HIGH FREQUENCY NOISE IN LAKE BAIKAL AS A BACKGROUND FOR THE ACOUSTIC DETECTION OF HIGH ENERGY NEUTRINOS *

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We review the ongoing work of the Baikal Collaboration on acoustic detection of super high energy neutrinos. Some results of the study of high frequency acoustic noise in Lake Baikal are presented. A lot of short impulses with different amplitudes and shapes were detected, which should be considered as a background for acoustic neutrino detection. However, most of the short impulses appear to be due to noise sound waves interference and can be eliminated by a correlation analysis. Only a few detected bipolar impulses probably were produced by quasi local sources.

1. Introduction

Since several years, feasibility studies towards acoustic detection of particle cascades ^{1,2} are performed in Lake Baikal ^{3,4}. They follow two lines: a) the detection of acoustic signals coinciding with Extensive Air Showers (EAS); b) study the feasibility of acoustic detection of cascades generated in neutrino interactions in deep water. In 2000, we detected characteristic bipolar acoustic signals with about 150 μ s duration, which probably have been generated in the region where the EAS core hit the water ³. In 2001-2003, special experiments have been performed to search for acoustic signals produced by EAS in water. In order to measure noise characteristics an autonomous hydro-acoustic recorder with two input channels has been developed. We have performed a series of hydro-acoustic measurements in Lake Baikal in order to investigate the spectrum of acoustic noise, its dependence on depth and angle of incidence, and its correlation with external factors like wind or processes in the ice cover of the Lake ⁴. In 2005, an acoustic system with four input channels was successfully tested. It can be regarded as a prototype of an elementary unit of a future underwater acoustic detector for super-high energy neutrinos.

2. The search for correlation between EAS and acoustic signals

To measure showers parameters a scintillator EAS array was deployed on the ice cover of Lake Baikal. The array consisted of 7 scintillation detectors with area 1 m² each. They were arranged uniformly along a circle with radius 80 m, one detector was placed in the centre of the circle. The EAS array was used as a trigger system for two acoustic data acquisition systems. The first one was deployed by ITEP group ⁵, the second one by Baikal-collaboration. In 2001, four our hydrophones were placed at the corners of a square with 40 meters side length, at a depth of 4 m. Fig.1a shows, for a typical data run, the distribution of the duration of detected bipolar acoustic impulses with amplitudes larger than $n\sigma$ (σ is the standard

Figure 1. Left (a): Distribution of the duration of bipolar acoustic pulses with amplitude larger than $n \cdot \sigma$. Right (b): Time variation of the integral noise over one year at a depth of 1000 m.

deviation of an integral recorder's noise). Most of the impulses appear as a result of the interference of acoustic waves generated by numerous sources. It was very difficult to extract and to identify weak signals in data collected by an antenna with widely spaced hydrophones. So, in what followed, we have been using rather compact acoustic antennas with a distance between hydrophones of about only 1 m. It allows to decrease the time window for the search of acoustic signals and to have a suitable accuracy of the reconstructed direction to the quasi-local source. To check the quality of operation of the acoustic system and of the reconstruction procedure, a special source of short acoustic signals was deployed at shallow depths below the EAS array. The typical difference between true and reconstructed position of the pinger then turned out to be less than 1 m. Only in a few cases the pinger signals was modified or time-shifted due to interferences with the acoustic background, resulting in larger errors. In total about 5000 EAS and a large number of acoustic pulses with widely varying form, duration and amplitude have been detected. A few short bipolar impulses probably were generated close to EAS core at the moment when it entered the water. However, taking into account the high noise level at shallow depths, it was not possible to decide whether at least one of them was really produced by an EAS. The similar conclusion was done by ITEP group ⁶.

3. The hydro-acoustic recorder

The autonomous hydro-acoustic recorder has two spherical piezo-ceramic hydrophones. Their signals are processed by preamplifiers with 80 dB am-

plication and frequency correction. The further processing is performed by a micro-controller which includes a 12-bit Flash-ADC with a maximum conversion rate of 0.2 Msamples/sec and a multi-channel analog multiplexer. The cut frequency of the low pass filter was set to 50 kHz, in accordance with the number of channels and the maximum conversion rate of the Flash ADC. Data are written to a 1 Gbyte flash card. The integrated instrument noise between 1 and 50 kHz is about 12.5 mPa.

4. The Results

Fig.1b shows the integral noise measured over one year, starting from April 1, 2003. One observes significant seasonal and daily variations of noise depending on meteorological conditions. Contrary to what one would expect intuitively, the average noise is larger when the Lake is covered by ice. This is since cracking ice provides a more powerful source of high frequency noise than wind and waves. In most cases, at winter time one or two maxima per day are observed due to changing of the ice temperature. Examples of the

Figure 2. Left (a): Dependence of the integral noise on depth and time. Right (b): Frequency spectra of acoustic signals.

depth dependence of noise integrated over the bandwidth of the recorder are shown in Fig.2a. The curves give the effective fluctuation of the acoustic noise field, expressed in milli-Pascal (mPa), for different meteorological conditions. It turns out to be difficult to draw generalized conclusions on the depth dependence of the noise since the depth effects are combined with meteorological effects. Data obtained at the same depth but at different time can differ considerably. Comparing data taken at windless, sunny weather, starting from (00:45 pm) at (26.03.2003) with the data which have been taken practically at the same time (05.04.2003) but at a cloudy day,

we may say that: in the first case sun shine changed the ice temperature and as a result the power of acoustic noise; in the second case the ice temperature was stable and the noise level at all depths was practically the same and very low. Fig.2b shows examples of the power spectral density (PSD) of the recorded noise signals. The spectrum obtained at(26.03.2003) is typical for stable meteorological conditions when any specific sources of noise like rain, gas seeps, ships and so on are absent. The bump in the spectrum (05.04.2003) probably appears due to the release of methane bubbles from the bottom of the Lake .

5. Summary and Outlook

The acoustic detection of high energy neutrinos and EAS in Lake Baikal as well in other natural basins is far from being trivial due to large level of background ⁷. The results of first measurements of acoustic noise in Lake Baikal show its complicated structure and strong dependence from different factors. We observed daily and seasonal variations which are stronger than the dependence on the depth. Occasional effects like rain or gas seep do also strongly change the acoustic background - the integral noise as well as the spectral characteristics. At stationary and homogenous meteorological conditions the integral noise power in the frequency range 1-50 kHz are depth-independent and as a rule its amplitude is around 10-200 mPa and rarely higher. The noise power spectrum decreases typically by 4-6 dB per octave. Many short impulses with different amplitudes and shapes are observed and should be considered as a background for acoustic neutrino detection. However, most of the short pulses appear to be due to interferences of noise sound waves and can be eliminated by a correlation analysis. Only a small part of bipolar pulses probably was produced by quasi-local sources. Rather compact antennas are preferable. A new acoustic recorder with four hydrophones for more detailed long-term studies of noise was designed and tested. The results of the test are presented in a second talk.

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