A Ton-Scale NaI Detector for Coherent Neutrino-Nucleus Scattering Studies

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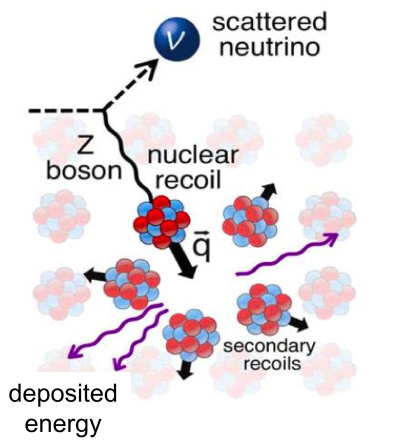
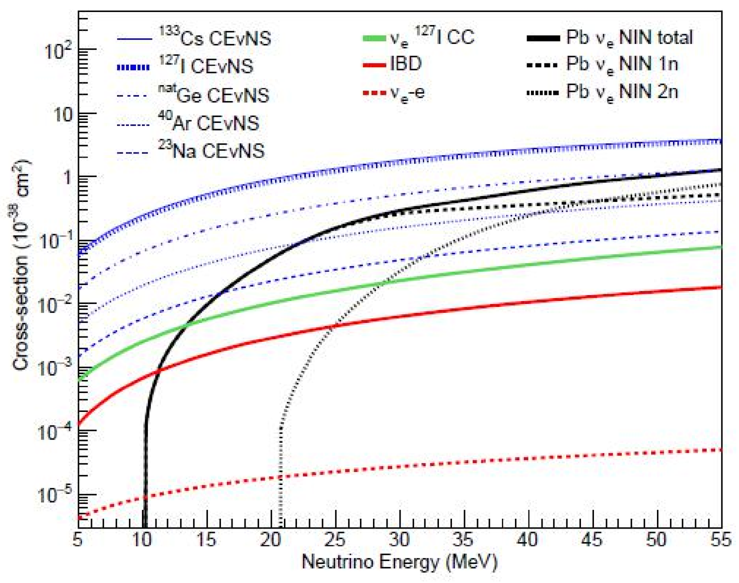
Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) Experiment



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

COHERENT Experiments
- CsI - initial results
- LAr - taking data
- NaI[Tl] 185 kg - taking data
- Ge - under development

- Want ton-scale NaI[Tl] detector for low-neutron number coherent scattering measurement.
- Reduce impact of ν flux uncertainty.
- Since N low, expect relatively higher recoil energies.



Neutrino interaction cross sections per target as a function of neutrino energy for COHERENT target materials.

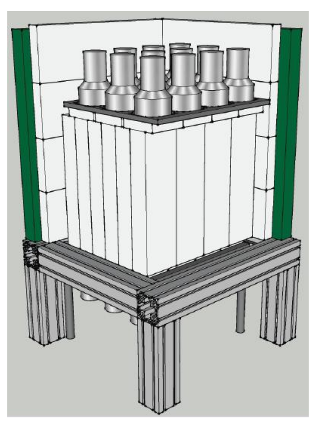
Charged Current Scattering Cross Section on Iodine: $\nu_e + {}^{127}\mathrm{I} \rightarrow e^- + {}^{127}\mathrm{Xe}^*$
Large mass detector with higher energy recoils - observable given by high-energy electrons - potential simultaneous measurement.

Design and Development

- ❖ NaI[Tl] paddle detectors being reused from Advanced Spectroscopic Portal Monitoring system
  - test detectors and characterize response
  - U Washington characterization and test procedure
- ❖ 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
  - γ-ray shielding (source from nearby pipes)
  - probably not need muon veto - inner detectors well shielded
- ❖ Low-energy recoil with high-efficiency requires high-gain
  - refurbishment of bases for high-gain signals

Simultaneous measurement of low-energy (~3 keV) CEvNS signal and high-energy (up to 55 MeV) CC observable requires consideration of optimum running conditions for both measurements.

Experience from prototype NaI[Tl] 185 kg detector currently taking data - informs design



- NaIνE 24, 7.7 kg NaI[Tl] scintillation detectors
- detector location about 20 m from target
- measurement of backgrounds in detector location
- study of sheilding, muon veto (active and passive)

Acknowledgments

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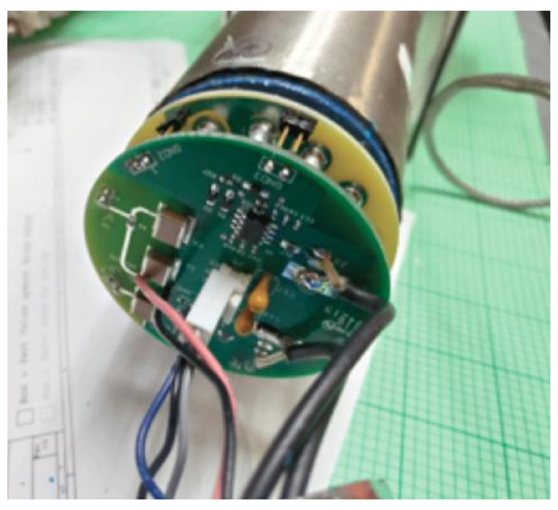
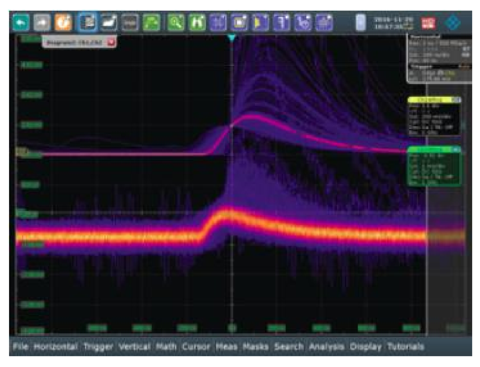
Dual Gain Base Design

Develop dual gain base for simultaneous low-energy (CEvNS) and high-energy (CC) measurements.
Two programs: ORNL/UT/Duke and U Washington.

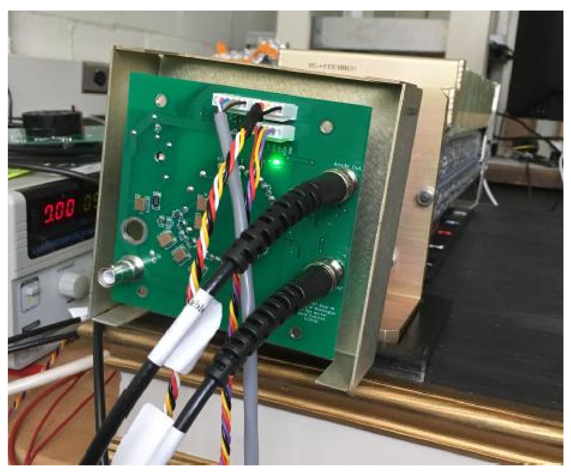


ORNL Dual Gain Base



^{137}Cs Source
HV 700V
~250 mV high gain
~750 μV low gain

Base Production at UT Knoxville

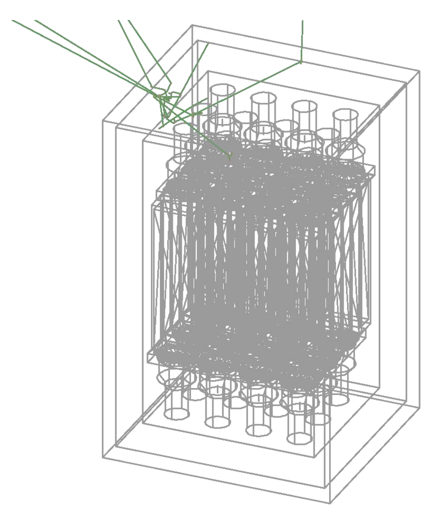


UW Dual Gain Base and HV

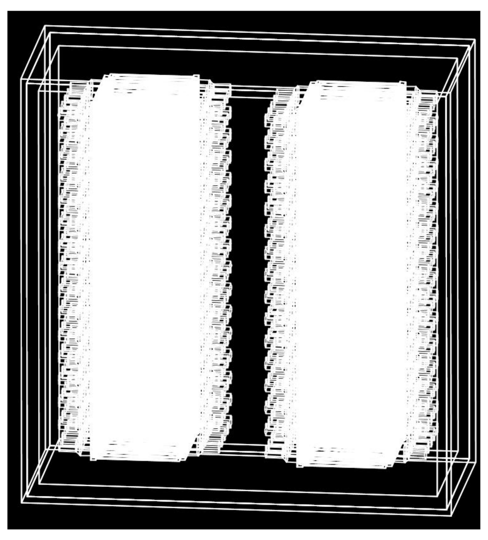
- Demonstrated sensitivity to ~3 keV
- Capable of measuring charged current to ~50 MeV
- HV supply on each board capable of driving 3 - 4 crystals
- Potentiometer built into base for gain matching

Simulations

- MCNP and GEANT4 based simulations underway for optimizing shielding
- Use 185 kg NaI Detector to compare model to data



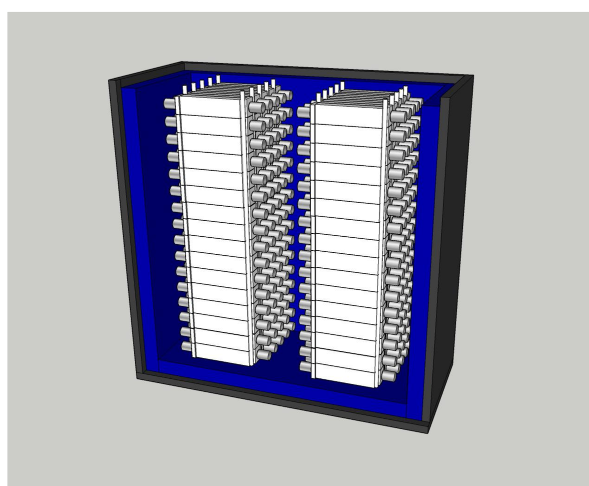
Neutron event in 185 kg NaI detector geometry with 4" H_2O and 2" Pb shielding



GEANT4 multi-ton NaI detector geometry with H_2O and Pb shielding

Proposed Design

- Propose modular design
- Initially 2 to 5 tons of NaI
  (less than 800 detectors)
- Stacks of ~180 detectors
  for ~1.35 T per stack
- Pb (grey) and water (blue) shielding



References

1. D. Akimov et al. (COHERENT Collaboration) "Observation of coherent elastic neutrino-nucleus scattering" *Science* 357 (2017). arXiv:1708.01294.
2. D. Akimov et al. (COHERENT Collaboration). "COHERENT 2018 at the Spallation Neutron Source." arXiv:1803.09183v2 (2018)