Particle physics study finds new data for extra Z-bosons and potential fifth force of nature

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The Large Hadron Collider is an enormous particle accelerator whose 17-mile tunnel straddles the borders of France and Switzerland. A group of physicists at the University of Nevada, Reno has analyzed data from the accelerator that could ultimately prove or disprove the possibility of a fifth force of nature.

As the largest science instrument ever built, the LHC has the science community buzzing with excitement as it may help in understanding the inner workings of Nature.

Remarkably, some of the new physics that may be studied at this $6 billion facility can be probed using low-cost experiments fitting in a typical laboratory room.

In a forthcoming *Physical Review Letter* article, the University of Nevada, Reno physicists are reporting an analysis of an experiment on violation of mirror symmetry in atoms. Their refined analysis sets new limits on a hypothesized particle, the extra Z-boson, carving out the lower-energy part of the discovery reach of the LHC.

Andrei Derevianko, an associate professor in the College of Science's Department of Physics, who has conducted groundbreaking research to improve the time-telling capabilities of the world's most accurate atomic clocks, is one of the principals behind what is believed to be the most accurate to-date low-energy determination of the strength of the electroweak coupling between atomic electrons and quarks of the nucleus.

Derevianko and his colleagues have determined the coupling strength by combining previous measurements made by Dr. Carl Wieman, a Nobel laureate in physics, with high-precision calculations in a cesium atom.

The original work by Wieman used a table-top apparatus at the University of Colorado in Boulder, Colo. The Boulder team monitored a "twinge" of weak force in atoms, which are otherwise governed by the electromagnetic force. The Standard Model of elementary particles, developed in the early 1970s, holds that heavy particles, called Z-bosons, carry this weak force. In contrast to the electromagnetic force, the weak force violates mirror symmetry: an atom and its mirror image behave differently. This is known to physicists as "parity violation."

The Boulder group's experiment opened the door to new inquiry, according to Derevianko.

"It pointed out a discrepancy, and hinted at a possibility for new physics, in particular, extra Z-bosons," he said.

Interpretation of the Boulder experiment requires theoretical input. The analysis requires detailed understanding of the correlated motion of 55 electrons of cesium atom. This is not an easy task as the number of memory units required for storing full quantum-mechanical wavefunctions exceeds the estimated number of atoms in the Universe. Special computational tools and approximations were developed. Compared to previous analyses, reaching the next level of accuracy required a factor of 1,000 increase in computational complexity.

The paper represents a dramatic improvement as researchers have struggled to develop a more precise test of the Standard Model. Derevianko's group, which included Dr. S. Porsev and a number of students, has worked on the analysis of the Boulder experiment for the past eight years.

"Finally, the computer technology caught up with the number-crunching demands of the problem and we were able to attack the problem," says Derevianko. "I have greatly benefited from collaborations in this complex problem. A fellow co-author, Kyle Beloy, for example, has recently been recognized as an Outstanding Graduate Researcher by the University."

In contrast to previous, less accurate interpretations of the Boulder experiment, Derevianko's group has found a perfect agreement with the prediction of the Standard Model. This agreement holds important implications for particle physics.

"Atomic parity violation places powerful constraints on new physics beyond the Standard Model of elementary particles," Derevianko said. "With this new-found precision, we are doing a better job of 'listening' to the atoms."

By refining and improving the computations, Derevianko said there is potential for a better understanding of hypothetical particles (extra Z-bosons) which could be carriers of a so-far elusive fifth force of nature. For years, physics researchers have grappled with experiments to prove or disprove the possibility of a fifth force of Nature.

There are four known fundamental forces of Nature. In addition to gravity, electromagnetism creates light, radio waves and other forms of radiation. Two other forces operate only on an atomic level: These are the strong force, which binds particles in the nucleus, and the weak force, which reveals itself when atoms break down in radioactive decay, or as in the Boulder experiment, through the parity violation.

The possibility of a fifth force could dispute the long-held belief that the force of gravity is the same for all substances.

"New physics beyond the Standard Model is the next frontier," Derevianko said, "and it's the theoretical motivation for much of this research."

More information: To read Derevianko's paper, go to: arxiv.org/abs/0902.0335

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