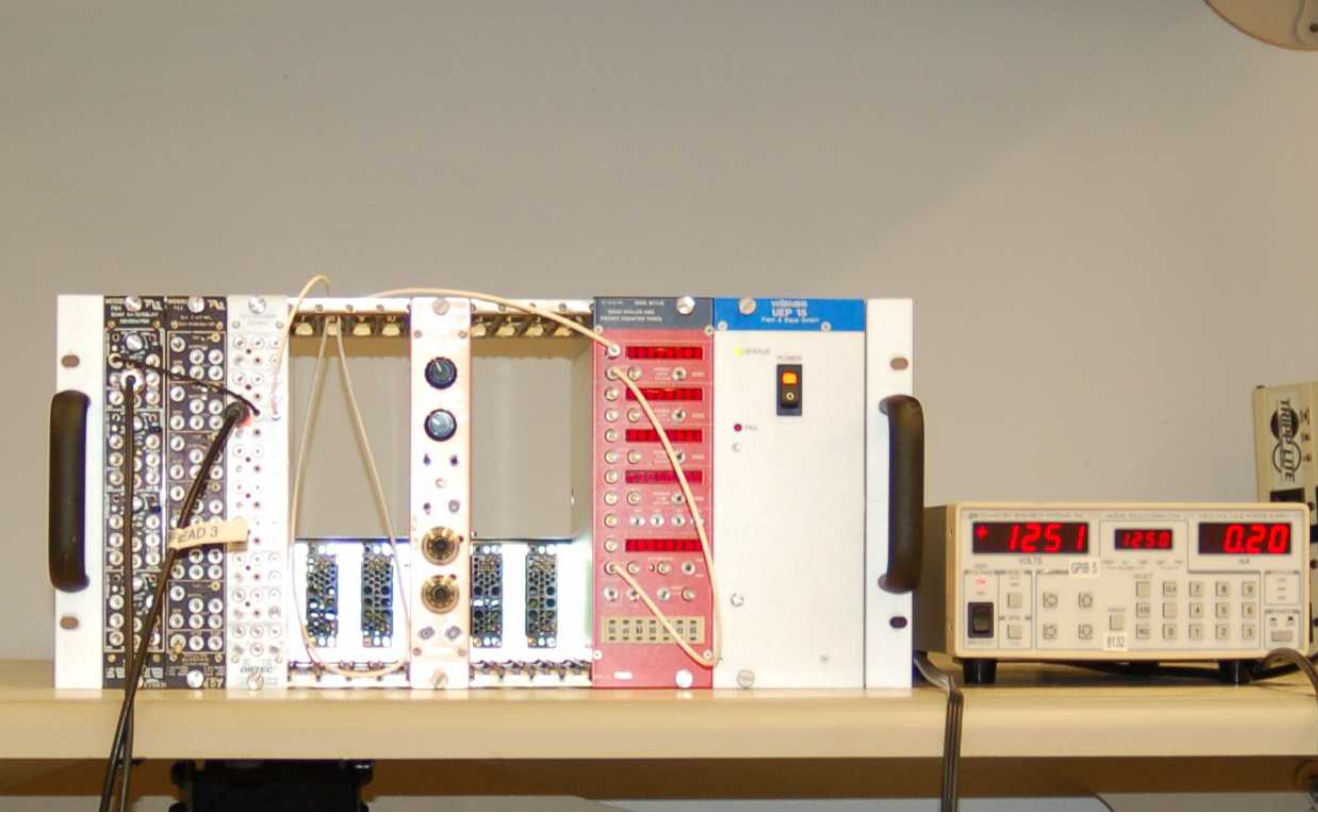


Calibration of MC-15 Neutron Multiplicity Detector via Muon-Induced Neutrons

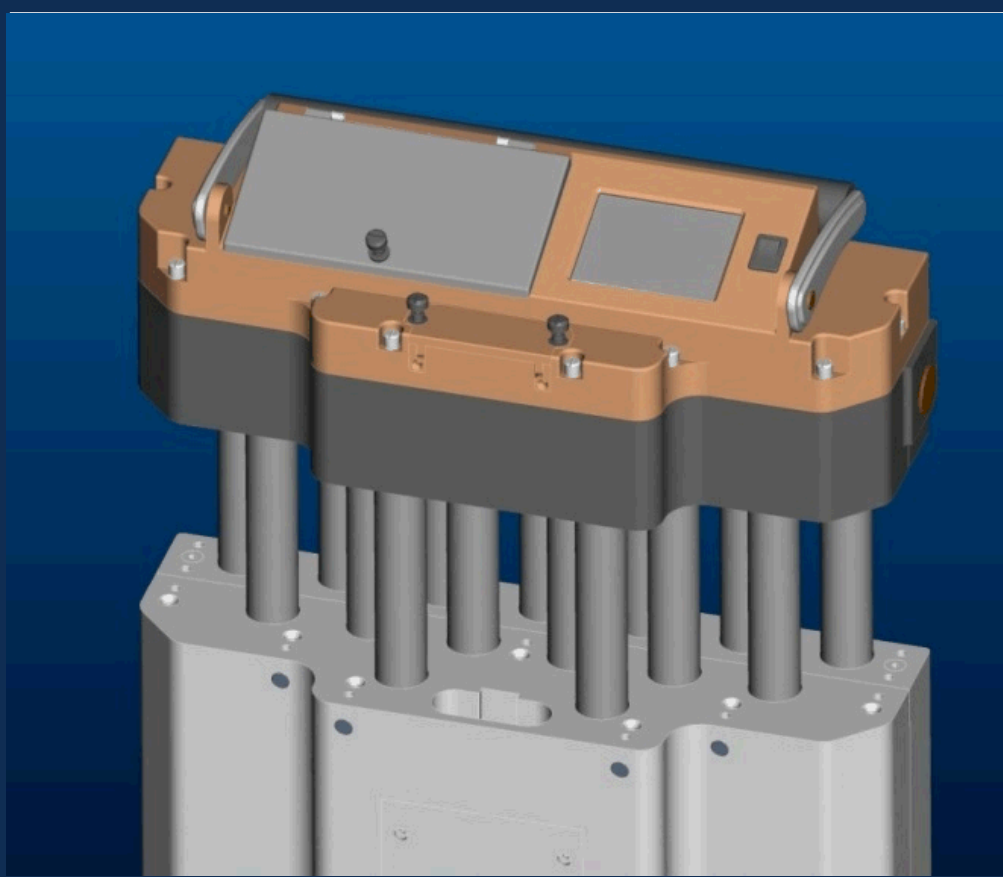
Interns: Tom Grimes, Kelsey Reamer Advisors: Scott Kiff, Pete Marleau
July 29th 2015



Abstract

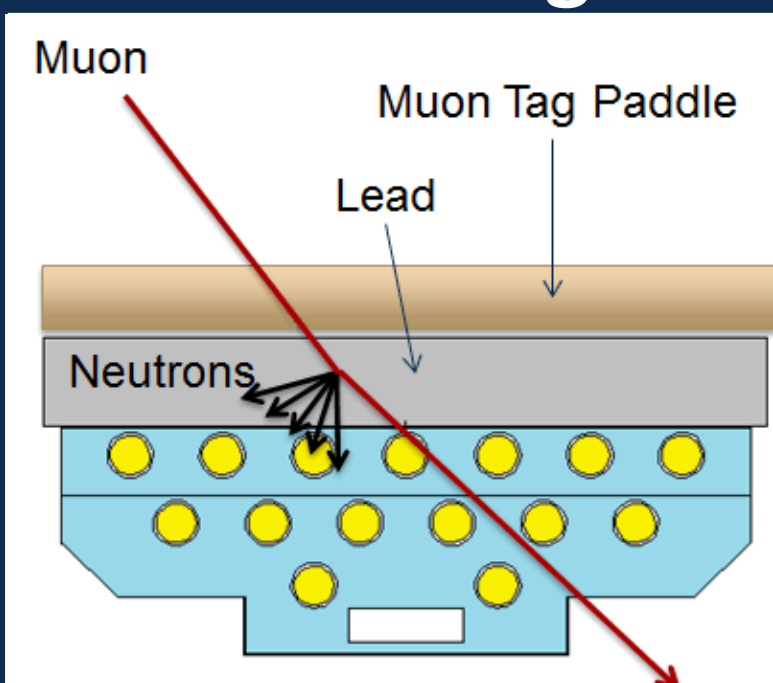
MC-15 detectors (so named for being a 15 tube neutron multiplicity counter) are the next generation of neutron detectors tasked with identifying special nuclear material encountered in the field. Because they will be deployed to locations without neutron sources readily available, being able to ensure that they are in calibration is of paramount concern. By using muon spallation reactions in lead to generate the neutrons, it is possible to create a detectable neutron source with great enough magnitude and distinctive multiplicity distribution to check the calibration of the detectors without distributing isotope sources to detector staging locations. By using the muon tag paddle, it should be possible to compensate for the variation in the natural background as a function of location

MC-15



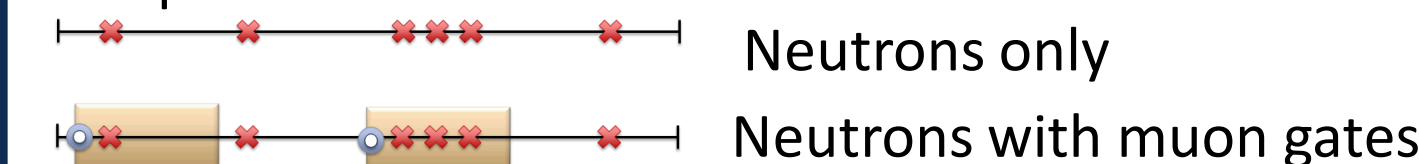
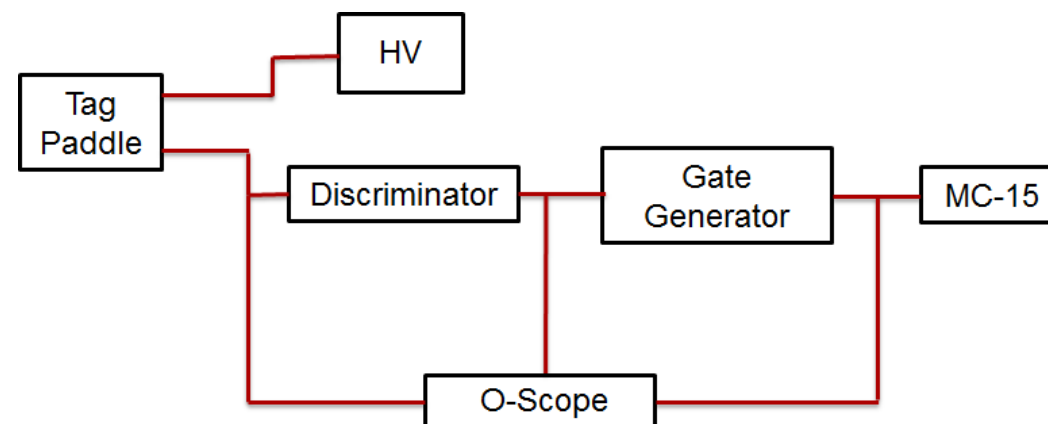
- Detector splits along center plane to become more sensitive to thermal neutrons
- Cadmium shielding used to reduce detection of neutrons thermalized elsewhere in the room
- High Density Poly Ethylene matrix used to thermalize neutrons in the detector
- ³He neutron capture reaction used as the detection reaction in the tubes

Tag Paddle Electronics

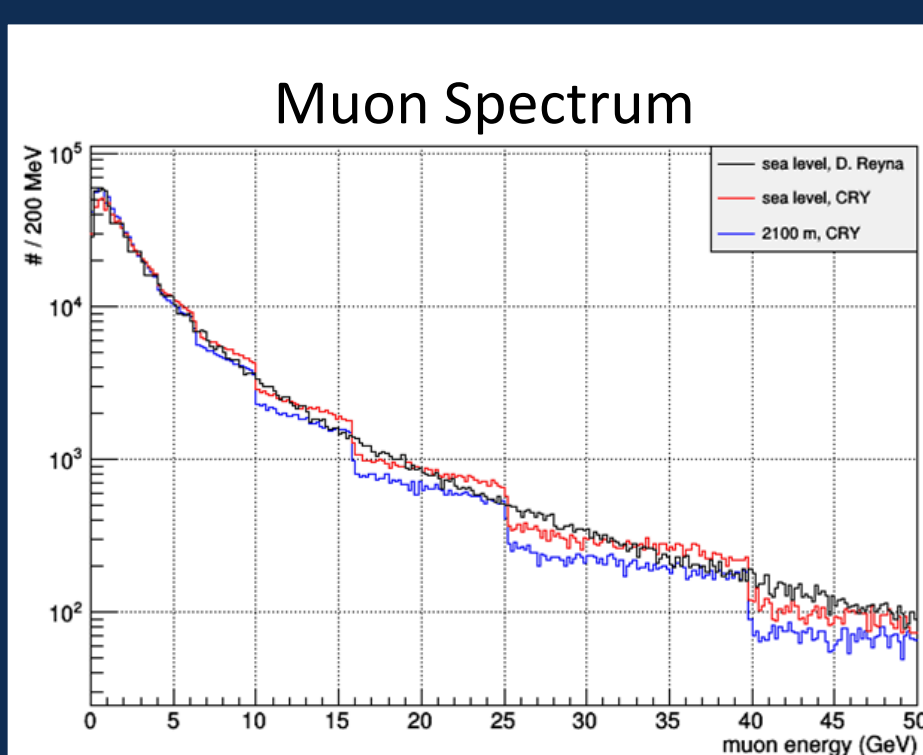


- Muons striking the tag paddle are the muons most likely to generate neutrons that are detected
- Using the muon tags to make gates, neutron detections/muon can be measured regardless of muon activity

- Discriminator creates a logic pulse on rising edge of muon signal
- Gate generator converts this pulse into MC-15 input



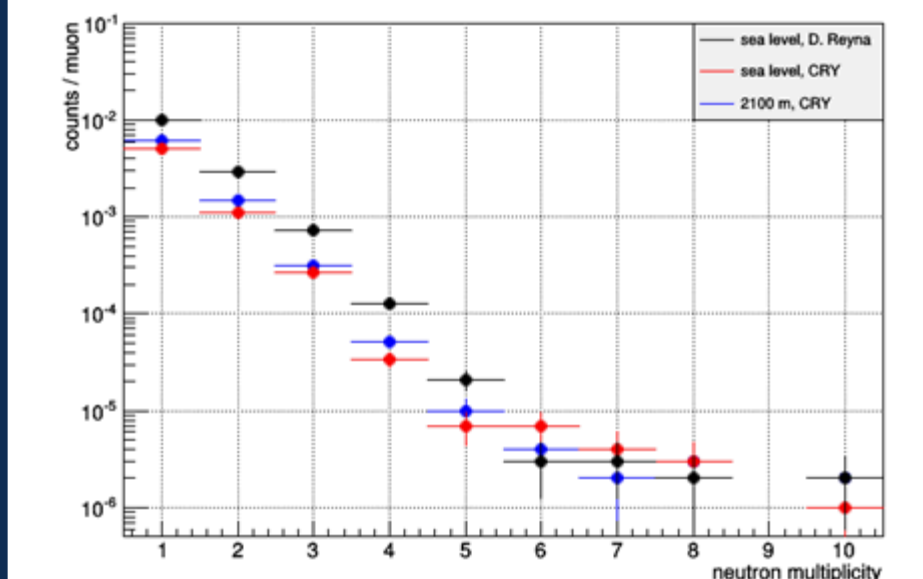
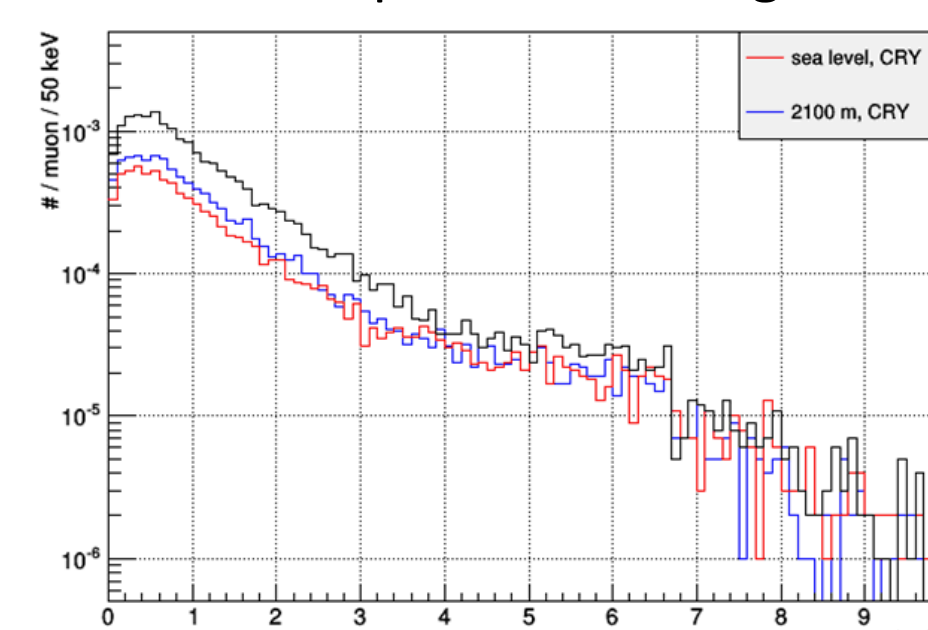
GEANT4 Simulations [1]



- Simulated using Cosmic Ray Shower Library (CRY) as well as 8127 in-house models
- High end of the spectrum responsible for most of the high multiplicity events
- Spectrum changes with overburden

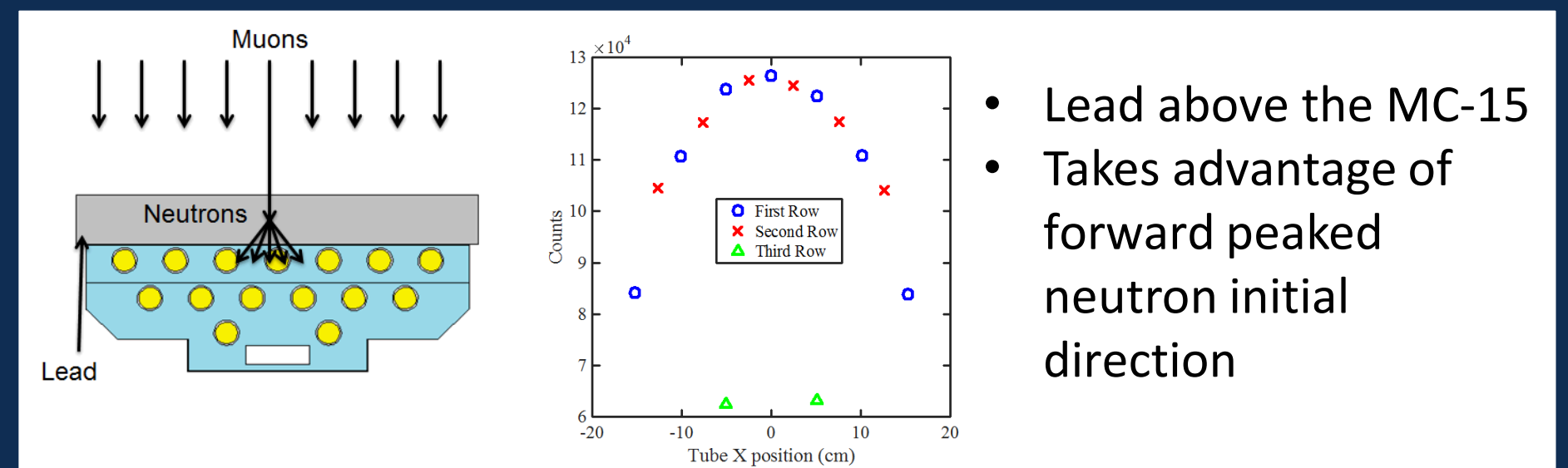
- 4" of lead were modeled
- Neutrons exiting the bottom surface were tallied

Neutron Spectrum Exiting Lead

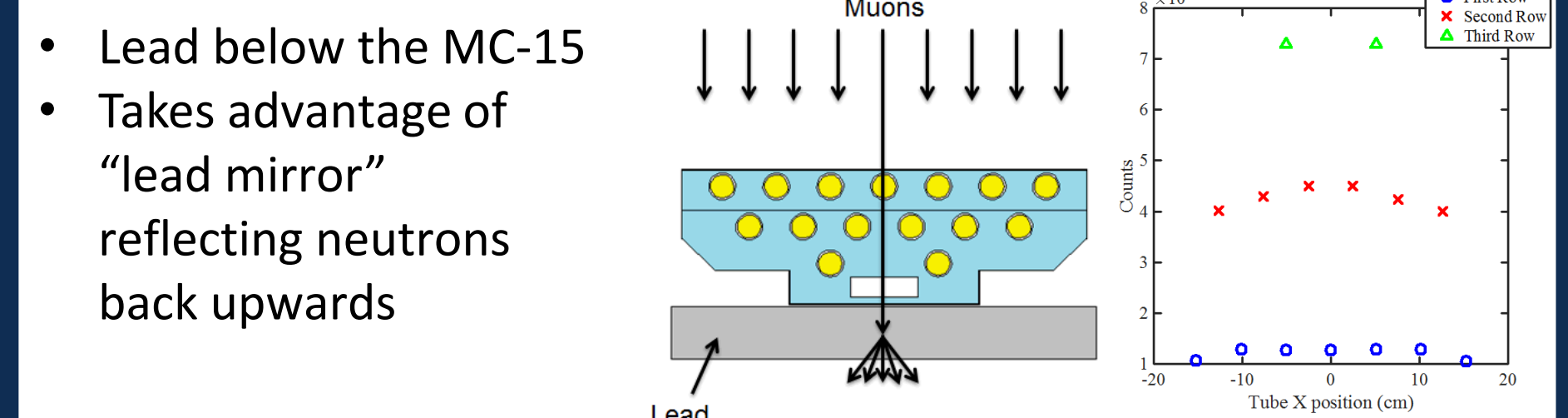


- An idealized (not the MC-15) detector was modeled in GEANT
- Simulations showed the possibility for very high multiplicity events

MCNPX-Polimi Simulation



- Lead above the MC-15
- Takes advantage of forward peaked neutron initial direction



- Lead below the MC-15
- Takes advantage of "lead mirror" reflecting neutrons back upwards

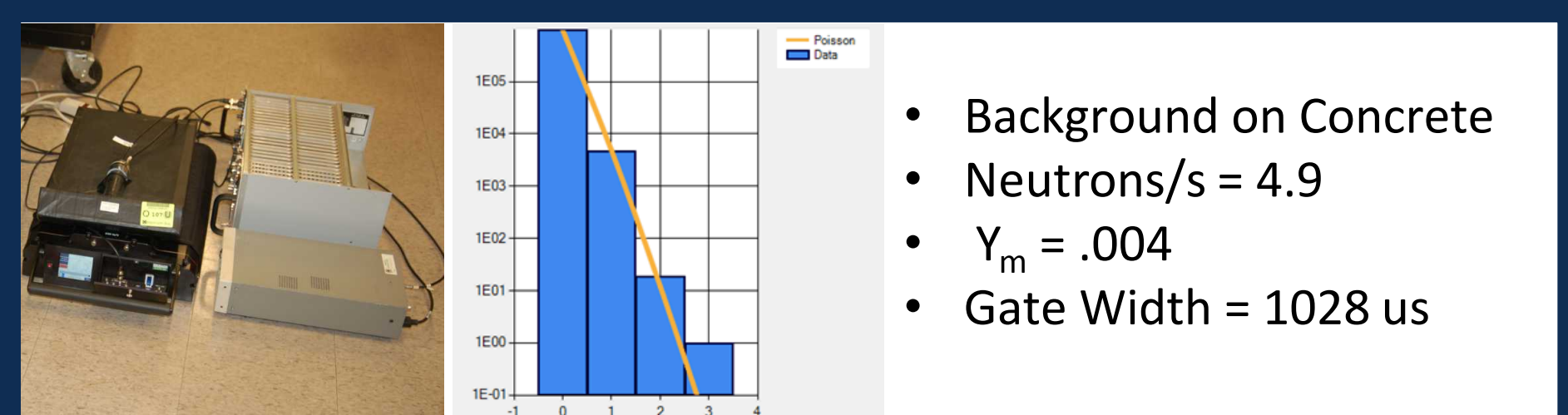
- Both scenarios allow the vast majority of neutrons to be detected in a 100 us gate
- In the orientations modeled, the MC-15 underneath the lead generates significantly more counts

Raw Count Rates

Description	Total Neutrons	Total Muons	Neutrons in 100us gate	CPS in Gate / CPS out of Gate
Background (Forklift)	2255	12203	23	4.21188
MC-15 Below 16"x16"x4" Lead	3686	12518	177	20.097
MC-15 Below 16"x16"x4" Lead + Poly Wrapper	3421	12485	89	10.67
MC-15 Above 16"x16"x4" Lead	4319	11938	123	12.2
MC-15 Above 16"x16"x8" Lead	5704	12192	279	21.039



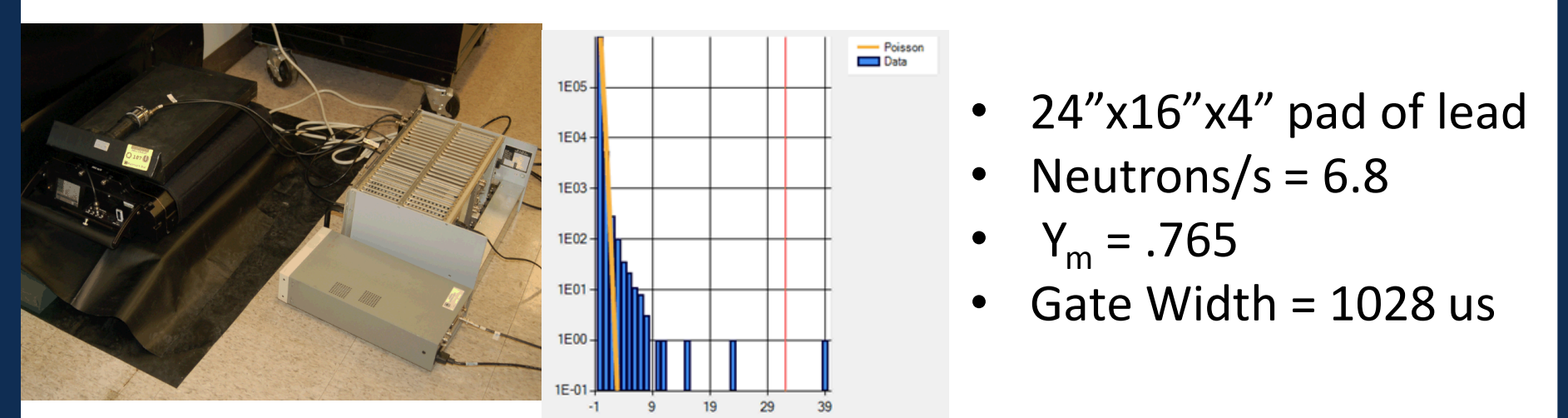
Feynman-Y



- Background on Concrete
- Neutrons/s = 4.9
- $Y_m = .004$
- Gate Width = 1028 us

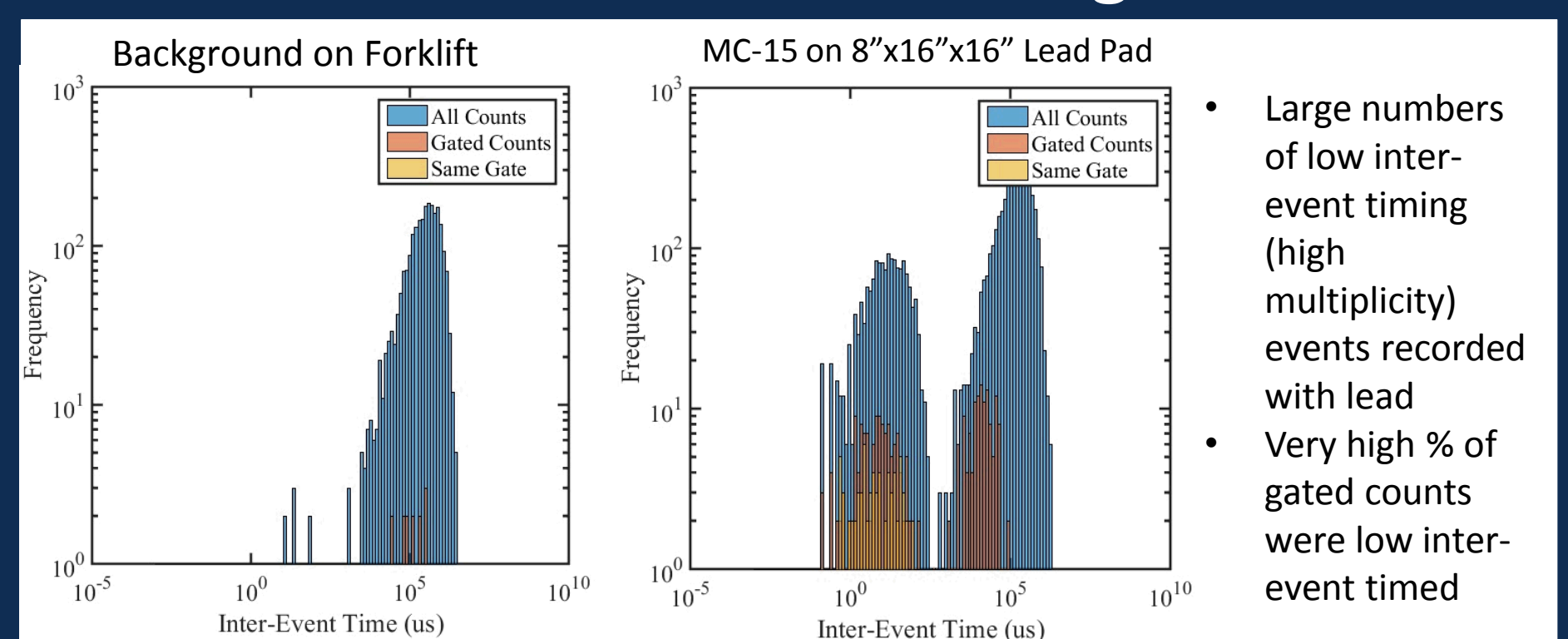


- ²⁵²Cf at 30cm
- Neutrons/s = 290
- $Y_m = .072$
- Gate Width = 1028 us



- 24"x16"x4" pad of lead
- Neutrons/s = 6.8
- $Y_m = .765$
- Gate Width = 1028 us

Inter-Event Timing



- Large numbers of low inter-event timing (high multiplicity) events recorded with lead
- Very high % of gated counts were low inter-event timed



Exceptional service in the national interest

[1] Marleau, Peter "Novel In-situ Calibration Method for Neutron Detectors without the use of Radiological Sources" Sandia National Lab 6-2-2014
[2] Kiff, Scott "MC-15: The Next-Generation Neutron Multiplicity Counter" Sandia National Lab 7-2-2015