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NEW PARTICLES IN THE $SU_L(2) \otimes U_Y(1) \otimes SU_L{}^*(2)$ MODEL

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In this paper we discuss the possibility of an extended electroweak gauge group $SU_L(2) \otimes U_Y(1) \otimes SU_L{}^*(2)$. This group has a natural low energy limit. New gauge vector bosons W^* and Z^* are predicted in a region below 1-2 TeV. The new neutral current couplings are determined from the general properties of the model. Some phenomenological consequences are presented. The model implies in an increase in the Higgs' production cross-section for electron-positron colliders.

The standard electroweak model has been successful in all experimental tests. The agreement between theory and experimental data is now at the level of quantum corrections. Nevertheless there is a general belief that the standard electroweak model is not the last theory. There is a large number of extended theories that try to improve the standard model. At least two general conditions must be satisfied by extended models: the first one is to reproduce the standard model results up to the energies now available and the second is a more unified description of fundamental interactions at higher energies. This program has not been successful so far. In many extended models the standard model results are obtained only after some fine tunings behavior of parameters and the unknown (possibly very large) scale of unification make predictions of new phenomena with very large uncertainties.

In this paper we discuss a class of models which improve these two points in a natural way; the low energy limit is a consequence of the structure of the model and the new interaction scale can be determined. This is done by a new electroweak symmetry group $SU_L(2) \otimes U_Y(1) \otimes SU_L{}^*(2)$ (from now on called SUS^*).

From a theoretical point of view this group can be justified in two ways. The first approach is the superstring inspired models with an $E_8 \otimes E_8$ structure. The low energy limit is compatible with $SU_L(2) \otimes U_Y(1) \otimes G$ but there is no clear prediction on the content of G. The most popular possibility so far studied is some combinations of new $U(1)'s$. In Witten's[1] original suggestion we have this simple possibility but larger groups such as a new $SU_L{}^*(2)$ are also mentioned. A few authors[2] have discussed some phenomenological consequences of this kind of model.

The second motivation for the SUS^* group comes from composite models. A general consequence of composite models is that the standard electroweak theory must be viewed as an effective model. The dynamics of composite models is unknown and it is very difficult to make predictions in this direction. But if the W and Z are composite particles this does not mean that the standard model must be abandoned. On the contrary, we can follow the standard model approach in order to answer the fundamental question on composite models: where are the excited states of the W and Z?

The minimal hypothesis that we must do in order to obtain an effective theory including new W^* and Z^* is a new gauge group $SU_L{}^*(2)$. The main consequences and the details of this approach were developed some time ago[3,4].

In both cases - superstring inspired or composite models - the choice of a new $SU_L{}^*(2)$ group has a very appealing consequence: we must include a new Higgs' doublet (with symmetry breaking scale v^*), similar to the standard Higgs ($\langle 0|\Phi|0\rangle = v$) in order to give mass to the new W^* and Z^*. This means that the low energy phenomenology of the standard model is practically unchanged without the fine tunings of couplings. In particular, we still have the ratio of neutral to charged current equal to one ($\rho \equiv 1$).

In the SUS^* model we have five input parameters - three couplings g, g' and g^*, and two vacuum expectation values v and v^*. Since $\sin^2\theta_w$ is an identity, we have four experimental parameters α, G_F, M_W and M_Z. The main point of this paper is to consider that at energies well above the symmetry breaking scale the two coupling constants g and g^* associated to $SU_L(2)$ and $SU_L{}^*(2)$ respectively are equal, $g = g^*$. With this condition we can determine uniquely all couplings and the W^* and Z^* masses.

It is a remarkable property of the SUS^* model that the new scale v^* implies new W^* and Z^* masses below 1-2 TeV. The usual Z couplings with matter are practically the same as the standard model ones and the new Z^* couplings with ordinary matter are fixed and naturally small.

In table 1 we show a possible choice of quantum numbers for the basic SUS^* representation that preserves the standard model phenomenology. For the general notation and details the reader can use reference 4.

With this assignment, neutral current couplings are determined and show little dependence on mixing angles. The new charged current couplings comes only in the case of mass mixing between ordinary and new leptons.

In figure 1 we show the SUS^* prediction for the new gauge boson masses. There is a strong dependence on the W mass, but we can see clearly that there is an upper bound on M_{W^*} and M_{Z^*} of the order of 1 TeV. All the standard parameters are taken from the averaged LEP results[5]. In figures 2 and 3 we show the differences $\Delta\Gamma = \Gamma_{SM} - \Gamma_{SUS^*}$ for the Z decay channels. Even for a relatively large mixing $\sin\alpha = 0.1$ there is no

significant difference between the two models. An interesting case is given by the decays $Z \longrightarrow N\bar{N}, N\bar{\nu}$. As the couplings are very small, even in the case of new neutrino with zero mass we have a small contribution to the invisible Z width as shown in figure 4. This opens the possibility of new zero mass neutrinos.

One of the most interesting predictions of the SUS^* model is the new Z^* behavior. A sharper determination of the W mass would improve the Z^* mass strongly. If we take $M_W = 80GeV$ the new Z^* mass is to be found around $512GeV$. In figure 5 we show the $e^+e^- \longrightarrow \mu^+\mu^-$ total cross section. We stress that the only parameter that is significantly affected by the W mass is the new Z^* (and W^*) mass.

Another clear prediction of the SUS^* model is given in the Higgs' sector as the coupling $Z^*ZH^0{}_{1,2}$ (where 1 and 2 refers to the ordinary and new Higgs) is determined we can calculate the process $e^+e^- \longrightarrow Z^* \longrightarrow H_{SM}Z \longrightarrow H_{SM}\mu^+\mu^-$.

As in the standard model, the Higgs' mass can not be determined theoretically. But if we take $M_W = 80GeV$ we see from figure 6 that there is an enormous enhancement in the total cross section for $e^+e^- \longrightarrow H_{SM}\mu^+\mu^-$ compared to the standard model result for a $300GeV$ Higgs.

In conclusion the extended $SU_L(2) \otimes U_Y(1) \otimes SU_L{}^*(2)$ model besides new interesting physical predictions has a unique characteristic of introducing a very small number of new parameters and shows a natural low-energy limit compatible with experimental data.

ACKNOWLEDGMENT

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	T_3	Y	T_3^*
ν_L	1/2	-1	0
e_L	-1/2	-1	0
e_R	0	-2	0
N_L	0	-1	1/2
E_L	0	-1	-1/2
E_R	0	-2	0
Φ^+	1/2	1	0
Φ^0	-1/2	1	0
Φ^{*+}	0	1	1/2
Φ^{*0}	0	1	-1/2

Table 1: Possible quantum numbers for the usual and new leptons in the SUS^* model. A similar assignment can be given to quarks.

REFERENCES

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3. J.A.Martins Simões , Nuovo Cimento, A**89**, 235(1985).
   Y.A.Coutinho et al., Phys. Rev. D**43**, 2104(1991).
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FIGURE CAPTIONS

1. The new W^* and Z^* masses in the SUS^* model.
2. The known $Z^0 \longrightarrow e^+e^-; \bar{\nu}\nu$ difference $\Delta\Gamma = \Gamma_{SM} - \Gamma_{SUS^*}$.
3. The total and hadronic width difference for the known Z^0 decays.
4. Partial width for the new decay channels $Z^0 \longrightarrow \bar{N}\nu; \bar{N}N$. The new neutrino mass is taken equal to zero.
5. The cross section for $e^+e^- \longrightarrow \mu^+\mu^-$.
6. A standard Higgs ($M_H = 300GeV$) production in the SUS^* model.

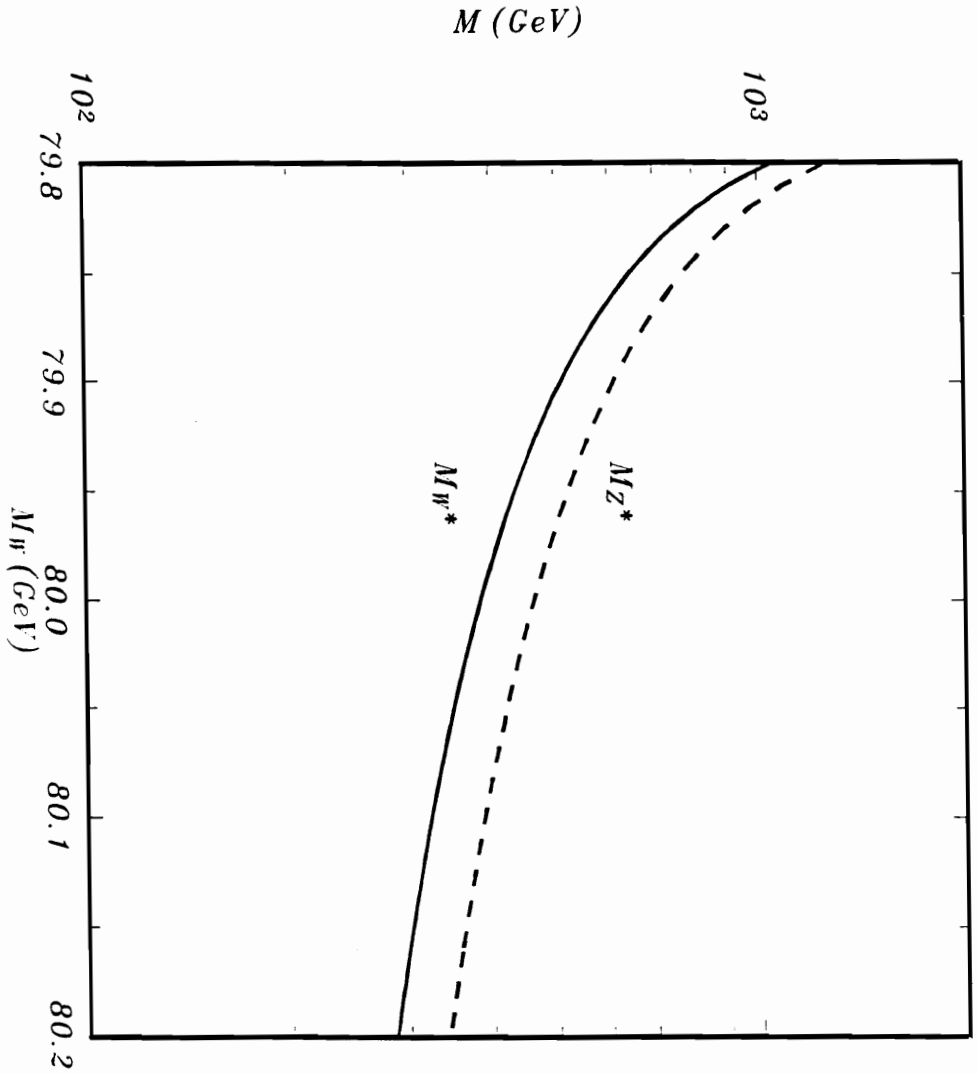

Figure 1

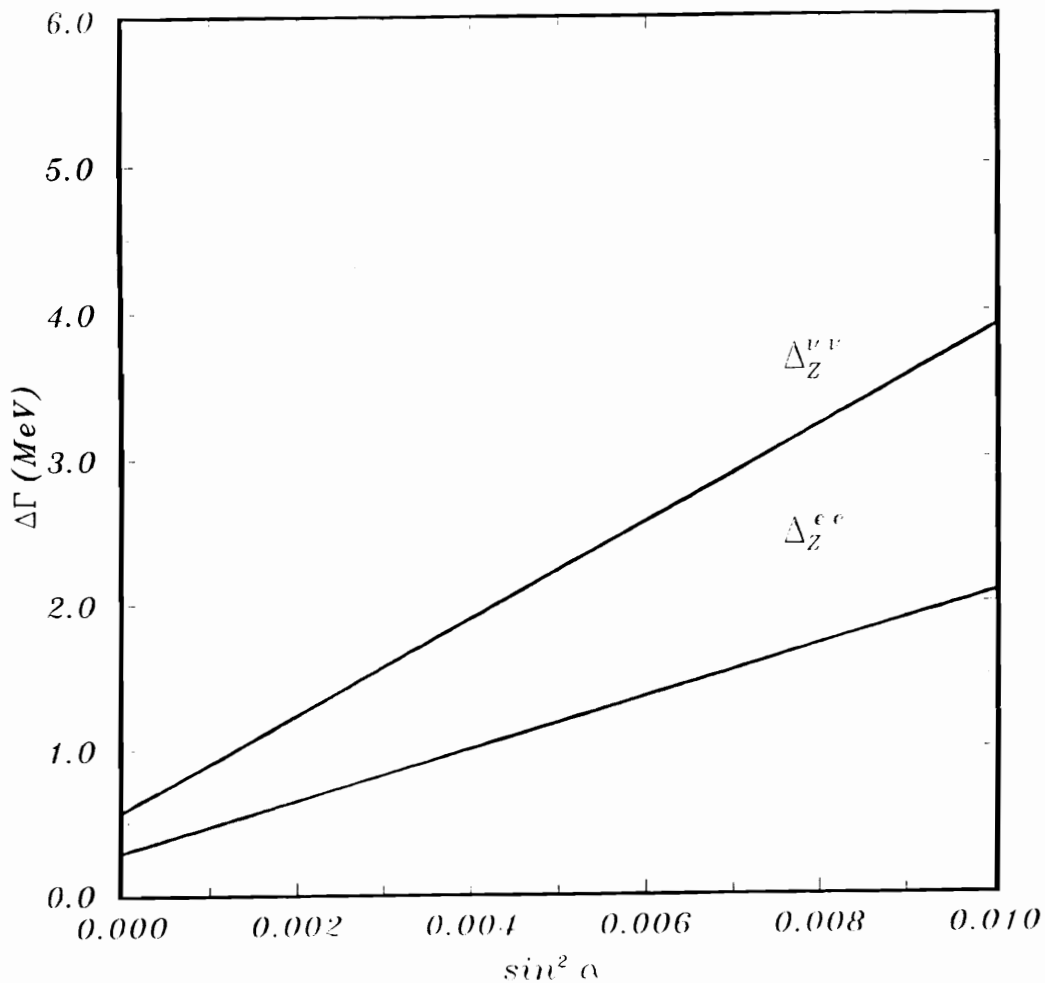
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ΔΓ (MeV)
$\Delta_Z^{\nu\nu}$
Δ_Z^{ee}
0.000
0.002
0.004
0.006
0.008
0.010
$\sin^2\alpha$

Figura 2

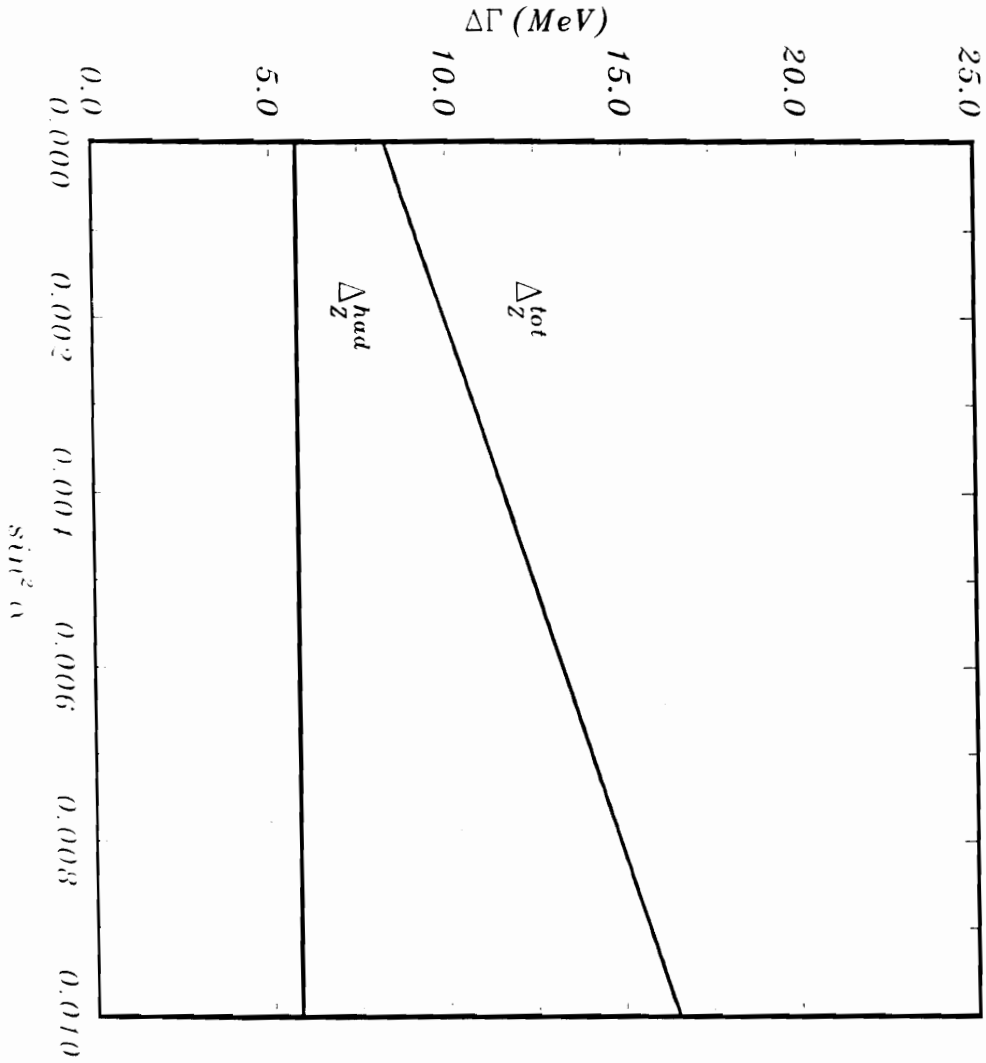
25.0
20.0
15.0
10.0
5.0
0.0
ΔΓ (MeV)
Δ_Z^{tot}
Δ_Z^{had}
0.000
0.002
0.004
0.006
0.008
0.010
$\sin^2\theta$

Figure 3

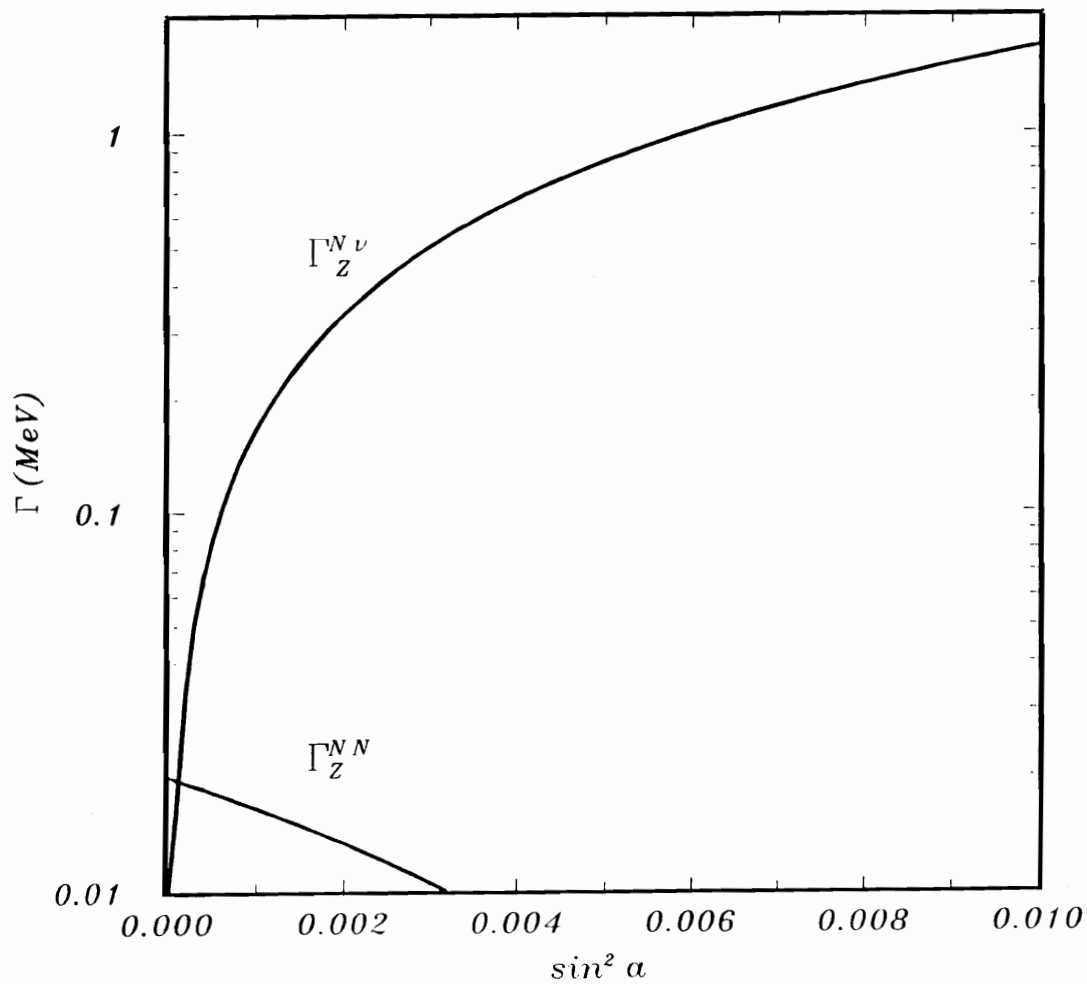
1
0.1
0.01
Γ (MeV)
$\Gamma_Z^{N\nu}$
Γ_Z^{NN}
0.000
0.002
0.004
0.006
0.008
0.010
$\sin^2 a$

Figure 4

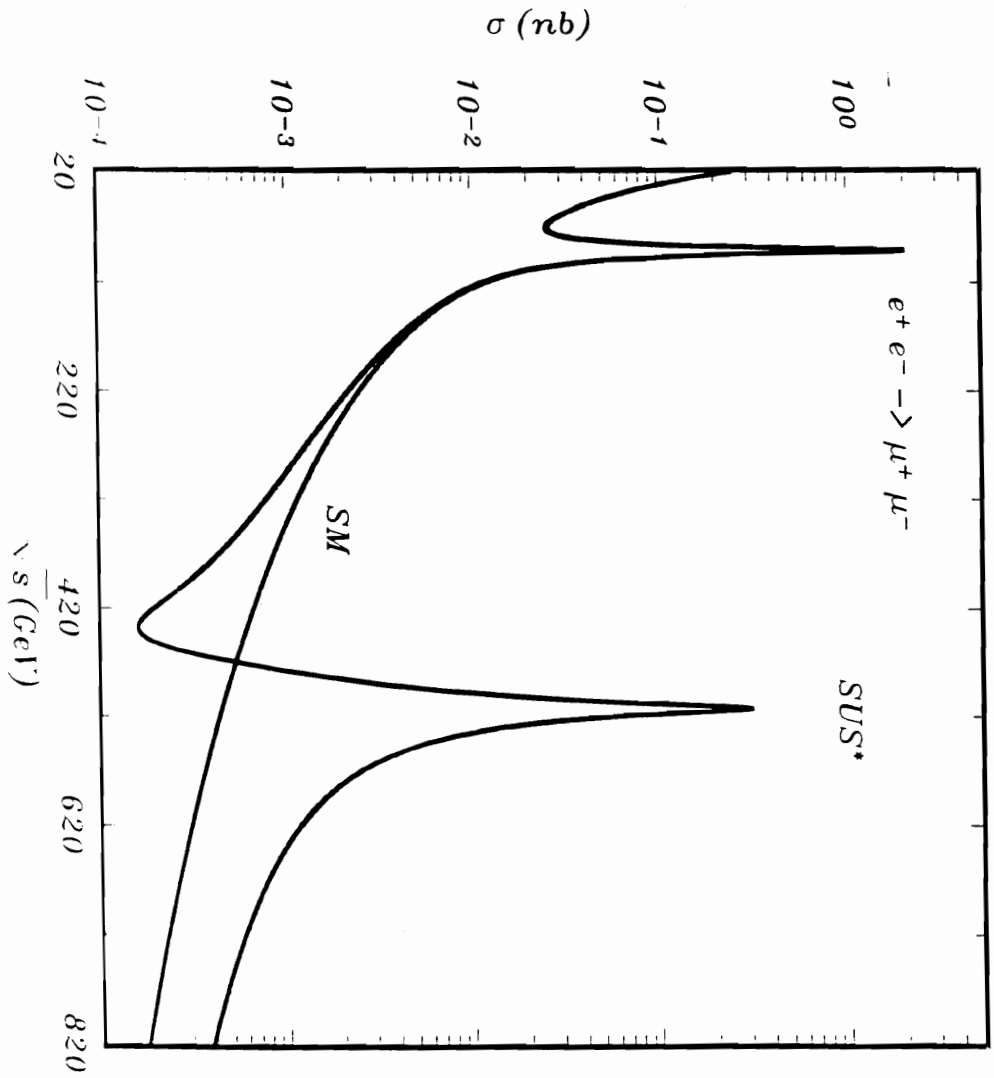

Figure 5

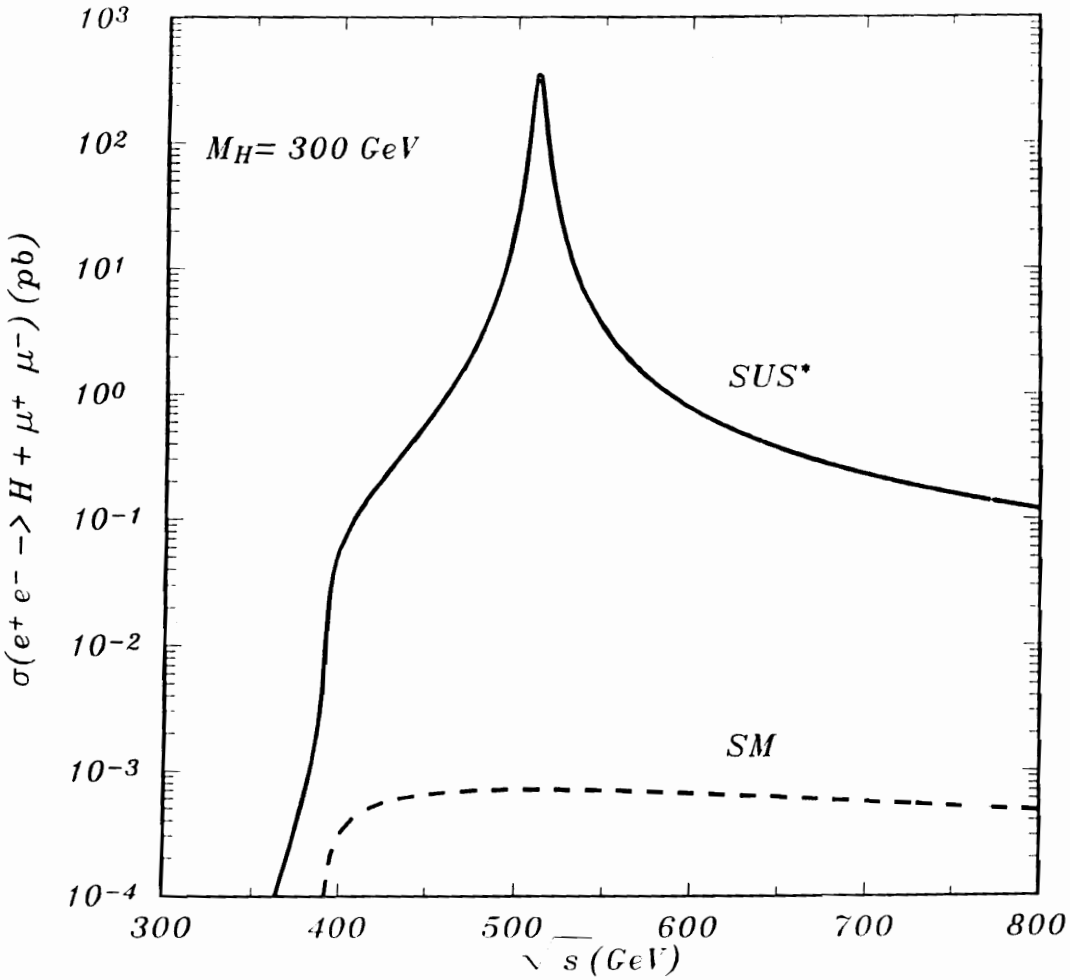
M_H= 300 GeV
SUS*
SM
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\sigma(e^+e^- \to H + \mu^+\mu^-)$ (pb)
300
400
500
600
700
800
$\sqrt{s}$ (GeV)

Figure 6