Higgs dynamics in the early universe

Vis, J.M. van de

Appendix A

Rates and parameters for electroweak baryogenesis

In this appendix we list the values of various parameters for our benchmark scenario. For the values of the coupling constants at the electroweak scale $\mu = m_Z$ we use

$$g' = 0.36\,, \quad g = 0.65\,, \quad g_s = 1.23\,, \quad y_t = 1\,, \quad y_b = 0.02\,, \quad y_\tau = 0.01\,. \tag{A.1}$$

The diffusion constants are taken from Refs. [268, 325]

$$D_t \simeq \frac{6}{T}\,, \quad D_q \simeq \frac{6}{T}\,, \quad D_\tau \simeq \frac{100}{T}\,, \quad D_l \simeq \frac{380}{T}\,, \quad D_h \simeq \frac{100}{T}\,. \tag{A.2}$$

The SM thermal masses $\delta m_i^{\rm Re}$ are [273]

$$\begin{aligned}
(\delta m_Q^{\rm Re})^2 &= \left(\frac{1}{6}g_s^2 + \frac{3}{32}g^2 + \frac{1}{288}g'^2 + \frac{1}{16}y_t^2 + \frac{1}{16}y_b^2\right) T^2\,,\\
(\delta m_{t_R}^{\rm Re})^2 &= \left(\frac{1}{6}g_s^2 + \frac{1}{18}g'^2 + \frac{1}{8}y_t^2\right) T^2\,,\\
(\delta m_{b_R}^{\rm Re})^2 &= \left(\frac{1}{6}g_s^2 + \frac{1}{72}g'^2 + \frac{1}{8}y_b^2\right) T^2\,,\\
(\delta m_L^{\rm Re})^2 &= \left(\frac{3}{32}g^2 + \frac{1}{32}g'^2 + \frac{1}{16}y_\tau^2\right) T^2\,,\\
(\delta m_{\tau_R}^{\rm Re})^2 &= \left(\frac{1}{8}g'^2 + \frac{1}{8}y_\tau^2\right) T^2\,,\\
(\delta m_H^{\rm Re})^2 &= \left(\frac{3}{16}g^2 + \frac{1}{16}g'^2 + \frac{1}{4}y_t^2 + \frac{1}{4}\left(\frac{m_H^2}{v_0^2} - 3v_0^2\kappa\right) + 3\phi_0^2\kappa\right) T^2\,.
\end{aligned} \tag{A.3}$$

For the Higgs mass we included the contribution from the dimension six operator $\kappa(\varphi^\dagger\varphi)^3$. The result for the thermal masses can be derived from the effective potential in the high-temperature expansion (5.7).

	Broken phase	Symmetric phase
$\Gamma_{\rm ss}$	0.26	0.26
$\Gamma_M^{(t)}$	104	0
$\Gamma_Y^{(t)}$	2.7	2.7
$\Gamma_M^{(b)}$	$3.7 \cdot 10^{-2}$	0
$\Gamma_Y^{(b)}$	$1.1 \cdot 10^{-3}$	$1.1 \cdot 10^{-3}$
$\Gamma_M^{(l)}$	$4.6 \cdot 10^{-2}$	0
$\Gamma_Y^{(l)}$	$1.0 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$
$\Gamma_{\rm ws}$	0	$4.7 \cdot 10^{-4}$

TABLE A.1: Asymptotic values of the interaction rates in the broken and symmetric phase. All rates are in GeV. The relaxation rates $\Gamma_M^{(f)}$ are a function of the bounce solution ϕ_b and vary over the bubble wall.

The thermal widths $\Gamma_{t,i}$ are [227]

$$\Gamma_{t,Q} = 0.16T\,, \qquad \Gamma_{t,L} = 0.002T\,, \tag{A.4}$$

where $\Gamma_{t,Q}$ is for quarks and $\Gamma_{t,L}$ for leptons.

For the nucleation temperature we use

$$T_N = 88\,\text{GeV}\,. \tag{A.5}$$

This value was obtained by taking $\kappa = 2.0\,\text{TeV}^{-2}$ (corresponding to a scale of new physics $\Lambda \approx 0.71\,\text{TeV}$. The value of the Higgs field in the broken vacuum, the bubble-wall width and the bubble-wall speed are given by:

$$v_N = 152\,\text{GeV}\,, \quad L_w = 0.11\,\text{GeV}^{-1}\,, \quad v_w = 0.05\,. \tag{A.6}$$

The numerical values of the interaction rates are listed in table A.1.