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TRANSPORT CALCULATION OF LOW ENERGY ELECTRONS UNDER THE STRONG ELECTRIC FIELD OF THUNDERCLOUDS

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Abstract

In order to investigate the influence of acceleration for low energy electrons under the strong electric field such as thunderclouds, the amount of energy deposition in air was determined by the EGS4 code combined the routine calculating the effect of external electric fields. The cut-off energy dependence was also calculated by using this code and the other Monte Carlo code PENELOPE to evaluate the influence of lower energy electrons. From the results of these calculations, the low energy electrons of several tens keV do not contribute to acceleration in such electric fields.

1 Introduction

In the transport calculation of electrons under the strong electric field such as thunderclouds, it is necessary to evaluate the influence of the low energy electrons. Then, the contribution of electron acceleration in the strong electric field with energy of several tens keV or less was calculated by using electron and photon transport Monte Carlo calculation code EGS4 [1] combined the influence of external electric field [2]. Varying the cut-off energy of electrons as a parameter, the variation of the energy deposition in air was also calculated by the code. Moreover, the energy deposition was compared with that by the other Monte Carlo code PENELOPE (version 2001) [3] whose cut-off energy is a few hundred eV.

2 Calculation Method

In the calculation, we have modeled the electric field in atmosphere as follows:

- Calculation region: cylinder with 500 m in radius and 2 km in height (see Figure 1),
- Atmospheric pressure and temperature: 1 atm., 20 °C,
- Direction of the electric field: upward (uniform),
- Emitted position and direction of electrons: at 1 km in height (center of the cylinder), downward emission.

Under the above geometrical and electrical conditions, we have calculated energy depositions in air by using the EGS4 code combined the influence of electron transport by external electric fields, and obtained the influence of electron acceleration.

Moreover, the PENELOPE code we used adopts the simulation algorithm based on a scattering model that combines numerical databases with analytical cross section models for the different interaction mechanisms, and is applicable to energies from a few hundred eV to $\sim 1\ GeV$. Here, in order to calculate the electron transport under external electric fields, we used the subroutine package `penfield.f` of the PENELOPE code.

3 Results and Discussion

3.1 Variation of the energy deposition

In order to obtain the energy deposition under a strong electric filed (200 kV/m), we calculated the energy deposition in air by the EGS4 code. Here, we emitted the low energy electrons with energy of 2, 5, 20, and 50 keV, respectively. As shown in Figure 2a-d, there is few influence of the electron acceleration for the electrons of several keV. However, it can be seen a small amount of influence of the acceleration for several tens keV electrons, and the increment of the energy deposition was about 8 % for the electrons with energy of 50 keV.

3.2 Variation of the field strength

When the energetic electrons (10 MeV) were emitted into air, we calculated how the amount of the energy deposition would vary by changing the electron cut-off energy by the EGS4 code. Here, we selected 10 keV and 50 keV as the electron cut-off energy. As illustrated in Figure 3a-c, the rate of acceleration has hardly changed. From this result, the low energy electrons of several tens keV do not contribute to acceleration in such electric fields.

3.3 Variation of the field strength

Moreover, we have calculated the energy deposition under the electric field by using the PENELOPE code. In this calculation, we have changed the cut-off energy from 0.1 keV to 50 keV for determining the influence of lower energy electrons. Figure 4 shows the energy deposition for the incident electron of 10 MeV. The energy deposition is hardly changed for these cut-off energies. Furthermore, we compared the difference of energy deposition calculated by EGS4 and PENELOPE (see Figure5). The difference was about several percents, and it will be in the statistical error.

From above results, the low energy electrons do not influence acceleration under the electric field such as thunderclouds.

References

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[3] F. Salvat, J. M. Fernandez-Varea, E. Acosta, and J. Sempau, "PENELOPE - A Code System for Monte Carlo Simulation of Electron and Photon Transport", *OECD/NEA Data Bank and RSICC* (2001)

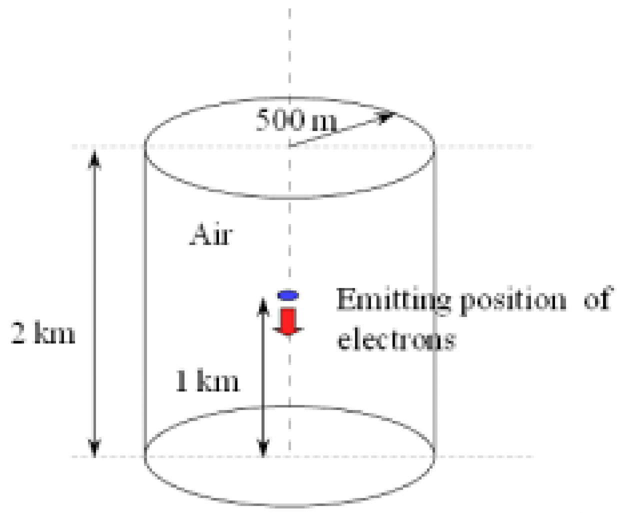

Figure 1: Geometry of Calculation

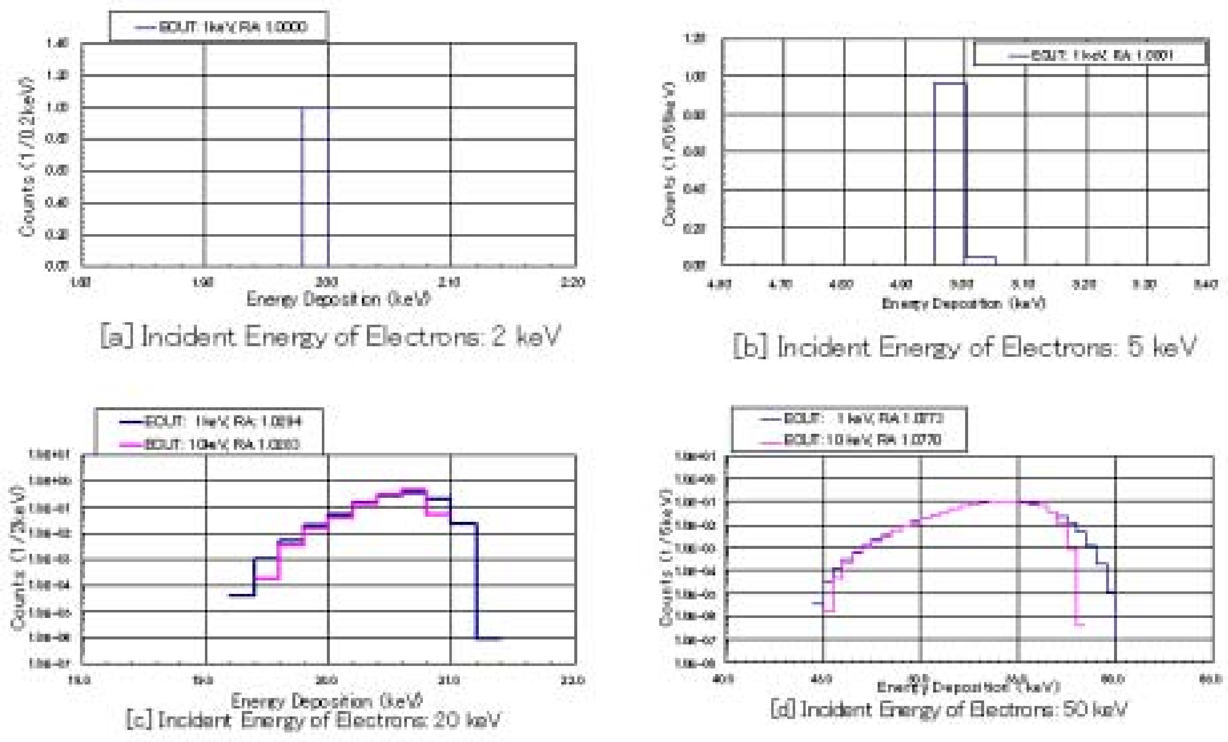

Figure 2: Rate of Acceleration (RA) under the Electric Field (200 kV/m)

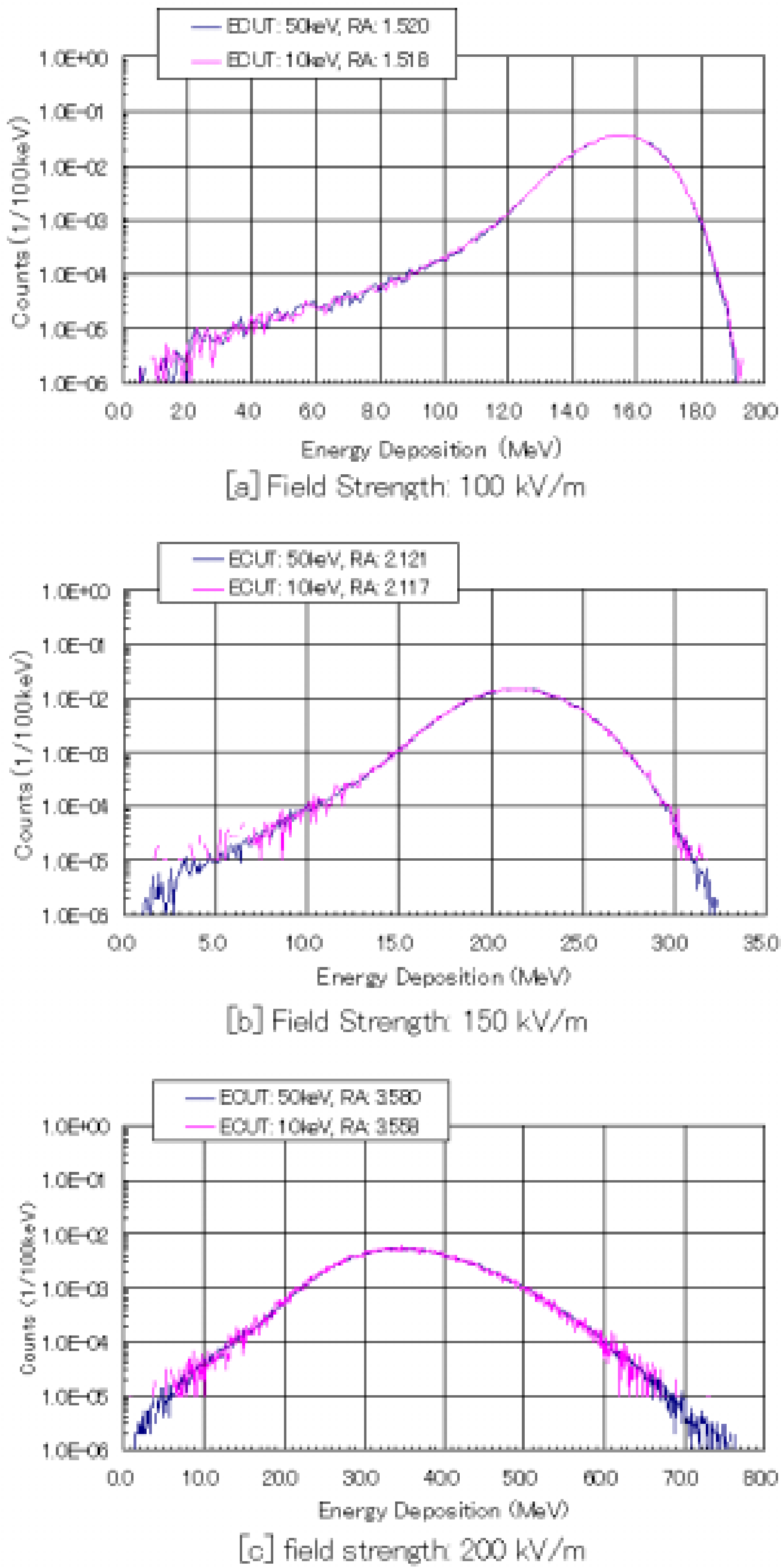

Figure 3: Rate of Acceleration (RA) of 10 MeV Electrons

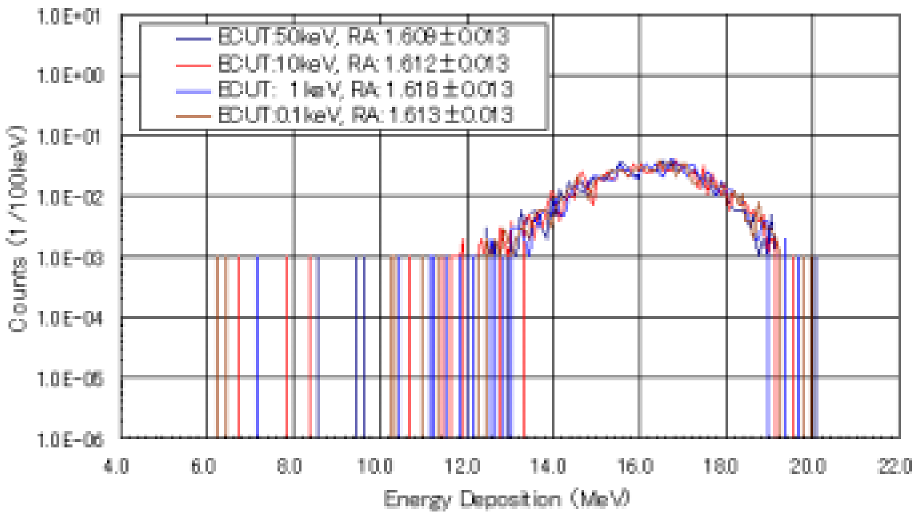

Figure 4: Rate of Acceleration (RA) of 10 MeV Electrons under the Electric Field (100 kV/m) by the PENELOPE code

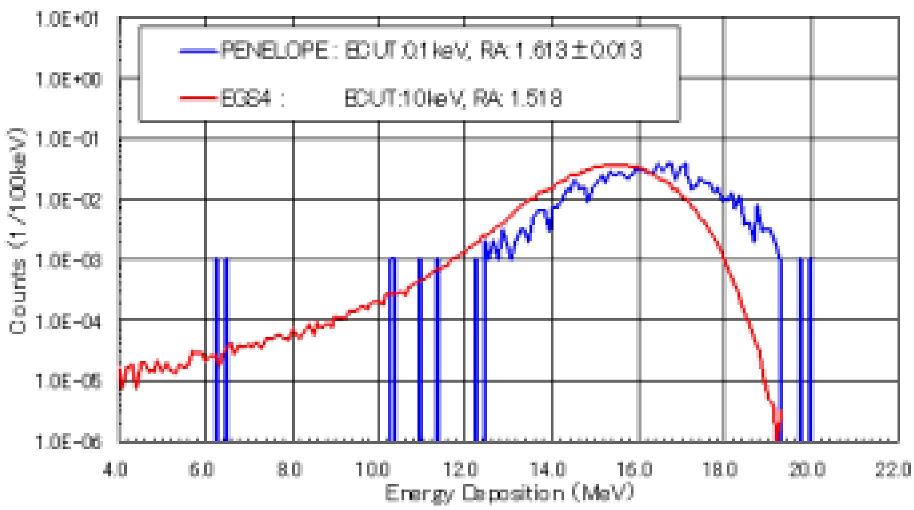

Figure 5: Comparison of Rate of Acceleration (RA) by the PENELOPE code with that by EGS4 [Field Strength: 100 kV/m, Electron Energy: 10 MeV]