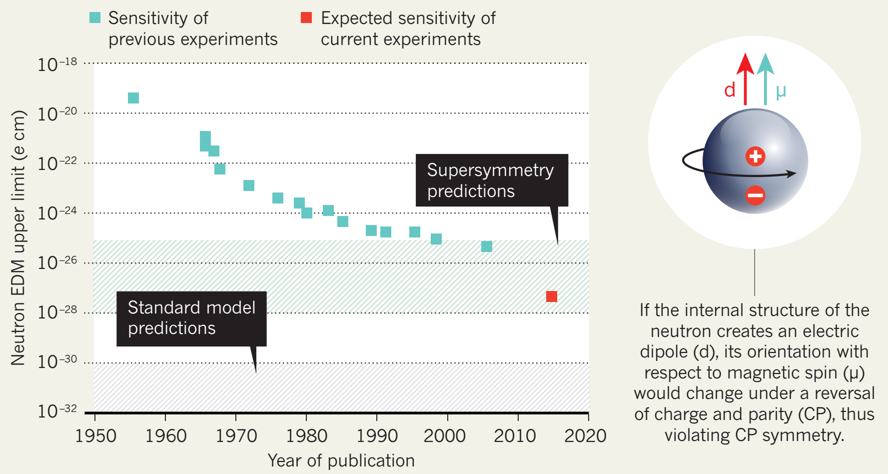
SOURCE: A. KNECHT

LOWERING THE BAR

The standard model of particle physics predicts a small electric dipole moment (EDM) for the neutron, well below the sensitivity of previous experiments. A larger dipole, predicted by some versions of supersymmetry, should lie within the range of three current experiments.



PHYSICS

Dipole hunt stuck in neutral

Physicists admit to delays as attempts to measure the neutron's charge are plagued by difficulties.

BY EUGENIE SAMUEL REICH

Discovered 80 years ago this month, the neutron is famous for what it lacks: electric charge. Yet this is a simplification of a deeper truth. Each neutron is made of charged quarks: two down quarks that each carry a negative charge one-third as strong as an electron's; and an up quark that carries a two-thirds positive charge.

In theory, this arrangement could create an electric dipole moment (EDM) — an offset between the centres of positive and negative charge. Measuring the EDM could reveal clues to physics as profound as that sought at the Large Hadron Collider (LHC) at CERN, Europe's particle-physics lab near Geneva, Switzerland. Unlike the LHC experiments, which rely on sheer energy, dipole measurements are so subtle and easily foiled that the three leading efforts are woefully behind schedule.

This week, a US team that is developing a neutron EDM experiment at the Oak Ridge National Laboratory in Tennessee is awaiting feedback from a technical-review committee after delays forced the group to update its research plans. A team at the Laue-Langevin Institute in Grenoble, France, had intended to begin taking data in 2009, but is still running tests on its apparatus. A third group, based in Switzerland, is aiming to collect its first batch of data later this year after problems prevented it from beginning its run in 2011.

"The experiments have all taken a lot longer than any of us thought they would," says Philip Harris, a physicist at the University of Sussex, UK, and spokesman for the Grenoble-based effort.

The stakes are high. An EDM for the neutron would violate charge–parity symmetry, which dictates that particle interactions are unchanged when particles are replaced by their antimatter counterparts and by their mirror images. The standard model of particle physics predicts subtle violations of charge–parity symmetry and proposes an EDM that is below the sensitivity of any currently achievable experiment. But a larger neutron EDM, possibly detectable by the latest efforts, could point to physics beyond the standard model (see 'Lowering the bar'). One popular theory, called supersymmetry — which predicts a zoo of undiscovered particles and interactions — includes the possibility that a process known as electroweak baryogenesis took place in the early Universe, producing more matter than antimatter and breaking the symmetry between charge and parity.

Physicists at the LHC are also seeking hints of supersymmetry. Yet as the US$6.5-billion LHC has forged ahead, the neutron EDM experiments, with modest budgets of tens of millions of dollars, have hit a wall. The Swiss-based experiment at the Paul Scherrer Institute in Villigen aims to measure the dipole moment by comparing the movement of neutrons in a strong electric field to that of mercury atoms in the same field. But the experiment has been sidetracked by contamination from an unknown source that destroyed the polarization of the mercury atoms. Researchers have had to replace several parts of the apparatus to solve the problem, says project spokesman Klaus Kirch, a physicist at the Swiss Federal Institute of Technology in Zurich.

The Grenoble-based experiment has run into different problems. It uses liquid helium to cool neutrons to almost absolute zero, then observes whether their behaviour changes in an electric field. But the researchers have been stymied because the liquid helium boils and begins to break down as stronger electric fields are applied.

The US experiment, co-funded by the Department of Energy and the National Science Foundation, has had a similar problem. It aims to detect the neutron's presumed EDM by looking for changes in the light emitted when cold neutrons interact with helium-3 nuclei in the presence of an electric field, a process that is subtly altered if the neutron has an EDM. The project's co-spokesman, Paul Huffman of North Carolina State University in Raleigh, says that trial runs on a test apparatus ran into problems when bubbles began to form on its electrodes. He says that the group is now searching for alternative electrode coatings and is considering increasing the pressure in the experiment, which might prevent the bubbling.

"The experiments have all taken a lot longer than any of us thought they would."

The US agencies funding that project are tracking the problem. Last year, the Department of Energy delayed a decision on whether to approve the experiment by two years to allow for more exploratory research and development. "What we basically did was to move the goalposts," says Peter Jacobs, a senior scientist at the Lawrence Berkeley National Lab in California, who was involved in the review. Now, a second technical-review committee is assessing the latest research plans for the experiment.

Despite the problems, nuclear and particle physicists continue to express broad support for the neutron EDM studies, which they say are a unique complement to the LHC work. "It's a constellation of experiments that is critical," says Michael Ramsey-Musolf, a theoretical physicist at the University of Wisconsin-Madison. ■