The Baikal Neutrino Telescope – Physics Results

Abstract **The Baikal Neutrino Telescope is located in Lake Baikal, Siberia. From 1998-2004, it was operating in its NT200 configuration. In 2005, this telescope with 192 PMTs was upgraded to NT200+, which has an instrumented volume of ~5 Mton of water (~100 times more than NT200), and is tailored to the search for diffuse astrophysical neutrinos. We report physics results obtained with NT200 in 1038 live-days from 1998-2003.**

The Baikal-Telescope has been pioneering the field of high energy neutrino astronomy. Until recently, Baikal was the only northern underwater neutrino detector watching the southern TeV-neutrino sky.
A design study for a km3-scale detector in Lake Baikal is conducted by the russian part of the collaboration. Km3 detector construction will start in 2010. DESY's mission in this pioneering experiment will be accomplished in 2008.

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The NT200+ Telescope

The deep underwater neutrino telescope **NT200+** was commissioned in 2005. It is the successor of the smaller **NT200**, operating since 1998 in Lake Baikal at a depth of 1100m [1].
Excellent water scattering properties allowed to extend the sensitive volume far beyond the NT200 geometry. NT200+ has three additional strings at radial distance of 100m from NT200 (fig.1), allowing for improved shower energy and vertex reconstruction.

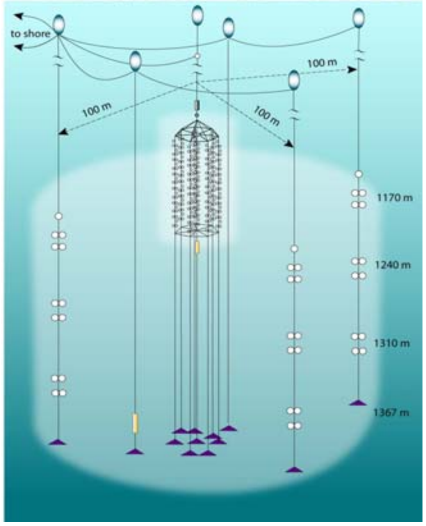


Fig.1: *Baikal Telescope **NT200+** : central NT200 and 3 strings at 100m radius. Instrumented volume: 5 Mton, detection volume at E_{shower}=10PeV: 20 Mton.*

Relativistic Magnetic Monopoles

For a Dirac charge g = 68.5 e, Cerenkov radiation emitted by monopoles is 8300 times that of a muon.
A monopole search is done for bright events (>30 pairs of PMTs hit) with upward moving light patterns ("time-vertical-coordinate correlation"); with an acceptance of 3-6x10^8 cm^2 sr [3]. From non-observation of candidate events, 90%CL upper limits are derived, see Fig.2.

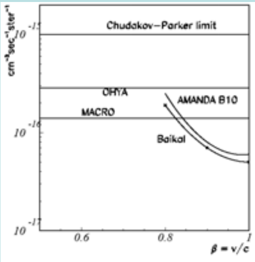


Fig.2: *90%CL Limits on flux of fast magnetic monopoles from BaikalNT200, compared to published results.*

A km3 Detector in Lake Baikal

Layout: ~1300-1700PMTs at ~90-100 strings
string: 12-16 PMTs, 300m length

Cascades: V_{eff} ~ 0.5-0.7 km^3 δ(lgE)~0.1 δθ_{med}~4°
Muons E_{thr} ~ 10-30 TeV

Milestones:
- TDR in 2008; R&D started in 2006.
- In-situ tests of new components uses running NT200+ telescope.
- Construction start ≥ 2010.

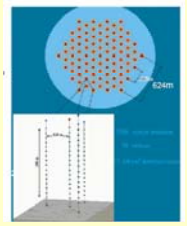


Fig.5: *Sketch of the km3-Baikal detector.*
The basic detector cell (4 strings, insert) and new technical solutions are studied with the existing NT200+ detector.

UHE Neutrinos

Main focus of neutrino telescopes is the detection of astrophysical neutrinos. In NT200, a search for bright cascades from ν-interactions in a volume much beyond the instrumented volume yields a sensitivity that is comparable to Mton detectors. The experimental signatures are (1) high number of hit PMTs and (2) suitable "upward" time pattern, thus efficiently cutting the high muon-brems background.

From the non-observation of events beyond background expectations, upper limits on an E^{-2} diffuse flux of ultrahigh energy neutrinos are derived, see fig.3. Restrictions on some models for UHE neutrino production are derived (table 1). For details, see [4]. NT200+ has ~4 times larger sensitivity than NT200.

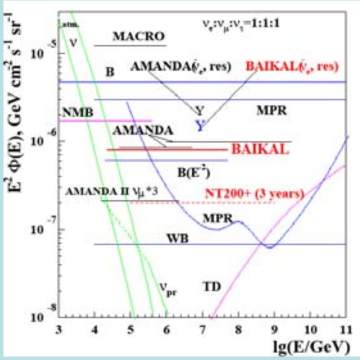


Fig.3: *All flavor neutrino flux limits for a E^{-2} spectrum from BAIKAL (and other exp.); and predictions for ν-flux from various source models and atm.BG. See [4].*

	BAIKAL	AMANDA
Model	$n_{90\%}/N_{\rm m}$	$n_{90\%}/N_{\rm m}$
$10^{-6} \times E^{-2}$	0.81	0.22
SS Quasar	0.25	0.21
SS05 Quasar	2.5	1.6
SP u	0.062	0.054
SP l	0.37	0.28
P $p\gamma$	1.14	1.99
M $pp + p\gamma$	2.86	1.19
MPR	4.0	2.0
SeSi	2.12	-

Table 1: Model rejection factors for models of astrophysical neutrino sources.

R&D for km3 - New Technology String

R&D Milestone for 2008:
Deployment of a km3-prototype string (new electronics, 200MHz FADC).
Common operation with NT200+ : full physics test.

Fig.6: *Sketch of the km3-prototype string, to be installed in 2008 with NT200+. Key elements of the new system have been tested in 2006/2007.*

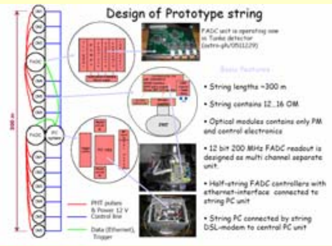
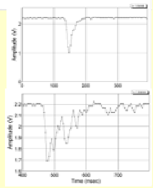


Fig.7: *Examples of signals from 13" PMTs; from muons (upper) and bright backward laser pulses (lower), recorded by 200MHz FADC in-situ with NT200+.*



WIMPs from Center of Earth

WIMPs annihilating in the center of the Earth will result in an enhanced flux of vertical upward neutrino events. A dedicated search technique, developed for vertical upgoing track patterns, yields a sensitive area of ~1800m^2 (E_μ>10GeV).
Events found for 1038 days of lifetime are compatible with the atmospheric neutrino flux. Resulting flux limits are shown in fig.4.

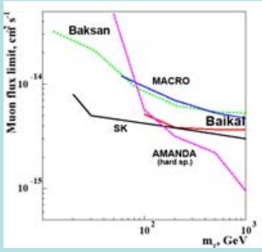


Fig.4: *Limits on flux of upward muons from WIMP annihilation in the center of Earth: Baikal NT200, and other experiments (normalized to Eth=1GeV).*

R&D for km3 - PMT Selection

NT200+ uses the 14.6" QUASAR PMT. For km3, various options for large area PMTs are under test: in-situ with the telescope and in laboratory. Emphasis is on large photocathode area, high quantum efficiency and optimal geometry (hemispherical) of PMT and optical module. Classical PMTs (e.g. R8055/Hamamatu and XP1807/Photonis), and also "smart" Quasar-like PMTs are considered.

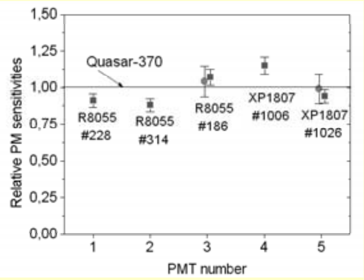


Fig.8: *Relative PMT sensitivities for R8055 (13") and XP1807 (12"), normalized to a Baikal Quasar PMT (laboratory and in-situ; prelim.).*

References:
[1] V.Aynutdinov et al., NIM A567 (20006) 433; [2] V.Baklanov et al, Astropart.Phys. 12 (1999) 75; [3] K.Antipin et al., Proc.Worksh.Exotic.Phys.,astroph/0701333 [4] V.Aynutdinov et al., Astropart.Phys. 25 (2006) 140
See also: V.Aynutdinov et al., ICRC2007, Merida, Mexico, paper 0639, 1084, 1088.