PHYSICS

Nuclear Theory Verified

Experimental confirmation of a fundamental theory in nuclear physics on the conservation of vector current in nuclear beta decay is reported by a Columbia University scientist.

➤ CONCLUSIVE EVIDENCE confirming a new fundamental theory in nuclear physics, the conservation of vector current in nuclear beta decay, has been obtained in experiments by Columbia University scientists.

Clear experimental confirmation of the theory was reported by Dr. Chien-Shiung Wu, professor of physics at Columbia who is known for her role in disproving the law of parity in 1957, to the American Physical Society meeting at the Statler-Hilton Hotel in New York.

The conservation theory confirmed in the experiments was originally proposed in 1958 by two theoretical physicists, Drs. R. Feynman and M. Gell-Mann, of California Institute of Technology, Pasadena.

Many scientists throughout the world have been trying to confirm the theory since 1958. The theory has "profound" significance for the understanding of the so-called "weak interactions," Dr. Wu said. Some of the most important discoveries concerning the particles and forces of the atomic nucleus have been made by studying weak interactions between particles.

The crucial confirmation made in the experiments on the conservation of vector current consisted of showing that the "beta spectrum" observed in the radioactive breakup of boron-12 and of nitrogen-12 agreed almost exactly with these spectra as predicted by the conserved vector current theory.

"Experimental results showed clearly the nearly equal but opposite effect of the conservation term on the electron and the positron spectra as predicted," Dr. Wu said. Confirmation of the theory has important consequences for other parts of nuclear theory.

"It puts the universal Fermi interaction on a much firmer foundation," Dr. Wu said, "since the lack of renormalization of the vector current in beta decay can now be rationally understood. It also gives strong support to the two-neutrino experiment."

Dr. Wu was assisted by Y. K. Lee and L. W. Mo in the experiments, partially supported by the Atomic Energy Commission.

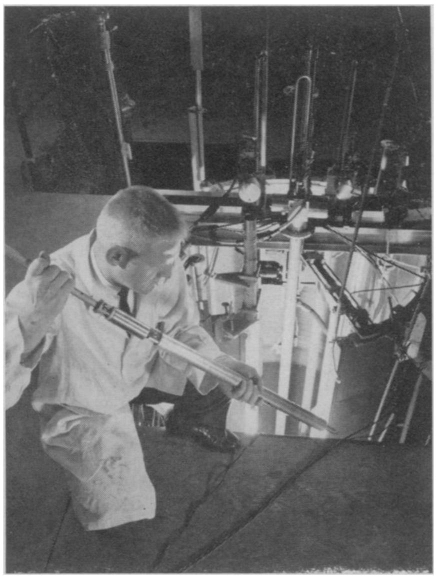
Conservation in weak interactions called conservation of vector current is analogous to the familiar case in electrodynamics where the electric charge "e" on all elementary particles is the same.

The weak interaction relates to a new type of force which is extremely weak compared to nuclear forces and electromagnetic forces. It is responsible for many relatively slow decay processes such as beta decay, muon decay, etc. The mu meson is a particle that resembles an electron in every respect except weight; it is 207 times heavier than an electron.

The hypothesis of conservation of vector currents in weak interaction was proposed to explain the mysteriously near equality observed in the interaction strength of beta decay and muon decay.

A neutron exists for only a fraction of its lifetime as a bare neutron; the rest of its life it exists as a proton surrounded by a negatively charged pion cloud (the pi mesons are now known to be principally responsible for the force that holds nuclei together), or as a neutron surrounded by a neutral pion cloud, etc. The neutron in the latter state is called a dressed or physical neutron to differentiate it from a bare neutron.

In the old beta theory, only the bare neutron is presumed to undergo beta decay, not the dressed neutron. Therefore, a neutron will beta decay for only a fraction of of its lifetime. In the old theory the effective decay constant of a neutron must be proportionally reduced or renormalized by the fraction of time spent as a dressed neutron. On the other hand, a muon does not lead such a double life; therefore its effective interaction strength should be the same as its intrinsic one.



General Dynamics

HIGH-ENERGY FUEL—New uranium-zirconium hydride fuel element, which will enable TRIGA nuclear research reactors to be "pulsed" to peak levels of 7 million to 9 million thermal kilowatts, is placed in the core of a reactor at General Dynamics' General Atomic Division in San Diego, Calif. In terms of electric power, the rate of energy production during the few milliseconds at the high energy levels will exceed that of the Grand Coulee Dam.

By the end of 1957, the conclusion was obtained that all three major decay processes in weak interactions could be described by a simple universal law. This law is known as the universal Fermi interaction, and it states that the bare interaction strength in beta decay and muon decay should be equal.

Instead, the effective interaction strength of the vector coupling in both decays was found to be nearly equal. Therefore the question arose as to why there was no renormalization required between the effective and the bare interaction strength in beta decay.

One speculation was that it might be due to a new conservation law that governs the vector current in beta decay so that no renormalization between the effective and the bare coupling constants of beta decay is needed. Taking this view, Drs. Feynman and Gell-Mann in 1958 proposed a simple and elegant explanation of the lack of renormalization of the vector coupling constants.

They proposed an exact analogy to another area of physics—electrodynamics. The electron is believed to be a simple particle with no charge distribution, whereas the proton is a very complicated object with a meson cloud surrounding the core. Yet the total charge of a proton is the same as the electric charge of an electron.

This occurs because the total charge is not changed when a virtual meson is emitted even though the charge distribution is changed.

As an analogy to the case in electrodynamics, Drs. Feynman and Gell-Mann suggested that the charged pions carry with them the beta interaction strength when they are emitted virtually from the nucleons, and that the vector part of the nuclear beta interaction is so arranged as to have no renormalization effects.

Drs. Feynman and Gell-Mann adopted the analogous mechanism to electrodynamics, where conserved electric current consists of the sum of both the charge current of the proton and charge current of pions. They therefore attributed beta-emitting power to the pions and postulated that the beta interaction current is also made up of the sum of the currents of the nucleon and pion.

Thus, the beta interaction strength of the physical nucleon should be the same whether it involves strong interaction with pions or not. This is known as the conserved vector current hypothesis.

One of the possible experimental tests for this hypothesis suggested is to measure carefully the shapes of the beta spectra of B-12 and N-12 and compare them with predicted spectrum shapes based on the conserved current hypothesis. Unfortunately, the predicted effects on the spectra due to the conserved current are extremely small. Furthermore, there are always distorting effects present in such measurement unless one takes special precautions.

• Science News Letter, 83:85 February 9, 1963