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Using the Cosmogenic Muon Background for Continuous Status-of-Health Monitoring of Neutron Detectors

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Presentation outline

- Description of the problem we're trying to solve
- Proposed solution
- Experimental apparatus/some optimization
- Field trials
- Conclusion

What is the problem?

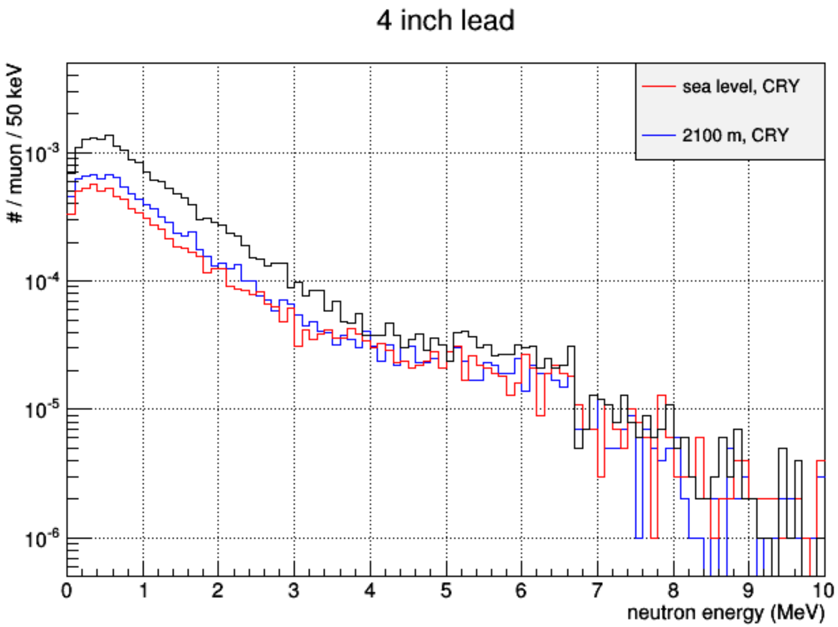
- Neutron detectors are used in many field applications
  - Safeguards measurements
  - Homeland/border security
  - Arms control (New START)
- Detector response to a calibration source is required for absolute measurements
  - Neutron sources often cannot be easily deployed to the field
  - Depending upon equipment pre-deployment staging practices, it may not even be easy to calibrate prior to field deployment
- A method to verify status-of-health and calibration without the use of isotopic sources or neutron generators is desired

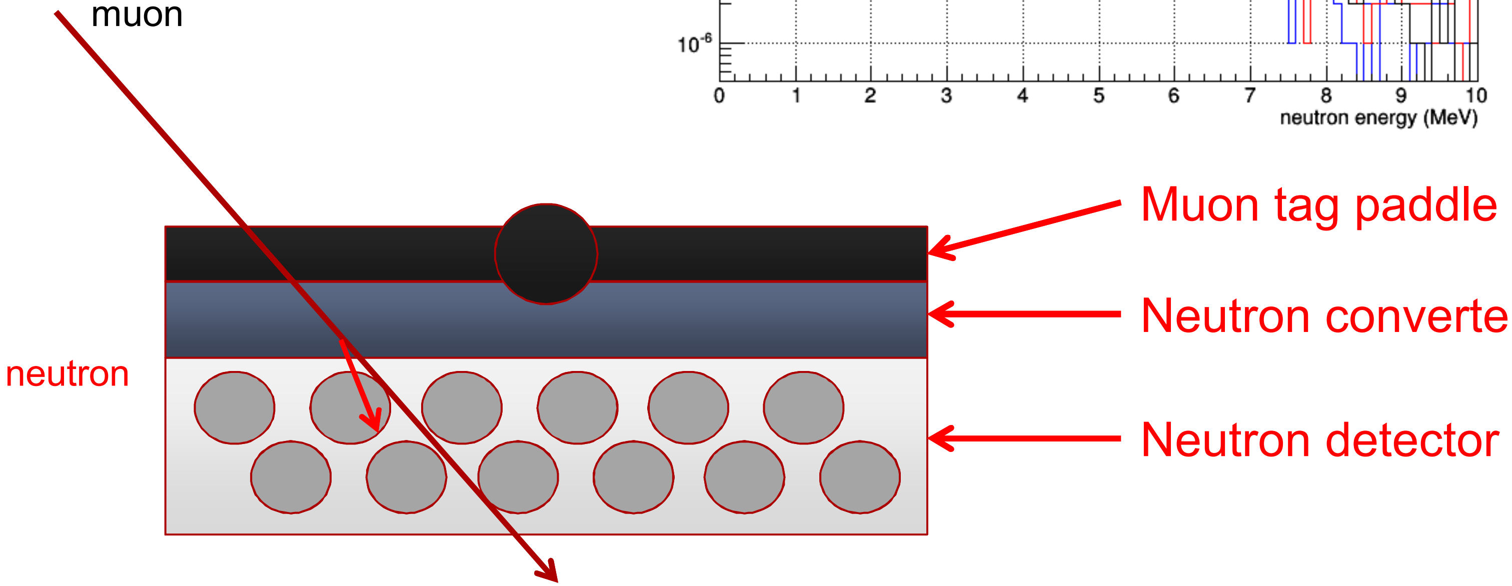
Proposed solution: using muon interactions in the environment to generate neutrons

- Muons interact with materials in the environment
  - Spallation
  - Capture
  - Cross-sections favor high atomic number, high-density materials
- Let's consider deployment of a portable muon target that is used to generate a source of neutrons for detector calibration purposes
  - Production rate and mass need to be considered
- Since the muon background varies in time and space, the absolute neutron production rate can also fluctuate
  - Solution: use a muon detector to open a counting gate
  - The response is then neutron signal (counts) per muon, and more stable vs. time and location

Neutrons production in a lead slab is predicted to be fairly stable vs. elevation

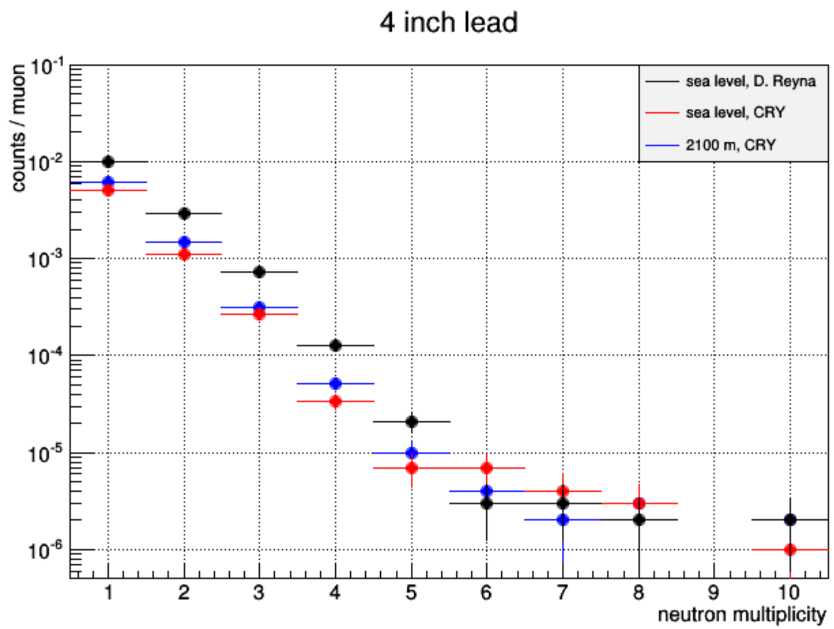
- Energy spectrum of neutrons exiting a 10 cm lead slab
  - GEANT4 simulation
  - (CRY: LLNL Cosmic-Ray Shower Library)

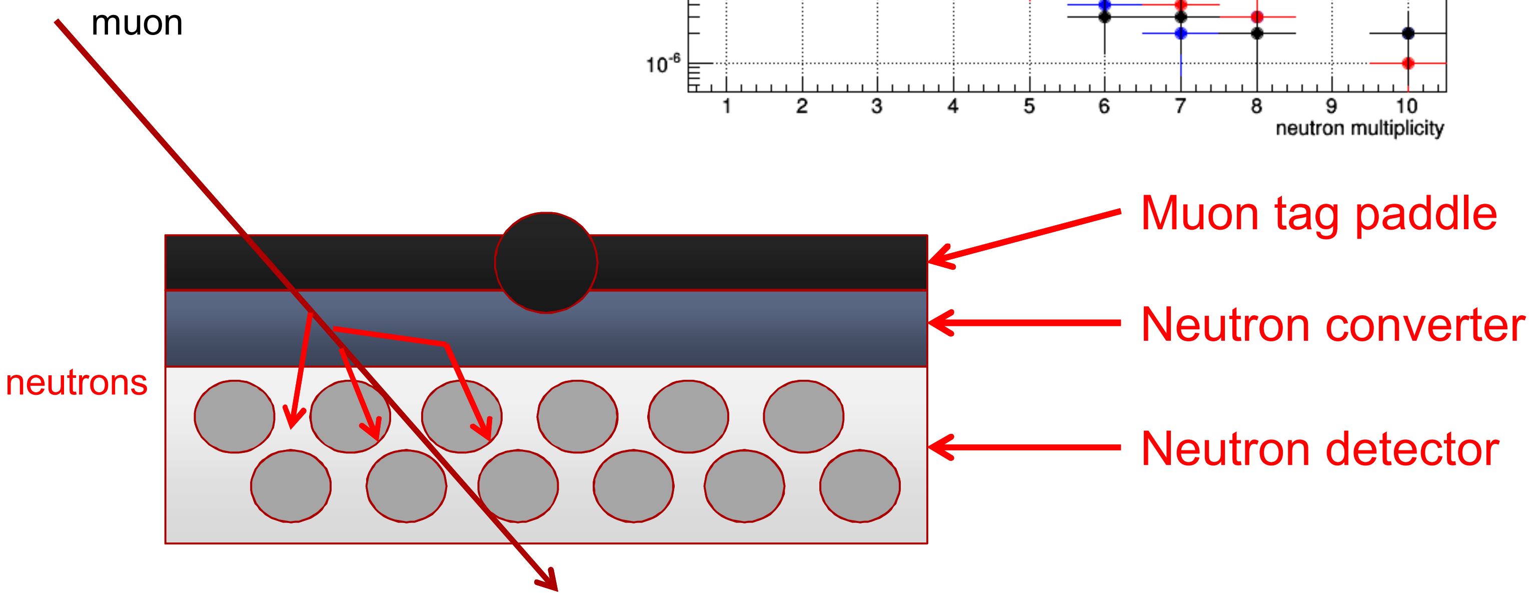




For multiplicity detectors, Feynman histograms may also be stable vs. elevation

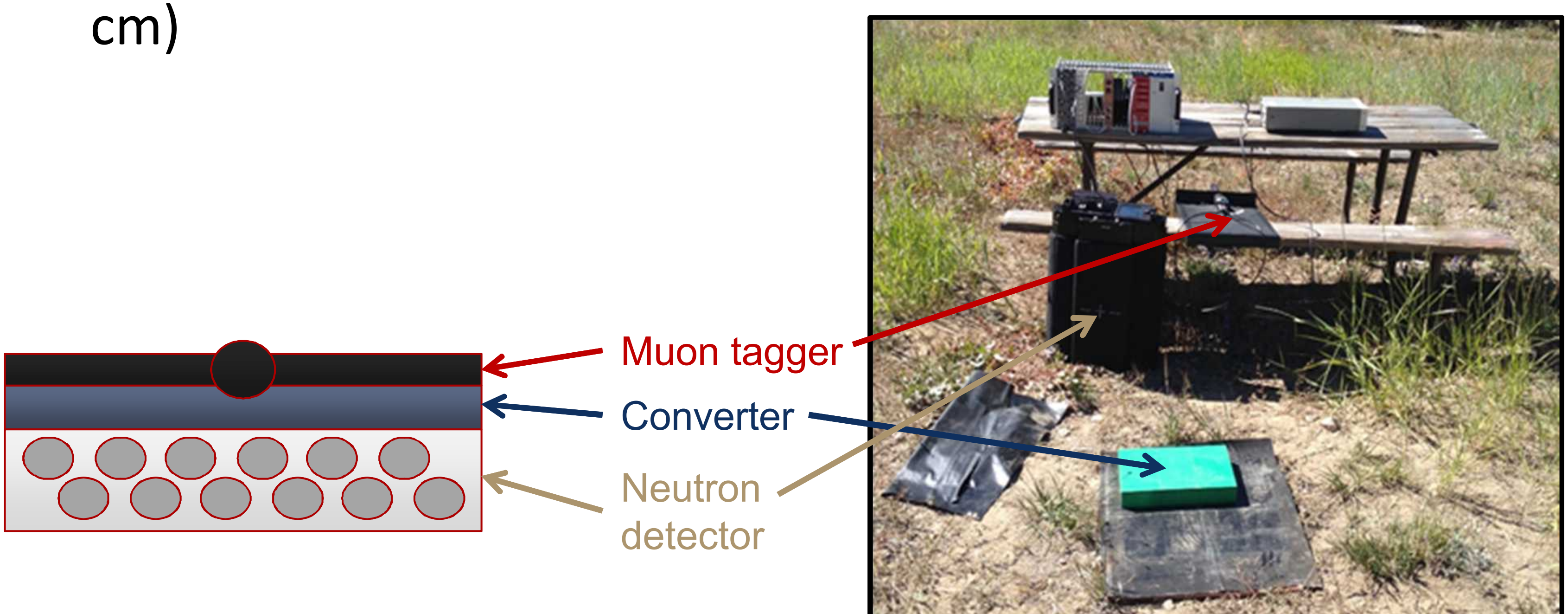
- Multiple neutrons will also arrive in coincidence
- This may allow multiplicity counter calibration on a correlated source





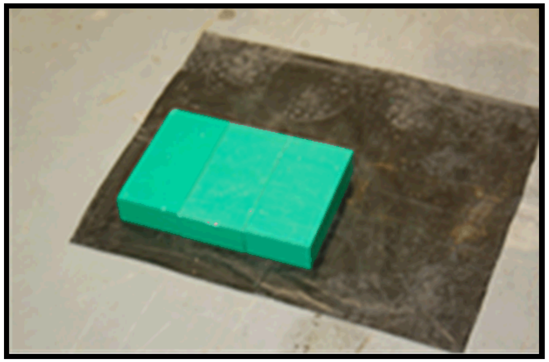
Experimental apparatus

- Neutron detector: an array of 15 ^{3}He tubes in an HDPE block
- Muon detector: a 2.5-cm thick plastic scintillator with a pulse-height threshold set above the ^{208}Tl line (2614 keV)
- Muon target: stacks of 3→16 lead bricks (5 cm × 10 cm × 20 cm)

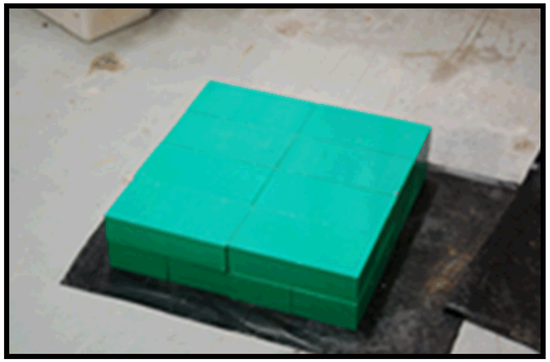


Laboratory experiments focused on systems with 0, 3, or 16 lead bricks

3 lead brick foundation

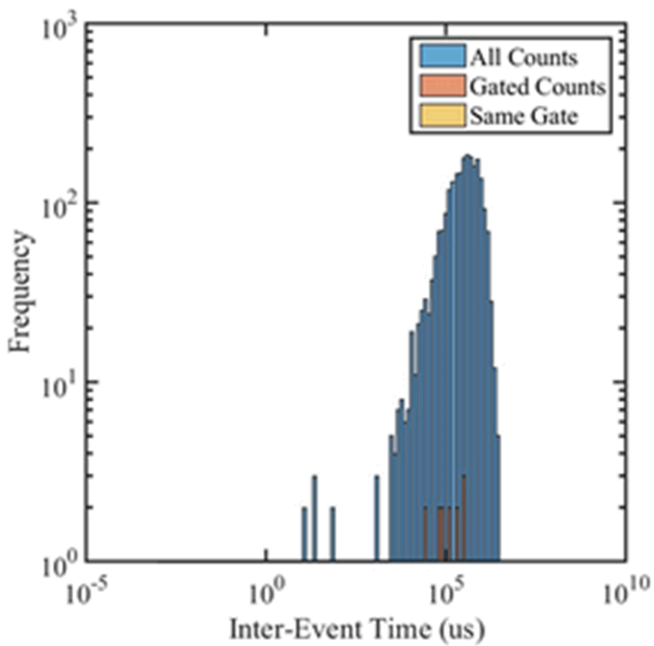


16 lead brick foundation

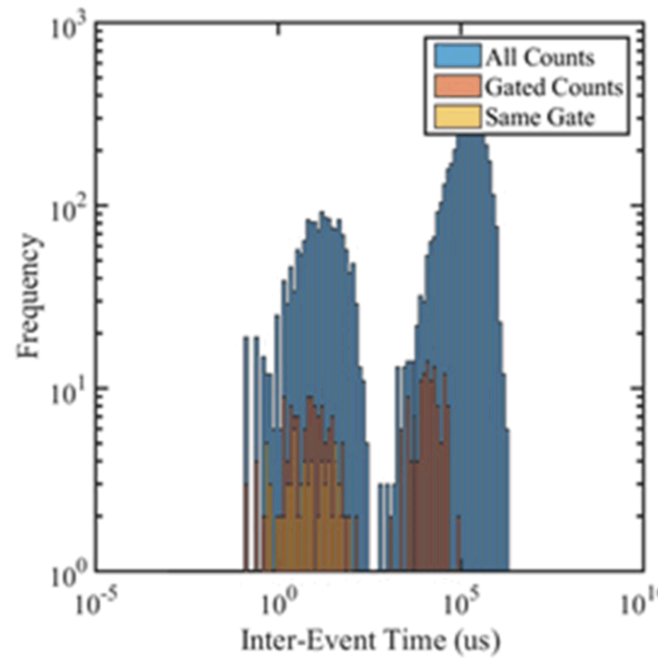


Laboratory experiments demonstrated the presence of a lead target generated neutrons in coincidence with detected muons

Neutron detector with no lead and raised above floor



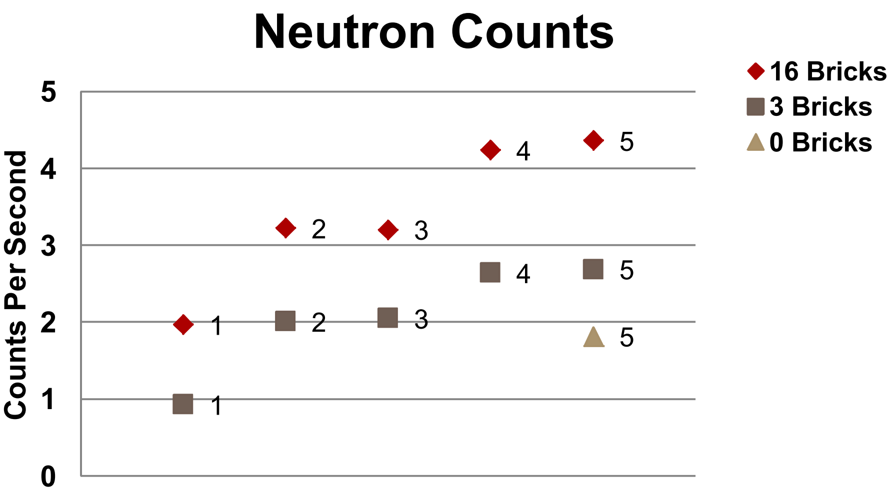
Neutron detector resting on 32 lead bricks (40 cm × 40 cm × 20 cm)

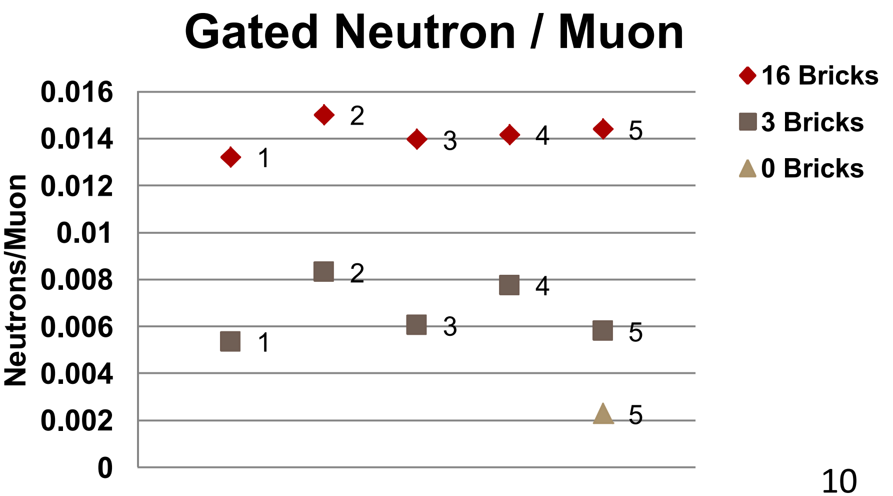


Experiments around the Sandia campus show this technique creates a reasonable neutron source with reduced temporal/spatial variance

Measurement locations at Sandia (617 ft/188 m)

Location #	Location Description
1	Thick-walled enclosure insulated with borated polyethylene
2	Thick-walled concrete room designed to shield accelerator neutrons
3	Office building. Neutron sources kept nearby contribute to background
4	Warehouse. Thin ceiling, shelves stacked with moderating material
5	Outside. 12 meters from nearest structure, sitting on gravel





Muon detection generates a 350-microsecond gate for counting neutrons

A field trip to Bear Valley, CA demonstrated large elevation effects may still be difficult to constrain

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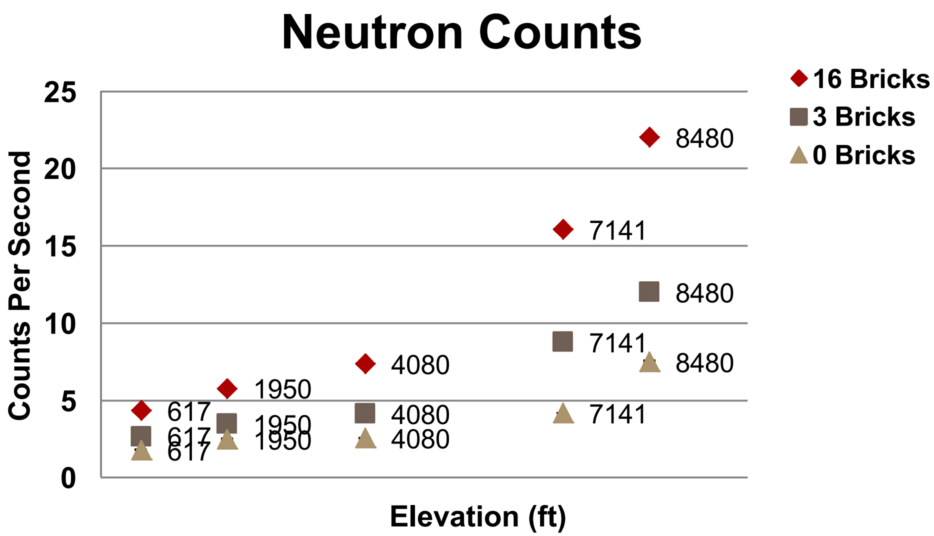
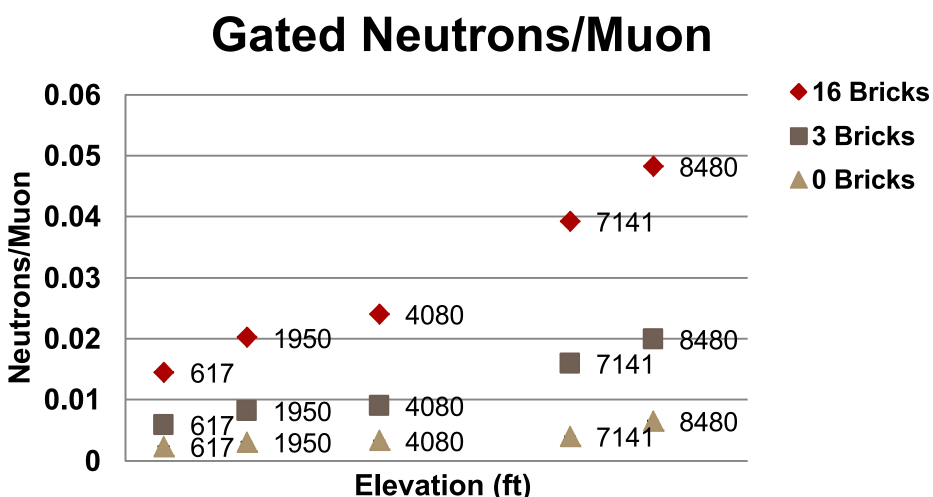
Measurement locations and elevations

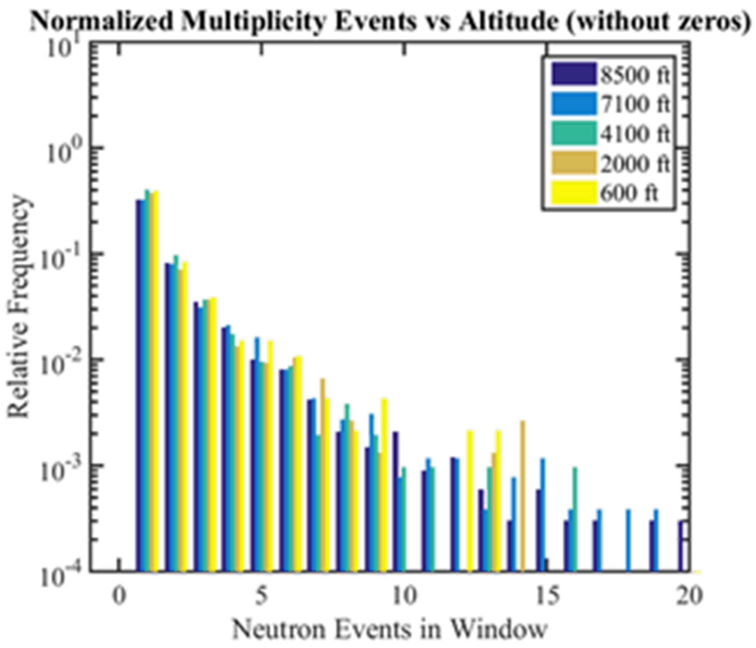
Elevation	Location Description
617 ft (188 m)	Sandia campus, Livermore, CA
1950 ft (594 m)	Chatom Winery, Vallecito, CA
4080 ft (1244 m)	Arnold, CA
7141 ft (2177 m)	Bear Valley, CA
8480 ft (2585 m)	Bear Valley Ski Resort hill



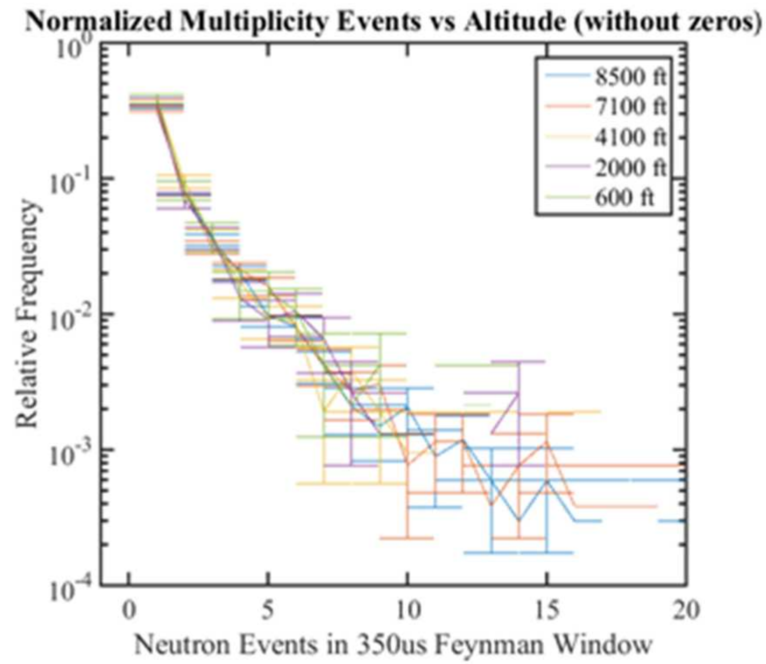


For multiplicity detectors, Feynman histograms may provide a more stable status-of-health tool

Performance seems fairly stable for low-multiplicity events…



…when counting statistics are considered, the uncertainty is large



Conclusions

- Using tagged muons to generate a source term for detector calibration and status-of-health checks looks promising
  - Reasonable neutron production rates
  - Muon tagging reduces temporal and spatial variance
- Simple metrics for small elevation changes
- More sophistication may be required for large elevation changes
- Ongoing work: optimization of geometry
- Future work: intentionally “breaking” detector to make sure techniques are sensitive to changes in the neutron detector

Acknowledgments

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