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 and could carry as much mass as all other known forms of matter put together − albeit traveling at almost the speed of light over vast distances. Their tiny mass also has important consequences for the structures in the Universe and they are a driving element in the explosion of Supernovae. Yet their most remarkable and important property was proposed by Ettore Majorana in the 1930s: Unlike all other particles that form known matter around us, neutrinos may be their own antiparticles.

The quest whether neutrinos can be their own antiparticles can be investigated through neutrino-less double beta decay. In the normal beta decay, a neutron inside a nucleus decays to a proton, an electron and an antineutrino. For several nuclei the ordinary beta decay is energetically forbidden, but the simultaneous conversion of two neutrons with the emission of two neutrinos (two neutrino double beta decay) is possible and has been measured for ^{48}Ca, ^{76}Ge, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{128}Te, ^{130}Te, ^{136}Xe or ^{150}Nd. The half-lifes for the two neutrino double beta decay are measured quite precisely and they are very long, in the range of 10^{21} y (for ^{128}Te an estimate gives 10^{24} y). This is about 100 billion times the age of the Universe. If neutrinos are Majorana particles, neutrino-less double beta decay should also occur at an even lower rate, with the half-life of more than 10^{26} y. 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. For example, for the half-life of 10^{27} y we would expect one decay per year in a detector made from about 100 kg of ^{76}Ge. Taking into account the normal radioactivity of e.g. mineral water, which is about 1 Bq/kg, we have about 3×10^{9} decays per year. It is therefore clear that the detector material needs to be about 10^{10} times more radio-pure than the ordinary matter. To achieve the appropriate radio-purity of the active target and construction materials is the main challenge of all the experiments searching for neutrino-less double beta decay.

Very recently, in October 2016, a new collaboration, LEGEND, was formed with the main goal to push for an experiment able to measure the half-life for the neutrino-less double beta decay of ^{76}Ge longest than 10^{27} y. It is supposed to be realized in stages. The first one would be based on ~200 kg of germanium detectors made from Ge enriched in ^{76}Ge to about 86%. In the second stage the mass of ^{enr}Ge could be increased to about 500 kg and then ultimately to about 1 ton. The location and technology of the ton-scale experiment will be evaluated in the future taking into account the progress and outcome of the 200/500-kg steps. Measurement of the half-life of 10^{27} y (with 200 kg of ^{76}Ge) or 10^{28} y (with 1000 kg of ^{76}Ge) is very challenging – practically a background-free detector is needed. Experiments based on germanium, as proved by GERDA, have however high potential to reach these goals.

In the LEGEND experiment the Ge crystals and the surrounding detector parts will be very carefully selected 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. Therefore, at least in the first stage of LEGEND, the germanium detectors will be mounted in the center of a huge vessel filled with extremely clean liquid argon, lined by ultrapure copper (GERDA cryostat). This in turn was surrounded by a 10-meter-diameter tank filled with pure water; the whole located underground below 1400 meters of rock (at laboratory Nazionali del Gran Sasso in Italy). Combining all these innovative and pioneering makes it possible to reduce the background to unprecedented and required levels.

Tasks included in the presented project are focused on significant improvement of the sensitivity for observation of the neutrino-less double beta decay in the LEGEND experiments. It will be achieved by development and implementation of novel background reduction techniques based on liquid argon purification, construction of new low-radioactivity electronics and selection of new type of high-purity detectors with efficient pulse shape discrimination abilities.

LEGEND is a world-wide collaboration with scientists from several research institutes or universities from Europe, North America and China.