POLARIZATION MEASUREMENTS IN ALEPH

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Measurements of the longitudinal polarization of various final state particles from Z decays have been performed with the ALEPH apparatus. Using all Z decays measured at LEPI and a new method in the τ analysis, new preliminary results are obtained for the τ polarization in Z decays into τ pairs, for the ν_τ helicity and for the Λ and Λ_b polarization in hadronic Z decays.

1 Introduction

The presence of both vector and axial vector $Zf\bar{f}$ couplings gives rise to longitudinal polarization in final state fermions from $e^+e^- \to Z \to f\bar{f}$. In the Standard Model this is predicted to be about -15% for leptons, -68% for *up*-type quarks and -94% for *down*-type quarks, depending on the value of $\sin^2\Theta_W$ and the τ polar angle. The measurement of τ polarization as a function of polar angle provides a determination of g_V/g_A for both electrons and taus. This gives a test of lepton universality and, in the context of the Standard Model, an accurate determination of the electroweak mixing angle.
The polarization of final state hadrons not only depends on the quark couplings to the Z, but also on the degree of spin-transfer from the quark to the final hadron. There exists no 'standard hadronization model' dealing with spin-transfer, but the measurements of the Λ and Λ_b polarization can perhaps serve as a guide for future models.

2 τ and ν_τ polarization

The competitive advantage of ALEPH in the measurement of the τ polarization comes mainly from its highly segmented electromagnetic calorimeter, enabling a sensitive analysis of the $\rho\nu_\tau$ and $a_1\nu_\tau$ channels with subsequent decays into final states with π^0's. In previous determinations the 'single τ method' was used [1], where the splitting of the events into two independent hemispheres is emphasized. Here a 'τ direction method' is used in addition, where silicon vertex detector information assists in choosing between the two ambiguous solutions to the τ direction in purely hadronic decays [2]. Since the event selection differs in the two methods, they are independent to a large degree. Both methods use a single optimized variable obtained from the momenta of the decay particles to estimate the polarization [3].

The longitudinal polarization, combining the results of the two methods [4] and using all the data at the Z peak, is subdivided into 9 bins of the lepton polar angle. Since the Z has spin 1, this function is given by:

$$P_\tau(\cos\Theta) = -\frac{A_\tau(1+\cos^2\Theta) + A_e 2\cos\Theta}{(1+\cos^2\Theta) + \frac{4}{3}A_{FB}2\cos\Theta} \quad (1)$$

$$A_l = \frac{2g_{Vl}g_{Al}}{g_{Vl}^2 + g_{Al}^2} \quad (2)$$

$$A_{FB} = \frac{3}{4}A_e A_\tau \quad (3)$$

From a fit [4] to the $\cos\Theta$ distribution above, the following asymmetries are extracted by ALEPH:

$$A_\tau = 14.52 \pm 0.55 \pm 0.32\% \quad (4)$$

$$A_e = 15.05 \pm 0.69 \pm 0.10\% \quad (5)$$

The ratio of the two asymmetries is 1.04 ± 0.06 – in agreement with lepton universality. Assuming universality, we get $A_l = 0.1475 \pm 0.0046$, and combining with the other three LEP measurements of τ polarization [5], we get $A_l = 0.1452 \pm 0.0034$. In the Standard Model this translates to:

$$\sin^2\Theta_W = 0.23176 \pm 0.00043 \quad (6)$$

This is consistent with the determination of $\sin^2\Theta_W$ from SLD, and is of similar accuracy. Thus about 60% of the weight in the world average value of $\sin^2\Theta_W$ comes from polarization measurements.
Using similar techniques, the ν_τ helicity has been determined by ALEPH to be [6]:

$$h_{\nu_\tau} = -0.992 \pm 0.011 \quad (7)$$

in good agreement with the Standard Models assumption of V-A structure in τ decays.

3 Λ and Λ_b polarization

The published studies of Λ polarization [7] and Λ_b polarization [8] have been updated with data taken during 1995 and the updates have been presented at earlier conferences [10,9]. The ALEPH result for the longitudinal Λ polarization is:

$$P_\Lambda = -0.311 \pm 0.047 \quad (8)$$

for Λ's carrying more than 30% of the beam momentum (40% on the average). If this is combined with the OPAL measurement [11], the result is: $P_\Lambda = -0.316 \pm 0.040$. The measurements seem to favor a prediction based on the static quark model over another prediction based on the measured polarized nucleon structure functions and SU(3) flavor symmetry (see e.g. Ref. [12] for a discussion and references).

The longitudinal Λ_b polarization is measured from the ratio between the lepton and the neutrino energy (measured from the the missing momentum) in events where a high p_T e^- or μ^- is produced in association with a Λ and a π^+. The updated result is:

$$P_{\Lambda_b} = -0.30^{+0.19}_{-0.16} \tag{9}$$

If we again combine with a recent OPAL measurement [13], the result is: $P_{\Lambda_b} = -0.39 \pm 0.13$. This result can be accommodated by a mechanism [14] whereby the originally strongly polarized b-quark looses its polarization while staying in Σ_b and Σ_b^* resonances before ending its life in a weakly decaying Λ_b.

References

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