Neutron Detector Optimization
Towards the Construction of OMNIS
Raison d’Etre

- The physics is important
- The experimental scheme is feasible
- There is a good site available

BUT

- There is a need for detector cost/performance optimization compatible with environmental/safety concerns
- There is a need for simulation validation
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UTD
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R. Burkart, Grad Student (TBD), Post-Doc (TBD)

LANL at Carlsbad
N. Elkins (and WIPP Team Members)
Physics Support Team
A. Bross, S. Colgate, G. Fuller,
C. Hargrove (and LAND Team Members),
G. McLaughlin, J. R. Wilson

Technical Support
F. Chase (UCLA machinist)
UCLA undergraduates
History of Key Ideas

• Need for complementary neutrino observatory sensitive to muon/tauon flavors

• Neutral current (NC) neutrino-nuclear excitations produce substantial number of neutrons for expected flux

• Most of the NC excitations due to higher energy muon/tauon neutrinos

• Charged current (CC) excitations due to electron neutrinos

• Significant number of multi-neutron events though the use of lead as a target material
Requirements for a Flavor-Sensitive SN Neutrino Detector

- Large NC and CC neutrino/nuclear target cross sections to yield $\geq 1000$ produced events for SN neutrino energies ($E_\nu \sim 10 – 50$ MeV) and reasonable target masses (~ ktons)
- Simple and robust neutron detection scheme
  - Time resolution
  - Energy resolution
  - Signal/background discrimination
- Reliability
- Cost-effectiveness
Intent of the Optimization Study

Key elements: Detector hardware development
in situ measurements
Monte Carlo simulation

Validation: Monte Carlos verified, not validated

Optimization: Material, Geometry, Readout
Cost Trades/Reduction
Environmental/Safety Considerations
Existing Work Used as Starting Point for Present Study


Evolution to Current Status

Target Material

Natural rock/salt → Lead/Iron → Lead

Choice of Lead dictated by
1. Higher neutron counts (high Z material)
2. Two neutron signal
3. Cost

Neutron Detector

BF$_3$ Gas → Gd or Li loaded scintillator → LiF+ZnS
Hydrocarbon or Graphite Moderator
MINOS experience → WLS fibers
Simulation of 1000-event arrival time profile of mu/tau neutrinos from 8 kpc Galactic supernova binned in 0.1 s intervals with cavern background fluctuations shown for comparison (assumes 50 eV tau neutrino mass; from Smith AstroPart. Phys. 8 1997)
Examples of detector-target configurations of progressively greater neutron collection efficiencies, with corresponding target masses for ~100 events for supernova at 8 kpc (from Smith Astropart. Phys. 16 2001)
The plotted points correspond, from left to right, to the six configurations (a) - (f) (from Smith Astropart. Phys. 16 2001)
Typical overlap between detector and background gamma signals for Gd-loaded scintillator (0.5% by weight) (from Smith Astropart. Phys. 16 2001).
Two typical configurations of low energy neutron detectors showing different possibilities for moderator/absorber configurations
(from Smith Astropart. Phys. 16 2001)

Components
Type 1: Combined moderator, absorber, converter
Type 2: Combined absorber, converter
Separate moderator

Examples
Type 1: Gd, $^6$Li, $^{10}$B loaded hydrocarbon scintillator
Type 2: H or C based moderator
$^6$Li+ZnS scintillator or $^6$Li Fibers
Details to be Resolved

• Smith 2001 (*op cit*) studied both Type 1 and 2 configurations, but only for Gd so that this work needs to be performed for the $^6$Li and $^{10}$B options including determination of integral signal distributions for Type 2 geometries (integral distributions for Type 2 were not done in Smith 2001).

• Merit of Type 2 configurations is the much reduced gamma sensitivity (due primarily to lower thickness) especially with the use of $^6$Li or $^{10}$B, but might have lower efficiency compared to Type 1 as well as quenching concerns.

  **However**, the use of Li+ZnS sheets is attractive, and motivates the cost/performance optimization to be done (including determination of optimal amount of $^6$Li as a function of cost/efficiency, and mitigation of quenching concerns).
Required Tasks

- Investigate methods for incorporating Li (and compare to Gd, B) in plastic and determine expected aging profiles
- Investigate the use of $^6$LiF+ZnS sheets following established scheme
- Optimize readout design utilizing WLS fiber(s) or cladding entire scintillator with WLS material
- Test neutron detector with calibrated neutron source (or cyclotron) in California
- Continual interaction of hardware development with simulation work to optimize configuration and validate simulations
- Calculation and simulation to establish capability as a nuclear weapon monitoring system
Schedule

Year 1
- Monte Carlo simulation calculations
- Optimization of neutron detector geometries
- Stable neutron counter design and test
- Cost/performance design optimization and selection

Year 2
- Monte Carlo simulation calculations
- Neutron detector testing at TBD cyclotron and at WIPP site
- *in situ* background measurements
- Initiate design of baseline 500 ton OMNIS detector (in conjunction with WIPP Team)
UCLA Responsibilities

K. Lee – As Project PI, responsible for successful completion of all tasks at UCLA and UTD; design, construction, and test of neutron detectors; supervision of undergraduate student helpers

M. Atac – Expert consultant regarding design, construction, and test of prototype neutron detectors

D. Cline – Scientific guidance

P. Smith – Expert participant/consultant regarding simulation work
UTD Responsibilities

Post-Doc (TBD) – Will conduct simulation work for which UTD is responsible in Year 1 of Study

E. Fenyves – Responsible for calculations relative to neutron detector use for security purposes; scientific guidance

W. Burgett – Administrative oversight, scientific guidance on UTD simulation effort; supervise post-doc and graduate student

R. Burkart – Assist in simulation work

Graduate Student (TBD) – Will take over simulation effort in Year 2 of Study; help with testing
Budget Summary

UCLA Year 1 : $113,000
UCLA Year 2 : $90,000
UCLA Cumulative : $203,000

UTD Year 1 : $99,934
UTD Year 2 : $58,168
UTD Cumulative : $158,102

Total Request : $361,102
# UCLA Budget Summary

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