Background Assessment for the PROSPECT Short-Baseline Reactor Experiment

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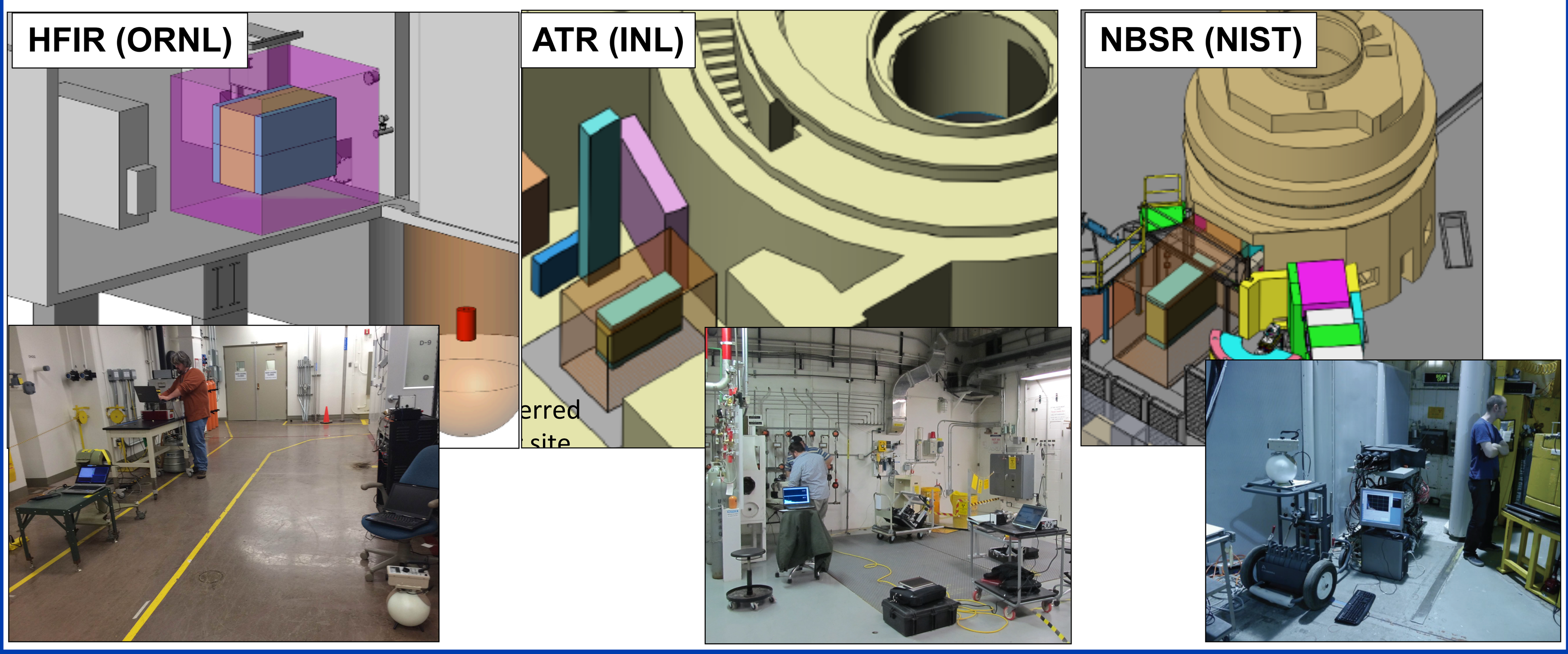
See also: K. Heeger: *PROSPECT Summary & Physics Potential*

T. Langford: *PROSPECT Scintillator Development*

Assessing PROSPECT Sites Close to Reactor Cores

- PROSPECT will deploy detectors close to research reactor cores
  - → Limited overburden and possible reactor correlated background
  - → Background measurements have been performed at 3 sites:



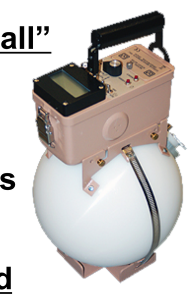
Background Measurements Performed

Neutron Rate/Spectrum

2" Stilbene Organic Crystal Scintillator

Relative fast neutron flux at all sites

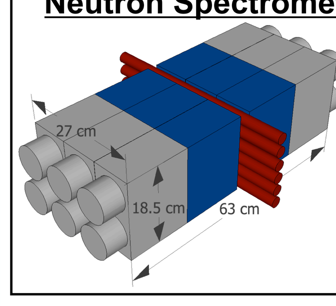
"REM Ball"



Moderated ^{3}He tube

Absolute thermal neutron flux at all sites

FaNS-1 Capture-gated Neutron Spectrometer



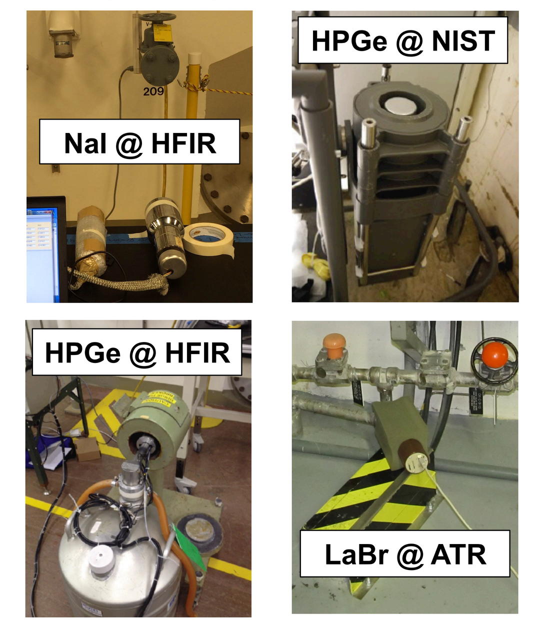
Plastic scint. & 3He tubes

Spectrum and absolute flux at NIST and HFIR

γ-ray Rate/Spectrum

Moderate Resolution: Same NaI(Tl) detectors used at all sites to provide relative comparison

High Resolution: Different HPGe and LaBr spectrometers used to identify background sources

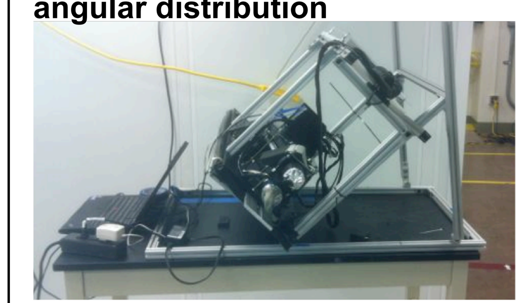


Muon Rate/Distribution

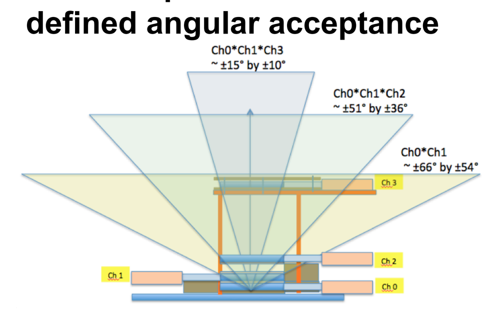
Muon telescope assembled from 3 plastic scint. panels.

Flux and angular distribution measured at all sites

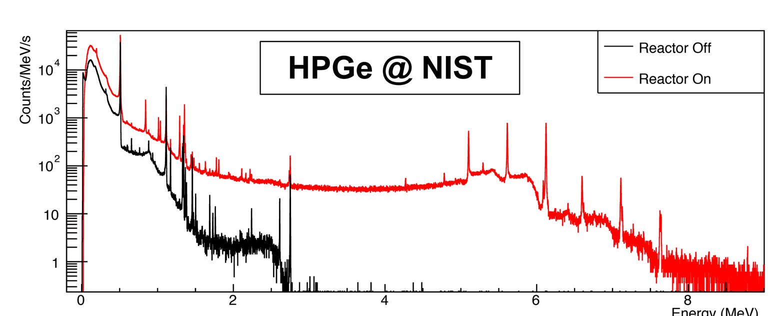
Telescope was tilted to measure angular distribution



Different panel combinations defined angular acceptance

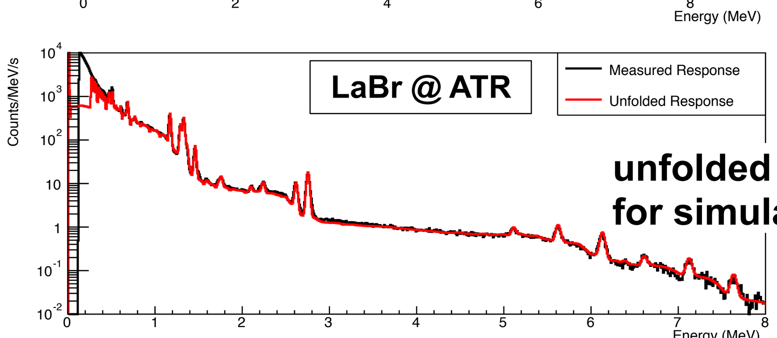


Gamma Ray Results

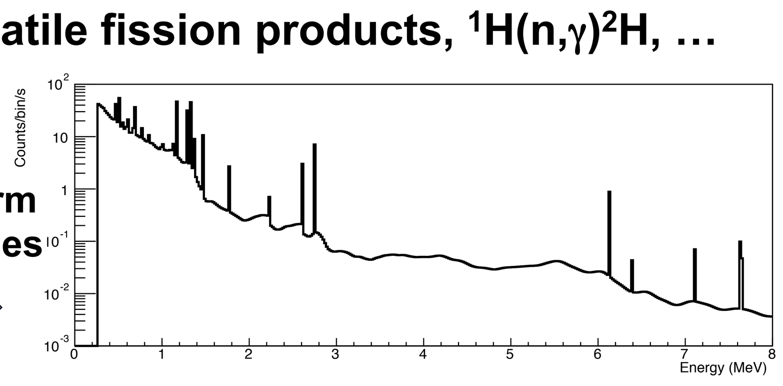


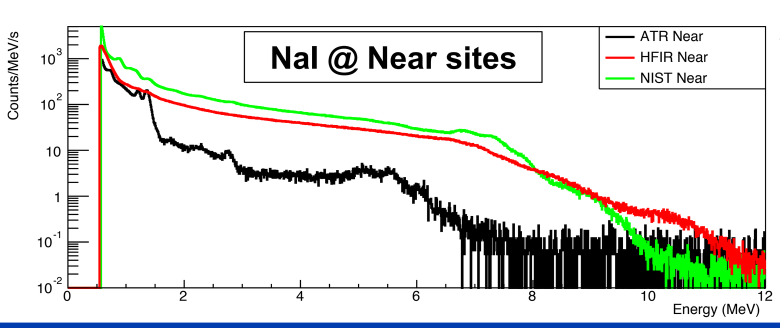
Reactor correlated activity observed:

- $^{16}O(n,p)^{16}N$, 6.1, 7.1, 8.9 MeV γ-rays (water)
- $^{54,56}Fe(n,\gamma)^{55,57}Fe$, 5.5-9.3 MeV γ-rays (steel)
- $^{27}Al(n,\alpha)^{24}Na$, 2.75 MeV γ-ray
- … volatile fission products, $^{1}H(n,\gamma)^{2}H$, …

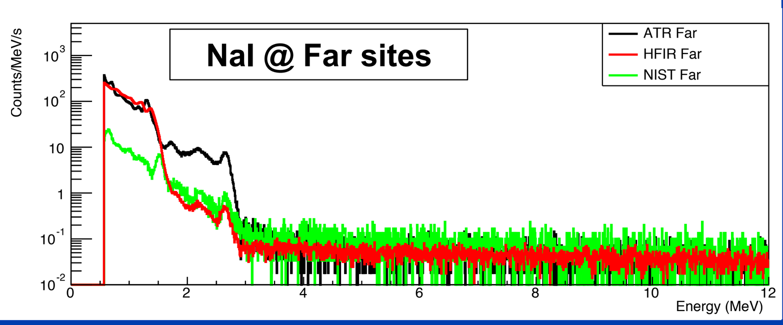


unfolded source term for simulation studies



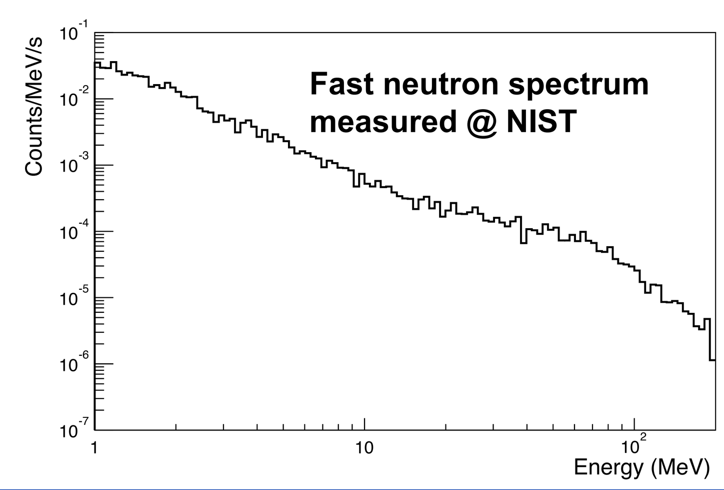


Variation observed between sites and Near/Far locations



Fast Neutron and Muon Results

- Fast neutron and muon fluxes vary with elevation and overburden as expected
  - ATR Near has high elevation and limited overburden → highest flux
  - Greater overburden at ATR Far compensates for elevation
  - NIST, HFIR similar
- Measured fast neutron spectra consistent with surface reference data



Site elevations and expected surface fast neutron flux

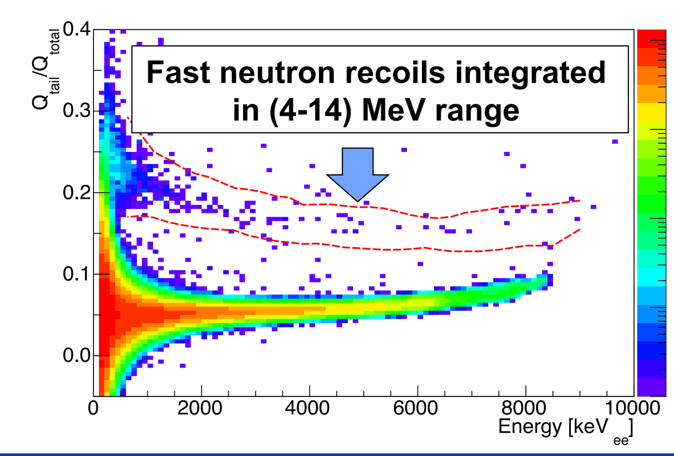
Location	Elevation	Fast Neutron Flux Relative to NYC
ATR	1435 m	3.37
HFIR	259 m	1.22
NIST	105 m	1.09

Relative measured muon rates

Reactor	Rate at Near Location (Hz)	Rate at Far Location (Hz)
ATR	0.78 ± 0.03	0.68 ± 0.02
HFIR	0.59 ± 0.02	0.71 ± 0.03
NIST	0.56 ± 0.01	0.69 ± 0.01

Relative measured fast neutron rates (Stilbene)

Location	Rate at Near Location (mHz)	Rate at Far Location (mHz)
ATR	4.7 ± 0.3	1.8 ± 0.2
HFIR	2.2 ± 0.2	3.5 ± 0.2
NIST	2.8 ± 0.2	2.8 ± 0.2



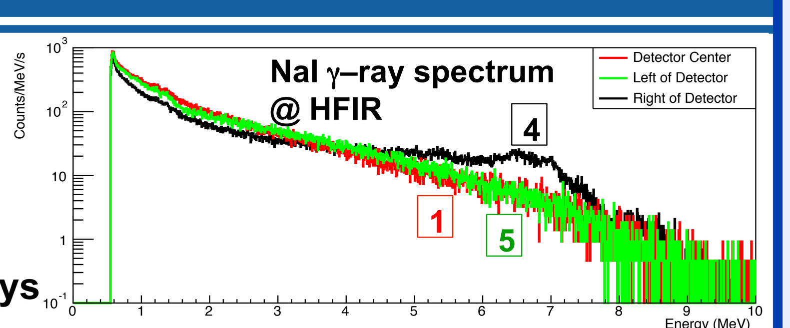
Spatial and Temporal Background Variations

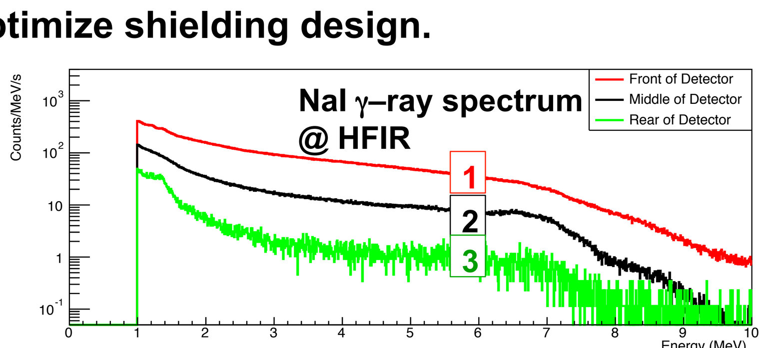
Significant variation in γ-ray/neutron flux observed:

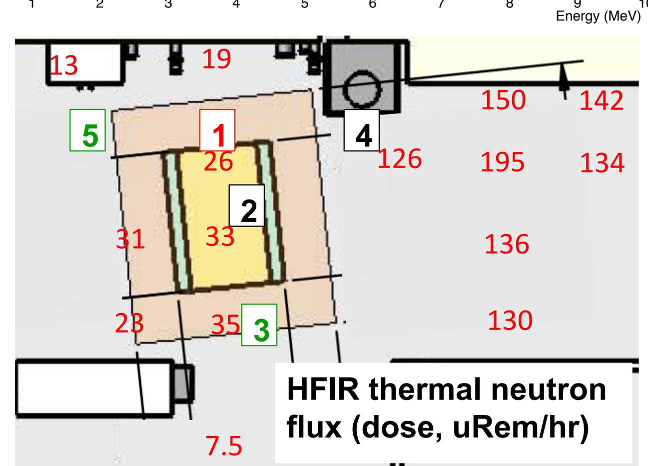
- irregular shielding and/or localized leakage paths
- proximity to piping carrying activated materials
- operation of nearby neutron beam experiments

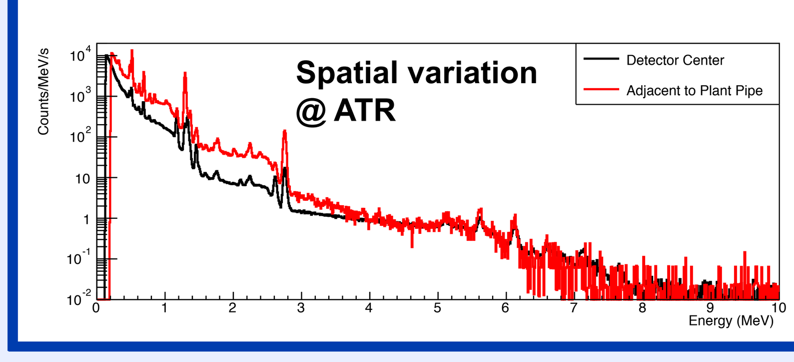
Neutron leakage can lead to significant localized γ-rays sources

Detailed background characterization is therefore essential to optimize shielding design.

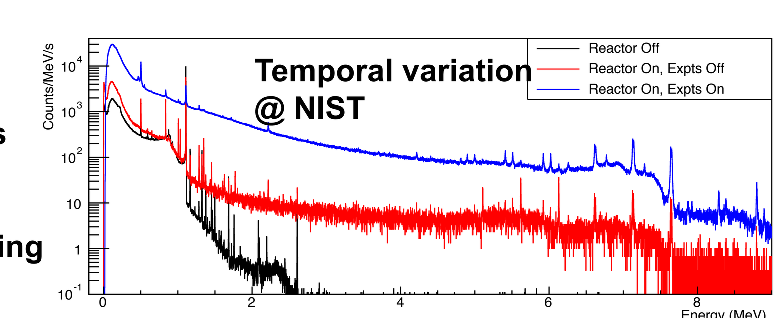




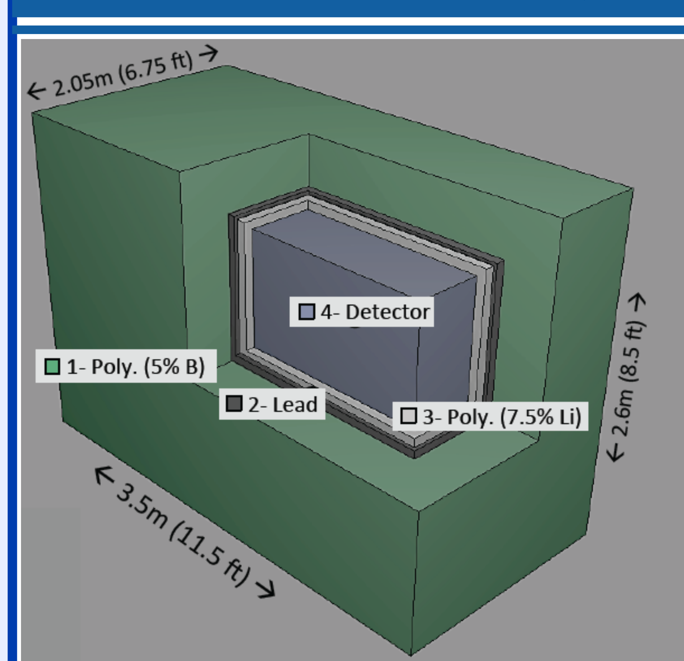




All sites exhibit variations based on position, surrounding activities



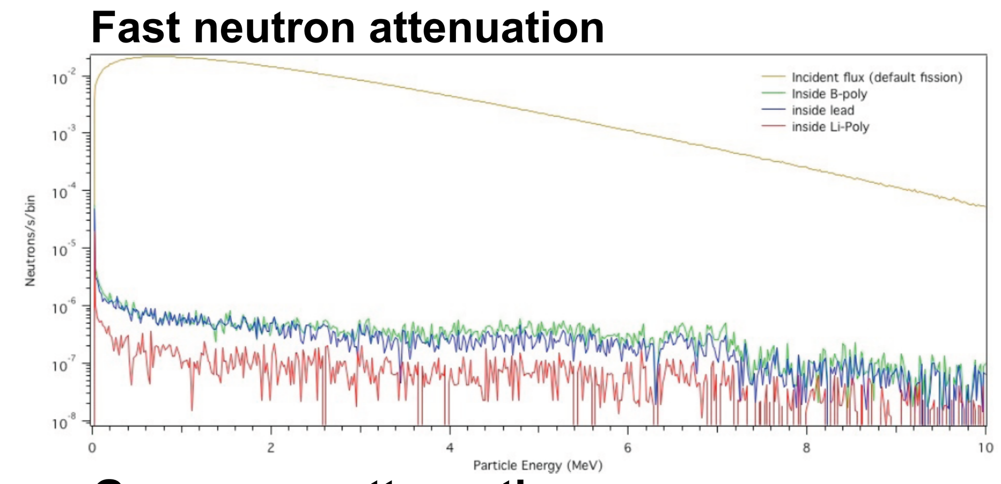
Shielding Concept Responds to Background Sources, Size & Weight Constraints



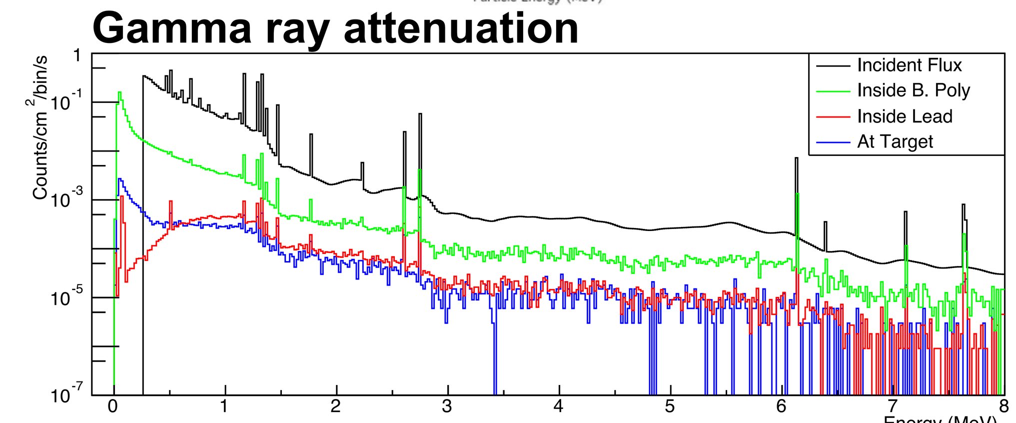
Shielding Factors from MCNP Simulation:

- γ-rays: 4e-3
- Neutrons: 2e-5 (fission)

Fast neutron attenuation



Gamma ray attenuation



- **Layer 1**: Borated poly attenuates fast neutrons, captures thermal neutrons prior to high-Z material
- **Layer 2**: Lead attenuates γ-rays
- **Layer 3**: Lithiated poly attenuates muon induced neutrons from Pb, produces no capture γ-rays close to target

Conclusions

- Background measurements have been performed at potential near and far detector locations for PROSPECT at 3 U.S. reactor sites
- Reactor correlated γ-ray and neutron background sources have been identified
- Cosmogenic backgrounds vary with elevation and overburden as expected
- Considerable spatial and temporal variations were encountered at all sites
- Extensive site characterization is therefore essential to shielding design
- Targeted shielding applied to localized sources could have large impact
  - Localized thermal neutron shielding could reduce high energy γ-ray fluxes

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