Follow up of the IceCube alerts on the Baikal-GVD telescope

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Abstract

High energy neutrino alerts observed by IceCube in Fall 2020, have been performed in fast regime using Baikal-GVD data first time. Search for correlations between alerts and events reconstructed in two modes, track and cascade, for the time windows ± 1 hour and ± 12 hours does not indicate statistically significant excess of the number over the expected number of background events.

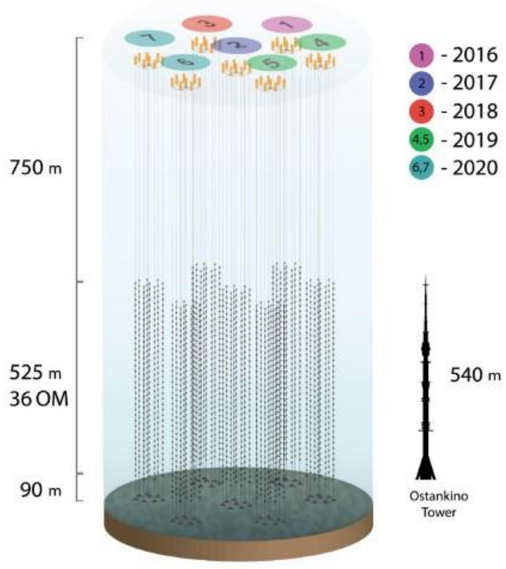
Upper limits on fluences of the neutrino emission are presented for nine directions of the alerts.

Installation work on Baikal

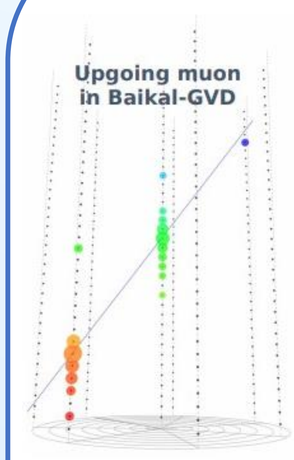
IceCube observatory

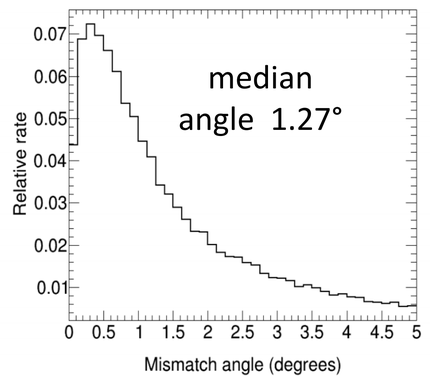
Baikal-GVD status

- 7 clusters have been operating since April 2020 with volume 0.35 km^3 [1].
- Baikal-GVD has been participating in the MM program since December 2018, having started receiving ANTARES alerts when it was 3 clusters, then 5 clusters in 2019 [2].
- For the first time since autumn 2020, Baikal GVD monitors IC alerts online.

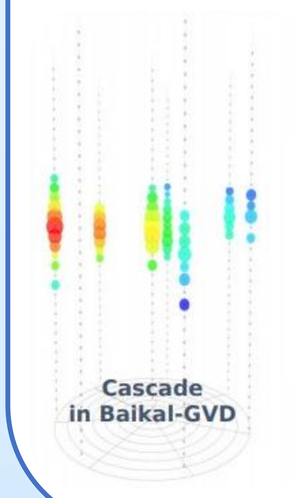


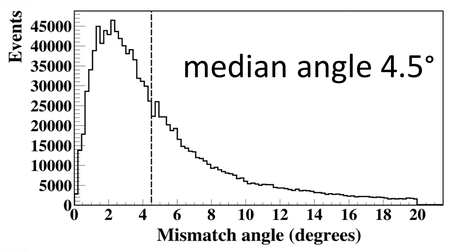
Reconstruction of cascades and tracks





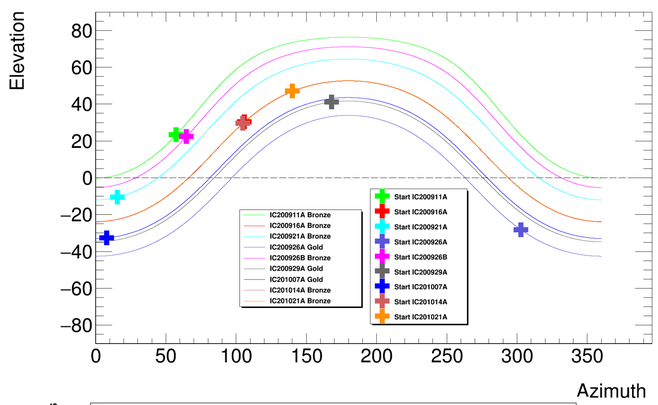
The distribution of the mismatch angles between MC neutrinos with an energy spectrum of E^{-2} and reconstructed muon trajectories. Selection neutrino cuts reject events with zenith above 120° [3].

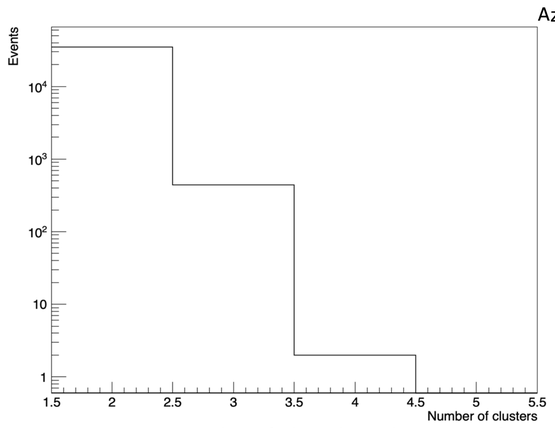




The distribution of events by angle ψ between the simulated and reconstructed shower directions for one cluster.

Daily tracks for IC events

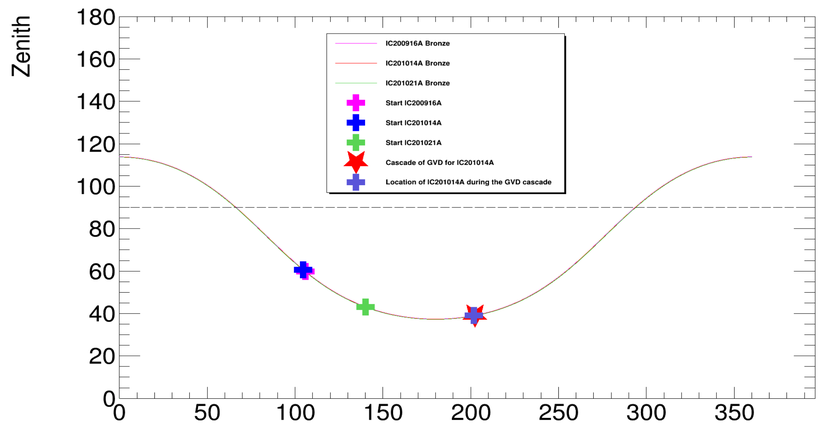




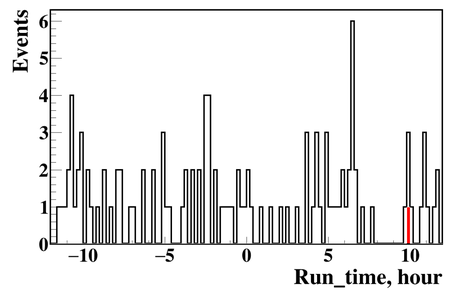
An example of the distribution of multicluster events (≥2 clusters) for ±12 h

Three alerts with the same visibility

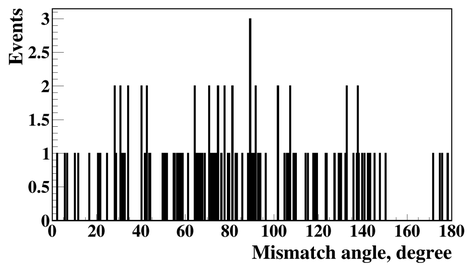
In figure(on left) are shown daily trajectories for nine directions of the IC alerts and their fixed elevation and azimuth at alert times on Baikal-GVD site: six events are visible in the upper hemisphere and three in the lower one. In figure (below) repeatedly are shown local coordinates for IC200916A, IC201014A and IC201021A on the same track due to their coincidence of declination values with an accuracy of tenths of degree. Also shown the GVD shower event reconstructed toward IC201014A after 4.96 hours with space angle less than 1°. There are 8 triggered modules. Shower energy is about 5 TeV. However, event rate is within background estimate (shown in Table).



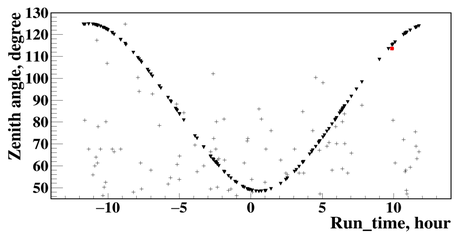
Search for neutrinos around IC200929A



Distribution of 113 highlighted shower events in the +/- 12 h interval around IC200929A

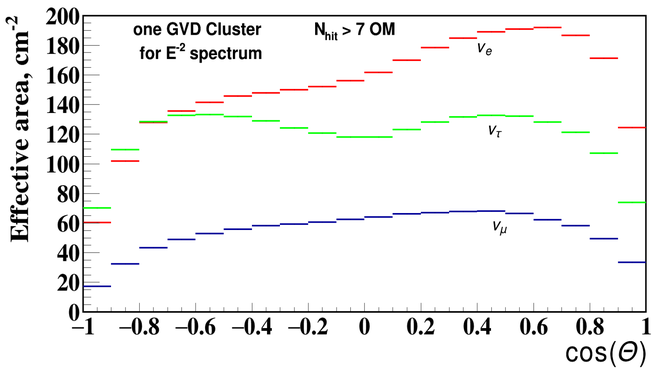


Distribution of events by angle ψ between the direction of the neutrino and the alert around IC200929A



The trajectory of the neutrino source for IC200929A and the coordinates of the selected cascades. Red color is the cascade < 5°.

Neutrino effective area for showers



Cascades with a value of ψ <5° were selected as events associated with the corresponding alert. As a result, three cascading events were identified for alerts: **IC200926B, IC200929A and IC201014A** in time intervals ± 12 hours [4].
The expected number of background events in cone 5° for each alert was determined from the complete Baikal-GVD 2019 data set. The probability of each of three events (see table). to be a background is 0.32 (0.99 σ), 0.29 (1.11 σ) and 0.36 (0.85 σ), respectively.

Upper limits on neutrino fluence

IceCube event	GCN number	Rank	Energy, TeV	Elevation (◦)	Nobs ±12h	Nbg per day	P-value	Fluence (E^{-2}) *TeV* cm-2
IC200911A	28411	Bronze	110.79	23.2	-	0.33	-	1.43×10^{-3}
IC200916A	28433	Bronze	110.48	30.3	-	0.29	-	1.12×10^{-3}
IC200921A	28468	Bronze	117.17	-10.6	-	0.36	-	1.13×10^{-3}
IC200926A	28504	Gold	670.50	-28.2	-	0.19	-	1.14×10^{-3}
IC200926B	28509	Bronze	121.42	22.3	1	0.39	0.32	2.5×10^{-3}
IC200929A	28532	Gold	182.89	41.1	1	0.35	0.29	2.5×10^{-3}
IC201007A	28575	Gold	682.65	-32.5	-	0.25	-	1.12×10^{-3}
IC201014A	28616	Bronze	146.93	29.5	1	0.44	0.36	2.44×10^{-3}
IC201021A	28715	Bronze	105.27	47.1	-	0.37	-	1.37×10^{-3}

Summary

The Baikal-GVD telescope data was analyzed for the first time in the online neutrino alert tracking mode.
No event was observed inside cone 5° towards 9 alerts for ±1 h , while there were detected 3 events for ±12 h (see Table). Background rates were estimated on base of data sample for 1495.15 live days (2018-2019).
The method of FC statistics [5] is applied to derive the Up.L. on number of events at 90\% C.L inside cone 5°.
For energy range 1TeV -10PeV and assumption of E^{-2} spectrum in the source and equal fluence in all flavors the upper limits on neutrino fluence is obtained by use shown average area. The results were obtained for cascades and single clusters.

No prompt coincidence in time and direction was found with IceCube alerts!

References:
[1] A.D. Avrorin, A.V. Avrorin, V.M. Aynutdinov et al.,., NF 83, N6, 511 (2020)
[2] S.A. Garre et al., Poster ID = 89384
[3] D. Zaborov et.al, Poster ID = 89407
[4] A.D. Avrorin, A.V. Avrorin, V.M. Aynutdinov et al., submitted to Astr.Lett., 2020
[5] G. Feldman and R. Cousins, Phys. Rev. D 57, 3873 (1998).

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