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The Baikal neutrino telescope: Results and prospects

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We review recent results on the search for high-energy extraterrestrial neutrinos, neutrinos induced by WIMP annihilation and neutrinos coincident with gamma ray bursts as obtained with the Baikal neutrino telescope NT-200. We describe the moderate upgrade of NT-200 towards a ∼10 Mton scale detector NT-200+.

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]. Here we present new limits, including data taken in 1999 (268 live days). We note that the year 2003 marks the tenth anniversary of the deployment of NT-36, the pioneering first stationary underwater array [2,3].

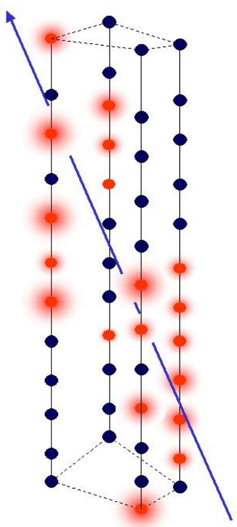

Figure 1. Upward-going muon track with 19 fired channels, recorded in 1996. Hit channels are marked in color, with the size of the aura indicating the recorded amplitude.

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Fig. 1 shows a textbook neutrino event (an upward-moving muon track) recorded with the early 4-string configuration in 1996 [4].

2. 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. Lack of significant light scattering allows monitoring of 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 is bright bremsstrahlung flashes along muons passing far outside the array (see [5] for details).

Candidate events do not show a statistically significant excess of hit multiplicites 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, with respect to the flux of all three flavors, is $\Phi_{\nu_e+\nu_\mu+\nu_\tau} E^2 = 1.2 \cdot 10^{-6}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{GeV}$, about twice below previous results [5]. The preliminary limit on $\tilde{\nu_e}$ at the W - resonance energy is: $\Phi_{\tilde{\nu_e}} \leq 5.4 \times 10^{-20}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$. Fig. 2 shows the experimental upper limits obtained by BAIKAL (this work), and AMANDA [6], as well as the projected sensitivity for NT-200+ (see below). Limits are compared to SSDS [7] and MPR [8] predictions. The slanted lines at the left side represent the atmospheric neutrino fluxes (dashed for ν_μ, solid for ν_e).

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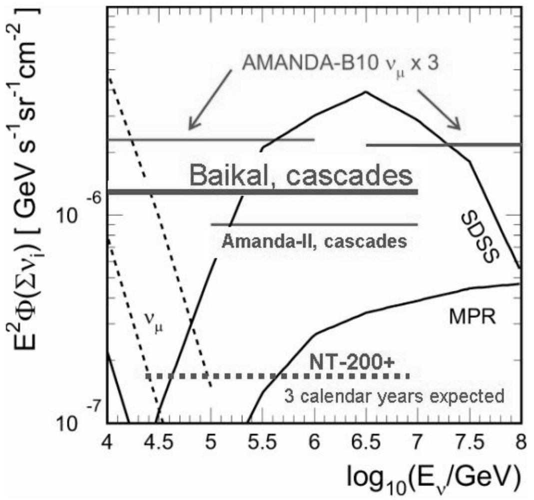

Figure 2. Experimental upper limits on neutrino fluxes (see text for explanation).

3. NEUTRINOS COINCIDENT WITH GRB

We have searched for high-energy cascades coincident with 772 gamma ray bursts (GRB), recorded between April 1998 and February 2000 by the BATSE detector and falling into online periods of NT-200 (386 triggered GRB, 336 non-triggered from Stern catalogue). After cuts for background reduction, we are left with one event within one of the ±100-second windows, where 0.47 events would have been expected from accidental coincidences. Precise limits on the fluence are being derived at present. With an effective volume in the Megaton range, NT-200 is the largest Northern detector for high-energy neutrinos from GRBs.

4. 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 (see [9]). Note that the threshold of 5-10 GeV for this analysis is lower than that of $\sim$ 15 GeV for atmospheric neutrinos spread across the full lower hemisphere. Fig. 3 (top) demonstrates that the angular distribution of events passing a special filter for events close to the vertical is well described by simulations including the effect of neutrino oscillations (assuming $\delta m^2 = 2.5 \cdot 10^{-3}$ eV^2).

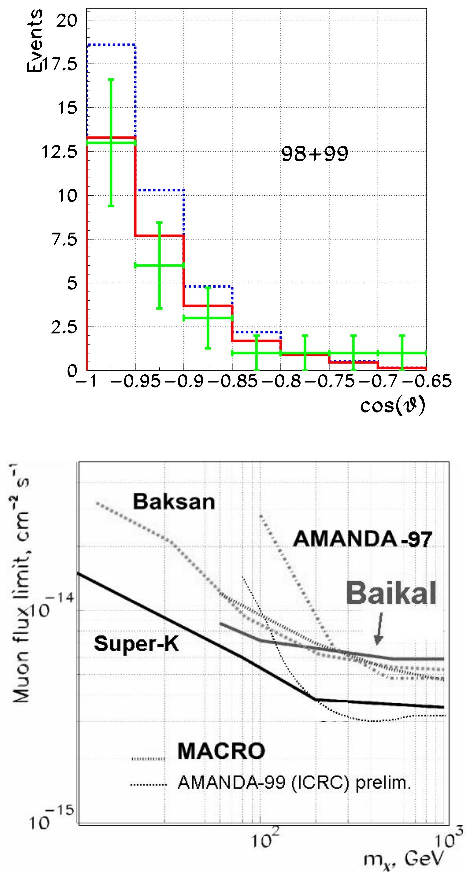

Figure 3. Top: Angular distribution of selected neutrino candidates compared to expected distributions including (full line) and excluding (dotted line) the effect of oscillations. Bottom: Flux limits from different experiments as a function of WIMP mass.

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. Fig. 3 (bottom) compares our new limits to those obtained by other experiments (see [9] for references).

5. UPGRADE TO NT200+

NT-200+ is an upgrade of NT-200 by three sparsely instrumented distant outer strings (see Fig. 4, top). The fenced volume is 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. The 3 strings allow for dramatically better vertex reconstruction of high-energy cascades than with NT-200 alone (see Fig. 4, bottom). NT-200+ will be installed in 2004 and 2005.

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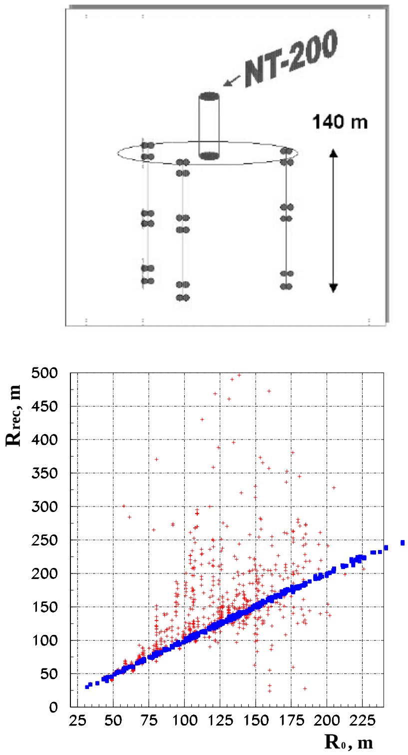

Figure 4. Top: Configuration of NT-200+. Bottom: Reconstructed vs. generated coordinates of cascades in NT-200+ (rectangles) and NT-200 (crosses).

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