MEASUREMENT OF FERMION PAIR PRODUCTION ABOVE THE Z RESONANCE WITH THE L3 DETECTOR AT LEP

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Since end of 1995 the LEP collider at CERN is operated at centre-of-mass energies well above the Z resonance. The measured cross sections and forward-backward charge asymmetries agree well with the Standard Model predictions. These measurements lead to an improved determination of the γ/Z-interference.

1 Introduction

In November 1995 LEP was operated for the first time at energies well above the Z resonance. During this run the L3 detector has collected a total integrated luminosity of 5 pb^{-1} at centre-of-mass energies, $\sqrt{s}$, between 130 GeV and 140 GeV. In July 1996 4.3 pb^{-1} have been collected and analysed at $\sqrt{s}=$ 161 GeV. The results obtained using 161 GeV data are still preliminary. In this article the measurements of the cross sections and – for the leptonic final states – forward-backward asymmetries for the following reactions are discussed:

$\mathrm{e^+e^-} \rightarrow \mathrm{hadrons}(\gamma)$ $\qquad$ $\mathrm{e^+e^-} \rightarrow \mathrm{e^+e^-}(\gamma)$

$\mathrm{e^+e^-} \rightarrow \mu^+\mu^-(\gamma)$ $\qquad$ $\mathrm{e^+e^-} \rightarrow \tau^+\tau^-(\gamma)$

In these reactions the (γ) indicates the possible presence of additional photons. For a large fraction of the events, initial-state radiation (ISR) photons lower the effective centre-of-mass energy, $\sqrt{s'}$, of the annihilation process to values close to the Z mass, m_{Z}('radiative return to the Z'). A cut on $\sqrt{s'}$ allows to determine the exclusive cross sections and asymmetries for high energy events, $\sqrt{s'} > m_{\mathrm{Z}}$. Together with the measurements on the Z-pole they are used to determine the properties of the Z boson in the framework of an S-Matrix ansatz. High energy measurements are in particular sensitive to the parameters describing the interference between photon and Z exchange.

2 Measurement of Fermion-Pair Production

Besides the measurement of the total cross section including all radiative effects, the aim is to probe the physics at high effective centre-of-mass energies, $\sqrt{s'} \approx \sqrt{s}$. To remove events from the radiative return to the Z, $\sqrt{s'}$ is required to be larger than 110 GeV. For $\mathrm{e^+e^-} \rightarrow \mathrm{e^+e^-}(\gamma)\sqrt{s'}$ is measured directly as

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the invariant mass of the two final state electrons. For the other reactions $\sqrt{s'}$ is estimated from the ISR photon energy, E_γ:

$$s' = s - 2 \cdot E_\gamma \sqrt{s} \tag{1}$$

In only about 15% of the events the ISR photon is observed in the detector, more often it escapes undetected along the beam pipe. Assuming a three–particle final state and $\vartheta_\gamma \equiv 0$, for these events $E\gamma$ is determined to be

$$E_\gamma = \sqrt{s} \cdot \frac{|\sin(\theta_1 + \theta_2)|}{\sin\theta_1 + \sin\theta_2 + |\sin(\theta_1 + \theta_2)|}. \tag{2}$$

θ_1, θ_2 are the polar angles of the outgoing fermions. For tau pair and hadron events they are approximated by the corresponding jet axes. A detailed description can be found in [1]. The measurements are compared to Standard Model calculations using the following parameters: m_Z= 91.190 GeV, $\alpha_s({m_\mathrm{Z}}^2)$ = 0.123, m_t = 174 GeV, $\alpha({m_\mathrm{Z}}^2)$ = 1/128.894 and m_H = 300 GeV.

3 Cross Sections and Leptonic Forward-Backward Asymmetries

The cross sections are measured for the total sample and for a sample where a cut on the effective centre-of-mass energy ($\sqrt{s'}$> 110 GeV) is applied (Fig. 1). The error from luminosity measurement and systematic errors of the selections are much smaller than the statistical errors. For the reaction $\mathrm{e}^+\mathrm{e}^- \rightarrow \mathrm{e}^+\mathrm{e}^-(\gamma)$ the cross section is given in the angular region $44^\circ \leq \vartheta \leq 136^\circ$. All cross sections agree well with the prediction from the Standard Model.

The forward-backward asymmetry, A_{fb}, is defined as $(\sigma_f - \sigma_b)/(\sigma_f + \sigma_b)$, where σ_f (σ_b) is the cross section for events with the fermion scattered with an angle smaller (larger) than 90° to the incoming electron. An acollinearity cut of 90° is applied. The measured values are corrected for background contamination and shown in figure 1 for the total and the high energy sample. Within their statistical error they agree with the Standard Model predictions.

4 Determination of $j_{\mathrm{had}}^{\mathrm{tot}}$

In the framework of the S-matrix ansatz [2] the lowest-order total cross section, σ^0_{tot} is given by formula (3). The parameters r_f, j_f and g_f scale the Z exchange, γ/Z interference and γ exchange contributions.

$$\sigma^0_a(s) = \frac{4}{3}\pi\alpha^2 \left[\frac{g^a_f}{s} + \frac{s r^a_f + (s - \overline{m}^2_Z) j^a_f}{(s - \overline{m}^2_Z)^2 + \overline{m}^2_Z \overline{\Gamma}^2_Z} \right], \quad \text{for a} = \mathrm{tot}, \mathrm{fb} \tag{3}$$

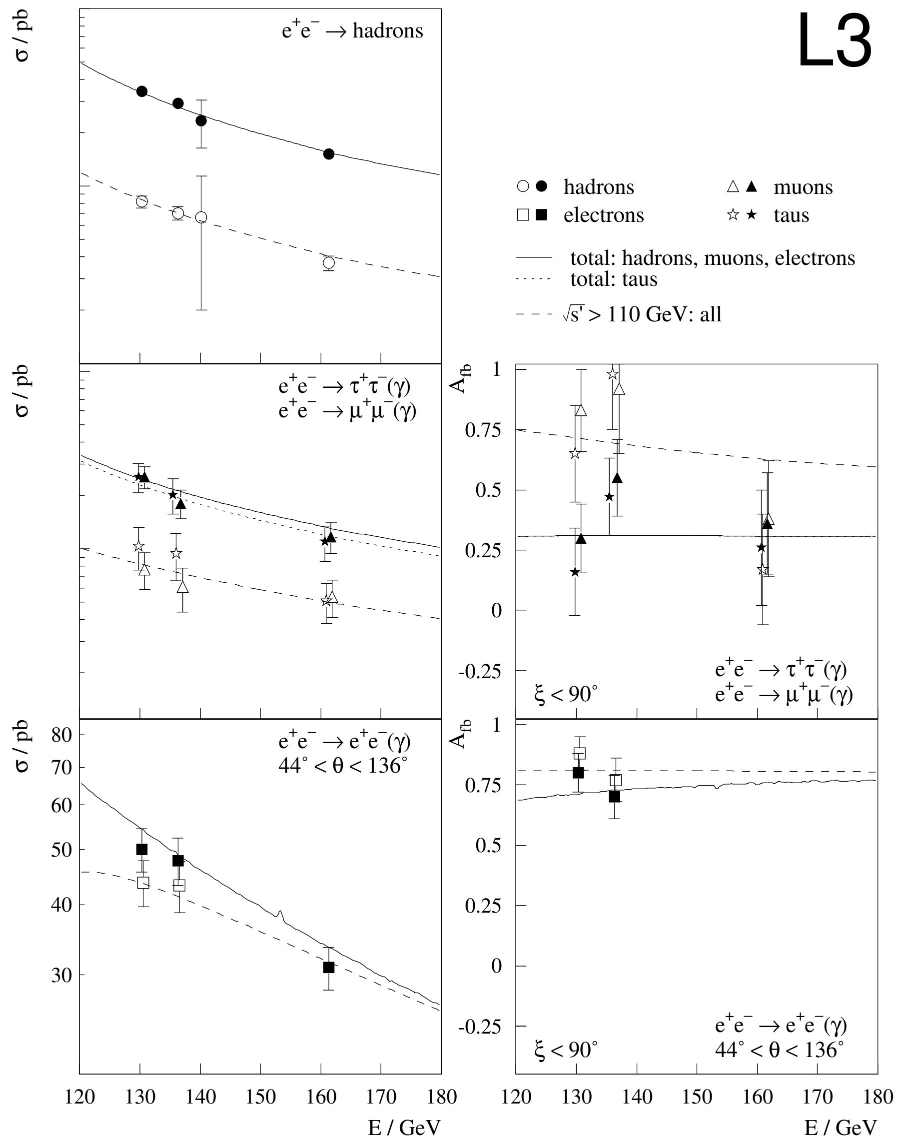

Figure 1: Cross sections and asymmetries ($\xi < 90°$) for the processes $e^+e^- \to$ hadrons(γ), $e^+e^- \to e^+e^-(\gamma)$, $e^+e^- \to \mu^+\mu^-(\gamma)$, $e^+e^- \to \tau^+\tau^-(\gamma)$ at energies from 130-161 GeV. 1996 data (161 GeV) is preliminary. The values are given for the total sample and for events with $\sqrt{s'}$<110 GeV. The lines are the Standard Model predictions.

The S-matrix parameters are determined in a χ^2 fit to the data presented here and that collected on the Z-pole. The results of fits to the Z-pole [3] data and to the complete data sample for the $j_{\rm had}^{\rm tot}$ are given in table 1. They agree well with the Standard Model prediction of 0.22. The error of $j_{\rm had}^{\rm tot}$ is reduced by using the data above the Z-pole by almost a factor of 2. Due to a correlation between the Z mass and $j_{\rm had}^{\rm tot}$ the error on m_Z is reduced accordingly (table 1).

data used	$j_{\rm had}^{\rm tot}$	m_Z [MeV]
Z-pole	0.18 ± 0.73	$91188 \pm 3 \pm 13$
+ 130-140 GeV	0.11 ± 0.39	$91189 \pm 3 \pm 7$
all (prel.)	0.09 ± 0.35	$91189 \pm 3 \pm 6$

Table 1: Result for $j_{\rm had}$ and $m_{\rm Z}$ from a fit within the S-matrix framework to the data collected on the Z-pole and including the data collected with $\sqrt{s'} > 110$ GeV.

5 Summary and Conclusion

At energies of 130-140 GeV and 161 GeV the hadronic cross section and the leptonic cross sections and forward-backward asymmetries have been measured. All measurements are well described by the Standard Model. They allow an improved determination of the γ/Z interference terms and improve the accuracy of the Z mass determined within the S-Matrix framework.

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References

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