Invariance Theory Upset

The positive and negative decay particles emerging from eta mesons leave bubble tracks that prove they do not behave identically—By Ann Ewing

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➤ THE LONG-HELD theory of physics that particles and antiparticles are mirror images of each other has been disproved.

In showing that this theory does not always hold true, scientists have discovered a way to tell absolutely whether a particle or an object anywhere in the universe is positively or negatively charged.

The overthrow of the so-called "invariance" of oppositely charged particles is the third upset to conservation laws in less than 10 years.

Physicists at Columbia University and the State University of New York at Stony Brook found that in the decay of the neutral particle known as the eta meson, the positive particle that emerges is more energetic and travels away from the reaction site faster than the emerging negative particle. This means that oppositely charged particles in interactions of intermediate strength react in different ways, not in the same way as had previously been thought.

The overthrow of the charge invariance principle resulted from an experiment carried out at Columbia's Nevis Laboratories at Irvington-on-Hudson, N.Y., and at Stony Brook. Details of the experiment were reported in Physical Review Letters, 16:1224, 1966.

The discovery has been hailed as a milestone in science bearing on the fundamental nature of matter from the nuclear to the cosmic world, since positive and negative charges are the prime factors in all electrical, magnetic, chemical and atomic reactions and interactions.

Directing the experiment was the leader of the Columbia group, Dr. Paolo Franzini, whose wife, Dr. Juliet Lee-Franzini, headed the group at Stony Brook. Financial support for the test came from the U.S. Atomic Energy Commission and also the New York State Research Foundation.

Prior to the new results, the theory was that oppositely charged particles were mirror images of each other. This theory, known as "charge conjugation invariance," held on steadfastly for decades until two years ago when Dr. Val Fitch of Princeton University and his co-workers observed a violation of the so-called CP invariance, a conservation law intimately connected with the principle of charge conjugation.

The 1964 experiments showed that time is sometimes a one-way street—it has only one direction of flow under certain circumstances. This discovery made the situation with respect to time the same as it was previously for parity.

In 1957, scientists discovered that nature makes a distinction between left-handed and right-handed in the jumbled world of particles within the atomic nucleus. This is a distinction in space, which had previously been thought symmetrical.

Now it is known that in addition to parity and time, charge is not symmetrical under all circumstances.

Following the 1964 overthrow of the time symmetry, Dr. Tsung-Dao Lee of Columbia, co-winner with Dr. C. N. Yang of Princeton University of the 1957 Nobel Prize in Physics for suggesting a test for the nonconservation of the parity principle, developed a theory to explain the violation of the symmetry of time. Others developed theories to deal with the same problem. Dr. Fitch had observed invariance violation only for the so-called weak interactions. For stronger forces in nature, the invariance principle was presumed to be preeminent. Now it, too, has fallen with the discovery that charge conjugation does not always hold true.

In the experiment, the Drs. Franzini, and Dr. Charles Baltay and Dr. Lawrence Kirsch of Columbia, with five other physicists, analyzed 1,441 instances of the decay of the eta meson into three kinds of pi mesons, or pions, one with a positive charge, one with a negative charge and one neutral.

They found that the positive pi meson traveled away from the completely disintegrated eta meson at a greater velocity than the negative pi meson.

Some 435,000 photographs, showing various decay patterns of the eta meson, were taken in the 30-inch Columbia-Brookhaven bubble chamber.

In the Columbia University photograph shown on the cover, tracks are seen at the left of positive pions, which travel in many numbers from bottom to top. The key reactions are illustrated in the drawing on the right.

When a positive pion hits a deuteron, it interacts to produce two protons (dark tracks resembling an arrowhead) and a neutral eta meson. The invisible eta meson disintegrates virtually instantaneously into a neutral pion, also invisible, and a positive and negative pion, which are seen as tracks diverging from the arrowhead vertex. These decay products, particle and antiparticle, were the ones observed to be asymmetric.

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