The LSND-ino
(with help from Extra Dimensions)

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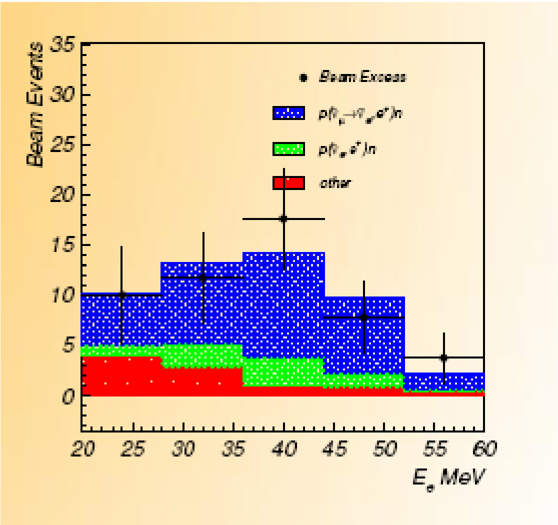
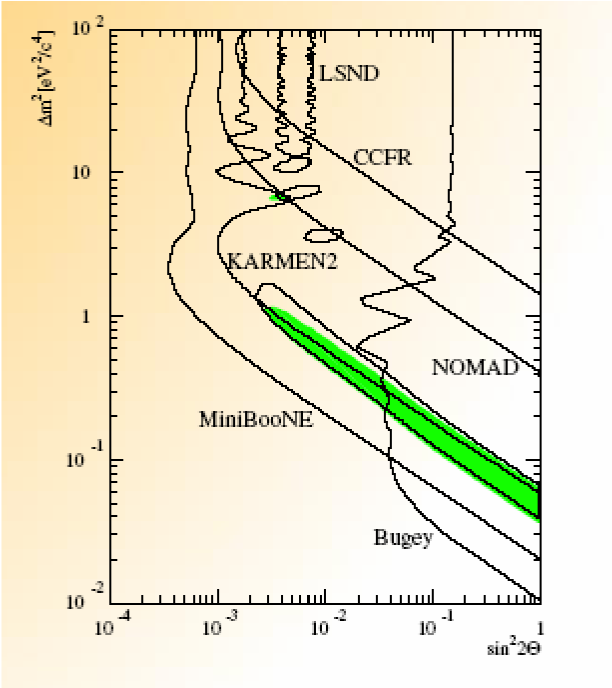
LSND data and inference





Third δm^2, and so fourth neutrino mass-state ν_4

Z-width requires ν_4 to be gauge-singlet – “sterile’

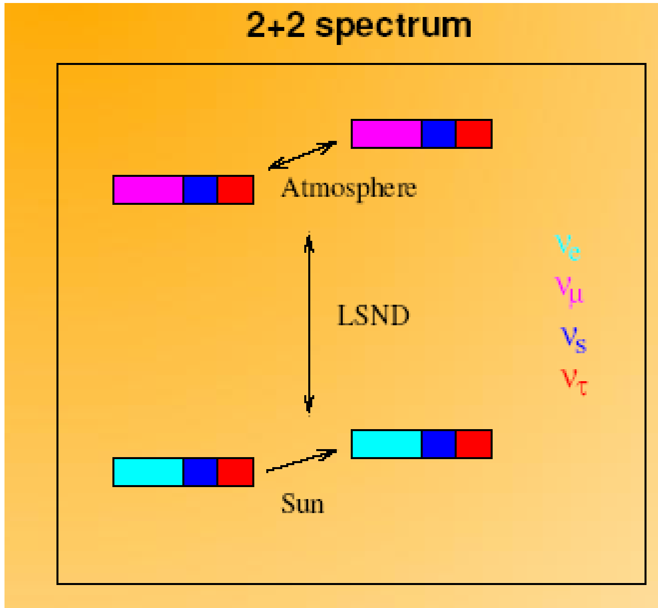
Incredible, yes; Credible, ????

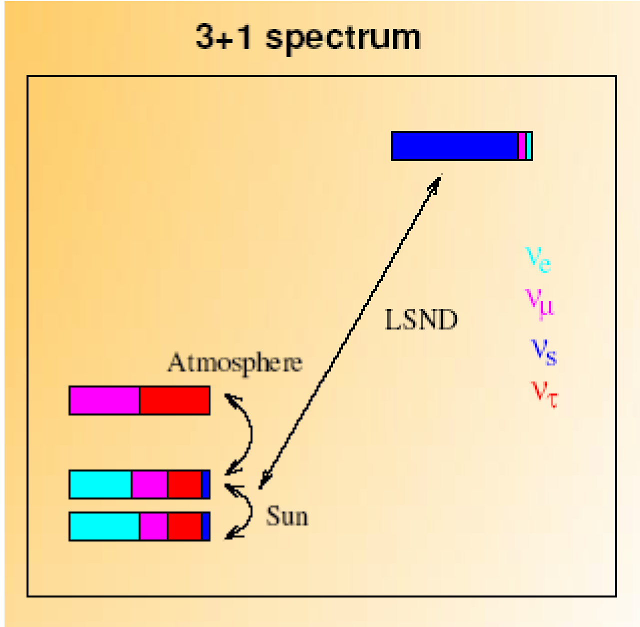
- Fails S. Biller's "redundancy criterion
  (and his second redundancy criterion too)

- Would I bet money on it being right?
  (I'd love to bet some of Don Perkin's money on it, and WIN)

- Mini-BooNE coming very soon,
  to a conference near you.

Failure of LSND stable sterile in 4D





2+2 spectrum:
oscillations of solar or
or atmospheric ν's into steriles!

3+1 spectrum:

BUGEY bound: $\sin^2 2\theta_{e\not{e}} = 4\,U_{e4}^2\,(1-U_{e4}^2)$

CDHS bound: $\sin^2 2\theta_{\mu\not{\mu}} = 4\,U_{\mu4}^2\,(1-U_{\mu4}^2)$

LSND: $\sin^2 2\theta_{\rm LSND} = 4U_{e4}^2 U_{\mu4}^2$

LSND is doubly suppressed! $\sin^2 2\theta_{\rm LSND} \simeq \frac{1}{4}\sin^2 2\theta_{e\not{e}}\sin^2 2\theta_{\mu\not{\mu}}$

Proposed models (some dead)

- Three (or Four) Nu with broken CPT DEAD (ALIVE)
- Lepton-number violating muon decay DEAD
- Five Nu oscillations
- Low reheat-temperature cosmology
- QGravity decoherence with broken CPT
- MaVans (mass-varying neutrinos)
- Four Nu with decay
- Extra-dimensional geodesics for sterile neutrinos

Commonality of models

- Have new parameters/new physics
  5th neutrino, DK to scalar, more spacetime, quantum gravity, new cosmology, coupling to DarkEnergy, …..

o Way beyond Standard Model

o Testable predictions

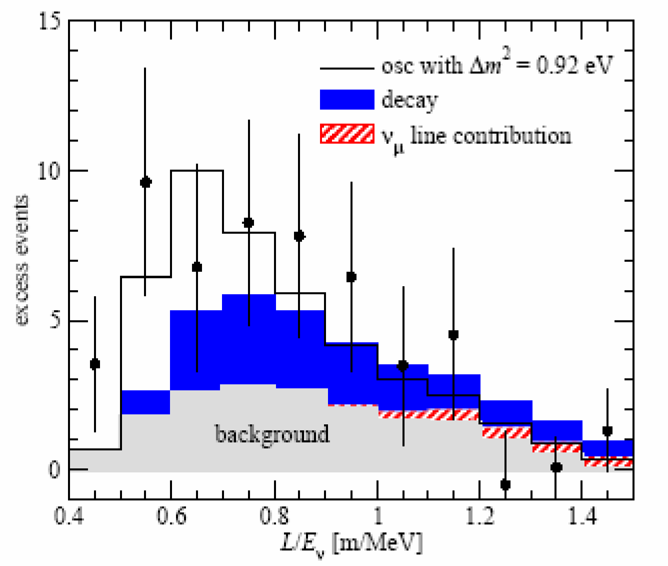
KeV-MeV ν_4 model

Explaining LSND by a decaying sterile neutrino

Sergio Palomares-Ruiz,[1,*] Silvia Pascoli,[2,†] and Thomas Schwetz[3,‡]

We propose an explanation of the LSND evidence for electron antineutrino appearance based on neutrino decay. We introduce a heavy neutrino, which is produced in pion and muon decays because of a small mixing with muon neutrinos, and then decays into a scalar particle and a light neutrino, predominantly of the electron type. We require values of $gm_4 \sim$ few eV, g being the neutrino–scalar coupling and m_4 the heavy neutrino mass, e.g. m_4 in the range from 1 keV to 1 MeV and $g \sim 10^{-6}$–10^{-3}.

arXiv:hep-ph/0505216



Fits

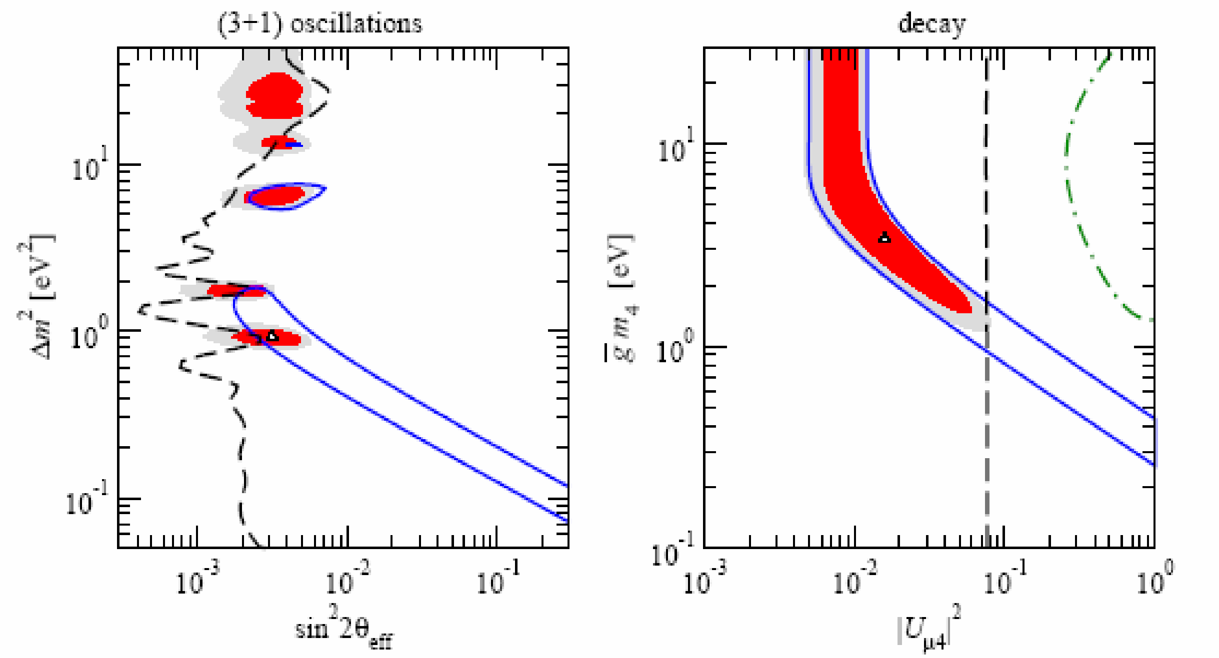
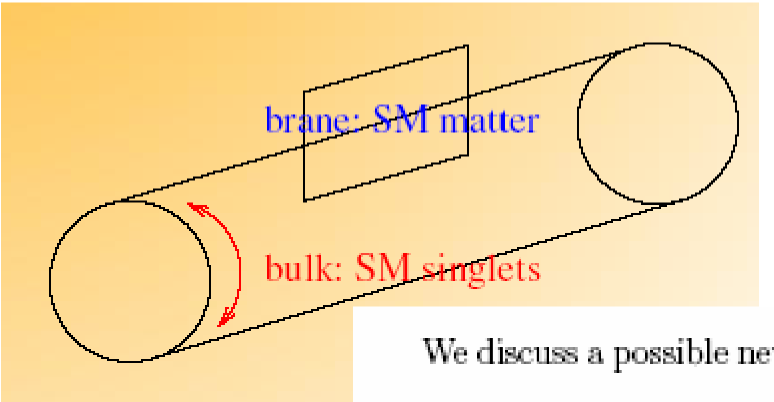


FIG. 3: Allowed regions for LSND+KARMEN (solid) and SBL disappearance+atmospheric neutrino experiments (dashed) at 99% CL, and the combination of these data (shaded regions) at 90% and 99% CL. The left panel corresponds to neutrino oscillations in the (3+1) mass scheme and the right panel to the decay scenario presented in this work. The dash-dotted curve in the right panel shows the 99% CL constraint from CDHS.

Note the parameter equivalences

Brane-Bulk resonance model



Sterile-active neutrino oscillations and shortcuts in the extra dimension

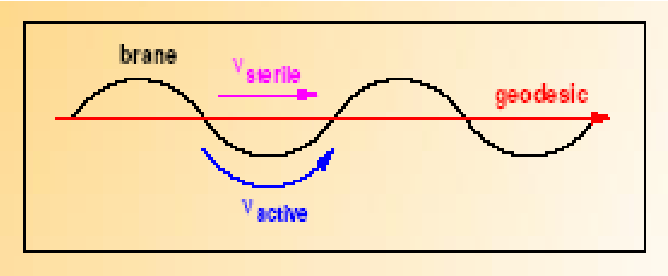
Heinrich Päs[1], Sandip Pakvasa[1], Thomas J. Weiler[2]

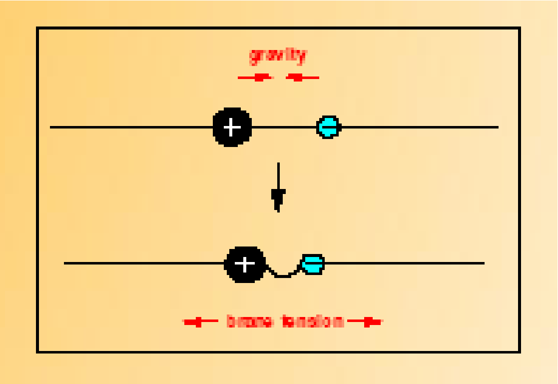
We discuss a possible new resonance in active-sterile neutrino oscillations arising in theories with large extra dimensions. Fluctuations in the brane effectively increase the path-length of active neutrinos relative to the path-length of sterile neutrinos through the extra-dimensional bulk. Well below the resonance, the standard oscillation formulas apply. Well above the resonance, active-sterile oscillations are suppressed. We show that a resonance energy in the range of $30 - 400$ MeV allows an explanation of all neutrino oscillation data, including LSND data, in a consistent four-neutrino model. A high resonance energy implies an enhanced signal in MiniBooNE and a low resonance energy a distorted energy spectrum in LSND. The numerical value of the resonance energy may be related back to the geometric aspects of the brane world.

arXiv:hep-ph/0504096

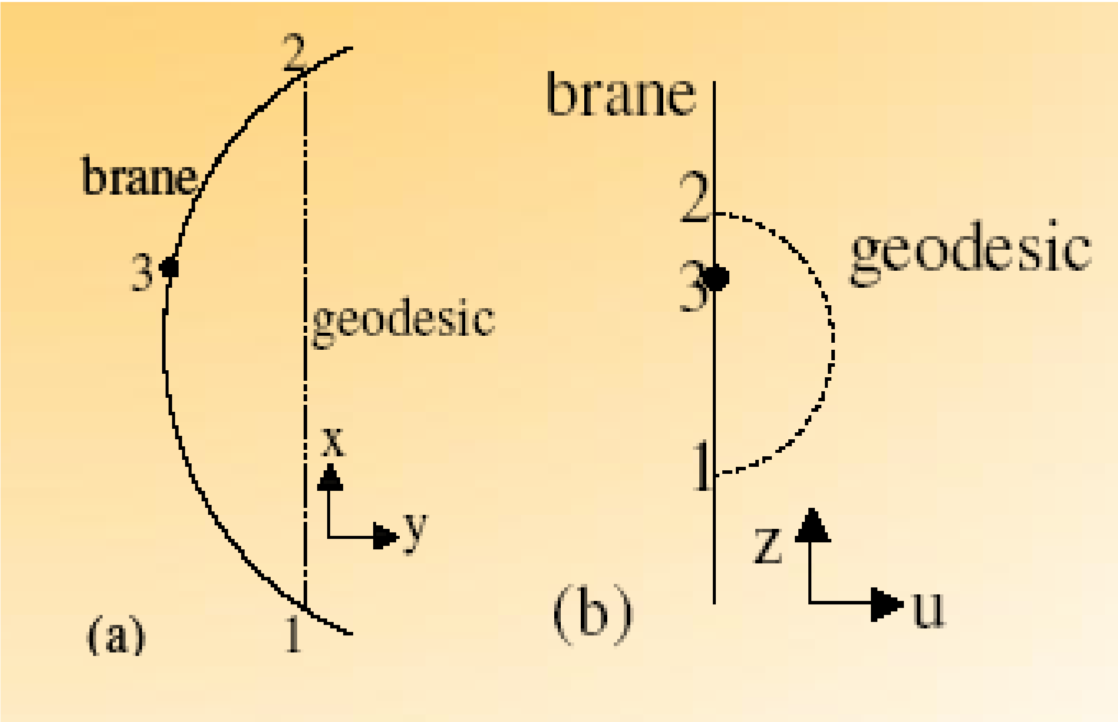
In QG/StringTheory, brane is dynamical, fluctuating

due to
Quantum Mechanics
Thermal Mechanics
In-Brane stresses (e.g. EM vs. gravity)
Out of Brane experiences
(e.g. trans-brane gravity)





A tale of two geodesics



BB-resonance

In this embedding spacetime, assume the brane exhibits periodic (for simplicity) oscillations in space

$$y = A \sin kx\,; \qquad (2)$$

The bulk-geodesic for the sterile neutrino is simply given by $y = 0$, which leads to travel distance of

$$x_g = x\,. \qquad ($$

The geodesic for the active state on the brane is slightly more complicated:

$$x_b = \int \sqrt{dx^2 + dy^2} = \int^x \sqrt{1 + A^2 k^2 \cos^2 kx}\; dx\,. \qquad ($$

We use subscripts b and g to denote the brane and bulk spaces, respectively.

In terms of the coordinate x, the parameter describing the shortcut in the bulk is

$$\epsilon(x) = \frac{x_b - x_g}{x_b} = 1 - \frac{x}{\int^x \sqrt{1 + A^2 k^2 \cos^2 kx}\; dx}\,. \qquad = \left(\frac{Ak}{2}\right)^2$$

which is the (fluctuation aspect ratio)^2

Two-flavor resonances

Define $|\nu_a>_U = |\nu_4> - < \nu_s | \nu_4 > | \nu_s >$

Evolution equation in flavor space:

$$i\frac{d}{dt}\begin{pmatrix}\nu_a(t)\\ \nu_s(t)\end{pmatrix} = H_F \begin{pmatrix}\nu_a(t)\\ \nu_s(t)\end{pmatrix}$$

Hamiltonian in the presence of bulk shortcuts:

$$H_F = +\frac{\delta m^2}{4E}\begin{pmatrix}\cos 2\theta & -\sin 2\theta\\ -\sin 2\theta & -\cos 2\theta\end{pmatrix} + E\,\frac{\epsilon}{2}\begin{pmatrix}-1 & 0\\ 0 & 1\end{pmatrix}$$

$\Rightarrow$ A Resonance exists at $E_{\rm res} = \sqrt{\frac{\delta m^2 \cos 2\theta}{2\,\epsilon}}$

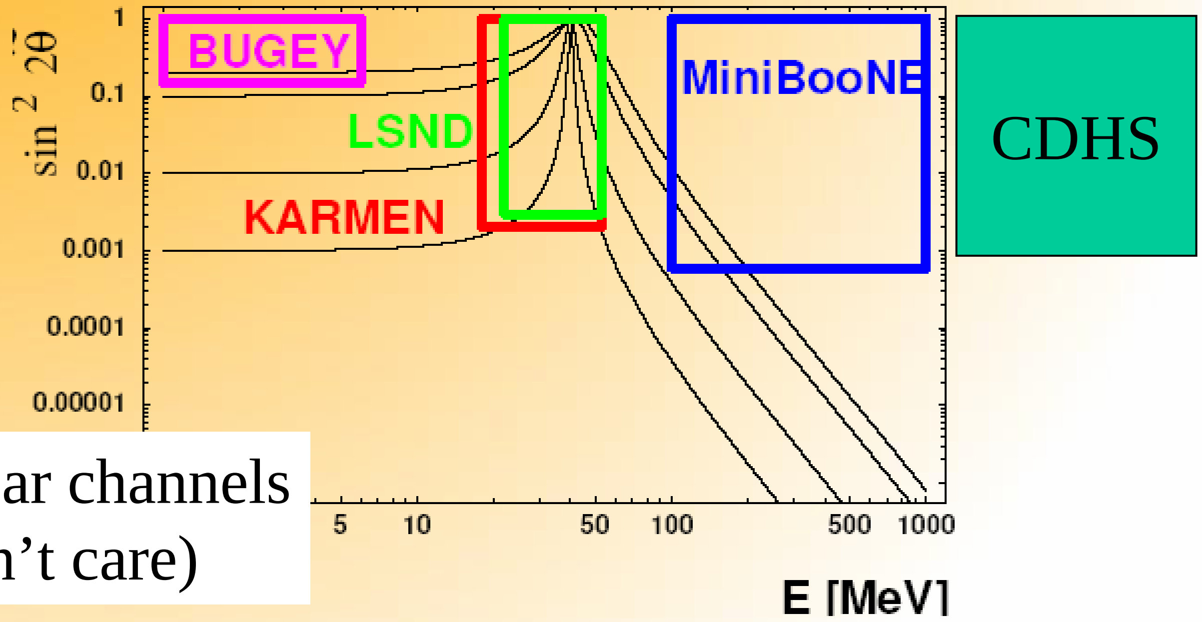
$\rightarrow$ choose $E_{\rm res} = 60 - 500$ MeV $\leftrightarrow \epsilon \simeq 10^{-18} - 10^{-16}$

Brane-Bulk Resonant Oscillation

$$P_{as} = \sin^2 2\tilde{\theta}\ \sin^2(\delta H\, D/2)$$

$$\sin^2 2\tilde{\theta} = \left[\frac{\sin^2 2\theta}{\sin^2 2\theta + (\cos 2\theta - A)^2}\right] \qquad \delta H = \frac{\delta m^2}{2E}\sqrt{(\cos 2\theta - A)^2 + \sin^2 2\theta}$$

$$A = (E_{\rm res}/E)^2$$



In nu and nubar channels (gravity doesn’t care)

Oscillations at $E \gg E_{\rm res}$ are suppressed!

Goodbye CDHS!

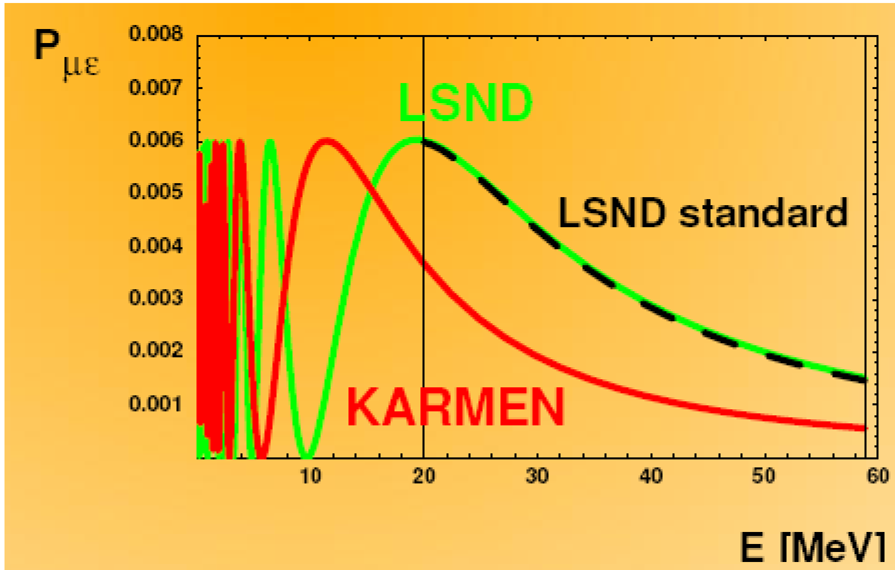
CDHS

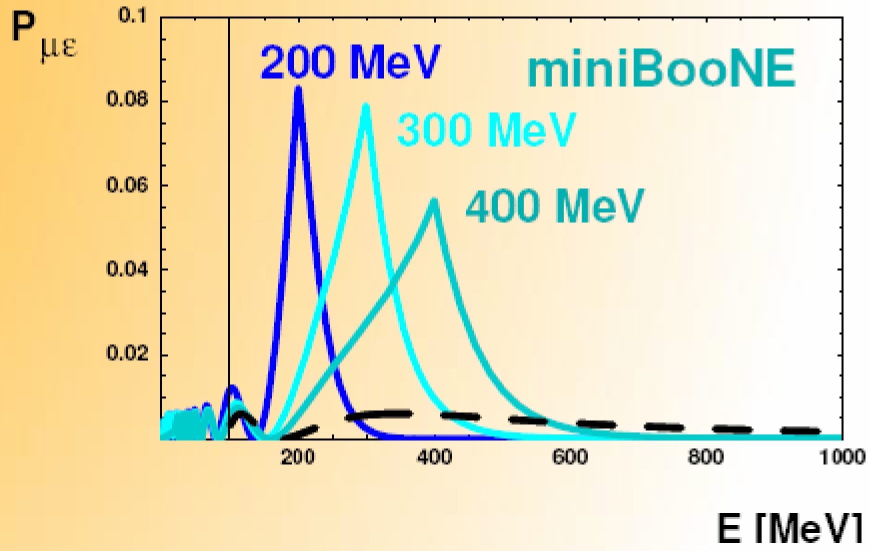
The accelerator oscillation experiment CDHS operated with neutrino energies above a GeV.

At energies $E \gg E_{\rm res}$ the active-sterile mixing is suppressed, and one can approximate

$$\sin^2 2\tilde{\theta}_{\mu\mu'} \simeq \cos^2\theta_+ \tan^2 2\theta \left(\frac{E}{E_{\rm res}}\right)^{-4} . \qquad (40)$$

Examples: n00 MeV resonance

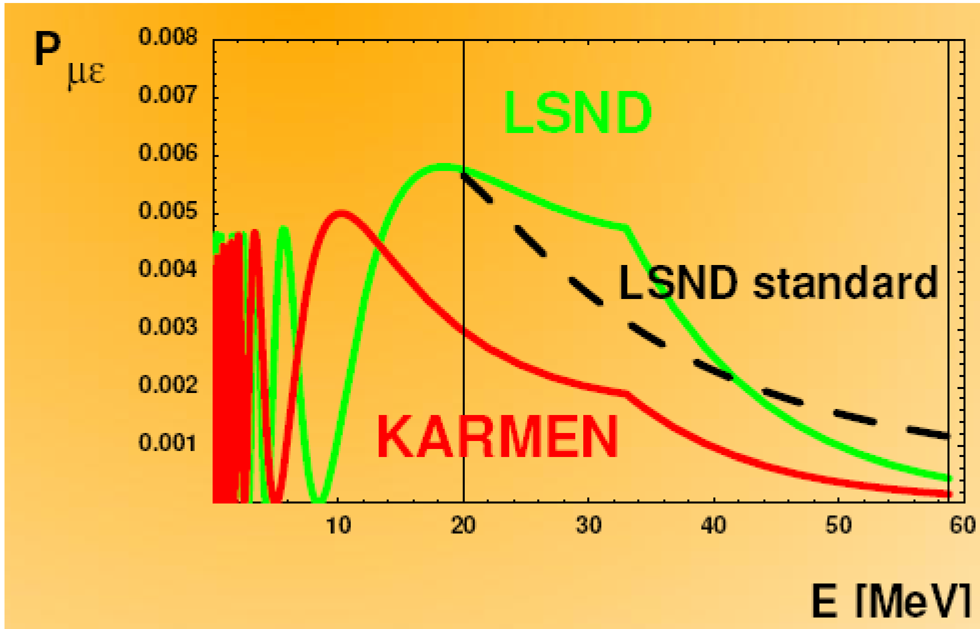




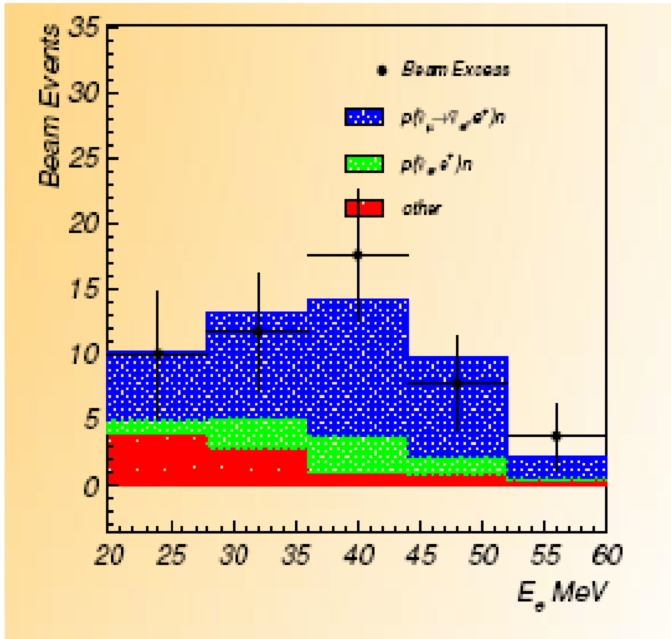
- $E_{\rm res} = 200$ MeV, 300 MeV, 400 MeV; $\sin^2\theta_* = 0.1$; $\sin^2 2\theta = 0.45$; $\delta m^2 = 0.8$ eV^2
- good fit to LSND spectrum, $P_{\rm LSND} > P_{\rm KARMEN}$
- enhanced miniBooNE signal in the energy range 100-600 MeV

And significant ν_μ disappearance for stopped-pion source (SNS)

Example: 40 MeV resonance



- $E_{\rm res} = 33$ MeV; $\sin^2\theta_* = 0.01$; $\sin^2 2\theta = 0.9$; $\delta m^2 = 0.7$ eV^2
- $P_{\rm LSND} > P_{\rm KARMEN}$



Conclusions

If LSND is correct, then ….
theory needs a HUGE accommodation.

(In)validation is “just around the corner,
With Fermilab’s MiniBooNE experiment

(altho some LSND models predict null MiniBooNE,
positive something else)