A Prototype Device for Acoustic Neutrino Detection in Lake Baikal

Baikal Collaboration

Institute for Nuclear Research, Russia, 60th October Anniversary pr.7a,Moscow 117312
K. ANTIPIN, V. AYNUTDINOV, V. BALKANOV, I. DANILCHENKO, G. DOMOGATSKY, A. DOROSHENKO, ZH. DZHILKIBAEV, O. GAPONENKO, A. KLABUKOV, A. KOSHECHKIN, S. MIKHEYEV, YU. PAVLOVA, A. PANFILOV, D. PETUKHOV, P. POKHIL, V. POLESHUK, A. SHEIFLER, V. ZHUKOV
Irkutsk State University, Russia, Gagarin blvd. 20, Irkutsk 664003
D.BOGORODSKY, N.BUDNEV, A. DYACHOK, O. GRESS, T. GRESS, O. GRISHIN, A. KOCHANOV, R. MIRGAZOV, G. PAN'KOV, L. PAN'KOV, V. RUBTZOV, B. TARASHANSKY.
Skobeltsin Institute of Nuclear Physics, Moscow State University, Russia
L. KUZMICHEV, E. OSIPOVA, E. POPOVA, V. PROSIN, A. SHIROKOV, I. YASHIN.
Nizni Novgorod State Technical University, Russia
S. FIALKOVSKY, V. KULEPOV, M. MILENIN.
Joint Institute for Nuclear Research, Dubna, Russia
I. BELOLAPTIKOV, K. GOLUBKOV, K. KONISCHEV, E. PLISKOVSKY, B. SHAIBONOV.
Kurchatov Institute, Russia
A. KLIMOV
St.Petersburg State Marine Technical University, Russia
M. ROSANOV.
DESY- Zeuthen, Zeuthen, Germany
E. MIDDELL, CH. SPIERING, R. WISCHNEWSKI.

Corresponding Authors: N. Budnev and G. Pankov

ICRC'07 Mérida, México

Abstract

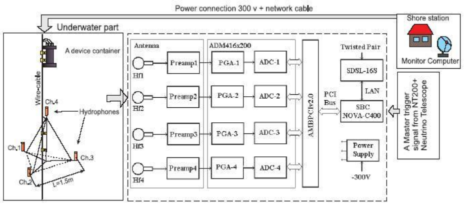
In April 2006, a 4-channel acoustic antenna has been put in long-term operation on Lake Baikal. The detector was installed at a depth of about 100m on the instrumentation string of the Baikal Neutrino Telescope NT200+. This detector may be regarded as a prototype of a subunit for a future underwater acoustic neutrino telescope. We describe the design of the acoustic detector and present first results obtained from data analysis. The device runs also in 2007, in common mode with NT200+.

Regimes of operation

The module is designed for operation together with the Baikal Neutrino Telescope NT200+.
There are 3 regimes of operation of the instrument:

- Transmitting of one second sample of data from all hydrophones to the shore computer centre after trigger signals from NT200 and outer strings.
- Online search for short acoustic pulses of definite shape, which can be interpreted as signals from quasi- local sources.
- An autonomous analysis of acoustic background statistics.

The Acoustic Device

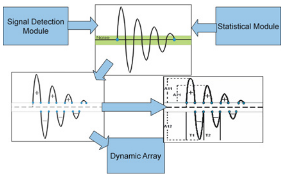


Schematic view of the underwater 4-channel digital device for detection of acoustic signals from high energy neutrinos. Installed at depth of 100m below surface, operated in common with the Baikal Neutrino Telescope NT200+.

Acoustic Antenna of the device

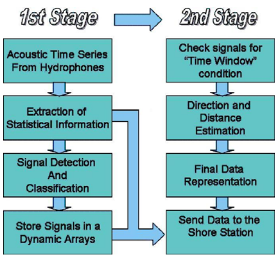
Signal Detection and Classification Procedure

The program performs online a search for signals, that \exceed the threshold, using calculated statistical characteristics and the calculated thresholds.



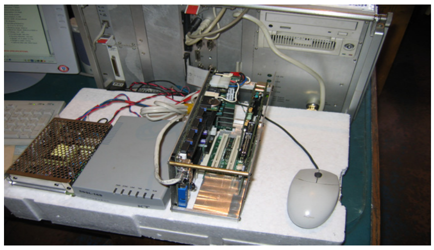
The program distinguishes the following properties of signals: time of registration, duration, number of periods, the maximal amplitude and others.
Impulses are classified by these parameters and the information about them is stored in corresponding dynamic arrays.

Online Data Handling



Block scheme of data handling, performed by the PC underwater.

Electronics



The underwater components: Power supply, DSL-modem, PC104 -Computer with PCI/ ADC Card (left to right:).

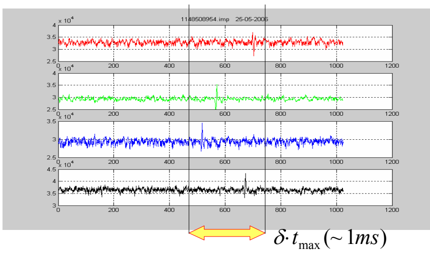
Reconstruction of Direction

For signals from distances >50m the acoustic front is flat.
We measure time coordinates of each signal: $(t_1, t_2, t_3, t_4)_{expe}$
The procedure of obtaining θ, φ consists in minimization of the functional

$$S = \sum_{i=1}^{4} [t_i - t_i^{exp}]^2 \frac{1}{\sigma_i^2} \quad \text{where} \quad t_i = t_0 + \frac{(\vec{r}_i - \vec{r}_0)\vec{n}}{V_s}$$

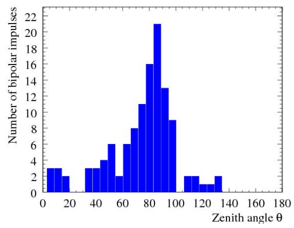
t_i – Start point of a signal in time series
r_0 – Position of center of the pyramid
r_i – Positions of hydrophones
t_0 – The moment of passage of sound front through r_0
σ_i – Time measurement error
V_s – Speed of sound in water

Pulse Selection



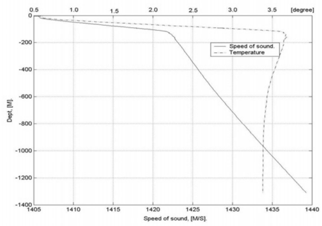
Example of experimental bipolar pulses. Those signals which satisfy to $t_{ij} < \delta \cdot t_{max}$ will be accepted.
Here $t_{max} = L_{ij}/V_s$ is the propagation time of a signal from one hydrophone to another, L_{ij} is the distance between two hydrophones, V_s - sound velocity at the depth where antenna is placed. We set δ=1.2.

Reconstructed Signal Direction



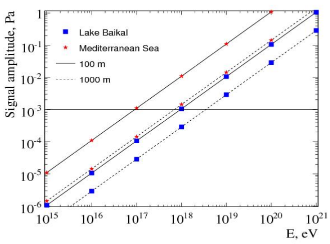
Distribution of reconstructed zenith angles triggered events (April - May 2006). Note: Acoustic signals from the lake surface and the upper 100m above the device have zenith angles between 0° and 90°.

Speed of Sound in Baikal Water



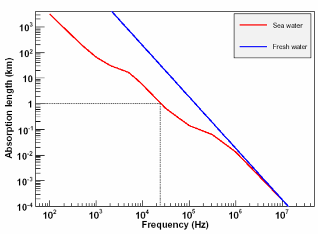
Sound speed and temperature as function of depth in Baikal water.

Acoustic signals from UHE cascades



Dependence of expected acoustic signal amplitudes generated by high-energy showers versus shower energy. Seawater compared to Baikal freshwater, for 100m and 1000m distance to shower. Indicated is a noise threshold of 1mPa for Lake Baikal.

Acoustic Absorption Length



Absorption length of sound in freshwater (Baikal) and seawater. Signals from UHE showers are mainly from 20-30kHz.

Conclusion

The results of the experiment have demonstrated the feasibility of the proposed acoustic pulse detection technique in searching for signals from UHE cascade. Although the Baikal water temperature is close to the temperature of its maximal density, the absence of strong acoustic noise sources in the lake's deep zone, the very low absorption and direction background suppression ("top" vs. "down") may allow for neutrino detection in Lake Baikal with a threshold of order 10^{18}-10^{19}eV.
In 2007, this prototype device was again deployed, and operates in common with the Neutrino Telescope NT200+.

References

[1] G.A. Askaryan. Atomnaya Energiya. 3, N.8:152, 1957
[2] C.S. Clay and H. Medwin. Acoustical Oceanography (Wiley, New York), 1977
[3] V. Aynutdinov et al. (Baikal Coll.), Int. J. Mod. Phys.A, 21S1: 117-121, 2006
[4] V. Aynutdinov et al. (Baikal Coll.), Acoustical Physics, 52. N.5: 495, 2006
[5] G.A. Askarian et al. NIM, 164: 267-278, 1979
[6] V. Aynutdinov et al. (Baikal Coll.), Int.J.Mod. Phys.A, 21S1: 202 -206, 2006
[7] N. Budnev et al. (Baikal Coll.), Proc. XVIII session of Russian acoustic society, Moscow, GEOS, II: 298-302, 2006
[8] C.T. Chen and F.J. Millero. Limnol. Oceanogr., 31.N.3: 657-662, 1986
[9] R.F. Weiss and E.C. Carmac., Nature, 349: 665-669, 1991
[10] V. Aynutdinov et al. (Baikal Coll.), ICRC2007, contributions 1084 and 1088