PHY 3107, Spring 2016, Homework #7

due Friday, March 25, at 9:30 am (beginning of class)

1.) The masses of the bosons relates to the distance scale of the various forces: an exchange boson can exist briefly, for a time given by the Uncertainty Principle as $\Delta t \approx \frac{\hbar}{2\Delta E} = \frac{\hbar}{2mc^2}$. In that time, the force can travel at most a distance $d = c\Delta t$. A) if the mass of the pion (thought to be the effective boson for the strong force) is 140 MeV, find the distance scale. B) if the mass of the $Z^0 = 90$ GeV, find the distance scale of the weak force. C) if the photon has no mass, what is the distance scale for the electromagnetic force?

2.) Conservation laws come into play lots of ways in finding how particles decay or which collisions can produce particular particles. a) Use conservation of lepton number to determine whether the following decays can occur:

$\mu^+ \rightarrow e^+ + \nu_e$
$\mu^- \rightarrow e^- + \gamma$
$\pi^- \rightarrow e^- + \overline{\nu_e}$
$\tau^+ \rightarrow e^+ + \nu_e + \overline{\nu_\tau}$
$\tau^+ \rightarrow \pi^+ + \overline{\nu_\tau}$

b) Two protons are smashed together at the LHC, and the kinetic energy converted into mass and new particles. Are these reactions possible?

$p + p \rightarrow p + p + p + \bar{p}$
$p + p \rightarrow p + \bar{p} + n + \bar{n}$
$p + p \rightarrow p + p + n + \bar{n}$
$p + p \rightarrow p + p + K^+ + \Lambda^0$
$p + p \rightarrow p + p + \Sigma^+ + K^0$
$p + p \rightarrow p + p + \pi^0$
$p + p \rightarrow p + p + \pi^+ + \pi^-$

3.) In the current running of the LHC at CERN, $p + p$ collisions happen at a center-of-mass energy of 13 TeV, or 6.5 TeV beams on 6.5 TeV beams of protons. A) this is our best chance to date of seeing if the electron has any substructure, or is really just a point-like particle. What will the distance scale be that we are probing with these collisions?

4.) In strong interactions, strangeness is conserved but in weak interactions strangeness changes by one unit. [In all cases, electric charge, baryon number, lepton number, and angular momentum are always conserved as far as we can tell.] The masses of the exchange bosons tell us whether reactions will occur quickly (e.g, via the strong interaction), or slowly (via the weak interaction). And of course, some reactions cannot occur at all. Which of the reactions shown below will be fast, slow or totally forbidden:

$\pi^- + p \rightarrow n + K^0$
$\bar{p} + p \rightarrow p + \pi^-$
$e^- + p \rightarrow \bar{\nu}_e$
$\Delta^{++} \rightarrow \pi^+ + \pi^+ + n$
$\Delta^{++} \rightarrow K^+ + K^+ + n$
$\pi^- + p \rightarrow K^0 + \Lambda^0$