Sterile neutrinos

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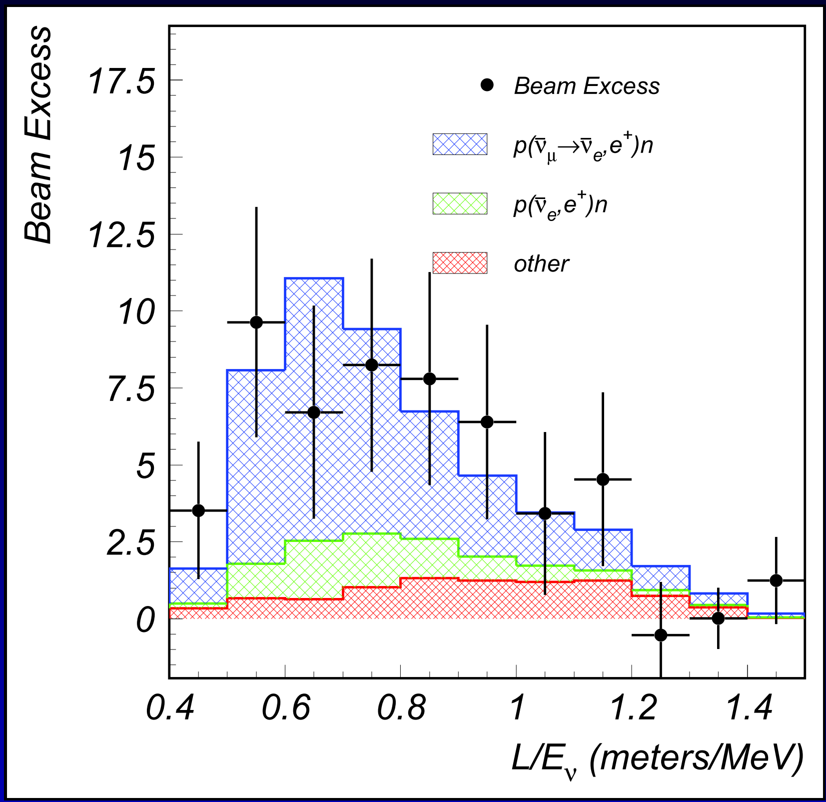
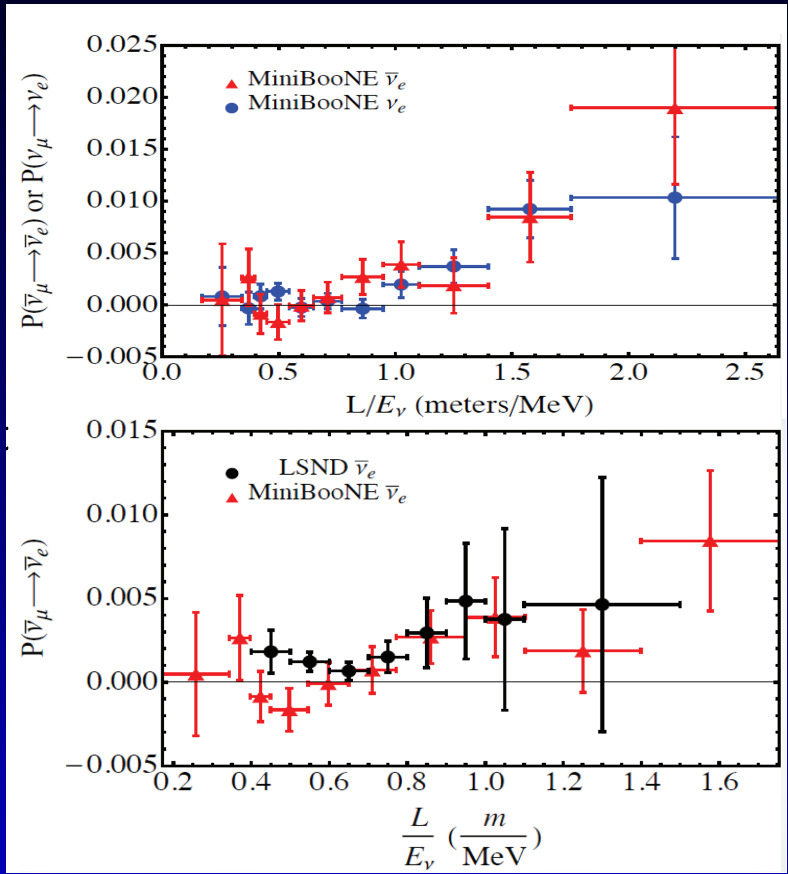
LSND and MiniBooNE

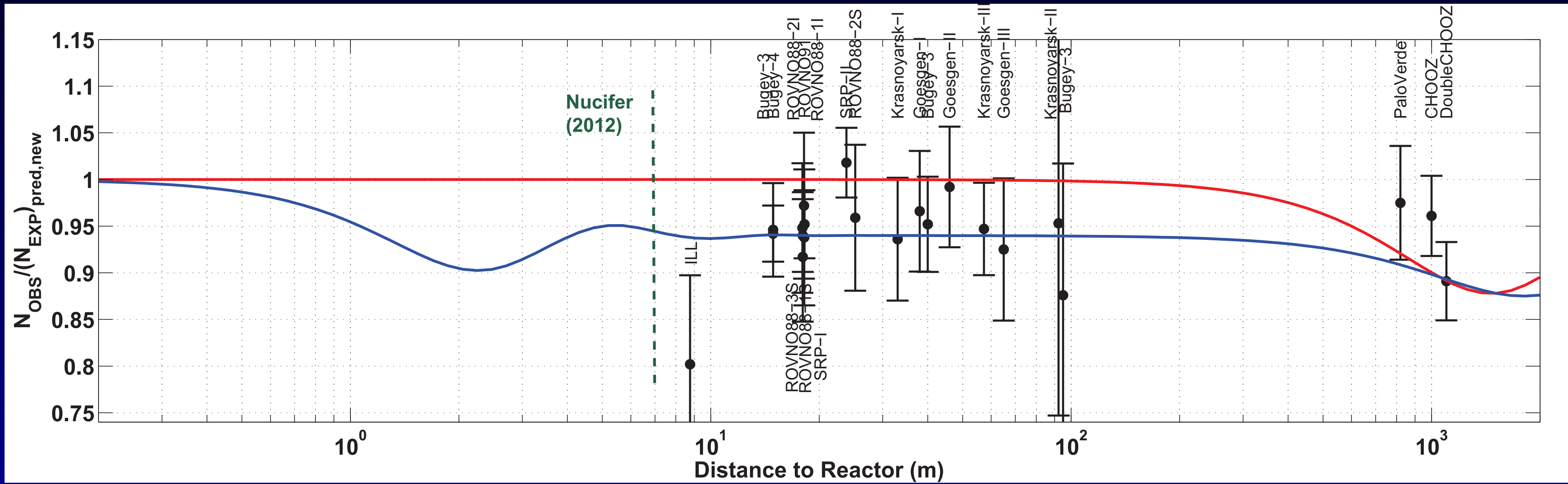




$$P(\bar{\nu}_\mu \to \bar{\nu}_e) \simeq 0.003$$

Tension between neutrino and antineutrino signals?

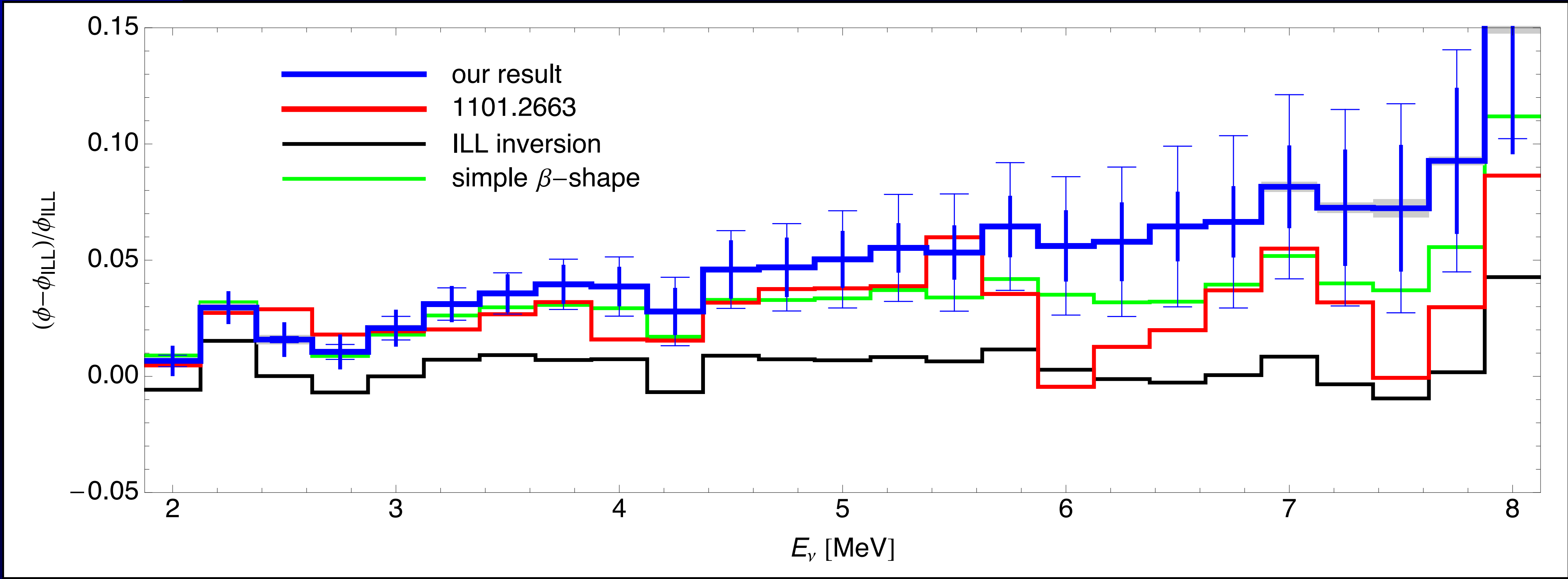
Reactor anomaly



6% deficit of $\bar{\nu}_e$ from nuclear reactors at short distances

- 3% increase in reactor neutrino fluxes
- decrease in neutron lifetime
- inclusion of long-lived isotopes (non-equilibrium correction)

Reactor antineutrino fluxes

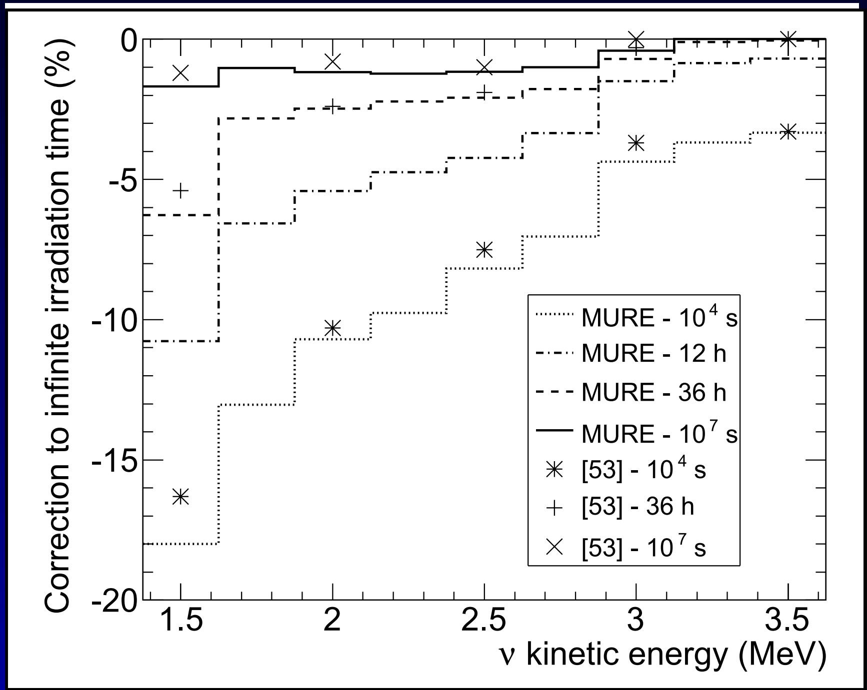


Shift with respect to ILL results, due to

a) different effective nuclear charge distribution

b) branch-by-branch application of shape corrections

Non-equilibrium corrections



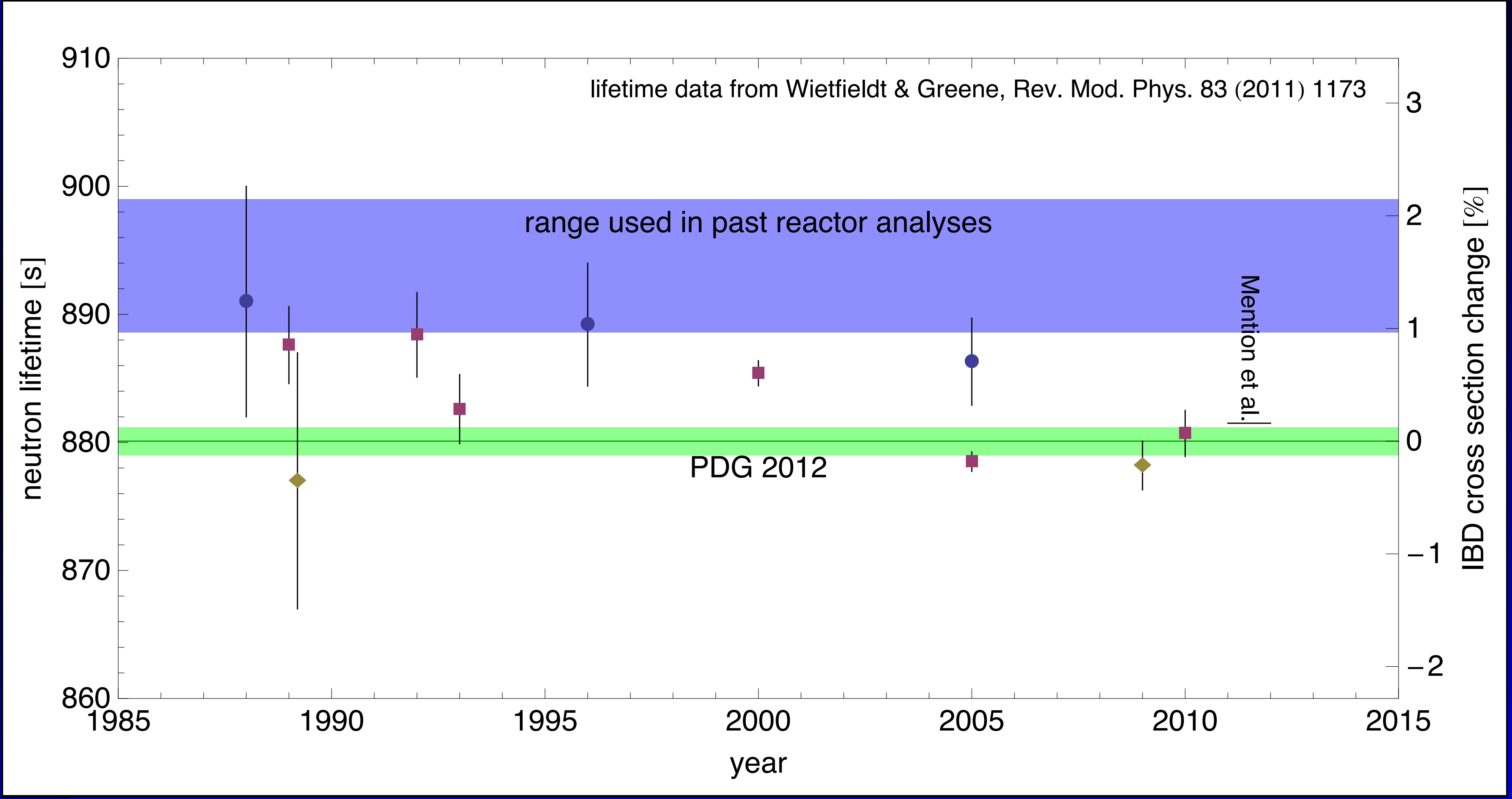
Mueller, *et al.*, RRC 83 (2011) 054615

only 2 dozen isotopes with $t_{1/2} > 12\,\mathrm{h}$ above inverse β-decay threshold

Extra shift due to long-lived isotopes

a) small nuclear physics uncertainty in β-decay
b) depends on detailed fuel history

Neutron lifetime



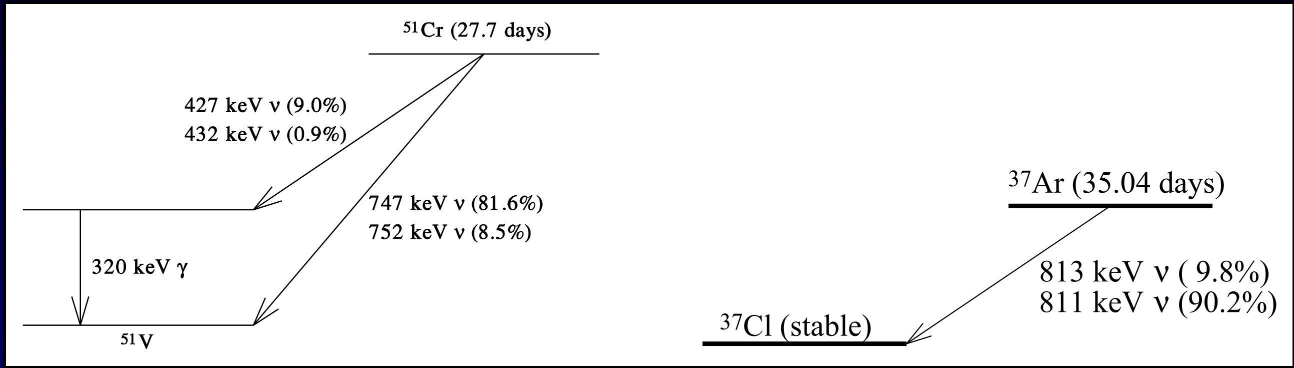
Gallium anomaly

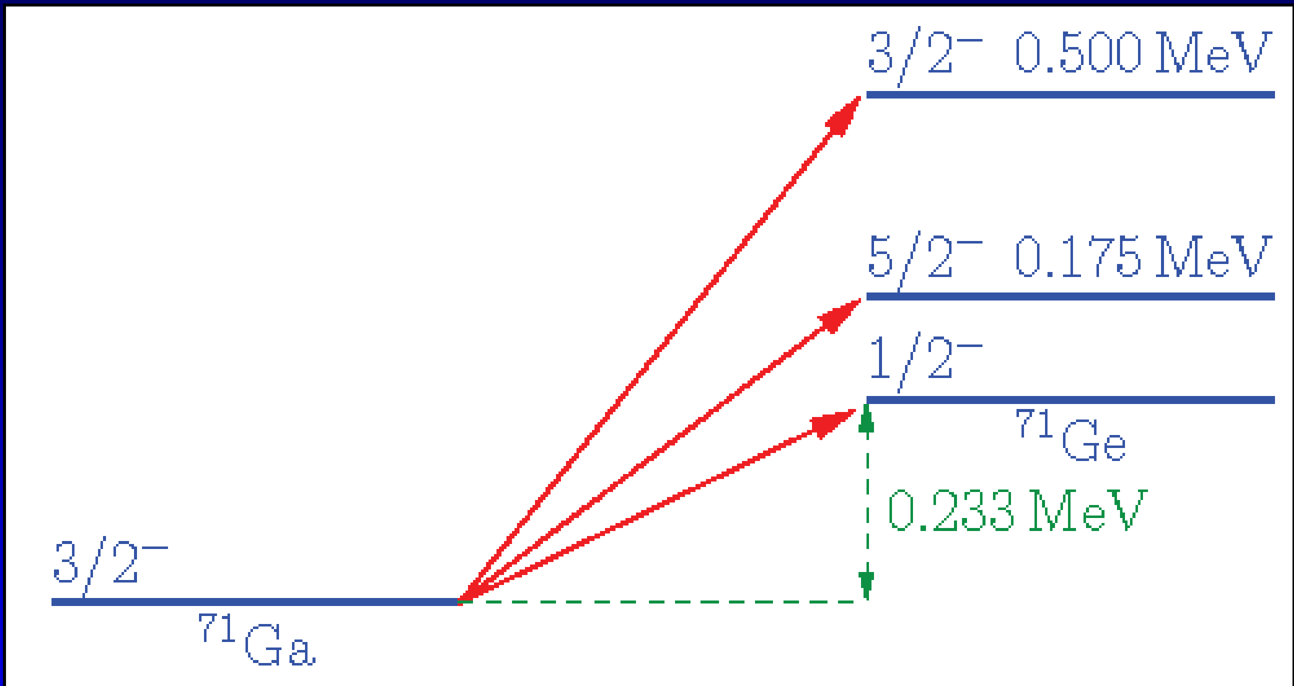
	GALLEX		SAGE	
k	G1	G2	S1	S2
source	^{51}Cr	^{51}Cr	^{51}Cr	^{37}Ar
R^k_{B}	0.953 ± 0.11	$0.812^{+0.10}_{-0.11}$	0.95 ± 0.12	$0.791 \pm ^{+0.084}_{-0.078}$
R^k_{H}	$0.84^{+0.13}_{-0.12}$	$0.71^{+0.12}_{-0.11}$	$0.84^{+0.14}_{-0.13}$	$0.70 \pm ^{+0.10}_{-0.09}$
radius [m]	1.9		0.7	
height [m]	5.0		1.47	
source height [m]	2.7	2.38	0.72	

25% deficit of ν_e from radioactive sources at short distances

- effect depends on nuclear matrix element
- interpretation as sterile neutrino is in conflict with large scale structure neutrino mass bounds over a large fraction of the parameter space

Nuclear matrix elements – I





Nuclear matrix elements – II

For example for the rate from ^{51}Cr this implies, following Haxton nucl-th/9804011v2, the following correction

$$0.667\frac{GT(5/2^-)}{GT(gs)} + 0.218\frac{GT(3/2^-)}{GT(gs)}$$

where $GT(gs)$ is the ground state β-decay Gamow-Teller matrix element determined from the β-decay of ^{71}Ge.
The problem is that $GT(5/2^-)$ and $GT(3/2^-)$ need be indirectly inferred, for instance from (p,n) exchange reaction measurements.

Astrophysics

Model	Data	N_{eff}	Ref.
N_{eff}	W-5+BAO+SN+H_0	$4.13^{+0.87(+1.76)}_{-0.85(-1.63)}$	[347]
	W-5+LRG+H_0	$4.16^{+0.76(+1.60)}_{-0.77(-1.43)}$	[347]
	W-5+CMB+BAO+XLF+f_{gas}+H_0	$3.4^{+0.6}_{-0.5}$	[350]
	W-5+LRG+maxBCG+H_0	$3.77^{+0.67(+1.37)}_{-0.67(-1.24)}$	[347]
	W-7+BAO+H_0	$4.34^{+0.86}_{-0.88}$	[339]
	W-7+LRG+H_0	$4.25^{+0.76}_{-0.80}$	[339]
	W-7+ACT	5.3 ± 1.3	[344]
	W-7+ACT+BAO+H_0	4.56 ± 0.75	[344]
	W-7+SPT	3.85 ± 0.62	[345]
	W-7+SPT+BAO+H_0	3.85 ± 0.42	[345]
	W-7+ACT+SPT+LRG+H_0	$4.08^{(+0.71)}_{(-0.68)}$	[351]
	W-7+ACT+SPT+BAO+H_0	3.89 ± 0.41	[352]
$N_{eff}+f_\nu$	W-7+CMB+BAO+H_0	$4.47^{(+1.82)}_{(-1.74)}$	[353]
	W-7+CMB+LRG+H_0	$4.87^{(+1.86)}_{(-1.75)}$	[353]
$N_{eff}+\Omega_k$	W-7+BAO+H_0	4.61 ± 0.96	[352]
	W-7+ACT+SPT+BAO+H_0	4.03 ± 0.45	[353]
$N_{eff}+\Omega_k+f_\nu$	W-7+ACT+SPT+BAO+H_0	4.00 ± 0.43	[352]
	W-7+CL+SPT+BAO+H_0	(< 3.74)	[354]
$N_{eff}+f_\nu+w$	W-7+CMB+BAO+H_0	$3.68^{(+1.90)}_{(-1.84)}$	[353]
	W-7+CMB+LRG+H_0	$4.87^{(+2.02)}_{(-2.02)}$	[353]
$N_{eff}+\Omega_k+f_\nu+w$	W-7+CMB+BAO+SN+H_0	$4.2^{+1.10(+2.00)}_{-0.61(-1.14)}$	[355]
	W-7+CMB+LRG+SN+H_0	$4.3^{+1.40(+2.30)}_{-0.54(-1.09)}$	[355]

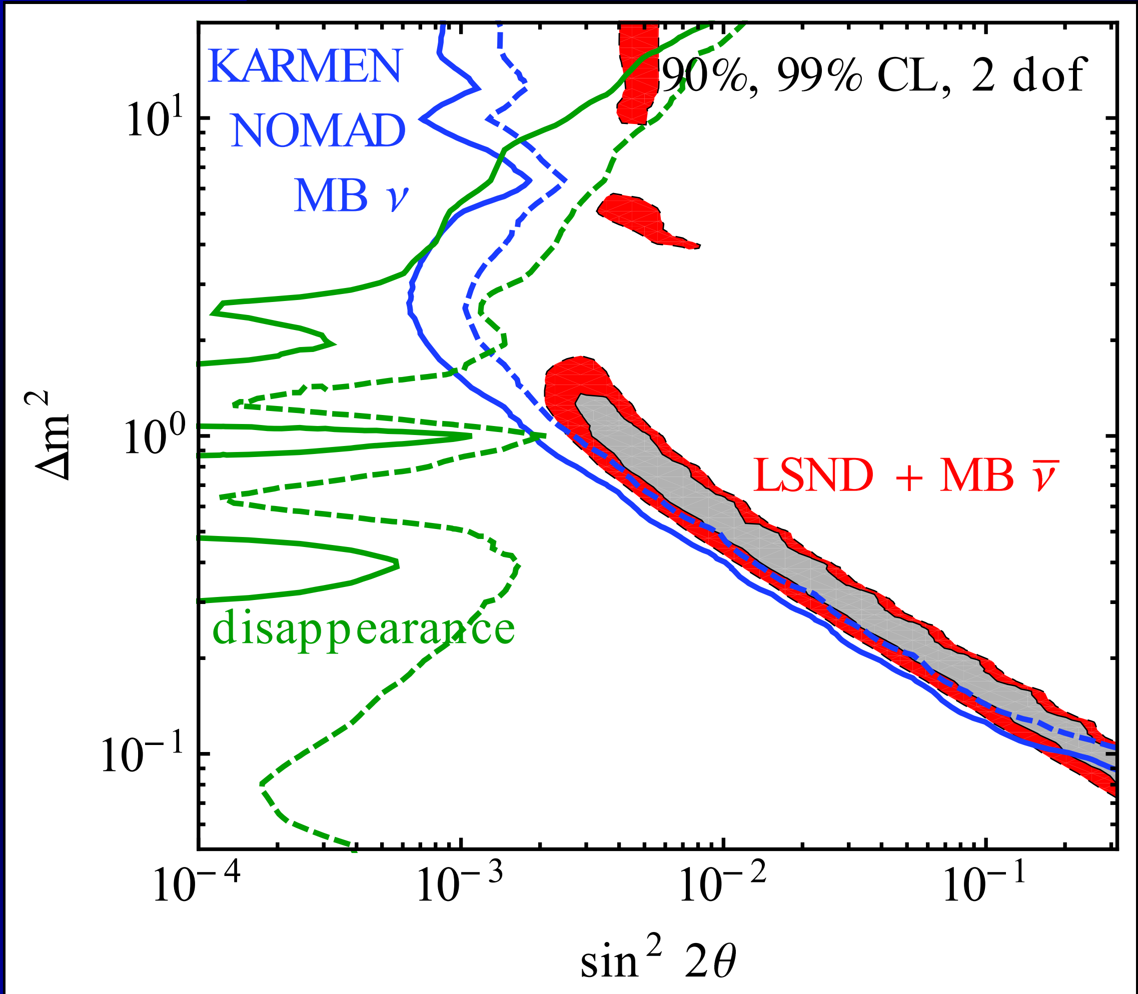
$N_{\rm eff} \simeq 4$ from relativistic energy density

BUT

$m_s \lesssim 1\,{\rm eV}$ from large scale structure

future data (PLANCK) will help to address this tension

Disappearance constraints



Absence of effects in

- atmospheric
- Bugey
- CDHS
- MINOS
- …

data creates considerable tension in 3+N sterile neutrino models

More details can be found in the sterile neutrino white paper, arXiv:1204.5379.

Sterile oscillation

In general, in a 3+N sterile neutrino oscillation model one finds that the energy averaged probabilities obey the following inequality

$$P(\nu_\mu \to \nu_e) \leq 4P(\nu_e \to \nu_e)P(\nu_\mu \to \nu_\mu)$$

independent of CP transformations. Therefore, a stringent test of the model is to measure

- $P(\nu_\mu \to \nu_e)$ – appearance
- $P(\bar{\nu}_\mu \to \bar{\nu}_e)$ – appearance
- $P(\nu_\mu \to \nu_\mu)$ or $P(\bar{\nu}_\mu \to \bar{\nu}_\mu)$ – disappearance
- $P(\nu_e \to \nu_e)$ or $P(\bar{\nu}_e \to \bar{\nu}_e)$ – disappearance

Summary

- All current hints are 3 σ-ish
- A lot of hidden, hard to control systematics and theory errors
- Tension in global fits (see talk by G. Karagiorgia)
- Need for new experiments (see talk by B. Fleming)
- What would be the consequence of a discovery for LBL physics?