THREE-JET DECAYS OF HIGGS-BOSON

V.Z. MUSTAFAYEV
Baku State University
Z. Khalilov st. 23, 370148, Baku, Azerbaijan

The 3-jet decay of the neutral Higgs-boson has been discussed on the basis of $H^0 \to q\bar{q}g$ Subprocess. The general expression for the differential decay width has been obtained in the lowest QCD order, which was analysed for the case, when one of the jets (Quark) is a leading one. It has been shown that contribution of an additional Gluon component into the 2-jet decay amounts to several percent.

1. At present the non-abelian gauging theory with spontaneous broken vacuum symmetry, put forward by Glashow, Weinberg and Salam (1), is considered to be the Standard Model of electroweak interaction. The model describes brilliantly the data in particle physics up to the experimentally obtained energies ~ 200 GeV cms. Such predictions of the model as availability of weak neutral currents, presence of heavy vector bosons $W^{\pm}$, Z^0, etc. have been confirmed (2). However, the model can not be considered perfectly reliable until such important component as Higgs sector has been experimentally discovered and studied. As known, it is required to have, at least, one massive neutral scalar boson, i.e. Higgs particle, in the Standard Model. The mass of the particle is not fixed in the model, being its free parameter. A number of consideration allows for establishing quite broad limits for this mass: $7\ GeV \leq m_H \leq 1$ TeV (3). The existence of such a particle (or particles) has not yet been confirmed by experiments. To find it, is the main direction of studies in the big laboratories of the world. Accordingly, the theoretical analysis of various reactions with Higgs bosons, specifically all possible decays of the particle outline the topical problem of today.

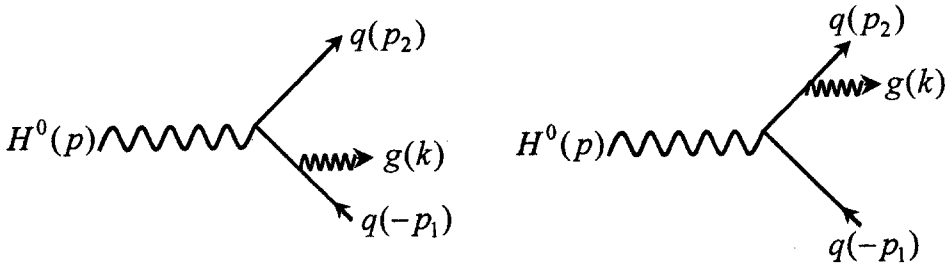
2. The paper reports on the 3-jet hadronic decay of neutral Higgs boson that develops as a result of the fundamental sub-process:

$$H^0(p) \to \bar{q}(p_1) + q(p_2) + g(k) \qquad (1)$$

where $q\bar{q}$ is a pair of quark-antiquark and g is gluon (4 momentum of particles is indicated in brackets). This is the fragmentation of final particles into hadrons that leads to the formation of jets.

In the lower order of QCD, process (1) can be described by the following diagrams:

The matrix element which fits the above mentioned diagrams has the following form



$$M = ig_s g_H \varphi(p)\bar{u}(p_2)\left\{\hat{e}^a \frac{\lambda^a}{2}\frac{i(\hat{p}_2+\hat{k})-m}{(p_2+k)^2+m^2} - \frac{i(\hat{p}_1+\hat{k})-m}{(p_1+k)^2+m^2}\frac{\lambda^a}{2}\hat{e}^a\right\}u(-p_1) \qquad (2)$$

Here $\varphi(p)$, $\bar{u}(p_2)$, $u(-p_1)$ are the wave functions of particles H^0, q, $\bar{q}$, respectively; $\hat{e}^a \equiv e^a_\mu \gamma_\mu$, were e^a_μ is 4-vector of gluon polarization, λ^a are Gell-Mann's matrices $(a = \overline{1,8})$, m is the quark mass, and g_s is QCD constant of the quark-gluon bond. The coupling constant of Higgs boson and fermion is proportional to the fermion mass: $g_s = (\sqrt{2}G)^{1/2} m$, where G is the Fermi constant.

The summing over polarization of final particles yields the following expression for the square of the matrix element

$$|M|^2 = 64 g_H^2 g_s^2 F \qquad ,(3)$$

$$F=\left(2m^2-\frac{m_H^2}{2}\right)\left(\frac{m^2}{x_1^2}+\frac{m^2}{x_2^2}+\frac{2m^2-m_H^2-2kP}{x_1x_2}\right)+\frac{(kP)^2}{x_1x_2}, \quad (4)$$

where $x_i=kP_i$.

The differential width of decay for the boson in rest can be expressed with the help of square of matrix element by the well-known method:

$$d\Gamma=(2\pi)^4\frac{|M|^2}{2m_H}\delta^4(p-p_2-k-p_1)\frac{d^3p_1}{(2\pi)^3 2E_1}\frac{d^3p_2}{(2\pi)^3 2E_2}\frac{d^3k}{(2\pi)^3 2\omega}, \quad (5)$$

where m_H accounts for the mass of Higgs boson.

Let us analyze this expression for a condition when one of jets, say, a quark one, is leading. As well known, this takes place if other two particles move together in the opposite direction. Assuming that $\vec{k}$ and $\vec{p}_1$ vectors are collinear and integrating with respect to all parameters, except for the energy of the leading quark, we obtain:

$$d\Gamma=\frac{2\sqrt{2}G\alpha_s m^2}{\pi^3 m_H}\frac{p_1^2 p_2}{\omega(m_H-E_2-p_2)}FdE_2 \quad (6)$$

Here $\alpha_s=\frac{g_s^2}{4\pi}$, energies of antiquark and gluon are expressed through the quark energy:

$$E_1=\frac{(m_H-E_2-p_2)^2+m^2}{\omega(m_H-E_2-p_2)},\quad \omega=\frac{m_H(m_H-2E_2)}{2(m_H-E_2-p_2)}, \quad (7)$$

Let us assume that mass of the Higg boson is very big, i.e. $m_H>>m$ (this supposition will be discussed further below). Then, neglecting where possible the quark mass, we obtain the following for the total width of decay into this channel:

$$\Gamma=\frac{\sqrt{2}G\alpha_s}{4\pi^3}m_H m^2 \quad (8)$$

And, at last, summing over the quarks colors with factor $N_c=3$ and by their flavors we will obtain finally for the width of jet decay

$$\Gamma=\frac{\sqrt{2}G\alpha_s}{4\pi^3}N_c m_H\sum_q m_q^2 \quad (9)$$

For an observer the decay discussed above will look as 2-jets. Therefore, it is interesting to compare the obtained formula with the width of an ordinary 2-jets decay on the basis of $H^0\to q\bar{q}$ reaction:

$$\Gamma=\frac{\sqrt{2}G}{8\pi}N_c m_H\sum_q m_q^2\left(1-4m_q^2/m_H^2\right) \quad (10)$$

The summation in (9) and (10) includes all quarks with masses $m_q<\frac{m_H}{2}$. Since Higgs boson has not been found at energies < 200 GeV, this condition is obviously true for u, d, s, c, b ($m_q<<m_H$) quarks. However, it is disputable for t-quark with estimated mass of m_t~170GeV If $m_H<2m_t$ then t-quark is not included in the sum and, therefore, $\frac{\Gamma}{\Gamma_{q\bar{q}}}\approx\frac{2\alpha_S}{\pi^2}\sim 0{,}05$. Provided the mass of Higgs boson lies in the range of few m_t, this relation increases twice. Higher values of $m_H>6m_t$ are beyond of *1 TeV*, and there is no sense to consider them. By this means the contribution of invisible gluon component into 2-jets decay amounts to several percent.

[1] *L. Glashow.* Nucl. Phys. - 1961. v.22, p.579.

[2] *S. Weinberg* Phys. Rev *S.* Lett. - 1967, v.19, p.1264.

[3] *Salam.* Elementary Particle Theory. Ed.*N.Svartholm.*- *Almquist and Wiksell*, 1968.- p.367.

[4] *G. Armison et al.* (UA1-Collaboration), Phys.Lett. 1983, v.122B, p.103.

[5] *M. Banner et al.* (UA2-Collaboration), Phys.Lett. 1983, v.122B, p.476.

[6] *G. Armison et al.* (UA1-Collaboration) Phys.Lett, 1983.- v.126B, p.398.

[7] *P. Bagnaia et al.* (UA2-Collaboration), Phys.Lett. 1983, v.129B, p.310.

[8] *L.B. Okun.* Leptons and Quarks. - M.: Nauka, 1990.

V.Z.Mustafayev

HİQQS-BOZONUN ÜÇ SIRNAQLI PARÇALANMASI

Işdə neytral Hiqqs-bozonun $H^0 \to q\bar{q}g$ altprosesi əsasında üç şırnaqlı paçcalanmasına baxılır. KXD nəzəriyyəsinin əsas yaxınlaşmasında parçalanmanın differensial eni üçün ümumi düstur hesablanır, alınan ifadə yüksək enerjili kvark halı üçün araşdırılır. Göstərilir ki, qlüonun iki şırnaqlı parçalanmaya verdiyi əlavə bir neçə faizdir.

В. З. Мустафаев

ТРЕХСТРУЙНЫЙ РАСПАД ХИГГС-БОЗОНА

В работе расматривается трехструйный распад нейтрального Хиггс-бозона на базе подпроцесса $H^0 \to q\bar{q}g$. В низшем порядке КХД получено общее выражение для дифференциальной ширины распада, которая проанализирована в случае, когда одна из струй (кварковая) является лидирующей. Показано, что вклад дополнительной глюонной компоненты в двухструйный распад составляет несколько процентов.

Дата поступления:21.11.2000

Редактор: ИГ. Джафаров