ASYMMETRY IN THE ANGULAR DISTRIBUTION OF INCLUSIVE Λ BARYONS FROM e^+e^- ANNIHILATIONS AT $\sqrt{s} = 29$ GeV

S. ABACHI, P. BARINGER, B.G. BYLSMA, R. DEBONTE, D. KOLTICK, F.J. LOEFFLER, E.H. LOW, R.L. McILWAIN, D.H. MILLER, C.R. NG, L.K. RANGAN [1], E.I. SHIBATA
Purdue University, West Lafayette, IN 47907, USA

M. DERRICK, K.K. GAN [2], P. KOOIJMAN, J.S. LOOS [3], B. MUSGRAVE, L.E. PRICE, J. REPOND, K. SUGANO, J.M. WEISS [4], D.E. WOOD [1]
Argonne National Laboratory, Argonne, IL 60439, USA

D. BLOCKUS, B. BRABSON, J.-M. BROM, C. JUNG [2], H. NEAL [5], H. OGREN, D.R. RUST
Indiana University, Bloomington, IN 47405, USA

C. AKERLOF, J. CHAPMAN, D. ERREDE, P. KESTEN [6], D.I. MEYER, D. NITZ, A.A. SEIDL [1], R. THUN, M. WILLUTZKY
University of Michigan, Ann Arbor, MI 48109, USA

and

B. CORK
Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA

Received 25 August 1986

A forward–backward asymmetry A, consistent with that expected from the γ–Z^0 interference term in the process $e^+e^- \to q\bar{q}$, is observed in the laboratory production angular distribution of high-momentum Λ baryons. The data were collected with the High Resolution Spectrometer at PEP. The asymmetry for Λ baryons with fractional energy $z = 2E/\sqrt{s}$ greater than 0.3 is $A = (-23 \pm 8 \pm 2)\%$.

At the energies of the PEP and PETRA e^+e^- storage rings, virtual production of the Z^0 is an observably important process. Several experiments [1] have measured the forward–backward asymmetries produced by the γ–Z^0 interference term in the reactions $e^+e^- \to c\bar{c}$ and $e^+e^- \to b\bar{b}$. Similar asymmetries are expected from the lighter quarks u, d, and s, but such effects have not yet been seen in e^+e^- annihilations; however, the corresponding t-channel effect has been seen in the scattering of polarized electrons from hydrogen and deuterium [2]. These asymmetries will

[1] Present address: Lockheed Missiles and Space Co., Sunnyvale, CA 94086, USA.
[2] Present address: Stanford Linear Accelerator Center, Stanford, CA 94305, USA.
[3] Present address: Bell Laboratories, Naperville, IL 60566, USA.
[4] Present address: SRI International, Menlo Park, CA 94025, USA.
[5] Present address: State University of New York at Stony Brook, Stony Brook, LI, NY 11794, USA.
[6] Present address: Brandeis University, Waltham, MA 02254, USA.

0370-2693/86/$ 03.50 © Elsevier Science Publishers B.V. (North-Holland Physics Publishing Division)

produce observable effects in the lab angular distribution of the light quark baryons. With baryons there is no confusion as to whether a leading particle comes from the quark or antiquark, as there would be with mesons. Non-leading baryons, of course, would not necessarily exhibit the asymmetry of the initial quark, so baryons with a large fractional energy $z = 2E/\sqrt{s}$ must be selected. The Λ baryon is a good choice for such a study because it is readily identifiable via its long-lived decay to $p\pi^-$ over a wide range of z values. Furthermore, at PEP energies, the Λ can be easily distinguished from its antiparticle ($\bar{\Lambda}$) because the proton must carry more momentum than the pion in the lab frame whenever the parent Λ has $z > 0.08$. The Lund fragmentation model [3] ‡1 can be used to estimate the effects of leading versus non-leading particles and predicts a forward–backward asymmetry of $\approx -10\%$ for Λ baryons with $z \geqslant 0.3$.

The Λ events were selected from a large sample of data collected with the High Resolution Spectrometer (HRS) at the PEP e^+e^- storage ring. Events corresponding to an integrated luminosity of 300 pb^{-1} at $\sqrt{s} = 29$ GeV were used in the present analysis. The HRS detector [4] features a fifteen-layer central drift chamber with tracking layers spanning the radial distances from 21 to 103 cm and covering 90% of 4π in solid angle, plus a two-layer outer drift chamber system at a radius of 190 cm, which covers 65% of 4π. Both chamber systems are contained within the 16.2 kG solenoidal magnetic field. The momentum resolution for tracks that pass through the outer drift chamber layers is $\sigma_p = 2 \times 10^{-3} p^2$ (GeV/c). Electromagnetic shower counters are also positioned within the magnet volume in both the barrel and endcap regions. These systems cover 58% and 27% of 4π, respectively. The energy resolution for the barrel system is $\sigma_E/E = 16\%/\sqrt{E}$ (E in GeV).

The selection of the hadronic data sample has been described elsewhere [5]. The cuts included the requirements of at least five charged tracks and a scalar sum of the momenta greater than 5.8 GeV/c. Events containing less than 7.0 GeV of charged particle energy were required to have a total energy (including the energy in the electromagnetic shower counters) of at least 8.0 GeV.

The decays $\Lambda \to p\pi^-$ were identified by selecting pairs of oppositely charged tracks coming from well-separated secondary decay vertices [6]. A three-dimensional secondary vertex was required to lie at a radial distance of between 1.5 and 75.0 cm from the primary interaction point, and the reconstructed neutral momentum was required to point back to within 0.2 cm of the origin. In making the mass assignments, the higher momentum of the two tracks was always interpreted as the proton. If the invariant mass was consistent with the K^0 mass when both tracks were interpreted as pions, the particle was rejected. Events containing a Λ at very high z ($z_\Lambda \geqslant 0.6$) were removed if there was a track in the opposite hemisphere with a measured momentum of greater than 10 GeV/c. This cut removed background from radiative Bhabha events in which either the final state e^+ or e^- combined with a track from a converted photon to form a "lambda". It is important to remove such events completely because of their strong asymmetry in the lab production angle.

In order to measure the asymmetry, the data were divided into a forward region (F) and a backward region (B). The Λ baryons at $\cos\theta \leqslant (\geqslant)\ 0$ and the $\bar{\Lambda}$ antibaryons at $\cos\theta \geqslant (\leqslant)\ 0$ were binned in the F(B) region, where θ is measured relative to the incoming positron beam direction. A cut of $|\cos\theta| \leqslant 0.8$ was imposed to minimize the necessary acceptance correction to the signal. The resulting $p\pi^-$ mass peaks, for $z_\Lambda \geqslant 0.3$, are shown in fig. 1a for the forward region and fig. 1b for the backward region. The solid lines on the plots represent fits to the data with a Breit–Wigner form ‡2 and a polynomial background shape. The central value and width of the Breit–Wigner were fixed to $m = 1.1156$ GeV, the known Λ mass [7], and $\Gamma = 6.3$ MeV, a resolution width determined from Monte Carlo reconstructions. The areas under the peaks give $F = 127.6 \pm 16.5$ and $B = 195.5 \pm 15.6$ events, corresponding to an uncorrected asymmetry $A_{obs} = (-20.9 \pm 7.2)\%$, where the error is statistical. An estimated systematic error of $\pm 1.7\%$ is associated with the uncertainties in these fits.

A correction factor κ, where $A_{obs} = A\kappa$, is needed

‡1 Version 5.3 of the Lund Monte Carlo was used in this analysis.

‡2 The Breit–Wigner form is a good approximation to the detector resolution function for the broad momentum range of the data sample.

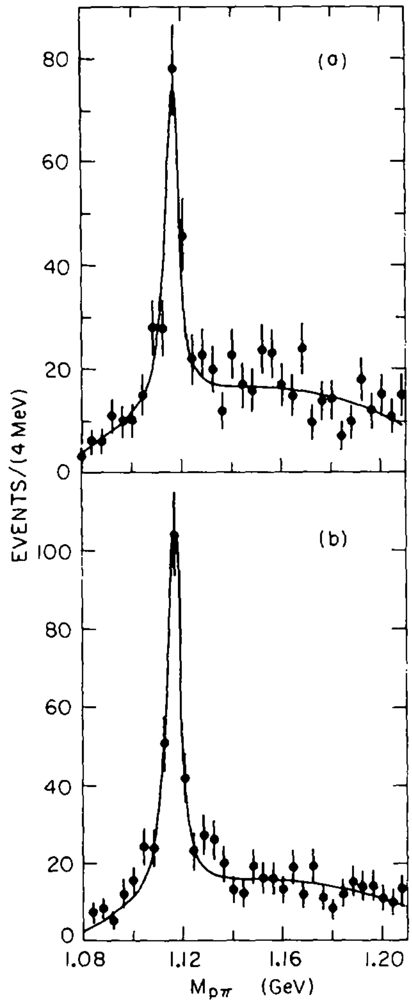

Fig. 1. Invariant mass spectra for neutral track pairs with a separated secondary vertex. The higher momentum track of the pair is interpreted as a p($\bar{p}$), the lower as π^- (π^+). Cuts $|\cos\theta| \leqslant 0.8$ and $z \geqslant 0.3$ are imposed. (a) shows $p\pi^-$ pairs at $\cos\theta \leqslant 0$ and $\bar{p}\pi^+$ pairs at $\cos\theta \geqslant 0$. (b) shows $p\pi^-$ pairs at $\cos\theta > 0$ and $\bar{p}\pi^+$ pairs at $\cos\theta \leqslant 0$.

because of the $|\cos\theta|$ cut and because the detector acceptance is not completely uniform within the measured angular range. The acceptance function in the $|\cos\theta| \leqslant 0.8$ region, as determined from the Monte Carlo simulation of the experiment, is well parametrized by $\epsilon(\theta) = N(1 + \epsilon_0 \cos^2\theta)$, where $\epsilon_0 = 0.6 \pm 0.3$. Together with the $|\cos\theta|$ cut, this yields $\kappa = 0.91 \pm 0.02$. The uncertainty in κ creates an additional systematic error of ±0.4% in the asymmetry. The

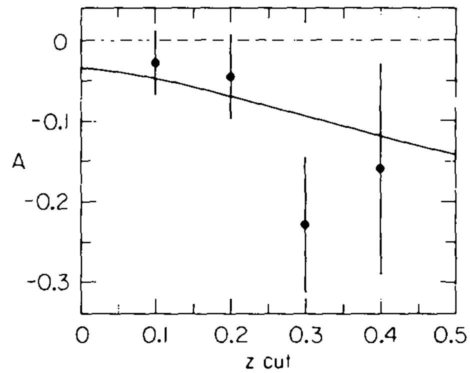

Fig. 2. Forward–backward asymmetry A plotted against the cut imposed on the fractional energy z of the Λ data. The solid curve shows the prediction of the Lund model as a function of this z cut.

asymmetry for $z \geqslant 0.3$ is thus $A = (-23 \pm 8 \pm 2)\%$.

A similar procedure was followed for different z cuts. For $z \geqslant 0.1$ the asymmetry is $A = (-2.8 \pm 3.6 \pm 2.0)\%$; for $z \geqslant 0.2$, $A = (-4.6 \pm 4.8 \pm 2.1)\%$; and for $z \geqslant 0.4$, $A = (-16 \pm 13 \pm 3)\%$. The asymmetries for the four z cut values are shown together in fig. 2. The solid curve in the figure shows the equivalent predictions of the Lund fragmentation model.

We see from fig. 2 that our data are in good agreement with the Lund model [‡3] which gives flavors of the initial quarks in events containing a Λ with $z \geqslant 0.3$ of 30% u, 30% s, 30% c, 8% d, and 2% b. In the standard model of the electroweak interactions [8], the asymmetry of the charge $+\frac{2}{3}$ quarks at $\sqrt{s} = 29$ GeV is –9.5%, and that of the charge $-\frac{1}{3}$ quarks exactly twice this amount. The measured values for c and b quarks are in good agreement with this prediction [1]. If the light quarks did not contribute to the Λ asymmetry, at $z \geqslant 0.3$, the value would be $A \approx -3\%$ from the decays of charm and bottom baryons. This is clearly less consistent with our measured value of $A = (-23 \pm 8 \pm 2)\%$, and we may therefore conclude that the electroweak effects in light quark production have been observed in e^+e^- annihilations.

We would like to express our gratitude to the technical staffs of PEP, and of the collaborating institu-

‡3 The parameters of the Lund model have been set to the values described in ref. [6].

tions, without whom this experiment would not have been possible. This work was supported in part by the US Department of Energy under Contracts W-31-109-Eng-38, DE-AC02-76ER01112, DE-AC03-76SF00098, DE-AC02-76ER01428, and DE-AC02-84ER40125.

References

[1] TASSO Collab., M. Althoff et al., Phys. Lett. B 126 (1983) 493; Z. Phys. C 22 (1984) 219;
CELLO Collab., H.J. Behrend et al., Z. Phys. C 19 (1983) 291;
JADE Collab., W. Bartel et al., Phys. Lett. B 146 (1984) 121, 437;
MARK J Collab., B. Adeva et al., Phys. Rep. 109 (1984) 131;
HRS Collab., M. Derrick et al., Phys. Lett. B 146 (1984) 261; Phys. Rev. Lett. 53 (1984) 1971;
TPC Collab., H. Arhara et al., Phys. Rev. D 31 (1985) 2719.

[2] C.Y. Prescott et al., Phys. Lett. B 77 (1978) 347; B 84 (1979) 524.

[3] B. Andersson, G. Gustafson and T. Sjostrand, Nucl. Phys. B 197 (1982) 45; Phys. Rep. 97 (1983) 32.

[4] HRS Collab., D. Bender et al., Phys. Rev. D 30 (1984) 515.

[5] HRS Collab., D. Bender et al., Phys. Rev. D 31 (1985) 1.

[6] HRS Collab., P. Baringer et al., Phys. Rev. Lett. 56 (1986) 1346.

[7] Particle Data Group, M. Aguilar-Benitez et al., Phys. Lett. B 170 (1986) 1.

[8] S.L. Glashow, A. Salam and S. Weinberg, Rev. Mod. Phys. 52 (1980) 515.