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Physics Results from the Baikal Neutrino Telescope

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The Baikal neutrino telescope NT200 is in operation since April, 1998. We present physics results obtained with this detector during 1998-2002. Since April 2005, the upgraded 10-Mton scale telescope NT200+ is operating. For a km3-scale neutrino telescope in Lake Baikal, the R&D phase has started in 2006.

1. Introduction

The Baikal Neutrino Telescope NT200 has been taking data since April 1998. On April 9th, 2005, the upgraded 10-Mton scale detector NT200+ was put into operation in Lake Baikal. Site properties, detector configuration and performance have been described elsewhere [1–6]. Fig. 1 sketches the new NT200+ telescope: The central detector NT200 (192 photomultiplier (PMT)) is fenced by 3 external strings with 12 PMT each, enclosing a geometric volume of 5 Mton [3].

In this paper we present selected physics results [4], obtained from NT200 data taken in 1038 live-time days between April 1998 and February 2003 (for atmospheric neutrinos, see [1,4,5]).

2. Selected results obtained with NT200

2.1. 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 that due to atmospheric neutrinos, which could result from annihilation of neutralinos - the favored candidate for cold dark matter - in the center of the Earth. Event selection is done by a series of cuts, tailored to the telescope response to nearly vertically upward moving muons, without explicit request for 3-dimensional track reconstruction, see [7] for details. Muons with zenith angle -1< $\cos(\theta)$ <-0.75 are selected, the detection area reaches 1800 m^2 for vertically upward muons.

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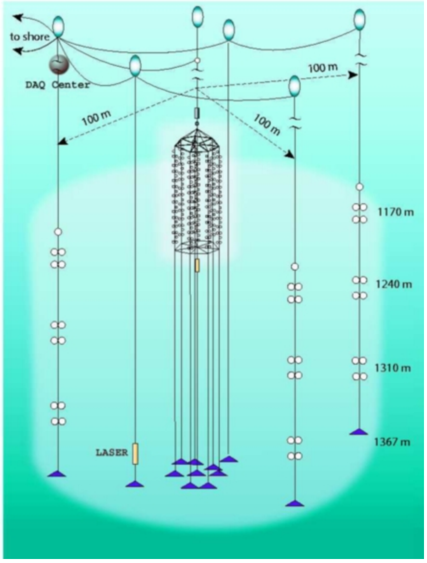

Figure 1. The upgraded Baikal telescope NT200+. The central NT200 is surrounded by 3 strings at 100 m radial distance.

With an energy threshold of $E_{\mathrm{th}} \sim 10\,\mathrm{GeV}$, this analysis is subjected to 25-30% muon event suppression due to neutrino oscillation.

From 1038 livetime days, 48 events have been selected as clear neutrino events. Angular distribution and rate are within 1σ consistent with MC-predictions, based on the Bartol96 atmospheric ν-flux, and recent Super-Kamiokande oscillation parameters (for references see [7]).

Regarding the 48 detected events as being induced by atmospheric neutrinos, we derive an upper limit on the additional flux of muons from the center of the Earth. The 90% C.L. muon flux limits for different neutralino masses obtained with NT200 are shown in Fig. 2, and are compared to limits from Baksan, MACRO, Super-Kamiokande and AMANDA (for details and references see [7]).

2.2. Search for fast magnetic monopoles

Fast magnetic monopoles that would pass through a deep underwater neutrino telescopes yield bright events ($\approx$ 8300 times more light than a muon). Baikal PMTs can detect them up to hundred meters. The signal selection requests a large number of hit channels, $N_{hit} > 35$, an indication of upward movement from raw data (time–z–correlation, C_{tz}), and good reconstruction as an upward track (for details and references see [8]).

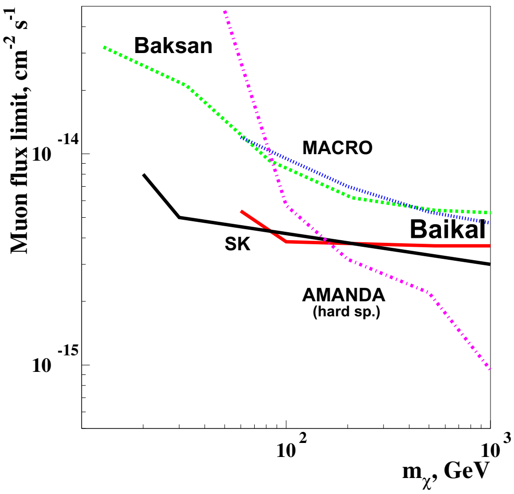

Figure 2. Limits on the excess muon flux from the center of the Earth as a function of WIMP mass for NT200 and other experiments (see [7]).

For 994 livetime days (1998-2002), no events from the experimental data sample pass all signal cuts. From the non-observation of candidate events in NT200 and the earlier stage telescopes NT36 and NT96 [8], a combined upper limit on the flux of fast monopoles with 90% C.L. is obtained, and is for $\beta = 0.8 - 1.0$ given in Fig. 3. This isotropic flux limit is compared to limits from the underground experiments Ohya and MACRO and to the AMANDA limit. Baikal NT200 obtains the currently most stringent limit.

2.3. High-energy cosmic neutrino search

The Baikal survey for high energy extraterrestrial neutrinos searches for bright cascades produced at the neutrino interaction vertex in a large volume around the telescope [2]. We select events with large number of hit channels N_{hit} (signal: bright cascades), and signature for upward moving light by time differences along the strings (background: energetic atmospheric muons).

With 1038 days of detector live time and 3.45×10^8 recorded events with $N_{\mathrm{hit}} \geq 4$, we observe no signal events after final cuts. Upper limits on the diffuse flux of extraterrestrial

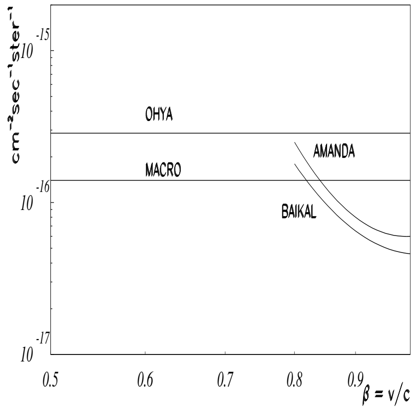

Figure 3. Upper limits on the flux of fast monopoles from Baikal and other experiments.

neutrinos can be derived, which depend on the signal spectral shape. For an E^{-2} behaviour of the neutrino spectrum and a flavor ratio at earth of $\nu_e : \nu_\mu : \nu_\tau = 1 : 1 : 1$, the 90% C.L. upper limit on the diffuse all-flavor neutrino flux is $E^2\Phi < 8.1 \times 10^{-7}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{GeV}$. At the Glashow resonance ($E_0 = 6.3\,\mathrm{PeV}$) we obtain the model-independent $\bar{\nu}_e$ flux limit $\Phi_{\bar{\nu}_e} < 3.3 \times 10^{-20}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$.

Both limits are shown in fig. 4. Also shown are the limits from AMANDA and MACRO, and various model predictions and theoretical bounds, as well as the atmospheric conventional and prompt neutrino fluxes (see [9] and for references [2]), and the expected 3-year sensitivity for the new telescope NT200+ [3].

3. Conclusion

The Baikal neutrino telescope NT200 is taking data since April 1998. Most important physics results are: an all-flavor upper flux limit for diffuse cosmic neutrinos for 20 TeV < E < 50 PeV, competitive limits on neutralino annihilation in the Earth, and the presently most stringent flux limit for fast magnetic monopoles. While the new telescope NT200+ is taking data (4 fold high energy neutrino sensitivity), we started research & development activities for a Gigaton Volume (cubic kilometer) Detector in Lake Baikal, with a technical design report due in 2008.

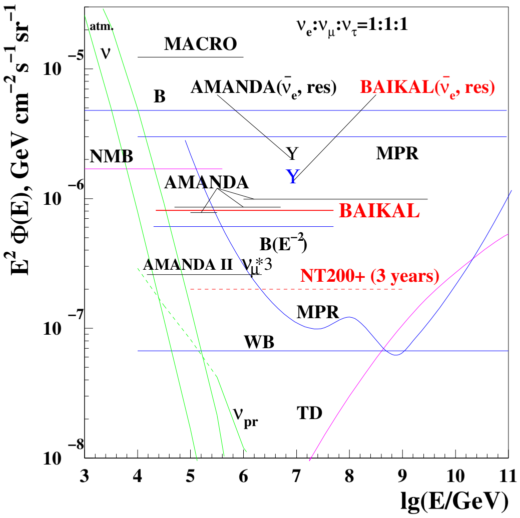

Figure 4. All-flavor neutrino flux predictions in different models of neutrino sources, compared to experimental upper limits to E^{-2} fluxes obtained by this analysis and other experiments (see text).

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