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## Observation of Inclusive B Meson Decays into $\Lambda_c^+$ Baryons

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## Abstract

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

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, and J/ $\psi$  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  $\Lambda_c^+$  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  $94.1 \text{ pb}^{-1}$  on the  $\Upsilon(4S)$  resonance and  $41.4 \text{ pb}^{-1}$  in the nearby continuum.

The ARGUS detector is a  $4\pi$  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  $\chi^2$  value is calculated for the allowed hypotheses: e,  $\pi$ , 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.

$\Lambda_c^+$  baryons were reconstructed in the channel  $\Lambda_c^+ \rightarrow p\bar{K}^-\pi^+$ . Since the momenta of  $\Lambda_c^+$  baryons from B decays are kinematically restricted to be less than 2.3 GeV/c, this requirement was applied to obtain the  $p\bar{K}^-\pi^+$  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  $p\bar{K}^-\pi^+$  mass is shown in fig. 2. A clear peak at 2.285 GeV/c<sup>2</sup> 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  $(2.285 \pm 0.002)$  GeV/c<sup>2</sup> and  $(10.9^{+3.0}_{-2.3})$  MeV/c<sup>2</sup> respectively. The width is consistent with the Monte Carlo predicted value of 9.3 MeV/c<sup>2</sup>, 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  $398 \pm 60$  events, while for the continuum we find  $89 \pm 31$  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  $\Lambda_c^+$  candidates. Subtracting the continuum data after scaling them to the luminosity and energy of the  $\Upsilon(4S)$  data, we find an excess of  $208 \pm 89$   $\Lambda_c^+$  baryons attributed to direct  $\Upsilon(4S)$  decays.

The acceptance of inclusively produced  $\Lambda_c^+$  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  $\Sigma_c$  decay to  $\Lambda_c^+\pi$ . All  $\Lambda_c^+$  decay to  $p\bar{K}^-\pi^+$ .
2. The other B decay is simulated by a modified Lund program, describ-

ing 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  $\Lambda_c^+$  baryons was obtained by weighting each candidate by one over the acceptance at the measured momentum of the  $p\bar{K}^-\pi^+$  combination. From this number of  $\Lambda_c^+$  baryons, and the number of B mesons in the data sample ( $179000 \pm 18000$ ), one derives a product of branching ratios  $\text{Br}(B \rightarrow \Lambda_c^+ X) \cdot \text{Br}(\Lambda_c^+ \rightarrow p\bar{K}^-\pi^+) = (0.30 \pm 0.12 \pm 0.06)\%$ .

This result, combined with the value of  $(2.2 \pm 1.0)\%$  inferred by MARK II [15] for the branching ratio for  $\Lambda_c^+ \rightarrow p\bar{K}^-\pi^+$ , would yield an inclusive branching ratio for B decays to  $\Lambda_c^+$  baryons of  $\text{Br}(B \rightarrow \Lambda_c^+ X) = (14 \pm 9)\%$ . The same inclusive branching ratio can also be derived from measurements of the inclusive proton and  $\Lambda$  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  $B \rightarrow \Lambda_c^+ X$ , one derives a value of  $(4.1 \pm 2.4)\%$  for  $\text{Br}(\Lambda_c^+ \rightarrow p\bar{K}^-\pi^+)$ , which agrees with the lower limit of 4.4% (90% CL) recently reported by the LEBE-EHS collaboration [16].

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

1. The  $\Upsilon(4S)$  data is fitted in separate momentum bins with a gaussian for the  $\Lambda_c^+$  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  $\Lambda_c^+$  baryons in the continuum data sample over the momentum range  $p(\Lambda_c^+) < 2.3$  GeV/c after scaling by the luminosity ratio. The  $\epsilon$  parameter of the Peterson function was determined to be  $\epsilon = 0.236$  by an analysis of  $\Lambda_c^+$  production in the continuum [18].

The resulting acceptance-corrected momentum spectrum of  $\Lambda_c^+$  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  $\Lambda_c^+$  baryon, with a product of branching ratios  $\text{Br}(B \rightarrow \Lambda_c^+ X) \cdot \text{Br}(\Lambda_c^+ \rightarrow p\bar{K}^- \pi^+) = (0.30 \pm 0.12 \pm 0.06)\%$ . Together with previously measured values for  $\text{Br}(B \rightarrow \Lambda_c^+ X)$ , we derive a result for the branching ratio for  $\Lambda_c^+ \rightarrow p\bar{K}^- \pi^+$  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  $\Lambda_c^+$ .

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## 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), " $\Lambda_c^+$  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**.

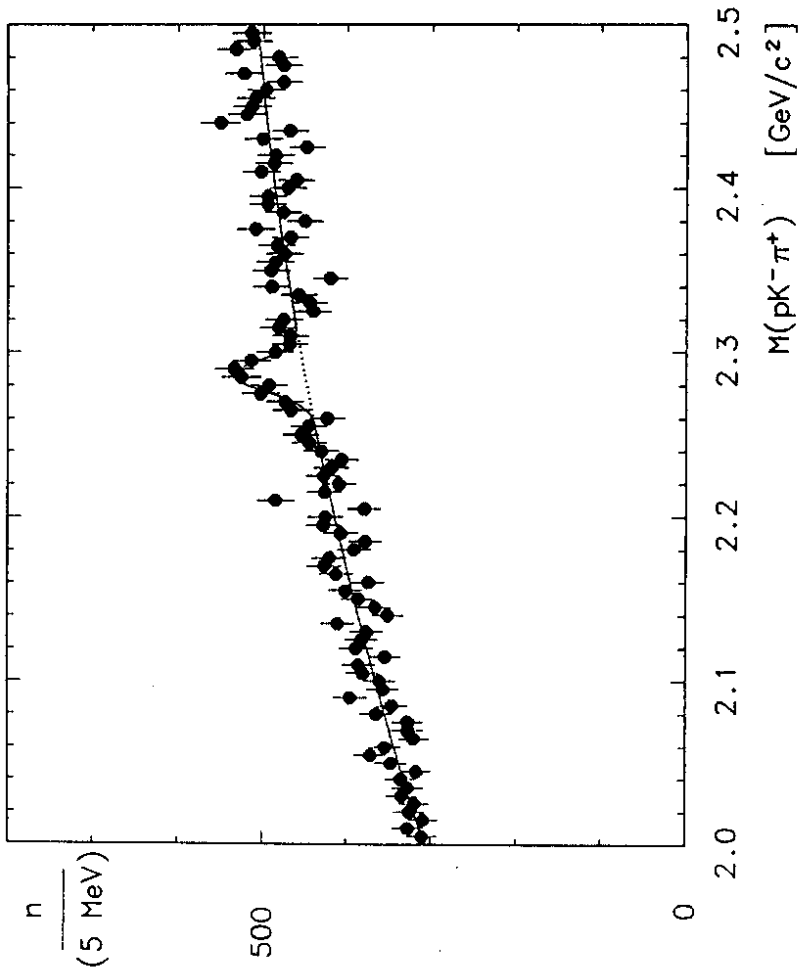


Figure 1: Invariant  $pK^- \pi^+$  mass distribution in the  $\Upsilon(4S)$  data with the requirement that the momentum of the  $pK^- \pi^+$  system be less than 2.3  $\text{GeV}/c$ .

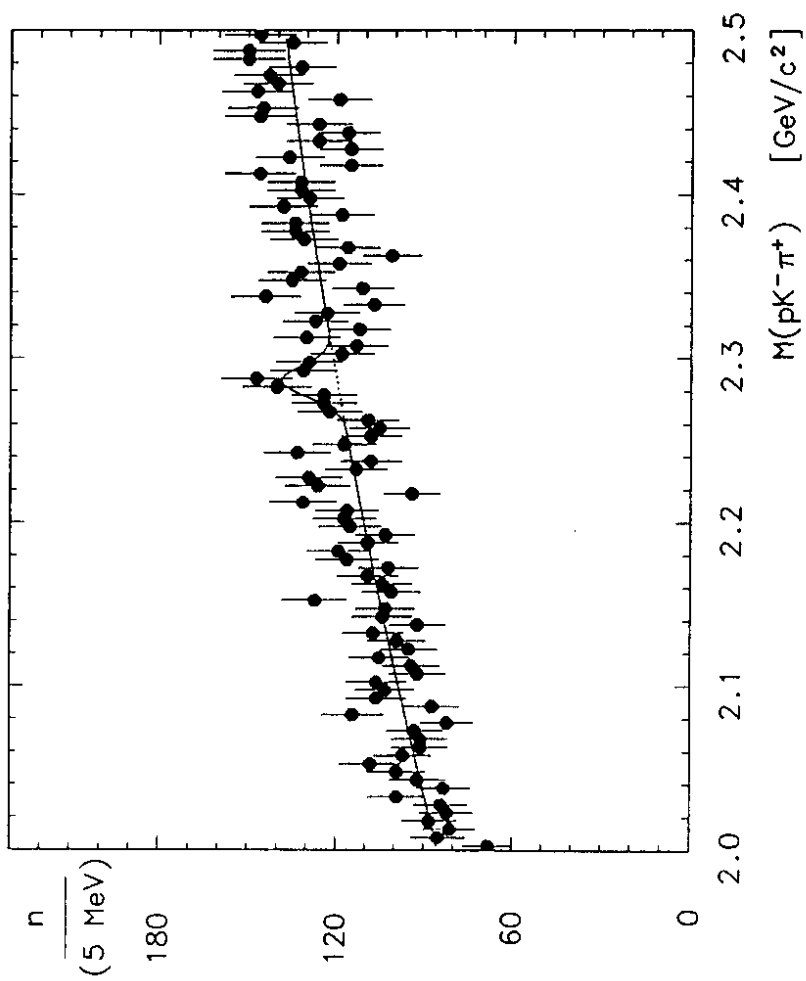


Figure 2: Invariant  $pK^- \pi^+$  mass distribution in the continuum data with  $x_p$  less than 0.48

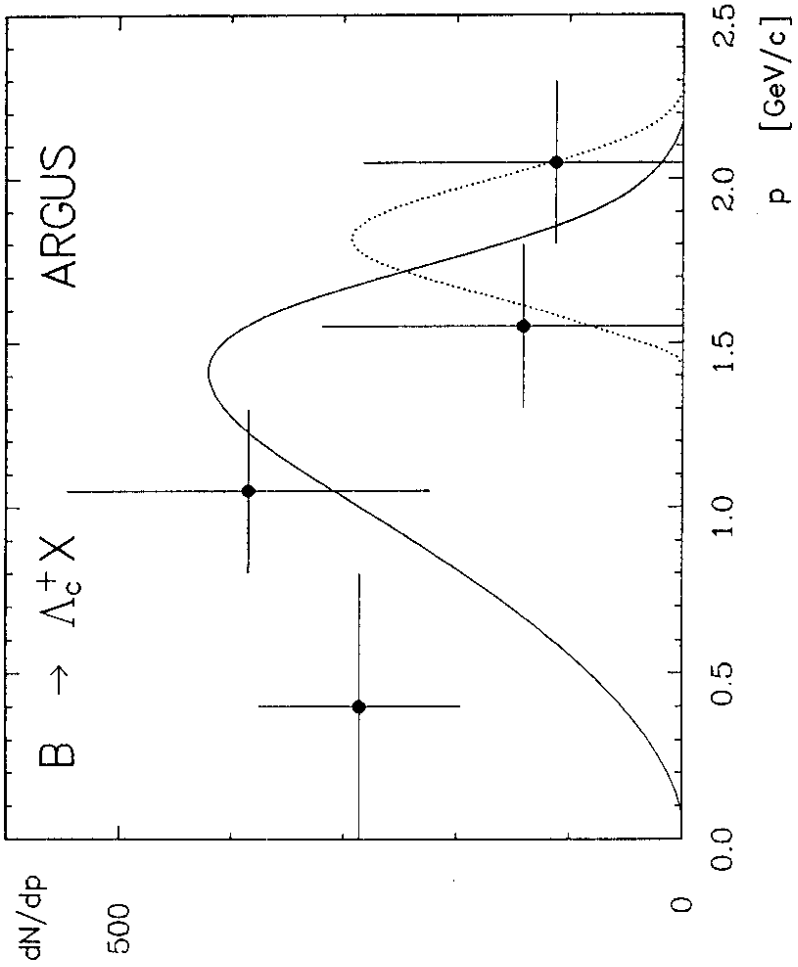


Figure 3: Momentum distribution of  $\Lambda_c^+$  baryons from B decays. The expected form of the contribution from two-body (dotted line) and three-body (solid line) B decays are shown. The three-body curve has been normalized to the number of entries in the data, the two-body normalization is arbitrary.