Short Baseline Neutrino Oscillations

How a new long range gauge interaction can allow a υ oscillation fit to Short Baseline data including LSND and MiniBooNe

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Ann Nelson, University of Washington
and IFT, Universidad Autónoma de Madrid
Collaborator: Jon Walsh

LiquidScintillatorNeutrinoDetector

- short baseline (30 m) neutrino oscillation experiment at Los Alamos
- $\bar{\nu}_\mu$ from $\bar{\mu}$ decay at rest at energies from 20-53 MeV
- ν_μ from π^+ decay with energies from 60-200 MeV
- Prob of conversion of $\bar{\nu}_\mu$ to $\bar{\nu}_e$ =0.264±0.081%
- Prob of conversion of ν_μ to ν_e =0.26±0.11%

LSND cont.

- An Outlier -doesn't fit into 3 ν oscillation scheme
- Even with additional sterile ν's is difficult to reconcile with other short baseline ν oscillation data

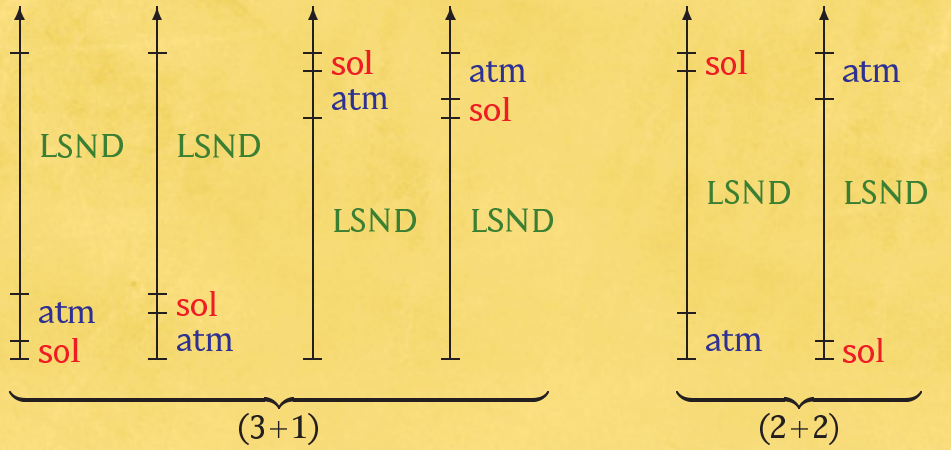


Figure 17. The two classes of six four–neutrino mass spectra, (3+1) and (2+2).

more than 4 ν?
gives too much
Helium:
not good for
cosmology

Some SBL ν expts

Channel	Experiment	Lowest Δm^2	$\sin^2 2\theta$ at high Δm^2	Best reach in $\sin^2 2\theta$
$\nu_\mu \to \nu_e$	LSND	$0.03\ \mathrm{eV}^2$	$> 2.5 \times 10^{-3}$	$> 1.2 \times 10^{-3}$
	KARMEN	$0.06\ \mathrm{eV}^2$	$< 1.7 \times 10^{-3}$	$< 1.0 \times 10^{-3}$
	NOMAD	$0.4\ \mathrm{eV}^2$	$< 1.4 \times 10^{-3}$	$< 1.0 \times 10^{-3}$
ν_e disappearance	Bugey	$0.01\ \mathrm{eV}^2$	$< 1.4 \times 10^{-1}$	$< 1.3 \times 10^{-2}$
	Chooz	$0.0001\ \mathrm{eV}^2$	$< 1.0 \times 10^{-1}$	$< 5 \times 10^{-2}$
ν_μ disappearance	CCFR84	$6\ \mathrm{eV}^2$	NA	$< 2 \times 10^{-1}$
	CDHS	$0.3\ \mathrm{eV}^2$	NA	$< 5.3 \times 10^{-1}$

cosmo

3+1

2+2

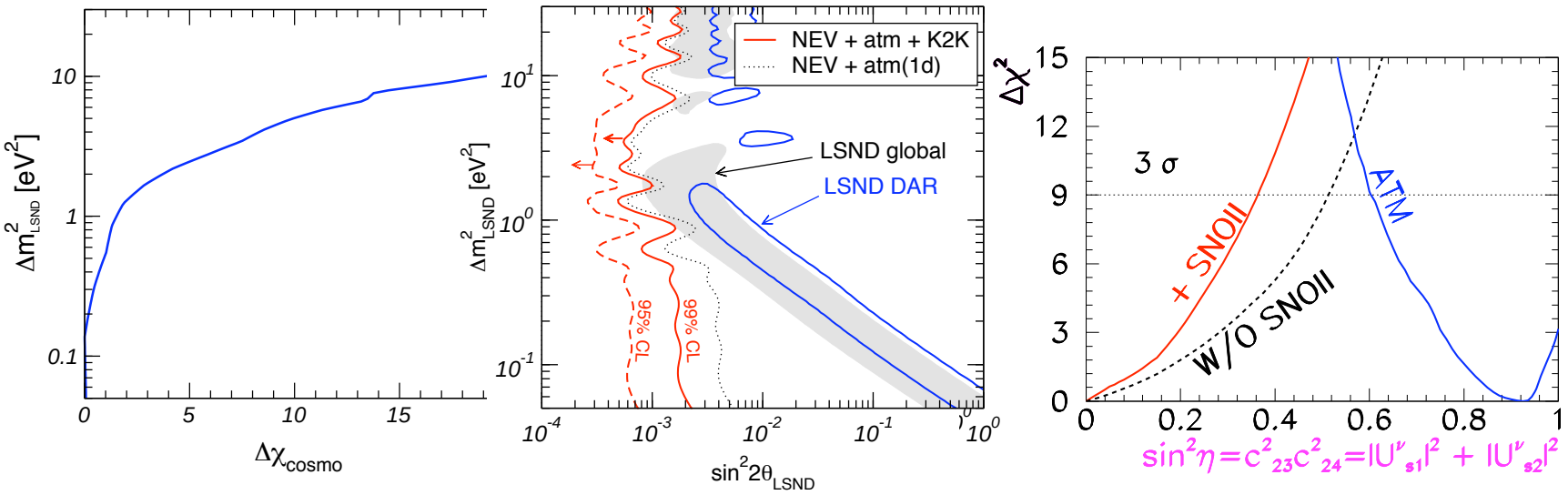


Figure 5. *Left*: Status of the 3+1 oscillation scenarios. *Right*: Present status of the bounds on the active-sterile admixture from solar and atmospheric neutrino data in (2+2)-models.

from Gonzalez-Garcia + Maltoni

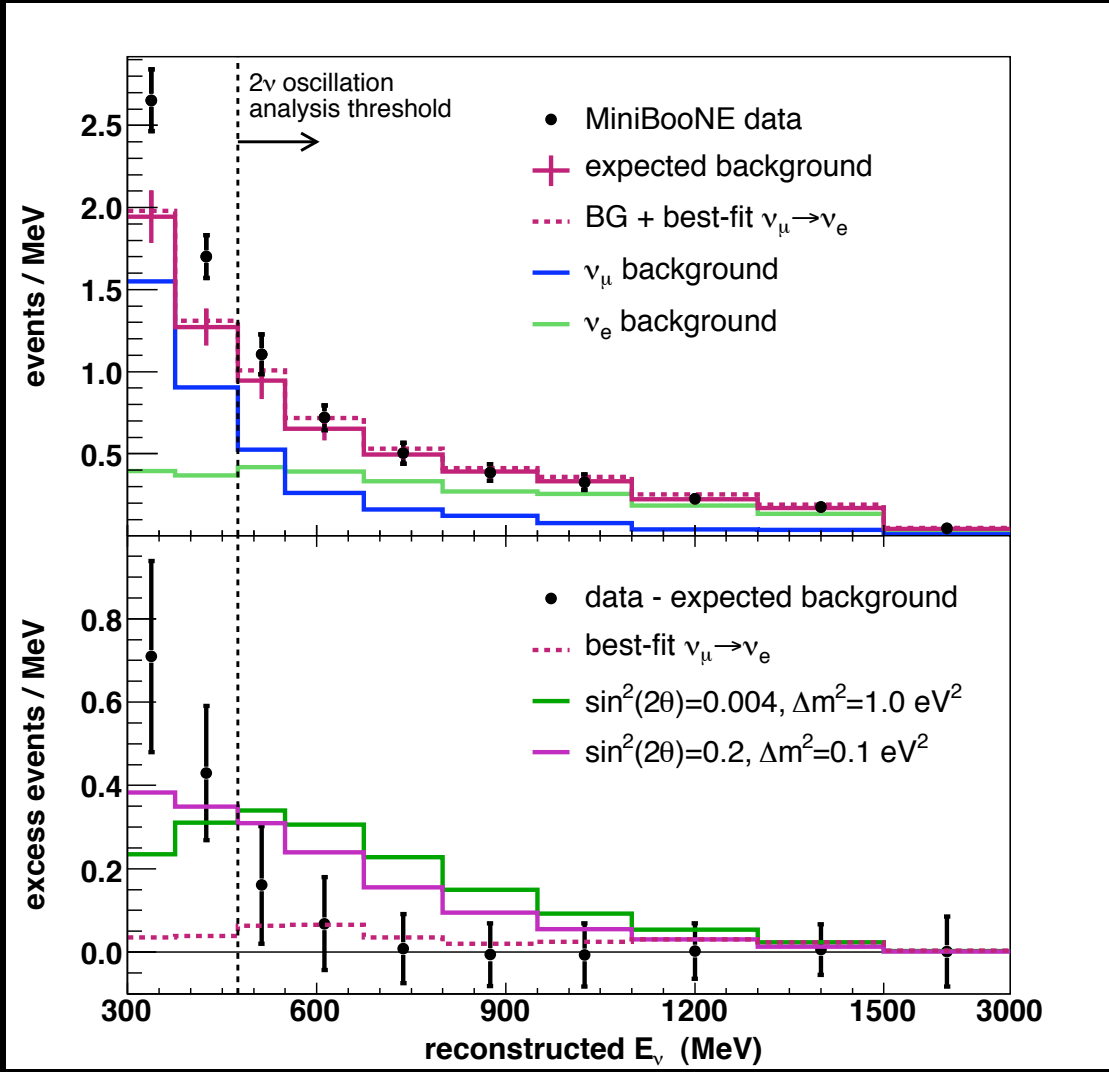
and Maltoni, Schwetz, Tórtola , Valle

LNSD vs SBL,cosmo

MiniBooNE

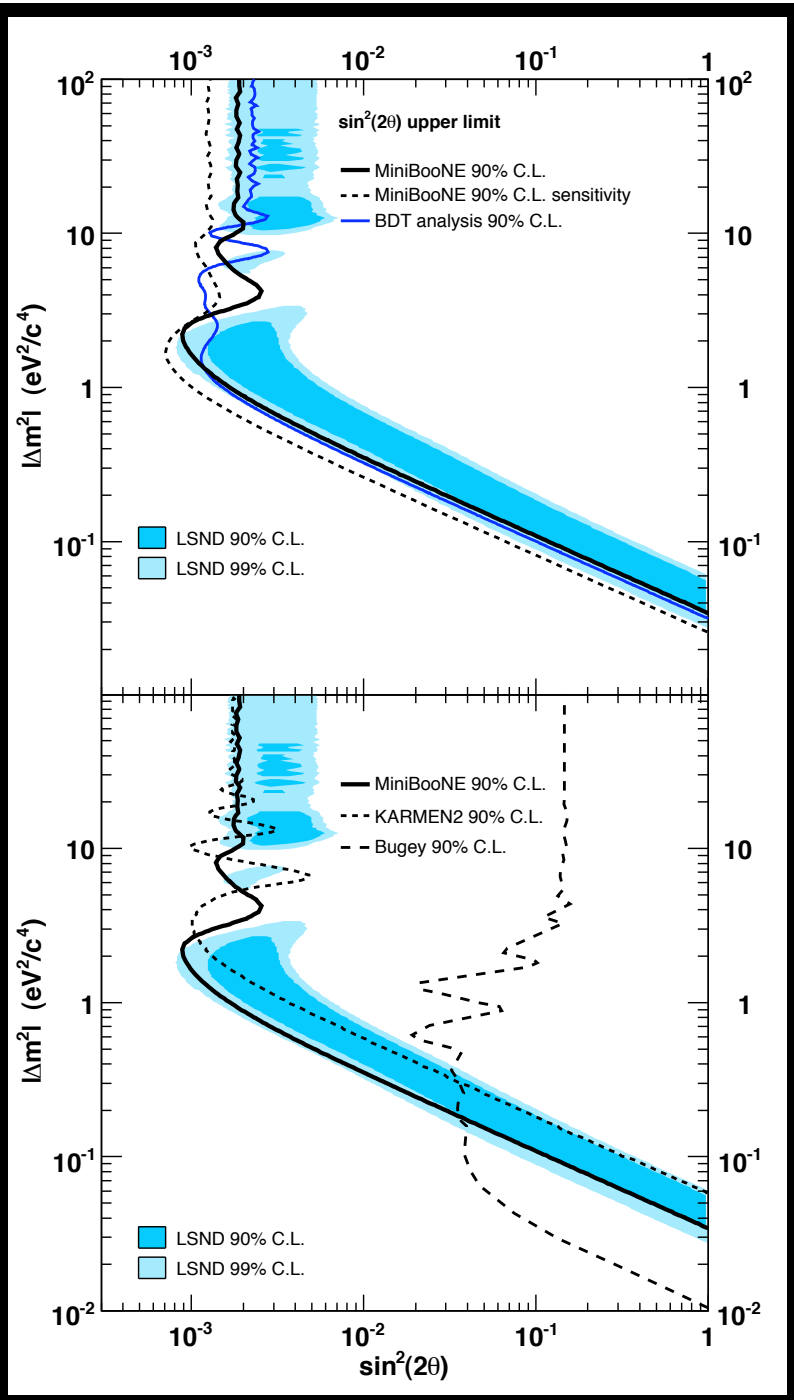
- E from 200 to 3000 MeV, average 750 MeV
- L ~ 541 m
- similar L/E to LSND, but higher E, L
- first data with ν_μ's does not confirm conventional ν oscillation interpretation of LSND
- excess of ν_e's below 475 MeV, 96 ±17±20, doesn't fit conventional ν oscillation interpretation
- currently running with $\overline{\nu}$'s.

MiniBooNE Oscillation results



MiniBooNE, Karmen, Bugey versus LSND

End of story?



Beyond standard neutrinos

- Neutrinos are unique!
- Only SM particle which can mix with "dark" (sterile) fermions
- Oscillations sensitive to GUT scale
- Oscillations sensitive to extremely feeble new interactions
- Neutrinos have history of surprises

The "lower"-energy region

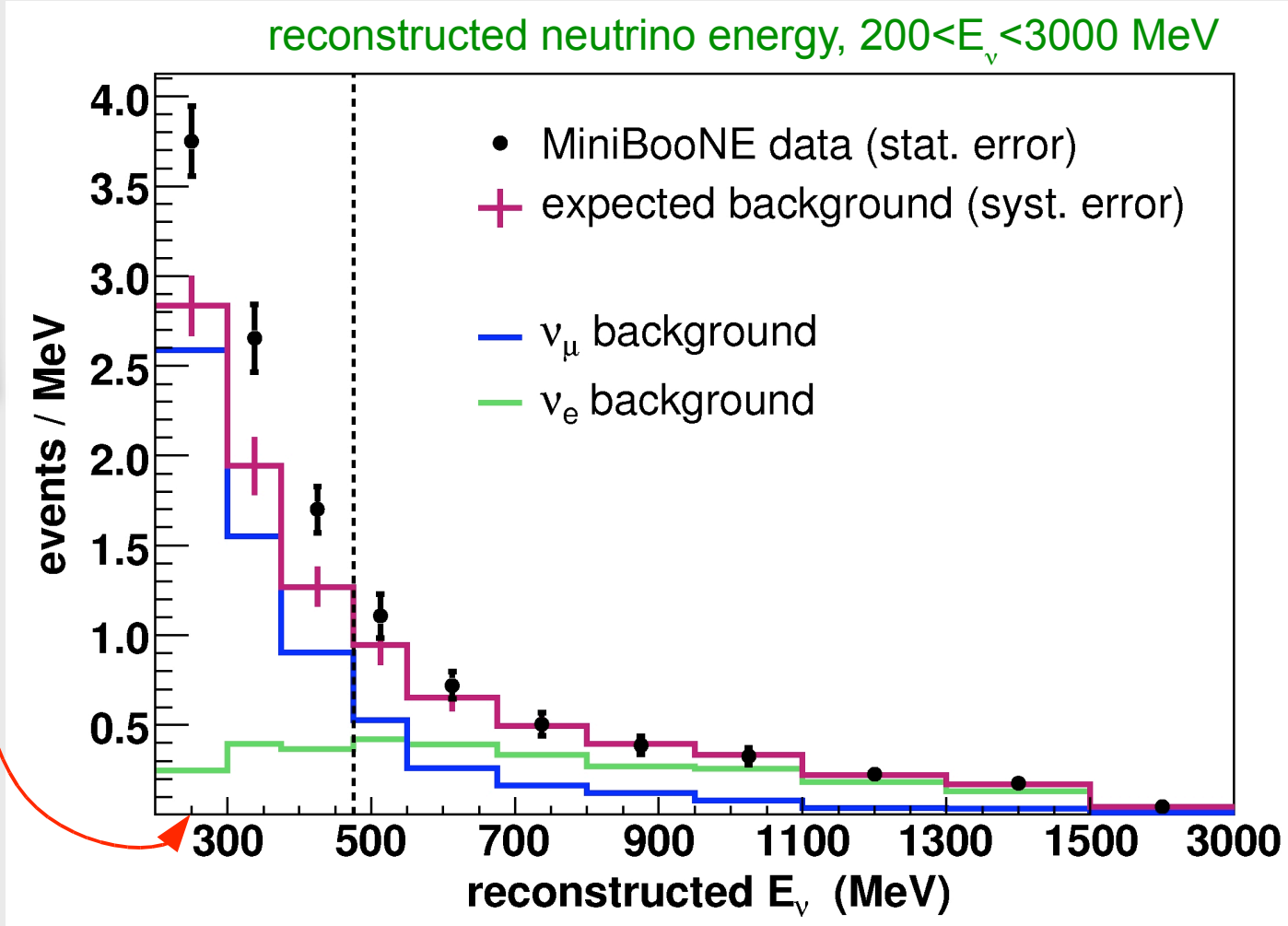
Summer MiniBooNE update

- examining lower energy
- excess persists in 200 < E_ν < 300 MeV bin

also refutation of muon internal brehmstrahlung interpretation

- NEW:

this energy bin



What if LSND is ν physics?

some others considered so far: various combinations of

- more than 3+1
- CPV
- new background for ν_e's
- ν_e disappearance
- increased background
- more exotic

T. Schwetz, arXiv:0710.2985 [hep-ph].

J. Dent, H. Pas, S. Pakvasa and T. J. Weiler, arXiv:0710.2524 [hep-ph].

H. Nunokawa, S. J. Parke and J. W. F. Valle, arXiv:0710.0554 [hep-ph].

D. Majumdar, arXiv:0708.3485 [hep-ph].

J. A. Harvey, C. T. Hill and R. J. Hill, arXiv:0708.1281 [hep-ph].

C. Giunti and M. Laveder, arXiv:0707.4593 [hep-ph].

X. Q. Li, Y. Liu and Z. T. Wei, arXiv:0707.2285 [hep-ph].

S. Goswami and W. Rodejohann, arXiv:0706.1462 [hep-ph].

J. C. Montero and V. Pleitez, arXiv:0706.0473 [hep-ph].

S. M. Bilenky, F. von Feilitzsch and W. Potzel, arXiv:0705.0345 [hep-ph].

M. Maltoni and T. Schwetz, arXiv:0705.0107 [hep-ph].

Motivation for our model

- ➡ We focus on essential differences between LSND, MiniBooNE experiments, take results at face value
- ➡ Consider physics which is intrinsically different for ν's versus $\overline{\nu}$'s
- ➡ anomalous energy dependence
- ➡ Note: MiniBooNE, LSND, CDHS all have oscillation baselines through matter
- ➡ suggests: new physics MSW-like effect

A new light gauge boson?

- Anomaly free candidate is gauged B-L (with 3 sterile 'right handed' neutrinos)
- MSW analog effect is opposite for $\nu, \overline{\nu}$
- MSW analog effect ~ $E\ \rho\ g^2/M_V^2$
- ρ nonzero and similar for LSND, MiniBooNE
- g must be < ~10^{-5} to agree with precision expts, eg g_e-2
- M_V must also be tiny to give big enough effect, < ~keV
- flavor diagonal for active neutrinos⇒no MSW effect?

Spontaneous B-L violation and Majorana ν masses

- a "mini seesaw" with eV mass singlet N's
- $\lambda, g, \lambda' \langle\phi\rangle$ are small
- nonzero $\langle\phi\rangle$ required for active-sterile mixing
- may allow for compatibility with cosmology

$$M = \begin{array}{c} \begin{array}{cc} \nu & N \end{array} \\ \begin{pmatrix} 0 & \lambda\langle H\rangle \\ \lambda^T\langle H\rangle & \lambda'\langle\phi\rangle \end{pmatrix} \end{array} \begin{array}{c} \nu \\ N \end{array}$$

$$H \approx E + \frac{M^\dagger M}{2E} + V$$

$$V = \begin{pmatrix} -VI_3 & 0 \\ 0 & VI_3 \end{pmatrix}$$

Anomalous matter effect

effective mass^2 matrix for neutrino oscillations:

$$M^2_{eff} = \begin{pmatrix} m^2 & mM \\ mM & 4VE + M^2 + m^2 \end{pmatrix}$$

- m≡ λ〈H〉 ~0.2 - 0.4 eV, 3 nearly degenerate eigenvalues govern large mixing angle LBL oscillations in matter at high energy
- V ≡ B-L potential, (negative)positive for (anti)ν's, ~ 10^{-8}-10^{-9} eV
- M≡ λ〈ϕ〉 ~1-2 eV, M^2 ~ 4VE in MiniBooNE low energy region

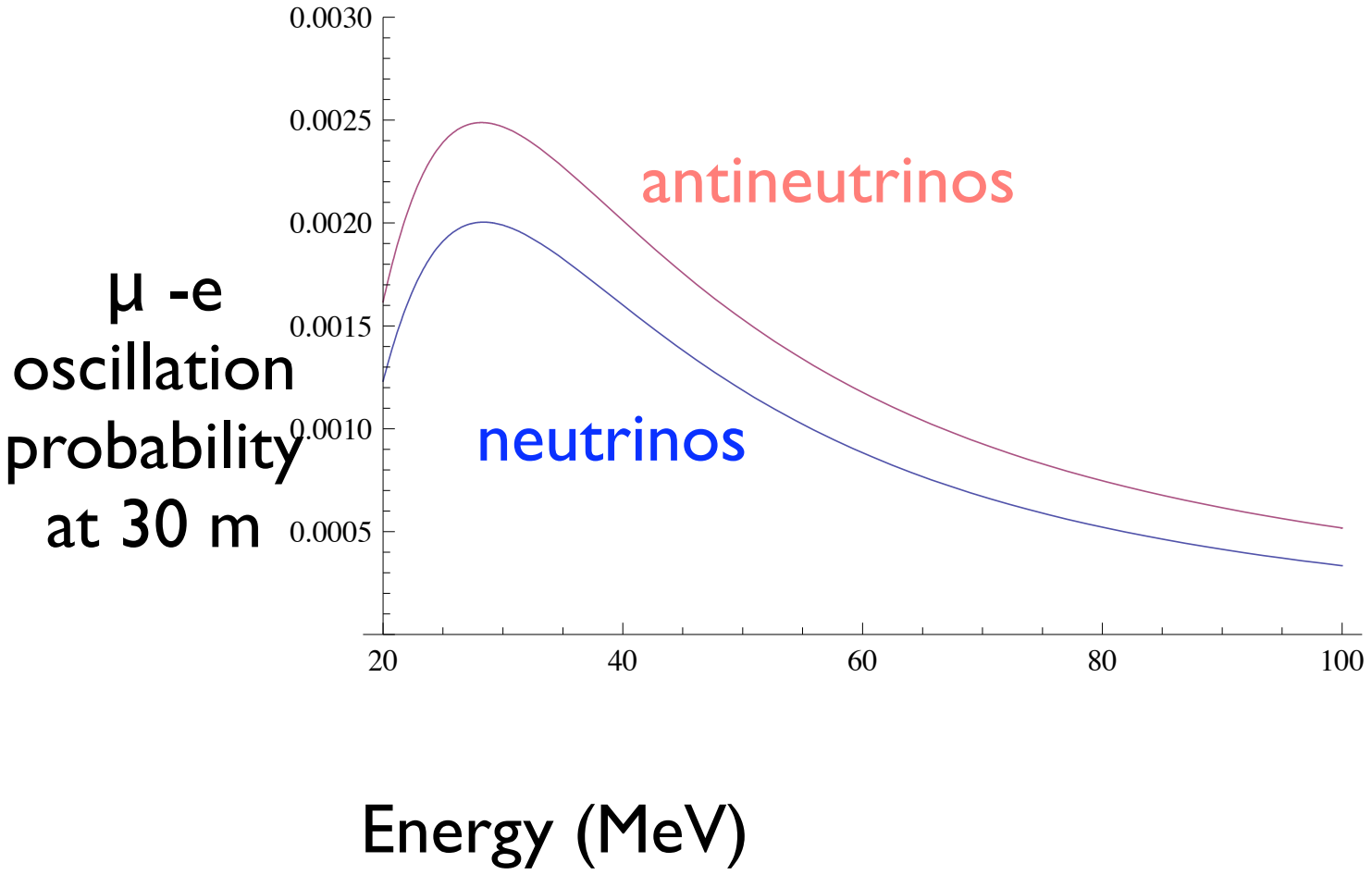
Heavy ν's mix with Effective Energy dependent mixing angle

- $\vartheta \approx m\,M/(4\,VE + M^2)$
- bigger for anti neutrinos (negative V)
- for neutrinos smaller at high energy

$$M^2_{eff} = \begin{pmatrix} m^2 & mM \\ mM & 4VE + M^2 + m^2 \end{pmatrix}$$

Effects of B-L potential

- eg m=.3 eV, M_1 =1 eV, M_2 heavy, V= .3 10^{-9}



Effects of B-L potential

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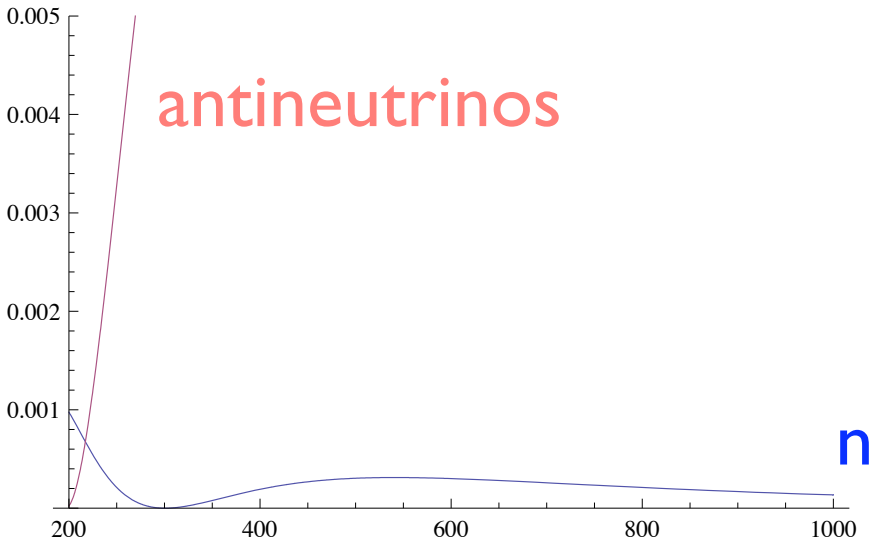
μ -e oscillation probability at 500 m

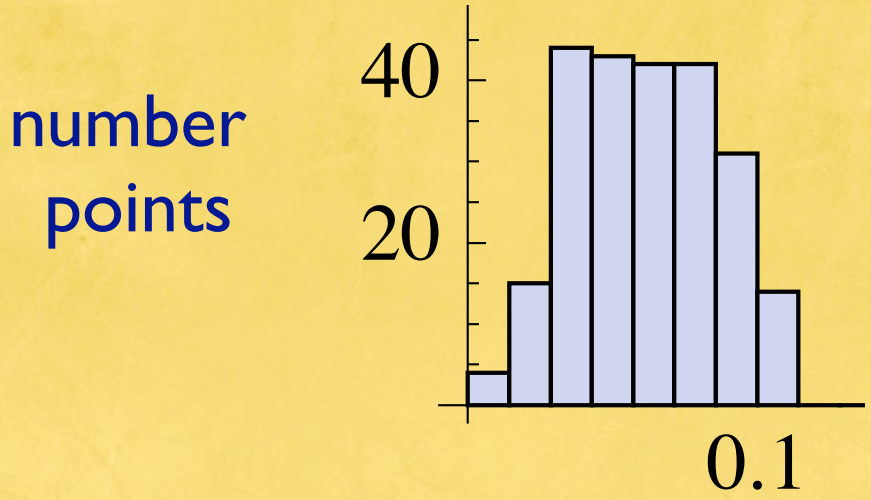


Energy (MeV)

Strategy

- fix mixing angles in m to solar, atmospheric values, with $\Theta_{13}=0$, take M diagonal⇒ only 2 eigenvalues of M affect oscillations involving ν_e
- scan V, m, M_1, M_2 for fit to LSND, MiniBooNe, CHOOZ,CDHS
- for points that fit, predict oscillation results for MiniBooNE anti neutrinos

Preliminary Prediction for large low energy anti neutrino oscillations at MiniBooNE



Oscillation prob at MiniBooNE

Minimum prob is 0.03

Summary

- If taken at face value, LSND anomaly requires dramatic new physics
- A new B-L force?
- gauge boson mass ~ keV
- sterile neutrinos at eV
- miniseesaw for neutrino mass
- nearly degenerate light neutrinos
- no $0\nu\beta\beta$ decay
- energy dependent, lepton sign dependent matter effect
- large signal for MiniBooNE antineutrinos