1-1994

Observation of inclusive B decays to the charmed baryons c++ and c0

PROCARIO, M.; te al.

M. THULASIDAS
Singapore Management University, manojt@smu.edu.sg

Observation of Inclusive B Decays to the Charmed Baryons Σ_c^{++} and Σ_c^0

M. Procario,[1] R. Balest,[2] K. Cho,[2] M. Daoudi,[2] W. T. Ford,[2] D. R. Johnson,[2] K. Lingel,[2] M. Lohner,[2] P. Rankin,[2] J. G. Smith,[2] J. P. Alexander,[3] C. Bebek,[3] K. Berkelman,[3] K. Bloom,[3] T. E. Browder,[3] D. G. Cassel,[3] H. A. Cho,[3] D. M. Coffman,[3] P. S. Drell,[3] R. Ehrlich,[3] R. S. Galik,[3] M. Garcia-Sciveres,[3] B. Geiser,[3] B. Gittelman,[3] S. W. Gray,[3] D. L. Hartill,[3] B. K. Heltsley,[3] C. D. Jones,[3] S. L. Jones,[3] J. Kandaswamy,[3] N. Katayama,[3] P. C. Kim,[3] D. L. Kreinick,[3] G. S. Ludwig,[3] J. Masui,[3] J. Mevissen,[3] N. B. Mistry,[3] C. R. Ng,[3] E. Nordberg,[3] J. R. Patterson,[3] D. Peterson,[3] D. Riley,[3] S. Salman,[3] M. Sapper,[3] F. Würthwein,[3] P. Avery,[4] A. Freyberger,[4] J. Rodriguez,[4] R. Stephens,[4] S. Yang,[4] J. Yelton,[4] D. Cinabro,[5] S. Henderson,[5] T. Liu,[5] M. Saulnier,[5] R. Wilson,[5] H. Yamamoto,[5] T. Bergfeld,[6] B. I. Eisenstein,[6] G. Gollin,[6] B. Ong,[6] M. Palmer,[6] M. Selen,[6] J. J. Thaler,[6] A. J. Sadoff,[7] R. Ammar,[8] S. Ball,[8] P. Baringer,[18] A. Bean,[8] D. Besson,[8] D. Coppage,[8] N. Copty,[8] R. Davis,[8] N. Hancock,[8] M. Kelly,[8] N. Kwak,[8] H. Lam,[8] Y. Kubota,[9] M. Lattery,[9] J. K. Nelson,[9] S. Patton,[9] D. Perticone,[9] R. Poling,[9] V. Savinov,[9] S. Schrenk,[9] R. Wang,[9] M. S. Alam,[10] I. J. Kim,[10] B. Nemati,[10] J. J. O'Neill,[10] H. Severini,[10] C. R. Sun,[10] M. M. Zoeller,[10] G. Crawford,[11] C. M. Daubenmier,[11] R. Fulton,[11] D. Fujino,[11] K. K. Gan,[11] K. Honscheid,[11] H. Kagan,[11] R. Kass,[11] J. Lee,[11] R. Malchow,[11] F. Morrow,[11] Y. Skovpen,[11,*] M. Sung,[11] C. White,[11] F. Butler,[12] X. Fu,[12] G. Kalbfleisch,[12] W. R. Ross,[12] P. Skubic,[12] J. Snow,[12] P. L. Wang,[12] M. Wood,[12] D. N. Brown,[13] J. Fast,[13] R. L. McIlwain,[13] T. Miao,[13] D. H. Miller,[13] M. Modesitt,[13] D. Payne,[13] E. I. Shibata,[13] I. P. J. Shipsey,[13] P. N. Wang,[13] M. Battle,[14] J. Ernst,[14] Y. Kwon,[14] S. Roberts,[14] E. H. Thorndike,[14] C. H. Wang,[14] J. Dominick,[15] M. Lambrecht,[15] S. Sanghera,[15] V. Shelkov,[15] T. Skwarnicki,[15] R. Stroynowski,[15] I. Volobouev,[15] G. Wei,[15] P. Zadorozhny,[15] M. Artuso,[16] M. Goldberg,[16] D. He,[16] N. Horwitz,[16] R. Kennett,[16] R. Mountain,[16] G. C. Moneti,[16] F. Muheim,[16] Y. Mukhin,[16] S. Playfer,[16] Y. Rozen,[16] S. Stone,[16] M. Thulasidas,[16] G. Vasseur,[16] G. Zhu,[16] J. Bartelt,[17] S. E. Csorna,[17] Z. Egyed,[17] V. Jain,[17] K. Kinoshita,[18] K. W. Edwards,[19] M. Ogg,[19] D. I. Britton,[20] E. R. F. Hyatt,[20] D. B. MacFarlane,[20] P. M. Patel,[20] D. S. Akerib,[21] B. Barish,[21] M. Chadha,[21] S. Chan,[21] D. F. Cowen,[21] G. Eigen,[21] J. S. Miller,[21] C. O'Grady,[21] J. Urheim,[21] A. J. Weinstein,[21] D. Acosta,[22] M. Athanas,[22] G. Masek,[22] H. P. Paar,[22] J. Gronberg,[23] R. Kutschke,[23] S. Menary,[23] R. J. Morrison,[23] S. Nakanishi,[23] H. N. Nelson,[23] T. K. Nelson,[23] C. Qiao,[23] J. D. Richman,[23] A. Ryd,[23] H. Tajima,[23] D. Schmidt,[23] D. Sperka,[23] and M. S. Witherell[23]

(CLEO Collaboration)

[1]*Carnegie-Mellon, Pittsburgh, Pennsylvania 15213*
[2]*University of Colorado, Boulder, Colorado 80309-0390*
[3]*Cornell University, Ithaca, New York 14853*
[4]*University of Florida, Gainesville, Florida 32611*
[5]*Harvard University, Cambridge, Massachusetts 02138*
[6]*University of Illinois, Champaign-Urbana, Illinois 61801*
[7]*Ithaca College, Ithaca, New York 14850*
[8]*University of Kansas, Lawrence, Kansas 66045*
[9]*University of Minnesota, Minneapolis, Minnesota 55455*
[10]*State University of New York at Albany, Albany, New York 12222*
[11]*Ohio State University, Columbus, Ohio 43210*
[12]*University of Oklahoma, Norman, Oklahoma 73019*
[13]*Purdue University, West Lafayette, Indiana 47907*
[14]*University of Rochester, Rochester, New York 14627*
[15]*Southern Methodist University, Dallas, Texas 75275*
[16]*Syracuse University, Syracuse, New York 13244*
[17]*Vanderbilt University, Nashville, Tennessee 37235*
[18]*Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061*
[19]*Carleton University, Ottawa, Ontario K1S 5B6 and the Institute of Particle Physics, Canada*
[20]*McGill University, Montréal, Québec H3A 2T8 and the Institute of Particle Physics, Canada*
[21]*California Institute of Technology, Pasadena, California 91125*
[22]*University of California, San Diego, La Jolla, California 92093*
[23]*University of California, Santa Barbara, California 93106*

(Received 21 December 1993)

Using data collected in the region of the $\Upsilon(4S)$ resonance with the CLEO II detector operating at the Cornell Electron Storage Ring, we report on evidence for the production of Σ_c^{++} and Σ_c^0 baryons in B decays, with $\Sigma_c \to \Lambda_c^+ \pi$. This observation is based on 77 ± 19 Σ_c^{++} and 76 ± 21 Σ_c^0 candidates from B decays. We find the product branching fractions $\mathcal{B}(\bar{B} \to \Sigma_c X)\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$ for $\Sigma_c = \Sigma_c^{++}, \Sigma_c^0,$ and Σ_c^+ to be $(2.1 \pm 0.8 \pm 0.7) \times 10^{-4}$, $(2.3 \pm 0.8 \pm 0.7) \times 10^{-4}$, and less than 4.8×10^{-4} at 90%

0031-9007/94/73(11)/1472(5)$06.00

confidence level, respectively. A study of the Σ_c^{++} and Σ_c^0 momentum spectra indicates that B decays to two-body final states with Σ_c are suppressed.

PACS numbers: 13.25.Hw

Both the CLEO [1] and ARGUS [2] collaborations have previously reported on the observation of the charmed baryons Σ_c^{++} and Σ_c^0 in nonresonant e^+e^- interactions at center-of-mass energies around 10.5 GeV [3]. Here, we report on evidence for Σ_c^{++} and Σ_c^0 production in B decays. Examination of the Σ_c^{++} and Σ_c^0 momentum spectra allows us to draw conclusions about the production mechanism for charmed baryons in B decays. Two-body B decays involving Σ_c^{++} can only proceed via W exchange in $\overline{B}^0 \to \Sigma_c^{++}\overline{\Delta}^{--}$. In the case of Σ_c^0 production, however, internal W-emission and W-exchange diagrams can give rise to two-body final states which result in a hard Σ_c^0 momentum spectrum. External W emission on the other hand involves at least three particles in the final state and results in a softer momentum spectrum for Σ_c baryons (Σ_c^0, Σ_c^+, or Σ_c^{++}). Several theoretical calculations which attempt to derive the two-body contribution to the charmed baryon production in B decays have recently been published. In the diquark model [4] baryons of spin $\frac{1}{2}(\frac{3}{2})$ are modeled as bound states of quarks and scalar (vector) diquarks. The b quark decays to a scalar diquark and an antiquark; the latter combines with the light antiquark accompanying the b quark to form an antidiquark. The creation of a $q\bar{q}$ pair then leads to a baryon and antibaryon in the final state. The authors of [5] calculate decay amplitudes based on QCD sum rules and by replacing both the B meson and the charmed baryon in the final state by suitable interpolating currents. In the pole model [6] the production of baryons in B decays, $\overline{B} \to \mathcal{B}_1\overline{\mathcal{B}}_2$, is decomposed into two steps: the production of an intermediate state in the strong process $\overline{B} \to \mathcal{B}_b\overline{\mathcal{B}}_2$, with $\overline{\mathcal{B}}_2$ being the accompanying baryon, followed by a weak transition of the b-flavored intermediate baryon $\mathcal{B}_b$ to the baryon $\mathcal{B}_1$. The calculations are carried out in the rest frame of $\mathcal{B}_b$. There are also treatments which determine the rates for exclusive baryonic B decays in terms of three reduced matrix elements [7], on the basis of the quark-diagram scheme [8], and using the constituent quark model [9]. The latter three do not quote explicit predictions on branching fractions.

The data sample used in this analysis consists of 895 pb^{-1} taken at the $\Upsilon(4S)$ resonance and 405 pb^{-1} at center-of-mass energies just below the threshold for producing B meson pairs, hereafter referred to as continuum. These data correspond to $935\,000 \pm 17\,000$ produced $B\overline{B}$ pairs, where we assumed that $\Upsilon(4S)$ always decays to $B\overline{B}$. The data were collected with the CLEO II detector at the Cornell Electron Storage Ring (CESR). The CLEO II detector is a general purpose solenoidal-magnet spectrometer and calorimeter with excellent charged particle and shower energy detection capabilities. A detailed description can be found elsewhere [10]. Events with at least 3 charged tracks, 1.5 GeV of energy deposited in the calorimeter, and a vertex along the beam direction within 5 cm of the interaction point are accepted as hadronic event candidates. Hadronic events selected from continuum data are used as a background sample.

The Σ_c^{++} and Σ_c^0 baryons are reconstructed through their decay to $\Lambda_c^+\pi^+$ and $\Lambda_c^+\pi^-$, respectively. We form Λ_c^+ candidates in the decay modes $pK^-\pi^+$, pK_S^0, $\Lambda\pi^+$, and $\Sigma^0\pi^+$ with $K_S^0 \to \pi^+\pi^-$, $\Lambda \to p\pi^-$, and $\Sigma^0 \to \Lambda\gamma$.

Primary tracks from the Λ_c^+ decay are required to have impact parameters within 3 standard deviations (σ) of the expected values, both along the beam line and in the plane perpendicular to the beam direction. We reconstruct K_S^0 and Λ candidates from oppositely charged tracks which intersect in the plane transverse to the beam direction. In addition, the combined momentum vector of the two charged tracks is required to point back to the interaction region in three dimensions. A pair of charged tracks is identified as a $K_S^0(\Lambda)$ candidate if the invariant mass of the pair when interpreted as a $\pi^+\pi^-$ $(p\pi^-)$ is within 3σ of the nominal K_S^0 (Λ) mass. If the mass of the K_S^0 (Λ) candidate, when interpreted as a $p\pi^-(\pi^+\pi^-)$, falls within the Λ (K_S^0) mass region, we reject it. We form Σ^0 candidates by combining Λ candidates as described above with photon candidates. All $\Lambda\gamma$ combinations with an invariant mass within 2σ of the nominal Σ^0 mass are accepted as Σ^0 candidates. The selection of K_S^0, Λ, and Σ^0 candidates is described in more detail in Refs. [11–13].

For the purpose of particle identification, we combine the dE/dx measurements in the central CLEO II drift chamber with time-of-flight information whenever it is available, and derive probabilities for each charged track to be consistent with either the pion, kaon, or proton mass hypothesis. We apply particle identification requirements to all primary charged tracks from the Λ_c^+ decay and to proton candidate tracks from the Λ decay. A primary charged track is defined to be a proton (kaon) if the probability for the specific mass hypothesis is greater than 5% and, at the same time, the probability for the pion hypothesis is less than 5% (32%) [14]. For the identification of charged pions from the primary vertex and proton candidate tracks from Λ's, we require the probability for the appropriate hypothesis to be greater than 0.3% [15]. The efficiencies of the particle identification requirements are derived from the data using pure samples of protons, kaons, and pions from the decays $\Lambda \to p\pi^-$, $D^{*+} \to D^0\pi^+$ with $D^0 \to K^-\pi^+$, and $K_S^0 \to \pi^+\pi^-$, respectively.

Since Λ_c^+ baryons which originate from B decays to Σ_c are kinematically limited to momenta less than

2.1 GeV/c, we only consider combinations with momenta below this value. To reduce contributions from the jetlike continuum production of Λ_c^+ baryons, we require the event shape [16] parameter R_2 to be less than 0.35. This requirement is approximately (93–98)% efficient for $\overline{B} \to \Lambda_c^+ X$ and $\overline{B} \to \Sigma_c X$ events, depending on the multiplicity of the final states. Combining the results of separate fits to the invariant mass distributions from the four Λ_c^+ decay modes, we observe 1775 ± 84 Λ_c^+ baryons in the $\Upsilon(4S)$ data and 190 ± 37 on the continuum. After subtracting the continuum contribution, corrected for luminosity and center-of-mass energy [17], we obtain a sample of 1359 ± 117 observed Λ_c^+ candidates from B meson decays.

To reconstruct Σ_c^{++} and Σ_c^0 candidates, we consider Λ_c^+ candidates as described above with masses falling within 2σ of the fitted Λ_c^+ mass. We then form $\Lambda_c^+\pi^+$ and $\Lambda_c^+\pi^-$ combinations using the remaining charged tracks in the event. The momenta of Σ_c baryons from B decays are limited to values less than 2.2 GeV/c. We therefore impose this upper limit on the Σ_c candidates found in the data. The sample of pions from the decay $\Sigma_c \to \Lambda_c^+\pi$ is restricted to the momentum region from 50 to 250 MeV/c. The lower limit is given by the threshold for charged particle tracking in the CLEO II detector. The upper limit is 98% efficient for secondary pions produced in two-body B decays to Σ_c and accepts all secondary pions from $\overline{B} \to \Sigma_c X$ decays of higher multiplicity. We require the impact parameters of these low momentum tracks to be within 2σ of the interaction point, where σ is determined from a sample of data $D^{*+} \to D^0\pi^+$ decays. This requirement applies to both the impact parameter along the beam direction and as measured in the plane perpendicular to the beam line.

In Figs. 1(a) and 1(b), we show the distributions for the mass differences $\Delta M^{++} = M(\Lambda_c^+\pi^+) - M(\Lambda_c^+)$ and $\Delta M^0 = M(\Lambda_c^+\pi^-) - M(\Lambda_c^+)$, respectively. The observed excesses in $\Upsilon(4S)$ data (solid squares) versus continuum data (histograms) serve as evidence for Σ_c^{++} and Σ_c^0 production in B decays. Similar distributions derived from the Λ_c^+ sidebands show no enhancement around the $\Sigma_c - \Lambda_c^+$ mass difference. The distributions in Figs. 1(a) and 1(b) are fitted to a Gaussian signal with width derived from Monte Carlo simulation and a background shape of the form $ax^{0.5} + bx^{1.5} + cx^{2.5}$. These fits give 89 ± 15 Σ_c^{++} and 88 ± 17 Σ_c^0 candidates observed in the on-resonance data and 12 ± 11 Σ_c^{++} and 12 ± 13 Σ_c^0 candidates in the scaled continuum data. After subtracting the continuum contribution, we obtain 77 ± 19 Σ_c^{++} and 76 ± 21 Σ_c^0 candidates from B meson decays.

To obtain the momentum spectra of Σ_c^{++} and Σ_c^0 baryons in B meson decays, we divide the momentum range accessible to these particles (0 to 2.2 GeV/c) into four intervals. In each momentum interval we derive the raw Σ_c^{++} and Σ_c^0 yields separately for the on-resonance and scaled continuum data. These yields are determined using the Λ_c^+ decay mode $pK^-\pi^+$ only, which accounts

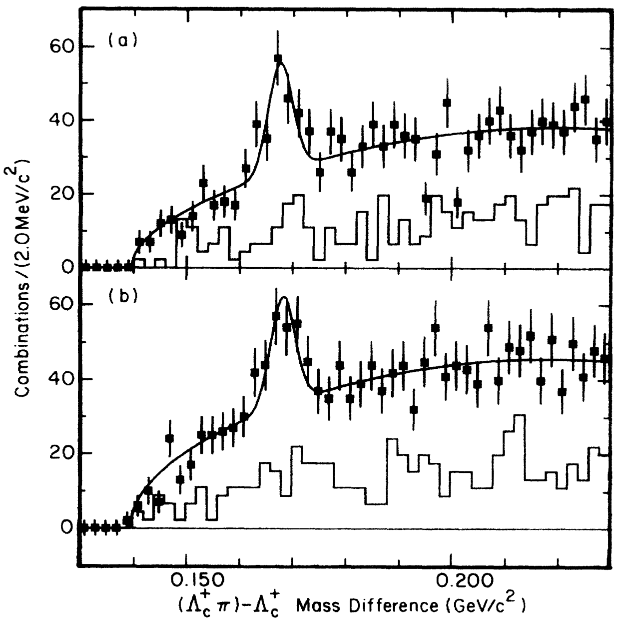

FIG. 1. The mass difference distributions (a) $\Delta M^{++} = M(\Lambda_c^+\pi^+) - M(\Lambda_c^+)$ and (b) $\Delta M^0 = M(\Lambda_c^+\pi^-) - M(\Lambda_c^+)$, derived from $\Upsilon(4S)$ data (solid squares) and from scaled continuum data (histograms). The contributions from all four Λ_c^+ decay modes are included and all selection criteria for Σ_c production in B decays are applied. The solid line represents a fit to the $\Upsilon(4S)$ data as described in the text.

for 70% of our total Λ_c^+ sample. Adding the other Λ_c^+ decay modes would increase the systematic errors on our final results with only marginal improvement in statistical significance. The raw yields $y_r(p)$ from B decays as well as the yields $y_c(p)$ corrected for the Σ_c^{++} and Σ_c^0 reconstruction efficiency are listed in Tables I and II. From Monte Carlo simulation, we find the Σ_c^{++} and Σ_c^0 reconstruction efficiencies to vary between 10% and 13% in the momentum region 0 to 2.2 GeV/c. Using the fact that Σ_c baryons always decay to $\Lambda_c^+\pi$, we derive the product branching fractions $\mathcal{B}(\overline{B} \to \Sigma_c^{++}X)\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = (2.1 \pm 0.8 \pm 0.7) \times 10^{-4}$ and $\mathcal{B}(\overline{B} \to \Sigma_c^0 X)\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = (2.3 \pm 0.8 \pm 0.7) \times 10^{-4}$ [18]. Our earlier measurement of Λ_c^+ production in B meson decays [12] yielded the product branching fraction $\mathcal{B}(\overline{B} \to$

TABLE I. Inclusive Σ_c^{++} production in B decays.

Δp (GeV/c)	Raw yield $\Delta y_r(p)$	Corr. yield $\Delta y_c(p)$	$(1/N_B)(dy_c/dp)$ [10^{-3}(GeV/c)$^{-1}$]
0.0–0.5	10.4 ± 6.3	80 ± 49	0.085 ± 0.052
0.5–1.0	26.7 ± 8.8	248 ± 82	0.265 ± 0.088
1.0–1.5	12.2 ± 7.9	118 ± 76	0.126 ± 0.082
1.5–2.2	−5.1 ± 8.3	−46 ± 74	−0.035 ± 0.057
0.0–2.2	44.2 ± 15	400 ± 143	

TABLE II. Inclusive Σ_c^0 production in B decays.

Δp (GeV/c)	Raw yield $\Delta y_r(p)$	Corr. yield $\Delta y_c(p)$	$(1/N_B)(dy_c/dp)$ $[10^{-3}(\text{GeV}/c)^{-1}]$
0.0–0.5	6.0 ± 5.7	46 ± 44	0.049 ± 0.047
0.5–1.0	16.3 ± 9.4	151 ± 88	0.162 ± 0.094
1.0–1.5	23.6 ± 8.7	228 ± 84	0.244 ± 0.090
1.5–2.2	−0.1 ± 9.2	−1 ± 82	−0.001 ± 0.063
0.0–2.2	45.8 ± 16.8	424 ± 153	

$\Lambda_c^+X)\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = (27 \pm 5 \pm 4) \times 10^{-4}$. We therefore find that Σ_c^{++} and Σ_c^0 production each account for roughly 8% of inclusive Λ_c^+ production in B meson decays. Assuming $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = (3.2 \pm 0.7)\%$ [19], we estimate the absolute branching fractions $\mathcal{B}(\overline{B} \to \Sigma_c^{++}X) = (0.67 \pm 0.24 \pm 0.21 \pm 0.15)\%$ and $\mathcal{B}(\overline{B} \to \Sigma_c^0X) = (0.71 \pm 0.26 \pm 0.22 \pm 0.16)\%$. In all our results the first error is statistical, the second is systematic, and the third error is due to the uncertainty in $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$. The systematic error in our measurement is dominated by uncertainties in the modeling of low momentum charged tracking efficiencies which range from 6% to 30%, depending on track momentum. Additional contributions to the systematic error result from uncertainties in the Λ_c^+ detection efficiency, the fitting procedure used in deriving the Σ_c^{++} and Σ_c^0 momentum spectra, and the momentum spectrum for low momentum pions from Σ_c decay. Each of these latter contributions is of the order of 10% or less.

The measured Σ_c^{++} and Σ_c^0 momentum spectra are shown as data points with error bars in Figs. 2(a) and 2(b), respectively. Superimposed on the measured spectra are the results from Monte Carlo simulation of the decays $\overline{B} \to \Sigma_c\overline{N}(m\pi)$ for $m = 0,\ldots,3$. In the simulation N denotes a proton or neutron. If p or n were to be replaced by a $\Delta(1232)$, the simulated curves would shift by roughly 100 MeV/c towards lower values. The above comparison indicates that two-body final states such as $\Sigma_c^0\overline{N}$ are suppressed and that B decays to the charmed baryons Σ_c^{++} and Σ_c^0 seem to be dominated by final states with two or more pions. Assuming that all contributions to the highest Σ_c^{++} and Σ_c^0 momentum intervals observed in data arise from two-body final states of the form $\overline{B}^0 \to \Sigma_c^{++}\overline{\Delta}^{--}$ and $\overline{B} \to \Sigma_c^0\overline{N}$, we find that at 90% confidence level (C.L.) these final states contribute to less than 25% and 33% of the inclusive Σ_c^{++} and Σ_c^0 branching fractions, respectively.

We have also searched for inclusive B decays to the charmed baryon Σ_c^+, using Λ_c^+ candidates combined with π^0's in the event. The π^0 candidates are formed from two showers occurring in the calorimeter which yield a $\gamma\gamma$ invariant mass within 2σ of the nominal π^0 mass. The π^0 momentum is required to be between 50 and 250 MeV/c. Because of large backgrounds from low momentum π^0's

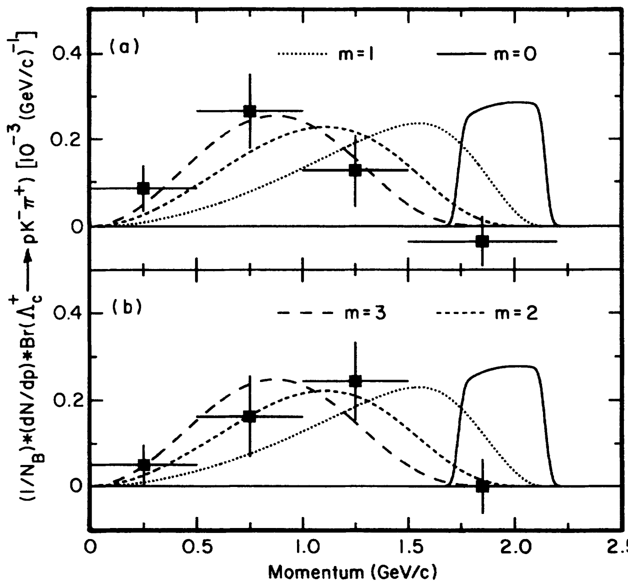

FIG. 2. Momentum spectra of (a) Σ_c^{++} and (b) Σ_c^0 baryons produced in B meson decays. The superimposed curves indicate the spectra derived from Monte Carlo simulation of the decays $\overline{B} \to \Sigma_c\overline{N}(m\pi)$ for $m = 0,\ldots,3$ and N denoting p or n. For the case $m = 0$ the normalization is arbitrary. All other curves have been normalized to data. Replacing the nucleon N by a $\Delta(1232)$ baryon would shift the Monte Carlo momentum spectra by roughly 100 MeV/c towards lower values.

we are only able to quote an upper limit on Σ_c^+ production in B meson decays and find that $\mathcal{B}(\overline{B} \to \Sigma_c^+X)\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) < 4.8 \times 10^{-4}$ (at 90% C.L.).

In summary, we have observed evidence for the inclusive production of the charmed baryons Σ_c^{++} and Σ_c^0 in B decays through their decays to $\Lambda_c^+\pi^+$ and $\Lambda_c^+\pi^-$, respectively. We have further measured the Σ_c^{++} and Σ_c^0 momentum spectra in B meson decays for the first time and find the product branching fractions $\mathcal{B}(\overline{B} \to \Sigma_cX)\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$ for $\Sigma_c = \Sigma_c^{++}$, Σ_c^0, and Σ_c^+ to be $(2.1 \pm 0.8 \pm 0.7) \times 10^{-4}$, $(2.3 \pm 0.8 \pm 0.7) \times 10^{-4}$, and less than 4.8×10^{-4} (at 90% C.L.), respectively. The shape of the observed momentum spectra indicates that B decays to two-body final states with Σ_c are suppressed. A similar observation has been made in the case of B decays to the charmed baryon Λ_c^+ [12]. Using $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = 3.2\%$, we find that $\mathcal{B}(\overline{B}^0 \to \Sigma_c^{++}\overline{\Delta}^{--}) < 0.17\%$ and $\mathcal{B}(\overline{B} \to \Sigma_c^0\overline{N}) < 0.23\%$ (both at 90% C.L.). This is consistent with recent theoretical calculations [4,5] which result in branching fractions for the processes $\overline{B} \to \Sigma_c^0\overline{N}$ or $\overline{B} \to \Lambda_c^+\overline{N}$ of order (0.1–0.3)%. But it is significantly lower than the prediction in the pole model by Jarfi *et al.* [6] for $B^- \to \Sigma_c^0\overline{p}$.

We gratefully acknowledge the effort of the CESR staff in providing us with excellent luminosity and running conditions. This work was supported by the National Science Foundation, the U.S. Department of Energy, the

Heisenberg Foundation, the SSC Fellowship program of TNRLC, and the A.P. Sloan Foundation.

*Permanent address: INP, Novosibirsk, Russia.

[1] CLEO Collaboration, T. Bowcock *et al.,* Phys. Rev. Lett. **62**, 1240 (1989).
[2] ARGUS Collaboration, H. Albrecht *et al.,* Phys. Lett. B **211**, 489 (1988).
[3] Throughout this discussion, reference to a state also implies reference to its charge conjugate state.
[4] P. Ball and H. G. Dosch, Z. Phys. **51**, 445 (1991).
[5] V. L. Chernyak and I. R. Zhitnitsky, Nucl. Phys. **B345**, 137 (1990).
[6] M. Jarfi *et al.,* Phys. Rev. D **43**, 1599 (1991).
[7] M. B. Savage and M. B. Wise, Nucl. Phys. **B326**, 15 (1989).
[8] Y. Kohara, Phys. Rev. D **43**, 2429 (1991).
[9] J. G. Körner, Z. Phys. **43**, 165 (1989).
[10] CLEO Collaboration, Y. Kubota *et al.,* Nucl. Instrum. Methods Phys. Res., Sect. A **320**, 66 (1992).
[11] CLEO Collaboration, P. Avery *et al.,* Phys. Rev. D **43**, 3599 (1991).
[12] CLEO Collaboration, G. Crawford *et al.,* Phys. Rev. D **45**, 752 (1992).
[13] CLEO Collaboration, P. Avery *et al.,* Phys. Lett. B **325**, 257 (1994).
[14] These requirements correspond to 2σ consistency cuts on the selected hypothesis together with pion vetos at the 2σ (1σ) level, respectively.
[15] This requirement corresponds to a 3σ consistency cut on the selected hypothesis.
[16] G. C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978). The parameter R_2 is the ratio of H_2 to H_0, where both charged tracks in the central detector and shower energies deposited in the crystal calorimeter have been used in the determination of R_2.
[17] The scale factor f used for the continuum data is 2.19. It is derived from the following formula:

$$f = \frac{\mathcal{L}_{\mathrm{on}\,4S}}{\mathcal{L}_{\mathrm{cont}}} \frac{E^2_{\mathrm{cont}}}{E^2_{\mathrm{on}4S}},$$

where $\mathcal{L}_{\mathrm{on}4S}$ and $\mathcal{L}_{\mathrm{cont}}$ denote the total integrated luminosities of the $\Upsilon(4S)$ and continuum data samples, respectively; $E_{\mathrm{on}4S}$ and E_{cont} stand for the corresponding average beam energies in the two data sets.
[18] In general, B decays to charmed baryons can also proceed via the transition $b \rightarrow c\bar{c}s$, leading to decays of the form $\overline{B} \rightarrow \Xi_c \overline{\Lambda}_c^- X$ and $\overline{B} \rightarrow \Xi \overline{\Sigma}_c X$. Our quoted branching fractions on $\overline{B} \rightarrow \Sigma_c X$ decays include the possible contribution from $B \rightarrow \Sigma_c X$ processes.
[19] Particle Data Group, K. Hikasa *et al.,* Phys. Rev. D **45**, S1 (1992).