Rare and forbidden hyperon decays at BESIII

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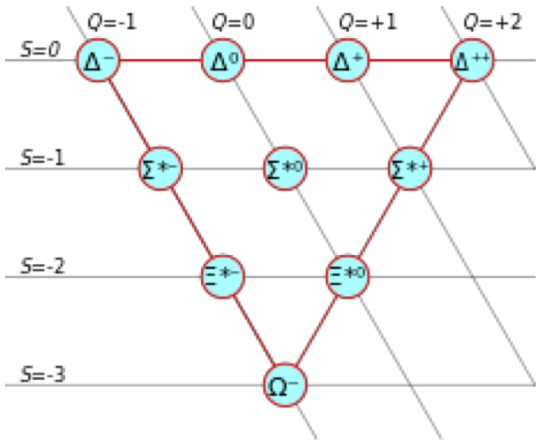
2019.02.15

Introduction



- A hyperon is any baryon containing one or more strange quarks, but no charm, bottom, or top quark.
- BESIII ~ 10^{10} J/psi, and psi(2S) events
- Hyperon-pair production rate ~10^{-3}
- Study the decay properties of spin-1/2 baryon octet

Hyperon production – two body

Decay mode	$\mathcal{B}(\times 10^{-3})$	N_B $(\times 10^6)$
$J/\psi \to \Lambda\bar{\Lambda}$	1.61 ± 0.15	16.1 ± 1.5
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	1.29 ± 0.09	12.9 ± 0.9
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	1.50 ± 0.24	15.0 ± 2.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$ (or c.c.)	0.31 ± 0.05	3.1 ± 0.5
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$ (or c.c.)	1.10 ± 0.12	11.0 ± 1.2
$J/\psi \to \Xi^0\bar{\Xi}^0$	1.20 ± 0.24	12.0 ± 2.4
$J/\psi \to \Xi^-\bar{\Xi}^+$	0.86 ± 0.11	8.6 ± 1.0
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	0.32 ± 0.14	3.2 ± 1.4
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	0.59 ± 0.15	5.9 ± 1.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.05 ± 0.01	0.15 ± 0.03

Hyperon production – three body

Decay mode	$\mathcal{B}(\times 10^{-4})$	N_B $(\times 10^6)$
$J/\psi \to pK^-\bar{\Lambda}$	8.9 ± 1.6	8.9 ± 1.6
$J/\psi \to \Lambda\bar{\Lambda}\pi^+\pi^-$	43 ± 10	43 ± 10
$J/\psi \to pK^-\bar{\Sigma}^0$	2.9 ± 0.8	2.9 ± 0.8
$J/\psi \to \Lambda\bar{\Sigma}^-\pi^+$ (or c.c.)	8.3 ± 0.7	8.3 ± 0.7
$J/\psi \to \Lambda\bar{\Sigma}^+\pi^{-*}$ (or c.c.)	8.3 ± 0.7	8.3 ± 0.7
$J/\psi \to pK^-\bar{\Sigma}(1385)^0$	5.1 ± 3.2	5.1 ± 3.2

Semileptonic hyperon decays

- Hyperon semileptonic decays can provide independent constraints on $|V_{ud}|$ and $|V_{us}|$
- Test the V-A structure of the charged currents
- Provide essential information on the structures of the nucleon and low-lying hyperons.

Decay mode	$\mathcal{B}$ $(\times 10^{-4})$	$\lvert\Delta S\rvert$	$g_1(0)/f_1(0)$
$\Lambda \to pe^-\bar{\nu}_e$	8.32 ± 0.14	1	0.718 ± 0.015
$\Sigma^+ \to \Lambda e^+\nu_e$	0.20 ± 0.05	0	–
$\Sigma^- \to ne^-\bar{\nu}_e$	10.17 ± 0.34	1	-0.340 ± 0.017
$\Sigma^- \to \Lambda e^-\bar{\nu}_e$	0.573 ± 0.027	0	–
$\Sigma^- \to \Sigma^0 e^-\bar{\nu}_e$	–	0	–
$\Xi^0 \to \Sigma^+ e^-\bar{\nu}_e$	2.52 ± 0.08	1	1.210 ± 0.050
$\Xi^- \to \Lambda e^-\bar{\nu}_e$	5.63 ± 0.31	1	0.250 ± 0.050
$\Xi^- \to \Sigma^0 e^-\bar{\nu}_e$	0.87 ± 0.17	1	–
$\Xi^- \to \Xi^0 e^-\bar{\nu}_e$	< 23 (90% C.L.)	0	–
$\Omega^- \to \Xi^0 e^-\bar{\nu}_e$	56 ± 28	1	–

Decay mode	$\mathcal{B}$ $(\times 10^{-6})$ @90% C.L.	ΔS
$\Sigma^+ \to ne^+\nu_e{}^*$	< 5	1
$\Xi^0 \to \Sigma^- e^+\nu_e{}^*$	< 900	1
$\Xi^0 \to pe^-\bar{\nu}_e$	< 1300	2
$\Xi^- \to ne^-\bar{\nu}_e$	< 3200	2
$\Omega^- \to \Lambda e^-\bar{\nu}_e$	–	2
$\Omega^- \to \Sigma^0 e^-\bar{\nu}_e$	–	2

Radiative hyperon decays

- Nature of (weak) radiative decays remains open question -> EM, Weak, Strong interaction

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

Rare and forbidden hyperon decays

$B_i \to B_f l^+ l^-$ dilepton decays

$B_i \to B_f \nu\bar{\nu}$ decays via a Z-type penguin

Lepton-number-violating decays with $\Delta L = 2$

Questions

Shan

- For the study of the semileptonic decays, is there any other better method expect to use the “tag technique”?

Amit

- In Table 7, What is the meaning of Type A decay modes are through a photon–penguin-like weak neutral current and Type B decay modes are through a Z–penguin-like weak neutral current ? And In Type A decay mode why is the sensitivity of the last decay channel is so high? (which is <30.0)

Suyu

- What's the relationship between B and B(90% C.L.)?
- I suppose B should in the range of B(90% C.L.).
- But if you focus on table 7, you may find B is out of the range B(90% C.L.).

Decay mode	Current data $\mathcal{B}$ ($\times 10^{-6}$)	Sensitivity $\mathcal{B}$ (90% C.L.) ($\times 10^{-6}$)	Type
$\Lambda \to ne^+e^-$	–	< 0.8	
$\Sigma^+ \to pe^+e^-$	< 7	< 0.4	
$\Xi^0 \to \Lambda e^+e^-$	7.6 ± 0.6	< 1.2	

Yuhang

- In page2, it says:"the Ω− can be only produced in the ψ(2S) decays owing to the allowed phase space". How to understand this?

Ryuta

- in $5.4, LNV and BNV are picked up and table 8 summarize the decay mode. Delta_L==2 can represent the possibility of Majorana neutrino model, and (Delta_L==1 && Delta_B==1/-1) would reflect the B-L conservation assumption, but what kind of models support the Delta_L==1 && Delta_B==0 case ?