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SCALAR AND PSEUDOSCALAR HIGGS BOSON
PRODUCTION IN HEAVY QUARK AND HEAVY
QUARKONIA DECAYS

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ՍԿԱԼՅԱՐ ԵՎ ԹՎԱՑՑԱԼ ՍԿԱԼՅԱՐ ՀԻԳՍԻ ԲՈՋՈՆՆԵՐԻ ԾՆՈՒՄԸ
ԾԱՆՐ ԲՎԱՐԿՆԵՐԻ ԵՎ ԲՎԱՐԿՈՆԻՈՒՄՆԵՐԻ ՏՐՈՂՄԱՆ ԺԱՄԱՆԱԿ

Ուսուցման ստիպված է միաքվարկ H° - և P° բոզոնների ծնման ուղին գերծանր քվարկոնիոլմների տրոհման ժամանակ: Ցույց է տրված, որ այդ ուղին գերակշռող է դառնում Հիգսի մասնիկների ծնման ժամանակ, $M > 2M_W$ քվարկոնիոլմների տրոհումներում, լայն տիրույթի զանգվածով գերծանր քվարկոնիոլմների համար: Ուսուցման ստիպված տրոհման մյուս վորումը հասնում է մինչև $\sim 10^{-2}$ -ի $m = 150$ ԳէՎ և $M_H = 10$ ԳէՎ: Ուսուցման ստիպված է նաև գերծանր քվարկների թույլ տրոհումներում H° և P° բոզոնների ծնումը, $\rho\rho(\rho\bar{\rho})$ - բախումների ժամանակ: Ցույց է տրված, որ այդ ուղին նկատելի է դառնում գերծանր քվարկներից $/m \gtrsim 300$ ԳէՎ/ գերծանր Հիգսի բոզոնների $/M_H \gtrsim 200$ ԳէՎ/ ծնման ժամանակ և համեմատելի է բոզոն-բոզոնային միաժուլման ուղիների հետ, որը համարվում է հաղորն-հաղորնային բախումների ժամանակ Հիգսի գերծանր մասնիկների ծնման հիմնական ուղին:

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РОЖДЕНИЕ СКАЛЯРНЫХ И ПСЕВДОСКАЛЯРНЫХ
ХИГГСОВСКИХ БОЗОНОВ В РАСПАДАХ
ТЯЖЕЛЫХ КВАРКОВ И ТЯЖЕЛЫХ КВАРКОНИЕВ

Изучен механизм однокваркового рождения H^0 - и P^0 -бозонов в распадах сверхтяжелых кваркониев. Показано, что этот механизм становится доминирующим в рождении хиггсовских частиц в распадах кваркониев с $M > 2M_W$ для широкой области масс тяжелого кваркония. Бренчинг изученного распада достигает $\sim 10^{-2}$ для $m = 150$ ГэВ и $M_H = 10$ ГэВ. Кроме того, изучено рождение H^0 - и P^0 -бозонов в слабых распадах сверхтяжелых кварков в pp ($p\bar{p}$)-столкновениях. Показано, что этот механизм становится заметным для рождения сверхтяжелых хиггсовских бозонов ($M_H \gtrsim 200$ ГэВ) от сверхтяжелых кварков ($m \gtrsim 300$ ГэВ) и сравним с механизмом бозон-бозонного слияния, который считается основным механизмом рождения сверхтяжелых хиггсовских частиц в адрон-адронных столкновениях.

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SCALAR AND PSEUDOSCALAR HIGGS BOSON PRODUCTION
IN HEAVY QUARK AND HEAVY QUARKONIA DECAYS

A mechanism of H^0 - and P^0 -boson single quark production in superheavy quarkonia decays is studied. This mechanism is shown to become dominant in the Higgs boson production in quarkonia decays with $M > 2M_W$ for the wide mass region of heavy quarkonium. The branching of the studied decay achieves $\sim 10^{-2}$ for $m = 150$ GeV and $M_H = 10$ GeV. Besides, the H^0 - and P^0 -boson production in weak decays of superheavy quarks in pp ($p\bar{p}$)-collisions is studied. This mechanism is shown to become significant for the production of superheavy Higgs bosons ($M_H \gtrsim 200$ GeV) from superheavy quarks ($m \gtrsim 300$ GeV) and comparable to the boson-boson fusion mechanism which is considered to be the main mechanism of superheavy Higgs particle production in hadron-hadron collisions.

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1. Introduction

As is known, the physics of $(Q\bar{Q})$ heavy quarkonium (a meson representing a weakly coupled system of heavy quark and antiquark [1,2]) is of exceptional interest for the study of weak, electromagnetic and strong interactions. With increasing quarkonium mass (beginning with bottomonium mass and higher) the system becomes more and more nonrelativistic, this making it especially applicable to check some models as well as to search for new particles (the Higgs scalar bosons, axions, supersymmetric particles). Besides, for superheavy quarkonium (with mass $M \gtrsim 100$ GeV) the role of weak, electromagnetic and strong interactions becomes opposite to what we usually have (see, e.g. reviews [3-5]).

In Fig.1 we present some decay modes of heavy quarkonium (in what follows we'll bear in mind the ground 1^3S_1 state of the $Q\bar{Q}$ system). With increasing quarkonium mass the relative contribution of electroweak decays [3-11] (Fig.1, a-e)

grows, since the widths of these decays grow with increasing heavy quark mass m (in nonrelativistic limit $M \simeq 2m$). Thus, for example, the width of quarkonium radiative decay with Higgs boson production [10] (see Fig.1c) grows as $\sim m^2$. But especially strongly grow the contributions of the so-called single quark decays of quarkonium shown in Fig.1d,e [6,7] which grow as m^3 and m^5 , respectively. The decay in Fig.1e already for $M \simeq 80$ GeV exceeds several times the quarkonium decay hadronic mode shown in Fig.1g. Such enhancement of contributions of Fig.1d,e diagrams is connected, of course, not only with strong growth of their widths with heavy quark masses but with the fact that in these decays there occurs collapse of quarkonium into free heavy quarks (i.e. it is more advantageous for the system to decay into free heavy quarks with a subsequent weak decay of one of them; the other quark passes without interaction, being a spectator) contrary to all other electroweak and hadronic decays which correspond to Q and \bar{Q} annihilation at small distances and are proportional to small quantity - squared radial wave function of the $Q\bar{Q}$ system at origin. Note, that the decay shown in Fig.1d is feasible only at $m > M_W$ (since it produces a real W -boson), and it is dominant in this mass region of heavy quark. In the region $40 \text{ GeV} \leq m < M_W$ already the decay shown in Fig.1e is dominant.

Besides the considered decays of superhigh quarkonium, one should note also channels of decays ($Q\bar{Q}$) into boson pairs W^+W^- , $Z\bar{Z}$, $Z\gamma$, ZH , HH studied in detail in Ref. [12] (see also references therein. The decays $(Q\bar{Q}) \rightarrow HH$ were

studied originally in Ref. [13]). These channels of super-heavy quarkonium decay become noticeable only for $M \gtrsim 300 \text{ GeV}$,

However attention should be called to the fact that there exists a problem of quarkonium formation from superheavy quarks, since the lifetime of superheavy quarks becomes much less (namely because of enhancement of weak decays of quarks with increase of their mass) than the time of construction of quarkonium by these quarks owing to strong interactions [14] ($t_{form} \sim \Lambda_{QCD}^{-1} \sim 10^{-23} \text{ s}$). In Ref. [14] it was shown that the bound system $(Q\bar{Q})$ cannot be formed if $m \gtrsim 125 \text{ GeV} |V_{Aq}|^{-2/3}$ where V_{Aq} is the mixing parameter. If Q is the upper quark of the doublet (e.g. t -quark or the upper quark of the fourth generation of fermions whose existence is not excluded by experiments now available), then $V_{Aq} \approx 1$, and we can see that the toponium system cannot be constructed if $m \gtrsim 125 \text{ GeV}$. In case if Q is the down quark of the fourth generation (or isosinglet, $-1/3$ charged quark, predicted in the E_6 model), then the $(Q\bar{Q})$ quarkonium can be formed for essentially large quark masses, since in this case the mixing parameter V_{Aq} is small ($V_{Aq} \sim \theta_c, \theta_c^2$ or even smaller [14], where θ_c is the Cabibbo angle). Therefore $(Q\bar{Q}) \rightarrow W^+W^-, ZZ, Z\gamma, ZH, HH$ decays giving a noticeable contribution to total width of quarkonium decay come only from quarkonia built of superheavy down quarks of isodoublets, since weak decays of these quarks will be suppressed by the mixing parameter V_{Aq} , and the $(Q\bar{Q})$ system therefore may be constructed.

2. $H^0(P^0)$ - Boson Production in the Mechanism of Single Quark Decay of Superheavy Quarkonium

In the present work we shall study the production of scalar (H^0) and pseudoscalar (P^0) Higgs bosons in decays of both heavy quarks and heavy quarkonia.

As we know, in the radiative decays of heavy quarkonia the H^0 - and P^0 -bosons can be produced via the Wilczek mechanism [10], shown in Fig.1c (see also [15,16]; in Refs. [17-21] the radiative and relativistic corrections to this mechanism are studied). As already emphasized, with increasing quark mass this channel of quarkonium decay becomes noticeable, this giving a possibility in case of existence of superheavy quarks ($m \gtrsim 50$ GeV) to search for H^0 - and P^0 -bosons with masses from several unities to a few tens GeV. Note, that the decay branching for the Wilczek mechanism is rather significant (achieves a few per cent) for quarkonium mass $M \sim 80$ GeV and $M_H \lesssim 60$ GeV. However, as soon as quarkonium decays with single quark decay enter into the game (see Fig.1d,e) at $M \gtrsim 80 - 100$ GeV, the decay branching $(Q\bar{Q}) \rightarrow H^0 + \gamma$ sharply decreases. However for quarkonia with such large masses there exists also a possibility of H^0 - and P^0 - boson production. Namely, via the mechanism of single quark decay of quarkonium (see Fig.1d), which, as said above, is dominant in quarkonium mass region $M > 2M_W$. In this mechanism the Higgs bosons may be produced both by heavy quark (see Fig.2a) and gauge boson (see Fig.2b), since the coupling constants of H^0 - and P^0 -bosons are proportional to masses of

particles they interact with. We neglect the contribution of the third diagram when H^0 - and P^0 -bosons are emitted by light quark q . Recall, that in the minimal model of electroweak interaction with one doublet of Higgs bosons there arises only one neutral H^0 -boson. P^0 -boson arises only in models containing no less than two doublets of Higgs bosons. Besides, pseudoscalar bosons necessarily are produced in supersymmetric models, since for the construction of supersymmetric Lagrangian one should introduce two doublets of Higgs bosons (P^0 -bosons also arise in technicolor models). It should be noted that the three-boson vertex PWW is absent; therefore only the Fig.2a diagram contributes to the P^0 -boson production in the mechanism under study (see Fig.2).

Amplitudes of scalar and pseudoscalar Higgs boson production have the form:

$$A_H = \frac{g}{2\sqrt{2}} (\sqrt{2} G_F)^{1/2} V_{aq} \bar{u}_a(p_2) [\gamma_\mu (1 - \gamma_5) \times$$

$$\times \frac{m(2m - \hat{k}_1)}{(p_1 - k_1)^2 - m^2} - 2M_W^2 \gamma_\nu (1 - \gamma_5) \frac{g_{\mu\nu} - \frac{(k_1 + k_2)_\mu (k_1 + k_2)_\nu}{M_W^2}}{(k_1 + k_2)^2 - M_W^2}] u_q(p_1) \epsilon_\mu(k_2), \quad (1)$$

$$A_P = -\frac{g}{2\sqrt{2}} (\sqrt{2} G_F)^{1/2} V_{aq} m y \bar{u}_a(p_2) \frac{\gamma_\mu \hat{k}_1 (1 + \gamma_5)}{(p_1 - k_1)^2 - m^2} u_q(p_1) \epsilon_\mu(k_2), \quad (2)$$

where notations for momenta are given in Fig.2; m and M_W are masses of heavy quark and W -boson, respectively; $\epsilon_\mu(k_2)$ is the W -boson polarization vector; y is the ratio of vacuum expectation values of two Higgs doublets (in the following we take $y = 1$; note, however, that now available

experimental restriction $y \leq 40$ [25] tells us that the obtained widths of the decay with P^0 -boson production, apparently, are essentially enhanced by the factor y^2); V_{aq} is the mixing parameter (obviously, further, we shall study decays of either toponium, i.e. Q is the t -quark, or quarkonium built of up-type heavy quark of the fourth family fermions. In both cases $V_{aq} \approx 1$, whereas for the down-type quark the mixing parameter will be small and the corresponding decay widths will be suppressed as $\sim |V_{aq}|^2$).

Kinematically our studied decay will go if $m > M_W + M_{H(P)}$ ($M_{H(P)}$ is the mass of $H^0(P^0)$ -boson), i.e. the t -quark mass must be at least larger than $M_W \approx 82$ GeV. The data available at present on $B^0 - \bar{B}^0$ transitions of groups ARGUS in e^+e^- -annihilation [26] and UA1 in $p\bar{p}$ -collisions [27] point out that in the framework of the standard model with three generations of fermions the mass of t -quark must be large ($m_t \approx 90 - 100$ GeV [28-32]). Therefore, the studied mechanism of H^0 - and P^0 -boson production in superheavy quarkonium decays (see Fig.2) and its comparison with the Wilczek mechanism (see Fig.1c) is of particular interest. In case when there exists the fourth upper quark t' , the t -quark mass may not necessarily be such large [28,29], and the studied decay will go from the new T' -quarkonium.

Without presenting detailed calculations, write down the final result for decay widths shown in Fig.2, with H^0 - and P^0 -boson production:

$$\begin{aligned}
\frac{d\Gamma_H}{dx_1 dx_3} &= \frac{G_F^2 m^3 M_W^2}{32\pi^3} \left\{ (\xi - 2C)^{-2} [(4 - \xi)A + 2\xi^{-1}(4 - \xi)B\mathcal{D} + \right. \\
&+ 4\xi^{-1}(C - 2)\mathcal{D}F + 2E(C - 2)] + 4\xi^2(\xi + 2F)^{-2} [2\xi^{-1}B\mathcal{D} + \\
&+ A + \xi^{-3}AF^2 - \xi^{-2}\xi A + 2E\xi^{-1} - 2\xi^{-2}\mathcal{D}F] - 4\xi(\xi + 2F)^{-1} \times \\
&\times (\xi - 2C)^{-1} [2A + 4\xi^{-1}B\mathcal{D} + \xi^{-2}F(\mathcal{D}C + AF - BE) - \xi^{-1}\xi A + \\
&\left. + 2\xi^{-1}E - 2\xi^{-2}\mathcal{D}F - E - 2\xi^{-1}\mathcal{D}F] \right\}, \tag{3}
\end{aligned}$$

$$\begin{aligned}
\frac{d\Gamma_P}{dx_1 dx_3} &= \frac{G_F^2 m^3 M_W^2}{32\pi^3} y^2 (\xi - 2C)^{-2} [2CE - \xi A + \\
&+ 4\xi^{-1}C\mathcal{D}F - 2\xi^{-1}\xi B\mathcal{D}], \tag{4}
\end{aligned}$$

$$A = \frac{x_2}{2}, \quad \mathcal{D} = \frac{1}{2}(1 - x_1 + \xi - \gamma), \tag{5}$$

$$B = \frac{x_3}{2}, \quad E = \frac{1}{2}(1 - x_3 + \gamma - \xi),$$

$$C = \frac{x_1}{2}, \quad F = \frac{1}{2}(1 - x_2 - \gamma - \xi).$$

Here $x_1 = 2E_{H(P)}/m$, $x_2 = 2E_q/m$, $x_3 = 2E_W/m$, where $E_{H(P)}$,

E_W - are energies of $H^0(P^0)$ - and W - bosons, respectively;

E_q - is energy of final relatively light quark whose mass is neglected ($m_q = 0$). $\gamma = (M_W/m)^2$, $\xi = (M_{H(P)}/m)^2$, where $M_{H(P)}$

is the $H^0(P^0)$ boson mass. From the energy conservation law it follows that

$$x_1 + x_2 + x_3 = 2, \tag{6}$$

and the region of integration over x_1 and x_3 is

$$\begin{cases} x_3^- < x_3 < x_3^+ , \\ 2\xi^{1/2} < x_1 < 1 + \xi - \gamma , \end{cases} \quad (7)$$

where

$$x_3^\pm = \frac{(2-x_1)(1+\xi+\gamma-x_1) \pm (1+\xi-\gamma-x_1)(x_1^2 - 4\xi)^{1/2}}{2(1+\xi-x_1)}$$

The dependence of obtained widths (see formulae (3) and (4)) on m and $M_{H(P)}$ is convenient to present in its ratio to the width of quarkonium radiative decay with $H^0(P^0)$ -boson production [10,15,16] :

$$\Gamma_w((Q\bar{Q}) \rightarrow H^0(P^0)\gamma) = \frac{G_F m^2}{\sqrt{2} \pi \alpha} \left(1 - \frac{\xi}{4}\right) \Gamma_0 , \quad (8)$$

where α is the fine-structure constant, and Γ_0 is the width of $(Q\bar{Q})$ quarkonium decay into muon pair via photon exchange. For Γ_0 in what follows we shall take the value $\Gamma_0 \simeq 5$ keV, following from the assumption that Γ_0/ℓ_q^2 (where ℓ_q is the heavy quark charge) is mass-independent, which holds successfully for charmonium and bottomonium; however this assumption will be fulfilled worse for toponium and possible heavier quarkonia. Indeed, with increasing quarkonium mass the system becomes more and more Coulomb-like, while for the Coulomb potential Γ_0 increases with quarkonium mass. However, both for the Coulomb potential and the most realistic potentials [33,34] this dependence changes Γ_0 only by a factor of

..5 - 2 with increase of quarkonium mass M from 20 to 300 GeV (see Fig.2a from Ref. [12]).

Figs. 3 and 4 show the dependence of the ratio $R = \Gamma_{H^{(P)}} / \Gamma_W$ on the heavy quark mass m for different values of $H^0(P^0)$ -boson masses. So, one can see from Fig.3 that at production of Higgs boson with $M_H = 20$ GeV, already for $m = 120$ GeV our studied mechanism is by an order of magnitude stronger than the radiative mechanism of H^0 -boson production in super-heavy quarkonium decays. For lighter Higgs bosons this regime comes sooner by the heavy quark mass m . So, for $M_H = 5$ GeV, $R \approx 10$ already at $m = 95$ GeV. As is seen from Figs. 3 and 4, the width of the studied decay for P^0 -boson is substantially less than that for H^0 -boson, in some cases it is less by 2-3 orders of magnitude (recall, that the decay widths of H^0 - and P^0 -bosons in the Wilczek mechanism are the same [15,16]). With increasing $H^0(P^0)$ -boson mass this difference somewhat decreases (see Fig.4). Clearly, for P^0 -boson production R will be > 1 at essentially larger masses of heavy quark m rather than for H^0 -boson. Diagrams in Figs. 3 and 4 are given for heavy quark mass up to 250 GeV (the upper limit for the t -quark mass is taken from the accounting of radiative corrections to $\sin^2 \theta_W$ [35] , where θ_W is the Weinberg angle).

Figs. 5-7 show the dependence $\frac{1}{\Gamma_{H^{(P)}}} \cdot \frac{d\Gamma}{dx_1}$ on x_1 (part of energy carried away by $H^0(P^0)$ -boson from quarkonium) at a fixed value of $M_{H^{(P)}} = 10$ GeV and different values of m . The diagram show clearly pronounced peaks in differential distributions (especially for H^0 -boson, see Fig.5). With

increasing mass m the peak for H^0 -boson production is slightly shifted to the left (towards smaller x_1), whereas for P^0 -boson it is shifted to the right (towards larger x_1). In Figs. 8-10 the same dependence is shown only for $M_{H(P)} = 50$ GeV. Already at large $M_{H(P)}$ the peak for P^0 -boson is practically nonshifted. Figs. 7, 10 and 11 give the dependence of $\frac{1}{\Gamma_{H(P)}} \cdot (d\Gamma_{H(P)} / dx_1)$ on x_1 for $m = 240$ GeV at different values of $M_{H(P)}$. One can see that with increasing $M_{H(P)}$ differential cross sections for H^0 - and P^0 -boson production are comparable and their peaks coincide.

Thus, we see that the studied mechanism of H^0 -boson production in superheavy quarkonium decays - via the mechanism of single quark decay of quarkonium - essentially prevails over the mechanism of H^0 -boson production in quarkonium radiative decay (the Wilczek mechanism, see Fig.1c). Practically for any masses of Higgs boson (from several unities to some tens GeV), beginning with some value of heavy quark mass m the ratio R becomes $\gg 1$. The studied mechanism of H^0 -boson production (see Fig.2) has good detection properties, since H^0 -boson is produced in association with W -boson, heavy quarks Q (spectator-quark) and q (e.g. with \bar{b} -quark if we study toponium decay). W -boson is a good trigger and we'll have fast muons in final state from heavy quark decays.

3. $H^0(P^0)$ -Boson Production in $pp(p\bar{p})$ -Collisions from Weak Decays of Superheavy Quarks

We have already emphasized the fact that when the heavy quark mass $m > M_W$, there appears a new channel of quark

decay with real W boson production. The width of this decay which is dominant for such masses m is [6,7] :

$$\Gamma(Q \rightarrow qW) = \frac{G_F m^3}{8\sqrt{2}\pi} (1 - 3\frac{m^2}{S^2} + 2\frac{m^4}{S^4}). \quad (8)$$

$H^0(P^0)$ -boson production in superheavy quark decays will proceed similarly to what we have in superheavy quarkonium (see Fig.2). Expressions for the decay widths of quarks with H^0 - and P^0 - boson production will coincide with the corresponding widths for quarkonium (see formulae (3) and (4)) with an accuracy up to 1/2 factor (in quarkonium decays the result is twice as large because in quarkonium this process may proceed on both quarks).

Fig.12 gives the ratio $R_1 = \Gamma_{H(P)}(Q \rightarrow qWH(P))/\Gamma(Q \rightarrow qW)$ as a function of m . One can see that with increasing quark mass the ratio R_1 grows (the figure presents curves for different values of $M_{H(P)}$). Similar results were obtained in Ref. [36]. However in this work they obtained incorrect phase space, since the region of integration over Ω_3 was wrong, and this had brought to an excess in the values of the ratio R_1 approximately by a factor of 1.5 - 2.

An interesting place for Higgs boson production via superheavy quark decays are $pp(p\bar{p})$ -collisions. Indeed, via the mechanism of two-gluon production of heavy quark pair (see, e.g. [37]) in pp and $p\bar{p}$ collisions we have an intense source of production of superheavy quarks which subsequently, weakly decaying, will produce H^0 - and P^0 -bosons. The cross section of such production of H^0 - and P^0 -bosons is

$\sigma_{H^{(p)}} = \sigma_{q\bar{q}} \cdot 2R_1 / (1 + R_1)$, where $\sigma_{q\bar{q}}$ is the cross section of production of heavy quark pair in $pp(p\bar{p})$ collisions. With account of a yearly integral luminosity ($L \sim 10^{40} \text{ cm}^{-2}$) planned at SSC and the fact that $\sigma_{q\bar{q}}$ for the superheavy quark production $\approx 10 \text{ pb}$ [37] (for $m \approx 1 \text{ TeV}$), we obtain, say, the production of ~ 1000 H^0 -bosons per year with a mass $M_H \approx 250 \text{ GeV}$ from quarks with $m \approx 700 \text{ GeV}$ (see Fig.12). The obtained cross section of H^0 -boson production is comparable with the cross section of Higgs particle production from the boson-boson fusion mechanism [38] which is considered the basic one for production of H^0 -bosons with $M_H \gtrsim 300 \text{ GeV}$. Note, that with increasing quark mass m the number of produced Higgs bosons grows, since R_1 grows more rapidly than $\sigma_{q\bar{q}}$ decreases with increasing m . Emphasize, that the considered mechanism is significant only for the production of heavy $H^0(P^0)$ -bosons ($M_{H^{(p)}} \gtrsim 200 \text{ GeV}$) from superheavy quarks ($m \gtrsim 300 \text{ GeV}$). These quarks may be upper-type quarks of the possible fourth doublet of quark family.

It is interesting that diagrams in Figs. 12-14 are at the same time branchings of heavy quarkonium decay with production of $H^0(P^0)$ -bosons studied in Sect.2 of this work. We see, that in the region of heavy quark masses m for which this mechanism was studied ($m \lesssim 250 \text{ GeV}$) the branching of the studied decay is $\sim 10^{-6} - 10^{-4}$ (for $m = 150 - 250 \text{ GeV}$ and $M_H = 100 \text{ GeV}$). Obviously, it is substantially higher for the production of lighter Higgs bosons. So, in the production of H^0 -boson with $M_H = 10 \text{ GeV}$ the decay branching achieves $\sim 3 \cdot 10^{-4} - 3 \cdot 10^{-2}$ for $m = 100 - 250 \text{ GeV}$.

Conclusion

In this work we have studied the mechanism of single quark production of H^0 - and P^0 -bosons in superheavy quarkonia decays (see Fig.2), and this mechanism is shown to become dominant in Higgs particle production in quarkonia decays with $M > 2M_W$ for a wide mass region of heavy quarkonium. The branching of the studied decay achieves $\sim 10^{-2}$ for light Higgs particle production ($M_H = 10 - 30$ GeV) with m varying from 150 to 250 GeV.

Also the H^0 - and P^0 -boson production in weak decays of superheavy quarks in $pp(p\bar{p})$ collisions is studied. This mechanism is shown to become significant for the superheavy Higgs boson production ($M_H \gtrsim 200$ GeV) from superheavy quarks ($m \gtrsim 300$ GeV) and is comparable with the boson-boson fusion mechanism [38] which is considered to be the basic mechanism of superheavy Higgs particle production in hadron-hadron collisions.

In conclusion note that we did not take into account effects connected with the presence of neutral flavor-changing currents (occurring, say, in technicolor models or within the standard model with a number of Higgs doublets more than three). These will be considered elsewhere.

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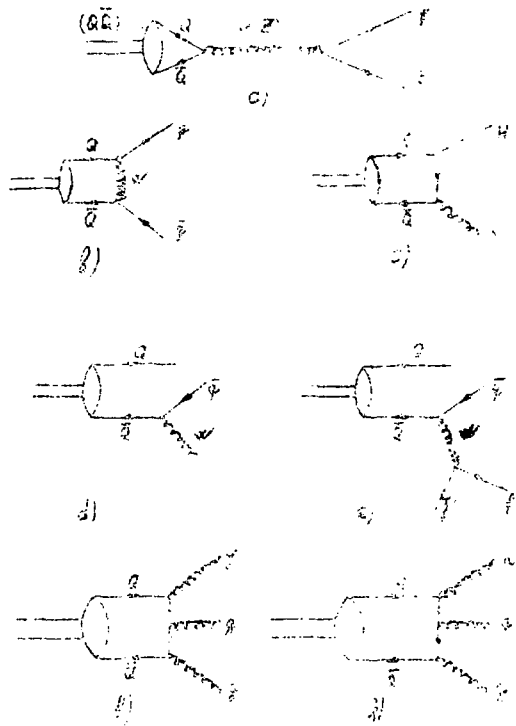


Fig. 1

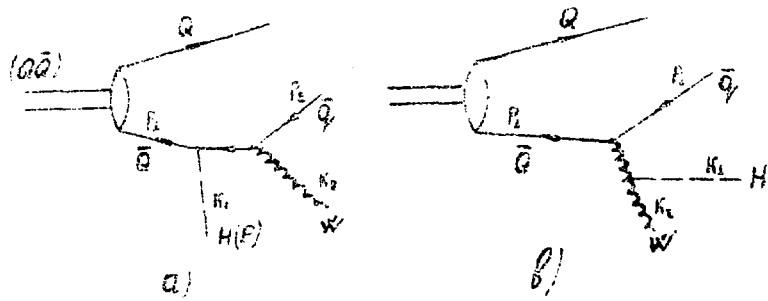


Fig. 2

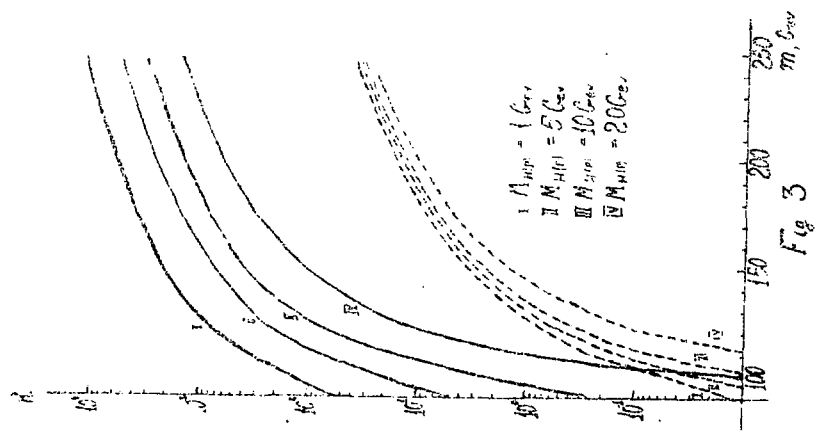


Fig. 3

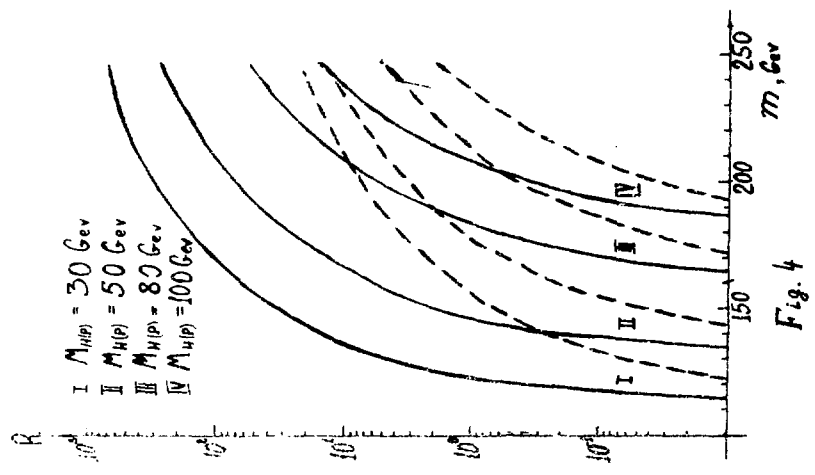


Fig. 4

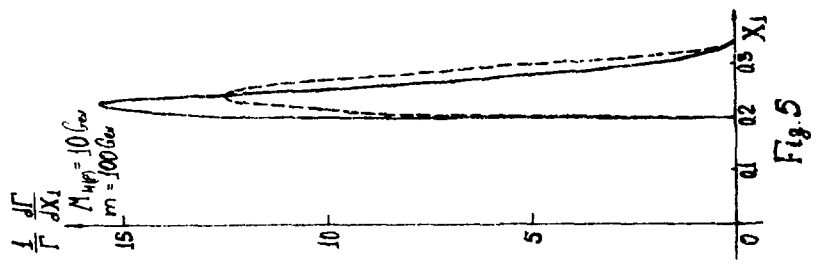
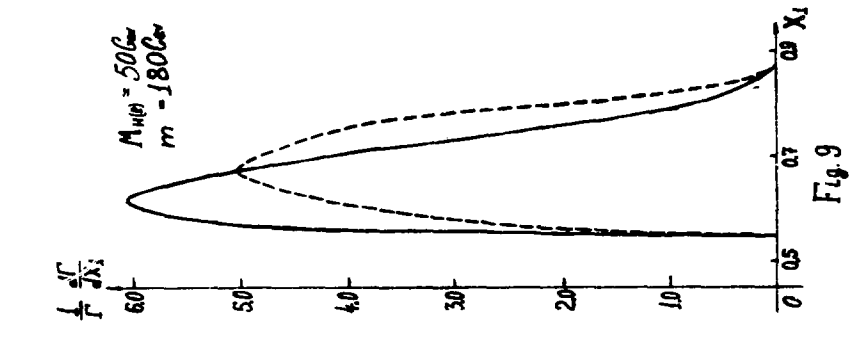
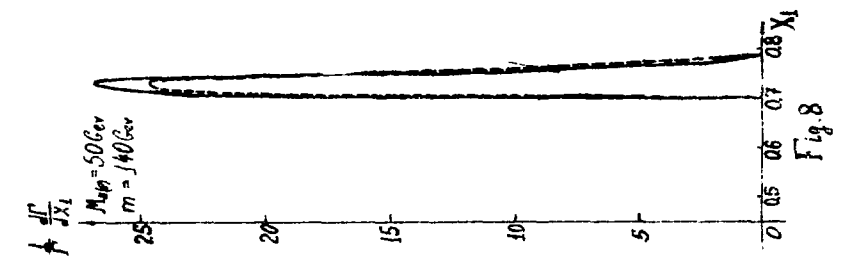
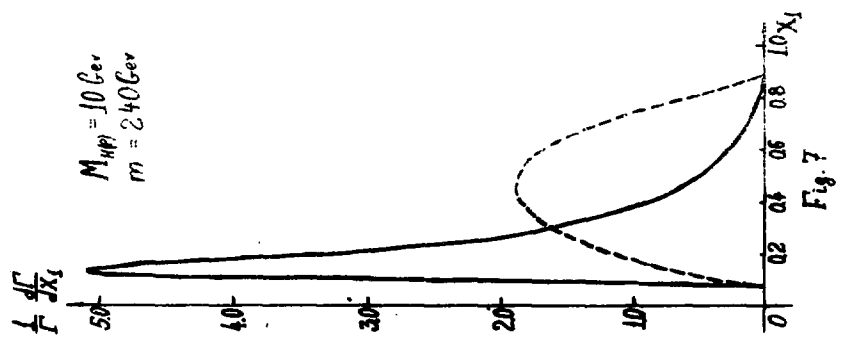
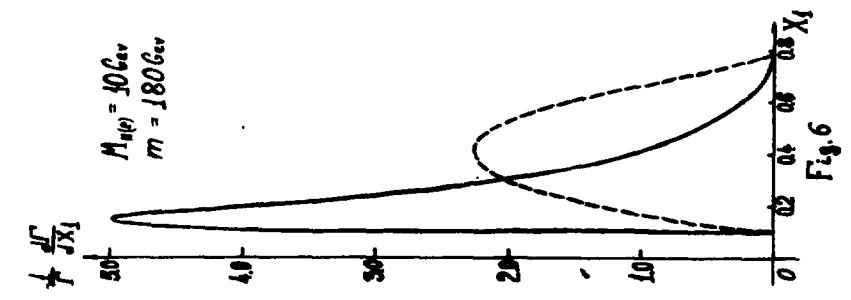


Fig. 5



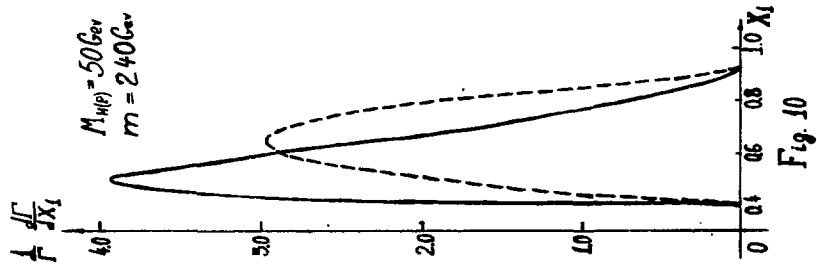


Fig. 10

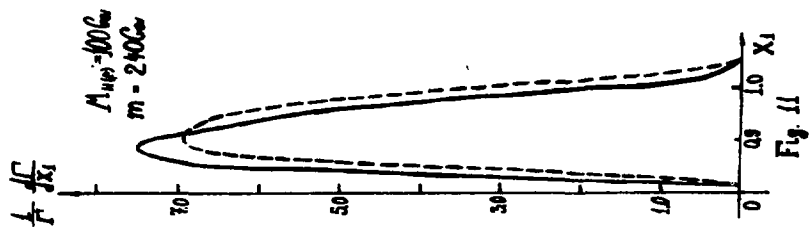


Fig. 11

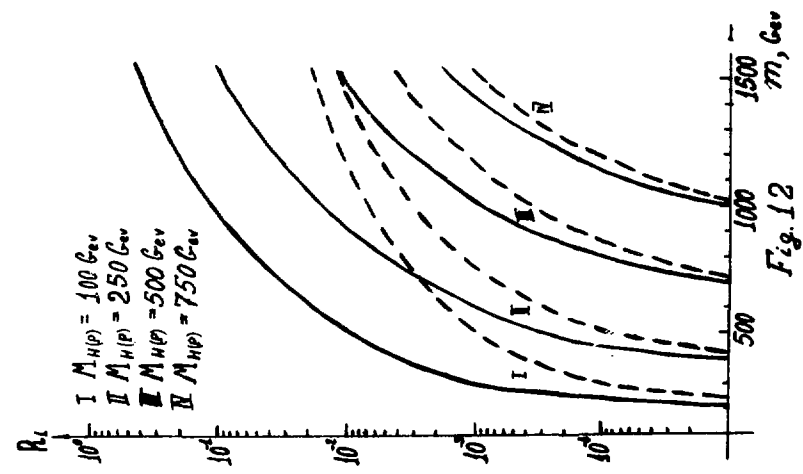


Fig. 12

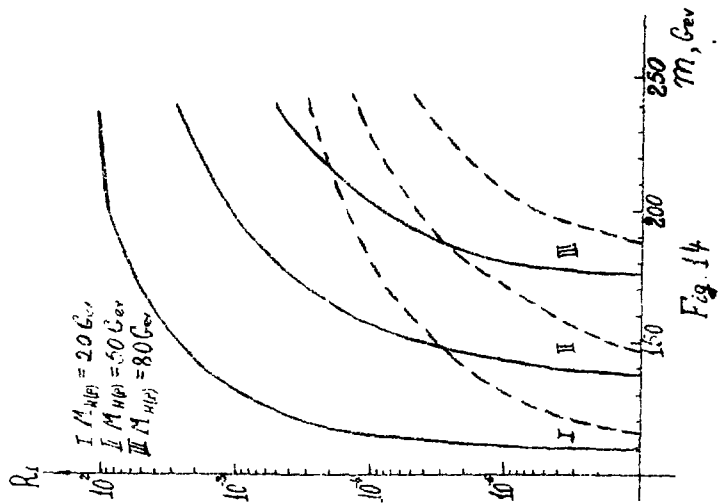
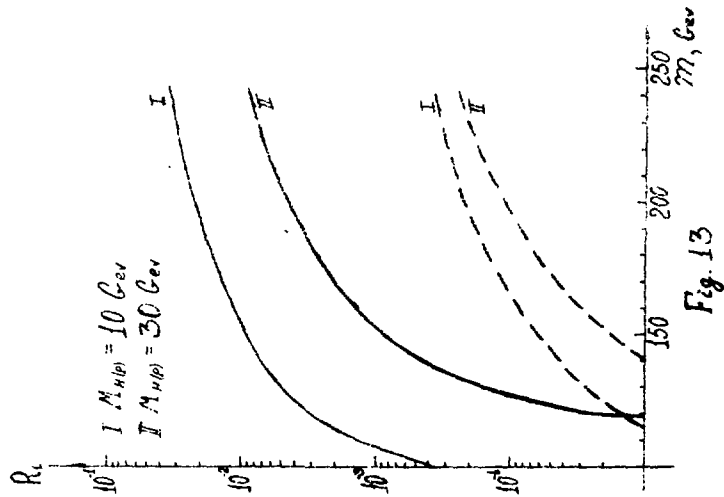


Figure Captions

- Fig.1. Diagrams corresponding to the main decays of heavy vector quarkonium ($Q\bar{Q}$).
- Fig.2. Diagrams corresponding to the mechanism of single quark decay ($Q\bar{Q}$) with the H^0 - and P^0 -boson production.
- Fig.3. The ratio $R = \Gamma_{H(P)} / \Gamma_W(Q\bar{Q} \rightarrow H^0(P^0)\gamma)$ as a function of heavy quark mass for different values of $H^0(P^0)$ -boson masses. Solid curves refer to H^0 -boson, dashed to P^0 -boson.
- Fig.4. R as a function of m for different values of $M_{H(P)}$
- Fig.5. Differential width $(1/\Gamma_{H(P)}) \cdot (d\Gamma_{H(P)}/dx_1)$ as a function of x_1 (part of energy carried away by $H^0(P^0)$ -boson from quarkonium) at $M_{H(P)} = 10$ GeV, and $m = 100$ GeV. Solid curves refer to H^0 -boson, dashed to P^0 -boson.
- Fig.6. The width $(1/\Gamma_{H(P)}) \cdot (d\Gamma_{H(P)}/dx_1)$ as a function of x_1 at $M_{H(P)} = 10$ GeV and $m = 180$ GeV.
- Fig.7. The width $(1/\Gamma_{H(P)}) \cdot (d\Gamma_{H(P)}/dx_1)$ as a function of x_1 at $M_{H(P)} = 10$ GeV and $m = 240$ GeV.
- Fig.8. The width $(1/\Gamma_{H(P)}) \cdot (d\Gamma_{H(P)}/dx_1)$ as a function of x_1 at $M_{H(P)} = 50$ GeV and $m = 140$ GeV.
- Fig.9. The width $(1/\Gamma_{H(P)}) \cdot (d\Gamma_{H(P)}/dx_1)$ as a function of x_1 at $M_{H(P)} = 50$ GeV and $m = 180$ GeV.
- Fig.10. The width $(1/\Gamma_{H(P)}) \cdot (d\Gamma_{H(P)}/dx_1)$ as a function of x_1 at $M_{H(P)} = 50$ GeV and $m = 240$ GeV.

- Fig.11. The width $(1/\Gamma_{H(P)})(d\Gamma_{H(P)}/dx_1)$ as a function of x_1 at $M_{H(P)} = 100$ GeV and $m = 240$ GeV.
- Fig.12. The dependence of the ratio $R_1 = \Gamma(Q \rightarrow qWH(P))/\Gamma(Q \rightarrow Wq)$ on the heavy quark mass m for different values of $H^0(P^0)$ -boson masses.
- Fig.13. R_1 as a function of m for the values $M_{H(P)} = 10$ and 30 GeV.
- Fig.14. R_1 as a function of m for the values $M_{H(P)} = 20, 50$ and 80 GeV.

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С.Г.ГРИГОРЯН, С.А.ЧАТРЧЯН
РОЖДЕНИЕ СКАЛЯРНЫХ И ПСЕВДОСКАЛЯРНЫХ ХИГГСОВСКИХ БОЗОНОВ В
РАСПАДАХ ТЯЖЕЛЫХ КВАРКОВ И ТЯЖЕЛЫХ КВАРКОНИЕВ

(на английском языке, перевод З.Н.Асланян)

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