Partial Wave Analysis of the Charmed Baryon Decay $\Lambda_c^+ \to \Lambda\pi^+\pi^0$

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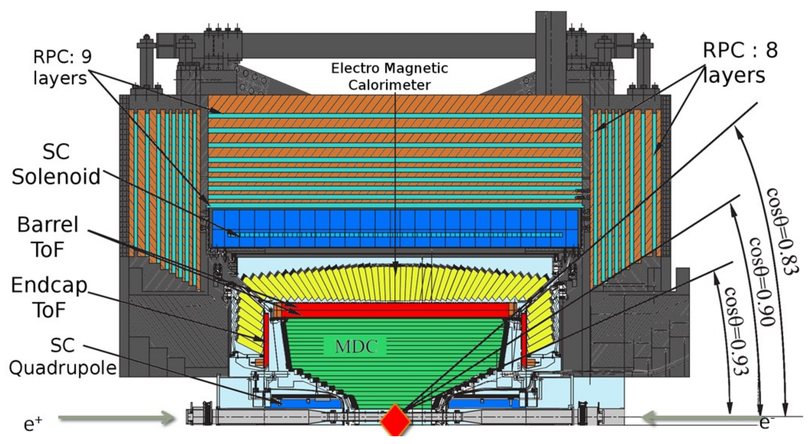
Abstract

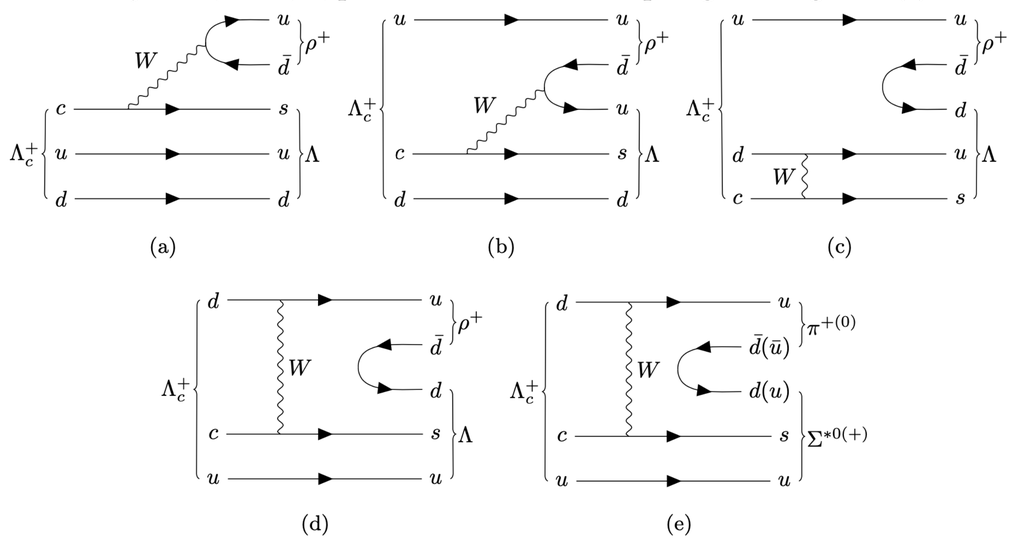
Based on e^+e^- collision samples corresponding to an integrated luminosity of 4.5 fb^{-1} collected with BESIII detector at center-of-mass energies between 4.6 GeV and 4.7 GeV, the first partial wave analysis of the charmed baryonic decay $\Lambda_c^+ \to \Lambda\pi^+\pi^0$ is performed. From the analysis results, the decays of $\Lambda_c^+ \to \Lambda\rho(770)^+$ and $\Lambda_c^+ \to \Sigma(1385)\pi$ are studied for the first time. In combination with the world average branching fraction $\mathcal{B}(\Lambda_c^+ \to \Lambda\pi^+\pi^0)$, we determine their absolute branching fractions for the first time. In addition, according to the results of the amplitudes from the partial wave analysis, the decay asymmetry parameters $\alpha_{\Lambda\rho(770)^+}$, $\alpha_{\Sigma(1385)^+\pi^0}$ and $\alpha_{\Sigma(1385)^0\pi^+}$ can also be obtained. These results are reported for the first time.

Introduction

- BEPCIl and BESIII
  - BEPCII/BESIII is a great upgrade for BES detector and BEPC accelerator.
  - BESIII consists of 4 sub-detectors:
    MDC(Main Draft Chamber), TOF (Time-Of-Flight System),
    EMC(Electromagnetic Calorimeter), MUC(Muon Chamber System).



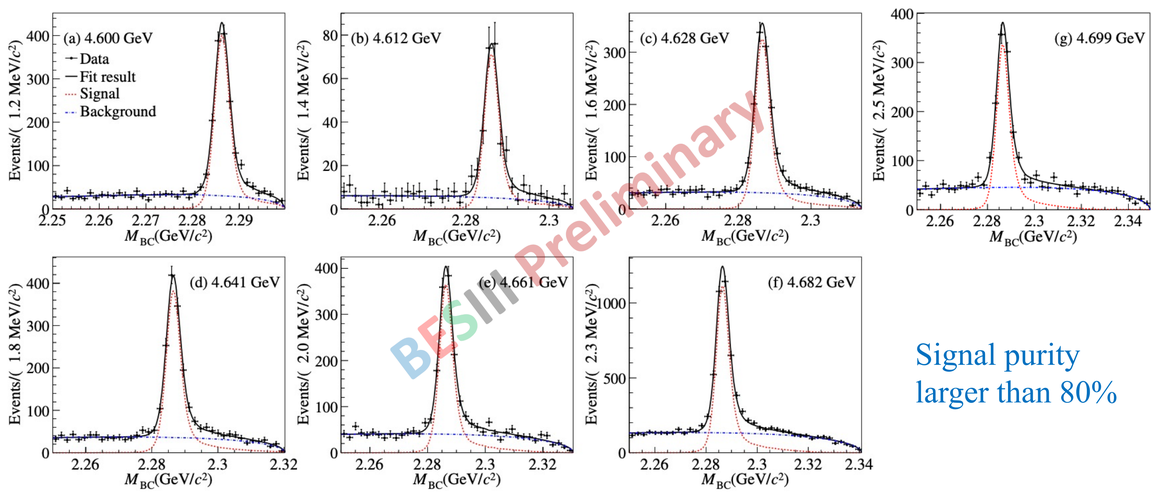
- Motivation:
  ① BF of decay $\Lambda_c^+ \to \Lambda\pi^+\pi^0$ measured by BESIII with high precision[1], but no previous study on intermediate structure.
  ② Precise measurement provides more stringent test of theoretical models, help to deepen our understanding the dynamics of charmed baryon decays.
  ③ Resonant process $\Lambda_c^+ \to \Lambda\rho(770)^+$, complicated topological diagrams including both factorizable and non-factorizable contributions (a-d)[2];
  while $\Lambda_c^+ \to \Sigma(1385)\pi$, pure non-factorizable topological diagrams (e)[3]:



Topological diagrams contributing to decays $\Lambda_c^+ \to \Lambda\rho(770)^+$ and $\Lambda_c^+ \to \Sigma(1385)\pi$

Event Selection

- Single Tag Method
  - Threshold production of $\Lambda_c^+\bar{\Lambda}_c^-$ samples, only one side reconstructed
  - Variables energy difference $\Delta E \equiv E_{\text{rec}} - E_{\text{beam}}$ and beam-constraint mass $M_{\text{BC}} \equiv \sqrt{E_{beam}^2/c^4 - p^2/c^2}$ used to extract signal candidates:

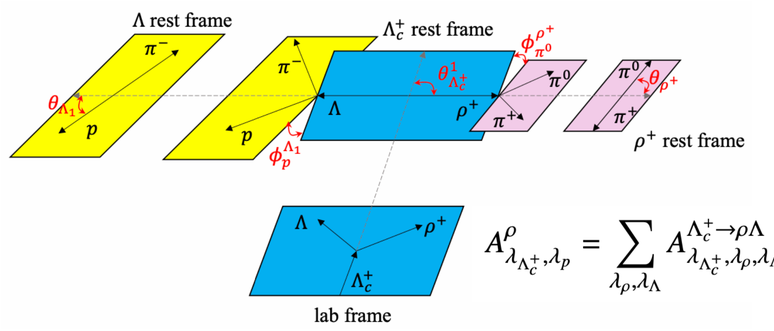


Signal purity larger than 80%

Result of M_{BC} fits on data for each energy point

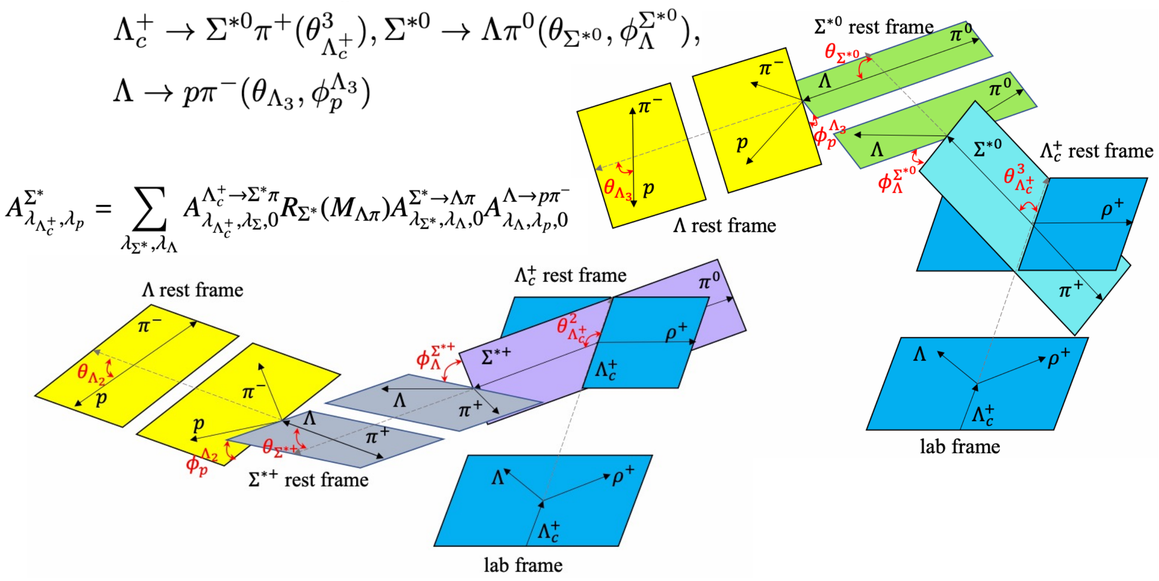
Partial Wave Analysis (PWA)

- Using helicity amplitude formalism[4], describe full amplitude with several quosi-two-body amplitude of different decay chains
  - For process $0 \to 1 + 2$: $A^{0\to1+2}_{\lambda_0,\lambda_1,\lambda_2} = H^{0\to1+2}_{\lambda_1,\lambda_2} D^{J_0*}_{\lambda_0,\lambda_1-\lambda_2}(\phi,\theta,0)$
  - $D^{J_0*}_{\lambda_0,\lambda_1-\lambda_2}(\phi,\theta,0)$ denotes Wigner-D function
- Different decay chains:
  - $\Lambda_c^+ \to \Lambda\rho(770)^+(\theta^1_{\Lambda_c^+}), \rho(770)^+ \to \pi^+\pi^0(\theta_{\rho^+}, \phi^{\rho^+}_{\pi^0}), \Lambda \to p\pi^-(\theta_{\Lambda_1}, \phi^{\Lambda_1}_p)$



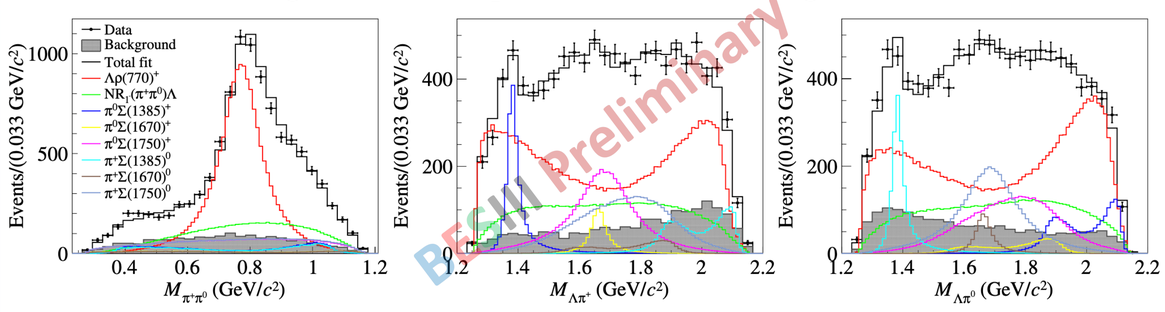
$$A^{\rho}_{\lambda_{\Lambda_c^+},\lambda_p} = \sum_{\lambda_\rho,\lambda_\Lambda} A^{\Lambda_c^+\to\rho\Lambda}_{\lambda_{\Lambda_c^+},\lambda_\rho,\lambda_\Lambda} R_\rho(M_{\pi^+\pi^0}) A^{\rho\to\pi^+\pi^0}_{\lambda_\rho,0,0} A^{\Lambda\to p\pi^-}_{\lambda_\Lambda,\lambda_p,0}$$

- $\Lambda_c^+ \to \Sigma^{*+}\pi^0(\theta^2_{\Lambda_c^+}), \Sigma^{*+} \to \Lambda\pi^+(\theta_{\Sigma^{*+}}, \phi^{\Sigma^{*+}}_{\Lambda}), \Lambda \to p\pi^-(\theta_{\Lambda_2}, \phi^{\Lambda_2}_p)$
  $\Lambda_c^+ \to \Sigma^{*0}\pi^+(\theta^3_{\Lambda_c^+}), \Sigma^{*0} \to \Lambda\pi^0(\theta_{\Sigma^{*0}}, \phi^{\Sigma^{*0}}_{\Lambda}),$
  $\Lambda \to p\pi^-(\theta_{\Lambda_3}, \phi^{\Lambda_3}_p)$



$$A^{\Sigma^*}_{\lambda_{\Lambda_c^+},\lambda_p} = \sum_{\lambda_{\Sigma^*},\lambda_\Lambda} A^{\Lambda_c^+\to\Sigma^*\pi}_{\lambda_{\Lambda_c^+},\lambda_\Sigma,0} R_{\Sigma^*}(M_{\Lambda\pi}) A^{\Sigma^*\to\Lambda\pi}_{\lambda_{\Sigma^*},\lambda_\Lambda,0} A^{\Lambda\to p\pi^-}_{\lambda_\Lambda,\lambda_p,0}$$

- Full amplitude is the coherent sum of all decay chains, then calculating module square and normalization
- Likelihood constructed by summing all signal candidates subtracting sideband backgrounds, then perform maximum log likelihood fit:



Projections of the fit results on invariant mass spectra

	Theoretical calculation		This work	PDG [1]
$10^2 \times \mathcal{B}(\Lambda_c^+ \to \Lambda\rho(770)^+)$	4.81 ± 0.58 [2]	4.0 [5]	4.06 ± 0.52	< 6
$10^3 \times \mathcal{B}(\Lambda_c^+ \to \Sigma(1385)^+\pi^0)$	2.8 ± 0.4 [3]	2.2 ± 0.4 [6]	5.86 ± 0.80	—
$10^3 \times \mathcal{B}(\Lambda_c^+ \to \Sigma(1385)^0\pi^+)$	2.8 ± 0.4 [3]	2.2 ± 0.4 [6]	6.47 ± 0.96	—
$\alpha_{\Lambda\rho(770)^+}$	-0.27 ± 0.04 [2]	-0.32 [5]	-0.763 ± 0.066	—
$\alpha_{\Sigma(1385)^+\pi^0}$	$-0.91^{+0.45}_{-0.10}$ [6]		-0.917 ± 0.083	—
$\alpha_{\Sigma(1385)^0\pi^+}$	$-0.91^{+0.45}_{-0.10}$ [6]		-0.79 ± 0.11	—

Results of branching fractions and decay asymmetry parameters

Summary

To summarize, based on e^+e^- collision sample corresponding to an integrated luminosity of 4.5 fb^{-1} collected with BESIII detector at center-of-mass energies from 4.6 GeV to 4.7 GeV, the first PWA of $\Lambda_c^+ \to \Lambda\pi^+\pi^0$ is performed. Our measurements serve as crucial inputs to improve the theoretical model calculations, and thus, help to deepen our understanding of the dynamics of the charmed baryon decay.

References

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