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**LNGS, XENON1T OBSERVES AN UNEXPECTED EXCESS OF EVENTS: TRITIUM, SOLAR AXIONS OR MAGNETIC MOMENT OF THE NEUTRINO?**

On 17 June, during an online seminar hosted by the INFN Gran Sasso National Laboratories (LNGS), XENON1T, one of the leading experiments in the direct search for dark matter, operating from 2016 to 2018 at the INFN LNGS, presented the analysis of its latest data, showing an unexpected excess of events. When the data of XENON1T, which contains 3.2 tonnes of ultra-pure liquid xenon, of which 2 tonnes are enclosed in the sensitive area of the detector, were compared with the expected background, an excess of 53 events was observed compared to the 232 expected. The excess is mainly present at low energy, below 7 keV, and is due to events evenly distributed in the sensitive volume of the detector and over the data acquisition period. The nature of this excess, which could also be due to a mere statistical fluctuation, is not yet fully understood because it has characteristics that make it compatible with various hypotheses. It could, in fact, be due to a minuscule presence of tritium, an isotope of hydrogen. But it could also be a sign of something much more exciting that would take us beyond the Standard Model, such as the existence of new particles, e.g. solar axions, or, according to another interesting hypothesis, it could involve new neutrino properties.

In the first case, the excess could reside in a new background source, not initially considered in the estimate, due to a small amount of tritium. Tritium, which can be present naturally in small traces in materials, is an isotope of hydrogen that decays spontaneously, emitting an electron with energy similar to that observed. Even a few atoms of tritium out of  $10^{25}$  atoms of xenon would suffice to explain the observed excess. At the moment there are no independent measurements to confirm or refute the presence of tritium in the detector, so a definitive answer to this explanation is not yet possible.

Another much more stimulating explanation could be the existence of a new particle. Indeed, the observed excess has an energy spectrum similar to that expected in the case of axions produced in the Sun. Axions

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are a hypothetical particle proposed to explain a particular symmetry in strong nuclear interactions, and the Sun could be a powerful source of these particles. Solar axions are not candidates for dark matter, but their discovery would mark the first observation of a class of particles well known theoretically but never observed yet, with a significant impact in the understanding of particle physics and astrophysical phenomena. If it were confirmed, this result would also have a significant impact on the search for dark matter, since the axions, produced in the primordial universe, represent a possible dark matter candidate. Alternatively, the excess could also be due to neutrinos, billions of which pass undisturbed through our bodies every second. This interpretation would imply that the magnetic moment of the neutrino - a property of elementary particles related to their spin - is larger than what expected by the Standard Model. This would be a strong indication in favour of a new physics model to explain the phenomenon.

Of the three possible explanations considered by the XENON collaboration, the observed excess is more in agreement with a sun axion signal. In statistical terms, the solar axion hypothesis has a significance of 3.5 sigma, equal to a probability of approximately 2 in 10,000 that the excess is due to a random fluctuation of the background, rather than a new signal. Although this significance is rather high, it is still not enough to conclude the definitive observation of solar axions. The significance of the tritium and magnetic moment of the neutrino hypotheses corresponds to 3.2 sigma, so they are also very much compatible with the experimental data.

The XENON1T result demonstrates the value of the technological solutions adopted and developed by the Collaboration and the extraordinary potential of the detector, which confirms to be the most sensitive in the world in the direct search for dark matter, and in general in the search for various rare events. In order to better understand the nature of this excess, the upgrade of the detector in the new phase called XENONnT will be crucial. Thanks to the aid of the LNGS staff and the XENON Collaboration personnel on site, the current health emergency has not stopped the upgrading works but only slowed them down a little: XENONnT will be in the data acquisition phase at the Gran Sasso Laboratories by the end of the year. ■