Muon spectra with MCEq

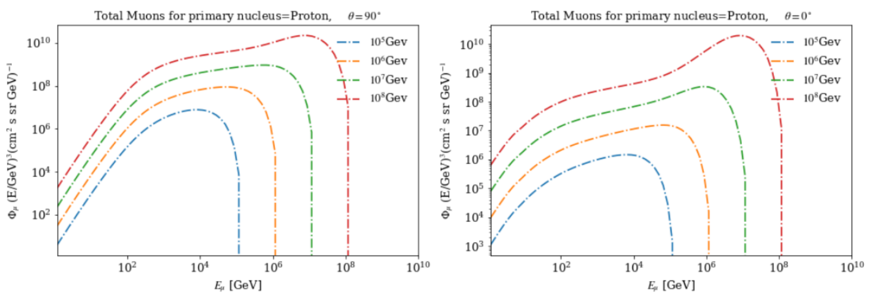

Figure 1: Muon flux for two different angles and proton as a primary nucleus. The primary flux model is H3a and the density model is ('CORSIKA', ('PLSouthPole', 'August')).

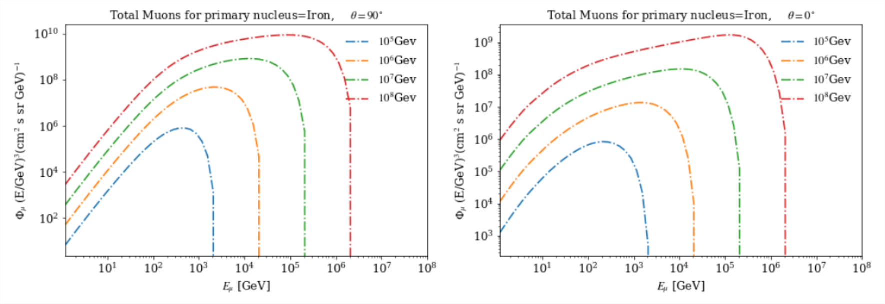

Figure 2: Muon flux for two different angles and Iron as a primary nucleus. The primary flux model is H3a and the density model is ('CORSIKA', ('PLSouthPole', 'August')).

Geometry and atmosphere

The MCEq.geometry — Extensive-Air-Shower geometry includes classes and functions modeling the geometry of the cascade trajectory.

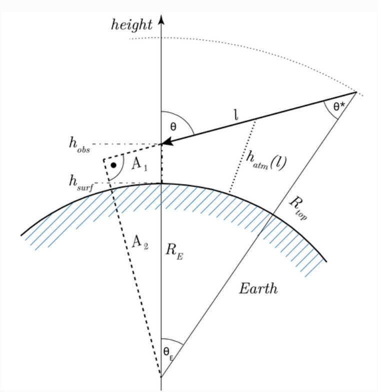

Figure 3: One-dimensional shower trajectory in the curved geometry of the Earth.

Geometry and atmosphere

The total path length and the height above the surface at each point of the trajectory are:

$$l(\theta) = \sqrt{R_{top}^2 - A_2(\theta)^2} - A_1(\theta)^2$$

$$h_{atm}(\Delta l) = \sqrt{A_2(\theta)^2 + (A_1(\theta) + l(\theta) - \Delta l)^2} - R_E^2$$

The only free variables are the height of the observation level h obs and the zenith angle at the detector θ. With the two relations above the slant depth in can be calculated as a function of the atmospheric density.

$$X(h_o) = \int_0^{h_o} dl \rho_{pair}(l)$$

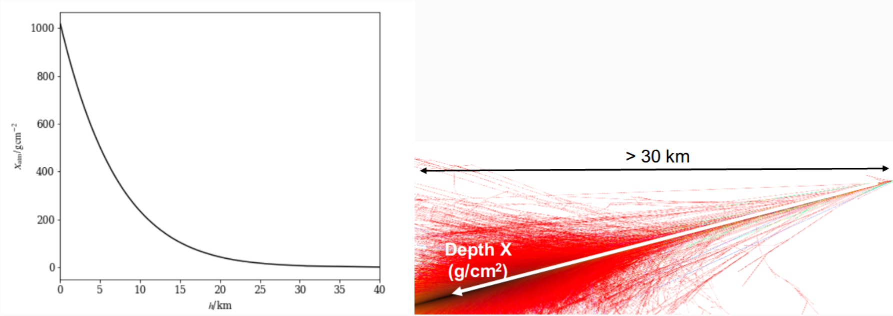

Figure 4: (Left) Slant depth in function of the height above the surface. The primary flux model is H3a, $\theta = 0^\circ$ and the desinty model is ('CORSIKA', ('PLSouthPole', 'August')). (Right) Example of the Air Shower simulation in CORSIKA [1].

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[1] Anatoli Fedynitch, A state-of-the-art calculation of atmospheric lepton fluxes 2017.

Number of muons

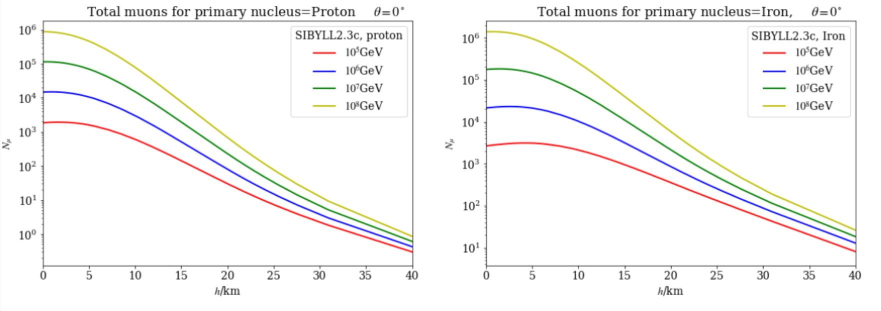

Figure 5: Number of muons as a function of height above the surface with a proton as a primary nucleus and $X_{atm} = 1000.0g/cm^2$.

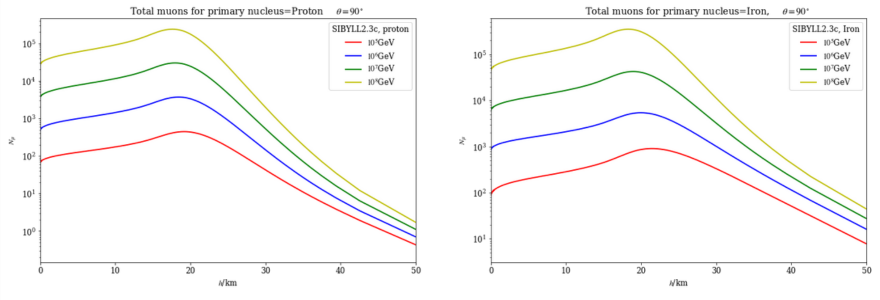

Figure 6: Number of muons as a function of height above the surface with a iron as a primary nucleus and $X_{atm} = 1000.0g/cm^2$.

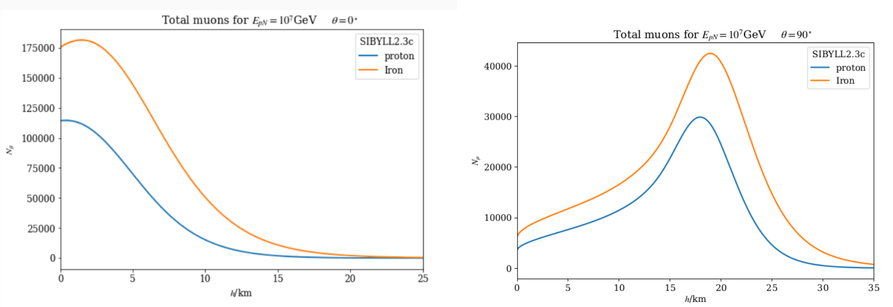

Figure 7: Comparison between the number of muons for the proton and iron as the primary nucleus.

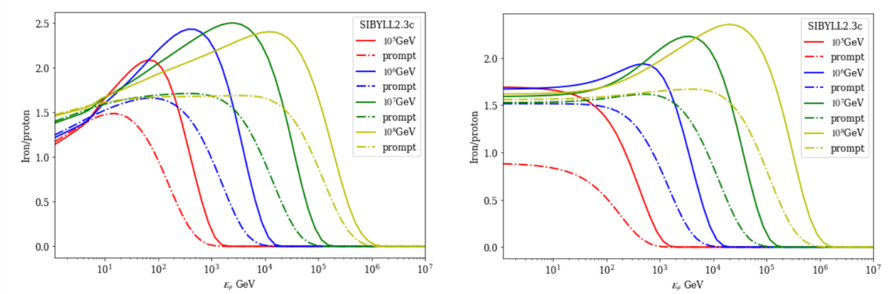

Figure 8: Ratio of the energy spectra for total and prompt muons. Two different angles have been used: $\theta = 0^\circ$ (right) and $\theta = 90^\circ$ (left). $X_{atm} = 1000.0g/cm^2$

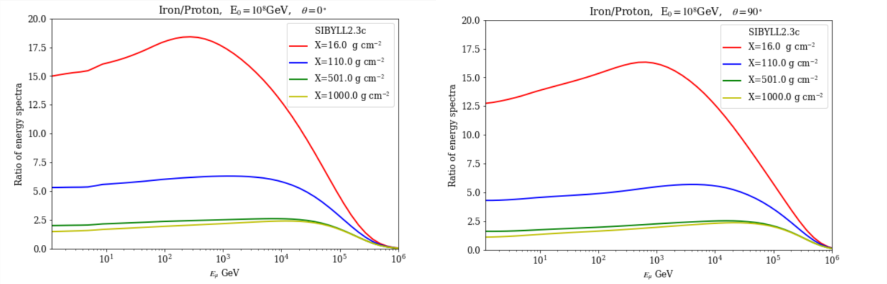

Figure 9: Ratio of the energy spectra for different values of slant depth (X_{atm}).

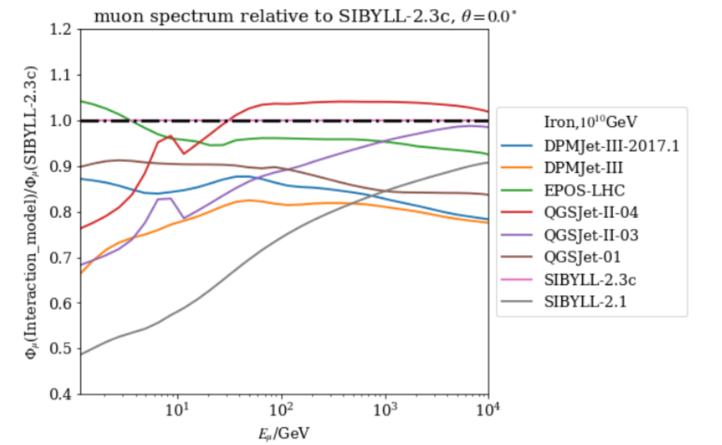

Figure 10: Muon spectrum relative to the hadronic model SIBYLL-2.3c for iron as a primary nucleus with $E_0 = 10^{10}$GeV and $\theta = 0.0°$.

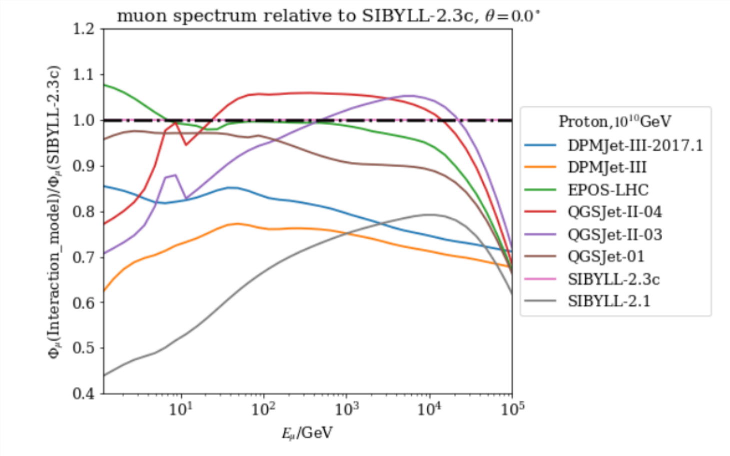

Figure 11: Muon spectrum relative to the hadronic model SIBYLL-2.3c for proton as a primary nucleus with $E_0 = 10^{10}$GeV and $\theta = 0.0°$.

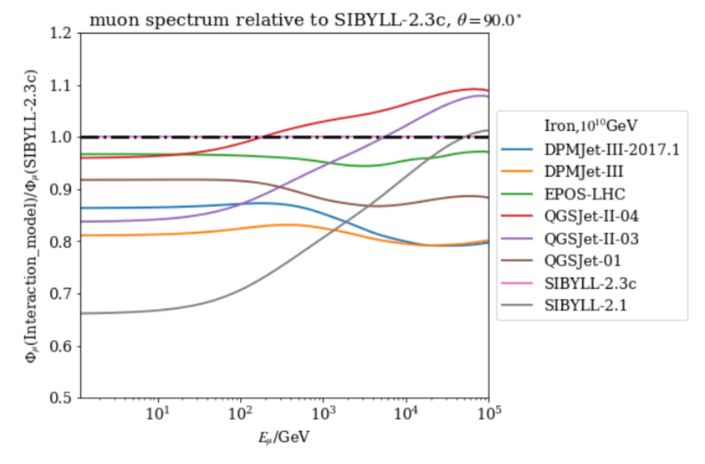

Figure 12: Muon spectrum relative to the hadronic model SIBYLL-2.3c for iron as a primary nucleus with $E_0 = 10^{10}$GeV and $\theta = 90°$.

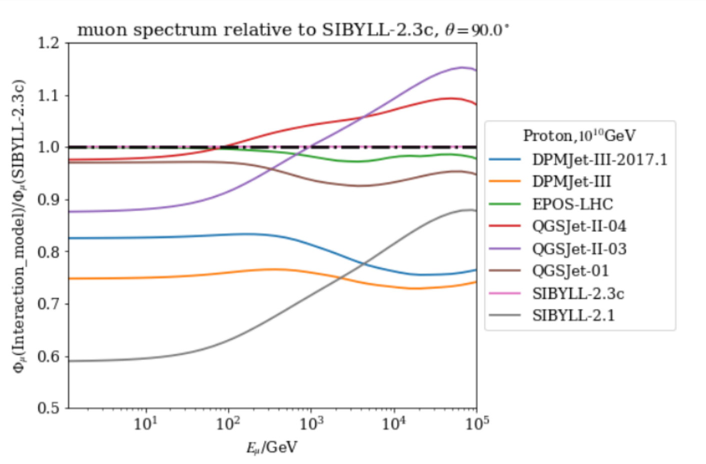

Figure 13: Muon spectrum relative to the hadronic model SIBYLL-2.3c for proton as a primary nucleus with $E_0 = 10^{10}$GeV and $\theta = 90^\circ$

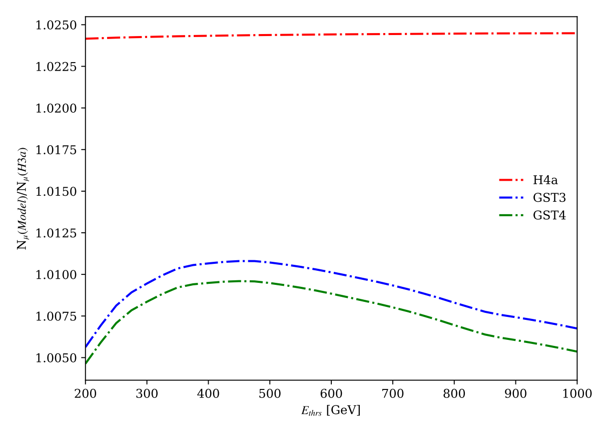

Figure 14: Ratio of the energy spectra of muons for different primary flux models. The angle is de average of 10 values between 0° - 90° , the density model used is ('CORSIKA',('PLSouthPole', 'August').