LENA

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Low energy neutrino astronomy has been extremely successful in the recent decades. Important goals that have been reached include the first detection of supernova neutrinos, solar neutrino spectroscopy and the discovery of neutrino oscillations. The aims of the LENA (Low Energy Neutrino Astronomy) project are an extension of this development to determine details of thermal solar fusion processes, a high statistics time resolved observation of a galactic supernova explosion and the measurement of the diffuse supernova neutrino background to gain information on the early star formation rate. The measurement of geoneutrinos in LENA will provide new information on the distribution of U and Th in the interior of the Earth and geophysical models will be probed. In particle physics, the search for proton decay into $K^+\bar{\nu}$ and other decay modes are central issues for LENA. In addition LENA can be used as a detector for future long baseline neutrino accelerator experiments. During the year 2005 optical properties of liquid scintillators and the potential of LENA for supernova relic neutrinos and proton decay have been investigated in detail.

The LENA detector is planned to have a cylindric shape with about 100 m length and 30 m diameter. An inside part of 13 m radius will contain approximately 50 kt of liquid scintillator while the outside part will be filled with water to act as a muon veto. Covering about 30% of the surface, 12 000 fully encapsulated photo multipliers with an effective aperture of 50 cm diameter each will collect the light produced by the scintillator. PXE (phenyl-o-xylylethane) is foreseen as main scintillator solvent. Optional mixtures with a pure mineral oil, like dodecane, are considered. The optical properties of a liquid scintillator based on PXE have first been investigated in the Counting Test Facility at the Gran Sasso underground laboratory. A yield of 372 ± 8 photo electrons per MeV has been measured in this experiment with an optical coverage of 20%. An attenuation length of ~ 12 m (at 430 nm) has been obtained by purging the liquid in a weak acidic alumina column. With these values an expected photo electron yield of ~ 120 pe/MeV can be estimated for events on the central axis of the LENA detector. In 2005 the optical properties of several scintillator blends which are possible candidates for the target of a later LENA detector have been investigated in Garching (diploma thesis Michael Wurm). The light yield as well as the attenuation and scattering lengths have been measured. In addition the positive effect of Al_2O_3 column purification has been demonstrated. These laboratory measurements show that liquid scintillators have optical properties which allow to perform sub-MeV neutrino astrophysics in LENA.

Several locations for the experiment are under discussion. In Europe, the possibilities are the Pyhäsalmi mine in Finland (CUPP: Center of Underground Physics in Pyhäsalmi), the deep sea NESTOR platform close to Pylos in Greece and the Frejus underground laboratory in the Alps. All European sites have a sufficient shielding of at least $\sim 4\,000$ meters water equivalent (mwe). Underground laboratories in the USA (Kimballton, Homestake and Henderson mines) expressed their interest in the LENA project as well.

Supernova relic neutrinos

The diffuse neutrino background generated by supernova explosions throughout the Universe (supernova relic neutrinos, SRN) provides valuable information on supernova explosion mechanisms as well as on the early star formation rate (SFR). The current best limit on the SRN-flux comes from the SuperKamiokande experiment, giving an upper limit of 1.2 $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for $\overline{\nu}_e$ with an energy threshold of 19.3 MeV. As the inverse beta decay on free protons $\overline{\nu}_e + p \to e^+ + n$ is used as detection reaction, LENA will lower this threshold to ~ 10 MeV, because the delayed coincidence measurement of the positron and the neutron (via the 2.2 MeV gamma emission after neutron capture on protons) is a very efficient tool to reject background events. The lower threshold is determined by the contribution due to nuclear power reactors and is therefore strongly dependent on the detector position. This has been studied in detail in 2005 by Michael Wurm. The SRN-event rates (between 40 and 80 counts per year, depending on the model) for LENA at CUPP have been calculated as well as the background due to surrounding nuclear power plants and atmospheric neutrinos. It has been shown that SFR up to a redshift of $z \sim 2$ can be determined and models for the gravitational collapse can be probed within a measuring time of about 10 years in LENA.

Proton decay

LENA provides unique sensitivity to the proton decay channel $p \to K^+\overline{\nu}$. This decay mode is favored in many SUSY theories and may be expected with a lifetime τ up to $\sim 10^{35}$ y. The experimental limits on this decay mode (SuperKamiokande with $\tau > 2.3 \cdot 10^{33}$ y) are essentially restrained by the capability of background suppression as the kaon has an energy below the Cherenkov threshold. In liquid scintillator detectors, the signature of the proton decay via $p \to K^+\overline{\nu}$ is the very distinctive signal of the energy deposited by the kaon followed by the short delayed event from the decay products of the kaon. A detailed study of the background events has been performed in 2005 (diploma thesis Teresa Marrodán Undagoitia). Based on Monte Carlo calculations the background rejection power of LENA for this decay mode was determined using pulse shape discrimination. It was shown that in LENA a lower limit of $\tau > 4 \cdot 10^{34}$ y at 90% C.L. can be achieved after 10 years of measurement [1].

References

[1] T. Marrodán Undagoitia *et al.*, Phys. Rev. **D72** (2005) 075014 and *arXiv:hep-ph/0511230*