Higgs decay into two photons in VHDMM

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Contents

1 Feynman Rules in Unitary gauge (from LanHEP)

Table 1: Feynman rules of the VHDMM in the unitary gauge obtained from LanHEP.

$A_\mu \quad W^+{}_\nu \quad W^-{}_\rho$	$-e\big(p_2^\rho g^{\mu\nu} - p_2^\mu g^{\nu\rho} - p_3^\nu g^{\mu\rho} + p_3^\mu g^{\nu\rho} + p_1^\nu g^{\mu\rho} - p_1^\rho g^{\mu\nu}\big)$
$A_\mu \quad \sim V^+{}_\nu \quad \sim V^-{}_\rho$	$-e\big(p_3^\mu g^{\nu\rho} - p_2^\mu g^{\nu\rho} - p_3^\nu g^{\mu\rho} + p_2^\rho g^{\mu\nu}\big)$
$\bar{f}_{ap} \quad f_{bq} \quad H$	$-\frac{1}{2}\frac{e\cdot M_f}{M_W\cdot s_w}\delta_{pq}\cdot\delta_{ab}$
$H \quad W^+{}_\mu \quad W^-{}_\nu$	$\frac{e\cdot M_W}{s_w}\cdot g^{\mu\nu}$
$H \quad \sim V^+{}_\mu \quad \sim V^-{}_\nu$	$-2\frac{M_W\cdot s_w\cdot\lambda_2}{e}\cdot g^{\mu\nu}$
$\bar{q}_{ap} \quad q_{br} \quad A_\mu$	$-Qe\delta_{pr}\gamma^\mu_{aq}\cdot\delta_{cb}$
$\bar{\ell}_a \quad \ell_b \quad A_\mu$	$e\gamma^\mu_{ac}\cdot\delta_{cb}$
$A_\mu \quad A_\nu \quad W^+{}_\rho \quad W^-{}_\sigma$	$-e^2\big(2g^{\mu\nu}g^{\rho\sigma} - g^{\mu\rho}g^{\nu\sigma} - g^{\mu\sigma}g^{\nu\rho}\big)$
$A_\mu \quad A_\nu \quad \sim V^+{}_\rho \quad \sim V^-{}_\sigma$	$-e^2\big(2g^{\mu\nu}g^{\rho\sigma} - g^{\mu\rho}g^{\nu\sigma} - g^{\mu\sigma}g^{\nu\rho}\big)$

2 Standard Model contribution

In this work we will calculate the contribution to the partial width decay $\Gamma(h \to \gamma\gamma)$ according to the new physics of the VHDMM. The contribution of the Standard Model a tree level is null, because the Higgs boson do not interact with photons directly. However, considering one-loop corrections we can find that

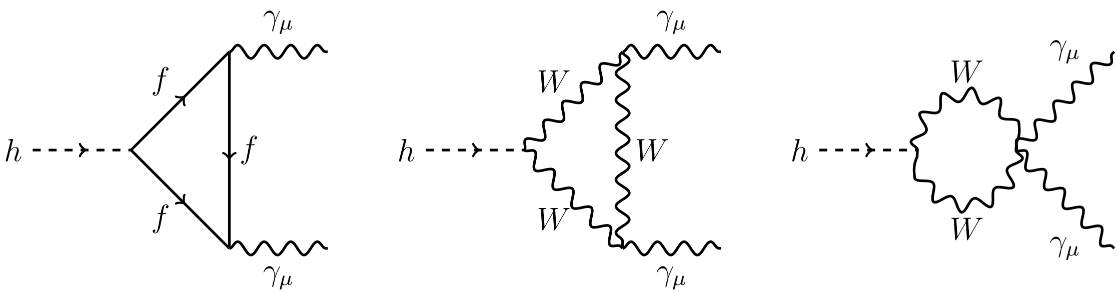
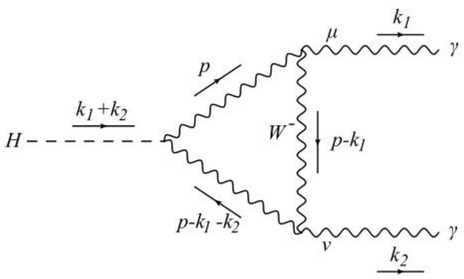


Figure 1: Feynman diagrams which contribute to the partial width decay in the standard model.

2.1 $W^\pm$ boson contribution

The first diagram is
Another diagram can be obtained performing an interchange of the final state photons, however the amplitude is exactly the same as the first. Therefore we just add a factor of 2 in the first amplitude. According with the 4-momentum conservation we have

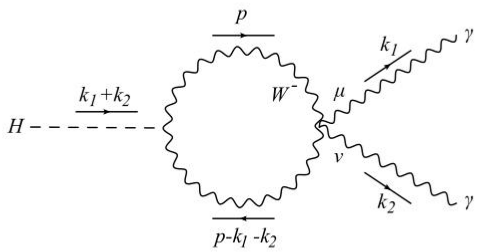
$$R = p - k_1 \qquad q = p - k_1 - k_2 \tag{1}$$



Considering the Feynman rules of table 1 the matrix $\mathscr{M}_{W1}$ is

$$\mathscr{M}_{W1} = 2(igM_W g_{\alpha\alpha})i\left(\frac{-g^{\alpha\beta}+p^\alpha p^\beta/M_W^2}{p^2-M_W^2+i\epsilon}\right)(-ie)\left[(k_1-R)^\beta g_{\mu\rho}+(p+R)^\mu g_{\rho\beta}-(p+k_1)^\rho g_{\mu\beta}\right]\epsilon^\mu(k_1)$$
$$i\left(\frac{-g^{\rho\sigma}+R^\rho R^\sigma/M_W^2}{R^2-M_W^2+i\epsilon}\right)(-ie)\left[(k_2-q)_\sigma g_{\nu\gamma}+(q+R)_\nu g_{\sigma\gamma}-(R+k_2)_\gamma g_{\nu\sigma}\right]\epsilon^\nu(k_2)i\left(\frac{-g^{\gamma\alpha}+q^\gamma q^\alpha/M_W^2}{q^2-M_W^2+i\epsilon}\right)$$

The second diagram contains a 4 leg vertex where interact 2 W bosons and 2 photons.



The matrix element of this diagram is $\mathscr{M}_{W2}$

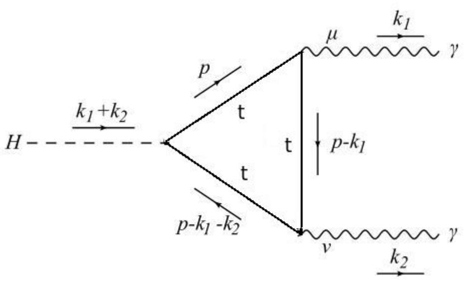
$$\mathscr{M}_{W2} = (igM_W g_{\alpha\alpha})i\left(\frac{-g^{\alpha\beta}+p^\alpha p^\beta/M_W^2}{p^2-M_W^2+i\epsilon}\right)(-ie^2)\left[2g_{\mu\nu}g_{\beta\gamma}-g_{\mu\beta}g_{\nu\gamma}-g_{\mu\gamma}g_{\nu\beta}\right]i\left(\frac{-g^{\gamma\alpha}+q^\gamma q^\alpha/M_W^2}{q^2-M_W^2+i\epsilon}\right)\epsilon^\mu(k_1)\epsilon^\nu(k_2)$$

After doing the integration and adding $\mathscr{M}_{W1}+\mathscr{M}_{W2}$, we found that

$$\mathscr{M}_W = \frac{e^2 g}{(4\pi)^2}\frac{1}{M_H^2 M_W}\left[M_H^2+6M_W^2-6M_W^2(M_H^2-2M_W^2)C_0(0,0,M_H^2,M_W^2,M_W^2,M_W^2)\right](M_H^2 g^{\mu\nu}-2k_2^\mu k_1^\nu)$$

2.2 quark top contribution

The top contribution is



Another diagram can be obtained performing an interchange of the final state photons, however the amplitude is exactly the same as the first. Therefore we just add a factor of 2 in the first amplitude. According with the 4-momentum conservation we have

$$R = p - k_1 \qquad q = p - k_1 - k_2 \tag{2}$$

Considering the Feynman rules of table 1 the matrix $\mathscr{M}_t$ is

$$\begin{aligned}
\mathscr{M}_C &= -2\frac{1}{2}ig\frac{m_t}{M_W}i\frac{(\not{p}+m_t)}{p^2-m_t^2}(-ieQ_t)\gamma^\mu i\frac{(\not{R}+m_t)}{R^2-m_t^2}(-ieQ_t)\gamma^\nu i\frac{(\not{p}+m_t)}{p^2-m_t^2}\epsilon^\mu(k_1)\epsilon^\nu(k_2) \\
&= ge^2Q_t^2\frac{m_t}{M_W}\frac{Tr\left[(\not{p}+m_t)\gamma^\mu(\not{R}+m_t)\gamma^\nu(\not{q}+m_t)\right]}{(p^2-m_t)(R^2-m_t)(q^2-m_t)}\epsilon^\mu(k_1)\epsilon^\nu(k_2)
\end{aligned}$$

3 VHDMM contribution

Due to the model VHDMM contains extra vectorial particles, there is some extra diagrams which contribute to the total process.