Neutrino Trident Production at the MINERvA Experiment

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INTRODUCTION

- We performed a detailed simulation and optimized search of the signature of neutrino Trident events in a Minerva-like experiment,

- Signal Definition:**
 - Two oppositely charged muons.
 - Coherent interaction (No hadronic shower)

- Why is it of interest?**
It could be used to look for new Z' Bosons and test extensions of the Standard Model[2]

Figure 1: Trident Feynman Diagram

RELEVANT BACKGROUNDS

Inclusive Single Charged Pion Production

- Passing Pions: Energetic Pions escaping the detector front end and thus confused for μ+'s (Detected by MINOS)
- Small Angle Pions: Angle between μ+ coming from decay and its parent π+ is < 0.5° so the pion track is confused for a mu+

Figure 2: Small Angle Pions Background

Figure 3: A π⁺ is produced near the front-end of the detector, escapes, and is detected as a μ⁺ by MINOS

SIMULATION FRAMEWORK

We simulated events coming from the NuMI ME Beam[5].

- Signal:** Produced with GENIE v.2.12.4 [3], modified to include the Trident production channel.
- Background:**
 - Problem: Not enough statistics for TMVA Analysis in the MINERvA ME Monte Carlo samples (POT = 9.5e20).
 - Solution: Events were produced in GENIE and propagated in a simplified version of the Minerva tracker region using GEANT4 v10.3.1

Figure 5: Ratio of Trident and Inclusive-CC Cross Sections

Charm Production

- Only two muons in Final State
- No hadronic shower OR
- Events with neutrons in the final state.

Why? Neutrons are not always visible to the detector

Figure 4: A Diagram for Charm Production

ANALYSIS AND RESULTS

Used the TMVA v.4.2.0 ROOT toolkit for Multivariate analysis to train and test two methods[4]:

- Boosted Decision Trees
- Boosted Fisher:

Depending on Detector design, not all observables will be available!!

We study several scenarios for different combinations of observables

Obs	Description
Z _{int}	Longitudinal Vertex Position
Θ ⁺	mu ⁺ angle with beam axis
Θ ⁻	mu ⁻ angle with beam axis
Θ ⁺⁻	Angle between mu ⁻ and mu ⁺
E ₊₋	Energy difference between mu ⁻ and mu ⁺
W ₊₋	Invariant Mass

Table 1: Observables considered

Case	Available observables					
1	Θ ⁺	Θ ⁻	Θ ⁺⁻	E ₊₋	W ₊₋	
2	Θ ⁺	Θ ⁻	Θ ⁺⁻	E ₊₋		
3	Z _{int}	Θ ⁺	Θ ⁻	Θ ⁺⁻		
4	Z _{int}	Θ ⁺	Θ ⁻			
5	Z _{int}	Θ ⁺				
6				Θ ⁺⁻	E ₊₋	W ₊₋
7				Θ ⁺⁻	E ₊₋	W ₊₋
8	Z _{int}			Θ ⁺⁻		
9		Θ ⁺	Θ ⁻	Θ ⁺⁻		
10		Θ ⁺	Θ ⁻			

Table 2: Different combinations of observables considered

Figure 6: Invariant mass (W) distributions. (Area Normalized)

Figure 8: Significance Plot for BDT and Boosted Fisher, for the different scenarios in Table 2.

CONCLUDING REMARKS

- When compared, BDT performed better than Boosted Fisher for all of the 10 scenarios
- Invariant mass (W) as well as the angle between muons (Θ⁺⁻) proved powerful for the signal selection

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