PHYSICAL REVIEW D VOLUME 40, NUMBER 5 1 SEPTEMBER 1989

Two-photon decay width of the Higgs boson in left-right-symmetric theories

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(Received 15 June 1989)

We calculate the W_R contribution to the two-photon decay width of the light neutral Higgs boson H_1^0 in left-right-symmetric models. We find that this contribution is suppressed relative to the standard-model (SM) W_L contribution by a factor $(M_L/M_R)^4$. This result arises because the W_R coupling to H_1^0 is not proportional to its own mass M_R, as a SM-like coupling would suggest, but rather to the lighter mass M_L. As a consequence, $\Gamma(H_1^0 \to \gamma\gamma)$ in left-right-symmetric theories has essentially the same value as in the standard model.

It has been pointed out[1] that an intermediate-mass Higgs boson $(0.5M_Z < m_H < 2M_Z)$ could be detected through the rare decay modes $H^0 \to \gamma\gamma$, $\gamma l^+ l^-$, $\tau^+\tau^-$, etc. In particular, the two-photon mode will be a spectacular one to detect. It was also[1] found that if $m_H < 2m_t$, this mode seems to be viable at the Superconducting Super Collider for $m_t > 80$ GeV.

The purpose of the present Rapid Communication is to report a calculation of the decay width for $H_1^0 \to \gamma\gamma$ within the framework of left-right-symmetric (L-R) models.[2] In these models with a minimal Higgs potential, when the mass of the W_R boson is much greater than the standard W_L boson, one of the neutral physical Higgs bosons H_1^0 is the L-R analogue of the neutral Higgs boson of the standard model (SM). The decay $H_1^0 \to \gamma\gamma$ can occur through scalar, fermion, and gauge-boson loops. Since the W_L loop dominates $\Gamma(H^0 \to \gamma\gamma)$ in the SM,[3] an immediate question arises as far as the W_R contribution in L-R models is concerned. In Ref. 1 it was found that $B(H^0 \to \gamma\gamma)$ is enhanced by about one order of magnitude if there is a new W gauge boson with SM coupling to H^0. However, the main conclusion of the present note is

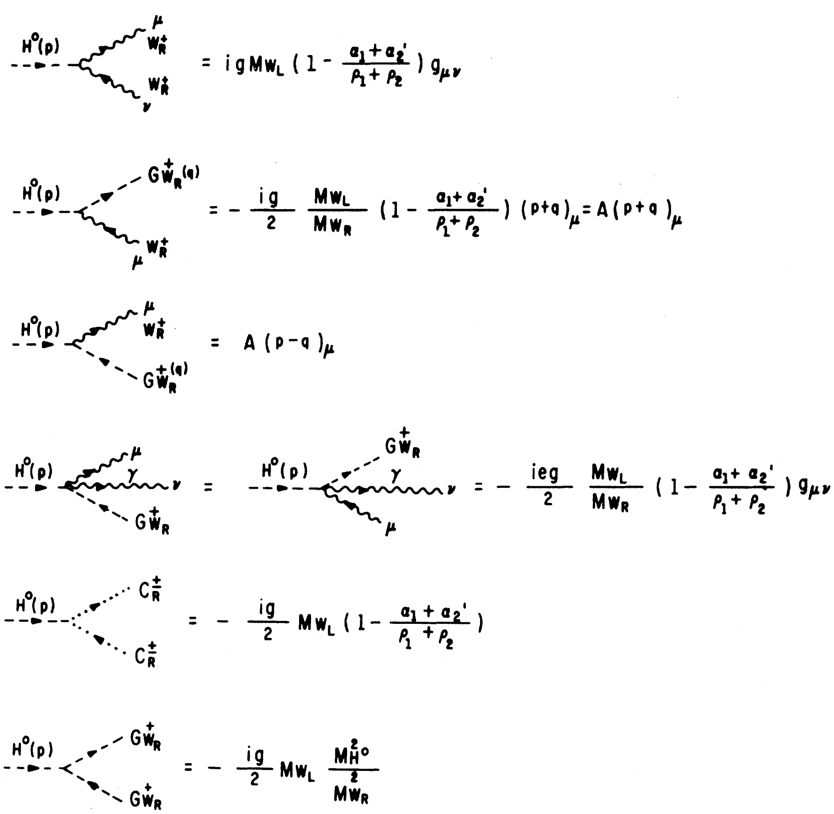

FIG. 1. Feynman rules used to compute the W_R contribution to $\Gamma(H_1^0 \to \gamma\gamma)$. Dashed lines denote unphysical (Goldstone) scalar mesons and dotted lines ghost fields.

that this expectation is not satisfied in L-R models because the W_R coupling to H_1^0 is not proportional to its own mass M_R, as a SM-like coupling would suggest, but rather to the lighter mass M_L.

The two-photon decay width of the SM neutral Higgs boson of mass m_H is given by[4]

$$\Gamma(H^0 \to \gamma\gamma) = \frac{\alpha^2 G_F m_H^3}{64\sqrt{2}\pi^3} \left| \sum_i F_i Q_i^2 \right|^2 , \tag{1}$$

where i = scalar (s), fermion (f), gauge boson (L), Q_i is the electric charge in units of e, and

$$\begin{aligned} F_s &= \tau_s (1 - \tau_s I^2) , \\ F_f &= -2\tau_f [1 + (1-\tau_f) I^2] , \\ F_L &= 2 + 3\tau_L + 3\tau_L (2 - \tau_L) I^2 , \end{aligned} \tag{2}$$

with $\tau_i = 4m_i^2/m_H^2$ and

$$I = \begin{cases} \arctan \dfrac{1}{\sqrt{\tau - 1}}, & \tau > 1 , \\ \dfrac{1}{2} \left[\pi + i \ln \dfrac{1 + \sqrt{1-\tau}}{1 - \sqrt{1-\tau}} \right], & \tau < 1 . \end{cases}$$

We shall consider the W_R contribution to $\Gamma(H_1^0 \to \gamma\gamma)$ in a class of L-R models where the W_L-W_R mixing angle ζ is small:[5,6]

$$\zeta \simeq \pm \frac{g_L}{g_R} \frac{2|\kappa\kappa'|}{|v_R|^2} , \tag{3}$$

with g_L and g_R the $SU(2)_L$ and $SU(2)_R$ gauge coupling constants, κ, κ' and v_R the vacuum expectation values of the two Higgs doublets and one of the Higgs triplets. In order to have $M_R \gg M_L$, these parameters satisfy $v_R \gg \kappa, \kappa'$.

We work in the 't Hooft-Feynman gauge. The Feynman rules necessary to compute the W_R contribution to $\Gamma(H_1^0 \to \gamma\gamma)$ are shown in Fig. 1. In Fig. 2 we show the Feynman diagrams involved in this computation. Since our result is quite sensitive to the $H_1^0 W_R W_R$ coupling, it deserves a special discussion. This coupling is originally given by

$$\frac{ig^2}{2} (\cos\theta^0 \kappa + 2 \sin\theta^0 v_R) , \tag{4}$$

where θ^0 is the mixing angle which defines the neutral-Higgs-boson mass eigenstates and is given by[5]

$$\tan 2\theta^0 = -\frac{\alpha_H \kappa v_R}{\rho_H v_R^2 - \lambda_H \kappa^2} , \tag{5}$$

where α_H, ρ_H, and λ_H are linear combinations of the scalar-boson self-couplings. If we consider the natural vacuum-expectation scenarios outlined in Ref. 7, then we do not expect highly correlated values among these self-couplings, and in the limit $v_R \gg \kappa$ Eq. (5) reduces to

$$\sin\theta^0 \simeq -\frac{\alpha_H}{2\rho_H} \frac{\kappa}{v_R} . \tag{6}$$

Therefore, the $H_1^0 W_R W_R$ coupling (4) turns out to be proportional to $g^2\kappa$ or gM_L as shown in Fig. 1.

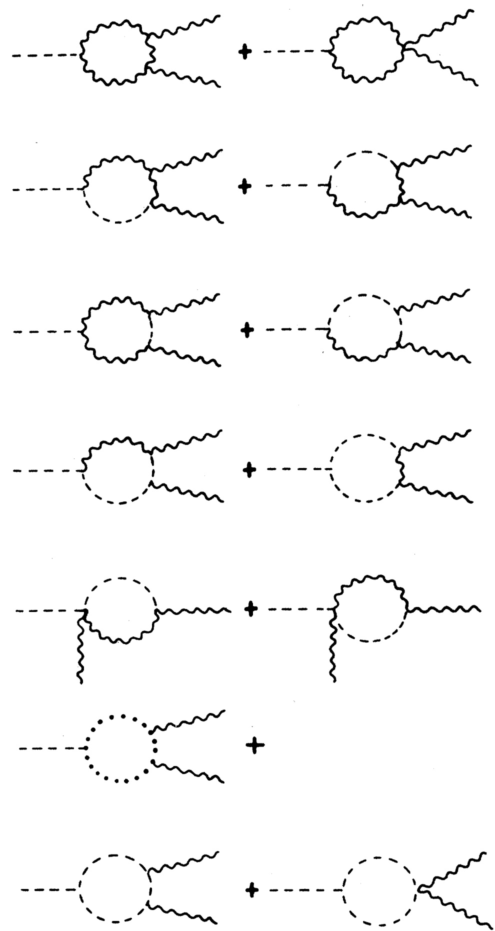

FIG. 2. Feynman diagrams for the W_R contribution to $\Gamma(H_i \to \gamma\gamma)$ in the 't Hooft-Feynman gauge.

The calculation of the diagrams shown in Fig. 2 reproduces the SM W_L contribution, except for the coupling constant associated with the $H_1^0 W_R W_R$ vertex. In fact, we have checked that in the appropriated limit our result reduces to the SM result given in Eqs. (1) and (2). The W_R contribution to $\Gamma(H_1^0 \to \gamma\gamma)$ can be expressed as the SM result (1) with a F_R function given by

$$F_R = \frac{1}{\tau_R} [2 + 3\tau_R + 3\tau_R (2 - \tau_R) I^2] , \tag{7}$$

where $\tau_R = 4M_R^2/m_H^2$. Since the functions f_i depend weakly on τ_i, we thus obtain that, if $g_L \simeq g_R$, the W_L and W_R contributions to $\Gamma(H_1^0 \to \gamma\gamma)$ are scaled by a factor $F_R \simeq (M_L/M_R)^2 F_L$. According to the known constraints[6,8] for M_R, even for the weakest bound $M_R > 300$ GeV, we get that the W_R contribution to $\Gamma(H_1^0 \to \gamma\gamma)$ is suppressed by at least an order of magnitude with respect to the SM W_L contribution. It should be mentioned that had the $H_1^0 W_R W_R$ coupling been proportional to gM_R, as expected in the SM, then both W_L and W_R contributions would have been of the same order of magnitude, and one should expect an enhancement of this decay width as observed in Ref. 1.

In conclusion, in L-R models we expect to have for the two-photon decay width of H_1^0 essentially the same value as in the SM. A possible enhancement of this decay width should be associated therefore to supersymmetric or two-Higgs-doublet models in general.[9]

We benefited from discussions with A. García, J. L. Lucio, M. H. Reno, and M. Yannick. One of us (M.A.P.) thanks the Physics Department of the Universidad Autónoma Metropolitana-Iztapalapa, where part of this work was done, for their warm hospitality. J.J.T. acknowledges support from Consejo Nacional de Ciéncia y Tecnología.

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