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III-6-19. Results on the Angular and Radial Distributions of Particles in Electron-Photon Showers

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Calculations are being completed for electron and photon radial and angular distribution functions in lead and in emulsion absorbers.

Electron primaries of energy 50, 100, 200, 500 and 1000 Mev and photon and electron secondaries of energy 10, 20, 50, 100, 200 and 500 Mev have been considered. The complete results are to be given in a set of 776 Tables.

The Monte Carlo calculations performed using the electronic computer, SILLIAC, took into account multiple scattering, collision losses and Compton effect; Bethe-Heitler cross-sections accurate at low and high energies were used.

§1. Introduction

During the past year and a half the Sydney group of cosmic ray theoreticians in collaboration with two scientists from the U.S.S.R. have made a concerted effort to prepare the electron-photon angular and radial distribution problem in a form suitable for the use of Monte Carlo techniques using the electronic computer, SILLIAC. This task was completed early in 1961. The first results published by Messel et al[1] gave the number angular, number radial and ordinary angular and radial distributions of electrons in lead and emulsion absorbers for the case of a primary electron of energy 1000 Mev and secondary electrons of energy 10, 20, 50, 100, 200 and 500 Mev.

Calculations are now being completed for the following distribution functions: $T_1^1(E_0, E, \leq R, n, t)$ and $T_2^1(E_0, E, \leq \Theta, n, t)$, which give the probability of finding exactly n secondary electrons, at a depth t, with energies greater than E and at a radial distance less than R from the shower axis (both t and R measured in radiation lengths); or in the case of the angular distribution $T_2^1(\Theta)$—at an angle less than Θ radians to the shower axis; the primary particle being an electron of energy E_0. The corresponding distribution functions for secondary photons are given by $T_1^2(R)$ and $T_2^2(\Theta)$. In addition we are obtaining results for the more usual distribution functions $Q_1^1(E_0, >E, \leq R, t)$, $Q_1^2(E_0, >E, \leq R, t)$ and $Q_2^1(E_0, >E, \leq\Theta, t)$, $Q_2^2(E_0, >E, \leq\Theta, t)$ obtained from $T_1^1(R)$, $T_1^2(R)$, $T_2^1(\Theta)$ and $T_2^2(\Theta)$ respectively as follows:

$$Q_1^i(R)=\sum_{n=0}^{\infty} nT_1^i(R), \qquad (i=1, 2)\,,$$

$$Q_2^i(\Theta)=\sum_{n=0}^{\infty} nT_2^i(\Theta), \qquad (i=1, 2)\,.$$

These give the average number of secondary electrons ($i=1$) or secondary photons ($i=2$) with energies greater than E at a depth t and within a radial distance R, or making an angle less than Θ with the direction of the original primary electron of energy E_0. To complete the picture results for the respective variances

$$\sigma^2_{Q_2^i}=\sum_{n=0}^{\infty} n^2 T_1^i(R)-[Q_1^i(R)]^2, \qquad (i=1, 2)$$

$$\sigma^2_{Q_2^i}=\sum_{n=0}^{\infty} n^2 T_2^i(\Theta)-[Q_2^i(\Theta)]^2, \qquad (i=1, 2)\,.$$

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are also being obtained.

Tables are being computed for *electron primary energies* of 50, 100, 200, 500 and 1000 Mev and *photon and electron secondaries* of energy 10, 20, 50, 100, 200 and 500 Mev for showers developing in lead and in emulsion absorbers. Thirteen depths, namely $t=0.5$, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0 and 10 radiation lengths, have been considered.

The authors' calculations take into account multiple scattering, collision losses and Compton effect; Bether-Heitler cross-sections accurate at low and high energies were used—see reference 1).

The complete results above will be contained in a set of 776 Tables which will be published shortly.

References

1) H. Messel, A. D. Smirnov, A. A. Varfolomeev and J. C. Butcher: Jour. Nuc. Phys. (in the press)

Discussion

Carmichael, H.: We have tried to compare Dr. Messel's tables for 1000 Mev primary electrons in lead with our measurements of the electromagnetic cascade in lead using ion-chambers and also using a Cerenkov counter (M. Bercovitch at Chalk River). We have also compared with the multiplate cloud chamber results of Wilson and McDiarmid at Ottawa (unpublished). In both cases we find that the discrepancy appears to be about a factor of two, that is, the calculation predicts only half the number of particles that are observed. We wonder whether it was wise of Dr. Messel to neglect the radiation going in the backwards direction. Also perhaps the calculation should be carried out to energies of the shower particles smaller than 10 Mev in order to obtain a more satisfactory agreement with experiment in lead.

Messel, H.: For backward particles calculation was made for first 1000 showers. As there were very few backward particles, we cut out backward particles. Below 10 Mev, the cross section is not known very accurately but under some assumption it is possible to calculate what you want and send it to those who wish to know it, but we will not publish it because they are not very accurate.

Nishimura, J.: As you are doing the calculations as accurate as possible, I propose to take the cross section for the Coulomb scattering taking into account of the finite size of the nucleus. We know this surely affect the large angle scattering, which is most responsible for the tail of the structure function.

Messel: Yes, at higher energies we must do so.