Physics 125 Problem Set 4

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due Friday, April 24 in class

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1. A famous process in experimental particle physics is the 'charged current' scattering of muon neutrinos and muon anti-neutrinos off of the u, d, *and* the $\overline{u}$ & $\overline{d}$ quarks present in the proton. By 'charged current,' it is meant that the vertices $\nu_\mu \to \mu^- W^+$ and $\overline{\nu}_\mu \to \mu^+ W^-$ are involved. The $W^\pm$ then form a vertex with the quarks or antiquarks in the nucleon. Assume that the energy of the incident neutrinos is insufficient to make b-quarks or t-quarks; neglect presence of anything but the 'valence' quarks in the proton (the uud) and the 'sea' quarks/antiquarks $u\overline{u}$ and $d\overline{d}$ arising from zwitterbewegung in the proton. Draw all the Feynman diagrams that give non-zero amplitudes for the scattering, and write down the 'CKM' factor next to the diagram. BTW, neutrino and anti-neutrino charged current scattering gives very important measurement of the anti-quark content of the proton (and neutron).

2. Compute the width (or upper limit on the width) in MeV of particles with the following lifetimes:

   (a) The proton.... take its mean lifetime to be $> 10^{32}$ years. It is nice to recall that there are very nearly $\pi \times 10^7$ seconds in a year.

   (b) The neutron... mean life of 886 seconds.

   (c) The muon.... mean life of 2.20×10^{-6} seconds. Also compute $c\tau_\mu$ in meters... can you explain why muons are regarded as 'stable' in the LHC experiments (what is the physical size of an LHC experiment)?

   (d) The charged pion... mean life of 2.6×10^{-8} seconds. Repeat the consideration made for the muon.... should this particle be considered stable at the LHC or not?

   (e) The D^0... mean life of 4.1×10^{-13} seconds. Repeat the consideration made for the charged pion.

   (f) The π^0... mean life of 8.4×10^{-17} seconds. Repeat the consideration made for the charged pion.

3. Griffiths 3.16

4. Griffiths 3.17

5. Griffiths 3.18

6. Griffiths 3.19

7. Griffiths 3.20
