SLAC-PUB-7233
ICHEP-96 PA10-026
July/22/96

Measurement of A_b and A_c at the Z^0 Resonance Using a Lepton Tag. *

The SLD Collaboration**
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

Abstract

The parity violation parameters of $Zb\bar{b}$ and $Zc\bar{c}$ couplings have been measured using the polar angle dependency of the Z^0-pole polarized cross section and tagging the bottom and charmed hadrons in the semileptonic decay channel. Both the muon and electron identification algorithms take advantage of multivariate techniques, incorporating information from the SLD Cerenkov Ring Imaging Detector. Based on the 1993-95 SLD samples of 50,000 Z^0 decays with a mean electron beam polarization of $\langle P_e \rangle = 63\%$, and 100,000 Z^0 decays with a mean electron beam polarization of $\langle P_e \rangle = 77\%$, this yields the following measurements of A_b and A_c:

$$A_b = 0.882 \pm 0.068\ (\text{stat}) \pm 0.047\ (\text{syst}),$$
$$A_c = 0.612 \pm 0.102\ (\text{stat}) \pm 0.076\ (\text{syst}).$$

Paper Contributed to the XXVIII International Conference on High Energy Physics, July/96, Warsaw, Poland

*This work was supported by Department of Energy contracts: DE-FG02-91ER40676 (BU), DE-FG03-92ER40701 (CIT), DE-FG03-91ER40618 (UCSB), DE-FG03-92ER40689 (UCSC), DE-FG03-93ER40788 (CSU), DE-FG02-91ER40672 (Colorado), DE-FG02-91ER40677 (Illinois), DE-AC03-76SF00098 (LBL), DE-FG02-92ER40715 (Massachusetts), DE-AC02-76ER03069 (MIT), DE-FG06-85ER40224 (Oregon), DE-AC03-76SF00515 (SLAC), DE-FG05-91ER40627 (Tennessee), DE-AC02-76ER00881 (Wisconsin), DE-FG02-92ER40704 (Yale); National Science Foundation grants: PHY-91-13428 (UCSC), PHY-89-21320 (Columbia), PHY-92-04239 (Cincinnati), PHY-88-17930 (Rutgers), PHY-88-19316 (Vanderbilt), PHY-92-03212 (Washington); the UK Science and Engineering Research Council (Brunel and RAL); the Istituto Nazionale di Fisica Nucleare of Italy (Bologna, Ferrara, Frascati, Pisa, Padova, Perugia); and the Japan-US Cooperative Research Project on High Energy Physics (Nagoya, Tohoku).

1 Introduction

Measurements of fermion asymmetries at the Z^0 resonance probe a combination of the vector and axial vector couplings of the Z^0 to fermions, $A_f = 2v_f a_f/(v_f^2 + a_f^2)$. The parameters A_f express the extent of parity violation at the Zff vertex and provide sensitive tests of the Standard Model.

The Born-level differential cross section for the reaction $e^+e^- \to Z^0 \to f\bar{f}$ is

$$d\sigma_f \,/\, dz \propto (1 - A_e P_e)(1 + z^2) + 2A_f(A_e - P_e)z\,, \tag{1}$$

where P_e is the longitudinal polarization of the electron beam ($P_e > 0$ for right-handed (R) polarization) and $z = \cos\theta$ is the direction of the outgoing fermion relative to the incident electron. The parameter A_f can be isolated by forming the left-right forward-backward asymmetry

$$\tilde{A}^f_{FB}(z) = \frac{[\sigma^f_L(z) - \sigma^f_L(-z)] - [\sigma^f_R(z) - \sigma^f_R(-z)]}{[\sigma^f_L(z) + \sigma^f_L(-z)] + [\sigma^f_R(z) + \sigma^f_R(-z)]} = \frac{|P_e| A_f\, 2z}{(1 + z^2)}\,, \tag{2}$$

although in this analysis we work directly with the basic cross section used in a scheme of a maximum likelihood fit. The following analysis, which is updated and improved upon the 1995 study [1], has been applied to the 1994-95 data sample. The lepton total and transverse momentum (with respect to the nearest jet) are used to classify each event by deriving probabilities for the decays ($Z^0 \to b\bar{b}, b \to lepton$), ($Z^0 \to b\bar{b}, \bar{b} \to \bar{c} \to lepton$), ($Z^0 \to b\bar{b}, b \to \bar{c} \to lepton$), ($Z^0 \to c\bar{c}, \bar{c} \to lepton$), and ($Z^0 \to background$ and $misidentified\ lepton$).

The lepton charge provides quark-antiquark discrimination, while the jet nearest in direction to the lepton approximates the quark direction. The parameters A_b and A_c are then extracted by a maximum likelihood fit of these data to the theoretical cross section including first order QCD with quark mass corrections effects taken into account.

2 Data Selection and Lepton Identification

The operation of the SLAC Linear Collider with a polarized electron beam has been described in detail elsewhere [2]. During the 1994-95 run, the SLC Large Detector (SLD) recorded an integrated luminosity of 5.4 pb^{-1} with a luminosity-weighted electron beam polarization of $|P_e| = 0.7734 \pm 0.0062$.

Charged particle tracking and momentum analysis is provided by the Central Drift Chamber [3] and the CCD-based vertex detector [4], with combined momentum resolution $\delta p_\perp / p_\perp = \sqrt{(.01)^2 + (.0026\ p_\perp/GeV)^2}$ in the plane perpendicular to the beam axis.

The Liquid Argon Calorimeter (LAC) [5] measures the energies of charged and neutral particles and is also used for electron identification. The LAC is segmented into projective towers with separate electromagnetic and hadronic sections. In the barrel LAC, which covers the angular range $|\cos\theta| < 0.82$, the electromagnetic towers have transverse size $\sim (36\ mrad)^2$ and are divided longitudinally into a front section of 6 radiation lengths and a back section of 15 radiation lengths. The barrel LAC electromagnetic energy resolution is $\sigma_E/E = 15\%/\sqrt{E(GeV)}$.

Muon tracking is provided by the Warm Iron Calorimeter (WIC) [6]. The WIC is 4 interaction lengths thick and surrounds the $2.8 + 0.7$ interaction lengths of the LAC and SLD magnet coil. Sixteen layers of plastic streamer tubes interleaved with 2 inch thick plates of iron absorber provide muon hit resolutions of 0.4 cm and 2.0 cm in the azimuthal and axial directions respectively.

The Cerenkov Ring Imaging Detector (CRID) [7] information (limited to the barrel region) has been included with different methods in both the electron and the muon identification (for the 94-95 data). It consists of liquid and gas Cerenkov radiators illuminating a large area UV photon detectors. Only the gas information has been included in this analysis, since the liquid covers only marginally the interesting momentum region. Electrons are distinguishable from pions in the region between 2 and 5 GeV and the muon identification (because of pion rejection) also improves considerably in this region. Kaons and protons rejection also helps the muon identification up to momenta of 15 GeV.

Events are selected by requiring at least 15 GeV of energy in the LAC and at least six tracks with $p_\perp > 250\ MeV$. These requirements select a sample of hadronic Z^0 events with negligible background. Leptons are identified in a sample of 93,000 hadronic Z^0 decays. Jets in Z^0 events are formed by combining calorimeter energy clusters according to the JADE algorithm [9] with parameter $y_{cut} = 0.005$. The jet axis closely approximates the b-quark direction in $Z^0 \to b\bar{b}$ events, with an angular resolution of $\sim 30\ mrad$.

Electrons are identified by using both LAC and CRID responses for tracks in the angular range $|\cos\theta| < 0.72$, which are extrapolated to the barrel LAC. The LAC information is extracted comparing the energies in nearby calorimeter towers to the energy deposition expected for electromagnetic showers; the CRID information is stored in likelihood function, one for each particle type hypothesis [8]. A Neural Network trained on Monte Carlo tracks [10], has been implemented to make optimal use of the amount of discriminant information available for the electrons. The performance of the electron identificaton has been tested on independent data samples of pure pions, from reconstructed K_s^0 decays, and pure electrons detected as photon conversions in the detector material. Pion misidentification, which is reduced to less than 0.8% at low momentum and falls slowly with increasing momentum, constitutes the largest part of background in the electron sample. The electron identification efficiency in hadronic events depends on track isolation and momentum, varying from roughly 50% for all electrons to 70% for the electrons with high momentum and transverse momentum used in the simple asymmetry analysis presented below. Electrons from photon conversions are identified and removed from the analysis sample with 90% efficiency.

The first step in the muon identification consists of matching extrapolated tracks from the Drift Chamber to hits in the WIC [11]. Muon identification is attempted for tracks with $p > 2$ GeV in the angular range $|\cos\theta| < 0.70$, although the muon identificaton efficiency falls off rapidly for $|\cos\theta| > 0.60$ (in the region between the barrel and the endcaps). The track error matrix, including the effects of multiple scattering, is used to compare CDC tracks with the fitted muon patterns in the WIC. For $|\cos\theta| < 0.60$, according to the MC, 87% of the muon tracks have successful matching between the CDC and the WIC. The second step of the muon identification exploits the information from the CRID and additional information from the WIC, such as the requirement that the candidate muons fully penetrate the WIC). The CRID $k - \mu$ separation variable alone rejects 51% of the remaining k and p (with only 2% loss in the signal), while, for $p < 6$ GeV, the $\pi - \mu$ separation variable rejects 57% of π (with 5% loss in the signal). Since the CRID information is momentum dependent, different sets of cuts on the distributions of the discriminant variables have been optimized in different momentum regions to achieve best purity and efficiency. MC studies show that pion punchthrough background is negligible. Muons from pion and kaon decays and hadronic showers are a significant background, but fall off rapidly with increasing momentum. From a study on a pure pions data sample, obtained from kinematically selected $K_s^0 \rightarrow \pi^+\pi^-$ decays, $\sim .3\%$ of pions (punchthrough), with $p > 2$ GeV, are identified as muons. The muon identification efficiency is 80% with a purity of 67% (8% misidentified tracks and 25% muons from light hadron decays) for $p > 2$ GeV and $|\cos\theta| < 0.60$.

3 Monte Carlo Simulation

A detailed Monte Carlo (MC) simulation of hadronic Z^0 decays is used to model the data. Z^0 decays are generated by the JETSET 7.4 program [12]. The B hadron decay model was tuned to reproduce existing data from other experiments. Semileptonic decays of B mesons are generated according to the ISGW formalism [13] with a 23% D^{**} fraction, while semileptonic decays of D mesons are generated with JETSET with the 1994 Particle Data Group branching ratios [14]. Particularly important experimental constraints are provided by the $B \rightarrow lepton$ and $B \rightarrow D$ momentum spectra measured by CLEO [15] [16], the $D \rightarrow lepton$ momentum spectrum measured by DELCO [17], and the $B \rightarrow hadron$ multiplicities measured by ARGUS [18].

The SLD detector response is simulated in detail using GEANT [19] and has been checked extensively against Z^0 data. Distributions of lepton momentum (p)

and transverse momentum (p_t) with respect to the nearest jet axis are shown in Fig. 1. The MC prediction for all lepton sources reproduces the data reasonably well. Leptons from b-quark decay clearly dominate at high p and p_t.

4 Maximum Likelihood Fit

A maximum likelihood analysis of all hadronic Z^0 events containing leptons is used to determine A_b and A_c. The likelihood function contains the following probability term for each lepton in the data:

$$P\left(p, p_t,\, P_e, z;\, A_b, A_c\right) \,\propto\, 1 \,+\, \left(\frac{A_e - P_e}{1 - A_e P_e}\right)\left(\frac{2z}{1+z^2}\right)$$
$$\times \Big\{\, f_b\,(1-2\bar{\chi})\,[1+\Delta^b_{QCD}(z)]\,A_b \,+\, f_c\,[1+\Delta^c_{QCD}(z)]\,A_c \,+\, f_{bkg}\,A_{bkg} \Big\}\,. \quad (3)$$

The quark direction is constructed from the lepton charge and the jet direction, $z = -Q\cos\theta$. The three signs governing the left-right forward-backward asymmetry — beam polarization P_e, lepton charge Q, and jet direction $\cos\theta$ — are incorporated automatically into the maximum likelihood probability function.

The lepton source fractions (f_b, f_c, f_{bkg}) are derived by counting leptons in the MC with similar p and p_t to each lepton in the data. The f_b term combines direct and cascade b-quark decays, signed according to their asymmetry contributions. A correction factor $(1-2\bar{\chi})$ is applied to all b-quark lepton sources to account for asymmetry dilution due to $B^0\bar{B}^0$ mixing, with $\bar{\chi} = .122$ taken from LEP measurements of the average mixing in $Z^0 \to b\bar{b}$ events. The background asymmetry A_{bkg} is derived as a function of p and p_t from tracks in the data not identified as leptons. A $cos\theta$ dependent QCD correction factor is applied to the theoretical asymmetry function to incorporate known QCD corrections to the cross section [20]. The effect of gluon radiation reduces the asymmetry by as much as 5% at $z=0$. Correction for this effect increases the asymmetry by 3% overall.

5 Results and Systematic Errors

Systematic errors have been estimated for a number of sources, summarized in table 1. Uncertainty in the jet axis simulation can affect the asymmetry measurement by distorting the lepton p_t spectrum. The resulting systematic error has been studied by examining the back-to-back angle of two jet events compared between data and MC. The electron sample is more sensitive to such systematics since both jet finding and electron identification algorithms rely on the same calorimeter response. The accuracy of the $B^\pm$ and B^0 lepton spectra are directly related to the uncertainty in the D^{**} branching fraction reported by the CLEO collaboration [15]. Most of the systematic errors have been evaluated following the recommendations from the LEP Electroweak Working Group [22]. The branching ratios used and their uncertainties are much closer to the world averages with respect to the previous analysis, especially the $BR(\bar{b} \to \bar{c} \to l)$. The background levels have been studied with the MC, but also with a data sample of pure pions from K_s^0 decays. The results obtained for the 94-95 data are as follows:

muons:

$A_b = 0.874 \pm 0.107(stat) \pm 0.044(syst)$

$A_c = 0.633 \pm 0.151(stat) \pm 0.072(syst)$

electrons:

$A_b = 0.880 \pm 0.107(stat) \pm 0.051(syst)$

$A_c = 0.620 \pm 0.162(stat) \pm 0.089(syst)$

combined:

$A_b = 0.877 \pm 0.076(stat) \pm 0.041(syst)$

$A_c = 0.627 \pm 0.111(stat) \pm 0.071(syst)$.

The combined final result takes into account the large systematic correlations between the muon and electron analyses. Including the published results [23] from the 93 data we obtain:

$A_b = 0.882 \pm 0.068(stat) \pm 0.047(syst)$

$A_c = 0.612 \pm 0.102(stat) \pm 0.076(syst)$.

6 Cross check

A direct method of measuring A_b is to form the left-right forward-backward asymmetry $\tilde{A}^f_{FB}$ in the angular distribution of a purified sample of $Z^0 \to b\bar{b}$ events containing leptons from semileptonic b decay with high p and high p_t. We perform this simple analysis in order to demonstrate the clear experimental asymmetry and as a crosscheck of the final result.

An elliptical cut on the leptons p and p_t, $\sqrt{(p/15.0)^2 + (p_t/1.0)^2} > 1.0$ for muons and $\sqrt{(p/6.0)^2 + (p_t/0.4)^2} > 2.5$ for electrons, provides a sample of leptons from b prompt and cascade decays with a purity of $\sim 65\%$ for electrons and $\sim 75\%$ for muons. A total of 1627 candidate muons and of 1437 candidate electrons are selected, and the experimental asymmetries are plotted in Fig. 2. The MC breakdown of the various sources contributing to the lepton sample is shown in table 2, together with their corresponding intrinsic asymmetry contributions. For A_c, the Standard Model value of 0.67 has been used for this analysis. The results from the high $(P,\ P_t)$ analysis for A_b are: $0.84 \pm 0.11(stat)$ for the muon sample and $0.88 \pm 0.12(stat)$ for the electron sample. These values are in agreement with the more precise maximum likelihood fit results quoted previously.

7 Conclusions

We have performed an improved measurement of A_b and A_c using lepton tags from our 1994-95 data sample. The value obtained for A_b from leptons can be combined with the results from the other measurements performed at SLC/SLD [1]. With a *Jet Charge* method: $A_b = 0.84 \pm 0.05(stat) \pm 0.05(syst)$. With a K^{+-} *tag*: $A_b = 0.91 \pm 0.09(stat) \pm 0.09(syst)$; for an SLD average:

$$A_b = 0.863 \pm 0.049.$$

Also the value obtained for A_c from leptons can be combined with an SLD measurement [1] obtained using reconstructed D^*, D^+, which gives $A_c = 0.64 \pm 0.11(stat) \pm 0.06(syst)$, for an SLD average:

$$A_c = 0.625 \pm 0.084.$$

These results can be compared with the Standard Model predictions of .935 for A_b and .667 for A_c.

References

[1] SLD Collaboration, K. Abe *et al.*, SLAC-PUB-95-7019 (1995)

[2] SLD Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **73**, 25 (1994).

[3] M. Fero *et al.*, Nucl. Inst. Meth. **A367**, 111 (1995)

[4] G. Agnew *et al.*, SLAC-PUB-5906 (1992).

[5] D. Axen *et al.*, Nucl. Inst. Meth. **A328**, 472 (1993).

[6] A. Benvenuti *et al.*, Nucl. Inst. Meth. **A276**, 94 (1989); **A290**, 353 (1990).

[7] SLD Design Report SLAC-273 UC-34D, May 1984, and revisions; D. Aston *et al.*, SLAC-PUB-4795, Nucl. Inst. Meth. A283, 582 (1989); K. Abe *et al.*, SLAC-PUB-5214, (1990).

[8] SLD Collaboration, K. Abe *et al.*, Nucl. Instr. and Meth. A371, 195 (1996).

[9] W. Bartel *et el.*, Z. Phys. **C33**, 23 (1986).

[10] D. Falciai, SLD Physics Note 44, Dec. 1995.

[11] D. Williams, Ph.D. Thesis, SLAC-0445 (1994).

[12] T. Sjostrand, Comp. Phys. Comm. **82**, 74 (1993).

[13] N. Isgur, D. Scora, B. Grinstein, M. Wise, Phys. Rev. **D39**, 799 (1989); code provided by P. Kim and CLEO Collaboration.

[14] Review of Particle Properties, Physical Review **D50**, 1173 (1994)

[15] R. Wang, Ph.D. Thesis, Minnesota Univ., UMI-95-17404 (1994); B. Barich *et al.*, PRL **C76**, 1570 (1996)

[16] M. Thulasidas, PhD thesis, Syracuse University (1993)

[17] W. Bacino *et al.*, Phys. Rev. Lett. **43**, 1073 (1979).

[18] H. Albrecht *et al.*, Z Phys. **C58**, 191 (1993).

[19] GEANT 3.21 program, CERN Applications Software Group, CERN Program Library.

[20] A. Djouadi, J. Kühn, and P. Zerwas, Z. Phys **C46**, 411 (1990); G. Altarelli and B. Lampe, Nucl. Phys. **391**, 3 (1993); J.B. Stav and H.A. Olsen, private communication.

[21] ALEPH Collab., Z Phys. **C62**, 179 (1994); DELPHI Collab., Phys. Lett. **B276**, 536 (1992); OPAL Collab., Z. Phys. **C60**, 19 (1993); L3 Collab., Phys. Lett. **B292**, 434 (1992).

[22] Presentation of LEP Electroweak Heavy Flavour Results for Summer 1996 Conferences, LEPHF/96-01/

[23] SLD Collaboration (K. Abe *et al.*). Phys. Rev. Lett. 74, 2895-2899 (1995).

**List of Authors

K. Abe,(19) K. Abe,(29) I. Abt,(13) T. Akagi,(27) N.J. Allen,(4) W.W. Ash,(27)†
D. Aston,(27) K.G. Baird,(24) C. Baltay,(33) H.R. Band,(32) M.B. Barakat,(33)
G. Baranko,(9) O. Bardon,(15) T. Barklow,(27) A.O. Bazarko,(10) R. Ben-David,(33)
A.C. Benvenuti,(2) G.M. Bilei,(22) D. Bisello,(21) G. Blaylock,(6) J.R. Bogart,(27)
B. Bolen,(17) T. Bolton,(10) G.R. Bower,(27) J.E. Brau,(20) M. Breidenbach,(27)
W.M. Bugg,(28) D. Burke,(27) T.H. Burnett,(31) P.N. Burrows,(15) W. Busza,(15)
A. Calcaterra,(12) D.O. Caldwell,(5) D. Calloway,(27) B. Camanzi,(11)
M. Carpinelli,(23) R. Cassell,(27) R. Castaldi,(23)(a) A. Castro,(21)
M. Cavalli-Sforza,(6) A. Chou,(27) E. Church,(31) H.O. Cohn,(28) J.A. Coller,(3)
V. Cook,(31) R. Cotton,(4) R.F. Cowan,(15) D.G. Coyne,(6) G. Crawford,(27)
A. D'Oliveira,(7) C.J.S. Damerell,(25) M. Daoudi,(27) R. De Sangro,(12)
R. Dell'Orso,(23) P.J. Dervan,(4) M. Dima,(8) D.N. Dong,(15) P.Y.C. Du,(28)
R. Dubois,(27) B.I. Eisenstein,(13) R. Elia,(27) E. Etzion,(4) D. Falciai,(22) C. Fan,(9)
M.J. Fero,(15) R. Frey,(20) K. Furuno,(20) T. Gillman,(25) G. Gladding,(13)
S. Gonzalez,(15) G.D. Hallewell,(27) E.L. Hart,(28) J.L. Harton,(8) A. Hasan,(4)
Y. Hasegawa,(29) K. Hasuko,(29) S. J. Hedges,(3) S.S. Hertzbach,(16)
M.D. Hildreth,(27) J. Huber,(20) M.E. Huffer,(27) E.W. Hughes,(27) H. Hwang,(20)
Y. Iwasaki,(29) D.J. Jackson,(25) P. Jacques,(24) J. A. Jaros,(27) A.S. Johnson,(3)
J.R. Johnson,(32) R.A. Johnson,(7) T. Junk,(27) R. Kajikawa,(19) M. Kalelkar,(24)
H. J. Kang,(26) I. Karliner,(13) H. Kawahara,(27) H.W. Kendall,(15) Y. D. Kim,(26)

M.E. King,[27] R. King,[27] R.R. Kofler,[16] N.M. Krishna,[9] R.S. Kroeger,[17]
J.F. Labs,[27] M. Langston,[20] A. Lath,[15] J.A. Lauber,[9] D.W.G.S. Leith,[27]
V. Lia,[15] M.X. Liu,[33] X. Liu,[6] M. Loreti,[21] A. Lu,[5] H.L. Lynch,[27] J. Ma,[31]
G. Mancinelli,[22] S. Manly,[33] G. Mantovani,[22] T.W. Markiewicz,[27]
T. Maruyama,[27] H. Masuda,[27] E. Mazzucato,[11] A.K. McKemey,[4]
B.T. Meadows,[7] R. Messner,[27] P.M. Mockett,[31] K.C. Moffeit,[27]
T.B. Moore,[33] D. Muller,[27] T. Nagamine,[27] S. Narita,[29] U. Nauenberg,[9]
H. Neal,[27] M. Nussbaum,[7] Y. Ohnishi,[19] L.S. Osborne,[15] R.S. Panvini,[30]
H. Park,[20] T.J. Pavel,[27] I. Peruzzi,[12][b] M. Piccolo,[12] L. Piemontese,[11]
E. Pieroni,[23] K.T. Pitts,[20] R.J. Plano,[24] R. Prepost,[32] C.Y. Prescott,[27]
G.D. Punkar,[27] J. Quigley,[15] B.N. Ratcliff,[27] T.W. Reeves,[30] J. Reidy,[17]
P.E. Rensing,[27] L.S. Rochester,[27] P.C. Rowson,[10] J.J. Russell,[27]
O.H. Saxton,[27] T. Schalk,[6] R.H. Schindler,[27] B.A. Schumm,[6] S. Sen,[33]
V.V. Serbo,[32] M.H. Shaevitz,[10] J.T. Shank,[3] G. Shapiro,[14] D.J. Sherden,[27]
K.D. Shmakov,[28] C. Simopoulos,[27] N.B. Sinev,[20] S.R. Smith,[27] M.B. Smy,[8]
J.A. Snyder,[33] P. Stamer,[24] H. Steiner,[14] R. Steiner,[1] M.G. Strauss,[16]
D. Su,[27] F. Suekane,[29] A. Sugiyama,[19] S. Suzuki,[19] M. Swartz,[27]
A. Szumilo,[31] T. Takahashi,[27] F.E. Taylor,[15] E. Torrence,[15] A.I. Trandafir,[16]
J.D. Turk,[33] T. Usher,[27] J. Va'vra,[27] C. Vannini,[23] E. Vella,[27]
J.P. Venuti,[30] R. Verdier,[15] P.G. Verdini,[23] S.R. Wagner,[27] A.P. Waite,[27]
S.J. Watts,[4] A.W. Weidemann,[28] E.R. Weiss,[31] J.S. Whitaker,[3]
S.L. White,[28] F.J. Wickens,[25] D.A. Williams,[6] D.C. Williams,[15]
S.H. Williams,[27] S. Willocq,[33] R.J. Wilson,[8] W.J. Wisniewski,[27]
M. Woods,[27] G.B. Word,[24] J. Wyss,[21] R.K. Yamamoto,[15] J.M. Yamartino,[15]
X. Yang,[20] S.J. Yellin,[5] C.C. Young,[27] H. Yuta,[29] G. Zapalac,[32]
R.W. Zdarko,[27] C. Zeitlin,[20] and J. Zhou,[20]

[1] *Adelphi University, Garden City, New York 11530*
[2] *INFN Sezione di Bologna, I-40126 Bologna, Italy*
[3] *Boston University, Boston, Massachusetts 02215*
[4] *Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[5] *University of California at Santa Barbara, Santa Barbara, California 93106*
[6] *University of California at Santa Cruz, Santa Cruz, California 95064*
[7] *University of Cincinnati, Cincinnati, Ohio 45221*
[8] *Colorado State University, Fort Collins, Colorado 80523*
[9] *University of Colorado, Boulder, Colorado 80309*
[10] *Columbia University, New York, New York 10027*
[11] *INFN Sezione di Ferrara and Università di Ferrara, I-44100 Ferrara, Italy*
[12] *INFN Lab. Nazionali di Frascati, I-00044 Frascati, Italy*
[13] *University of Illinois, Urbana, Illinois 61801*
[14] *Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720*
[15] *Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*

[16] *University of Massachusetts, Amherst, Massachusetts 01003*
[17] *University of Mississippi, University, Mississippi 38677*
[19] *Nagoya University, Chikusa-ku, Nagoya 464 Japan*
[20] *University of Oregon, Eugene, Oregon 97403*
[21] *INFN Sezione di Padova and Università di Padova, I-35100 Padova, Italy*
[22] *INFN Sezione di Perugia and Università di Perugia, I-06100 Perugia, Italy*
[23] *INFN Sezione di Pisa and Università di Pisa, I-56100 Pisa, Italy*
[24] *Rutgers University, Piscataway, New Jersey 08855*
[25] *Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX United Kingdom*
[26] *Sogang University, Seoul, Korea*
[27] *Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309*
[28] *University of Tennessee, Knoxville, Tennessee 37996*
[29] *Tohoku University, Sendai 980 Japan*
[30] *Vanderbilt University, Nashville, Tennessee 37235*
[31] *University of Washington, Seattle, Washington 98195*
[32] *University of Wisconsin, Madison, Wisconsin 53706*
[33] *Yale University, New Haven, Connecticut 06511*
† *Deceased*
[a] *Also at the Università di Genova*
[b] *Also at the Università di Perugia*

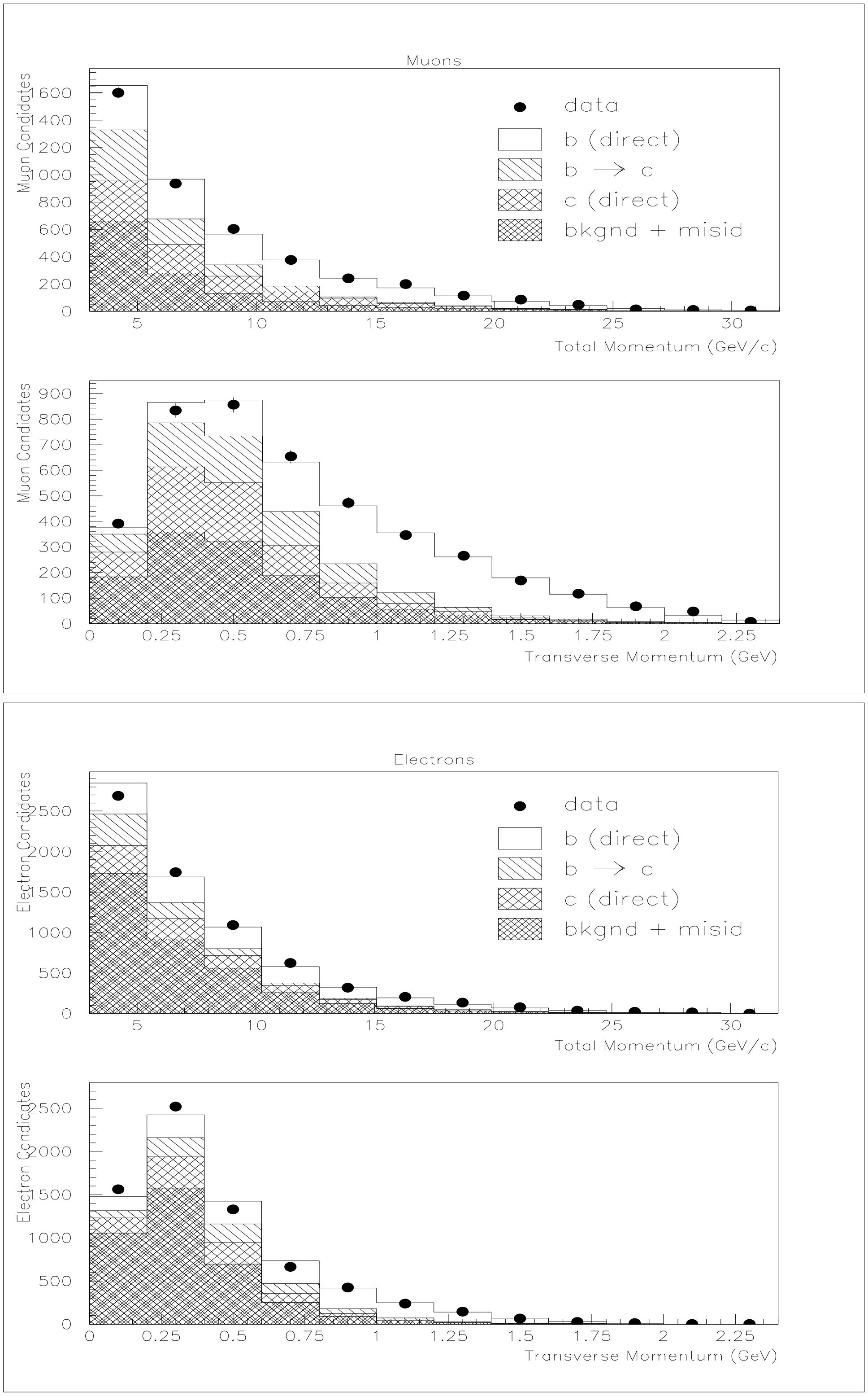

Figure 1: Distributions of momentum and transverse momentum with respect to the nearest jet for identified muons and electrons in the data (points), compared to the MC prediction (histograms) for various sources.

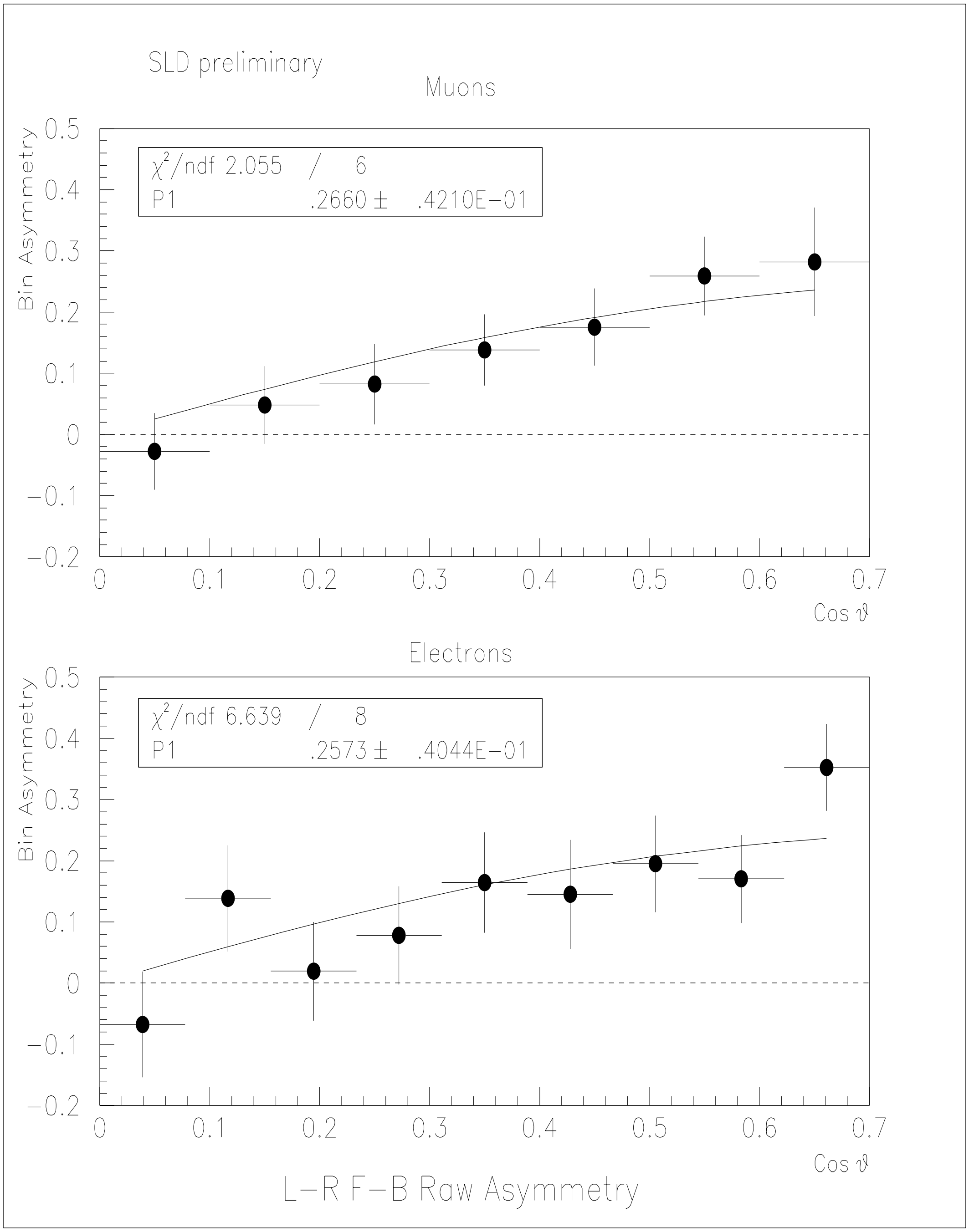

Figure 2: Experimentally observed left-right forward-backward asymmetry (data points with statistical errors) compared with the theoretical asymmetry function $|P_e|A_b 2z/(1+z^2)$ (solid line) fit to data.

Source	Parameter variation	$\delta A_b(\mu)$	$\delta A_b(e)$	$\delta A_c(\mu)$	$\delta A_c(e)$
Monte Carlo weights	f_b, f_c variation	$\pm.022$	$\pm.026$	$\pm.012$	$\pm.035$
Track efficiency	MC-data multiplicity match	$\pm.014$	$\pm.001$	$\pm.002$	$<.001$
Jet axis simulation	10 mrad smearing	$\pm.015$	$\pm.034$	$\pm.003$	$\pm.033$
Background level	$\pm10\%(\mu)$, $\pm5\%(e)$	$\pm.014$	$\pm.009$	$\pm.027$	$.\pm013$
Background asymmetry	$\pm40\%$	$\mp.005$	$\mp.002$	$\pm.020$	$\pm.043$
BR($Z^0 \to b\bar{b}$)	$R_b = .2216 \pm .0017$	$\mp.002$	$\mp.004$	$\pm.001$	$\pm.001$
BR($Z^0 \to c\bar{c}$)	$R_c = .16 \pm .01$	$\pm.006$	$\pm.004$	$\mp.030$	$\mp.031$
BR($b \to l$)	$(10.75 \pm 0.23)\%$	$\mp.006$	$\mp.007$	$\pm.009$	$\pm.011$
BR($\bar{b} \to \bar{c} \to l$)	$(8.10 \pm 0.37)\%$	$\pm.004$	$\pm.006$	$\mp.027$	$\mp.017$
BR($b \to \bar{c} \to l$)	$(1.3 \pm 0.5)\%$	$\pm.004$	$\pm.006$	$\mp.035$	$\pm.033$
BR($b \to \tau \to l$)	$(0.472 \pm 0.075)\%$	$<.001$	$<.001$	$\pm.009$	$\pm.001$
BR($b \to J/\psi \to l$)	$(0.07 \pm 0.02)\%$	$\pm.002$	$\pm.003$	$<.001$	$\pm.003$
BR($\bar{c} \to l$)	$(9.8 \pm 0.5)\%$	$\pm.004$	$\pm.003$	$\mp.021$	$\mp.025$
B lept. spect. - D^{**} fr.	$(23 \pm 10)\%$, B^+,B^0; $(32 \pm 20)\%$, B_s	$\pm.006$	$\pm.007$	$\pm.007$	$\pm.003$
D lept. spect.	$ACCMM1\,(^{+ACCMM2}_{-ACCMM3})$ [22]	$\pm.009$	$\pm.009$	$\pm.002$	$\pm.002$
B_s fraction in $b\bar{b}$ event	$.115 \pm .050$	$\pm.007$	$\pm.005$	$\mp.006$	$\mp.012$
Λ_b fraction in $b\bar{b}$ event	$.072 \pm .020$	$\pm.012$	$\pm.002$	$\mp.007$	$\mp.005$
b fragmentation	$\epsilon_b = .0045$-$.0075$	$\pm.001$	$\pm.001$	$\pm.006$	$\pm.005$
c fragmentation	$\epsilon_c = .045$-$.070$	$\mp.009$	$\mp.005$	$\pm.015$	$\pm.012$
Polarization	$< P_e >= .7734 \pm .0062$	$\mp.007$	$\mp.007$	$\mp.004$	$\mp.004$
Second order QCD	Δ_{QCD} uncertainty	$\pm.004$	$\pm.004$	$\pm.009$	$\pm.009$
B mixing χ	$\chi = .122 \pm .006$	$\pm.014$	$\pm.016$	$<.001$	$\pm.001$
Total Systematic		.044	.051	.072	.089

Table 1: Systematic errors for the maximum likelihood analysis (1994-95)

Lepton Source	Muon fraction	Electron fraction	Asymmetry
$b \to l$	0.67	0.59	$(1-2\chi)A_b$
$\overline{b} \to \overline{c} \to l$	0.07	0.05	$-(1-2\chi)A_b$
$b \to \overline{c} \to l$	0.01	0.01	$(1-2\chi)A_b$
$\overline{c} \to l$	0.10	0.09	$-A_c$
Background true leptons	0.07	0.09	A_{bkg}
Midisdentified	0.08	0.17	A_{bkg}

Table 2: Composition of the high $(p,\, p_t)$ lepton sample and corresponding contributions to the left-right forward-backward asymmetry