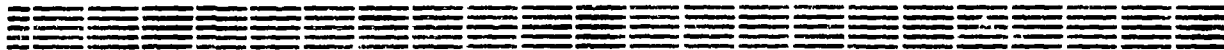


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CONJOINED HADROPRODUCTION OF H_c -BOSON AND
 1S_0 STATE OF HEAVY QUARKONIA

ЦНИИатоминформ
ЕРЕВАН — 1987

Ա.Ս. ԲԱՂԵԱՍՏՐՅԱՆ, Ռ.Շ. ԵԳՈՐՅԱՆ

H_0 - Հիգսի բոզոնի եվ ծանր ԲԱՐԿՈՆԻՈՒՄԻ

${}^1S_0(\eta_Q)$ - Վիճակի ՀԱՄԱՅԵՎ ՀԱԴԲՈՆԱԾՆՈՒԹՅՈՒՆ

Հետազոտվում է H_0 Հիգսի բոզոնի և $Q\bar{Q}$ ($Q = c, b, t, \dots$) ծանր չվարկոնիումի ${}^1S_0(\eta_Q)$ վիճակի համատեղ հաղորդման երևույթի ԼԲԻՎ կարվածքը և նրանում այսպես կոչվող QH և GGH դիագրամների ներդրումները: Ցույց է տրված, որ Հիգսի բոզոնի զանգվածի աճի դեպքում առկա է GGH ներդրման ուժեղացման երևույթը:

Երևանի Փիզիկայի ինստիտուտ

ԵՐԵՎԱՆ 1987

Препринт ЕФМ-960(10)-87

А.С.БАГДАСАРЯН, Р.Ш.ЕГОСРЯН

СОВМЕСТНОЕ АДРОРОЖДЕНИЕ ХИГГСОВСКОГО БОЗОНА
 H_0 И ${}^1S_0(\eta_a)$ - СОСТОЯНИЯ ТЯЖЕЛОГО КВАРКОНИЯ

Изучается полное сечение совместного адророждения стандартного хиггсовского бозона H_0 и ${}^1S_0(\eta_a)$ - состояния тяжелого кваркония $Q\bar{Q}$ ($Q = c, b, t, \dots$). Анализируются вклады в сечение совместного порождения от так называемых QH и GQH диаграмм. Показано, что при увеличении массы хиггсовского бозона имеет место "эффект усиления GQH вклада".

Ереванский физический институт

Ереван 1987

A.S. BAGDASSARIAN, R.Sh. EGORIAN

CONJOINED HADROPRODUCTION OF H_0 -BOSON AND
 1S_0 STATE OF HEAVY QUARKONIA

The total cross section of associated hadroproduction of standard H_0 boson and 1S_0 (1S_0) state of $Q\bar{Q}$ ($Q=c, b, t, \dots$) heavy quarkonium is studied. Contributions of the so-called QH and GGH diagrams to the associated production cross section are analyzed. It is shown that with the growth of the Higgs boson mass, there "the effect of GGH contribution increase" takes place.

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1. Introduction

The possibility for the search for Higgs bosons of the GWS model [1-3] in the modern elementary particle physics led to appearance in recent years of a number of works devoted to the study of different mechanisms of the H_0 boson production and to techniques of their identification.

The H_0 boson production mechanisms considered in literature are the inclusive and exclusive ones in e^+e^- annihilations, hadron-hadron collisions and decays of heavy quarkonium (for more details see ref.[4]).

The most important of the inclusive production mechanisms is [4] the direct hadroproduction of H_0 boson due to "gluon" production of H_0 [5]. But the gluon mechanism of H_0 hadroproduction at relatively small masses $M_H / < 2M_W \approx 160$ GeV / poorly identifies H_0 because of large Drell-Yang background (e.g., see ref.[4]), and possible backgrounds from other scalar particles.

However, theoretically, it is apparently possible to isolate Higgs signals from the above mentioned backgrounds when considering differential spectra $d\sigma/dq_{\perp}^2$ of the H_0 boson [6,7].

In some works [8,9] they hold that the observation of H_0 boson in exclusive processes is preferable to that in

inclusive ones, even when the H_0 inclusive production cross section is essentially larger.

Among the most interesting processes of the H_0 exclusive production are those of associated production of the H_0 and gauge bosons Z_0, W^\pm in e^+e^- annihilations [10,11] and in PP ($P\bar{P}$) collisions [12], also in processes of associated hadroproduction of the H_0 and heavy quark pairs [13,14].

In refs. [15,16] the exclusive H_0 production is considered in association with heavy vector quarkonium V ($V=J/\psi, \Upsilon, T$) in the reaction $e^+e^- \rightarrow H_0 + V$.

Below we shall discuss the hadroproduction of H_0 in association with the 1S_0 state (later on with other C-even $^3P_{0,1,2}$ -states and C-odd $^3S_1, ^1P_1$ -states) of the heavy quarkonium $Q\bar{Q}$ ($Q=c,b,t,\dots$), though from a practical point of view one is better study, first of all, the process of the associated production of H_0 and vector quarkonium. The coproduction of the H_0 boson and 1S_0 quarkonium ($\eta_{(Q)}$ -meson) is interesting due to the fact, that in the lowest order of PT it looks like the hadroproduction of the H_0 with a pair of heavy quarks Q, \bar{Q} . That is why, all the effects not connected with the phase volume must manifest themselves similarly in both processes (in the first case we deal with a two-particle phase volume, in the second - with a three-particle one).

It will be further clear that in case of hadroproduction of the H_0 boson and 1S_0 state of quarkonium there comes forth the so-called "effect of GGH contribution increase" with growing M_H .

2. Different Mechanisms of Conjoined Hadroproduction
of H_0 Boson and 1S_0 (1Q_0) State of Quarkonium
 $Q\bar{Q}$ ($Q=c,b,t,\dots$)

There can be different mechanisms of coproduction of the H_0 boson and 1S_0 -quarkonium: $q\bar{q} \rightarrow H_0 + ^1S_0 + \dots$, $gQ \rightarrow H_0 + ^1S_0 + \dots$, $Gq(\bar{q}) \rightarrow H_0 + ^1S_0 + \dots$.

Dominant diagrams (in the leading order of PT), which correspond to the quark, gluon and quark-gluon mechanisms of the associated hadroproduction of the H_0 and 1S_0 , are shown in figs. 1-3, respectively.

At a trivial comparison of diagrams in figs. 1-3 one can see that the leading-order PT diagrams of the quark and quark-gluon channels (figs. 1 and 3) contain an additional order α_s (in the cross section) as compared to the leading-order PT diagrams of the gluon channel (fig. 2). Consequently, it is the gluon mechanism that dominates in the coproduction of the H_0 boson and 1S_0 quarkonium.

In the diagram 2a (also in 1a, 3a, 3d) the H_0 boson is "bound" with the heavy quark Q ($Q=c,b,t,\dots$), while in the diagrams 2b and 2c (and in other diagrams in figs. 1 and 3) it is "bound" with gluons through a heavy-quark loop.

As it is known, the Higgs boson of the standard model (SM) "is bound" with gluons not directly, but through a fermion loop [17] (see Fig. 4). It leads to the fact that the amplitude of $H_0 \rightarrow g\bar{g}$ contains the factor α_s^2/N_c . Even in the case of the H_0 boson it seems that contributions of the so-called odd diagrams (figs. 2b and 2c) to the total cross-

section (and also to other differential characteristics) are depressed by α_s as compared with the contributions of the so-called QH diagrams (2a) for all $Q=c,b,t,\dots$.

But, it is not always so, because the vertex $H_0 \rightarrow 2G$ is very cleverly constructed. Roughly saying, it is proportional to the invariant mass of gluon pairs or to the square of the H_0 boson mass. This leads to the fact that the smallness in g_{HGG} over α_s/π will be compensated for a large value of M_H in the diagrams 2b and 2c (and also in the remaining QH diagrams in figs 1 and 3) when the production of the H_0 boson is considered ($M_H \gtrsim 20$ GeV). Hence, the former ignoring of diagrams with gluon emission of the H_0 boson at $M_H (M_H \gg M_{\eta_c})$ large enough, is, apparently, not acceptable (e.g., in case of the associated production of H_0 and η_c).

Calculations confirming this hypothesis will be given in the following paragraphs.

3. Nonrelativistic Approach to Description of Amplitudes of Transitions $G+G \rightarrow {}^1S_0$ and $G+G \rightarrow {}^1S_0 + H_0$

It is seen from fig.2 that to evaluate both the total cross section and partial contributions of individual diagrams to the total cross section, one must have explicit expressions for the amplitudes of transitions $G + G \rightarrow {}^1S_0 + H_0$ (or ${}^1S_0 \rightarrow 2G + H_0$), $G + G \rightarrow {}^1S_0$ (${}^1S_0 \rightarrow 2G$) and $G + G \rightarrow H_0$ ($H_0 \rightarrow 2G$). Here we shall use the following explicit form of the effective point vertex $H_0 \rightarrow 2G$

$$M_{H_0 \rightarrow 2G}^{\alpha\beta, ab} (q_1, q_2) = \delta_{ab} \frac{N_H U^{-1} \alpha_s}{3} \frac{1}{g_s} \left\{ g_s^{\alpha\beta} (q_1, q_2) - g_H^{\beta} q_2^{\alpha} \right\} \quad (1)$$

where α and β are vector indices, a and b are colour indices of gluons with momenta q_1 and q_2 (see fig.4); N_H is the number of different kinds of heavy quarks with $m_Q > 0.2 M_H$, $U \approx 246$ GeV.

The approach based on the minimal local effective Lagrangian does not pay for itself when describing multiparticle decays of heavy quarkonia [18]. So, to describe the amplitudes of transitions $^1S_0 \rightarrow 2G$ and $^1S_0 \rightarrow 2G + H_0$, we shall use a nonrelativistic approach which repels itself from the notion of 1S_0 -state as from a system of weakly bound nonrelativistic quarks Q and \bar{Q} . At such an approach the amplitude of $^1S_0 \rightarrow 2G$ is determined by the sum of diagrams shown in fig.5 as:

$$M_{^1S_0 \rightarrow 2G}^{\alpha\beta, ab} (q_1, q_2) = \frac{\delta_{ab}}{2} g_s^2 \psi_0 \left\{ \text{Sp} \left[(m + \hat{P}) \gamma_5 (m - \hat{P}) \times \right. \right. \\ \left. \left. \times \gamma_\beta \frac{(m + \hat{P} - \hat{q}_1)}{m^2 - (P - q_1)^2} \gamma_\alpha \right] + \left[\begin{array}{c} 1 \leftrightarrow 2 \\ \alpha \leftrightarrow \beta \end{array} \right] \right\} \quad (2)$$

where α and β , a and b are the vector and colour indices of gluons with momenta q_1 and q_2 ,

[19], $2p = q$ is the full four-momentum of the 1S_0 -state (η_Q meson). But the amplitude of $^1S_0 \rightarrow 2G + H_0$ is determined by the sum of six diagrams shown in fig. 6 as:

$$M_{^1S_0 \rightarrow 2GH_0}^{\alpha\beta, ab} (q_1, q_2; \Delta) = \frac{\delta_{ab}}{2} g_s^2 \psi_0 m_Q U^{-1} \left\{ \text{Sp} \left[(m + \hat{P}) \gamma_5 (m - \hat{P}) \times \right. \right. \\ \left. \left. \times \frac{(m - \hat{P} + \hat{\Delta})}{m^2 - (P - \Delta)^2} \gamma_\beta \frac{(m + \hat{P} - \hat{q}_1)}{m^2 - (P - q_1)^2} \gamma_\alpha \right] + \left[\begin{array}{c} 1 \leftrightarrow 2 \\ \alpha \leftrightarrow \beta \end{array} \right] + \text{"cycle"} \right\} \quad (3)$$

where $1/2$ comes from the identity of gluons, the operation "cycle" means a procedure of transitions $q_1 \rightarrow q_2 \rightarrow \Delta \rightarrow q_1$, $\alpha \rightarrow \beta \rightarrow 1 \rightarrow \alpha$.

Making definite transformations in (2) and (3), we shall obtain the following simple expressions for the amplitudes of $^1S_0 \rightarrow 2G$ and $^1S_0 \rightarrow 2GH_0$.

$$M_{^1S_0 \rightarrow 2G}^{\alpha\beta, \alpha\bar{\beta}}(q_1, q_2) = \delta_{\alpha\bar{\beta}} (2g_s^2 \Psi_0 M_{q\bar{q}}) i\epsilon^{\alpha\beta\bar{\beta}\bar{\alpha}} g_2^\beta q_1^\alpha (q_1, q_2)^{-1} \quad (4)$$

$$M_{^1S_0 \rightarrow 2GH}^{\alpha\beta, \alpha\bar{\beta}}(q_1, q_2; \Delta) = \delta_{\alpha\bar{\beta}} (g_s^2 \Psi_0 M_{q\bar{q}}^3 U^{-1}) i\epsilon^{\alpha\beta\bar{\beta}\bar{\alpha}} g_2^\beta q_1^\alpha (a_{12} + a_{1\Delta} + a_{2\Delta}) \quad (5)$$

where $M_{Q\bar{Q}}$ is the η_s -meson mass, $a_{12} \equiv \{(q_1, \Delta + q_2)(q_2, \Delta + q_1)\}^{-1}$,

$$a_{1\Delta} \equiv \{(q_1, \Delta + q_2)(\Delta, q_1 + q_2)\}^{-1}, \quad a_{2\Delta} \equiv \{(q_2, \Delta + q_1)(\Delta, q_1 + q_2)\}^{-1}.$$

4. The Effect of the GGH Contribution Increase

Here it will be shown that it is unacceptable to ignore the diagrams with the gluon production of H_0 (diagrams 2b and 2c) when the associated hadroproduction of relatively heavy H_0 boson ($M_H \gtrsim 20$ GeV) with the 1S_0 -states of $c\bar{c}$ and $b\bar{b}$ (in the six-quark scheme) quarkonia is considered already at energies of existing and planned accelerators of $P\bar{P}$ and PP beams.

Before analyzing the obtained results, note that when the number of quarks is limited by the t -quark, the mass of which, according to data of the group UI [20], is in the range of $30 \text{ GeV} \leq m_t \leq 50 \text{ GeV}$, then the condition $m_Q > 0.2 M_H$

of application of the effective point vertex (1) yields the following values for N_H :

$$N_H = 2 \quad \text{at } 10 \text{ GeV} < M_H < 22.5 \text{ GeV} \quad (m_b = 4.5 \text{ GeV})$$

$$N_H = 1 \quad \text{at } 22.5 \text{ GeV} < M_H < \begin{cases} 150 \text{ GeV}, m_t = 30 \text{ GeV} \\ 200 \text{ GeV}, m_t = 40 \text{ GeV} \\ 250 \text{ GeV}, m_t = 50 \text{ GeV} \end{cases} \quad (m_b = 4.5 \text{ GeV})$$

$$N_H = 0 \quad \text{at } M_H > 250 \text{ GeV}.$$

If assumed that there exist also other heavy quarks (heavier than the t-quark), then the N_H is to be increased by the number of quarks, the condition $N_H = 0$ being already met at $M_H > 5 \cdot$ the mass of the heaviest quark.

Below we shall analyze the results obtained by us in the framework of the six-quark scheme.

The complete set of Feynman diagrams which determine the cross section of the process $h_1 h_2 \rightarrow G + G \rightarrow H_0 + {}^1S_0$ is shown in fig.7 .

The cross section of this process is expressed as:

$$\sigma = \sum_i \sigma^{(i)} = \iint dx_1 dx_2 D_1^G(x_1) D_2^G(x_2) \sum_i \sigma_i \quad (i = 1, 2, \dots, 9) \quad (7)$$

where x_1 and x_2 are the portions of momenta of, correspondingly, h_1 and h_2 hadrons taken away by gluons; $D^G(x)$ is the gluon structure function; σ_i is the cross section corresponding to the i-th diagram in fig.7 .

Let us first consider the relation $(\sigma^{(2)} + \sigma^{(3)})/\sigma^{(1)}$ where $\sigma^{(1)}$, $\sigma^{(2)}$ and $\sigma^{(3)}$ are the partial contributions of diagrams 7.1 , 7.2 and 7.3 to the total cross section σ .

Using the explicit forms of the amplitudes $M_{H_0} \rightarrow 2G$, $M_{1S_0} \rightarrow 2G$ and $M_{1S_0} \rightarrow 2GH_0$ from (1), (4) and (5), we obtain:

$$\frac{\sigma^{(1)}}{\Gamma(1S_0 \rightarrow \text{hadrons})} = \frac{16(G_F \sqrt{2})^2}{M_{Q\bar{Q}}} \int_{\tau_0}^1 dx_1 D^G(x_1) \int_{\tau_0/x_1}^1 dx_2 D^G(x_2) \times \int_0^\pi d(\cos \theta) \frac{1}{(\alpha^2 - \beta^2 \cos^2 \theta)^2} \times \left\{ \left(\frac{M_{Q\bar{Q}}^2}{Sx_1 x_2} \right)^3 \left(1 - \frac{1}{\alpha'} \right)^2 \beta \right\} \quad (8)$$

$$\frac{(\sigma^{(2)} + \sigma^{(3)})}{\Gamma(1S_0 \rightarrow \text{hadrons})} = \frac{N_H^2}{72} \left(\frac{x_3}{\pi} \right)^2 \frac{G_F \sqrt{2}}{M_{Q\bar{Q}}} \int_{\tau_0}^1 dx_1 D^G(x_1) \int_{\tau_0/x_1}^1 dx_2 D^G(x_2) \left\{ \left(\frac{M_{Q\bar{Q}}^2}{Sx_1 x_2} \right) \beta \times \int_0^\pi d(\cos \theta) \left[\frac{1}{2} \left(\frac{\alpha' - \beta \cos \theta}{\alpha - \beta \cos \theta} \right)^2 + \frac{(\alpha' + \beta \cos \theta)^2}{(\alpha + \beta \cos \theta)^2} + 2\beta^2 (1 - \cos^2 \theta) \right] \right\} \times \quad (9)$$

$$\times \left[\left(\frac{\alpha - \beta \cos \theta}{\alpha - \beta \cos \theta} \right)^2 + \left(\frac{\alpha + \beta \cos \theta}{\alpha + \beta \cos \theta} \right)^2 \right] \right\}$$

where

$$\alpha' = 1 + (M_H^2 - M_{Q\bar{Q}}^2)/(Sx_1 x_2), \quad \alpha = 1 - (M_H^2 - M_{Q\bar{Q}}^2)/(Sx_1 x_2), \\ \beta = \left[1 - (M_H^2 - M_{Q\bar{Q}}^2)/(Sx_1 x_2) \right]^{1/2} \left[1 - (M_H^2 + M_{Q\bar{Q}}^2)/(Sx_1 x_2) \right]^{1/2}, \quad c = 1 - (M_H^2 + M_{Q\bar{Q}}^2)/(Sx_1 x_2), \\ G_F \sqrt{2} = (246 \text{ GeV})^{-2}, \quad \tau_0 = (M_H + M_{Q\bar{Q}})^2/s, \quad D^G(x) = (1/x) \times x^{-2} (1-x)^2. \\ M_{Q\bar{Q}} \text{ is the } \eta_{Q\bar{Q}}\text{-meson mass, } M_H \text{ is the Higgs boson mass.}$$

Numerical estimations of the behaviour of the relation $(\sigma^{(2)} + \sigma^{(3)})/\sigma^{(1)}$ for various \sqrt{S} as a function of M_H in the H_0 hadroproduction with the $\eta_c, \eta_c', \eta_c''$ mesons are plotted in figs. 8a, 8b and 8c, respectively.

As is seen from fig. 8a, at the associated hadroproduction of the H_0 and $1S_0$ state of $c\bar{c}$ -quarkonium (η_c -meson) at $\sqrt{S} = 540 \text{ GeV}$ the relation $(\sigma^{(2)} + \sigma^{(3)})/\sigma^{(1)} = 1$ near $M_H \approx$

≈ 36 GeV, but at $M_H > 37$ GeV $(\sigma^{(2)} + \sigma^{(3)}) > \sigma^{(1)}$.

Thus, the ignoring of GGH-type diagrams (e.g., 7.2, 7.3) leads to the H_0 and η_c hadroproduction total cross section's decrease by several times in a quite wide range of masses

$$35 \text{ GeV} < M_H < \begin{cases} 150 \text{ GeV, } m_t = 30 \text{ GeV,} \\ 200 \text{ GeV, } m_t = 40 \text{ GeV, } \sqrt{S} = 540 \text{ GeV,} \\ 250 \text{ GeV, } m_t = 50 \text{ GeV,} \end{cases}$$

and

$$23 \text{ GeV} < M_H < \begin{cases} 150 \text{ GeV, } m_t = 30 \text{ GeV,} \\ 200 \text{ GeV, } m_t = 40 \text{ GeV, } \sqrt{S} = 2 \text{ TeV} \\ 250 \text{ GeV, } m_t = 50 \text{ GeV.} \end{cases}$$

It is seen from the behaviour of the relation $(\sigma^{(2)} + \sigma^{(3)})/\sigma^{(1)}$ at the associated hadroproduction of H_0 and η_c (see fig.8b) that the account of GGH diagrams is necessary at high energies $\sqrt{S} \geq 1$ TeV.

In case of associated hadroproduction of H_0 and η_t $\sum \sigma_{\text{GGH}}/\sigma^{(1)} < 1$ at any \sqrt{S} and $M_H < 250$ GeV (see fig. 8c). And this is not accidental. Since we deal with a six-quark scheme, then the heaviest quark in the loop (in the amplitude $H_0 \rightarrow 2G$) can be the t-quark. And as we consider the process $h_1 h_2 \rightarrow H_0 + \eta_t$, then in the GGH diagrams will always be depression by α_s (the growth due to the t-quark loop is already impossible) as compared to the QH diagrams. Thus, at coproduction of H_0 and η_c or H_0 and η_b in hadron collisions, the increase of the gluon-gluon-Higgs (GGH) contribution with growing M_H comes into effect. This effect becomes essential for the energy ranges of already existing

and planned accelerators of PP and $P\bar{P}$ beams.

Since this effect has nothing to do with the phase volume, but results from the clever structure of the vertex $H_0 \rightarrow 2G$, then, we believe, it will also be essential in case of the associated hadroproduction of H_0 with a pair of unbound heavy $c\bar{c}$ and b,\bar{b} quarks (i.e. in the process $h_1 h_2 \rightarrow H_0 + c + \bar{c} + \dots$ and $h_1 h_2 \rightarrow H_0 + b + \bar{b} + \dots$).

The dominance of the gluon mechanism in the direct H_0 hadroproduction at high energies also follows from here.

5. The Total Cross Section of the Conjoined Hadroproduction of H_0 Boson and 1S_0 State of Bound Heavy Quarks Q, \bar{Q} ($Q = c, b, t$)

It follows from the analysis made in the paragraph 4, that the total cross section of the associated hadroproduction of H_0 and 1S_0 state of the $c\bar{c}$ -quarkonium is determined by a set of Feynmann diagrams shown in fig.7, at $\sqrt{S} = 540$ GeV in the range of $30 \text{ GeV} < M_H < 150 \text{ GeV}$ ($m_t = 30 \text{ GeV}$); 200 GeV ($m_t = 40 \text{ GeV}$); 250 GeV ($m_t = 50 \text{ GeV}$), if the number of quarks is limited by the t-quark.

The total cross section of the process $h_1 h_2 \rightarrow H_0 + ^1S_0$ ($b\bar{b}$) too is determined by the set of these diagrams at $\sqrt{S} \geq 1 \text{ TeV}$, $100 \text{ GeV} < M_H < 150 \text{ GeV}$ ($m_t = 30 \text{ GeV}$); 200 GeV ($m_t = 40 \text{ GeV}$); 250 GeV ($m_t = 50 \text{ GeV}$) in the six-quark scheme.

Beyond the above mentioned mass ranges of M_H at $\sqrt{S} \geq 540 \text{ GeV}$, the total cross section of both processes $h_1 h_2 \rightarrow H_0 + ^1S_0(c\bar{c})$ and $h_1 h_2 \rightarrow H_0 + ^1S_0(b\bar{b})$ is mainly determined

by the diagram 7.1. This diagram is essential for the total cross section of the process $h_1 h_2 \rightarrow H_0 + {}^1S_0(t\bar{t})$ (in the six-quark scheme) at any $\sqrt{S} \geq 540$ GeV and M_H .

The dependence of the total cross section of the associated hadroproduction of H_0 and ${}^1S_0(Q\bar{Q})$ ($Q = c, b, t$) on M_H at different values of \sqrt{S} is shown in fig.9.

We think, that the study of the $d\sigma/dq_{\perp}^2$ spectrum of the H_0 boson coproduced with quarkonium in the hadron collisions is also interesting. It is particularly important for the vector quarkonia in order to compare it with the behaviour of the spectrum $d\sigma/dq_{\perp}^2$ of the H_0 boson coproduced with the gauge bosons W^{\pm}, Z_0 in hadron collisions.

As this problem is of self-contained interest, we shall consider it after the processes of the associated hadroproduction of H_0 with all the other levels of the quarkonium $Q\bar{Q}$ ($Q = c, b, t$) are studied.

6. Summary

In the framework of six-quark scheme we considered the total cross section σ of the associated hadroproduction of the Higgs H_0 boson and 1S_0 state of bound heavy quarks Q and \bar{Q} ($Q = c, b, t$). It was shown that the gluon mechanism was dominating for that process.

At such mechanism of the associated production of the H_0 boson and the 1S_0 state of the $Q\bar{Q}$ -quarkonium (η_Q -meson), to the total cross section can contribute both the diagrams with the H_0 production from "direct" quarks (from the quark-

nium "tail") and the diagrams with the H_0 gluon production (through the heavy quark loop, the so-called GGH diagrams).

At high energies \sqrt{s} in the process $h_1 h_2 \rightarrow H_0 + \eta_c$ and $h_1 h_2 \rightarrow H_0 + \eta_b$ the small contribution of GGH diagrams in the highest order of FT, which is due to additional multiplier α_s/\sqrt{s} in the GGH vertex, is compensated for larger values of M_H . This effect of the GGH contribution increase with M_H in the associated hadroproduction of the H_0 boson and η_c (or η_b) meson is because of "inclusion" of the great contribution of the t-quark loops ($m_t \approx 160$ GeV) under M_H growing (at high energies of colliding hadrons). That is why there is no such effect in the process $h_1 h_2 \rightarrow H_0 + \eta_s$ (see Fig. 1). It is also to be noted that the GGH diagrams (see Fig. 1) are not included in the calculation of the GGH contribution and compared with the GGH diagrams, but results from the clever structure of the tails $\sim O(1/M_H)$, they it will be essential in any process of associated hadroproduction of the H_0 boson and a pair of both bound and unbound quarks at large \sqrt{s} and in quite a wide range of M_H . This circumstance necessitates one to correctly take their effect into account in the experiments on search for the H_0 boson produced in hadron collisions in association with a pair of both bound and free quarks.

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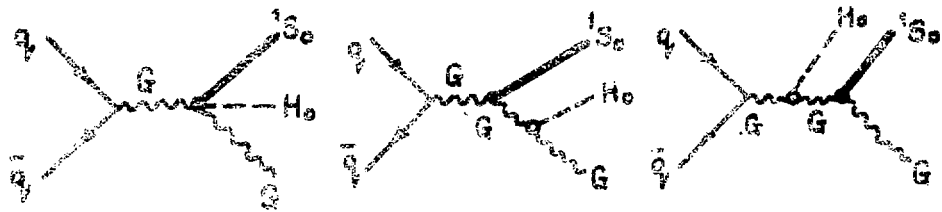


FIG. 1

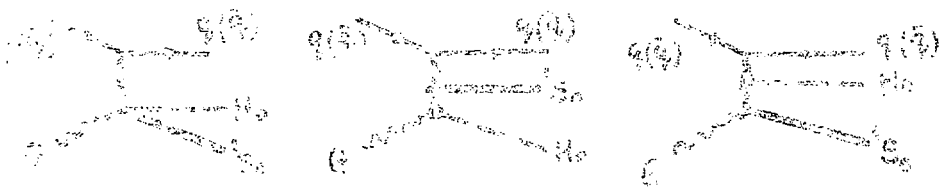
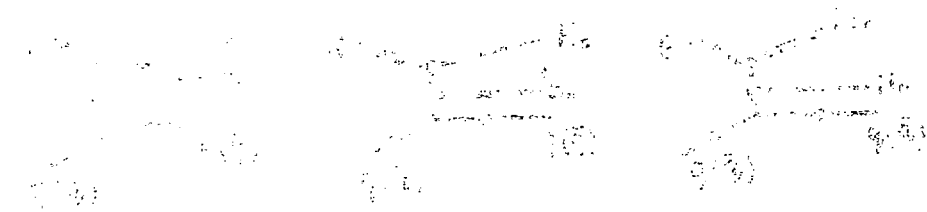
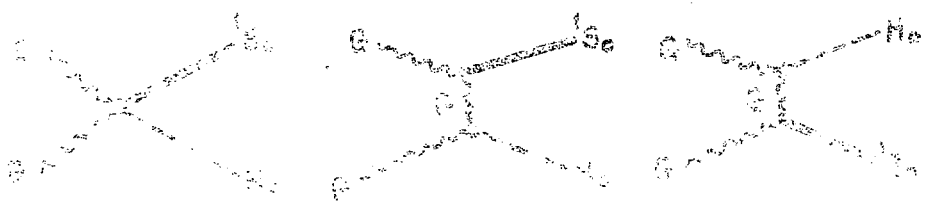


FIG. 2

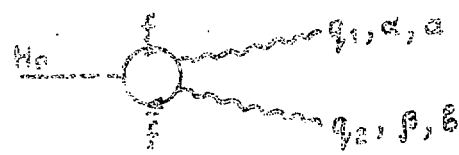


FIG. 4

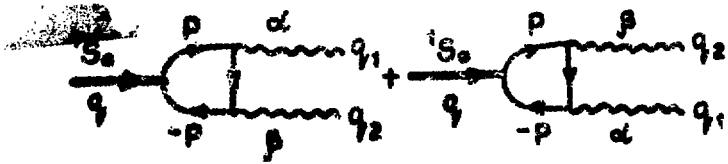


Fig. 5

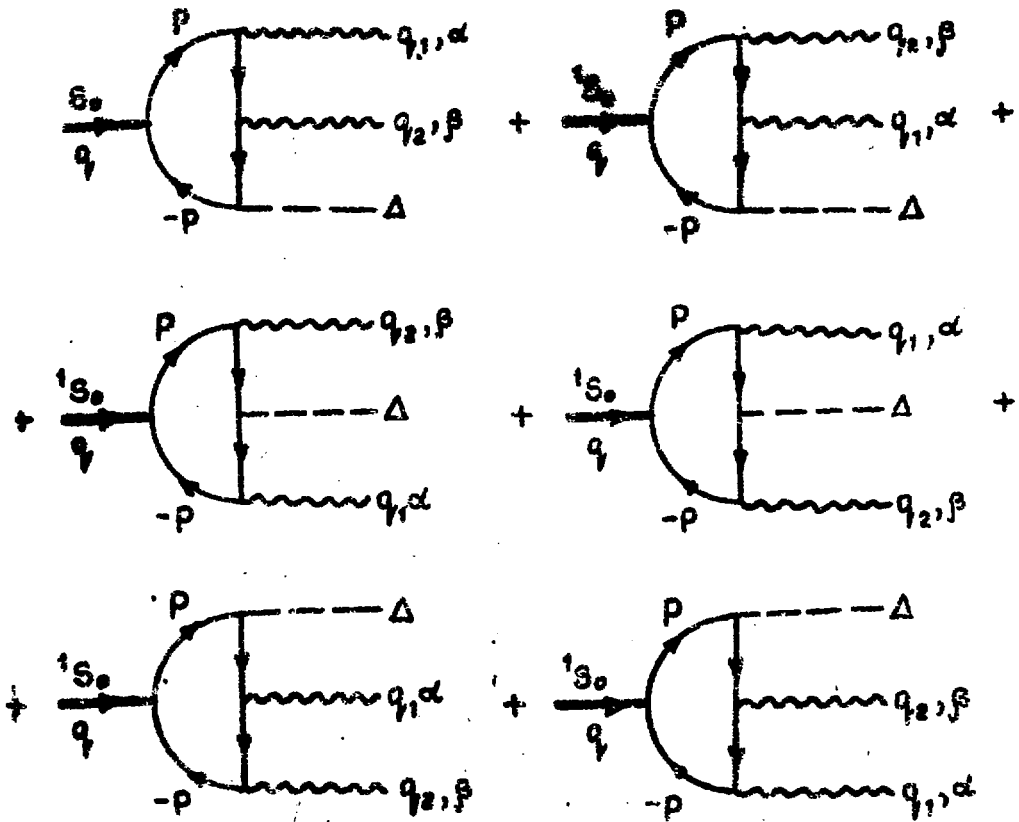


Fig. 6

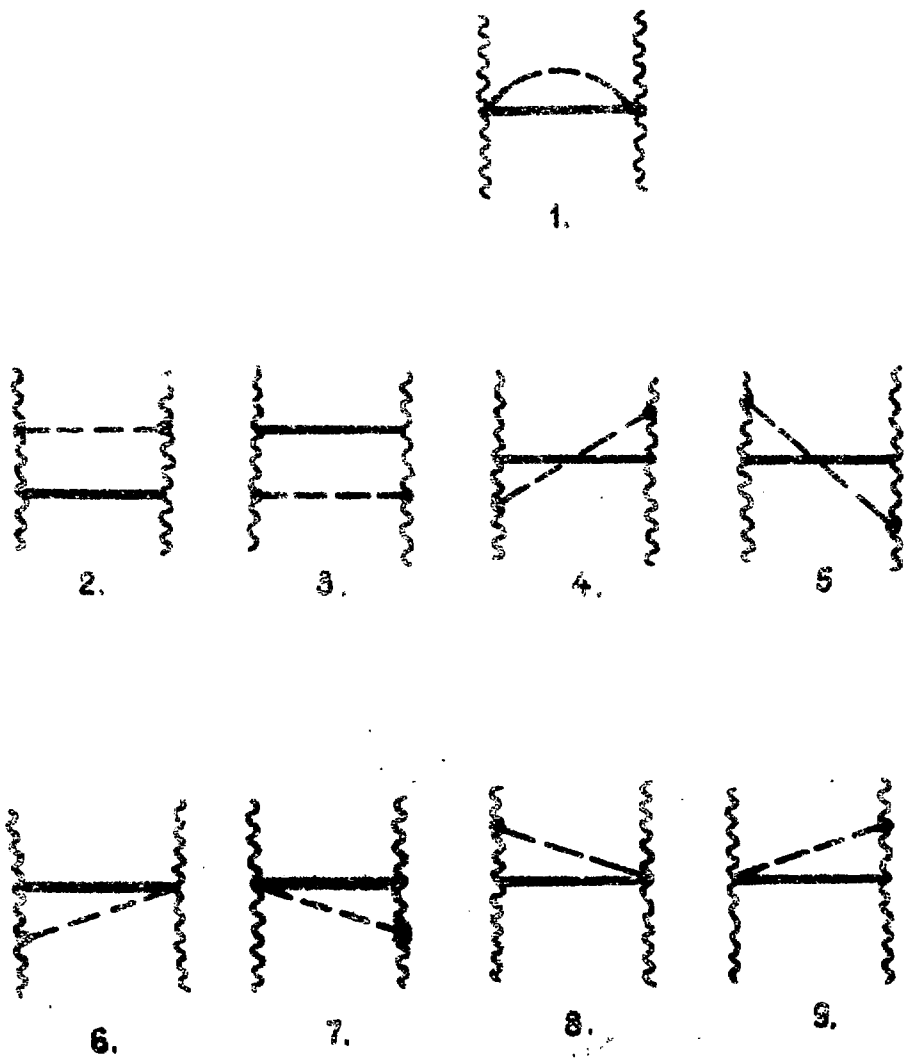


Fig. 7.

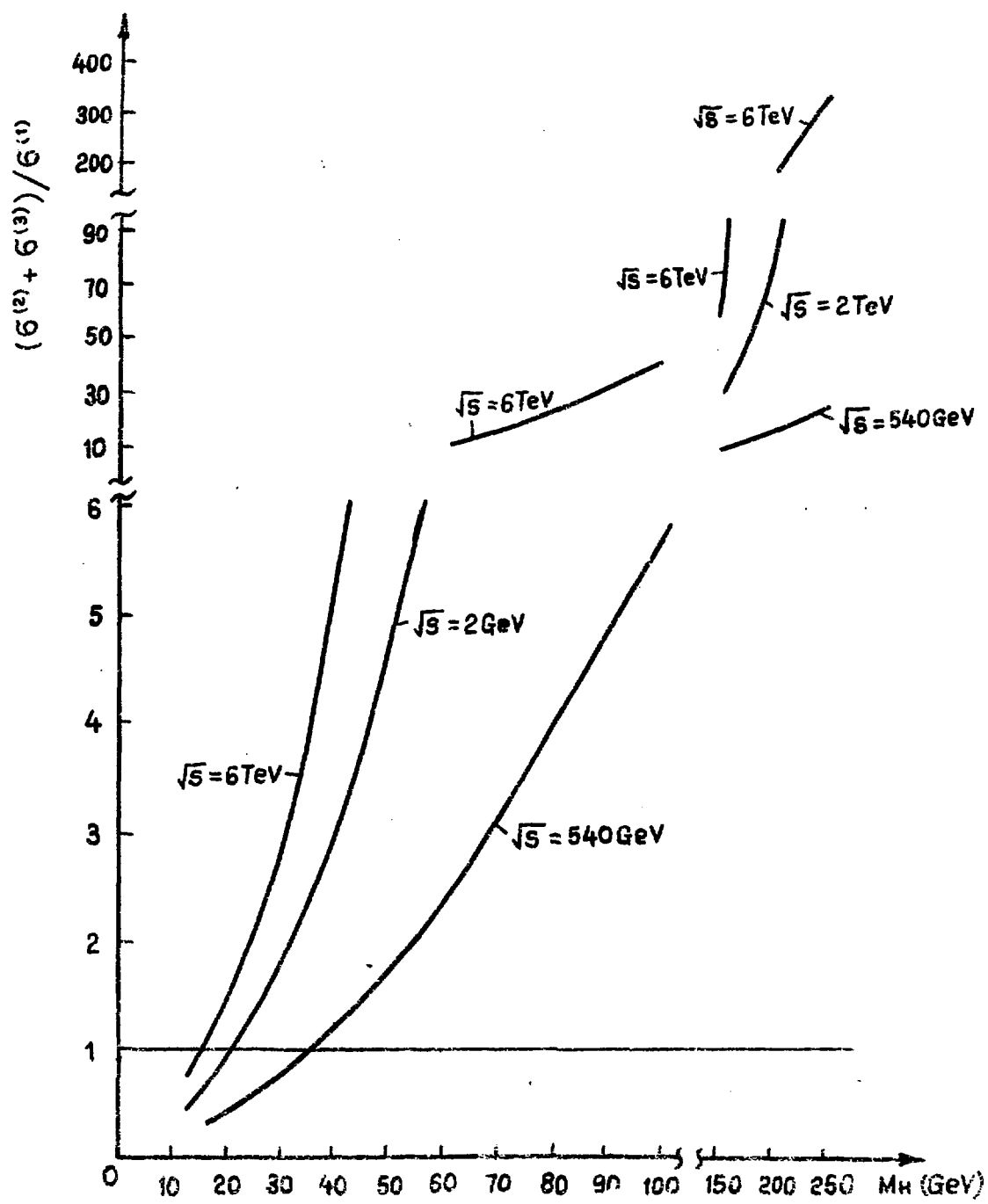


Fig. 8a

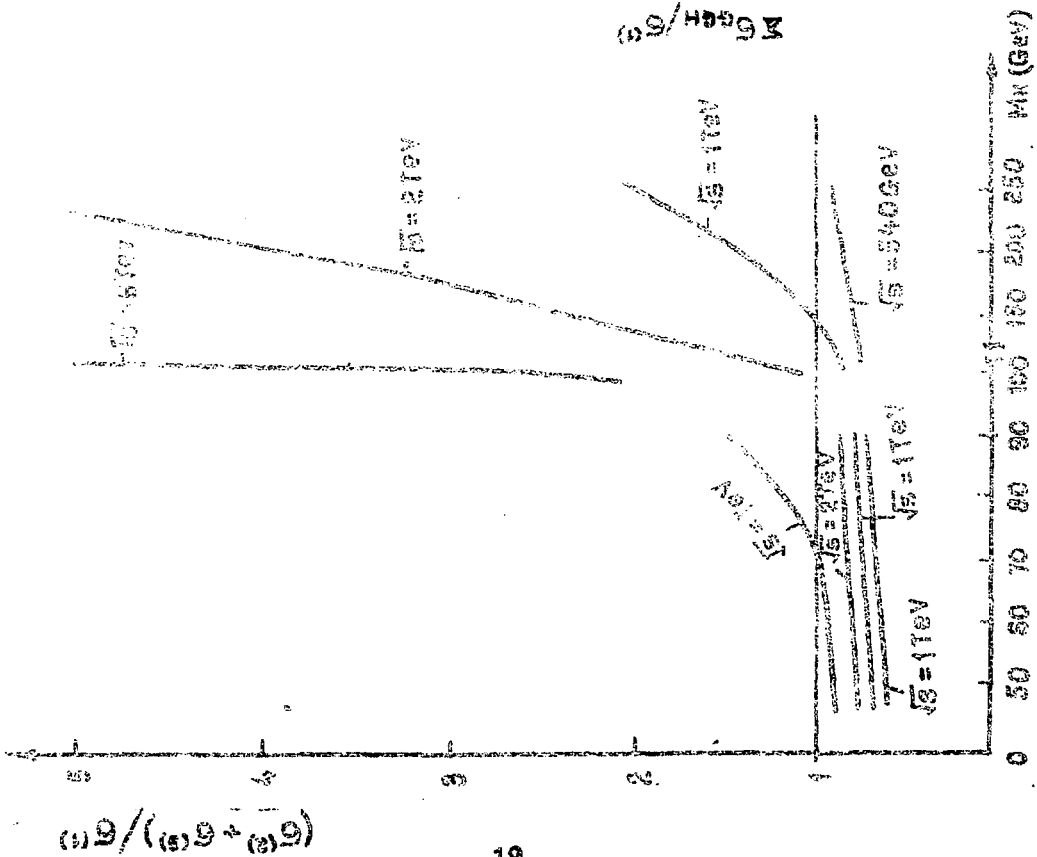


FIG. 8b

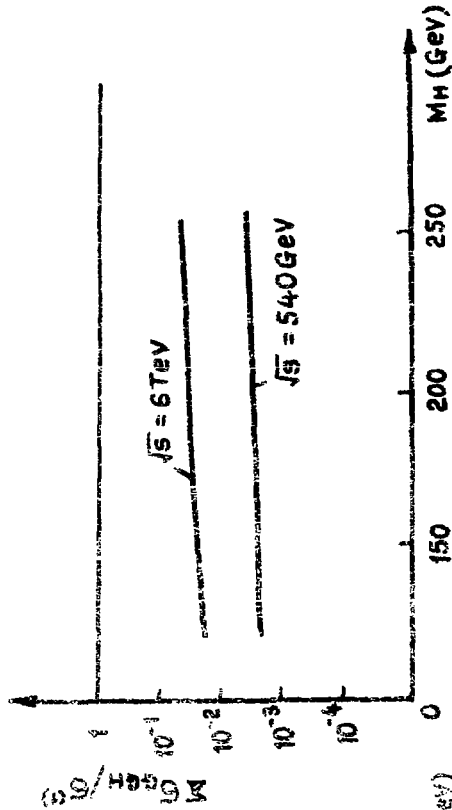


FIG. 8c

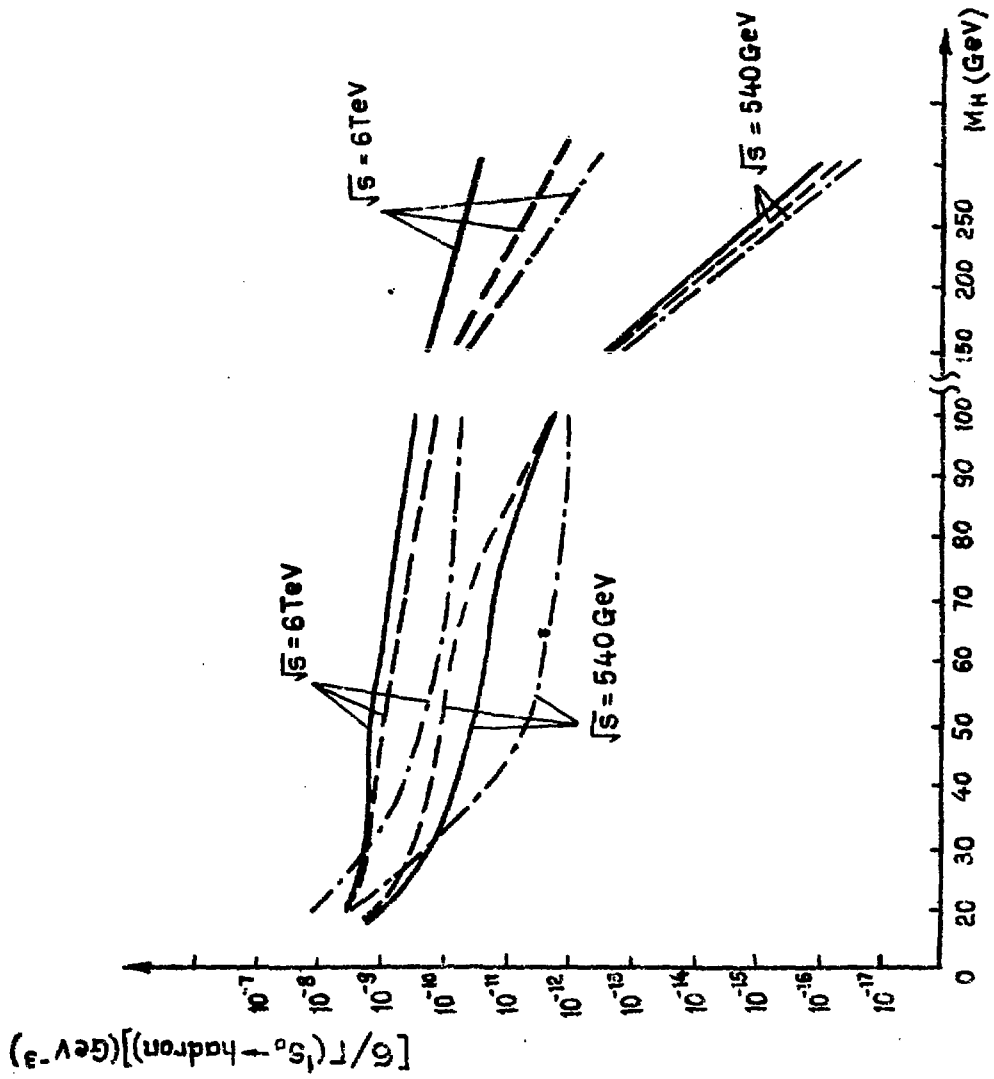


FIG.9

Figure Captions

- Fig.1 Dominant (in the leading order of PT) diagrams for the associated hadroproduction of H_0 and 1S_0 in the quark channel ($q\bar{q} \rightarrow H_0 + ^1S_0 + \dots$).
- Fig.2 Dominant (in the leading order of PT) diagrams for the associated hadroproduction of H_0 and 1S_0 in the gluon channel ($GG \rightarrow H_0 + ^1S_0 + \dots$).
- Fig.3 Dominant (in the leading order of PT) diagrams for the associated hadroproduction of H_0 and 1S_0 in the quark-gluon channel ($Gq(q) \rightarrow H_0 + ^1S_0 + \dots$).
- Fig.4 Diagram corresponding to the amplitude of the decay $H_0 \rightarrow 2G$.
- Fig.5 Diagrams for the amplitude $^1S_0 \rightarrow 2G$.
- Fig.6 Diagrams for the amplitude $^1S_0 \rightarrow 2G + H_0$.
- Fig.7 Complete set of Feynmann diagrams for the cross section of the associated production of the H_0 boson and the 1S_0 -quarkonium in the gluon channel: 1. is the so-called QH diagram, 2. - 5. are the so-called GGH diagrams, 6. - 9. are interference QH-GGH diagrams.
- Fig.8 Dependence of $(\sigma^{(2)} + \sigma^{(3)})/\sigma^{(1)}$ on M_H in the hadroproduction of H_0 with η_c (a); η_b (b); and of $\Sigma\sigma_{GGH}/\sigma^{(1)}$ on M_H in the hadroproduction of H_0 with η_t (c) ($M\eta_c = 3.1$ GeV; $M\eta_b = 9.46$ GeV; $M\eta_t = 60$ GeV).
- Fig.9 Dependence of the total cross section of associated hadroproduction of H_0 and 1S_0 state of quarkonium at different values of \sqrt{s} . The solid line corresponds to

the process $h_1 h_2 \rightarrow H_0 + {}^1S_0(cc)$, the dashed line - to
 $h_1 h_2 \rightarrow H_0 + {}^1S_0(b\bar{b})$, the dash-dotted line - to $h_1 h_2 \rightarrow$
 $H_0 + {}^1S_0(t\bar{t})$ (h_1, h_2 are protons (or antiprotons)).

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(на английском языке, перевод Папьян Г.А.)

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