SLAC-PUB-6362
October 1993
(T/E)

A STUDY OF JET HANDEDNESS AT THE Z^0 RESONANCE*

The SLD Collaboration
Represented by
HIROAKI MASUDA
Stanford Linear Accelerator Center
Stanford, CA 94309 USA

ABSTRACT

We present a preliminary study of jet handedness in hadronic decays of Z^0 bosons measured in the SLD experiment at the SLAC Linear Collider (SLC). Following the proposal of Nachtman and Efremov *et al.*, we defined a scalar quantity for each hadronic jet and measured the sign asymmetry (jet handedness) of this quantity for samples of quark jets and antiquark jets, which are expected to be oppositely polarized in Z^0 decays. From our preliminary study, no evidence for a significantly non-zero handedness was observed. Assuming standard model values of quark polarizations, we set an upper limit on the analyzing power of our handedness method.

Introduction

The transport of parton polarization through the hadronization process is of fundamental interest in quantum chromodynamics (QCD). It is presently an open question whether the polarization of a parton produced in a hard collision is observable via the final-state fragmentation products in its resulting jet. The Z^0 resonance is an ideal place to study this issue because quarks produced in Z^0 decays are expected to be highly polarized. Nachtmann [1] and Efremove *et al.* [2] have speculated that the underlying parton polarization may be observable semi-inclusively via a triple product of track momenta in a jet. They note that the simplest parity-conserving and spin-dependent amplitude has the form: $M \propto \vec{\sigma} \cdot (\vec{k}_1 \times \vec{k}_2)$, where $\vec{k}_i$ are 3-momenta of two decay products, and $\vec{\sigma}$ is the spin of the decaying particle. The simplest example of such a process is the strong decay of the a_1 meson [3]. For a jet, an analogous triple-vector product Ω which might contain information of the longitudinal parton polarization may be defined:

$$\Omega \equiv \frac{\vec{t} \cdot (\vec{k}_1 \times \vec{k}_2)}{|\vec{k}_1 \times \vec{k}_2|}, \qquad (1)$$

where $\vec{t}$ is a unit vector along the jet axis, and $\vec{k}_1$ and $\vec{k}_2$ are the momenta of two particles in the jet chosen by some prescription, *e.g.*, the two fastest particles. The jet is defined as left- (right-) handed if Ω is negative (positive). For an ensemble of jets the handedness is defined as the asymmetry in the number of left- and right-handed jets:

$$H \equiv \frac{N_{\Omega<0} - N_{\Omega>0}}{N_{\Omega<0} - N_{\Omega>0}}. \qquad (2)$$

It can then be asserted that $H = \alpha P$, where P is the average polarization of the underlying partons in the ensemble of jets, and α is the analyzing power of the handedness method.

A method which observes such a polarization in an e^+e^- annihilation could be applied to samples of jets resulting from lepton-hadron or hadron-hadron collisions, elucidating the spin dynamics of such collisions.

Jet Handedness in Z^0 Decays

The longitudinal polarization P_i of up- (down-) type quarks produced in the decay $Z^0 \to q\bar{q}$ is -0.67 (-0.94) in the Standard Model. The polarizations of the quark and antiquark have the same magnitude but opposite signs. The average polarization of all jets in Z^0 decays is therefore zero. One must distinguish quark from antiquark jets to observe a non-zero polarization. One way to do this is to take the charge of tracks in the jets into account and define the triple-vector product Ω such that $\vec{k}_1$ is always a positive track momentum and $\vec{k}_2$ a negative one. Because quarks and antiquarks of a given flavor have opposite charges, the handedness of the two types of jets is expected to be equal. With this definition, however, the sign of the handedness should be opposite for up- and down-type quarks. One might then expect a maximum observable handedness of

$$H^{ch} = \frac{2P_u\sigma_u - 3P_d\sigma_d}{2\sigma_u + 3\sigma_d} \simeq 0.39, \qquad (3)$$

where σ_u and σ_d are the production cross sections of up- and down-type quarks, respectively.

The SLD [4] is uniquely placed to separate samples of quark and antiquark jets using the large forward-backward asymmetry induced by the highly polarized electron beam in the SLC [5]. For jets in the forward

*Work supported by Department of Energy contract DE–AC03–76SF00515.

hemisphere, defined as in the direction of the electron beam, one would expect a maximum handedness,

$$H^{pol} = \frac{2P_u\sigma_u + 3P_d\sigma_d}{2\sigma_u + 3\sigma_d} A_{FB} \simeq 0.84 A_{FB}, \qquad (4)$$

where A_{FB} is the forward-backward quark asymmetry which depends on the electron beam polarization p_e. Electrons of mean longitudinal polarization $\pm 22\%$ (1992) and $\pm 62\%$ (1993) were used to produce Z^0 bosons at the SLC.

Handedness Measurements

The analysis presented here is based on charged tracks measured in the central drift chamber, and in the vertex detector. The triggers and selection used for hadronic events are described in [6]. From the 1992 and the first part of the 1993 data samples, 6476 and 20662 events were used for this analysis, respectively.

Charge Analysis

We first applied a method similar to that reported by Efremov [7]. A sample of $q + \bar{q}$ jets was selected in the following manner. First, events were required to be classified as 2-jet events using the JADE clustering algorithm [8] at y_{cut}=0.03, and the jet acolliniarity angle was required to be less than 20°. The charge sum of the three highest-momentum tracks in each jet was required to be ± 1, and the invariant masses of both opposite-sign pairs to be between 0.6 and 1.6 GeV/c^2, where the particles were assumed to have the pion mass. These cuts are intended to select jets containing particles whose strong decays resemble those of the a_1 meson. For each jet the handedness measure Ω (eq.(1)) was calculated using higher invariant mass pair and taking $\vec{k}_1$ as the momentum of the positive charged particle and $\vec{k}_2$ as that of the negative one. Taking the asymmetry (eq.(2)) to obtain the handedness, we found: $H^{ch}_{meas.} = 2.4 \pm 1.1$(stat.)% (*preliminary*). Our measurement may be related to the expected Standard Model handedness via the analysing power of the method $H^{ch}_{meas.} = \alpha^{ch} H^{ch}$ from which we derived $\alpha^{ch} = 6.1 \pm 2.7$(stat.)% (*preliminary*), which corresponds to an upper limit of $\alpha^{ch} < 11\%$ at 95% confidence level.

Polarization Analysis

Next we define Ω by considering the three fastest particles in each jet which was selected by the same jet selection criteria as the *charge analysis*, taking the pair with highest invariant mass, and assigning $\vec{k}_1$ as the momentum of the fastest particle, irrespective of its charge. The handedness was then calculated separately for forward and backward jets in events produced with left- and right-handed electrons. The results from the 1993 data are shown in Table 1.

Table 1: Measured handedness (%) in forward and backward jets in events produced with average longitudinal polarization p_e of electron beam. The sign in parentheses indicates the expected handedness sign from the Standard Model prediction for each case. All results are preliminary.

p_e (%)	-62	$+62$
forward	-2.1 ± 2.4 $(-)$	$+0.9 \pm 2.6$ $(+)$
backward	-1.7 ± 2.4 $(+)$	-3.1 ± 2.7 $(-)$

With the present statistics, no evidence for a non-zero handedness is observed. We combined the forward and backward results by changing their relative signs and averaged the left- and right-handed electron polarization results to get the analysing power α^{pol} of this method, where $H^{pol}_{meas}(p_e) = \alpha^{pol} H^{pol}(p_e)$. The result is $\alpha^{pol} = 4.9 \pm 4.8$(stat.)%, (*preliminary*) which corresponds to an upper limit of $\alpha_{pol} < 14\%$ at 95% confidence level.

Systematic Checks

We performed the handedness analysis on event samples generated using Monte Carlo programs, JETSET [9] and HERWIG [10], which simulate the hadronic decays of Z^0 bosons. The transfer of spin polarization in the non-perturbative hadronization regime has not been calculated in QCD. One would therefore expect to obtain zero handedness for these event samples. Any statistically significant non-zero handedness would indicate an intrinsic bias in the handedness method. Handedness consistent with zero within statistical errors was obtained for both the JETSET and HERWIG event samples. This indicates that this handedness method does not produce any intrinsic bias.

Summary

We have searched for evidence of parton polarization in hadronic Z^0 decays using the jet handedness technique. We found no evidence, within statistical errors, for a non-zero handedness with our method. We are continuing our investigation of the handedness methods to observe parton polarization.

References

[1] O. Nachtmann, *Nucl. Phys. B* 127 (1977) 314.

[2] A.V.Efremov it et al., CERN–TH.6430/92 (1992).

[3] N. A. Törnqvist, HU–TFT–92–50 (1992).

[4] SLD Design Report, SLAC–REPORT 273, (1984).

[5] N. Phinney, *Int. J. Mod. Phys. A, Proc. Suppl.* **2A** (1993) 45.

[6] SLD Collab., K. Abe *et al.*, *Phys. Rev. Lett.* **70** (1993) 2515, SLD Collab., K. Abe *et al.*, *Phys. Rev. Lett.* **71** (1993) 2528.

[7] A. V. Efremov, talk presented at the *10th International Symposium on High Energy Spin Physics*, Nagoya, Japan, November 1992.

[8] JADE Collab., W. Bartel *et al.*, *Z. Phys.* **C33** (1986) 23.

[9] T. Sjöstrand, *Comput. Phys. Commun.* **43** (1987) 367.

[10] G. Marchesini and B. R. Webber, *Nucl. Phys. B* **310** (1988) 461; I. Knowles, private communications.