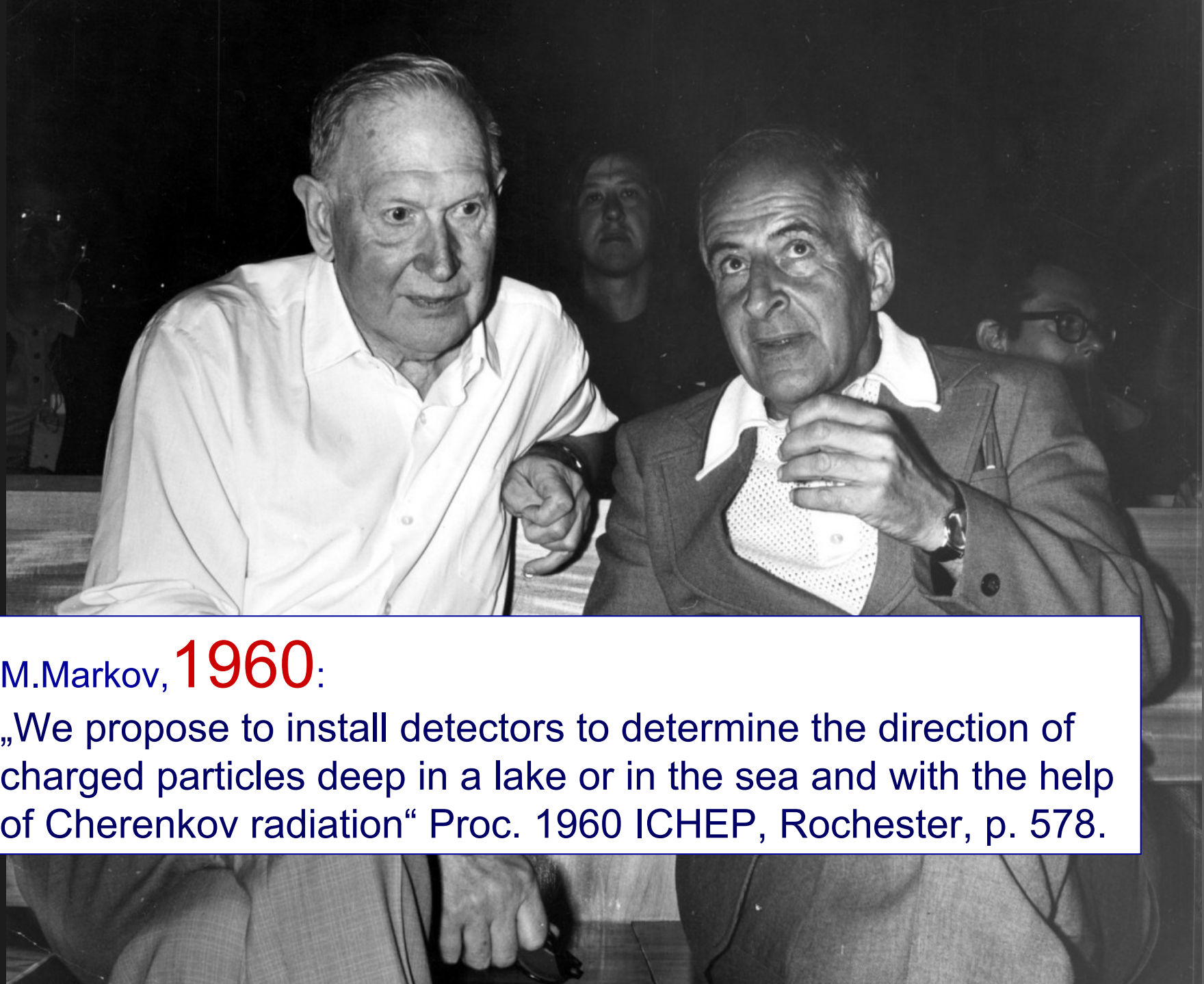
Status of the BAIKAL-GVD Project

Zh.-A. Dzhilkibaev, INR (Moscow),
for the Baikal Collaboration
Moscow, 22-28 August, 2013



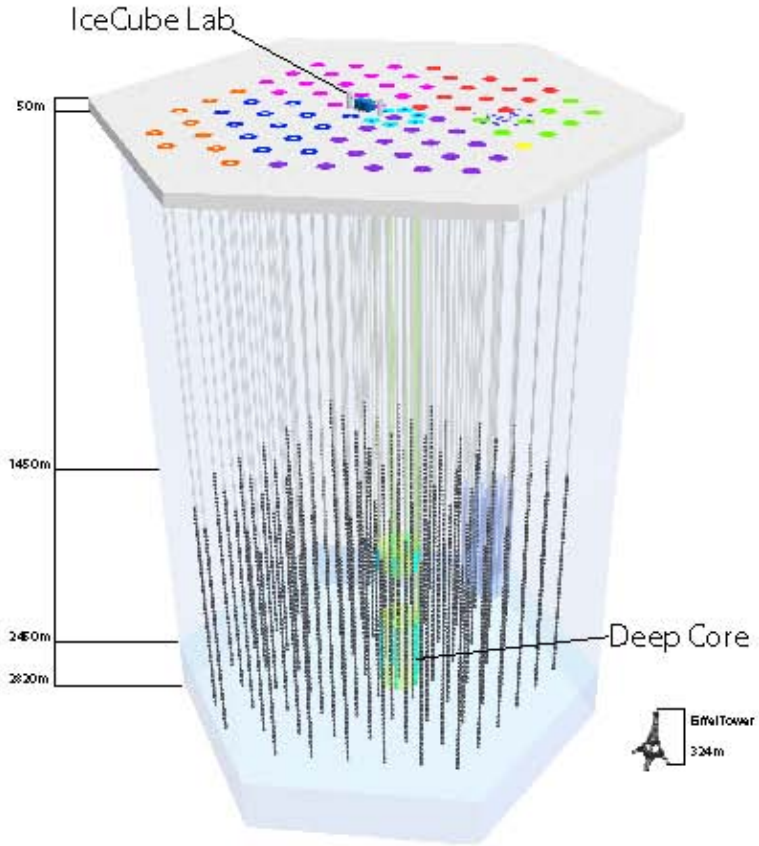
M.Markov, 1960:

„We propose to install detectors to determine the direction of charged particles deep in a lake or in the sea and with the help of Cherenkov radiation“ Proc. 1960 ICHEP, Rochester, p. 578.


KM3NeT
(~2020)
A
N
N
Baikal-GVD
(~2020)
© 1990 Tom Van Sant, Inc. / The GeoSphere Projec
Santa Monica, California
IceCube
(2011)

IceCube

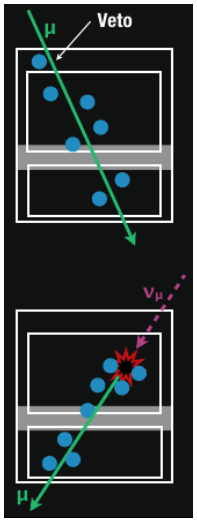
- 5160 PMTs
- 1 km^3 volume
- 86 strings
- 17 m PMT-PMT spacing per string
- 120 m string spacing
- Angular resolution $\sim 1^o$
- Completed 2010

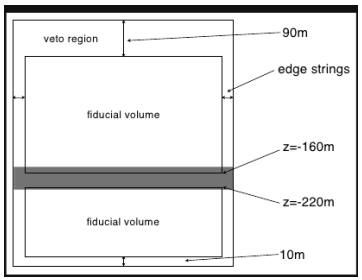


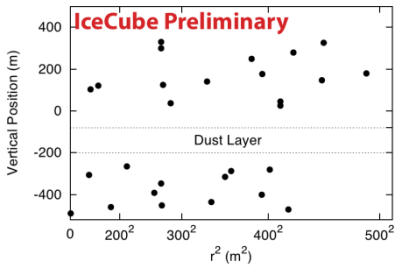
Astrophysical neutrinos: ~E^{-2}
oscillations -> $\nu_e:\nu_\mu:\nu_\tau = 1:1:1$
ν_e ν_τ ν_μ(NC) -> cascades (~80%)
ν_μ(CC) -> tracks (muons)

28 contained HE-events observed (4.3σ)!

May 2010 / May 2012 (662 days of livetime)
Reconstructed energy: 50 TeV – 1.2 PeV
Fiducial volume ~0.4 km^3

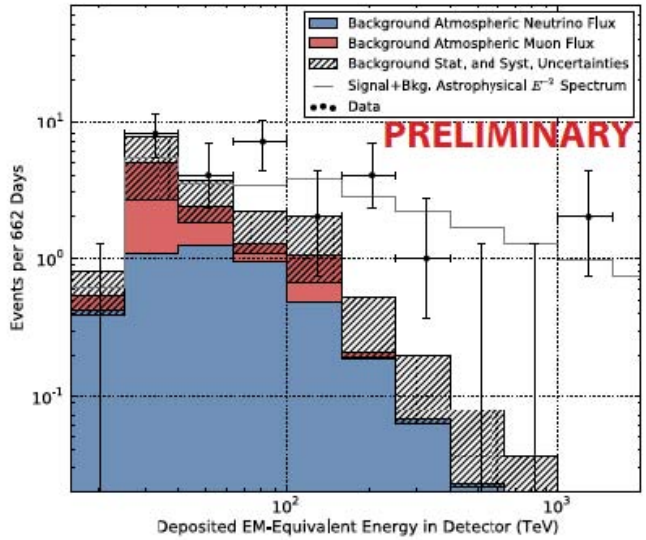






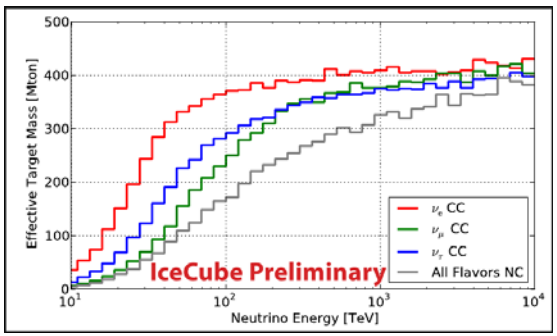
Uniform in fiducial volume

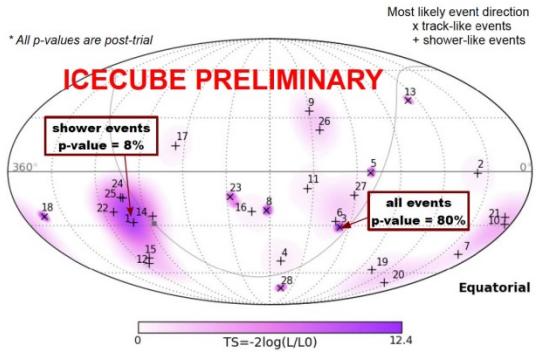
- 28 ev. (7 with μ; 21 without)
  10.6 expected bg. events
- Flavor distribution consistent with 1:1:1
- Energy spectrum very hard
- Angular distribution compatible with isotropic flux
- No significant clustering

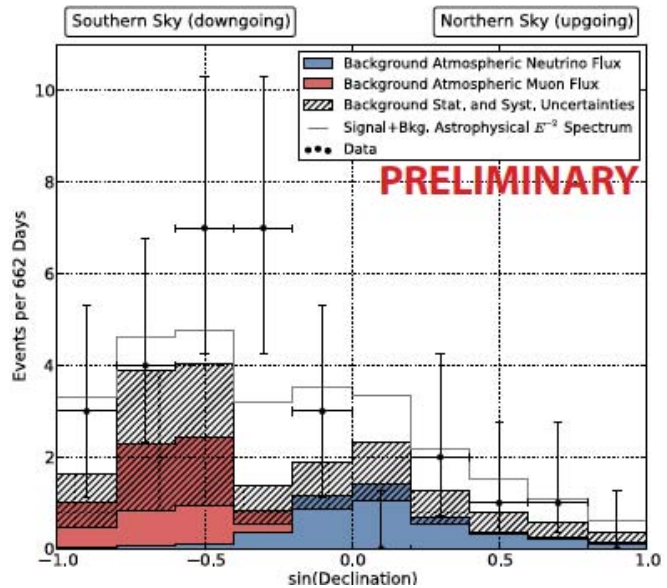


Angular resolution 10°-15°
Energy resolution ~10%

Effective volume

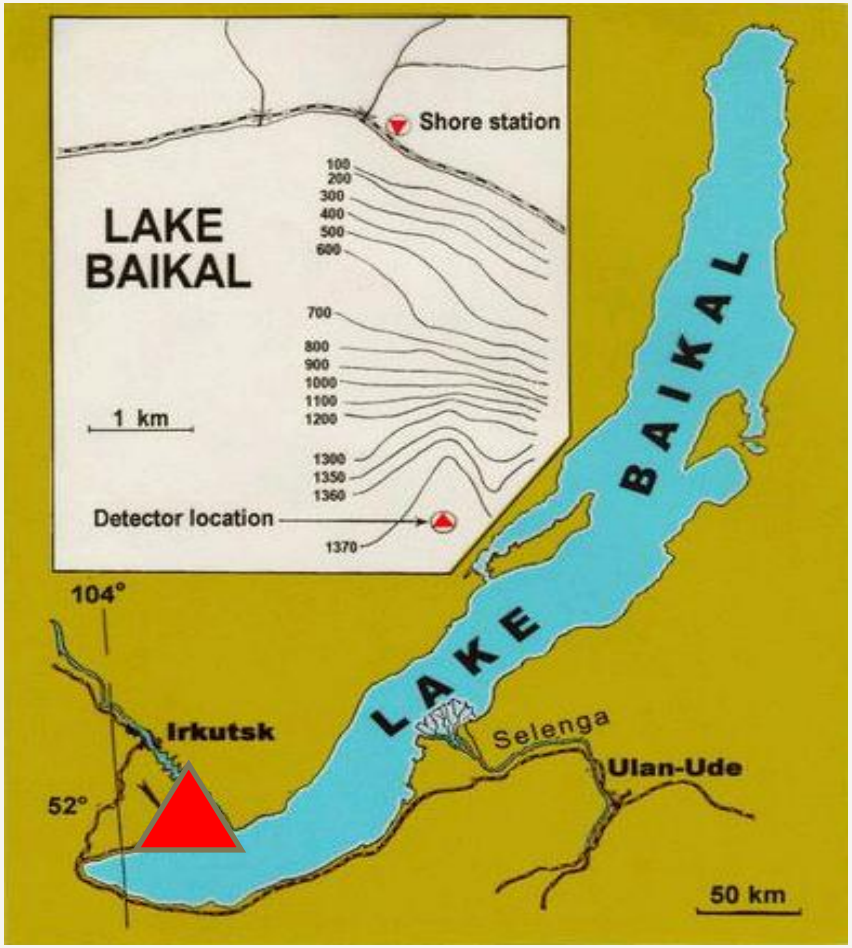




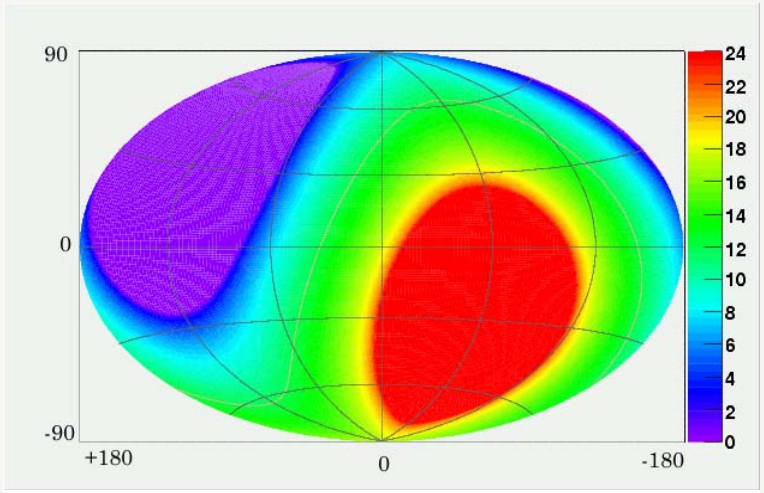


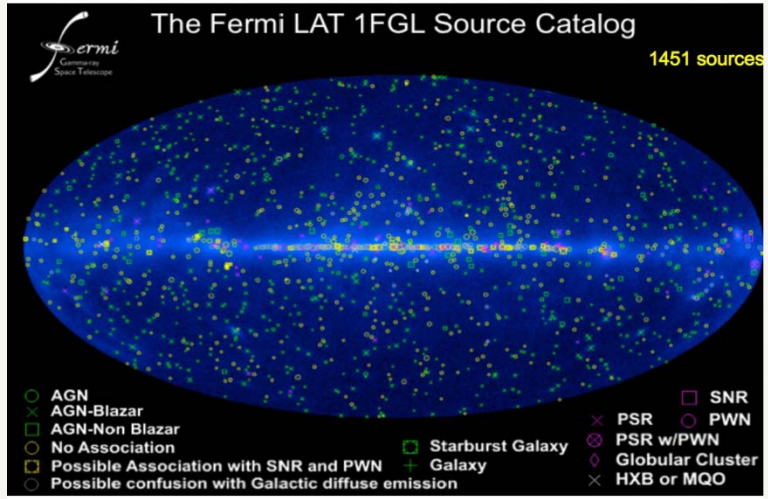
• Location: 104º25’ E; 51º46’ N

Northern hemisphere– GC (~18h/day) and Galactic plane survey



The GVD sky view





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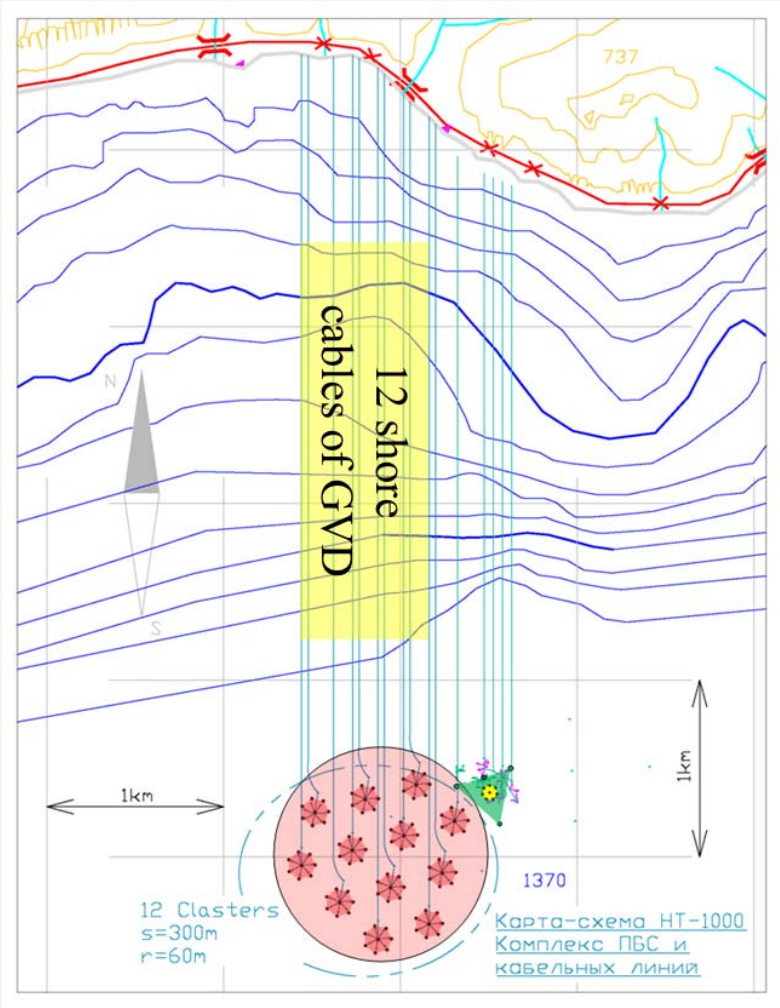
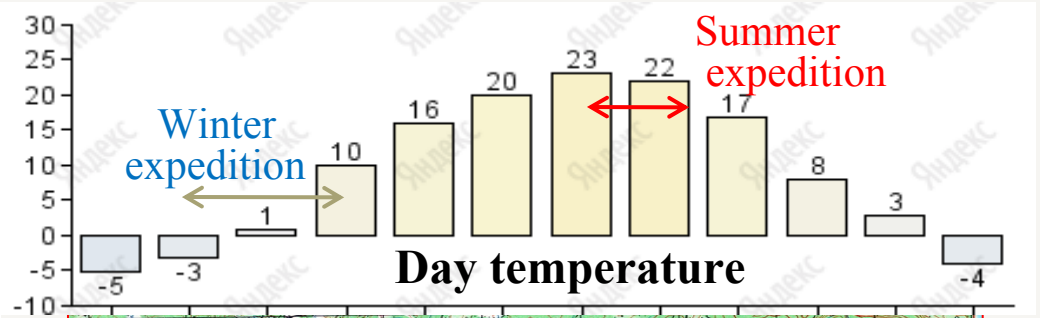
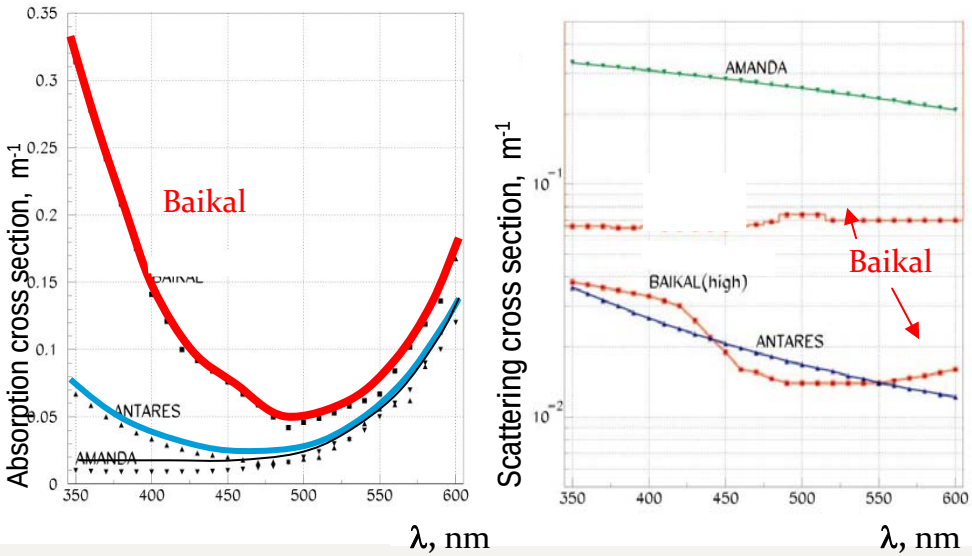




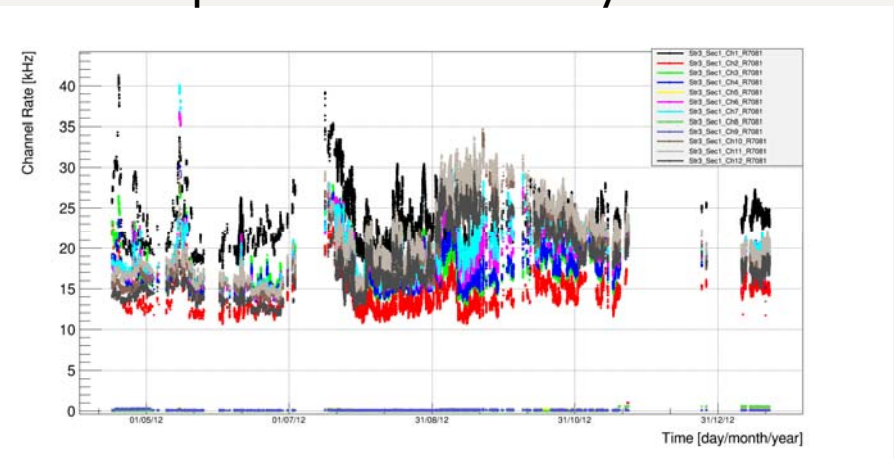
Depth – 1360 m; Flat the lake bed at >3 km from the shore – allows > 250 km^3 Instrumented Water Volume!

Water properties allow detection of all flavor neutrinos with high direction-energy resolution!



- **Absorption length – 22-24 m**
- **Scattering length: 30-50 m (L_{eff} ~ 300-500 m),**
- **Strongly anisotropic phase function: $\langle\cos\theta\rangle \sim 0.9$**

PMTs Counting rates
April 2012 – February 2013

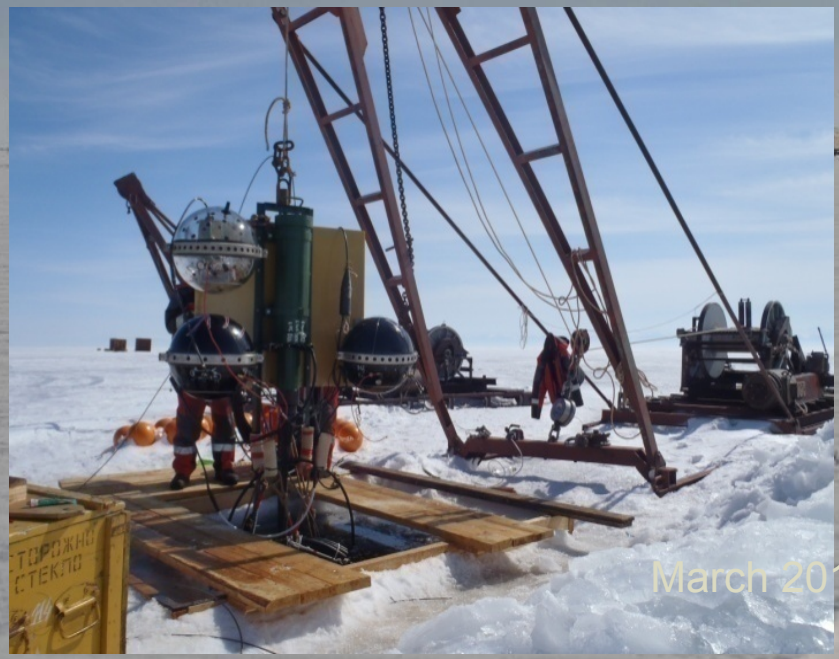


- **Moderately low background in fresh water:**
  15 – 40 kHz (10'' R7081HQE)
  absence of high luminosity bursts from biology and ^{40}K background.

• Strong ice cover during ~2 months:

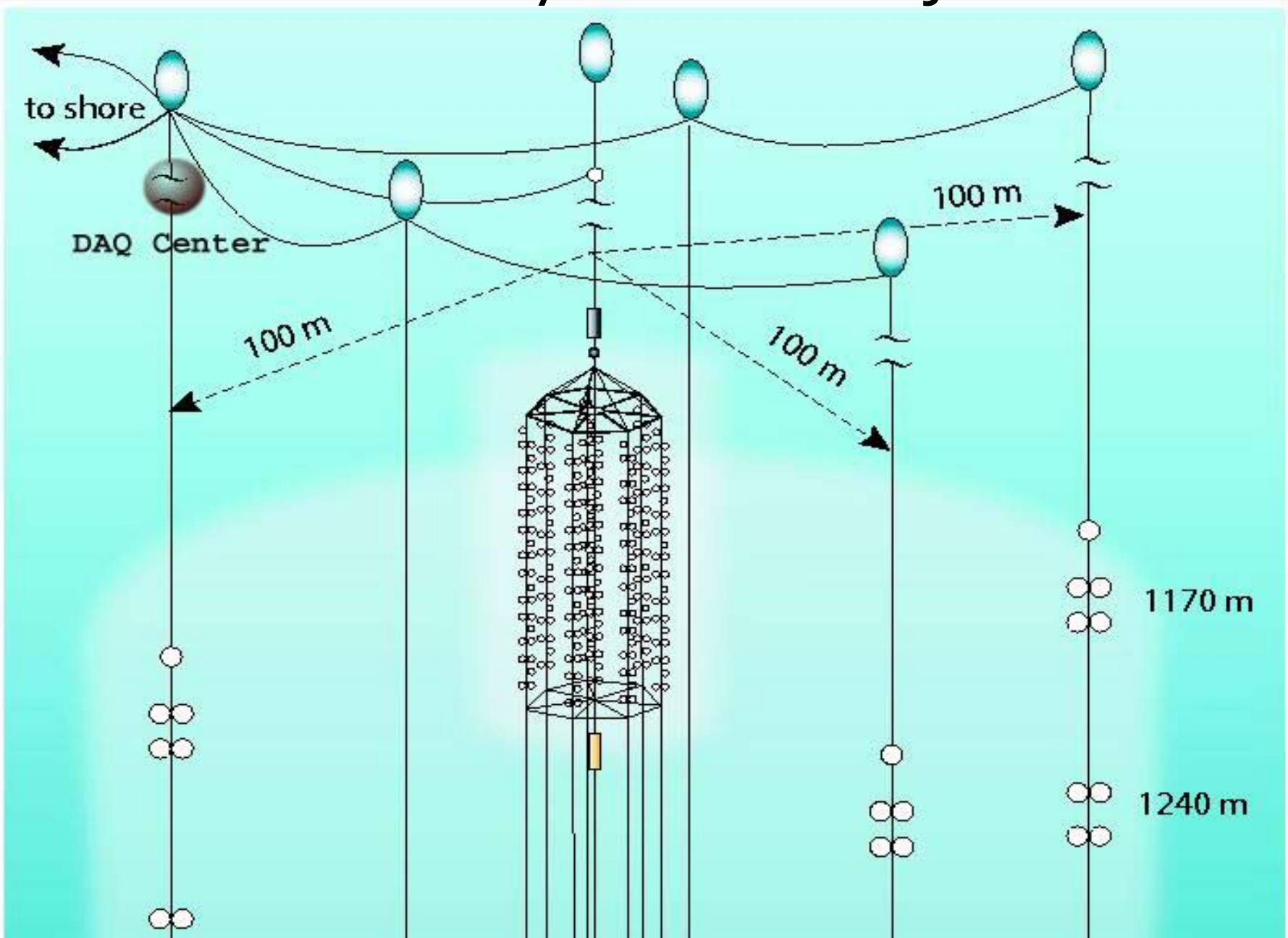
- Telescope deployment, maintenance, upgrade and rearrangement
- Installation & test of a new equipment
- All connections are done on dry
- Fast shore cable installation (3-4 days)
- Simultaneous deployment of strings

Dry mating

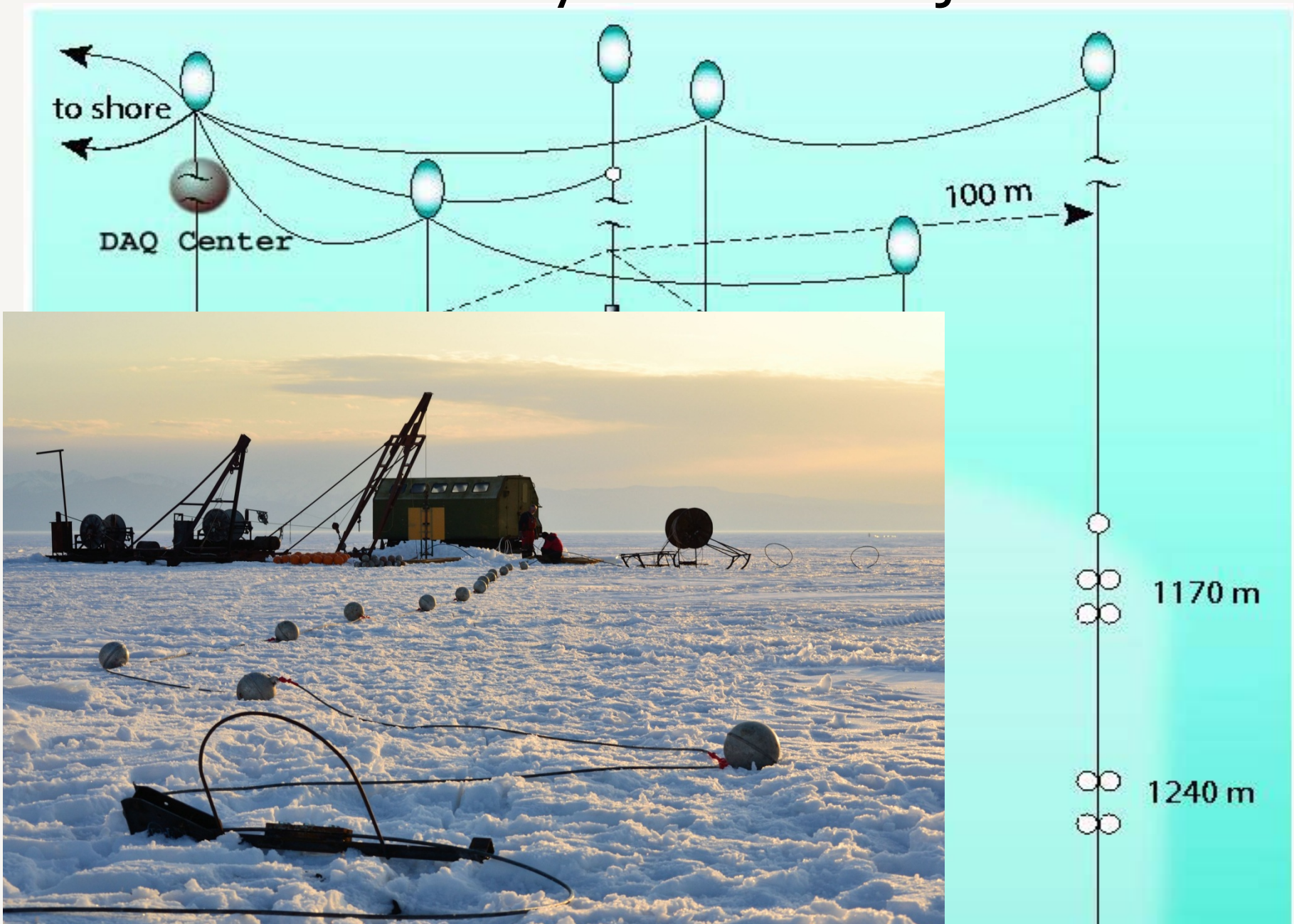


March 2011

All connections on dry without bed junction boxes



All connections on dry without bed junction boxes

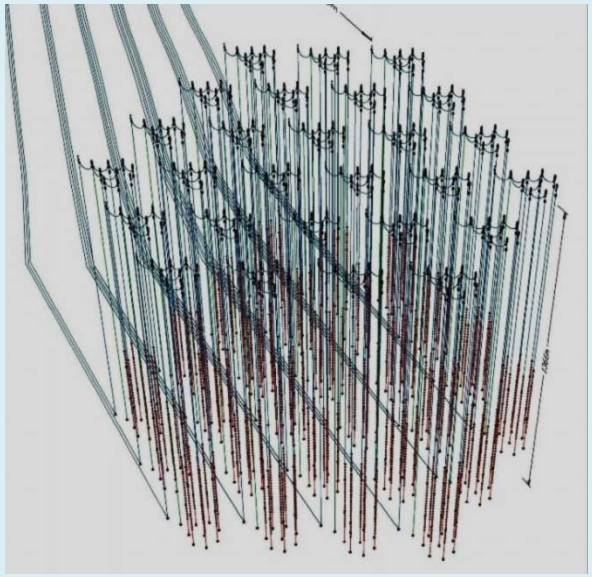


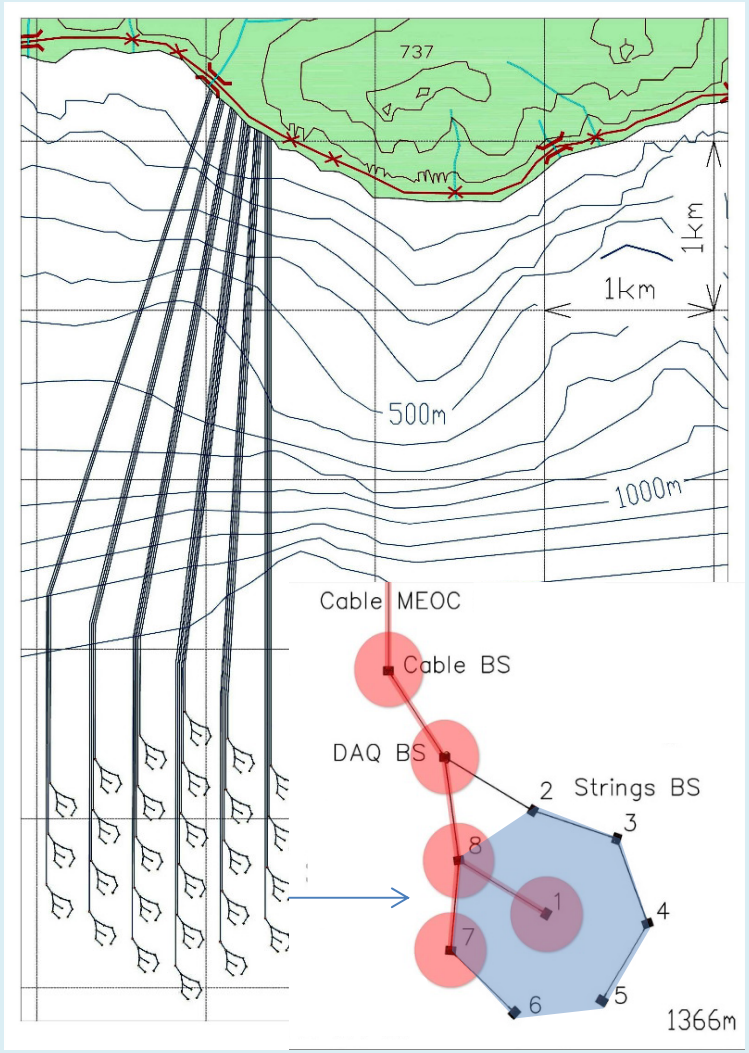
Gigaton Volume Detector (Lake Baikal)

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

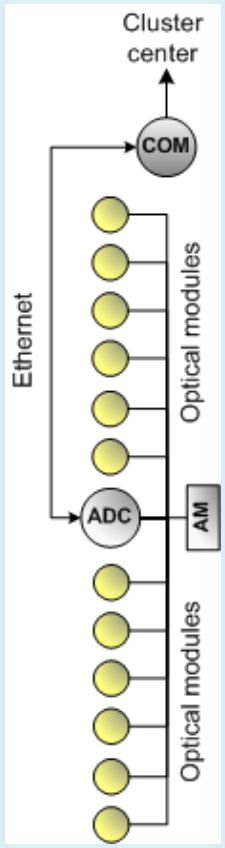




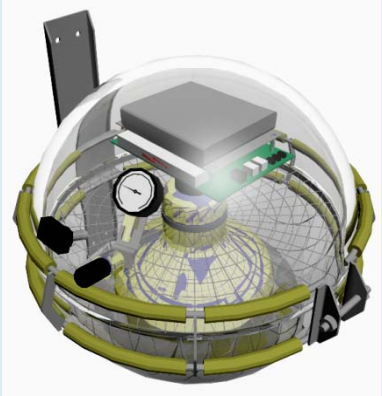
GVD array

1st GVD cluster: 8 strings

- Installed strings and cable stations



Section: basic detection unit

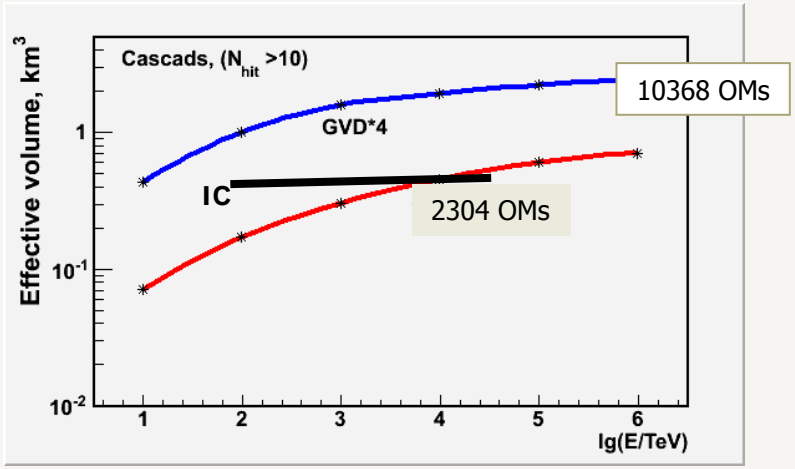


Optical module

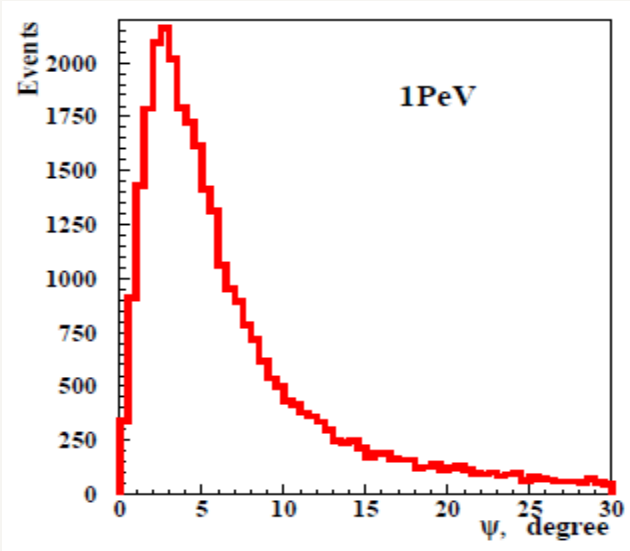
GVD Performance

Cascades: (E>10 TeV):

V_{eff} ~0.4–2.4 km^3

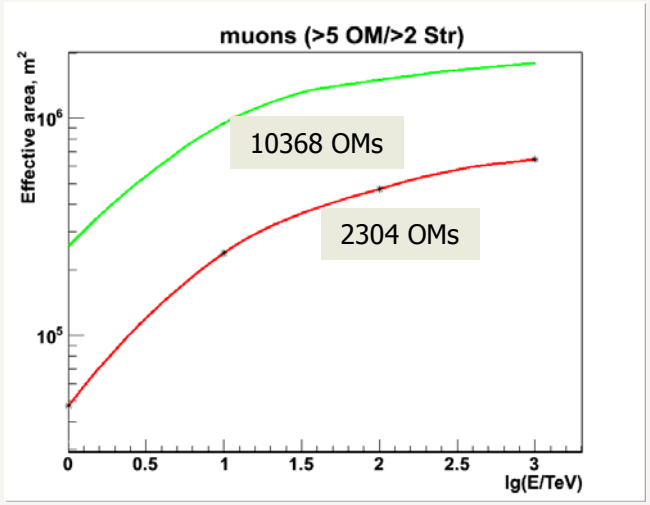


Directional resolution: 3.5^o - 5.5^o

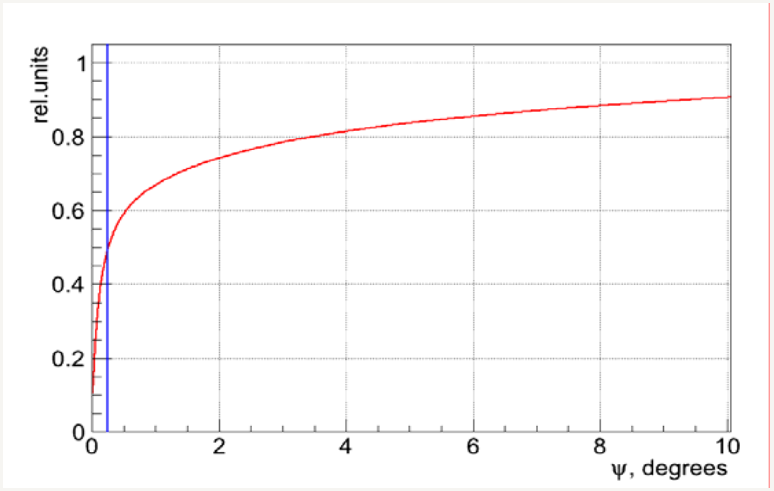


Muons: (E>1 TeV):

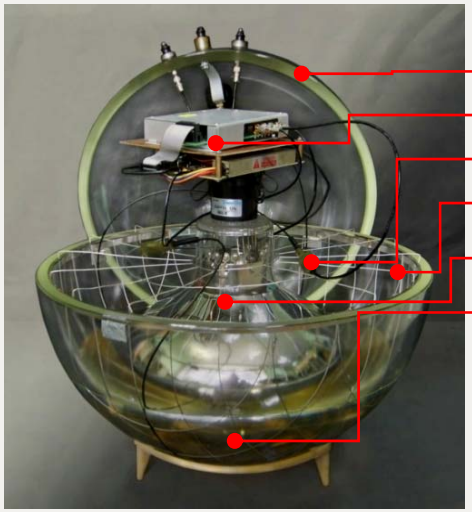
S_{eff} ~ 0.3–1.8 km^2



Directional resolution - 0.25^o

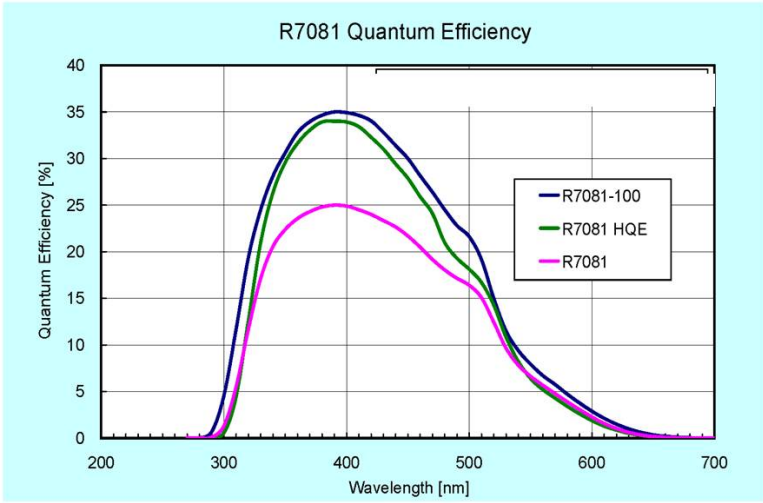


Optical module (OM)

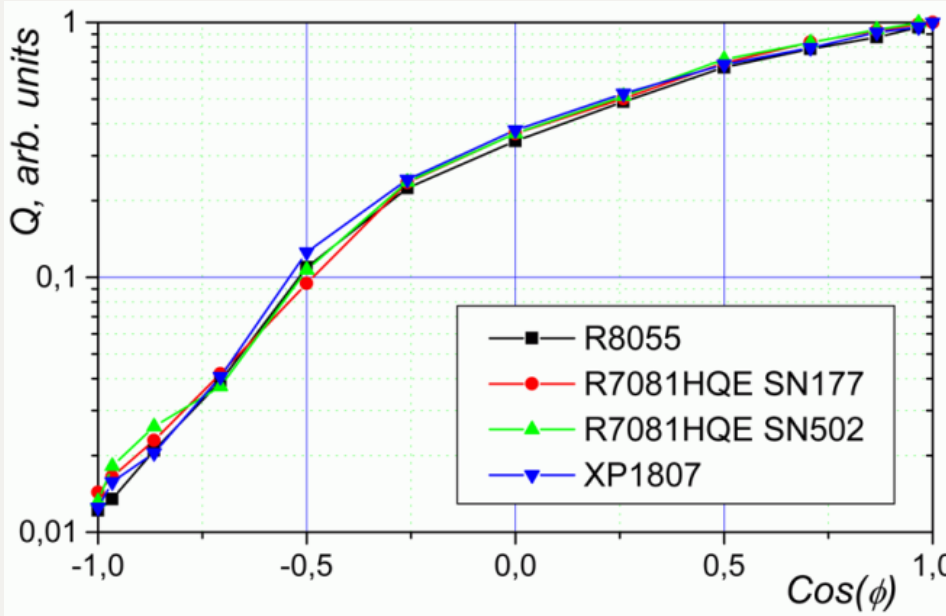


- Glass pressure-resistant sphere VITROVEX (17”)
- OM electronics: amplifier, HV DC-DC, RS485 controller
- 2 on-board LED flashers: 1…10^8 pe., 430 nm, 5 ns
- Mu-metal cage
- **PMT R7081HQE : *D*=10”, ~0.35QE**
- Elastic gel

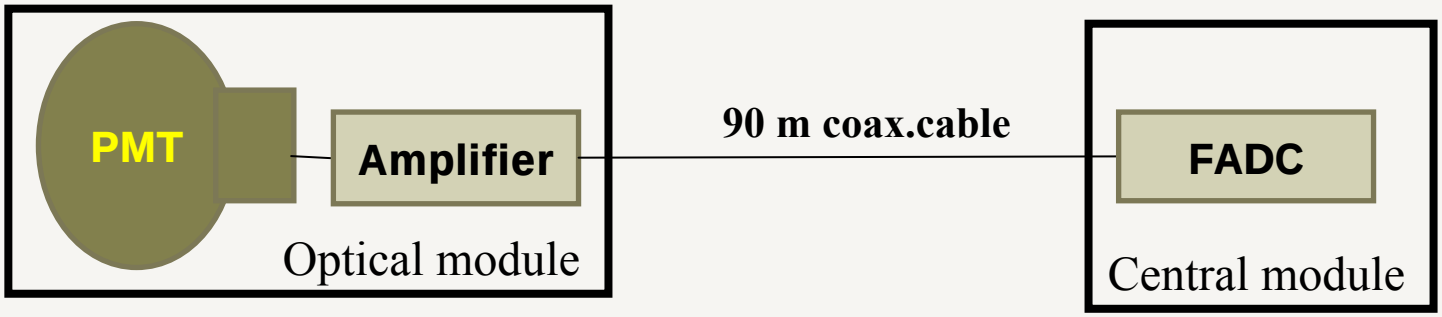
Quantum efficiency

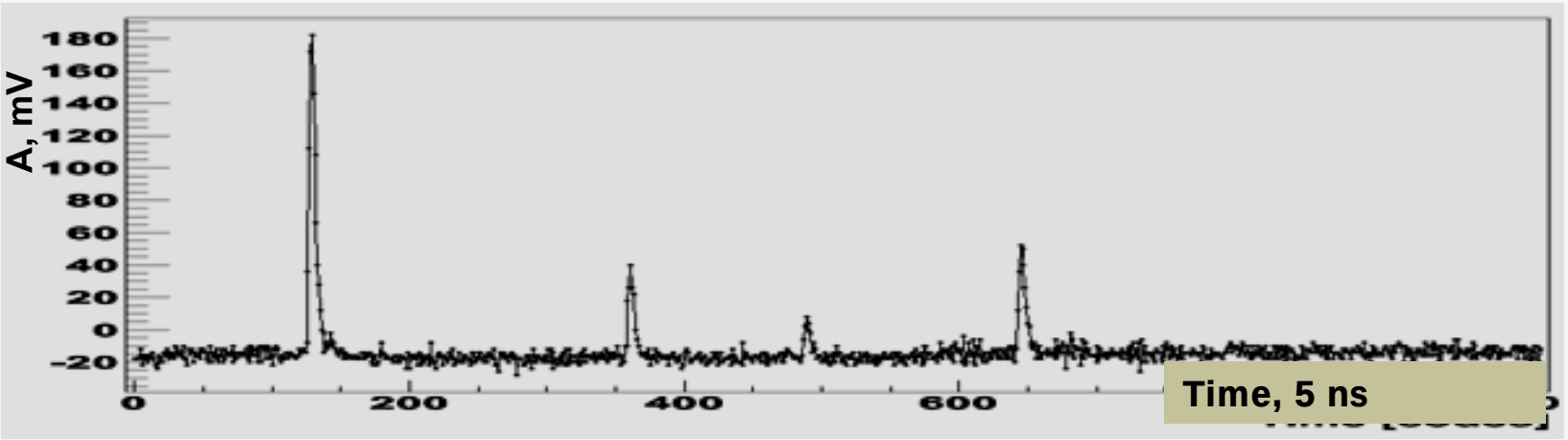


Angular sensitivity



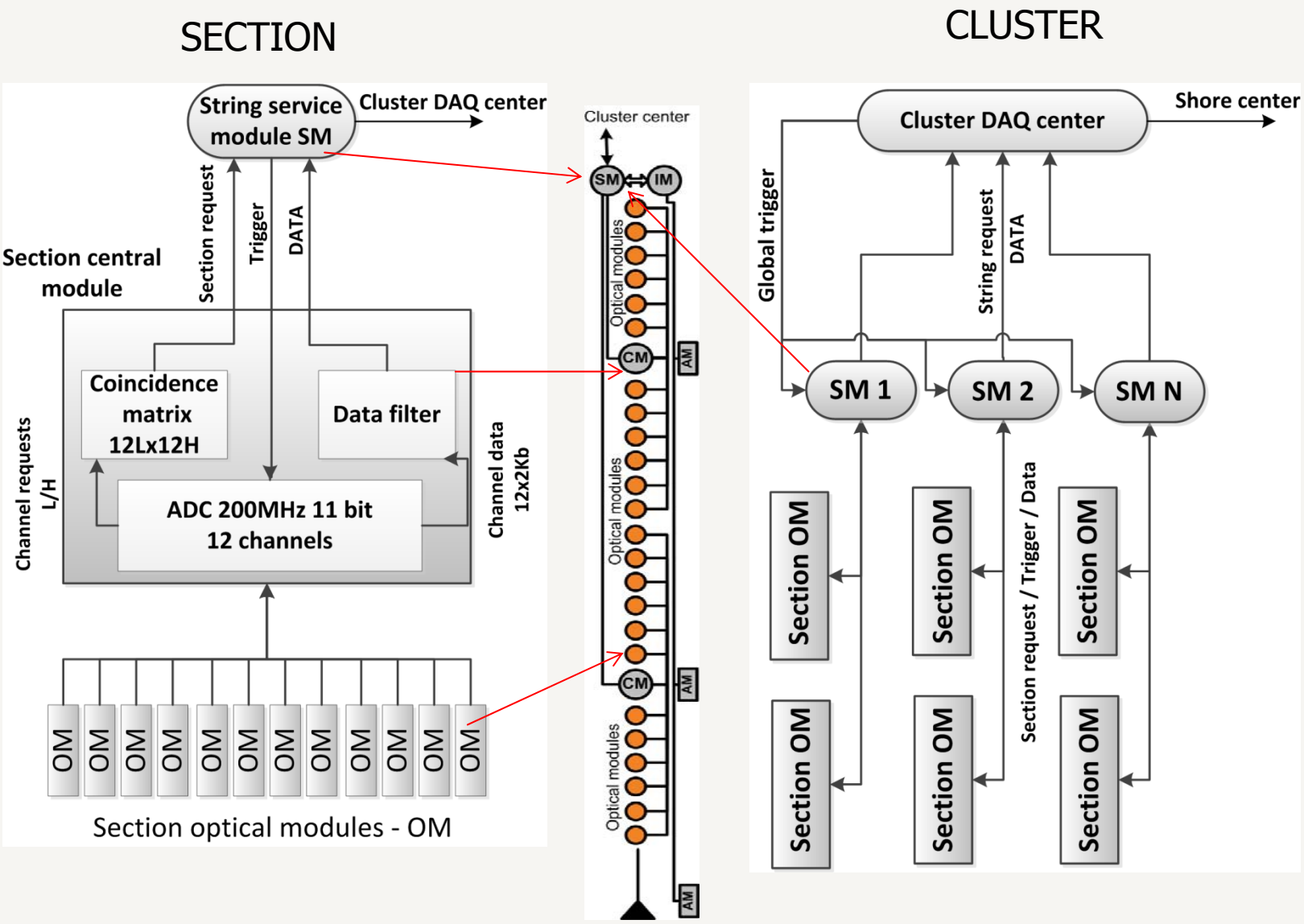
Measuring channel





- Nominal PMT gain 1×10^7 (PMT voltage 1250 – 1650 V)
- Amplifier, $k_{amp}=10$;
- Pulse width ~20 ns
- ADC: 12 bit 200 MHz FADC (5 ns time bin);
- Waveform information is recorded in a programmable interval (up to 30 mks)
- Linearity range: 1 ─ 100 p.e.;

Triggering and Data Transmission



Project time-line

STReport http://baikalweb.jinr.ru/GVD

Research & Development

Prototyping & Construction

Prototype Strings

Data Taking

2008 2009 2010 2011 2012 2013 2015 2020

Design, production and long-term in-situ tests of key elements and systems of GVD:

- Optical Modules
- FADC-readout system
- Section Trigger Logics
- Calibration system
- Data Transmission
- Cluster Trigger System, DAQ
- Data Transport to Shore

Engineering Arrays

Cluster 8 strings

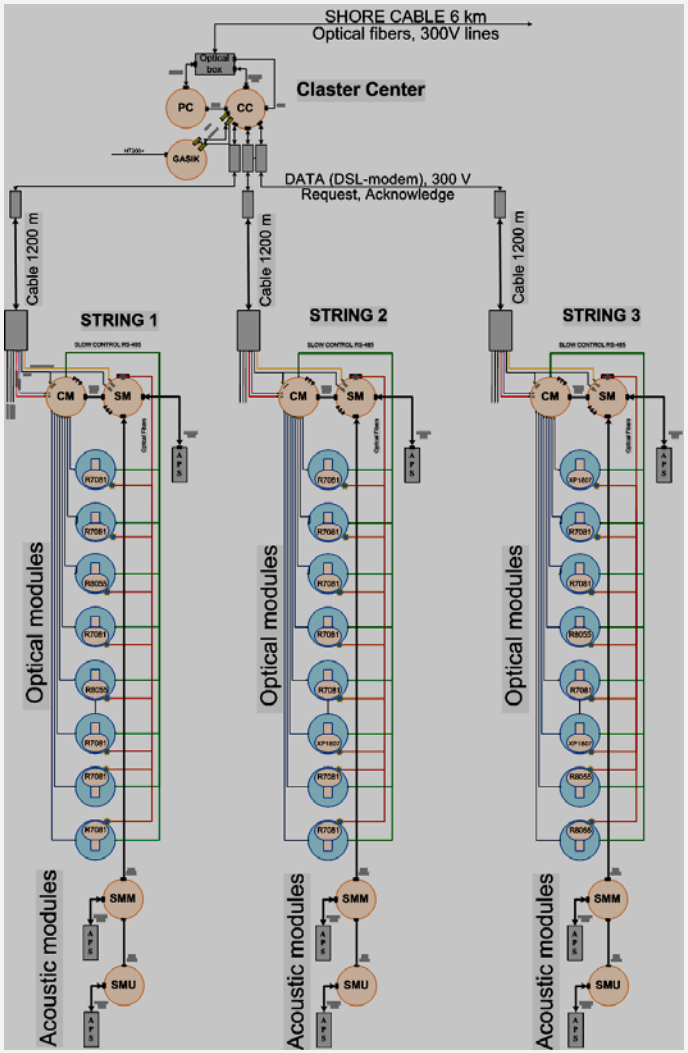
3 full strings (72 OM)

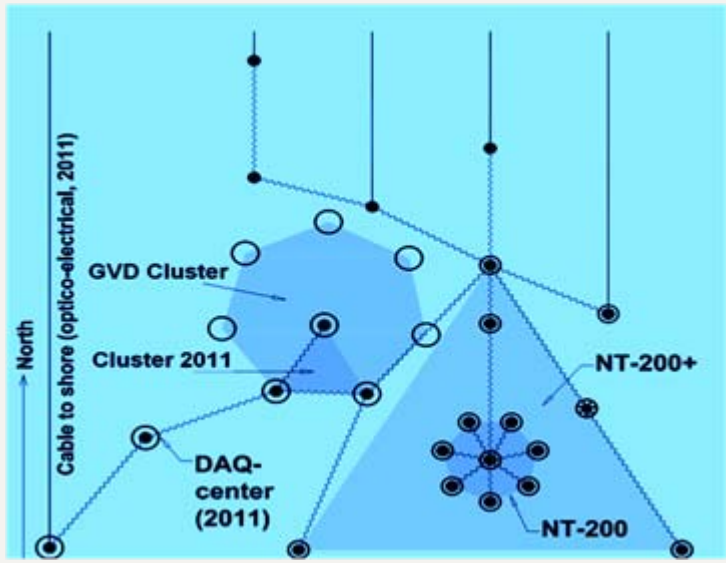
3-strings array (36 OMs), 1 full-scale string (24 OMs)

3-strings array (24 OM). Optical-electric cable to shore. Cluster DAQ-center. Shore station.

Prototyping Phase

Engineering array 2011 - technical design





3 Strings

- Size reduced sections:8 optical modules, CM and SM.
- Acoustic positioning system, 3 modules on each string.

Cluster DAQ center

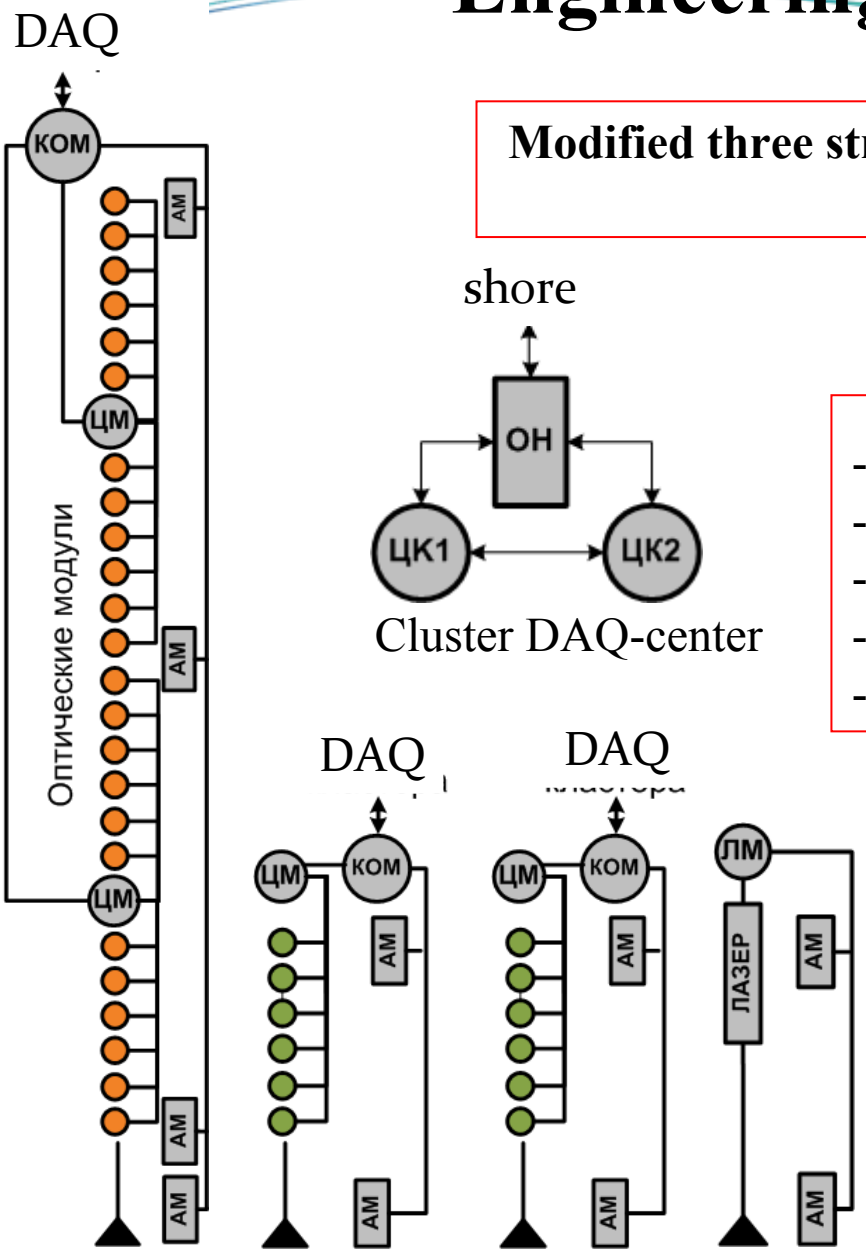
Cluster DAQ center provides the string triggering, power supply, and communication to shore.

Communication lines

Connection between the strings and cluster DAQ center: 1.2 km copper cable. Connection to shore – optical cable 6 km.

Engineering array 2012

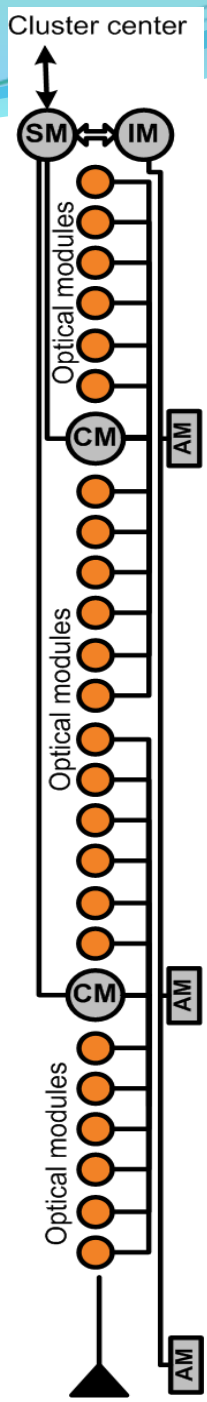
Modified three string array comprising full scale GVD string



- 24 OM with Hamamatsu R-7081HQE:
- 12 OM with XP1807 и R8055
- 10 acoustic modems (AM)
- DAQ-Center
- Instrumentation string

Engineering array 2012

First full scale GVD string with 24 OMs (2 sections) has been deployed.



String modernizations

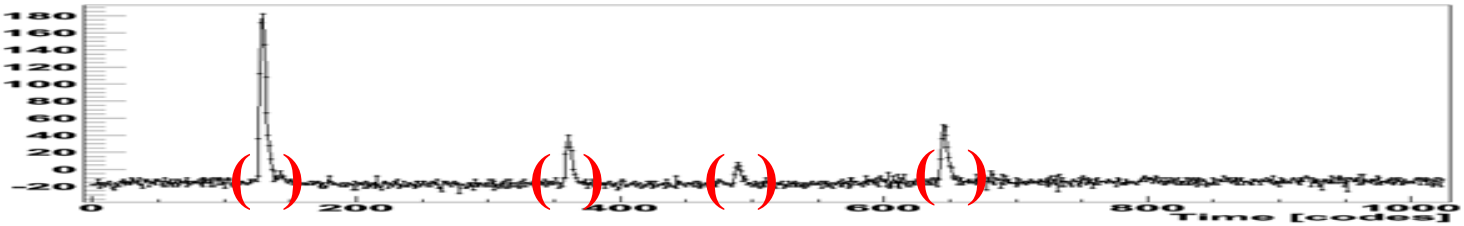
1. Optical modules:

One OM connector (SubConn LF, 5 pin) instead of two coax. conn:

- reliability increasing;
- separation power supply and analog pulse lines → decreasing the channel thresholds (0.5 p.e. to 0.25 p.e.)

2. String central module electronics:

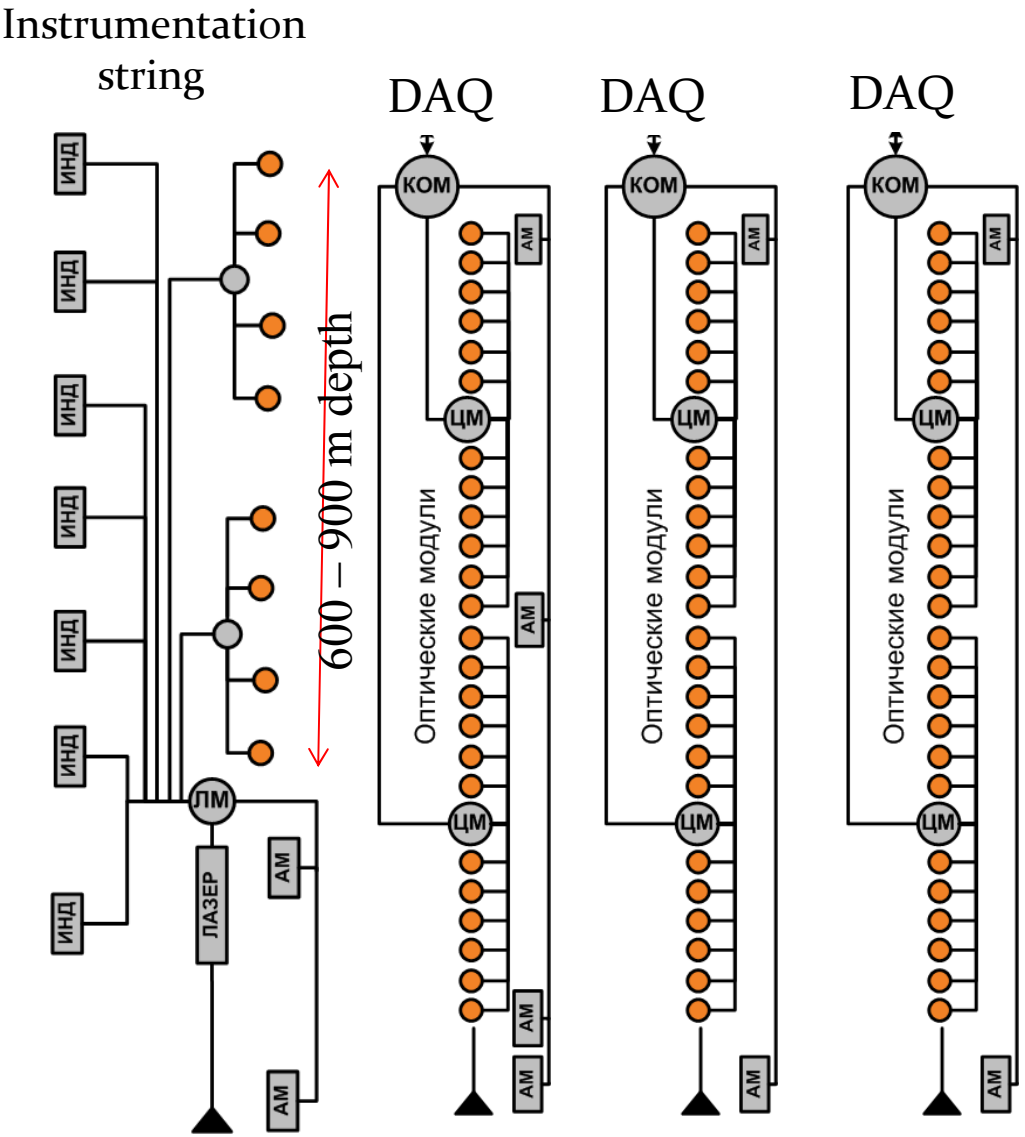
Master boards : new FPGA Xilinx "Spartan 6" instead of "Spartan 3" for on-line data processing (cut out waveform data without pulses).



On-line data processing provides increasing the event transmission rate with 10 Mbit DSL-modem to factor ~100 (10Hz → 1 kHz)

Engineering array 2013

The first stage of GVD Cluster comprising 3 strings



72 OM (R7081HQE, R7081-100)
3 Strings
6 Sections

Positioning System:
12 - Acoustic Modems

Instrumentation string:
-8 OM (600-900 m depth)
-11 Acoustic sensors (50-1220 m depth)
-2 Acoustic Modems
-Laser (1215 m depth)

Engineering arrays (2012-2015)

2012

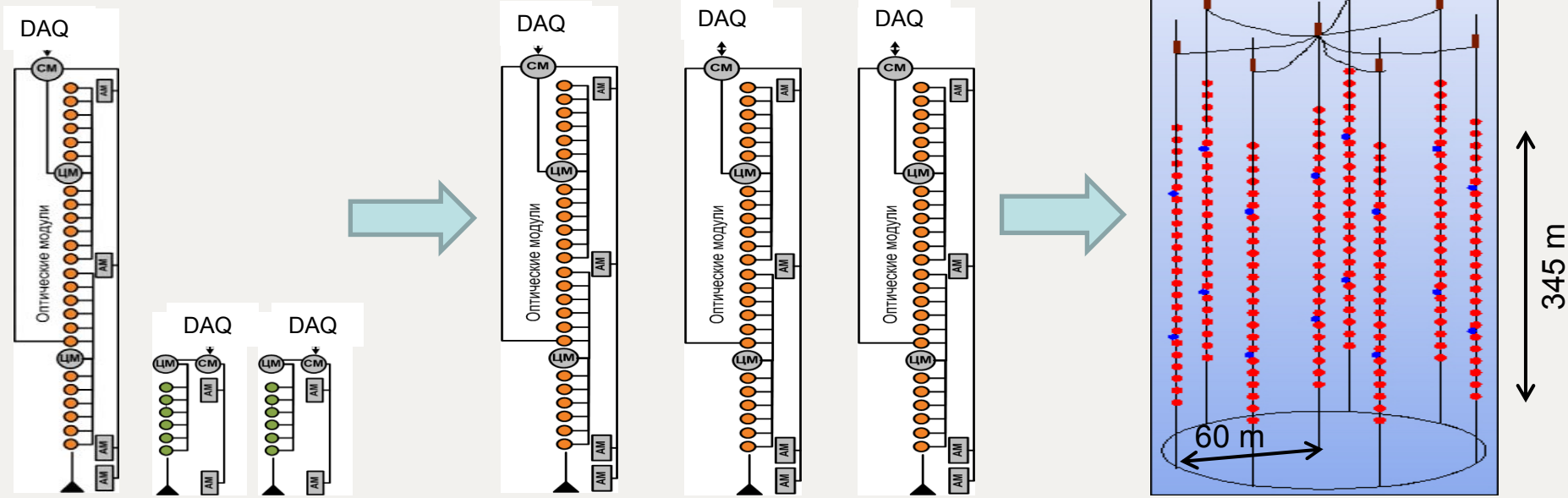
3 strings, first full-scale GVD string (24 OMs)
Data taking from April 2012 yr.

2013

3 full-scale strings (72 OMs), update of section electronics
Data taking from April 2013 yr.

2014-2015

First Cluster (8 strings)
(ANTARES-scale array)



~10^6 м^3 instrumented volume

~4×10^6 м^3

Time schedule of the BAIKAL-GVD

2013 - 2015 - verification of final versions of the GVD elements and systems, start of the first phase of construction with deployment of the first Cluster, data taking

2015 – 2018 – the first phase of construction (12-14 Clusters), data taking

2018 – 2020 - the final phase of construction (27 Clusters), data taking

Conclusion:

- During 2006-2010 the key elements and systems of the GVD have been developed, produced and tested in Lake Baikal. Scientific-Technical Report (STR) has been prepared

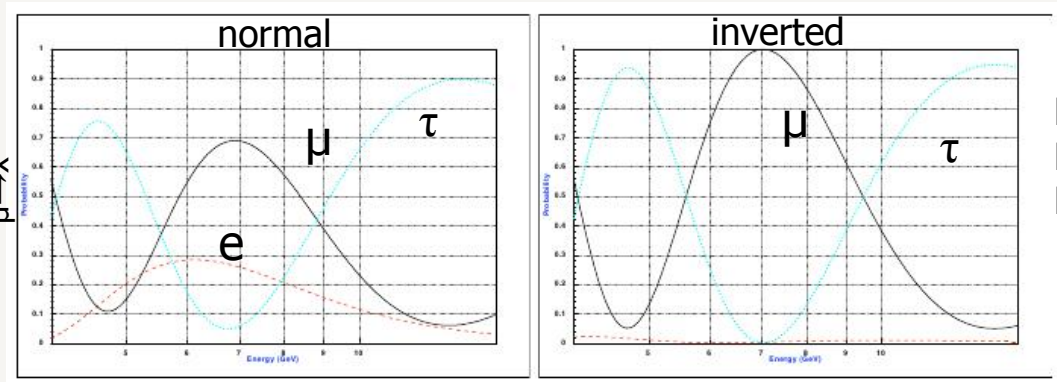
- Prototyping & Construction Phase of Project is started in 2011 with deployment of the 3-string engineering array – prototype of the GVD Cluster in Lake Baikal, which comprises all elements and systems of the future telescope

- Prototyping Phase of project will conclude in 2015 with deployment in Lake Baikal of the ANTARES-scale array – the first Cluster of BAIKAL-GVD.

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} ~ 0.7 (30% difference);
For 10^{20}p.o.t. @ Mton Volume N_μ ~ 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.