Hyperon Physics at BESIII

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On behalf of the BESIII collaboration

Outline

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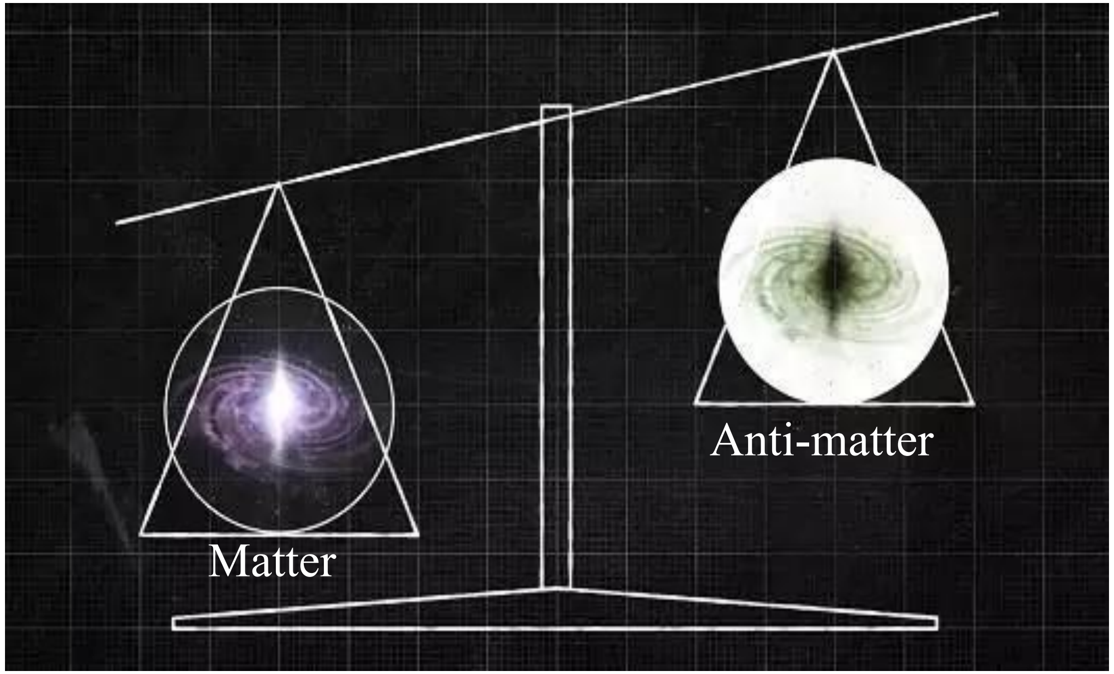
Mystery of matter-antimatter asymmetry



- According to the Big Bang theory:
  - ✓ Matter and anti-matter have the same amount
- The observed universe is matter dominant:

$$(n_B - n_{\bar{B}})/n_\gamma \sim 10^{-10}$$

- The standard model predicted value：

$$(n_B - n_{\bar{B}})/n_\gamma \sim 10^{-18}$$

- Why has the anti-matter disappeared？
- Sakharov's three conditions：
  - ✓ Baryon number violation
  - ✓ C and CP violation
  - ✓ Thermal non-equilibrium

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

Roadmap of CP violation in flavored hadrons

➢ **All of them are consistent with CKM theory in the Standard Model but too small to explain the matter-dominant world.**

21 Mar 2025

Breaking news from LHCb!

5.2σ CPV in Λ_b decay:

$\Lambda_b \to p\pi^+\pi^-K^-$

Nature 643 (2025) 1223

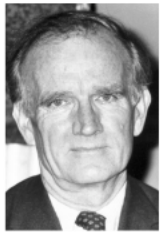
BABAR

BELLE

K meson CPV | B meson CPV | D meson CPV | Baryon

1964 | 2001 | 2019

James Watson Cronin



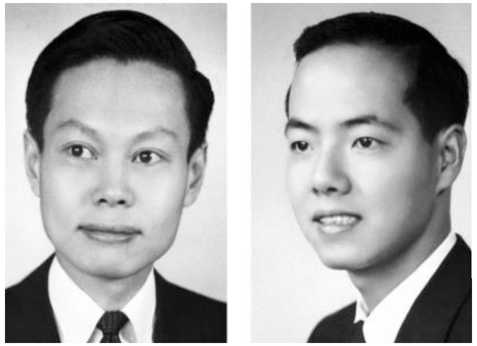
Val Logsdon Fitch

LHCb

[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)

Search for CPV in the baryon system is one of the main goals in today's large collider experiments.

Non-leptonic hyperon 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 decay to a spin-1/2 baryon B_f and a π can be completely described by three decay parameters:

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

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

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

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

Semileptonic decays: Extraction of V_{us}

Prelude: The Cabibbo-angle anomaly

In the SM： First-row unitarity relation

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$

2.3σ tension

A hint of new physics?

PDG 2025： Independent measurements

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9984 \pm 0.0007$$

- $|V_{ub}|$: Small（$|V_{ub}|^2 \cong 1.5\times10^{-5}$）➡ The effect could be ignored in current precision
- $|V_{ud}|$: Most precise; results from different decays are consistent at $\mathcal{O}(10^{-4})$ ➡ Precise and reliable
- $|V_{us}|$: $\sigma(|V_{us}|) = 2.6\times\sigma(|V_{ud}|)$; inconsistence between results from different decays

PRL **92**, 251803 (2004)

Most precise	Second most precise	Largest uncertainty
Kaon： 2.2σ tension from CKM unitarity	**Tau：** 3.6σ deviation from CKM unitarity	**Hyperon：** consistent with CKM unitarity
$|V_{us}| = 0.2243 \pm 0.0008$	$|V_{us}| = 0.2207 \pm 0.0014$	$|V_{us}| = 0.2250 \pm 0.0027$
PDG 2024	HFLAV 2022	**Dominated by the $\Lambda \to pe^-\bar{\nu}_e$**

Kaon ↔ Tau: 2.2σ tension

Semileptonic hyperon decays gives additional inputs for $|V_{us}|$!

Other topics of hyperon physics

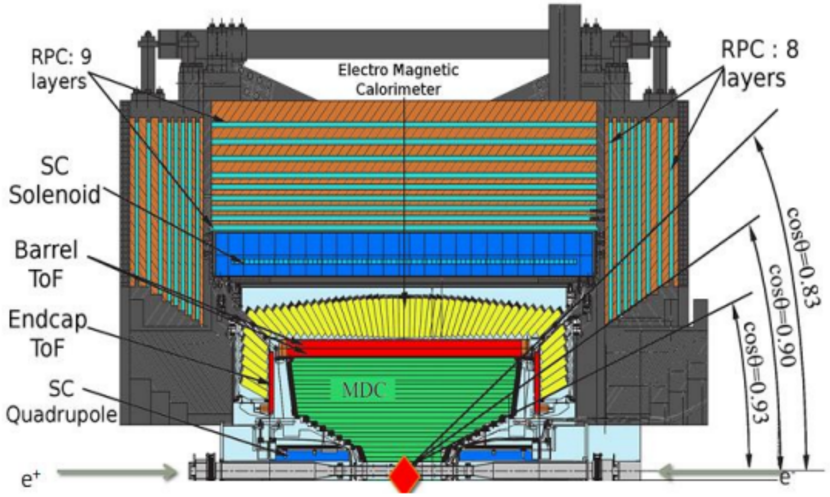
- Hyperon weak radiative decays
  - flavor changing neutral current (FCNC) process ($s \to d\gamma$ transition)
  - significant non-perturbative QCD effects
  - …
- Hyperon-nucleus interactions
  - Hyperon puzzle in neutron stars

- ……

Study hyperons at BESIII

Electromagnetic Calorimeter
CsI(Tl): L=28 cm
Barrel σ_E=2.5%
Endcap σ_E=5.0%

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



Main Drift Chamber
Small cell, 43 layer
σ_{xy}=130 μm
dE/dx~6%
σ_p/p= 0.5% at 1 GeV

Time Of Flight
Plastic scintillator
σ_T(barrel)=80 ps
σ_T(endcap)=110 ps
(update to 65 ps with MRPC)

With 10 billion J/ψ and 2.7 billion $\psi(3686)$ collected at BESIII, $\sim10^7$ entangled hyperon pairs can be produced, which enables precise studies of the hyperon physics.

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

Decay mode	$B(\times10^{-3})$	$N_B(\times10^6)$
$J/\psi\to\Lambda\bar{\Lambda}$	1.89 ± 0.09	~18.9
$J/\psi\to\Sigma^0\bar{\Sigma}^0$	1.172 ± 0.032	~11.7
$J/\psi\to\Sigma^+\bar{\Sigma}^-$	1.07 ± 0.04	~10.7
$J/\psi\to\Xi^0\bar{\Xi}^0$	1.17 ± 0.04	~11.7
$J/\psi\to\Xi^-\bar{\Xi}^+$	0.97 ± 0.08	~9.7
$\psi(2S)\to\Omega^-\bar{\Omega}^+$	0.057 ± 0.003	~0.17

More $\psi(3686)$ data has been taken after the upgrade of BEPCII and BESIII inner tracker.

A hyperon factory

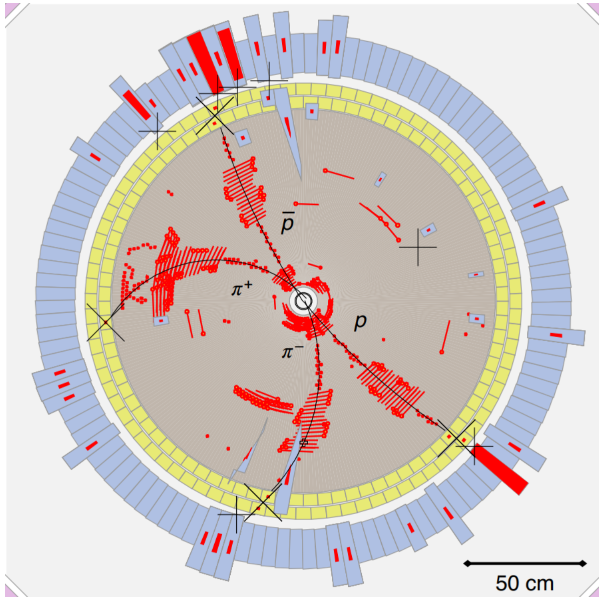
$e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to p\pi^-, \bar{\Lambda} \to \bar{p}\pi^+$

Differential cross-section of this process:

$$\mathcal{W}(\xi) = \mathcal{F}_0(\xi) + \alpha_{J/\psi}\mathcal{F}_5(\xi) + \alpha_-\alpha_+ \times \left[\mathcal{F}_1(\xi) + \sqrt{1-\alpha_{J/\psi}^2}\cos(\Delta\Phi)\mathcal{F}_2(\xi) + \alpha_{J/\psi}\mathcal{F}_6(\xi)\right] + \sqrt{1-\alpha_{J/\psi}^2}\sin(\Delta\Phi)[\alpha_-\mathcal{F}_3(\xi) + \alpha_+\mathcal{F}_4(\xi)] \quad (1)$$

spin-correlation

polarization



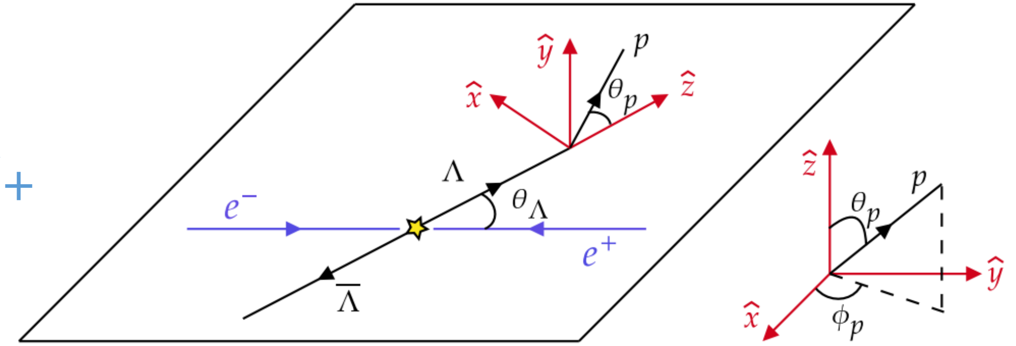
If $\sin\Delta\Phi \neq 0$, Λ is transverse polarized.

↓

Independent measurement of α_-, α_+

↓

Test CP symmetry



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)

Search for CPV in Λ decay

Two BESIII papers have been published:

[1] 1.3 billion: Nature Phys.15(2019)631

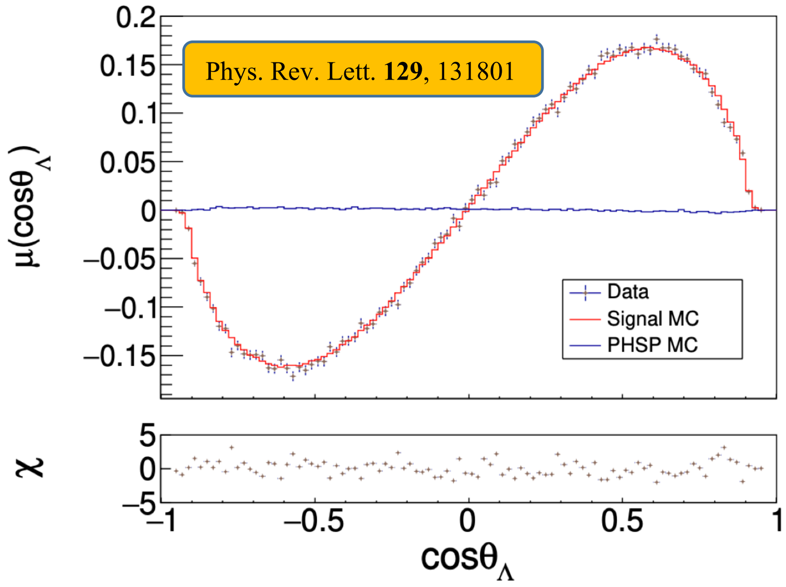
[2] 10 billion: Phys. Rev. Lett. 129 (2022) 13, 131801

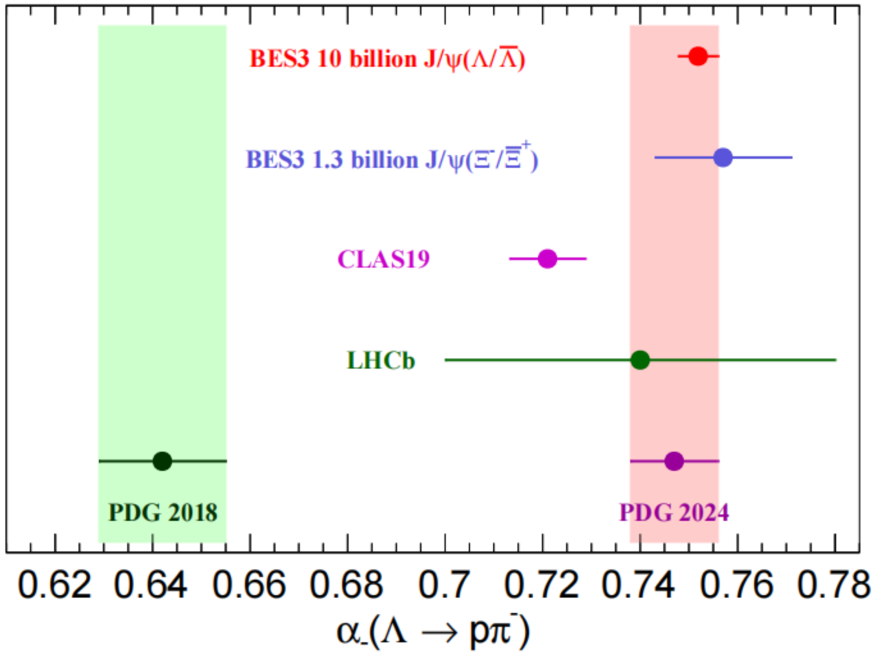
Par.	Newest BESIII results
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0031$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0066$
α_-	$0.7519 \pm 0.0036 \pm 0.0024$
α_+	$-0.7559 \pm 0.0036 \pm 0.0030$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0012$
α_{avg}	$0.7542 \pm 0.0010 \pm 0.0024$

3.2 M $\Lambda\bar{\Lambda}$ pairs were reconstructed.

- Most precise measurement of Λ decay parameter
- Most precise A_{CP} measurement in hyperon decay:

$$A_{CP} = \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}} = -0.0025 \pm 0.0046 \pm 0.0011$$





Search for CPV in Σ^+ decay

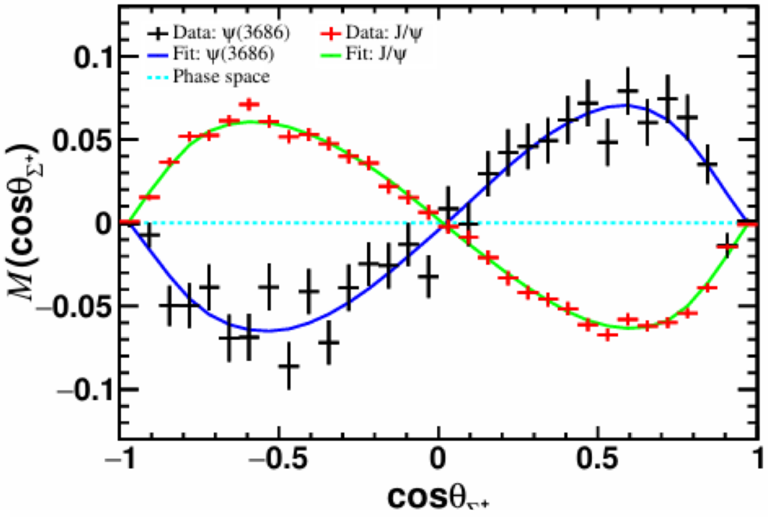
$$e^+e^- \to J/\psi, \psi(3686) \to \Sigma^+\bar{\Sigma}^-,\ \Sigma^+ \to p\pi^0,\ \bar{\Lambda} \to \bar{p}\pi^0$$

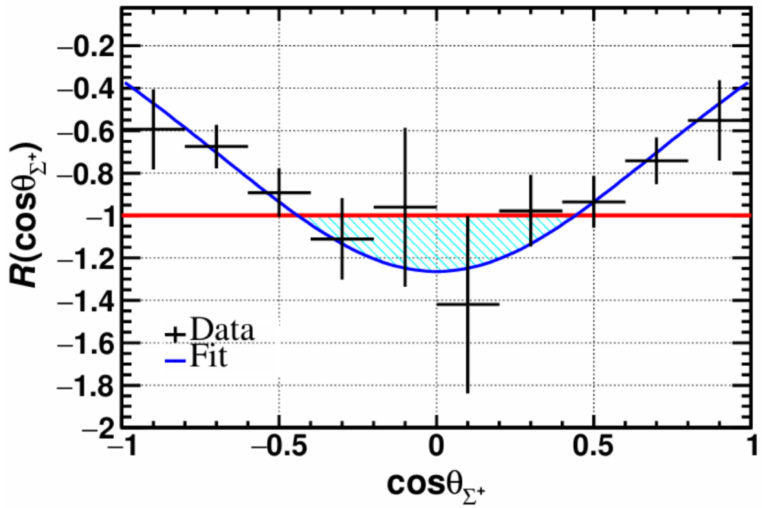
10B J/ψ and 2.7B $\psi(3686)$ 1.12 M $\Sigma^+\bar{\Sigma}^-$ pairs reconstructed

Parameter	Phys. Rev. Lett. 135, 141804 (2025)	Phys. Rev. Lett. 131, 191802 (2023)
$\alpha_{J/\psi}$	$-0.5047 \pm 0.0018 \pm 0.0010$	$-0.508 \pm 0.006 \pm 0.004$
$\Delta\Phi_{J/\psi}$	$-0.2744 \pm 0.0033 \pm 0.0010$	$-0.270 \pm 0.012 \pm 0.009$
α_0	$-0.975 \pm 0.011 \pm 0.002$	$-0.998 \pm 0.037 \pm 0.009$
$\bar{\alpha}_0$	$0.999 \pm 0.011 \pm 0.004$	$0.990 \pm 0.037 \pm 0.011$
$\alpha_{\psi(3686)}$	$0.7133 \pm 0.0094 \pm 0.0065$	$0.682 \pm 0.030 \pm 0.011$
$\Delta\Phi_{\psi(3686)}$	$0.427 \pm 0.022 \pm 0.003$	$0.379 \pm 0.070 \pm 0.014$
$\langle\alpha_0\rangle$	$-0.9869 \pm 0.0011 \pm 0.0016$	$-0.994 \pm 0.004 \pm 0.002$
A_{CP}	$-0.0118 \pm 0.0083 \pm 0.0028$	$0.004 \pm 0.037 \pm 0.010$

- Opposite directions of Σ^+ polarizations in J/ψ and $\psi(3686)$ decays
- Most precise measurements of the Σ^+ decay parameters
- Most precise CP test in the decays of Σ^+

Polarizations of Σ^+





Polarization ratio of Σ^+ between J/ψ and $\psi(3686)$ decays

Semileptonic decays: Determination of form factors

Decay width of $\Lambda \to pe^-\overline{\nu}_e$ in the SM

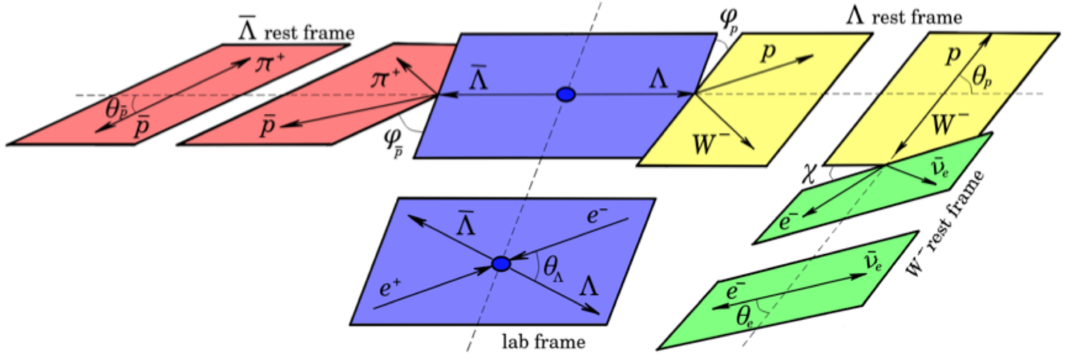
$$\Gamma_{\rm SM} = \frac{\mathcal{B}_{\Lambda\to pe^-\overline{\nu}_e}}{\tau_\Lambda} = \frac{G_F^2|V_{us}|^2 f_1(0)^2\Delta^5}{60\pi^3}\Big[\Big(1-\frac{3}{2}\delta+\frac{6}{7}\delta^2\Big)+\frac{4}{7}\delta^2 g_w^2 + \Big(3-\frac{9}{2}\delta+\frac{12}{7}\delta^2\Big)g_{av}^2+\frac{12}{7}\delta^2 g_{av2}^2+\frac{6}{7}\delta^2 g_w+(-4\delta+6\delta^2)g_{av}g_{av2}\Big]$$

PRD **70**, 114036 (2004)

$$\Delta \equiv M_\Lambda - M_p$$

$$\delta \equiv \frac{M_\Lambda - M_p}{M_\Lambda}$$

Formalism from Varvara [2302.07665]



$$\begin{aligned} d\Gamma \propto \mathcal{W}(\boldsymbol{\xi};\alpha_\psi,\Delta\Phi,g_{av}^\Lambda,g_w^\Lambda,\alpha_{\bar{\Lambda}}) = &\sigma_\Lambda^{sl}(\boldsymbol{\xi}'')\Big[\mathcal{F}_0(\boldsymbol{\xi}')+\alpha_\psi\mathcal{F}_1(\boldsymbol{\xi}')\\ &+a_\Lambda^{sl}(\boldsymbol{\xi}'')\alpha_{\bar{\Lambda}}\Big(\mathcal{F}_2(\boldsymbol{\xi}')+\alpha_\psi\mathcal{F}_3(\boldsymbol{\xi}')+\sqrt{1-\alpha_\psi^2}\cos(\Delta\Phi)\mathcal{F}_4(\boldsymbol{\xi}')\Big)\\ &+I_\Lambda^{sl}(\boldsymbol{\xi}'')\alpha_{\bar{\Lambda}}\Big(\mathcal{F}_2'(\boldsymbol{\xi}')+\alpha_\psi\mathcal{F}_3'(\boldsymbol{\xi}')+\sqrt{1-\alpha_\psi^2}\cos(\Delta\Phi)\mathcal{F}_4'(\boldsymbol{\xi}')\Big)\\ &+\sqrt{1-\alpha_\psi^2}\sin(\Delta\Phi)\Big(a_\Lambda^{sl}(\boldsymbol{\xi}'')\mathcal{F}_5(\boldsymbol{\xi}')+I_\Lambda^{sl}(\boldsymbol{\xi}'')\mathcal{F}_5'(\boldsymbol{\xi}')+\alpha_{\bar{\Lambda}}\mathcal{F}_6(\boldsymbol{\xi}')\Big)\Big]\end{aligned}$$

where $\boldsymbol{\xi} = (\theta_\Lambda,\theta_p,\phi_p,\theta_e,q^2,\theta_{\bar{p}},\phi_{\bar{p}})$ while $\boldsymbol{\xi}' = (\theta_\Lambda,\theta_p,\phi_p,\theta_{\bar{p}},\phi_{\bar{p}})$ and $\boldsymbol{\xi}'' = (\theta_e,q^2)$.

$g_{av}^\Lambda \equiv g_{av}^\Lambda(q^2)$ and $g_w^\Lambda \equiv g_w^\Lambda(q^2)$

Determination of form factors of $\Lambda \to p e^- \bar{\nu}_e$

Observable	This work	Previous result
g_{av}^-	$0.742^{+0.075}_{-0.057} \pm 0.009$	0.718 ± 0.015 [PDG2024]
g_{av}^+	$-0.706^{+0.069}_{-0.073} \pm 0.014$	-
$\langle g_{av} \rangle$	$0.729^{+0.048}_{-0.047} \pm 0.007$	-
g_w^-	$0.93 \pm 0.51 \pm 0.17$	0.15 ± 0.30 [PRD41(1990)780]
g_w^+	$0.89 \pm 0.49 \pm 0.20$	-
$\langle g_w \rangle$	$0.89 \pm 0.35 \pm 0.14$	-
$\langle g_{av} \rangle$	$0.706^{+0.089}_{-0.086} \pm 0.026$	-
$\langle g_w \rangle$	$0.77^{+0.53}_{-0.49} \pm 0.14$	-
$\langle g_{av2} \rangle$	$-0.19^{+0.65}_{-0.63} \pm 0.18$	-

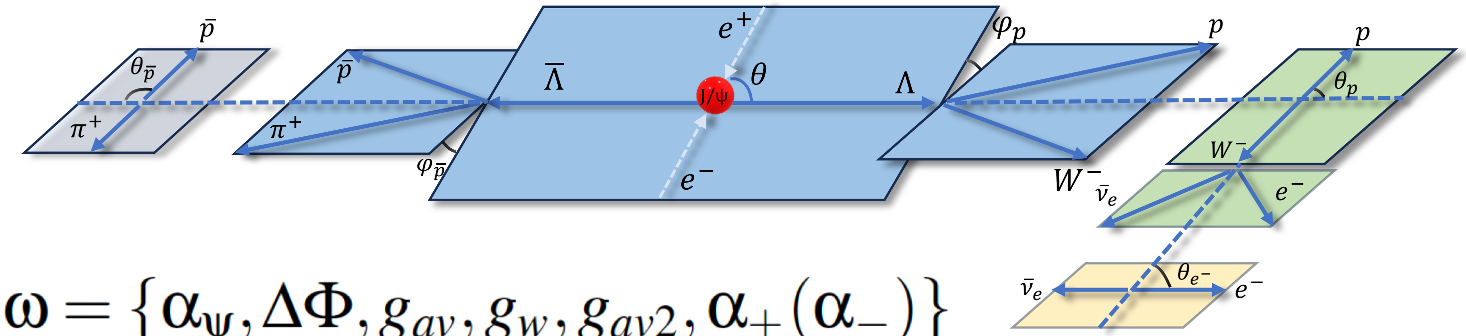
Assuming $g_{av2} = 0$ (first six rows)

BESIII: arXiv:2509.09266

- The first exploitation of polarization and quantum entanglement in baryon semi-leptonic decays.
- The first usage of joint angular-distribution fit method in hyperon semi-leptonic dacyas.

The innovative methodology significantly enhances the single-event sensitivity

- This work:
  $1.8 \cdot 10^3$ events $\to \sigma_{\langle g_{av} \rangle} = 0.049$,
  $\sigma_{\langle g_w \rangle} = \mathbf{0.38}$
- Fermilab [PRD41(1990)780]:
  $37 \cdot 10^3$ events $\to \sigma_{g_{av}} = 0.020$
  $\sigma_{g_w} = \mathbf{0.30}$



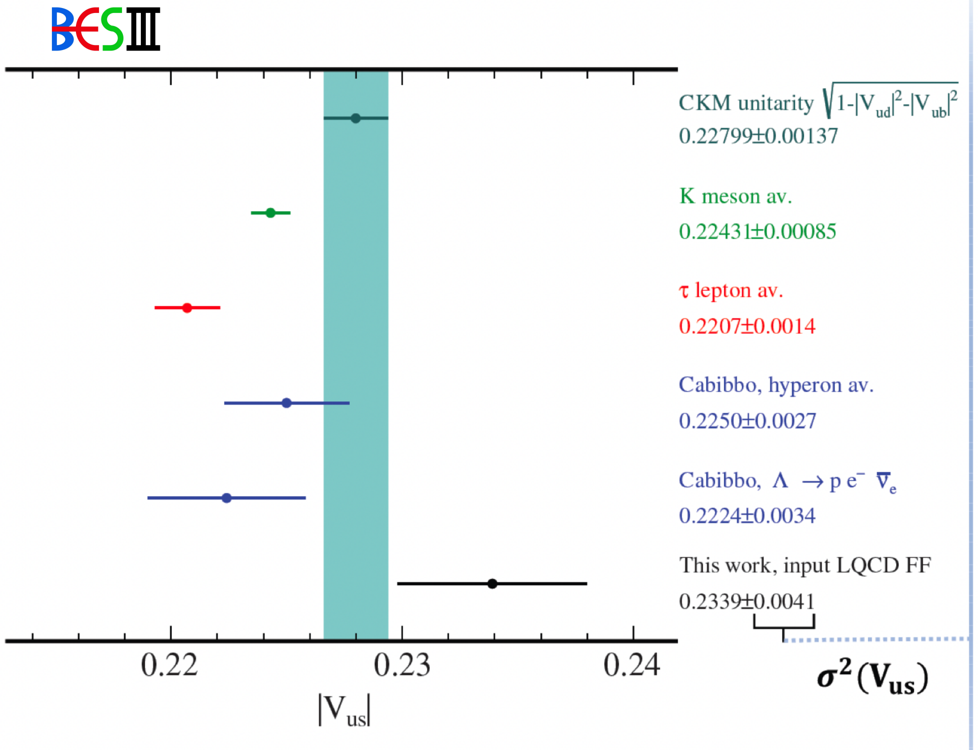
$$\omega = \{\alpha_\psi, \Delta\Phi, g_{av}, g_w, g_{av2}, \alpha_+(\alpha_-)\}$$

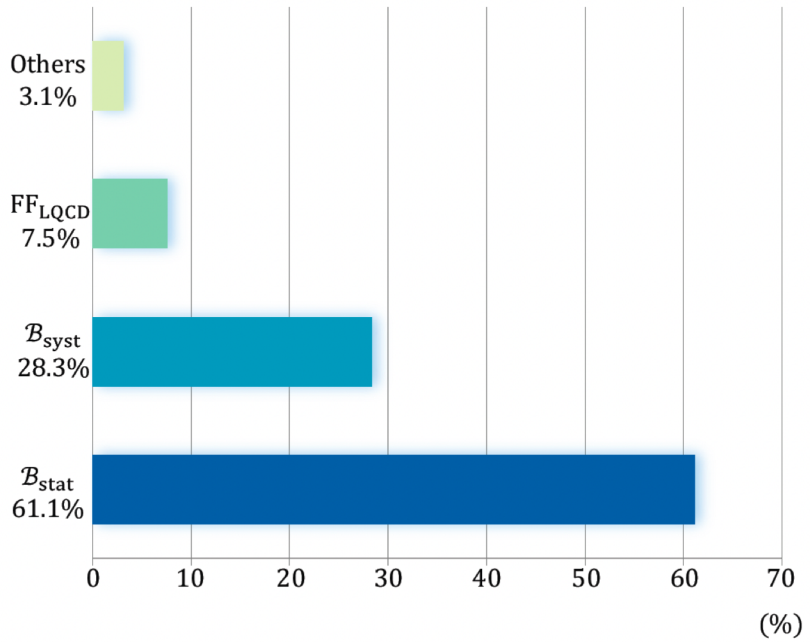
Extraction of $|V_{us}|$ from $\Lambda \to p e^- \bar{\nu}_e$

BESIII: arXiv:2509.09266

- Assume SU(3) symmetry is conserved, $f_1 = \sqrt{3/2}$ [PRL92(2004)251803]
  $|V_{us}|_{\text{SU(3)}} = 0.2190 \pm 0.0036_{\text{BESIII BF}} \pm 0.0087_{\text{BESIII FF}} \pm 0.0004_{\tau_\Lambda} \pm 0.0005_{\text{RC}}$

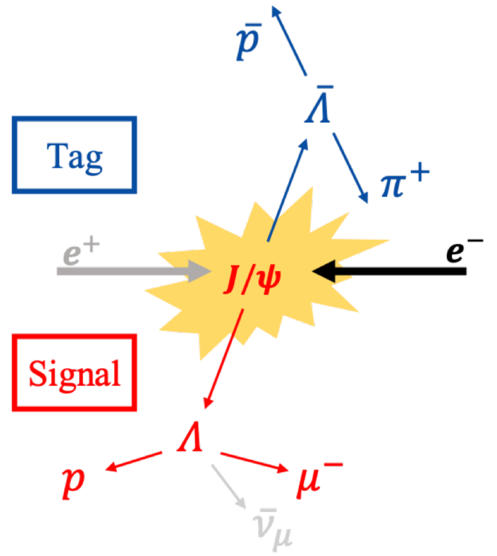
- Using LQCD FF prediction [PRL 135, 231901 (2025)]
  $|V_{us}|_{\text{LQCD}} = 0.2339 \pm 0.0038_{\text{BESIII BF}} \pm 0.0004_{\tau_\Lambda} \pm 0.0006_{\text{RC}} \pm 0.0011_{\text{LQCD}}$

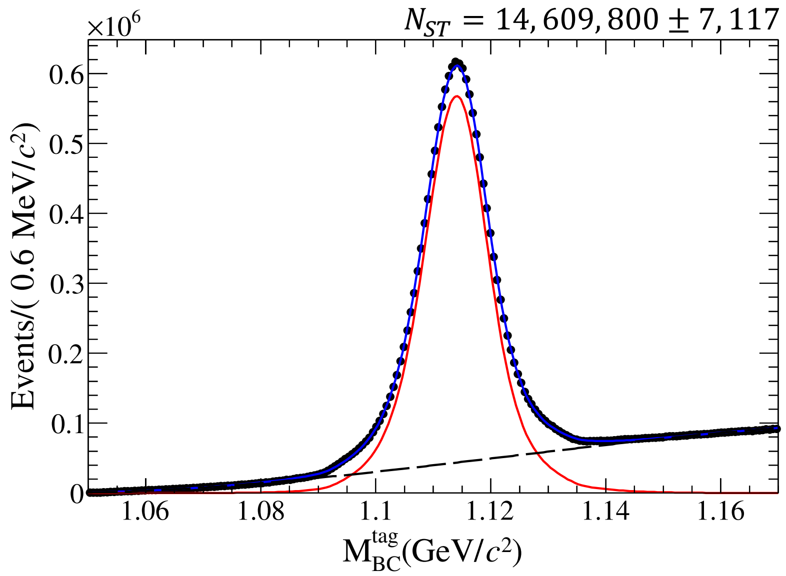


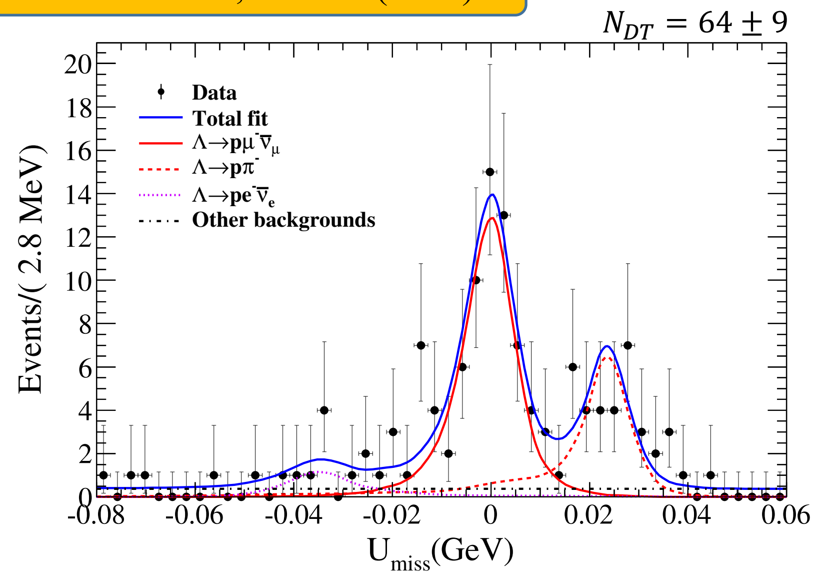


Absolute BF measurement of $\Lambda \to p\mu^-\bar{\nu}_\mu$

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







First absolute BF measurement

$$\mathcal{B}(\Lambda \to p\mu^-\bar{\nu}_\mu) = (1.48 \pm 0.21 \pm 0.08)\times 10^{-4}$$

- ✓ Update measurement after a 50-year hiatus
- ✓ The first study of its absolute BF
- ✓ The most precise result to date

Test lepton flavor universality

$$R^{\mu e} = \frac{\mathcal{B}(\Lambda \to p\mu^-\bar{\nu}_\mu)}{\mathcal{B}(\Lambda \to pe^-\bar{\nu}_e)_{PDG}} = 0.178 \pm 0.028$$

Consistent with LFU

0.153 ± 0.008

Search for CP violation

$$\Delta_{CP} = \frac{\mathcal{B}_{\Lambda \to p\mu^-\bar{\nu}_\mu} - \mathcal{B}_{\bar{\Lambda} \to \bar{p}\mu^+\nu_\mu}}{\mathcal{B}_{\Lambda \to p\mu^-\bar{\nu}_\mu} + \mathcal{B}_{\bar{\Lambda} \to \bar{p}\mu^+\nu_\mu}} = 0.02 \pm 0.14 \pm 0.02$$

Consistent with CP symmetry

Search for Strong CPV in $\Sigma^0(\to \Lambda\gamma)$ decay

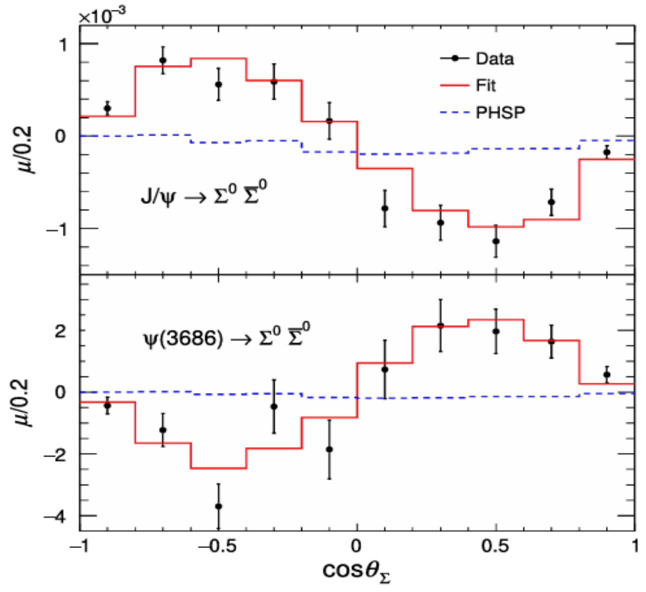
The CPV sources in SM:

- Weak interaction, CKM (observed, but too small)
- Strong interaction, θ-term (Not yet observed)

10 B J/ψ and 2.7 B $\psi(3686)$

$e^+e^- \to J/\psi, \psi(3686) \to \Sigma^0(\to \Lambda\gamma)\bar{\Sigma}^0(\to \bar{\Lambda}\gamma), \Lambda \to p\pi^-, \bar{\Lambda} \to \bar{p}\pi^+$

Parameter	Phys. Rev. Lett. 133 (2024) 10, 101902
$\alpha_{J/\psi}$	$-0.4133 \pm 0.0035 \pm 0.0077$
$\Delta\Phi_{J/\psi}$ (rad)	$-0.0828 \pm 0.0068 \pm 0.0033$
$\alpha_{\psi(3686)}$	$0.814 \pm 0.028 \pm 0.028$
$\Delta\Phi_{\psi(3686)}$ (rad)	$0.512 \pm 0.085 \pm 0.034$
α_{Σ^0}	$-0.0017 \pm 0.0021 \pm 0.0018$
$\bar{\alpha}_{\Sigma^0}$	$0.0021 \pm 0.0020 \pm 0.0022$
α_{Λ}	$0.730 \pm 0.051 \pm 0.011$
$\bar{\alpha}_{\Lambda}$	$-0.776 \pm 0.054 \pm 0.010$
A_{CP}^{Σ}	$(0.4 \pm 2.9 \pm 1.3) \times 10^{-3}$
A_{CP}^{Λ}	$(-3.0 \pm 6.9 \pm 1.5) \times 10^{-2}$



Polarizations of Σ^0

Similar behavior is observed in Σ^+, but not in Λ or Ξ!

Opposite directions of the Σ^0 polarization

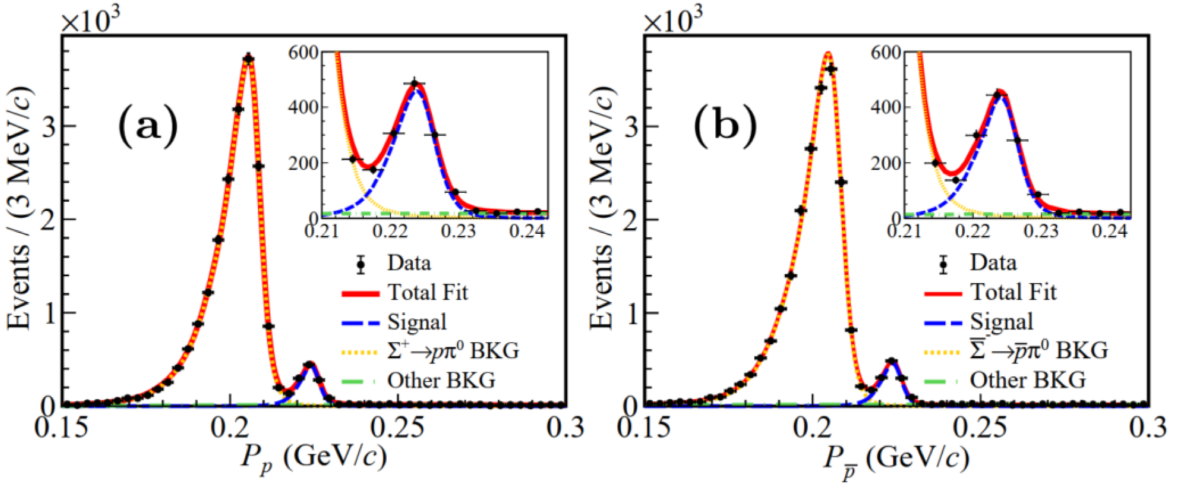
The first attempt to measure the P-violating decay parameter of $\Sigma \to \Lambda\gamma$.

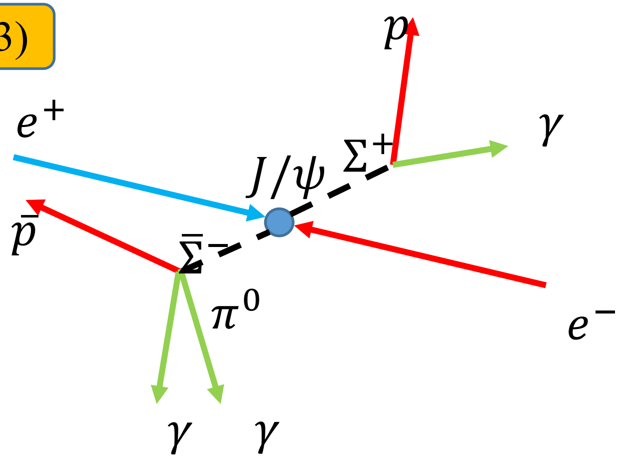
The first strong-CP test in hyperon decays.

Radiative decay: $\Sigma^+ \to p\gamma$ in $J/\psi \to \Sigma^+\bar{\Sigma}^-$

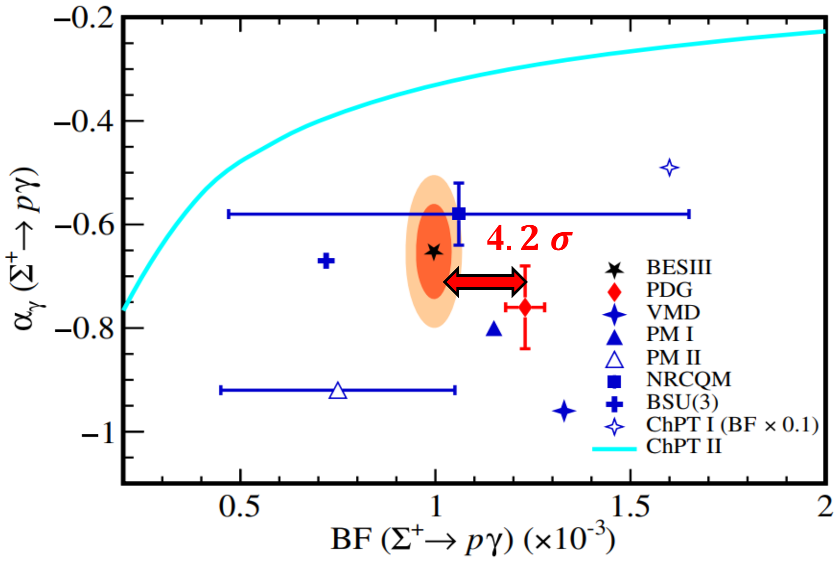
Phys. Rev. Lett. 130, 211901(2023)

Signal side: momentum distributions of proton in the rest frame of Σ :





The decay rate deviates from previous value by 4.2σ



The decay BF $(0.996 \pm 0.022_{stat} \pm 0.017_{syst}) \times 10^{-3}$

The decay parameter: $-0.651 \pm 0.056_{stat} \pm 0.020_{syst}$

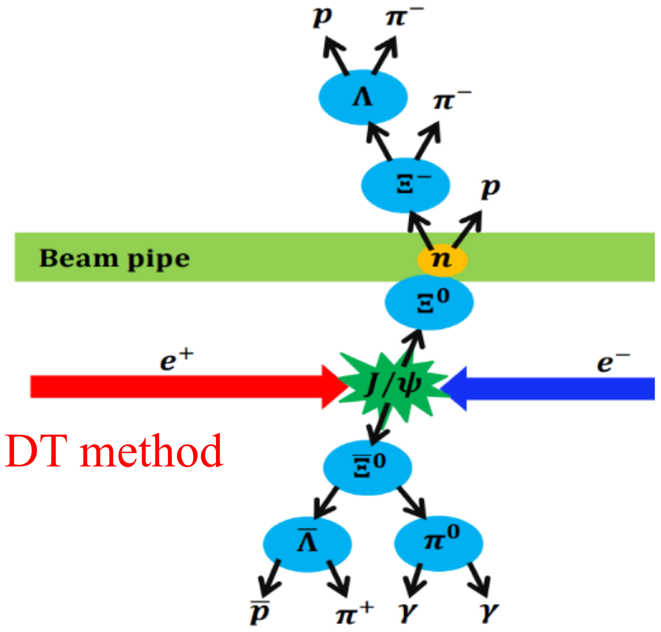
The CP asymmetry is calculated to be

$$A_{CP} = (\alpha_- + \alpha_+)/(\alpha_- - \alpha_+) = 0.095 \pm 0.087 \pm 0.022$$

$$\Delta_{CP} = (\mathcal{B}_+ - \mathcal{B}_-)/(\mathcal{B}_+ + \mathcal{B}_-) = 0.006 \pm 0.011 \pm 0.006$$

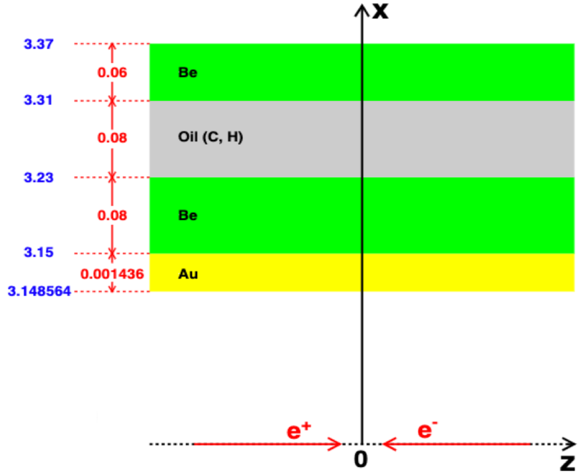
Study hyperon-nucleon interaction at BESIII

- Stable hyperon beam with well-known kinematics is challenging
- The study of hyperon-nucleon interaction is crucial to solving the “hyperon puzzle” of neutron stars



DT method

intense monoenergetic Ξ^0 baryon



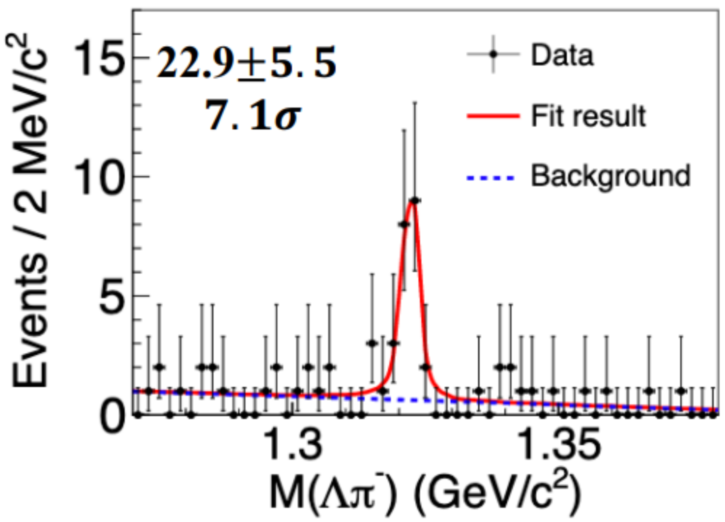
For Ξ^0 momentum is 0.818 GeV/c

$$\sigma(\Xi^0 n \rightarrow \Xi^- p) = (7.4 \pm 1.8_{\text{stat}} \pm 1.5_{\text{sys}})\ \text{mb}$$

(assuming the effective number of reaction neutrons in ^{9}Be is 3)

$$\sigma(\Xi^0 + {}^9\text{Be} \rightarrow \Xi^- + p + {}^8\text{Be}) = (22.1 \pm 5.3_{\text{stat}} \pm 4.5_{\text{sys}})\ \text{mb}$$

Phys. Rev. Lett. 130 (2023) 251902



$\Xi^0 n \rightarrow \Xi^- p$ is observed for the first time

The first study of hyperon–nucleon interactions in electron-positron collisions!

The cross sections of $\Lambda N \rightarrow \Sigma^+ X$, $\Lambda p \rightarrow \Lambda p$, and $\bar{\Lambda} p \rightarrow \bar{\Lambda} p$ have also been measured with the same method.

PRC 109 (2024) 5, L052201
PRL 132, 231902 (2024)

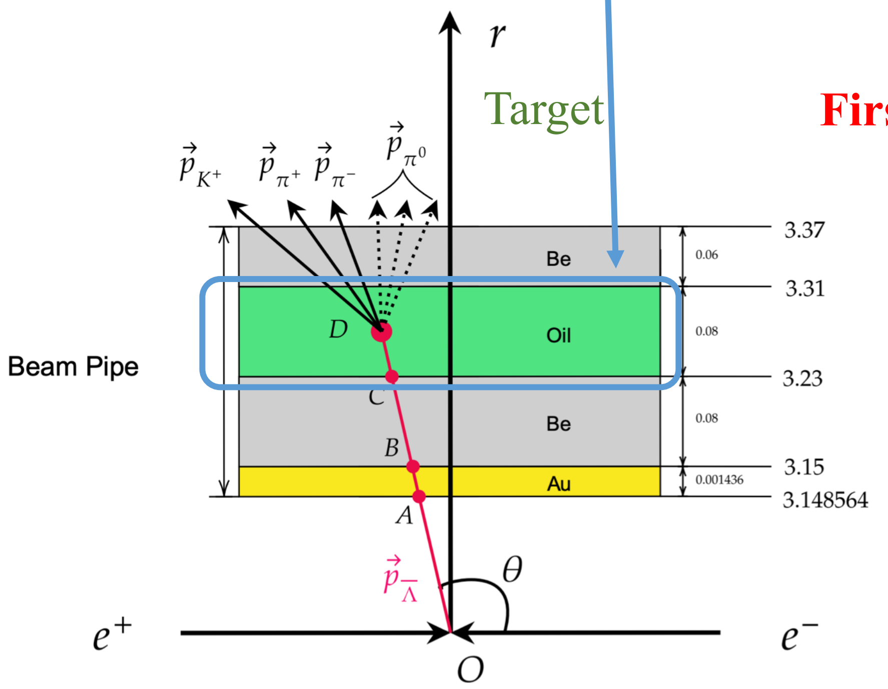
First study of *anti*-hyperon-nucleon interaction at BESIII

Reaction chain: $J/\psi \to \Lambda\bar{\Lambda}$, $\bar{\Lambda} + p \to K^+\pi^+\pi^- + k\pi^0$ ($k = 1,2,3$)

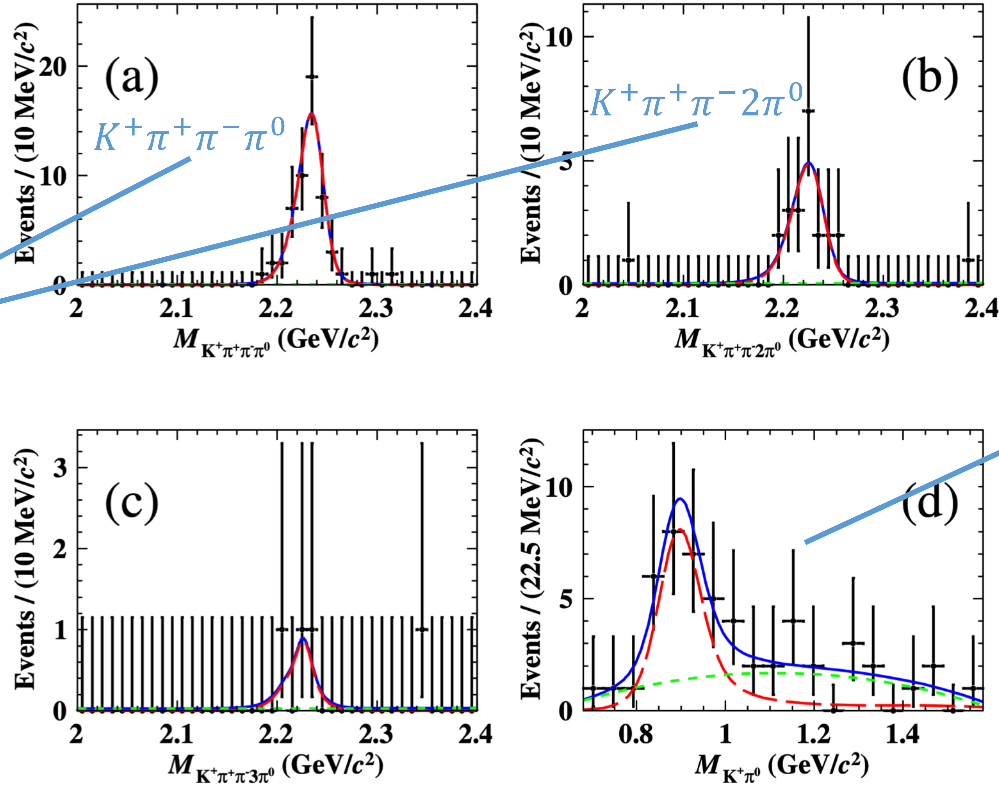
Phys. Rev. Lett. 136, 171904 (2026)

Two-body decay, $P_{\bar{\Lambda}} \approx 1.074$ GeV/c

hydrogen in the cooling oil



First observation



Intermediate $K^*(892)^+$ in $k = 1$ channel

Channel	Cross section (upper limit)
$\bar{\Lambda}p \to K^+\pi^+\pi^-\pi^0$	$8.5^{+1.2}_{-1.1} \pm 0.4$
$\bar{\Lambda}p \to K^+\pi^+\pi^-2\pi^0$	$7.9^{+1.9}_{-1.7} \pm 0.4$
$\bar{\Lambda}p \to K^+\pi^+\pi^-3\pi^0$	$3.1^{+2.2}_{-1.5} \pm 0.2$ (< 7.2)
$\bar{\Lambda}p \to K^*(892)^+\pi^+\pi^-$	$12.5^{+3.8}_{-3.4} \pm 1.2$

Study hyperon-nucleus interaction at BESIII

Chin. Phys. C 48 (2024) 7, 073003

J/ψ, $\psi(3686)$ →

Hyperon beam

- $pK^-\bar{\Lambda}$
- $\Lambda\bar{\Lambda}$
- $\Sigma^+\bar{\Sigma}^-$
- $\Xi^-\bar{\Xi}^+$
- $\Omega^-\bar{\Omega}^+$

Possible reactions

- $\Lambda + p$ → $\Sigma^+ n$, $K^+\Lambda\Lambda$, $K^+\Xi^- p$
- $\Lambda + n \rightarrow \Sigma^- p$
- $\Sigma^- + p \rightarrow \Sigma^0 n, \Lambda n$
- $\Sigma^+ + n \rightarrow \Sigma^0 p, \Lambda p$
- $\Xi^- + p \rightarrow \Xi^0 n, \Lambda\Lambda$
- $\Xi^0 + n \rightarrow \Lambda\Lambda$

Many interesting results will be coming soon, expecially for anti-hyperon-nucleon interaction!

Summary

- BESIII has made fruitful achievements in hyperon decays!
  - ✓ Hyperon polarization measurement and CPV searches
  - ✓ Hyperon semi-leptonic decays
  - ✓ Hyperon weak radiative decays
  - ✓ Hyperon-nucleon interaction studies
  - ✓ …
- More exciting hyperon results are expected in the near future.

Thank you!

Search for CPV in Ξ decay

Phys. Rev. D 99, 056008 (2019)
Phys. Lett. B 772, 16 (2017)

$$\mathcal{W}(\vec{\omega},\vec{\zeta}) = \sum_{\mu,\nu=0}^{3} C_{\mu\nu} \sum_{\mu'=0}^{3} \sum_{\nu'=0}^{3} a^{\Xi}_{\mu\mu'} a^{\bar{\Xi}}_{\nu\nu'} a^{\Lambda}_{\mu'0} a^{\bar{\Lambda}}_{\nu'0}$$

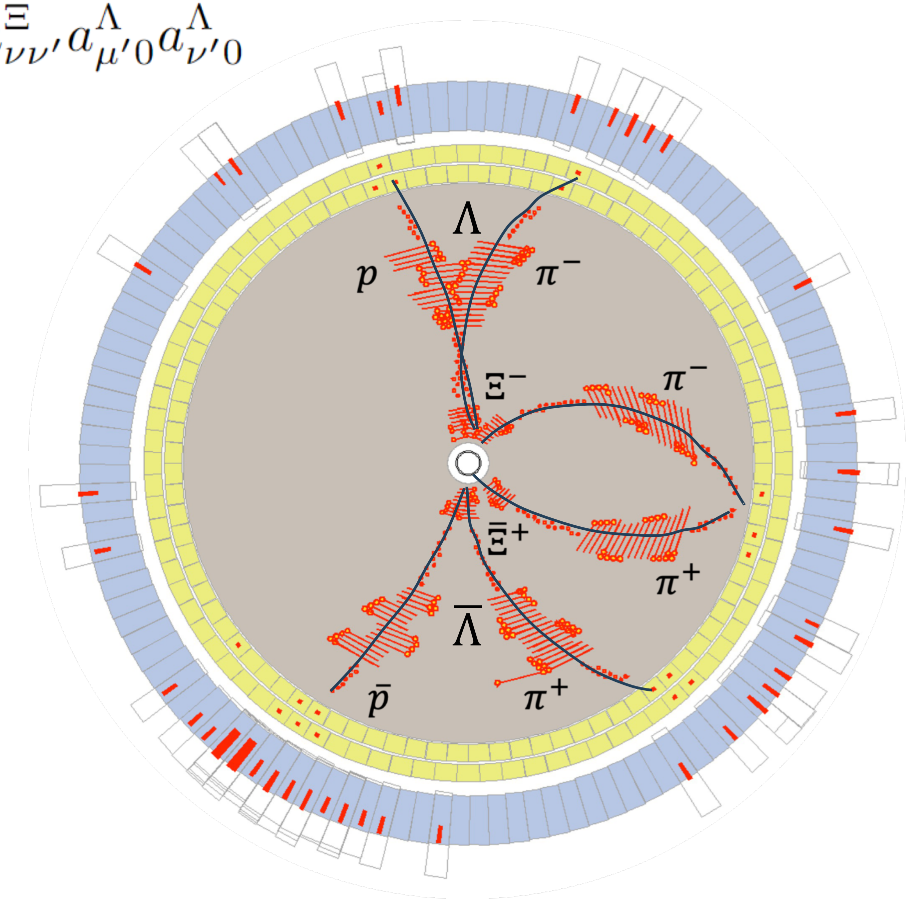
spin-aligned

quantum entangled

$$e^+e^- \to J/\psi \to \Xi\bar{\Xi}$$

$\Xi \to \Lambda\pi$, $\Lambda \to p\pi^-$

$\bar{\Xi} \to \bar{\Lambda}\pi$, $\bar{\Lambda} \to \bar{p}\pi^+$



Through the sequential decays of Ξ, the CPV phase can be directly measured!

The *perfect* reaction for hyperon CPV searches!

Search for CPV in Ξ decay

The precision of our analysis (73K $\Xi^-\bar{\Xi}^+$) 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!

Ξ^- 1.3 billion J/ψ

Parameter	Nature **606** (2022) 64-69	Previous result
α_ψ	0.586±0.012±0.010	0.58±0.04±0.08
$\Delta\Phi$	1.213±0.046±0.016 rad	–
α_Ξ	−0.376±0.007±0.003	−0.401±0.010
ϕ_Ξ	0.011±0.019±0.009 rad	−0.042 ± 0.011 ± 0.011
$\bar{\alpha}_\Xi$	0.371±0.007±0.002	HyperCP: PRL 93(2004) 011802
$\bar{\phi}_\Xi$	−0.021±0.019±0.007 rad	–
α_Λ	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}^{Ξ}	$(6\pm13\pm6)\times10^{-3}$	–
$\Delta\phi_{CP}^{\Xi}$	$(-5\pm14\pm3)\times10^{-3}$ rad	–
A_{CP}^{Λ}	$(-4\pm12\pm9)\times10^{-3}$	$(-6\pm12\pm7)\times10^{-3}$
$\langle\phi_\Xi\rangle$	0.016±0.014±0.007 rad	

The results have been updated with 10B J/ψ, consistant, but with much improved precision.

Phys. Rev. Lett. 136, 201802 (2026)

First measurements of the weak (CPV) phase difference in Ξ^-/Ξ^0 decays

Three CP tests in Ξ^-/Ξ^0 decays

320K $\Xi^0\bar{\Xi}^0$ pairs

10 billion J/ψ Ξ^0

Parameter	Phys. Rev. D 108, L031106 (2023)
$\alpha_{J/\psi}$	$0.514\pm0.006\pm0.015$
$\Delta\Phi$(rad)	$1.168\pm0.019\pm0.018$
α_Ξ	$-0.3750\pm0.0034\pm0.0016$
$\bar{\alpha}_\Xi$	$0.3790\pm0.0034\pm0.0021$
ϕ_Ξ(rad)	$0.0051\pm0.0096\pm0.0018$
$\bar{\phi}_\Xi$(rad)	$-0.0053\pm0.0097\pm0.0019$
α_Λ	$0.7551\pm0.0052\pm0.0023$
$\bar{\alpha}_\Lambda$	$-0.7448\pm0.0052\pm0.0017$
$\xi_P-\xi_S$(rad)	$(0.0\pm1.7\pm0.2)\times10^{-2}$
$\delta_P-\delta_S$(rad)	$(-1.3\pm1.7\pm0.4)\times10^{-2}$
A_{CP}^{Ξ}	$(-5.4\pm6.5\pm3.1)\times10^{-3}$
$\Delta\phi_{CP}^{\Xi}$(rad)	$(-0.1\pm6.9\pm0.9)\times10^{-3}$
A_{CP}^{Λ}	$(6.9\pm5.8\pm1.8)\times10^{-3}$
$\langle\alpha_\Xi\rangle$	$-0.3770\pm0.0024\pm0.0014$
$\langle\phi_\Xi\rangle$(rad)	$0.0052\pm0.0069\pm0.0016$
$\langle\alpha_\Lambda\rangle$	$0.7499\pm0.0029\pm0.0013$

PRD(L) Editor's Suggestion