**Variation in Particle Generation with Muon Energy**

A subset of data from the study described in Sec. [Chao's section on Geant4 muon MC] was used to find spectra for the energies and multiplicities of neutrons and gammas generated from muon interactions in cavern rock, as a function of muon energy. Having quantified the changes in these particles, it is then possible to estimate the expected backgrounds at a given depth, using the well-measured depth-dependent muon energy spectrum.

Monte Carlo results indicate that the change in neutron and gamma generation with muon energy is dominated by an increase in average multiplicity per muon, while the energy spectra for individual particles is not significantly shifted. This suggests no significant change in energy spectrum shape between depths. The significant change in backgrounds comes from the change in multiplicity with muon energy, which acts as a multiplier with the increase in muon flux for a given depth.

Figure 2: Neutron multiplicity (left) and kinetic energy (right) for several selected muon energy ranges.



Figure 3: Average number of neutrons detected in the simulation cavern per detected muon, as a function of muon energy.



Figure 4: Gamma multiplicity for several selected muon energy ranges.



Figure 5: Gamma energy spectra for several selected muon energy ranges.



Figure 6: Average number of gammas detected in the simulation cavern per detected muon, as a function of muon energy.