

» FOCUS



GERDA PAVES THE WAY FOR LEGEND

Neutrinos are essential particles for understanding nature. Unfortunately, since they interact very little with matter, they are extremely evasive and it is, therefore, necessary to confront ever new technological challenges to be able to study them in depth. These are decisive scientific undertakings because understanding nature in detail would lead to a turning point in our knowledge. In particular, the study of an extremely rare, hypothetical process, which has still never been observed, called double beta decay without neutrino emission, would make it possible to understand whether the neutrino is a Majorana particle, or if it coincides with its antiparticle.

The GERDA (GERmanium Detector Array) experiment, at INFN Gran Sasso National Laboratories (LNGS), has investigated this process, using a technology based on Germanium crystals enriched from the germanium-76 Isotope. The experiment recently published its final results in the Physical Review Letters, determining the strictest [limit](#) on the half-life of this rare decay, fixing it at 1.8×10^{26} years, more than a million billion times the life of the universe. This exceptional result was obtained thanks to the extremely limited number of background events in the region of the signal, 5.2×10^{-4} counts/(keV kg yr): the lowest level ever obtained in the world in similar experiments. GERDA thus confirms that it has reached all the goals that were set for it, demonstrating the opportunity for a new generation of experiments with even greater sensitivity.

The history of research into double beta decay without neutrinos begins with a germanium detector of just 0.1 kg chosen for its excellent energy resolution by the research group of the INFN division and University of Milan, led by Ettore Fiorini. From that time, the experimental sensitivity has increased by a factor of one million. The continuous increase in the mass of detectors (which also constitute the source of decay), the strong reduction in background events in the region where the signal is expected, the optimisation of the underground installations for reducing the cosmic background radiation, and the enrichment of

» FOCUS

the detectors made of germanium-76 isotope by the natural fraction of 7.8% to approximately 90% were essential to this progress.

The GERDA experiment began operating in 2011 in the underground experimental facilities of the LNGS. In the final configuration of the experiment, 41 germanium detectors were used, comprising a total mass of 44.2 kg with an enrichment of approximately 87% of the germanium-76 isotope. The key to success was the use of pioneering techniques: unlike previous germanium experiments, the GERDA detectors were made to function “naked”, i.e., without their encapsulation, within a cryostat containing ultrapure liquid argon at a temperature of 87 degrees Kelvin (-186 degrees Celsius), which acts both as a cooling mechanism and as a shield for background events. This configuration, reducing the quantity of matter around the detectors, helps to minimise natural radioactivity. The active background suppression makes use of two complementary techniques. On the one hand, light detectors that can indicate whether a signal in the germanium detectors comes from natural background radiation are placed in the liquid argon. On the other hand, the study of the temporal profile of the signals gathered by the detectors makes it possible to further distinguish between background and signal events. Finally, detectors and cryostat are immersed in a container of ultrapure water as an additional screen against photons, neutrons and muons. While the equipment was operating, the GERDA collaboration developed detectors with a new design and innovative analysis to best make use of the equipment’s potential.

The GERDA experience leads us to believe that the background level could be reduced even further, so that it would be possible to design an experiment with a much higher mass of germanium capable of reducing the background events to the point that, for the whole data acquisition, lasting several years, no unwanted event would be registered in the interval of research fixed by the energy resolution of the detectors. The future LEGEND experiment has precisely this goal of increasing the sensitivity of the half-life of the double beta decay without neutrinos to 10^{28} years (one hundred times more than the GERDA result). In a first phase, called LEGEND-200, in the same facility as GERDA’s, 200 kg of germanium detectors will be used. ■