THE LATERAL DISTRIBUTIONS OF CHARGED PARTICLES OF ENERGY GREATER THAN 0.3 E_{crit} IN ELECTRON-PHOTON CASCADES IN LEAD AND AIR

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In the recent investigations, both theoretical and experimental, the disagreement between cascade theory and experimental data is pointed out. In the present paper the radial distributions obtained from the Monte-Carlo simulations are compared with the well known results of the analytical theory for all particles in cascades. In the paper the data on mean radius of the electron lateral distribution in air are compared with those in lead

Lateral development of the electromagnetic cascades

In order to study the three dimensional behaviour of electromagnetic cascades, our simulation was made for the cascades initiated at the top of atmosphere and at a depth of 712 g/cm^2 for different energies. It shows, tnat the lateral distributions of particles are narrower than the NKG distributions with an age parameter describing the longitudinal development of the cascades /6,7/. We also found that the initiating point of the cascade development has an effect on the width of the electron lateral distribution. It appeared that the width of the distribution is determined by the density of the atmosphere at so-called effective height above the considered level and this gives the possibility of removing the differencies in the shape of distributions for different starting points of the cascades. The effective height was estimated as equal to 2 cascade units. The investigation of the effect of primary particle energy on the width of the electron lateral distribution shows that the mean distance of particles from the cascade axis corrected for the density effect increases with primary particle energy. Basing on our simulations we have approximated the electron lateral distribution by a simple formula:

$$\rho(x) = C(s, z) \cdot X_1^{\,s+0.5\cdot z-2} \cdot (1+X_1)^{z-5.3}$$

where: $x=r/r_0$; $X_1 = x\cdot\eta(t-2)/(m\cdot\eta(t))$; $m=0.8-0.2\cdot s$

r - the distance from the cascade axis ;
r_0 - the Molier unit ; C - the normalization param.,
$\eta(t), \eta(t-2)$ - the density of air for the observation level, the density 2 c.u. above the observation level

$$s = \frac{3t}{t+2\ln(E_0/\varepsilon_k)} \qquad z = \frac{3(t-2)}{(t-2)+2\ln(E_0/\varepsilon_k)}$$

From that formula we derived the value of so-called the local age parameter for different distances from the cascade axis. The local age parameter is defined as the age parameter obtained from the NKG formulae on the basis of particle density at two distances from the axis. The result is shown

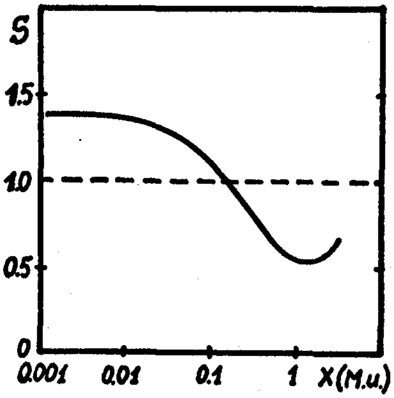

Fig.1 The value of the local age parameter as a function of distance X from the cascade axis : solid line - our approximation , broken line - the age parameter describing the longitudinal development. The ratio of electron densities at distances form the axis X_{i-1} and X_i where $X_i=X$, lg X_{i-1}/X_i was taken.

in Fig.1 . This analysis shows that the local age parameter changes form a value clearly greater than the NKG age parameter at small distances to significantly lower one at distances greater then the 0.1 Molier unit. It means that the method of describing the lateral distributions of electrons by the NKG function with one parameter can lead to different results depending on the distances at which this parameter is estimated .

<u>The comparison of simulation of the electromagnetic cascades with the other results</u>

In this part we compare our approximation with those proposed by Nishimura-Kamata/1/, Greisen/2/, Hillas/4/ and Uchaikin/5/.

The comparison of the mean distances of particles from the cascade axis obtained from our results with the Hillas ones is shown in Fig.2a. Comparison of the analytical results

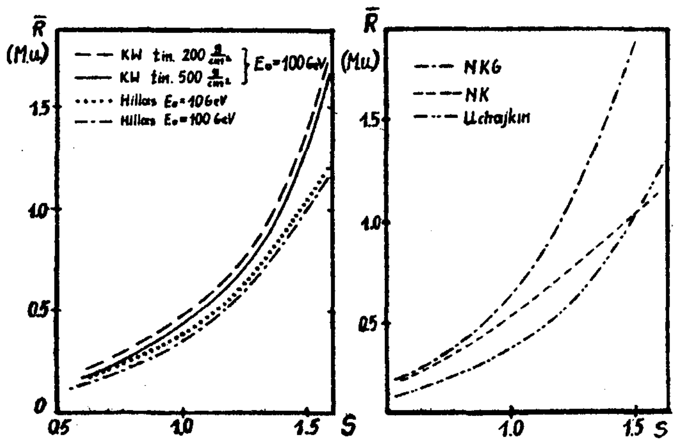

Fig.2 The mean distances of electrons from the cascade axis as a function of age parameter s .

for the same stage of the cascade development /NKG, NK and Uchaikin formulae / is shown in Fig. 2b. Thus it is seen that reconstruction of such parameters as age parameter and number of particles on the basis of the proposed lateral distributions cannot give the same results.

The comparison of the relative numbers of particles at small distances from the cascades axis for two different stages of the cascade development with the Hillas, NKG, NK and Uchaikin formulae is shown in Fig. 3

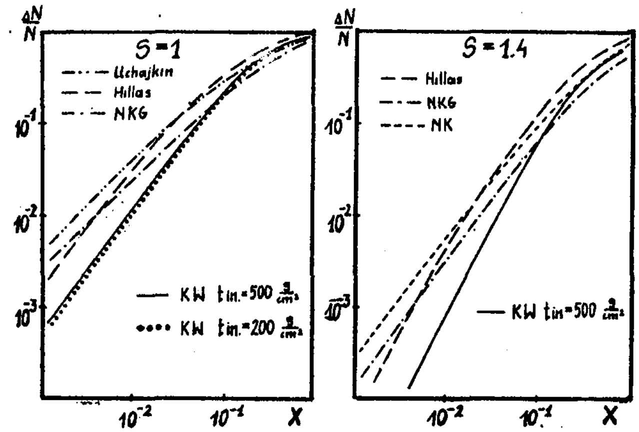

Fig. 3 The relative numbers of electrons as a function of X

The present situation is such that near the axis the evident differencies between the curves exist. These deviations have significant consequancies for the experimental investigations. For instance, that flat distributions of electrons at small distances from the axis would lead to underestimation of the energy in subcores in EAS.

The comparison of simulation of the electromagnetic cascades with various energy threshold in different absorbers.

In simulations of the electromagnetic cascades the lateral distributions were obtained for various energy thresholds. The comparison of the mean distances of particles with threshold $30\ m_ec^2$ and $60\ m_ec^2$ in cascade initiated by primary photon of energy 50 GeV in air as a function of age parameter is shown in Fig. 4. In lead the mean distances of particles with the similar value of ratio E_{thr}/E_{crit} is also shown /$E_{thr}=4\ m_ec^2$/ in Fig. 4. for cascades initiated by primary photons of energy 10 GeV /for this energy the LPM effect does not play any role/ The mean distances of particles are compared in Molier units. It can be seen that there is a good agreement between the values of meas distances of particles obtained from the simulation in very differing absorbers - lead and air. It is demonstrated that the mean radii of the lateral distributions in lead can be obtained from those in air, if the same ratio of the threshold energy to the critical energy is taken.

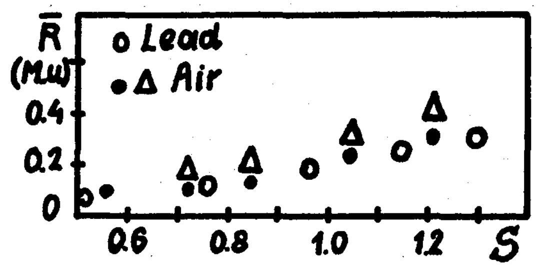

Fig.4 The mean distances of electrons with threshold $30\ m_ec^2$ and $60\ m_ec^2$ in air and $4\ m_ec^2$ in lead for cascades initiated by primary photons of energy 50 GeV at the depth 712 g/cm^2 in air and 10 GeV in lead.

Conclusions

The method applied in EAS research for estimation of parameters / i.e. age parameter and a number of particles / is based on assumption that the lateral distributions of particles in air showers are of the same type as in the electro magnetic cascades. The lateral distributions are always reconstructed by fitting the NKG function to the experimentally measured densities of particles at several distances from the shower axis. The signalized incoherences in EAS research / 8 / i.e. change of the age parameter with distances can be explained as a results of applying the incorrect formula / NKG ones /. This effect may be still better visible for higher energy threshold of secondary particles.

The formula proposed by us though not so easy for direct use in EAS research explain the discrepancies between experimental data and NKG formula, for instance the change of age parameter with distance.

The present results show that the applied Monte - Carlo method for significantly different absorbers seems to be good.

Acknowledgments

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