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PRECISION ELECTROWEAK PHYSICS WITH THE SLD/SLC: THE LEFT-RIGHT POLARIZATION ASYMMETRY*

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ABSTRACT

Following a brief review of a commonly used general framework for the analysis of radiative corrections and possible new physics, the recent precision results from the SLD/SLC are discussed and used to test the standard electroweak model. In the 1993 SLD/SLC run, the SLD recorded 50,000 Z events produced by the collision of longitudinally polarized electrons on unpolarized positrons at a center-of-mass energy of 91.26 GeV. The luminosity-weighted average polarization of the SLC electron beam was (63.0±1.1)%. We measure the left-right cross-section asymmetry in Z boson production, A_{LR}, to be $0.1628 \pm 0.0071\,(\mathrm{stat}) \pm 0.0028\,(\mathrm{syst})$ which determines the effective weak mixing angle to be $\sin^2\theta_W^{\mathrm{eff}} = 0.2292 \pm 0.0009\,(\mathrm{stat}) \pm 0.0004\,(\mathrm{syst})$ [1]. When averaged with our 1992 result [2], we obtain $\sin^2\theta_W^{\mathrm{eff}} = 0.2294 \pm 0.0010$. This result differs from analogous LEP results at the level of about $2.5\,\sigma$. The world averages of electroweak data are comfortably in agreement with the standard model.

1. A Brief Discussion of Electroweak Radiative Corrections

We have recently entered an exciting era where precision electroweak measurements are becoming sensitive to purely electroweak radiative corrections. In order to discuss these new experimental results, it is best to make clear what assumptions regarding possible new physics are included in the analysis when the standard electroweak model is tested, and which of the many conventions are to be used. In what follows, I will briefly outline the parameterization of loop corrections used in the discussion of the SLD results. There are presently three very well determined electroweak constants [3]

$$
\begin{aligned}
\alpha(M_Z^2) &= 128.87(12)^{-1} , \\
G_F &= 1.116639(2) \times 10^{-5}\ \mathrm{GeV}^{-2} \qquad (1) , \\
M_Z &= 91.187(7)\ \mathrm{GeV} ,
\end{aligned}
$$

which at tree level in the electroweak model with its three parameters (the couplings g, g' and the vacuum expectation value of the Higgs field ϕ) would be a complete set. At loop level, however, more parameters are needed. The framework of our analysis will follow Lynn, Peskin and Stuart [4], where the following assumptions are made :

1. The gauge group of electroweak physics is SU(2)×U(1) (Z, Z' mixing, for example, is not included in this discussion).
2. The symmetry breaking sector has a global SU(2) "custodial" symmetry that insures :

$$\rho = M_W^2 / M_Z^2 cos^2\theta_W = 1 + \mathcal{O}(\alpha) \qquad (2) .$$

3. Vacuum polarization effects are dominant, compared to vertex and box corrections (the "oblique hypothesis").

In addition, if we assume that any new particles are heavy, so that Taylor expansions are appropriate descriptions of the vacuum polarization corrections, the gauge boson self-energy functions are :

$$\Pi_{ij}(q^2) \;=\; \Pi_{ij}(0) + q^2\Pi'_{ij}(0) \tag{3}$$

for vector bosons $W_1, W_2, W_3,$ and B for $i = 1, 2, 3, Q$.

Hence, the relevant terms are :

$$\begin{aligned}
\Pi_{11}(q^2) &= \Pi_{11}(0) + q^2\Pi'_{11}(0)\\
\Pi_{33}(q^2) &= \Pi_{33}(0) + q^2\Pi'_{33}(0)\\
\Pi_{3Q}(q^2) &= \qquad\quad\; q^2\Pi'_{3Q}(0)\\
\Pi_{QQ}(q^2) &= \qquad\quad\; q^2\Pi'_{QQ}(0),
\end{aligned} \tag{4}$$

where symmetry and gauge invariance have been applied to reduce the total number of independent terms to six. With the three experimental numbers mentioned above, this leaves us with three undetermined parameters. These three parameters are defined in the "S,T,U" scheme of Peskin and Takeuchi [5] as,

$$\begin{aligned}
\alpha S &= 4e^2[\Pi'_{33}(0) - \Pi'_{3Q}(0)]\\
\alpha T &= 4\frac{e^2}{s^2c^2Z^2}[\Pi_{11}(0) - \Pi_{33}(0)]\\
\alpha U &= 4e^2[\Pi'_{11}(0) - \Pi'_{33}(0)] \; ,
\end{aligned} \tag{5}$$

where $e = gs$ and s and c are the sine and cosine of the weak mixing angle. The S parameter is a measure of the weak isospin conserving new heavy sector. The T parameter is equal to $\alpha^{-1}\Delta\rho$, and is a measure of weak isospin breaking in the heavy sector (for example, the top quark to bottom quark mass splitting). The U parameter introduces very small effects and will be ignored. As is well known, a heavy fermion doublet results in a change of the T parameter which is quadratic in the mass splitting. The minimal standard model Higgs boson contributes offsets logarithmic in the Higgs mass to both S and T, though these effects are opposite in sign—we note that these offsets are relative to a completely arbitrary reference value of the Higgs mass, taken here to be 300 GeV. We will return to a discussion of the S and T parameters in our discussion of global fits to electroweak data.

1. The A_{LR} Measurement

The left-right asymmetry is defined as $A_{LR} \equiv (\sigma_L - \sigma_R) / (\sigma_L + \sigma_R)$, 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 vector (v_e) and axial-vector (a_e) couplings of the Z boson to the electron current,

$$A_{LR} = \frac{2v_e a_e}{v_e^2 + a_e^2} = \frac{2\left[1 - 4\sin^2\theta_W^{\rm eff}\right]}{1 + \left[1 - 4\sin^2\theta_W^{\rm eff}\right]^2} , \tag{6}$$

where the effective electroweak mixing parameter is defined [6] as

$$\sin^2\theta_W^{\rm eff} \equiv \frac{1 - v_e/a_e}{4} .$$

We use the SLD detector to count the number (N_L, N_R) of hadronic decays of the Z boson (and with low efficiency $\tau^+\tau^-$ decays) for each of the two longitudinal polarization states (L,R) of the electron beam. The electron beam polarization is measured precisely with a Compton polarimeter. From these measurements we determine the left-right asymmetry,

$$A_{LR}(E_{\rm c.m.}) = \frac{1}{\langle \mathcal{P}_e^{lum} \rangle} \cdot \frac{N_L - N_R}{N_L + N_R} , \tag{7}$$

where $E_{\rm c.m.}$ is the mean luminosity-weighted collision energy and $\langle \mathcal{P}_e^{lum} \rangle$ is the mean luminosity-weighted polarization. This measurement does not require knowledge of the absolute luminosity, detector acceptance, or detector efficiency.

3. Operation of the SLC with Polarized Beams

The operation of the SLC with a polarized electron beam is illustrated schematically in Figure 1. Polarized electrons are produced by photoemission from a GaAs photocathode, where the circular polarization of the laser used to induce photoemission (and hence, the helicity of each electron pulse) is chosen randomly. In 1993 a "strained-lattice" photocathode, in which a degeneracy in the valence band energy levels of GaAs is removed, was used to achieve polarizations in excess of 60% [7]. The electron spin orientation is longitudinal at the source and remains longitudinal until the transport to the Damping Ring (DR). In the Linac-to-Ring

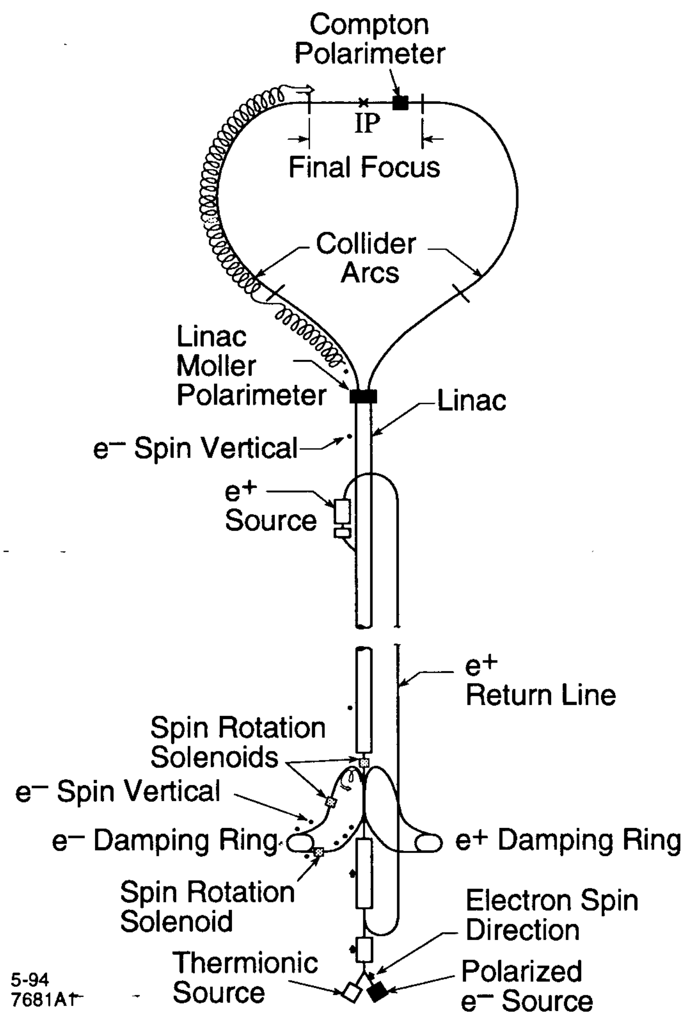

Figure 1: The SLC.

(LTR) transport, the electron spins precess, with spin precession angle is given in terms of the anamolous magnetic moment g

$$\theta_{\text{precession}} = \left(\frac{g-2}{2}\right) \frac{E}{m}\, \theta_{\text{bend}} \,, \tag{8}$$

into a transverse orientation at the entrance to the LTR spin rotator solenoid.

This solenoid then rotates the electron spin to be vertical in the DR to preserve the polarization during the 8 ms storage time (the electron bunch has an energy spread of about 1% entering the DR, which is sufficient to completely diffuse any net horizontal polarization due to rapid spin precession during the damping cycle). The spin orientation is vertical upon extraction from the DR; it remains vertical during injection into the linac and during acceleration to 46 GeV down the linac. The spin transmission of this system is 0.99, with the loss resulting from the beam energy in the DR being 1.19 GeV, slightly lower than the design energy of 1.21 GeV. This causes the spin precession in the LTR to be proportionately smaller, and hence a small residual horizontal component of polarization is lost. The north SLC Arc transports the electron beam from the linac to the SLC Interaction Point (IP), and is comprised of 23 achromats, each of which consists of 20 combined function magnets. The spin precession in each achromat is 1085°, while the betatron phase advance is 1080°. The SLC Arc is therefore operating near a spin tune resonance, a fact that is exploited to control the transport of the polarization. A pair of vertical betatron oscillations in the arcs is used to adjust the spin direction [8]. The amplitudes of these oscillations are empirically adjusted to achieve longitudinal polarization at the IP. The luminosity-weighted mean e^+e^- center-of-mass energy ($E_{\text{c.m.}}$) is measured with precision energy spectrometers [9] to be 91.26±0.02 GeV.

4. Polarimetry at the SLC

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 frequency-doubled Nd:YAG laser of wavelength 532 nm. The scattered and unscattered components of the electron beam remain unseparated until they pass through a pair of dipole magnets. The scattered electrons are dispersed horizontally and exit the vacuum system through a thin window. Multichannel Cherenkov and proportional tube detectors measure the momentum spectrum of the scattered electrons in the interval from 17 to 30 GeV/c.

The counting rates in each detector channel are measured for parallel and anti-parallel combinations of the photon and electron beam helicities. The asymmetry formed from these rates is equal to the product $\mathcal{P}_e \mathcal{P}_\gamma A(E)$ where $\mathcal{P}_\gamma$ is the circular polarization of the laser beam at the electron-photon crossing point and $A(E)$ is the theoretical asymmetry function at the accepted energy E of the scattered electrons [11]. Figure 2 shows the asymmetry function and the Compton scattering cross section. For the first 26.9% of the data sample, $\mathcal{P}_\gamma$ was measured to be (97±2)%. For the latter 73.1% of the sample, the laser polarization was maintained at (99.2±0.6)% by continuously monitoring and correcting phase shifts in the laser transport system. The energy scale of the polarimeter is calibrated from measurements of the electron endpoint energy for Compton scattering (17.36 GeV) and the energy at which the asymmetry is zero (25.15 GeV).

Polarimeter data are acquired continually during the operation of the SLC. We obtain $\mathcal{P}_e$ from the observed asymmetry using the measured value of $\mathcal{P}_\gamma$ and the theoretical asymmetry function (including ~1% corrections for detector effects). The absolute statistical precision attained in a 3 minute interval is typically $\delta\mathcal{P}_e = 1\%$. The good agreement between the measured and simulated asymmetry functions is illustrated in Figure 3

The systematic uncertainties that affect the polarization measurement are summarized in Table I. After the uncertainty on the laser polarization, the largest contributions are due to the linearity of the Cherenkov detector (monitored by varying the gain on the first phototube stages) and the analyzing power calibration which includes energy scale and response function uncertainties. The total relative systematic uncertainty is estimated to be $\delta\mathcal{P}_e/\mathcal{P}_e = 1.3\%$.

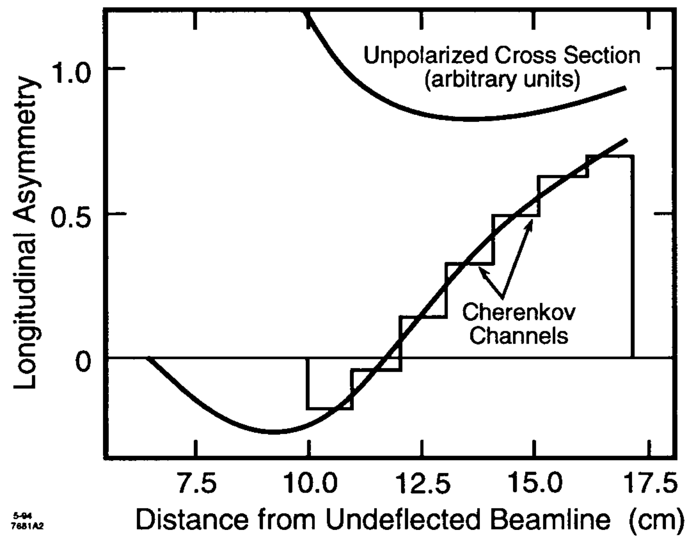

Figure 2: Compton cross-section and asymmetry.

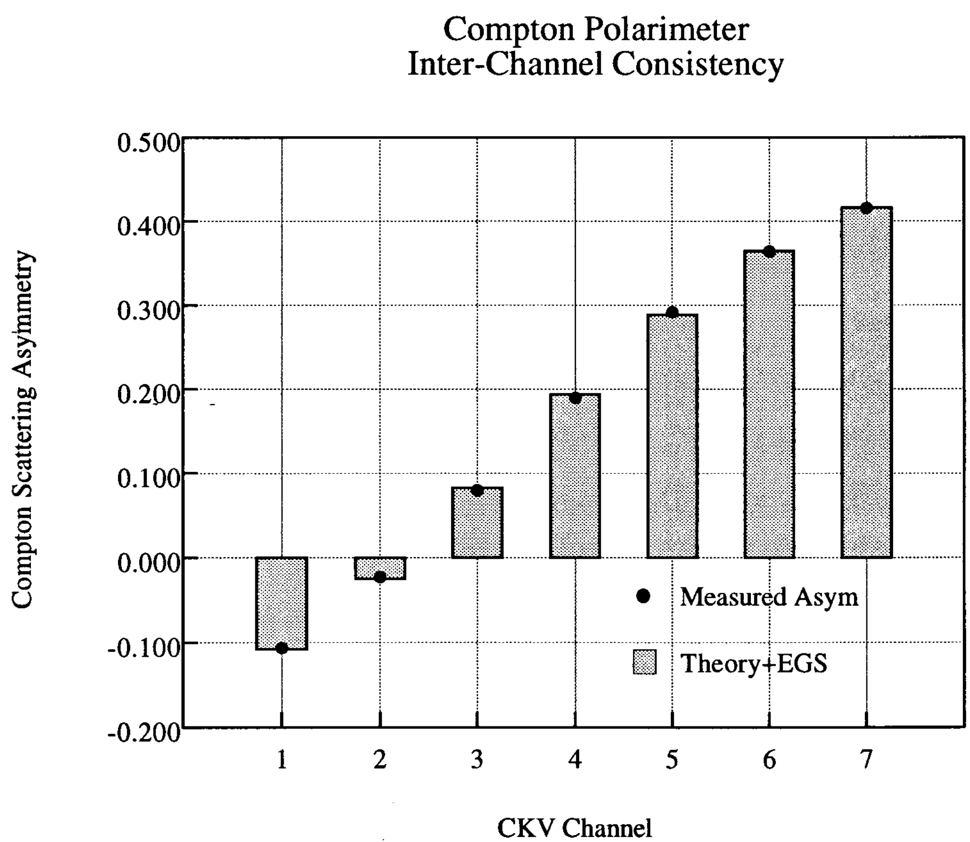

Figure 3: Measured and simulated Compton asymmetry.

Table I: Systematic uncertainties for the A_{LR} measurement.

Systematic Uncertainty	$\delta\mathcal{P}_e/\mathcal{P}_e$ (%)	$\delta A_{LR}/A_{LR}$ (%)
Laser polarization	1.0	
Detector calibration	0.4	
Detector linearity	0.6	
Interchannel consistency	0.5	
Electronic noise	0.2	
Total polarimeter uncertainty	1.3	1.3
Chromaticity correction (ξ)		1.1
Corrections in Eq. (9)		0.1
Total systematic uncertainty		1.7

Since the net spin precession angle in the SLC arc depends upon the energy of each beam particle, the finite beam energy spread leads to a distribution of spin directions at the IP. The combination of this effect with small variations in the orbit-dependent arc spin rotation angle causes the typical longitudinal polarization at the IP to be 95–96% of the polarization in the linac (the two effects are comparable in magnitude). This result follows from measurements of the arc spin rotation matrix performed with a beam of very small energy spread ($\lesssim 0.1\%$) using the spin rotation solenoids and the Compton polarimeter. These measurements determine the electron polarization in the linac, $\mathcal{P}_e^{lin}$, to be (65.7±0.9)%. On several occasions, $\mathcal{P}_e^{lin}$ was directly measured with a diagnostic Møller polarimeter located at the end of the linac, and was found to be (66±3)% [12]. We have examined a number of effects that could cause the beam polarization measured at the electron-photon crossing point $\mathcal{P}_e$ to differ from the luminosity-weighted beam polarization, $\mathcal{P}_e^{lum} \equiv \mathcal{P}_e(1+\xi)$, at the SLC IP. In 1992, all were found to cause fractional differences ξ that are smaller than 0.001. In 1993, due to very small vertical emittance, the vertical beam size at the IP was limited by third-order chromatic aberrations in the final focus optics. This causes the off-energy electrons to populate the edges of the luminous region. The on-energy electrons with larger average longitudinal polarization therefore contribute more to the total luminosity and ξ can be nonnegligible.

A model based upon the measured energy dependence of the arc spin rotation, $d\Theta_s/dE = (2.47 \pm 0.03)$ rad/GeV, and the expected dependence of the luminosity on beam energy ($\mathcal{L}(E)$) suggest that ξ is very small ($\xi \lesssim 0.002$) for the Gaussian core ($\Delta E/E \simeq 0.2\%$) of the beam energy distribution, $N(E)$. However, $N(E)$ is observed to have a low-energy tail extending to $\Delta E/E \simeq 1\%$. This small population of low-energy electrons does not contribute to the luminosity, but is measured by the polarimeter, leading to a calculated correction factor, $\xi = 0.019 \pm 0.005$. Measurements of $\mathcal{P}_e$ for different settings of an energy-defining collimator near the start of the north arc agree well with the predictions of the model.

We prefer to employ a conservative and essentially model-independent estimate which implicitly includes the energy tail. The correction ξ is rigorously limited to be less than the *difference* between: (1) the observed maximum fractional deviation of $\mathcal{P}_e$ from the polarization in the linac, and (2) the minimum fractional deviation of the luminosity-weighted polarization $\mathcal{P}_e(1+\xi)$ from the polarization in the linac. Effect (1) is bounded to be less than 0.047 by our measurements of polarization loss in the arc. Effect (2) is bounded to be larger than 0.014 by a calculation using a purely Gaussian energy distribution of narrow width (0.15% RMS), conservative assumptions for $\mathcal{L}(E)$ [13], and the measured value of $d\Theta_s/dE$. We use the central value and width of the allowed range, 0 to 0.033, to derive the correction factor, $\xi = 0.017 \pm 0.011$, which is applied to our data. In 1994, improvements in the electron beam energy distribution, $d\Theta_s/dE$, and the chromatic effects on $\mathcal{L}(E)$, should reduce ξ to less than 0.005.

Following the 1993 SLC/SLD run, the photocathode used for that run was taken to a test beamline with a newly commissioned Mott polarimeter. This polarimeter analyzes the rate asymmetry in elastic scattering of a polarized electron beam from nuclei in an uranium target. This polarimeter was built at UC Irvine and was calibrated there against another Mott polarimeter [14]. The SLAC Mott polarimeter measured the 1993 SLC photocathode to give a beam polarization of $(64 \pm 2)\%$, providing another cross-check on the Compton measurement.

5. Z° Event Selection

The e^+e^- collisions are measured by the SLD detector which has been described elsewhere [15]. The triggering of the SLD and the selection of Z events are improved versions of the 1992 procedures [2]. The trigger relies on a combination of calorimeter and tracking information, while the event selection is entirely based on the liquid argon calorimeter (LAC) [16]. 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 [17]. 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 a minimum of 9 clusters (12 clusters if $|\cos\theta|$ is larger than 0.8, where θ is the angle of the thrust axis [18] with respect to the beam axis).

We estimate that the combined efficiency of the trigger and selection criteria is (93±1)% for hadronic Z decays and is (25±1)% for tau pairs. 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 beam-related backgrounds and to e^+e^- final state events. We use our data and a Monte Carlo simulation to estimate the background fraction due to these sources to be $(0.23 \pm 0.10)\%$. The background fraction due to cosmic rays and two-photon processes is (0.02±0.01)%.

A total of 49,392 Z events satisfy the selection criteria. We find that 27,225 (N_L) of the events were produced with the left-handed electron beam and 22,167 (N_R) were produced with the right-handed beam [19]. The measured left-right cross section asymmetry for Z production is

$$A_m \equiv (N_L - N_R)/(N_L + N_R) = 0.1024 \pm 0.0045 \ .$$

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.

6. The Determination of A_{LR}

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,

$$A_{LR} = \frac{A_m}{\left\langle \mathcal{P}_e^{lum} \right\rangle} + \frac{1}{\left\langle \mathcal{P}_e^{lum} \right\rangle} \Bigg[f_b(A_m - A_b) - A_{\mathcal{L}} + A_m^2 A_{\mathcal{P}} - E_{\mathrm{c.m.}} \frac{\sigma'(E_{\mathrm{c.m.}})}{\sigma(E_{\mathrm{c.m.}})} A_E - A_\varepsilon + \left\langle \mathcal{P}_e^{lum} \right\rangle \mathcal{P}_p \Bigg] , \tag{9}$$

where $\langle \mathcal{P}_e^{lum} \rangle$ is the mean luminosity-weighted polarization for the 1993 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 [20] 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 [21].

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

$$\left\langle \mathcal{P}_e^{lum} \right\rangle = (1+\xi) \cdot \frac{1}{N_Z} \sum_{i=1}^{N_Z} \mathcal{P}_i = (63.0 \pm 1.1)\% , \tag{10}$$

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 $\langle \mathcal{P}_e^{lum} \rangle$ is dominated by the systematic uncertainties on the polarization measurement and the chromaticity correction, ξ.

The corrections defined in equation (9) are found to be small. The correction for residual background contamination is moderated by a nonzero left-right background asymmetry ($A_b = 0.031 \pm 0.010$) arising from e^+e^- final states which remain in the sample. Residual linear polarization of the polarized electron source laser beam can produce a small left-right asymmetry in the electron current ($\lesssim 10^{-3}$). This asymmetry and the left-right asymmetries of all quantities that are correlated with it were reduced by once reversing the spin rotation solenoid at the entrance to the

SLC damping ring. The net luminosity asymmetry is estimated from measured asymmetries of the beam current and the rate of radiative Bhabha scattering events observed with a monitor located in the North Final Focus region of the SLC to be $A_{\mathcal{L}} = (+3.8 \pm 5.0) \times 10^{-5}$. A less precise cross check is performed by examining the sample of 125,375 small-angle Bhabha scattering events detected by the luminosity monitoring system (LUM) [22]. Since the left-right cross section asymmetry for small-angle Bhabha scattering is expected to be very small ($\sim -1.5\times10^{-4}\,\mathcal{P}_e$ in the LUM acceptance), the left-right asymmetry formed from the luminosity Bhabha events is a direct measure of $A_{\mathcal{L}}$. The measured value of $(-32\pm28)\times10^{-4}$ is consistent with the more precisely determined one. The polarization asymmetry is directly measured to be $A_{\mathcal{P}} = (-3.3 \pm 0.1) \times 10^{-3}$. The measured left-right beam energy asymmetry of $(+4.4\pm0.1)\times10^{-7}$ arises from the small residual left-right beam current asymmetry due to beam-loading of the accelerator (the coefficent of the A_E term in equation (9) is -1.9). The SLD has a symmetric acceptance in polar angle [23] which implies that the efficiency asymmetry A_ε is negligible. The dominant source of positron polarization [21] is expected to be the Sokolov-Ternov effect in the positron damping ring [24]. Since the polarizing time in the SLC damping rings is about 960 s and the positron storage time is 16.6 ms, the positron polarization at IP must be less than 1.5×10^{-5}. The corrections listed in equation (9) change A_{LR} by $(+0.10\pm0.08)\%$ of the uncorrected value.

Using Eq. (9), we find the left-right asymmetry to be

$$A_{LR}\,(91.26\ \mathrm{GeV}) \;=\; 0.1628 \pm 0.0071\,(\mathrm{stat}) \pm 0.0028\,(\mathrm{syst})\ .$$

The various contributions to the systematic error were summarized in Table I. Correcting this result to account for photon exchange and for electroweak interference that 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],

$$\begin{aligned} A^0_{LR} &= 0.1656 \pm 0.0071\,(\mathrm{stat}) \pm 0.0028\,(\mathrm{syst}) \\ \sin^2\theta^{\mathrm{eff}}_W &= 0.2292 \pm 0.0009\,(\mathrm{stat}) \pm 0.0004\,(\mathrm{syst})\ . \end{aligned}$$

We note that this is the most precise single determination of $\sin^2\theta_W^{\rm eff}$ yet performed. Combining this value of $\sin^2\theta_W^{\rm eff}$ with our previous measurement at $E_{\rm c.m.} = 91.55$ GeV [2], we obtain the value, $\sin^2\theta_W^{\rm eff} = 0.2294 \pm 0.0010$ which corresponds to the pole asymmetry, $A_{LR}^0 = 0.1637 \pm 0.0075$.

7. Conclusions

We have performed the most precise single determination of $\sin^2\theta_W^{\rm eff}$ to date. Our method has small and well understood systematic errors and a total error presently dominated by statistical uncertainties (the statistical error is over two times larger than the relative systematic uncertainty of 1.7%). If we combine the 1993 value of $\sin^2\theta_W^{\rm eff}$ with our previous measurement from 1992, we obtain the value, $\sin^2\theta_W^{\rm eff} = 0.2294 \pm 0.0010$. This result can be compared to the determination of $\sin^2\theta_W^{\rm eff}$ from measurements of unpolarized asymmetries at the Z^0 resonance performed by the LEP collaborations (ALEPH, DELPHI, L3, and OPAL). The LEP collaborations combine roughly 30 individual measurements of quark and lepton forward-backward asymmetries and of final state τ-polarization, to give a LEP global average of $\sin^2\theta_W^{\rm eff} = 0.2322 \pm 0.0005$ [26]. The LEP and SLD results differ by about 2.5 standard deviations. It is interesting to note that in order to bring the SLD result into coincidence with the LEP average the reported polarization would have to shift by 14% relative, or over ten times our quoted systematic uncertainty. A fit to all the world's data from the e^+e^- experiments, the W mass measurements, deep inelastic neutrino experiments, and atomic parity violation measurements give a result consistent with the standard model; the constaints in the S,T plane for the individual measurements are shown in Figure 4, and the global fit contour is shown in Figure 5. The central value for this fit is $S = -0.34 \pm 0.23$, $T = 0.25 \pm 0.22$. If the LEP results for $\sin^2\theta_W^{\rm eff}$ are excluded from the fit, the result becomes $S = -1.05 \pm 0.36$, $T = 0.05 \pm 0.24$. We note that negative values for S cannot be accomodated in most extensions of the standard model.

Due to the large radiative corrections to the asymmetries arising from the heavy top quark, our tests will become even more stringent if the recent results for the top mass ($m_t = 174 \pm 16$ GeV) presented by the CDF collaboration [27] are confirmed.

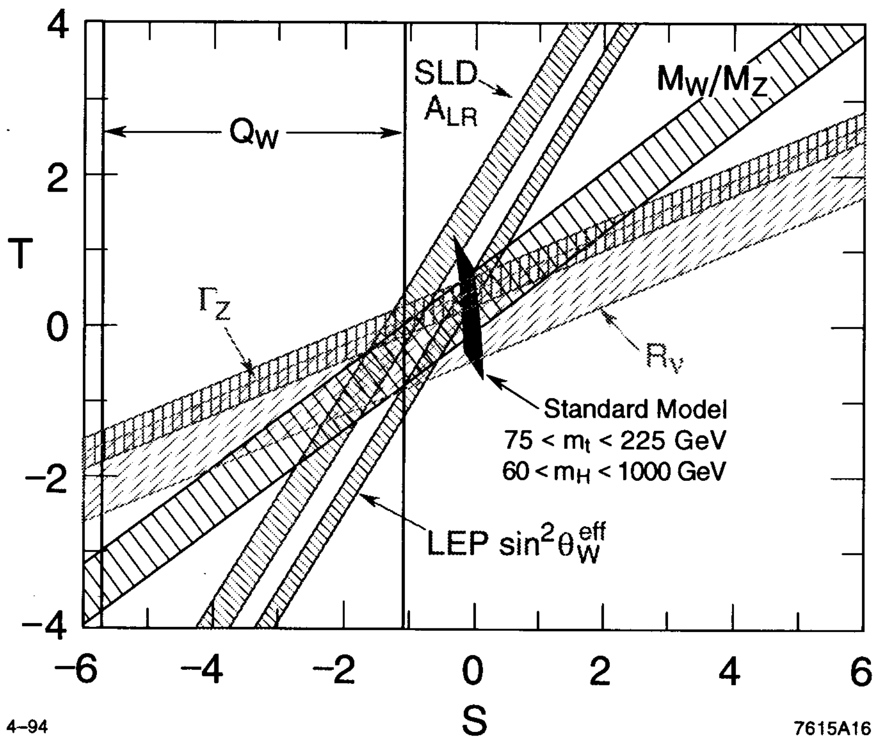

Figure 4: Constraints on S,T from electroweak data.

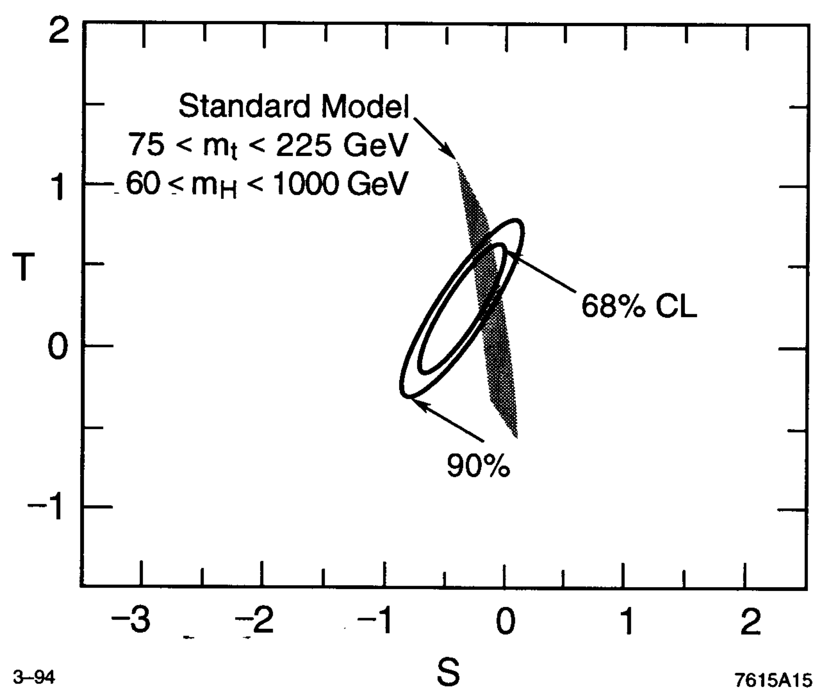

Figure 5: S,T fit to the world's electroweak data.

If the standard model is assummed to be correct, the SLD A_{LR} result predicts the pole top mass to be $m_t = 250$ GeV $\pm$ 20 GeV (exp) $\pm$ 20 GeV (m_H), where the second error reflects our ignorance regarding the Higgs mass in the range 60 GeV to 1000 GeV and should not be interpreted as a gaussian error. This deviates from the CDF result by a little more than 2 standard deviations [28].

The present running period for SLD began June 1, 1994, and the expected integrated luminosity for this run is expected to be over 100K events. Due to further improvements in the polarized source, the electron beam polarization has already been increased to about 80%. We anticipate reducing our systematic error to the 1% level, and should achieve a precision of ± 0.0005 for $\sin^2\theta_W^{\rm eff}$ with this new data. With LEP errors improving as well, the electroweak precision enterprize should be very exciting in the coming year.

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8. T. Limberg, P. Emma, and R. Rossmanith, SLAC–PUB–6210 (May 1993).
9. J. Kent *et al.,* SLAC–PUB–4922 (March 1989).
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11. See S. B. Gunst and L. A. Page, *Phys. Rev.* **92** (1953) 970.
12. It is important to account for atomic momentum effects in the Møller target. See L. G. Levchuk, KHFTI–92–32 (June 1992); and M. Swartz *et al.,* SLAC–PUB–6467 (May 1994).
13. The form for $\mathcal{L}(E)$ used here is dominated by chromatic effects and maximizes the luminosity weighted polarization.
14. The calibration of the UC Irvine Mott polarimeter is described in H. Hopster and D. L. Abraham, *Rev. Sci. Instrum.* **59** (1988) 49.
15. *The SLD Design Report*, SLAC Report 273, 1984.
16. D. Axen *et al., Nucl. Inst. Methods* **A328** (1993) 472.
17. The energy imbalance is defined as a normalized vector sum of the energy clusters as follows, $E_{imb} = \sum |\vec{E}_{\text{cluster}}| / \sum |E_{\text{cluster}}|$.
18. E. Fahri, *Phys. Rev. Lett.* **39** (1977) 1587.

19. The beam helicity 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.

20. 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.

21. 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 would affect the measurement.

22. S. C. Berridge *et al., IEEE Trans. Nucl. Sci.* **NS–39** (1992) 242.

23. 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 (leads to a symmetric acceptance in polar angle).

24. A. A. Sokolov and I. M. Ternov, *Dokl. Akad. Nauk. SSSR* **153** (1963) 1052.

25. The quantities A^0_{LR} and $\sin^2\theta_W^{\rm eff}$ are related by equation (6) and are completely equivalent. In units of $\sin^2\theta_W^{\rm eff}$, the electroweak interference correction is -0.0004. Our calculation agrees with results given by the EXPOSTAR program described in D. C. Kennedy *et al., Z. Phys.* **C53** (1992) 617, and by the ZFITTER program described in D. Bardin *et al.,* CERN–TH. 6443/92 (May 1992).

26. The LEP results were presented by A. Blondel and M. Pepe-Altarelli at this conference. See also CERN–PPE/93–157 (August 1993).

27. F. Abe *et al.,* FERMILAB–PUB–94–097-E (April 1994), submitted to *Phys. Rev. D.*

28. See Ref. [3], M. Swartz, regarding the effect of the value of $\alpha(M_Z^2)$ on the global fit results given here.

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