# Hyperon physics at BESIII

Lake Louise Winter Institute 2024

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# Outline

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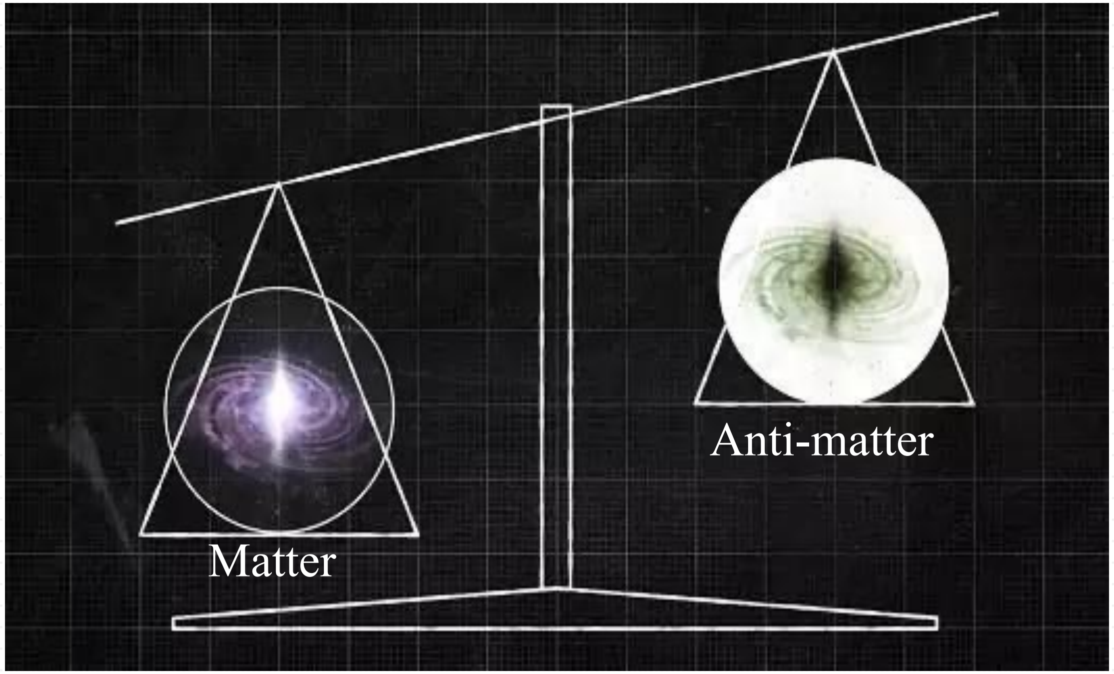
# *CPV* in hyperon decays

PART.01

LLWI2024

# Mystery of matter-antimatter asymmetry




- According to the Big Bang theory:
  - Matter and anti-matter have the same amount
- The observed universe is matter dominant:
  $(n_B - n_{\bar{B}})/n_\gamma \sim 10^{-10}$
  New Journal of Physics 14 (2012) 095012
- The standard model predicted value:
  $(n_B - n_{\bar{B}})/n_\gamma \sim 10^{-20}$
  Gavela, Hernandez, Orloff, Pene, CERN 93/7081
- Why has the anti-matter disappeared?
- Sakharov's three conditions :
  1. Baryon number violation
  2. $C$ and $CP$ violation
  3. Thermal non-equilibrium

Pisma Zh. Eksp. Teor. Fiz., 1967, 5: 32-35

# CP violation (CPV)

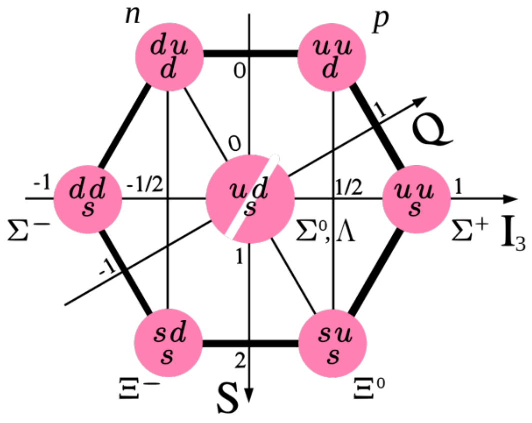
$$V_{CKM} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta_{13}} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta_{13}} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta_{13}} & s_{23}c_{13} \\ s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta_{13}} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta_{13}} & c_{23}c \end{pmatrix}$$

$$\delta_{13} \rightarrow V_{CKM}^{*} \neq V_{CKM} \rightarrow CPV!$$

$CPV$ has been observed at $K$, $B$, $D$ meson systems, but not enough to explain the matter-dominant Universe.


[1] Phys. Rev. 104 (1956) 254-258
[2] Phys. Rev. 105 (1957) 1413-1414
[3] Phys. Rev. Lett., 1964, 13: 138-140
[4] Phys. Rev. Lett., 2001, 87: 091801
[5] Phys. Rev. Lett., 2001, 87: 091802
[6] Phys. Rev. Lett., **122**, 211803 (2019)


A new possibility: search for $CPV$ in entangled hyperon-antihyperon pairs.




$+\ \Omega^{-}(sss)$ spin-$\frac{3}{2}$

# *CPV* in hyperon non-leptonic weak decays


**General Partial Wave Analysis of the Decay of a Hyperon of Spin $\frac{1}{2}$**

T. D. Lee* and C. N. Yang

*Institute for Advanced Study, Princeton, New Jersey*

(Received October 22, 1957)

Phys. Rev. 108, 1645 (1957)

The amplitude of spin-1/2 hyperon $B_i$ decays to a spin-1/2 baryon $B_f$ and a pion can be described by three decay asymmetry parameters:

$$\alpha_Y = \frac{2\,\mathrm{Re}\,(S^* P)}{|S|^2 + |P|^2}, \quad \beta_Y = \frac{2\,\mathrm{Im}\,(S^* P)}{|S|^2 + |P|^2}, \quad \gamma_Y = \frac{|S|^2 - |P|^2}{|S|^2 + |P|^2}$$

$$\alpha_Y^2 + \beta_Y^2 + \gamma_Y^2 = 1$$

$$\beta_Y = (1 - \alpha_Y^2)^{\frac{1}{2}} sin\phi_Y, \quad \gamma_Y = (1 - \alpha_Y^2)^{\frac{1}{2}} cos\phi_Y$$

*CP* conservation： $\alpha_Y = -\bar{\alpha}_Y, \quad \phi_Y = -\bar{\phi}_Y$

*CPV* can be searched by comparing the decay parameters between the hyperon and anti-hyperon

# Recent results from BESIII

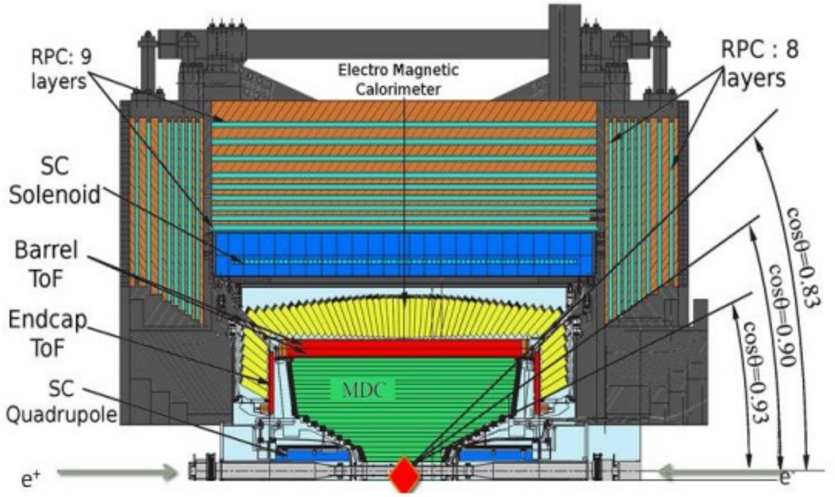
PART.02

LLWI2024

# Study hyperons at BESIII

**Electromagnetic Calorimeter**
CsI(Tl): L=28 cm
Barrel $\sigma_E$=2.5%
Endcap $\sigma_E$=5.0%

**Muon Counter**
RPC
Barrel: 9 layers
Endcap: 8 layers
$\sigma_{spatial}$=1.48 cm




**Main Drift Chamber**
Small cell, 43 layer
$\sigma_{xy}$=130 $\mu$m
dE/dx~6%
$\sigma_p/p$= 0.5% at 1 GeV

**Time Of Flight**
Plastic scintillator
$\sigma_T$(barrel)=80 ps
$\sigma_T$(endcap)=110 ps
(update to 65 ps with MRPC)

With 10 billion $J/\psi$ and 2.7 billion $\psi(3686)$ collected at BESIII. About $10^7$ entangled hyperon pairs can be produced, which enables precise studies of the hyperon physics.

Front. Phys. 12(5), 121301 (2017)

| Decay mode | $B(\times 10^{-3})$ | $N_B(\times 10^6)$ |
|---|---|---|
| $J/\psi \to \Lambda\bar{\Lambda}$ | $1.89 \pm 0.09$ | ~18.9 |
| $J/\psi \to \Sigma^0\bar{\Sigma}^0$ | $1.172 \pm 0.032$ | ~11.7 |
| $J/\psi \to \Sigma^+\bar{\Sigma}^-$ | $1.07 \pm 0.04$ | ~10.7 |
| $J/\psi \to \Xi^0\bar{\Xi}^0$ | $1.17 \pm 0.04$ | ~11.7 |
| $J/\psi \to \Xi^-\bar{\Xi}^+$ | $0.97 \pm 0.08$ | ~9.7 |
| $\psi(2S) \to \Omega^-\bar{\Omega}^+$ | $0.057 \pm 0.003$ | ~0.17 |

# $e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}, \Lambda(\bar{\Lambda}) \to p\pi$

Differential cross-section of $e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}$ :

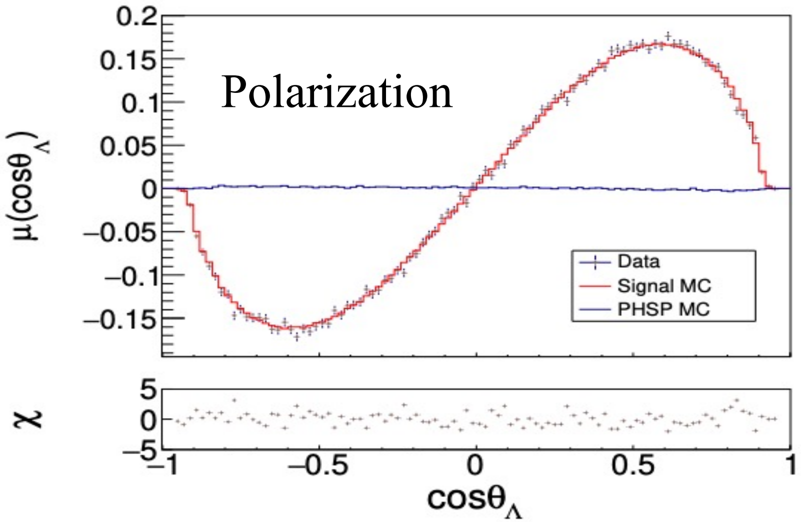
Nuovo Cim. A 109, 241 (1996)
Phys. Rev.185 D 75, 074026 (2007)
Nucl. Phys. A190 771, 169 (2006)
Phys. Lett. B 772, 16(2017)

$$d\sigma \sim 1 + \alpha_\psi \cos^2\theta_\Lambda + (\alpha_\psi + \cos^2\theta_\Lambda) s^z_\Lambda s^z_{\bar{\Lambda}} + \sin^2\theta_\Lambda s^x_\Lambda s^x_{\bar{\Lambda}} - \alpha_\psi \sin^2\theta_\Lambda s^y_\Lambda s^y_{\bar{\Lambda}} + \sqrt{1-\alpha_\psi^2}\cos\Delta\Phi \sin\theta_\Lambda \cos\theta_\Lambda (s^x_\Lambda s^z_{\bar{\Lambda}} + s^z_\Lambda s^x_{\bar{\Lambda}}) + \sqrt{1-\alpha_\psi^2}\sin\Delta\Phi \sin\theta_\Lambda \cos\theta_\Lambda (s^y_\Lambda + s^y_{\bar{\Lambda}})$$

SPIN CORRELATIONS

POLARIZATIONS

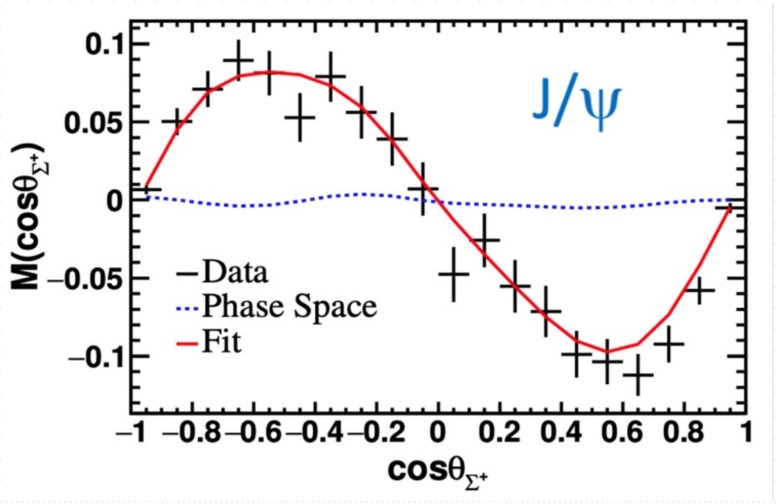
| Par. | 10B $J/\psi$ Phys. Rev. Lett. 129, 131801 (2022) | 1.3B $J/\psi$ Nature Phys.15(2019)631 |
|---|---|---|
| $\alpha_{J/\psi}$ | $0.4748 \pm 0.0022 \pm 0.0031$ | $0.461 \pm 0.006 \pm 0.007$ |
| $\Delta\Phi$ | $0.7521 \pm 0.0042 \pm 0.0066$ | $0.740 \pm 0.010 \pm 0.009$ |
| $\alpha_-$ | $0.7519 \pm 0.0036 \pm 0.0024$ | $0.750 \pm 0.009 \pm 0.004$ |
| $\alpha_+$ | $-0.7559 \pm 0.0036 \pm 0.0030$ | $-0.758 \pm 0.010 \pm 0.007$ |
| $A_{CP}$ | $-0.0025 \pm 0.0046 \pm 0.0012$ | $0.006 \pm 0.012 \pm 0.007$ |
| $\alpha_{avg}$ | $0.7542 \pm 0.0010 \pm 0.0024$ | - |

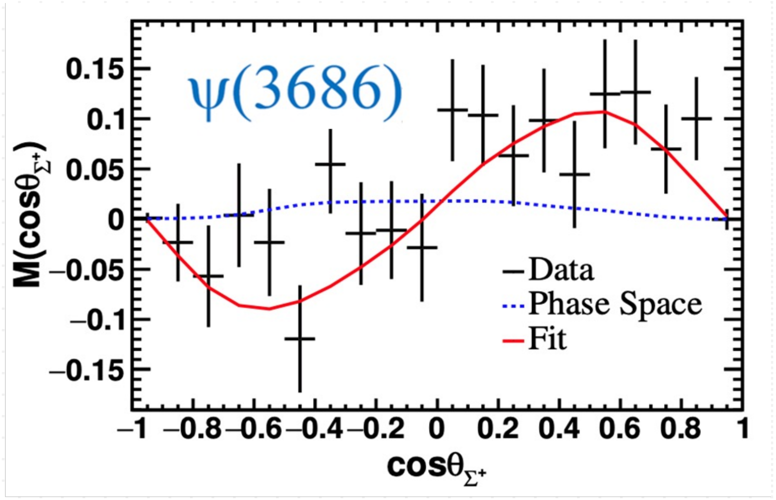



Most precise $CP$ asymmetry, $A_{CP} = \frac{\alpha_- + \bar{\alpha}_+}{\alpha_- - \bar{\alpha}_+}$ , in hyperon sector.

$\alpha_-: \Lambda \to p\pi^-$
$\alpha_+: \bar{\Lambda} \to \bar{p}\pi^+$

# $\Sigma^+$ Polarization and $CP$ tests in $\Sigma^+$ decays




## Polarizations of $\Sigma^+$

Opposite directions of the $\Sigma^+$ polarization in $J/\psi$ and $\psi(3686)$!

Phys. Rev. Lett. 125, 052004 (2020) — 1.3B $J/\psi$ and 0.45B $\psi(3686)$

Phys. Rev. Lett. 131, 191802 (2023) — 10B $J/\psi$

| Parameter | $\Sigma^+ \to p\pi^0, \bar{\Sigma}^- \to \bar{p}\pi^0$ | $\Sigma^+ \to p\pi^0, \bar{\Sigma}^- \to \bar{n}\pi^- + c.c.$ |
|---|---|---|
| $\alpha_{J/\psi}$ | $-0.508 \pm 0.006 \pm 0.004$ | $-0.5156 \pm 0.0030 \pm 0.0061$ |
| $\Delta\Phi_{J/\psi}$ | $-0.270 \pm 0.012 \pm 0.009$ | $-0.2772 \pm 0.0044 \pm 0.0041$ |
| $\alpha_{\psi(3686)}$ | $0.682 \pm 0.03 \pm 0.011$ | - |
| $\Delta\Phi_{\psi(3686)}$ | $0.379 \pm 0.07 \pm 0.014$ | - |
| $\alpha_0(\Sigma^+ \to p\pi^0)$ | $-0.998 \pm 0.037 \pm 0.009$ | - |
| $\bar{\alpha}_0(\bar{\Sigma}^- \to \bar{p}\pi^0)$ | $0.990 \pm 0.037 \pm 0.011$ | - |
| $\alpha_+(\Sigma^+ \to n\pi^+)$ | - | $0.0481 \pm 0.0031 \pm 0.0019$ |
| $\bar{\alpha}_-(\bar{\Sigma}^- \to \bar{n}\pi^-)$ | - | $-0.0565 \pm 0.0047 \pm 0.0022$ |

Two $CP$ tests are performed in the decays of $\Sigma^+$:

$$A_{CP}(\Sigma^+ \to p\pi^0) = \frac{\alpha_0 + \bar{\alpha}_0}{\alpha_0 - \bar{\alpha}_0} = -0.004 \pm 0.037 \pm 0.010$$

$$A_{CP}(\Sigma^+ \to n\pi^+) = \frac{\alpha_+ + \bar{\alpha}_-}{\alpha_+ - \bar{\alpha}_-} = -0.080 \pm 0.052 \pm 0.028$$

# $CP$ tests in $\Xi$ decays

Joint angular distribution of $e^+e^- \to J/\psi \to \Xi\bar{\Xi}, \Xi \to \Lambda(\to p\pi^-)\pi, \bar{\Xi} \to \bar{\Lambda}(\to \bar{p}\pi^+)\pi$ :

$$W = \sum_{\mu,\bar{\nu}=0}^{3} C_{\mu\bar{\nu}} \sum_{\mu',\bar{\nu}'=0}^{3} a^{\Xi}_{\mu,\mu'} a^{\bar{\Xi}}_{\bar{\nu},\bar{\nu}'} a^{\Lambda}_{\mu',0} a^{\bar{\Lambda}}_{\bar{\nu}',0}$$

Phys. Rev. D 99, 056008 (2019)

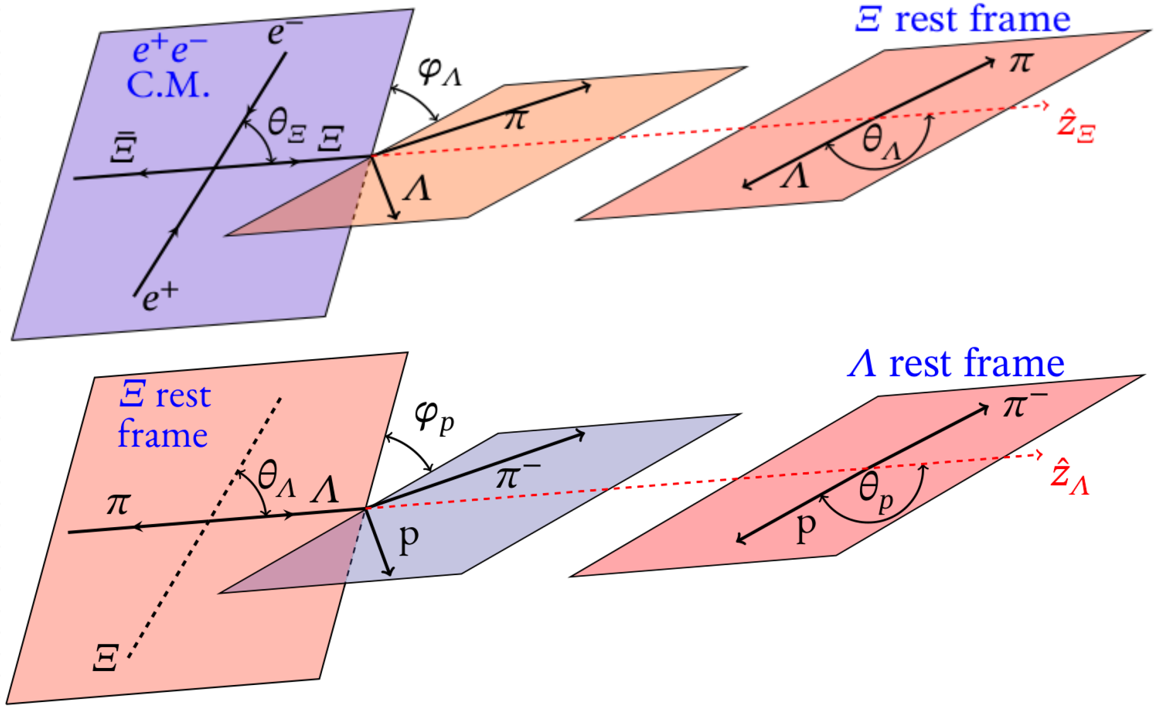
$d\Gamma \propto W(\xi,\omega)$, $\xi$: 9 kin. variables

**8 parameters:**

Production

$$\omega = (\alpha_\Psi, \Delta\Phi, \alpha_\Xi, \phi_\Xi, \alpha_\Lambda, \bar{\alpha}_\Xi, \bar{\phi}_\Xi, \bar{\alpha}_\Lambda)$$

Decay




$$A_{CP} = \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}} \approx -\tan(\delta_P - \delta_S)\tan(\xi_P - \xi_S)$$

$$\Delta\phi_{CP} = \frac{\phi + \bar{\phi}}{2} \approx \frac{\alpha}{\sqrt{1-\alpha^2}}\cos\phi\tan(\xi_P - \xi_S)$$

If the strong phase difference $(\delta_P - \delta_S)$ is close to 0, $A_{CP}$ will be suppressed, however, $\Delta\phi_{CP}$ won't suffer from this problem.

$\Delta\phi_{CP}$ can be directly determined through the sequential decays of the hyperon. This is a big advantage of $\Xi^{0(-)}$ hyperon compared to $\Lambda$ or $\Sigma^{\pm}$ hyperon

# $CP$ tests in $\Xi$ decays

Phys. Rev. Lett. 93 (2004) 011802

The precision of our analysis (73K events) is comparable with the measurement from HyperCP (144M events), which means that the accuracy of a single event is more than 1000 times higher than HyperCP!

## $\Xi^-$(1.3B $J/\psi$)

| Parameter | Nature **606** (2022) 64-69 | Previous result |
|---|---|---|
| $\alpha_\psi$ | 0.586±0.012±0.010 | 0.58±0.04±0.08 |
| $\Delta\Phi$ | 1.213±0.046±0.016 rad | – |
| $\alpha_\Xi$ | −0.376±0.007±0.003 | −0.401±0.010 |
| $\phi_\Xi$ | 0.011±0.019±0.009 rad | −0.042 ± 0.011 ± 0.011 |
| $\bar{\alpha}_\Xi$ | 0.371±0.007±0.002 | – |
| $\bar{\phi}_\Xi$ | −0.021±0.019±0.007 rad | – |
| $\alpha_\Lambda$ | 0.757±0.011±0.008 | 0.750±0.009±0.004 |
| $\bar{\alpha}_\Lambda$ | −0.763±0.011±0.007 | −0.758±0.010±0.007 |
| $\xi_P-\xi_S$ | $(1.2\pm3.4\pm0.8)\times10^{-2}$ rad | – |
| $\delta_P-\delta_S$ | $(-4.0\pm3.3\pm1.7)\times10^{-2}$ rad | $(10.2\pm3.9)\times10^{-2}$ rad |
| $A_{CP}^{\Xi}$ | $(6\pm13\pm6)\times10^{-3}$ | – |
| $\Delta\phi_{CP}^{\Xi}$ | $(-5\pm14\pm3)\times10^{-3}$ rad | – |
| $A_{CP}^{\Lambda}$ | $(-4\pm12\pm9)\times10^{-3}$ | $(-6\pm12\pm7)\times10^{-3}$ |
| $\langle\phi_\Xi\rangle$ | 0.016±0.014±0.007 rad | |

First measurements of the weak phase difference in $\Xi^-/\Xi^0$ decays

Three CP tests in $\Xi^-/\Xi^0$ decays

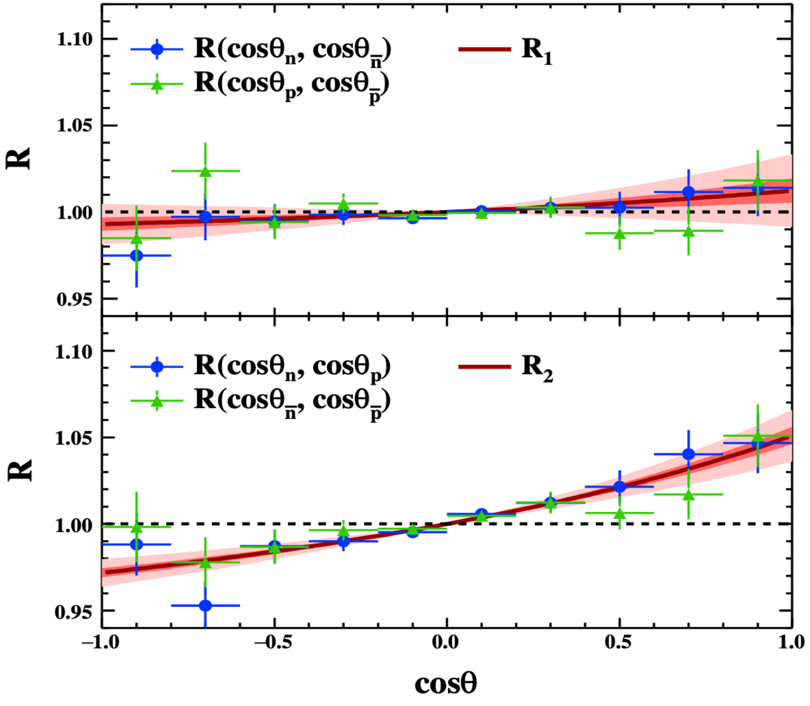
## $\Xi^0$ (10B $J/\psi$)

| Parameter | Phys.Rev.D 108 (2023) 3, L031106 | Previous result |
|---|---|---|
| $\alpha_{J/\psi}$ | $0.514\pm0.006\pm0.015$ | $0.66\pm0.06$ [34] |
| $\Delta\Phi$(rad) | $1.168\pm0.019\pm0.018$ | - |
| $\alpha_\Xi$ | $-0.3750\pm0.0034\pm0.0016$ | $-0.358\pm0.044$ [18] |
| $\bar{\alpha}_\Xi$ | $0.3790\pm0.0034\pm0.0021$ | $0.363\pm0.043$ [18] |
| $\phi_\Xi$(rad) | $0.0051\pm0.0096\pm0.0018$ | $0.03\pm0.12$ [18] |
| $\bar{\phi}_\Xi$(rad) | $-0.0053\pm0.0097\pm0.0019$ | $-0.19\pm0.13$ [18] |
| $\alpha_\Lambda$ | $0.7551\pm0.0052\pm0.0023$ | $0.7519\pm0.0043$ [13] |
| $\bar{\alpha}_\Lambda$ | $-0.7448\pm0.0052\pm0.0017$ | $-0.7559\pm0.0047$ [13] |
| $\xi_P-\xi_S$(rad) | $(0.0\pm1.7\pm0.2)\times10^{-2}$ | - |
| $\delta_P-\delta_S$(rad) | $(-1.3\pm1.7\pm0.4)\times10^{-2}$ | - |
| $A_{CP}^{\Xi}$ | $(-5.4\pm6.5\pm3.1)\times10^{-3}$ | $(-0.7\pm8.5)\times10^{-2}$ [18] |
| $\Delta\phi_{CP}^{\Xi}$(rad) | $(-0.1\pm6.9\pm0.9)\times10^{-3}$ | $(-7.9\pm8.3)\times10^{-2}$ [18] |
| $A_{CP}^{\Lambda}$ | $(6.9\pm5.8\pm1.8)\times10^{-3}$ | $(-2.5\pm4.8)\times10^{-3}$ [13] |
| $\langle\alpha_\Xi\rangle$ | $-0.3770\pm0.0024\pm0.0014$ | - |
| $\langle\phi_\Xi\rangle$(rad) | $0.0052\pm0.0069\pm0.0016$ | - |
| $\langle\alpha_\Lambda\rangle$ | $0.7499\pm0.0029\pm0.0013$ | $0.7542\pm0.0026$ [13] |

# Test the $CP$ symmetry and $\Delta I = 1/2$ rule in $\Xi^-$ decays

$e^+e^- \to J/\psi \to \Xi^-\bar{\Xi}^+, \Xi^- \to \Lambda(\to p\pi^-)\pi^-, \bar{\Xi}^+ \to \bar{\Lambda}(\to \bar{n}\pi^0)\pi^+$

| Parameters | arXiv:2309.14667 (Accepted by PRL) | 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] |
| $\alpha_\Xi$ | $-0.367 \pm 0.004^{+0.003}_{-0.004}$ | $-0.376 \pm 0.007 \pm 0.003$ [17] |
| $\phi_\Xi$ (rad) | $-0.016 \pm 0.012^{+0.004}_{-0.008}$ | $0.011 \pm 0.019 \pm 0.009$ [17] |
| $\bar{\alpha}_\Xi$ | $0.374 \pm 0.004^{+0.003}_{-0.004}$ | $0.371 \pm 0.007 \pm 0.002$ [17] |
| $\bar{\phi}_\Xi$ (rad) | $0.010 \pm 0.012^{+0.003}_{-0.013}$ | $-0.021 \pm 0.019 \pm 0.007$ [17] |
| $\alpha_{\Lambda-}$ | $0.764 \pm 0.008^{+0.005}_{-0.006}$ | $0.7519 \pm 0.0036 \pm 0.0024$ [37] |
| $\alpha_{\Lambda+}$ | $-0.774 \pm 0.009^{+0.005}_{-0.005}$ | $-0.7559 \pm 0.0036 \pm 0.0030$ [37] |
| $\alpha_{\Lambda 0}$ | $0.670 \pm 0.009^{+0.009}_{-0.008}$ | $0.75 \pm 0.05$ [29] |
| $\bar{\alpha}_{\Lambda 0}$ | $-0.668 \pm 0.008^{+0.006}_{-0.008}$ | $-0.692 \pm 0.016 \pm 0.006$ [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] |
| $A^\Xi_{CP}$ | $-0.009 \pm 0.008^{+0.007}_{-0.002}$ | $0.006 \pm 0.013 \pm 0.006$ [17] |
| $\Delta\phi^\Xi_{CP}$ (rad) | $-0.003 \pm 0.008^{+0.003}_{-0.007}$ | $-0.005 \pm 0.014 \pm 0.003$ [17] |
| $A^-_{CP}$ | $-0.007 \pm 0.008^{+0.002}_{-0.003}$ | $-0.0025 \pm 0.0046 \pm 0.0012$ [37] |
| $A^0_{CP}$ | $0.001 \pm 0.009^{+0.005}_{-0.007}$ | - |
| $A^\Lambda_{CP}$ | $-0.004 \pm 0.007^{+0.003}_{-0.004}$ | - |
| $\alpha_{\Lambda 0}/\alpha_{\Lambda-}$ | $0.877 \pm 0.015^{+0.014}_{-0.010}$ | $1.01 \pm 0.07$ [29] |
| $\bar{\alpha}_{\Lambda 0}/\alpha_{\Lambda+}$ | $0.863 \pm 0.014^{+0.012}_{-0.008}$ | $0.913 \pm 0.028 \pm 0.012$ [18] |




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

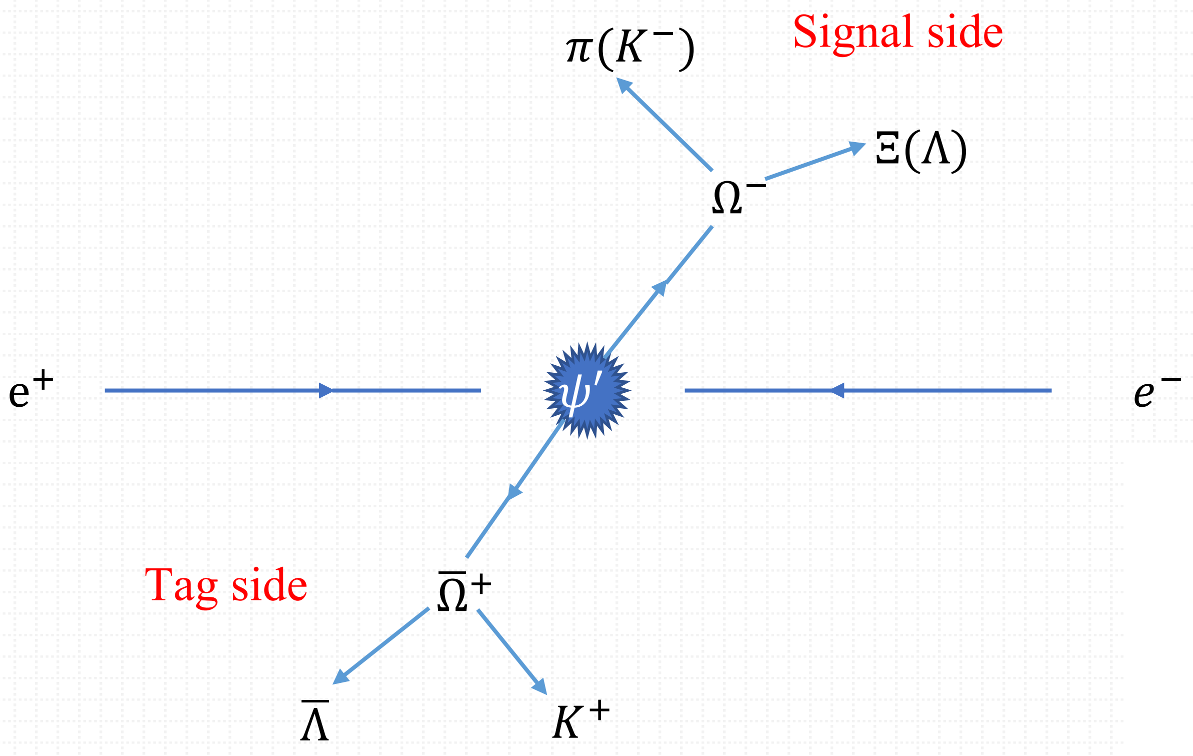
$$R_2 = (1 + \langle\alpha_{\Lambda 0}\rangle\langle\alpha_\Xi\rangle \cos\theta)/(1 + \langle\alpha_{\Lambda -}\rangle\langle\alpha_\Xi\rangle \cos\theta)$$

5 $CP$ tests are performed.

According to $\Delta I$=1/2 rule, the ratio between the decay parameter $\alpha_{\Lambda 0}$ ($\Lambda \to n\pi^0$) and $\alpha_{\Lambda-}$ ($\Lambda \to p\pi^-$) should be 1.

Our result: $< \alpha_{\Lambda 0} >/< \alpha_{\Lambda-} > = 0.870 \pm 0.012^{+0.011}_{-0.010}$ indicate the $\Delta I$=1/2 rule is violated in the decays of $\Lambda$.

# Absolute BF measurement of the $\Omega^-$ and test of the $\Delta I = 1/2$ rule




Partial reconstruction to improve the efficiencies, only a $\pi^-$, a $\pi^0$ and a $K^-$ in the signal side for the decay channels $\Omega^- \to \Xi^0\pi^-, \Omega^- \to \Xi^-\pi^0$, and $\Omega^- \to \Lambda K^-$, respectively.

| BFs | $\mathcal{B}_{\Omega^-\to\Xi^0\pi^-}$ | $\mathcal{B}_{\Omega^-\to\Xi^-\pi^0}$ | $\mathcal{B}_{\Omega^-\to\Lambda K^-}$ |
|---|---|---|---|
| This work | $25.03 \pm 0.44 \pm 0.53$ | $8.43 \pm 0.52 \pm 0.28$ | $66.3 \pm 0.8 \pm 2.0$ |
| PDG | $23.6 \pm 0.7$ | $8.6 \pm 0.4$ | $67.8 \pm 0.7$ |

Phys. Rev. D 108 (2023) 9, L091101

If $\Delta I$=1/2 rule is valid in $\Omega^-$ decay, the BF ratio between two decay channels $\Omega^- \to \Xi^0\pi^-, \Omega^- \to \Xi^-\pi^0$ should be 2. This ratio in PDG is $2.74 \pm 0.15$, inconsistent with the prediction of the $\Delta I$=1/2 rule.

The result was only measured by one experiment, and therefore, received some skepticism!

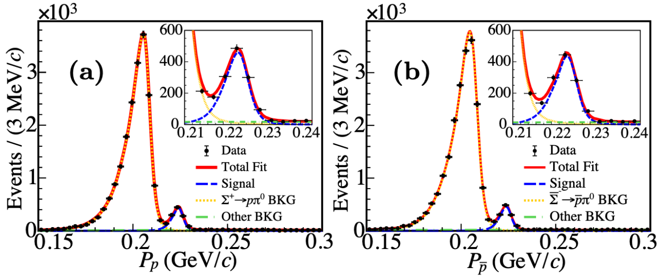
Our result: $R = 2.97 \pm 0.19 \pm 0.11$, consistent with the PDG value, confirms the $\Delta I$=1/2 rule is not suitable for describing the decays of the $\Omega^-$ hyperon.

# More results of hyperon physics at BESIII…

Semileptonic and radiative decays:

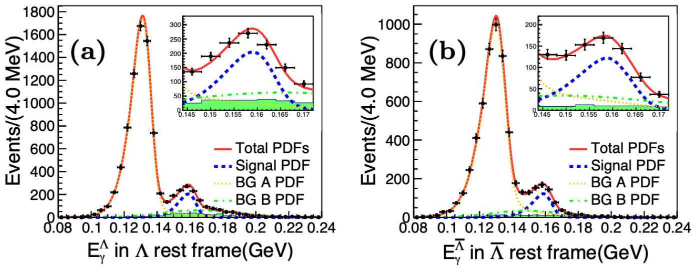
$\Sigma^+ \to p\gamma$

Phys. Rev. Lett. **130**, 211901(2023)



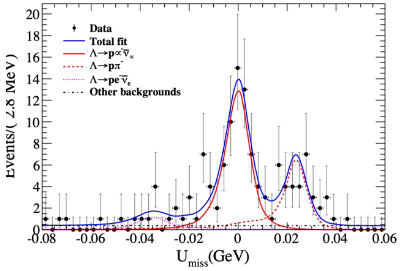

$\Lambda \to n\gamma$

Phys. Rev. Lett. **129**, 212002 (2022)



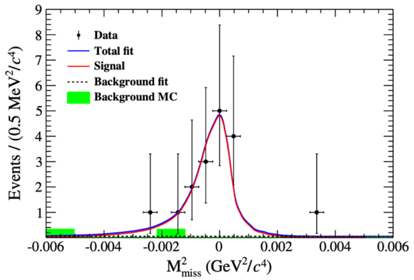

$\Lambda \to p\mu^+\bar{\nu}_\mu$

Phys. Rev. Lett. **127** (2021) 12, 121802




$\Sigma^+ \to \Lambda e^+\bar{\nu}_e$

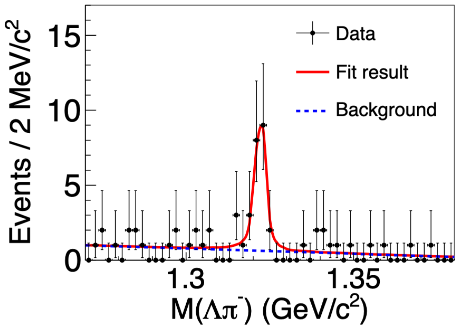
Phys. Rev. D **107**, 072010 (2023)




Hyperon-nucleus interactions:

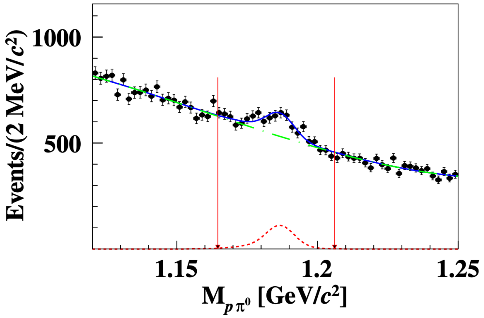
$\Xi^0 n \to \Xi^- p$

Phys. Rev. Lett. **130**, 251902 (2023)



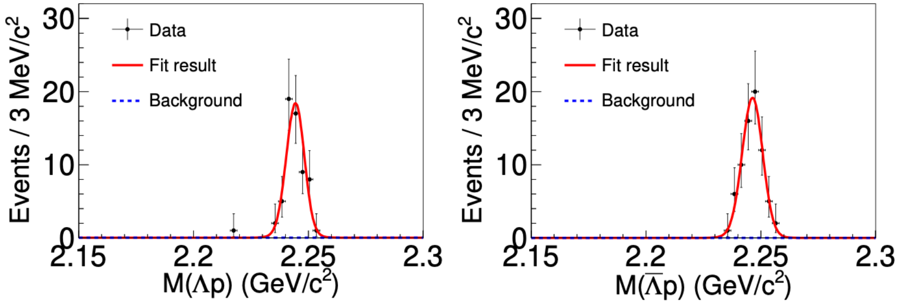

$\Lambda N \to \Sigma^+ X$

arXiv:2310.00720

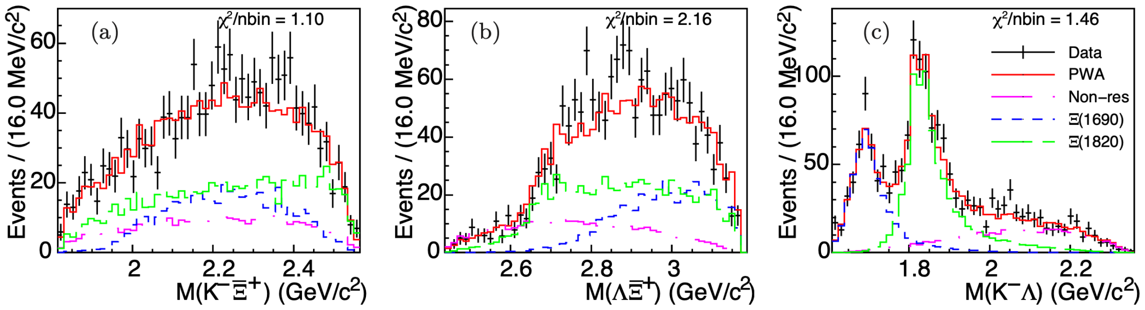



$\bar{\Lambda}p \to \bar{\Lambda}p, \Lambda p \to \Lambda p$

arXiv:2401.09012




Study of excited Ξ:




arXiv:2308.15206

# Summary

PART.03

LLWI2024

# Summary

- ✓ BESIII has made fruitful achievements in the studies of hyperon physics:
  - ✓ Precise CP tests are performed in hyperon decays;
  - ✓ The $\Delta I = 1/2$ rule is found to be unsuitable for describing the decays of the $\Lambda$ and $\Omega^-$ hyperons.
- ✓ More exciting hyperon results will come in the near future.

THANKS!

# Backup

# Hyperon Polarization

$$P_y(\cos\theta_Y) = \frac{\sqrt{1-\alpha_\psi^2}\sin\Delta\Phi_\psi \cos\theta_Y \sin\theta_Y}{1+\alpha_\psi \cos^2\theta_Y}$$

$$\mu(cos\theta_Y) = \frac{\alpha - \bar{\alpha}}{2} \frac{1+\alpha_\psi\, cos^2\,\theta_Y}{3+\alpha_\psi} P_y(cos\theta_Y)$$

$$\mu^k(\cos\theta_\Xi) = \frac{1}{N^k}\sum_i^{N^k}(\sin\theta_\Lambda^i \sin\varphi_\Lambda^i + \sin\theta_{\bar{\Lambda}}^i \sin\varphi_{\bar{\Lambda}}^i)$$