

Mass varying neutrinos in neutrino oscillation experiments

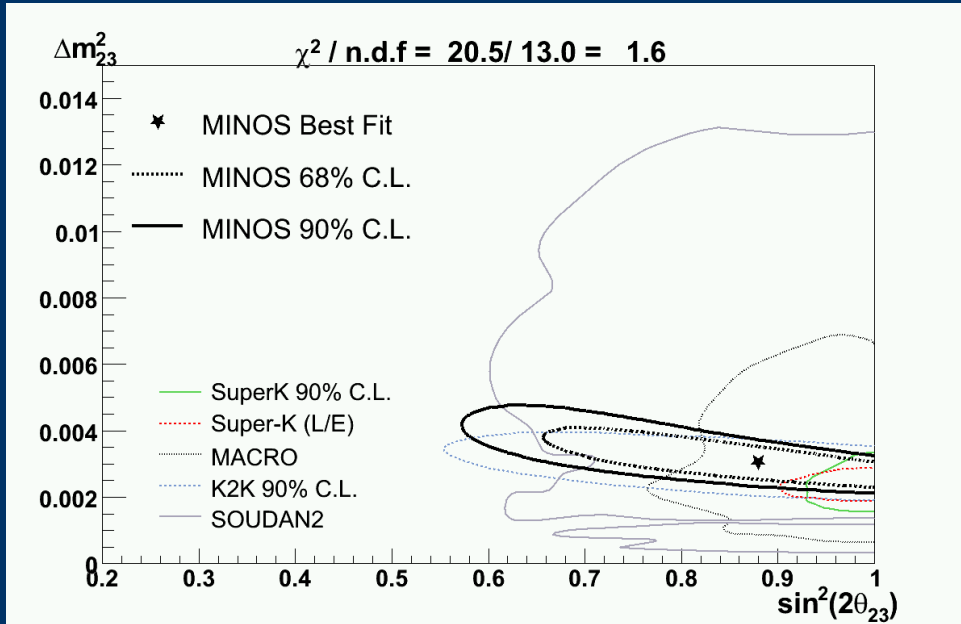
Pedro Cunha de Holanda
FMA-IFUSP

M.C. Gonzalez-Garcia, PCH, R. Zukanovich Funchal, PRD73 (2006) 033008.
M.C. Gonzalez-Garcia, PCH, M. Maltoni, R. Zukanovich Funchal, in preparation.

Indication for Neutrino Oscillations

- Chooz, Bugey, Palo Verde < 100 m
 - CDHS, Karmen, Chorus, Nomad < 100 m
 - KamLAND ~150 km
 - K2K ~300 km
 - Minos ~750 km
 - atmospheric neutrinos ~ 12.000 km
 - Solar Neutrinos ~ 700.000 km
-
-

Neutrino oscillation parameters

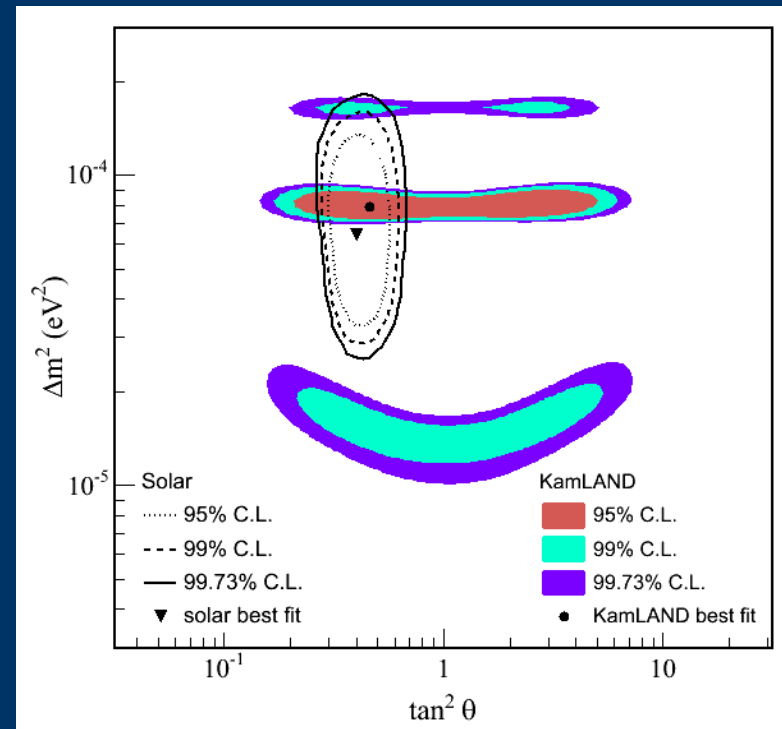


<http://www-numi.fnal.gov/>

no evidence for $\theta_{13} \neq 0$.

2 large mixing angles and
2 mass scales

T. Araki et al. PRL.94:081801,2005



Indication for Neutrino Oscillations

- Chooz, Bugey, Palo Verde vacuum
 - CDHS, Karmen, Chorus, Nomad vacuum
 - KamLAND Earth (3g/cm^3)
 - K2K Earth (3g/cm^3)
 - Minos Earth (3g/cm^3)
 - atmospheric neutrinos Earth ($3\text{-}15\text{g/cm}^3$)
 - Solar Neutrinos Sun (100g/cm^3)
-
-

Why Mass-Varying Neutrinos^[1,2]?

- signal of neutrinos conversion always involve evolution in matter.
- dark energy scale $[(2 \times 10^{-3} \text{ eV})^4] \sim$ neutrino mass splitting (10^{-4} eV^2) .
- address the cosmological coincidence problem, by assuming m_ν as a dynamical quantity, which depends on interactions with a scalar field (acceleron) $\rightarrow \rho_\nu \sim \rho_\Lambda$.

[1] Rob Fardon, Ann E. Nelson and Neil Weiner, JCAP 10 (2004) 005.

[2] David Kaplan, Ann E. Nelson and Neal Weiner, PRL 93 (2004) 091801.

MaVaN's evolution in 2 families

$$i \frac{d}{dr} \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix} = \frac{1}{2E} \mathbf{U}_{\theta_{12}} \begin{pmatrix} 0 & M_3^2(r) \\ M_3^2(r) & (m_2^0 - M_2(r))^2 \end{pmatrix} \mathbf{U}_{\theta_{12}}^\dagger + \begin{pmatrix} V_{CC}(r) & 0 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix}$$

- m_2^0 : neutrino mass in vacuum ($m_1^0=0$)^[3].
- \mathbf{U}_θ : 2x2 neutrino mixing matrix.
- $V_{CC}(r)$: standard interaction terms with matter
- M_i : MaVaN's components.

$$M_i(r) = \alpha_i \left[\frac{\rho(r)}{(\text{gr}/\text{cm}^3)} \right]$$

[3] Marco Cirelli, M. C. Gonzalez-Garcia, Carlos Peña-Garay, NPB 719 (2005) 219.

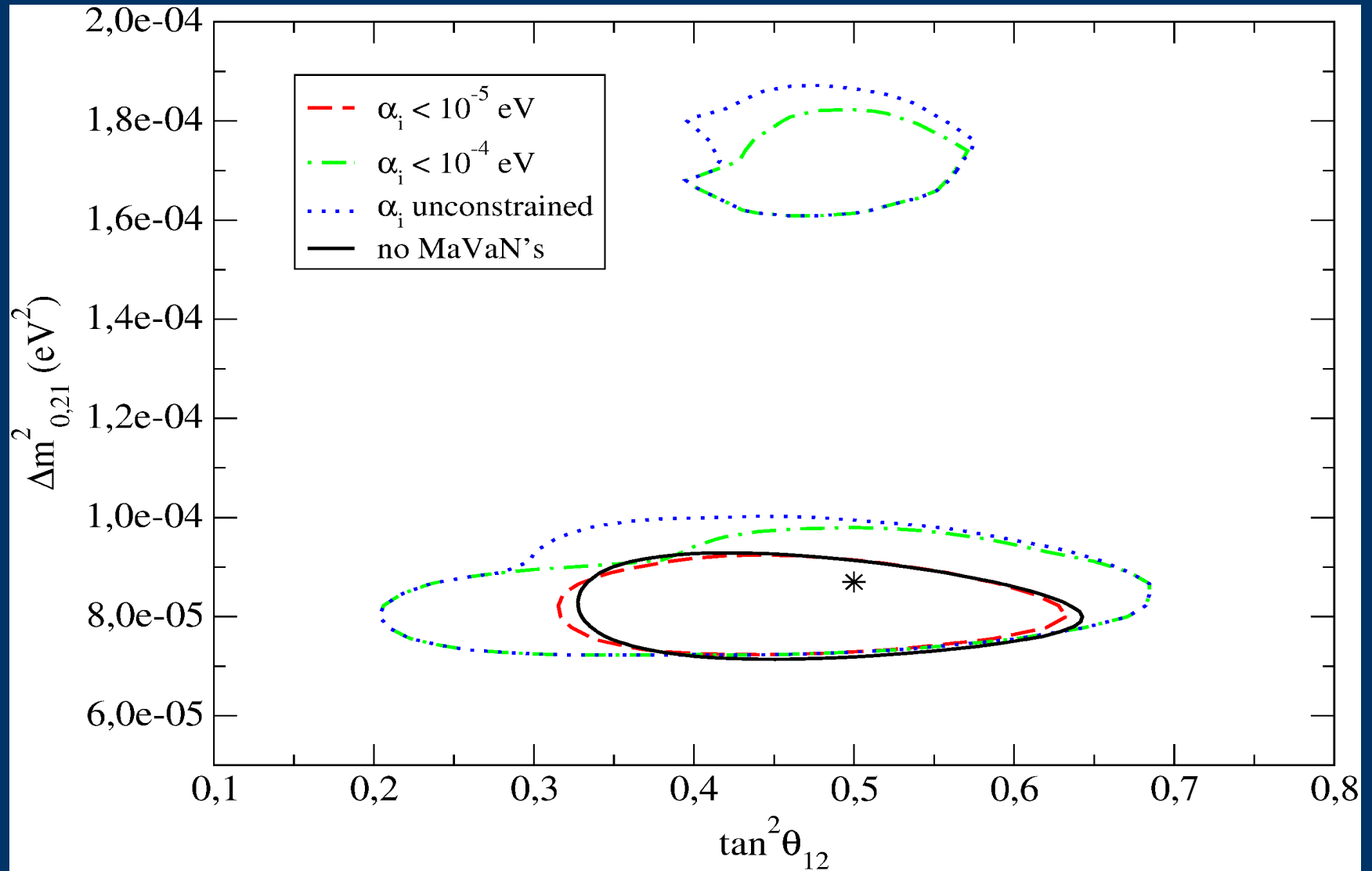
Fitting the Data

- 2 total rates from Gallium experiments
- 1 total rates from Homestake
- 44 spectral data from Super-Kamiokande
- 34 spectral data from SNO-I
- 38 spectral data from SNO-II

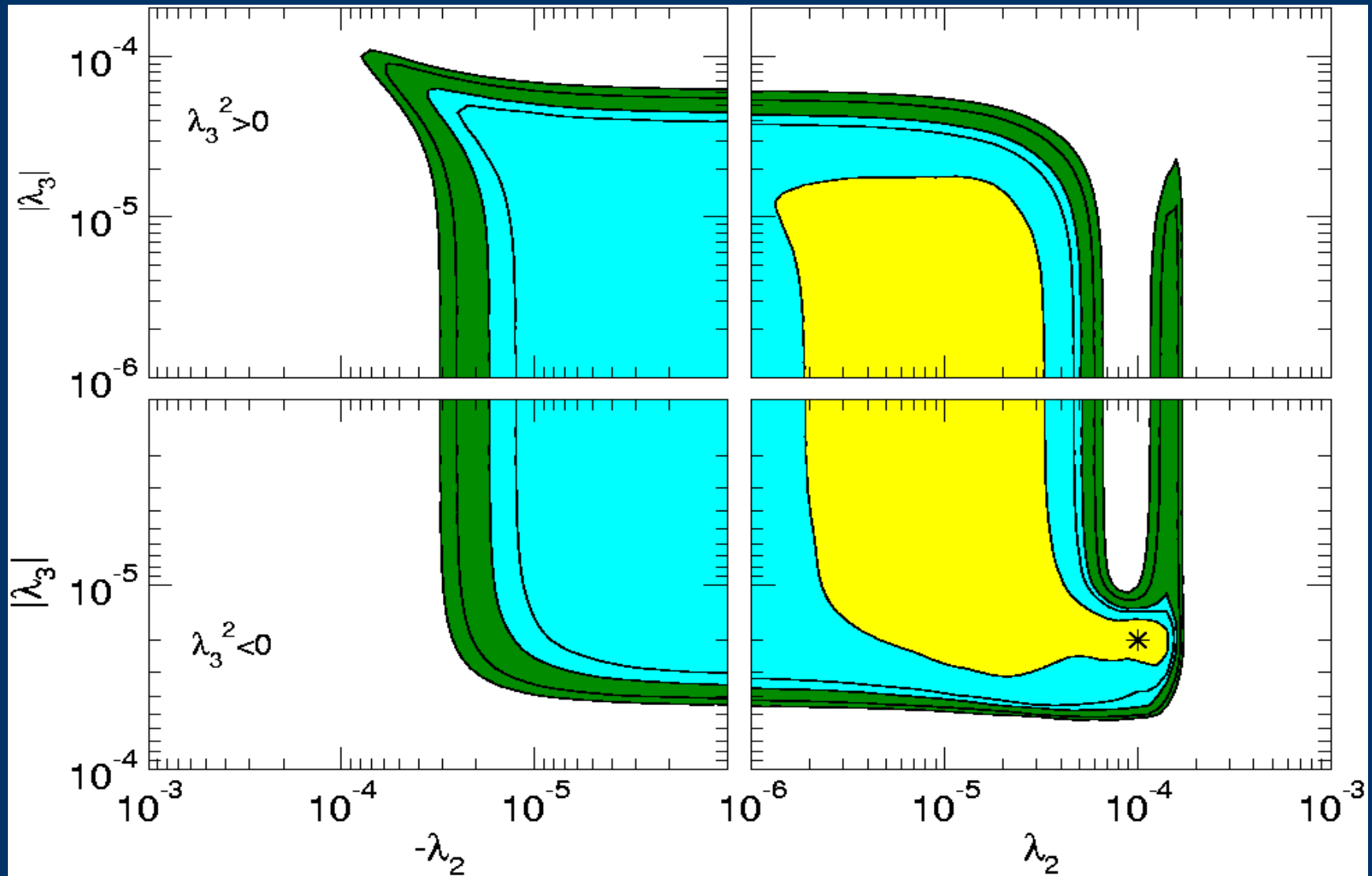
- 13 spectral data from KamLAND

see also <http://neutrinos.if.usp.br/gefan/programas/nusolar/solar.html>

Limits in n 's Oscillation Parameters



Limits in MaVaN's Parameters



Numerical aspects from fit

- 119 solar data + 13 reactor data.
 - 4 free parameters (α_2 , α_3 , Δm^2 , θ).
 - $\Delta\chi^2_{\min}=2.5$ (compared to standard analysis).
 - limits obtained:
 - $-5.6 \cdot 10^{-5} < \alpha_2 < 1.7 \cdot 10^{-4}$
 - $|\alpha_3| < 8.4 \cdot 10^{-5}$ (for $\alpha_3^2 > 0$).
 - $|\alpha_3| < 5.2 \cdot 10^{-5}$ (for $\alpha_3^2 < 0$).
-
-

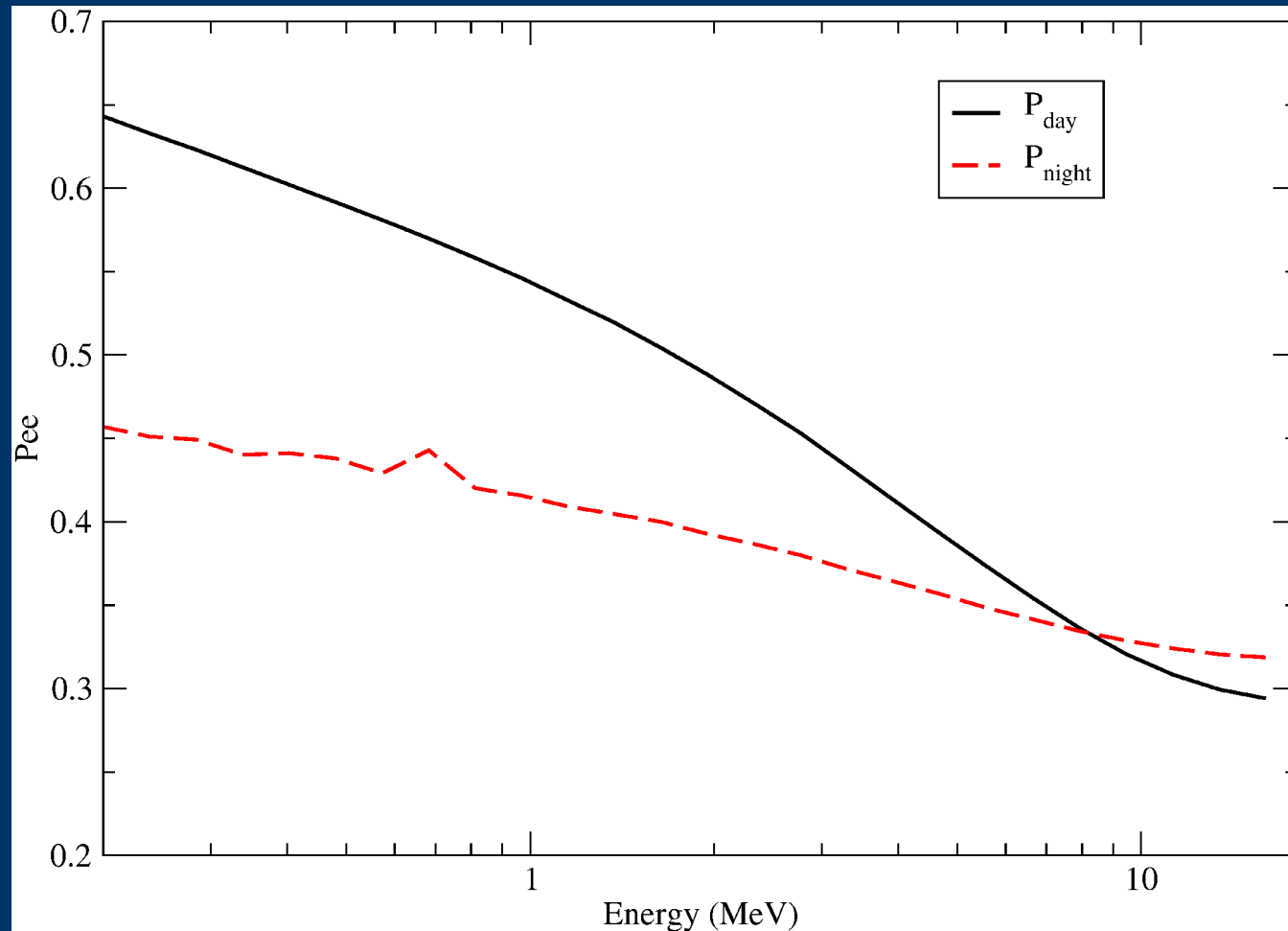
Conclusions - I

- Strong limits in MaVaN's parameters from Solar + reactor data
 - No big help in fitting the data ($\Delta\chi^2 = -2.5$ with 2 extra parameters).
 - Vacuum oscillation at KamLAND.
-
-

MaVaN's as the leading conversion mechanism

- vacuum masses (10^{-9}eV^2) and mixing (10^{-2}) are very small.
 - KamLAND, K2K and Minos probe effective and almost constant mass and mixings due to environmental effects.
 - Atmospheric neutrinos probe effective mass and mixings, but with some zenithal dependence.
 - The question is: what about solar neutrinos?
-
-

Non-adiabatic transitions at the surface of the Sun produces some survival probability similar to LMA!



Concerning features:

- Regeneration effect in Earth comes naturally.
- Down-going atmospheric neutrinos do not oscillate.
- Upward-going atmospheric neutrinos oscillate too much.

Nice features:

- Regeneration effect in Earth comes naturally.
 - Seasonality in low energy experiments
 - Regeneration for the Berilium line
- Could be tested soon^[4].

[4] Thomas Schwetz, Walter Winter, PLB 633 (2006) 557.

Conclusions - II

- Non-adiabatic transitions can lead to important effects for large values of α 's (could $m=0$?).
 - Strong environmental effect in KamLAND, K2K, Minos, atmospheric neutrinos, ...
 - Could other neutrino oscillation probe be more sensitive than solar neutrinos?
 - geo-neutrinos.
 - supernova neutrinos.
-
-