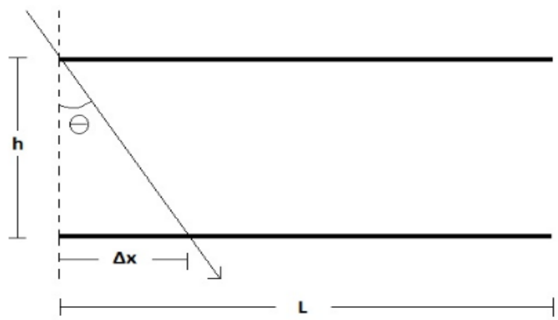
Nikhef Project: Simulation

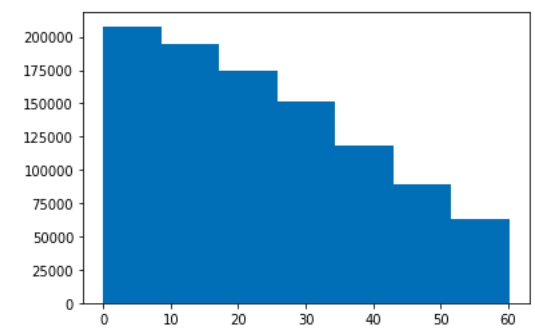
In the simulation the allpix-squared program is going to be used. First of all we have to test the detectable events for a variety of scintillators shapes but also we have to find the lower and highest energy value of muons for which muons are still detectable.

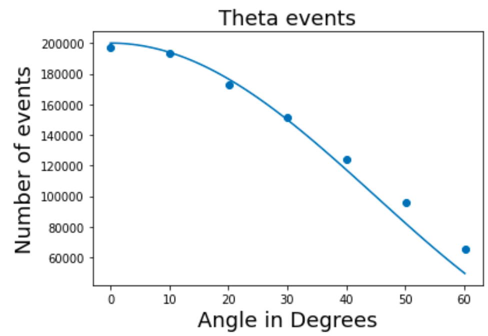
Our detector consist two square layers of scintillators. For this simulation the lower grid of scintillators is placed by its center at zero(0,0,0) and the maximum x,y being +-L/2 (with L being the length of each scintillator) at a horizontal plane. Considering the isotropic flux of a huge sky area we can assume that the grids are continuous surfaces. The upper layer has the same morphology except the z coordinate being h. The h value is calculated in order to all muons can be detectable, knowing that there is a cut-off at 60 degrees of theta (angle from the zenith). We have to define an angle cut-off θ_max, the h can be found by: $\tan(\theta\_max)=L/h \Rightarrow h=L/\tan(\theta\_max)$.

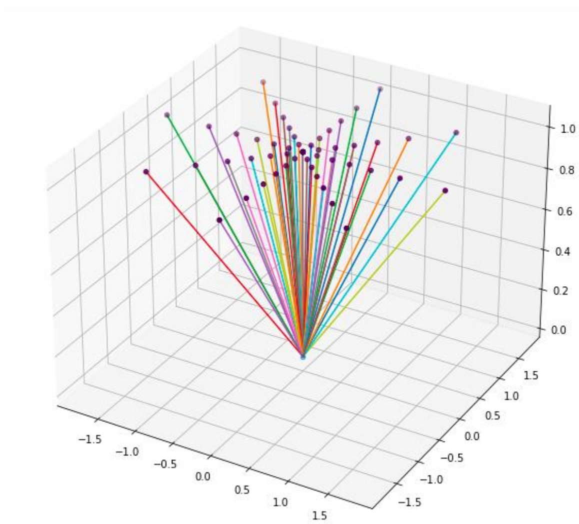


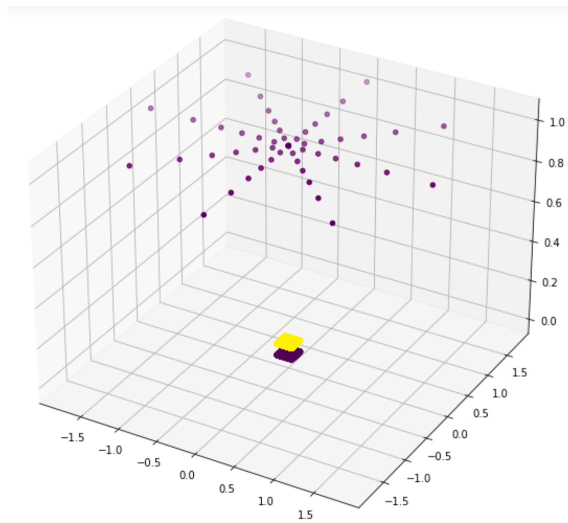
*A small correction on the shape of the grid should be by the exact shape of the grids, regarding this we could chose properly the angles or angles ranges knowing that the measurements wouldn't be θ but Δθ. We could also make a program for the data analysis, given the positions of the triggered detectors to calculate the Δθ,Δφ of the track.

The angular distribution for theta of cosmic muons follows a distribution $\cos(\theta)^2$ with a cut-off that we define, while the azimuthal angle follows a normal distribution with values $[-2\pi, +2\pi]$. So we choose a number of theta divisions and phi divisions for the possible positions of the source in our simulation (knowing that in allpix you can use one source per simulation). We choose the point of (0,0,h/2) as a point of the track of muons and the other (source point) being on a x-y plane at height H, regarding the shape of layers this trick can cover almost all the possible muons' tracks. By the above we can find all the source positions and directions for each case for the simulation. We then can define an initial total number of events and find the number of events by the given distribution. Then for each phi value the number of events is the theta number of events divided by the possible phi values, regarding the uniform distribution of phi. If we wanted to have a more random case that follows the given distributions we could use a metropolis hastling algorithm for the number of events. Example:









In the above example we used θ_max=60,7 θ values from 0 to 60 degrees and 8 ϕ values. So far we have the number of events for each direction. Then for each of those cases we have to find the number of events that correspond to each energy value and have to follow the energy distribution of muons. The energy spectrum of the muons is:

$$\frac{dN_\mu}{dE_\mu}(E_\mu,\theta) \simeq 0.14\, E_\mu^{-2.7} \left[\frac{1}{1+\frac{1.1 E_\mu cos\theta}{\epsilon_\pi}} + \frac{0.054}{1+\frac{1.1 E_\mu cos\theta}{\epsilon_K}} \right]$$

All the above will be used for only calculating the number of events for each case of θ,ϕ,E simulation. In the allpix formation of the scintillators’ layers we will use the exact dimensions and positions, this could lead to differences even at the detectable events by changing only the angle ϕ (although it has a uniform distribution).

In general by the simulation as a result we want to have the number of detectable events for each parameters values and the peaks of the two measurable pulses for each event (we could try to find it by other results of the simulation such as the integrated charge in the detector and by knowing the pulse’s shape ,if it's universal, we could calculate the peak). In the end we could try to make an ML regression algorithm to try to reconstruct the energy given the theta, phi and SiMP pulse peak and then test that to the experimental data. We could try to correct the simulated SiMP values by fitting them to observations and try to test the ML algorithm again for a smaller energy range of values (by placing a lead plate on the detector).

We can also perform the same process for the simple case of the initial cosmic watch morphology with one detector and two in coincidence by trying a variety of scintillator shapes. By that we can observe and test how the number of detectable events changes with the shape of the scintillators and energy, we can compare those results with experimental data. Finally we could try to check if the energy can be reconstructed by even at the simple case, but it is obviously much more difficult given that the direction is unknown. A more probable reconstruction would be the direction (or the angle theta) if the energy possible values have been restricted by a lead plate on the detector. The other possibility would be to construct the marginal probability distributions of the energy and theta given the SiMP's pulse peak.