TERRESTRIAL NEUTRINO EXPERIMENTS

Giunti, C., & Kim, C. W. (2007). Fundamentals of Neutrino Physics and Astrophysics. Oxford University Press. doi:10.1093/acprof:oso/9780198508717.001.0001

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PandA @ UNM

OUTLINE

- Some Q&A's about Neutrino Experiments
- Exclusion Curve
- Sensitivity
- Results of Experiments
- Summary

Q&A'S

Q&A's

What Does Theory Tell Us about Neutrino Oscillation

The transition probability from one flavor state ν_α to another ν_β,

$$P\left(\frac{L}{E}\right) = \frac{1}{2}\sin^2 2\theta \left(1 - \cos\left(\frac{\Delta m^2}{2}\frac{L}{E}\right)\right)$$

What Do Experiments Tell Us about Neutrino Oscillation

Experiments detect neutrino triggered events N^{obs} through reactions. One example of those reactions is

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

We can calculate a probability of neutrino disappearance,

$$P_{obs} = 1 - \frac{N^{obs}}{N^{exp}} .$$

N^{exp} is the number of neutrinos that should be detected if we assume no oscillation has happened.

Q&A'S

Should The Two Probabilities Be The Same?

No.

- Detectors: size range $[L_l, L_u]$;
- Neutrinos: energy spectrum $[E_l, E_u]$.

Detectors detect averaged probability.

What Average?

- Average over distribution of $\frac{L}{E}$: $\phi(\frac{L}{E})$.
- Gaussian $\phi(\frac{L}{E})$:

$$\langle P \rangle = \frac{1}{2}\sin^2 2\theta \left(1 - \cos\left(\frac{\Delta m^2}{2}\left\langle\frac{L}{E}\right\rangle\right)\exp\left(-\frac{1}{2}\left(\frac{\Delta m^2}{2}\sigma_{L/E}\right)^2\right)\right)$$

What Can Experiment Tell Us

No sign of oscillation $\Rightarrow$ Upper limit of probability

$$\langle P \rangle \leq P^{max}$$

Gaussian:

$$\sin^2 2\theta \leq \frac{2P^{max}}{1 - \cos\left(\frac{\Delta m^2}{2}\left\langle \frac{L}{E} \right\rangle\right) \exp\left(-\frac{1}{2}\left(\frac{\Delta m^2}{2}\sigma_{L/E}\right)^2\right)}$$

EXCLUSION CURVE

EXCLUSION CURVE

Exclusion

$$\sin^2 2\theta \leq \frac{2P^{max}}{1-\cos\left(\frac{\Delta m^2}{2}\left\langle \frac{L}{E}\right\rangle\right)\exp\left(-\frac{1}{2}\left(\frac{\Delta m^2}{2}\sigma_{L/E}\right)^2\right)} \Rightarrow \sin^2 2\theta \leq \frac{2P^{max}}{f(\Delta m^2\langle \frac{L}{E}\rangle)}$$

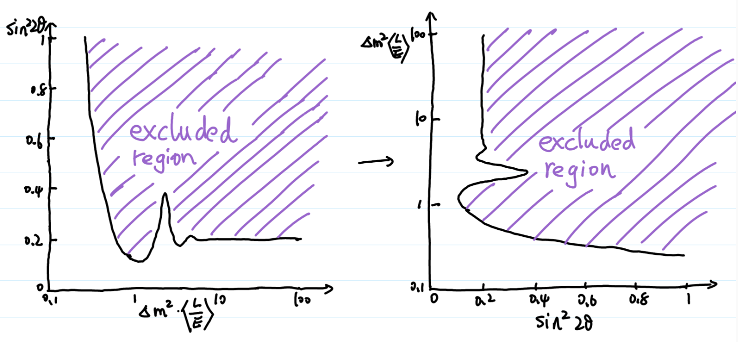


Figure: Exclusion Curves

SENSITIVITY

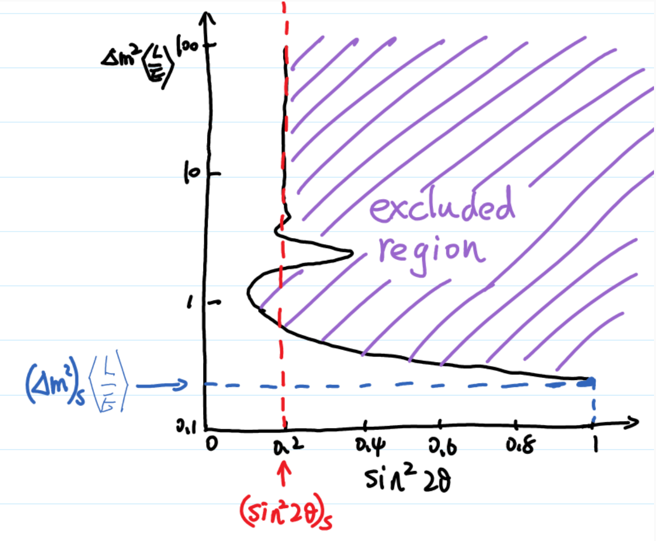


Figure: Sensitivity

Sensitivity

$$(\sin^2 2\theta)_s \propto P^{max} \sim \frac{L}{\sqrt{N^{src}\sigma(E)\eta M_{det}}}$$

$$(\Delta m^2) \propto \frac{E}{L}\sqrt{P^{max}} \sim E\frac{1}{\sqrt{L}\sqrt[4]{N^{src}\sigma(E)\eta M_{det}}}$$

Sensitivity of Δm^2

$\nearrow$ L $\rightarrow$ $\searrow$ Δm^2 which also $\nearrow$ $\sin 2\theta$

$\nearrow$ power of source + $\nearrow$ M_{det} to keep the sensitivity of $\sin^2 2\theta$

EXPERIMENTS

BASELINE

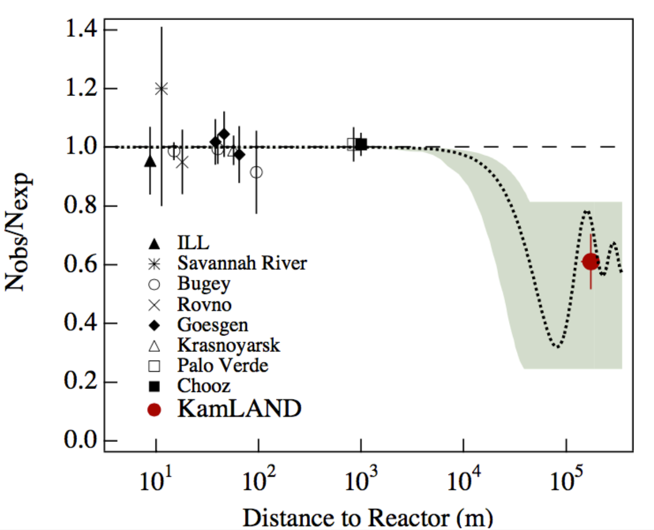


Figure: Baselines. Figure from Ref 1.

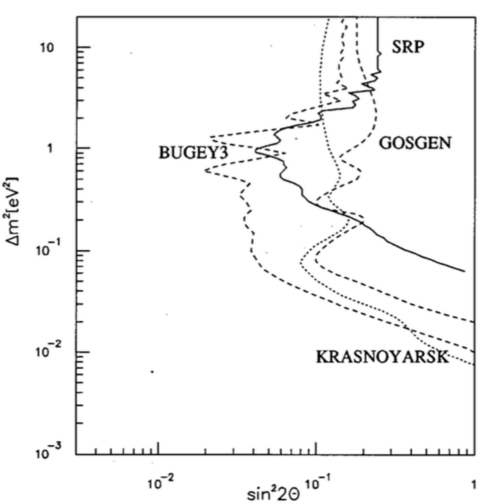


Figure: Short baseline

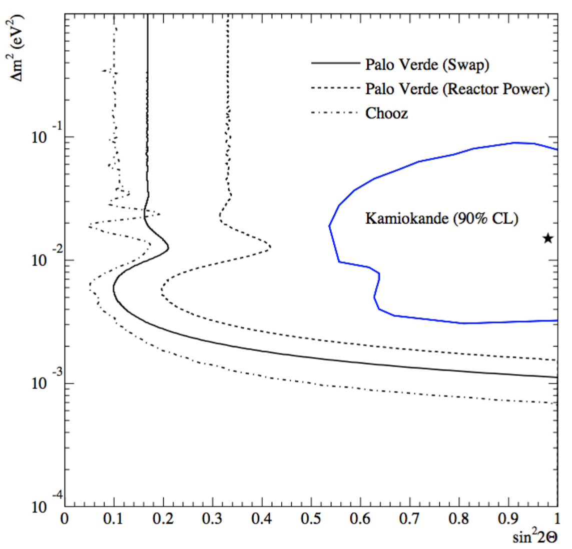
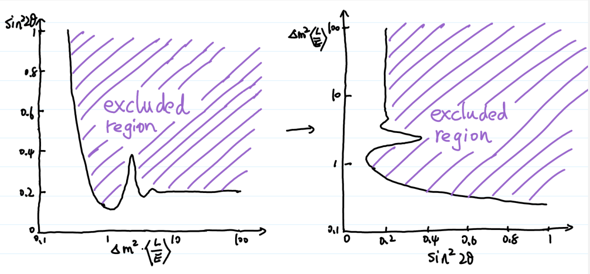


Figure: Long baseline

Analysis

- $L \nearrow$: $(\sin^2 2\theta_\nu)_s \nearrow$, $(\Delta m^2)_s \searrow$

Exclusion Curves



REFERENCES

1. Giunti, C., & Kim, C. W. (2007). Fundamentals of Neutrino Physics and Astrophysics. Oxford University Press. doi:10.1093/acprof:oso/9780198508717.001.0001
2. F. Boehm, et al. (2001). Final results from the Palo Verde neutrino oscillation experiment. Phys. Rev. D, 64, 112001.
3. `http://docs.neutrino.xyz/experiments.html`

BACKUPS

Backups

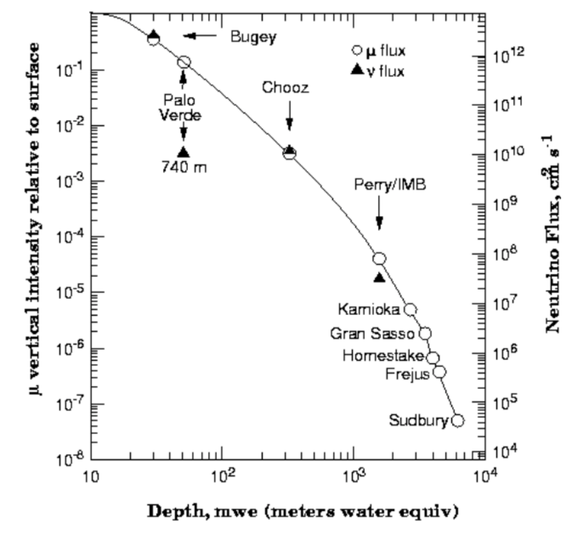


Figure: Background

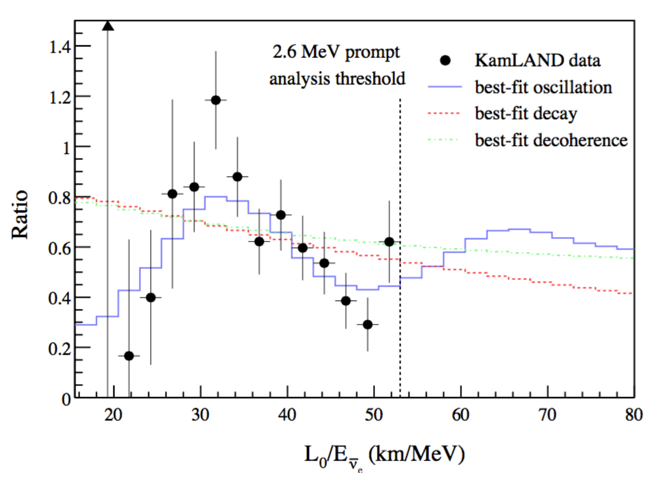


Figure: KamLand Result

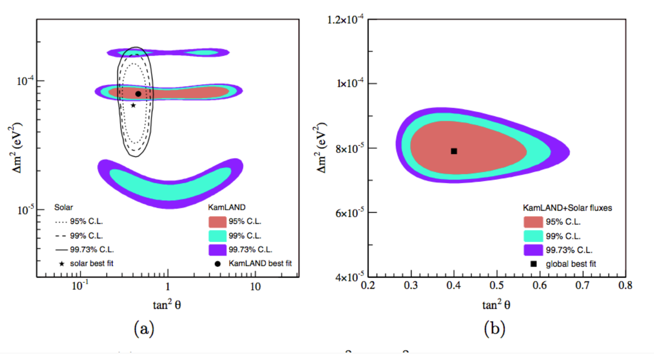


Figure: KamLand Result