Charm at Last: How Sweet It Is

For more than a year and a half the running headline story in particle physics has been the discovery of one after another of the ultraheavy, oddly behaving particles designated psi or J. By now, something like nine members and cousins of the psionic family have been catalogued, and there may be more to come. Many theorists have attributed the odd behavior of the psi particles to a theoretically proposed new property (quantum number) that is whimsically named charm.

The problem with using the psi's as evidence for charm's actual existence is that they themselves do not display it openly, or "nakedly" as some commentators like to put it. Theory says the psi's contain both charm and anticharm, since they are made of a charmed quark and an anticharmed antiquark. (Quarks are the building blocks out of which particles are constructed according to the most widely accepted theory.) Theory postulates that there should also be particles that exhibit charm nakedly (being made up of a charmed quark and an uncharmed antiquark), but these have not shown up experimentally until now.

This week the news from the SPEAR storage ring at the Stanford Linear Accelerator Center is that a candidate for a nakedly charmed particle has now been found. The experiment is the same one that was codiscoverer of the original psi particle in November 1974. In it, beams of accelerated electrons and positrons are struck together so that they annihilate each other and produce new particles. The experiment, operated by a consortium of physicists drawn from the staffs of SLAC and the Lawrence Berkeley Laboratory, just keeps on running to see what more new things it can find. The experiment and the laboratory generally are funded by the U.S. Energy Research and Development Administration.

The supposed new particle has a mass of about 1.86 billion electron-volts (1.86 GeV), very nearly twice that of the proton. It was first seen to decay into two familiar particles of the class called hadrons (a K meson and a pi meson). Later another decay mode, into a K and three pi's, was found. It is these characteristic decays that make the experimenters think the new particle conforms to the theoretical expectation of what a nakedly charmed particle should be. About 100 examples of the new particle were found among 24,000 electron-positron annihilation reactions. According to an ERDA announcement of the discovery on June 8, the physicists performed numerous checks to increase the certainty that they had what they thought they had.

The new particle's mass fits well into a scheme of related nakedly charmed particles of the class called mesons that was theorized last year in an article in the PHYSICAL REVIEW (section D, 12:147) by Sheldon L. Glashow of Harvard University and collaborators. According to the general theory of how particles are made of quarks, any meson should be made of one quark and one antiquark. Before the introduction of charmed quarks to the theory, there were three kinds of uncharmed quarks (called, N, P, and lambda) with corresponding antiquarks, and the Glashow theory uses all the possible permutations to arrive at a family of six nakedly charmed quarks. Two of these lie at about the appropriate mass level, combinations of the charmed quark with the P and N antiquarks. Of these it seems most likely that the one found is the charmed quark plus P antiquark.

The reason the discovery was not made before now, according to Roy Schwitters of SLAC, one of the experimenters, is basically that there was just not enough data to pick up such rare events. The region around the energy of 4 GeV, where the experiment happens to be operating right now, is particularly rich in data and has a better signal-to-noise-ratio.

Theory says a nakedly charmed particle should be made in conjunction with a nakedly anticharmed particle, and there appear to be some things recoiling from the 1.86 particle that might be that. But Schwitters says it is premature to put that interpretation on them, although a report in another periodical, which cited no sources, did so.

Of course there is a certain grain of salt to be taken with all this. As Schwitters says, the experimenters cannot definitely prove that they have an example of naked charm, but what has been seen fits the theoretical prediction so well that it seems convincing. As the ERDA announcement puts it, there is "much work to be done to see if it really is charm" and not some unexpected phenomenon. One part of that work is to search for some of the other five states predicted by Glashow. Schwitters says the experimenters are looking at two particular points in the neighborhood of the 4-GeV energy range where they suspect others of Glashow's predicted states may appear. □

Pionium, another new quasi-atom

Of all the particles known to physics, the oddest and most useless may be the muon. Often referred to as "the heavy electron," the muon shares all the properties of the electron except mass and stability. The muon is about 207 times as heavy as the electron and has a lifetime of about 2 microseconds. Physics knows many unstable particles whose place in the overall scheme of nature is mysterious and obscure, but most of them have properties that make them significantly different from one another. None is so close as the muon to being the exact twin of another. Physicists who believe that God is an economical being wonder why He made the muon.

Some light may be shed on the nature of the muon by studies of a new kind of quasi-atom, called pionium, which has just been discovered at Brookhaven National Laboratory by a group led by Melvin Schwartz of Stanford University. Quasi-atoms are systems in which particles not normally found in atoms become bound together in a way analogous to the proton and electron in a hydrogen atom and exhibit an atom-like hierarchy of discrete energy levels. Examples are positronium (electron and positron) and muonium (electron and muon). Quasi-atoms are generally unstable structures either because they are subject to matter-antimatter annihilation (positronium) or because one or more of their constituents is radioactively unstable (muonium).

Pionium is a structure made of a muon and a pion. The pion is one of the particles believed to play a role in the exchange of forces that holds atomic nuclei together. It is much shorter lived than the muon, lasting only about 20 picoseconds.

The neat thing about pionium is that the only forces that both its constituents respond to are electromagnetic forces, and so the force that binds them must be purely electromagnetic with no admixture of other kinds of force. The theory of electromagnetic forces in particle physics, quantum electrodynamics, is the most thoroughly understood of all particle-physics force theories, and it will allow the expected force between the muon and pion to be calculated quite exactly. Faith in quantum electrodynamics is so strong that if experiment shows any discrepancy, the difference can be attributed to unknown properties of the muon, and it could give some insight into the outstanding mystery of that particle's existence.

Experimentally, pionium quasi-atoms appeared among the decay products of the long-lived neutral K meson. (Long life in this case means 50 picoseconds.) Twenty-seven percent of all such decays yield a pion, a muon and a neutrino, but it is extremely rare that the pion and muon should stick together as pionium instead of going their separate ways. In fact, it