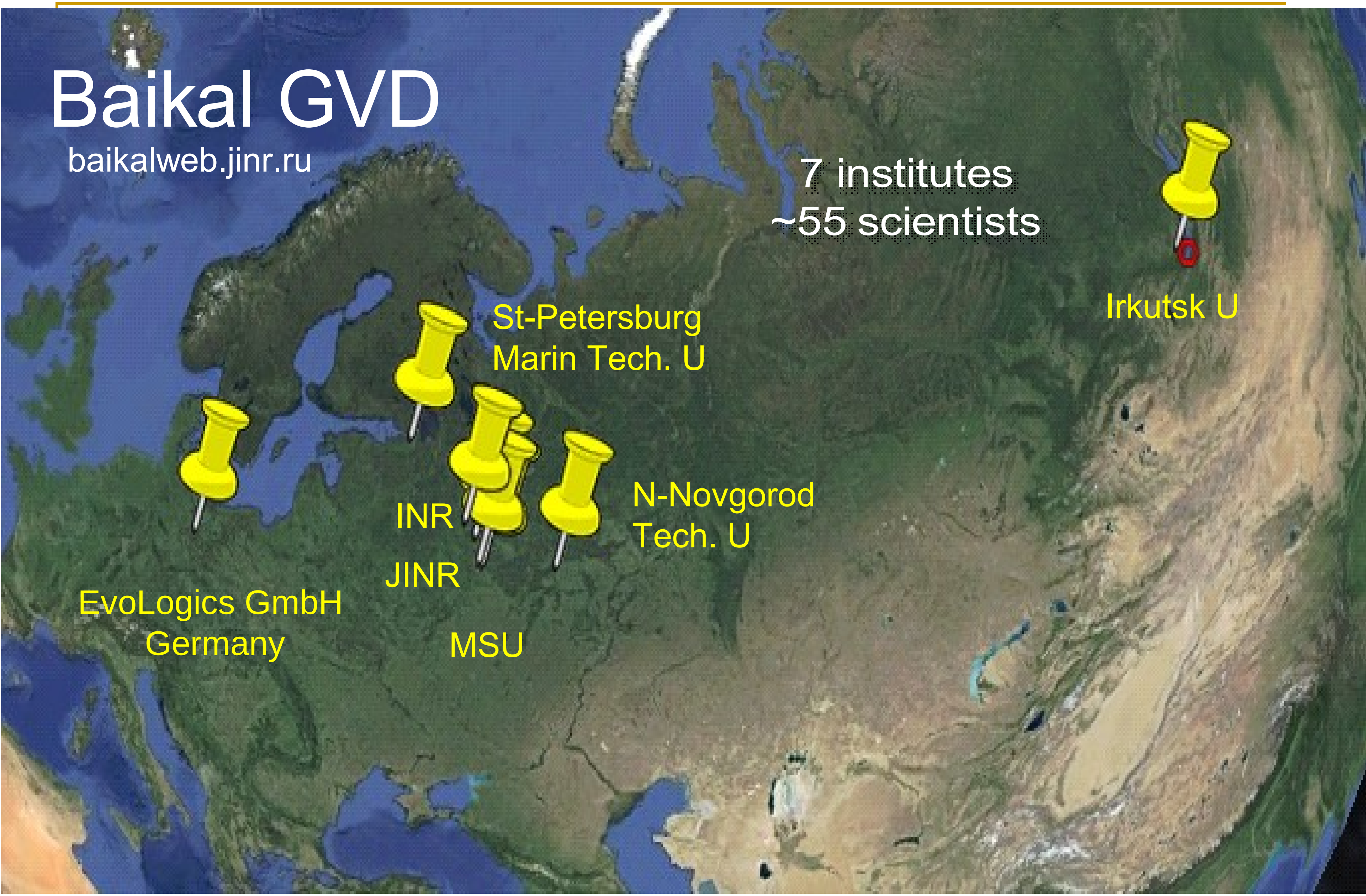
EUROPEAN PHYSICAL SOCIETY HEP2015

Baikal-GVD: first cluster Dubna

Olga Suvorova (INR, RAS)

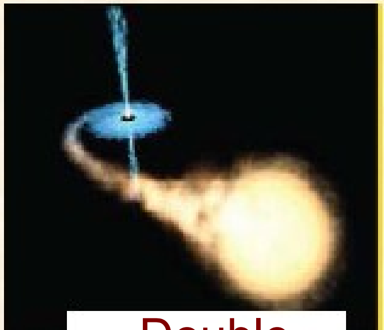
on behalf of the Baikal collaboration

EPS, High Energy and Particle Physics, 22-29 July 2015, Vienna, Austria


Baikal GVD
baikalweb.jinr.ru
7 institutes
~55 scientists
Irkutsk U
St-Petersburg
Marin Tech. U
INR
JINR
MSU
N-Novgorod
Tech. U
EvoLogics GmbH
Germany

Astrophysical targets: visible objects in GeV-TeV gamma-rays and dark matter clumps

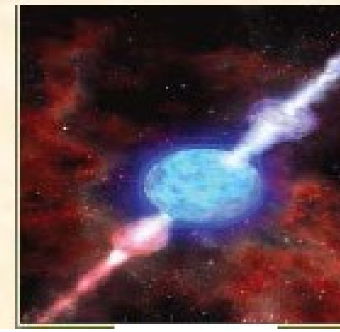
SNRs



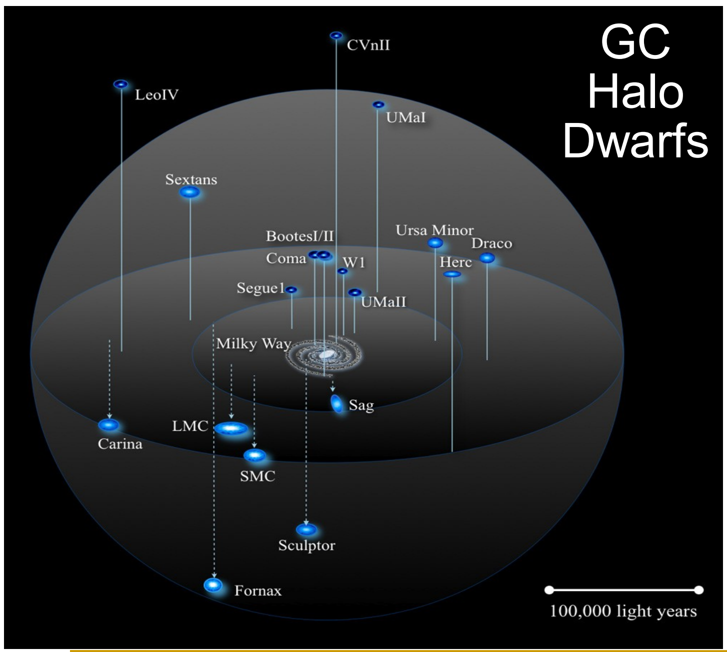
Double systems

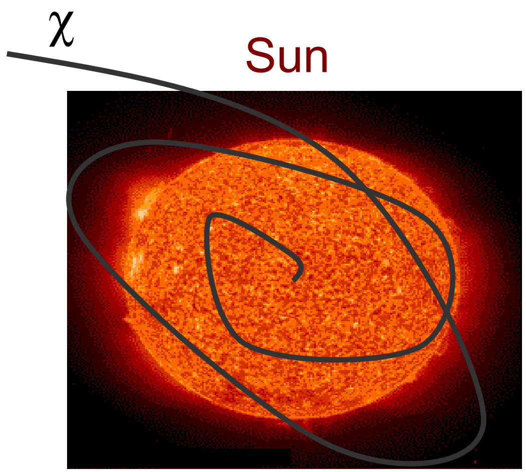
Pulsars

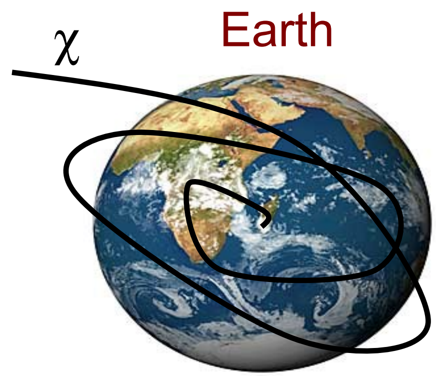
AGN



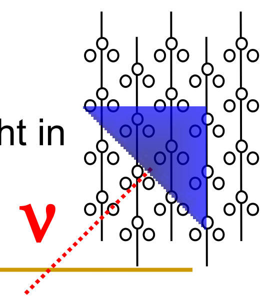
GRB



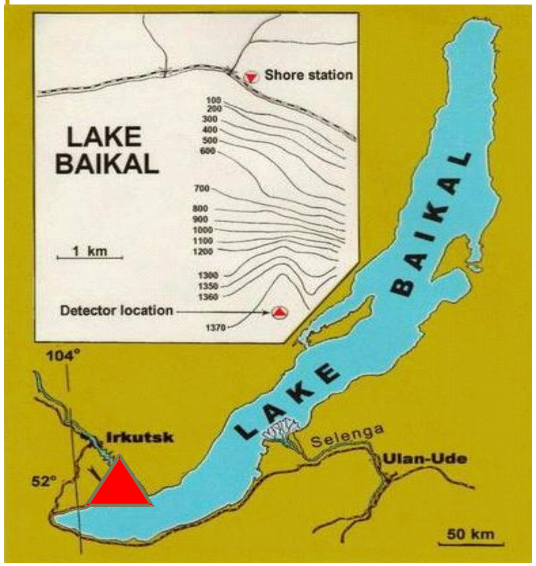




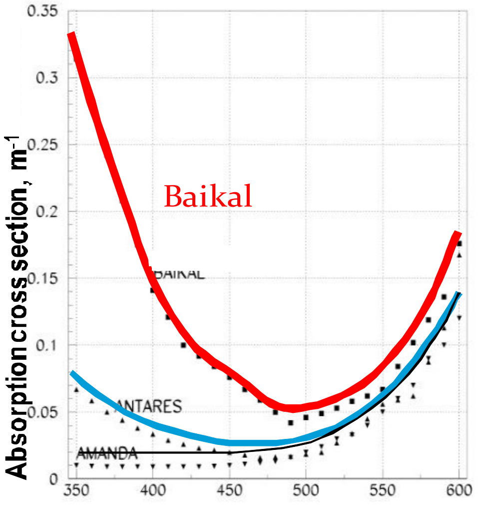
Observation of Cherenkov light in large natural volume of fresh water in Lake Baikal

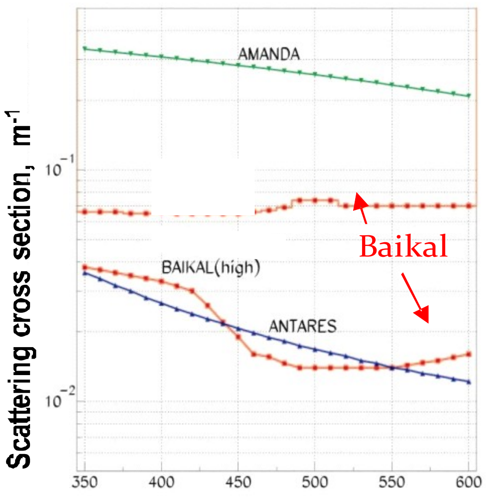


The Baikal site and water properties

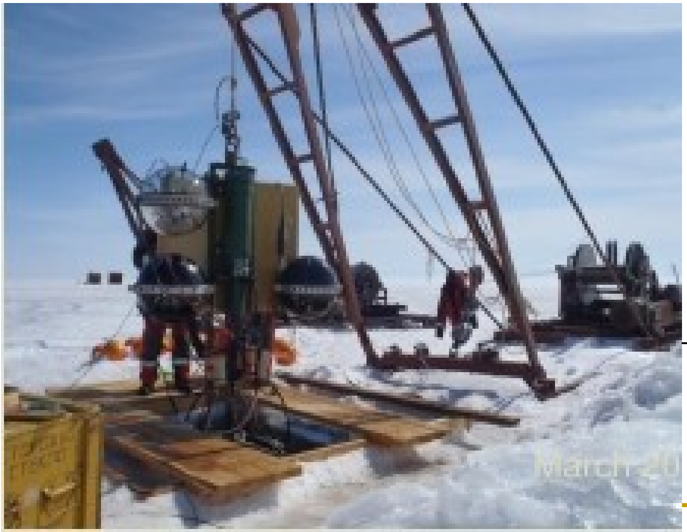


3.6 km to shore, 1370 m max depth



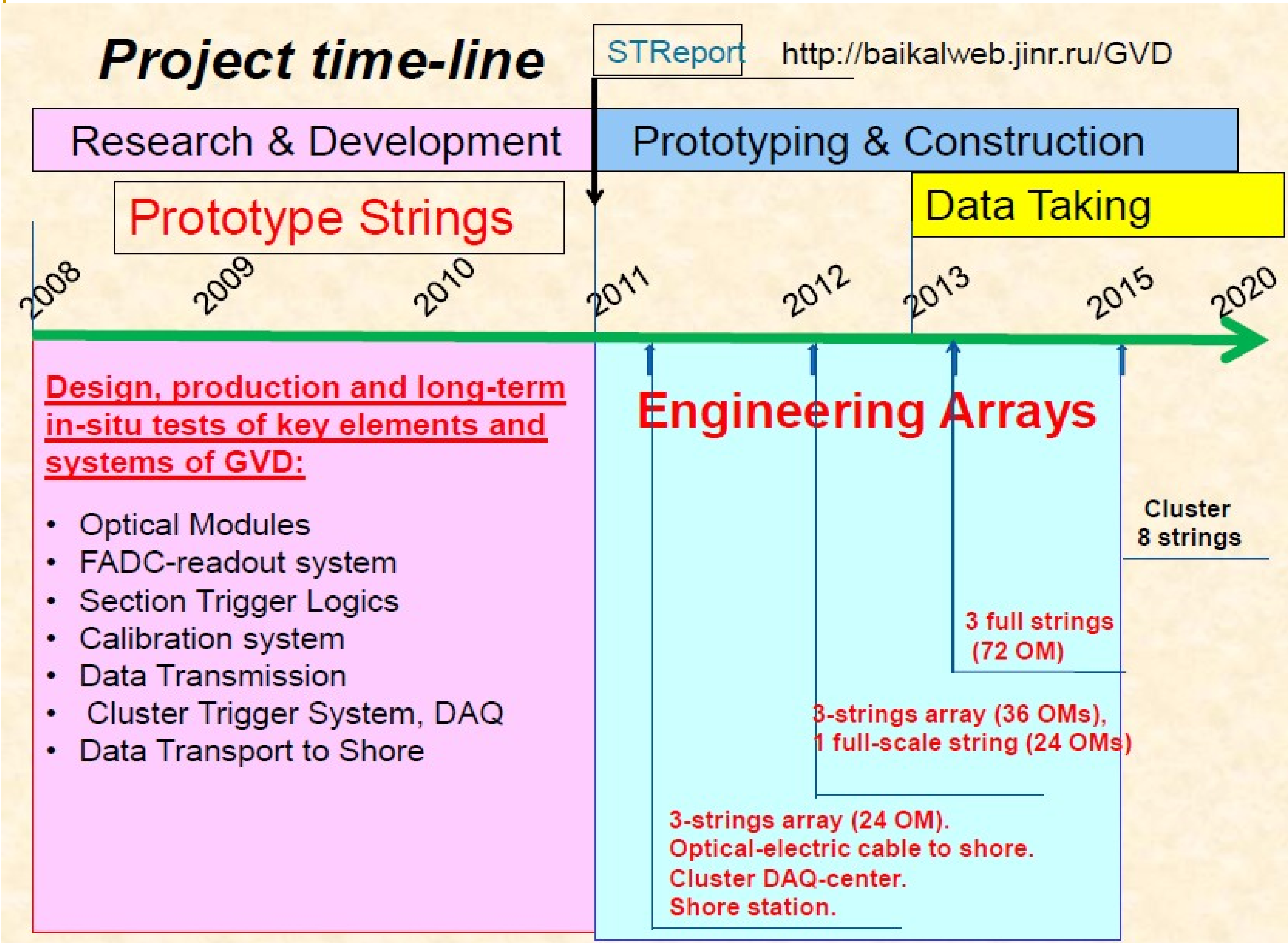


Absorption length – 22-24 m ; Scattering length: 30-50 m
(L_{eff} ~ 300-500 m)



- No high luminosity bursts from biology.
- No K^{40} background.
- Deployment simplicity: ice is a natural deployment platform

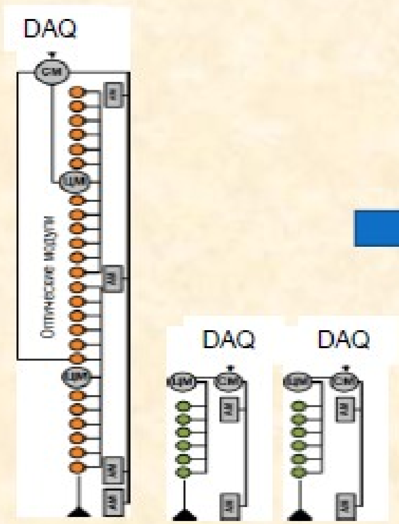
- **Telescope installation, maintenance, upgrade and rearrangement**
- **Installation & test of a new equipment**
- **All connections are done on dry**
- **Fast shore cable installation (3-4 days)**


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.

Engineering arrays (2012-2014)

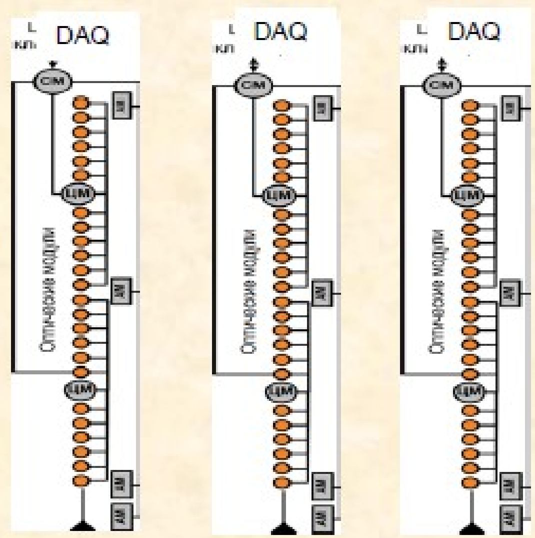
2012

3 strings, first full-scale GVD string (24 OMs)
Data taking from
April 2012 – Feb. 2013.



2013

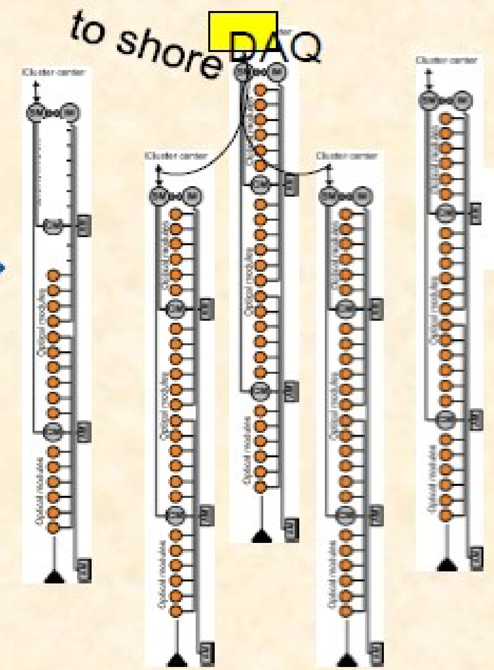
3 full-scale strings (72 OMs),
update of section electronics
Data taking
April 2013 – Feb.2014



~10^6 м^3 instrumented volume

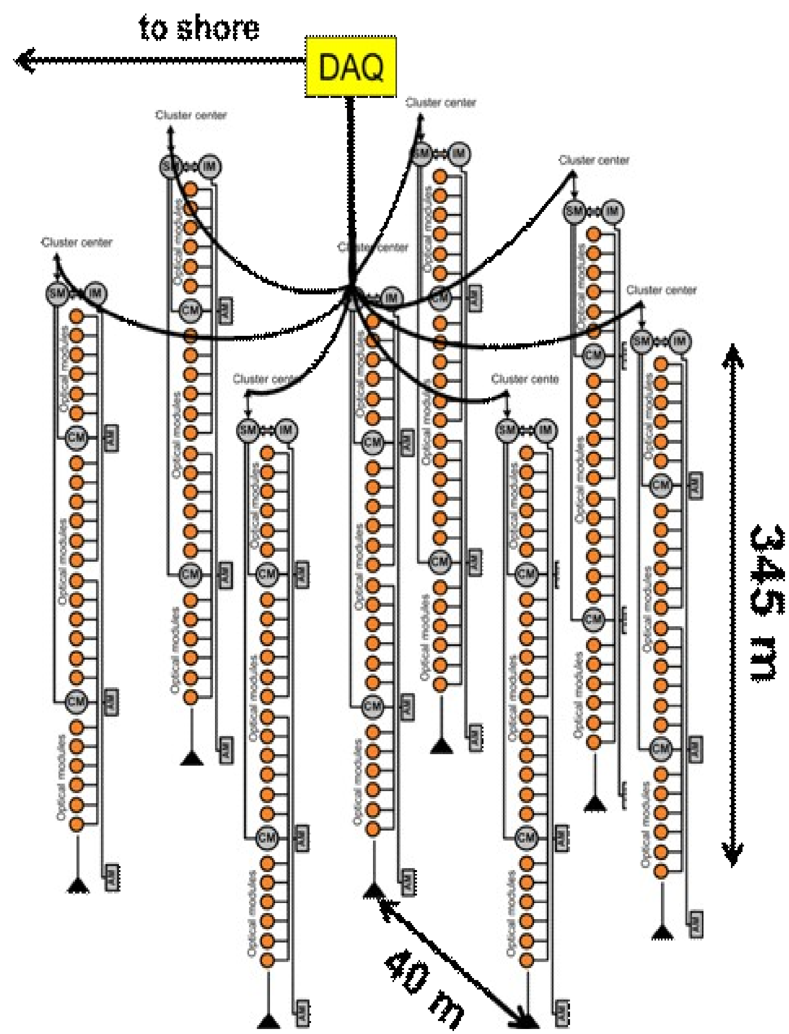
2014

5 strings (112 OMs)
Data taking since
April 2014 - now



~2×10^6 м^3

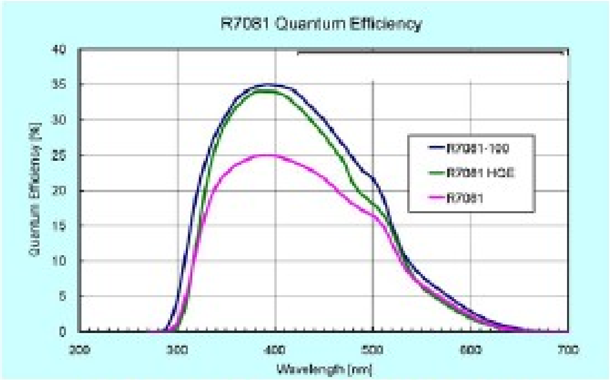
April 2015: first cluster of the GVD



- 192 OMs located at 8 strings;
  - 2 sections per string
  - 12 OMs per section
  - each OM spaced by15 m
- DAQ-center
- Optical cable to shore
- Acoustic positioning system;
- Active depth 950 — 1300 m

the peripherical strings have been located at a reduced radius of 40 m around a central one (compared to 60 m for the baseline configuration)

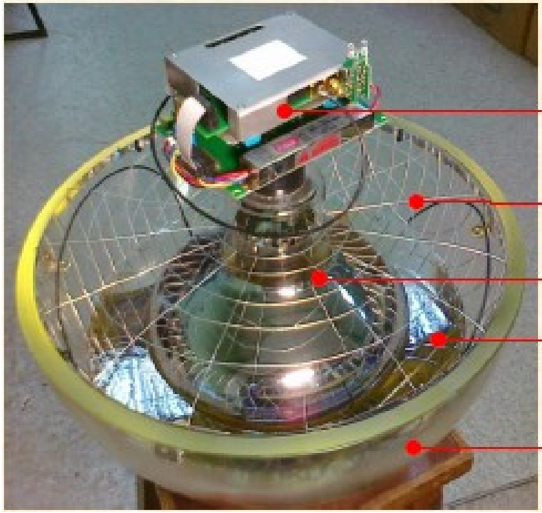
Optical module design



Quantum efficiency

R7081-100 Hamamatsu

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



OM electronics

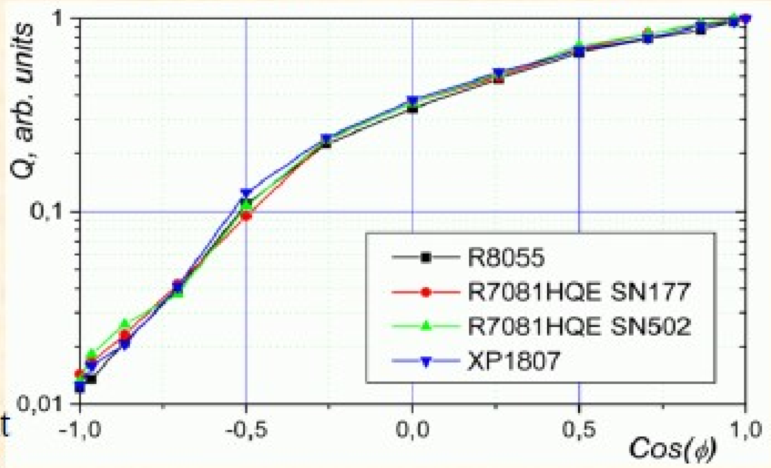
Mu-metal cage

PMT

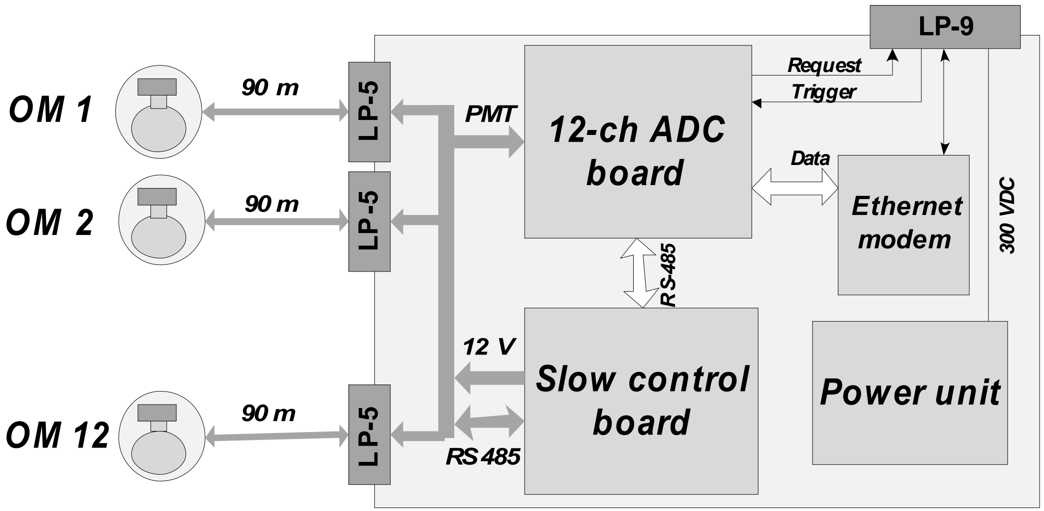
Optical gel

Glass pressure-resistant sphere VETROVEX (17")

Angular sensitivity



Section: 12 OMs and CEM

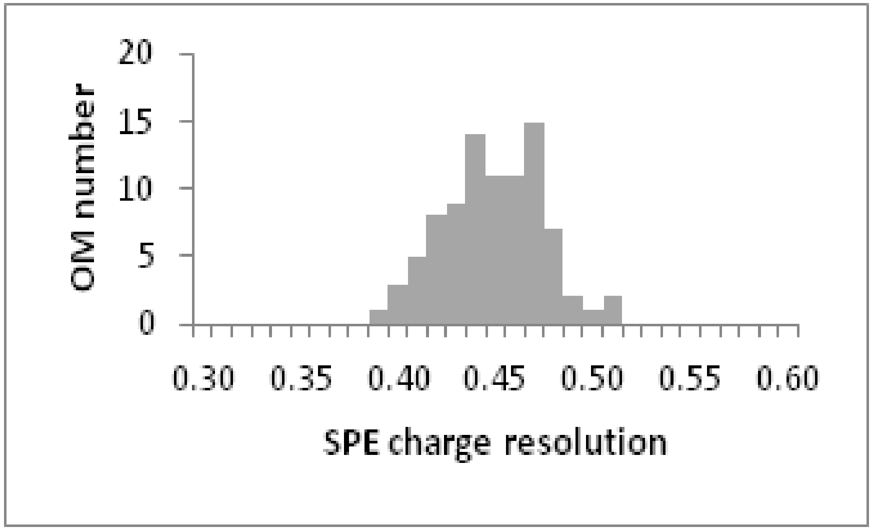


12-channel ADC unit:	PMTs analog pulse conversion, time synchronization, data processing, local trigger.
Data transmission:	Two outputs of ADC board: optical output (for future detector extension) and 100 BASE-TX (present stage).
shDSL modem:	Extending the Ethernet line up to 1 km.
Slow control board:	OM power on/off and control of OM operation (RS485).

Optical module: functions and calibrations

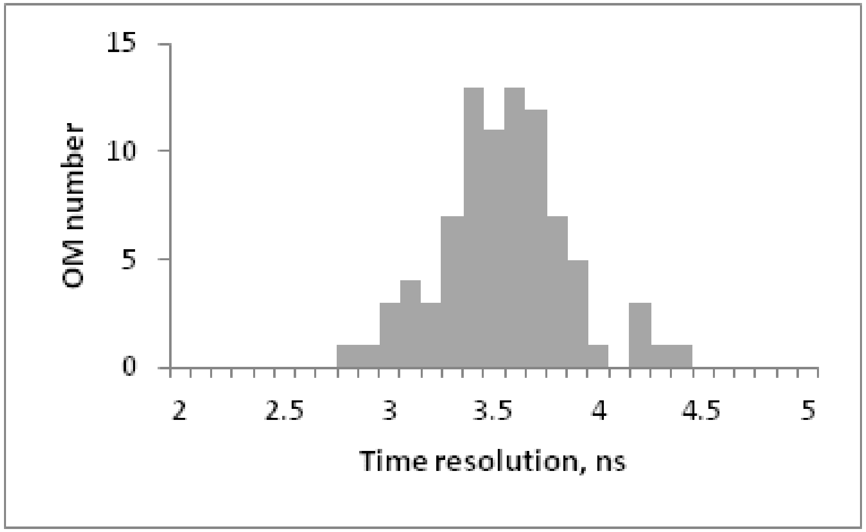
Basic functions for section operation

- Detection of the particle radiation
- Shaping of the output analog pulse for signal transmission to the ADC board
- Control of the PMT operation modes
- Calibration and monitoring of the parameters of OM electronic components.

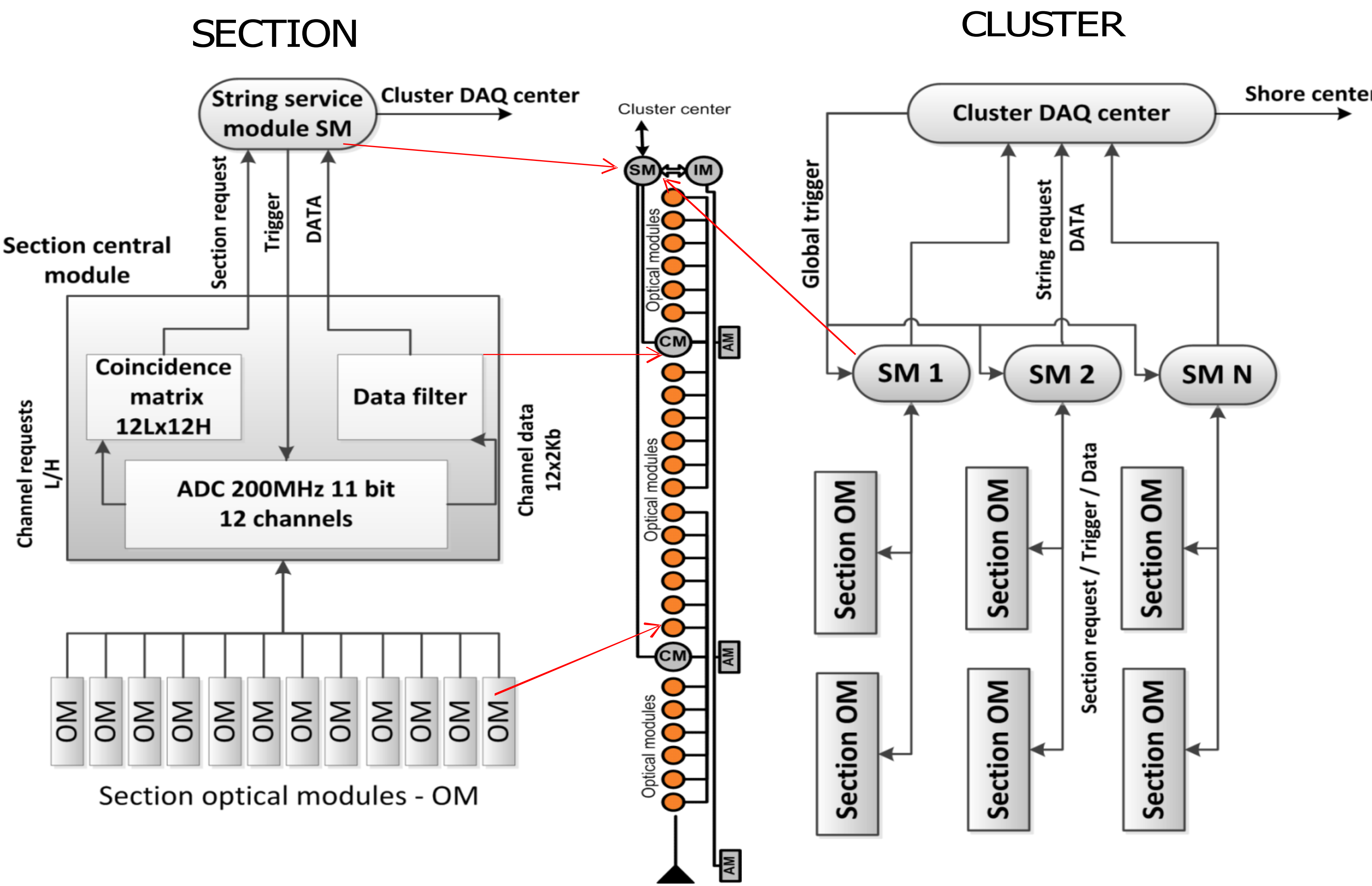


Fully automatized test procedures

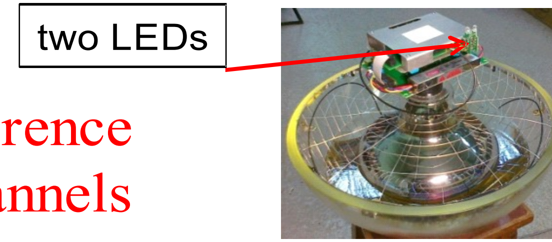
- Electronic components, stress tst, modes var.
- Adjustment of the PMT power supply volt.
- Performance with oscilloscope LeCroy
- SPE spectrum, threshold 0.2SPE
- Nonlinearity of measuring channels (LED pulses, linearity range ~100p.e.)



Triggering and Data Transmission

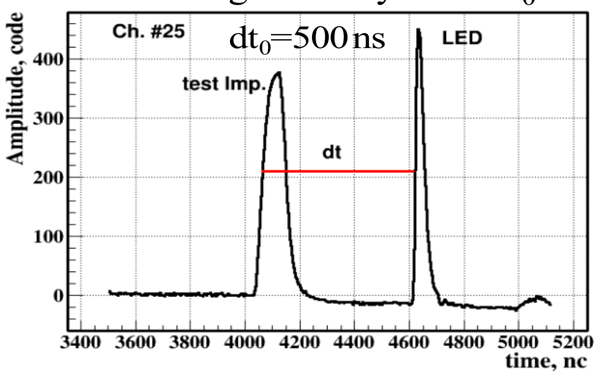


Time calibration – two methods

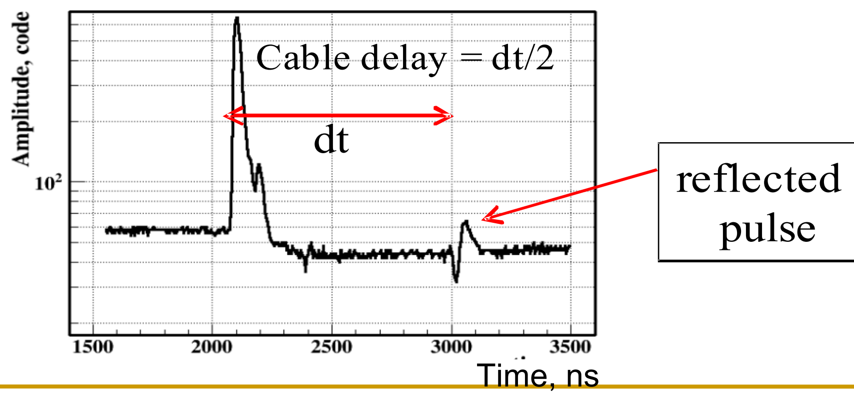


Measurement of signal delay of each channel

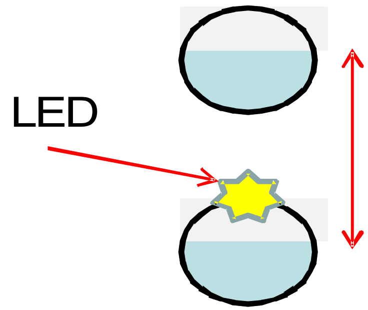
PMT signal delay = dt-dt$_0$



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

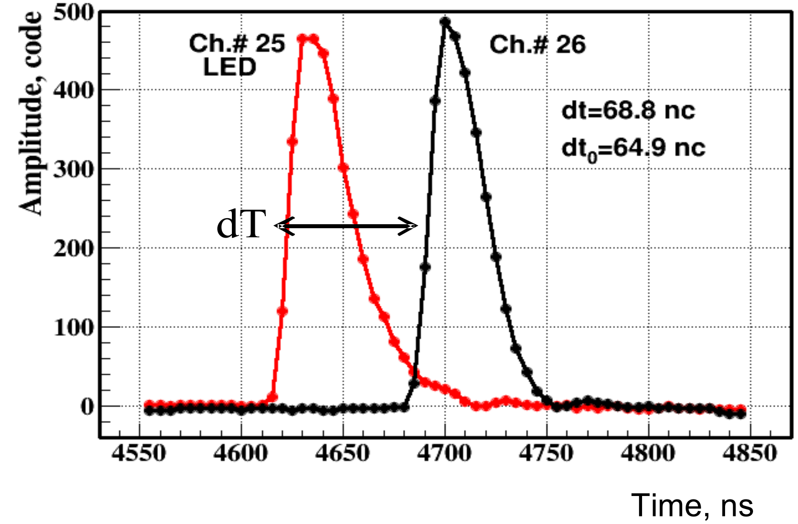


Time difference of two channels



15 m- distance between OMs

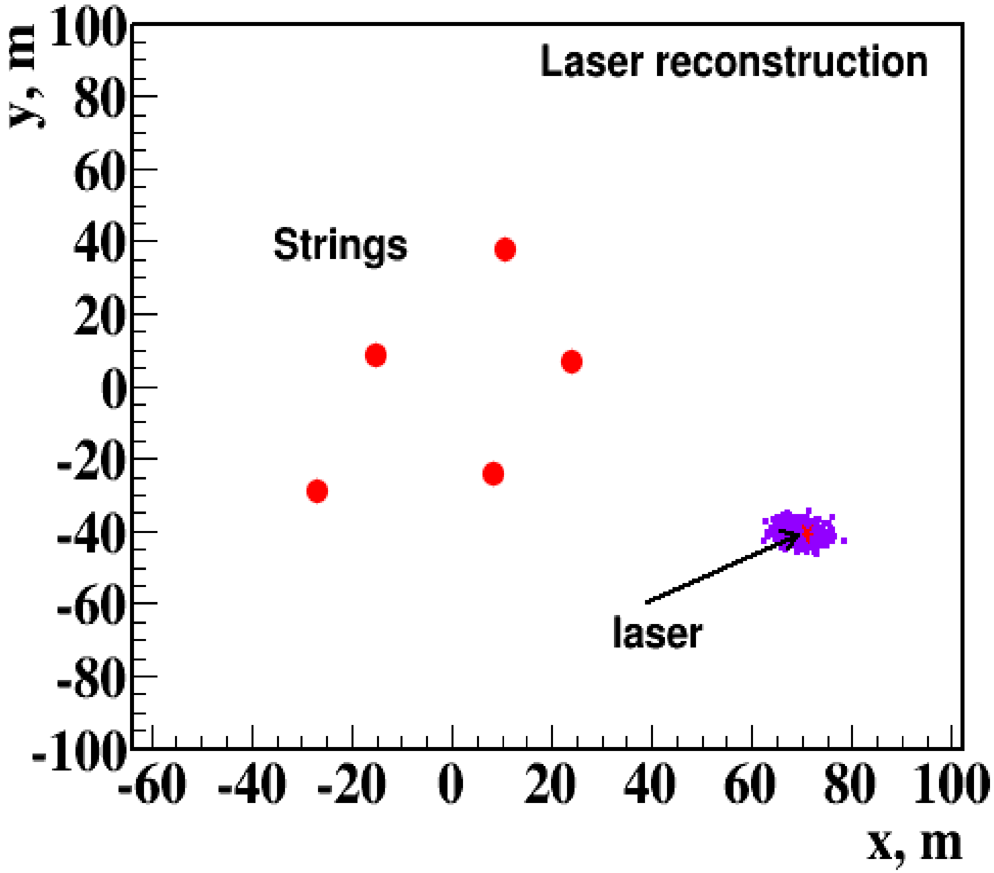
dT_0 = 64.9 ns – expected time difference



Reconstruction of laser-light source position

- Laser and OMs coordinates from data of acoustic positioning system
- Time offsets of OMs from LED calibration
- Iterative reconstruction procedure – OMs with residual $\delta t > 15$ ns are excluded from analysis

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



External calibration laser:

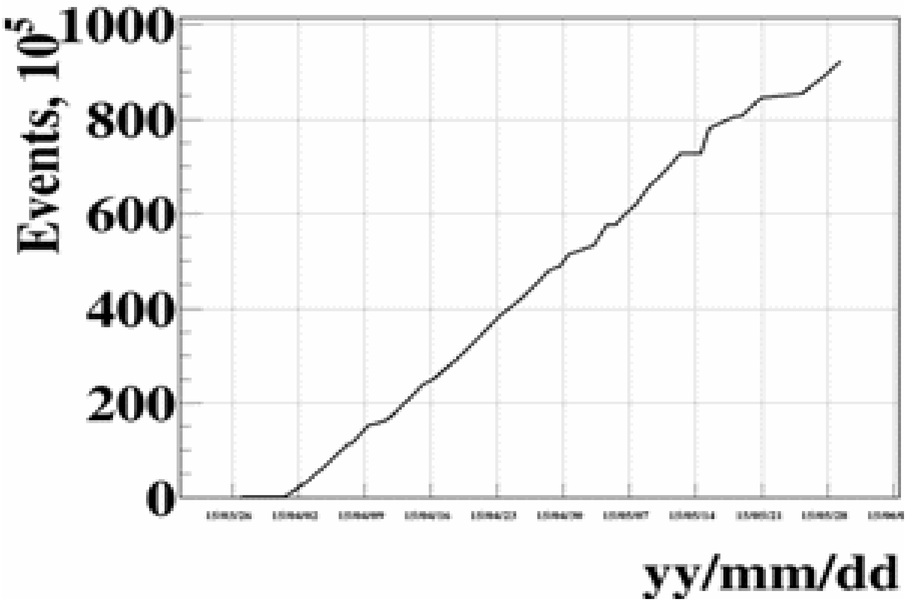
- 480 nm light pulses

- Five fixed intensities: ~10^12 – 6·10^13 □ / *pulse*
(~10 PeV – 600 PeV shower energy)

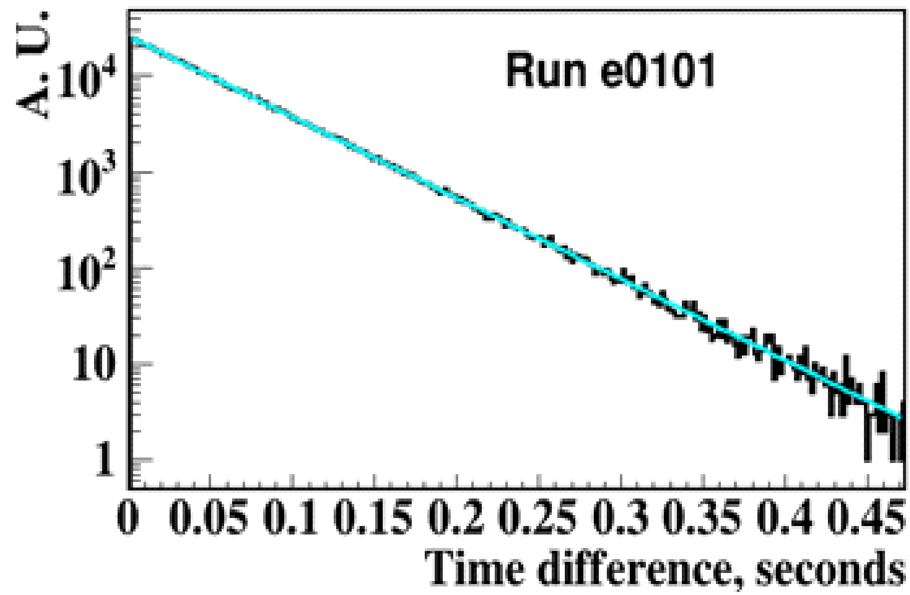
- Distances: 50 – 250 m.

Operation-2015

Cumulative number of events

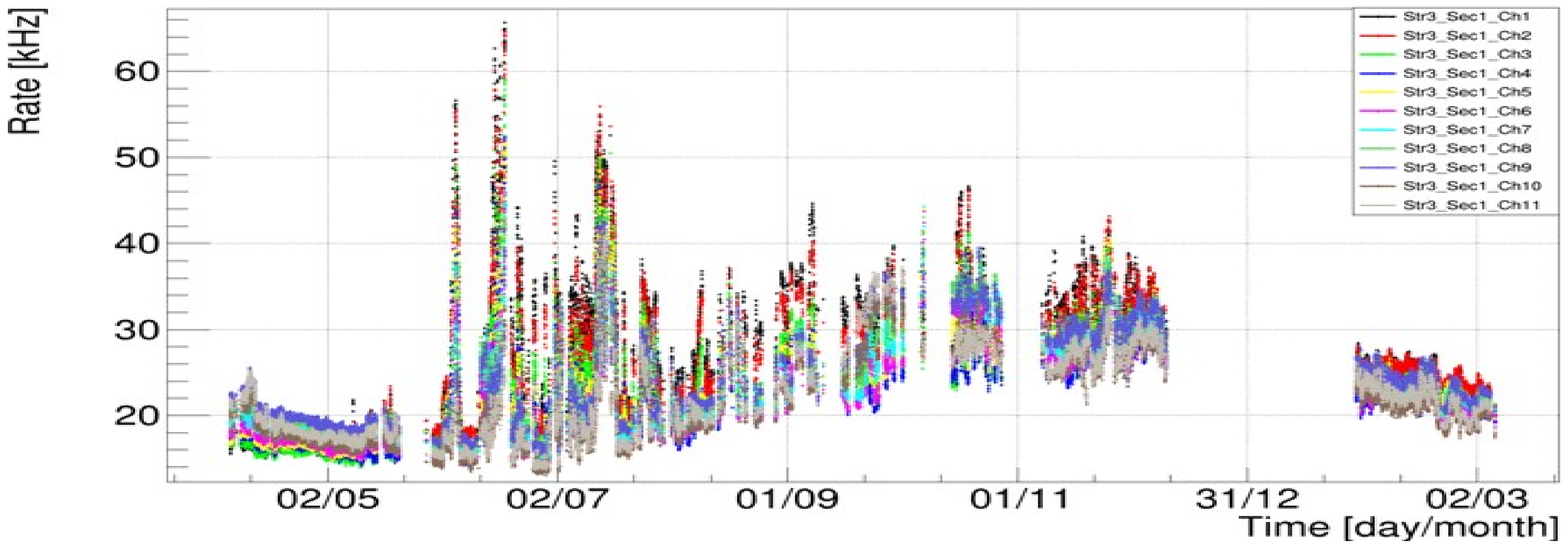


ΔT between subsequent events

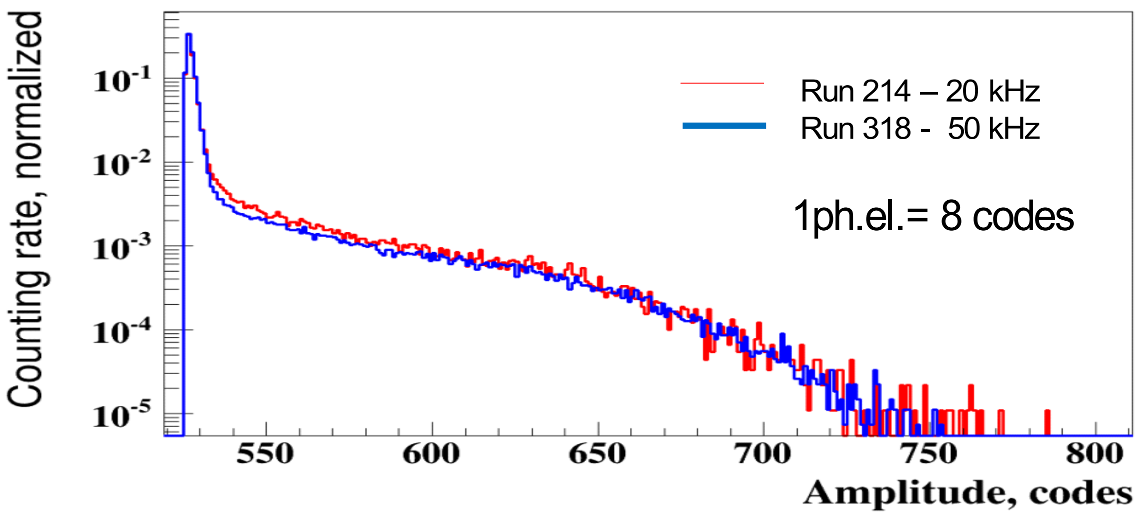


Operation-2014, 2015

Counting rates of OMs



Amplitude distribution of selected OM recorded pulses



Atmospheric muons

Runs - (156 – 169)

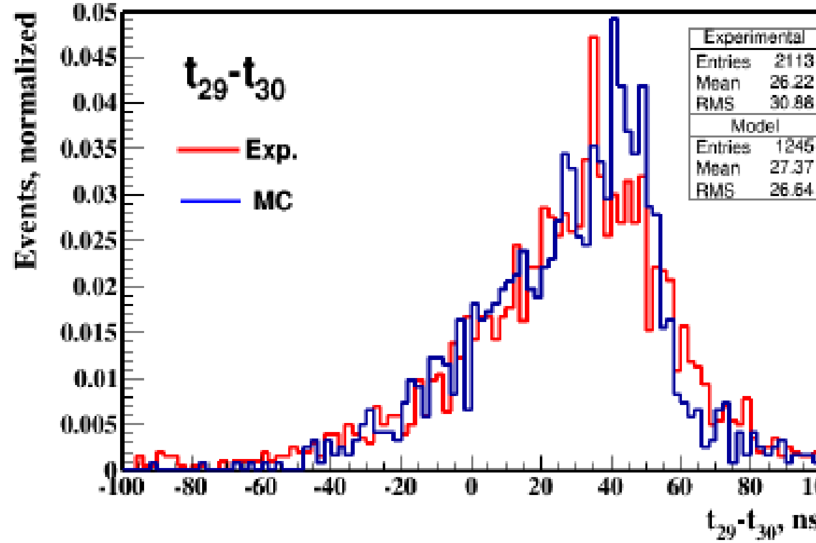
Statistics - 1707896 events

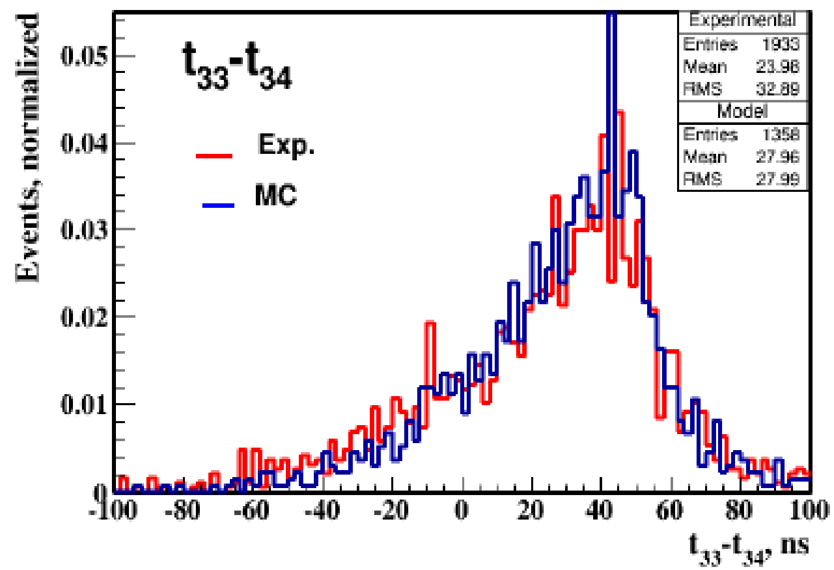
Trigger - 4 OMs /section

Selection – Q > 2 ph.el.

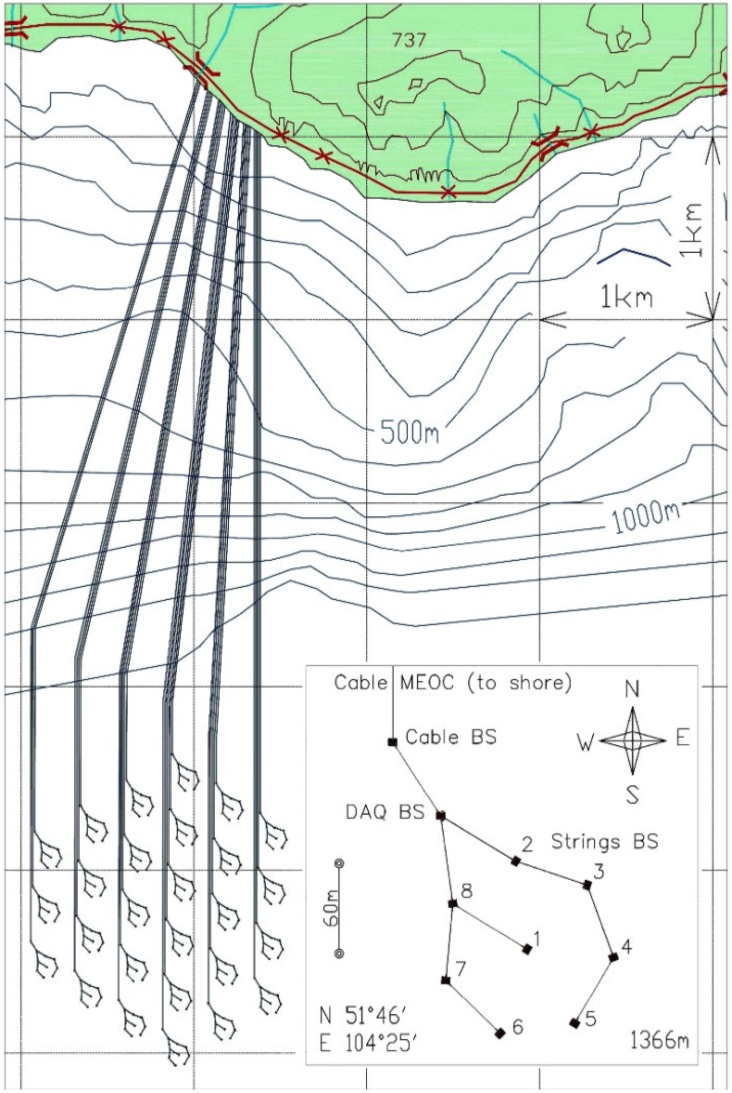
LED – calibration

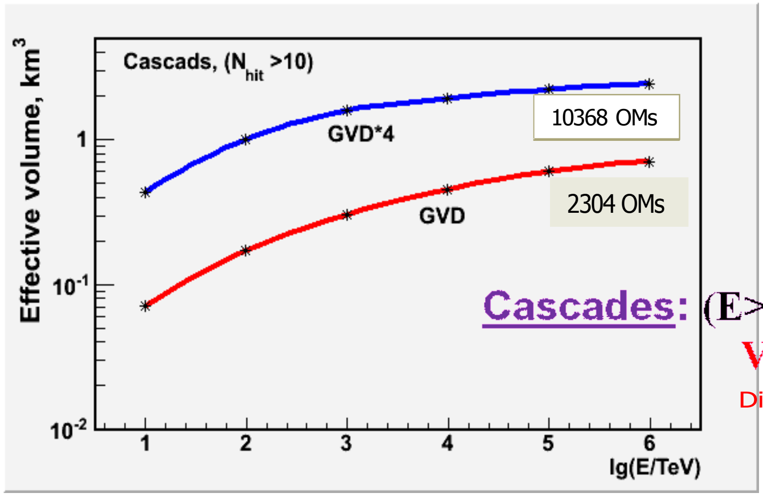
Data consistent with expectation

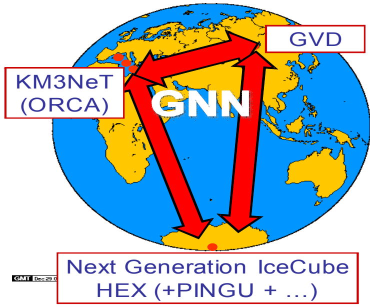




GVD with 12 clusters and more; Performance



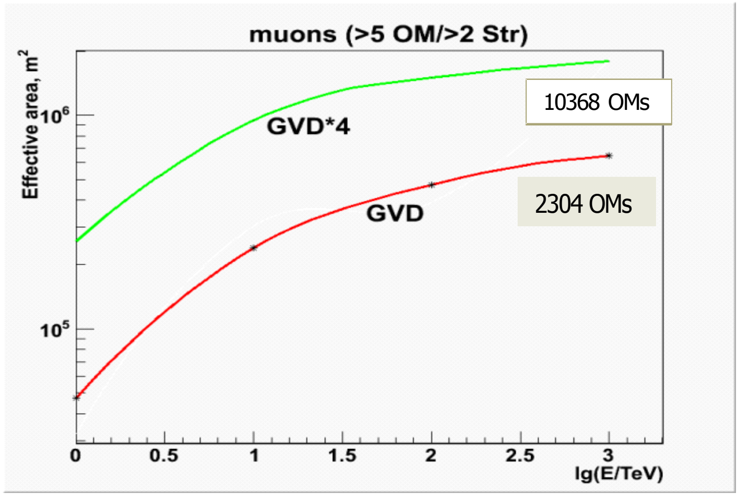




Cascades: (E>10 TeV):

V_{eff} ~0.4–2.4 km³

Direction resolution: 3.5° - 5.5°



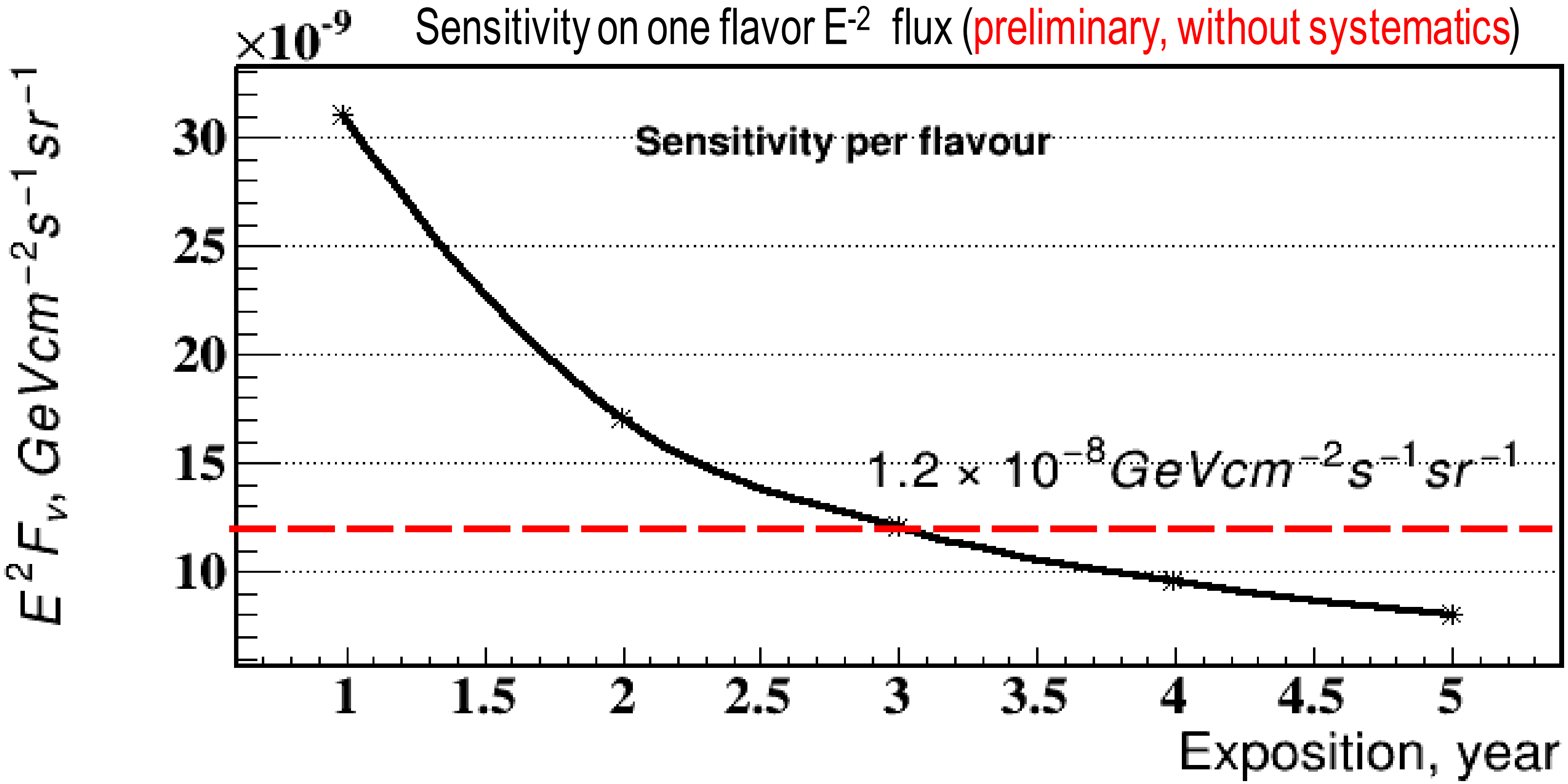
Muons: (E>1 TeV):

S_{eff} ~ 0.3–1.8 km²

Direction resolution - 0.25°

Sensitivity to neutrino induced showers

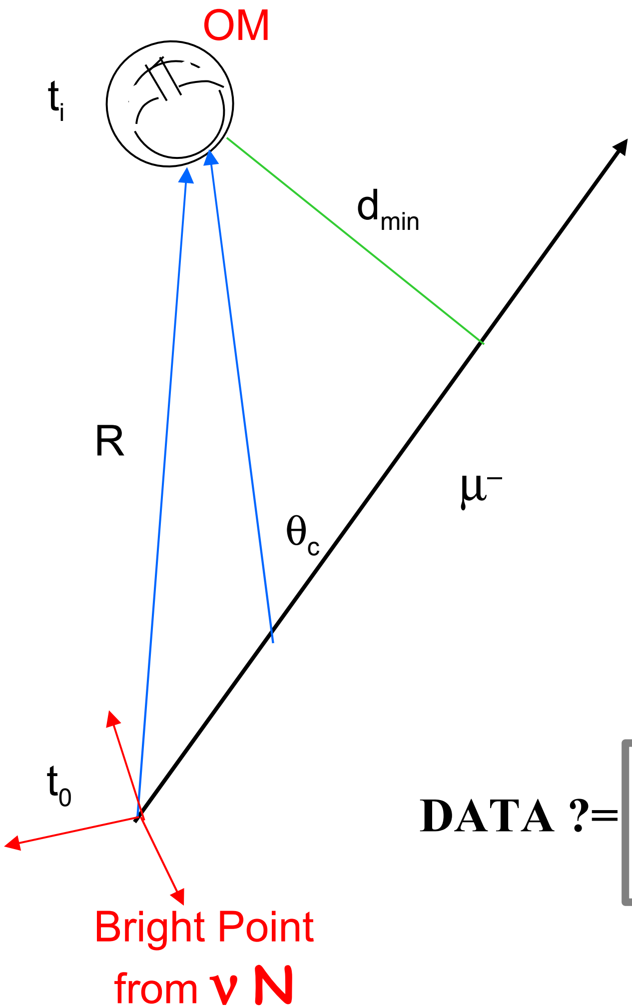
Sensitivity on one flavor E^{-2} flux (preliminary, without systematics)



Expected number of events
for 1 year exposition:
1 ev. from astrophysical IC flux
0.05 ev – atm. ν ;
0.05 ev. – atm. μ

Sensitivity to neutrino induced muons

Expected rate of muons



Model dependent function

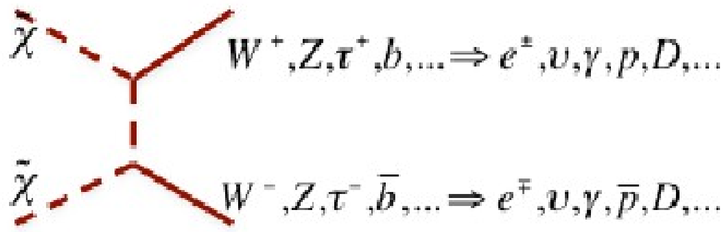
$$N_\mu = \int_{E_{th}}^{E_{max}} A^{\nu}_{eff}(E_\nu, \theta_\nu, \phi_\nu) \frac{d\Phi_\nu}{dE_\nu \, d\Omega_\nu} dE_\nu \, d\Omega_\nu$$

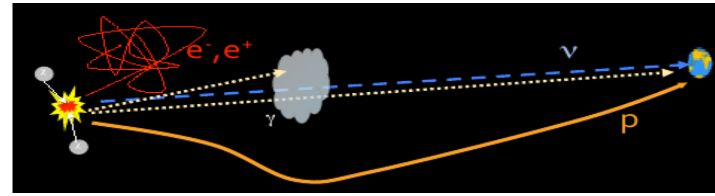
Detector function

DATA ?= SIGNAL ν + ATM ν + ATM μ + KHz_noise

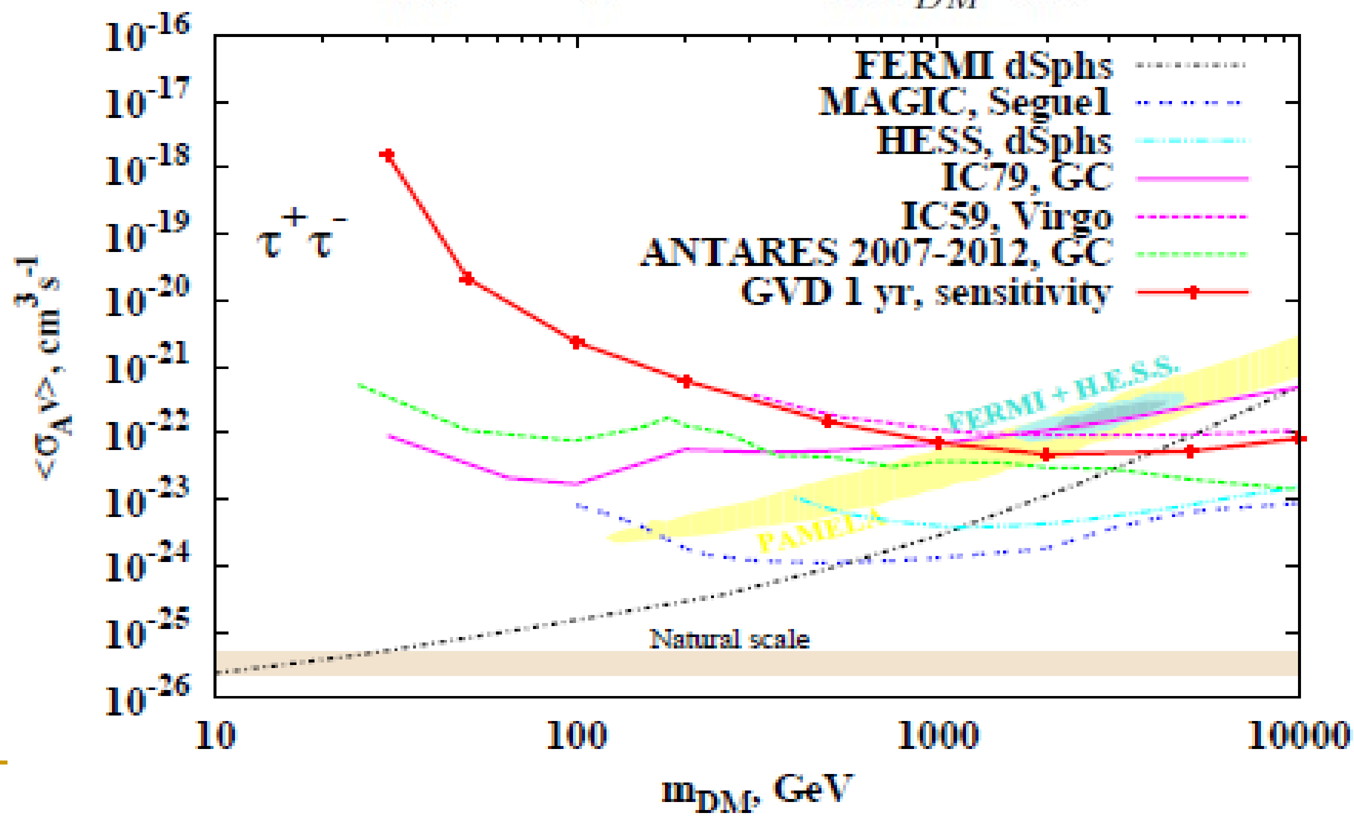
MC estimate

GVD sensitivity to DM annihilations in the GC



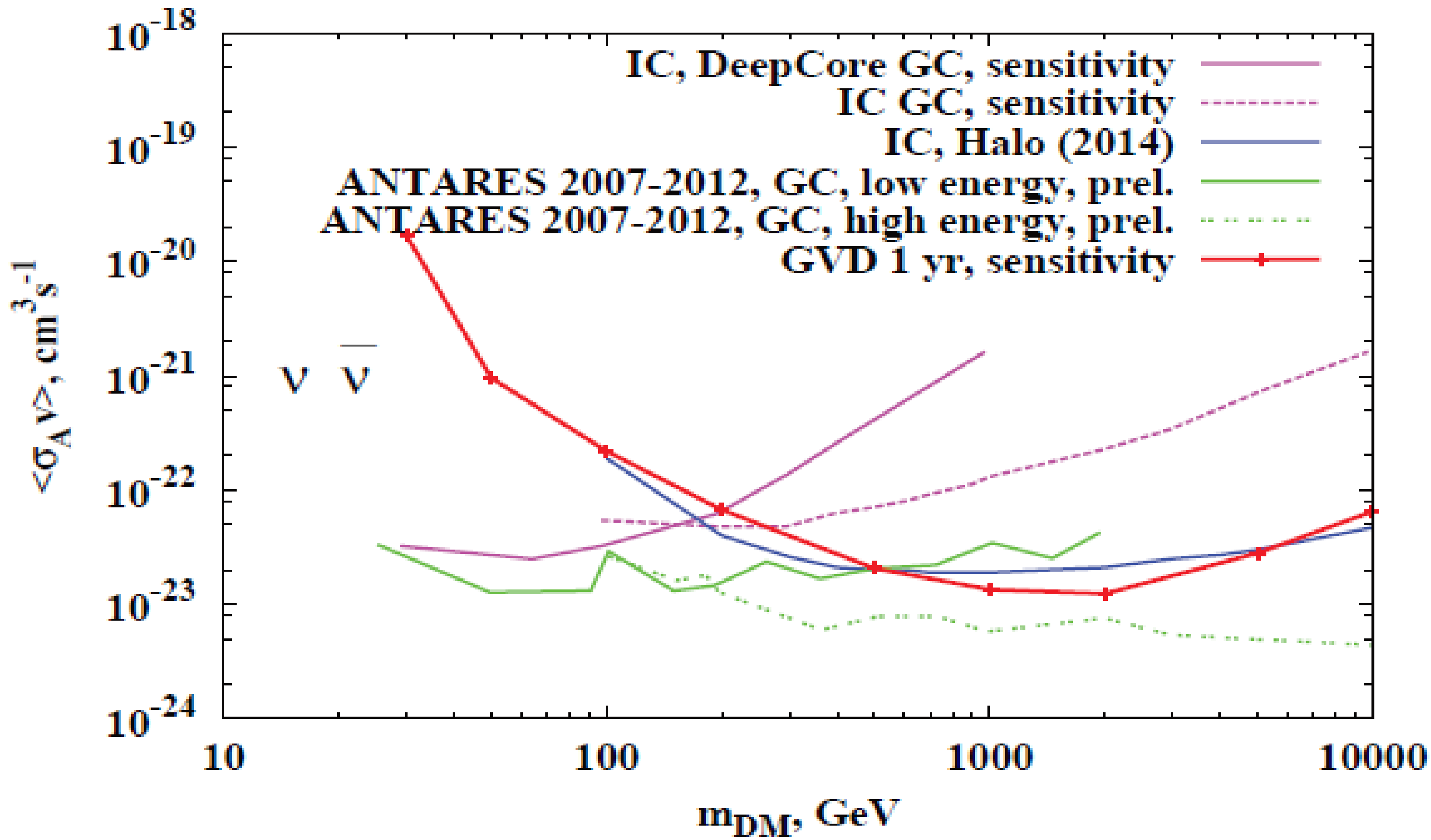


$$\frac{d\phi_\nu}{dE} = \frac{\langle\sigma_A v\rangle}{2} J_2(\Psi) \frac{R_0\rho^2_{local}}{4\pi m^2_{DM}} \frac{dN_\nu}{dE}$$



GVD sensitivity vs stringent bounds on Galactic DM with NTs

Comparison for annihilation $\chi\bar{\chi} \to \nu\bar{\nu}$



SUMMARY

In early April 2015, the first Dubna cluster of the Baikal Gigaton Volume Detector is in operation. It comprises 192 optical modules. The modules are arranged at depths down to 1,300 m.

Over its next stages of evolution, the telescope will be stepwise extended by deploying new clusters. By 2020, it is planned to consist of 10-12 clusters with a total volume of about 0.4 cubic kilometers (GVD phase-1).

Thank you!

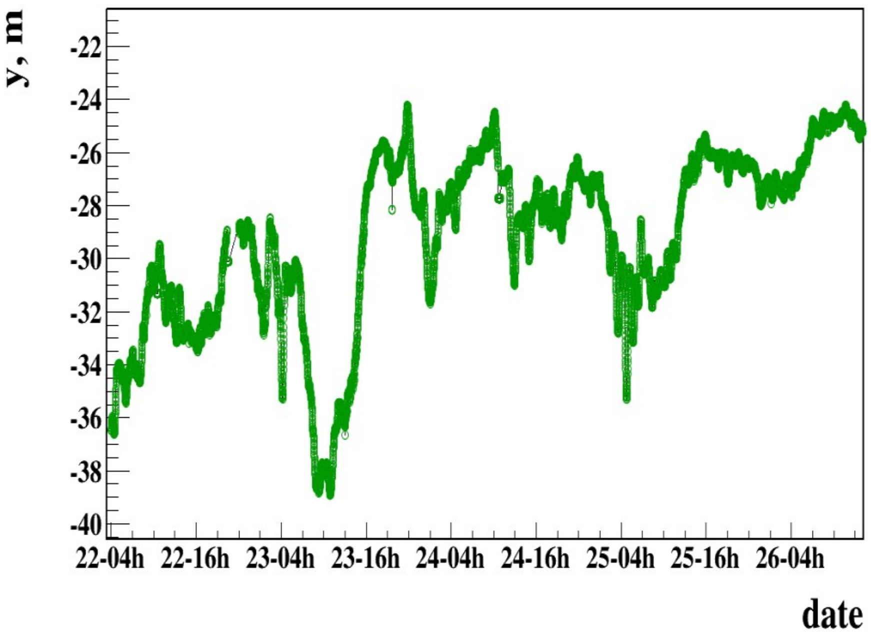
Backup slides

Operation-2014

Performance of acoustic positioning system:

- data every 30 seconds
- high resolution

Horizontal displacement of hydrophone



Vertical displacement