"BEST" – Baksan Experiment on Sterile Transitions

BEST – the gallium experiment for a sterile neutrino search

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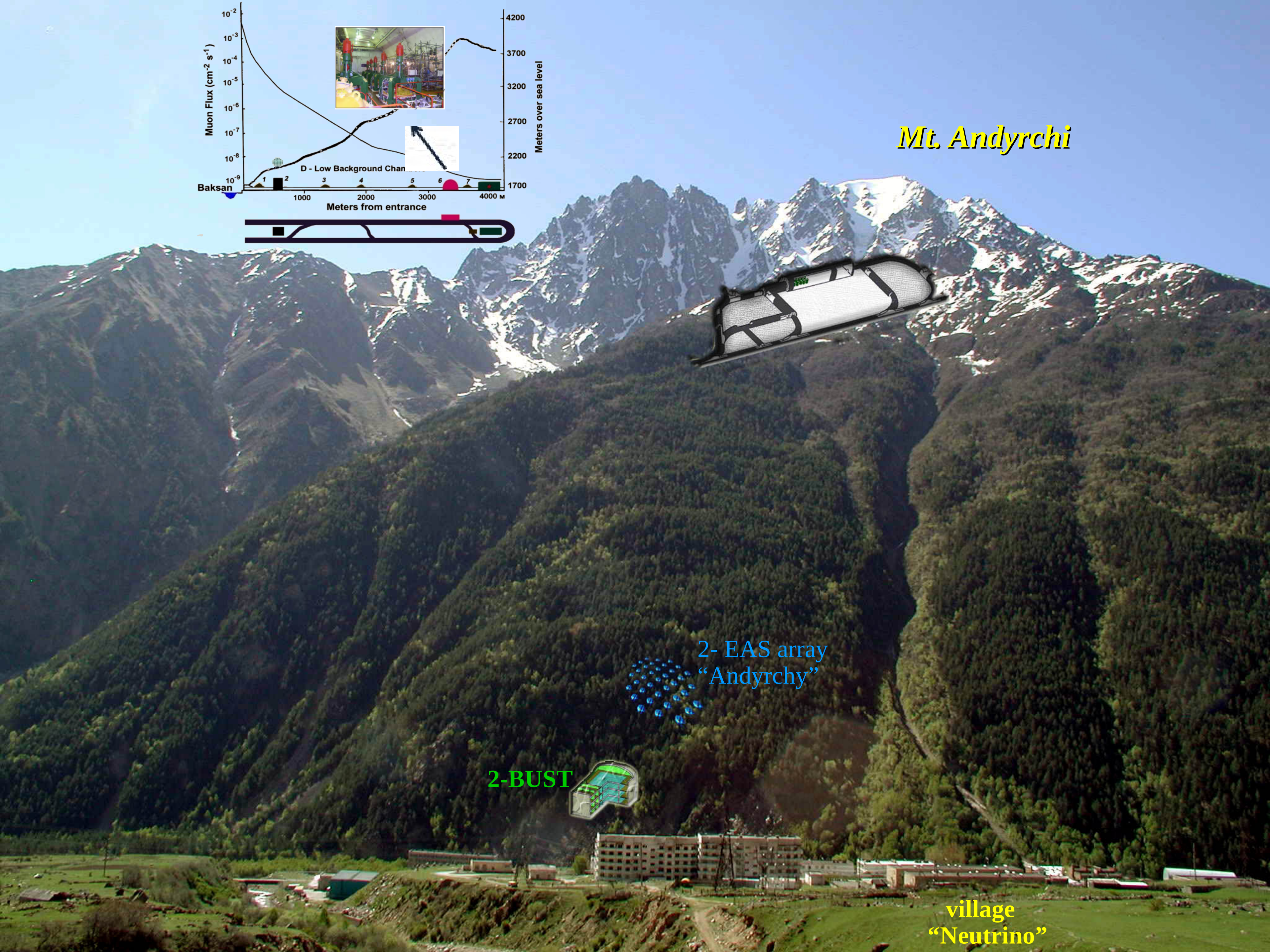
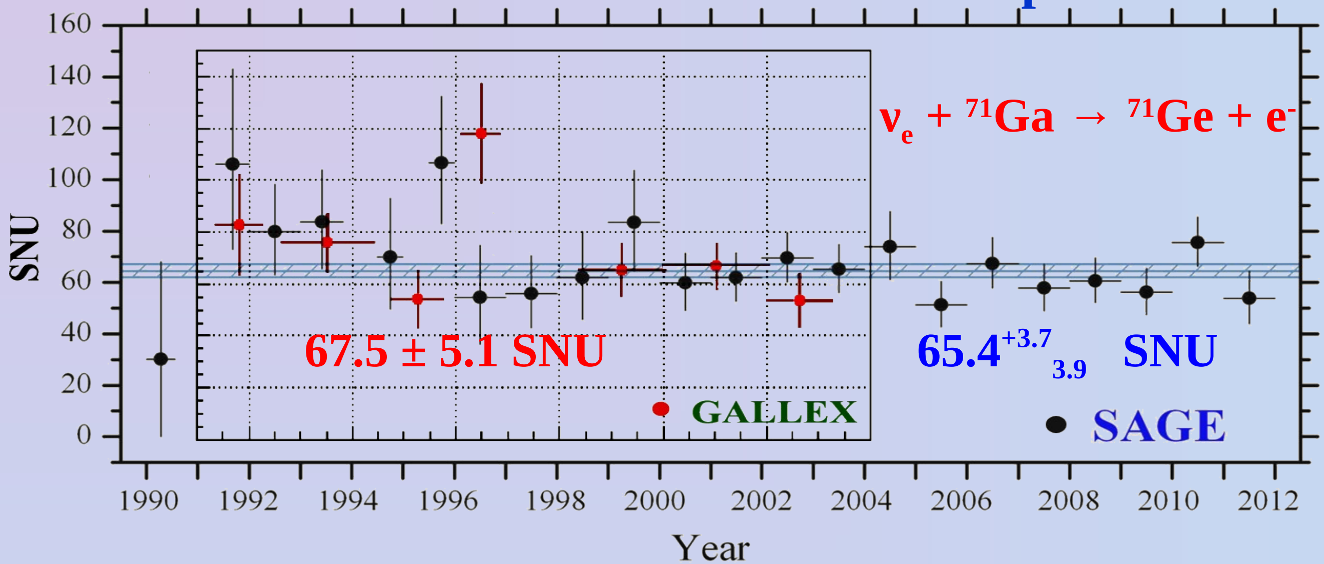


Muon Flux (cm-2 s-1)
Meters over sea level
D - Low Background Chan
Baksan
Meters from entrance
1000
2000
3000
4000 м
1700
2200
2700
3200
3700
4200
Mt. Andyrchi
2- EAS array
“Andyrchy”
2-BUST
village
“Neutrino”


SAGE
Global intensity of muon
- (3.03 ± 0.19) × 10^{-9} (cm^{2}s)$^{-1}$
Average energy of muon
- 381 GeV
Fast neutron flux (>3MeV)
– (6.28 ± 2.20) × 10^{-8} (cm^{2}s)$^{-1}$
Ga$_{met}$ ~ 50 tons
LGGNT
l = 60 m
w = 10 m
h = 12 m
Low background
concrete – 60 cm

SAGE & GALLEX – solar neutrino experiments



1SNU = 1 interaction/s in a target that contains 10^{36} atoms of the neutrino-absorbing isotope

- a very good agreement between their results
- **[*pp*+^{7}Be+CNO+*pep*+^{8}B|Ga] = 66.1 ± 3.1 SNU ~ 53 % of SSM prediction**

[*pp*|Ga] = 39.7 $(1^{+0.13}_{-0.14})$ SNU **= 3.38 (1 ± 0.14) × 10^{10} ν_e /(cm^2 s)**

- *pp* neutrinos flux at Earth at the present time: **(6.0 ± 0.8)) × 10^{10} /(см^2 с)**

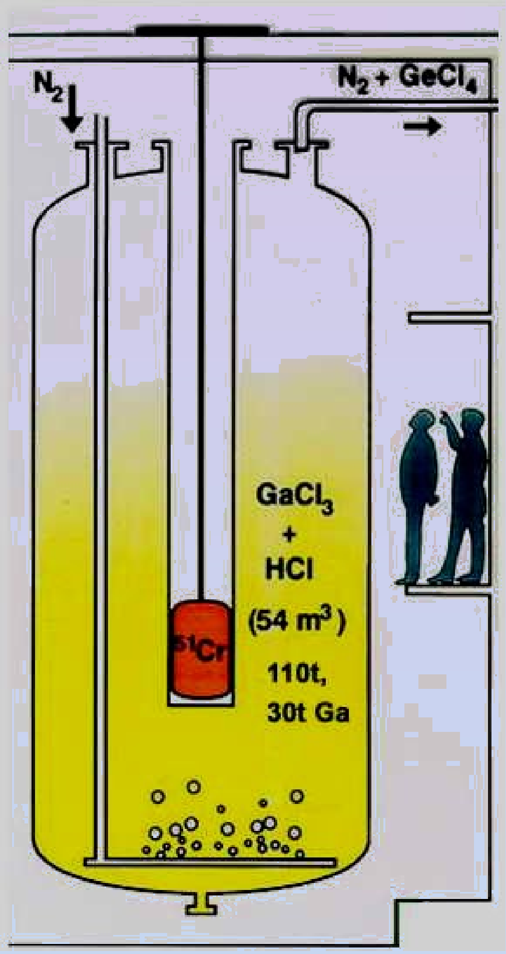
(5.97±0.04) × 10^{10} ν_e /(cm^2 s) (BPS08(GS)) (high metallicity)

(6.04±0.03) × 10^{10} ν_e /(cm^2 s) (BPS08(AGS05)) (low metallicity)

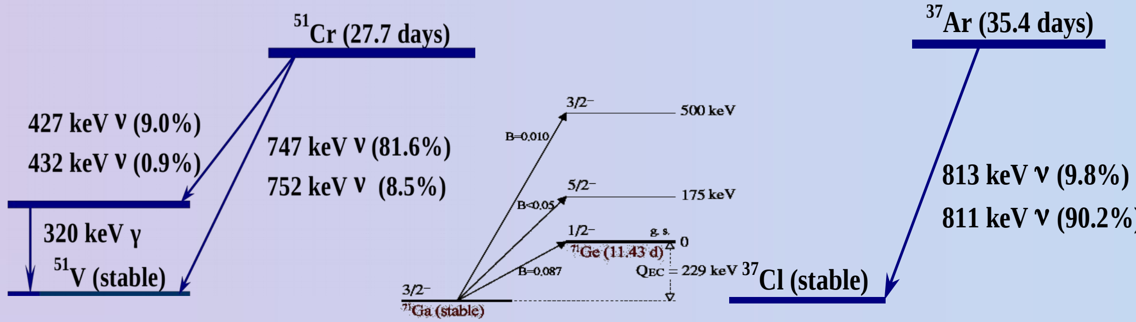
PHYSICAL REVIEW C 80, 015807 (2009)

Gallium source experiments

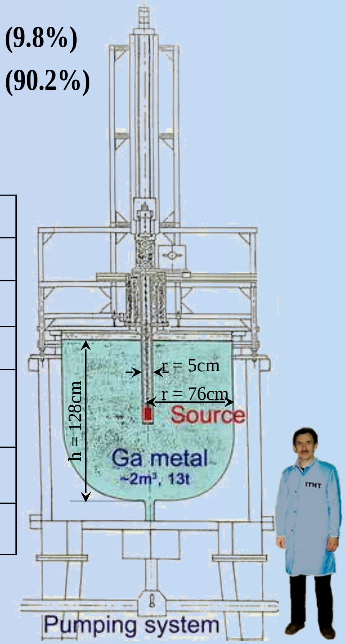
GALLEX



Gallex has twice used ^{51}Cr



SAGE



	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 $\rho(^{71}Ge/d)$	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	

SAGE has used ^{51}Cr and ^{37}Ar

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

Ratio of measured to predicted [Bahcall 97] rate (R):
(no uncertainty on cross sectection included)

The reason of low result in the source experiments can be :

(1) the capture rate, predicted by Bahcall, can be overestimated (W.Haxton),
(2) statistical fluctuation (probability~5%),
(3) electron neutrinos disappear due to a real physical effect. For example, neutrino oscillations with a transition from active to sterile neutrinos with $\Delta m^2 \sim 1 eV^2$.

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Consequences of $^{71}Ga(^3He, t)\,^{71}Ge$ and Q_{EC} -value measurements:

1. contribution from excited states: 7.2% ± 2.0% (5.1% by Bahcall)[(1)]

Recent measurement of $^{71}Ga(^3He, t)^{71}Ge$ (At RCNP, Japan)

2. Q_{EC} is close to the value employed by Bahcall[(2)] :

233.7 ± 1.2 keV (232.7 ± 0.15 keV used by Bahcall)

Penning trap Q-value determination of the $^{71}Ga(\nu,e^-)^{71}Ge$ reaction using threshold charge breeding of on-line produced isotopes (at ISAC/TRIUMF Canada)

3. the observed discrepancy is NOT due to any unknowns in Nuclear Physics.

↓

The deficit of neutrinos in the Ga source experiments can be a real physical effect of unknown origin, such as a transition to sterile neutrinos

$$R^{Ga}_{ave\text{-}Frefers} = 0.84 \pm 0.05\ (2.9\sigma)$$

[S Gariazzo, C Giunti, M Laveder, Y F Li, E M Zavanin, arXiv:1507.08204v1 [hep-ph]]

(1) D. Frekers, H. Ejiri, H. Akimune et al., Phys. Lett. B 706, 134 (2011)

(2) D. Frekers, M. C. Simon, C. Andreoiu et al., Phys. Lett. B 722, 4–5 (2013)

GALLEX:

$R_1(Cr) = 0.953 \pm 0.11$

$R_2(Cr) = 0.812 \pm 0.10$

SAGE:

$R_3(Cr) = 0.95 \pm 0.12$

$R_4(Ar) = 0.791 \pm 0.084$

R – ratio of the measured production rate to that expected [Bahcall 97] (no uncertainty on cross section included)

Gallium anomaly - $R_{ave\text{-}Bahcall} = 0.87 \pm 0.05\ (2.6\sigma)$; $R^{Ga}_{ave\text{-}Frefers} = 0.84 \pm 0.05\ (2.9\sigma)$

Region of allowed mixing parameters inferred from 4 gallium source experiments assuming oscillations to a sterile neutrino

$$P_{ee} = 1 - \sin^2 2\theta \cdot \sin^2\left(1.27 \frac{\Delta m^2 (eV^2) \cdot L(m)}{E_\nu (MeV)}\right)$$

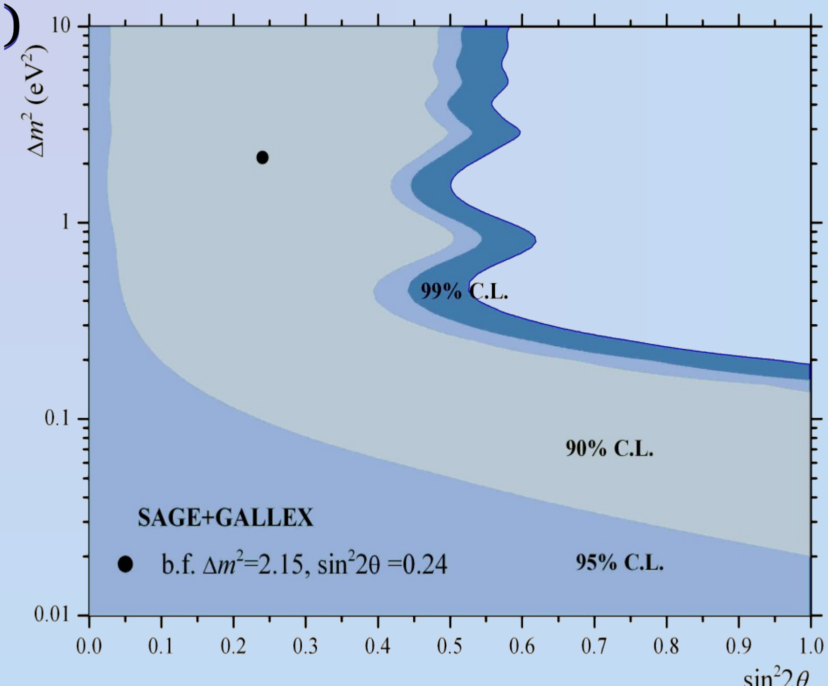
In Ga experiments: $E_\nu \sim 1$ MeV, $L \sim 1$ m

Oscillations affect the capture rate with $\Delta m^2 \sim 1\ eV^2$

Limits for oscillation parameters obtained in the four artificial neutrino source experiments: the best-fit point (•) at

$\Delta m^2 = 2.15\ eV^2$, $\sin^2(2\theta) = 0.24$

$\chi^2/dof = 1.77/2$, GOF=41%



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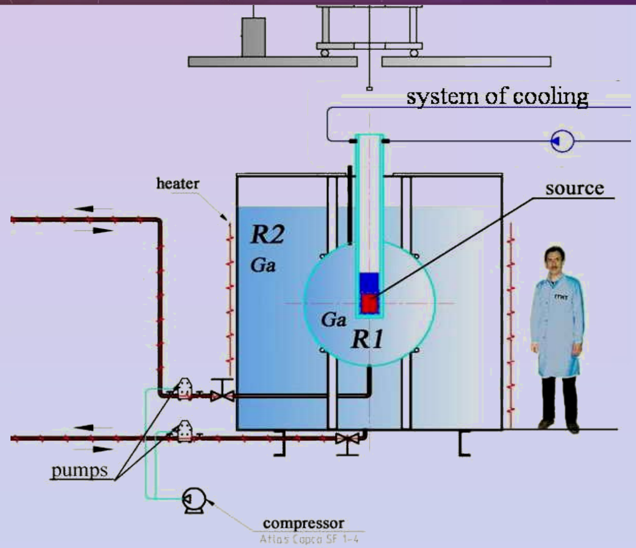
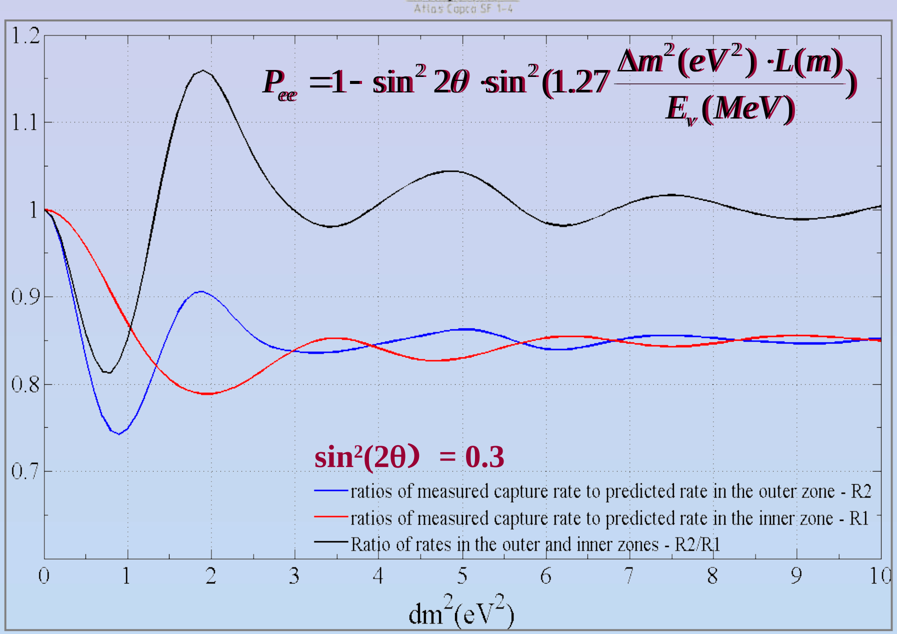
BEST (^{51}Cr) 3MCi source

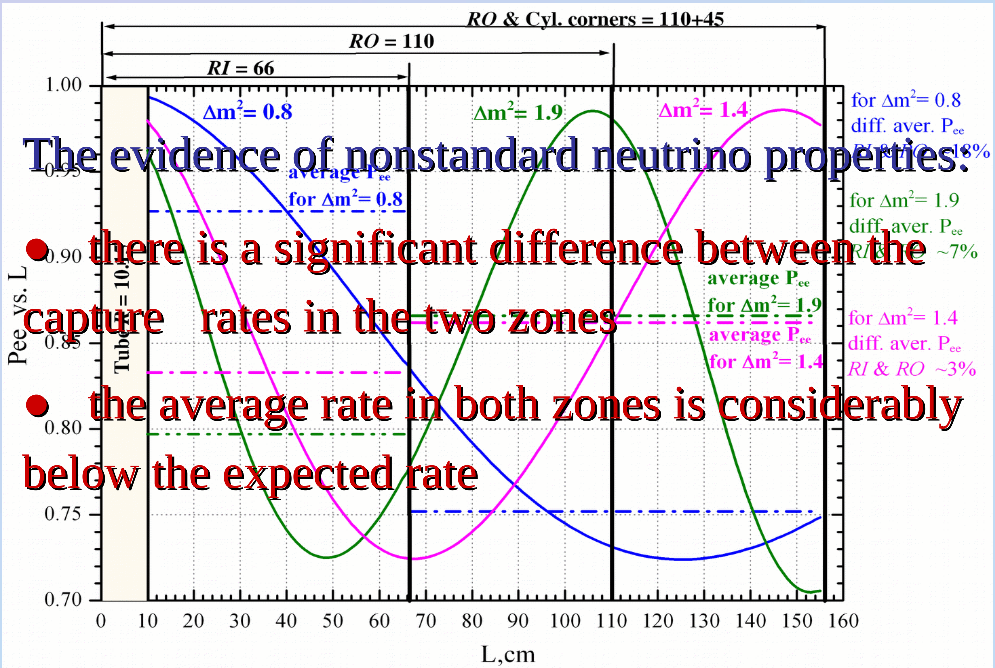


Target: 50 t Ga metall

Masses of the zones: 8 t and 42 t

Path length in each zone: <L> = 55cm, which provides the expected production rate ^{71}Ge at the start of the first exposure: 64.5 atoms/day





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

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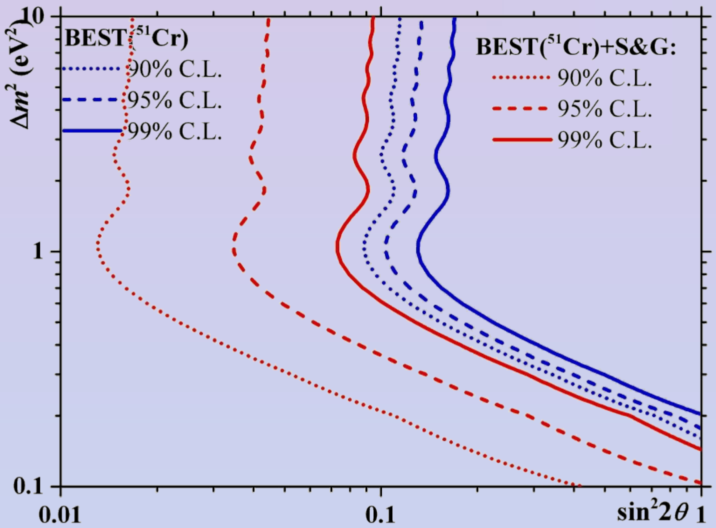
BEST (^{51}Cr) 3MCi source



The region in Δm^2 - $\sin^2(2\theta)$ space to which BEST(^{51}Cr) will be sensitive

The region in Δm^2 - $\sin^2(2\theta)$ space to which BEST(^{51}Cr) experiment combined with 4 Ga source experiments will be sensitive

Statistics of the experiment

Expected ν capture rates from the source in each zone in the absence of oscillation for 10 exposures of 9 days each :

> Total number of the captures in 1 zone ~ 1650
> Total number of ^{71}Ge pulses in 1 zone ~ 873

Production rate from solar ν : [~0.0197 atoms ^{71}Ge/(day – 1 tonne Ga)]
1.18 at. ^{71}Ge in 8 tonne of Ga,
6.20 at. ^{71}Ge in 42 tonne of Ga

> Statistical uncertainty: 3.7% in 1 zone
2.6% in the entire target

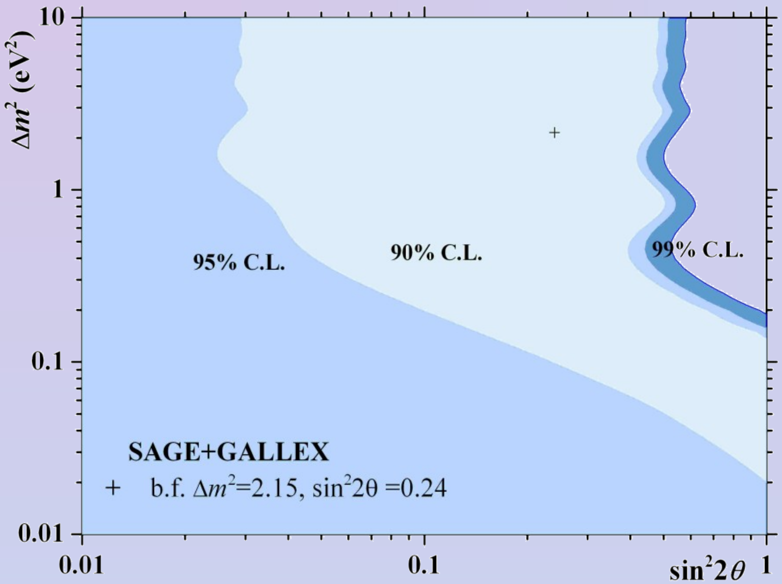
> Total systematic uncertainty : ±2.6%

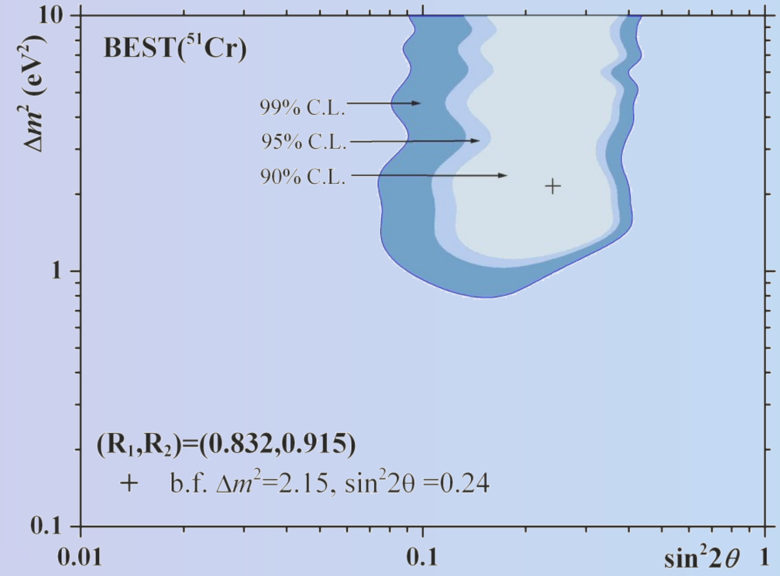
> Statistical and systematic uncertainties combined in quadrature :

4.5% in 1 zone
3.7% in the entire target

> With the Bahcall cross section uncertainty:

5.5% and 4.8%

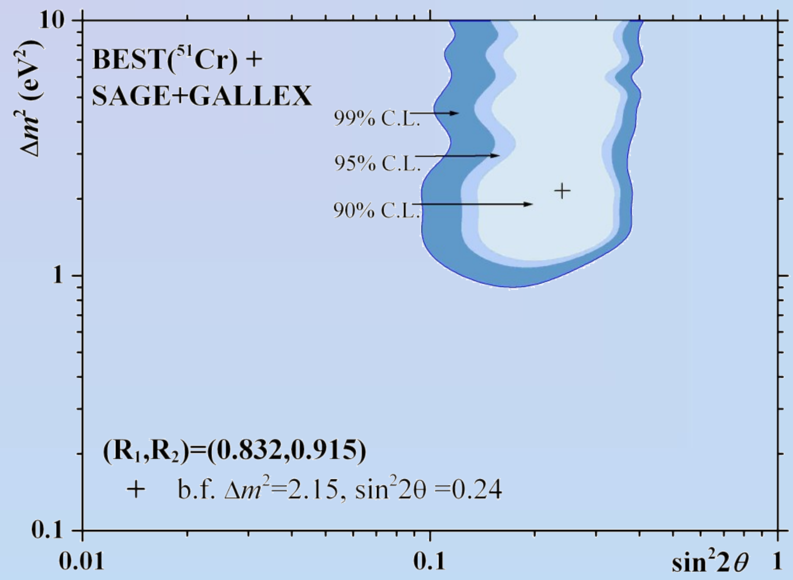




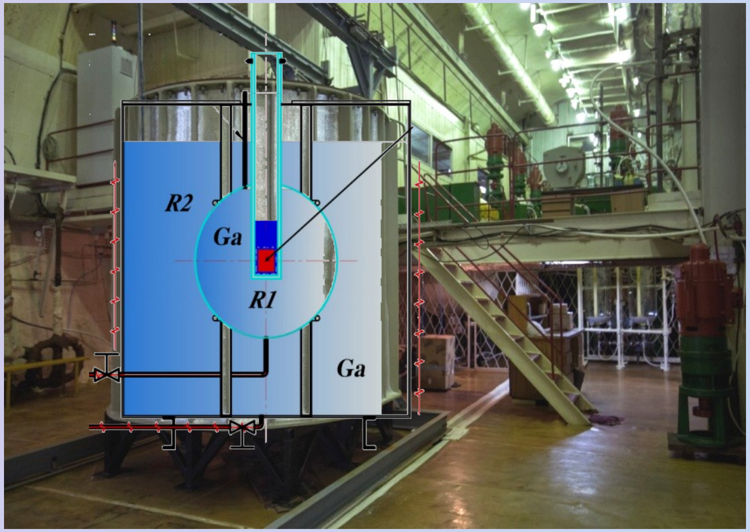
Regions of allowed oscillation parameters for possible result of the BEST(^{51}Cr) experiment, and BEST(^{51}Cr) combined with results of 4 previous experiments with sources SAGE and GALLEX (SG) .

"+" sign indicates the best fit point, which is corresponded b.f. SG.

R_1 and R_2 are the ratios of the measured rate to the predicted rate in the inner and outer zones, respectively.



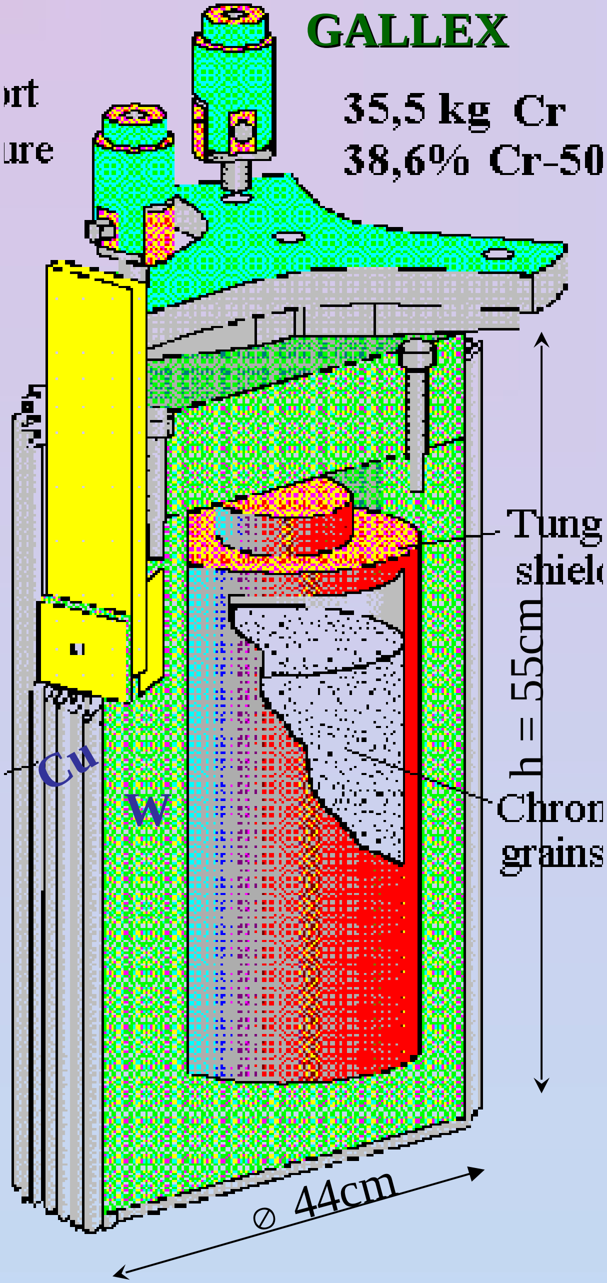
Work stages on creation of the BEST installations



Result analysis from 2 zones Ga target from solar extractions since 2015 to 2018 years (for 20 pair extractions). Extractions and counting of ^{71}Ge atoms were performed independently for each zone.

Run	**Number runs**	**Peak**	**Best Fit (SNU)**	
sph	**(40)**	**K+L**	**69.5**	**+43.7/ -40.4 (SNU)**
cylr	**(40)**	**K+L**	**58.5**	**+9.7 / -9.2 (SNU)**
comb	**(80)**	**K+L**	**59.1**	**+9.5 / -9.1 (SNU)**

The global best fit capture rate is 64.6 +/- 2.4 SNU (with statistical uncertainty only) for SAGE solar data from January 1990 through December 2014 (244 runs)



(1) 1.17± 2.1% MCi 1994 –1995

(2) 1.87 ± 3.9% MCi 1995 –1996

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

SAGE

517 ± 1.2% kCi

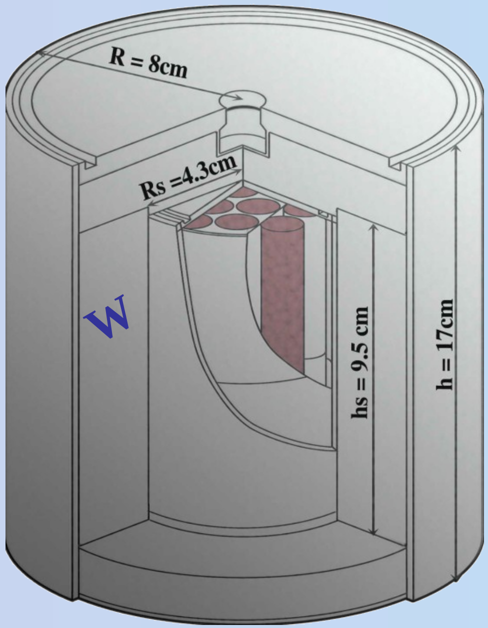
^{51}**Cr** produced by irradiating 512.7 g of 92.4%-enriched ^{50}Cr in high-flux fast neutron breeder reactor BN-350

1994 –1995

409 ± 0.5% kCi

^{37}**Ar** produced by irradiating 330 kg of CaO in the fast neutron breeder reactor BN-600

2004



3.8 MCi ± 0,5%!

^{51}**Cr**

Project: to irradiate 3 kg of 97%-enriched ^{50}Cr in the research reactor SM-3

2019

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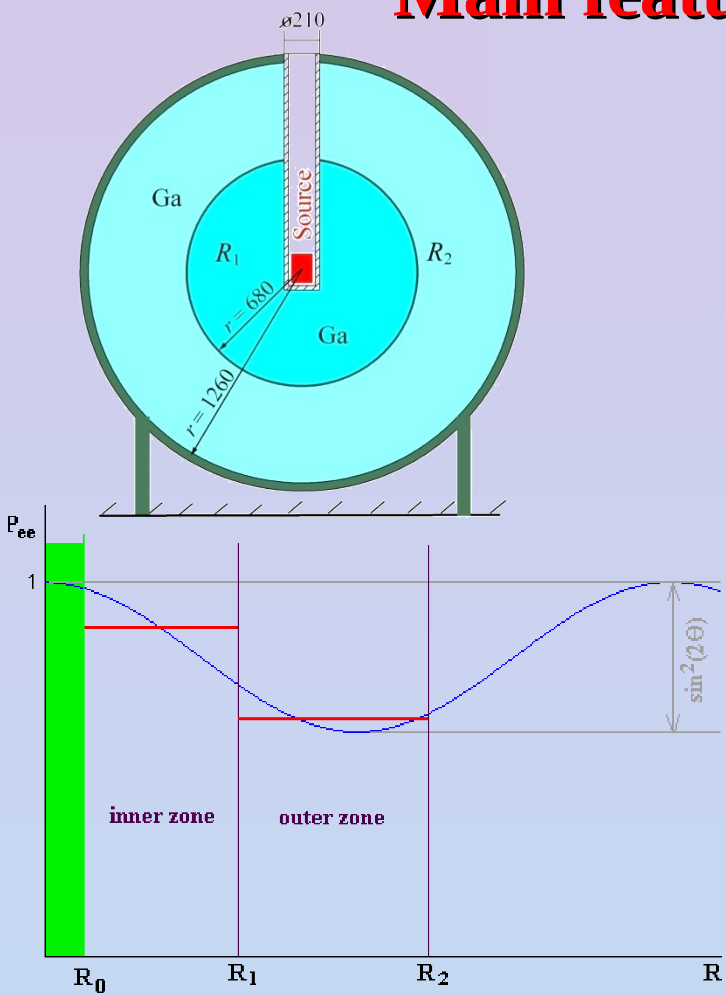
Main features of the BEST :



Schematic drawing of proposed neutrino source experiment. R_1 and R_2 are the ratios of measured capture rate to predicted rate in the absence of oscillations in the inner and outer zones, respectively.

- **A Search for Electron Neutrino disappearance via charged-current (CC) reaction only:**

$$\nu_e + {}^{71}Ga \rightarrow {}^{71}Ge + e^-$$

- **Monochromatic spectrum of compact source – observation of the pure sinusoid of oscillation transitions:**

$$P_{ee} = 1 - \sin^2 2\theta \cdot \sin^2\left(1.27\frac{\Delta m^2(eV^2)\cdot L(m)}{E_\nu(MeV)}\right)$$

- **Precisely known intensity of the source.**
- **Possibility to study the dependence of the rate on the distance to the source.**
- **Very Short Baseline.**
- **Almost zero background. Mainly from the Sun.**

The source, 3 MCi, provides a capture rate in the Ga that will exceed the rate from the Sun by several factors of ten.

- **Very well known experimental procedures developed in SAGE solar measurements .**

The manufacture of a prototype on 0.5 t of a large scale scintillation detector is started

Thank you for your attention