Background Characterization at HFIR for Reactor Antineutrino Measurements

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ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Neutrinos can’t be blocked or suppressed

High detection efficiency

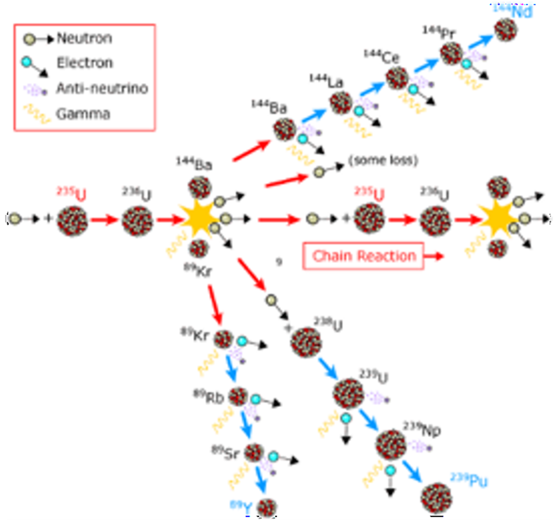
Neutrino emissions carry information directly from the reactor core in real time

Enable to study neutrino properties (**CEvNS, IBD**)

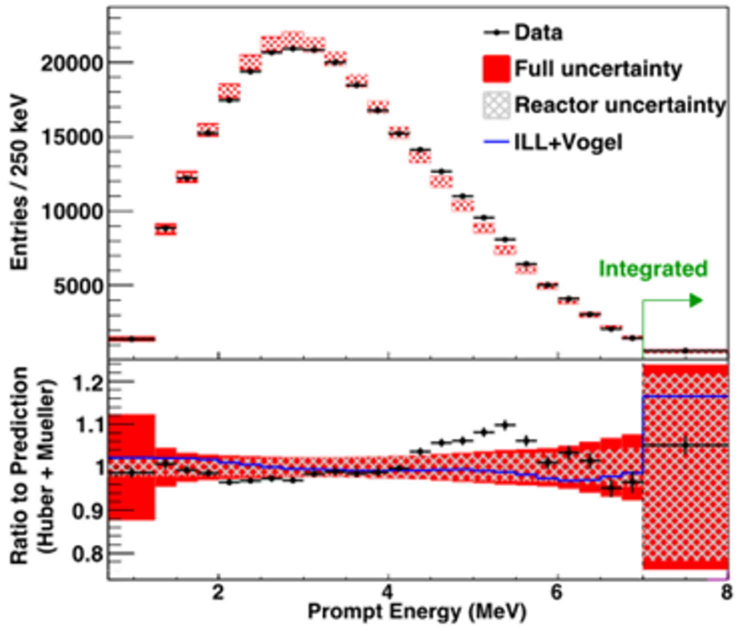
- Detector response
  - Sensitivity
  - Calibration
  - Benchmark detectors
- Backgrounds
  - Reactor Gammas & Neutrons
  - Cosmogenic neutrons
  - Others: Magnetic fields

Neutrino flux origin and spectra

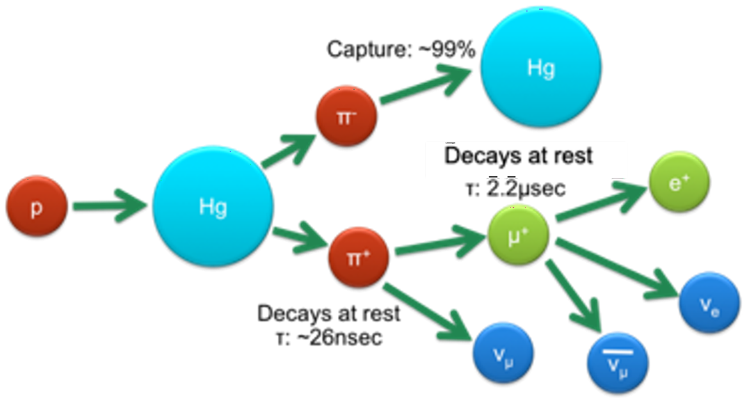
HFIR Fission



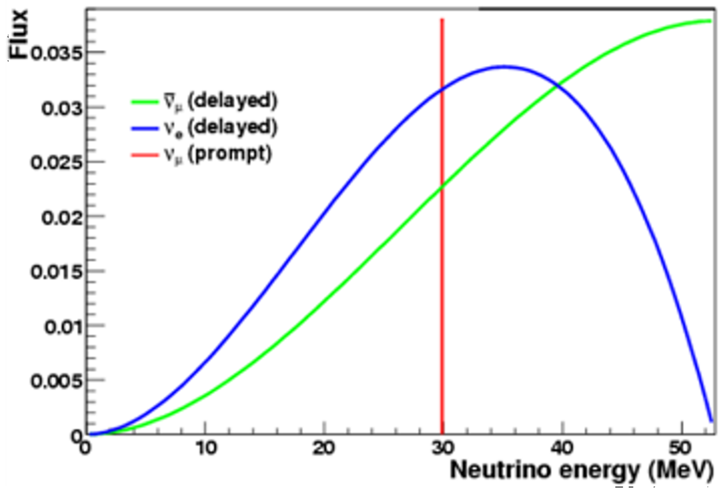
Beta decay fission fragments ($\overline{\nu}_e$)



SNS Spallation



Pion-decay-at-rest neutrino source



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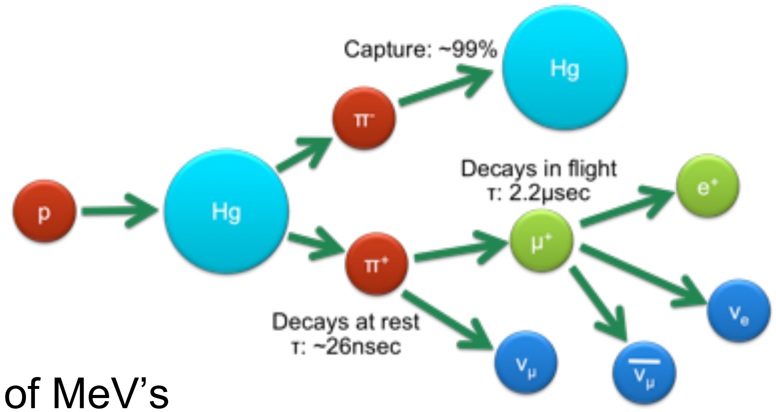
ORNL Neutrino Sources

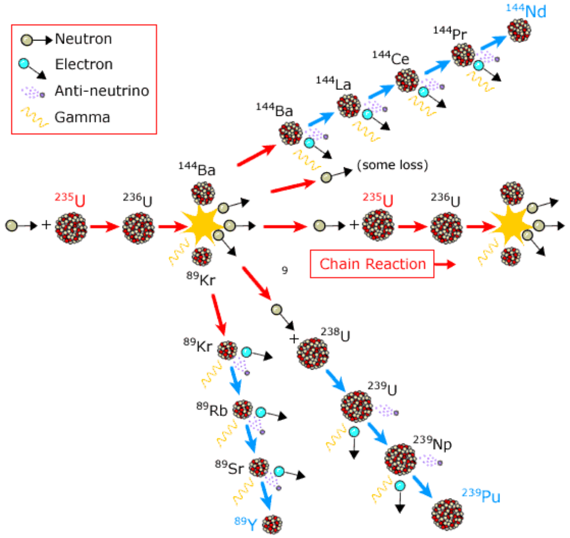
Spallation Neutron Source (SNS)

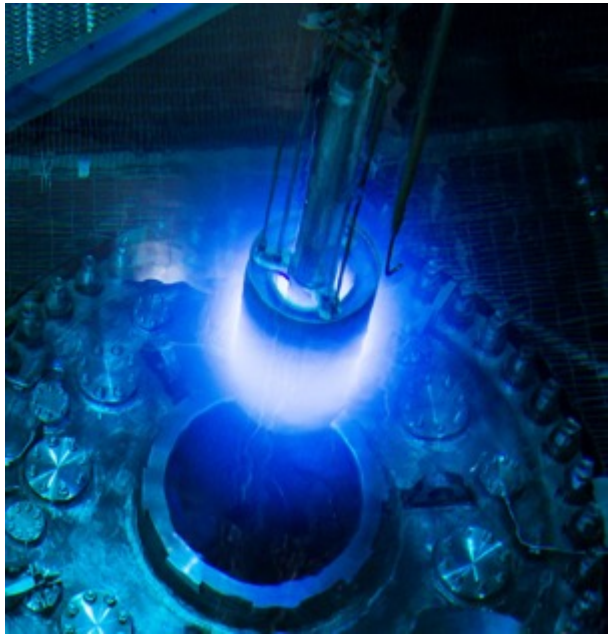
- Pulsed neutron source
- 1 GeV protons on Hg target
- 1.4 MW beam power
- STS - Second Target Station
- PPU – Proton Power Upgrade
- Intense neutrino flux in the 10s of MeV’s
- Sharp time structure



High Flux Isotope Reactor (HFIR)

- 85 MW research reactor
- Compact core (ø: 0.4m h: 0.5m)
- HEU (99% ν’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 × 10^{15} n/cm^2 s

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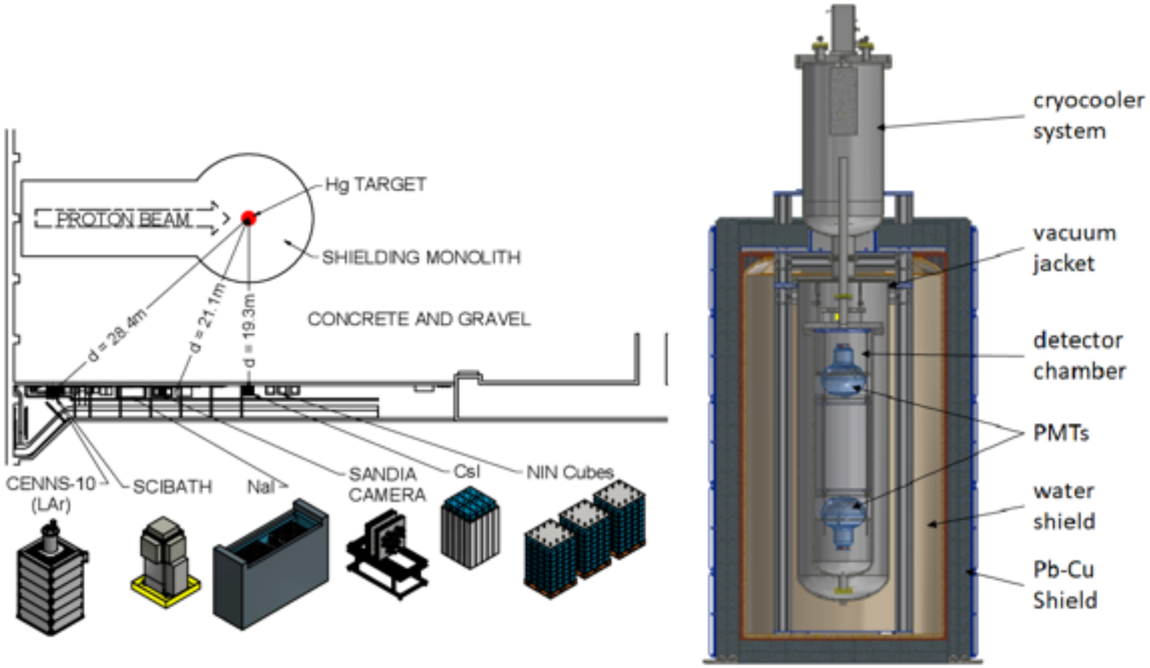
Neutrino Detection at a Reactor and at a Pi-DAR

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

Reactor

Pi-DAR Source



(a) (b)

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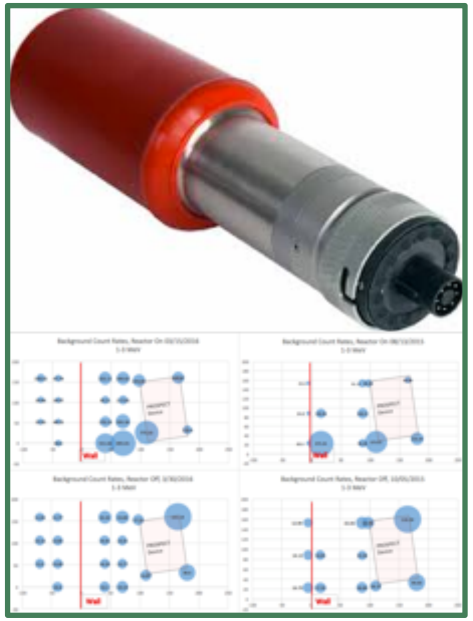
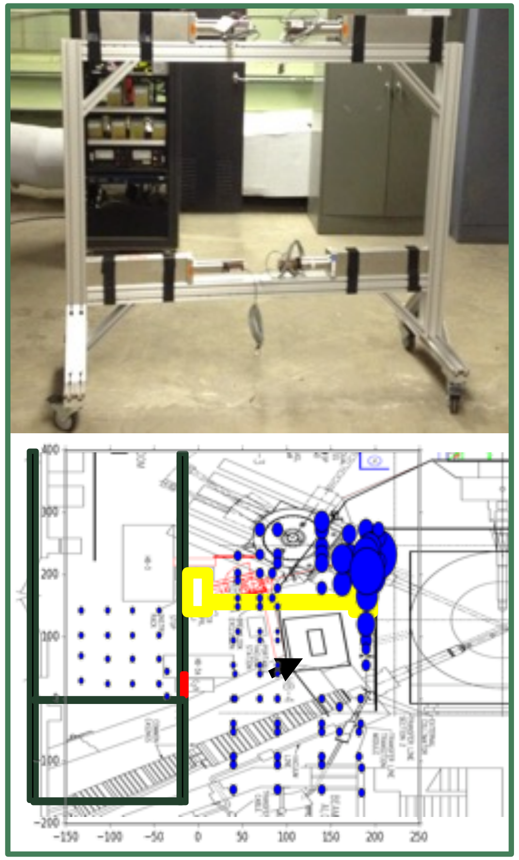
Evolution of background studies



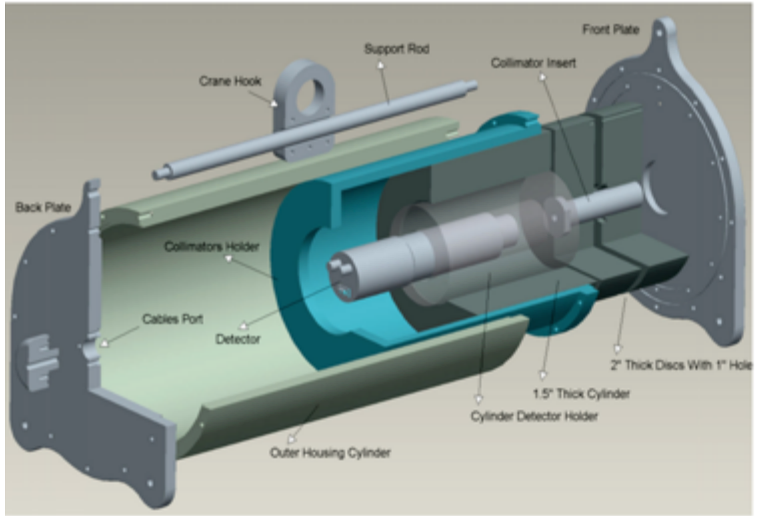
Single measurements with 3” NaI(TI)

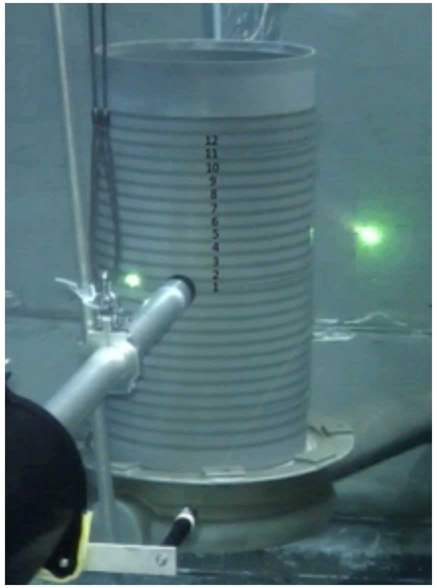


2 x 2 NaI(TI) array

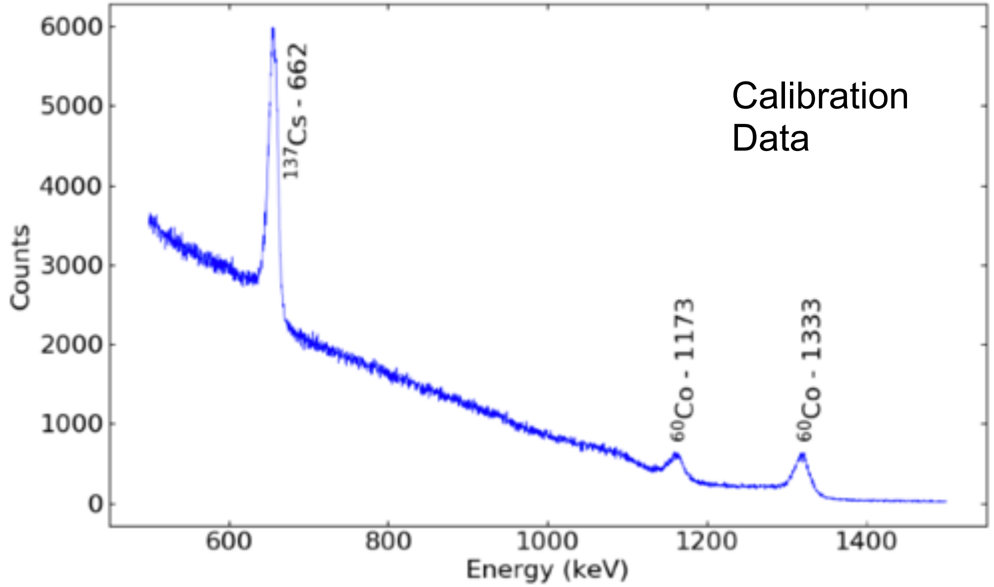
DANG – 8 NaI(TI), 8 NE213 and 2 ^{3}He

Gamma-ray analysis of HRIBF core

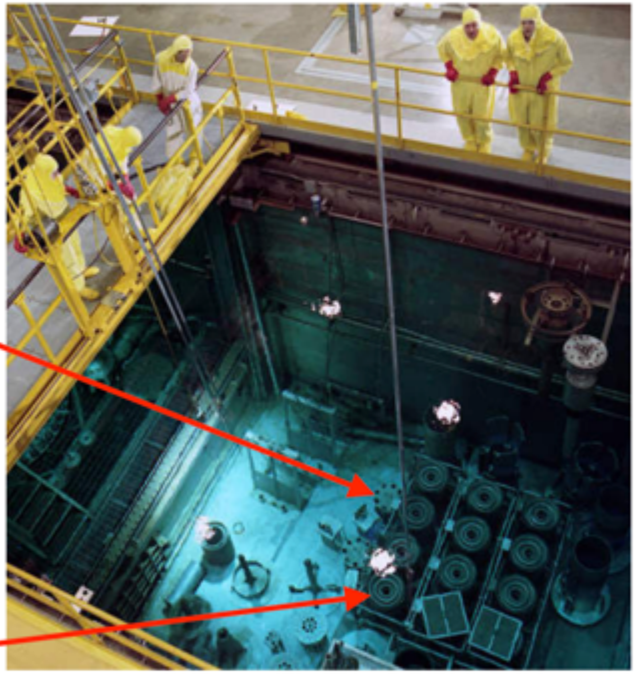




Sensor Technologies for Nuclear Physics Applications, C. Gilbert UTK 2019



Crap Rack (^{60}C)

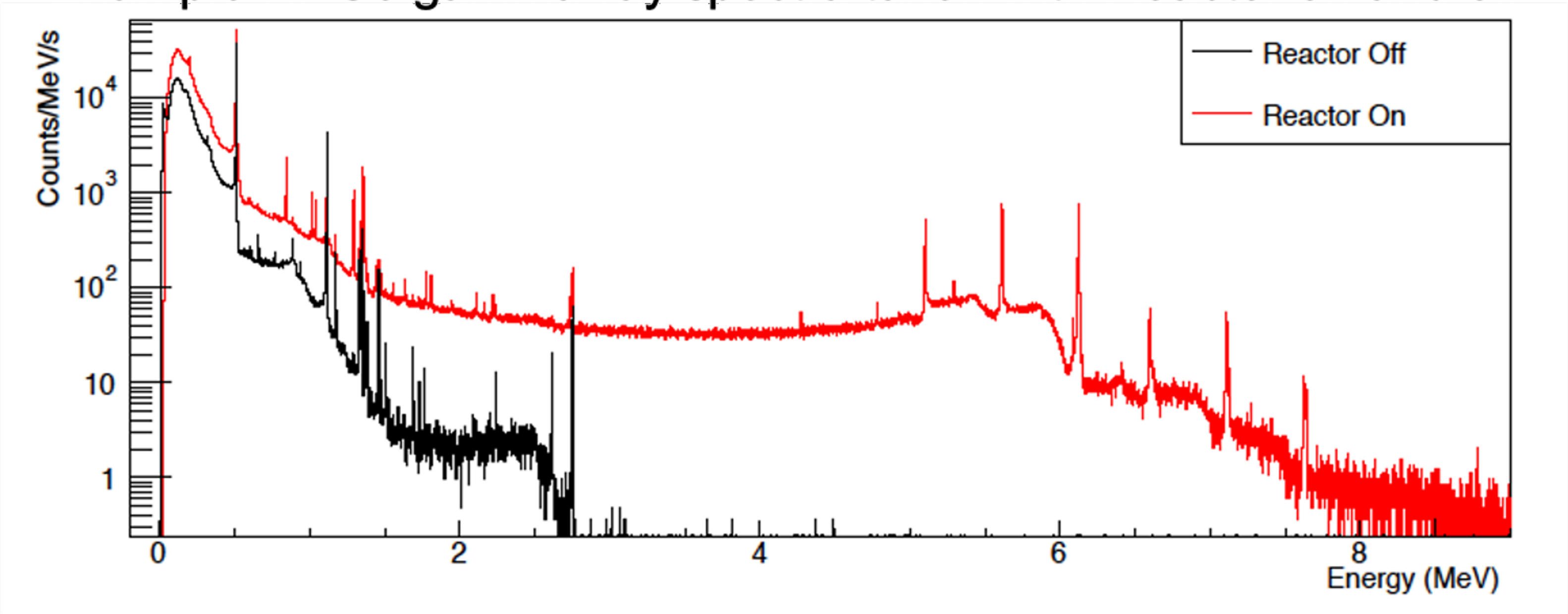


Spent Fuels (^{137}Cs)

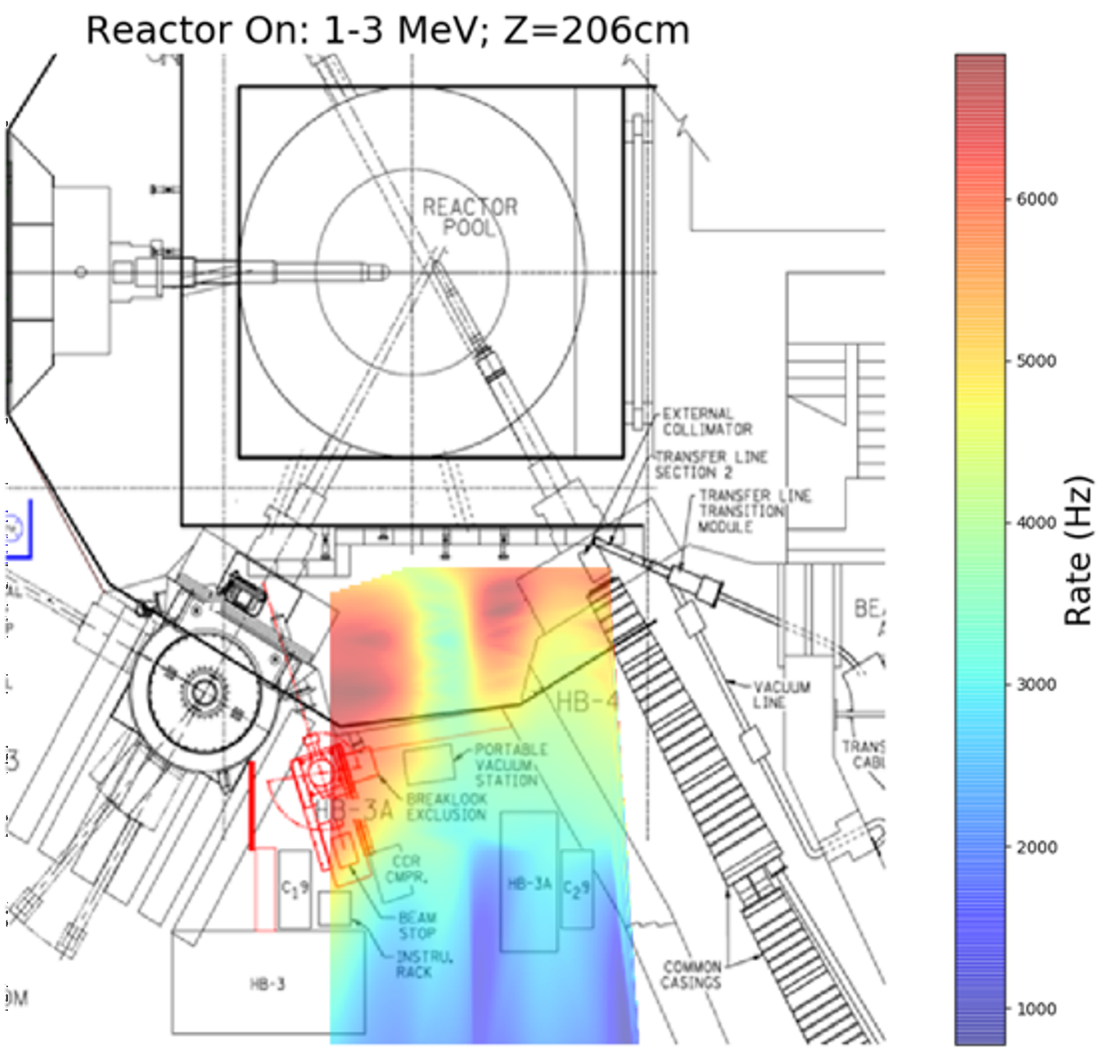
Reactor gamma background

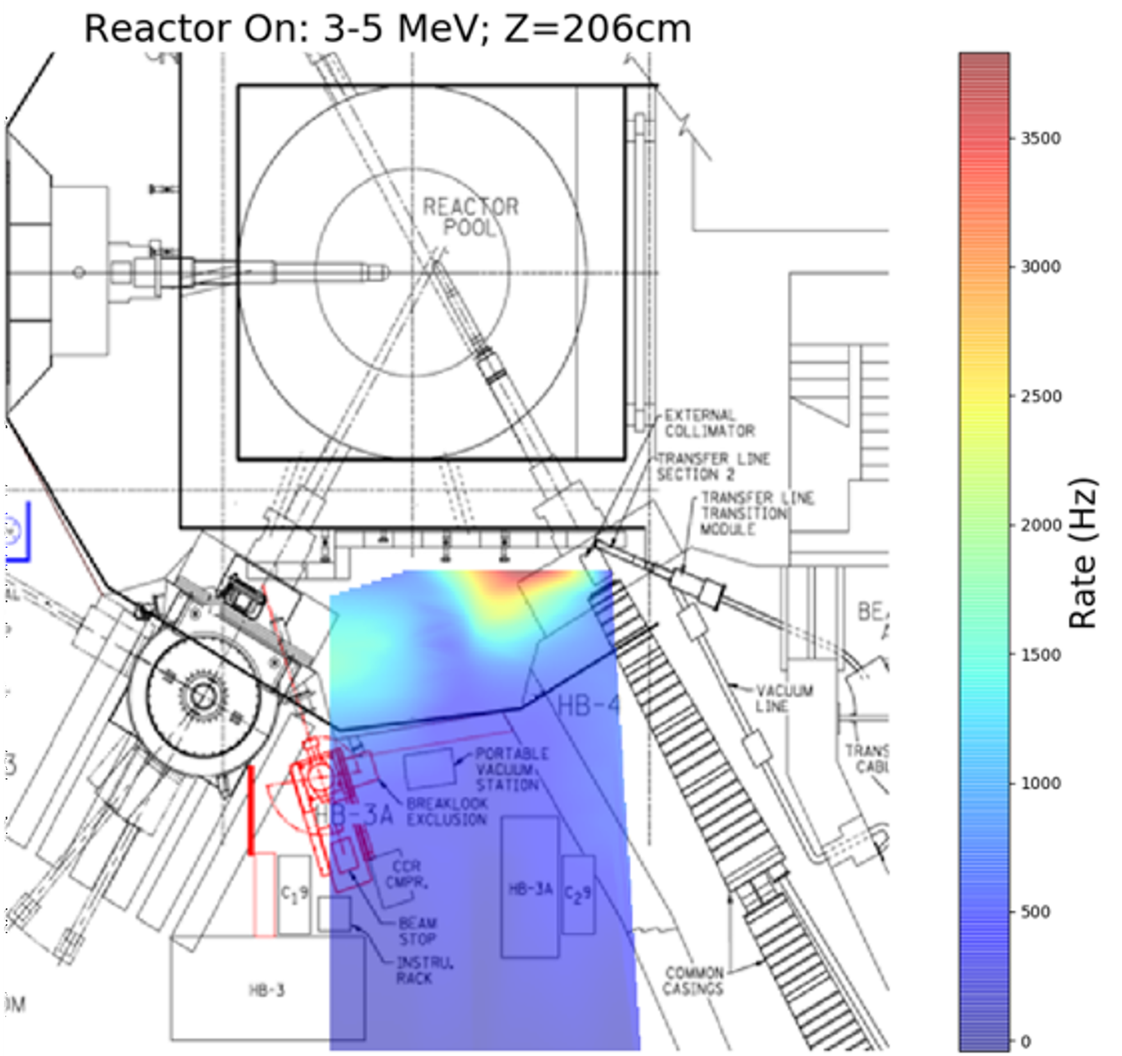
- Characterize the background radiation fields encountered at HFIR,
- Understand the sources of those backgrounds
- Develop background mitigation strategies appropriate for low-background experiments

Example HPGe gamma-ray spectra taken with Reactor on and off



Backgrounds – Spatial Variance





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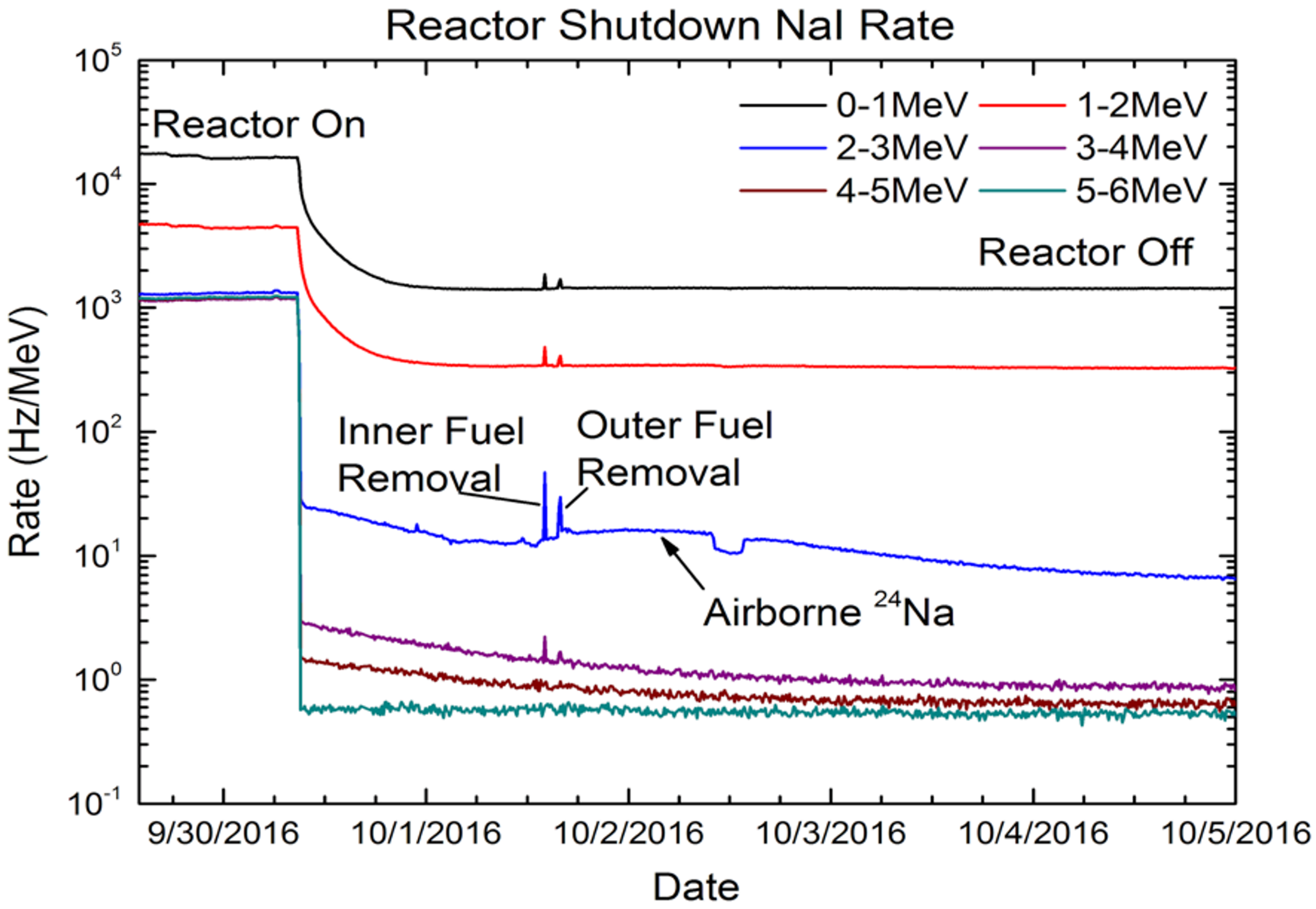
Backgrounds – Temporal Variance



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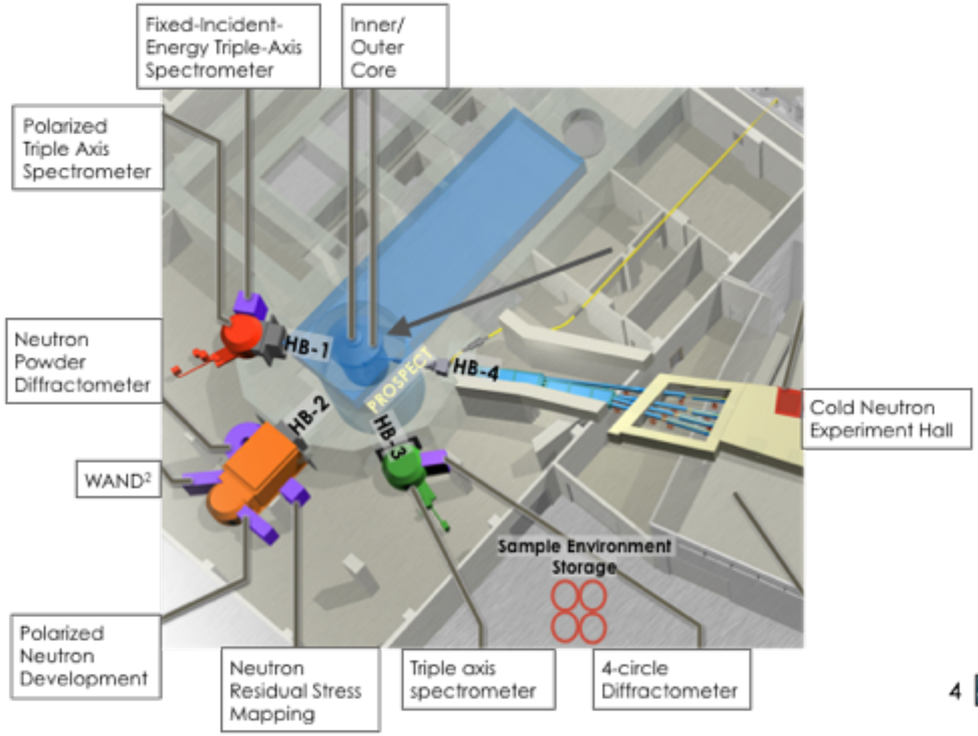
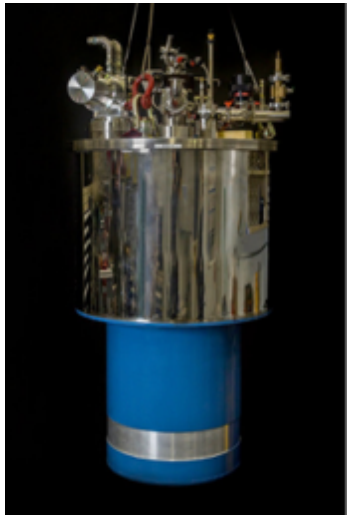
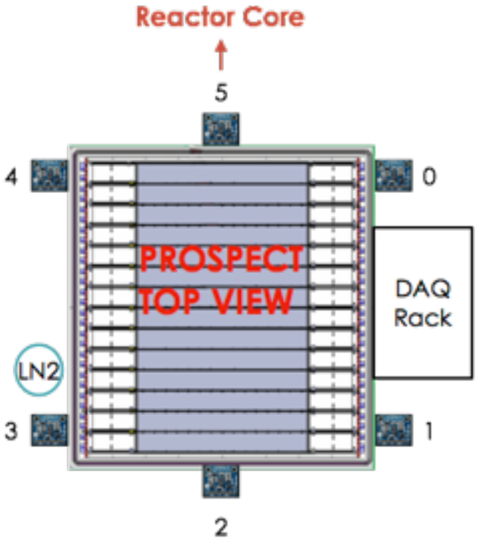
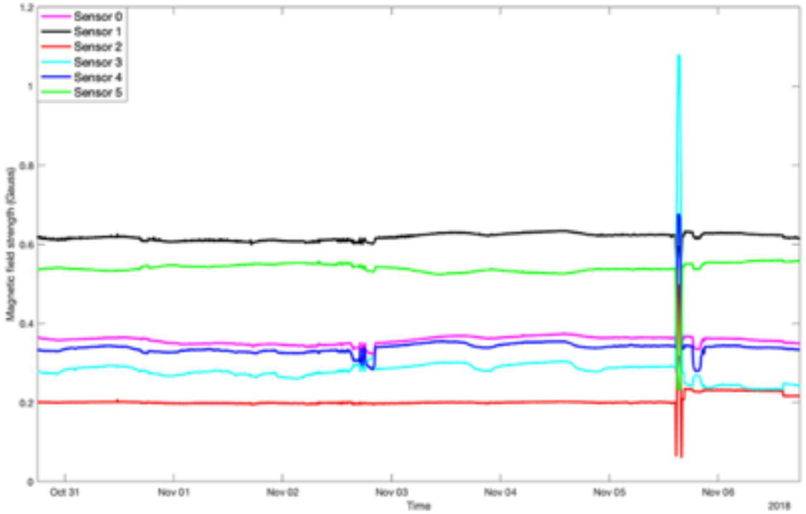
Magnetometer to Characterize Stray Magnetic Fields Near PROSPECT

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

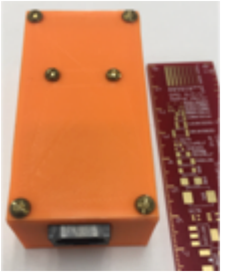




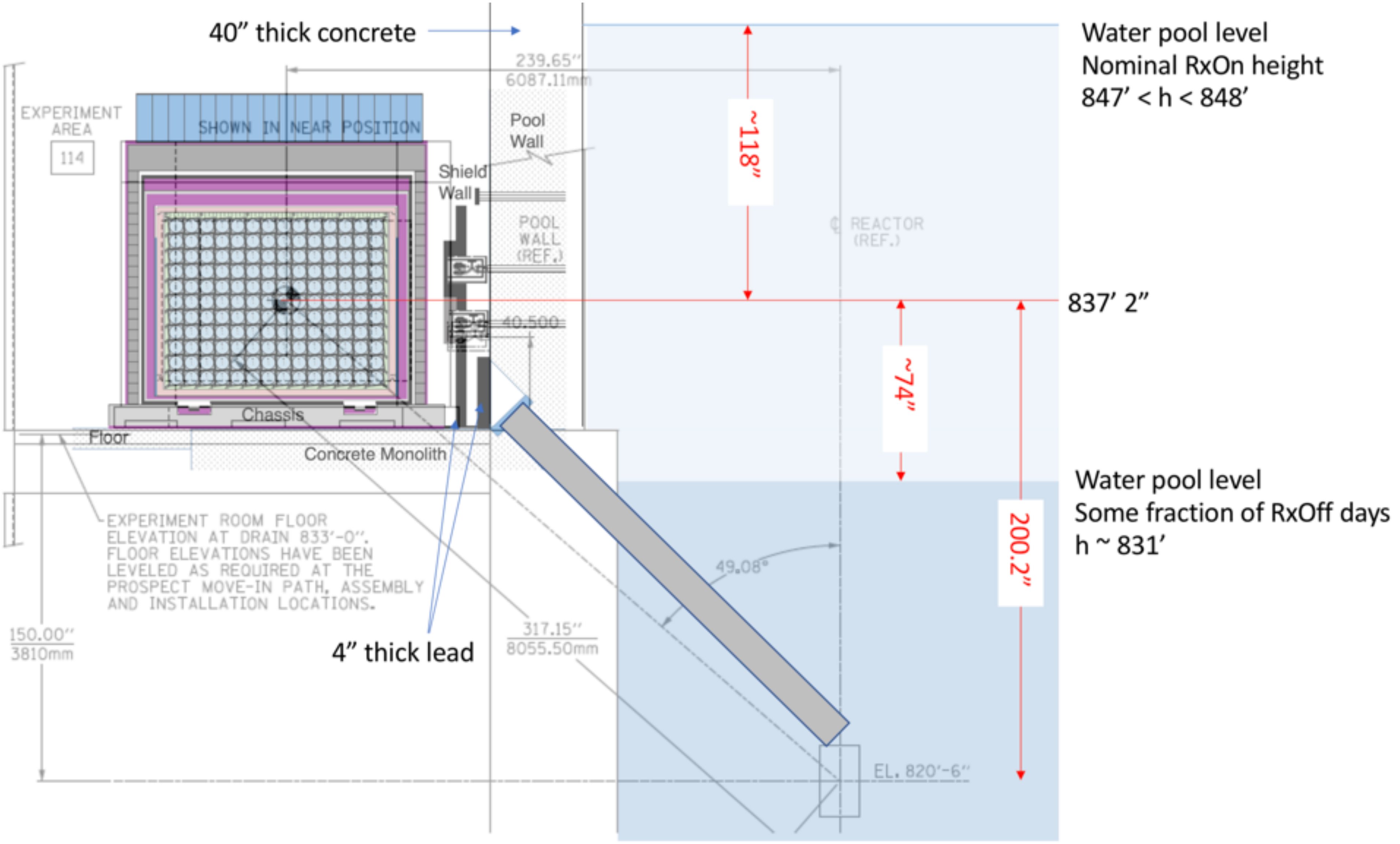




Spike correlated to testing ramp up and down of Mag-E (8 T) on HB-2A



Future Work – Directional Measurements



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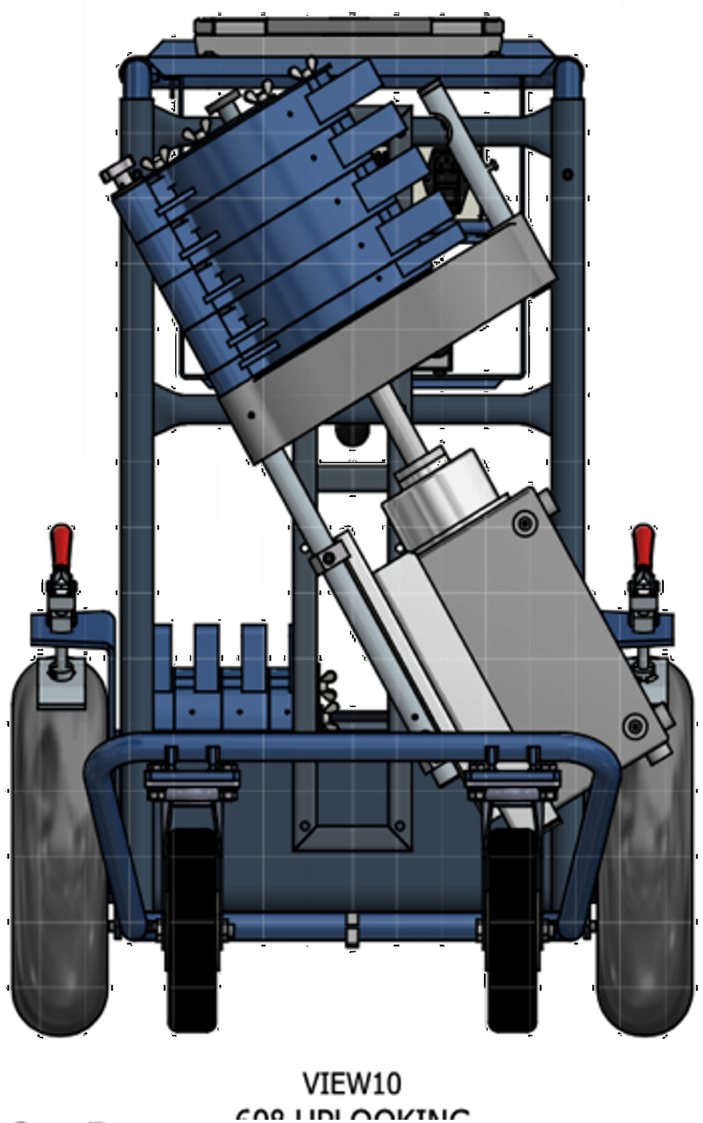
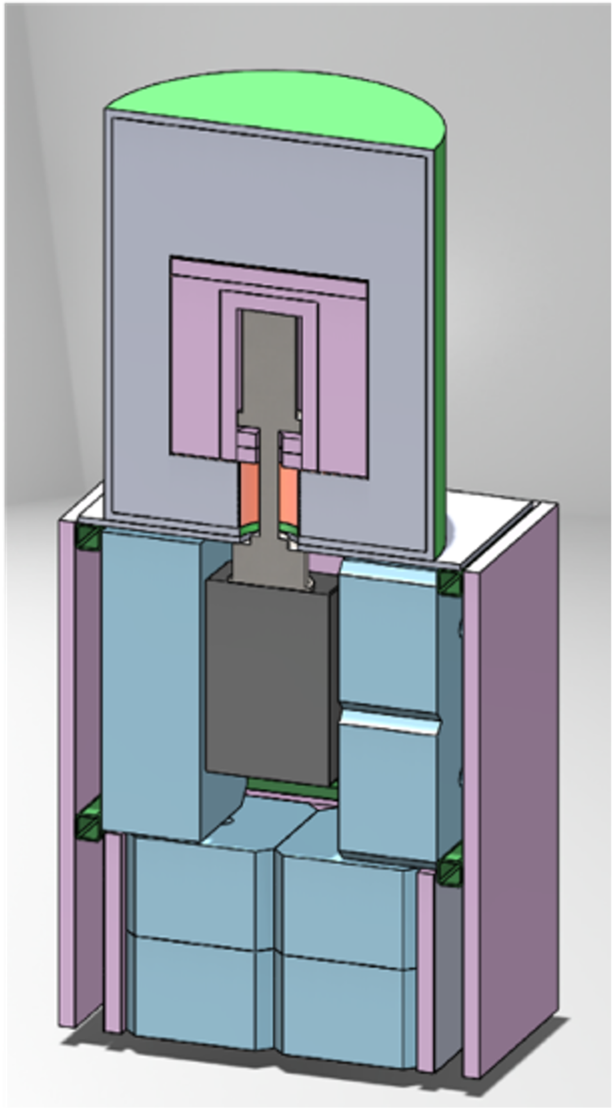
Background Measurement Devices



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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