Improving the value of the neutrino absorption cross - section on gallium and prospects of short - baseline experiments for studying neutrino oscillations.

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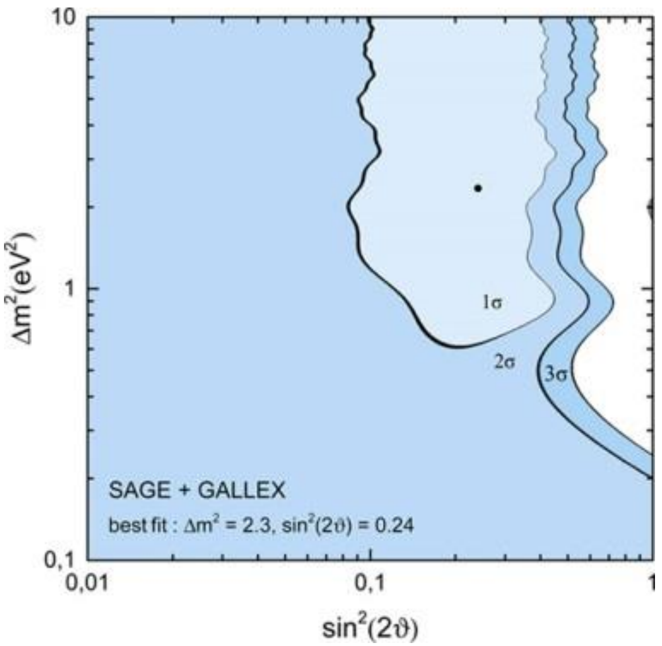
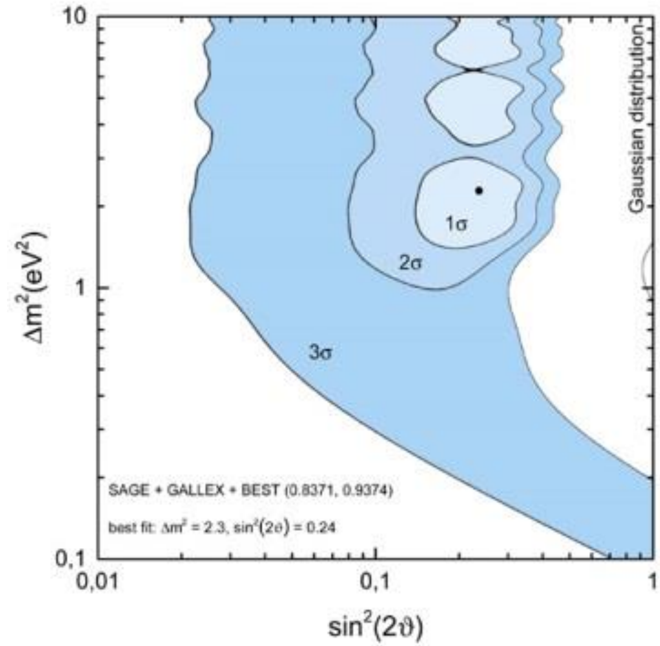
Gallium Anomaly

	SAGE ^{51}Cr	SAGE ^{37}Ar	GALLEX ^{51}Cr 1	GALLEX ^{51}Cr 2
Активность, кКи	516.6 ± 6.0	409 ± 2	1714^{+30}_{-43}	1868^{+89}_{-57}
$p^{изм}$, атомов ^{71}Ge/сут	14.0 ± 1.5 ± 0.8	$11.0^{+1.0}_{-0.9}$ ± 0.6	11.9 ± 1.1 + 0.7	10.7 ± 1.2 ± 0.7
Масса Ga (т)	13.1 (метал.)	13.1 (метал.)	30.4 ($GaCl_3$:HCl)	30.4 ($GaCl_3$:HCl)
$R = p^{изм}/p^{теор}$	0.95 ± 0.12	0.79 ± 0.10	0.953 ± 0.11	0.812 ± 0.11

SAGE GALLEX BEST



Allowed regions of oscillations parameters with combining SAGE + GALLEX



Allowed regions of oscillations parameters with combining SAGE + GALLEX + BEST

Full statistical uncertainty of the experiment BEST: $\pm$ 4.5% – for each zone
$\pm$ 3.7% – all target

Theoretical uncertainty +3.6%\−2.8%

[1]. Vladislav Barinov, Vladimir Gavrin, Dmitry Gorbunov, and Tatiana Ibragimova. Best sensitivity to o(1) ev sterile neutrino. Phys. Rev. D, 93:073002, Apr 2016.

Absorption Cross Section

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

$$\sigma = \sigma_0 \langle \omega_e^2 G(Z, \omega_e) \rangle$$

$$\sigma_0 = \frac{4\pi^3 \ln 2 \alpha \hbar^3}{m_e^3 c^4} \left(\frac{2I_f + 1}{2I_i + 1} \right) \frac{Z}{ft_{1/2}(I_f \rightarrow I_i)}$$

Scale factor for the cross section value

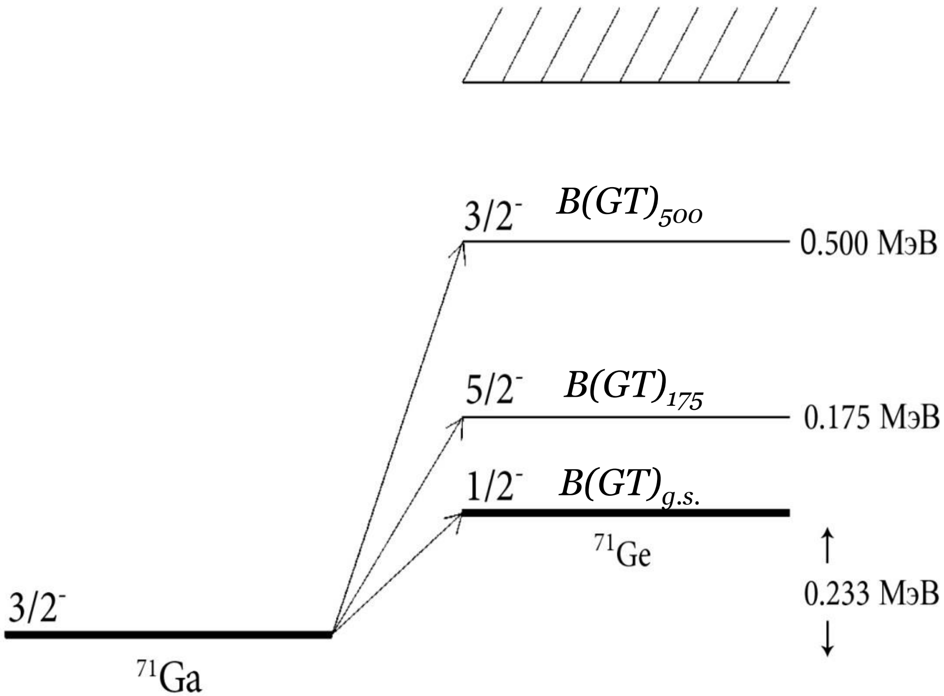
$$ft_{1/2}(I_f \rightarrow I_i) = \frac{2\pi^3 \ln 2 \hbar^7}{m_e^5 c^4} \frac{1}{(G_V^2 |M_{i,f}|_F^2 + G_A^2 |M_{i,f}|_{GT}^2)}$$

ft – value

$$\langle \omega_e^2 G(Z, \omega_e) \rangle = \frac{1}{2\pi \alpha Z} \frac{\int_{\omega_e^{min}}^{\omega_e^{max}} \omega_e p_e F(Z, \omega_e) \phi(q_\nu) d\omega_e}{\int_0^{\omega_e^{max}} \phi(q_\nu) dq_\nu}$$

The dimensionless phase space factor, averaged by electron energies

The scheme of the decay of ^{71}Ga and the spectra of artificial sources



Spectrum of ^{51}Cr

E_ν (МэВ)	Относительные доли
0.752	8.49 (1) %
0.747	81.63 (1) %
0.432	0.93 (1) %
0.427	8.95 (1) %

Spectrum of ^{37}Ar

E_ν (МэВ)	Относительные доли
0.813	9.80 (1) %
0.811	90.20 (1) %

Calculations

Q = 233.5 ± 1.2 кэВ – Frekers
Q = 232.69 ± 0.15 кэВ - Old

$T1/2(^{71}Ge) = 11.43 \pm 0.03$ д

$\log ft1/2\ (^{71}Ge) = 4.353 \pm 0.005$

$B(GT)g.s. = 0.086 \pm 0.001$

$\sigma_0 = (8.6 \pm 0.1) \times 10^{-46}$ см²

$\sigma_0^{Bahcall} = (8.611 \pm 0.011) \times 10^{-46}$ см²

[2]. Penning-trap q-value determination of the reaction using threshold charge breeding of on - line produced isotopes. Physics Letters B, 722(4 - 5):233 – 237, 2013.

Matrix elements of the transitions and the results of calculations

$E_x(^{71}\mathrm{Ge})$ [keV]	J^π	$\frac{d\sigma}{d\Omega}(q=0)$ [mb/sr]	GT %	$B(\mathrm{GT})$ $\times 10^{-2}$
g.s.	$\frac{1}{2}^-$	0.786(9)	92	8.52(11)[a]
175	$\frac{5}{2}^-$	0.071(4)	40	0.34(26)
500	$\frac{3}{2}^-$	0.171(4)	87	1.76(14)
708	$\frac{3}{2}^-$	0.018(1)	55	0.11(5)
808	$\frac{1}{2}^-$	0.210(4)	92	2.29(10)
1096	$\frac{3}{2}^-$	0.184(4)	84	1.83(17)

$\sigma(^{51}\mathrm{Cr}) = (59.20 \pm 1.14) \times 10^{-46}$ см²

$\sigma(^{37}\mathrm{Ar}) = (71.5 \pm 1.5) \times 10^{-46}$ см²

$\sigma(^{51}\mathrm{Cr}) = (59.2 \pm 1.1) \times 10^{-46}$ см²

$\sigma(^{37}\mathrm{Ar}) = (71.5 \pm 1.4) \times 10^{-46}$ см²

C. Giunti

$$\sigma = \sigma_{g.s.}\left[1 + \lambda_{175}\frac{B(GT)_{175}}{B(GT)_{g.s.}} + \lambda_{500}\frac{B(GT)_{500}}{B(GT)_{g.s.}}\right]$$

[3]. C. Giunti, M. Laveder, Y. F. Li, Q. Y. Liu, and H. W. Long. Update of Short-Baseline Electron Neutrino and Antineutrino Disappearance. Phys. Rev., D86:113014, 2012.

[4]. D. Frekers et al. Precision evaluation of the 71Ga(*νe*, *e*−) solar neutrino capture rate from the (3He, *t*) charge - exchange reaction. Phys. Rev. C, 91:034608, Mar 2015.

Absorption Cross Section for ^{65}Zn

E_ν (МэВ)	Относительные доли
1.352	48.35 (11) %
0.236	50.23 (11) %

$\sigma(^{65}\mathrm{Zn}) = (94.3 \pm 2.1) \times 10^{-46}$ см²

$$\sigma = \sigma_{g.s.} \left[1 + \frac{\sum_{E_x} \lambda_{E_x} B(GT)_{E_x}}{B(GT)_{g.s.}} \right]$$

$\lambda_{175} = 0.7969$, $\lambda_{500} = 0.4789$, $\lambda_{708} = 0.3146$, $\lambda_{808} = 0.2466$, $\lambda_{1096} = 0.0934$

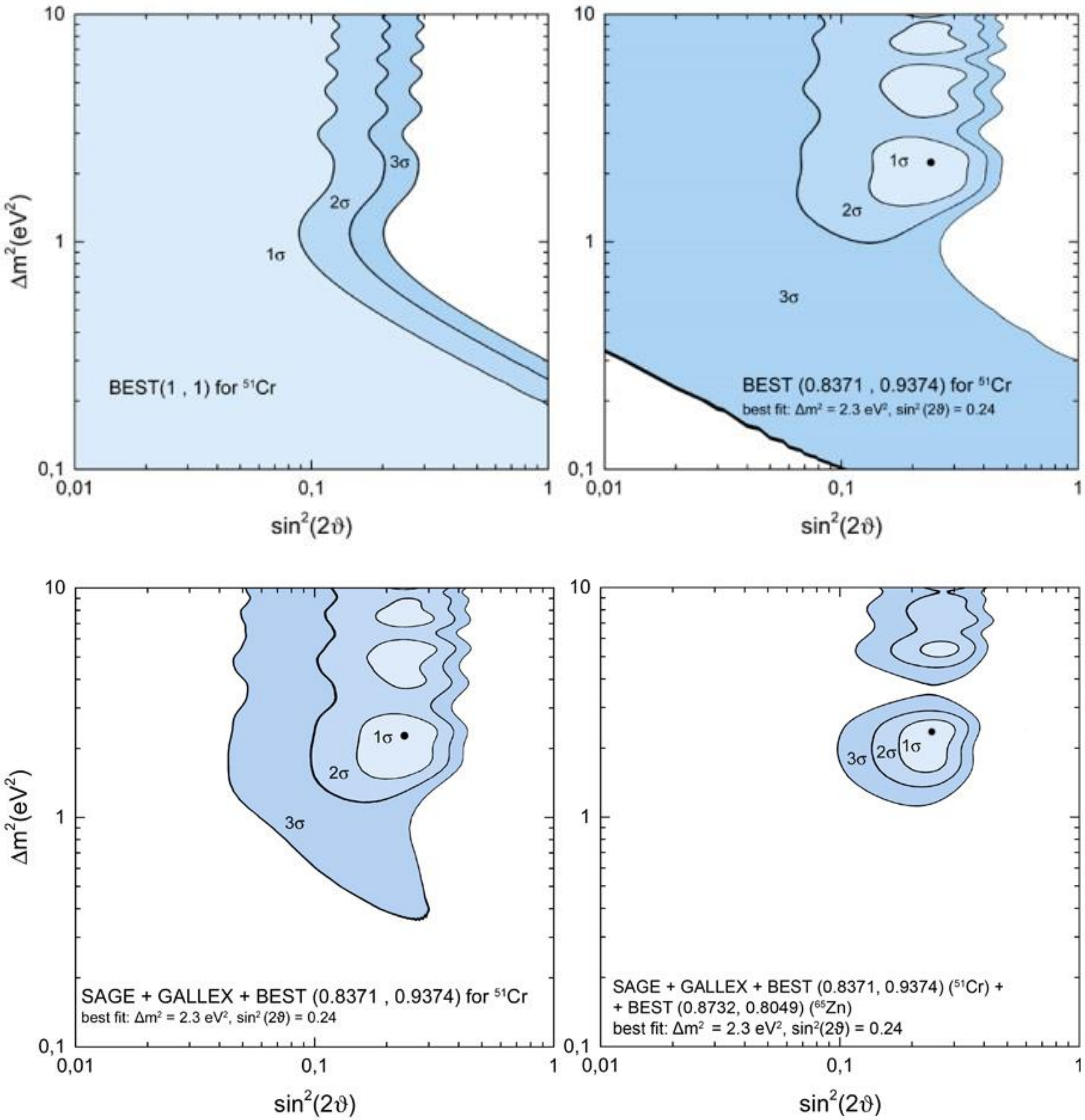
Uncertainties

The relative uncertainty of the cross sections obtained during the work is 2% for the 51Cr and 37Ar sources, and 2.2% for the 65Zn source.
The results obtained for 51Cr and 37Ar agree with that presented in [3]

Taking into account the refined value of the neutrino absorption cross section in gallium obtained in this paper, the resulting error of the BEST experiment using the 51Cr source will be 4.9% for each of the bands and 4.17% for the total target, instead of 5.5% and 4.8%, respectively

If a 65Zn source is used in the BEST experiment, the resulting error is 5.0% for each of the zones and 4.3% for the full target, respectively

Sensitivity Contours



Conclusions

- Refined values of the neutrino absorption cross sections for gallium for ^{51}Cr and ^{37}Ar sources are obtained, and it is shown that, despite the consideration of all the uncertainties in the cross section, the results will change insignificantly. A value of the absorption cross section for ^{65}Zn was separately obtained and a formula was obtained with the calculated relative phase space factors

- Obtained updated areas of allowed oscillation parameters for combining SAGE + GALLEX + BEST

- It is also shown in the paper that the main results presented in [1] remain true and there are no more uncertainties in the cross section for the absorption of neutrinos by gallium, which could eliminate the discrepancy between the SAGE and GALLEX experiments

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Thank you for your attention!