ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ СО АН СССР

V.L.Chernyak, A.A.Ogloblin

EXCLUSIVE DECAYS OF HIGGS BOSON

PREPRINT 84-165

НОВОСИБИРСК

ABSTRACT

Various two-particle decay widths of Higgs boson are calculated: $H^0 \to \bar{\pi}\pi$, $\bar{K}K$, $\bar{D}(1870)D$, $\bar{B}(5200)B$, $\psi(3100)\psi$, $\Upsilon(9640)\Upsilon$, ...

I. INTRODUCTION

The standard Glashow-Salam-Weiberg model of electro-weak interactions includes one neutral Higgs boson H°. (The properties of H°-boson are described, for instance, in the review /1/).

The purpose of this work is to calculate various two-particle decay widths of H°-boson for decays into hadrons containing both light u,d,s and heavy c,b-quarks.

The Lagrangian of the H°-boson interaction with quarks has the form:

$$L_{int} = C_0 H \sum_{quarks} m_i \bar{\Psi}_i \Psi_i \,, \qquad C_0 = -\left(G_F\sqrt{2}\right)^{1/2}, \tag{1}$$

where: H° is the H°-boson field, Ψ_i are the operators of quark fields, m_i are quark current masses, G_F is Fermi constant, $C_0 \simeq -4\cdot 10^{-3}\,GeV^{-1}$. Because coupling constants of H°-boson are proportional to current quark masses, it is evident that H° interacts mainly with the heavy quarks c,b,t, fig.1.

The main contribution into the interaction of H° with usual hadrons made of light u and d quarks gives the mechanism shown in fig.2: H°-boson transforms into a pair of heavy quarks which annihilate then into gluons /2,3/. The effective Lagrangian has the form (in the limit $m_Q \gtrsim M_H$, where m_Q is the heavy quark mass and M_H is the H°-boson mass) /3/:

$$L^{eff}_{int} = C_0 H \Big\{ \sum_{u,d,s} m_i \bar{\Psi}_i \Psi_i - \frac{\alpha_s}{12\pi} N_h \left(G^a_{\mu\nu}\right)^2 - $$

$$ - \frac{1}{30}\frac{\alpha_s^2}{M_H^2} \sum_{u,d,s} \left(\bar{\Psi}_i \gamma_\mu \lambda^a \Psi_i\right)^2 + O\left(1/M_H^4\right)\Big\}, \tag{2}$$

where N_h is the number of heavy quark flavours.

Below in this paper we use the well known at present methods for finding the asymptotic behaviour of exclusive processes in QCD /4/. The mass of H°-boson, M_H, is considered large in comparison with the masses of particles it decays.

II. THE QUALITATIVE DISCUSSION

There is a number of different contributions into two-particle decay amplitudes.

1. The contributions like those shown in fig.3a for decays into two mesons or in fig.3b for two baryon decays. These contributions are due to direct interaction of H° with quarks and are connected with two-particle wave functions for mesons and three-particle ones for baryons. So, such contributions are of importance for decays into hadrons containing at least one s, c or b-quark ($H^0 \to \bar{D}(1870)D, \bar{B}(5200)B, \bar{K}K, \ldots$), while for decays into hadrons containing u or d quarks only ($H^0 \to \pi\pi, \rho\rho, \bar{N}N, \ldots$) these contributions are negligible.*

Because quark turns over its helicity at the vertex at which it interacts with H°-boson, the contribution to amplitude connected with two leading twist wave functions equals zero. As a result, in comparison with its "natural value" $\sim C_0 m_Q f_a^2/M_H$, $f_a = f_D, f_B, f_K$, the amplitude contains additional suppression factors $\sim m_Q/M_H$ and/or $\bar{k}_\perp/M_H$ where m_Q is the current quark mass and $\bar{k}_\perp$ is the mean quark transverse momentum inside of hadron, $\bar{k}_\perp \simeq 300$-400 MeV. For the same reason, the contributions of the diagrams like those in fig.4 which include a product

---

* In what follows we consider two meson decays only because $\Gamma(H^0 \to \bar{B}B)/\Gamma(H^0 \to MM) \sim O(1/M_H^4)$ at large M_H.

Table I

M_H (GeV)	5	8	15	30
$\Gamma(H^0 \to \bar{D}D)$	80 eV	8 eV	0,35 eV	10^{-2} eV
$Br\left(\frac{H^0 \to \bar{D}D}{H^0 \to hadrons}\right)$	0.5%	$2\cdot10^{-2}$%	$0.5\cdot10^{-4}$%	10^{-9}%
$\Gamma(H^0 \to \bar{B}B)$	–	–	350 eV	10 eV
$Br\left(\frac{H^0 \to \bar{B}B}{H^0 \to hadrons}\right)$	–	–	0.05%	10^{-6}%
$\Gamma(H^0 \to \gamma\Psi)$	2 eV	1 eV	0.7 eV	0.3 eV
$\Gamma(H^0 \to \gamma\Upsilon)$	–	–	6 eV	2.5 eV

$\Gamma(H^0 \to \bar{D}D) \simeq 4\Gamma(H^0 \to h_c h_c) \simeq 8\Gamma(H^0 \to \Psi\Psi)$,

$\Gamma(H^0 \to \bar{B}B) \simeq 4\Gamma(H^0 \to h_b h_b) \simeq 8\Gamma(H^0 \to \Upsilon\Upsilon)$.

Table II

Table II

M_H(GeV)	2	5	8	15	30
$\Gamma(H^0\to\pi\pi)$	0.2 eV	$0.4\cdot10^{-1}$ eV	$0.2\cdot10^{-1}$ eV	$3\cdot10^{-3}$ eV	$1.5\cdot10^{-3}$ eV
$\Gamma(H^0\to\bar{K}K)$	17 eV	$3\cdot10^{-1}$ eV	$0.8\cdot10^{-1}$ eV	$0.8\cdot10^{-2}$ eV	$2.5\cdot10^{-3}$ eV
$Br\left(\frac{H^0\to\bar{K}K}{H^0\to hadrons}\right)$	12%	$1.5\cdot10^{-3}$%	$0.2\cdot10^{-3}$%	10^{-6}%	$2\cdot10^{-10}$%
$\Gamma(H^0\to\bar{Q}Q)$	86 eV	21KeV	34 KeV	660 KeV	1.3 GeV
$\Gamma(H^0\to 2g)$	51eV	354 eV	1.5 KeV	2.4 KeV	19 KeV

APPENDIX

The leading twist wave functions of pseudoscalar mesons $P=\pi, K, D, B, \eta_c, \eta_b$ are determined by the matrix elements of bilocal operators

$$\langle 0|\bar{\Psi}_2(z)\gamma_\mu\gamma_5\Psi_1(-z)|P(q)\rangle = i f_P q_\mu \int_{-1}^{1} d\zeta\, e^{i\zeta(zq)}\varphi_P^A(\zeta),$$

$$\int_{-1}^{1} d\zeta\,\varphi_P^A(\zeta)=1,\quad \zeta=x_1-x_2,\quad |q_z|\to\infty. \qquad (A1)$$

The constants f_P determine the wave function values at the origin /4/:

$$f_\pi\simeq 133\,\text{MeV},\; f_K\simeq f_D\simeq 165\,\text{MeV},\; f_B\simeq 90-100\,\text{MeV},$$

$$f_{\eta_c}\simeq 385\,\text{MeV},\; f_{\eta_b}\simeq 690\,\text{MeV}. \qquad (A2)$$

The wave functions $\varphi^A_{\eta_c}(\zeta)$ and $\varphi^A_{\eta_b}(\zeta)$ are much like to $\delta(\zeta)$ functions in the non-relativistic limit. For the wave functions $\varphi^A_D(\zeta)$ and $\varphi^A_B(\zeta)$ we use the simplest model form: $\varphi^A_D(\zeta)\simeq \simeq\delta(\zeta-0.60)$, $\varphi^A_B(\zeta)\simeq\delta(\zeta-0.84)$ which corresponds to $\langle x_q\rangle_D\simeq 0.20$, $\langle x_q\rangle_B\simeq 0.08$ (see /4/).

The wave functions of non-leading twist are determined by the matrix elements:

$$\langle 0|\bar{\Psi}_2(z)i\gamma_5\Psi_1(z)|P(q)\rangle = f_P\frac{M_P^2}{m_1+m_2}\int_{-1}^{1} d\zeta\, e^{i\zeta(zq)}\varphi_P^P(\zeta),$$

$$\int_{-1}^{1} d\zeta\,\varphi_P^P(\zeta)=1, \qquad (A3)$$

where M_P is the meson mass and $m_{1,2}$ are the current quark masses. We have used in the text the following model functions /4/:

$$\varphi_\pi^p(\zeta) \simeq \varphi_K^p(\zeta) \simeq 1/2, \quad \varphi_{\eta_c}^p(\zeta) \simeq \varphi_{\eta_b}^p(\zeta) \simeq \delta(\zeta),$$
$$\varphi_D^p(\zeta) \simeq \delta(\zeta - 0.60), \quad \varphi_B^p(\zeta) \simeq \delta(\zeta - 0.84). \qquad \text{(A4)}$$

The K-meson three-particle wave function $\varphi_{3K}(x)$ is determined by the matrix element /4/:

$$\langle K^+(q) | \bar{u}(z_2) \sigma_{\mu\nu} \gamma_5 g_s G^a_{\rho\lambda}(z_3) \frac{\lambda^a}{2} s(z_1) | 0 \rangle =$$
$$= f_{3K} \left[(q_\mu g_{\nu\lambda} - q_\nu g_{\mu\lambda}) q_\rho - (\lambda \leftrightarrow \rho) \right] \cdot \int_0^1 d_3x \, e^{i \Sigma x_i (z_i q)} \varphi_{3K}(x),$$
$$\int_0^1 d_3x \, \varphi_{3K}(x) = 1, \quad d_3x = dx_1 dx_2 dx_3 \, \delta(1 - \Sigma x_i). \qquad \text{(A5)}$$

We have used in the text /4/:

$$f_{3K} \simeq f_{3\pi} \simeq 0.4 \cdot 10^{-2}\,\text{GeV}^2, \quad \varphi_3^{as}(x) = 360\, x_1 x_2 x_3^2, \qquad \text{(A6)}$$

$$\varphi_{3K}(x) \simeq \varphi_{3\pi}(x) = \varphi_3^{as}(x) \cdot 14 \cdot \left[1.5 (x_1^2 + x_2^2) + 4.53 x_3^2 - 3.72 x_3 + 0.38 \right].$$

The wave functions of $\Psi(3100)$ and $\Upsilon(9640)$ mesons are determined in the non-relativistic approximation by the following matrix element /4/:

$$\langle 0 | \bar{Q}_\beta(z) Q_\alpha(-z) | V(q) \rangle = \frac{f_V M_V}{4} \left(\hat{\varepsilon} + \sigma_{\mu\nu} \frac{P_\mu}{M_V} \varepsilon_\nu \right)_{\alpha\beta} \cdot \int_{-1}^1 d\zeta \, e^{i\zeta (zq)} \varphi_V(\zeta), \qquad \text{(A7)}$$

where M_V is the meson mass and ε is the polarization vector, $f_\Psi \simeq f_{\eta_c} \simeq 385\,\text{MeV}$, $f_\Upsilon \simeq f_{\eta_b} \simeq 690\,\text{MeV}$,

$$\varphi_V(\zeta) \simeq \delta(\zeta). \qquad \text{(A8)}$$

$$\Gamma(H^0 \to \Psi\Psi) \simeq 0.3 \cdot 10^{-4}\,\text{GeV}^6/M_H^5; \quad \Gamma(H^0 \to \Upsilon\Upsilon) \simeq 0.3 \cdot 10^{-1}\,\text{GeV}^6/M_H^5. \qquad (17)$$

As one can expect beforehand (compare (10),(13) and (17)), all decay widths are of the same order of magnitude.

3. The decays $H^0 \to \gamma\Psi, \gamma\Upsilon$.

The decay amplitudes are described by the diagrams like those shown at fig.6 and have the form /6/:

$$T_i = C_0 m_i (\varepsilon_\gamma \varepsilon_V) e q_i f_i \int_{-1}^1 d\zeta \, \varphi_V(\zeta) / 1 - \zeta, \qquad (18)$$

where: ε_γ is the photon polarization vector, ε_V is the vector meson polarization vector, $q_c = 2/3$ for c-quark, $q_b = -1/3$ for b-quark, $\varphi_V(\zeta) \simeq \delta(\zeta)$ are the meson wave functions, $e^2/4\pi = \alpha \simeq 1/137$. It is worth noting that the amplitude (18) does not depend on the H^0-boson mass. The decay width has the form:

$$\Gamma(H^0 \to \gamma V) \simeq \alpha q_i^2 C_0^2 f_i^2 M_i^2 / 8 M_H, \qquad (19)$$

$$\Gamma(H^0 \to \gamma\Psi) \simeq \frac{10^{-8}\,\text{GeV}^2}{M_H}; \quad \Gamma(H^0 \to \gamma\Upsilon) \simeq \frac{8 \cdot 10^{-8}\,\text{GeV}^2}{M_H}.$$

Comparison of the decay widths $H^0 \to VV$ (17) and $H^0 \to \gamma V$ (19) shows that $(H^0 \to \gamma\Psi)/(H^0 \to \Psi\Psi) \gtrsim 1$ at $M_H \gtrsim 8\,\text{GeV}$ and $(H^0 \to \gamma\Upsilon)/(H^0 \to \Upsilon\Upsilon) \gtrsim 1$ at $M_H \gtrsim 30\,\text{GeV}$ (we suppose that the t-quark mass is larger than 30GeV), although the decays $H^0 \to \gamma V$ are electromagnetic while $H^0 \to VV$ are the strong decays.

4. The decay $H^0 \to \pi\pi$.

Because the current masses of u- and d-quarks are very small, the main contributions to this decay give the diagrams like those shown at fig.5 which include the heavy quark loop. In accordance with the fig.5 diagram, the operator $(G^a_{\mu\nu})^2$ in the effective Lagrangian (2) can be rewritten as the operator:

$$(G^a_{\mu\nu})^2 = -4\pi\bar{\alpha}_s \int dx\,dy\, J^a_\mu(x) J^a_\mu(y) \frac{2(q_1 q_2)}{q_1^2 q_2^2} e^{iq_1x + iq_2y}\, dq_1 dq_2\,, \quad (20)$$

where $J^a_\mu = \sum_i \bar{\Psi}_i \gamma_\mu \frac{\lambda^a}{2} \Psi_i$ is the current operator, q_1 and q_2 are the gluon momenta in fig.5. The decay amplitude is the matrix element of the operator (20) between the states $\langle \pi^+\pi^- |$ and $|0\rangle$ (the contribution of third term in the effective Lagrangian (2) into the decay amplitude $H^0 \to \pi^+\pi^-$ is small, $\lesssim 1/20$, in comparison with the contribution (21)):

$$T_\pi = -\frac{\bar{\alpha}_s}{12\pi} N_h C_0 \frac{64}{9} \pi \bar{\alpha}_s f_\pi^2 \left| \int_{-1}^{1} \frac{d\xi\, \varphi^A_\pi(\xi)}{1-\xi} \right|^2, \quad (21)$$

where: $\varphi^A_\pi(\xi)$ is the pion wave function of leading twist, N_h is the number of heavy quark flavours with $2m_i \gtrsim M_H$. Substituting into (21) /4/: $\varphi^A_\pi(\xi) \simeq 15(1-\xi^2)\xi^2/4$, $f_\pi \simeq 133\,MeV$, one has

$$T_\pi \simeq -N_h C_0 \cdot (10^{-2}\,GeV^2),$$
$$\Gamma(H^0 \to \pi\pi) \simeq (3\cdot 10^{-6}\,GeV^4) \frac{N_h^2 C_0^2}{M_H} \simeq (4.8\cdot 10^{-11}\,GeV^2) N_h^2 / M_H. \quad (22)$$

The decay width $H^0 \to \pi\pi$ is presented in table II in its dependence on the H°-boson mass, M_H. Let us point out that

the decay width $H^0 \to \pi\pi$ decreases more slowly with M_H than the decay widths $H^0 \to \bar{D}D, \psi\psi$. Hence for instance, $\Gamma(H^0 \to \pi\pi)/\Gamma(H^0 \to \psi\psi) \simeq 1$ at $M_H \simeq 30\,GeV$.

5. The decay $H^0 \to \bar{K}K$.

The calculation of this decay is much more difficult because there are in this case ($m_s \simeq 150\,MeV$) a number of interfering contributions of the same order of magnitude.

The contribution to the amplitude $H^0 \to K^+K^-$ from the fig.5 diagram has the form:

$$T_K^{(gl)} = -\frac{\bar{\alpha}_s}{12\pi} N_h C_0 \frac{64}{9} \pi \bar{\alpha}_s f_K^2 \left| \int_{-1}^{1} \frac{d\xi\, \varphi^A_K(\xi)}{1-\xi} \right|^2. \quad (23)$$

The contribution to the amplitude from the diagrams like those shown at figs. 3a and 4 and other analogous diagrams has the form:

$$T_K^{(2)} = -\frac{64}{9} \pi \bar{\alpha}_s C_0 \frac{f_K^2 M_K^2}{M_H^2} \int_{-1}^{1} \frac{d\xi_1 d\xi_2\, T_K(\xi_1, \xi_2)}{(1-\xi_1)^2 (1-\xi_2)}\,,$$
$$T_K(\xi_{1,2}) = 2\varphi^A_K(\xi_1)\varphi^P_K(\xi_2) + (1-\xi_1)\varphi^P_K(\xi_1)\varphi^A_K(\xi_2) - \frac{m_s^2}{M_K^2}\varphi^A_K(\xi_1)\varphi^A_K(\xi_2)\,; \quad (24)$$

$$T_K^{(3)} = 8\pi\bar{\alpha}_s C_0 \frac{f_K m_s f_{3K}}{M_H^2} \int_0^1 d_3x \frac{\varphi_{3K}(x)}{x_1(1-x_2)^2} \int_{-1}^{1} \frac{d\xi\, \varphi^A_K(\xi)}{(1-\xi)^2} \left[1 - \frac{4}{9}(1-\xi)\right].$$

Here: $\varphi^A_K(\xi)$ and $\varphi^P_K(\xi)$ are two-particle K-meson wave functions of leading and nonleading twist correspondingly, $\varphi_{3K}(x)$ is the three-particle K-meson wave function, M_K is the K-meson mass, $m_s \simeq 150\,MeV$ is the s-quark current mass. Substituting into (23),(24) the explicit form of the K-meson wave functions /4/, one obtains:

$$T_K^{(gl)} \simeq \left(-10^{-2}\,GeV^2\right) N_h C_0 , \tag{25}$$

$$T_K^{(2)} \simeq -\frac{1.2\,GeV^4}{M_H^2} C_0 , \quad T_K^{(3)} \simeq \frac{0.4\,GeV^4}{M_H^2} C_0 .$$

The decay width $H^0 \to \bar{K}K$ is presented in table II in its dependence on the H°-boson mass, M_H. As one can expect beforehand, the ratio $(H^0\to\pi\pi)/(H^0\to\bar{K}K)$ increases with increasing of M_H and becomes ~ 1 at large values of M_H.

IV. CONCLUSIONS

Calculations of various two-particle decay widths of H°-boson have been presented above. We want to emphasize that available at present methods for finding the asymptotic behaviour of exclusive processes and known properties of hadron wave functions /4/ allow one to do concrete calculations and to obtain numerical predictions for various decay widths.

However, the accuracy of the above described predictions is not high (tipically within a factor 2-3 in probabilities). This is due mainly to poorly known at present properties of a number of higher twist hadronic wave functions. For this reason, we did not try to obtain as precise predictions as possible (for instance, we have neglected all logarithmic corrections and used simplified models for a number of wave functions). As far as, it seems, the analogous calculations are lacking at present in the literature, our main purpose was to present the characteristic values for various exclusive decay widths and

to give reliable numbers for experimentalists.

Let us point finally that although all above calculations have been performed within a "standard model" framework, it is not difficult to obtain the values of decay widths for any other model using the above formulas.

We are grateful to A.R.Zhitnitsky for useful discussions.

FIGURE CAPTIONS

fig.1 Direct interaction of H° with heavy quarks

fig.2 Various contributions into the effective Lagrangian describing the interaction of H°-boson with light hadrons

fig.3a The contribution to two meson decays which includes the product of two two-particle wave functions

fig.3b The contribution to two baryon decays

fig.4 The contribution to two meson decays which includes the product of two- and three-particle wave functions

fig.5 The contributions to two light meson decays which are due to a heavy quark loop

fig.6 Diagrams for the decays $H^0 \to \gamma\Psi, \gamma\Upsilon$

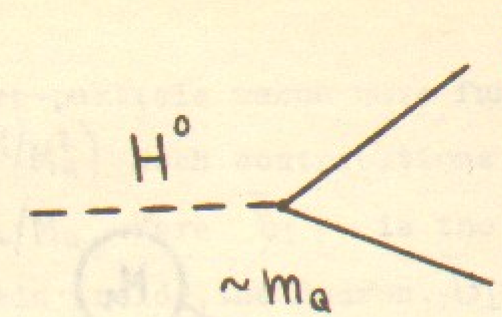

fig.1

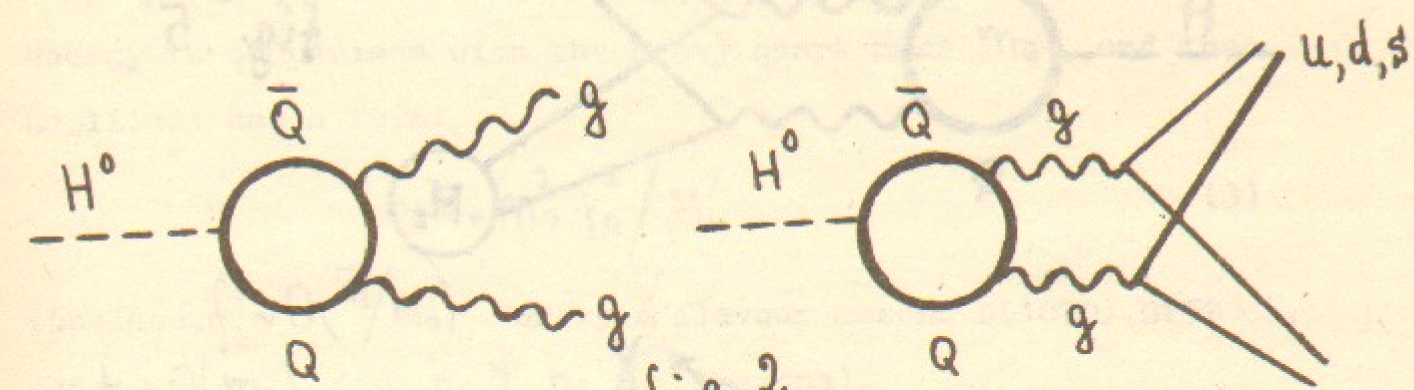

fig.2

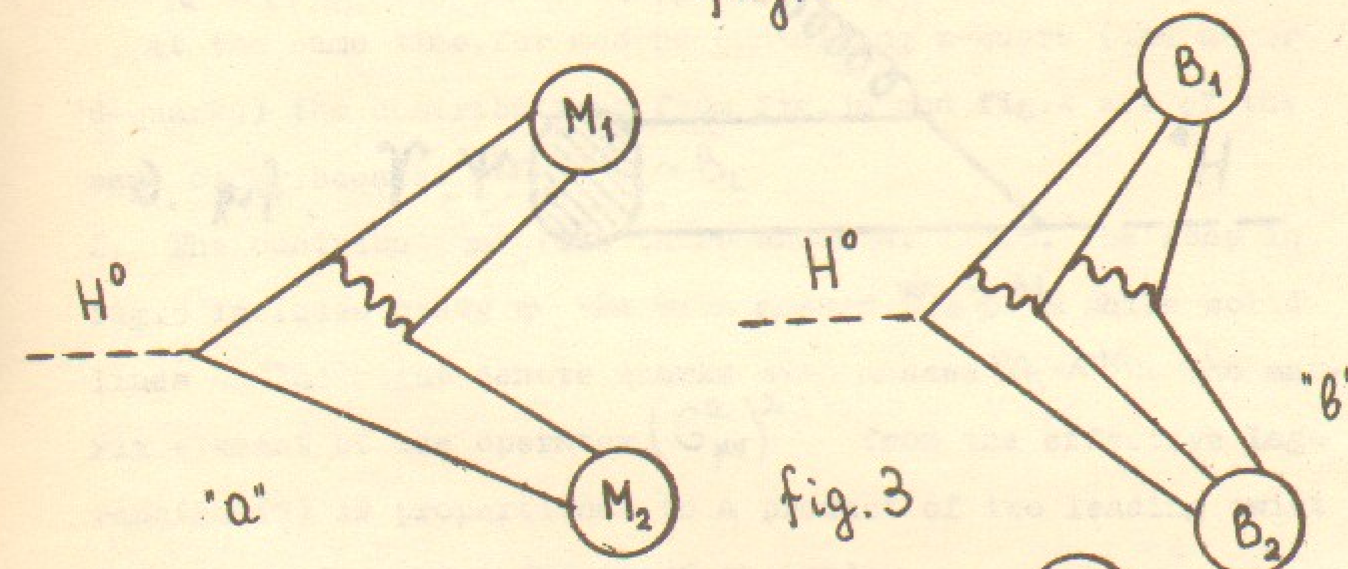

fig.3

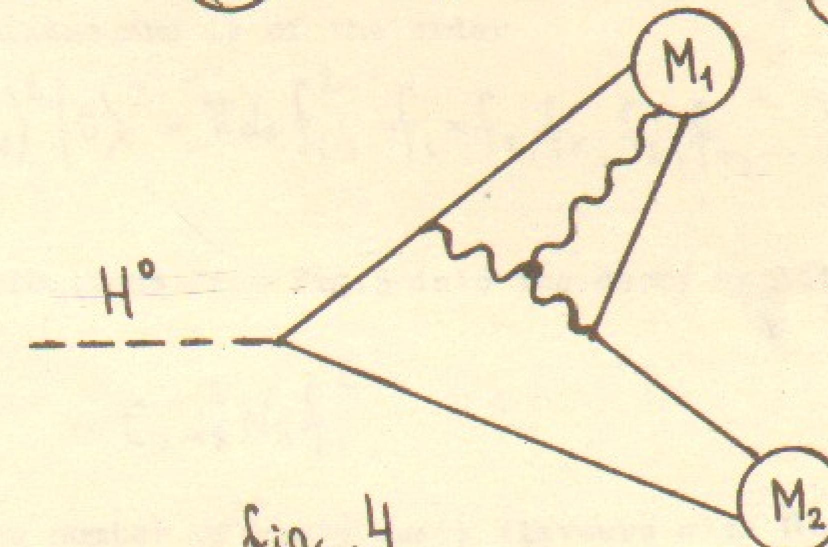

fig.4

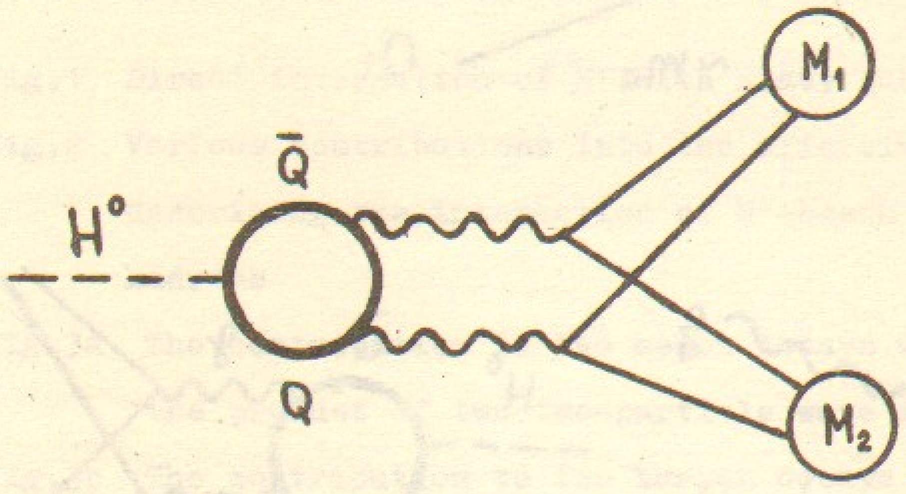

fig .5

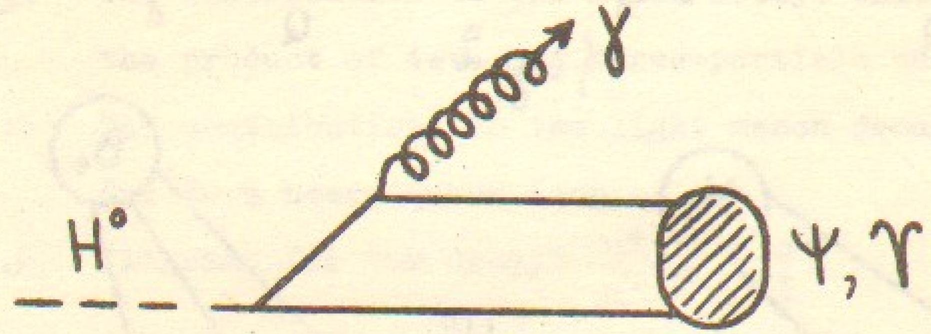

fig .6

of two- and three-particle meson wave functions are of the same order $\sim O(1/M_H^2)$. Such contributions contain the additional suppression $\sim \bar{B}_\perp/M_H$ where $\bar{B}_\perp$ is the characteristic value of the gluon field inside the hadron, $\bar{B}_\perp \sim \bar{K}_\perp$.

Therefore, for mesons which contain the heavy quarks c,b,..., $m_c, m_b \gg \bar{K}_\perp, \bar{B}_\perp$, one can neglect $\bar{K}_\perp, \bar{B}_\perp$ and the quark binding energy in comparison with the heavy quark mass m_Q, and the amplitude has a form:

$$\sim C_0 m_Q^2 f_Q^2 / M_H^2 , \tag{3}$$

(besides, $f_Q^2 \sim O(\bar{K}_\perp^3/m_Q)$ for open flavour mesons D(1870), B(5200), and $f_Q \sim O(m_Q)$ for $\eta_c, \Psi, \eta_b, \Upsilon$ mesons).

At the same time, for mesons containing s-quark (and u- or d-quarks) the contributions from fig.3a and fig.4 are of the same order, because $m_s \sim \bar{K}_\perp \sim \bar{B}_\perp$.

2. The contributions like those shown at fig.5. The loop in fig.5 includes heavy quarks with masses $m_Q \gtrsim M_H$ while solid lines on the right denote quarks with masses $m_i \ll M_H$. The matrix element of the operator $(G^a_{\mu\nu})^2$ from the effective Lagrangian (2) is proportional to a product of two leading twist meson wave functions, and is of the order

$$\langle M_1, M_2 | (G^a_{\mu\nu})^2 | 0 \rangle \sim \Pi \alpha_s f_i^2 , \quad f_i = f_\pi, f_K, f_D, f_\Psi, \ldots \tag{4}$$

Hence, the contributions from fig.5 into the decay amplitude have the form:

$$\sim C_0 \alpha_s^2 N_h f_i^2 , \tag{5}$$

where N_h is the number of heavy quark flavours with $m_Q \gtrsim M_H$

It is clear that these contributions are the dominant ones for the decays $H^0 \to \pi\pi, \rho\rho, \ldots$ The contributions from fig.3a and fig.5 are of the same order for the decays $H^0 \to \bar{K}K, \bar{K}^*K^*, \varphi\varphi, \ldots$ at not too large M_H. As M_H increases, the role of fig.5 contributions increases also (compare (5) and (3)) and they become dominant at large values of M_H.

III. CALCULATION OF DECAY WIDTHS

1. The decays $H^0 \to \bar{D}(1870)D, \bar{B}(5200)B, \eta_c\eta_c, \eta_b\eta_b$.

The main contribution give diagrams like those shown at fig. 3a. As was explained above, one can neglect $\bar{K}_\perp$ and $\bar{B}_\perp$ in comparison with m_c or m_b. The amplitudes for the decays $H^0 \to D^+D^-$ and $H^0 \to B^+B^-$ have the form (the properties of various wave functions are described in the appendix):

$$T_i = -\frac{64}{9}\pi\bar{\alpha}_s \frac{C_0}{M_H^2} f_i^2 M_i^2 \int_{-1}^{1} d\xi_1 d\xi_2 \, T_i(\xi_1,\xi_2)/(1-\xi_1)^2(1-\xi_2), \tag{6}$$

$$T_i(\xi_{1,2}) = 2\varphi_i^A(\xi_1)\varphi_i^P(\xi_2) + (1-\xi_1)\varphi_i^P(\xi_1)\varphi_i^A(\xi_2) - \left(\frac{m_i + m_d}{M_i}\right)^2 \varphi_i^A(\xi_1)\varphi_i^A(\xi_2).$$

Here: m_i is the heavy quark mass (m_c, m_b), M_i is the meson mass (M_D, M_B), $f_i = f_D, f_B$ are the values of wave functions at the origin and $\varphi_i^A(\xi)$ and $\varphi_i^P(\xi)$ are the wave functions of leading and nonleading twist correspondingly. For approximate calculation of (6) we use (here and below we neglect all logarithmic corrections) /4/:

$$f_D \simeq 170\,\text{MeV}, \; f_B \simeq 100\,\text{MeV}, \; m_c \simeq 1.5\,\text{GeV}, \; m_b \simeq 4.7\,\text{GeV},$$
$$\varphi_D^A(\xi) \simeq \varphi_D^P(\xi) \simeq \delta(\xi - 0.60), \; \varphi_B^A(\xi) \simeq \varphi_B^P(\xi) \simeq \delta(\xi - 0.84). \tag{7}$$

In this case: $$T_D \simeq \frac{|C_0|}{M_H^2}\pi\bar{\alpha}_s (20\,\text{GeV}^4) \simeq \frac{|C_0|}{M_H^2}(20\,\text{GeV}^4), \tag{8}$$

$$T_B \simeq \frac{|C_0|}{M_H^2}\pi\bar{\alpha}_s \cdot (640\,\text{GeV}^4) \simeq \frac{|C_0|}{M_H^2} \cdot (640\,\text{GeV}^4). \tag{8}$$

The decay widths $H^0 \to \bar{D}D$ and $H^0 \to \bar{B}B$ are equal:

$$\Gamma_{D,B} = 2|T_{D,B}|^2 / 16\pi M_H, \tag{9}$$

$$\Gamma(H^0 \to \bar{D}D) \simeq C_0^2 \cdot (16\,\text{GeV}^8)/M_H^5; \quad \Gamma(H^0 \to \bar{B}B) \simeq C_0^2 \cdot (1.6 \cdot 10^4\,\text{GeV}^8)/M_H^5.$$

Using $C_0^2 = G_F\sqrt{2} \simeq 1.6 \cdot 10^{-5}\,\text{GeV}^{-2}$ one has:

$$\Gamma(H^0 \to \bar{D}D) \simeq \frac{2.6 \cdot 10^{-4}\,\text{GeV}^6}{M_H^5}; \quad \Gamma(H^0 \to \bar{B}B) \simeq \frac{2.6 \cdot 10^{-1}\,\text{GeV}^6}{M_H^5}. \tag{10}$$

The decay amplitudes $H^0 \to \eta_c\eta_c$ and $H^0 \to \eta_b\eta_b$ also have the form (6) but the wave functions of η_c and η_b mesons are much like to $\delta(\xi)$ functions. We use for the approximate calculation/4/:

$$f_{\eta_c} \simeq f_\psi \simeq 385\,\text{MeV}, \quad f_{\eta_b} \simeq f_\Upsilon \simeq 690\,\text{MeV},$$
$$\varphi_i^A(\xi) \simeq \varphi_i^P(\xi) \simeq \delta(\xi). \tag{11}$$

In this case:

$$T_{\eta_c} \simeq |C_0| \cdot (20\,\text{GeV}^4)/M_H^2, \quad T_{\eta_b} \simeq |C_0| \cdot (600\,\text{GeV}^4)/M_H^2,$$

$$\Gamma(H^0 \to \eta_c\eta_c) \simeq \frac{|C_0|^2}{M_H^5} \cdot (4\,\text{GeV}^8) \simeq \frac{0.6 \cdot 10^{-4}\,\text{GeV}^6}{M_H^5}, \tag{12}$$

$$\Gamma(H^0 \to \eta_b\eta_b) \simeq \frac{|C_0|^2}{M_H^5} (3.6 \cdot 10^3\,\text{GeV}^8) \simeq \frac{0.6 \cdot 10^{-1}\,\text{GeV}^6}{M_H^5}$$

According to the Appelquist-Politzer recipe, the inclusive decay width for the H°-boson decays into hadrons containing quarks of definite flavour is determined by the fig.1 diagram and is equal $(M_H \gg 2m_Q)$:

$$\Gamma(H^\circ \to \bar{Q}Q) = 3C_0^2 m_Q^2 M_H / 8\pi, \quad C_0^2 = G_F\sqrt{2}. \tag{13}$$

The decay width of H°-boson into gluons is equal:

$$\Gamma(H^\circ \to 2gl) = \left(\frac{\alpha_s}{\pi}\right)^2 C_0^2 N_h^2 M_H^3 / 72\pi. \tag{14}$$

The decay widths $H^\circ \to \bar{D}D, \bar{B}B, \eta_c\eta_c, \eta_b\eta_b$ and corresponding branching ratios are given in table I in their dependence on the H°-boson mass, M_H.

2. The decays $H^\circ \to \psi\psi, \Upsilon\Upsilon$.

The main contributions also give diagrams like fig.3a. Taking the wave functions of ψ and Υ mesons in the form of $\delta(\vec{z})$ functions, one obtains for the decay amplitude:

$$T_i^{\lambda_1\lambda_2} = \frac{128}{9}\pi\alpha_s M_i^2 f_i^2 C_0 \Lambda^{\lambda_1\lambda_2}/M_H^4,$$
$$\Lambda^{\lambda_1\lambda_2} = (\varepsilon^{\lambda_2}p_1)(\varepsilon^{\lambda_1}p_2) - (p_1p_2)(\varepsilon^{\lambda_1}\varepsilon^{\lambda_2}), \tag{15}$$

where ε^{λ_1} and ε^{λ_2} are the polarization vectors. In the rest system of H°-boson:

$$|T_i^{++}| = |T_i^{--}| = \frac{64}{9}\pi\alpha_s |C_0| M_i^2 f_i^2 / M_H^2; \quad T_i^{00} \simeq 0, \tag{16}$$

$$|T_\psi^{\pm\pm}| \simeq \frac{|C_0|}{M_H^2}\cdot(10\,\mathrm{GeV}^4), \quad |T_\Upsilon^{\pm\pm}| \simeq \frac{|C_0|}{M_H^2}\cdot(300\,\mathrm{GeV}^4),$$

REFERENCES

/1/ A.I.Vainshtein, V.I.Zakharov and M.A.Shifman, Uspekhy Phys. Nauk (USSR), 131(1980)537

/2/ F.Wilczek, Phys.Rev.Lett. 39(1977)1304

/3/ M.A.Shifman, A.I.Vainshtein and V.I.Zakharov, Phys.Lett. 78B(1978)443

/4/ V.L.Chernyak and A.R.Zhitnitsky, Phys.Rep.112(1984)175

/5/ M.A.Shifman and M.I.Vysotsky, Nucl.Phys. B186(1981)475

В.Л.Черняк, А.А.Оглоблин

ЭКСКЛЮЗИВНЫЕ РАСПАДЫ ХИГГСОВСКОГО БОЗОНА

Препринт
№ 84-165

Работа поступила - 20 ноября 1984 г.

Ответственный за выпуск - С.Г.Попов
Подписано к печати 4.XII-1984 г. МН 06240
Формат бумаги 60x90 1/16 Усл.1,4 печ.л., 1,1 учетно-изд.л.
Тираж 290 экз. Бесплатно. Заказ № 165.

Ротапринт ИЯФ СО АН СССР, г.Новосибирск, 90