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IS THE LHC ON THE BRINK OF DISCOVERING NEW PHYSICS?

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Current paradigm: It is believed that the electron, muon and tauon behave similarly in particle interactions. | Photo Credit: CERN

Once in a way, the world of physics is in a state of upheaval – experiments are carried out that reveal limitations to older, established theories, and new physics is born. In this manner, on March 23, a wave of excitement propagated through the particle physics community when researchers from the LHCb experiment at CERN, situated in the Franco-Swiss border, announced the results of their latest analysis of data.

While the findings were not sufficiently strong to be counted as a discovery, CERN scientists were excited enough to reveal that if the anomaly they had detected was confirmed, “It would require a new physical process, such as the existence of new fundamental particles or interactions.” Spokesperson for LHCb, Professor Chris Parkes from the University of Manchester and CERN qualified this by saying, “More studies on related processes are under way using the existing LHCb data. We will be excited to see if they strengthen the intriguing hints in the current results.”

What was this excitement all about? It is necessary to delve into the world of elementary particles to understand this.

Broadly speaking, elementary particles are classified into the particles called baryons – which include protons, neutrons and their antiparticles the antiprotons etc. The “middle mass” particles, roughly speaking, are called the mesons and they include members such as the K and B particles.

You then have the leptons, which include the electron and its cousins the muon and tau particles and the anti-particles. At a still smaller scale, there are tiny particles called quarks and gluons. There are six flavours of quarks: up, down, truth, beauty, charm and strange. They too have antiquarks associated with them.

In this particle zoo, while the baryons are made up of combinations of three quarks, the mesons contain two quarks, more accurately a quark and antiquark pair, and the leptons are truly fundamental and are thought to be indivisible.

Until now it is believed that the electron, muon and tauon and their antiparticles, though they differ in mass, behave similarly in particle interactions.

By interactions here, is meant the following: If a huge particle accelerator such as the LHC were to accelerate beams of hadrons (such as protons) to very high speeds, a fraction of that of light, and then cause them to collide. Basically, smash through the repulsive nuclear forces and shatter them, the hadrons would break up into constituents which would recombine to form short-lived particles, which would decay into stabler states. Roughly speaking, during this process, they are imaged in a huge multistorey detector and the number of specific processes and particles are counted.

One such process that was measured was the decay of a meson B (which contained the beauty quark) into K-meson (which contains the strange quark) and a muon-antimuon pair, and this was compared with the decay of B into K and an electron-antielectron pair.

The expectation is that the ratio of the strengths of these two sets of interactions would be just one. This is because the muons are not essentially different from the electrons as per the Standard Model, the presently accepted theoretical model of all elementary particle interactions. This is called the lepton universality principle.

However, what the LHCb has seen is that the ratio is not 1, but it is approximately 0.846. However, the discrepancy is only at the level of 3.1 sigma, which is a measure of the chances that it might be due to a fluke. Scientists have agreed that in order to declare something a discovery, it should have a significance of 5 sigma or more (which is a much lower chance of a fluke).

Commenting on what would happen if, with analysis of more data, this significance was found to increase, Prof. Rahul Sinha of The Institute of Mathematical Sciences, Chennai, says, “The standard model will no longer be a complete description of particles and their interactions. It assumes as a starting point that electron, muon and tau interactions are universal and hence of the same strength.”

Prof. Rahul Sinha and collaborators have worked on these so-called flavour-changing neutral current penguin decays since the mid 1990s. “These interactions are highly suppressed in the standard model, and they were understood to be important even in the late 1970s,” he says.

According to Prof. Sinha, “It was realised by mid-1990s that they are small but not vanishingly small because of the very heavy top quark… In 1996, we realised that the decay b (quark) to s (quark) and lepton-antilepton pair can result in many observables because of the rich kinematics. Hence, we realised that this was great mode to look for new physics. It took several more years before they were observed.”

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