News of Physics (and beyond)

New answers, new questions

Eleven years ago, in July, at the press conference at CERN, the discovery of the Higgs boson was announced. The blessing of middle age allows me to be both old enough to understand the significance of this discovery at the time, and young enough to remember the emotions that went with it. However, with important discoveries of elementary particles, it is a bit like with CSI movies – the audience is shown a (sometimes spectacular) murder, then specialists enter the action, documenting the event and trying to better understand what actually happened, beyond the reach of the cameras and the script.

Answers to the questions from page 13:

Question 1. In this situation, we should take into account that if the acquaintance had a son and a daughter, the mother would have only a 50% chance of bringing the son. Therefore, the table from Figure 4 in the article should be modified by narrowing the coloured, plain rectangles twice. This leads to an answer of 50%.

Question 2. The interpretation of this situation seems somewhat subjective, but in the author's opinion, it should be assumed that the friend did not answer our question ("Is at least one child a boy born on Monday?"), but two separate questions: "Do you have at least one son?" and "Do you have at least one child born on Monday?". If we had actually asked her those questions (in a sense we did when we chose "Monday"), we would estimate the chances of having two boys as ⅓ (it is helpful to visualize this situation using Figure 3 from the article).

This is exactly what the Higgs boson has been subjected to for over a decade. Individual results, sometimes documented in these pages, confirmed with increasing accuracy that the experimentally determined properties of this particle are consistent with the predictions of the Standard Model of elementary particles. And theoretical physicists have been patiently waiting for some discrepancies to emerge that might indicate that the Standard Model needed to be extended.

Studying the Higgs boson is not an easy task. It is an uncharged particle and interacts only weakly, which means that the probability of its production is minuscule. It takes really high energies and large numbers of colliding particles to collect any statistically significant sample. Even in a collider as large as the LHC, only one such particle is produced every two seconds of the machine's operation. It is therefore not surprising that it takes years to determine the characteristics of some rare processes involving the Higgs boson.

An example of such a rare process is the decay of the Higgs boson into the Z boson, a massive, neutral particle that carries the weak force, and a photon known from electromagnetic interactions. The Standard Model predicts that in only 0.15% cases the Higgs boson decays this way. Even worse, the appearance of the Z boson also has to be detected somehow. It is not easy, because it is also an unstable particle, too short-lived to be directly observed. It is identified by its decay products - an electron-positron pair or a muon-antimuon pair, which occurs in 6.6% of decays. This means that assuming 100% efficiency of the detectors - and this is a senselessly optimistic assumption! – only one in ten thousand decaying Higgs bosons will produce a signal of interest that we could observe.

The importance of the decay of the Higgs boson into a Z boson and a photon is that, according to the Standard Model, it does not occur directly, but is – in a certain way –assisted by other particles present in nature, perhaps also those that have not yet been detected. Thus, if the measured probability of this decay were significantly different from the predictions of the Standard Model, this would be an argument for the existence of such new particles, and their masses are close to the energy scale achieved by colliding particles at the LHC.

The ATLAS and CMS Collaborations. 2023. Evidence for the Higgs boson decay to a Z boson and a photon at the LHC. ATLAS-CONF-2023-025

To experimentally determine the probability in question, teams of physicists at the ATLAS and CMS detectors had to join forces. Using artificial intelligence methods to analyze the data, the researchers found it to be 0.34% with a measurement uncertainty of 0.11%. On the one hand, this may cause some concern, because the determined value is 2.2 times higher than the predictions, but on the other hand, the measurement uncertainties are still large enough that compliance with the Standard Model is not yet ruled out, although the probability of random statistical fluctuation of such an order is not very large and amounts to only 6%. We will probably have to wait a few more years to solve the riddle of what has actually been measured...

Krzysztof TURZYŃSKI

Faculty of Physics, University of Warsaw