MiniBooNE

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Motivation

Experiment

Physics

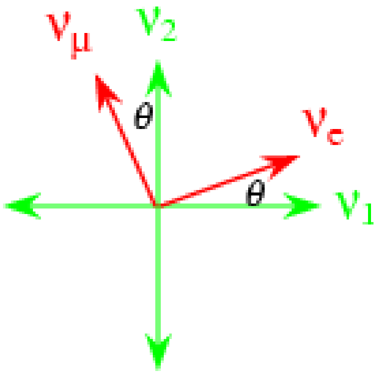
Summary

Neutrino Oscillations

We see the number of neutrinos we expect, just not the flavor we expect

- Number of ν_e less than expected from the sun but total number correct
- ν_μ from atmosphere disappearing, ν_e amount correct
- Accelerator ν_μ, reactor ν_e behave similiarly

The current explanation is flavor oscillations



2D "neutrino space"

- 2 flavor mixing case (good approx for 3 ν)
- A neutrino of energy E (MeV) will change flavor after it travels a distance L (km) with probability

$$P(\nu_\alpha \rightarrow \nu_\beta) = \sin^2(2\theta)\sin^2(1.27\ \Delta m^2\ L/E)$$

Δm^2 : difference of square of mass eigenstate ($\Delta m^2 = m_1^2 - m_2^2$)

θ: mixing angle between the mass and flavor basis

Neutrino Oscillations

3 observed oscillation regions

positive signal allowed regions for Δm^2 vs $\sin^2(2\theta)$ with L, E fixed

Neutrinos from sun $\nu_e \rightarrow \nu_x$

Homestake, Sage/Gallex, SNO, KamLAND

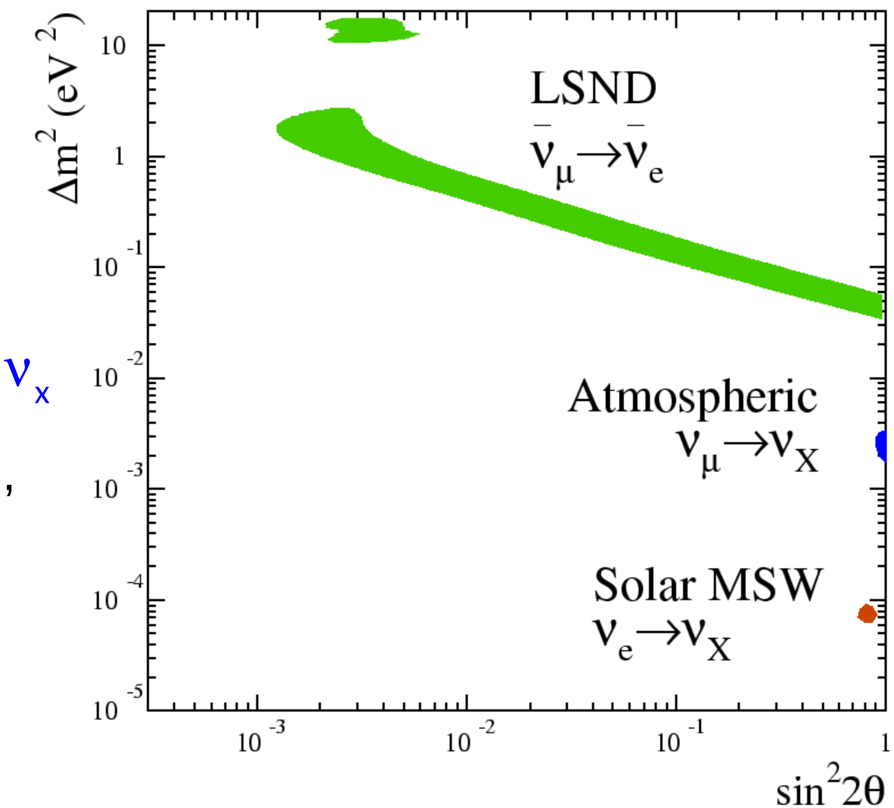
Neutrinos from atmosphere $\nu_\mu \rightarrow \nu_x$

Super-Kamiokande, Macro, Soudan, K2K

Anti-neutrinos from accelerator $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

LSND...

check with MiniBooNE



Sterile Neutrinos

If LSND is confirmed by MiniBooNE

=> 3 Δm^2 regions

But only 2 are possible with 3 ν

$$\Delta m_{31}^2 = \Delta m_{32}^2 + \Delta m_{21}^2$$

$$2\times10^{-3}\,eV^2 + 7\times10^{-5}\,eV^2 \neq 1\,eV^2$$

A fourth neutrino would have to be "sterile"

- Only interact via gravity
- Light sterile n not present in W, Z decay

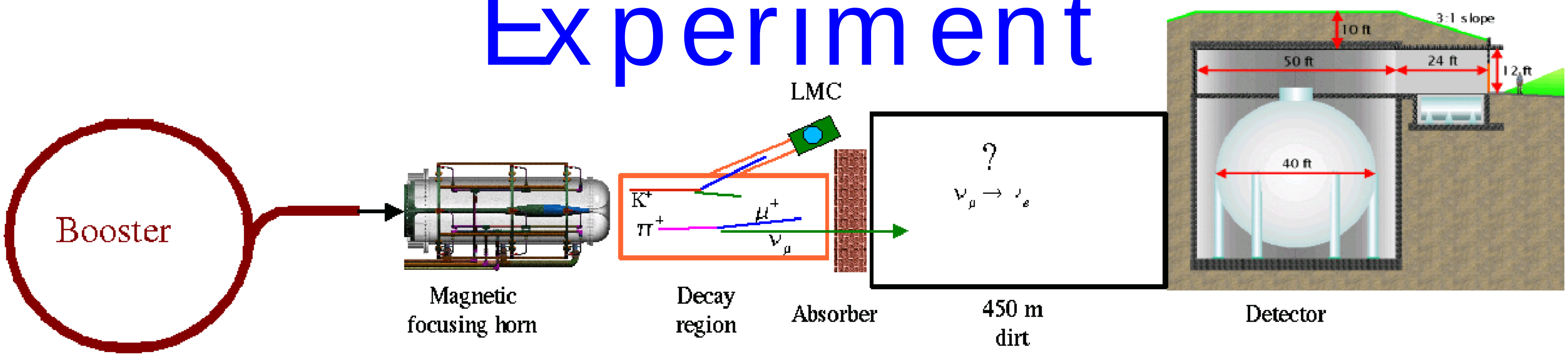
"Only one more" disfavored by other allowed regions

- Currently 3 active+ 2 sterile models fit atm, solar data

Other possibilities

- Neutrino decay
- CPT violation (or CP violation and sterile neutrinos) would mean different oscillation probability (and therefore different Δm^2) for ν, $\bar{\nu}$

Experiment



8 GeV protons from FNAL Booster hit Be target, producing mesons

Magnetic horn focuses positively charged mesons (π+)

Increases neutrino flux by factor of ~5

Change current direction, focus π- , get anti neutrinos

π+ decay, producing muon neutrinos

99.5 %pure beam

1 ν candidate every ~2 min

ν_μ interact in Cherenkov detector

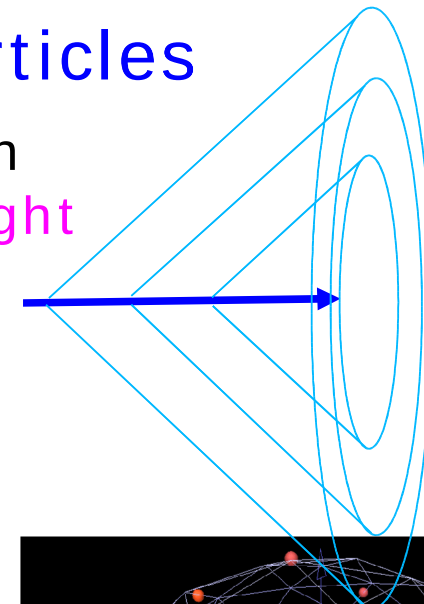
12m diameter, mineral oil (CH_2)

1280 inner PMTs, 240 veto PMTs

Experiment

Detecting Charged Particles

If a charged particle is moving faster than v = c/n, then it will radiate Cherenkov light



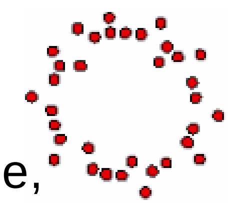
"Light Boom"

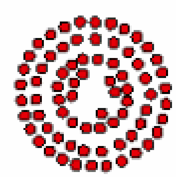
Forward directed cones of light

This light pattern differs for different particles

Electrons and photons pair produce, multiple scatter

=> "fuzzy rings"



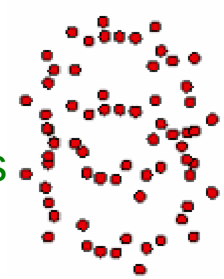


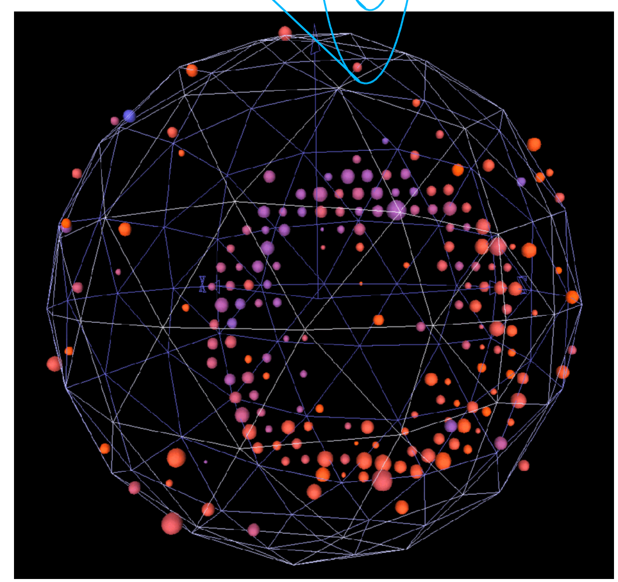
Muons radiate constant light per distance

=> "clean ring"

Neutral pions decay to two photons

=> two (electron like) rings

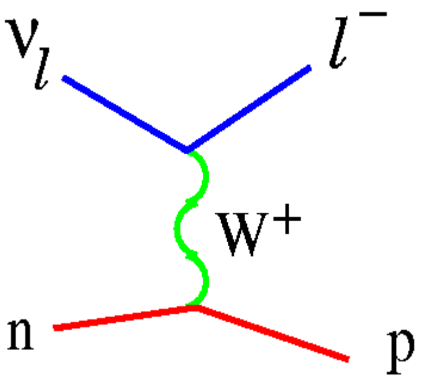




A "typical" muon in MiniBooNE

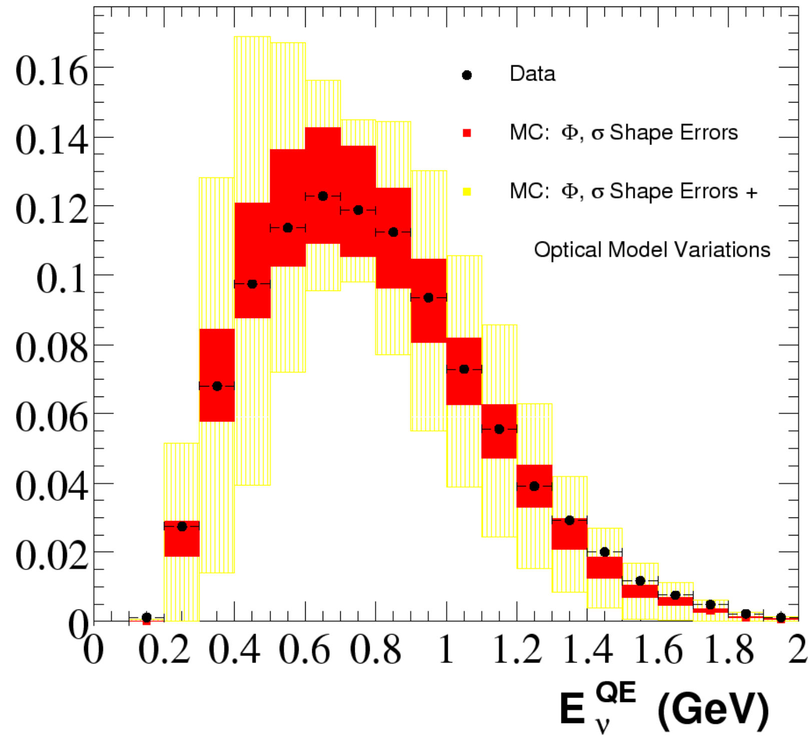
Physics with MiniBooNE
Oscillations

Charged Current (CC)



Look for less ν_μ or more ν_e than expectation

- ν_μ events have muon
- ν_e events have electron

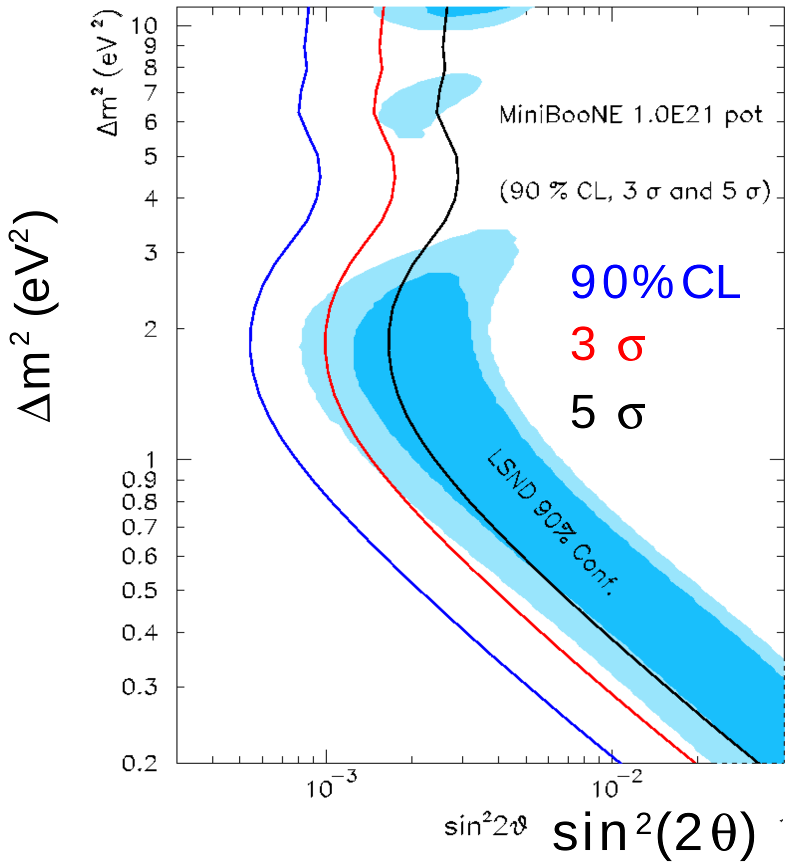


Possible ν_μ

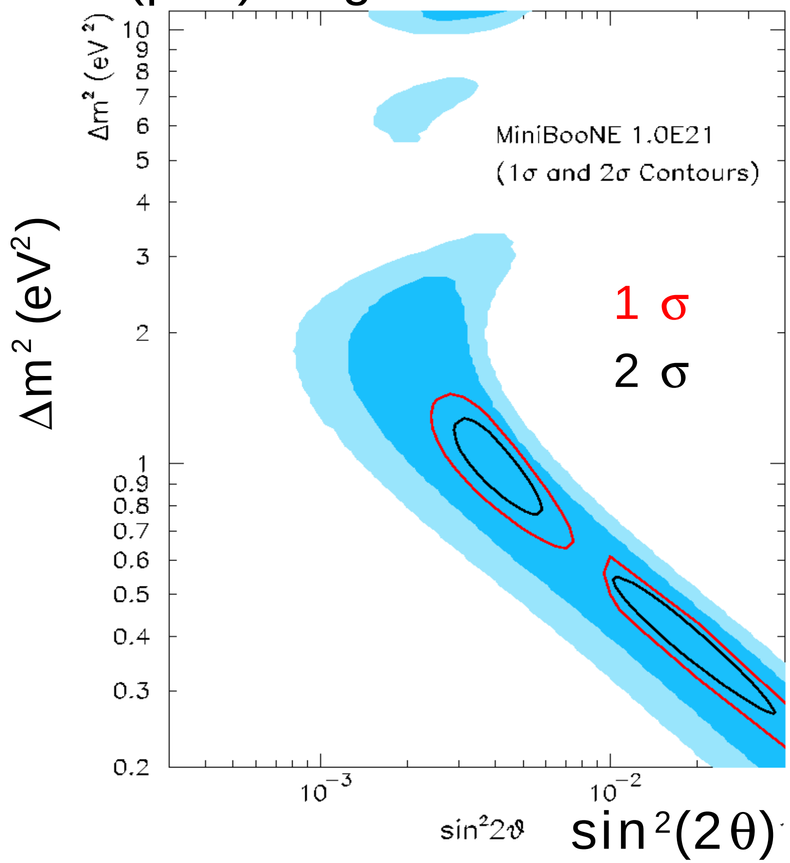
- in time window of beam
- Minimal veto hits (reduce cosmic ray bkrd)
- Within fiducial volume (for good reconstruction)
- Neutrino energy reconstructed from muon energy + scattering angle relative to beam

Physics with MiniBooNE
Oscillations

Sensitivity of MiniBooNE for 1E21 protons on target (pot) no signal



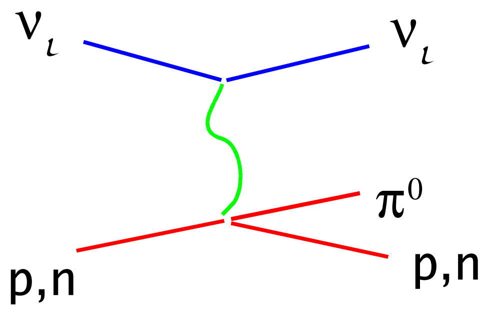
Allowed regions MiniBooNE for 1E21 protons on target (pot) signal

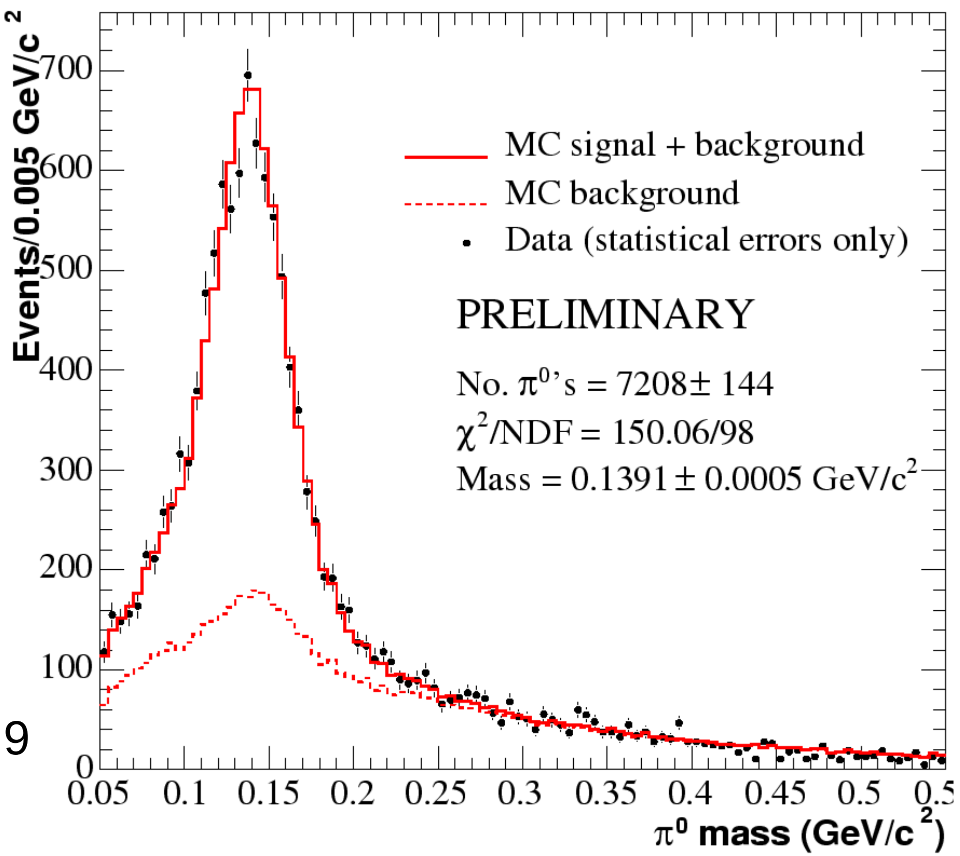


Physics with MiniBooNE

NC π^0

Neutral Current (NC) pion production





Important background

- Mimics ν_e with γ s from decay

Event selection:

- No decay electrons
- 2 rings w/ energy > 40MeV
- $-0.9 <$ cos (opening angle) < 0.9
- Reconstruct pion mass

Mass peak as expected, 55% pure, 42% efficient

Use this sample to measure NC π^0 cross section

Summary

- Only two distinct Δm^2 regions are allowed, unless new physics exists
  - Three are observed, check final one
- With the worlds largest neutrino data set at 1GeV MiniBooNE will
  - confirm or refute LSND's oscillation signal
  - make improved cross section measurements (such as NC π^0)
- Expect results late this year!