search & discovery

Second-class currents in beta decay?

Denys Wilkinson has recently raised again the issue of whether or not second-class currents exist in the weak interaction. Second-class currents are defined as having the opposite behavior under G-parity as first-class currents. The G-parity operation is the product of charge conjugation and charge symmetry (which rotates the isotopic spin through 180 deg). Although known to be conserved in strong interactions, G parity might very well not be a useful symmetry for the discussion of weak interactions.

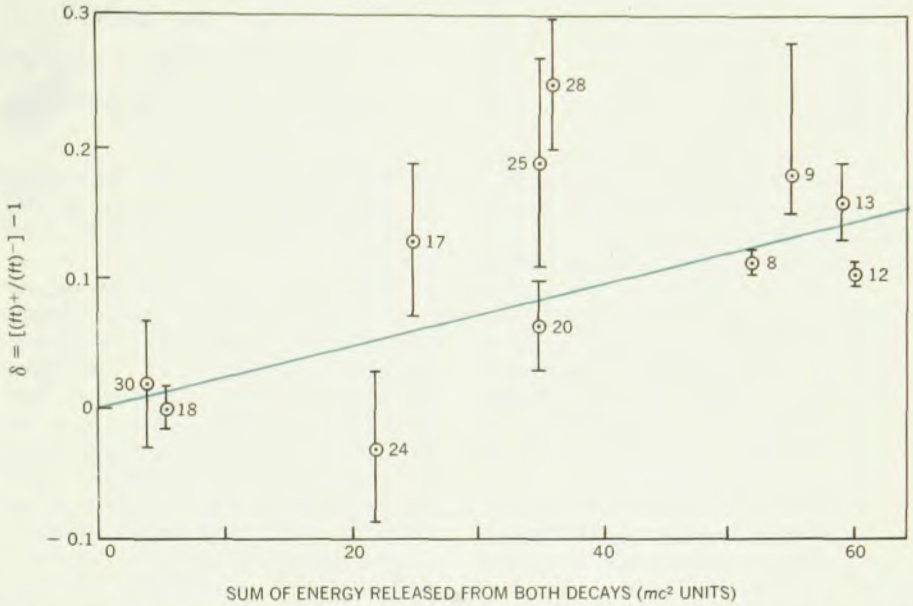
Still, the highly successful conserved vector current theory, which uses no second-class currents, has stood up exceedingly well since it was developed twelve years ago by Richard Feynman, Murray Gell-Mann, Robert Marshak, E. C. George Sudarshan and others. The more recent modification by Nicola Cabibbo, to allow for strange-particle decay, also does not include second-class currents.

If second-class currents exist, one would expect that, after correcting for nuclear and electromagnetic differences, pairs of mirror nuclei would have identical intrinsic beta-decay rates. Wilkinson analyzed existing data and, together with David Alburger (Brookhaven) has developed some new data. Wilkinson says that the present data are consistent with second-class currents, although they by no means prove that the currents exist.

The conserved vector current picture makes an analogy with electromagnetism. One thinks of two currents interacting with each other, the nucleon (or hadronic) current and the lepton current, L_μ. If the analogy were exact, the interaction strength would then just be the product of the two currents.

In beta decay, however, spin is significant. Enrico Fermi had guessed that the nucleon spin would not flip. However it was later found by George Gamow and Edward Teller that in some cases the nucleon spin does flip. If one ignored the strong interaction, the hadronic current could be written as $\gamma_\mu (1 + \gamma_5)$. The first term, the vector component, represents the spin not flipping and the second, the axial vector component, represents the spin flipping.

continued on page 19



Importance of second-class currents in beta decay. Each point represents a mirror pair; the number beside the point is *A* value. Ordinate is δ, the ratio of intrinsic decay rate for positron emission to that for electron emission, minus one. If second-class currents exist, δ should be proportional to the sum of the energy released from both kinds of decay. Straight-line behavior is consistent with second-class currents.

Experimenters vie for first crack at Batavia

With Robert R. Wilson's recent announcement that the Batavia accelerator might have a beam in mid-1971 and that a low-intensity beam of 500 GeV could be produced not long after (PHYSICS TODAY, June, page 29), high-energy physicists are clamoring for a chance at being first to use the new machine. A call for proposals brought more than 80 replies, enough for several years' worth of experiments. Edwin Goldwasser, deputy director of the National Accelerator Laboratory, told us that some time this month NAL may tentatively accept some of the proposals—those that require a university group to start work now so that it could be ready in summer or fall of 1972.

The program advisory committee met for a week last month in an intensive attempt to find out what kinds of experiments should be the first on the accelerator. With the benefit of that advice NAL is now deciding what kind of equipment will be needed, which apparatus should be built by university groups, which by NAL. This fall NAL will probably commit itself to one or two fairly large pieces.

What kinds of experiments do people want to do? Of course every time a new energy realm opens up, the natural thing to do is search for those mythical particles theorists continue to talk about—the magnetic monopole, the intermediate vector boson, and of course the quark (which some experimenters claim is no longer just a gleam in Gell-Mann's eye).

Total cross sections are another must, especially because preliminary results from the 70-GeV accelerator at Serpukhov on π^-–p and K^-–p (PHYSICS TODAY, October 1969, page 57) suggest to some observers that the Pomeranchuk theorem could be wrong. The theorem predicts that for strong interactions, in the high-energy limit, the cross the absolute cross section to about 3%. Such precision is needed to distinguish between various theories.

Although CERN physicists have been actively engaged in joint experiments with Soviet scientists at Serpukhov and French physicists are installing the Mirabelle bubble chamber there, negotiations between the Soviet State Committee for the Utilization of Atomic Energy and AEC had lasted for several years. Several preliminary proposals from US experimenters were sent from AEC to Serpukhov.

This spring an exchange of letters between AEC chairman Glenn Seaborg and Andronik M. Petrosyants of the State Committee finally appears to have cleared the way for the first US–Soviet collaboration. NAL had extended an invitation to Soviet physicists to attend NAL's summer study, and Seaborg had categorically agreed that one or more joint US–Soviet experiments could be performed at NAL (although NAL would not promise a specific experiment before receiving a detailed proposal).

Meanwhile some of the Americans proposing experiments had fallen by the wayside, preferring either to wait for the Batavia machine to turn on, or to do an experiment at the CERN Intersecting Storage Rings. But the UCLA–Dubna experiment, which Seaborg specifically suggested to Petrosyants, is particularly convenient for both sides. The Dubna group was already scheduled to start running the experiment in mid-October. And the UCLA participation should improve the accuracy considerably. UCLA will bring over some of the readout electronics, a Hewlett-Packard 2116 B and the associated software to permit on-line operation. The Dubna experimenters will set up the beam, supply the target, wire chambers, shower counters and some readout electronics. —GBL

Second-class currents

continued from page 17

Such a simple description works when there are no strong interactions.

The conserved vector current theory makes the hypothesis that when you switch on the strong interactions the vector component is unaffected. The axial-vector current, however, cannot be conserved. If it were, for example, the ordinary decay of a π^+ into a μ^+ and a neutrino would not occur. So the axial vector component gets multiplied by a factor λ, which results from the strong interaction. λ is the ratio of the axial vector coupling constant g_A to the vector coupling constant g_V and can be experimentally determined (current value is -1.226 ± 0.011).

What can one say from general principles like Lorentz invariance about the form of the Hamiltonian when one introduces the strong interactions? In the limit when momentum transfer is low (much less than the rest mass of the nucleon) the Hamiltonian is:

$$H = [\gamma_\mu(1 + \lambda\gamma_5) + i\sigma_{\mu\nu}(A + B\gamma_5)\,\partial/\partial x_\nu + (C + D\gamma_5)\partial/\partial x_\mu]L_\mu$$

The last four of the six terms are called "induced terms" because they are induced by the strong interaction. The first term and the A and C terms are hadronic vector current terms. Conserved vector current theory says that the first term stays equal to one when the strong interactions are turned on, that A (the weak-magnetism term) is numerically equal to the difference between the anomalous magnetic moments of the neutron and proton, and that C (induced scalar term) is equal to zero. From dispersion relations one can show that D (induced pseudoscalar term) is approximately equal to -0.04. The unknown quantity is B, the induced tensor term.

Confirmation. Conserved vector current theory has had three important confirmations. The theory predicts that the intrinsic decay rate will be the same for all beta decays in which the initial and final spin are zero and there is no parity change. Because there is no change in overall spin, only the vector component is involved. In the eight such transitions known, the rates agree.

Another confirmation is the theory's prediction that the branching ratio for $\pi^+ \rightarrow \pi^0 + e^+ + \nu$ will be $(1.035 \pm 0.005) \times 10^{-8}$. Experiments give a value of $(1.023 \pm 0.069) \times 10^{-8}$.

The third verification was the theory's prediction of a difference between the shape of the beta-decay spctrum for B^{12} and N^{12}. Instead of the "allowed" straight-line behavior, the induced weak-magnetism current produced a bow upwards for one and a bow downwards for the other of the predicted magnitude. While these spectra were being accurately determined, it turned out that the intrinsic decay rates were different, too.

Look in the mirror. In the mean time Steven Weinberg had pointed out that if one studied the mirror pair B^{12} and N^{12} (or other mirror pairs) one might find out something about the induced tensor current. He showed that under the G-parity operation the only terms in the Hamiltonian to change sign are B and C. (The contribution from C would be negligible in beta decay and in any case would be zero under conserved vector current theory.) The terms that changed sign under G parity he called "second-class currents."

In the isobaric triad of mass 12 one can turn the ground state of B^{12} into that of N^{12} by converting two neutrons into two protons in states identical to those of the two neutrons. So under charge symmetry the two nuclei have

NEW f/2 SCHMIDT TELESCOPE at Goddard Space Flight Center is designed for fixed-focus astronomical observations in the presence of changes in ambient temperature. This feature is desirable in photographing comets that are close to sun and can only be observed for short times at dusk and before dawn. Design employs low-expansion CER-VIT rods to maintain spacing between 23-inch CER-VIT primary mirror and focal region assembly. Telescope will also be used to probe solar wind at remote locations by recording orientations of ionized gas components of comet tails. Photo shows comet camera being lowered onto telescope mount.

identical structures. Similarly in their beta decay to C^{12}, B^{12} and N^{12} are linked by the charge conjugation of the leptons. If the weak interactions are invariant under the combination of charge symmetry and charge conjugation in this sense, then the intrinsic rate of decay of B^{12} and N^{12} will be the same (after one corrects for electromagnetic and nuclear effects). That is, if when one goes from B^{12} to N^{12} one only has plus terms in the Hamiltonian ($B = 0$ as well as $C = 0$), then the strength of decay when N^{12} decays will be the same as for B^{12}. But if the minus-sign terms are present, they will subtract from the N^{12} decay if they added to the B^{12} decay; then one will observe different intrinsic decay rates.

Subsequent experiments showed that in fact the intrinsic decay rates differed by more than 10%. Careful nuclear-structure calculations by Roger Blin-Stoyle and M. Rosina showed that the discrepancy might be a real one. That was five years ago, and there the matter rested until last Christmas when Wilkinson decided to look into the present experimental knowledge of mirror-pair beta decay.

Relative decay rates. In actual nuclear-physics experiments one finds the intrinsic decay rate by determining the ft value (where t is the halflife of the transition and f is a statistical factor depending on the amount of energy available for the transition). If there are no second-class currents the ratio of the ft value for positron emission to the ft value for electron emission would be equal to one. So $\delta = [(ft)^+/(ft)^-]-1$ is a measure of how important second-class currents are.

Although the effect of finite B is difficult to calculate, as energy goes up the expression simplifies and δ becomes directly proportional to the sum of the energy released from the two kinds of decay, Wilkinson told us. He feels that when energy released is as high as 10 MeV, the simple form should be good to a few percent.

Wilkinson's examination of the data showed that many ft values were not known well enough. A plot of δ vs. the sum of the energy released looked like a straight line if one disregarded a few maverick mirror pairs. So Wilkinson and his long-time collaborator, Alburger, decided to make new measurements for the isotopes that appeared uncertain.[2,3] Their measurements on $A = 18$, 20 and 25 made the situation much clearer; there are now no major discrepancies. When we visted the two men at Brookhaven late in July they were measuring the lifetimes of Na^{20} and B^{13} to see if the straight-line behavior would still look good.

Then Wilkinson was going to the University of Washington, where he will spend a sabbatical year on leave from Oxford University, where he is the professor of experimental physics (somewhat of a misnomer, because he is equally famous as a theorist).

[Wilkinson also has been active as an ornithologist. When doctors gave him six months to live after he received an overdose of radiation (he still doesn't know how) in World War II, he became interested in bird navigation. He showed that the traditional method of releasing birds in a group and timing how long they took to return to their nests was producing results that could be predicted from a diffusion model. Although experimenters then discarded the technique in favor of individual release of birds, ornithologists still haven't come up with an explanation of how birds do find their nests again, though they have established that some birds are indeed able to.]

Wilkinson pointed out that one would expect ft values to be the same only if the nuclear structure of the mirror pair is exactly the same; but it cannot be, if only for the differing electromagnetic interaction in the two nuclei. In $A = 12$, for instance, the binding energy of the last proton in N^{12} is different than that of the last neutron in B^{12}; so the wave functions will overlap differently when they decay to C^{12}, causing a different decay rate. But the best calculations on $A = 12$ suggest a difference of only 2%, whereas experimentally the difference is 12%. One thing Wilkinson plans to do in Seattle is to collaborate with Ernest Henley there on some nuclear-structure calculations.

Where else can one look for evidence of second-class currents in mirror nuclei? One needs a big energy release for the straight-line behavior to be valid. This occurs when the central member is an even–even nucleus because it costs a lot of energy to break it up. One soon runs out of even–even nuclei, though, as one needs too many neutrons to hold the nucleus together. The big energy release also occurs in odd-mass nuclei when one starts from a mirror pair; one tends to run out of the higher Z member of the pair because, again, as Z increases one needs more neutrons.

High-energy physics also provides a test for second-class currents, but it is far from definitive. One can look at the mirror beta decay of the Σ^+ hyperon into Λ^0 and the Σ^- hyperson into Λ^0 to see if the intrinsic decay rates are the same (provided that hyperons decay by the same process as ordinary neutrons and protons). Because the events are rare, the data are not accurate. The data suggest, Wilkinson told us, that if there is a second-class current it behaves oppositely to what one sees in nuclei. That is, in nuclei, positron emission is slower than electron emission. The statistically insignificant data for Σ decay tend towards the opposite effect.

One can also look for second-class currents in muon capture by C^{12}, and other light nuclei but one cannot look at the mirror situation. Wilkinson says calculations may show a slight indication of second-class currents.

Wilkinson emphasized that he is not claiming that second-class currents do exist. He does say that there is a linear dependence of the intrinsic decay-rate discrepancy on energy that is consistent with second-class currents. And that lots more work needs to be done. —GBL

References

1. D. H. Wilkinson, Phys. Lett. **31B**, 447 (1970).
2. D. H. Wilkinson, D. E. Alburger, Phys. Rev. Lett. **24**, 1134 (1970).
3. D. E. Alburger, D. H. Wilkinson, Phys. Lett. **32B**, 190 (1970).

First observatory in Israel to have 40-inch telescope

The Tel Aviv University Observatory is expected to be completed by November. Anticipated research, using primarily a 40-inch wide-field Ritchey–Chretien reflecting telescope, includes infrared observations of star formation, and studies of young clusters and stars known to be losing mass. Israel's first astronomical observatory is supported equally by Tel Aviv University and the Israeli government, the Smithsonian Institution, and the American Friends of Tel Aviv University. The Observatory director is Uri Feldman. Staff members of the Smithsonian Astrophysical Observatory will conduct joint research with Israeli astronomers.

Deep space network equipment available for radio astronomy

Cal Tech's Jet Propulsion Laboratory has announced that some of the equipment in its Deep Space Network (DSN) is available free for limited use by qualified radio scientists. DSN equipment includes a 210-foot paraboloid and an 85-foot paraboloid at Goldstone, California and 85-foot paraboloids overseas.

The 210-foot antenna is now used in the 2.3-GHz range with zenith system temperatures under 20 K and 0.6 aperture efficiency. It will shortly have equipment in the 8-GHz range with about 30-K system temperature and 0.4 to 0.5 efficiency. About 5% of the time on the 210-foot will be alloted for radio astronomy.

Detailed technical information and proposal procedures are available from Don Spitzmesser, CIT JPL, 238-334, 4800 Oak Grove Drive, Pasadena, Calif. 91103. Proposals should be sent to Jesse Greenstein at Cal Tech, who heads experiment-selection panel. □