THE PRODUCTION OF HIGGS BOSONS IN NON-ELASTIC NEUTRINO-QUARK SCATTERING

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The neutral Higgs boson production has been discussed in the $nq \to nlH^o$ inelastic scattering. The cross section of the process has been obtained in the $m_q << m_w$ region and for the ratio of this section to the one for $nq \to lq$ reaction it has been shown that linear growth is possible (~Gs).

As is well known, the Standard Model (SM) of Electroweak Interaction assumes existence of neutral massive scalar Higgs bosons [1]. However, in spite of the fact that many predictions of the model were proved by experiments, and particularly, heavy $W^{\pm}$ and Z^0 bosons were discovered /2/, the Higgs sector of the model has not been yet studied. The search for Hiqqs particles were extended to the energy area of 200 GeV in cms and intensively continued, since the mass of these particles is a free parameter of the theory and can be found in a relatively wide range: $7GeV £ m_H £ 1TeV$ [3]. Therefore, the current requirement is the theoretical investigation of all possible reactions with participation of Higgs bosons.

The present paper discusses the production of Higgs particles in non-elastic neutrino-quark scattering:

$$n(k_1) + q(p_1) \to l(k_2) + q(p_2) + H^0(k) \ , \qquad (1)$$

where 4 momenta of particles are indicated in brackets.

The coupling constant of Higgs boson and other particles is proportional to the mass of particles. Taking into account that quark's mass is $m_q << m_w$ (this is true for *u,d,s,c,b*-quarks but untrue for *t*-quark with mass of m_t *~170 GeV*), it is possible to assume that a diagram with radiation of Higgs boson by intermediate *W* bosons will be the main contribution into the process (1).

The corresponding amplitude can be written as follows:

$$M = -\frac{Gm_w^2}{\sqrt{2}} g_H j D_1 D_2 l_m \left(d_{mn} + \frac{q_{2m} q_{2n}}{m_w^2} \right) J_n \ , \qquad (2)$$

where l_m and J_v are lepton and quark weak currents,

$D_{1,2} = (q_{1,2}^2 + m_w^2 - i\tilde{A}_w m_w)^{-1}$, $q_{1,2}$ - 4-impulses of virtual *W*-boson prior and after remission of Higgs boson,

$g_H = (\sqrt{2}G)^{\frac{1}{2}} m_w^2$ is the couplings constant of Higgs and *W*-bosons.

Assuming reasonably the left longitudinal polarization of the final lepton and summing up by quark polarization, we obtain for the square matrix element the following:

$$|M|^2 = 64G^2 m_w^4 g_H^2 d_1 d_2 (k_1 p_1)(k_2 p_2) \ , \qquad (3)$$

where $d_{1,2} = \left[(q_{1,2}^2 + m_w^2)^2 + \tilde{A}_w^2 m_w^2 \right]^{-1}$. Here, we took into account that quarks, masses are $m_{1.2} << m_W$.

In accordance with the general rules, the differential effective cross section of the process (1) can be written as

$$ds = (2p)^4 N_c \frac{|M|^2}{4e_1 m_1} d^4(k_1 + p_1 - k_2 - p_2 - k) \frac{d^3 k_2}{(2p)^4 2e_2} \frac{d^3 p_2}{(2p)^4 2E_2} \frac{d^3 k}{(2p)^4 2w} \ , \qquad (4)$$

where e_1, e_2, w are energies of the initial and final quarks and Higgs boson, respectively, N_c=3 is the color factor.

Since out of three final particles only lepton is actually detected, then the section that has been integrated by momenta of quark and Higgs boson is of real interest , i.e. dependent only on the lepton parameters. The integration is convenient to perform by using invariant method. Introducing the integration by intermediate 4-momentum q_1, the section can be presented as follows:

$$ds = \frac{2G^2 m_w^4 g_H^2}{(2p)^5} \frac{d^3 k_2}{e_2} \int d^4 q_1 d^4 (k_1 - k_2 - q_1) d_1 (k_2 Q) \ , \qquad (5)$$

where

$$Q_m = \int \frac{P_{2m}}{wE_2} d_2 d^4 (q_1 + p_1 - p_2 - k) d^3 p_2 d^3 k \ , \qquad (6)$$

It is evident that 4-vector Q_m depends solely on p_1 and q_1 and can be written in the following way:

$$Q_m = Ap_{1m} + Bq_{1m} \qquad (7)$$

Let us introduce the standard kinematic invariants of the reaction:

$$s \equiv -(k_1 + p_1)^2 = 2m_1\varepsilon_1 + m_1^2 > 0, \qquad t \equiv q_1^2 = 4\varepsilon_1\varepsilon_2 \sin^2\frac{\theta}{2} > 0$$
$$\nu \equiv -p_1 q_1 = m_1(\varepsilon_1 - \varepsilon_2) > 0, \qquad u = 2\nu - t + m_1^2 > 0, \tag{8}$$

where energies ε_1, ε_2 and the exit angle of lepton θ are given in L.S. A and B coefficients are expressed through kinematic invariants with the help of two functions $f_1 \equiv p_1Q$, $f_2 \equiv q_1Q$:

$$A = -\frac{f_1 t + f_2 \nu}{\nu^2 + m_1^2 t}, \quad B = \frac{f_2 m_1^2 - f_1 \nu}{\nu^2 + m_1^2 t} \tag{9}$$

It is convenient to calculate f_1 and f_2 functions in the frame, where $\vec{q}_1 + \vec{p}_1 = \vec{p}_2 + \vec{k} = 0$. Being expressed through invariants, they are equal (everywhere, where possible, it has been assumed that $m_1, m_2 << m_W$ and $m_1, m_2 << E_1E_2$) to:

$$f_1 = \frac{\pi}{2\sqrt{\nu^2 + m_1^2 t}}(J_0 - \ln y), \qquad f_2 = -\frac{\pi}{2\sqrt{\nu^2 + m_1^2 t}}\left[(a+1)J_0 - \ln y\right]$$
$$J_0 = \frac{1}{x}\left(arctg\frac{y}{x} - arctg\frac{1}{x}\right), \quad y = 1 + a\frac{u + t + m_1^2}{u}, \quad a = \frac{u + m_2^2 - m_H^2}{m_W^2}, \quad x = \frac{\Gamma_W}{m_W}. \tag{10}$$

In such a manner, the process section (1) in L-system takes the form:

$$\frac{d^2\sigma}{d\varepsilon_2 \sin\theta d\theta} = \frac{2G^2 g_H^2}{(2\pi)^4}\frac{\varepsilon_2}{\left(\frac{q_1^2}{m_W^2} + 1\right)^2 + \frac{\Gamma_W^2}{m_W^2}}\left(Am_1\varepsilon_2 + B\frac{q_1^2}{2}\right) \tag{11}$$

Taking into account the relationship $\varepsilon_2 d\varepsilon_2 \sin\theta d\theta = \frac{dt d\nu}{s - m_1^2}$ and at the same time disregarding the small value Γ_W^2 / m_W^2 in the denominator, we finally write down the cross section in the completely invariant form:

$$\frac{d^2\sigma}{dt d\nu} = \frac{G^2 g_H^2}{(2\pi)^4}\frac{A\left(1 - \frac{2\nu}{s - m_1^2}\right) + B\frac{t}{s - m_1^2}}{\left(1 + \frac{t}{m_W^2}\right)^2} \tag{12}$$

Let us compare this expression with the same one for inelastic scattering $\nu q \to lq$ without Higgs production:

$$\frac{d\sigma_0}{dt} = \frac{G^2}{\pi}\frac{s - m_2^2}{s - m_1^2}\frac{1}{\left(1 + \frac{t}{m_W^2}\right)^2} \tag{13}$$

For high energies of the neutrino $(s >> m_1^2, m_2^2)$ comparison of cross sections will give the ratio:

$$R = \frac{d\sigma / dt}{d\sigma_0 / dt} = \frac{\sqrt{2}Gm_W^4}{16\pi^3}F, \tag{14}$$

where

$$F = \int_{\nu_{min}}^{\nu_{max}}\left[\left(1 - \frac{2\nu}{s}\right)A + \frac{t}{s}B\right]d\nu,$$
$$\nu_{min} \approx \frac{m_H^2}{2}, \quad \nu_{max} \approx \frac{s}{2} \tag{15}$$

It is difficult to estimate the integral, but assuming a weak ν-dependence of the integrand, we may consider that the integral value is proportional to the range of integration: $F \sim s / m_W^4$ (the mass in the denominator is required by the for the right of dimensionality reasons). In this case we obtain $R \sim Gs$, i.e. it shows a linear growth.

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