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Aboveground Backgrounds: Measurement and Simulation

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and
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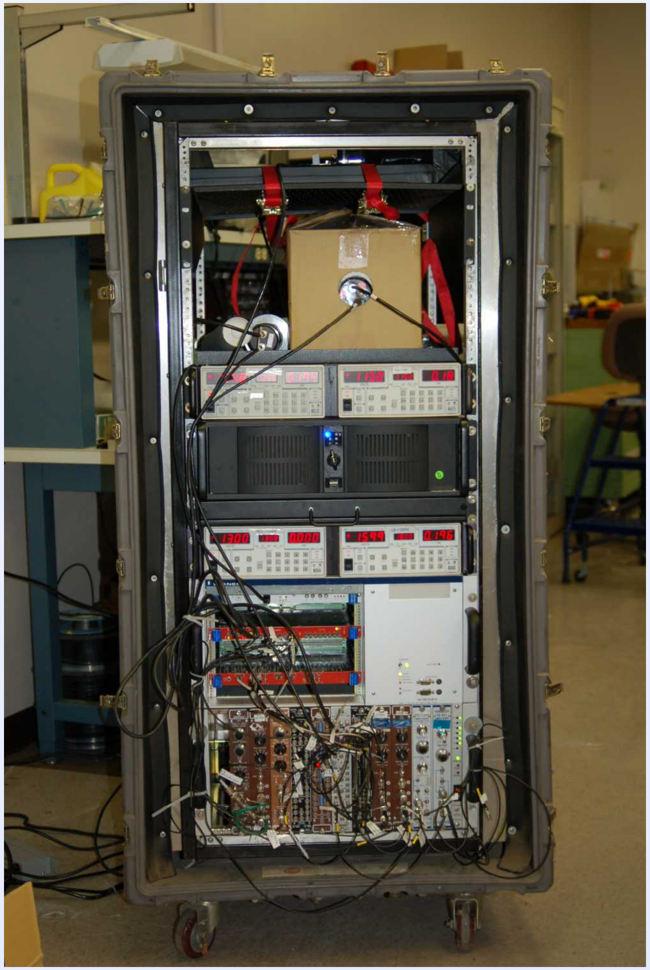
Purpose of Background Tasks

- Measure backgrounds
  - Measure absolute rates aboveground
    - Allow predictions of actual detector design responses
  - Get rates at various locations
    - Allow identification of site-specific backgrounds
    - Allow relative predictions of backgrounds (scaling from belowground to aboveground)
  - Absolute vs. relative
    - Absolute normalizations are difficult to measure and to implement
- Simulation
  - Intended to provide real event rates
  - Became more focused on shielding evaluation
  - Still intend to improve our detector modeling for better predictions

Portable Background Detector Assembly

- Detectors
  - NaI
    - Gamma spectrum with 6% energy resolution at 662 keV
    - Energy range- 60 keV to 4 MeV
  - Liquid Scintillator
    - 2” cell with Eljen 301 scintillator
    - Gamma/Neutron pulse shape discrimination
    - Energy range 60 keV to 4 MeV
  - Muon Paddle
    - Allows for correlations between muons and gamma/neutrons
  - ^{3}He
- Portable-19” shock mount crate
- Deployed
  - Sandia National Laboratories
  - University of Chicago 2/08
  - Columbia Generating Station-power block 9/08

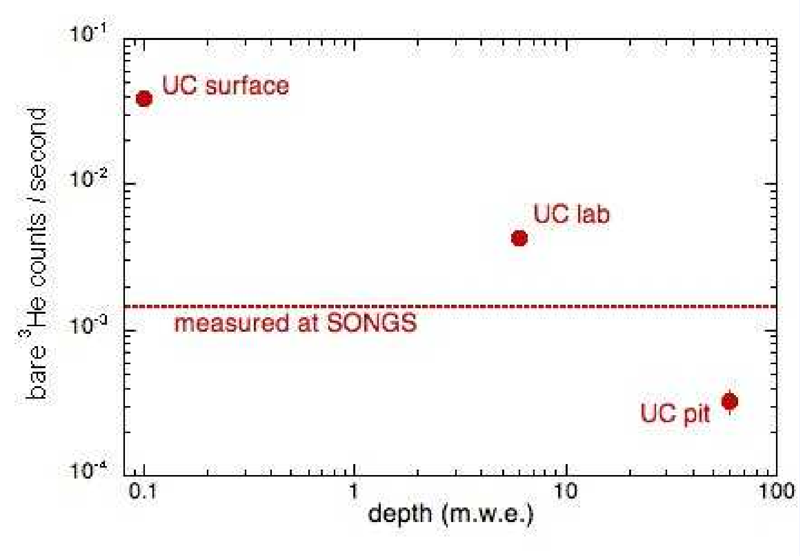


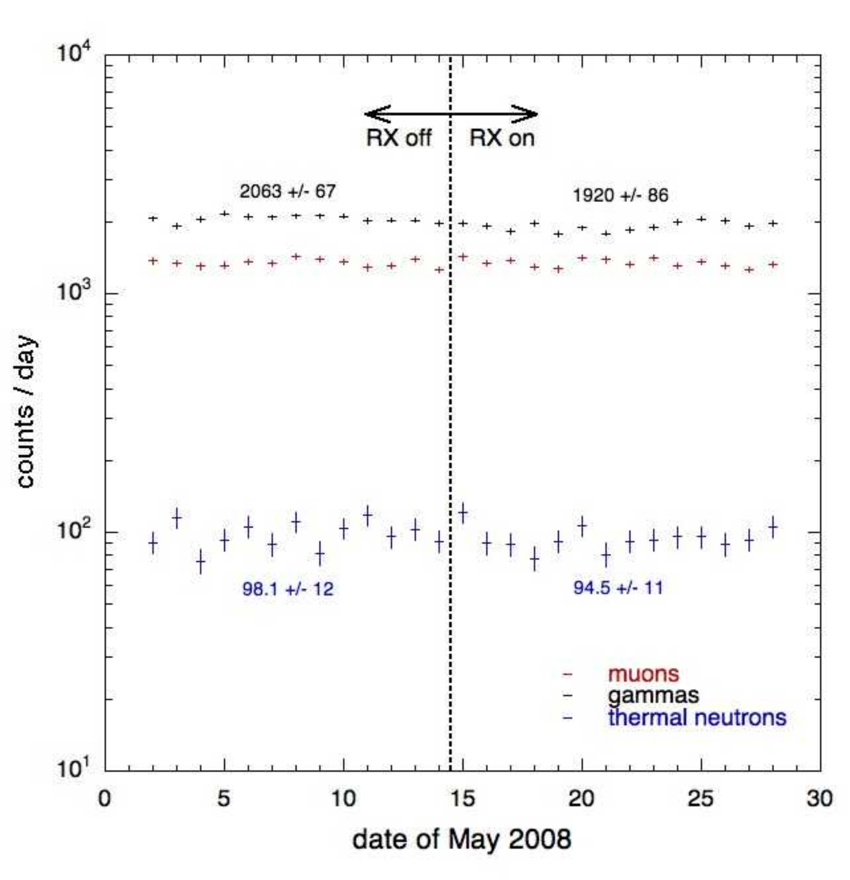
Comparison of Scalar Rates at Various Locations

Deployment location	Gamma Rate (NaI) [Hz]	Muon Rate [Hz]	Fast neutron (2" cell) rate [Hz]	Slow neutron (^3He) rate [Hz]
Livermore, Ca	93.38	26.7	0.67	0.035
UC 2nd floor	129.69	25.0	0.1	0.014
UC at 6 mwe	92.36	13.7	6×10^{-3}	1.0×10^{-3}
CGS 471'	50.47	16.9	0.67	0.043

Additional Detectors Deployed at SONGS

- Alternate set of detectors deployed specifically at SONGS
  - Clear depth dependence of thermal neutron rates
  - Monitor of reactor based backgrounds during deployment
- Still need to correlate these detectors with other background measurements
  - Will deploy primary set of detectors at SONGS in June 2009 to get cross calibrations

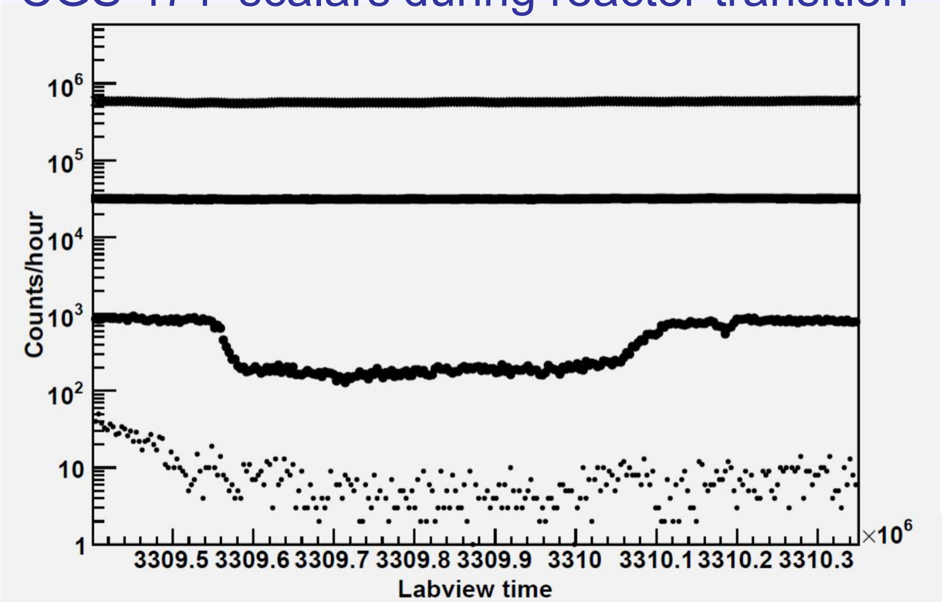


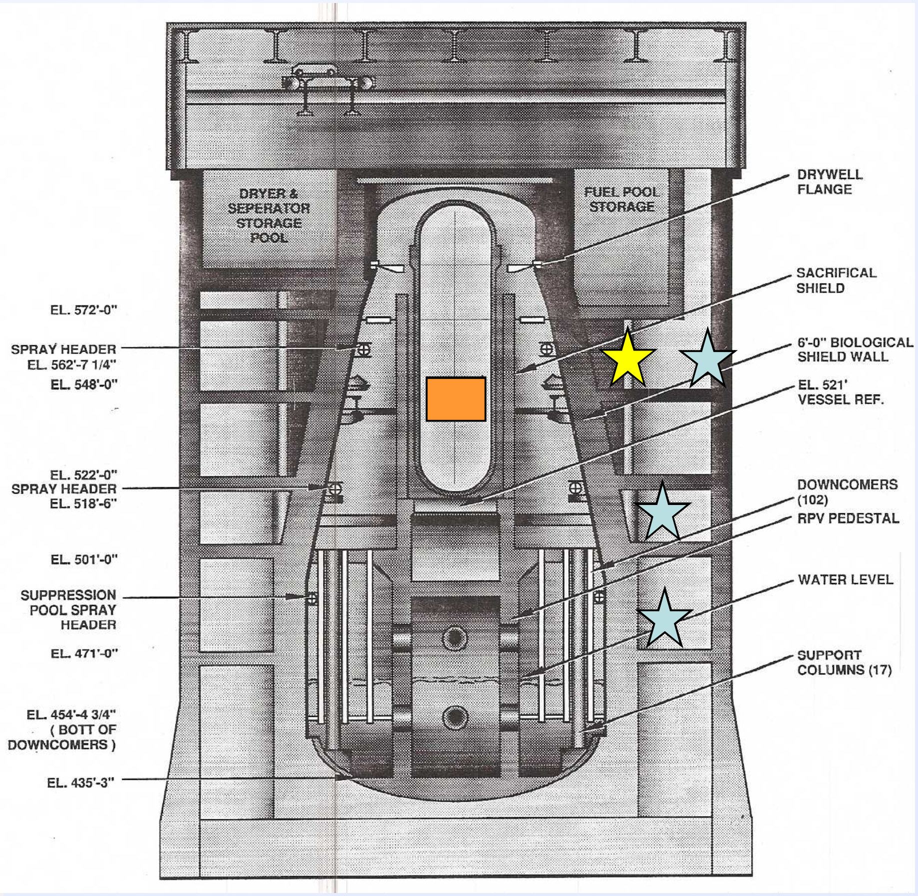


Monitoring Location Properties Has Added Value

Columbia Generating Station: Deployed Background Detectors at various locations for consideration of possible antineutrino detector deployments

CGS 471’ scalars during reactor transition



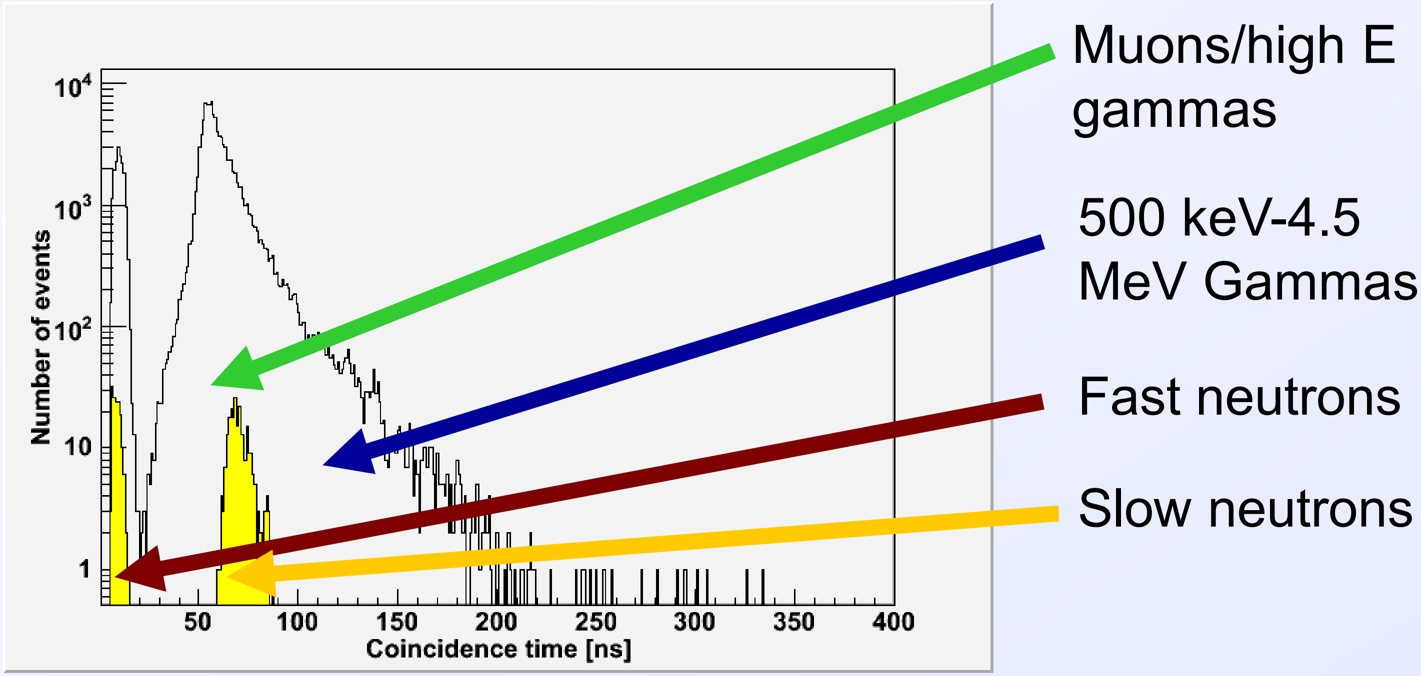


☆ = Closest location 2 mrem/hr
☆ = Alternate location <1 mrem/hr

How do we use background information

- Bare rates give us accidentals
  - Random correlations of any two depositions create a background
  - Absolute rates are not necessary if we can scale from SONGS
    - Deployment of Background Assembly detectors at SONGS will happen this month
- Time-correlated backgrounds
  - Difficult to get from individual background detectors
  - Fast neutron recoil followed by capture
    - Can calculate n-p reaction, but best estimates will come from direct measurements
  - Multiple neutron from same cosmic shower
    - Must be measured from correlated detectors to properly estimate

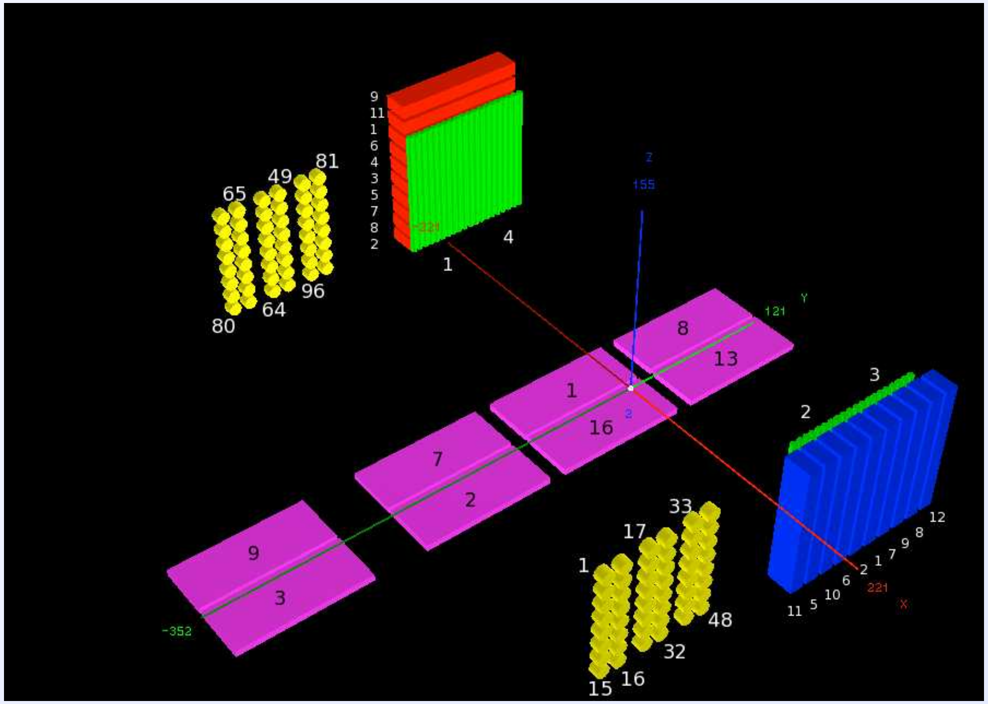
Timing Correlations in Background Detectors



- Recorded time correlations relative to muon panel in Background Assembly
  - Most correlated signals due to cosmic rays occur within 300 ns
  - Not enough volume to look for capture of fast neutrons after recoils

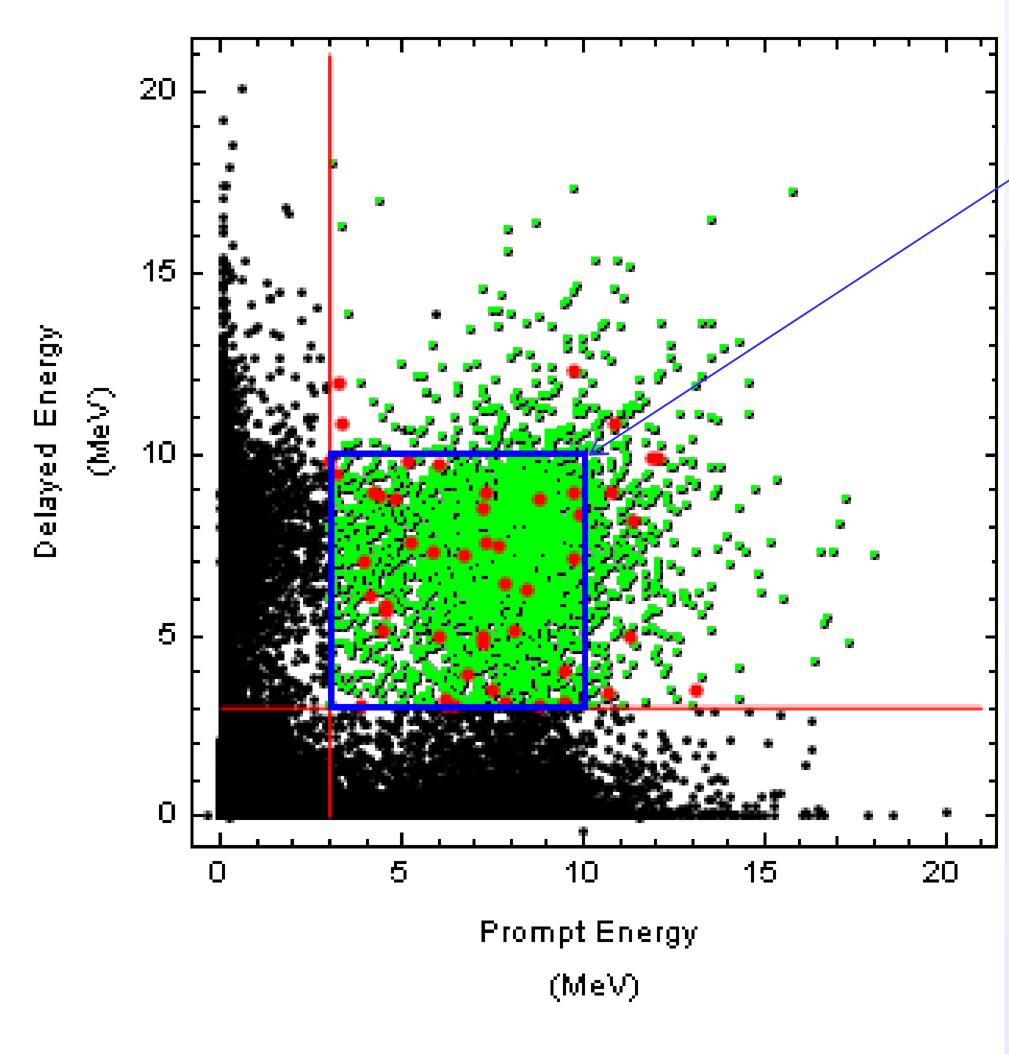
More Detectors Allows Better Correlation Search

- Highly reconfigurable system borrowed from ongoing fissile material monitoring R&D from LLNL
  - ~300 kg of Liquid and Plastic cells
    - Liquids have excellent PSD
  - 40 ^{3}He detectors
  - Muon veto paddles
- 5 ns digitization everywhere allows good correlations between detectors
- Significant mass allows capture of fast-neutron events



Antineutrino-like backgrounds can be measured directly – fast neutron rejection via PSD imposed in software to quantify the effects of particle identification

Preliminary Analysis Using the Multi-Detector System



Prompt and delayed energies in this box consistent with antineutrinos

- Only red points have energies and inter-event times consistent with antineutrinos

Many events with ns-scale interevent times

Thermal neutron tag not yet imposed

Fast neutron rejection not yet imposed

Aboveground Increases Reliance on Shielding

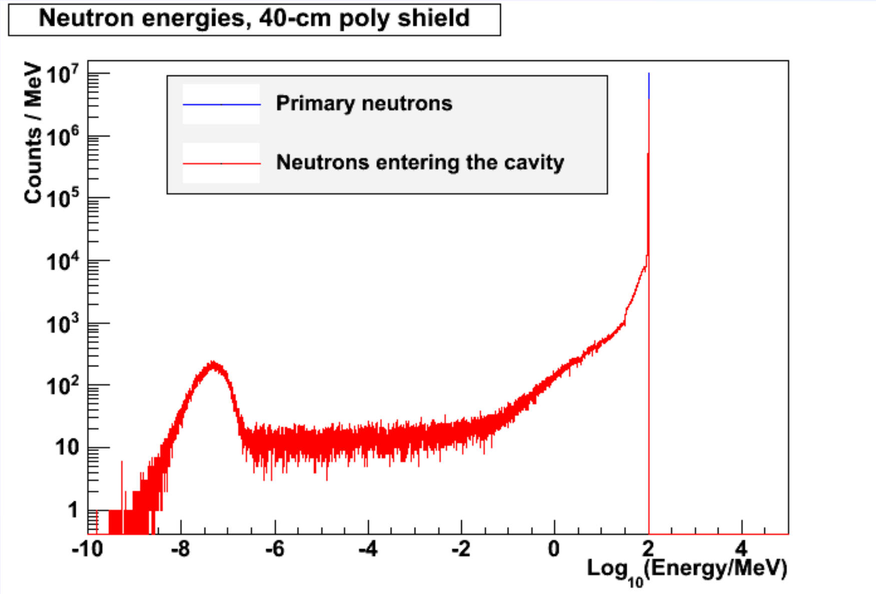
Background Type	Source	SONGS1 Detector	Aboveground Detector
Background γ's (U/Th/K)	Detector components, surroundings	Reduced by shield, material selection	Reduced by shield, material selection
Neutrons	Muogenic, inside detector	Reduced by veto, shield, overburden	Reduced by veto, shield
	Muogenic, outside detector	Reduced by overburden, shield	Reduced by shield
	Hadronic interactions inside detector	Eliminated by overburden	Reduced by veto, shield
	Hadronic interactions outside detector	Eliminated by overburden	Reduced by shield
Hadronic cosmic flux (non-neutron)		Eliminated by overburden	Reduced by veto, shield
Electromagnetic cosmic flux		Eliminated by overburden	Reduced by veto, shield

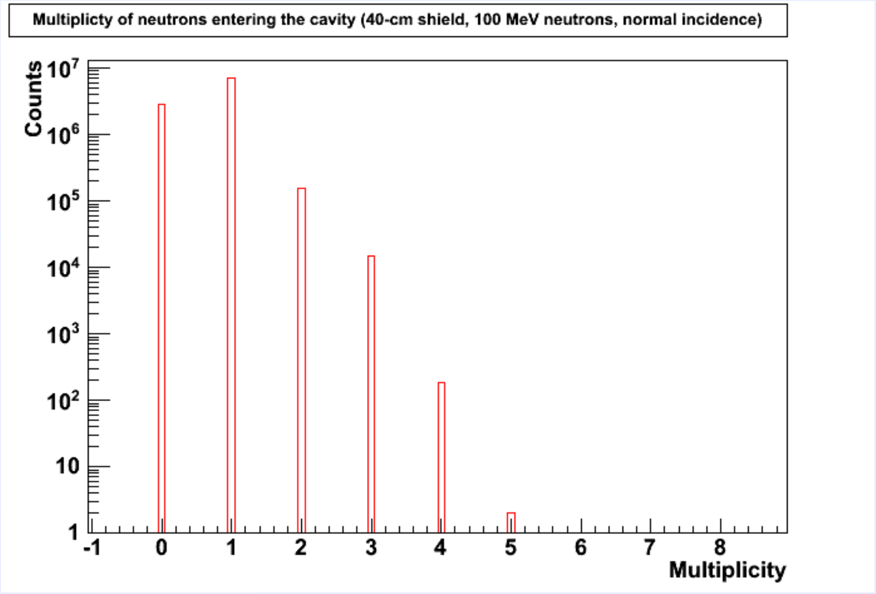
Need for Shielding and Muon Veto

- A shield can control backgrounds more simply than detector design
  - Gammas don't change and are tolerable
  - Need to reduce neutron impact is severe
- Fast neutron calculation is sobering
  - Require a proton recoil of >10 MeV
    - quenched signal will be in positron signal region
  - Calculation based on Hess Spectrum and differential n-p cross-section
    - Expect 5×10^5 events per day (~6Hz) per ton of LS (unshielded)
- Neutron shielding and muon vetos can be improved from songs1
  - Previous veto allowed cosmogenic neutrons (~95% efficient)
  - Replacing water with HDPE gives 25% better neutron moderation
  - Use of borated poly for inner 1" surface can "soak up" thermal neutrons
    - Thermal neutron absorption length λ~0.5cm in 5% Borated Poly
      - 1" of Borated poly is 5 λ for > 99% attenuation

Simulations to Determine Shielding Effectiveness

- We are also investigating the effectiveness of shielding against fast neutrons by montecarlo
  - e.g. 100 MeV neutrons into 40cm of poly:
    - ~35% of primaries "punch through"
    - ~70% of the time at least one neutron gets through
- Validated results by comparing MCNP-Polimi and Geant4





Note: neutrons multiply in the shield

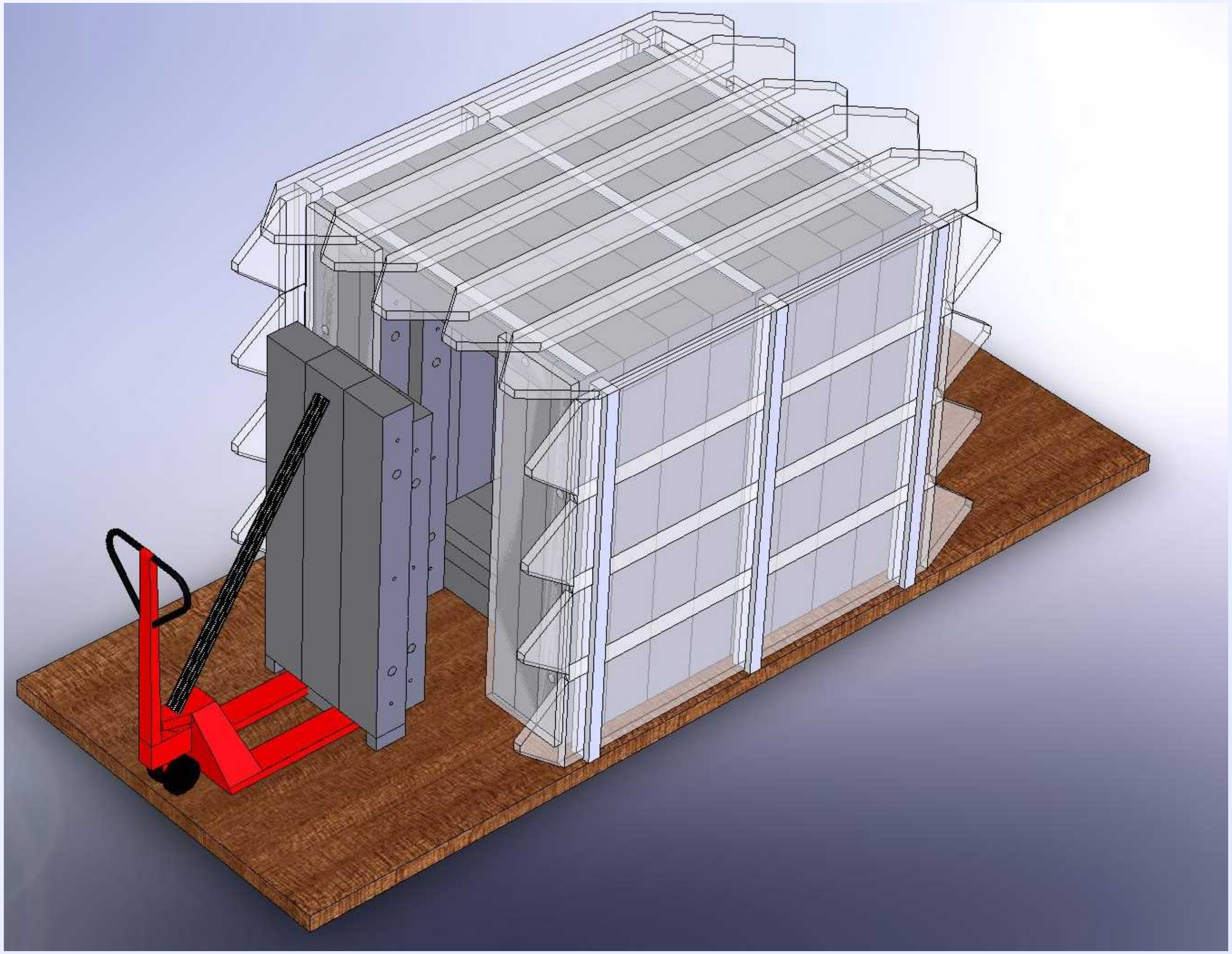
Shield designs for aboveground

Interior Volume:
1.5m x 1m x 1.5m

45 cm HDPE on all sides

Hermetic Muon Veto

Designed to fit within a
20' shipping container



Requirement for Good Veto efficiency

- Shield material is a muon target
  - ~2 kHz Rate of muons > 1GeV
  - About 3-4 neutrons/second produced in the poly shield
- Require good muon detection to veto production
  - 97% efficiency should be sufficient to keep un-tagged neutrons below background goals
  - Studies of 1” plastic show this is achievable
- Veto deadtime will then be a dominant factor
  - Plan to use 2” thick plastic to reduce veto trigger rate from low energy gammas while maintaining veto efficiency for muons

Summary

- Background measurements have been very useful
  - Determining likely locations for deployments
  - Comparing aboveground rates to known below ground environments
    - Relative measurements have proven more practical than absolute for detector development
    - Expect complete comparisons to SONGS tendon gallery later this year
  - Multi-detector system will allow us to make a novel determination of neutrino-like events in the ambient background environment
- Simulations have allowed us to refine our estimations
  - Primarily used for improving shield designs
  - Comparisons to background detectors will continue to be useful for validations