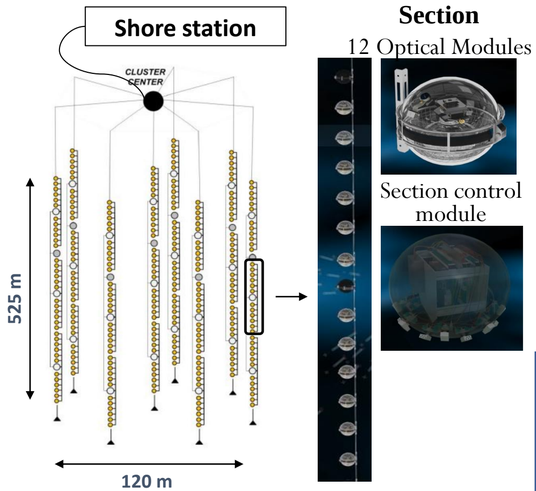
Time synchronization of Baikal-GVD clusters

Vladimir Aynutdinov, INR RAS, for the Baikal Collaboration

(see full author list on https://baikalgvd.jinr.ru/collaboration)

Currently, the construction of the Baikal-GVD neutrino telescope is underway in Lake Baikal. The 2021 telescope configuration includes 8 clusters of 288 photodetectors each. The photodetectors form a spatial structure located at a lake depth of about one kilometer, designed to register the Cherenkov radiation of charged particles formed as a result of the interaction of neutrinos. The purpose of the work is to study the influence of the accuracy of Baikal-GVD synchronization system on the angular resolution of the telescope.



Section

12 Optical Modules

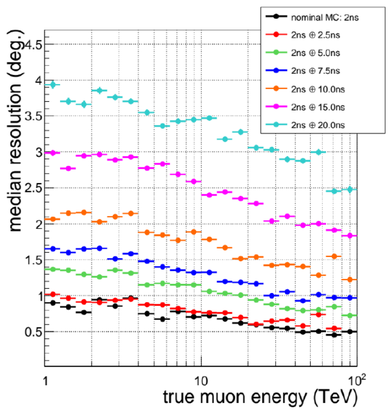
Section control module

String

- 3 Sections, 36 OMs
- String control module
- 15 m step between OMs

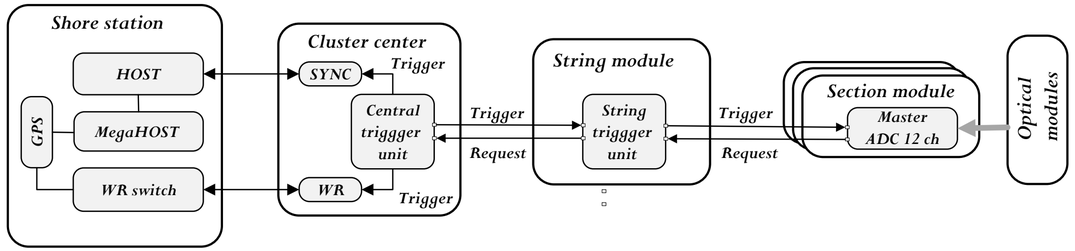
Cluster

- 8 strings, 288 OMs
- Cluster DAQ center
- Shore optical cable
- Depths from 750 -1275 m
- 60 m step between strings



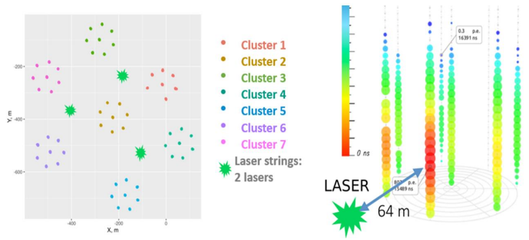
Dependence of the angular resolution of the Baikal-GVD cluster (using χ^2-based track reconstruction algorithm) on the accuracy of the time measurement by the telescope channels.

Inner-cluster Sync: common trigger of the cluster Pulses from the optical modules are sent to 12-ch ADC unit of the *Master*, forming 12 measuring channels. The *Master* generates a section *request*, the condition for the formation of which is the coincidence of signals from two adjacent OMs. The *request* signals from all sections of the string are combined in the string trigger module, forming a *string request*. *String requests* are sent to the central trigger module of the cluster, which forms a *common trigger*. The *common trigger* is passed to the string modules, where it branches into three sections. Trigger signals initiates the process of forming of the time frames for the channels, which comprise information about the shape of the optical module pulses.



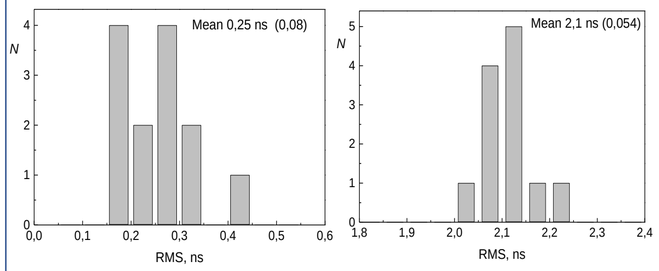
Inter-cluster Sync: synchronizing the clocks of all clusters. The time of formation of a *common trigger* (time of cluster event) is measured using two independent systems *WR* (White Rabbit) and *SSBT* (Synchronization System of Baikal neutrino Telescope). The *SSBT* includes three types of units: the *SYNC* unit located in the center of the cluster, and the *HOST* and *MegaHOST* synchro-units located at the shore station. The *SYNC* unit provides a time measurement of the common trigger. The single clock frequency for the *SYNC* of all clusters comes from the onshore *HOST* units. The *MegaHOST* generates a single clock frequency of 100 MHz for all *HOSTs*. *MegaHOST* is synchronized with an external GPS / GLONASS receiver with an accuracy of 15 ns UTC.

Measurement method

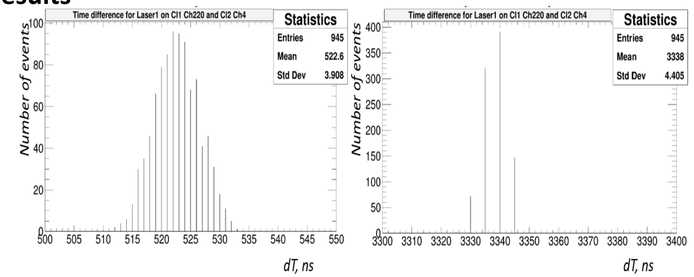


To study the characteristics of the synchronization system of the telescope a series of calibration measurements was analyzed which included simultaneous illumination of several clusters by a laser light source.

Measurement results



Distribution of channel pairs on the RMS of the measured time difference: on one section (left) and on different sections (right).



Distribution of the laser events on the difference in their time *dT*, measured on two clusters by two independent synchronization systems: *WR* (left) and *SSBT* (right)

Studies of the Baikal-GVD synchronization system with a laser calibration light source showed the correctness of its operation and allowed us to evaluate the synchronization accuracy for all structural elements of the telescope DAQ. The results obtained are in good agreement with the expectation. The accuracy of channel synchronization within a single telescope section is significantly better than 1 ns. For different sections of the cluster, this accuracy is 2.1 ± 0.05 ns, which is in good agreement with the expected value of 2.04 ns. At this level of accuracy, the cluster sync system does not affect the angular resolution of the Baikal-GVD cluster. The results of measurements of the sync accuracy of two clusters performed by two independent systems are consistent with each other and give the accuracy of inter-cluster synchronization at the level of 4 ns. The work was partially supported by RFBR grants 20-02-00400 and 19-29-11029.