Unexpected Zeta Particle Baffles Physicists

The finding by an American-European collaboration working in Germany may point the way beyond the "Standard Model" of particle physics

In mid-July at the Twenty Second International Conference on High Energy Physics held in Leipzig, East Germany, a group of 79 American and European researchers that calls itself the crystal ball collaboration disclosed its tentative discovery of the zeta particle. The zeta, which is confounding theorists everywhere because it fits none of their predictions, emerged during experiments at the German Electron Synchrotron (DESY) laboratory in Hamburg.

The zeta was quite unexpected and no one knows what to make of it. "We don't know what the thing is, but, whatever it is, it will be interesting," says Steven Weinberg of the University of Texas at Austin, one of the fathers of the concatenation of quantum field theories called the Standard Model. One possibility that many would like to see come true is that the zeta is the enigmatic Higgs particle, the major piece still missing from the Standard Model. With a mass of 8.322 billion electron volts (GeV), the zeta is not out of line, although the theory does not predict a specific value for the Higgs mass. Some of the zeta's other properties, however, seriously conflict with predictions. If the zeta were a Higgs, it would be the first sign that the Standard Model needs modification. While it is not all encompassing, the Standard Model up to now has correctly described phenomena in its domain of applicability.

It is also interesting that the discovery came in a relatively low-energy accelerator, the electron-positron collider DORIS. Although it was rebuilt 2 years ago, with a maximum collision energy of about 11 GeV, DORIS is essentially two generations behind the 100-GeV electron machines now under construction. Moreover, the crystal ball detector, which ran for several years at the Stanford Linear Accelerator Center, was flown across the Atlantic to DESY especially for use with the revamped DORIS. If the zeta lives up to its potential, some expensive gambles will have paid off unexpectedly well.

DESY officials decided to upgrade DORIS to make possible detailed investigations of the upsilon family of particles. First discovered at the Fermi National Accelerator Laboratory near Chicago in 1977, the upsilons comprise a bottom quark and antiquark bound together and have masses in the neighborhood of 10 GeV. They are created in DORIS when oppositely circulating beams of electrons and positrons collide. The energy of an annihilating electron-positron pair goes into making the upsilon.

The upsilon loosely resembles the hy drogen atom in that it is a two-body quantum mechanical system. In particular, transitions from higher energy states to lower energy ones can occur with the emission of radiation. Because the force binding the quarks is the strong nuclear or color force of quantum chromodynamics rather than the electromagnetic force, the radiation is much more energetic than that in the atomic system and comes in the form of gamma rays. Another difference is that any upsilon can and does decay into other elementary particles very rapidly.

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The strategy at DESY was to have two detectors, one with the capability of tracking the decay products of the upsilons and one more specialized for their radiative transitions. Moving the crystal ball to DESY fit naturally into this plan because it had already proved its value as a high-resolution and sensitive detector of gamma rays in analogous spectroscopic studies of the family of psi particles (charm quark and antiquark). The heart of the instrument is a roughly spherical array of 732 sodium iodide crystals, which surround the collision point. Light generated when gamma photons or other particles strike the crystals gives the particles' energies and directions of flight. The crystal ball was originally the creation of a California Institute of Technology/Harvard University/Princeton University/Stanford collaboration. In moving to Europe, the group took on many more members, including one from the University of Capetown, South Africa.

As noted in the paper delivered at Leipzig, the crystal ball group, whose U.S. spokesman is Elliott Bloom of Stanford, was well aware of theorists' predictions that Higgs or even more exotic entities might be found among the remains of so-called heavy meson decays, such as those of the upsilons. In fact, the experiment was intended to search for these in parallel with the more routine upsilon spectroscopy work. The data consist of a spectrum showing the number of gamma photons recorded as a function of photon energy. A peak in a narrow energy range signals a transition.

Data were collected for two initial states. The upsilons produced in electron-positron annihilation are, in analogy with atomic physics, triplet S states; that is, they have no orbital angular momentum but the spin angular momenta of its quarks are aligned so there is a nonzero total angular momentum of 1. The two initial states were those with principal quantum number $n = 1$ and 2.

The essence of the results is that, about one time in 200, the 1S upsilon emits a gamma photon of energy 1.069 GeV in making a transition to an unknown state, the zeta particle, rather than decaying directly. However, no transitions to the zeta were observed from the 2S upsilon.

The lifetime of the zeta is determined from the width of the peak in the spectrum. It turns out that the peak is narrower than the instrumental resolution of the crystal ball, so that only a lower bound on the lifetime of just under 10^{-23} second is possible, which is relatively long for such a massive entity.

How reliable is the result? The data include 100,000 upsilons. To extract a small signal from a large background, physicists apply various selection criteria to the events (cuts in the jargon). The crystal ball group made two different sets of cuts that in effect resulted in two sets of statistically independent data, both of which showed the zeta. Taken together, the data show a 5 standard deviation effect. "I don't see any way to criticize the experiment," comments Karl Berkelman of Cornell University, which also has an electron-positron machine that is used mainly for upsilon studies.

One of Cornell's two detectors is also

a sodium-iodide-based instrument, although of a different geometry than that of the crystal ball. It was designed by a Columbia University/State University of New York at Stony Brook collaboration. According to Paulo Franzini of Columbia, the group reported at the Leipzig meeting that it also had radiative transition data for the energy range covering the zeta and had found no effect.

Statistical and estimated systematic uncertainties make the findings less incompatible than they first appear. The resolution will come with more data. A new 6-week run is under way at DESY and another search is under discussion at Cornell. Better statistics are only a few months off.

As far as theorists are concerned, there are two major stumbling blocks to understanding the zeta. One is the frequency with which it is produced in upsilon decays, which is much too high. The branching ratio for a particular decay path is the fraction of total decays that follow the path. "For most of the possible interpretations of the zeta as some kind of exotic particle, the branching ratio for its production from ordinary particles would have to be low," says Weinberg. The branching ratio for the production of a Higgs from an epsilon, according to the simplest version of the Standard Model, is about 100 times smaller than the 0.5 percent reported by the crystal ball group. Expanded versions with more than one Higgs do better, but there is another problem.

Why does the zeta come in 1*S* but not 2*S* upsilon decays? Since both consist of a bottom quark and antiquark, there should be no difference in the rates at which they decay into a Higgs. Many theorists have already started in on this problem. One early hope—that the interactions between between 2*S* and 2*P* (orbital angular momentum =1) states may somehow suppress the production of Higgs particles—now seems unlikely to be the full explanation.

The least revolutionary explanation for the zeta is that it is the singlet 1*S* (quark spins antiparallel) upsilon that should have a lower mass than the triplet 1*S* and has not yet been found. However, the theoretically predicted mass is so much greater than that of the zeta that no one gives this explanation much chance. "It is essentially impossible for the zeta to be the [singlet 1*S*]," says Bloom.

The most revolutionary candidates come from the contenders for a more all-encompassing theory than the Standard Model provides. In supersymmetry, for example, all the elementary constituents of matter have twins. The zeta could be a bound state of two gluinos, the twins of the gluons that carry the color force between quarks, as these have been predicted to form during heavy meson decays. Here the theoretical branching ratio is only a factor of 10 lower than the experimental one.

A finding possibly related to the zeta is about to be published by a group working at Stanford called the Mark III collaboration comprising physicists from Caltech, the University of California at Santa Cruz, the University of Illinois, Stanford, and the University of Washington. According to David Hitlin of Caltech, who is spokesman for the group, there is a particle of mass 2.22 GeV, the xi, that is produced in radiative decays of the psi particle. It likewise is long-lived with a lower bound on the lifetime twice that of the zeta.

If the zeta and xi are related, what are the options? Henry Tye, a Cornell theorist, says that it is conceivable that these are particles comprising four quarks rather than two, so-called molecular hadron states. Burton Richter, the director-designate at Stanford, suggests the particles could be signals of internal structure within the quarks themselves.

All in all, theorists have complained of a lack of experimental evidence that can help them select which of many proposed paths they should follow in extending the Standard Model into a more complete account of the world of elementary particles. If they are lucky, the zeta particle may start them on their way.—**Arthur L. Robinson**

Steroid Hormone Systems Found in Yeast

Sex steroids and corticosteroids in yeasts may explain their pathogenicity and yield clues to the evolution and function of hormones

David Feldman, who is chief of endocrinology at Stanford University School of Medicine, has spent most of his career studying steroid hormones in humans. But a few years ago he sat in his backyard with his colleagues and discussed how far back in evolution mammalian-like steroid hormones and receptors might go. "People kept looking at simpler and simpler organisms [and finding hormones and receptors]," Feldman noted. "But they went in small jumps—to amphibia or sharks. We felt it was worthwhile to make a big leap back and look for mammalian-like steroid receptors and hormones in really simple organisms."

Since there was already evidence for yeast peptide hormones, Feldman and his colleagues decided to look for steroid hormones and receptors in *Candida*, a well-studied yeast that frequently infects people, especially when their immune systems are suppressed. Working with David Loose, a graduate student, Feldman and David Schurman, an orthopedist at Stanford who is interested in joint infections, looked first for the receptors. "To our amazement, we found a binding site for corticosteroids that looked somewhat like the receptors we see all the time in mammalian cells," Feldman recalls. "We got very excited and we asked, 'What is it there for? They must have something like a hormone as well.' "

Now Feldman and his associates have discovered what appear to be mammalian-like receptors and steroid hormones in at least three different species of yeast—a finding that has implications for the understanding of what hormones do and how hormone systems evolved as well as possibly for the treatment of fungal infections, since some of these yeasts are pathogenic. It also fits in well with recent, and independently developed, findings by Jesse Roth of the National Institutes of Health and others that peptide hormones, such as insulin, are widespread, occurring even in bacteria (*Science*, 12 March 1982, p. 1383).

The first thing that the Stanford researchers point out is that these are not hormones in the usual sense of the word. Ordinarily, endocrinologists define a hormone as a substance that is produced in one part of the body and acts on cells elsewhere—a chemical messenger within an animal. Since yeasts are single-celled