Parity and chivalry in nuclear physics

Forty years ago, the world of physics was stunned by the discovery that nuclear beta-decay does not respect symmetry between left and right. But the credit for this conclusion has not been properly attributed.

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On 15 January 1957, the physics department of Columbia University in New York held a press conference, and the following day headlines on the front page of *The New York Times* declared "Basic concept in physics reported upset in tests. Conservation of parity in nuclear theory challenged by scientists at Columbia and Princeton Institute." It was unusual in those days for scientific results, however important, to be announced first at a press conference rather than at a scientific meeting or in a professional journal. The scientific paper appeared a month later on 15 February 1957 in *Physical Review*, and this fortieth anniversary of publication provides a good opportunity to look at those controversial events.

The great excitement was triggered by results from an experiment suggested the previous summer by theorists T. D. Lee and C. N. Yang to test the conservation of parity in weak interactions. Lee, from Columbia University, and Yang, from the Institute for Advanced Study in Princeton, had been considering one of the most puzzling effects of the time, the so-called 'θ–τ' paradox. θ and τ are two short-lived 'strange' subatomic particles, so called because although they are made readily in particle collisions through strong interactions, they decay only on the longer timescales typical of weak interactions. The additional puzzle was that they have exactly the same mass, but can decay to states of different 'parity'.

Parity refers to a complete inversion in space, which has the effect, for example, of turning a right-handed corkscrew into a left-hand one. A system that has right–left symmetry will not change under the parity operation and is said to have positive parity, whereas a handed system, such as a corkscrew, does change and is said to have negative parity. The θ and τ decayed to sets of particles with opposite parity (two pions and three pions respectively), implying that they could not be the same particle, unless parity could somehow change in the weak decays. However, physicists believed that parity is conserved (stays the same) in all basic physical processes.

Lee–Yang hypothesis

In 1956, as more conventional explanations for the θ–τ puzzle were unsuccessful, Lee and Yang began to consider seriously the alternative of parity non-conservation and set out to discover whether there were other weak interactions in which parity was not conserved. After working through a great deal of experimental evidence from nuclear beta-decay, they realized that no experiment had measured an effect that would change hands under parity. The key would be to measure something that changes, such as momentum, relative to something that does not, such as direction of spin.

In June 1956, Lee and Yang submitted a paper to *Physical Review* in which they suggested ways of testing for parity conservation[1]. One idea was to measure the electron emission in β-decay from oriented nuclei to see if the intensity changed when the polarizing field was reversed. Any asymmetry would be proof of parity violation.

The NBS test

In the United States, the National Bureau of Standards (NBS) was one of only two places where nuclear orientation work, by Ambler, Hudson and Temmer, was being done. C. S. Wu, a colleague of Lee's at Columbia University and an authority on β-decay, approached Ambler, who three years earlier had polarized γ-decaying cobalt-60 (^{60}Co) nuclei in his thesis work at the Clarendon Laboratory in Oxford. As a result it was decided late in July that the parity experiment would be carried out at NBS by Ambler, Hudson, Hayward (an experimental nuclear physicist), Hoppes (his research assistant), all from the NBS, and Wu.

Although the technique of γ-ray nuclear orientation experiments at millikelvin temperatures was well established by 1956, β-decay experiments presented special difficulties. Because of the strong absorption of β-rays, the scintillation detector had to be inside the cryostat and the light pulses transmitted to a photomultiplier at room temperature. For the same reason, the β-activity had to be concentrated in a 50-μm outer layer of the single-crystal cooling substance. To prevent this exposed layer from warming above the temperature of the bulk of the crystal, the thermal insulation had to be much better than in the γ-ray experiments. Thus it was not until December 1956 that the forward–backward asymmetry of the β-emission, on reversing the polarizing field, was first observed. The reason for describing these difficulties is that at the time many people thought that there was no more to the experiment than for Wu to turn up at NBS and receive from Ambler and Hudson a cerium magnesium nitrate crystal doped with ^{60}Co — and parity conservation tumbled.

Indeed, in his Rutherford memorial lecture in 1958, P. M. S. Blackett said "It took Wu and colleagues 48 hours to show experimentally that the β-particles emitted from magnetically oriented ^{60}Co nuclei were emitted asymetrically with regard to the direction of the magnetic field." But he also pointed out that experimentalists were discouraged by the theorists from wasting their time on experiments that were bound to confirm parity conservation[2].

On 12 January 1957 the paper was ready to be sent to *Physical Review*. In those days it was usual to list authors in alphabetical order, unless one was the leader of the team or the originator. But, in this instance, it would have been unseemly for the 'A' and the 'H' authors to suggest such an order; the proposal would have had to come from the 'W' author. When this did not happen, the chivalrous suggestion was made that as Wu was the only woman she might sign first. (One wonders whether 40 years on such a suggestion would be regarded as an early example of affirmative action or a sexist remark!) So the authors of the paper describing the NBS parity violation experiment were listed as Wu, Columbia University, and underneath, on a separate line, Ambler, Hayward, Hoppes and Hudson, NBS[3].

This gave the impression that Wu was the principal author, and as a result the experiment was and is often referred to as the "Wu experiment". This attribution was first made by Garwin *et al.*[4], whose paper on parity violation in meson decay followed the paper by Wu *et al.*[3]. They thanked Wu for "reports of *her* results of the ^{60}Co experiments", rather than the *NBS* results. When in 1978 Wu was chosen as the first physics recipient of the prestigious Wolf Prize, the the NBS experiment was cited as "her most famous work".

The purpose of this note is to state for the record that the NBS parity violation experiment was a collaborative team effort in which nuclear physicists and cryophysicists pooled their knowledge and expertise to carry out an experiment proposed by Lee and Yang, thus confirming their hypothesis that parity is not conserved in β-decay. In writing this article, we relied on published papers, unpublished or personal information and somewhat shaky reminiscences of one of us (N. K.). We are grateful to Ralph Hudson for putting us right on some facts. □

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