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Absolute branching fractions of Λ_c^+ hadronic decays at BESIII

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Abstract

Based on 567 pb^{-1} of e^+e^- collision data at $\sqrt{s}$ = 4.6 GeV accumulated with the BESIII detector, we measure absolute branching fractions of Λ_c^+ hadronic decays using a double tag technique. Among measurement for twelve Λ_c^+ decay modes, we obtain branching fraction $B(\Lambda_c^+ \to pK^-\pi^+) = (5.77 \pm 0.27)\%$. This is the first model-independent measurement of their absolute branching fractions at the $\Lambda_c^+\Lambda_c^-$ pair threshold, after Λ_c^+ was discovered 30 years ago.

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1. Introduction

Λ_c was firstly observed in 1980s by the MarkII experiment **[1]**. While its properties have been well identified in experiments, no measurements of branching fractions (BF) of its decays are model-independent.

Most of BF are measured relative to $\Lambda_c^+ \to pK^-\pi^+$ **[2]** which is determined on model assumption.

Absolute BF of Λ_c^+ decays still not well determined until Belle's first model-independent measurement:

$$\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+) = (6.84 \pm 0.24^{+0.21}_{-0.27})\% \ \textbf{[3]}.$$

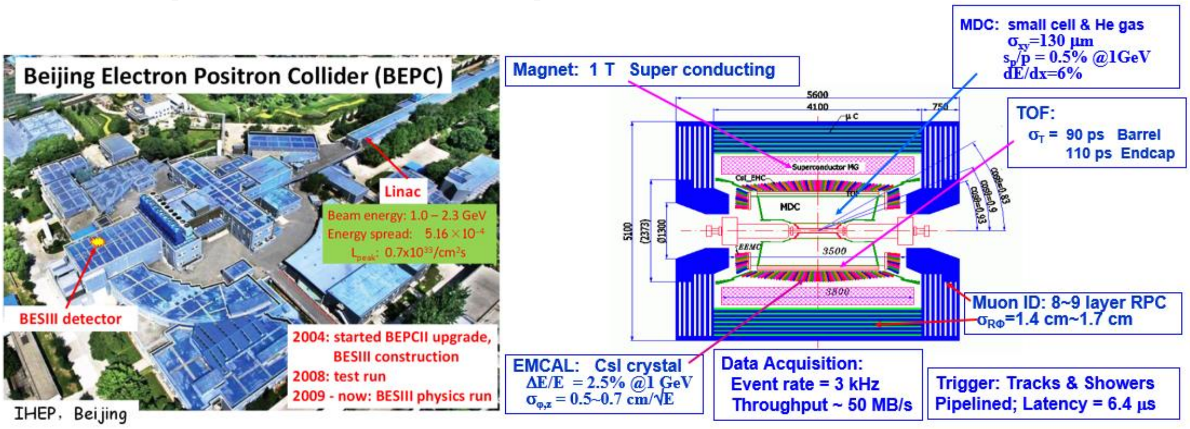
The precision reaches to 4.7%.

BESIII collected the world largest on-threshold data at the center-of-mass energy $\sqrt{s}$=4.6 GeV. The data set is unique in the world and can provide model-independent measurement of $\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+)$ using the double-Λ_c^+ tagging technique.

- No additional hadrons accompany the $\Lambda_c^+\Lambda_c^-$ pairs are produced.
- Lots of systematic uncertainties cancel (double tag method).

2. BESIII and BEPC

The BESIII detector is a spectrometer located at BEPCII, which is a double-ring e^+e^- collider working at the center-of-mass energy range from 2 to 4.6 GeV. The cylindrical core of the BESIII detector consists of a helium-based multi-layer drift chamber (MDC), a plastic scintillator time-of-flight system (TOF), and a CsI (Tl) electromagnetic calorimeter (EMC), which are all enclosed in a superconducting solenoid magnet providing a 1.0 T magnetic field. The solenoid is supported by an octagonal flux-return yoke with modules of resistive plate muon counters interleaved with steel. The momentum resolution for charged particles at 1 GeV/c is 0.5%, and the resolution of the ionization energy loss per unit path-length (dE/dx) is 6%. The EMC measures photon energies with a resolution of 2.5% (5%) at 1 GeV in the barrel (end cap). The time resolution of the TOF is 80 ps in the barrel and 110 ps in the end cap. A detailed description of the BESIII detector is provided in Reference **[4]**.



Left Figure: the BEPC schematic. Right Figure: the BESIII schematic

Figure 1: BEPC and BESIII detector.

3. Determine BF($\Lambda_c^\pm \to \boldsymbol{hadrons}$) in experiment

Two variables reflecting energy and momentum conservation are used to identify valid signals of $\Lambda_c^\pm$candidates.

Firstly, we calculate the energy difference, $\Delta E = E - E_0$, where E is the total measured energy of the $\Lambda_c^\pm$ candidate and E_0 is the mean value of the e^+ and e^- beams in the center-of-mass system of the head-on e+e− beams. Candidates are rejected if they fail the ΔE requirements. The distributions of ΔE in data are shown in Figure 2.

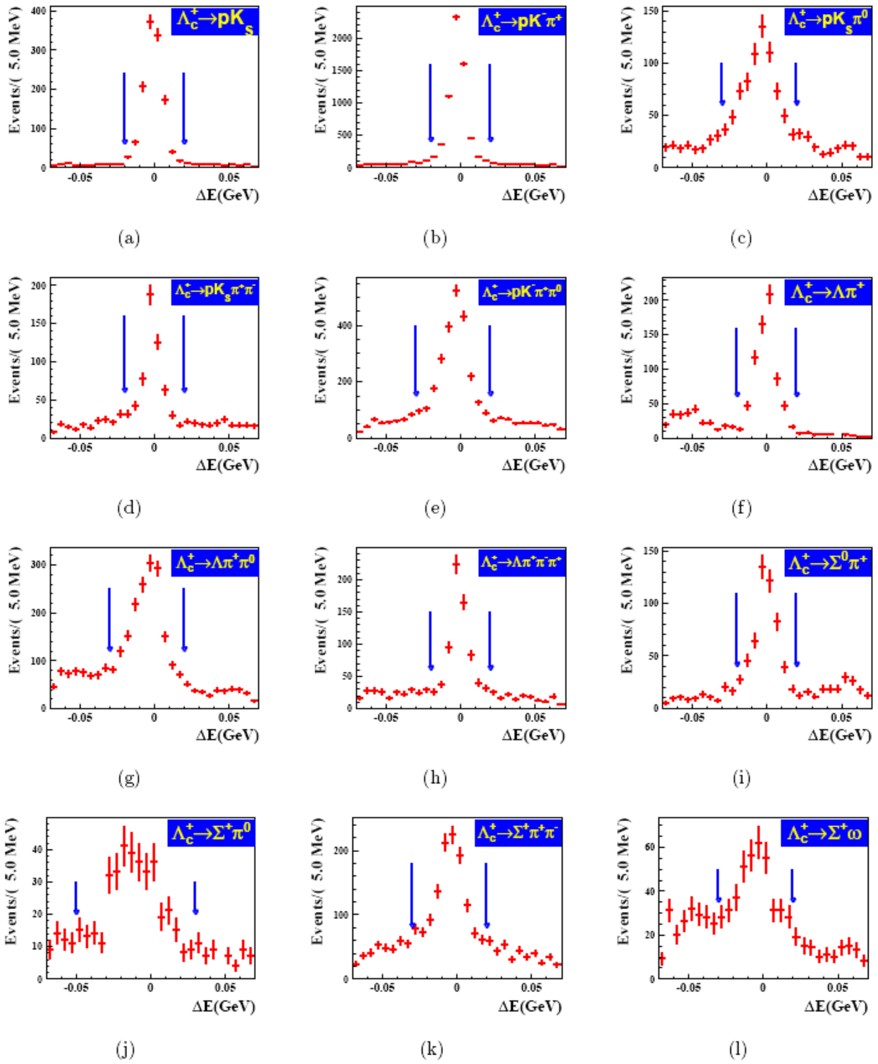


Figure 2: Distribution of the ΔE in data for different decay mode.

Secondly, we define the beam-constrained mass M_{BC} of the candidates by substituting the beam energy E_0 for the energy E of the $\Lambda_c^\pm$ candidates, $M_{BC}^2 = E_0^2 - p^2$, where p is the measured total momentum in the center-of-mass system of the head-on e^+e^- beams. $\Lambda_c^\pm$ signals peak in M_{BC} at c $\Lambda_c^\pm$ mass. To obtain data yields, we fit the M_{BC} (see Figure 3 and 4)distributions for events with $M_{BC} > 2.25$GeV.

Following a technique firstly introduced by the MARKIII Collaboration **[5, 6]**, we select ST events in which either a Λ_c^+ or Λ_c^- is reconstructed out of all the final state particles, and DT events in which both the Λ_c^+ and Λ_c^- are reconstructed. Absolute branching fractions for Λ_c^+ or Λ_c^- decays can then be obtained from the relative yields of ST events to DT events, with correction of their relative tagging efficiencies estimated in MC simulations. This will provide a clean and model-independent BF measurement without knowing the total number of $\Lambda_c^+\Lambda_c^-$ events produced.

If CP violation is negligible, the BF of Λ_c^+ decay to mode i^+, B_{i+}, and Λ_c^- decay to mode i^-, B_{i-} are equal. Therefore, we denote $B_{i+} = B_{i-} = B_i$. The observed yields of reconstructed ST events which combined $\Lambda_c^+ \to i^+$ and $\Lambda_c^- \to i^-$, N_i^{ST} will be $N_i^{ST} = N_{\Lambda_c^+\Lambda_c^-} \cdot B_i \cdot \varepsilon_i^{ST}$, where $N_{\Lambda_c^+\Lambda_c^-}$ is the total number of $\Lambda_c^+\Lambda_c^-$ pair produced and ε_i^{ST} is the efficiency for detecting ST modes. The DT yields $N_i^{DT} = N_{\Lambda_c^+\Lambda_c^-} \cdot B_i \cdot B_j \cdot \varepsilon_{ij}^{DT}$, where ε_{ij}^{DT} is the efficiency for detecting DT modes. Hence, we have $N_{-j}^{DT} = \sum_i N_{ij}^{DT} = B_j \cdot \sum_i (\frac{N_i^{ST}}{\varepsilon_i^{ST}} \cdot \varepsilon_{ij}^{DT})$. So the ration of the DT yield to the ST yield provides an absolute measurement of the branching fraction B_j. DT yield and the ST yield are listed in Table 1.

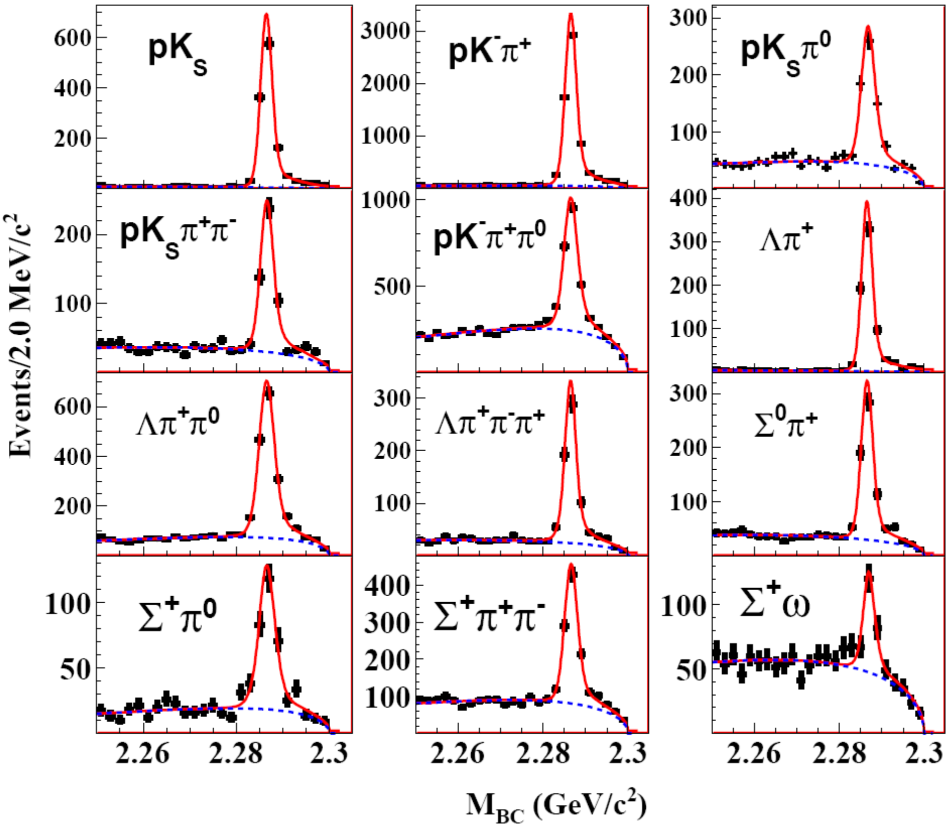


Figure 3: Fit results obtained from the ST *MBC* distributions in **data** for different decay modes which combined charge conjugation modes. Points with error bars are data, solid lines are the sum of fit functions, blue dashed lines are the ARGUS functions.

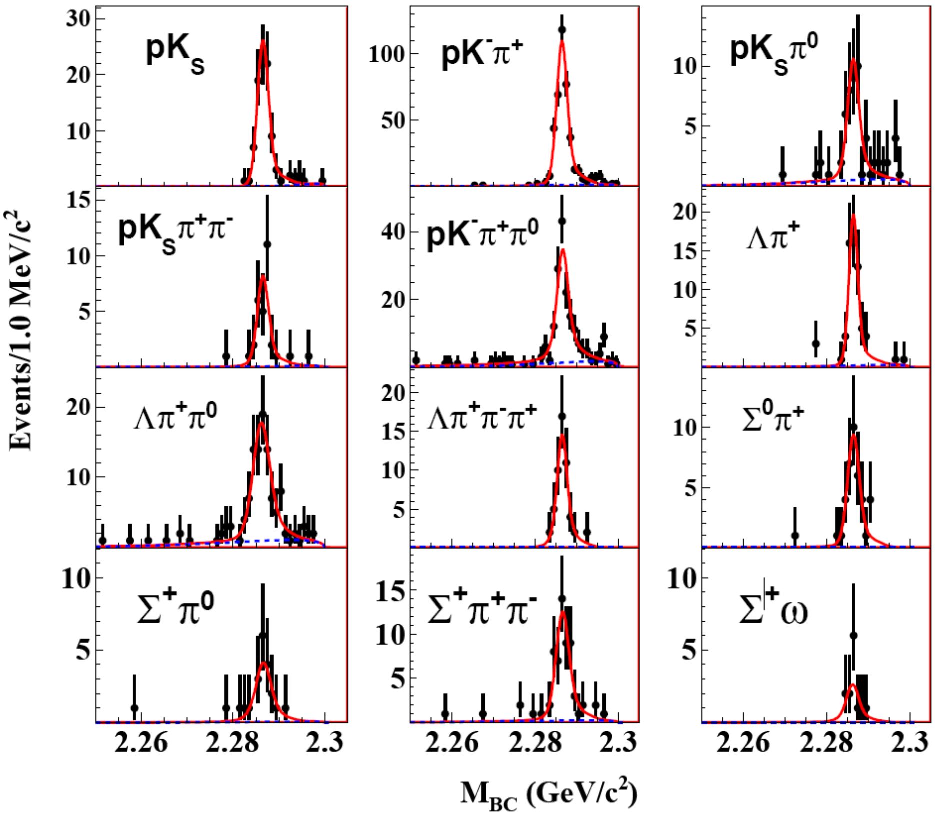


Figure 4: Fit results in the DT MBC distributions in data for different decay modes.

modes	N_i^{ST}	$\varepsilon_i^{ST}(\%)$	N_{-j}^{DT}
pK_S	1243 ± 37	56.9 ± 0.2	89 ± 10
$pK^-\pi^+$	6308 ± 88	51.7 ± 0.2	390 ± 21
$pK_S\pi^0$	558 ± 33	21.4 ± 0.3	40 ± 7
$pK_S\pi^+\pi^-$	454 ± 28	21.2 ± 0.3	29 ± 6
$pK^-\pi^+\pi^0$	1848 ± 71	20.4 ± 0.2	148 ± 14
$\Lambda\pi^+$	706 ± 27	43.2 ± 0.2	59 ± 8
$\Lambda\pi^+\pi^0$	1497 ± 52	16.1 ± 0.1	89 ± 11
$\Lambda\pi^+\pi^-\pi^+$	608 ± 31	12.4 ± 0.1	53 ± 7
$\Sigma^0\pi^+$	586 ± 32	33.5 ± 0.6	39 ± 6
$\Sigma^+\pi^0$	271 ± 25	21.2 ± 0.4	20 ± 5
$\Sigma^+\pi^+\pi^-$	836 ± 43	20.8 ± 0.3	56 ± 8
$\Sigma^+\omega$	157 ± 22	10.8 ± 0.5	56 ± 8

Table 1: ST yields and DT yields and corresponding ST detection efficiencies which combined charge conjugation modes. The uncertainties are statistical only. These efficiencies don't include any sub-decay branching fractions.

4. Global fit to extract branching fractions

To obtain the branching ratios B of Λ_c^+, we use a least square fitter to handle the statistical and correlated systematic uncertainties among the different decay modes simultaneously. The method was generally discussed in Reference **[7]**. Our direct observables are the numbers of signal events from ST and DT, denote as **n**. With extraction of the backgrounds, their expected values are functions of branching fractions and the total number $\Lambda_c^+\Lambda_c^-$ events, namely $N_{\Lambda_c^+\Lambda_c^-}$. The observed signal events in each mode receive possible cross feed contributions from other signal processes and contaminations from peaking backgrounds which are not belonging to the process of interest. Based on our studies, peaking backgrounds in this measurement are suppress to a negligible level, thus are not considered in the global fit. The efficiencies-corrected yields, denoted by **c**, can be expressed as:

$$\mathbf{c} = \mathbf{E}^{-1}\mathbf{n},$$

where, **E** is the signal efficiencies matrix which describes detection efficiencies (diagonal elements) and cross feed probabilities (off-diagonal elements). If we have a set of N yields (N=24 in this analysis) in our measurement, 40 the **E** is a N × N matrix. Based on the lease square principle, The χ^2 can be constructed as:

$$\chi^2 \equiv (\boldsymbol{c} - \tilde{\boldsymbol{c}})\boldsymbol{T}\ \mathrm{Vc\text{-}1}(\boldsymbol{c} - \tilde{\boldsymbol{c}}) + 2\boldsymbol{\lambda}_{\boldsymbol{\alpha}}^{\boldsymbol{T}}\mathrm{g}(\tilde{\boldsymbol{c}}, \boldsymbol{m}),$$

where **m** indicates unknown parameters, including the branching ratios (B) of interest and $N_{\Lambda_c^+\Lambda_c^-}$, a set of **M** (**M**=13 in this analysis) unknown free parameters. The $\tilde{\boldsymbol{c}}$ is the expected value of efficiency-corrected yields, it can be calculated from the expected B and $N_{\Lambda_c^+\Lambda_c^-}$. The $\boldsymbol{\lambda}_{\boldsymbol{\alpha}}$ are the vectors of Lagrange multipliers. Minimizing the χ^2 leads to find the optimized value of **m**. There are many approaches in χ^2 minimization. We adopt the iterative procedure. That is, the estimated values in step **k**, $\mathbf{m}^{\mathbf{k}}$, are used as seeds for calculating the estimators $\mathbf{m}^{\mathbf{k+1}}$ in the step k+1. The fit procedure is to reiterate until the χ^2 converges.

Based on the global fit, we get the result of $N_{\Lambda_c^+\Lambda_c^-}$ and BFs of the 12 Λ_c^+ decay modes. The results of the fit are shown in TABLE 2. The precision on B($\Lambda_c^+ \to pK^-\pi^+$) is comparable with Belle's result, and precisions of the other 11 modes are improved significantly.

Decay modes	global fit $\mathcal{B}$	PDG $\mathcal{B}$	Belle $\mathcal{B}$
pK_S	1.48 ± 0.08	1.15 ± 0.30	
$pK^-\pi^+$	5.77 ± 0.27	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S\pi^0$	1.77 ± 0.12	1.65 ± 0.50	
$pK_S\pi^+\pi^-$	1.43 ± 0.10	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	4.25 ± 0.22	3.4 ± 1.0	
$\Lambda\pi^+$	1.20 ± 0.07	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	6.70 ± 0.35	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	3.67 ± 0.23	2.6 ± 0.7	
$\Sigma^0\pi^+$	1.28 ± 0.08	1.05 ± 0.28	
$\Sigma^+\pi^0$	1.18 ± 0.11	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	3.58 ± 0.22	3.6 ± 1.0	
$\Sigma^+\omega$	1.47 ± 0.18	2.7 ± 1.0	

Table 2: Comparison of our branching ratios results with world measurements. The uncertainties in our result is statistical.

References

[1] G. S. Abrams, M. S. Alam, C. A. Blocker, A. Boyarski, M. Breidenbach, D. L. Burke, W. C. Carithers and W. Chinowsky et al., Phys. Rev. Lett. 44 (1980) 10.

[2] K.A. Olive et al. (Particle Data Group), Chinese. Phys. C38, 090001 (2014).

[3] A. Zupanc et al. [Belle Collaboration], Phys. Rev. Lett. 113, 042002 (2014).

[4] M. Ablikim et al. [BESIII Collaboration], Nucl. Instrum. Meth. A 614, 345 (2010).

[5] R.M.Baltrusaitis et al. [MARK-III Collaboration], Phys. Rev. Lett. 56, 2140 (1986).

[6] J.Adler et al. [MARK-III Collaboration], Phys. Rev. Lett. 60, 89 (1988).

[7] Y. Guan, X. R. Lu, Y. Zheng and Y. S. Zhu, Chinese Phys. C 37, 106201 (2013).