HIGGS BOSON DECAY CHANNELS

S.K. Abdullayev, M.Sh. Gojayev, F.A. Saddigh
Baku State University, Azerbaijan
s_abdullayev@mail.ru, m_qocayev@mail.ru, f_seddig@yahoo.com

The Weinberg-Salam unified theory of electroweak interactions (standard model) has achieved great success. That is neutral weak current has been observed in experiment, $W^{\pm}, Z^0$-gauge bosons are discovered and some of allegations are investigated successfully in experiment. One of the important acclaim of standard model is the prediction for the existence of scalar Higgs boson. Some experiments are carried out for the discovery of Higgs boson in different experimental labs. Finally in Tevatron and CERN new information is getting achieved concerning the existence of Higgs boson with mass of 125 GeV.

In this work we get to analyze Standard Model Higgs boson main decay channels:

$$H \to f + \bar{f}, \tag{1}$$

$$H \to Z + f + \bar{f}, \tag{2}$$

$$H \to W^{\pm} + f + \bar{f}, \tag{3}$$

$$H \to \gamma + \gamma, \ \ H \to \gamma + Z^0. \tag{4}$$

The transition amplitude of process (1) is given by:

$$M(H \to f\bar{f}) = \frac{m_f}{\eta} \bar{u}(p_1, \lambda_1) \upsilon(p_2, \lambda_2) H(p). \tag{5}$$

Here $p_1(\lambda_1)$ and $p_2(\lambda_2)$ are 4-momentum (helicity) for fermion and antifermion and p stands for 4-momentum of Higgs boson.

The decay width of Higgs boson to fermion-antifermion pair is:

$$\Gamma(H \to f\bar{f}) = N_C \cdot \frac{M_H}{8\pi\eta^2} \cdot m_f^2, \tag{6}$$

N_C is the number of colors; it’s value is 1 for leptons and 3 for quarks.

We have the following amplitude for process (2):

$$M(H \to Z^0 f\bar{f}) = \frac{M_Z^2}{\eta} \frac{e}{\sin\theta_W \cos\theta_W} \frac{u_\mu(k) H(p)}{q^2 - M_Z^2} \bar{u}(p_1, \lambda_1) \gamma_\mu [g_L(1+\gamma_5) + g_R(1-\gamma_5)] \upsilon(p_2, \lambda_2), \tag{7}$$

where θ_W – is the weak mixing angle:

$$g_L = I_f^{(3)} - Q_f \sin^2\theta_W, \ g_R = -Q_f \sin^2\theta_W.$$

The interaction between fermion and Z^0 has a vector and axial-vector components. This achievement leads to the conservation of the helicity of the fermion at high energies. The conservation of helicity requires the fermion and antifermion to have opposite helicities: $f_L \bar{f}_R$ or $f_R \bar{f}_L$. Therefore, for the reaction (2) there will be only two independent helicity amplitudes:

F_{LR} and F_{RL} (here first and second indices show the helicity of fermion and antifermion). These helicity amplitudes describe the following decay channels:

$$H \to Z^0 + f_L + \bar{f}_R,\ H \to Z^0 + f_R + \bar{f}_L.$$

We obtain the following decay widths:

$$\Gamma(H \to Zf_L\bar{f}_R) = \frac{e^2 N_C}{768\pi^2} \cdot \frac{M_Z^2}{\eta} \cdot M_H \cdot \frac{g_L^2}{x_W(1-x_W)} R(x), \tag{8}$$

$$\Gamma(H \to Zf_R\bar{f}_L) = \frac{e^2 N_C}{768\pi^2} \cdot \frac{M_Z^2}{\eta} \cdot M_H \cdot \frac{g_R^2}{x_W(1-x_W)} R(x). \tag{9}$$

Where $R(x) = 47x^2 - 60x + 15 - \dfrac{2}{x} - 3(4x^2 - 6x + 1)\ln x + \dfrac{6(20x^2 - 8x + 1)}{\sqrt{4x-1}} \arccos\left(\dfrac{3x-1}{2x^{3/2}}\right)$,

$x = M_Z^2 / M_H^2$ and $x_W = \sin^2\theta_W$.

We finally obtain for massless fermions

$$\Gamma(H \to Zf_L\bar{f}_R) = \frac{e^2}{768\pi^2} \cdot \frac{M_Z^2}{\eta^2} \cdot \frac{M_H R(x)}{x_W(1-x_W)} \cdot \sum_f (g_L^2 + g_R^2) N_C, \tag{10}$$

We have the following values of g_L and g_R:

	$\nu_e; \nu_\mu; \nu_\tau$	$e; \mu; \tau$	$u; c$	$d; s; b$
g_L	$\frac{1}{2}$	$-\frac{1}{2} + x_W$	$\frac{1}{2} - \frac{2}{3}x_W$	$-\frac{1}{2} + \frac{1}{3}x_W$
g_R	0	x_W	$-\frac{2}{3}x_W$	$\frac{1}{3}x_W$

Performing the sum we obtain:

$$\sum_f (g_L^2 + g_R^2) N_C = 3\left(\frac{7}{4} - \frac{10}{3}x_W + \frac{40}{9}x_W^2\right).$$

Thus we find the following decay width:

$$\Gamma(H \to Zf\bar{f}) = \frac{1}{64\pi^2}\left(\frac{M_Z}{\eta}\right)^4 \cdot M_H \left(\frac{7}{4} - \frac{10}{3}x_W + \frac{40}{9}x_W^2\right) R(x). \tag{11}$$

The decay width of the Higgs boson to two off-shell gauge boson WW^* is given by:

$$\Gamma(H \to WW^*) = \Gamma(H \to Wf\bar{f}) = \frac{3}{64\pi^2}\left(\frac{M_W}{\eta}\right)^4 \cdot M_H . R(x). \tag{12}$$

The processes $H \to \gamma + \gamma$ and $H \to \gamma + Z^0$ take plase through loop diagrams, they have decay rates:

$$\Gamma(H \to \gamma\gamma) = \left(\frac{\alpha}{\pi}\right)^2 Q^4 \frac{M_H^3}{64\pi\eta^2} n^2 |D(n)|^2. \tag{13}$$

$$\Gamma(H \to \gamma Z^0) = \left(\frac{\alpha}{\pi}\right)^2 \cdot \frac{Q^2}{32\pi\eta^2} \cdot \frac{(g_L + g_R)^2}{x_W(1-x_W)} M_H^3 n^2 |D(n)|^2. \tag{14}$$