Class #08 (Feb. 29) Reading Questions - Cosmic Onion, Chapt. 10 & 11 (to pg 154)

Summary: Chapter 10 describes the precision tests of the standard model carried out at the CERN Large Electron Positron Collider (LEP) facility between 1989 and 2000. LEP originally ran at a total collision energy near the rest mass of the Z-boson (~90 GeV) and thus acted as a "Z-factory". The most dramatic result coming out of LEP's large scale study of Z production and decay was that the data clearly ruled out the possibility of a fourth generation of particles. This result stems from the fact that if there were more generations, the Z-boson would have additional neutrino decay modes that will modify the Z lifetime. LEP was also able to provide estimates of the top quark mass (and latter the Higgs mass) before either of these particles were actually produced. After 1997 LEP ran at energies of 200 GeV which allowed for the production of W+/W- pairs. LEP's high precision results provided strong experimental evidence that Z and W are truly elementary particles and, more generally, that the 3-generation standard model provides a correct description of nature. Chapter 11 discusses CP-symmetry and the surprising violation of this symmetry by neutral K-mesons (K0). While the K0 meson itself does not obey CP-symmetry, one can construct two different mixtures of K0 and anti-K0 that do respect this symmetry. Experimental evidence for this mixing comes from the identification of a long-lived and short-lived version of this particle. CP symmetry demands that these two forms (K-long and K-short) undergo different types of decay and this is confirmed experimentally. However, in 1964 it was shown that K-long can also, very occasionally, undergo a CP-violating decay. One consequence of this is that for certain decays of K-long there is a very slight imbalance in the matter versus antimatter version of the decay. Thus, the weak interaction is not entirely symmetric with respect to matter and antimatter. This feature is built into the standard model through the CKM matrix (which we will discuss after spring break).

Questions:

1. The Z-boson decays "democratically" into a quark/anti-quark or lepton/anti-lepton pair. Explain why there are a total of 21 different possible decays of this type for the Z.

2. Why does the Z lifetime depend on the number of generations of leptons? How do you get a lifetime out of the data shown in Fig. 10.1?

3. LEP did not have enough energy to produce the top-quark, yet in 1994 LEP was able to provide a estimate of the top-quark mass. How was this estimate obtained and how close was it to the actual top mass first reported in 1995?

4. Let C(X)=charge conjugation and P(X)=parity change for particle X. If X=left-handed neutrino, what is the result of C(X), P(X), and CP(X)?

5. Explain why K-long is "allowed" to decay into 3 pions but a decay into 2 pions should be "forbidden". Also, explain why this 3 pion decay gives K-long a longer lifetime than K-short.

Your Question: Please give a well-formulated question that you have regarding the material covered in this reading assignment.