

# High-T Potential.

$$V = -\mu_H^2 h^2 + \lambda h^4 + \frac{1}{2} \mu_S^2 S^2 - A S h^2 + V_T$$

$$V_T = \frac{T^4}{2\pi^2} \left( \sum_{B,F} n_B J_B \left( \frac{m_B^2}{T^2} \right) + n_F J_F \left( \frac{m_F^2}{T^2} \right) \right)$$

$$V = -(\mu_H^2 - c_h) T^2 h^2 - \epsilon T h^3 + \lambda h^4 - A(h^2 + C_S T^2) S + \frac{1}{2} \mu_S^2 S^2$$

$$J_B \simeq -\frac{\pi^4}{45} + \frac{\pi^2}{12} \frac{m^2}{T^2} - \frac{\pi}{6} \frac{m^3}{T^3} \dots - \epsilon(hS)T$$

$$J_F \simeq \frac{7\pi^4}{360} - \frac{\pi^2}{24} \frac{m^2}{T^2}$$

$$V_T = \frac{T^2}{24} \left( \sum n_B m_B^2 \right) - \frac{T^2}{48} \left( \sum n_F m_F^2 \right) - \frac{T}{12\pi} \sum n_B m_B^3$$

(neglect an field-independent parts)

$$m_W^2 = \frac{1}{2} g^2 h^2, \quad m_Z^2 = \frac{g^2 + g'^2}{2} h^2, \quad m_t^2 = y_t^2 h^2$$

$$m_X^2 = -2\mu_H^2 - 2AS + 4\lambda h^2$$

$$m_{S,h}^2 = -\mu_H^2 + \frac{1}{2} \mu_S^2 - AS + 6\lambda h^2 \pm \frac{1}{2} \sqrt{\text{sqrt}}$$

$$\begin{aligned} \text{sqrt} = & 16A^2 h^2 + 4A^2 S^2 + 8\mu_H^2 AS + 4\mu_S^2 AS - 48\lambda AS h^2 \\ & + 4\mu_H^4 + \mu_S^4 - 144\lambda^2 h^4 + 4\mu_H^2 \mu_S^2 - 48\lambda \mu_H^2 h^2 \\ & - 24\lambda \mu_S^2 h^2 \end{aligned}$$

$$\begin{aligned}
T^2: \frac{1}{24} \sum m_B m_B^2 &= \frac{1}{24} \left( 6 \cdot \frac{1}{2} g^2 h^2 + 3 \cdot \frac{g^2 + g'^2}{2} h^2 + \frac{1}{2} \cdot 12 \eta_t^2 h^2 \right. \\
&\quad \left. + 3(-2\mu_H^2 - 2AS + 4\lambda h^2) \right. \\
&\quad \left. + 2(-\mu_H^2 + \frac{1}{2}\mu_S^2 - AS + 6\lambda h^2) \right) \\
&= \frac{1}{48} (9g^2 h^2 + 3g'^2 h^2 + 12\eta_t^2 h^2 - 16AS + 4\lambda h^2) \\
&\quad (\text{field-independent part neglected})
\end{aligned}$$

$$= \underbrace{\frac{1}{16} (3g^2 + g'^2 + 4\eta_t^2 + 16\lambda) h^2}_{C_h} - \underbrace{\frac{1}{3} AS}_{C_s}$$

If neglect scalar contribution in  $C_h$ :

$$C_h = \frac{1}{24v^2} (6m_W^2 + 3m_Z^2 + 6m_t^2)$$

$$= \frac{1}{8v^2} (2m_W^2 + m_Z^2 + 2m_t^2) \quad (\text{Same as SM})$$

$$\begin{aligned}
T: \frac{1}{12\pi} \sum m_B m_B^3 &= \frac{1}{12\pi} \left( 6 \cdot \frac{1}{2\sqrt{2}} g^3 h^3 + 3 \cdot \frac{(g^2 + g'^2)^{3/2}}{2\sqrt{2}} \right. \\
&\quad \left. + 3(-2\mu_H^2 - 2AS + 4\lambda h^2) \right)^{3/2} \quad E_{SM} \\
&\quad + m_H^2(h,s) + m_S^2(h,s) \quad E(h,s)
\end{aligned}$$

$$E_{\text{SM}} = \frac{1}{4\pi v^3} (2m_n^3 + m_t^3)$$

$$E(h.s) = \left( 3 m_x^{3/2} + m_n^{3/2} + m_s^{3/2} \right) (h.s)$$