Measurement of Branching Fraction of Singly Cabibbo-suppressed Decays $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^+ K_S^0$

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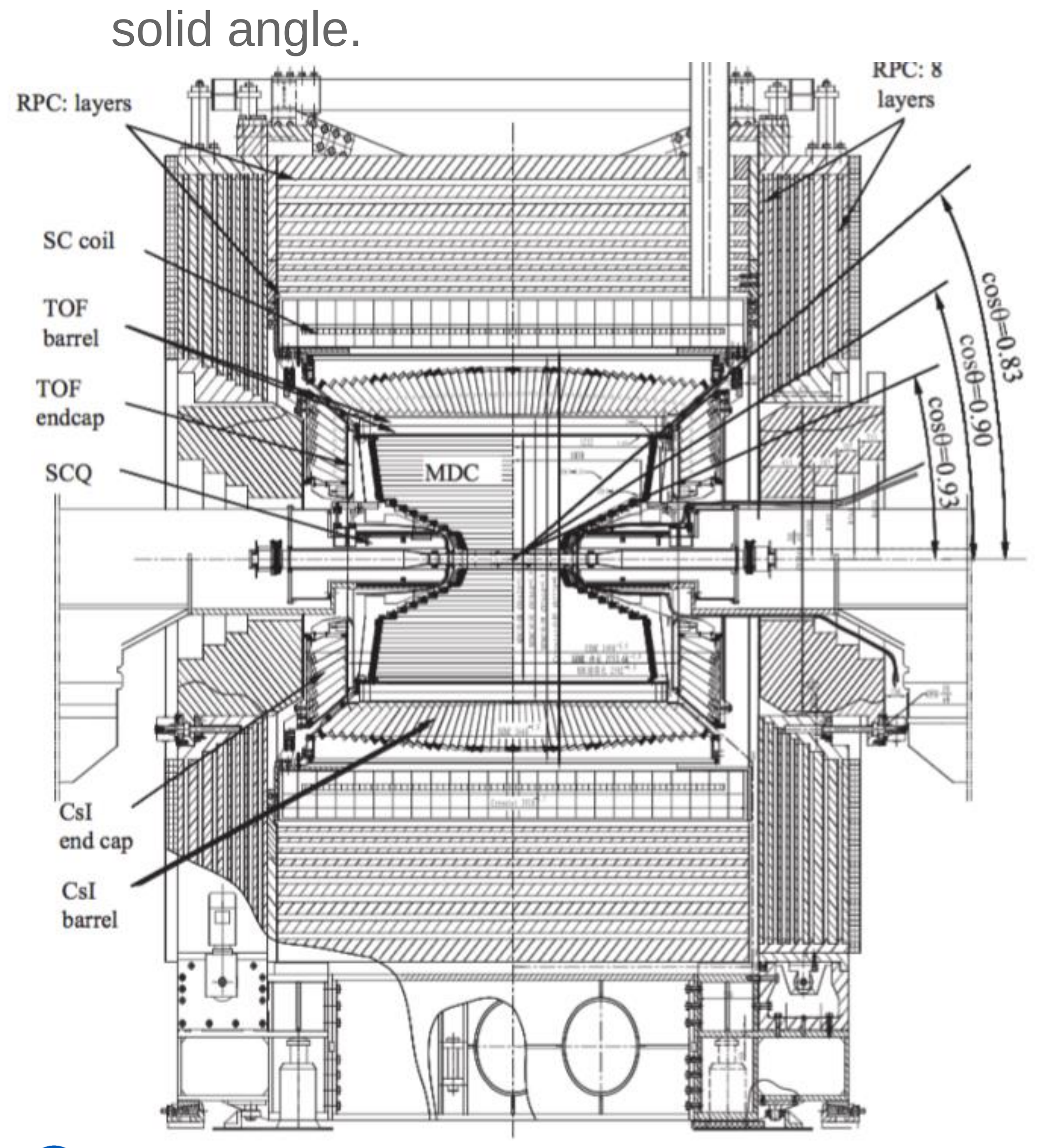
Abstract

Based on data collected in the energy region between 4.6 GeV and 4.7 GeV with the BESIII detector, two singly Cabibbo-suppressed (SCS) decays $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^+ K_S^0$ are studied. The branching fractions (BF) of the SCS decays are important for validating and improving these theoretical-model calculations. Furthermore, improved measurements may clarify the tension between the predictions in different models. The BFs of $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^+ K_S^0$ are measured to be $(4.7 \pm 0.9(stat.) \pm 0.1(syst.) \pm 0.3(ref.)) \times 10^{-4}$ and $(4.8 \pm 1.4(stat.) \pm 0.2(syst.) \pm 0.3(ref.)) \times 10^{-4}$, respectively. The BF of $\Lambda_c^+ \to \Sigma^+ K_S^0$ decay is measured for the first time.

Introduction

- BEPC operated at $\sqrt{s} = 2.0 \sim 4.95$ GeV with a peak luminosity of 1×10^{33} cm^{-2}s^{-1}.
- The BESIII detector covers 93% of full solid angle.



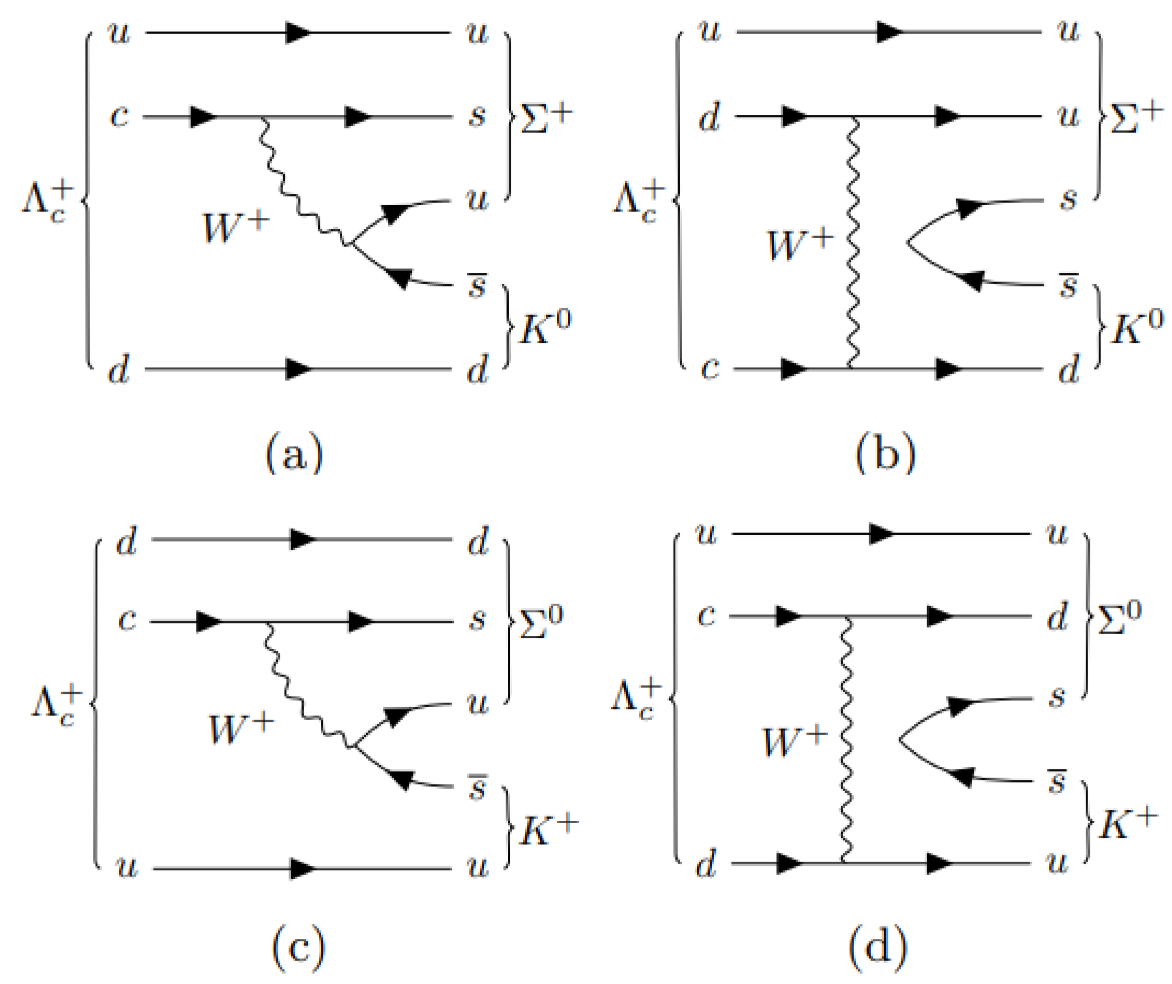
Ⓐ The sketch map of the BESIII detector

① The main performance parameters [1] of the BESIII detector

Performance	Value
Momentum resolution at 1GeV/c	0.5%
Ionization energy loss dE/dx resolution	6%
EMC energy resolution at 1GeV in the barrel	2.5%
end-cap	5.0%
Time resolution in the region of TOF barrel	68 ps
end-cap	60 ps

Motivation

- The $\Lambda_c \to \Sigma^0 K^+$ and $\Sigma^+ K_S^0$ modes only receive nonfactorizable contributions from (a)(c) internal W-emission and (b)(d) W-exchange diagrams.



Ⓑ The Feynman diagrams of the SCS decays

- Different methodologies are applied to account for nonfactorizable contributions and give predictions shown in Table ②.
- It is important to test these predictions and clarify the tension between different predictions.
- The data samples collected at $\sqrt{s} =$ 4.6~4.7 GeV corresponding to integrated luminosity of 4.4 fb^{-1} are suitable for studying the SCS decays $\Lambda_c \to \Sigma^0 K^+$ and $\Sigma^+ K_S^0$.

Event Selection

Single tag method are used for the event selection:

- Threshold production of $\Lambda_c^+ \bar{\Lambda}_c^-$ samples, only one side reconstructed.
- To extract signals, we use energy difference $\Delta E = E - E_{\rm beam}$ and beam-constraint mass $M_{BC} = \sqrt{E_{\rm beam}^2/c^4 - p^2c^2}$.

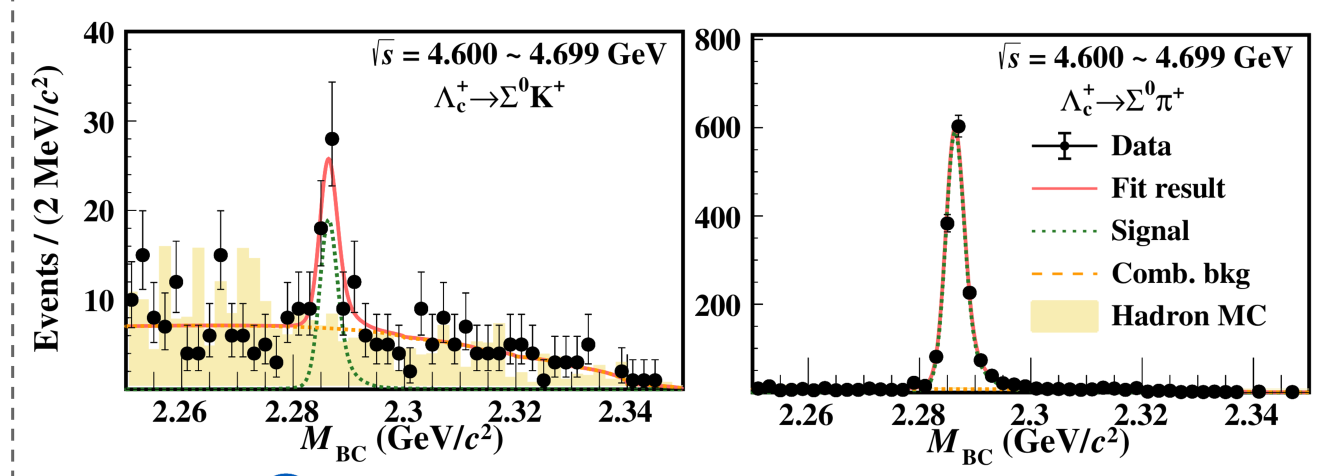
② The predictions, PDG value and our result of BFs for the SCS decays (in unit of 10^{-4})

	$\mathcal{B}(\Sigma^0 K^+)$	$\mathcal{B}(\Sigma^+ K_S^0)$
QCD Corrections [2]	$2 \sim 8$	$2 \sim 4$
MIT bag model [3]	7.2 ± 1.8	7.2 ± 1.8
Diagrammatic analysis [4]	5.5 ± 1.6	9.6 ± 2.4
$SU(3)_F$ flavor symmetry [5]	5.4 ± 0.7	5.4 ± 0.7
IRA method [6]	5.0 ± 0.6	1.0 ± 0.4
PDG 2020 [7]	5.2 ± 0.8	N/A
Our result	$\mathbf{4.7 \pm 1.0}$	$\mathbf{4.8 \pm 1.4}$

Relative branching fraction measurement

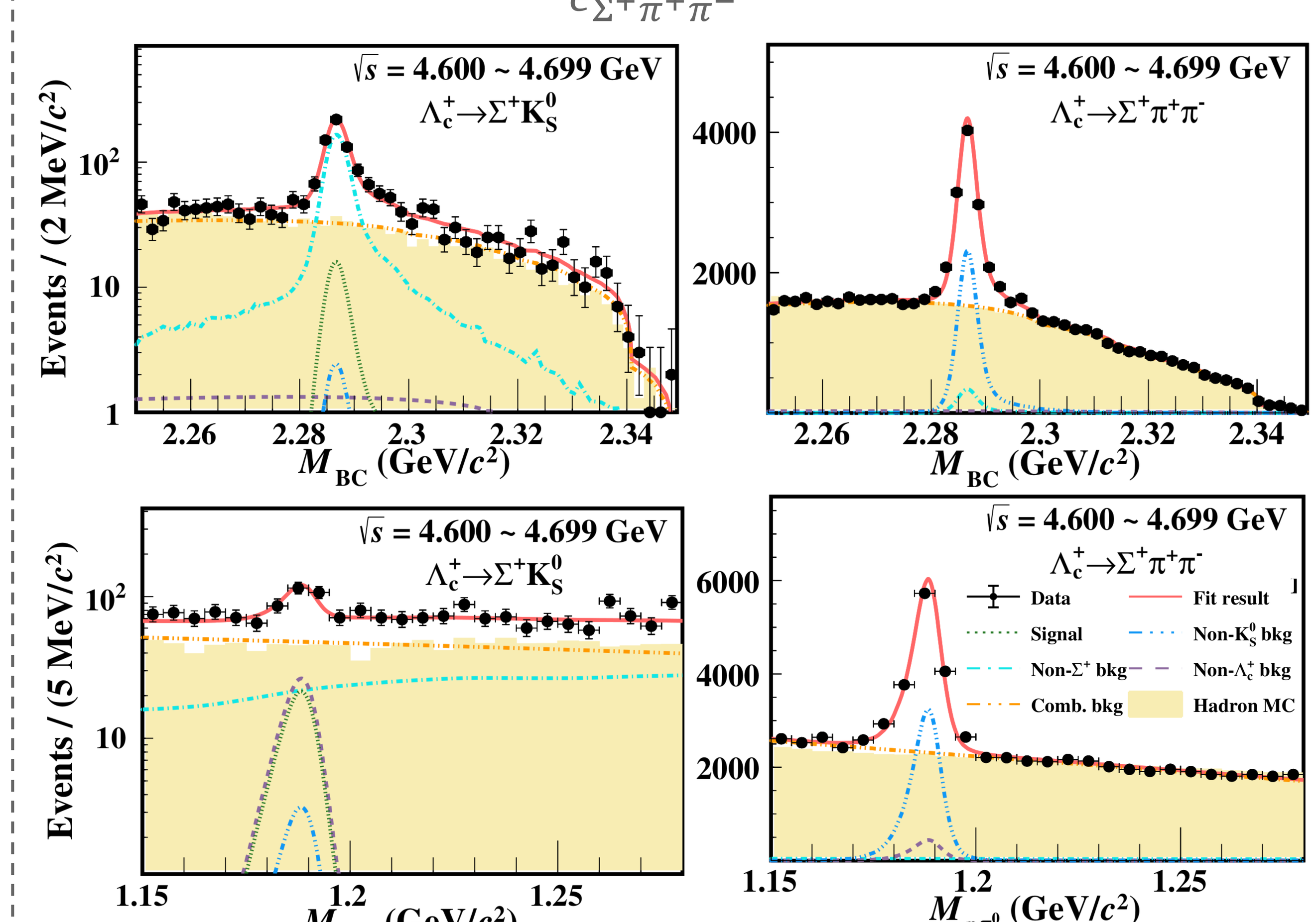
To mitigate systematic uncertainties associated with Σ detection, we measure $R_{\Sigma^0 K^+} \equiv \mathcal{B}(\Lambda_c^+ \to \Sigma^0 K^+)/\mathcal{B}(\Lambda_c^+ \to \Sigma^0 \pi^+)$ and $R_{\Sigma^+ K_S^0} \equiv \mathcal{B}(\Lambda_c^+ \to \Sigma^+ K_S^0)/\mathcal{B}(\Lambda_c^+ \to \Sigma^+ \pi^+ \pi^-)$.

- For $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^0 \pi^+$ modes, unbinned maximum likelihood fit to $M_{\rm BC}$ spectra is used to extract signal yields. Signal shape is derived from MC simulation convolved with Gaussian functions. The continuum backgrounds are described with ARGUS functions.



Ⓒ Fit results of the $M_{\rm BC}$ spectra of $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^0 \pi^+$ modes

- For $\Lambda_c^+ \to \Sigma^+ K_S^0$ and $\Sigma^+ \pi^+ \pi^-$ modes, 2D unbinned maximum likelihood fit to $M_{\rm BC}$ and $M_{p\pi^0}$ is used. Besides continuum backgrounds, peaking backgrounds from $\Lambda_c^+ \to p K_S^0 \pi^0$ are also considered. Cross-feeds from $\Lambda_c^+ \to \Sigma^+ \pi^+ \pi^-$ is calculated with $n_{\rm cross-feed} = \frac{\epsilon_{\rm cross-feed}}{\epsilon_{\Sigma^+\pi^+\pi^-}} \cdot n_{\Sigma^+\pi^+\pi^-}$.



Ⓓ The $M_{\rm BC}$ and $M_{p\pi^0}$ projections of 2D fit results of $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^0 \pi^+$ modes

Conclusion

Using singe tag method, the SCS decays $\Lambda_c^+ \to \Sigma^0 K^+$ and $\Sigma^+ K_S^0$ are studied. The BFs are then determined as shown in Table ②. The results are consistent with $SU(3)_F$ flavor symmetry [3,5]. The prediction in Ref. [6] differs from our result by 2.5σ, indicating a reassessment of the IRA method may be needed.

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Beijing Spectrometer(BESIII) Experiment