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Searches for physics beyond the standard model in $f\bar{f}$ production at LEP II

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Abstract. Preliminary combinations of measurements of the 4 LEP Collaborations of the process $e^+e^- \to f\bar{f}$ at LEP II are presented. The combined results are interpreted in terms of contact interactions and the exchange of Z' bosons and within models of low-scale gravity in large extra dimensions.

Keywords. Beyond the standard model; $f\bar{f}$; LEP.

1. Introduction

Measurements of the process $e^+e^- \to f\bar{f}$ at energies above the Z^0 provide a test of the standard model at the $\mathcal{O}(1\%)$ level and can be used to place tight constraints on physics beyond the standard model. LEP data taking is now over and, although results are still preliminary, many of the measurements now include the full data set and results from individual LEP experiments have been combined. Further details can be obtained from [1] and references therein.

2. Analysis of $e^+e^- \to f\bar{f}$ at LEP II

Within the standard model (SM), the process $e^+e^- \to f\bar{f}$ at energies above the Z^0 resonance is mediated by Z^0 and γ exchange. QED radiative corrections are significant, leading to a substantial enhancement of the total cross-section. These effects come predominantly from the process of radiative return in which an initial state photon is emitted, reducing the invariant mass of the hard scattering ($\sqrt{s'}$) from the e^+e^- invariant mass ($\sqrt{s}$) to approximately the mass of the $Z^0(M_Z)$. Kinematic quantities can be used to separate these events from non-radiative events where $\sqrt{s'} \sim \sqrt{s}$, which are typically more sensitive to physics beyond the standard model.

The LEP II programme delivered approximately 700 pb^{-1} of integrated luminosity per experiment at centre-of-mass energies from $\sqrt{s} \sim 130$ to $\sqrt{s} \sim 207\,\mathrm{GeV}$. Measurements for non-radiative samples of events have been averaged to give LEP combined results [1].

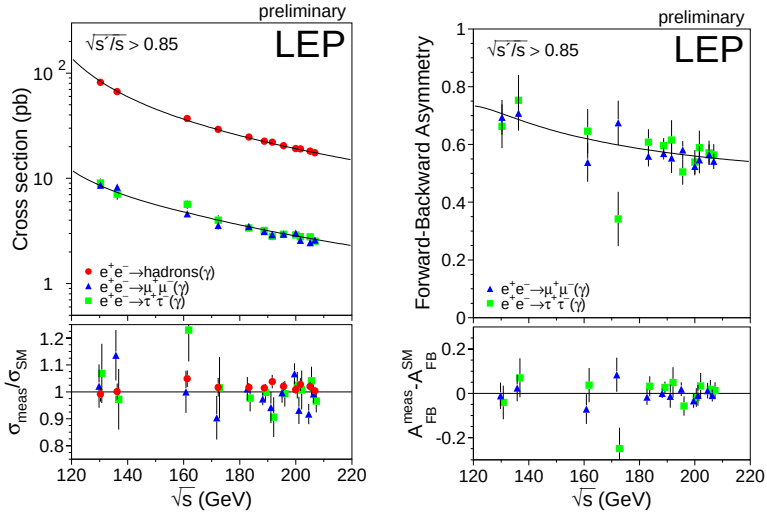

Figure 1. Preliminary LEP combined cross-section and forward–backward asymmetry results for $e^+e^-\to q\bar{q}$, $e^+e^-\to\mu^+\mu^-$ and $e^+e^-\to\tau^+\tau^-$.

Cross-section and forward–backward asymmetries from the individual LEP experiments have been combined. Details of the LEP averaging procedure can be found in [1]. The averaging procedure provides a full set of averaged results and a full correlation matrix; these can be found at [2]. The preliminary results of the averaging procedure are shown in figure 1. Correlations between hadronic cross-section results at different energies are significant, in the region of 15–30% of the errors. Other correlations are smaller. Combining the measurements from the four LEP experiments over all energies, the non-radiative hadronic cross-sections are determined to a precision of 1.0%, to be compared to the theoretical precisions of 0.26% [3] The hadronic cross-sections are ∼1.8 standard deviations above the predictions of ZFITTER [4].

Differential cross-sections, $\mathrm{d}\sigma/\mathrm{d}\cos\theta$, for samples of non-radiative events in e^+e^-, $\mu^+\mu^-$ and $\tau^+\tau^-$ final states have been combined between the different experiments. For the e^+e^- final states, combining differential cross-sections is preferable to combining cross-sections and asymmetry measurements since large corrections are not required to account for the differences in the angular acceptance of the experiments.

The LEP experiments have also made measurements of b and c quark production at LEP II. Results on the ratios of the heavy quark production cross-section to the total hadronic cross-section (R_q) and the heavy quark forward–backward asymmetries (A^q_FB) have been reported. The available heavy flavour results have been combined [1] using a technique similar to that used to combine LEP I heavy flavour results. For measurements of b quark production the contributions from c quark backgrounds are fixed to the SM predictions, and vice versa. Averaging the data over all energies, R_b is determined to a precision of ∼2.5% and A^b_FB to ∼0.06.

3. Interpretation

Precise measurements of the $e^+e^- \to f\bar{f}$ process can be used to search for physics beyond the standard model in a wide variety of models. Typically the sensitivity to these new phenomena come from the interference of the new physics with the SM processes in the virtual exchange of new particles, and the samples of non-radiative events have the highest sensitivity.

The combined LEP data have been used to search for four fermion contact interactions, Z' bosons, leptoquarks, and gravity in large extra dimensions. Details of these models and the method used to place limits can be found in [1].

Preliminary 95% confidence lower limits on the energy scale associated with four fermion contact interactions, Λ, are derived assuming a coupling $g^2 = 4\pi$. The limits obtained depend on the model considered. For a combination of $\mu^+\mu^-$ and $\tau^+\tau^-$ final states, limits on Λ range from 8.6 to 21.7 TeV for contact interaction in the process $e^+e^- \to l^+l^-$. For the process $e^+e^- \to b\bar{b}$ limits range from 2.2 to 15.3 TeV.

An extra, heavy, neutral gauge boson, Z', is predicted in a number of extensions of the standard model. The largest preliminary 95% confidence limit, $M_{Z'} > 1790$ GeV is found for the sequential standard model (SSM), where the Z' couplings to fermions are taken to be identical to the SM Z^0 couplings.

The best preliminary limits on the scale associated with gravity in large extra dimensions, M_s, from $e^+e^- \to f\bar{f}$ at LEP come from measurements of the $e^+e^- \to e^+e^-$ differential cross-sections yielding limits of 1.20 and 1.09 TeV for positive and negative interference with the SM respectively.

4. Summary

The LEP II $e^+e^- \to f\bar{f}$ data provide a test of the standard model at the $\mathcal{O}(1\%)$ level. Preliminary data are in good agreement with predictions, and provide tight constraints on physics beyond the standard model. The radiative return events can also be used to cross-check the determination of the LEP beam energy. Data taking is over now. Some of the results presented here use data from the full LEP II data set. The LEP Collaborations are working to finalise their analyses, and also combined final results. In some areas small improvements can be expected, in others, particularly the measurements of heavy flavours production, more substantial improvements are possible.

Acknowledgements

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