Electromagnetic Shower Simulations

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Abstract

A qualitative and comparative study of electromagnetic showers simulated the Monte Carlo codes Geant4, EGS5 and AIRES, is presented. Particularly, we simulate the passage through air of electrons or photons of different energies and in the order of the MeVs. As the particle propagates, it gives rise to an electromagnetic shower. We analyse the longitudinal development of the shower, as well as its lateral dispersion and energy distribution. We find that there is a qood qualitative agreement between the three Monte Carlo codes used.

I. Introduction

At high energies, the most likely electron interaction is radiation, giving rise to secondary photons that in turn can materialize into an electron-positron pair. This results in a multiplicative cycle known as *electromagnetic shower* which can be initiated by an electron (or positron) or a photon. At somewhat lower energies the charged electrons or positrons suffer energy losses due to the interactions with other charged particles located in the propagating medium. In the case of photons, other processes like Compton scattering or photoelectric effect for example, become the most probable ones.

Because of the complexity of the processes involved, analytical descriptions of the electromagnetic shower are prohibitively difficult except under severe approximation. In this sense, the Monte Carlo technique provides a much better way for solving the shower generation problem, not only because all of the fundamental processes can be included, but because arbitrary geometries can be modeled and hypothetical scenarios can also be considered. Another fundamental reason for using the Monte Carlo method to simulate showers is that it allows a study of shower-by-shower fluctuations.

II. Simulations

We simulate the passage of electrons or photons of different energies and in the order of the MeVs through 100 m of air in standard conditions for temperature and pressure (STP) and with three different Monte Carlo Codes: Geant4 [1], EGS5 [2] and AIRES [3]. Then, we compare the longitudinal developments, lateral dispersion and energy distribution of the shower particles.

III. Results

We present in Fig. 1 and Fig. 2 the longitudinal development of electrons in the case of showers initiated by an electron (left) or a photon (right) of 15 (up) and 30 (down) MeV. As expected, at the lower primary energy, the electrons of the shower are completely stopped by the medium before than in the case of the greater primary energy.

Fig. 3 represents the lateral dispersion of the electrons of the shower for the three different Monte Carlo Codes. The color scale represents the amount of electrons per ring area defined by the begining and end of each bin (logarithmic scale).
As the shower advances there is a lateral dissemination of the particles. Initially, at the first levels, there are more particles around the core.

In Fig. 4 we present the electrons's energy distribution of a shower initiated by a photon of 30 MeV. The color scale represents the number of electrons per each bin (logarithmic scale). The lowest energy of the simulation was set up at 100 keV.

IV. Conclusions

There is a good qualitative agreement between the results obtained by Geant4, EGS5 and AIRES. This comparison should be improved by defining statistical parameters that allow comparing the different results in a quantitative approach.

Although the electromagnetic processes are well known, the parameterization used by the simulators are not coincident. Thus, it is essential to study these parameters in detail in order to ensure that the comparisons between them are done using similar model configurations.

Finally, the intention is to extend this study to high energies and to hadronic cascades.

References

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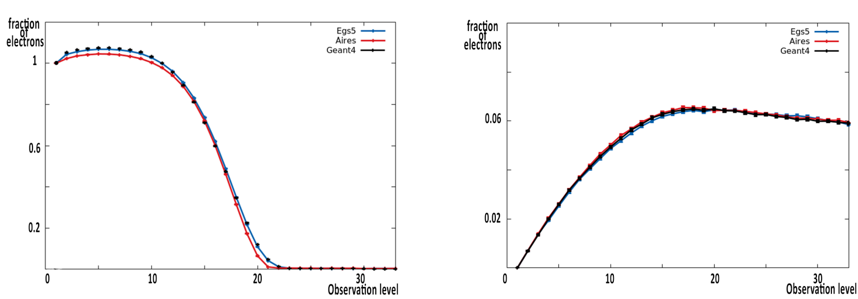

Figure 1: *Longitudinal development of electrons. Shower initiated by an electron (left) and a photon (right) of* 15 *MeV. The figure corresponds to an average of 200000 cases.*

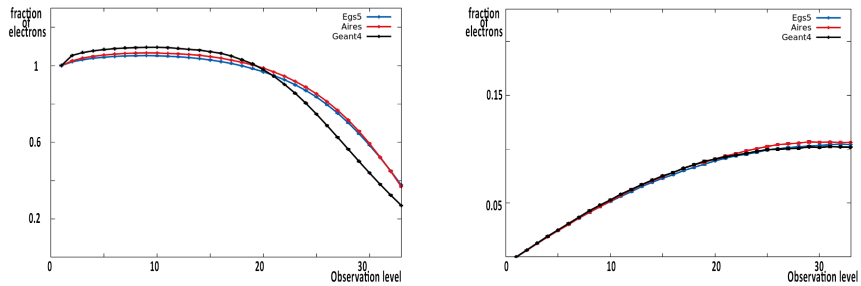

Figure 2: *Longitudinal development of electrons. Shower initiated by an electron (left) and a photon (right) of* 30 *MeV. The figure corresponds to an average of 200000 cases.*

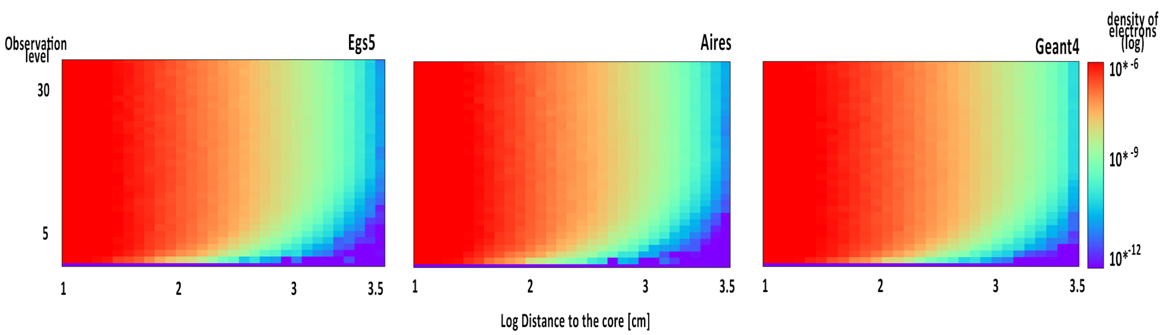

Figure 3: *Lateral dispersion of electrons. Shower initiated by a photon of* 15 *MeV. The figure corresponds to an average of 200000 cases.*

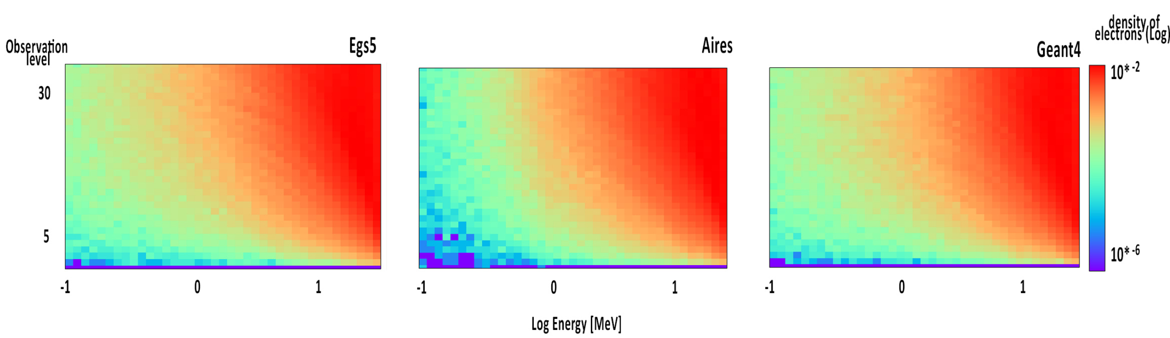

Figure 4: *Energy distribution of electrons. Shower initiated by a photon of* 30 *MeV. The figure corresponds to an average of 200000 cases.*