Antineutrino Anomaly at Daya Bay and Sterile Neutrino

– Final Presentation: PHY802 Survey of Nuclear Physics by Prof. Witek Nazarewicz

Chi-En Teh (Fanurs)
teh@nscl.msu.edu
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Abstract

Proposed in 2011, the reactor antineutrino anomaly was thought to be a potential hint for the search of sterile neutrino ν_s, a hypothetical fourth flavor of neutrinos. In 2017, the Daya Bay Collaboration reported a correlation between reactor core fuel evolution and changes in the reactor antineutrino flux. A 7.8% discrepancy between the observed and predicted ^{235}U yields suggests that this isotope may be the primary contributor to the anomaly, disfavoring the potential existence of sterile neutrino.

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Outline

1. Background of Reactor Antineutrino Anomaly
2. A closer look into the $\bar{\nu}_e$ deficit by Daya Bay Collaboration
3. Conslusion and Prospect

Antineutrino Anomaly of Nuclear Reactors

In 2011, calculations[*] showed that $\bar{\nu}_e$ flux from reactors suffer from deficit:

Reactor Antineutrino Anomaly

Observation $<$ Theory by 5.7%, significant at the level of 98.6% C.L.

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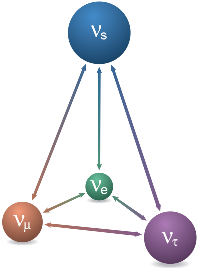
Popular conjecture: The missing $\bar{\nu}_e$'s turned into *sterile neutrinos* ν_s?

- Hypothetical fourth flavor
- Only interacts via gravity



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Recent research by Daya Bay Collaboration[*]

- 2.2 million inverse β decays (IBDs; $\bar{\nu}_e$ capture) observed from 2011-2015.
- Four primary fission isotopes: ^{235,238}U, ^{239,241}Pu (the rest $< 0.3\%$).

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- 2.2 million inverse β decays (IBDs; $\bar{\nu}_e$ capture) observed from 2011-2015.
- Four primary fission isotopes: ^{235,238}U, ^{239,241}Pu (the rest $< 0.3\%$).
- Successfully reproduce the antineutrino anomaly.

The total IBD yield, $\bar{\sigma}_f$ is given by

	$\bar{\sigma}_f (\times 10^{-43}$ cm^2/fission)
Daya Bay	$5.90(13)$
Huber-Mueller (2011)	$6.22(14)$

$\approx 5.1\%$ deficit was observed

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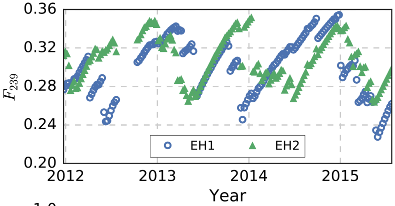
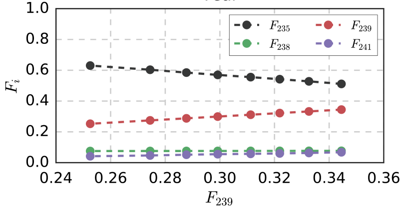
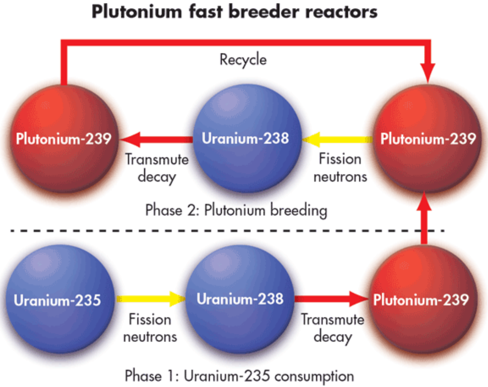
Effective fission fraction – a previously overlooked variable

- Take account of the *effective fission fraction* $F_i(t)$, where the subscript i uniquely identifies the four fission isotopes by their mass numbers.

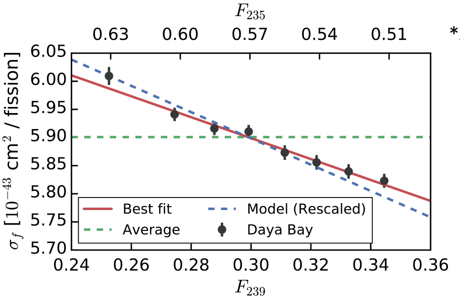






Sorensen, K. (2016, Sep 28). *What's the Difference Between Thorium and Uranium Nuclear Reactors?* Retrieved from http://www.machinedesign.com/

The Huber-Mueller Model (H-M)



*All cross sections are in the unit of $\times 10^{-43}$ cm^2/fission.

	$\bar{\sigma}_f = \sum_i \bar{F}_i \sigma_i$
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decompose by i

i	235	238	239	241
$\bar{F}_i$	57.1%	7.6%	29.9%	5.4%
σ_i^{Daya}	6.17(17)	10.1(10)	4.27(26)	6.04(60)

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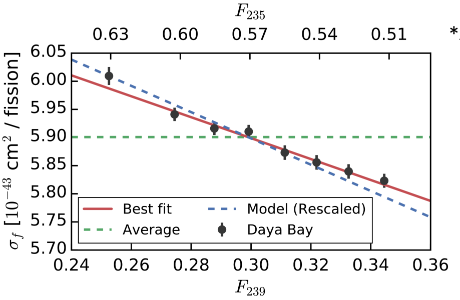

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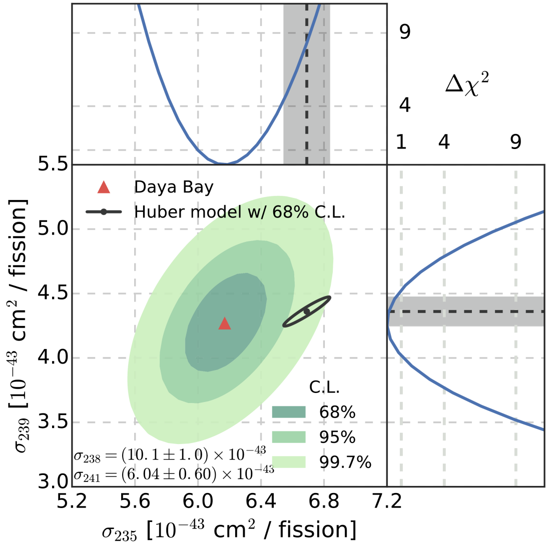
σ_i^{Daya}	$6.17(17)$	$10.1(10)$	$4.27(26)$	$6.04(60)$
$\sigma_i^{\text{H-M}}$	Expect $\approx 5.1\%$ *extra* $\bar{\nu}_e$ for all i if ν_s exists			

IBD yields of ^{235}U and ^{239}Pu



IBD yields of ^{235}U and ^{239}Pu

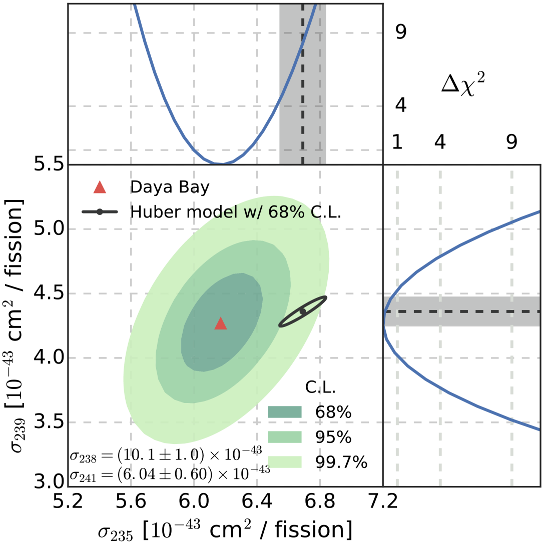
Introduce deficit:

$$\Delta\sigma_i := \frac{\sigma_i^{\text{Daya}} - \sigma_i^{\text{H-M}}}{\sigma_i^{\text{H-M}}}$$

$$\Longrightarrow \Delta\sigma_{235} \approx -7.8\%$$

Hypothesis: $\Delta\sigma_{235} = \Delta\sigma_{239}$

- p-value $= 0.0049$
- reject with $2.8\sigma_{\text{std}}$ C.L.



Conslusion and Prospect

- A model that invokes sterile neutrino requires an equal fractional flux deficit.
- Daya Bay Collaboration rejects this at $2.8\sigma_{\mathsf{std}}$.
- Instead, the research favors for an incorrect prediction of the ^{235}U flux as the primary cause to the anomaly.

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- Instead, the research favors for an incorrect prediction of the ^{235}U flux as the primary cause to the anomaly.
- But to fully resolve the anomaly, the precise contribution of β decay in each fission isotope to the antineutrino spectrum has to be identified.

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Q&A

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