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RADIAL PROFILES OF PHOTON INITIATED ELECTROMAGNETIC SHOWERS BETWEEN 100 AND 3500 MeV

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It is shown that the radial dependence of the density of shower electrons ionization loss may be approximated by some universal function $F(x)$ of the dimensionless variable x only. This function has its asymptotics as $F(x) \sim e^{-x}$ at large enough x.

The investigation has been performed at the Laboratory of High Energies JINR (Dubna) and at the Institute of Physics, Warsaw University of Technology (Warsaw).

Радиальные профили электромагнитных ливней, вызываемых гамма-квантами с энергией 100—3500 МэВ

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Показано, что радиальная зависимость плотности ионизационных потерь ливневых электронов может быть аппроксимирована некоторой универсальной функцией $F(x)$, зависящей только от безразмерной переменной x. При достаточно больших x асимптотикой этой функции является экспонента: $F(x) \sim e^{-x}$.

Работа выполнена в Лаборатории высоких энергий ОИЯИ (Дубна) и в Институте физики Варшавского технического университета (Варшава).

I. Introduction

It has been found earlier[1] that the average radial profile $E_r(r|E_\gamma, t)$ of showers created in liquid xenon by gamma quanta of energy E_γ = 100—3500 MeV is related with the corresponding plane distribution $f_p(p|E_\gamma, t)$ of shower electrons ionization loss according to the equation:

$$f_p(p|E_\gamma, t) = 2\int_p^\infty \frac{F_r(r|E_\gamma, t)}{\sqrt{1-(p/r)^2}}\, dr, \qquad (1)$$

where r is a distance from the shower axis (SA), p is its projection in the picture plane, in which the normalized density of partial summary projection ranges $f_p(p|E_\gamma, t)$ of shower electrons was measured within squares having sides $\Delta t = 0.6$ radiation length (rl) along the SA and $\Delta p = 0.3$ rl. As a result of the fit to the experimental data of exponential function

$$f_p(p \mid E_\gamma, t) = \frac{1}{\bar{p}(E_\gamma, t)} e^{-p/\bar{p}(E_\gamma, t)} \tag{2}$$

the following parametrization of the average plane shower width was obtained/2/:

$$\bar{p}(E_\gamma, t) = \alpha + \beta(E_\gamma) \cdot t. \tag{3}$$

Here $\alpha = (4.2 \pm 1.2) \cdot 10^{-2}$ rl, $\beta(E_\gamma) = a - b \cdot \ln E_\gamma$, $a = (7.5 \pm 0.3) \cdot 10^{-2}$, $b = (6.6 \pm 0.4) \cdot 10^{-3}$ when E_γ is in MeV.

The equation has a unique solution of the form/1/:

$$F_r(r \mid E_\gamma, t) = \frac{1}{\pi r^2} \int_\infty^r \frac{d}{dp} [p \cdot f_p(p \mid E_\gamma, t)] \frac{dp}{\sqrt{1 - (r/p^2)}} . \tag{4}$$

Substituting the function (2) into (4) we can obtain the exact formula for the average radial distribution of ionization loss in electromagnetic showers.

In the present work we show that this distribution may be expressed by means of a universal function determining its radial shape.

II. Radial Shower Profile

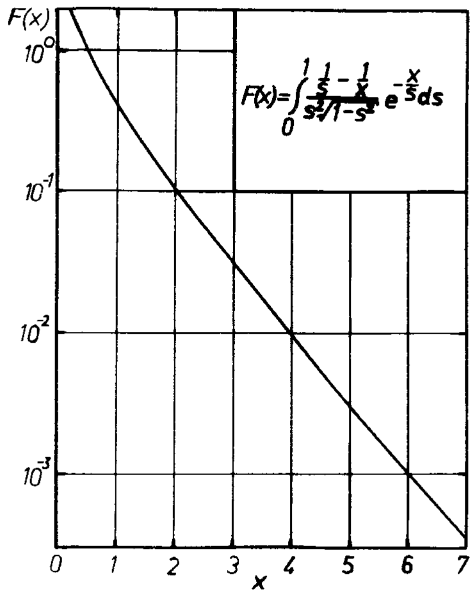
Let us denote for short: $\bar{p} = \bar{p}(E_\gamma, t)$, $x = r/\bar{p}$, $s = r/p$ and $F_r(x) = F_r(r \mid E_\gamma, t)$. Then from (4) and (2) we have

$$F_r(x) = \frac{1}{\pi \bar{p}^2} \cdot F(x) , \tag{5}$$

where the function

$$F(x) = \int_0^1 \frac{\frac{1}{s} - \frac{1}{x}}{s^2 \sqrt{1 - s^2}} e^{-x/s} ds , \tag{6}$$

depending on the dimensionless variable x, determines the radial behaviour of the density $F_r(x)$ of shower electrons ionization loss, whereas all information about the primary photon energy E_γ as well as



Radial dependence of the density of shower electrons ionization lass

(homogeneous) absorbent properties and a shower depth t is contained in the parameter $\bar{p}$. The figure displays the function (6) within the interval of $x = 0.2—7$.

It is to be shown strictly that at higher values of x ($x \geq 2$) $F(x) \sim e^{-x}$ as can be seen in the figure.

Mention finally the suggestion[3] that the solution of (1) is as follows

$$F_r(r) = \frac{1}{\pi \bar{p}^2} K_0(x) , \qquad (7)$$

where $K_0(x)$ is the McDonald function. But then it would satisfy the equation:

$$r^2 F_r''(r) + rF_r'(r) - (\frac{r}{\bar{p}})^2 F_r(r) = 0 \qquad (8)$$

which is not the case.

References

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