

Summary

This thesis investigates the couplings of the Z boson to the electron and the tau lepton. The cross section σ_τ , the forward-backward charge asymmetry $A_{fb,\tau}$ and the polarization asymmetry P of the reaction $e^+e^- \rightarrow Z \rightarrow \tau^+\tau^-$ are determined. These quantities can be precisely calculated in the Standard Model which describes the interactions between elementary particles. This theory predicts the electron and tau couplings to be same. The facilities used to experimentally test this prediction are the L3 detector and the Large Electron Positron collider at CERN.

The constants describing the couplings of the Z boson to the electron and the tau are the axial and vector-axial neutral current coupling constants g_{Ae} , g_{Ve} , $g_{A\tau}$ and $g_{V\tau}$ respectively. The first part of chapter 1 shows how they are embedded in the theory. The dependence of σ_τ , $A_{fb,\tau}$ and P on these constants is discussed in the second part of chapter 1.

In the L3 experiment τ 's decay close to the interaction region and only their decay products can be measured. Tau decay proceeds through the intermediate charged vector boson W and is parity violating. Consequently the angular decay distributions of τ decay products depend on the helicity of the τ and from these distributions the polarization is obtained. Chapter 2 discusses this dependence and the connection with the charged current parameters of the W vertex.

The L3 detector registers the decay products from the Z bosons with drift chambers and calorimeters. The signals are reconstructed and trajectories of particles and their momenta or energies are determined. Chapter 3 describes the response of the detector elements to electrons, photons, pions and muons and the signal reconstruction.

The measurements of σ_τ , $A_{fb,\tau}$ and P are presented in chapters 4 to 6. The selection of τ pairs is based on their low multiplicity and their decay into at least one neutrino which carries away part of the τ energy. The cross section, σ_τ , is calculated from the number of selected τ pairs and the integrated luminosity using estimates of the selection efficiencies. The latter are derived from Monte Carlo simulations or directly from data. The selection efficiency of τ pairs in the full solid angle is close to 50% and the background is 4%. The most precise result is:

$$\sigma_\tau = 1.474 \pm 0.012 \text{ (stat.)} \pm 0.010 \text{ (sys.) nb at } \sqrt{s} = 91.29 \text{ GeV.}$$

The measurement of $A_{fb,\tau}$ uses a subsample of the cross-section sample. The direction of a τ - either forward or backward with respect to the incoming electron - is determined and the full differential cross-section distribution is derived. $A_{fb,\tau}$ follows from a fit to this distribution. The corrections to account for background and charge confusion are very small. The most precisely determined asymmetry is:

$$A_{fb,\tau} = 0.01 \pm 0.01 \text{ (stat.)} \pm 0.002 \text{ (sys.) at } \sqrt{s} = 91.29 \text{ GeV.}$$

The $\tau^- \rightarrow \rho^- \nu_\tau \rightarrow \pi^- \pi^0 \nu_\tau$ decay channel is used to measure the polarization since this decay can be reliably selected and reconstructed and allows the best polarization measurement of all channels. Hemispheres with one charged track are considered and the calorimetric response in a cone around this track is analyzed to determine the number of π^0 's. A ρ is reconstructed if a π^0 and a π^- can be identified, and final selection criteria are applied. The purity of the sample is 86% and the non- τ background 1.5%. The two-dimensional decay distribution is derived from the energies of the ρ and the energy differences of the π^- and the π^0 . Comparison with helicity

dependent Monte Carlo distributions yields the polarization results:

$$\begin{aligned} A_\tau &= -P^0 = 0.139 \pm 0.030 \text{ (stat.)} \pm 0.013 \text{ (sys.)}, \\ A_e &= -\frac{4}{3}P_{\text{fb}}^0 = 0.171 \pm 0.042 \text{ (stat.)} \pm 0.008 \text{ (sys.)}. \end{aligned}$$

In chapter 7 the neutral current coupling constants are obtained from a fit to the measurements of σ_τ , $A_{\text{fb},\tau}$ and $P^0(\cos\theta)$ and the L3 measurements of σ_{had} , σ_e and $A_{\text{fb},e}$. The Standard Model prediction that \bar{g}_{A1} and \bar{g}_{V1} are the same for $l = e, \tau$ is confirmed at the level of 1% and 25% respectively:

$$\left. \begin{aligned} \bar{g}_{A\tau} / \bar{g}_{Ae} &= 1.004 \pm 0.006 \\ \bar{g}_{V\tau} / \bar{g}_{Ve} &= 0.94 \pm 0.27 \end{aligned} \right\} \text{ (this thesis).}$$

The combined data from all LEP experiments and data from the SLD experiment corroborate this conclusion. At the end of the LEP I running period the precision on the above ratios is expected to reach 0.1% and 4% respectively, thus providing a stringent test of the universality of the neutral current coupling constants.