

# SEARCH FOR EXOTIC PHYSICS WITH FOUR-FERMION COUPLING AT LEP

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Preliminary results of measurements of fermion-pair production at LEP2 are used to derive limits on new physics phenomena. Combinations of the cross sections and asymmetries of the 4 LEP collaborations are interpreted in terms four-fermion contact interactions, exchange of  $Z'$  and leptoquarks. Results on the search for extra dimensions are also presented.

## 1 Introduction: Fermion-Pair Production at LEP2

In the years from 1995 to 2000 LEP delivered an integrated luminosity of  $700 \text{ pb}^{-1}$  to each experiment at c.m.s. energies between 130 GeV and 209 GeV. This allows a precise measurement of the process  $e^+e^- \rightarrow f\bar{f}$  and therefore a test of the Standard Model at high energies.

The individual experiments' analyses of cross-sections are combined for the  $e^+e^- \rightarrow q\bar{q}$ ,  $\mu^+\mu^-$ ,  $\tau^+\tau^-$ ,  $b\bar{b}$ ,  $c\bar{c}$  channels, forward-backward asymmetry measurements are combined for the  $\mu^+\mu^-$ ,  $\tau^+\tau^-$ ,  $b\bar{b}$ ,  $c\bar{c}$  final states. The averages are made for the samples of events with  $\sqrt{s'} > 0.85\sqrt{s}$  in order to suppress a 'pollution' of potential signals of new physics by radiative returns to the Z peak. A detailed description of the combination procedure can be found in Reference 1 and references therein. The results are shown in Figure 1. The combination of published and preliminary results of the  $R_q = \sigma_q/\sigma_{had}$  and  $A_{FB}^q$  measurements<sup>1</sup> are shown in Figure 2.

## 2 Interpretations

Although all measurements confirm the Standard Model predictions so far, new physics phenomena could be hidden in small deviations from theoretical expectations. A fit to the combined data including a variety of new physic models may reveal new effects or to place limits on their parameters. All limits presented here are given at the 95% confidence level.

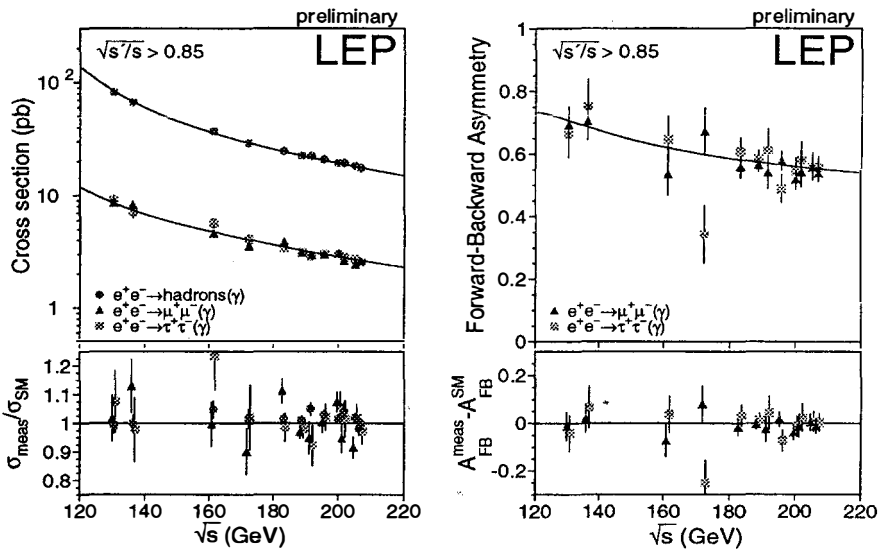


Figure 1: Combined LEP results on cross sections and forward-backward asymmetries for  $q\bar{q}$ ,  $\mu^+\mu^-$  and  $\tau^+\tau^-$  final states as a function of centre-of-mass energy.

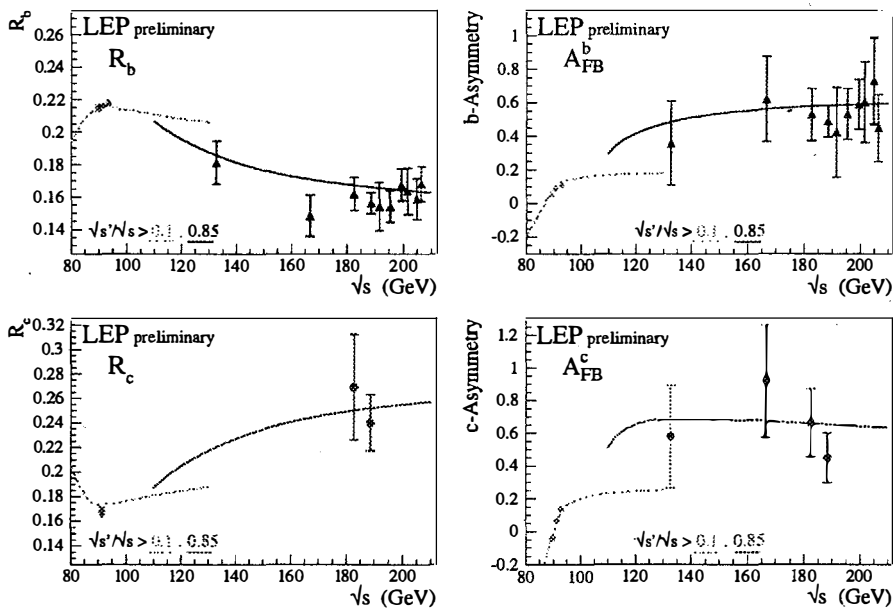


Figure 2: Combined LEP results on  $R_b$ ,  $R_c$  and on forward-backward asymmetry for  $b\bar{b}$  and  $c\bar{c}$  final states as a function of centre-of-mass energy.

Table 1: 95% confidence level lower limits on the  $Z'$  mass and  $\chi$ ,  $\psi$ ,  $\eta$ , L-R and SSM models.

Model	$\chi$	$\psi$	$\eta$	L-R	SSM
$m_{Z'}^{li}m$ (GeV/c <sup>2</sup> )	715	478	454	862	2090

### 2.1 Contact Interactions

Four fermion contact interactions<sup>2</sup> parametrise interactions beyond the Standard Model by an effective scale,  $\Lambda$ . Models can be defined by assuming different helicity couplings between initial and final state currents with either constructive (+) or destructive(-) interference between Standard Model and contact term. No deviations  $\epsilon \propto 1/\Lambda^2$  from the Standard Model predictions have been obtained for the considered final states. Bounds on  $\epsilon$  were derived and converted into limits on  $\Lambda^+$  and  $\Lambda^-$ . The results are shown in Figures 3 for averaged and combined  $\mu^+\mu^-$  and  $\tau^+\tau^-$  final states assuming lepton universality, for  $b\bar{b}$  and for  $c\bar{c}$  final states.

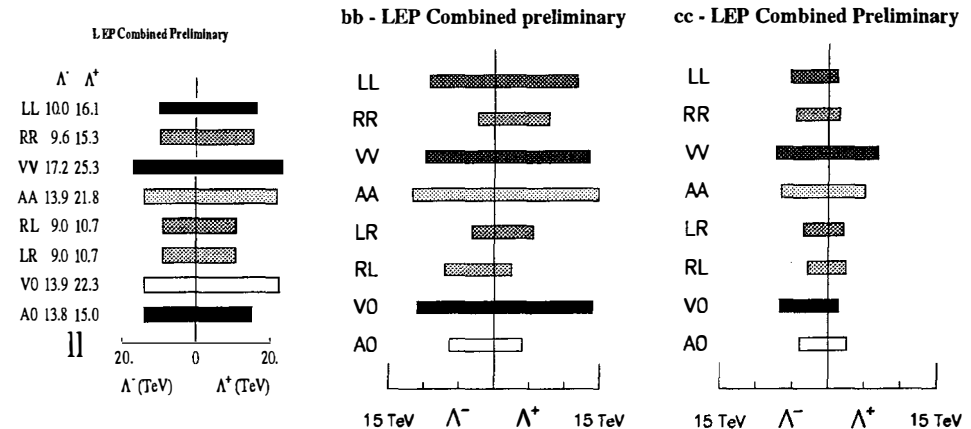


Figure 3: Limits on the scale of Contact Interactions in  $e^+e^- \rightarrow l^+l^-$ ,  $b\bar{b}$  and  $c\bar{c}$  using LEP combined results from 133 to 209GeV.

### 2.2 Extra Z Bosons

Additional heavy gauge bosons,  $Z'$ , are predicted by many theories. The combined hadronic and leptonic cross sections and leptonic forward-backward asymmetries were used to fit the data to models from an  $E_6$  GUT or from left-right symmetries<sup>3</sup>. No evidence for the existence of a  $Z'$  was found. Table 1 presents limits on the mass  $m_{Z'}$  for the special models  $\chi$ ,  $\psi$ ,  $\eta$  and L-R and for the Sequential Standard Model (SSM), that proposes a  $Z'$  with exactly the same couplings to fermions like the Z.

### 2.3 Leptoquarks

Leptoquarks mediate lepton-quark transitions. Following the basics in References 4, scalar (S) and vector (V) leptoquarks could be exchanged in the u- or t-channel of the process  $e^+e^- \rightarrow q\bar{q}$ . Assuming a coupling of electromagnetic strength,  $g = \sqrt{4\pi}\alpha_{em}$ , and one type of leptoquarks much lighter than the others, limits on the masses of leptoquarks are derived and presented in

Table 2: Lower limits on the LQ mass assuming  $g_{L,R} = \sqrt{4\pi\alpha}$ . For  $\tilde{S}_{1/2}(L)$  no limit can be set.

LQ type	$m_{LQ}^{min}(\text{GeV}/c^2)$	LQ type	$m_{LQ}^{min}(\text{GeV}/c^2)$
$S_0(L) \rightarrow eu$	789	$V_{1/2}(L) \rightarrow ed$	305
$S_0(R) \rightarrow eu$	639	$V_{1/2}(R) \rightarrow eu, ed$	227
$\tilde{S}_0(R) \rightarrow ed$	210	$\tilde{V}_{1/2}(L) \rightarrow eu$	176
$S_1(L) \rightarrow eu, ed$	364	$V_0(L) \rightarrow e\bar{d}$	1070
$S_{1/2}(L) \rightarrow e\bar{u}$	189	$V_0(R) \rightarrow e\bar{d}$	167
$S_{1/2}(R) \rightarrow e\bar{u}, e\bar{d}$	240	$\tilde{V}_0(R) \rightarrow e\bar{u}$	497
$\tilde{S}_{1/2}(L) \rightarrow e\bar{d}$	-	$V_1(L) \rightarrow e\bar{u}, e\bar{d}$	664

Table 2. In most cases the kinematical limits of searches for direct leptoquark production at LEP are exceeded by this indirect search. Further, the bounds presented here, complement the searches at HERA<sup>5</sup>.

#### 2.4 Extra Dimensions

Recently, theories of quantum gravity in extra spatial dimensions<sup>6</sup> have been an elegant means to escape the hierarchy problem: Gravitons are considered to propagate in a compactified higher dimensional space while Standard Model particles exist in the usual 3+1 space-time dimensions. The Planck mass in the 'normal' 4 dimensions is related to a fundamental scale  $M_D \approx \Lambda_{ew}$  in  $n+4$  dimensions by  $M_{Pl}^2 = R^n M_D^{n+2}$ , where  $R$  is the compactification radius of extra dimensions. The exchange of gravitons could contribute to the processes  $e^+e^- \rightarrow f\bar{f}, \gamma\gamma, ZZ, W^+W^-$ . The search for indirect effects of low scale gravity was performed by all LEP collaborations separately<sup>7</sup> and has not yet been combined. The best sensitivity can be reached in the process  $e^+e^- \rightarrow e^+e^-$ . Including this channel, preliminary results on  $M_S \propto M_D$  range between 0.98 TeV/ $c^2$  and 1.17 TeV/ $c^2$  for a theory parameter  $\lambda = -1$  and between 0.84 TeV/ $c^2$  and 1.06 TeV/ $c^2$  for  $\lambda = +1$ .

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