LSND & Rare Muon Decay

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hep-ph/0204236

KITP, SB
3/25/03

1. Description of LSND & KARMEN & Results
2. Possible Explanations:
   - ν oscillations: sterile, CPTV
   - Rare μ Decay Mode
3. Possible Exptl Tests
4. Model for Rare μ Decay Mode
5. Summary.

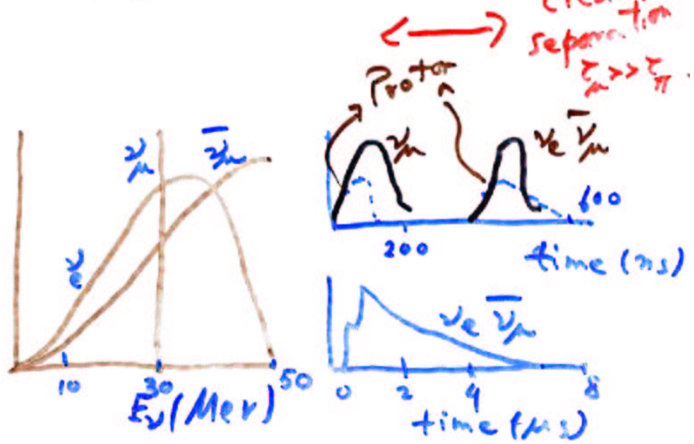
LSND ≡ Liquid Scintillator Neutrino Detector @ Los Alamos

KARMEN ≡ Karlsruhe et al. @ Rutherford - Medium-Energy-Neutrino-experiment

π^+ decay at rest (DAR)

$\pi^+ \to \mu^+ \nu_\mu$ (Both mono-energetic).

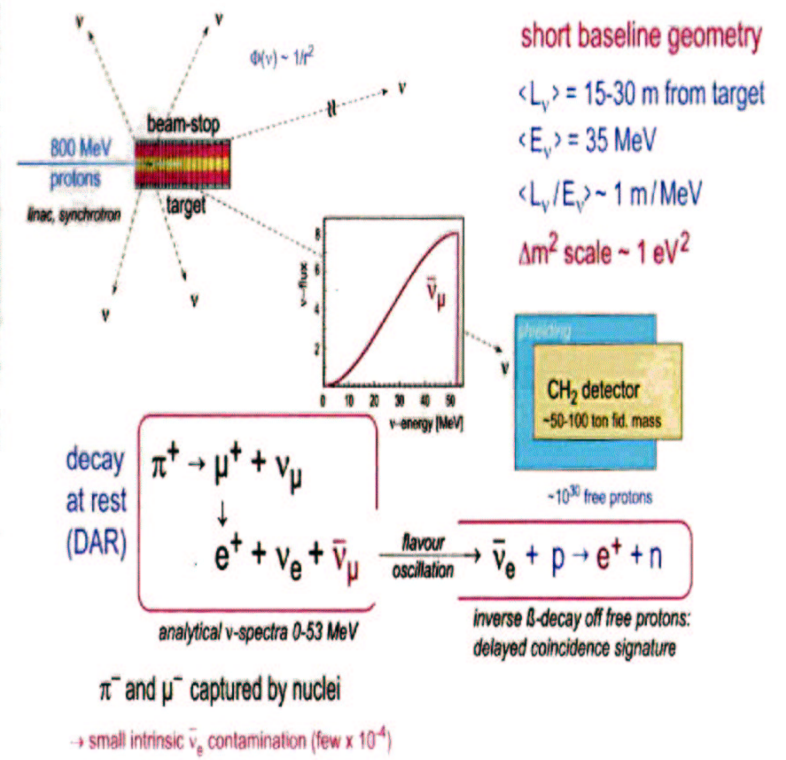
$\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$ (Known spectra).



Index .pdf-file << Prev Next >>

G. Drexlin: LSND and Karmen (3/38)

$\bar{\nu}_\mu$ - $\bar{\nu}_e$ Oscillation Searches at Beam Stop Sources



· Search for $\bar{\nu}_e$ in LS Detector via Reines–Cowan Technique.

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

· $e^+ \to e^+e^- \to 2\gamma$ prompt signal.

· $n \to n + p \to d + \gamma$ ↳ 2.2 MeV
Delayed signal
$\Delta t \sim O(ms)$.

Same technique in all Reactor ν expts & KamLand.

Expected BG.

π^- decay in flight $\to \mu^- \bar{\nu}_\mu$

$\mu^- \to e^- \bar{\nu}_e \nu_\mu$
(DAR)

Rate from this expected of order $(0.8)\cdot 10^{-3}$

Further suppressed by software cuts

e.g. total BG events in KARMEN $\sim O(10)$
... LSND $\sim O(100)$

· LSND sees a signal for $\bar{\nu}_e$ in $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$

· KARMEN sees no signal.

· Final joint Analysis yields small allowed region in $\delta m^2 - \sin^2 2\theta$ plane assuming neutrino oscillation. This is the ONLY (claimed) observation of APPEARANCE yet.

$$P(\bar{\nu}_\mu \to \bar{\nu}_e) = \sin^2 2\theta \, \sin^2(\phi)$$

$$\phi = \delta m^2 L / 4E$$

$L \sim 18-30\,m$ ... $E \sim 25-50$ MeV:

- LSND looked for $\nu_\mu \to \nu_e$ oscillations from ν_μ's in π^+ Decay in Flight (D/F)

  $\pi^+ \to \mu^+ \nu_\mu$ (not monochromatic)

  $\nu_\mu \to \nu_e$

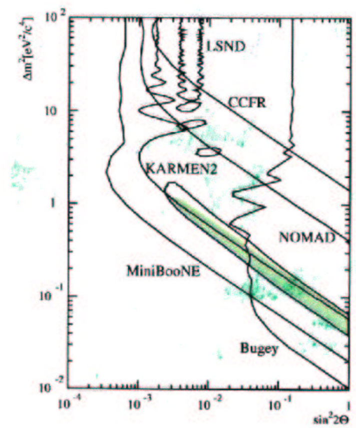
  $\nu_e + N \to N' + e^-$

  (N = ^{12}C)

- Evidence Weak ($\sim 2\sigma$).
- Signature Poor (no tag)
- BG High.
- Less Convincing than $\bar{\nu}$.

From now on we will ignore this (weak) signal.

#7 Joint Analysis of LSND + KARMEN Data.



Slight dependence on whether DIF $\nu_\mu \to \nu_e$ signal included or NOT.

FIG. 10: Parameter regions deduced in this work (grey area) compared with existing limits of experiments (Bugey $\bar{\nu}_e \to \bar{\nu}_x$ [18], CCFR $\nu_\mu \to \nu_e$ [19] and NOMAD $\nu_\mu \to \nu_e$ [20]) and the envisaged sensitivity of the MiniBooNE experiment (with final single horn design [21]).

applied a unified frequentist approach to both likelihood analyses individually. The results underline the feasibility of as well as the necessity for such an approach.

A quantitative joint statistical analysis has been performed leading to a level of 36% incompatibility of the experimental outcomes, corresponding to individual confidence levels of 60%. For the cases of statistical compatibility, the common parameter regions have been identified on the basis of the unified frequentist approach applied to the combined likelihood function of KARMEN 2 and LSND. The derived confidence regions in ($\sin^2(2\Theta)$,Δm^2) clearly differ from an often applied but incorrect graphical overlap of the confidence regions of the individual experiments. There are two oscillation scenarios with either $\Delta m^2 \approx 7\,\mathrm{eV}^2/c^4$ or $\Delta m^2 < 1\,\mathrm{eV}^2/c^4$ compatible with both experiments.

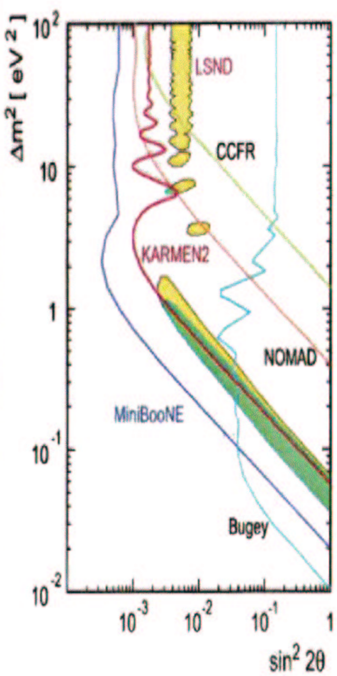
We performed a joint statistical analysis incorporating some of the systematic uncertainties of the experiments, such as neutrino flux uncertainty, accuracy of known cross sections and resolution functions of both experiments. Further –unknown– systematic uncertainties

76

G. Drexlin: LSND and Karmen (31/38)

Conclusions

final oscillation results from LSND and KARMEN2 published
and compatibility analysis submitted for publication



LSND (1993-98)

combined DAR & DIF analysis (new reconstr.)
$87.9 \pm 22.4 \pm 6.0$ *beam excess* events
$P = (0.264 \pm 0.067 \pm 0.045)\%$

KARMEN2 (1997-01)

final DAR oscillation analysis 4y of data
15 evts. ↔ (15.8 ± 0.5) bg expect. *no excess*
$\sin^2 2\theta < 1.7 \times 10^{-3}$, most stringent limit so far

LSND & KARMEN2

detailed statistical analysis using full inform.
incompatibility at individual 60% Confid. Levels
areas of stat. compatibility only at $\Delta m^2 < 1$ eV^2
L-number violating μ-decays excluded

LSND Effect

- $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$ normal mode
- In DAR see $\bar{\nu}_e$ at a level $(1-3)\cdot 10^{-3}$.

What could be the origin?

- $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations?

  need $\delta m^2 \sim O(eV^2)$
  $\sin^2 2\vartheta \sim 0.005$.

- New Rare Decay Mode?

  $\mu^+ \to e^+ \bar{\nu}_e X$.
  with B.R. of $O(10^{-3})$

- In ~~$\mu \to e \bar{\nu}_e \bar{\nu}_\mu$~~ $\pi^+ \to \mu^+ \nu_\mu$ → ν_e channel DIF evidence weaker.

If oscillations, need 4th sterile ν,

4th → • Because $\delta m^2_{Sol} + \delta m^2_{ATM} + \delta m^2_{LSND} \neq 0$

ster → • Because of $\Gamma(Z \to \nu_i \bar{\nu}_i)$..

Options (for Theorists)

A. Ignore LSND

B. Live with 4th sterile neutrino

C. Give up CPT conservation

D. Rare Decay of $\mu^+ \to e^+ \bar{\nu}_e \nu_x$

Mini-Boone Will test (B) & (C)

$\pi^+ \to \mu^+ \nu_\mu \longrightarrow \nu_e$ appearance

eventually $\pi^- \to \mu^- \bar{\nu}_\mu \longrightarrow \bar{\nu}_e$ "

But does not check LSND because it does not use $\bar{\nu}$'s from μ-decay.

Possible 4ν schemes

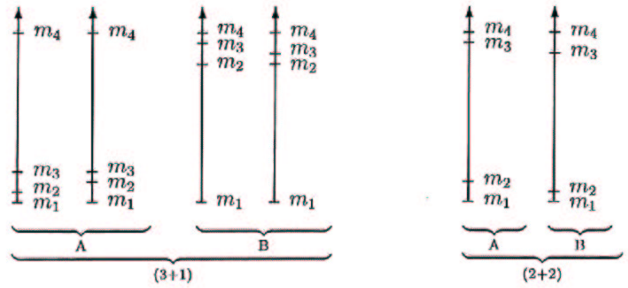


FIG. 39. The six types of 4-neutrino mass spectra. The different distances between the masses on the vertical axes represent the different scales of mass-squared differences required to explain solar, atmospheric and LSND data with neutrino oscillations.

Possible Problem?

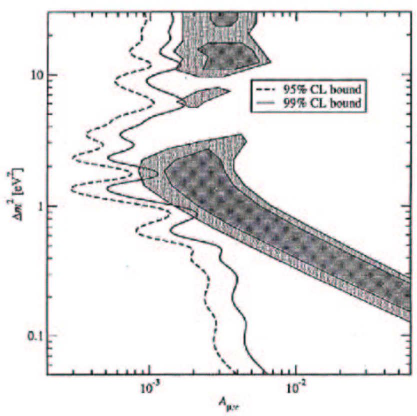


FIG. 40. Upper bounds (at 95 and 99% CL) on $A_{\mu;e} \equiv 4|U_{e4}U_{\mu 4}|^2$ in the context of (3+1)-schemes. The shaded regions are the regions allowed by LSND at 90 and 99% CL.

In 3(+)1 scheme $P_{\mu e}(LSND) = A_{\mu e} \sin^2 \frac{\delta m^2 L}{4E}$

$A_{\mu e} = 4 U_{\mu 4}^2 U_{e4}^2$ → Bounded by BUGEY (CHOOZ)

↳ Bounded by CDHS

125

Problems with 4ν scenarios for LSND

Maltoni, Schwetz, Valle (2002)

- In 3+1 schemes

$$P_{\mu e} = A_{\mu e} \sin^2(\delta m_L^2 L/4E)$$

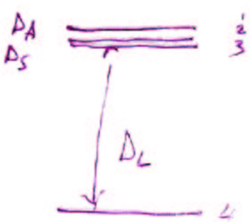
$A_{\mu e}$ ↳ $4U_{\mu 4}^2 U_{e4}^2$

$U_{\mu 4}^2$ ↓ bounded by CDHS

U_{e4}^2 ↳ bounded by Bugey/CHOOZ

With $A_{\mu e}$ thus constrained & $P_{\mu e}$ (LSND + KARMEN).

no fit is possible.



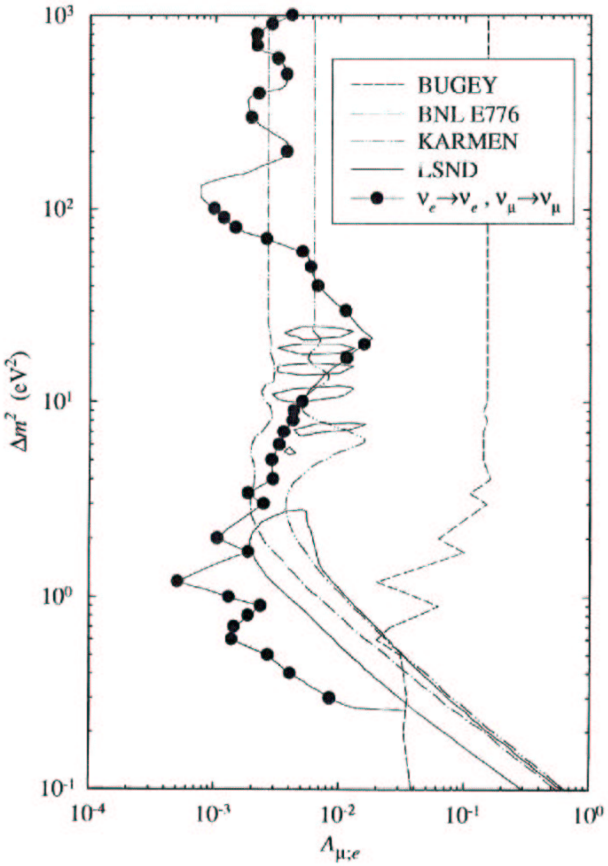


Figure 2: Exclusion regions at 90% CL in the $A_{\mu;e}$–Δm^2 plane for small $|U_{e4}|^2$ and $|U_{\mu 4}|^2$ in the model with mixing of four neutrinos and a mass hierarchy discussed in Section 3. The regions excluded by the BNL E776 and KARMEN $\nu_\mu \to \nu_e$ appearance experiments are bounded by the dash-dotted and dash dot-dotted curves, respectively. The dashed line represents the results of the Bugey experiment. The curve passing through the circles is obtained from the results of the Bugey, CDHS and CCFR84 experiments using Eq.(20). The region allowed by the LSND experiment is shown as the shadowed region limited by the two solid curves.

Pierce & Murayama
Post-WMAP

Maltoni et al. →

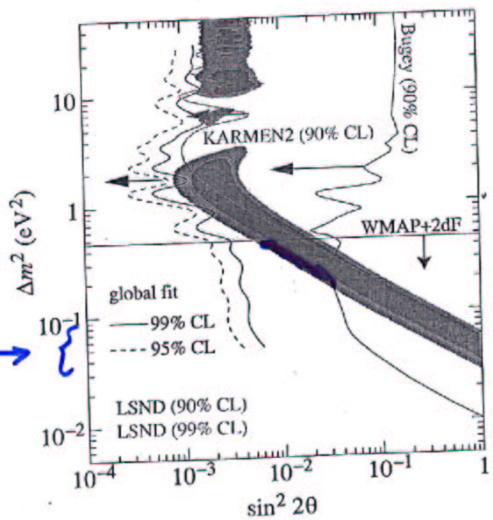


FIG. 1: The LSND Allowed region, with Bugey and Karmen [17] exclusion regions. The constraints from the global fit [18] as well as the limit from the combination of WMAP and 2dFGRS data are also shown. The contours from the global fit would, of course, continue on to lower values of Δm^2, but Ref. [18] did not show this region.

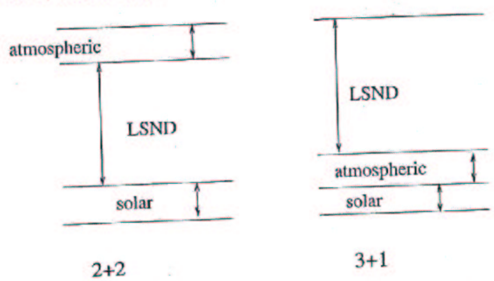


FIG. 2: Sample neutrino spectra in the light of LSND. Different permutations are also possible.

couplings to the other particles of the standard model.

[16] found this 2+2
while a 3+1 spectru
level[16, 18]. The
in large part due
baseline disappeara
and Bugey. Addi
only marginally ir
next two sections,
contradicted by cos

III. BIG-B

By measuring tl
can place bounds o
at the time of Bi
These bounds are
of effective allowe
degrees of freedom
of the universe, w
an earlier time, at
translates into mc
to photon ratio, η
^{4}He abundance al
η places a bound
fixed N_ν^{eff}, a high
primordial ^{4}He; sc
the constraint on
In the era befor
data alone were
ments of primord
for the separate
analysis by [23]
and consequently
disfavored by BBN
light element abu
some measuremer
substantially low
presence of these
often taken [25].
found that even
confidence level.
However, after
the situation has
determined [9]
to an η = 6.5
above, the expe
Y_p = 0.249 ± 0.0

8

- In 2⊕2 schemes there must be some ν_s mixing present in solar & atm. ν's. Current limits getting strong enuf to rub out this fit to LSND.

Current Bounds:

$\frac{1}{2}\Delta_A$ — P_s (ATM) < 0.45

$\frac{3}{4}\Delta_s$ — P_s (SOL) < 0.35

(Global) @ 99% c.l.

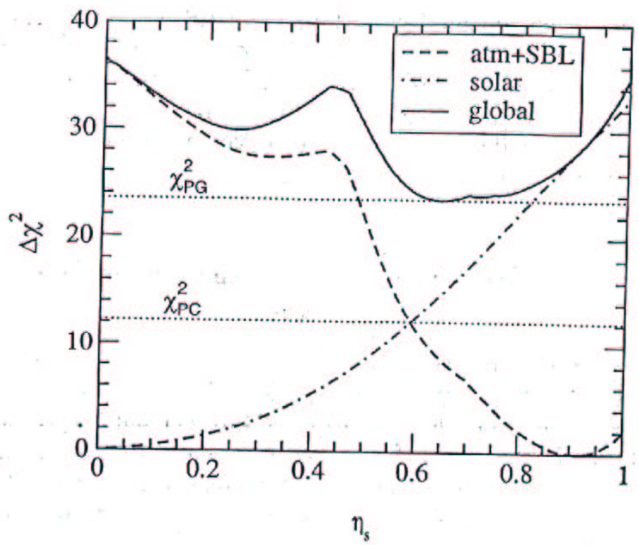
⇒ P_s (total) < 0.8 → getting smaller with time!

Possible Problem?

However, Päs & Weiler ....

Tune in Tomorrow.

Maltoni, Schwetz, Valle



igure 6. $\Delta\chi^2_{SOL}$, $\Delta\chi^2_{ATM+SBL}$ and $\bar{\chi}^2_{global}$ as a function of η_s in (2+2) oscillation :hemes. Also shown are the values χ^2_{PC} and χ^2_{PG} relevant for parameter consistency ıd parameter g.o.f., respectively.

r the parameter obtained from the two data sets and calculating the C.L. at hich the difference is consistent with zero. According to Eq. (A.5) we find

$$\chi^2_{PG} \equiv \bar{\chi}^2_{min} = 23.5\,. \qquad (5)$$

valuated for 1 d.o.f.[4] such a high χ^2-value leads to the marginal parameter o.f. of 1.3×10^{-6}.

Caveat: Päs, Song, Weiler hep-ph/0209373

If U_{e3} (and its generalisations U_{e3}, U_{en} in 4x4 MNS matrix) allowed to be non-zero, Then fits for 2⊕2 are possible.

Need a general analysis (global) of solar ⊕ Atm. ⊕ SBL ⊕ LSND with U_{e3} & $U_{en} \neq 0$ before ruling out 2⊕2 possibility.

i.e.

Solar $\nu_e \to \nu'' = a\nu_\tau + b\nu_s + \varepsilon\nu_\mu$

ATM $\nu_\mu \to \nu' = \alpha\nu_\tau + \beta\nu_s + \varepsilon'\nu_e$

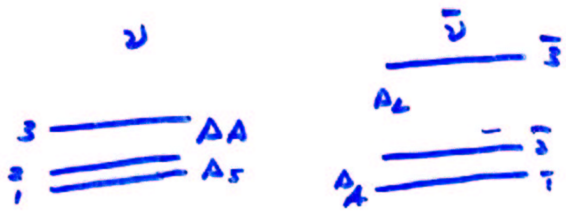
LSND $\nu_e \to \nu''' = \delta\nu_\mu + \xi\nu_s$.

Then $b^2 + \beta^2 \neq 1$ but $b^2 + \beta^2 = 1 - \xi^2$

CPTV with 3 flavors & LSND

(Murayama, Yanagida, Barenboim, Borissov, Lykken, …)

Proposal:



Implications:

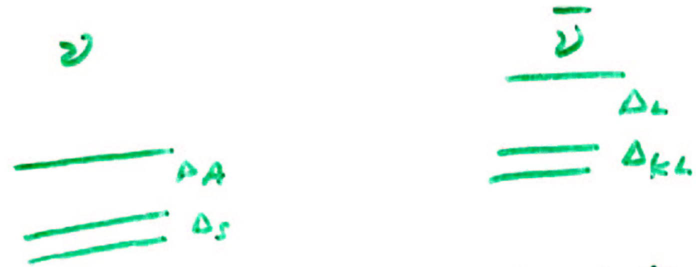
- MINI-BOONE will see oscillation ONLY in $\bar\nu$ channel
- Even if LMA correct for Solar, KamLand will not see it. (depletion)
- LSND result for $\bar\nu_\mu \to \bar\nu_e$ fluctuation

DEC. 6, 2002 Kamland observes depletion of $\bar\nu_e$'s at $L/E \sim \frac{175\ km}{(2-8)\ MeV}$ consistent with LMA & with CPT.

- Interesting Theoretical issues. H_{eff} - non-local but seemingly → L-I ν propagator is LV.

New (post-Kamland) Proposal for CPTV & LSND

Barenboim et al. hep-ph/03…



- To test, need to distinguish ν & $\bar\nu$ events in atm. data (e.g. INO)
- Borexino/KL discrepancy…
- $\Delta_{KL} \neq \Delta_{solar}$ (near equality is an accident)
- MINI-BOONE should see $\bar\nu_\mu \to \bar\nu_e$ BUT NOT $\nu_\mu \to \nu_e$ with Δ_{LSND}.

Comments on CPTV

- for CPTV give up
  - Lorentz Inv.
  - or
  - Locality [or hermiticity ...]
- e.g. $H_0 = \int \frac{d^3p}{(2\pi)^3} \sum_s \left[\sqrt{p^2+m^2}\, a_p^{\dagger s} a_p^s + \sqrt{p^2+\bar{m}^2}\, b_p^{\dagger s} b_p^s \right]$

→ seems Lorentz Inv. & is non-local.

But Greenberg showed that ν propagators (off-shell) violate L.I. So all loops or virtual ν's lead to L.V. [not clear how much!]

- Origin of CPTV? Quantum gravity, Extra Dimensions...
- Why large only in Neutrinos?
  - RH ν's "different"
  - may live in bulk

LV-CPTV e.g. {Coleman-Glashow, Kostelecky} $\bar{\psi} \gamma_\mu \psi b_\mu$ ... {b_μ = constant 4-vector}

MINI BOONE @ FNAL.

$\pi^+ \to \mu^+ \nu_\mu \to E \sim 0.5 - 1.5$ GeV

(ν_e BG $\sim 10^{-4}$)

$L \sim 500$ m.

[$L/E \sim 1$ m/MeV ~ as in LSND, so probe similar δm^2]

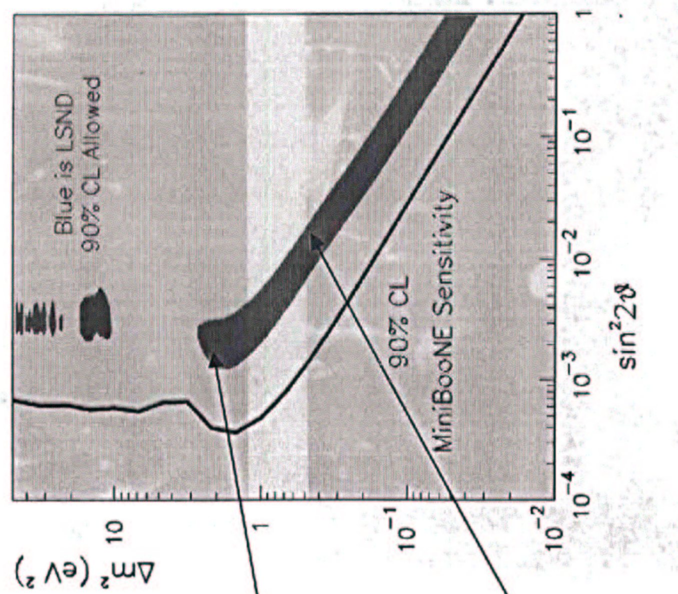
Started Data Taking in June 2002.

Expected To announce results by June 2004.

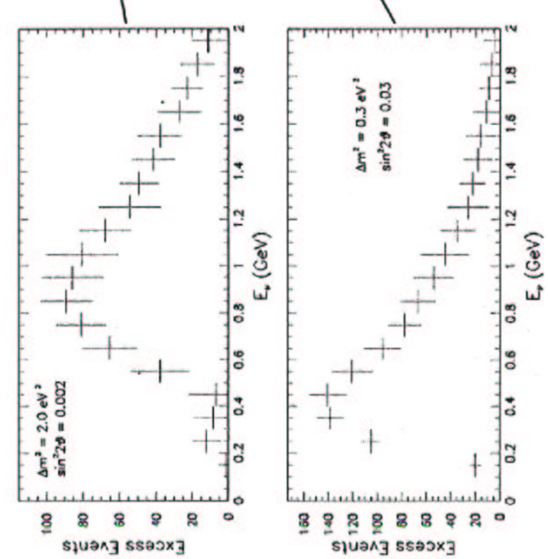
Confirm or Rule out Oscillation Interpretation of LSND with a 4th Sterile ν (or CPTV).

82

MiniBooNE expected sensitivity



With two years of running MiniBooNE should be able to confirm or rule out the entire LSND signal region.



85

Rare μ-Decay Hypothesis

Possible Modes:

$\mu^+ \to e^+ \bar{\nu}_e \nu_i \qquad (i = e, \mu, \tau)$

Can be related to $\mu^+ \to e^+ + e^+ + \bar{l}_i$ by SU(2). with unacceptable rates

$i \equiv e \Rightarrow \mu \to 3e \qquad Br < 10^{-12}$

$i \equiv \mu \Rightarrow \mu^+ + e^- \longleftrightarrow \mu^- + e^+ \qquad Br. < 10^{-6}$

$i \equiv \tau \Rightarrow \tau^+ \to \mu^+ + e^- + e^- \qquad Br < 10^{-6}$.

Even with SU(2) violation, not possible to account for

$Br(\mu^+ \to e^+ \bar{\nu}_e \nu_i) \sim 2 \cdot 10^{-3}$

So lepton flavor violation not enuf!

[Grossman, Bergmann, Herczeg, S.P.]

[Also ruled out by KARMEN $\Rightarrow$ B.R. $< 0.8 \cdot 10^{-3}$]

87

Flavor Violation not enuf.

Need L-violation.

(A) $\mu^+ \to e^+ + \bar{\nu}_e + \bar{\nu}_i \quad (i = e, \mu, \tau)$

[Of course $\bar{\nu}_i \equiv \nu_{st}$ OK but uninteresting]

(models: Babu & S.P.)

Safe after $SU(2)$ rotation.

Possible couplings describing (A)

$$\frac{v^3}{\Lambda^5} (\bar{\mu}_L e_R)(\nu_{eL}^T c^{-1} \nu_{iL})$$

or

$$\frac{v^3}{\Lambda^5} (\bar{\mu}_R e_L)(\nu_{eL}^T c^{-1} \nu_{iL})$$

Possible to construct Baroque Models, new particles ~ 400 GeV

These could come from:

Φ = Higgs = $\begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$, $\psi_i = \begin{pmatrix} \nu_i \\ \ell_i \end{pmatrix}_L$

$$O_1 \equiv \frac{1}{\Lambda^5} (\bar{\psi}_\mu e_R \Phi)(\psi_e^T c^{-1} \psi_i \Phi \Phi)$$

or

$$O_2 \equiv \frac{1}{\Lambda^5} (\bar{\mu}_R \psi_e \Phi^\dagger)(\psi_e^T c^{-1} \psi_i \Phi \Phi)$$

Safe after $SU(2)_L$ rotation?

e.g. $(\bar{\mu}_L e_R)(\nu_{eL}^T c^{-1} \nu_{\tau L})$

$\xrightarrow{SU(2)} (\bar{\nu}_{\mu L} e_R)(\nu_{eL}^T c^{-1} \tau_L)$

$\Rightarrow$ gives rise to rare decay mode (L-viol.) of τ:

$\tau^- \to e^- (\bar{\nu}_{\mu L} \nu_e)$

etc

Existence Proof

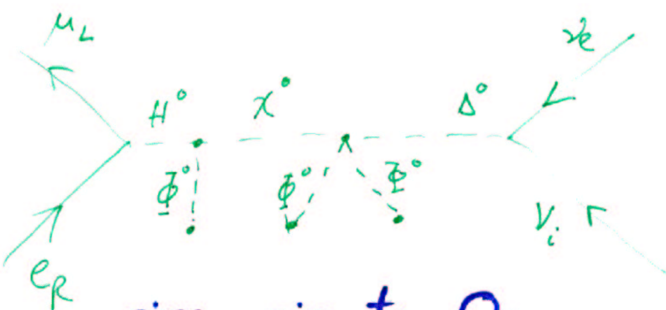
Gauge Models in which operators such as O_1 or O_3 arise

- new scalar fields

$\Delta \; (I=1, Y=$ [illegible]$)$

$\chi \; (I=1, Y=0) \qquad H \; (I=\tfrac{1}{2}, Y=\tfrac{1}{2})$.

$$\mathcal{L} = h_{\mu e}\, \bar{\psi}_\mu e_R H + f_{ei}\, \psi_e^T C^{-1} \psi_i \Delta + M_0 H^\dagger \chi \phi + \lambda' \Delta \chi \phi^\dagger \phi + h.c.$$



gives rise to O_1

$$G_{eff} = \frac{h_{\mu e} f_{ei} \lambda' M_0 v^3}{(m_{\chi_0}^2 m_{H_0}^2 m_{\Delta_0}^2)}$$

$BR\,(2\cdot 10^{-3}) \Rightarrow$ lowest mass $M_1 < 440$ GeV

Similar Models for O_2.

Other L-violating Processes.

If $i = e$: $L_e + 3L_\mu$ & L_τ unbroken
No $\mu \to 3e$, $\tau \to \mu ee$ etc

$i = \mu$: L_μ, L_τ unbroken

$i = \tau$: $L_\mu + L_\tau$ & $L_e + 2L_\mu$ unbroken.

- No other un-wanted L-violating Decays
- No large Majorana ν-masses induced (Protected by these symmetries)
[New scalars have no VEVS]

[ν mass will have to be generated by the "conventional" see-saw mechanism].

- ϕ_H cannot have vev (fine tuning).

Other Effects

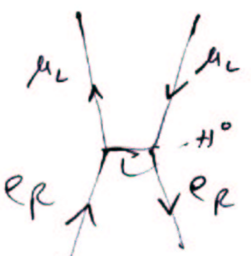
- Radiative Connections to μ Decay shifted by 0.1 %

$$G_\mu = \frac{\pi \alpha}{\sqrt{2}\, m_W^2 (1 - m_W^2/m_Z^2)(1 - \Delta r)}$$

$$\Delta r = \Delta r_{SM} + 0.001$$

Current uncertainty in $\Delta r \approx \pm 0.002$ (from ± 5 GeV in m_t alone)

- $e^+e^- \to \mu^+\mu^-$ gets contribution from

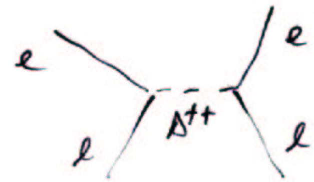


$$G_{eff} = |h_{\mu e}|^2 / 2 m_{H^0}^2$$

$$m_{H^0} / h_{\mu e} \gtrsim 380 \text{ GeV}$$

- $e^+e^- \to l_i \bar{l}_i$

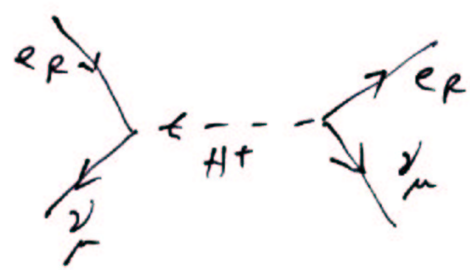
via



$$G_{eff} = f_{ei}^2 / 2 m_{\Delta^{++}}^2$$

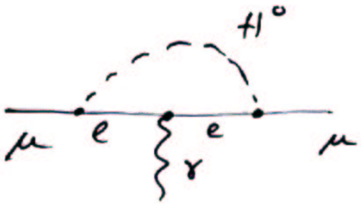
$$m_{\Delta^{++}} / |f_{ei}| > \begin{cases} 760 \text{ GeV} & i = e \\ 1460 \text{ GeV} & i = \mu \\ 780 \text{ GeV} & i = \tau \end{cases}$$

- $e^+e^- \to \nu \bar{\nu} \gamma$



$$m_{H^+} / |h_{\mu e}| \gtrsim 375 \text{ GeV}$$

- $(g-2)_\mu$

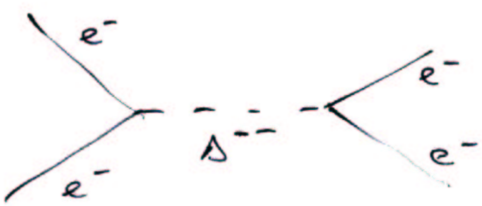


$$\delta a_\mu = \frac{h_{\mu e}^2}{24\pi^2}\, m_\mu^2 / m_{H^0}^2 \sim 47 \cdot 10^{-10}\, |h_{\mu e}|^2 \left(\frac{100\ \mathrm{GeV}}{m_{H^0}}\right)$$

Can be within the sensitivity of current g-2 expt.
Current "Discrepancy" ~ (30 - 36) 10^{-10}. (Hagiwara et al.)

- $e^- + e^- \longrightarrow \Delta^{--} \longrightarrow e^- + e^-$

Resonant Production of Δ^{--} at $e^- e^-$ Collider.



Summary

- L-violating Mode $\mu^+ \to e^+ + \bar{\nu}_e + \bar{\nu}_i$ can account for LSND data (consistently with KARMEN) for $B.R. \sim 1.5 \cdot 10^{-3}$
- Tests:
    - No L/E dependence of Rate
    - NULL Result at Mini-Boone
    - Need to look at μ-decays & not π-decays to test LSND e.g. {ORLAND ⟵ SNS}
        - ν - Factories.
    - Await results from TWIST to check $\rho = 0.7485$ & not 0.75
- Expect new scalar fields with some (H^0) with masses < 450 GeV

$\mu^{\pm}$-Decay Distribution

$$\frac{d^2\Gamma^{\pm}}{dx\, d(\cos\theta_e)} = \frac{m_\mu}{4\pi^3} W_{e\mu}^4 G_F^2 \sqrt{x^2 - x_0^2}$$

$$\Big[x(1-x) + \rho\Big\{\tfrac{2}{9}(4x^2 - 3x - x_0^2)\Big\} + \eta\, x_0 (1-x) \pm P_\mu \cos\theta_e \Big\{ \xi \Big(\tfrac{1}{3}\sqrt{x^2 - x_0^2}\, [1 - x + \tfrac{2}{3}\delta\,[4x - 3 + \sqrt{1 - x_0^2} - 1]] \Big) \Big\} \Big]$$

where $x = E_e/m_\mu$ $\quad x_0 = m_e/W_{e\mu}$ $\{x_0 \le x \le 1\}$

$W_{e\mu} = (m_\mu^2 + m_e^2)/2m_\mu$

S.M. (V−A) $\Rightarrow$ $\rho = 3/4$, $\eta = 0$, $\xi = 1$, $\delta = 3/4$

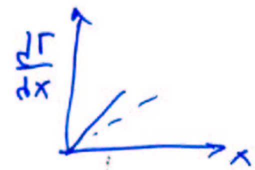
For O_1 $\Rightarrow$ $\rho = 0$, $\eta = 0$, $\xi = -3/4$, $\delta = 0$

For O_2 $\Rightarrow$ $\rho = 0$, $\eta = 0$, $\xi = +3/4$, $\delta = 0$

Shifts in ρ, η, ξ, δ

$\rho = 3/4 - 3/4\,\varepsilon$, $\eta = 0$, $\xi = 1 \begin{matrix} -\varepsilon \\ +\frac{1}{2}\varepsilon \end{matrix}$, $\delta = 3/4 - 3/4\,\varepsilon$

Michel parameter	SM	This model	Current value	TWIST Sensitivity
ρ	3/4	$3/4 - 3/4\,\varepsilon$	0.7518 ± 0.0026	± 0.0001
η	0	0	-0.007 ± 0.013	± 0.003
δ	3/4	$3/4 - 3/4\,\varepsilon$	0.7486 ± 0.0038	± 0.0014
ξ	1	$1 \begin{matrix} -\varepsilon \\ +\frac{1}{2}\varepsilon \end{matrix}$	$1.0027 \pm 0.0079 \pm 0.003$	± 0.00013



TWIST sensitivity to couplings

Coupling	Value in this model	TWIST limit
g^V_{LR}	~ 0.08	0.018
g^V_{RL}	~ 0.08	0.012

TWIST @ TRIUMF

TWIST (TRIUMPH)

sensitivity for $\rho \sim 10^{-4}$!

- Radiative Corrections ?
  - Order α (Kinoshita, Sirlin / Berman} 1959)

    ~4.3 %

    taken into account
  - Order $\alpha^2 \ln m_\mu/m_e$, $\alpha^2 (\ln m_\mu/m_e)^2$

    calculated recently Arbuzov, Melnikov et al. (2002)

    $\delta\rho \sim$ few$\cdot 10^{-4}$.
  - order α^2 yet to be calculated

    ⟹ theoretical error $\sim O(2\cdot 10^{-4})$.

This is adequate to test an effect at a level of 10^{-3}.

Predictions of Rare Decay Explanation of LSND

- No L/E Dependence at LSND or similar expts
- MINI-BOONE will NOT see any effect since they do NOT look at μ Decays (only π decays)
- Effective ρ in μ-decay will deviate from 3/4 to 0.7485

  Currently 0.751 ± 0.0026
  Future TWIST @ TRIUMF sensitivity $- 10^{-4}$.
- Expect new scalar particles in mass range below $\Lambda < 400$ GeV

  → see below.

$\Delta L = 2$ μ-decay explanation for LSND already living dangerously !!

$\mu^+ \to e^+ \bar{\nu}_e \bar{\nu}_\alpha$.

- KARMEN Bound:

(for $\rho = 0$) B.R. < $1.7 \cdot 10^{-3}$ @ 90% C.L.

hep-ex/0302017

- LSND Requirement: (W. Louis, p.c.)

(for $\rho = 0$) B.R. $\cong (3.4 \pm 0.9)\, 10^{-3}$

Small Window

All explanations of LSND Live Dangerously.