Obituary

Chien-Shiung Wu (1912–97)

Experimental physicist,
co-discoverer
of parity violation

Chien-Shiung Wu died of a stroke on 16 February 1997. Forty years earlier, on 15 February 1957, *The Physical Review* (105, 1413) published the historic paper, "Experimental test of parity conservation in beta decay", by C. S. Wu of Columbia University and E. Ambler, R. W. Hayward, D. D. Hoppes and R. P. Hudson of the National Bureau of Standards (NBS). In that paper, through investigations on the beta-decay of cobalt-60, they established for the first time the non-conservation of parity (P) and the violation of particle–antiparticle conjugation symmetry (C) in physics, both of which had been taken for granted as basic laws of nature.

Parity in physics means right–left symmetry. That is, take two systems which are mirror images of each other but otherwise entirely identical: parity conservation says (which also seems self-evident) that except for this mirror difference all subsequent evolution of these two systems should remain identical. This is precisely what the ^{60}Co experiment showed to be untrue. Now we know that parity violation exists nearly maximally in all weak processes (that is, those such as beta decay which involve the weak nuclear force). But before 1956, the 'self-evident' nature of parity made physicists unwilling even to entertain the possibility of its violation.

Discoveries in physics are made by looking in a new direction, quite often with the latest detection technology. The experiment on ^{60}Co was one such example. However, once parity was known to be violated, there were hundreds of other experiments that could be readily performed within a few days at many laboratories. This rare circumstance made the discovery of parity violation a particularly dramatic event.

At that time, almost the entire physics community wanted to participate in the overthrow of parity by undertaking experiments with other particles (pions, muons and hyperons), other nuclei and other decay processes. Wu, Ambler, Hayward, Hoppes and Hudson, and a few of their close colleagues who also engaged in the quest, chose to inform the world by holding a press conference at Columbia University on 15 January 1957, before the publication of their paper. This gave all

physicists an even start in verifying or extending this discovery. The human aspect of Wu's work on the experiment, her pleasure in collaborating with her co-authors at NBS and her joy in discovery are well documented in her moving account in *Adventures in Experimental Physics* (Gamma volume, World Science Education, Princeton, 1973).

Chien-Shiung Wu was born on 31 May 1912, shortly after the overthrow of the Qing (Manchu) Dynasty on 10 October of the preceding year. (The Chinese character for 'chien' means 'healthy' and for 'shiung' means 'male'.) Her birthplace was Liuhu, a small town near Shanghai. At that time the Western educational system did not exist in China and girls were educated at home, if at all. Through the encouragement of her father, she went to Shanghai to enrol in a class taught by Dr Hu Shi, the leading Chinese scholar (who revolutionized the Chinese language from the classical to the present form). Hu Shi immediately recognized her talents and gave her the confidence to enter the National Central University in Nanjing, where she received her BS degree in 1934.

Wu came to the United States in 1936 and received her PhD from the University of California, Berkeley, in 1940. She then taught at Smith College and Princeton University before joining Columbia in 1944, where she spent 37 years of her life doing research and teaching. She received many honours, including the Wolf prize (1976). Throughout her life, she was dedicated to science, meticulous in her experiments, and charming and gracious under all circumstances.

In 1934, Fermi proposed his theory of beta decay, but later on there were serious discrepancies between it and experiment. Then, in 1949 and 1950, through a series of experiments, Wu and her collaborators measured the allowed and forbidden beta spectra, corrected many previous mistakes,

disproved the alternative Konopinski–Uhlenbeck formulation and firmly established Fermi's theory. In 1963, she, Y. K. Lee and L. W. Mo observed the magnetic equivalent of the weak nuclear force, thereby confirming the symmetry between the weak and electromagnetic currents, which set the cornerstone for the later unification of these two basic forces into a single one — the electroweak force.

The ^{60}Co experiment of Wu *et al.* was a turning point in physics. The experiment itself established the violation of parity and charge conjugation symmetry, but it also started an avalanche of tests for all kinds of symmetry violations. In 1964, from the experiment by Christenson, Cronin, Fitch and Turlay, it was found that the joint symmetry CP and the time reversal symmetry T were both violated. However, as far as we know, the symmetry CPT remains intact; that is, we regain symmetry through the combined interchange of particle and antiparticle, right and left, and past and future.

The origin of these symmetry violations is still a mystery. Presumably, at the time of the Big Bang, the Universe was CP symmetric. Yet our very existence depends on CP asymmetry, which accounts for the preponderance of protons and electrons (matter) over antimatter in the Universe. CP violation has to have played a key role in making that happen, and thanks to the work of Wu and others an exciting new horizon opened up. The search for the origin and new signals of CP and T violations is the driving force of the high-energy B Facility accelerators in the United States and Japan.

When Madame Curie passed away, Einstein wrote as follows. All of his words apply equally to Chien-Shiung Wu. "At a time when a towering personality has come to the end of her life, let us not merely rest content with recalling what she has given to mankind in the fruits of her work. It is the moral qualities of its leading personalities that are perhaps of even greater significance for a generation and for the course of history than purely intellectual accomplishments. ... Her strength, her purity of will, ... her objectivity, her incorruptible judgement, all these were of a kind seldom found joined in a single individual. ... Once she had recognized a certain way as the right one, she pursued it without compromise and with extreme tenacity."

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