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Z^0 Pole Measurements of Parity Violation Parameters A_b and A_c at SLC/SLD*

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Abstract

SLC/SLD provides the ideal experimental environment to directly measure the parity violation parameters at the $Zb\bar{b}$, $Zc\bar{c}$ vertex decays. Three different analysis techniques exploit the multi-purpose detector capabilities and are briefly described; the updated result obtained with the semileptonic decay method is presented.

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1 Introduction

The electroweak process $e^+e^- \to Z^0 \to f\overline{f}$ is described at the tree level by the differential cross-section

$$\frac{d\sigma^f}{d\cos\theta} \propto (1 \mp A_e|P_e|)(1+\cos^2\theta) + 2(A_e \mp |P_e|)A_f\cos\theta, \qquad (1)$$

where $P_e = \pm|P_e|$ is the initial state longitudinal polarization ($P_e = 0$ if unpolarized), θ is the polar angle of f fermion and $A_{f(e)}$ is the parity violation parameter of the $Zf\overline{f}$ ($Ze\overline{e}$) vertex coupling. The slope of the $\cos\theta$ linear term in Eq. 1 is the product of A_f with an "effective" initial state parity violation parameter, $A_e - P_e$, which is equal to A_e if $P_e = 0$ and increases (decreases) if $P_e \to -100\%$ ($+100\%$). The Standard Model value of A_e is $\approx$ 0.16.

In order to directly measure A_f it is necessary:

(i) to isolate the $\cos\theta$ linear term in Eq. 1; this can be done by forming the *Forward-Backward* cross-sections combination

$$F - B = \sigma^f(\cos\theta) - \sigma^f(-\cos\theta) \sim 4(A_e \mp |P_e|)A_f|\cos\theta| \qquad (2)$$

(FB asymmetry after normalization);

(ii) to eliminate the A_e dependency; this can be achieved, if $P_e \neq 0$, by a

Left-Right combination of $F - B$ expressions ($LRFB$ asymmetry) :

$$\frac{(F-B)_L - (F-B)_R}{(F+B)_L + (F+B)_R} = \frac{2|P_e|A_f|\cos\theta|}{1+|\cos\theta|^2}. \tag{3}$$

A sample of 100,000 Z^0 decays collected in the 1994-95 run with average electron beam polarization $|P_e| = (77.2 \pm 0.5)\%$, and 50,000 Z^0 decays collected in the 1993 run with $|P_e| = (63.0 \pm 1.1)\%$, has been analyzed with three different techniques; competitive determinations of A_b and A_c have been obtained given the large statistical gain, compared to FB asymmetry measurements, of $(P_e/A_e)^2 \sim 25$ (at $|P_e| \sim 75\%$) provided by the $LRFB$ asymmetry.

The selection of $Z^0 \to b\bar{b}$ ($Z^0 \to c\bar{c}$) event can be implemented with different techniques: in the following we will describe the b event selection procedure.

2 Semileptonic Decay Method

A b flavor tag is performed in this method by exploiting the charge correlation between lepton and parent b quark in semileptonic B hadron decays. The b quark direction estimator is the lepton closest reconstructed jet axis (JADE reconstruction procedure [1]).

Electrons and muons identification algorithms rely on the response of the Liquid Argon Calorimeter [2] and the Warm Iron Calorimeter [3] respectively. Both algorithms take advantage of the Cerenkov Ring Imaging Detector (CRID) [4] response to reduce, with momentum depending efficiencies, misidentified leptons background.

For the electrons, a Neural Network based identification [5] has been implemented to make optimal use of all detector information available. Leptons identification algorithms have been tested on pure data track samples: pions from reconstructed K^0_S decays and electrons from photon conversions in detector material.

SLD Monte Carlo simulation predicts in each bin of track momentum (p) and transverse momentum with respect to the nearest jet (p_t), lepton sources fractions in a scheme of maximum likelihood fit to the differential cross section, in which A_b and A_c are free parameters. Monte Carlo/Data comparison of lepton candidate distributions of p and p_t (Fig. 1) lend us confidence on the correct simulation of the data sample.

The clear experimental asymmetry shown in Fig. 2 is obtained from data using a kinematical cut in p and p_t, not included in the likelihood scheme, which enriches the sample of b decay leptons to a purity of $\sim 70\%$.

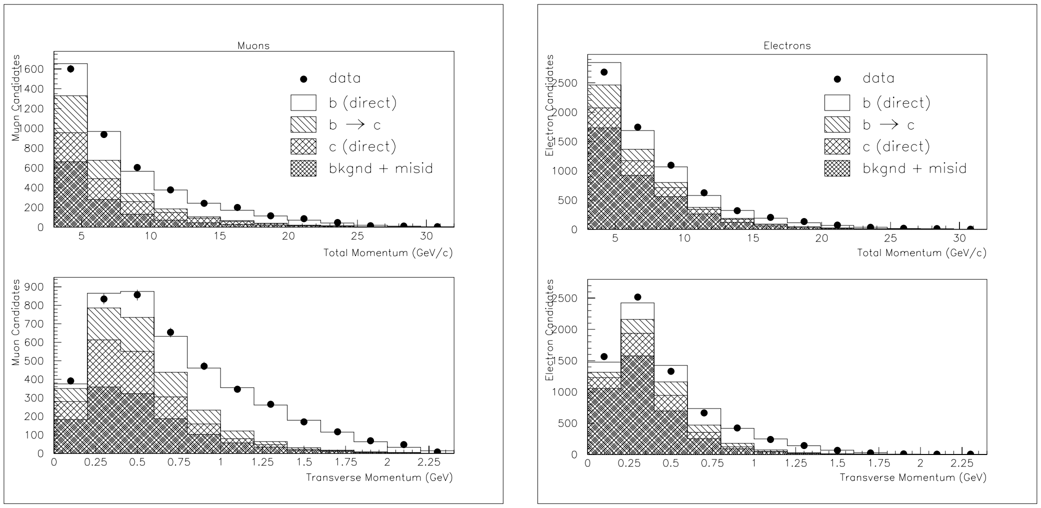

Figure 1: *MC/Data muons (on left side) and electrons (on right side) distributions of p and p_t.*

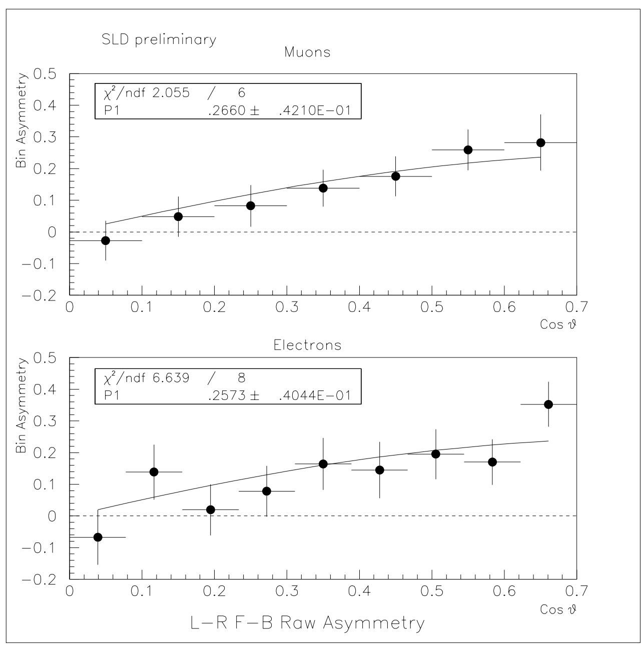

Figure 2: *Experimentally observed Left-Right Forward-Backward aymmetries compared with theoretical function.*

Systematic source	δA_b	δA_c
Lepton mis-ID rate	0.009	0.017
Background asymmetry	0.003	0.022
Jet axis simulation	0.029	0.022
MC weights	0.016	0.017
Tracking efficiency	0.009	0.002
R_b = 0.2216±0.0017	–0.003	0.001
R_c = 0.16±0.01	0.005	–0.030
$\overline{\chi}$ = 0.122±0.006	0.017	0.000
Br($b \to \ell$) = 10.75±0.23%	–0.007	0.010
Br($b \to c \to \ell$) =8.10±0.37%	0.005	–0.023
b fragmentation	0.001	0.006
c fragmentation	0.006	0.014
Br($b \to \bar{c} \to \ell$)	0.005	0.034
Br($b \to \tau \to \ell$)	0.000	0.006
Br($c \to \ell$)	0.004	0.023
$b \to \ell$ model	0.016	0.023
$c \to \ell$ model	0.011	0.007
Beam polarization	0.009	0.005
QCD correction	0.005	0.012
Total systematic	0.047	0.076

Table 1: *Systematic errors for A_b and A_c with the semileptonic method.*

Systematic errors (Tab. 1) have been evaluated according to a world-wide accepted set of prescriptions [6]; the branching ratios used are in much better agreement with the world averages with respect to the 1995 result. The preliminary muon and electron combined results ([7]) for the whole 1993-95 data sample are:

$$A_b = 0.88 \pm 0.07(stat) \pm 0.05(syst),$$

$$A_c = 0.61 \pm 0.10(stat) \pm 0.08(syst).$$

3 Jet-Charge Method

This is the method which holds the highest analysing power [8]: b events are selected using a $2D$ impact parameter tag (61% efficiency and 89% purity); a momentum weighted event charge is then formed to obtain the b flavor tag and sign the thrust axis of the tagged events accordingly.(Fig. 3).

The correct-sign probability can be totally inferred from data (*self-calibration*) under the assumption that event hemispheres are uncorrelated. However interhemisphere correlations are not negligible: they are induced by fundamental physical mechanisms, such as total charge conservation, which are differently described in the available hadronization process models. The systematic in the estimation of hemisphere correlation has been evaluated using three different event generators (Fig. 3) and turns out to be one of the largest errors in the analysis (3.7%).

A maximum likelihood fit including event flavor composition and correct-sign probabilities, is used to extract A_b; the preliminary 1993-95 result obtained is $A_b = 0.843 \pm 0.046(stat) \pm 0.051(syst)$.

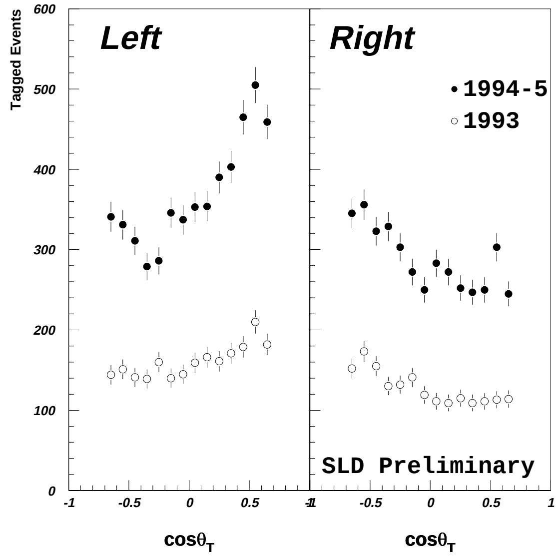

Figure 3: *Distributions of the signed thrust axis for events with* $P_e < 0$ *(left) and* $P_e > 0$ *(right) in the tagged 1993-95 data sample. The clear FB asymmetry described by Eq. 1 is enhanced in the 1994-95 tagged data sample given the higher polarization value.*

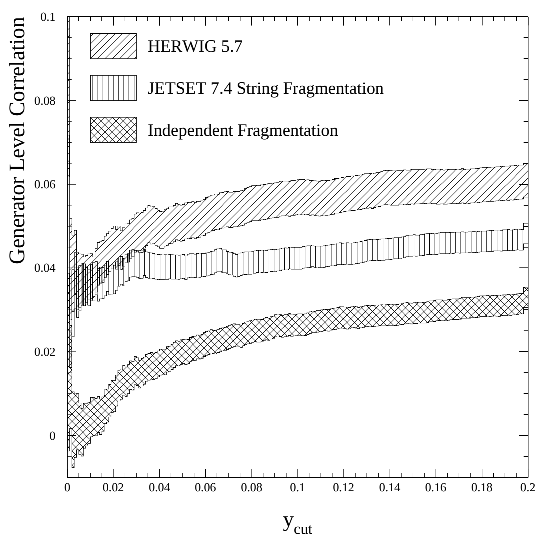

Figure 4: *Comparison of generator-level correlations in the JETSET 7.4 string fragmentation model (default), JETSET's independent fragmentation option, and HERWIG 5.7. The correlations are shown for two-jet events where jets are found with the JADE algorithm, as a function of the jet resolution parameter* y_{cut}.

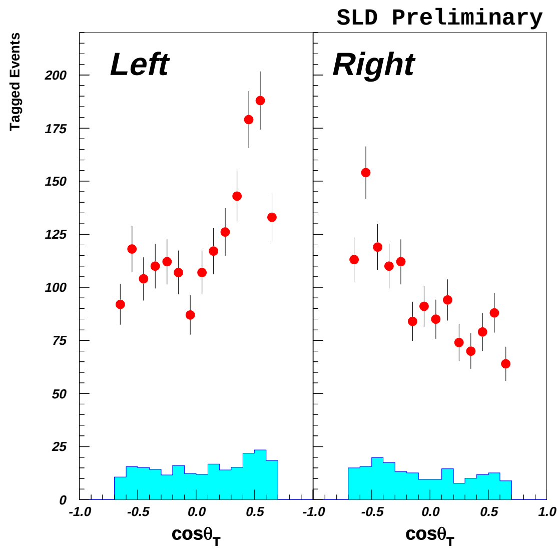

Figure 5: *Distributions of the signed thrust axis with kaon event charge, for events with* $P_e < 0$ *(left) and* $P_e > 0$ *(right) in the tagged 1994-95 data sample. The dashed areas represent the charm background showing the same* FB *asymmetry sign of signal events.*

4 Kaon-Charge Method

This method exploits the kaon production in b events; kaons produced in the decay chain $\overline{B} \to D \to K^-$ inherit the charge sign of b parent quark.

Kaon identification is based on the gas radiator response of the CRID, for tracks in the momentum region $3 - 20\,GeV$, belonging to a lifetime tagged events sample; the identification is calibrated using data pions from K^0_S decays and data τ-decays (1-prong and 3-prong topologies) which have well known small $K^\pm$ production rates ($\pi \to K = 7.2\%$, purity $= 75\%$). The charge of identified kaons is used to build the event charge which signs the event thrust axis (Fig. 5). The fraction of correct signed b events (71%) is obtained from Monte Carlo.

After subtraction of $udsc$ background, A_b is obtained as a Monte Carlo scaling factor needed to fit the $LRFB$ data asymmetry [9]:

$$A_b = 0.91 \pm 0.09(stat) \pm 0.09(syst).$$

5 Combined A_b, A_c Results

A simultaneous fit to A_b and A_c has been performed including all the measurements described in the previous sections and another SLD determination of A_c which uses reconstructed charmed mesons [10]. All the systematic correlations between measurements have being taken into account, the combined SLD results are

$$A_b = 0.863 \pm 0.049$$

$$A_c = 0.625 \pm 0.084.$$

In the $Zb\bar{b}$ parametrization scheme of Takeuchi *et al.* [11], the deviations from the SM predictions are expressed in terms of two quantities, in addition to $\delta sin^2\theta_W^{eff}$: a cross section like variable ξ_b and a parity violation like

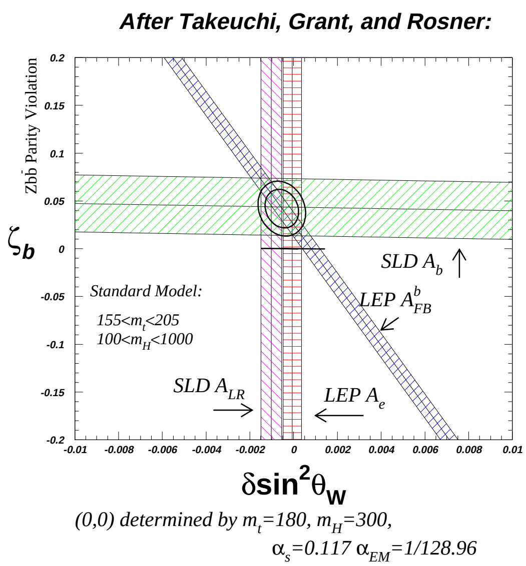

Figure 6: *$Zb\bar{b}$ coupling parity violation vs.* $\delta sin^2\theta_W^{eff}$.

variable ζ_b. Fig. 6 shows the (ζ_b, $\delta sin^2\theta_W^{eff}$) plot as constrained by current experimental results. The SM point at (0,0) is determined by $m_{top} = 180\,GeV$, $m_H = 300\,GeV$, $\alpha_S = 0.117$ and $\alpha_{EM} = 1/128.96$; the horizontal segment below (0,0) is given by SM m_{top}, m_H variations; the 68% and 90% C.L. contours for the best fit to all data are also shown.

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