Hypothetical new particle could solve two major problems in particle physics

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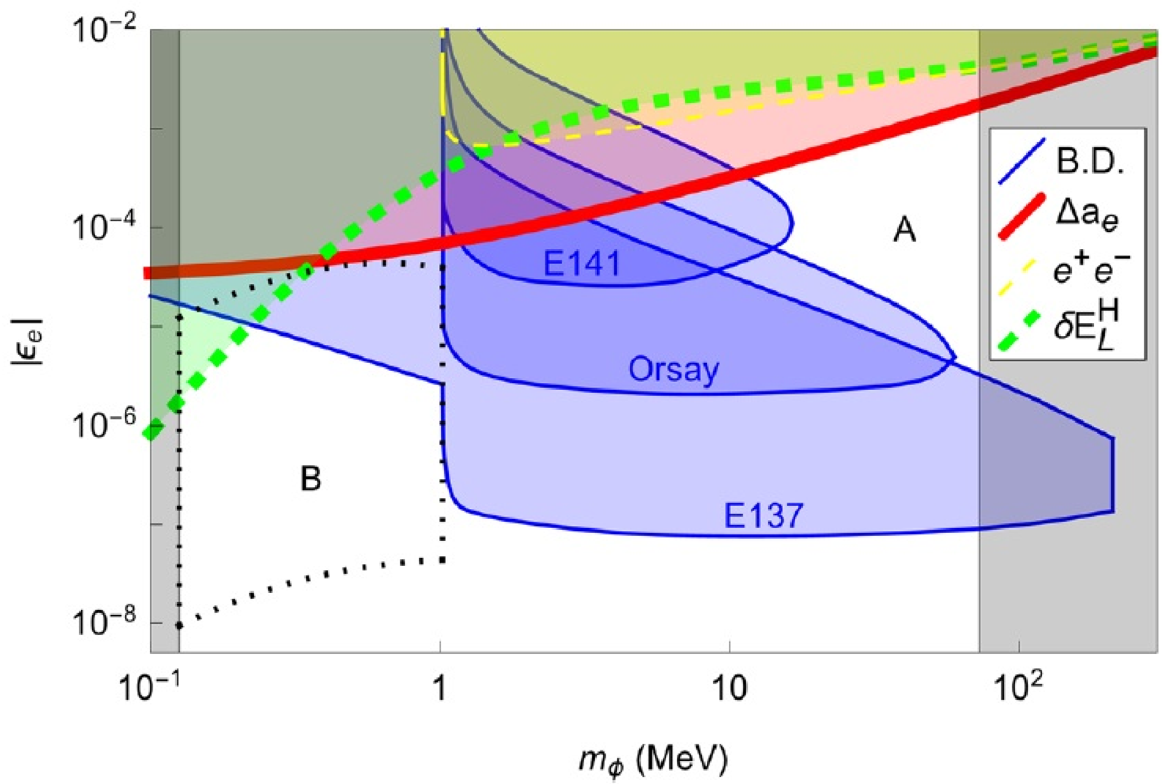

Using constraints from previous experiments, the physicists identified two regions, A and B (dotted), to search for the new particle in proposed experiments. Credit: Liu et al. ©2016 American Physical Society

(Phys.org)—Although the Large Hadron Collider's enormous 13 TeV energy is more than sufficient to detect many particles that theorists have predicted to exist, no new particles have been discovered since the Higgs boson in 2012. While the absence of new particles is informative in itself, many physicists are still yearning for some hint of "new physics," or physics beyond the standard model.

In a new paper published in *Physical Review Letters*, physicists Yu-Sheng Liu, David McKeen, and Gerald A. Miller at the University of Washington in Seattle have hypothesized the existence of a new particle that looks very enticing because it could simultaneously solve two important problems: the proton radius puzzle and a discrepancy in muon anomalous magnetic moment measurements that differ significantly from standard model predictions.

"The new particle can account for two seemingly unrelated problems," Miller told *Phys.org*. "We also point out several experiments that can further test our hypothesis."

The physicists describe the hypothetical new particle as an "electrophobic scalar boson." Currently there are five bosons in the standard model, only one of which is a scalar (the Higgs), meaning it has zero spin. All five bosons have been experimentally confirmed, and all are force carriers that play a role in holding matter together.

One of the distinct features of the new hypothetical particle is that, although it is predicted to bind to protons and neutrons, it would bind very weakly or not at all to electrons, making it "electrophobic." The scientists showed that this electrophobic property would allow the particle to solve both the proton and muon problems.

In the proton radius puzzle, the problem is that the proton radius seems to have a different size depending on what type of particle is orbiting it. Experiments have found that the proton radius is slightly larger when it is orbited by an electron than when it is orbited by a muon, which is identical to the electron except for being 200 times heavier. Assuming that the discrepancy is not due to measurement error (which it very well may be, considering how difficult it is to measure a particle that is less than a femtometer [10^{-15} meters] across), the results may point to the existence of a previously unknown fundamental force that pulls protons and muons closer together, but does not act between protons and electrons.

"The principle of lepton universality is a pillar of the standard model," Miller said, referring to the idea that all leptons, including electrons and muons, should behave in the same way. "Our particle violates this principle, because interactions with muons and electrons are different."

The second problem involves the muon's anomalous magnetic moment, which is a measure of how quantum effects contribute to the magnetic moment of a particle. So far, the most precise measurement disagrees with the standard model by more than three standard deviations. Once again, physicists think that the discrepancy may indicate physics beyond the standard model, or else more accurate measurements are needed. If the answer is new physics, then the new particle suggests that the proton and muon problems may be related.

"The proton radius puzzle can be explained if there is a new additional attractive interaction between the muon and proton," Miller said. "Such an interaction must also contribute to the muon anomalous magnetic moment. The proton radius puzzle (contribution to the Lamb shift) determines the strength of the interaction that contributes to the muon anomalous magnetic moment. The new contribution is just large enough to account for the current disagreement between theory and experiment. The equations in our paper allow us to obtain definite numbers, and these numbers can work out to be just right to account for both puzzles. New experiments will determine whether this is true physics or just a coincidence."

The physicists emphasize that they make no assumptions about the hypothetical particle other than that it could explain both of these puzzles. By constraining the mass of the hypothetical particle using data from previous experiments, the physicists predict that its mass would lie somewhere between 100 keV and 100 MeV.

Although previous experiments have already explored part of this predicted range, the physicists have identified two unexplored regions that may be ideal places to look. They expect that future high-precision experiments involving protons and muons may be able to search for the particle in these regions.

"We constrain the parameter space (mass and couplings) of this new particle in a finite range (except for the coupling of electrons)," Liu said. "So experimentalists can discover or exclude it by looking at a specific place, instead of measuring zero more and more accurately, like in the electron experiments."

In the meantime, the physicists are also looking forward to improved measurements of the muon anomalous magnetic moment—if the discrepancy remains, the results will offer further support for the existence of the new particle. The scientists also plan to apply some of the methods they developed here to look for other new particles.

"Our work on this has allowed us to develop new theoretical tools to aid in the search for other kinds of bosons with different quantum numbers," Miller said. "We will be applying those tools. Another direction is to develop a deeper theory that accommodates our new boson."

More information: Yu-Sheng Liu, David McKeen, and Gerald A.

Miller. "Electrophobic Scalar Boson and Muonic Puzzles." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.117.101801. Also at arXiv:1605.04612 [hep-ph]