EUROPEAN STRATEGY FOR
ASTROPARTICLE PHYSICS

PARIS | 21-22 November 2011

Astroparticle Strategy in Russia

Victor Matveev
Russian Academy of Sciences

Today is the time of changing in ApP Strategy in Russia. The Strategy was the competition with other countries.

The current ApP Strategy in Russia is the integration in ApP global efforts.

The main step in this Strategy is cooperation and coordination with ASPERA.

One way is the use the European facilities by Russian scientists.

Inverse way is the use the Russian facilities by European scientists.

ApP European experiments with participation of Russian scientists

- LVD (Gran Sasso) ~ ¾ of apparatus
- NEMO-3, SuperNEMO isotopes, Nemo-3 scintillation calorimeter
- GERDA (Gran Sasso) ^{76}Ge, part of veto system
- ZEPLIN III – anticoincidence, xenon
- KATRIN (Karlsruhe) methods, auxiliary measurements
- ANTARES, NESTOR
- Double Chooz, Edelweiss smaller contributions
- Opera, BOREXINO (Gran Sasso)
- Pamela

ApP Russian projects with European participation: **Tunka Collaboration**

S.F.Beregnev, S.N.Epimakhov, N.N. Kalmykov, N.I.KarpovE.E. Korosteleva, V.A. Kozhin, L.A. Kuzmichev, M.I. Panasyuk, E.G.Popova, V.V. Prosin, A.A. Silaev, A.A. Silaev(ju), A.V. Skurikhin, L.G.Sveshnikova I.V. Yashin,
– **Skobeltsyn Institute of Nucl. Phys. of Moscow State University, Moscow, Russia**;

N.M. Budnev, A.V.Diajok , O.A. Chvalaev, O.A. Gress, A.V.Dyachok, E.N.Konstantinov, A.V.Korobchebko, R.R. Mirgazov, L.V. Pan’kov, Yu.A. Semeney, A.V. Zagorodnikov
– **Institute of Applied Phys. of Irkutsk State University, Irkutsk, Russia**;

B.K. Lubsandorzhiev, B.A. Shaibonov(ju) , N.B. Lubsandorzhiev
– **Institute for Nucl. Res. of Russian Academy of Sciences, Moscow, Russia**;

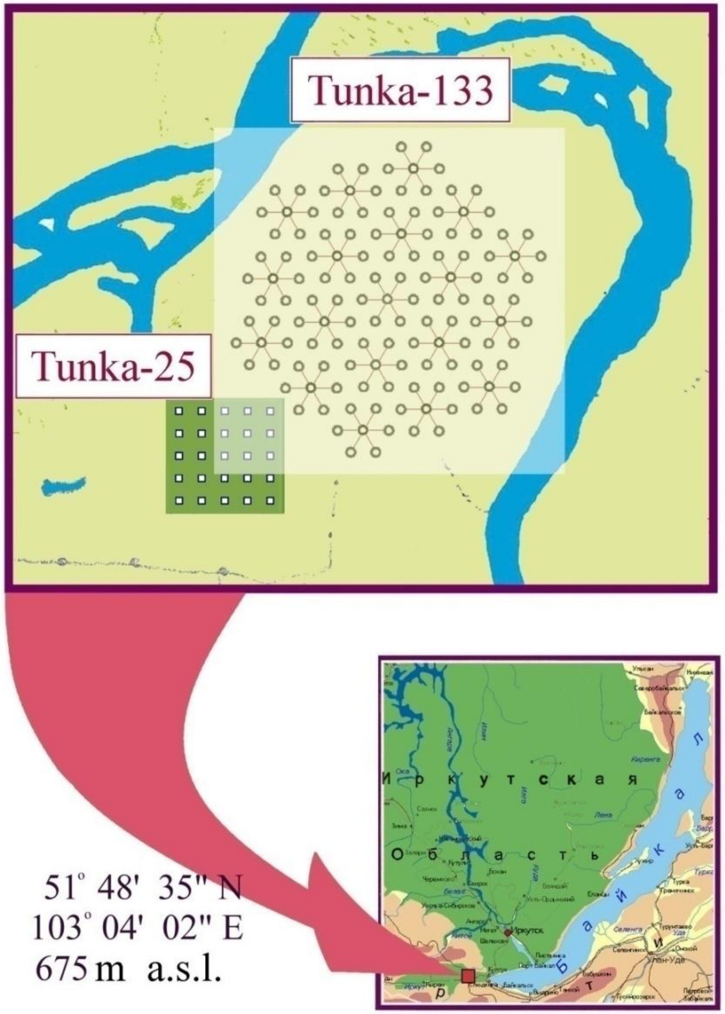
V.S. Ptuskin
– **IZMIRAN, Troitsk, Moscow Region, Russia**;

Ch. Spiering, R. Wischnewski
– **DESY-Zeuthen, Zeuthen, Germany**;

A.Chiavassa
– **Dip. di Fisica Generale Universita' di Torino and INFN, Torino, Italy**.

D. Besson, J. Snyder, M. Stockham
Department of Physics and Astronomy, University of Kansas, USA

Search for the Acceleration Limit of Galactic Sources

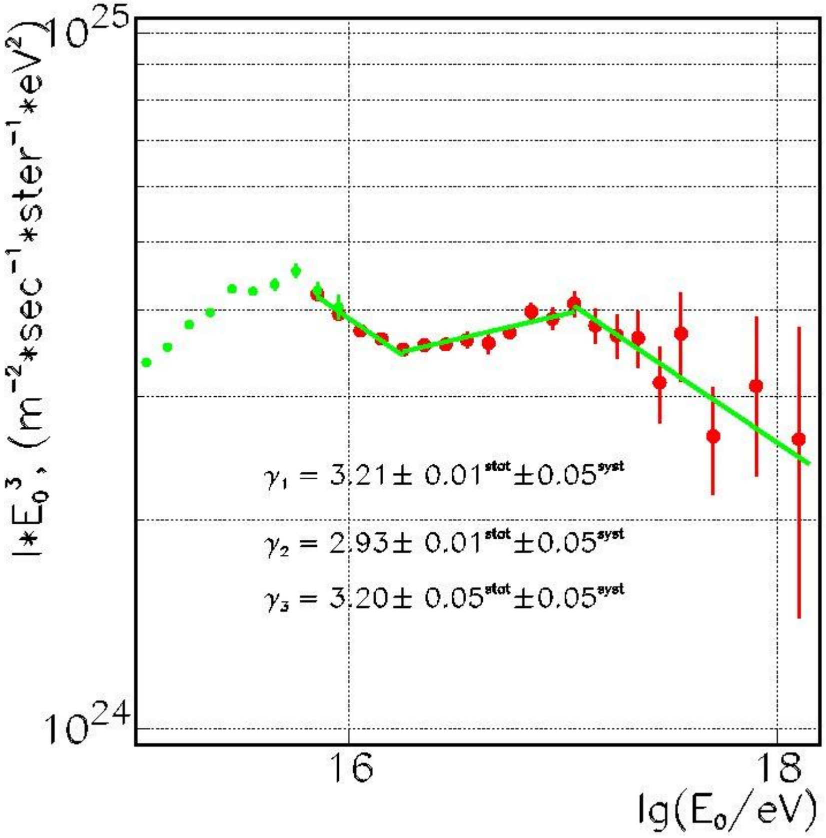


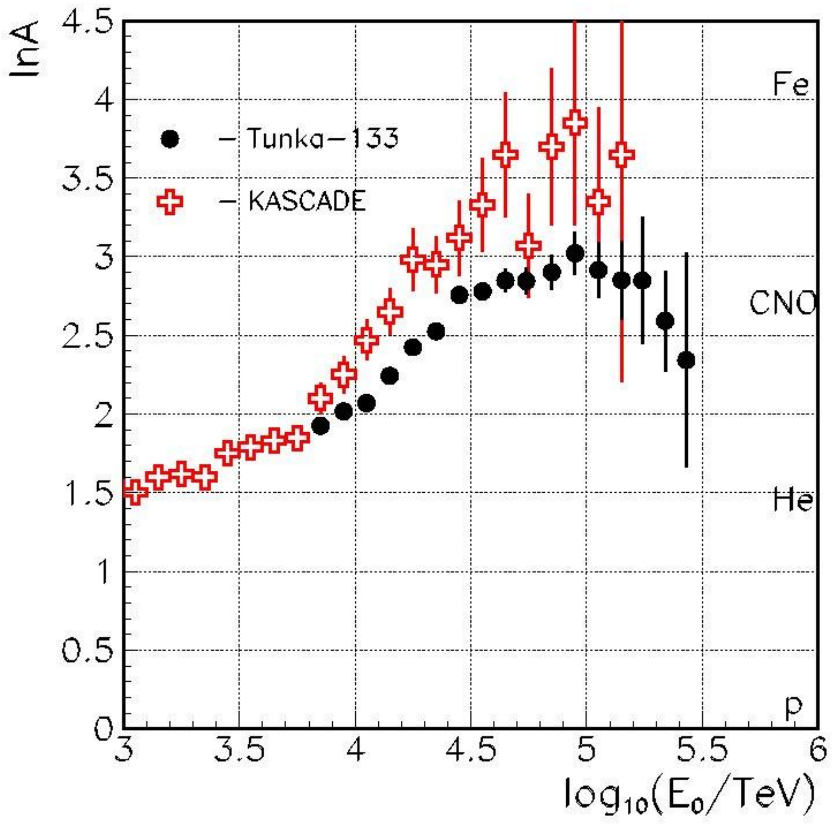
Detailed study of cosmic rays energy spectrum and mass composition in the energy range 10^{15} –10^{18} eV

Tunka-133 – 1 km^2 “dense” EAS Cherenkov light array

133 wide –view optical detectors on 1 sq.km area (PMT EMI 9350 Ø 20 cm)

Main results of 2011

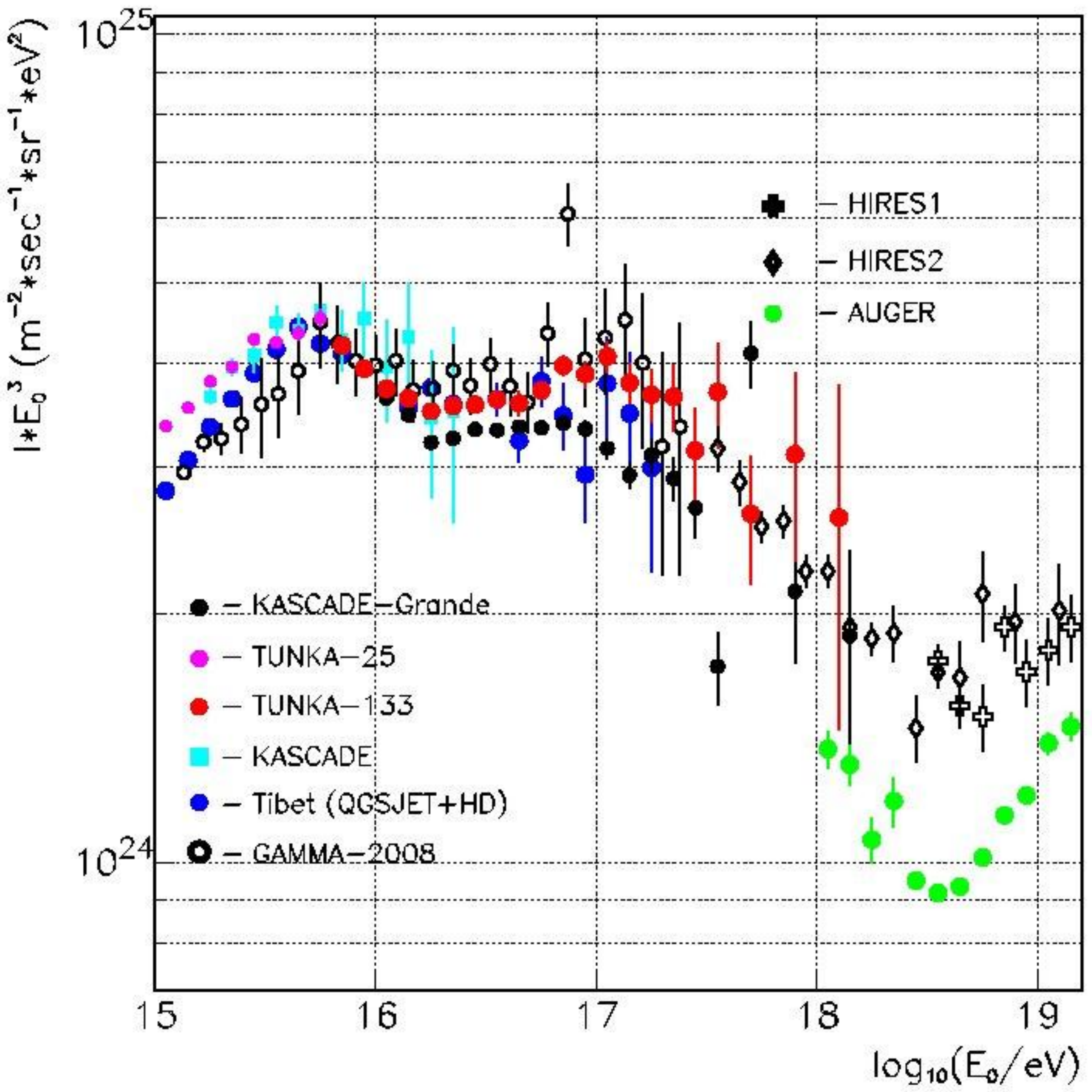




Energy spectrum cannot be fit with single power law index

Mass composition become "lighter" at $E > 10^{17}$ eV

Primary energy spectrum



Next steps -I

1. Deployment of 42 distant optical detectors to increase the accuracy of energy reconstruction for the outside events.
   In operation from the end of October 2011

2. Deployment of scintillation array for absolute energy calibration at $3 \cdot 10^{16} – 10^{17}$ eV .
   In summer 2012 : scintillation detectors from KASCADE-Grande will be moved to Tunka - **Tunka-Grande ?**

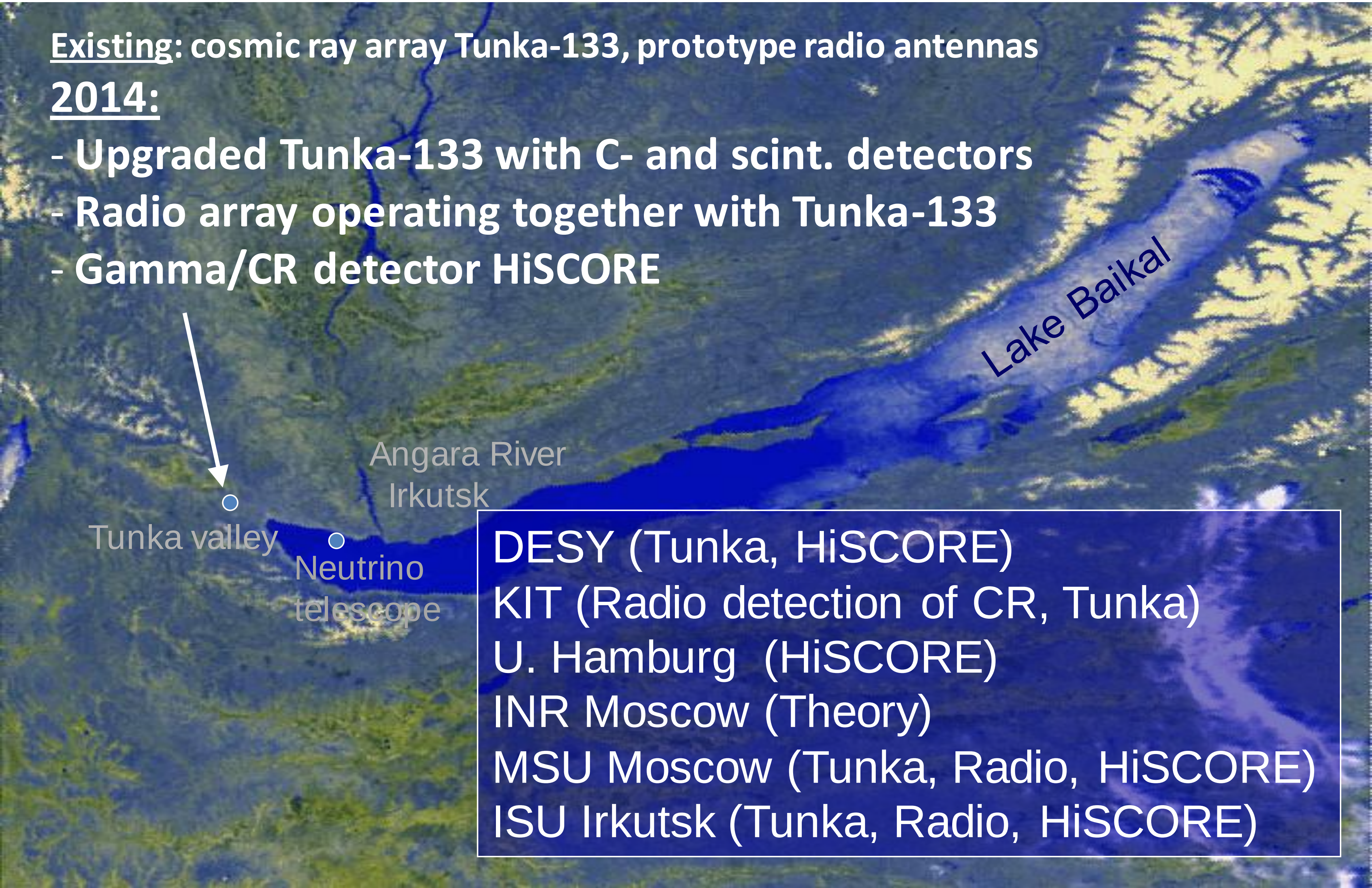
3. Deployment of fluorescent detector at 10 km from the array for common operation.

Helmholtz-Russian Joint Research Group

Existing: cosmic ray array Tunka-133, prototype radio antennas

2014:

- **Upgraded Tunka-133 with C- and scint. detectors**
- **Radio array operating together with Tunka-133**
- **Gamma/CR detector HiSCORE**



DESY (Tunka, HiSCORE)
KIT (Radio detection of CR, Tunka)
U. Hamburg (HiSCORE)
INR Moscow (Theory)
MSU Moscow (Tunka, Radio, HiSCORE)
ISU Irkutsk (Tunka, Radio, HiSCORE)

ASTROPARTICLE PHYSICS

Workshop on Russian-German Perspectives

Dark Matter Neutrino Properties Proton Decay Cosmic Rays Neutrino and Gamma-Ray Astronomy

- **Broschüre zu gemeinsamen Projekten im Frühjahr 2012**
- **Workshop in Berlin im März 2012**

https://indico.desy.de//event/AstroGRY | C. Spiering | christian.spiering@desy.de | G.V. Domogatsky | domogats@pcbai10.inr.ruhep.ru | G. A. Shelkov | chelkov@jinr.ru

Image credit: J-P Metsävainio

JINR | Dubna | 8/9 December 2011

Workshop sponsored by BMBF and JINR

Deutsch-Russisches Jahr der Bildung, Wissenschaft und Innovation 2011/12

Российско-Германский год образования, науки и инноваций 2011/12

Sites of priority experiments

Organization of AP Research in Russia

- General Coordination – Russian Academy of Sciences (RAS)
- Management – RAS, RF Ministry of Education and Science (MES), Russian Space Agency (RSA), Moscow State University (MSU)
- Financing – RAS, MES, RSA, MSU, Russian Foundation for Basic Research
- Consulting and Expertise – RAS Council on Cosmic Rays, RAS Neutrino Council

State Programs of Support for AP Studies

- Program of the Presidium of RAS “Neutrino Physics and Neutrino Astrophysics” (originally “Physics of Cosmic Rays and Neutrino Physics”), working since 2001
- Special project “Space Microphysics” of the Russian Foundation for Basic Research , working since 2009

Regular meetings on AP physics in Russia

- Russian Cosmic Ray Conference (biennial)
- International School “Particles and Cosmology” (biennial)
- International Conference “Non-Accelerator New Physics” (NANP)
- International Workshop “UHE Cosmic Rays and their Sources”
- Schools of young scientists “Non-accelerator High-energy Physics” and “Fundamental Interactions and Cosmology”

Scope and Scale of Astroparticle Physics in Russia

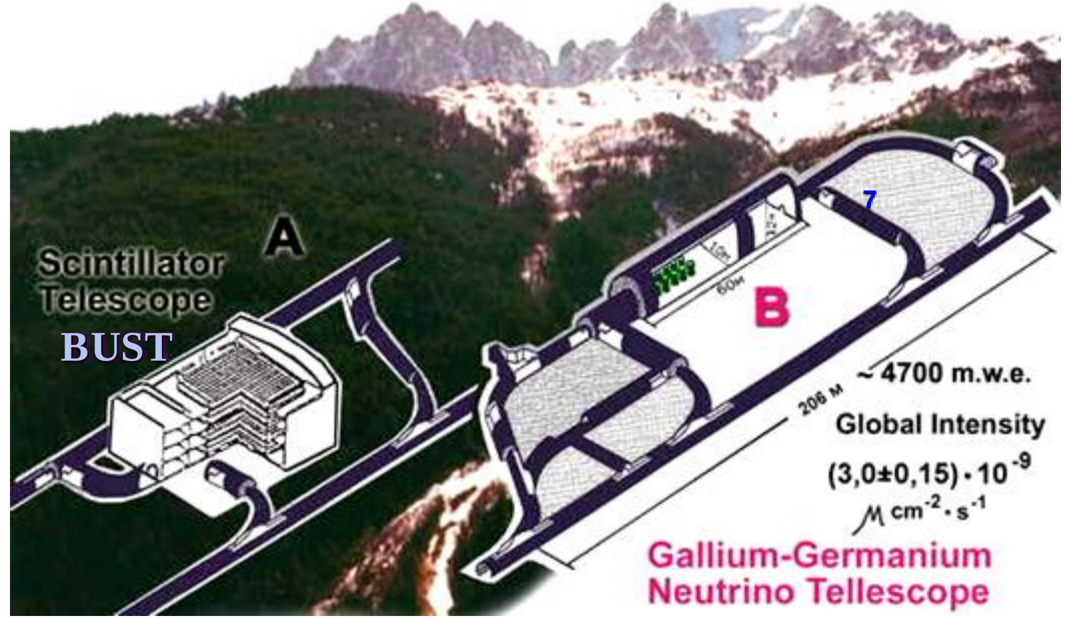
Annual Funding (Million Euros)	Lab Operation	Inves- tment	Salaries	OTHER	TOTAL
INR RAS	1.34	1.0	2.3	0.26	4.9
Baksan and Baikal	1.14	1.0	1.6	0.26	4.0
LPI RAS	0.24	0.50	1.00	0.10	1.84
IKFIA SB RAS (Yakutsk)	0.40	0.27	0.40	0.06	1.07
MSU	0.26	0.12	0.45	0.03	0.86
MEPHI	0.20	0.20	0.40	0.04	0.84
ITEPH	0.04	0.16	0.32	0.02	0.54
JINR (Dubna)	0.08	0.08	0.27	0.06	0.49
Kurchatov	0.25	0.11	0.11	0.02	0.49
ISU (Irkutsk)	0.03	0.04	0.11	0.08	0.26
Total	2.84	2.48	5.36	0.67	11.35
European Union	26	51	90	10	177

Scope and Scale of Astroparticle Physics in Russia

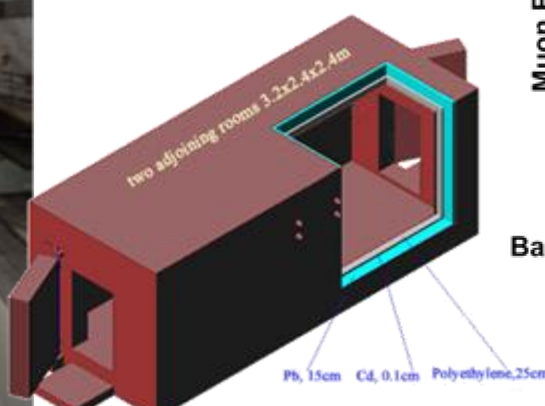
PERSONNEL	Scientists, Engineers	Postdocs and Grad. Students	OTHER	TOTAL
INR RAS	175	26	70	271
Baksan and Baikal	90	16	64	170
LPI RAS	158	7	16	181
IKFIA SB RAS (Yakutsk)	28	6	6	40
MSU	50	15	38	103
MEPHI	60	30	6	96
ITEPH	56	10	6	72
JINR (Dubna)	41	9	9	59
Kurchatov	21	10	3	34
ISU (Irkutsk)	14	11	8	33
Total	603	124	162	889
European Union	1021	708	197	1926

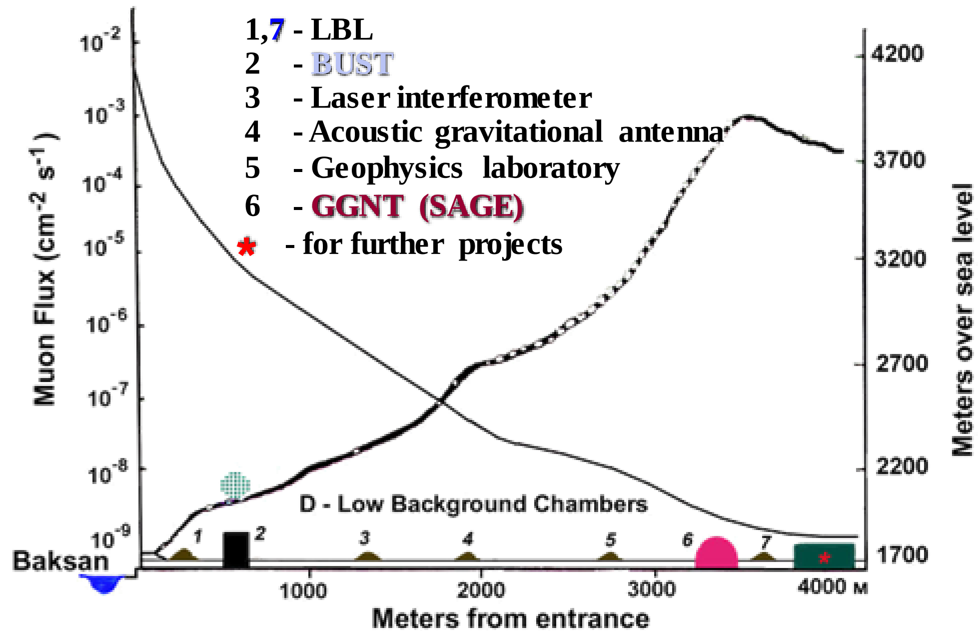

BUST 17m×17m×11m
~850 m.w.e.


GGNT 60m×10m×12m
~4700 m.w.e.


Scintillator Telescope
BUST
A
B
7
~4700 m.w.e.
Global Intensity
(3,0±0,15)·10^-9
cm^-2·s^-1
Gallium-Germanium
Neutrino Tellescope


LBL 3.2m×2.4m×2.4m
~5000 m.w.e.


two adjoining rooms 3.2x2.4x2.4m
Pb, 15cm
Cd, 0.1cm
Polyethylene,25cm


1,7 - LBL
2 - BUST
3 - Laser interferometer
4 - Acoustic gravitational antenna
5 - Geophysics laboratory
6 - GGNT (SAGE)
* - for further projects
Muon Flux (cm^-2 s^-1)
Meters over sea level
D - Low Background Chambers
Baksan
Meters from entrance
1000
2000
3000
4000 м
4200
3700
3200
2700
2200
1700

SAGE

Presently SAGE is the only experiment sensitive to the *pp* neutrinos

It has the longest almost uninterrupted time of measurements among operating solar neutrino experiments

20.6 year period (1990 – 08.2010): 200 runs, 374 separate counting sets

Result : $65.4^{+2.7}_{-2.7}(stat)\ ^{+2.6}_{-2.8}(syst)\ SNU$ ***or*** $65.4^{+3.7}_{-3.9}\ SNU$

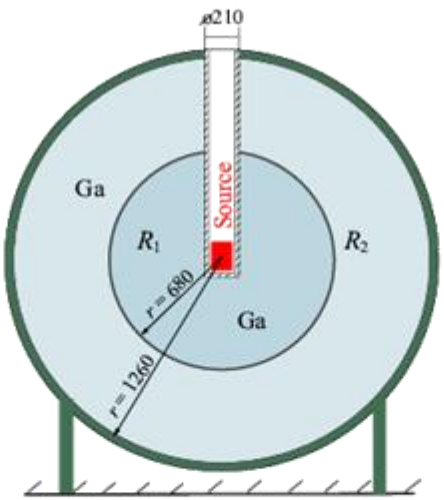
The weighted average of the results of all Ga experiments:

SAGE and **GALLEX/GNO is now**

66.1±3.1 SNU

SAGE continues to perform regular solar neutrino extractions every four weeks with ~50 t of Ga

New Ga source experiment



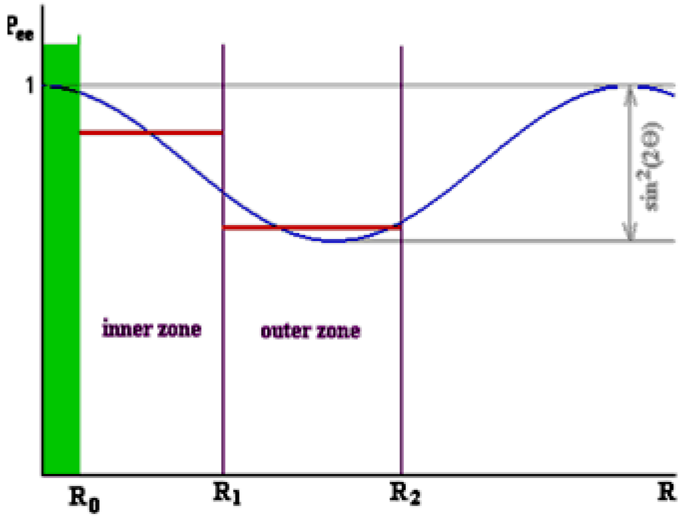
We propose to place a very intense source of ^{51}Cr (3MCi) at the center of a 50-tonne target of gallium metal that is divided into two zones and to measure the neutrino capture rate in each zone [arxiv:1006.2103v2]

Capture rate $R = AD <L> \sigma$

$D = \rho\, N0\, f\, M$ – the atomic density of the target isotope

$<L>$ – the average ν path length

σ – cross section { 5.8×10^{-45} cm^2 *[Bahcall PRC.56, 1997]*}

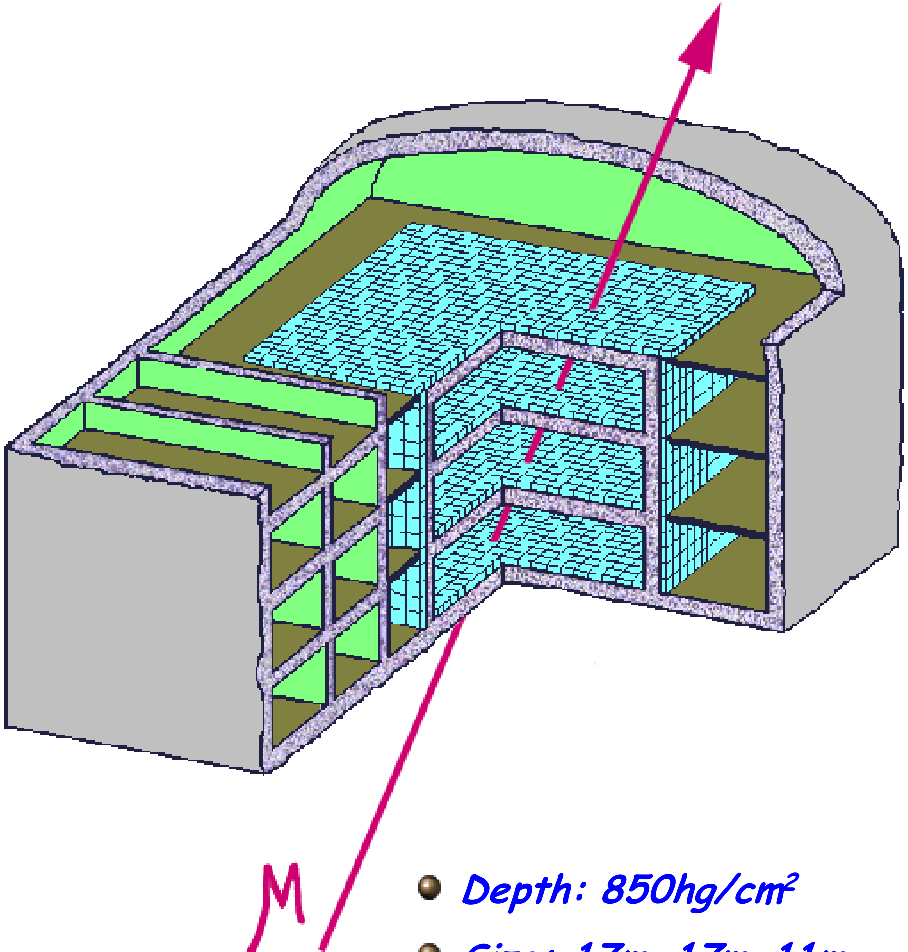


The evidence of nonstandard neutrino properties:

- there is a significant difference between the capture rates in the two zones
- the average rate in both zones is considerably below the expected rate

It is evident, it is only with certain specific outcomes that a two-zone Ga experiment will unambiguously differentiate between an oscillation interpretation or other possible interpretations of the Ga source anomaly

Balkan Underground Scintillation Telescope



- *Depth: 850hg/cm²*
- *Size: 17m×17m×11m*
- *Number of tanks: 3150*
- *Tank size: 70cm×70cm×30cm*
- *Rate: 17 Hz*
- *upward/downward: 10^{-7}*

(in operation since December of 1978)

Goals:

❖ Neutrino physics

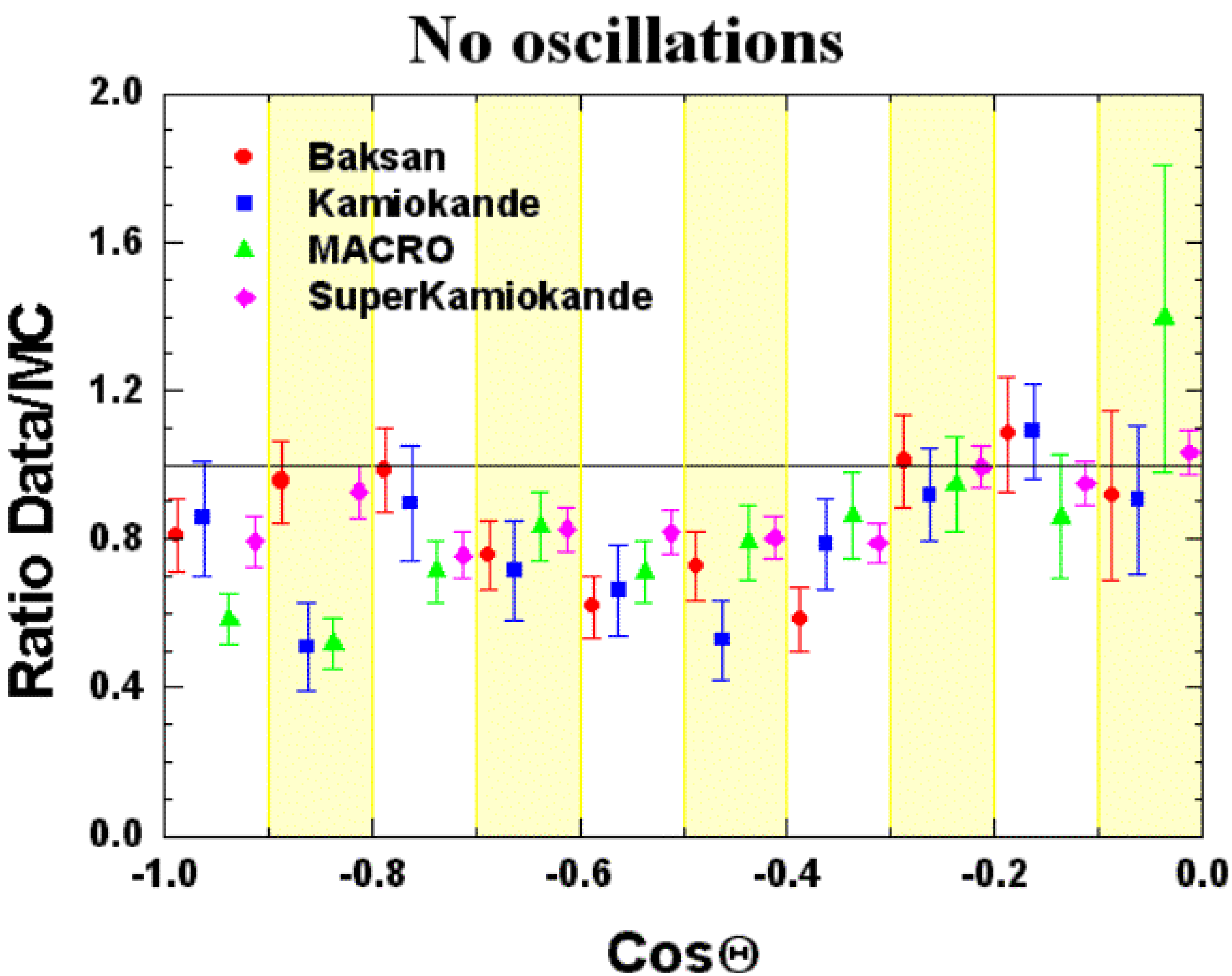
- ➢ Atmospheric neutrinos – upward–going muons.
- ➢ Neutrino burst from gravitational collapse.

❖ Cosmic ray physics

- ➢ Shape of primary spectrum
- ➢ Chemical composition
- ➢ Anisotropy

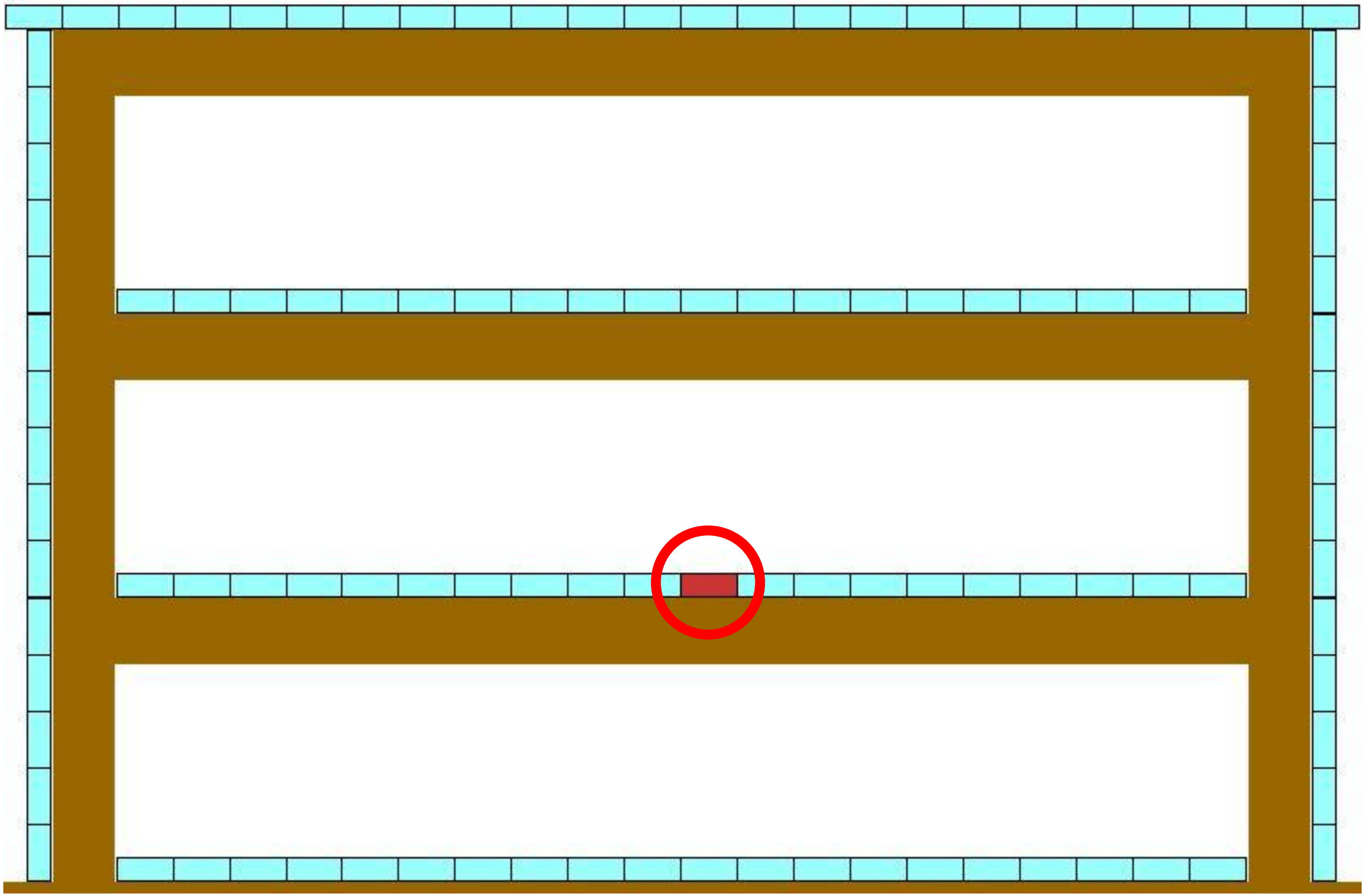
❖ Exotic

- ➢ Search for magnetic monopole
- ➢ Observations of high energy muon (E > 200 GeV) bursts during powerful solar flares


No oscillations
Baksan
Kamiokande
MACRO
SuperKamiokande
Ratio Data/MC
Cos Θ
2.0
1.6
1.2
0.8
0.4
0.0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0

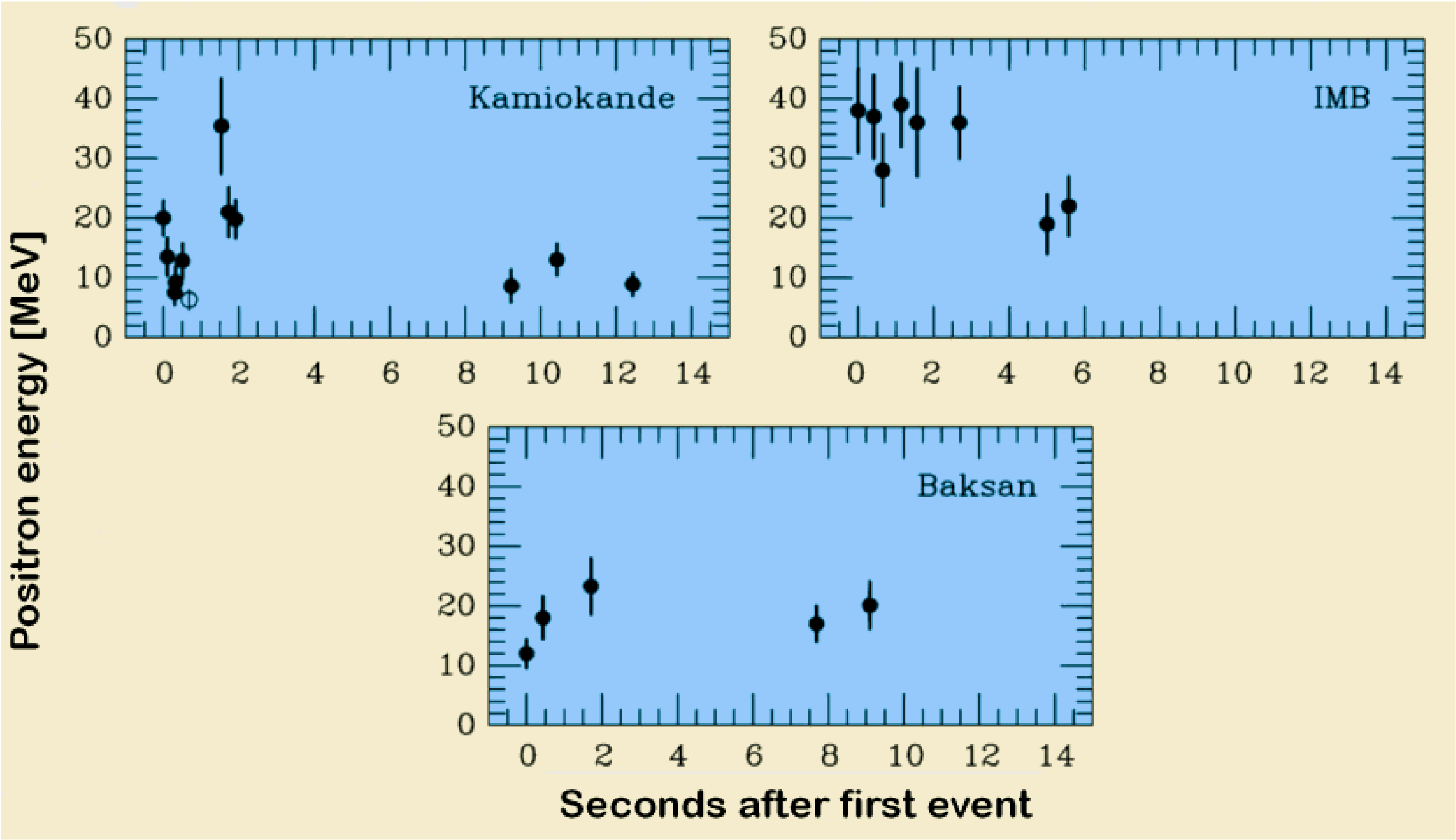
$$\bar{\nu_e} + p \rightarrow n + e^+$$

SUPERNOVA WATCH

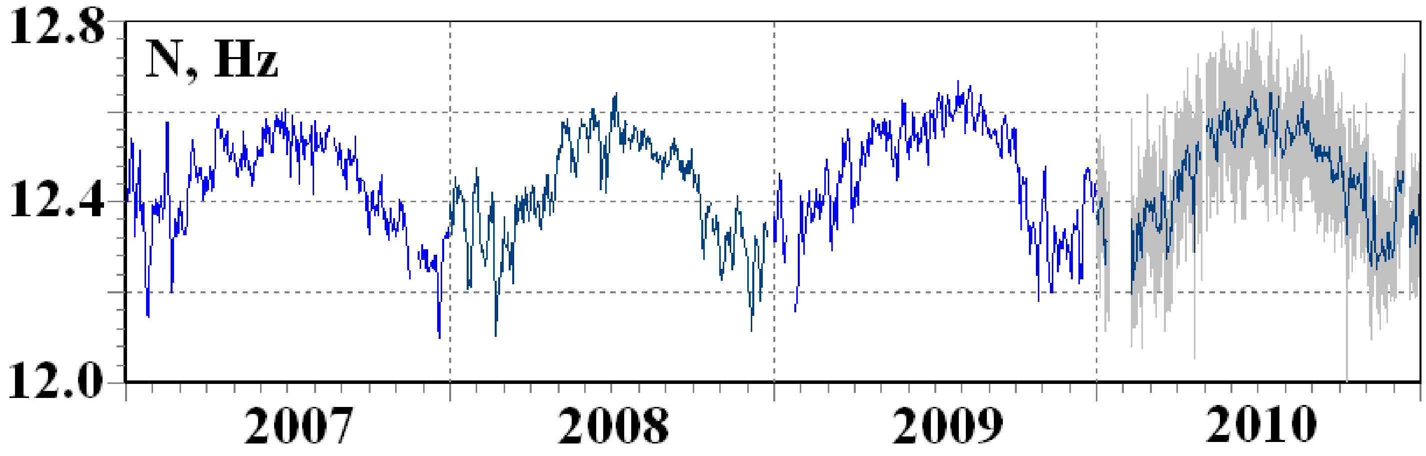


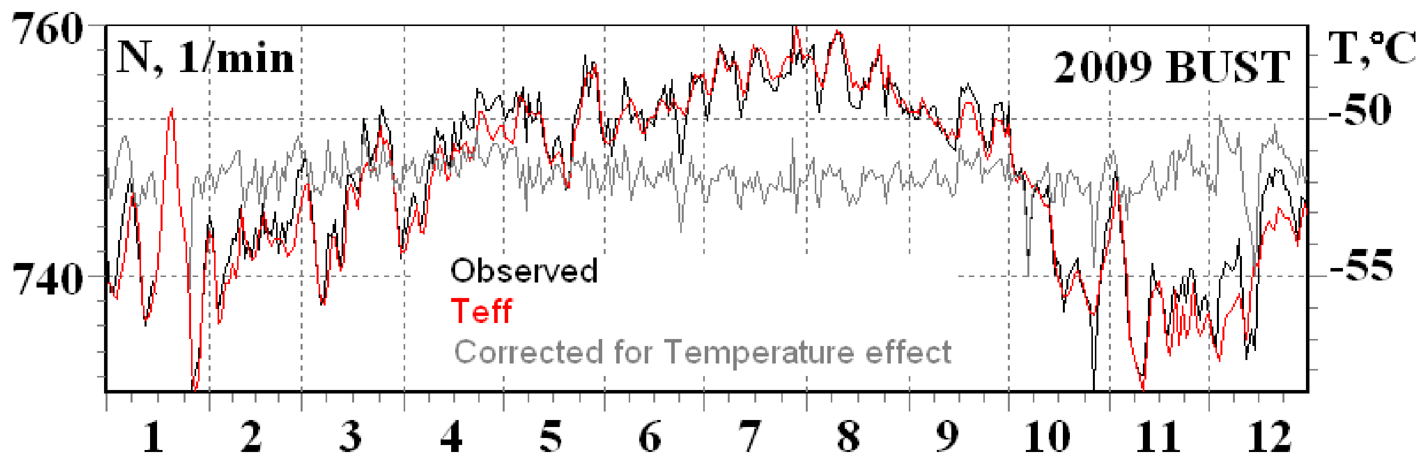
Baksan Underground Scintillation Telescope

Neutrino Signal of Supernova 1987A



Dependence of cosmic ray muons intensity on atmosphere temperature





Global Forecast System (GFS) temperature model,
National Centers for Environmental Prediction (NCEP, USA).
http://www.nco.ncep.noaa.gov/pmb/products/gfs/

Plans

- **Modernization of BUST:**
  - **New electronics**
  - **Add target to increase probability of SN detection**

- **Long-term consideration:**

New large-scale scintillator detectors

Geo & SN antineutrinos

~ 5 kt, ν energy 1÷50 MeV

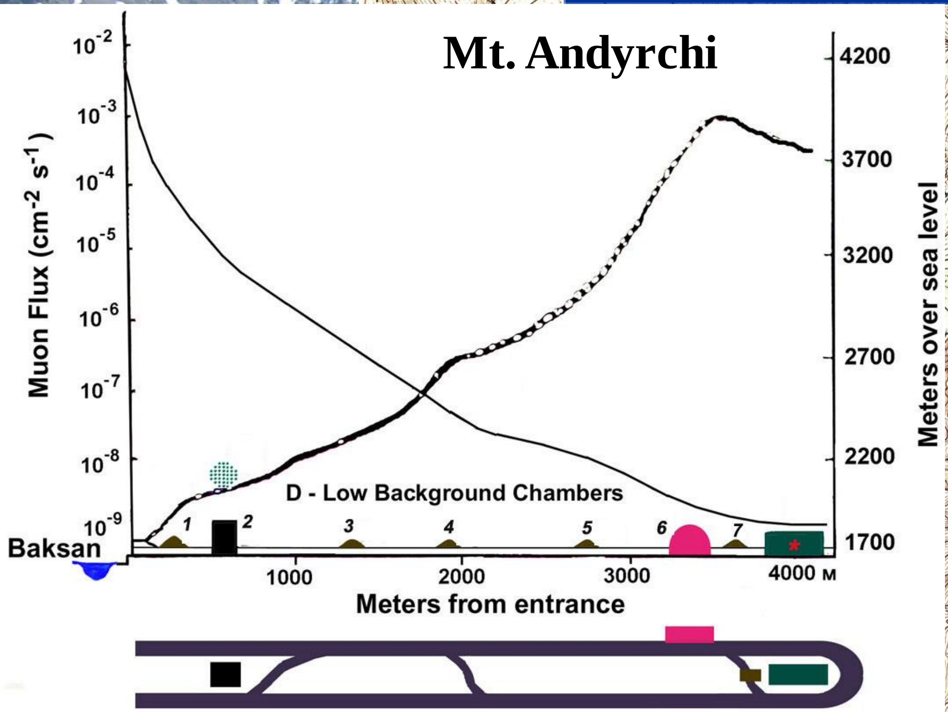
Solar & SN neutrinos

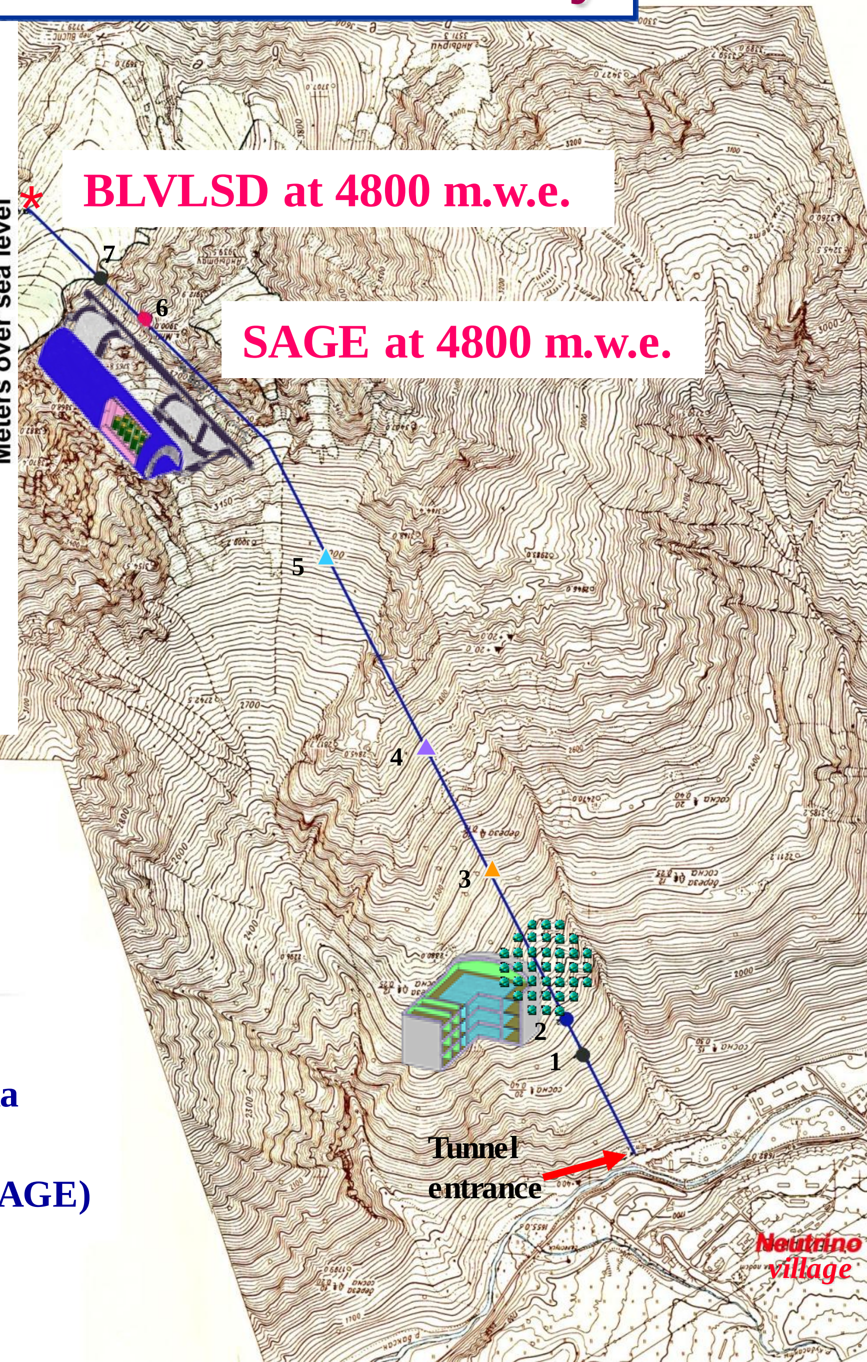
~ 1 kt, ν energy 0.5÷20 MeV

Proton decay & atmospheric neutrinos

~ 100 kt, ν energy >0.5 GeV

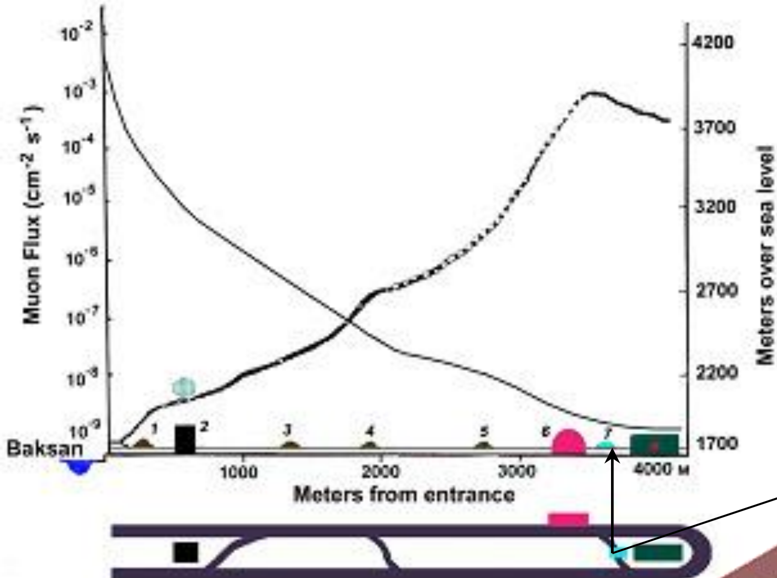
Baksan Neutrino Observatory

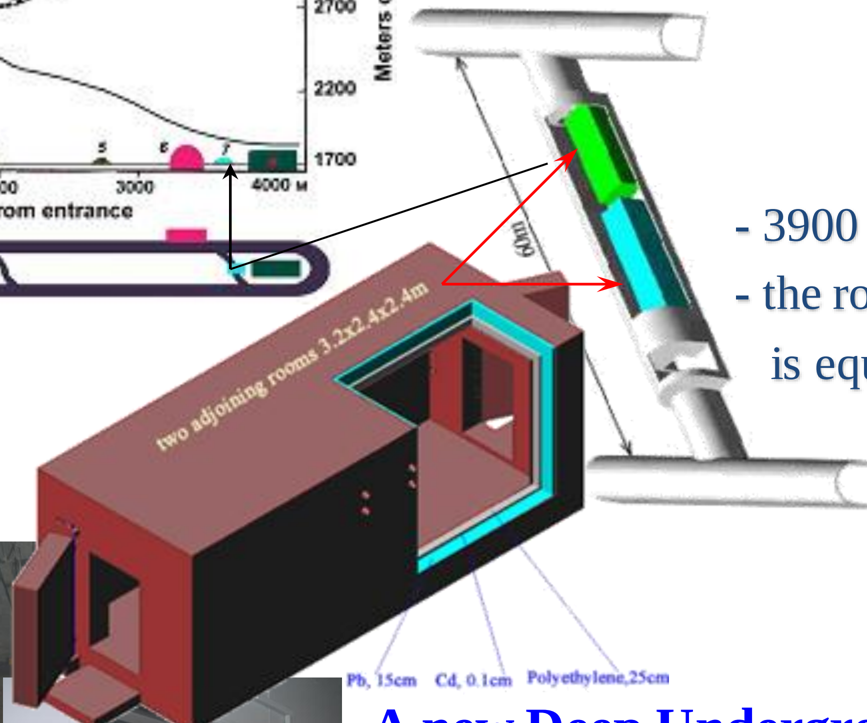


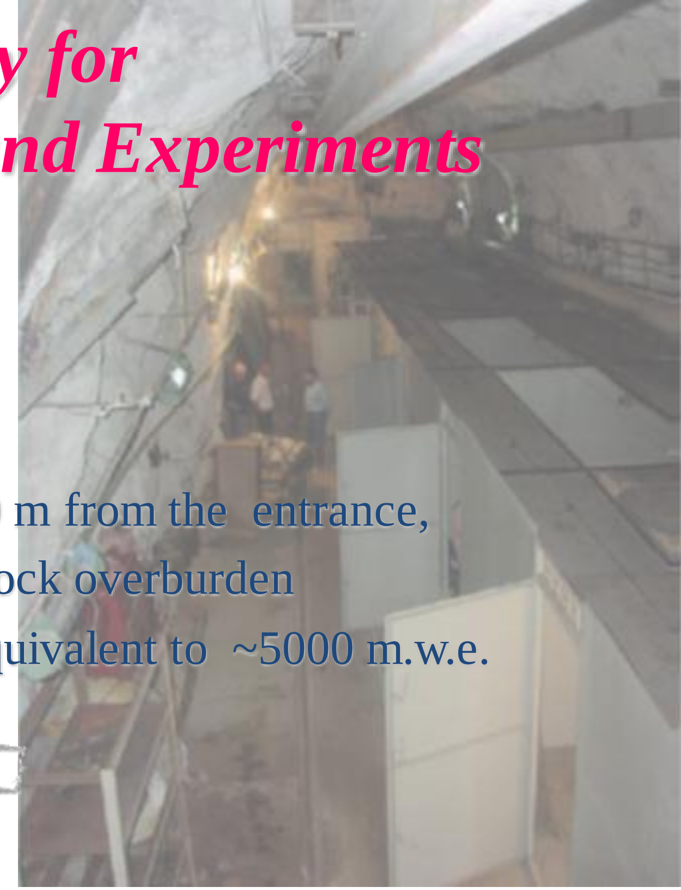


1,7 - Low-background chambers
2 - BUST
3 - Laser interferometer
4 - Acoustic gravitational antenna
5 - Geophysics laboratory
6 - Ga-Ge Neutrino Telescope (SAGE)
- EAS array “Andyrchi”

The Laboratory for Low Background Experiments







- 3900 m from the entrance,
- the rock overburden is equivalent to ~5000 m.w.e.

A new Deep Underground Low-Background Laboratory gives unique conditions for low-background research such as

- **double beta decay**
- **Dark Matter**

and for other rare processes.

BAIKAL Neutrino Experiment
Search for high energy neutrinos & exotic phenomena

- Simple deployment (low cost);
- Moderately low background;
- Good water properties:
  Scatt. Length ~ 30-60 m
  Abs. Length: ~25 m

NT200+/Baikal-GVD

Planned **G**igaton **V**olume **D**etector

KM3NeT

ANTARES

NESTOR

NEMO

Institute for Nuclear Research, Moscow

Irkutsk State University, Irkutsk

Moscow State University, Moscow

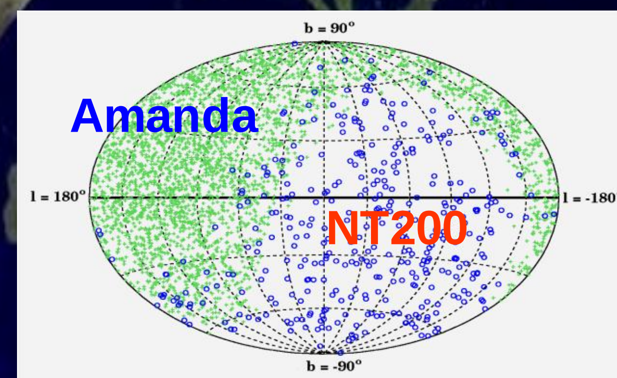
DESY, Zeuthen

Joint Institute for Nuclear Research, Dubna

Nizhny Novgorod State Technical University

St.Petersburg State Marine University

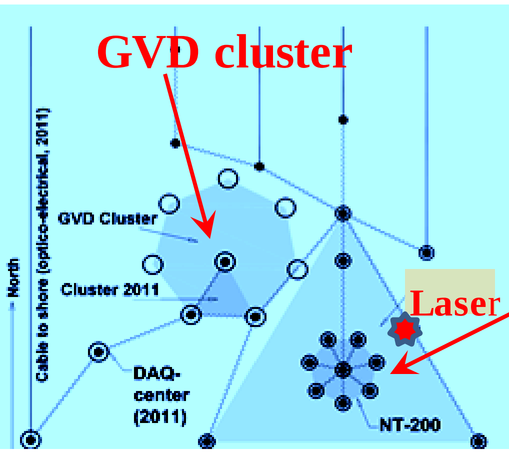
Kurchatov Institute, Moscow



AMANDA/IceCube

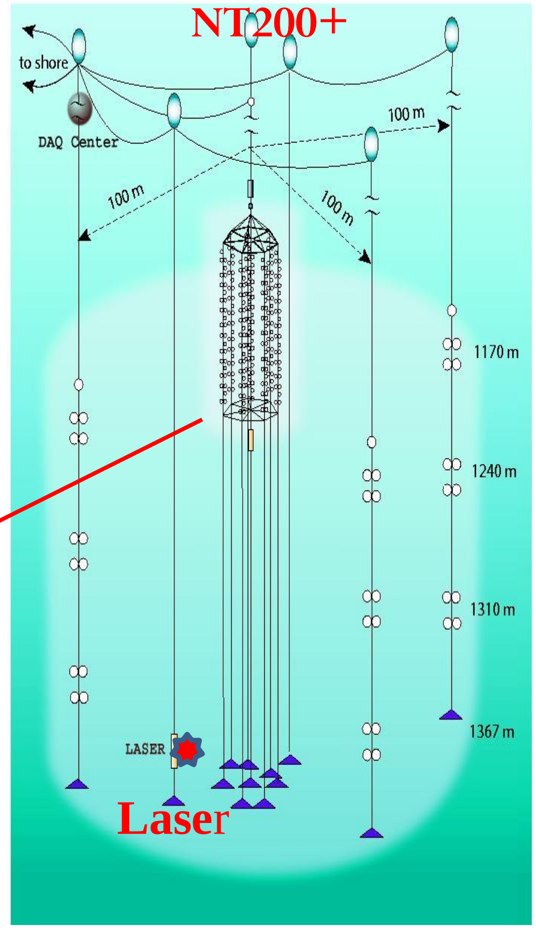
Status of Baikal experiment

GVD prototype cluster was installed in April 2011.



GVD prototype cluster

- 3 strings × 8 OM
- Cluster DAQ Center
- Optical shore cable



NT200+ is operating now in Lake Baikal

Central part - NT200

8 strings : 192 optical modules

Height x ∅ = 70m x 40m,

Eff. shower volume: 10 TeV ~ 0.2 Mton

NT200+ = **NT200 + 3 outer strings**

228 optical modules

Height x ∅ = 210m x 200m,

Eff. shower volume: 10^4TeV ~ 10 Mton

The Baikal collaboration follows since several years a R&D program for a kilometer-scale Gigaton Volume Detector in Lake Baikal (BAIKAL-GVD). The main scientific goal of GVD is to map the high-energy neutrino sky in the Southern Hemisphere including the region of the galactic center.

GVD design

Configuration

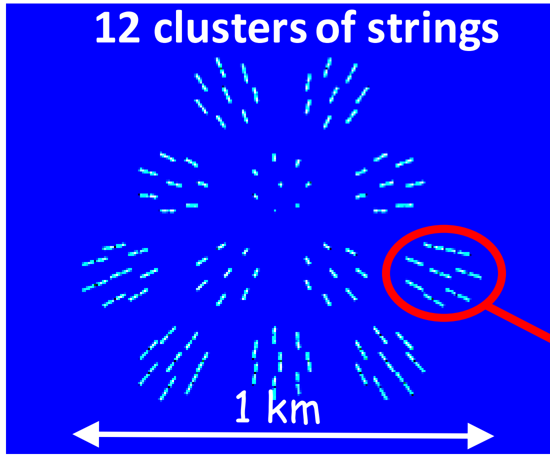
12 clusters ×8 strings

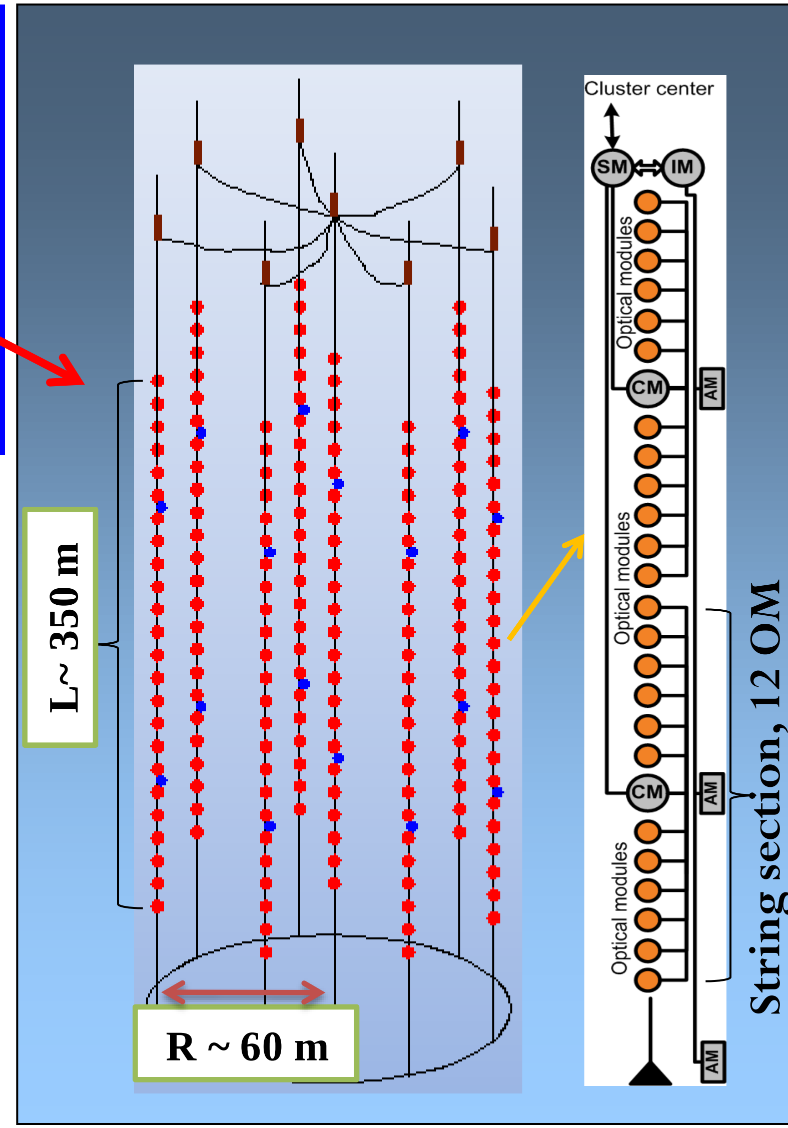
String: 2 section ×12OM

H=300 m

R=60 m,

Z=15 m





Effective cascade volume

Conditions 15/3: at least 15 hit OMs on 3 strings.

Cascade energy >100TeV

$$V_{eff} = 0.1\text{–}0.7\,km^3, \delta(lgE) \sim 0.1, \Delta\theta_{med} \sim 5^o\text{-}7^o$$

Effective muon area

Conditions 6/3: at least 6 hit OMs on 3 strings.

Muon energy *>3 TeV*

$$S_{eff} \sim 0.1\text{–}0.8\,km^2, \delta(lgE) \sim 0.4, \Delta\theta_{med} \sim 0.5^o$$

NEUTRINO PROPERTIES

- Magnetic moment

  Krasnoyarsk reactor (IAE, SPINP)

  $(3\text{-}5) \bullet 10^{-11}\ \mu_B$ (2010)

  Kalinin nuclear plant (ITEP,JINR)

  $(3 - 4.5) \bullet 10^{-11}\ \mu_B$ (2009)

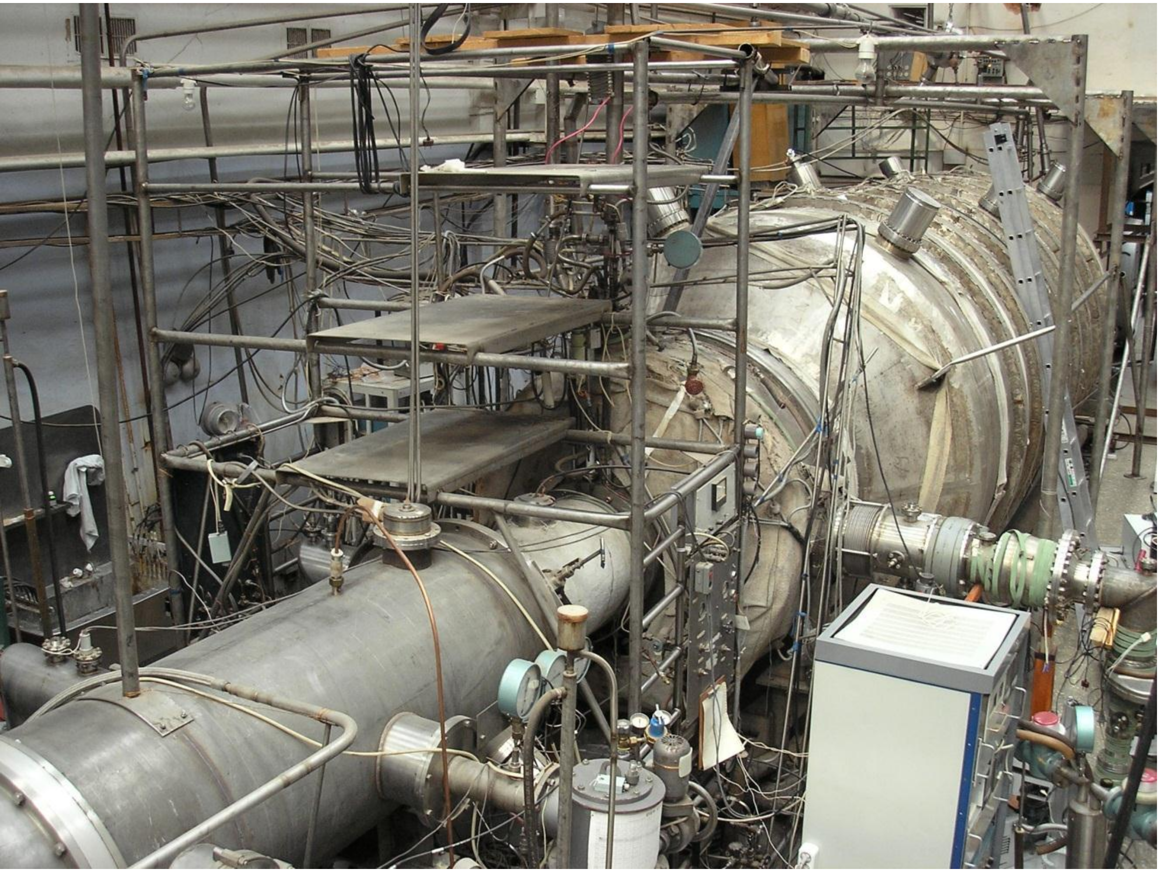
  $1.5 \bullet 10^{-11}\ \mu_B$ (2011)

- Mass

  Troitsk ν-mass II experiment (INR)

  0.8 eV (2010)

Troitsk ν-mass II experiment



From 1993 on, regular measurements of beta spectrum with the "Troitsk nu-mass" set-up.

Results give best upper limit for neutrino mass in direct beta decay experiments.

$m_\nu < 2.05$ eV

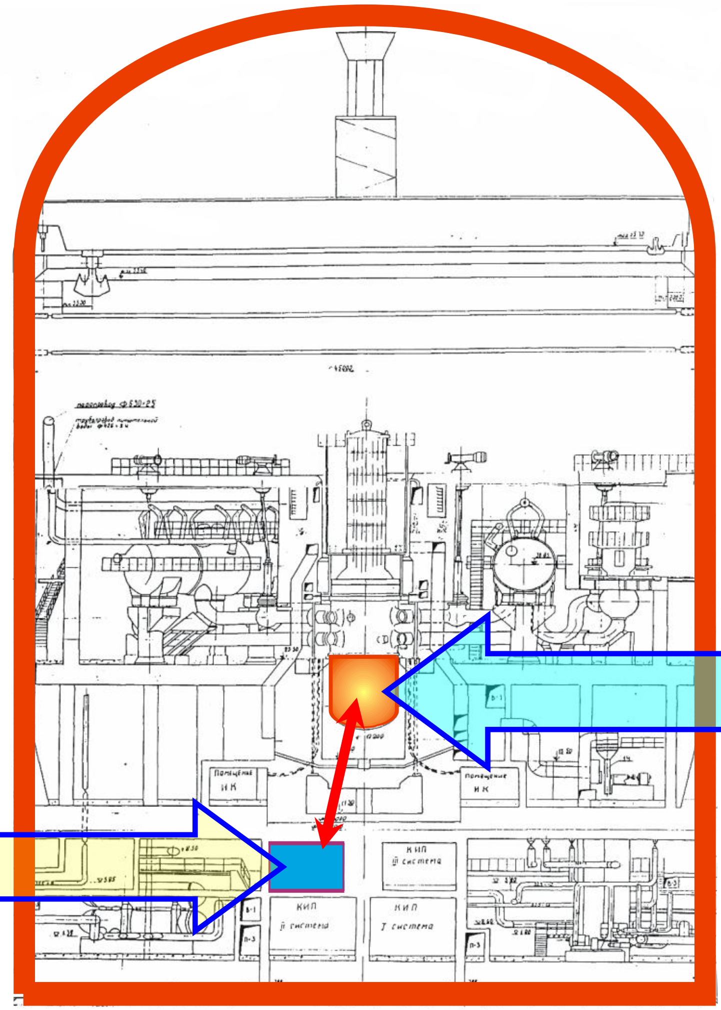
Spectrometer enlarged to obtain better resolution.

New spectrometer resolution about 1.3 eV.

Sensitivity to neutrino mass 0.8 eV

By now, modernization is completed, first run was finished in September and first data is obtained (resolution function of spectrometer)

Overburden
(reactor, equipment, etc.):
~70 m of W.E.



Technological room just under reactor
13.9 m only!
$2.7\times10^{13}\ \nu/cm^2/s$

Reactor #2 of the "Kalininskaya" Nuclear Power Plant
(400 km North from Moscow)
Power: 3 GW_{th}

ON: 315 days/yr
OFF: 50 days/yr

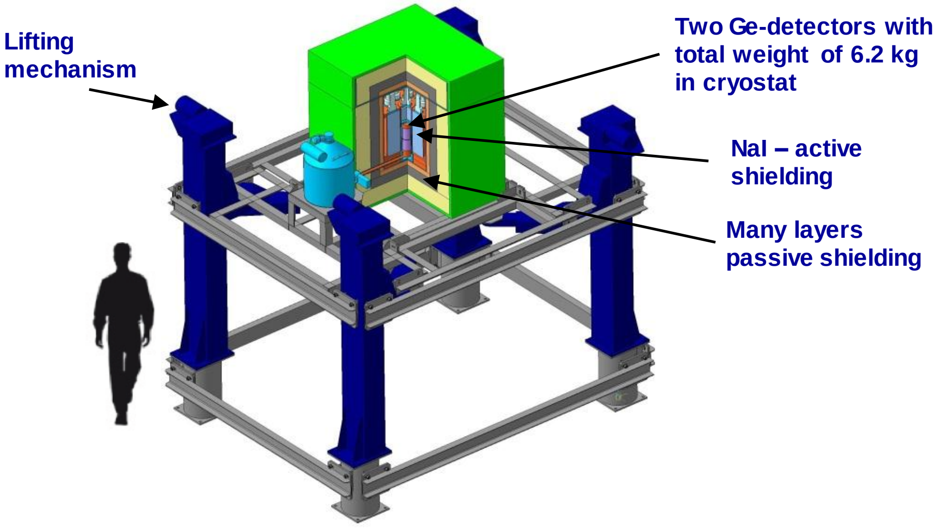
Neutrino experiments at Kalininskaya nuclear power plant (KNPP)

The Project GEMMA

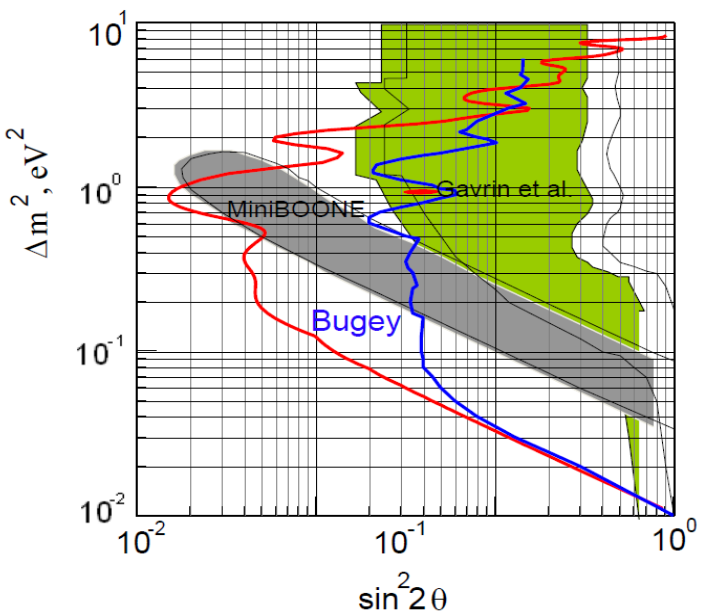
The best world limit on value of neutrino magnetic moment was obtained in GEMMA I experiment:
$\mu < 2.8\text{x}10^{-11}$ Bohr magneton

The neutrino magnetic moment is very sensitive to New physics beyond the Standard Model

Now the experiment GEMMA II is in progress
Its sensitivity is $(1.0 \div 1.5)\text{ x }10^{-11}$ Bohr magneton



Spectrometer GEMMA II with lifting mechanism



Estimated limits (red) on oscillation parameters from DANSS measurements during one year at distances 11 and 16 m from reactor core

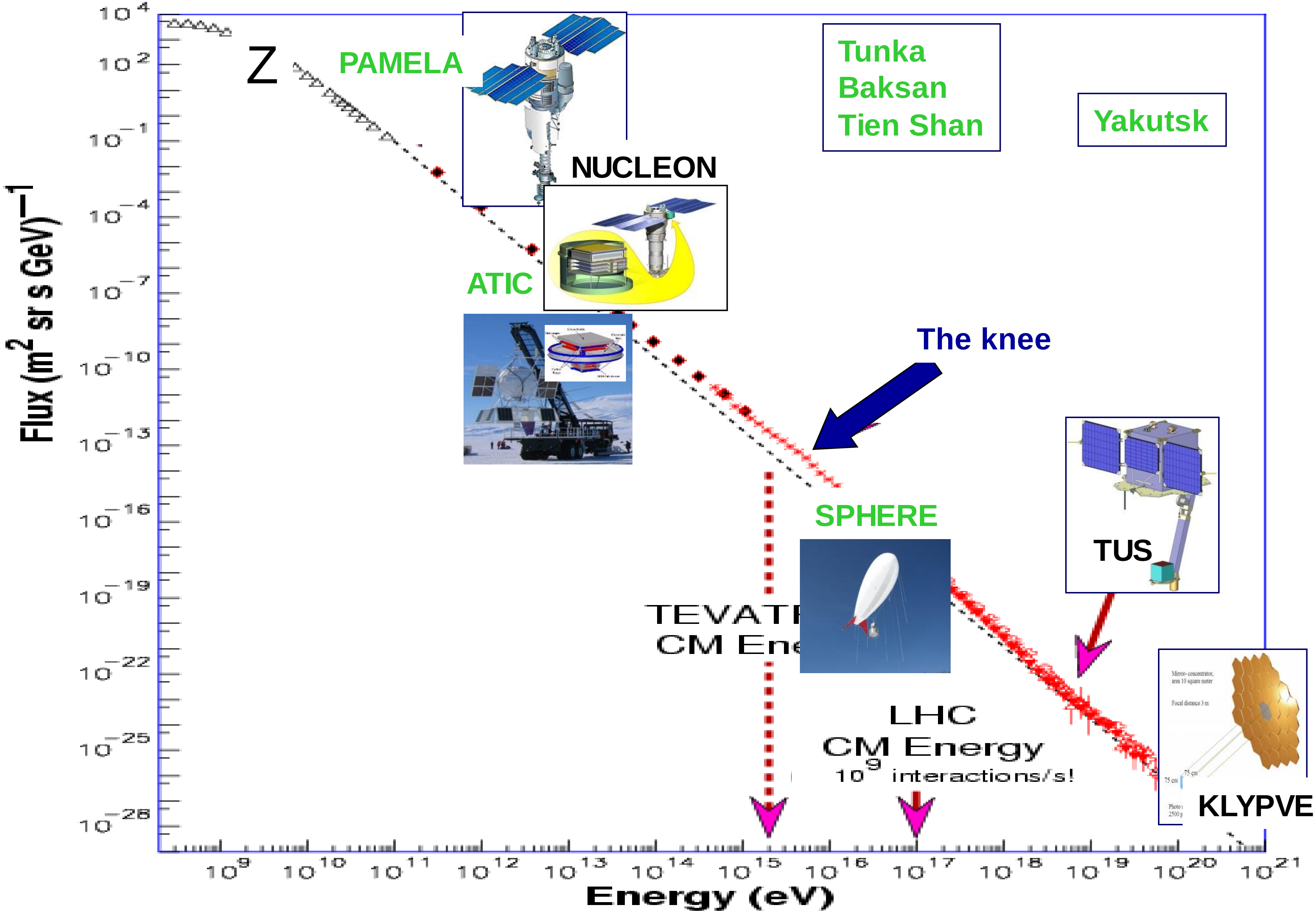
The Project DANSS

The technological goal of the project is to create a solid scintillator spectrometer able to detect reactor antineutrinos and to measure the reactor parameters:

1. Thermal reactor power with accuracy of 2 % in one day of measurements
2. Amount of produced ^{239}Pu with accuracy of (3-4)% in 5 days
3. Tomography of the reactor core
4. Consistency of fuel composition before and after refueling.

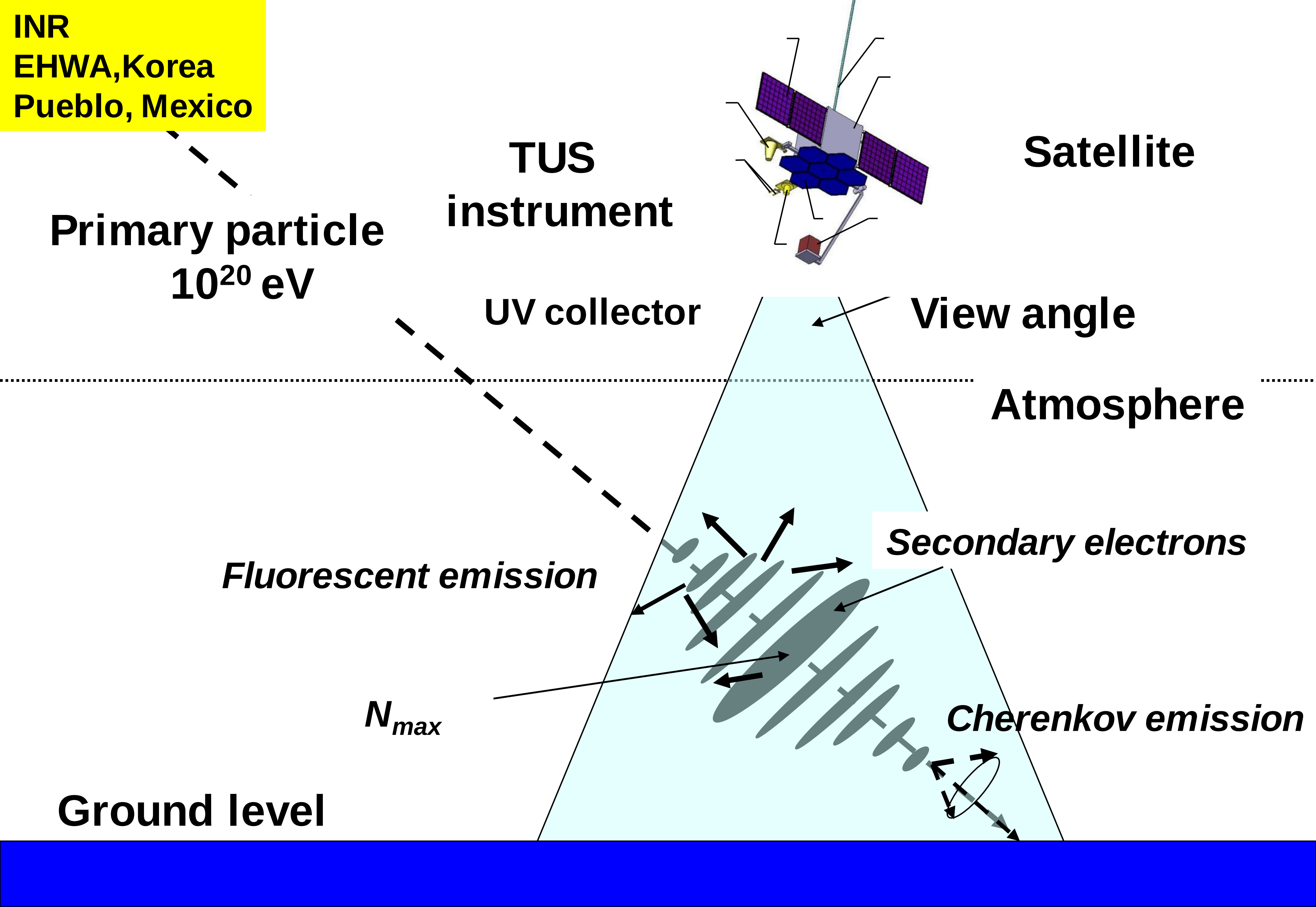
The scientific goal of the project DANSS is searching for short - baseline neutrino oscillation connected with possible existence of sterile neutrinos.

Russian contributions to high-energy cosmic ray experiments – status 2008

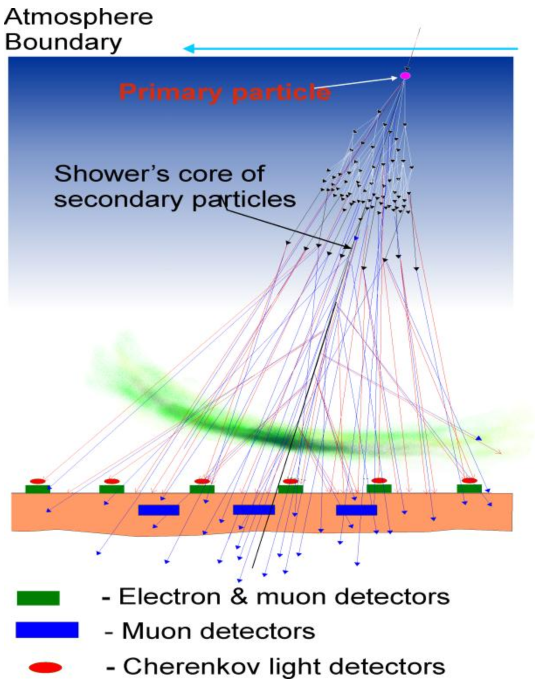


“Mikhailo Lomonosov” 2011

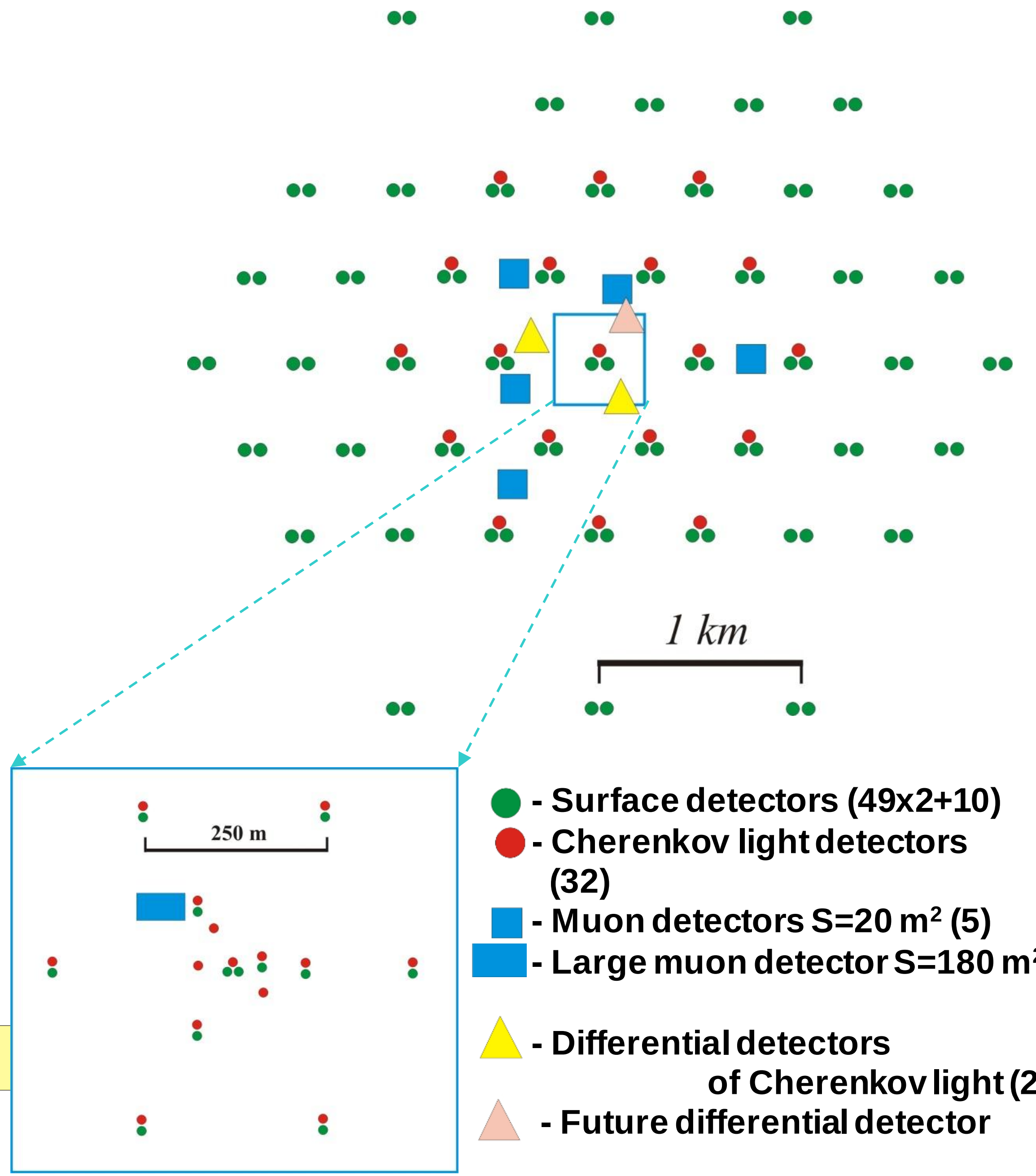
MSU
JINR
INR
EHWA,Korea
Pueblo, Mexico



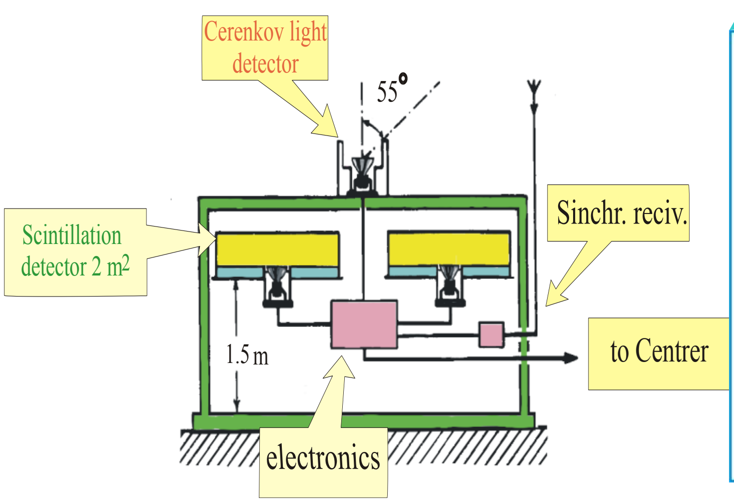
Extensive Air Shower (EAS)



Yakutsk EAS Array (area S=12 km²)



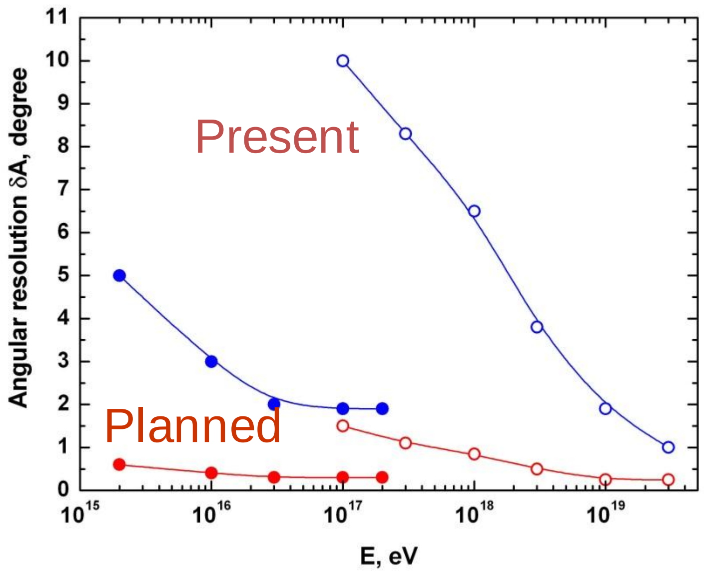
Single array station



Modernization of Yakutsk EAS array (2007-2011)

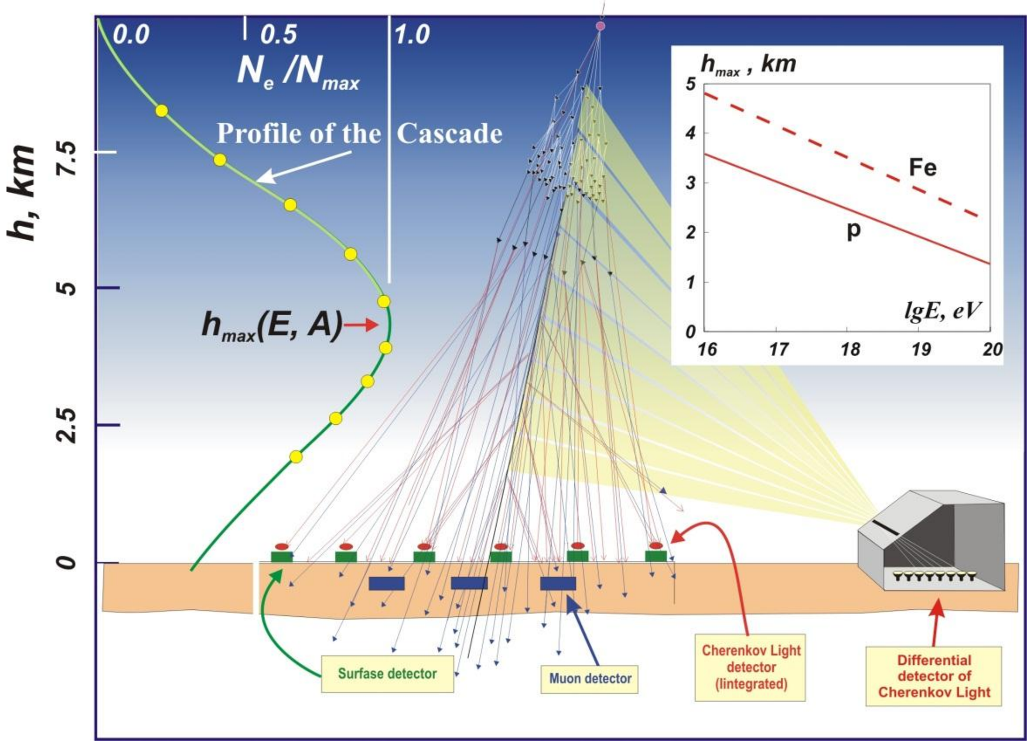
Detector synchronization will be improved from 100 ns up to 10 ns

This will provide better angular resolution:



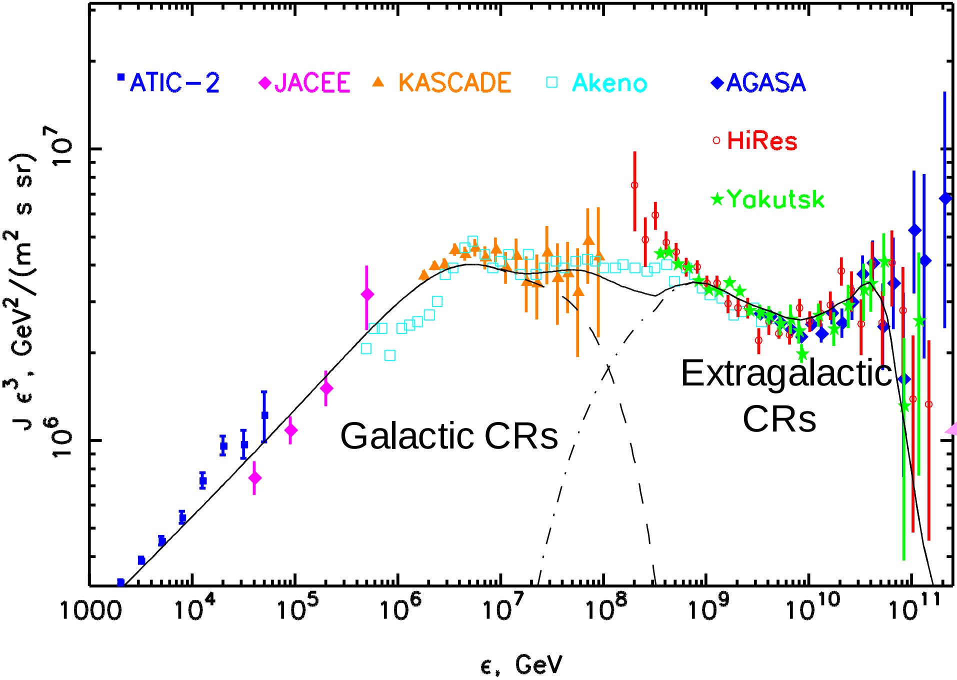
Supplement by new detectors:

differential Cherenkov light detectors to study Cosmic Ray composition



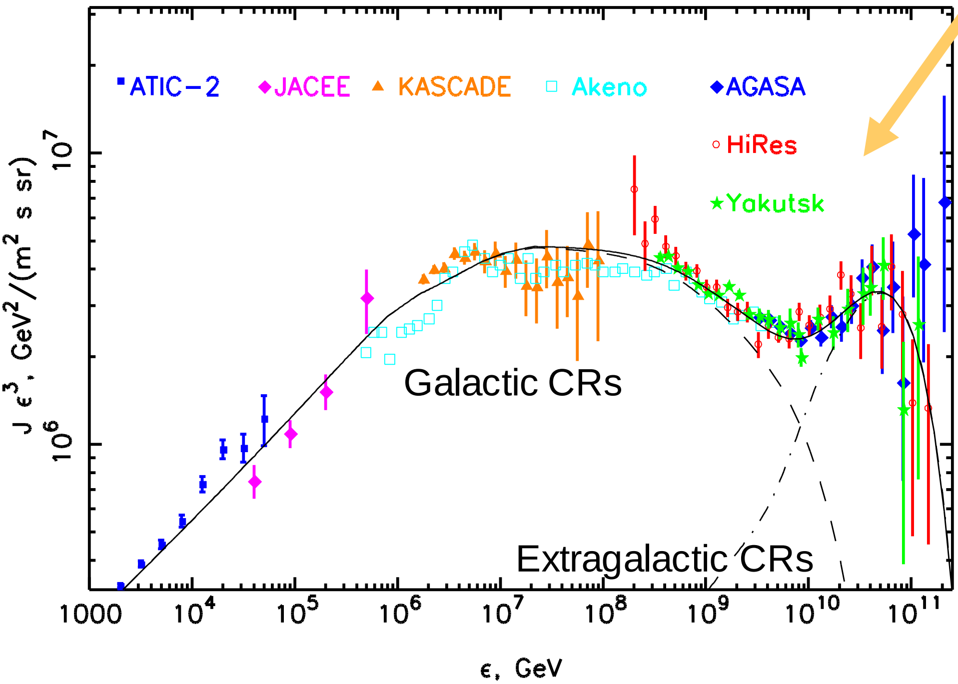
Cosmic Ray spectrum and composition

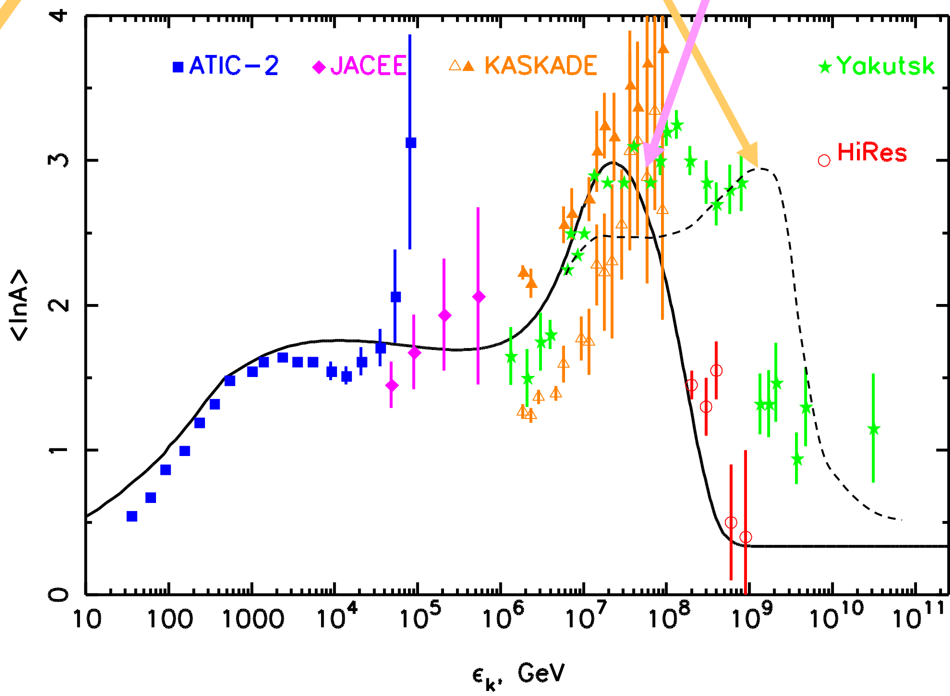
Precise measurement of CR spectrum and composition at 10^{17}-10^{19} eV is needed to find transition region between galactic and extragalactic CR components



CRs from Galactic SuperNova Remnants + extragalactic CRs

Galactic CRs (from SNRs + reacceleration) + extragalactic CRs



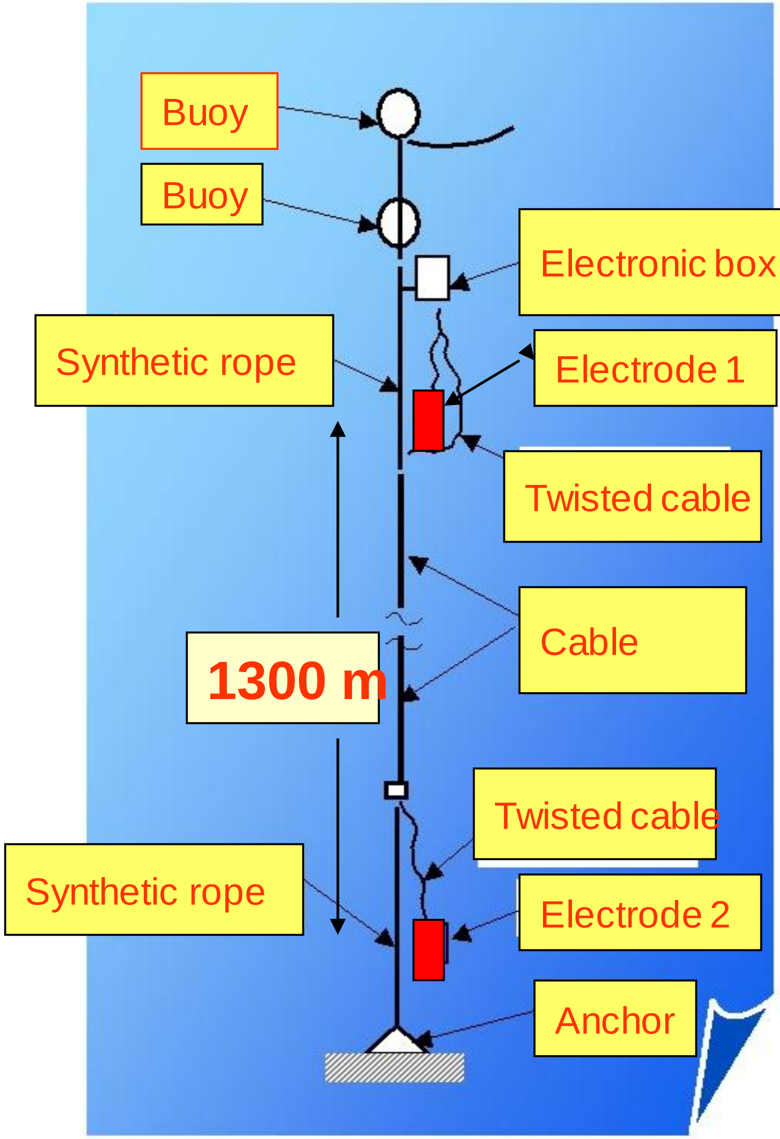


ApP and Interdisciplinarity

- The earth electric field into lake Baikal

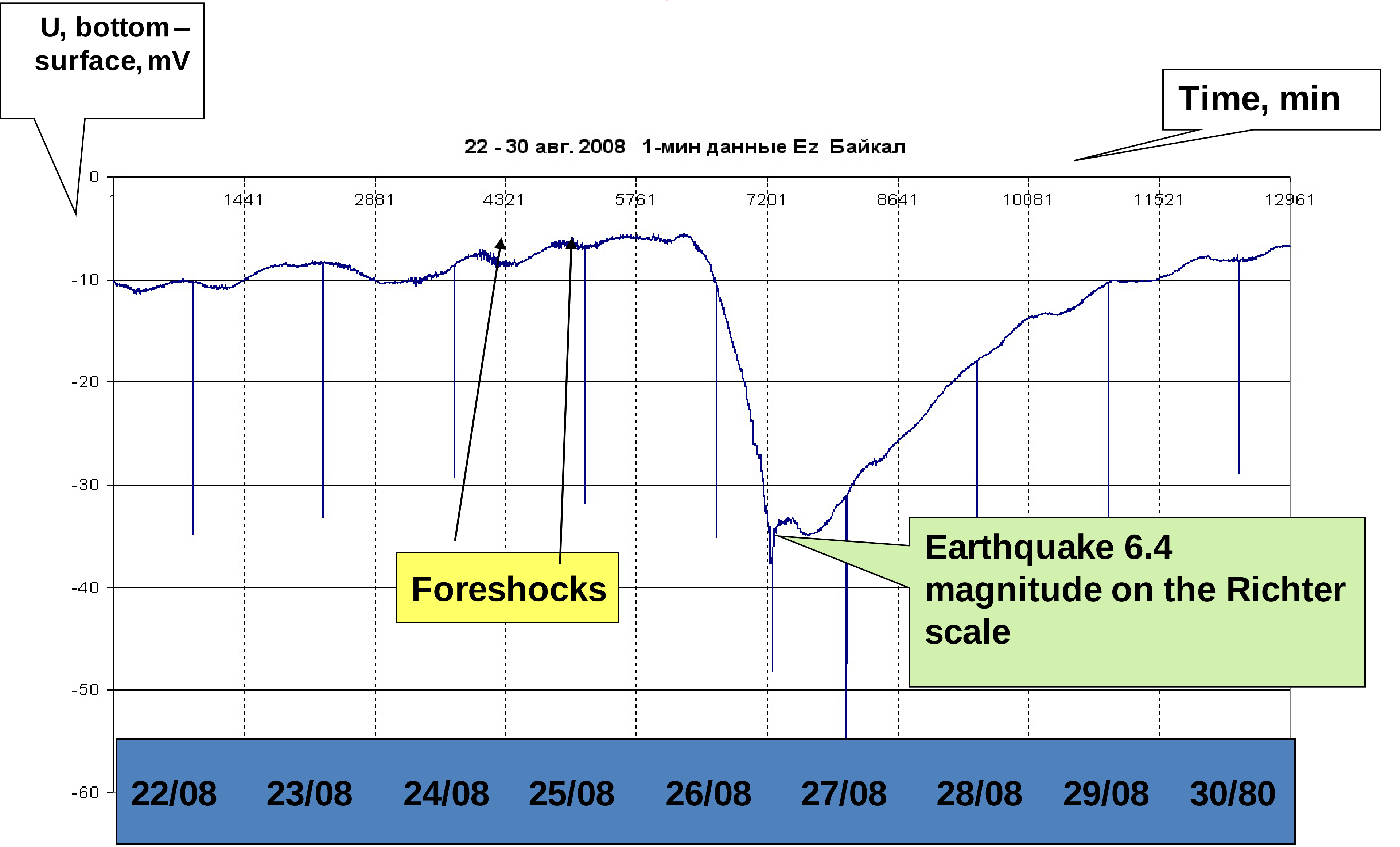
  was investigated in the frame Baikal neutrino experiment. (Irkutsk University, INR Moscow, …)
- The strong response of electric field into lake Baikal on earthquake was recorded.

Geophysical Mooring

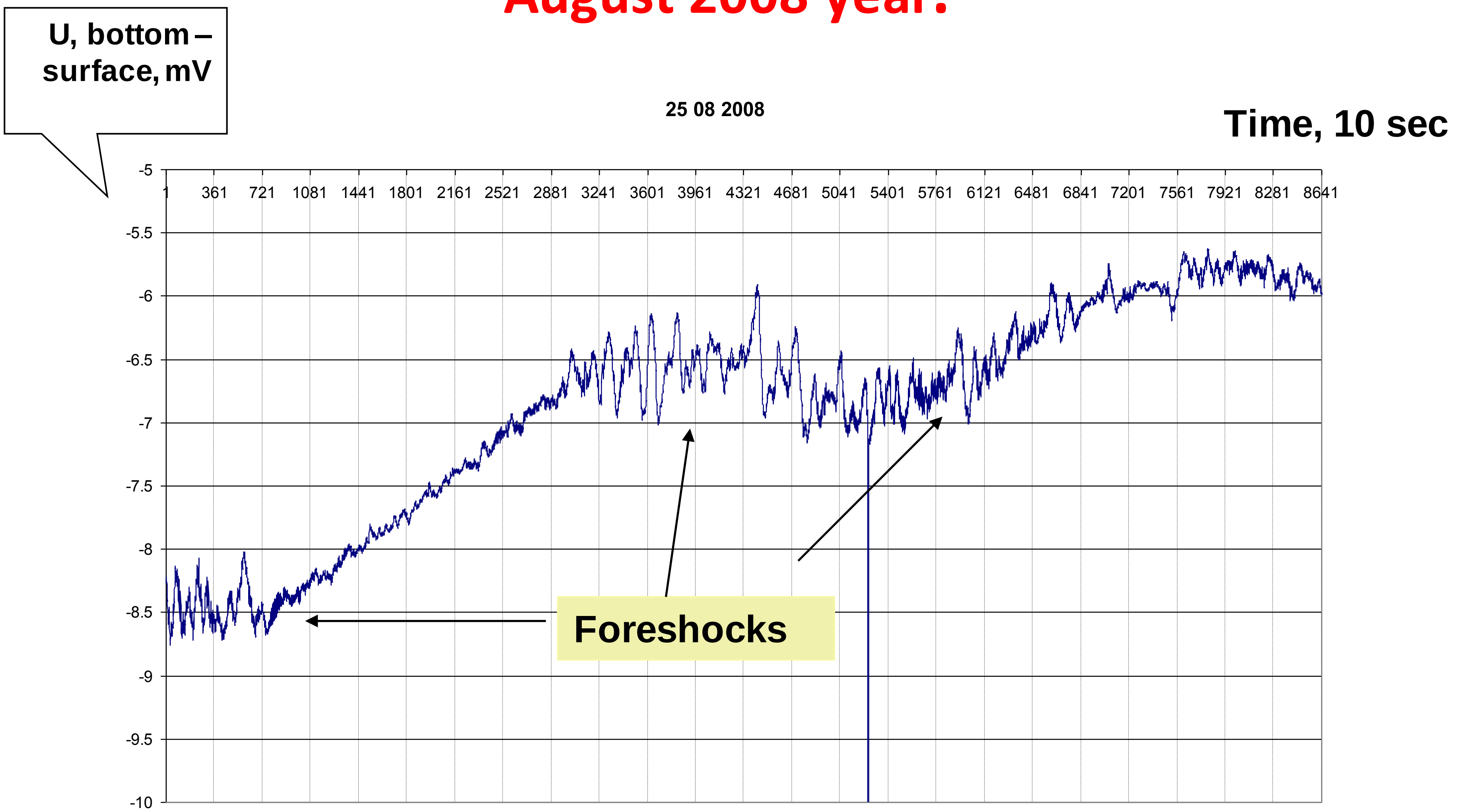


Surface – bottom electric potential difference

22 – 30 August 2008 year.



Surface – bottom electric potential difference **25 August 2008 year.**

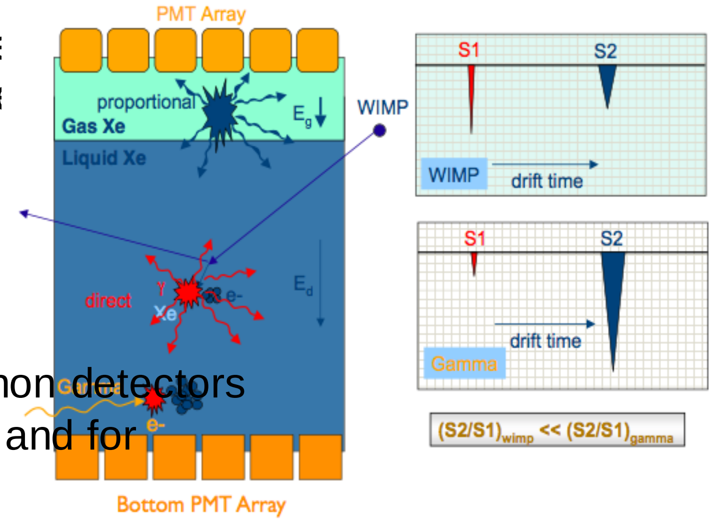


ApP and Development of the technologies

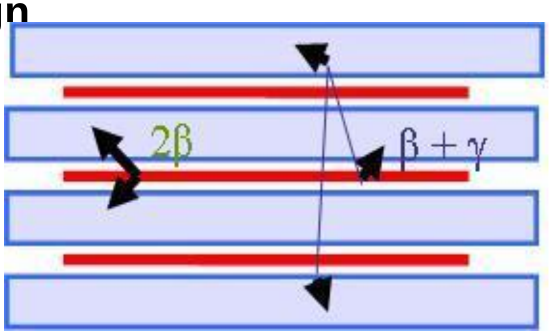
**1. Development of the technologies for neutrino dete
and Dark matter searches on the base of liquid nobl**

RED collaboration
(NRC “Kurchatov Institute”, ITEP, MEPhI, INR MSU)

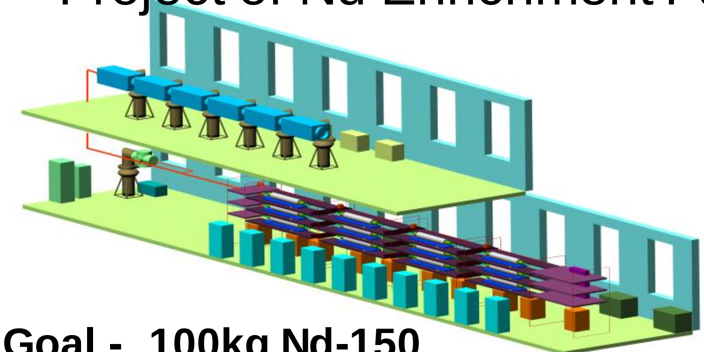
Goal:
Development of large-scale (100-1000 kg) two-face xenon detectors
for neutrino coherent scattering on nuclei investigation and for
Dark matter searches



**2. Neutrinoless double beta-decay searches in 150Nd
development of the enriched isotope production met
and experiment design**



Project of Nd Enrichment Facility



**Goal - 100kg Nd-150
60%**

Geiger mode multy-pixel avalanche photodiode
First development was done by Golovin (Moscow)

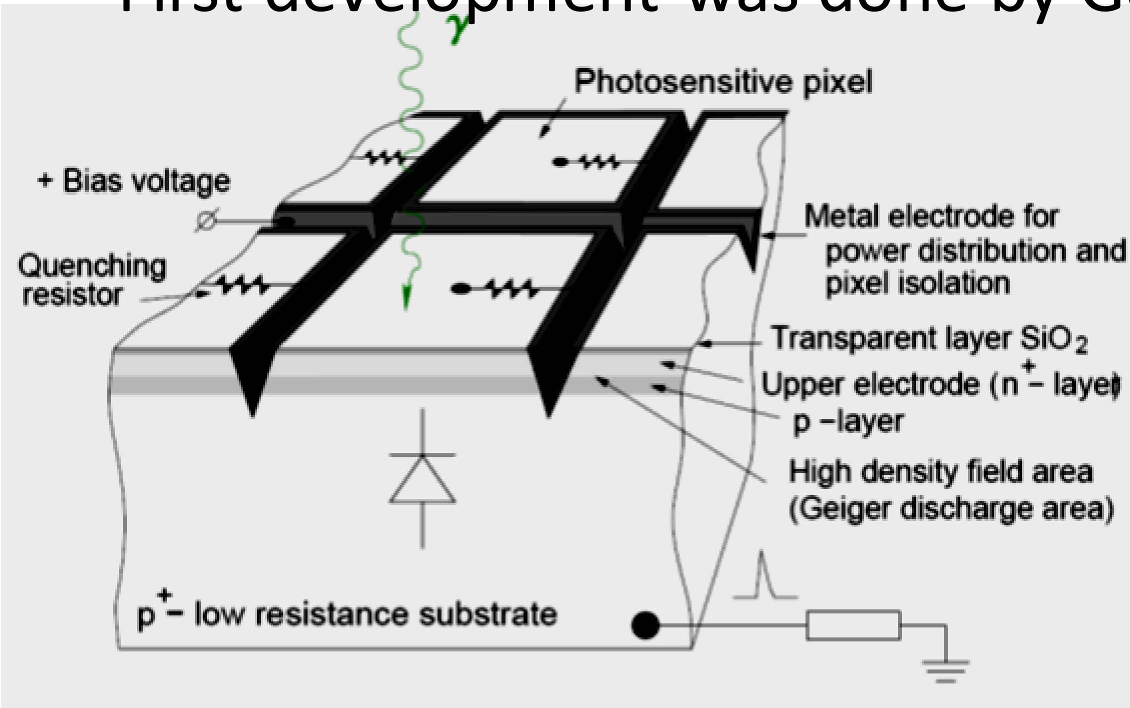
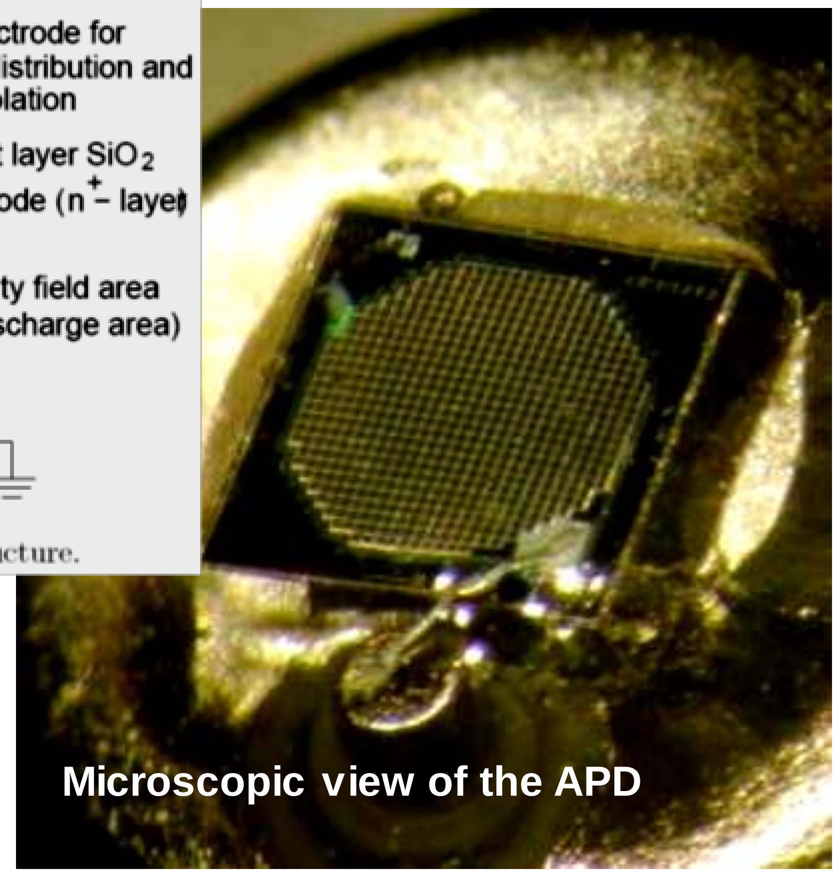
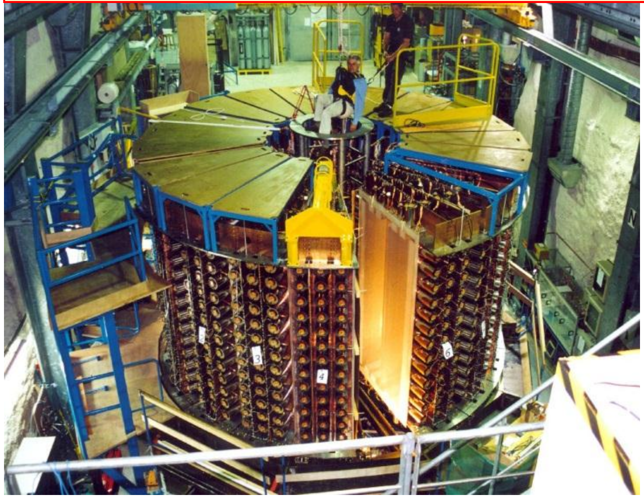


Figure 2: The schematic view of the MRS photodiode structure.

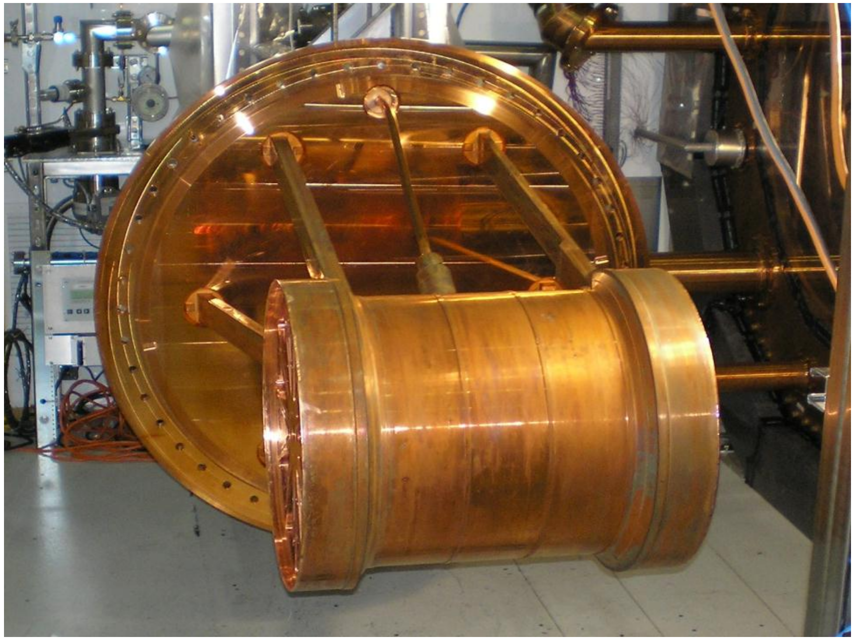


Double beta decay (NEMO-3, DEVIS, SuperNEMO, EXO, GERDA, MAJORANA, EXCITED STATES, R&D)

The NEMO3 detector (…, ITEP, JINR)



The EXO-200 detector (…, ITEP)



$0\nu\beta\beta$ of ^{100}Mo:

$T_{1/2}(0\nu\beta\beta) > 1.1 \cdot 10^{24}$ y @90% C.L.

⇓

$\langle m_\nu \rangle < 0.29 - 0.93$ eV

Two neutrino decay is detected for ^{48}Ca, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{130}Te, ^{150}Nd.
In ^{100}Mo and ^{150}Nd transition to 0^+ excited state of daughter nuclei is detected too (such experiments were originally proposed in ITEP).

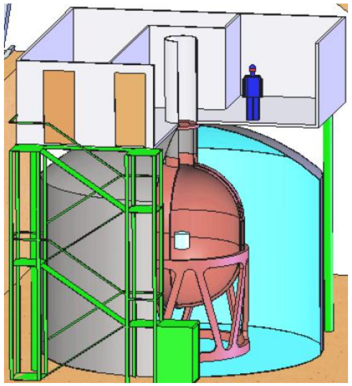
<u>EXO-200 experiment.</u> First time 2ν decay of ^{136}Xe is detected:

$T_{1/2}(^{136}Xe) =$
$[2.11 \pm 0.04 (stat) \pm 0.21(syst)] \times 10^{21}$ y

ALL ENRICHED ISOTOPES ARE PRODUCED IN RUSSIA

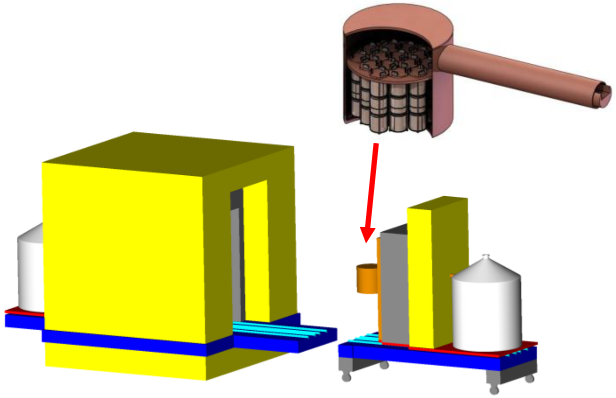
Main goal of future experiments (~ 2015-2020) is $<m_\nu>$ ~ 0.01 – 0.1 eV

GERDA (…, INR, ITEP, JINR, KIAE)

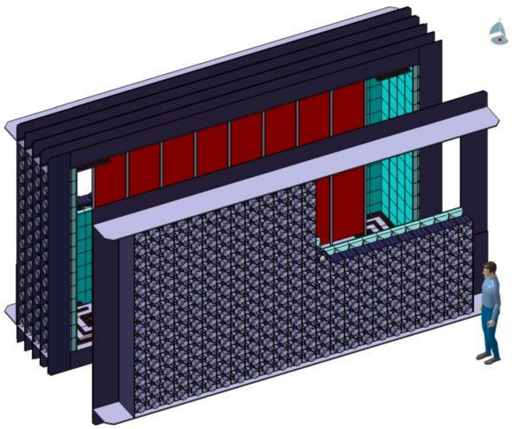


GERDA-MAJORANA:
1000 kg of ^{76}Ge

MAJORANA (…, ITEP, JINR)



SuperNEMO (…, ITEP, JINR)



100 kg of ^{82}Se

EXO (…, ITEP)

1000 kg of ^{136}Xe

ALL ENRICHED ISOTOPES WILL BE PRODUCED IN RUSSIA

Summary

- Russia has a long and strong tradition in APP.
- During two recent decades APP in Russia was under a disadvantage, many plans canceled, a lot of young researchers left the field or the country.
- Nevertheless, main research centers and facilities have survived.
- Some exciting experiments to come.
- Several unique infrastructures are available (Baikal, Baksan, etc).
- Encouraging national plans exist, foreign collaborators are welcome.
- Close collaboration with Europe was successful and forms a natural component of the Russian APP strategy.