Results from the BAIKAL Neutrino Telescope

V.Ayutdinov[1], V.Balkanov[1], I.Belolaptikov[4], L.Bezrukov[1], N.Budnev[2], A.Chensky[2], D.Chernov[3], I.Danilchenko[1], Zh.-A.Dzhilkibaev[1], G.Domogatsky[1], A.N.Dyachok[2], O.Gaponenko[1], O.Gress[2], T.Gress[2], A.Klabukov[1], A.Klimov[8], S.Klimushin[1], K.Konischev[4], A.Koshechkin[1], V.Kulepov[6], L.Kuzmichev[3], Vy.Kuznetzov[1], B.Lubsandorzhiev[1], S.Mikheyev[1], M.Milenin[6], R.Mirgazov[2], N.Moseiko[3], E.Osipova[3], A.Panfilov[1], G.Pan'kov[2], L.Pan'kov[2], Yu.Parfenov[2], A.Pavlov[2], E.Pliskovsky[4], P.Pokhil[1], V.Polecshuk[1], E.Popova[3], V.Prosin[3], M.Rosanov[7], V.Rubtzov[2], Yu.Semeney[2], B.Shaibonov[1], Ch.Spiering[5], O.Streicher[5], B.Tarashanky[2], R.Vasiliev[4], E.Vyatchin[1], R.Wischnewski[5], I.Yashin[3], V.Zhukov[1]

(1) Institute for Nuclear Research, Moscow, Russia, (2) Irkutsk State University, Irkutsk,Russia, (3) Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia, (4) Joint Institute for Nuclear Research, Dubna, Russia, (5) DESY–Zeuthen, Zeuthen, Germany, (6) Nizhni Novgorod State Technical University, Nizhni Novgorod, Russia, (7) St.Peterburg State Marine University, St.Petersburg, Russia, (8) Kurchatov Institute, Moscow, Russia

Abstract

We review the present status of the Baikal Neutrino Project, present updated results on the search for high energy extraterrestrial neutrinos, fast magnetic monopoles and neutrinos induced by WIMP annihilation in the center of the Earth and compare the recorded atmospheric neutrino flux to predictions.

1. Introduction

The Baikal Neutrino Telescope NT-200 is operated in Lake Baikal, Siberia, at a depth of 1.1 km. A description of the detector as well as physics results from data collected in 1996 and 1998 (70 and 234 live days, respectively) have been presented elsewhere [1-3]. Here we present new limits including data taken in 1999 (268 live days). Data taken in 2000 are presently being analyzed. We also describe NT-200+ – an upgrade of NT-200 by three sparsely instrumented distant outer strings which increase the fiducial volume for high energy cascades to a few dozen Mtons. A prototype string of 140 m length with 12 optical modules was deployed in March 2003, and electronics, data acquisition and calibration systems for NT-200+ have been tested.

pp. 1353–1356

2. Atmospheric Muon Neutrinos as Calibration Tool

The clearest signature of neutrino induced events is a muon crossing the detector from below. Track reconstruction algorithms as well as background rejection have been described elsewhere [1]. Since on the one side the energy threshold for this particular analysis (15-20 GeV) is higher than in underground detectors, and on the other side NT-200 is much smaller than Amanda, event rates of atmospheric neutrinos are small compared to these experiments. Nevertheless, atmospheric neutrinos serve as an important calibration tool and demonstrate the understanding of the detector performance. The data set yields 84 upward going muons. The MC simulation of upward muon tracks due to atmospheric neutrinos gives 80.5 events. The angular distribution for both experiment and simulation as well as the skyplot of upward muons are shown in Fig. 1.

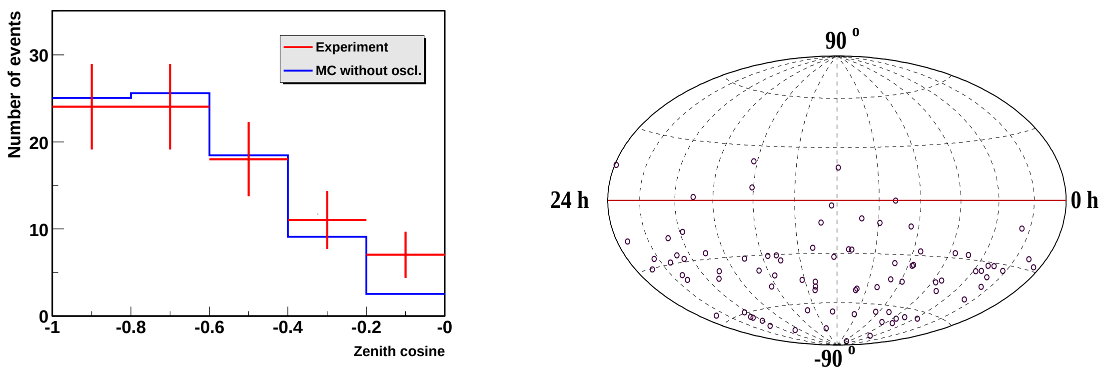

Fig. 1. Left: Angular distribution of experimental events and MC data. Right: Skyplot (equatorial coordinates) of neutrino events.

3. Search for Neutrinos from WIMP Annihilation

The search for WIMPs with the Baikal neutrino telescope is based on a possible signal of nearly vertically upward going muons, exceeding the flux of atmospheric neutrinos [2]. With no significant excess observed, we derive improved upper limits on the flux of muons from the direction of the center of Earth related to WIMP annihilation. Note that the threshold of 8-10 GeV for this analysis is lower than that for atmospheric neutrinos spread across the full lower hemisphere (see above). Fig.2 compares our new limits to those obtained by other experiments (see [4] and references given in [2]).

4. Search for Relativistic Magnetic Monopoles

Events due to relativistic monopoles ($\beta > 0.75$) are distinguished by their high light output, allowing identification of events beyond the geometrical boundaries of the detector. The search strategy has been described in [2]. An improved analysis including data from 1996 to 1999 yields a limit about a factor of two

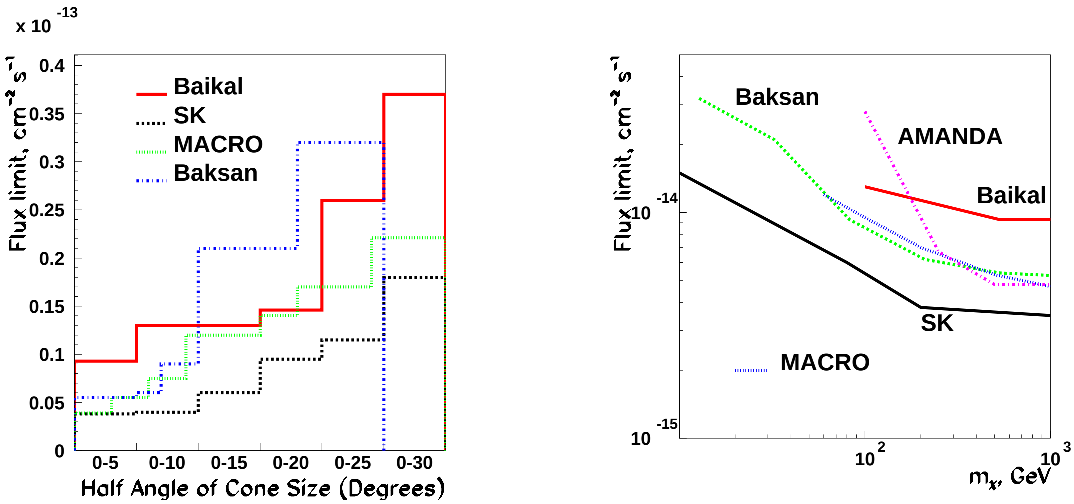

Fig. 2. Left: Limits on the excess muon flux from the center of the Earth versus half-cone of the search angle. Right: Flux limits as a function of WIMP mass.

below the limit published earlier. This limit is compared to those from other experiments (see [5] and references in [2]) in Fig. 3.

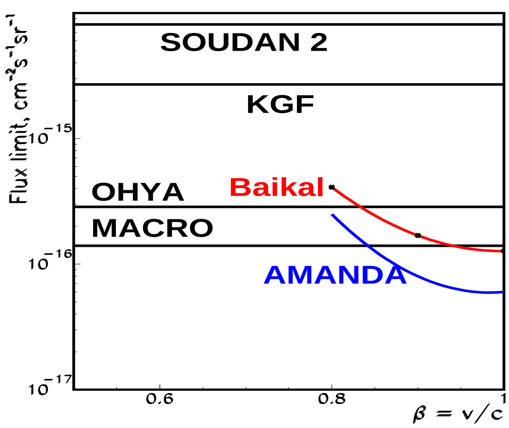

Fig. 3.: Upper limits on the flux of fast monopoles obtained in different experiments.

5. A Search for Extraterrestrial High Energy Neutrinos

The BAIKAL survey for high energy neutrinos searches for bright cascades produced at the neutrino interaction vertex in a large volume around the neutrino telescope [3]. Lack of significant light scattering allows to monitor a volume exceeding the geometrical volume by an order of magnitude. This results in sensitivities of NT-200 comparable to those of the much larger Amanda-B10 detector. The background to this search are bright bremsstrahlung flashes along downward muons passing far outside the array. The method has been described in [3].

Candidate events do not show a statistically significant excess of hit multiplicity compared to the simulated background from atmospheric muons. Assuming an E^{-2} shape of the neutrino spectrum and a flavor ratio $\nu_e : \nu_\mu : \nu_\tau = 1:1:1$, the new, preliminary 90% C.L. upper limit is $\Phi_{\nu_e} E^2 = 4 \cdot 10^{-7}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{GeV}$, about twice below previous results [3]. The preliminary limit on $\tilde{\nu}_e$ at the W - resonance energy is: $\Phi_{\tilde{\nu}_e} \leq 5.4 \times 10^{-20}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$. These limits do not yet include the effect of systematic uncertainties. Fig.4 (left) shows the experimental upper limits [3] as well as theoretical limits obtained by Berezinsky (B), by Waxman and Bahcall (WB), by Mannheim et al.(MPR), and predictions for neutrino fluxes from Stecker and Salamon (SS) and Protheroe (P).

Fig.4 (right) shows NT-200+ with its three additional outer (plus one possible central) strings. It will allow a much better vertex identification and hence a significantly more precise *measurement* of cascade energy in a volume around NT-200. The sensitivity of NT-200+ to high energy cascades will be four times better than that of NT-200, with a moderate 20 percent increase of optical modules only.

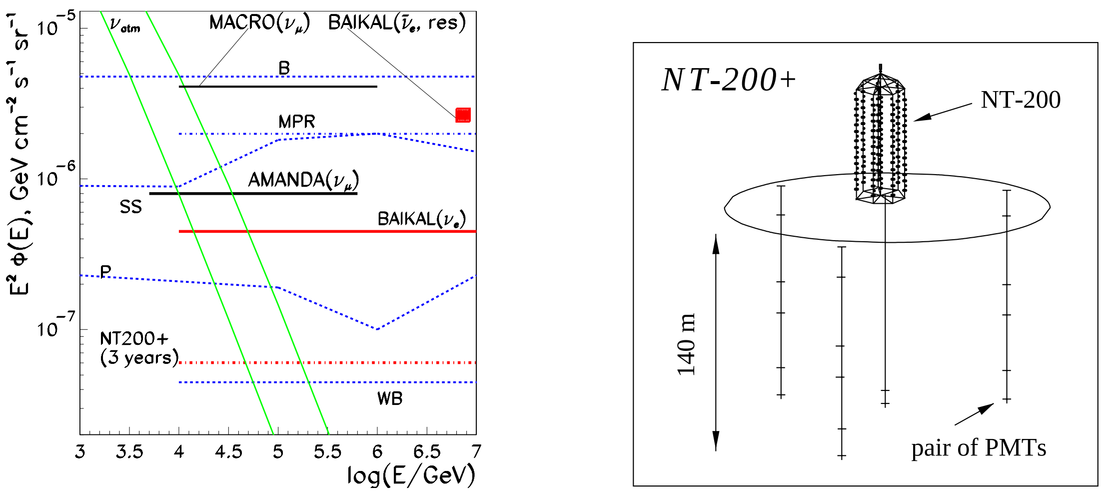

Fig. 3. Left: Experimental upper limits on the neutrino fluxes as well as flux predictions in different models of neutrino sources (see text). Right: The NT-200+ configuration.

This work was supported by the Russian Ministry of Research,the German Ministry of Education and Research and the Russian Fund of Basic Research (grants 03-02-31004, 02-02-17031, 02-07-90293 *and* 01-02-17227), *Grant of President of Russia* NSh-1828.2003.2 *and by the Russian Federal Program "Integration" (project no.* E0248).

6. References

1. Belolaptikov I. et al. 1997, Astr.Ph. 7, 263; and Astr.Ph. 12 (1999) 75.
2. Balkanov V. et al. 2001, Nucl.Ph.(Proc.Sup.) B91, 438.
3. Balkanov V. et al., astro-ph/0211571.
4. Habig A. et al. 2001, Proc.of the XVII ICRC, 1558.
5. Ambrosio M. et al. 2002, Eur.Ph.J. C25, 511.