Telescope takes next step

Top: the central trigger electronics in its pressure glass spheres, ready to descend into Lake Baikal. Bottom: a pair of light sensors in water about 10 m below the ice cover of the lake, before deployment to a depth of 1.1 km.

In April, while Lake Baikal in Siberia was iced over was successfully upgraded with three additional for diffuse fluxes of cosmic neutrino

On 9 April 2005, another sunny and bitterly cold day on the south-west shore of Lake Baikal in Siberia, NT200+ was commissioned as the successor to the neutrino telescope NT200. With an effective volume of 10 million tonnes, NT200+ forms one of a trio of large high-energy neutrino telescopes currently in operation, together with Super-Kamiokande in Japan and the Antarctic Muon and Neutrino Detector Array (AMANDA) at the South Pole.

Every year in February and March, the Baikal Neutrino Telescope is hauled up close to the surface of the thick layer of ice that covers the lake in winter for routine maintenance. Then, in early April, in a race against the steadily warming environment, the ice camp with all its containers and winches is dismantled and stored on shore. The telescope is re-deployed to its operational depth of 1.1 km below the surface and switched back on for another year of operation. With a stable ice cover on the lake lasting well into April, nature has been kind this year to the 50 physicists and technicians, who have struggled over two Siberian winters to accomplish their ambitious programme to upgrade NT200.

The existing NT200 telescope consists of 192 glass spheres, 40 cm in diameter, each housing a 37 cm phototube. The first, smaller stage of the telescope was commissioned in 1993, and became the first stationary underwater Cherenkov telescope for high-energy neutrinos in a natural environment (*CERN Courier* September 1996 p24). The full array was completed in 1998 and has been taking data ever since.

The glass spheres are arranged in pairs along eight vertical strings

p to high-energy frontier

, the neutrino telescope 1.1 km below the surface strings. Renamed NT200+ it is tailored to search s at energies of peta-electron-volts.

that are attached to an umbrella-like frame at a depth of 1.1 km. The phototubes record the Cherenkov light emitted by charged particles as they pass through the water. Three electrical cables, 5 km long with seven wires each, connect NT200 to the shore 3.5 km away and enable the array to be operated throughout the year. Two of these cables were changed in 2004 and 2005. The reliability and performance of the telescope were also improved during this period, with embedded high-performance PCs installed underwater. In addition, new modems operating at 1 Mbit/s have increased the transfer rate to shore by two orders of magnitude.

NT200 looks at the sky for sources of high-energy cosmic neutrinos. Galactic candidates for high-energy sources include supernova remnants and micro-quasars, while extragalactic sources include active galactic nuclei and gamma-ray bursts. If individual sources are too weak to produce an unambiguous directional signal, the integrated neutrino flux from all sources might still produce a detectable "diffuse signal". This flux could be identified by an excess of particles at high energies above the background – which is dominantly muons produced in the atmosphere above the detector, with a small contribution from muons generated in the interactions of atmospheric neutrinos.

The most important result of the first four years of NT200 comes from a search for such a diffuse neutrino flux. It is based on a principle that works only in media with small light scattering, such as water. The idea is not only to watch the geometrical volume of the detector, but also to look for bright events in the large volume ▷

A glass cylinder housing a powerful nitrogen laser, the light of which – shifted to the blue – illuminates all photomultipliers and allows a time synchronization of about 2 ns. The light flash also mimics high-energy particle cascades in an energy range from 20 TeV to 10 PeV.

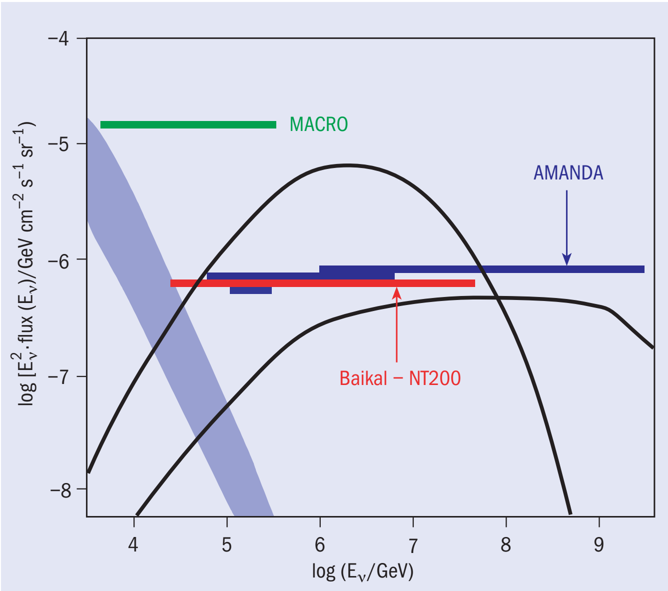

Fig. 1. The best current experimental limits on the flux of diffuse high-energy cosmic neutrinos of all three types. The limit from the Baikal experiment (1998–2002) covers an energy range of 20 TeV to 50 PeV. The various AMANDA limits are for one year. The upper curve denotes a model for neutrino production in active galactic nuclei, which is excluded by the new limits since it predicts a fourfold higher flux; the lower curve represents another model that can be tested only with more and better data. The band at the left side denotes the known flux of neutrinos generated in the atmosphere.

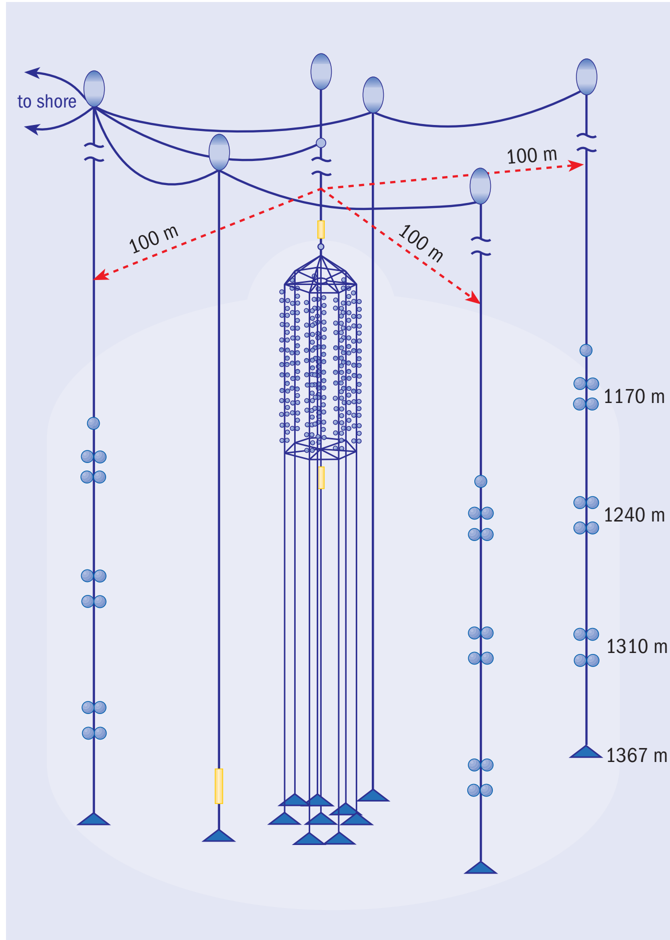

Fig. 2. The new NT200+ adds three outer strings to NT200, which has operated since 1998. Each string carries 12 light sensors. Calibration lasers are shown in yellow.

between the detector and the bottom of the lake. Because of the small light scattering, wave fronts are preserved over 100 m or more. This results in good pattern recognition for bright particle cascades occurring far outside the geometrical volume, and it enables distant high-energy cascades generated by neutrinos to be distinguished from bright bremsstrahlung showers along the much more frequent downward-going muons. No such events in excess of background have been found.

This result can be transformed into a limit on the flux of cosmic neutrinos, for a given spectral distribution. Assuming a reference spectrum that falls with the inverse square of the neutrino energy, four years of Baikal data yield the flux limit shown in figure 1. For comparison, the limits obtained in one year with the much larger AMANDA telescope are shown. Both experiments have entered new territory and exclude several models for sources of cosmic neutrinos.

It is this success that motivated the upgrade to NT200+. In the new configuration, three 140 m strings with 12 photomultipliers each are arranged at a radius of 100 m from NT200, so that they surround most of the sensitive volume (figure 2). This enables a much better determination of the shower vertex and dramatically improves the energy resolution. As a result, the upgrade, which adds only 36 photomultipliers to the existing 192, yields a fourfold rise of the sensitivity at 10 PeV – certainly a cost-effective way to do better physics.

The results from NT200 have demonstrated that a deep underwater detector with an instrumented volume of 80 kt can reach an effective volume of a few megatonnes at peta-electron-volt energies. NT200+, with its moderate but cleverly arranged additional instrumentation, will boost the effective volume to more than 10 Mt. If successful, this could become the prototype for an even larger, sparsely instrumented detector for high energies.

● The Baikal Telescope is a joint Russian-German project, with the Institute for Nuclear Research (INR) in Moscow, the Moscow State University, the Joint Institute for Nuclear Research, Dubna, the Irkutsk State University (all Russia) and DESY (Germany).

Résumé

Le télescope du Baïkal va explorer de nouveaux territoires

Le télescope à neutrinos du lac Baïkal est un détecteur immergé par environ 1.1 km de fond. Les opérations de maintenance et d'amélioration ont lieu en février et mars, époque où le lac est recouvert d'une épaisse couche de glace. Cette année, le télescope existant, NT200, a été doté de trois lignes supplémentaires de tubes photomultiplicateurs. Rebaptisé NT200+, le détecteur ainsi amélioré recherchera des flux diffus de neutrinos cosmiques à des énergies de l'ordre du péta-électron-volt.

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