Low q^2 issues in hyperon decays

周小蓉
中国科学技术大学

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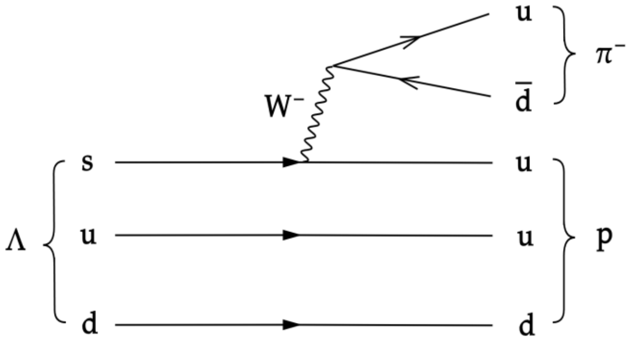
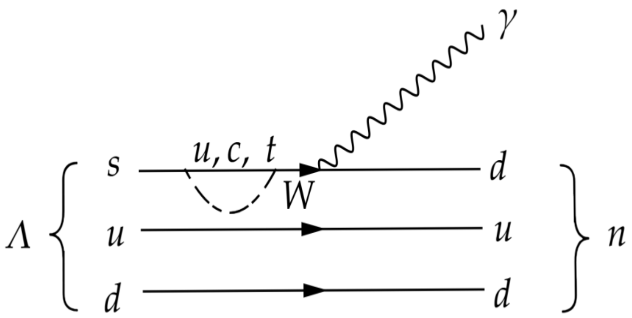
超子的衰变

超子三类衰变

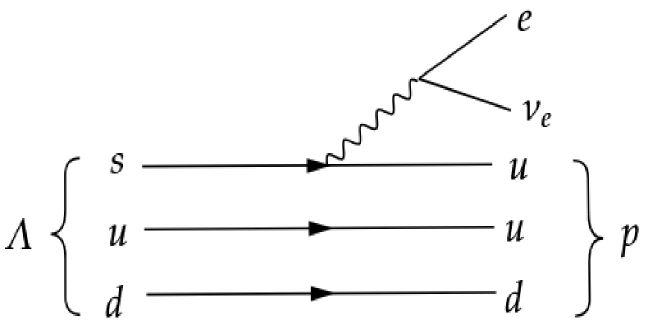
强子末态弱衰变 $\mathcal{O}(1)$



弱辐射衰变$\mathcal{O}(10^{-3})$



半轻衰变$\mathcal{O}(10^{-3})$



- 超子衰变的理论描述：低能有效理论（ChPT，VMD，NRCQM，pole model etc.），Lattice QCD
- 超子衰变存在的问题：
  - $\Delta I = 1/2$规则，S/P波问题，Hara定理

ΔI =1/2 rule in Kaon decay

- **In $K \to \pi\pi$ decay, their amplitudes:**

$$A(K^+ \to \pi^+\pi^0) = \frac{3}{2} A_2 e^{i\chi_2} \qquad \Delta I = \frac{3}{2} \text{ transition}$$

$$A(K^0 \to \pi^+\pi^-) = A_0 e^{i\chi_0} + \frac{1}{\sqrt{2}} A_2 e^{i\chi_2} \qquad \Delta I = \frac{1}{2} \text{ transition}$$

$$\frac{\mathrm{Re}(A_0)}{Re(A_1)} \approx \frac{\sqrt{\mathcal{B}(K^+ \to \pi^+\pi^0)\tau_{K_s}}}{\sqrt{\mathcal{B}(K_s \to \pi^+\pi^-)\tau_{K^+}}} = \sqrt{\frac{0.21 \cdot 0.1ns}{0.69 \cdot 12ns}} = \frac{1}{22}$$

- **The $\Delta I = 1/2$ rule** means the weak transitions changing isospin by 1/2 are enhanced over the 3/2 transitions in S-wave

Current precision $\omega = Re(A_0)/Re(A_2) = 22.35 \pm 0.06$

- Direct CP violation in $K \to \pi\pi$ arises from interference between isospin amplitudes

$$\frac{\varepsilon'}{\varepsilon} = \frac{i\omega e^{i(\delta_2 - \delta_0)}}{\sqrt{2}\varepsilon}\left[\frac{\mathrm{Im}(A_2)}{\mathrm{Re}(A_2)} - \frac{\mathrm{Im}(A_0)}{\mathrm{Re}(A_0)}\right] = (21.7 \pm 8.4) \times 10^{-4}$$

ΔI =1/2 rule in Kaon decay

- **$\Delta I = 1/2$ rule**: $\omega = Re(A_0)/Re(A_2) = 22.35 \pm 0.06$
- **A factor of 2** is provided by perturbative QCD correction to the 4-quark operators
- **Dual QCD approach** (1/N expansion method, mainly long-distance contribution)

$\omega = Re(A_0)/Re(A_1) = 16.0 \pm 1.5$ *Eur.Phys.J.C* 74 (2014) 2871

- **RBC-UKQCD Lattice QCD**

$\omega = Re(A_0)/Re(A_1) = 12 \pm 1.7$ PRL110, 152001 (2012)

$\omega = Re(A_0)/Re(A_1) = 31.0 \pm 11.1$ PRD91, 074503, 054509 (2015)

$\omega = Re(A_0)/Re(A_1) = 19.9 \pm 2.3 \pm 4.4$ PRD102, 054509 (2020)

- QCD dynamics is dominantly responsible for the ΔI = 1/2 rule, but new physics contributions at the level of 15% could still be present.

ΔI =1/2 rule in Hyperon decay

- The ΔI =1/2 rule is also applicable in the decay of **hyperons, e.g. $\Lambda \to p\pi^-$ and $\Lambda \to n\pi^0$**

$$S(\Lambda_-) = -\sqrt{\frac{2}{3}} S_{11} e^{i(\delta_{11}^S + \xi_1^S)} + \sqrt{\frac{1}{3}} S_{33} e^{i(\delta_{33}^S + \xi_3^S)}, \qquad S(\Lambda_0) = \sqrt{\frac{1}{3}} S_{11} e^{i(\delta_{11}^S + \xi_1^S)} + \sqrt{\frac{2}{3}} S_{33} e^{i(\delta_{33}^S + \xi_3^S}$$

$$P(\Lambda_-) = -\sqrt{\frac{2}{3}} P_{11} e^{i(\delta_{11}^P + \xi_1^P)} + \sqrt{\frac{1}{3}} P_{33} e^{i(\delta_{33}^P + \xi_3^P)}, \qquad P(\Lambda_0) = \sqrt{\frac{1}{3}} P_{11} e^{i(\delta_{11}^P + \xi_1^P)} + \sqrt{\frac{2}{3}} P_{33} e^{i(\delta_{33}^P + \xi_3^P}$$

- If there no ΔI =3/2 transition in Λ decay

$$\alpha_0/\alpha_- = 1$$

$$\Gamma(\Lambda \to n\pi^0)/\Gamma(\Lambda \to p\pi^-) = 1/2$$

- **Why test ΔI =1/2 rule in Λ decay:**
  - Test the ΔI = 1/2 rule in both S-wave and ***P*-wave**: $S1/S3$ and $P1/P3$
  - ΔI =3/2 transition contributes in CPV of decay width

$$\Delta_{\mathrm{CP}} = \frac{\Gamma - \bar{\Gamma}}{\Gamma + \bar{\Gamma}} = \frac{P_{1,1} P_{3,3} \sin\left(\xi_{1,1}^P - \xi_{3,3}^P\right) \sin\left(\delta_1^P - \delta_3^P\right)}{P_{1,1}^2 + S_{1,1}^2} + \frac{S_{1,1} S_{3,3} \sin\left(\xi_{1,1}^S - \xi_{3,3}^S\right) \sin\left(\delta_1^S - \delta_3^S\right)}{P_{1,1}^2 + S_{1,1}^2}$$

ΔI =1/2 rule in Hyperon decay

- The ΔI =1/2 and ΔI =3/2 amplitudes in Hyperon is related with **decay widths** and **decay asymmetries**

$$\alpha_{[\Lambda]} := \frac{2\alpha_{[\Lambda p]} + \alpha_{[\Lambda n]}}{3} = 2\tilde{S}_1 \tilde{P}_1 \cos\left(\delta_1^P - \delta_1^S\right)\left[1 + \frac{1}{3}\left(1 - 2\tilde{S}_1^2\right)\left(2\Delta_{[\Lambda p]} + \Delta_{[\Lambda n]}\right)\right] \tag{1a}$$

$$\frac{\alpha_{[\Lambda p]} - \alpha_{[\Lambda n]}}{\alpha_{[\Lambda]}} = \frac{-3}{\sqrt{2}}\left[\frac{\tilde{S}_3}{\tilde{S}_1}\frac{\cos\left(\delta_1^P - \delta_3^S\right)}{\cos\left(\delta_1^P - \delta_1^S\right)} + \frac{\tilde{P}_3}{\tilde{P}_1}\frac{\cos\left(\delta_1^S - \delta_3^P\right)}{\cos\left(\delta_1^P - \delta_1^S\right)}\right] + 3\sqrt{2}\left[\tilde{S}_1 \tilde{S}_3 \cos\left(\delta_1^S - \delta_3^S\right) + \tilde{P}_1 \tilde{P}_3 \cos\left(\delta_1^P - \delta_3^P\right)\right] + \left(1 - 2\tilde{S}_1^2\right)\left(\Delta_{[\Lambda p]} - \Delta_{[\Lambda n]}\right) \tag{1b}$$

$$\frac{\Gamma\left(\Lambda \to p\pi^-\right) - 2\Gamma\left(\Lambda \to n\pi^0\right) r_\Lambda}{\Gamma\left(\Lambda \to p\pi^-\right) + \Gamma\left(\Lambda \to n\pi^0\right) r_\Lambda} = -\sqrt{8}\left[\tilde{S}_1 \tilde{S}_3 \cos\left(\delta_1^S - \delta_3^S\right) + \tilde{P}_1 \tilde{P}_3 \cos\left(\delta_1^P - \delta_3^P\right)\right] - \frac{4}{3}\left(\Delta_{[\Lambda p]} - \Delta_{[\Lambda n]}\right)\tilde{P}_1^2 \tag{1c}$$

Decay width $\Gamma\left(\Lambda \to p\pi^-\right) = (64.1 \pm 0.5)\%$; $\Gamma\left(\Lambda \to n\pi^0\right) = (35.9 \pm 0.5)\%$.

Phase-space volumes $r_\Lambda = 0.965815(8)$.

Corrections $\Delta_{[\Lambda p]} = 0.007769(3)$; $\Delta_{[\Lambda n]} = -0.023631(6)$ due to different masses in the kinematical factors.

$N - \pi$ scattering Phase shifts: $\delta_1^S = 6.52(9)$; $\delta_1^P = -0.79(8)$; $\delta_3^S = -4.60(7)$; $\delta_3^P = -0.75(4)$. ($|\mathbf{q}| = 103$ MeV$/c$)

PHYSICAL REVIEW D 105, 116022 (2022)

Hyperon Hadronic Weak Decay

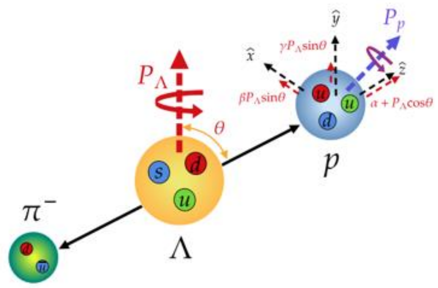
- **Effective Lagranian of the decay:**

$$\mathcal{L} = \frac{eG_F}{2}\bar{B}_f(P + S\gamma_5)\sigma^{\mu\nu}B_iF_{\mu\nu}$$

$$S = \Sigma^i S_i e^{i(\delta_i^S + \xi_i^S)}$$
$$P = \Sigma^i P_i e^{i(\delta_i^P + \xi_i^P)}$$

- i runs the change in isospin ΔI
- δ_i is the strong final-state interaction phase
- ξ_i is the weak interaction phase

- **Observables:**



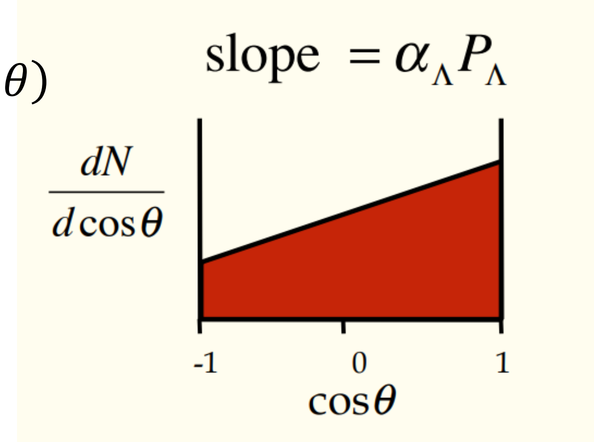
$$\Gamma = \frac{e^2G_F^2}{\pi}\left(|S|^2 + |P|^2\right)$$

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

$$\beta_Y = \sqrt{1-\alpha_Y^2}\sin\phi_Y \qquad \gamma_Y = \sqrt{1-\alpha_Y^2}\cos\phi_Y$$

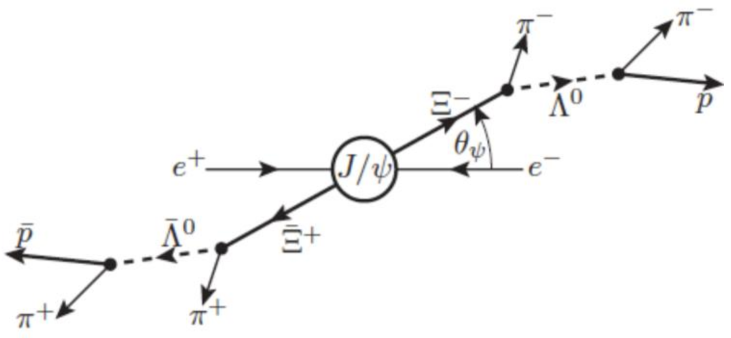
- Anisotropic proton decay distribution

$$\frac{dN}{d\cos\theta} = \frac{N_0}{2}(1 + \alpha_\Lambda P_\Lambda \cos\theta)$$



Hyperon Hadronic Weak Decay at e+e- collider

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



- J/ψ produced almost at rest
- $\Xi^-\bar{\Xi}^+$ produced back-to-back, spin-correlated
- Decay occurs within a few cm of IP
- Low momentum π^- and π^+
- Clean topology, low background rate: 1:400

☐ The first reaction: $J/\psi \to \Xi^-\bar{\Xi}^+$

- Two helicity amplitudes $|J;\ J_z\rangle = |1;\ +1\rangle, |1; -1\rangle$
- Interference between them produces a θ_ψ-dependent production for Ξ hyperons that are spin-polarized:

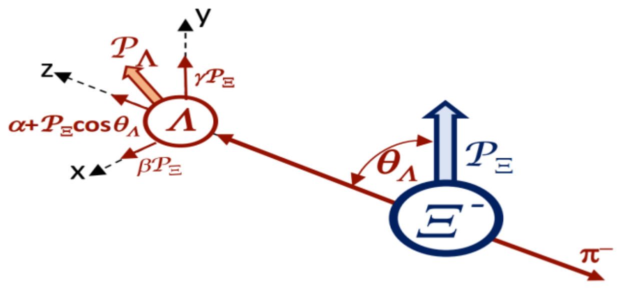
$$\frac{1}{N}\frac{dN}{d\cos\theta_\psi} = \frac{3}{4\pi}\frac{1+\alpha_\psi\cos^2\theta_\psi}{3+\alpha_\psi}$$

$$\mathcal{P}_\Xi = \frac{\sqrt{1-\alpha_\psi^2}\sin\theta_\psi\cos\theta_\psi\sin\Delta\Phi}{1+\alpha_\psi\cos^2\theta_\psi},$$

衰变道	α_ψ	$\Delta\Phi_\psi$	最大极化率（%）
$J/\psi \to \Lambda\bar{\Lambda}$	$0.475 \pm 0.002 \pm 0.003$	$0.752 \pm 0.004 \pm 0.007$	24.7
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	$-0.508 \pm 0.006 \pm 0.004$	$-0.270 \pm 0.012 \pm 0.009$	16.4
$J/\psi \to \Xi^-\bar{\Xi}^+$	$0.586 \pm 0.012 \pm 0.010$	$1.213 \pm 0.046 \pm 0.016$	30.1
$J/\psi \to \Xi^0\bar{\Xi}^0$	$0.514 \pm 0.006 \pm 0.015$	$1.168 \pm 0.019 \pm 0.018$	32.1

Hyperon Hadronic Weak Decay at e$^+$e$^-$ collider

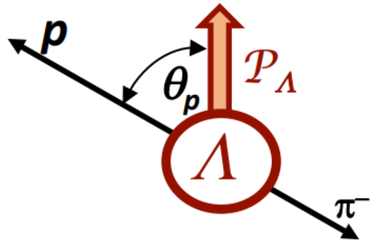
- **The next two reactions: $\Xi^- \to \Lambda\pi^-(\bar{\Xi}^+ \to \bar{\Lambda}\pi^+)$**
  - In Ξ^- and $\bar{\Xi}^+$ rest frames: $\frac{dN}{d\cos\theta_\Lambda} \propto 1 + \alpha_\Xi \mathcal{P}_\Xi \cos\theta_\Lambda$



$$\mathbf{P}_\Lambda = \frac{(\alpha_\Xi + \mathcal{P}_\Xi \cos\theta_\Lambda)\hat{\mathbf{z}} + \mathcal{P}_\Xi\beta_\Xi\hat{\mathbf{x}} + \mathcal{P}_\Xi\gamma_\Xi\hat{\mathbf{y}}}{1 + \alpha_\Xi\mathcal{P}_\Xi\cos\theta_\Lambda}$$

  - The decay angle $\theta_\Lambda(\theta_{\bar{\Lambda}})$ relative to P_Ξ direction
  - P_Λ is polarization of Λ with $\hat{x}$, $\hat{y}$, $\hat{z}$ oriented in helicity frame
  - **α, β, γ are the Lee-Yang decay parameters of Ξ** that can be determined with $\frac{dN}{d\cos\theta}$ and P_Λ

- **The last two reactions: $\Lambda \to p\pi^-(\bar{\Lambda} \to \bar{n}\pi^0)$**
  - In Λ and $\bar{\Lambda}$ rest frames: $\frac{dN}{d\cos\theta_p} \propto 1 + \alpha_\Lambda\mathcal{P}_\Lambda\cos\theta_p$.



  - The decay angle $\theta_p(\theta_{\bar{p}})$ relative to P_Λ direction
  - Only **α of Λ can be determined** since proton polarization is not measured.

A joint angular analysis of $J/\psi \to \Xi^- \bar{\Xi}^+$

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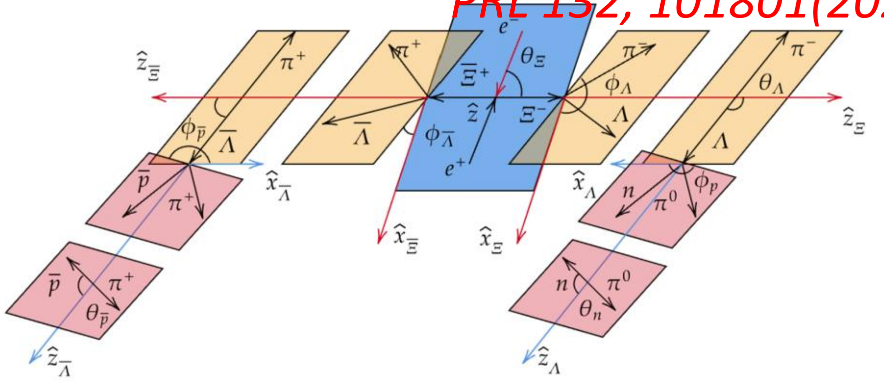


$$e^+e^- \to J/\psi \to \Xi^-\bar{\Xi}^+ \to \Lambda(\to n\pi^0)\pi^-\bar{\Lambda}(\to \bar{p}^-\pi^+)\pi^+, \text{(neutron channel)}$$

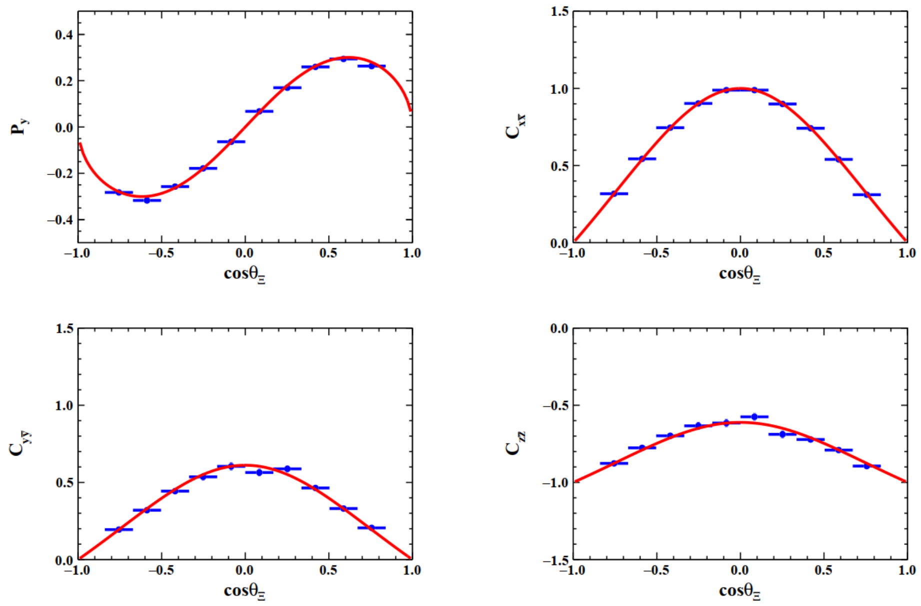
$$e^+e^- \to J/\psi \to \Xi^-\bar{\Xi}^+ \to \Lambda(\to p^+\pi^-)\pi^-\bar{\Lambda}(\to \bar{n}\pi^0)\pi^+. \text{(anti-neutron channel)}$$

$$\mathcal{W}(\xi;\omega) = \sum_{\mu,v=0}^{3} C_{\mu v} \sum_{\mu',v'=0}^{3} a^{\Xi}_{\mu\mu'} a^{\Xi}_{vv'} a^{\Lambda}_{\mu'0} a^{\bar{\Lambda}}_{v'0}$$

- Spin density matrix ($J/\psi \to \Xi^-\bar{\Xi}^+$):

$$C_{\mu\bar{v}} = 2 \times \begin{pmatrix} 1+\alpha_\psi \cos^2\theta & 0 & \beta_\psi \sin\theta\cos\theta & 0 \\ 0 & \sin^2\theta & 0 & \gamma_\psi \sin\theta\cos\theta \\ -\beta_\psi \sin\theta\cos\theta & 0 & \alpha_\psi \sin^2\theta & 0 \\ 0 & -\gamma_\psi \sin\theta\cos\theta & 0 & -(\alpha_\psi + \cos^2\theta) \end{pmatrix}$$

$$\beta_\psi = \sqrt{1-\alpha_\psi^2}\sin(\Delta\Phi) \quad \gamma_\psi = \sqrt{1-\alpha_\psi^2}\cos(\Delta\Phi)$$

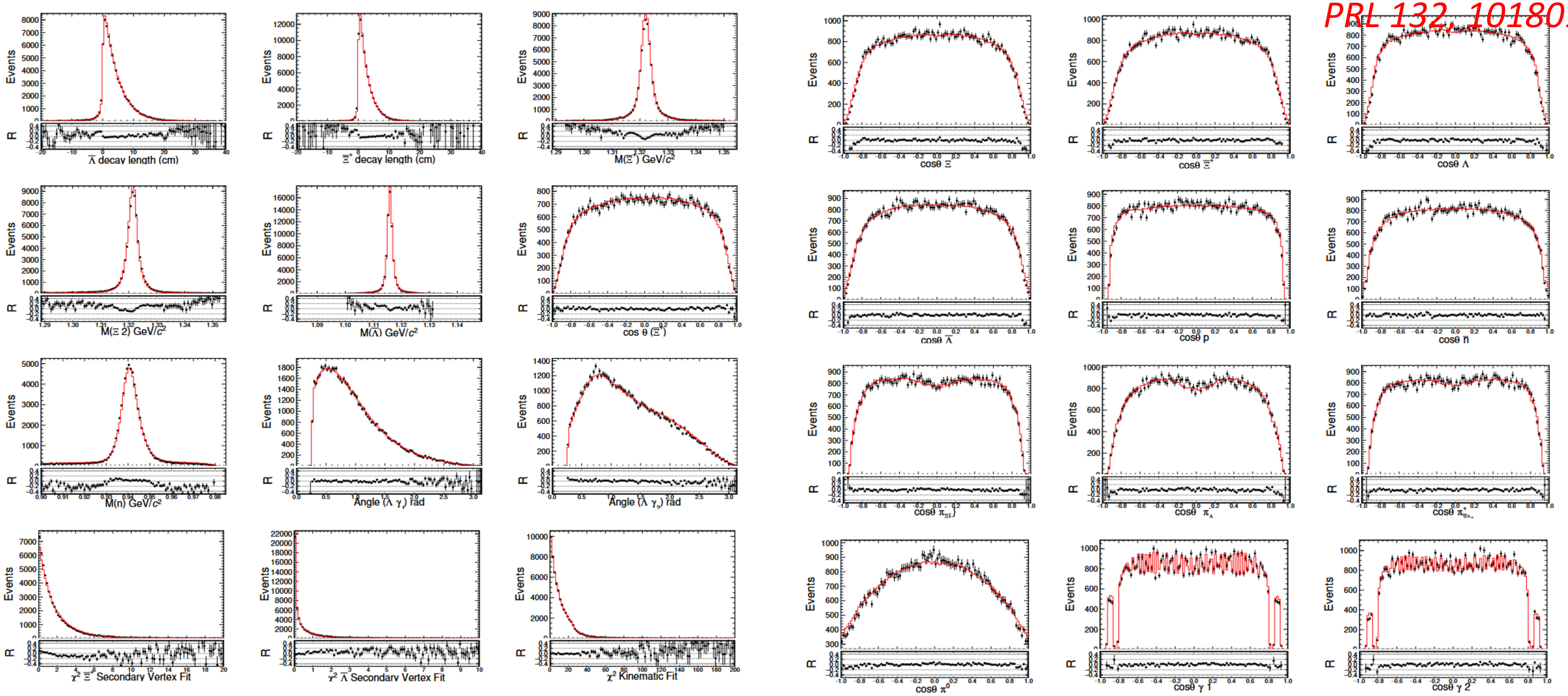


- For $\frac{1}{2}^+ \to \frac{1}{2}^+ + 0^-$decay ($\Xi^- \to \Lambda\pi^-$):

$$a^{\Xi}_{\bar{h}} = \begin{pmatrix} 1 & 0 & 0 & \alpha \\ \alpha\cos\phi\sin\theta & \gamma\cos\theta\cos\phi - \beta\sin\phi & -\beta\cos\theta\cos\phi - \gamma\sin\phi & \sin\theta\cos\phi \\ \alpha\sin\theta\sin\phi & \beta\cos\phi + \gamma\cos\theta\sin\phi & \gamma\cos\phi - \beta\cos\theta\sin\phi & \sin\theta\sin\phi \\ \alpha\cos\theta & -\gamma\sin\theta & \beta\sin\theta & \cos\theta \end{pmatrix}$$

A joint angular analysis of $J/\psi \to \Xi^-\bar{\Xi}^+$

PRL 132, 101801(2024)



The fit yields 143973±414 signal events and a purity of 91.2%.
Good consistence between data and simulation

A joint angular analysis of $J/\psi \to \Xi^- \bar{\Xi}^+$

- **Production parameters** are consistent with previous results, verifying the polarization and spin correlation.
- Precision of $\boldsymbol{\alpha_0}$ **and** $\boldsymbol{\bar{\alpha}_0}$ are improved by factor of 4 and 1.7.
- **Strong and weak-phase** difference are measured.

$$(\delta_P - \delta_S)_{\mathrm{SM}} = (1.9 \pm 4.9) \times 10^2 \ \mathrm{rad}$$

$$(\xi_P - \xi_S)_{\mathrm{SM}} = (1.8 \pm 1.5) \times 10^4 \ \mathrm{rad}$$

$$(\delta_P - \delta_S)_{\mathrm{HyperCP}} = (10.2 \pm 3.9) \times 10^2 \ \mathrm{rad}$$

- **Four CP observables** are constructed from decay parameters.

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

Disparity in Λ decay that reveals ΔI =1/2 rule

Test of CP violation

$$R\left(\cos\theta_p, \cos\theta_{\bar{p}}\right) = \frac{1 + \alpha_{\Lambda-}\alpha_{\Xi}\cos\theta_p}{1 + \alpha_{\Lambda+}\bar{\alpha}_{\Xi}\cos\theta_{\bar{p}}}$$

Test of $\Delta I = 1/2$ rule

$$R\left(\cos\theta_n, \cos\theta_p\right) = \frac{1 + \alpha_{\Lambda 0}\alpha_{\Xi}\cos\theta_n}{1 + \alpha_{\Lambda-}\alpha_{\Xi}\cos\theta_p}$$

The average of the ratio

$$\langle\alpha_{\Lambda 0}\rangle / \langle\alpha_{\Lambda-}\rangle = 0.870 \pm 0.012^{+0.011}_{-0.010}$$

Consistent with kaon decay

$$S_1/S_3 = 28.4 \pm 1.3^{+1.1}_{-1.0} \pm 3.9$$

$$P_1/P_3 = -13.0 \pm 1.4^{+1.1}_{-1.2} \pm 0.7$$

Observed for the first time, different from S-wave

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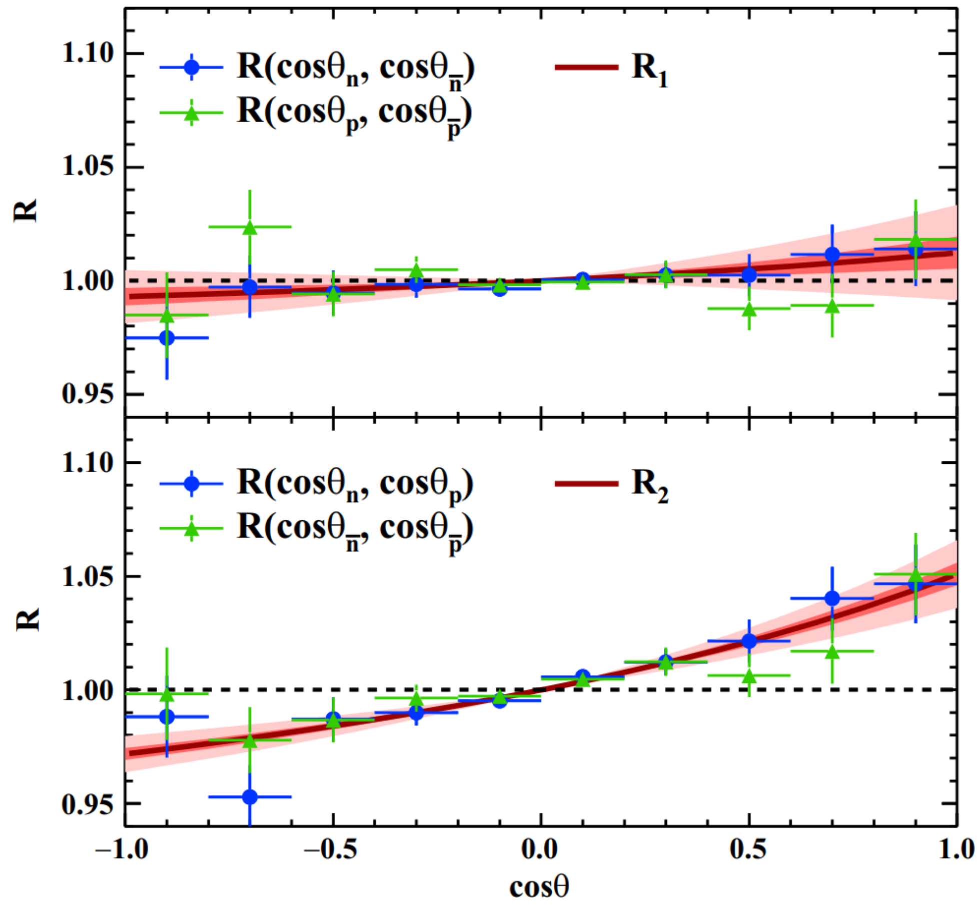


S/P wave puzzle

- Three parameters fully describe the hyperon hadronic weak decays:

$$\Gamma = \frac{e^2 G_F^2}{\pi}\left(|S|^2 + |P|^2\right) \qquad \alpha_Y = \frac{2\mathrm{Re}(S^* P)}{|S|^2 + |P|^2} \qquad \phi_Y = \sin^{-1}\frac{\beta_Y}{\sqrt{1-\alpha_Y^2}}$$

S/P wave puzzle: the S wave in hyperon decay follows SU(3) symmetry, while the P wave doesn't.

In the ChPT, if the two low energy constants can describe well the experimental S-wave amplitudes, they reproduce very poorly the P-wave amplitudes

It is the S/P wave puzzle that limits the precision of SM predictions of CPV!

$$\alpha_Y |= \frac{2|S_Y||P_Y|\cos\left((\delta^P_{y\pi} - \delta^S_{y\pi}) + (\xi^P_Y - \xi^S_Y)\right)}{|S_Y|^2 + |P_Y|^2}$$

$$\alpha_{\bar{Y}} = -\frac{2|S_Y||P_Y|\cos\left((\delta^P_{y\pi} - \delta^S_{y\pi}) - (\xi^P_Y - \xi^S_Y)\right)}{|S_Y|^2 + |P_Y|^2}$$

$$\mathcal{A}^Y_{CP} \equiv \frac{\alpha_Y + \alpha_{\bar{Y}}}{\alpha_Y - \alpha_{\bar{Y}}} = -\sin\left(\delta^P_{y\pi} - \delta^S_{y\pi}\right)\sin\left(\xi^P_Y - \xi^S_Y\right)$$

$$\mathcal{B}^\Xi_{CP} \equiv \frac{\beta_\Xi + \beta_{\bar{\Xi}}}{\alpha_\Xi - \alpha_{\bar{\Xi}}} = \tan\left(\xi^P_\Xi - \xi^S_\Xi\right) \approx \xi^P_\Xi - \xi^S_\Xi$$

CPV observables	SM predictions	BESIII data
A^Λ_{CP}	$(-3\sim3)\times10^{-5}$	$(-2.5\pm4.6\pm1.2)\times10^{-3}$
A^Ξ_{CP}	$(0.5\sim6)\times10^{-5}$	$(6\pm13.4\pm5.6)\times10^{-3}$
B^Ξ_{CP}	$(-3.8\sim-0.3)\times10^{-4}$	$(1.2\pm3.4\pm0.8)\times10^{-2}$

S/P wave puzzle

- Using the **ChPT approaches**, with updated decay parameters, the updated S-wave and P-wave are obtained (R.X. Shi, L.S. Geng, *Sci.Bull*. 68 (2023) 779-782).
- The **P-wave in $\Lambda \to p\pi^-$ and $\Xi^- \to \Lambda\pi^-$ differs a lot from** E. E. Jenkins, NPB 375, 561 (1992)
- It could be improved with updated α_0 from $\Lambda \to n\pi^0$

TABLE V. Experimental S- and P-wave hyperon non-leptonic decay amplitudes extracted from the most recent pdgLive [3], BESIII measurements [51, 52] and CLAS data [53].

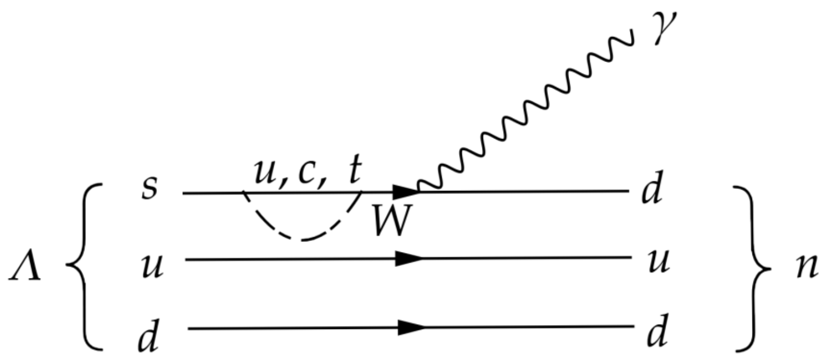
Decay modes	$\mathcal{B}$ [3]	α_π [3, 51–53]	ϕ_π (°) [3, 52]	$s = A_S^{(\mathrm{Expt})}$		$p = A_P^{(\mathrm{Expt})}\lvert\vec{q}\rvert/(E_f + m_f)$	
				This work	[49]	This work	[49]
$\Sigma^+ \to n\pi^+$	0.4831(30)	0.068(13)	167(20)	0.06(1)	0.06(1)	1.81(1)	1.81(1)
$\Sigma^- \to n\pi^-$	0.99848(5)	−0.068(8)	10(15)	1.88(1)	1.88(1)	−0.06(1)	−0.06(1)
$\Lambda \to p\pi^-$	0.639(5)	0.7462(88)	−6.5(35)	1.38(1)	1.42(1)	0.62(1)	0.52(2)
$\Xi^- \to \Lambda\pi^-$	0.99887(35)	−0.376(8)	0.6(12)	−1.99(1)	−1.98(1)	0.39(1)	0.48(2)
$\Sigma^+ \to p\pi^0$	0.5157(30)	−0.982(14)	36(34)	−1.50(3)	−1.43(5)	1.29(4)	1.17(7)
$\Lambda \to n\pi^0$	0.358(5)	0.74(5)	···	−1.09(2)	−1.04(1)	−0.48(4)	−0.39(4)
$\Xi^0 \to \Lambda\pi^0$	0.99524(12)	−0.356(11)	21(12)	1.62(10)	1.52(2)	−0.30(10)	−0.33(2)

Updated one: $0.670 \pm 0.009^{+0.009}_{-0.008}$

Weak Radiative Hyperon Decay

- The radiative decay was thought to be a simple reaction since it is free of final-state interaction.
- There are seven WRHD processes:

$B_i \to \gamma B_f$	$BF(10^{-3})$	α_γ
$\Lambda \to \gamma n$	1.75±0.15	–
$\Sigma^+ \to \gamma p$	1.23 ± 0.05	-0.76 ± 0.08
$\Sigma^0 \to \gamma n$	–	–
$\Xi^0 \to \gamma\Lambda$	1.17 ± 0.07	-0.70 ± 0.07
$\Xi^0 \to \gamma\Sigma^0$	3.33 ± 0.10	-0.69 ± 0.06
$\Xi^- \to \gamma\Sigma^-$	1.27 ± 0.23	1.0 ± 1.3
$\Omega^- \to \gamma\Xi^-$	$< 0.46(90\%C.L.)$	–



- Effective Lagrangian

$$\mathcal{L} = \frac{eG_F}{2}\bar{B}_f\left(a^{\mathrm{PC}} + b^{\mathrm{PV}}\gamma_5\right)\sigma^{\mu\nu}B_i F_{\mu\nu}$$

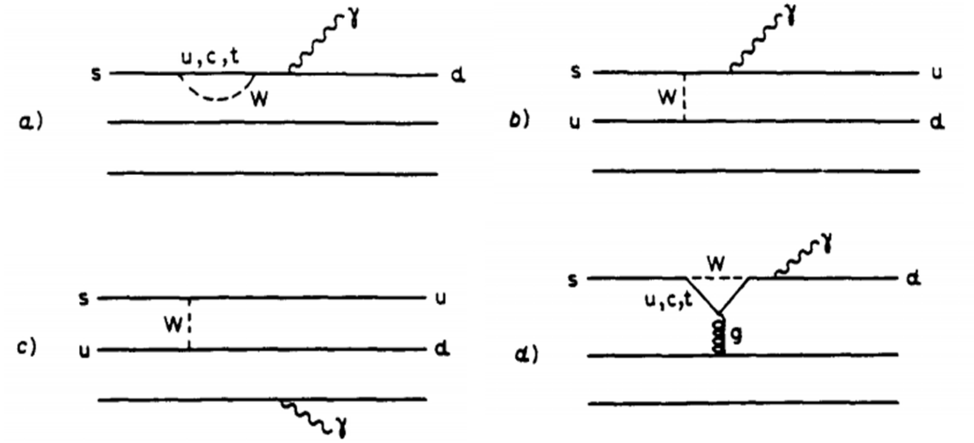
- Observables:

$$\Gamma = \frac{e^2G_F^2}{\pi}\left(|a|^2 + |b|^2\right)\cdot\left|\vec{k}\right|^3,$$

$$\alpha_\gamma = \frac{2\mathrm{Re}(ab^*)}{|a|^2+|b|^2}$$

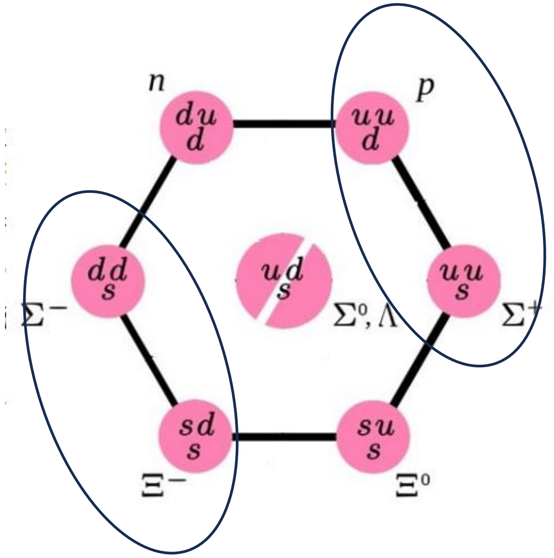
“Hara theorem” for WRHD

- Most attempts study the **single quark transition operator for $s \to d\gamma$**. The remaining two quarks are assumed to be spectators.



- **The “Hara theorem”:**
  - The U-spin properties of the weak and EM Hamiltonian imply that the PV part of the radiative weak decay vanishes in **U-spin symmetry**
  - If one assumes that m_d != m_s, the ratio of PV amplitude to PC is $(m_s-m_d)/(m_s+m_d)$ implying **small but positive asymmetry parameter**.

- For a U-spin doublet such as p, Σ^+, or Σ^-, Ξ^-, Hara theorem requires the **PV amplitudes vanish**



“Hara theorem” for WRHD

PHYSICAL REVIEW VOLUME 188, NUMBER 5 25 DECEMBER 1969

Asymmetry Parameter and Branching Ratio of $\Sigma^+ \to p\gamma$*

Lawrence K. Gershwin,† Margaret Alston-Garnjost, Roger O. Bangerter, Angela Barbaro-Galtieri, Terry S. Mast, Frank T. Solmitz, and Robert D. Tripp
Lawrence Radiation Laboratory, University of California, Berkeley, California 94720

(Received 25 August 1969)

An experiment to study the decay $\Sigma^+ \to p\gamma$ was performed in the Berkeley 25-in. hydrogen bubble chamber. An analysis was made of 48 000 events of the type $K^- p \to \Sigma^+\pi^-$, $\Sigma^+ \to p +$neutral with K^- momenta near 400 MeV/c. The Σ's produced in this momentum region are polarized because of the interference of the Y_0^* (1520) amplitude with the background amplitudes. We have measured the proton asymmetry parameter α for 61 $\Sigma^+ \to p\gamma$ events with an average polarization of 0.4. We found $\alpha = -1.03_{-0.42}^{+0.52}$. $SU(3)$ predicts a value $\alpha = 0$. A more restricted sample of events was used to determine the $\Sigma^+ \to p\gamma$ branching ratio. From 31 $\Sigma^+ \to p\gamma$ events and 11 670 $\Sigma^+ \to p\pi^0$ events, we found $(\Sigma^+ \to p\gamma)/(\Sigma^+ \to p\pi^0) = (2.76 \pm 0.51) \times 10^{-3}$. The result is in agreement with the previous measurements.

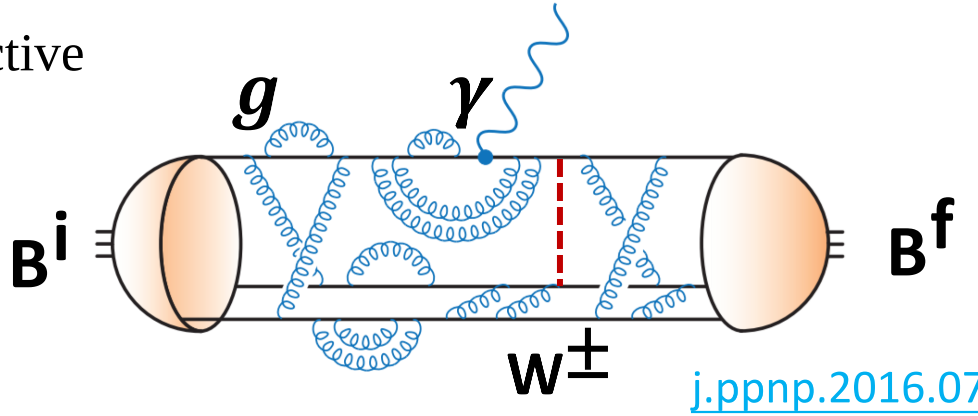
A single quark transition model is inadequate in describing the baryon radiative weak decays

"Hara theorem" for WRHD

- **Non-pQCD effect plays a essential role**, low energy effective theories needed
- A symphony of **strong**, **weak** and **EM** interaction

Decay modes	Data [6, 7, 21, 23]	Broken SU(3) model [11]	QM [12]	NRCQM [13]
	$\mathcal{B} \times 10^{-3}$			
$\Lambda \to n\gamma$	0.832(38)(54)	0.77	1.84	1.83(96)
$\Sigma^+ \to p\gamma$	0.996(21)(18)	0.72	1.30	1.06(59)
$\Sigma^0 \to n\gamma$	···	···	4.3×10^{-9}	10^{-10}
$\Xi^0 \to \Lambda\gamma$	1.17(7)	1.02	0.93	0.96(32)
$\Xi^0 \to \Sigma^0\gamma$	3.33(10)	4.42	3.82	9.75(418)
$\Xi^- \to \Sigma^-\gamma$	0.127(23)	0.16	0.13	···
	α_γ			
$\Lambda \to n\gamma$	−0.16(10)(5)	−0.93	−0.94	−0.67(6)
$\Sigma^+ \to p\gamma$	−0.652(56)(20)	−0.67	−0.74	−0.58(6)
$\Sigma^0 \to n\gamma$	···	···	0.01	0.37(4)
$\Xi^0 \to \Lambda\gamma$	−0.704(19)(64)	−0.97	−0.64	0.72(11)
$\Xi^0 \to \Sigma^0\gamma$	−0.69(6)	−0.92	−0.52	0.33(4)
$\Xi^- \to \Sigma^-\gamma$	1.0(13)	0.8	0.76	···

- The WRHD provide low-energy constants constraints, that will bring inputs for Semi-leptonic decay and weak hadronic decay
- **However, there is no one unified model to describe all WRHDs in a satisfied way.**



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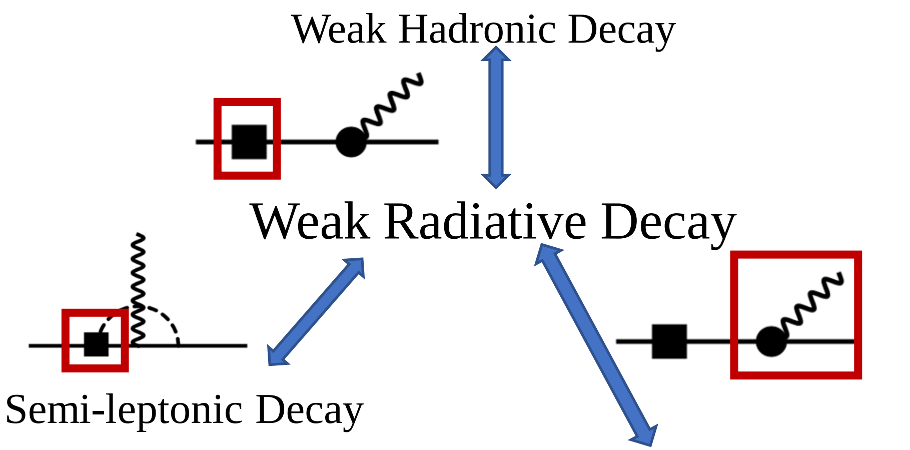

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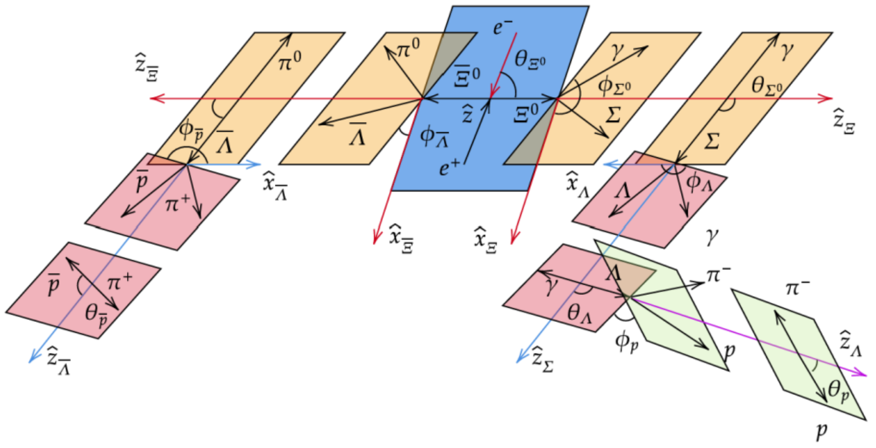
Joint angular analysis for WRHD at e^+e^- collider

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



For $J/\psi \to \Xi^0\bar{\Xi}^-$

$$C_{\mu\nu} = \begin{pmatrix} 1+\alpha_\psi \cos^2\theta_{\Xi^0} & 0 & \beta_\psi \sin\theta_{\Xi^0}\cos\theta_{\Xi^0} & 0 \\ 0 & \sin^2\theta_{\Xi^0} & 0 & \gamma_\psi \sin\theta_{\Xi^0}\cos\theta_{\Xi^0} \\ -\beta_\psi \sin\theta_{\Xi^0}\cos\theta_{\Xi^0} & 0 & \alpha_\psi \sin^2\theta_{\Xi^0} & 0 \\ 0 & -\gamma_\psi \sin\theta_{\Xi^0}\cos\theta_{\Xi^0} & 0 & -(\alpha_\psi + \cos^2\theta_{\Xi^0}) \end{pmatrix}$$

For $\frac{1}{2}^+ \to \frac{1}{2}^+ + 0^-$ decay ($\Xi^0 \to \Lambda\pi^0$)

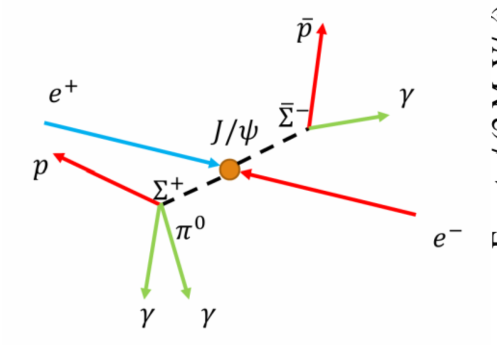
$$a_{\mu\mu'} = \begin{pmatrix} 1 & 0 & 0 & \alpha \\ \alpha\cos\phi\sin\theta & \gamma\cos\phi\cos\theta - \beta\sin\phi & -\beta\cos\phi\cos\theta - \gamma\sin\phi & \cos\phi\sin\theta \\ \alpha\sin\phi\sin\theta & \beta\cos\phi + \gamma\cos\theta\sin\phi & \gamma\cos\phi - \beta\cos\theta\sin\phi & \sin\phi\sin\theta \\ \alpha\cos\theta & -\gamma\sin\theta & \beta\sin\theta & \cos\theta \end{pmatrix}$$

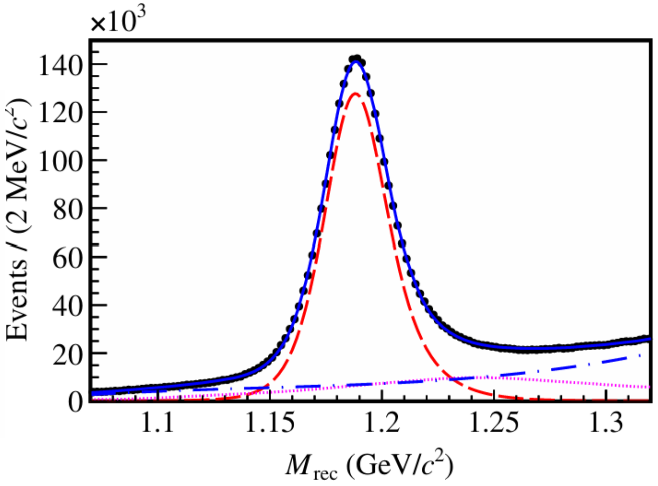
For $\frac{1}{2}^+ \to \frac{1}{2}^+ + 1^-$ decay ($\Xi^0 \to \Sigma^0\gamma$)

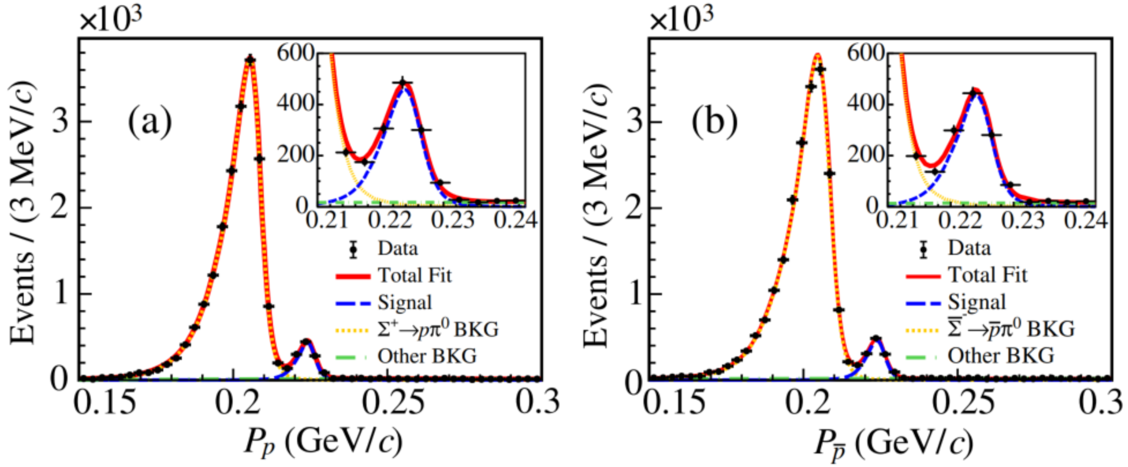
$$b_{\nu\nu'} = \begin{pmatrix} 1 & 0 & 0 & -\alpha \\ \alpha\cos\phi\sin\theta & 0 & 0 & -\cos\phi\sin\theta \\ \alpha\sin\theta\sin\phi & 0 & 0 & -\sin\theta\sin\phi \\ \alpha\cos\theta & 0 & 0 & -\cos\theta \end{pmatrix}$$

WRHD process $\Sigma^+ \to p\gamma$

PRL130, 211901 (2023)







Double-tag method:

$$N_{ST} = N_{J/\psi\to\Sigma^+\bar{\Sigma}^-} \times \mathcal{B}_{\bar{\Sigma}^-\to\bar{p}\pi^0} \times \varepsilon_{ST}$$

$$N_{DT} = N_{J/\psi\to\Sigma^+\bar{\Sigma}^-} \times \mathcal{B}_{\bar{\Sigma}^-\to\bar{p}\pi^0} \times \mathcal{B}_{\Sigma^+\to p\gamma} \times \varepsilon_{DT}$$

$$\mathcal{B}_{\Sigma^+\to p\gamma} = \frac{N_{DT}}{N_{ST}} \times \frac{\varepsilon_{ST}}{\varepsilon_{DT}}$$

Modes	$\Sigma^+ \to p\gamma$	$\bar{\Sigma}^- \to \bar{p}\gamma$
ST Yield	2 177 771 ± 2285	2 509 380 ± 2301
ST Eff (%)	39.02	44.31
DT Eff (%)	21.16	23.20
Individual BF	$(1.007 \pm 0.032) \times 10^{-3}$	$(0.994 \pm 0.030) \times 10^{-3}$
Simultaneous BF	$(0.997 \pm 0.022) \times 10^{-3}$	

WRHD process $\Sigma^+ \to p\gamma$

PRL130, 211901 (2023)

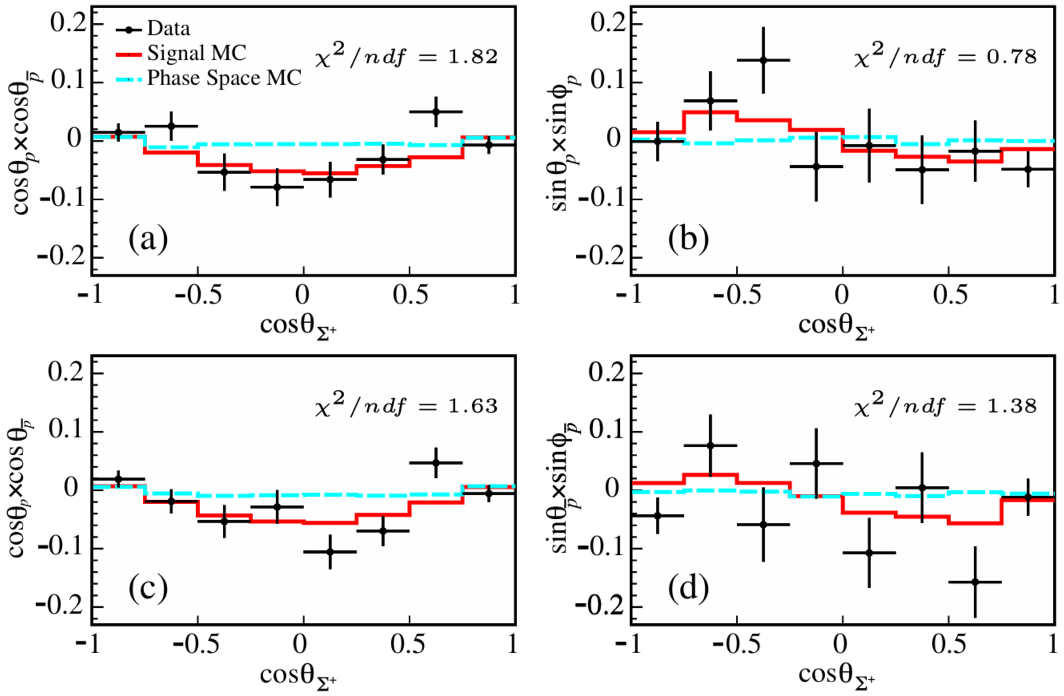
$$\mathcal{L} = \prod_{i=1}^{N} \frac{\mathcal{W}_i(\xi, H)}{\mathcal{N}} \qquad \mathcal{N} = \frac{1}{N_{\mathrm{MC}}} \sum_{j=1}^{N_{\mathrm{MC}}} \mathcal{W}_i^{\mathrm{MC}}(\xi, H)$$

- $\mathcal{W}_i$: differential cross section
- $\mathcal{N}$: normalization factor based on PHSP MC
- $H = \left(\alpha_{J/\psi}, \Delta\Phi_{\Psi}, \alpha_{\Sigma^+\to p\gamma}, \alpha_{\bar{\Sigma}^-\to\bar{p}\pi^0}\right)$

$$M_1(\cos\theta_{\Sigma^+}) = \frac{m}{N}\sum_{i=1}^{N_k} \cos\theta_{\bar{p}}^i \cos\theta_p^i,$$

$$M_2(\cos\theta_{\Sigma^+}) = \frac{m}{N}\sum_{i=1}^{N_k} \sin\theta_p^i \sin\phi_p^i,$$

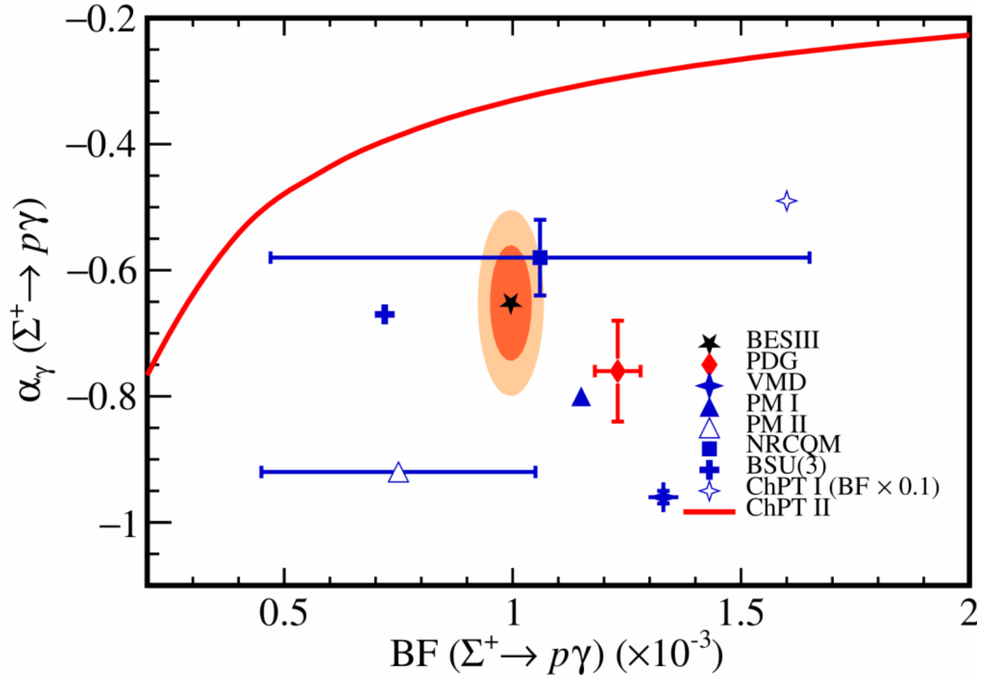
Parameter	value
α_ψ	-0.508 ± 0.006
$\Delta\Phi$	-0.270 ± 0.012
$\alpha_{\Sigma^+\to p\pi^0}$	-0.980 ± 0.017
$\alpha_{\Sigma^+\to p\gamma}$	**Iterated from this analysis**



Processes	$\Sigma^+ \to p\gamma$	$\bar{\Sigma}^- \to \bar{p}\gamma$
Individual fit	-0.587 ± 0.082	0.710 ± 0.076
Simultaneous fit	-0.651 ± 0.056	

WRHD process $\Sigma^+ \to p\gamma$

PRL130, 211901 (2023)



Mode	$\Sigma^+ \to p\gamma$	$\bar{\Sigma}^- \to \bar{p}\gamma$
N_{ST}^{obs}	$2\,177\,771 \pm 2285$	$2\,509\,380 \pm 2301$
ε_{ST} (%)	39.00 ± 0.04	44.31 ± 0.04
N_{DT}^{obs}	1189 ± 38	1306 ± 39
ε_{DT} (%)	21.16 ± 0.03	23.20 ± 0.03
Individual BF (10^{-3})	1.005 ± 0.032	0.993 ± 0.030
Simultaneous BF (10^{-3})	$0.996 \pm 0.021 \pm 0.018$	
Individual α_γ	-0.587 ± 0.082	0.710 ± 0.076
Simultaneous α_γ	$-0.651 \pm 0.056 \pm 0.020$	

- The **accuracies** of the BF and α_γ are **improved by 78% and 34%**
- The measured BF is **lower than the world average value by 4.2σ**
- The accurate result will provide **input and constraints for ChPT**

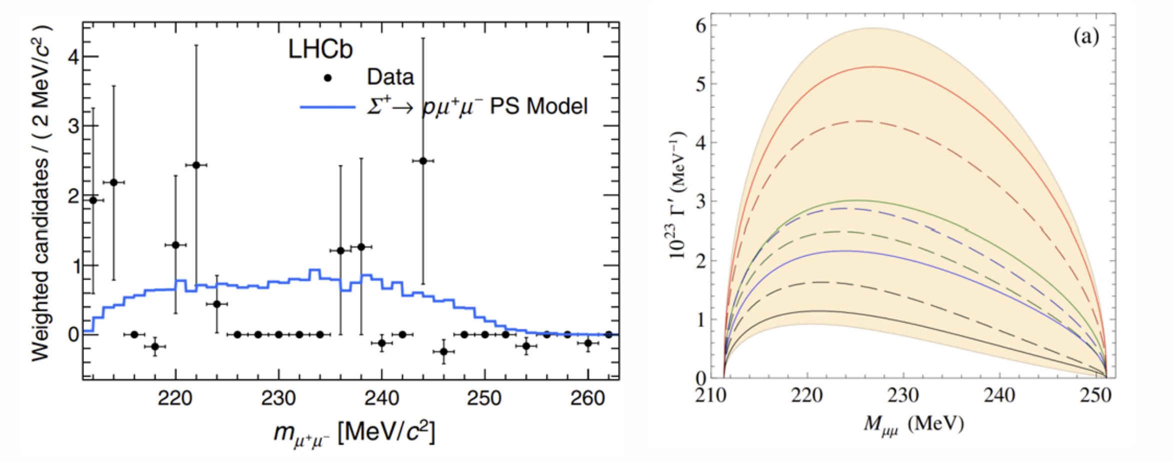
WRHD process $\Sigma^+ \to p\gamma$

PRL130, 211901 (2023)

Input for new physics in $\Sigma^+ \to pl^+l^-$

- Smoke screen of new physics in $\Sigma+ \to p\mu+\mu-$ decay PRL94 (2005) 021801, PRL120 (2018) 22, 22180

- Experiment results of WRHDs provide SM expectations on such decays – narrowing the range for NP!



CP observables:

$$\Delta_{CP} = \frac{\mathcal{B}_+ - \mathcal{B}_-}{\mathcal{B}_+ + \mathcal{B}_-} = 0.006 \pm 0.011_{\text{stat.}} \pm 0.004_{\text{syst.}},$$

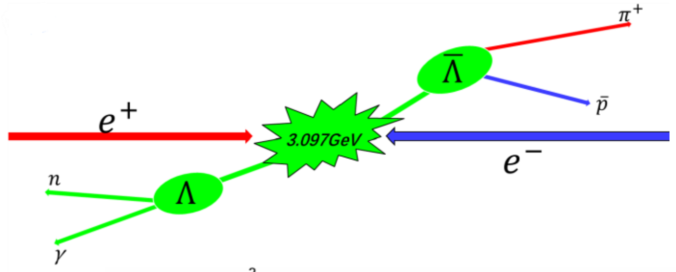
$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+} = 0.095 \pm 0.087_{\text{stat.}} \pm 0.018_{\text{syst.}}.$$

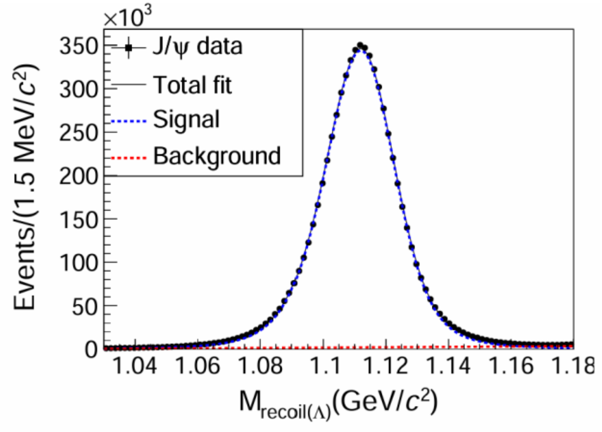
- May be significantly enhanced by NP up to $\mathcal{O}$ 10 % (PRL109 (2012), 171801, JHEP 01 (2013) 027, JHEP 04 (2017) 027, JHEP 08 (2017) 09
- Extensive experimental studies on K, D and B meson radiative decays

SM on $\Sigma^+ \to p\gamma$	Δ_{CP}	A_{CP}
PhysRevD.51.2271	$10^{-5} - 10^{-4}$	
Commun. Theor. Phys. 19.475		$10^{-5} - 10^{-4}$
arxiv:2312.17568	2×10^{-5}	

WRHD process $\Lambda \to n\gamma$

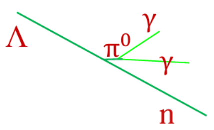
PRL 129, 212002 (2022)





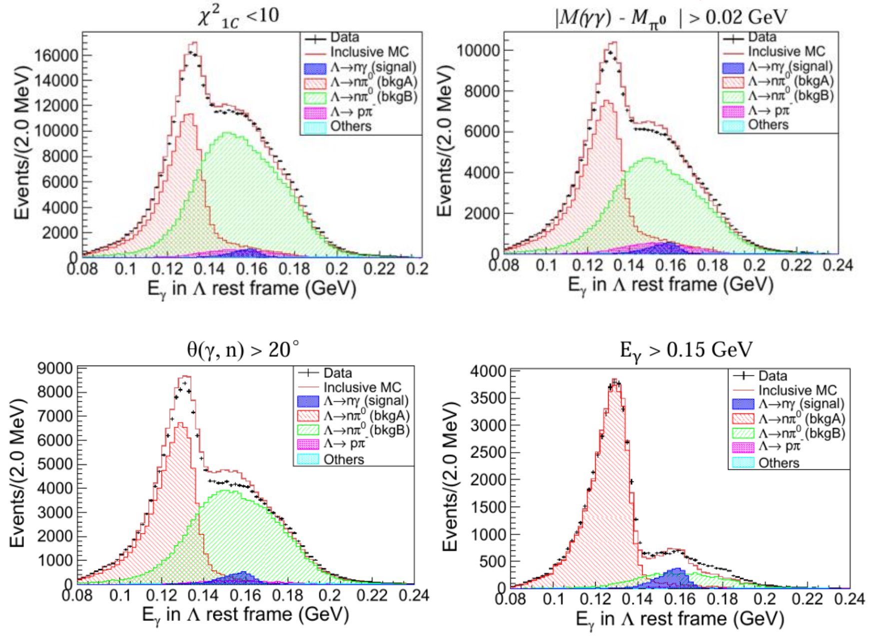
- **Dominant background:**

$\Lambda \to n\pi^0$

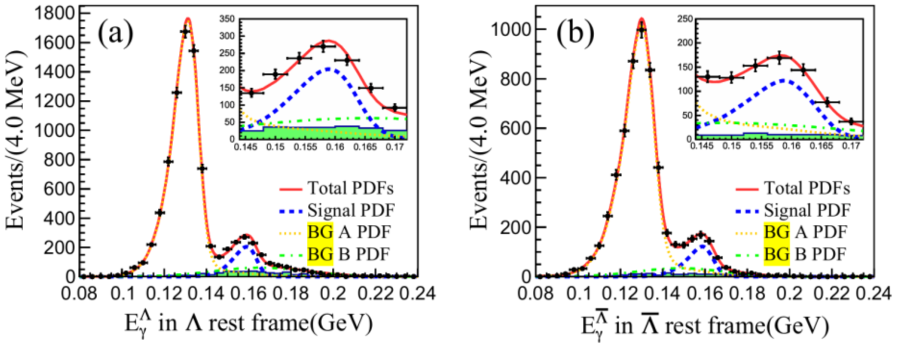


- **BKG A: photon candidate is from π^0 decay.**
- **BKG B: photon candidate is not from π^0 decay.**

- **Sources of noise photons:**
- **(Anti-)neutron-related secondary shower;**
- **Mis-identification of photons and neutron showers;**
- **Noise showers from beam-BKG.**



After further BDT selection



Decay mode	$\Lambda \to n\gamma$	$\bar{\Lambda} \to \bar{n}\gamma$
$N_{\rm ST}$ ($\times 10^3$)	6853.2 ± 2.6	7036.2 ± 2.7
$\varepsilon_{\rm ST}$ (%)	51.13 ± 0.01	52.53 ± 0.01
$N_{\rm DT}$	723 ± 40	498 ± 41
$\varepsilon_{\rm DT}$ (%)	6.58 ± 0.04	4.32 ± 0.03
BF ($\times 10^{-3}$)	$0.820 \pm 0.045 \pm 0.066$	$0.862 \pm 0.071 \pm 0.084$
	$0.832 \pm 0.038 \pm 0.054$	
α_γ	$-0.13 \pm 0.13 \pm 0.03$	$0.21 \pm 0.15 \pm 0.06$
	$-0.16 \pm 0.10 \pm 0.05$	

WRHD process $\Lambda \to n\gamma$

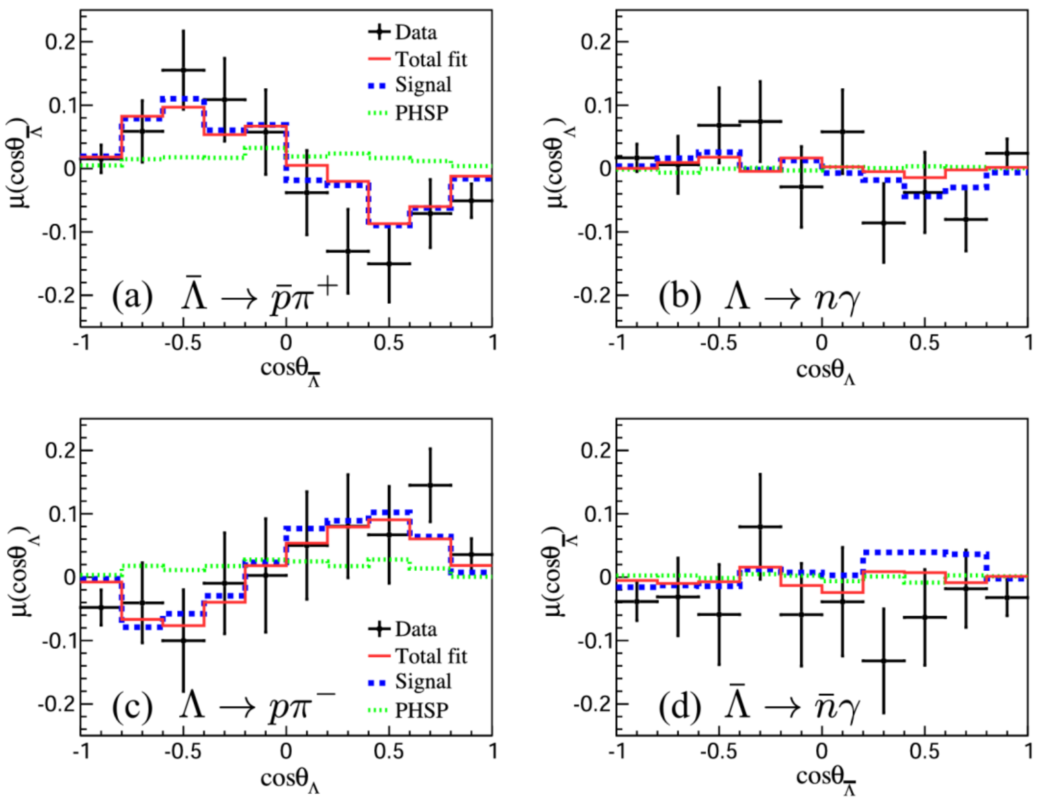
PRL 129, 212002 (2022)

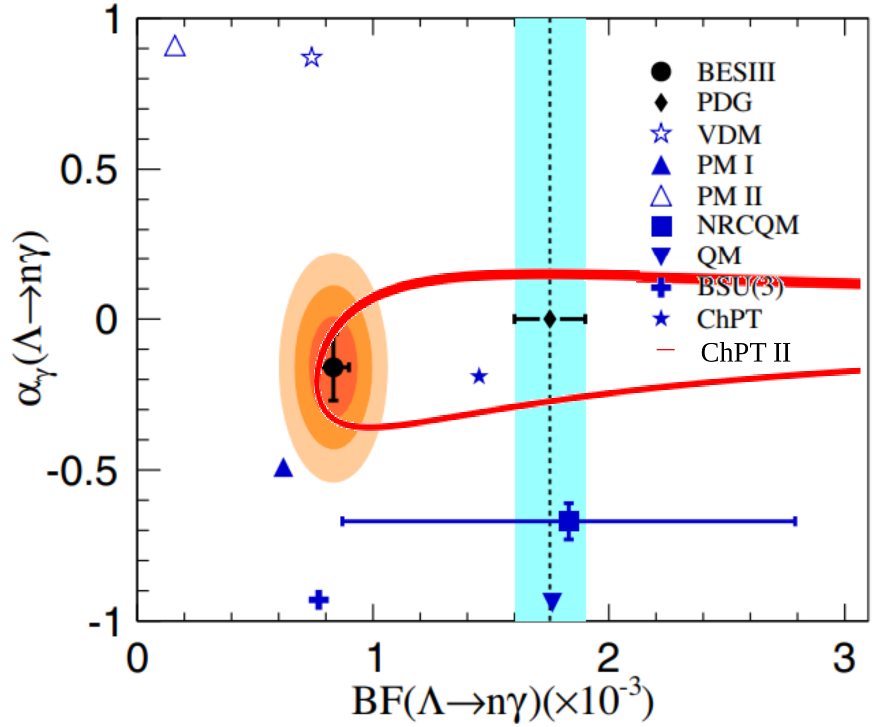
$$-\ln\mathcal{L}_{sig} = -\ln\mathcal{L}_{data} + \ln\mathcal{L}_{bkgA} + \ln\mathcal{L}_{bkgB}$$

$$-\ln\mathcal{L} = -\sum_{i=1}^{i=N} \ln\frac{\omega(\xi, \alpha_\gamma)}{\mathcal{S}}$$

- ☐ **Contributions of BKG A / B should be subtracted .**
- ☐ **BKG A and BKG B contributions are estimated by DIY MC with same numbers in data**

α_ψ **(J/ψ decay parameter) = 0.461, ΔΦ (helicity phase) = 0.74,** $\alpha_1(\Lambda \to p\pi^-)$ **= 0.75 ,** α_γ $(\bar{\Lambda} \to \gamma\bar{n})$ **= ?**

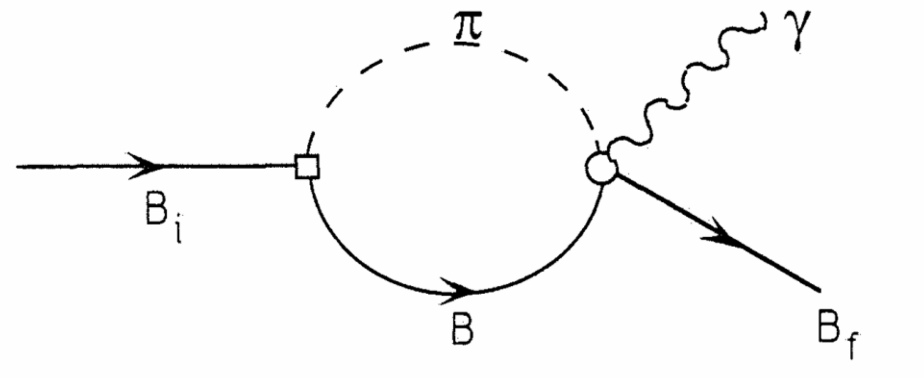




- **First** measurement on α_γ
- **5.6σ** deviation of BF from world average value

WRHD process $\Lambda \to n\gamma$

Unitarity Bounds:



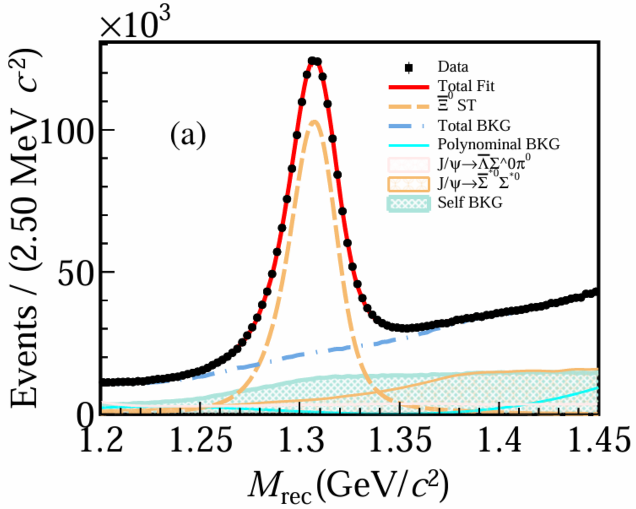
- For the WRHD processes, $Im\ M(Y \to B\gamma)$ can be expressed in terms of the amplitudes of the $\boldsymbol{Y \to B\pi^0}$ and of those of **pion photoproduction on nucleons** $(\boldsymbol{\gamma B \to \pi B'})$
- However, the updated BF of $\boldsymbol{\Lambda \to n\gamma}$, $(\mathbf{0.832 \pm 0.038 \pm 0.054}) \times \mathbf{10^{-3}}$**, is close to the lower bounds.**

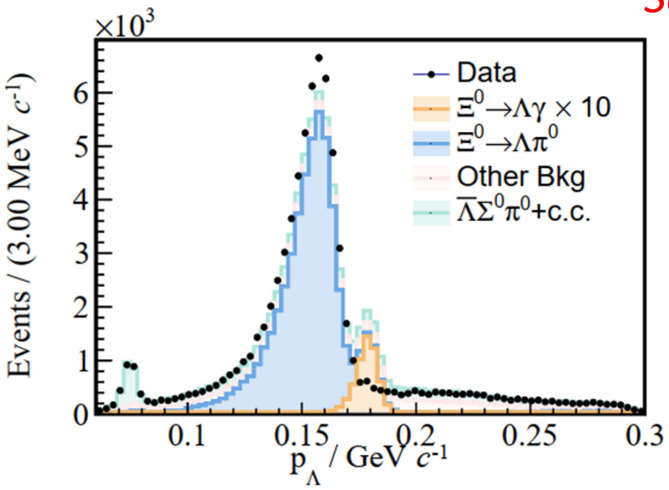
Table 4.1 Comparison of estimates of πB contributions to the branching fractions of WRHD. (in units of 10^{-3})

	Zakharov[52]	Farrar[53]		Kogan[54]		Reid[55,56]
Process	lower bound	lower bound	full estimate	lower bound	full estimate	full estimate
$\Sigma^+ \to p\gamma$	0.07±0.04	0.007	0.3±1.2			$0.77^{+1.29}_{-0.49}$
$\Lambda \to n\gamma$	0.83	0.85	1.9±0.8			$1.20^{+0.46}_{-0.04}$
$\Xi^- \to \Sigma^-\gamma$	0.13			0.10	0.17	
$\Omega^- \to \Xi^-\gamma$				0.008	0.01	

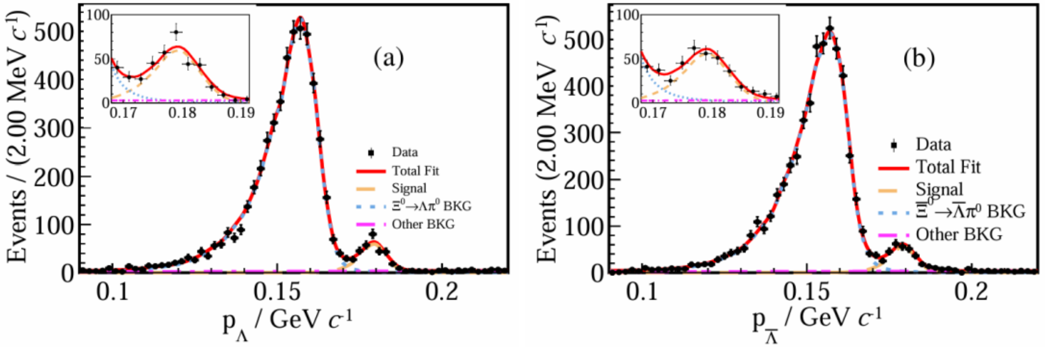
WRHD process $\Xi^0 \to \Lambda\gamma$

Sci.Bull. 70 (2025) 454-459





Modes	$\Xi^0 \to \Lambda\gamma$	$\bar{\Xi}^0 \to \bar{\Lambda}\gamma$
ST Yield	1 400 541 ± 1989	1 611 216 ± 2111
ε_{ST} (%)	17.61 ± 0.01	19.77 ± 0.01
ε_{DT} (%)	4.43 ± 0.02	4.77 ± 0.02
Individual BF	$(1.391 \pm 0.093) \times 10^{-3}$	$(1.344 \pm 0.099) \times 10^{-3}$
Simultaneous BF	$(1.379 \pm 0.068) \times 10^{-3}$	
Correction factor	1.032	1.014
Corrected individual BF	$(1.348 \pm 0.090) \times 10^{-3}$	$(1.326 \pm 0.098) \times 10^{-3}$
Corrected simultaneous BF	$(1.347 \pm 0.066) \times 10^{-3}$	



WRHD process $\Xi^0 \to \Lambda\gamma$

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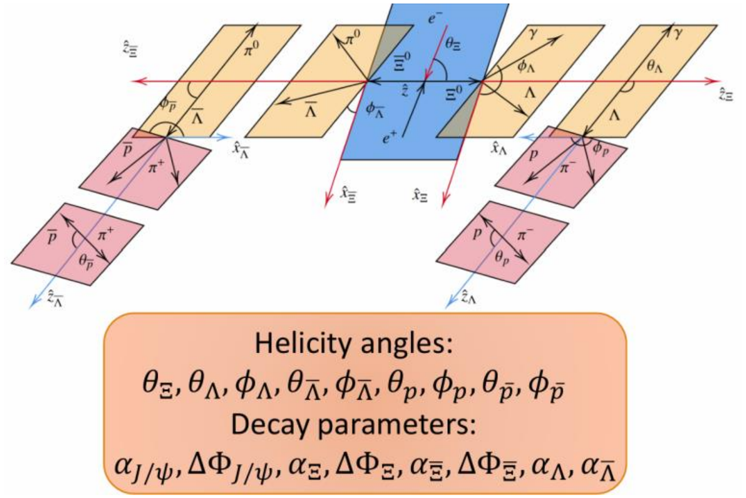
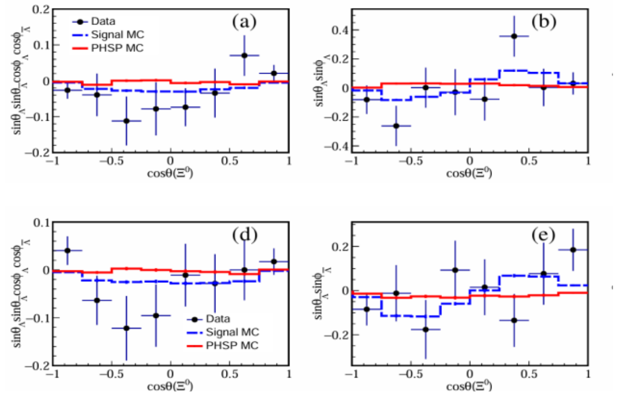
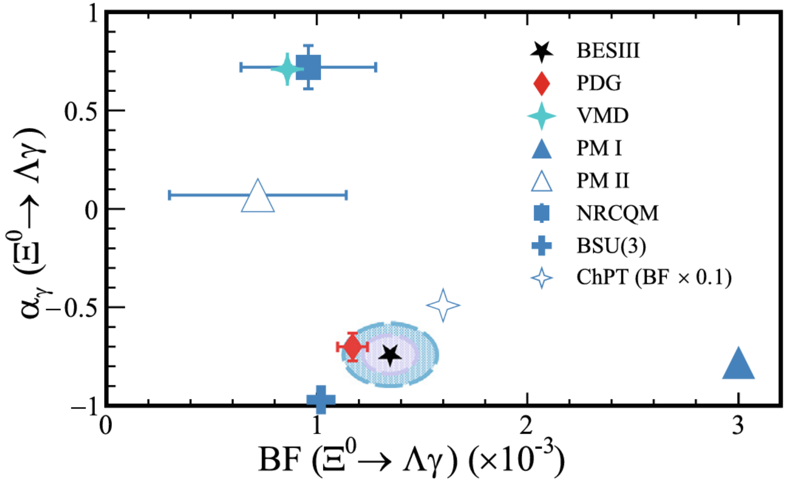
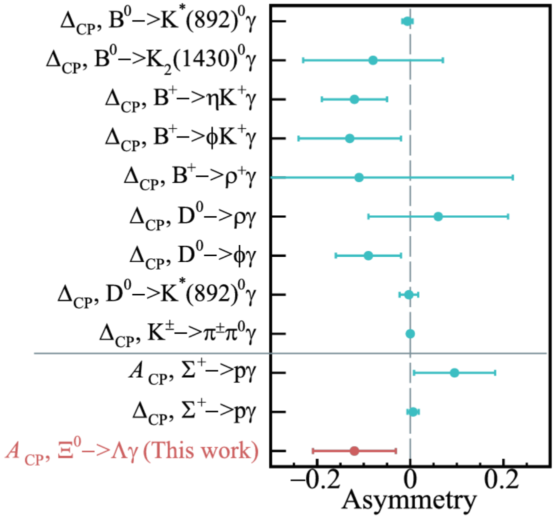


α_Ψ	0.514
$\Delta\Phi$	1.168
$\alpha_{\Xi^0\to\Lambda\gamma}$	this analysis
$\alpha_{\bar{\Xi}^0\to\bar{\Lambda}\gamma}$	this analysis
$\alpha_{\Xi^0\to\Lambda\pi^0}$	−0.375
$\Delta\Phi_{\Xi^0\to\Lambda\pi^0}$	0.005
$\alpha_{\bar{\Xi}^0\to\bar{\Lambda}\pi^0}$	0.379
$\Delta\Phi_{\bar{\Xi}^0\to\bar{\Lambda}\pi^0}$	−0.005
α_Λ	0.755
$\alpha_{\bar{\Lambda}}$	−0.745



Processes	$\Xi^0 \to \Lambda\gamma$	$\bar{\Xi}^0 \to \bar{\Lambda}\gamma$
Individual fit	-0.652 ± 0.092	0.830 ± 0.080
Simultaneous fit	-0.741 ± 0.062	





$$A_{CP} = \frac{\alpha_\gamma + \bar{\alpha}_\gamma}{\alpha_\gamma - \bar{\alpha}_\gamma} = -0.120 \pm 0.084_{\text{stat.}} \pm 0.029_{\text{syst.}}$$

HWRD at fix-target experiments

- **Fixed target experiments govern the results in 1965-2010 (~23 papers from over 5 experiments)**

$\Sigma^+ \to p\gamma$			
时间	实验名或实验方案	分支比（$\times 10^{-3}$）	α_γ
2023	BESIII	$0.996 \pm 0.021 \pm 0.018$	$-0.652 \pm 0.056 \pm 0.020$
1995	E761	1.20 ± 0.08	-
1992	SPEC	-	-0.720 ± 0.086
1989	CNTR	1.45 ± 0.31	-
1987	CNTR	1.23 ± 0.20	-
1985	CNTR	1.27 ± 0.18	-
1980	HBC	1.09 ± 0.20	-0.53 ± 0.36
1969	HBC	1.1 ± 0.2	-
1969	HBC	1.42 ± 0.26	-1.03 ± 0.52
1965	HBC	1.9 ± 0.4	-

$\Lambda \to n\gamma$			
时间	实验名或实验方案	分支比（$\times 10^{-3}$）	α_γ
2022	BESIII	$0.846 \pm 0.039 \pm 0.052$	$-0.160 \pm 0.101 \pm 0.046$
1994	E761	1.75 ± 0.15	-
1992	SPEC	1.78 ± 0.24	-

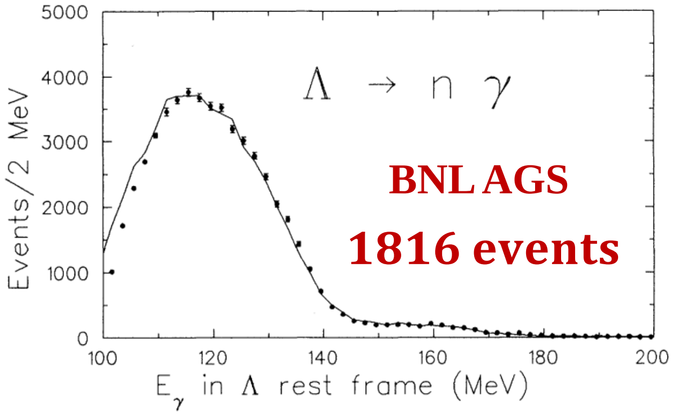
$\Xi^0 \to \Lambda\gamma$			
时间	实验名或实验方案	分支比（$\times 10^{-3}$）	α_γ
2010	NA48	-	-0.704 ± 0.064
2004	NA48	1.17 ± 0.09	-0.78 ± 0.18
2000	NA48	1.91 ± 0.34	-
1990	SPEC	1.06 ± 0.18	-0.43 ± 0.44

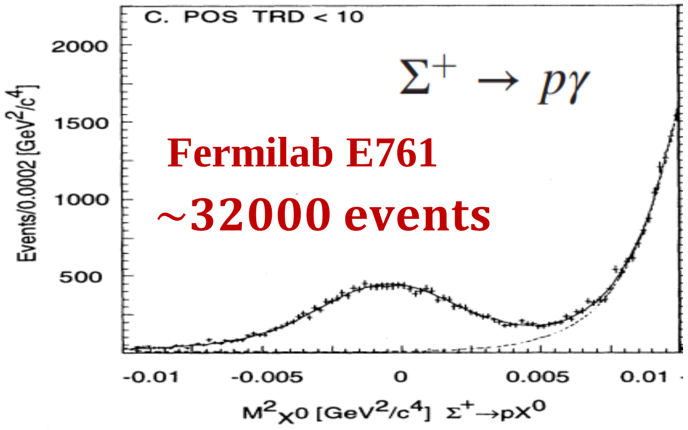
$\Xi^0 \to \Sigma^0\gamma$			
时间	实验名或实验方案	分支比（$\times 10^{-3}$）	α_γ
2010	NA48	-	-0.729 ± 0.076
2001	KTEV	3.34 ± 0.09	-0.63 ± 0.09
2000	NA48	3.16 ± 0.76	-
1989	SPEC	3.56 ± 0.42	0.20 ± 0.32

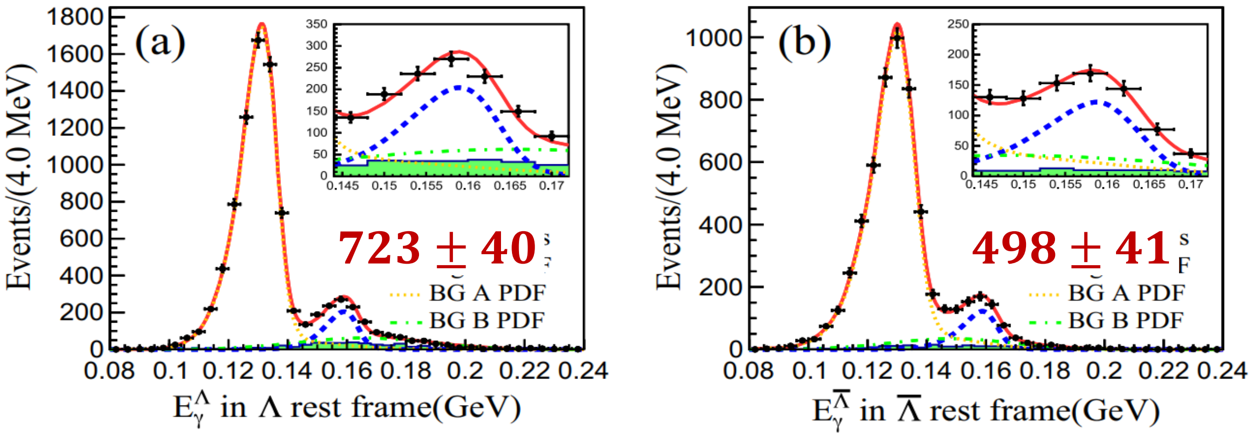
$\Xi^- \to \Sigma^-\gamma$			
时间	实验名或实验方案	分支比（$\times 10^{-3}$）	α_γ
1994	E761	0.122 ± 0.023	-
1987	SPEC	0.227 ± 0.102	-

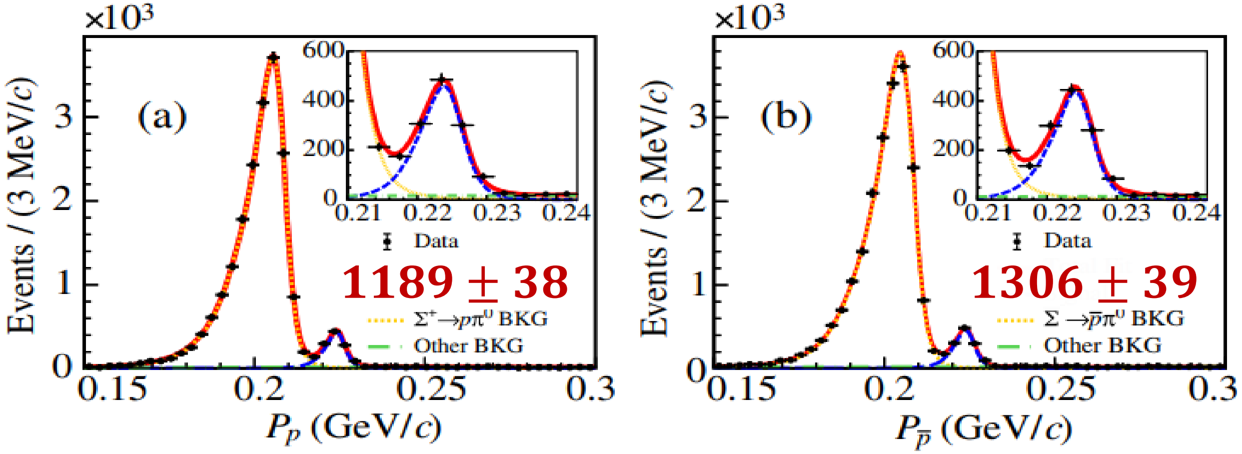
$\Omega^- \to \Xi^-\gamma$			
时间	实验名或实验方案	分支比（$\times 10^{-3}$）	α_γ
1994	E761	<0.46	-
1984	SPEC	<0.22	-
1979	SPEC	<0.31	-

HWRD at fix-target and e^+e^- and Experiments









- Hyperons at e^+e^- : less statistics compare with large flux hyperon beam with polarization, but with better precision, charge-conjugate channels
- **The power of quantum correction and joint angular analysis!**

Summary

- The precision of hyperons decays are limited by the **non-pQCD issues**: the $\Delta I = 1/2$ rule, S/P wave puzzle and Hara theorem are reported.

- Experimental measurement of hadronic weak decay and weak radiative decay of Hyperon are **improved at BESIII with its unique data**, and more attempts are ongoing.

- A **unified picture** of theoretical description for these decays is needed to understand the non-pQCD at these **extreme low q^2 regions**.

谢谢