ν_e and $\bar{\nu}_e$ disappearance in Gallium and Neutrino experiments

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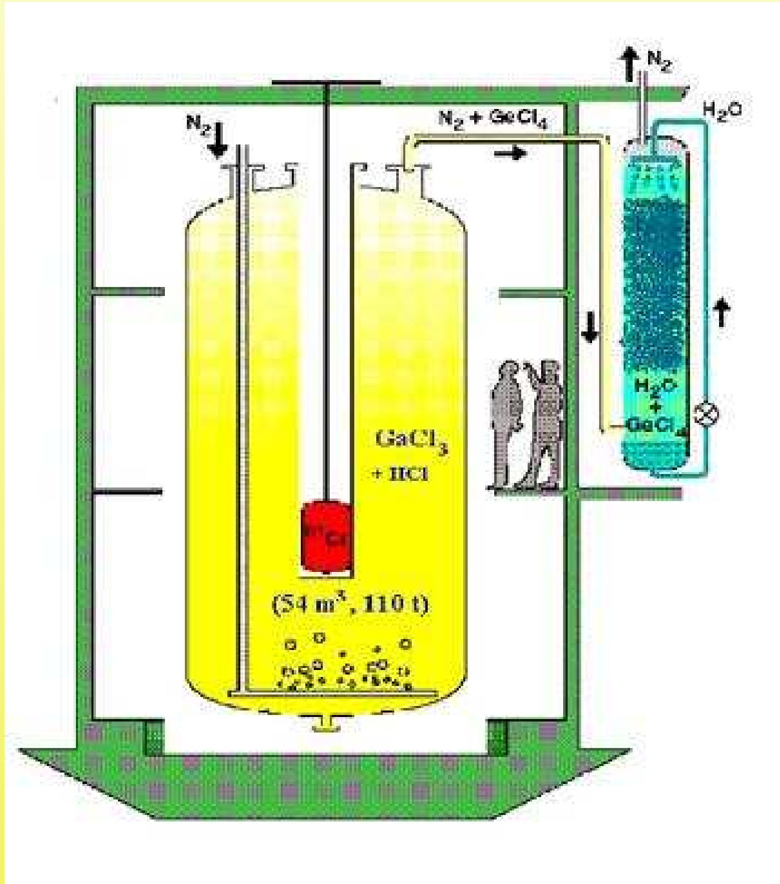
Ga experiments: GALLEX and SAGE

The Gallium radioactive source experiments were designed to test the GALLEX and SAGE solar neutrino detectors. Electron neutrinos come from the decay of ^{51}Cr and ^{37}Ar radioactive (placed inside the detectors) sources which decay through electron capture emitting monoenergetic ν_e detected through the reaction

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

	^{51}Cr				^{37}Ar	
E(keV)	747	752	427	432	811	813
B.R. (%)	81.63	8.49	8.95	0.93	90.2	9.8

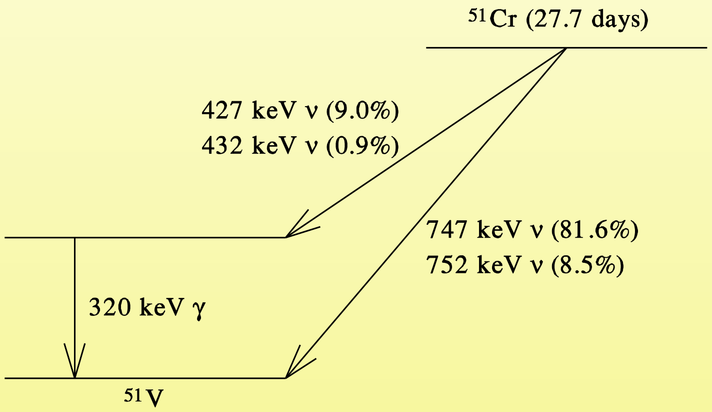


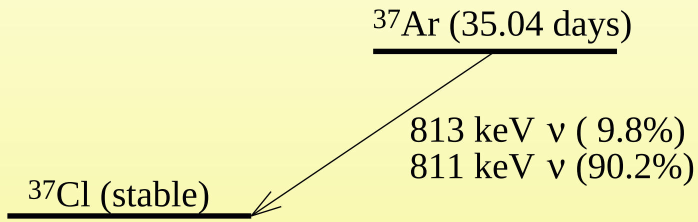
Ga experiments

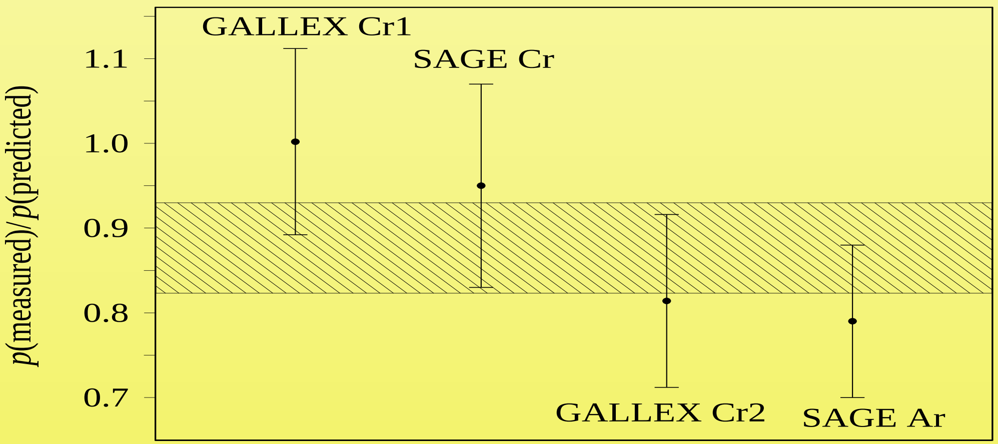
Electron capture

$$\boxed{{}^{51}_{24}\mathbf{Cr} + \mathbf{e}^- \quad\longrightarrow\quad {}^{51}_{23}\mathbf{V} + \nu_\mathbf{e}}$$

$$\boxed{{}^{37}_{18}\mathbf{Ar} + \mathbf{e}^- \quad\longrightarrow\quad {}^{37}_{17}\mathbf{Cl} + \nu_\mathbf{e}}$$







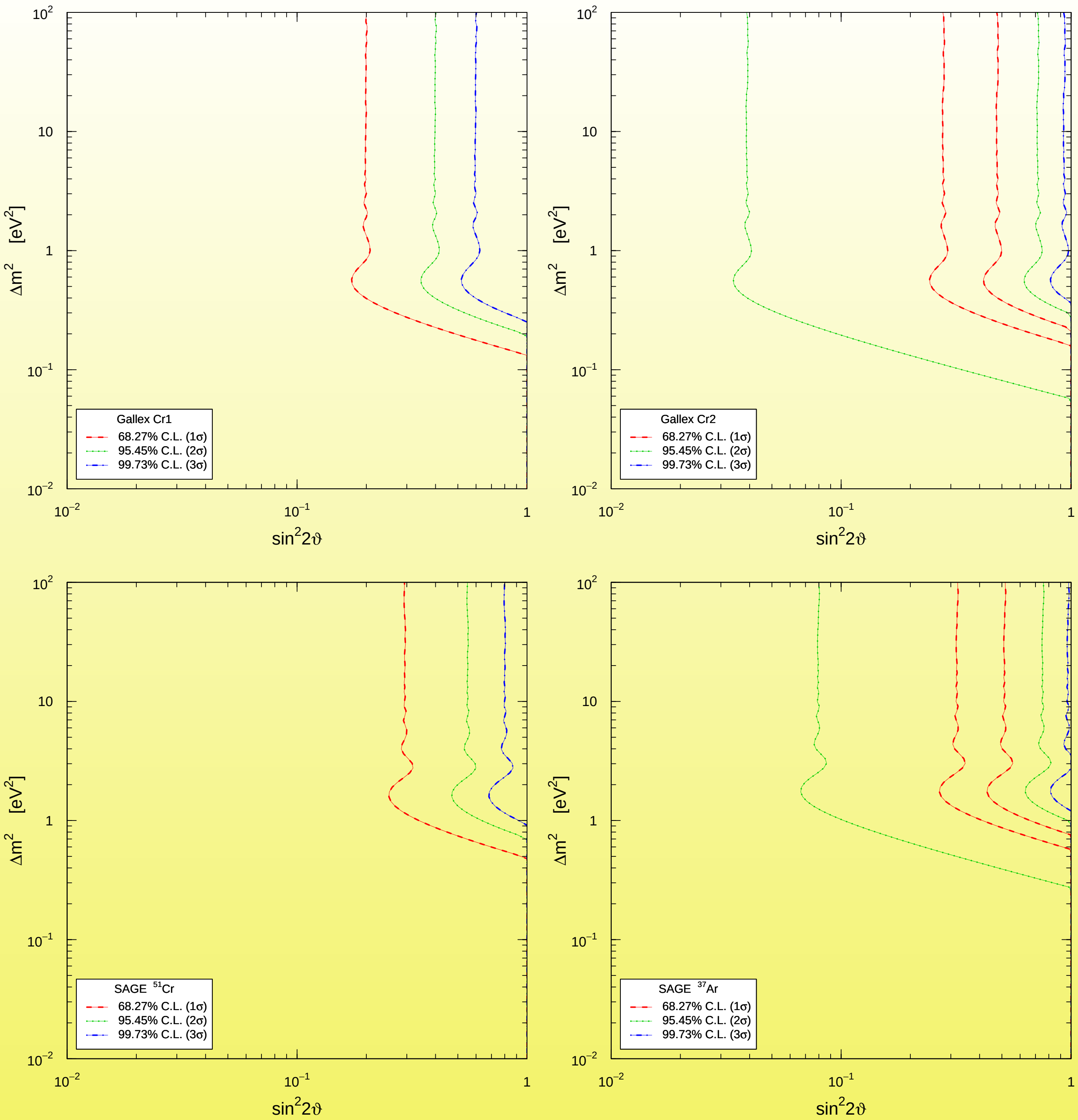
SAGE, PRC 73 (2006) 045805

Weighted average

$$\mathbf{R = 0.88 \pm 0.05}.$$

Ga experiments

Individual analysis: 2σ allowed bands for GALLEX-Cr2 and SAGE ^{37}Ar, with $\mathbf{\Delta m^2 \gtrsim 1\,eV^2}$.



Ga experiments

Combined least-squares analysis for the Gallium experiments. It shows a 1σ allowed region, and we find

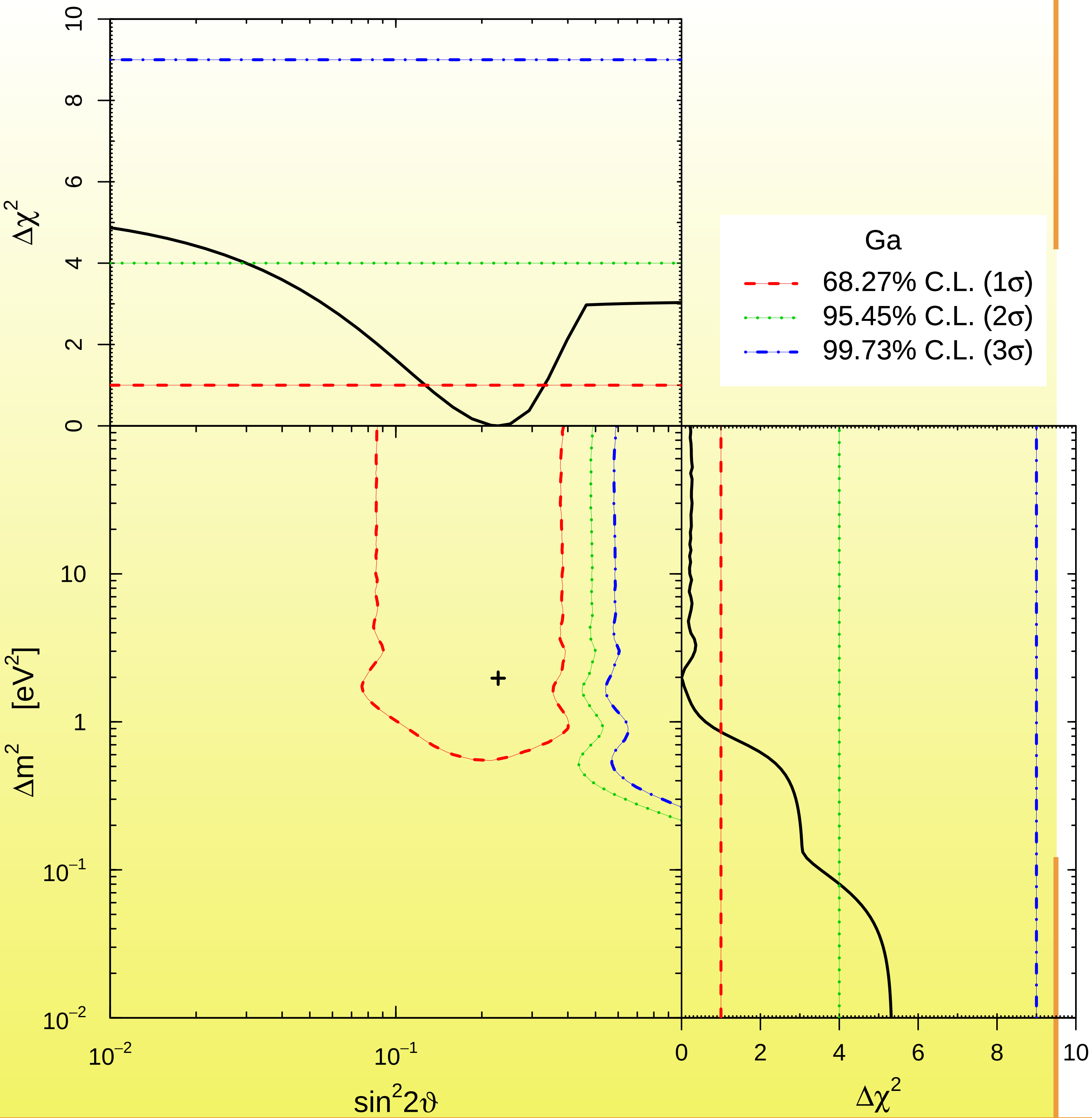
$$\mathbf{\Delta m^2_{bf} = 2.00\,eV^2}$$

$$\sin^2(2\theta)_{\mathbf{bf}} = \mathbf{0.23}$$

and at 1σ (68.27 % C.L.)

$$\mathbf{\Delta m^2 > 0.90\,eV^2}$$

$$\sin^2(2\theta)_{\mathbf{bf}} = \mathbf{0.13 - 0.34}$$



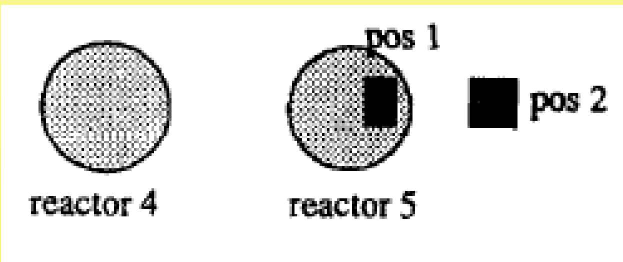
Reactor experiments

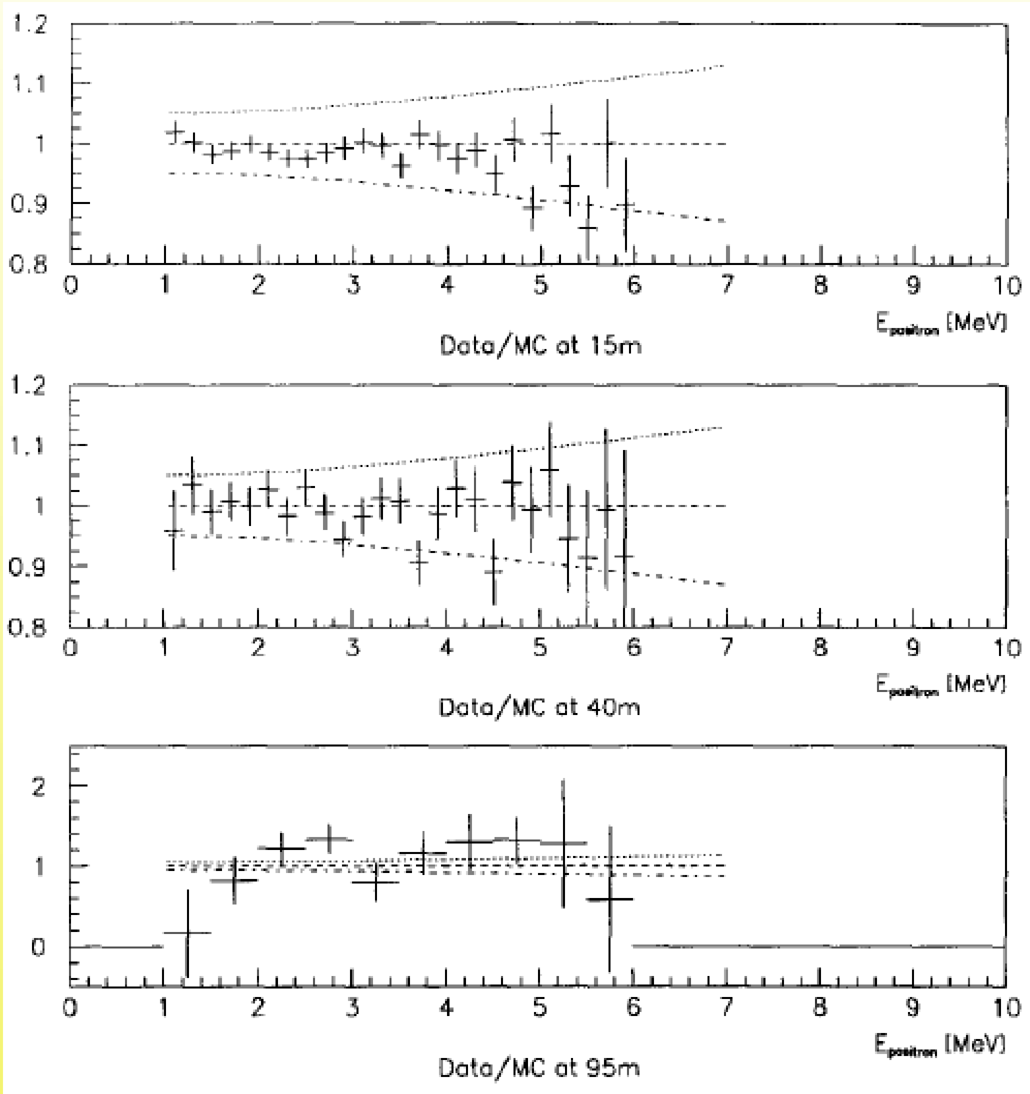
Electron antineutrino detected through the inverse beta decay process

$$\bar{\nu}_e + p \to n + e^+$$

with the energy relation $E_\nu = E_{e^+} + 1.8$MeV.

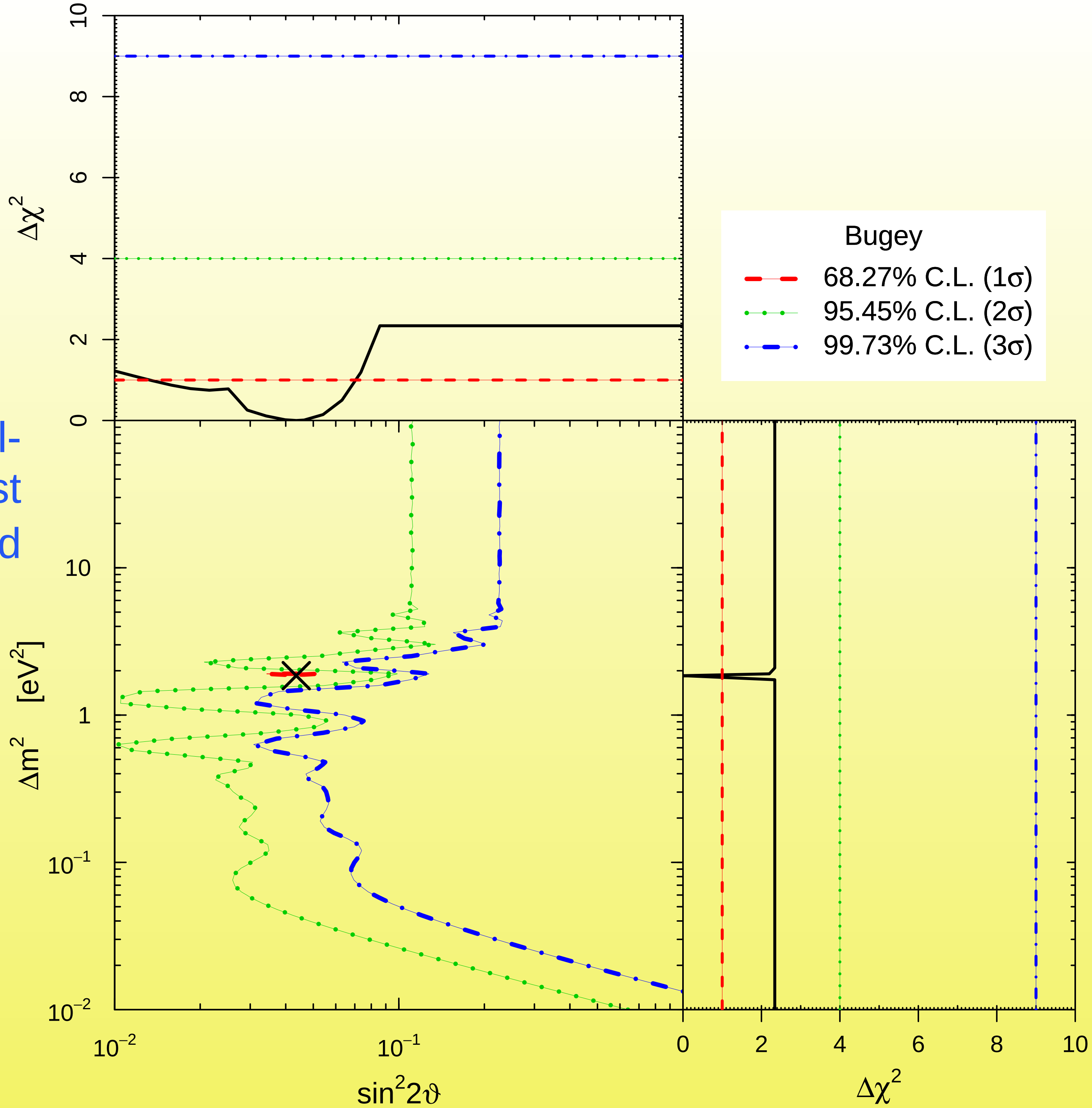
The **Bugey** experiment searches for $\bar{\nu}_e$ disappearance at the three distances ($L_j = 15, 40, 95$ m) and collected $N_j = 25, 25, 10$ (for $j = 1, 2, 3$) energy bins (data).





Bugey, NPB 434 (1995) 503

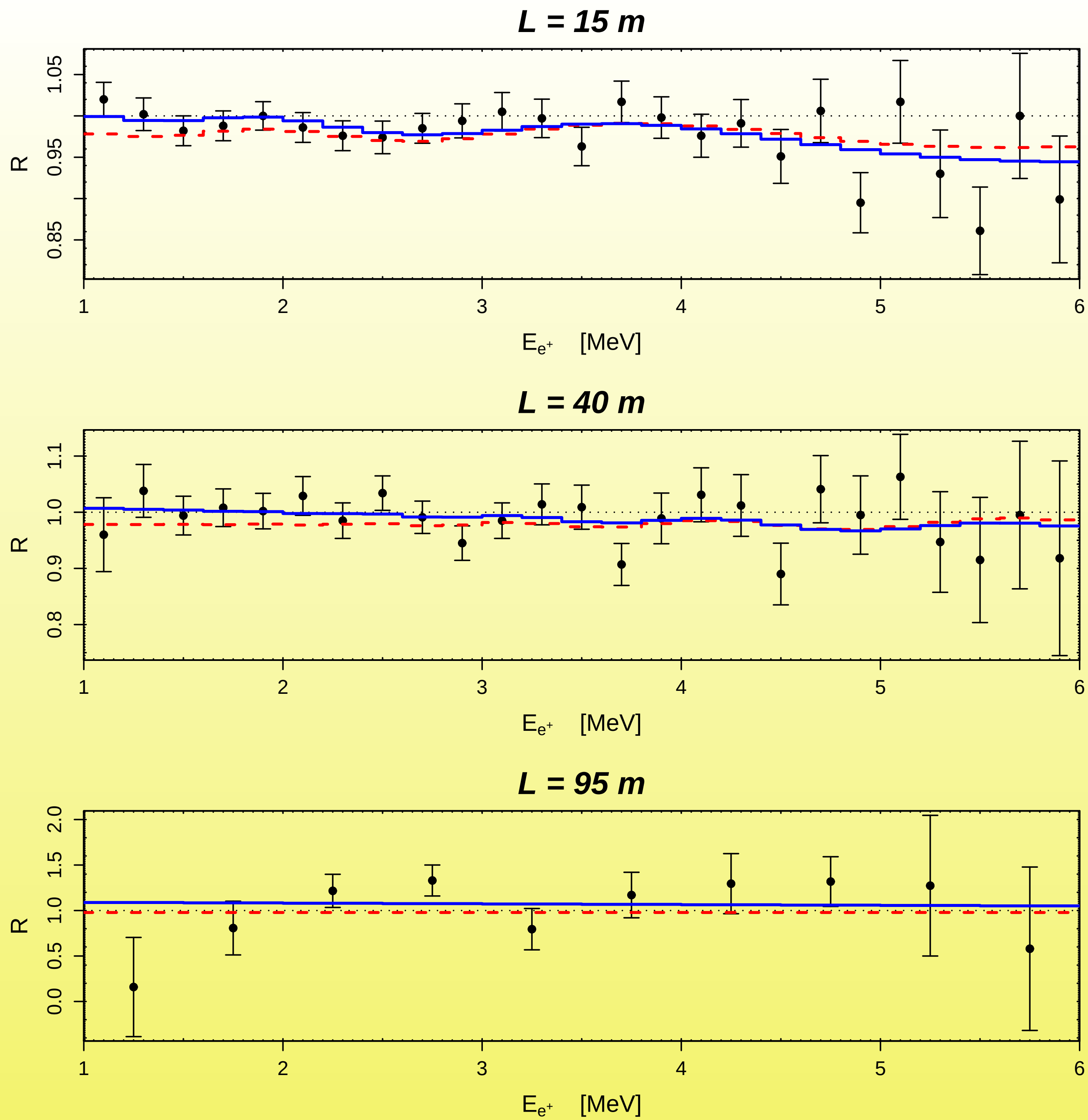
Bugey



We find a narrow 1σ allowed region with the best fit at $\Delta m^2 = 1.85 eV^2$ and $\sin^2 2\theta = 0.043$

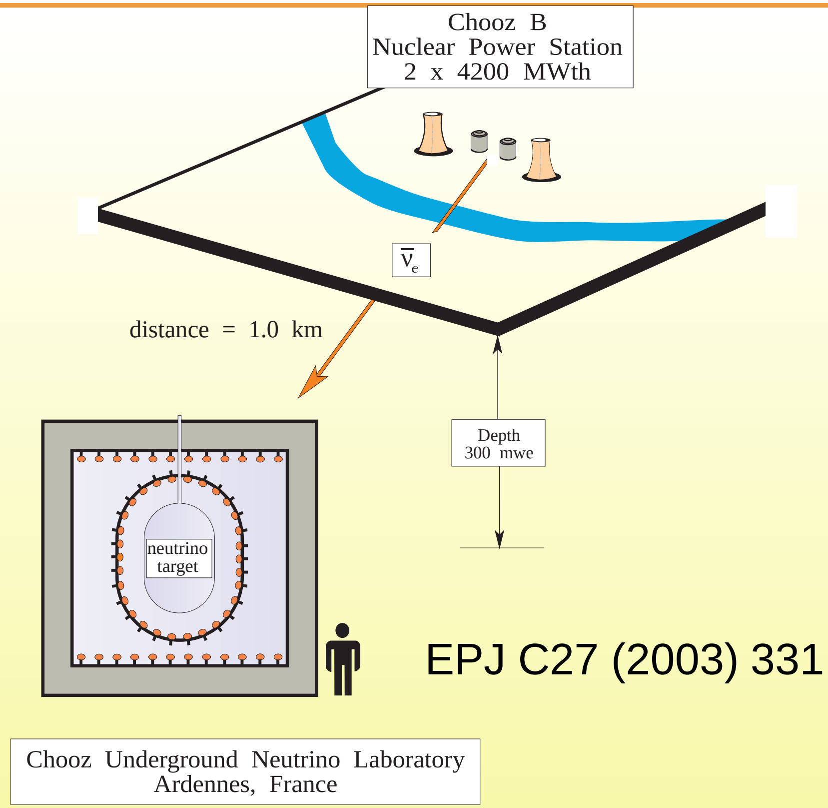
Bugey spectra

Histogram relative to the best fit against the Bugey experimental data.



Chooz

The ratio of the number of observed to the expected events (in absence of oscillations) is $R_{\text{Chooz}} = 1.01 \pm 0.04$.



$$P_{\nu_e \to \nu_e}(L, E) = 1 - \sin^2(2\theta)\sin^2\left(1.27\frac{\Delta m^2(eV^2)L(m)}{E(MeV)}\right)$$

average to

$$\langle P_{\bar{\nu}_e \to \bar{\nu}_e} \rangle = 1 - \frac{1}{2}\sin^2 2\theta,$$

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Experiment	L	E	Δm^2
Bugey (SBL)	$\sim$ 10 m	$\sim$ 1 MeV	$\sim$ 0.1 eV^2
Chooz (LBL)	$\sim$ 1 km	$\sim$ 1 MeV	$\sim 10^{-3}$ eV^2

Which is then combined with the previous analysis, excluding values of $\sin^2(2\theta) \gtrsim 0.1$ for $\Delta m^2 \lesssim 3 \times 10^{-2}$, where Bugey is not sensitive.

Combined Fit

The combined analysis confirms the weak indication in favor of neutrino oscillations with

$$\mathbf{\Delta m^2 \simeq 1.85eV^2}$$

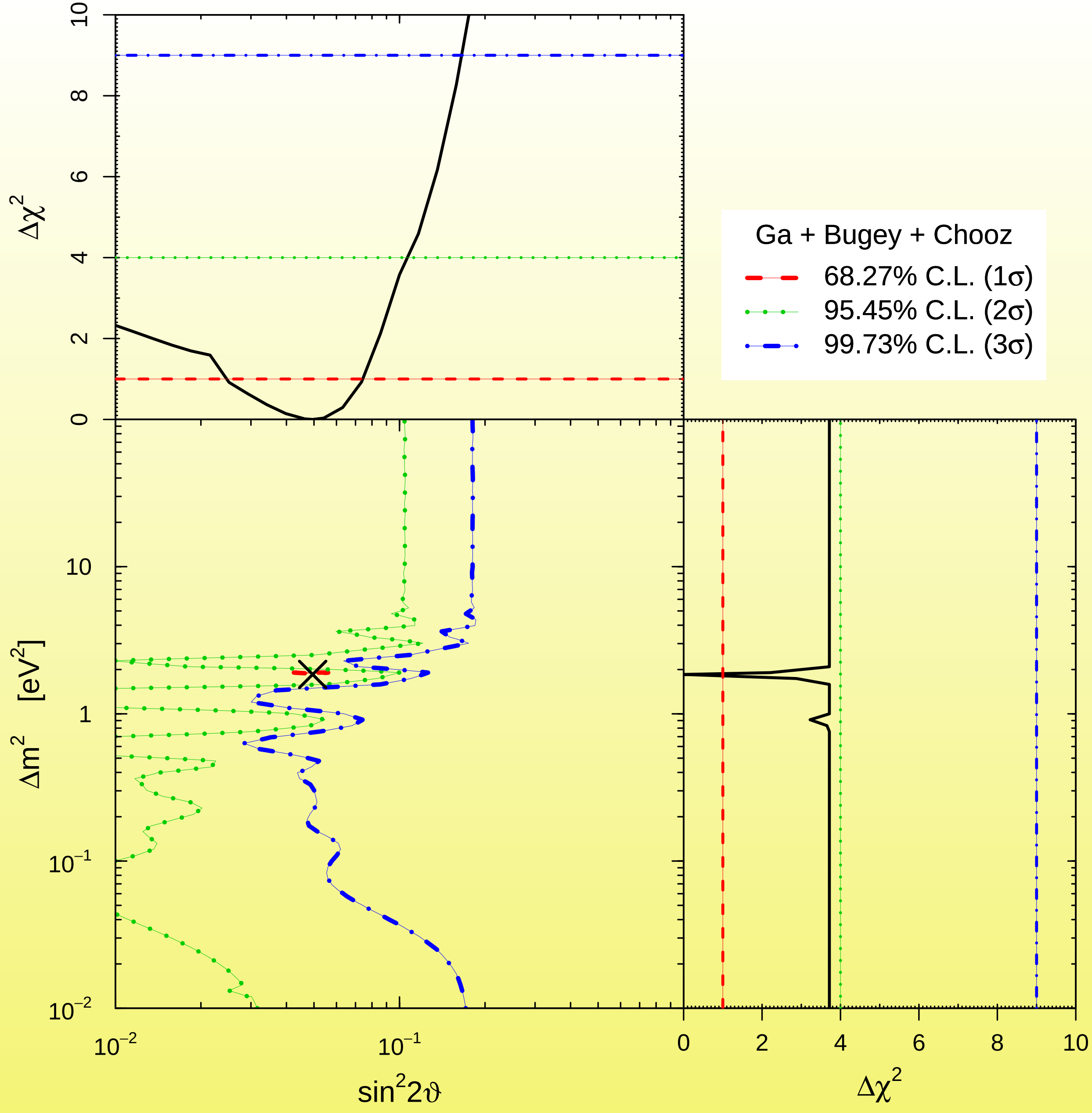
and

$$\mathbf{0.03} \lesssim \sin^2 2\theta \lesssim \mathbf{0.07}.$$

Our Best Fit:

$$\chi^2_{\text{min}} = 53.40,$$

$$\sin^2 2\theta = 0.05 \quad \Delta m^2 = 1.85\text{eV}^2.$$



Conclusions

- From Gallium experiments, **we found a possible indication of $\nu_e \to \nu_s$ oscillation** with $\sin^2 2\theta \gtrsim 0.03$ and $\Delta m^2 \gtrsim 0.1$ eV^2.
- The Bugey data present a **weak indication in favor of neutrino oscillations** with $0.01 \lesssim \sin^2 2\theta \lesssim 0.07$ and $1.8 \lesssim \Delta m^2 \lesssim 1.9$ eV^2.
- The combined analysis of the Gallium, Bugey and CHOOZ data, the **weak indication persists**, with **compatible results** with the Bugey and CHOOZ reactor experiments.

M.A.A., C. Giunti, M. Laveder, ***Limits on ν_e and $\bar{\nu}_e$ disappearance from Gallium and reactor experiments***, `arXiv:0711.4222`.