

News about ghost particles

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This model of the GERDA experiment shows the onion-like structure which suppresses interfering signals from the environment. The germanium diodes in the center of the cryostat filled with liquid argon (-186°C) are to a larger scale. Credit: MPI for Nuclear Physics

(Phys.org) —Neutrinos are the most elusive particles having extremely weak interactions with all other particles. They have rather unusual properties and are even expected to be identical with their own

antiparticles. So far this property is, however, not experimentally verified even though many studies of neutrinos over the last 60 years have already boosted our understanding of elementary particle physics.

Now scientists of the GERDA collaboration obtained new strong limits for the so-called neutrino-less double beta decay, which tests if neutrinos are their own [antiparticles](#). The result rules out an earlier claim and has various important implications for cosmology, astrophysics and particle physics and it adds information about neutrino masses.

Besides photons, neutrinos are the most abundant particles in the Universe. They are often called 'ghost particles', because they interact extremely weakly with matter. They are therefore an invisible, but very important component of the Universe, which could carry altogether as much mass as all other known forms of matter, albeit traveling almost at the [speed of light](#) over fantastic distances. Their tiny masses have also important consequences for the structures in the Universe and they are the driving element in the explosion of Supernovae. But their most remarkable and important property has been proposed by Ettore Majorana in the 1930ies: Unlike all other particles that form the known matter around us, neutrinos may be their own antiparticles.

The GERDA (GERmanium Detector Array) experiment, which is operated at the Laboratori Nazionali del Gran Sasso underground laboratory of the Istituto Nazionale di Fisica Nucleare in Italy, is aiming to resolve the question whether neutrinos are in fact their own antiparticles, and to determine their mass. GERDA looks for so-called double beta decay processes in the germanium isotope Ge-76 with and without the emission of neutrinos, the latter being a consequence of the Majorana properties. In normal beta decay, a neutron inside a nucleus decays to a proton, an electron and an antineutrino. For nuclei like Ge-76, normal beta decay is energetically forbidden, but the simultaneous conversion of two neutrons with the emission of two

antineutrinos is possible and has been measured by GERDA recently with unprecedented precision. This is one of the rarest decays ever observed with a half-life of about 2×10^{21} years, which is about 100 billion times longer than the age of the Universe. If neutrinos are Majorana particles, neutrino-less double beta decay should also occur at an even lower rate. In this case, the antineutrino from one beta decay is absorbed as neutrino by the second beta-decaying neutron, which becomes possible if [neutrinos](#) are their own antiparticle.

In GERDA germanium crystals are both source and detector. Ge-76 has an abundance of about 8% in natural germanium and its fraction was therefore enriched more than 10-fold before the special detector crystals were grown. Searching for a needle in a haystack is trivial compared to the detection of double beta decay, since environmental radioactivity is a background occurring at a rate at least a billion times higher than double beta decay. The GERDA detector crystals and the surrounding detector parts were therefore very carefully chosen and processed. The observation of the extremely rare process requires in addition very delicate techniques to further suppress backgrounds from cosmic particles, natural radioactivity of the surroundings and even the experiment itself. The scientists met this challenge by mounting the detectors in the center of a huge vessel that is filled with extremely clean liquid argon, lined by ultrapure copper, which in turn is surrounded by a 10-meter-diameter tank filled with highly pure water; the whole located underground below 1400 meter of rock. Combining all these innovative and pioneering techniques it was possible to reduce the background to unprecedented levels.

Data taking started in fall 2011 using 8 detectors the size of a tin can and weighting two kilograms each. Subsequently, 5 additional newly designed detectors were commissioned. Until recently, the signal region was blinded and the scientists focused on the optimization of the data analysis procedures. The experiment has now completed its first phase

with 21 kg?years of data accumulated. The analysis in which all calibrations and cuts had been defined before the data in the signal region were processed, revealed no signal of neutrino-less [double beta decay](#) in Ge-76 which leads to the world's best lower limit for the half-life of $2,1 \cdot 10^{25}$ years. Combined with information from other experiments, this result rules out an earlier claim for a signal by others. The new results from GERDA have interesting consequences for the knowledge on neutrino masses, extensions of the standard model of elementary particle physics, astrophysical processes and cosmology.

The next steps for GERDA will be to add additional newly produced detectors effectively doubling the amount of Ge-76. Data taking will then continue in a second phase after some further improvements are implemented to achieve even stronger background suppression.

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