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ԵՐԵՎԱՆԻ ՖԻԶԻԿԱԿԱՆ ԻՆՍՏԻՏՈՒՏ
ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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SOME PECULIARITIES OF CONJOINED HADROPRODUCTION OF STANDARD HIGGS BOSON AND HEAVY QUARK PAIR

ЦНИИатоминформ

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Ռ.Ե. ՅԳՈՐՅԱՆ, Ս.Գ. ՄԱՏԻՆՅԱՆ

ՍՏԱՆԴԱՐՏ ՀԻԳՍԻ ԲՈԶՈՆԻ ԵՎ ԾԱՆՐ ՔՎԱՐԿՆԵՐԻ ԶՈՒՅԳԻ ՄԻԱՍՆԱԿԱՆ ՀԱԴՐՈՆԱԾՆՄԱՆ ՈՐՈՇԱԿԻ ԱՌԱՆՁՆԱՀԱՏԿՈՒԹՅՈՒՆՆԵՐԸ

Քննարկվում է H_0- բոզոնի և ծանր քվարկների Q և $\bar{Q}$($Q=c,b,t,...$) զույգի միասնական հադրոնածնման լրիվ կտրվածքի մեջ H_0- բոզոնի ,,գլյուոնային,, ծնման դիագրամների /GGH-դիագրամների/ ներդրումը: Համեմատվում են GGH- դիագրամների և QH - դիագրամների /H_0-բոզոնի ,,անմիջական,, քվարկային ծնման դիագրամների/ գումարային ներդրումը σ_{tot} -ում: Ցույց է տրված, որ M_H-ի մեծացման դեպքում առկա է գերակշռում GGH ներդրման մի երևույթը:

Երևանի Ֆիզիկայի ինստիտուտ
ԵՐԵՎԱՆ 1986

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С.Г.МАТИНЯН

НЕКОТОРЫЕ ОСОБЕННОСТИ СОВМЕСТНОГО АДРОРОЖДЕНИЯ СТАНДАРТНОГО ХИГГСОВСКОГО БОЗОНА И ПАРЫ ТЯЖЕЛЫХ КВАРКОВ

Обсуждается вклад в полное сечение совместного адророждения H_0 - бозона и пары тяжелых кварков Q и $\bar{Q}$ ($Q = c, b, t, \ldots$) от диаграмм с "глюонным рождением H_0 - бозона (так называемых GGH - диаграмм). Сравниваются вклады в σ_{tot} от диаграмм GGH и диаграмм с "прямым" кварковым рождением H_0 (QH - диаграмм). Показано, что при увеличении M_H в "игру" вступает эффект усиления GGH вклада.

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SOME PECULIARITIES OF CONJOINED HADROPRODUCTION OF STANDARD HIGGS BOSON AND HEAVY QUARK PAIR

A contribution to total cross section of conjoined hadroproduction of the H_0-boson and the heavy quark pair Q and $\bar{Q}$ ($Q = c, b, t, \dots$) from the H_0-boson "gluonic" production diagrams (the so-called GGH-diagrams) is being discussed. A comparison is carried out between contributions to σ_{tot} from the GGH-diagrams and the "direct" H_0 quark production diagrams (QH-diagrams). It is shown that with increasing M_H the enhancement effect of the GGH contribution "enters the game".

Yerevan Physics Institute

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The experimental detection of the neutral scalar Higgs boson H_0 of the standard Glashow - Weinberg - Salam (GWS) electroweak interaction model is a highly important and complicated problem in the modern elementary particle physics.

Various mechanisms of H_0-boson production as well as ways of its identification have been discussed in the literature.

The mechanism of the H_0-boson hadroproduction associated with a heavy-quark pair was considered in Refs. [1 ?]. Authors of these works assume that the contribution to total cross section (as well as to differential spectra) in the perturbation theory lowest order is made by diagrams shown in Fig. 1.

In all these diagrams the H_0-boson is emitted by the heavy quark (antiquark) $Q = c, \bar{b}, t, \ldots$, owing to which a comparatively large vertex $g_{HQ} = m_Q / v$ (m_Q is the heavy quark mass, $v \approx 246$ GeV) available in the cross section brings to the present-day observed value of total cross section in a rather wide range of masses M_H. However in these works there are not considered diagrams shown in Fig. 2, where the Higgs boson is produced owing to the two-gluon fusion (call them gluon-gluon-Higgs (GGH) diagrams).

As is known, the Higgs boson of the GWS standard model "couples" to the

gluons indirectly, doing this rather through the fermion loop [3] (see Fig.3), The result is that the amplitude for the process $H_0 \to 2G$ contains the factor α_s/π . Presumably namely for this reason, in Refs. [1,2] the contribution to total cross section from diagrams depicted in Fig. 2 is considered suppressed over α_s for all $Q = c, b, t, \ldots$ as compared to contribution from diagrams of Fig. 1.

However this is not always the case since the amplitude for the process $H_0 \to 2G$ is organized highly intricately. Roughly speaking, it is proportional to the gluon pair invariant mass, or, more roughly, to the H_0 - boson squared mass. This will result in the fact that the smallness in g_{HGG} over α_s/π will be compensated by a large value of M_H in the diagrams of Fig. 2. And as far as the vertices for the emitted H_0-boson in all diagrams of Fig. 1 are "insensitive" to mass M_H being sensitive to mass m_Q only, then at sufficiently large M_H and small m_Q (for example, at $Q = c$) contributions of the diagrams of Fig.1 and Fig.2 to total cross section perhaps will be comparable.

This assumption actually was confirmed by our calculations carried out with the use of the explicit form of the amplitude $H_0 \to 2G$ (for example, see Ref. [4]):

$$M^{\alpha\beta;ab}_{H_0 \to 2G}(q_1, q_2) = \delta^{ab} \frac{1}{3} N_H U \frac{\alpha_s}{\pi} \left\{ g^{\alpha\beta}(q_1 q_2) - q_1^\alpha q_2^\beta - q_1^\beta q_2^\alpha \right\} \qquad (1)$$

where α and β are the vector-, while a and b are the color indices of gluons with momenta q_1 and q_2 (see Fig. 3); N_H is the number of various sorts of heavy quarks with $m_Q > 0{,}2\, M_H$.

Before turning to the analysis of results obtained, note that if the number of quarks is limited by the t-quark whose mass according to the UI group data [5] lies in the range $30\ \text{GeV} \lesssim m_t \lesssim 50\ \text{GeV}$, then the condition

$m_Q > 0{,}2\, M_H$ - application of the effective point vertex (1) gives the following values for N_H :

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

$$N_H = 1 \quad \text{at} \quad 22.5\ \text{GeV} < M_H < \begin{cases} 150\ \text{GeV}, & m_t = 30\ \text{GeV} \\ 200\ \text{GeV}, & m_t = 40\ \text{GeV} \quad (m_g = 4.5\ \text{GeV}) \\ 250\ \text{GeV}, & m_t = 50\ \text{GeV} \end{cases} \qquad (2)$$

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

If we suppose that there exist also some other heavy quarks (heavier than the t-quark), then the N_H must be enlarged by the number of quarks and in this case the condition $N_H = 0$ will take place already at $M_H > 5 \times$ x mass of the heaviest quark.

But here we'll analyze our obtained results in the framework of the six-quark scheme.

Calculations show that, e.g. in the H_0 hadroproduction with the $c, \bar{c}$ pair at energies $\sqrt{s} = 540$ GeV the total contribution of diagrams of Fig.2 to σ_{tot} and the total contribution of diagrams of Fig.1 to σ_{tot} are comparable at $M_H \approx 35 - 36$ GeV, while at $M_H > 37$ GeV the contribution $\sum \sigma^{(2)}$ prevails over $\sum \sigma^{(1)}$ (see Fig. 4).

As is seen from Fig.4, the neglect of the GGH-type diagrams will reduce several times the total cross section of H_0 production with the $c, \bar{c}$ pair in a rather wide mass region:

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

and

$$20\ \text{GeV} < M_H < \begin{cases} 150\ \text{GeV}, & m_t = 30\ \text{GeV} \\ 200\ \text{GeV}, & m_t = 40\ \text{GeV} \\ 250\ \text{GeV}, & m_t = 50\ \text{GeV} \end{cases} \quad \text{at} \quad \sqrt{s} = 2\ \text{TeV}$$

In Fig. 5 and Fig. 6 we have plotted $\Sigma\sigma^{(2)}/\Sigma\sigma^{(1)}$ for various $\sqrt{s}$ as a function of M_H at H_o hadroproduction with the $\beta, \bar{\beta}$ and $t, \bar{t}$ quark pair.

One can see from Fig. 5 that in the consideration of conjoined hadroproduction of H_o and $\beta, \bar{\beta}$ pair, the account of GGH diagrams is necessary at high energies $\sqrt{s} \gtrsim 1$ TeV. For example, at $\sqrt{s} = 2$ TeV in the mass range $150\ \text{GeV} < M_H < 250\ \text{GeV}$.

Fig. 6 shows that in conjoined H_o $t, \bar{t}$ hadroproduction the contribution of GGH diagrams can be neglected even if admitting $m_t = 30$ GeV (here $(\Sigma\sigma^{(2)}/\Sigma\sigma^{(1)})\big|_{M_H = 150\,\text{GeV}} \approx 2.5 \cdot 10^{-2}$ and $\sqrt{s} = 2$ TeV).

The account of the interference diagrams QH - GGH does not distort strongly the enhancement effect at large M_H $(M_H \gg m_Q)$.

Thus here, just like in the case of the H_o-boson hadroproduction associated with the heavy $^1S_0$ quarkonium, the "enhancement effect of gluon-gluon-Higgs contribution" at increasing M_H[6] takes place. And this effect becomes essential when considering $h_1 h_2 \to H_o + c + \bar{c} + \ldots$ and $h_1 h_2 \to H_o + \beta + \bar{\beta} + \ldots$ processes already for energy ranges of the current and planned $p\bar{p}$ and pp beam accelerators.

This circumstance necessitates the experimentalists to take account of the "GGH contribution enhancement effect" when searching for the H_o-boson produced in hadron collisions associated with a pair of free or bound heavy quarks Q and $\bar{Q}$.

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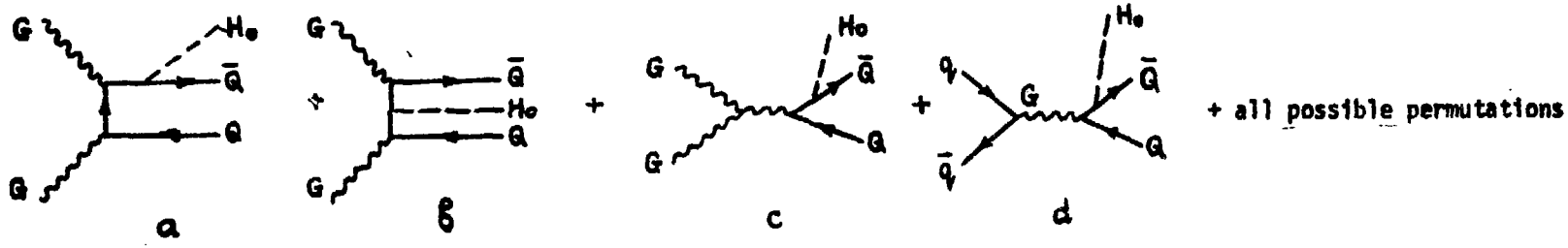
G
G
H₀
Q̄
Q
a
G
G
Q̄
H₀
Q
β
+
G
G
H₀
Q̄
Q
c
+
q
q̄
G
H₀
Q̄
Q
d
+ all possible permutations

Fig.1

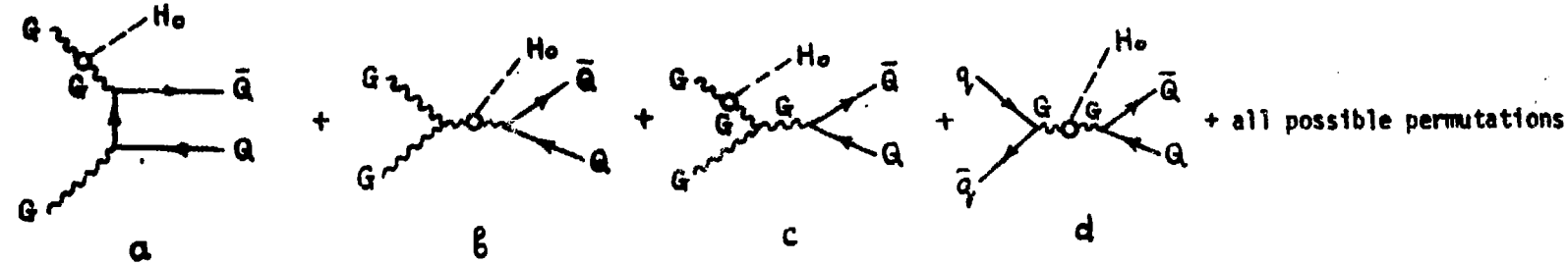
G
G
H₀
G
Q̄
Q
a
+
G
G
H₀
Q̄
Q
β
+
G
G
G
H₀
Q̄
Q
c
+
q
q̄
G
G
H₀
Q̄
Q
d
+ all possible permutations

Fig.2

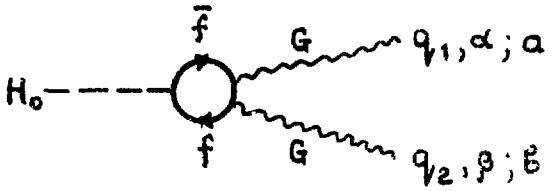
$\bar{f}$
G
$q_1, \alpha; a$
H_0
f
G
$q_2, \beta; b$

Fig.3

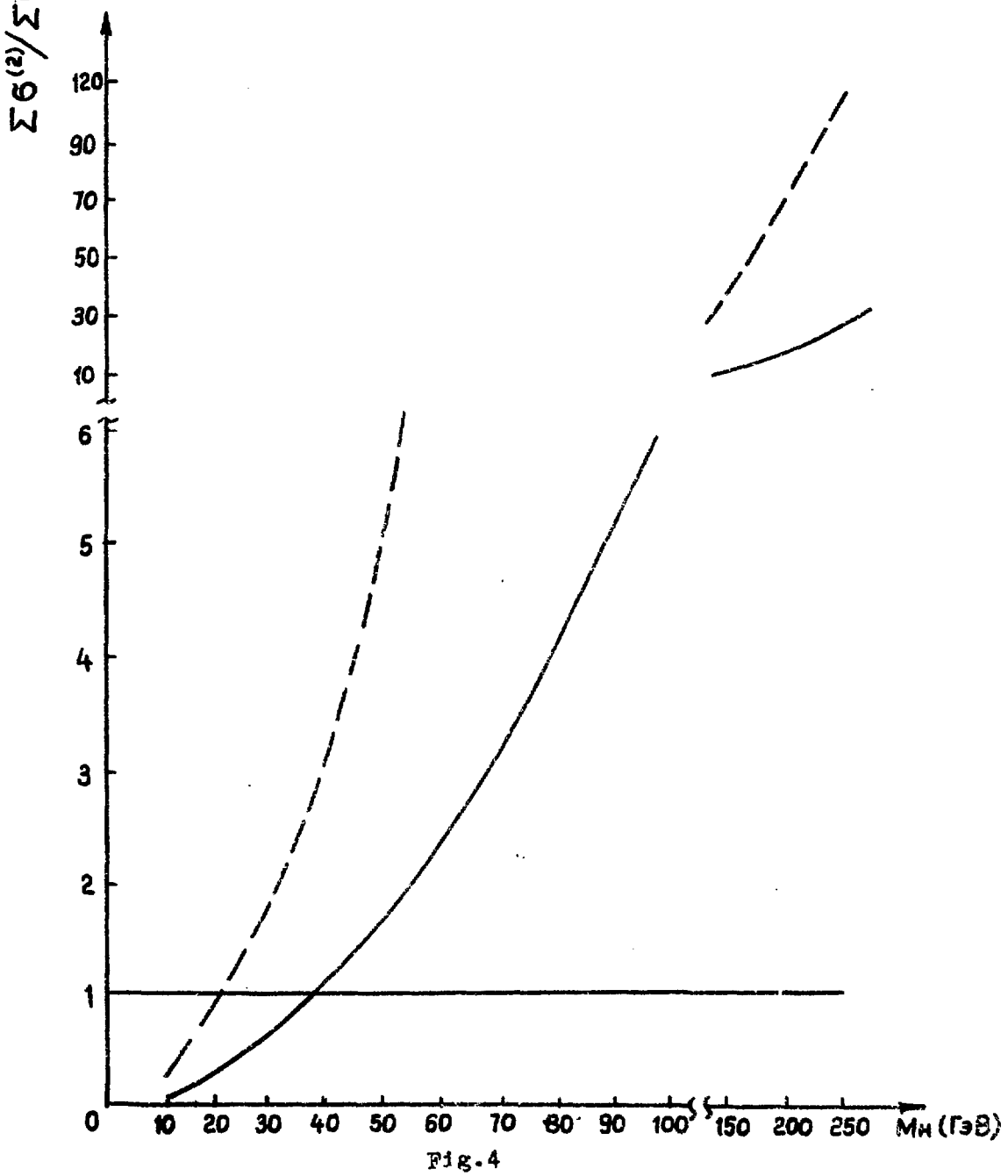
$\Sigma\sigma^{(2)}/\Sigma\sigma^{(1)}$
120
90
70
50
30
10
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
150
200
250
M_H (ГэВ)

Fig.4

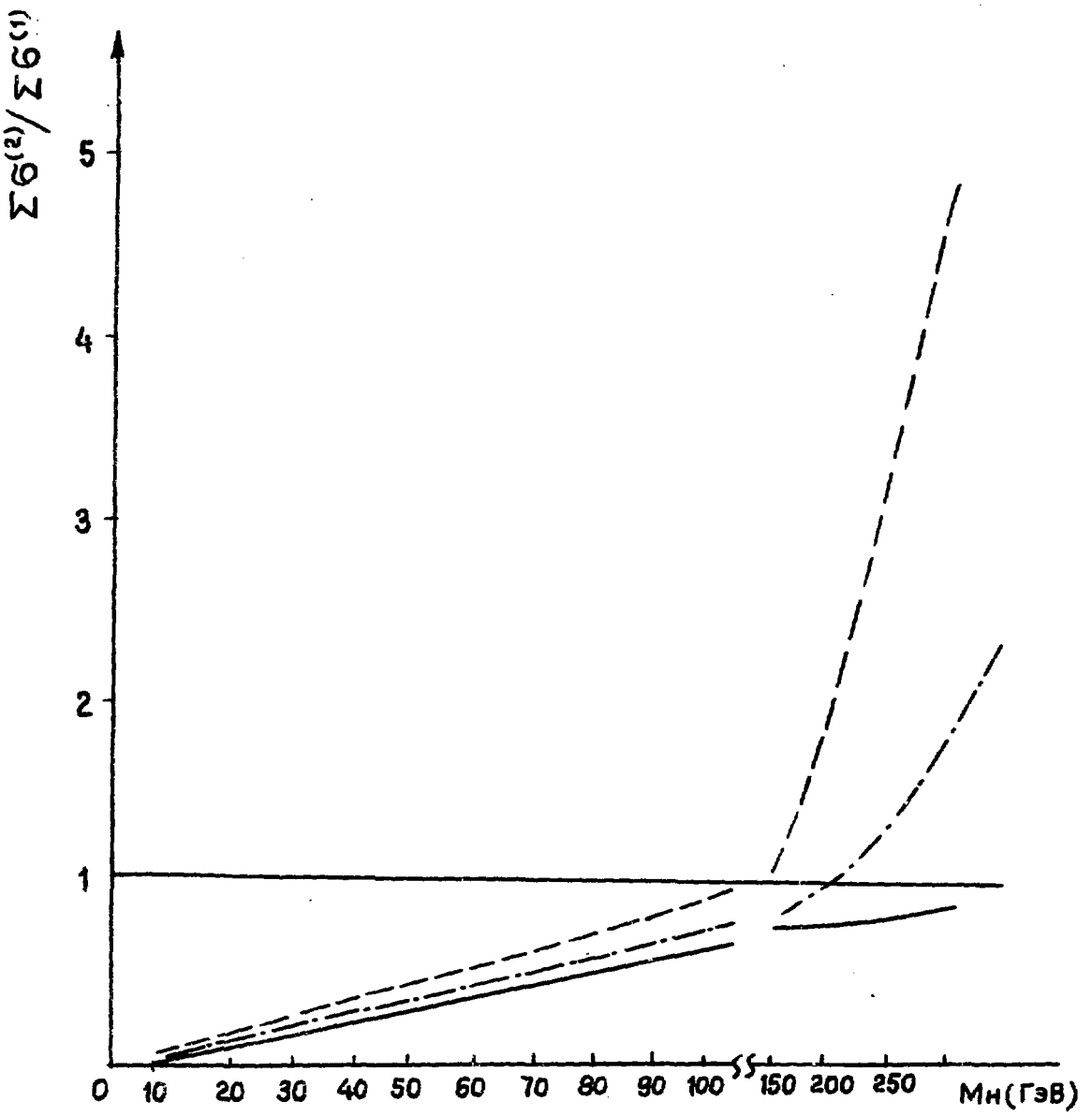
$\Sigma\sigma^{(2)}/\Sigma\sigma^{(1)}$
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
150
200
250
M_H(ГэВ)

Fig.5

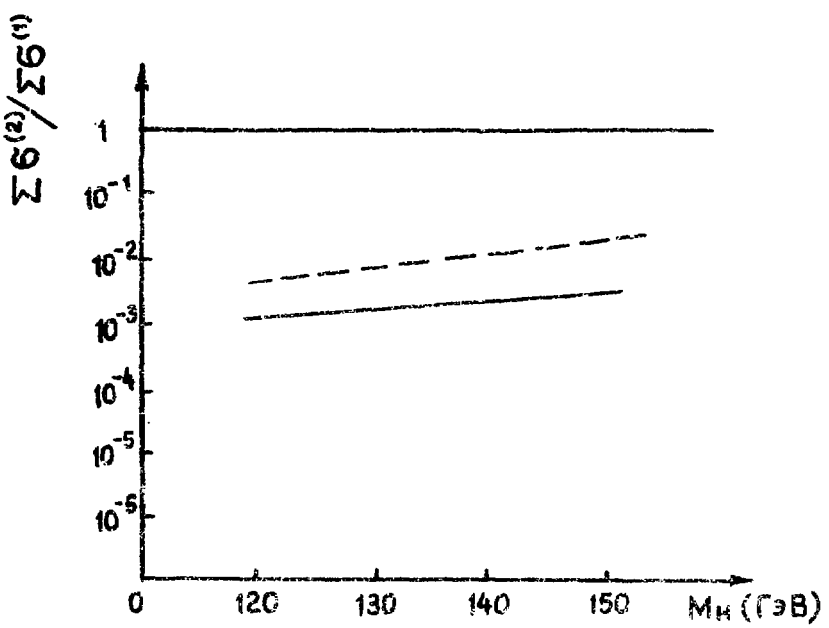
$\Sigma\sigma^{(2)}/\Sigma\sigma^{(1)}$
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-5}
0
120
130
140
150
M_H (ГэВ)

Fig.6

Figure Captions

Fig. 1. The so-called "QH-diagrams" that describe the "direct" quark H_o-boson hadroproduction associated with heavy quark pair Q and $\bar{Q}$ ($Q = c, b, t, \ldots$).

Fig. 2. The so-called "GGH-diagrams" that describe the "gluon" production of H_o-boson associated with heavy quark pair Q and $\bar{Q}$ ($Q = c, b, t, \ldots$).

Fig. 3. Diagram corresponding to the two-gluon decay of H_o .

Fig. 4. Ratio of contributions to total cross section of $\Sigma\sigma^{(2)}$ and $\Sigma\sigma^{(1)}$ diagrams as a function of M_H at H_o hadroproduction with $c, \bar{c}$ pair ($m_c = 1.5$ GeV). Solid line refers to $\sqrt{s} = 540$ GeV, dashed line to $\sqrt{s} = 2$ TeV.

Fig. 5. Ratio of contributions to total cross section of $\Sigma\sigma^{(2)}$ and $\Sigma\sigma^{(1)}$ diagrams as a function of M_H at H_o hadroproduction with $b, \bar{b}$ pair ($m_b = 4.5$ GeV). Solid line refers to $\sqrt{s} = 540$ GeV, dashed - to $\sqrt{s} = 2$ TeV, dash-dotted - to $\sqrt{s} = 1$ TeV.

Fig. 6. Ratio of contributions to total cross section of $\Sigma\sigma^{(2)}$ and $\Sigma\sigma^{(1)}$ diagrams as a function of M_H at H_o hadroproduction with $t, \bar{t}$ pair ($m_t = 30$ GeV). Solid line refers to $\sqrt{s} = 540$ GeV, dashed to $\sqrt{s} = 2$ TeV.

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