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Search for doubly charmed baryons Ξ_{cc}^{+} and Ξ_{cc}^{++} in *BABAR*

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We search for the production of doubly charmed baryons in e^+e^- annihilations at or near a center-of-mass energy of 10.58 GeV, in a data sample with an integrated luminosity of 232 fb^{-1} recorded with the *BABAR* detector at the PEP-II storage ring at the Stanford Linear Accelerator Center. We search for Ξ_{cc}^+ baryons in the final states $\Lambda_c^+ K^- \pi^+$ and $\Xi_c^0 \pi^+$, and Ξ_{cc}^{++} baryons in the final states $\Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^0 \pi^+ \pi^+$. We find no evidence for the production of doubly charmed baryons.

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I. INTRODUCTION AND OVERVIEW

The lowest-mass doubly charmed baryons are predicted to be the members of an isospin doublet ($\Xi_{cc}^+ = ccd$ and $\Xi_{cc}^{++} = ccu$ [1]) with $J^P = \frac{1}{2}^+$ and $L = 0$. There are many theoretical predictions for the Ξ_{cc}^+ and Ξ_{cc}^{++} masses and lifetimes [2–11]. The predicted masses lie in a range of approximately 3.5 to 3.8 GeV/c^2 [3–8]. The mass difference between the Ξ_{cc}^+ and the Ξ_{cc}^{++} is predicted to be on the order of 1 MeV/c^2 [9]. The Ξ_{cc}^+ and Ξ_{cc}^{++} lifetimes are expected to be between about 0.1 and 0.2 ps, and 0.5 and 1.5 ps, respectively [10,11]. Theoretical estimates for branching fractions relevant to this paper are $B(\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+) = 0.03$, $B(\Xi_{cc}^+ \to \Xi_c^0 \pi^+) = 0.02$, $B(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+) = 0.05$, and $B(\Xi_{cc}^{++} \to \Xi_c^0 \pi^+ \pi^+) = 0.05$ [12].

Several predictions have been made for the production cross sections of doubly charmed baryons in e^+e^- annihilations [13–15]; the predictions range from 1 to 250 fb for an e^+e^- center-of-mass (CM) energy near 10.58 GeV, and translate into $\mathcal{O}(10^2\text{–}10^4)$ doubly charmed baryons produced in the *BABAR* data set of 232 fb^{-1} analyzed here. Measured cross sections for double-$c\bar{c}$ production in Belle [16] and *BABAR* [17] are an order of magnitude larger than nonrelativistic QCD predictions. Calculations for $c\bar{c}\,c\bar{c}$ and $cc\,\bar{c}\,\bar{c}$ cross sections are very similar; therefore, the predicted cross sections for doubly charmed baryons may also have been underestimated.

The SELEX collaboration, which uses the Fermilab 600 GeV/c charged hyperon beam, has published evidence for the Ξ_{cc}^+ baryon in the $\Lambda_c^+ K^- \pi^+$ and pD^+K^- decay modes with a mass of (3518.7 ± 1.7) MeV/c^2 [18,19]. The Ξ_{cc}^{++} baryon, detected in the decay mode $\Lambda_c^+ K^- \pi^+ \pi^+$, with a mass of 3460 MeV/c^2, was reported by SELEX at ICHEP 2002 [20]. The $\Xi_{cc}^+ - \Xi_{cc}^{++}$ mass difference of 60 MeV/c^2 is not consistent with theoretical expectations. SELEX sets an upper limit (at 90% confidence level) of 33 fs on the lifetime of the Ξ_{cc}^+ baryon, in conflict with theoretical predictions. The photoproduction experiment FOCUS does not observe any Ξ_{cc} states [21] although they observe 19, 500 Λ_c^+ baryons, compared to 1650 for SELEX.

In this paper, we describe a search for the production of Ξ_{cc} baryons in a data sample corresponding to an integrated luminosity of 232 fb^{-1} recorded with the *BABAR* detector at the PEP-II asymmetric-energy e^+e^- storage ring at the Stanford Linear Accelerator Center. Events containing $\Lambda_c^+ \to pK^- \pi^+$ candidates are searched for the presence of $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ and $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ candidates. Events containing $\Lambda \to p\pi^-$ candidates are searched for the presence of $\Xi_{cc}^+ \to \Xi_c^0 \pi^+$ and $\Xi_{cc}^{++} \to \Xi_c^0 \pi^+ \pi^+$ candidates where $\Xi_c^0 \to \Xi^- \pi^+$ and $\Xi^- \to \Lambda \pi^-$.

The *BABAR* detector is described in detail elsewhere [22]. The tracking of charged particles is provided by a five-layer double-sided silicon vertex tracker (SVT) and a 40-layer drift chamber (DCH). Discrimination among charged pions, kaons, and protons relies on ionization energy loss ($\mathrm{d}E/\mathrm{d}x$) in the DCH and SVT, and on Cherenkov photons detected in a ring-imaging detector (DIRC). A CsI(Tl) crystal calorimeter is used to identify electrons and photons. These four detector subsystems are mounted inside a 1.5-T solenoidal superconducting magnet. The instrumented flux return for the solenoidal magnet provides muon identification.

For event simulations, we use the Monte Carlo (MC) generators JETSET74 [23] and EVTGEN [24] with a full detector simulation based on GEANT4 [25]. These simulations are used to estimate the reconstruction efficiencies of the searches. For each of the four Ξ_{cc} decay channels used in our searches, we produce approximately 100 000 simulated $e^+e^- \to c\bar{c}$ events in which at least one of the primary charm quarks hadronizes into a Ξ_{cc}. The distribution of momentum in the CM frame (p^*) for simulated Ξ_{cc} peaks at about 2.5 GeV/c, with 80% above 2.0 GeV/c and 62% above 2.3 GeV/c. The Ξ_{cc}^+ and Ξ_{cc}^{++} baryons are simulated with the SELEX masses of 3520 and 3460 MeV/c^2, respectively. The Ξ_{cc}^+, Ξ_{cc}^{++}, and Λ_c^+ decays are generated according to phase space.

We search for Ξ_{cc} production as an excess of candidates in the distribution of the difference in the measured masses of the Ξ_{cc} and the candidate daughter baryon. Some mass uncertainties cancel in this mass difference, improving the mass resolution and thereby the signal-to-background ratio. We use the following notation: $\Delta M(A - B) \equiv M(A) - M(B)$, where A is the parent and B is the daughter baryon. $M(X)$ refers to the measured invariant mass of the X candidate.

Selection criteria are chosen to maximize $\epsilon/\sqrt{B}$, where ϵ is the simulated reconstruction efficiency and B is the number of candidates in data in upper and lower sidebands of the mass-difference regions in which we search for Ξ_{cc}

signals. During this process the search regions were hidden to minimize potential experimenter bias.

Charm hadrons carry a significant fraction of the initial energy of the charm quark, whereas random combinations of charged particles in an event form lower-energy candidates. To take advantage of this difference, we select Ξ_{cc} candidates for which the p^* of the Ξ_{cc} is above a minimum value. For Ξ_{cc} decay modes containing a Λ_c^+, the optimal requirement is $p^* > 2.3$ GeV/c. Because the background levels for events containing a Ξ_c candidate are lower, we apply the less stringent requirement $p^* > 2.0$ GeV/c. To facilitate comparisons with theoretical predictions, we repeat the searches with no requirement on p^*.

We conduct searches for Ξ_{cc} near the masses of the states observed by SELEX and over wider ranges that include many of the theoretically predicted masses. We use MC techniques to account for the width of the search region in the statistical interpretation of the results.

II. SEARCH FOR DECAYS TO $\Lambda_c^+ K^- \pi^+ (\pi^+)$

In the searches for $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ and $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$, we reconstruct the Λ_c^+ baryon in its decay to $pK^-\pi^+$. Pion, kaon and proton candidates are identified using the SVT, DCH and DIRC. The χ^2 probability for the Λ_c^+ daughter particles and for the Ξ_{cc} daughter particles to each come from a common vertex is required to be above 1%. The number of reconstructed Λ_c^+ signal events is approximately 600 000.

The distribution of the mass difference $\Delta M(\Xi_{cc} - \Lambda_c^+)$ is shown in Fig. 1 for candidates with $M(\Lambda_c^+)$ between 2281 and 2291 MeV/c^2 ($\pm 0.8\sigma$), and also for $M(\Lambda_c^+)$ sidebands ($2256 < M(\Lambda_c^+) < 2281$ MeV/c^2 and $2291 < M(\Lambda_c^+) < 2316$ MeV/c^2). To search for a signal in data and to estimate the efficiency, we perform two-dimensional fits to $M(\Lambda_c^+)$ and $\Delta M(\Xi_{cc} - \Lambda_c^+)$. The range of $M(\Lambda_c^+)$ used in all fits is 2256 to 2316 MeV/c^2. We search for Ξ_{cc} states with masses between 3390 and 3600 MeV/c^2 ($\Delta M(\Xi_{cc} - \Lambda_c^+)$ between 1100 and 1310 MeV/c^2). The mass-difference sidebands in data are between 890 and 1100 MeV/c^2, and 1310 and 1520 MeV/c^2.

Approximately half of all background Ξ_{cc} candidates are due to true Λ_c^+ particles combined with random pion and kaon candidates from the rest of the event. This background is fit with a Gaussian shape in $M(\Lambda_c^+)$ and a linear shape in $\Delta M(\Xi_{cc} - \Lambda_c^+)$. Another significant background contribution is from false Λ_c^+ candidates. This source of background is fit with the product of a linear function in $M(\Lambda_c^+)$ and a linear function in $\Delta M(\Xi_{cc} - \Lambda_c^+)$.

MC simulations show that Ξ_{cc} signals peak in three different ways in the $M(\Lambda_c^+)$ versus $\Delta M(\Xi_{cc} - \Lambda_c^+)$ plane. In most cases, the Ξ_{cc} is reconstructed correctly and the measured values of both $M(\Lambda_c^+)$ and $\Delta M(\Xi_{cc} - \Lambda_c^+)$ lie close to the generated values; such candidates are fit with the product of two Gaussian distributions, one in each variable. The MC signal resolution for $\Delta M(\Xi_{cc} - \Lambda_c^+)$ is 3.5 MeV/c^2 and 3.0 MeV/c^2 for Ξ_{cc}^+ and Ξ_{cc}^{++}, respectively. When Ξ_{cc} candidates are reconstructed from the correct tracks but the kaon and/or pion from the Λ_c^+ decay is swapped with the kaon and/or pion from the Ξ_{cc} decay,

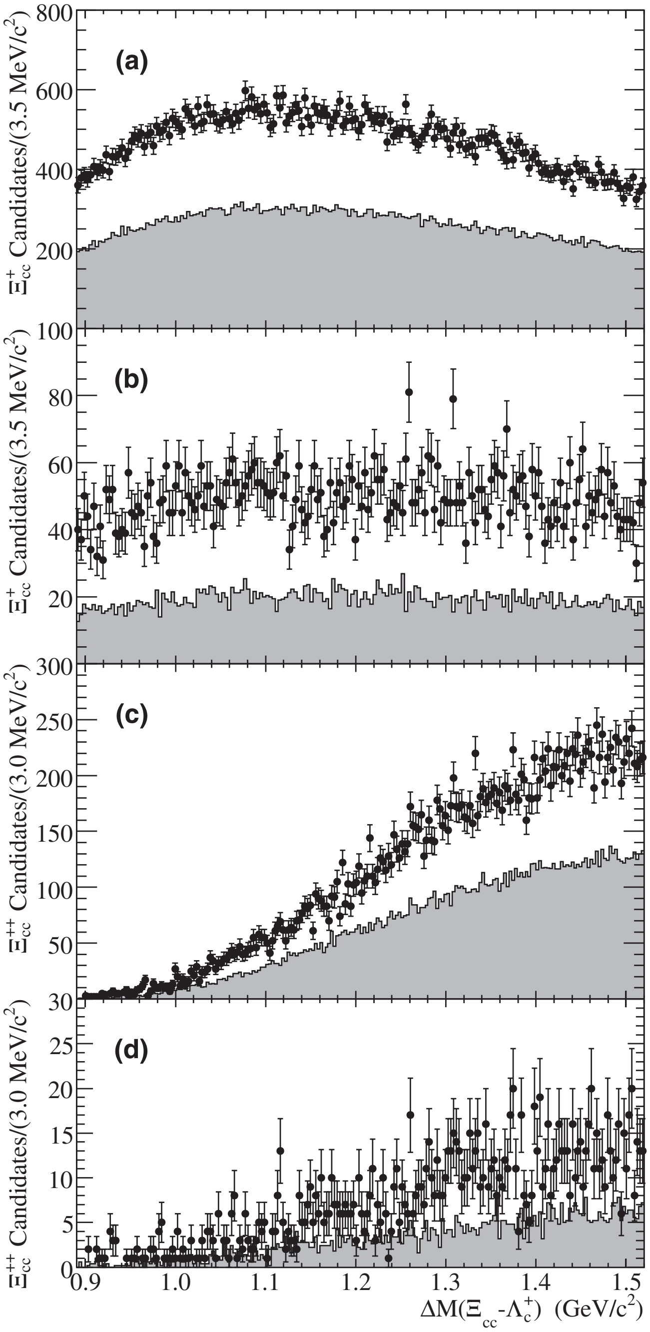

FIG. 1. Distributions of the mass difference $\Delta M(\Xi_{cc} - \Lambda_c^+)$ for (a,b) Ξ_{cc}^+ and (c,d) Ξ_{cc}^{++} candidates with (a,c) no p^* requirement and (b,d) $p^* > 2.3$ GeV/c. Data points with error bars correspond to candidates near the Λ_c^+ mass: $2281 < M(\Lambda_c^+) < 2291$ MeV/c^2. Shaded histograms correspond to candidates in $M(\Lambda_c^+)$ sidebands ($2256 < M(\Lambda_c^+) < 2281$ MeV/c^2 and $2291 < M(\Lambda_c^+) < 2316$ MeV/c^2), scaled to represent the expected amount of non-Λ_c^+ background in the data projections.

TABLE I. Efficiencies determined from $e^+e^- \rightarrow \Xi_{cc}X$ simulations. With the p^* criterion applied, the efficiency is calculated for Ξ_{cc} baryons generated with p^* above 2.3 GeV/c for the Λ_c^+ modes and 2.0 GeV/c for the Ξ_c modes. The first error is statistical; the second is systematic.

p^* Criterion	Particle	Λ_c^+ Mode Eff. (%)	Ξ_c^0 Mode Eff. (%)
Yes	Ξ_{cc}^{++}	$4.2 \pm 0.1 \pm 0.2$	$6.1 \pm 0.1 \pm 0.6$
Yes	Ξ_{cc}^{+}	$10.4 \pm 0.1 \pm 0.5$	$9.3 \pm 0.1 \pm 0.7$
No	Ξ_{cc}^{++}	$3.6 \pm 0.1 \pm 0.2$	$5.9 \pm 0.1 \pm 0.5$
No	Ξ_{cc}^{+}	$9.7 \pm 0.1 \pm 0.5$	$9.0 \pm 0.1 \pm 0.7$

the reconstruction has the correct $M(\Xi_{cc})$ but an incorrect $M(\Lambda_c^+)$. These events are fit in both MC simulations and data with a Gaussian function in $\Delta M(\Xi_{cc} - \Lambda_c^+) + M(\Lambda_c^+) = M(\Xi_{cc})$ and are included as part of the signal. When the Λ_c^+ is correctly reconstructed but is combined with an incorrect pion and/or kaon to form the Ξ_{cc}, the reconstruction has the correct $M(\Lambda_c^+)$ but an incorrect $\Delta M(\Xi_{cc} - \Lambda_c^+)$. Such events are not distinguishable from Λ_c^+ combinatoric background.

Each shape parameter describing the signal is constrained in the fit to lie within a range determined from the Monte Carlo simulation, allowing for possible inaccuracies in the simulation. The integral of the signal function is allowed to be negative. Efficiencies for the reconstruction of Ξ_{cc} baryons decaying to $\Lambda_c^+K^-\pi^+$ and $\Lambda_c^+K^-\pi^+\pi^+$ are calculated from the signal yields from fits to the MC simulated samples. These efficiencies are listed in Table I. The systematic uncertainties are due to inaccuracies in the simulation of tracking reconstruction (0.8% per track, added linearly) and particle identification (1.0% per kaon, 1.0% per pion, and 4.0% per proton). When setting upper limits on production cross sections, additional systematic uncertainties arise due to the uncertainties on the integrated luminosity (1.0%) and $\sigma(e^+e^- \rightarrow \Lambda_c^+X)B(\Lambda_c^+ \rightarrow pK^-\pi^+)$ (4.7%).

We conduct searches for a signal within 10 MeV/c^2-wide regions around the Ξ_{cc}^+ and Ξ_{cc}^{++} masses reported by SELEX, and within the 210 MeV/c^2-wide region described earlier. The wide search region is divided into 21 sequential 10 MeV/c^2 search subregions. For each subregion, we perform a two-dimensional fit over a 100 MeV/c^2-wide range in mass difference centered on the subregion, constraining the mean of the Gaussian signal function to lie within that subregion.

The significance of any potential signal is determined through the use of parametrized MC simulations. Samples of pairs of variables $(M(\Lambda_c^+), \Delta M(\Xi_{cc} - \Lambda_c^+))$ are generated according to the background shapes measured in data, with no signal contribution. The distributions of $M(\Lambda_c^+)$ versus $\Delta M(\Xi_{cc} - \Lambda_c^+)$ from these simulations are then searched in the same manner as in data. A significance measure N/σ_N, where N is the fitted number of signal candidates and σ_N is the uncertainty on this number, is determined for each fit. In order to statistically combine the results of the 21 fits into one search, only the largest of the 21 significance measures is used. The significance measure from data is compared to the distribution of significance measures from the MC simulations that represent those data. This comparison gives the probability of measuring this particular value of N/σ_N or higher in data under the hypothesis that no Ξ_{cc} are produced.

None of the Λ_c^+ decay mode searches finds evidence for Ξ_{cc}. The most statistically significant signal is for a Ξ_{cc}^+ baryon with $\Delta M(\Xi_{cc}^+ - \Lambda_c^+)$ between 1250 MeV/c^2 and 1260 MeV/c^2, when candidates are required to have $p^* > 2.3$ GeV/c. With a significance measure of $N/\sigma_N = 66/24$, we find that there is an 8% probability that background alone could produce this signal. This corresponds to a significance of 1.4σ, which does not constitute evidence for the Ξ_{cc}^+ baryon.

Using efficiencies (ϵ) listed in Table I and integrated luminosity (L) of (232 ± 2) fb^{-1}, we extract values for the upper limit on the production cross section times branching fraction(s) ($\mathcal{S}$) directly from negative-log-likelihood functions. A conversion factor $\mathcal{F} = L\epsilon$ and its uncertainty $\sigma_{\mathcal{F}}$ are incorporated in a Gaussian extension to the likelihood function ($\mathcal{L}$) so that all systematic uncertainties are included in the results. $\mathcal{L}$ takes the form

TABLE II. The 95%-confidence-level upper limits on measured rates for the production of Ξ_{cc} baryons with and without a p^* requirement of 2.3 GeV/c for Λ_c^+ modes and 2.0 GeV/c for the Ξ_c modes. The columns labeled $N^{+(+)}$ give the upper limits on the number of signal $\Xi_{cc}^{+(+)}$ baryons. $\sigma^{+(+)}$ denotes the production cross section $\sigma(e^+e^- \rightarrow \Xi_{cc}^{+(+)}X)$; σ in the denominator indicates that the cross section has been normalized to $\sigma(e^+e^- \rightarrow \Lambda_c^+X)B(\Lambda_c^+ \rightarrow pK^-\pi^+)$. The factor B in a column heading signifies that the values in the column correspond to a cross section times the branching fractions $B(\Xi_{cc}^{+(+)} \rightarrow \Lambda_c^+K^-\pi^+(\pi^+))B(\Lambda_c^+ \rightarrow pK^-\pi^+)$ for decay modes with Λ_c^+ and $B(\Xi_{cc}^{+(+)} \rightarrow \Xi_c^0\pi^+(\pi^+))B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$ for decay modes with Ξ_c^0. For each wide mass range, the upper limit corresponds to the maximum upper limit over the range.

	Upper Limits for $\Xi_{cc} \rightarrow \Lambda_c^+K^-\pi^+(\pi^+)$						Upper Limits for $\Xi_{cc} \rightarrow \Xi_c^0\pi^+(\pi^+)$			
	N^+	σ^+B	$(\sigma^+/\sigma)B$	N^{++}	$\sigma^{++}B$	$(\sigma^{++}/\sigma)B$	N^+	σ^+B	N^{++}	$\sigma^{++}B$
Wide Mass Range	328	14.5 fb	13.3×10^{-4}	199	23.9 fb	22.0×10^{-4}	58	4.3 fb	58	6.6 fb
Wide Mass Range, p^* Req.	106	4.4 fb	5.6×10^{-4}	54	5.5 fb	6.9×10^{-4}	41	3.0 fb	28	3.1 fb
SELEX Mass	169	7.5 fb	6.9×10^{-4}	91	10.9 fb	10.0×10^{-4}	26	2.0 fb	49	5.6 fb
SELEX Mass, p^* Req.	53	2.2 fb	2.7×10^{-4}	31	3.2 fb	4.0×10^{-4}	18	1.3 fb	31	3.4 fb

$$\mathcal{L} = e^{-(N-\mathcal{S}f-n_b)} e^{-(\mathcal{F}-f)^2/2\sigma_{\mathcal{F}}^2} \prod_{i}^{N} P(\vec{x}_i; \mathcal{S}, f, n_b, \vec{a}),$$

where N is the total number of fitted events; $\mathcal{S}f = n_s$ and n_b are the fitted number of signal and background events, respectively; f is the fitted conversion factor from $\mathcal{S}$ to n_s; $\vec{a}$ are shape parameters; and P is the probability function for the data point $\vec{x}_i$. The value of $\mathcal{S}$ for which $-\ln\mathcal{L}$ is 1.35 units above the minimum value for which $\mathcal{S}$ is positive is interpreted as the 95%-confidence-level upper limit. These limits are listed in Table II.

To facilitate comparison with the production rate of Λ_c^+ and to take advantage of the cancellation of the $\Lambda_c^+ \to pK^-\pi^+$ branching fraction, we also normalize the upper limits to $\sigma(e^+e^- \to \Lambda_c^+ X)B(\Lambda_c^+ \to pK^-\pi^+)$, measured with 22 fb^{-1} of data collected at $\sqrt{s} \sim 10.54$ GeV; these upper limits are also listed in Table II. The p^* criterion that is applied to the Ξ_{cc} candidates is also applied to the Λ_c^+ candidates in the normalization mode.

III. SEARCH FOR DECAYS TO $\Xi_c^0\pi^+(\pi^+)$

In the search for $\Xi_{cc}^+ \to \Xi_c^0\pi^+$ and $\Xi_{cc}^{++} \to \Xi_c^0\pi^+\pi^+$ decays, the Ξ_c^0 is detected in the decay chain $\Xi_c^0 \to \Xi^-\pi^+$, $\Xi^- \to \Lambda\pi^-$, $\Lambda \to p\pi^-$. We search for Ξ_{cc} states with masses between 3370 and 3770 MeV/c^2 ($\Delta M(\Xi_{cc} - \Xi_c^0)$ between 900 and 1300 MeV/c^2). The mass-difference sidebands in data are $800 < \Delta M(\Xi_{cc} - \Xi_c^0) < 900$ MeV/c^2 and $1300 < \Delta M(\Xi_{cc} - \Xi_c^0) < 1400$ MeV/c^2.

For Λ and Ξ^- candidates, we require a minimum signed three-dimensional flight distance of $+2.0$ cm and $+0.5$ cm, respectively, where the flight distance is the projection of the vector from the primary vertex to the decay point, onto the momemtum vector of the candidate. Λ candidates are required to be within ± 3.6 MeV/c^2 ($\pm 3\sigma$) of the world average mass [26]. Ξ^- candidates are required to be within ± 5.4 MeV/c^2 ($\pm 3\sigma$) of the world average mass difference $\Delta M(\Xi^- - \Lambda)$, and Ξ_c^0 candidates are required to be within ± 14 MeV/c^2 ($\pm 2\sigma$) of the world average mass difference $\Delta M(\Xi_c^0 - \Xi^-)$ [26]. For all candidate baryons, we require the vertex fit to have a χ^2 probability greater than 0.01%. The number of reconstructed Ξ_c^0 signal events is approximately 11 700. Figure 2 shows the distributions of mass difference for all Ξ_{cc} candidates that satisfy these criteria, with no p^* requirement and with $p^* > 2.0$ GeV/c. The reconstruction efficiencies are given in Table I.

Systematic uncertainties arise mainly from possible inaccuracies in the simulation of track reconstruction and particle identification (5% for Ξ_{cc}^+ and 6% for Ξ_{cc}^{++}), vertex quality (6%), and mass and mass-difference resolutions (1%); the values in parentheses are the relative uncertainties in these efficiencies. Other sources include uncertainties in the total luminosity (1.0%) and in the branching fractions for $\Lambda \to p\pi^-$ (0.8%) and $\Xi^- \to \Lambda\pi^-$ (0.03%).

To search for a signal in the 400 MeV/c^2-wide search region, we fit the mass-difference distribution with two Gaussian functions, with common means and fixed widths, to represent the signal, and a first-order polynomial for the background. The values of the Gaussian widths are determined from the MC simulation; the root-mean-squared

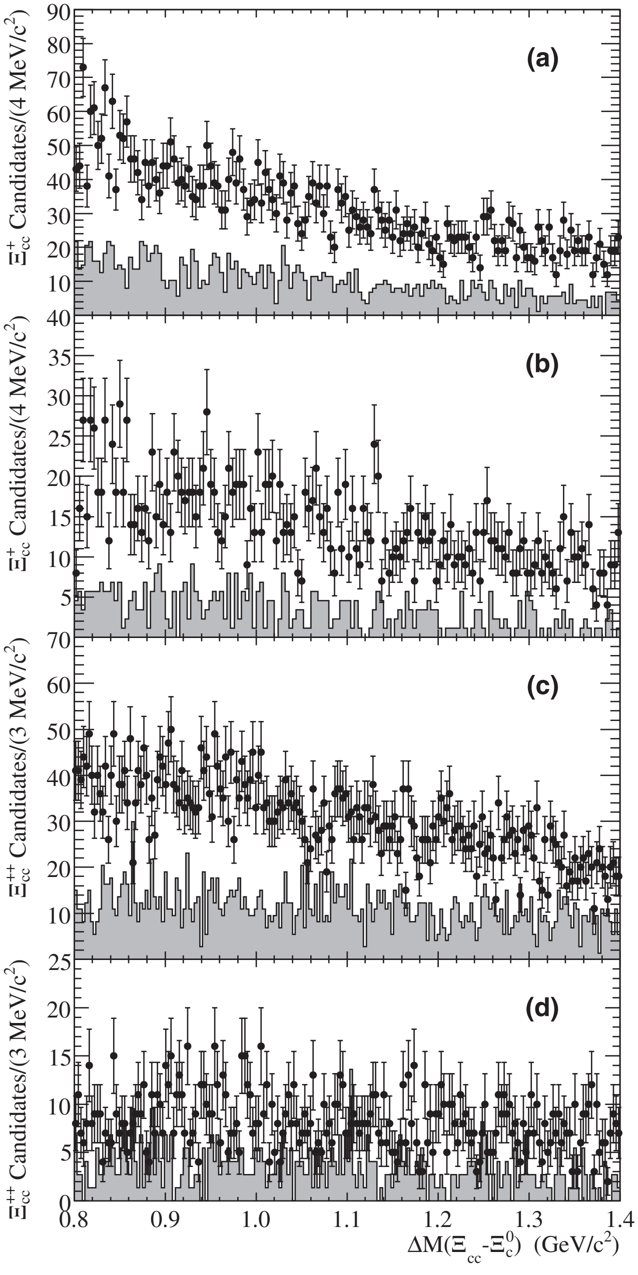

FIG. 2. Distributions of the mass difference $\Delta M(\Xi_{cc} - \Xi_c^0)$ for (a,b) Ξ_{cc}^+ and (c,d) Ξ_{cc}^{++} candidates with (a,c) no p^* requirement and (b,d) $p^* > 2.0$ GeV/c. Data points with error bars correspond to Ξ_{cc} candidates reconstructed using Ξ_c^0 candidates near the Ξ_c^0 mass, $2457 < M(\Xi_c^0) < 2485$ MeV/c^2; the shaded histograms correspond to $M(\Xi_c^0)$ sidebands ($2451 < M(\Xi_c^0) < 2457$ MeV/c^2 and $2487 < M(\Xi_c^0) < 2501$ MeV/c^2) scaled to represent the expected amount of non-Ξ_c^0 background in the $M(\Xi_c^0)$ signal region.

deviation for $\Delta M(\Xi_{cc}^{+} - \Xi_c^0)$ is 5.5 MeV$/c^2$ and for $\Delta M(\Xi_{cc}^{++} - \Xi_c^0)$ it is 4.2 MeV$/c^2$. We conduct 50 fits with the mean of the Gaussian signal function constrained to lie in 50 10-MeV$/c^2$ ranges, each of which overlaps neighboring ranges by 2 MeV$/c^2$. Using a MC approach, we calculate the upper limit on the number of signal events using the statistically most significant of the 50 fits. To do this, we generate N signal events according to the Gaussian signal function and background events according to a first-order polynomial, where the number of background events is determined from the mass-difference sidebands. We fit the resulting MC distribution as described above for data, and record the number of signal events S for the statistically most significant fit. We repeat this process 10 000 times, varying N by the fractional systematic uncertainty on efficiency. We then find the value F for which only 5% of the trials have $S < F$. We repeat the above process starting with different values of N to find the value of N for which F is the number of signal events found in the most significant fit in data. This value of N is the 95% CL upper limit on the number of events, shown in Table II for both Ξ_{cc}^{+} and Ξ_{cc}^{++}, with and without p^* requirements. We also present in Table II the limits obtained when we explicitly search for the states observed by SELEX. For comparison, the measured rate for the singly charmed Ξ_c baryon in *BABAR* is $\sigma(e^+e^- \to \Xi_c^0 X)B(\Xi_c^0 \to \Xi^-\pi^+) = (388 \pm 39 \pm 41)$ fb [27].

V. SUMMARY

In conclusion, we have searched for doubly charmed baryons in e^+e^- annihilations at or near a center-of-mass energy of 10.58 GeV. We do not observe any significant signals for the Ξ_{cc}^{+} baryon in the decay modes $\Lambda_c^+ K^- \pi^+$ and $\Xi_c^0 \pi^+$, or for the Ξ_{cc}^{++} baryon in the decay modes $\Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^0 \pi^+ \pi^+$.

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[1] Throughout this paper, whenever a particle or decay mode is given, the charge conjugate is also implied.

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