DEUTSCHES ELEKTRONEN – SYNCHROTRON

DESY 92–074
May 1992

Measurement of Inclusive Baryon Production in B Meson Decays

The ARGUS Collaboration

ISSN 0418-9833

NOTKESTRASSE 85 · D-2000 HAMBURG 52

DESY 92-074 ISSN 0418-9833
May 1992

Measurement of Inclusive Baryon Production in B Meson Decays

The ARGUS Collaboration

H. Albrecht, H. I. Cronström[1], H. Ehrlichmann, T. Hamacher, R. P. Hofmann,
T. Kirchhoff, A. Nau, S. Nowak[2], M. Reidenbach, R. Reiner, H. Schröder, H. D. Schulz,
M. Walter[2], R. Wurth
DESY, Hamburg, Germany

R. D. Appuhn, C. Hast, H. Kolanoski, A. Lange, A. Lindner, R. Mankel, M. Schieber,
T. Siegmund, B. Spaan, H. Thurn, D. Töpfer, A. Walther, D. Wegener
Institut für Physik[3]*, Universität Dortmund, Germany*

M. Paulini, K. Reim, H. Wegener
Physikalisches Institut[4]*, Universität Erlangen-Nürnberg, Germany*

R. Mundt, T. Oest, W. Schmidt-Parzefall
II. Institut für Experimentalphysik, Universität Hamburg, Germany

W. Funk, J. Stiewe, S. Werner
Institut für Hochenergiephysik[5]*, Universität Heidelberg, Germany*

K. Ehret, A. Hölscher, W. Hofmann, A. Hüpper, S. Khan, K. T. Knöpfle, J. Spengler
Max-Planck-Institut für Kernphysik, Heidelberg, Germany

D. I. Britton[6], C. E. K. Charlesworth[7], K. W. Edwards[8], E. R. F. Hyatt[6], H. Kapitza[8],
P. Krieger[9][7], D. B. MacFarlane[6], P. M. Patel[6], J. D. Prentice[7], P. R. B. Saull[6], S. C. Seidel[7],
K. Tzamariudaki[6], R. G. Van de Water[7], T.-S. Yoon[7]
Institute of Particle Physics[10]*, Canada*

D. Reßing, M. Schmidtler, M. Schneider, K. R. Schubert, K. Strahl, R. Waldi, S. Weseler
Institut für Experimentelle Kernphysik[11]*, Universität Karlsruhe, Germany*

G. Kernel, P. Križan, E. Križnič, T. Podobnik, T. Živko
Institut J. Stefan and Oddelek za fiziko[12]*, Univerza v Ljubljani, Ljubljana, Slovenia*

L. Jönsson
Institute of Physics[13]*, University of Lund, Sweden*

V. Balagura, I. Belyaev, M. Danilov, A. Droutskoy, A. Golutvin, I. Gorelov, G. Kostina,
V. Lubimov, P. Murat, P. Pakhlov, F. Ratnikov, S. Semenov, V. Shibaev, V. Soloshenko,
I. Tichomirov, Yu. Zaitsev
Institute of Theoretical and Experimental Physics[14]*, Moscow, Russia*

Abstract

Using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY, we have studied B meson decays into baryons p and Λ. From the simultaneous analysis of p and Λ yields, $p\overline{p}$ and $\Lambda\overline{p}$ correlations, and various lepton–baryon and lepton–baryon–antibaryon correlations the inclusive branching ratio is found to be $BR(B \rightarrow baryons) = (6.8\pm0.5\pm0.3)\%$.

1 Introduction

Baryonic B decays offer a unique opportunity to study baryon production in weak decays. The mechanism of baryon production in meson decays is not well understood, and present theoretical studies refer mainly to two–body baryonic final states [1].

The measurements of the inclusive proton and Λ rates in B decays have been reported by CLEO and ARGUS [2,3,4]. These measurements allowed for extracting the total branching ratio $B_b = BR(B \rightarrow baryons)$ under certain assumptions. Because of absorption in the inner detector material, the protons and Λ's have been selected in the restricted momentum range above 0.3 GeV/c. Due to the fact that the proton spectrum from B decays peaks at low momenta, the model dependent extrapolation to the entire momentum range causes large uncertainties in $BR(B \rightarrow pX)$ and $BR(B \rightarrow \Lambda X)$ and consequently in B_b. In order to extract the value of B_b the unmeasured $BR(B \rightarrow nX)$ has been assumed to be the equal to as $BR(B \rightarrow pX)$.

This paper reports on the measurement of B_b using a different method [5]. Since baryons are always accompanied by antibaryons, a simultaneous analysis of the number of events with one reconstructed baryon and with reconstructed baryon–antibaryon pairs provides information about the unmeasured branching ratio $BR(B \rightarrow nX)$. In addition, the determination of B_b does not require model–dependent assumptions on the shape of the baryon spectra at low momenta as in the previous analyses [3,4].

Since B meson decays are dominated by $b \rightarrow c$ transitions, we assume in the following that stable baryons are always produced either as a decay product of a charmed baryon or in the fragmentation of the remaining B decay products (figure 1). The production of non–charmed baryon–antibaryon pairs in the fragmentation is expected to be suppressed [3,4]. With these assumptions, the species (p or Λ) of a baryon in a B decay is independent of the species of the antibaryon in the same decay.

This leads to the following set of equations for the numbers of events with a

---

[1] Supported in part by the Institute of Physics, University of Lund, Sweden
[2] DESY, IfH Zeuthen
[3] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 054DO51P.
[4] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 054ER12P.
[5] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 055HD21P.
[6] McGill University, Montreal, Quebec, Canada.
[7] University of Toronto, Toronto, Ontario, Canada.
[8] Carleton University, Ottawa, Ontario, Canada.
[9] Supported in part by the Walter C. Sumner Foundation.
[10] Supported by the Natural Sciences and Engineering Research Council, Canada.
[11] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 054KA17P.
[12] Supported by the Department of Science and Technology of the Republic of Slovenia and the Internationales Büro KfA, Jülich.
[13] Supported by the Swedish Research Council.
[14] Supported in part by the International Technology Center BINITEC, Moscow, Russia.

reconstructed proton, Λ, or one of the combinations $p\overline{p}$, $p\overline{\Lambda}$, and $\Lambda\overline{\Lambda}$: [1]

$$
\begin{aligned}
N_p &= N_B \cdot B_b \cdot \; (\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c + f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) && (1)\\
N_\Lambda &= N_B \cdot B_b \cdot \; (\theta_\Lambda \epsilon_\Lambda^c + f_\Lambda \epsilon_\Lambda^h) && (2)\\
N_{p\overline{p}} &= N_B \cdot B_b \cdot \; (\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c)(f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) + \\
& \tfrac{1}{2} N_B \cdot B_b^2 \cdot \; ((\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c)^2 + (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h)^2) && (3)\\
N_{p\overline{\Lambda}} &= N_B \cdot B_b \cdot \; ((\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c) f_\Lambda \epsilon_\Lambda^h + \theta_\Lambda \epsilon_\Lambda^c (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h)) + \\
& \tfrac{1}{2} N_B \cdot B_b^2 \cdot \; ((\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c)\theta_\Lambda \epsilon_\Lambda^c + (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) f_\Lambda \epsilon_\Lambda^h) && (4)\\
N_{\Lambda\overline{\Lambda}} &= N_B \cdot B_b \cdot \; \theta_\Lambda \epsilon_\Lambda^c f_\Lambda \epsilon_\Lambda^h + \\
& \tfrac{1}{2} N_B \cdot B_b^2 \cdot \; ({\theta_\Lambda}^2 {\epsilon_\Lambda^c}^2 + {f_\Lambda}^2 {\epsilon_\Lambda^h}^2) && (5)
\end{aligned}
$$

where

N_B is the number of B mesons produced in $\Upsilon(4S)$ decays;

θ_p (θ_Λ) is the branching ratio for the decay of charmed baryons into protons (Λ's) in the accepted momentum interval;

f_p (f_Λ) is the relative fraction of protons (Λ's) produced in the hadronization processes in the accepted momentum interval;

ϵ_p^c (ϵ_p^h) is the acceptance for protons from charmed baryon decays (hadronization processes) in the accepted momentum interval;

ϵ_Λ^c (ϵ_Λ^h) is the analogous acceptance for Λ's;

$\epsilon_{p|\Lambda}^c$ ($\epsilon_{p|\Lambda}^h$) is the branching ratio $\Lambda \to p\pi^-$ times the acceptance for protons originating from Λ decays.

The presence of an additional high momentum lepton in the event allows to distinguish whether a stable baryon originates from the charmed baryon decay or from the fragmentation. The lepton charge tags the flavour of the B meson decaying into baryons because, due to phase space considerations, a fast lepton with momentum greater than 1.5 GeV/c and a pair of baryons originate from different B mesons. This is supported by the fact that the branching ratio of semileptonic decays containing baryons is smaller than 0.16% [6]. This tagging is diluted by $B\overline{B}$ mixing which will be discussed below. Without mixing, we obtain the following equations for the numbers of events containing a fast lepton together with a single baryon or a baryon–antibaryon pair:

$$
\begin{aligned}
N_{l^\pm p\overline{p}} &= N_l \cdot B_b \cdot (\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c)(f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) && (6)\\
N_{l^+ p} &= N_l \cdot B_b \cdot (\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c) && (7)\\
N_{l^- p} &= N_l \cdot B_b \cdot (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) && (8)\\
N_{l^+ \Lambda} &= N_l \cdot B_b \cdot \theta_\Lambda \epsilon_\Lambda^c && (9)\\
N_{l^- \Lambda} &= N_l \cdot B_b \cdot f_\Lambda \epsilon_\Lambda^h && (10)\\
N_{l^+ p\overline{\Lambda}} &= N_l \cdot B_b \cdot (\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c) f_\Lambda \epsilon_\Lambda^h && (11)\\
N_{l^- p\overline{\Lambda}} &= N_l \cdot B_b \cdot \theta_\Lambda \epsilon_\Lambda^c (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) && (12)
\end{aligned}
$$

where N_l is the number of events with a fast lepton.

In total there are 12 equations containing 5 unknown quantities: B_b, θ_p, θ_Λ, f_p, and f_Λ. In principle, the branching ratio $BR(B \to baryons)$ can already be extracted from equations (6) to (8) only:

$$B_b = \frac{N_{l^+ p} \cdot N_{l^- p}}{N_l \cdot N_{l^\pm p\overline{p}}} \qquad (13)$$

Nevertheless, using all available information provides the determination of B_b with higher accuracy. Moreover, the consistency of our assumptions can be checked from the consistency of equations (1) to (12) with experimental data.

2 Data Analysis

The data used for this analysis were taken on the $\Upsilon(4S)$ resonance using the ARGUS detector at the e^+e^- storage ring DORIS II. The data sample comprises an integrated luminosity of 234 pb^{-1} on the $\Upsilon(4S)$ resonance and 92 pb^{-1} in the nearby continuum. The number of B mesons in the sample is 398000 ± 17000, assuming that the $\Upsilon(4S)$ resonance decays only to $B\overline{B}$ pairs. The ARGUS detector, its trigger requirements and particle identification capabilities have been described in detail elsewhere [7].

Charged particles are required to originate from the main vertex with a polar angle θ in the range $|\cos(\theta)| < 0.92$. Particle identification is based on a likelihood ratio calculated from measurements of specific ionization and time–of–flight [7].

Proton candidates are selected in the momentum range from 0.4 to 1.1 GeV/c where they can be identified almost unambiguously. A proton hypothesis is accepted if the corresponding likelihood value exceeds 0.15. To reduce the number of protons originating from interactions in the inner detector material, a cut on the distance in radial direction between the track and the main vertex $\delta R < 0.35$ cm is applied. To calculate the probabilities for π and K mesons to be misidentified as protons we used samples of particles, namely π mesons from $K_S^0 \to \pi^+\pi^-$ and K mesons from

---

[1] Unless otherwise stated references in this paper to a specific charged state are to be interpreted as implying the charge–conjugate state as well.

the decay $\phi \to K^+K^-$. The misidentification rate was found to be $(0.8 \pm 0.2)\%$ at momenta from 1.0 to 1.1 GeV/c and negligeable at smaller momenta.

Λ hyperons are detected in the decay channel $\Lambda \to p\pi^-$. The decay vertex is required to be geometrically reconstructed. Converted photons are rejected by a cut on the opening angle between the proton and pion candidate, requiring $\cos(p, \pi^-) < 0.995$. To suppress Λ particles produced in the inner detector material, the angle between the flight direction of the Λ and the vector $\vec{d}$, connecting the main and the secondary vertex, has to satisfy the condition $cos(\vec{p}, \vec{d}) > 0.95$. We use Λ's in the same momentum interval as protons, namely $0.4\ GeV/c < p_\Lambda < 1.1\ GeV/c$. The contribution of Λ's from $\Upsilon(4S)$ decays with momenta above 1.1 GeV/c is not substantial [3,4], in contrast to the contribution of Λ's from the continuum.

For lepton identification, the size and lateral spread of the associated energy deposition in the calorimeter, or the quality of the match between the projected particle track and the associated hit in the muon chambers are included in the calculation of the electron and muon likelihood ratios, respectively. In particular, for muons a hit in a layer of the muon chambers outside the magnet return yoke is required. A lepton hypothesis is accepted if the appropriate likelihood ratio exceeds 70%. Contamination from photon conversion is suppressed by eliminating electron candidates which have an invariant mass of less than 100 MeV/c^2 when combined with any oppositely charged particle in the event consistent with the electron hypothesis. With these requirements leptons are identified with high efficiency and a small misidentification rate of $(0.5 \pm 0.1)\%$ for electrons and $(2.0 \pm 0.5)\%$ for muons [7]. The lepton momenta are required to be greater than 1.5 GeV/c in order to ensure that the lepton and the baryons originate from different B mesons in the event. In addition a cut in the lepton momentum of $p < 2.3\ GeV/c$ has been applied which coincides with the kinematical bound for leptons produced in $b \to c$ transition. It suppresses leptons originating from the continuum.

To suppress the continuum contribution the thrust value of the event [8] is required to be less than 0.8 and the total multiplicity $N_{tot} = N_{ch} + \frac{1}{2}N_\gamma$ where N_{ch} (N_γ) is the number of charged (neutral) particles in the event is required to be greater than 5. To eliminate the background from beam-gas and beam-wall interactions the cut on the variable f [9]:

$$f = \frac{P_{sum}}{\sqrt{s}} - 2.5 \cdot \frac{P_z^2}{\sqrt{s}} > 0.4 \qquad (14)$$

is applied where $P_{sum} = \sum \left|\vec{P^i}\right|$ is the sum of the charged and neutral particle momenta and $P_z = \sum P_z^i$ is the sum of the momentum component along the beam line. The efficiency of this cut is determined from data and is found to be $(94 \pm 2)\%$.

2.1 Analysis of p and $p\overline{p}$ Events

Since the proton sample suffers from a large background produced by interactions of particles in the beam pipe, only events with antiprotons are analysed in the reaction $B \to pX$. In the momentum interval $0.4\ GeV/c < p_{\overline{p}} < 1.1\ GeV/c$ we find 18954 antiprotons on the $\Upsilon(4S)$ resonance and 5103 in the continuum data. The last number must be scaled by a factor of (2.47 ± 0.10) in order to account for the difference in integrated luminosities and cross section. The number of misidentified antiprotons has been extracted from the observed spectrum for hadrons in $\Upsilon(4S)$ decays folded with the known misidentification rates. After subtracting the continuum contribution and fakes, 6296 ± 221 antiprotons from $\Upsilon(4S)$ decays remain. The momentum spectrum of these antiprotons is shown in figure 2.

The sample with reconstructed $p\overline{p}$ pairs is intrinsically cleaner. In order to estimate the contribution from protons produced by interactions in the inner detector material, the distributions of the distances δR for protons and antiprotons have been compared. As these distributions do not show any difference within statistics even at large δR, the background of faked protons turns out to be negligeable.

After subtracting the background from continuum interactions and misidentified $p\overline{p}$ pairs (see table 1), we obtain 2179 ± 117 events where both p and $\overline{p}$ have momenta in the range from 0.4 to 1.1 GeV/c.

2.2 Analysis of Λ , $\Lambda\overline{p}$, and $\Lambda\overline{\Lambda}$ Events

In the analysis of events with single Λ hyperons, only $\overline{p}\pi^+$ combinations are used in order to keep the background small. Figure 3 displays the $\overline{p}\pi^+$ invariant mass distributions for $\Upsilon(4S)$ and for scaled continuum data, indicating an excess of events attributed to direct B decays. The signals have been fitted with the sum of two Gaussians with free widths and equal mean value; the second Gaussian with a larger width is necessary to account for multiple scattering of the decay products of Λ's decaying inside the beam pipe. The parameters of the two Gaussians have been fixed from a fit using the large statistics available for $\overline{\Lambda}$ hyperons. The fits result in 752 ± 77 events with $\overline{\Lambda}$ produced in direct $\Upsilon(4S)$ decays. The momentum spectrum of the $\overline{\Lambda}$'s is shown in figure 4.

For the studies of the samples containing combinations of a Λ hyperon with an antibaryon or a fast lepton, the parameters of the two Gaussians are kept fixed. The numbers of events with $\Lambda\overline{p}$ and $\Lambda\overline{\Lambda}$ are listed in table 1 along with contributions from different background sources. The background from Λ's produced in strangeness exchange reactions in the inner detector material has been determined by comparing the numbers of Λ and $\overline{\Lambda}$ hyperons which do not point to the main vertex, analogously to the study of $p\overline{p}$ events. The analysis of $cos(\vec{p},\vec{d})$ distribution shows that this background is small (see table 1).

2.3 Analysis of Events with a Fast Lepton

The charge of the fast lepton tags the flavour of the B meson decaying into baryons. Wrong tags can arise from $B\overline{B}$ oscillations and the small fraction of secondary leptons from charm decays with momenta above 1.5 GeV/c. The probability for this effect is denoted by the parameter α. It leads to the reverse of the B flavour in equations (7) to (12). In order to take this effect into account, the equations for the pairs of final states with the opposite lepton charge are replaced by their linear combinations. For example, the equations (7) and (8) are rewritten as:

$$N_{l^+p} = N_l \cdot B_b \cdot ((\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c) \cdot (1-\alpha) + (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) \cdot \alpha) \qquad (7')$$

$$N_{l^-p} = N_l \cdot B_b \cdot ((\theta_p \epsilon_p^c + \theta_\Lambda \epsilon_{p|\Lambda}^c) \cdot \alpha + (f_p \epsilon_p^h + f_\Lambda \epsilon_{p|\Lambda}^h) \cdot (1-\alpha)) \qquad (8')$$

The value of α is (0.14 ± 0.02) which comprises the sum of (0.08 ± 0.015) from $B\overline{B}$ mixing [10] [2] and (0.06 ± 0.015) from secondary leptons as determined by a Monte Carlo simulation.

The background from hadrons misidentified as leptons is reliably estimated from data. Using observed hadron spectra and the lepton misidentification rates noted in chapter 2, this background is found to be 1090±220. After subtraction of the continuum contribution and fake leptons there remain 19500±300 events with a fast lepton.

The numbers of events containing a fast lepton and various combinations of baryons are listed in table 1 together with the background contributions. The background from protons produced in the inner detector material is estimated by comparing the δR distributions for protons and antiprotons, using the large statistics available for baryonic events without requiring a lepton. The momentum spectra of protons produced in the decays of charmed baryons and in hadronization processes are shown in figures $5a$ and $5b$, respectively.

3 Determination of the Efficiencies

The proton and Λ reconstruction efficiencies as well as the probability to reconstruct protons from Λ decays have been determined by a Monte Carlo simulation of the detector [11]. In order to determine average efficiencies integrated over the accepted momentum interval, the knowledge of the momentum spectra of stable baryons produced in charmed baryon decays and in the fragmentation process is necessary. For protons, both spectra are obtained from the analysis of events with protons and leptons. For Λ's, the statistics are limited; the corresponding spectra agree within errors with the proton spectra. Therefore we use the observed proton spectra in pl^+ and pl^- events to average the acceptances of all species of baryons. The efficiencies integrated over the accepted momentum interval for protons and Λ hyperons are presented in table 2.

The reconstruction efficiency for baryon–antibaryon pairs is well approximated by the product of the corresponding reconstruction efficiencies for single baryons. The Monte Carlo simulation shows that possible corrections due to momentum correlations of the two baryons lie within 2%.

The efficiency of the cut on the event thrust and total multiplicity depends on whether the event contains a fast lepton or not. The corresponding efficiencies are found to be $(87 \pm 2)\%$ and $(92 \pm 3)\%$, respectively.

4 Results

The five variables B_b, θ_p, θ_Λ, f_p, and f_Λ are determined with an overall least–square fit to the equations (1) to (12). The χ^2 per degree of freedom is found to be 11/7 which corresponds to a confidence level of 13%. This demonstrates that the assumption about independent production of baryons and antibaryons is consistent with experimental data.

The fit results are presented in table 3 along with the statistical and systematic errors. The systematic errors are estimated by a Monte Carlo method in which the parameters of equations (1) to (12) are varied within their errors. The branching ratio $B_b = BR(B \rightarrow baryons)$ is found to be

$$(6.8 \pm 0.5 \pm 0.3)\%.$$

The branching ratio B_b can also be determined using only l^+p, l^-p and $l^{\pm}p$ combinations. From formula (13) one obtains $B_b = (6.8 \pm 1.3 \pm 0.2)\%$, which is in a good agreement with the solution of the whole system of equations. The systematical error is smaller because this result is almost independent on efficiencies which cancel out in the ratio (13).

CLEO [4] recently measured the same branching ratio and obtained $BR(B \rightarrow baryons) = (6.4 \pm 0.8 \pm 0.8)\%$ by extrapolating the measured momentum spectra into the low momentum region.

---

[2] The equations (3) to (5) are corrected for $B\overline{B}$ mixing as well.

The production of Λ_c in inclusive B decays is measured to be $BR(B \to \Lambda_c X) \times BR(\Lambda_c \to pK^+\pi^-) = (0.28 \pm 0.05)\%$ [4,12]. Assuming that the decays $B \to \Xi_c X$ and $B \to \Omega_c X$ are suppressed, the decay of a B mesons into a charmed baryon proceeds via a Λ_c, *i.e.*, $B_b = BR(B \to \Lambda_c X)$. This allows to determine the branching ratio

$$BR(\Lambda_c \to pK^+\pi^-) = (4.0 \pm 0.3 \pm 0.8)\%.$$

In summary, we have measured the inclusive branching ratio $BR(B \to baryons) = (6.8 \pm 0.5 \pm 0.3)\%$ independent on assumptions about baryon spectra in B decays. The branching ratio $BR(\Lambda_c \to pK^+\pi^-)$ is found to be $(4.0 \pm 0.3 \pm 0.8)\%$.

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] M.Shifman, Proceedings of the 1987 International Symposium on Lepton and Photon Interactions at High Energies, Hamburg, 1987;
M.J.Savage and M.B.Wise, Nucl.Phys. **B326** (1989) 15;
M.Jarfi *et al*, Phys.Rev. **D43** (1991) 1599;
Y.Kohara, Phys.Rev. **D43** (1991) 2429;
S.M.Sheikholeslami and M.P.Khanna, Phys.Rev. **D44** (1991) 770.

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

[3] H.Albrecht *et al.*, ARGUS Collaboration, Z.Phys. **C42** (1989) 519.

[4] G.Crawford *et al.*, CLEO Collaboration, Phys.Rev. **D45** (1992) 752.

[5] A.Golutvin, Proceedings of the XXIV International Conference on High Energy Physics, Munich, 1988;
K.R.Schubert, Proceedings of the International Conference on Heavy Quark Physics, Ithaca, 1989.

[6] H.Albrecht *et al.*, ARGUS Collaboration, Phys.Lett. **B249** (1990) 359.

[7] H.Albrecht *et al.*, ARGUS Collaboration, Nucl. Instr. and Methods **A275** (1989) 1.

[8] E.Farhi, Phys.Rev.Lett. **39** (1977) 1587.

[9] H.Albrecht *et al.*, ARGUS Collaboration, Z.Phys. **C41** (1989) 557.

[10] M.Danilov, Proceedings of the International Conference on High Energy Physics, Geneva, 1991.

[11] H.Gennow, Int.Rep. DESY-F15-85-02 (1985).

[12] H.Albrecht *et al.*, ARGUS Collaboration, Phys.Lett. **B207** (1988) 109.

Table 1. Signal and background summary for baryon events [a] .

	$\Upsilon(4S)$	Cont	$\Upsilon(4S)$ direct [b]	p or Λ from material	Fake protons	Fake leptons	Signal
$\overline{p}$	18954	5103	6370 ± 220	—	74 ± 24	—	6296 ± 220
$\overline{\Lambda}$	2071 ± 49	535 ± 24	752 ± 77	—	—	—	752 ± 77
$p\overline{p}$	5508	1349	2181 ± 117	0.2 ± 9.0	2.3 ± 1.0	—	2179 ± 117
$\Lambda\overline{p}$	1129 ± 35	298 ± 18	394 ± 56	7.3 ± 5.5 [c]	0.5 ± 0.5	—	386 ± 56
$\Lambda\Lambda$	102 ± 10	43.5 ± 6.7	-5.3 ± 17	—	—	—	-5.3 ± 17
l^+p	546	76	359 ± 32	5 ± 10	11.7 ± 4.2	8.8 ± 2.1	333 ± 34
l^-p	659	68	491 ± 32	5 ± 10	17.0 ± 5.6	15.6 ± 3.7	453 ± 34
$l^{\pm}p\overline{p}$	173	20	124 ± 17	—	—	5.3 ± 2.7	119 ± 17
$l^+\Lambda$	88 ± 10	12 ± 3.6	58 ± 13	1.5 ± 1	—	1.5 ± 0.4	55 ± 13
$l^-\Lambda$	49 ± 7	7 ± 2.7	32 ± 9.7	1.5 ± 1	—	0.8 ± 0.2	30 ± 10
$l^+\Lambda\overline{p}$	28 ± 5.8	—	28 ± 5.8	—	—	0.8 ± 0.5	27 ± 6
$l^-\Lambda\overline{p}$	7	1	4.5 ± 3.5	—	—	—	4.5 ± 3.5

---

[a] Charge conjugate combinations are included except for the $\overline{p}$ and $\overline{\Lambda}$ samples.

[b] The errors do not include the error on the scale factor between $\Upsilon(4S)$ and continuum data which is taken into account in the fit of formulae (1) – (12).

[c] Combined contributions of p and Λ from the material.

Table 2. Proton and Λ reconstruction efficiencies and the probability to find protons from Λ decays.

Baryon source	p reconstruction efficiency	Λ reconstruction efficiency	Probability to find protons from Λ decays
Baryons from charmed baryon decays	0.770 ± 0.007	0.166 ± 0.033	0.23 ± 0.05
Baryons from hadronization	0.788 ± 0.007	0.191 ± 0.029	0.30 ± 0.06

Table 3. Fit results for the system of equations (1) – (12). The total branching ratio is given for the full momentum range. The baryon yields are shown for the measured momentum interval from 0.4 to 1.1 GeV/c .

Total branching ratio $B_b = BR(B \to baryons)$	$0.068 \pm 0.005 \pm 0.003$
Proton yield from charmed baryon decays, θ_p	$0.23 \pm 0.03 \pm 0.03$
Λ yield from charmed baryon decays, θ_Λ	$0.30 \pm 0.05 \pm 0.07$
Proton yield from hadronization, f_p	$0.42 \pm 0.04 \pm 0.01$
Λ yield from hadronization, f_Λ	$0.06 \pm 0.04 \pm 0.02$

Figure Captions

Figure 1: Baryon production in B meson decays.

Figure 2: Momentum spectrum of antiprotons from B meson decays, corrected for the momentum dependent reconstruction efficiency.

Figure 3: Invariant mass distribution of $\bar{p}\pi^+$ combinations for $\Upsilon(4S)$ data (histogram) and scaled continuum data (hatched histogram). The curve corresponds to the fit described in the text.

Figure 4: Momentum spectrum of Λ's from B meson decays, corrected for the momentum dependent reconstruction efficiency.

Figure 5: Momentum spectra of protons from B meson decays with the B flavor tagged by the charge of the fast lepton:
a) pl^+ combinations – protons from charmed baryon decays;
b) pl^- combinations – protons from hadronization processes.

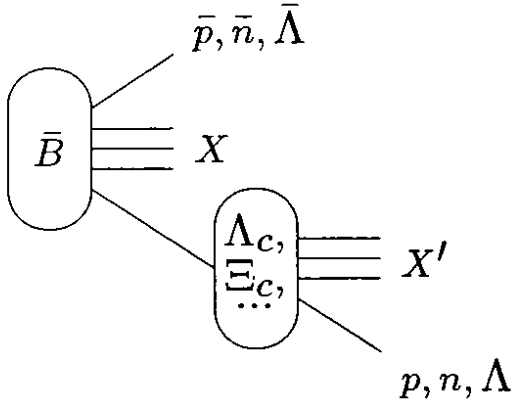

Figure 1.

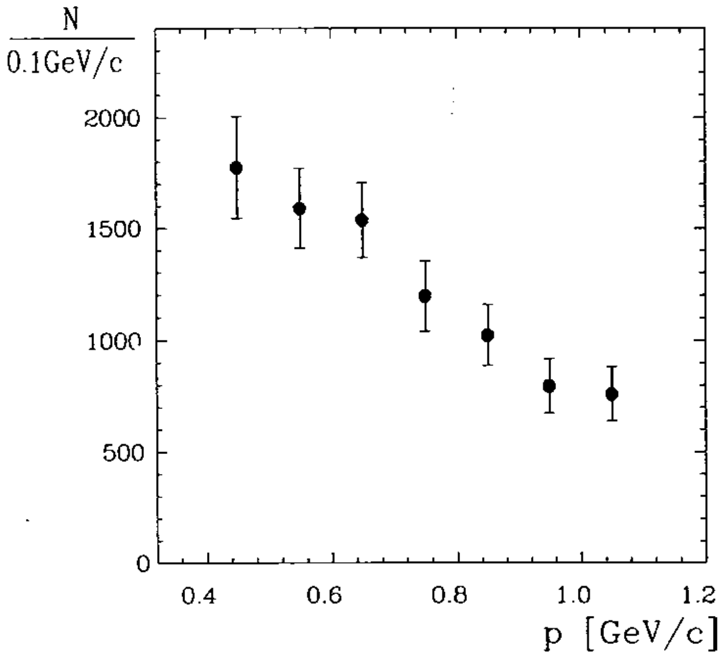

Figure 2.

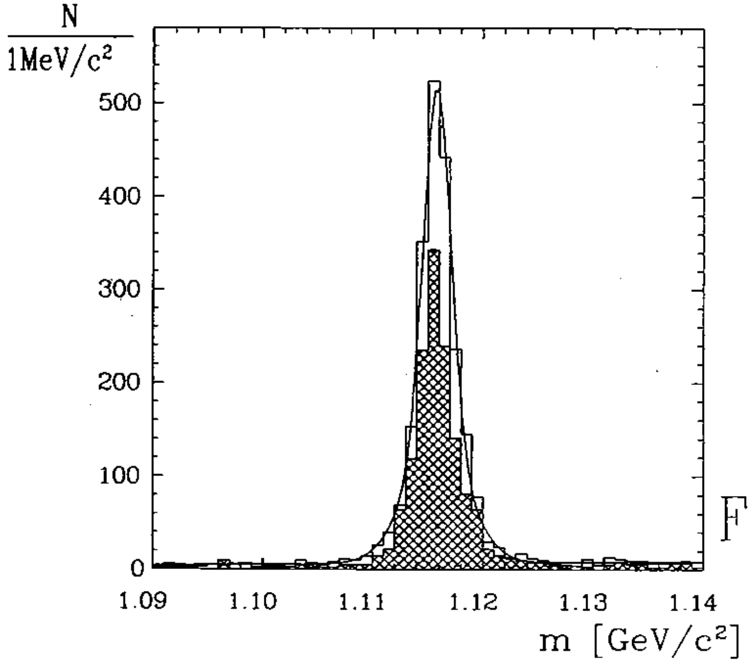

Figure 3.

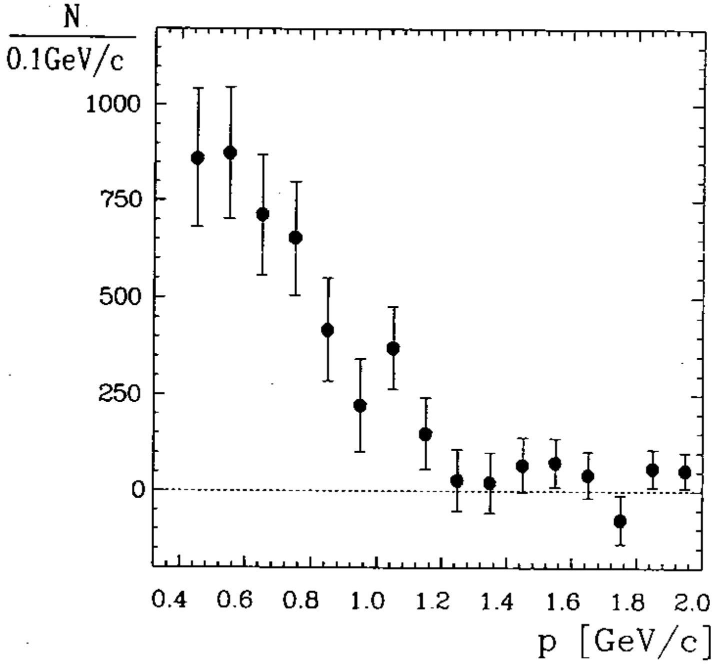

Figure 4.

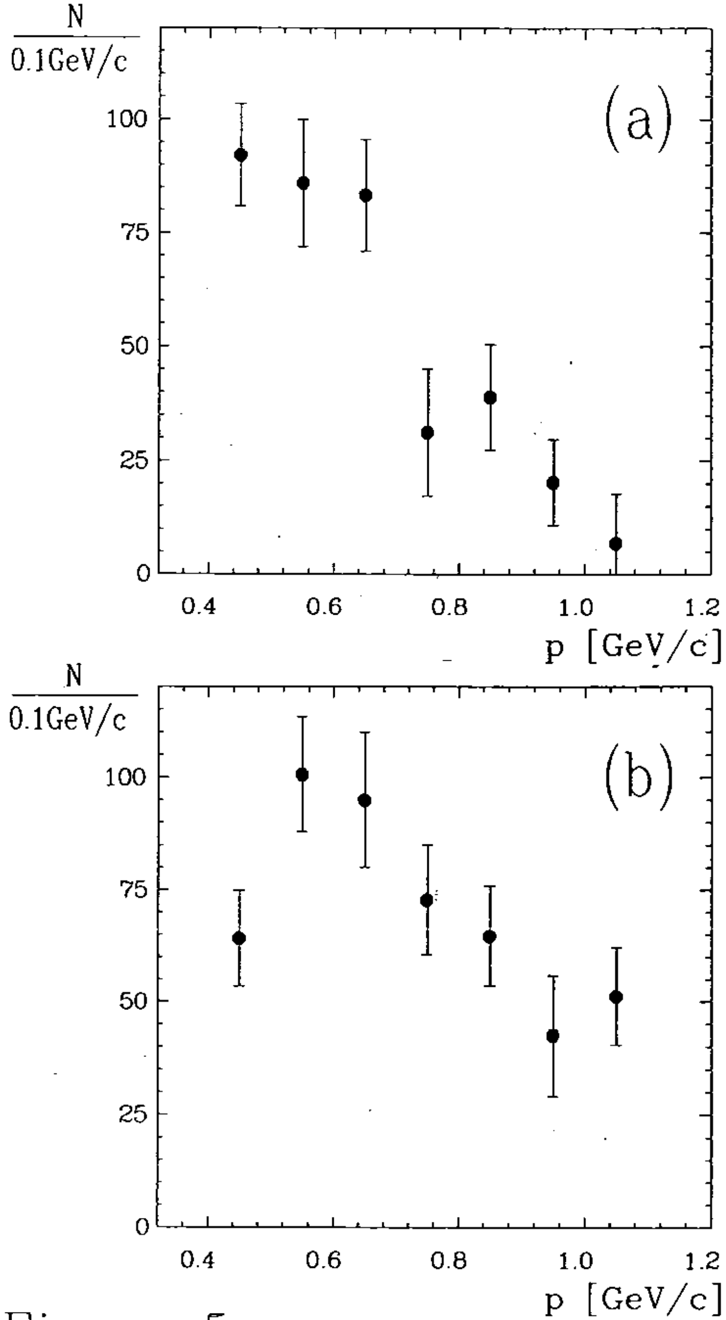

Figure 5.