

Abstract

Corsika is a cosmic ray shower simulator that tracks secondary particles until they reach the Earth's surface. Tracking all secondaries for primary energies above 10^{18} eV becomes computationally prohibitive, and produces large output files that are difficult to process. This project is investigating thinning in Corsika in order to reduce computational time and output file size.

Thinning reduces the number of particles tracked replacing multiple particles with a single particle which is assigned a weight. The weight is equal to the sum of the energies divided by the energy of the tracked particle.

Our goal is to investigate thinning and unthinning Corsika simulations, and the resulting fluctuations that are introduced.

Introduction

IceTop is part of the IceCube project, a one cubic kilometer neutrino telescope in the Antarctic ice. IceTop is on the surface directly above IceCube telescope and consists of an array of ice tanks with two digital optical modules (DOMs) that record the light produced by secondary particles. Corsika simulations are used to help understand the performance of the IceTop array and interpret data.

This study looked at how zenith angles affect simulation run time, and also investigated the fluctuations due to the stochastic nature of the production of secondary particles. In addition, the affect of thinning on run time was explored. Ultimately, the goal is to compare the results from unthinned simulations to non-thinned results.

A thinning level of 10^{-7} was used which means that in an interaction that produced particles with energies less than 10^7 of the primary particle energy, only one particle was kept. It is assigned a weight that accounts for the energy of the removed particles. This introduces artificial fluctuations in the predicted detector response. The surviving particle either hits the tank and produces a large response or misses and produces nothing. An algorithm for unthinning has been implemented and will

Procedure

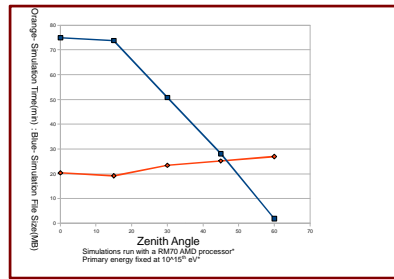
Test 1:
Corsika was used to investigate the effect of zenith angles on calculation times and file sizes. A 10^9 GeV energy proton was used and the zenith angle was varied from 0 to 60 degrees in 15 degree intervals.

Test 2:
Two sets of 100 showers were generated, with and without thinning, to compare the fluctuations. The Lateral Distribution Functions (LDF) were computed for electromagnetic portion of the showers and for the muons. Two provide a more consistent set of showers for comparison. One set of secondary particles were produced down to an energy of 10% of the primary particle energy. These secondary particles were stored and then read in using the STACKIN option. This eliminated the significant variable due to the first few interactions and allowed us to look at the inherent fluctuations for the lower energy interactions where the thinning takes place. The histograms shown are of 10^6 GeV energy level, where it is still feasible to produce unthinned showers for comparison.

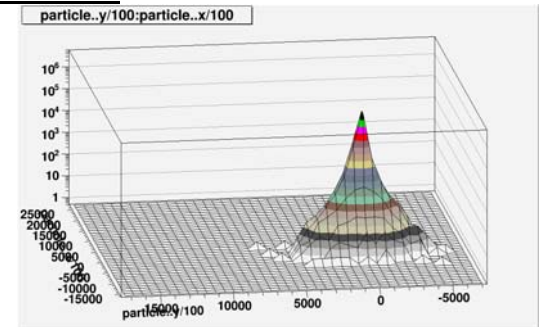


Results

Zenith Angle VS. Simulation Time and File Size

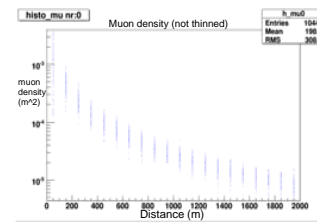


Calculation time can vary by about 25% by changing the zenith angle of the primary particle, while the amount of particles that make it to the ground drop significantly as shown by the file size drop.

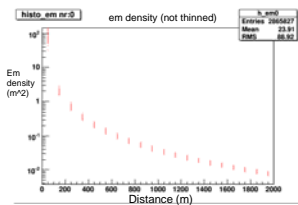


A 3D histogram of particle density, the highest point is the core of the cosmic shower. 10^{16} eV primary energy. X and Y axis are distances in meters, the Z axis is amount of particles.

non-thinned Data

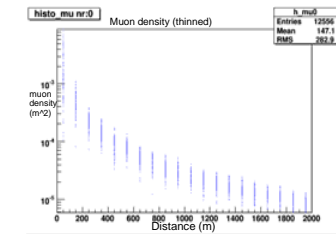


Fluctuations in the muon density with 100 simulations *no thinning, STACKIN option used.

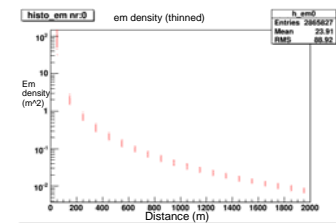


Fluctuations in the electromagnetic particle density with 100 simulations *no thinning, STACKIN option used.

Thinned Data



Fluctuations in the muon density with 100 simulations *thinning and STACKIN options used.



Fluctuations in the electromagnetic particle density with 100 simulations *thinning and STACKIN option used.

*The four graphs above were produced at 10^{15} eV energy.

Conclusion

- Increasing the zenith angle from 0 to 60° increases computation time by ~25% while significantly lowering the file size because few particles reach the ground at high angles.
- The STACKIN option allows comparison to made between unthinned and non-thinned results with significantly smaller number of events.
- The next step is to implement an unthinning algorithm in the reconstruction software, and optimize the thinning level.

Acknowledgements

I would like to thank Dr. Tamburro for guiding me through this project, Dr. Madsen for giving me the opportunity, UW-River Falls, UW-Waukesha, and the IceCube project.

*This work was supported the National Science Foundation IceCube project and the Office of International Programs

