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Short note

Ice shielding in the large scale GENIUS experiment for double beta decay and dark matter search

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Abstract. We suggest here the use of ice as shielding material in the large scale GENIUS experiment for the ultimate sensitive double beta decay and dark matter search. The idea is to pack a working volume of several tons of liquid nitrogens, which contains the "naked" Ge detectors, inside an ice shielding. Very thin plastic foil would be used in order to prevent leakage of the liquid nitrogen. Due to the excellent advantages of ice shielding (high purity and low cost, self-supporting ability, thermo-isolation and optical properties, safety) this could be another possible way of realization of the GENIUS project.

PACS. 29.40.Wk Solid-state detectors – 95.35.+d Dark matter (stellar, interstellar, galactic, and cosmological – 95.55.Vj Neutrino, muon, pion, and other elementary particle detectors; cosmic ray detectors

The GENIUS project, which would operate one to ten tons of high purity Ge (enriched in ^{76}Ge and natural) semiconductor detectors, was proposed [1–3] with the aim to increase by a major step the present sensitivity for double beta decay and dark matter search [3–4]. The expected enhanced sensitivity for the neutrino mass is in the range of 10^{-2}–10^{-3} eV, which would allow to check the atmospheric neutrino puzzle and at least part of the solar neutrino problem. Besides that the GENIUS experiment would result in additional significant contributions to testing several classes of GUT models. Some of them are tests of R-parity breaking and conserving supersymmetry models – including sneutrino masses –, leptoquark masses and mechanism and right-handed W-boson masses comparable to LHC. The second issue of the experiment is the search for dark matter in the universe. The full MSSM parameter space for prediction of neutralinos as dark matter particles could be covered even in the first step of the experiment using only about 100 kg of natural Ge detectors making the GENIUS project competitive to LHC in the search for supersymmetry [1–3].

It is well known that the ultimate sensitivity of the super- low background experiments for double beta decay and dark matter search is limited by the available source strengths (mass of the source) from one side and by the detector background from another side. The first origin of background is due to secondary cosmic rays and can be eliminated by the proper deep underground site for the experiment. The second part of the background (most crucial for sensitivity) is determined by the radioactive impurities in the detector itself, in the materials used for detector mounting and shielding, and in the surroundings.

In order to overcome both sensitivity limitations (source strengths and background) the main idea of the GENIUS project is to operate with a large amount of "naked" HP Ge detectors placed directly in liquid nitrogen serving as cooling and shielding medium simultaneously [1–3]. Indeed, this solution could allow to minimize the quantity of materials needed for the mounting of the crystals to a negligible level, and liquid nitrogen could be purified to a very high level. As it was shown using GEANT Monte Carlo simulations [1–3] the required demands to the radioactive contamination in the liquid nitrogen are on the level of 1×10^{-15} g/g for ^{40}K and ^{238}U; 5×10^{-15} g/g for ^{232}Th and 0.05 mBq/m^3 for ^{222}Rn. All these requirements (except for radon) are less stringent than those which have been already achieved in the Counting Test Facility for the Borexino experiment: $(2-5) \times 10^{-16}$ g/g for ^{232}Th and ^{238}U contamination in the liquid scintillators [5].

In accordance with Monte Carlo simulations [1–3] the required dimensions of the liquid nitrogen shield, which could fully suppress the radioactivity from the surroundings (measured, for instance, in the Gran Sasso Underground Laboratory) should be of about 10 m in diameter and 10 m height. These dimensions could be somewhat less (9 m in diameter and 9 m height) for the Solotvina Underground Laboratory located in a salt mine [6], since there the radioactivity level is lower than that in the Gran Sasso Underground Laboratory. Anyway, it is clear that production, purification, operation and continuos maintenance (together with safety requirements) of about one kiloton of liquid nitrogen in any underground laboratory would lead to considerable costs and would require some efforts.

In attempt to make the GENIUS experiment less expensive and more simple in realization we suggest here the use of ice as shielding material for the GENIUS project. It is supposed that the working volume of about several tons of liquid nitrogen (in contrast to one kiloton in the initial GENIUS project), which contains the naked Ge detectors, will be placed inside the ice shielding. Very thin plastic foil (with total mass of about one kg) would be used in order to separate the volume containing the detectors and to prevent leakage of the liquid nitrogen.

Positive aspects of the ice shielding are as follows:

1. The ice shield can be made extremely pure. Note that the water plant in the Gran Sasso Underground Laboratory for the Borexino experiment is already in operation with a productivity of about 3 m^3/hour and a radio-purity level of 7×10^{-15} g/g (U, Th); 1×10^{-11} g/g (K natural), and <8 mBq/m^3 for ^{222}Rn [5]. As it was mentioned earlier, the actual radio-purity of the liquid scintillators which is also achieved for the Borexino project is even much better: $(2-5) \times 10^{-16}$ g/g (Th, U) [5]. Therefore further purification of the water to satisfy GENIUS demands seems to be quite realistic. It is important that the *initial* purity of the water will be frozen in the ice shield, contrary to the large detectors using water as working or shielding medium (Superkamiokande, SNO, Borexino), where *continuos* purification of the water during experiment is strongly needed.

2. Ice is self-supporting material, therefore mounting of the ice shield for the GENIUS experiment should be simple. We are considering now different possible methods for ice shield mounting but is seems that building it from ice blocks with freezing of the seams could be the most practical and effective one. The drilling of any holes in ice could be made very easy and fast with help of hot water as it was shown by the AMANDA South Pole neutrino experiment [7].

3. Ice shielding should be very cheap because water is cheap and natural freezing could be applied for production of the ice blocks (during winter time). Due to that there should be no cost limitations for any ice shield dimensions.

4. Ice is a very good thermoinsulator itself, therefore an ice shielding could be kept for years with help of simple plastic foam isolation. On the other hand ice shield is a good thermoinsulator for the inner GENIUS detector volume (of several m^3) with liquid nitrogen.

5. As it was already shown by the AMANDA experiment ice is a very good Cherenkov medium with excellent optical properties (absorption length at 370 nm of about 100 m or more) [7]. Thus ice shielding with a limited number of phototubes frozen in some of the outer blocks could serve as effective veto system for muons and gammas in the GENIUS detector.

6. Finally, safety requirements for the ice shielding placed in any underground laboratory are much less stringent than those for the liquid nitrogen.

Concluding, we present here the idea of ice shielding as an alternative way for the realization of the GENIUS project with its great potential for modern particle physics, cosmology and astrophysics.

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