Hyperon pair production and CPV study at BESIII

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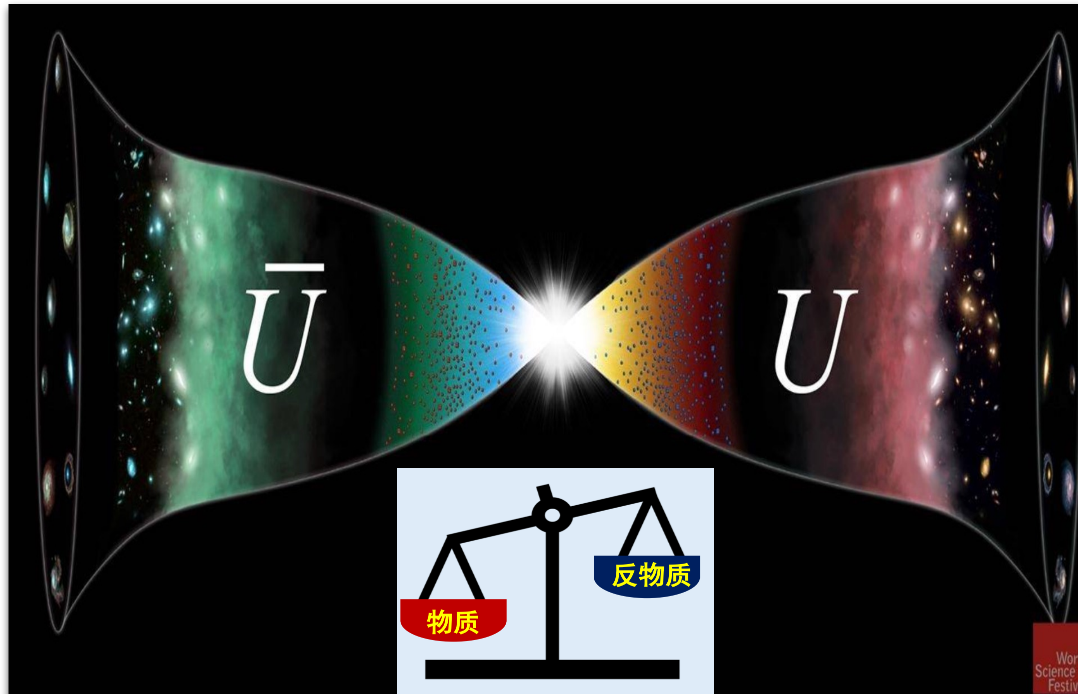
Outline

- Introduction
- Recent overview
  - Hyperon polarization and CPV
    - Λ, Σ, Ξ hyperons
  - Hyperon pair production
    - Near threshold ($\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$, $\Omega\bar{\Omega}$)
    - Above open charm threshold ($\Lambda\bar{\Lambda}$, $\Xi\bar{\Xi}$)
- Summary

研究背景

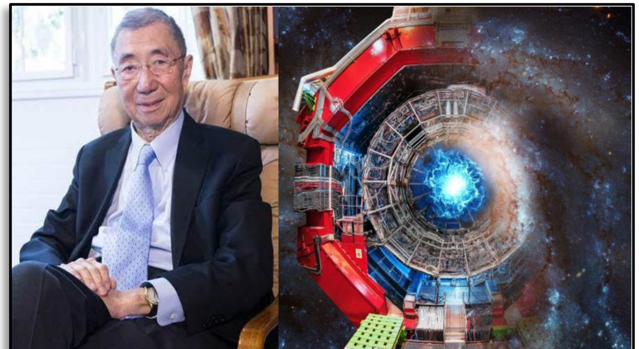
理解正反物质不对称性起源是当今物理学的重大前沿



《自然》杂志公布的125个挑战全球科学界的重要基础性问题，其中“宇宙是怎样形成”和“物质基本结构是什么”等，都与正反物质不对称性起源相关

实验探索正反物质不对称性起源的途径

天上



丁肇中领导的AMS实验

悟空（DAMPE）实验

地表

STAR

重离子对撞
（美国）

LHCb　Belle II

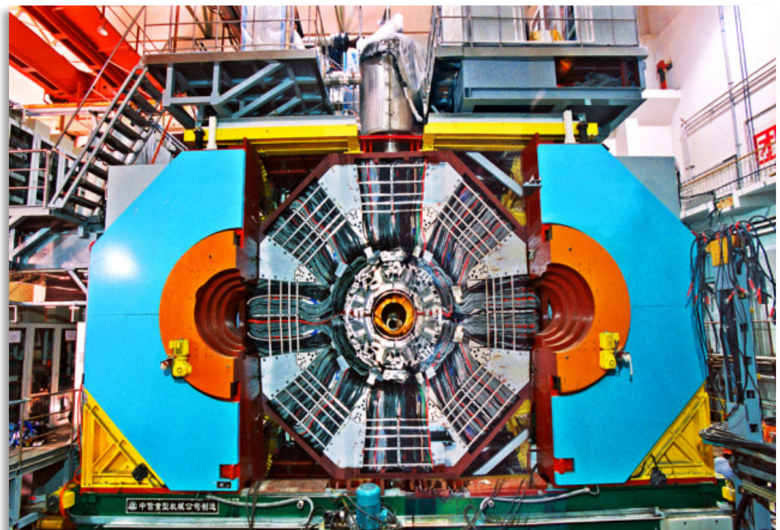
B介子工厂
（欧洲和日本）

BESIII

正负电子对撞
（中国）

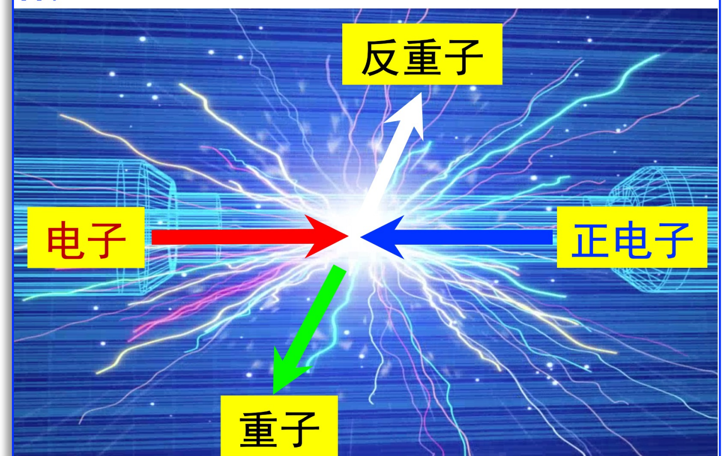
我国的BESIII实验能否在探索正反物质不对称性研究方面占有一席之地？

□ 北京正负电子对撞机/BESIII实验是一个极好的产生具有**量子纠缠**正反重子对的理想场所，为研究正反物质不对称性提供了**绝佳的平台**



覆盖了所有轻味重子对的产生

$p\bar{p}/n\bar{n}, \Lambda\bar{\Lambda}, \Sigma\bar{\Sigma}, \Sigma(1385)\bar{\Sigma}(1385), \Xi\bar{\Xi}, \Xi(1530)\bar{\Xi}(1530), \Omega^-\bar{\Omega}^+$



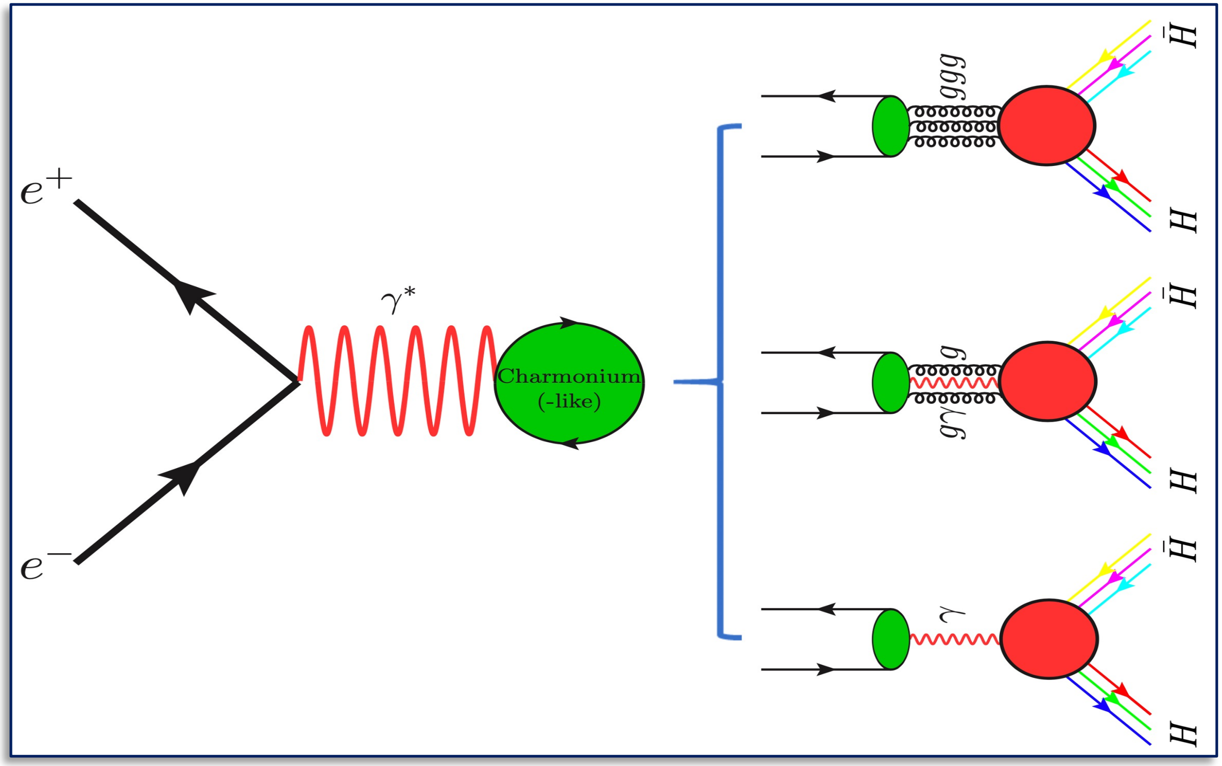
■ 关键科学问题

1. BESIII实验上产生正反重子对的产额有多大？

2. 如何测量与正反物质不对称相关的物理量？

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

☐ Main Feynman Diagrams

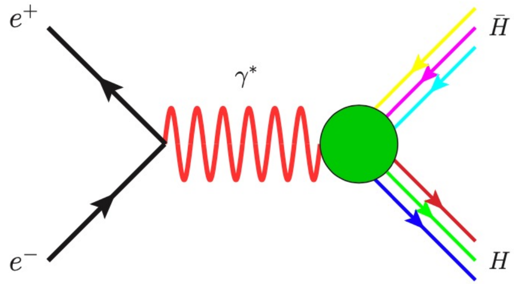


X. F. Wang, RMFS, 3, 0308074 (2022)

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

$\mathrm{H\bar{H}}$ 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}, $G_{E/M}$)**

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

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

☐ Understand the internal structure of hyperon

☐ Provide extra insights for Charmonium(-like) states

Why hyperon CPV at BESIII

SM Prediction: CPV: 10^{-4}

- World's largest data samples: 10B J/ψ, 3B $\psi(3686)$
- Large BR for hyperon pair production in J/ψ and $\psi(3686)$
- Quantum entangled pair productions
- Clean background, etc.

Decay mode	Br($\times 10^{-4}$)	Eff. (%)	$N^{exp.}$	sensitivity
$J/\psi \to \Lambda\bar{\Lambda}$	18.9 ± 0.9	40	3,000,000	~10^{-3}
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	11.7 ± 0.3	18	860,000	~10^{-2}
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	15.0 ± 2.4	24	960,000	~10^{-2}
$J/\psi \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	10.7 ± 0.8	10	350,000	~10^{-2}
$J/\psi \to \Sigma(1385)^{\pm}\bar{\Sigma}(1385)^{\mp}$	11.6 ± 0.5	10	350,000	~10^{-2}
$J/\psi \to \Xi^0\bar{\Xi}^0$	11.7 ± 0.4	7	300,000	~10^{-3}
$J/\psi \to \Xi^-\bar{\Xi}^+$	9.7 ± 0.8	15	600,000	~10^{-3}-10^{-4}
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$ or c.c.	3.2 ± 1.4	5	50,000	~10^{-2}
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$ or c.c.	3.2 ± 0.8	5	50,000	~10^{-2}
$\psi(3686) \to \Lambda\bar{\Lambda}$	3.8 ± 0.1	40	180,000	~10^{-2}
$\psi(3686) \to \Sigma^0\bar{\Sigma}^0$	2.4 ± 0.9	15	20,000	~10^{-1}
$\psi(3686) \to \Sigma^+\bar{\Sigma}^-$	2.3 ± 0.1	19	20,000	~10^{-1}
$\psi(3686) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	0.7 ± 0.1	8	10,000	~10^{-1}
$\psi(3686) \to \Sigma(1385)^{\pm}\bar{\Sigma}(1385)^{\mp}$	0.9 ± 0.1	10	10,000	~10^{-1}
$\psi(3686) \to \Xi^0\bar{\Xi}^0$	2.3 ± 0.4	5	10,000	~10^{-2}
$\psi(3686) \to \Xi^-\bar{\Xi}^+$	2.9 ± 0.1	10	25,000	~10^{-3}
$\psi(3686) \to \Xi(1530)^0\bar{\Xi}^0$ or c.c.	0.5 ± 0.3	2	1,000	~10^{-1}
$\psi(3686) \to \Xi(1530)^-\bar{\Xi}^+$ or c.c.	1.2 ± 0.1	2	1,000	~10^{-1}

How to construct CPV observables

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

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

- **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: $\alpha_H = -\alpha_{\bar{H}}, \ldots$**
- **Then, one can construct CPV observables ($\Xi \to \pi\Lambda$):**

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

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

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

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

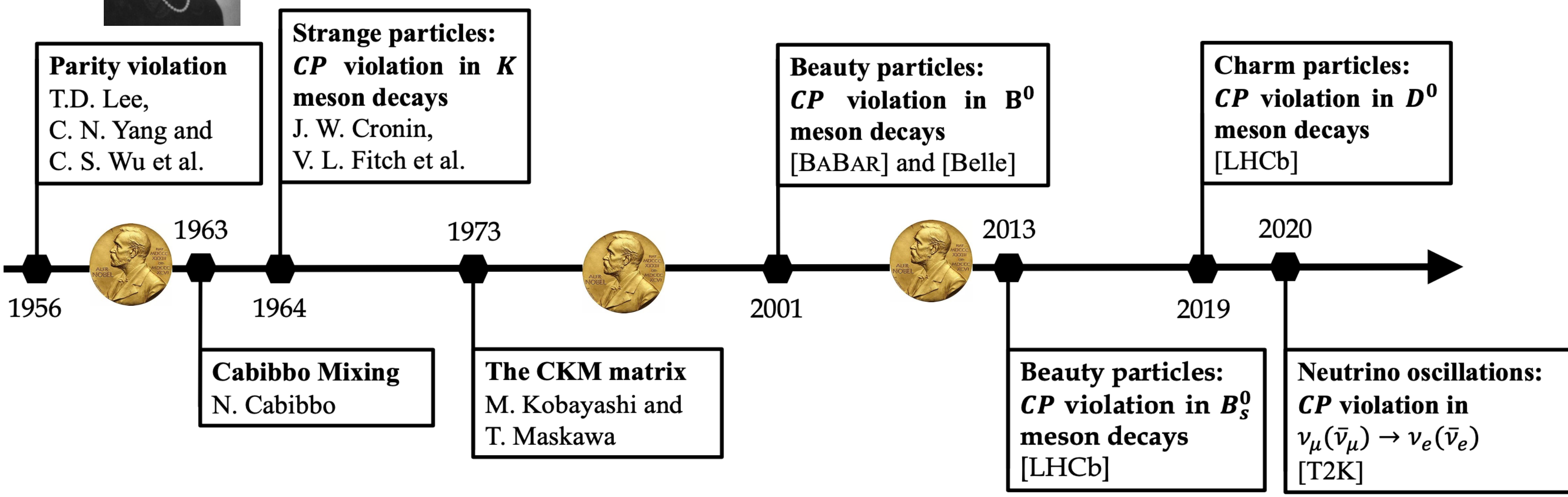
$$\delta_P - \delta_S \simeq \arctan\left(\frac{\beta_{\Xi}}{\alpha_{\Xi}}\right) \simeq \arctan\left(\frac{\sqrt{1-\langle\alpha_{\Xi}^2\rangle}}{\langle\alpha_{\Xi}\rangle}\langle\phi_{\Xi}\rangle\right)$$

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

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

Roadmap of CP violation



<u>Symmetry 2023, 15(1), 214</u>

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

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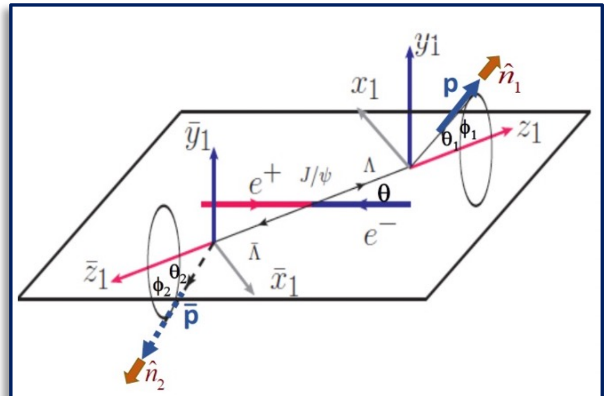
Observation of Λ spin polarization in $J/\psi \to \Lambda\bar{\Lambda}$

Data Sample: 1.3 B J/ψ

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

◻ A 5D angular distribution analysis



Unpolarized-term

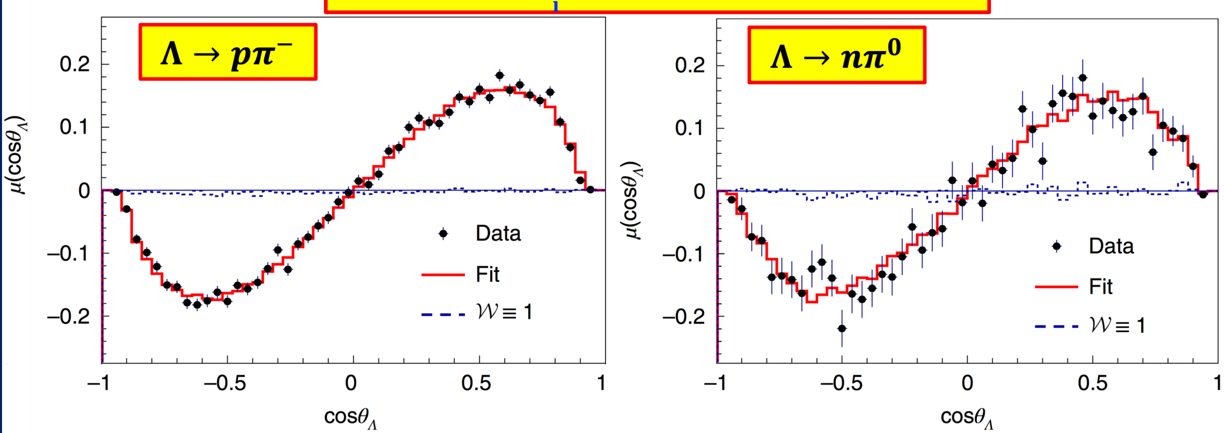
Entangled-terms

$$W(\xi;\Omega) = 1 + \alpha_\psi cos\theta_\Lambda^2$$
$$+\alpha_-\alpha_+\left[\sin^2\theta_\Lambda(n_{1,x}n_{2,x} - \alpha_\psi n_{1,y}n_{2,y}) + (\cos^2\theta_\Lambda + \alpha_\psi)n_{1,z}n_{2,z}\right]$$
$$+\alpha_-\alpha_+\sqrt{1+\alpha_\psi}\cos(\Delta\Phi)\, sin\theta_\Lambda cos\theta_\Lambda(n_{1,x}n_{2,x} + n_{1,z}n_{2,z})$$
$$+\sqrt{1+\alpha_\psi^2}\sin(\Delta\Phi)\, sin\theta_\Lambda cos\theta_\Lambda(\alpha_- n_{1,y} + \alpha_+ n_{2,y})$$

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:

$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

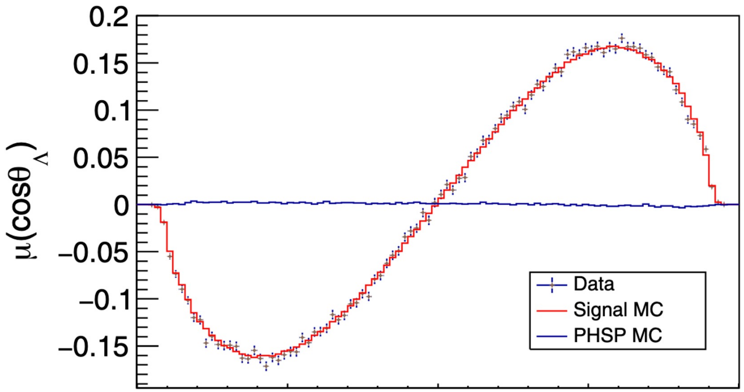
Test of $\Delta I = \frac{3}{2}$ contribution

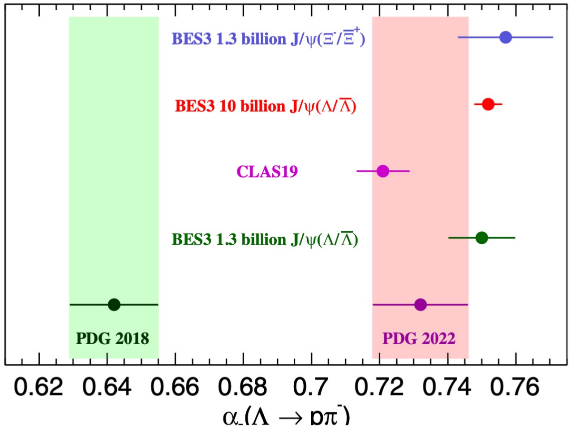
- **First observation of hyperon spin polarization, and first test of CPV in Λ decay with precision over previous measurements**

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)





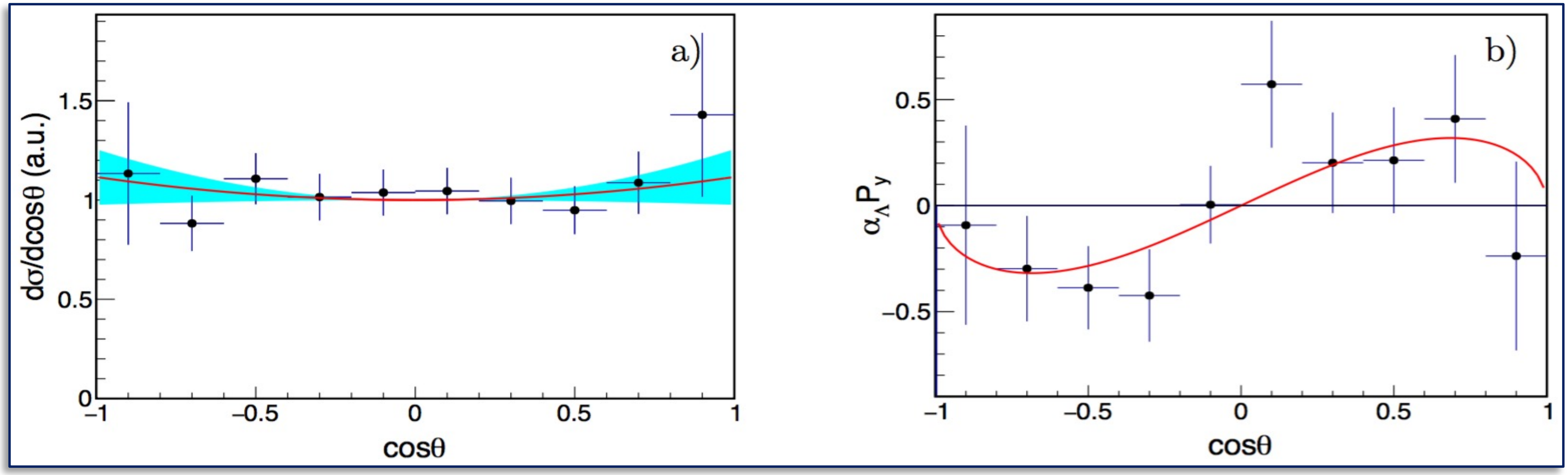
Par.	This work	Previous results [8]
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0024$	$0.461 \pm 0.006 \pm 0.007$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0080$	$0.740 \pm 0.010 \pm 0.009$
α_-	$0.7519 \pm 0.0036 \pm 0.0019$	$0.750 \pm 0.009 \pm 0.004$
α_+	$-0.7559 \pm 0.0036 \pm 0.0029$	$-0.758 \pm 0.010 \pm 0.007$
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)



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

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

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

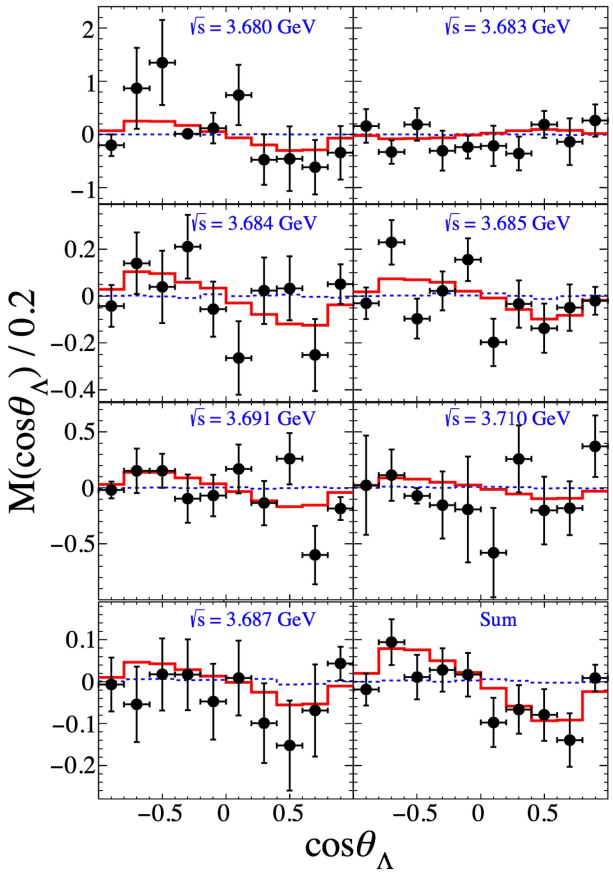
$$R = \left|\frac{G_E}{G_M}\right| = 0.96 \pm 0.14 \pm 0.02$$

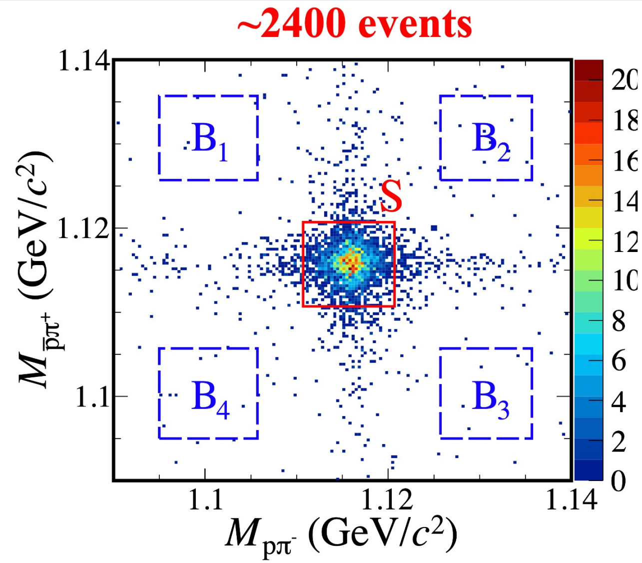
- **First complete determination of baryon time-like EMFFs**
- **More information for understanding $\Lambda\bar{\Lambda}$ production near threshold**

Λ hyperon spin polarization around ψ(3686)

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

arXiv:2303.00271





$\sqrt{s}$ (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}	$0.52^{+0.38}_{-0.39} \pm 0.02$	$0.0^{+64.7}_{-56.7} \pm 1.6$	$0.89^{+0.48}_{-0.50} \pm 0.02$

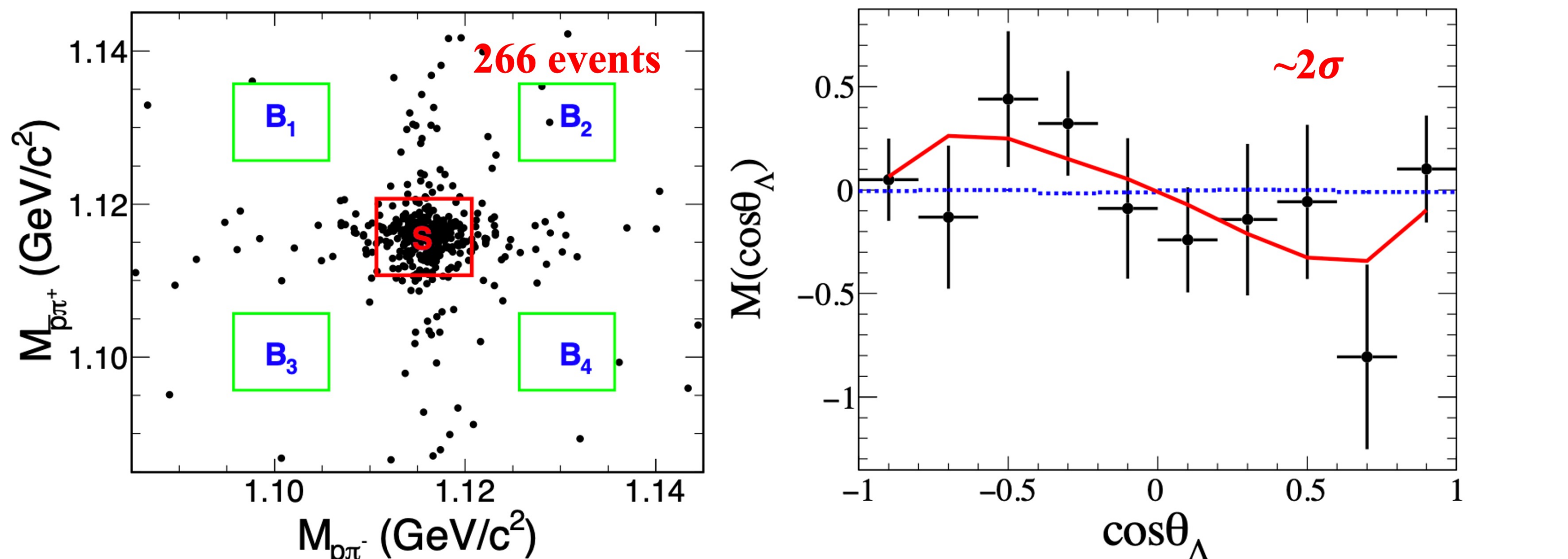
- **CP is fixed to be zero, more information for understanding the production mechanism of $\Lambda\bar{\Lambda}$ in $\psi(3686)$**

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 $\psi(3770)$**

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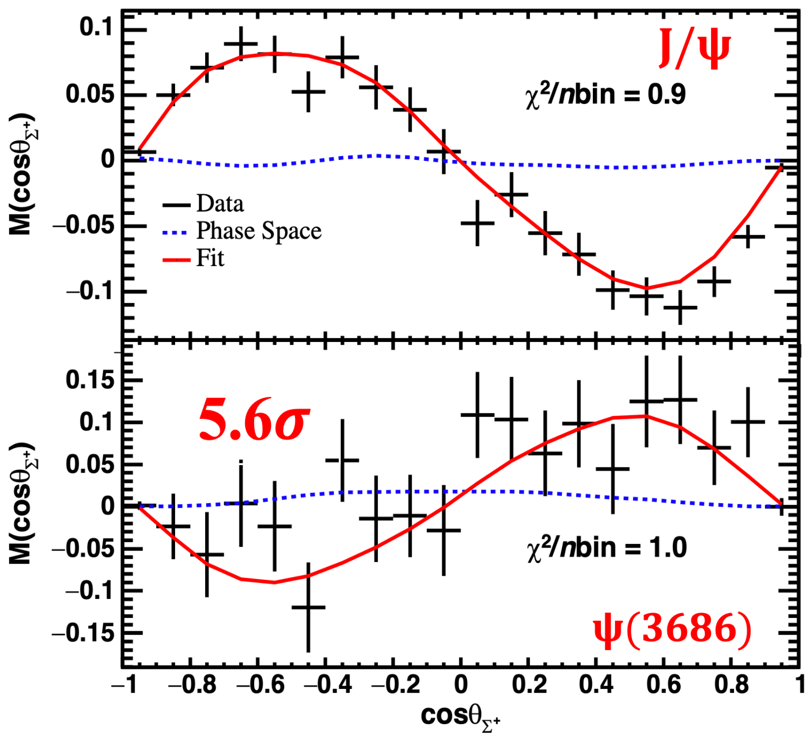
Observation of $\Sigma^+(p\pi^0)$ spin polarization in $\psi \to \Sigma^+\bar{\Sigma}^-$

Data Sample: 1.3B J/ψ & 448M $\psi(3686)$

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	$-0.998 \pm 0.037 \pm 0.009$
$\bar{\alpha}_0$	$0.990 \pm 0.037 \pm 0.011$

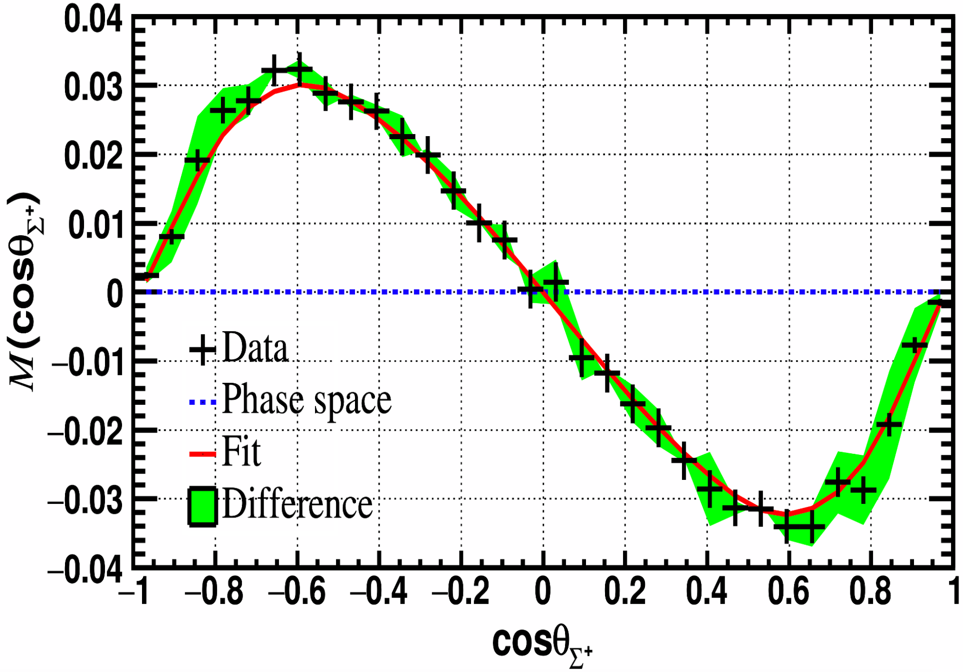
☐ Test of CP violation:

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

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}	$-0.080 \pm 0.052 \pm 0.028$
$\langle\alpha_+\rangle$	$0.0506 \pm 0.0026 \pm 0.0019$

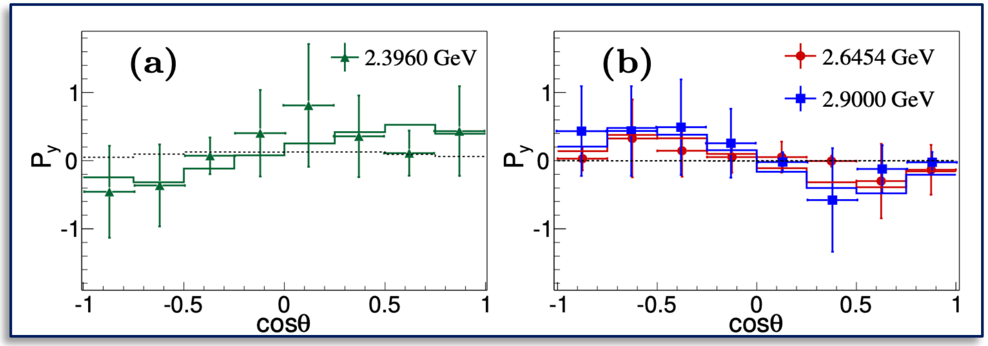
- Both $\alpha_{J/\psi}$ and $\Delta\Phi$ are consistent with $\Sigma^+(p\pi^0)$ mode
- Test of CP violation:

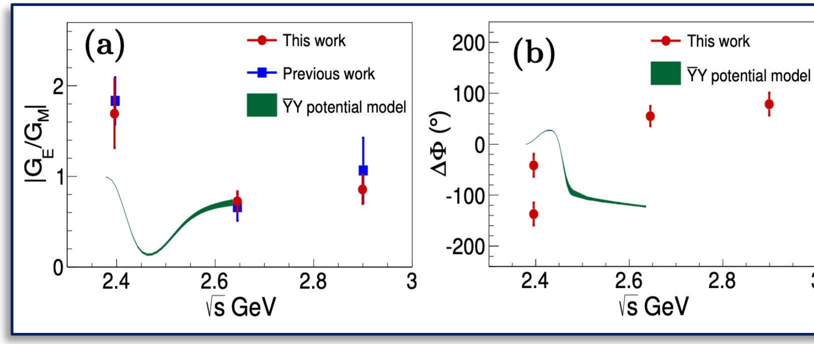
$$A_{CP}^{\Sigma^+(n\pi^+)} = \frac{\alpha_0 + \bar{\alpha}_0}{\alpha_0 - \bar{\alpha}_0} = -0.080 \pm 0.052 \pm 0.028 \approx 0?$$

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





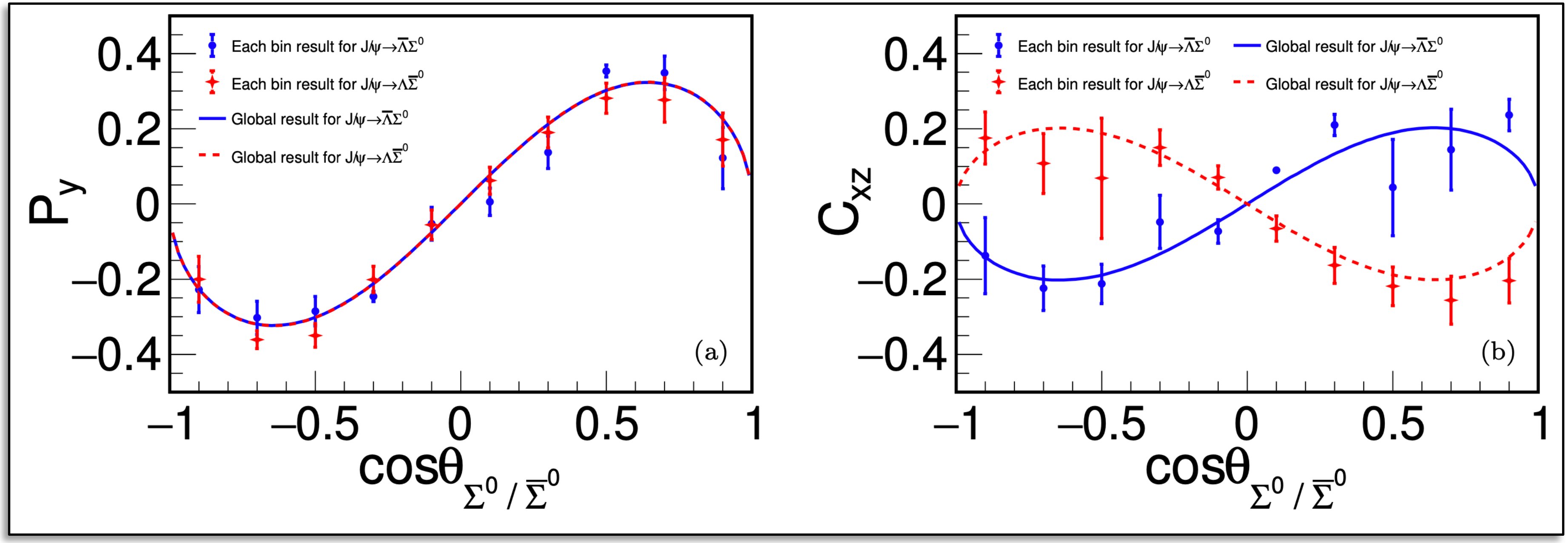
$\sqrt{s}$ (GeV)	2.3960	2.6454	2.9000
α	-0.47 ± 0.18 ± 0.09	0.41 ± 0.12 ± 0.06	0.35 ± 0.17 ± 0.15
$\Delta\Phi$ (°)	-42 ± 22 ± 14 (-138 ± 22 ± 14)	55 ± 19 ± 14	78 ± 22 ± 9
$\sin\Delta\Phi$	-0.67 ± 0.29 ± 0.18		
$\lvert G_E/G_M \rvert$	1.69 ± 0.38 ± 0.20	0.72 ± 0.11 ± 0.06	0.85 ± 0.16 ± 0.15

- **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)]**

Observation of Σ^0 spin polarization in $J/\psi \to \Lambda\bar{\Sigma}^0 + c.c.$

Data Sample: 10B J/ψ

arXiv: 2309.04139



$$\alpha_{J/\psi} = 0.418 \pm 0.028 \pm 0.010, \qquad R = \left|\frac{G_E}{G_M}\right| = 0.860 \pm 0.029 \pm 0.010$$

$$\Delta\Phi_1 = 1.011 \pm 0.094 \pm 0.010, \ \Delta\Phi_2 = 2.128 \pm 0.094 \pm 0.010$$

$$\Delta\Phi = \Delta\Phi_1 \pm \Delta\Phi_2 \approx \pi$$

$$\Delta\Phi_{CP} = \pi - \Delta\Phi \approx 0$$

- ☐ **Provide a new exploration for direct CP violation study**

Outline

- Introduction
- Recent overview
  - Hyperon polarization and CPV
    - Λ, Σ, Ξ hyperons
  - Hyperon pair production
    - Near threshold ($\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$, $\Omega\bar{\Omega}$)
    - Above open charm threshold ($\Lambda\bar{\Lambda}$, $\Xi\bar{\Xi}$)
- Summary

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

Data Sample: 1.3B J/ψ

Nature 606, 64 (2022)

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

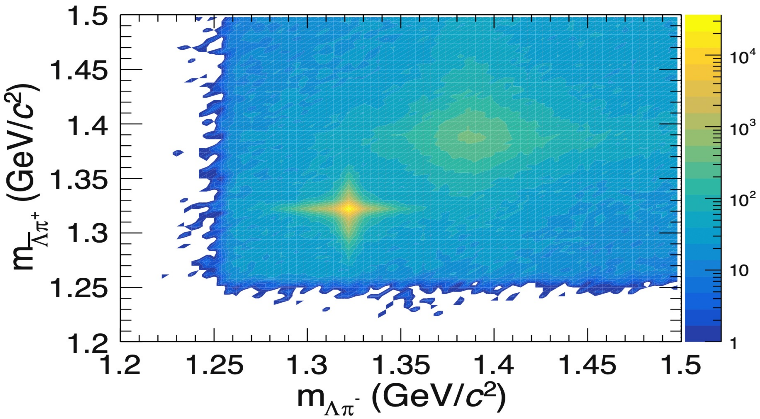
The BESIII Collaboration

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

8772 Accesses | **96** Altmetric | Metrics

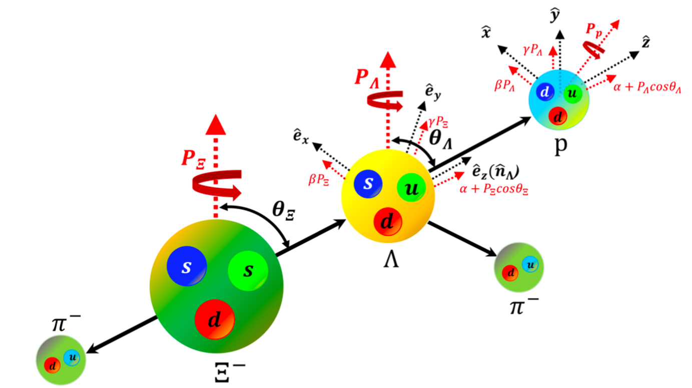
Abstract

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].



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

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

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

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

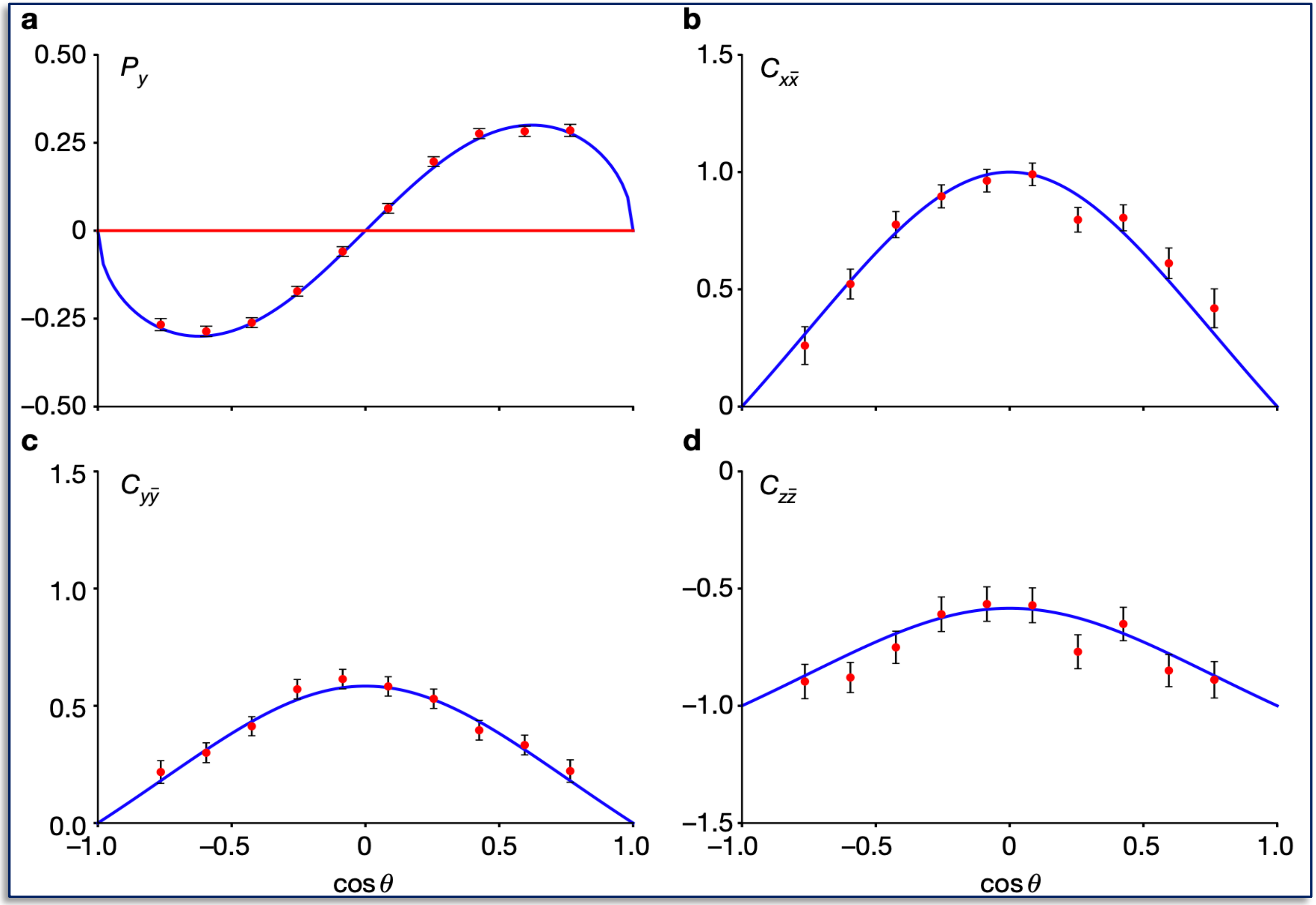
Parameters extraction by a 9D angular distribution analysis

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

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

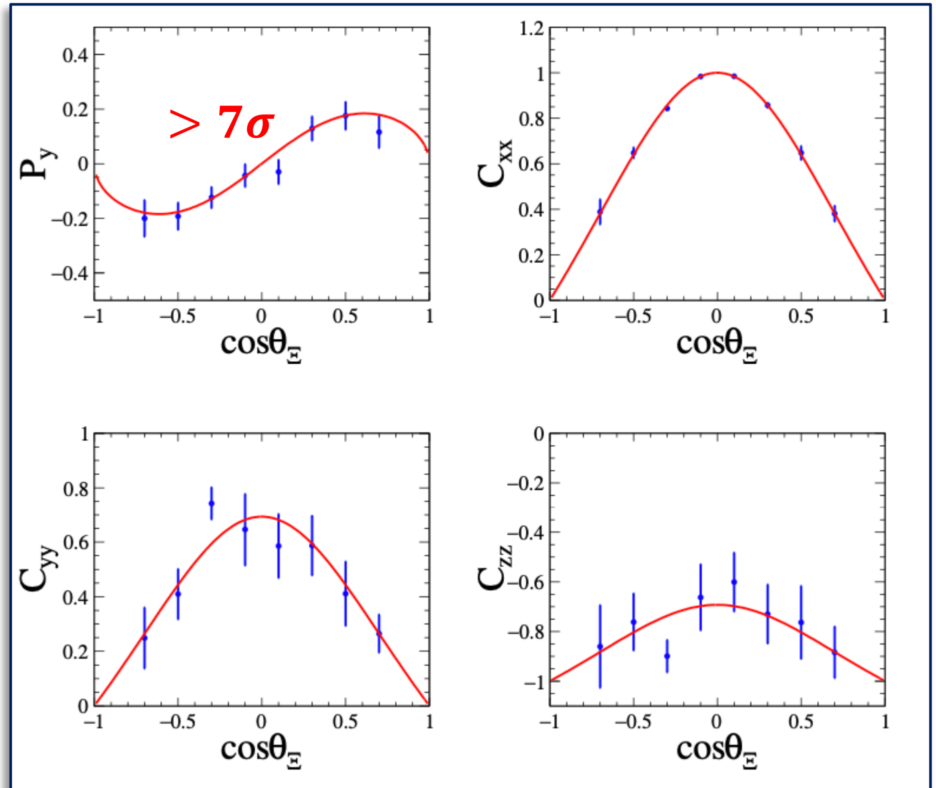
- ❑ Observation of Ξ^- spin polariztion, non-zero weak phase difference
- ❑ Most precise test for CPV on strange hyperon decay
- ❑ Update with 10 billion J/ψ is ongoing

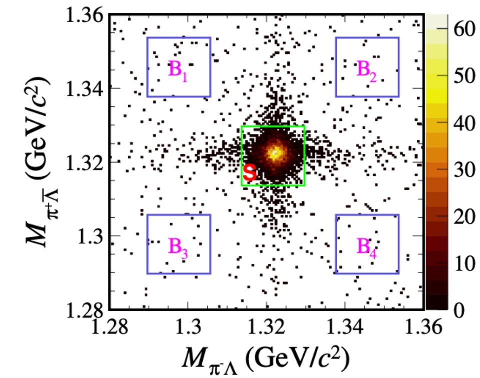
Ξ^- spin polarization and CPV in $\psi(3686) \to \Xi^-\bar{\Xi}^+$

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)	$-49.9 \pm 52.1 \pm 2.6$	$-4.8 \pm 13.7 \pm 2.9$

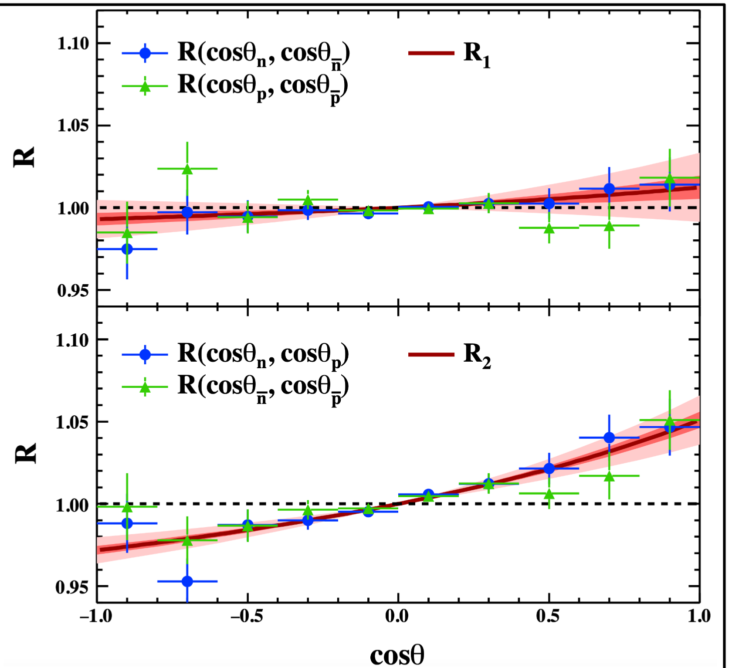
- **Both $\alpha_{\psi(3686)}$ and $\Delta\Phi$ are very different from the J/ψ peak**
- **Other parameters and CPV values are consistent with the J/ψ peak.**

Test of $\Delta I = \frac{1}{2}$ and CPV in $J/\psi \to \Xi^-\bar{\Xi}^+$ with $\Lambda \to \bar{n}\pi^0$

Data Sample: 10B M J/ψ

~144000 events

arXiv:2309.14667



$$R_1 = (1 + \alpha_\Lambda \alpha_\Xi \cos\theta)/(1 + \bar{\alpha}_\Lambda \bar{\alpha}_\Xi \cos\theta)$$

$$R_2 = (1 + \langle\alpha_{\Lambda 0}\rangle\langle\alpha_\Xi\rangle \cos\theta)/(1 + \langle\alpha_{\Lambda -}\rangle\langle\alpha_\Xi\rangle$$

Parameters	This work	Previous result
$\alpha_{J/\psi}$	$0.611 \pm 0.007^{+0.013}_{-0.007}$	$0.586 \pm 0.012 \pm 0.010$ [17]
$\Delta\Phi_{J/\psi}$ (rad)	$1.30 \pm 0.03^{+0.02}_{-0.03}$	$1.213 \pm 0.046 \pm 0.016$ [17]
α_Ξ	$-0.367 \pm 0.004^{+0.003}_{-0.004}$	$-0.376 \pm 0.007 \pm 0.003$ [17]
ϕ_Ξ (rad)	$-0.016 \pm 0.012^{+0.004}_{-0.008}$	$0.011 \pm 0.019 \pm 0.009$ [17]
$\bar{\alpha}_\Xi$	$0.374 \pm 0.004^{+0.002}_{-0.004}$	$0.371 \pm 0.007 \pm 0.002$ [17]
$\bar{\phi}_\Xi$ (rad)	$0.010 \pm 0.012^{+0.002}_{-0.013}$	$-0.021 \pm 0.019 \pm 0.007$ [17]
$\alpha_{\Lambda-}$	$0.764 \pm 0.008^{+0.005}_{-0.006}$	$0.7519 \pm 0.0036 \pm 0.0024$ [35]
$\alpha_{\Lambda+}$	$-0.774 \pm 0.009^{+0.005}_{-0.005}$	$-0.7559 \pm 0.0036 \pm 0.0030$ [35]
$\alpha_{\Lambda 0}$	$0.670 \pm 0.009^{+0.009}_{-0.008}$	0.75 ± 0.05 [28]
$\bar{\alpha}_{\Lambda 0}$	$-0.668 \pm 0.008^{+0.006}_{-0.008}$	$-0.692 \pm 0.016 \pm 0.006$ [18]
$\delta_P - \delta_S$ (rad)	$0.033 \pm 0.020^{+0.008}_{-0.012}$	$-0.040 \pm 0.033 \pm 0.017$ [17]
$\xi_P - \xi_S$ (rad)	$0.007 \pm 0.020^{+0.018}_{-0.005}$	$0.012 \pm 0.034 \pm 0.008$ [17]
A^Ξ_{CP}	$-0.009 \pm 0.008^{+0.007}_{-0.002}$	$0.006 \pm 0.013 \pm 0.006$ [17]
$\Delta\phi^\Xi_{CP}$ (rad)	$-0.003 \pm 0.008^{+0.002}_{-0.007}$	$-0.005 \pm 0.014 \pm 0.003$ [17]
A^-_{CP}	$-0.007 \pm 0.008^{+0.002}_{-0.003}$	$-0.0025 \pm 0.0046 \pm 0.0012$ [35]
A^0_{CP}	$0.001 \pm 0.009^{+0.005}_{-0.007}$	$A^\Lambda_{CP} = (2A^-_{CP} + A^0_{CP})/3$ -
A^Λ_{CP}	$-0.004 \pm 0.007^{+0.003}_{-0.004}$	-
$\alpha_{\Lambda 0}/\alpha_{\Lambda -}$	$0.877 \pm 0.015^{+0.014}_{-0.010}$	1.01 ± 0.07 [28]
$\bar{\alpha}_{\Lambda 0}/\alpha_{\Lambda +}$	$0.863 \pm 0.014^{+0.012}_{-0.008}$	$0.913 \pm 0.028 \pm 0.012$ [18]

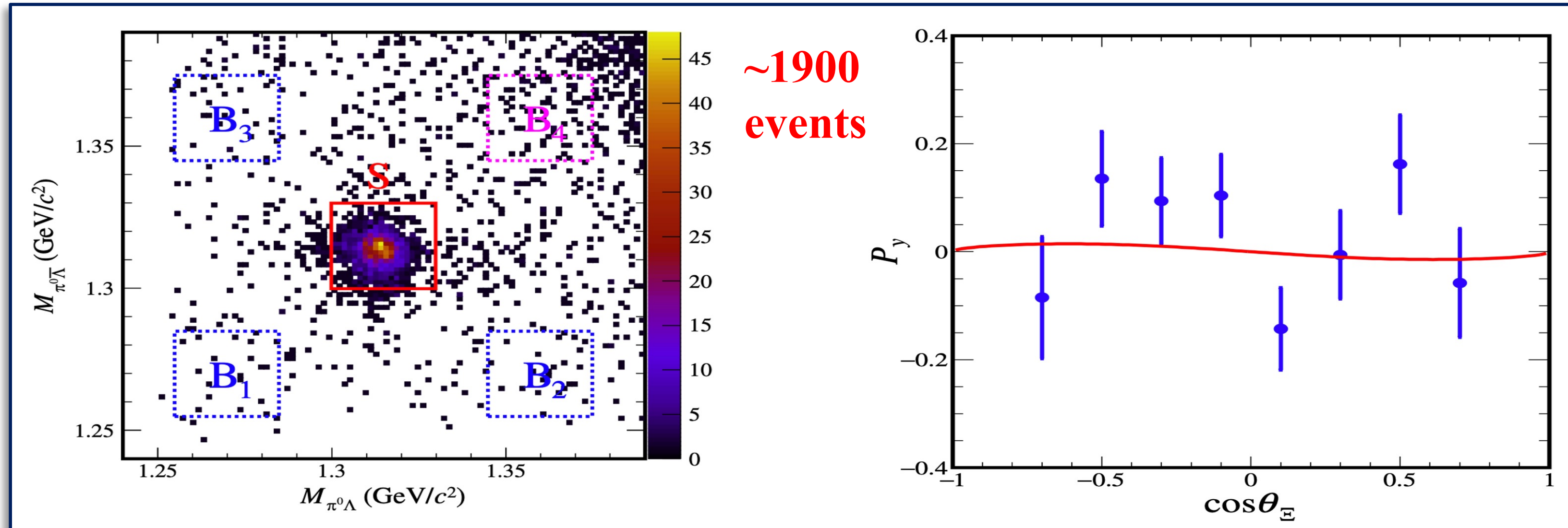
- **Most precise determination for $\alpha_{\Lambda/\bar{\Lambda}}$, first test CPV in neutron final states**
- **Ratio in S-wave: $S_{\Delta I=\frac{1}{2}}/S_{\Delta I=\frac{3}{2}} = 28.4 \pm 1.3^{+1.1}_{-1.0} \pm 3.9$,**

  while P-wave: $P_{\Delta I=\frac{1}{2}}/P_{\Delta I=\frac{3}{2}} = -13.0 \pm 1.4^{+1.1}_{-1.2} \pm 0.7$.

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}	$-0.007 \pm 0.082 \pm 0.025$	–	–
$\Delta\phi_{CP}^{\Xi}$	$-0.079 \pm 0.082 \pm 0.010$	–	–

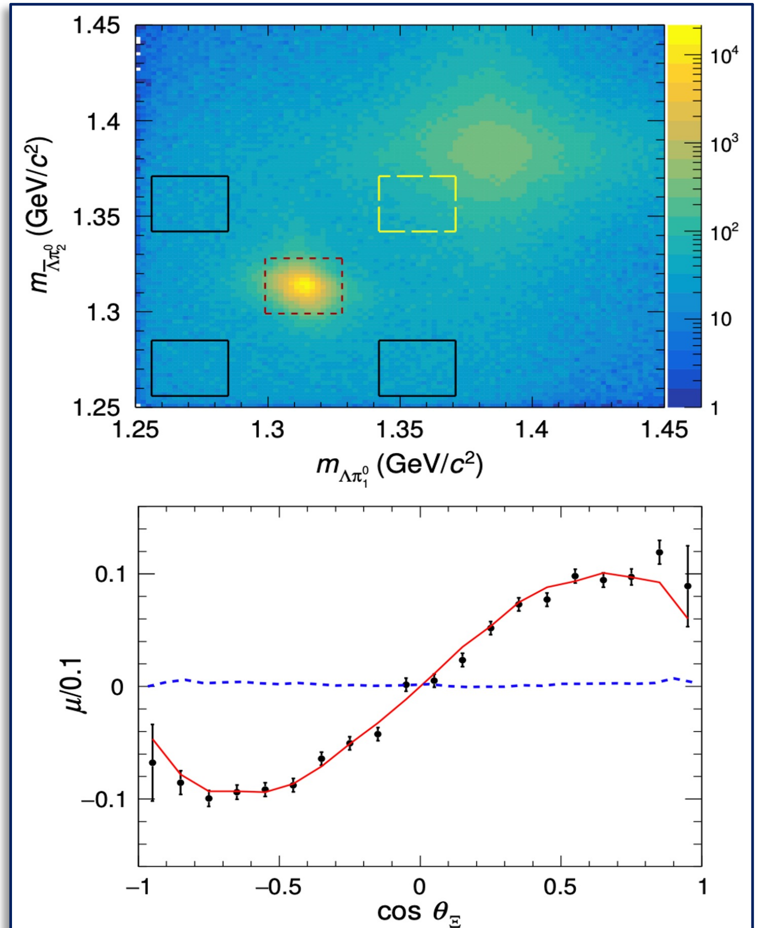
- **No spin polarization observed (limited statistics?)**
- **Fisrt simultaneous determination of Ξ^0 and $\bar{\Xi}^0$ decay parameters**
- **CP is conservation within 1σ uncertainty**

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

Data Sample: 10B M J/ψ

~330000 events

Phys. Rev. D 108, L031106 (2023)



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})**

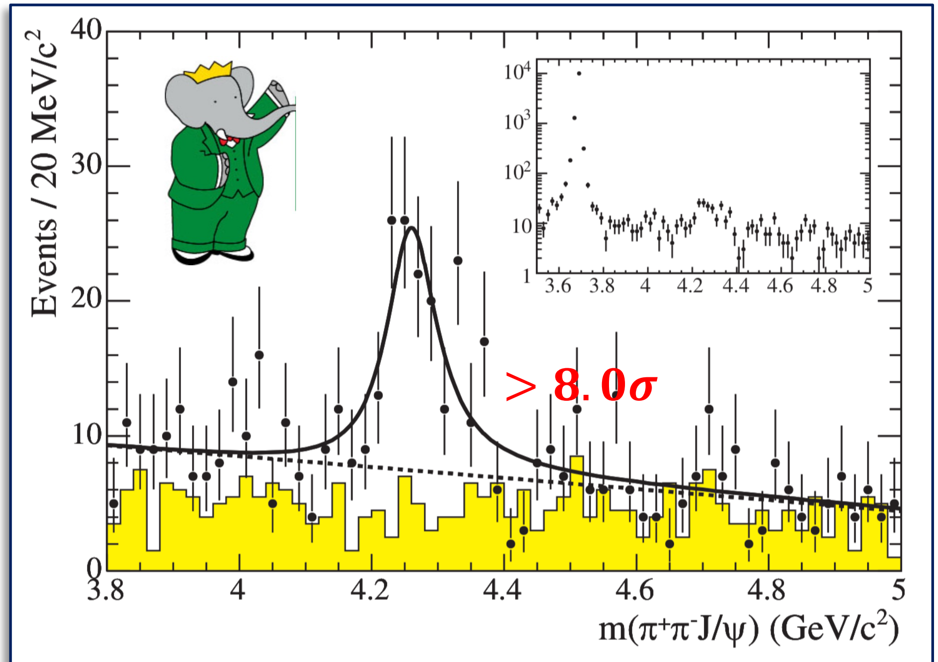
Outline

- Introduction
- Recent overview
  - Hyperon polarization and CPV
    - ✓ Λ, Σ, Ξ hyperons
  - **Hyperon pair production**
    - ✓ Near threshold ($\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$, $\Omega\bar{\Omega}$)
    - ✓ Above open charm threshold ($\Lambda\bar{\Lambda}$, $\Xi\bar{\Xi}$)
- Summary

Discovery of Y(4260)

PRL **95,** 142001 (2005)

- ❑ **Y(4260) is observed first at BaBar via ISR method**



$e^+e^- \to \gamma_{ISR}\pi^+\pi^- J/\psi$

Single-resonance assumption

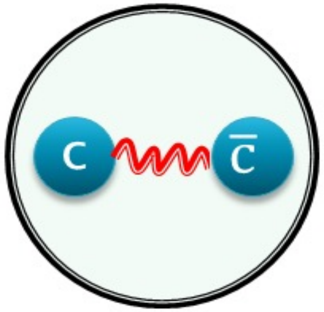
$N^{obs} = 125 \pm 23$

$M = 4259 \pm 8(stat)^{+2}_{-6}(syst)MeV$

$\Gamma = 88 \pm 23(stat)^{+6}_{-4}(syst)MeV$

- **Signifying the presence of one or more previously unobserved $J^{PC} = 1^{--}$ states containing hidden charm**
- **No quantum number determined due to the limited statistics**

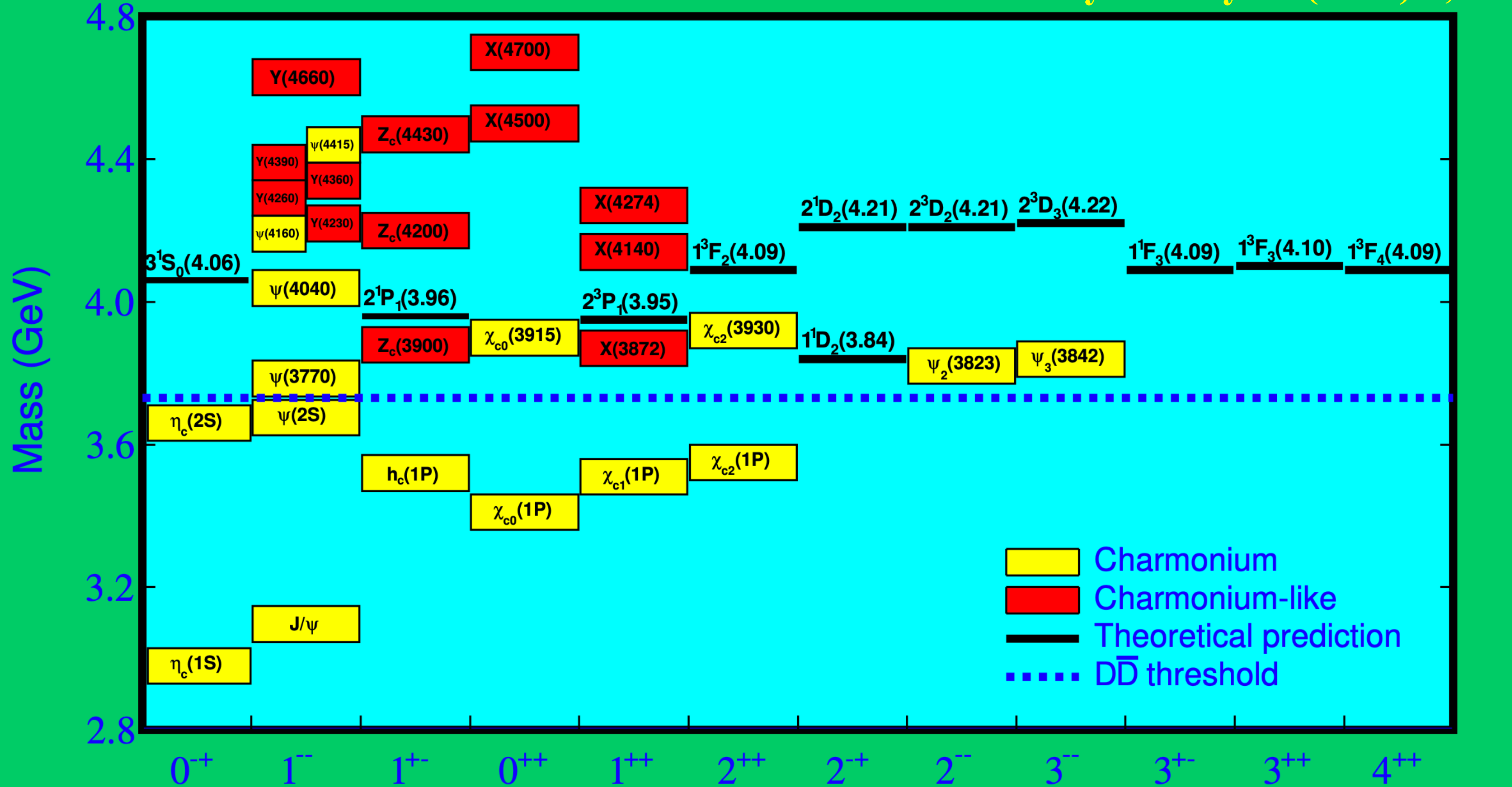
Charmonium (-like) state



■ Nonrelativistic $c\bar{c}$ bound state

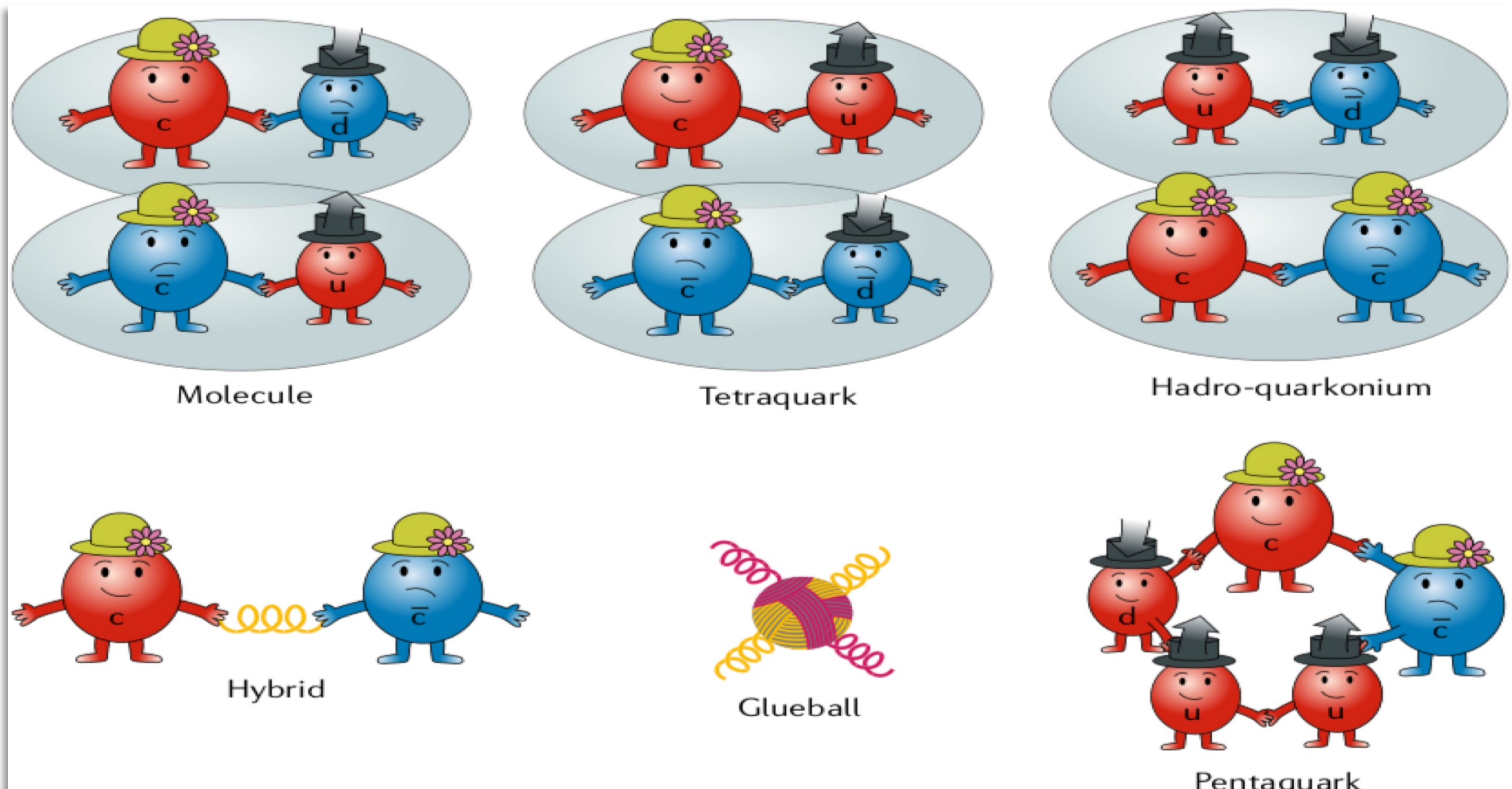
➢ J/ψ (1^3S_1), first member with $J^{PC} = 1^{--}$(1974)

Symmetry 14 (2022) 1, 65



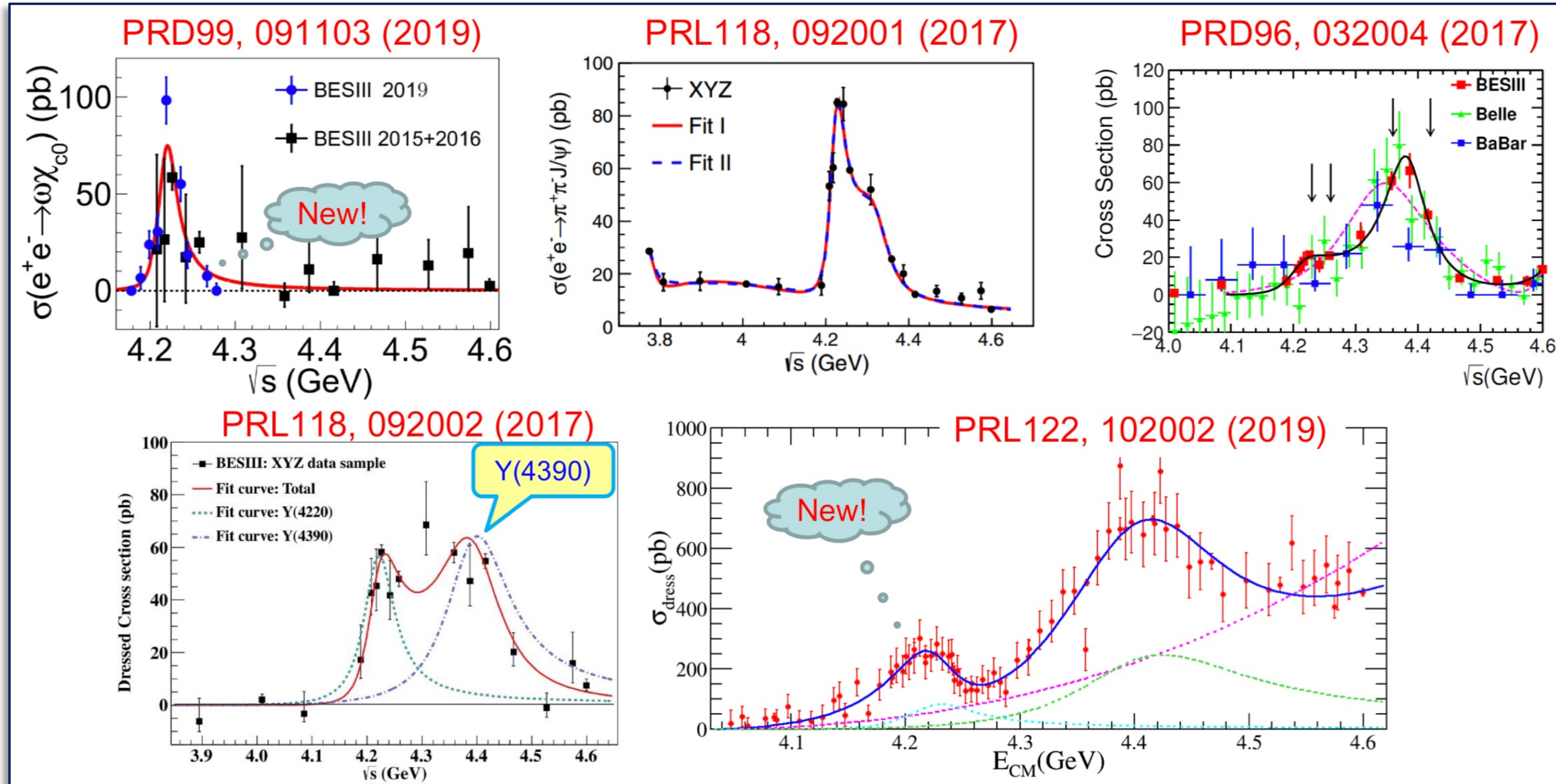
Non-standard hadron model

C. Z. Yuan S. L. Olsen, Nature Rev. Phys. 1 (2019) no.8, 480-494



- **Which one is the winner?**

BESIII Study of Y(4260)



Y(4220) appears in $\omega\chi_{c0}$, $\pi^+\pi^- J/\psi$, $\pi^+\pi^-\psi'$, $\pi^+\pi^- h_c$, $D^0 D^{*-}\pi^+$

Mass~4220 MeV, width~ 60 MeV!

No study in hyperon anti-hyperon final states?

Outline

- Introduction
- Recent overview
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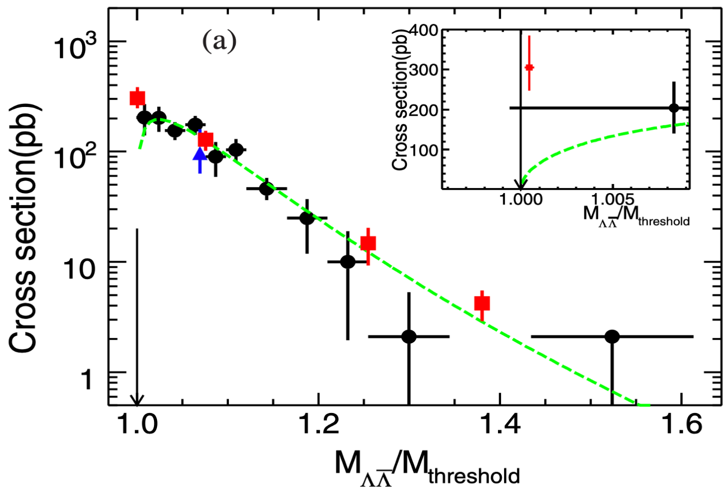
  - Hyperon pair production
    - Near threshold ($\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$, $\Omega\bar{\Omega}$)
    - Above open charm threshold ($\Lambda\bar{\Lambda}$, $\Xi\bar{\Xi}$)
- Summary

Observation of an enhancement near $\Lambda\bar{\Lambda}$ threshold

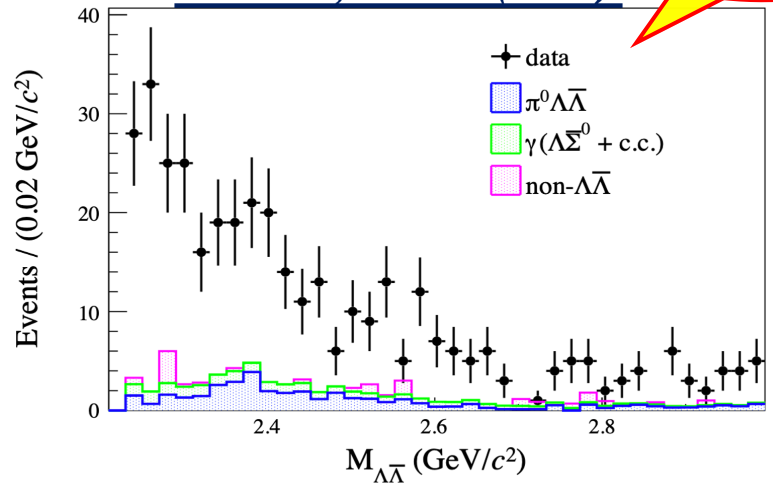
Data Sample: ~40/pb (4 points: 2.2324, 2.4, 2.8 and 3.08 GeV)

PRD 97. 032013 (2018)

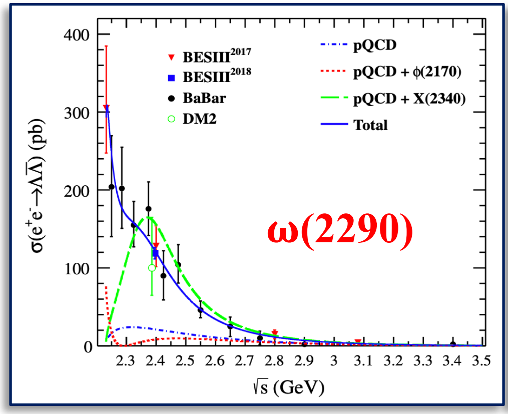


PRD 107, 072005 (2023)

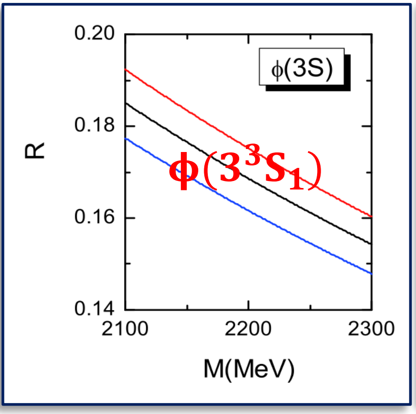
ISR



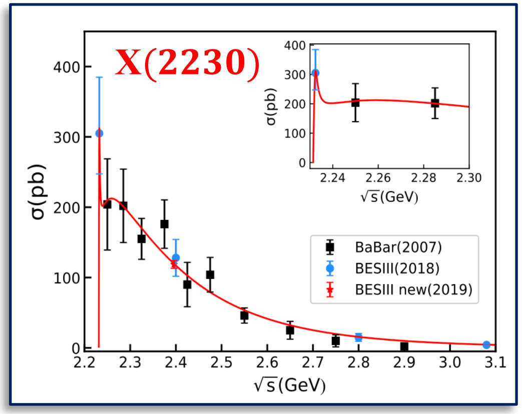
- Consistent with previous experiments (*BABAR* and *DM2*), improved precision
- More complicated physics scenario?



Cao et al, PRD 98, 094006 (2018)

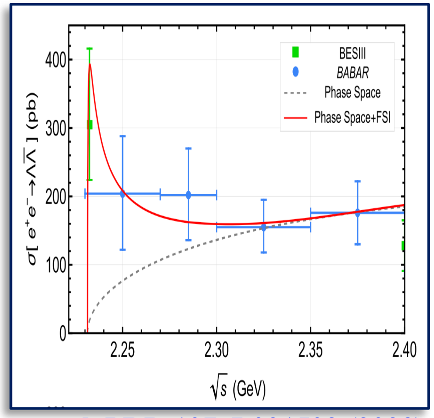


Xiao et al, CPC 43, 113105 (2019)



Xie et al, CPL. 39 (2022) 011201

Final state interaction

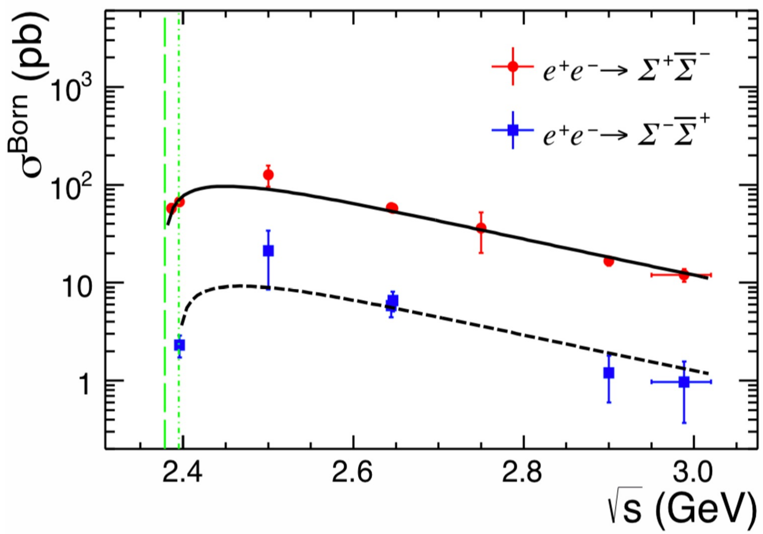


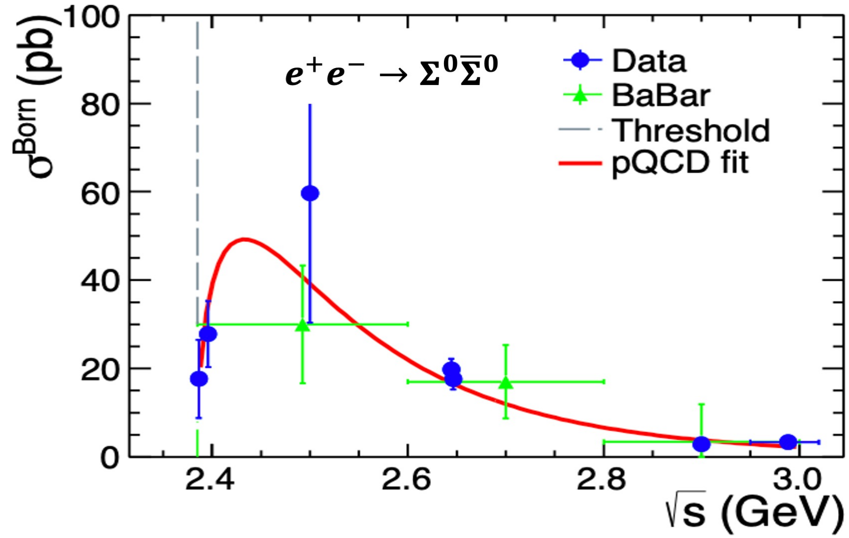
Qian et al, PRD 107, L091502 (2023)

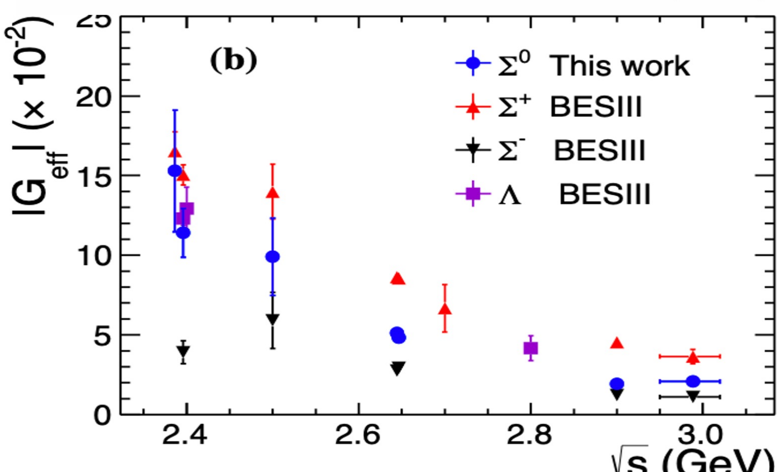
Measurement of $\sigma^B(e^+e^- \to \Sigma\bar{\Sigma})$ near threshold

Data Sample: ~400/pb (6 points: 2.3864 to 3.0200 GeV)

PLB814 (2021) 136059,
PLB831 (2022)136187







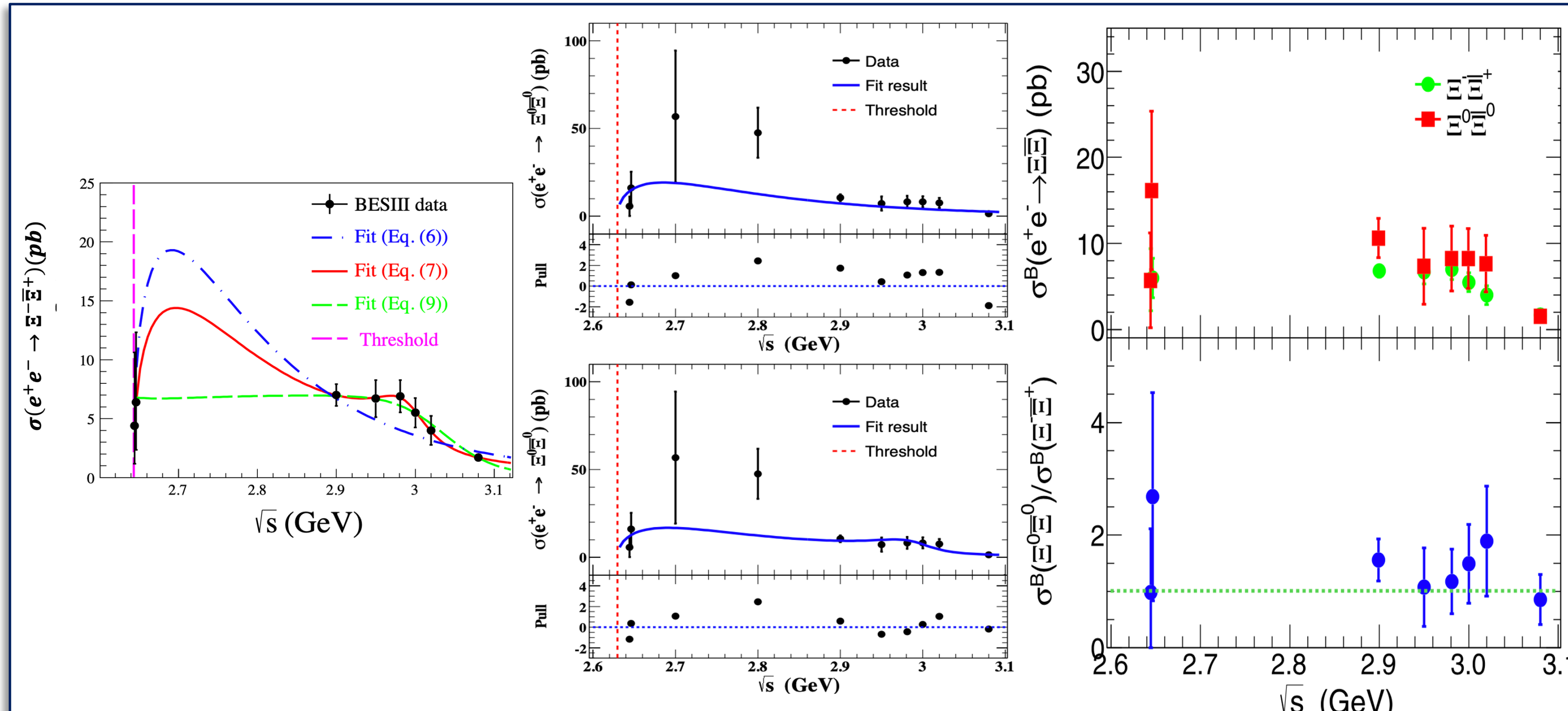
- No obvious threshold enhancement
- Nonzero cross sections near threshold
- Different cross sections observed
- More complicated physics scenario?
  - **VMD by Jujun Xie et al.** PRD107, 076008(2023)
  - …

Measurement of $\sigma^B(e^+e^- \to \Xi\bar{\Xi})$ near threshold

Data Sample: ~360/pb (8 points: 2.644 to 3.080 GeV)

PRD103, 012005(2021), PLB820,(2021)136557

- First study for $\Xi\bar{\Xi}$ production near threshold

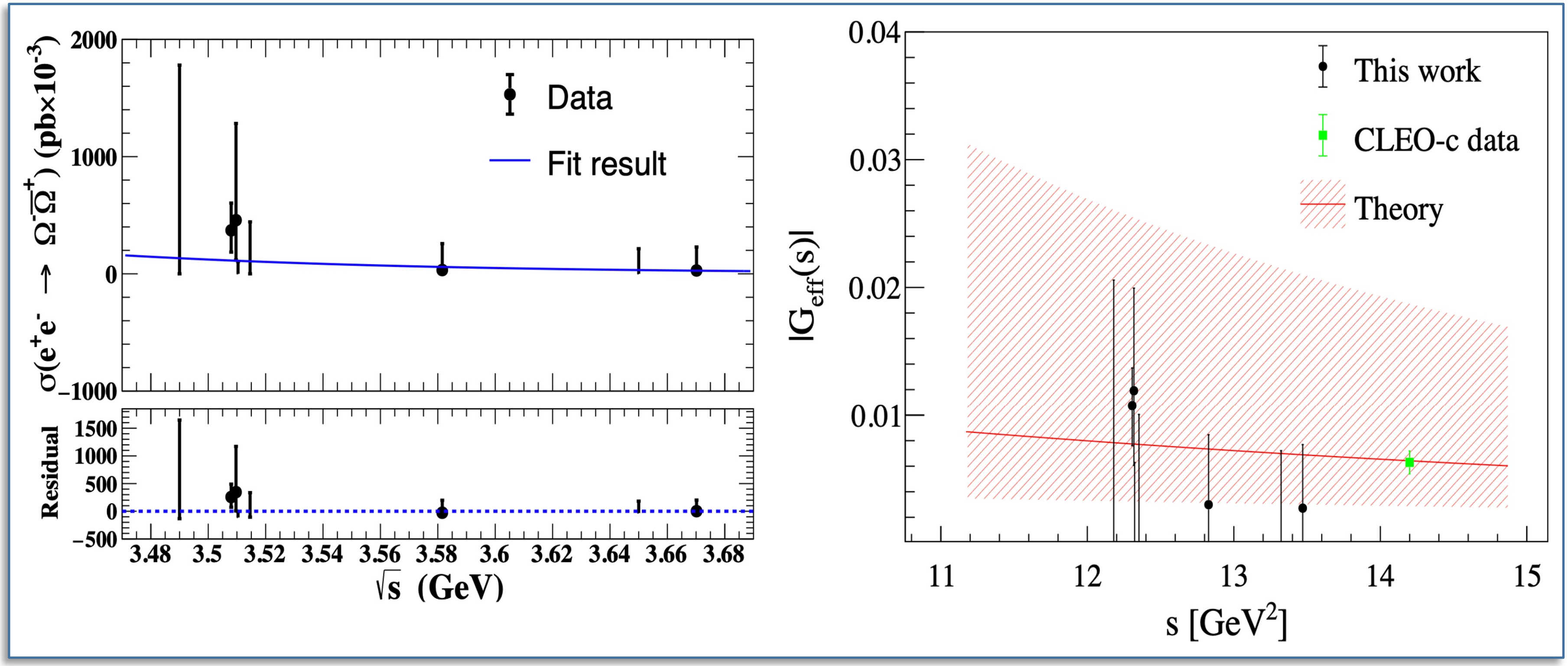


- No obvious $\Xi\bar{\Xi}$ threshold enhancement
- Ratio of cross sections agrees with the expectation of isospin symmetry

Search for the $\Omega^-\bar{\Omega}^+$ production near threshold

Data Sample: 8 points: (3.49 -- 3.67 GeV)

Phys.Rev.D 107 (2023) 5, 052003

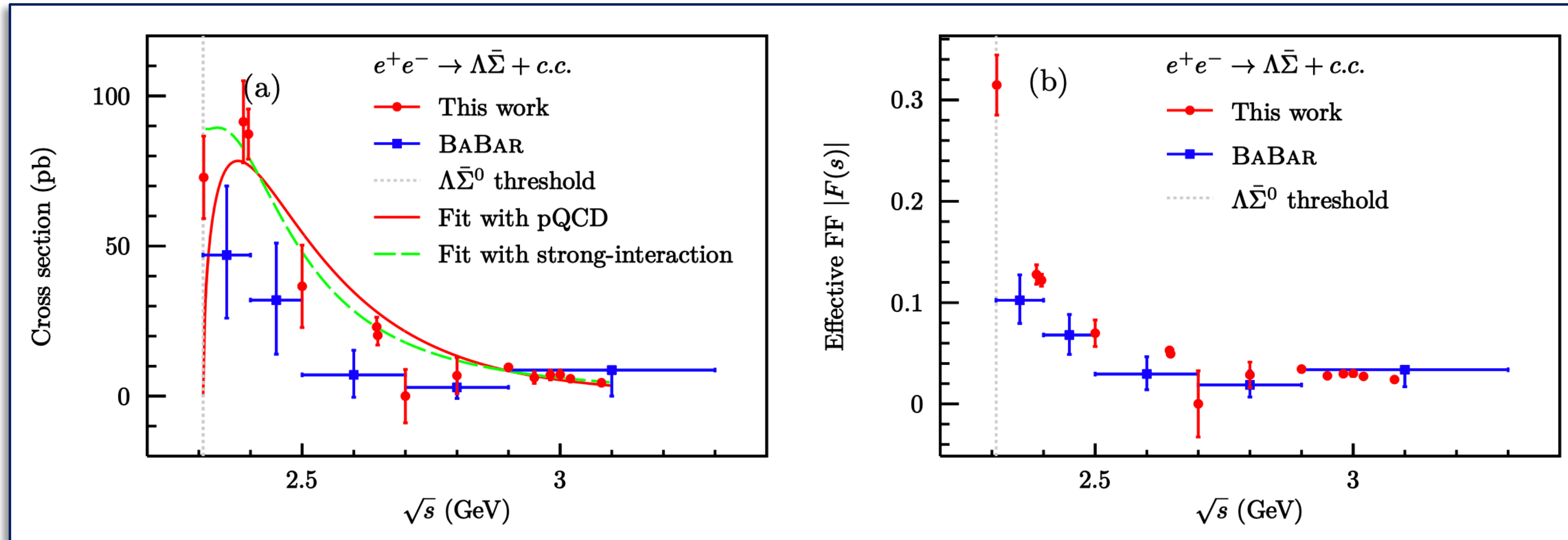


- **No obvious threshold enhancement**
- **Effective form factor agrees with the expectation of quark model**

Measurement of $\sigma^B(e^+e^- \to \Lambda\bar{\Sigma}^0)$ near threshold

Data Sample: ~480/pb (2.3094 to 3.0800 GeV)

arXiv:2308.03361



- **Cross sections agrees with BaBar, but with high precision**
- **A non-zero Born cross section is observed at 2.3094 GeV, new threshold enhancement at 2.3 GeV?**
- **Plateau model provides the better description than pQCD motivated function near threshold**

Outline

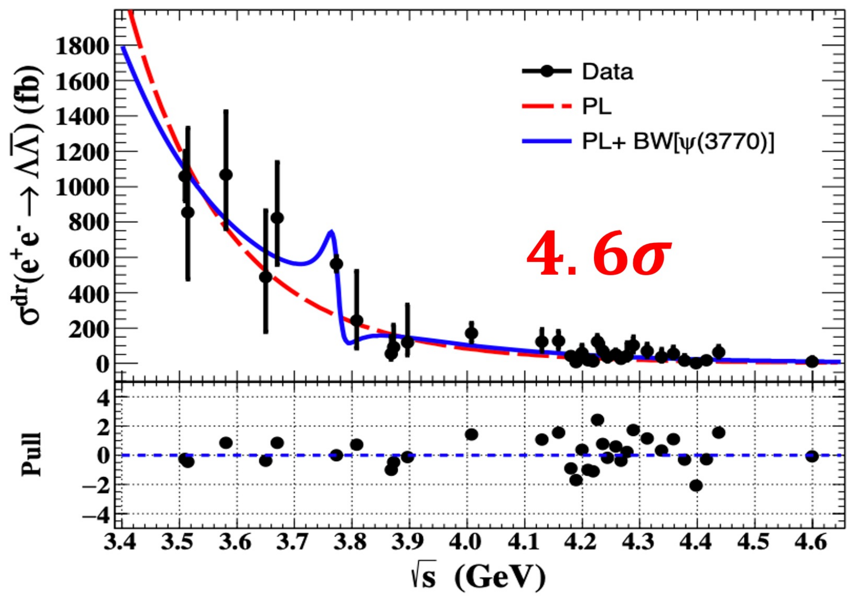
- Introduction
- Recent overview
  - Hyperon polarization and CPV
    - Λ, Σ, Ξ hyperons
  - **Hyperon pair production**
    - Near threshold ($\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$, $\Omega\bar{\Omega}$)
    - **Above open charm threshold ($\Lambda\bar{\Lambda}$, $\Xi\bar{\Xi}$)**
- Summary

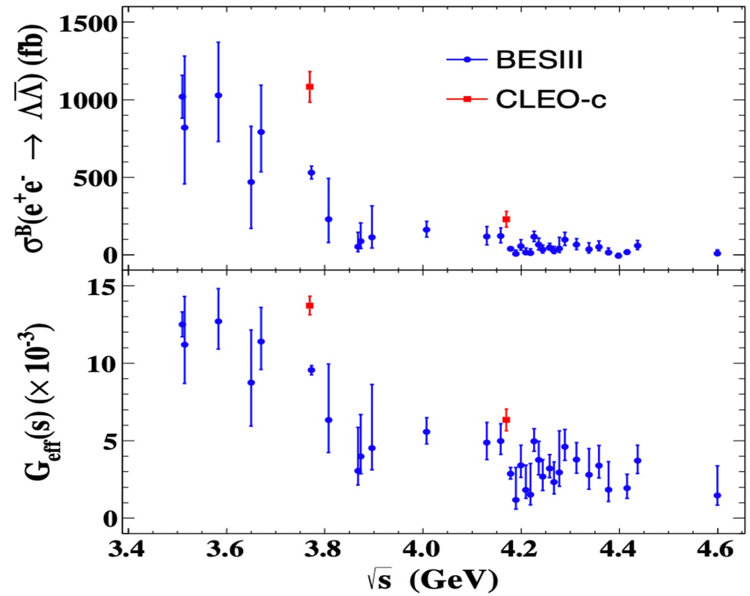
Study of $e^+e^- \to \Lambda\bar{\Lambda}$ above open charm

Data Sample: 20.0 fb^{-1} @ $\sqrt{s}$=3.51-4.6GeV

PRD104, L091104(2021) (Letter)

■ First study of $e^+e^- \to \Lambda\bar{\Lambda}$ above open charm threshold





	Fit I	Fit II	
σ_0 (fb)	379 ± 22	320^{+750}_{-340}	
n	8.8 ± 0.4	8.2 ± 0.6	
ϕ (°)	···	183^{+57}_{-40}	240^{+17}_{-115}
σ_ψ (fb)	0 (fixed)	240^{+1470}_{-190}	1440^{+270}_{-1390}
χ^2/ndof	62.0/31	34.6/29	
$\mathcal{B}$ ($\times 10^{-5}$)	···	$2.4^{+15.0}_{-1.9}$	$14.4^{+2.7}_{-14.0}$

❑ For other charmonium states

$\Gamma_{ee}B_{\psi(4040)} < 5.5\times10^{-3}eV$,

$\Gamma_{ee}B_{\psi(4160)} < 0.7\times10^{-3}eV$,

$\Gamma_{ee}B_{\psi(4260)} < 0.8\times10^{-3}eV$,

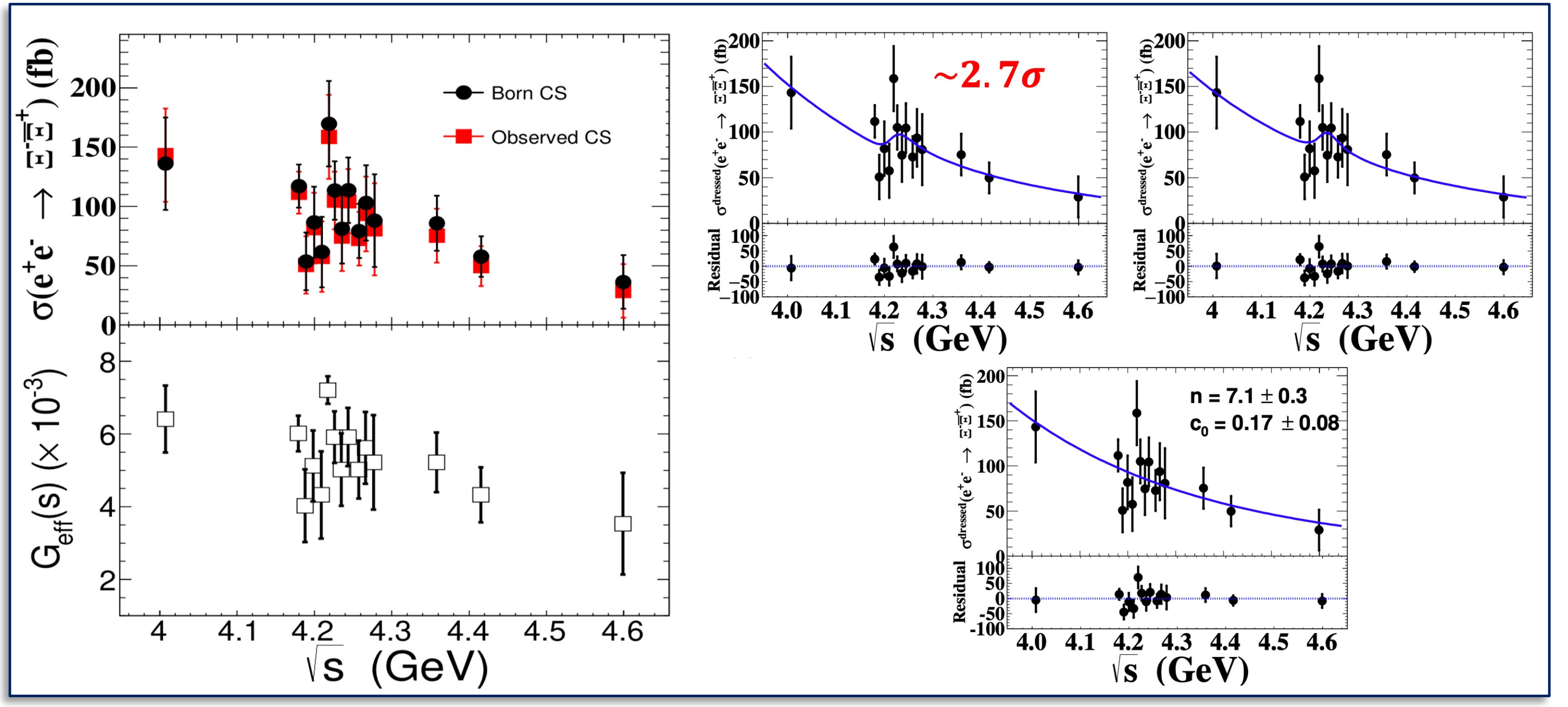
$\Gamma_{ee}B_{\psi(4415)} < 1.8\times10^{-3}eV$.

Study of $e^+e^- \to \Xi^-\bar{\Xi}^+$ above open charm

Data Sample: 11.0 fb^{-1} @ $\sqrt{s}$=4.009-4.6GeV

Phys.Rev.Lett. 124, 032002, (2020)

□ First study of $e^+e^- \to \Xi^-\bar{\Xi}^+$ above open charm threshold

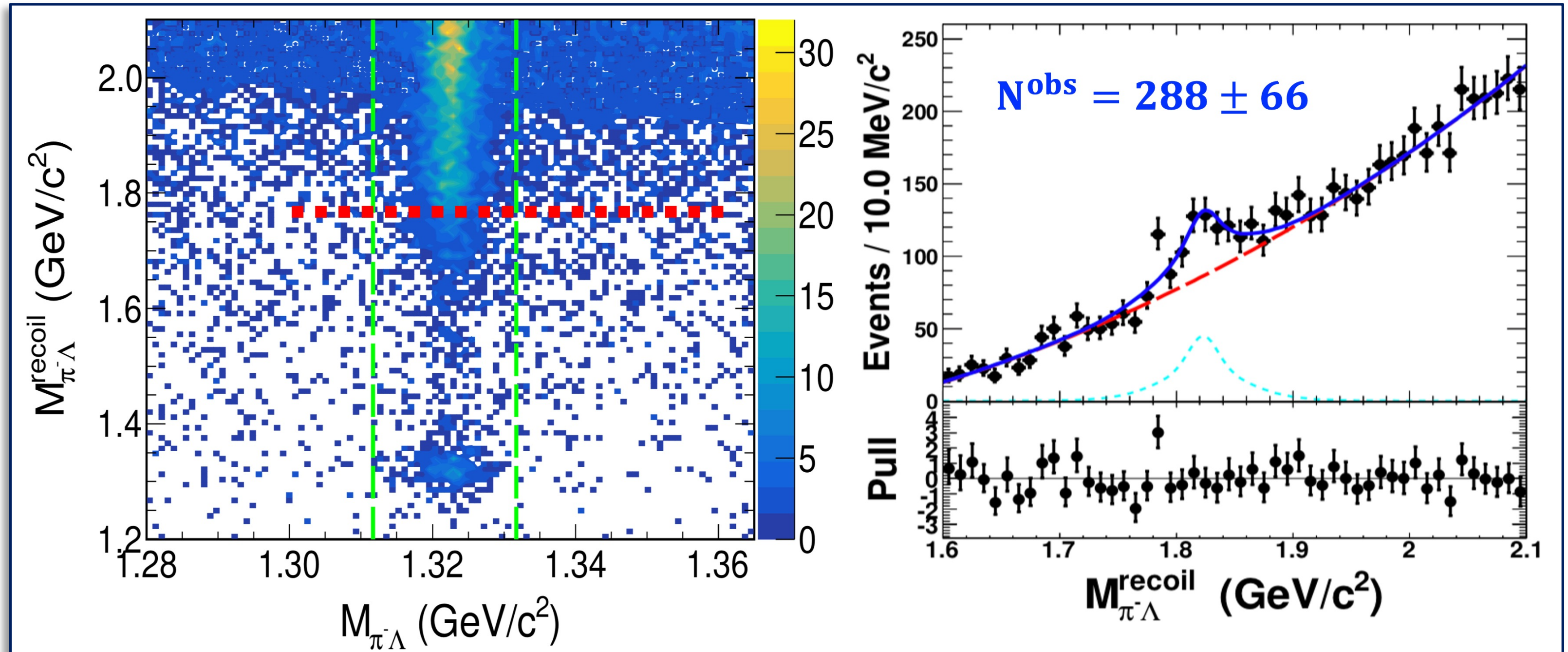


- No obvious significances for ψ(4230/4260)→ $\Xi^-\bar{\Xi}^+$ observed.
- Provide more experimental information to understand the nature of Y (4260)
- Charmless decays of the Y (4260) are expected by the hybrid model (F. E. Close and P. R. Page, PLB628,215(2005))

Study of $e^+e^- \to \Xi^-\bar{\Xi}^+$ above open charm

Phys.Rev.Lett. 124, 032002, (2020)

- Observed an excited Ξ state by combining all energy points



- Observed $e^+e^- \to \Xi^{\mp}X(1820)$ with **6.2σ** significance

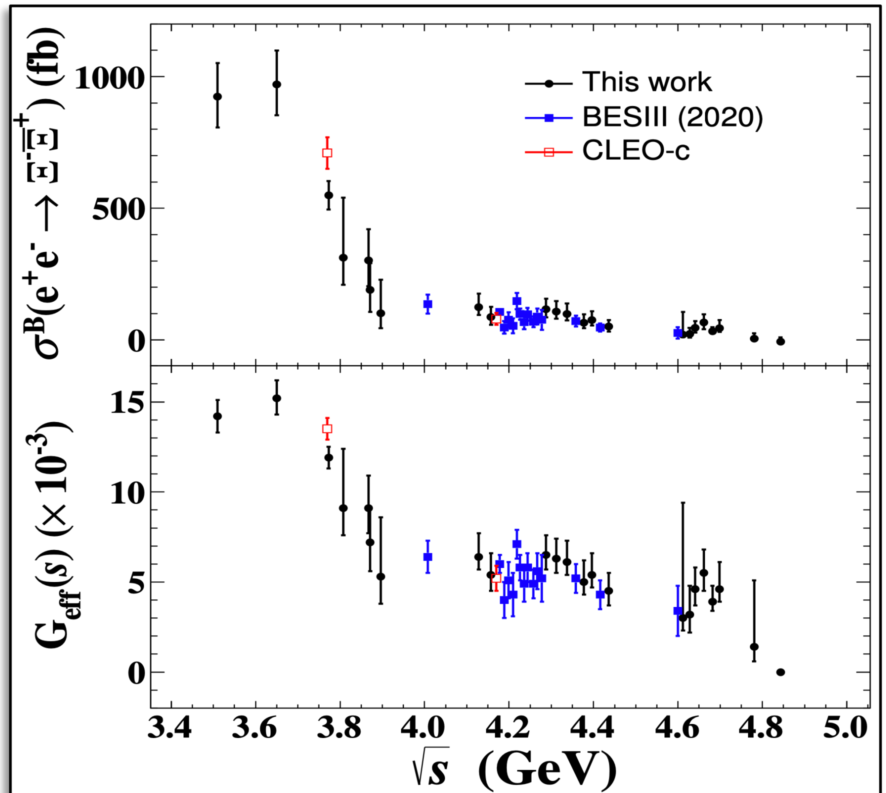
$$M = (1825.5 \pm 4.7 \pm 4.7)\text{GeV}$$
$$\Gamma = (17.0 \pm 15.0 \pm 7.9)\text{MeV}$$

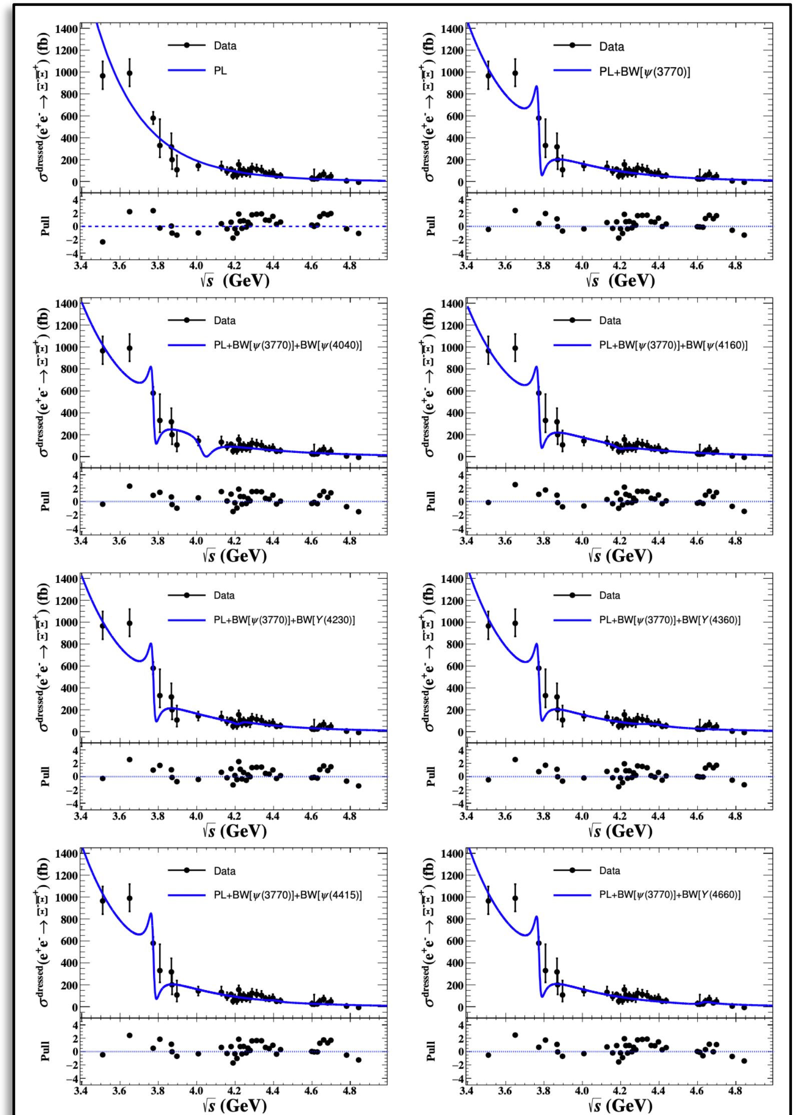
- Consistent with the PDG values of $\Xi(1820)$
- JPC has not determined due to limited statistics

Study of $e^+e^- \to \Xi^-\bar{\Xi}^+$ above open charm

Data Sample: 13.0 fb^{-1} @ $\sqrt{s}$=3.5-4.9GeV

arXiv:2309.04215

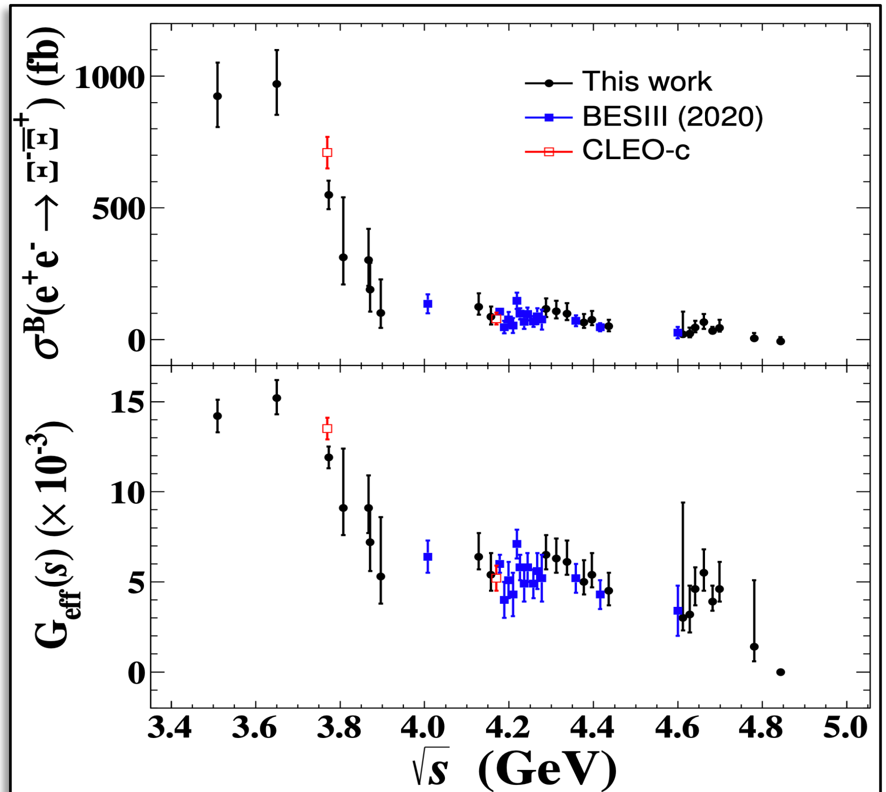


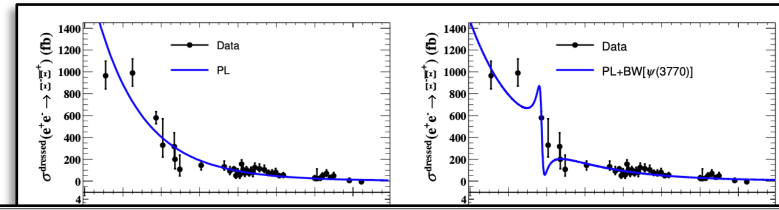


Study of $e^+e^- \to \Xi^-\bar{\Xi}^+$ above open charm

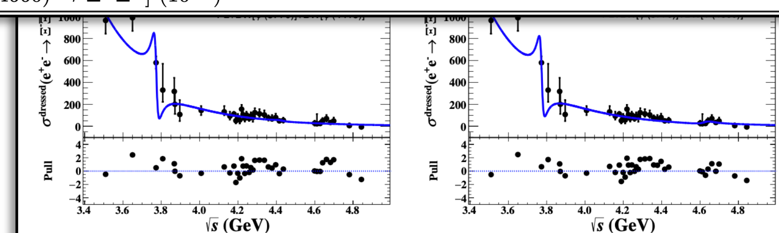
Data Sample: 13.0 fb^{-1} @ $\sqrt{s}$=3.5-4.9GeV

arXiv:2309.04215

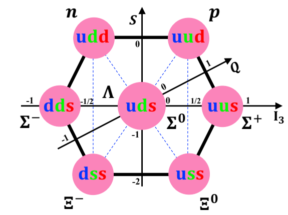


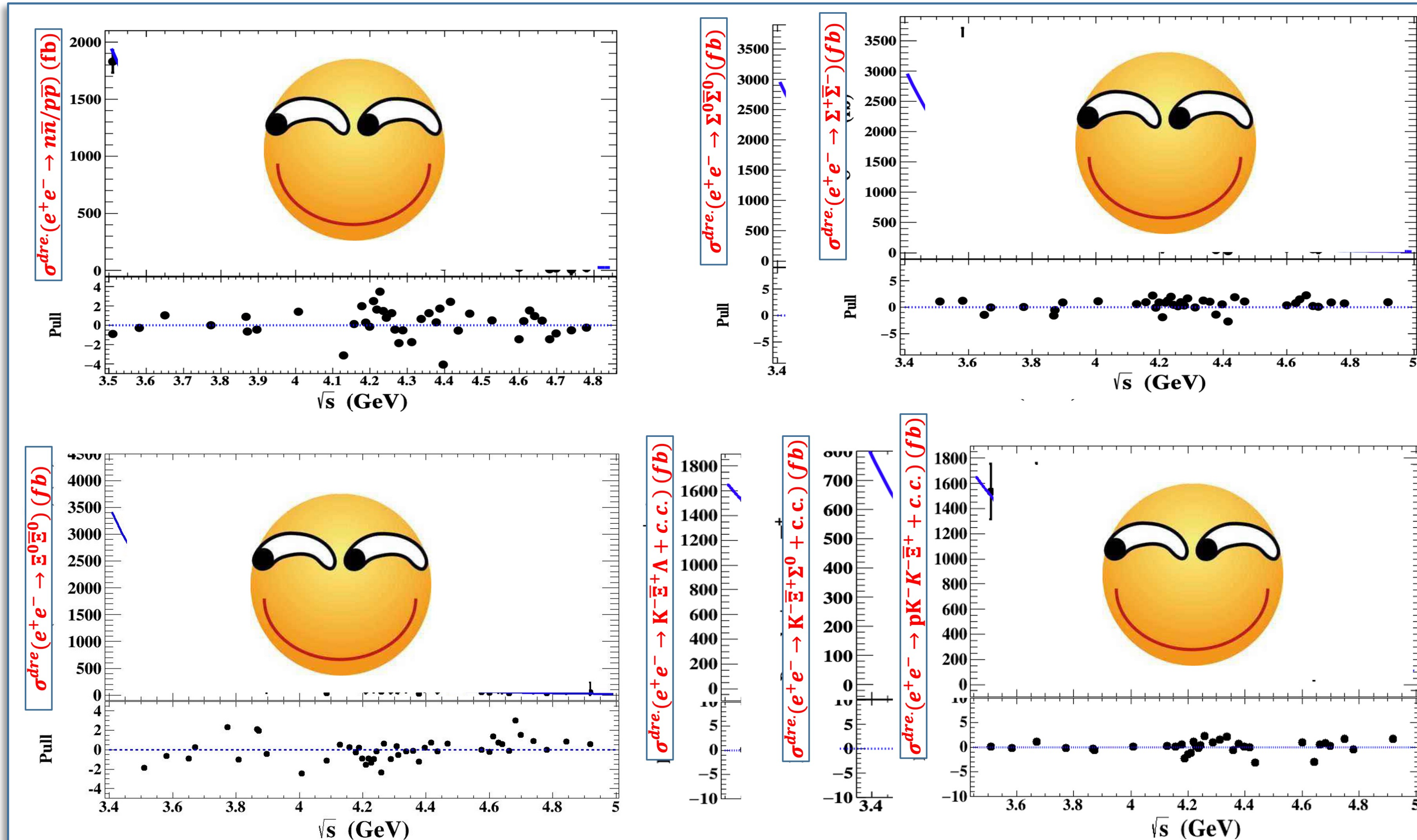


Resonance parameter	Solution I	Solution II	$\chi^2/n.d.f$
$\phi_{\psi(3770)}$ (rad)	-2.1 ± 0.2	$-$	
$\Gamma_{ee}\mathcal{B}_{\psi(3770)}$ (10^{-3} eV)	35.5 ± 9.2	$-$	$45.0/(38-4)$
$\mathcal{B}[\psi(3770) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	136.0 ± 35.2	$-$	
$\phi_{\psi(4040)}$ (rad)	-1.9 ± 0.2	-2.5 ± 0.1	
$\Gamma_{ee}\mathcal{B}_{\psi(4040)}$ (10^{-3} eV)	15.2 ± 27.6 (< 44.0)	19.7 ± 30.9 (< 51.9)	$37.1/(38-6)$
$\mathcal{B}[\psi(4040) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	17.8 ± 32.2 (< 51.4)	23.0 ± 36.1 (< 60.6)	
$\phi_{\psi(4160)}$ (rad)	-1.7 ± 0.1	-2.3 ± 0.1	
$\Gamma_{ee}\mathcal{B}_{\psi(4160)}$ (10^{-3} eV)	29.8 ± 2.5 (< 32.9)	33.9 ± 2.7 (< 37.2)	$38.1/(38-6)$
$\mathcal{B}[\psi(4160) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	61.7 ± 5.2 (< 68.1)	70.2 ± 5.6 (< 77.0)	
$\phi_{Y(4230)}$ (rad)	-1.7 ± 0.1	-2.2 ± 0.1	
$\Gamma_{ee}\mathcal{B}_{Y(4230)}$ (10^{-3} eV)	19.4 ± 1.9 (< 22.3)	22.0 ± 2.1 (< 25.1)	$39.5/(38-6)$
$\mathcal{B}[Y(4230) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	$-$	$-$	
$\phi_{Y(4360)}$ (rad)	-1.8 ± 0.1	-2.1 ± 0.1	
$\Gamma_{ee}\mathcal{B}_{Y(4360)}$ (10^{-3} eV)	36.0 ± 3.2 (< 41.2)	39.4 ± 3.3 (< 44.8)	$41.7/(38-6)$
$\mathcal{B}[Y(4360) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	$-$	$-$	
$\phi_{\psi(4415)}$ (rad)	-1.7 ± 0.1	-2.2 ± 0.1	
$\Gamma_{ee}\mathcal{B}_{\psi(4415)}$ (10^{-3} eV)	16.5 ± 1.9 (< 19.8)	18.3 ± 2.0 (< 21.7)	$44.5/(38-6)$
$\mathcal{B}[\psi(4415) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	28.3 ± 3.3 (< 34.0)	31.4 ± 3.4 (< 37.2)	
$\phi_{Y(4660)}$ (rad)	-1.6 ± 0.1	-2.2 ± 0.1	
$\Gamma_{ee}\mathcal{B}_{Y(4660)}$ (10^{-3} eV)	13.6 ± 2.0 (< 18.0)	15.3 ± 2.2 (< 19.9)	$41.1/(38-6)$
$\mathcal{B}[Y(4660) \to \Xi^-\bar{\Xi}^+]$ (10^{-6})	$-$	$-$	



More are onging …





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 $B\bar{B}$ production in Charmonium decay and in e^+e^- annihilation achieved:**
  - ✓ Observation of hyperon transverse polarization
  - ✓ CPV study in Λ, Σ, Ξ hyperon
  - ✓ More new/precise study for hyperon pair production
  - ✓ Still need more experimental/theoretical efforts
- **More new results are on the way!**

Thanks for your attention!

Backup

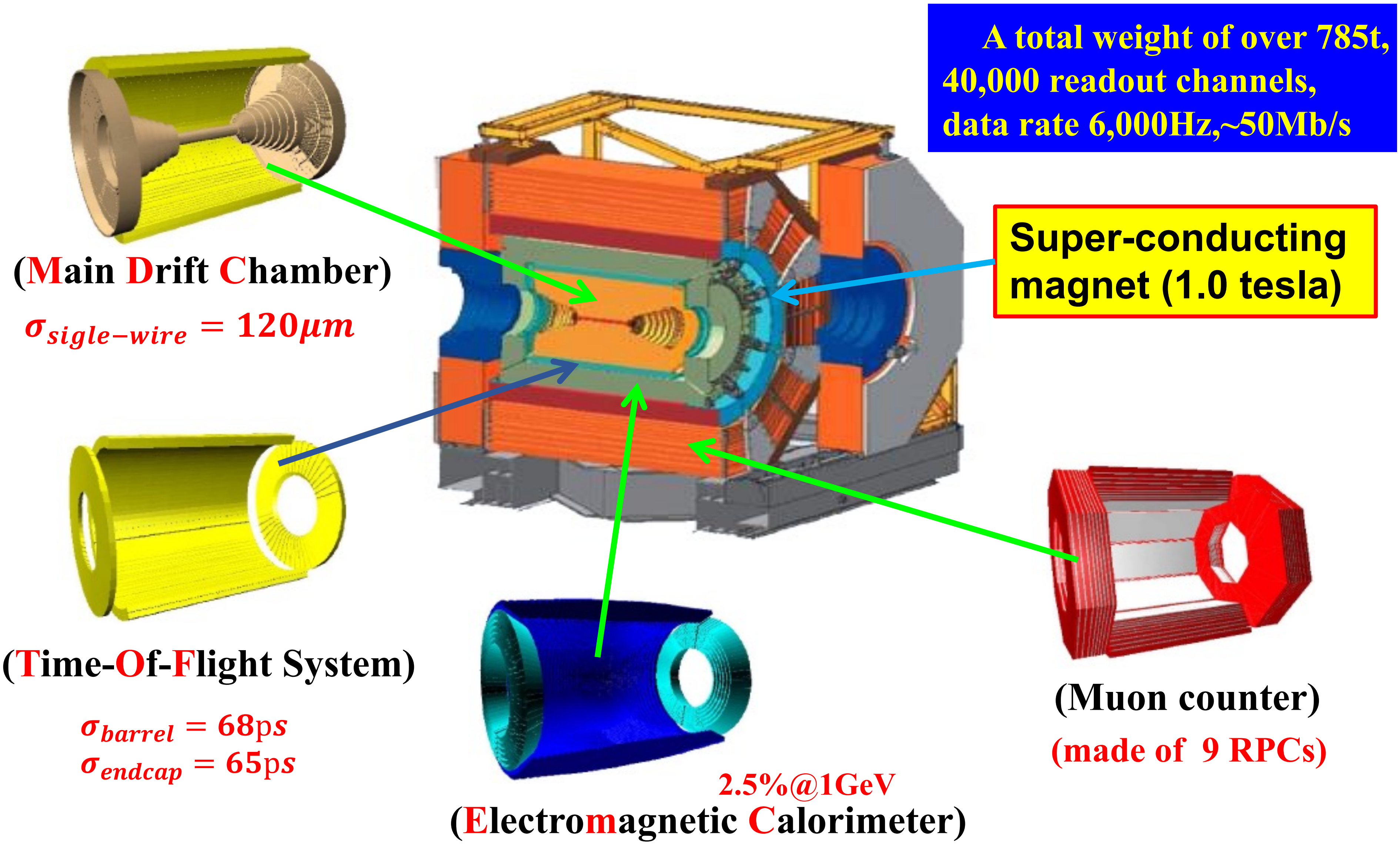
Beijing Electron Positron Collider-II

Physics data taking was started in 2009 !

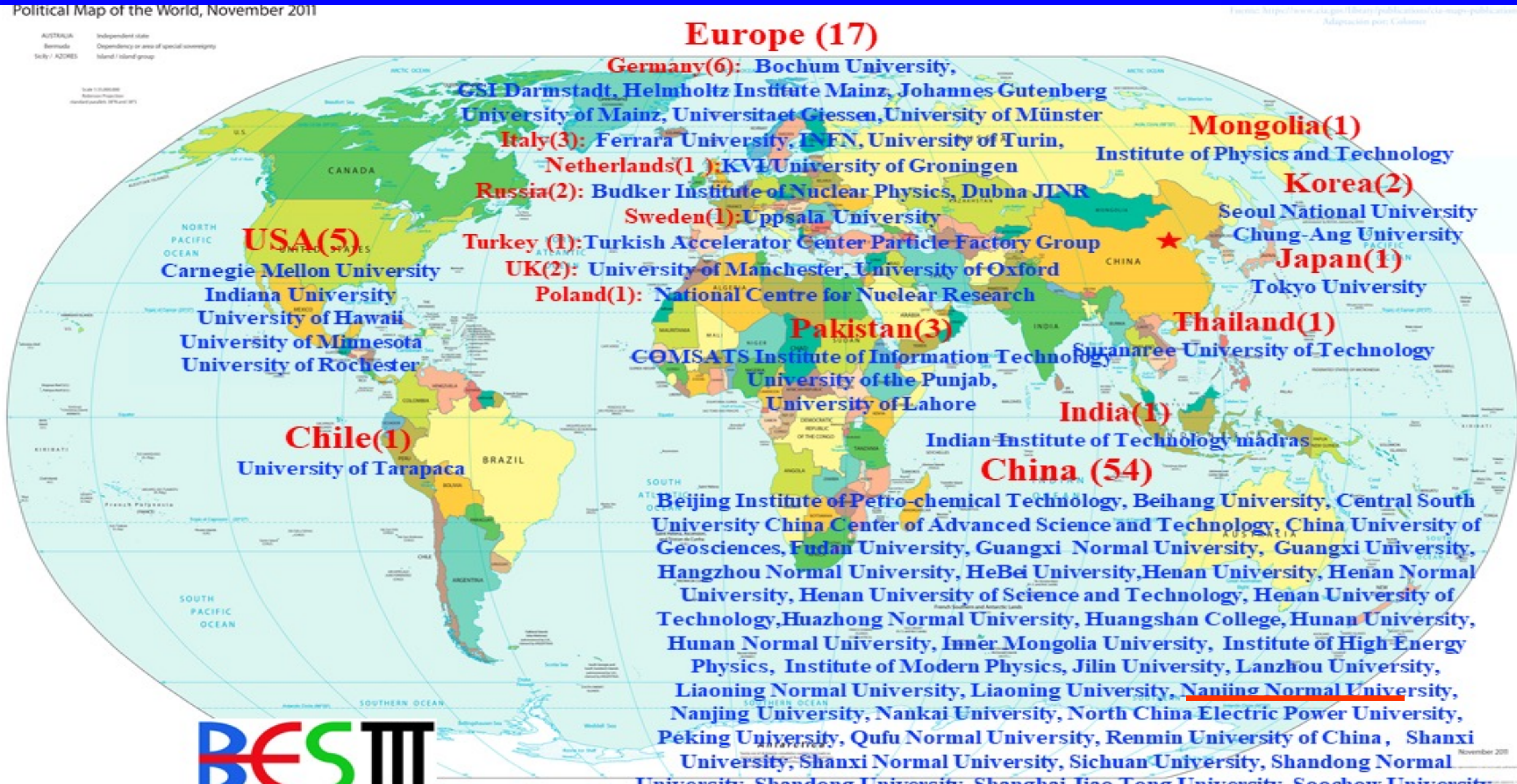
Beam energy:
1-2.5 GeV
Design Lum:
1×10^{33} $cm^{-2}s^{-1}$
Opt. energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
Bunches No.:
93
Bunch length:
1.5 cm
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

Reached peaking luminosity: $1.0\times10^{33}\ cm^{-2}s^{-1}$

Beijing Spectrometer-III detector



BESIII 合作组



Europe (17)

Germany(6): Bochum University, GSI Darmstadt, Helmholtz Institute Mainz, Johannes Gutenberg University of Mainz, Universitaet Giessen, University of Münster
Italy(3): Ferrara University, INFN, University of Turin,
Netherlands(1): KVI/University of Groningen
Russia(2): Budker Institute of Nuclear Physics, Dubna JINR
Sweden(1): Uppsala University
Turkey (1): Turkish Accelerator Center Particle Factory Group
UK(2): University of Manchester, University of Oxford
Poland(1): National Centre for Nuclear Research

Mongolia(1)

Institute of Physics and Technology

Korea(2)

Seoul National University
Chung-Ang University

Japan(1)

Tokyo University

USA(5)

Carnegie Mellon University
Indiana University
University of Hawaii
University of Minnesota
University of Rochester

Pakistan(3)

COMSATS Institute of Information Technology
University of the Punjab,
University of Lahore

Thailand(1)

Suranaree University of Technology

India(1)

Indian Institute of Technology madras

Chile(1)

University of Tarapaca

China (54)

Beijing Institute of Petro-chemical Technology, Beihang University, Central South University China Center of Advanced Science and Technology, China University of Geosciences, Fudan University, Guangxi Normal University, Guangxi University, Hangzhou Normal University, HeBei University, Henan University, Henan Normal University, Henan University of Science and Technology, Henan University of Technology, Huazhong Normal University, Huangshan College, Hunan University, Hunan Normal University, Inner Mongolia University, Institute of High Energy Physics, Institute of Modern Physics, Jilin University, Lanzhou University, Liaoning Normal University, Liaoning University, Nanjing Normal University, Nanjing University, Nankai University, North China Electric Power University, Peking University, Qufu Normal University, Renmin University of China, Shanxi University, Shanxi Normal University, Sichuan University, Shandong Normal University, Shandong University, Shanghai Jiao Tong University, Soochow University, South China Normal University, Southeast University, Sun Yat-sen University, Tsinghua University, University of Chinese Academy of Sciences, University of Jinan, University of Science and Technology of China, University of Science and Technology Liaoning, University of South China, Wuhan University, Xinyang Normal University, YanTai University, YunNan University, Zhejiang University, Zhengzhou University

BESIII

~500 members
From 86 institutions in 17 countries

BESIII: 13 years data taking

- Data sets by far
  - 10×10^9 J/ψ events
  - 3×10^9 ψ(2S) events
  - Scan data [2.0,4.6]GeV, 130 energy points, about 2.0 fb^{-1}
  - Large data sets for XYZ study above 4.0GeV about 22 fb^{-1}
  - Unique data sets at open charm threshold
    - 3.773GeV, 2.93 fb^{-1} $D\bar{D}$ [20 fb^{-1} 2023]
    - 4.008GeV, 0.48 fb^{-1} $D_s\bar{D}_s$
    - 4.18-4.23GeV, 6.32 fb^{-1} $D_s\bar{D}_s^*$
    - 4.6-4.7GeV, 4.4 fb^{-1} $\Lambda_c^+\bar{\Lambda}_c^-$