POSTER #554

A Ton-Scale NaI Detector for Neutrino-Nucleus Scattering Measurements

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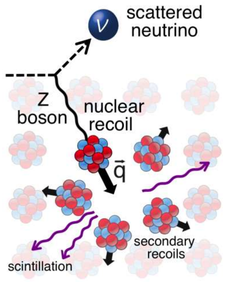
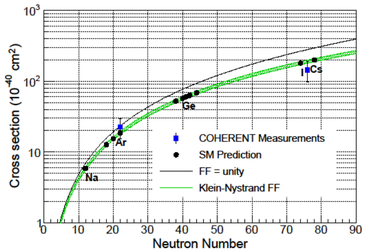
Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) Experiment



- A neutrino elastically scatters off a nucleus via exchange of a Z, and the nucleus recoils as a whole
- Coherent process up to $E_\nu \sim 50$ MeV
- Enhancement of elastic scattering cross section.
- Standard model prediction - N^2 cross section dependence
- Observable = nuclear recoil < 50 keV deposited

COHERENT Experiments
- CsI - initial results [1]
- LAr - initial results [2] (See poster #49)
- NaI[Tl] 185 kg - taking data (See Poster #420)
- Ge – 16 kg under construction (See Poster #553)



- Want ton-scale NaI[Tl] detector for low-neutron number coherent scattering measurement on Na
  - expect relatively higher recoil energies
- With unpaired proton, may be able to probe axial contributions
- Measurement of CEνNS on Iodine – compare to CsI measurement

Inelastic Neutrino-Nucleus Scattering

$$^{127}I + \nu_e \rightarrow {}^{127}Xe^* + e^-$$

Charged Current Scattering Cross Section on Iodine:
Large mass detector with higher energy recoils - observable given by high-energy electrons - potential simultaneous measurement.

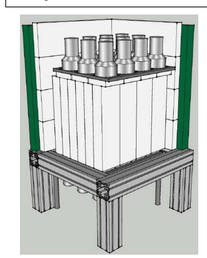
Nuclear physics studies – comparison with models
Probe g_A quenching in weak processes at momentum transfer ~ 30 MeV (relevant for 0νββ decay)
Exclusive cross section previously measured, ~34% uncertainty [3]
Possible to measure both exclusive and inclusive cross section

Design and Development

Simultaneous measurement of low-energy (~3 keVee- 25 keVee) CEνNS signal and high-energy (up to 53 MeV) CC observable requires consideration of optimum running conditions for both measurements.

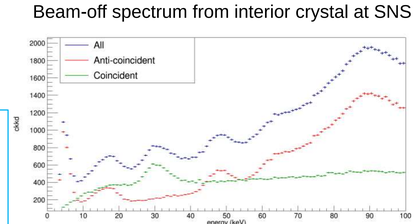
- NaI[Tl] paddle detectors being reused from Advanced Spectroscopic Portal Monitoring system (7.7 kg per crystal)
  - test detectors and characterize response
  - U Washington characterization and test procedure
  - Testing at University of Washington and Duke University
- Detector location constraints (location in basement hallway of Spallation Neutron Source at ORNL)
  - maximum size 40" (101 cm) from wall including shielding
- Shielding requirements
  - neutron shielding and γ-ray shielding from environment
  - determine need for muon veto - inner detectors well shielded
  - Studies currently being developed for background reduction
- Low-energy recoil (access to ^{127}I CEνNS signal) with high-efficiency requires high-gain - refurbishment of bases for high-gain signals

Experience from prototype NaI[Tl] 185 kg detector



- NaIvE 24, 7.7 kg NaI[Tl] scintillation detectors
- detector location about 20 m from target
- measurement of backgrounds in detector location

Beam-off spectrum from interior crystal at SNS



- Beam-off backgrounds consistent with initial lab tests
- Muon veto provides modest improvement – subtract coincident events
- Beam-on backgrounds low enough for CEνNS signal
- Muon background reduced with software and veto for CC signal

Data analysis from NaIvE
Sam Hedges Poster #420
Muon background studies
Peibo An poster #13

REFERENCES CITED
[1] D. Akimov *et. al* (COHERENT), *Science* **357**, 1123–1126 (2017)
[2] D. Akimov *et. al* (COHERENT), arXiv:2003.10630 (2020)
[3] J.R. Distel, et. al, *Phys. Rev. C* **68** 054613 (2003)

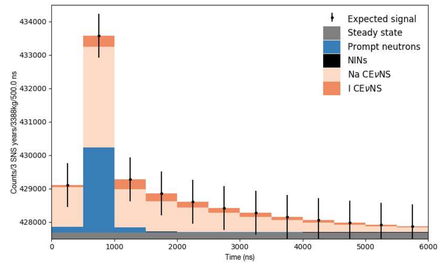
Expected Signals

Simulation studies 3.4 kg NaI[Tl] 7 modules – 63, 7.7-kg crystals

CEνNS Signal (Top Figure)
- 13 keVnr threshold for ^{23}Na
- intrinsic backgrounds from tests
- best fits of prompt neutron, neutrino-induced neutrons from CsI[Na] result in MCNP simulation
- Assume quenching factor data flat in energy region of interest
- Errors shown are statistical

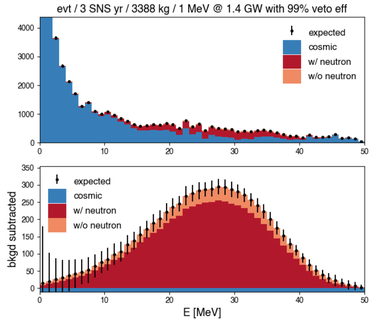
Significance of ~3σ/year for ^{23}Na recoils for counting experiment

Arrival time structure of the CEνNS signal and backgrounds

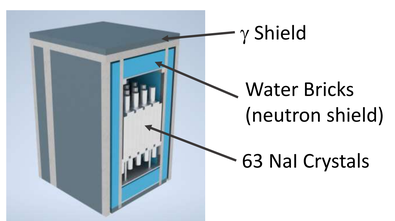


Charged Current Signal (Bottom Figures)
- With/without neutron in final state
- Backgrounds from NaIνE prototype
- Assumed 99% efficient muon veto
- Charged-current signal simulated in detector using modified version of MARLEY (**M**odel of **A**rgon **R**eaction **L**ow-**E**nergy **Y**ields)

Inclusive measurement possible in large mass NaI detector



- Deployment of Initial Module in Fall 2020
- 5 Modules - Dual Gain Bases Deployed Summer 2021



Acknowledgments

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