



# Time and amplitude calibration of the Baikal-GVD neutrino telescope

Vladimir Aynutdinov, Bair Shaybonov for Baikal collaboration September, 2015

## **Calibration vs DAQ**



- Cluster DAQ center (30 m below surface)
- Electro-optical cable to shore (~6 km)

Measuring channel: Channel consists of PMT, amplifier, cable from OM to the Section center (90 m), ADC. Calibration of the channel (time and amplitude).

Section: Section provides the Request: coincidence of neighboring pairs of OMs with 0.5 p.e. and 3 p.e. thresholds. Request is transmitted to the DAQ center. Cluster DAQ Center provides a global trigger, that transmitted to all sections (ADCs stop and waveform data are sent to the shore). Calibration of the section time offset.

**Cluster DAQ center** connected to shore with optical line. **Time calibration and clock synchronization of the Cluster.** 



#### **Calibration facility**



Block diagram of the OM calibration facility

#### Test pulse (PMT delay measurement)

Reference (test) pulse generated directly to the measuring channel and gives a time mark of the start time of the LED flash.

Amplitude	376.5 ± 1.6 mV
FWHM	92.63 ± 0.016 ns
Rising edge	47.31 ± 0.079 ns
Rear edge	56.3 ± 0.11 ns



#### **LED flasher:**

2 blue LEDs L7113, 201/2=16°, FWHM ~6 ns

- LED intensities regulation: 1...~10<sup>8</sup> photons
- Flashes delay regulation  $\text{LED}_1$  :  $\text{LED}_2$ : 0 ... 1000 ns
- Light propagation distance for maximum LED intensity
- ~100 m along the string in Baikal water.



Spectral characteristic of the LED Kingbright L7113

#### Time calibration of the channels (technique)



4

#### Time calibration of the channels (results)



The time offset of the channels in dependence of the PMT voltage

#### Time calibration of the channels with LED (accuracy estimation)



6

4

2

0

-10

-5

Calibration accuracy ~2 ns

0

5

 $dT_{LED} - dT_{TST}$ , ns

two adjacent channels.

The distribution of the channels on  $dT_{LED} - dT_{TST}$ 

6

10

#### Time calibration of the section (technique)





Time difference between different pairs of channels of two strings: expected and measured values.

Relative time offsets of the strings measured with different pairs of channels.

- Section calibration accuracy ~2 ns (including channel calibration uncertainties).
- Systematic uncertainties (OM rotation around string, the bend of the string, light scattering in water) is under investigation.

## Amplitude calibration of the channels (linearity range)

The objective of the calibration is the converting ADC channels to photoelectrons.

There are two methods of amplitude calibration:

- The measuring of PMT noise spectrum;
- SPE spectrum measuring with LED



SPE spectrum measuring with LEDs: The SPE pulse (the first LED) is triggered by delayed pulse with large amplitude (the second LED) for PMT noise suppression





Distribution of the channels on A<sub>SPE</sub>.

### Amplitude calibration of the channels (nonlinearity range)



The fit of individual channel  $\rightarrow$  estimating S(N<sub>pe</sub>) with 10% precision up to ~ 10<sup>3</sup> p.e.

#### Summary

- The methods and systems used to perform the time and amplitude calibration for the Baikal-GVD neutrino detector have been reviewed. They have been successfully tested in situ.
- Cross-checks between two independent time calibration methods give an agreement of ~2 ns.

## THANK YOU

## **Backup slides**



#### **LED** flashes detection





- Trigger logic: 2-level adjustable digital comparator forms low threshold L and high threshold *H* channel requests
- Data channel (triggered) consists of double-buffered memory and data transmitter.
- Monitor channel (non-triggered) includes peak detector and amplitude analyzer.

- Trigger logic(L&H coincidence of neighboring channels
- Data readout from ADC buffer

Clock Generation & **Distribution Circuit** 

- Control of OM mode of operation
- Connection via local Ethernet to the cluster **DAQ** center

DDR MEMORY From Upper Level

#### **GVD** cluster architecture



STRING

#### **Basic principles of GVD** design:

- Simplicity of all elements;
- Deployment convenience from the ice cover;
- Detector extendability and configuration flexibility

#### **Basic GVD elements**

- Optical module (OM);
- Section: 12 OM (spaced by 15m) & Section electronic module (12 FADCs)
- String: 2 Sections & String electronic module
- Cluster: 8 strings & DAQ center.

Section electronic



#### **Triggering and Data Transmission**

