5th Roma International Conference on Astroparticle Physics

Data acquisition system for the Baikal-GVD neutrino telescope

Vladimir Aynutdinov for Baiakal collaboration

September 30, 2014

OUTLINE

1. Baikal site

2. GVD design and electronics

3. Engineering array 2014

4. Summary

Collaboration

7 Institutions, ~ 50 authors

State Marine U. Petersburg

JINR Dubna

INR, MSU Moscow

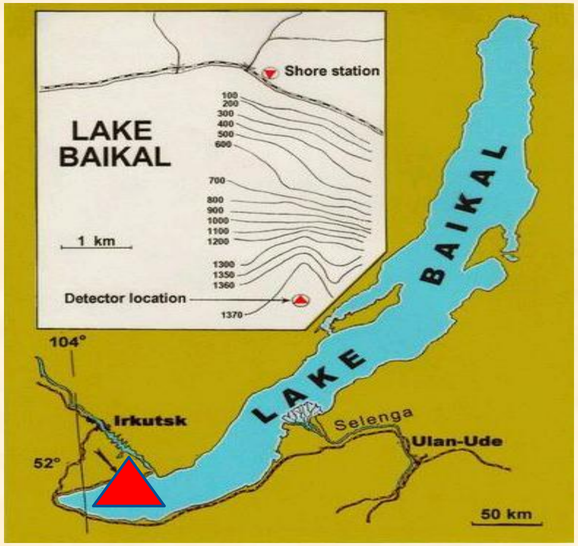
Techn State U. Nizhni Novgorod

Germany: EvoLogics GmbH

Irkutsk State University

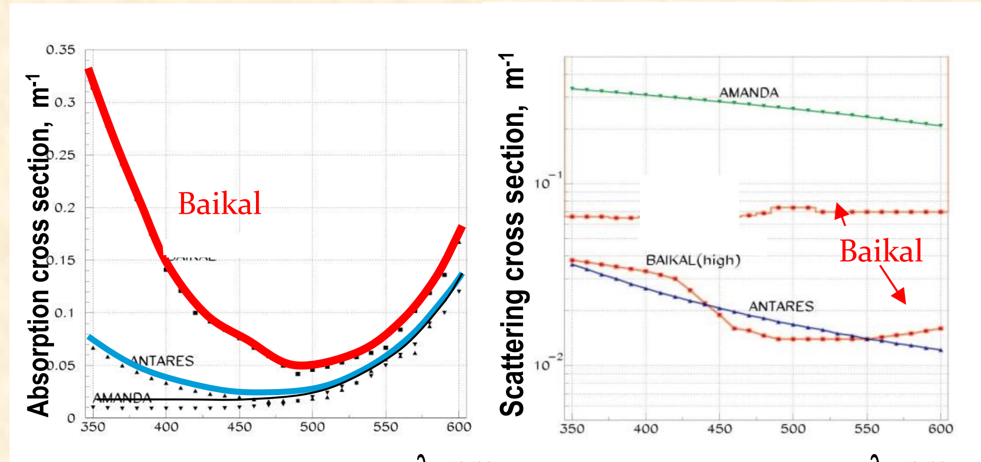
The BAIKAL Site

Lake Baikal, Siberia



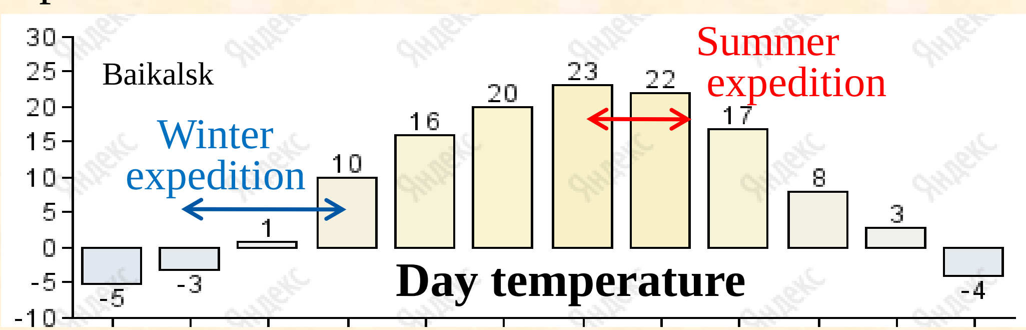
1370 m maximum depth.

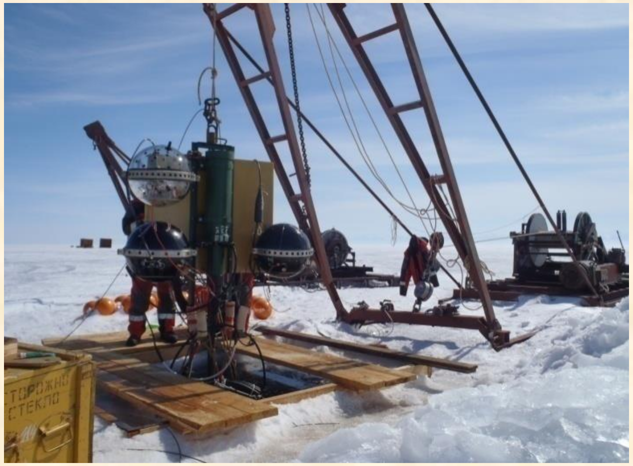
- Distance to shore ~4 km
- No high luminosity bursts from biology.
- No K^{40} background.
- Deployment simplicity: ice is a natural deployment platform



Baikal water properties: Abs.Length: 22 ± 2 m

Scatt.Length: 30-50 m



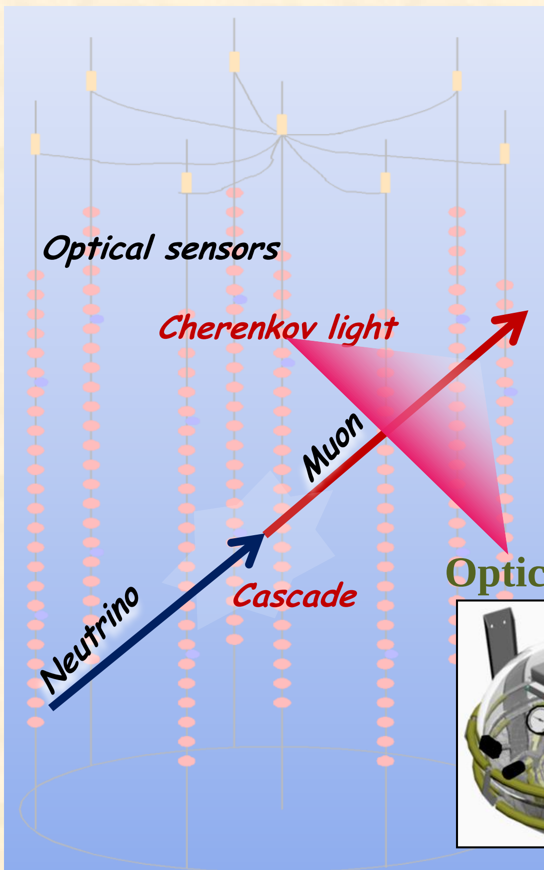


Gigaton Volume Detector GVD

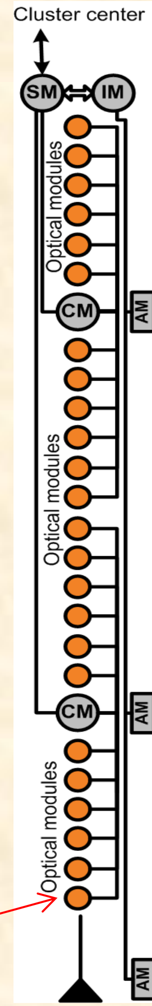
2015 – 1 Cluster with 8 strings (196 OM)

2020 –12 Cluster (1st GVD phase - 0.4 km³)

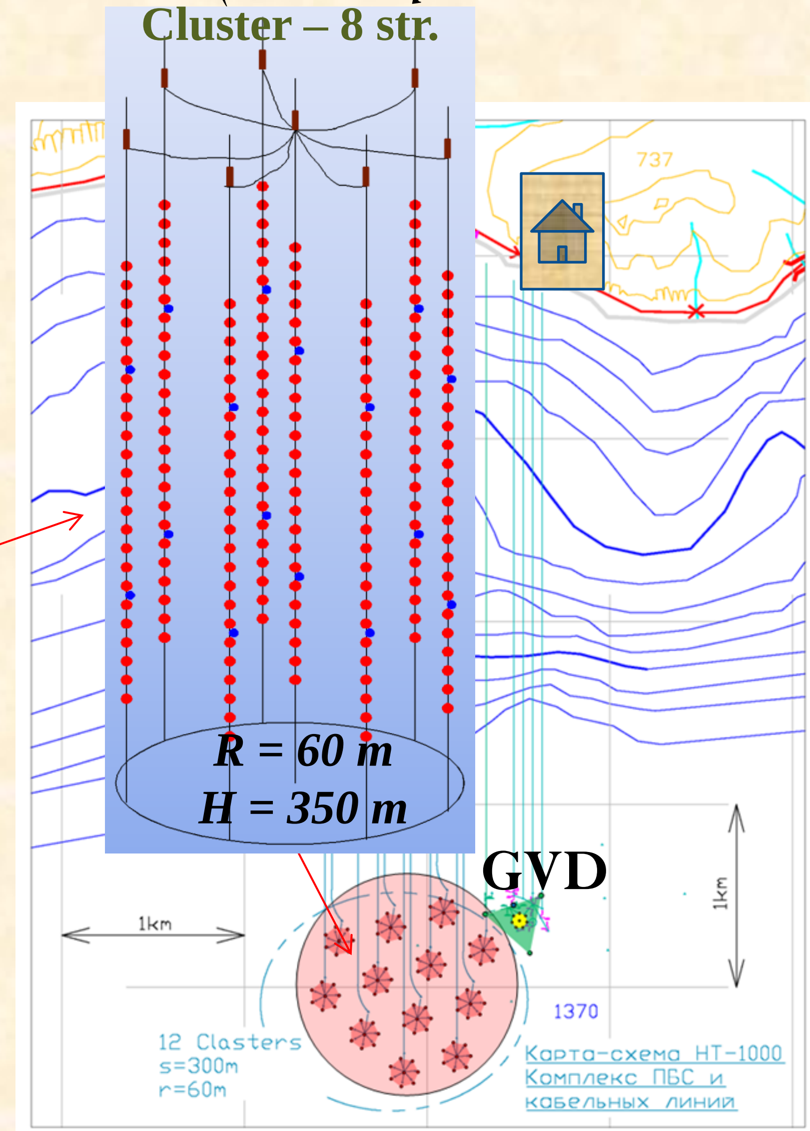
The pressure-resistant optical sensors register flashes of the Cherenkov light emitted by charged particles from collisions of high-energy neutrinos.



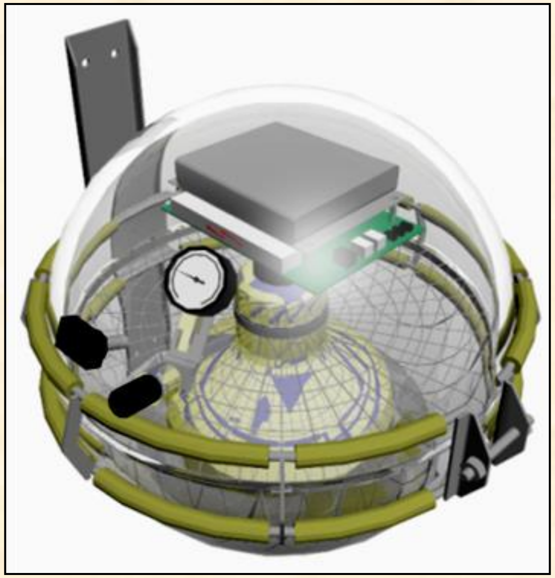
Optical module.

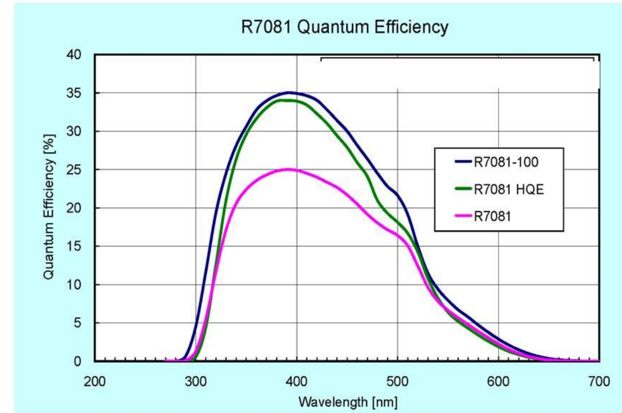


String
24 OM



GVD Optical module



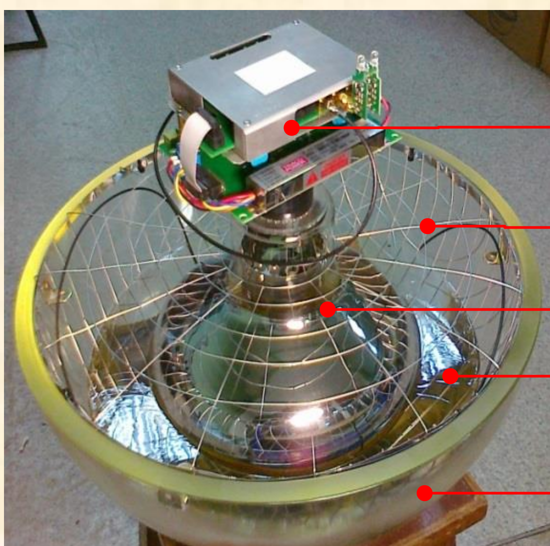


Quantum efficiency

R7081-100 Hamamatsu

D=10 inch. SBA photocathode QE ≈ 35% @ 400nm; Gain ~10^7, dark count ~8 kHz

Angular sensitivity



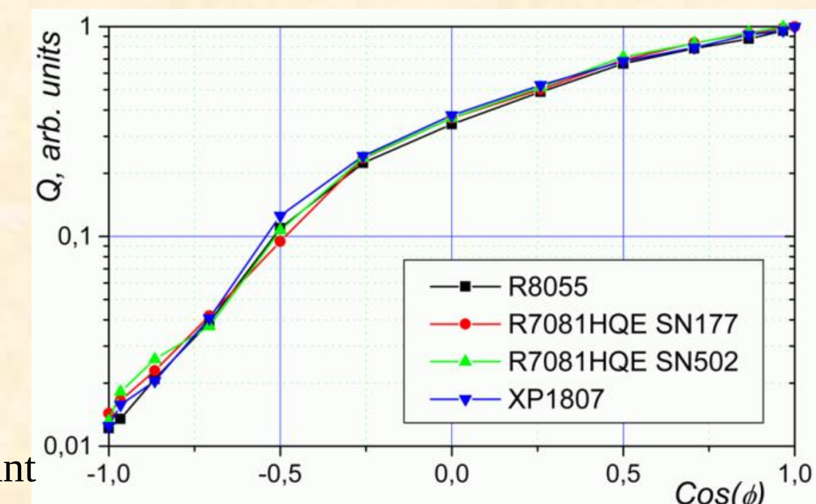
OM electronics

Mu-metal cage

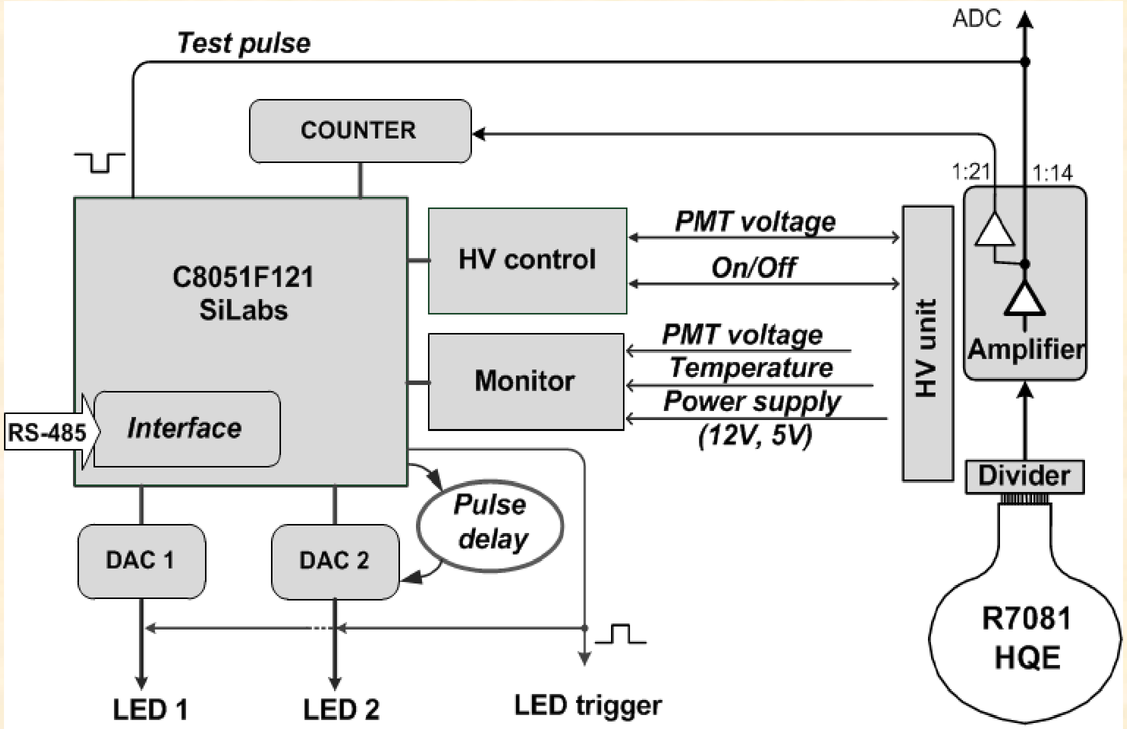
PMT

Optical gel

Glass pressure-resistant sphere VETROVEX (17")



Optical module electronics



HV converter: SHV 12-2.0 K 1000 P

0 …+ 2000 VDC, stability 0.05%

ripple and noise 8 mVpk-pk

Passive divider: 18 MΩ

2-channel amplifier: Output channel and PMT noise monitoring channel.

LED flasher: 2 LEDs L7113: 470 nm, ~6 ns

- Intensities regulation: 1…~10^8 photons

- Flashes delay regulation: 0 … 1000 ns

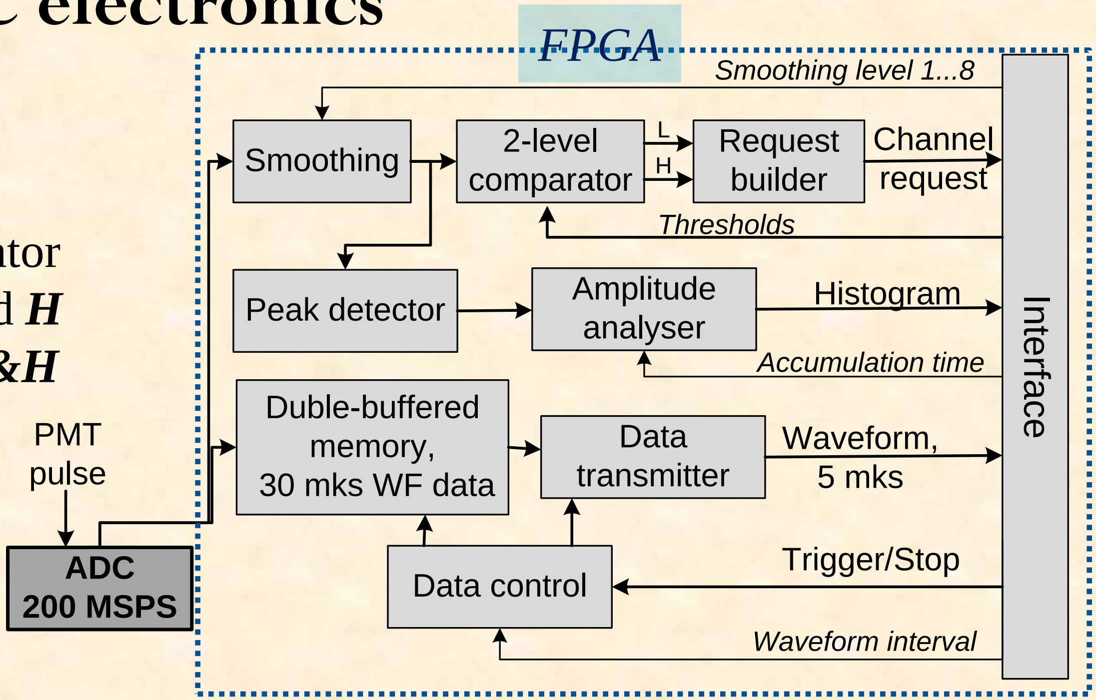
Slow control board: SiLabs C8051F121

Control of electronics operation and monitoring of PMT parameters via RS485 interface.

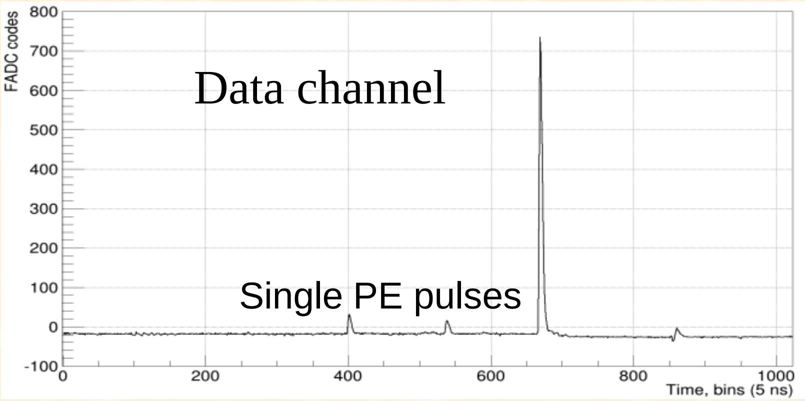
Power consumption – max 0.3A×12V

ADC electronics

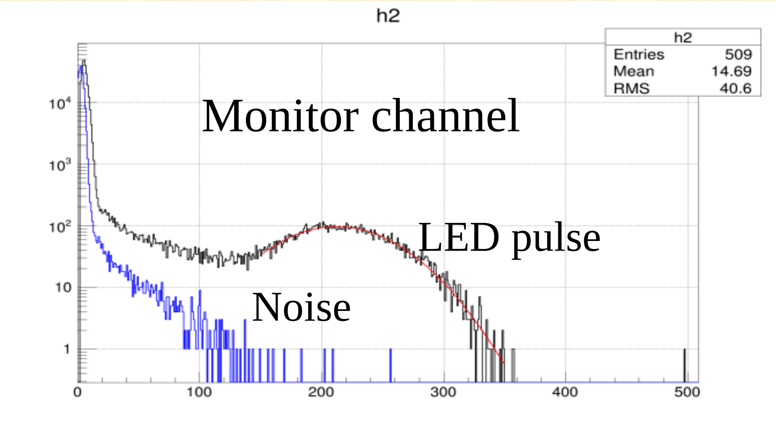
FADC (AD9430) 12bit, 200 MSPS
FPGA (Xilinx Spartan 6)
-Trigger channel: 2-level digital comparator forms low threshold ***L*** and high threshold ***H*** channel requests (GVD basic trigger: ***L&H*** coincidence of neighboring channels).
- Data channel (triggered) consists of double-buffered memory and data transmitter.
- Monitor channel (non-triggered) includes peak detector and amplitude analyzer.



Functional scheme of one FADC channel

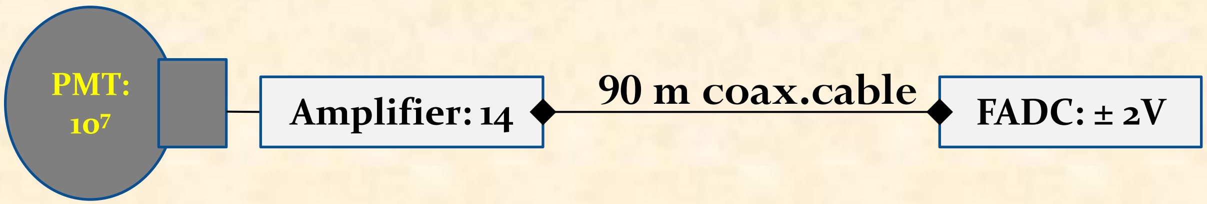


Waveform stamp example (5 mks)

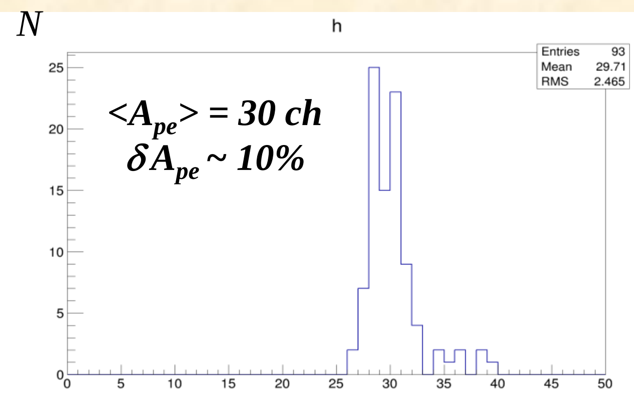


Monitor histogram examples

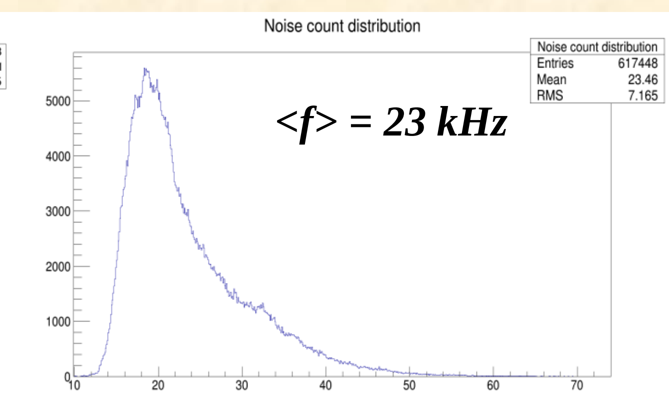
Measuring channel



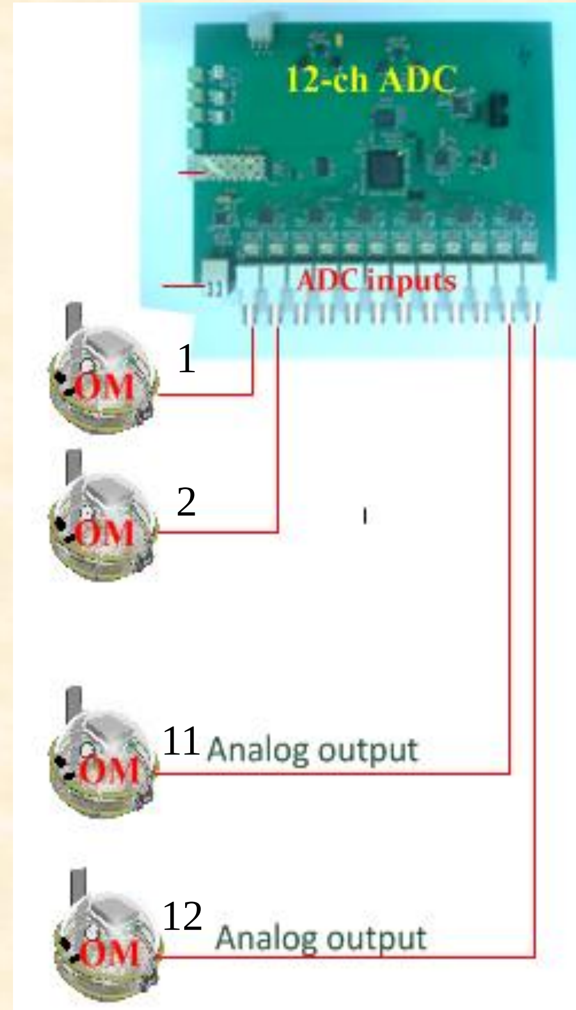
- PMT: nominal gain: 1×10^7; Amplifier: $k_{amp}=14$; Cable: ~0.7: **10^8 in total**
- Pulse width after cable: ~20 ns FWHM.
- FADC: 4V. 12 bit, 5 ns time bin.
- Linearity range: $1 - 10^2$ p.e.;
- Count rate (0.3 PE) ~ 25 kHz in average.
- Threshold (min): $\sim 0.20\times A_{pe}$



Distribution of the channels on A_{pe} (2014), ADC chan.



Count rate distribution for all channels (2014), kHz.



GVD Section: 12 channels

GVD Section

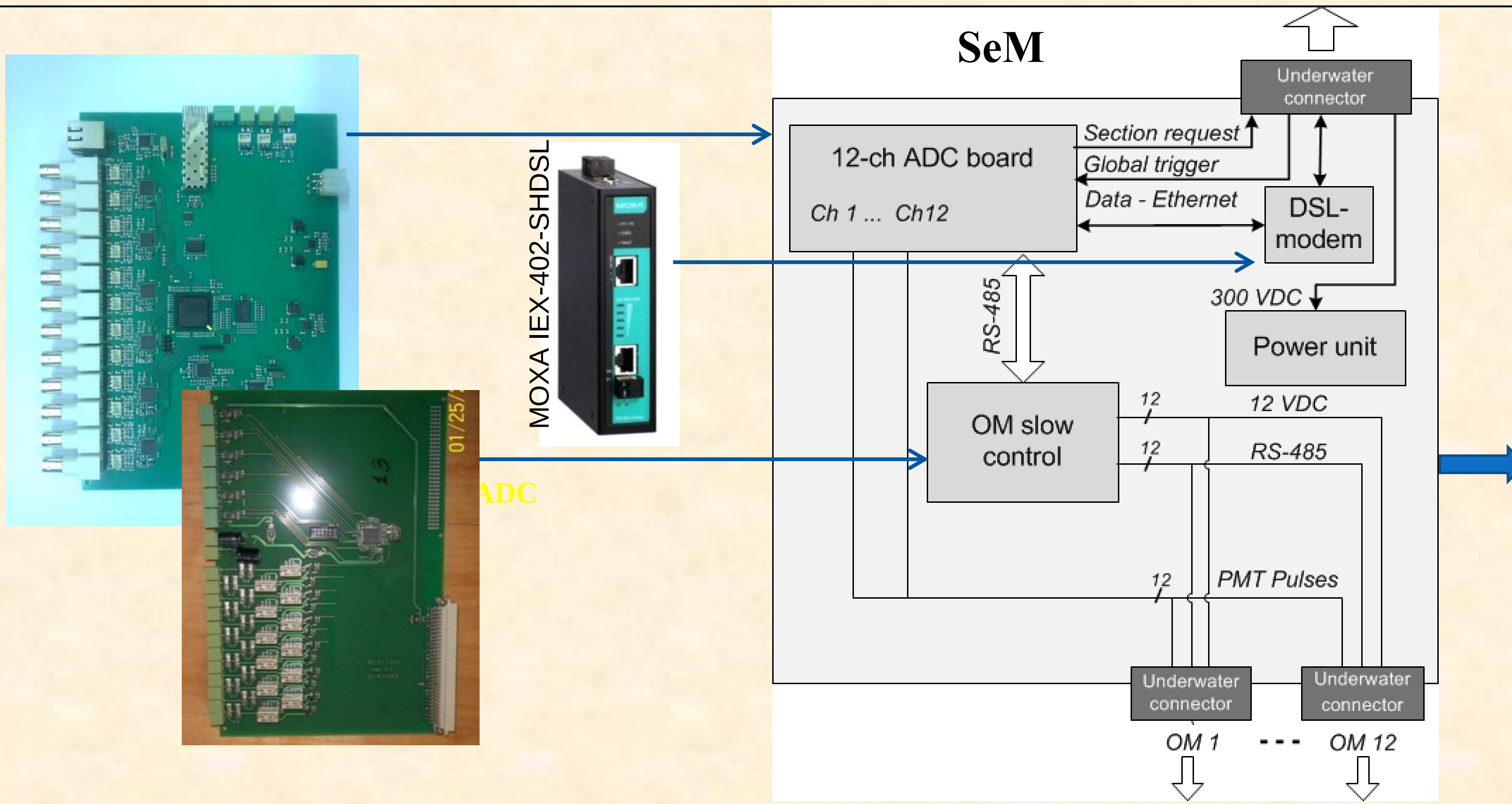
Section (basic DAQ cell) – 12 OM and Section electronics module (SeM).

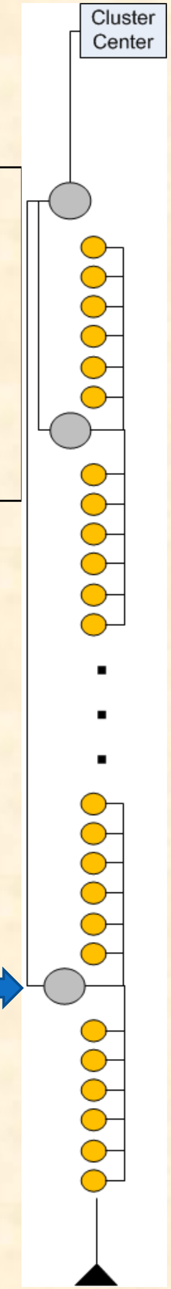
12-channel ADC unit: PMTs analog pulse conversion, time synchronization, data processing, local trigger.

Data transmission: Two outputs of ADC board: optical output (for future detector extension) and 100 BASE-TX (present stage).

shDSL modem: Extending the Ethernet line up to 1 km.

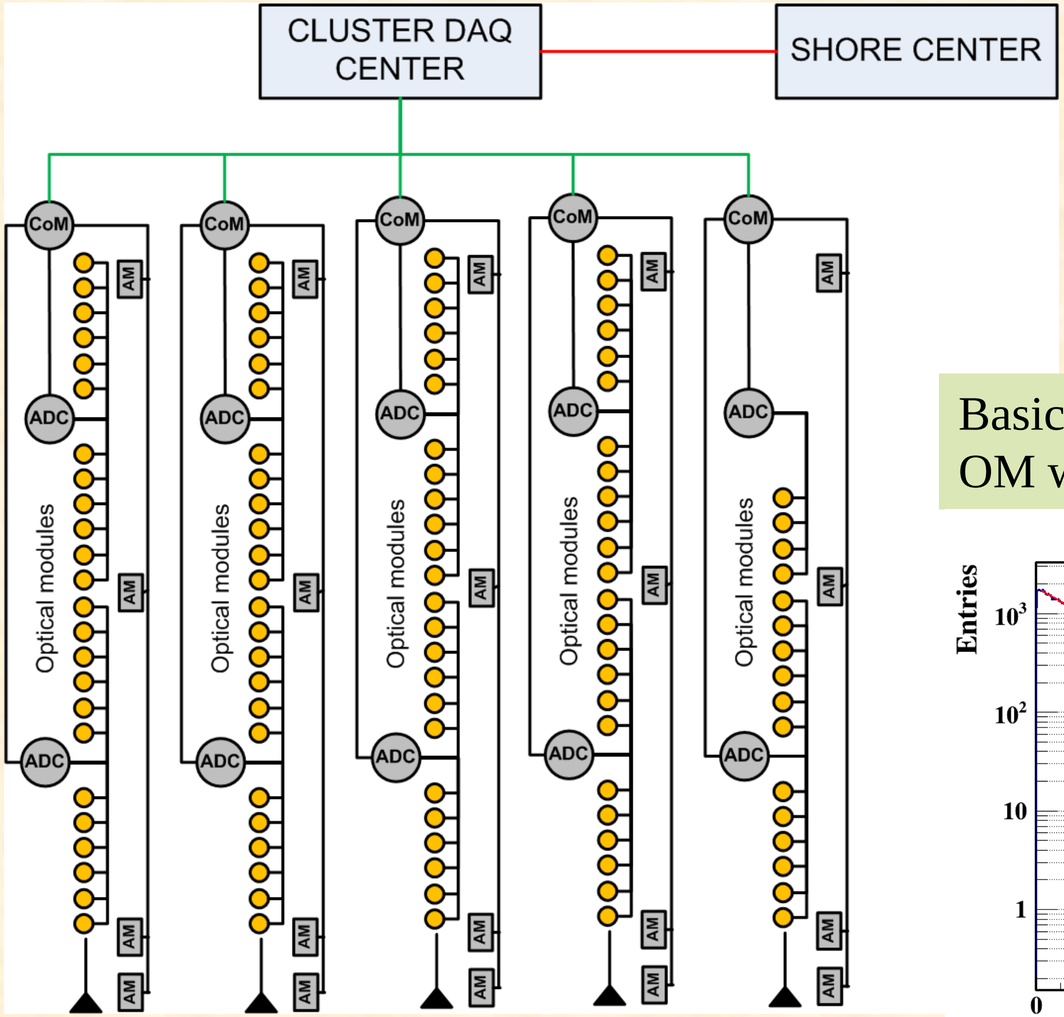
Slow control board: OM power on/off and control of OM operation (RS485).





Engineering array 2014

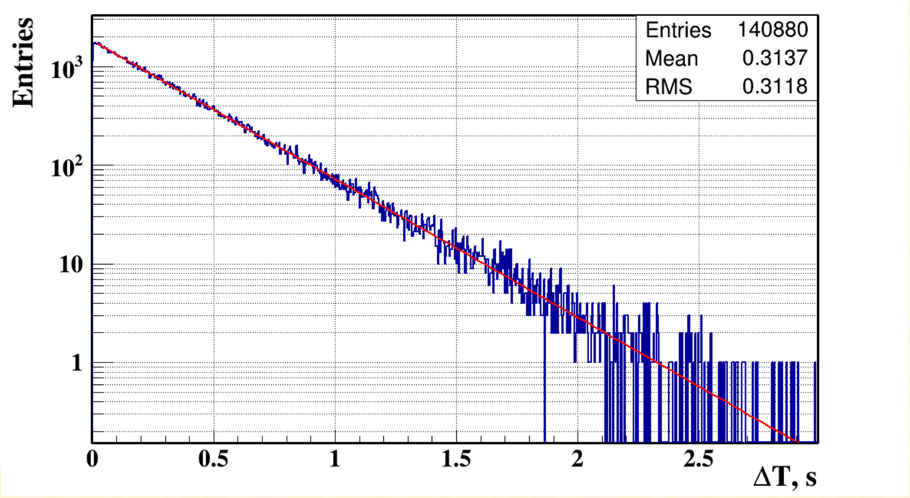
The current stage of Baikal-GVD Cluster comprising 5 strings (112 OM)



14 April – 25 September: 169 days

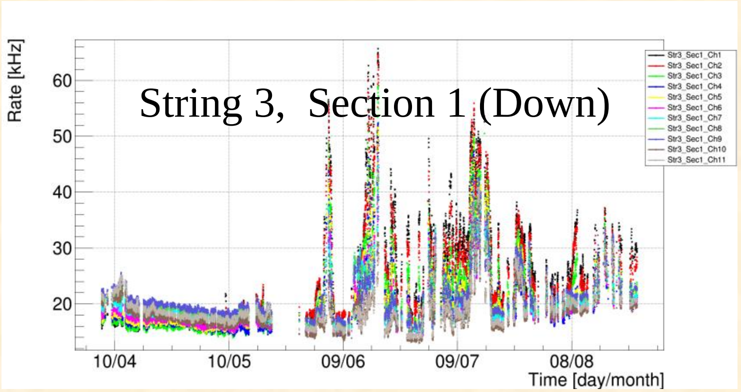
- **Data taking: 122 days**
- **Efficiency: 72.2%**
- **Total: 452 Runs**
- **Data : 1.26 10^8 events**

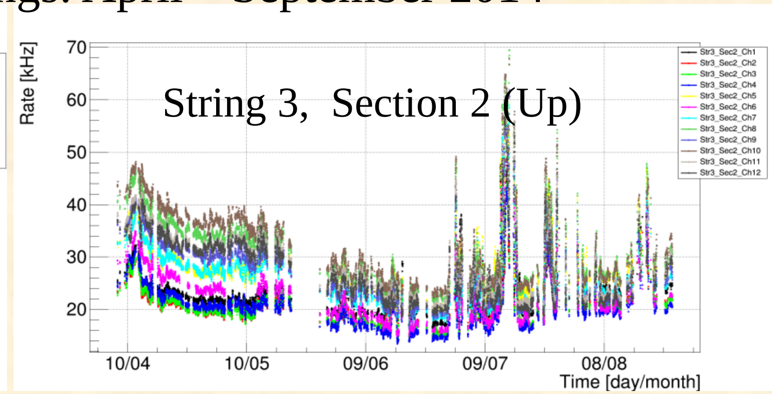
Basic trigger: coincidences of neighboring OM with low and high thresholds (1 & 3 p.e.)

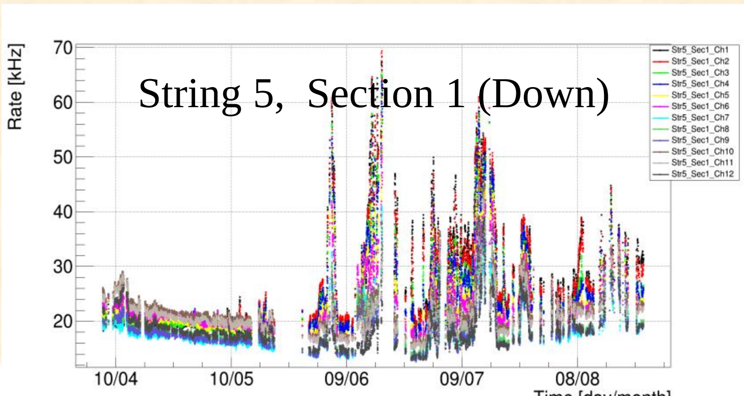


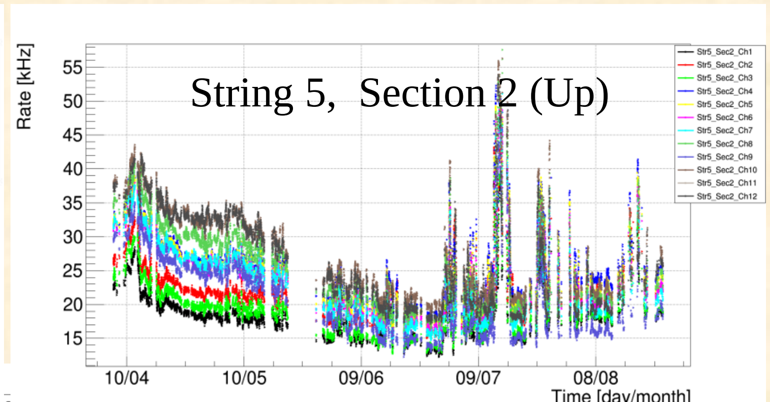
Background condition

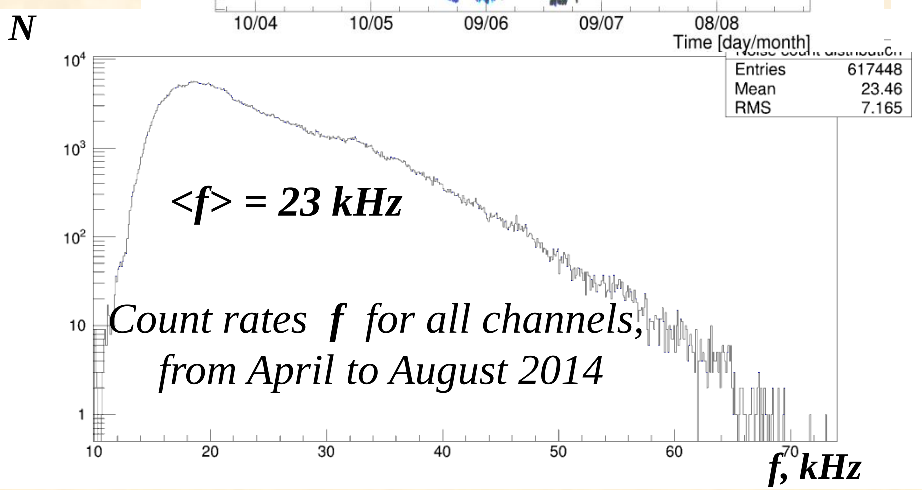
Channel count rate for two strings: April – September 2014









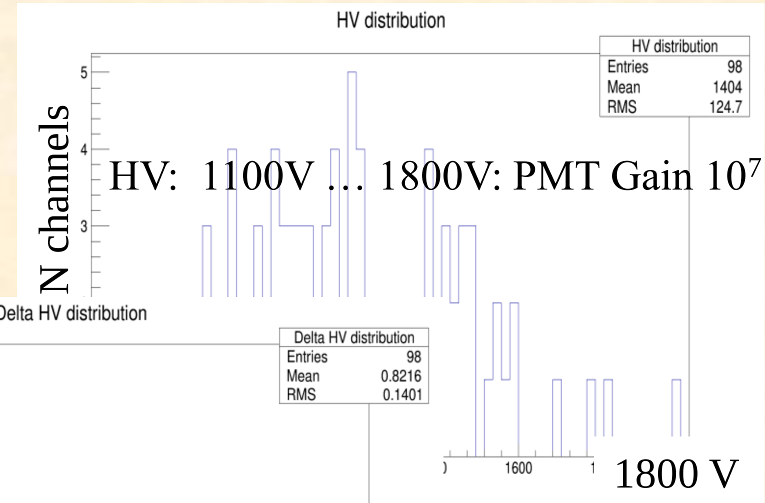


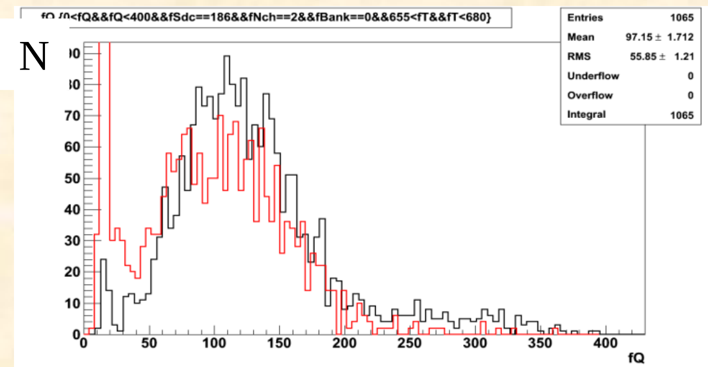
1. Significant count rate variations depending the season (chemiluminescence).
2. Strong correlation between peak of activity.
3. Average count rate ~20-25 kHz (0.3 p.e.)

Stability of the channels

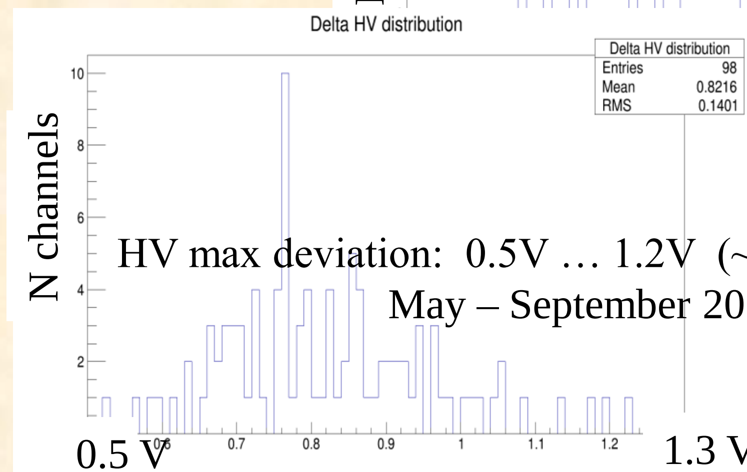
Selected parameters:

- PMT high voltage (*HV*)
- Channel gain (*G*)
- Noise rejection factor (η): count rate ratio for thresholds 2 p.e / 0.5 p.e.

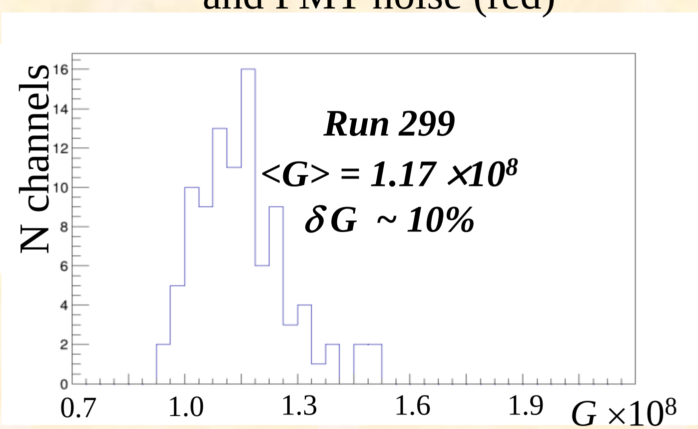




SPE spectrum measured with LED (black) and PMT noise (red)



Channel distribution on max. HV deviation



Channel distribution on the Gain

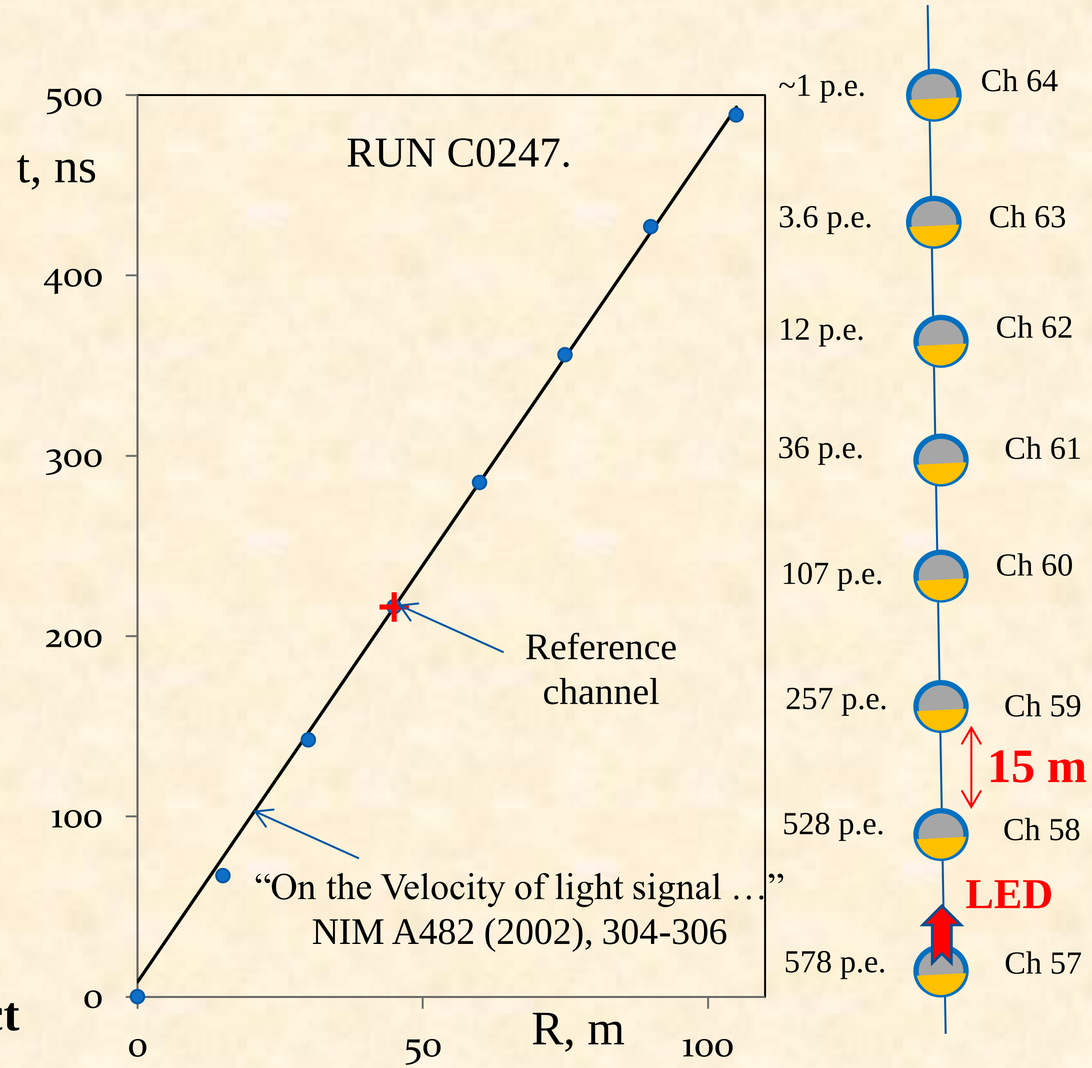
Data	12 May RUN 142	10 Jul RUN 299	21 Aug RUN 399
$< G>$	$1.12\ (0.02) \times 10^{8}$	$1.17(0.02) \times 10^{8}$	$1.14\ (0.02) \times 10^{8}$
$< \delta G >$, %	9.9	10.1	9.3
$< \eta >$	$3.36\ (0.12) \times 10^{-1}$	$3.39\ (0.18) \times 10^{-1}$	$3.25\ (0.15) \times 10^{-1}$

LED flashes detection

LEDs L7113: 470 nm, FWHM: 6 ns

Light propagation distance for maximum LED intensity ~100 m along the string in Baikal water.

- **Experimental time consistent with expectation for the *Q* up to $2{\times}10^2$ p.e. within ~3 ns accuracy.**
- **Possibilities of time walk effect direct estimation**



Atmospheric muon detection

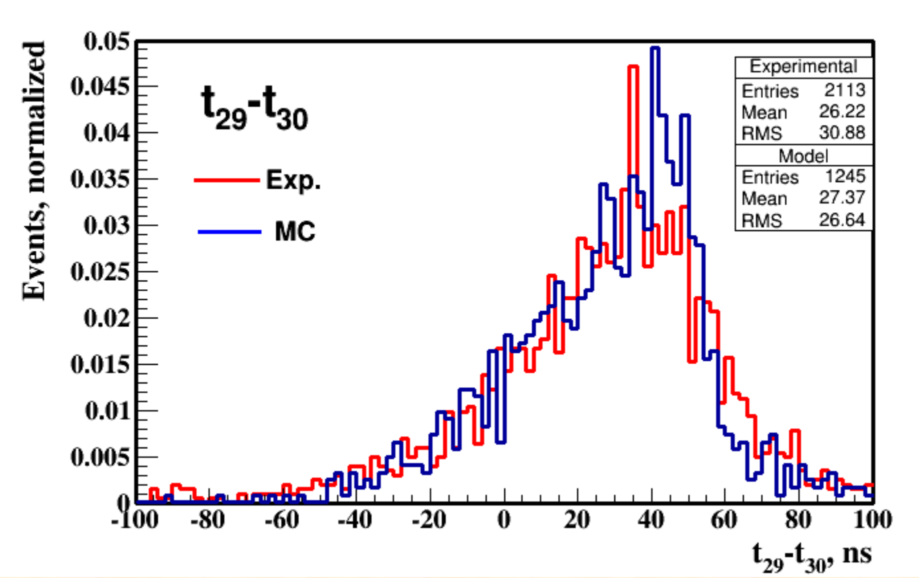
Trigger
Coincidence of neighboring OM

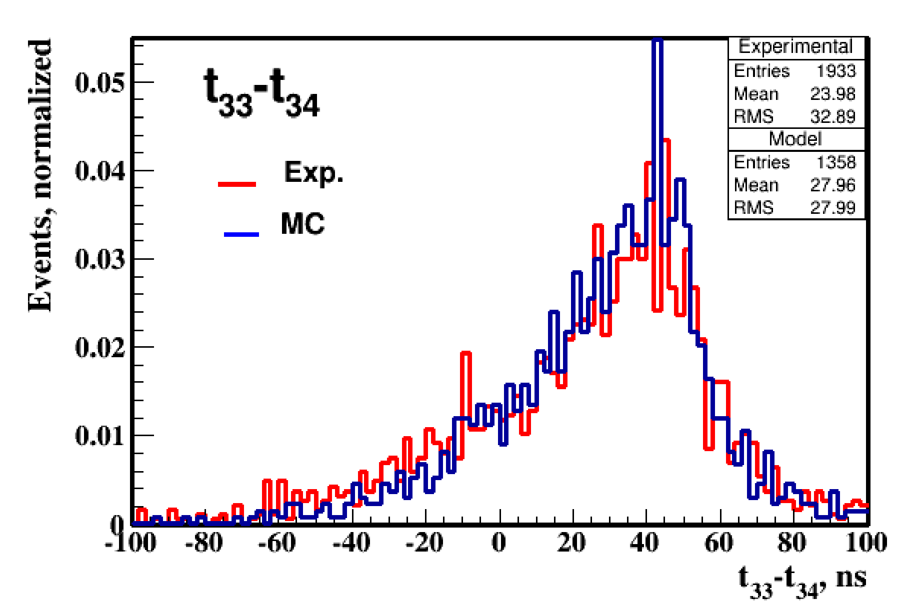
Statistics
14 Apr – 25 Sep: 1.17×10^8 events

Selection – Q > 2 p.e.

Time calibration: LED

Data consistent with expectation





dt distribution between neighboring channels

Summary

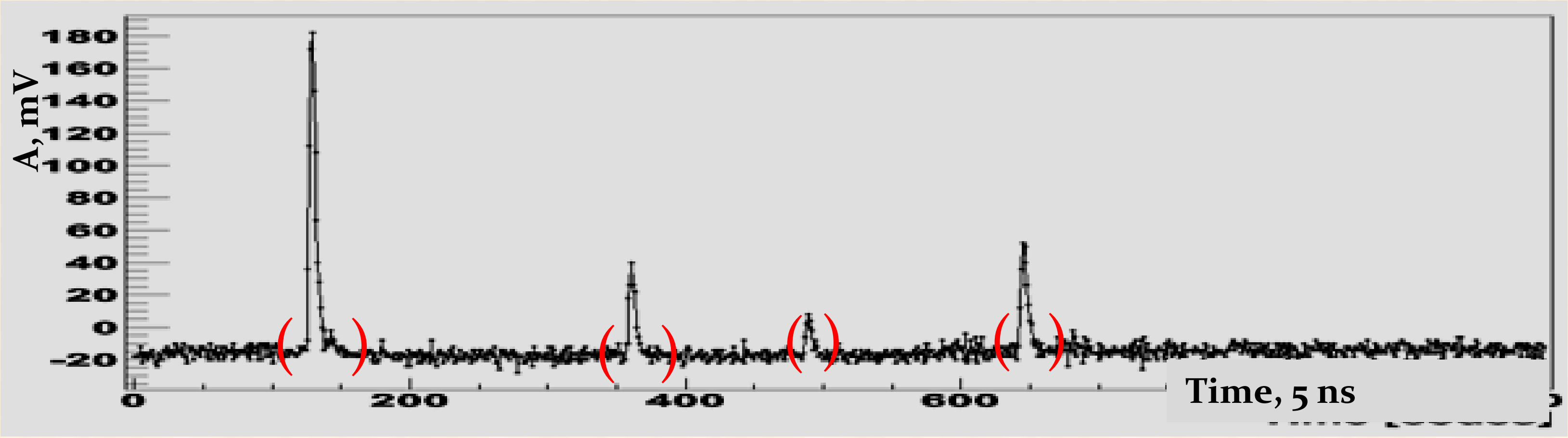
1. Results obtained on GVD engineering array demonstrate reliable, stable and correctness operation basic elements of the telescope.

2. Baikal -GVD technical design is basically finalized.

3. The nearest plans (April 2015): full scale GVD cluster in Baikal lake (8 strings).


THANK YOU

Backup slides



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

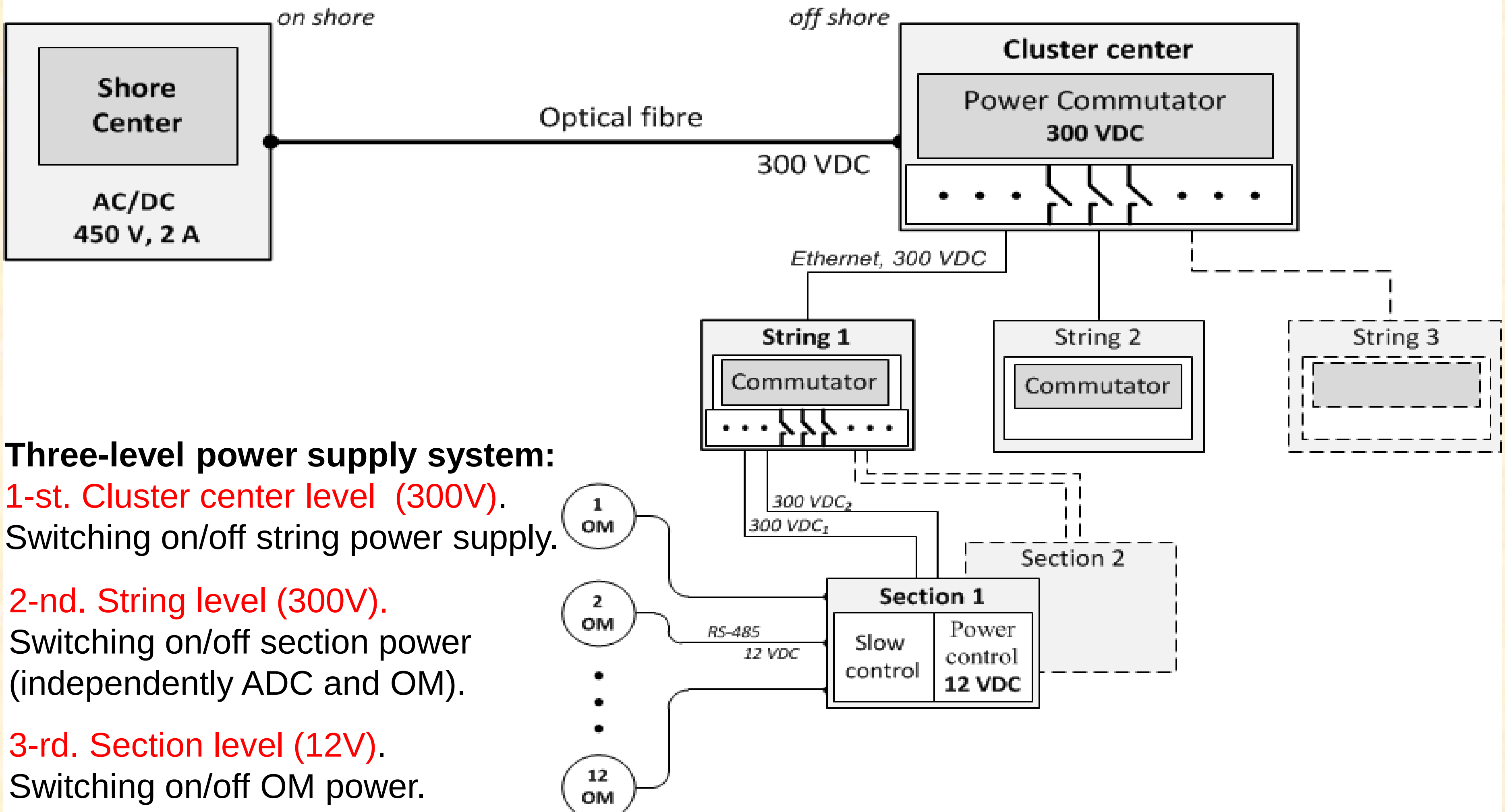
Trigger rate is limited by the data transmission rate from the strings to DAQ-center: 5-6 Mbit (Ethernet, shDSL modem, 1 km line length).

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

Power supply

300 VDC power supply system.

Power commutator 300 VDC (12 channels) was specially designed for Baikal at



Three-level power supply system:

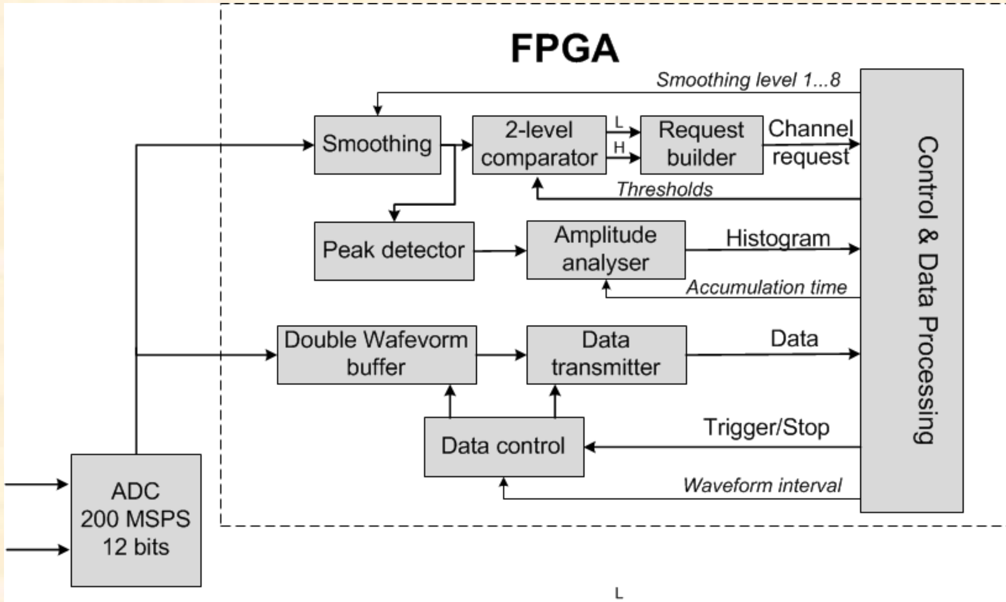
1-st. Cluster center level (300V).
Switching on/off string power supply.

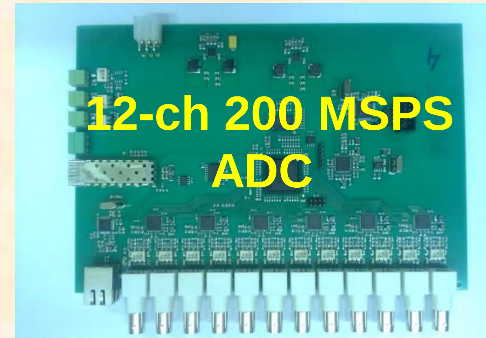
2-nd. String level (300V).
Switching on/off section power (independently ADC and OM).

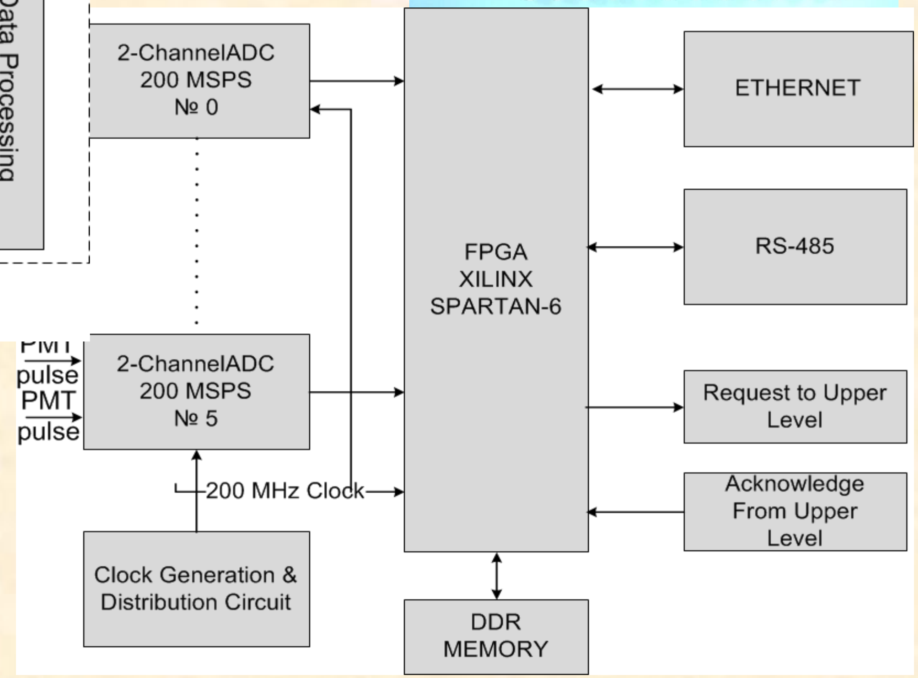
3-rd. Section level (12V).
Switching on/off OM power.

String power consumption: 0.45A×300V => Cluster (8 strings) ~1.2 KW

ADC board



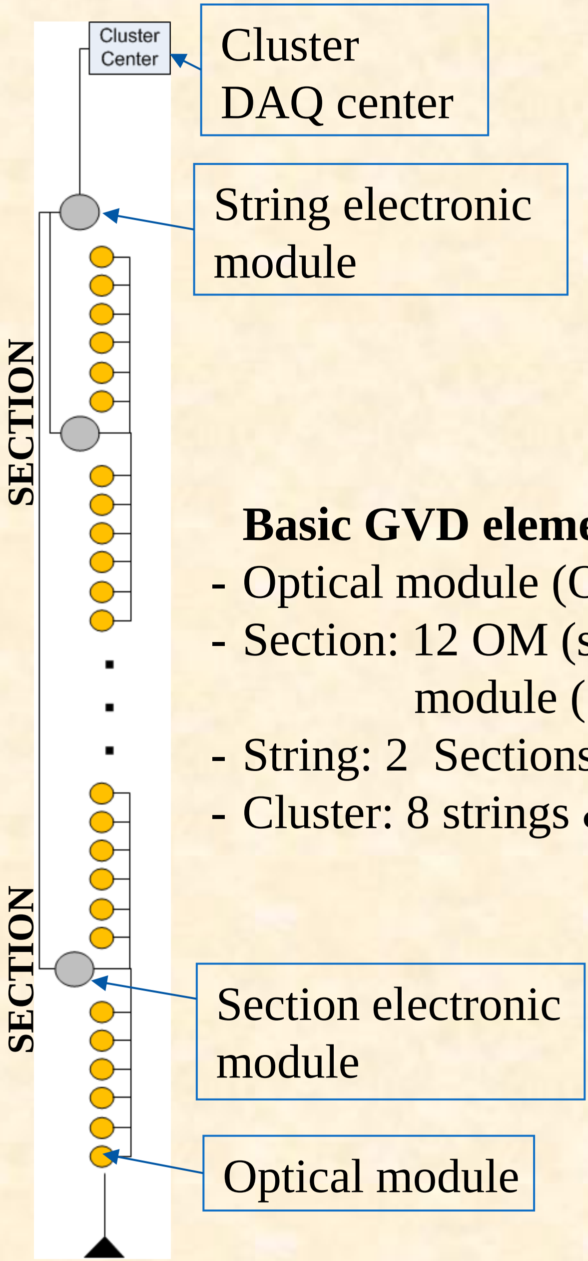




FADC (AD9430) 12bit, 200 MSPS
FPGA (Xilinx Spartan 6)
- Trigger logic: 2-level adjustable digital comparator forms low threshold ***L*** and high threshold ***H*** channel requests
- Data channel (triggered) consists of double-buffered memory and data transmitter.
- Monitor channel (non-triggered) includes peak detector and amplitude analyzer.

- Trigger logic(***L&H*** coincidence of neighboring channels
- Data readout from ADC buffer
- Control of OM mode of operation
- Connection via local Ethernet to the cluster DAQ center

GVD cluster architecture

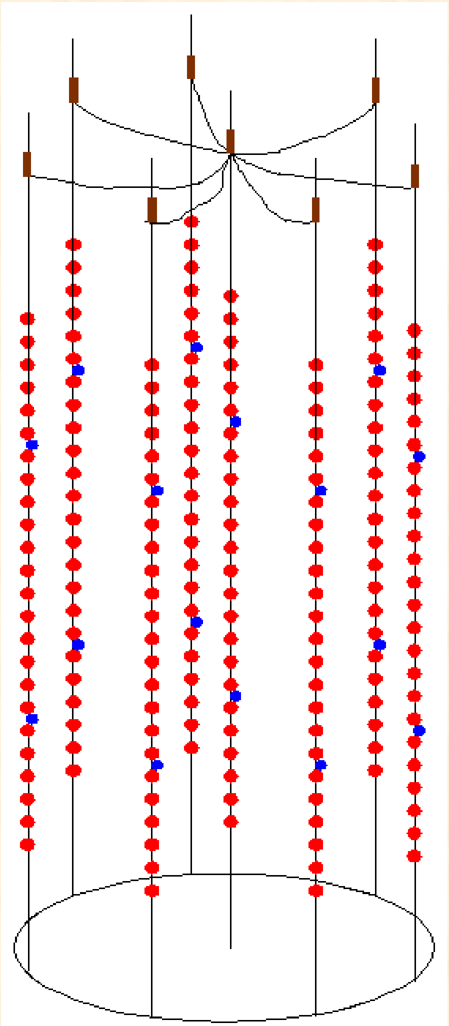


Basic principles of GVD design:

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

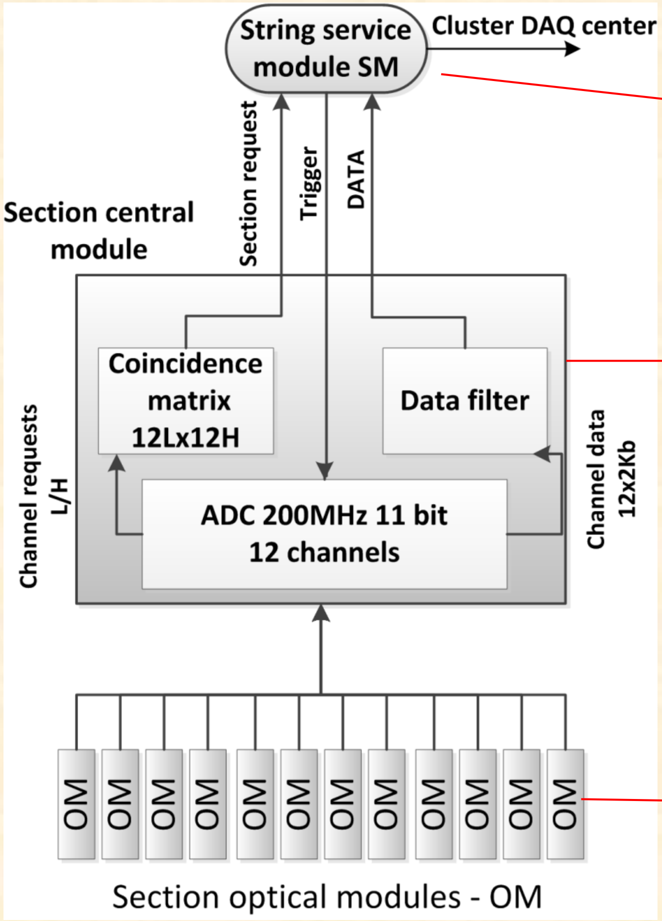
Basic GVD elements

- 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.

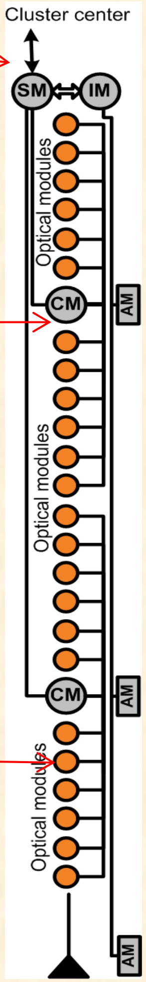


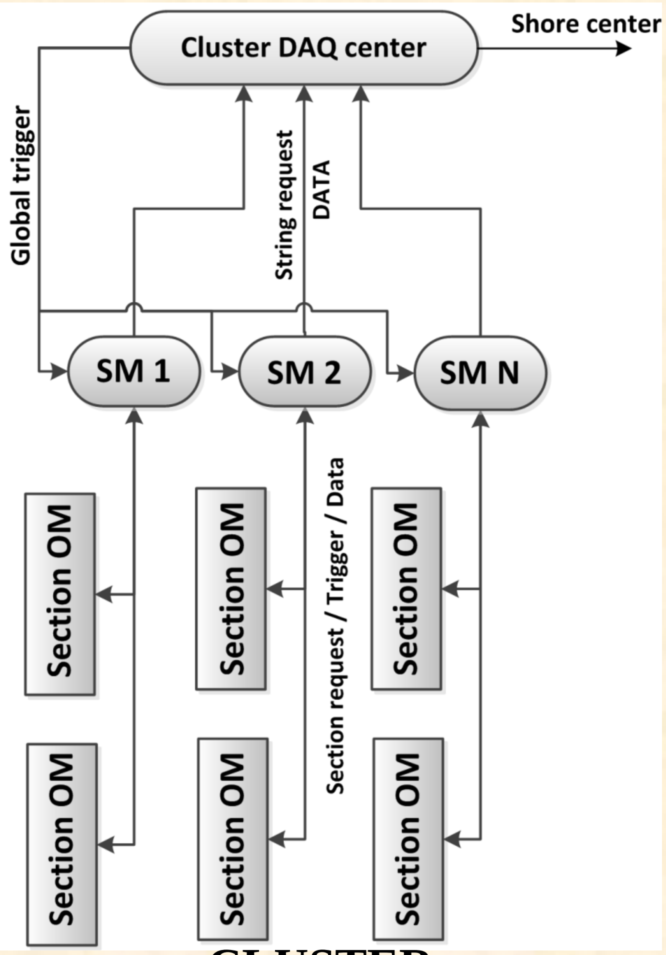
Cluster with 8 two-section strings (2015)

Triggering and Data Transmission



SECTION



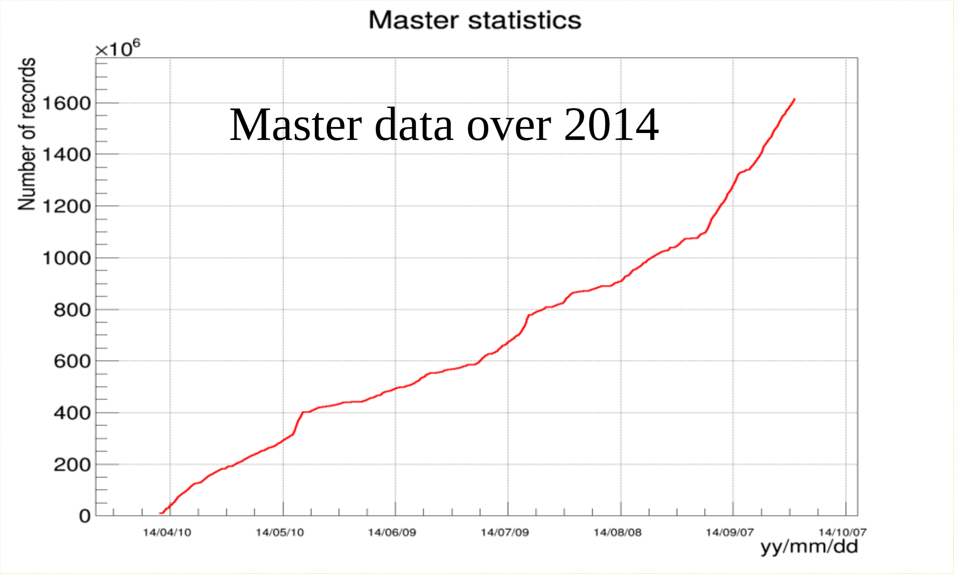


CLUSTER

Operational statistics

14 April – 25 September: 169 days

- **Data taking: 122 days**
- **Efficiency: 72.2%**
- **Total: 452 Runs**
- **Data : 1.26 10^8 events**
- **Monitoring: 803 799 records**



Time between events