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OBSERVATION OF INCLUSIVE B MESON DECAYS INTO Λ_c^+ BARYONS

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Observation of Inclusive B Meson Decays into Λ_c^+ Baryons

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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:

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

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 $\Lambda_c^+/\Sigma_c + \bar{\Lambda}/\bar{p} + \pi$, 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±1.0)% 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 ± 2.9)%. Using this result for the inclusive branching ratio for $B \to \Lambda_c^+X$, one derives a value of (4.1 ± 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 ($B \to \Sigma_c/\Lambda_c^+ + \bar{p}/\bar{n}/\bar{\Delta}$) and three-body phase space decays ($B \to \Sigma_c/\Lambda_c^+ + \bar{p}/\bar{n}/\bar{\Delta} + \pi$) 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 $Br(B \to \Lambda_c^+ X) \cdot Br(\Lambda_c^+ \to pK^-\pi^+) = (0.30 \pm 0.12 \pm 0.06)\%$. Together with previously measured values for $Br(B \to \Lambda_c^+ X)$, we derive a result for the branching ratio for $\Lambda_c^+ \to pK^-\pi^+$ 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^+.

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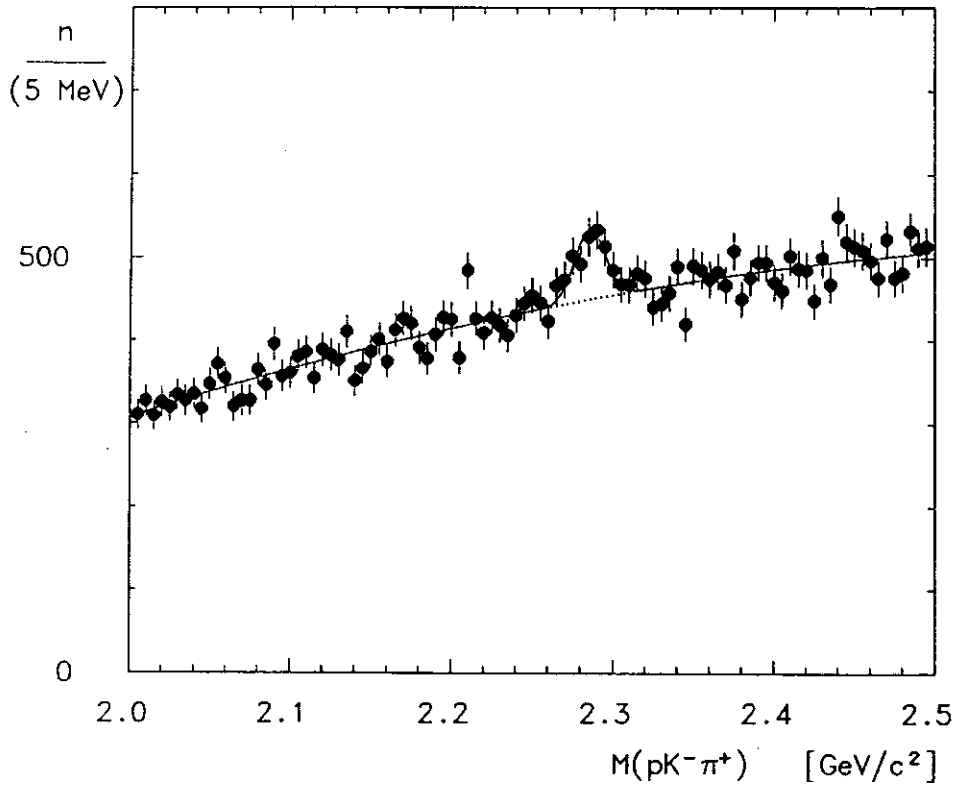

Figure 1: Invariant $pK^-\pi^+$ mass distribution in the $\Upsilon(4S)$ data with the requirement that the momentum of the $pK^-\pi^+$ system be less than 2.3 GeV/c.

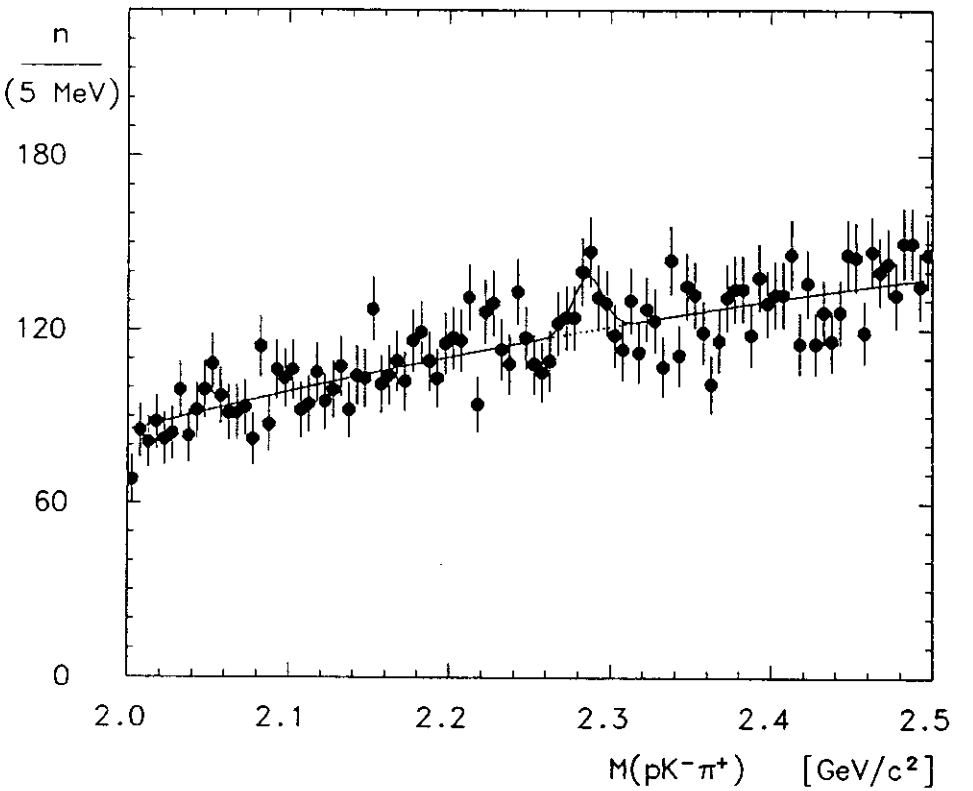

Figure 2: Invariant $pK^-\pi^+$ mass distribution in the continuum data with x_p less than 0.48

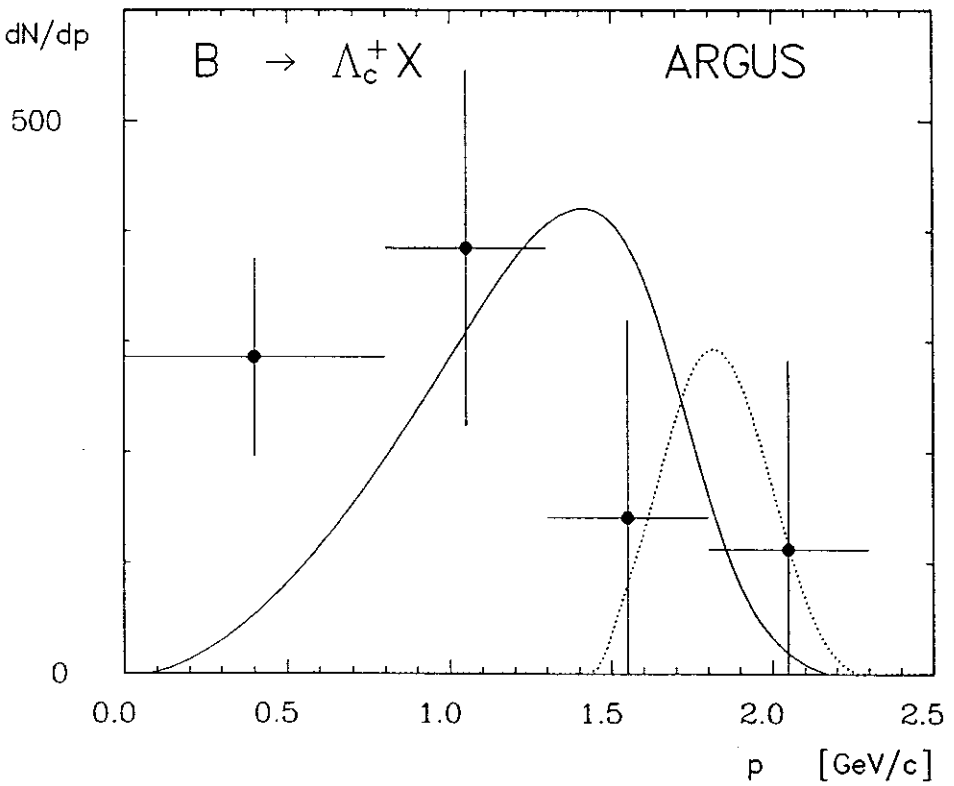

Figure 3: Momentum distribution of Λ_c^+ baryons from B decays. The expected form of the contribution from two-body (dotted line) and three-body (solid line) B decays are shown. The three-body curve has been normalized to the number of entries in the data, the two-body normalization is arbitrary.