Lagrangien du Modèle Standard

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\begin{aligned}
\mathcal{L}_{SM} =\ & \sum_{\ell=e,\mu,\tau} i\bar{\psi}_\ell \gamma^\mu \partial_\mu \psi_\ell + \sum_{\ell'=\nu_e,\nu_\mu,\nu_\tau} i\bar{\psi}_{\ell'} \gamma^\mu \partial_\mu \psi_{\ell'} + \sum_i^3 \sum_{q=u,c,t} i\bar{\psi}_{q_i} \gamma^\mu \partial_\mu \psi_{q_i} + \sum_i^3 \sum_{q'=d,s,b} i\bar{\psi}_{q'_i} \gamma^\mu \partial_\mu \psi_{q'_i} \\
& -\frac{1}{2}(\partial_\mu W_\nu^+ - \partial_\nu W_\mu^+)(\partial^\mu W^{-\nu} - \partial^\nu W^{-\mu}) - \frac{1}{4}(\partial_\mu Z_\nu - \partial_\nu Z_\mu)(\partial^\mu Z^\nu - \partial^\nu Z^\mu) \\
& -\frac{1}{4}(\partial_\mu A_\nu - \partial_\nu A_\mu)(\partial^\mu A^\nu - \partial^\nu A^\mu) - \frac{1}{4}\sum_{a=1}^8 (\partial_\mu G_\nu^a - \partial_\nu G_\mu^a)(\partial^\mu G^{a\nu} - \partial^\nu G^{a\mu}) + \frac{1}{2}\partial_\mu h \partial^\mu h \\
& -\sum_{\ell=e,\mu,\tau} \frac{\lambda_\ell v}{\sqrt{2}} \bar{\psi}_\ell \psi_\ell - \sum_i^3 \sum_{q=u,c,t} \frac{\lambda_q v}{\sqrt{2}} \bar{\psi}_{q_i} \psi_{q_i} - \sum_i^3 \sum_{q'=d,s,b} \frac{\lambda_{q'} v}{\sqrt{2}} \bar{\psi}_{q'_i} \psi_{q'_i} \\
& -\left(\frac{gv}{2}\right)^2 W_\mu^+ W^{-\mu} - \frac{1}{2}\left(\frac{gv}{2\cos\theta_W}\right)^2 Z_\mu Z^\mu - \frac{1}{2}\left(-2m^2\right)h^2 \\
& +\frac{g}{4\cos\theta_W}\left(\sum_{\ell=e,\mu,\tau} \bar{\psi}_\ell \gamma^\mu(4\sin^2\theta_W - 1 + \gamma^5)\psi_\ell Z_\mu + \sum_{\ell'=\nu_e,\nu_\mu,\nu_\tau} \bar{\psi}_{\ell'}\gamma^\mu(1-\gamma^5)\psi_{\ell'} Z_\mu\right) \\
& +\frac{g}{4\cos\theta_W}\left(\sum_i^3 \sum_{q=u,c,t} \bar{\psi}_{q_i}\gamma^\mu(1 - \frac{8}{3}\sin^2\theta_W - \gamma^5)\psi_{q_i} Z_\mu + \sum_i^3 \sum_{q'=b,s,b} \bar{\psi}_{q'_i}\gamma^\mu(\frac{4}{3}\sin^2\theta_W - 1 + \gamma^5)\psi_{q'_i} Z_\mu\right) \\
& +\frac{g}{2\sqrt{2}}\left(\sum_{\ell=e,\mu,\tau} \bar{\psi}_{\nu_\ell}\gamma^\mu(1-\gamma^5)\psi_\ell W_\mu^+ + \sum_{\ell=e,\mu,\tau} \bar{\psi}_\ell \gamma^\mu(1-\gamma^5)\psi_{\nu_\ell} W_\mu^-\right) \\
& +\frac{g}{2\sqrt{2}}\left(\sum_i^3 \sum_{\substack{q=u,c,t\\q'=d,s,b}} V_{qq'}\bar{\psi}_q \gamma^\mu(1-\gamma^5)\psi_{q'_i} W_\mu^+ + \sum_i^3 \sum_{\substack{q=u,c,t\\q'=d,s,b}} V_{qq'}^* \bar{\psi}_{q'_i}\gamma^\mu(1-\gamma^5)\psi_{q_i} W_\mu^-\right) \\
& +g_{em}\left(-\sum_{\ell=e,\mu,\tau} \bar{\psi}_\ell \gamma^\mu \psi_\ell A_\mu + \frac{2}{3}\sum_{q=u,c,t} \bar{\psi}_{q_i}\gamma^\mu \psi_{q_i} A_\mu - \frac{1}{3}\sum_{q'=d,s,b} \bar{\psi}_{q'_i}\gamma^\mu \psi_{q'_i} A_\mu\right) \\
& +g_s\left(\sum_{i,j}^3 \sum_a^8 \sum_{q=u,c,t} \bar{\psi}_{q_j}\gamma^\mu \psi_{q_i} G_\mu^a T_{ij}^a + \sum_{i,j}^3 \sum_a^8 \sum_{q'=d,s,b} \bar{\psi}_{q'_j}\gamma^\mu \psi_{q'_i} G_\mu^a T_{ij}^a\right) \\
& -\sum_{\ell=e,\mu,\tau} \frac{\lambda_\ell}{\sqrt{2}}\bar{\psi}_\ell \psi_\ell h - \sum_i^3 \sum_{q=u,c,t} \frac{\lambda_q}{\sqrt{2}}\bar{\psi}_{q_i}\psi_{q_i} h - \sum_i^3 \sum_{q'=d,s,b} \frac{\lambda_{q'}}{\sqrt{2}}\bar{\psi}_{q'_i}\psi_{q'_i} h \\
& +ig_{em}\left[\partial_\mu A_\nu W^{-\mu}W^{+\nu} + \partial_\mu W_\nu^+ W^{-\nu}A^\mu + \partial_\mu W_\nu^- W^{+\mu}A^\nu - \partial_\mu A_\nu W^{-\nu}W^{+\mu}\right. \\
& \left.\qquad -\partial_\mu W_\nu^+ W^{-\mu}A^\nu - \partial_\mu W_\nu^- W^{+\nu}A^\mu\right] \\
& +ig\cos\theta_W\left[\partial_\mu Z_\nu W^{-\mu}W^{+\nu} + \partial_\mu W_\nu^+ W^{-\nu}Z^\mu + \partial_\mu W_\nu^- W^{+\mu}Z^\nu - \partial_\mu Z_\nu W^{-\nu}W^{+\mu}\right. \\
& \left.\qquad -\partial_\mu W_\nu^+ W^{-\mu}Z^\nu - \partial_\mu W_\nu^- W^{+\nu}Z^\mu\right] + \frac{g^2 v}{2}W_\mu^+ W^{-\mu}h + \frac{g^2 v}{4\cos^2\theta_W}Z_\mu Z^\mu h - \lambda v h^3 \\
& +g_{em}^2\left[W_\nu^+ W^{-\mu}A_\nu A^\mu - W_\mu^+ W^{-\mu}A_\nu A^\nu\right] + g^2\cos^2\theta_W\left[W_\nu^+ W^{-\mu}Z_\nu Z^\mu - W_\mu^+ W^{-\mu}Z_\nu Z^\nu\right] \\
& +g^2\cos\theta_W \sin\theta_W\left[2W_\mu^+ W^{-\mu}Z_\nu A^\nu - W_\mu^+ W^{-\nu}A_\nu Z^\mu - W_\mu^+ W^{-\nu}A^\mu Z_\nu\right] \\
& +\frac{g^2}{2}\left[W_\mu^- W^{-\mu}W_\nu^+ W^{+\nu} - W_\mu^- W^{+\mu}W_\nu^- W^{+\nu}\right] + \frac{g^2}{4}W_\mu^+ W^{-\mu}h^2 + \frac{g^2}{8\cos^2\theta_W}Z_\mu Z^\mu h^2 - \frac{\lambda}{4}h^4 \\
& -\frac{g_s}{2}\sum_{a,b,c}^8 f^{abc}(\partial_\mu G_\nu^a - \partial_\nu G_\mu^a)G^{\mu b}G^{\nu c} - \frac{g_s^2}{4}\sum_{\substack{a,b,c\\d,e,f}}^8 f^{abc}f^{ade}G_\mu^b G_\nu^c G^{\mu d}G^{\nu e}
\end{aligned}
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$g_{em} = g\sin\theta_W,\ v^2 = \frac{-m^2}{\lambda}\ (m^2 < 0, \lambda > 0),\ m_\ell = \frac{\lambda_\ell v}{\sqrt{2}},\ m_q = \frac{3\lambda_q v}{\sqrt{2}},\ m_W = \frac{gv}{2},\ m_Z = \frac{gv}{2\cos\theta_W},\ m_h = \sqrt{-2m^2}$