Prospects of Dark Matter Search with PCGe under deepwater

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Introduction

Experiments gear up towards direct detection of dark matter candidates like Weakly Interacting Massive Particles (WIMPs). These experiments require low energy threshold and radio-pure detecting materials with ability to discriminate γ–rays, electrons and neutron scattering. Thus, we can explore weak interaction cross-section of WIMP by observing sub-keV energy events induced by WIMP scattering off target nuclei. To reduce the cosmogenic radioactivity, experimental efforts are focused on using natural resources like mountains, Antarctic Ice and seawater. There are various uncertainties in neutron background (bkg) evaluation due to uncertainties in rock composition, purity of shielding material and mountain topology. Whereas, seawater composition is well understood provides flat sea surface, low neutron production rate with excellent neutron absorbing capability, and very cost effective. In transforming countries (like India) exploring this alternative approach of setting up deep seawater experiment is a feasible option.

In addition to above mentioned benefits and available mechanical cooling system for Germanium detectors of different mass possessing high energy resolution force us to use HPGe detectors of ORTEC X-Cooler II [1, 2] at deep underwater laboratory. The typical rate of LN_2 evaporation at room temperature is 0.36 Lt/day [3] and temperature at the depth of 3000 m is in between 2-4^{o}C [4] and each 3500m depth of seawater will give >100 m extra over burden of freshwater. Therefore, with a 100 Lt dewar an experiment can survive up 275 days without any interruption and this period is enough to settle-down the cosmogenic bkg.

The WIMP searches requires above 5 km. w. e. depth. It can be achieved with the help of proper layering of minimum required shielding and by the usage of cosmic-ray, neutron and anti-Compton veto detectors. Thus, a further control on bkg in the sub-keV region can be achieved. Therefore experimental searches on dark matter and 0νββ-decay can be performed.

The muon flux and induced activity is reduced by about one order of magnitude for every increase in depth of 1.5 km. w. e. Therefore, muon induced fast neutrons play an important role in demonstrating the experimental sensitivity. Fast neutrons deposit energy via elastic and/or inelastic scattering processes. The elastic scattering is main concern for dark matter searches, since its energy deposits are in the low energy region of interest. The neutron flux incident on shielding around a detector can vary by factor of about 2-3, depending on the cavern size due to back scattering of neutrons from cavern walls. The neutrons from rock interact in shielding materials such as lead and mesmerizes as WIMP signal in region of interest. The usage of boron loaded polyethylene shield close to target detector reduces 0.5 km. w. e. bkg. The raw event rate in region of interest can be further reduced by a factor more than 7 by exploiting detector granularity, pulse-shape discrimination and detector segmentation, and use of active neutron veto of 99% efficiency can further reduce bkg level down to more than 3km. w. e. under ground. Proper under water ventilation system [5] and pressure vessel that can sustain up to a depth of ~10 km underwater have been deployed. Longer than 40 km, single high voltage & signal cables are in experimental use [6].

Possible sites around the WORLD

The Mariana Trench is located at 11^{o}21'N & 142^{o}12'E near Japan is in Pacific Ocean is the deepest part (location) of earth's oceans (earth itself) with a depth of 10994 meters. The director of film "*Titanic*", Mr. James Cameron visited this place in March 2012. The Indian scientists have possibility to explore Tillanchong Island site in Andaman and Nicobar Islands. It has 4161m of depth at only 15km away from sea shore, where control room of experiment can be setup, is shown in Fig. 1. Additional possible sites are tabulated in Table 1. The depth measurement through the Google earth was calibrated with the depth of ANTARIS site for the table 1.

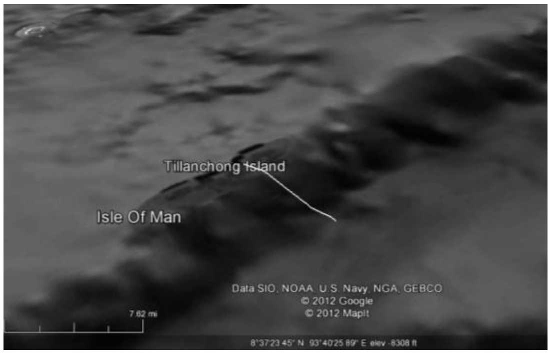

Fig. 1: Google photo of the Tillanchong Island.

Location	**Depth** (in meter)	**Distance from the shore**
16°10'05.37''S / 54°47'48.60''E Tromelin Island **(South Africa)**	4900	~45 km
20°53'05.86''S / 57°49'44.53''E Flacq **(Mauritius)**	4757	~50 km
20°44'16.84''S / 56°57'42.53''E Savanne **(Mauritius)**	4309	~50 km
8°34'22.07''N / 93°44'07.67''E Tillanchong Island **(India)**	4161	~15 km
8°14'54.58''N / 93°51'04.68''E Trinkat Island **(India)**	3993	~35 km
*12°43'N/81°06'E Chennai **(India)***	*3350*	*~70 km*

Table 1: Possible locations for underwater experiments that have distance less than 50km from the shore.

Preliminary lay-out of Detector

The design of an underwater dark matter search experiment presents a challenging task as it has to match various requirements concerning the detector performance, technical feasibility and project budget. During mid twentieth century several deep underwater experiments have been performed using plastic scintillation detector for studies on cosmic-ray flux [7] and scientists have used HPGe detector system to determine radio-nuclide levels in 105-KE Basin floor and walls. The ANTEC Technology provided submersible vessel [8]. The vessel was constructed by stainless steel and was designed to include HPGe detector, Pb shielding, tungsten collimator and LN_2 cryostat. The power supply and DAQ cables were fed through watertight connections in vessel. The vessel also included a vent tube of sufficient length to vent nitrogen gas [8]. Although mechanically cooled HPGe is available, it demonstrated successful operation of HPGe detector in underwater laboratory using LN_2.

A detector assembly incorporating all the above mentioned requirements of dark matter search with support systems and electronic modules is shown in Fig. 2. The setup consist of p+ point contact HPGe detector of initial mass 1 kg, 4π coverage by layered NaI(Tl) anti-Compton and liquid scintillation neutron detectors along with electronic modules of DAQ with remote control capabilities and a 100 liters LN_2 dewar. The entire configuration will

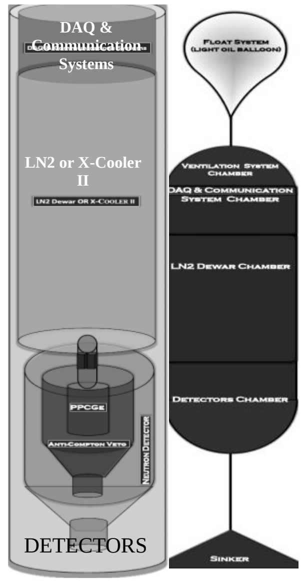

Fig. 2: Preliminary layout of detector assembly.

be inside a high pressure & water resistant vessel that will float ~1km up from the sea bed or as required, with the help of light-oil filled balloon. Vessel will get stability with a heavy Pb sinker. The vessel will be connected to the shore based control room through power cables. This type of experiment provides a high probability to explore the properties of WIMP. In the final phase setting up the assembly in Mariana Trench will enrich the scientific goal and stamp India's name in understanding the 23% of universe energy density. A detailed study and feasibility of this experiment will be presented.

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