New Form of CP Violation Discovered

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Finding something expected has brought researchers at the Department of Energy's Stanford Linear Accelerator Center (SLAC) one step closer to discovering the unexpected.

SLAC's BaBar collaboration has discovered that CP violation—an asymmetry between the behavior of matter and antimatter—exists even in a very rare class of particle decays. This result offers the most sensitive avenue yet for exploring matter-antimatter asymmetries, with implications for the future understanding of physics beyond the Standard Model.

"BaBar has proven to be a fantastic instrument for exploring the origins of matter-antimatter asymmetries, allowing us to probe with exquisite precision very rare processes related to how the early universe came to be matter dominated," said David MacFarlane, BaBar Spokesperson and Professor at the Stanford Linear Accelerator Center.

The Standard Model theory provides a beautifully consistent picture of the building blocks of the subatomic world around us and the forces between them. Yet we now know it only describes 5 percent of the total mass of universe and leaves many fundamental questions in particle physics and cosmology unanswered. The very rare particle decays studied by the BaBar collaboration could offer the first hints of a breakdown of the Standard Model. By reaching the threshold where asymmetries in such decays can be seen, the BaBar collaboration has opened the door to finding new physics.

"Demonstrating a significant level of CP violation in these rare modes is a watershed for BaBar," said Professor Fernando Palombo of the INFN (the Italian Nuclear Physics Institute) and the Department of Physics of the University of Milan. "It also allows us to pose the next question: does the size of the asymmetry match expectations from the Standard Model?"

The recent result was made by looking at a "penguin mode"—named for the penguin-like shape formed by its decay diagram—in which a B particle decays into two other particles called an Eta-prime meson and a neutral K meson. Although this penguin decay is ten times more rare than the interactions previously used to measure matter–antimatter asymmetry, SLAC researchers are now able to clearly demonstrate a difference between the decays of the B particle and its antiparticle in these important modes. The analysis finds a difference in the time evolution of matter and antimatter with amplitude of 0.58±0.10, which differs from zero asymmetry by about 5.5 standard deviations.

"Such rare decays are very challenging to identify, but over the past few years we have learned to cleanly isolate one event in a million," said Professor James Smith of the University of Colorado. "We're looking forward to much more data and many more exciting results to come."

To date, the BaBar collaboration has recorded 1,200 examples of this particular decay and expects to more than double its dataset in the next two years. Penguin decay modes in general offer a particularly sensitive opportunity to search for new physics because they involve quantum loop processes that could include virtual particles of very high mass. Present results offer hints that new, unexplained physics may exist in penguin modes. Yet only with a larger dataset will researchers be able to say with certainly that they have seen interactions not explained by current theories. “The B Factory, already delivering events at over four times the original design rate, is being upgraded this fall to improve performance by almost another factor of two," said John Seeman, SLAC Assistant Director for PEP-II and Linear Accelerator Systems.

This new line of investigation may lead to the discovery of new types of interactions and even new particles. In addition, penguin decays are sensitive to new physics that may explain why there is more matter than antimatter left over in the universe from the Big Bang than predicted by the Standard Model.

"One of the fundamental questions facing particle physics and cosmology is the abundance of matter in the universe," said SLAC Director Jonathan Dorfan. "This new result could prove an exciting step toward understanding how that abundance came about." Some 600 scientists and engineers from 75 institutions in Canada, China, France, Germany, Italy, the Netherlands, Norway, Russia, Spain the United Kingdom, and the United States are working on BaBar. SLAC is funded by the Department of Energy's Office of Science.

An article describing this work was recently submitted to *Physical Review Letters* for publication.

Source: Stanford Linear Accelerator Center