PROCEEDINGS OF SCIENCE

The LAGUNA project – towards the giant liquid based detectors for proton decay searches and for low energy neutrino astrophysics

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A next generation European deep underground neutrino observatory is considered within the LAGUNA design study. Three detector options are presently considered: GLACIER liquid argon Time Projection Chamber; LENA liquid scintillator and MEMPHYS water Cherenkov. It will provide both: the high statistics measurement of neutrinos from variety of sources, and high sensitivity searches for matter instability. To accommodate such giant detectors a new underground laboratory is required. The LAGUNA design study considers the following seven candidate sites in Europe: Boulby (UK), Canfranc (Spain), Fréjus (France/Italy), Pyhäsalmi (Finland), Polkowice-Sieroszowice (Poland), Slanic (Romania) and Umbria (Italy). The three detection techniques and summary of the physics potential of proposed detectors are discussed in this short paper.

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1.Introduction

Several important issues can be addressed to the next generation experiments with very large volume of active medium and signal to noise ratio guaranteed by their underground localization. The proton stability, the core-collapse supernova explosion mechanism, probing the Sun and the Earth interior and CP violation in the lepton sector certainly belong to such fundamental physics subjects. The candidate sites for a new European underground laboratory able to host a giant-size detector are identified in the LAGUNA design study. This brief paper presents three liquid-based detection techniques (liquid argon, liquid scintillator and water) and their physics potential. The details can be found in [1].

2. Liquid-based detection techniques.

GLACIER [2] is a 100 kton liquid argon (LAr) Time Projection Chamber (TPC) of the diameter of 70m and height of 20m. The events can be reconstructed in 3D with excellent space resolution by exploiting the liquid ionization by charged particles and collection of scintillation and Cherenkov light. Very long (up to 20m) electron drift distance requires extremely high argon purity and the detector operation in the so-called bi-phase mode: electrons produced by ionization in the liquid phase will be extracted, by electric filed, to the gas phase and amplified. The single phase LAr TPC technique has been pioneered by the ICARUS collaboration [3].

LENA [4] is a 50 kton liquid scintillator tank of the length of 100m and diameter of 26m, surrounded by 2m of water for vetoing Cherenkov muons entering the inner part of the detector. The large detector radius requires an attenuation length of about 10m, which can be achieved by using e.g. PXE as scintillator solvent purified in an Aluminium-column, as has been shown by the BOREXINO collaboration [5]. The light produced by the scintillator will be collected by 12000 photomultipliers of 50cm diameter each. This configuration corresponds to about 30% of the surface coverage.

MEMPHYS [6], an extrapolation of the Super-Kamiokande water Cerenkov detector [7], consists of 3-5 separate tanks 65m in diameter and 65m height each. Such dimensions meet the requirements of attenuation length of Cherenkov light and pressure of water on the bottom multipliers. Three tanks represent a total fiducial mass of 440 kton. Relativistic charged particles passing the water produce a cone of Cherenkov light which is imaged as a ring of photomultipliers covering the detector inner walls. A detector surface coverage of 30% can be obtained with about 81000 photomultipliers of 30cm diameter per tank.

3. Physics potential

The broad physics program covered by these detectors includes: proton decay searches and studies of neutrinos produced in the: supernova explosion (also diffuse supernova neutrino background), Sun, atmosphere, Earth’s interior (geo-neutrinos), nuclear reactors and particle accelerators beams. It is extensively discussed in [1]. Only proton decay and geo-neutrinos are briefly presented below.

In the Standard Model (SM) the proton is a stable particle, whereas in the Grand Unified Theories (GUTs) proton decays are predicted. Therefore, the observation of proton decay will be a further proof for the existence of physics beyond the SM. The majority of SUSY and non-

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SUSY models predict the proton partial lifetime τ_p at the level of 10^{33}-10^{37} years. This region will be accessible for detectors studied in LAGUNA. Here we discuss the expected limits at the 90% C.L. only for two decay channels: (1) $p \rightarrow \pi^0 e^+$ and (2) $p \rightarrow \nu K^+$ and 10 years of detector exposure (MEMPHYS mass equal to 500 kton). The e^+ and two electromagnetic showers is a clear signature for (1) in the GLACIER LAr detector giving $\tau_p/B > 0.4 \times 10^{35}$ years, where B stands for the (unknown) branching ratio. A 938 MeV energy signal from π^0 and e^+ traveling in opposite directions will be evidence for (1). Three showering rings will identify (1) in water Cherenkov MEMPHYS detector allowing to reach $\tau_p/B > 10^{35}$ years. The channel (2) is very clean in the GLACIER detector due to very precise dE/dx and range identification of charged kaon and its decay products. This leads into a limit $\tau_p/B > 0.6 \times 10^{35}$ years. The prompt mono-energetic kaon signal, together with various delayed signals from its decay products will identify (2) in the LENA detector. In case that no signal is observed during 10 years of detector exposure the τ_p/B is greater than 0.4×10^{35} years. Since the K^+ is below the Cherenkov threshold for channel (2) for MEMPHYS, the detection of kaon decay products is needed. The limit $\tau_p/B > 0.2 \times 10^{35}$ years can be obtained.

The beta-decays of uranium and thorium chains in the Earth interior originate electron antineutrinos, called geo-neutrinos. In the LENA detector, the inverse beta decay (IBD) reaction is the dominant channel for their detection. Assuming the detector location at Pyhäsalmi ~1000 events/year is expected, with background of ~240 events/year of reactor neutrinos and ~10 events/year of radio purity background. Such high statistics measurement of geo-neutrinos flux can test geophysical models of the Earth. This number has to be compared to the first geo-neutrinos observation by KamLAND collaboration, which reported a signal of 25±18 events over 127±13 events of total background [8]. The observation of geo-neutrinos in MEMPHYS detector requires very challenging 2 MeV threshold, whereas the threshold in LAr is too high for geo-neutrinos detection since no free protons are available.

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