PIZZA SEMINAR

vPRISM: a Neutrino Spectrometer and the sterile neutrino searches...



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Neutrinos Group

Neutrinos in Standard Model

- Three known flavours
- Leptons with zero electric charge
 → only feel weak force
- Massless

Neutrino Interactions





Neutrino oscillation: Beyond Standard Model

3

 $\begin{pmatrix} \nu_{\mu} \\ \nu_{\tau} \end{pmatrix}$ Weak Eigenstates

 l_{α}^{-}

 ν_{α} Creation













T2K: An Example

9





Off-Axis Technique



Advantages:

- Quasi Monochromatic Beam
- Tuned at expected oscillation maximum
- Background reduction





Neutrinos are slippery

• Desirable to link the true energy (E_{ν}) of neutrino with the lepton kinematics of our observables:

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Final State Interaction



CCQE (Charged Current Quasi-Elastic)

Final State Interaction





Neutrinos are slippery

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17

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- Have to deal with Final State Interactions (FSI) problems:
- Rely on neutrino interaction models to link the reconstructed information with the true information

Neutrino Interaction Models CCQE Assumption



MiniBooNE Cross Section measurements

Theoretical Cross Section predictions





Neutrino Interaction Models



There are a few different neutrino interactions models that could explain this effect, but which is the good one?



Pionless- Δ^{++} decay Events (Fake CCQE) Multinucleon Interactions Events (Fake CCQE)

Nucleus

Real QE

Events

Nucleus

 M^+

Neutrinos are slippery

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- Have to deal with Final State Interactions (FSI) problems: ullet
- Rely on neutrino interaction models to link the reconstructed information with the true information:



Neutrino Interaction Models

22

Neutrinos are slippery

• Desirable to link the true energy (E_{ν}) of neutrino with the lepton kinematics of our observables:

We only have the information involving the final leptonic state kinematics: $p_l \& \theta$

- Have to deal with Final State Interactions (FSI) problems:
- Rely on neutrino interaction models to link the reconstructed information with the true information:



What we would like to have...

A near detector with the same features than the far detector:

□ Same flux

□ Same target

□ Same detection type

vPRISM: a Neutrino Spectrometer

25

v beam

26







4`

50 m tall and 6 m diameter water Cherenkov detector, with OA angle technique from 1° to 4°, placed at 1 km (still to be fixed) from the neutrino source



Take a Linear Combination

49

-0.5

+1.0

-0.2

 $\Phi_i^{\nu p}(E_{\nu}) =$ basis functions from the spectra of OA angles in i bins

$$\Phi(E_{\nu}) = \sum_{i=1}^{N_{OA}} C_i \Phi_i^{\nu p}(E_{\nu})$$





Take another Linear combination

+1.0

-0.8

+0.2



Take another Linear combination

 Recreate oscillated neutrino flux at SK using near detector

v beam

 Directly measure muon kinetic variables for given value of oscillation parameters





vPRISM Advantages

36

A neutrino spectrometer:

We can take linear combinations and construct whatever "Energy Spectrum" we want

We know a new form of reconstructing the energy:

Event vertex \rightarrow Off-Axis Angle (OAA) \rightarrow True Energy \rightarrow Model Independent

We can predict the oscillated events at SK because:

It is the same detector type: water Cherenkov

It would be able to reproduce the same flux

 With the previous features and if placed at L = 1 km, it becomes a short-baseline neutrino oscillation setup for testing Sterile Neutrino Oscillations in future neutrino experiments.

vPRISM: a Sterile Neutrino tester

37

Sterile Neutrinos

MiniBooNE experiment anomaly



97 non-background events could not be unexplained

$$\Delta m_{new}^2 \ge 1 eV^2 \quad \Delta m_{21}^2 \quad |\Delta m_{31}^2| \quad |\Delta m_{23}|$$

$$\mathcal{V}_e, \mathcal{V}_\mu, \mathcal{V}_\tau + \mathcal{V}_s$$

They are not interacting via weak force, but they could mix with the active neutrinos



Sterile Neutrinos at vPRISM

• At L = 1 km flight path, "standard" neutrino oscillations are totally negligible

• Looking for ν_e appearance: $\nu_\mu \to \nu_s \to \nu_e$ (Trying to constrain MiniBooNE results)

- Considered 3 m of inner detector radius
- ✓ We take into account statistical, flux and cross section errors

 V_{e}

✓ We made two different signal analyses:

 $\frac{\nu_e}{\nu_u}$

Flux and Cross sections systematics are very related to each other, so they should cancel

Sensitivity Plots



 ν_e



 v_e/v_μ

We cover almost all MiniBooNE sensitivity region with 3 m of Inner Detector Radius



 Neutrino Interactions models are a source of bias for oscillation parameters measures

Until now we rely on complicated neutrino interaction models

• vPRISM is a real good project to make our results model independent

Neutrino Spectrometer

 The features of vPRISM (if placed at L = 1 km) make it a good short-baseline experiment for testing sterile neutrinos

Sensitivity studies are very promising in comparison with MiniBooNE anomaly

Thanks for your attention



As long as a pizza box remains closed, it exists in a quantum state where it both does and does not contain pizza. Until you open it, then it definitely doesn't contain pizza.

CollegeHun

BackUp Slides

43

Neutrino oscillation: Beyond Standard Model rino Mixing $\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$ Neutrino Mixing Creation Mass eigenstates **PMNS Mixing Matrix** $|\nu_{\alpha}\rangle = \sum_{i=1}^{N} U_{\alpha i}^{*} |\nu_{i}\rangle$

Travel $|v_i(L,t)\rangle$

 $|\nu_i(L,t)\rangle = e^{-i(E_it - p_iL)}|\nu_i\rangle$

 $\langle v_{\beta} | v_{\alpha}(L) \rangle \approx \sum_{i=1}^{N} U_{\beta i} e^{-i \frac{m_i^2}{2E} L} U_{\alpha i}^* | v_i \rangle$

Detection

 l_{α}

Neutrino Mass Hierarchy

