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Z WIDTH AND BRANCHING RATIOS IN EXTENDED GAUGE MODELS*

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ABSTRACT

We study the effects of a possible new heavy neutral vector boson Z_H on the partial and total widths of the Z_L which are being studied at LEP. The analysis is formulated in as general terms as possible, without commitment to a particular model. The constraints on m_{Z_H} from CDF and the new data on m_W/m_{Z_L} and m_{Z_L} are taken into account. As expected, the induced deviations are at the level of a few per cent. The allowed range decreases with increasing m_t . The lepton widths and the peak cross-sections are particularly sensitive. A fourth light neutrino is excluded also in extended gauge models.

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In this note we study realistic deviations from the predictions of the standard model that could possibly be induced by a new heavy vector boson Z_H . The total and partial widths of the light Z_L and related quantities like the peak cross-section are at present being actively studied at LEP [1-4] and SLC [5]. A summary of the present data together with the standard model predictions for $m_{Z_L} = 91.10 \pm 0.06 \text{ GeV}$ is presented in Table 1. We aim at a determination of the sensitivity of the different observables to a new heavy Z_H . Our formulation of extended gauge models is somewhat different and more physically motivated than in other similar analyses [6-8]. We also take into account the lower limits on the Z_H mass that follow from recent data collected at hadron colliders (especially by CDF [9]) and the new information obtained from the measurement of m_{Z_L} at SLC/LEP [1-5] and of $\frac{m_W}{m_{Z_L}}$ by CDF [9] and UA2 [10].

We first consider models with an extra $U(1)$. At tree level, before symmetry breaking, the neutral current interaction is given by:

$$\mathcal{L}_{NC} = g W_3 J_{3L} + g' B J_Y + g_N Z_N J_N \quad (1)$$

with J_{3L} and J_Y being the familiar $SU(2) \otimes U(1)$ currents, related to the electromagnetic current by $J_{em} = J_{3L} + J_Y$. In this case, Z_N has no projection on the photon and the definition of $\sin \theta_W$ from $e = g \sin \theta_W W_3 + \cos \theta_W B$, the orthogonal combination $Z_5 = \cos \theta_W W_3 - \sin \theta_W B$ and Z_N . One obtains:

$$\mathcal{L}_{NC} = \frac{e}{\sin \theta_W \cos \theta_W} Z_5 (J_{3L} - \sin^2 \theta_W J_{em}) + e A J_{em} + g_N Z_N J_N \quad (2)$$

Clearly, Z_5 has couplings which are formally identical to those of the neutral vector boson Z of the standard model.

After symmetry breaking Z_5 and Z_N are mixed, with the mass matrix given in general by

$$\mathcal{M}^2 = \begin{pmatrix} m_0^2 & \mu^2 \\ \mu^2 & m_N^2 \end{pmatrix} \quad (3)$$

The physical vector bosons Z_L and Z_H :

$$\begin{pmatrix} Z_L \\ Z_H \end{pmatrix} = \begin{pmatrix} \cos \xi & \sin \xi \\ -\sin \xi & \cos \xi \end{pmatrix} \begin{pmatrix} Z_5 \\ Z_N \end{pmatrix} \quad (4)$$

are mass eigenstates with masses m_{Z_L} and m_{Z_H} . Thus one has:

$$m_N^2 = m_{Z_H}^2 - (m_0^2 - m_{Z_L}^2) \quad (5)$$

$$\mu^2 = \sqrt{(m_{Z_H}^2 - m_0^2)(m_0^2 - m_{Z_L}^2)} \quad (6)$$

$$\tan^2 \xi = \frac{m_0^2 - m_{Z_L}^2}{m_{Z_H}^2 - m_0^2} \quad (7)$$

Without going into a detailed description of several possible versions of the Higgs sector, we only specify two general restrictions. First, for simplicity, we only consider models with doublet or singlet Higgses under $SU(2)_L$. At tree level this implies the relation:

$$\cos^2 \theta_W = \frac{m_W^2}{m_0^2} \equiv \frac{m_W^2}{\rho m_{Z_L}^2} \quad (8)$$

where $\rho = 1 + \delta \rho_H$ deviates from unity because of the correction $\delta \rho_H$ induced by $Z_5 - Z_N$ mixing. Beyond the tree level ρ is further modified by electroweak radiative corrections, as we shall discuss later on. Second, we also explicitly impose the physically motivated criterion that all mixing effects decrease at large m_{Z_H} so that the standard model is recovered for $m_{Z_H} \rightarrow \infty$. Precisely, we assume that, for large m_{Z_H} ,

$$\tan \xi = a \frac{m_{Z_L}^2}{m_{Z_H}^2} \quad (9)$$

with a (asymptotically) constant. The vanishing of a for $m_{Z_H} \rightarrow \infty$ is also admissible, but this case would lead to comparatively smaller effects and we do not consider it here. Given the existing limits on m_{Z_H} , to be discussed later, we adopt Eq. (9) as completely adequate for the

present purposes. As seen from Eqs. (6), (7) the assumed behaviour for tq ξ is equivalent to requiring that the mixing term μ^2 in Eq. (3) be bounded by a constant when $m_{Z_H}^2 \rightarrow m_0^2 \rightarrow \infty$. We are aware that this behaviour is not necessary from a technical point of view, but we consider it physically reasonable.

From Eqs. (7), (8), (9), it also follows that

$$\delta\rho_M = \frac{m_0^2 - m_{Z_L}^2}{m_{Z_L}^2} \simeq \frac{m_{Z_H}^2}{m_{Z_L}^2} t q^2 \quad \xi = \alpha^2 \frac{m_{Z_L}^2}{m_{Z_H}^2} \quad (10)$$

Note that $\delta\rho_M$ is positive definite.

Beyond the tree level, electroweak radiative corrections will be treated in an improved Born approximation [11,12] which correctly takes into account large logarithms (i.e., $\frac{\alpha}{\pi} \log \frac{m_{Z_L}^2}{m_t^2}$ or $\frac{\alpha_W}{\pi} \log \frac{m_{Z_L}^2}{m_{t_l}^2}$ where t_l is a light fermion) and quadratic terms in the top mass or other heavy exotic particles (i.e., terms of order $G_F m_t^2$). Loop effects due to the heavy gauge boson Z_H are generally small [13] for the range of parameters we are interested in and will be neglected here. This approximation is certainly adequate for our indicative purposes. Near the Z_L pole the vector and axial vector couplings for $Z_S \rightarrow f\bar{f}$ are given by

$$\begin{aligned} g_V^f &= T_{3L}^f - 2\tilde{s}_{W'}^2 Q_{em}^f \\ g_A^f &= -T_{3L}^f \end{aligned} \quad (11)$$

where $\tilde{s}_{W'}^2$ is the effective $\sin^2\theta_W$ for on-shell Z couplings given by

$$\tilde{s}_{W'}^2 = 1 - \frac{m_W^2}{\rho m_{Z_L}^2} \quad (12)$$

or

$$\tilde{s}_{W'}^2 = \frac{(37.2802)^2}{\rho(1 - \delta\alpha)m_{Z_L}^2} \quad (13)$$

where $\delta\alpha \simeq 0.060$ is the usual correction [11] to the squared electric charge and

$$\rho = 1 + \delta\rho = 1 + \delta\rho_M + \delta\rho_t + \delta\rho_{SB} + \dots \quad (14)$$

Then $\delta\rho_M$ is the effect of mixing given by Eq. (10), $\delta\rho_t \simeq \frac{3G_F m_t^2}{8\sqrt{2}\pi^2} + \dots$ includes the large quadratic effects of the heavy top quark, $\delta\rho_{SB}$ is a possible additional effect arising from the

symmetry breaking sector. $\delta\rho_{SB} = 0$ if only doublet and singlet Higgses under $SU(2)_L$ are present as we assume. Finally, the ellipsis indicates small terms (i.e., terms with no large logs or quadratic mass effects). Note that, when the additional mixing effect from $\delta\rho_M$ is neglected, $\tilde{s}_{W'}^2$ reduces to the effective $\tilde{s}_W^2$ defined in the standard model, for on-shell Z couplings, according to [11,12,14,15]

$$\tilde{s}_{W'}^2 = \tilde{s}_W^2 - \frac{\tilde{s}_W^2 c_W^2}{(c_W^2 - \tilde{s}_W^2)} \frac{\delta\rho_M}{\rho} + 0(\delta\rho_M^2) \quad (15)$$

At present the best value of $\tilde{s}_{W'}^2$ is given by [12,14,15]

$$\tilde{s}_{W'}^2 \simeq 0.233 \pm 0.002 \quad (16)$$

including all uncertainties from our ignorance of m_t , m_H .

A limit on $\delta\rho$ is directly obtained from the ratio $\frac{m_W}{m_{Z_L}}$ measured by CDF [9] and UA2 [10] and the value of $m_{Z_L} = 91.10 \pm 0.06 \text{ GeV}$ obtained by combining the LEP and SLC experiments [1-5]. From $\frac{m_W}{m_{Z_L}} = 0.779 \pm 0.010$, one obtains $\rho = 1.01 \pm 0.01$ or $\delta\rho < 0.020$. The top quark contribution to $\delta\rho$ is about 2.10^{-3} for $m_t \simeq 80 \text{ GeV}$ and increases with m_t^2 , so that

$$\delta\rho_M < 0.020 - 0.002 \left[\frac{m_t}{80 \text{ GeV}} \right]^2 \quad (17)$$

The limit in Eq. (17) is a generous one. One could improve it by a sizeable amount if the whole of the neutral current data were reanalyzed [16,17], including the effects of Z_H . However, this refinement is not so important for our purposes.

In this class of models the partial widths for $Z_L \rightarrow f\bar{f}$ are given, in the improved Born approximation, by

$$\Gamma_f = \frac{G_F m_{Z_L}^2}{6\pi\sqrt{2}} N_c^f \left[\cos^2 \xi (g_V^{f2} + g_A^{f2}) + 2\cos \xi \sin \xi (g_V^f g_V^{f'} + g_A^f g_A^{f'}) + \sin^2 \xi (g_V^{f'2} + g_A^{f'2}) \right] \quad (18)$$

where $g_{V,A}^f$ are given in Eqs. (11), $g_{V,A}^{f'}$ are the vector and axial couplings for $Z_N \rightarrow f\bar{f}$ and $N_c^f \simeq 3(1 + \delta_{QCD} + \delta_{QED}^f)$ for quarks and $N_c^f \simeq (1 + \delta_{QED}^f)$ for leptons ($\delta_{QCD} \simeq \alpha_s(m_{Z_L})/\pi +$

..., $\delta_{QED}^f \simeq \frac{3Q_f^2 \alpha}{4\pi}$). If, for simplicity, terms of order $\sin^2 \xi$ are neglected, the differences $\delta\Gamma_f = \Gamma_f - (\Gamma_f)_{SM}$ with respect to the Standard Model are given by

$$\delta\Gamma_f = \frac{G_F m_{Z_H}^3}{24\pi\sqrt{2}} N_c^f [A_f \delta\rho_M + B_f t g\xi] \quad (19)$$

with:

$$\begin{aligned} A_f &= 4\bar{\rho} \left[(T_{3L}^f - 2s_{1W}^2) Q^f \right]^2 + T_{3L}^2 + \frac{4s_{1W}^2 c_{1W}^2}{c_{1W}^2 - s_{1W}^2} Q^f (T_{3L}^f - 2s_{1W}^2 Q^f) \\ B_f &= 8\bar{\rho} \left[(T_{3L}^f - 2s_{1W}^2) Q^f \right] g_V^f - T_{3L} g_A^f \end{aligned} \quad (20)$$

and $\bar{\rho} = 1 + \delta\rho_t$. The last term in A_f is due to the effect of $\delta\rho_M$ on $\bar{s}_{1W}^2$ given by Eq. (15). While the values of A_f are fixed by the standard model, the constants B_f depend on the particular $U(1)$ model through the couplings $g_{V,A}^f$ of Z_N . Note that the case of $Z \rightarrow b\bar{b}$ is exceptional because, as is well known, there are additional large terms from vertex diagrams, which are taken into account [11,18] by replacing in Eqs. (18), (19), (20) for $f = b, \bar{b} \rightarrow \rho_b = 1 - \frac{1}{3}\delta\rho_t$ and $\bar{s}_{1W}^2 \rightarrow \bar{s}_{1W}^2 (1 + \frac{2}{3}\delta\rho_t)$.

The peak cross-section for $e^+e^- \rightarrow f\bar{f}$ provides a particular combination of widths which is measured with great accuracy. After deconvolution of QED radiative corrections:

$$\sigma_{peak}^f = \frac{12\pi}{m_{Z_H}^2} \frac{\Gamma_e \Gamma_f}{\Gamma_T^2} \quad (21)$$

The factor of ρ which appears in the widths cancels out in the ratio, so that the peak cross-section is not very sensitive to the top quark mass (except for the presence of ρ_b in Γ_T). However, the remaining effect of $\delta\rho_M$ and the mixing term in $t g\xi$ can conspire to produce relatively large corrections to σ_{peak}^f .

We first discuss a set of well-known models where the extra $U(1)$ is contained in an E_6 simple group [19]. In these models the extra $U(1)$ generator is a superposition of two suitably chosen colour singlet neutral generators, Y' and Y'' , which exist in E_6 in addition to T_{3L} , Y : $J_N = \cos\theta_2 J_{Y'} - \sin\theta_2 J_{Y''}$. In the following we consider arbitrary values of θ_2 and we assume $g_N = g'$. The lower limit on the Z_H mass derived from the CDF data in these models was

studied in Ref. [7] as a function of θ_2 . Their result for the ELHQI structure functions [20] is plotted in Fig. 1.

The lower limit on m_{Z_H} together with the limit on $\delta\rho_M$ given in Eq. (17) leads to a corresponding limit on $t g\xi$, obtained by Eq. (10). For each channel $Z \rightarrow f\bar{f}$ one can then plot the allowed range for the quantities $\delta\Gamma_f$, given in Eq. (19), and $\delta\sigma_{peak}^f$, as functions of θ_2 . These plots are shown in Figs. 2 to 7 for $m_t = 100, 200 \text{ GeV}$. We see that the deviations from the Standard Model can be as large as $+6 - 7\%$ for the partial widths into charged leptons and neutrinos, while the hadronic and total widths are at most changed by about $+3\%$. The maximum deviations are smaller for heavier m_t because the limits on $\delta\rho_M$ and $t g\xi$ are sharpened in this case. Note that only very small (Γ_L, Γ_ν) or negligible (Γ_A, Γ_T) negative variations are possible. Actually the interference term in Eqs. (18), (19), proportional to $t g\xi$, is symmetric and could lead to values of $\delta\Gamma_f$ of either sign (as observed in Ref. [6]). However we find that the coefficient of the $\delta\rho_M$ term in Eq. (19) is large enough and positive so that the resulting values of $\delta\Gamma_f$ are predominantly positive. In order to cancel the effect of $\delta\rho_M$, other new physics terms with negative signs should be present (e.g., $\delta\rho_{SB}$). On σ_{peak}^f the effects of ρ cancel in the ratio, and consequently the pattern of possible deviations is almost symmetric. We see that effects up to $\pm 10\%$ in the charged leptonic channels and up to $\pm 6\%$ in the total hadronic channel can be produced.

As a different exercise on models with an extra $U(1)$ we considered a toy model where the couplings of Z_N are proportional to the standard Z_ξ couplings:

$$g_N = k g_\xi \quad (22)$$

Clearly in this model the partial widths and the low energy effective four-fermion interaction become:

$$\Gamma_f = (1 + \delta\rho_M) (\cos\xi + k \sin\xi)^2 \Gamma_{SM}(\bar{s}_{1W}^2) \quad (23)$$

and

$$\begin{aligned} \mathcal{L}_{NC} &\simeq \rho \left[(\cos\xi + k \sin\xi)^2 + \frac{m_{Z_H}^2}{m_{Z_H'}^2} (-\sin\xi + k \cos\xi)^2 \right] \cdot (J_{3L} - \sin^2\theta_W J_{em})^2 \\ &= \rho_{eff} (J_{3L} - \sin^2\theta_W J_{em})^2 \end{aligned} \quad (24)$$

respectively.

For example, with k large and negative one can try to make Γ_f small, while ρ_{eff} can be kept close enough to unity by tuning the term proportional to $\frac{m_{Z_L}^2}{m_{Z_H}^2}$ in the square bracket of Eq. (24). For each k , the CDF bound [9] ($\sigma B < 0.85\text{pb}$ at 90 %c.d) leads to a lower limit on m_{Z_H} (e.g. for $|k| = 1$, $m_{Z_H} > 380\text{GeV}$; for $|k| = 5$, $m_{Z_H} > 640\text{GeV}$, etc.). The limit, Eq. (17), on $\delta\rho_M$ from $\frac{m_{Z_L}^2}{m_{Z_H}^2}$ is valid also in this case. Then for each k the limit on m_{Z_H} becomes an upper limit on $tg\xi$. Finally, the analysis of $\nu - q, \nu - e$ and $e - q$ neutral current data leads to constraints on ρ_{eff} . For $m_t = 95\text{GeV}$ we obtain from Ref. [21] that $0.991 < \rho_{eff} < 1.013$. Given these limits it is purely a matter of algebra to derive the allowed range of $\delta\Gamma_f/\Gamma_f$. Clearly in this model all channels are equally affected so that $\delta\Gamma_f/\Gamma_f$ does not depend on f . Consequently, $\delta\sigma_{peak} = 0$ for all channels. For $m_t \leq 100\text{GeV}$ we find in this case

$$-6.1\% \leq \frac{\delta\Gamma_f}{\Gamma_f} \leq +2.8\% \quad (25)$$

Smaller ranges would be obtained for larger values of m_t . We have checked that the constraints imposed by the agreement of the line shape with the standard model are in all cases respected. We see that, while this model is interesting in that the allowed range is displaced toward the negative side, the absolute values of the variations are comparable to those for the previous set of models.

Going beyond the models with an extra $U(1)$, we first consider left-right models, based on $SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$ [22]. In this class of models the mass and the mixing parameter of W_R , the right-handed charged vector-boson, appear as additional parameters. Thus one can either assume that the W_R is very heavy and its effect can be neglected, or take advantage of these additional parameters to enlarge the allowed domain for the predicted values of the physical quantities under study. The first option is suggested by the existing lower bounds on m_{W_R} which are obtained from the $K_L - K_S$ mass difference, assuming that the absolute values of the entries of the mixing matrix are the same for right- and left-handed quarks. If the W_R effects are neglected, the situation reproduces that of a model with an extra $U(1)$, with couplings given by the generator $B - L$. We used in this case the limit $m_{Z_H} > 370\text{GeV}$ obtained [7] from the CDF data [9] with the EHLQ1 structure functions [20]. For $g_L = g_R$

the resulting allowed ranges of $\delta\Gamma_f$ and $\delta\sigma_{peak}/\sigma_{peak}$ are reported in Table 2. As expected, the results are quite similar, in magnitude and sign, to those obtained for the models with an extra $U(1)$. Alternatively, one can take advantage of the mixing in the charged sector. For example, by using the fact that the shifts of m_{W_L} and m_{Z_L} with respect to the standard model induce opposite effects on $\delta\rho_M$, according to

$$\frac{\delta\rho_M}{\rho_M} = \frac{\delta m_W^2}{m_W^2} - \frac{\delta m_Z^2}{m_Z^2} \quad (26)$$

one can make $\delta\rho_M \simeq 0$. In this case, somewhat larger effects can be tolerated as shown in Table 3.

The charged sector can also be generalized in different ways. One can be as unconventional as to imagine two separated $SU(2)$ for quarks and leptons as in the scheme recently discussed by Georgi et al. [23]. Also in that model the resulting value of $\delta\rho_M$ can be small due to a compensation between the W and Z mass shifts. The model contains two additional parameters: a mixing angle φ and a coefficient $1/x$ for the additional (with respect to the Standard Model) quark current. The CDF direct search in leptonic channels provides the limitation $m_{Z_H} > 250\text{GeV}$ [24]. The relation among $\sin^2\theta_W$ appearing in neutral current processes and m_{Z_L} requires $\frac{\sin^2\theta}{x} \leq 0.019 - 3.35\Delta\theta_L$ once low-energy $\nu - q$ data [24] are taken into account. Since $1/x$ enhances the hadronic processes one cannot tolerate $1/x > 0.5$, otherwise the agreement with the observed semi-leptonic branching ratio of B particles is lost [24]. Taken together, these limitations still allow for deviations in the total Z width as large as -10% .

Departures from the Standard Model could even be more radical. In particular, the possibility exists of describing the symmetry breaking sector of the Standard Model in terms of non-linear realizations of the electroweak symmetry, a natural approach if the symmetry breaking sector is strongly interacting. The resulting model [25] is no longer renormalizable but it leads to an effective phenomenological Lagrangian still useful for testing the electroweak interactions at energy scales smaller than $\sim 1\text{TeV}$. In its minimal version, the model contains three gauge vector bosons $V^\pm, V_0$ and deviations to the $\rho = 1$ relation are strongly suppressed. More interestingly, V_0 does not decouple and sizeable effects can be transmitted to the Z scale even if V_0 is very massive, escaping the current CDF bounds. In particular, the analysis performed

above is no longer applicable, since, for instance, Eq. (9) does not hold true. A numerical analysis shows that the allowed ranges of $\delta\Gamma_f$ and $\delta\sigma_{peak}$ are smaller than in the previous cases, at least in the minimal version of the model where the additional V bosons do not couple directly to the ordinary fermions, but only indirectly through the gauge vector boson mixing.

In conclusion, we find that in all cases the effects of Z_H on the Z_L widths cannot exceed the level of a few per cent. The allowed range is further reduced if m_t is increased. The leptonic widths and the peak cross-sections are more sensitive than the hadronic and total widths. The allowed effects are in all cases relatively small. At the moment the maximum allowed deviations from the Standard Model are of the order of the experimental errors. As a consequence, the present data are not precise enough to provide new significant constraints on extended gauge models. However, we are not far from that point: with new data being rapidly accumulated at LEP the next round of results should provide important information on these very interesting generalizations of the Standard Model.

Finally, one might wonder whether a fourth neutrino could be resuscitated in an extended gauge model by suitably fixing the couplings of a new Z_N . We see from Fig. 8 that this is not possible if the new round of results from the ALEPH experiment are taken into account: a fourth light neutrino is excluded also in extended gauge models.

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FIGURE CAPTIONS

- 1) Lower bounds on $M_{Z''}$ in extra- $U(1)$ models vs. θ_2 from Ref. [7].
- 2) Maximal deviations of Γ_L in extra- $U(1)$ models vs. θ_2 .
- 3) Maximal deviations of Γ_ν in extra- $U(1)$ models vs. θ_2 .
- 4) Maximal deviations of Γ_h in extra- $U(1)$ models vs. θ_2 .
- 5) Maximal deviations of Γ_T in extra- $U(1)$ models vs. θ_2 .
- 6) Maximal deviations of $\sigma_p^{(L)}$ in extra- $U(1)$ models vs. θ_2 .
- 7) Maximal deviations of $\sigma_p^{(b)}$ in extra- $U(1)$ models vs. θ_2 .
- 8) The total width versus the peak hadronic cross-section. The box corresponds to the experimental errors. Standard Model and extra- $U(1)$ ($\theta_2 = 90^\circ$) predictions are shown for $N_\nu = 3, 4$.

	$\Gamma_t(MeV)$	$\Gamma_{ino}(MeV)$	$\Gamma_h(MeV)$	$\Gamma_T(MeV)$	$\sigma_{peak}^h(nb)$
ALEPH	85.4 ± 5.3	569 ± 92	1833 ± 116	2680 ± 150	39.1 ± 1.6
DELPHI	-	-	-	2420 ± 230	-
L3	88 ± 5	576 ± 80	-	2588 ± 137	-
OPAL	88.1 ± 4.6	552 ± 111	1787 ± 121	2600 ± 130	41.7 ± 2.4
MARK II	-	460 ± 100	-	2420^{+450}_{-380}	42 ± 4
<i>ALBPH</i> <i>NewRen</i>	84.2 ± 1.9	493 ± 43	1791 ± 48	2537 ± 58	41.4 ± 0.8
SM	83.5 ± 0.5	500 ± 3	1740 ± 20	2490 ± 25	41.4 ± 0.1

TABLE 1

Data from LEP and SLC experiments [1]-[5]. The Standard Model predictions are also shown for $M_{Z_t} = 91.10 \pm 0.06 GeV$ and $m_t = 80 - 200 GeV$, $m_H = 10^{+1}_{-1} GeV$.

	$m_t = 100$		$m_t = 200$	
$\delta\Gamma_t$	+ 5.5	-2.2	+ 3.4	-1.8
$\delta\Gamma_b$	+ 6.2	-1.0	+ 3.5	-1.0
$\delta\Gamma_h$	+ 65	-2.7	+34	-2.7
$\delta\Gamma_T$	+ 80	-2.3	+41	-2.4
$d\sigma_p^{(l)}/\sigma_p^{(l)}$	+ 0.068	-0.080	+ 0.047	-0.051
$d\sigma_p^{(h)}/\sigma_p^{(h)}$	+ 0.039	- 0.041	+0.027	-0.027

TABLE 2

Maximal deviations for widths and peak cross-sections in the left-right model neglecting W_R effects.

	$m_t = 100$		$m_t = 200$	
$\delta\Gamma_t$	+ 7.7	-6.0	+ 6.8	-6.1
$\delta\Gamma_b$	+ 8.1	-5.3	+ 6.5	-5.2
$\delta\Gamma_h$	+ 77	-34	+53	-34
$\delta\Gamma_T$	+ 93	-36	+62	-37
$d\sigma_p^{(l)}/\sigma_p^{(l)}$	+ 0.12	- 0.12	+ 0.12	- 0.12
$d\sigma_p^{(h)}/\sigma_p^{(h)}$	+ 0.063	- 0.063	+0.063	-0.063

TABLE 3

Maximal deviations for widths and peak cross-sections in the left-right model allowing for $\delta\rho_M = 0$ from W_R effects.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 8

Fig. 7