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Constraints on New Heavy Gauge Bosons from $e^+e^- \to W^+W^-$

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We discuss the potential of the International Linear Collider (ILC) to probe $Z - Z'$ mixing and Z' mass by the reaction $e^+e^- \to W^+W^-$ with longitudinally polarized e^+e^- beams. We perform here a generic analysis of the deviations of the differential cross section from the Standard Model prediction, and apply it to a specific class of extended weak gauge models called as 'minimal-Higgs' models.

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1. Introduction

A rather common feature of extended electroweak models is the prediction that one (or more) neutral heavy gauge bosons Z' should exist [1–3]. At present, direct Z' production searches at the LHC indicate a lower limit on $M_{Z'}$ of the order of 2.5–3.0 TeV depending on the Z' models [4, 5]. If the collider energy were still not high enough to produce such heavy particle, Z' searches would focus on possible 'indirect' manifestations through deviations of observables from the Standard Model (SM) predictions.

With the increased e^+e^- energy available at ILC, the reaction

$$e^+ + e^- \to W^+ + W^- \tag{1}$$

should represent a convenient tool to search for Z' effects [6]. Indeed, in this process, lack of gauge cancelation among the different amplitudes due to nonstandard physics should lead to deviations from the SM cross section rapidly increasing with energy and therefore, in principle, to enhanced sensitivity to the existence of the Z' if efficient W^+W^- reconstruction could be performed.

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2. Z' models and $Z - Z'$ mixing

Here, we concentrate on the Z' models originated from the exceptional group E_6: Z'_χ, Z'_ψ, Z'_η and Z'_I Refs. [1–3]. In the extended gauge theories predicting the existence of an extra neutral Z' gauge boson, Z and Z' denote the weak gauge boson eigenstates of $SU(2)_L \times U(1)_Y$ and of the extra $U(1)'$, respectively. The mass eigenstates, Z_1 and Z_2, diagonalizing the mass matrix, are then obtained by the rotation of the fields Z and Z' by a mixing angle ϕ that will play an important role in our analysis. In general, such mixing effects reflect the underlying gauge symmetry and/or the Higgs sector of the model. To a good approximation, for $M_1 \ll M_2$, in specific 'minimal-Higgs models',

$$\phi \simeq -s_{\mathrm{W}}^2 \, \frac{\sum_i \langle \Phi_i \rangle^2 I_{3L}^i Q_i'}{\sum_i \langle \Phi_i \rangle^2 (I_{3L}^i)^2} = \mathcal{C} \, \frac{M_1^2}{M_2^2}. \tag{2}$$

In the case of E_6 superstring-inspired models $\mathcal{C}$ can be expressed as

$$\mathcal{C} = 4 s_{\mathrm{W}} \left(A - \frac{\sigma - 1}{\sigma + 1} B \right), \tag{3}$$

where $s_W = \sin\theta_W$, σ is the ratio of vacuum expectation values squared, and the constants A and B are determined by the mixing angle β: $A = \cos\beta/2\sqrt{6}$, $B = \sqrt{10}\sin\beta/12$.

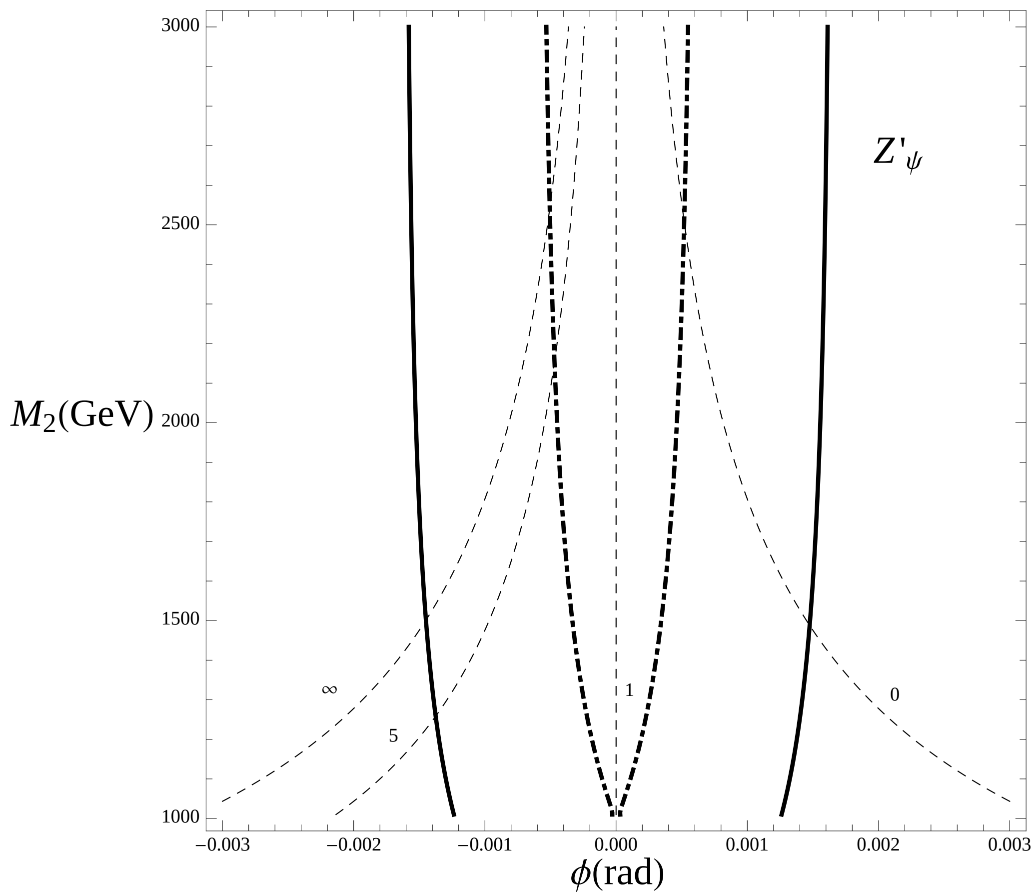

FIG. 1. Discovery reach for the ψ model in the (ϕ, M_2) plane obtained from polarized initial e^+ and e^- beams with $(P_L = \pm 0.8,\ \bar{P}_L = \mp 0.5)$ and unpolarized final $W^\pm$ states. Solid thick (dash-dotted) lines correspond to energy $\sqrt{s} = 0.5$ TeV (1 TeV) and $\mathcal{L}_{\rm int} = 0.5$ ab^{-1} (1 ab^{-1}). Also shown are the additional constraints in the minimal Higgs case (dashed lines) for $\sigma = 0,\ 1,\ 5,\ \infty$.

3. Constraints on $Z - Z'$ mixing

Our numerical results are presented as the bounds on 2-dim plane (ϕ, M_2) obtained from conventional χ^2 analysis of the polarized differential cross section of process (1) (see Ref. [8]) and summarized in Fig. 1 and Table 1. Specifically, as an example, Fig. 1 shows the 95% C.L. allowed contours in $\phi - M_2$ for the ψ model. The additional constraints in the minimal Higgs models are also shown for various values of σ.

Table 1. Discovery reach on the mass M_2 (in TeV) for extra Z'_χ, Z'_ψ, Z'_η bosons within minimal Higgs models with $\sigma = 0$, 1, 5, ∞ and constraints on the mass M_2 from ATLAS experiment.

Z' model	Z'_χ	Z'_ψ	Z'_η
$\sigma = 0$	2.17 (3.66)	1.49 (2.51)	0.95 (1.66)
$\sigma = 1$	2.17 (3.66)	no limit	1.13 (1.93)
$\sigma = 5$	2.17 (3.66)	1.26 (2.15)	1.55 (2.61)
$\sigma = \infty$	2.17 (3.66)	1.50 (2.54)	1.72 (2.88)
ATLAS	2.54	2.38	2.44

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