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Measurements of Parity-Violation Parameters at SLD*

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Abstract

We present direct measurements of the parity-violation parameters A_b, A_c, and A_s at the Z^0 resonance with the SLD detector. The measurements are based on approximately 530k hadronic Z^0 events collected in 1993-98. Obtained results are $A_b = 0.914 \pm 0.024$ (SLD combined: preliminary), $A_c = 0.635 \pm 0.027$ (SLD combined: preliminary), and $A_s = 0.895 \pm 0.066(stat.) \pm 0.062(sys.)$.

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1 Introduction

In the Standard Model, the Z^0 coupling to fermions has both vector (v_f) and axial-vector (a_f) components. Measurements of fermion asymmetries at the Z^0 resonance probe a combination of these components given by $A_f = 2v_f a_f/(v_f^2 + a_f^2)$. The parameter A_f expresses the extent of parity violation at the $Zf\bar{f}$ vertex and its measurement provides a sensitive test of the Standard Model.

At the Stanford Linear Collider (SLC), the ability to manipulate the longitudinal polarization of the electron beam allows the isolation of A_f through formation of the left-right forward-backward asymmetry:

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

where P_e is the longitudinal polarization of the electron beam, and $z = \cos\theta$ is the direction of the outgoing fermion relative to the incident electron.

The measurements described here are based on 530k Z^0-decay events taken in 1993-98 with the SLC Large Detector (SLD)[1]. The average electron polarization is $|P_e| = 73 \pm 0.5\%$[2]. Polarized electron beams, a small and stable SLC interaction region, the high resolution CCD vertex detector[3], and the excellent particle identification with Čerenkov Ring imaging Detector (CRID)[4] provide precision electroweak measurements.

2 A_b measurements

In order to tag the b-quark, topologically reconstructed mass of the secondary vertex[5] is used. The secondary vertex is reconstructed with charged tracks, and its invariant mass is calculated. To account for neutral particles and missing tracks, the vertex mass is corrected: we calculate the P_T-corrected mass M_{P_T} by estimating a missing P_T from the acolinearity between the momentum sum of the vertex and the direction of the vertex flight path. Applying the cut of $M_{P_T} > 2\ GeV/c^2$, we identify the b-quark with 98% purity and 50% efficiency.

To determine the b-quark charge, we uses 4 different methods: 1) vertex charge, 2) jet charge, 3) cascade kaon and 4) lepton.

The vertex-charge analysis uses the track charge sum of the secondary vertex to identify the charge of the primary quark[6]. We introduce the Neural Network technique to reject background and to associate the tracks to the secondary vertices. It improves the b-tagging efficiency to 57%. In this analysis, we reconstruct the tracks which has hits in the vertex detector only. By adding such tracks, we enhance the charge separation performance to 83%. The b-tagging purity and correct charge probability are estimated using opposite hemisphere information.

In the jet-charge analysis, we use the net momentum-weighted jet-charge[7]. The track charge sum and difference between the two hemispheres are used to extract the analyzing power from data, thereby reducing MC dependencies and lowering systematic effects.

In the kaon analysis, we use the charged kaon in the decay $\bar{B} \to D \to K^-$, to determine the b charge[8]. CRID is used to identify $K^\pm$ with high-impact parameter tracks. The charges of the kaon candidates are summed in each hemisphere and the difference between the two hemisphere charges is used to determine the polarity of the thrust axis for the b-quark direction.

Electrons and muons are used to identify the charge and direction of the primary b quark[9]. Geometrical information is used to separate cascade and prompt leptons. In the electron analysis, we also use the Neural Network for source classification.

Fig.1 shows the preliminary results from the SLD and LEP measurements, where the LEP measurements are derived from $A_b = 4A_{FB}^{0,b}/(3A_e)$ using $A_e = 0.1500 \pm 0.0016$ (the combined SLD A_{LR} and LEP A_{lepton}). The combined preliminary SLD result for A_b is obtained as $A_b = 0.914 \pm 0.024$.

3 A_c measurements

At the SLD, four different techniques are used to measure the A_c: 1) inclusive charm-asymmetry measurement with kaon charge and vertex charge, 2) lepton, 3) exclusively reconstructed D^* and D-mesons, and 4) using P_T spectrum of soft-pion from D^*.

In the inclusive charm analysis, c-quarks are tagged using intermediate P_T-corrected-mass vertices[10]. It provides 82% purity and 29% efficiency for $Z^0 \to c\bar{c}$ events. A b veto is applied to reject any event with high vertex mass in either hemisphere. For the hemispheres with a secondary vertex, a secondary track identified as $K^\pm$ from the CRID, or a non-zero vertex charge, is used to sign the charm quark direction. The background is mostly b events and its fraction is constrained by the double-tag calibration. This analysis has significantly high statistical power and the systematic errors are still very much under control.

We also measure the charm asymmetry with traditional technique using electrons and muons which not only tag the c events but also determine the c-quark direction from the lepton[9].

The exclusive reconstruction of charmed mesons provide the cleanest technique for the charm-asymmetry measurements[11]. We use four decay modes to identify D^{*+}: the decay $D^{*+} \to \pi_s^+ D^0$ followed by $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^0$ (Satellite resonance), $D^0 \to K^-\pi^+\pi^-\pi^+$, or $D^0 \to K^- l^+ \nu_l$ (l =e or μ). We also identify D^+ and D^0 mesons via the decay of $D^+ \to K^-\pi^+\pi^+$ and $D^0 \to K^-\pi^+$ (not from D^{*+}). In this analysis, we reject $Z^0 \to b\bar{b}$ events using P_T-corrected mass of the reconstructed vertices. The random-combinatoric background can be estimated from the mass sidebands.

The soft-pions from the decay $D^{*+} \to D^0\pi_s^+$ are also used to tag c-quarks[11]. To determine the D^* direction, charged tracks and neutral clusters are clustered into jets. We also reject the $b\bar{b}$ background using P_T-corrected-mass of reconstructed vertices. Using the momenta transverse to the jet axis (P_T) for tracks, we select the soft-pion candidates which have small P_T value. The largest systematic uncertainty is the choice of the background P_T shape.

Fig.2 shows the preliminary results from the SLD and LEP measurements. The combined preliminary SLD result for A_c is obtained as $A_c = 0.635 \pm 0.027$.

4 Measurement of A_s

In this analysis, we use high-momentum strange particles[12]. We require both event hemispheres have $K^{\pm}$ with $p > 9$ GeV/c, or K_s^0 with $p > 5$ GeV/c. CRID is used to identify $K^{\pm}$. To determine the s-quark charge, we require at least one hemisphere have $K^{\pm}$. The heavy-quark background are rejected by identifying B and D decay vertices. We obtain 66% purity for $Z^0 \to s\bar{s}$ events.

From the 1993-98 SLD data, we get the result of $A_s = 0.895 \pm 0.066(stat.) \pm 0.062(sys.)$. As a test of d-type quark universality, we compare it with the SLD combined A_b measurement: $A_b/A_s = 1.02 \pm 0.10$. These are consistent within the error.

5 Conclusion

SLD produces world class measurements of parity-violation parameters. The SLD measurements of A_c and A_s are now the most precise single measurements in the world. The measured A_b, A_c and A_s results are consistent with the Standard Model.

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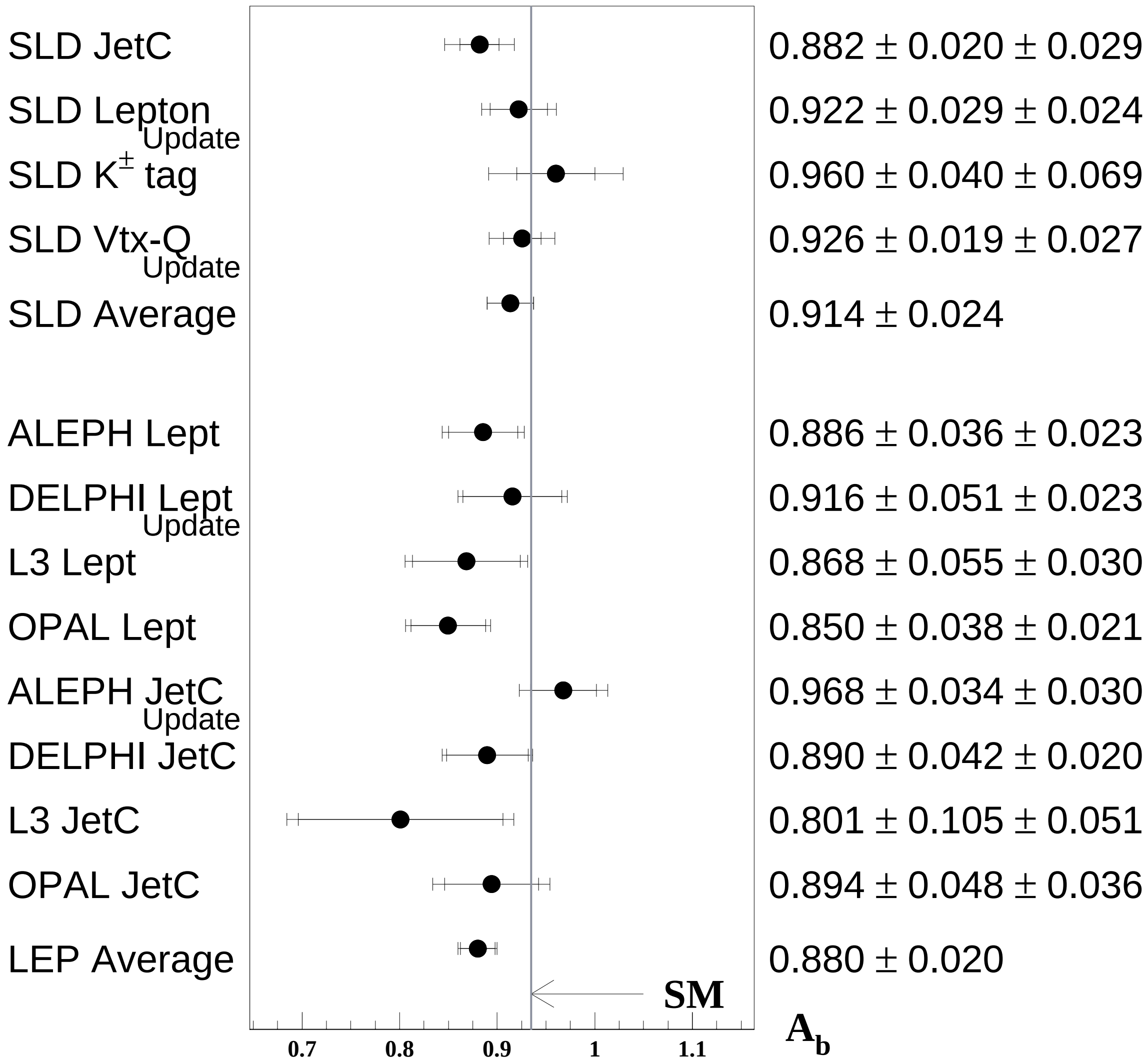

Figure 1: The world A_b measurements (Summer 2000). LEP measurements are derived from $A_b = 4A_{FB}^{0,b}/(3A_e)$ using $A_e = 0.1500 \pm 0.0016$ (the combined SLD A_{LR} and LEP A_{lepton}).

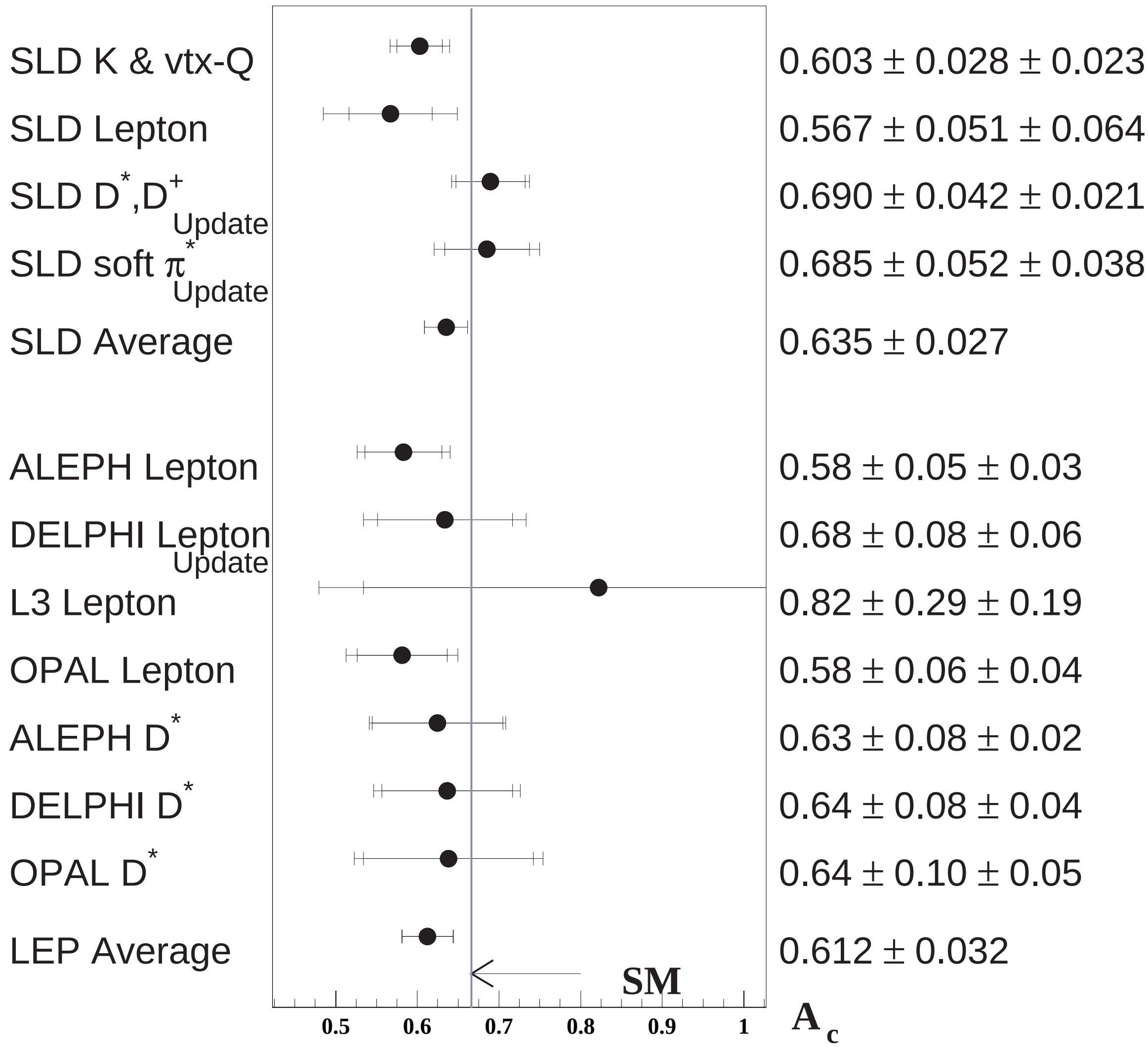

Figure 2: The world A_c measurements (Summer 2000). LEP measurements are derived from $A_c = 4A_{FB}^{0,c}/(3A_e)$ using $A_e = 0.1500 \pm 0.0016$ (the combined SLD A_{LR} and LEP A_{lepton}).