Strange new subatomic particles discovered at atom smasher

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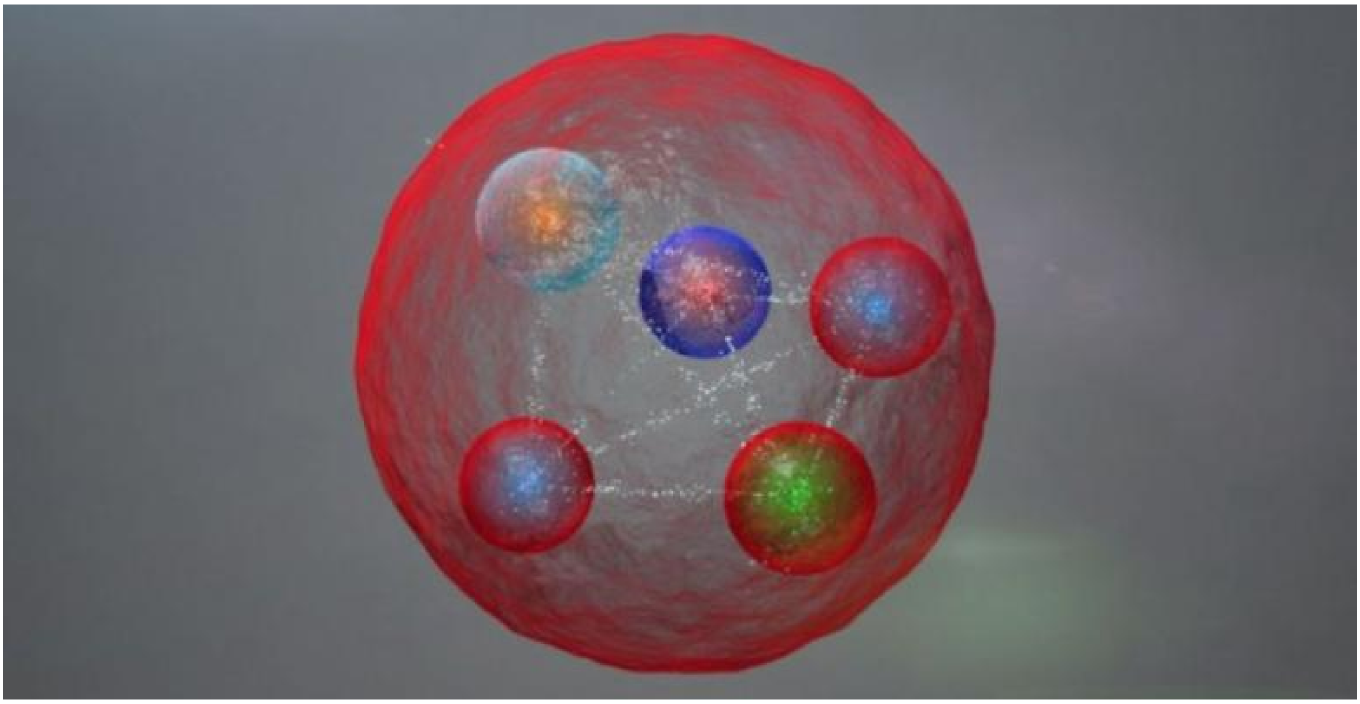

The discovery has "filled a big hole" in the theory that describes how matter is built up from the fundamental particles known as quarks, says Guy Wilkinson, a spokesman at LHCb, one of the four main detectors at the Large Hadron Collider (LHC), which was behind the find. That theory, put forward by physicist Murray Gell-Mann in 1964, describes how the protons and neutrons that make up atomic nuclei are themselves composed of three quarks and how other particles known as mesons are made from pairs of quarks and their antimatter counterparts, antiquarks. However, Gell-Mann's scheme also pointed to the existence of pentaquarks, made up of four quarks and an antiquark. The lack of any evidence for such particles over the past 50 years, says Wilkinson, "didn't throw the theory into disrepute but was becoming increasingly troublesome."

To catch the elusive prey, Wilkinson and colleagues studied the decay of "lambda-b" particles created by protons colliding within LHCb. They measured the combined energy of two of the decay products—a proton and a meson known as J/Psi, which consists of a "charm" quark and antiquark—and then totted up how many times they recorded each energy value across the thousands of collisions they studied. They found that the number of pairings with a certain energy—a little under five times the mass of the proton—was far higher than would be expected by chance. (Energy and mass are equivalent, according to Einstein's equation $E = mc^2$.) The researchers concluded that that was the mass of a fleeting "charmonium" pentaquark containing two up quarks, one down quark, one charm quark, and one anticharm quark.

LHCb collected the data back in 2011 and 2012, but Wilkinson's team held back from announcing their discovery to avoid the fate of those who had made the earlier claims of pentaquark sightings. Twelve years ago, about a dozen research groups from around the world announced that they had evidence for a lighter pentaquark known as theta-plus, but more detailed studies showed that all of the claims were illusory.

To insure their result was robust, the LHCb collaboration made use of data showing not only the energy of the particles produced in the CERN collisions but also their directions. Running these data through a computer model, they found that they could get the experimental results and model output to agree only when they included two charmonium pentaquarks in the lambda-b decay process—one having a mass of 4.45 gigaelectronvolts (GeV) and the other a mass of 4.38 GeV. (For comparison, a proton weighs in at 0.94 GeV.) The research has been uploaded to the arXiv server and submitted to the journal *Physical Review Letters.*

Physicists from outside the collaboration agree that the result looks convincing. "They appear to have found strong evidence for a 'heavy quark' pentaquark state," says Ken Hicks of Ohio University. Curtis Meyer of Carnegie Mellon University in Pittsburgh, Pennsylvania, agrees. "In reading the paper, I have seen nothing that I can easily point to as a potential problem," he says, although he adds that "with any result like this, confirmation is very important."

The LHC started up again in April after a 2-year shutdown to upgrade the machine to operate at higher energies. Now, the fresh data that will flow into LHCb should enable scientists to study the pentaquarks' structure, Wilkinson says. It is not clear at this point, he explains, whether all five quarks are bound tightly together inside the new particle, or whether instead three quarks group together as they do inside protons and neutrons and the other two form a separate meson—a bit like two atoms combining to form a molecule.

Wilkinson says that because pentaquarks might be formed inside collapsing stars, their discovery might tell us more about what stars are composed of and how they evolve. The new data might also lead to the discovery of other pentaquarks with different masses. "Now that we know nature allows five quarks to be bound together, it would be very strange indeed if just this set of quarks is allowed to coexist in this manner," he says. "There should be many others. We will just have to go and hunt for them."