Search for sterile neutrino mixing at Daya Bay

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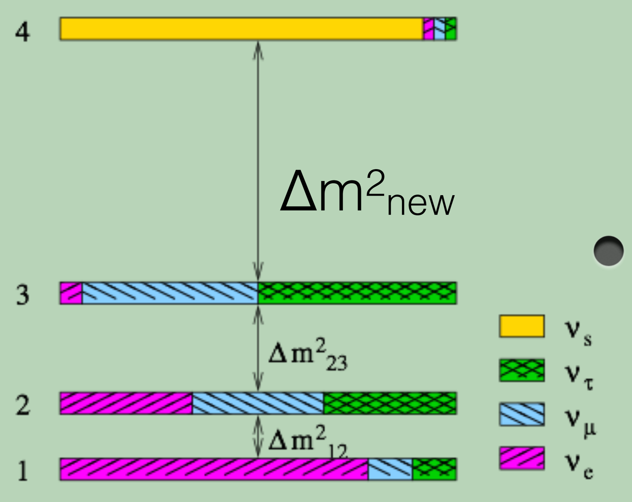
Introduction

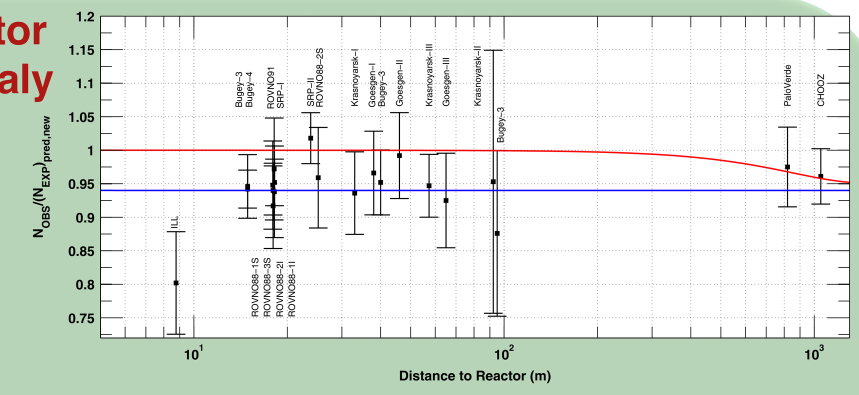
Sterile neutrinos

- Three-flavor neutrino mixing framework has been successful in explaining most of the experimental results
- Yet, additional flavors of neutrino can exist provided that they do not contribute to the Z-decay width (sterile)

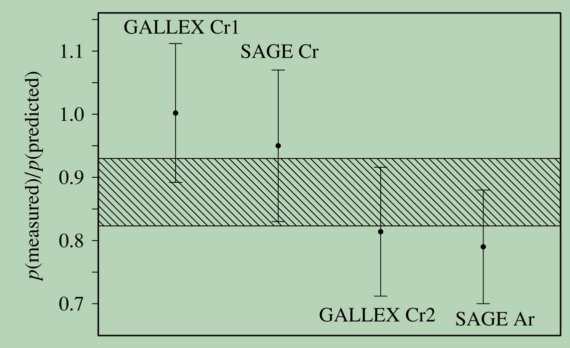


- Such "sterile" flavor neutrinos can produce additional mode of neutrino oscillation
- Many possible hints, including reactor anomaly, gallium anomaly, LSND/MiniBooNE results and cosmological observations

Reactor anomaly

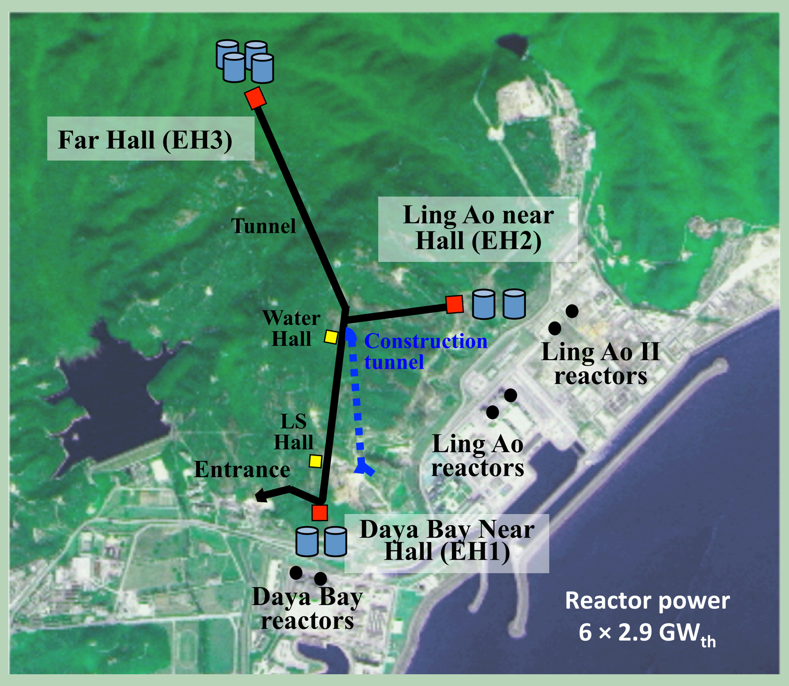


Gallium anomaly

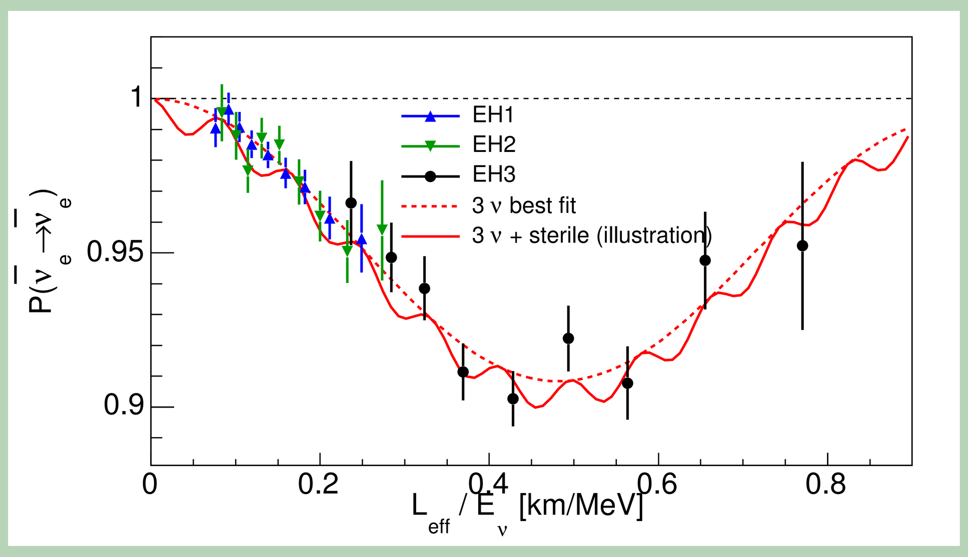


Daya Bay experiment

Daya Bay: High precision measurement of reactor antineutrino flux at multiple baseline

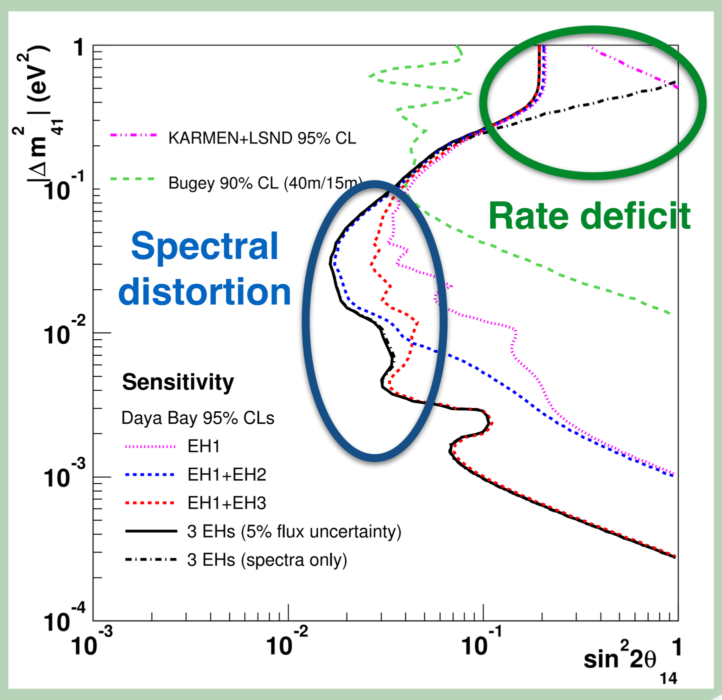


Oscillation effects would appear as additional rate deficit and spectral distortion



$$P(\bar{\nu}_e \to \bar{\nu}_e) \simeq 1 - \cos^4\theta_{14}\sin^2 2\theta_{13}\sin^2\left(\frac{\Delta m^2_{ee}L}{4E_\nu}\right) - \sin^2 2\theta_{14}\sin^2\left(\frac{\Delta m^2_{41}L}{4E_\nu}\right)$$

Location	IBD Candidates	Distance to Reactor Core (m)		
		Daya Bay	Ling Ao	Ling Ao-II
EH1	203809	364	857	1307
EH2	92912	1348	480	528
EH3	41589	1912	1540	1548



Analysis Methods

Multiple independent methods

Testing oscillation hypothesis

Improved analysis based on previous spectral analysis for $\sin^2 2\theta_{13}$ and Δm^2_{ee} measurement

(A) Simultaneous fit of observed spectra at three EHs with reactor flux model

- Uses all the information available.
- Rely on the current knowledge of the reactor antineutrino flux (possible bias)

(B) Pure relative rate+shape comparison

- Mostly independent of reactor antineutrino flux model
- Loose sensitivity at high Δm^2

Setting CL intervals

(1) Feldman-Cousins method

- Evaluate: $\Delta\chi^2(\Delta m^2_{41}, \sin^2 2\theta_{14}) = \chi^2(\Delta m^2_{41}, \sin^2 2\theta_{14}) - \chi^2(\text{best})$
- Value of $\Delta\chi^2$ corresponding to a certain confidence level is statistically determined by a large set of toy MC sample.
- Unified treatment of "parameter estimation" and "limit setting"

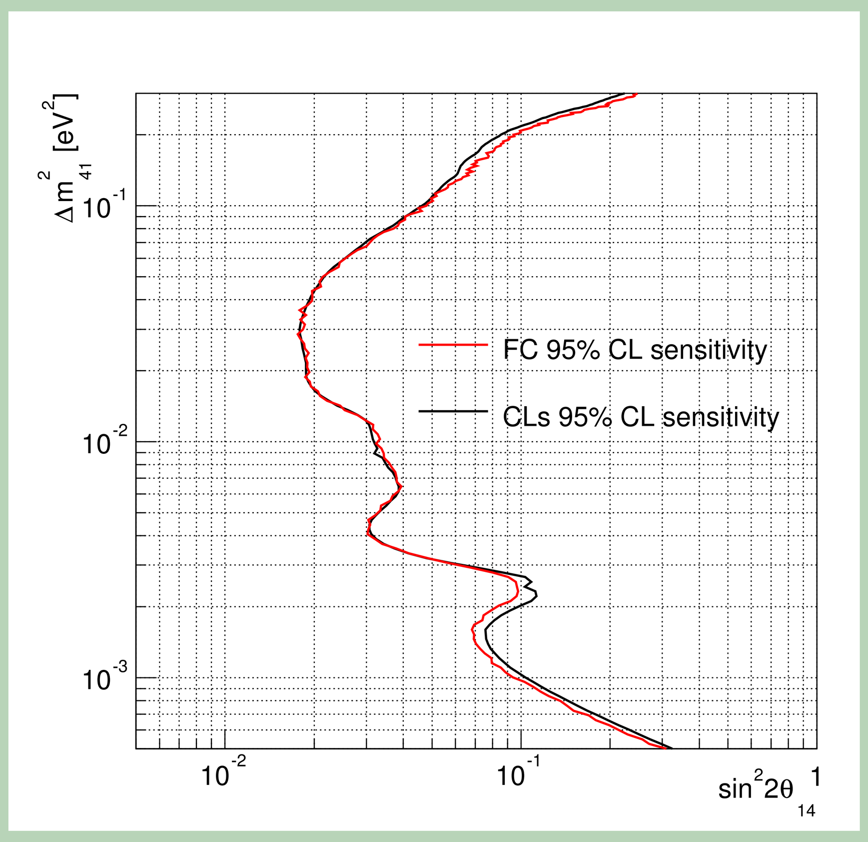
(2) "CL_S" method

- Two-hypotheses test between 3ν standard model and 3+1 model

$$\Delta\chi^2 = \chi^2((3+1)\nu) - \chi^2(3\nu)$$

- Determine CL_S= as: $CL_s = \frac{1-p_1}{1-p_0}$
- Less computationally intensive and stable
- Can only be used for "limit setting"

All the methods show consistent sensitivity at $\Delta m^2 < 0.3$ eV^2, where most of the sensitivity come from relative shape comparison



Results and Conclusions

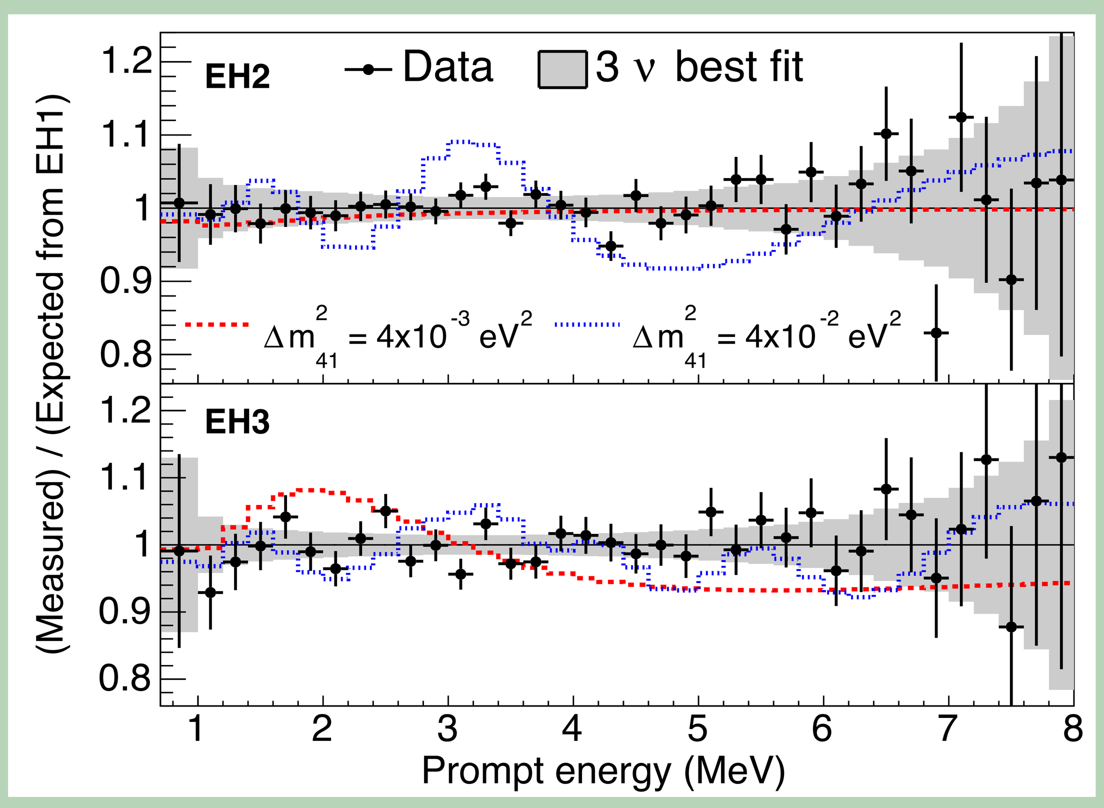
Oscillation hypothesis test

$\chi^2(3+1\nu, \text{best}) = 158.8/153$,
$\chi^2(3\nu) = 162.6/155$
$\Delta\chi^2 = 3.8$ ➔ p-value = 0.74

No significant signal for sterile neutrino mixing observed

Limit to $\bar{\nu}_e$ disappearance

- Set limit at $10^{-3} < \Delta m^2_{41} < 0.3$ eV^2
- World's best limit at $10^{-3} < \Delta m^2_{41} < 0.1$ eV^2, which was largely unexplored.
- Expect factor of two improvement at most of the Δm^2_{41} region with three or more years of data.



Publication is in preparation