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ASSOCIATED HADROPRODUCTION OF A STANDARD H_0-BOSON AND γ-QUANTUM

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ՍՏԱՆԴԱՐՏ H_0-ԲՈԶՈՆԻ ԵՎ γ-ՔՎԱՆՏԻ ՀԱՄԱՏԵՂ ՀԱԴՐՈԾՆՈՒՄԸ

Քննարկվում է $h_1h_2\to H_0+\gamma+X$ գործընթացը։ Հաշվված է H_0 բոզոնի $d\sigma/dq_\perp^2$ բաշխումը։

Երևանի ֆիզիկայի ինստիտուտ

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1. Introduction

The discovery of the H_0-boson of the GAS model [1-3] will become an important event in the contemporary elementary-particle physics. Therefore, all the existing and planning accelerators have a "higgs" search subprogram.

However, due to nonfixed mass of the H_0-boson in the model and multi particle nature of the final state of the H_0-boson decay the detection and identification of the H_0 is rather difficult. This is the cause of the appearance of numerous papers in the literature wherein various processes of H_0-boson production are studied.

From the viewpoint of the convenience of H_0-boson detection, of certain interest is the class of processes in which the H_0 is produced together with the γ-quantum.

The associated production of the H_0-boson and γ-quantum in heavy quarkonia decays was considered by Wilczek [4]. (In Refs.[5] and [6] the higher theoreticopertubative and relativistic corrections to the cross section of the process $Q\bar{Q}\to H_0+\gamma$ are analyzed).

The Wilczek mechanism of H_0 production ($Q\bar{Q}\to H_0\gamma$) is of interest for light H_0 ($m_H\leq 10$GeV) being inapplicable for the six-quark scheme when the H_0-boson mass is larger than the double t-quark mass ($M_H>2m_t$).

Such restrictions over M_H mass are absent in the similar

Wilczek mechanism of H_0 production in processes of hadron-hadron collisions.

The associated W-fusion production of H_0 and γ in the hadronic reactions ($h_1h_2 \to W^+W^- + X \to H_0\gamma + X$) is considered in Ref.[7].

In the present paper we consider the quark mechanism of associated production of H_0 and γ in the processes of hadron-hadron collision $h_1h_2 \to q\bar{q} + X \to H_0\gamma + X$ which is of independent interest and differs greatly from the W-fusion mechanism in topology of hadronic accompaniment.

2. Quark Mechanism of Associated Production of H_0 and γ in hh-Collisions

The Higgs sector of the lagrangian of the GWS model is known to be of following form

$$\mathcal{L}_H^{GWS} = \left(\frac{1}{2}\partial_\mu H_0\right)^2 - \frac{M_H^2}{2} H_0^2 - \frac{M_H^2}{2V} H_0^3 - \frac{M_H^2}{8V^2} H_0^4 + \frac{M_W^2}{V^2} W_\mu^+ W_\mu^- H_0^2 + \frac{M_Z^2}{2V^2} Z_\mu^2 H_0^2 + \frac{2M_W^2}{V} W_\mu^+ W_\mu^- H_0 + \frac{M_Z^2}{V} Z_\mu^2 H_0 - \frac{m_f}{V} \bar{f} f H_0 , \qquad (1)$$

where $V \equiv (G_F\sqrt{2})^{1/2} \simeq 246\,\text{GeV}$, and under f the fermions are implied. From (1) as well as from the fact of the smallness of the current quark masses it follows that the diagram with the $\gamma\gamma H_0$ vertex (see Fig.1) is dominant for the process

$h_1h_2 \to W^+W^- + X \to H_0\gamma + X$. Here under the $\gamma\gamma H_0$ vertex we imply a sum of loop diagrams of the $H_0 \to \gamma\gamma$ decay as shown in Fig.2. In the framework of the GWS and provided that there is no quark heavier than the t-quark, the main contribution to the $H_0 \to 2\gamma$ amplitude is made by two diagrams: t-quark-loop and W-boson-loop [8].

Proceeding from the above-stated arguments and from the requirements of Lorentz-invariance, C-invariance and gauge invariance for $H_0 \to \gamma\gamma$ [9] amplitude one can easily obtain the following expression for the vertex (see Fig.3):

$$M^{\mu\beta}_{\gamma\gamma H_0}(q_1,q_2) = \frac{i\alpha M_H^2 V(C_t + C_W)}{\pi M_W (q_1q_2)} \left(g^{\mu\nu}(q_1q_2) - q_1^{\mu} q_2^{\nu}\right), \qquad (2)$$

$$C_t = -\frac{Q_t m_t}{M_H^2}\left[2 - \left(\frac{4m_t^2}{M_H^2} - 1\right) I\left(\frac{m_t^2}{M_H^2}\right)\right],$$

$$C_W = \frac{3M_W^2}{M_H^2} + \frac{2M_W^2}{M_H^2}\left(2 - \frac{3M_W^2}{M_H^2}\right) I\left(\frac{M_W^2}{M_H^2}\right),$$

$$I(\lambda) = \begin{cases} 2(\arcsin(1/2\sqrt{\lambda}))^{1/2}, & \lambda > 1/4 \\ \frac{\pi^2}{2} - 2\ln^2\left[\frac{1+(1-4\lambda)^{1/2}}{2\sqrt{\lambda}}\right] + 2i\pi \ln\left[\frac{1+(1-4\lambda)^{1/2}}{2\sqrt{\lambda}}\right], & \lambda < 1/4 \end{cases}$$

where μ and β are vector indices of photons with momenta q_1 and q_2, α is an electromagnetic interaction constant, M_H, M_W, m_t are masses of the H_0-boson, W-boson and t-quark, respectively.

Thus, it follows from above that the diagram shown in Fig.4 is dominant for the cross section $d\sigma/dq_\perp^2$ of the process $q\bar{q} \to H_0 + \gamma$, and the differential cross section $d\sigma/dq_\perp^2 dy$ of

H_0-boson production corresponding to the process $h_1h_2\to q\bar{q}+X\to H_0\gamma+X$ is of the form

$$\frac{d\sigma(h_1h_2\to \bar{q}qX\to H_0\gamma X)}{dq_\perp^2\, d.\ln(x_1/x_2)} = \frac{\alpha}{4sN}\sum Q_q^2\iint \frac{dx_1}{x_1}\frac{dx_2}{x_2}\left[D^q_{h_1}(x_1)\,D^{\bar{q}}_{h_2}(x_2) + D^{\bar{q}}_{h_1}(x_1)\,D^q_{h_2}(x_2)\right]\delta(l^2)\,\frac{1}{\Delta^4}\left\{-\frac{1}{4}\,\mathrm{Tr}(\hat{K}_1\gamma_\mu\hat{K}_2\gamma_\nu)\right\} \quad (3)$$

$$M^{\mu\lambda}_{\gamma\gamma H_0}(\Delta,-1)\; M^{\nu\lambda}_{\gamma\gamma H_0}(\Delta,-1),$$

where x_1 and x_2 are respectively the shares of momenta of hadrons h_1 and h_2 carried away by q and $\bar{q}$, $D^q(x)$ and $D^{\bar{q}}(x)$ are the structure functions of q and $\bar{q}$, $\sqrt{s}$ is collision energy, N is the number of colors, and Q_q is the charge of q quark in the units of e.($Q_u=2/3$, $Q_d=Q_s=-1/3$).

Substituting the explicit form of vertex $\gamma\gamma H_0$ from (2) to $M^{\mu\lambda}_{\gamma\gamma H_0}$ and $M^{\nu\lambda}_{\gamma\gamma H_0}$ and simplifying, we'll obtain the following form of spectrum $d\sigma/dq_\perp^2$ for the H_0-boson:

$$\left.\frac{d\sigma(H_0\gamma)}{dq_\perp^2\, dy}\right|_{y=0} = \frac{\alpha A^2}{4SN}\sum_{q=u,d,s} Q_q^2\int_{\xi}^{z_{max}} dz\left\{-\frac{z(1-z)}{(q_\perp^2+M_H^2(1-z))^2} + \frac{2q_\perp^2\, z^2\,(1-z)^2}{(q_\perp^2+M_H^2(1-z)^2)^2\,(q_\perp^2+M_H^2(1-z))}\right\} \quad (4)$$

$$\left[D^q_{h_1}\left(\xi+\frac{q_\perp^2\, z}{S\xi(1-z)}\right) D^{\bar{q}}_{h_2}\left(\frac{\xi}{z}\right) + D^{\bar{q}}_{h_1}\left(\xi+\frac{q_\perp^2\, z}{S\xi(1-z)}\right) D^q_{h_2}\left(\frac{\xi}{z}\right)\right]$$

where

$$A=i\alpha M_H^2 V(C_t+C_W)/\pi M_W\,,\quad \xi=\left(\frac{M_H^2+q_\perp^2}{S}\right)^{1/2},$$

$$z_{max}=(1-\xi)\xi S/(q_\perp^2+(1-\xi)\xi S),\quad y=\ln(x_1/x_2).$$

3. Numerical Estimates for the Cross Section $d\sigma/dq_\perp^2$ of Associated Production of H_0-Boson and γ in $p\bar{p}$ and pp Collisions

In order to estimate numerically the H_0-boson spectrum $d\sigma/dq_\perp^2$ in $p\bar{p}$ and pp collisions, it is necessary: to substitute the corresponding numerical values of coefficients of the right-hand side (4), to use some parameterization of structure functions $D^{\bar{q}}(x)$ and $D^q(x)$, to substitute different values for $q_\perp$, collision energy $\sqrt{S}$ and mass M_H.

For $D^q(x)$ and $D^{\bar{q}}(x)$ we use the following parameterization (see, e.g.[10]):

$$D^{\bar{u}}_{\bar{p}}(t)=D^u_p(t)=U_p(t)+S(t)=1.742t^{-1/2}(1-t)^3(1+2.3t)+0.26t^{-1}(1-t)^9$$

$$D^{\bar{d}}_{\bar{p}}(t)=D^d_p(t)=d_p(t)+S(t)=1.107t^{-1/2}(1-t)^3+0.26t^{-1}(1-t)^9, \quad (5)$$

$$D^u_{\bar{p}}(t)=D^{\bar{u}}_p(t)=D^d_{\bar{p}}(t)=D^{\bar{d}}_p(t)=S(t)=0.26t^{-1}(1-t)^9,$$

where $U_p(t)$, $d_p(t)$ are respectively distributions of the valence u- and d-quarks in the proton, $S(t)$ is a distribution for each of the sea u-,d-,s- and $\bar{u}$-,$\bar{d}$-,$\bar{s}$-quarks.

We choose for $\sqrt{S}$ those values which correspond to energies of the existing and planned $\bar{p}p$ and pp colliders (CERN $\bar{p}p$ has $\sqrt{S}$=630GeV, FNAL $\bar{p}p$ has $\sqrt{S}$=1800GeV,LHC pp has $\sqrt{S}$=17TeV, SSC pp has $\sqrt{S}$=40TeV [11]).

Figs.5 and 6 show the behaviors of $d\sigma/dq_{\perp}^{2}$ of H_0-bosons produced respectively in $\bar{p}p$ and pp collisions depending on $q_{\perp}$, collision energy $\sqrt{S}$, mass M_H. It should be also noted that the account of higher orders of perturbation theory results in the appearance of squared multiplier of double-logarithmic form factor of a quark $d\sigma/dq_{\perp}^{2} \sim T_F^2$ in the cross section of H_0-boson production.

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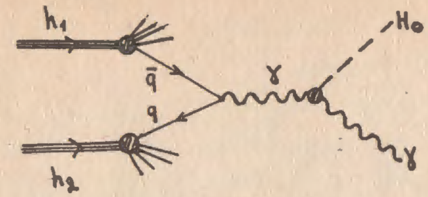

Fig.1

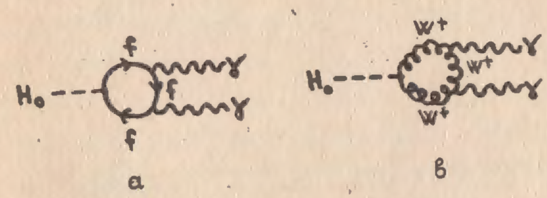

Fig.2

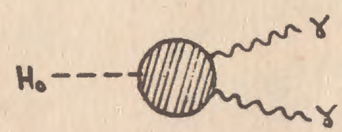

Fig.3

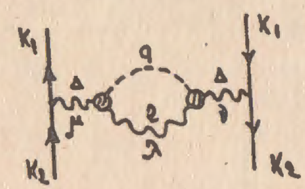

Fig.4

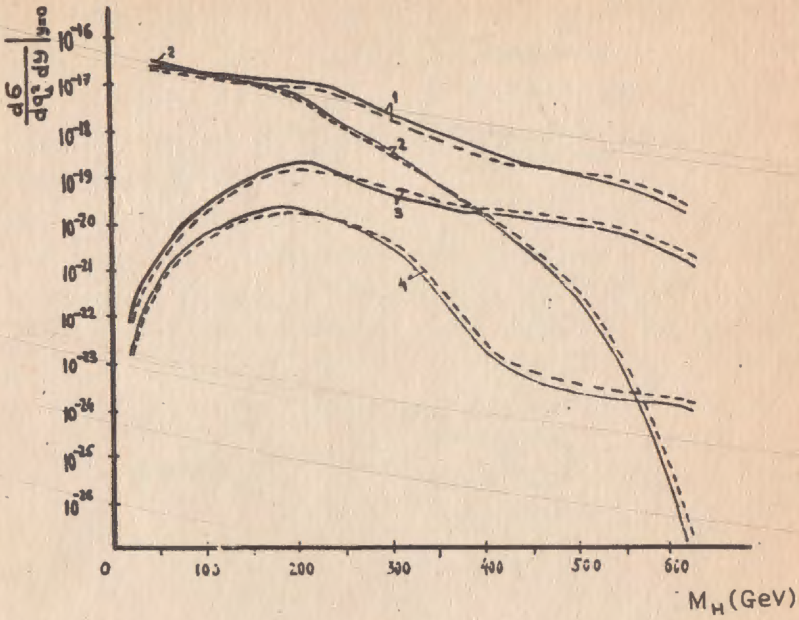

Fig.5

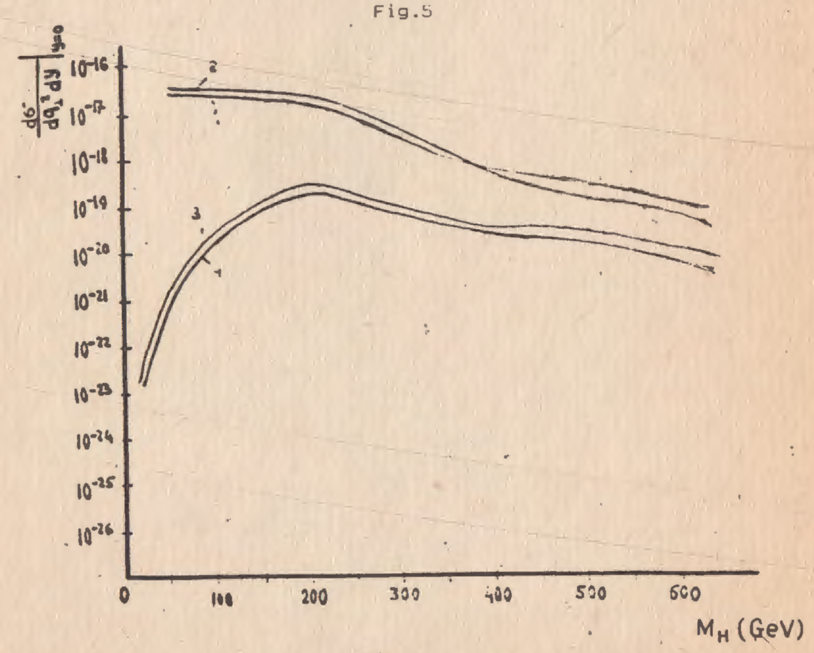

Fig.6

Figure Captions

Fig.1 Dominant diagram for the process $h_1h_2 \to q\bar{q}+X \to H_0\gamma+X$.

Fig.2 Two classes of loop diagrams that make the main contribution to the amplitude of $H_0 \to 2\gamma$ decay:a)fermion-loop, b)gauge-loop.

Fig.3 Diagram corresponding to vertex $\gamma\gamma H_0$.

Fig.4 Dominant diagram for the cross section $d\sigma/dq_\perp^2$ of the process $q\bar{q} \to H_0+\gamma$.

Fig.5 The shape of spectrum $d\sigma/dq_\perp^2$ of H_0-boson produced in $p\bar{p}$ collisions depending on M_H (solid curves 1-4 refer to the values m_t=100,100,100,100GeV, $\sqrt{S}$=1800, 630, 1800, 630GeV, and $q_\perp$=5,5,100,100GeV; dashed curves 1-4 refer to the values m_t=50, 50, 50, 50GeV, $\sqrt{S}$=1800, 630, 1800, 630GeV, and $q_\perp$=5, 5, 100, 100GeV).

Fig.6 The shape of spectrum $d\sigma/dq_\perp^2$ of H_0-boson produced in pp collisions depending on M_H (curves 1-4 refer to the values m_t=100, 100, 100, 100GeV, $\sqrt{S}$=40, 17, 40, 17TeV, and $q_\perp$=5, 5, 100, 100GeV).

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