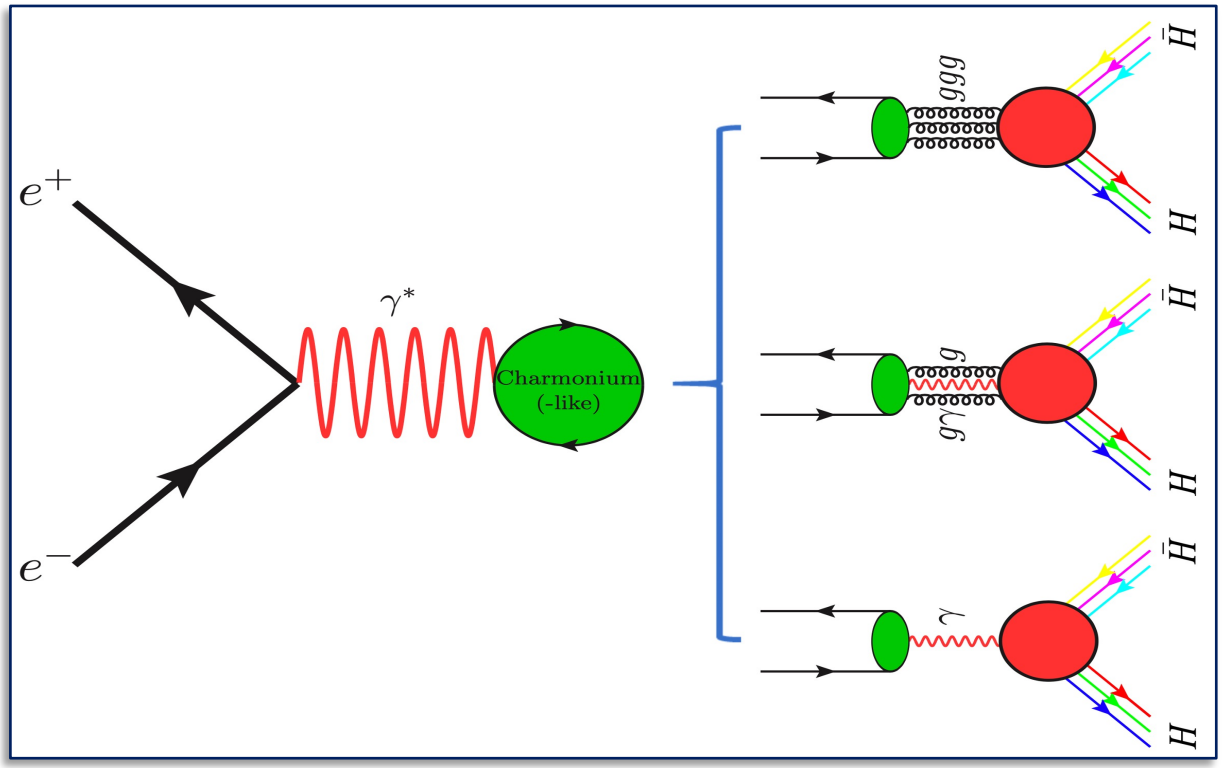
Hyperon

- Introduction
- Recent results
  - Spin polarization/CPV in Λ hyperon
  - Spin polarization/CPV in Σ hyperon
  - Spin polarization/CPV in Ξ hyperon
- Summary

See Prof. Haibo Li's talk
for more hyperon physics results

$H\bar{H}$ production in Charmonium (-like) decay

- **Main Feynman Diagrams**

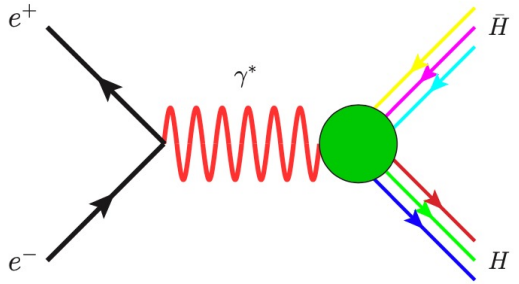


X. F. Wang, RMFS, 3, 0308074 (2022)

- **Provide a rich laboratory to prob non-pQCD, hyperon property/CPV, pQCD, etc.**

$H\bar{H}$ production in e^+e^- annihilation

- One photon exchange



- Differential cross section with combination of $G_{E/M}$

$$\frac{d\sigma^B(s)}{d\Omega} = \frac{\alpha^2\beta C}{4s}[|G_M(s)|^2(1+\cos^2\theta) + \frac{1}{\tau}|G_E(s)|^2\sin^2\theta]$$

- Form factor (G_{eff}, $G_{E/M}$)

$$|G_{\text{eff}}(s)| = \sqrt{\frac{2\tau|G_M(s)|^2 + |G_E(s)|^2}{2\tau+1}} = \sqrt{\frac{\sigma^B(s)}{(1+\frac{1}{2\tau})\cdot(\frac{4\pi\alpha^2\beta}{3s})}}$$

$$R = |\frac{G_E(s)}{G_M(s)}| = \sqrt{\frac{\tau(1-\eta)}{1+\eta}} \quad \left(\frac{d\sigma^B(s)}{d\cos\theta} \propto 1+\eta\cos^2\theta\right)$$

- Understand the internal structure of hyperon
- Provide extra insights for Charmonium(-like) states

How to construct CPV observables

☐ Amplitude for $H_{1/2} \to H'_{1/2} M_{pse}$:

$$\mathcal{A} = \mathcal{S} + \mathcal{P}\boldsymbol{\sigma}\cdot\hat{\boldsymbol{n}} \quad \begin{cases} \mathcal{S} = |\mathcal{S}|e^{i(\delta_{\mathcal{S}}+\xi_{\mathcal{S}})} \\ \mathcal{P} = |\mathcal{P}|e^{i(\delta_{\mathcal{P}}+\xi_{\mathcal{P}})} \end{cases}$$

■ **Lee–Yang parameters in hyperon decay**

$$\alpha_H = \frac{2Re(\mathcal{S}^*\mathcal{P})}{|\mathcal{S}|^2+|\mathcal{P}|^2}$$

$$\beta_H = \frac{2Im(\mathcal{S}^*\mathcal{P})}{|\mathcal{S}|^2+|\mathcal{P}|^2}$$

$$\gamma_H = \frac{|\mathcal{S}|^2-|\mathcal{P}|^2}{|\mathcal{S}|^2+|\mathcal{P}|^2}$$

$$\alpha_H^2+\beta_H^2+\gamma_H^2 = 1$$

$$\beta_H = \sqrt{1-\alpha_H^2}cos\phi_H, \gamma_H = \sqrt{1-\alpha_H^2}sin\phi_H$$

$$\phi_H = \tan^{-1}\frac{\beta_H}{\gamma_H}$$

■ **If CP conservation: $\alpha_H = -\alpha_{\bar{H}}$, …**

■ **Then, one can construct CPV observables ($\Xi \to \pi\Lambda$):**

$$A_{CP}^{\Xi} = \frac{\alpha_\Xi + \bar{\alpha}_{\bar{\Xi}}}{\alpha_\Xi - \bar{\alpha}_{\bar{\Xi}}}$$

$$B_{CP}^{\Xi} = \frac{\beta_\Xi + \bar{\beta}_{\bar{\Xi}}}{\beta_\Xi - \bar{\beta}_{\bar{\Xi}}}$$

$$C_{CP}^{\Xi} = \frac{\gamma_\Xi + \bar{\gamma}_{\bar{\Xi}}}{\gamma_\Xi - \bar{\gamma}_{\bar{\Xi}}}$$

$$\Delta\phi_{CP}^{\Xi} = \frac{\phi_\Xi + \bar{\phi}_{\bar{\Xi}}}{2}$$

$$\delta_P - \delta_S \simeq \arctan\left(\frac{\beta_\Xi}{\alpha_\Xi}\right) \simeq \arctan\left(\frac{\sqrt{1-\langle\alpha_\Xi^2\rangle}}{\langle\alpha_\Xi\rangle}\langle\phi_\Xi\rangle\right)$$

$$\xi_P - \xi_S \simeq \frac{\beta_\Xi + \bar{\beta}_{\bar{\Xi}}}{\alpha_\Xi - \bar{\alpha}_{\bar{\Xi}}} \simeq \frac{\sqrt{1-\langle\alpha_\Xi^2\rangle}}{\langle\alpha_\Xi\rangle}\Delta\phi_{CP}^{\Xi}$$

T. D. Lee, C. N. Yang. Phys. Rev. 108, 1645 (1957)

Roadmap of CP violation

Parity violation
T.D. Lee,
C. N. Yang and
C. S. Wu et al.

Strange particles:
***CP* violation in *K* meson decays**
J. W. Cronin,
V. L. Fitch et al.

Beauty particles:
***CP* violation in B^0 meson decays**
[BABAR] and [Belle]

Charm particles:
***CP* violation in D^0 meson decays**
[LHCb]

1956 — 1963 — 1964 — 1973 — 2001 — 2013 — 2019 — 2020

Cabibbo Mixing
N. Cabibbo

The CKM matrix
M. Kobayashi and
T. Maskawa

Beauty particles:
***CP* violation in B_s^0 meson decays**
[LHCb]

Neutrino oscillations:
***CP* violation in**
$\nu_\mu(\bar{\nu}_\mu) \rightarrow \nu_e(\bar{\nu}_e)$
[T2K]

Symmetry 2023, 15(1), 214

- ❑ **All are consistent with CKM theory in SM**
- ❑ **But no evidence in hyperon system ($CPV^{SM} \sim 10^{-4}$)**

Outline

Hyperon

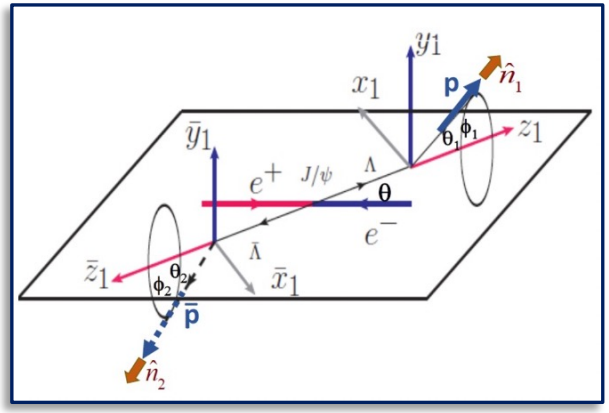
- Introduction
- **Recent results**
  - **Spin polarization/CPV in Λ hyperon**
  - Spin polarization/CPV in Σ hyperon
  - Spin polarization/CPV in Ξ hyperon
- Summary

Observation of Λ spin polarization in $J/\psi \to \Lambda\bar{\Lambda}$

Data Sample: 1.3 B J/ψ

Nature Physics **15**, 631 (2019)

A 5D angular distribution analysis



Unpolarized-term

$$W(\xi;\Omega) = 1 + \alpha_\psi cos\theta_\Lambda^2$$

Entangled-terms

$$+\alpha_-\alpha_+\left[\sin^2\theta_\Lambda(n_{1,x}n_{2,x} - \alpha_\psi n_{1,y}n_{2,y}) + (\cos^2\theta_\Lambda + \alpha_\psi)n_{1,z}n_{2,z}\right]$$

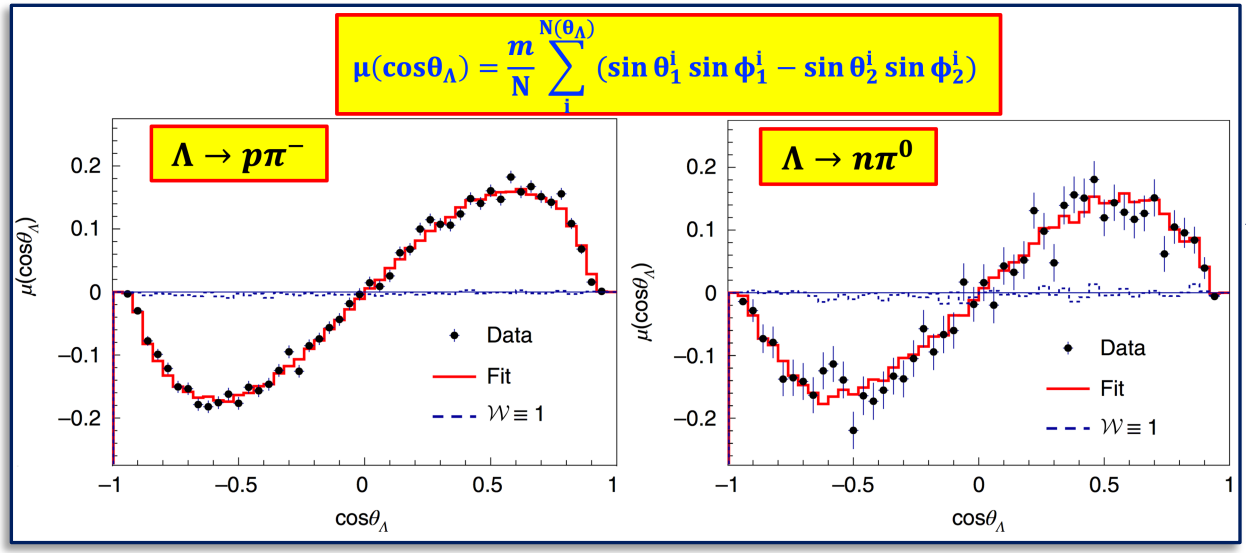
$$+\alpha_-\alpha_+\sqrt{1+\alpha_\psi}\cos(\Delta\Phi)\, sin\theta_\Lambda cos\theta_\Lambda(n_{1,x}n_{2,x} + n_{1,z}n_{2,z})$$

$$+\sqrt{1+\alpha_\psi^2}\sin(\Delta\Phi)\, sin\theta_\Lambda cos\theta_\Lambda(\alpha_- n_{1,y} + \alpha_+ n_{2,y})$$

Polarized-term

5 angle parameters: $\xi = \{\theta_\Lambda, \theta_p, \phi_p, \theta_{\bar{\Lambda}}, \phi_{\bar{\Lambda}}\}$; 4 unknown parameters: $\Omega = \{\alpha_\psi, \Delta\Phi, \alpha_-, \alpha_+\}$

$$\mu(\cos\theta_\Lambda) = \frac{m}{N}\sum_i^{N(\theta_\Lambda)}(\sin\theta_1^i \sin\phi_1^i - \sin\theta_2^i \sin\phi_2^i)$$



Clear Λ hyperon transverse polarization signal observed for the first time!

Observation of Λ spin polarization in $J/\psi \to \Lambda\bar{\Lambda}$

Data Sample: 1.3B J/ψ

Nature Physics **15**, 631 (2019)

Table 1 | Summary of the results

Parameters	This work	Previous results
α_{ψ}	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 (ref. [14])
$\Delta\Phi$	$42.4 \pm 0.6 \pm 0.5°$	-
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 (ref. [6])
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 (ref. [6])
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	-
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 (ref. [6])
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	-

First observation of a transverse polarization

>5σ difference (17% higher than) to PDG

Test of CP violation: $A_{CP} = \dfrac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$

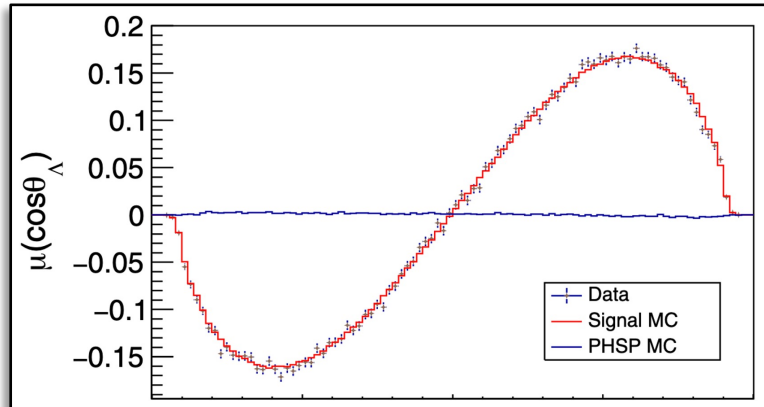
Test of $\Delta I = \frac{3}{2}$ contribution

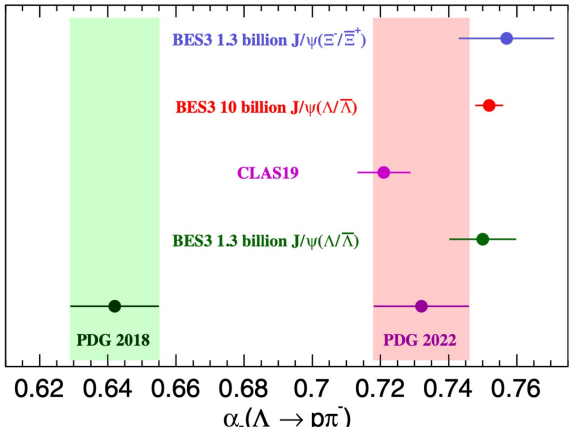
- **First observation of hyperon spin polarization, and first test of CPV in Λ decay with precision over previous measurements**

Most precise measurement of Λ spin polarization and CPV in $J/\psi \to \Lambda\bar{\Lambda}$

Data Sample: 10B J/ψ

Phys. Rev. Lett. 129, 131801 (2022)





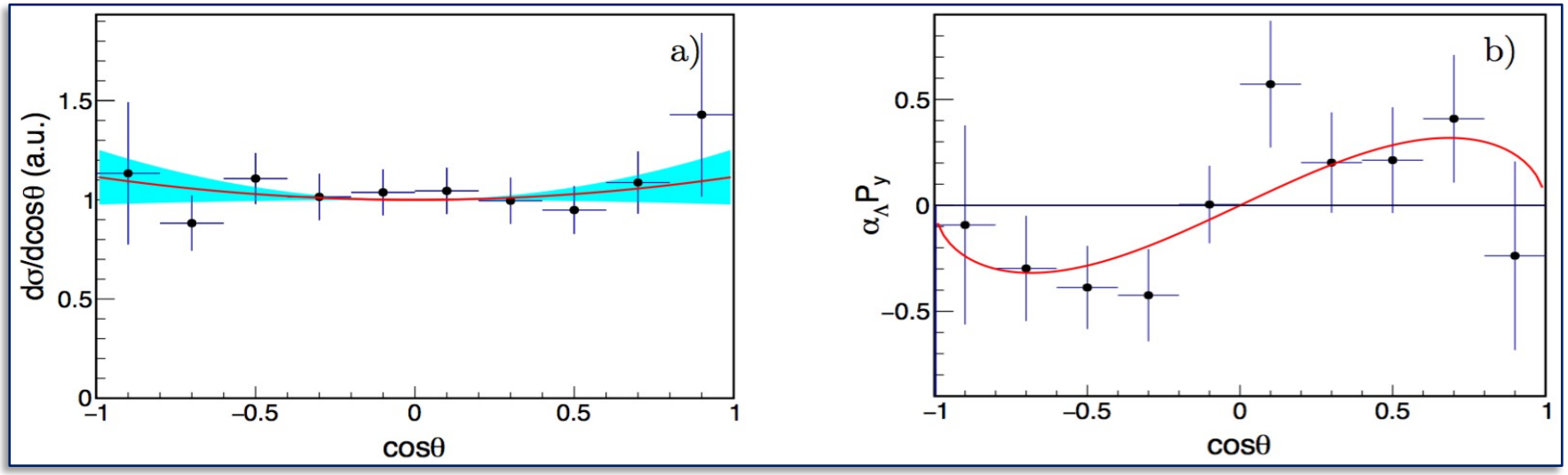
Par.	This work	Previous results [8]
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0024$	$0.461 \pm 0.006 \pm 0.007$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0080$	$0.740 \pm 0.010 \pm 0.009$
α_-	$0.7519 \pm 0.0036 \pm 0.0019$	$0.750 \pm 0.009 \pm 0.004$
α_+	$-0.7559 \pm 0.0036 \pm 0.0029$	$-0.758 \pm 0.010 \pm 0.007$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0011$	$0.006 \pm 0.012 \pm 0.007$
$\alpha_{\rm avg}$	$0.7542 \pm 0.0010 \pm 0.0020$	-

- CP is still conservation within 1σ uncertainty
- Results are consistent with previous measurements, and with higher precison ($\sim 10^{-3}$)

Measurement of Λ spin polarization in $e^+e^- \to \Lambda\bar{\Lambda}$

Data Sample: 66.9 pb^{-1} @ $\sqrt{s}$=2.396GeV

PRL 123,122003 (2019)



$$\Delta\Phi = \Phi_E - \Phi_M = (37 \pm 12 \pm 6)^o$$

$$\sigma = 118.7 \pm 5.3 \pm 5.1\ \text{pb}$$

$$|G_{eff.}| = 0.123 \pm 0.003 \pm 0.003$$

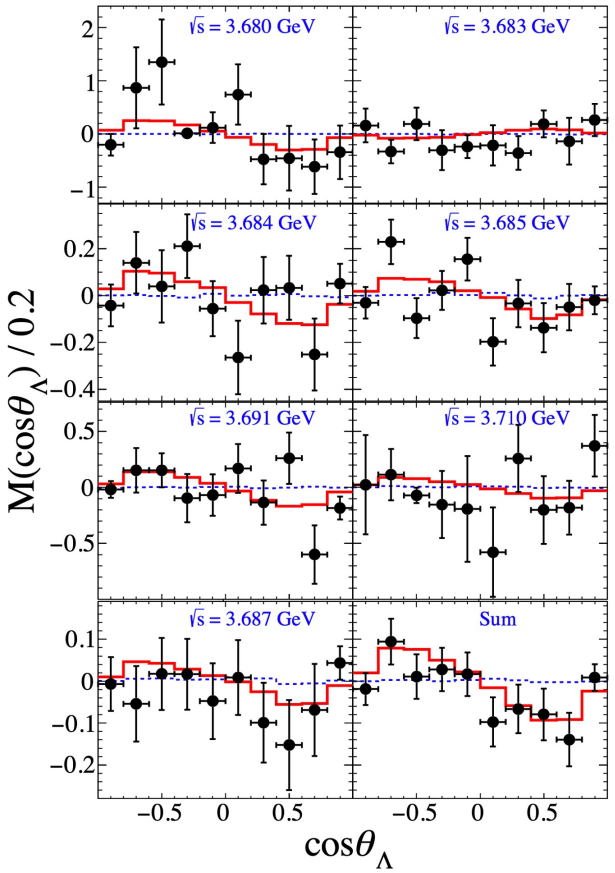
$$R = \left|\frac{G_E}{G_M}\right| = 0.96 \pm 0.14 \pm 0.02$$

- First complete determination of baryon time-like EMFFs
- More information for understanding $\Lambda\bar{\Lambda}$ production near threshold

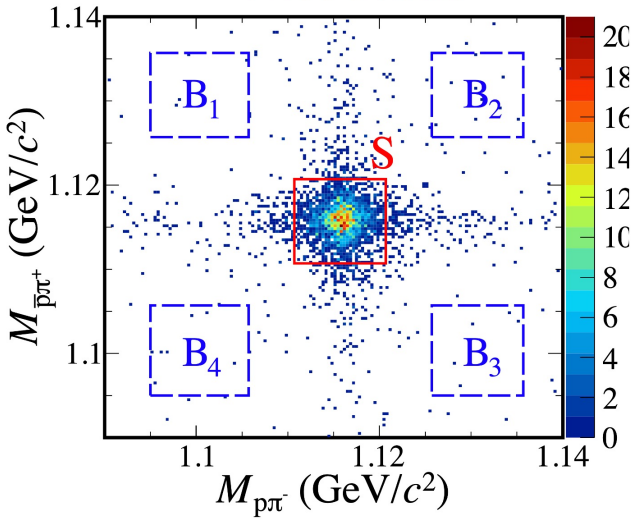
Λ hyperon spin polarization around ψ(3686)

Data Sample: $333\ pb^{-1}\ \sqrt{s} = 3.68 - 3.71 GeV$

arXiv:2303.00271



~2400 events



$\sqrt{s}$ (MeV)	N_{obs}	η	$\Delta\Phi(^\circ)$	R^Ψ
3680	31^{+7}_{-6}	$0.12^{+0.46}_{-0.43} \pm 0.02$	$110.6^{+34.4}_{-37.8} \pm 1.6$	$1.00^{+0.64}_{-0.70} \pm 0.02$
3683	78^{+10}_{-9}	$0.95^{+0.18}_{-0.20} \pm 0.02$	$-108.9^{+181.6}_{-185.6} \pm 1.6$	$0.27^{+0.49}_{-0.54} \pm 0.05$
3684	385^{+21}_{-20}	$0.59^{+0.18}_{-0.18} \pm 0.02$	$28.0^{+24.1}_{-18.3} \pm 1.6$	$0.85^{+0.23}_{-0.23} \pm 0.02$
3685	831^{+30}_{-29}	$0.64^{+0.11}_{-0.12} \pm 0.02$	$20.1^{+12.6}_{-12.0} \pm 1.6$	$0.78^{+0.15}_{-0.15} \pm 0.03$
3687	876^{+31}_{-30}	$0.71^{+0.12}_{-0.13} \pm 0.02$	$12.0^{+14.9}_{-13.2} \pm 1.6$	$0.64^{+0.16}_{-0.17} \pm 0.03$
3691	176^{+14}_{-13}	$0.83^{+0.14}_{-0.23} \pm 0.02$	$112.9^{+44.1}_{-63.0} \pm 1.6$	$0.32^{+0.36}_{-0.52} \pm 0.04$
3710	53^{+8}_{-7}	$0.52^{+0.38}_{-0.39} \pm 0.02$	$0.0^{+64.7}_{-56.7} \pm 1.6$	$0.89^{+0.48}_{-0.50} \pm 0.02$

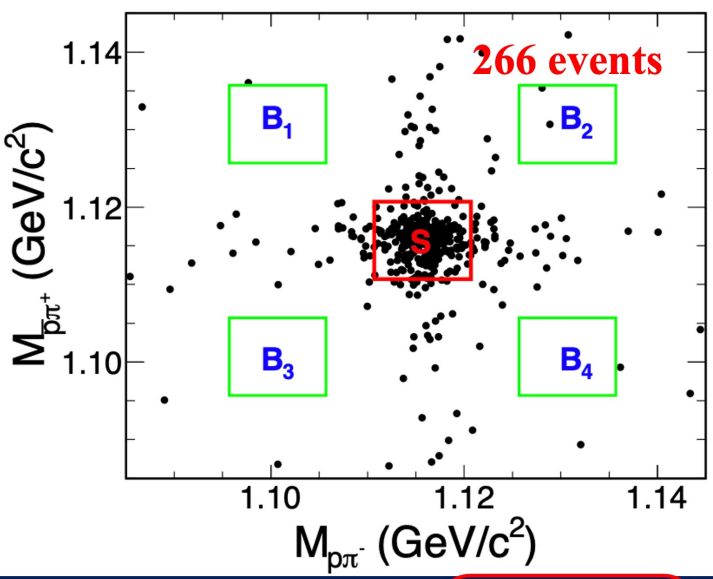
- **CP is fixed to be zero, more information for understanding the production mechanism of $\Lambda\bar{\Lambda}$ in $\psi(3686)$**

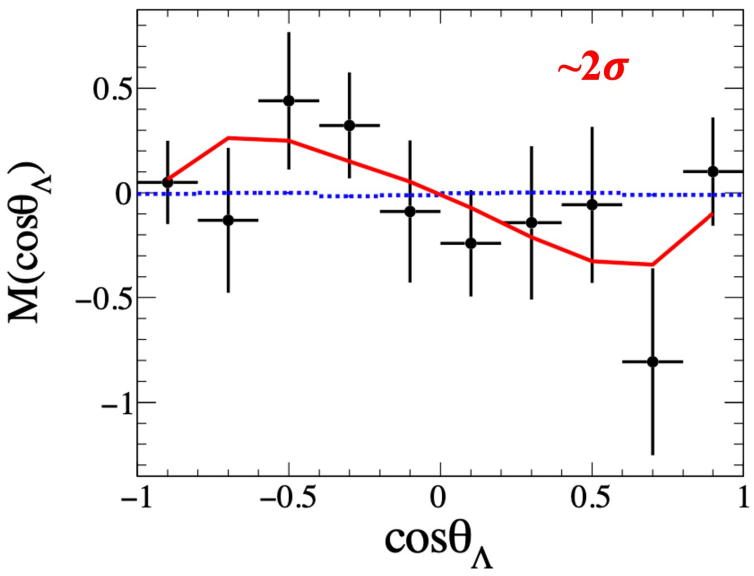
The Λ spin polarization in $\psi(3770) \to \Lambda\bar{\Lambda}$

Data Sample: 2.9 fb^{-1} $\psi(3770)$

PRD(Letter) 105,L011101 (2022)

Moment: $M(\cos\theta) = \frac{m}{N}\sum_i^{N(\theta_\Sigma)}(\sin\theta_p^i \sin\phi_p^i - \sin\theta_{\bar{p}}^i \sin\phi_{\bar{p}}^i)$





Para.	ψ(3686) scan data	$\psi(3770) \to \Lambda\bar{\Lambda}$ [24]	$J/\psi \to \Lambda\bar{\Lambda}$ [33]	$e^+e^- \to \Lambda\bar{\Lambda}$ ($\sqrt{s}$ = 2.396 GeV) [34]
η	$0.69^{+0.07}_{-0.07} \pm 0.02$	$0.85^{+0.12}_{-0.20} \pm 0.02$	$0.4748 \pm 0.0022 \pm 0.0031$	$0.12 \pm 0.14 \pm 0.02$
$\Delta\Phi^\Psi$ (°)	$23^{+8.8}_{-8.0} \pm 1.6$	$71^{+66}_{-46} \pm 5$	$43.09 \pm 0.24 \pm 0.38$	$37 \pm 12 \pm 6$
R^Ψ	$0.71^{+0.10}_{-0.10} \pm 0.03$	$0.48^{+0.21}_{-0.35} \pm 0.04$	$0.8162 \pm 0.0023 \pm 0.0033$	$0.96 \pm 0.14 \pm 0.02$

- **CP is fixed to be zero, more information for understanding the Λ hyperon structure, the production of of $\Lambda\bar{\Lambda}$ in $\psi(3770)$**

Outline

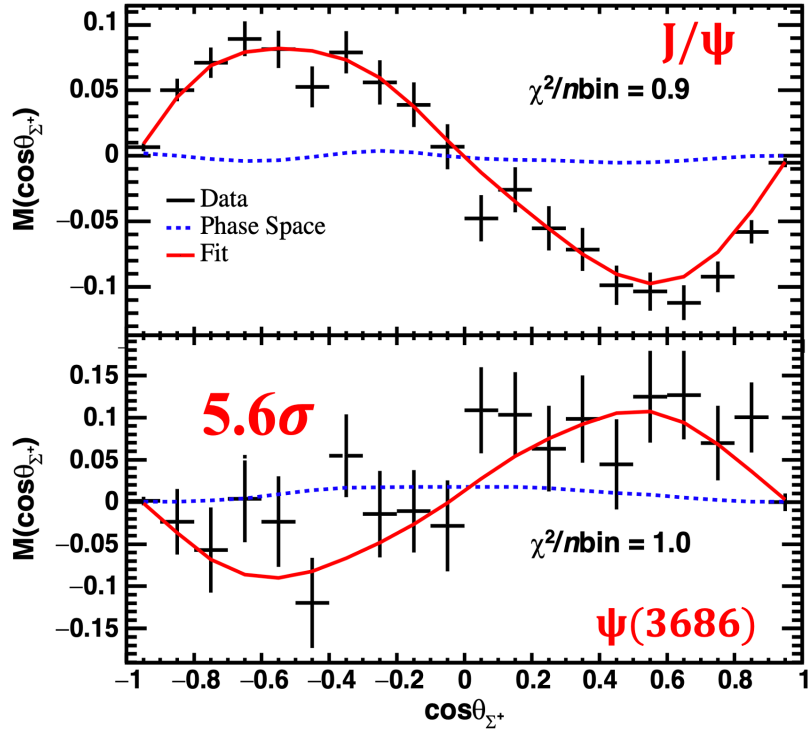
Hyperon

- Introduction
- **Recent results**
  - Spin polarization/CPV in Λ hyperon
  - **Spin polarization/CPV in Σ hyperon**
  - Spin polarization/CPV in Ξ hyperon
- Summary

Observation of $\Sigma^+(p\pi^0)$ spin polarization in $\psi \to \Sigma^+\bar{\Sigma}^-$

Data Sample: 1.3B J/ψ & 448M ψ(3686)

Phys. Rev. Lett. 125, 052004 (2020)



Par.	Measured value
$\alpha_{J/\psi}$	$-0.508 \pm 0.006 \pm 0.004$
$\Delta\Phi_{J/\psi}$	$-0.270 \pm 0.012 \pm 0.009$
$\alpha_{\psi'}$	$0.682 \pm 0.03 \pm 0.011$
$\Delta\Phi_{\psi'}$	$0.379 \pm 0.07 \pm 0.014$
α_0	$-0.998 \pm 0.037 \pm 0.009$
$\bar{\alpha}_0$	$0.990 \pm 0.037 \pm 0.011$

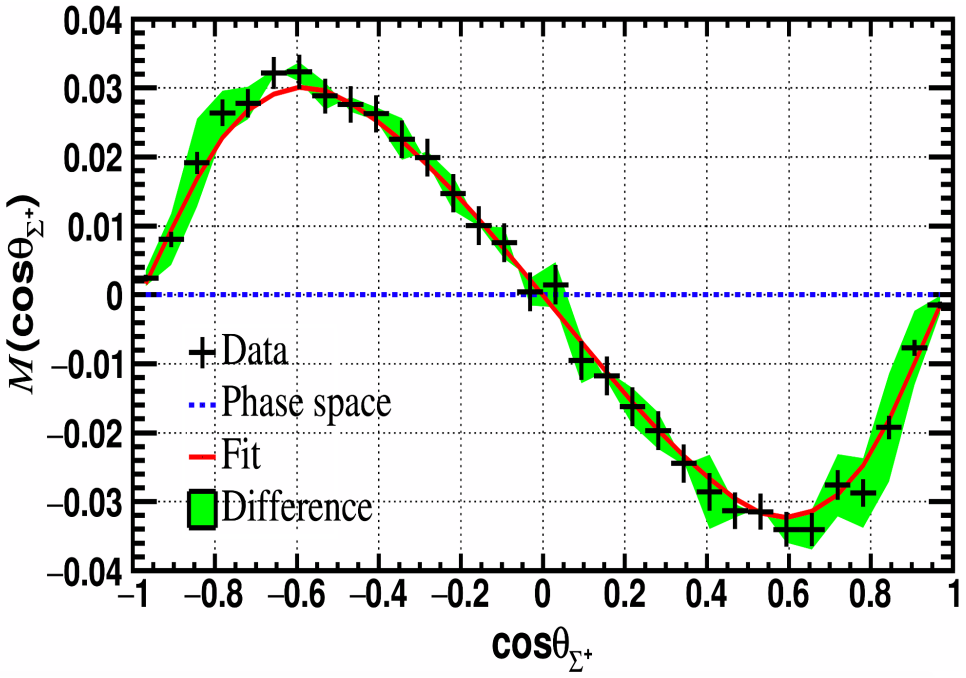
☐ Test of CP violation:

$$A_{CP}^{\Sigma^+(p\pi^0)} = \frac{\alpha_0 + \bar{\alpha}_0}{\alpha_0 - \bar{\alpha}_0} = -0.015 \pm 0.037 \pm 0.008 \approx 0?$$

Observation of $\Sigma^+(n\pi^+)$ spin polarization in $J/\psi \to \Sigma^+\bar{\Sigma}^-$

Data Sample: 10B J/ψ

arXiv:2304.14655



Parameter	This work
$\alpha_{J/\psi}$	$-0.5156 \pm 0.0030 \pm 0.0061$
$\Delta\Phi_{J/\psi}$(rad)	$-0.2772 \pm 0.0044 \pm 0.0041$
α_+	$0.0481 \pm 0.0031 \pm 0.0019$
$\bar{\alpha}_-$	$-0.0565 \pm 0.0047 \pm 0.0022$
α_+/α_0	$-0.0490 \pm 0.0032 \pm 0.0021$
$\bar{\alpha}_-/\bar{\alpha}_0$	$-0.0571 \pm 0.0053 \pm 0.0032$
A_{CP}	$-0.080 \pm 0.052 \pm 0.028$
$\langle\alpha_+\rangle$	$0.0506 \pm 0.0026 \pm 0.0019$

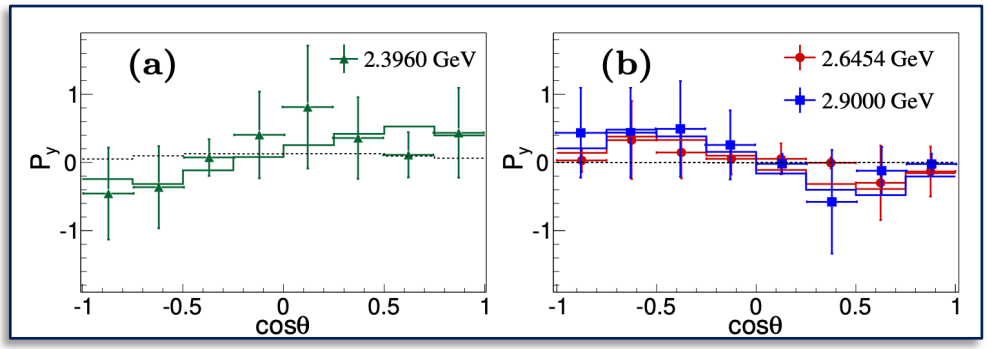
- Both $\alpha_{J/\psi}$ and $\Delta\Phi$ are consistent with $\Sigma^+(p\pi^0)$ mode
- Test of CP violation:

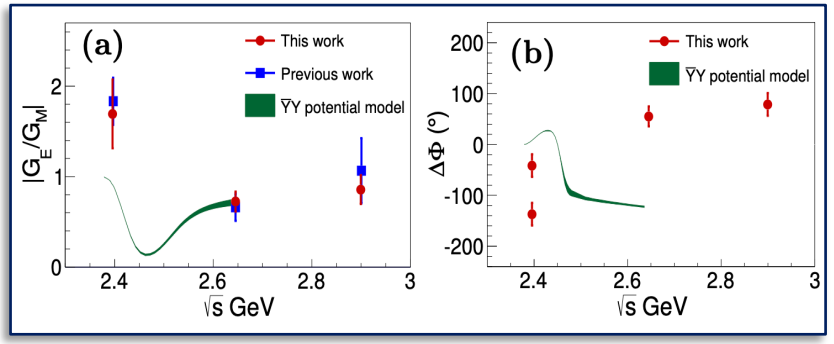
$$A_{CP}^{\Sigma^+(n\pi^+)} = \frac{\alpha_0 + \bar{\alpha}_0}{\alpha_0 - \bar{\alpha}_0} = -0.080 \pm 0.052 \pm 0.028 \approx 0?$$

Measurement of Σ^+ spin polarization in $e^+e^- \to \Sigma^+\bar{\Sigma}^-$

Data Sample: 66.9 pb^{-1} @ $\sqrt{s}$=2.396, 2.65 and 2.9GeV

arXiv:2307.15894





$\sqrt{s}$ (GeV)	2.3960	2.6454	2.9000
α	-0.47 ± 0.18 ± 0.09	0.41 ± 0.12 ± 0.06	0.35 ± 0.17 ± 0.15
$\Delta\Phi$ (°)	-42 ± 22 ± 14 (-138 ± 22 ± 14)	55 ± 19 ± 14	78 ± 22 ± 9
$\sin\Delta\Phi$	-0.67 ± 0.29 ± 0.18		
$\lvert G_E/G_M \rvert$	1.69 ± 0.38 ± 0.20	0.72 ± 0.11 ± 0.06	0.85 ± 0.16 ± 0.15

- The Σ^+hyperon EMFF is first explored in a wide four-momentum transfer range with q^2 from 5.7 to 8.4 GeV
- $\Delta\Phi < 0$ at $\sqrt{s} = 2.39$ GeV, $\Delta\Phi > 0$ at $\sqrt{s} = 2.64$ and 2.9GeV, $\Delta\Phi = 0$ exist between these points? an important input for understanding the asymptotic behavior [A. Mangoni *et al*, PRD104, 116016 (2021)]

Outline

Hyperon

- Introduction
- **Recent results**
  - Spin polarization/CPV in Λ hyperon
  - Spin polarization/CPV in Σ hyperon
  - **Spin polarization/CPV in Ξ hyperon**
- Summary

Ξ^- hyperon spin polarization and CPV in $J/\psi \to \Xi^-\bar{\Xi}^+$

Data Sample: 1.3B J/ψ

Nature 606, 64 (2022)

nature

Explore content | About the journal | Publish with us

nature > articles > article

Article | Open Access | Published: 01 June 2022

Probing CP symmetry and weak phases with entangled double-strange baryons

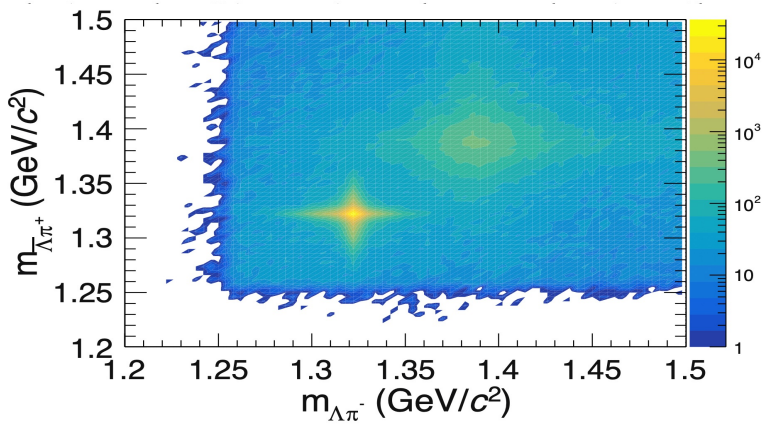
The BESIII Collaboration

Nature **606**, 64–69 (2022) | Cite this article

8772 Accesses | **96** Altmetric | Metrics

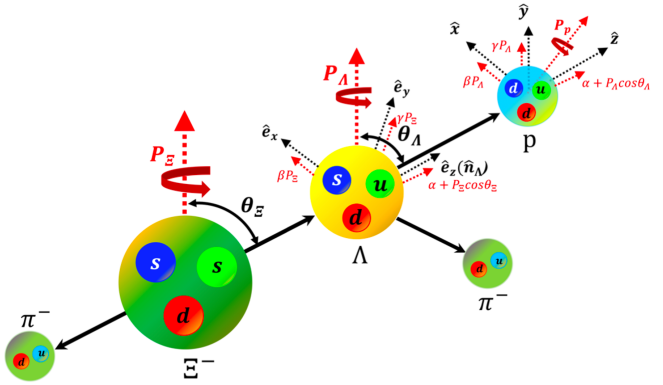
Abstract

Though immensely successful, the standard model of particle physics does not offer any



Extended Data Fig. 2 | Invariant mass distributions of the Ξ^- and $\bar{\Xi}^+$ signal candidates. Distribution of the invariant masses $m_{\Lambda\pi^-}$ versus $m_{\bar{\Lambda}\pi^+}$. The $\Xi^-\bar{\Xi}^+$ candidates appear as an enhancement around $m_{\Lambda\pi^-} = m_{\bar{\Lambda}\pi^+} = 1.32$ GeV/c^2. The structure at $m_{\Lambda\pi^-} = m_{\bar{\Lambda}\pi^+} = 1.39$ GeV/c^2 is from the reaction $J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$.

precision to the most precise previous measurement[4].



$$\mathcal{W}(\boldsymbol{\xi};\boldsymbol{\Omega}) = \sum_{\mu,\bar{\nu}=0}^{3} C_{\mu\bar{\nu}}(\theta_\Xi;\alpha_\psi,\Delta\Phi)\sum_{\mu'=0}^{3}\sum_{\nu'=0}^{3} a^{\Xi^-}_{\mu\mu'}a^{\Lambda}_{\mu'0}a^{\bar{\Xi}^+}_{\nu\nu'}a^{\bar{\Lambda}}_{\nu'0}$$

9 angle parameters: $\boldsymbol{\xi} = \{\theta_\Xi, \theta_\Lambda, \theta_{\bar{\Lambda}}, \phi_\Lambda, \phi_{\bar{\Lambda}}, \theta_p, \theta_{\bar{p}}, \phi_p, \phi_{\bar{p}}\}$

8 unknown parameters: $\boldsymbol{\Omega} = \{\alpha_\psi, \Delta\Phi, \alpha_\Xi, \phi_\Xi, \alpha_\Lambda, \alpha_{\bar{\Xi}}, \phi_{\bar{\Xi}}, \alpha_{\bar{\Lambda}}\}$

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

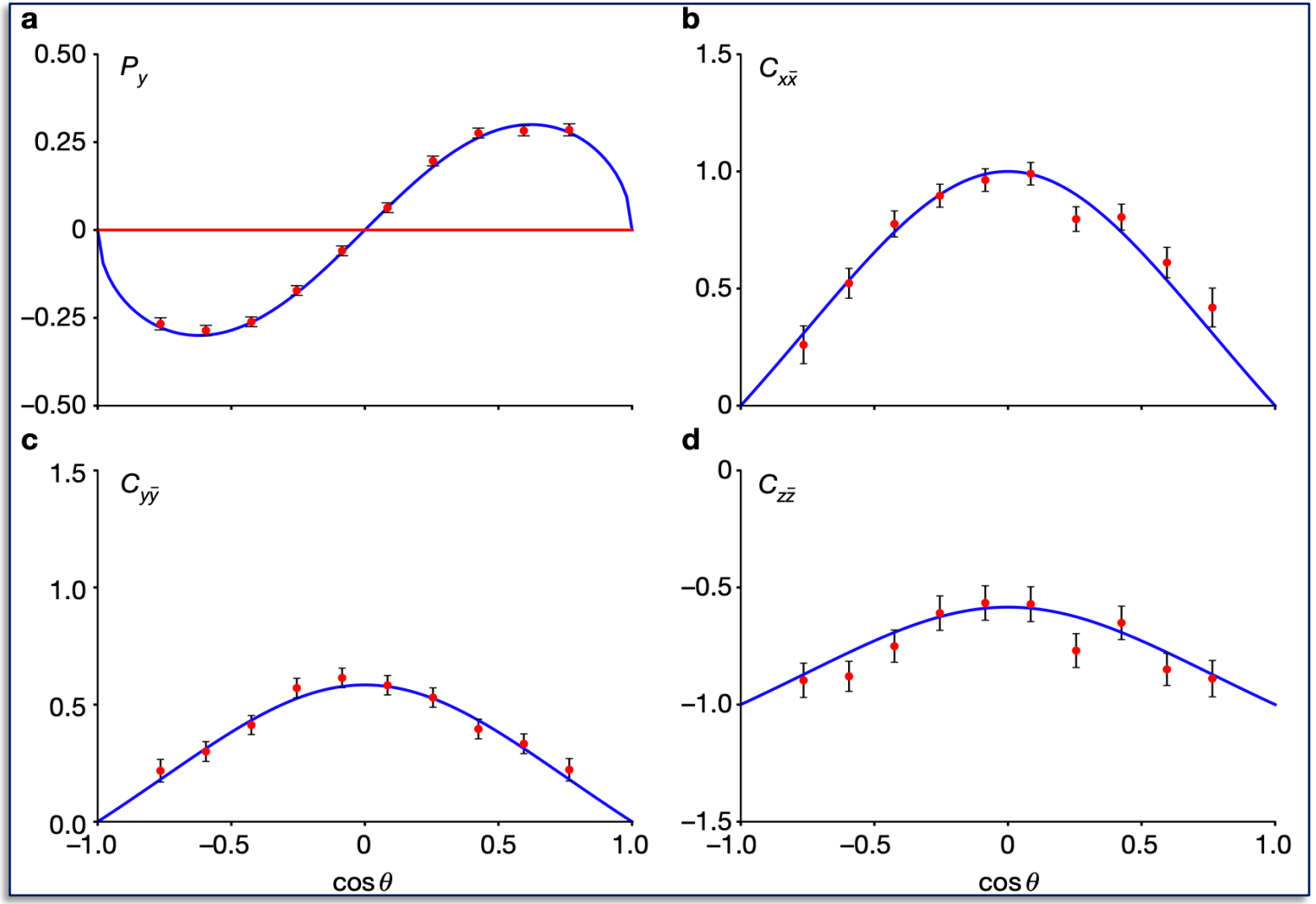
Parameters extraction by a 9D angular distribution analysis

Ξ^- hyperon spin polarization and CPV in $J/\psi \to \Xi^-\bar{\Xi}^+$

Data Sample: 1.3 B J/ψ

~73,000

Nature 606, 64 (2022)



Ξ^- hyperon spin polarization and CPV test in $J/\psi \to \Xi^-\bar{\Xi}^+$

Data Sample: 1.3 B J/ψ

~73,000

Nature 606, 64 (2022)

Table 1 | Summary of results

Parameter	This work	Previous result	Reference
α_ψ	0.586±0.012±0.010	0.58±0.04±0.08	Ref. [49]
$\Delta\Phi$	1.213±0.046±0.016 rad	–	
α_Ξ	−0.376±0.007±0.003	−0.401±0.010	Ref. [26]
ϕ_Ξ	0.011±0.019±0.009 rad	−0.037±0.014 rad	Ref. [26]
$\bar{\alpha}_\Xi$	0.371±0.007±0.002	–	
$\bar{\phi}_\Xi$	−0.021±0.019±0.007 rad	–	
α_Λ	0.757±0.011±0.008	0.750±0.009±0.004	Ref. [4]
$\bar{\alpha}_\Lambda$	−0.763±0.011±0.007	−0.758±0.010±0.007	Ref. [4]
$\xi_P-\xi_S$	$(1.2\pm3.4\pm0.8)\times10^{-2}$ rad	–	
$\delta_P-\delta_S$	$(-4.0\pm3.3\pm1.7)\times10^{-2}$ rad	$(10.2\pm3.9)\times10^{-2}$ rad	Ref. [3]
A_{CP}^{Ξ}	$(6\pm13\pm6)\times10^{-3}$	–	
$\Delta\phi_{CP}^{\Xi}$	$(-5\pm14\pm3)\times10^{-3}$ rad	–	
A_{CP}^{Λ}	$(-4\pm12\pm9)\times10^{-3}$	$(-6\pm12\pm7)\times10^{-3}$	Ref. [4]
$\langle\phi_\Xi\rangle$	0.016±0.014±0.007 rad		

Non-zero phase: Ξ^- spin polariztion

First measurement: $\bar{\alpha}_\Xi$, $\bar{\phi}_\Xi$, $\xi_P-\xi_S$, A_{CP}^{Ξ}, $\Delta\phi_{CP}^{\Xi}$

Strong/ weak phase difference

Three CP observables

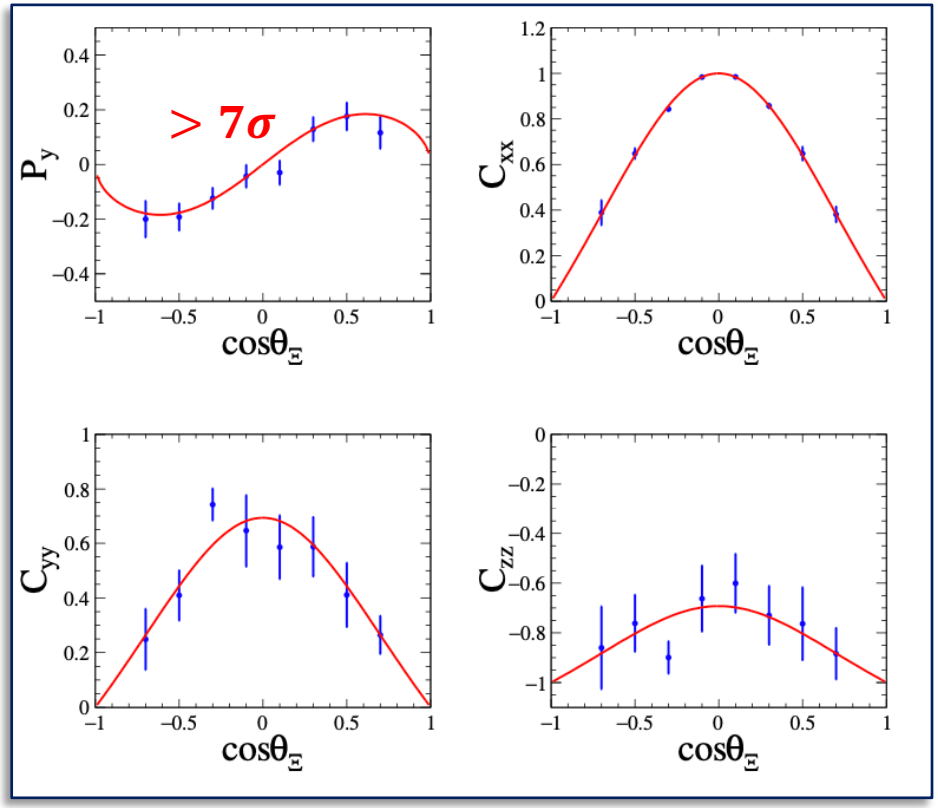
- **Observation of Ξ^- spin polariztion, non-zero weak phase difference**
- **Most precise test for CPV on strange hyperon decay**
- **Update with 10 billion J/ψ is ongoing**

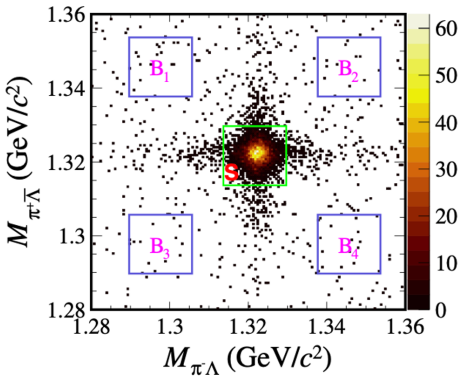
Ξ^- spin polarization and CPV in $\psi(3686) \to \Xi^-\bar{\Xi}^+$

PRD(Letter) 106, L091101 (2022)

Data Sample: 448 M ψ(3686)

~5000 events





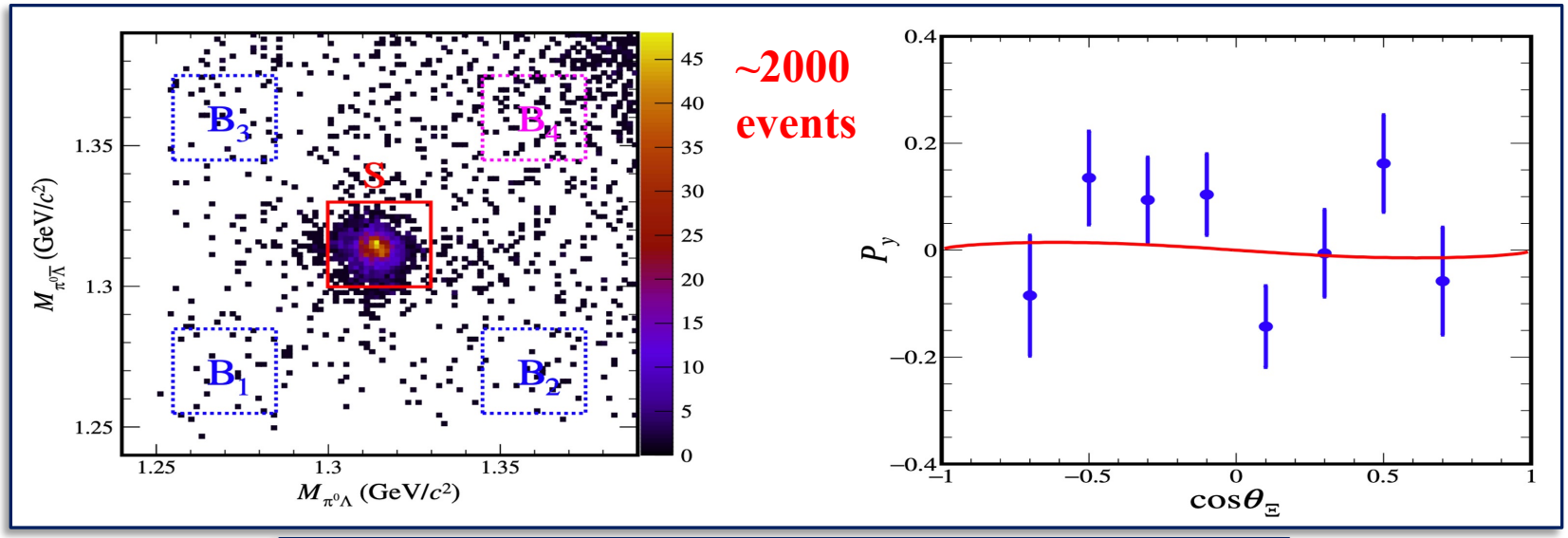
Parameter	$\psi(3686) \to \Xi^-\bar{\Xi}^+$	$J/\psi \to \Xi^-\bar{\Xi}^+$
α_ψ	$0.693 \pm 0.048 \pm 0.049$	$0.586 \pm 0.012 \pm 0.010$
$\Delta\Phi$ (rad)	$0.667 \pm 0.111 \pm 0.058$	$1.213 \pm 0.046 \pm 0.016$
α_{Ξ^-}	$-0.344 \pm 0.025 \pm 0.007$	$-0.376 \pm 0.007 \pm 0.003$
$\alpha_{\bar{\Xi}^+}$	$0.355 \pm 0.025 \pm 0.002$	$0.371 \pm 0.007 \pm 0.002$
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)	$-49.9 \pm 52.1 \pm 2.6$	$-4.8 \pm 13.7 \pm 2.9$

- **Both $\alpha_{\psi(3686)}$ and $\Delta\Phi$ are very different from the J/ψ peak**
- **Other parameters and CPV values are consistent with the J/ψ peak.**

Ξ^0 hyperon spin polarization and CPV in $\psi(3686) \to \Xi^0\bar{\Xi}^0$

Data Sample: 448 M ψ(3686)

PRD(Letter) 108, L011101 (2023)



Param.	This work	BESIII [38]	PDG [33]
$\alpha_{\psi(3686)}$	$0.665 \pm 0.086 \pm 0.081$	$0.650 \pm 0.090 \pm 0.140$	–
$\Delta\Phi$	$-0.050 \pm 0.150 \pm 0.020$	–	–
α_{Ξ^0}	$-0.358 \pm 0.042 \pm 0.013$	–	-0.356 ± 0.011
ϕ_{Ξ^0}	$0.027 \pm 0.117 \pm 0.011$	–	0.366 ± 0.209
$\alpha_{\bar{\Xi}^0}$	$0.363 \pm 0.042 \pm 0.013$	–	–
$\phi_{\bar{\Xi}^0}$	$-0.185 \pm 0.116 \pm 0.017$	–	–
A_{CP}^{Ξ}	$-0.007 \pm 0.082 \pm 0.025$	–	–
$\Delta\phi_{CP}^{\Xi}$	$-0.079 \pm 0.082 \pm 0.010$	–	–

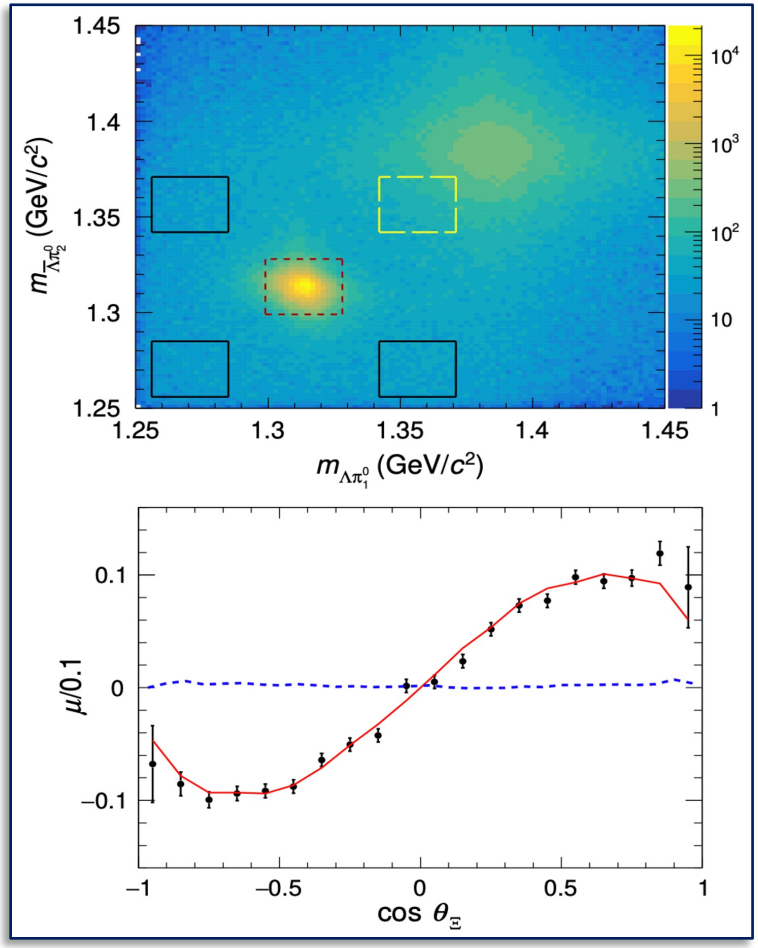
- No spin polarization observed (limited statistics?)
- Fisrt simultaneous determination of Ξ^0 and $\bar{\Xi}^0$ decay parameters
- CP is conservation within 1σ uncertainty

Ξ^0 hyperon spin polarization and CPV in $J/\psi \to \Xi^0\bar{\Xi}^0$

Data Sample: 10B M J/ψ

~330000 events

arXiv:2305.09218



Parameter	This work
$\alpha_{J/\psi}$	$0.514 \pm 0.006 \pm 0.015$
$\Delta\Phi$(rad)	$1.168 \pm 0.019 \pm 0.018$
α_Ξ	$-0.3750 \pm 0.0034 \pm 0.0016$
$\bar{\alpha}_\Xi$	$0.3790 \pm 0.0034 \pm 0.0021$
ϕ_Ξ(rad)	$0.0051 \pm 0.0096 \pm 0.0018$
$\bar{\phi}_\Xi$(rad)	$-0.0053 \pm 0.0097 \pm 0.0019$
α_Λ	$0.7551 \pm 0.0052 \pm 0.0023$
$\bar{\alpha}_\Lambda$	$-0.7448 \pm 0.0052 \pm 0.0017$
$\xi_P - \xi_S$(rad)	$(0.0 \pm 1.7 \pm 0.2) \times 10^{-2}$
$\delta_P - \delta_S$(rad)	$(-1.3 \pm 1.7 \pm 0.4) \times 10^{-2}$
A_{CP}^Ξ	$(-5.4 \pm 6.5 \pm 3.1) \times 10^{-3}$
$\Delta\phi_{CP}^\Xi$(rad)	$(-0.1 \pm 6.9 \pm 0.9) \times 10^{-3}$
A_{CP}^Λ	$(6.9 \pm 5.8 \pm 1.8) \times 10^{-3}$
$\langle\alpha_\Xi\rangle$	$-0.3770 \pm 0.0024 \pm 0.0014$
$\langle\phi_\Xi\rangle$(rad)	$0.0052 \pm 0.0069 \pm 0.0016$
$\langle\alpha_\Lambda\rangle$	$0.7499 \pm 0.0029 \pm 0.0013$

- Most precise determination of Ξ^0 hyperon decay parameters, consistent with the ψ(3686) decay
- CP is still conservation within 1σ uncertainty (10^{-3})

Summary

- **BESIII is successfully operating since 2008**
  - ✓Collected large data samples in the τ-charm physics region
  - ✓Continues to take data in coming years
- **Many studies for hyperon spin polarization and CPV in Charmonium decay and in e^+e^- annihilation achieved:**
  - ✓ Observation of hyperon transverse polarization
  - ✓ CPV study in Λ, Σ, Ξ hyperon
  - ✓ Still need more experimental/theoretical efforts
- **More new results are on the way!**

Thanks for your attention!