Radiative Higgs boson decays $H \to f\bar{f}\gamma$ beyond the standard model

Chong-Sheng Li and Shou-Hua Zhu
Department of Physics, Peking University, Beijing 100871, People's Republic of China
and CCAST (World Laboratory), P.O. Box 8730, Beijing 100080, People's Republic of China

Cong-Feng Qiao
CCAST (World Laboratory), P.O. Box 8730, Beijing 100080, People's Republic of China

(Received 20 January 1998; published 7 May 1998)

Neutral Higgs boson radiative decays of the form $h_0, H, A \to f\bar{f}\gamma$, in the light fermion limit $m_f \to 0$, are calculated in the two Higgs doublet model at the one-loop level. Comparisons with the calculation within the standard model are given, which indicates that these two models are distinguishable in the decay mode fermion-antifermion photon. Our results show that the concerned process may stand as an implement to identifying the Higgs character in the case where there is an intermediate-mass Higgs boson detected. [S0556-2821(98)05511-8]

PACS number(s): 13.85.Qk, 14.70.Hp, 14.80.Bn, 14.80.Cp

I. INTRODUCTION

The discovery of the Higgs boson is one of the most important goals for future high energy physics. Although the Higgs mass cannot be precisely predicted in the standard model (SM), it can be constrained and deduced from detecting some processes it involves. The direct search in the experiments at the CERN e^+e^- collider LEP via the $e^+e^- \to Z^*H$ yields a lower bound of ~ 77.1 GeV on the Higgs boson mass [1]. This search is being extended to the present LEP2 experiments, which will probe Higgs boson masses up to about 95 GeV [2]. After LEP2 the search for the Higgs particles will be continued at the CERN Large Hadron Collider (LHC) for Higgs boson masses up to the theoretical upper limit. The detection of the Higgs boson at the LHC will be divided into two mass regions: $M_W \leqslant M_H \leqslant 130$ GeV, the so-called intermediate-mass range, and $130\ \text{GeV} \leqslant M_H \leqslant 800$ GeV. For searching for the intermediate-mass Higgs boson, the decay $H \to \gamma\gamma$ is still one of the important discovery modes [3], although the techniques of secondary vertex detection in experiments have been greatly improved in recent years, which allows the detection of secondary vertices from the decay of b quarks in the decay of $H \to b\bar{b}$ at hadron colliders [4]. For $M_H > 2M_W, 2M_Z$, Higgs boson decays to real weak bosons become dominant.

A recent investigation [5] indicates that the radiative process $H \to f\bar{f}\gamma$ also has some unique characteristics and could be used to supplement Higgs boson searches for the intermediate-mass Higgs boson, where f is a light fermion. However, if the Higgs boson should be detected, to determining whether it is a Higgs boson of the SM, or one of its extensions, is also necessary. Many extensions of the SM contain more than one Higgs doublet. The two Higgs doublet model (2HDM) is one of the extensions [6], which has drawn much attention these years, because in the minimal supersymmetric extension of the SM (MSSM) [6,7] two Higgs doublets have to be introduced [8]. In the 2HDM, there are three neutral and two charged Higgs bosons, $h_0, H, A, H^{\pm}$ of which h_0 and H are CP even and A is CP odd.

In this paper we study the $H \to f\bar{f}\gamma$ process in the context of the MSSM Higgs sector, where H denotes h_0, H, and A. We present the decay widths versus Higgs boson mass changing in the intermediate-mass region, and compare with the results of the same process in the SM in the case of different parameter choices. In Sec. II, we present expres-

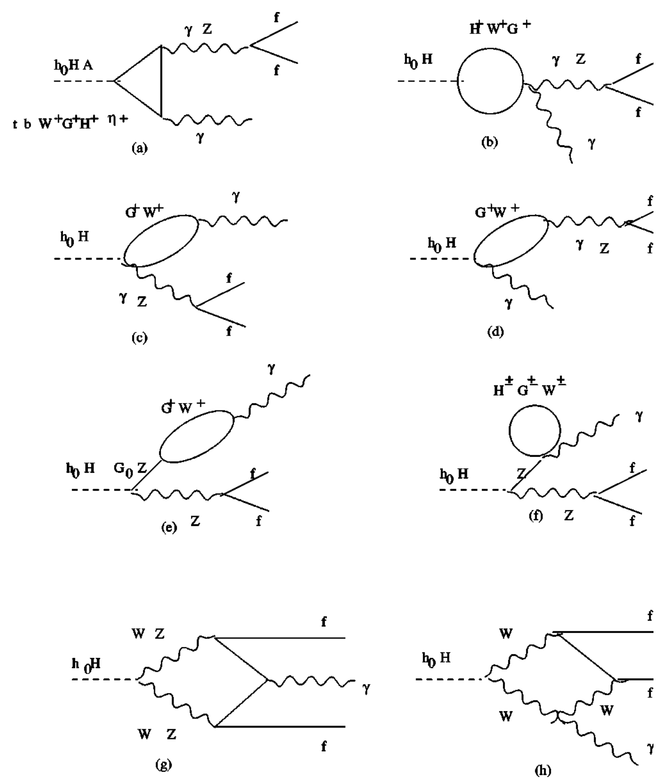

FIG. 1. The generic Feynman diagrams of $h_0, H, A \to f\bar{f}\gamma$ processes.

sions for the decay amplitudes. In Sec. III, we give our numerical results and discussions.

II. FORMALISM OF HIGGS BOSONS DECAY WIDTHS

The Higgs bosons, h_0,H,A couple to fermions proportionally to their masses. Hence, the lowest-order diagrams of the processes $h_0,H,A\to f\bar{f}\gamma$ are those of loop diagrams in the $m_f\to 0$ limit. We perform the calculations in the Feynman–'t Hooft gauge and generally set $m_f=0$ except for the phase-space intergrations.

The relevant Feynman diagrams for those processes are shown in Fig. 1. The amplitudes for $A\to f\bar{f}\gamma$ can be expressed as

$$M_A=M_A^\gamma+M_A^Z, \tag{1}$$

where

$$M_A^\gamma=f_A^\gamma(k_1\cdot k_3-k_2\cdot k_3)\bar{u}(k_1)\not\epsilon\gamma_5 v(k_2)(k_2-k_1)\cdot\epsilon\bar{u}(k_1)\not\epsilon\gamma_5 v(k_2) \tag{2}$$

and

$$\begin{aligned}M_A^Z=2f_A^Z[&a_f(k_2\cdot k_3-k_1\cdot k_3)\bar{u}\not\epsilon v(k_2)\\&-v_f(k_2\cdot k_3-k_1\cdot k_3)\bar{u}(k_1)\not\epsilon\gamma_5 v(k_2)\\&+a_f\bar{u}(k_1)\not k_3\gamma_5 v(k_2)(k_1-k_2)\cdot\epsilon\\&-v_f\bar{u}(k_1)\not k_3\gamma_5 v(k_2)(k_1-k_2)\cdot\epsilon]\end{aligned} \tag{3}$$

with

$$f_A^\gamma=\frac{-ie^3gQ_f}{24(k_1\cdot k_2+m_f^2)m_W\pi^2}[\tan\beta m_b^2C_0(2k_1\cdot k_2,0,m_A^2,m_b^2,m_b^2,m_b^2)+4\cot\beta m_t^2C_0(2k_1\cdot k_2,0,m_A^2,m_t^2,m_t^2,m_t^2)], \tag{4}$$

$$\begin{aligned}f_A^Z=&\frac{-ie^3g}{16\pi^2\sin\theta_w\cos\theta_w m_W(2k_1\cdot k_2-m_Z^2+i\Gamma_Z m_Z)}[(-1/2+2/3\sin^2\theta_w)m_b^2\tan\beta C_0(2k_1\cdot k_2,0,m_A^2,m_b^2,m_b^2,m_b^2)\\&+2(-1/2+4/3\sin^2\theta_w)\cot\beta m_t^2C_0(2k_1\cdot k_2,0,m_A^2,m_t^2,m_t^2,m_t^2)].\end{aligned} \tag{5}$$

Here and below, $v_f=(I_{w,f}^3-2\sin^2\theta_w Q_f)/2\sin\theta_w\cos\theta_w$, $a_f=I_{w,f}^3/2\sin\theta_w\cos\theta_w$, k_1, k_2, and k_3 denote momentums of light fermions and photons, respectively, $\tan\beta=v_2/v_1$, i.e., the ratio of the two vacuum expectation values, and C_0,C_{ij} and D_0,D_{ij} are the three-point and four-point Feynman integrals [9].

The amplitude for $h_0\to f\bar{f}\gamma$ is given by

$$M_{h_0}=M_{h_0}^{tri}+M_{h_0}^{box}, \tag{6}$$

where

$$M_{h_0}^{tri}=M_{h_0}^{tri,\gamma}+M_{h_0}^{tri,Z},\quad M_{h_0}^{box}=M_{h_0}^{box,W}+M_{h_0}^{box,Z}, \tag{7}$$

with

$$M_{h_0}^{tri,\gamma}=M_{h_0}^{tri,\gamma,fermions}+M_{h_0}^{tri,\gamma,H^\pm}+M_{h_0}^{tri,\gamma,X}, \tag{8}$$

$$M_{h_0}^{tri,Z}=M_{h_0}^{tri,Z,fermions}+M_{h_0}^{tri,Z,X}+M_{h_0}^{tri,Z,H^\pm}, \tag{9}$$

$$M_{h_0}^{box,W}=\bar{u}(k_1)(\not\epsilon f_1^{box,W}+\not k_3 f_2^{box,W}\epsilon\cdot k_1+\not k_3 f_3^{box,W}\epsilon\cdot k_2)(1-\gamma_5)v(k_2), \tag{10}$$

$$M_{h_0}^{box,Z}=\bar{u}(k_1)(\not\epsilon f_1^{box,Z}+\not k_3 f_2^{box,Z}\epsilon\cdot k_1+\not k_3 f_3^{box,Z}\epsilon\cdot k_2)\left[4a_f^2-\frac{2I_{w,f}^3Q_f}{\cos^2\theta_w}+2(\tan\theta_w Q_f)^2-4a_f(a_f-\tan\theta_w Q_f)\gamma_5\right]v(k_2). \tag{11}$$

Here, X denotes $W^\pm,G^\pm,\eta^\pm$, and

$$\begin{aligned}M_{h_0}^{tri,\gamma,fermions}=&\frac{e^3gQ_f}{24(k_1\cdot k_2+m_f^2)m_W\pi^2}\bar{u}(k_1)[-k_3\cdot(k_1+k_2)\not\epsilon+\not k_3\epsilon\cdot(k_1+k_2)]v(k_2)[(-C_0+4C_{12})\\&\times(2k_1\cdot k_2,0,m_{h_0}^2,m_b^2,m_b^2,m_b^2)\sin\alpha\sec\beta-4(-C_0+4C_{12})(2k_1\cdot k_2,0,m_{h_0}^2,m_t^2,m_t^2,m_t^2)\cos\alpha\csc\beta],\end{aligned} \tag{12}$$

$$M_{h_0}^{tri,\gamma,H^\pm}=\frac{e^3 g Q_f}{8(k_1\cdot k_2+m_f^2)m_W\cos\theta_w\pi^2}\overline{u}(k_1)[-k_3\cdot(k_1+k_2)\not\epsilon+\not k_3\epsilon\cdot(k_1+k_2)]v(k_2)$$
$$\times[-2\cos\theta_w m_W\sin(\alpha-\beta)+m_Z\cos(2\beta)\sin(\alpha+\beta)]C_{12}(2k_1.k_2,0,m_{H^\pm}^2,m_{H^\pm}^2,m_{H^\pm}^2), \quad (13)$$

$$M_{h_0}^{tri,\gamma,X}=\frac{-e^3 g Q_f}{8(k_1.k_2+m_f^2)\cos\theta_w\pi^2}\overline{u}(k_1)[-k_3\cdot(k_1+k_2)\not\epsilon f_{h_0,\gamma}^2+\not k_3\epsilon\cdot(k_1+k_2)f_{h_0,\gamma}^1]v(k_2), \quad (14)$$

$$M_{h_0}^{tri,Z,fermions}=\frac{-e^3 g}{96\cos\theta_w m_W(2k_1\cdot k_2-m_Z^2+i\Gamma_z m_Z)\pi^2\sin\theta_w}\overline{u}(k_1)\{2v_f[-k_3\cdot(k_1+k_2)\not\epsilon+\not k_3\epsilon\cdot(k_1+k_2)]-2a_f[-k_3\cdot(k_1$$
$$+k_2)\not\epsilon\gamma_5+\not k_3\gamma_5\epsilon\cdot(k_1+k_2)]\}v(k_2)[\sec\beta\sin\alpha m_b^2(-3+4\sin^2\theta_w)(C_0-4C_{12})(2k_1\cdot k_2,0,m_{h_0}^2,m_b^2,m_b^2,m_b^2)$$
$$-2\csc\beta\cos\alpha m_t^2(-3+8\sin^2\theta_w)(C_0-4C_{12})(2k_1\cdot k_2,0,m_{h_0}^2,m_t^2.m_t^2,m_t^2)], \quad (15)$$

$$M_{h_0}^{tri,Z,H^\pm}=\frac{-e^2 g^2\cos(2\theta_w)}{8\cos\theta_w(2k_1\cdot k_2-m_Z^2+i\Gamma_z m_Z)\pi^2}\overline{u}(k_1)\{2v_f[-k_3\cdot(k_1+k_2)\not\epsilon+\not k_3\epsilon\cdot(k_1+k_2)]-2a_f[-k_3.(k_1+k_2)\not\epsilon\gamma_5$$
$$+\not k_3\gamma_5\epsilon\cdot(k_1+k_2)]\}v(k_2)\left[-\sin(\alpha-\beta)m_W+\frac{m_Z\cos(2\beta)\sin(\alpha+\beta)}{2\cos\theta_w}\right]C_{12}(2k_1.k_2,0,m_{H^\pm}^2,m_{H^\pm}^2,m_{H^\pm}^2), \quad (16)$$

$$M_{h_0}^{tri,Z,X}=\frac{-e^2 g^2}{32\cos^2\theta_w(2k_1\cdot k_2-m_Z^2+i\Gamma_z m_Z)\pi^2}\overline{u}(k_1)\{2v_f[-k_3\cdot(k_1+k_2)f_{h_0,Z}^2\not\epsilon+\not k_3\epsilon\cdot(k_1+k_2)]f_{h_0,Z}^1$$
$$-2a_f[-k_3\cdot(k_1+k_2)f_{h_0,Z}^2\not\epsilon\gamma_5+\not k_3\gamma_5\epsilon\cdot(k_1+k_2)f_{h_0,Z}^1]\}v(k_2). \quad (17)$$

In the above equations $f_{h_0,\gamma}^i$, $f_{h_0,Z}^i$, $f_i^{box,W}$, and $f_i^{box,Z}$ are form factors, and their explicit expressions are given by

$$f_{h_0,\gamma}^1=-4\cos\theta_W m_W\sin(\alpha-\beta)C_0(2k_1\cdot k_2,0,m_W^2,m_W^2,m_W^2)+[6\cos\theta_W m_W\sin(\alpha-\beta)+m_Z\cos(2\beta)\sin(\alpha$$
$$+\beta)]C_{12}(2k_1\cdot k_2,0,m_W^2,m_W^2,m_W^2), \quad (18)$$

$$f_{h_0,\gamma}^2=f_{h_0,\gamma}^1-\frac{\cos\theta_w m_W}{4}\left[6\sin(\alpha-\beta)-\frac{2m_{h_0}^2\sin(\alpha-\beta)-m_Z^2\cos(2\beta)\sin(\alpha+\beta)}{k_1\cdot k_3+k_2\cdot k_3}\right]C_0(2k_1\cdot k_2,0,m_W^2,m_W^2,m_W^2), \quad (19)$$

$$f_{h_0,Z}^1=4\cos^2\theta_w\sin(\alpha-\beta)\{(3\cos\theta_w m_W-m_Z\sin^2\theta_w)C_0(2k_1\cdot k_2,0,m_W^2,m_W^2,m_W^2)$$
$$+[-20\cos^3\theta_w m_W\sin(\alpha-\beta)+\cos\theta_w\sin^2\theta_w m_W\sin(\alpha-\beta)+3\cos^2\theta_w\sin^2\theta_w m_Z$$
$$-\cos(2\theta_w)m_Z\cos(2\beta)\sin(\alpha+\beta)]C_{12}(2k_1\cdot k_2,0,m_W^2,m_W^2,m_W^2)\}, \quad (20)$$

$$f_{h_0,Z}^2=f_{h_0,Z}^1-\frac{\cos\theta_w m_W}{4}C_0(2k_1\cdot k_2,0,m_W^2,m_W^2,m_W^2)$$
$$\times\left\{6\sin(\alpha-\beta)\cos^2\theta_w-\frac{[(2\cos^2\theta_w+1)m_{h_0}^2-3\cos^2\theta_w m_Z^2]\sin(\alpha-\beta)-m_Z^2\sin^2\theta_w\cos(2\beta)\sin(\alpha+\beta)}{k_1\cdot k_3+k_2\cdot k_3}\right\}, \quad (21)$$

$$f_1^{box,W}=\frac{eg^3 m_W\sin(\alpha-\beta)}{128\pi^2}\{3C_0(0,2k_2\cdot k_3,m_{h_0}^2,m_W^2,0,m_W^2)+(3m_W^2-8k_2\cdot k_3)D_0(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)$$
$$-8k_2\cdot k_3 D_1(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)$$
$$+2(3k_1\cdot k_2+4k_1\cdot k_3-4k_2\cdot k_3)D_2(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)$$
$$-6k_2\cdot k_3 D_3(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)+8D_{00}(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)\}$$
$$+(k_1\cdot k_3\leftrightarrow k_2\cdot k_3), \quad (22)$$

$$f_2^{box,W}=-\frac{eg^3m_W\sin(\alpha-\beta)}{16\pi^2}(D_1+D_{23})(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)+(k_1\cdot k_3\leftrightarrow k_2\cdot k_3), \tag{23}$$

$$f_3^{box,W}=\frac{eg^3m_W\sin(\alpha-\beta)}{16\pi^2}(D_0+D_2+D_2-D_{13}-D_{23})(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_W^2,0,m_W^2,m_W^2)+(k_1\cdot k_3\leftrightarrow k_2\cdot k_3), \tag{24}$$

$$f_1^{box,Z}=\frac{e^3gm_Z\sin(\alpha-\beta)Q_f}{16\pi^2\cos\theta_w}\times[-C_0(0,k_2\cdot k_3,m_{h_0}^2,m_Z^2,m_f^2,m_Z^2)+2(k_2\cdot k_3D_1+D_{00})(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_f^2,m_Z^2,m_Z^2,m_f^2)], \tag{25}$$

$$f_2^{box,Z}=\frac{e^3gm_Z\sin(\alpha-\beta)Q_f}{8\pi^2\cos\theta_w}(D_{22}+D_{23})(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_f^2,m_Z^2,m_Z^2,m_f^2), \tag{26}$$

$$f_3^{box,Z}=-\frac{e^3gm_Z\sin(\alpha-\beta)Q_f}{8\pi^2\cos\theta_w}(D_1+D_{12}+D_{13})(0,0,m_{h_0}^2,0,2k_1\cdot k_2,2k_2\cdot k_3,m_f^2,m_Z^2,m_Z^2,m_f^2). \tag{27}$$

The amplitude of the process $H\to f\bar{f}\gamma$ can be simply obtained by substituting $\alpha\to 3\pi/2+\alpha$ and $m_{h_0}\to m_H$ in the amplitude of $h_0\to f\bar{f}\gamma$.

For the simplicity of calculating the amplitude squares, we can parametrize the amplitudes of the process $(h_0,H,A)\to f\bar{f}\gamma$ in a general form

$$M=\bar{u}(k_1)(g_1\not{\epsilon}+g_2\not{\epsilon}\gamma_5+g_3\not{k}_3\epsilon\cdot k_1+g_4\not{k}_3\gamma_5\epsilon\cdot k_1+g_5\not{k}_3\epsilon\cdot k_2+g_6\not{k}_3\gamma_5\epsilon\cdot k_2)v(k_2). \tag{28}$$

Therefore, the amplitude square is given by

$$\sum_{spins}|M|^2=8[(g_1^2+g_2^2)(k_1\cdot k_2)+2\mathrm{Re}(g_3g_5^\dagger+g_4g_6^\dagger)(k_1\cdot k_2k_2\cdot k_3k_1\cdot k_3)]. \tag{29}$$

Here g_i are form factors, which can be expressed as the combinations of the form factors given above. Their tedious expressions are not shown here.

The differential decay widths can be written as

$$\frac{d\Gamma(h_0,H,A\to f\bar{f}\gamma)}{d(k_1\cdot k_2)}=\frac{1}{256\pi^3}\frac{1}{m_{h_0,H,A}^3}\int_{(k_2\cdot k_3)_{min}}^{(k_2\cdot k_3)_{max}}d(k_2\cdot k_3)\sum_{spin}|M|^2$$

with

$$(k_2\cdot k_3)_{min}=\frac{1}{4}[m_{h_0,H,A}^2-2(m_f^2+k_1\cdot k_2)]\times\left(1-\sqrt{1-\frac{2m_f^2}{m_f^2+k_1\cdot k_2}}\right),$$

$$(k_2\cdot k_3)_{max}=\frac{1}{4}[m_{h_0,H,A}^2-2(m_f^2+k_1\cdot k_2)]\times\left(1+\sqrt{1-\frac{2m_f^2}{m_f^2+k_1\cdot k_2}}\right).$$

III. NUMERICAL RESULTS AND DISCUSSIONS

In our numerical calculation the relevant parameters are chosen as

$$m_t=176\ \mathrm{GeV},\quad m_b=4.5\ \mathrm{GeV},\quad \alpha(M_z)=1/128,$$
$$M_z=91.2\ \mathrm{GeV},\quad M_w=80.3\ \mathrm{GeV},\quad \Gamma_z=2.5\ \mathrm{GeV}, \tag{30}$$

The Higgs boson masses m_{h_0}, m_H, and $m_{H^\pm}$ are determined by m_A and $\tan\beta$ as follows [10]:

$$m_{h_0}^2=\frac{1}{2}[m_A^2+M_z^2+\epsilon-\sqrt{(m_A^2+M_z^2+\epsilon)^2-4m_A^2M_z^2\cos^22\beta-4\epsilon(m_A^2\sin^2\beta+M_z^2\cos^2\beta)}], \tag{31}$$

$$m_H^2=m_A^2+M_z^2-m_{h_0}^2+\epsilon, \tag{32}$$

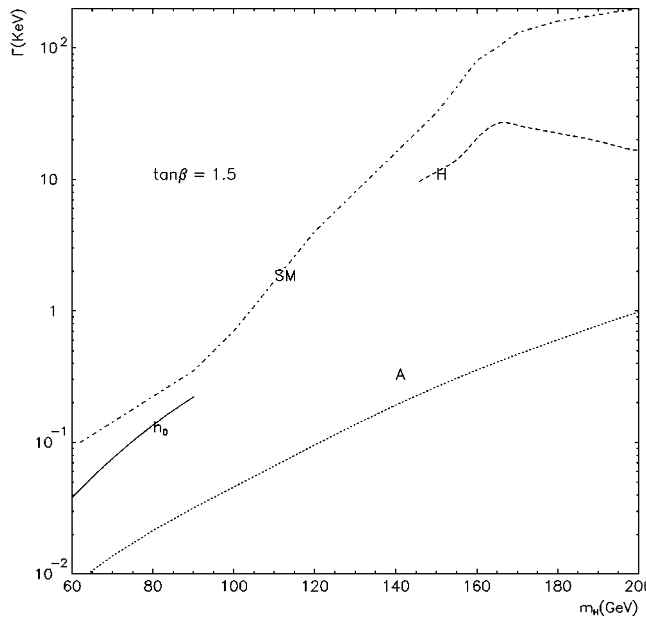

FIG. 2. The neutral Higgs boson decay widths versus Higgs boson masses of $h_0,H,A\to f\bar{f}\gamma$ processes in MSSM with $\tan\beta=1.5$.

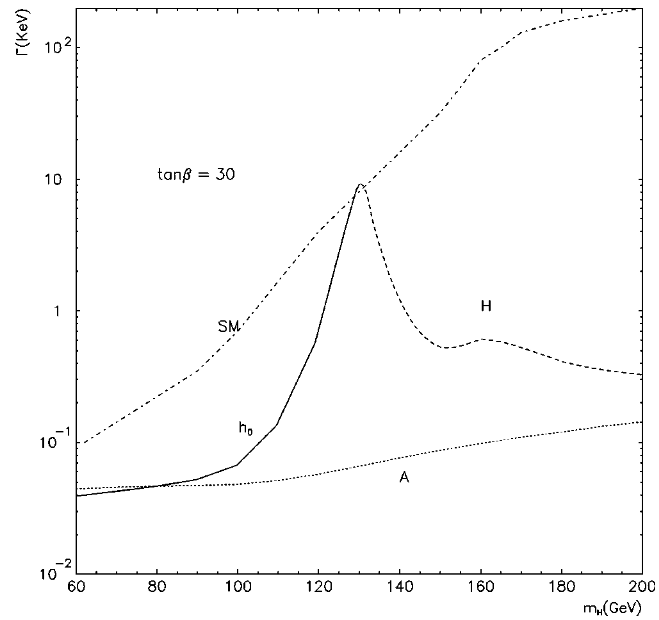

FIG. 3. The neutral Higgs boson decay widths versus Higgs boson masses of $h_0,H,A\to f\bar{f}\gamma$ processes in MSSM with $\tan\beta=30$.

and

$$m_{H^\pm}^2=m_A^2+m_W^2 \tag{33}$$

with

$$\epsilon=\frac{3G_F}{\sqrt{2}\pi^2}\frac{m_t^4}{\sin^2\beta}\log\left(1+\frac{m_S^2}{m_t^2}\right). \tag{34}$$

Here the m_S is a common squark mass which is equal to 1 TeV in our numerical calculations. The mixing angle α is fixed by tan β and the Higgs boson mass m_A:

$$\tan 2\alpha=\tan 2\beta\frac{m_A^2+M_z^2}{m_A^2-M_z^2+\epsilon/\cos 2\beta}, \tag{35}$$

where $-\pi/2<\alpha<0$.

Figures 2 and 3 show the total decay widths of the processes $h_0,H,A\to f\bar{f}\gamma$ versus the Higgs mass varying in the intermediate range for two values tan $\beta=1.5$ and tan $\beta=30$. As can be seen from these figures, the total decay widths for $h_0,H,A\to f\bar{f}\gamma$, where the neutrino, electron, muon, and light quarks contributions are included, have some obvious characters compared with the two-photon widths of the MSSM Higgs boson decays [11,12]. First, in the case of $\tan\beta=1.5$ the width $\Gamma_{H\to f\bar{f}\gamma}$ can exceed the width $\Gamma_{H\to\gamma\gamma}$ for 140 GeV$\leqslant m_H\leqslant$200 GeV. However, in the same Higgs boson mass range $\Gamma_{h_0\to f\bar{f}\gamma}$ and $\Gamma_{A\to f\bar{f}\gamma}$ are smaller than $\Gamma_{h_0\to\gamma\gamma}$ and $\Gamma_{A\to\gamma\gamma}$, respectively. And, the width $\Gamma_{H\to f\bar{f}\gamma}$ is less than that of the width $\Gamma_{H\to\gamma\gamma}$ for $m_H<140$ GeV.

Second, in the case of tan $\beta=30$ the width $\Gamma_{H\to f\bar{f}\gamma}$ is still larger than $\Gamma_{H\to\gamma\gamma}$ for 140 GeV$<M_H<$200 GeV and $\Gamma_{h_0\to f\bar{f}\gamma}$ is smaller than $\Gamma_{h_0\to\gamma\gamma}$. Only in the vicinity of $M_{h_0,H}\approx 130$ GeV are the decay widths $\Gamma_{h_0\to f\bar{f}\gamma}$ and $\Gamma_{H\to f\bar{f}\gamma}$ about the same as $\Gamma_{h_0\to\gamma\gamma}$ and $\Gamma_{H\to\gamma\gamma}$, respectively. Again, the width for the radiative decay of the pseudoscalar $\Gamma_{A\to f\bar{f}\gamma}$ is smaller than $\Gamma_{A\to\gamma\gamma}$ for $M_A<200$ GeV.

Comparing with the same process of the SM [5], we find that in general the widths in the MSSM case are less than that in the SM case, except the Higgs boson mass is around 130 GeV, where the predictions of the SM and MSSM on the $f\bar{f}\gamma$ widths are almost the same and indistinguishable.

In conclusion, in addition to being a supplement in searching the Higgs boson through the Higgs boson decay to two photons, the radiative decay of Higgs boson $H\to f\bar{f}\gamma$ would be a more observable channel in searching the Higgs boson in future experiments, since the radiative decay widths can be larger than the two-photon decay mode for some favorable parameter space. Besides, our calculation also shows that the process $h_0,H,A\to f\bar{f}\gamma$ may play an important role in identifying the Higgs boson being of the SM or the MSSM on the basis of the size of decay widths if the Higgs boson is discovered via this process.

ACKNOWLEDGMENTS

This work was supported in part by the National Natural Science Foundation of China, the State Commission of Science and Technology of China, and the Hua Run Science Foundation of China.

[1] P. Janot, EuroConference on High-Energy Physics, Jerusalem, 1997.
[2] See, for example, M. Spira, Report CERN-TH/97-68, hep-ph/9705337, and references therein.
[3] A. Stange, W. Marciano, S. Willenbrock, Phys. Rev. D **49**, 1354 (1994).
[4] J. F. Gunion, H. E. Haber, G. Kane, and S. Dawson, *The Higgs Hunter's Guide* (Addison-Wesley, Reading, MA, 1990), p. 25.
[5] A. Abbasabadi, D. Bowser-Chao, D. A. Dicus, and W. W. Repko, Phys. Rev. D **55**, 5647 (1997).
[6] For example, see, W.-S. Hou, R. S. Willey, and A. Soni, Phys. Rev. Lett. **58**, 1608 (1987); B. Grinstein, M. J. Savage, and M. B. Wise, Nucl. Phys. **B319**, 217 (1989).
[7] H. P. Nilles, Phys. Rep. **110**, 1 (1984).
[8] S. Dimopoulos and H. Georgi, Nucl. Phys. **B193**, 150 (1981); E. Witten, *ibid.* **B231**, 419 (1984).
[9] G. Passarino and M. Veltman, Nucl. Phys. **B160**, 151 (1979); A. Denner, Fortschr. Phys. **41**, 4 (1993); R. Mertig, Guide to FeynCalc 1.0, University of Wurzberg, 1992.
[10] See, for example, J. R. Espinosa and M. Quiros, Phys. Lett. B **266**, 389 (1991); J. Gunion and A. Turski, Phys. Rev. D **39**, 2710 (1989); **40**, 2333 (1990); M. Carena, M. Quiros, and C. E. M. Wagner, Nucl. Phys. **B461**, 407 (1996).
[11] M. Spira, A. Djouadi, D. Graudenz, and P. M. Zerwas, Nucl. Phys. **B453**, 17 (1995).
[12] A. Djouadi, M. Spira, and P. M. Zerwas, Phys. Lett. B **311**, 255 (1993).