PHYS 528 Homework #6

Due: ~~Mar.11, 2021~~ March 16, 2021

0. Final project topics.

   Choose a topic for the final project. A list of potential topics can be found here:

   https://particletheory.triumf.ca/PHYS528/fproj.html

   Please check your topic with me before you begin on the project and fix it by Mar.17. I will help you get started by suggesting some reading material.

1. Higgs decays to fermions.

   a) Use Eq. (34) of `notes-06` to deduce the vertex corresponding to the Higgs coupling to bottom quarks. Don't forget quark colours!

   b) Apply this to compute the decay rate of the Higgs boson to $b\bar{b}$.

   c) Compare this result to the decay rates for Higgs to $c\bar{c}$ and $\tau\bar{\tau}$. To do so, find the numerical values of these widths (in MeV) for a Higgs mass of $m_h = 125$ GeV.

   Hint: you can look up fermion masses at https://pdglive.lbl.gov/.
   Hint: don't forget to take colours into account.

2. Z decays in the SM.

   Compute the partial decay widths of the Z^0 into each of the SM fermions. You may ignore the fermion mass whenever it is smaller than one tenth the Z^0 mass: $m_f < m_Z/10$. Note that the branching fraction of a particular decay mode with partial width Γ_i is defined to be $\mathrm{BR}_i = \Gamma_i/\Gamma_{tot}$. Plug numbers into your formulas and compare to data: *http://pdglive.lbl.gov/.*
   Hint: there are lots of terms, but many of them vanish!
   Hint: $P_L P_R = 0$, $P_L^2 = P_L$, $P_L\gamma^\mu = \gamma^\mu P_R$, $tr(\gamma^\mu\gamma^\nu\gamma^\rho\gamma^\sigma\gamma^5) = -4i\epsilon^{\mu\nu\rho\sigma}$.
   Hint: an $\epsilon^{\mu\nu\rho\sigma}$ *term can only be non-zero if it connects with* ***four*** *independent 4-vectors.*
   Hint: don't forget to take colours into account.

3. Invisible Z decays.

   Suppose the SM contains a new "invisible" LH chiral fermion with a coupling strength g_L to the Z^0. (That is, the Lagrangian interaction is $\bar{\psi}_L\gamma^\mu Z_\mu g_L\psi_L$.) Derive the upper limit on the size of the coupling g_L as a function of the fermion mass m_ψ from the requirement that its contribution to the invisible decay width of the Z^0 be less than $\Delta\Gamma_{inv} < 2$ MeV.
   Hint: you should be able to reuse the calculation from question #2.