Muons: the next discovery particles?

Electrons, positrons, protons, antiprotons: These particles have formed the basis for much of the particle physics research and many of the discoveries of the past hundred years. Will there be other particles that play a similar role in the future?

Muons are very much like electrons, but 200 times more massive. They don't have any constituent parts so they create clean collisions. Their higher mass means they don't give off as much energy as X-rays when they are guided along curved paths. They are a tool that can be used to explore fundamental physics with high precision and at the high energies needed to study the next generation of particles beyond the Standard Model of physics. They are also extremely sensitive, in measurable ways, to the effects of currently unknown physics, mostly due to their higher mass.

Photo: Reidar Hahn, Fermilab

There's just one problem. They only live for about two thousandths of a second. That means they are difficult to create in sufficiently large quantities that survive long enough to use as the precision tools they could be.

Fortunately, nature has a loophole described by Einstein's special theory of relativity. When particles are moving with high energy at nearly the speed of light, they have significantly longer lifetimes. Muons created 15 kilometers above the surface of the Earth can be detected at ground level because of this effect. Otherwise, they would travel less than one kilometer before decaying.

With these extended lifetimes, muons can be created, accelerated, stored, and either studied by themselves or slammed into targets—or each other. When they do finally decay, they give rise to a supply of muon neutrinos, which are useful for other studies. Getting to this point, however, will be extremely technically challenging.

The research, design, and engineering needed to make muon accelerators and colliders have for a long time been thought too difficult to even attempt. But some physicists have rethought the problem in light of more sophisticated accelerator technologies and now think a muon collider is quite feasible.

It will still be a long road to a working muon collider, but the effort will create other kinds of particle physics machines and experiments along the way. A muon collider might be the technology needed to explore the new world of particles that physicists expect the Large Hadron Collider to reveal. Perhaps in 50 years we will look back at the history of particle physics and the list of key discovery particles will include that heftier, short-lived cousin of the electron, the muon.

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