General Discussion Points

- Hall C Scientific Highlights
  - One-Page "Easy" Writeup on Finalized Hall C Experiments (or not)
  - Would like to add to Hall C Webpages
- Summer Hall C Meeting
  - Physics Oriented
  - Adjacent to June 11-13 Users Meeting?
  - Organization?
- 2003 Conferences/Workshops
  - Coordinating/Nominating Committee?
- January 2004 Meeting and Structure?
- Other suggestions for change/improvement?

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.

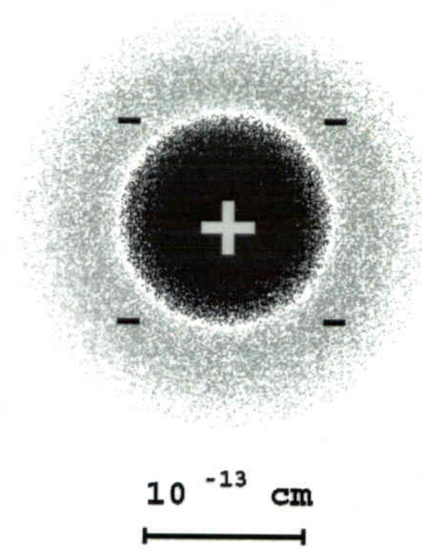
Those findings may help scientists better understand matter on scales that are both smaller and larger than neutrons themselves, says theorist Franz Gross of the College of William and Mary in Williamsburg, Va., and the Jefferson Lab. For example, the data may shed light on the locations and interactions 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).

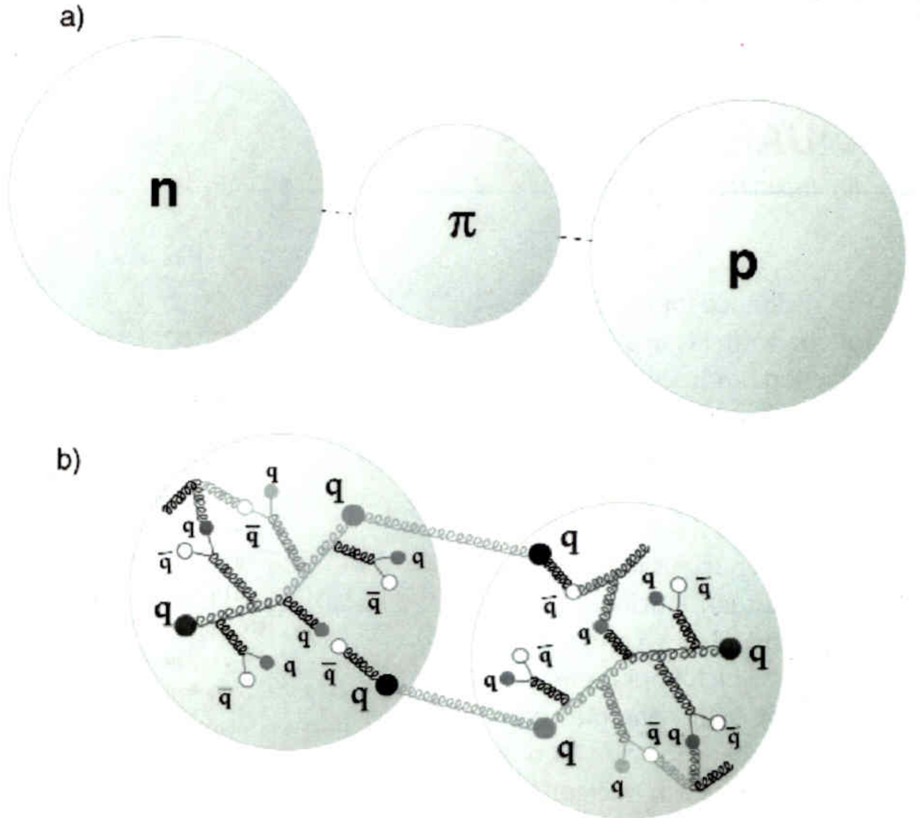


Now, to look at the neutron's electric-charge structure, Semenov, Kelly, and their colleagues have used exquisitely cold deuterium, an isotope of hydrogen whose nucleus contains a neutron as well as a single proton. They mapped the electric-charge layout with an accuracy of about 4 percent of the nucleon's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

EVIDENCE FOR THE ONSET OF QUARK EFFECTS

American Institute of Physics



Above: Graphic adapted from "Nuclear Physics, The Core of Matter, the Fuel of Stars," National Research Council, 1999.

Evidence for the onset of quark effects in a nuclear reaction has been observed for the first time. When a particle strikes a nucleus at low energies, one can effectively describe the resulting behavior of the nucleus in terms of its constituent nucleons (neutrons and protons) and the mesons which hold them together. At low energies, one does not have to worry about the fact that each nucleon is itself made of three quarks held together by gluons (Illustration a).

When a particle strikes a nucleus at high energies, however, it penetrates the nucleus so deeply that this "effective theory" breaks down, and one must describe the nuclear action in terms of only quarks and gluons (Illustration b). There is a middle ground, alas, where neither descriptive picture can do the job completely.

Just as urbanologists strive to locate where a city truly ends and its suburbs begin, physicists wish to find the boundary at which nucleon-based descriptions give way to quark-based ones. Towards this end, researchers study the behavior of the deuteron, the simplest nucleus, made of a proton and a neutron bound together.

In experiments at Jefferson Lab, a multi-institutional collaboration fired a high-energy electron beam at a copper target, which decelerated the electrons, creating high-energy photons as a result. In a process known as "photodisintegration," the photons impinged upon a deuterium target, and broke apart deuterons into their constituent protons and neutrons.

The researchers then studied the properties of protons emitted at various angles from the collision. When the emitted proton has at least 1 GeV/c of momentum perpendicular (transverse) to the incoming beam, the data were best described by quark-counting rules, which take into account the behavior of individual quarks.

The transverse momentum translates to an interaction with the nucleus at a distance scale of 0.1 fermi (10^{-16} m), about a tenth of the width of a proton. In this situation, an individual quark, rather than the entire nucleon, absorbs the momentum of the collision. This was surprising, since the 0.1-fermi distance scale is larger than many current theoretical expectations for the onset of quark-counting-rule behavior.

Editor's note: Results from this experiment were published in the Sept. 3, 2001 issue of Physical Review Letters by E. C. Schulte et al.