SCIENCE

Mysterious Subatomic Particle May Represent Exotic New Form of Matter

BY ADAM MANN 06.17.13

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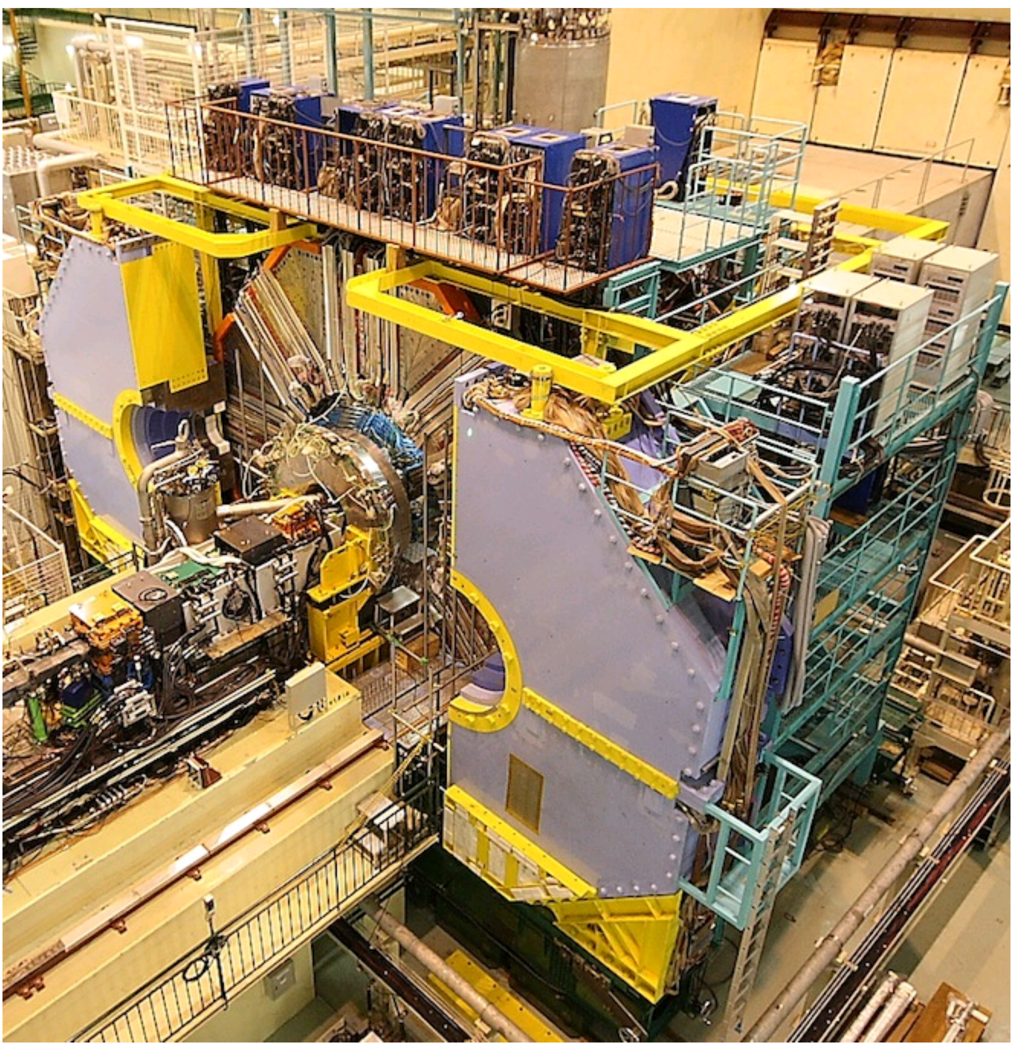


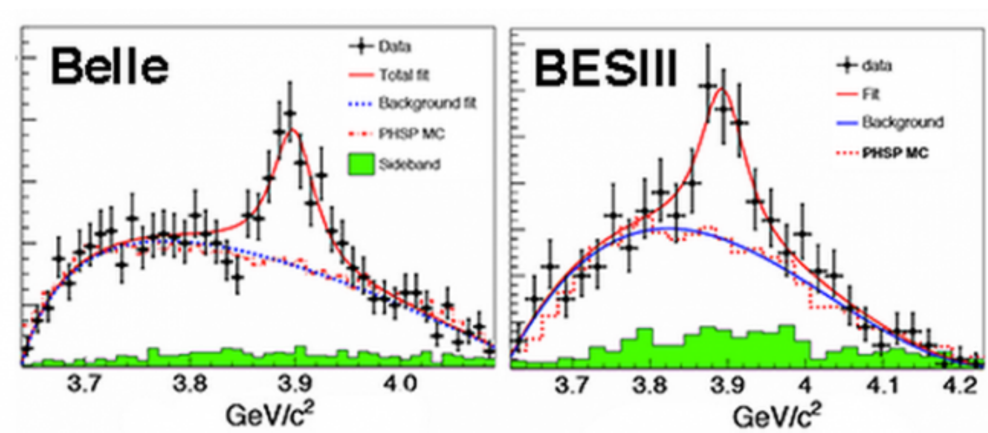
The Belle detector in Japan. *O3/Wikimedia*

In the course of exploring the properties of a strange subatomic particle, physicists may have stumbled upon something even stranger: a mysterious and exotic new form of matter.

collaborations: the Belle experiment at the Japanese High Energy Accelerator Research Organization (KEK) and BESIII experiment run by the Institute of High Energy Physics (IHEP) in China.

Both teams were looking at a particle called Y(4260) that had been discovered in 2005 but whose nature has mystified researchers since. By smashing together electrons and their antiparticle, positrons, the experiments produced large numbers of Y(4260), which lives for only 10-23 seconds before falling apart into other particles. The teams noticed that their data had a peculiar bump around 3.9 gigaelectronvolts (GeV), an energy corresponding to roughly four times the weight of a proton.

“Inspired by this discovery, we decided to further study the Y(4260) decay, which indeed did not disappoint us,” said particle physicist Zhiqing Liu, lead author of a paper from the Belle experiment that appeared in Physical Review Letters on June 17. A second paper from BESIII, of which Liu is also a member, appears in the same issue.



The data bump from Belle and BESIII. *Physical Review Letters*

The teams have enough data to conclude they have discovered something new, a putative particle named Z(3900). But the scientists are still not entirely sure what to make of it. One possibility is that Z(3900) represents a subatomic structure made of four quarks, something that has never been solidly seen before.

Before we continue, let’s break things down for those who get cross-eyed whenever subatomic lingo starts getting thrown around. Much of the matter we see in our universe is made of itsy-bitsy units known as quarks. There are six known quark types — named up, down, strange, charm, bottom, and top quarks – and they can combine in various ways.

neutrons, is made when three quarks come together. Another class of particles can occur when two quarks are bound (technically, these are made from a quark and an antiquark). The most famous of these two-quark particles are kaons and pions. Though there have been hints of them in the past, no one has ever definitely discovered a particle with more than three quarks.

A special force called the strong force is responsible for gluing all these quarks together. The particle carrying this force is called the gluon and it is akin to the photon, which carries the electromagnetic force, except that it can only be found inside of atomic nuclei.

The Y(4260) particle is thought to be a certain exotic type of particle with two quarks and an extra gluon, though its exact characteristics are still unknown.

“In trying to explore the properties of this gluonic exotic, they found another exotic,” said particle physicist Eric Swanson of the University of Pittsburgh, who was not involved with the work.

The experiments have now produced more than 460 of these strange Z(3900) particles, suggesting that they are real phenomena and not simply a statistical fluke in the data. The new exotic particle appears to have an electric charge and contains at least a charm quark and an anti-charm quark. The simplest explanation for the rest of the particle’s properties is that it also contains an up and anti-down quark for a total of four quarks.

“We haven’t seen anything like that before and for that reason it’s exciting,” said Swanson. While previous experiments have detected hints of such particles, Belle and BESIII’s data is the cleanest and most experimentally solid to date, he added.

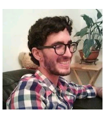
But there could still be other possible interpretations. Scientists already know that two-quark particles exist. So what looks like four quarks bound together could actually turn out to be two two-quark particles interacting so strongly that they look like a four-quark particle. Such a finding would be known as a “hadron molecule” – another strange object speculated to exist in the subatomic world but never definitively seen. This is the explanation that Liu is leaning towards.

“The hadron molecule is just my personal preference,” he said. “But

Swanson points out that there is another, more prosaic interpretation: that Z(3900) is composed of two two-quark particles interacting but not really strongly enough to stick together. This explanation would fit the data but isn't nearly as exciting.

The next step for both collaborations is to produce many new Z(3900) particles and watch how they decay, which should give some clues as to their properties. If the data shows they decay like ordinary, known particles, it could rule out the exotic interpretations. But if not, the scientists may have found something extremely interesting.

"We hope to reveal the nature of this particle in the following year," said Liu.



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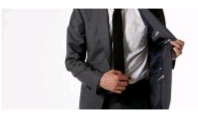

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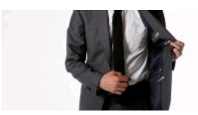

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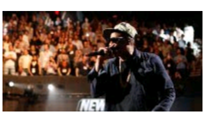

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