BAIKAL-GVD

Prototyping Phase – 2013

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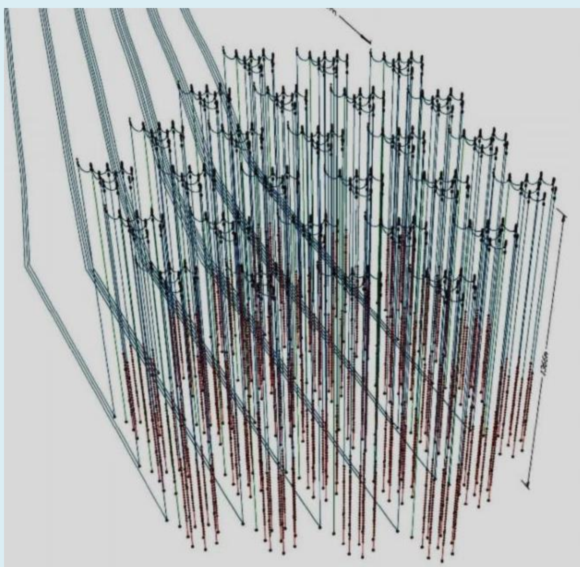
for the Baikal Collaboration
MANTS, Garching, 14-15 October, 2013

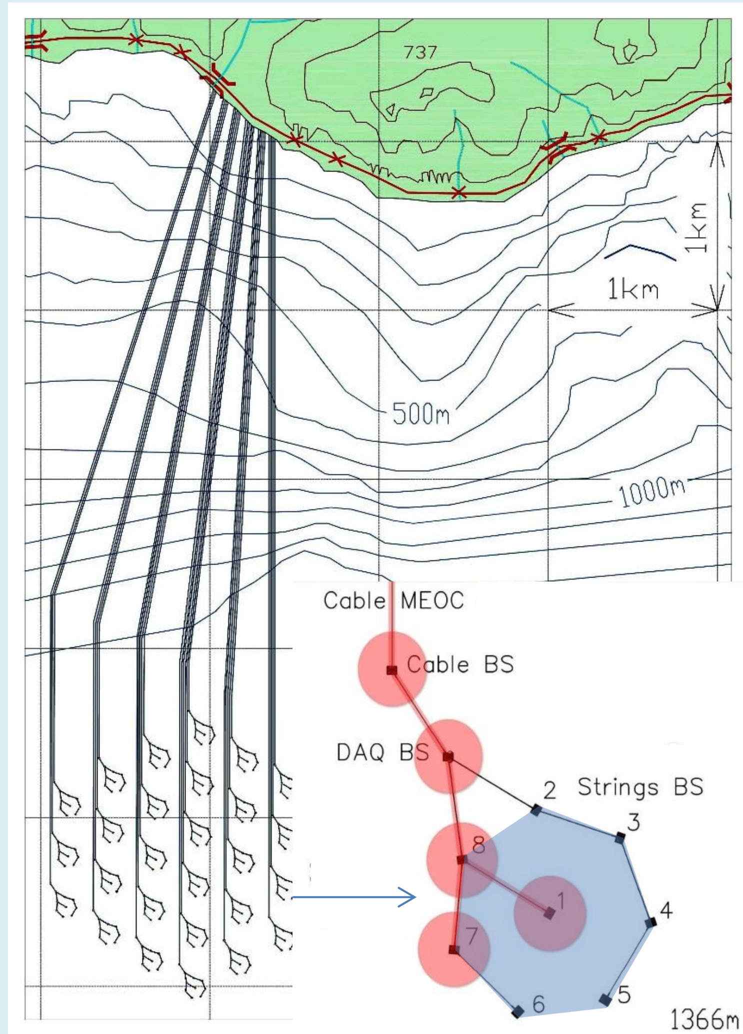
Gton Volume Detector (Lake Baikal)

10368 photo-sensors at 216 strings
27 subarrays (clusters with 8 strings)
String: 4 sections, 48 photo-sensors
Active depths: 600 – 1300 m
To Shore: 4 – 6 km

Instrumented water volume
V= 1.5 km^3 S = 2 km^2

Angular resolution
Muons: 0.25 degree
Showers: 3.5-5.5 degree

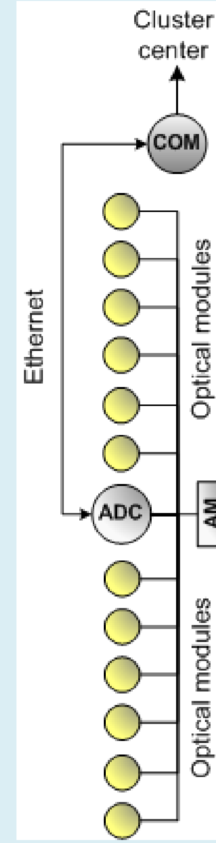




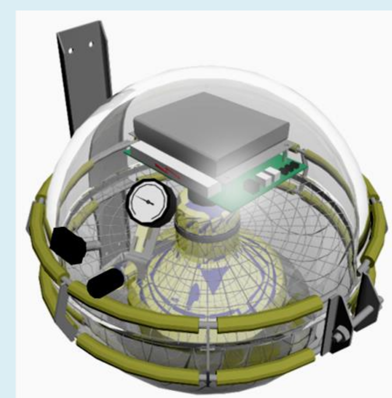
GVD array

1st GVD cluster: 8 strings

- Installed strings and cable stations

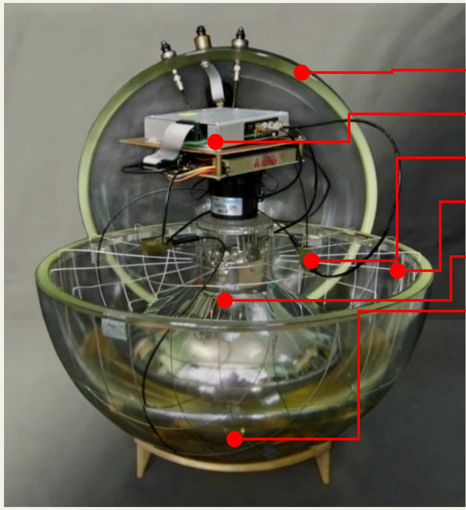


Section: basic detection unit



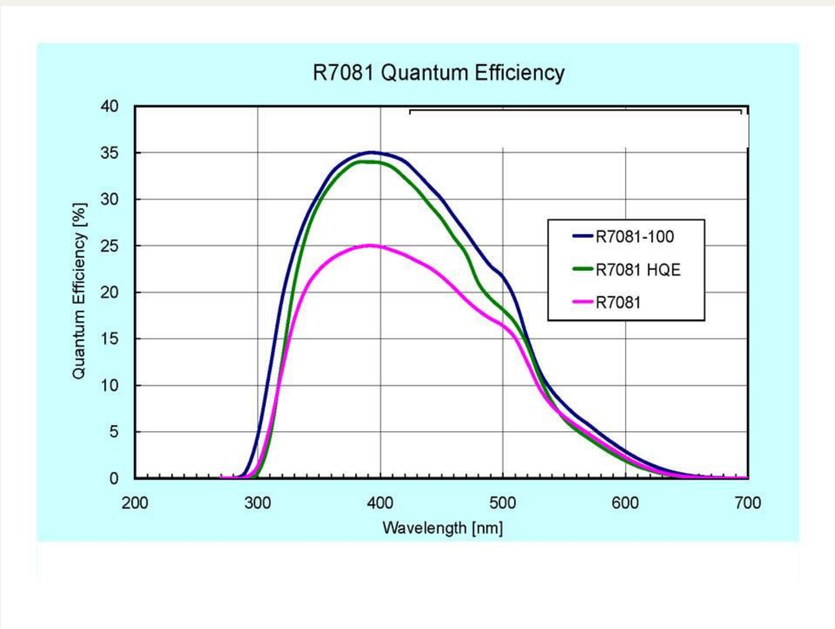
Optical module

Optical module (OM)

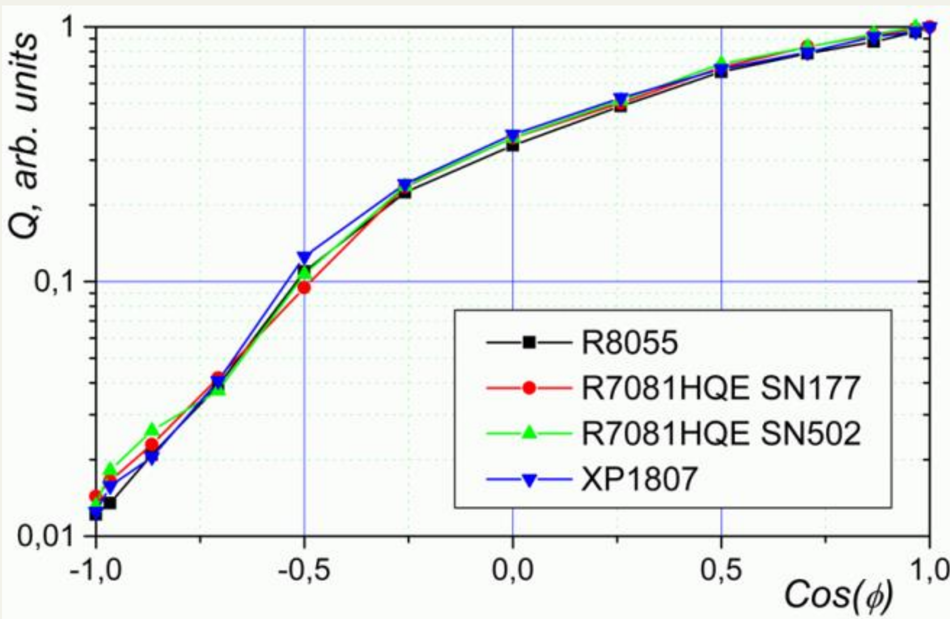


Glass pressure-resistant sphere VITROVEX (17”)
OM electronics: amplifier, HV DC-DC, RS485 controller
2 on-board LED flashers: 1…10^8 pe., 470 nm, 5 ns
Mu-metal cage
PMT R7081HQE : *D*=10”, ~0.35QE
Elastic gel

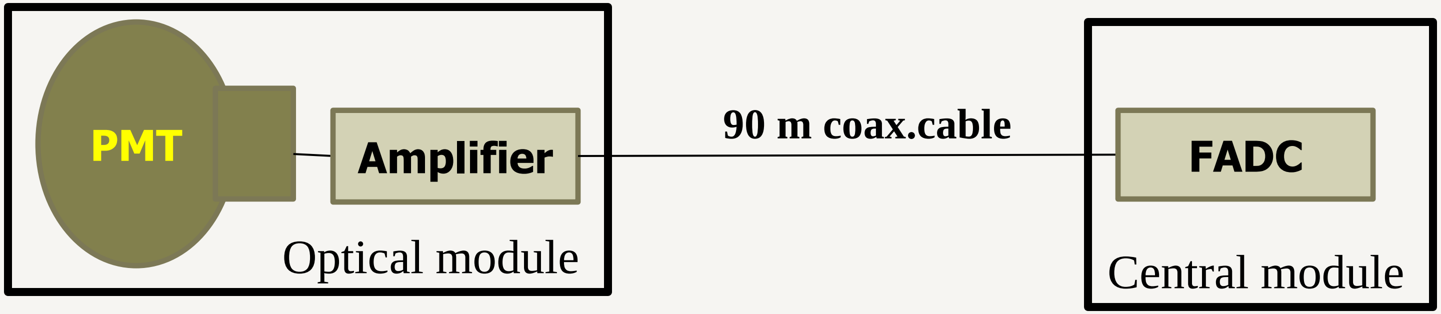
Quantum efficiency

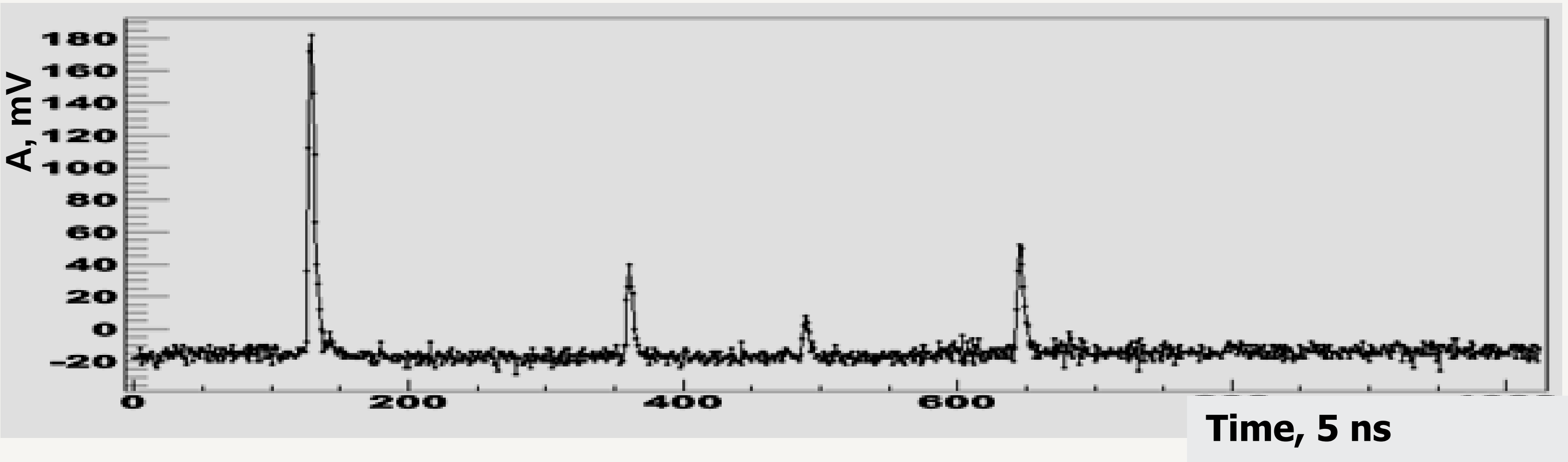


Angular sensitivity



Measuring channel



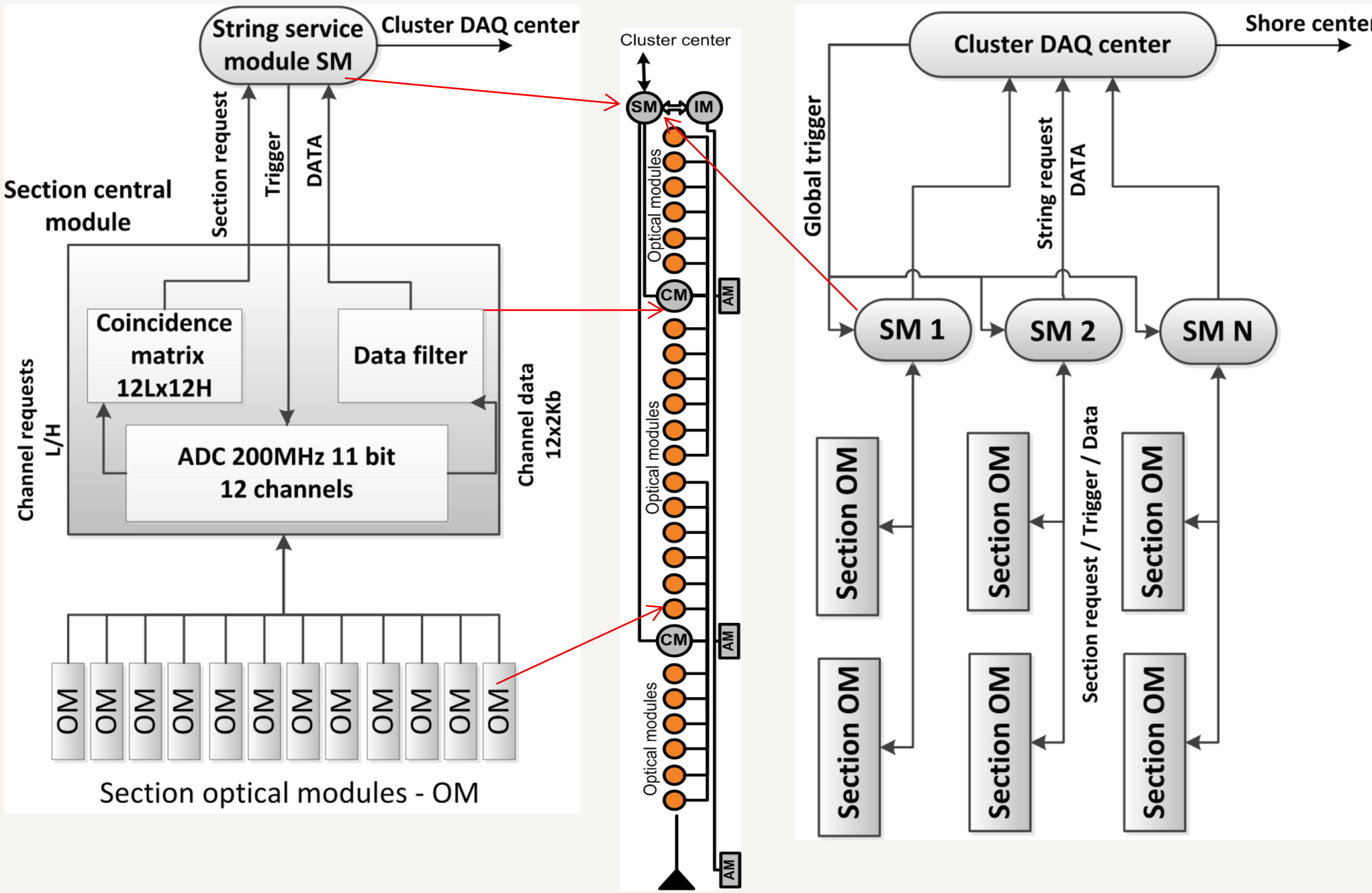


- Nominal PMT gain 1×10^7 (PMT voltage 1250 – 1650 V)
- Amplifier, $k_{amp}=10$;
- Pulse width ~20 ns
- ADC: 11 bit 200 MHz FADC (5 ns time bin);
- Waveform information is collected for a programmable interval (up to 30 mks)
- Linearity range: 1 ─ 100 p.e.;

Triggering and Data Transmission

SECTION

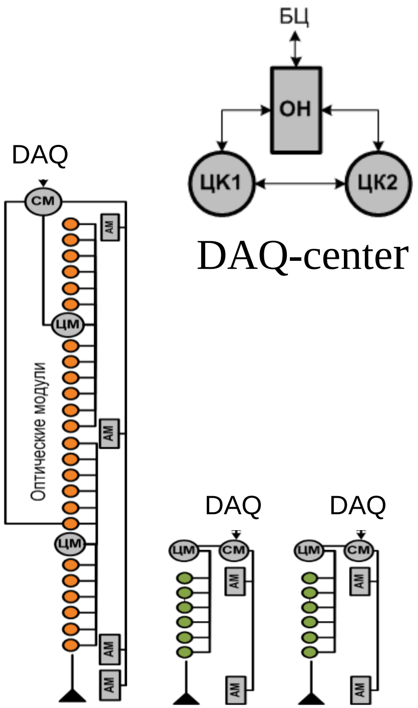
CLUSTER



Engineering arrays (2012-2015)

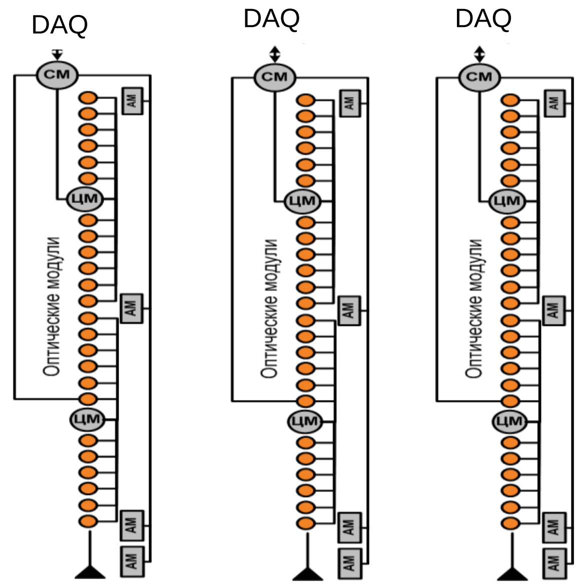
April 2012

3 strings, first full-scale GVD string (24 OMs)



April 2013

3 full-scale strings (72 OMs), update of section electronics



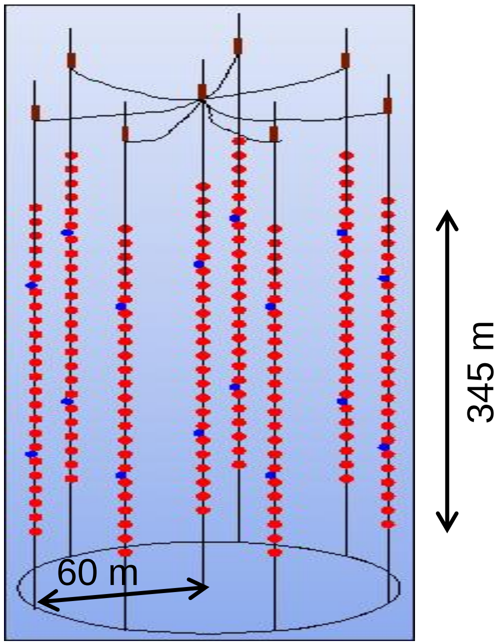
~10^6 м^3 instrumented volume

2014-2015

Demonstration Cluster

8 strings

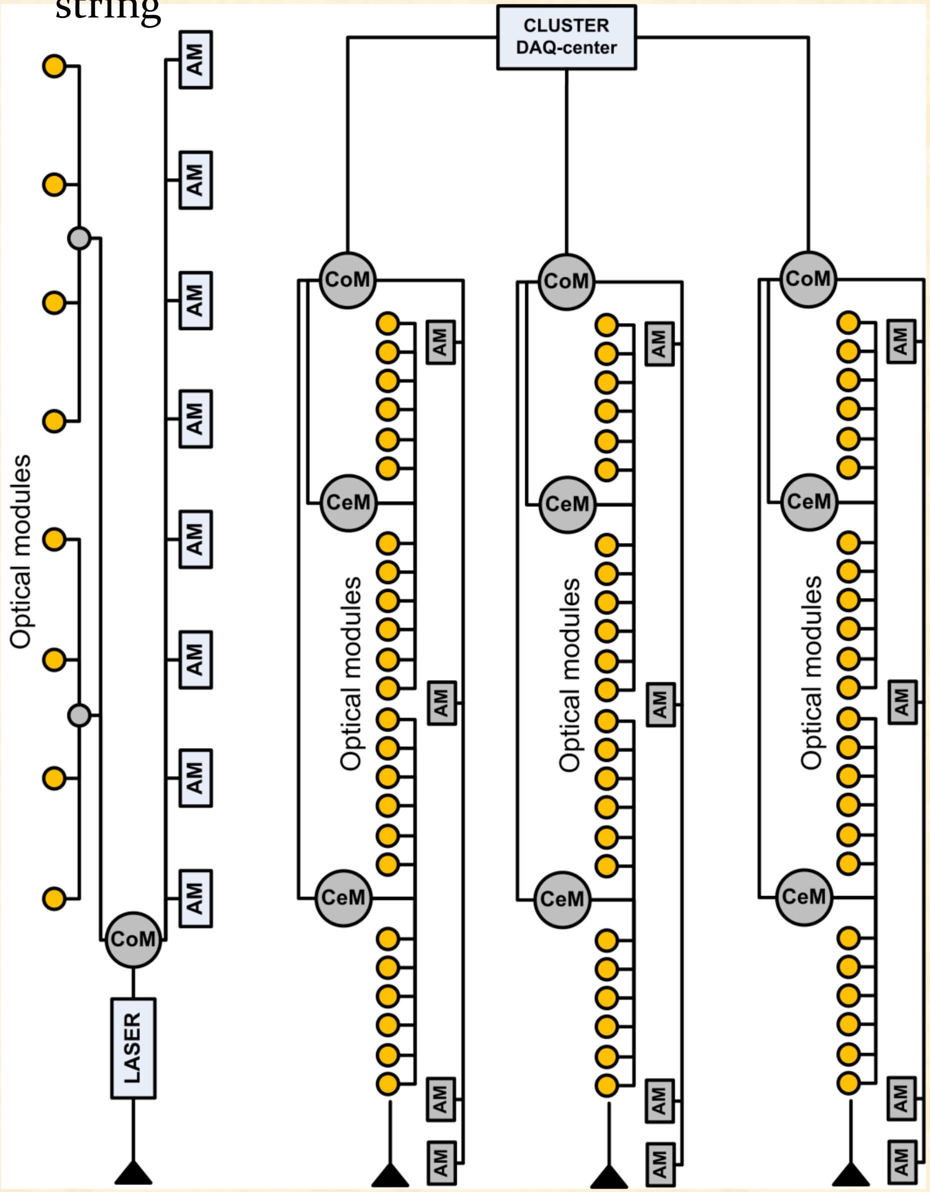
(ANTARES-scale array)



~4×10^6 м^3

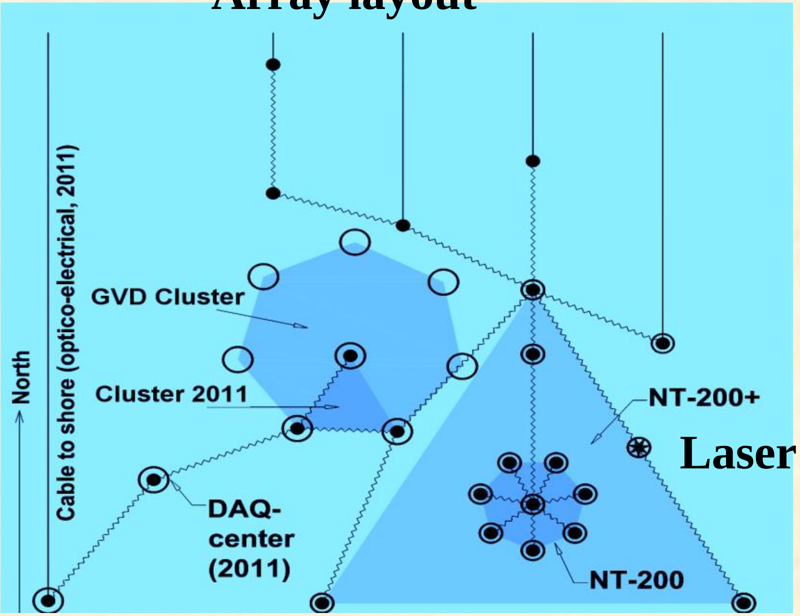
The first stage of Demonstration Cluster

Instrumentation string

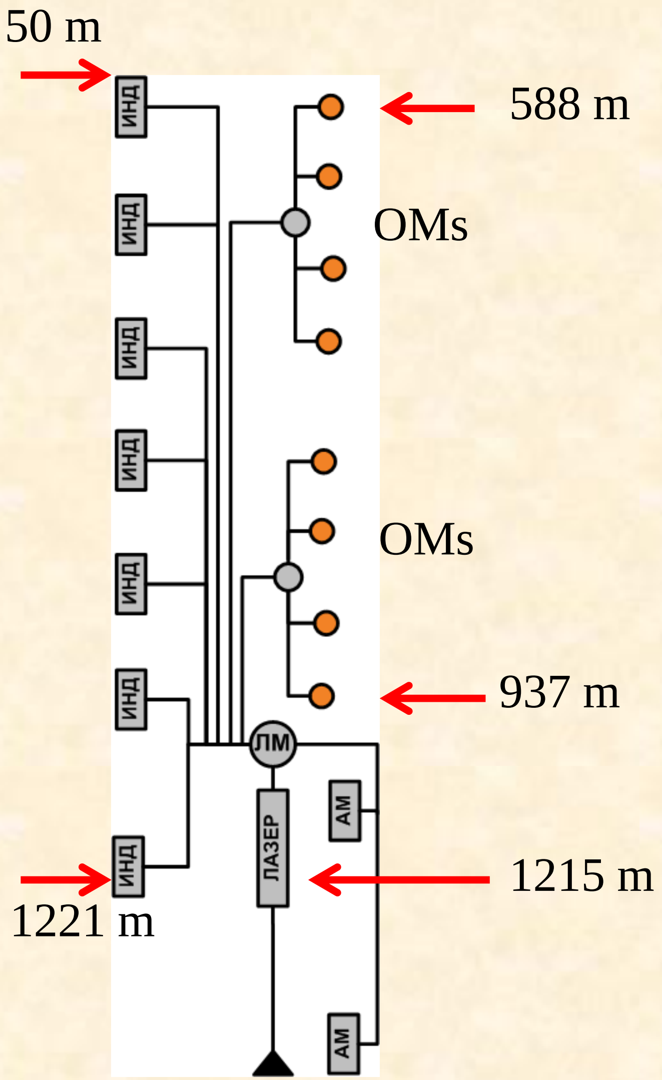


- 72 OMs (R7081HQE, R7081-100)
- 3 Strings (24 OMs /Str.)
- 6 Sections (12 OMs / Sec.)
- OMs vertical spacing – 15 m
- String length - 345 m
- Distances between strings – 40m
- 12 Acoustic Modems (4 AM / Str.)
- DAQ-Center
- Instrumentation string
- Cable to shore

Array layout



Instrumentation string

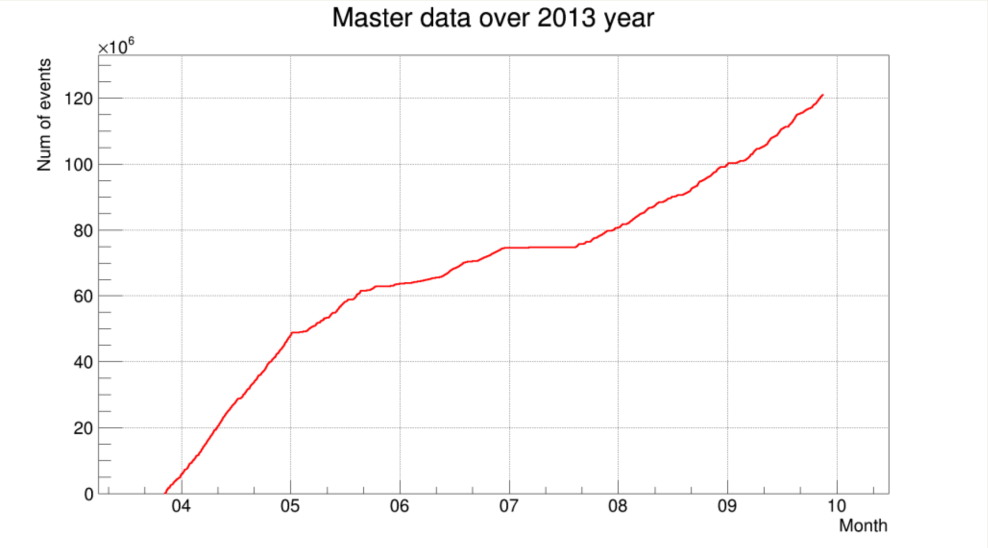


- 8 OMs at 588–937 m depths for light background monitoring
- 10 acoustic sensors at 75-1220 m depths for string shape behaviour monitoring
- 2 Acoustic modems (EvoLogics)
- Laser based calibration light source

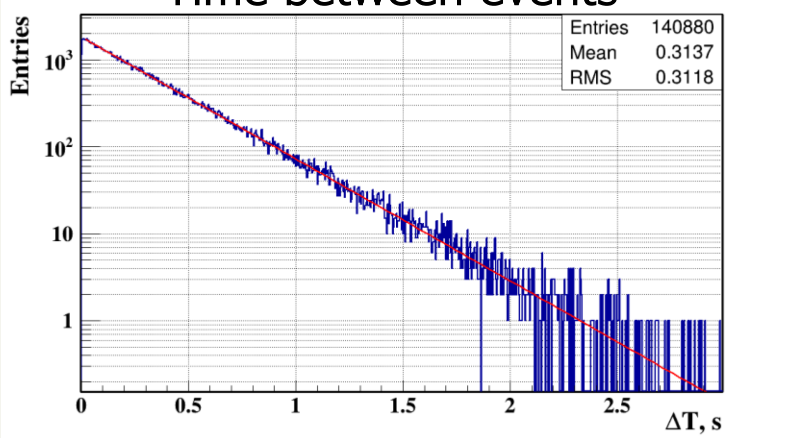
Operational statistics

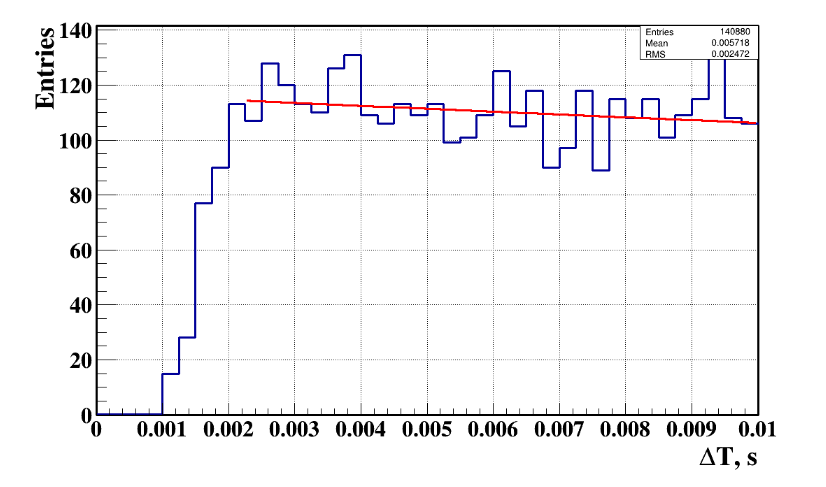
10 April – 7 October - 182 days

- Data taking: 131 days
- Efficiency: 71.8%
- Total: 458 Runs
- Data : 120930710 events
- Monitoring: 687269 events

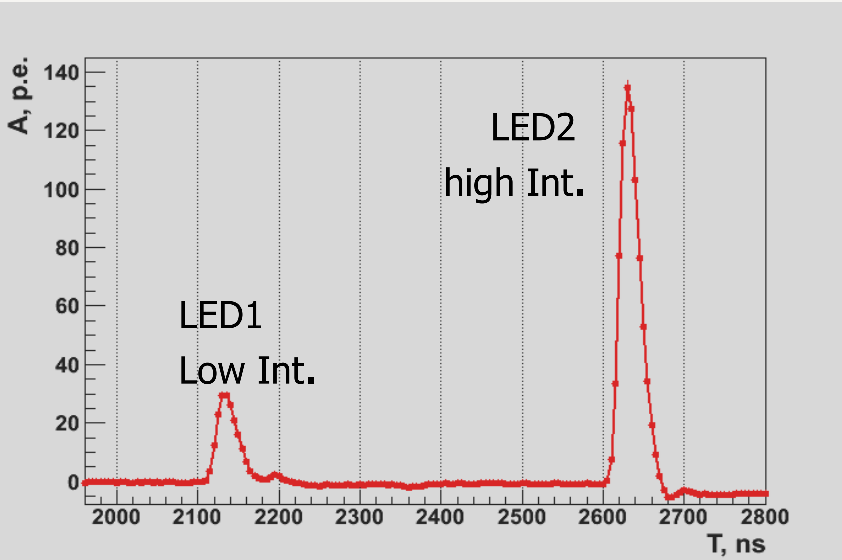


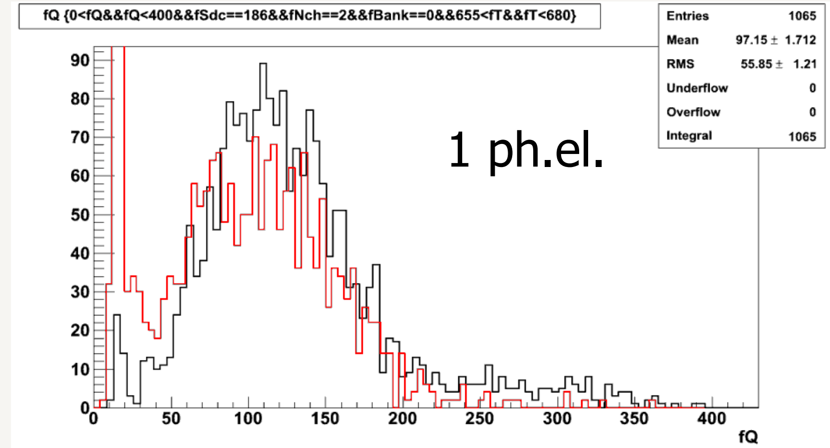
Time between events

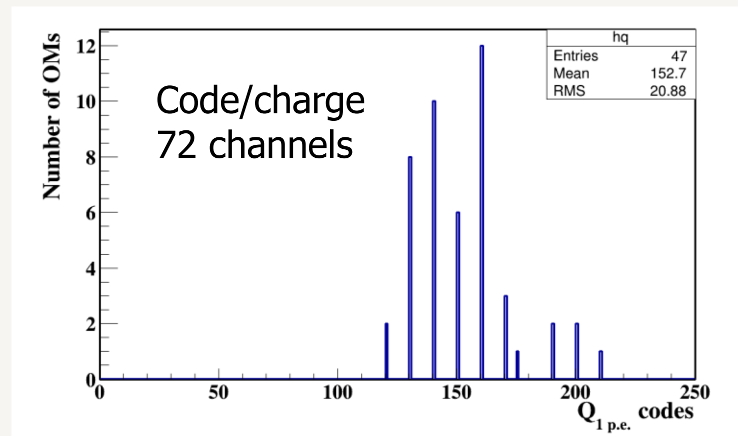


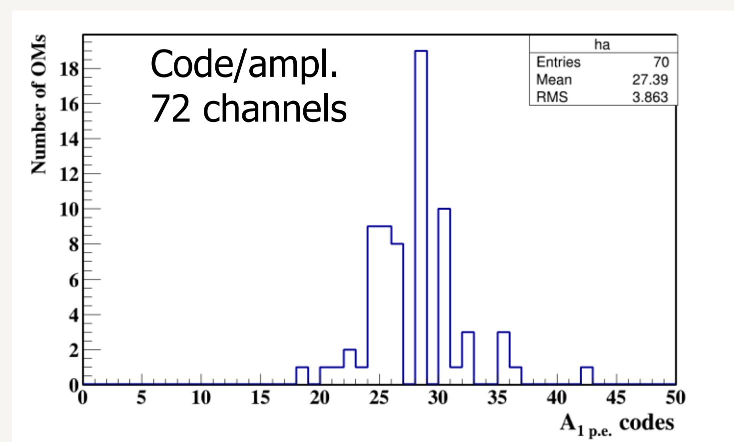


Amplitude calibration







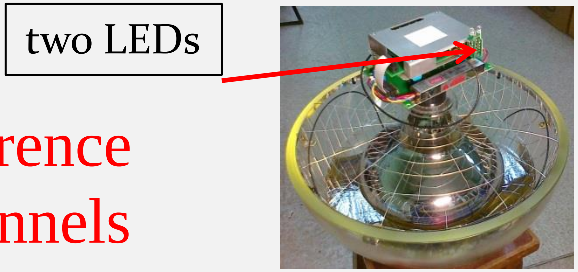


Calibration methods:

1 – two LEDs with high and low (10% OM detection probability) intensities

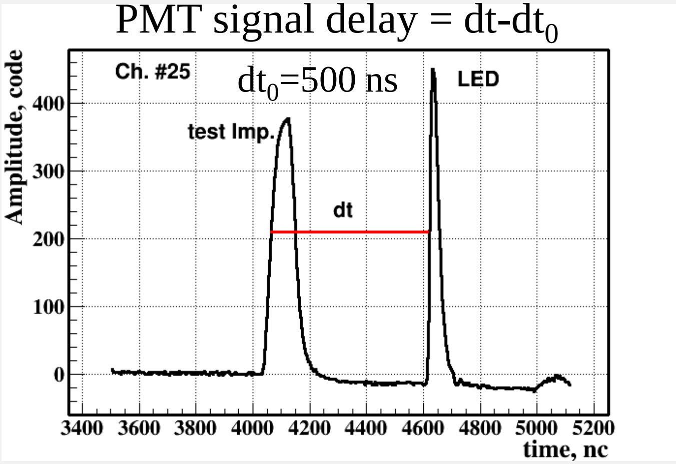
2 – analysis of noise pulses

Time calibration – two methods

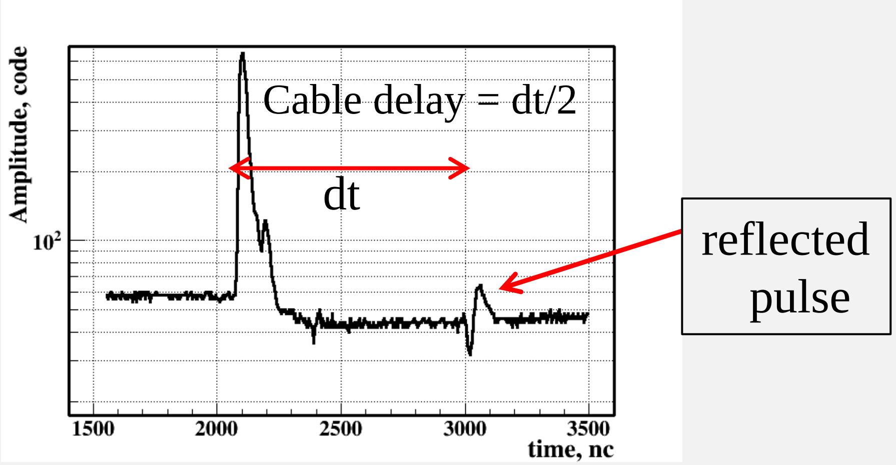


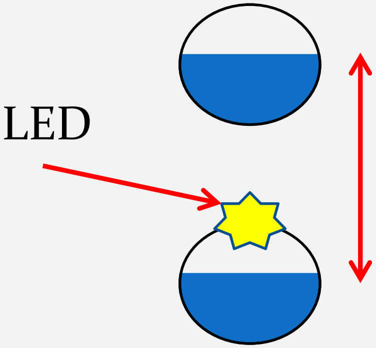
Measurement of signal delay of each channel

Time difference of two channels



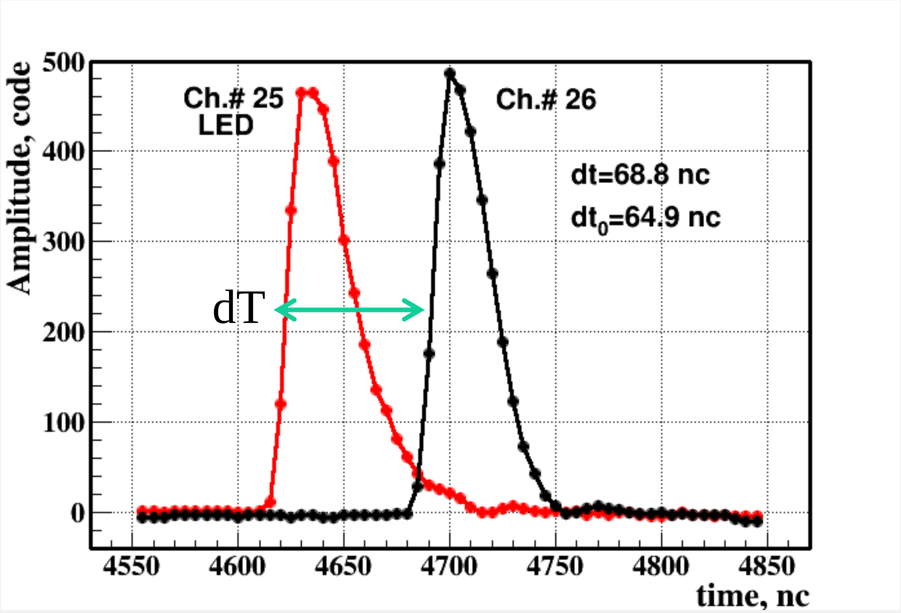
Signal delay in cable (~90 m) is measured in lab.





15 m- distance between OMs

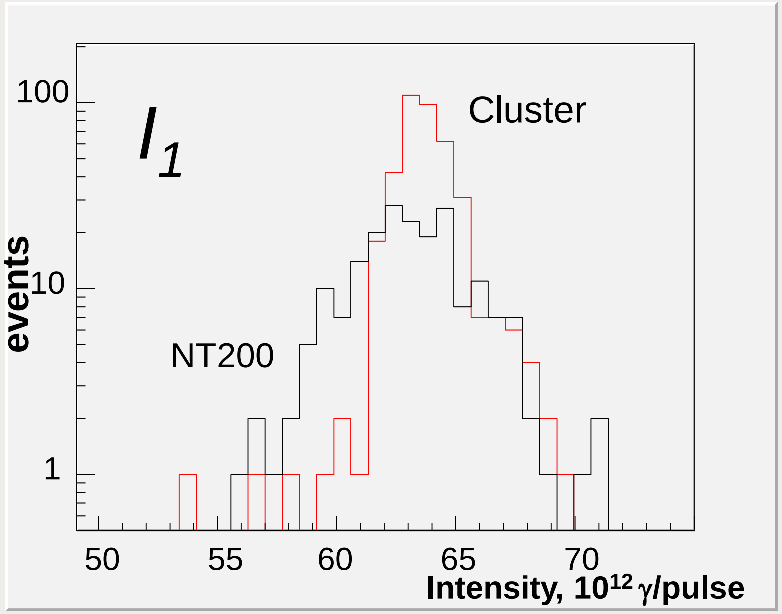
dT_0 = 64.9 ns – expected time difference



Laser intensity reconstruction (2011)

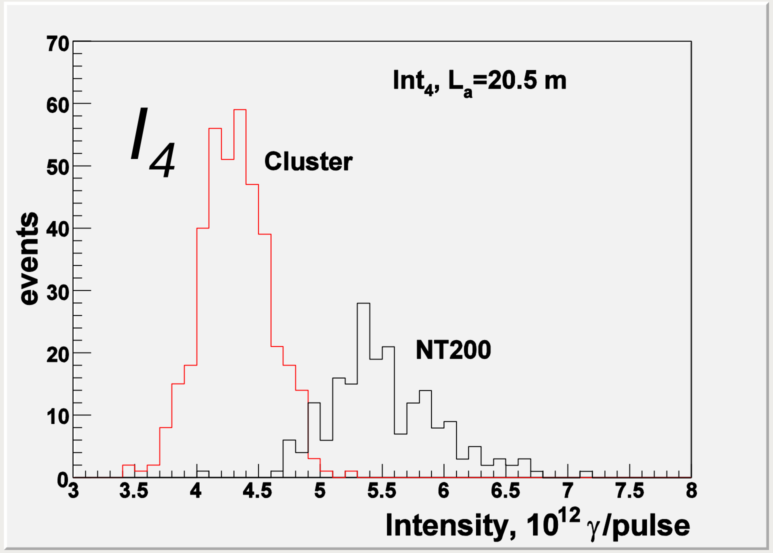
External calibration laser:

- 480 nm light pulses;
- Five fixed intensities: ~10^{12} – 6×10^{13} γ / *pulse*
  (~10 PeV – 600 PeV shower energy)
- Distances: 110 – 180 m.



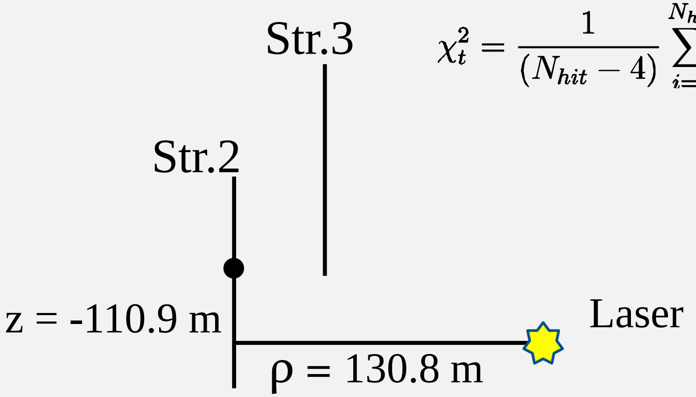
Average values of reconstructed intensities for five light source output series

I, 10^{12} γ/*pulse*	I_1	I_2	I_3	$I_4^{\cdot}$	I_5
Cluster	**64**	**27**	**9.7**	**4.3**	**2.4**
NT200	**63**	**28**	**10.4**	**5.5**	**3.8**



Distributions of reconstructed laser intensities: NT200 and Cluster

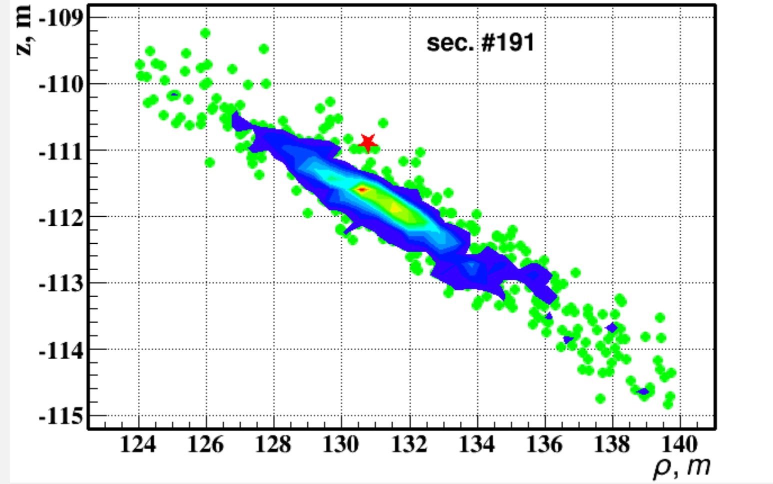
Reconstruction of laser-light source position



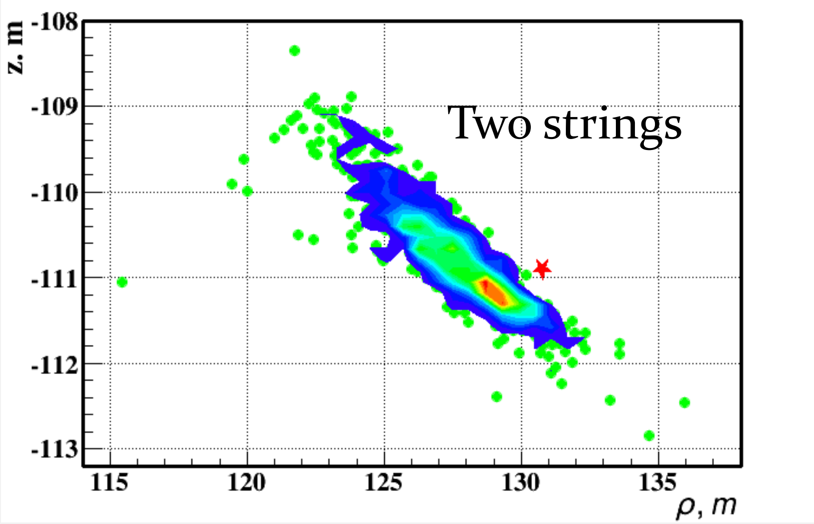
$$\chi_t^2 = \frac{1}{(N_{hit}-4)} \sum_{i=1}^{N_{hit}} \frac{(T_i(x,y,z,t_0)-t_i)^2}{\sigma_{ti}^2},$$

Laser and OMs coordinates from
data of acoustic positioning system

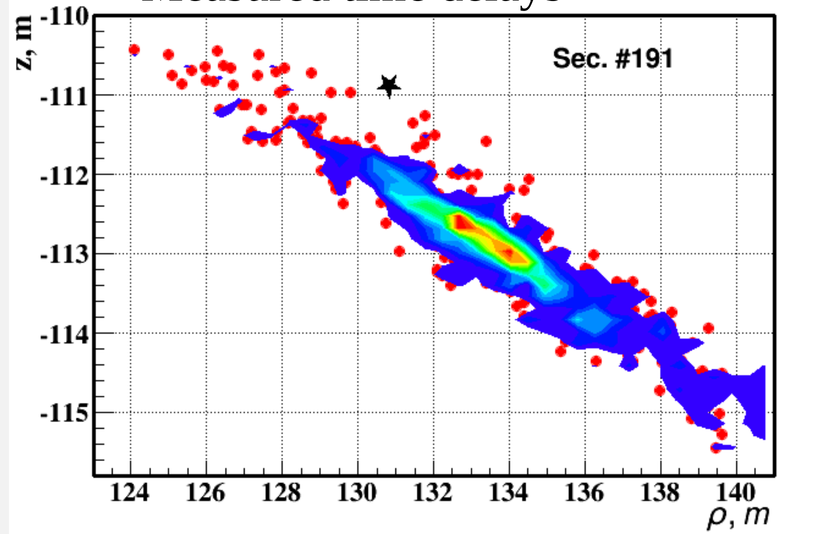
Time shifts – LED calibration



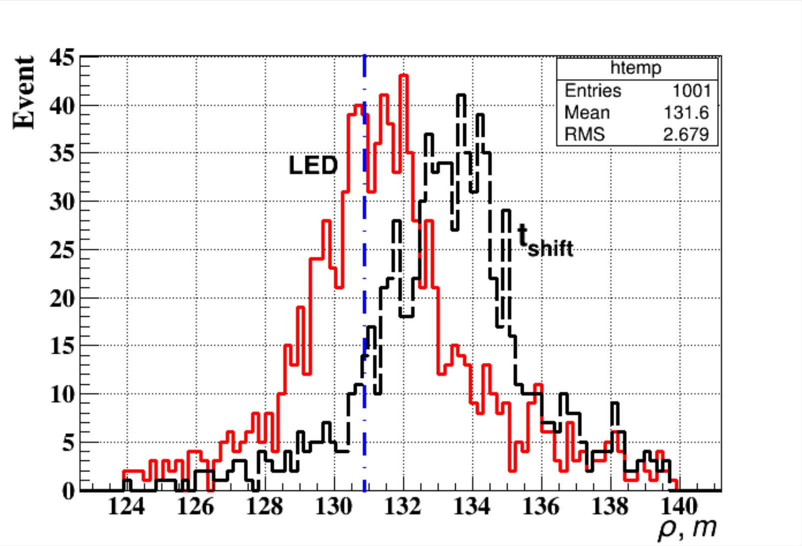
Time shifts – LED calibration



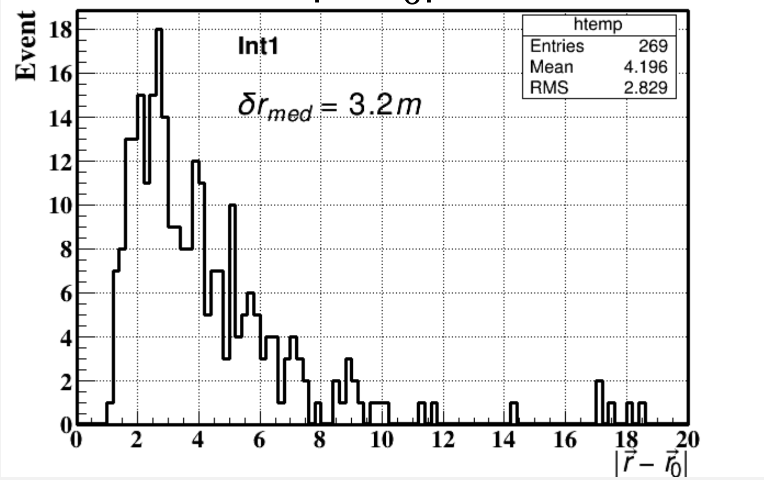
Measured time delays

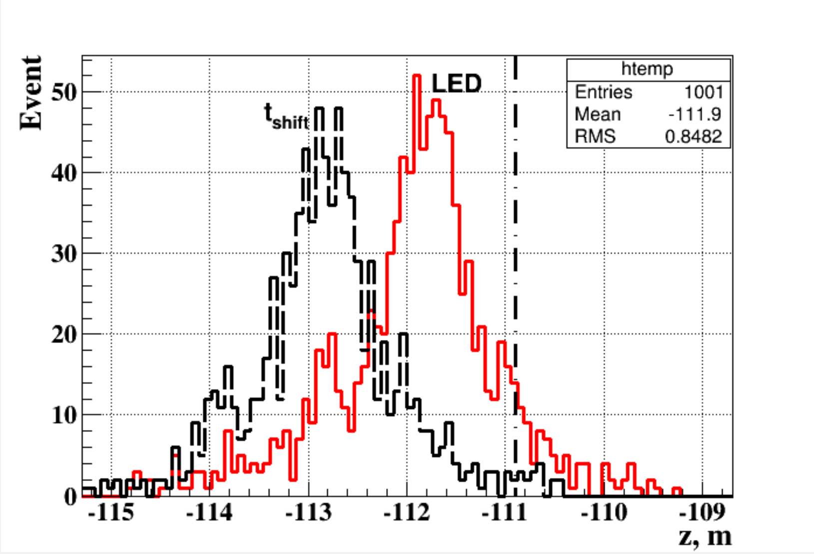


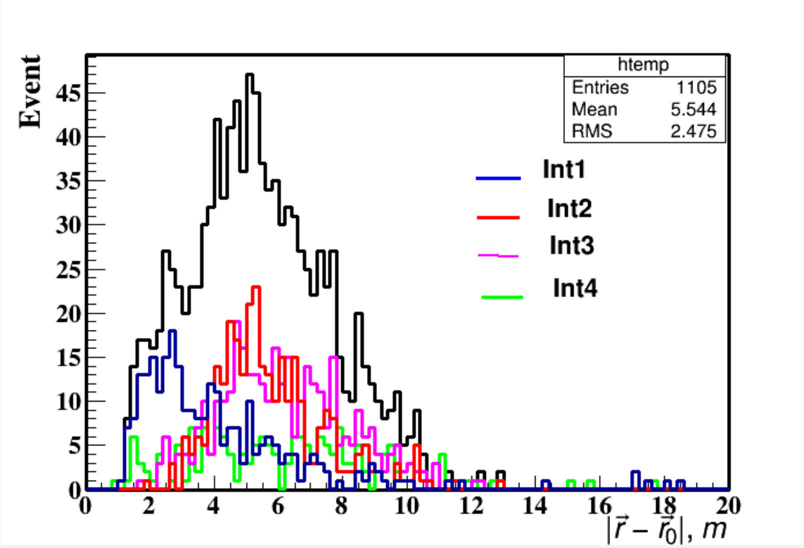
Reconstruction of laser-light source position



$\delta r = |\mathbf{r} - \mathbf{r}_0|$







Atmospheric muons

Runs - (156 – 169)

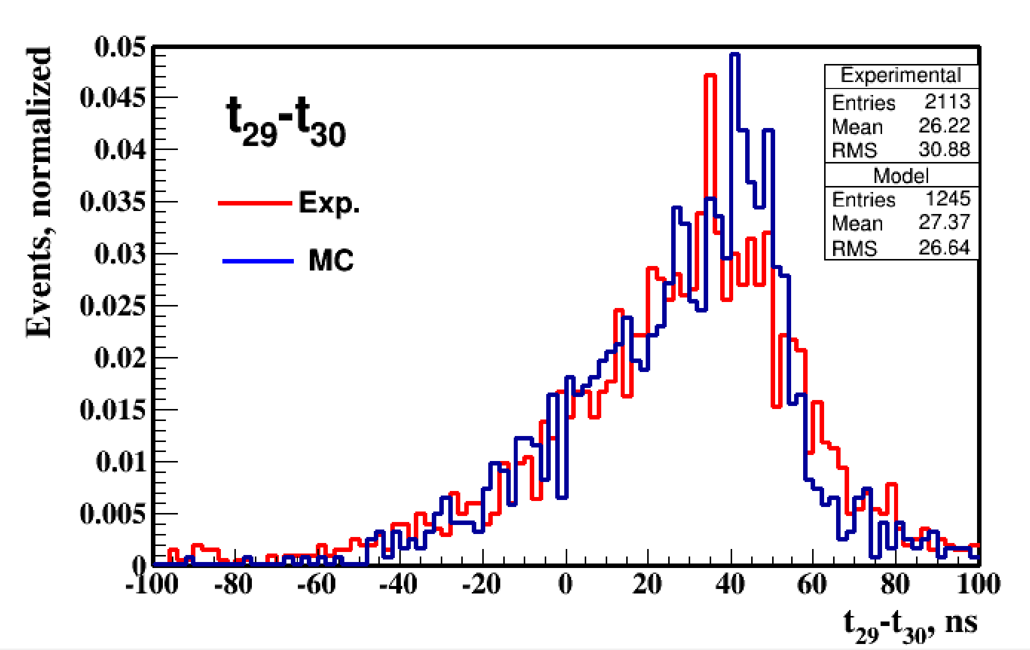
Statistics - 1707896 events

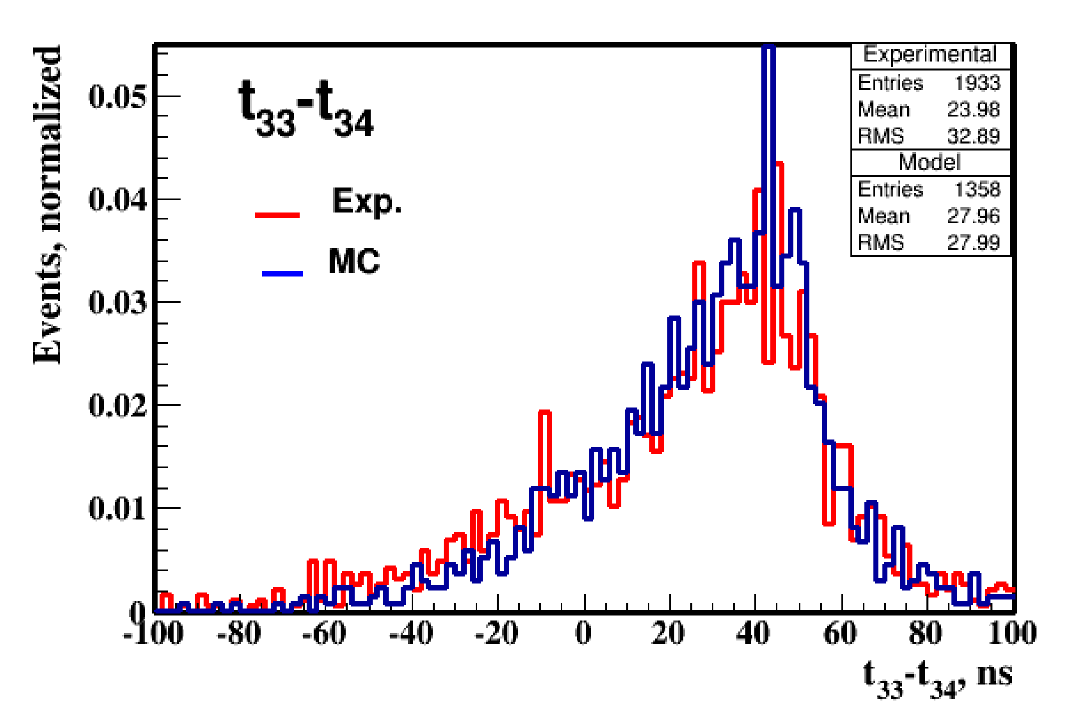
Trigger - 4 OMs /section

Selection – Q > 2 ph.el.

LED – calibration

Data consistent with expectation





FPGA XILINX Spartan 3 -> XILINX Spartan 6

1. ADC:

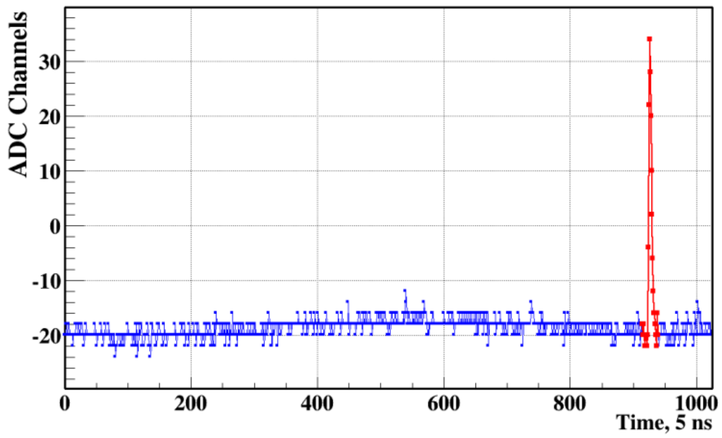
- Dead time minimization: Replacing of a single ADC data buffer for Spartan 3 (~1.5 ms dead time) with a double ADC buffer for Spartan 6
- Increasing the number of bins of the channel amplitude histograms: 250 mV -> 2 mV

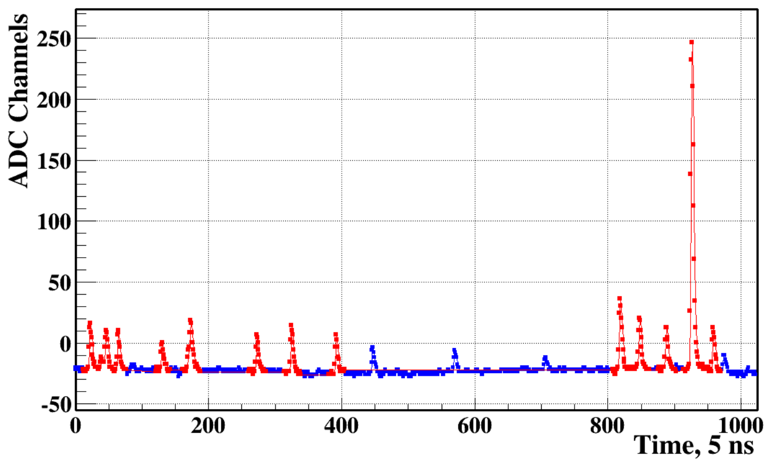
2. Master:

Increasing allowed trigger rate: 5-10Hz -> 50Hz

Trigger rate is limited by the data transmission rate from the strings to DAQ-center: 5-6 Mbit (Ethernet, shDSL modem, 1 km line length).

New firmware of the Master board: on-line data filtering. Cut the pulses from data frame and paste to output data stream. Rejection factor : 30-40

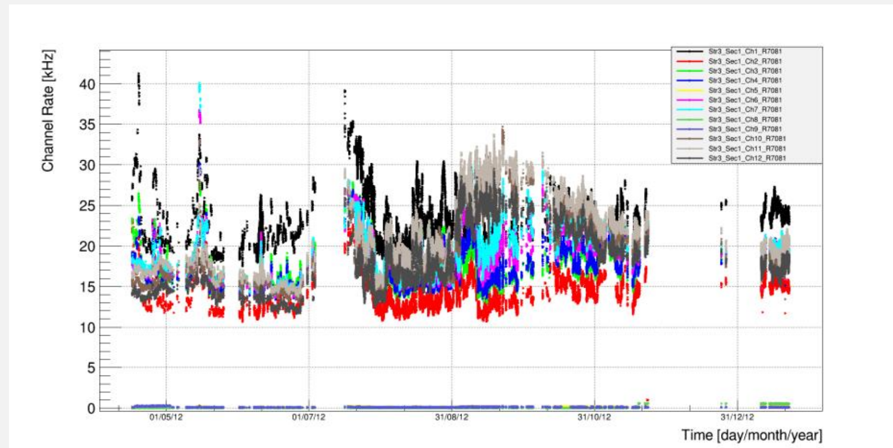




Light background at 1000 – 1300 m depths

NT200 GVD

April 2012 – February 2013

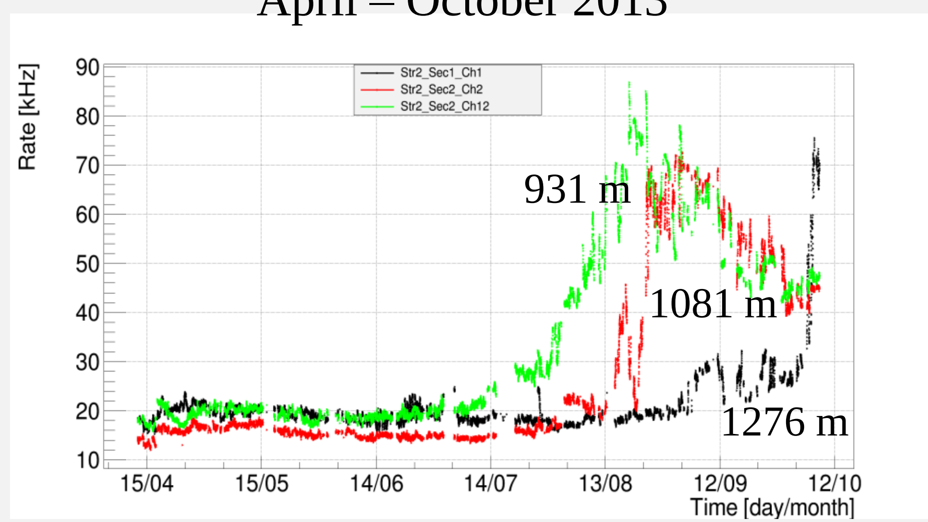


During 2011 – 2012 OMs counting rates were stable at a level of 15-30kHz

During 2013 counting rates rise from 15-10 kHz (April-June) up to 80 kHz In July-September)

~200 m thick water layer with high background intensity sinking with velocity about of (6 -7) m/day

April – October 2013

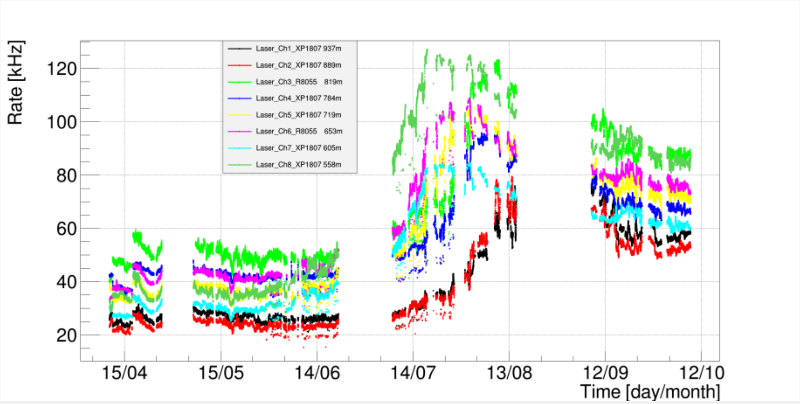


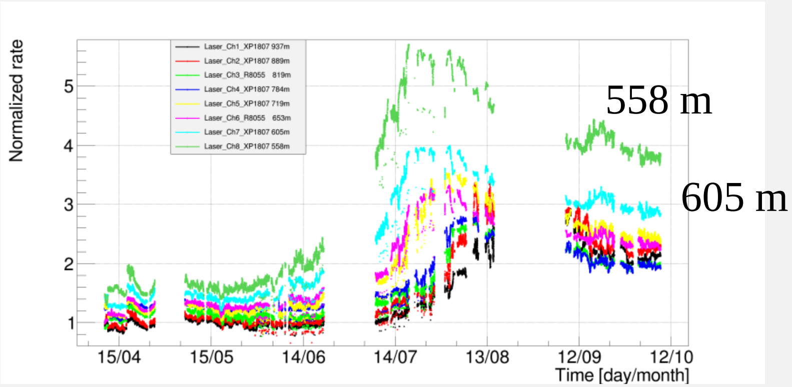
Instrumentation string

Depth – 588m – 937 m

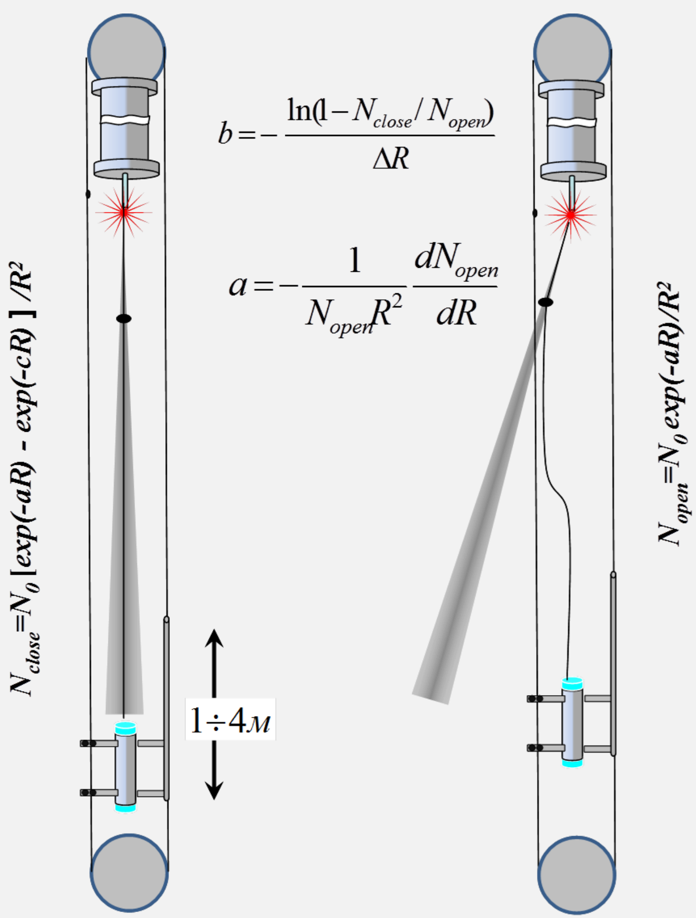
Temporal behaviour of light background

- April – June:
  - noise level increase on factor ~2 with depth decreasing from 940 m to 600 m
- July –August: background increase on all depths due to sinking layer of water with high luminosity
- August – October: noise level decrease with time

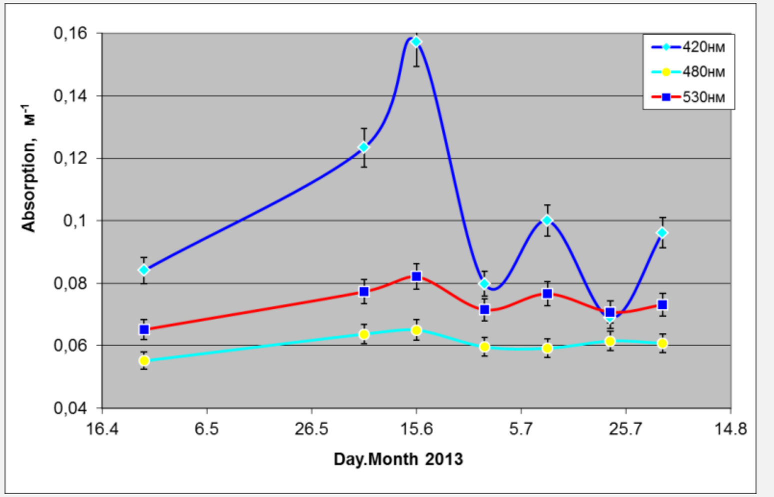




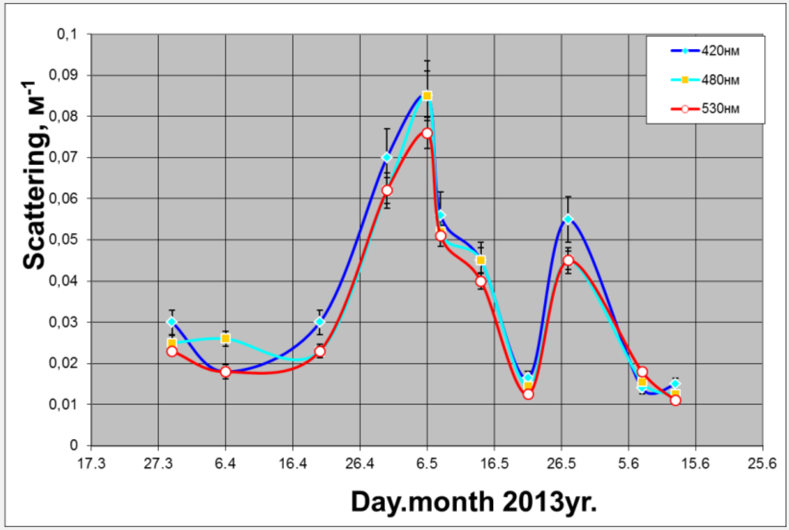
Water optical properties: new device for in-situ measurements



Absorption



Scattering



Nearest plans

2013 – operation of the first stage of demonstration cluster, production and lab. tests of two new strings

2014 - deployment and operation of 5 string array – the second stage of demonstration cluster,
production and lab. tests of three new strings

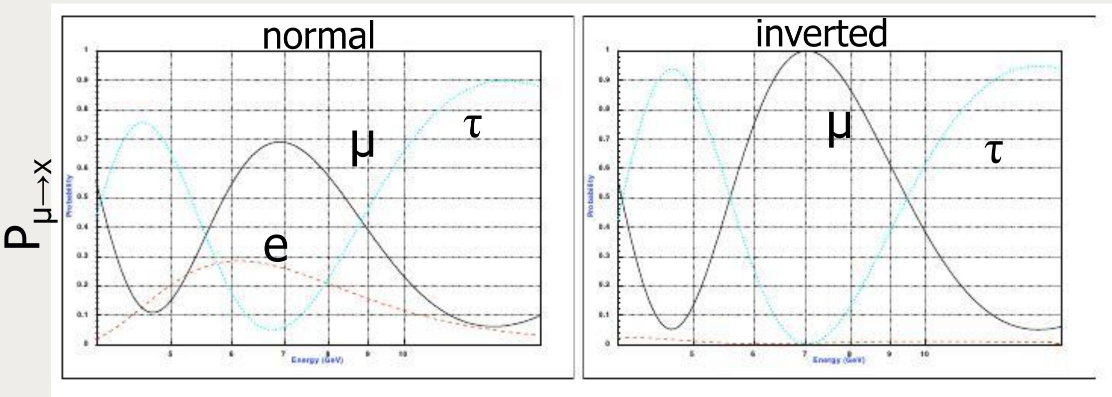
2015 – deployment and data taking with GVD demonstration cluster comprising 8 strings

Multi-megaton array with ~1 GeV threshold

(low energy phenomena - neutrino oscillations, dark matter …)

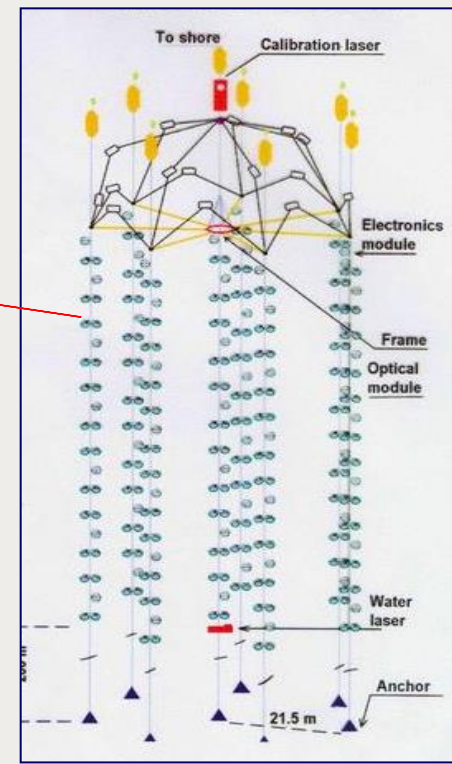
- Atm. Neutrinos: energy – zenith angles distributions of muons and cascades
- Long Base Line Experiments: CERN-BAIKAL

F.Vissany et al.,arXiv:1301.4577



	Fermilab	CERN	J-PARC
South Pole	11600	11800	11400
Sicily	**7800**	1230	9100
Baikal Lake	8700	**6300**	3300

Energy 6-8 GeV; distance 6000-8000 km;
$N^{NH}/N^{IH} \sim 0.7$ (30% difference);
For 10^{20}p.o.t. @ Mton Volume $N_{\mu} \sim 1000$ events



Multi-Megaton low threshold array in Lake Baikal:
The same detection system as for GVD!
Configuration – 9 independent subarrays (heptagons)
OMs – 1500 – 3000;
Positioning precision during deployment < 1 m
Heptagon strings deflections due to water currents during year-exposition < 1m
These allow OM spacing ~ 3 m (vert.); 7-10 m (hor.);
Reconstruction of energy and direction of secondary muons and cascades allows selection of events induced by neutrinos of all flavors.