Astrophysics with the NOvA Experiment

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Design overview

- NuMI beam
- Near Detector: Measures initial beam composition
- Far Detector: Observes oscillated beam
Detector Technology

- Segmented plastic and scintillator tracking calorimeter
- Two functionally identical detectors
- Near: 300 t, underground
- Far: 14 kt, on surface

**Near**

- 14,000 ton
- 60 m
- 15.5 m x 15.5 m x 3.9 m
- 896 hor.+vert. planes
- 384 cells/plane
- 344,064 total cells

**Far**

- 290 ton
- 12.8 m x 3.9 m x 3.9 m

![Near Detector Image]
Airbus A380 for scale
Multi-muon seasonal effect at the Near Detector

- Well known: underground muon rate higher in the summer
- Atmospheric profile depends on temperature
- Less dense → more $\pi$ and K decay
- MINOS ND observed more multi-$\mu$ in winter
- NOvA ND in same location; effect confirmed

![Graphs showing seasonal effect on muon rate and temperature]
Multi-muon seasonal effect at the Near Detector

- No clear explanation
  - Dimuonic decays of $\eta$ and $\rho$? No, branching ratios too small.
  - Geometric effect from high altitude decays? Effect too small.
  - From atmospheric layer hotter in winter? CORSIKA simulations do not support this.
  - Increased probability of pion interactions in the winter $\rightarrow$ more secondary pions? Seems like a good explanation, but a detailed study is lacking.

- NOvA collects statistics at 3 times the rate of MINOS
- Multi-muon rates will be studied as function of zenith angle, muon separation, multiplicity, year-to-year differences and other variables
Monopole Search

- Magnetic monopoles predicted by various grand unified theories
- Search for a monopole component of cosmic rays
- Far Detector: large surface area
- On surface → sensitive to lighter monopoles that don’t reach far underground
- Signal: highly ionizing track. Acts like a charge of 68.5e
- Might be slow. NOvA is sensitive down to $\beta \approx 10^{-4}$
Monopole Search

- Separate triggers for fast ($\beta \approx 1$) and slow ($\beta \ll 1$) monopoles
- Slow: select by timing
- Fast: select by energy deposition

- Implicitly select any heavy particle that is slow or highly ionizing
  - Strangelets, black holes ...
- Results targeted for this year
Supernova

- Sensitive to galactic core-collapse supernovae
- Primary channel is inverse beta decay: 10-50 MeV $e^+$
- Expect 2200 events for 10 kpc
- Trigger on excess of “noise” — burst of 2–4 hit clusters

5 ms, 10 kpc: 
**Data cosmics, simulated SN events ($e^+$ only)**
Supernova

- Trigger $\rightarrow$ write out 45 s continuous data
- We also subscribe to SNEWS alerts
- And KamLAND’s pre-supernova alerts (arXiv:1506.01175)
Upward-going muons

- Dedicated trigger running since Dec 2014
- Look for an excess pointing back to the Sun

- Sensitive to lower mass WIMPS
- Focus has been trigger improvements
- Shifting to simulation and analysis

Timing is the main discriminant
Summary

- NOvA has a rich program of astrophysical measurements
  - Near Detector multi-muon studies
  - Magnetic monopole search
  - Supernova neutrinos
  - Dark matter search

- More planned
  - Cosmic ray E/W asymmetry: Earth's $\vec{B}$
  - Cosmic ray anisotropy: Sun's $\vec{B}$
  - High energy muon flux
  - Far Detector multiple muons
  - Gravitational wave follow-ups
  - Atmospheric neutrinos
  - Solar atmospheric neutrinos