Background Characterization at HFIR for Reactor Antineutrino Measurements

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Neutrinos can’t be blocked or suppressed

High detection efficiency

Neutrino emissions carry information directly from the reactor core in real time

Enable to study neutrino properties (CEvNS, IBD)

• Detector response
  – Sensitivity
  – Calibration
  – Benchmark detectors

• Backgrounds
  – Reactor Gammas & Neutrons
  – Cosmogenic neutrons
  – Others: Magnetic fields
Neutrino flux origin and spectra

HFIR Fission

SNS Spallation

Beta decay fission fragments ($\nu_e$)

Pion-decay-at-rest neutrino source
ORNL Neutrino Sources

Spallation Neutron Source (SNS)
- Pulsed neutron source
- 1 GeV protons on Hg target
- 1.4 MW beam power
- STS - Second Target Station
- PPU – Proton Power Upgrade
- Intense neutrino flux in the 10s of MeV’s
- Sharp time structure

High Flux Isotope Reactor (HFIR)
- 85 MW research reactor
- Compact core (Ø: 0.4m h: 0.5m)
- HEU (99% v’s from $^{235}$U)
- ~7 cycles/year 24 days Ron/Roff
- Huge neutrino flux
- No time structure
- High backgrounds @ surface

HFIR and the SM-3 Russia, produce the highest steady state n fluxes in the world

Peak thermal neutron flux of $2.5 \times 10^{15}$ n/cm$^2$ s
Neutrino Detection at a Reactor and at a Pi-DAR

Tight space constraints and limited overburden to attenuate cosmic ray backgrounds is a significant technical challenge.
Evolution of background studies

Single measurements with 3" NaI(TI)

2 x 2 NaI(TI) array

DANG – 8 NaI(TI), 8 NE213 and 2 $^3$He
Gamma-ray analysis of HRIBF core

Sensor Technologies for Nuclear Physics Applications, C. Gilbert UTK 2019
Reactor gamma background

- Characterize the background radiation fields encountered at HFIR,
- Understand the sources of those backgrounds
- Develop background mitigation strategies appropriate for low-background experiments

Example HPGe gamma-ray spectra taken with Reactor on and off
Backgrounds – Spatial Variance

Reactor On: 1-3 MeV; Z=206cm

Reactor On: 3-5 MeV; Z=206cm
Backgrounds – Temporal Variance
Magnetometer to Characterize Stray Magnetic Fields Near PROSPECT

- Superconducting magnets ranging from 5-11 Tesla are used on various beamlines
- High field magnets (25-30 Tesla) are being considered

Spike correlated to testing ramp up and down of Mag-E (8 T) on HB-2A
Future Work – Directional Measurements

- 40” thick concrete
- 4” thick lead
- Water pool level
  Nominal RxOn height
  $847' < h < 848'$
- Water pool level
  Some fraction of RxOff days
  $h \sim 831'$
Background Measurement Devices

- ORTEC mechanically cooled HPGe Detector
- ORTEC Lead Shield (Right)
  - Borated-Poly inserts (pink)
  - Water Bricks (blue)
  - Static with high amounts of shielding
- MIRION Detector Shield Cart (left)
  - Rotates and Moves for directional measurements
  - Lead Shield collimator for detector end-cap
Summary

- Main challenge: cosmogenic backgrounds resulting from the limited amount of overburden, and reactor-related backgrounds caused by the proximity of the detector to the reactor core.
- Backgrounds have been characterized at the HFIR reactor.
- Directional measurements are underway.
- A segmented detector design based on IBD can achieve a desired signal to-noise ratio.

REFERENCES:

Characterization of Reactor Background Radiation at HFIR for the PROSPECT Experiment, Blaine Heffron UTK Thesis 2017

Deployment of magnetometers to monitor stray magnetic fields near the PROSPECT detector, Corey E Gilbert, AIP Conf. Proc. 2019
Thank you!

Questions?

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