Physicists Discover New Particle: the Bottom-most 'Bottomonium'

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(PhysOrg.com) -- Thirty years ago, particle physics delighted in discovering the "bottomonium" family—the set of particles that contain both a bottom quark and an anti-bottom quark but are bound together with different energies. Ever since, researchers have sought to ascertain the lowest energy state of these tiny yet important particles.

Now, for the first time, collaborators on the BaBar experiment at the U.S. Department of Energy's (DOE) Stanford Linear Accelerator Center (SLAC) have detected and measured the lowest energy particle of the bottomonium family, called the η_b (pronounced eta-sub-b).

"Faced with the end of its run, the BaBar collaboration decided to focus its remaining time on investigating some of the states of bottomonium," said Associate Director of the DOE Office of Science for High Energy Physics Dennis Kovar. "This exciting result achieves one of the principal aims of this final data collection run."

SLAC Director Persis Drell added: "This is a tremendous achievement for both the PEP-II accelerator and the BaBar collaboration. Congratulations to everyone involved."

Every system of matter contains a "ground state"—a lowest energy level to which the system is ever trying to get, shedding energy as it does so. The ground state provides a baseline from which to measure the other more energetic states of the particle, and is key to understanding the fundamental laws that govern how quarks interact and behave.

When a bottom quark and an anti-bottom quark are pulled together by the strong force, they form a quark "atom"—much like an electron and a proton come together under the electromagnetic force to create a hydrogen atom. This bottom quark "atom," the ηb, can be excited to various higher-energy states, from the first excited state (called the "Upsilon(1S)") to the even higher states ("Upsilon(2S)," "Upsilon(3S)" and so on).

To determine the ground state, the BaBar collaboration gathered data in which the collision of an electron and a positron created a bottom quark and anti-bottom quark bound pair in the Upsilon(3S) state that in turn decayed by emitting a gamma ray and leaving behind the η_b ground state, which then decayed into still more particles. As this sequence of events occurred just once in every two or three thousand Upsilon(3S) decays in the BaBar detector, the collaboration needed to collect more than 100 million collisions in which the Upsilon(3S) state was created to ensure a precise measurement of the η_b.

"This very significant observation was made possible by the tremendous luminosity of the PEP-II accelerator and the great precision of the BaBar detector, which was so well calibrated over the BaBar experiment's 8-plus years of operation," said BaBar Spokesperson Hassan Jawahery, a physics professor at the University of Maryland. "These results were highly sought after for over 30 years and will have an important impact on our understanding of the strong interactions."

To make the observation even more difficult, experimentalists had to battle very high levels of background noise. Some of that is due to other decay processes that involve the Upsilon(1S) state, which has a similar energy and needs to be isolated from the signal to detect the η_b.

The motion of the bottom quark and anti-bottom quark within the η_b is slightly different from that of the Upsilon(1S)—due to the role of spin in quark interactions—and that introduces a very slight difference in energy between the particles. This slight split—known as "hyperfine splitting"—between the Upsilon(1S) and the η_b has been seen in other systems before, including the charm quark system, but this is the first time it has ever been observed in the bottom quark system. The hyperfine splitting is so small that the experimenters had to go to extraordinary lengths to definitively discover the η_b.

"Because the bottom quark is heavier than the charm quark, it offers theoretical physicists a more powerful handle for understanding the phenomena," said BaBar Physics Analysis Coordinator Soeren Prell, a physics professor at Iowa State University. Paradoxically, measurements of the heaviest quarks (the bottom is second heaviest, only behind the top quark), though hardest to observe, give some of the most precise measurements of the fundamental properties of the strong force.

The BaBar collaboration expects to release further results from its most recent data collection run over the next few months.

Some 500 scientists and engineers from 74 institutions in Canada, France, Germany, Italy, the Netherlands, Norway, Russia, Spain, the United Kingdom, and the United States work on BaBar. SLAC is funded by the U.S. Department of Energy's Office of Science.

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