Implications of Confirmation of the LSND $\overline{\nu_\mu} \rightarrow \overline{\nu_e}$ Oscillation Signal

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Outline

- Introduction to Oscillations
- LSND
- MiniBooNE
- NP Theories
- NP Experiments

Current Oscillation Status

P = $\mathrm{Sin}^2 2\theta \mathrm{Sin}^2(1.27\Delta m^2 L/E)$

ä Solar ν

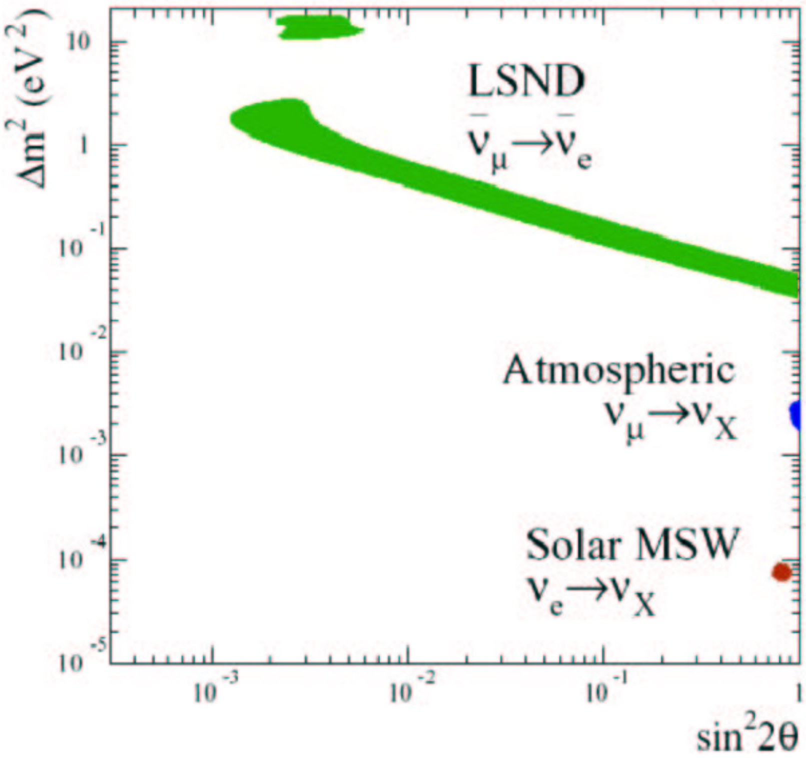
- Deficit of ν_e from $\odot$
- $\triangle \mathrm{m}^2 \approx 8 * 10^{-5}\mathrm{eV}^2$

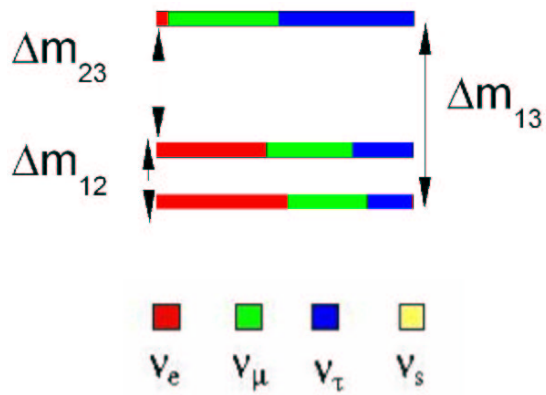
ä Atmospheric ν

- Zenith $\sphericalangle$ deficit of ν_μ
- $\triangle \mathrm{m}^2 \approx 2 * 10^{-3}\mathrm{eV}^2$

ä LSND Accelerator ν

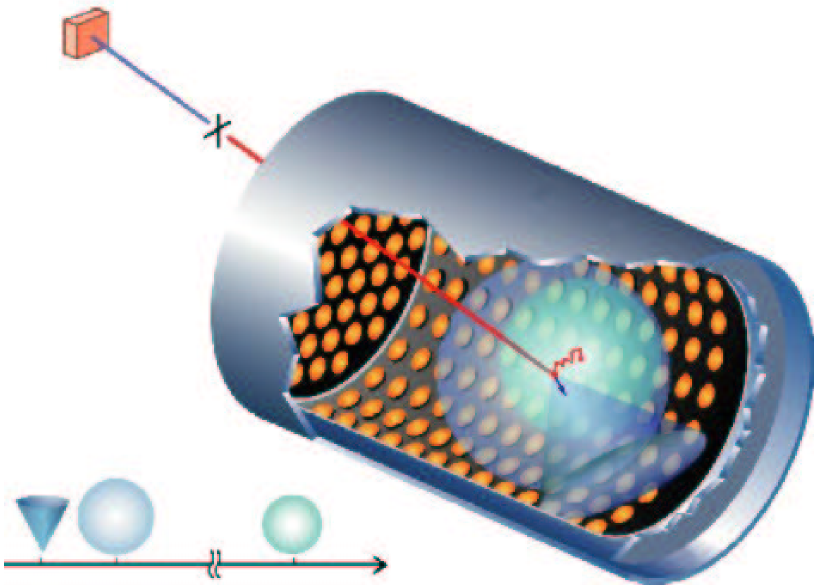
- Excess of $\overline{\nu_e}$ in $\overline{\nu_\mu}$ beam
- $\triangle \mathrm{m}^2 \approx 0.1 \rightarrow 10\ \mathrm{eV}^2$

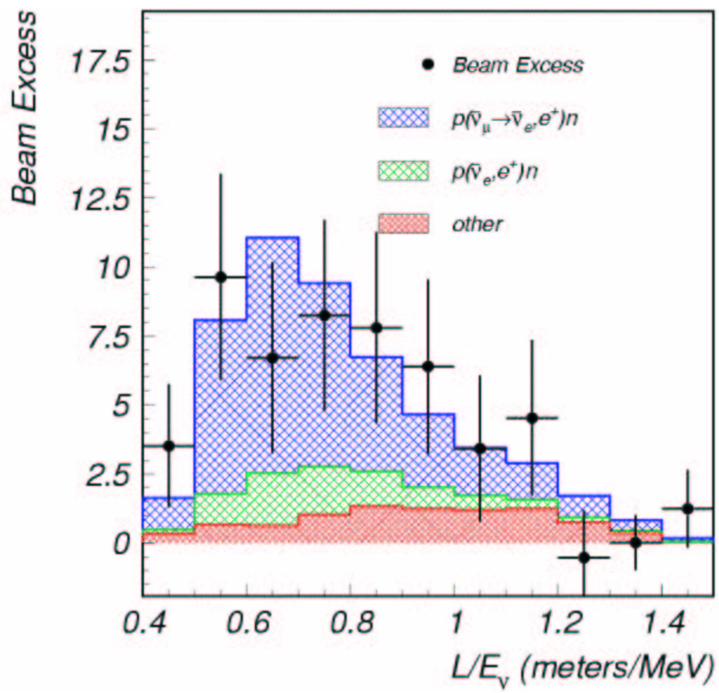




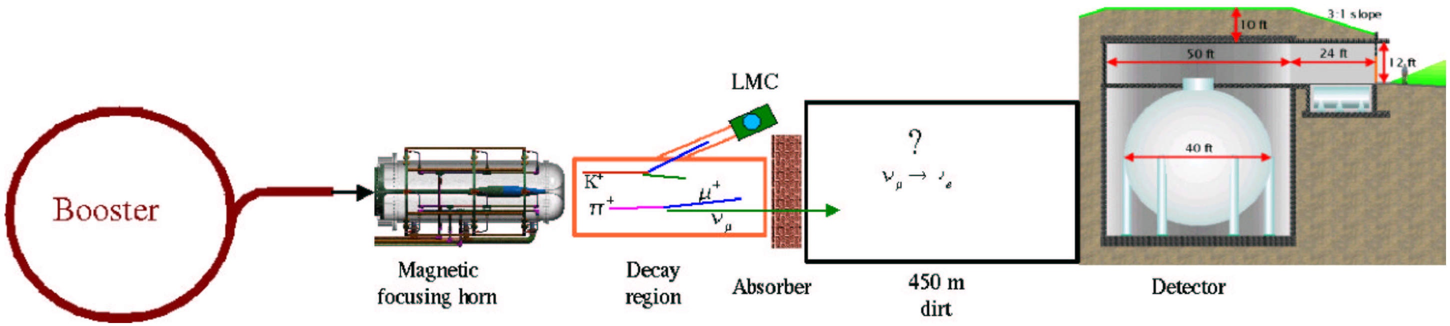
LSND

- 800 MeV proton beam, 600 μs pulses 120 Hz apart $\rightarrow$ water target
- 167 ton, liquid scintillator, 25$\%$ PMT coverage
- $E_\nu \sim$ 20 - 53 MeV, L $\sim$ 25 - 35 m (L/E $\sim$ 1 m/MeV)
- Measure $\overline{\nu}_\mu \rightarrow \overline{\nu_e}$ osc. from DAR : P = 2.64 $\pm$ 0.67 $\pm$ 0.45 x 10^{-3}, see 4 σ excess

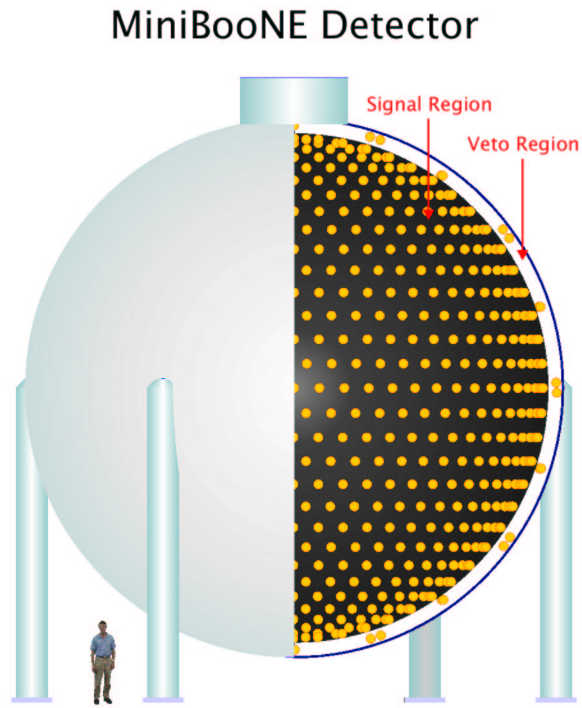




MiniBooNE



- 8 GeV proton beam, 1.6 μs pulses 5 Hz apart $\rightarrow$ Be target
- 800 ton, non-scintillating mineral oil, 10$\%$ PMT coverage
- $E_\nu \sim$ 700 MeV, L $\sim$ 541 m (L/E $\sim$ 0.77 m/MeV)
- Measure $\nu_\mu \rightarrow \nu_e$ osc. from DIF



MiniBooNE vs LSND

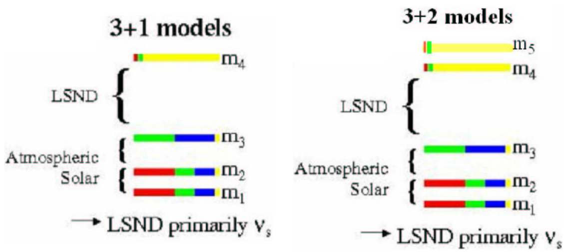
	MiniBooNE	LSND
Energy	8 GeV	800 MeV
Duty Factor	8*10^{-6}	0.072
ν source	$\pi^+ \rightarrow \mu^+$ DIF	$\pi^+ \rightarrow \mu^+$ DAR
Backgrounds	mis-ID, intrinsic ν_e	Beam-Off, intrinisic $\overline{\nu_e}$, π^- DIF
Oil	No Scint.	Scint

Physics of Positive LSND

ä Sterile νs

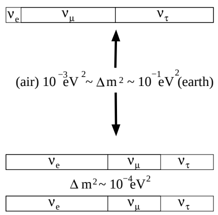
- Weak isospin singlets - high mass states (LSND) mostly sterile ν, 3+n models
- *hep-ph 0403158, Cirelli, Marandella, Strumia, Vissani,*

  hep-ph 0305255, Sorel, Conrad, Shaevitz



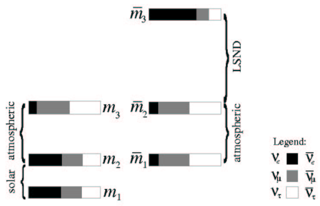
ä Mass Varying νs

- Mass depends on medium
- *hep-ph 0401099, Kaplan, Nelson, Weiner, hep-ph 0405141, Zurek*



ä CPT Violation

- Allow $\triangle \mathrm{m}^2_{\nu} > \triangle \mathrm{m}^2_{\nu}$, 3 ν model
- *hep-ph 0402005, Mavromatos*



ä Lorentz Violation

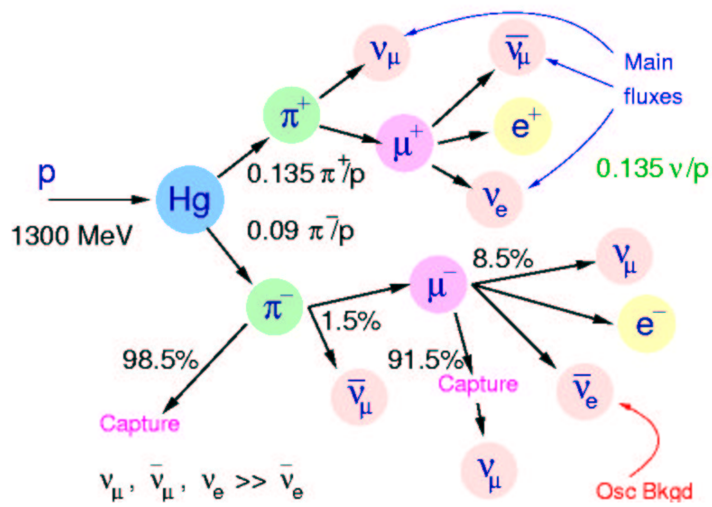
- ν oscillations explained by small Lorentz violation
- Osc. depends on direction of prop.
- *hep-ph 0406255, Kostelecky, Mewes*

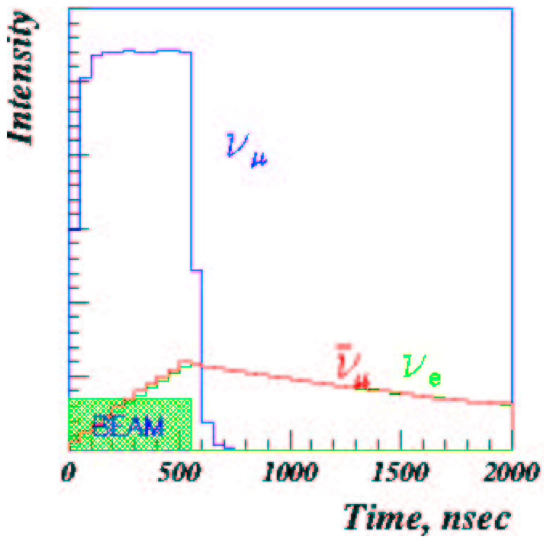
Tests of NP : MiniBooNE

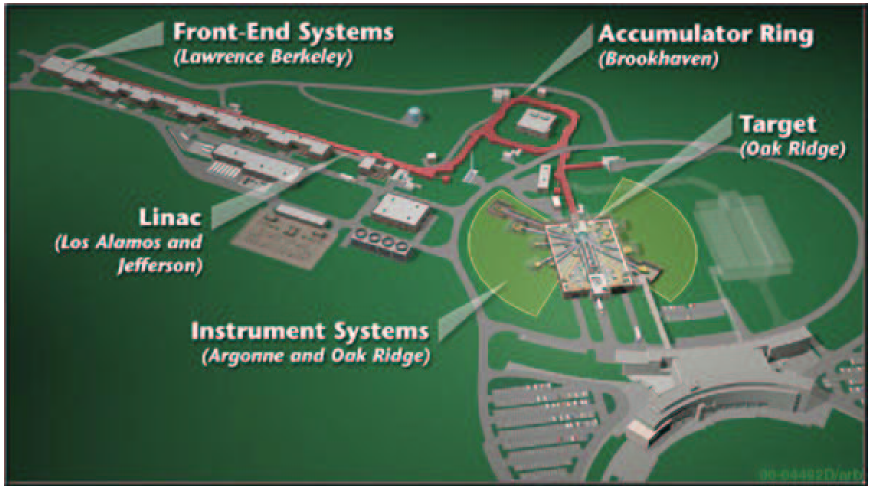
- Sterile νs
  - Second detector (BooNE), measure NC cross section
- Mass Varying νs
  - If measure oscillation in $0.1\mathrm{eV}^2 < \triangle\mathrm{m}^2 < 0.25\mathrm{eV}^2$ (BUGEY excludes)
- CPT
  - Run in $\overline{\nu}$ mode, compare P($\overline{\nu_\mu} \rightarrow \overline{\nu_e}$), P($\nu_\mu \rightarrow \nu_e$)
- Lorentz Violation
  - Look for sidereal variations in oscillation probability
- $\rightarrow$ DIF = difficult sys. from beam flux, σ

Tests of NP : SNS

- 1 GeV proton beam, 700 ns pulses 60 Hz apart $\rightarrow$ Hg target
- Hg absorbs most π^-, μ^- before decay
- provides DAR ν from π^+, μ^+
- $\tau_{\pi^+} <$ 700 ns $< \tau_{\mu^+} \rightarrow$ good temporal separation of $\nu_\mu, \nu_e, \overline{\nu_\mu}$
- Primary backgrounds : cosmic rays (μ, neutrons), machine neutrons
- Secondary backgrounds : DAR π^-, μ^-



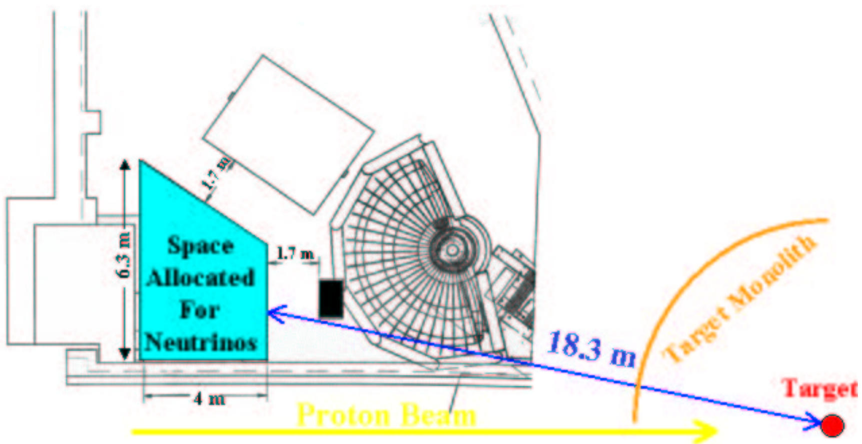


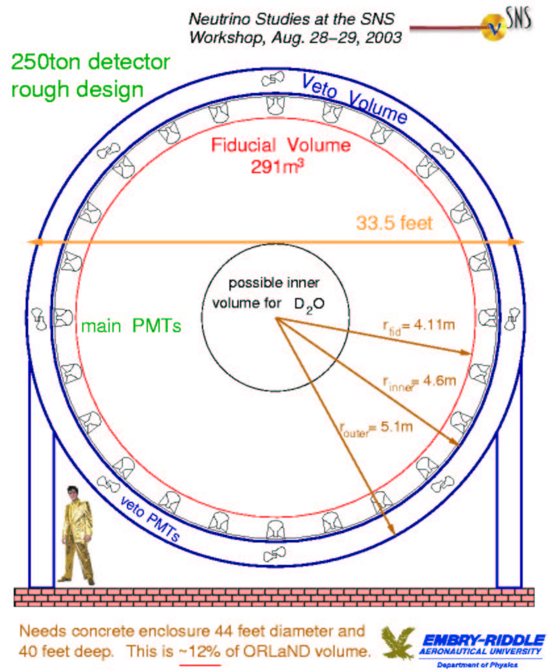


SNS Physics

- Two detectors : one inside the Target Hall, one $\sim$100 m from target
- Target Hall det : fill with liquid or aqueous nuclei ($^{12}C, ^{2}H$), test cross sections (calibrate ν flux)
- BooNE-like : 800 ton, liquid scintillator
- $\mathrm{El}\nu\mathrm{is}$: 250 ton, 25$\%$ pmt coverage

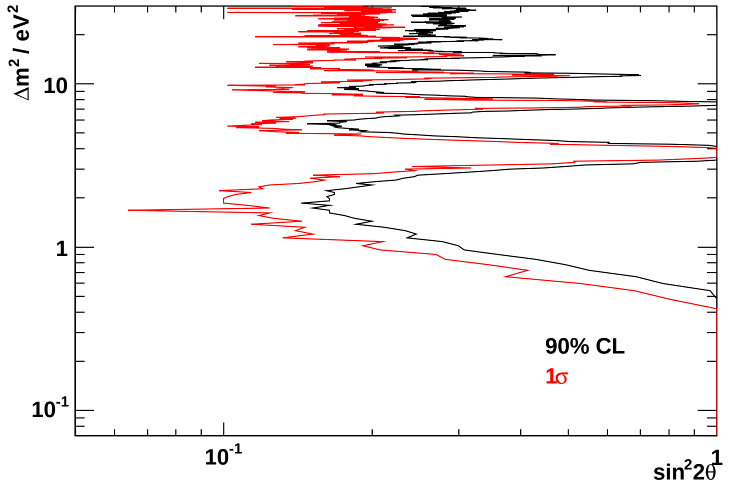
  hep-ex 0309014, VanDalen



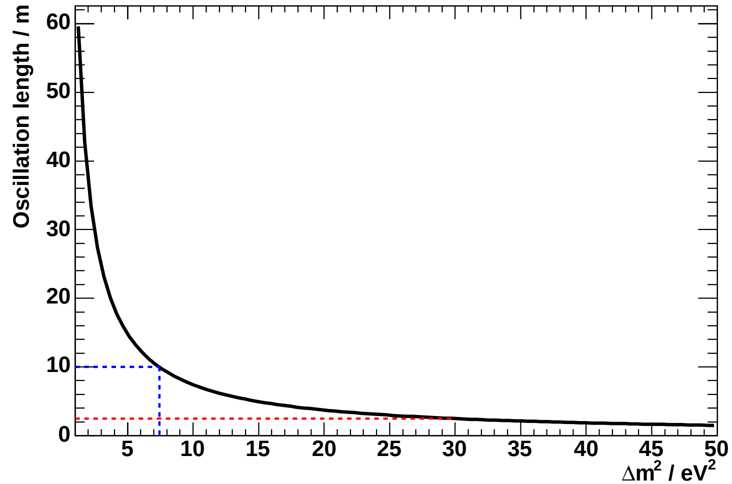


SNS vs LSND

	SNS	LSND
Energy	1.3 GeV	800 MeV
Duty Factor	4.2*10^{-5}	0.072
S/B	$\sim$10	$\sim$1
Bgd	no DIF	DIF



- Both DAR : E for $\overline{\nu_\mu}$ same (35 MeV)
- SNS $\longrightarrow$ larger detector, higher E = ν flux, more statistics
- SNS $\longrightarrow$ two detectors, test C cross section for better flux measurement, measure NC (15.11 NC)



Tests of NP : Minos

- Two detectors : one at FNAL (1 km from source), one 735 km away
- 120 GeV proton beam $\rightarrow$ graphite
- 5.4, 1 kton plastic scintillator detectors
- FNAL beam = high E, produce τ from $\nu_\mu \rightarrow \nu_\tau$ osc
- Sterile νs
  - NC cross section, distinguish $\nu_\mu \rightarrow \nu_\tau$ from $\nu_\mu \rightarrow \nu_{sterile}$
- Mass Varying νs
  - If measure $\mathrm{Sin}^2 2\theta_{13} >$ CHOOZ

Summary

- If LSND signal confirmed need to determine which NP model is correct, measure oscillation parameters more precisely
- 4 possible models, many permutations
- NP can be explored with additional detector at FNAL (BooNE), SNS
- Eagerly awaiting MiniBooNE results!