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Around the validity of the thinning method in the simulation of electromagnetic shower - the application to the LPM shower -

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Abstract. Recently, the thinning method has been widely utilized for air shower simulation to save computation time, keeping some accuracy on the calculation. In particular, this technique is applied to the calculation in the atmosphere. Surely, the results obtained by this method give rather accurate values as for the average values, while it could not give accurate results as for individual shower. In this paper, we compare individual shower by exact Monte Carlo method and corresponding ones by the thinning method in both the case of the BH shower and the LPM shower.

1 Introduction

Calculation for simulation in air shower requires huge computing time to obtain significant results for the analysis of physical events. The thinning method(Hillas (1981)), a kind of the approximate methods for exact simulation, has been introduced into air shower simulation to save computing time in one hand and to keep some accuracy in another hand. Except rigorous Monte Carlo method, any other approximate methods inevitably introduce inaccuracy into calculations. Stochastic fluctuations which are inherent in physical processes concerned are surely distorted by the introduction of the approximated methods. One of the demerits of the thinning method produce artificial fluctuation, which may mislead to analysis of individual cascade shower, particularly to the analysis of the LPM shower, because the LPM shower has originally strong fluctuation, compared with the BH shower.

As we could not expect to get a large amount of the LPM air shower, we are forced to study individual behavior of the LPM air shower, not their average behavior. It is suggested that the hybrid method is utilized for the analysis of individual LPM shower in the atmosphere instead of the thinning method, because the hybrid method produce less fluctuation in the showers than the thinning method do.

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2 The characteristics of the LPM shower. Demonstration by full Monte Carlo method

The characteristics of the LPM shower is summarized in two points:
[a] The average behavior of the LPM shower is quite different from that of the BH shower.
(Konishi (1978)).
[b] Individual behavior of the LPM shower is quite different from its average behavior of the LPM shower.
(Konishi (1991))
To emphasize the characteristics of the LPM effect in the electromagnetic cascade shower, we show the relation between individual LPM shower and their averaged in lead in Figure 1, because the LPM effect appear strongly in heavy material, as the LPM effect is a kind of the density effect.

The calculations are carried out by full Monte Carlo method. The multi-peak structure in individual LPM shower is essential characteristics of the LPM shower. It is easily understood that individual behavior of the LPM shower is quite different from the average ones. In Figure 2, on the contrast to Figure 1, we show an example of the BH showers by the full Monte Carlo method. Compared with the LPM shower, the BH shower is too less fluctuated . There are little difference between individual shower and average one.

Let us show here the LPM shower by the thinning method. In Figure 3 we give the corresponding one by the thinning method to Figure 1. Comparison between Figure 1 and Figure 3 shows that there are not clear difference between the LPM shower by full Monte Carlo method and the LPM shower by thinning method. The reason is as follows. As is clearly shown in Figures in our previous paper(Konishi (1991)) the fundamental structure of the LPM shower are essentially decided at the early stage of the shower development where small number of energetic shower particle are accideanally located, which produce possible diversity among the LPM showers. In present calculation of the LPM shower by thinning method, essential part of the shower is calculated by Full Monte Carlo method, not by thinning method, even if

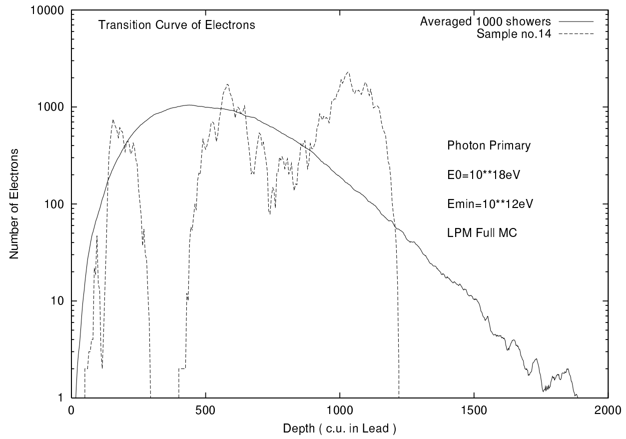

Fig. 1. One example of the LPM shower in lead by full Monte Carlo method and the average behaviors of the LPM showers.

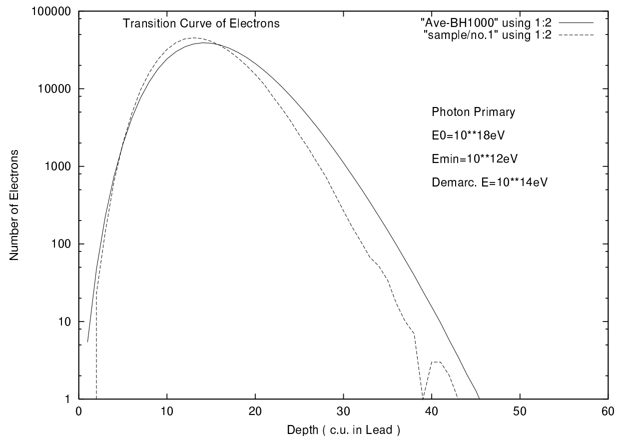

Fig. 2. One example of the BH shower in lead by full Monte Carlo method and averaged behavior of the BH showers.

thinning method is adopted totally. (Notice that demarcation energy ratio is rather high) Therefore, both methods produce roughly same characteristics of the LPM showers in this case.

To examine the degree of fluctuations in the electromagnetic cascade showers, we calculate the relative standard deviations of shower particle number in the LPM showers by full Monte Carlo and thinning method in Figure 4 and 5. It is easily understood from these Figures that the fluctuation is rather stronger in the thinning method than in full Monte Carlo method, which come from addition of artificial fluctuation introduced by thinning method. Further, for the comparison of the BH showers with the LPM shower, we give corresponding quantities in the BH showers in Figures 6 and 7. The situation is the same as in the LPM showers. Compared with the LPM shower, the BH shower is too less fluctuated. Nevertheless, strong fluctuation due to thinning method is occurred in the small number of samplings.

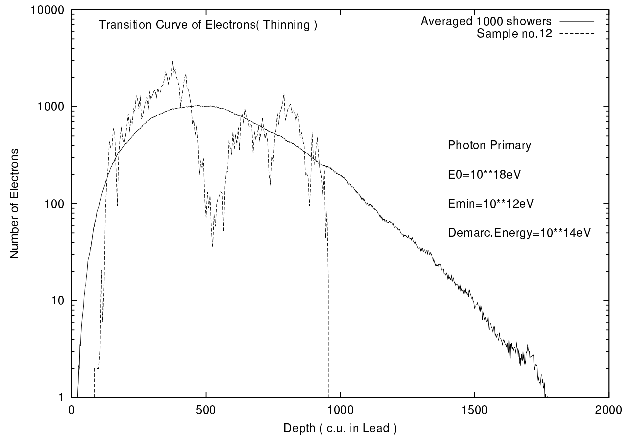

Fig. 3. One example of the LPM shower by thinning method and the averaged behaviors of the LPM shower.

3 The LPM shower in the atmosphere by the hybrid method

The LPM effect in the atmosphere is far weak compared with that in lead due to its lower density of the medium. The LPM effect in the atmosphere becomes effective beyond 10^{19} eV. Another characteristics of the LPM effect in the atmosphere is influenced by the change of the air density on position to position.

We adopt the hybrid method for the calculation of the LPM shower in the atmosphere to minimize artificial fluctuation in the showers. Our hybrid method is as follows: [a] We follow shower particles whose energies are greater than 10^{16} eV by full Monte Carlo method. [b] For shower particles whose energies are less than 10^{16} eV , we calculate new showers under Approximation B whose primaries are these particles by numerical method. Namely, we adopt average behavior of the electromagnetic shower concerned. For shower whose primary energies are less than 10^{16} eV, we could completely neglect the LPM effect . Namely, we could expect smaller fluctuation in this energy region, as the showers concerned become the BH showers.

In Figure 8, we give a transition curve of electron numbers in a LPM shower together with averaged over 500 hundreds of the LPM showers. We give results obtained by Full Monte Carlo method in lower part of the figure, while we give results obtained by hybrid method (Monte Carlo plus Average) in upper part of the Figure. It is understood that the development of this shower is strongly deviated from its averaged and such big deviation from the averaged comes from energy configuration among shower particles at the early stage of shower development.

We give the transition curve of electron numbers in individual LPM shower attached to average values, It is easily understood that there are big fluctuation around average values,coming from the LPM effect, although the LPM shower in the atmosphere never has the multi-peak structure which appeares in the LPM shower in lead.

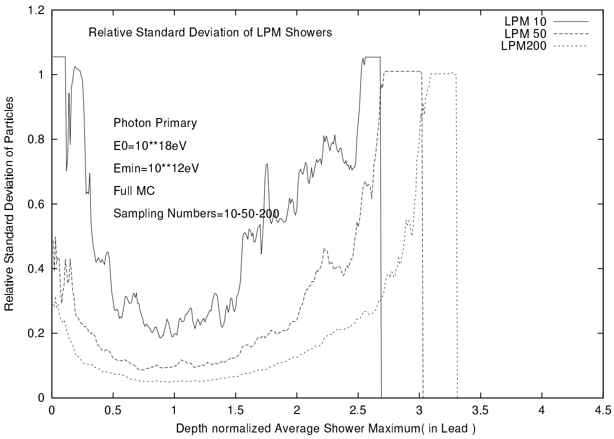

Fig. 4. Relative standard deviation of shower particles in the LPM shower by full Monte Carlo method.

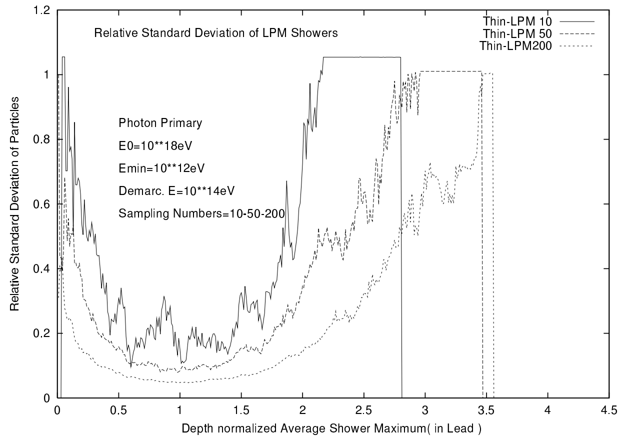

Fig. 5. Relative standard deviation of shower particles in the LPM showers by thinning method.

Finally, we mention to the average behaviors of the LPM showers by the hybrid method. In Figure 7,8 and 9 , total number of electrons are given for different starting points. It is understood that average behaviors of the LPM shower are different for different starting points, because the LPM effect is sensitive to positions where different densities are given.

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References

Hillas,A.M., Proc.17th ICRC,Paris,8(1981)T-53
Konishi,E. et al.,Nuovo CimentoA44(1978)509
Misaki,A.,Phys.Rev.D40(1989)3078
Misaki,A.,Nuovo CimentoC13(1990)414
Konishi,E. et al.,J.Phys.G:Nucl.Part.Phys.,7(1991)719
Misaki,A.,Nucl.Phys.(Proc.Suppl.)33A,B(1993)192

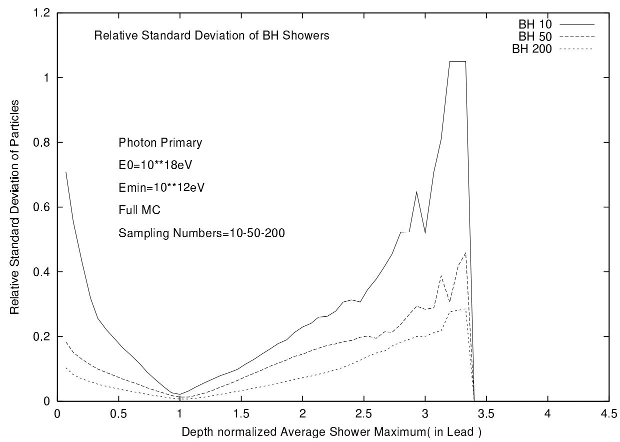

Fig. 6. Relative Standard deviation of shower particles in the BH shower by full Monte Carlo method.

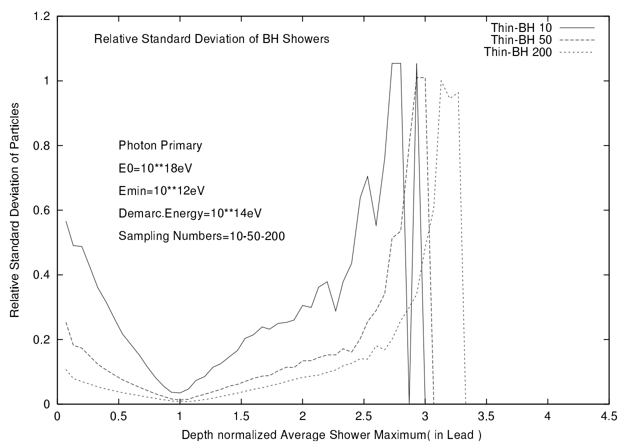

Fig. 7. Relative standard deviation of shower particles in the BH showers by thinning method.

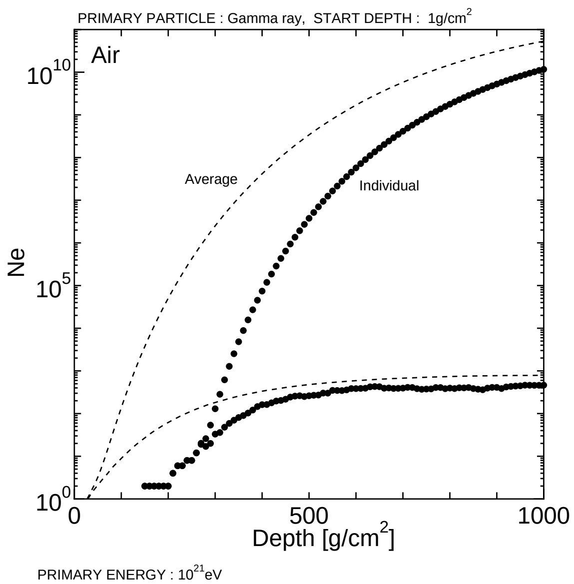

Fig. 8. One example of individual LPM shower in the atmosphere by the hybrid method and the averaged behavior of the LPM shower. Threshold energies of electrons of the upper and lower curves are 10^6 eV and 10^{16} eV respectively.

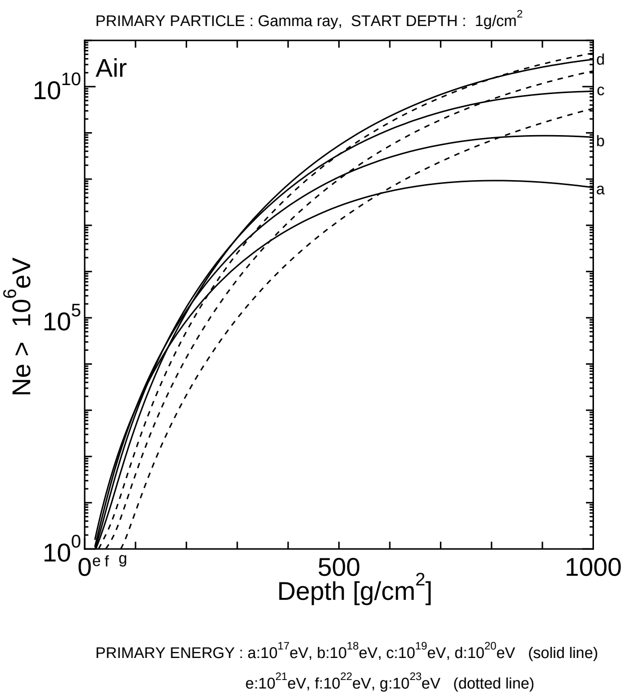

Fig. 9. The averaged behaviors of the LPM shower in the atmosphere by hybrid method, assuming that LPM showers start at $1g/cm^2$ in the atmosphere.

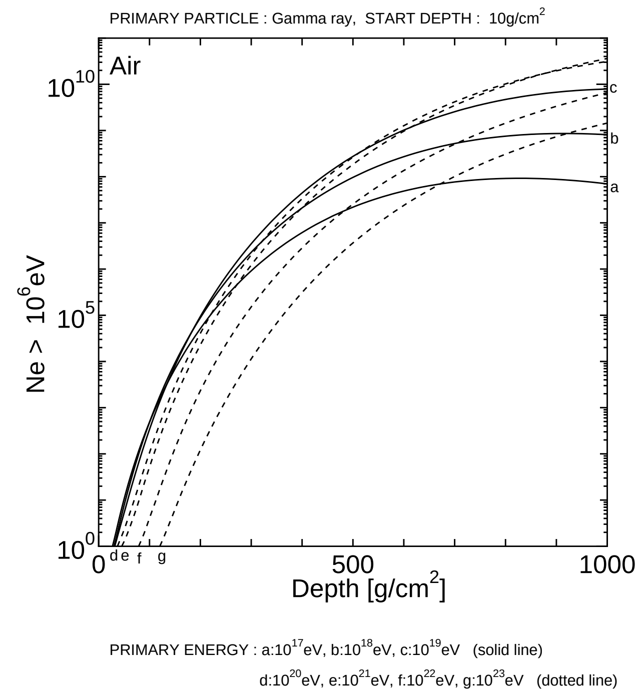

Fig. 10. The same behaviors of the LPM shower as in Figure 9, assuming that the LPM showers start at $10g/cm^2$ in the atmosphere.

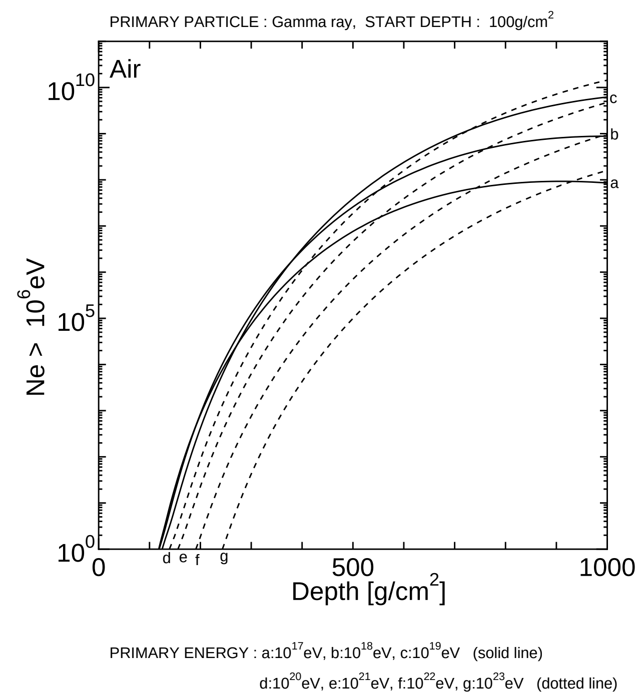

Fig. 11. The same behaviors of the LPM showers as in Figure 9, assuming that the LPM shower start at $100g/cm^2$.