First measurements of track-like events with Baikal-GVD using a χ^2-like track fit

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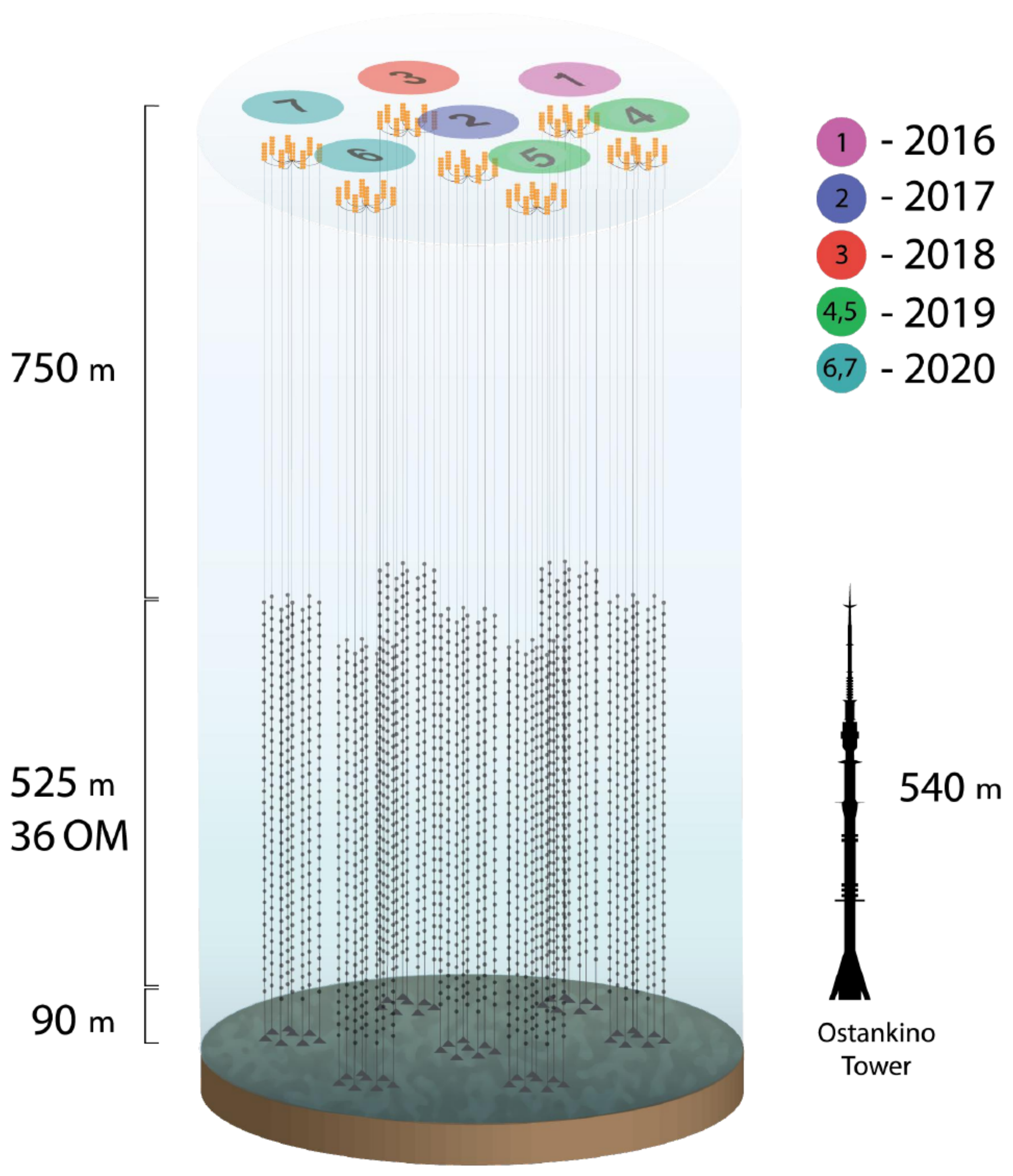
1. Introduction

Baikal Gigaton Volume Detector (Baikal-GVD) is a 1 km^3 neutrino detector currently under construction in Lake Baikal, Russia. A fast χ^2-based reconstruction algorithm has been developed to reconstruct track-like events in Baikal-GVD. The algorithm has been applied to data collected in 2019 from the first five operational detector clusters. Both the downgoing atmospheric muon flux and the upgoing atmospheric neutrino flux are observed. This analysis is limited to single-cluster data, favoring nearly-vertical tracks.

2. The Baikal-GVD detector

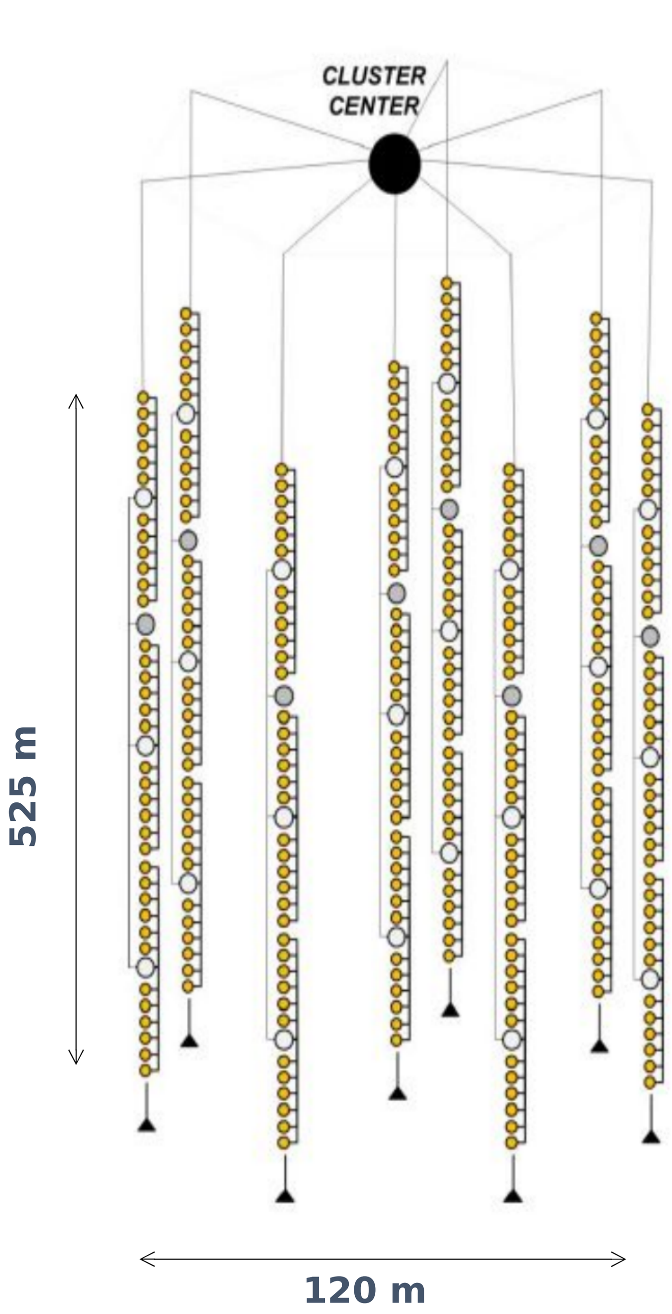


The detector consists of several thousand optical sensors arranged on vertical strings. Each string holds 36 optical modules (OMs) spaced every 15 m along the string. The strings are grouped into clusters of 8 strings each. Today Baikal-GVD consists of 7 clusters, occupying a volume of water of ≈ 0.35 km^3.

The optical module comprises a 10-inch high-quantum-efficiency PMT (Hamamatsu R7081-100).

Baikal-GVD optical module

Baikal-GVD cluster



3. χ2-like track fit

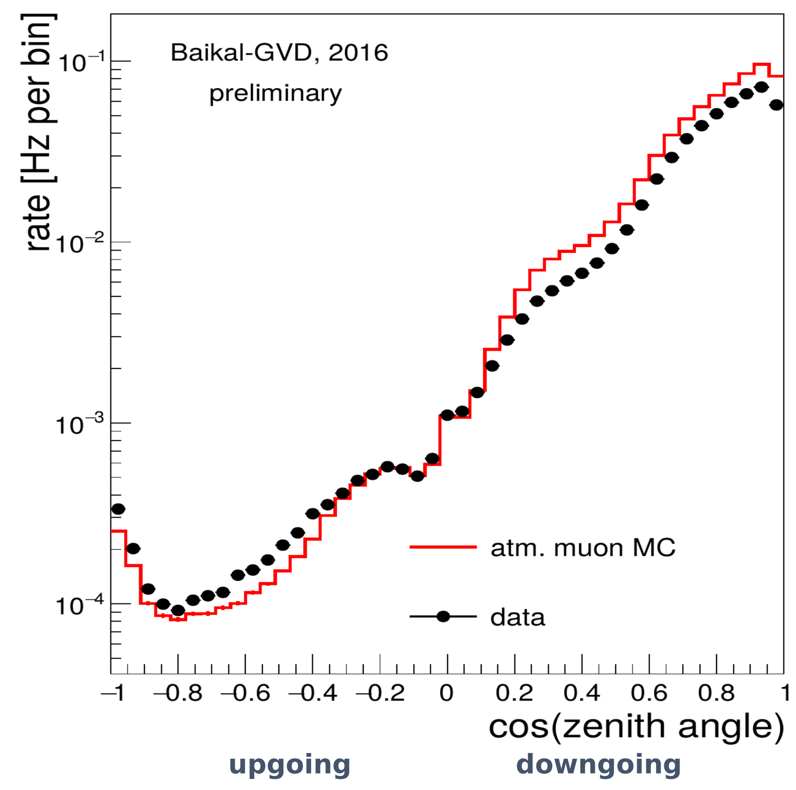
The track fit algorithm minimizes the quality function

$$Q = \chi^2(t) + f(q, r)$$

where $\chi^2(t)$ is the chi-square sum of the time residuals (difference between the expected and observed hit time) with respect to direct Cherenkov light from the muon; $f(q, r)$ is the sum of products of charges deposited in OMs and their distances from the track, multiplied by a normalization constant (relative weight of the second term).

4. Observations of atmospheric muons

event rate before quality cuts



The observed zenith angle distribution of the atmospheric muon events is in fair agreement with preliminary MC predictions.

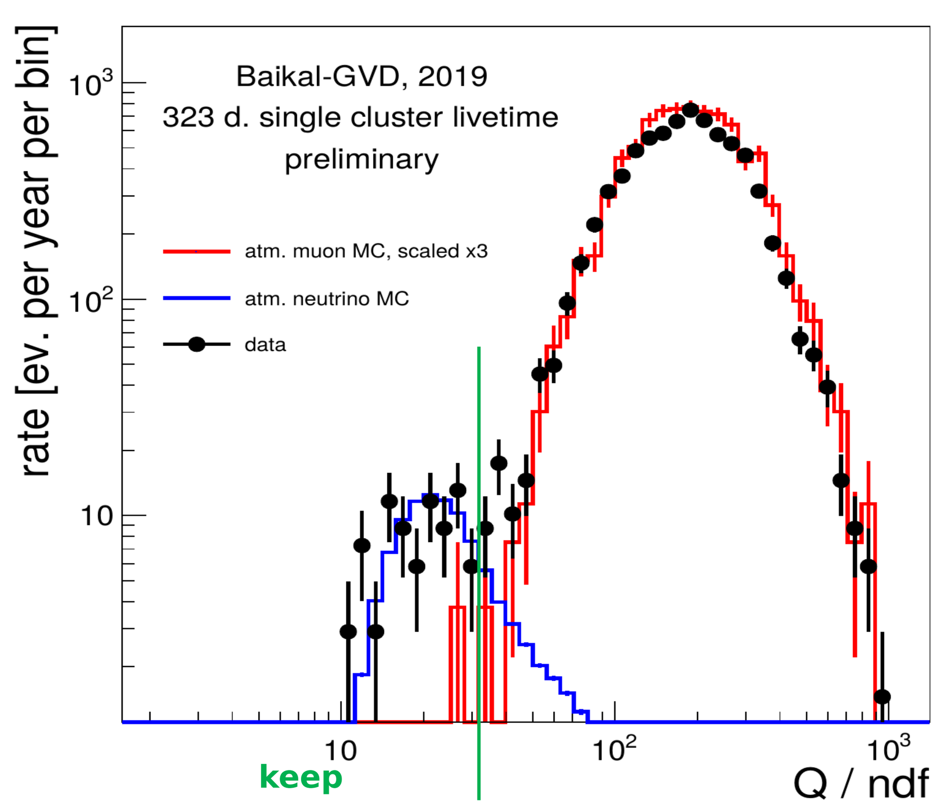
The data sample is dominated by muon bundles

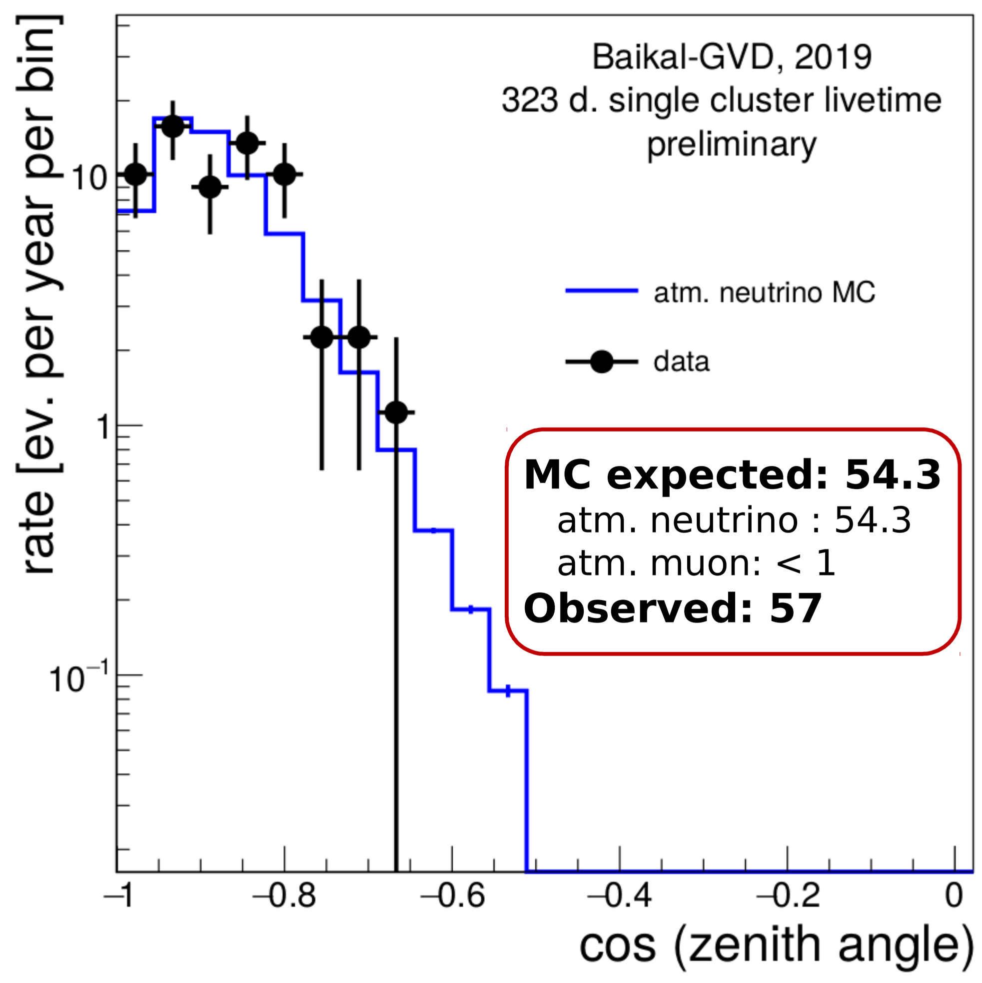
5. Observations of atmospheric neutrinos

The atmospheric neutrino event selection uses a cut on the reconstructed zenith angle, the fit quality, the track length, and some auxiliary quality cuts.

Shown here are data collected between Apr 1 and Jun 30, 2019 from 5 GVD clusters (single-cluster equivalent live time = 323 days).

upgoing: θ_{zenith} > 120 deg.





A reasonable agreement between real data and Monte Carlo predictions is observed for the atmospheric neutrino flux.

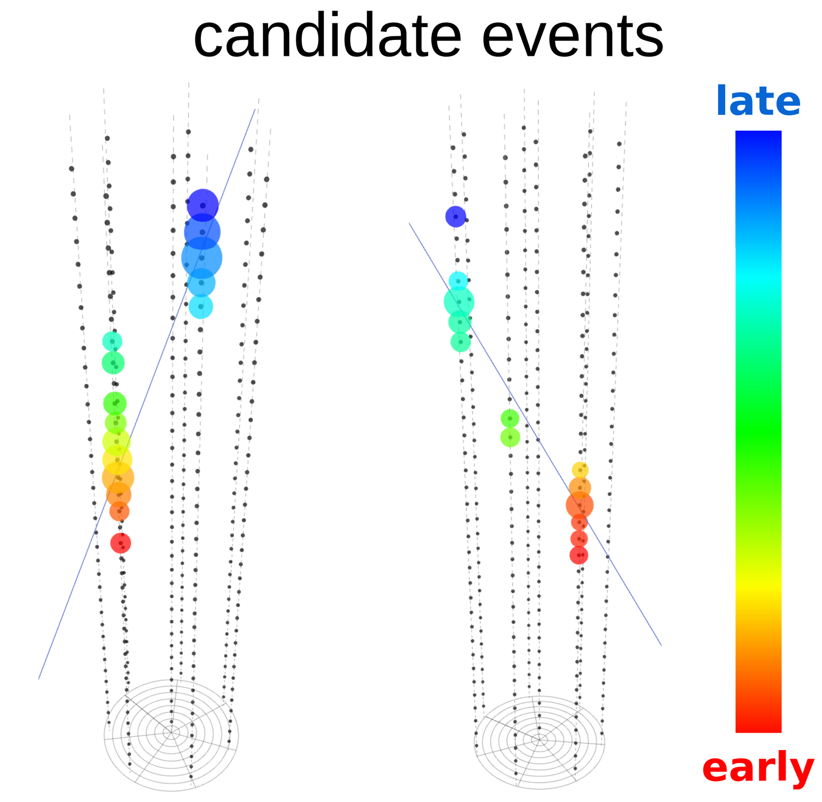
The expected zenith angle resolution in this analysis is 1° or better.

Near-horizontal events are disfavored by the event selection.

6. Conclusion

The Baikal-GVD neutrino telescope has been collecting data in partial configurations since 2016. A χ2-like track fitting algorithm has been developed and applied to the experimental data from the individual GVD clusters, permitting the observation of the atmospheric muon and the atmospheric neutrino fluxes. The data are found to be in reasonable agreement with preliminary Monte Carlo simulations. A multi-cluster data analysis is in preparation.

Examples of neutrino candidate events



cluster 1, run 157
evt. 1414137
θ_{zenith} = 161.78°
$N_{strings}$ = 2
N_{hits} = 15

cluster 5, run 162
evt. 1939721
θ_{zenith} = 148.07°
$N_{strings}$ = 3
N_{hits} = 13

Acknowledgements

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