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Higgs Mass

$$V(\phi) = \mu^2(\phi^\dagger\phi) + \lambda(\phi^\dagger\phi)^2$$

$$\phi = \begin{pmatrix} \phi^+ \\ \phi_1 + i\phi_2 \end{pmatrix}$$, minimization: $|\langle\phi\rangle|^2 = \frac{2\mu^2}{\lambda}$

$$V(\phi) = \mu^2\left(|(\phi^+)|^2 + \phi_1^2 + \phi_2^2\right) + \lambda\left(|\phi^+|^2 + \phi_1^2 + \phi_2^2\right)^2$$

$$\phi_1 \to \frac{v+h}{\sqrt{2}}, \quad \phi^+, \phi_2 = 0$$

$$\mathcal{L}_{kin}(\phi) = \frac{1}{2}\left(\partial_\mu(v+h)\,\partial^\mu(v+h)\right)$$

$$= \frac{1}{2}\partial_\mu(h)\,\partial^\mu(h)$$

$$V(\phi) = V(\phi\, v+h) = \frac{1}{2}\mu^2(v+h)^2 + \frac{1}{4}\lambda(v+h)^4$$

$$= \lambda v^2 h^2 + \frac{1}{4}\lambda h^4 + \lambda v h^3 - \frac{1}{4}\lambda h^4$$

$$\mathcal{L}(h) = \frac{1}{2}(\partial_\nu h)(\partial^\mu h) - \lambda v^2 h^2$$

$$\Rightarrow \boxed{m_h = \sqrt{2\lambda v^2}}$$

- If we ~~con~~ include the complex field, $\phi^* = i\epsilon$

$$\phi^2 = \phi^* \phi = \frac{1}{2}\left[(v+h)^2 + \epsilon^2\right], \quad \mu^2 = -\lambda v^2$$

$$\mathcal{L}_{kin} = \frac{1}{2}\partial_\mu(h+v-i\epsilon)\partial^\mu(v+h+i\epsilon)$$

$$= \frac{1}{2}(\partial_\mu h)^2 + \frac{1}{2}\partial_\mu \epsilon^2, \quad \partial_\mu v = 0$$

$$\Rightarrow V(\phi, \phi^*) = \mu^2 \phi^2 + \lambda \phi^4$$

$$= -\frac{1}{2}\lambda v^2\left[(v+h^2) + \epsilon^2\right] + \frac{\lambda}{4}\left[(v+h)^2 + \epsilon^2\right]^2$$

$$= -\frac{1}{4}\lambda v^4 + \lambda v^2 h^2 + \lambda v h^3 + \frac{\lambda h^4}{4} + \frac{\lambda \epsilon^4}{4}$$

$$+ \lambda v h \epsilon^2 + \frac{\lambda h^2 \epsilon^2}{2}$$

$$\mathcal{L}(h,\epsilon) \subset \underbrace{\frac{1}{2}(\partial_\mu h)^2 - (\lambda v^2) h^2}_{\text{massive scalar 'h'}}$$

$$+ \frac{1}{2}(\partial_\mu \epsilon^2) + (0 \cdot \xi^2)$$

neglecting higher order / constant terms.

$\phi^{\#} \equiv 0$

vev.

$+ \ldots$