

Updated calculations of the reach of Fermilab Tevatron upgrades for Higgs bosons in the MSSM, mSUGRA and mGMSB models <sup>1</sup>

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One of the crucial predictions of supersymmetric models that reduce to the Minimal Supersymmetric Standard Model (MSSM) at the weak scale is that the lightest Higgs scalar should have mass  $m_h \lesssim 125 - 130$  GeV[1]. Recent results on the reach of Fermilab Tevatron upgrades for Standard Model (SM) Higgs bosons show that masses of order 120-180 GeV may be probed [2, 3, 4, 5], depending on integrated luminosity, detector performance and signal and background modeling. Thus, the discovery of a Higgs boson (or a new limit of around 120-130 GeV on its mass) will severely constrain supersymmetric models as well.

In this report, we update previous calculations made by our group [6] pertaining to the reach of Fermilab Tevatron upgrades for Higgs bosons in supersymmetric models. We present reach results for SUSY Higgs bosons within the MSSM, the minimal Supergravity model (mSUGRA) and in the minimal Gauge Mediated SUSY Breaking model (mGMSB). In this update, 95% CL exclusion contours and  $5\sigma$  discovery contours are presented for integrated luminosity values of 2, 5 and 20  $\text{fb}^{-1}$ .

Recently, new results have been presented at the Fermilab Run 2 workshop on

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the reach for SM Higgs bosons [5]. In this report we translate these results into a reach in parameter space of the MSSM, mSUGRA and mGMSB models. We follow the general procedure outlined in Ref. [6] but with the following improvements:

- We use the updated SM signal and background results presented by John Conway at the Run 2 summary meeting. The results used include the Run 2 improved  $m_{b\bar{b}}$  mass resolution and acceptance, but do not include possible enhancements due to use of neural nets [5].
- We include in this update results for the  $\ell\nu b\bar{b}$  channel, the  $\nu\bar{\nu} b\bar{b}$  channel and the  $\ell^+\ell^- b\bar{b}$  channel. The resulting significances were added in quadrature.

In Fig. 1, we show results for the MSSM in the  $m_A$  vs.  $\tan\beta$  plane taking soft SUSY breaking masses  $M_{SUSY} = 1$  TeV and weak scale  $A$  parameters  $A_i = 0$  for  $i = t, b$  and  $\tau$ , and  $\mu > 0$ . As noted in Ref. [7], these results are somewhat sensitive to the various input parameters  $M_{SUSY}$ ,  $A_i$  and  $\text{sgn}(\mu)$  that enter the third generation sfermion mass matrices (which in turn affect the Higgs boson masses via radiative corrections). We show the current constraints from LEP Higgs searches, along with the ultimate reach of LEP2 for SUSY Higgs bosons, which should cover the low  $\tan\beta$  region of parameter space. With  $5 \text{ fb}^{-1}$  of integrated luminosity, the Fermilab Tevatron experiments should be able to probe nearly the entire parameter plane at the 95% CL. (Experiments will probe the region to the right of the  $h$  contour and within the  $H$  contour.) This would leave a small window of non-observability around  $m_A \sim 110$  GeV; this window is, however, filled in at  $20 \text{ fb}^{-1}$ . The region where a  $5\sigma$   $h$  signal at  $20 \text{ fb}^{-1}$  is seeable is also shown below the correspondingly labelled contour.

The corresponding results for the mSUGRA model are shown in Figs. 2 and 3 for  $\tan\beta = 2$  and for  $\mu < 0$  and  $\mu > 0$ . The TH region is excluded either due to a lack of appropriate electroweak symmetry breaking, or because the lightest neutralino is not the lightest SUSY particle (LSP). The EX region is excluded by the negative results from LEP2 searches for chargino pair production, which require  $m_{\tilde{W}_1} > 85$  GeV. The ultimate reach of the LEP2 experiments is to cover the entire region of the parameter planes shown. Likewise, Fermilab Tevatron experiments should be able to explore the entire plane shown at 95% CL with  $2 \text{ fb}^{-1}$  or at  $5\sigma$  with  $20 \text{ fb}^{-1}$ . In addition, in the lower left corner of Fig. 2,  $h$  production can be seen at  $5\sigma$  with  $5 \text{ fb}^{-1}$ .

The corresponding mSUGRA plots for  $\tan\beta = 10$  are shown in Figs. 4 and 5. The light Higgs boson is typically heavier at large  $\tan\beta$  than at small, so the ultimate reach of LEP2 is much more limited in this case. However, Fermilab Tevatron experiments should be able to probe the entire plane shown at 95% CL with  $5 \text{ fb}^{-1}$  of data. The Tevatron discovery potential at the  $5\sigma$  level is much more limited.

Finally, mSUGRA expectations for  $\tan\beta = 35$  are shown in Figs. 6 and 7. In these cases, there is no ultimate reach of LEP2 for Higgs bosons beyond the already existing parameter space bounds. Tevatron experiments can probe nearly the whole plane up to  $m_{1/2} \sim 1200 - 1400$  GeV at the 95% CL with  $5 \text{ fb}^{-1}$  of data, but discovery at the  $5\sigma$  level will require an integrated luminosity larger than  $20 \text{ fb}^{-1}$ .

We have also updated our results for the mGMSB model. These are shown in the  $\Lambda$  vs.  $\tan\beta$  plane are shown in Figs. 8 and 9, for  $n_5 = 1$  and messenger scale  $M = 10^6$  GeV. In these cases, the whole plane can be probed by Tevatron experiments at the 95% CL with  $5 \text{ fb}^{-1}$  of data. However, the reach of LEP2 and Fermilab Tevatron experiments at the  $5\sigma$  level is limited to the low  $\tan\beta$  region of the parameter plane shown.

As an extreme case, we show similar results for the mGMSB model with the number of messengers  $n_5 = 4$ , in Figs. 10 and 11. In these cases, most of the parameter plane can be probed at 95% CL with  $5 \text{ fb}^{-1}$  of data, except for the regions shown at higher  $\tan\beta$  with  $\Lambda \gtrsim 250 - 275$  GeV. These holes can be filled at 95% CL with the higher integrated luminosity value of  $20 \text{ fb}^{-1}$ .

In summary, luminosity upgrades of the Tevatron collider may provide tantalizing indirect evidence for supersymmetry via signals for a Higgs boson. The non-observation of any signal will essentially exclude a wide class of SUSY models at the 95% CL. Furthermore these experiments may provide tantalizing indication for the existence of a light Higgs boson, though definitive evidence at the  $5\sigma$  level may require an integrated luminosity beyond  $20 \text{ fb}^{-1}$  that is currently envisioned for future upgrades.

## References

- [1] For a recent review, see H. Haber, hep-ph/9901365 (1999).
- [2] A. Stange, W. Marciano and S. Willenbrock, Phys. Rev. D49, 1354 (1994) and Phys. Rev. D50, 4491 (1994).
- [3] See contribution by U. Heintz, S. Kuhlmann and S. Willenbrock to *The TeV-2000 Group Report*, ed. by D. Amedei and R. Brock, Fermilab-Pub-96/082 (1996).
- [4] S. Kim, S. Kuhlmann and W. M. Yao, in *New Directions for High Energy Physics, Snowmass 96*, ed. by D. G. Cassel, L. Trindle Gennari and R. H. Siemann.
- [5] See talk presented by John Conway at Summary Meeting of the Fermilab Run 2 workshop.
- [6] H. Baer, B. W. Harris and X. Tata, Phys. Rev. D59, 015003 (1999).
- [7] M. Carena, S. Mrenna and C. Wagner, hep-ph/9808312 (1998).

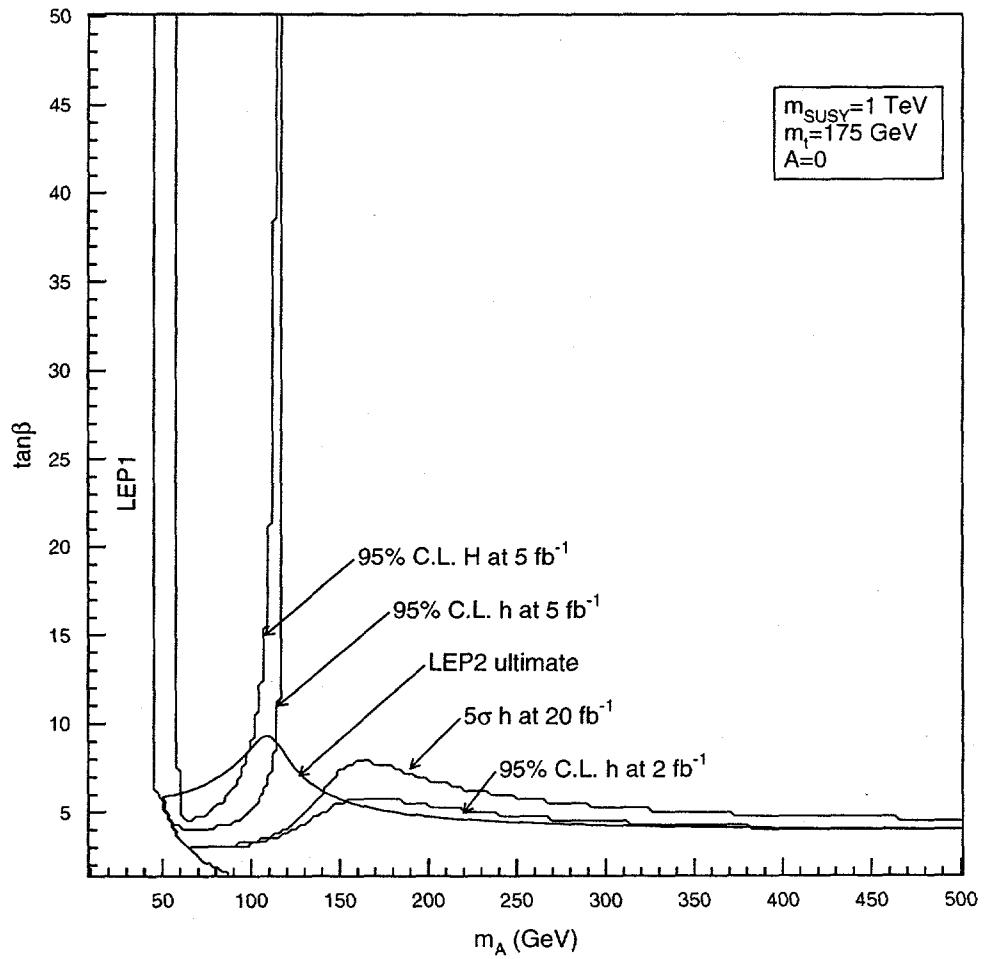


Figure 1: Regions of  $m_A$  vs.  $\tan\beta$  plane of the MSSM accessible to Higgs searches at the Fermilab Tevatron collider and CERN LEP2. We take  $M_{\text{SUSY}} = 1 \text{ TeV}$ ,  $A_t = 0$  and  $m_t = 175 \text{ GeV}$ .

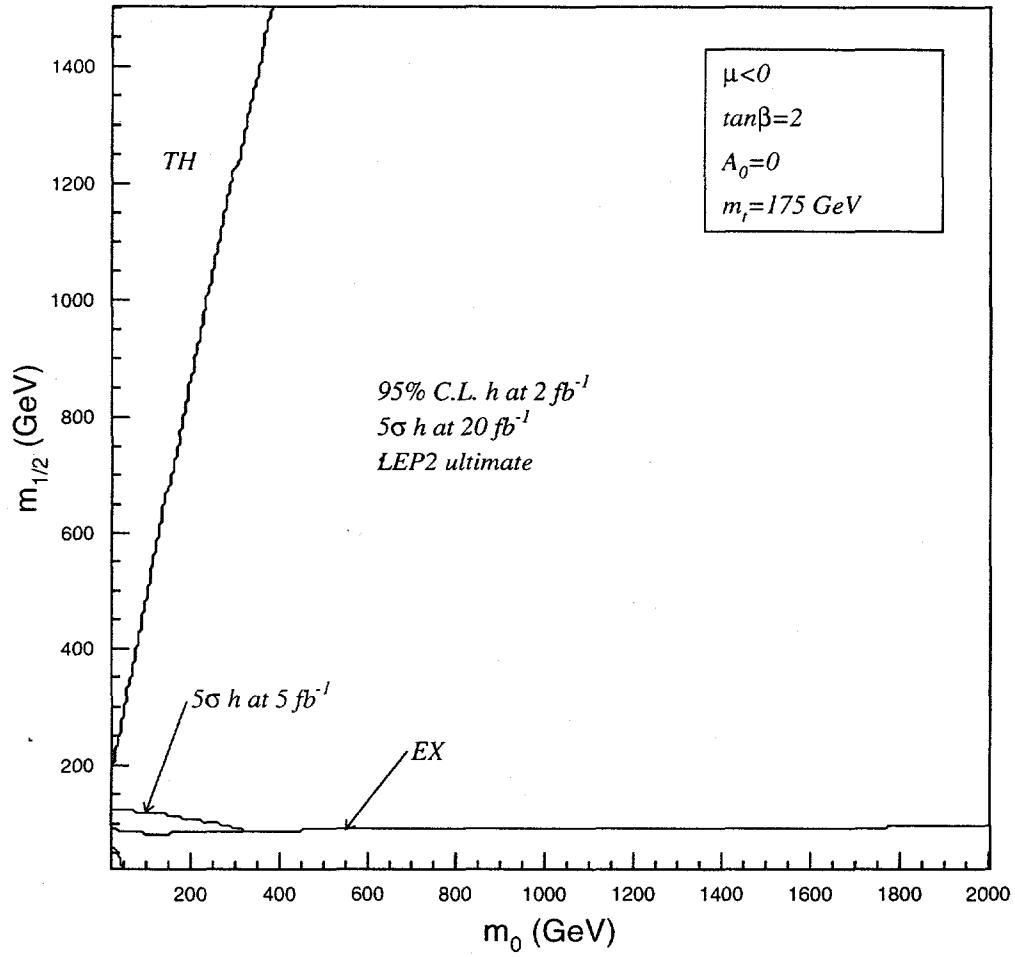


Figure 2: Regions of mSUGRA model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175 \text{ GeV}$ ,  $A_0 = 0$ ,  $\tan\beta = 2$  and  $\mu < 0$ .

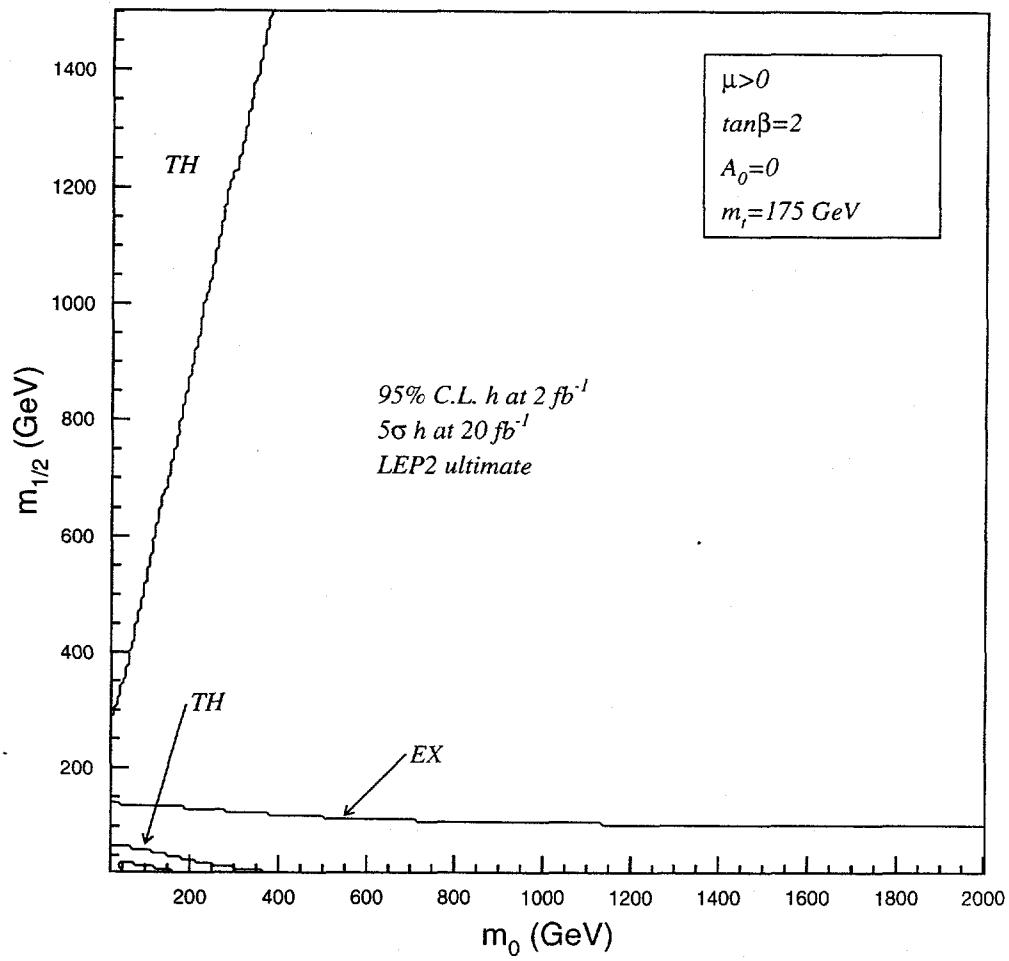


Figure 3: Regions of mSUGRA model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175 \text{ GeV}$ ,  $A_0 = 0$ ,  $\tan\beta = 2$  and  $\mu > 0$ .

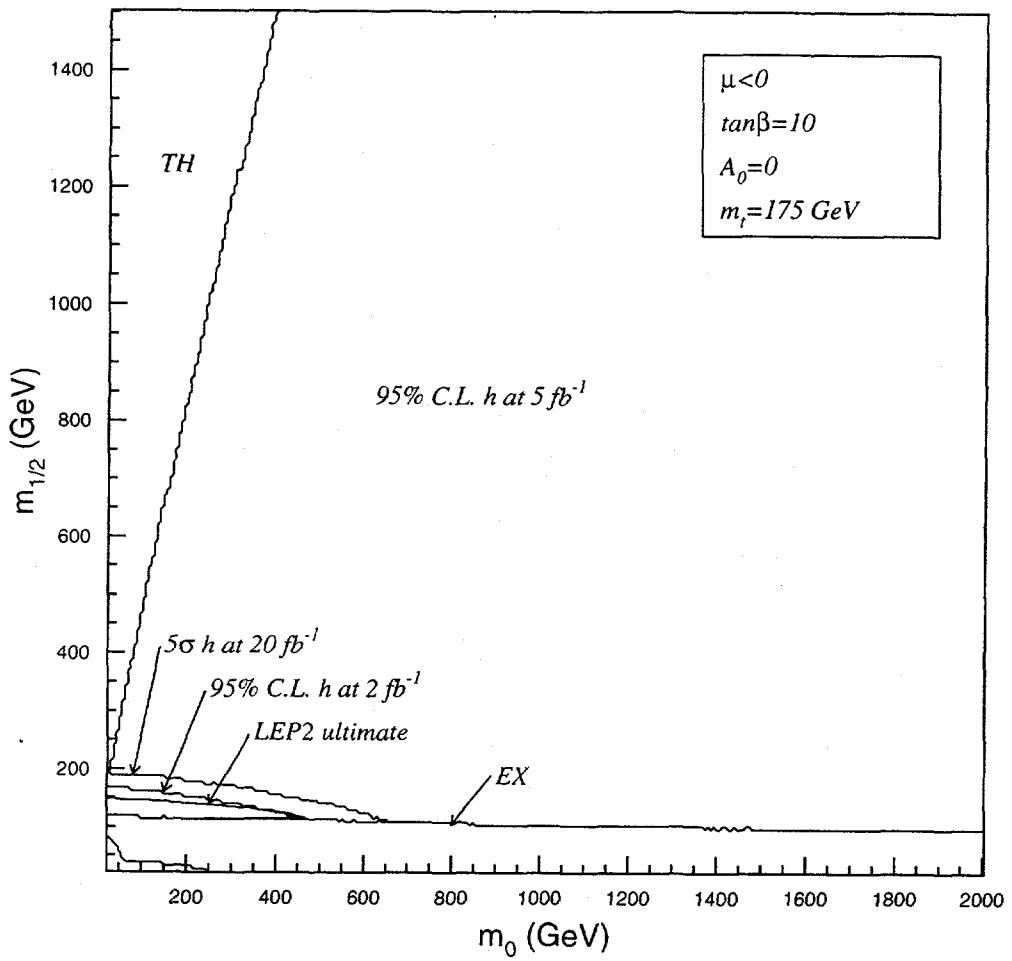


Figure 4: Regions of mSUGRA model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175 \text{ GeV}$ ,  $A_0 = 0$ ,  $\tan\beta = 10$  and  $\mu < 0$ .

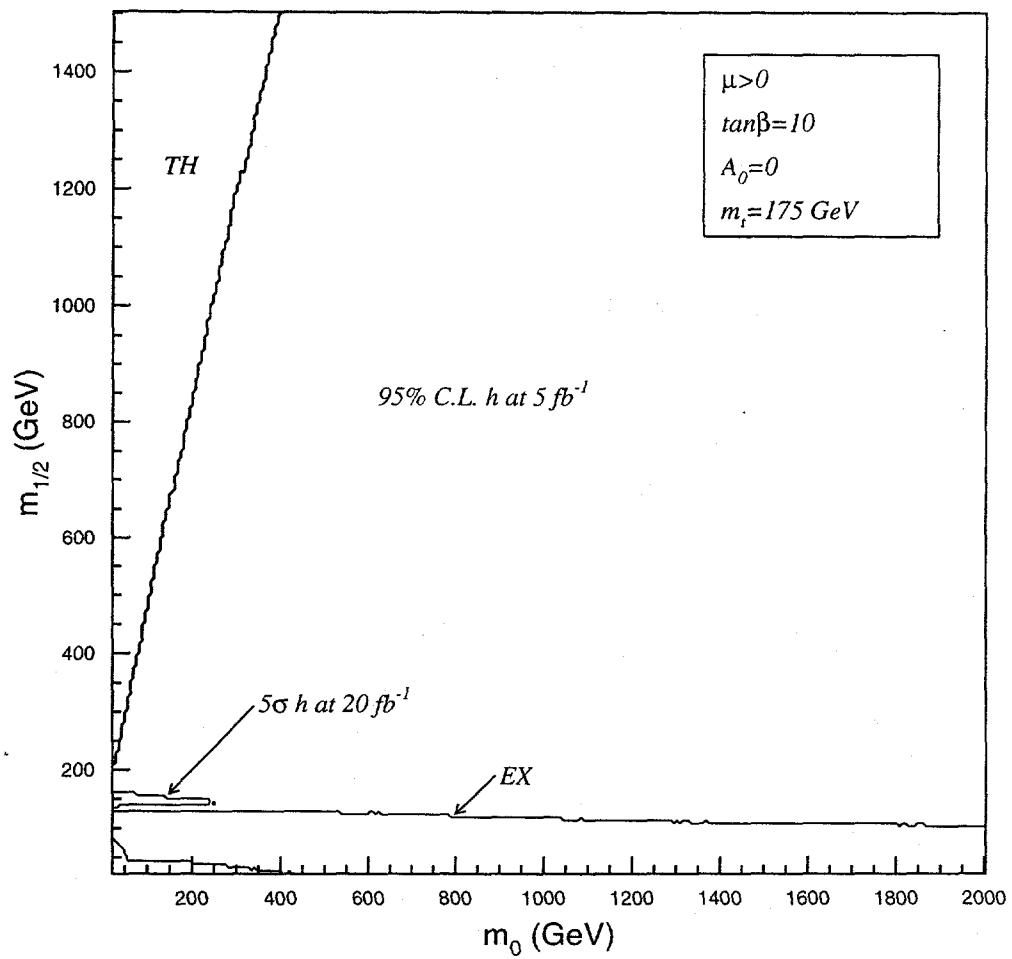


Figure 5: Regions of mSUGRA model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175 \text{ GeV}$ ,  $A_0 = 0$ ,  $\tan\beta = 10$  and  $\mu > 0$ .

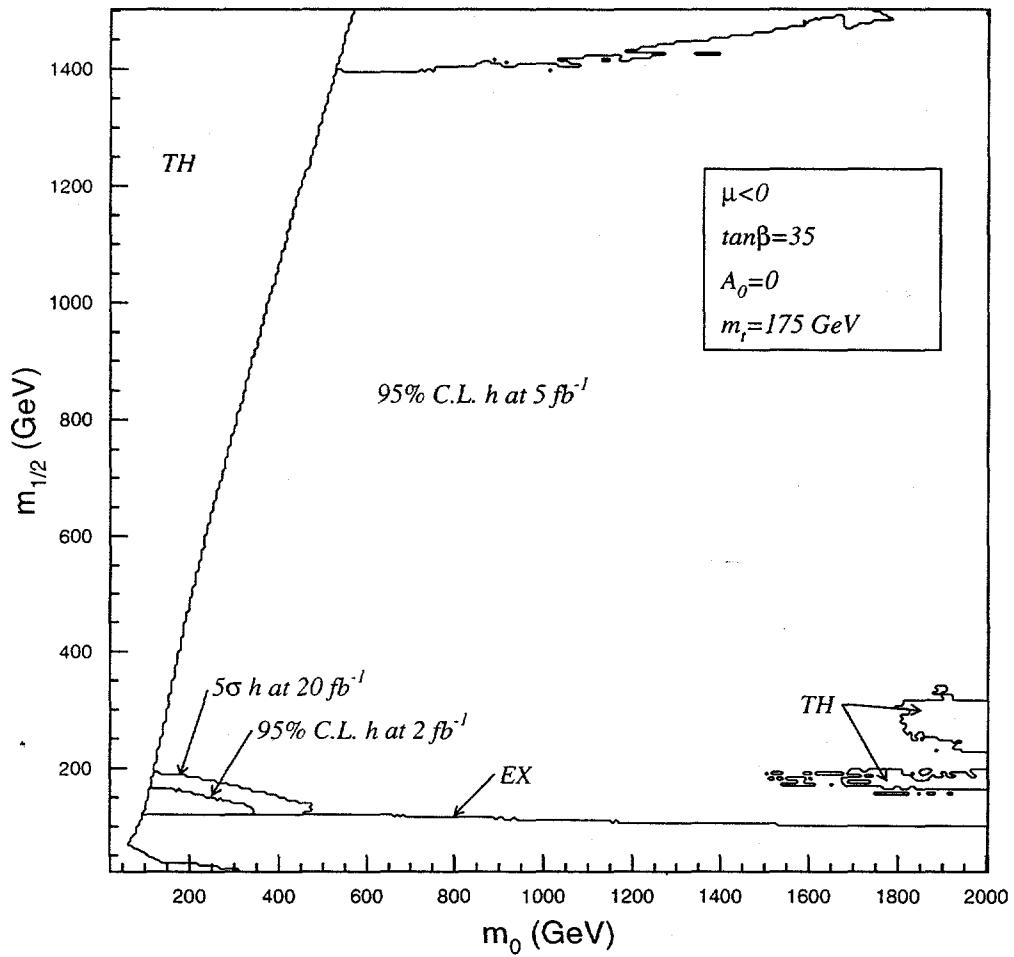


Figure 6: Regions of mSUGRA model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175$  GeV,  $A_0 = 0$ ,  $\tan\beta = 35$  and  $\mu < 0$ .

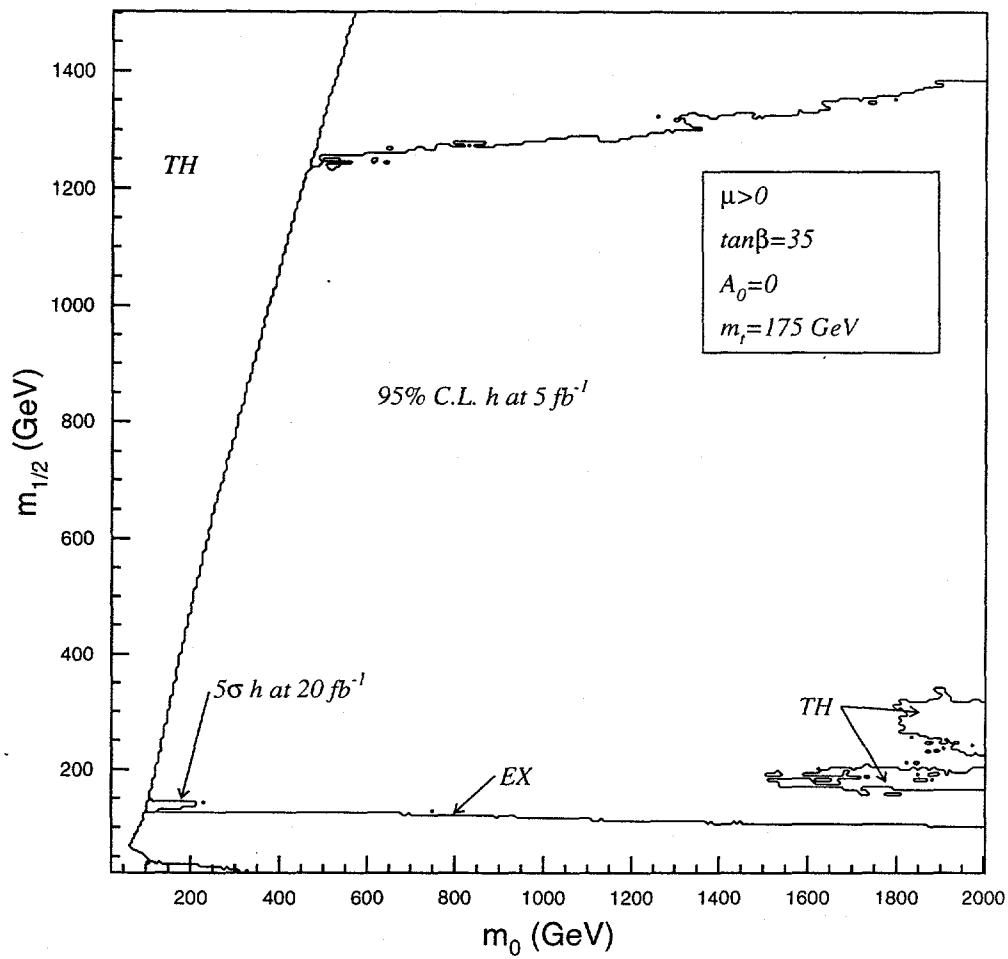


Figure 7: Regions of mSUGRA model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175$  GeV,  $A_0 = 0$ ,  $\tan \beta = 35$  and  $\mu > 0$ .

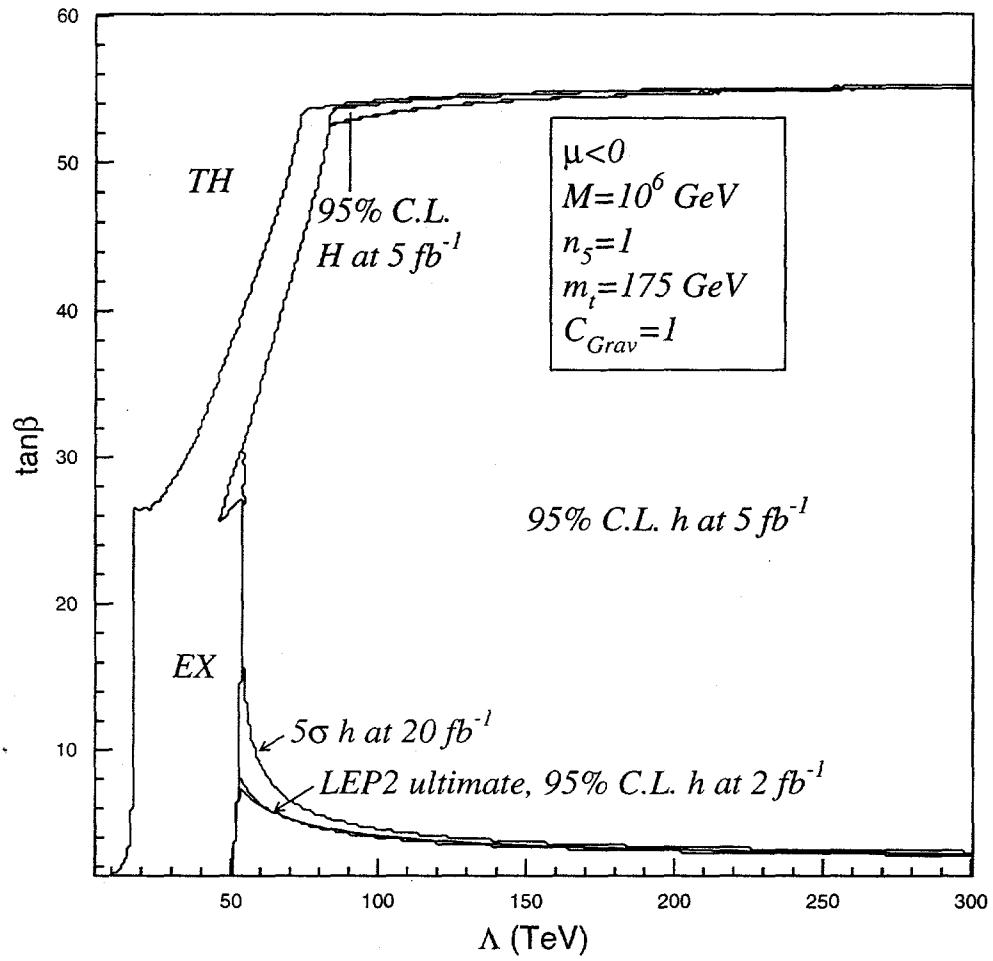


Figure 8: Regions of mGMSB model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175 \text{ GeV}$ ,  $M = 10^6 \text{ GeV}$ ,  $n_5 = 1$  and  $\mu < 0$ .

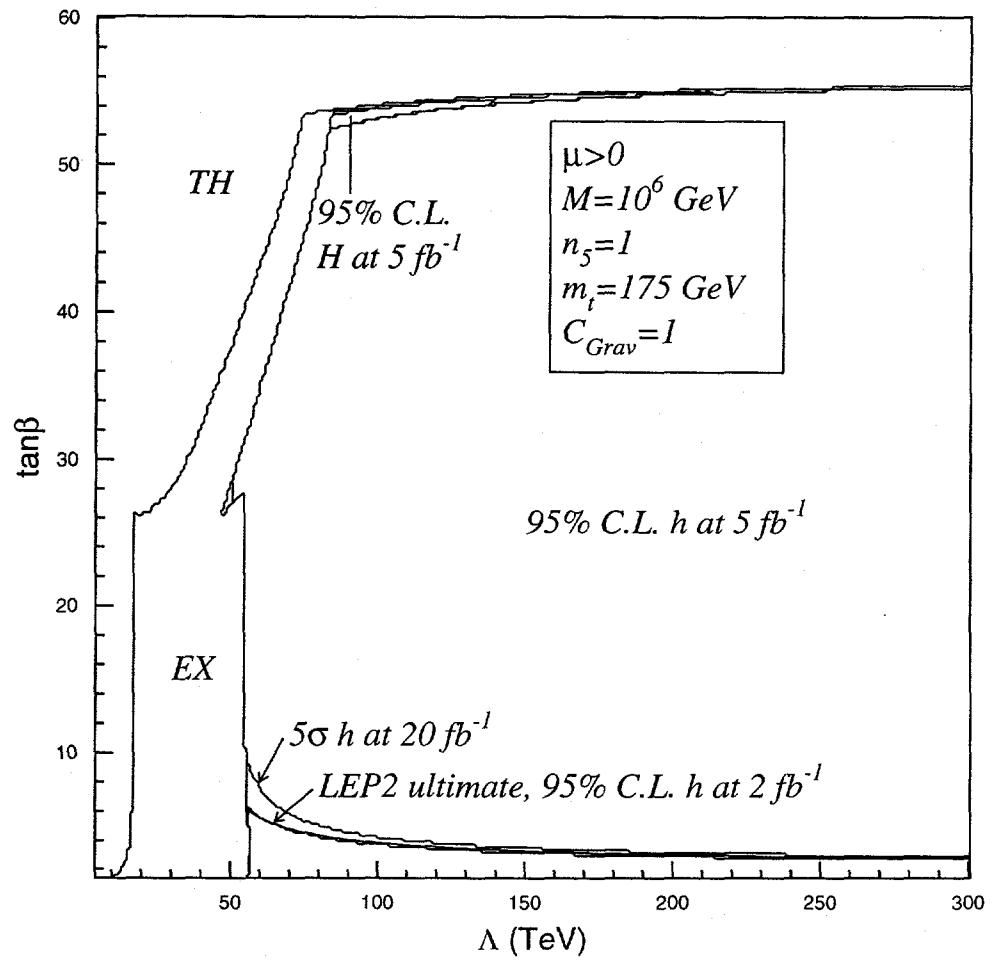


Figure 9: Regions of mGMSB model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175 \text{ GeV}$ ,  $M = 10^6 \text{ GeV}$ ,  $n_5 = 1$  and  $\mu > 0$ .

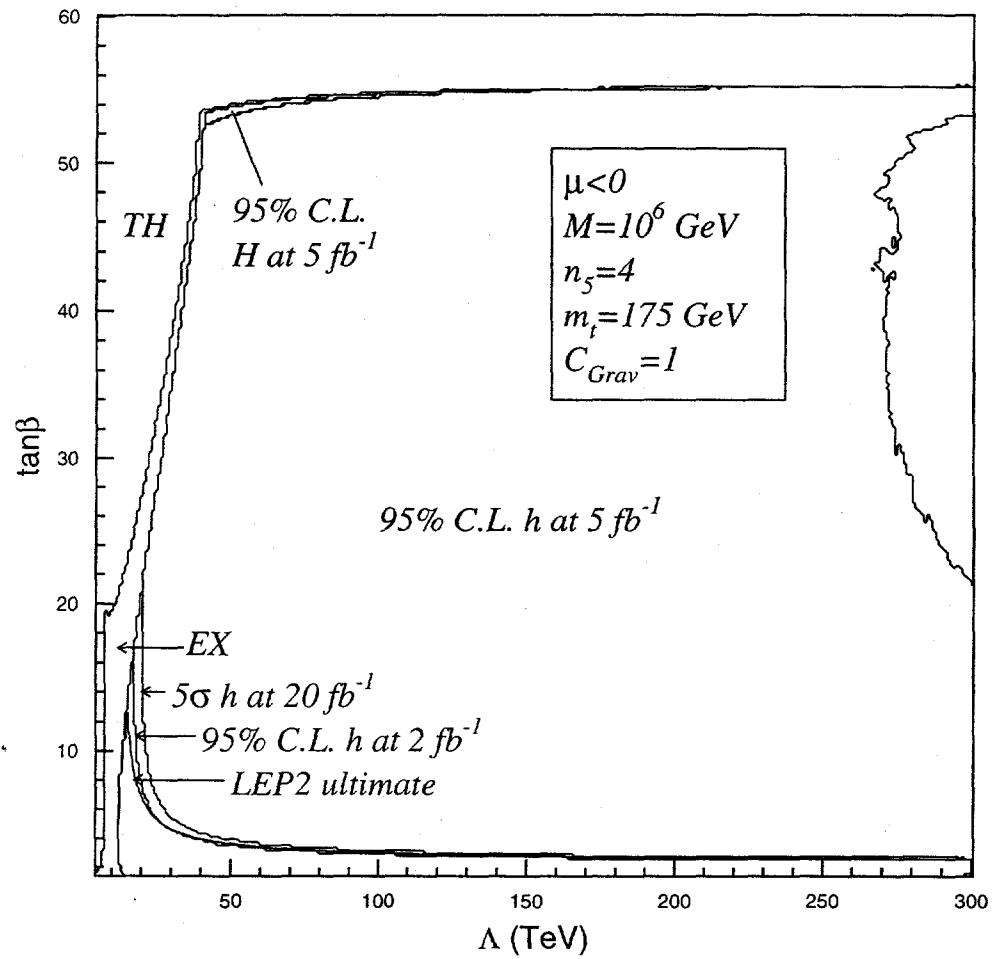


Figure 10: Regions of mGMSB model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175$  GeV,  $M = 10^6$  GeV,  $n_5 = 4$  and  $\mu < 0$ .

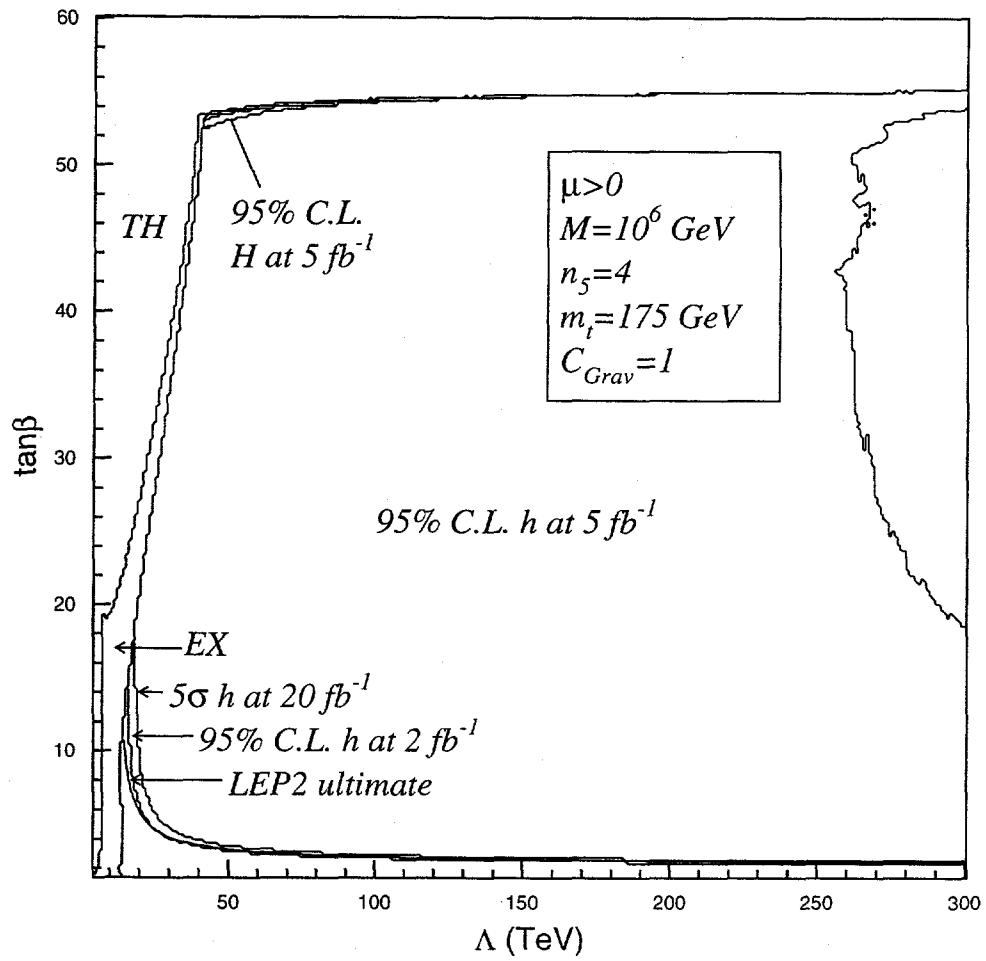


Figure 11: Regions of mGMSB model parameter space accessible to current and future Higgs boson searches at LEP2 and the Fermilab Tevatron. We take  $m_{top} = 175$  GeV,  $M = 10^6$  GeV,  $n_5 = 4$  and  $\mu > 0$ .