Neutrino Trident Production from NuTeV

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Outline

1. Experimental Background
2. Neutrino Trident Background
3. Measurement
4. Comparisons & Conclusions

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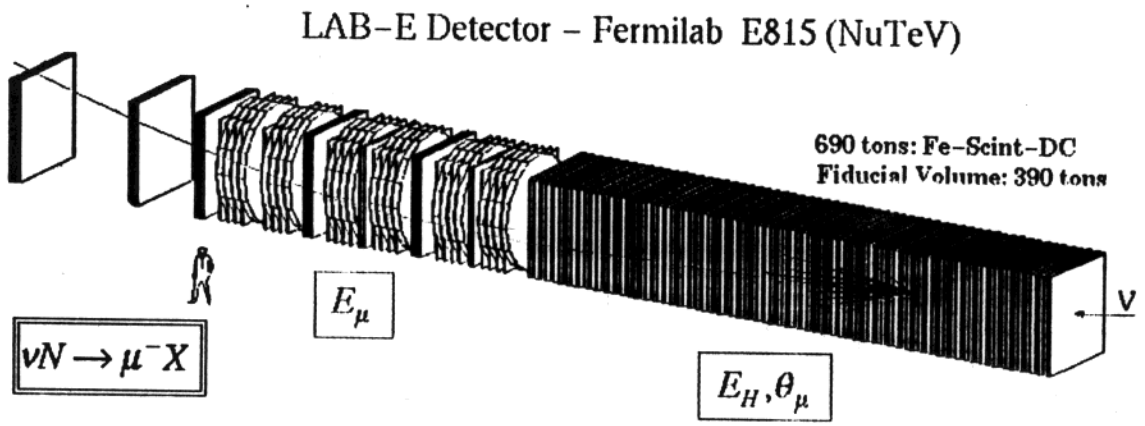
The NuTeV Experiment

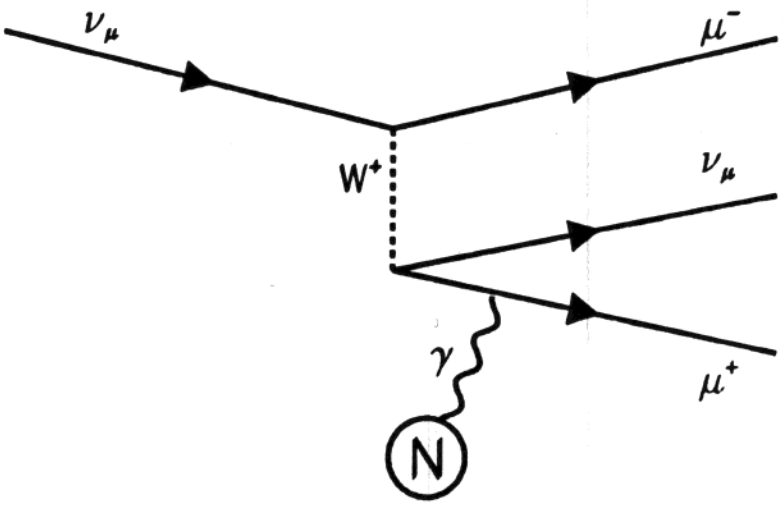


$$\nu + N \to ???$$

- 690 ton iron target/calorimeter $(\frac{\Delta E_H}{E_H} = \frac{0.89}{\sqrt{E_H(GeV)}})$
- Toroid spectrometer $(\frac{\Delta p_\mu}{p_\mu} = 0.11)$
- Sign-Selected Beam:
  - ▷ 3×10^{18} proton on target
  - ▷ 10^6 neutrino interactions
  - ▷ 3×10^5 anti-neutrino interactions
- Ran June, 1996 - Sept. 1997
- Measures: $\sin^2\theta_W$, structure functions, α_s, strange sea, charm mass, V_{cd}, neutrino oscillations, neutral heavy lepton searches and more...

Neutrino Tridents

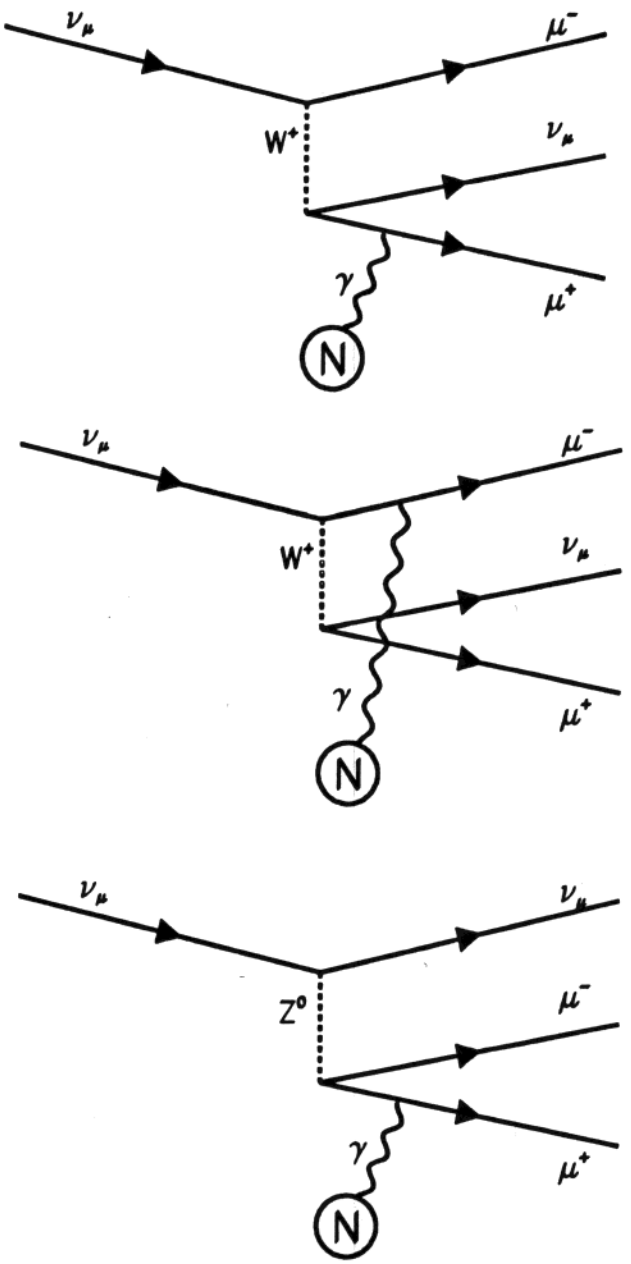
- $\nu_\mu N \to \mu^+ \mu^- \nu_\mu N$ (three leptons)
- Neutrino interactions with the electromagnetic field of the nucleus/nucleon



- Test of the Standard Model: W-Z interference
- Proposed in the early 1960s
- Early 1970s: V-A vs. GSW
- 1990s: Experimental measurement (CHARM, CHARM II, CCFR, NuTeV)

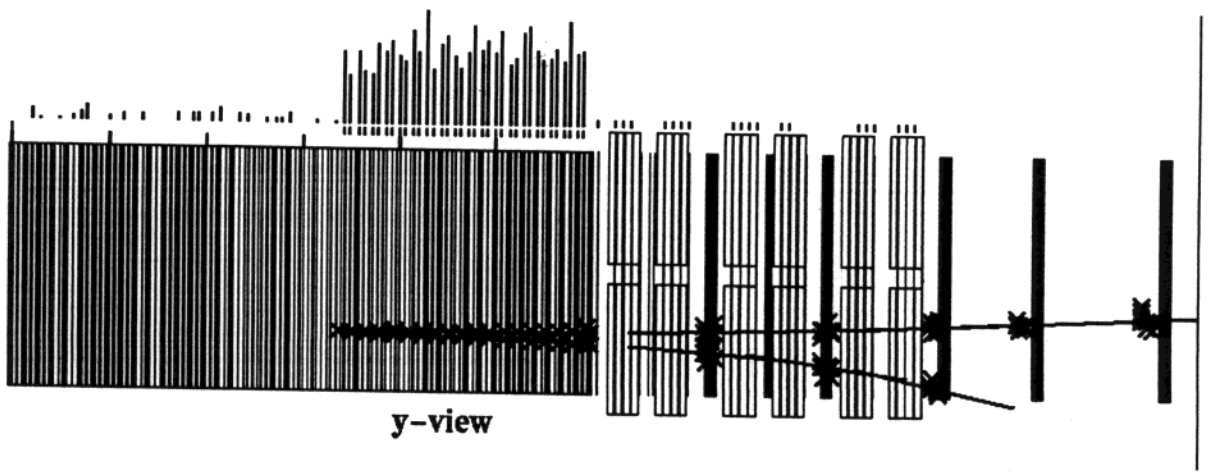
Neutrino Trident Diagrams

W-Z interference (40% destructive)



Trident Characteristics in NuTeV

- No visible incoming particle
- Two muons out (dimuon event)
- Small opening angle between muons
- No hadronic energy (E_{had})
- Small invariant mass ($M_{\mu\mu}$)



Other Low-E_{had} Dimuon Sources

- Charm production

  $\nu_\mu + N \rightarrow \mu^- + c + X$ (< 0.7 events)

  $\hookrightarrow \mu^+ + \nu_\mu$

- π/K decay

  $\nu_\mu + N \rightarrow \mu^- + X$ (< 0.2 events)

  $\hookrightarrow \pi/K + Y$

  $\hookrightarrow \mu^+\nu_\mu$ or $\mu^+\nu_\mu\pi^0$

- Vector meson production

  $\nu_\mu + N \rightarrow \nu_\mu + V^0 + X \qquad V^0 = \{\rho^0, \omega, \phi, J/\psi\}$

  $\hookrightarrow \mu^+ + \mu^-$

  $\nu_\mu + N \rightarrow \mu^- + D_s^{+*} + X$

  $\hookrightarrow \gamma + D_s^+$

  $\hookrightarrow \mu^+ + Y$

- $\pi^\pm$ production

  $\nu_\mu + N \rightarrow \mu^- + \pi^+ + X$

  $\hookrightarrow \mu^+ + \nu_\mu$

- $\tau\mu$ trident production

  $\nu_\mu + N \rightarrow \mu^- + \tau^+ + \nu_\tau + N$

  $\hookrightarrow \mu^+ + \nu_\mu + \overline{\nu}_\tau$

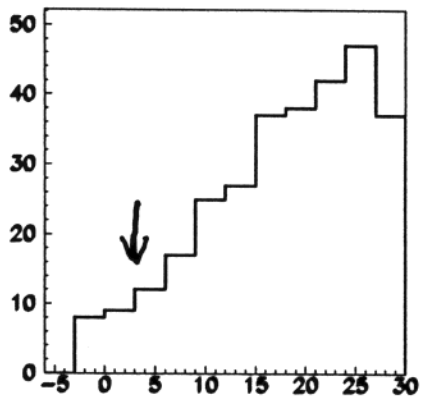
Trident Selection

- Fiducial volume
- Very low hadronic energy ($E_{had} < 3$ GeV)
- Two muons (toroid analyzed)
- Muons oppositely charged
- Muon energy minimum ($E_{\mu} > 9$ GeV)
- Small invariant mass ($M_{\mu\mu} < 2.3$ GeV/c^2)

Trident Background Estimate

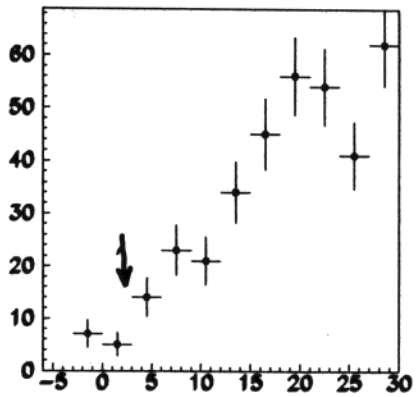
- Relax E_{had} and $M_{\mu\mu}$ cuts
- Plot E_{had} for above and below $M_{\mu\mu}$ cut

$M_{\mu\mu} < 2.3$ GeV/c^2



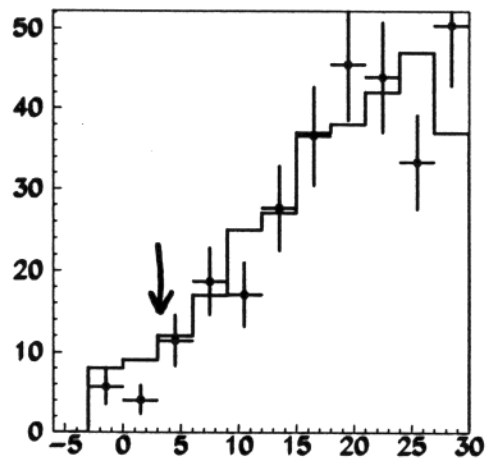
$E_{had}(GeV)$

$M_{\mu\mu} > 2.3$ GeV/c^2



$E_{had}(GeV)$

- Normalize areas



$E_{had}(GeV)$

- Estimate signal and background for $E_{had} < 3$ GeV

Preliminary Trident Results

Theory:

Standard Model (GSW): 10.8 $\pm$ 0.3 events

V-A: 18.3 $\pm$ 0.6 events

Results:

	Data	Background	GSW	V-A
ν mode	12	7.6 ± 2.5	7.2 ± 0.3	12.26 ± 0.5
$\bar{\nu}$ mode	5	2.0 ± 1.4	3.6 ± 0.2	6.1 ± 0.3
Combined	17	9.8 ± 2.9	10.8 ± 0.3	18.3 ± 0.6

Conclusions

- We observe low-E_{had} dimuon production in NuTeV
- The low-$M_{\mu\mu}$ events are consistent with Standard Model predictions for trident production
- We will add statistics by increasing the acceptance (lowering second muon constraints)
- Additional statistics will be gained by combining with data from the previous CCFR experiment
- This will yield the highest statistics neutrino trident analysis to date
- We will also study the other sources of low-E_{had} dimuon events