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Bound neutrons pave way to free ones

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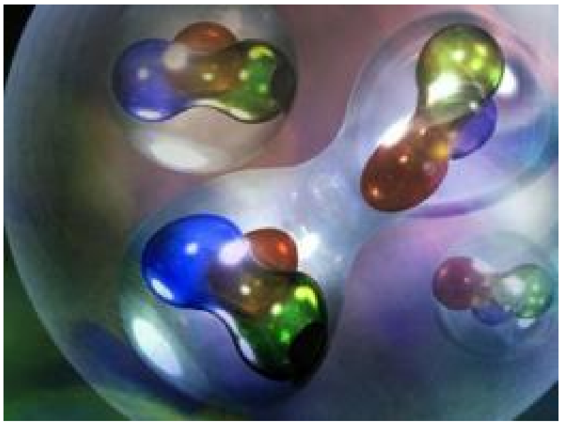

Some experiments seem to show that the building blocks of protons and neutrons inside a nucleus are somehow different from that of free ones (the EMC Effect). Other experiments show they behave differently when they pair up (Short-Range Correlations): they move faster and frequently overlap. Combining the data from experiments addressing these two effects, nuclear physicists showed that the two were connected. This connection has allowed scientists, for the first time, to extract information through experimentation about the internal structure of free neutrons, without the assistance of a theoretical model. Credit: DOE's Jefferson Lab

(PhysOrg.com) -- A study of bound protons and neutrons conducted at the Department of Energy's Thomas Jefferson National Accelerator Facility has allowed scientists, for the first time, to extract information through experimentation about the internal structure of free neutrons, without the assistance of a theoretical model. The result was published in the Feb. 4 issue of *Physical Review Letters*.

The major hurdle for scientists who study the internal structure of the neutron is that most neutrons are bound up inside the nucleus of atoms to protons. In nature, a free neutron lasts for only a few minutes, while in the nucleus, neutrons are always encumbered by the ubiquitous proton.

To tease out a description of a free neutron, a group of scientists compared data collected at Jefferson Lab and the SLAC National Accelerator Laboratory that detail how bound protons and neutrons in the nucleus of the atom display two very different effects. Both protons and neutrons are referred to as nucleons.

"Both effects are due to the nucleons behaving like they are not free," says Doug Higinbotham, a Jefferson Lab staff scientist.

Nucleons appear to differ when they are tightly bound in heavier nuclei versus when they are loosely bound in light nuclei. In the first effect, experiments have shown that nucleons tightly bound in a heavy nucleus pair up more often than those loosely bound in a light nucleus.

"The first thing was the probability of finding two nucleons close together in the nucleus, what we call a short-range correlation," says Larry Weinstein, a professor at Old Dominion University. "And the probability that the two nucleons are in a short-range correlation increases as the nucleus gets heavier."

Meanwhile, other experiments have shown a clear difference in how the proton's building blocks, called quarks, are distributed in heavy nuclei versus light nuclei. This difference is called the EMC Effect.

"People were measuring and discussing the EMC effect. And people were discussing things about the short-range correlations effect. Nobody bothered to look to see if there's any connection between them," adds Eliezer Piasetzky, a professor at Tel Aviv University in Israel.

When the group combined the data from a half-dozen experiments regarding these two different effects on one graph, they found that the two effects were correlated.

"Take a quantity that tells you how strong the EMC Effect is. And then take another quantity that tells you how many short-range correlations you have," Higinbotham explains. "And you see that when one is big, the other one is big. When one is small, the other one is small."

The scientists say that it's unlikely that one effect causes the other. Rather, the data shows that there is a common cause for both.

"I think that we certainly agree that from the position picture, it's due to nucleons overlapping that is causing this. And in the momentum picture, it is the high-momentum nucleons that are causing this. And, of course, it's quantum mechanics, so choose your picture," Higinbotham explains.

The group says the common cause may have remained a mystery for so long, because while the two effects they are studying are obviously related when laid out on a graph, the connection was previously obscured by the different, yet related ways in which the two effects are studied.

"When you do a measurement for the EMC Effect, what you do is you look inside the nucleon. You break open the nucleon and see inside. What happens inside the nucleon is very different from the short-range correlations, which is what happens between two different nucleons," Piasetzky says.

"What's very new here is that we have linked two fields that were completely disconnected. So now you can start asking questions about what that connection can help us learn," Higinbotham says.

They say the next step is to further compare the data from all of the source experiments that they used in their analysis to see if data for one effect may now be used to learn something new about the other. Then, of course, they'd like to use the knowledge that the two effects are connected to design new experiments for shining a light on other secrets buried in the nucleus of the atom.

More information: link.aps.org/doi/10.1103/PhysRevLett.106.052301

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