CERN has discovered a very charming particle

Enlarge / Particle tracks from the LHCb detector.

reader comments

46 with 41 posters participating

Share this story

The quark model was an intellectual revolution for physics. Physicists were faced with an ever-growing zoo of unstable particles that didn’t seem to have a role in the Universe around us. Quarks explained all that through an (at least superficially) simple set of rules that built all of these particles through combinations of two or three quarks.

While that general outline seems simple, the rules by which particles called “gluons” hold the quarks together in particles are fiendishly complex, and we don’t always know their limits. Are there reasons that particles seem to stop at collections of three quarks?

With the advent of ever-more powerful particle colliders, we’ve found some indications that the answer is “no.” Reports of four-quark and even five-quark particles have appeared in different experiments. But questions remain about the nature of the interactions in these particles. Now, CERN has announced a new addition to growing family of tetraquarks, a collection two charm quarks and two anti-charm quarks.

How do you put that together?

The quark-based particles we're most familiar with, the proton and neutron, are composed of three of the lightest quarks bound tightly together via gluons. We've also discovered heavier versions of these familiar particles, where one of the up or down quarks is replaced by a heavier quark, like a strange or bottom. In addition, there is a large collection of unstable particles, collectively called mesons, that involve two quarks of various masses, also held together by gluons.

So, what happens when you try to cram more quarks in? We're not entirely sure. There are two possibilities that are being considered. In one case, the new high-quark-count particles are made the same way that familiar ones are: gluons bind them tightly together into a single particle. An alternative, however, is that the large number of quarks comes about because two more familiar particles are tightly associated. So, a tetraquark could simply be a tight association of a pair of two-quark particles. A pentaquark would be put together from a two-quark meson associating with a three-quark particle.

Unfortunately, we've found it difficult to tell these two options apart. These high-quark-count particles tend to decay extremely rapidly to familiar particles, and it's generally only the decay of those latter particles that we can track. That makes it challenging to determine exactly what's going on further back. So, the more ways we can look at these things, the better. And that brings us to the latest results from CERN, in which a team of scientists has analyzed the data from the first few runs of the LHC.

The data comes out of the LHCb experiment, a detector that's specialized in particles containing the very heavy bottom (or beauty) quark. But it's capable of picking up heavier quarks more generally. And the new particle has a lot of heavier

quarks.

Needs more charm

So far, all the high-quark-count particles we've found have been a mix of mostly lighter up and down quarks, with a couple of their heavier peers thrown in. But the CERN team was interested in looking for combinations where all the quarks were either charm or anti-charm. Charm quarks are from the middle generation of quarks; charm and strange are heavier than up or down but far lighter than top or bottom.

How would we find something like that? Conveniently, a four-charm particle should decay through an intermediate state that involves a pair of two-charm particles. And these we know very well as the J/ψ particle. (Two groups found this particle at roughly the same time and, in a rare moment of compromise, the names given to it by both of them have stuck.) Since we know how J/ψ particles decay, we can simply look for pairs of decays coming out of a single proton-proton collision.

The decay of J/ψ particles can, in turn, be recognized by the appearance of a muon-antimuon pair that originates from a single location. (Muons can be thought of as heavier, unstable cousins of the electron.) Since there should be two of the J/ψ particles, then we need to look for two pairs of muon tracks in the aftermath of a collision.

So, the researchers scanned a range of energies for an excess of these events. And they find one in the appropriate energy range for a four-charm particle that is five standard deviations from the expected background noise. That means it meets the standard for discovery in particle physics.

The new particle, currently unnamed, is the first with more than three quarks that is composed entirely of one type of quark, as well as the first to be composed entirely of heavier quarks. And, given that the specific quark is called "charm,"

its existence opens vast possibilities for puns-and that’s without even getting into the fact that the technical term for the full family of particles containing these quarks is “charmonium.”

What’s its deal?

But the big question hasn’t been answered: what’s the nature of the new particle? We don’t know if it’s simply two J/ψ particles in tight association or whether there’s a single particle composed of four charm quarks. The answer is fairly important, since it would provide information on the strong force that governs all quark-gluon interactions.

Still, the more of these particles we have to study, the greater the chances are that we’ll be able to determine the details of what it takes to build them. So, while it would have been nice if this particle immediately heralded the solution to an outstanding question, its discovery is likely to represent progress toward a solution.

The arXiv. Abstract number: 2006.16957 (About the arXiv).

https://arstechnica.com/?p=1690926