ASPERA Workshop

The next generation projects in Deep Underground Laboratories

Deep underground laboratories in Russia

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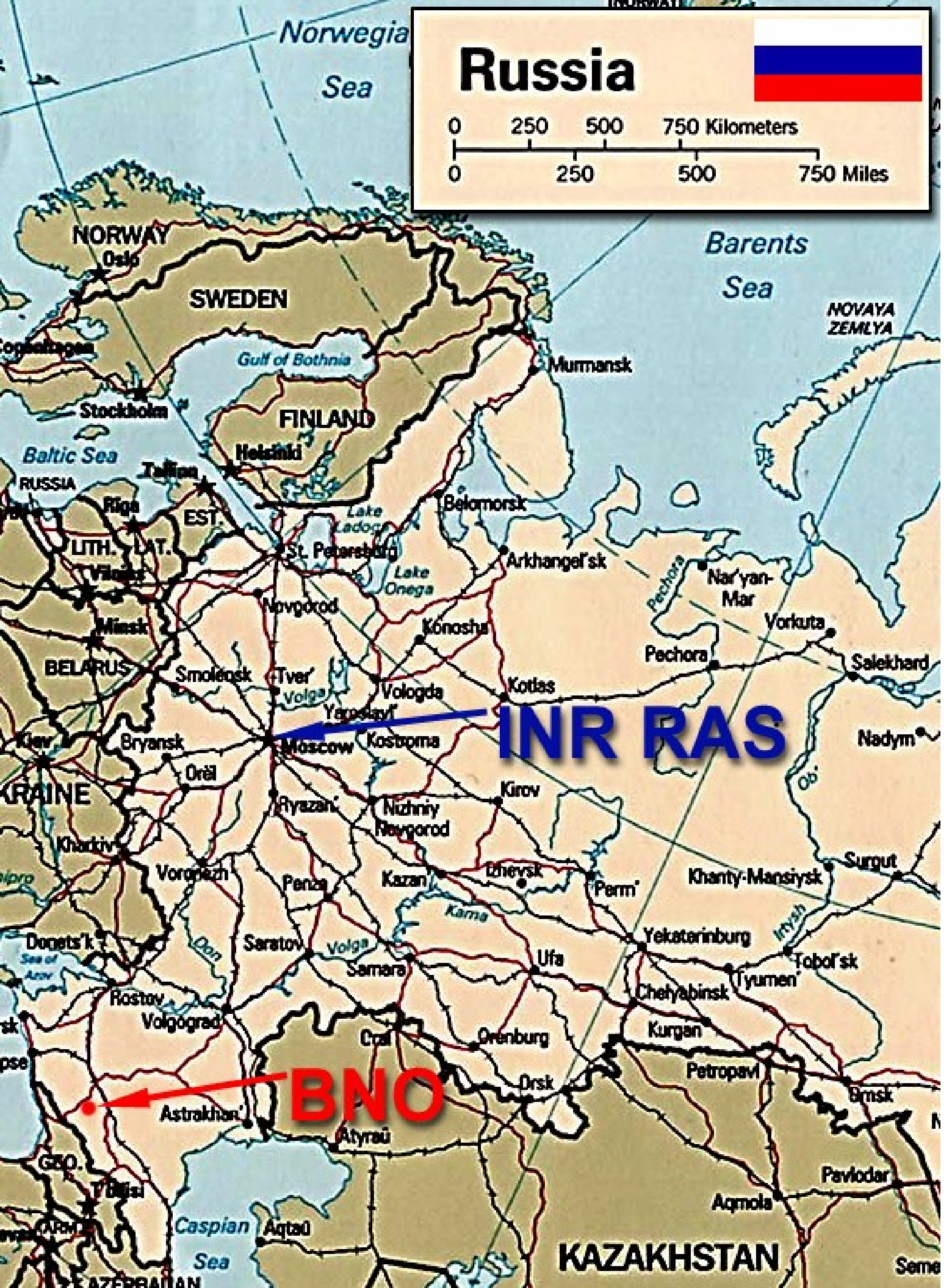
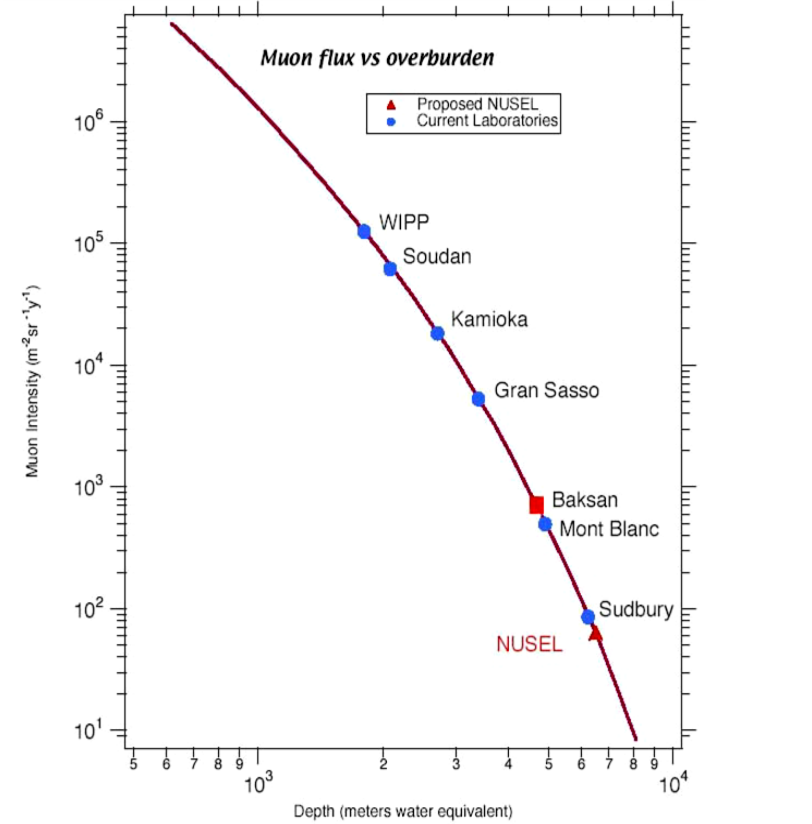
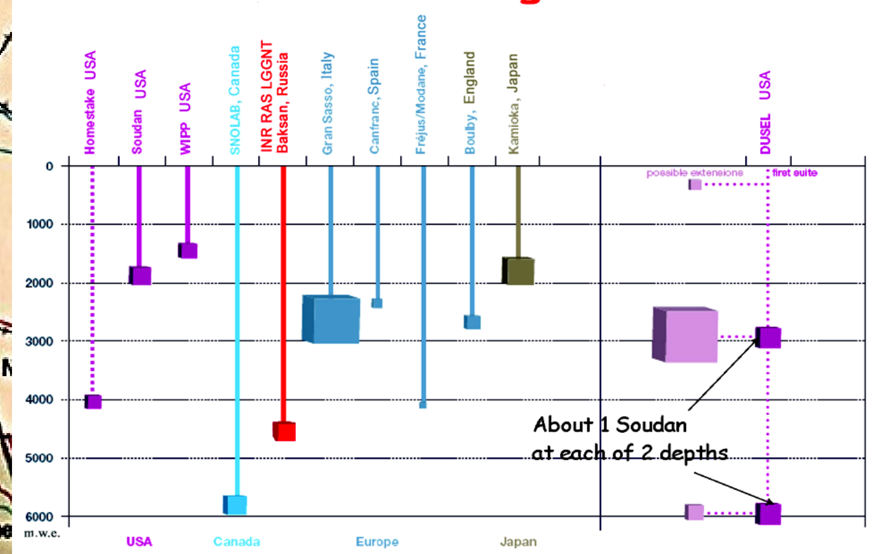


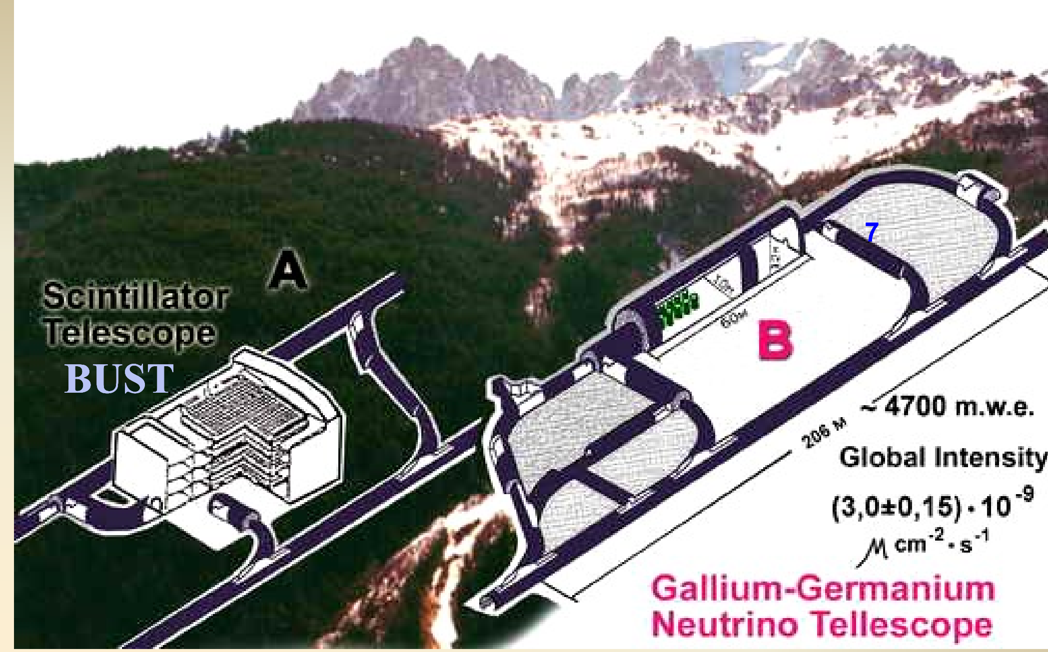


Science Underground

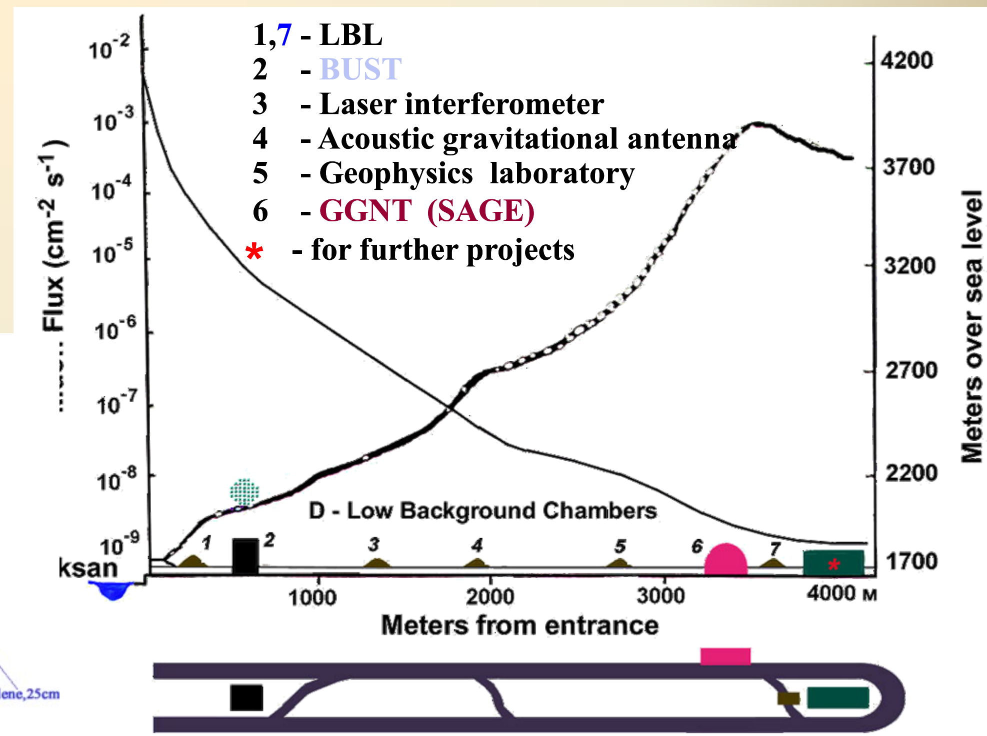


Baksan Neutrino Observatory

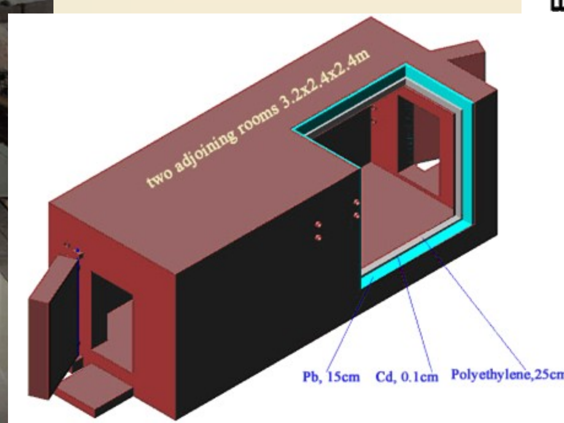

BUST 17m×17m×11m
~850 m.w.e.


Scintillator
Telescope
BUST
A
B
7
60м
206 м
~4700 m.w.e.
Global Intensity
(3,0±0,15)·10^{-9}
μ cm^{-2}·s^{-1}
Gallium-Germanium
Neutrino Tellescope


GGNT 60m×10m×12m
~4700 m.w.e.


1,7 - LBL
2 - BUST
3 - Laser interferometer
4 - Acoustic gravitational antenna
5 - Geophysics laboratory
6 - GGNT (SAGE)
* - for further projects
Flux (cm^{-2} s^{-1})
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
4200
3700
3200
2700
2200
1700
Meters over sea level
D - Low Background Chambers
1
2
3
4
5
6
7
ksan
1000
2000
3000
4000 м
Meters from entrance


LBL 3.2m×2.4m×2.4m
~5000 m.w.e.

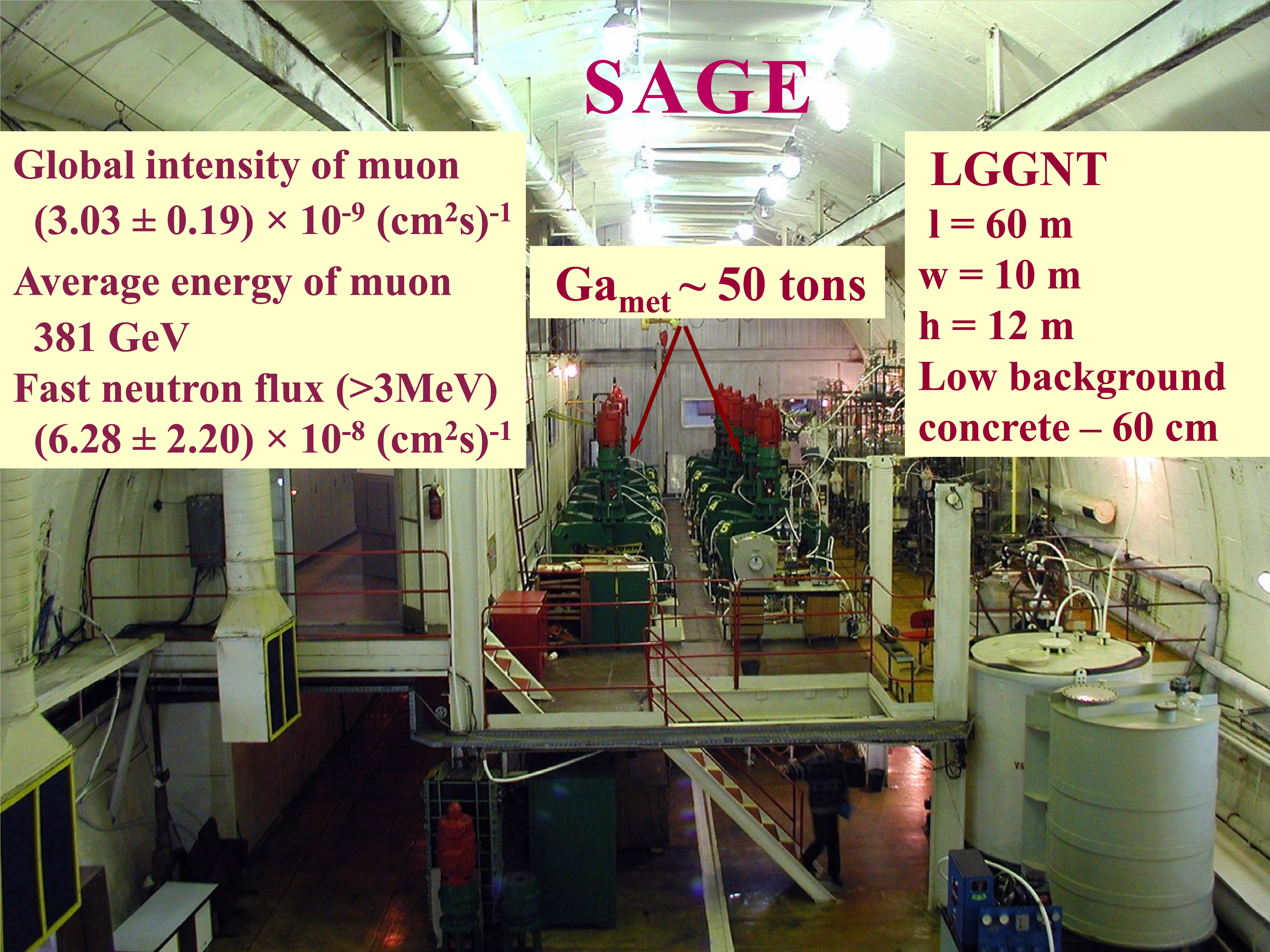

two adjoining rooms 3.2x2.4x2.4m
Pb, 15cm
Cd, 0.1cm
Polyethylene,25cm

SAGE

Global intensity of muon
$(3.03 \pm 0.19) \times 10^{-9}\ (\mathrm{cm}^2\mathrm{s})^{-1}$
Average energy of muon
381 GeV
Fast neutron flux (>3MeV)
$(6.28 \pm 2.20) \times 10^{-8}\ (\mathrm{cm}^2\mathrm{s})^{-1}$

$\mathrm{Ga}_{met} \sim 50$ tons

LGGNT
l = 60 m
w = 10 m
h = 12 m
Low background concrete – 60 cm



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

Ga experiments

have developed the technology of preparation of intensive reactor-produced neutrino sources which are ideal tool for calibration of low energy solar neutrino detectors and which also can be used for investigation of neutrino properties

	GALLEX		SAGE	
	m(Ga)=30 t		m(Ga)=13 t	
Source	^{51}Cr -1	^{51}Cr -2	^{51}Cr	^{37}Ar
Activity, MCi	1.714	1.868	0.517	0.409
Measured production rate p (^{71}Ge/d)	11.9 ±1.1 ±0.7	10.7 ±1.2 ±0.7	14.0 ±1.5 ±0.8	$11.0^{+1.0}_{-0.9} \pm 0.6$
$R = (p_{meas}/p_{pred})$	0.95±0.11	0.81±0.11	0.95±0.12	0.79±0.10
R_{comb}	0.88 ± 0.08		0.86 ± 0.08	

$$R = p_{\mathrm{measured}}/p_{\mathrm{predict}} = 0.87 \pm 0.05$$

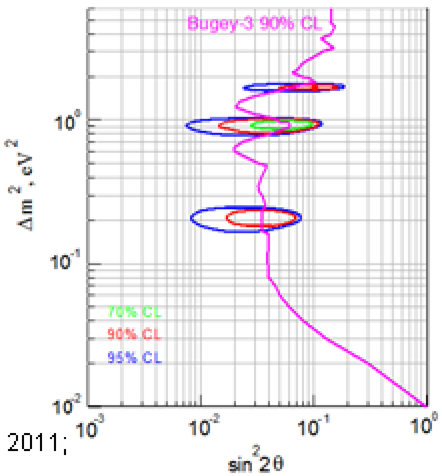
The unexpectedly low capture rate of neutrinos in Ga source experiments can be explained in frame of neutrino oscillations by assuming transitions from active to sterile neutrinos occur with Δm^2 about 1eV^2.

This interpretation agrees with the results of a number of reactor and accelerator experiments.

Spectral reactor experiments joint analysis

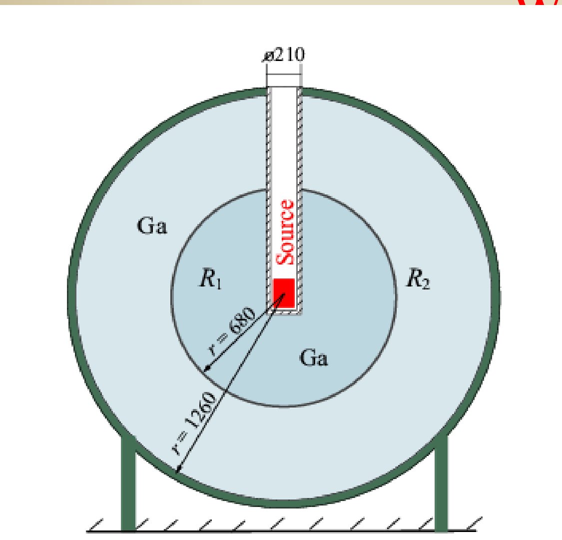
Experiment	Distance, m	Δm^2, eV^2	$\sin^2 2\theta$
Gösgen	38, 46, 65	0.88	0.1-0.06
Rovno	18, 25	0.9	0.09
Bugey-3	15, 40, 95	0.45-1.7	0.09-0.03
Savannah River	18, 24	3.84	0.085

$\Delta m^2 = 0.93$ eV^2,
$\sin^2 2\theta = 0.064$



V. Sinev preprint INR RAS-1278 (rus) , 2011;
ArXive: 1103.2452 [hep-ex]

New Ga source experiment



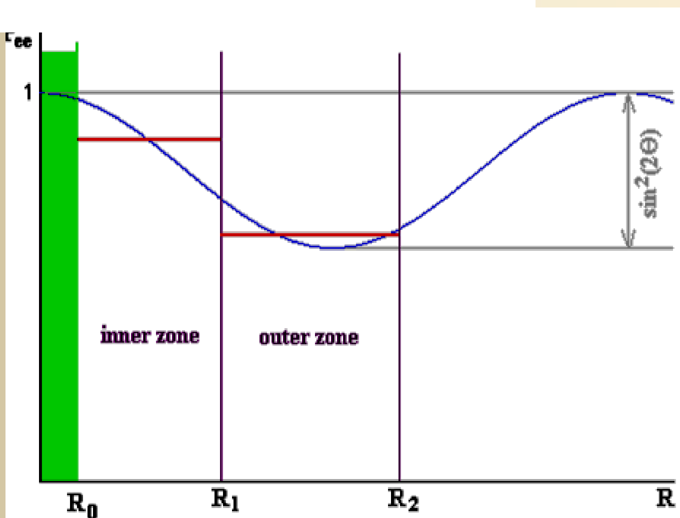
e propose to place a very intense source of ^{51}Cr (3MCi) the center of a 50-tonne target of gallium metal that is vided into two zones and to measure the neutrino pture rate in each zone [arxiv:1006.2103v2]

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]*}

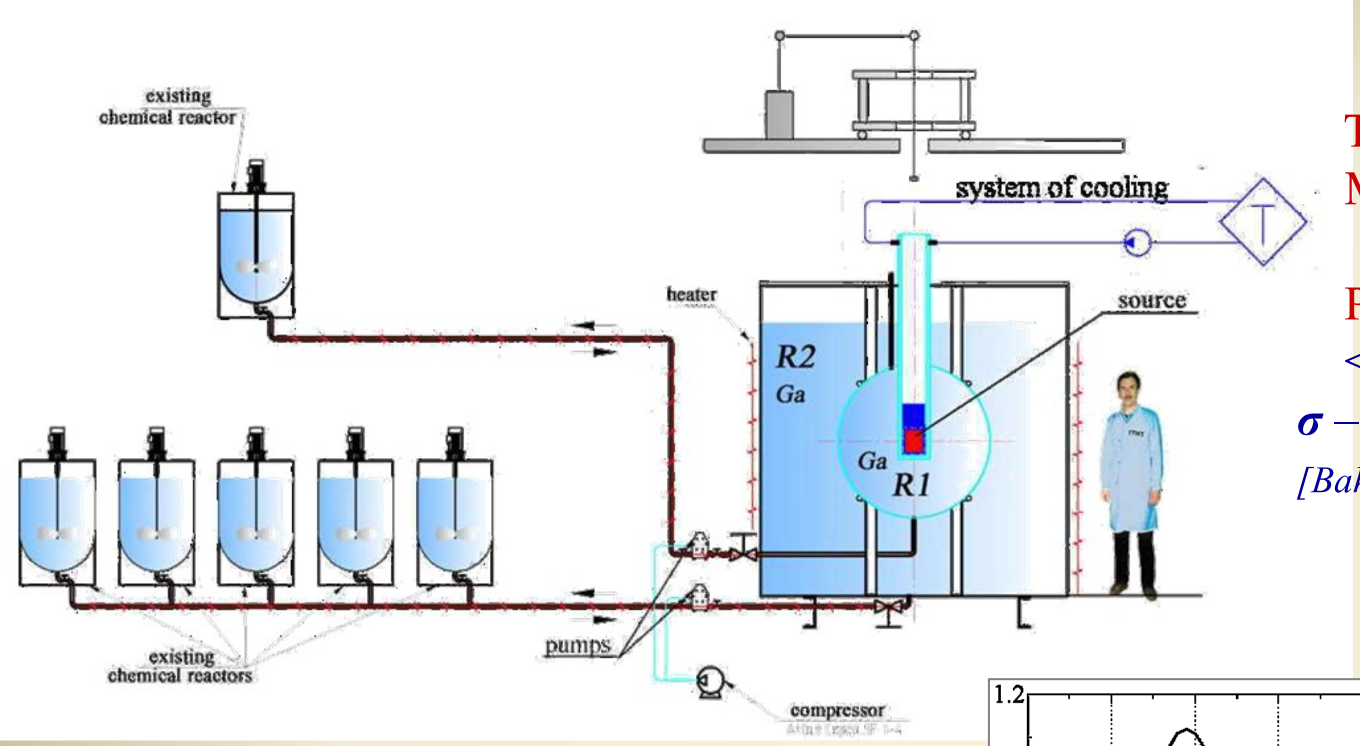


The evidence of nonstandard neutrino properties:

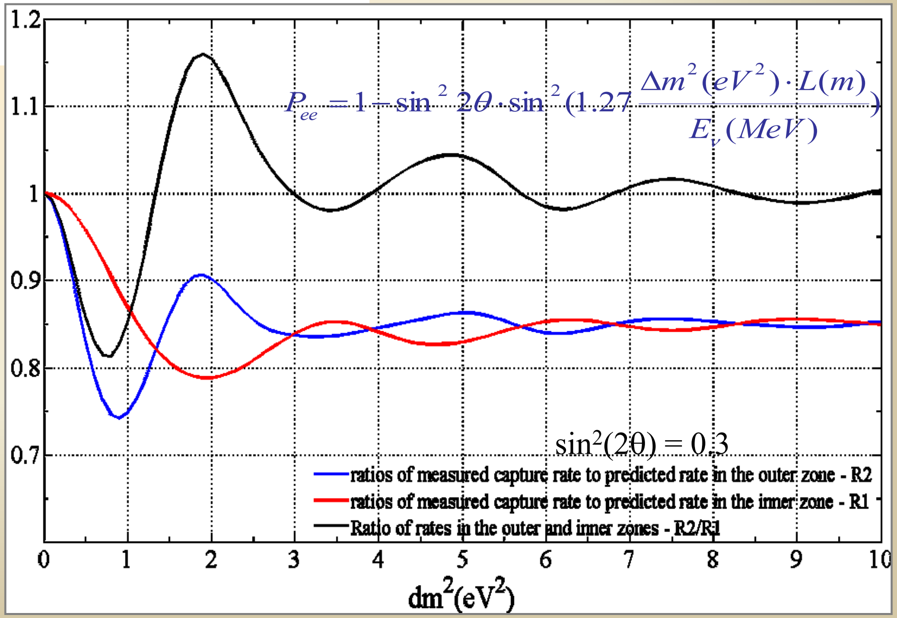
- there is a significant difference between the capture rates in the two zones
- the average rate in both zones is considerably below the expected rate

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

Sketch of two zone Ga experiment

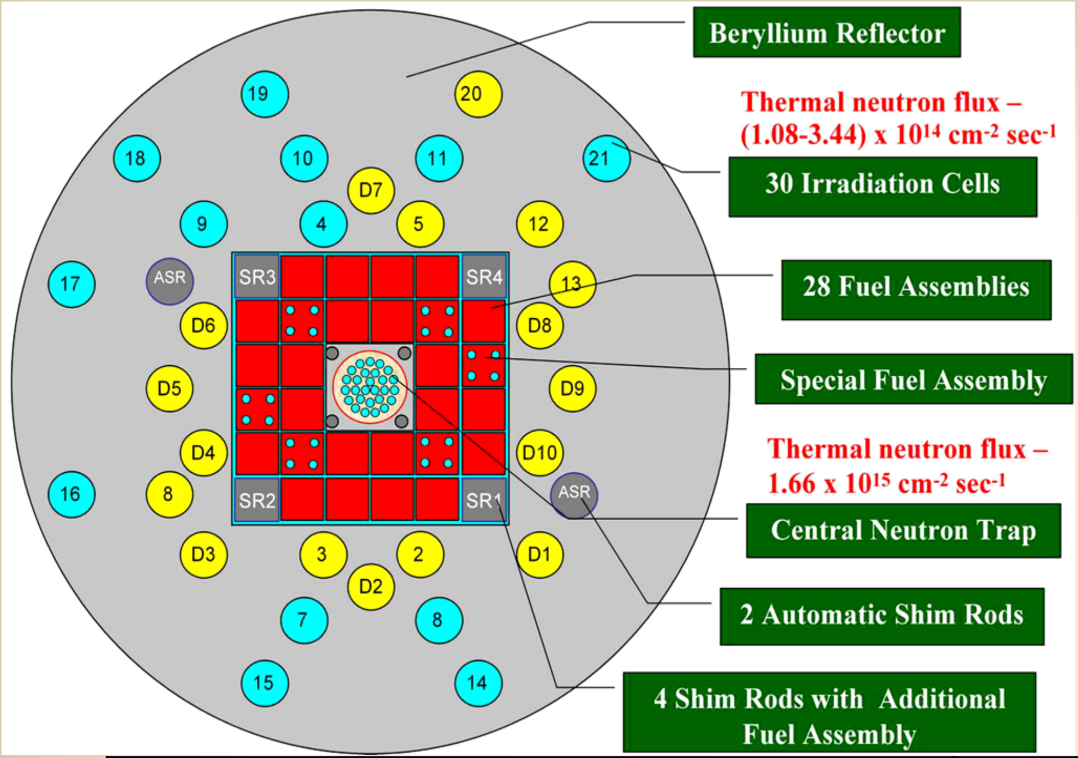


Target: 50 т Ga metall
Masses of the zones:
8 t and 42 t
Path length in each zone:
<L> = 55 cm
σ – cross sect. {5.8×10^{-45} cm^2
[Bahcall PRC.56, 1997] }

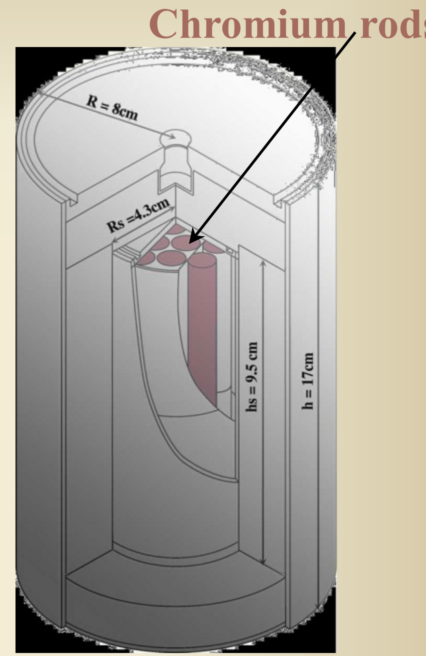


10 measurements of 9 days each
(9 days of source exposure and
1 day when the source is placed in the calorimeter)
Total number of the captures ~ 1650 in 1 zone
Total number of ^{71}Ge pulses ~ 873
Production rate from solar neutrinos is constant:
1.18 ^{71}Ge at. in 8 tonne of Ga and
6.20 ^{71}Ge at. in 42 tonne of Ga
Statistical + systematic uncertainties:
4.5% in 1zone, 3.7% in the entire target
(With the cross section uncertainty: 5.5 % and 4.8%)

Reactor SM Cross-section



Sketch of source



Loading of neutron trap of reactor SM	Version III.5 of chromium irradiation mode	Version III.6 of chromium irradiation mode
	11+1+11+5+11+1+11+12	12+1+12+5+12+1+12+1+12
	50,4 eff.d	**54.0 eff.d**
27 cells with 3 rods with ∅8×95 mm each Mass of chromium in the cell 98,8 g Volume of the cell - 14,3 cm^3 Total mass of chromium 2669 g Density of thermal neutron flux 5,0 x 10^{14} cm^{-2} s^{-1} Coeff. rez. self-shielding 0,899	**^{51}Cr activities: Specific 1080 Ci/g Total: 2,85 MCi**	**^{51}Cr activities: Specific 1150 Ci/g Total: 3,06 MCi**

The search for sterile neutrinos is now a field of most active investigation

Accelerator experiments (NuMu- antiNuMu flux)

MicroBooNE LArTPC detector designed to advance LAr R&D and determine whether the MiniBooNE low-energy excess is due to electrons or photons. Approximately 70-ton fiducial volume detector, located near MiniBooNE (Received Stage-1 approval at Fermilab and initial funding from DOE and NSF.
May begin data taking as early as 2011.
Currently, a 170L LAr TPC, called ArgoNeut, is taking data in the NuMI beam in front of the MINOS detector

BooNE involves moving MiniBooNE or building a 2nd detector at a distance of ~200 m from the BNB target. With two detectors the systematic errors will be greatly reduced and will allow precision appearance and disappearance searches for neutrinos & antineutrinos
OscSNS would involve building a "MiniBooNE-like" detector with higher PMT coverage at a distance of ~60 m from the Spalation Neutron Source (SNS) beam stop at ORNL which produces π^+s which decay at rest.

Neutrino beam from the CERN-PS. Two strictly identical 600 ton liquid argon time projection chamber (LAr-TPC) in the "near" and "far" positions, at 850 and 127 m from the target are simultaneously recorded in order to evidence possible oscillation effects. (The ICARUS T600 as "Far" detector and The additional T150 detector (to be constructed)

Reactor neutrino experiments (antiNue)
Double Chooz [14], Daya Bay

Neutrino source experiments(Nue)
SAGE,2-ZONE -(3MCi);
BOREXINO, - (?);

UPCOMING AND PROPOSED

Accelerator experiments (appearance-disappearance) ν_μ & anti-ν_μ

- **MicroBooNE** to determine whether the MiniBooNE low-energy excess is due to electrons or photons. Approximately LArTPC 70-ton fiducial volume detector, located **near MiniBooNE** (Received Stage-1 approval at Fermilab and initial funding from DOE and NSF. May begin data taking as early as 2011.

(Currently, a 170L LAr TPC, called ArgoNeut, is taking data in the NuMI beam in front of the MINOS detector)

- **BooNE** involves moving MiniBooNE or building a **2nd detector** at a distance of ~200 m from the BNB target. With two detectors the systematic errors will be greatly reduced and will allow precision appearance and disappearance searches for neutrinos & antineutrinos
- **OscSNS** would involve building a "MiniBooNE-like" detector (1 kton mineral oil Cherenkov detector ∅12 m) with higher PMT coverage at a distance of ~60 m from the Spalation Neutron Source (SNS) beam stop at ORNL which produces π^+s, which decay at rest.
- **LAr-TPC** from ν-beam from the **CERN-PS**. Two strictly identical 600 ton LAr-TPC in the "near" and "far" positions, at 850 and 127 m from the target are simultaneously recorded in order to evidence possible oscillation effects. (Possible use the ICARUS T600 as "Far" detector and the additional T150 detector (to be constructed).

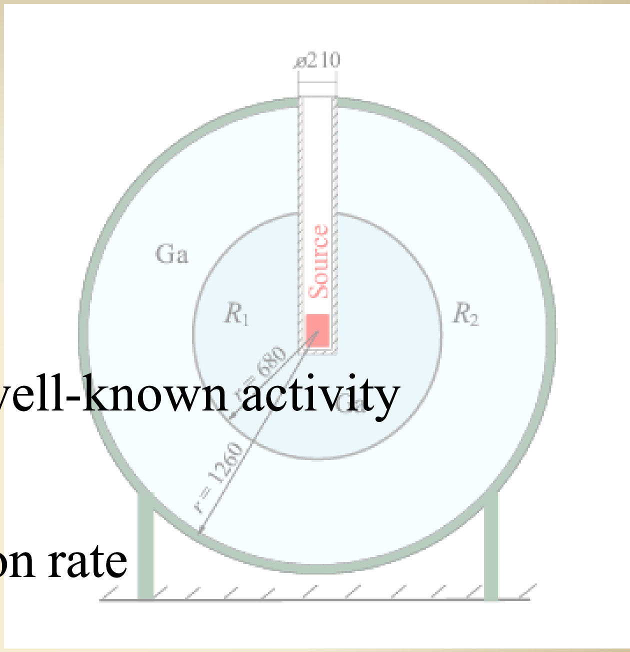
The nuclear reactor experiments look for the disappearance of anti-ν_e with an average energy of 3 MeV -4MeV.

- **Double-Chooz** – 2 detectors 10.3 m^3 cylinder, filled with 0.1% Gd loaded LS. To measure the angle θ13. The far detector will be placed at 1050 m distance from the cores (300 m.w.e.). The second identical detector (near detector) will be installed at 410 m away from the nuclear cores under a hillof 115 m.w.e. Taking data since 2010 (France).
- **Daya Bay** 8 identical detectors 20 tons of Gd doped liquid scintillator (Gd-LS). Two identical sets of near detectors at distances between 300 m and 500 m set of identical detectors (the end of 2011), the far detectors, will be located ~1.5 km north of the two near detector sets.(the end of 2012)

Artifical source experiments look for the disappearance of ν_e

- **Ga source experiment –** intense monochromatic source of ^{51}Cr (3MCi) at the center of a 50-tonne target of Ga metal that is divided into two zones (with path length in each zone ~55cm), to measure the neutrino capture rate in each zone.
- **BOREXINO source experiment – 270 t LS, sphere ∅ 8.5m,** intense monochromatic source of ^{51}Cr (5-10MCi) at 7 m from detector center (source would be in water), to measure the total counts in the entire detector volume or Spatial waves - oscillation wavelength smaller than detector size (~ 7 m), but larger that the spatial resolution (~ 15 cm), the distribution of the event distance from the source shows oscillations

The proposed Ga experiment has several advantages:



- independent measurements on two different baselines
- nearly-monochromatic neutrino and the source with well-known activity
- very compact source of pure ν_e flux
- the dense target of Ga metal provides a high interaction rate and good statistical accuracy
- all procedures are well understood and were used in the prior solar and source experiments
- the absence of background and uncertainties connected with inaccurate knowledge of neutrino spectrum will provide the simplicity of results interpretation

The proposed experiment has the potential to test neutrino oscillation transitions with $\Delta m^2 > 0.5$ eV^2

Plans

- **Modernization of BUST:**
  - *New electronics*
  - *Add target to increase probability of SN detection*
- ***Ga 2-zone source experiment***
- **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