Not-So-Neutral Neutron: Clearer View of Neutron Reveals Charged Locales

Science News, week of April 29, 2002

Textbooks say the neutron has no electric charge, but physicists have long suspected that the particle is a more complicated beast. A new accelerator study is helping physicists see clearly an aspect of neutron structure they could only guess at before: Neutrons may be electrically neutral overall but charged at different locations within their tiny volumes.

The new data from the Thomas Jefferson National Accelerator Facility in Newport News, Va., reveal a slight positive charge at the neutron's center and a slight negative charge at its surface.

Those findings may help scientists better understand matter on scales that are both smaller and larger than neutrons themselves, says theorist Franz Gross of the College of William and Mary in Williamsburg, Va., and the Jefferson Lab. For example, the data may shed light on the locations and interactions of quarks, the smaller, fundamental constituents of neutrons and protons. They also may provide insights into how neutrons and protons, which are collectively known as nucleons, arrange themselves to form atomic nuclei, Gross says.

Andrei Yu Semenov of Kent State University in Ohio and a member of the Jefferson experimental team presented the new neutron data last week in Albuquerque at a joint meeting of the American Physical Society and the High Energy Astrophysics Division of the American Astronomical Society.

For decades, physicists have investigated nucleon structures by firing electrons at them (SN: 8/27/94, p. 140). From the way the electrons scatter off the particles, it's been possible to infer the locations and strengths of the electric charges and magnetic fields of the nucleons.

In the past few years, researchers have greatly reduced uncertainties in such measurements by exploiting magnetic field orientations, or polarizations, of both the electron beam and the nucleon targets. The technique is akin to "getting a new pair of glasses" for viewing nucleons, says James J. Kelly of the University of Maryland in College Park.

In previous experiments, scientists at the Jefferson Lab have already used that technique to probe the electrical structure of the proton, and last year the researchers found surprising evidence that the distributions of the particle's electric and magnetic fields are different (SN: 5/5/01, p. 277: http://www.sciencenews.org/20010505/fob3.asp).

Now, to look at the neutron's electric-charge structure, Semenov, Kelly, and their colleagues have used exquisitely cold deuterium, an isotope of hydrogen whose nucleus contains a neutron as well as a single proton. They mapped the electric-charge layout with an accuracy of about 4 percent of the nucleon's diameter, Kelly says. That's when the neutron's inner positivity and outer negativity became unmistakable.

T. William Donnelly of the Massachusetts Institute of Technology notes that recent, lower-energy experiments in both the United States and Europe had already revealed an uneven distribution of charge in the neutron. Without the new high-energy data from the Jefferson experiments, however, the picture would have remained fuzzy. Says Donnelly, "These are really quite breakthrough measurements."