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An Improved Measurement of the Left-Right Z^0 Cross Section Asymmetry†

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Abstract

We present a new measurement of the left-right cross section asymmetry (A_{LR}) for Z boson production by e^+e^- collisions. The measurement was performed at a center-of-mass energy of 91.28 GeV with the SLD detector at the SLAC Linear Collider (SLC). The luminosity-weighted average polarization of the SLC electron beam was (77.23±0.52)%. Using a sample of 93,644 Z decays, we measure the pole-value of the asymmetry, A^0_{LR}, to be 0.1512±0.0042(stat.)±0.0011(syst.) which is equivalent to an effective weak mixing angle of $\sin^2\theta^{\rm eff}_W = 0.23100 \pm 0.00054({\rm stat.}) \pm 0.00014({\rm syst.})$.

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In 1993, the SLD Collaboration performed a precise measurement of the left-right cross section asymmetry in the production of Z bosons by e^+e^- collisions [1]. In this letter, we present a substantially improved measurement based upon new data recorded during the 1994/95 run of the SLAC Linear Collider (SLC) with larger beam polarization and better control of systematic uncertainties.

The left-right asymmetry is defined as $A^0_{LR} \equiv (\sigma_L - \sigma_R) / (\sigma_L + \sigma_R)$, where σ_L and σ_R are the e^+e^- production cross sections for Z bosons at the Z-pole energy with left-handed and right-handed electrons, respectively. The Standard Model predicts that this quantity depends upon the effective vector (v_e) and axial-vector (a_e) couplings of the Z boson to the electron current,

$$A^0_{LR} = \frac{2v_e a_e}{v_e^2 + a_e^2} \equiv \frac{2\left[1 - 4\sin^2\theta_W^{\rm eff}\right]}{1 + \left[1 - 4\sin^2\theta_W^{\rm eff}\right]^2}, \tag{1}$$

where the effective electroweak mixing parameter is defined [2] as $\sin^2\theta_W^{\rm eff} \equiv (1 - v_e/a_e)/4$. Note that A^0_{LR} is a sensitive function of $\sin^2\theta_W^{\rm eff}$ and depends upon virtual electroweak radiative corrections including those which involve the top quark and Higgs boson and those arising from new phenomena. The recent measurement of the top quark mass [3] has, as a determination of a previously unknown parameter of the Standard Model, greatly enhanced the power of this measurement as a test of the prevailing theory.

We measure the left-right asymmetry by counting hadronic and (with low efficiency) $\tau^+\tau^-$ final states produced in e^+e^- collisions near the Z-pole energy for each of the two longitudinal polarization states of the electron beam. The asymmetry formed from these rates, A_{LR}, must then be corrected for residual effects arising from pure photon exchange and Z-photon interference to extract A^0_{LR}. The measurement requires knowledge of the absolute beam polarization, but does not require knowledge of the absolute luminosity, detector acceptance, or efficiency [4].

The operation of the SLC with a polarized electron beam has been described previously [5]. In 1994, the beam polarization at the SLC source [6] was increased from 63% to $\sim$ 80% by the use of a thinner (0.1 μm) strained-lattice GaAs photocathode [7] which was illuminated by a pulsed Ti:Sapphire laser operating at 845 nm. The circular polarization state of each laser pulse (and hence, the helicity of each electron pulse) was chosen randomly. The electron spin orientation was manipulated in the SLC North Arc by a pair of large amplitude betatron oscillations to achieve longitudinal polarization at the SLC interaction point (IP) [8]. The maximum luminosity of the collider was approximately 6×10^{29} cm^{-2}sec^{-1}. The luminosity-weighted mean e^+e^- center-of-mass energy (E_{cm}) is measured with precision energy spectrometers [9] to be 91.280$\pm$0.025 GeV.

The longitudinal electron beam polarization ($\mathcal{P}_e$) is measured by a Compton scattering polarimeter [10] located 33 m downstream of the IP. After it passes through the IP and before it is deflected by dipole magnets, the electron beam collides with a circularly polarized photon beam produced by a pulsed frequency-doubled Nd:YAG laser of wavelength 532 nm operating at $\sim$17 Hz. Since the accelerator produces electron pulses at 120 Hz, the polarimeter samples each seventh machine pulse. The scattered and unscattered components of the electron beam remain unseparated until they pass through a dipole-quadrupole spectrometer. The scattered electrons are dispersed horizontally and exit the vacuum system through a thin window. A multichannel Cherenkov detector observes the scattered electrons in the interval from 17 to 30 GeV/c.

The counting rates in each detector channel are measured for three combinations of electron and photon beam parameters: parallel electron and photon helicities, antiparallel helicities, and photon beam absent. The latter combination is used to measure detector background. The asymmetry formed from the background-subtracted counting rates is equal to the product $\mathcal{P}_e\mathcal{P}_\gamma\mathcal{A}_i$ where $\mathcal{P}_\gamma$ is the circular polarization of the laser beam at the electron-photon crossing point and $\mathcal{A}_i$ is the analyzing power of the i^{th} detector channel. The laser polarization was maintained at (99.6$\pm$0.2)% by continuously monitoring and correcting phase shifts in the laser transport system. The analyzing powers of the detector channels incorporate resolution and spectrometer effects and differ slightly from the theoretical Compton asymmetry function at the mean accepted energy for each channel [11]. The minimum energy of a Compton-scattered electron for the initial electron and photon energies is 17.36 GeV. The location of this kinematic endpoint at the detector was monitored by frequent scans of the detector horizontal position during polarimeter operation. This technique determines and monitors the analyzing powers of each detector channel.

Polarimeter data are acquired continually during the operation of the SLC. The absolute statistical precision attained in a 3 minute measurement is typically $\delta\mathcal{P}_e = 0.8\%$. The systematic uncertainties that affect the polarization measurement are summarized in Table I. The total relative systematic uncertainty is estimated to be $\delta\mathcal{P}_e/\mathcal{P}_e = 0.64\%$.

Due to energy-spread-induced spin diffusion in the SLC arc and imperfect spin orientation, the longitudinal polarization of the electron beam at the IP was typically 98% of the polarization in the linac. This estimate follows from a measurement of the arc spin rotation matrix performed with a beam of very small energy spread ($\lesssim 0.05\%$) using a pair of spin rotation solenoids and the Compton polarimeter. The electron polarization in the linac was determined to be (78.6±0.9)% and was consistent with a direct measurement using a diagnostic Møller polarimeter [12] of (81±3)%.

In our previous Letter [1], we examined an effect that causes the beam polarization measured by the Compton Polarimeter, $\mathcal{P}_e$, to differ from the luminosity-weighted beam polarization, $\mathcal{P}_e(1+\xi)$, at the SLC IP. While the Compton polarimeter measures the polarization of the entire electron bunch, chromatic aberrations in the SLC final focus optics reduce the contribution of off-energy electrons to the luminosity. The on-energy electrons with larger average longitudinal polarization therefore contribute more to the total luminosity and ξ can be non-negligible. To first order, the magnitude of ξ depends quadratically on the width of the beam energy distribution $N(E)$, the energy dependence of the arc spin rotation $d\Theta_s/dE$, and the dependence of the luminosity per electron on beam energy $d\mathcal{L}(E)/dE$.

During the 1994/95 run, a number of measures in the operation of the SLC and in monitoring procedures significantly reduced the size of this *chromaticity* correction and its associated error. The fractional RMS beam energy spread was reduced to approximately 0.12% (0.20% in 1993) and non-Gaussian tails in the beam energy distribution were reduced to a negligible level [13]. Optimization of the SLC arc spin transport system reduced the measured energy dependence of the spin rotation in the arc to $d\Theta_s/dE = 1.4$ rad/GeV (2.5 rad/GeV in 1993). Finally, $d\mathcal{L}(E)/dE$ was reduced by improvements in the SLC final focus optics [14]. Constraints on $d\mathcal{L}(E)/dE$ were made directly from our data via a determination of the Z production rate as a function of beam energy, with consistent results obtained from the observed energy dependence of the beam size and from simulations of the final focus optics [14]. We then determine a contribution to ξ of $+0.0020 \pm 0.0014$ due to the chromaticity effect, which is smaller by a factor of eight than it was in 1993. An effect of similar magnitude arises due to the small precession of the electron spin in the final focusing elements between the SLC IP and the polarimeter. This effect contributes -0.0011 ± 0.0001 to ξ. The depolarization of the electron beam by the e^+e^- collision process is expected to be negligible [15]. The contribution of depolarization to ξ is determined to be 0.000 ± 0.001 by comparing polarimeter data taken with and without beams in collision. Combining the three effects described above, the overall correction factor is determined to be $\xi = 0.0009 \pm 0.0017$.

The e^+e^- collisions are measured by the SLD detector which has been described elsewhere [16]. The trigger relies on a combination of calorimeter and tracking information; the event selection is based on the liquid argon calorimeter (LAC) [18] and the central drift chamber tracker (CDC) [19]. For each event candidate, energy clusters are reconstructed in the LAC. Selected events are required to contain at least 22 GeV of energy observed in the clusters and to manifest a normalized energy imbalance of less than 0.6 [20]. The left-right asymmetry associated with final state e^+e^- events is expected to be diluted by the t-channel photon exchange subprocess. Therefore, we exclude e^+e^- final states by requiring that each event candidate contain at least 4 selected CDC tracks, with at least 2 tracks in each hemisphere defined with respect to the beam axis, or at least 4 tracks in either hemisphere (this track topology requirement excludes Bhabha events which contain a reconstructed gamma conversion). The selected CDC tracks are required to extrapolate to within 5 cm radially and 10 cm along the beam direction of the IP, to have a minimum momentum transverse to the beam direction of 100 MeV/c, and to form a minimum angle of 30 degrees with the beam direction.

We estimate that the combined efficiency of the trigger and selection criteria is (89±1)% for hadronic Z decays. Tau pairs constitute (0.3±0.1)% of the sample. Because muon pair events deposit little energy in the calorimeter, they are not included in the sample. The residual background in the sample is due primarily to e^+e^- final state events. We use our data and a Monte Carlo simulation to estimate this background fraction to be (0.08±0.08)%. The background fraction due to cosmic rays, two-photon events and beam related processes is estimated to be (0.03±0.03)%.

A total of 93,644 Z events satisfy the selection criteria. We find that 52,179 (N_L) of the events were produced with the left-handed electron beam and 41,465 (N_R) were produced with the right-handed beam. The measured left-right cross section asymmetry for Z production is [21]

$$A_m \equiv (N_L - N_R)/(N_L + N_R) = 0.11441 \pm 0.00325.$$

We have verified that the measured asymmetry A_m does not vary significantly as more restrictive criteria (calorimetric and tracking-based) are applied to the sample and that A_m is uniform when binned by the azimuth and polar angle of the thrust axis.

The measured asymmetry A_m is related to A_{LR} by the following expression which incorporates a number of small correction terms in lowest-order approximation,

$$\begin{aligned} A_{LR} = \frac{A_m}{\langle \mathcal{P}_e \rangle} + \frac{1}{\langle \mathcal{P}_e \rangle} \Big[& f_b(A_m - A_b) - A_{\mathcal{L}} + A_m^2 A_{\mathcal{P}} \\ & - E_{cm} \frac{\sigma'(E_{cm})}{\sigma(E_{cm})} A_E - A_\varepsilon + \langle \mathcal{P}_e \rangle \mathcal{P}_p \Big], \end{aligned} \tag{2}$$

where $\langle \mathcal{P}_e \rangle$ is the mean luminosity-weighted polarization for the 1994-5 run; f_b is the background fraction; $\sigma(E)$ is the unpolarized Z cross section at energy E; $\sigma'(E)$ is the derivative of the cross section with respect to E; A_b, $A_{\mathcal{L}}$, $A_{\mathcal{P}}$, A_E, and A_ε are the left-right asymmetries [22] of the residual background, the integrated luminosity, the beam polarization, the center-of-mass energy, and the product of detector acceptance and efficiency, respectively; and $\mathcal{P}_p$ is any longitudinal positron polarization which is assumed to have constant helicity [23].

The luminosity-weighted average polarization $\langle \mathcal{P}_e \rangle$ is estimated from measurements of $\mathcal{P}_e$ made when Z events were recorded,

$$\langle \mathcal{P}_e \rangle = (1+\xi) \cdot \frac{1}{N_Z} \sum_{i=1}^{N_Z} \mathcal{P}_i = (77.23 \pm 0.52)\%, \tag{3}$$

where N_Z is the total number of Z events, and $\mathcal{P}_i$ is the polarization measurement associated in time with the i^{th} event. The error on $\langle \mathcal{P}_e \rangle$ is dominated by the systematic uncertainties on the polarization measurement.

The corrections defined in equation (2) are found to be small. The correction for residual background contamination is moderated by a non-zero left-right background asymmetry ($A_b = 0.055 \pm 0.021$) arising from e^+e^- final states which remain in the sample. Residual electron current asymmetry ($\lesssim 10^{-3}$) from the SLC polarized source was reduced by twice reversing a spin rotation solenoid at the entrance to the SLC damping ring. The net luminosity asymmetry is estimated from the measured asymmetry of the rate of radiative Bhabha scattering events observed with a monitor located in the North Final Focus region of the SLC to be $A_{\mathcal{L}} = (-1.9 \pm 0.3) \times 10^{-4}$. A less precise cross check is performed by examining the left-right asymmetry of the sample of 246,845 small-angle Bhabha scattering events detected by the luminosity monitoring system (LUM) [24]. Since the theoretical left-right asymmetry for small-angle Bhabha scattering is very small [$\mathcal{O}(10^{-4})\mathcal{P}_e$ within the LUM acceptance], the measured asymmetry of $(-18 \pm 20) \times 10^{-4}$ is a direct determination of $A_{\mathcal{L}}$ and is consistent with the more precisely determined one. The polarization asymmetry is directly measured to be $A_{\mathcal{P}} = (+2.4 \pm 1.0) \times 10^{-3}$. The left-right beam energy asymmetry arises from the small residual left-right beam current asymmetry due to beam-loading of the accelerator and is measured to be $(+9.2 \pm 0.2) \times 10^{-7}$. The coefficient of the energy asymmetry in equation (2) is a very sensitive function of the center-of-mass energy and is found to be 0.0 ± 2.5 for $E_{cm} = 91.280 \pm 0.025$ GeV. The SLD has a symmetric acceptance in polar angle [4] which implies that the efficiency asymmetry A_ε is negligible. As was discussed in our previous publication [1], the positron polarization at the SLC IP is less than 1.5×10^{-5}. The corrections listed in equation (2) change A_{LR} by $(+0.2 \pm 0.06)\%$ of the uncorrected value.

Using equation (2), we find the left-right asymmetry to be

$$A_{LR}(91.28\text{ GeV}) = 0.1485 \pm 0.0042(\text{stat.}) \pm 0.0010(\text{syst.}).$$

The various contributions to the systematic error are summarized in Table I. Correcting this result to account for photon exchange and for electroweak interference which arises from the deviation of the effective e^+e^- center-of-mass energy from the Z-pole energy (including the effect of initial-state radiation), we find the pole asymmetry A^0_{LR} and the effective weak mixing angle to be [25]

$$A^0_{LR} = 0.1512 \pm 0.0042(\text{stat.}) \pm 0.0011(\text{syst.})$$
$$\sin^2\theta_W^{\text{eff}} = 0.23100 \pm 0.00054(\text{stat.}) \pm 0.00014(\text{syst.})$$

where the systematic uncertainty includes the uncertainty on the electroweak interference correction (see Table I) which arises from the ±25 MeV uncertainty on center-of-mass energy scale. Combining this value of $\sin^2\theta_W^{\text{eff}}$ with our previous measurements [17,1] we obtain the value,

$$A^0_{LR} = 0.1543 \pm 0.0039$$
$$\sin^2\theta_W^{\text{eff}} = 0.23060 \pm 0.00050.$$

This $\sin^2\theta_W^{\text{eff}}$ determination is smaller by 2.5 standard deviations than the recent average of 23 measurements performed by the LEP Collaborations [26].

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REFERENCES

[1] K. Abe *et al.*, *Phys. Rev. Lett.* **73**, 25 (1994) [hep-ex/9404001].

[2] We follow the convention used by the LEP Collaborations in *Phys. Lett.* **B276**, 247 (1992).

[3] CDF Collaboration: F. Abe, *et al.*, *Phys. Rev. Lett.* **74**, 2626 (1995) [hep-ex/9503002]; D0 Collaboration: S. Abachi, *et al.*, *Phys. Rev. Lett.* **74**, 2632 (1995) [hep-ex/9503003].

[4] The value of A_{LR} is unaffected by decay-mode-dependent variations in detector acceptance and efficiency provided that the efficiency for detecting a fermion at some polar angle (with respect to the electron direction) is equal to the efficiency for detecting an antifermion at the same polar angle.

[5] M. Woods, AIP Conference Proceedings 343, 230 (1995).

[6] R. Alley, *et al.*, *Nuc. Inst. Meth.* **A365**, 1 (1995).

[7] T. Maruyama *et al.*, *Phys. Rev.* **B46**, 4261 (1992).

[8] T. Limberg, P. Emma, and R. Rossmanith, SLAC-PUB-6210, May 1993.

[9] J. Kent *et al.*, SLAC-PUB-4922, March 1989.

[10] R. King, SLAC-Report-452; changes to the polarimeter for the 1994-95 SLD run are not described in this report and include a higher repetition rate Nd:YAG laser, improved laser polarization diagnostics, and the addition of a quadrupole magnet to the Compton spectrometer magnets.

[11] See S.B. Gunst and L.A. Page, *Phys. Rev.* **92**, 970 (1953).

[12] M. Swartz *et al.*, *Nucl. Instr. Meth.* **A363**, 526 (1995) [hep-ex/9412006].

[13] F.-J. Decker, R. Holtzapple, and T. Raubenheimer, Proceedings of the 17th International Linear Accelerator Conference, Tsukuba, Japan (1994), p. 47.

[14] F.Zimmermann *et al.*, SLAC-PUB-95-6790, June 1995.

[15] P. Chen and K. Yokoya, *Proceedings of the Eighth International Symposium on High-Energy Spin Physics*, Minneapolis, MN, 1988, pg. 938.

[16] The SLD Design Report, SLAC Report 273, 1984.

[17] K. Abe *et al.*, *Phys. Rev. Lett.* **70**, 2515 (1993). Details of the calorimetric event selection can be found in J. Yarmartino, SLAC REPORT 426, February 1994.

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

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

[20] The energy imbalance is defined as a normalized vector sum of the energy clusters as follows, $E_{imb} = |\sum \vec{E}_{cluster}|/\sum |E_{cluster}|$.

[21] The absolute sign of A_m is inferred from the sign of the measured Compton scattering asymmetry, the measured helicity of the polarimeter laser, and the theoretical sign of the Compton scattering asymmetry.

[22] The left-right asymmetry for a quantity Q is defined as $A_Q \equiv (Q_L - Q_R)/(Q_L + Q_R)$ where the subscripts L,R refer to the left- and right-handed beams, respectively.

[23] Since the colliding electron and positron bunches are produced on different machine cycles and since the electron helicity of each cycle is chosen randomly, any positron helicity arising from the polarization of the production electrons is uncorrelated with electron helicity at the IP. The net positron polarization from this process vanishes rigorously. However, positron polarization of constant helicity does affect the measurement.

[24] S.C. Berridge *et al.*, *IEEE Trans. Nucl. Sci.* **NS-39**, 242 (1992).

[25] The quantities A^0_{LR} and $\sin^2\theta^{\rm eff}_W$ are related by equation (1) and are completely equivalent. The correction for electroweak interference and pure photon exchange, $A^0_{LR} - A_{LR}(91.280)$ is determined with the ZFITTER 4.9 program of D. Bardin, *et*

al. (CERN-TH. 6443/92, May 1992) and is found to be 0.00265 ± 0.00049.

[26] A. Blondel, *Proceedings of the XXVIIIth International Conference on High Energy Physics*, 25-31 July 1996, Warsaw, Poland.

TABLES

TABLE I. Systematic uncertainties that affect the A_{LR} measurement. The uncertainty on the electroweak interference correction is caused by the ±25 MeV on the SLC energy scale.

Systematic Uncertainty	$\delta\mathcal{P}_e/\mathcal{P}_e$ (%)	$\delta A_{LR}/A_{LR}$ (%)	$\delta A^0_{LR}/A^0_{LR}$ (%)
Laser Polarization	0.20		
Detector Linearity	0.50		
Analyzing Power Calibration	0.29		
Electronic Noise	0.20		
Total Polarimeter Uncertainty	0.64	0.64	
Chromaticity and I.P. Corrections (ξ)		0.17	
Corrections in Equation (2)		0.06	
A_{LR} Systematic Uncertainty		0.67	0.67
Electroweak Interference Correction			0.33
A^0_{LR} Systematic Uncertainty			0.75