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**Study of the baryonic  $B$  decay  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$** 

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We report the measurement of the baryonic  $B$  decay  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$ . Using a data sample of  $467 \times 10^6 B\bar{B}$  pairs collected with the BABAR detector at the PEP-II storage ring at SLAC, the measured branching fraction is  $(2.98 \pm 0.16_{\text{(stat)}} \pm 0.15_{\text{(syst)}} \pm 0.77_{\text{(}\Lambda_c\text{)}}) \times 10^{-4}$ , where the last error is due to the uncertainty in  $\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)$ . The data suggest the existence of resonant subchannels  $B^- \rightarrow \Lambda_c(2595)^+ \bar{p} \pi^-$  and, possibly,  $B^- \rightarrow \Sigma_c^{++} \bar{\Delta}^- \pi^-$ . We see unexplained structures in  $m(\Sigma_c^{++} \pi^- \pi^-)$  at  $3.25 \text{ GeV}/c^2$ ,  $3.8 \text{ GeV}/c^2$ , and  $4.2 \text{ GeV}/c^2$ .

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## I. INTRODUCTION

The large mass of the  $B$  meson allows a wide spectrum of baryonic decays, which have, in total, a

branching fraction of  $(6.8 \pm 0.6)\%$  [1]. This makes  $B$  decays a good place to study the mechanisms of baryon production. One approach to investigate the baryonization process in  $B$  decays is to measure and compare their exclusive branching fractions and study the dynamic structure of the decay, i.e., the influence of resonant subchannels.

In this paper, we present a study of the decay  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$  [2]. This decay is a resonant subchannel of the five-body final state  $B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^- \pi^-$ , which has the largest hitherto known branching fraction among all baryonic  $B$  decays and hence is a good starting point for further investigations. The analyzed decay can be

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compared with  $B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-$  and  $\bar{B}^0 \rightarrow \Sigma_c^{++} \bar{p} \pi^-$ , which have similar quark content and phase space.

Large differences between the branching fractions of  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$ ,  $B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-$ , and  $\bar{B}^0 \rightarrow \Sigma_c^{++} \bar{p} \pi^-$  could indicate a considerable impact of intermediate states on baryonic  $B$  decays. For example, the decay  $B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-$  allows a number of resonant three-body decays (including  $\bar{N}$ ,  $\bar{\Delta}^0$ , and  $\rho^0$  resonances) that cannot occur in  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$ . The importance of resonant subchannels can be quantified, e.g., by the ratio of  $[\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-) + \mathcal{B}(B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-)] / \mathcal{B}(B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^- \pi^-)$ .

The CLEO Collaboration measured  $\mathcal{B}(B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^- \pi^-) = (22.5 \pm 3.5 \pm 5.8) \times 10^{-4}$  and  $\mathcal{B}(B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-) = (4.4 \pm 1.7 \pm 1.1) \times 10^{-4}$  [3]. The decay  $\bar{B}^0 \rightarrow \Sigma_c^{++} \bar{p} \pi^-$  was measured by the CLEO [3] and the Belle [4] Collaborations. The Particle Data Group has calculated an average of  $\mathcal{B}(\bar{B}^0 \rightarrow \Sigma_c^{++} \bar{p} \pi^-) = (2.2 \pm 0.7 \pm 0.6) \times 10^{-4}$  [1]. For all these branching fractions the first uncertainty is the combined statistical and systematic error, and the second one is due to the uncertainty in  $\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+) = (5.0 \pm 1.3)\%$  [1].

## II. THE BABAR EXPERIMENT

This analysis is based on a data set of about  $426 \text{ fb}^{-1}$ , corresponding to  $467 \times 10^6 B\bar{B}$  pairs. The sample was collected with the BABAR detector at the PEP-II asymmetric-energy  $e^+e^-$  storage ring, which was operated at a center-of-mass energy equal to the  $\Upsilon(4S)$  mass. For generation of Monte Carlo (MC) simulated data we use EVTGEN [5] for event generation and GEANT4 [6] for detector simulation.

The BABAR detector is described in detail elsewhere [7]. The selection of proton, kaon, and pion candidates is based on measurements of the energy loss in the silicon vertex tracker and the drift chamber, and of the Cherenkov radiation in the detector of internally reflected Cherenkov light [8]. The average efficiency for pion identification is approximately 95%, with a typical misidentification rate of 10% due to other charged particles such as muons and kaons, depending on the momentum and the polar angle of the particle. The efficiency for kaon identification is about 95% with a misidentification rate less than 5% due to protons and pions. The efficiency for proton and antiproton identification is about 90% with a misidentification rate about 2% due to kaons.

## III. DECAY RECONSTRUCTION

The decay  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$  is reconstructed in the subchannel  $\Sigma_c^{++} \rightarrow \Lambda_c^+ \pi^+$ ,  $\Lambda_c^+ \rightarrow p K^- \pi^+$ . For the reconstruction of the  $B$  candidate the entire decay tree is fitted simultaneously. A vertex fit is performed for  $B^-$ ,  $\Sigma_c^{++}$ , and  $\Lambda_c^+$ , and the  $\chi^2$  fit probability is required to exceed 0.1%.

To suppress background, the invariant mass of the  $pK^- \pi^+$  combination is required to satisfy  $2275 \text{ MeV}/c^2 < m_{pK^- \pi^+} < 2296 \text{ MeV}/c^2$ , i.e., compatible with coming from the decay  $\Lambda_c^+ \rightarrow pK^- \pi^+$ . This selection corresponds to 2.8 times the observed width of reconstructed  $\Lambda_c^+$  candidates, which are centered at  $m_{pK^- \pi^+} = 2285.4 \text{ MeV}/c^2$ . The separation of signal from background in the  $B$ -candidate sample is obtained using two kinematic variables,  $\Delta E = E_B^* - \sqrt{s}/2$  and  $m_{\text{ES}} = \sqrt{(s/2 + \mathbf{p}_i \cdot \mathbf{p}_B)^2/E_i^2 - |\mathbf{p}_B|^2}$ , where  $\sqrt{s}$  is the center-of-mass (CM) energy of the  $e^+e^-$  pair and  $E_B^*$  the energy of the  $B$  candidate in the CM system.  $(E_i, \mathbf{p}_i)$  is the four-momentum vector of the  $e^+e^-$  CM system and  $\mathbf{p}_B$  the  $B$ -candidate momentum vector, both measured in the laboratory frame. For correctly reconstructed  $B$  decays,  $m_{\text{ES}}$  is centered at the  $B$  meson mass and  $\Delta E$  is centered at zero. Throughout this analysis,  $B$  candidates are required to have  $m_{\text{ES}}$  within 8 MeV ( $3.4\sigma$ ) of the measured  $B$  mass of  $m_{\text{ES}} = 5279.1 \text{ MeV}$ .

Figure 1 shows the distribution of  $\Delta M \equiv m(\Lambda_c^+ \pi^+) - m(\Lambda_c^+)$  in data for candidates that satisfy the criteria described above for  $m_{\text{ES}}$  and  $m_{pK^- \pi^+}$  and for which  $\Delta E$  is between  $-60 \text{ MeV}$  and  $+40 \text{ MeV}$ . We perform a binned minimum  $\chi^2$  fit using a second-order polynomial for the description of the background and the sum of a Voigt distribution (the convolution of a Breit-Wigner function with a Gaussian function) and a Gaussian to parametrize the  $\Sigma_c^{++}$  signal. A detailed explanation of the fit function is given in Sec. IV. The fitted  $\Sigma_c^{++}$  signal yield is  $N = 1020 \pm 95$ .

Figure 2 shows the  $\Delta E$  distribution in data for candidates that satisfy the criteria described above for  $m_{\text{ES}}$  and  $m_{pK^- \pi^+}$  and for which  $\Delta M$  is between  $0.157 \text{ GeV}/c^2$  and  $0.178 \text{ GeV}/c^2$ . The latter is a selection of  $\Sigma_c^{++}$  candidates with an efficiency of 92% in signal MC data.

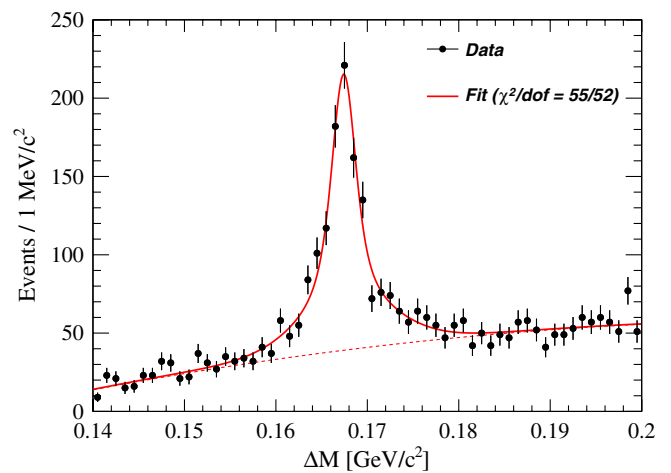


FIG. 1 (color online). Fitted  $\Delta M$  distribution for  $B$  candidates in data. All candidates are required to satisfy the selection criteria on  $m_{\text{ES}}$ ,  $m_{pK^- \pi^+}$ , and  $\Delta E$ .

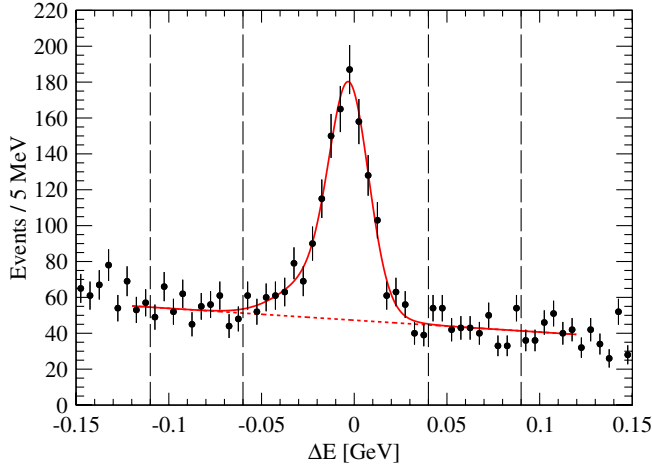


FIG. 2 (color online). Fitted  $\Delta E$  distribution in data with selection criteria applied to  $m_{pK^-\pi^+}$ ,  $m_{ES}$ , and  $\Delta M$ . The goodness of the fit is  $\chi^2/\text{dof} = 36/40$ . The  $\Delta E$  signal region is between  $-60$  MeV and  $40$  MeV and is enclosed by the two sideband regions that each have a width of  $50$  MeV.

In the binned minimum  $\chi^2$  fit we use the sum of two Gaussian functions for the signal and a linear function for the background. The second Gaussian accommodates  $B$  decays with missing energy due to final state radiation. Each Gaussian has a mean parameter ( $\mu$ ) and a standard deviation ( $\sigma$ ). The joint normalization is described by  $N_{\text{sig}}$  and the fraction of the first Gaussian is  $f_1$ . We parametrize the background shape of the  $\Delta E$  distribution as a first-order polynomial, which provides a good description of the  $\Delta E$  distribution for candidates in the  $m_{ES}$  sideband in the range  $5.20 \text{ GeV}/c^2 < m_{ES} < 5.26 \text{ GeV}/c^2$ . All parameters are permitted to vary during fitting. Table I presents the resulting signal parameters. The signal yield is  $840 \pm 55$  events.

#### IV. SIGNAL EXTRACTION

There are two sources of background that contribute to the signal in  $\Delta E$  and  $\Delta M$ . The first one is  $B$  decays that have the same final state, in particular  $B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^- \pi^-$ , and the other one is  $B$  decays that have a  $\Sigma_c^{++}$  among its decay products, e.g.,  $\bar{B}^0 \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^0$ . To reject this background, we make a binwise fit using  $\Delta M$  as a discriminating

TABLE I. The parameters for the double-Gaussian function describing the signal contribution in the fit to the  $\Delta E$  distribution shown in Fig. 2.  $f_1$  is the fraction of the signal in the narrower Gaussian.

Parameter	Fit result
$N_{\text{sig}}$	$840 \pm 55$
$f_1$	$(70 \pm 23)\%$
$\mu_1$	$(-2.7 \pm 1.2) \text{ MeV}$
$\sigma_1$	$(10 \pm 1.6) \text{ MeV}$
$\mu_2$	$(-16 \pm 14) \text{ MeV}$
$\sigma_2$	$(20 \pm 5.6) \text{ MeV}$

variable to create a background-subtracted  $\Delta E$  distribution from which we extract the true signal yield in order to determine  $\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-)$ . The binwise fitting procedure is described in the following paragraph.

After applying the selection in  $m_{pK^-\pi^+}$  and  $m_{ES}$  (no selection in  $\Delta M$ ), we divide the  $\Delta E$  range  $(-105, 105)$  MeV into 14 equal slices and fit the  $\Delta M$  distribution in each slice separately in the range  $0.14 \text{ GeV}/c^2 < \Delta M < 0.2 \text{ GeV}/c^2$ . In the fits the  $\Sigma_c^{++}$  signal is represented by the sum of a Voigt function and a Gaussian function. The Voigt distribution has four parameters ( $N_{\text{sig}}, \mu, \Gamma, \sigma$ ) and models the signal peak region, where  $\mu$  is the mean of the Voigt and represents the  $\Sigma_c^{++}$  mass, which is fixed to the value obtained from an inclusive analysis of  $\Sigma_c^{++} \rightarrow \Lambda_c^+ \pi^+$  candidates in the data. The parameter  $\Gamma$  is the intrinsic width of the  $\Sigma_c^{++}$  and is fixed to the 2010 Review of Particle Properties (RPP) value [1], and  $\sigma$  describes the detector resolution in  $\Delta M$  for the  $\Sigma_c^{++}$  determined, independently for each  $\Delta E$  slice, from the signal MC data. The remaining parameter  $N_{\text{sig}}^i$  is the fitted  $\Sigma_c^{++}$  signal yield in each of the  $\Delta E$  bins.

There is a correlation between  $\Delta M$  and  $\Delta E$  that is very prominent due to the inaccurate momentum measurement of the slow  $\pi^+$  from the  $\Sigma_c^{++}$  decay. As a result the  $\Sigma_c^{++}$  signal has tails in the  $\Delta M$  distribution that are modeled by the Gaussian function whose parameters are determined, independently for each  $\Delta E$  slice, from the signal MC data. The background is represented by a second-order polynomial. This shape was determined from the sidebands  $|\Delta E| \in (50, 300)$  MeV and, compared to the other polynomials, gives the best  $\chi^2$  fit probability. The fits in  $\Delta M$  determine the background level and the number of  $\Sigma_c^{++}$  baryons.

Figure 3 shows the  $\Sigma_c^{++}$  signal yield as a function of  $\Delta E$ . We fit this distribution with the same functions described in

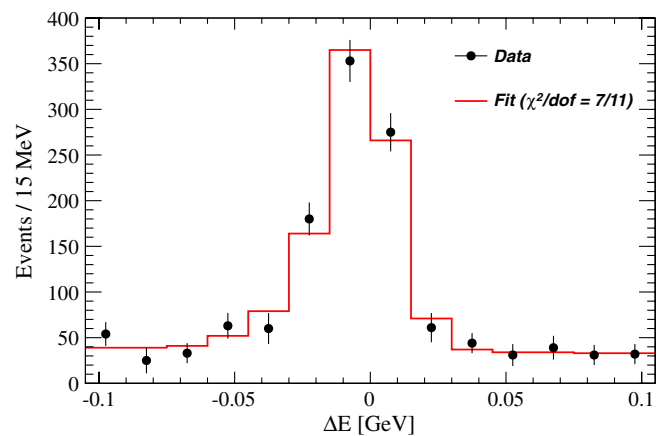


FIG. 3 (color online).  $\Delta E$  distribution for  $B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-$  candidates in data. The points with error bars represent the number of  $\Sigma_c^{++}$  candidates  $N_{\text{sig}}^i$  from a fit to  $\Delta M \equiv m(\Lambda_c^+ \pi^+) - m(\Lambda_c^+)$ . All signal parameters for the  $\Delta E$  distribution, except  $N_{\text{sig}}$ , are fixed to those shown in Table I.

Sec. III and fix the signal parameters, except for  $N_{\text{sig}}$ , to those determined there. The true signal yield is  $N_{\text{sig}} = 787 \pm 43$  events.

## V. EFFICIENCY

The efficiency is calculated from the simulated events. These events were generated uniformly in four-body phase space (PS), but the actual decay distribution is, *a priori*, unknown. Therefore, when calculating the efficiency, we weight the MC events so that we reproduce the distributions of the two-body invariant mass distributions for the decay products of the  $B$  candidates in data. The resulting efficiency is checked by repeating the procedure using the three-body masses and then again using the angles between the  $B$  daughters in the  $B$  rest frame. The different procedures give an average efficiency of  $(11.3 \pm 0.2_{\text{(syst)}})\%$ , which is used to determine the branching fraction. Out of the efficiencies from the different procedures, we use the maximum deviation from the average efficiency as systematic uncertainty. The statistical uncertainty, due to the use of the data, is negligible compared to the statistical uncertainty in the event yield. The efficiency calculated using unweighted events is 11.0%.

## VI. SYSTEMATIC UNCERTAINTIES

We estimate the uncertainty on the signal extraction in three different ways: (1) the fit to  $\Delta E$  in Fig. 3 is repeated separately for each shape parameter in Table I, while permitting this parameter to float. The absolute deviations ( $\delta N$ ) in the event yield to our true signal yield  $N_{\text{sig}} = 787$

TABLE II. The results of the fits to  $\Delta E$  in Fig. 3 while the given parameter is allowed to float.  $\delta N$  is the absolute deviation to our true signal yield  $N_{\text{sig}} = 787$ .

Floating parameter	Fit result	$\delta N$
$f_1$	$(70 \pm 7.7)\%$	2
$\mu_1$	$(-2.8 \pm 1.0)$ MeV	0
$\sigma_1$	$(11 \pm 0.9)$ MeV	8
$\mu_2$	$(-15 \pm 5.2)$ MeV	2
$\sigma_2$	$(18 \pm 4.6)$ MeV	11

add up to 23 (see Table II). (2) We use a second-order polynomial for the background while letting all other parameters fixed ( $\delta N = 5$ ), and (3) we fit only the background with a first-order polynomial and subtract its integral from the histogram content in the range  $-60 \text{ MeV} < \Delta E < 45 \text{ MeV}$  in order to obtain an alternative signal yield ( $\delta N = 3$ ). The absolute values of the deviations in the event yields from all of these variations add up to 31. The resulting relative uncertainty on the signal yield is 4.0%. Other systematic errors come from track reconstruction efficiency (2.4%) [9], efficiency (1.8%), and the number of produced  $B\bar{B}$  pairs in the data sample (1.1%). The total relative uncertainty on the branching fraction is 5.1%.

## VII. BRANCHING FRACTION RESULTS

Using the results from the signal extraction, efficiency determination, and estimation of systematic errors, we find

$$\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-) \cdot \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+) = \frac{N_{\text{sig}}}{\varepsilon \cdot N_{B\bar{B}}} = (1.49 \pm 0.08_{\text{(stat)}} \pm 0.08_{\text{(syst)}}) \times 10^{-5}, \quad (1)$$

$$\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-) = \frac{N_{\text{sig}}}{\varepsilon \cdot N_{B\bar{B}} \cdot \mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)} = (2.98 \pm 0.16_{\text{(stat)}} \pm 0.15_{\text{(syst)}} \pm 0.77_{(\Lambda_c)}) \times 10^{-4}. \quad (2)$$

In Eq. (2) the last error is due to the uncertainty in  $\mathcal{B}(\Lambda_c^+ \rightarrow p K^- \pi^+)$ .

## VIII. FRACTION OF PS DISTRIBUTED DECAYS

To compare the two-body and three-body invariant masses of the  $B$  decay products in data with PS, we determine an effective PS fraction of the total branching ratio. To do this, we assume that the resonant substructures are due to the intermediate states  $\Lambda_c^{*+} \rightarrow \Sigma_c^{++} \pi^-$  and  $\bar{\Delta}^{--} \rightarrow \bar{p} \pi^-$ , and the remainder is distributed according to four-body PS. We investigate all two-dimensional planes that are spanned by the two-body invariant masses of the  $B$  decay products, e.g.  $m(\Sigma_c^{++} \pi_s^-)$  against  $m(\bar{p} \pi_f^-)$ , to look for a range that is free from  $\Lambda_c^{*+}$  and  $\bar{\Delta}^{--}$  resonances and hence can be described by a four-body PS distribution. The symbol

$\pi_s^-$  refers to the  $\pi^-$  that has the lower momentum in the  $e^+ e^-$  CM system. The other  $\pi^-$  is denoted as  $\pi_f^-$ . We see no indication of  $\bar{\Delta}^{--}$  and  $\Lambda_c^{*+}$  resonances for  $B$  candidates in the range  $3.050 \text{ GeV}/c^2 < m(\Sigma_c^{++} \pi_s^-) < 3.450 \text{ GeV}/c^2$ , where the normalization of the PS distribution is determined by fitting the sideband-subtracted data (Fig. 4).

From the ratio of the efficiency-corrected integrals of the distributions in Fig. 4, we calculate an effective PS fraction:

$$\frac{\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-)_{\text{PS}}}{\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-)} = \frac{389}{11.0\%} \cdot \frac{11.3\%}{816} = 49\%. \quad (3)$$

This percentage will be used to normalize the PS projection in the two-body and three-body invariant mass distributions in Figs. 5–7.

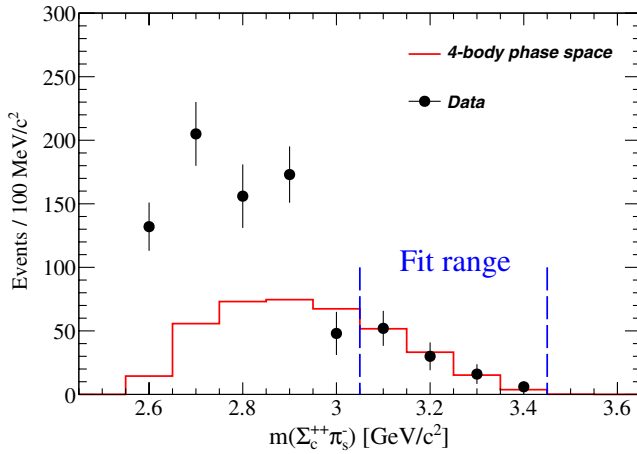


FIG. 4 (color online). The  $m(\Sigma_c^{++}\pi_s^-)$  distribution in data (points with error bars) and for simulated four-body phase space decays (histogram). The distribution in data results from a sideband subtraction in  $\Delta E$  according to the definition in Fig. 2.

### IX. RESONANT SUBCHANNELS

Figure 5 shows the invariant mass distribution of  $\bar{p}\pi^- = \{\bar{p}\pi_s^-, \bar{p}\pi_f^-\}$  [sum of the distributions of  $m(\bar{p}\pi_s^-)$  and  $m(\bar{p}\pi_f^-)$ ] after sideband subtraction in  $\Delta E$  (see Fig. 2 for the definition of the sidebands) and efficiency correction. The efficiency correction here and in the other invariant masses of the  $B$  daughters is determined from PS MC data for the particular mass that is considered. The differences between data and PS in the range  $m(\bar{p}\pi^-) \in (1.2, 1.7)$   $\text{GeV}/c^2$  are compatible with the existence of the resonances  $\bar{\Delta}^{--}(1232, 1600, 1620)$ .

Figure 6 shows the invariant mass of  $\Sigma_c^{++}\pi^- = \{\Sigma_c^{++}\pi_s^-, \Sigma_c^{++}\pi_f^-\}$  after efficiency correction and sideband subtraction in  $\Delta E$ . The large number of events at threshold

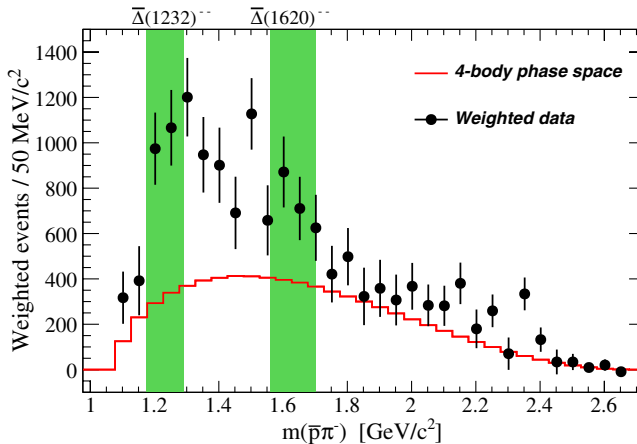


FIG. 5 (color online). The  $m(\bar{p}\pi^-)$  distribution in data and simulated four-body phase space decays. The shaded vertical ranges represent a width of one  $\Gamma$  and are centered at the average mass of  $\bar{\Delta}^{--}(1232)$  and  $\bar{\Delta}^{--}(1620)$ , respectively. The parameters are taken from the RPP [1]. The range of  $\bar{\Delta}^{--}(1600)$  is not drawn since its parameters have large uncertainties.

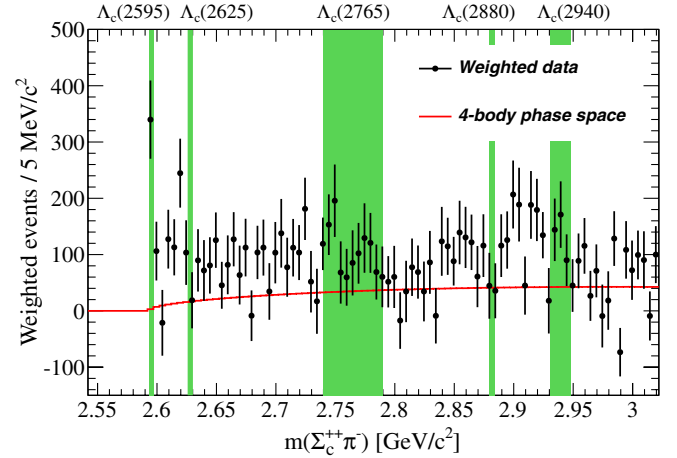


FIG. 6 (color online). The  $m(\Sigma_c^{++}\pi^-)$  distribution in data after efficiency correction and  $\Delta E$ -sideband subtraction. The solid line shows four-body phase space decays. The shaded vertical ranges represent a width of one  $\Gamma$  and are centered at the average mass of the respective  $\Lambda_c^{*+}$  resonance. The parameters are taken from the RPP [1].

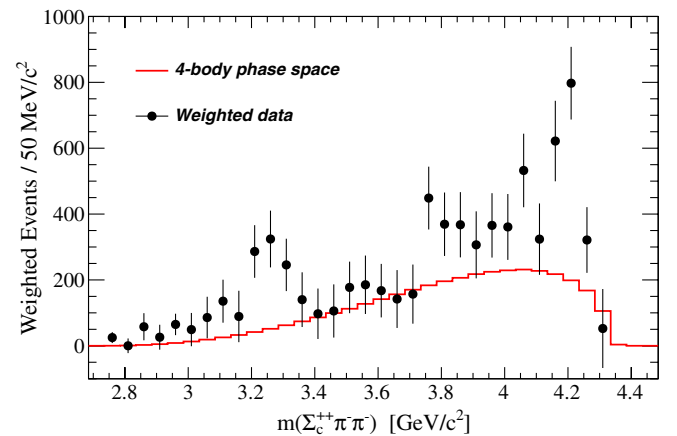


FIG. 7 (color online). The  $m(\Sigma_c^{++}\pi^-\pi^-)$  distribution in data and simulated four-body phase space decays. The histogram in data includes efficiency correction and  $\Delta E$ -sideband subtraction according to the definition in Fig. 2.

are consistent with the decay  $B^- \rightarrow \Lambda_c(2595)^+ \bar{p}\pi^-$ . There are no significant signals for other  $\Lambda_c^{*+}$  resonances.

In the three-body invariant mass distribution  $m(\Sigma_c^{++}\pi^-\pi^-)$  (Fig. 7) we see unexplained structures at 3.25  $\text{GeV}/c^2$ , 3.8  $\text{GeV}/c^2$ , and 4.2  $\text{GeV}/c^2$ . However, because of the limited number of signal candidates, it is not possible to analyze these enhancements in more detail.

We find no indication of a threshold enhancement in the baryon-antibaryon mass distribution.

### X. SUMMARY AND CONCLUSIONS

We have measured the branching fraction  $\mathcal{B}(B^- \rightarrow \Sigma_c^{++}\bar{p}\pi^-\pi^-) = (2.98 \pm 0.22 \pm 0.77_{(\Lambda_c)}) \times 10^{-4}$ . This improves on the previous measurement by CLEO [3].



We have calculated an effective PS fraction of 49% for the observed decay, which may indicate the importance of resonant substructures in baryonic  $B$  decays. By comparing the data and four-body PS in the distributions of the invariant masses of the  $B$  daughters, we find suggestions for the resonant subchannels  $B^- \rightarrow \Lambda_c(2595)^+ \bar{p} \pi^-$  and, possibly,  $B^- \rightarrow \Sigma_c^{++} \bar{\Delta}^{--} \pi^-$ . Additionally, we see unexplained structures in  $m(\Sigma_c^{++} \pi^- \pi^-)$  at 3.25 GeV/ $c^2$ , 3.8 GeV/ $c^2$ , and 4.2 GeV/ $c^2$ .

Combining our measurement with the results  $\mathcal{B}(B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-) = (4.4 \pm 2.0) \times 10^{-4}$  and  $\mathcal{B}(B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^-) = (22.5 \pm 6.8) \times 10^{-4}$  from CLEO [3], we calculate the resonant fractions  $\frac{\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-)}{\mathcal{B}(B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^-)} = (13.2 \pm 4.1)\%$  and  $\frac{\mathcal{B}(B^- \rightarrow \Sigma_c^{++} \bar{p} \pi^- \pi^-) + \mathcal{B}(B^- \rightarrow \Sigma_c^0 \bar{p} \pi^+ \pi^-)}{\mathcal{B}(B^- \rightarrow \Lambda_c^+ \bar{p} \pi^+ \pi^-)} = (33 \pm 13)\%$ .

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