Monte Carlo Simulations of Neutron Background in MI-12

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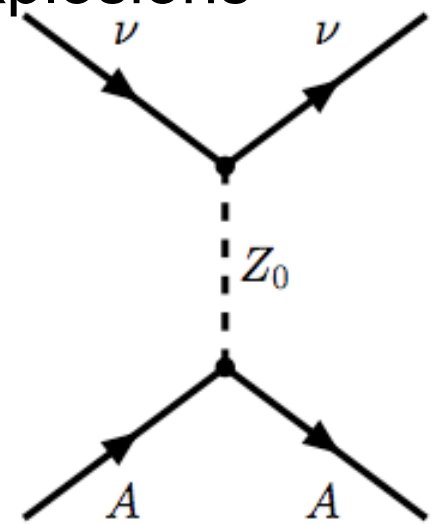
Despite predictions in 1974 that coherent neutral current neutrino-nucleus scattering (NCvAs) is the dominant mechanism for radiating energy away in a supernova, detectors are only just now sensitive enough to make observations of the nuclear recoil energy signature on the order of tens of keV. We look at Monte Carlo simulations of particle interactions from a proton beam hitting the beryllium target in the first stage of the Booster Neutrino Experiment (MiniBooNE) at Fermi National Accelerator Laboratory. Understanding these interactions will lead to an estimation of neutrons in the background of future measurements. Using a model of the target and shielding located at the MI-12 building using G4beamline, we can estimate the flux of neutrons that will be seen in the liquid argon detector as a background to coherent-NCvAs events. Based on the area of the detector above the target, steel, and concrete shielding, a neutron flux of 3.057 neutrons per cm^2 per pulse should be expected out of the concrete shielding 3.5 meters above the target.

Coherent Neutrino Scattering

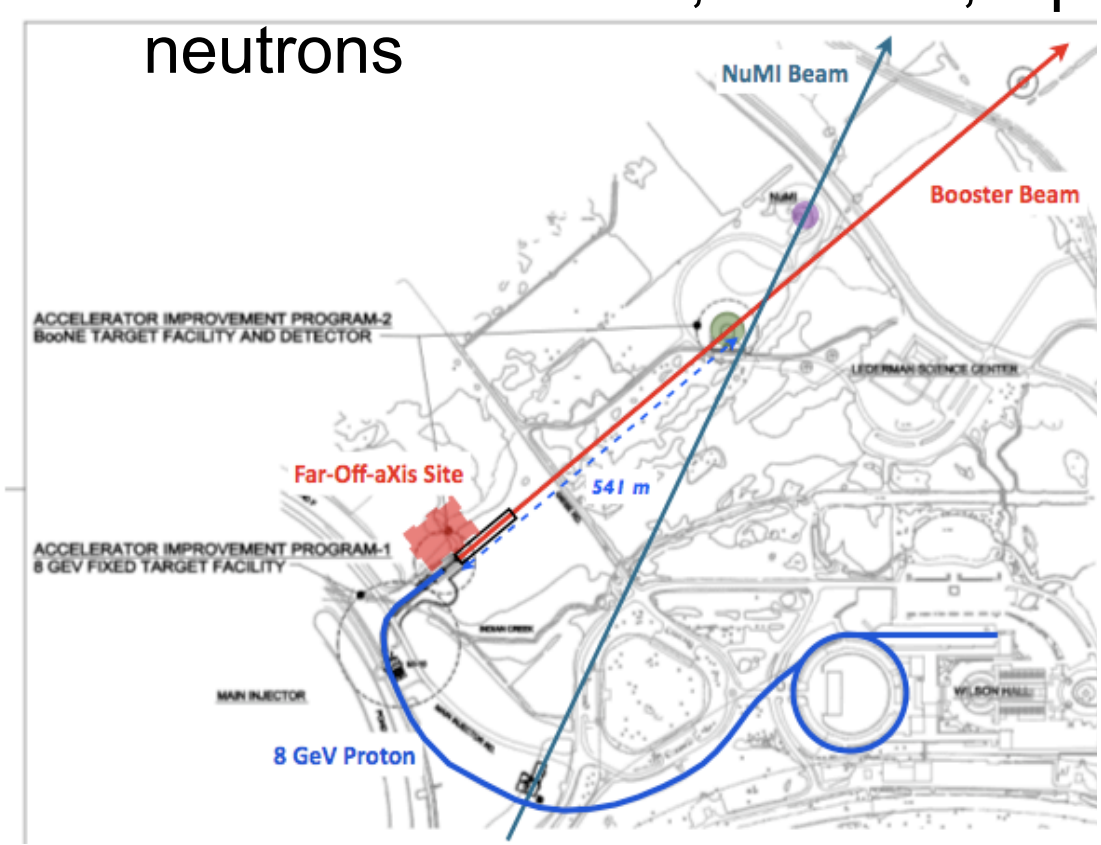
- Predicted in 1974 but not yet detected
  - Ton-scale noble gas detectors just sensitive enough now
  - Explains neutrino role in supernova explosions
- Possible to detect
  - Requires low momentum neutrinos
    - Energy of Neutrinos about 50 MeV
      - Cross section at this energy is 10^{-39} cm^2
    - Off-axis of Booster Neutrino Beam
      - Not studied as throughly as on-axis beam



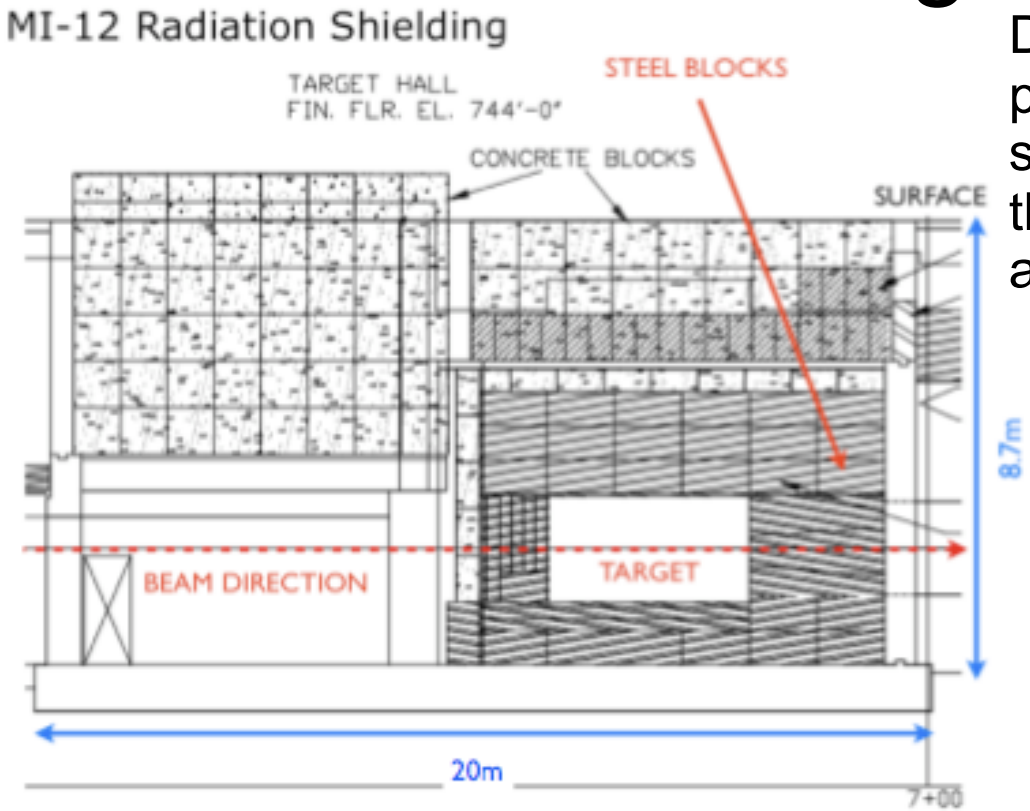
$$\pi^+ \Rightarrow \mu^+ + \nu_\mu \quad \mu^+ \Rightarrow \bar{\nu}_\mu + \nu_e$$

Far Off-Axis Site (MI-12)

- MI-12 building houses beryllium target
  - Space for ton-scale liquid Argon detector
- Collisions of $5*10^{12}$ protons per pulse
  - Produce neutrinos, mesons, leptons, gammas, and neutrons



MI-12 Shielding Specifications



During construction, the beamline path is visible. The steel shielding surround the target on all sides, and there are multiple layers of concrete above it.

MI-12 Target Specifications

Proton Beam:5*10^12 8 GeV protons/pulse

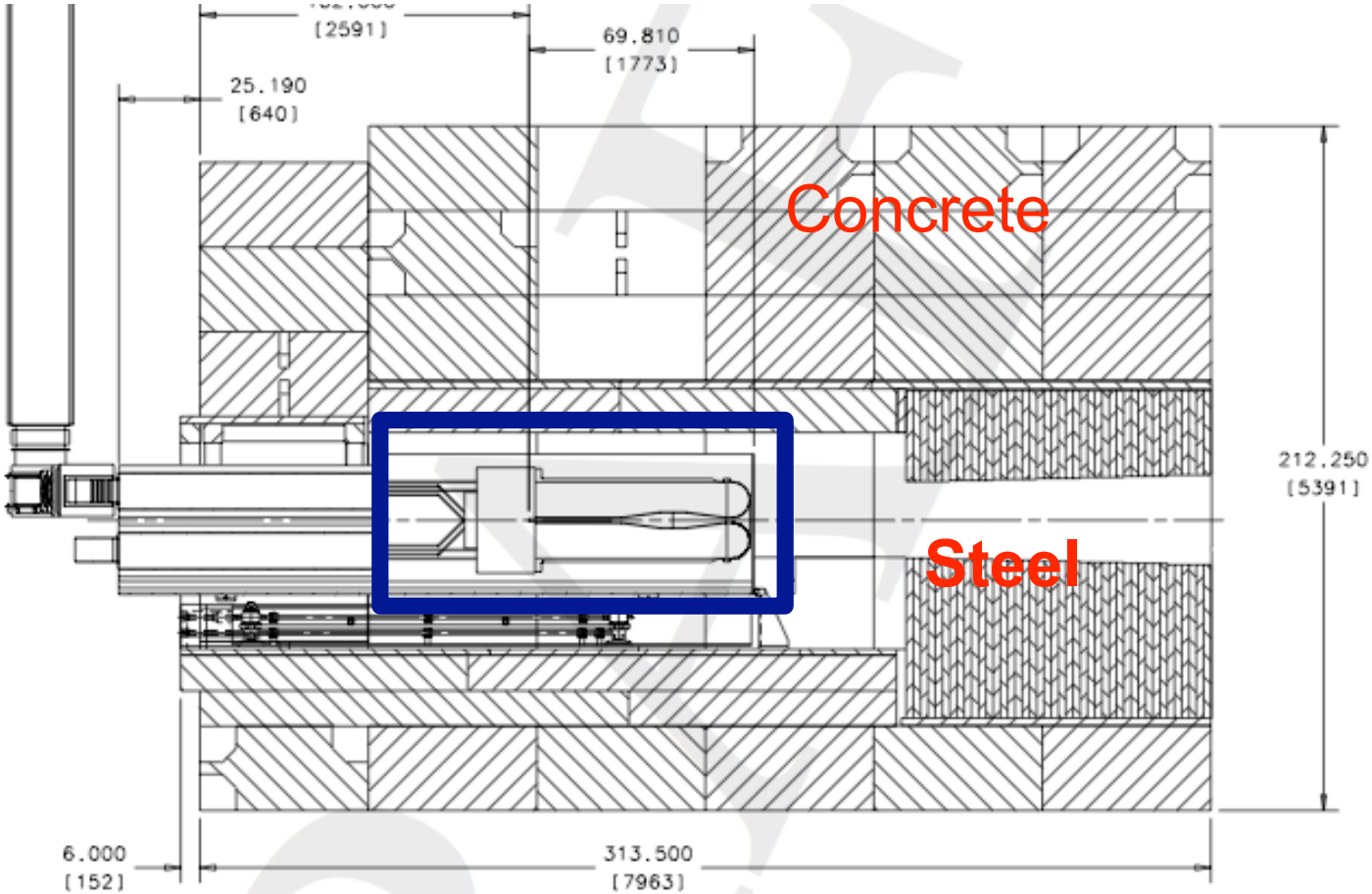


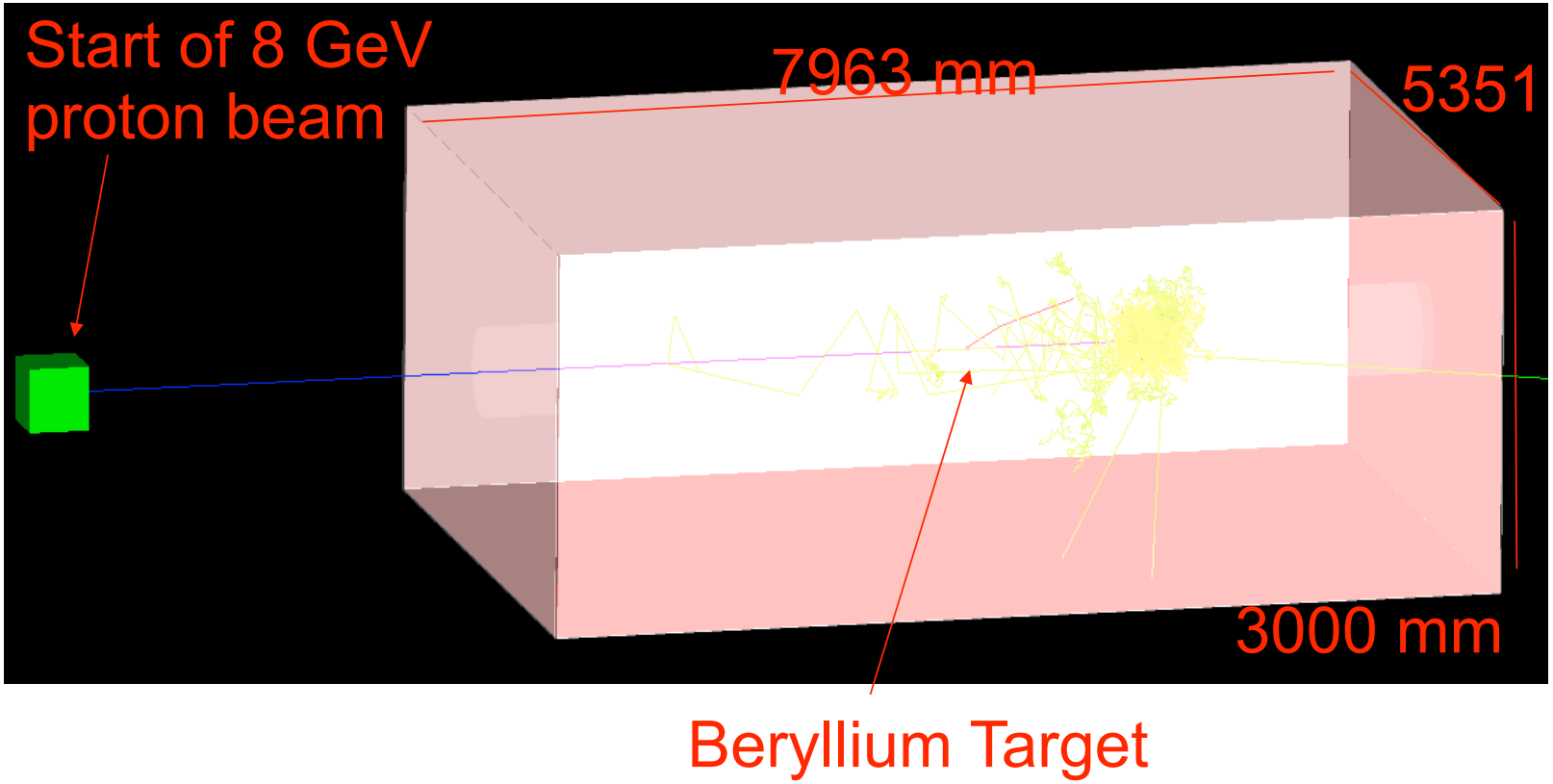
Figure 3.9: An elevation view of the target pile, including the horn, adjuster module, shielding steel. T stripline extends upward at the left.

G4beamline

- http://www.muonsinc.com/muons3/G4beamline
- single-particle tracking program based on Geant4
- Command-line or GUI for Visualization
- Virtual Detectors, pre-defined materials
- Coordinates centered on beamline, with Right Hand Rule
  - X is horizontal (positive to beam left)
  - Y is vertical (positive traveling up)
  - Z is along beamline (positive traveling downstream)
- ROOT, ASCII, Gaussian, Rectangular, Elliptical Beams

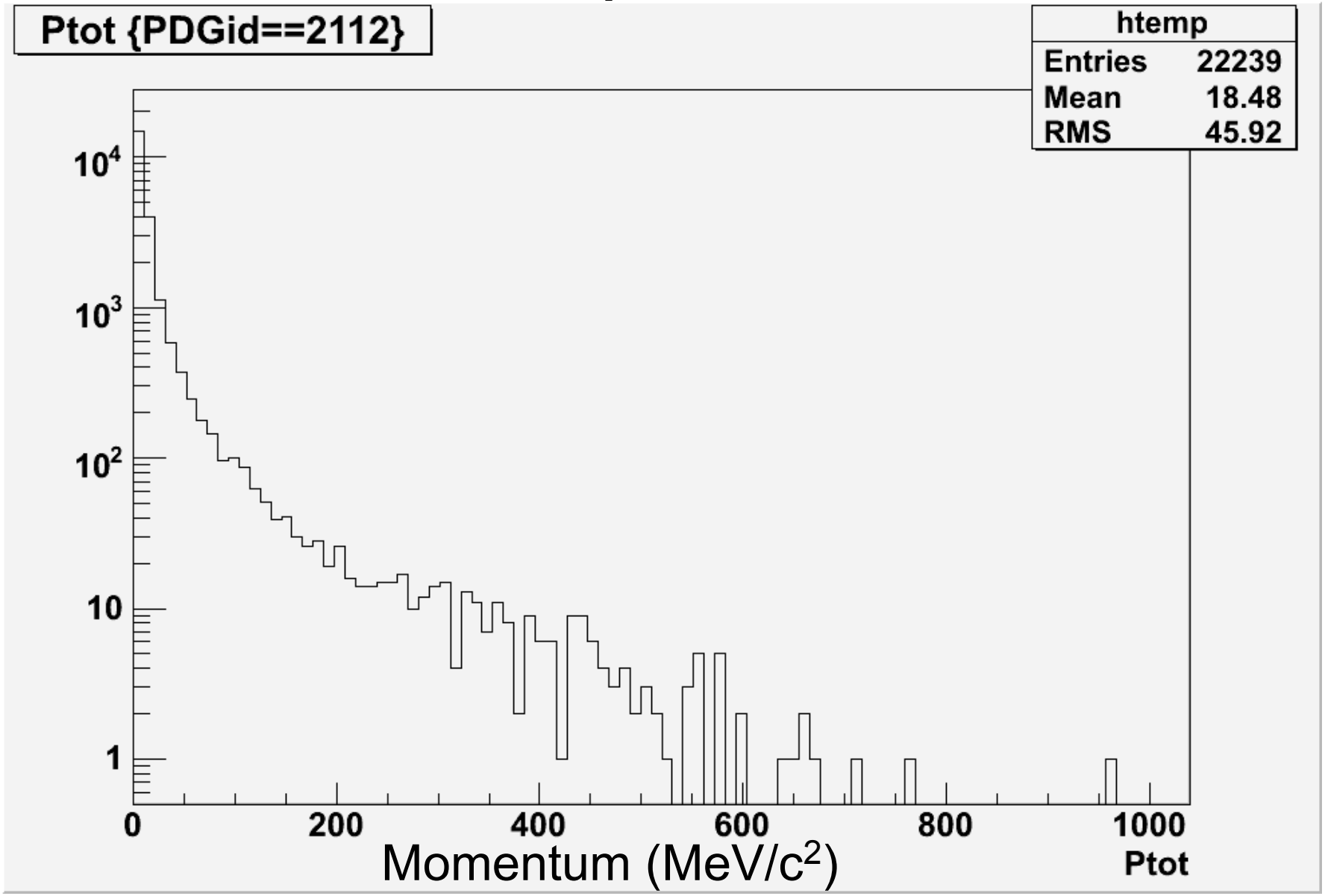
MiniBooNE Model
Target and Steel Shield

No Magnet Horn

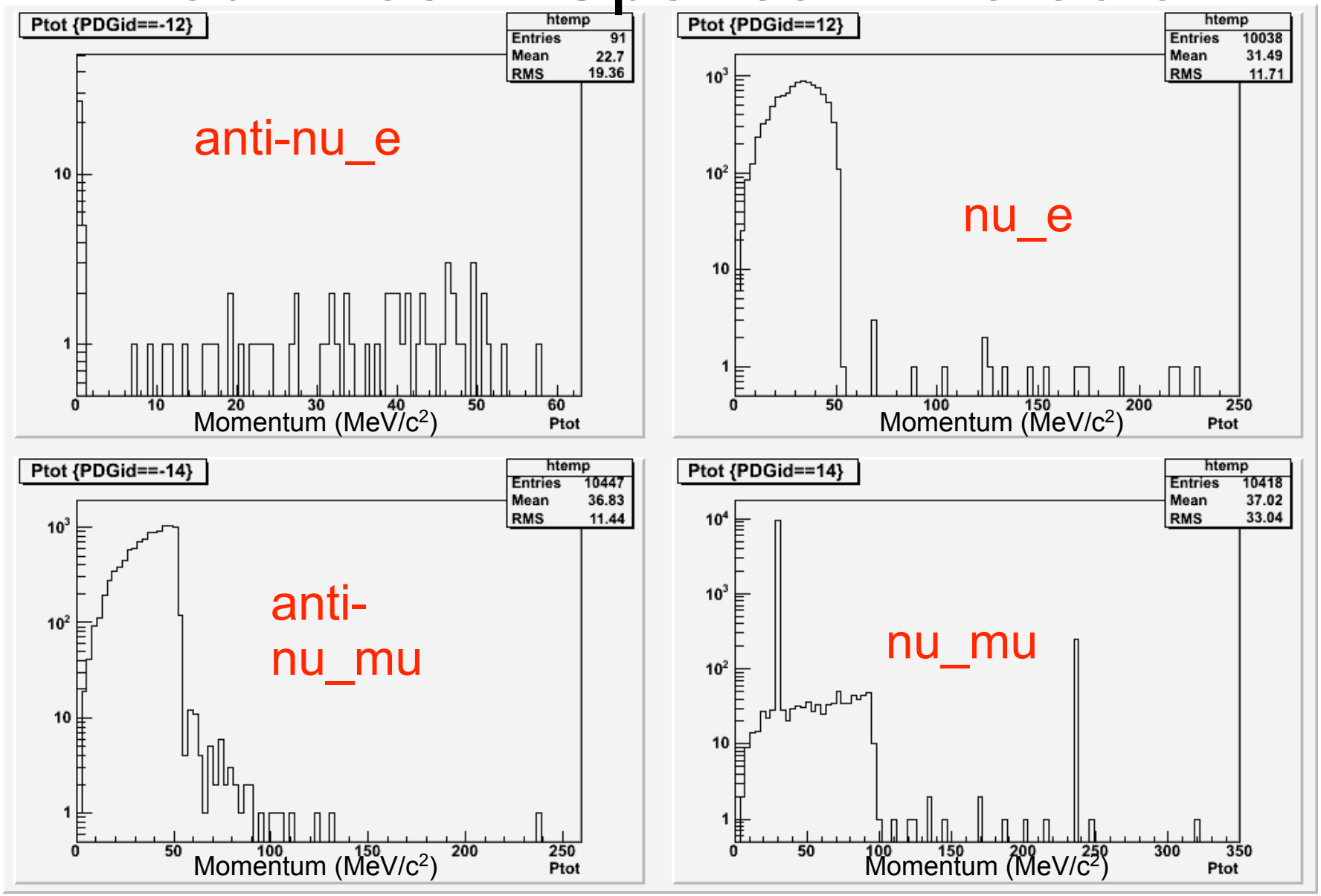


500,000 events created

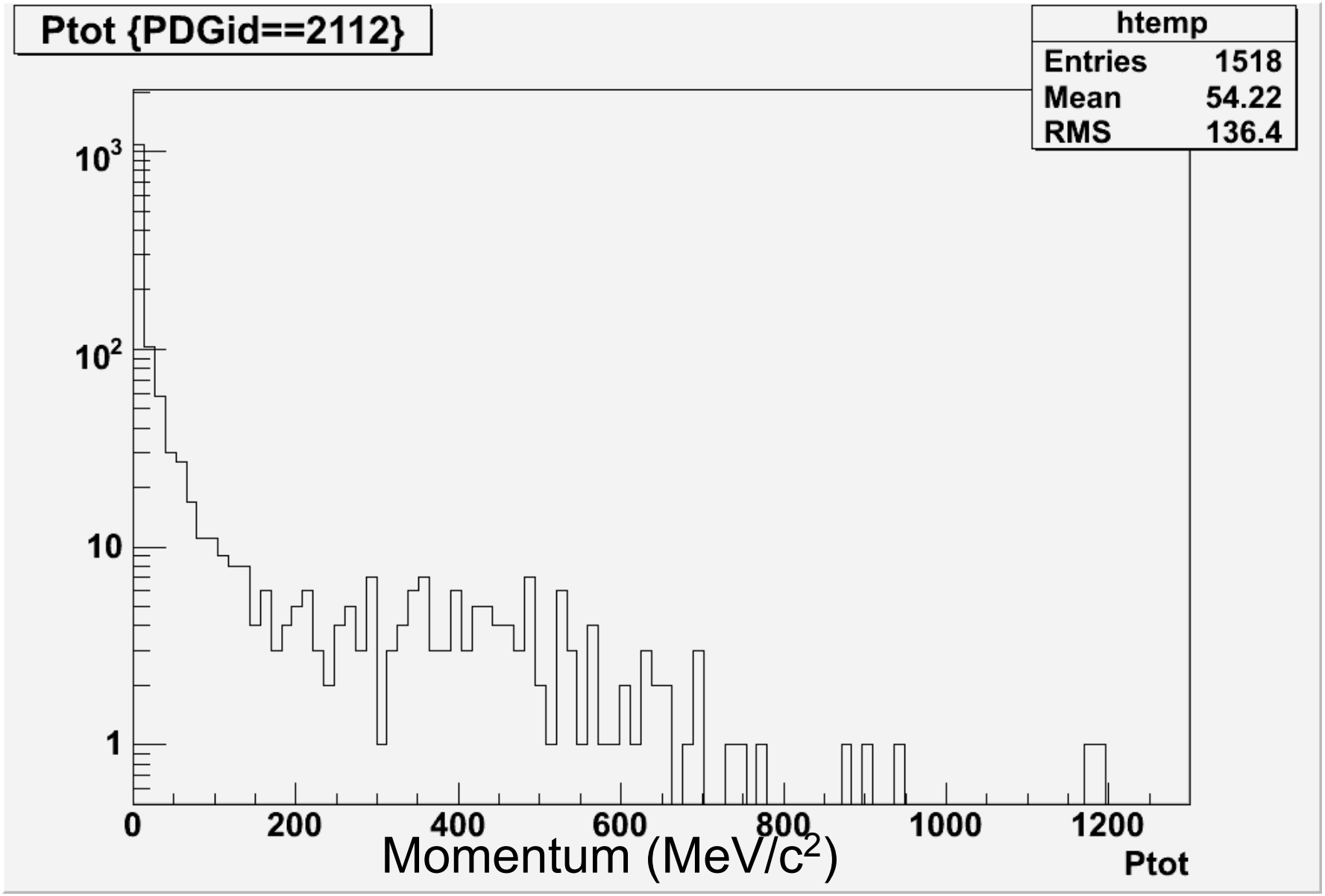
Neutrons in Upstream Detector



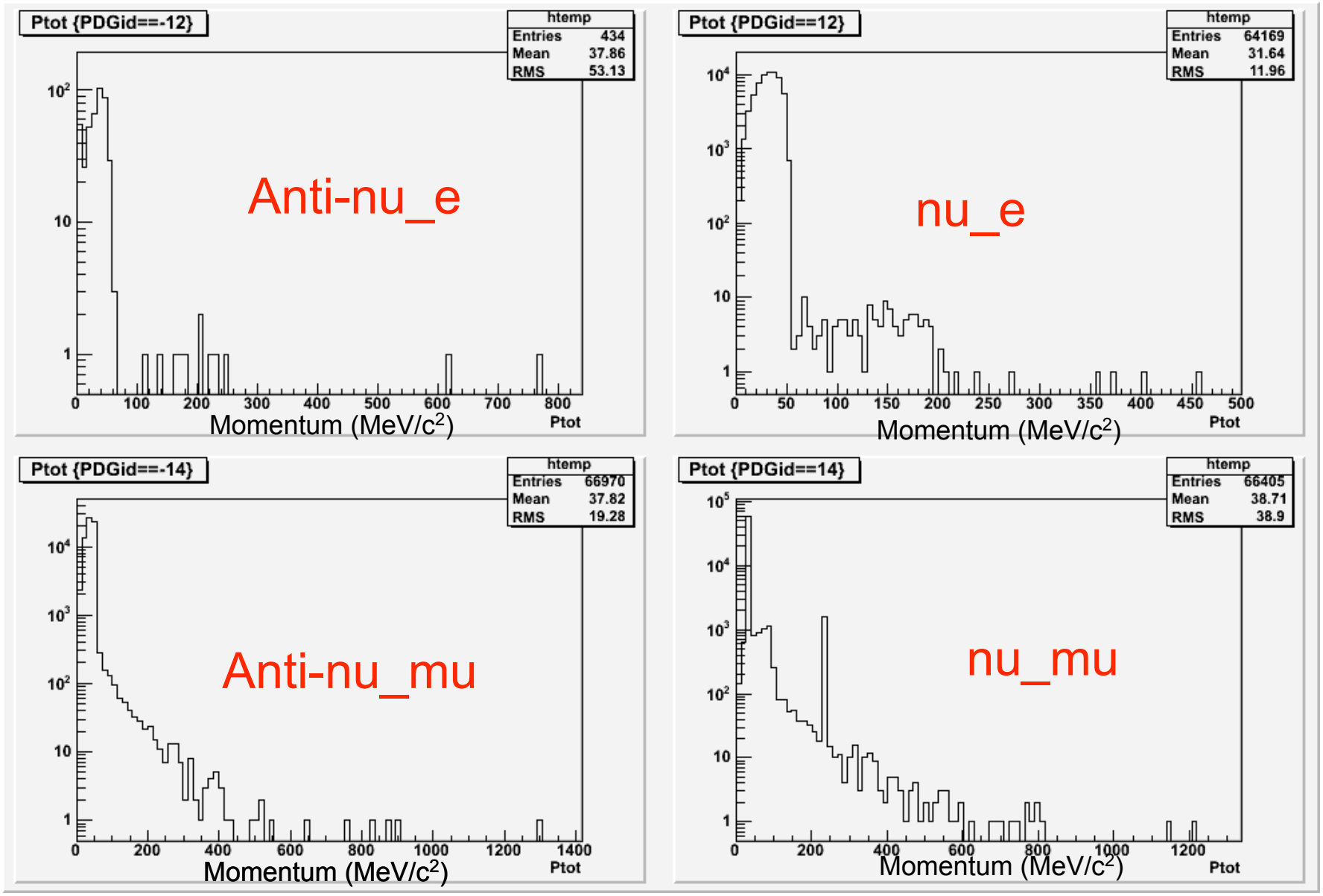
Neutrinos in Upstream Detector



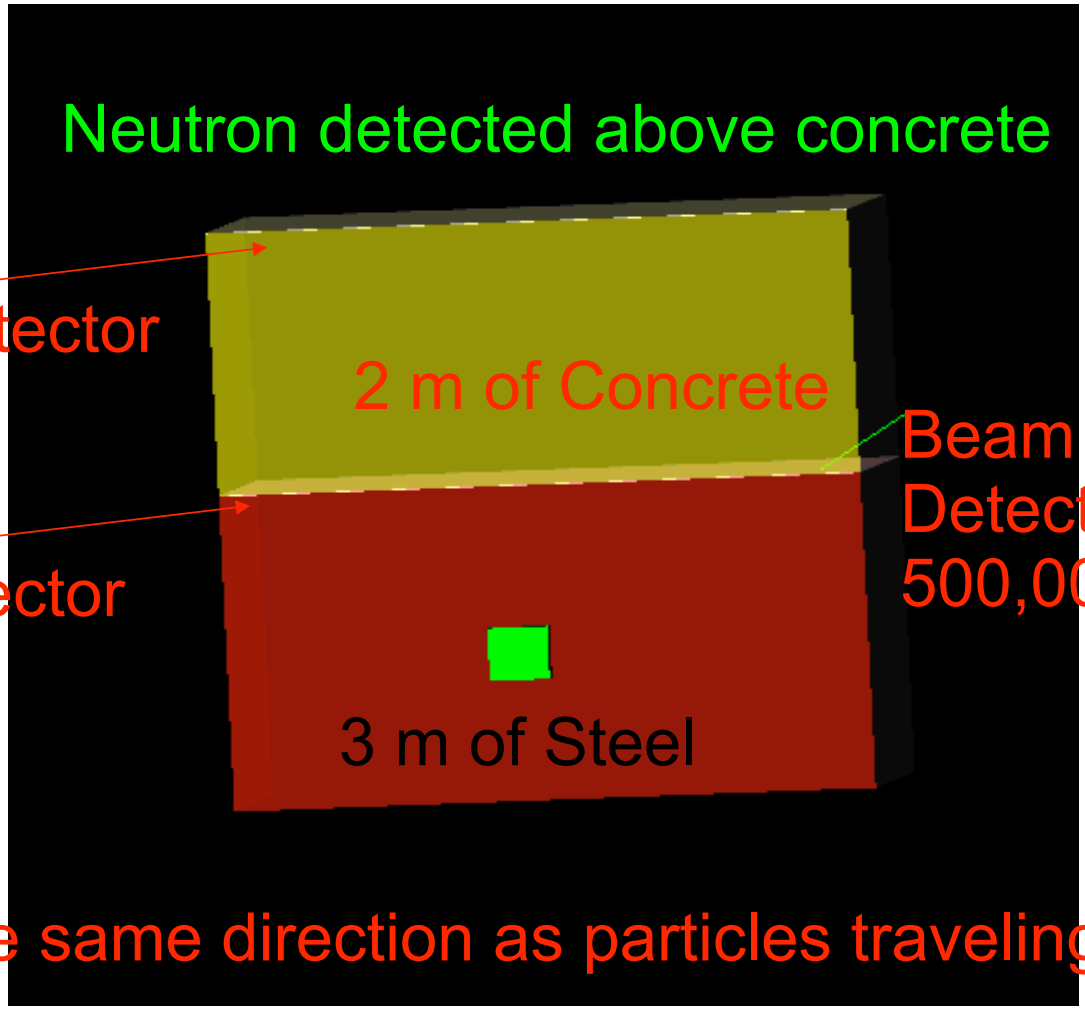
Neutrons in Top Detector



Neutrinos in Top Detector



Addition of Concrete Shielding



Virtual Detector

Virtual Detector

Beam from Top Detector creating 500,000 events

Looking in the same direction as particles traveling downstream

Flux Calculation

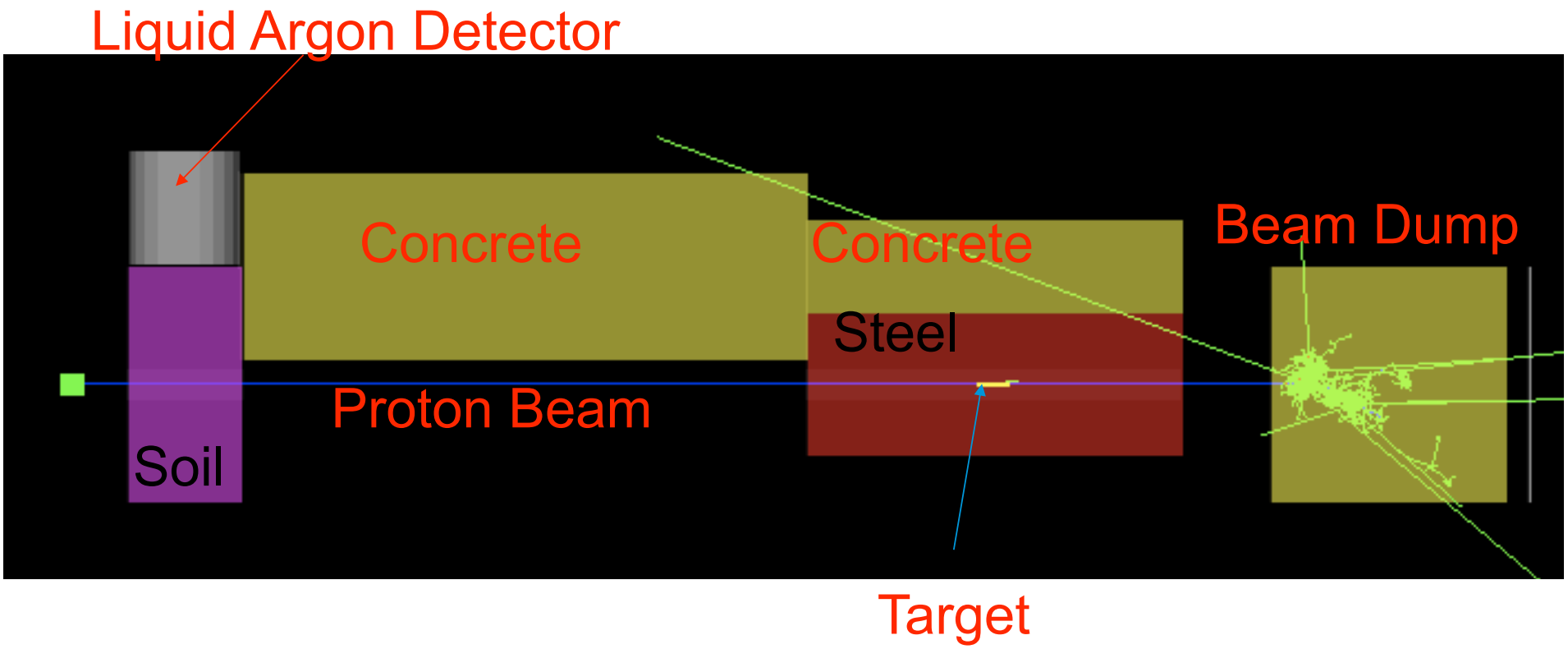
$$\frac{\text{Neutrons} \times 10^9 \text{ neutrons expected per pulse}}{\text{Area} \times 10^7 \text{ neutrons simulated}} =$$

$$\frac{16{,}035 \text{ neutrons} * 100}{524{,}398 \text{ cm}^2} = 3 \text{ neutrons per pulse/cm}^2$$

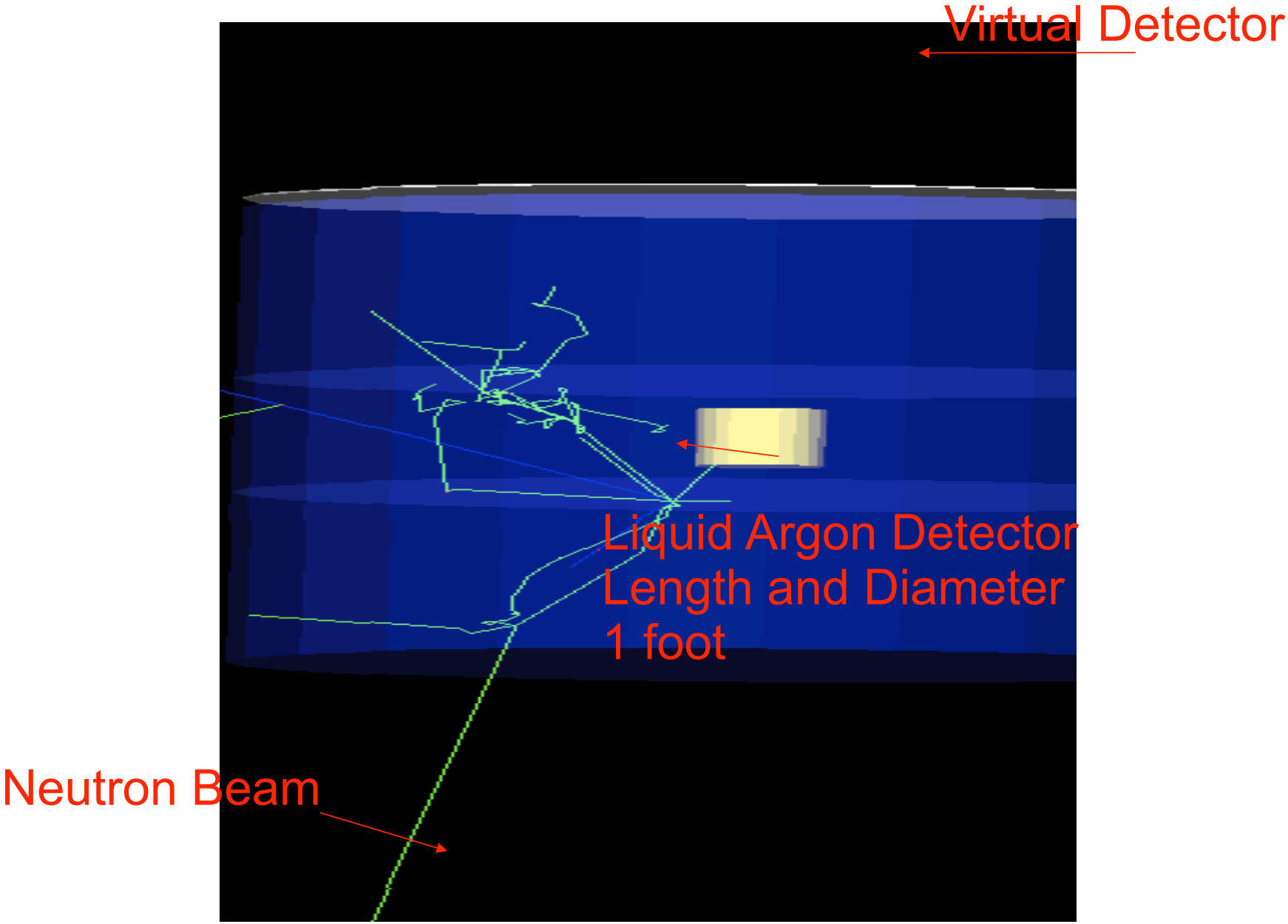
Since 5 pulses per second,

expect 15 neutrons /cm^2 /second just above the concrete shielding, 3.5 meters above target

Target, Shielding, and Liquid Argon Detector



Liquid Argon Detector



Summary

- Coherent neutrino scattering has not been detected since proposal in 1974
  - Detectable at Fermilab
  - Off-axis from low energy neutrinos
- Neutron background in MI-12
  - Simulated by G4beamline
  - Expect 3 neutron events/cm^2/pulse outside concrete shielding 3.5 m above target
  - Expect 15 neutron events/cm^2/second outside concrete shielding 3.5 m above target