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Quark study breaks old puzzle in particle physics

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University of Chicago scientists have solved a 20-year-old puzzle in particle physics using data from an experiment conducted for an entirely different purpose.
Physicists had long known that something was amiss regarding their understanding of how some quarks interact in the beta decay of particles, a common form of radioactivity. Either dozens of experiments conducted over a period of more than three decades were wrong, or the scientists' theories were. Now, in a set of four papers, University of Chicago scientists have demonstrated that the theories are correct.

"Our result is quite consistent with theoretical predictions," said Edward Blucher, Associate Professor in Physics at the University of Chicago. Blucher and Richard Kessler, also of the University of Chicago, and Sasha Glazov, who recently moved from Chicago to DESY, the German particle physics laboratory, authored the three papers, which were signed by their 55 fellow members of the Kaons at the Tevatron collaboration at Fermi National Accelerator Laboratory. The papers have been accepted for publication in Physical Review D and Physical Review Letters.

Blucher and his colleagues based their finding on data collected during an experiment at Fermi National Accelerator Laboratory in 1997. "Our measurements are significantly more precise than the average of all measurements that have been done before," Blucher said.

The Fermilab experiment was designed to search for a phenomenon called CP violation, a process that causes nature to produce more matter than antimatter. The team, then led by Bruce Winstein, the Samuel K. Allison Distinguished Service Professor in Physics at the University of Chicago, announced making the definitive observation of a new type of CP violation in 1999. The only other observation of CP violation prior to that came in 1964, in an experiment that earned the 1980 Nobel Prize in physics for James Cronin and Val Fitch.

But it turned out that the design of the CP violation experiment directly benefited this new thrust of research.

"It's a tour de force and it reflects the enormous care with which Ed Blucher and his colleagues created this data," said Cronin, the University Professor Emeritus in Physics at the University of Chicago. "Everything fits together in a really perfect way."

Winstein, meanwhile, called the work "quite a bold set of papers" from Blucher, Kessler and Glazov. "These three guys just stuck to it and were insistent on trying to understand every little effect. What they did is something I'm quite proud of," Winstein said.

The project re-enforces scientists' understanding of the weak nuclear force, one of the four fundamental forces of nature. It governs the emission of radioactive beta particles and is the force that powers the sun.

In previous experiments, physicists measured how up quarks were coupled to down quarks and strange quarks.

In the precise accounting system of particle physics, the way these quarks couple to one another should add up to one. "When you added up the numbers, you came up a little bit short of what you expected from theory," Blucher said.

Experiment 865 at Brookhaven National Laboratory last year became the first to suggest otherwise. The Brookhaven data, based on a study of charged kaons, conflicted with previous experiments. "Now we've done similar, much more complete measurements on the neutral kaon and found a similar shift," Blucher said.

Strange quarks are a component of the neutral kaon particles that were produced in the Fermilab experiment.

Thus Blucher's team was able to study one of the critical elements in question-how up quarks couple to strange quarks-by observing how one form decays into the other.

The team's work marked the first time that all relevant measurements had been made together in one modern, statistically rigorous experiment. The measurements revealed that the coupling strength of strange quarks to up quarks was 3 percent higher than what had been determined by previous experiments.

The new results are approximately twice as accurate as previous experiments partly because of the rigorous computer simulations the team members put together to test the performance of their particle detector. "We've been able to take advantage of all the work that we've done over several years to correct all of the small flaws that were found in how the detector was simulated," Blucher said.

During the course of their research, Blucher and his colleagues discovered that a one of the theoretical components their measurements depended upon was incomplete. They took the problem to Jonathan Rosner, a Professor in Physics at Chicago. Soon, one of his graduate students, Troy Andre, began performing the calculations Blucher needed to bolster the validity of his measurements.

Andre's paper will be published in Physical Review D. That paper, together with the other three, add up to a fairly big change in the particle physics world. "I can't remember a case in the last 10 to 20 years where quantities that had been measured and understood for that long had shifted by such a large amount," Blucher said.