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STUDIES OF THE LONGITUDINAL DEVELOPMENT
OF HIGH-ENERGY ELECTRON-PHOTON
CASCADE SHOWERS IN COPPER

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operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

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C. D. Zerby and H. S. Moran

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Abstract

Numerical results of the track lengths of photons and charged particles and the energy deposition as a function of depth out to 10 radiation lengths in copper are presented for the case of electron-initiated electron-photon cascade showers. The incident energy varied from 50 to 45,000 Mev in these cases.

Monte Carlo methods were used to calculate the longitudinal development of the showers in order to obtain the data that are presented. The Bethe-Heitler cross sections which include screening and the correct energy dependence were used for bremsstrahlung and pair production events. The Klein-Nishina formula was used for Compton scattering. Energy losses by ionization collisions were treated as a continuous energy degradation process.

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I. Introduction

In the theory of high-energy electron-photon cascade showers it is convenient to separate the lateral spread of the shower and its longitudinal development into two separate problems. This can be done most easily at high energies where the angular deflections of the radiation caused by the various interactions that can take place are predominantly small. In this case the longitudinal development can be approximated very well by ignoring the angular deflections and assuming that the shower develops along the direction of the initiating particle. This approximation has been the usual one in the treatment of the longitudinal development of showers and is used in every case that is referred to in this paper. The lateral spread of the radiation is not discussed here.

The analytic treatments of the longitudinal development of showers have been summarized by Rossi.¹ The most complete analysis has been achieved using "approximation A" (Ref. 1). Under this approximation the asymptotic forms of the bremsstrahlung and pair production cross sections are used and all other interactions are ignored, including energy degradation by ionization collisions.

Monte Carlo calculations of the longitudinal development of electron- and photon-initiated showers in lead for source energies from 20 to 500 Mev have been reported by Wilson.^{2*} In his calculations the correct energy dependence for bremsstrahlung and pair production interactions was used and energy degradation by Compton scattering and ionization collisions was included. Wilson also investigated the effects of multiple Coulomb scattering on the longitudinal development of the shower.

Butcher and Messel³ have also reported Monte Carlo calculations of the longitudinal development of electron-photon cascade showers in aluminum and air for source energies from 50 to 50,000 Mev. These data were generated using the correct energy dependence for the elementary interactions. Although both photon- and electron-initiated showers were calculated, only information on the electrons in the shower was presented.

The present calculation also uses the Monte Carlo method for estimating the longitudinal development of electron-photon cascade

*See the discussion of this work in Section V.

showers. The purpose of constructing the calculation was to provide a versatile tool for studying the details of showers developed in media of any elemental composition. In particular, the details of the photon spectra and track lengths can be generated by the calculation for use in determining photonuclear source strengths in various materials.

In Section II the physical processes that were included in the calculation are discussed. This is followed by a description of the Monte Carlo calculation in Section III and a description of the resulting computer program in Section IV. Comparisons of the results of the present calculation with the results of previous calculations and an experiment are given in Section V. The data from a comprehensive set of calculations for electron-initiated showers in copper are presented in Section VI. The initial electron energy varied from 50 to 45,000 Mev in these studies.

II. Physical Processes

Relatively few physical processes have to be considered to calculate accurately the longitudinal development of high-energy electron-photon cascade showers. For the energy degradation and transport of the photons it is adequate to consider only pair production and Compton events. For the energy degradation and transport of the electrons and positrons only radiative and ionization collisions need be considered. Of the remaining interactions that can take place, most of them can be neglected because of their small cross sections relative to the cross sections for the interactions that are retained. Hence, photonuclear events and nonelastic events of charged particles with nuclei can be excluded from the calculation. Direct pair production by positrons and electrons and annihilation in flight of the positrons can be neglected for the same reason. Nuclear Coulomb scattering, on the other hand, has a relatively large cross section, but it also can be neglected because the scattered radiation is concentrated in the forward direction with negligible energy degradation and does not seriously affect the longitudinal development of high-energy cascade showers.

In the remainder of this section each process that was retained in the calculation is described.

Pair Production

The differential cross section for the production of a positron-electron pair which includes the effects of screening and is applicable at high photon energy ($\alpha \gg 1$) and high positron and electron energies ($E_+ \gg 1$, $E_- \gg 1$) is given by⁴

$$d\sigma_p = \alpha_0 r_e^2 Z(Z+1) \frac{dE_+}{\alpha^3} \left\{ (E_+^2 + E_-^2) \left[\phi_1(\gamma) - \frac{4}{3} V(Z) \right] + \frac{2}{3} E_+ E_- \left[\phi_2(\gamma) - \frac{4}{3} V(Z) \right] \right\}, \quad (1)$$

where the quantity α_0 is the fine structure constant, r_e is the classical electron radius, and Z is the nuclear charge. The energies are expressed in mc^2 units. The functions $\phi_1(\gamma)$ and $\phi_2(\gamma)$ are tabulated⁴ as a function

of the argument $\gamma = 100 \alpha / E_+ E_- Z^{1/3}$ for $\gamma < 10$. For $\gamma \geq 10$ they are represented by $\phi_1(\gamma) = \phi_2(\gamma) = 4 \ln (200/\gamma) - 2$. The function $V(Z)$ is given by

$$V(Z) = \ln Z + 3f(Z) \left(1 - \frac{6}{0.511 \alpha} \right), \quad (2)$$

where

$$f(Z) = a^2 \left[(1 - a^2)^{-1} + 0.20206 - 0.0369a^2 + 0.0083a^4 - 0.002a^6 \right]$$

and $a = Z\alpha_0$. This expression for $V(Z)$ differs from the form derived originally by Bethe and Heitler⁵ using the Born approximation. The factor $3f(Z)$ in the second term on the right of Eq. 2 is a correction term to account for Coulomb forces and was suggested by Davis, Bethe, and Maximon.⁶ The quantity in parentheses in Eq. 2 is an empirical correction term which was also suggested by Davis, Bethe, and Maximon.⁶ Its form was selected so that the correction would be near unity at high photon energy and zero at 6 Mev where the Born approximation cross section agrees with the experimental values.

The usual factor of Z^2 in the cross section for pair production in the presence of electrostatic field of the nucleus has been replaced by $Z(Z + 1)$ in Eq. 1 to account approximately for production in the field of the atomic electrons. If we write the factor in question as $Z(Z + \nu)$, then we note that Bethe and Ashkin³ quote values of ν from 1.14 to 1.40 which depend on the atomic charge and which are applicable at very high energies. On the other hand, Heitler⁷ quotes a value of 0.8 for ν which is applicable at moderately high energies. The compromise of $\nu = 1$ which was used in this calculation was chosen because it represented an approximate average value.

Equation 1 can be put in better form by changing the independent variable to $x = E_+/\alpha$ so that

$$d\sigma_p = \Phi(Z) dx \left\{ \left\{ \phi_1(\gamma) \left[1 - \frac{4}{3} x(1-x) \right] - \frac{2}{3} x(1-x) \phi_3(\gamma) \right\} - \frac{9}{7} \left[K(Z) - \frac{P(Z)}{\alpha} \right] \left[1 - \frac{4}{3} x(1-x) \right] \right\}, \quad (3)$$

where

$$K(Z) = \frac{28}{27} \left[\ln Z + 3f(Z) \right], \quad (3a)$$

$$P(Z) = \frac{28 \times 6f(Z)}{9 \times 0.511}, \quad (3b)$$

$$\phi_3(\gamma) = \phi_1(\gamma) - \phi_2(\gamma), \quad (3c)$$

$$\gamma = \frac{\gamma_1}{x(1-x)}, \quad (3d)$$

$$\gamma_1 = \frac{100}{Z^{1/3} \alpha}, \quad (3e)$$

$$\Phi(Z) = \alpha_0 r_e^2 Z(Z+1). \quad (3f)$$

The total cross section for pair production is then given by

$$\sigma_p = \Phi(Z) F(\gamma_1) - \Phi(Z) K(Z) + \Phi(Z) \frac{P(Z)}{\alpha}, \quad (4)$$

where

$$F(\gamma_1) = \int_0^1 \left\{ \phi_1(\gamma) \left[1 - \frac{4}{3} x(1-x) \right] - \frac{2}{3} x(1-x) \phi_3(\gamma) \right\} dx. \quad (5)$$

It should be noted that F depends only on γ_1 and is therefore valid for all elements.*

*The fact that part of the pair production cross section could be represented in the form given in Eq. 5 was suggested by Bethe and Ashkin.⁴

For a medium with an elemental composition of N_i nuclei per cm^3 of nuclei with charge Z_i , $i = 1, 2, 3, \dots$, the macroscopic differential cross section is obtained from Eq. 3 as

$$d\Sigma_p = dx \left\{ \left\{ \overline{\phi}_1(\gamma_2) \left[1 - \frac{4}{3} x(1-x) \right] - \frac{2}{3} x(1-x) \overline{\phi}_3(\gamma_2) \right\} - \frac{9}{7} \left[\overline{K} - \frac{\overline{P}}{\alpha} \right] \left[1 - \frac{4}{3} x(1-x) \right] \right\}, \quad (6)$$

where

$$\overline{K} = \sum_i N_i \Phi(Z_i) K(Z_i), \quad (6a)$$

$$\overline{P} = \sum_i N_i \Phi(Z_i) P(Z_i), \quad (6b)$$

$$\overline{\phi}_1(\gamma_2) = \sum_i N_i \Phi(Z_i) \phi_1(\gamma), \quad (6c)$$

$$\overline{\phi}_3(\gamma_2) = \sum_i N_i \Phi(Z_i) \phi_3(\gamma), \quad (6d)$$

$$\gamma_2 = \gamma_0/x(1-x), \quad (6e)$$

and

$$\gamma_0 = 100/\alpha. \quad (6f)$$

The total cross section for a mixture is given by

$$\Sigma_p = \overline{F}(\gamma_0) - \overline{K} + \frac{\overline{P}}{\alpha}, \quad (7)$$

where

$$\bar{F}(\gamma_0) = \sum_i N_i \Phi(Z_i) F(\gamma_1).$$

At photon energies below 100 Mev the pair production cross section for individual elements was taken from the data presented by Grodstein⁸ and tabulated for use in the calculation. A cross-section table for any particular mixture of elements is easily generated from these data.

At energies below 30 Mev use was made of the form of the differential cross section for pair production reported by Hough.⁹ This form is an approximation to the Bethe-Heitler equation at low energies. It can be written in the form of the distribution function

$$h(x) = \frac{1}{1+M} h_1(x) + \frac{M}{1+M} h_2(x), \quad 0 \leq x \leq 1, \quad (8)$$

where $x = (E - 1)(\alpha - 2)^{-1}$. The quantities E and α are the electron and photon energies in mc^2 units, respectively,

$$h_1(x) = \frac{8}{\pi} x^{1/2} (1-x)^{1/2}, \quad (8a)$$

$$h_2(x) = 30x(1-x)(1-2x)^2, \quad (8b)$$

$$M = \frac{P}{13.91\pi},$$

$$P = Q - 0.52 \text{ for } \alpha > 4.2 \quad (8c)$$

$$= 0 \quad \text{for } 2 < \alpha \leq 4.2,$$

and

$$Q = (1 - 2\alpha^{-1}) \left[\frac{4}{3} (1 - \alpha^{-2})(L - 1) - 4\alpha^{-2} F(F - 1) - 16\alpha^{-4} F(L - F) \right], \quad (8d)$$

with

$$L = 2\alpha^2(\alpha^2 - 4)^{-1} \ln \left(\frac{\alpha}{2} \right), \quad (8e)$$

$$F = \alpha(\alpha^2 - 4)^{-1/2} \ln \left[\left(\frac{\alpha}{2} \right) + \left(\frac{\alpha^2}{4} - 1 \right)^{1/2} \right]. \quad (8f)$$

Compton Scattering

The differential cross section for Compton scattering of unpolarized incident photons is given by the Klein-Nishina expression⁴

$$d\sigma_c = \pi r_e^2 \left(\frac{\alpha'}{\alpha} \right)^2 \left[\frac{\alpha}{\alpha'} + \frac{\alpha'}{\alpha} - 1 + \mu^2 \right] d\mu, \quad (9)$$

where μ is the cosine of the polar angle of scattering. The initial energy of the photon, α , is related to the final energy, α' , by the Compton relation $\alpha' = \alpha/[1 + \alpha(1 - \mu)]$. The total cross section for Compton scattering is given by

$$\sigma_c = 2\pi r_e^2 \left\{ \frac{1 + \alpha}{\alpha^3} \left[\frac{2\alpha(1 + \alpha)}{1 + 2\alpha} - \ln(1 + 2\alpha) \right] + \frac{1}{2\alpha} \ln(1 + 2\alpha) - \frac{1 + 3\alpha}{(1 + 2\alpha)^2} \right\}. \quad (10)$$

This function was tabulated for use in the calculation.

Bremsstrahlung

The differential cross section for bremsstrahlung events which includes the effects of screening and is applicable for high incident energies ($E_0 \gg 1$) and high photon and final energies ($\alpha \gg 1$, $E \gg 1$) is given by⁴

$$d\sigma_b = \alpha_0 r_e^2 Z(Z + 1) \frac{d\alpha}{\alpha} \left\{ \left(1 + \frac{E^2}{E_0^2} \right) \left[\phi_1(\gamma) - \frac{4}{3} \ln Z \right] - \frac{2}{3} \frac{E}{E_0} \left[\phi_2(\gamma) - \frac{4}{3} \ln Z \right] \right\}, \quad (11)$$

where again the energies are given in mc^2 units. It should be noted that a correction term for the Coulomb forces is not required in the bremsstrahlung expression as it is in the one for pair production.⁶

The functions $\phi_1(\gamma)$ and $\phi_2(\gamma)$ are the same as those used in the expression for pair production but the argument of the function is now given by $\gamma = 100\alpha/E_0EZ^{1/3}$. Again in Eq. 11 the factor Z^2 has been replaced by $Z(Z+1)$ for the same reasons that were given in regard to the pair production cross section.

The differential cross section for bremsstrahlung given in Eq. 11 has a singularity at $\alpha = 0$. This singularity is most easily avoided by cutting off the low photon energy part of the cross section. By letting the cross section be zero for production of photons below an energy $\alpha = \epsilon E_0$, the average fractional energy loss neglected in an individual radiative collision is ϵ . In the calculation it was convenient to choose $\epsilon = 2 \times 10^{-4}$, so that the error introduced is small.

Following the development of the total pair production cross section, we put Eq. 11 in the form

$$d\sigma_b = \Phi(Z) dx \left\{ \frac{2(1-x)}{x} \left[\phi_1(\gamma) - \frac{\phi_2(\gamma)}{3} \right] + x\phi_1(\gamma) - \frac{4}{3} \left[\frac{4}{3} \frac{(1-x)}{x} + x \right] \ln Z \right\}, \quad (12)$$

where $x = \alpha/E_0$, $\gamma = \gamma_1 x / (1-x)$, and $\gamma_1 = 100/E_0 Z^{1/3}$. Since the singularity at $\alpha = 0$ has been removed the total cross section becomes

$$\sigma_b = \Phi(Z) G(\gamma_1, \epsilon) - \Phi(Z) I(\epsilon) \ln Z, \quad (13)$$

where

$$I(\epsilon) = \frac{4}{3} \left[-\frac{4}{3} \ln \epsilon - \frac{4}{3} (1 - \epsilon) + \frac{1}{2} - \frac{\epsilon^2}{2} \right] \quad (13a)$$

and

$$G(\gamma_1, \epsilon) = \int_{\epsilon}^1 \left\{ \frac{2(1-x)}{x} \left[\phi_1(\gamma) - \frac{\phi_2(\gamma)}{3} \right] + x \phi_1(\gamma) \right\} dx. \quad (13b)$$

The function $G(\gamma_1, \epsilon)$ depends only on γ_1 and ϵ and is valid for all elements.

For a medium with a mixture of elements the macroscopic differential cross section is

$$\begin{aligned} d\Sigma_b = dx \left\{ \frac{2(1-x)}{x} \left[\overline{\phi}_1(\gamma_2) - \frac{\overline{\phi}_2(\gamma_2)}{3} \right] \right. \\ \left. + x \overline{\phi}_1(\gamma_2) - \frac{4}{3} \left[\frac{4}{3} \frac{(1-x)}{x} + x \right] \overline{Q} \right\}, \quad (14) \end{aligned}$$

where $\gamma_2 = \gamma_0 x / (1-x)$, $\overline{\phi}_2(\gamma_2) = \overline{\phi}_1(\gamma_2) - \overline{\phi}_3(\gamma_2)$, and $\overline{\phi}_1(\gamma_2)$ and $\overline{\phi}_3(\gamma_2)$ are given by Eqs. 6c and 6d, respectively. The new function $\overline{Q}$ is defined by

$$\overline{Q} = \sum_i N_i \Phi(Z_i) \ln Z_i. \quad (14a)$$

The total cross section for the bremsstrahlung in a medium with a mixture of elements is given by

$$\Sigma_b = \overline{G}(\gamma_0, \epsilon) - \overline{Q} I(\epsilon), \quad (15)$$

where

$$\overline{G}(\gamma_0, \epsilon) = \sum_i N_i \Phi(Z_i) G(\gamma_1, \epsilon). \quad (15a)$$

Ionization Collisions

Since there are a large number of collisions made by charged particles with the bound atomic electrons, it is most economical to treat energy degradation by ionization collisions as a continuous process. The stopping power equations for this process are given as¹⁰

$$-\frac{dE}{dx} = \frac{2\pi r_e^2 NZ}{\beta^2} \left[\ln \frac{\beta^2(E-1)}{2I^2(1-\beta^2)} - \left(2\sqrt{1-\beta^2} - 1 + \beta^2 \right) \ln 2 \right. \\ \left. + 1 - \beta^2 + \frac{1}{8} \left(1 - \sqrt{1-\beta^2} \right)^2 \right] \quad (16)$$

for electrons and

$$-\frac{dE}{dx} = \frac{2\pi r_e^2 NZ}{\beta^2} \left[\ln \frac{2\beta^2(E-1)}{I^2(1-\beta^2)} - \frac{\beta^2}{12} \right. \\ \left. \left\{ 23 + \frac{14}{\gamma+1} + \frac{10}{(\gamma+1)^2} + \frac{4}{(\gamma+1)^3} \right\} \right] \quad (17)$$

for positrons. In Eqs. 16 and 17 the quantity E is the total energy of the charged particle, $\beta = v/c$, and $\gamma = (1 - \beta^2)^{-1/2}$. I , which depends on Z , is the average ionization potential that can be obtained from the tabulation of Bethe and Ashkin⁴ and N is the nuclear density of nuclei with charge Z . Equations 16 and 17 do not include the shielding effect of the polarization of the medium, but this is not likely to introduce a serious error since the density effect does not alter the stopping power formula except at high energies where losses by radiative collisions dominate the energy degradation problem.

For higher energies, $E \gg 1$, Eqs. 16 and 17 reduce to

$$S(E) \equiv -\frac{dE}{dx} = 2\pi r_e^2 NZ \left[\ln \frac{E^3}{2I^2} + b \right], \quad (18)$$

where $b = 1/8$ for electrons and $b = \ln 4 - (23/12)$ for positrons. For mixtures the stopping power equation can be represented as

$$S(E) = A \ln E + B, \quad (19)$$

$$A = 6\pi r_e^2 \sum_i N_i Z_i, \quad (19a)$$

$$B = 2\pi r_e^2 \sum_i N_i Z_i (b - \ln 2I_i^2). \quad (19b)$$

The range, $R(E)$ of the charged particles is calculated from

$$R(E) = \int_0^E \frac{dE'}{S(E')}. \quad (20)$$

If the stopping power formula given in Eq. 19 is used in this equation, then the ranges will be inaccurate; however, the difference $R(E_1) - R(E_2)$ should be very accurate if $E_1 > E_2 \gg 1$. Since the difference will be all that is required, we insert Eq. 19 into 20 and obtain

$$R(E) = \frac{E}{A} f(q), \quad (21)$$

where

$$q = \ln E + \frac{B}{A}, \quad (21a)$$

$$f(q) = e^{-q} E_1(q), \quad (21b)$$

$$E_1(q) = \int_{-\infty}^q \frac{e^x dx}{x}. \quad (21c)$$

The quantity B/A has values ranging from approximately 4 to 7; hence at high energies $q \gg 1$ the asymptotic form of $E_1(q)$,

$$E_1(q) \sim e^q \left(\frac{1}{q} + \frac{1}{q^2} + \frac{2!}{q^3} + \frac{3!}{q^4} + \dots \right), \quad (22)$$

can be used.

III. The Monte Carlo Procedure

In the first part of this section several selection techniques are described which were constructed especially for this problem. In the latter part of the section a description of the method of performing the complete Monte Carlo calculation is presented. A description of how the individual selection techniques were used is also included.

Selection Techniques

Basic to all the selection techniques is the use of pseudo-random numbers that are uniformly distributed on the interval $(0,1)$. These numbers, which are designated as R_i , were generated as needed by the congruence method.¹¹

A diagram of the technique used for selecting the energies of the electron and positron in a pair production event is shown in Fig. 1. This technique is based on Eq. 6 and is applicable at high photon energy ($\alpha \gg 1$). In the routine a value of x is selected from the correct distribution by first selecting a value from the distribution for the asymptotic form of the pair production cross section and then rejecting or accepting it with the appropriate probability.

At energies below 30 Mev the selection technique for the pair production interaction presented in Fig. 1 has a low efficiency and one must turn to an alternate technique for economy. Below 30 Mev the technique that was used is based on Eq. 8 and is shown in Fig. 2. The values of E given at the "yes" exit of some of the decision boxes are the efficiencies of the decision or, in other words, the probability that a yes exit will be achieved in a single test. The function Q shown in Fig. 2 is given in Eq. 8d and was tabulated for use in the routine.

The routine used for Compton scattering, which is based on Eq. 9, is shown in Fig. 3. It is assumed that the value of $\sigma \equiv \sigma_c$ required in the routine has been obtained from a tabulation of Eq. 10 prior to entering the routine. This selection technique for Compton scattering is valid only for $\alpha > 2.733$.

Fig. 1. A Method of Selecting the Energies of the Electron and Positron Created in Pair Production by Photons with Energies Above 30 Mev. The selection technique is based on Eq. 6 in the text.

Fig. 2. A Method of Selecting the Energies of the Electron and Positron Created in Pair Production by Photons with Energies Below 30 Mev. The selection is based on Eq. 8 in the text.

Fig. 3. A Method of Selecting the Cosine of the Polar Angle of Scattering, μ , with the Energy After Scattering, α' , of a Compton-Scattered Photon. This method is valid only for $\alpha > 2,733$.

The technique for selecting the energies of the photon and charged particle after a bremsstrahlung event is shown in Fig. 4. This technique is based on Eq. 14. The principle of the method is to select the energy of the photon from the distribution for the asymptotic form of the bremsstrahlung cross section and then to reject or accept the selection with the proper probability so that the final energy distribution conforms to the desired one.

The Complete Problem

The Monte Carlo calculation was carried out in a straightforward manner. For a photon that appeared in the cascade, the total interaction cross section, Σ_γ , which is the sum of the pair production cross section and Compton cross section, was calculated first. The macroscopic cross section for pair production for photon energies above 100 Mev was obtained from Eq. 7; for energies below 100 Mev the cross section was obtained from tables as described above. The macroscopic Compton cross section was always obtained from tables which were constructed with the use of Eq. 10.

Once the total cross section was obtained for the photon, a distance to the next interaction point, x , was selected from the exponential distribution $\Sigma_\gamma \exp(-\Sigma_\gamma x)$. At the point of interaction the choice between a Compton event and a pair production event was made by selecting a pseudo-random number R and letting a pair production event take place if $R < \Sigma_p/\Sigma_\gamma$. If $R \geq \Sigma_p/\Sigma_\gamma$ a Compton event takes place.

If a pair production event takes place the energies of the created pair are selected using the technique presented in Fig. 1 or Fig. 2 depending on the energy of the incident photon. For Compton events the energy of the scattered photon was selected using the technique presented in Fig. 3, and, since it presented no inconvenience, the photon was allowed to change direction. Compton scattering was the only physical process in which a direction change was allowed. The change of direction was carried out by using the polar angle of scattering from the selection technique shown in Fig. 3. A random azimuth angle was selected next and the coordinates of the collision were rotated to a fixed system. The

Fig. 4. A Method of Selecting the Energy of the Proton, α , and the Final Charged-Particle Energy, E , after a Radiation Collision by a Charged Particle with Initial Energy E_0 . The selection technique is based on Eq. 14 in the text.

recoil electron was then added to the cascade after its energy and momentum had been calculated from the kinematics of the collision.

The treatment of the charged particles in the cascade is in fact only slightly more complicated than the treatment of the photons in spite of the fact they lose energy by ionization collisions. This is so because the macroscopic bremsstrahlung cross section, Σ_b (see Eq. 15), with the low-energy photon cutoff is almost constant with respect to energy. Hence, with very little error, the distance between bremsstrahlung collisions, x , can be selected from the exponential distribution $\Sigma_b \exp(-\Sigma_b x)$.

If the distance to the next bremsstrahlung collision by a charged particle was greater than the distance y required to degrade its energy below 11 mc^2 , then the particle was assumed to stop after traveling a distance y and 11 mc^2 of energy was deposited at that point. The distance y was determined from $y = R(E_i) - R(E_f)$, where E_i corresponds to the initial energy of the charged particle and $E_f = 11.0$. The ranges $R(E)$ were obtained from Eq. 21. If $x < y$ the energy of the charged particle at the collision point was determined from the relation $R(E) - x = f(q_f)E_f/A$ with $q_f = \ln E_f + B/A$, which was solved for E_f by an iteration process. At the point of collision a photon was added to the cascade and the charged particle was degraded in energy. The partition of energy between the pair was selected using the technique presented in Fig. 4.

IV. The Computer Program

The present version of the computer program, which was written for the IBM-7090, will develop cascades in slabs of a homogeneous material with mixtures of up to 20 elements. The composition is specified by input to the program and the cross sections are set up automatically. The slab can be infinitely thick or have a finite thickness. The cascades can be initiated by normally incident positrons, electrons, or photons at any incident energy up to 50 Gev.

Another feature of the program is the variable nature of the energy bounds for spectral data. It is possible to arbitrarily select up to 15 such bounds other than the source energy which automatically divides the spectral data into the corresponding number of intervals.

The results of a cascade calculation include information on the track length* in each energy interval for each half radiation length¹ of thickness for photons and for charged particles. The radiation length, X_0 , is calculated for mixtures from

$$X_0 = \left(4 \bar{\Phi} \ln 183 - \frac{4}{3} \bar{Q} \right)^{-1}, \quad (23)$$

where $\bar{Q}$ is defined in Eq. 14a and $\bar{\Phi} = \sum_i N_i \Phi(Z_i)$.

The track length is calculated in the following way: If a particle makes a collision in the spatial interval of interest with energy in the energy interval of interest, then the value $1/\Sigma_T$ is recorded (Σ_T is the macroscopic total cross section). The total of all the values $1/\Sigma_T$ in the interval divided by the number of particles incident on the slab is an estimate of the track length for the particular interval of interest.

In addition to the track length, the flux of particles for each energy interval integrated over the entire plane at each half radiation

*Track length is equivalent to the flux which has been normalized to one source particle per second and integrated over a volume element. The units of track length are, for example, cm per Mev per source particle. Track length times the macroscopic cross section (cm^{-1}) gives the total number of reactions in the volume element per Mev.

length depth is obtained for photons and for charged particles. The flux is normalized to one incident particle per second; hence, the units are particles per incident particle. This quantity is calculated by storing the value $1/\gamma$ whenever a particle crosses the plane of interest in the energy interval of interest. The quantity γ is the direction cosine of the particle with respect to the normal to the slab. The total of all values of $1/\gamma$ divided by the number of particles incident on the slab is the estimate of the desired quantity. If the photons were not allowed to deviate from the incident direction, then the flux, as described here, would correspond to the particles crossing the plane of interest in the energy interval of interest per source particle. This is true because γ would always be equal to unity.

The method of calculating the flux just described provides an independent check of the track length since the average of the flux at two succeeding depths times the distance between the planes should correspond to the track length in that interval.

Another set of data that is calculated is the probability of finding exactly n ($n = 0, 1, \dots, 9$) particles with energy above each of the energy bounds at each half radiation length depth out to a maximum of 10 radiation lengths. These data are calculated for photons and charged particles.

The last set of data obtained from the calculation is the energy deposited in the slab as a function of depth for charged particles and for photons. The set of data for the charged particles is calculated by storing the energy deposited in each spatial interval by ionization collisions before the particles are degraded below some selected lower energy bound. Since the charged particles are not followed when their energy degrades below the lower energy bound, the kinetic energy of each electron or the total energy of each positron plus one rest mass unit of energy to account for annihilation is deposited at the position where the particle is no longer followed. The energy deposited by the photons is calculated by assuming that photons degraded below the lower energy bound or created in that energy range as bremsstrahlung are totally absorbed at the position of the event.

V. Comparisons With Other Calculations and With Experiment

Several cases were calculated for comparison with the data reported by Butcher and Messel.³ It was found that the results of the two calculations agreed very well in every case and in every detail. Three examples of the comparison are shown in Figs. 5, 6, and 7. The data presented in Fig. 5 are for 200-Mev electrons incident on a slab of air. Presented in the figure is the number of charged particles with energies above 10 Mev which cross planes at various depths in the slab. The depths are given in radiation lengths (see Eq. 23). The solid curve is a fit to the statistical data presented by Butcher and Messel and the data points are from the present calculation. It can be seen that the agreement of the two sets of statistical data is very good. Similar data for aluminum slabs are shown in Fig. 6 for several different source energies; again the agreement of the two calculations is very good. Figure 7 shows a comparison for the case of photons of various energies incident on slabs of aluminum. The agreement here is also very good except near the maximums of the curves for energies above 50 Mev. On the whole, however, the agreement is good.

In contrast to the good agreement with the calculation of Butcher and Messel is the disagreement with the calculation of Wilson.² Two figures from Wilson's paper¹² are reproduced in Figs. 8 and 9 and data points from the present calculation are superimposed for comparison. Figure 8 shows the charged particles crossing planes at various depths in a lead slab for the case of incident electrons, and Fig. 9 shows similar data for the case of incident photons. These two sets of data from Wilson's paper were selected for comparison because they were not altered to take into account multiple Coulomb scattering.

Wilson's data is for charged particles above 8 Mev but he found little difference between these data and the number of charged particles above 10 Mev.¹³ For this reason, the results of the present calculation for charged particles above 10 Mev are compared with his data. When it is noticed that the incident energies for Wilson's data and the incident energies of the apparently matching data from this calculation are quite different, it will be recognized that there is considerable difference

Fig. 5. The Number of Charged Particles in Showers Initiated by 200-Mev Electrons Which Cross Planes at Various Depths in Air. The solid line is a fit to the data of Butcher and Messel. The data points are from the present calculation.

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Fig. 6. The Number of Charged Particles in Showers Initiated by 50- to 500-Mev Electrons Which Cross Planes at Various Depths in Aluminum. The solid lines are fits to the data of Butcher and Messel. The data points are from the present calculation.

Fig. 7. The Number of Charged Particles in Showers Initiated by 50- to 500-Mev Photons Which Cross Planes at Various Depths in Aluminum. The solid lines are fits to the data of Butcher and Messel. The data points are from the present calculation.

Fig. 8. The Number of Charged Particles with Energy Above E_c in Electron-Initiated Showers that Cross Planes at Various Depths in Lead. The solid lines are the data of Wilson for $E_c = 8$ Mev. The incident energy corresponding to Wilson's data are indicated on the curves. The data points are from the present calculation for $E_c = 10$ Mev. The incident energy corresponding to these data are given in the legend. Note that the incident energies are different for the matching curves and data points.

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Fig. 9. The Number of Charged Particles with Energy Above E_c in Photon-Initiated Showers that Cross Planes at Various Depths in Lead. The solid lines are the data of Wilson for $E_c = 8$ Mev. The incident energy corresponding to Wilson's data are indicated on the curves. The data points are from the present calculation for $E_c = 10$ Mev. The incident energy corresponding to these data are given in the legend. Note that the incident energies are different for the matching curves and data points.

in the results from the two calculations. The data from this calculation are considerably below Wilson's data.

The data shown in Figs. 8 and 9 can be compared with analytic results. The area under the curves should correspond to the integral of the track length. From approximation A we have the track length for charged particles given by¹

$$T(E) = 0.437 (E_0/E^2), \quad (24)$$

where E_0 is the source energy and $T(E)$ has units of radiation lengths per Mev if E is in Mev units. The integral of $T(E)$ from $E = 10$ Mev to E_0 is the "integrated track length" for charged particles given by

$$T = 0.437 \left(\frac{E_0}{10} - 1 \right) \quad (25)$$

and should be comparable with the area under the curves shown in Figs. 8 and 9 when they are extended to infinity.

To make a positive comparison of the analytic and Monte Carlo results we will consider the case of source photons shown in Fig. 9. In this case the Monte Carlo results should be below the approximation A results for three reasons: (1) the area under the Monte Carlo result can only be obtained to ten radiation lengths; (2) the Monte Carlo results include energy loss by ionization collisions so that the track length at low energies (~ 10 Mev) should be below approximation A results which do not include this loss; and (3) at the higher energies ($\sim E_0$) the true charged-particle track length should be lower than that indicated in Eq. 24 because the latter gives a finite track length at $E = E_0$, although it should be zero for photon-initiated showers using Born approximation cross sections. The area under Wilson's curve for $E_0 = 500$ Mev on Fig. 9 is 27.8 radiation lengths, whereas Eq. 25 gives $T = 21.4$. This overestimate by Wilson's data in comparison with Eq. 25 persists at other energies and indicates his data is a considerable overestimate of the correct answer.

Although the argument is not as conclusive in the case of incident electrons since the true electron track length at $E \sim E_0$ should be above approximation A results,* it is not very likely that this will be sufficient to change the fact that the integral under the curves in Fig. 8 should be below the values given by Eq. 25. Hence, again, one must conclude that Wilson's data is an overestimate for source electrons.

The experimental results of Kantz and Hofstadter¹⁴ on energy deposition by a 185-Mev electron beam incident on various materials affords another check of the calculation. In this case the agreement is not very satisfactory, as is apparent from the comparison shown in Fig. 10 for lead. For this comparison the experimental data was arbitrarily normalized to the calculated data.

In the calculation the shower was normally cut off at 10 Mev so that particles which degraded below that energy were assumed to be totally absorbed. This case is shown as curve A in Fig. 10. Because the agreement with experiment was so poor, the cutoff energy was lowered in three successive steps to 6, 4, and 2 Mev as shown in curves B, C, and D, respectively. Although the agreement improved at each step, there still remains a serious discrepancy.

As the cutoff energy was lowered in the calculation the lower energy photons migrated to greater depths. Hence there was a transport of energy to greater depths with the result that the magnitude of the energy deposition decreased near the source and increased at large depths. This also resulted in a shift of the peak in the energy deposition curve to greater depths as seen in Fig. 10.

The energy deposition by ionization collisions (Eq. 18) at 185 Mev is indicated as a point at zero depth for comparison with the cases computed with cutoff energies. All the curves should actually terminate at this point. The reason they do not is because the curves represent a smooth fit to data which was obtained in histogram form where the interval width was one-half radiation length. This interval width was too large to indicate the correct shape of the curves near zero depth and, therefore, the curves are not shown in this region.

*See Figs. 13 and 14 in Section VI.

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Fig. 10. Energy Deposited at Various Depths in Lead by Showers Initiated by 185-Mev Electrons. The solid lines are the experimental data of Kantz and Hofstadter. The remaining curves are from the present calculation. For curve A shower particles which were degraded below a lower bound of 10 Mev were assumed to be totally absorbed. For curves B, C, and D the lower-energy bound was 6, 4, and 2 Mev, respectively. The experimental curve was arbitrarily normalized to the calculated data.

It is difficult to estimate which of the computed curves is the best since the angular deflections of the charged particles in the cascade were neglected. (The photon deflections were included as discussed in Section III.) For this reason it is most likely that the shift in the energy deposition to greater depths will not be as great as indicated in the case of the 2-Mev lower energy bound. In any case it is not likely that consideration of the angular deflections will significantly improve the comparison with experiment and the reason for the discrepancy remains unknown.

VI. Electrons Incident on Copper

A series of calculations were run to study the development of electron-initiated cascades in an infinitely thick slab of copper. Incident energies of 50, 100, 200, 400, and 700 Mev and 1.4, 3, 5, 10, 20, and 45 Gev were selected. The 20- and 45-GeV cases were run with 400 source electrons each, and the remaining cases were run with 1,000 source electrons each. The total running time on the IBM-7090 was 60 hr.

The track lengths* for photons and charged particles in the entire volume of the slab are presented in Figs. 11 through 14. The dashed line in each case represents the analytic results under approximation A which are independent of the type of radiation initiating the shower. They were obtained from¹

$$T(E) = 0.437 \frac{E_0 X_0}{E^2} \quad (26)$$

for charged particles and

$$T(E) = 0.572 \frac{E_0 X_0}{E^2} \quad (27)$$

for photons. In these equations E_0 is the source energy, E the degraded energy, and X_0 the radiation length (for copper $X_0 = 1.43$ cm). These equations are expected to hold when $E_c \ll E \ll E_0$, where E_c is the critical energy¹ (for copper $E_c = 21.8$ Mev). Indeed, Figs. 11 and 12 show that the approximate analytic results do fit the Monte Carlo data rather well for photons in the energy range below approximately $0.6E_0$ and above the critical energy. The fit of the approximate analytic results to the Monte Carlo solutions is not nearly so good for the charged particles, as is shown in Figs. 13 and 14. In this case the discrepancies at low energies are due to the fact that the energy loss by ionization collisions is becoming important in comparison with bremsstrahlung energy loss.

*See the footnote at the bottom of page 20.

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Fig. 11. Photon Track Lengths in Cascade Showers Initiated by 50- to 700-Mev Electrons Incident on an Infinite Slab of Copper. Dashed lines are from the track length formula using Approximation A. Data points are from the present calculation.

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Fig. 12. Photon Track Lengths in Cascade Showers Initiated by 1.4- to 45-Gev Electrons Incident on an Infinite Slab of Copper. Dashed lines are from the track length formula using Approximation A. Data points are from the present calculation.

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Fig. 13. Charged Particle Track Lengths in Cascade Showers Initiated by 50- to 700-Mev Electrons Incident on an Infinite Slab of Copper. The dashed line is from the track length formula using Approximation A for 700-Mev source particles; data points at the source energies were calculated using Eq. 28; the remaining points are from the Monte Carlo calculation.

Fig. 14. Charged Particle Track Lengths in Cascade Showers Initiated by 1.4- to 45-Gev Electrons Incident on an Infinite Slab of Copper. Dashed lines are from the track length formula using Approximation A; data points at the source energies were calculated using Eq. 28; the remaining points are from the Monte Carlo calculation.

Near the source energy the discrepancy is due to the fact that the Monte Carlo calculation is sensitively dependent on the initiating particle and when the showers are initiated by electrons the charged particle track length lies above the analytic result. In contrast, it can be seen in Figs. 11 and 12 that the photon track length of the electron-initiated showers is below the analytic result near the source energy.

In Figs. 13 and 14 the charged-particle track length at the source energy for the electron-initiated showers was calculated analytically from

$$T(E_0) = \frac{1}{S(E_0)} \quad (28)$$

where $S(E_0)$ is given by Eq. 19. The derivation of this equation* is based on the fact that the bremsstrahlung cross section, Σ_b , is finite and the flux of charged particles, $\phi(E, x)$, at depth x near the source plane is related to the incident flux $\phi(E', 0)$ by the expression¹

$$\phi(E, x) = \frac{S(E')}{S(E)} \phi(E', 0) \exp \left[- \int_E^{E'} \frac{\Sigma_b(E'') dE''}{S(E'')} \right] \quad (28a)$$

where x , E , and E' are related through

$$x = \int_E^{E'} \frac{dE''}{S(E'')} \quad (28b)$$

For the case at hand a monoenergetic incident beam at energy E_0 with unit intensity the incident flux is represented by

$$\phi(E', 0) = \delta(E' - E_0). \quad (28c)$$

The track length at energy E is obtained from¹

$$T(E) = \int_0^\infty \phi(E, x) dx$$

*We are indebted to F. S. Alsmiller for many helpful discussions on this subject and for the method of derivation presented here.

with the use of Eqs. 28a and 28c yielding

$$T(E) = \int_0^{\infty} \frac{S(E')}{S(E)} \delta(E' - E_0) \exp \left[- \int_E^{E'} \frac{\Sigma_b(E'')}{S(E'')} dE'' \right] dx$$

which can be integrated by transforming to the integration variable E' .

This is done with the use of Eq. 28b yielding

$$T(E) = \frac{1}{S(E)} \exp \left[- \int_E^{E_0} \frac{\Sigma_b(E'')}{S(E'')} dE'' \right]. \quad (28d)$$

Equation 28d is valid only for energy E near the source energy E_0 . When E is set equal to E_0 , Eq. 28 results. Equation 28 is the same as that deduced in connection with the analysis of showers as discussed by Rossi.¹⁵

The derivative of the track length at the source energy is easily obtained from Eq. 28d as

$$\lim_{E \rightarrow E_0} \frac{dT(E)}{dE} = \frac{\Sigma_b(E_0) - \frac{dS(E_0)}{dE_0}}{[S(E_0)]^2}. \quad (29)$$

Equation 29 was used to verify the slope of the curves near the source energy shown in Figs. 13 and 14.

The track length for photons in Figs. 11 and 12 has been fitted with an empirical formula over a limited range. For showers initiated in copper by electrons with energies above 200 Mev, the photon track length is given by

$$T(E) = \frac{X_0}{E_0} \left[\frac{0.572}{(E/E_0)^2} - 0.272(E/E_0 - 0.025) \right] \text{ for } E/E_0 > 0.025 \quad (30)$$

$E_0 > 200 \text{ Mev.}$

The detailed track length data in various depth intervals for both photons and charged particles have been included in the Appendix.

The calculated energy deposited in the copper by the electron-initiated showers is shown in Figs. 15 and 16. These data represent the sum of the energy deposited by charged particles and photons using a low-energy bound of 10 Mev as discussed at the end of Section IV. These data should be

Fig. 15. Energy Deposition in a Copper Slab by Photon-Electron Cascades Initiated by Normally Incident 50- to 1400-Mev Electrons

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Fig. 16. Energy Deposition in a Copper Slab by Photon-Electron Cascades Initiated by Normally Incident 3- to 45-GeV Electrons

considered as approximate because of the relatively high low-energy bound. The possible modification of the curves by including the transport of the low-energy particles is suggested by the data presented in Fig. 10.

Acknowledgement

We would like to express our appreciation to W. K. H. Panofsky who suggested this problem and to F. S. Alsmiller for many helpful discussions.

Appendix

Tables 1 through 22 present the detailed track length data for photons and charged particles calculated from electron-initiated showers in copper. The track lengths are given in each half-radiation length of depth out to 10 radiation lengths and from 10 radiation lengths to infinity at various energies. The track length is given in units of cm/Mev and the energy in units of Mev. Actually the integral track length was determined in an energy interval and then divided by the interval width to obtain the data presented in the tables. The midpoint of the energy interval is the energy that is recorded.

The total track length which is the sum of all the track length entries at each energy is also recorded. The total track lengths were the values used to construct Figs. 11 through 14.

It should be remembered in using these data that they are not absolute values but represent statistical estimates. Hence fluctuations in the estimates will be noticed when comparing entries in adjoining intervals when the intervals are small. In most cases it is beneficial to plot the data over several intervals to get a good indication of the trends and a reasonable method of deducing the best estimate of the absolute value.

An index to the tables is given on the following page.

Table Number

<u>Incident Energy</u>	Photon	Charged Particle
	<u>Track Lengths</u>	<u>Track Lengths</u>
50 Mev	1	2
100 "	3	4
200 "	5	6
400 "	7	8
700 "	9	10
1.4 Gev	11	12
3.0 "	13	14
5.0 "	15	16
10.0 "	17	18
20.0 "	19	20
45.0 "	21	22

Table 1. Photon Track Length for Electron-Initiated Showers in Copper
Electron Source Energy: 5C Mev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	1.46×10^{-2}	3.10×10^{-2}	2.28×10^{-2}	2.73×10^{-2}	1.82×10^{-2}	2.09×10^{-2}	1.16×10^{-2}	1.64×10^{-2}	1.18×10^{-2}	9.11×10^{-3}	2.73×10^{-3}
17	1.04×10^{-2}	1.73×10^{-2}	1.85×10^{-2}	1.61×10^{-2}	1.10×10^{-2}	1.10×10^{-2}	8.06×10^{-3}	5.22×10^{-3}	7.51×10^{-3}	2.36×10^{-3}	2.92×10^{-3}
25	4.20×10^{-3}	9.06×10^{-3}	7.75×10^{-3}	6.49×10^{-3}	6.20×10^{-3}	1.94×10^{-3}	2.24×10^{-3}	1.62×10^{-3}	2.26×10^{-3}	6.45×10^{-4}	2.24×10^{-3}
31.25	8.61×10^{-3}	2.03×10^{-2}	8.63×10^{-3}	1.30×10^{-2}	9.24×10^{-3}	4.30×10^{-3}	4.96×10^{-3}	5.54×10^{-3}	1.24×10^{-3}	3.71×10^{-3}	6.17×10^{-4}
38.75	5.89×10^{-3}	4.14×10^{-3}	5.25×10^{-3}	2.94×10^{-3}	2.37×10^{-3}	5.94×10^{-4}	1.76×10^{-3}	5.82×10^{-4}	5.92×10^{-4}	1.16×10^{-3}	0
46.25	0	1.71×10^{-3}	1.70×10^{-3}	1.13×10^{-3}	5.64×10^{-4}	0	0	0	5.74×10^{-4}	0	5.67×10^{-4}

Table 1 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	3.65×10^{-3}	5.48×10^{-3}	6.40×10^{-3}	7.33×10^{-3}	4.56×10^{-3}	1.81×10^{-3}	9.17×10^{-4}	0	2.74×10^{-3}	5.48×10^{-3}	2.25×10^{-1}
17	2.92×10^{-3}	2.92×10^{-3}	2.84×10^{-3}	2.30×10^{-3}	1.17×10^{-3}	1.17×10^{-3}	1.18×10^{-3}	0	0	4.61×10^{-3}	1.30×10^{-1}
25	9.87×10^{-4}	9.78×10^{-4}	9.45×10^{-4}	9.63×10^{-4}	0	3.13×10^{-4}	9.80×10^{-4}	0	0	1.62×10^{-3}	5.14×10^{-2}
31.25	2.47×10^{-3}	1.23×10^{-3}	6.06×10^{-4}	6.17×10^{-4}	0	6.07×10^{-4}	0	0	0	0	8.56×10^{-2}
38.75	1.19×10^{-3}	5.98×10^{-4}	1.18×10^{-3}	6.00×10^{-4}	5.99×10^{-4}	0	0	5.98×10^{-4}	0	0	3.01×10^{-2}
46.25	0	0	0	0	0	0	0	0	0	0	0

Table 2. Charged Particle Track Length for Electron-Initiated Showers in Copper
 Electron Source Energy: 50 Mev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	6.34×10^{-3}	1.88×10^{-2}	1.46×10^{-2}	2.50×10^{-3}	2.32×10^{-3}	1.84×10^{-3}	9.84×10^{-4}	1.16×10^{-3}	1.20×10^{-3}	6.69×10^{-4}	4.24×10^{-4}
17	6.18×10^{-3}	1.95×10^{-2}	8.20×10^{-3}	1.22×10^{-3}	1.06×10^{-3}	4.92×10^{-4}	2.81×10^{-4}	5.86×10^{-4}	2.57×10^{-4}	1.64×10^{-4}	2.34×10^{-4}
25	9.24×10^{-3}	1.65×10^{-2}	1.32×10^{-3}	2.37×10^{-4}	8.36×10^{-5}	5.57×10^{-5}	1.67×10^{-4}	2.64×10^{-4}	3.96×10^{-5}	2.78×10^{-5}	1.25×10^{-4}
31.25	1.21×10^{-2}	1.21×10^{-2}	9.24×10^{-5}	9.25×10^{-5}	4.62×10^{-5}	4.62×10^{-5}	9.23×10^{-6}	2.77×10^{-5}	2.77×10^{-5}	9.24×10^{-6}	0
38.75	2.34×10^{-2}	1.72×10^{-3}	0	0	0	0	0	9.20×10^{-6}	9.20×10^{-6}	0	0
46.25	3.70×10^{-2}	0	0	0	0	0	0	0	0	0	0

Table 2 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	4.57×10^{-4}	3.51×10^{-4}	6.38×10^{-4}	3.89×10^{-4}	2.13×10^{-4}	2.13×10^{-4}	1.77×10^{-4}	3.57×10^{-5}	3.54×10^{-5}	8.49×10^{-4}	5.41×10^{-2}
17	2.57×10^{-4}	4.70×10^{-5}	1.41×10^{-4}	1.64×10^{-4}	0	0	7.04×10^{-5}	1.40×10^{-4}	2.35×10^{-5}	3.75×10^{-4}	3.94×10^{-2}
25	2.79×10^{-5}	0	6.97×10^{-5}	1.40×10^{-5}	0	0	1.39×10^{-5}	2.79×10^{-5}	6.96×10^{-5}	1.40×10^{-5}	2.84×10^{-2}
31.25	3.69×10^{-5}	0	2.77×10^{-5}	0	9.25×10^{-6}	0	0	0	0	0	2.47×10^{-2}
38.75	9.20×10^{-6}	0	0	0	0	0	0	0	0	0	2.51×10^{-2}
46.25	0	0	0	0	0	0	0	0	0	0	3.70×10^{-2}

Table 3. Photon Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 100 Mev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	1.46×10^{-2}	3.91×10^{-2}	5.37×10^{-2}	5.11×10^{-2}	5.28×10^{-2}	4.38×10^{-2}	2.55×10^{-2}	3.55×10^{-2}	2.19×10^{-2}	2.92×10^{-2}	1.73×10^{-2}
17	1.51×10^{-2}	2.19×10^{-2}	3.01×10^{-2}	3.71×10^{-2}	2.89×10^{-2}	2.37×10^{-2}	1.84×10^{-2}	1.39×10^{-2}	1.62×10^{-2}	8.71×10^{-3}	1.16×10^{-2}
25	8.45×10^{-3}	1.56×10^{-2}	1.85×10^{-2}	1.36×10^{-2}	1.46×10^{-2}	1.07×10^{-2}	1.17×10^{-2}	8.49×10^{-3}	6.16×10^{-3}	6.82×10^{-3}	1.94×10^{-3}
35	1.79×10^{-3}	7.76×10^{-3}	1.05×10^{-2}	8.99×10^{-3}	6.27×10^{-3}	5.41×10^{-3}	5.09×10^{-3}	4.49×10^{-3}	4.56×10^{-3}	2.12×10^{-3}	1.20×10^{-3}
45	3.71×10^{-3}	6.55×10^{-3}	4.28×10^{-3}	3.72×10^{-3}	2.28×10^{-3}	3.12×10^{-3}	2.86×10^{-3}	1.98×10^{-3}	1.71×10^{-3}	8.49×10^{-4}	8.48×10^{-4}
62.5	1.94×10^{-3}	3.00×10^{-3}	3.46×10^{-3}	1.77×10^{-3}	1.42×10^{-3}	1.51×10^{-3}	1.41×10^{-3}	6.20×10^{-4}	2.66×10^{-4}	4.44×10^{-4}	5.30×10^{-4}
77.5	7.66×10^{-4}	1.45×10^{-3}	1.27×10^{-3}	1.10×10^{-3}	7.71×10^{-4}	3.39×10^{-4}	7.72×10^{-4}	2.55×10^{-4}	3.42×10^{-4}	2.54×10^{-4}	3.42×10^{-4}
92.5	6.62×10^{-4}	4.14×10^{-4}	3.30×10^{-4}	1.66×10^{-4}	4.98×10^{-4}	0	8.23×10^{-5}	0	8.33×10^{-5}	8.26×10^{-5}	0

Table 3 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	2.09×10^{-2}	8.19×10^{-3}	1.63×10^{-2}	1.82×10^{-2}	1.00×10^{-2}	7.28×10^{-3}	5.45×10^{-3}	2.73×10^{-3}	5.48×10^{-3}	2.82×10^{-2}	5.07×10^{-1}
17	8.65×10^{-3}	6.83×10^{-3}	5.77×10^{-3}	2.33×10^{-3}	4.02×10^{-3}	2.87×10^{-3}	1.14×10^{-3}	2.31×10^{-3}	2.31×10^{-3}	1.04×10^{-2}	2.72×10^{-1}
25	2.93×10^{-3}	2.92×10^{-3}	2.24×10^{-3}	6.53×10^{-4}	1.64×10^{-3}	1.94×10^{-3}	6.59×10^{-4}	1.62×10^{-3}	1.29×10^{-3}	2.91×10^{-3}	1.35×10^{-1}
35	1.19×10^{-3}	6.11×10^{-4}	5.96×10^{-4}	3.01×10^{-4}	1.21×10^{-3}	5.98×10^{-4}	3.05×10^{-4}	6.00×10^{-4}	0	6.12×10^{-4}	6.42×10^{-1}
45	5.64×10^{-4}	5.71×10^{-4}	2.88×10^{-4}	2.80×10^{-4}	2.89×10^{-4}	2.83×10^{-4}	2.84×10^{-4}	0	2.84×10^{-4}	8.54×10^{-4}	3.56×10^{-1}
62.5	1.78×10^{-4}	1.79×10^{-4}	1.74×10^{-4}	8.69×10^{-5}	2.66×10^{-4}	0	8.96×10^{-5}	0	0	9.05×10^{-5}	1.74×10^{-2}
77.5	4.28×10^{-4}	3.40×10^{-4}	0	0	0	0	8.61×10^{-5}	0	0	8.52×10^{-5}	8.61×10^{-3}
92.5	0	0	0	0	8.30×10^{-5}	0	0	0	8.33×10^{-5}	0	2.48×10^{-3}

Table 4. Charged Particle Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 100 Mev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	3.78×10^{-3}	1.33×10^{-2}	2.07×10^{-2}	1.74×10^{-2}	1.12×10^{-2}	6.35×10^{-3}	5.85×10^{-3}	4.41×10^{-3}	3.39×10^{-3}	2.25×10^{-3}	2.26×10^{-3}
17	3.61×10^{-3}	1.22×10^{-2}	1.72×10^{-2}	1.20×10^{-2}	6.30×10^{-3}	3.23×10^{-3}	3.51×10^{-3}	2.41×10^{-3}	1.92×10^{-3}	1.41×10^{-3}	9.14×10^{-4}
25	3.21×10^{-3}	1.02×10^{-2}	1.13×10^{-2}	6.42×10^{-3}	3.19×10^{-3}	1.74×10^{-3}	1.42×10^{-3}	9.47×10^{-4}	8.36×10^{-4}	4.46×10^{-4}	4.88×10^{-4}
35	3.52×10^{-3}	8.51×10^{-3}	7.79×10^{-3}	2.90×10^{-3}	1.12×10^{-3}	4.42×10^{-4}	4.01×10^{-4}	3.59×10^{-4}	2.63×10^{-4}	1.24×10^{-4}	9.67×10^{-5}
45	3.07×10^{-3}	7.76×10^{-3}	5.53×10^{-3}	1.53×10^{-3}	2.61×10^{-4}	5.64×10^{-4}	1.93×10^{-4}	1.79×10^{-4}	2.75×10^{-5}	8.26×10^{-5}	1.24×10^{-4}
60	4.53×10^{-3}	7.65×10^{-3}	2.62×10^{-3}	2.13×10^{-4}	1.23×10^{-4}	9.59×10^{-5}	8.91×10^{-5}	6.85×10^{-5}	6.86×10^{-6}	2.74×10^{-5}	1.37×10^{-5}
62.5	4.74×10^{-3}	7.28×10^{-3}	1.88×10^{-3}	1.69×10^{-4}	1.32×10^{-4}	9.59×10^{-5}	5.47×10^{-5}	8.68×10^{-5}	3.65×10^{-5}	4.11×10^{-5}	1.37×10^{-5}
77.5	8.25×10^{-3}	6.32×10^{-3}	5.46×10^{-3}	2.28×10^{-5}	2.28×10^{-5}	0	9.11×10^{-6}	0	0	0	0
92.5	2.42×10^{-2}	2.45×10^{-4}	9.09×10^{-6}	0	0	0	0	0	0	0	0

Table 4 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	1.87×10^{-3}	1.09×10^{-3}	1.20×10^{-3}	8.83×10^{-4}	4.94×10^{-4}	9.52×10^{-4}	4.56×10^{-4}	5.64×10^{-4}	4.24×10^{-4}	1.73×10^{-3}	1.01×10^{-1}
17	5.85×10^{-4}	7.03×10^{-4}	7.51×10^{-4}	3.28×10^{-4}	4.45×10^{-4}	2.81×10^{-4}	3.75×10^{-4}	2.81×10^{-4}	7.03×10^{-5}	5.85×10^{-4}	6.91×10^{-2}
25	4.73×10^{-4}	1.53×10^{-4}	1.67×10^{-4}	2.09×10^{-4}	2.09×10^{-4}	1.81×10^{-4}	1.67×10^{-4}	4.19×10^{-5}	0	3.06×10^{-4}	4.21×10^{-2}
35	2.35×10^{-4}	6.93×10^{-5}	5.53×10^{-5}	6.91×10^{-5}	1.38×10^{-5}	1.11×10^{-4}	2.77×10^{-5}	5.52×10^{-5}	1.39×10^{-5}	1.11×10^{-4}	2.63×10^{-2}
45	5.50×10^{-5}	0	4.13×10^{-5}	9.63×10^{-5}	1.38×10^{-5}	1.10×10^{-4}	8.25×10^{-5}	0	0	2.75×10^{-5}	1.97×10^{-2}
60	2.06×10^{-5}	0	2.06×10^{-5}	4.11×10^{-5}	0	1.37×10^{-5}	0	0	0	1.37×10^{-5}	1.56×10^{-2}
62.5	4.57×10^{-6}	3.65×10^{-5}	2.28×10^{-5}	0	0	0	1.37×10^{-5}	9.12×10^{-6}	1.37×10^{-5}	0	1.46×10^{-2}
77.5	4.55×10^{-6}	4.56×10^{-6}	0	0	0	4.55×10^{-6}	0	0	0	4.56×10^{-6}	1.47×10^{-2}
92.5	0	0	0	0	0	0	0	0	0	0	2.42×10^{-2}

Table 5. Photon Track Length for Electron-Initiated Showers in Copper
Electron Source Energy: 200 Mev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.28×10^{-2}	4.10×10^{-2}	8.29×10^{-2}	7.56×10^{-2}	1.04×10^{-1}	9.29×10^{-2}	8.39×10^{-2}	5.74×10^{-2}	5.57×10^{-2}	5.01×10^{-2}	4.28×10^{-2}
17	1.16×10^{-2}	2.65×10^{-2}	3.81×10^{-2}	5.19×10^{-2}	5.15×10^{-2}	3.87×10^{-2}	4.27×10^{-2}	3.59×10^{-2}	3.66×10^{-2}	2.60×10^{-2}	2.48×10^{-2}
25	7.12×10^{-3}	1.90×10^{-2}	2.39×10^{-2}	2.83×10^{-2}	2.62×10^{-2}	2.57×10^{-2}	1.59×10^{-2}	1.85×10^{-2}	2.05×10^{-2}	1.72×10^{-2}	1.49×10^{-2}
35	5.42×10^{-3}	1.32×10^{-2}	1.62×10^{-2}	1.84×10^{-2}	1.56×10^{-2}	1.20×10^{-2}	1.03×10^{-2}	6.31×10^{-3}	6.29×10^{-3}	5.41×10^{-3}	5.42×10^{-3}
45	3.14×10^{-3}	4.82×10^{-3}	1.14×10^{-2}	1.11×10^{-2}	1.28×10^{-2}	6.23×10^{-3}	5.97×10^{-3}	6.24×10^{-3}	2.56×10^{-3}	3.70×10^{-3}	1.14×10^{-3}
60	1.61×10^{-3}	6.01×10^{-3}	6.18×10^{-3}	8.19×10^{-3}	3.63×10^{-3}	4.71×10^{-3}	4.70×10^{-3}	3.66×10^{-3}	2.28×10^{-3}	1.87×10^{-3}	1.47×10^{-3}
85	1.42×10^{-3}	3.69×10^{-3}	3.61×10^{-3}	3.10×10^{-3}	3.01×10^{-3}	1.68×10^{-3}	7.56×10^{-4}	9.23×10^{-4}	7.53×10^{-4}	8.47×10^{-4}	5.05×10^{-4}
125	1.12×10^{-3}	1.45×10^{-3}	1.60×10^{-3}	1.08×10^{-3}	7.98×10^{-4}	5.58×10^{-4}	5.18×10^{-4}	2.86×10^{-4}	2.36×10^{-4}	2.81×10^{-4}	2.32×10^{-4}
128	7.78×10^{-4}	1.87×10^{-3}	1.21×10^{-3}	1.36×10^{-3}	8.19×10^{-4}	4.27×10^{-4}	4.30×10^{-4}	3.89×10^{-4}	2.33×10^{-4}	1.55×10^{-4}	7.81×10^{-5}
155	3.79×10^{-4}	1.40×10^{-3}	7.95×10^{-4}	1.06×10^{-3}	3.04×10^{-4}	3.04×10^{-4}	3.04×10^{-4}	1.90×10^{-4}	1.89×10^{-4}	1.51×10^{-4}	0
185	3.34×10^{-4}	6.69×10^{-4}	3.34×10^{-4}	2.61×10^{-4}	7.42×10^{-5}	2.98×10^{-4}	1.12×10^{-4}	1.86×10^{-4}	0	3.73×10^{-5}	0

Table 5 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	5.10x10 ⁻²	3.38x10 ⁻²	3.91x10 ⁻²	3.82x10 ⁻²	2.19x10 ⁻²	2.83x10 ⁻²	2.00x10 ⁻²	1.27x10 ⁻²	1.28x10 ⁻²	6.92x10 ⁻²	1.04x10 ⁰
17	1.56x10 ⁻²	1.86x10 ⁻²	1.51x10 ⁻²	1.86x10 ⁻²	9.32x10 ⁻³	7.46x10 ⁻³	6.97x10 ⁻³	5.22x10 ⁻³	6.98x10 ⁻³	3.13x10 ⁻²	5.19x10 ⁻¹
25	6.50x10 ⁻³	5.48x10 ⁻³	4.85x10 ⁻³	3.90x10 ⁻³	5.48x10 ⁻³	4.56x10 ⁻³	5.19x10 ⁻³	3.26x10 ⁻³	2.26x10 ⁻³	6.20x10 ⁻³	2.65x10 ⁻¹
35	4.21x10 ⁻³	2.40x10 ⁻³	2.69x10 ⁻³	1.77x10 ⁻³	1.80x10 ⁻³	8.92x10 ⁻⁴	3.05x10 ⁻⁴	5.99x10 ⁻⁴	1.49x10 ⁻³	5.42x10 ⁻³	1.36x10 ⁻¹
45	1.15x10 ⁻³	2.29x10 ⁻³	8.53x10 ⁻⁴	1.14x10 ⁻³	1.42x10 ⁻³	1.13x10 ⁻³	2.79x10 ⁻⁴	8.55x10 ⁻⁴	5.71x10 ⁻⁴	1.71x10 ⁻³	8.04x10 ⁻²
60	1.35x10 ⁻³	4.05x10 ⁻⁴	8.10x10 ⁻⁴	5.34x10 ⁻⁴	0	4.13x10 ⁻⁴	1.32x10 ⁻⁴	5.49x10 ⁻⁴	2.72x10 ⁻⁴	3.94x10 ⁻⁴	4.92x10 ⁻²
85	3.40x10 ⁻⁴	8.51x10 ⁻⁵	3.37x10 ⁻⁴	1.65x10 ⁻⁴	4.23x10 ⁻⁴	0	8.60x10 ⁻⁵	8.40x10 ⁻⁵	0	3.36x10 ⁻⁴	2.21x10 ⁻²
125	9.39x10 ⁻⁵	4.58x10 ⁻⁵	4.65x10 ⁻⁵	4.75x10 ⁻⁵	1.41x10 ⁻⁴	0	0	0	0	4.80x10 ⁻⁵	8.59x10 ⁻³
128	1.17x10 ⁻⁴	1.17x10 ⁻⁴	7.67x10 ⁻⁵	7.87x10 ⁻⁵	0	7.75x10 ⁻⁵	0	3.89x10 ⁻⁵	0	0	8.26x10 ⁻³
155	0	1.14x10 ⁻⁴	3.76x10 ⁻⁵	0	3.79x10 ⁻⁵	4.67x10 ⁻⁵	0	3.75x10 ⁻⁵	0	0	5.34x10 ⁻³
185	0	3.73x10 ⁻⁵	0	0	3.72x10 ⁻⁵	0	0	0	0	0	2.38x10 ⁻³

Table 6. Charged Particle Track Length for Electron-Initiated Showers in Copper
Electron Source Energy: 200 Mev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.36×10^{-3}	1.20×10^{-2}	2.67×10^{-2}	2.93×10^{-2}	2.88×10^{-2}	2.36×10^{-2}	1.62×10^{-2}	1.30×10^{-2}	9.77×10^{-3}	9.36×10^{-3}	7.83×10^{-3}
17	2.41×10^{-3}	1.06×10^{-2}	1.77×10^{-2}	2.00×10^{-2}	1.89×10^{-2}	1.37×10^{-2}	9.58×10^{-3}	8.06×10^{-3}	6.09×10^{-3}	4.48×10^{-3}	4.17×10^{-3}
25	1.82×10^{-3}	7.90×10^{-3}	1.29×10^{-2}	1.35×10^{-2}	1.15×10^{-2}	7.42×10^{-3}	5.79×10^{-3}	3.75×10^{-3}	2.88×10^{-3}	2.21×10^{-3}	2.07×10^{-3}
35	1.67×10^{-3}	6.12×10^{-3}	7.97×10^{-3}	8.60×10^{-3}	6.62×10^{-3}	3.79×10^{-3}	3.23×10^{-3}	2.34×10^{-3}	1.08×10^{-3}	1.01×10^{-3}	9.95×10^{-4}
45	1.17×10^{-3}	4.64×10^{-3}	6.80×10^{-3}	5.97×10^{-3}	4.32×10^{-3}	2.54×10^{-3}	1.82×10^{-3}	1.17×10^{-3}	5.09×10^{-4}	8.26×10^{-4}	5.09×10^{-4}
60	1.25×10^{-3}	4.74×10^{-3}	4.87×10^{-3}	4.43×10^{-3}	2.39×10^{-3}	1.42×10^{-3}	6.86×10^{-4}	3.49×10^{-4}	4.46×10^{-4}	2.54×10^{-4}	2.06×10^{-4}
85	1.55×10^{-3}	3.79×10^{-3}	3.66×10^{-3}	2.35×10^{-3}	9.96×10^{-4}	3.59×10^{-4}	2.36×10^{-4}	1.64×10^{-4}	8.19×10^{-5}	1.00×10^{-4}	9.55×10^{-5}
125	2.07×10^{-3}	3.66×10^{-3}	1.93×10^{-3}	4.94×10^{-4}	6.80×10^{-5}	2.72×10^{-5}	6.12×10^{-5}	5.21×10^{-5}	3.85×10^{-5}	4.76×10^{-5}	9.06×10^{-6}
155	3.33×10^{-3}	3.90×10^{-3}	8.10×10^{-4}	8.37×10^{-5}	4.52×10^{-6}	9.05×10^{-6}	2.49×10^{-5}	2.26×10^{-6}	9.05×10^{-6}	6.78×10^{-6}	0
185	1.36×10^{-2}	1.53×10^{-3}	4.52×10^{-6}	0	0	0	0	0	0	0	0

Table 6 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)									
	Depth Interval (Radiation Lengths)									
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞
12	6.83×10^{-3}	4.28×10^{-3}	3.63×10^{-3}	3.24×10^{-3}	2.43×10^{-3}	2.21×10^{-3}	1.94×10^{-3}	1.24×10^{-3}	1.73×10^{-3}	5.78×10^{-3}
17	3.30×10^{-3}	1.66×10^{-3}	1.97×10^{-3}	1.22×10^{-3}	1.31×10^{-3}	1.36×10^{-3}	8.67×10^{-4}	6.79×10^{-4}	6.09×10^{-4}	2.53×10^{-3}
25	1.36×10^{-3}	7.24×10^{-4}	8.08×10^{-4}	6.40×10^{-4}	7.80×10^{-4}	4.31×10^{-4}	1.53×10^{-4}	3.89×10^{-4}	3.34×10^{-4}	1.06×10^{-3}
35	4.84×10^{-4}	5.39×10^{-4}	2.35×10^{-4}	4.42×10^{-4}	2.07×10^{-4}	4.70×10^{-4}	4.14×10^{-5}	1.24×10^{-4}	1.52×10^{-4}	3.59×10^{-4}
45	3.03×10^{-4}	1.93×10^{-4}	1.65×10^{-4}	1.10×10^{-4}	1.65×10^{-4}	1.93×10^{-4}	1.38×10^{-5}	2.75×10^{-5}	5.51×10^{-5}	2.48×10^{-4}
60	1.99×10^{-4}	1.37×10^{-4}	7.55×10^{-5}	3.43×10^{-5}	8.91×10^{-5}	5.86×10^{-5}	6.84×10^{-6}	2.74×10^{-5}	0	7.54×10^{-5}
85	6.37×10^{-5}	0	3.19×10^{-5}	2.73×10^{-5}	1.36×10^{-5}	9.11×10^{-6}	0	0	0	9.10×10^{-6}
125	0	6.80×10^{-6}	2.04×10^{-5}	0	0	1.36×10^{-5}	6.80×10^{-6}	0	0	0
155	0	9.04×10^{-6}	6.78×10^{-6}	0	2.26×10^{-6}	0	0	0	0	0
185	0	0	0	0	0	0	0	0	0	0
										Totals
										2.12×10^{-1}
										1.31×10^{-1}
										7.84×10^{-2}
										4.65×10^{-2}
										3.17×10^{-2}
										2.17×10^{-2}
										1.35×10^{-2}
										8.52×10^{-3}
										8.21×10^{-3}
										1.52×10^{-2}

Table 7. Photon Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 40C Mev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	1.64×10^{-2}	5.38×10^{-2}	9.91×10^{-2}	1.20×10^{-1}	1.36×10^{-1}	1.50×10^{-1}	1.44×10^{-1}	1.55×10^{-1}	1.36×10^{-1}	1.28×10^{-1}	1.16×10^{-1}
17	1.04×10^{-2}	3.41×10^{-2}	6.23×10^{-2}	7.56×10^{-2}	1.03×10^{-1}	9.12×10^{-2}	8.69×10^{-2}	8.32×10^{-2}	6.71×10^{-2}	6.93×10^{-2}	6.88×10^{-2}
25	7.46×10^{-3}	2.33×10^{-2}	3.46×10^{-2}	4.61×10^{-2}	4.23×10^{-2}	4.83×10^{-2}	4.02×10^{-2}	4.22×10^{-2}	3.43×10^{-2}	3.11×10^{-2}	2.79×10^{-2}
35	3.93×10^{-3}	1.51×10^{-2}	2.23×10^{-2}	3.01×10^{-2}	2.51×10^{-2}	2.74×10^{-2}	2.47×10^{-2}	1.90×10^{-2}	1.65×10^{-2}	1.54×10^{-2}	1.72×10^{-2}
45	4.56×10^{-3}	7.92×10^{-3}	1.79×10^{-2}	2.33×10^{-2}	1.70×10^{-2}	1.71×10^{-2}	1.02×10^{-2}	1.14×10^{-2}	1.22×10^{-2}	7.65×10^{-3}	8.82×10^{-3}
60	3.21×10^{-3}	9.10×10^{-3}	1.08×10^{-2}	1.23×10^{-2}	1.02×10^{-2}	8.61×10^{-3}	8.41×10^{-3}	6.35×10^{-3}	6.18×10^{-3}	4.04×10^{-3}	4.44×10^{-3}
85	2.00×10^{-3}	4.86×10^{-3}	6.70×10^{-3}	6.04×10^{-3}	5.37×10^{-3}	4.26×10^{-3}	4.11×10^{-3}	2.44×10^{-3}	2.51×10^{-3}	1.52×10^{-3}	1.52×10^{-3}
125	1.40×10^{-3}	2.57×10^{-3}	2.39×10^{-3}	3.39×10^{-3}	2.86×10^{-3}	2.34×10^{-3}	1.45×10^{-3}	1.27×10^{-3}	7.51×10^{-4}	7.56×10^{-4}	5.61×10^{-4}
175	5.80×10^{-4}	1.84×10^{-3}	1.52×10^{-3}	1.84×10^{-3}	1.93×10^{-3}	1.04×10^{-3}	4.47×10^{-4}	4.02×10^{-4}	4.04×10^{-4}	4.04×10^{-4}	2.23×10^{-4}
250	4.30×10^{-4}	8.78×10^{-4}	8.06×10^{-4}	5.91×10^{-4}	4.66×10^{-4}	3.23×10^{-4}	2.33×10^{-4}	2.16×10^{-4}	5.39×10^{-5}	1.26×10^{-4}	7.15×10^{-5}
310	4.05×10^{-4}	5.81×10^{-4}	4.04×10^{-4}	2.12×10^{-4}	3.16×10^{-4}	1.76×10^{-4}	1.94×10^{-4}	1.41×10^{-4}	1.77×10^{-5}	3.51×10^{-5}	1.75×10^{-5}
370	2.95×10^{-4}	3.13×10^{-4}	1.04×10^{-4}	1.56×10^{-4}	1.22×10^{-4}	3.46×10^{-5}	5.21×10^{-5}	5.21×10^{-5}	3.47×10^{-5}	1.74×10^{-5}	3.47×10^{-5}

Table 7 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	1.04×10^{-1}	8.47×10^{-2}	8.76×10^{-2}	6.56×10^{-2}	5.56×10^{-2}	6.10×10^{-2}	5.56×10^{-2}	3.18×10^{-2}	3.01×10^{-2}	1.76×10^{-1}	2.01×10^0
17	5.19×10^{-2}	3.93×10^{-2}	3.54×10^{-2}	3.36×10^{-2}	3.47×10^{-2}	2.44×10^{-2}	2.24×10^{-2}	1.96×10^{-2}	1.33×10^{-2}	7.69×10^{-2}	1.10×10^0
25	2.56×10^{-2}	2.02×10^{-2}	1.66×10^{-2}	1.27×10^{-2}	1.10×10^{-2}	1.24×10^{-2}	1.23×10^{-2}	6.48×10^{-3}	3.56×10^{-3}	3.08×10^{-2}	5.29×10^{-1}
35	1.41×10^{-2}	1.11×10^{-2}	9.94×10^{-3}	9.32×10^{-3}	3.00×10^{-3}	3.03×10^{-3}	2.11×10^{-3}	2.40×10^{-3}	4.81×10^{-3}	1.09×10^{-2}	2.87×10^{-1}
45	7.08×10^{-3}	5.12×10^{-3}	3.98×10^{-3}	2.84×10^{-3}	3.14×10^{-3}	1.98×10^{-3}	1.15×10^{-3}	1.69×10^{-3}	2.84×10^{-4}	3.42×10^{-3}	1.69×10^{-1}
60	3.48×10^{-3}	2.56×10^{-3}	1.75×10^{-3}	1.76×10^{-3}	2.57×10^{-3}	8.14×10^{-4}	5.43×10^{-4}	4.03×10^{-4}	2.69×10^{-4}	1.33×10^{-3}	9.92×10^{-2}
85	1.35×10^{-3}	9.27×10^{-4}	5.01×10^{-4}	3.34×10^{-4}	5.90×10^{-4}	3.38×10^{-4}	2.48×10^{-4}	1.67×10^{-4}	2.50×10^{-4}	4.22×10^{-4}	4.65×10^{-2}
125	8.51×10^{-4}	3.73×10^{-4}	1.86×10^{-4}	2.79×10^{-4}	9.31×10^{-5}	9.19×10^{-5}	1.41×10^{-4}	4.82×10^{-5}	0	1.41×10^{-4}	2.20×10^{-2}
175	8.83×10^{-5}	1.33×10^{-4}	8.97×10^{-5}	0	4.54×10^{-5}	4.50×10^{-5}	0	0	4.43×10^{-5}	9.05×10^{-5}	1.12×10^{-2}
250	5.36×10^{-5}	0	1.80×10^{-5}	0	0	1.78×10^{-5}	0	0	1.79×10^{-5}	7.22×10^{-5}	4.37×10^{-3}
310	1.76×10^{-5}	1.75×10^{-5}	0	1.76×10^{-5}	1.75×10^{-5}	0	0	0	0	1.75×10^{-5}	2.59×10^{-3}
370	0	0	0	0	0	0	0	0	0	0	1.22×10^{-3}

Table 8. Charged Particle Track Length for Electron-Irradiated Showers in Copper

Electron Source Energy: 400 Mev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.33×10^{-3}	1.55×10^{-2}	2.99×10^{-2}	4.20×10^{-2}	1.80×10^{-2}	4.43×10^{-2}	4.09×10^{-2}	3.23×10^{-2}	2.61×10^{-2}	2.32×10^{-2}	1.94×10^{-2}
17	2.20×10^{-3}	1.15×10^{-2}	2.05×10^{-2}	3.03×10^{-2}	3.25×10^{-2}	3.10×10^{-2}	2.65×10^{-2}	2.07×10^{-2}	1.61×10^{-2}	1.48×10^{-2}	1.12×10^{-2}
25	1.63×10^{-3}	8.05×10^{-3}	1.51×10^{-2}	2.06×10^{-2}	2.10×10^{-2}	1.95×10^{-2}	1.53×10^{-2}	1.12×10^{-2}	9.13×10^{-3}	7.18×10^{-3}	6.14×10^{-3}
35	1.51×10^{-3}	6.25×10^{-3}	1.12×10^{-2}	1.32×10^{-2}	1.37×10^{-2}	1.18×10^{-2}	8.07×10^{-3}	6.22×10^{-3}	5.09×10^{-3}	3.59×10^{-3}	3.73×10^{-3}
45	1.09×10^{-3}	5.38×10^{-3}	8.50×10^{-3}	1.02×10^{-2}	9.49×10^{-3}	7.92×10^{-3}	5.92×10^{-3}	4.29×10^{-3}	2.99×10^{-3}	2.33×10^{-3}	1.68×10^{-3}
60	1.01×10^{-3}	4.20×10^{-3}	5.80×10^{-3}	7.04×10^{-3}	5.98×10^{-3}	4.93×10^{-3}	3.52×10^{-3}	2.47×10^{-3}	1.82×10^{-3}	1.37×10^{-3}	8.91×10^{-4}
85	8.64×10^{-4}	3.08×10^{-3}	4.50×10^{-3}	3.99×10^{-3}	3.31×10^{-3}	2.82×10^{-3}	1.50×10^{-3}	1.06×10^{-3}	7.55×10^{-4}	6.14×10^{-4}	4.23×10^{-4}
125	7.45×10^{-4}	2.45×10^{-3}	2.63×10^{-3}	2.35×10^{-3}	1.77×10^{-3}	9.52×10^{-4}	5.41×10^{-4}	4.73×10^{-4}	3.29×10^{-4}	1.93×10^{-4}	1.09×10^{-4}
175	8.54×10^{-4}	1.95×10^{-3}	1.97×10^{-3}	1.14×10^{-3}	6.64×10^{-4}	2.90×10^{-4}	1.55×10^{-4}	1.63×10^{-4}	1.06×10^{-4}	5.15×10^{-5}	4.61×10^{-5}
250	9.38×10^{-4}	1.76×10^{-3}	1.23×10^{-3}	4.22×10^{-4}	1.77×10^{-4}	4.73×10^{-4}	3.83×10^{-4}	3.38×10^{-4}	1.47×10^{-4}	9.02×10^{-5}	0
310	1.52×10^{-2}	1.84×10^{-2}	7.03×10^{-3}	1.25×10^{-3}	1.58×10^{-4}	6.75×10^{-5}	5.63×10^{-5}	4.51×10^{-5}	0	1.01×10^{-4}	4.50×10^{-5}
370	7.02×10^{-2}	1.44×10^{-2}	9.90×10^{-4}	0	2.25×10^{-5}	0	0	1.13×10^{-5}	1.13×10^{-5}	0	0

Table 8 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)									
	Depth Interval (Radiation Lengths)									
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞
12	1.58×10^{-2}	1.49×10^{-2}	1.08×10^{-2}	7.87×10^{-3}	7.82×10^{-3}	6.84×10^{-3}	5.35×10^{-3}	3.61×10^{-3}	3.07×10^{-3}	1.47×10^{-2}
17	9.89×10^{-3}	7.94×10^{-3}	5.74×10^{-3}	5.27×10^{-3}	3.77×10^{-3}	3.26×10^{-3}	2.34×10^{-3}	1.57×10^{-3}	1.62×10^{-3}	7.10×10^{-3}
25	6.00×10^{-3}	3.79×10^{-3}	2.56×10^{-3}	3.13×10^{-3}	2.01×10^{-3}	1.78×10^{-3}	9.19×10^{-4}	7.10×10^{-4}	6.25×10^{-4}	2.90×10^{-3}
35	2.74×10^{-3}	2.43×10^{-3}	1.73×10^{-3}	8.57×10^{-4}	1.27×10^{-3}	7.05×10^{-4}	5.39×10^{-4}	4.28×10^{-4}	3.59×10^{-4}	1.05×10^{-3}
45	1.40×10^{-3}	1.53×10^{-3}	1.00×10^{-3}	3.03×10^{-4}	6.33×10^{-4}	4.68×10^{-4}	2.34×10^{-4}	2.06×10^{-4}	1.10×10^{-4}	4.26×10^{-4}
60	7.67×10^{-4}	6.58×10^{-4}	2.33×10^{-4}	2.47×10^{-4}	2.95×10^{-4}	9.59×10^{-5}	7.54×10^{-5}	9.60×10^{-5}	8.23×10^{-5}	2.19×10^{-4}
85	3.37×10^{-4}	2.96×10^{-4}	7.73×10^{-5}	1.50×10^{-4}	1.09×10^{-5}	3.64×10^{-5}	5.91×10^{-5}	6.37×10^{-5}	3.64×10^{-5}	5.91×10^{-5}
125	8.70×10^{-5}	7.34×10^{-5}	4.90×10^{-5}	2.99×10^{-5}	1.90×10^{-5}	1.90×10^{-5}	1.36×10^{-5}	5.44×10^{-6}	5.44×10^{-6}	1.36×10^{-5}
175	3.53×10^{-5}	1.90×10^{-5}	2.71×10^{-6}	5.43×10^{-6}	2.71×10^{-6}	0	0	0	1.35×10^{-5}	0
250	7.89×10^{-5}	1.13×10^{-5}	0	0	0	0	0	0	0	1.13×10^{-5}
310	1.23×10^{-5}	2.25×10^{-6}	0	0	0	0	0	0	0	0
370	0	0	0	0	0	0	0	0	0	0
										Totals
12	4.15×10^{-1}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}
17	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}
25	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}
35	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}
45	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}
60	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}
85	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}
125	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}
175	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}
250	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}
310	2.66×10^{-1}	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}
370	1.59×10^{-1}	9.64×10^{-2}	6.61×10^{-2}	4.18×10^{-2}	2.41×10^{-2}	1.29×10^{-2}	7.47×10^{-3}	4.69×10^{-2}	2.66×10^{-1}	1.59×10^{-1}

Table 9. Photon Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 700 Mev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.09×10^{-2}	6.81×10^{-2}	1.03×10^{-1}	1.58×10^{-1}	2.01×10^{-1}	2.01×10^{-1}	2.27×10^{-1}	2.75×10^{-1}	2.33×10^{-1}	2.28×10^{-1}	2.37×10^{-1}
17	1.15×10^{-2}	4.04×10^{-2}	7.27×10^{-2}	9.01×10^{-2}	1.20×10^{-1}	1.30×10^{-1}	1.42×10^{-1}	1.29×10^{-1}	1.11×10^{-1}	1.33×10^{-1}	1.16×10^{-1}
25	8.06×10^{-3}	2.62×10^{-2}	4.42×10^{-2}	6.83×10^{-2}	6.92×10^{-2}	6.99×10^{-2}	7.39×10^{-2}	7.29×10^{-2}	7.02×10^{-2}	6.01×10^{-2}	5.72×10^{-2}
35	5.35×10^{-3}	1.83×10^{-2}	2.79×10^{-2}	3.51×10^{-2}	4.00×10^{-2}	4.12×10^{-2}	4.26×10^{-2}	3.39×10^{-2}	3.55×10^{-2}	2.49×10^{-2}	2.72×10^{-2}
45	4.83×10^{-3}	1.20×10^{-2}	2.25×10^{-2}	2.21×10^{-2}	2.70×10^{-2}	2.93×10^{-2}	1.79×10^{-2}	2.16×10^{-2}	2.02×10^{-2}	1.50×10^{-2}	1.34×10^{-2}
60	4.12×10^{-3}	9.55×10^{-3}	1.34×10^{-2}	1.60×10^{-2}	1.93×10^{-2}	1.65×10^{-2}	1.66×10^{-2}	1.49×10^{-2}	1.25×10^{-2}	1.14×10^{-2}	8.74×10^{-3}
85	2.18×10^{-3}	5.85×10^{-3}	7.14×10^{-3}	1.01×10^{-2}	1.11×10^{-2}	9.20×10^{-3}	7.57×10^{-3}	6.37×10^{-3}	5.46×10^{-3}	4.01×10^{-3}	3.44×10^{-3}
125	1.68×10^{-3}	3.18×10^{-3}	5.05×10^{-3}	4.77×10^{-3}	4.68×10^{-3}	3.98×10^{-3}	3.37×10^{-3}	2.87×10^{-3}	2.35×10^{-3}	1.32×10^{-3}	1.08×10^{-3}
175	1.17×10^{-3}	1.75×10^{-3}	3.14×10^{-3}	2.69×10^{-3}	2.60×10^{-3}	2.24×10^{-3}	1.79×10^{-3}	1.75×10^{-3}	1.17×10^{-3}	8.57×10^{-4}	4.50×10^{-4}
250	4.98×10^{-4}	1.62×10^{-3}	1.45×10^{-3}	1.21×10^{-3}	1.16×10^{-3}	7.77×10^{-4}	5.82×10^{-4}	5.61×10^{-4}	2.39×10^{-4}	2.38×10^{-4}	2.37×10^{-4}
350	2.93×10^{-4}	8.58×10^{-4}	7.95×10^{-4}	3.97×10^{-4}	6.91×10^{-4}	3.98×10^{-4}	3.13×10^{-4}	2.09×10^{-4}	8.36×10^{-5}	8.40×10^{-5}	2.07×10^{-5}
437.5	2.15×10^{-4}	5.58×10^{-4}	5.38×10^{-4}	4.10×10^{-4}	2.34×10^{-4}	2.93×10^{-4}	1.27×10^{-4}	1.07×10^{-4}	7.82×10^{-5}	3.92×10^{-5}	5.86×10^{-5}
542.5	1.73×10^{-4}	2.41×10^{-4}	1.73×10^{-4}	2.41×10^{-4}	2.21×10^{-4}	1.06×10^{-4}	1.06×10^{-4}	7.70×10^{-5}	3.84×10^{-5}	1.92×10^{-5}	9.64×10^{-6}
647.5	9.55×10^{-5}	1.24×10^{-4}	2.29×10^{-4}	1.14×10^{-4}	5.72×10^{-5}	3.82×10^{-5}	2.86×10^{-5}	0	0	9.55×10^{-5}	1.91×10^{-5}

Table 9 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	2.04x10 ⁻¹	1.77x10 ⁻¹	1.65x10 ⁻¹	1.50x10 ⁻¹	1.45x10 ⁻¹	1.06x10 ⁻¹	8.74x10 ⁻²	8.84x10 ⁻²	7.57x10 ⁻²	4.41x10 ⁻¹	3.59x10 ⁰
17	1.17x10 ⁻¹	8.25x10 ⁻²	8.37x10 ⁻²	7.41x10 ⁻²	7.40x10 ⁻²	4.84x10 ⁻²	4.91x10 ⁻²	3.78x10 ⁻²	2.95x10 ⁻²	1.87x10 ⁻¹	1.88x10 ⁰
25	4.56x10 ⁻²	3.93x10 ⁻²	4.05x10 ⁻²	2.47x10 ⁻²	2.57x10 ⁻²	2.74x10 ⁻²	2.08x10 ⁻²	1.60x10 ⁻²	1.50x10 ⁻²	5.66x10 ⁻²	9.33x10 ⁻¹
35	2.27x10 ⁻²	2.20x10 ⁻²	2.10x10 ⁻²	1.32x10 ⁻²	1.08x10 ⁻²	1.02x10 ⁻²	7.82x10 ⁻³	6.31x10 ⁻³	5.10x10 ⁻³	2.89x10 ⁻²	4.80x10 ⁻¹
45	1.36x10 ⁻²	9.40x10 ⁻³	8.57x10 ⁻³	8.52x10 ⁻³	7.96x10 ⁻³	5.40x10 ⁻³	5.12x10 ⁻³	3.15x10 ⁻³	2.84x10 ⁻³	1.05x10 ⁻²	2.81x10 ⁻¹
60	7.12x10 ⁻³	6.32x10 ⁻³	4.99x10 ⁻³	2.56x10 ⁻³	3.48x10 ⁻³	1.60x10 ⁻³	1.89x10 ⁻³	2.41x10 ⁻³	1.48x10 ⁻³	4.30x10 ⁻³	1.79x10 ⁻¹
85	3.19x10 ⁻³	2.19x10 ⁻³	1.93x10 ⁻³	1.35x10 ⁻³	1.18x10 ⁻³	1.09x10 ⁻³	4.19x10 ⁻⁴	7.55x10 ⁻⁴	4.13x10 ⁻⁴	1.94x10 ⁻³	8.69x10 ⁻²
125	9.82x10 ⁻⁴	8.90x10 ⁻⁴	6.09x10 ⁻⁴	5.67x10 ⁻⁴	5.15x10 ⁻⁴	4.71x10 ⁻⁴	2.31x10 ⁻⁴	3.78x10 ⁻⁴	1.38x10 ⁻⁴	4.69x10 ⁻⁴	3.96x10 ⁻²
175	4.02x10 ⁻⁴	2.72x10 ⁻⁴	8.86x10 ⁻⁵	2.70x10 ⁻⁴	1.34x10 ⁻⁴	1.35x10 ⁻⁴	0	4.54x10 ⁻⁵	0	9.07x10 ⁻⁵	2.10x10 ⁻²
250	1.30x10 ⁻⁴	2.15x10 ⁻⁴	1.29x10 ⁻⁴	6.48x10 ⁻⁵	2.12x10 ⁻⁵	2.19x10 ⁻⁵	1.09x10 ⁻⁴	0	0	8.67x10 ⁻⁵	9.34x10 ⁻³
350	6.26x10 ⁻⁵	6.28x10 ⁻⁵	6.28x10 ⁻⁵	0	2.08x10 ⁻⁵	2.09x10 ⁻⁵	0	0	0	0	4.37x10 ⁻³
437.5	0	9.72x10 ⁻⁶	1.96x10 ⁻⁵	1.95x10 ⁻⁵	9.75x10 ⁻⁶	9.75x10 ⁻⁶	2.93x10 ⁻⁵	9.81x10 ⁻⁶	0	0	2.75x10 ⁻³
542.5	1.93x10 ⁻⁵	9.58x10 ⁻⁶	9.65x10 ⁻⁶	0	9.61x10 ⁻⁶	0	0	0	0	0	1.45x10 ⁻³
647.5	9.57x10 ⁻⁶	1.91x10 ⁻⁵	9.57x10 ⁻⁶	0	0	0	0	0	0	0	7.54x10 ⁻⁴

Table 10. Charged Particle Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 700 Mev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.40×10^{-3}	1.52×10^{-2}	3.50×10^{-2}	5.57×10^{-2}	6.33×10^{-2}	7.37×10^{-2}	6.82×10^{-2}	6.31×10^{-2}	5.77×10^{-2}	4.63×10^{-2}	4.23×10^{-2}
17	2.04×10^{-3}	1.21×10^{-2}	2.59×10^{-2}	4.18×10^{-2}	4.60×10^{-2}	4.86×10^{-2}	4.63×10^{-2}	4.35×10^{-2}	3.61×10^{-2}	2.99×10^{-2}	2.37×10^{-2}
25	1.24×10^{-3}	9.65×10^{-3}	1.79×10^{-2}	2.59×10^{-2}	3.12×10^{-2}	3.10×10^{-2}	3.06×10^{-2}	2.51×10^{-2}	2.11×10^{-2}	1.57×10^{-2}	1.43×10^{-2}
35	1.09×10^{-3}	6.38×10^{-3}	1.28×10^{-2}	1.79×10^{-2}	2.14×10^{-2}	1.96×10^{-2}	1.79×10^{-2}	1.48×10^{-2}	1.14×10^{-2}	9.04×10^{-3}	8.38×10^{-3}
45	1.07×10^{-3}	5.24×10^{-3}	9.67×10^{-3}	1.29×10^{-2}	1.52×10^{-2}	1.47×10^{-2}	1.25×10^{-2}	9.69×10^{-3}	7.33×10^{-3}	6.47×10^{-3}	4.42×10^{-3}
60	8.42×10^{-4}	4.12×10^{-3}	7.62×10^{-3}	9.15×10^{-3}	1.10×10^{-2}	9.59×10^{-3}	7.24×10^{-3}	5.62×10^{-3}	4.33×10^{-3}	3.57×10^{-3}	2.40×10^{-3}
85	6.49×10^{-4}	2.92×10^{-3}	5.07×10^{-3}	5.89×10^{-3}	5.81×10^{-3}	4.90×10^{-3}	3.84×10^{-3}	3.08×10^{-3}	1.94×10^{-3}	1.67×10^{-2}	1.11×10^{-3}
125	4.92×10^{-4}	1.89×10^{-3}	3.37×10^{-3}	3.78×10^{-3}	3.31×10^{-3}	2.35×10^{-3}	1.72×10^{-3}	1.35×10^{-3}	8.97×10^{-4}	6.80×10^{-4}	4.70×10^{-4}
175	4.31×10^{-4}	1.62×10^{-3}	2.14×10^{-3}	2.17×10^{-3}	1.64×10^{-3}	1.08×10^{-3}	8.51×10^{-4}	5.88×10^{-4}	4.31×10^{-4}	2.74×10^{-4}	2.47×10^{-4}
250	3.92×10^{-4}	1.27×10^{-3}	1.33×10^{-3}	9.62×10^{-4}	6.35×10^{-4}	5.24×10^{-4}	3.14×10^{-4}	1.84×10^{-4}	1.31×10^{-4}	8.39×10^{-5}	6.36×10^{-5}
350	4.86×10^{-4}	1.10×10^{-3}	8.47×10^{-4}	5.27×10^{-4}	2.92×10^{-4}	1.41×10^{-4}	3.92×10^{-5}	3.24×10^{-5}	3.78×10^{-5}	2.30×10^{-5}	5.41×10^{-6}
437.5	5.44×10^{-4}	9.65×10^{-4}	6.87×10^{-4}	3.54×10^{-4}	1.64×10^{-4}	5.53×10^{-5}	2.19×10^{-5}	1.80×10^{-5}	1.09×10^{-5}	5.14×10^{-6}	5.14×10^{-6}
542.5	8.32×10^{-4}	9.71×10^{-4}	4.46×10^{-4}	1.21×10^{-4}	2.76×10^{-5}	4.50×10^{-6}	4.50×10^{-6}	5.78×10^{-6}	6.42×10^{-7}	3.85×10^{-6}	2.57×10^{-6}
647.5	4.09×10^{-3}	9.46×10^{-4}	1.03×10^{-4}	6.42×10^{-6}	6.42×10^{-7}	0	0	0	0	0	0

Table 10 (continued)

	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
Energy (Mev)	Depth Interval (Radiation Lengths)										Totals
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	3.43x10 ⁻²	2.99x10 ⁻²	2.52x10 ⁻²	2.01x10 ⁻²	1.55x10 ⁻²	1.51x10 ⁻²	1.35x10 ⁻²	8.44x10 ⁻³	8.58x10 ⁻³	3.70x10 ⁻²	7.30x10 ⁻¹
17	2.01x10 ⁻²	1.71x10 ⁻²	1.47x10 ⁻²	1.24x10 ⁻²	9.87x10 ⁻³	7.94x10 ⁻³	7.24x10 ⁻³	4.52x10 ⁻³	4.34x10 ⁻³	1.78x10 ⁻²	4.70x10 ⁻¹
25	1.09x10 ⁻²	8.86x10 ⁻³	8.01x10 ⁻³	5.75x10 ⁻³	6.12x10 ⁻³	3.83x10 ⁻³	3.59x10 ⁻³	1.88x10 ⁻³	1.76x10 ⁻³	7.95x10 ⁻³	2.82x10 ⁻¹
35	5.47x10 ⁻³	5.39x10 ⁻³	3.57x10 ⁻³	3.46x10 ⁻³	2.46x10 ⁻³	2.02x10 ⁻³	1.22x10 ⁻³	1.19x10 ⁻³	1.44x10 ⁻³	3.40x10 ⁻³	1.70x10 ⁻¹
45	3.14x10 ⁻³	3.11x10 ⁻³	2.22x10 ⁻³	1.76x10 ⁻³	1.20x10 ⁻³	1.29x10 ⁻³	7.57x10 ⁻⁴	7.43x10 ⁻⁴	7.98x10 ⁻⁴	1.84x10 ⁻³	1.16x10 ⁻¹
60	1.82x10 ⁻³	1.48x10 ⁻³	1.18x10 ⁻³	8.36x10 ⁻⁴	6.51x10 ⁻⁴	4.73x10 ⁻⁴	4.25x10 ⁻⁴	5.83x10 ⁻⁴	3.97x10 ⁻⁴	8.29x10 ⁻⁴	7.41x10 ⁻²
85	8.49x10 ⁻⁴	6.81x10 ⁻⁴	5.09x10 ⁻⁴	4.09x10 ⁻⁴	2.45x10 ⁻⁴	2.82x10 ⁻⁴	2.04x10 ⁻⁴	1.27x10 ⁻⁴	1.23x10 ⁻⁴	3.04x10 ⁻⁴	4.06x10 ⁻²
125	3.94x10 ⁻⁴	2.56x10 ⁻⁴	1.47x10 ⁻⁴	1.60x10 ⁻⁴	1.03x10 ⁻⁴	8.97x10 ⁻⁵	3.81x10 ⁻⁵	3.81x10 ⁻⁵	2.18x10 ⁻⁵	1.28x10 ⁻⁴	2.17x10 ⁻²
175	5.15x10 ⁻⁵	8.95x10 ⁻⁵	1.25x10 ⁻⁴	6.24x10 ⁻⁵	3.25x10 ⁻⁵	1.37x10 ⁻⁵	5.42x10 ⁻⁶	1.35x10 ⁻⁵	8.13x10 ⁻⁶	2.98x10 ⁻⁵	1.19x10 ⁻²
250	2.71x10 ⁻⁵	2.57x10 ⁻⁵	3.79x10 ⁻⁵	1.49x10 ⁻⁵	5.41x10 ⁻⁶	4.06x10 ⁻⁶	2.57x10 ⁻⁵	1.08x10 ⁻⁵	1.35x10 ⁻⁶	8.12x10 ⁻⁶	6.06x10 ⁻³
350	4.05x10 ⁻⁶	5.40x10 ⁻⁶	0	0	0	2.70x10 ⁻⁶	0	0	0	0	3.55x10 ⁻³
437.5	3.21x10 ⁻⁶	5.78x10 ⁻⁶	1.93x10 ⁻⁶	4.50x10 ⁻⁶	1.93x10 ⁻⁶	1.93x10 ⁻⁶	1.28x10 ⁻⁶	0	0	0	2.85x10 ⁻³
542.5	5.14x10 ⁻⁶	0	0	0	0	6.42x10 ⁻⁷	0	0	0	0	2.43x10 ⁻³
647.5	0	0	0	0	0	0	0	0	0	0	5.14x10 ⁻³

Table 11. Photon Track Length for Electron-Initiated Showers in Copper
 Electron Source Energy: 1.4 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.09×10^{-2}	6.28×10^{-2}	1.31×10^{-1}	2.13×10^{-1}	2.76×10^{-1}	3.47×10^{-1}	3.92×10^{-1}	4.05×10^{-1}	4.41×10^{-1}	4.32×10^{-1}	4.41×10^{-1}
17	1.56×10^{-2}	5.32×10^{-2}	7.61×10^{-2}	1.25×10^{-1}	1.88×10^{-1}	2.02×10^{-1}	2.32×10^{-1}	2.44×10^{-1}	2.73×10^{-1}	2.63×10^{-1}	2.49×10^{-1}
25	1.23×10^{-2}	3.04×10^{-2}	5.31×10^{-2}	7.19×10^{-2}	9.86×10^{-2}	1.15×10^{-1}	1.36×10^{-1}	1.47×10^{-1}	1.35×10^{-1}	1.33×10^{-1}	1.22×10^{-1}
35	5.08×10^{-3}	1.80×10^{-2}	3.66×10^{-2}	5.22×10^{-2}	5.83×10^{-2}	7.43×10^{-2}	6.18×10^{-2}	7.18×10^{-2}	6.73×10^{-2}	7.36×10^{-2}	6.58×10^{-2}
45	3.99×10^{-3}	1.31×10^{-2}	2.53×10^{-2}	3.27×10^{-2}	3.80×10^{-2}	4.66×10^{-2}	4.75×10^{-2}	5.03×10^{-2}	3.78×10^{-2}	3.70×10^{-2}	3.68×10^{-2}
60	2.68×10^{-3}	1.07×10^{-2}	1.77×10^{-2}	2.21×10^{-2}	2.50×10^{-2}	3.00×10^{-2}	3.07×10^{-2}	2.66×10^{-2}	2.64×10^{-2}	2.28×10^{-2}	1.98×10^{-2}
85	2.10×10^{-3}	7.79×10^{-3}	9.37×10^{-3}	1.21×10^{-2}	1.60×10^{-2}	1.62×10^{-2}	1.26×10^{-2}	1.39×10^{-2}	1.40×10^{-2}	1.15×10^{-2}	1.00×10^{-2}
120	7.01×10^{-4}	4.76×10^{-3}	6.83×10^{-3}	7.72×10^{-3}	8.48×10^{-3}	7.81×10^{-3}	8.18×10^{-3}	7.42×10^{-3}	6.61×10^{-3}	4.71×10^{-3}	4.84×10^{-3}
170	1.20×10^{-3}	2.81×10^{-3}	3.64×10^{-3}	4.73×10^{-3}	5.21×10^{-3}	4.10×10^{-3}	4.09×10^{-3}	3.04×10^{-3}	2.40×10^{-3}	2.03×10^{-3}	1.92×10^{-3}
250	5.62×10^{-4}	1.81×10^{-3}	2.22×10^{-3}	2.65×10^{-3}	2.39×10^{-3}	2.05×10^{-3}	1.58×10^{-3}	1.60×10^{-3}	1.21×10^{-3}	6.69×10^{-4}	4.54×10^{-4}
350	5.44×10^{-4}	8.78×10^{-4}	1.09×10^{-3}	1.59×10^{-3}	1.26×10^{-3}	7.54×10^{-4}	8.58×10^{-4}	6.49×10^{-4}	2.73×10^{-4}	4.60×10^{-4}	2.51×10^{-4}
450	3.07×10^{-4}	7.36×10^{-4}	7.99×10^{-4}	7.38×10^{-4}	7.98×10^{-4}	5.12×10^{-4}	3.89×10^{-4}	3.89×10^{-4}	2.67×10^{-4}	2.05×10^{-4}	2.05×10^{-4}
600	2.11×10^{-4}	5.44×10^{-4}	6.05×10^{-4}	5.24×10^{-4}	4.33×10^{-4}	3.79×10^{-4}	1.91×10^{-4}	1.61×10^{-4}	1.31×10^{-4}	6.07×10^{-5}	5.05×10^{-5}
875	1.46×10^{-4}	2.68×10^{-4}	2.68×10^{-4}	1.98×10^{-4}	1.41×10^{-4}	9.89×10^{-5}	7.54×10^{-5}	7.06×10^{-5}	5.65×10^{-5}	2.83×10^{-5}	1.41×10^{-5}
1,085	1.17×10^{-4}	1.59×10^{-4}	1.40×10^{-4}	1.22×10^{-4}	7.01×10^{-5}	6.55×10^{-5}	3.74×10^{-5}	3.27×10^{-5}	1.87×10^{-5}	9.34×10^{-6}	9.35×10^{-6}
1,295	4.65×10^{-5}	1.21×10^{-4}	3.73×10^{-5}	6.52×10^{-5}	2.33×10^{-5}	1.40×10^{-5}	9.32×10^{-6}	1.40×10^{-5}	0	0	0

Table 11 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	4.34x10 ⁻¹	3.92x10 ⁻¹	3.68x10 ⁻¹	3.17x10 ⁻¹	2.93x10 ⁻¹	2.65x10 ⁻¹	2.24x10 ⁻¹	2.12x10 ⁻¹	1.91x10 ⁻¹	1.09x10 ⁰	6.95x10 ⁰
17	2.40x10 ⁻¹	2.13x10 ⁻¹	1.87x10 ⁻¹	1.53x10 ⁻¹	1.49x10 ⁻¹	1.38x10 ⁻¹	1.44x10 ⁻¹	9.99x10 ⁻²	9.89x10 ⁻²	4.81x10 ⁻¹	3.82x10 ⁰
25	1.09x10 ⁻¹	8.70x10 ⁻²	9.18x10 ⁻²	7.88x10 ⁻²	7.43x10 ⁻²	5.44x10 ⁻²	5.68x10 ⁻²	4.65x10 ⁻²	3.70x10 ⁻²	1.96x10 ⁻¹	1.89x10 ⁰
35	4.63x10 ⁻²	4.69x10 ⁻²	4.33x10 ⁻²	3.19x10 ⁻²	3.55x10 ⁻²	2.45x10 ⁻²	2.60x10 ⁻²	1.98x10 ⁻²	1.84x10 ⁻²	7.60x10 ⁻²	9.53x10 ⁻¹
45	3.52x10 ⁻²	2.67x10 ⁻²	2.42x10 ⁻²	2.25x10 ⁻²	1.59x10 ⁻²	1.45x10 ⁻²	1.05x10 ⁻²	7.13x10 ⁻³	7.69x10 ⁻³	3.72x10 ⁻²	5.71x10 ⁻¹
60	2.08x10 ⁻²	1.74x10 ⁻²	1.18x10 ⁻²	1.06x10 ⁻²	9.15x10 ⁻³	8.33x10 ⁻³	7.93x10 ⁻³	5.23x10 ⁻³	4.30x10 ⁻³	1.58x10 ⁻²	3.46x10 ⁻¹
85	7.56x10 ⁻³	7.83x10 ⁻³	5.88x10 ⁻³	4.95x10 ⁻³	4.36x10 ⁻³	3.20x10 ⁻³	2.02x10 ⁻³	2.26x10 ⁻³	2.02x10 ⁻³	5.29x10 ⁻³	1.71x10 ⁻¹
120	4.65x10 ⁻³	2.95x10 ⁻³	1.76x10 ⁻³	1.94x10 ⁻³	1.77x10 ⁻³	1.29x10 ⁻³	8.81x10 ⁻⁴	5.90x10 ⁻⁴	3.57x10 ⁻⁴	1.82x10 ⁻³	8.61x10 ⁻²
170	1.73x10 ⁻³	1.46x10 ⁻³	9.44x10 ⁻⁴	6.77x10 ⁻⁴	5.67x10 ⁻⁴	6.40x10 ⁻⁴	3.38x10 ⁻⁴	2.63x10 ⁻⁴	1.49x10 ⁻⁴	6.04x10 ⁻⁴	4.26x10 ⁻²
250	4.97x10 ⁻⁴	6.04x10 ⁻⁴	4.12x10 ⁻⁴	2.60x10 ⁻⁴	2.15x10 ⁻⁴	1.73x10 ⁻⁴	1.72x10 ⁻⁴	4.34x10 ⁻⁵	0	2.60x10 ⁻⁴	1.98x10 ⁻²
350	2.72x10 ⁻⁴	1.05x10 ⁻⁴	6.28x10 ⁻⁵	6.27x10 ⁻⁵	1.04x10 ⁻⁴	0	4.22x10 ⁻⁵	0	0	4.19x10 ⁻⁵	9.28x10 ⁻³
450	1.03x10 ⁻⁴	8.18x10 ⁻⁵	6.16x10 ⁻⁵	2.05x10 ⁻⁵	0	2.06x10 ⁻⁵	2.05x10 ⁻⁵	2.05x10 ⁻⁵	0	0	5.67x10 ⁻³
600	6.06x10 ⁻⁵	0	3.02x10 ⁻⁵	1.00x10 ⁻⁵	1.01x10 ⁻⁵	0	0	1.00x10 ⁻⁵	0	2.01x10 ⁻⁵	3.40x10 ⁻³
875	1.88x10 ⁻⁵	4.71x10 ⁻⁶	0	9.43x10 ⁻⁶	0	4.69x10 ⁻⁶	0	4.69x10 ⁻⁶	0	0	1.41x10 ⁻³
1,085	9.35x10 ⁻⁶	0	4.67x10 ⁻⁶	0	0	4.69x10 ⁻⁶	0	4.68x10 ⁻⁶	0	0	8.04x10 ⁻⁴
1,295	4.65x10 ⁻⁶	0	0	0	0	0	0	0	0	0	3.49x10 ⁻⁴

Table 12. Charged Particle Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 1.4 Gev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	3.63×10^{-3}	1.88×10^{-2}	4.02×10^{-2}	6.70×10^{-2}	9.42×10^{-2}	1.08×10^{-1}	1.18×10^{-1}	1.26×10^{-1}	1.13×10^{-1}	1.11×10^{-1}	9.77×10^{-2}
17	2.25×10^{-3}	1.30×10^{-2}	3.25×10^{-2}	4.96×10^{-2}	6.70×10^{-2}	7.34×10^{-2}	8.07×10^{-2}	7.89×10^{-2}	7.31×10^{-2}	6.96×10^{-2}	6.16×10^{-2}
25	1.87×10^{-3}	8.18×10^{-3}	2.12×10^{-2}	3.16×10^{-2}	4.35×10^{-2}	4.89×10^{-2}	5.34×10^{-2}	5.01×10^{-2}	4.57×10^{-2}	4.11×10^{-2}	3.55×10^{-2}
35	1.20×10^{-3}	6.56×10^{-3}	1.51×10^{-2}	2.34×10^{-2}	2.87×10^{-2}	3.44×10^{-2}	3.56×10^{-2}	3.18×10^{-2}	2.78×10^{-2}	2.51×10^{-2}	1.97×10^{-2}
45	9.91×10^{-4}	4.88×10^{-3}	1.20×10^{-2}	1.88×10^{-2}	2.21×10^{-2}	2.54×10^{-2}	2.42×10^{-2}	2.05×10^{-2}	1.94×10^{-2}	1.62×10^{-2}	1.30×10^{-2}
60	6.58×10^{-4}	4.08×10^{-3}	8.57×10^{-3}	1.27×10^{-2}	1.64×10^{-2}	1.74×10^{-2}	1.47×10^{-2}	1.30×10^{-2}	1.22×10^{-2}	9.61×10^{-3}	7.30×10^{-3}
85	4.82×10^{-4}	3.00×10^{-3}	5.70×10^{-3}	8.95×10^{-3}	9.64×10^{-3}	9.84×10^{-3}	8.39×10^{-3}	7.71×10^{-3}	6.37×10^{-3}	5.08×10^{-3}	3.93×10^{-3}
120	4.59×10^{-4}	1.87×10^{-3}	3.77×10^{-3}	5.13×10^{-3}	5.87×10^{-3}	5.58×10^{-3}	4.52×10^{-3}	3.98×10^{-3}	3.25×10^{-3}	2.43×10^{-3}	1.69×10^{-3}
170	3.59×10^{-4}	1.34×10^{-3}	2.72×10^{-3}	3.40×10^{-3}	3.43×10^{-3}	3.03×10^{-3}	2.48×10^{-3}	2.04×10^{-3}	1.48×10^{-3}	9.42×10^{-4}	7.23×10^{-4}
250	3.14×10^{-4}	1.12×10^{-3}	1.60×10^{-3}	1.88×10^{-3}	1.84×10^{-3}	1.43×10^{-3}	1.23×10^{-3}	8.35×10^{-4}	5.21×10^{-4}	3.61×10^{-4}	2.49×10^{-4}
350	2.24×10^{-4}	8.96×10^{-4}	1.12×10^{-3}	1.13×10^{-3}	1.02×10^{-3}	6.69×10^{-4}	4.74×10^{-4}	2.59×10^{-4}	2.22×10^{-4}	1.62×10^{-4}	1.30×10^{-4}
450	2.23×10^{-4}	6.71×10^{-4}	9.08×10^{-4}	7.14×10^{-4}	5.78×10^{-4}	3.85×10^{-4}	2.39×10^{-4}	1.58×10^{-4}	5.94×10^{-5}	6.75×10^{-5}	4.32×10^{-5}
600	1.91×10^{-4}	5.46×10^{-4}	5.67×10^{-4}	4.26×10^{-4}	2.44×10^{-4}	1.53×10^{-4}	9.44×10^{-5}	4.72×10^{-5}	4.45×10^{-5}	2.23×10^{-5}	1.28×10^{-5}
875	2.92×10^{-5}	5.03×10^{-5}	3.66×10^{-5}	1.53×10^{-5}	7.50×10^{-6}	3.21×10^{-6}	1.57×10^{-6}	6.41×10^{-7}	6.74×10^{-7}	2.57×10^{-7}	3.53×10^{-7}
1,085	4.32×10^{-4}	4.93×10^{-4}	2.24×10^{-4}	6.38×10^{-5}	1.12×10^{-5}	4.81×10^{-6}	9.62×10^{-7}	4.81×10^{-6}	4.76×10^{-7}	0	0
1,295	2.03×10^{-3}	5.07×10^{-4}	7.37×10^{-5}	8.01×10^{-6}	1.92×10^{-6}	3.20×10^{-7}	3.20×10^{-7}	0	0	0	0

Table 12 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	8.69x10 ⁻²	7.88x10 ⁻²	6.61x10 ⁻²	5.47x10 ⁻²	4.73x10 ⁻²	4.02x10 ⁻²	3.34x10 ⁻²	2.87x10 ⁻²	2.48x10 ⁻²	1.10x10 ⁻¹	1.47
17	5.51x10 ⁻²	4.53x10 ⁻²	4.12x10 ⁻²	3.26x10 ⁻²	2.82x10 ⁻²	2.37x10 ⁻²	1.95x10 ⁻²	1.59x10 ⁻²	1.37x10 ⁻²	5.60x10 ⁻²	9.33x10 ⁻¹
25	3.13x10 ⁻²	2.54x10 ⁻²	2.20x10 ⁻²	1.74x10 ⁻²	1.54x10 ⁻²	1.24x10 ⁻²	1.02x10 ⁻²	8.41x10 ⁻³	6.86x10 ⁻³	2.56x10 ⁻²	5.56x10 ⁻¹
35	1.79x10 ⁻²	1.49x10 ⁻²	1.09x10 ⁻²	1.00x10 ⁻²	8.28x10 ⁻³	7.10x10 ⁻³	4.80x10 ⁻³	4.08x10 ⁻³	2.76x10 ⁻³	1.16x10 ⁻²	3.42x10 ⁻¹
45	1.07x10 ⁻²	9.45x10 ⁻³	6.66x10 ⁻³	5.32x10 ⁻³	5.16x10 ⁻³	3.80x10 ⁻³	3.22x10 ⁻³	2.63x10 ⁻³	1.90x10 ⁻³	6.66x10 ⁻³	2.33x10 ⁻¹
60	6.65x10 ⁻³	5.24x10 ⁻³	3.96x10 ⁻³	3.43x10 ⁻³	2.46x10 ⁻³	2.09x10 ⁻³	1.99x10 ⁻³	1.25x10 ⁻³	9.25x10 ⁻⁴	3.12x10 ⁻³	1.48x10 ⁻¹
85	3.00x10 ⁻³	2.48x10 ⁻³	1.69x10 ⁻³	1.66x10 ⁻³	1.18x10 ⁻³	8.96x10 ⁻⁴	7.37x10 ⁻⁴	4.87x10 ⁻⁴	2.59x10 ⁻⁴	1.34x10 ⁻³	8.28x10 ⁻²
120	1.32x10 ⁻³	9.25x10 ⁻⁴	8.84x10 ⁻⁴	6.66x10 ⁻⁴	5.13x10 ⁻⁴	4.39x10 ⁻⁴	2.79x10 ⁻⁴	1.94x10 ⁻⁴	1.19x10 ⁻⁴	3.91x10 ⁻⁴	4.43x10 ⁻²
170	4.70x10 ⁻⁴	4.86x10 ⁻⁴	4.43x10 ⁻⁴	3.98x10 ⁻⁴	1.60x10 ⁻⁴	1.99x10 ⁻⁴	1.40x10 ⁻⁴	1.02x10 ⁻⁴	3.84x10 ⁻⁵	1.47x10 ⁻⁴	2.45x10 ⁻²
250	2.08x10 ⁻⁴	2.08x10 ⁻⁴	1.33x10 ⁻⁴	1.08x10 ⁻⁴	7.85x10 ⁻⁵	5.82x10 ⁻⁵	3.25x10 ⁻⁵	3.25x10 ⁻⁵	2.17x10 ⁻⁵	5.14x10 ⁻⁵	1.23x10 ⁻²
350	1.09x10 ⁻⁴	8.11x10 ⁻⁵	5.67x10 ⁻⁵	3.24x10 ⁻⁵	2.03x10 ⁻⁵	1.89x10 ⁻⁵	8.11x10 ⁻⁶	1.35x10 ⁻⁶	0	1.76x10 ⁻⁵	6.65x10 ⁻³
450	3.91x10 ⁻⁵	4.45x10 ⁻⁵	1.89x10 ⁻⁵	1.21x10 ⁻⁵	1.08x10 ⁻⁵	1.35x10 ⁻⁶	0	1.35x10 ⁻⁶	6.75x10 ⁻⁶	4.05x10 ⁻⁶	4.18x10 ⁻³
600	1.01x10 ⁻⁵	1.01x10 ⁻⁵	6.75x10 ⁻⁶	4.72x10 ⁻⁶	4.05x10 ⁻⁶	0	0	0	0	4.05x10 ⁻⁶	2.39x10 ⁻³
875	4.17x10 ⁻⁷	6.41x10 ⁻⁸	0	0	0	6.41x10 ⁻⁸	2.24x10 ⁻⁷	2.25x10 ⁻⁷	0	0	1.46x10 ⁻⁴
1,085	0	6.41x10 ⁻⁷	9.62x10 ⁻⁷	0	0	0	0	0	0	0	1.24x10 ⁻³
1,295	0	0	0	0	0	0	0	0	0	0	2.63x10 ⁻³

Table 13. Photon Track Length for Electron-Initiated Showers in Copper
 Electron Source Energy: 3 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	4.74×10^{-2}	1.58×10^{-1}	3.28×10^{-1}	4.86×10^{-1}	8.15×10^{-1}	2.07	1.31	1.66	1.55	1.84	1.89
17	1.84×10^{-2}	5.03×10^{-2}	1.24×10^{-1}	1.76×10^{-1}	2.77×10^{-1}	3.30×10^{-1}	4.19×10^{-1}	4.41×10^{-1}	4.98×10^{-1}	4.88×10^{-1}	5.29×10^{-1}
25	1.07×10^{-2}	3.31×10^{-2}	6.48×10^{-2}	1.02×10^{-1}	1.41×10^{-1}	1.76×10^{-1}	2.29×10^{-1}	2.48×10^{-1}	2.61×10^{-1}	2.73×10^{-1}	2.68×10^{-1}
35	6.92×10^{-3}	2.40×10^{-2}	4.48×10^{-2}	6.40×10^{-2}	9.44×10^{-2}	1.15×10^{-1}	1.22×10^{-1}	1.41×10^{-1}	1.40×10^{-1}	1.39×10^{-1}	1.41×10^{-1}
45	4.80×10^{-3}	1.56×10^{-2}	3.52×10^{-2}	4.38×10^{-2}	5.73×10^{-2}	7.21×10^{-2}	8.54×10^{-2}	9.11×10^{-2}	8.84×10^{-2}	8.53×10^{-2}	8.11×10^{-2}
60	2.81×10^{-3}	1.26×10^{-2}	2.17×10^{-2}	3.07×10^{-2}	4.21×10^{-2}	4.32×10^{-2}	5.16×10^{-2}	5.34×10^{-2}	5.52×10^{-2}	5.37×10^{-2}	5.18×10^{-2}
85	2.59×10^{-3}	7.56×10^{-3}	1.30×10^{-2}	1.94×10^{-2}	2.29×10^{-2}	2.84×10^{-2}	2.75×10^{-2}	3.02×10^{-2}	2.77×10^{-2}	2.55×10^{-2}	2.37×10^{-2}
120	1.82×10^{-3}	5.46×10^{-3}	8.93×10^{-3}	1.14×10^{-2}	1.43×10^{-2}	1.53×10^{-2}	1.56×10^{-2}	1.64×10^{-2}	1.39×10^{-2}	1.21×10^{-2}	1.27×10^{-2}
170	1.31×10^{-3}	2.66×10^{-3}	5.17×10^{-3}	6.53×10^{-3}	8.92×10^{-3}	8.36×10^{-3}	8.71×10^{-3}	7.81×10^{-3}	7.54×10^{-3}	6.39×10^{-3}	5.74×10^{-3}
250	7.79×10^{-4}	2.37×10^{-3}	3.00×10^{-3}	3.58×10^{-3}	3.94×10^{-3}	4.31×10^{-3}	3.97×10^{-3}	3.39×10^{-3}	3.17×10^{-3}	2.98×10^{-3}	2.01×10^{-3}
350	5.24×10^{-4}	1.30×10^{-3}	1.88×10^{-3}	2.01×10^{-3}	2.01×10^{-3}	2.14×10^{-3}	2.43×10^{-3}	1.53×10^{-3}	1.48×10^{-3}	1.15×10^{-3}	9.64×10^{-4}
450	4.31×10^{-4}	1.17×10^{-3}	1.19×10^{-3}	1.29×10^{-3}	1.50×10^{-3}	1.52×10^{-3}	1.23×10^{-3}	9.22×10^{-4}	6.35×10^{-4}	7.38×10^{-4}	5.32×10^{-4}
600	2.31×10^{-4}	5.54×10^{-4}	1.04×10^{-3}	9.27×10^{-4}	7.65×10^{-4}	5.84×10^{-4}	6.75×10^{-4}	6.44×10^{-4}	4.63×10^{-4}	2.51×10^{-4}	2.62×10^{-4}
850	1.96×10^{-4}	3.33×10^{-4}	4.84×10^{-4}	4.44×10^{-4}	4.83×10^{-4}	2.87×10^{-4}	3.07×10^{-4}	1.90×10^{-4}	1.24×10^{-4}	1.24×10^{-4}	9.15×10^{-5}
1,200	1.32×10^{-4}	2.99×10^{-4}	3.38×10^{-4}	2.55×10^{-4}	2.65×10^{-4}	1.57×10^{-4}	1.08×10^{-4}	3.92×10^{-5}	7.35×10^{-5}	5.88×10^{-5}	3.92×10^{-5}
1,700	9.07×10^{-5}	1.43×10^{-4}	1.85×10^{-4}	1.39×10^{-4}	1.10×10^{-4}	5.40×10^{-5}	4.54×10^{-5}	3.56×10^{-5}	2.26×10^{-5}	2.27×10^{-5}	9.73×10^{-6}
1,875	7.97×10^{-5}	1.29×10^{-4}	1.01×10^{-4}	9.04×10^{-5}	7.54×10^{-5}	4.74×10^{-5}	4.52×10^{-5}	2.15×10^{-5}	3.45×10^{-5}	8.62×10^{-6}	8.62×10^{-6}
2,325	5.14×10^{-5}	8.99×10^{-5}	6.64×10^{-5}	4.50×10^{-5}	3.00×10^{-5}	1.93×10^{-5}	1.28×10^{-5}	2.35×10^{-5}	6.43×10^{-6}	4.29×10^{-6}	4.28×10^{-6}
2,775	2.77×10^{-5}	3.84×10^{-5}	3.41×10^{-5}	2.35×10^{-5}	1.92×10^{-5}	6.40×10^{-6}	2.13×10^{-6}	0	2.14×10^{-6}	0	0

Table 13 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	1.84	1.83	1.70	1.53	1.41	1.40	1.20	1.07	9.09x10 ⁻¹	6.51	3.05x10 ¹
17	5.10x10 ⁻¹	4.68x10 ⁻¹	4.34x10 ⁻¹	4.38x10 ⁻¹	3.91x10 ⁻¹	3.77x10 ⁻¹	2.97x10 ⁻¹	2.98x10 ⁻¹	2.34x10 ⁻¹	1.53	8.32
25	2.52x10 ⁻¹	2.33x10 ⁻¹	2.29x10 ⁻¹	1.97x10 ⁻¹	1.81x10 ⁻¹	1.49x10 ⁻¹	1.49x10 ⁻¹	1.19x10 ⁻¹	1.10x10 ⁻¹	6.02x10 ⁻¹	4.03
35	1.41x10 ⁻¹	1.18x10 ⁻¹	1.15x10 ⁻¹	1.03x10 ⁻¹	8.13x10 ⁻²	6.71x10 ⁻²	6.44x10 ⁻²	5.65x10 ⁻²	5.12x10 ⁻²	2.48x10 ⁻¹	2.08
45	8.19x10 ⁻²	7.76x10 ⁻²	6.85x10 ⁻²	5.69x10 ⁻²	4.95x10 ⁻²	4.60x10 ⁻²	3.75x10 ⁻²	3.52x10 ⁻²	2.28x10 ⁻²	1.18x10 ⁻¹	1.25
60	4.17x10 ⁻²	3.88x10 ⁻²	3.91x10 ⁻²	2.95x10 ⁻²	2.43x10 ⁻²	2.04x10 ⁻²	1.99x10 ⁻²	1.48x10 ⁻²	1.25x10 ⁻²	5.98x10 ⁻²	7.20x10 ⁻¹
85	1.97x10 ⁻²	1.96x10 ⁻²	1.82x10 ⁻²	1.40x10 ⁻²	1.27x10 ⁻²	1.05x10 ⁻²	8.33x10 ⁻³	7.06x10 ⁻³	5.55x10 ⁻³	2.42x10 ⁻²	3.68x10 ⁻¹
120	9.00x10 ⁻³	7.96x10 ⁻³	6.59x10 ⁻³	5.53x10 ⁻³	4.90x10 ⁻³	3.77x10 ⁻³	4.01x10 ⁻³	1.76x10 ⁻³	2.00x10 ⁻³	7.56x10 ⁻³	1.81x10 ⁻¹
170	4.33x10 ⁻³	3.98x10 ⁻³	3.20x10 ⁻³	2.47x10 ⁻³	1.84x10 ⁻³	1.47x10 ⁻³	1.43x10 ⁻³	1.32x10 ⁻³	9.79x10 ⁻⁴	2.90x10 ⁻³	9.30x10 ⁻²
250	1.64x10 ⁻³	1.71x10 ⁻³	1.40x10 ⁻³	1.03x10 ⁻³	8.83x10 ⁻⁴	3.02x10 ⁻⁴	3.00x10 ⁻⁴	4.53x10 ⁻⁴	3.23x10 ⁻⁴	8.87x10 ⁻⁴	4.24x10 ⁻²
350	4.19x10 ⁻⁴	6.27x10 ⁻⁴	6.29x10 ⁻⁴	2.51x10 ⁻⁴	2.30x10 ⁻⁴	3.14x10 ⁻⁴	2.09x10 ⁻⁴	3.35x10 ⁻⁴	8.39x10 ⁻⁵	2.71x10 ⁻⁴	2.08x10 ⁻²
450	4.31x10 ⁻⁴	3.07x10 ⁻⁴	2.05x10 ⁻⁴	2.05x10 ⁻⁴	1.84x10 ⁻⁴	6.17x10 ⁻⁵	4.09x10 ⁻⁵	4.09x10 ⁻⁵	6.15x10 ⁻⁵	1.64x10 ⁻⁴	1.28x10 ⁻²
600	1.81x10 ⁻⁴	1.61x10 ⁻⁴	1.61x10 ⁻⁴	1.21x10 ⁻⁴	8.06x10 ⁻⁵	6.06x10 ⁻⁵	7.06x10 ⁻⁵	2.00x10 ⁻⁵	0	6.06x10 ⁻⁵	7.32x10 ⁻³
850	7.20x10 ⁻⁵	2.62x10 ⁻⁵	3.27x10 ⁻⁵	3.92x10 ⁻⁵	1.30x10 ⁻⁵	1.96x10 ⁻⁵	6.53x10 ⁻⁶	1.31x10 ⁻⁵	1.31x10 ⁻⁵	1.31x10 ⁻⁵	3.31x10 ⁻³
1,200	1.96x10 ⁻⁵	1.96x10 ⁻⁵	1.47x10 ⁻⁵	0	4.88x10 ⁻⁶	0	4.89x10 ⁻⁶	0	0	0	1.83x10 ⁻³
1,700	1.30x10 ⁻⁵	3.24x10 ⁻⁶	0	6.47x10 ⁻⁶	3.25x10 ⁻⁶	0	0	0	0	0	9.23x10 ⁻⁴
1,875	2.15x10 ⁻⁶	4.31x10 ⁻⁶	2.15x10 ⁻⁶	2.15x10 ⁻⁶	2.16x10 ⁻⁶	0	0	0	0	0	6.55x10 ⁻⁴
2,325	4.28x10 ⁻⁶	2.14x10 ⁻⁶	0	2.14x10 ⁻⁶	2.14x10 ⁻⁶	0	0	0	0	0	3.64x10 ⁻⁴
2,775	2.13x10 ⁻⁶	2.13x10 ⁻⁶	0	0	0	0	0	0	0	0	1.58x10 ⁻⁴

Table 14. Charged Particle Track Length for Electron-Initiated Showers in Copper
 Electron Source Energy: 3 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	4.03×10^{-3}	1.80×10^{-2}	5.01×10^{-2}	8.93×10^{-2}	1.28×10^{-1}	1.70×10^{-1}	1.94×10^{-1}	2.26×10^{-1}	2.36×10^{-1}	2.27×10^{-1}	2.24×10^{-1}
17	2.39×10^{-3}	1.22×10^{-2}	3.82×10^{-2}	6.57×10^{-2}	9.18×10^{-2}	1.21×10^{-1}	1.39×10^{-1}	1.52×10^{-1}	1.54×10^{-1}	1.54×10^{-1}	1.45×10^{-1}
25	1.57×10^{-3}	1.01×10^{-2}	2.74×10^{-2}	4.58×10^{-2}	6.08×10^{-2}	7.93×10^{-2}	9.19×10^{-2}	9.50×10^{-2}	9.53×10^{-2}	9.53×10^{-2}	8.64×10^{-2}
35	1.04×10^{-3}	7.93×10^{-3}	1.86×10^{-2}	3.11×10^{-2}	4.19×10^{-2}	5.21×10^{-2}	5.98×10^{-2}	5.95×10^{-2}	5.85×10^{-2}	5.74×10^{-2}	5.11×10^{-2}
45	1.16×10^{-3}	5.86×10^{-3}	1.39×10^{-2}	2.29×10^{-2}	3.18×10^{-2}	3.92×10^{-2}	4.25×10^{-2}	4.33×10^{-2}	4.36×10^{-2}	3.90×10^{-2}	3.62×10^{-2}
60	7.06×10^{-4}	4.49×10^{-3}	1.14×10^{-2}	1.74×10^{-2}	2.35×10^{-2}	2.75×10^{-2}	2.81×10^{-2}	2.80×10^{-2}	2.66×10^{-2}	2.55×10^{-2}	2.14×10^{-2}
85	6.37×10^{-4}	3.23×10^{-3}	7.68×10^{-3}	1.14×10^{-2}	1.44×10^{-2}	1.70×10^{-2}	1.71×10^{-2}	1.69×10^{-2}	1.66×10^{-2}	1.30×10^{-2}	1.20×10^{-2}
120	3.43×10^{-4}	2.16×10^{-3}	4.91×10^{-3}	7.37×10^{-3}	9.11×10^{-3}	1.01×10^{-2}	9.70×10^{-3}	9.80×10^{-3}	8.25×10^{-3}	7.51×10^{-3}	6.16×10^{-3}
170	2.91×10^{-4}	1.42×10^{-3}	3.07×10^{-3}	4.43×10^{-3}	5.45×10^{-3}	5.82×10^{-3}	5.78×10^{-3}	5.12×10^{-3}	4.52×10^{-3}	3.59×10^{-3}	2.76×10^{-3}
250	1.57×10^{-4}	1.09×10^{-3}	2.02×10^{-3}	2.63×10^{-3}	2.95×10^{-3}	3.01×10^{-3}	2.65×10^{-3}	2.40×10^{-3}	1.82×10^{-3}	1.68×10^{-3}	1.21×10^{-3}
350	1.23×10^{-4}	7.19×10^{-4}	1.26×10^{-3}	1.62×10^{-3}	1.67×10^{-3}	1.59×10^{-3}	1.48×10^{-3}	1.22×10^{-3}	9.86×10^{-4}	6.50×10^{-4}	4.76×10^{-4}
450	1.32×10^{-4}	5.94×10^{-4}	9.85×10^{-4}	1.18×10^{-3}	1.25×10^{-3}	1.04×10^{-3}	8.87×10^{-4}	7.33×10^{-4}	4.64×10^{-4}	3.17×10^{-4}	1.86×10^{-4}
600	1.36×10^{-4}	4.54×10^{-4}	7.33×10^{-4}	7.54×10^{-4}	7.78×10^{-4}	6.39×10^{-4}	4.52×10^{-4}	3.22×10^{-4}	2.35×10^{-4}	1.38×10^{-4}	1.15×10^{-4}
850	1.05×10^{-4}	3.34×10^{-4}	4.30×10^{-4}	4.35×10^{-4}	3.70×10^{-4}	2.99×10^{-4}	1.81×10^{-4}	1.17×10^{-4}	8.26×10^{-5}	5.43×10^{-5}	5.52×10^{-5}
1,200	1.18×10^{-4}	2.76×10^{-4}	2.77×10^{-4}	2.55×10^{-4}	1.80×10^{-4}	1.06×10^{-4}	7.84×10^{-5}	4.38×10^{-5}	2.36×10^{-5}	2.32×10^{-5}	1.01×10^{-5}
1,700	1.25×10^{-4}	2.12×10^{-4}	2.13×10^{-4}	1.19×10^{-4}	5.83×10^{-5}	3.59×10^{-5}	1.86×10^{-5}	6.73×10^{-6}	4.71×10^{-6}	3.81×10^{-6}	1.12×10^{-6}
1,875	1.38×10^{-4}	2.28×10^{-4}	1.72×10^{-4}	8.39×10^{-5}	4.23×10^{-5}	2.15×10^{-5}	8.97×10^{-6}	6.13×10^{-6}	4.48×10^{-6}	4.48×10^{-6}	8.97×10^{-7}
2,325	1.85×10^{-4}	2.34×10^{-4}	1.11×10^{-4}	4.24×10^{-5}	1.39×10^{-5}	4.48×10^{-6}	2.24×10^{-6}	2.39×10^{-6}	1.20×10^{-6}	7.47×10^{-7}	5.98×10^{-7}
2,775	9.67×10^{-4}	2.49×10^{-4}	4.87×10^{-5}	5.68×10^{-6}	1.34×10^{-6}	2.99×10^{-7}	0	0	0	0	0

Table 14 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	2.11x10 ⁻¹	1.91x10 ⁻¹	1.65x10 ⁻¹	1.56x10 ⁻¹	1.39x10 ⁻¹	1.09x10 ⁻¹	9.62x10 ⁻²	8.26x10 ⁻²	7.23x10 ⁻²	3.65x10 ⁻¹	3.15
17	1.32x10 ⁻¹	1.19x10 ⁻¹	1.05x10 ⁻¹	9.58x10 ⁻²	7.99x10 ⁻²	6.36x10 ⁻²	5.39x10 ⁻²	4.91x10 ⁻²	3.94x10 ⁻²	1.97x10 ⁻¹	2.01
25	7.73x10 ⁻²	6.87x10 ⁻²	5.91x10 ⁻²	5.38x10 ⁻²	4.38x10 ⁻²	3.53x10 ⁻²	3.10x10 ⁻²	2.64x10 ⁻²	2.11x10 ⁻²	9.30x10 ⁻²	1.20
35	4.60x10 ⁻²	4.10x10 ⁻²	3.46x10 ⁻²	2.99x10 ⁻²	2.29x10 ⁻²	1.86x10 ⁻²	1.61x10 ⁻²	1.36x10 ⁻²	1.03x10 ⁻²	4.42x10 ⁻²	7.16x10 ⁻¹
45	2.95x10 ⁻²	2.58x10 ⁻²	2.33x10 ⁻²	1.81x10 ⁻²	1.43x10 ⁻²	1.23x10 ⁻²	9.95x10 ⁻³	8.27x10 ⁻³	6.88x10 ⁻³	2.58x10 ⁻²	4.93x10 ⁻¹
60	1.76x10 ⁻²	1.57x10 ⁻²	1.30x10 ⁻²	1.06x10 ⁻²	8.15x10 ⁻³	6.77x10 ⁻³	5.65x10 ⁻³	4.55x10 ⁻³	3.54x10 ⁻³	1.40x10 ⁻²	3.14x10 ⁻¹
85	9.56x10 ⁻³	8.18x10 ⁻³	6.11x10 ⁻³	4.83x10 ⁻³	3.85x10 ⁻³	3.34x10 ⁻³	2.90x10 ⁻³	2.07x10 ⁻³	1.67x10 ⁻³	6.24x10 ⁻³	1.79x10 ⁻¹
120	4.86x10 ⁻³	3.72x10 ⁻³	2.95x10 ⁻³	2.30x10 ⁻³	1.98x10 ⁻³	1.35x10 ⁻³	9.89x10 ⁻⁴	8.60x10 ⁻⁴	7.28x10 ⁻⁴	2.56x10 ⁻³	9.76x10 ⁻²
170	2.32x10 ⁻³	1.50x10 ⁻³	1.29x10 ⁻³	1.13x10 ⁻³	9.90x10 ⁻⁴	6.28x10 ⁻⁴	5.04x10 ⁻⁴	3.91x10 ⁻⁴	4.02x10 ⁻⁴	9.72x10 ⁻⁴	5.24x10 ⁻²
250	9.09x10 ⁻⁴	6.45x10 ⁻⁴	6.17x10 ⁻⁴	4.42x10 ⁻⁴	2.83x10 ⁻⁴	2.54x10 ⁻⁴	2.20x10 ⁻⁴	1.68x10 ⁻⁴	1.11x10 ⁻⁴	2.44x10 ⁻⁴	2.55x10 ⁻²
350	3.43x10 ⁻⁴	3.09x10 ⁻⁴	1.58x10 ⁻⁴	1.38x10 ⁻⁴	9.05x10 ⁻⁵	1.01x10 ⁻⁴	9.59x10 ⁻⁵	9.59x10 ⁻⁵	5.40x10 ⁻⁵	1.23x10 ⁻⁴	1.33x10 ⁻²
450	1.90x10 ⁻⁴	1.40x10 ⁻⁴	9.85x10 ⁻⁵	6.07x10 ⁻⁵	6.34x10 ⁻⁵	3.51x10 ⁻⁵	2.02x10 ⁻⁵	3.51x10 ⁻⁵	1.35x10 ⁻⁵	4.45x10 ⁻⁵	3.47x10 ⁻³
600	9.17x10 ⁻⁵	5.46x10 ⁻⁵	3.98x10 ⁻⁵	3.84x10 ⁻⁵	1.82x10 ⁻⁵	2.16x10 ⁻⁵	1.89x10 ⁻⁵	1.48x10 ⁻⁵	8.76x10 ⁻⁶	1.68x10 ⁻⁵	5.08x10 ⁻³
850	2.74x10 ⁻⁵	1.75x10 ⁻⁵	1.62x10 ⁻⁵	6.74x10 ⁻⁶	6.29x10 ⁻⁶	8.53x10 ⁻⁶	1.80x10 ⁻⁶	4.04x10 ⁻⁶	0	1.35x10 ⁻⁶	2.55x10 ⁻³
1,200	1.18x10 ⁻⁵	4.04x10 ⁻⁶	1.01x10 ⁻⁶	0	1.35x10 ⁻⁶	1.68x10 ⁻⁶	0	3.37x10 ⁻⁷	1.68x10 ⁻⁶	3.37x10 ⁻⁷	1.41x10 ⁻³
1,700	0	1.35x10 ⁻⁶	1.12x10 ⁻⁶	1.12x10 ⁻⁶	1.80x10 ⁻⁶	2.24x10 ⁻⁷	0	4.49x10 ⁻⁷	0	0	8.07x10 ⁻⁴
1,875	2.09x10 ⁻⁶	4.46x10 ⁻⁷	2.99x10 ⁻⁷	5.98x10 ⁻⁷	5.98x10 ⁻⁷	0	0	0	0	0	7.10x10 ⁻⁴
2,325	0	2.95x10 ⁻⁷	1.49x10 ⁻⁷	0	0	0	0	0	0	0	5.99x10 ⁻⁴
2,775	0	0	0	0	0	0	0	0	0	0	1.27x10 ⁻³

Table 15. Photon Track Length for Electron-Initiated Showers in Copper
 Electron Source Energy: 5 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	4.02×10^{-2}	1.57×10^{-1}	3.77×10^{-1}	6.66×10^{-1}	1.05	1.47	1.79	2.21	2.46	2.48	2.95
17	1.05×10^{-2}	4.97×10^{-2}	1.50×10^{-1}	2.18×10^{-1}	3.33×10^{-1}	4.75×10^{-1}	5.28×10^{-1}	6.46×10^{-1}	6.88×10^{-1}	7.57×10^{-1}	7.80×10^{-1}
25	8.37×10^{-3}	4.62×10^{-2}	8.10×10^{-2}	1.32×10^{-1}	1.99×10^{-1}	2.56×10^{-1}	2.94×10^{-1}	3.64×10^{-1}	3.75×10^{-1}	4.38×10^{-1}	4.30×10^{-1}
35	5.71×10^{-3}	2.16×10^{-2}	4.77×10^{-2}	9.23×10^{-2}	1.20×10^{-1}	1.41×10^{-1}	1.83×10^{-1}	2.13×10^{-1}	2.09×10^{-1}	2.10×10^{-1}	2.30×10^{-1}
45	2.56×10^{-3}	2.10×10^{-2}	3.03×10^{-2}	5.86×10^{-2}	8.36×10^{-2}	9.96×10^{-2}	1.23×10^{-1}	1.31×10^{-1}	1.47×10^{-1}	1.37×10^{-1}	1.44×10^{-1}
60	5.22×10^{-3}	1.25×10^{-2}	2.16×10^{-2}	3.97×10^{-2}	5.62×10^{-2}	6.57×10^{-2}	7.31×10^{-2}	8.22×10^{-2}	8.95×10^{-2}	9.04×10^{-2}	8.90×10^{-2}
85	2.19×10^{-3}	9.40×10^{-3}	1.50×10^{-2}	2.24×10^{-2}	3.12×10^{-2}	3.79×10^{-2}	3.96×10^{-2}	4.58×10^{-2}	4.08×10^{-2}	4.12×10^{-2}	4.33×10^{-2}
120	1.94×10^{-3}	5.64×10^{-3}	8.71×10^{-3}	1.62×10^{-2}	1.78×10^{-2}	1.97×10^{-2}	2.35×10^{-2}	2.45×10^{-2}	2.32×10^{-2}	1.99×10^{-2}	2.02×10^{-2}
170	1.61×10^{-3}	4.57×10^{-3}	6.53×10^{-3}	8.21×10^{-3}	1.11×10^{-2}	1.38×10^{-2}	1.27×10^{-2}	1.20×10^{-2}	1.22×10^{-2}	1.04×10^{-2}	8.90×10^{-3}
250	6.90×10^{-4}	2.56×10^{-3}	3.93×10^{-3}	4.81×10^{-3}	5.26×10^{-3}	6.72×10^{-3}	6.23×10^{-3}	6.25×10^{-3}	4.79×10^{-3}	4.92×10^{-3}	3.95×10^{-3}
350	5.44×10^{-4}	1.47×10^{-3}	2.43×10^{-3}	3.06×10^{-3}	2.99×10^{-3}	3.10×10^{-3}	2.95×10^{-3}	3.06×10^{-3}	2.70×10^{-3}	2.30×10^{-3}	2.14×10^{-3}
450	4.71×10^{-4}	1.31×10^{-3}	1.94×10^{-3}	1.95×10^{-3}	2.35×10^{-3}	1.91×10^{-3}	1.72×10^{-3}	1.54×10^{-3}	1.60×10^{-3}	1.23×10^{-3}	1.29×10^{-3}
600	2.82×10^{-4}	9.15×10^{-4}	1.04×10^{-3}	1.36×10^{-3}	1.28×10^{-3}	1.09×10^{-3}	1.06×10^{-3}	9.47×10^{-4}	8.35×10^{-4}	8.46×10^{-4}	5.23×10^{-4}
850	2.31×10^{-4}	6.07×10^{-4}	7.86×10^{-4}	6.87×10^{-4}	7.26×10^{-4}	6.57×10^{-4}	5.61×10^{-4}	4.75×10^{-4}	3.95×10^{-4}	2.57×10^{-4}	3.04×10^{-4}
1,200	1.67×10^{-4}	3.38×10^{-4}	3.87×10^{-4}	3.53×10^{-4}	3.78×10^{-4}	2.89×10^{-4}	2.70×10^{-4}	1.72×10^{-4}	1.52×10^{-4}	1.13×10^{-4}	1.03×10^{-4}
1,700	9.07×10^{-5}	1.94×10^{-4}	1.94×10^{-4}	1.82×10^{-4}	1.75×10^{-4}	1.17×10^{-4}	1.07×10^{-4}	9.07×10^{-5}	4.86×10^{-5}	5.51×10^{-5}	5.51×10^{-5}
2,500	4.04×10^{-5}	1.02×10^{-4}	8.85×10^{-5}	1.04×10^{-4}	6.74×10^{-5}	7.99×10^{-5}	5.20×10^{-5}	2.31×10^{-5}	1.73×10^{-5}	2.89×10^{-5}	1.35×10^{-5}
3,125	3.19×10^{-5}	6.13×10^{-5}	7.54×10^{-5}	6.39×10^{-5}	4.72×10^{-5}	2.30×10^{-5}	1.40×10^{-5}	7.79×10^{-6}	1.04×10^{-5}	1.02×10^{-5}	6.38×10^{-6}
3,875	3.56×10^{-5}	4.84×10^{-5}	3.82×10^{-5}	3.05×10^{-5}	1.65×10^{-5}	1.53×10^{-5}	6.36×10^{-6}	1.15×10^{-5}	2.55×10^{-6}	2.55×10^{-6}	0
4,625	1.90×10^{-5}	1.65×10^{-5}	2.79×10^{-5}	8.89×10^{-6}	1.02×10^{-5}	1.02×10^{-5}	3.81×10^{-6}	7.62×10^{-6}	2.54×10^{-6}	0	0

Table 15 (continued)

Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)											
Energy (Mev)	Depth Interval (Radiation Lengths)										Totals
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	2.86	2.77	2.75	2.75	2.56	2.28	2.27	2.01	1.88	1.32x10 ¹	5.10x10 ¹
17	7.96x10 ⁻¹	7.57x10 ⁻¹	7.52x10 ⁻¹	7.04x10 ⁻¹	6.51x10 ⁻¹	6.28x10 ⁻¹	5.94x10 ⁻¹	5.05x10 ⁻¹	4.66x10 ⁻¹	3.07	1.36x10 ¹
25	4.03x10 ⁻¹	3.89x10 ⁻¹	3.88x10 ⁻¹	3.54x10 ⁻¹	3.51x10 ⁻¹	3.05x10 ⁻¹	2.68x10 ⁻¹	2.45x10 ⁻¹	2.17x10 ⁻¹	1.25	6.79
35	2.04x10 ⁻¹	2.19x10 ⁻¹	1.94x10 ⁻¹	1.76x10 ⁻¹	1.73x10 ⁻¹	1.42x10 ⁻¹	1.27x10 ⁻¹	1.08x10 ⁻¹	1.08x10 ⁻¹	5.15x10 ⁻¹	3.44
45	1.30x10 ⁻¹	1.30x10 ⁻¹	1.10x10 ⁻¹	1.10x10 ⁻¹	9.84x10 ⁻²	8.31x10 ⁻²	7.37x10 ⁻²	6.32x10 ⁻²	5.83x10 ⁻²	2.81x10 ⁻¹	2.11
60	7.86x10 ⁻²	7.50x10 ⁻²	6.27x10 ⁻²	6.40x10 ⁻²	5.28x10 ⁻²	4.57x10 ⁻²	3.27x10 ⁻²	3.11x10 ⁻²	2.88x10 ⁻²	1.37x10 ⁻¹	1.23
85	3.89x10 ⁻²	3.35x10 ⁻³	2.98x10 ⁻²	2.77x10 ⁻²	2.37x10 ⁻²	2.14x10 ⁻²	1.80x10 ⁻²	1.51x10 ⁻²	1.25x10 ⁻²	5.21x10 ⁻²	6.01x10 ⁻¹
120	1.91x10 ⁻²	1.52x10 ⁻²	1.44x10 ⁻²	1.14x10 ⁻²	1.11x10 ⁻²	7.96x10 ⁻³	6.89x10 ⁻³	5.25x10 ⁻³	5.13x10 ⁻³	2.13x10 ⁻²	2.99x10 ⁻¹
170	8.38x10 ⁻³	6.31x10 ⁻³	6.19x10 ⁻³	5.48x10 ⁻³	4.02x10 ⁻³	3.60x10 ⁻³	3.68x10 ⁻³	2.71x10 ⁻³	2.15x10 ⁻³	7.48x10 ⁻³	1.52x10 ⁻¹
250	3.95x10 ⁻³	3.49x10 ⁻³	2.52x10 ⁻³	2.07x10 ⁻³	1.47x10 ⁻³	1.19x10 ⁻³	1.32x10 ⁻³	8.84x10 ⁻⁴	5.60x10 ⁻⁴	2.40x10 ⁻³	7.03x10 ⁻²
350	1.51x10 ⁻³	1.34x10 ⁻³	1.00x10 ⁻³	6.70x10 ⁻⁴	6.69x10 ⁻⁴	3.77x10 ⁻⁴	4.81x10 ⁻⁴	3.35x10 ⁻⁴	2.31x10 ⁻⁴	8.82x10 ⁻⁴	3.42x10 ⁻²
450	8.80x10 ⁻⁴	9.41x10 ⁻⁴	6.14x10 ⁻⁴	3.68x10 ⁻⁴	4.71x10 ⁻⁴	3.49x10 ⁻⁴	2.67x10 ⁻⁴	2.05x10 ⁻⁴	1.64x10 ⁻⁴	4.30x10 ⁻⁴	2.20x10 ⁻²
600	3.53x10 ⁻⁴	4.43x10 ⁻⁴	2.92x10 ⁻⁴	1.71x10 ⁻⁴	1.31x10 ⁻⁴	1.81x10 ⁻⁴	6.05x10 ⁻⁵	6.03x10 ⁻⁵	1.11x10 ⁻⁴	1.41x10 ⁻⁴	1.21x10 ⁻²
850	2.51x10 ⁻⁴	1.06x10 ⁻⁴	1.12x10 ⁻⁴	4.62x10 ⁻⁵	2.64x10 ⁻⁵	6.61x10 ⁻⁵	3.96x10 ⁻⁵	1.32x10 ⁻⁵	1.98x10 ⁻⁵	3.96x10 ⁻⁵	6.42x10 ⁻³
1,200	6.38x10 ⁻⁵	6.37x10 ⁻⁵	4.91x10 ⁻⁵	3.92x10 ⁻⁵	9.78x10 ⁻⁶	0	1.47x10 ⁻⁵	4.92x10 ⁻⁶	4.91x10 ⁻⁶	2.45x10 ⁻⁵	3.00x10 ⁻³
1,700	3.57x10 ⁻⁵	2.27x10 ⁻⁵	1.30x10 ⁻⁵	9.72x10 ⁻⁶	6.48x10 ⁻⁶	6.49x10 ⁻⁶	6.48x10 ⁻⁶	9.70x10 ⁻⁶	3.24x10 ⁻⁶	3.24x10 ⁻⁶	1.43x10 ⁻³
2,500	7.71x10 ⁻⁶	0	7.71x10 ⁻⁶	3.86x10 ⁻⁶	1.93x10 ⁻⁶	1.93x10 ⁻⁶	0	0	0	0	6.39x10 ⁻⁴
3,125	1.28x10 ⁻⁶	2.56x10 ⁻⁶	2.55x10 ⁻⁶	0	1.28x10 ⁻⁶	1.23x10 ⁻⁶	0	1.28x10 ⁻⁶	0	0	3.64x10 ⁻⁴
3,875	0	0	0	0	2.54x10 ⁻⁶	0	0	1.27x10 ⁻⁶	0	0	2.11x10 ⁻⁴
4,625	1.27x10 ⁻⁶	2.54x10 ⁻⁶	0	0	0	0	0	0	0	0	1.12x10 ⁻⁴

Table 16. Charged Particle Track Length for Electron-Irradiated Showers in Copper
 Electron Source Energy: 5 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.40×10^{-3}	1.91×10^{-2}	5.66×10^{-2}	1.02×10^{-1}	1.66×10^{-1}	2.26×10^{-1}	2.76×10^{-1}	3.28×10^{-1}	3.41×10^{-1}	3.59×10^{-1}	3.56×10^{-1}
17	1.97×10^{-3}	1.43×10^{-2}	4.16×10^{-2}	8.31×10^{-2}	1.20×10^{-1}	1.60×10^{-1}	1.94×10^{-1}	2.25×10^{-1}	2.35×10^{-1}	2.43×10^{-1}	2.42×10^{-1}
25	1.34×10^{-3}	1.16×10^{-2}	2.90×10^{-2}	5.51×10^{-2}	8.31×10^{-2}	1.05×10^{-1}	1.30×10^{-1}	1.44×10^{-1}	1.50×10^{-1}	1.50×10^{-1}	1.40×10^{-1}
35	1.31×10^{-3}	8.29×10^{-3}	2.03×10^{-2}	3.81×10^{-2}	5.50×10^{-2}	7.01×10^{-2}	8.60×10^{-2}	9.13×10^{-2}	9.69×10^{-2}	9.40×10^{-2}	8.64×10^{-2}
45	1.05×10^{-3}	6.20×10^{-3}	1.58×10^{-2}	2.80×10^{-2}	4.09×10^{-2}	5.20×10^{-2}	6.04×10^{-2}	6.45×10^{-2}	6.89×10^{-2}	6.16×10^{-2}	5.83×10^{-2}
60	6.10×10^{-4}	5.07×10^{-3}	1.24×10^{-2}	2.07×10^{-2}	2.84×10^{-2}	3.78×10^{-2}	4.14×10^{-2}	4.35×10^{-2}	4.39×10^{-2}	3.95×10^{-2}	3.59×10^{-2}
85	5.32×10^{-4}	3.81×10^{-3}	8.25×10^{-3}	1.31×10^{-2}	1.93×10^{-2}	2.37×10^{-2}	2.60×10^{-2}	2.63×10^{-2}	2.51×10^{-2}	2.21×10^{-2}	2.07×10^{-2}
120	4.08×10^{-4}	2.67×10^{-3}	6.01×10^{-3}	9.65×10^{-3}	1.27×10^{-2}	1.44×10^{-2}	1.48×10^{-2}	1.43×10^{-2}	1.30×10^{-2}	1.28×10^{-2}	1.11×10^{-2}
170	3.53×10^{-4}	1.89×10^{-3}	3.83×10^{-3}	5.89×10^{-3}	7.57×10^{-3}	8.21×10^{-3}	8.26×10^{-3}	7.68×10^{-3}	7.31×10^{-3}	6.55×10^{-3}	5.95×10^{-3}
250	2.11×10^{-4}	1.11×10^{-3}	2.53×10^{-3}	3.62×10^{-3}	4.31×10^{-3}	4.46×10^{-3}	4.27×10^{-3}	4.05×10^{-3}	3.83×10^{-3}	3.15×10^{-3}	2.55×10^{-3}
350	1.62×10^{-4}	8.04×10^{-4}	1.65×10^{-3}	2.20×10^{-3}	2.55×10^{-3}	2.43×10^{-3}	2.56×10^{-3}	2.32×10^{-3}	1.79×10^{-3}	1.41×10^{-3}	1.16×10^{-3}
450	1.35×10^{-4}	6.32×10^{-4}	1.13×10^{-3}	1.70×10^{-3}	1.79×10^{-3}	1.54×10^{-3}	1.45×10^{-3}	1.29×10^{-3}	8.50×10^{-4}	7.99×10^{-4}	6.01×10^{-4}
600	1.24×10^{-4}	5.00×10^{-4}	8.40×10^{-4}	1.05×10^{-3}	9.95×10^{-4}	9.33×10^{-4}	8.55×10^{-4}	6.76×10^{-4}	5.03×10^{-4}	4.05×10^{-4}	3.66×10^{-4}
850	8.08×10^{-5}	2.98×10^{-4}	5.23×10^{-4}	5.64×10^{-4}	5.05×10^{-4}	5.00×10^{-4}	3.92×10^{-4}	3.05×10^{-4}	2.18×10^{-4}	1.85×10^{-4}	1.37×10^{-4}
1,200	5.72×10^{-5}	2.21×10^{-4}	3.40×10^{-4}	3.24×10^{-4}	3.05×10^{-4}	2.52×10^{-4}	1.75×10^{-4}	1.11×10^{-4}	9.05×10^{-5}	6.73×10^{-5}	4.95×10^{-5}
1,700	5.58×10^{-5}	1.68×10^{-4}	2.32×10^{-4}	1.91×10^{-4}	1.34×10^{-4}	9.42×10^{-5}	5.97×10^{-5}	4.78×10^{-5}	3.81×10^{-5}	3.10×10^{-5}	2.13×10^{-5}
2,500	7.01×10^{-5}	1.53×10^{-4}	1.28×10^{-4}	8.30×10^{-5}	5.27×10^{-5}	2.92×10^{-5}	2.06×10^{-5}	1.01×10^{-5}	7.40×10^{-6}	4.17×10^{-6}	3.36×10^{-6}
3,125	8.87×10^{-5}	1.30×10^{-4}	1.03×10^{-4}	5.58×10^{-5}	2.31×10^{-5}	1.23×10^{-5}	5.02×10^{-6}	4.12×10^{-6}	2.78×10^{-6}	2.06×10^{-6}	1.08×10^{-6}
3,875	1.11×10^{-4}	1.31×10^{-4}	6.89×10^{-5}	2.06×10^{-5}	4.57×10^{-6}	1.34×10^{-6}	1.34×10^{-6}	1.43×10^{-6}	1.17×10^{-6}	1.08×10^{-6}	8.96×10^{-8}
4,625	5.65×10^{-4}	1.62×10^{-4}	2.72×10^{-5}	3.05×10^{-6}	8.96×10^{-7}	3.59×10^{-7}	6.27×10^{-7}	8.96×10^{-8}	8.96×10^{-8}	0	0

Table 16 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	3.42x10 ⁻¹	3.21x10 ⁻¹	3.02x10 ⁻¹	2.71x10 ⁻¹	2.48x10 ⁻¹	2.28x10 ⁻¹	1.93x10 ⁻¹	1.61x10 ⁻¹	1.49x10 ⁻¹	7.87x10 ⁻¹	5.24
17	2.23x10 ⁻¹	2.06x10 ⁻¹	1.91x10 ⁻¹	1.74x10 ⁻¹	1.57x10 ⁻¹	1.35x10 ⁻¹	1.15x10 ⁻¹	9.76x10 ⁻²	8.34x10 ⁻²	4.32x10 ⁻¹	3.37
25	1.29x10 ⁻¹	1.26x10 ⁻¹	1.12x10 ⁻¹	9.77x10 ⁻²	8.79x10 ⁻²	7.61x10 ⁻²	6.40x10 ⁻²	5.33x10 ⁻²	4.67x10 ⁻²	2.19x10 ⁻¹	2.01
35	7.80x10 ⁻²	7.53x10 ⁻²	6.38x10 ⁻²	5.83x10 ⁻²	5.12x10 ⁻²	4.06x10 ⁻²	3.61x10 ⁻²	2.86x10 ⁻²	2.45x10 ⁻²	1.12x10 ⁻¹	1.22
45	5.29x10 ⁻²	4.78x10 ⁻²	4.25x10 ⁻²	3.75x10 ⁻²	3.17x10 ⁻²	2.62x10 ⁻²	2.23x10 ⁻²	1.82x10 ⁻²	1.47x10 ⁻²	6.41x10 ⁻²	8.15x10 ⁻¹
60	3.27x10 ⁻²	3.03x10 ⁻²	2.61x10 ⁻²	2.19x10 ⁻²	1.79x10 ⁻²	1.59x10 ⁻²	1.24x10 ⁻²	9.93x10 ⁻³	8.22x10 ⁻³	3.40x10 ⁻²	5.19x10 ⁻¹
85	1.83x10 ⁻²	1.59x10 ⁻²	1.39x10 ⁻²	1.13x10 ⁻²	9.10x10 ⁻³	7.37x10 ⁻³	5.82x10 ⁻³	4.72x10 ⁻³	4.20x10 ⁻³	1.52x10 ⁻²	2.95x10 ⁻¹
120	9.53x10 ⁻³	9.00x10 ⁻³	6.94x10 ⁻³	5.71x10 ⁻³	4.44x10 ⁻³	3.33x10 ⁻³	2.78x10 ⁻³	2.30x10 ⁻³	1.88x10 ⁻³	6.73x10 ⁻³	1.65x10 ⁻¹
170	4.87x10 ⁻³	3.90x10 ⁻³	3.10x10 ⁻³	2.52x10 ⁻³	1.86x10 ⁻³	1.54x10 ⁻³	1.19x10 ⁻³	1.04x10 ⁻³	7.87x10 ⁻⁴	2.88x10 ⁻³	8.72x10 ⁻²
250	2.03x10 ⁻³	1.57x10 ⁻³	1.35x10 ⁻³	1.03x10 ⁻³	6.77x10 ⁻⁴	5.79x10 ⁻⁴	5.01x10 ⁻⁴	3.49x10 ⁻⁴	3.51x10 ⁻⁴	9.24x10 ⁻⁴	4.34x10 ⁻²
350	9.32x10 ⁻⁴	6.92x10 ⁻⁴	5.61x10 ⁻⁴	4.66x10 ⁻⁴	3.93x10 ⁻⁴	2.86x10 ⁻⁴	1.66x10 ⁻⁴	1.18x10 ⁻⁴	1.20x10 ⁻⁴	2.92x10 ⁻⁴	2.31x10 ⁻²
450	5.65x10 ⁻⁴	4.20x10 ⁻⁴	3.02x10 ⁻⁴	2.69x10 ⁻⁴	1.66x10 ⁻⁴	1.47x10 ⁻⁴	8.23x10 ⁻⁵	7.83x10 ⁻⁵	5.53x10 ⁻⁵	1.35x10 ⁻⁴	1.42x10 ⁻²
600	2.35x10 ⁻⁴	2.02x10 ⁻⁴	1.97x10 ⁻⁴	1.08x10 ⁻⁴	7.15x10 ⁻⁵	4.79x10 ⁻⁵	5.33x10 ⁻⁵	4.52x10 ⁻⁵	3.91x10 ⁻⁵	8.09x10 ⁻⁵	8.33x10 ⁻³
850	9.66x10 ⁻⁵	7.72x10 ⁻⁵	4.81x10 ⁻⁵	3.55x10 ⁻⁵	3.10x10 ⁻⁵	2.11x10 ⁻⁵	1.35x10 ⁻⁵	1.71x10 ⁻⁵	1.08x10 ⁻⁵	1.66x10 ⁻⁵	4.07x10 ⁻³
1,200	3.91x10 ⁻⁵	3.03x10 ⁻⁵	1.72x10 ⁻⁵	1.62x10 ⁻⁵	1.21x10 ⁻⁵	7.07x10 ⁻⁶	6.40x10 ⁻⁶	1.01x10 ⁻⁶	1.68x10 ⁻⁶	8.08x10 ⁻⁶	2.13x10 ⁻³
1,700	1.08x10 ⁻⁵	8.52x10 ⁻⁶	5.61x10 ⁻⁶	5.61x10 ⁻⁶	1.35x10 ⁻⁶	2.24x10 ⁻⁷	8.97x10 ⁻⁷	0	2.02x10 ⁻⁶	1.35x10 ⁻⁶	1.11x10 ⁻³
2,500	1.88x10 ⁻⁶	1.61x10 ⁻⁶	2.15x10 ⁻⁶	1.35x10 ⁻⁷	0	0	0	0	2.69x10 ⁻⁷	5.38x10 ⁻⁷	5.68x10 ⁻⁴
3,125	4.48x10 ⁻⁷	1.79x10 ⁻⁷	8.96x10 ⁻⁸	0	8.96x10 ⁻⁸	0	0	2.69x10 ⁻⁷	4.48x10 ⁻⁷	0	4.30x10 ⁻⁴
3,875	0	8.96x10 ⁻⁸	0	0	0	0	0	0	0	0	3.43x10 ⁻⁴
4,625	0	0	0	0	0	0	0	0	0	0	7.59x10 ⁻⁴

Table 17. Photon Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 10 Gev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.75×10^{-2}	8.85×10^{-2}	2.07×10^{-1}	3.71×10^{-1}	6.39×10^{-1}	9.74×10^{-1}	1.25	1.73	1.99	2.26	2.56
17	1.72×10^{-2}	7.12×10^{-2}	1.27×10^{-1}	2.63×10^{-1}	3.94×10^{-1}	5.77×10^{-1}	8.29×10^{-1}	1.05	1.19	1.28	1.48
25	1.37×10^{-2}	4.10×10^{-2}	7.22×10^{-2}	1.41×10^{-1}	2.34×10^{-1}	3.34×10^{-1}	4.50×10^{-1}	5.72×10^{-1}	6.41×10^{-1}	7.33×10^{-1}	7.55×10^{-1}
35	6.01×10^{-3}	3.54×10^{-2}	5.65×10^{-2}	9.91×10^{-2}	1.62×10^{-1}	2.17×10^{-1}	2.68×10^{-1}	3.47×10^{-1}	3.58×10^{-1}	3.74×10^{-1}	4.43×10^{-1}
45	9.17×10^{-3}	1.64×10^{-2}	3.90×10^{-2}	7.32×10^{-2}	1.12×10^{-1}	1.43×10^{-1}	2.03×10^{-1}	2.25×10^{-1}	2.73×10^{-1}	2.54×10^{-1}	2.59×10^{-1}
60	4.68×10^{-3}	9.77×10^{-3}	2.79×10^{-2}	4.36×10^{-2}	6.94×10^{-2}	1.01×10^{-1}	1.19×10^{-1}	1.24×10^{-1}	1.41×10^{-1}	1.57×10^{-1}	1.59×10^{-1}
85	2.51×10^{-3}	1.03×10^{-2}	2.07×10^{-2}	2.75×10^{-2}	3.98×10^{-2}	5.69×10^{-2}	6.75×10^{-2}	6.86×10^{-2}	8.42×10^{-2}	8.85×10^{-2}	7.90×10^{-2}
120	2.36×10^{-3}	6.04×10^{-3}	1.27×10^{-2}	1.88×10^{-2}	2.97×10^{-2}	3.06×10^{-2}	4.03×10^{-2}	4.67×10^{-2}	4.21×10^{-2}	4.06×10^{-2}	3.94×10^{-2}
170	1.03×10^{-3}	3.27×10^{-3}	7.77×10^{-3}	1.21×10^{-2}	1.42×10^{-2}	1.86×10^{-2}	1.97×10^{-2}	2.26×10^{-2}	2.36×10^{-2}	2.30×10^{-2}	1.97×10^{-2}
250	9.16×10^{-4}	2.21×10^{-3}	3.72×10^{-3}	6.08×10^{-3}	8.83×10^{-3}	9.17×10^{-3}	1.06×10^{-2}	1.11×10^{-2}	1.08×10^{-2}	1.21×10^{-2}	9.86×10^{-3}
350	7.33×10^{-4}	1.77×10^{-3}	3.03×10^{-3}	4.81×10^{-3}	4.39×10^{-3}	4.55×10^{-3}	6.28×10^{-3}	5.24×10^{-3}	6.17×10^{-3}	3.35×10^{-3}	4.82×10^{-3}
450	7.19×10^{-4}	1.44×10^{-3}	1.99×10^{-3}	2.71×10^{-3}	3.12×10^{-3}	2.87×10^{-3}	3.48×10^{-3}	3.59×10^{-3}	3.69×10^{-3}	3.12×10^{-3}	2.26×10^{-3}
600	3.26×10^{-4}	9.06×10^{-4}	1.53×10^{-3}	2.01×10^{-3}	2.24×10^{-3}	2.47×10^{-3}	1.91×10^{-3}	1.96×10^{-3}	1.99×10^{-3}	1.69×10^{-3}	1.64×10^{-3}
850	2.97×10^{-4}	6.10×10^{-4}	9.40×10^{-4}	1.39×10^{-3}	1.09×10^{-3}	9.89×10^{-4}	9.40×10^{-4}	8.58×10^{-4}	9.23×10^{-4}	7.42×10^{-4}	7.26×10^{-4}
1,200	2.28×10^{-4}	3.43×10^{-4}	5.15×10^{-4}	6.03×10^{-4}	5.88×10^{-4}	5.83×10^{-4}	5.93×10^{-4}	5.49×10^{-4}	4.46×10^{-4}	3.48×10^{-4}	2.99×10^{-4}
1,700	1.04×10^{-4}	2.27×10^{-4}	3.27×10^{-4}	3.95×10^{-4}	3.14×10^{-4}	3.27×10^{-4}	2.88×10^{-4}	1.85×10^{-4}	1.82×10^{-4}	1.00×10^{-4}	1.52×10^{-4}
2,500	5.39×10^{-5}	1.62×10^{-4}	2.10×10^{-4}	1.98×10^{-4}	1.62×10^{-4}	1.58×10^{-4}	8.67×10^{-5}	1.18×10^{-4}	4.81×10^{-5}	4.43×10^{-5}	5.59×10^{-5}
3,500	3.44×10^{-5}	8.03×10^{-5}	8.04×10^{-5}	8.99×10^{-5}	9.95×10^{-5}	6.70×10^{-5}	4.59×10^{-5}	3.64×10^{-5}	3.44×10^{-5}	2.10×10^{-5}	2.10×10^{-5}
4,500	1.53×10^{-5}	6.10×10^{-5}	5.91×10^{-5}	5.91×10^{-5}	6.67×10^{-5}	4.00×10^{-5}	2.10×10^{-5}	1.14×10^{-5}	1.53×10^{-5}	2.48×10^{-5}	1.14×10^{-5}
6,000	2.38×10^{-5}	4.18×10^{-5}	3.80×10^{-5}	2.66×10^{-5}	2.28×10^{-5}	2.09×10^{-5}	1.90×10^{-5}	1.24×10^{-5}	8.55×10^{-6}	4.75×10^{-6}	5.70×10^{-6}
6,250	1.96×10^{-5}	4.81×10^{-5}	2.97×10^{-5}	2.85×10^{-5}	2.28×10^{-5}	1.65×10^{-5}	8.23×10^{-6}	6.97×10^{-6}	5.06×10^{-6}	1.27×10^{-6}	1.90×10^{-6}
7,750	1.20×10^{-5}	2.21×10^{-5}	2.84×10^{-5}	2.09×10^{-5}	7.59×10^{-6}	8.85×10^{-6}	2.53×10^{-6}	3.79×10^{-6}	1.26×10^{-6}	1.90×10^{-6}	0
9,250	9.48×10^{-6}	1.33×10^{-5}	1.01×10^{-5}	6.42×10^{-6}	3.16×10^{-6}	4.42×10^{-6}	2.53×10^{-6}	2.53×10^{-6}	2.53×10^{-6}	0	1.26×10^{-6}

Table 17 (continued)

	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
Energy (Mev)	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	2.49	2.74	2.81	2.66	2.69	2.68	2.27	2.22	2.16	1.60x10 ¹	5.09x10 ¹
17	1.51	1.52	1.51	1.46	1.40	1.35	1.27	1.13	1.09	7.85	2.74x10 ¹
25	7.91x10 ⁻¹	7.43x10 ⁻¹	7.28x10 ⁻¹	7.98x10 ⁻¹	7.08x10 ⁻¹	6.51x10 ⁻¹	6.21x10 ⁻¹	5.57x10 ⁻¹	5.16x10 ⁻¹	3.22	1.33x10 ¹
35	4.42x10 ⁻¹	4.36x10 ⁻¹	4.05x10 ⁻¹	3.54x10 ⁻¹	4.02x10 ⁻¹	3.51x10 ⁻¹	2.84x10 ⁻¹	2.85x10 ⁻¹	2.49x10 ⁻¹	1.50	7.07
45	2.67x10 ⁻¹	2.63x10 ⁻¹	2.57x10 ⁻¹	2.59x10 ⁻¹	2.10x10 ⁻¹	1.93x10 ⁻¹	1.79x10 ⁻¹	1.47x10 ⁻¹	1.36x10 ⁻¹	7.69x10 ⁻¹	4.29
60	1.57x10 ⁻¹	1.36x10 ⁻¹	1.38x10 ⁻¹	1.24x10 ⁻¹	1.19x10 ⁻¹	1.10x10 ⁻¹	9.93x10 ⁻²	8.31x10 ⁻²	7.19x10 ⁻²	3.66x10 ⁻¹	2.36
85	8.25x10 ⁻²	8.31x10 ⁻²	7.28x10 ⁻²	6.33x10 ⁻²	5.49x10 ⁻²	5.02x10 ⁻²	4.28x10 ⁻²	3.82x10 ⁻²	3.24x10 ⁻²	1.53x10 ⁻¹	1.22
120	4.33x10 ⁻²	3.59x10 ⁻²	3.35x10 ⁻²	3.07x10 ⁻²	2.89x10 ⁻²	2.08x10 ⁻²	1.63x10 ⁻²	1.68x10 ⁻²	1.38x10 ⁻²	6.41x10 ⁻²	6.13x10 ⁻¹
170	2.02x10 ⁻²	1.88x10 ⁻²	1.51x10 ⁻²	1.25x10 ⁻²	1.23x10 ⁻²	9.56x10 ⁻³	8.92x10 ⁻³	7.41x10 ⁻³	7.13x10 ⁻³	2.53x10 ⁻²	3.03x10 ⁻¹
250	7.28x10 ⁻³	6.96x10 ⁻³	7.70x10 ⁻³	6.52x10 ⁻³	5.73x10 ⁻³	4.26x10 ⁻³	3.46x10 ⁻³	2.59x10 ⁻³	2.05x10 ⁻³	7.72x10 ⁻³	1.40x10 ⁻¹
350	2.98x10 ⁻³	3.40x10 ⁻³	3.61x10 ⁻³	2.30x10 ⁻³	2.41x10 ⁻³	1.67x10 ⁻³	1.36x10 ⁻³	9.41x10 ⁻⁴	9.42x10 ⁻⁴	2.77x10 ⁻³	6.75x10 ⁻²
450	2.36x10 ⁻³	2.05x10 ⁻³	1.28x10 ⁻³	1.23x10 ⁻³	1.28x10 ⁻³	8.19x10 ⁻⁴	1.07x10 ⁻³	7.67x10 ⁻⁴	3.53x10 ⁻⁴	8.21x10 ⁻⁴	4.10x10 ⁻²
600	1.16x10 ⁻³	9.82x10 ⁻⁴	8.06x10 ⁻⁴	6.80x10 ⁻⁴	5.29x10 ⁻⁴	3.27x10 ⁻⁴	2.52x10 ⁻⁴	3.02x10 ⁻⁴	4.03x10 ⁻⁴	6.29x10 ⁻⁴	2.47x10 ⁻²
850	5.93x10 ⁻⁴	4.29x10 ⁻⁴	3.47x10 ⁻⁴	2.47x10 ⁻⁴	2.80x10 ⁻⁴	1.15x10 ⁻⁴	6.58x10 ⁻⁵	1.15x10 ⁻⁴	6.59x10 ⁻⁵	1.65x10 ⁻⁴	1.19x10 ⁻²
1,200	1.57x10 ⁻⁴	1.91x10 ⁻⁴	1.13x10 ⁻⁴	5.39x10 ⁻⁵	9.32x10 ⁻⁵	6.87x10 ⁻⁵	9.31x10 ⁻⁵	4.90x10 ⁻⁵	3.43x10 ⁻⁵	8.34x10 ⁻⁵	6.03x10 ⁻³
1,700	8.11x10 ⁻⁵	5.84x10 ⁻⁴	5.50x10 ⁻⁵	4.22x10 ⁻⁵	1.30x10 ⁻⁵	2.59x10 ⁻⁵	1.62x10 ⁻⁵	1.29x10 ⁻⁵	3.25x10 ⁻⁶	1.95x10 ⁻⁵	2.93x10 ⁻³
2,500	3.85x10 ⁻⁵	2.70x10 ⁻⁵	1.16x10 ⁻⁵	7.70x10 ⁻⁶	7.70x10 ⁻⁶	5.79x10 ⁻⁶	7.72x10 ⁻⁶	7.71x10 ⁻⁶	0	7.69x10 ⁻⁶	1.41x10 ⁻³
3,500	9.56x10 ⁻⁶	1.91x10 ⁻⁶	1.91x10 ⁻⁶	1.34x10 ⁻⁵	3.82x10 ⁻⁶	3.82x10 ⁻⁶	5.74x10 ⁻⁶	0	3.82x10 ⁻⁶	0	6.54x10 ⁻⁴
4,500	5.72x10 ⁻⁶	7.63x10 ⁻⁶	0	5.72x10 ⁻⁶	1.50x10 ⁻⁶	0	0	0	0	0	4.06x10 ⁻⁴
6,000	0	9.51x10 ⁻⁷	2.85x10 ⁻⁶	1.90x10 ⁻⁶	0	0	0	0	0	0	2.30x10 ⁻⁴
6,250	3.17x10 ⁻⁶	1.90x10 ⁻⁶	0	0	1.50x10 ⁻⁶	0	0	6.34x10 ⁻⁷	0	0	1.96x10 ⁻⁴
7,750	1.26x10 ⁻⁶	6.33x10 ⁻⁷	6.32x10 ⁻⁷	0	0	0	0	0	0	1.26x10 ⁻⁶	1.13x10 ⁻⁴
9,250	6.32x10 ⁻⁷	0	6.32x10 ⁻⁷	0	0	6.32x10 ⁻⁷	0	0	0	0	5.75x10 ⁻⁵

Table 18. Charged Particle Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 10 Gev

Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	3.35×10^{-3}	2.39×10^{-2}	5.93×10^{-2}	1.17×10^{-1}	2.14×10^{-1}	2.99×10^{-1}	4.10×10^{-1}	4.91×10^{-1}	5.89×10^{-1}	6.13×10^{-1}	6.65×10^{-1}
17	2.81×10^{-3}	1.73×10^{-2}	4.14×10^{-2}	8.92×10^{-2}	1.47×10^{-1}	2.14×10^{-1}	2.87×10^{-1}	3.49×10^{-1}	4.04×10^{-1}	4.21×10^{-1}	4.57×10^{-1}
25	1.81×10^{-3}	1.17×10^{-2}	3.08×10^{-2}	6.21×10^{-2}	1.01×10^{-1}	1.44×10^{-1}	1.88×10^{-1}	2.23×10^{-1}	2.51×10^{-1}	2.57×10^{-1}	2.80×10^{-1}
35	1.35×10^{-3}	8.02×10^{-3}	2.36×10^{-2}	4.54×10^{-2}	7.28×10^{-2}	1.01×10^{-1}	1.25×10^{-1}	1.46×10^{-1}	1.60×10^{-1}	1.65×10^{-1}	1.68×10^{-1}
45	1.10×10^{-3}	7.26×10^{-3}	1.92×10^{-2}	3.48×10^{-2}	5.44×10^{-2}	7.52×10^{-2}	8.68×10^{-2}	1.12×10^{-1}	1.14×10^{-1}	1.15×10^{-1}	1.19×10^{-1}
60	6.85×10^{-4}	5.12×10^{-3}	1.34×10^{-2}	2.59×10^{-2}	3.60×10^{-2}	4.83×10^{-2}	6.35×10^{-2}	7.52×10^{-2}	7.68×10^{-2}	7.98×10^{-2}	7.26×10^{-2}
85	8.87×10^{-4}	3.37×10^{-3}	9.41×10^{-3}	1.61×10^{-2}	2.49×10^{-2}	3.29×10^{-2}	3.99×10^{-2}	4.46×10^{-2}	4.52×10^{-2}	4.67×10^{-2}	4.48×10^{-2}
120	4.25×10^{-4}	2.31×10^{-3}	6.24×10^{-3}	1.05×10^{-2}	1.69×10^{-2}	2.20×10^{-2}	2.35×10^{-2}	2.82×10^{-2}	2.58×10^{-2}	2.53×10^{-2}	2.44×10^{-2}
170	2.20×10^{-4}	1.62×10^{-3}	4.40×10^{-3}	7.20×10^{-3}	1.05×10^{-2}	1.27×10^{-2}	1.53×10^{-2}	1.49×10^{-2}	1.43×10^{-2}	1.34×10^{-2}	1.31×10^{-2}
250	2.54×10^{-4}	1.19×10^{-3}	2.61×10^{-3}	4.54×10^{-3}	6.81×10^{-3}	7.40×10^{-3}	7.57×10^{-3}	7.23×10^{-3}	7.60×10^{-3}	7.15×10^{-3}	6.42×10^{-3}
350	1.72×10^{-4}	8.61×10^{-4}	1.89×10^{-3}	3.31×10^{-3}	3.71×10^{-3}	4.23×10^{-3}	4.19×10^{-3}	4.07×10^{-3}	4.10×10^{-3}	3.81×10^{-3}	3.20×10^{-3}
450	1.01×10^{-4}	6.78×10^{-4}	1.50×10^{-3}	2.28×10^{-3}	2.81×10^{-3}	2.97×10^{-3}	2.66×10^{-3}	2.70×10^{-3}	2.53×10^{-3}	2.01×10^{-3}	1.89×10^{-3}
600	1.23×10^{-4}	4.15×10^{-4}	9.90×10^{-4}	1.34×10^{-3}	1.49×10^{-3}	1.62×10^{-3}	1.71×10^{-3}	1.59×10^{-3}	1.47×10^{-3}	1.24×10^{-3}	1.01×10^{-3}
850	6.29×10^{-5}	3.67×10^{-4}	6.04×10^{-4}	8.06×10^{-4}	9.97×10^{-4}	9.87×10^{-4}	9.48×10^{-4}	8.14×10^{-4}	6.41×10^{-4}	5.19×10^{-4}	4.34×10^{-4}
1,200	5.29×10^{-5}	2.37×10^{-4}	3.82×10^{-4}	5.24×10^{-4}	5.84×10^{-4}	5.26×10^{-4}	4.65×10^{-4}	3.72×10^{-4}	3.05×10^{-4}	2.11×10^{-4}	1.74×10^{-4}
1,700	3.75×10^{-5}	1.63×10^{-4}	2.74×10^{-4}	3.20×10^{-4}	2.87×10^{-4}	2.81×10^{-4}	2.15×10^{-4}	1.45×10^{-4}	1.08×10^{-4}	7.47×10^{-5}	7.31×10^{-5}
2,500	3.15×10^{-5}	1.14×10^{-4}	1.55×10^{-4}	1.77×10^{-4}	1.51×10^{-4}	1.16×10^{-4}	8.25×10^{-5}	5.65×10^{-5}	3.81×10^{-5}	2.65×10^{-5}	2.60×10^{-5}
3,500	3.27×10^{-5}	8.53×10^{-5}	1.12×10^{-4}	1.02×10^{-4}	6.05×10^{-5}	4.61×10^{-5}	3.24×10^{-5}	2.38×10^{-5}	1.61×10^{-5}	1.43×10^{-5}	9.55×10^{-6}
4,500	3.27×10^{-5}	7.44×10^{-5}	7.57×10^{-5}	4.88×10^{-5}	3.42×10^{-5}	2.33×10^{-5}	1.53×10^{-5}	1.10×10^{-5}	5.24×10^{-6}	2.82×10^{-6}	3.63×10^{-6}
6,250	3.59×10^{-5}	7.12×10^{-5}	5.26×10^{-5}	2.97×10^{-5}	1.08×10^{-5}	5.47×10^{-6}	2.91×10^{-6}	1.79×10^{-6}	9.86×10^{-7}	8.51×10^{-7}	8.07×10^{-7}
7,750	5.62×10^{-5}	6.90×10^{-5}	3.41×10^{-5}	1.20×10^{-5}	3.23×10^{-6}	9.41×10^{-7}	3.14×10^{-7}	3.58×10^{-7}	3.58×10^{-7}	6.27×10^{-7}	8.96×10^{-8}
9,250	2.89×10^{-4}	8.20×10^{-5}	1.55×10^{-5}	3.36×10^{-6}	9.86×10^{-7}	3.95×10^{-8}	1.79×10^{-7}	4.48×10^{-8}	8.96×10^{-8}	4.48×10^{-8}	0

Table 18 (continued)

	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
Energy (Mev)	Depth Interval (Radiation Lengths)										Totals
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	6.76x10 ⁻¹	6.58x10 ⁻¹	6.30x10 ⁻¹	5.99x10 ⁻¹	5.64x10 ⁻¹	5.02x10 ⁻¹	4.58x10 ⁻¹	4.15x10 ⁻¹	3.81x10 ⁻¹	2.16	1.05x10 ¹
17	4.51x10 ⁻¹	4.22x10 ⁻¹	3.95x10 ⁻¹	3.97x10 ⁻¹	3.54x10 ⁻¹	3.20x10 ⁻¹	2.88x10 ⁻¹	2.58x10 ⁻¹	2.12x10 ⁻¹	1.23	6.76
25	2.76x10 ⁻¹	2.59x10 ⁻¹	2.42x10 ⁻¹	2.30x10 ⁻¹	2.09x10 ⁻¹	1.84x10 ⁻¹	1.59x10 ⁻¹	1.42x10 ⁻¹	1.20x10 ⁻¹	6.13x10 ⁻¹	3.98
35	1.60x10 ⁻¹	1.56x10 ⁻¹	1.55x10 ⁻¹	1.33x10 ⁻¹	1.18x10 ⁻¹	1.08x10 ⁻¹	9.51x10 ⁻²	7.60x10 ⁻²	6.66x10 ⁻²	3.16x10 ⁻¹	2.40
45	1.04x10 ⁻¹	1.08x10 ⁻¹	9.86x10 ⁻²	9.33x10 ⁻²	7.89x10 ⁻²	6.34x10 ⁻²	6.11x10 ⁻²	4.99x10 ⁻²	4.24x10 ⁻²	1.95x10 ⁻¹	1.63
60	7.12x10 ⁻²	7.23x10 ⁻²	6.30x10 ⁻²	5.72x10 ⁻²	4.69x10 ⁻²	4.11x10 ⁻²	3.50x10 ⁻²	2.91x10 ⁻²	2.38x10 ⁻²	1.05x10 ⁻¹	1.04
85	4.30x10 ⁻²	3.83x10 ⁻²	3.47x10 ⁻²	2.78x10 ⁻²	2.39x10 ⁻²	2.05x10 ⁻²	1.75x10 ⁻²	1.52x10 ⁻²	1.27x10 ⁻²	4.87x10 ⁻²	5.91x10 ⁻¹
120	2.23x10 ⁻²	2.13x10 ⁻²	1.72x10 ⁻²	1.36x10 ⁻²	1.22x10 ⁻²	1.06x10 ⁻²	8.30x10 ⁻³	6.38x10 ⁻³	6.26x10 ⁻³	2.18x10 ⁻²	3.26x10 ⁻¹
170	1.13x10 ⁻²	9.09x10 ⁻³	7.95x10 ⁻³	6.96x10 ⁻³	6.01x10 ⁻³	4.66x10 ⁻³	3.87x10 ⁻³	3.45x10 ⁻³	3.22x10 ⁻³	9.55x10 ⁻³	1.74x10 ⁻¹
250	5.42x10 ⁻³	4.39x10 ⁻³	3.83x10 ⁻³	2.99x10 ⁻³	2.40x10 ⁻³	2.06x10 ⁻³	1.76x10 ⁻³	1.47x10 ⁻³	1.05x10 ⁻³	3.68x10 ⁻³	8.78x10 ⁻²
350	2.94x10 ⁻³	2.31x10 ⁻³	1.72x10 ⁻³	1.36x10 ⁻³	1.33x10 ⁻³	1.02x10 ⁻³	8.65x10 ⁻⁴	5.67x10 ⁻⁴	4.39x10 ⁻⁴	1.52x10 ⁻³	4.76x10 ⁻²
450	1.71x10 ⁻³	1.30x10 ⁻³	8.91x10 ⁻⁴	7.69x10 ⁻⁴	5.67x10 ⁻⁴	3.58x10 ⁻⁴	3.10x10 ⁻⁴	3.41x10 ⁻⁴	1.89x10 ⁻⁴	6.11x10 ⁻⁴	2.92x10 ⁻²
600	7.55x10 ⁻⁴	5.92x10 ⁻⁴	4.55x10 ⁻⁴	3.34x10 ⁻⁴	2.70x10 ⁻⁴	2.28x10 ⁻⁴	2.04x10 ⁻⁴	1.28x10 ⁻⁴	8.63x10 ⁻⁵	2.97x10 ⁻⁴	1.63x10 ⁻²
850	3.15x10 ⁻⁴	2.45x10 ⁻⁴	1.98x10 ⁻⁴	1.27x10 ⁻⁴	1.52x10 ⁻⁴	1.13x10 ⁻⁴	6.29x10 ⁻⁵	4.04x10 ⁻⁵	2.92x10 ⁻⁵	1.16x10 ⁻⁴	8.58x10 ⁻³
1,200	1.41x10 ⁻⁴	1.19x10 ⁻⁴	6.97x10 ⁻⁵	5.18x10 ⁻⁵	3.91x10 ⁻⁵	2.63x10 ⁻⁵	1.92x10 ⁻⁵	1.01x10 ⁻⁵	1.23x10 ⁻⁵	2.76x10 ⁻⁵	4.35x10 ⁻³
1,700	5.09x10 ⁻⁵	3.68x10 ⁻⁵	2.69x10 ⁻⁵	2.09x10 ⁻⁵	7.85x10 ⁻⁶	6.06x10 ⁻⁶	6.50x10 ⁻⁶	6.28x10 ⁻⁶	2.92x10 ⁻⁶	7.63x10 ⁻⁶	2.15x10 ⁻³
2,500	2.10x10 ⁻⁵	1.15x10 ⁻⁵	6.86x10 ⁻⁶	3.36x10 ⁻⁶	4.30x10 ⁻⁶	2.02x10 ⁻⁶	2.15x10 ⁻⁶	5.38x10 ⁻⁷	1.21x10 ⁻⁶	1.61x10 ⁻⁶	1.03x10 ⁻³
3,500	5.11x10 ⁻⁵	3.09x10 ⁻⁶	4.17x10 ⁻⁶	2.15x10 ⁻⁶	5.38x10 ⁻⁷	1.35x10 ⁻⁷	4.03x10 ⁻⁷	0	1.35x10 ⁻⁷	0	5.49x10 ⁻⁴
4,500	2.96x10 ⁻⁶	2.02x10 ⁻⁶	1.08x10 ⁻⁶	4.03x10 ⁻⁷	4.03x10 ⁻⁷	2.69x10 ⁻⁷	4.03x10 ⁻⁷	0	0	0	3.35x10 ⁻⁴
6,250	1.79x10 ⁻⁷	3.58x10 ⁻⁷	3.58x10 ⁻⁷	3.58x10 ⁻⁷	8.96x10 ⁻⁸	0	1.34x10 ⁻⁷	0	0	4.48x10 ⁻⁷	2.15x10 ⁻⁴
7,750	4.48x10 ⁻⁸	0	0	0	0	0	0	0	0	1.34x10 ⁻⁷	1.77x10 ⁻⁴
9,250	0	0	0	0	0	0	0	0	0	0	3.92x10 ⁻⁴

Table 19. Photon Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 20 GeV

Radiation Length: 1.432 cm

Energy (MeV)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/MeV)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.73×10^{-2}	9.33×10^{-2}	2.98×10^{-1}	4.96×10^{-1}	9.47×10^{-1}	1.39	2.05	2.73	3.39	3.62	4.25
17	1.16×10^{-2}	7.08×10^{-2}	1.69×10^{-1}	2.80×10^{-1}	5.52×10^{-1}	8.87×10^{-1}	1.23	1.54	1.99	2.23	2.53
25	1.21×10^{-2}	3.39×10^{-2}	1.20×10^{-1}	2.12×10^{-1}	3.49×10^{-1}	5.43×10^{-1}	7.61×10^{-1}	8.65×10^{-1}	1.10	1.25	1.30
35	6.03×10^{-3}	3.01×10^{-2}	6.09×10^{-2}	1.34×10^{-1}	2.40×10^{-1}	3.19×10^{-1}	3.90×10^{-1}	5.31×10^{-1}	5.81×10^{-1}	7.25×10^{-1}	7.25×10^{-1}
45	5.01×10^{-3}	2.27×10^{-2}	4.55×10^{-2}	1.02×10^{-1}	1.66×10^{-1}	2.41×10^{-1}	3.02×10^{-1}	3.73×10^{-1}	3.86×10^{-1}	4.56×10^{-1}	4.91×10^{-1}
60	4.36×10^{-3}	1.40×10^{-2}	3.55×10^{-2}	6.26×10^{-2}	9.73×10^{-2}	1.51×10^{-1}	1.81×10^{-1}	2.33×10^{-1}	2.57×10^{-1}	2.70×10^{-1}	2.96×10^{-1}
85	2.09×10^{-3}	1.13×10^{-2}	2.46×10^{-2}	4.15×10^{-2}	6.21×10^{-2}	8.46×10^{-2}	1.06×10^{-1}	1.31×10^{-1}	1.30×10^{-1}	1.52×10^{-1}	1.64×10^{-1}
120	2.65×10^{-3}	5.73×10^{-2}	1.47×10^{-2}	2.41×10^{-2}	3.69×10^{-2}	4.78×10^{-2}	5.66×10^{-2}	6.88×10^{-2}	7.65×10^{-2}	8.02×10^{-2}	8.28×10^{-2}
170	1.22×10^{-3}	5.64×10^{-3}	9.46×10^{-3}	1.70×10^{-2}	2.20×10^{-2}	2.87×10^{-2}	3.50×10^{-2}	4.16×10^{-2}	4.10×10^{-2}	4.32×10^{-2}	4.29×10^{-2}
250	1.08×10^{-3}	2.37×10^{-3}	5.38×10^{-3}	9.60×10^{-3}	1.24×10^{-2}	1.66×10^{-2}	1.83×10^{-2}	1.91×10^{-2}	2.10×10^{-2}	2.04×10^{-2}	1.78×10^{-2}
350	6.29×10^{-4}	2.24×10^{-3}	3.98×10^{-3}	6.49×10^{-3}	8.16×10^{-3}	9.77×10^{-3}	9.84×10^{-3}	9.41×10^{-3}	1.05×10^{-2}	1.08×10^{-2}	1.08×10^{-2}
450	3.59×10^{-4}	1.74×10^{-3}	2.71×10^{-3}	4.61×10^{-3}	5.07×10^{-3}	6.19×10^{-3}	5.99×10^{-3}	5.27×10^{-3}	7.07×10^{-3}	6.15×10^{-3}	5.68×10^{-3}
600	2.01×10^{-4}	1.23×10^{-3}	2.06×10^{-3}	2.74×10^{-3}	3.37×10^{-3}	3.76×10^{-3}	3.72×10^{-3}	4.38×10^{-3}	3.60×10^{-3}	3.80×10^{-3}	2.95×10^{-3}
850	1.81×10^{-4}	6.92×10^{-4}	1.04×10^{-3}	1.70×10^{-3}	2.05×10^{-3}	2.24×10^{-3}	2.13×10^{-3}	2.18×10^{-3}	1.78×10^{-3}	1.73×10^{-3}	1.75×10^{-3}
1,200	1.96×10^{-4}	4.41×10^{-4}	8.21×10^{-4}	8.83×10^{-4}	7.48×10^{-4}	1.08×10^{-3}	1.18×10^{-3}	9.19×10^{-4}	8.34×10^{-4}	8.70×10^{-4}	6.62×10^{-4}
1,700	2.03×10^{-4}	3.49×10^{-4}	4.87×10^{-4}	4.46×10^{-4}	5.68×10^{-4}	6.65×10^{-4}	5.11×10^{-4}	5.43×10^{-4}	3.73×10^{-4}	4.14×10^{-4}	3.73×10^{-4}
2,500	5.78×10^{-5}	1.97×10^{-4}	2.65×10^{-4}	2.36×10^{-4}	2.41×10^{-4}	3.52×10^{-4}	2.50×10^{-4}	2.60×10^{-4}	2.36×10^{-4}	1.49×10^{-4}	1.30×10^{-4}
3,500	2.87×10^{-5}	1.00×10^{-4}	1.43×10^{-4}	1.58×10^{-4}	1.39×10^{-4}	1.39×10^{-4}	1.10×10^{-4}	9.08×10^{-5}	8.13×10^{-5}	7.65×10^{-5}	3.83×10^{-5}
4,500	5.24×10^{-5}	9.53×10^{-5}	6.67×10^{-5}	7.63×10^{-5}	1.33×10^{-4}	9.05×10^{-5}	7.15×10^{-5}	5.24×10^{-5}	3.81×10^{-5}	4.77×10^{-5}	3.81×10^{-5}
6,000	1.67×10^{-5}	4.04×10^{-5}	5.46×10^{-5}	6.66×10^{-5}	4.52×10^{-5}	5.47×10^{-5}	4.04×10^{-5}	2.38×10^{-5}	1.90×10^{-5}	1.66×10^{-5}	1.43×10^{-5}
8,500	9.39×10^{-6}	2.50×10^{-5}	4.22×10^{-5}	4.22×10^{-5}	2.66×10^{-5}	2.66×10^{-5}	1.25×10^{-5}	1.25×10^{-5}	3.13×10^{-6}	1.09×10^{-5}	4.70×10^{-6}
12,500	9.15×10^{-6}	1.86×10^{-5}	1.48×10^{-5}	1.32×10^{-5}	1.23×10^{-5}	6.93×10^{-6}	6.93×10^{-6}	3.78×10^{-6}	3.78×10^{-6}	1.26×10^{-6}	2.21×10^{-6}
15,500	8.81×10^{-6}	1.53×10^{-5}	9.44×10^{-6}	9.76×10^{-6}	7.24×10^{-6}	3.15×10^{-6}	2.20×10^{-6}	1.89×10^{-6}	1.57×10^{-6}	6.30×10^{-7}	0
18,500	5.66×10^{-6}	9.75×10^{-6}	4.41×10^{-6}	2.52×10^{-6}	3.46×10^{-6}	3.78×10^{-6}	9.44×10^{-7}	1.26×10^{-6}	3.15×10^{-7}	0	0

Table 19 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	4.59	4.85	5.15	5.67	5.09	5.15	4.97	4.85	4.37	3.80x10 ¹	1.02x10 ²
17	2.75	2.82	3.03	2.91	2.79	2.75	2.67	2.54	2.31	1.84x10 ¹	5.45x10 ¹
25	1.43	1.44	1.52	1.51	1.44	1.32	1.29	1.17	1.09	8.20	2.69x10 ¹
35	8.44x10 ⁻¹	8.43x10 ⁻¹	7.32x10 ⁻¹	8.06x10 ⁻¹	7.81x10 ⁻¹	7.17x10 ⁻¹	6.51x10 ⁻¹	5.90x10 ⁻¹	5.55x10 ⁻¹	3.74	1.41x10 ¹
45	4.86x10 ⁻¹	5.03x10 ⁻¹	5.19x10 ⁻¹	4.62x10 ⁻¹	4.40x10 ⁻¹	4.29x10 ⁻¹	3.82x10 ⁻¹	3.59x10 ⁻¹	3.03x10 ⁻¹	2.03	8.50
60	3.14x10 ⁻¹	2.97x10 ⁻¹	2.87x10 ⁻¹	2.72x10 ⁻¹	2.52x10 ⁻¹	2.32x10 ⁻¹	2.15x10 ⁻¹	1.89x10 ⁻¹	1.74x10 ⁻¹	1.00	4.83
85	1.58x10 ⁻¹	1.58x10 ⁻¹	1.45x10 ⁻¹	1.37x10 ⁻¹	1.27x10 ⁻¹	1.06x10 ⁻¹	9.97x10 ⁻²	9.18x10 ⁻²	7.55x10 ⁻²	4.30x10 ⁻¹	2.44
120	7.46x10 ⁻²	7.65x10 ⁻²	7.34x10 ⁻²	6.38x10 ⁻²	5.67x10 ⁻²	5.41x10 ⁻²	4.81x10 ⁻²	3.81x10 ⁻²	3.54x10 ⁻²	1.76x10 ⁻¹	1.19
170	3.89x10 ⁻²	3.84x10 ⁻²	3.29x10 ⁻²	3.15x10 ⁻²	2.65x10 ⁻²	2.42x10 ⁻²	2.16x10 ⁻²	1.85x10 ⁻²	1.31x10 ⁻²	7.42x10 ⁻²	6.08x10 ⁻¹
250	1.89x10 ⁻²	1.72x10 ⁻²	1.60x10 ⁻²	1.34x10 ⁻²	1.18x10 ⁻²	1.18x10 ⁻²	8.74x10 ⁻³	7.07x10 ⁻³	6.16x10 ⁻³	2.45x10 ⁻²	2.80x10 ⁻¹
350	8.00x10 ⁻³	8.68x10 ⁻³	6.12x10 ⁻³	6.02x10 ⁻³	4.98x10 ⁻³	4.34x10 ⁻³	3.66x10 ⁻³	2.51x10 ⁻³	2.67x10 ⁻³	1.04x10 ⁻²	1.40x10 ⁻¹
450	5.88x10 ⁻³	4.91x10 ⁻³	4.00x10 ⁻³	4.10x10 ⁻³	2.77x10 ⁻³	2.66x10 ⁻³	2.30x10 ⁻³	1.48x10 ⁻³	1.64x10 ⁻³	4.97x10 ⁻³	8.56x10 ⁻²
600	3.17x10 ⁻³	2.64x10 ⁻³	1.74x10 ⁻³	1.61x10 ⁻³	1.24x10 ⁻³	1.11x10 ⁻³	9.06x10 ⁻⁴	6.04x10 ⁻⁴	5.79x10 ⁻⁴	2.31x10 ⁻³	4.77x10 ⁻²
850	1.30x10 ⁻³	1.06x10 ⁻³	1.01x10 ⁻³	4.46x10 ⁻⁴	5.93x10 ⁻⁴	4.46x10 ⁻⁴	5.60x10 ⁻⁴	2.64x10 ⁻⁴	3.30x10 ⁻⁴	1.07x10 ⁻³	2.45x10 ⁻²
1,200	7.11x10 ⁻⁴	4.78x10 ⁻⁴	3.68x10 ⁻⁴	3.43x10 ⁻⁴	2.08x10 ⁻⁴	1.96x10 ⁻⁴	2.57x10 ⁻⁴	8.58x10 ⁻⁵	9.81x10 ⁻⁵	4.17x10 ⁻⁴	1.18x10 ⁻²
1,700	2.68x10 ⁻⁴	1.95x10 ⁻⁴	2.68x10 ⁻⁴	1.62x10 ⁻⁴	1.05x10 ⁻⁴	2.43x10 ⁻⁵	6.49x10 ⁻⁵	6.49x10 ⁻⁵	6.49x10 ⁻⁵	1.22x10 ⁻⁴	6.27x10 ⁻³
2,500	1.11x10 ⁻⁴	1.01x10 ⁻⁴	4.82x10 ⁻⁵	7.23x10 ⁻⁵	5.78x10 ⁻⁵	4.33x10 ⁻⁵	1.92x10 ⁻⁵	9.61x10 ⁻⁶	1.44x10 ⁻⁵	5.77x10 ⁻⁵	2.91x10 ⁻³
3,500	2.39x10 ⁻⁵	5.26x10 ⁻⁵	4.78x10 ⁻⁶	2.39x10 ⁻⁵	9.57x10 ⁻⁶	1.44x10 ⁻⁵	4.78x10 ⁻⁶	9.56x10 ⁻⁶	0	1.43x10 ⁻⁵	1.27x10 ⁻³
4,500	2.38x10 ⁻⁵	2.38x10 ⁻⁵	0	9.53x10 ⁻⁶	1.91x10 ⁻⁵	9.53x10 ⁻⁶	4.77x10 ⁻⁶	0	0	9.53x10 ⁻⁶	8.63x10 ⁻⁴
6,000	4.75x10 ⁻⁶	1.19x10 ⁻⁵	9.51x10 ⁻⁶	4.75x10 ⁻⁶	2.38x10 ⁻⁶	2.38x10 ⁻⁶	2.38x10 ⁻⁶	0	2.38x10 ⁻⁶	2.37x10 ⁻⁶	4.35x10 ⁻⁴
8,500	0	3.13x10 ⁻⁶	1.56x10 ⁻⁶	1.56x10 ⁻⁶	1.56x10 ⁻⁶	0	0	0	0	0	2.24x10 ⁻⁴
12,500	6.30x10 ⁻⁷	0	9.45x10 ⁻⁷	6.30x10 ⁻⁷	3.15x10 ⁻⁷	0	0	0	0	0	9.55x10 ⁻⁵
15,500	0	0	6.30x10 ⁻⁷	0	3.15x10 ⁻⁷	0	3.15x10 ⁻⁷	0	0	0	6.14x10 ⁻⁵
18,500	3.15x10 ⁻⁷	6.29x10 ⁻⁷	0	0	0	0	3.15x10 ⁻⁷	0	0	6.29x10 ⁻⁷	3.40x10 ⁻⁵

Table 20. Charged Particle Track Length for Electron-Initiated Showers in Copper
Electron Source Energy: 20 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	1.76×10^{-3}	1.78×10^{-2}	7.09×10^{-2}	1.59×10^{-1}	2.74×10^{-1}	4.35×10^{-1}	6.38×10^{-1}	8.11×10^{-1}	9.43×10^{-1}	1.08	1.18
17	1.99×10^{-3}	1.59×10^{-2}	5.34×10^{-2}	1.16×10^{-1}	2.01×10^{-1}	3.21×10^{-1}	4.65×10^{-1}	5.45×10^{-1}	6.55×10^{-1}	7.34×10^{-1}	7.96×10^{-1}
25	6.61×10^{-4}	1.26×10^{-2}	3.73×10^{-2}	8.20×10^{-2}	1.43×10^{-1}	2.23×10^{-1}	2.96×10^{-1}	3.65×10^{-1}	4.18×10^{-1}	4.64×10^{-1}	5.01×10^{-1}
35	1.21×10^{-3}	9.60×10^{-3}	3.01×10^{-2}	5.50×10^{-2}	1.02×10^{-1}	1.45×10^{-1}	1.99×10^{-1}	2.40×10^{-1}	2.71×10^{-1}	3.03×10^{-1}	3.16×10^{-1}
45	1.17×10^{-3}	8.67×10^{-3}	1.95×10^{-2}	4.64×10^{-2}	7.20×10^{-2}	1.12×10^{-1}	1.47×10^{-1}	1.76×10^{-1}	2.02×10^{-1}	2.13×10^{-1}	2.20×10^{-1}
60	8.56×10^{-4}	6.20×10^{-3}	1.74×10^{-2}	3.37×10^{-2}	5.42×10^{-2}	7.92×10^{-2}	9.69×10^{-2}	1.17×10^{-1}	1.38×10^{-1}	1.41×10^{-1}	1.41×10^{-1}
85	8.30×10^{-4}	4.18×10^{-3}	1.20×10^{-2}	2.19×10^{-2}	3.69×10^{-2}	5.03×10^{-2}	6.34×10^{-2}	7.48×10^{-2}	8.18×10^{-2}	8.39×10^{-2}	8.42×10^{-2}
120	3.31×10^{-4}	3.05×10^{-3}	7.34×10^{-3}	1.49×10^{-2}	2.31×10^{-2}	3.05×10^{-2}	3.76×10^{-2}	4.49×10^{-2}	4.68×10^{-2}	4.88×10^{-2}	4.94×10^{-2}
170	5.03×10^{-4}	1.93×10^{-3}	5.32×10^{-3}	1.06×10^{-2}	1.56×10^{-2}	1.92×10^{-2}	2.42×10^{-2}	2.65×10^{-2}	2.76×10^{-2}	2.72×10^{-2}	2.68×10^{-2}
250	2.03×10^{-4}	1.34×10^{-3}	3.63×10^{-3}	6.48×10^{-3}	9.10×10^{-3}	1.19×10^{-2}	1.30×10^{-2}	1.35×10^{-2}	1.45×10^{-2}	1.47×10^{-2}	1.40×10^{-2}
350	1.32×10^{-4}	9.79×10^{-4}	2.30×10^{-3}	3.74×10^{-3}	5.59×10^{-3}	6.97×10^{-3}	7.44×10^{-3}	8.13×10^{-3}	7.87×10^{-3}	7.53×10^{-3}	6.81×10^{-3}
450	1.05×10^{-4}	5.67×10^{-4}	1.68×10^{-3}	2.77×10^{-3}	4.25×10^{-3}	4.79×10^{-3}	5.25×10^{-3}	5.20×10^{-3}	4.94×10^{-3}	4.57×10^{-3}	3.92×10^{-3}
600	6.91×10^{-5}	5.68×10^{-4}	1.31×10^{-3}	1.80×10^{-3}	2.42×10^{-3}	2.89×10^{-3}	3.16×10^{-3}	2.92×10^{-3}	3.07×10^{-3}	2.70×10^{-3}	2.22×10^{-3}
850	5.72×10^{-5}	3.50×10^{-4}	7.51×10^{-4}	1.12×10^{-3}	1.46×10^{-3}	1.59×10^{-3}	1.64×10^{-3}	1.71×10^{-3}	1.60×10^{-3}	1.43×10^{-3}	1.01×10^{-3}
1,200	6.90×10^{-5}	2.09×10^{-4}	4.28×10^{-4}	7.19×10^{-4}	8.31×10^{-4}	8.44×10^{-4}	9.48×10^{-4}	8.12×10^{-4}	6.67×10^{-4}	5.84×10^{-4}	3.96×10^{-4}
1,700	4.04×10^{-5}	1.51×10^{-4}	3.27×10^{-4}	4.18×10^{-4}	4.59×10^{-4}	5.14×10^{-4}	4.63×10^{-4}	4.01×10^{-4}	3.34×10^{-4}	2.47×10^{-4}	2.04×10^{-4}
2,500	1.92×10^{-5}	1.02×10^{-4}	1.83×10^{-4}	2.26×10^{-4}	2.32×10^{-4}	2.55×10^{-4}	1.94×10^{-4}	1.50×10^{-4}	1.26×10^{-4}	8.54×10^{-5}	9.01×10^{-5}
3,500	2.08×10^{-5}	7.83×10^{-5}	1.36×10^{-4}	1.35×10^{-4}	1.62×10^{-4}	1.16×10^{-4}	8.27×10^{-5}	7.06×10^{-5}	4.74×10^{-5}	5.04×10^{-5}	3.36×10^{-5}
4,500	1.85×10^{-5}	4.57×10^{-5}	9.04×10^{-5}	9.55×10^{-5}	9.28×10^{-5}	7.40×10^{-5}	5.68×10^{-5}	4.27×10^{-5}	2.76×10^{-5}	2.45×10^{-5}	1.38×10^{-5}
6,000	1.31×10^{-5}	4.32×10^{-5}	6.25×10^{-5}	6.17×10^{-5}	4.18×10^{-5}	3.48×10^{-5}	2.69×10^{-5}	1.63×10^{-5}	1.28×10^{-5}	8.57×10^{-6}	7.06×10^{-6}
8,500	1.10×10^{-5}	4.02×10^{-5}	4.78×10^{-5}	3.67×10^{-5}	2.29×10^{-5}	1.41×10^{-5}	7.51×10^{-6}	7.06×10^{-6}	2.58×10^{-6}	2.69×10^{-6}	2.69×10^{-6}
12,500	1.90×10^{-5}	3.16×10^{-5}	2.46×10^{-5}	1.18×10^{-5}	5.89×10^{-6}	3.72×10^{-6}	1.84×10^{-6}	1.12×10^{-6}	4.26×10^{-7}	4.48×10^{-7}	1.34×10^{-7}
15,500	2.93×10^{-5}	3.27×10^{-5}	1.55×10^{-5}	6.38×10^{-6}	2.33×10^{-6}	1.01×10^{-6}	6.05×10^{-7}	2.24×10^{-7}	1.12×10^{-7}	8.96×10^{-8}	0
18,500	1.43×10^{-4}	3.56×10^{-5}	8.20×10^{-6}	1.66×10^{-6}	1.34×10^{-7}	2.69×10^{-7}	1.34×10^{-7}	0	0	8.96×10^{-8}	0

Table 20 (continued)

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										Totals
	Depth Interval (Radiation Lengths)										
	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	
12	1.23	1.28	1.29	1.23	1.19	1.09	1.01	8.92x10 ⁻¹	8.11x10 ⁻¹	5.44	2.11x10 ¹
17	8.36x10 ⁻¹	8.42x10 ⁻¹	8.20x10 ⁻¹	7.91x10 ⁻¹	7.45x10 ⁻¹	6.75x10 ⁻¹	6.39x10 ⁻¹	5.70x10 ⁻¹	5.03x10 ⁻¹	3.14	1.35x10 ¹
25	5.21x10 ⁻¹	5.22x10 ⁻¹	4.93x10 ⁻¹	4.64x10 ⁻¹	4.45x10 ⁻¹	4.01x10 ⁻¹	3.64x10 ⁻¹	3.20x10 ⁻¹	2.81x10 ⁻¹	1.65	8.00
35	3.25x10 ⁻¹	3.17x10 ⁻¹	2.99x10 ⁻¹	2.85x10 ⁻¹	2.65x10 ⁻¹	2.36x10 ⁻¹	2.05x10 ⁻¹	1.78x10 ⁻¹	1.55x10 ⁻¹	8.66x10 ⁻¹	4.80
45	2.22x10 ⁻¹	2.16x10 ⁻¹	2.03x10 ⁻¹	1.97x10 ⁻¹	1.73x10 ⁻¹	1.47x10 ⁻¹	1.38x10 ⁻¹	1.17x10 ⁻¹	1.02x10 ⁻¹	5.34x10 ⁻¹	3.27
60	1.46x10 ⁻¹	1.39x10 ⁻¹	1.34x10 ⁻¹	1.18x10 ⁻¹	1.09x10 ⁻¹	9.49x10 ⁻²	8.22x10 ⁻²	6.91x10 ⁻²	6.03x10 ⁻²	3.05x10 ⁻¹	2.08
85	8.29x10 ⁻²	8.03x10 ⁻²	7.44x10 ⁻²	6.44x10 ⁻²	5.58x10 ⁻²	5.05x10 ⁻²	4.22x10 ⁻²	3.56x10 ⁻²	3.01x10 ⁻²	1.49x10 ⁻¹	1.18
120	4.59x10 ⁻²	4.40x10 ⁻²	3.96x10 ⁻²	3.38x10 ⁻²	2.78x10 ⁻²	2.64x10 ⁻²	2.11x10 ⁻²	1.77x10 ⁻²	1.47x10 ⁻²	6.57x10 ⁻²	6.43x10 ⁻¹
170	2.46x10 ⁻²	2.26x10 ⁻²	2.07x10 ⁻²	1.75x10 ⁻²	1.53x10 ⁻²	1.19x10 ⁻²	1.00x10 ⁻²	8.82x10 ⁻³	6.37x10 ⁻³	3.19x10 ⁻²	3.55x10 ⁻¹
250	1.26x10 ⁻²	1.10x10 ⁻²	9.45x10 ⁻³	7.58x10 ⁻³	6.16x10 ⁻³	5.66x10 ⁻³	4.61x10 ⁻³	3.75x10 ⁻³	3.02x10 ⁻³	1.27x10 ⁻²	1.79x10 ⁻¹
350	6.35x10 ⁻³	5.35x10 ⁻³	4.53x10 ⁻³	3.55x10 ⁻³	2.94x10 ⁻³	2.49x10 ⁻³	1.96x10 ⁻³	1.77x10 ⁻³	1.52x10 ⁻³	4.98x10 ⁻³	9.29x10 ⁻²
450	3.61x10 ⁻³	3.14x10 ⁻³	2.53x10 ⁻³	2.00x10 ⁻³	1.51x10 ⁻³	1.31x10 ⁻³	1.13x10 ⁻³	9.35x10 ⁻⁴	7.22x10 ⁻⁴	2.44x10 ⁻³	5.74x10 ⁻²
600	2.01x10 ⁻³	1.53x10 ⁻³	1.12x10 ⁻³	8.73x10 ⁻⁴	7.84x10 ⁻⁴	5.55x10 ⁻⁴	5.75x10 ⁻⁴	4.89x10 ⁻⁴	4.11x10 ⁻⁴	1.38x10 ⁻³	3.29x10 ⁻²
850	8.51x10 ⁻⁴	5.95x10 ⁻⁴	4.81x10 ⁻⁴	3.96x10 ⁻⁴	3.45x10 ⁻⁴	3.22x10 ⁻⁴	2.14x10 ⁻⁴	1.61x10 ⁻⁴	1.43x10 ⁻⁴	5.15x10 ⁻⁴	1.67x10 ⁻²
1,200	3.82x10 ⁻⁴	3.23x10 ⁻⁴	2.58x10 ⁻⁴	2.16x10 ⁻⁴	1.68x10 ⁻⁴	1.27x10 ⁻⁴	9.59x10 ⁻⁵	6.73x10 ⁻⁵	6.31x10 ⁻⁵	1.49x10 ⁻⁴	8.36x10 ⁻³
1,700	1.88x10 ⁻⁴	1.36x10 ⁻⁴	1.11x10 ⁻⁴	9.64x10 ⁻⁵	7.46x10 ⁻⁵	5.38x10 ⁻⁵	3.65x10 ⁻⁵	2.97x10 ⁻⁵	2.30x10 ⁻⁵	5.05x10 ⁻⁵	4.36x10 ⁻³
2,500	7.57x10 ⁻⁵	5.72x10 ⁻⁵	3.53x10 ⁻⁵	2.02x10 ⁻⁵	2.56x10 ⁻⁵	1.65x10 ⁻⁵	8.74x10 ⁻⁶	7.06x10 ⁻⁶	2.69x10 ⁻⁶	1.78x10 ⁻⁵	1.93x10 ⁻³
3,500	1.58x10 ⁻⁵	1.51x10 ⁻⁵	1.01x10 ⁻⁵	6.72x10 ⁻⁶	5.72x10 ⁻⁶	6.72x10 ⁻⁷	3.03x10 ⁻⁶	3.36x10 ⁻⁶	3.36x10 ⁻⁷	6.05x10 ⁻⁶	9.99x10 ⁻⁴
4,500	8.74x10 ⁻⁶	6.39x10 ⁻⁶	3.03x10 ⁻⁶	5.04x10 ⁻⁶	4.37x10 ⁻⁶	4.37x10 ⁻⁶	2.69x10 ⁻⁶	3.36x10 ⁻⁷	6.72x10 ⁻⁷	1.34x10 ⁻⁶	6.19x10 ⁻⁴
6,000	4.03x10 ⁻⁶	4.21x10 ⁻⁶	1.85x10 ⁻⁶	1.18x10 ⁻⁶	8.40x10 ⁻⁷	1.01x10 ⁻⁶	5.04x10 ⁻⁷	1.68x10 ⁻⁷	0	1.18x10 ⁻⁶	3.44x10 ⁻⁴
8,500	1.46x10 ⁻⁶	1.01x10 ⁻⁶	6.72x10 ⁻⁷	7.84x10 ⁻⁷	2.24x10 ⁻⁷	6.72x10 ⁻⁷	4.48x10 ⁻⁷	7.84x10 ⁻⁷	1.48x10 ⁻⁷	1.12x10 ⁻⁷	2.02x10 ⁻⁴
12,500	0	4.48x10 ⁻⁸	0	1.57x10 ⁻⁷	1.12x10 ⁻⁷	1.57x10 ⁻⁷	6.72x10 ⁻⁸	0	0	4.48x10 ⁻⁸	1.01x10 ⁻⁴
15,500	0	6.72x10 ⁻⁸	2.24x10 ⁻⁸	0	0	0	0	0	0	2.24x10 ⁻⁸	8.84x10 ⁻⁵
18,500	0	0	0	0	0	0	0	0	0	0	1.89x10 ⁻⁶

Table 21. Photon Track Length for Electron-Initiated Showers in Copper
 Electron Source Energy: 45 Gev Radiation Length: 1.432 cm

Energy (Mev)	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.05×10^{-2}	9.55×10^{-2}	2.73×10^{-1}	6.05×10^{-1}	1.11	1.87	2.56	4.03	5.37	6.46	7.41
17	1.44×10^{-2}	6.65×10^{-2}	1.85×10^{-1}	3.97×10^{-1}	7.01×10^{-1}	1.17	1.69	2.41	3.15	3.81	4.49
25	1.05×10^{-2}	4.67×10^{-2}	1.33×10^{-1}	2.40×10^{-1}	4.35×10^{-1}	7.27×10^{-1}	9.83×10^{-1}	1.49	1.77	2.09	2.47
35	1.35×10^{-2}	3.07×10^{-2}	7.96×10^{-2}	1.75×10^{-1}	2.75×10^{-1}	4.44×10^{-1}	5.99×10^{-1}	8.61×10^{-1}	1.05	1.28	1.45
45	7.10×10^{-3}	1.70×10^{-2}	4.75×10^{-2}	1.22×10^{-1}	2.12×10^{-1}	3.31×10^{-1}	4.19×10^{-1}	5.79×10^{-1}	6.93×10^{-1}	8.33×10^{-1}	8.89×10^{-1}
60	5.03×10^{-3}	1.84×10^{-2}	4.59×10^{-2}	8.41×10^{-2}	1.39×10^{-1}	2.14×10^{-1}	2.90×10^{-1}	3.67×10^{-1}	4.46×10^{-1}	5.00×10^{-1}	5.81×10^{-1}
85	2.29×10^{-3}	9.38×10^{-3}	2.91×10^{-2}	4.74×10^{-2}	8.72×10^{-2}	1.26×10^{-1}	1.64×10^{-1}	2.11×10^{-1}	2.50×10^{-1}	2.86×10^{-1}	3.04×10^{-1}
120	1.61×10^{-3}	6.77×10^{-3}	1.72×10^{-2}	3.20×10^{-2}	4.87×10^{-2}	6.89×10^{-2}	9.96×10^{-2}	1.25×10^{-1}	1.40×10^{-1}	1.68×10^{-1}	1.66×10^{-1}
170	1.97×10^{-3}	6.47×10^{-3}	1.19×10^{-2}	1.88×10^{-2}	2.99×10^{-2}	4.35×10^{-2}	5.90×10^{-2}	6.93×10^{-2}	7.51×10^{-2}	8.83×10^{-2}	9.08×10^{-2}
250	8.60×10^{-4}	3.18×10^{-3}	7.05×10^{-3}	1.22×10^{-2}	2.02×10^{-2}	2.53×10^{-2}	2.99×10^{-2}	3.97×10^{-2}	4.03×10^{-2}	4.42×10^{-2}	4.43×10^{-2}
350	6.25×10^{-4}	2.30×10^{-3}	4.33×10^{-3}	7.47×10^{-3}	1.05×10^{-2}	1.49×10^{-2}	1.69×10^{-2}	2.04×10^{-2}	2.14×10^{-2}	2.24×10^{-2}	2.15×10^{-2}
450	5.11×10^{-4}	1.28×10^{-3}	3.37×10^{-3}	5.37×10^{-3}	6.55×10^{-3}	9.98×10^{-3}	1.16×10^{-2}	1.29×10^{-2}	1.39×10^{-2}	1.45×10^{-2}	1.40×10^{-2}
600	3.61×10^{-4}	1.12×10^{-3}	2.61×10^{-3}	3.97×10^{-3}	5.64×10^{-3}	5.59×10^{-3}	6.58×10^{-3}	7.41×10^{-3}	7.94×10^{-3}	8.75×10^{-3}	8.45×10^{-3}
850	3.34×10^{-4}	7.10×10^{-4}	1.63×10^{-3}	2.26×10^{-3}	3.11×10^{-3}	3.77×10^{-3}	4.05×10^{-3}	4.32×10^{-3}	4.07×10^{-3}	4.01×10^{-3}	3.87×10^{-3}
1,200	1.55×10^{-4}	6.00×10^{-4}	8.07×10^{-4}	1.77×10^{-3}	1.82×10^{-3}	2.10×10^{-3}	2.27×10^{-3}	2.10×10^{-3}	2.16×10^{-3}	2.15×10^{-3}	1.46×10^{-3}
1,700	1.43×10^{-4}	4.10×10^{-4}	6.15×10^{-4}	8.27×10^{-4}	1.15×10^{-3}	1.16×10^{-3}	1.22×10^{-3}	1.06×10^{-3}	1.08×10^{-3}	1.03×10^{-3}	9.09×10^{-4}
2,500	8.93×10^{-5}	2.35×10^{-4}	4.02×10^{-4}	7.23×10^{-4}	5.48×10^{-4}	5.81×10^{-4}	6.34×10^{-4}	5.81×10^{-4}	4.55×10^{-4}	4.15×10^{-4}	4.83×10^{-4}
3,500	6.46×10^{-5}	1.29×10^{-4}	2.26×10^{-4}	2.58×10^{-4}	3.15×10^{-4}	3.07×10^{-4}	2.95×10^{-4}	2.10×10^{-4}	2.22×10^{-4}	2.50×10^{-4}	2.22×10^{-4}
4,500	3.62×10^{-5}	1.29×10^{-4}	1.69×10^{-4}	1.17×10^{-4}	1.73×10^{-4}	2.37×10^{-4}	1.33×10^{-4}	1.65×10^{-4}	1.77×10^{-4}	8.04×10^{-5}	8.85×10^{-5}
6,000	3.01×10^{-5}	7.42×10^{-5}	1.12×10^{-4}	1.36×10^{-4}	1.00×10^{-4}	7.82×10^{-5}	7.62×10^{-5}	1.04×10^{-4}	1.04×10^{-4}	5.01×10^{-5}	5.41×10^{-5}
8,5000	1.87×10^{-5}	5.47×10^{-5}	5.73×10^{-5}	5.87×10^{-5}	6.27×10^{-5}	5.73×10^{-5}	4.67×10^{-5}	3.87×10^{-5}	1.87×10^{-5}	2.40×10^{-5}	2.13×10^{-5}
12,000	9.99×10^{-6}	3.69×10^{-5}	3.99×10^{-5}	2.50×10^{-5}	4.49×10^{-5}	2.89×10^{-5}	2.50×10^{-5}	1.60×10^{-5}	1.80×10^{-5}	4.99×10^{-6}	4.99×10^{-6}
17,000	7.31×10^{-6}	1.46×10^{-5}	1.99×10^{-5}	2.13×10^{-5}	1.93×10^{-5}	8.64×10^{-6}	1.40×10^{-5}	9.97×10^{-6}	1.99×10^{-6}	4.65×10^{-6}	1.99×10^{-6}
25,000	3.19×10^{-6}	1.27×10^{-5}	1.08×10^{-5}	7.57×10^{-6}	5.18×10^{-6}	7.17×10^{-6}	2.79×10^{-6}	1.99×10^{-6}	1.19×10^{-6}	1.99×10^{-6}	7.97×10^{-7}
28,125	3.78×10^{-6}	7.41×10^{-6}	7.41×10^{-6}	6.71×10^{-6}	6.29×10^{-6}	3.36×10^{-6}	2.24×10^{-6}	2.38×10^{-6}	1.12×10^{-6}	6.99×10^{-7}	6.99×10^{-7}
34,875	3.50×10^{-6}	4.05×10^{-6}	7.35×10^{-6}	3.77×10^{-6}	2.80×10^{-6}	1.40×10^{-6}	1.40×10^{-6}	4.19×10^{-7}	6.99×10^{-7}	4.19×10^{-7}	0
41,625	2.52×10^{-6}	2.94×10^{-6}	4.28×10^{-6}	1.40×10^{-6}	1.54×10^{-6}	8.39×10^{-7}	5.59×10^{-7}	5.59×10^{-7}	0	1.40×10^{-7}	0

Table 21 (continued)

	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
Energy (Mev)	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	8.75	8.73	1.06x10 ¹	1.09x10 ¹	1.15x10 ¹	1.14x10 ¹	1.11x10 ¹	1.12x10 ¹	1.06x10 ¹	1.03x10 ²	2.29x10 ²
17	5.13	5.13	5.94	6.20	3.78	3.78	6.20	5.96	5.63	5.08x10 ¹	1.22x10 ²
25	2.86	2.88	3.17	3.39	3.30	3.26	3.11	3.01	2.78	2.27x10 ¹	6.10x10 ¹
35	1.57	1.64	1.69	1.75	1.71	1.75	1.65	1.49	1.38	1.04x10 ¹	3.14x10 ¹
45	1.06	1.01	1.03	1.07	1.06	9.97x10 ⁻¹	9.36x10 ⁻¹	9.27x10 ⁻¹	7.90x10 ⁻¹	5.71	1.88x10 ¹
60	6.17x10 ⁻¹	6.41x10 ⁻¹	6.48x10 ⁻¹	6.24x10 ⁻¹	6.35x10 ⁻¹	5.91x10 ⁻¹	5.35x10 ⁻¹	4.97x10 ⁻¹	4.56x10 ⁻¹	2.99	1.09x10 ¹
85	3.33x10 ⁻¹	3.34x10 ⁻¹	3.43x10 ⁻¹	3.37x10 ⁻¹	3.25x10 ⁻¹	2.92x10 ⁻¹	2.63x10 ⁻¹	2.49x10 ⁻¹	2.14x10 ⁻¹	1.32	5.54
120	1.73x10 ⁻¹	1.70x10 ⁻¹	1.68x10 ⁻¹	1.69x10 ⁻¹	1.49x10 ⁻¹	1.32x10 ⁻¹	1.22x10 ⁻¹	1.10x10 ⁻¹	9.69x10 ⁻²	5.48x10 ⁻¹	2.72
170	9.52x10 ⁻²	8.22x10 ⁻²	8.85x10 ⁻²	8.17x10 ⁻²	7.07x10 ⁻²	6.49x10 ⁻²	5.80x10 ⁻²	5.09x10 ⁻²	4.51x10 ⁻²	2.25x10 ⁻¹	1.36
250	4.24x10 ⁻²	4.32x10 ⁻²	3.82x10 ⁻²	3.51x10 ⁻²	3.25x10 ⁻²	2.80x10 ⁻²	2.63x10 ⁻²	2.23x10 ⁻²	1.92x10 ⁻²	8.87x10 ⁻²	6.44x10 ⁻¹
350	1.95x10 ⁻²	2.09x10 ⁻²	1.83x10 ⁻²	1.78x10 ⁻²	1.64x10 ⁻²	1.27x10 ⁻²	1.08x10 ⁻²	8.89x10 ⁻³	8.17x10 ⁻³	3.63x10 ⁻²	3.13x10 ⁻¹
450	1.31x10 ⁻²	1.12x10 ⁻²	1.07x10 ⁻²	9.78x10 ⁻³	8.54x10 ⁻³	7.22x10 ⁻³	5.68x10 ⁻³	5.43x10 ⁻³	3.99x10 ⁻³	2.02x10 ⁻²	1.90x10 ⁻¹
600	7.39x10 ⁻³	6.24x10 ⁻³	6.26x10 ⁻³	5.10x10 ⁻³	4.48x10 ⁻³	3.27x10 ⁻³	2.91x10 ⁻³	2.57x10 ⁻³	2.17x10 ⁻³	8.94x10 ⁻³	1.09x10 ⁻¹
850	3.32x10 ⁻³	2.73x10 ⁻³	3.01x10 ⁻³	2.34x10 ⁻⁴	1.77x10 ⁻³	1.53x10 ⁻³	1.41x10 ⁻³	1.13x10 ⁻³	8.08x10 ⁻⁴	3.68x10 ⁻³	5.35x10 ⁻²
1,200	1.78x10 ⁻³	1.35x10 ⁻³	1.28x10 ⁻³	1.08x10 ⁻³	9.82x10 ⁻⁴	7.13x10 ⁻⁴	6.21x10 ⁻⁴	4.55x10 ⁻⁴	3.93x10 ⁻⁴	1.23x10 ⁻³	2.73x10 ⁻²
1,700	7.11x10 ⁻⁴	5.46x10 ⁻⁴	4.44x10 ⁻⁴	3.90x10 ⁻⁴	3.35x10 ⁻⁴	2.73x10 ⁻⁴	3.14x10 ⁻⁴	2.25x10 ⁻⁴	1.03x10 ⁻⁴	4.99x10 ⁻⁴	1.35x10 ⁻²
2,500	2.64x10 ⁻⁴	2.64x10 ⁻⁴	2.11x10 ⁻⁴	1.58x10 ⁻⁴	1.54x10 ⁻⁴	1.18x10 ⁻⁴	8.93x10 ⁻⁵	7.31x10 ⁻⁵	6.91x10 ⁻⁵	1.46x10 ⁻⁴	6.48x10 ⁻³
3,500	1.53x10 ⁻⁴	1.17x10 ⁻⁴	7.67x10 ⁻⁵	6.46x10 ⁻⁵	7.26x10 ⁻⁵	2.42x10 ⁻⁵	3.63x10 ⁻⁵	1.21x10 ⁻⁵	3.63x10 ⁻⁵	5.65x10 ⁻⁵	3.15x10 ⁻³
4,500	6.43x10 ⁻⁵	3.62x10 ⁻⁵	6.43x10 ⁻⁵	3.62x10 ⁻⁵	2.41x10 ⁻⁵	3.62x10 ⁻⁵	2.41x10 ⁻⁵	2.01x10 ⁻⁵	1.61x10 ⁻⁵	3.22x10 ⁻⁵	1.86x10 ⁻³
6,000	3.21x10 ⁻⁵	2.61x10 ⁻⁵	2.21x10 ⁻⁵	1.00x10 ⁻⁵	8.01x10 ⁻⁶	2.01x10 ⁻⁶	4.01x10 ⁻⁶	2.00x10 ⁻⁶	0	2.01x10 ⁻⁵	1.02x10 ⁻³
8,500	1.33x10 ⁻⁵	1.20x10 ⁻⁵	4.00x10 ⁻⁶	9.33x10 ⁻⁶	9.33x10 ⁻⁶	2.67x10 ⁻⁶	0	2.67x10 ⁻⁶	0	6.67x10 ⁻⁶	5.19x10 ⁻⁴
12,000	4.99x10 ⁻⁶	4.99x10 ⁻⁶	2.00x10 ⁻⁶	9.99x10 ⁻⁷	2.00x10 ⁻⁶	2.00x10 ⁻⁶	2.00x10 ⁻⁶	9.99x10 ⁻⁷	0	0	2.75x10 ⁻⁴
17,000	0	6.64x10 ⁻⁷	0	1.33x10 ⁻⁶	6.65x10 ⁻⁷	6.65x10 ⁻⁷	6.65x10 ⁻⁷	0	0	0	1.28x10 ⁻⁴
25,000	1.20x10 ⁻⁶	3.99x10 ⁻⁷	7.97x10 ⁻⁷	0	0	3.98x10 ⁻⁷	0	0	0	3.99x10 ⁻⁷	5.86x10 ⁻⁵
28,125	4.20x10 ⁻⁷	0	2.80x10 ⁻⁷	0	1.40x10 ⁻⁷	0	1.40x10 ⁻⁷	0	0	1.40x10 ⁻⁷	4.32x10 ⁻⁵
34,875	2.80x10 ⁻⁷	1.40x10 ⁻⁷	0	0	0	0	0	0	0	0	2.62x10 ⁻⁵
41,625	0	0	0	0	0	0	0	0	0	0	1.48x10 ⁻⁵

Table 22. Charged Particle Track Length for Electron-Initiated Showers in Copper

Electron Source Energy: 45 Gev

Radiation Length: 1.432 cm

	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
Energy (Mev)	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5
12	2.05x10 ⁻²	9.55x10 ⁻²	2.80x10 ⁻¹	6.06x10 ⁻¹	1.14	1.87	2.70	4.04	5.37	6.46	7.41
17	1.44x10 ⁻²	6.65x10 ⁻²	1.86x10 ⁻¹	3.98x10 ⁻¹	7.26x10 ⁻¹	1.17	1.77	2.42	3.15	3.81	4.49
25	1.05x10 ⁻²	4.67x10 ⁻²	1.34x10 ⁻¹	2.40x10 ⁻¹	4.46x10 ⁻¹	7.27x10 ⁻¹	1.02	1.49	1.78	2.09	2.47
35	1.35x10 ⁻²	3.07x10 ⁻²	7.96x10 ⁻²	1.75x10 ⁻¹	2.82x10 ⁻¹	4.44x10 ⁻¹	6.12x10 ⁻¹	8.51x10 ⁻¹	1.05	1.28	1.45
45	7.10x10 ⁻³	1.70x10 ⁻²	4.90x10 ⁻²	1.22x10 ⁻¹	2.14x10 ⁻¹	3.01x10 ⁻¹	4.25x10 ⁻¹	5.80x10 ⁻¹	6.94x10 ⁻¹	8.33x10 ⁻¹	8.89x10 ⁻¹
60	5.04x10 ⁻³	1.84x10 ⁻²	4.59x10 ⁻²	8.41x10 ⁻²	1.40x10 ⁻¹	2.14x10 ⁻¹	2.92x10 ⁻¹	3.67x10 ⁻¹	4.46x10 ⁻¹	5.00x10 ⁻¹	5.81x10 ⁻¹
85	2.29x10 ⁻³	9.38x10 ⁻³	2.90x10 ⁻²	4.74x10 ⁻²	8.83x10 ⁻²	1.26x10 ⁻¹	1.67x10 ⁻¹	2.11x10 ⁻¹	2.50x10 ⁻¹	2.86x10 ⁻¹	3.04x10 ⁻¹
120	1.75x10 ⁻³	6.77x10 ⁻³	1.72x10 ⁻²	3.20x10 ⁻²	4.91x10 ⁻²	6.89x10 ⁻²	1.01x10 ⁻¹	1.25x10 ⁻¹	1.40x10 ⁻¹	1.68x10 ⁻¹	1.66x10 ⁻¹
170	1.98x10 ⁻³	6.47x10 ⁻³	1.19x10 ⁻²	1.88x10 ⁻²	3.01x10 ⁻²	4.35x10 ⁻²	5.95x10 ⁻²	6.93x10 ⁻²	7.51x10 ⁻²	8.83x10 ⁻²	9.08x10 ⁻²
250	8.60x10 ⁻⁴	3.18x10 ⁻³	7.05x10 ⁻³	1.22x10 ⁻²	2.03x10 ⁻²	2.63x10 ⁻²	3.00x10 ⁻²	3.97x10 ⁻²	4.03x10 ⁻²	4.42x10 ⁻²	4.43x10 ⁻²
350	6.25x10 ⁻⁴	2.30x10 ⁻³	4.34x10 ⁻³	7.47x10 ⁻³	1.05x10 ⁻²	1.49x10 ⁻²	1.69x10 ⁻²	2.04x10 ⁻²	2.14x10 ⁻²	2.24x10 ⁻²	2.15x10 ⁻²
450	5.11x10 ⁻⁴	1.28x10 ⁻³	3.38x10 ⁻³	5.37x10 ⁻³	6.55x10 ⁻³	9.98x10 ⁻³	1.17x10 ⁻²	1.30x10 ⁻²	1.39x10 ⁻²	1.45x10 ⁻²	1.40x10 ⁻²
600	2.76x10 ⁻⁴	1.33x10 ⁻³	1.78x10 ⁻³	3.90x10 ⁻³	5.03x10 ⁻³	6.14x10 ⁻³	7.20x10 ⁻³	8.08x10 ⁻³	8.66x10 ⁻³	8.46x10 ⁻³	8.18x10 ⁻³
850	1.98x10 ⁻⁴	8.25x10 ⁻⁴	1.83x10 ⁻³	2.39x10 ⁻³	3.00x10 ⁻³	3.50x10 ⁻³	3.89x10 ⁻³	4.21x10 ⁻³	4.24x10 ⁻³	3.81x10 ⁻³	3.63x10 ⁻³
1,200	4.97x10 ⁻⁵	2.75x10 ⁻⁴	6.07x10 ⁻⁴	1.05x10 ⁻³	1.35x10 ⁻³	1.52x10 ⁻³	1.89x10 ⁻³	1.70x10 ⁻³	1.70x10 ⁻³	1.55x10 ⁻³	1.35x10 ⁻³
1,700	3.12x10 ⁻⁵	1.63x10 ⁻⁴	4.09x10 ⁻⁴	6.60x10 ⁻⁴	8.12x10 ⁻⁴	9.43x10 ⁻⁴	9.54x10 ⁻⁴	9.05x10 ⁻⁴	8.56x10 ⁻⁴	7.38x10 ⁻⁴	6.34x10 ⁻⁴
2,500	2.21x10 ⁻⁵	1.11x10 ⁻⁴	2.34x10 ⁻⁴	3.35x10 ⁻⁴	4.51x10 ⁻⁴	4.52x10 ⁻⁴	4.55x10 ⁻⁴	3.93x10 ⁻⁴	3.91x10 ⁻⁴	3.07x10 ⁻⁴	2.85x10 ⁻⁴
3,500	1.65x10 ⁻⁵	8.28x10 ⁻⁵	1.65x10 ⁻⁴	2.04x10 ⁻⁴	2.33x10 ⁻⁴	2.66x10 ⁻⁴	2.65x10 ⁻⁴	2.23x10 ⁻⁴	2.07x10 ⁻⁴	1.34x10 ⁻⁴	1.02x10 ⁻⁴
4,500	1.25x10 ⁻⁵	6.61x10 ⁻⁵	1.11x10 ⁻⁴	1.61x10 ⁻⁴	1.77x10 ⁻⁴	1.71x10 ⁻⁴	1.50x10 ⁻⁴	1.27x10 ⁻⁴	1.11x10 ⁻⁴	8.74x10 ⁻⁵	6.16x10 ⁻⁵
6,000	1.05x10 ⁻⁵	4.35x10 ⁻⁵	8.28x10 ⁻⁵	1.05x10 ⁻⁴	1.16x10 ⁻⁴	9.74x10 ⁻⁵	7.47x10 ⁻⁵	7.19x10 ⁻⁵	5.47x10 ⁻⁵	2.76x10 ⁻⁵	1.79x10 ⁻⁵
8,500	8.70x10 ⁻⁶	3.36x10 ⁻⁵	5.79x10 ⁻⁵	6.30x10 ⁻⁵	5.76x10 ⁻⁵	4.65x10 ⁻⁵	4.15x10 ⁻⁵	3.15x10 ⁻⁵	2.03x10 ⁻⁵	1.53x10 ⁻⁵	9.92x10 ⁻⁶
12,000	5.81x10 ⁻⁶	2.35x10 ⁻⁵	3.13x10 ⁻⁵	3.64x10 ⁻⁵	3.08x10 ⁻⁵			1.19x10 ⁻⁵	9.93x10 ⁻⁶	6.88x10 ⁻⁶	3.83x10 ⁻⁶
17,000	5.58x10 ⁻⁶	1.88x10 ⁻⁵	2.52x10 ⁻⁵	2.01x10 ⁻⁵	1.31x10 ⁻⁵	8.41x10 ⁻⁶	5.53x10 ⁻⁶	3.54x10 ⁻⁶	1.37x10 ⁻⁶	1.47x10 ⁻⁶	8.98x10 ⁻⁷
28,125	8.71x10 ⁻⁶	1.53x10 ⁻⁵	1.12x10 ⁻⁵	6.09x10 ⁻⁶	2.85x10 ⁻⁶	1.38x10 ⁻⁶	8.06x10 ⁻⁷	4.50x10 ⁻⁷	2.55x10 ⁻⁷	1.63x10 ⁻⁷	1.25x10 ⁻⁷
34,875	1.26x10 ⁻⁵	1.55x10 ⁻⁵	7.63x10 ⁻⁶	2.64x10 ⁻⁶	8.28x10 ⁻⁷	3.09x10 ⁻⁷	1.55x10 ⁻⁷	9.96x10 ⁻⁸	4.18x10 ⁻⁸	1.19x10 ⁻⁸	6.57x10 ⁻⁸
41,625	6.43x10 ⁻⁵	1.70x10 ⁻⁵	3.35x10 ⁻⁶	4.96x10 ⁻⁷	1.27x10 ⁻⁷	4.18x10 ⁻⁸	1.99x10 ⁻⁸	1.99x10 ⁻⁸	9.96x10 ⁻⁹	7.96x10 ⁻⁹	1.99x10 ⁻⁹

Table 22 (continued)

	Track Length Per Incident Particle in the Indicated Depth Interval (cm/Mev)										
	Depth Interval (Radiation Lengths)										
Energy (Mev)	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-∞	Totals
12	8.75	9.49	1.06x10 ¹	1.09x10 ¹	1.15x10 ¹	1.14x10 ¹	1.11x10 ¹	1.12x10 ¹	1.06x10 ¹	1.03x10 ²	2.29x10 ²
17	5.13	5.49	5.94	6.20	6.30	6.31	6.20	5.96	5.63	5.08x10 ¹	1.22x10 ²
25	2.86	3.03	3.17	3.39	3.30	3.26	3.11	3.01	2.78	2.27x10 ¹	6.10x10 ¹
35	1.57	1.70	1.69	1.75	1.71	1.75	1.65	1.49	1.38	1.04x10 ¹	3.14x10 ¹
45	1.06	1.05	1.03	1.07	1.06	9.97x10 ⁻¹	9.36x10 ⁻¹	9.27x10 ⁻¹	7.90x10 ⁻¹	5.71	1.88x10 ¹
60	6.18x10 ⁻¹	6.56x10 ⁻¹	6.48x10 ⁻¹	6.24x10 ⁻¹	6.36x10 ⁻¹	5.91x10 ⁻¹	5.35x10 ⁻¹	4.97x10 ⁻¹	4.56x10 ⁻¹	2.99	1.09x10 ¹
85	3.33x10 ⁻¹	3.40x10 ⁻¹	3.43x10 ⁻¹	3.37x10 ⁻¹	3.25x10 ⁻¹	2.92x10 ⁻¹	2.63x10 ⁻¹	2.49x10 ⁻¹	2.14x10 ⁻¹	1.32	5.54
120	1.73x10 ⁻¹	1.71x10 ⁻¹	1.68x10 ⁻¹	1.69x10 ⁻¹	1.49x10 ⁻¹	1.32x10 ⁻¹	1.22x10 ⁻¹	1.10x10 ⁻¹	9.70x10 ⁻²	5.48x10 ⁻¹	2.72
170	9.52x10 ⁻²	8.29x10 ⁻²	8.85x10 ⁻²	8.17x10 ⁻²	7.07x10 ⁻²	6.50x10 ⁻²	5.80x10 ⁻²	5.09x10 ⁻²	4.52x10 ⁻²	2.26x10 ⁻¹	1.36
250	4.24x10 ⁻²	4.34x10 ⁻²	3.82x10 ⁻²	3.51x10 ⁻²	3.25x10 ⁻²	2.80x10 ⁻²	2.63x10 ⁻²	2.23x10 ⁻²	1.92x10 ⁻²	8.87x10 ⁻²	6.44x10 ⁻¹
350	1.95x10 ⁻²	2.12x10 ⁻²	1.83x10 ⁻²	1.78x10 ⁻²	1.64x10 ⁻²	1.27x10 ⁻²	1.08x10 ⁻²	8.90x10 ⁻³	8.17x10 ⁻³	3.63x10 ⁻²	3.13x10 ⁻¹
450	1.31x10 ⁻²	1.12x10 ⁻²	1.08x10 ⁻²	9.78x10 ⁻³	8.54x10 ⁻³	7.22x10 ⁻³	5.69x10 ⁻³	5.43x10 ⁻³	4.00x10 ⁻³	2.02x10 ⁻²	1.90x10 ⁻¹
600	6.85x10 ⁻³	6.70x10 ⁻³	6.39x10 ⁻³	5.34x10 ⁻³	4.45x10 ⁻³	4.33x10 ⁻³	3.04x10 ⁻³	2.52x10 ⁻³	1.96x10 ⁻³	8.61x10 ⁻³	1.09x10 ⁻¹
850	3.47x10 ⁻³	2.96x10 ⁻³	2.56x10 ⁻³	2.46x10 ⁻³	1.63x10 ⁻³	1.54x10 ⁻³	1.37x10 ⁻³	1.24x10 ⁻³	9.25x10 ⁻⁴	3.81x10 ⁻³	5.35x10 ⁻²
1,200	1.21x10 ⁻³	1.04x10 ⁻³	7.83x10 ⁻⁴	6.41x10 ⁻⁴	5.66x10 ⁻⁴	4.27x10 ⁻⁴	3.60x10 ⁻⁴	2.81x10 ⁻⁴	2.18x10 ⁻⁴	7.18x10 ⁻⁴	1.93x10 ⁻²
1,700	5.12x10 ⁻⁴	4.17x10 ⁻⁴	3.72x10 ⁻⁴	2.95x10 ⁻⁴	2.08x10 ⁻⁴	1.74x10 ⁻⁴	1.39x10 ⁻⁴	9.46x10 ⁻⁵	7.86x10 ⁻⁵	2.50x10 ⁻⁴	9.64x10 ⁻³
2,500	2.30x10 ⁻⁴	1.79x10 ⁻⁴	1.20x10 ⁻⁴	1.10x10 ⁻⁴	9.16x10 ⁻⁵	5.90x10 ⁻⁵	4.48x10 ⁻⁵	4.03x10 ⁻⁵	3.07x10 ⁻⁵	9.42x10 ⁻⁵	4.44x10 ⁻³
3,500	8.68x10 ⁻⁵	6.89x10 ⁻⁵	4.85x10 ⁻⁵	3.12x10 ⁻⁵	3.20x10 ⁻⁵	2.55x10 ⁻⁵	1.76x10 ⁻⁵	1.42x10 ⁻⁵	1.05x10 ⁻⁵	3.29x10 ⁻⁵	2.27x10 ⁻³
4,500	4.59x10 ⁻⁵	3.04x10 ⁻⁵	1.79x10 ⁻⁵	2.50x10 ⁻⁵	1.19x10 ⁻⁵	1.13x10 ⁻⁵	1.08x10 ⁻⁵	3.69x10 ⁻⁶	3.69x10 ⁻⁶	1.08x10 ⁻⁵	1.41x10 ⁻³
6,000	1.55x10 ⁻⁵	1.57x10 ⁻⁵	1.32x10 ⁻⁵	8.22x10 ⁻⁶	5.25x10 ⁻⁶	4.82x10 ⁻⁶	4.11x10 ⁻⁶	3.12x10 ⁻⁶	3.26x10 ⁻⁶	3.69x10 ⁻⁶	7.78x10 ⁻⁴
8,500	6.33x10 ⁻⁶	5.96x10 ⁻⁶	3.59x10 ⁻⁶	2.17x10 ⁻⁶	2.36x10 ⁻⁶	3.59x10 ⁻⁶	1.99x10 ⁻⁶	9.45x10 ⁻⁷	3.78x10 ⁻⁷	7.56x10 ⁻⁷	4.14x10 ⁻⁴
12,000	1.99x10 ⁻⁶	1.56x10 ⁻⁷	9.21x10 ⁻⁷	4.25x10 ⁻⁷	8.51x10 ⁻⁷	4.25x10 ⁻⁷	5.67x10 ⁻⁷	5.67x10 ⁻⁷	0	5.67x10 ⁻⁷	
17,000	1.04x10 ⁻⁶	4.73x10 ⁻⁸	9.45x10 ⁻⁸	2.36x10 ⁻⁷	3.78x10 ⁻⁷	3.45x10 ⁻⁷	2.36x10 ⁻⁷	0	0	1.89x10 ⁻⁷	1.06x10 ⁻⁴
28,125	1.29x10 ⁻⁷	6.37x10 ⁻⁸	1.59x10 ⁻⁸	2.38x10 ⁻⁸	2.19x10 ⁻⁸	2.79x10 ⁻⁸	1.59x10 ⁻⁸	2.39x10 ⁻⁸	0	3.98x10 ⁻⁸	4.77x10 ⁻⁵
34,875	6.37x10 ⁻⁸	3.19x10 ⁻⁸	1.39x10 ⁻⁸	5.97x10 ⁻⁹	1.19x10 ⁻⁸	9.96x10 ⁻⁹	5.97x10 ⁻⁹	5.97x10 ⁻⁹	5.97x10 ⁻⁹	5.97x10 ⁻⁹	4.00x10 ⁻⁵
41,625	5.97x10 ⁻⁹	1.99x10 ⁻⁹	0	1.99x10 ⁻⁹	0	0	0	0	0	0	8.54x10 ⁻⁵

References

1. B. B. Rossi, High Energy Particles (Prentice-Hall, Inc., New York, 1952).
2. R. R. Wilson, Phys. Rev. 86, 261 (1952).
3. J. C. Butcher and H. Messel, Nucl. Phys. 20, 15 (1960).
4. H. A. Bethe and J. Ashkin, "Passage of Radiation Through Matter," Experimental Nuclear Physics, Edited by E. Segre, Vol. 1, p. 166 (John Wiley and Sons, Inc., New York, 1953).
5. H. A. Bethe and W. Heitler, Proc. Roy. Soc. (London) A146, 83 (1934).
6. Davis, Bethe, and Maximon, Phys. Rev. 93, 788 (1954).
7. W. Heitler, The Quantum Theory of Radiation (Oxford University Press, London, 1954).
8. G. W. Grodstein, "X-Ray Coefficients from 10 kev to 100 Mev," National Bureau of Standards Report NBS-583.
9. P. V. C. Hough, Phys. Rev. 73, 266 (1948).
10. E. A. Uehling, Ann. Rev. Nuclear Science 4, 315 (1956).
11. O. Taussky and J. Todd, Symposium on Monte Carlo Methods, Edited by H. A. Meyer (John Wiley and Sons, Inc., New York, 1954).
12. R. R. Wilson, Phys. Rev. 86, 261 (1952), Figs. 7 and 8.
13. R. R. Wilson, private communication.
14. A. Kantz and R. Hofstadter, Nucleonics 12, March, p. 36 (1954).
15. B. B. Rossi, High Energy Particles, p. 272 (Prentice-Hall, Inc., New York, 1952).

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