BESIII上超子绝对分支比的测量

第二届强子物理新发展研讨会

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Outline

01 Hyperon weak radiative decays

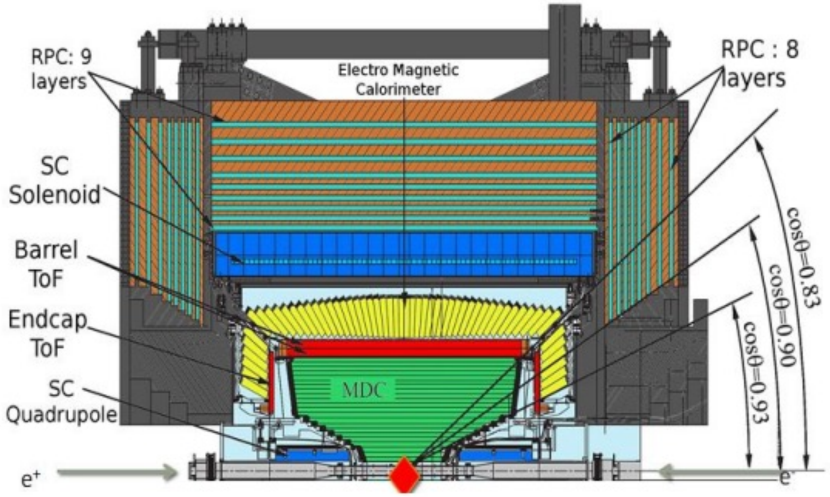
02 Hyperon semi-leptonic decays

03 Hyperon nonleptonic decays

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, $\sim 10^7$ entangled hyperon pairs can be produced, which enables precise measurements of the hyperon absolute BFs.

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 ± 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

Hyperon weak radiative decays

PART.01

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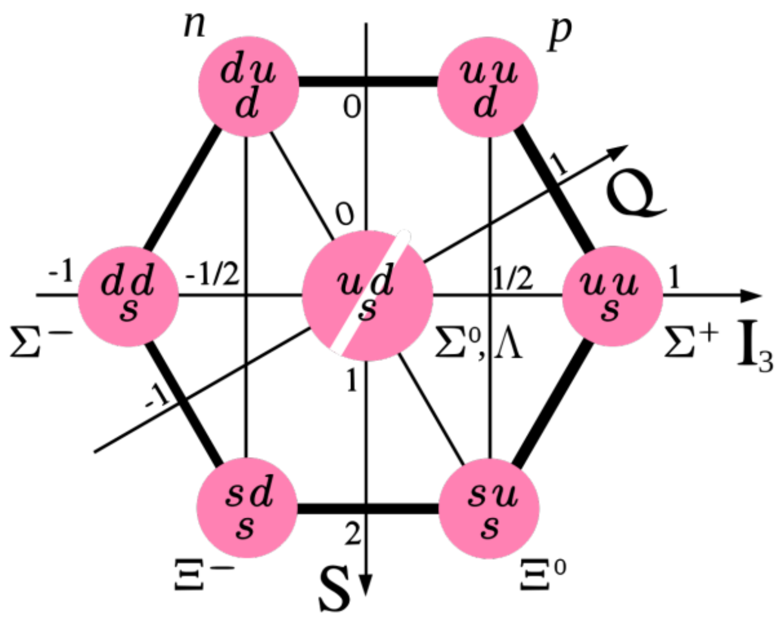
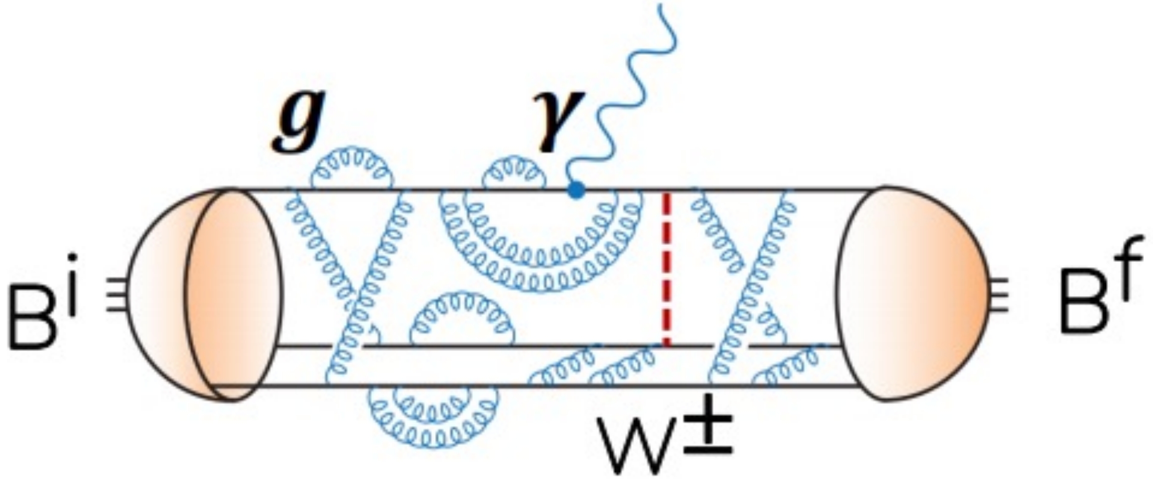
Physics Motivation

Hyperon weak radiative decays (WRHDs)

- flavor changing neutral current (FCNC) process ($s \to d\gamma$ transition)
- significant non-perturbative QCD effects
- A symphony of strong, weak, and EM interaction



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



Prog. Part. Nucl. Phys. **91** (2016) 1-100
Int. J. Mod. Phys. A **10** (1995) 3817-3876

Physics Motivation

Puzzle!

Phys. Rev. Lett. 12 (1964) 378-379

- Hara's theorem predicts the parity-violating decay amplitudes for the $\Sigma^+ \to p\gamma$ and $\Xi^- \to \Sigma^-\gamma$ decays vanish in the SU(3) limit.
- The experimentally measured asymmetry decay parameter for $\Sigma^+ \to p\gamma$ is surprisingly large.

α_γ

$-0.720 \pm 0.086 \pm 0.045$	35k	[2] FOUCHER	1992	SPEC	Σ^+ 375 GeV
$-0.86 \pm 0.13 \pm 0.04$	190	KOBAYASHI	1987	CNTR	$\pi^+ p \to \Sigma^+ K^+$
$-0.53^{+0.38}_{-0.36}$	46	MANZ	1980	HBC	$K^- p \to \Sigma^+ \pi^-$
$-1.03^{+0.52}_{-0.42}$	61	GERSHWIN	1969B	HBC	$K^- p \to \Sigma^+ \pi^-$

- In the SM, the branching fraction of $\Omega^- \to \Xi^-\gamma$ is very small, there are many new physics models can enhance it so that this decay can serve as a probe for the physics beyond SM.

Phys. Rev. D 53, 3620 (1996)
Phys. Rev. D 61, 114022 (2000)

Phys. Rev. Lett. **129** (2022) 21, 212002

$\Lambda \to n\gamma$

$J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to n\gamma, \bar{\Lambda} \to \bar{p}\pi^+ + c.c.$

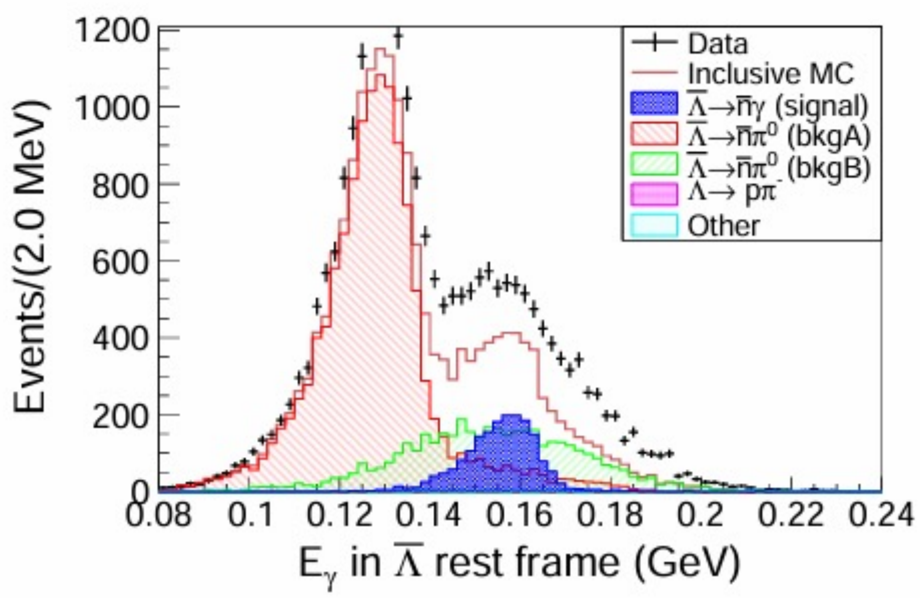
Analysis Method Highlights

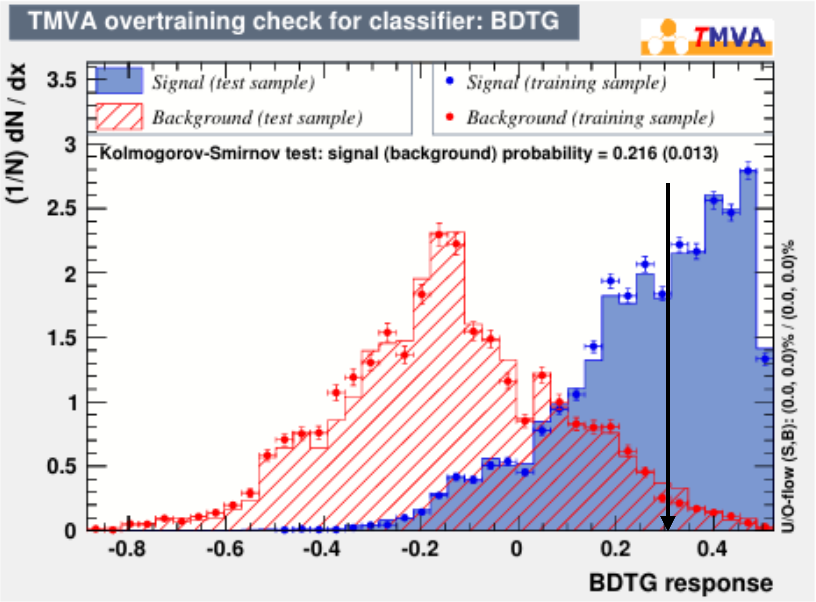
Kinematic fit with missing particle/energy

- **Hypothesis:** $\bar{\Lambda}(\to \bar{p}\pi^-)\gamma + n$(missing particle)
- **Hypothesis:** $\Lambda(\to p\pi^+)\gamma + \bar{n}$(missing energy, the direction of the anti-neutron is reconstructed)
- **Superiority of well-constrained kinematics**

MVA-base background photon suppression

Rejected 96.9% background B with 50.1% signal efficiency

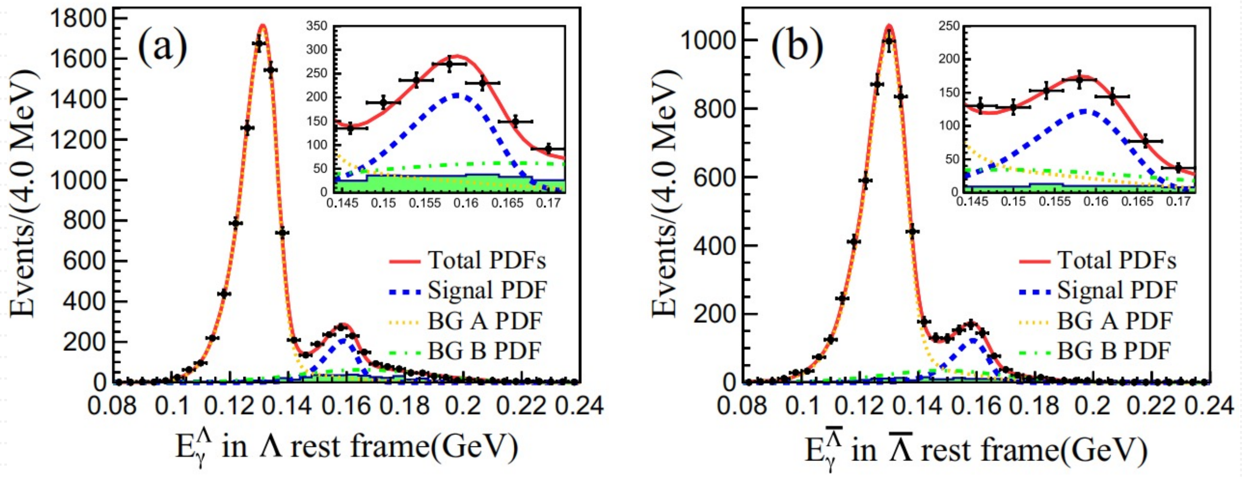




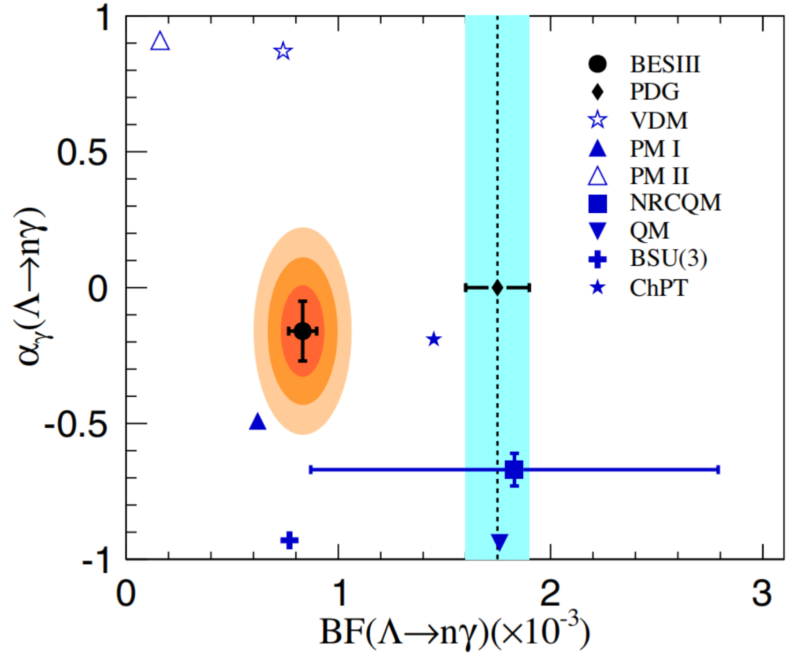
$\Lambda \to n\gamma$

Phys. Rev. Lett. **129** (2022) 21, 212002

Analysis results



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 ($\times 10^{-3}$)	$0.820 \pm 0.045 \pm 0.066$	$0.862 \pm 0.071 \pm 0.084$
	$\mathbf{0.832 \pm 0.038 \pm 0.054}$	
α_γ	$-0.13 \pm 0.13 \pm 0.03$	$0.21 \pm 0.15 \pm 0.06$
	$\mathbf{-0.16 \pm 0.10 \pm 0.05}$	



PDG2022: BF= $(1.75 \pm 0.15)\times 10^{-3}$

First measurement on α_γ

5.6σ deviation of BF

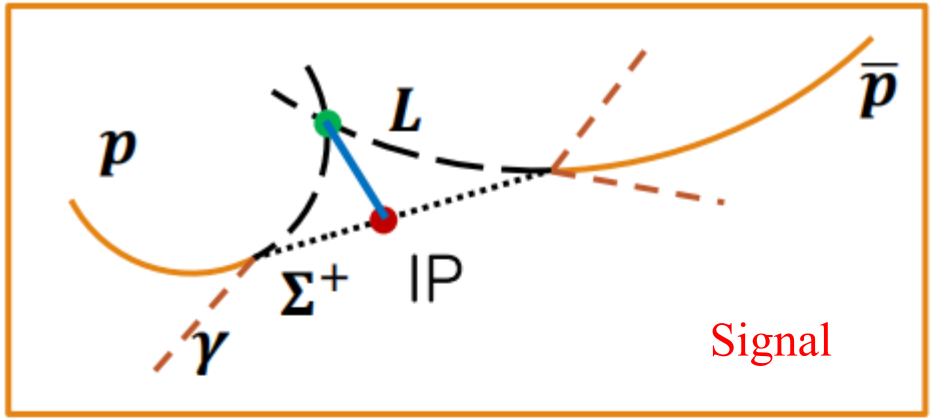
$\Sigma^+ \to p\gamma$

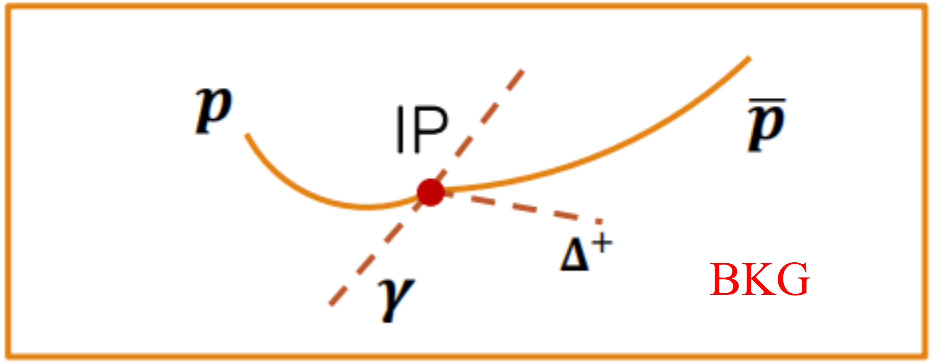
$J/\psi \to \Sigma^+\bar{\Sigma}^-, \Sigma^+ \to p\gamma, \bar{\Sigma}^- \to \bar{p}\pi^0 + c.c.$

Analysis Method Highlights

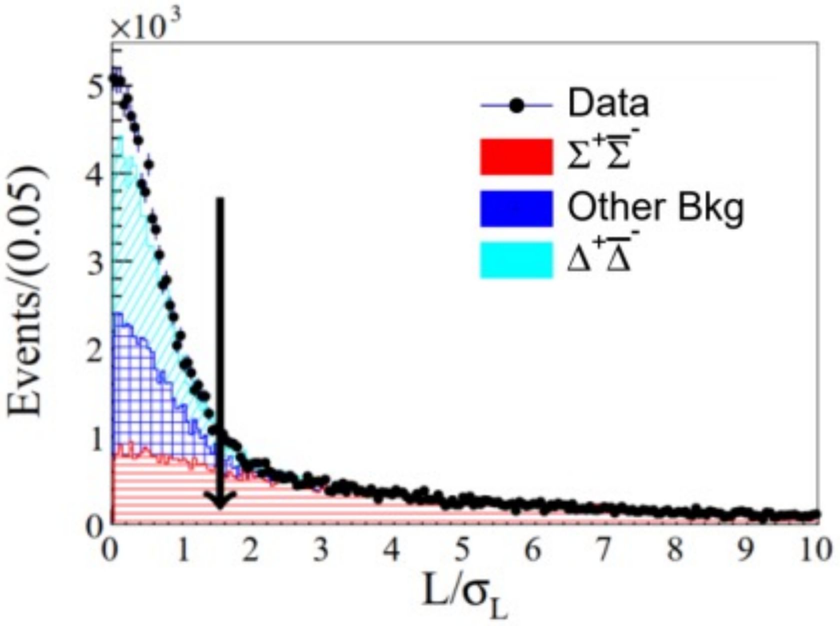
Phys. Rev. Lett. **130** (2023) 21, 211901

Utilize joint decay length to discriminate short-lived baryons from signals





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

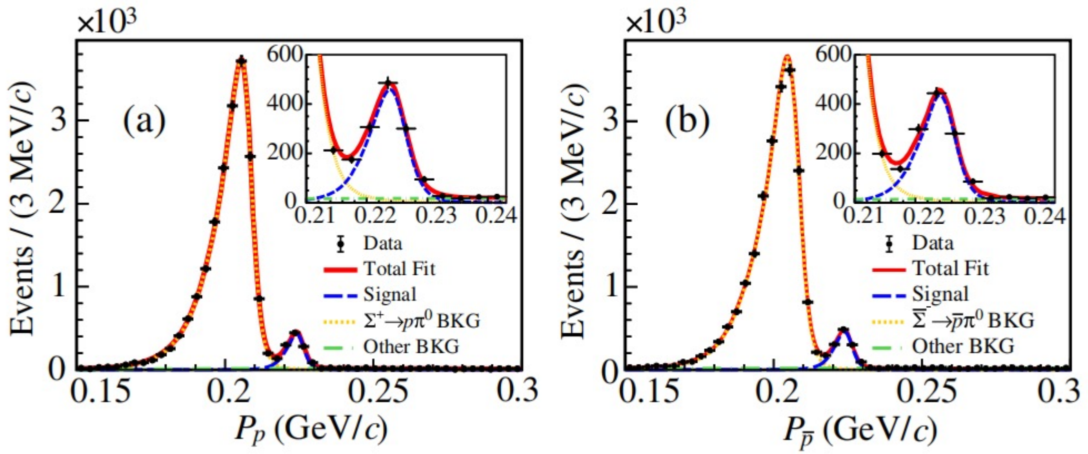


Signal efficiency > 78%
Background efficiency < 7%

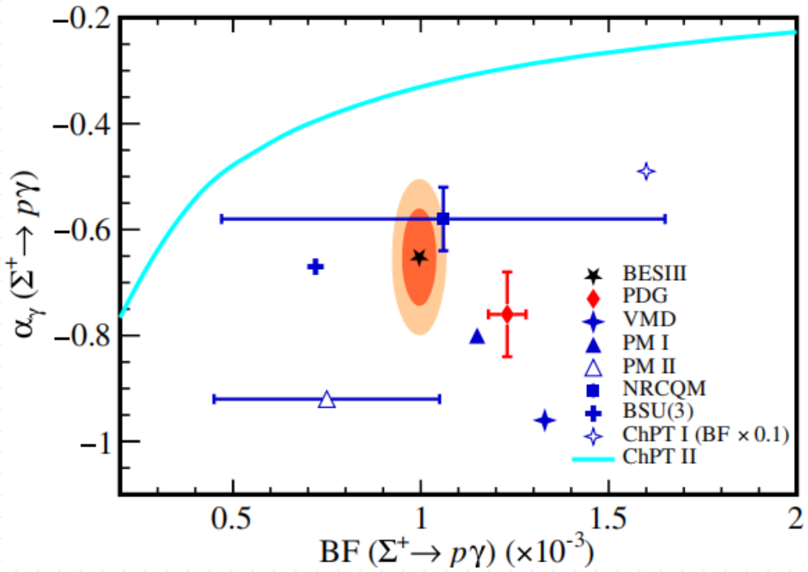
$\Sigma^+ \to p\gamma$

Analysis results

Phys. Rev. Lett. **130** (2023) 21, 211901



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	$-0.651 \pm 0.056 \pm 0.020$	



Significantly improved accuracy
- BF: 78%
- α_γ: 34%

PDG: BF= $(1.23 \pm 0.05) \times 10^{-3}$

4.2σ deviation

Ongoing analysis

In the final internal review stage, the results will be released very soon!

$\Xi^0 \to \Lambda\gamma$		
Experiment	BF(10^{-3})	α_γ
BESIII	$xxx \pm 0.066 \pm 0.054$	$xxx \pm 0.062 \pm 0.019$
PDG	1.17 ± 0.07	-0.70 ± 0.07

$\Xi^0 \to \Sigma^0\gamma$		
Experiment	BF(10^{-3})	α_γ
BESIII	$xxx \pm 0.21 \pm 12$	$xxx \pm 0.095 \pm 0.015$
PDG	3.33 ± 0.10	-0.69 ± 0.06

Competitive precision with PDG.

Hyperon semi-leptonic decays

PART.02

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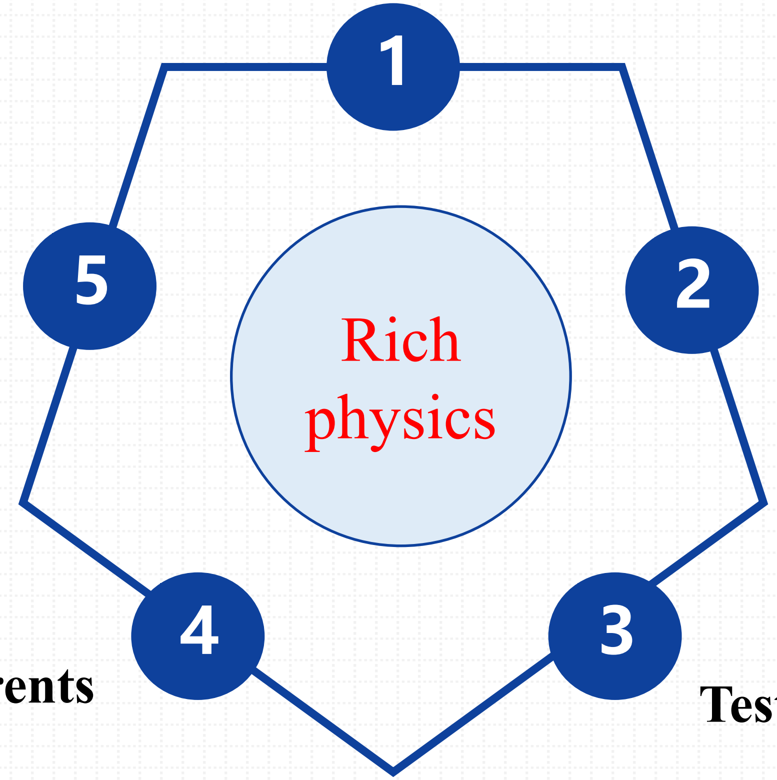
Physics Motivation

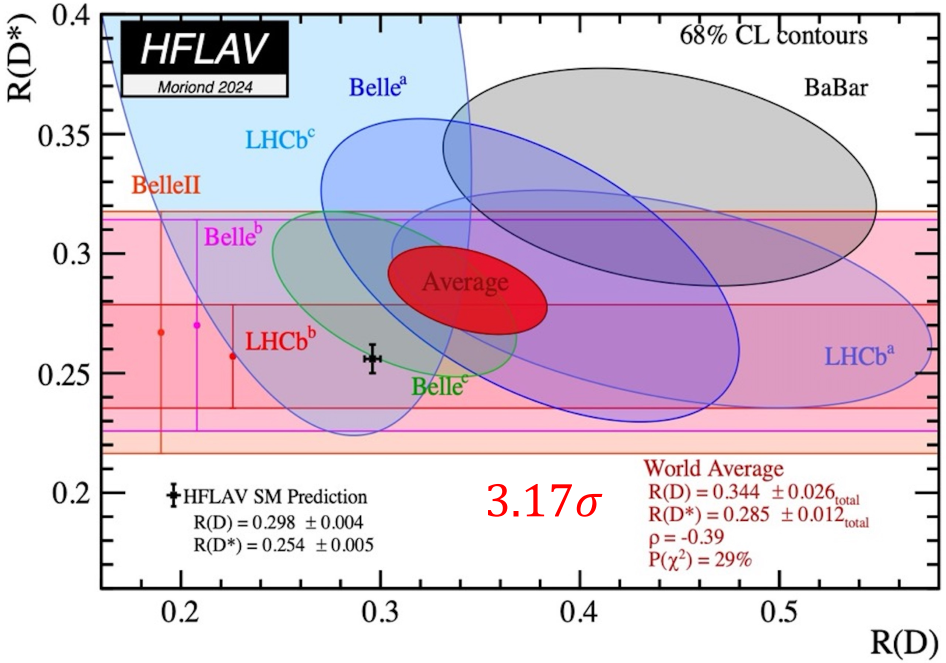


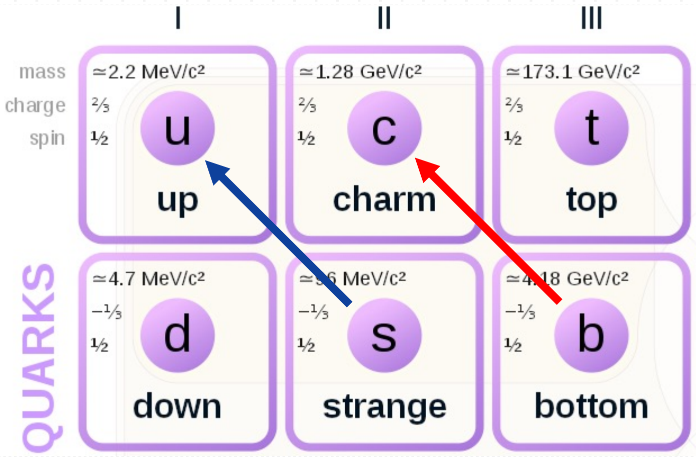
Test lepton flavor universality

$$R(D^{(*)}) = \frac{\mathcal{B}(\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)}l^-\bar{\nu}_l)}$$

$$R^{\mu e} = \frac{\mathcal{B}(B \to b\mu^-\bar{\nu}_\mu)}{\mathcal{B}(B \to be^-\bar{\nu}_e)}$$

Average of R(D) and R(D*) from HFLAV (2024)





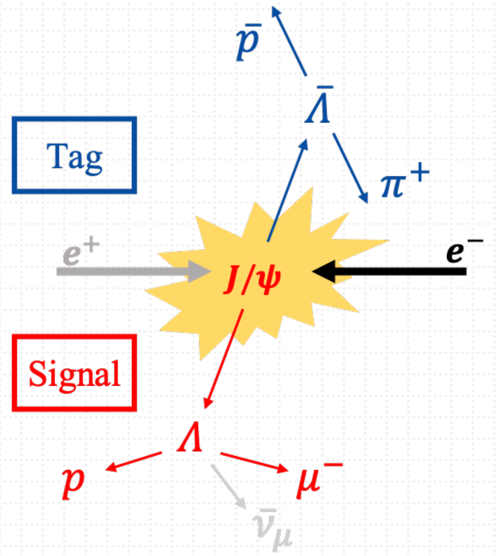
Phys. Rev. Lett. **114**, 161802 (2015)

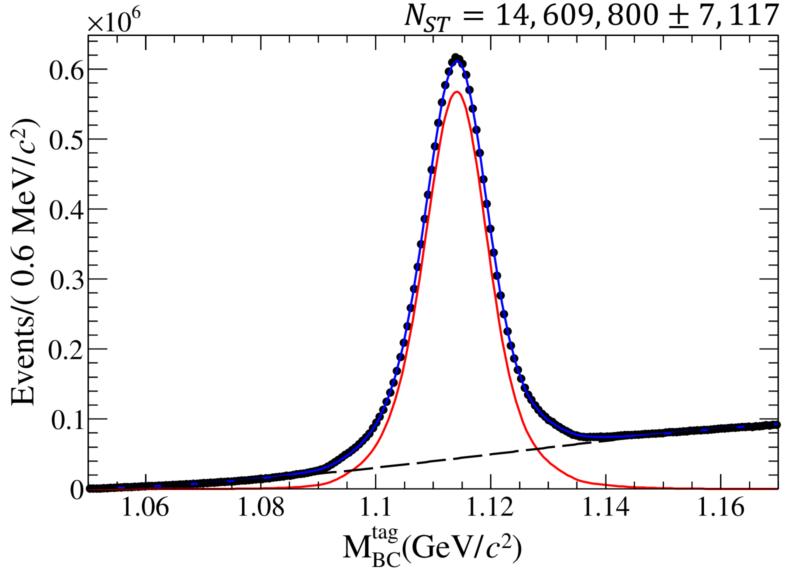
Experiment vs. SM NLO for $R^{\mu e}$ from hyperon semileptonic decays.

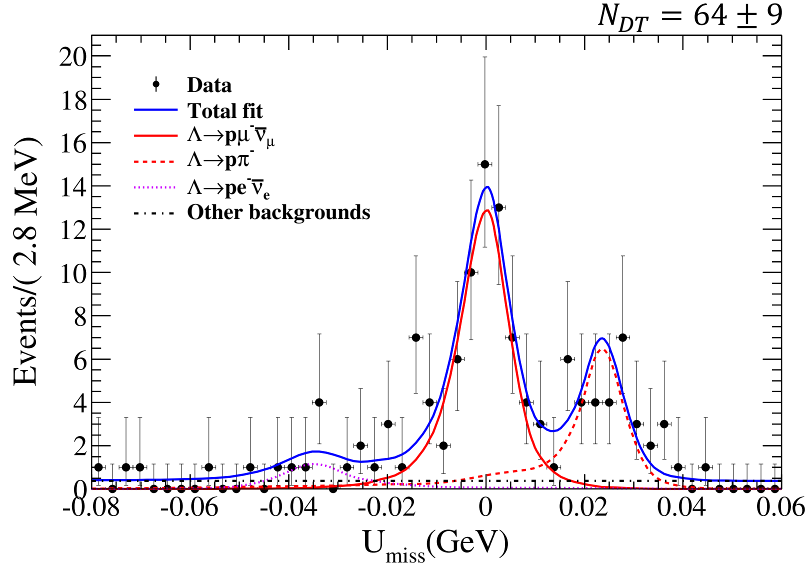
$R^{\mu e}$	$\Lambda \to pl^-\bar{\nu}_l$	$\Sigma^- \to nl^-\bar{\nu}_l$	$\Xi^0 \to \Sigma^+ l^-\bar{\nu}_l$	$\Xi^- \to \Lambda l^-\bar{\nu}_l$
Experiment	0.189±0.041	0.442±0.039	0.0092±0.0014	0.6±0.5
SM NLO	0.153±0.008	0.444±0.022	0.0084±0.0004	0.275±0.014

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

PRL 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 about 50 years of break
- ✓ The first study at a collider experiment
- ✓ 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

Search for CP violation

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

Consistent with CP symmetry

Search for second-class currents

- About second-class currents, previous nuclear β decay experiments gave contradictory conclusions.
  - ✓ Refs. [1-4] are in favor of the existence of the second-class currents
  - ✓ Refs. [5-8] reported the absence of second-class currents.

- In hyperon β decay, axial-vector form factor g_2 is related to second-class currents, but the flavor-SU(3)-symmetry-breaking effects [9-10] or second-class currents [11] can cause a nonzero axial-vector form factor g_2, and some of the experiments suggest a large g_2 [12].

[1] Phys. Rev. Lett. **35**, 1566 (1975).
[2] Phys. Rev. Lett. **34**, 1533 (1975).
[3] Phys. Rev. C **59**, 1113 (1999).
[4] Phys. Rev. C **95**, 035501 (2017).
[5] Phys. Rev. Lett. **26**, 1127 (1971).
[6] Phys. Rev. Lett. **32**, 314 (1974).
[7] Eur. Phys. J. A **7**, 307 (2000).
[8] Phys. Rev. C **84**, 055501 (2011).
[9] Phys. Rev. D **8**, 2963 (1973).
[10] Phys. Rev. D **79**, 074508 (2009).
[11] Annu. Rev. Nucl. Part. Sci. **53**, 39 (2003).
[12] Phys. Rev. D **3**, 2638 (1971).

$\Sigma^+ \to \Lambda e^+ \nu_e$

- To search for the second-class currents, a unique observable (R) was first proposed by S. Weinberg [1] in 1958.

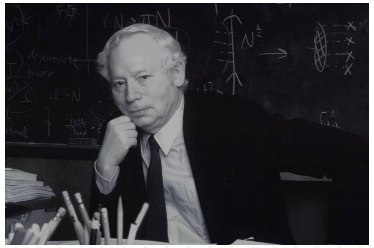
$$R \equiv \frac{\Gamma(\Sigma^- \to \Lambda e^- \bar{\nu}_e)}{\Gamma(\Sigma^+ \to \Lambda e^+ \nu_e)}$$

- If there are no second-class currents, R value should be just the phase-space ratio for these two decays, no matter flavor-SU(3)-symmetry-breaking effects exist or not, so any experimental deviation from this deduction would be decisive evidence for the existence of second-class currents.

PHYSICAL REVIEW VOLUME 112, NUMBER 4 NOVEMBER 15, 1958

Charge Symmetry of Weak Interactions*

STEVEN WEINBERG
Columbia University, New York, New York
(Received June 25, 1958)



Phys. Rev. **112**, 1375 (1958)

$\Sigma^+ \to \Lambda e^+ \nu_e$

- T. D. Lee and C. N. Yang calculate R based on no second-class currents.

$$R = 1.57$$

PHYSICAL REVIEW VOLUME 119, NUMBER 4 AUGUST 15, 1960

Implications of the Intermediate Boson Basis of the Weak Interactions: Existence of a Quartet of Intermediate Bosons and Their Dual Isotopic Spin Transformation Properties

T. D. LEE
Columbia University, New York, New York

AND

C. N. YANG
Institute for Advanced Study, Princeton, New Jersey

(Received April 11, 1960)


Chen Ning Yang


Tsung-Dao Lee

Phys. Rev. **119**, 1410 (1960)

$\Sigma^+ \to \Lambda e^+ \nu_e$

$$R \equiv \frac{\Gamma(\Sigma^- \to \Lambda e^- \bar{\nu}_e)}{\Gamma(\Sigma^+ \to \Lambda e^+ \nu_e)} = \frac{\mathcal{B}(\Sigma^- \to \Lambda e^- \bar{\nu}_e) \cdot \tau_{\Sigma^+}}{\mathcal{B}(\Sigma^+ \to \Lambda e^+ \nu_e) \cdot \tau_{\Sigma^-}}$$

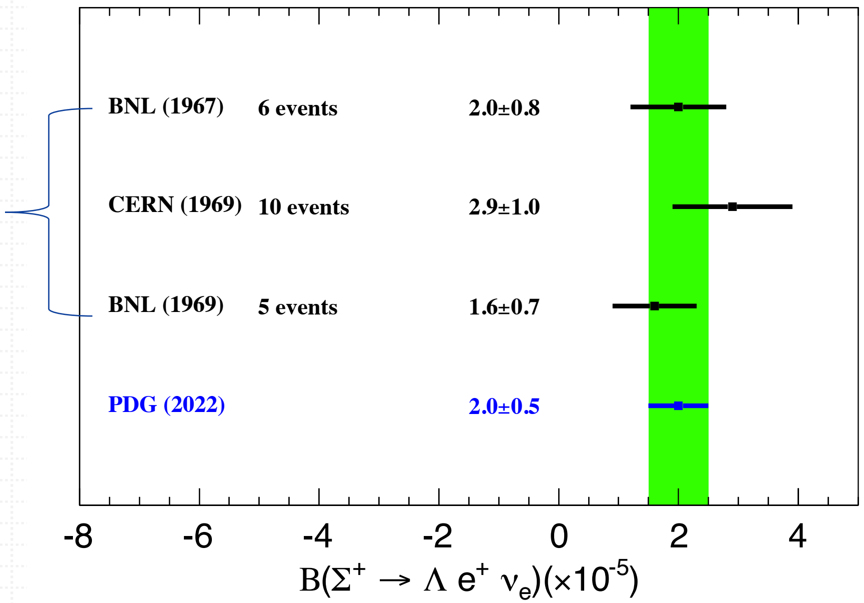
From PDG2022 :

$$\sigma[\mathcal{B}(\Sigma^- \to \Lambda e^- \bar{\nu}_e)] \sim 4.7\%$$

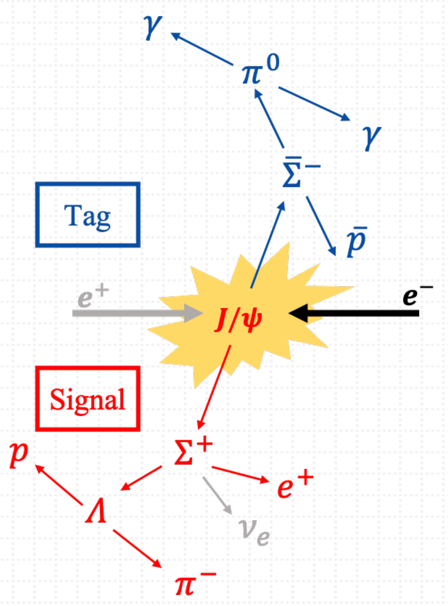
$$\sigma[\mathcal{B}(\Sigma^+ \to \Lambda e^+ \nu_e)] \sim 25\%$$

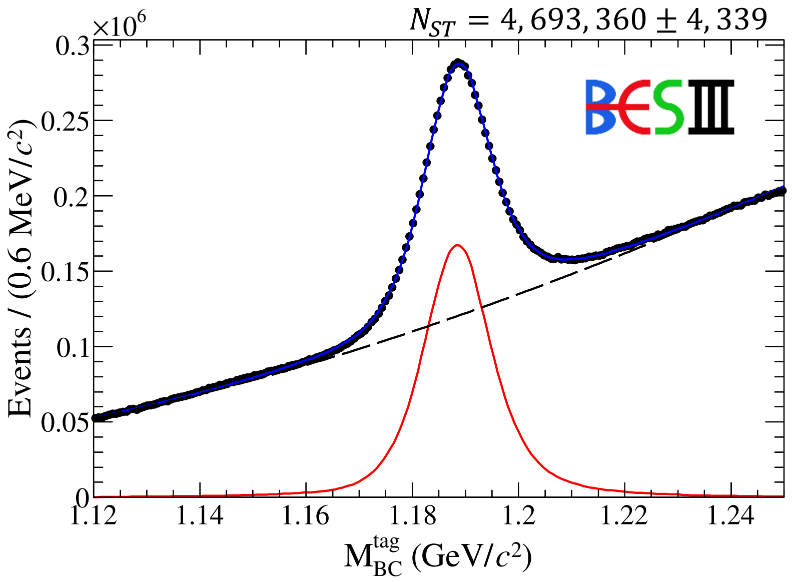
☹

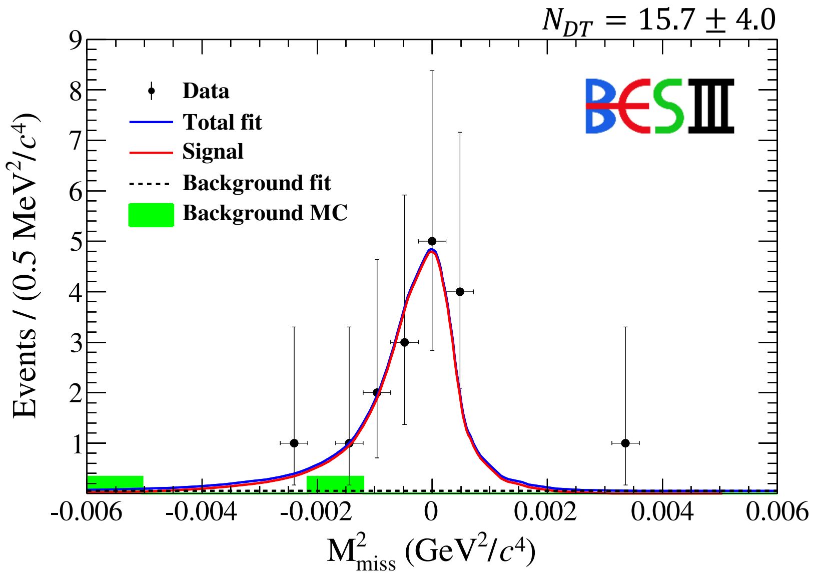
1. Fixed-target experiments
2. Bubble chamber pictures
3. Indirect measurement



$\Sigma^+ \to \Lambda e^+ \nu_e$







First derect measurement of absolute BF

$$\mathcal{B}(\Sigma^+ \to \Lambda e^+ \nu_e) = (2.93 \pm 0.74 \pm 0.13) \times 10^{-5}$$

Search for second-class currents

$$R \equiv \frac{\Gamma(\Sigma^- \to \Lambda e^- \bar{\nu}_e)}{\Gamma(\Sigma^+ \to \Lambda e^+ \nu_e)} = \frac{\mathcal{B}(\Sigma^- \to \Lambda e^- \bar{\nu}_e)_{PDG} \cdot \tau_{\Sigma^+ PDG}}{\mathcal{B}(\Sigma^+ \to \Lambda e^+ \nu_e) \cdot \tau_{\Sigma^- PDG}} = 1.06 \pm 0.28$$

- ✓ Update measurement after about 50 years break
- ✓ The first study at a collider experiment
- ✓ The most precise result in a single experiment

NO evindence for second-class currents

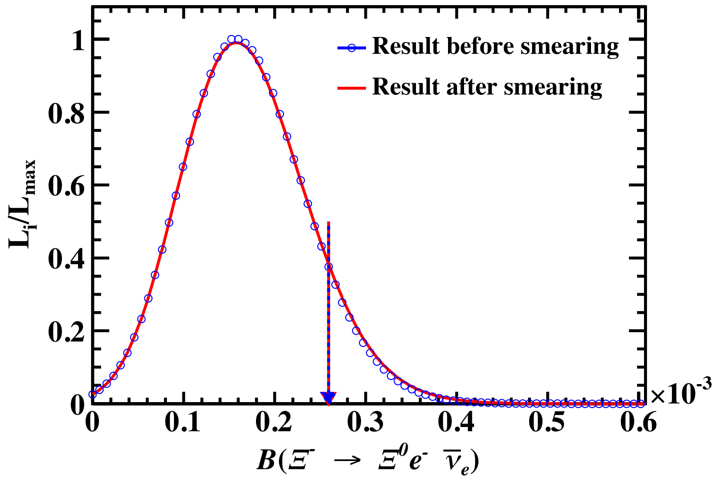
Rare/forbidden decays

Search for the hyperon semi-leptonic decay $\Xi^- \to \Xi^0 e^- \bar{\nu}_e$

BESIII, PRD **104**, 072007 (2021)

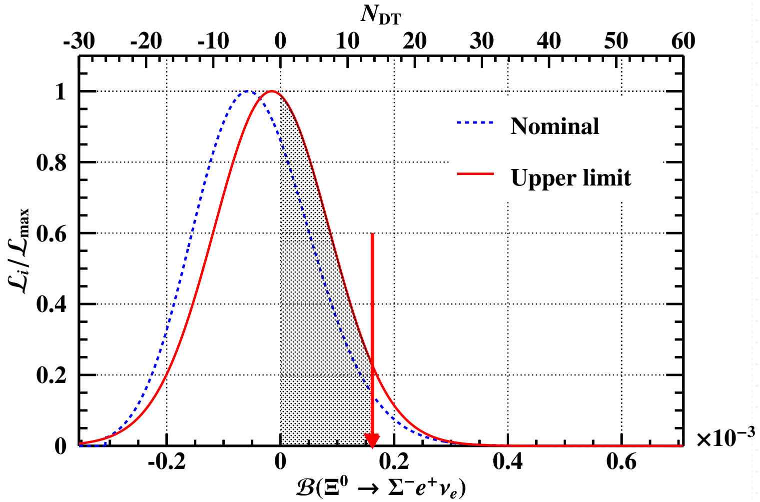
Search for hyperon $\Delta S = \Delta Q$ violating decay $\Xi^0 \to \Sigma^- e^+ \nu_e$

BESIII, PRD **107**, 012002 (2023)



$\mathcal{B}(\Xi^- \to \Xi^0 e^- \bar{\nu}_e) < 2.59\times10^{-4}$ @90%CL

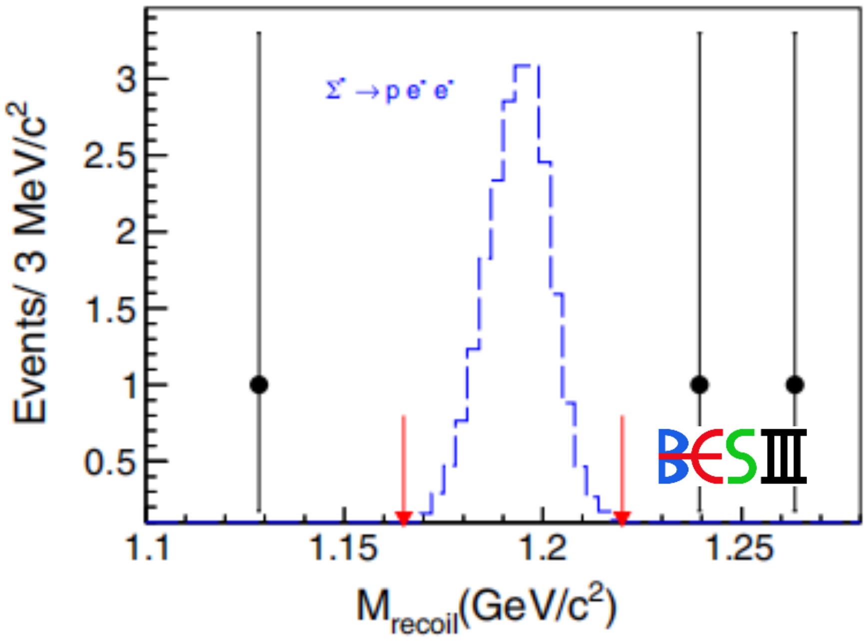
$\mathcal{B}(\Xi^0 \to \Sigma^- e^+ \nu_e) < 1.6\times10^{-4}$ @90%CL



Rare/forbidden decays

Search for the hyperon lepton number violating decay $\Sigma^- \to pe^-e^-$

PHYS. REV. D 103, 052011 (2021)



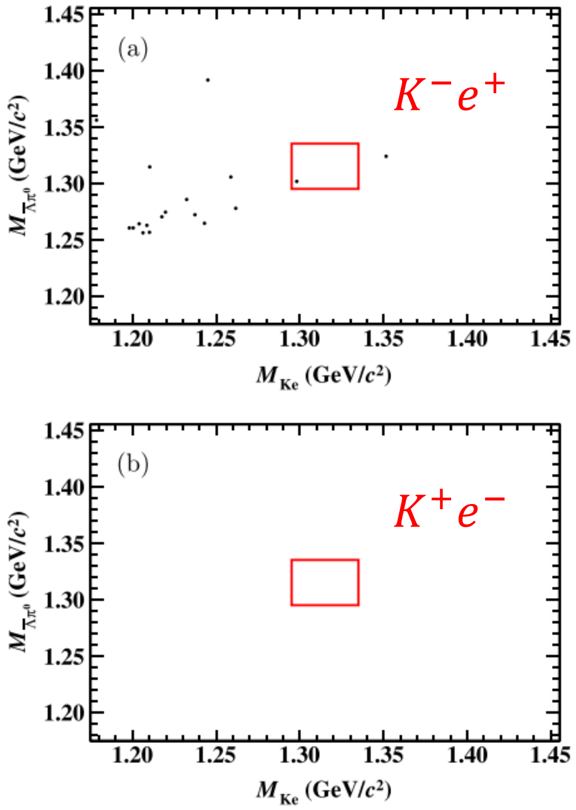
$\mathcal{B}(\Sigma^- \to pe^-e^-) < 6.7\times10^{-5}$ @90%CL

$\mathcal{B}(\Xi^0 \to K^-e^+) < 3.6\times10^{-6}$ @90%CL

$\mathcal{B}(\Xi^0 \to K^+e^-) < 1.9\times10^{-6}$ @90%CL

Search for hyperon baryon and lepton number violating decay $\Xi^0 \to Ke$

PHYS. REV. D 108, 012006 (2023)



Ongoing analysis

$g_{av} \equiv \frac{g_1(0)}{f_1(0)}$, $g_w \equiv \frac{f_2(0)}{f_1(0)}$

$|V_{us}|$

$\Lambda \to p e^- \bar{\nu}_e$			
Experiment	BF(10^{-4})	g_{av}	g_w
BESIII	$xxx \pm 0.22 \pm 0.15$	$xxx \pm 0.048 \pm 0.007$	$xxx \pm 0.35 \pm 0.14$
PDG	8.34 ± 0.14	-0.718 ± 0.015	

Very large uncertainties

g_w

CERN	PLB37(1971)535	0.89±0.61
CERN	PLB43(1973)237	0.80±0.90
CERN	Z.Phys.C21(1983)1	1.32±0.81
Fermilab	PRD41(1990)780	0.15±0.30

$\Xi^- \to \Lambda e^- \bar{\nu}_e$		
Experiment	BF(10^{-4})	g_{av}
BESIII	$xxx \pm 0.40 \pm 0.10$	$xxx \pm 0.068 \pm 0.019$
PDG	5.63 ± 0.31	-0.25 ± 0.05

$\Omega^- \to \Xi^0 e^- \bar{\nu}_e$	
Experiment	BF(10^{-3})
BESIII	$xxx \pm 1.3(stat)$
PDG	5.6 ± 2.8

First observation

Hyperon nonleptonic decays

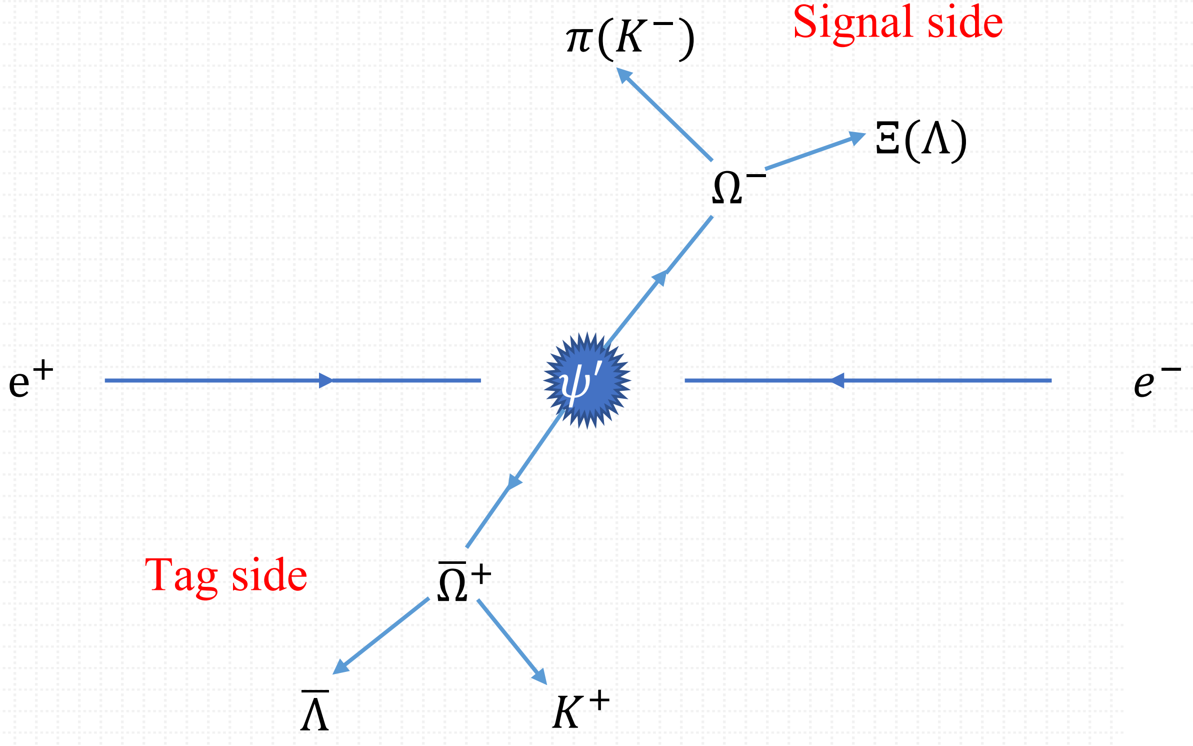
PART.03

强子物理论坛

Physics Motivation

- Dominant decay models of the hyperons, many studies will benefit from precise measurements of BFs of the hyperon nonleptonic decays.
- All the previous results of the hyperon nonleptonic decays are relative BFs, no absolute BFs are measured.

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



Partial reconstruction to improve the efficiencies, only a π^-, a π^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 ± 0.7	8.6 ± 0.4	67.8 ± 0.7

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

If ΔI=1/2 rule is valid in Ω^- 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 ± 0.15, inconsistent with the prediction of the ΔI=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 ΔI=1/2 rule is not suitable for describing the decays of the Ω^- hyperon.

Search for $\Delta S = 2\ \Omega^-$ nonleptonic

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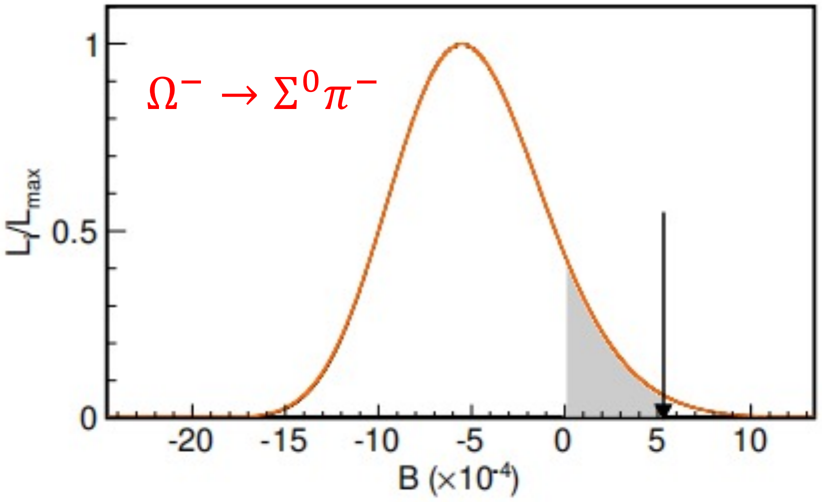
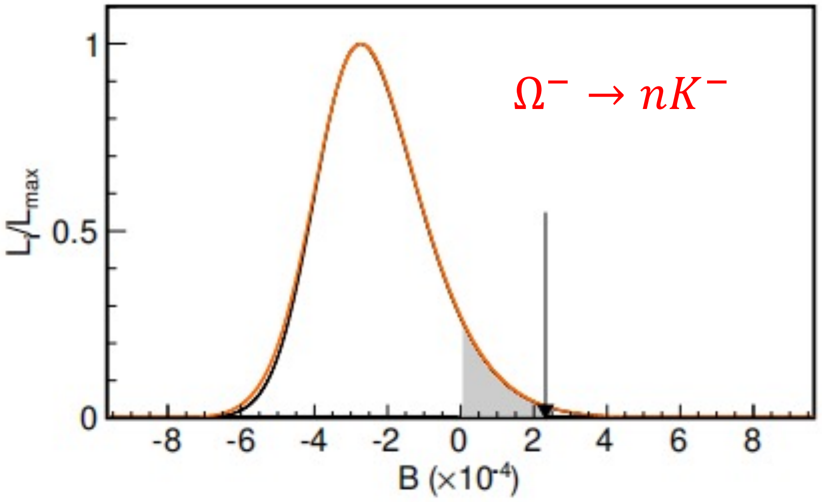
In the SM, $\Delta S = 2$ nonleptonic hyperon decays are highly suppressed, however, there are new physics models that can enhance the BF of such decays, the $\Delta S = 2$ nonleptonic hyperon decays could be used as probes for new physics.



(a)



(b)

$$\mathcal{B}(\Omega^- \to \Sigma^0\pi^-) < 5.4\times10^{-4}\quad @90\%CL$$

$$\mathcal{B}(\Omega^- \to nK^-) < 2.4\times10^{-4}\quad @90\%CL$$

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Ongoing analysis

$\Sigma^+ \to p\pi^0$		$\Sigma^+ \to n\pi^+$	
Experiment	BF(%)	Experiment	BF(%)
BESIII	$xxx \pm 0.06 \pm 0.16$	BESIII	$xxx \pm 0.06 \pm 0.12$
PDG	51.57 ± 0.30	PDG	48.31 ± 0.30

Summary

PART.05

强子物理论坛

Summary

- ✓ BESIII has made fruitful achievements in the studies of hyperon absolute decay BFs:
  - ✓ Hyperon weak radiative decays
  - ✓ Hyperon semi-leptonic decays
  - ✓ Hyperon nonleptonic decays

- ✓ More exciting hyperon results are expected in the next several years.

THANKS!

Backup

Measure the CKM matrix element $|V_{us}|$

In the SM: First-row unitarity relation

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

2.2σ tension ⟺ A hint of new physics?

PDG 2022: Independent measurements

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.99848 \pm 0.00070$$

- $|V_{ub}|$: Small（$|V_{ub}|^2 \cong 1.7\times10^{-5}$）➜ 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

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 2022	HFLAV 2022	**Dominated by the $\Lambda \to p e^- \bar{\nu}_e$**

2.2σ tension (Kaon ↔ Tau)

Measure the CKM matrix element $|V_{us}|$

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

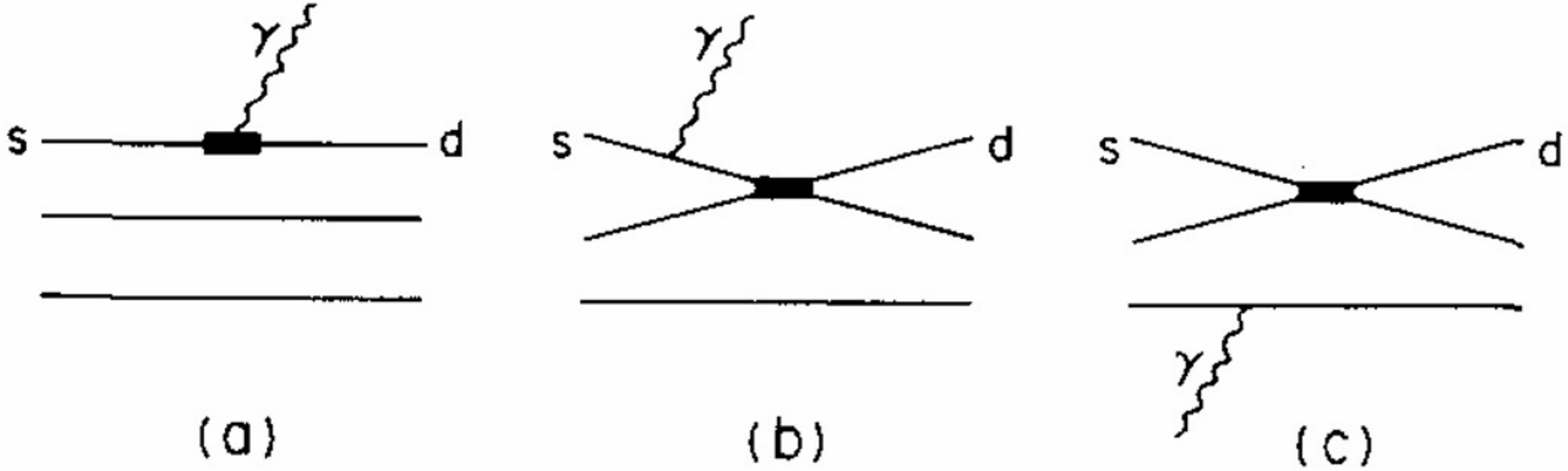
$$\Gamma_{\rm SM} = \frac{\mathcal{B}_{\Lambda\to pe^-\bar{\nu}_e}}{\tau_\Lambda} = \frac{G_F^2|V_{us}|^2 f_1(0)^2\Delta^5}{60\pi^3}\Big[\Big(1-\frac{3}{2}\delta+\frac{6}{7}\delta^2\Big)+\frac{4}{7}\delta^2 g_w^2 + \left(3-\frac{9}{2}\delta+\frac{12}{7}\delta^2\right)g_{av}^2 + \frac{12}{7}\delta^2 g_{av2}^2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

PRD **70**, 114036 (2004)

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

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

- Extracting $|V_{us}|$, requires $\mathcal{B}_{\Lambda\to pe^-\bar{\nu}_e}$, $f_1(0)$, $g_{av} \equiv \frac{g_1(0)}{f_1(0)}$, $g_w \equiv \frac{f_2(0)}{f_1(0)}$, and $g_{av2} \equiv \frac{g_2(0)}{f_1(0)}$,
  - $f_1(0)$: From LQCD
  - $\mathcal{B}_{\Lambda\to pe^-\bar{\nu}_e}$, g_{av}, g_w, and g_{av2}: From experimental measurement



γ
s
d
(a)
γ
s
d
(b)
s
d
γ
(c)

Physics Motivation

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（$\times10^{-3}$）	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（$\times10^{-3}$）	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（$\times10^{-3}$）	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（$\times10^{-3}$）	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（$\times10^{-3}$）	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（$\times10^{-3}$）	α_γ
1994	E761	<0.46	-
1984	SPEC	<0.22	-
1979	SPEC	<0.31	-