Λ_c^+ Physics at BESIII

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Jing Maoqiang

Introduction

- The decays of charm baryon provide crucial information for the study of both strong and weak interactions.

- The hadronic decays of $\Lambda_{\boldsymbol{c}}^{+}$ provide important input to b physics, while the semi-leptonic (SL) decays of $\Lambda_{\boldsymbol{c}}^{+}$ provide a stringent test on non-perturbative theoretical models.

The production of Λ_c^+

- Born cross section of $e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$ reaction is measured at four CM energies: $\sqrt{s}$= 4574.5, 4580.0, 4590.0 and 4599.5 MeV.

- At each CM energy, ten Cabibbo-favored hadronic decay modes as well as the ten corresponding charge-conjugate modes are independently reconstructed.

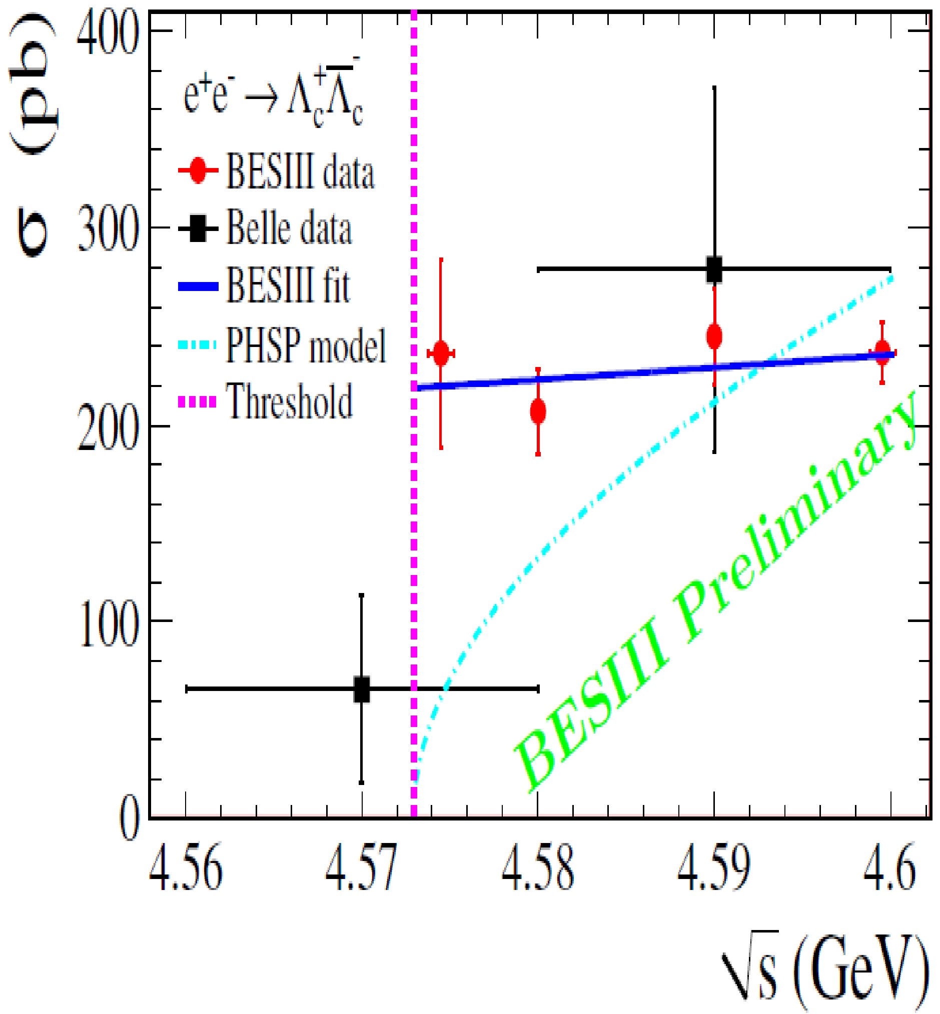
$\Lambda_c^+ \to pK^-\pi^+$, pK_S^0, $\Lambda\pi^+$, $pK^-\pi^+\pi^0$, $pK_S^0\pi^0$, $\Lambda\pi^+\pi^0$, $pK_S^0\pi^+\pi^-$, $\Lambda\pi^+\pi^+\pi^-$, $\Sigma^0\pi^+$, and $\Sigma^+\pi^+\pi^-$

- Each mode will produce one measurement of the Born cross section and the total cross section is obtained from weighted average over the 20 individual measurements

The production of Λ_c^+

Table 1. The average Born cross section of $e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$ measured at each CM energy, where the uncertainties are statistical and systematic, respectively. (BESIII preliminary results)

$\sqrt{s}$ (MeV)	$\mathcal{L}_{\rm int}$ (pb^{-1})	$f_{\rm ISR}$	σ (pb)
4574.5	47.67	0.45	$236 \pm 11 \pm 46$
4580.0	8.545	0.66	$207 \pm 17 \pm 13$
4590.0	8.162	0.71	$245 \pm 19 \pm 16$
4599.5	566.9	0.74	$237 \pm 3 \pm 15$



The production of Λ_c^+

- The data fulfilling all selection criteria are divided into ten bins in $\cos\theta_{\Lambda_c^+}$. In each $\cos\theta_{\Lambda_c^+}$ bin, the total yield is obtained by summing yields of all the ten tagged modes.
- The total yields of Λ_c^+ and $\overline{\Lambda}_c^-$ are combined bin-by-bin and the shape function $f(\theta) \propto (1 + \alpha_{\Lambda_c} cos^2\theta)$ is fitted to the combined data.

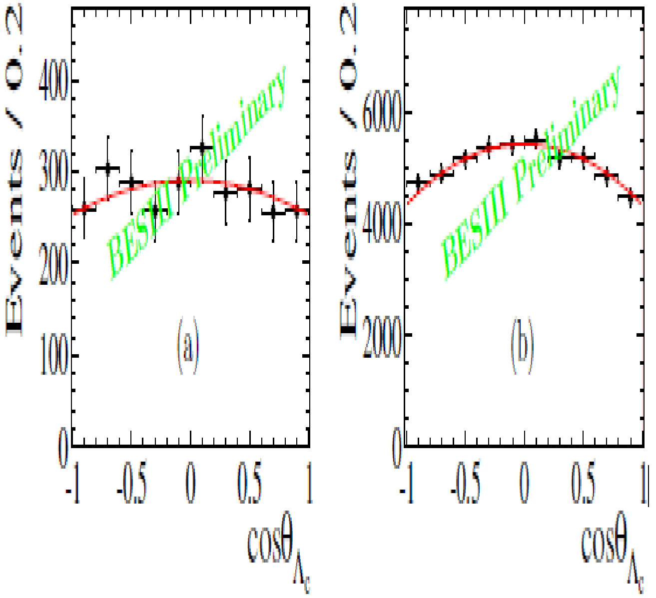


Figure 2. The angular distribution and corresponding fit results in data at $\sqrt{s} = 4574.5$ MeV (a) and 4599.5 MeV (b).

Table 2 listed the resulting α_{Λ_c} parameters obtained from the fits, as well as the $|G_E/G_M|$ ratios extracted using the equation:

$$|G_E/G_M|^2(1-\beta^2) = (1-\alpha_{\Lambda_c})/(1+\alpha_{\Lambda_c}). \quad (2)$$

Table 2. Shape parameters of the angular distribution and $|G_E/G_M|$ ratios at $\sqrt{s} = 4574.5$ and 4599.5 MeV. The uncertainties are statistical and systematic. (BESIII preliminary results)

$\sqrt{s}$ (MeV)	α_{Λ_c}	$\lvert G_E/G_M\rvert$
4574.5	$-0.13 \pm 0.12 \pm 0.08$	$1.14 \pm 0.14 \pm 0.07$
4599.5	$-0.20 \pm 0.04 \pm 0.02$	$1.23 \pm 0.05 \pm 0.03$

Λ_c^+ hadronic decay

- To identify the $\Lambda_c^+\bar{\Lambda}_c^-$ signal candidates, we firstly reconstruct one baryon (called single tag (ST)) through the signal states of any of the singly tagged modes.

$$N_j^{\mathrm{ST}} = N_{\Lambda_c^+\bar{\Lambda}_c^-} \cdot \mathcal{B}_j \cdot \varepsilon_j$$

- Then we define double-tag (DT) events as those where the partner Λ_c^+ recoiling against the $\bar{\Lambda}_c^-$ is reconstructed in one of the signal modes.

$$N_{ij}^{\mathrm{DT}} = N_{\Lambda_c^+\bar{\Lambda}_c^-} \cdot \mathcal{B}_i \cdot \mathcal{B}_j \cdot \varepsilon_{ij}$$

- The ratio of the DT yield and ST yield provides an absolute measurement of the BF.

$$\mathcal{B}_i = \frac{N_{ij}^{\mathrm{DT}}}{N_j^{\mathrm{ST}}} \frac{\varepsilon_j}{\varepsilon_{ij}}$$

Λ_c^+ semi-leptonic decay

- Using the similar strategy in hadronic decay measurements, we select the data sample of $\bar{\Lambda}_c^-$ baryons by reconstructing exclusive hadronic decays.
- The ST $\bar{\Lambda}_c^-$ are reconstructed using eleven hadronic decay modes.

$$\bar{\Lambda}_c^- \rightarrow \bar{p}K_S^0,\ \bar{p}K^+\pi^-,\ \bar{p}K_S^0\pi^0,\ \bar{p}K^+\pi^-\pi^0,\ \bar{p}K_S^0\pi^+\pi^-,\ \bar{\Lambda}\pi^-,\ \bar{\Lambda}\pi^-\pi^0,$$
$$\bar{\Lambda}\pi^-\pi^+\pi^-,\ \bar{\Sigma}^0\pi^-,\ \bar{\Sigma}^-\pi^0 \text{ and } \bar{\Sigma}^-\pi^+\pi^-$$

- The signal candidates for $\Lambda_c^+ \rightarrow \Lambda l^+ \upsilon_l$ are selected from the remaining tracks recoiling against the ST $\bar{\Lambda}_c^-$ candidates. As the neutrino is missing, we employ a kinematic variable

$$U_{\text{miss}} = E_{\text{miss}} - c|\vec{p}_{\text{miss}}|$$

E_{miss} and p_{miss} are the missing energy and momentum

Λ_c^+ semi-leptonic decay

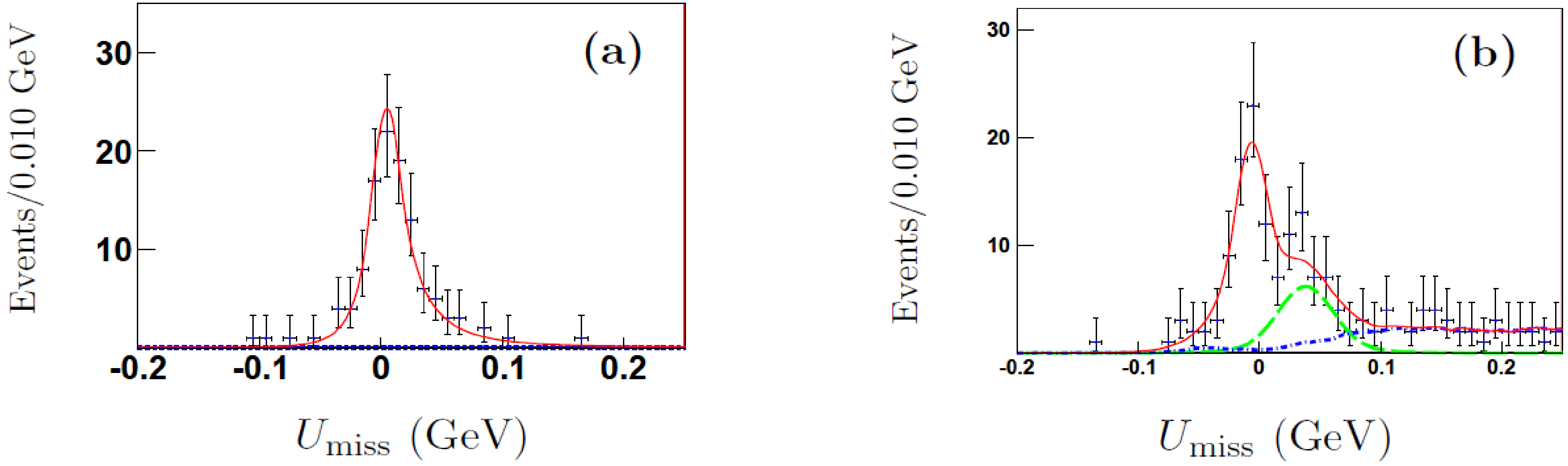
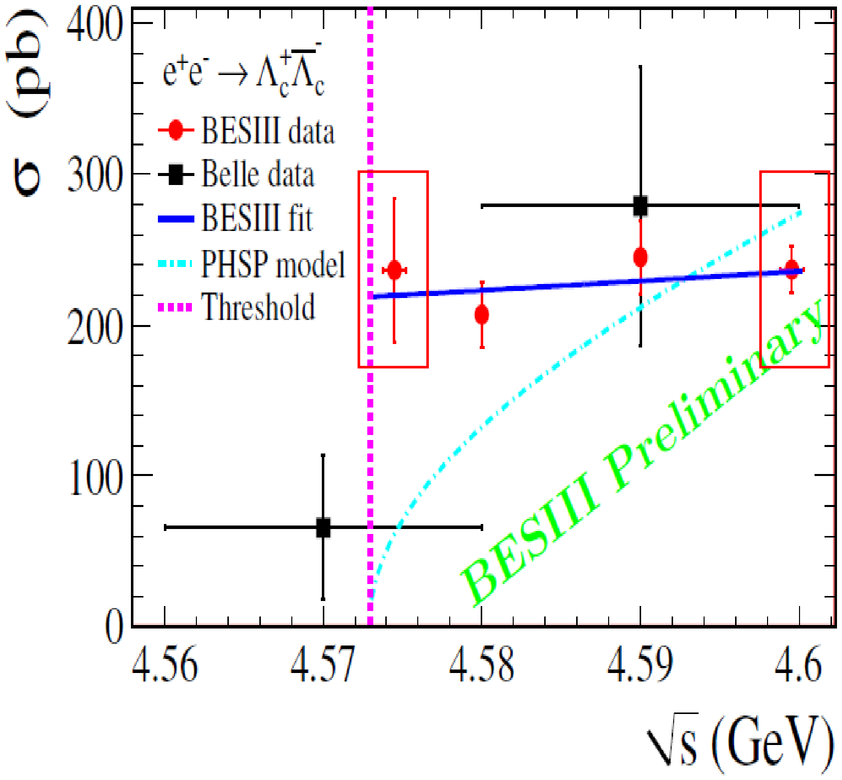


Figure 3. (a) Fit to the $U_{\rm miss}$ distribution of process $\Lambda_c^+ \to \Lambda e^+ \nu_e$. (b) Fit to the $U_{\rm miss}$ distribution of process $\Lambda_c^+ \to \Lambda \mu^+ \nu_\mu$. The points with error bars are data, the (red) solid curve shows the total fit and the (blue) dashed curve is the background shape. The green-dashed line in the right subfigure denotes the MC-driven background shapes which is supposed to simulate the remaining background.

- The absolute BF for $\Lambda_c^+ \to \boldsymbol{\Lambda e^+ \upsilon_e}$is determined by

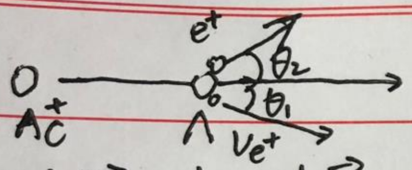
$$\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = \frac{N_{\rm semi}}{N^{\rm tot}_{\bar{\Lambda}_c^-} \times \varepsilon_{\rm semi} \times \mathcal{B}(\Lambda \to p\pi^-)}$$

- Question from Ryuta: In the Figure 1, there are 4 red points from BESIII data, and the point at 4574.5 (most left one) shows bigger uncertainty in X-axis (sqrt(s)) direction, compared with the center two (4580.0, 4590.0) though the luminosity is much higher. Is there any specific reason for that ?



- Actually, I agree with Ryuta because higher luminosity will result in be lower uncertainty, but the most left and right points have the highest uncertainty

- Question from Xin: On page 5, it says “For signal events, Umiss is expected to peak around zero.” Could you explain why?



θ_1 and θ_2 are very small, so:

$$|\vec{p}_{miss}| = |\vec{p}_{\Lambda_c^+} - \vec{p}_\Lambda - \vec{p}_{e^+}| \approx p_{\Lambda_c^+} - p_\Lambda - p_{e^+}$$

$$E_{miss} = E_{beam} - E_\Lambda - E_{e^+} \qquad E_{beam} \approx E_{\Lambda_c^+} = cp_{\Lambda_c^+}$$

$$E_\Lambda = cp_\Lambda \qquad E_{e^+} = cp_{e^+}$$

around.

$$\therefore U_{miss} = E_{miss} - c|\vec{p}_{miss}| \approx cp_{\Lambda_c^+} - cp_\Lambda - cp_{e^+} - cp_{\Lambda_c^+} + cp_\Lambda + cp_{e^+} = 0$$