AAP 2018 @LLNL

Constraining on the Solar Δm^2 using Daya Bay and RENO

arXiv: 1808.09150

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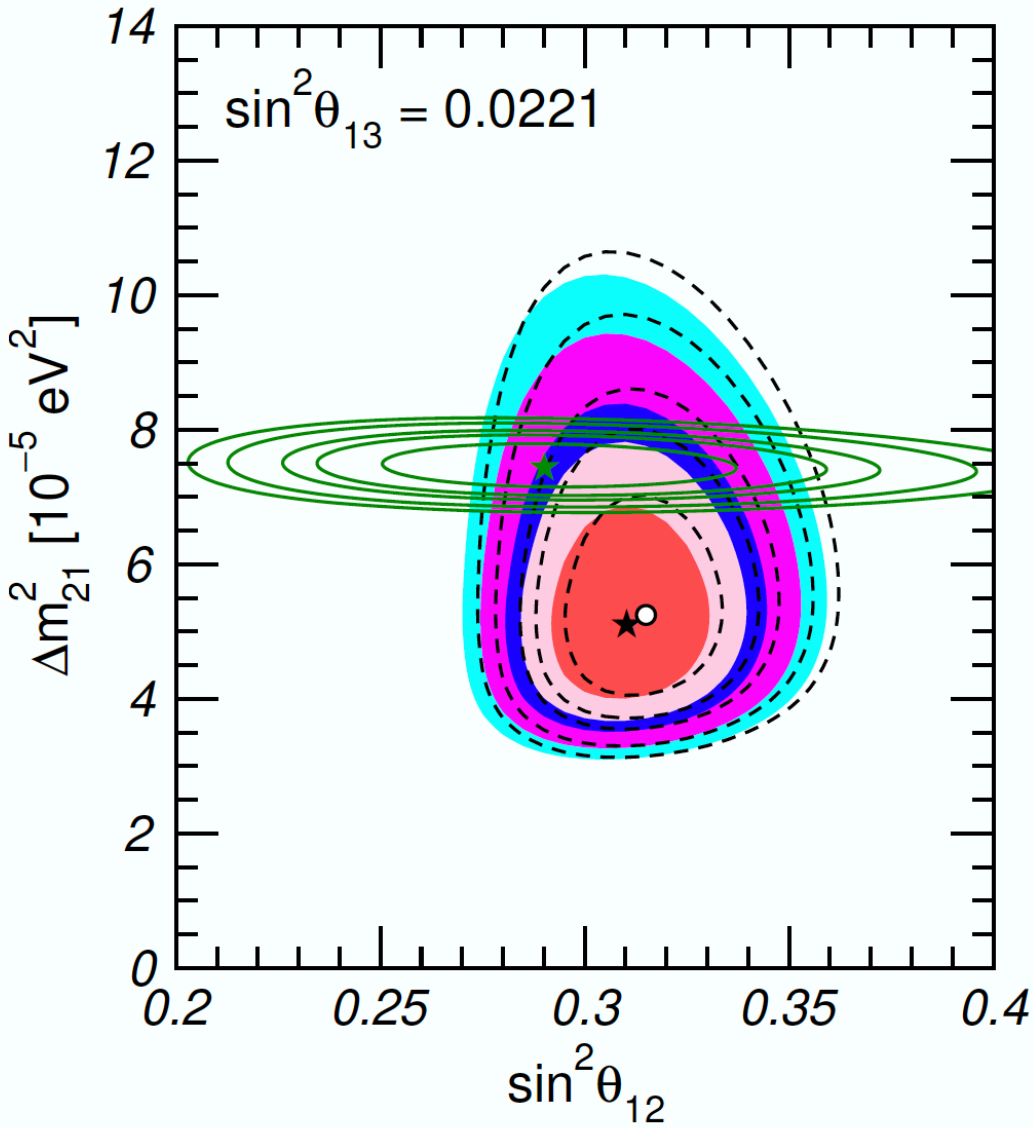
Tension between KamLAND and SNO/SK



1σ, 90%, 2σ, 99%, 3σ CL for 2 dof

- Best fit values

KamLAND:

$$\Delta m^2_{21} = 7.50^{+0.20}_{-0.20} \times 10^{-5}\ \mathrm{eV}^2,$$

SNO/SK:

$$\Delta m^2_{21} = 5.1^{+1.3}_{-1.0} \times 10^{-5}\ \mathrm{eV}^2,$$

~2 σ tension

Reactor θ_{13} Experiments

Currently running reactor θ_{13} experiments, Daya Bay & RENO can also constrain Δm^2_{21}.

RENO

Double Chooz

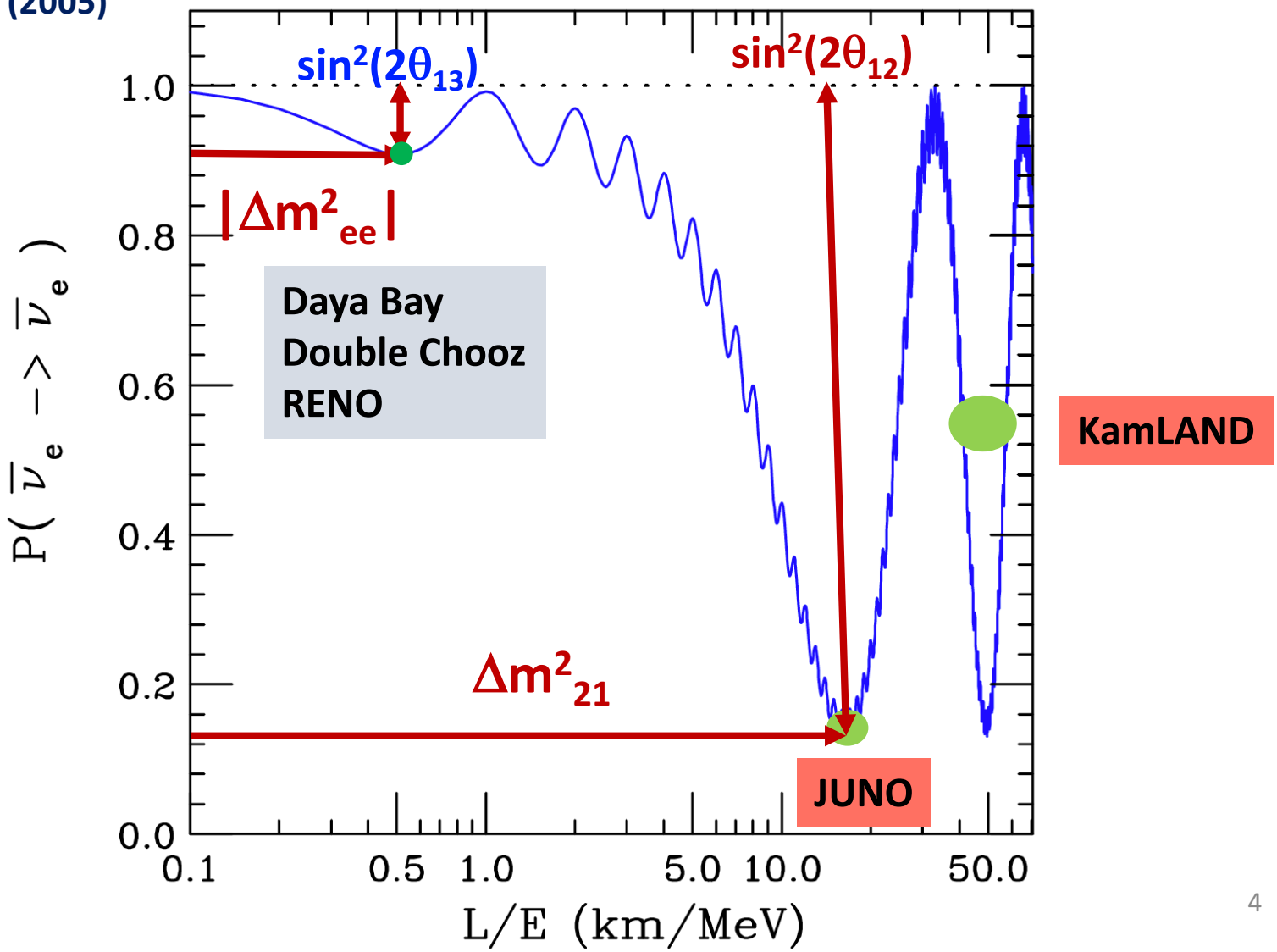
Daya Bay

Short baseline (reactor term) **Medium baseline** (Solar term)

$$P_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2 2\theta_{13} \sin^2(\Delta m^2_{ee} \frac{L}{4E}) - \cos^4 \theta_{13} \sin^2 2\theta_{12} \sin^2(\Delta m^2_{21} \frac{L}{4E})$$

Nunokawa, Parke, Funchal
PRD 72, 013009 (2005)

$$\Delta m^2_{ee} \equiv \cos^2 \theta_{12} \Delta m^2_{31} + \sin^2 \theta_{12} \Delta m^2_{32}$$

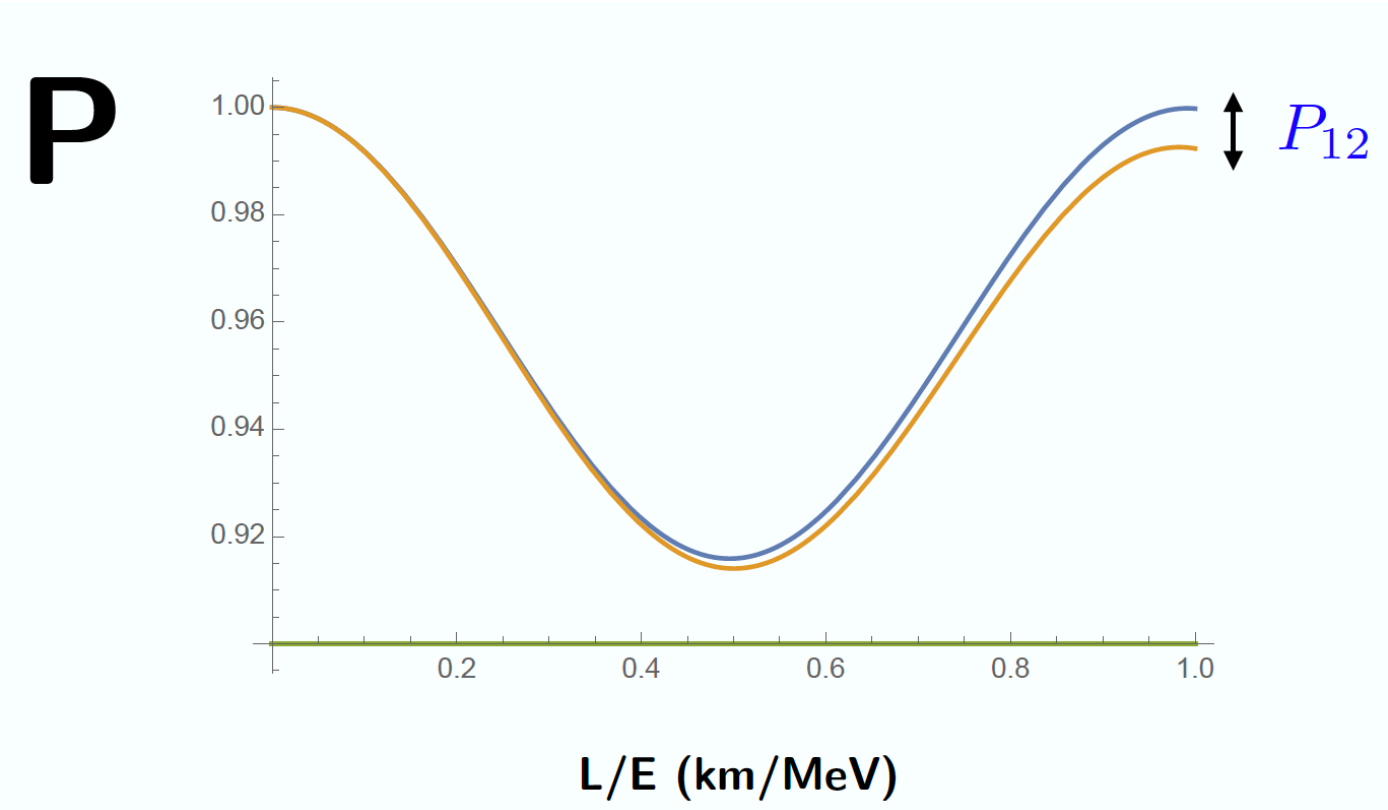


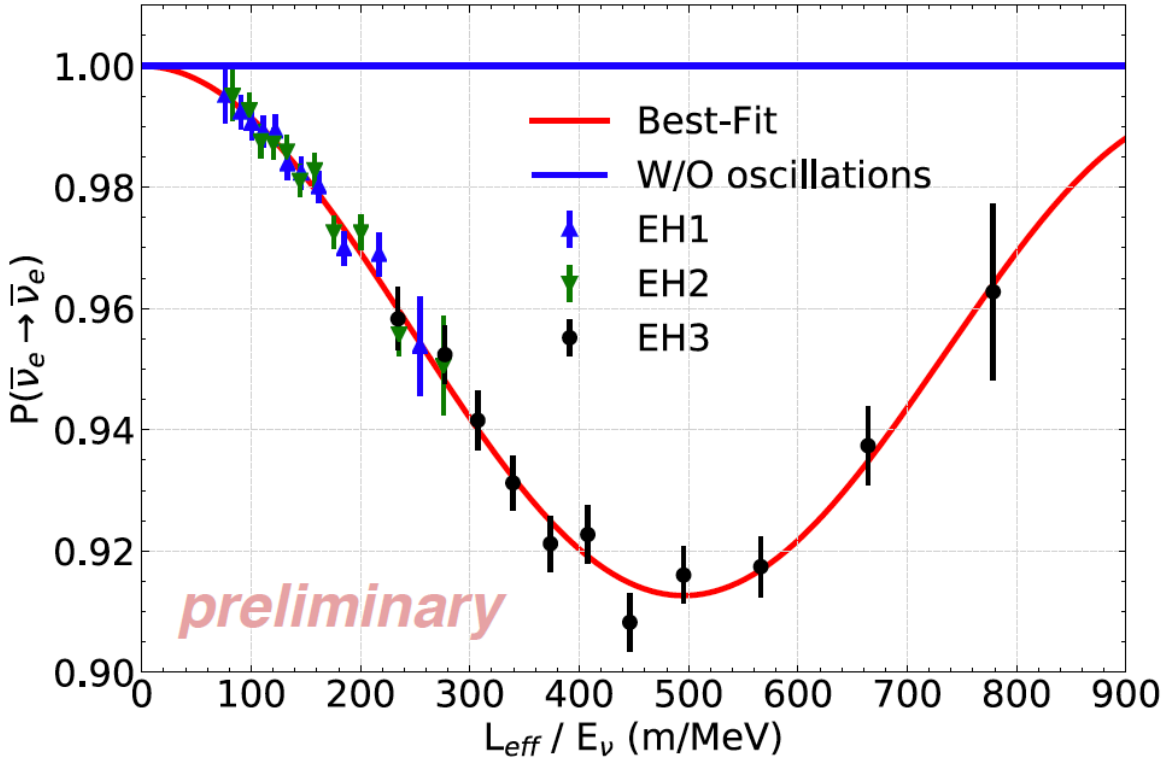
Short baseline (reactor term) **Medium baseline** (Solar term)

$$P_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2 2\theta_{13} \sin^2(\Delta m^2_{ee} \frac{L}{4E}) - \cos^4 \theta_{13} \sin^2 2\theta_{12} \sin^2(\Delta m^2_{21} \frac{L}{4E})$$

$P_{13} < 0.1$ $P_{12} < 0.01$

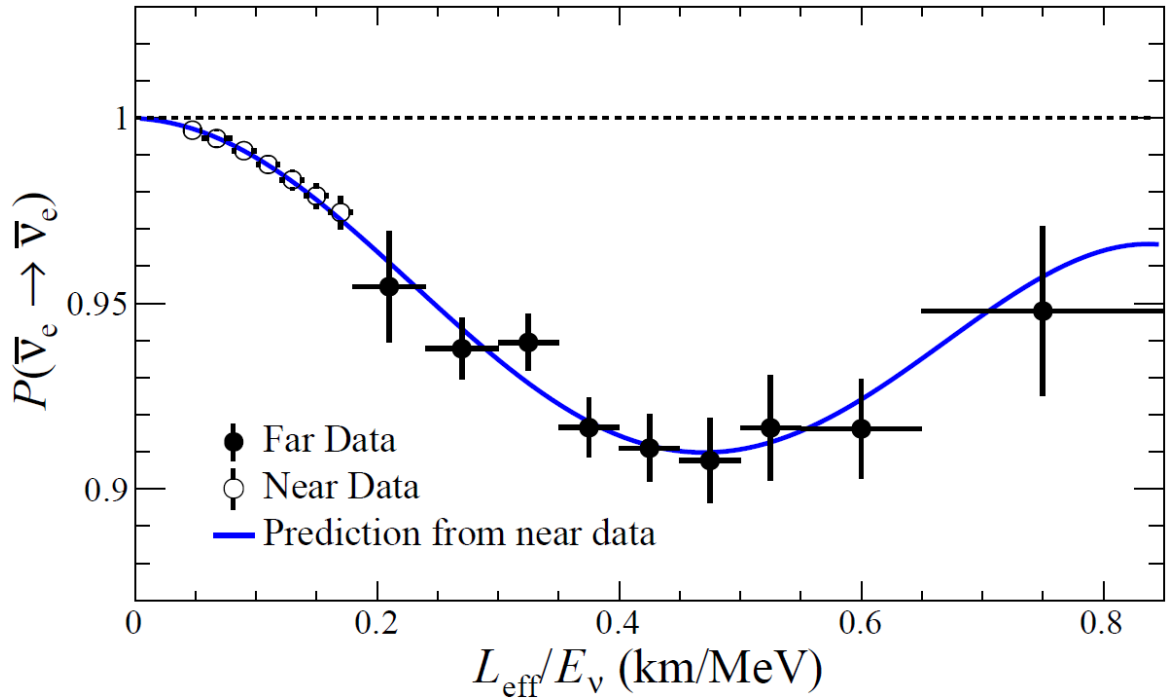
$P_{12} \sim \sin^2(2\theta_{12}) X (\Delta m^2_{21} L/4E)^2$





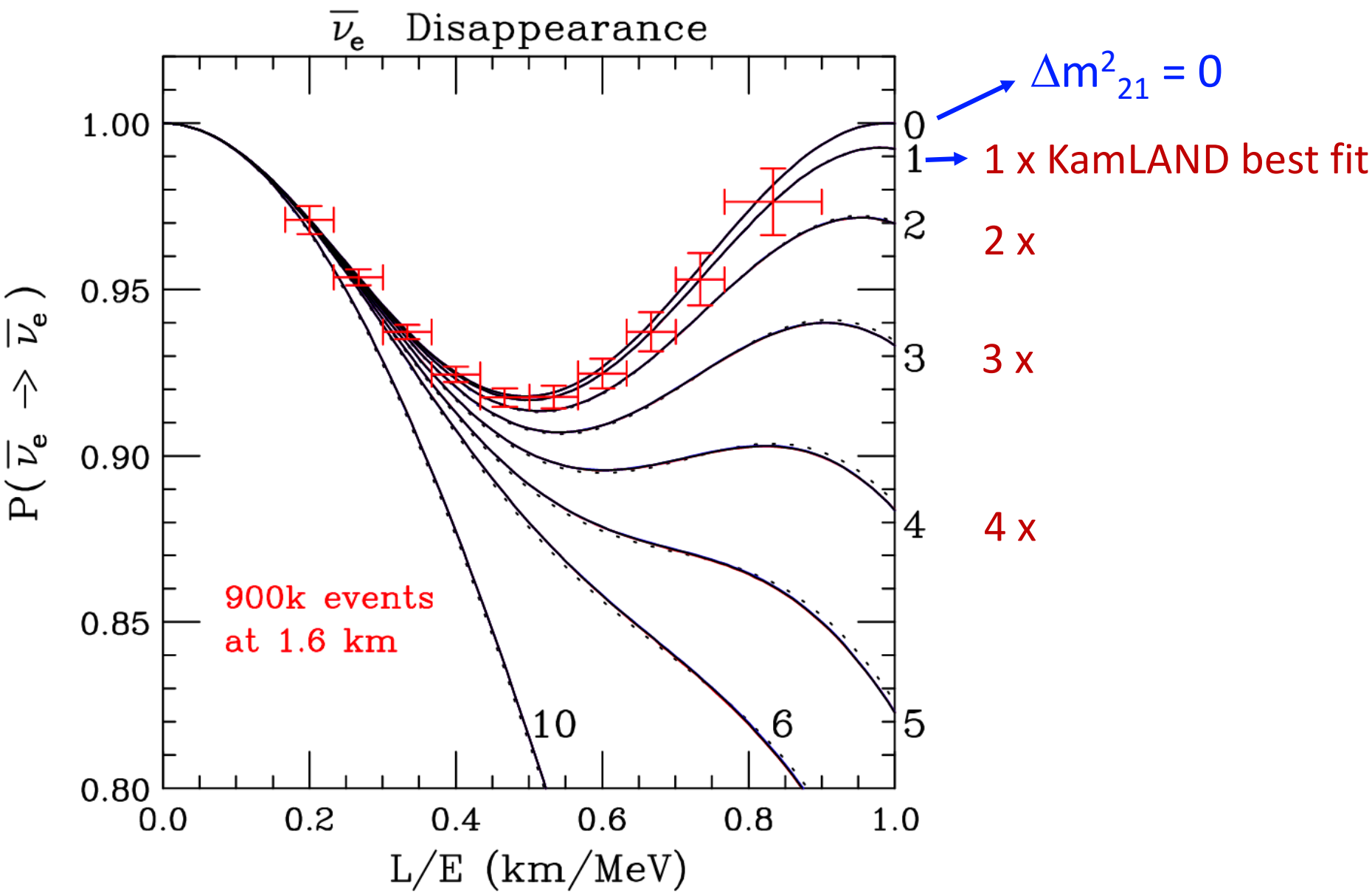
Daya Bay 1958 days
@ Neutrino 2018

~500 k events @ Far



RENO 2200 days
@ Neutrino 2018

~100 k events @ Far


$\overline{\nu}_e$ Disappearance
$P(\overline{\nu}_e \rightarrow \overline{\nu}_e)$
1.00
0.95
0.90
0.85
0.80
0.0
0.2
0.4
0.6
0.8
1.0
L/E (km/MeV)
900k events
at 1.6 km
10
6
0
1
2
3
4
5
$\Delta m^2_{21} = 0$
1 x KamLAND best fit
2 x
3 x
4 x

Simulation study with GLOBES

P. Huber, J. Kopp, M. Lindner, M. Rolinec and W. Winter, arXiv: help-ph/0701187; P. Huber, M. Lindner and W. Winter, arXiv: hep-ph/0407333.

Chi2 employed in our GLOBES code

$$\chi^2 = \sum_{i=1}^{\mathrm{N_{bins}}} \frac{(O_i^{\mathrm{F/N}} - X_i^{\mathrm{F/N}})^2}{U_i^{\mathrm{F/N}}} + \sum_{r=1}^{6} \left(\frac{f}{\sigma_{\mathrm{flux}}^r}\right)^2 + \left(\frac{\epsilon}{\sigma_{\mathrm{eff}}}\right)^2 + \left(\frac{s}{\sigma_{\mathrm{scale}}}\right)^2 + \sum_{d=\mathrm{N,F}} \left(\frac{b^d}{\sigma_{\mathrm{bkg}}^d}\right)^2, \qquad (12)$$

Systematic uncertainties & other information:

F. P. An *et al.* [Daya Bay Collaboration], Phys. Rev. D **95**, 072006 (2017).

S.H. Seo *et al.* [RENO Collaboration], Phys. Rev. D **98**, 012002 (2018).

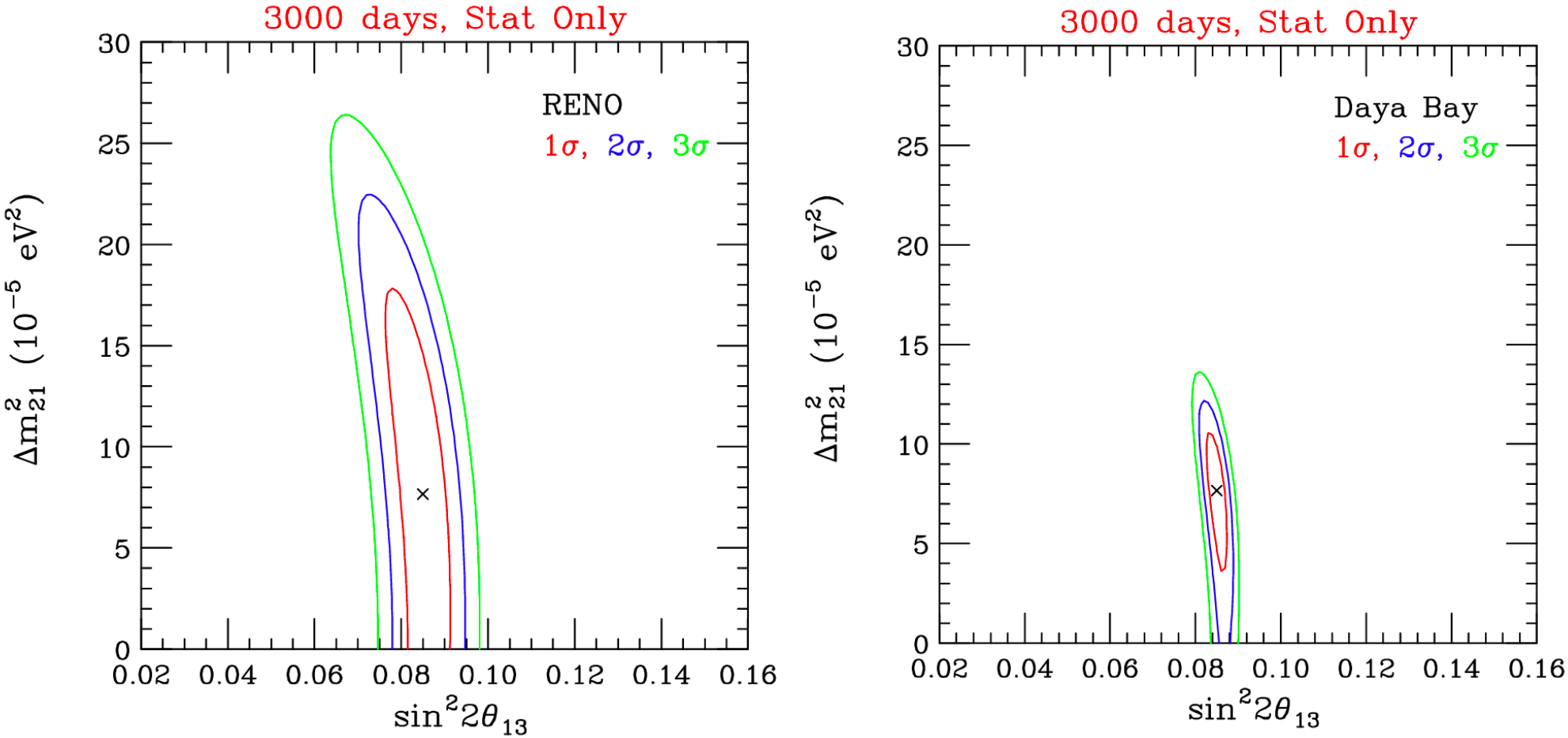
Quantities derived from our GLOBES setting

	Site	Daya Bay	RENO
L_{eff}	Near Far	(400.4, 512.6) m 1610 m	367.0 m 1440 m
IBD ν_e rate	Near Far	(1320, 1195) /day 297.8 /day	617.2 /day 61.35 /day

<u>3000 live days of data</u>

Daya Bay: 893k events @ Far (L_{eff})
RENO : 184k events @Far (L_{eff})

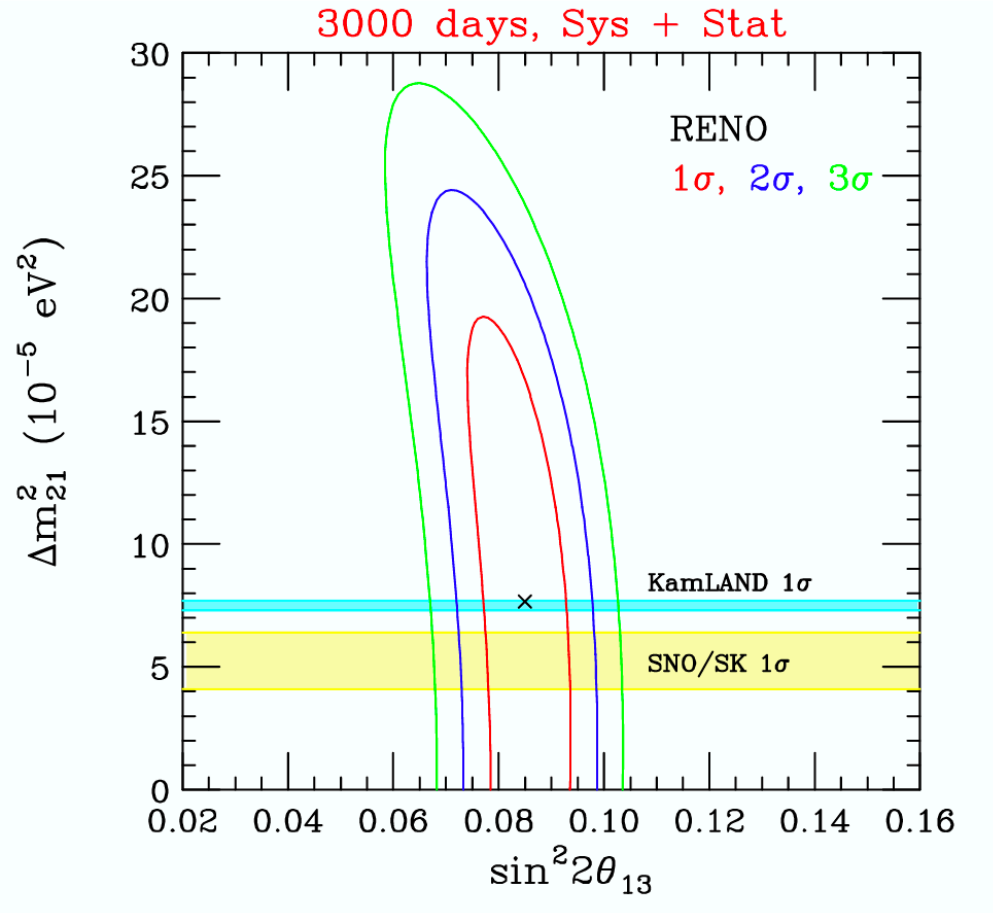
Statistical error only

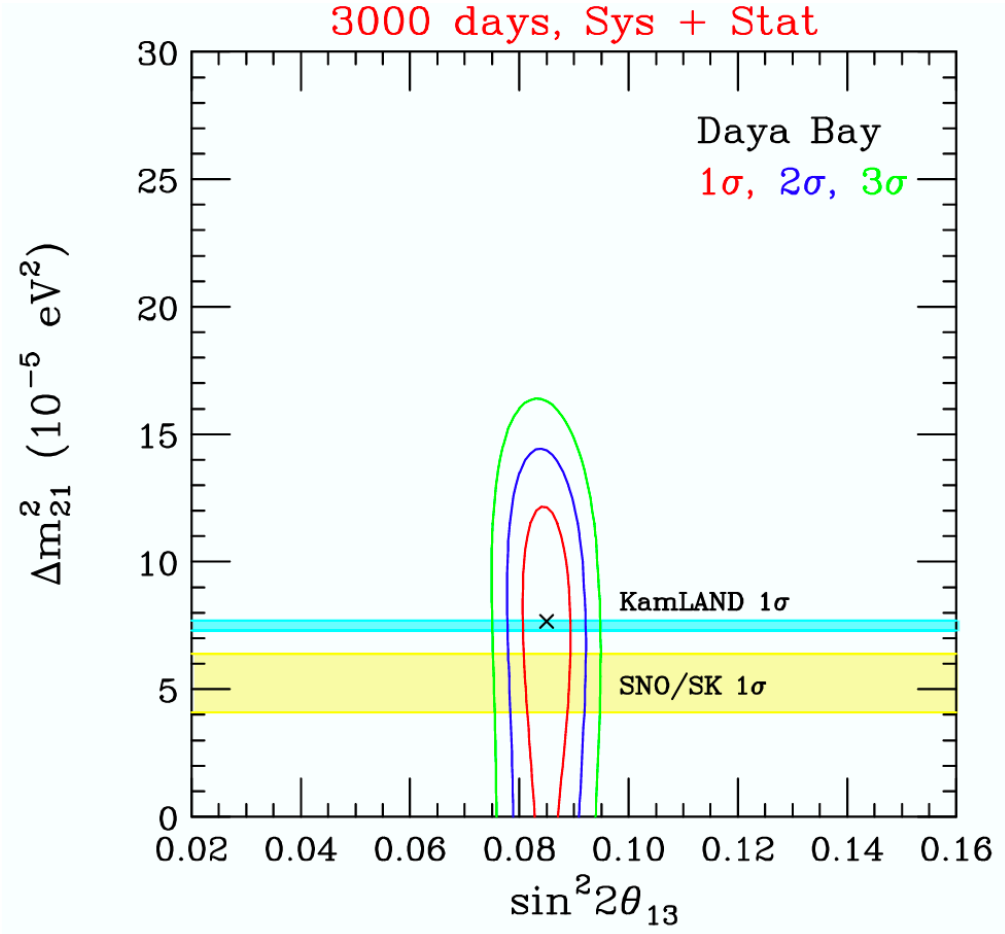


True values used in our simulation

$$\sin^2\theta_{12} = 0.304, \quad \Delta m^2_{21} = 7.65 \times 10^{-5}\ \mathrm{eV}^2,$$
$$\sin^2(2\theta_{13}) = 0.085, \quad \Delta m^2_{31} = 2.50 \times 10^{-3}\ \mathrm{eV}^2.$$

Stat. + Sys. error



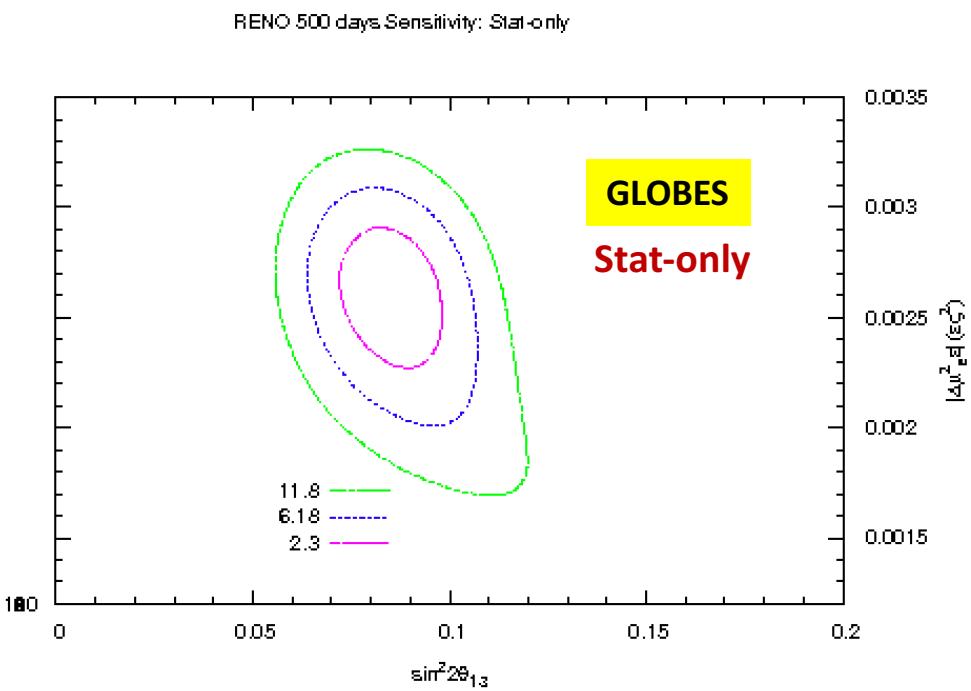


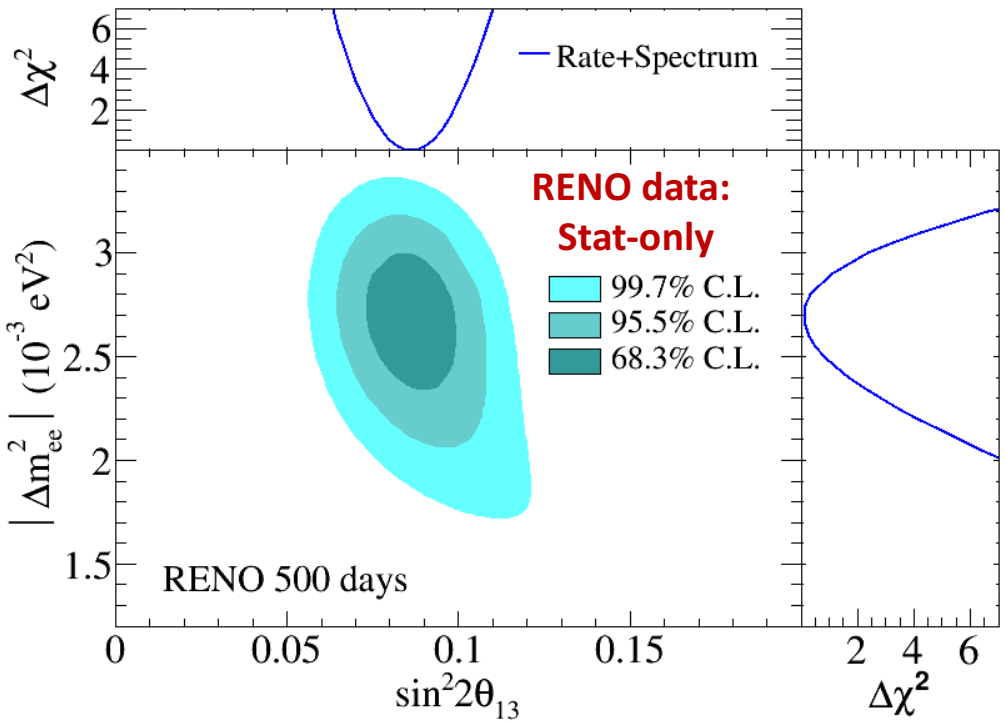
L/E ~ 0.5 km/MeV compared to KamLAND L/E ~ 50 km/MeV

Our GLOBES simulation Validation

Statistical error only

RENO 500 days



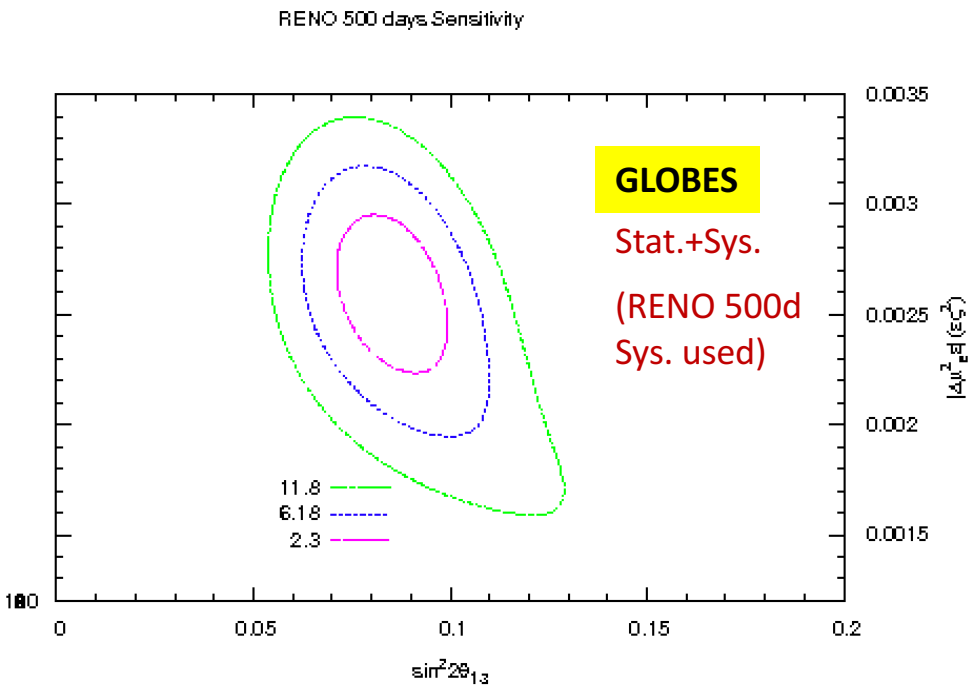


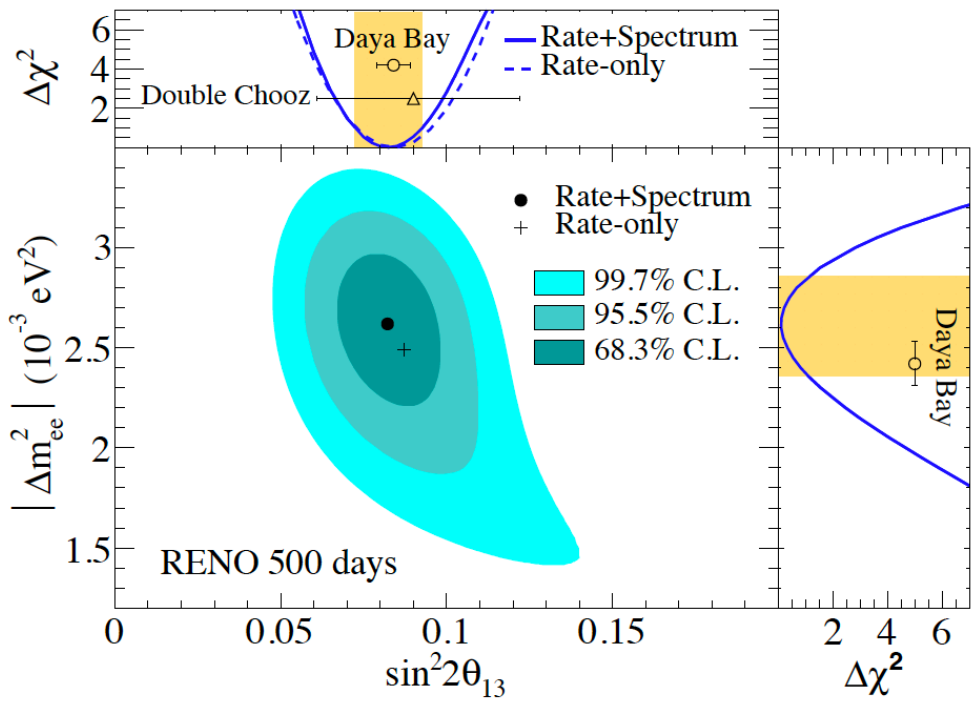
Our GLOBES simulation Validation

Stat. + Sys. error

RENO 500 days

PRD 98, 012002 (2018)





Summary

arXiv: 1808.09150

- Currently there is a tension (2σ) on Δm^2_{21} between KamLAND and SK/SNO.

- JUNO will resolve the tension in the next decade.

- Currently running reactor θ_{13} experiment, Daya Bay & RENO, can also constrain Δm^2_{21}.

This is the only new information on Δm^2_{21} until JUNO.

- Actual results need to be obtained by each experiment.