MEASUREMENT OF THE TAU LEPTON LIFETIME WITH THE L3 DETECTOR

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The lifetime of the τ lepton is measured with data collected in 1994 by the L3 detector at LEP. The precise track position information of the Silicon Microstrip Detector is exploited. The τ lepton lifetime is determined from the signed impact parameter distribution for 30322 τ decays into one charged particle and from the decay length distribution for 3891 τ decays into three charged particles. By combining the two methods the preliminary result is $\tau_\tau = 290.1 \pm 4.0$ fs.

1 Introduction

The LEP1 accelerator, running at the Z resonance, provides very favourable conditions for measurement of the τ lepton lifetime - one of the shortest accessible directly in particle physics. The event sample is characterized by high efficiency and purity, and large boost of the τ, leading to an average decay length of ~ 2.2 mm - well above the precision of silicon vertex detectors.

The L3 experiment [1] has installed a Silicon Microstrip Detector (SMD) [2] with intrinsic resolution in the $r - \varphi$ plane of $\sim 8\ \mu m$ in front of the Time Expansion Chamber (TEC) [3] to enhance qualitatively the tracking capabilities. Data collected in 1994 (corresponding to 46 pb^{-1}) are used to measure the τ lifetime with the two classical methods: decay length (DL) in 3-prong and impact parameter (IP) in 1-prong τ decays.

2 Selection of $Z \to \tau^+\tau^-$ Decays

Hadronic Z decays are suppressed by selecting low track multiplicity highly collimated pairs of jets. $e^+e^-(\gamma)$ and $\mu^+\mu^-(\gamma)$ events are reduced by requiring missing energy. The other backgrounds are negligible. In the fiducial volume $|\cos\theta_t| < 0.72$, where θ_t is given by the thrust axis of the event, the selection efficiency estimated with Monte Carlo events is $77.7 \pm 0.1\%$. The remaining backgrounds are 0.5% (e^+e^-), 0.6% ($\mu^+\mu^-$), 0.2% ($q\bar{q}$). Additional cuts are applied on the track quality: transverse momentum $p_t > 0.5\ GeV/c$, at least 40 TEC hits out of 62 maximum and one hit from the SMD inner $r\varphi$ layer. For the 3-prong decays at least 2 tracks should have SMD hits.

3 Tracking Performance

A new method to calibrate the TEC has been developed. Events with back-to-back e^+e^- or $\mu^+\mu^-$ with SMD hits on both tracks and fixed curvature give a precise independent trajectory through the central chamber. They are used to fit directly the drift distance to time relation for each wire. The resulting single wire resolution varies from 36 to 75 μm depending on the drift distance. After the iterative procedure of TEC calibration - SMD alignment has converged, we apply corrections for residual local biases, which are below 20 μm. The final IP resolution is 26 μm for 72 % of the tracks.

4 Lifetime Measurement

For both methods the lifetime is extracted from the experimental distribution (δ_i, σ_i) of the DL or the IP by an unbinned maximum-likelihood method. The likelihood function is given by a convolution between a physics function P and a double Gaussian resolution function R. An additional term for the background fraction f_b is added:

$$\log L = \sum_{i=1}^{N} \log \{(1 - f_B) P(\tau_\tau, \delta') \otimes R(\delta', \delta_i, \sigma_i) + f_B B(\delta_i, \sigma_i)\}$$

Correction factors for the calculated errors σ_i and the relative fraction of the 2 Gaussians are obtained from the fit to the data. For the DL method P is an exponential function related to the average decay length. For the IP method P is determined from the signed IP distribution at generator level, taking the possibility of wrong sign assignment due to the uncertainty in the τ flight direction into account. A parametrisation with a sum of 3 exponential functions for positive and 3 for negative IP gives good results.

In the DL method a sample of 3891 3-prong τ decays with decay lengths in the range [-10, 20] mm and a calculated DL error < 3 mm is used. For the IP method we select 30322 1-prong τ decays with a calculated IP error < 150 μm and IP in the range [-1.0, 1.5] mm. The experimental distributions together with the fit results are shown in figure 1. The quality of the fit is good both in the peak and in the tails of the distributions. The results are:

$$\tau_\tau = 293.0 \pm 5.3(stat.) \pm 2.5(syst.)\ fs \quad DL$$

$$\tau_\tau = 287.5 \pm 3.8(stat.) \pm 3.9(syst.)\ fs \quad IP$$

The systematic errors come from uncertainties in the selection and in the background fraction, in the knowledge of the physics and the resolution functions P and R and from possible biases and variations in the fit procedure. They are compared for both methods in table 1.

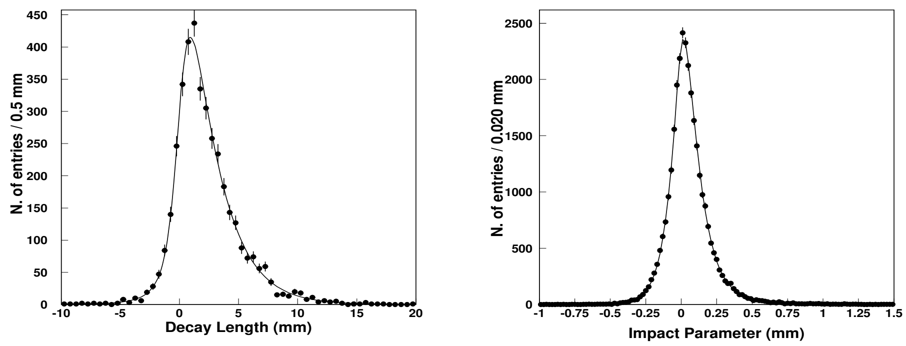

Figure 1: DL and IP distributions. The points are the data and the solid line is the fit result.

Table 1: Systematic errors in the lifetime measurement in [fs]

Source of error	DL Method	IP Method
Selection	Sec. vertex cut: 0.5	-
Background uncertainty	0.5	1.0
Physics function	-	2.2
Resolution function	1.5	2.6
Beam spot size	-	0.5
Fit: possible bias	1.5	1.5
Variation of fit range	1.2	0.5
Total	2.5	3.9

5 Summary

The τ lepton lifetime is measured with 1994 L3 data using the signed impact parameter and the decay length methods. The two results are independent as they are obtained from different sets of τ decays. By combining them we get $\tau_\tau = 290.1 \pm 4.0$ fs. Adding earlier L3 results for the 1991-94 data sample we obtain $\tau_\tau = 291.6 \pm 3.4$ fs which is in agreement with the PDG 1996 value [4].

References

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