Can we distinguish an MSSM Higgs from a SM Higgs at a Linear Collider?\footnote{Talk presented at the Linear Collider Workshop 2000 (LCWS2000), 24-28 October 2000, Fermilab, Batavia, Illinois, USA.}

Heather E. Logan\footnote{Electronic address: logan@fnal.gov}

Theoretical Physics Department  
Fermi National Accelerator Laboratory, Batavia, IL 60510-0500, USA\footnote{Fermilab is operated by Universities Research Association Inc. under contract no. DE-AC02-76CH03000 with the U.S. Department of Energy.}

Abstract. We study the prospects for distinguishing the CP-even Higgs boson of the minimal supersymmetric extension of the Standard Model (MSSM) from the Standard Model (SM) Higgs boson by measuring its branching ratios at an $e^+e^-$ linear collider. The regions of the $M_A - \tan \beta$ plane in which an MSSM Higgs boson can be distinguished from the SM Higgs boson depend strongly upon the supersymmetric parameters that enter the radiative corrections to the Higgs mass matrix and the Higgs couplings to fermions. In some regions of parameter space it is possible to extract the supersymmetric correction to the relation between the $b$ quark mass and its Yukawa coupling from Higgs branching ratio measurements.
the Higgs mass matrix lead to corrections to the mixing angle $\alpha$ for the two CP-even MSSM Higgs bosons, which affect the Higgs couplings to fermions and vector bosons. The vertex corrections to the Higgs-fermion Yukawa couplings (denoted $\Delta_b$ for $b$ quarks) primarily modify the Higgs couplings to $b\bar{b}$ and depend on the parameters $\mu M_{\tilde{g}}$ and $\mu A_t$ and the squark masses. Explicit formulae may be found in Refs. [1,2].

We examine three benchmark scenarios (Table 1) that lead to very different behaviors for $H_{MSSM}$. These scenarios are chosen so that the Higgs mass is above its present upper bound from LEP and to maximize the effect of the choice of MSSM parameters on the behavior of the Higgs BRs. We use the program HDECAY [3] to which we have added the Yukawa vertex corrections. In each of the benchmark scenarios we compute the mass and BRs of $H_{MSSM}$ at each point in the $M_A - \tan \beta$ plane. We compare the BRs of $H_{MSSM}$ to those of $H_{SM}$ with the same mass and plot contours of $\delta BR \equiv |BR_{MSSM} - BR_{SM}|/BR_{SM}$. In Table 2 we show the expected uncertainties of BR measurements at a LC for a 120 GeV SM Higgs boson from Refs. [4] ($\sqrt{s} = 500$ GeV with 200 fb$^{-1}$) and [5] ($\sqrt{s} = 350$ or 500 GeV with 500 fb$^{-1}$). In Fig. 1 we plot the 1$\sigma$ and 2$\sigma$ contours (based on the uncertainties from Ref. [4] (Table 2)) of $\delta BR(b)$, $\delta BR(W)$ and $\delta BR(g)$ in the three benchmark scenarios.

In the top left panel of Fig. 1 we examine the no mixing scenario. In this scenario the reach in $M_A$ for distinguishing $H_{MSSM}$ from $H_{SM}$ is fairly independent of $\tan \beta$. With the uncertainties in Ref. [4] (Table 2), $BR(g)$ gives the greatest reach in $M_A$, allowing one to distinguish $H_{MSSM}$ from $H_{SM}$ at $1\sigma$ ($2\sigma$) for $M_A \lesssim 725$ GeV ($475$ GeV).

In the top right panel of Fig. 1 we examine the maximal mixing scenario. In this scenario we find significant deviations in $BR(b)$ and $BR(g)$ from their SM values even at very large $M_A > 1$ TeV. We find that one can distinguish $H_{MSSM}$ from $H_{SM}$ at $1\sigma$ using $\delta BR(g)$ even for $M_A \simeq 2$ TeV, while at $2\sigma$ the reach in $\delta BR(g)$ and $\delta BR(b)$ are comparable and one can distinguish $H_{MSSM}$ from $H_{SM}$ for $M_A \lesssim 650$.
FIGURE 1. The 1σ and 2σ contours of $\delta BR(b)$ (black), $\delta BR(W)$ (red or dark gray) and $\delta BR(g)$ (green or light gray) in the no mixing scenario (top left), the maximal mixing scenario (top right), and the large $\mu$ and $A_t$ scenario with $\mu = -A_t = 1.2$ TeV (bottom left) and $\mu = -A_t = -1.2$ TeV (bottom right). In the maximal mixing scenario (top right) we plot $M_A$ between 0.1 and 2 TeV and $\delta BR(g) = 0.16$ and 0.10 (here $\delta BR(g) = 0.08$ lies above $M_A = 2$ TeV).

Finally, in Ref. [1] we show that it is possible to extract $\Delta_b$ from measure-
FIGURE 2. Contours of the fractional error in the determination of $\Delta_b$ in the large $\mu$ and $A_t$ scenario. Here $\mu = -A_t = 1.2$ TeV (left) and $\mu = -A_t = -1.2$ TeV (right).

In Fig. 2 we show the fractional error in the determination of $\Delta_b$ from measurements of ratios of branching ratios: $\Delta_b = (1 - \sqrt{x})/(\sqrt{x} - \sqrt{y})$ with $x = (BR(b)/BR(\tau))/BR(b)/BR(\tau))_{SM}$ and $y = (BR(c)/BR(\tau))/BR(c)/BR(\tau))_{SM}$. In Fig. 2 we show the fractional error in the determination of $\Delta_b$ from measurements of $BR(b)/BR(\tau)$ and $BR(c)/BR(\tau)$ in the large $\mu$ and $A_t$ scenario (see Table 1), in which $\Delta_b$ is quite sizeable. We assume BR uncertainties as in Ref. [4]. Note that for $\mu > 0$ (the left panel of Fig. 2), $\Delta_b$ can only be distinguished from zero for moderate to large $\tan \beta$ and $M_A \lesssim 170$ GeV. In contrast, for $\mu < 0$ (the right panel of Fig. 2), $\Delta_b$ can be determined with 10% accuracy even for $M_A$ as large as 600 GeV for large $\tan \beta$. This measurement of $\Delta_b$ may ultimately be combined with other measurements to determine the underlying SUSY parameters.

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