The anomaly of the mass of the W boson will lead to a new world in physics

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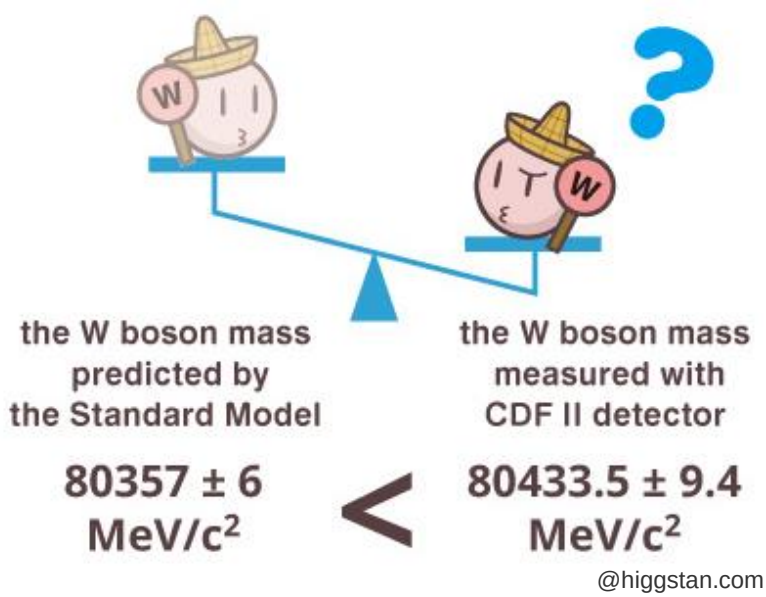
In April 2022, a truly astonishing study was reported that caused quite a stir in the physics community: the measured mass of the W boson particle differed significantly from the expected value.

It is said that all matter in the world is composed of elementary particles such as electrons and quarks. The theory that describes the various properties of elementary particles and forces is called the Standard Model. At present, almost all experimental results are currently consistent with the predictions of the Standard Model. The discovery of the Higgs boson in 2012 confirmed the existence of all particles predicted by the Standard Model, thus confirming the validity of the Standard Model as a theory.

Among elementary particles, gauge bosons play a role in mediating forces. A force is generated between two elementary particles when they exchange gauge particles with each other. The gauge bosons that mediate the weak interaction, a force that causes radioactive decay of atomic nuclei, are called W bosons (electrically charged) and Z bosons (electrically neutral). According to the Standard Model, the mass of the W boson is predicted to be 80357 ± 6 MeV/c^2 (MeV/c^2 is the unit of mass). Measurements of W boson masses made with various particle accelerators have generally not deviated from this prediction. However, The Collider Detector at Fermilab (CDF) Collaboration has estimated the mass of the W boson to be 80433.5 ± 9.4 MeV/c^2, based on experimental data from the Tevatron particle accelerator. This deviates from the Standard Model prediction by 7 uncertainties. In the particle physics community, an uncertainty of 5 or more is considered to be an anomaly, so we can say that this W boson mass is an anomaly.



The results of this experiment indicate that a theory beyond the Standard Model may be needed. This does not mean that the Standard Model was wrong. The Standard Model is indeed regarded as a correct theory and can give precise predictions up to a certain extent. However, in this experiment, it can be regarded as a measurement of what is not fully covered by the Standard Model. In other words, we need a theory that is upward compatible with the Standard Model and can explain all experimental results, including the mass of the W boson.

One of the leading candidates for theories beyond the Standard Model is supersymmetry theory. Supersymmetry theory is a theory that assumes that for each elementary particle in the Standard Model, there exists a counterpart elementary particle called a supersymmetric particle. This theory is said to be able to explain not only experimental results that can be explained by the Standard Model, but also those that cannot yet be explained. For example, observations have shown that outer space is filled with dark matter, which is still unidentified. Supersymmetric particles are a strong candidate for the identity of dark matter. The fact that the mass of the W boson deviates

from that predicted by the Standard Model can also be explained by the supersymmetry theory. On the other hand, since supersymmetric particles themselves have not yet been discovered, supersymmetry theory has not yet been confirmed as a theory. Researchers are continuing to further explore the theory, search for particles, and measure physical quantities with accelerators to confirm the theory beyond the Standard Model.

The establishment of physics beyond the Standard Model is expected to lead to new technologies for human society. Historically speaking, the physical world has seen a repetition of the process whereby the establishment of a theory leads to the practical application of that theory for the benefit of human society. Newton's establishment of mechanics in the 17th century made it possible to design and control products in the industrial field, thereby promoting industrialization. Maxwell's establishment of electromagnetism in the 19th century made it possible to use electromagnetic waves as technology in a wide range of areas, such as wifi. The establishment of quantum mechanics in the 20th century made possible the control of semiconductors currently used in various electrical appliances, and also served as the foundation for the next generation of computers, the quantum computer, which is now under development and can perform far more calculations than any computer before it.

Since the Standard Model has only been established in the last decade, it is expected to take several more decades before the Standard Model can be put to practical use. When it comes to physics beyond the Standard Model, it is more difficult to predict when it will be established. Nevertheless, the establishment of a new physics beyond the Standard Model will eventually, though we yet cannot know exactly what it is, bring new possibilities previously unimaginable to human society. Therefore, it can be said that the results of the W boson mass anomaly measurement may be the first step in

creating a trend that will lead to the foundation for a more convenient and prosperous society.

References

[1] CDF Collaboration *et al*., *Science* **376**, 170-176 (2022) 8 April 2022