New Evidence for Fifth Quark

As physicists conceive of things at present, most of the known elementary particles consist of even more fundamental entities, quarks. Firm evidence for the existence of at least four kinds of quarks has been in hand for some time, and the discovery 2 years ago of a particle called the upsilon strongly suggested a fifth variety of quark. This summer, an international team of physicists from Indiana University at Bloomington, France's Center for Nuclear Studies at Saclay, Imperial College, London, and the University of Southampton has come up with seemingly conclusive evidence for the fifth quark, which is called the b quark. The names bottom or beauty have sometimes been given to b for no reason relating to the physical properties of the particles themselves.

Elementary particle physicists regard the finding as highly significant. The idea of quarks and the theory that tries to explain their properties, quantum chromodynamics, constitute the current best hope for understanding the strong nuclear force, which is the force responsible for binding the constituents of atomic nuclei together. Thus, finding evidence for the existence of a b quark with the expected properties is encouraging.

What was discovered, however, was not the b quark itself—quarks are generally assumed not to exist as isolated entities but only bound together in combinations of two or three in the form of the elementary particles known as mesons and baryons, respectively. A proton, for example, is a baryon. The researchers found, in experiments with the 500-GeV proton-synchrotron at the European Organization for Nuclear Research (CERN) near Geneva, a meson with a mass of 5.3 GeV. (With Einstein's $E = mc^2$ in mind, physicists measure mass in terms of the equivalent energy.) This meson consists, according to the quark model, of a b quark and an anti-quark of the type found in protons and neutrons. This latter quark would be a down or d quark, or an up or u quark. Since the mass of the proton is only 1 GeV, almost all of the mass of the new meson, termed a B meson, is due to the b quark, by far the heaviest of the five.

Another theory, the so-called unified gauge theory, which many physicists believe has successfully combined explanations for the electromagnetic force and weak force (responsible for such phenomena as radioactive beta decay of nuclei) into one theory, suggests that quarks come in pairs. Confirmation of the existence of the b quark thus enhances experimenters' determination to find its mate, the t (top or truth) quark.

As described by Ray Crittenden of Indiana, discovery of the B meson came in part from a suggestion by CERN theorist Harold Fritzsch. From experiments at the Fermi National Accelerator Center, where the upsilon was discovered, and the Deutsches Elektronen Synchrotron (DESY) laboratory near Hamburg, where its existence was confirmed, almost everyone knew that the mass of the B meson, if it existed, would be about 5.3 GeV. The problem in particle physics experiments is to know what to look for; that is, what is the signature of a short-lived new particle among the confusing array of debris shooting out from high-energy collisions in an accelerator. Fritzsch suggested a likely signature.

A second contribution to the discovery was perhaps just a little luck. Elementary particle theorists are notorious for their ability to concoct an abundance of models to cover every possible experimental outcome. Said one experimentalist, "One theorist can produce ten predictions in a week, but it takes me three years to do one experiment." In other words, it is no surprise that some other group did not make the discovery first because there are so many ways to conduct the search.

What really made the experiment successful, however, was the detector. The researchers took advantage of some very high speed electronics developed by the Saclay members of the group. The experiment itself involved bombarding a beryllium target with negatively charged pi mesons having energies in the range 150 to 200 GeV.

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At the far end of the detector was a huge mass of iron that prevented everything but mu mesons, which are highly penetrating particles, from getting through. Whenever a pair of oppositely charged mu mesons did get through, they triggered the electronics to analyze all the particles in the detector, which comprised two parts, one to measure momenta and one to measure velocities. Computer reconstruction of the collision event permits the masses of particles created in the collision but decaying too quickly to be detected directly to be deduced. The mu meson pairs are created when a particle called the J/psi decays, and the J/psi is an expected decay product of the B meson. Hence the use of the pair of mu mesons as a triggering event for the analysis.

An interesting sidelight of the B-meson story is that the discovery was made with a proton-synchrotron. It is a fair judgment to say that the glamor accelerators of the 1970's have been the electron-positron colliding beam storage rings, in part because they can be precisely tuned to study the properties of a new particle and in part because they have higher effective collision energies per dollar spent in building them. Most physicists expected the B meson to be found in an electron-positron machine, probably the one just going into operation at Cornell. Nonetheless, the J/psi particle was found in 1974 in a proton-synchrotron at the same time it was seen in a colliding beam storage ring; the upsilon was found first in a proton machine; and now the B meson has been uncovered in one. As one theorist put it, "Maybe the dinosaurs are back."

How soon the discovery can be confirmed is an open question. The group's detector is sufficiently unusual to require considerable time and expense for other researchers to modify their detectors to achieve a comparable capability. Since CERN officials are confident enough to grant the group as much running time as it needs for the next few months, the most probable source of additional information will be the group itself.—ARTHUR L. ROBINSON

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