Cosmogenic Background Simulation for Homestake 4850ft Level

Chao Zhang
University of South Dakota

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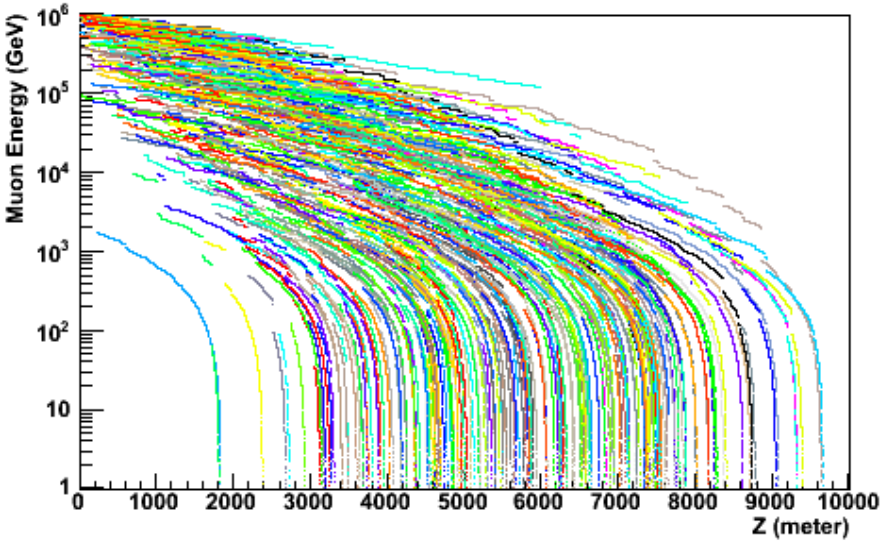
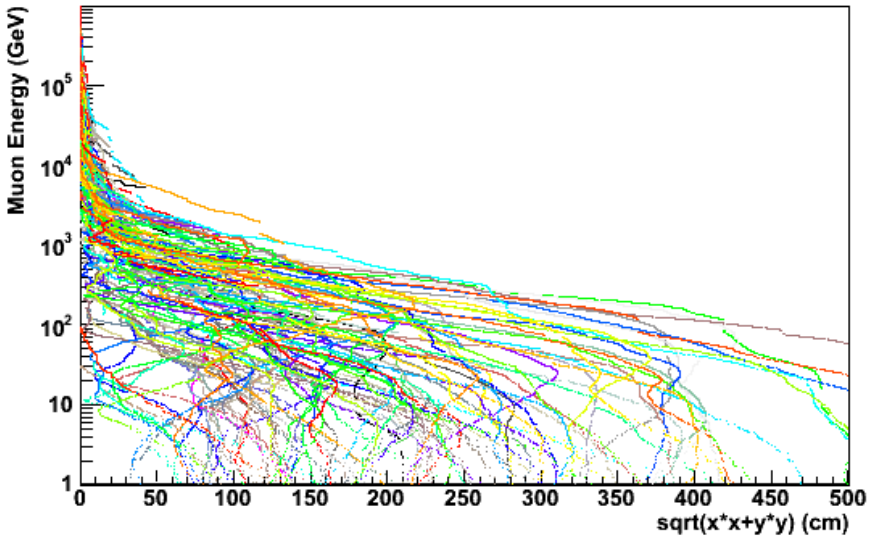
Outline

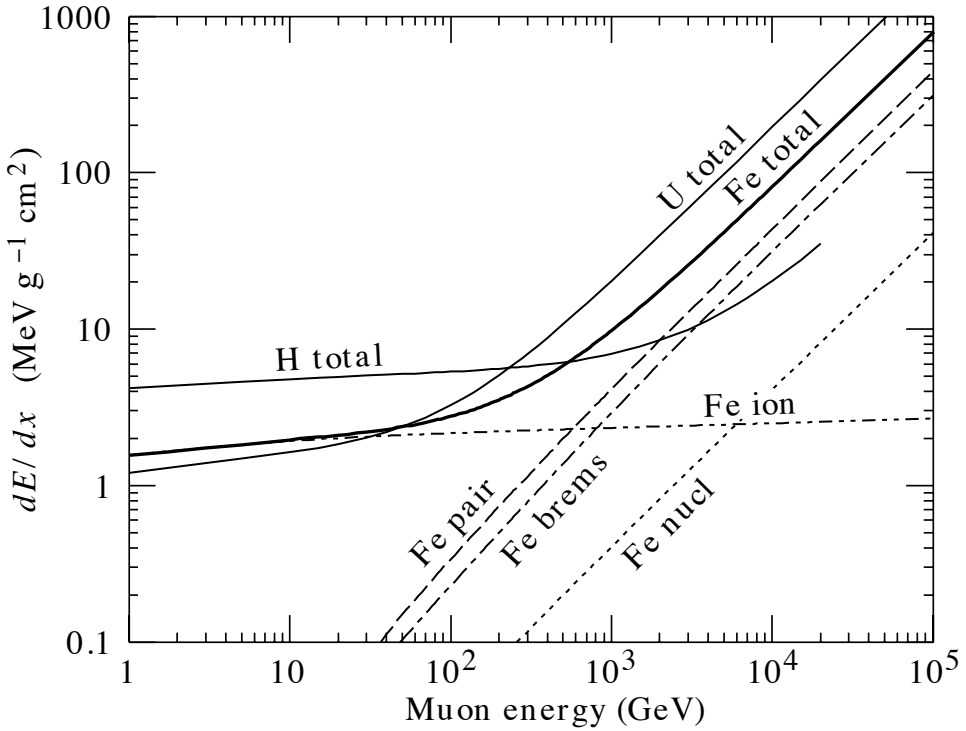
- Validation of Geant4 Sim
- Muon casting at surface and the mountain profile at Homestake Mine area.
- Muon energy and angular distribution at Homestake Mine 4850ft level --- comparison with MUSUN and Mei&Hime results.
- Secondary neutrons at 4850ft level.

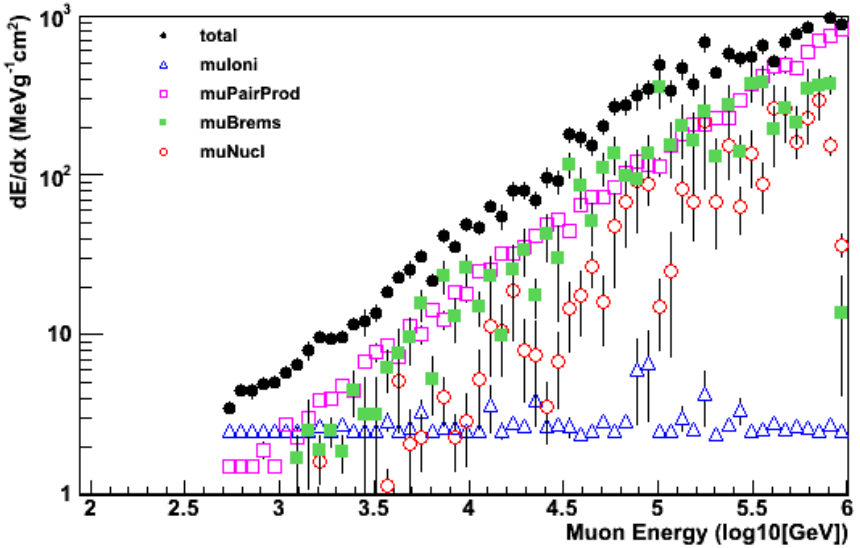
Muons Travel in Rock(G4.9.5)





1. Homestake rock sample.
2. Muons with fixed energy 1PeV and vertically downwards.
3. Average depth 1Pev muon can reach is 6~7 km. So a casting area with radius of 10km on the surface is big enough for a full simulation.





- Energy loss through different channels.

Muon Tracking from Surface

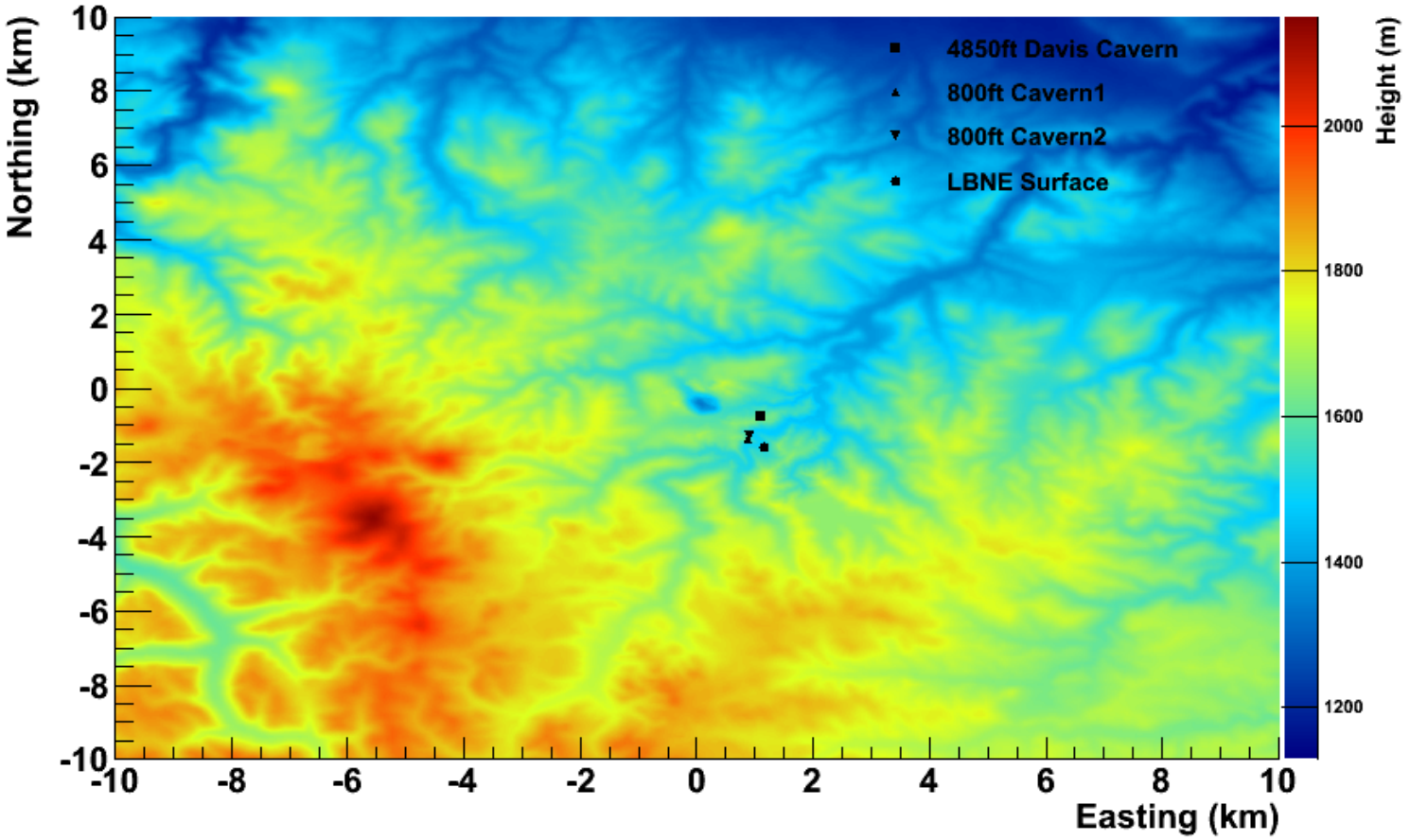
- Surface Muon Flux(Gaisser formula):

$$\frac{dN_\mu}{dE_{\mu,0}} \approx \frac{0.14 \cdot E_{\mu,0}^{-2.7}}{\mathrm{cm^2 sr\ s\ GeV}} \times \left(\frac{1.0}{1 + \frac{1.1 \cdot E_{\mu,0} cos(\theta)}{\epsilon_\pi}} + \frac{0.054}{1 + \frac{1.1 E_{\mu,0} cos(\theta)}{\epsilon_K}} \right)$$

  - In this formula, the muon decay effect is neglected which make it slightly off from experimental data at low energy range. The rewrite formula[guan et. al., http://escholarship.org/uc/item/6jm8g76d]:

$$\frac{dI}{dE_\mu d\cos\theta} = 0.14 \left(\frac{E_\mu}{GeV} (1 + \frac{3.64 GeV}{E_\mu [\cos\theta^*]^{1.29}}) \right)^{-2.7} \left[\frac{1}{1 + \frac{1.1 E_\mu \cos\theta^*}{115 GeV}} + \frac{0.054}{1 + \frac{1.1 E_\mu \cos\theta^*}{850 GeV}} \right]$$

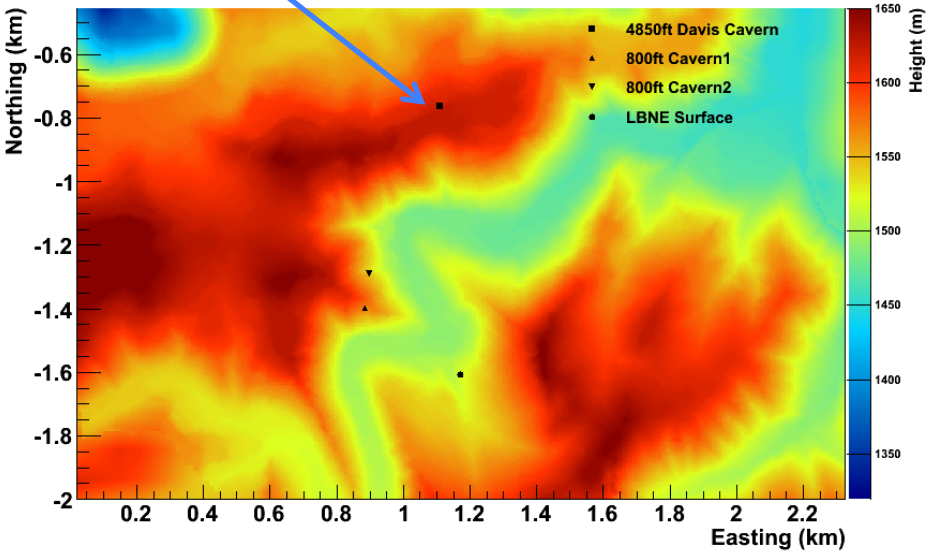
Surface mountain profile



The surface mountain profile at Homestake Mine area --- the satellite data from CGIAR (http://srtm.csi.cgiar.org/)

Surface mountain profile --- Zoomin

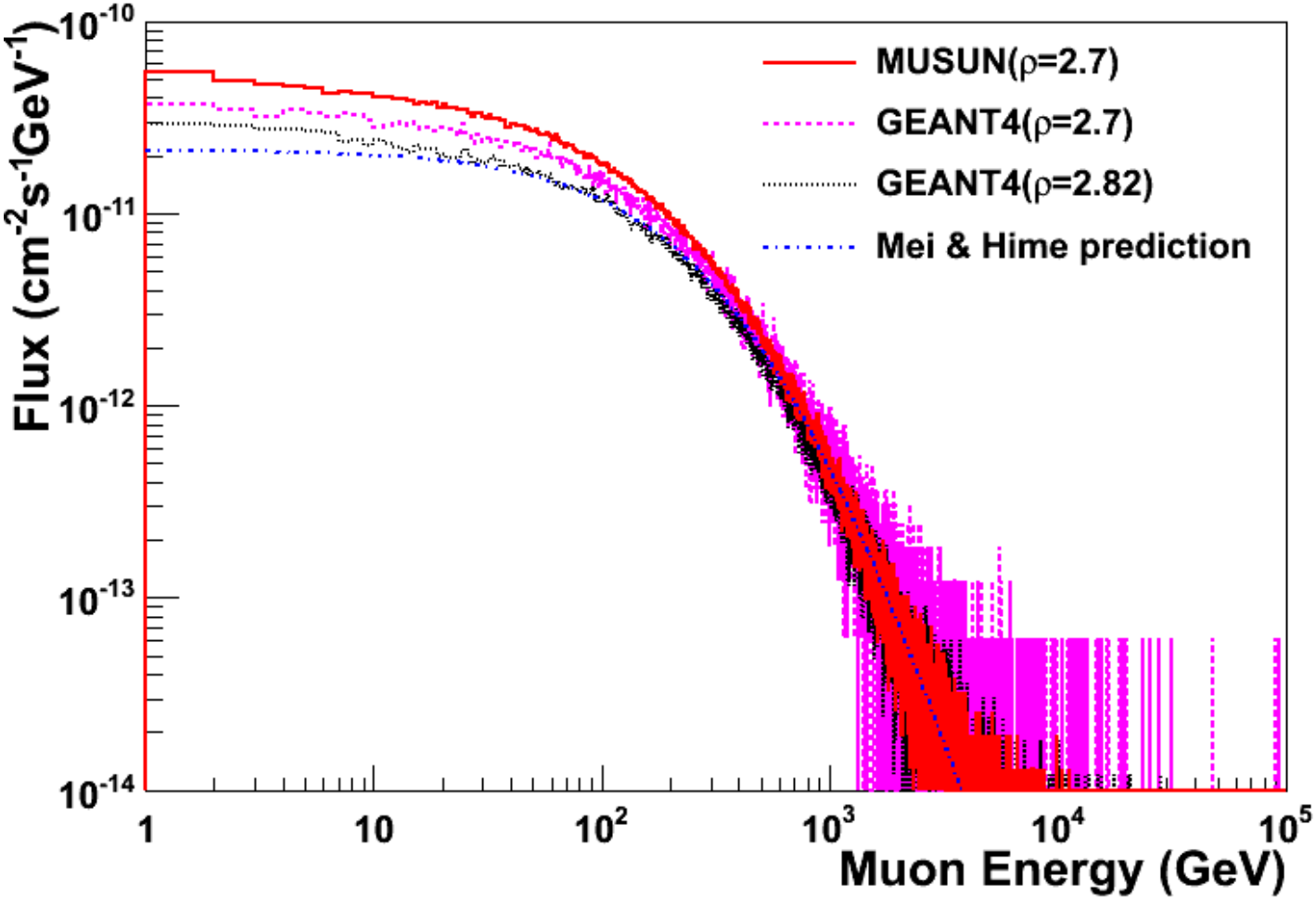
Yates shaft to Davis Cavern



Muon Casting and Selection

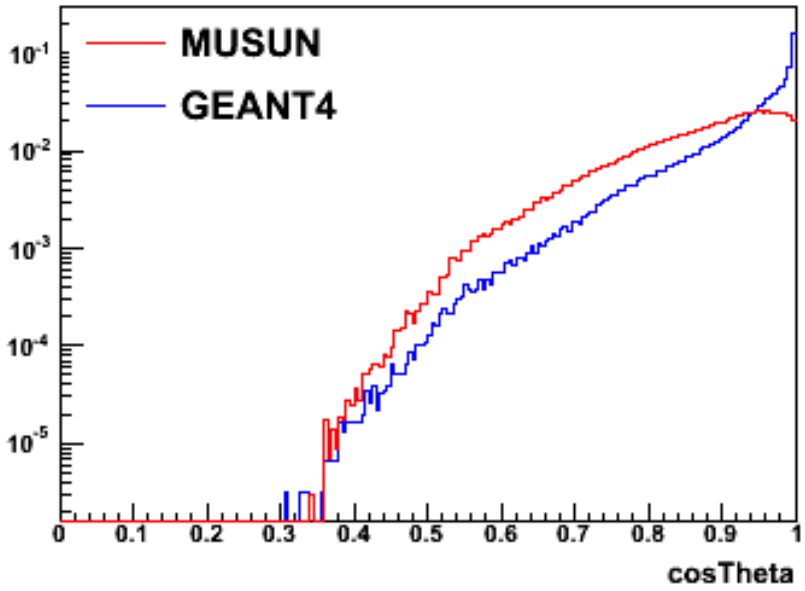
- Surface position: uniformly distributed on a sheet 10km*10km(easier to calculate live time.) then compare the angle to the experimental hall to match the real position in the mountain profile.
- Energy and angle: get randomly from the modified Gaisser formula: energyTheta-> GetRandom2(E, cosTheta). For the 4850ft level, we take the energy range[1TeV, 1PeV].
- Only those muon direction can reach the detector (34m^3, with extended tolerance of 6 meter) are selected for Geant4 tracking.

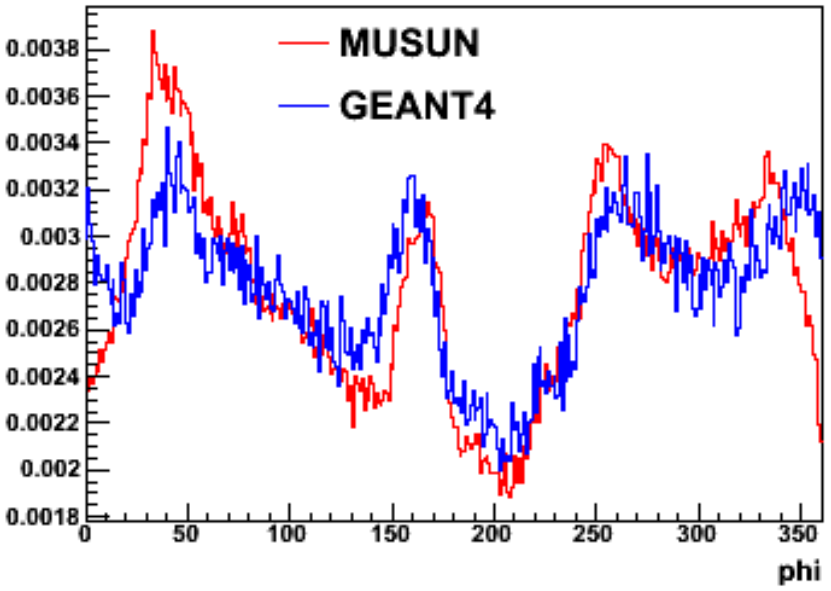
Muon Energy



Muon energy spectrum at 4850 ft Davis Cavern estimated by MUSUN, G4(rho2.7), G4 (rho2.82)and Mei&Hime prediction. The absolute flux calculated by them are 6.46e-9/cm^2/s, 5.450e-9 /cm^2/s, 4.32e-9 /cm^2/s and 4.40e-9 /cm^2/s, respectively.

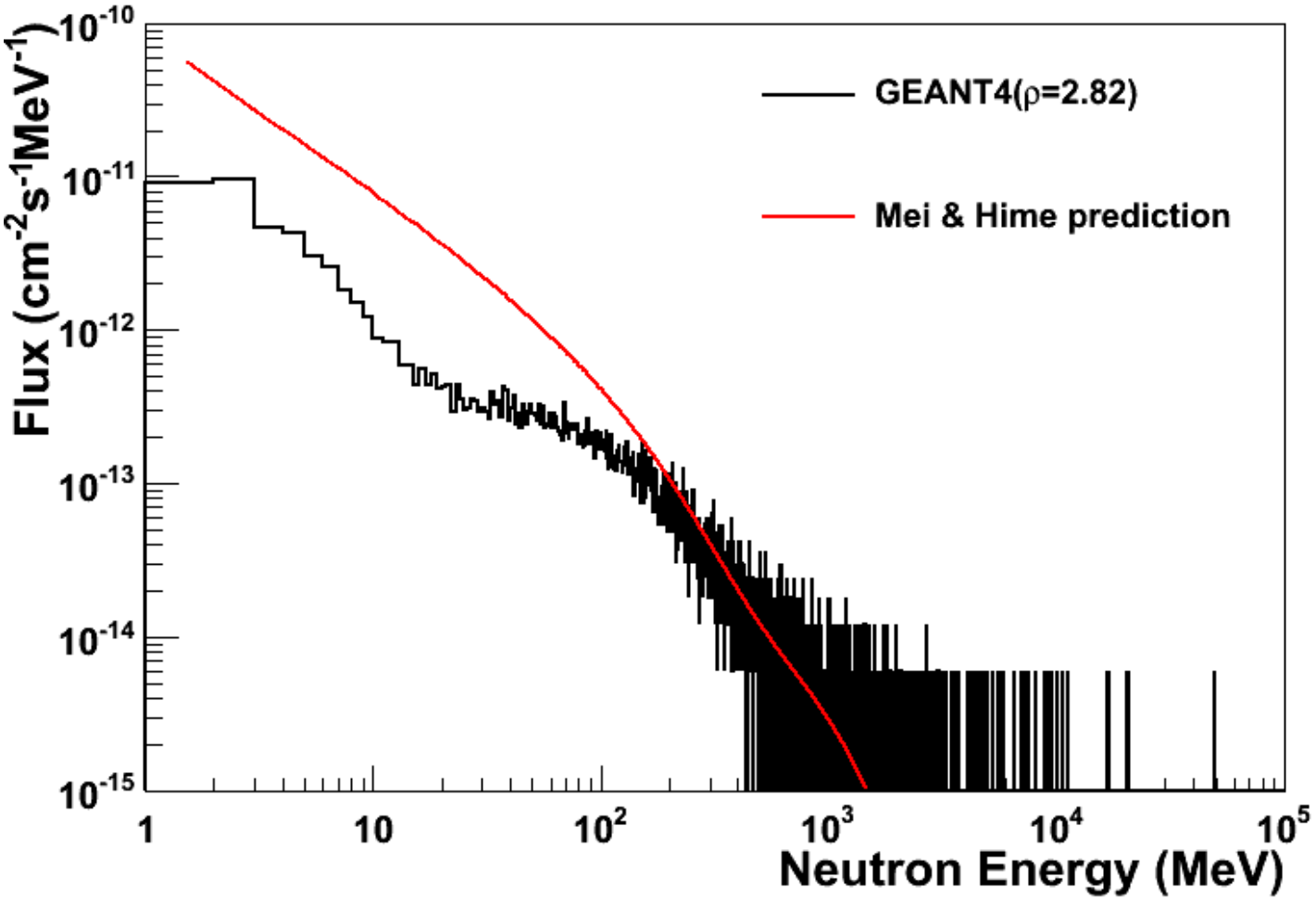
Muon Angular Distribution





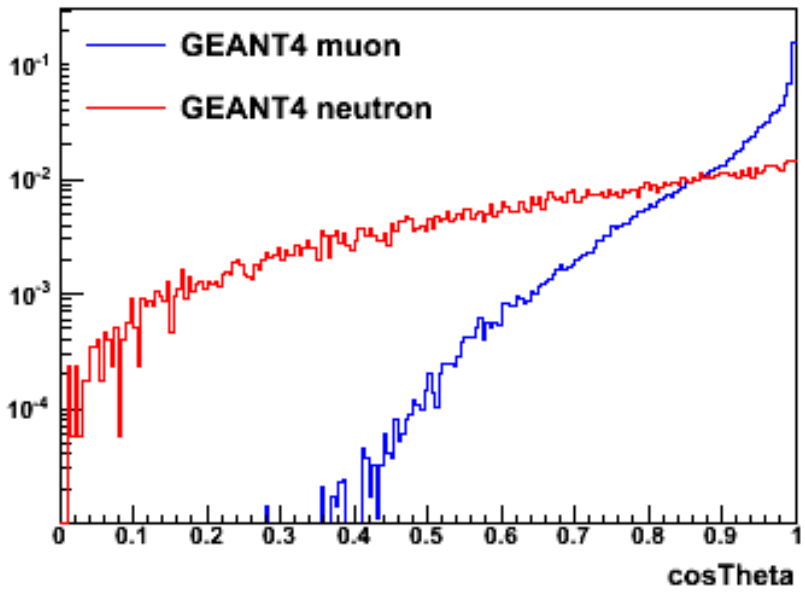
Comparison of muon angular distribution at 4850 ft Davis Cavern estimated by MUSUN and GEANT4.

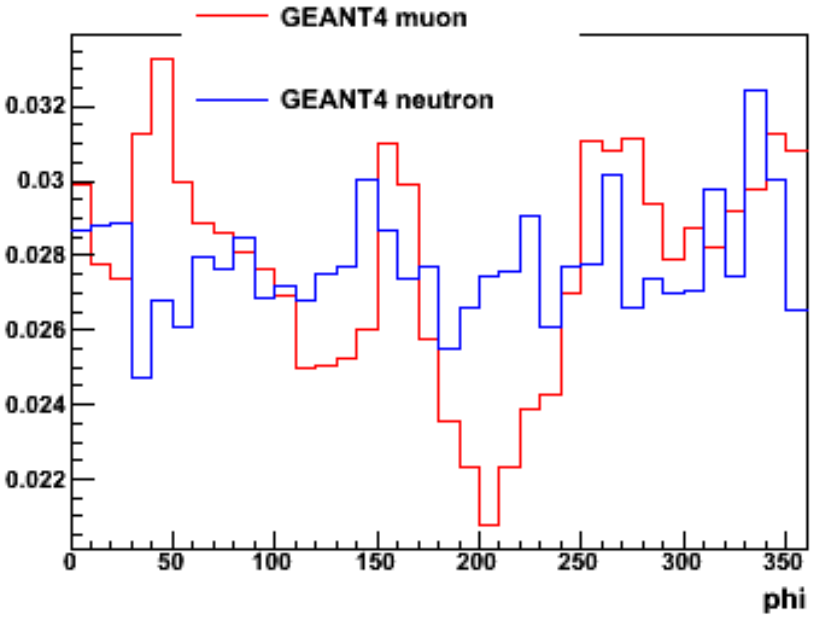
Secondary Neutron Energy



Comparison of secondary neutron energy distribution at 4850 ft Davis Cavern estimated by GEANT4(1.05e-10/cm^2/s) and Mei&Hime prediction(5.39e-10/cm^2/s).

Secondary Neutron Angle





Summary

- Using Geant4 to track cosmic ray muons to deep underground is valid.
- Surface hill effect and density variation can be studied relatively easier by Geant4.
- Underground muon/neutron spectrum and angular spectrum can be retrieved through the tracking processes.