Class #07 (Feb. 22) Reading Questions - Cosmic Onion, Chapt. 9

Summary: Chapter 9 describes the discovery of additional generations of quarks and leptons. The development of electroweak (EW) theory was based on the isospin groupings: (nu_e, e), (nu_mu, mu), and (u, d). Symmetry and aesthetics strongly suggested that the strange quark should also be paired with a fourth quark, charm, giving a fourth doublet (c, s). The existence of a c-quark would also explain why an s -> d conversion, which was predicted by the EW theory, was not observed experimentally. In particular, the c quark would give a set of Feynman diagrams that exactly cancelled the diagrams for the s->d process (the so-called GIM mechanism). However, for GIM to work the c quark could not be too massive. The discovery of the J/psi particle (the c, anti-c meson) in November 1974 initiated a new and highly productive era of particle discovery. Once the c mass was known experimentalists knew where to look for other c-containing hadrons, and they found them. In 1975 a new lepton was also discovered (the tau) which seemed to spoil the elegant two-generation quark, lepton pattern. Then in 1977 the Upsilon meson, comprised of a bottom and anti-bottom quark, was found demonstrating that a third generation of quarks also existed. No one doubted that a top quark and tau-neutrino must also exist to complete the third generation doublets: (t, b), (nu_tau, tau). And, indeed, top and nu_tau were discovered (after MUCH effort) in 1995 and 2000, respectively. The big surprise here was the super heavy mass of the top quark which is 40 times more massive than the bottom quark. These results raise the questions: Are there more generations to be found and does this generation pattern suggest an additional layer of underlying substructure?

Questions:

1. Describe the two different experimental approaches used by the Richter and Ting teams in the discovery of the J/psi particle. Which team actually found this particle first?

2. What is the theoretical explanation for the observation that the massive J/psi (charm, anti-charm) meson has a much longer lifetime than the lighter phi (strange, anti-strange) meson?

3. The J/psi particle is comprised of a charm and anti-charm quark so it carries zero net charm. What was the first hadron with non-zero charm to be found and what decay signature was searched for as evidence of a charmed quark?

4. Figure 9.2 illustrates that the weak interaction operates only within distinct lepton or quark pairs, without lepton-quark mixing or cross-generational mixing. From our earlier study of strangeness, explain why this picture cannot be completely true.

5. Explain how the decay of the top quark, shown in Fig. 9.7, is similar to beta-decay.

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