Neutral Current Interactions in MINOS: A Search for Sterile Neutrinos
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Neutrino Events in MINOS

- Charged Current Interaction
- Neutrino interactions occur in two types, charged current (CC) and neutral current (NC).
- In the MINOS detectors, a νμ CC event appears as a long muon track with hadronic activity at the vertex.
- NC events appear as short diffuse hadronic showers.
- Hadronic shower energy is determined from the amount of light produced in the scintillator.

Far Detector Data

- Measurements of Z° width at LEP exclude more than 3 light active neutrinos.
- A 4th neutrino cannot couple to Z°.
- Cannot participate in weak interactions → sterile neutrino

Near Detector Data

- The total rate of NC events is unchanged by oscillations between 3 active neutrinos.
- If sterile neutrino mixing occurs, MINOS will observe a deficit in NC event rate.

Sterile Neutrino Search with MINOS

- If they exist, sterile neutrinos would be possible dark matter candidates
- No νs mixing between 3 active neutrinos
- Cannot participate in weak interactions
- No evidence for sterile neutrinos in MINOS data

Event Pre-Selection Cuts

- Beam quality and detector quality cuts:
  - Beam positioning, magnetic horns energized, detector running within operational parameters
- Fiducial Volume cuts
- High rate of neutrino interactions in Near Detector (ND) may cause reconstruction failures:
  - Split events from a single neutrino interaction
  - Event with vertex erroneously reconstructed inside fiducial volume
- Eliminate a large fraction using a series of cuts based on timing and topology.

Event classified as NC-like if:

- Event length < 60 planes
- Has no reconstructed track or
- Has one reco'ed track that does not protrude more than 5 planes beyond the shower.

Neutron Current Event Selection

- Error envelopes shown reflect systematic uncertainties due to cross-section modeling and beam modeling.
- MC oscillated with MINOS CC best fit: ∆m² = 2.38x10⁻³ eV², sin²(2θ) = 1

Neutrino Events in MINOS

- Unoscillated Far Detector (FD) energy spectrum is not the same as the ND spectrum.
- Measured ND energy spectrum is used to predict the FD energy spectrum using the Far/Near Ratio method.

4-Flavour Measurement

- CC Background is changed by oscillations between active neutrinos.
- For the 0-3 GeV reconstructed energy range, a 1.15 deficit between Data and osc. Monte Carlo is observed.

- NC Disappearance Fraction
  \[ \text{MC}_{\text{DATA}} = \text{MC}_{\text{OS}} (1 - f) + \text{CC}_{\text{BD}} \]

- For E_{vis} < 3 GeV:
  \[ f < 0.35, 90\% \text{ C.L.} \]

Sterile Neutrino Search with MINOS

- 3-Flavour Measurement
  \[ F_{D}^{\text{DATA}} = F_{D}^{\text{CC}} - F_{D}^{\text{ND}} \]
  - Create a reconstructed energy vs. true energy 2D histogram from NC-selected events in FD.
  - Oscillation weights are calculated for bins of true energy.
  - For each bin of true energy, the reconstructed energy projection is multiplied by the corresponding oscillation weight.
  - Prediction is obtained by multiplying each bin by ND^{CC}/ND^{ND}.

- 4-Flavour Measurement
  - Assume ∆m² = 0
  - Oscillation at single mass scale
  - Fit for |Uµ3|² and |Us3|²
  - Fix |Uτ3|² = 0 (CHOOZ limit, θ13=3m2)
  - Find |Us3|² = 0.18 ± 0.12

90% C.L. contours for the fits to |Uµ3|² and |Us3|²

90% C.L. sensitivity curves for different NuMI beam exposures

- Limit on |Us3|² will improve significantly as more data is collected.