COSMIC RAYS

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The energy threshold of the detector is about 2 GeV. Taking the energy deposited in rock to be 2 MeV/(g cm^{-2}) and the density of rock to be 2.5 g/cm^3 results in the energy threshold corresponding to 4 meters of rock. Take the detector depth to be 4 meters.[1]

The differential muon energy spectrum at the surface is:

$$\frac{dN}{dE} = 0.14E^{2.7}\left[\frac{1}{1+\frac{1.1E\cos\theta}{115\text{ GeV}}} + \frac{1}{1+\frac{1.1E\cos\theta}{850\text{ GeV}}}\right] \tag{1}$$

muons/cm^2/sec/sr/GeV where θ is the zenith angle of the muon. The two terms in the brackets corresponds to pion and kaon decays, respectively. For below 10 GeV:

$$\frac{dN}{dE} = 0.14E^{2.7} \tag{2}$$

The earth is flat. The angular distribution underground, for a energy threshold E_0 is the threshold energy for a muon at an angle θ to penetrate the slant depth of $d/\cos\theta$, is:

$$\frac{dN}{d\Omega} = \int_{E_0(\theta)}^{\infty} \frac{dN}{dE} dE \tag{3}$$

$$= \frac{0.14}{1.7}\left(\frac{\cos\theta}{E_{min}}\right)^{1.7} \tag{4}$$

$$= 0.082\left(\frac{\cos\theta}{E_{min}}\right)^{1.7} \text{ muons/cm}^2\text{/sec/sr} \tag{5}$$

The flux through a horizontal and a vertical surface is dN/dA_h and dN/dA_v, respectively.

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[1]If we could get a interest free loan from the Fed, I'd put 8 meters of rock over the detector such that any muon that gets to it would be much more energetic than our signal

Table 1. Cuboid parameters

Height (m)	Width (m)	Length (m)	A_h (m^2)	A_v(m^2)	R_h (Hz)	R_v(Hz)	Total (Hz)
5	5	13	65	180	169	126	295

$$\frac{dN}{dA_h} = \int_0^{2\pi}\int_0^1 \cos\theta \frac{dN}{d\Omega} d(\cos\theta)d\phi \tag{6}$$

$$= 2\pi \int_0^1 \cos\theta \frac{dN}{d\Omega} d(\cos\theta) \tag{7}$$

$$= 2\pi \int_0^1 \cos\theta \left[0.082\left(\frac{\cos\theta}{E_{min}}\right)^{1.7}\right] d(\cos\theta) \tag{8}$$

$$= 2.6 \text{ muons/m}^2\text{/sec} \tag{9}$$

$$\frac{dN}{dA_v} = \int_{-\pi/2}^{\pi/2} \cos\phi \int_0^1 \sin\theta \frac{dN}{d\Omega} d(\cos\theta)d\phi \tag{10}$$

$$= 2\int_0^1 \sin\theta \frac{dN}{d\Omega} d(\cos\theta) \tag{11}$$

$$= 2\int_0^1 \sin\theta \left[0.082\left(\frac{\cos\theta}{E_{min}}\right)^{1.7}\right] d(\cos\theta) \tag{12}$$

$$= 0.7 \text{ muons/m}^2\text{/sec} \tag{13}$$

Now compare to total detector surface. I am going to define a cuboid around the detector where I have assumed 2 kt of detector . The rates can be computed (TABLE 1).

Cosmics rays will never fake the muon signal. The duty factor is $\mathcal{O}(10^{-4})$ therefore the expected muon rate is 0.3 Hz. Over five operation years (5×10^7 seconds) including the duty factor, there will be 1 million cosmic rays. This is the same order as the rock muons.