Long-standing tension in the Standard Model addressed

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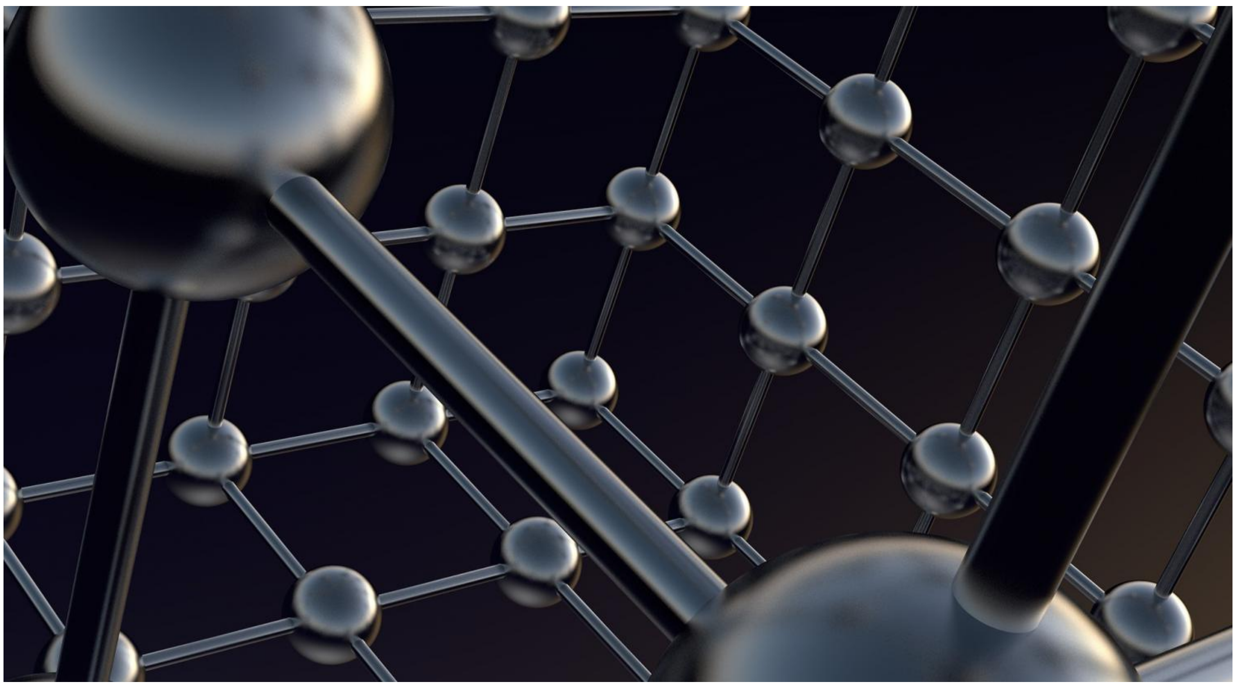

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The best-known particle in the lepton family is the electron, a key building block of matter and central to our understanding of electricity. But the electron is not an only child. It has two heavier siblings, the muon and the tau lepton, and together they are known as the three lepton flavors. According to the Standard Model of particle physics, the only difference between the siblings should be their mass: the muon is about

200 times heavier than the electron, and the tau-lepton is about 17 times heavier than the muon. It is a remarkable feature of the Standard Model that each flavor is equally likely to interact with a W boson, which results from the so-called lepton flavor universality. Lepton flavor universality has been probed in different processes and energy regimes to high precision.

In a new study, described in a paper posted today on the arXiv and first presented at the LHCP 2020 conference, the ATLAS collaboration presents a precise measurement of lepton flavor universality using a brand-new technique.

ATLAS physicists examined collision events where pairs of top quarks decay to pairs of W bosons, and subsequently into leptons. "The LHC is a top-quark factory, and produced 100 million top-quark pairs during Run 2," says Klaus Moenig, ATLAS Physics Coordinator. "This gave us a large unbiased sample of W bosons decaying to muons and tau leptons, which was essential for this high-precision measurement."

They then measured the relative probability that the lepton resulting from a W-boson decay is a muon or a tau-lepton—a ratio known as $R(\tau/\mu)$. According to the Standard Model, $R(\tau/\mu)$ should be unity, as the strength of the interaction with a W boson should be the same for a tau-lepton and a muon. But there has been tension about this ever since the 1990s when experiments at the Large Electron-Positron (LEP) collider measured $R(\tau/\mu)$ to be 1.070 ± 0.026, deviating from the Standard Model expectation by 2.7 standard deviations.

The new ATLAS measurement gives a value of $R(\tau/\mu) = 0.992 \pm 0.013$. This is the most precise measurement of the ratio to date, with an uncertainty half the size of that from the combination of LEP results. The ATLAS measurement is in agreement with the Standard Model expectation and suggests that the previous LEP discrepancy may be due to a fluctuation.

"The LHC was designed as a discovery machine for the Higgs boson and heavy new physics," says ATLAS Spokesperson Karl Jakobs. "But this result further demonstrates that the ATLAS experiment is also capable of measurements at the precision frontier. Our capacity for these types of precision measurements will only improve as we take more data in Run 3 and beyond."

Although it has survived this latest test, the principle of lepton flavor universality will not be completely out of the woods until the anomalies in B-meson decays recorded by the LHCb experiment have also been definitively probed.

More information: Test of the universality of τ and μ lepton couplings in W-boson decays from $t\bar{t}$ events with the ATLAS detector. arXiv:2007.14040 [hep-ex]. arxiv.org/abs/2007.14040

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