G-Zero Finds that Ghostly Strange Quarks Influence Proton Structure

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In research performed at the Department of Energy's Jefferson Lab, nuclear physicists have found that strange quarks do contribute to the structure of the proton. This result indicates that, just as previous experiments have hinted, strange quarks in the proton's quark-gluon sea contribute to a proton's properties. The result comes from work performed by the G-Zero collaboration, an international group of 108 physicists from 19 institutions and was presented at a Jefferson Lab physics seminar June 17.

Protons are found in the heart of all matter: the nucleus of the atom. Physicists have long known that protons are primarily built of particles called quarks, along with particles called gluons that bind the quarks together. There are three permanent quarks in the proton that come in two "flavors": two "up" and one "down." Up and down quarks are the lightest of the possible six flavors of quarks that appear to exist in the universe.

In addition to the proton's three resident quarks, the peculiar rules of quantum mechanics allow other particles to appear from time to time. These ghostly particles usually vanish in a tiny fraction of a second, but it's possible that they stay around long enough to influence the structure of the proton. Nuclear physicists set out to catch some of these ghostly particles in the act. They determined that the next-lightest quark, the "strange" quark, would be the most likely to have a visible effect.

According to Doug Beck, a professor of physics at the University of

Illinois at Urbana-Champaign and the spokesperson for the G-Zero collaboration, one way to see these strange quarks is to measure them through the weak interaction. "If we look with photons via the electromagnetic interaction, we see quarks inside the proton. And then, if we do it with the weak interaction, we see a very similar, yet distinctly different view of the quarks. And it's by comparing those pictures that we can get at the strange quark contribution," Beck says.

Since the hydrogen nucleus consists of a single proton, G-Zero researchers sent a polarized beam of electrons into a hydrogen target. They then watched to see how many protons were "scattered," essentially knocked out of the target, by the electrons. Throughout the experiment, the researchers alternated the electron beam's polarization (spin).

"We run the beam with polarization in one direction, and we look to see how many protons are scattered. Then we turn the beam around, in polarization at least, and measure for exactly the same amount of time again and look to see how many protons are scattered. And there will be a different number by about 10 parts per million," Beck says. That's because the electromagnetic force is mirror-symmetric (the electrons' spin will not affect the number of protons scattered), while the weak force is not (electrons polarized one way will interact slightly differently than electrons spinning oppositely).

"The relative difference in those counting rates tells us how big the weak interaction piece is in this scattering of electrons from protons. We compare it to the strength of the electromagnetic interaction between electrons and protons, and that gives us the answer that we're looking for," Beck explains.

What the researchers found was that strange quarks do contribute to the structure of the proton. In particular, Beck says the collaboration found that strange quarks contribute to the proton's electric and magnetic fields

-- in other words, its charge distribution and magnetization.

"All quarks carry charge, and one of the things we measure is where the strange quarks are located in the proton's overall charge distribution," Beck explains, "And then there's a related effect. There are these charged quarks inside the protons, and they're moving around. And when charged objects move around, they can create a magnetic field. In G-Zero, we also measure how strange quarks contribute to the proton's magnetization."

G-Zero allowed the researchers to extract a quantity representing the strange quark's contribution to a combination of the proton's charge and magnetization. "The data indicate that the strange quark contributions are non-zero over the entire range of our measurements," Beck says, "And there are a couple of points that overlap other measurements. They agree, so that's a good thing."

However, by itself, the G-Zero result does not yet allow the researchers to separate the strange quark's contribution to the charge from its contribution to the magnetization. "There's another G-Zero run coming up in December, and that will help us to try to disentangle this combination of the contribution to the charge and the magnetization. So that will give us one more measurement that will allow us to look at those quantities separately," Beck says.

G-Zero is a multi-year experimental program designed to measure, through the weak force, the strange quark contribution to proton structure. G-Zero was financed by the U.S. Department of Energy and the National Science Foundation. In addition, significant contributions of hardware and scientific/engineering manpower were also made by IN2P3-CNRS in France and NSERC in Canada. To date, more than 100 scientists, 22 graduate students and 19 undergraduate students have been involved with G-Zero.

Beck presented the results at a public physics seminar titled "Strange Quark Contributions to Nucleon Structure? Results from the Forward G0 Experiment" on Fri., June 17 at Jefferson Lab in Newport News, Va. The formal scientific paper has been submitted for review and publication.

Several other experiments, including the SAMPLE experiment at MIT-Bates, the A4 experiment at the Mainz Laboratory in Germany, and HAPPEx at Jefferson Lab were also designed to spot strange quarks in the proton.

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