DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 88-012
February 1988

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by

ARGUS Collaboration

ISSN 0418-9833

NOTKESTRASSE 85 · 2 HAMBURG 52

DESY 88-012
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[1] Weizmann Institute of Science, Rehovot, Isreal, supported by the Minerva Stiftung.
[2] Supported by the Bundesministerium für Forschung und Technologie, Federal Republic of Germany, under contract number 054DO51P
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[8] Supported by the Natural Sciences and Engineering Research Council, Canada.
[9] Supported by the U.S. National Science Foundation.
[10] Supported by Raziskovalna skupnost Slovenije, the Internationales Büro KfA, Jülich, and DESY, Hamburg.
[11] Supported by the Swedish Research Council.
[12] Supported by the U.S. Department of Energy, under contract DE-AS09-80ER10690.

Abstract

We report the first direct observation of B meson decays into Λ_c^+ baryons using the decay channel $\Lambda_c^+ \to pK^-\pi^+$. The product of branching ratios $Br(B \to \Lambda_c^+ X) \cdot Br(\Lambda_c^+ \to pK^-\pi^+) = (0.30 \pm 0.12 \pm 0.06)\%$ is derived from an observed signal of 208 ± 89 events. Using previous measurements of inclusive baryon rates we find a branching ratio for $\Lambda_c^+ \to pK^-\pi^+$ of $(4.1 \pm 2.4)\%$. The measured Λ_c^+ momentum spectrum indicates that multi-particle final states dominate the decays $B \to \Lambda_c^+ X$.

The decay of B mesons into charmed mesons has been established by a variety of studies including the exclusive reconstruction of B mesons in semileptonic [1] and purely hadronic channels [2,3,4], as well as the inclusive measurements of D, D_s and J/ψ meson production [4,5,6,7]. In the framework of the standard model, baryons are also expected to appear as decay products of B mesons. Phase space arguments in the context of the spectator model lead to expected branching ratios of between 5% and 10% for B decays into charmed baryons [8]. Indirect evidence for these decays has been recently derived from baryon correlation studies [9,10]. In this paper we report the first direct observation of Λ_c^+ production in B decays.

The ARGUS detector, operating at the electron-positron storage ring DORIS II at DESY, was used to collect the data for this analysis. The sample comprises an integrated luminosity of 94.1 pb^{-1} on the $\Upsilon(4S)$ resonance and 41.4 pb^{-1} in the nearby continuum.

The ARGUS detector is a 4π spectrometer described in more detail in references [11,12]. The momenta of charged particles are measured with the central and vertex drift chambers; particles are identified by specific ionization and time-of-flight measurements. For each charged particle, a χ^2 value is calculated for the allowed hypotheses: e, π, K and p. Then a likelihood ratio l_i for each assignment is determined:

$$l_i = \frac{w_i e^{-\frac{\chi_i^2}{2}}}{\sum_j w_j e^{-\frac{\chi_j^2}{2}}}, \quad i,j = e, \pi, K, p$$

The weights are chosen to be $w_e = w_K = w_p = 1$ and $w_\pi = 5$, in rough approximation to the observed abundances. A track is used for all particle hypotheses for which $l_i \geq 0.01$. Multihadron events were selected by requiring at least 3 tracks, either pointing to the interaction region and originating from a common vertex, or accompanied by an energy deposition of at least 1.7 GeV in the shower counters.

Λ_c^+ baryons were reconstructed in the channel $\Lambda_c^+ \to pK^-\pi^+$. Since the momenta of Λ_c^+ baryons from B decays are kinematically restricted to be less than 2.3 GeV/c, this requirement was applied to obtain the $pK^-\pi^+$ invariant mass spectrum for the $\Upsilon(4S)$ sample shown in fig. 1. For the continuum data this requirement corresponds to a cut on the scaled momentum x_p at 0.48; the invariant $pK^-\pi^+$ mass is shown in fig. 2. A clear peak at 2.285 GeV/c^2 is observed in the $\Upsilon(4S)$ data. The signal is parametrized by a gaussian and the background by a third-order polynomial for the fits to the mass spectra. The mass and width of the gaussian were determined from the $\Upsilon(4S)$ data to be (2.285 ± 0.002) GeV/c^2 and $(10.9^{+3.0}_{-2.3})$ MeV/c^2 respectively. The width is consistent with the Monte Carlo predicted value of 9.3 MeV/c^2, which was then used for all subsequent fits. The simulation also shows that the width of the signal does not vary significantly in the momentum range below 2.3 MeV/c. In the $\Upsilon(4S)$ sample we observe 398 ± 60 events, while for the continuum we find 89 ± 31 events. Reflections of $D^\pm$ and $D_s{}^\pm$ decays do not contribute to the observed signal, as shown by Monte Carlo simulation and by changing the mass assignment of the decay particles for the Λ_c^+ candidates. Subtracting the continuum data after scaling them to the luminosity and energy of the $\Upsilon(4S)$ data, we find an excess of 208 ± 89 Λ_c^+ baryons attributed to direct $\Upsilon(4S)$ decays.

The acceptance of inclusively produced Λ_c^+ baryons as a function of momentum was studied using a Monte Carlo simulation. For this purpose $\Upsilon(4S)$ decays were generated where:

1. One B decays to $\Lambda_c^+/\Sigma_c + \bar{\Delta}/\bar{p} + \pi$, followed, where appropriate, by a Σ_c decay to $\Lambda_c^+\pi$. All Λ_c^+ decay to $pK^-\pi^+$.

2. The other B decay is simulated by a modified Lund program, describing the main features of inclusive B decays [13].

The Monte Carlo events were passed through a detailed simulation of the ARGUS detector [14] and reconstructed with the standard analysis program. The acceptance rises slowly from 0.35 to 0.50 in the momentum range from 0 to 2.3 GeV/c. The corrected number of Λ_c^+ baryons was obtained by weighting each candidate by one over the acceptance at the measured momentum of the $pK^-\pi^+$ combination. From this number of Λ_c^+ baryons, and the number of B mesons in the data sample (179000 ± 18000), one derives a product of branching ratios $Br(B \to \Lambda_c^+X)\cdot Br(\Lambda_c^+ \to pK^-\pi^+) = (0.30 \pm 0.12 \pm 0.06)\%$.

This result, combined with the value of $(2.2\pm1.0)\%$ inferred by MARK II [15] for the branching ratio for $\Lambda_c^+ \to pK^-\pi^+$, would yield an inclusive branching ratio for B decays to Λ_c^+ baryons of $Br(B \to \Lambda_c^+X) = (14\pm9)\%$. The same inclusive branching ratio can also be derived from measurements of the inclusive proton and Λ rates in B decays [9,10]. Such an approach yields a smaller value of $(7.4 \pm 2.9)\%$. Using this result for the inclusive branching ratio for $B \to \Lambda_c^+X$, one derives a value of $(4.1 \pm 2.4)\%$ for $Br(\Lambda_c^+ \to pK^-\pi^+)$, which agrees with the lower limit of 4.4% (90% CL) recently reported by the LEBC-EHS collaboration [16].

Information about the relative contribution of the various exclusive modes to the inclusive signal can be inferred from the Λ_c^+ momentum spectrum. This distribution is derived from the data as follows:

1. The $\Upsilon(4S)$ data is fitted in seperate momentum bins with a gaussian for the Λ_c^+ peak and a third-order polynomial for the background.

2. The continuum contribution in each of these momentum bins is determined by integrating the Peterson fragmentation function [17], normalized to the number of observed Λ_c^+ baryons in the continuum data sample over the momentum range $p(\Lambda_c^+) < 2.3$ GeV/c after scaling by the luminosity ratio. The ϵ parameter of the Peterson function was determined to be $\epsilon = 0.236$ by an analysis of Λ_c^+ production in the continuum [18].

The resulting acceptance-corrected momentum spectrum of Λ_c^+ baryons from B decays is shown in fig. 3. For comparison, the momentum spectra expected for two-body ($B \rightarrow \Sigma_c/\Lambda_c^+ + \bar{p}/\bar{n}/\bar{\Delta}$) and three-body phase space decays ($B \rightarrow \Sigma_c/\Lambda_c^+ + \bar{p}/\bar{n}/\bar{\Delta} + \pi$) are also shown. Qualitatively, it is clear that there can only be a small two-body component in the spectrum, and that even the three-body contribution provides only a poor description of the observed spectrum. Having no reliable model to predict the form of the multi-body contribution in the high momentum region, we are unable to extract a quantitative limit for the two-body component.

In summary we report the first direct observation of B decays into the Λ_c^+ baryon, with a product of branching ratios $Br(B \rightarrow \Lambda_c^+ X) \cdot Br(\Lambda_c^+ \rightarrow pK^-\pi^+) = (0.30 \pm 0.12 \pm 0.06)\%$. Together with previously measured values for $Br(B \rightarrow \Lambda_c^+ X)$, we derive a result for the branching ratio for $\Lambda_c^+ \rightarrow pK^-\pi^+$ of $(4.1 \pm 2.4)\%$. The shape of the momentum spectrum excludes a dominant contribution from two-body decays of the B mesons into the Λ_c^+.

Acknowledgements

It is a pleasure to thank U. Djuanda, E. Konrad, E. Michel and W. Reinsch for their competent technical help in running the experiment and processing the data. We thank Dr.H. Nesemann, B. Sarau and the DORIS group for the excellent operation of the storage ring. The visiting groups wish to thank the DESY directorate for the support and kind hospitality extended to them.

References

[1] H. Albrecht et al. (ARGUS), Phys. Lett. **197B** (1987) 452.

[2] H. Albrecht et al. (ARGUS), Phys. Lett. **185B** (1987) 218.

[3] C. Bebek et al. (CLEO), Phys. Rev. **D36** (1987) 1289.

[4] H. Albrecht et al. (ARGUS), Phys. Lett. **199B** (1987) 451.

[5] D. Bortoletto et al. (CLEO), Phys. Rev. **D35** (1987) 19.

[6] P. Haas et al. (CLEO), Phys. Rev. Lett. **56** (1986) 2781;
H. Albrecht et al. (ARGUS), Phys. Lett. **187B** (1987) 425.

[7] H. Albrecht et al. (ARGUS), Phys. Lett. **162B** (1985) 395;
P. Haas et al. (CLEO), Phys. Rev. Lett. **55** (1985) 1248.

[8] I.I. Bigi, Phys. Lett. **106B** (1981) 510.

[9] M.S. Alam et al. (CLEO), Phys. Rev. Lett. **59** (1987) 22.

[10] R. Ammar (ARGUS), Proc. of the Int. Europhysics Conf., Uppsala (1987) 360.

[11] H. Albrecht et al. (ARGUS), Phys. Lett. **134B** (1984) 137.

[12] H. Albrecht et al. (ARGUS), Phys. Lett. **150B** (1985) 235.

[13] H. Albrecht et al. (ARGUS), Phys. Lett. **192B** (1987) 245.

[14] H. Gennow, DESY Internal report **F15-85-02** (1985).

[15] G. Abrams et al. (MARK II), Phys. Rev. Lett. **44** (1980) 10.

[16] M. Aguilar-Benitez et al. (LEBC-EHS), "Λ_c^+ production characteristics in proton-proton interactions at 400 GeV/c", CERN/EP **87-126**.

[17] C. Peterson et al., Phys. Rev. **D27** (1983) 105.

[18] H. Albrecht et al. (ARGUS), DESY **88-011**.

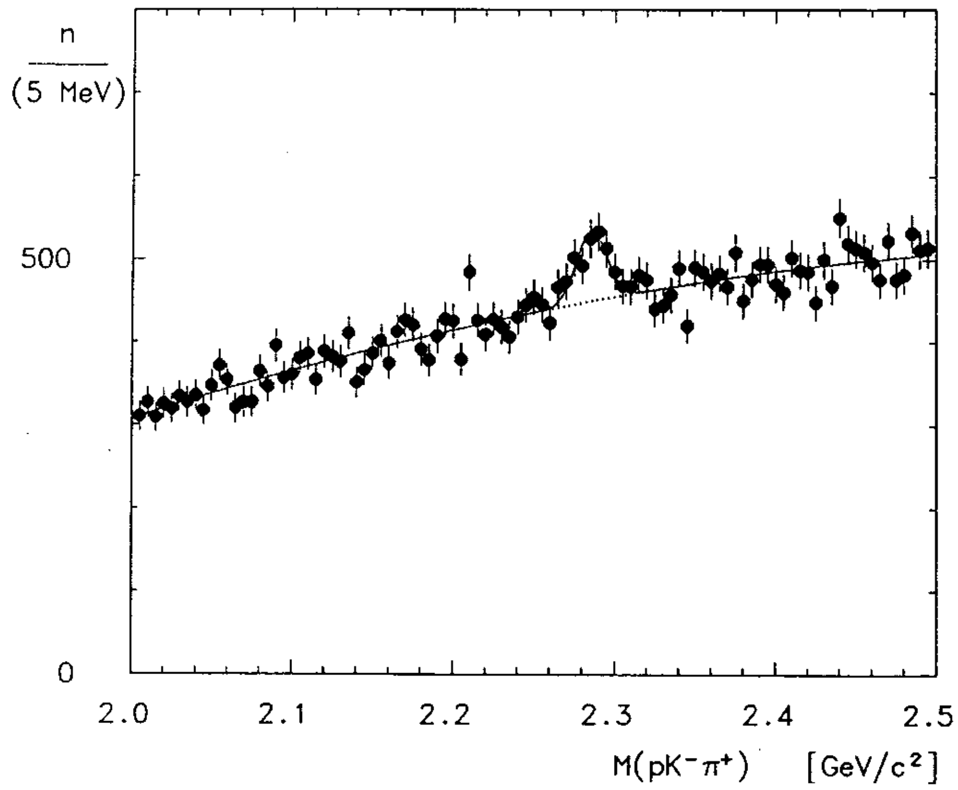

Figure 1: Invariant $pK^-\pi^+$ mass distribution in the $\Upsilon(4S)$ data with the requirement that the momentum of the $pK^-\pi^+$ system be less than 2.3 GeV/c.

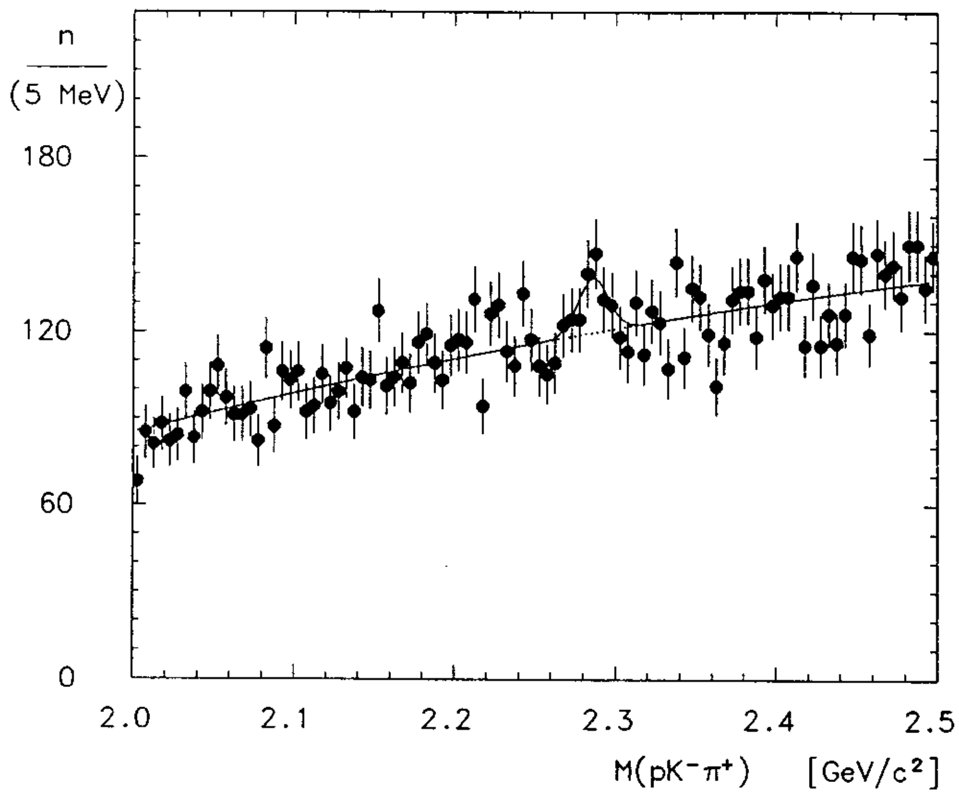

Figure 2: Invariant $pK^-\pi^+$ mass distribution in the continuum data with x_p less than 0.48

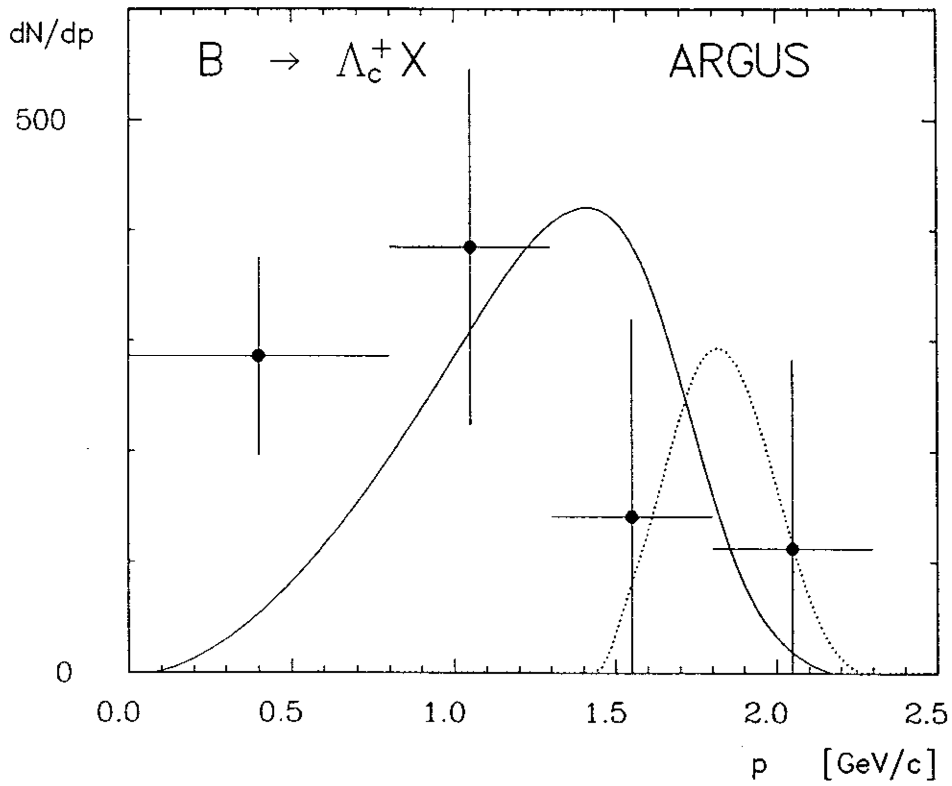

Figure 3: Momentum distribution of Λ_c^+ baryons from B decays. The expected form of the contribution from two-body (dotted line) and three-body (solid line) B decays are shown. The three-body curve has been normalized to the number of entries in the data, the two-body normalization is arbitrary.