NuTeV Anomaly Helps Shed Light on Physics of the Nucleus

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(PhysOrg.com) -- A new calculation clarifies the complicated relationship between protons and neutrons in the atomic nucleus and offers a fascinating resolution of the famous NuTeV Anomaly.

The calculation, published in the journal Physical Review Letters on June 26, was carried out by a collaboration of researchers from the Department of Energy's Thomas Jefferson National Accelerator Facility, Tokai University and the University of Washington. It grew out of attempts to make sense of the complex environment found in the nucleus of the atom.

The calculation began with the EMC Effect, a famous result in the world of nuclear physics that showed that the structures of protons and neutrons in a nucleus are different from protons and neutrons found outside a nucleus.

"I was at CERN when the EMC Effect was discovered more than 20 years ago," said Anthony Thomas, Jefferson Lab Chief Scientist and an author on the paper. "It's such a fundamental piece of information about the structure of nuclei that I wanted to understand it."

Thomas and his colleagues, Ian Cloet, a JSA Thesis prize winner in 2008, and Wolfgang Bentz, a long term visitor at Jefferson Lab in 2008, had theorized that the internal structures of protons and neutrons are modified by the presence of other protons and neutrons inside the nucleus.

Meanwhile, another landmark result, the NuTeV Anamoly, provided Thomas and his colleagues with another puzzle regarding the nucleus. Experimenters at Fermilab's NuTeV (Neutrinos at the Tevatron) experiment sent a beam of neutrinos into a steel target and measured the ratio of two types of subatomic particles - neutrinos and muons - that emerged. They found that about one percent fewer neutrino-target collisions produced neutrinos than predicted by the Standard Model.

"Many people were convinced that they had discovered evidence for physics beyond the Standard Model," said Thomas.

He and his colleagues pored over the experimental information and began applying their theories for the EMC Effect to it. They found that one common assumption that was used in the analysis of the NuTeV data involved a correction for a natural imbalance in the number of protons and neutrons in the nucleus of iron, the most common element in NuTeV's steel target.

"The correction made for the extra neutrons involved a subtraction of the structure function of the extra neutrons," Cloet explained. "But according to our theoretical model of the EMC Effect, those extra neutrons generate a force that subtly changes the structure of every proton and neutron in the nucleus."

The theorists went further, combining this newly discovered effect with another correction for the difference in masses of different quarks in the protons and neutrons (charge symmetry violation). When they applied the two corrections to the NuTeV analysis, they found that the experiment showed excellent agreement with the Standard Model.

As a consequence, the NuTeV result may now be interpreted as providing crucial evidence for the idea that the structure of a proton or neutron is fundamentally modified when it is bound in a nucleus.

"Now, the next thing is to carry out an experiment to test this explanation directly," Thomas said. "You can make measurements that directly test whether it's right or wrong."

More information: I.C. Cloët, W. Bentz, and A.W. Thomas, *Phys. Rev. Lett.* 102, 252301 (2009),
link.aps.org/doi/10.1103/PhysRevLett.102.252301

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