

# Measurement of the absolute branching fraction of the inclusive semileptonic $\Lambda_c^+$ decay

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# Outline

## 1 Overview

- about  $\Lambda_c^+$
- About this research
- What does the result tell us

## 2 About this experiment

- Double Tag
  - Tagging  $\bar{\Lambda}_c^-$

## 3 PID

## 4 References

## Section 1

### Overview

The lowest-lying charmed baryon  $\Lambda_c^+$  was discovered more than 40 years ago[1][2] , but its decays have not yet been fully mapped out due to the many available modes (about 80 kinds according to PDG2018).

BESIII collaboration measured the absolute branching fraction of  $\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e$  to be  $(3.63 \pm 0.43)\%$  [3]. compared with the absolute branching fraction of  $\Lambda_c^+ \rightarrow X e^+ \nu_e$  measured by MARK II as  $(4.5 \pm 1.7)\%$ . [4]

This research [5] aims to measure the the absolute branching fraction of  $\Lambda_c^+ \rightarrow Xe^+ \nu_e$  more precisely, and to determine the inclusive semileptonic decay widths  $\frac{\Gamma(\Lambda_c^+ \rightarrow Xe^+ \nu_e)}{\Gamma(D \rightarrow Xe^+ \nu_e)}$ .

And the result is:  $\mathcal{B}(\Lambda_c^+ \rightarrow Xe^+ \nu_e) = (3.95 \pm 0.34 \pm 0.09)\%$   
 $\frac{\Gamma(\Lambda_c^+ \rightarrow Xe^+ \nu_e)}{\Gamma(D \rightarrow Xe^+ \nu_e)} = 1.26 \pm 0.12$

$\mathcal{B}(\Lambda_c^+ \rightarrow X e^+ \nu_e) = (3.95 \pm 0.34 \pm 0.09)\%$ : center value is larger than that of  $\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e) = (3.63 \pm 0.43)\%$ . But it's difference is less than  $1\sigma$ . It is difficult to determine if there is other kinds of semileptonic decay. if there is, its absolute branching fraction will be much smaller than that of  $\Lambda_c^+ \rightarrow X e^+ \nu_e$

$\frac{\Gamma(\Lambda_c^+ \rightarrow X e^+ \nu_e)}{\Gamma(D \rightarrow X e^+ \nu_e)} = 1.26 \pm 0.12$ : This ratio is predicted to be 1.67 using an effective-quark theory calculation. [6] and 1.2 based on a calculation using the heavy-quark expansion [7]. A more precise measurement is needed to verify those theory.

This research used a double-tag method to obtain the branching fraction of the inclusive semileptonic  $\Lambda_c^+$  decay.

And used a common way to choose valid track, filter by invariant mass and beam energy, linear correction for particle identification (PID) and "Right Sign-Wrong Sign" method.

We can tell from symmetry, when electron and positron annihilations, they create matter and antimatter. Then matter and antimatter decay, not affected by each other. The branching fraction should be the same among them.

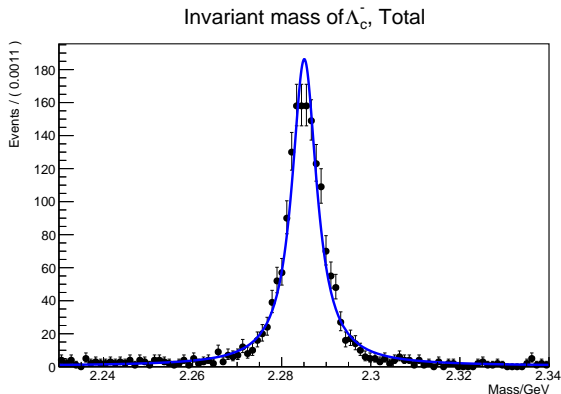
When it comes to  $\Lambda_c^+$  and  $\bar{\Lambda}_c^-$ ,  $e^+e^- \rightarrow \Lambda_c^+\bar{\Lambda}_c^-$  is the process that produces  $\Lambda_c^\pm$ .

It is difficult to figure out how many  $\Lambda_c^+\bar{\Lambda}_c^-$  pairs are produced in an experiment. But due to the decay of  $\Lambda_c^+$  and  $\bar{\Lambda}_c^-$  are independent (statistically independent):

We always have :  $\Pr(A | B) = \Pr(A)$ , where "A" means  $\Lambda_c^+$  decays into  $Xe^+\nu_e$  and "B" means  $\bar{\Lambda}_c^-$  decays into  $\bar{p}K_S^0$  or  $\bar{p}K^+\pi^-$ , which have a low background and easy to reconstruct.



That is the mathematical way to explain Double-Tag in this experiment. When doing the data analysis. We first fully reconstruct one  $\bar{\Lambda}_c^-$ . (Efficiency is about 58%)



**Figure:** Reconstructed invariant mass from MC sample, by  $\bar{p}K_S^0$  and  $\bar{p}K^+\pi^-$

When reconstructed by  $\bar{p}K_S^0$  and  $\bar{p}K^+\pi^-$  separately:

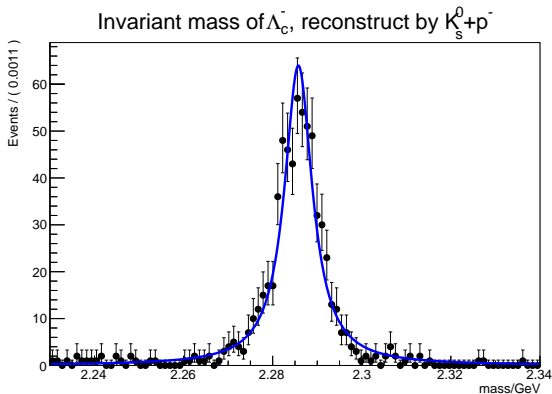


Figure: Reconstructed invariant mass from MC sample, by  $\bar{p}K_S^0$

When reconstructed by  $\bar{p}K_S^0$  and  $\bar{p}K^+\pi^-$  separately:

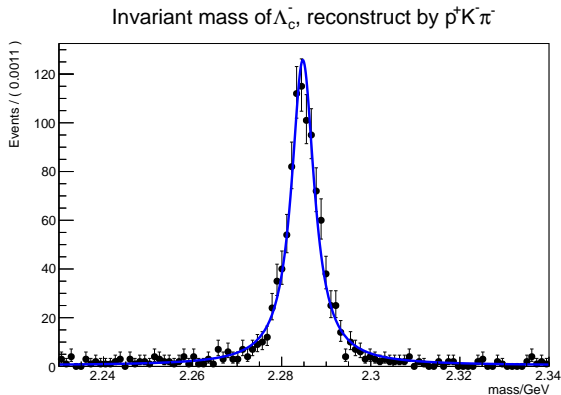


Figure: Reconstructed invariant mass from MC sample, by  $\bar{p}K^+\pi^-$




To suppress combinatorial backgrounds,  $\Delta E \equiv E_{\bar{\Lambda}_c^-} - E_{\text{beam}}$  should in  $(-3\sigma, 3\sigma)$  and  $M_{\text{BC}} = \sqrt{E_{\text{beam}}^2/c^4 - |\vec{p}_{\bar{\Lambda}_c^-}|^2/c^2}$  should satisfy  $2.282 < M_{\text{BC}} < 2.300 \text{ GeV}/c^2$




After the selection, the efficiency falls to 45%. Less than the efficiency listed in the article:

**Table:** Summary of  $\Delta E$  requirements, detection efficiencies and ST yields for the different tag modes. (Copied from article)

Tag mode	$\Delta E$ (MeV)	Efficiency (%)	Yield
$\bar{\Lambda}_c^- \rightarrow \bar{p} K_S^0$	$(-21, 19)$	$56.5 \pm 0.3$	$1214 \pm 36$
$\bar{\Lambda}_c^- \rightarrow \bar{p} K^+ \pi^-$	$(-20, 16)$	$50.1 \pm 0.1$	$6092 \pm 82$



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