The Neutron Multiplicity Meter at Soudan

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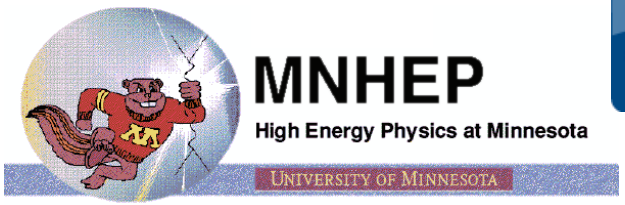
The Neutron Multiplicity Meter (NMM) Collaboration



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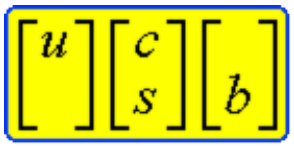

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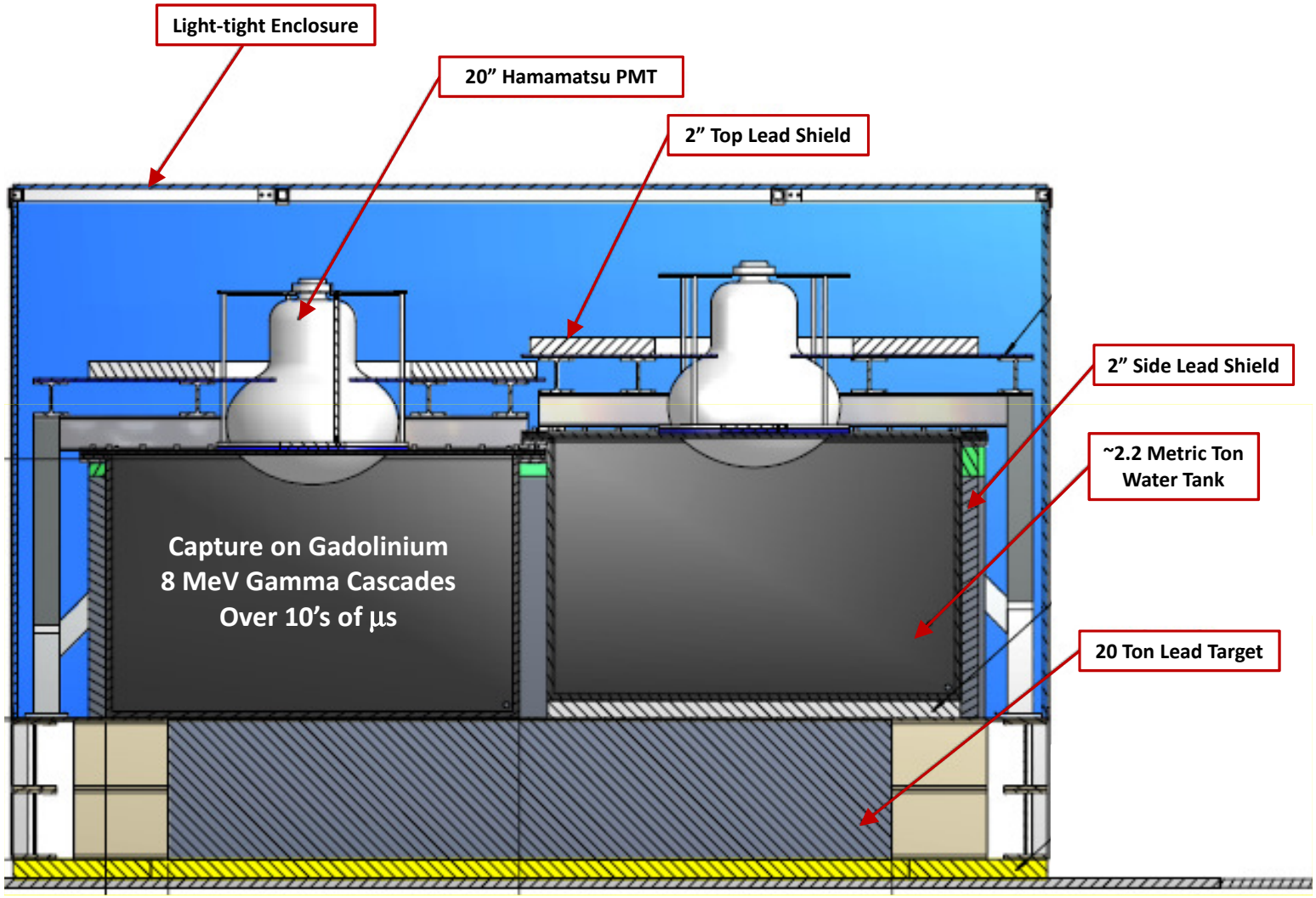
The Neutron Multiplicity Meter



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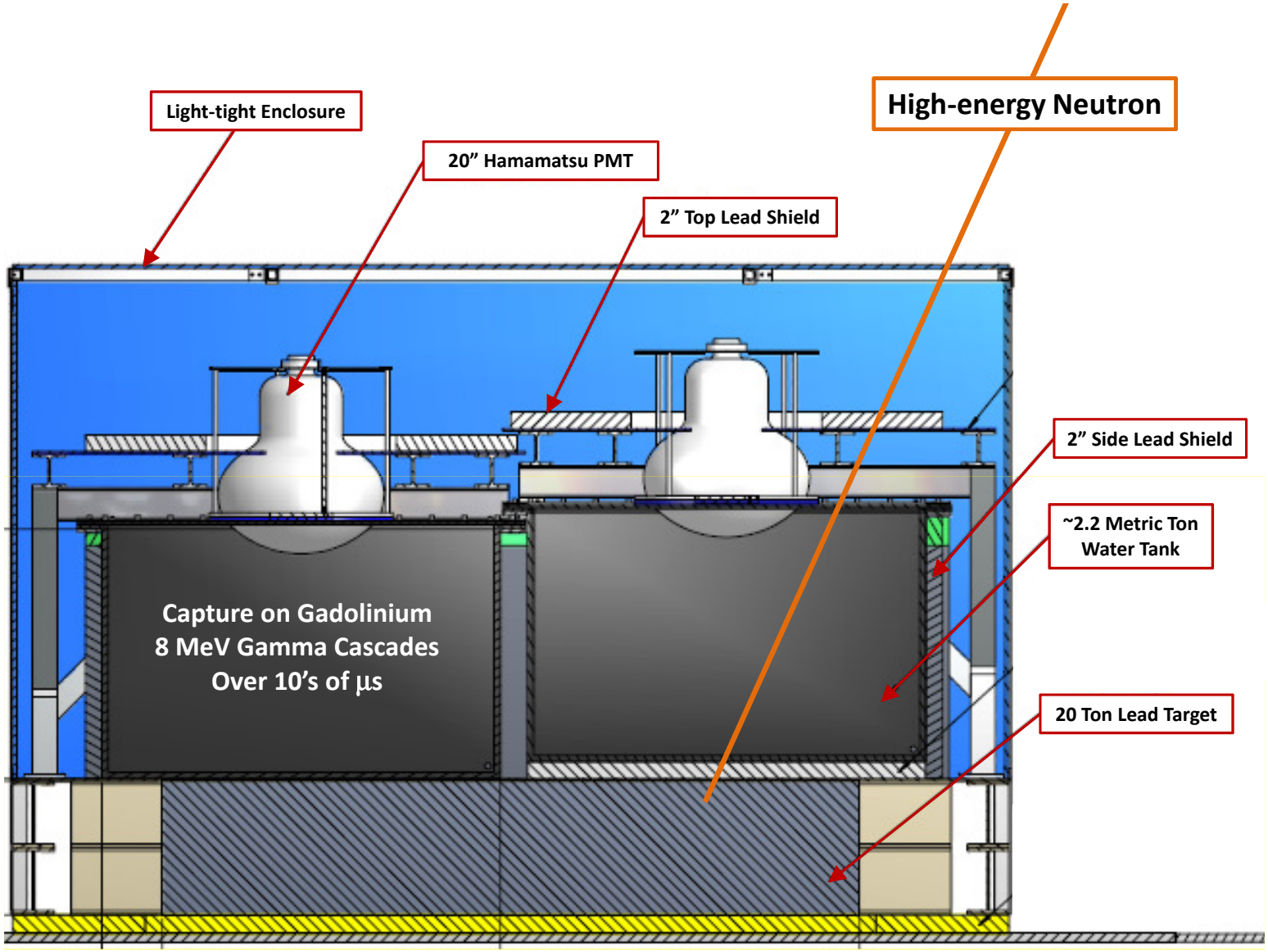

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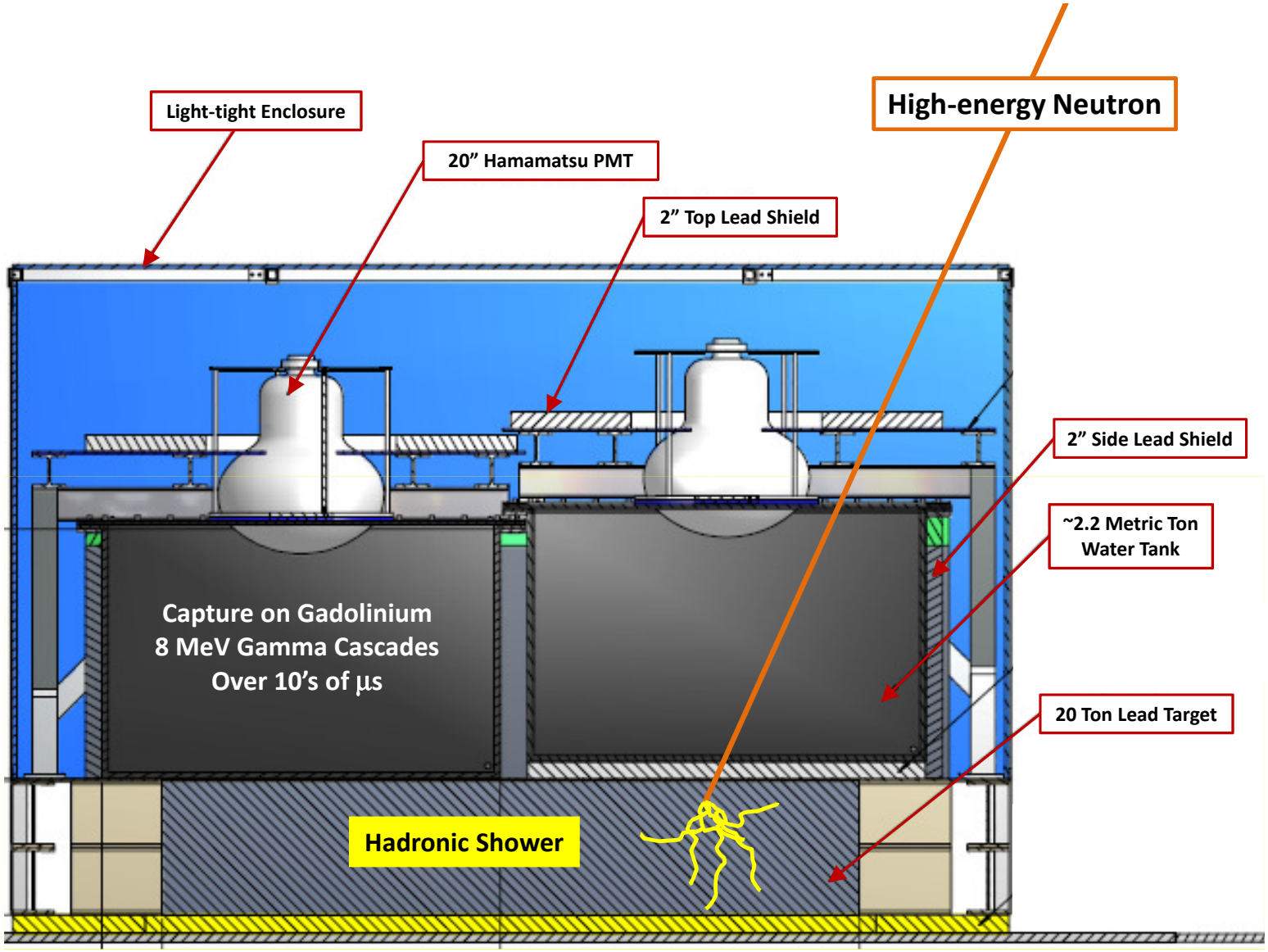
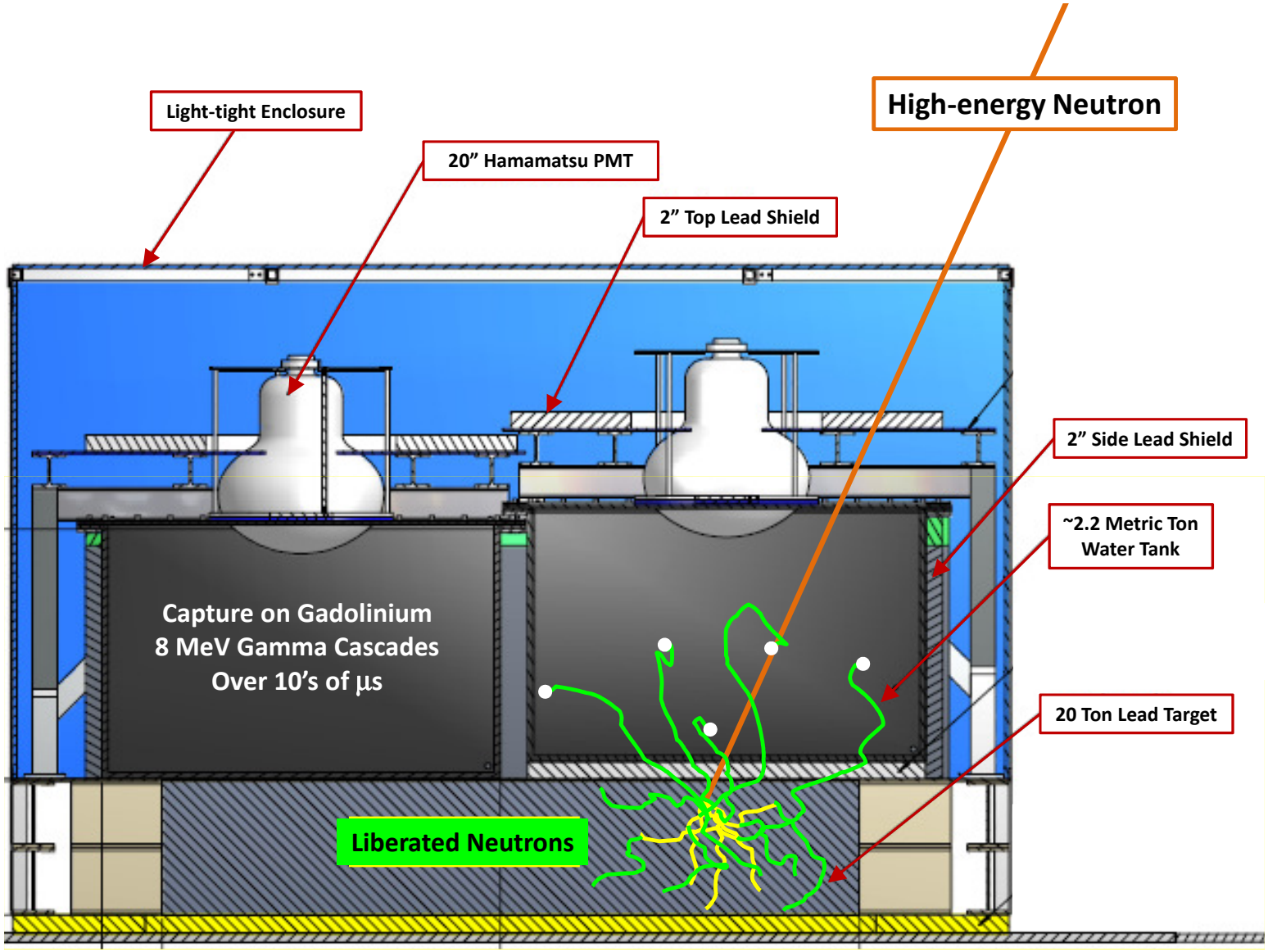


The Neutron Multiplicity Meter



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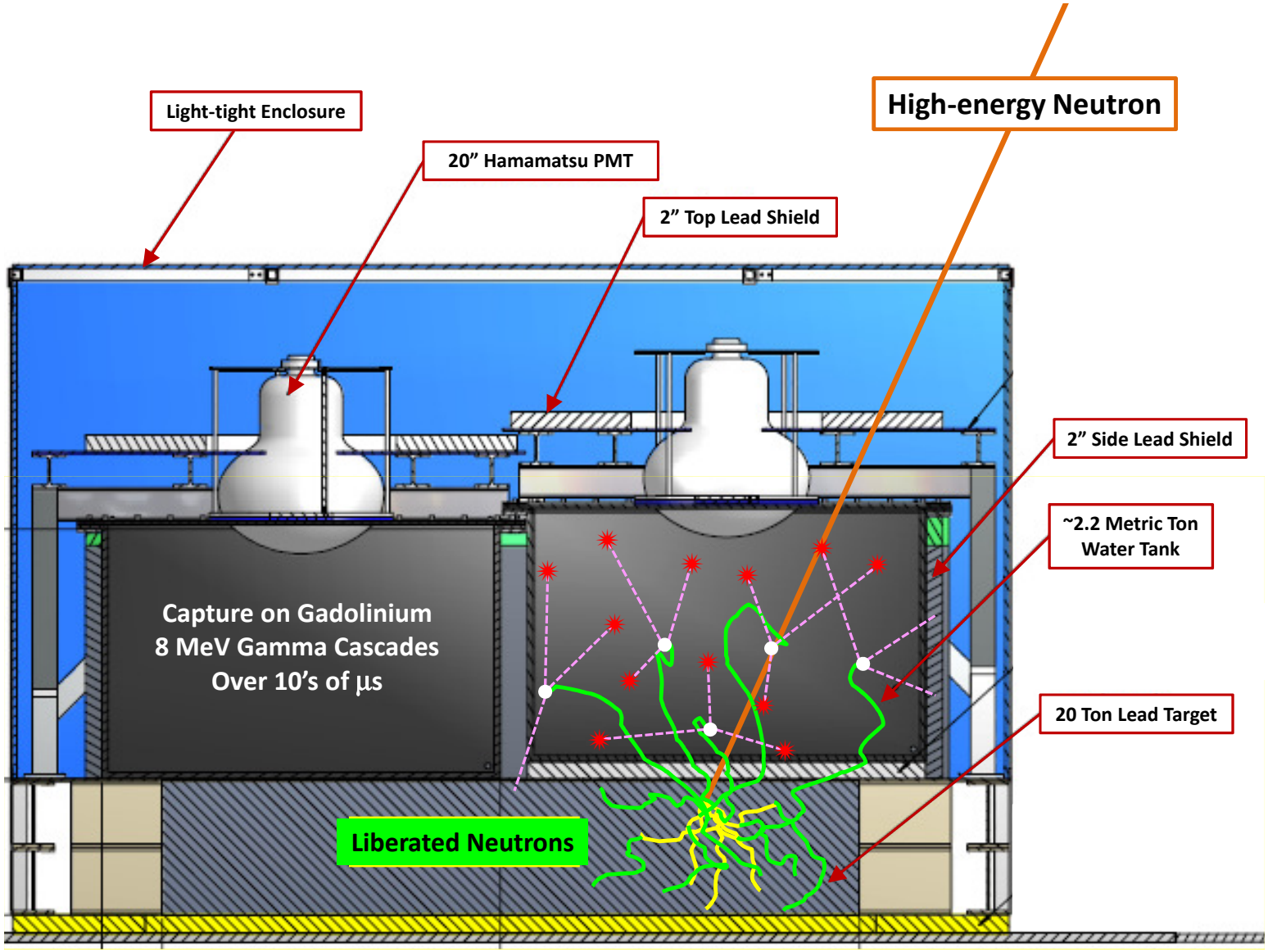
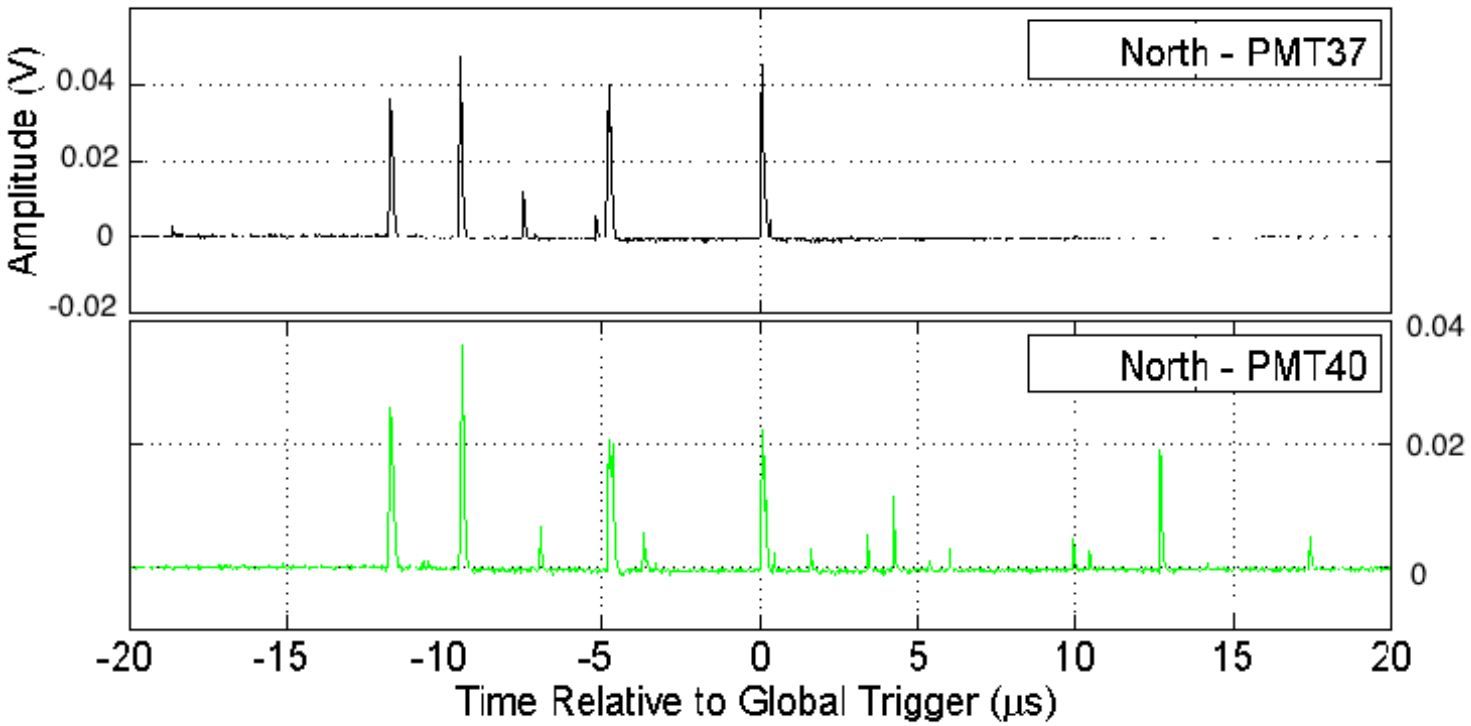


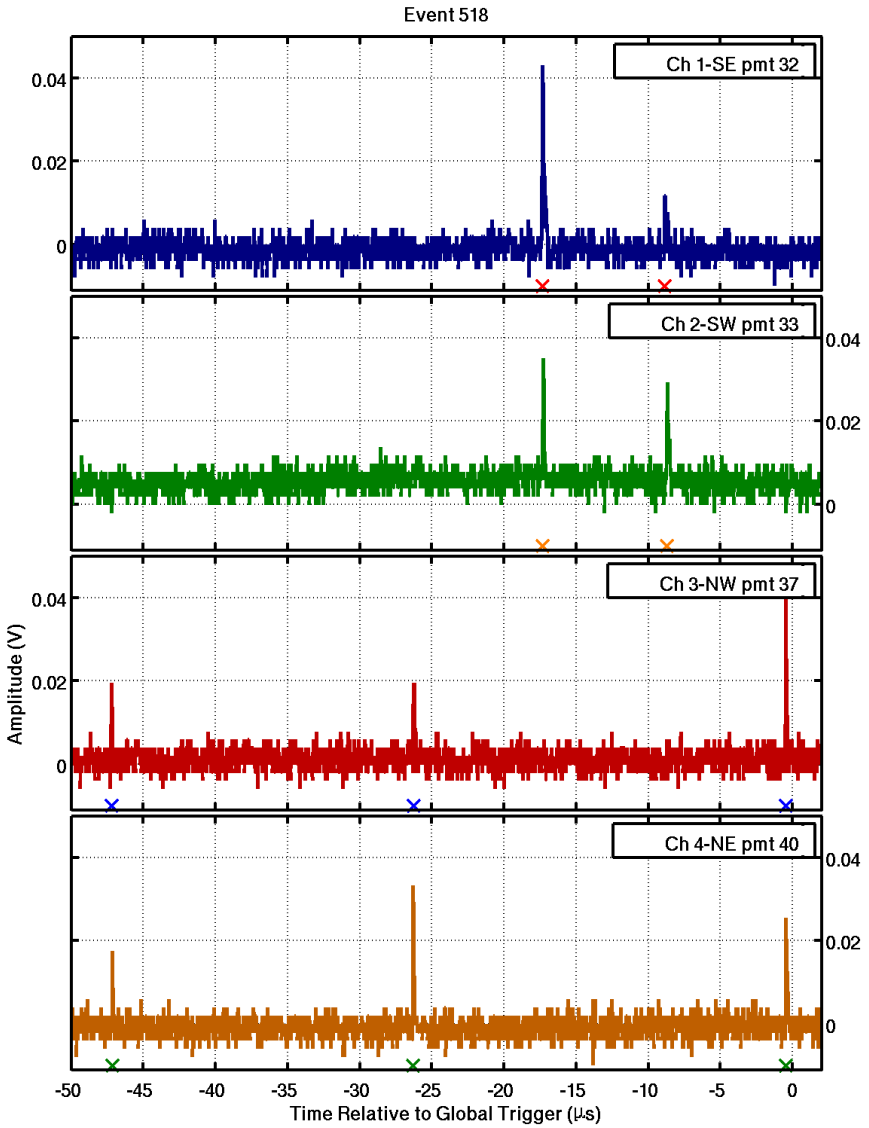
Candidate Signal Event

- Relatively large coincident pulse heights.
- Clustered pulse train.

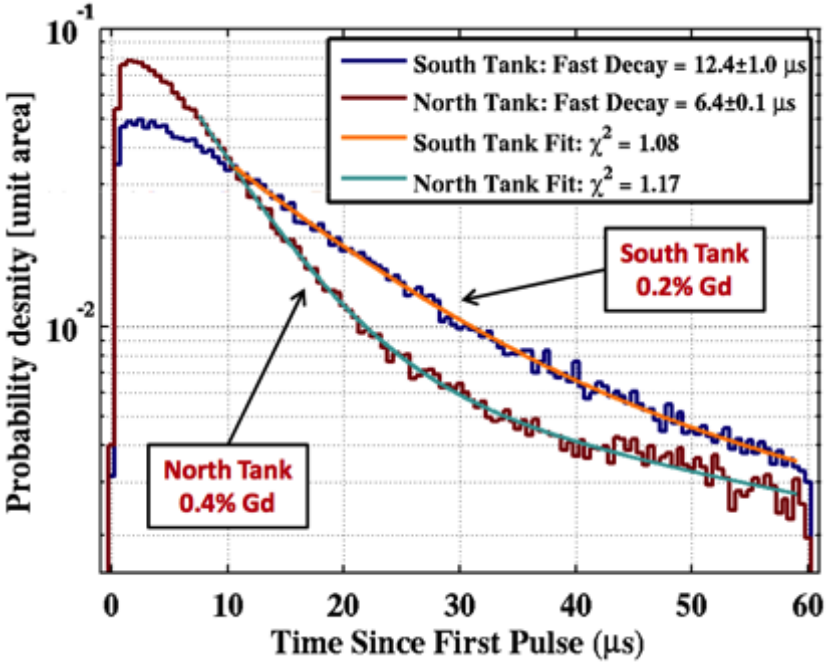


Gamma Background

- Relatively small coincident pulse heights.
- Truly random timing.
- Usually spread between tanks.

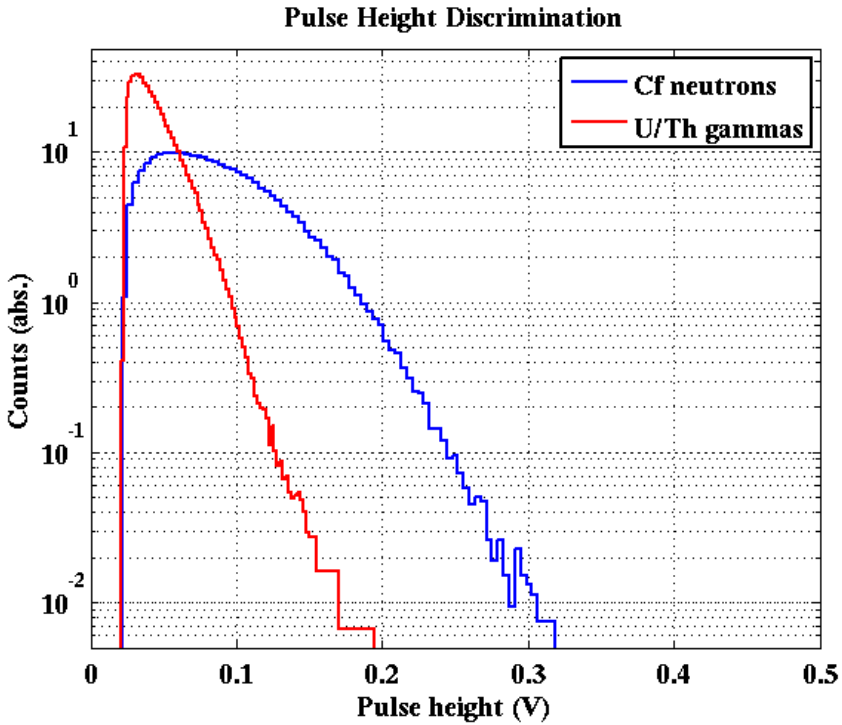


Gamma Background Rejection



Discrimination based on pulse timing.

- U/Th gammas $\sim$ 1 per 2 ms
- n-Captures cluster toward beginning of event and the characteristic time depends on Gd concentration
- Effective partially by the event trigger condition.



Discrimination based on pulse height.
Use neutron pulse-height likelihood.

Pulse-height Discrimination

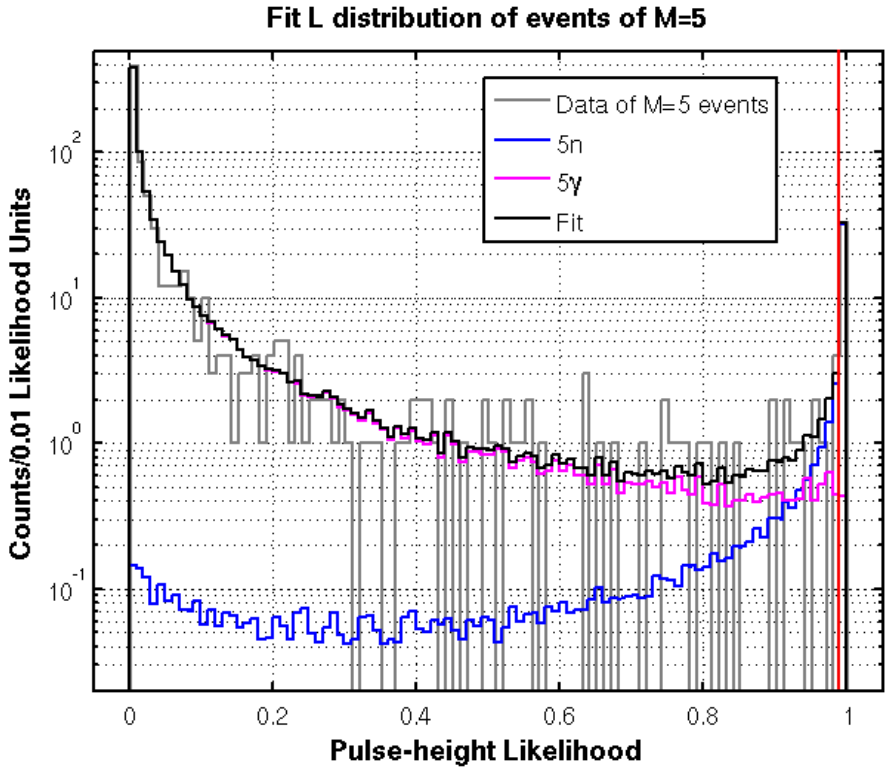
- Pulse height distributions for neutron and photon, $P_n(A)$, $P_g(A)$
- likelihood for all-neutron and all-gamma,

$$n \equiv \prod_i P_n(A_i),$$

$$g \equiv \prod_i P_g(A_i).$$

- Define a pulse-height likelihood function

$$L \equiv \frac{n}{n+g}.$$



Multipicity-5 events from ∼6 months data.

- Signal and background components from MCs based on individual neutron and gamma pulse-height distributions from calibration data;
- $\chi^2 = 82.8/94$;
- Indicating the efficiency $\sim 68\%$ and the expected background leakage ~ 0.4 events for a cut $L > 0.99$.

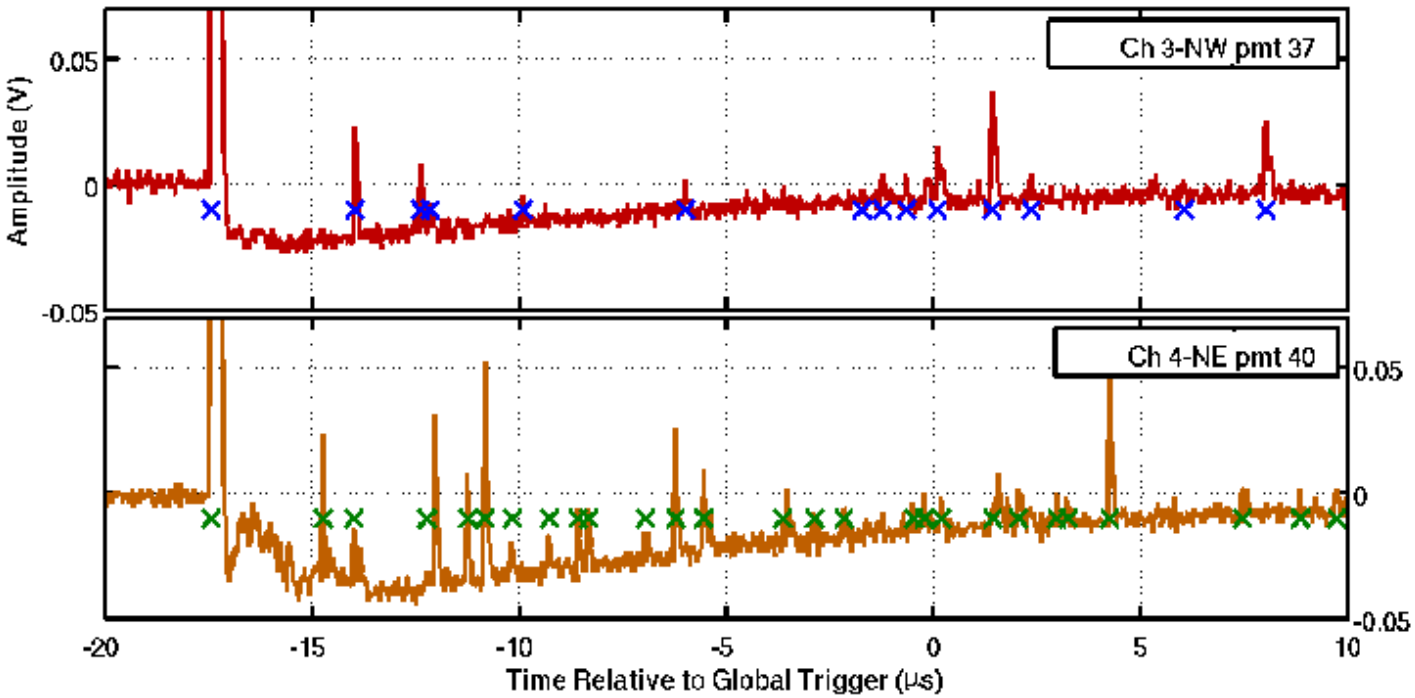
Status of the Experiment

- Two years of data have been taken.
  - Sufficient statistics for a 10% measurement of the underground flux of neutrons at 2000 m.w.e. with energies greater than ~ 50 MeV.
- Working to estimate contributions from all backgrounds to measured multiplicity distribution (and refine cuts as useful)
  - Additional neutron flux created by muons hitting lead target
  - Skewing of multiplicity distribution due to muon or muon-induced shower particles interacting in water tanks
  - Effects of phototube afterpulsing

Muon Background

Large dE/dx events ($> 80\%$ of all recorded events)

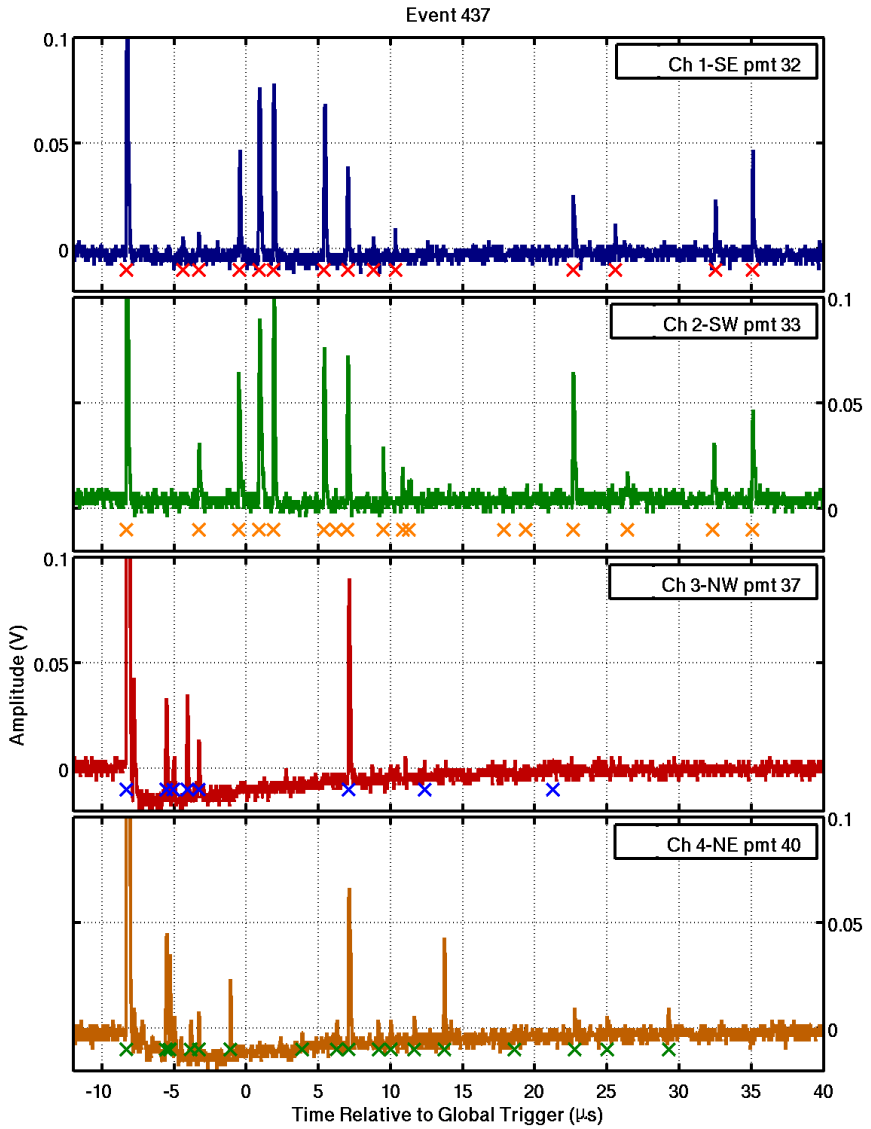
- Large initial pulse with after pulsing
- Large individual channel multiplicities, but few coincidences
- We currently remove muons by cutting events with any hit$>$300 mV.



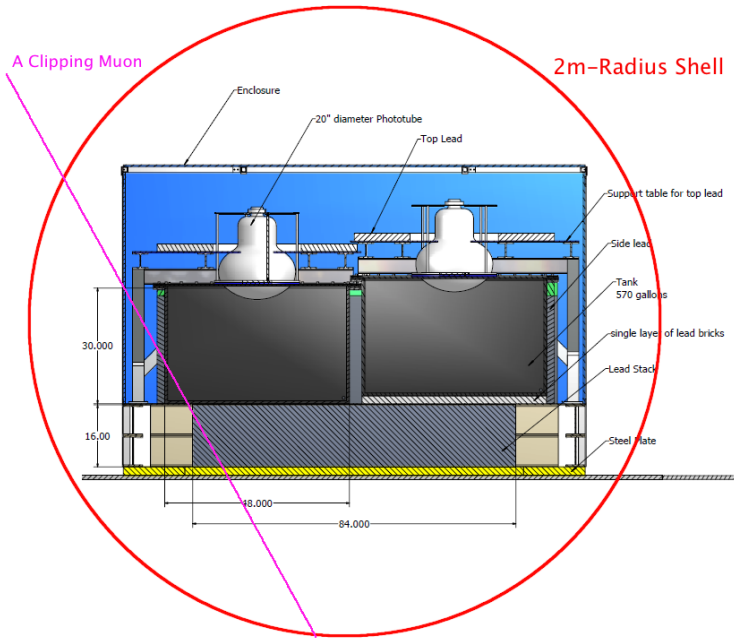
Muon Background

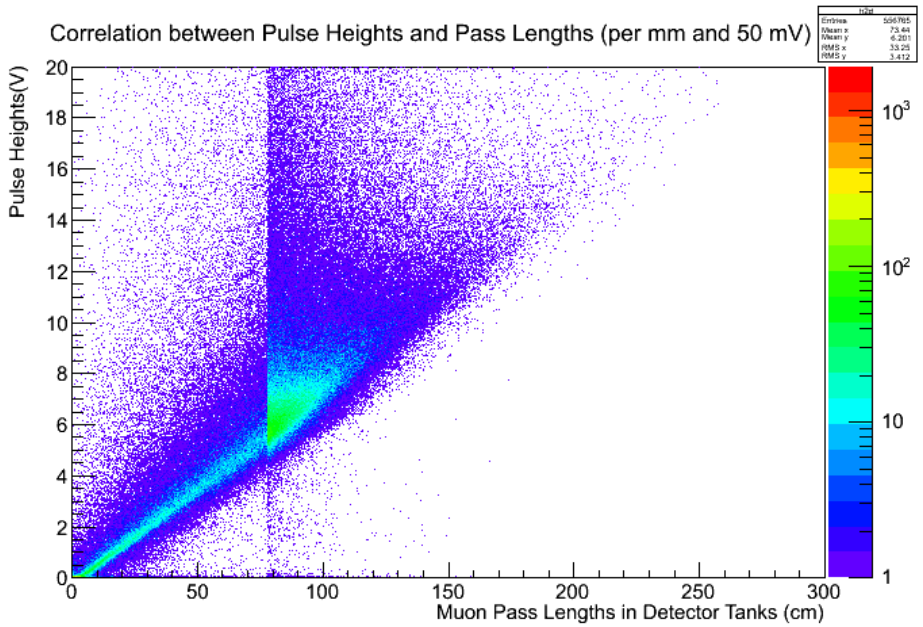
Clipping muons.

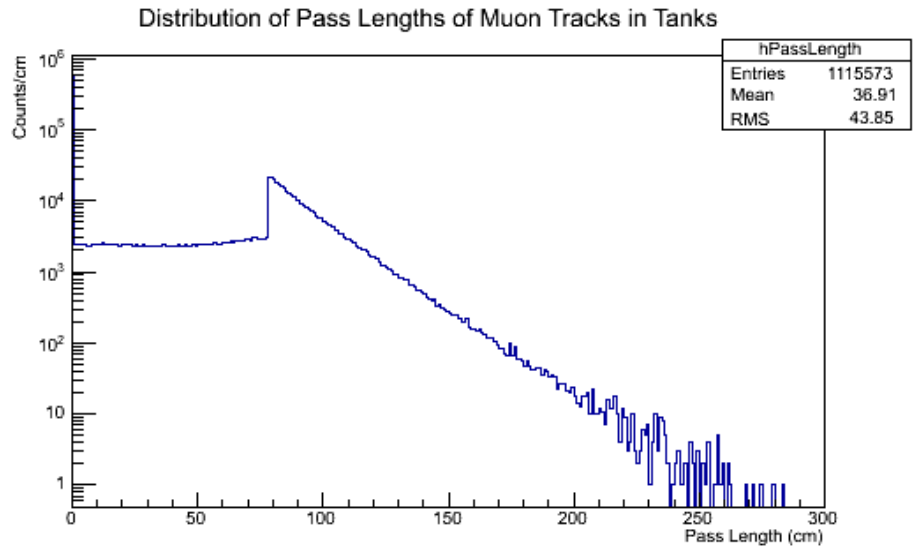
- May or may not be accompanied by large initial pulse
- Some will initiate hadronic showers in Pb
- Low rate of a true indistinguishable background



Muon Background Study (In Progress)







- Information from full-cavern muon detector not instrumented for 2 years of data in hand.
- Clipping muons may cause indistinguishable events.
- Geant4 simulation study with the NMM detector model.
- Using primary muon data from MUSIC/MUSUN simulation results (Angie Reisetter).
- Pre-select muons passing 2m-radius shell around the detector (out of 1E8).

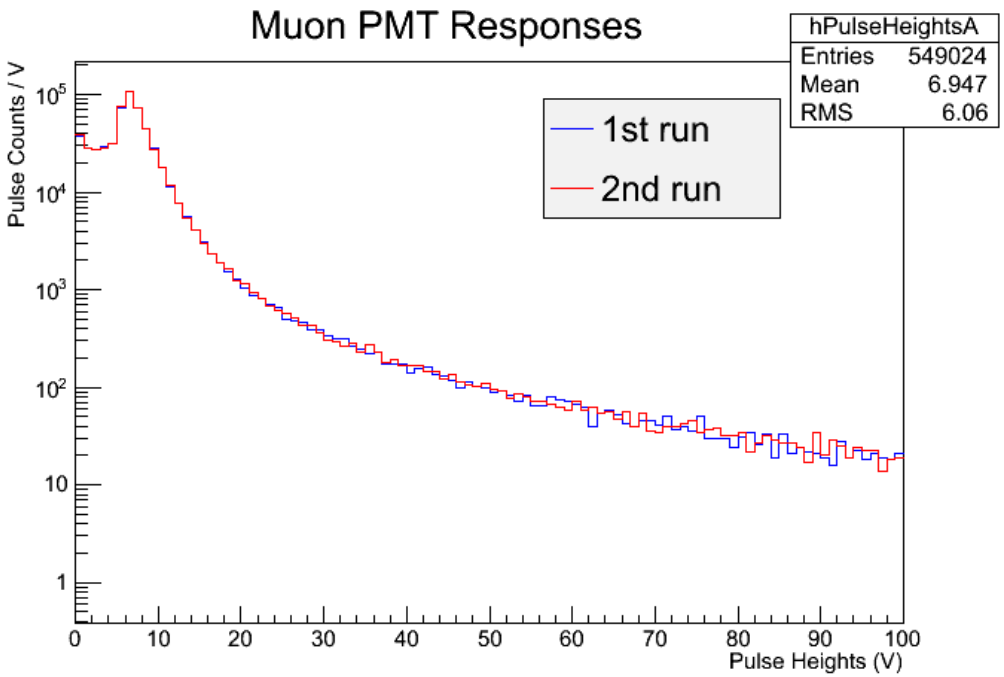
Simulation of Muon Background

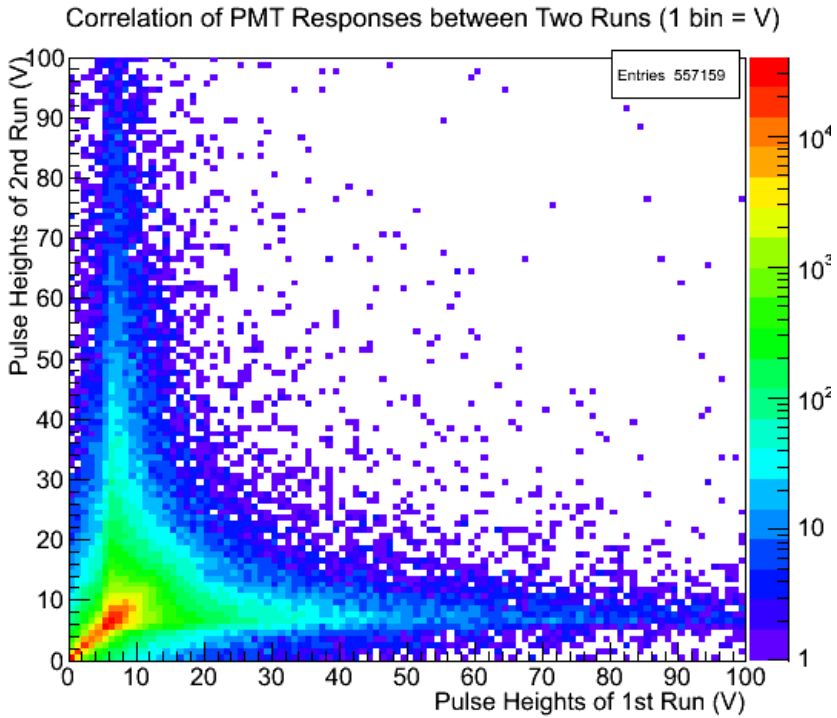
To obtain larger statistics for events passing the muon cut, select muons most likely to give a low-pulse-height response.

- Perform two simulation runs for all 1.1E6 pre-selected muons;
- Examine pulse-height correlations for identical primary muons in the two runs;
- Re-throw (in larger numbers) primary muons that are most likely to cause small pulse heights to study the degree to which clipping muons are confused with neutron captures for high-multiplicity candidate events.
- Re-throw (in larger numbers) the muons that hit the lead target to liberate high-energy neutrons but have low-pulse heights.

Pulse-height Correlations of two simulation runs

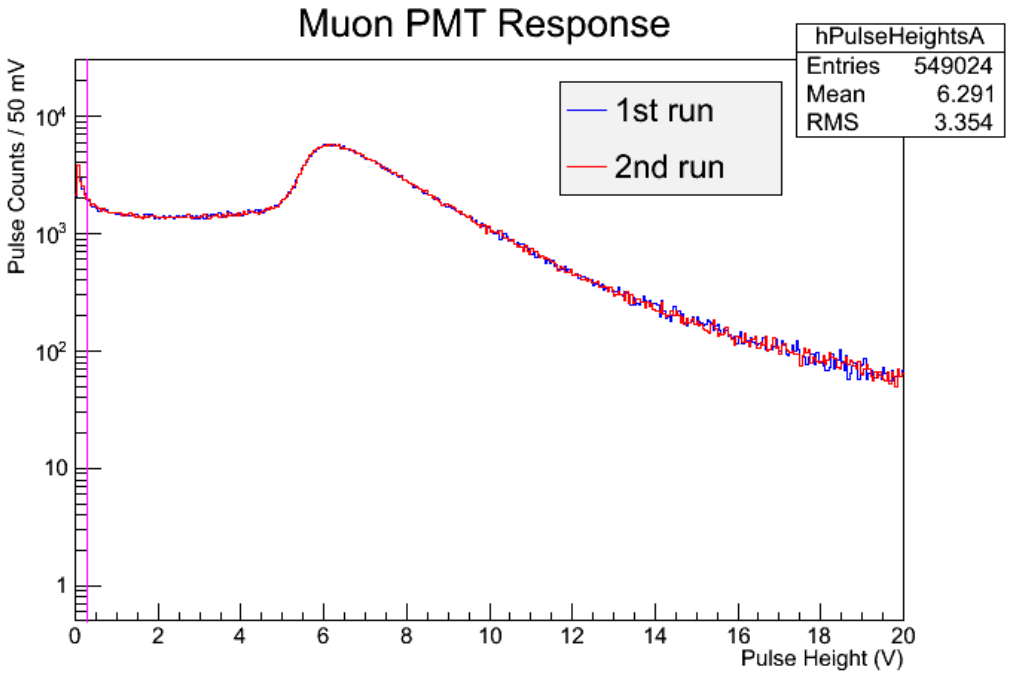
Scale of 100 V

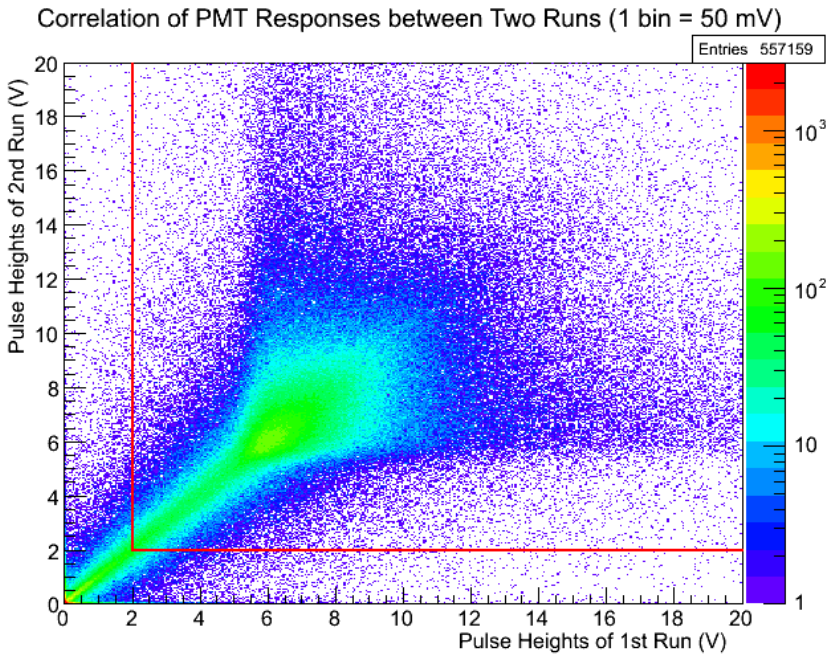




Pulse-height Correlations of two simulation runs

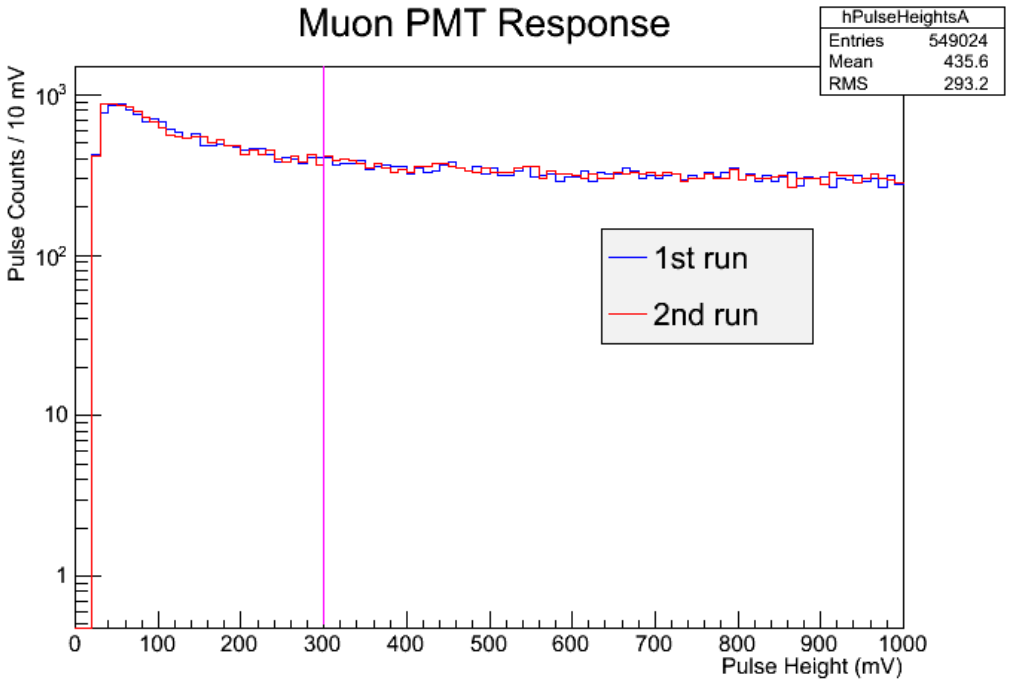
Scale of 20 V

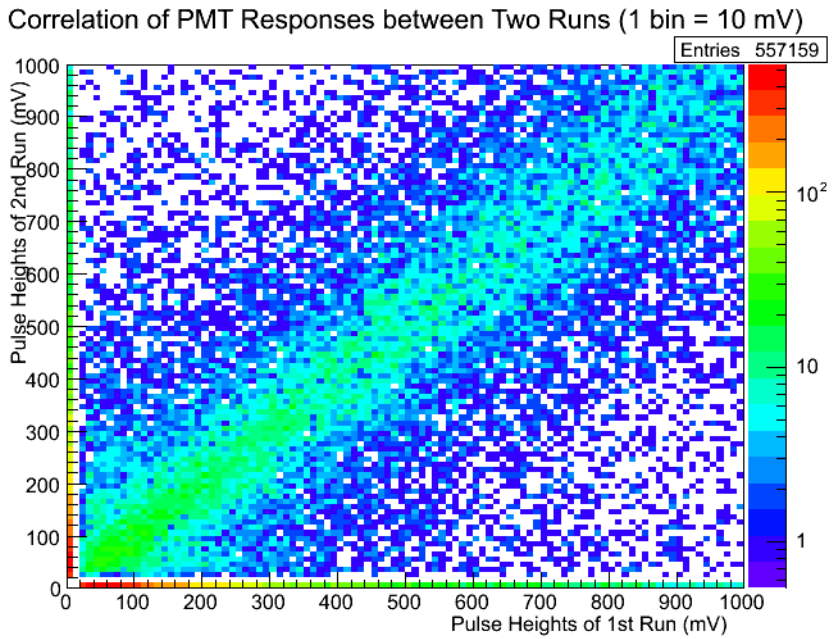




Pulse-height Correlations of two simulation runs

Scale of 1 V





- Large number of ~ 100 mV hits in one MC run with 0 mV in other (from shower) indicates possibly significant skew of multiplicity distribution that will be examined by full MC to be run in future.
- Rethrowing of low-pulse-height muons hitting lead will be done soon.

Summary

- Two years of data have been collected
  - Will provide a 10% measurement of the high-energy-neutron flux entering the Soudan Underground Laboratory.
- Fits to pulse-height likelihood show that the gamma background is negligible for multiplicities > 4.
- Working to estimate backgrounds that might cause systematic skewing of the observed multiplicity distribution (e.g., clipping muons & PMT after pulsing).
- Upgrading readout electronics to allow correlated data acquisition with full-cavern muon detector (see Anthony Villano's talk).

Backup Slides

Combined Timing & Pulse-height Discrimination