Search for astrophysical neutrino sources at the Baksan Underground Scintillation Telescope

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Abstract Baksan Underground Scintillation Telescope is an underground detector located at the Northern Caucasus (Russia). The BUST can detect an astrophysical flux of neutrinos from Galactic sources as an excess of cosmic ray muon neutrinos arriving from the source direction. The search performed using 38 years (live time = 31.05) of the BUST dataset to look for a statistically significant excess of events arriving within a solid angle. No significant excess of events produced by astrophysical sources is found. Since the number of detected events is compatible with the number of expected background events upper limit on the muon neutrino flux is determined.

Keywords: Cosmic Rays, Neutrino, Astrophysics, Galaxies, Local Sources

1. Experimental Data

The Baksan Underground Scintillation Telescope (BUST) [l] is located in the underground laboratory at the effective depth of 850m.w.e. The detector itself is a parallelepiped 16.7 x 16.7 x ll m^3, all sides of which are entirely covered by liquid scintillator counters of the standard type (0.7m x 0.7m x 0.3m). There are also two additional horizontal layers inside, at distances of 3.6 and 7.2 meters from the bottom. Thus the detector consists of four horizontal and four vertical planes, each separated from the other by m160g/cm2 of absorber. The total number of the detectors is 3180. Every counter is viewed with one PMT (the 15 cm diameter photocathode). The construction of BUST allows one to identify tracks of muons crossing the telescope. Separation of arrival directions between up and down hemispheres is made by time-of-flight (TOF) method with time resolution 5 ns [2]. The angular resolution of the BUST for reconstructed events is about 1.6°.The detection of upward-going muons is performed by means of the time-of-flight method. In first period (1978 – 2000) two hardware triggers are used in order to reject downward-going atmospheric muons. Trigger I covers the zenith angle range 95° — 180°, while trigger II selects horizontal muons in the range 80° — 100°, for more details see ref [3,4]. Since 2000 year no use hardware triggers for select neutrino events.

The data used for this analysis have been collected from December of 1978 until June of 2017, for a total of 31.05 live-years. It was found that 1635 events survived these cuts.

2. **Search for astrophysical sources**

In this work we calculate real live-time for selected astrophysical objects. ***Fig1*** shows dependence of BUST detector live-time for declination (δ). The search for a neutrino induced signal has been performed within angular windows of 5° around a exact coordinates of selected astrophysical objects. The size of the window was derived by Monte Carlo simulations of point-like neutrino sources with power law spectra (γ =2.5), and is the cone opening angle including 90% of the effect. The scattering angle between incident neutrino and daughter muon, multiple Coulomb scattering of the muon in the rock, and the angular resolution of the detector have been taken into account.

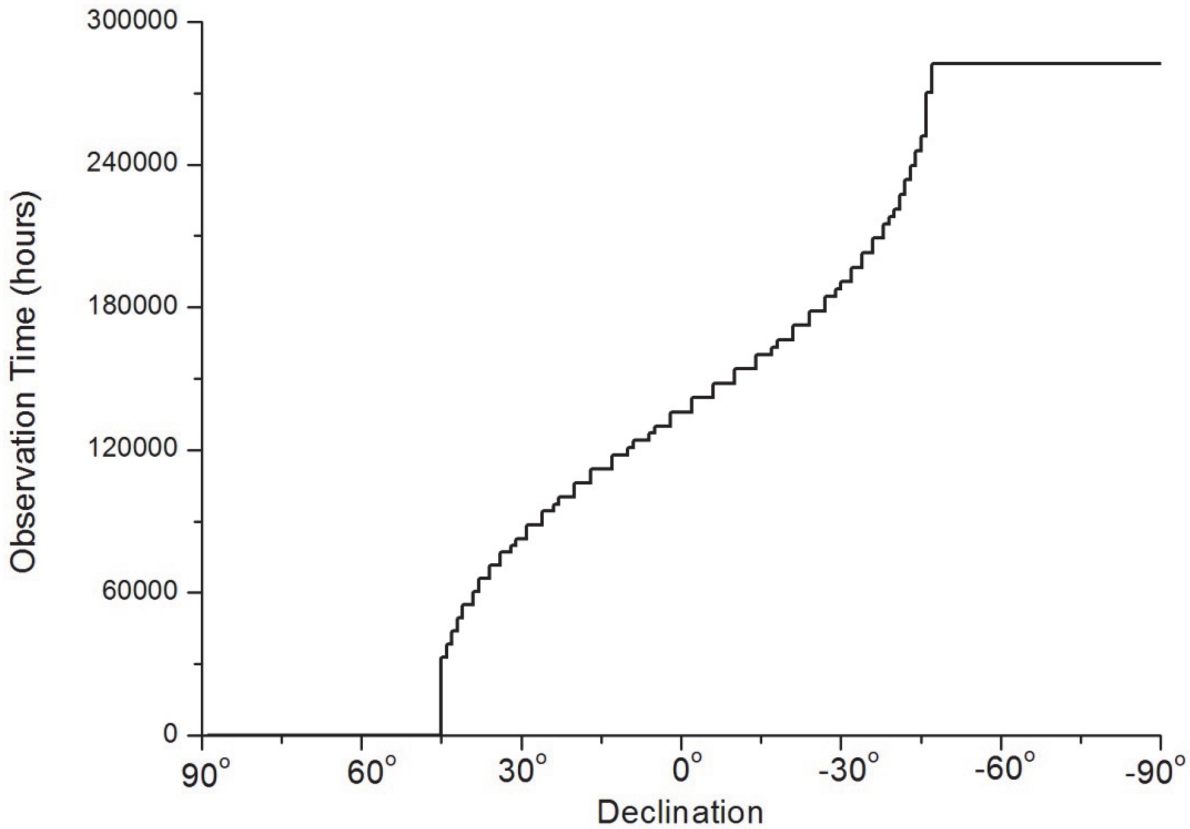

Fig1. *Dependence live-time according by declination - δ*

Table1 shows the number of upward-going muons observed within the window and the expected background, which was evaluated from simulations of the angular distribution of atmospheric neutrino induced muons and randomization of the event arrival times. The neutrino flux of [5] has been used. No evidence is found for any excess, and 90% C.L. limits for muon fluxes are given in fifth column of ***Table1***. For this search we have used the entire sample of 1635 events.

Table1. *Baksan flux limits on astrophysical muon neutrino sources*

Object	α(°)	δ(°)	Background	Events	μ Flux (cm-2 s-1) 90% C.L.
G.C.	265.6°	- 28.9	6.5	5	$0.32 \cdot 10^{-14}$
NGC 1952	83.6	+22.0	1.9	0	$0.87 \cdot 10^{-14}$
Vela X-1	135.5	-40.3	6.5	4	$0.15 \cdot 10^{-14}$
SS433	288.0	+5.0	2.8	1	$0.63 \cdot 10^{-14}$
3c273	187.3	+2.0	2.9	4	$0.52 \cdot 10^{-14}$
NGC 5128	201.4	-43.0	6.8	5	$0.15 \cdot 10^{-14}$
Cen. X-3	170.3	-60.6	6.3	3	$0.11 \cdot 10^{-14}$
Cyg. X-3	307.7	+40.8	0.1	0	$0.99 \cdot 10^{-14}$
Gem. SN437	98.5	+17.8	2.1	2	$1.35 \cdot 10^{-14}$
Scorp. X-1	245.0	-15.6	4.2	3	$0.37 \cdot 10^{-14}$

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