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MEASUREMENTS OF GLUON SPIN-SENSITIVE QUANTITIES AT THE Z^0 RESONANCE*

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Abstract

We present preliminary measurements of scaled jet energies and the Ellis-Karliner angle in 3-jet hadronic events from the Z^0 decay. Good agreement is found between the data and the QCD prediction. A scalar gluon model is clearly excluded.

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1. Introduction

Distributions of the scaled jet energies and the Ellis-Karliner angle¹, θ_{EK} , in $Z^0 \rightarrow q\bar{q}g$ events are sensitive to the spin of the gluon. Several groups^{2,3} have used these distributions to determine the gluon spin and to test a scalar gluon model at energies around 30 GeV. We present these distributions at the Z^0 resonance, where the differences between the vector gluon (QCD) predictions and the scalar gluon predictions are larger. Similar analyses were done at OPAL⁴ and L3⁵.

Fig 1. the 3-jet event plane (a), and the Ellis-Karliner Angle (b).

The $\mathcal{O}(\alpha_s)$ cross-section for $q\bar{q}g$ events in e^+e^- annihilation at the Z^0 resonance can be written, assuming massless partons, as^{6,7}:

$$\frac{d^2\sigma^V(x_1, x_2)}{dx_1 dx_2} \sim \frac{x_1^3 + x_2^3 + (2 - x_1 - x_2)^3}{(1 - x_1)(1 - x_2)(x_1 + x_2 - 1)} \quad (1)$$

$$\text{or } \frac{d^2\sigma^S(x_1, x_2)}{dx_1 dx_2} \sim \frac{x_1^2(1 - x_1) + x_2^2(1 - x_2) + (2 - x_1 - x_2)^2(x_1 + x_2 - 1)}{(1 - x_1)(1 - x_2)(x_1 + x_2 - 1)} - \frac{10C_a^2}{C_v^2 + C_a^2} \quad (2)$$

where $x_i = 2E_i/E_{cm}$, $x_1 > x_2 > x_3$, are the scaled parton energies (Fig. 1a), and C_v and C_a are the vector and axial-vector coupling constants. Eq. (1) is from the vector gluon (the standard QCD) theory, and Eq. (2) is from a scalar gluon model. For massless partons, one has:

$$x_i = \frac{\sin\theta_i}{\sin\theta_1 + \sin\theta_2 + \sin\theta_3} \quad (i = 1, 2, 3) \quad (3)$$

$$\cos\theta_{EK} = \frac{(x_2 - x_3)}{x_1} \quad (4)$$

where the θ_i are the angles between the two jets opposite to jet i ; and θ_{EK} , the Ellis-Karliner angle, is the angle between jets 1 and 2 in the rest frame of jets 2 and 3 (see Fig. 1b). The cross-section can also be written in terms of any single x_i and $\cos\theta_{EK}$. Distributions of each individual variable, obtained by integration of the above cross-sections, are clearly different for the two gluon spins.

2. Data Selection

A total of 9,000 hadronic Z^0 s measured by the SLD⁸ experiment are used in this analysis. We use only the charged tracks measured in the central drift chamber⁸.

Details of the track and event selection cuts are described elsewhere⁹. 3-jet events are selected at $y_{cut} = 0.02$ using the JADE jet-finding algorithm¹⁰. We require $|\cos\bar{\theta}| > 0.704$ where $\bar{\theta}$ is the angle between the electron beam direction and the normal to the event plane (Fig. 1a). 1418 events survived these cuts. The background in the three-jet sample from non-hadronic Z^0 decays is negligible.

3. Results and Conclusion

The variables x_i and $\cos\theta_{EK}$ are calculated using Eqs. (3) and (4) and the jet axes from the JADE jet-finding algorithm. Using only the angles reduces the effects of not detecting all the energy in each jet. Monte Carlo events are generated using the JETSET 6.3¹¹ and HERWIG 5.3¹² programs and passed through a detailed SLD detector simulation and the same selection criterion as applied to the real data. The Monte Carlo results and the data agree well within statistical errors. A bin-by-bin correction is applied using the JETSET 6.3 simulation to correct the data to

Fig. 2 comparison of the measured distributions with vector(QCD) and scalar gluon predictions at the parton level.

the parton level. Fig. 2 shows the corrected distributions of x_1 , x_2 , x_3 and $\cos\theta_{EK}$, compared with leading order scalar and vector (QCD) gluon calculations. Both equations 1 and 2 are implemented in JETSET 7.3¹¹ program, by which all the theoretical distributions are generated. The vector gluon calculation agrees with the data. The scalar gluon model does not agree with the data. The following table shows the χ^2 per degree of freedom between the data and calculations.

χ^2/df between data and vector/scalar gluon predictions.				
	x_1	x_2	x_3	$\cos\theta_{EK}$
Vector Gluon	0.69	1.17	1.01	0.99
Scalar Gluon	7.33	17.1	16.5	22.9

In conclusion, a scalar gluon model is convincingly excluded by the data, which is in good agreement with the predictions of QCD. Similar results were obtained at OPAL⁴ and L3⁵.

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