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RELATIVISTIC EFFECTS IN $V \to H^{\circ}\gamma$ DECAY

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ՌԵԼՅԱՏԻՎԻՍՏԱԿԱՆ ԷՖԵԿՏՆԵՐԸ $V \to H^{\circ}\gamma$ ՏՐՈՀՄԱՆ ՄԵՋ

Հետազոտված են ռելյատիվիստական էֆեկտների ազդեցությունները $V \to H^{\circ}\gamma$ ճառագայթային տրոհման լայնքի վրա: Ցույց է տրված, որ այդ էֆեկտները զգալիորեն նվազեցնում են ոչ ռելյատիվիստիկ քվարկային մոդելից բխող լայնքի արժեքները:

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И.Г.АЗНАУРЯН, С.Г.ГРИГОРЯН, С.Г.МАТИНЯН

РЕЛЯТИВИСТСКИЕ ЭФФЕКТЫ В РАСПАДЕ $V \to H^{\circ}\gamma$

Исследовано влияние релятивистских эффектов на ширину радиационного распада $V \to H^{\circ}\gamma$. Показано, что эти эффекты существенно уменьшают значение этой ширины, задаваемой нерелятивистской кварковой моделью.

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RELATIVISTIC EFFECTS IN $V \to H^\circ \gamma$ DECAY

The influence of the relativistic effects on the width of $V \to H^\circ \gamma$ radiative decay is investigated. These effects are shown to decrease essentially the value of this width given by nonrelativistic quark model.

Yerevan Physics Institute

Yerevan 1986

In recent years an intense search for the light Higgs bosons (H^0-bosons) in the radiative decay of vector bottonium $\Upsilon(9.46)$ has been carried out [1,2]. Experimental investigations are being performed with orientation to this decay width value resulting from nonrelativistic quark model [3]:

$$R = \frac{\Gamma(V \to H^0 + \gamma)}{\Gamma(V \to \mu^+ \mu^-)} = \frac{G_F \, M_V^2}{4\sqrt{2}\,\pi\alpha}\left(1 - \frac{M_H^2}{M_V^2}\right), \qquad (1)$$

where M_V and M_H are masses of vector quarkonium and H^0-boson, respectively.

However, as stressed in Ref. 4, account of radiative corrections [5] as well as of mixing effects of H^0 and P-even states of bottonium [6,7] results in a noticeable decrease of ratio R. In this connection, it is extremely important to investigate the influence of relativistic effects on this ratio which also may turn out essential, since from the consideration of bottonium mass spectrum it follows that the mean value of v^2/c^2 in $\Upsilon(9.46)$ is not small: $\langle v^2/c^2 \rangle \simeq 0.1$.

In the present work we shall give results of calculations connected with account of relativistic effects in $V \to H^0 \gamma$ decay. While estimating the relativistic effects, we considered the Higgs bosons with masses satisfying the relation $M_V - M_H \gg \alpha_s^2 M_V$. This allows to ignore diagrams with QCD-corrections, for as shown in Ref. 5 , at these values of M_V the contribution of these diagrams to R is relatively small, being $\simeq 35$ %. The particle Υ(9.46) we considered as a pure $1^3 S_1$ state, since in all models describing bottonium mass spectrum with respect to QCD-interaction between quarks, the admixture of other states in Υ(9.46) is negligibly small (see, e.g. [8]).

The calculations were carried out in infinite momentum frame (i.m.f.) obtained by boost along the z axis, where $K_0 = -K_z = \frac{M_V^2 - M_H^2 - K_\perp^2}{4P}$, K - is photon momentum, P - is bottonium momentum, $P \to \infty$. From time-ordered diagrams of noncovariant perturbation theory describing $V \to H^0 \gamma$ process(Fig.1), only the diagram of Fig.1a survives in this system. The form of transition $V \to q\bar{q}$ vertex in i.m.f. can be obtained using the results of Ref. 9 , where the general method is found for constructing such transition vertices corresponding to definite values of spins, orbital and total angular momenta of quarks in the meson rest frame. For illustration, we shall present only the first two terms of expansion of our results in powers of p^2/m^2 (p is the value of quark momentum in the bottonium rest frame, m is the quark mass):

$$R = \frac{G_F m^2}{\sqrt{2}\,\pi\alpha}\left(1 - \frac{M_H^2}{M_V^2}\right)\left(\frac{M_V^2 - M_H^2}{4m^2 - M_H^2}\right)^2 \cdot I , \tag{2}$$

$$I = 1 + \frac{\Delta}{3} - \frac{10}{3} \cdot \frac{\Delta}{1 - M_H^2/(4m^2)} , \tag{3}$$

$$\Delta = \int \frac{p^2}{m^2} \varphi(p^2) p^2 dp \Big/ \int \varphi(p^2) p^2 dp , \tag{4}$$

where $\varphi(p^2)$ is radial part of quark wave function in bottonium.

One can see from formulae (2)-(4) that the account of relativistic corrections of p^2/m^2 order leads to a decrease in the value of R . This effect is strengthened by the fact that the numerical value of quantity Δ is larger than the mean value of p^2/m^2 in Υ which is large enough in bottonium system. The factor $[(M_V^2 - M_H^2)/(4m^2 - M_H^2)]^2$ also leads to a decrease in ratio R since $M_V < 2m$ in all the models describing bottonium mass spectrum. Note that the term containing $\Delta/(1 - M_H^2/(4m^2))$ in formula (3) (the one which is just responsible for the decrease in R) increases with growing M_H (recall that our consideration holds for $M_V - M_H \gg \alpha_s^2 \cdot M_V$, i.e. for bottonium with $M_\Upsilon \simeq 9.4$ GeV, in fact for $M_H \lesssim 7.5 \div 8$ GeV) and gives rise to still stronger decrease in ratio R due to relativistic effects.

The results of numerical calculations of ratio R without their expansion in powers of p^2/m^2 are given in Fig.2. The curves correspond to the values of b -quark mass and wave function $\varphi(p^2)$ obtained in Ref. 10 . Note that the results do not change noticeably when taking the mentioned quantities from other works.

So one can see that the account of relativistic effects in the radiative mechanism of H^0-boson production in vector quarkonium decays leads to a strong decrease in the width of this decay. For bottonium we obtain that ratio R decreases nearly twice for $M_H \lesssim 4$ GeV and three-four times for $M_H \simeq 6 \div 8$ GeV (see Fig.2).

Note that the relativistic effects can be significant also in toponium radiative decays, where the same value as in bottonium is expected for the mean value of v^2/c^2 [10] .

Thus, the relativistic effects give rise to a strong suppression of the value of R . In the same direction, as mentioned, work the radiative corrections for the $V \to H^0 + \gamma$ process [5] . The results here obtained strengthen substantially the claim [4] that the experimental conclusion about the absence of the light Higgs bosons with $M_H \lesssim 10$ GeV in radiative decays of Υ seems to be premature.

We'd like to call to experimentalists to clear up this problem by essential improvement of the sensitivity of the experiments on monochromatic photons search in bottonium decays.

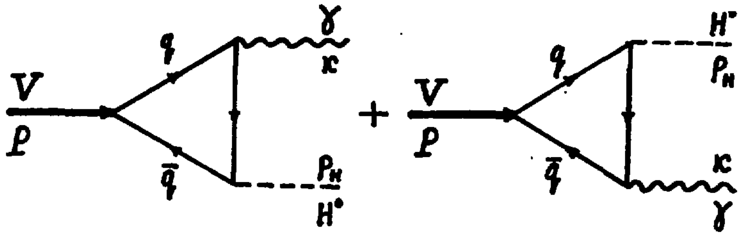

Fig.1. Diagrams of noncovariant perturbation theory for $V \to H^{\circ} + \gamma$ decay.

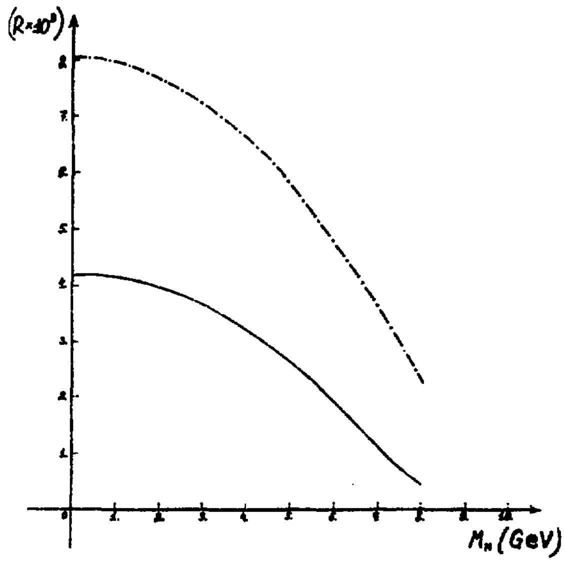

Fig.2. R as a function of the Higgs boson mass M_H. Dash-dotted line refers to nonrelativistic approximation (formula (1)). Solid one is obtained with account of the relativistic effects.

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РЕЛЯТИВИСТСКИЕ ЭФФЕКТЫ В РАСПАДЕ $V \to H^{\circ} + \gamma$

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

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