Département de physique nucléaire et corpusculaire
Section de Physique
Université de Genève

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ADVANCED PARTICLE PHYSICS II

http://dpnc.unige.ch/∼bravar/PPA2

Exercises - 12^{th} Assignment

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1. What is a symmetry? Think what the concept of symmetry means to you and how you can show that a system posses some symmetries. Find some examples of hidden symmetry and try to explain how the symmetry is hidden. What is a broken symmetry?

2. Show that the mass term $m\overline{\psi}\psi$ can e rewritten as

$$m\overline{\psi}\psi = m\left(\overline{\psi_R}\psi_L + \overline{\psi_L}\psi_R\right)$$

and that it is not invariant under $SU(2)_L \times U(1)_Y$ transformations.

3. Why the Higgs potential cannot contain terms with odd powers of the field ϕ?

4. Verify the substituion

$$\phi(x) = \frac{1}{\sqrt{2}}\left(v + \eta(x) + i\xi(x)\right)$$

that leads to the Lagrangian on slide 18.
Work out the interaction term $WW(\xi, \eta)$ and draw the corresponding Feynman diagrams.

5. Work out the full derivation of the gauge invariant $SU(2)$ Lagrangian with the Higgs field and gauge away the Golstone bosons (slides 24 and 25).
Show that the SU(2) field $\phi(x)$ expressed in the unitary gauge absorbs the unphysical degrees of freedom corresponding to the Goldston bosons, which arise in the spontaneous breaking of the local SU(2) symmetry.

6. From the mass matrix on slide 28 and its eigenvalues, show that the eigenstates in the diagonal basis are

$$A_\mu = \frac{g'W^0_\mu + gB_\mu}{\sqrt{g^2 + g'^2}} \qquad \text{and} \qquad Z_\mu = \frac{gW^0_\mu - g'B_\mu}{\sqrt{g^2 + g'^2}}$$

where A_μ and Z_μ are the physical fields for the photon and Z boson.

7. Show that

$$\frac{1}{2v^2} = \frac{G_F}{\sqrt{2}} \ ,$$

where v is the vacuum expectation value of the Higgs field $v = \langle 0|h|0\rangle$.

8. What is the dominant process for Higgs production in e^+e^- annihilation? and why? Draw the lowest order Feynman diagrams for the processes

$$e^+e^- \to hZ$$

and

$$e^+e^- \to h\nu_e\bar{\nu}_e \ ,$$

which are the main production mechanism for the Higgs boson at a future high energy e^+e^- collider.
Compare the cross sections for $e^+e^- \to h \to b\bar{b}$, $\mu^+\mu^- \to h \to b\bar{b}$, and $\mu^+\mu^- \to \gamma \to b\bar{b}$ as $\sqrt{s} = m_H$.