

RESULT OF MONTE-CARLO SIMULATION OF ELECTRON-PHOTON  
CASCADES IN LEAD AND LAYERS OF LEAD-SCINTILLATOR

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Results of Monte-Carlo simulation of electromagnetic cascade development in lead and lead-scintillator sandwiches are analysed. It is demonstrated, that the structure function for "core approximation" is not applicable in the case in which the primary energy is higher than 100 GeV. The simulation data has shown that introduced inhomogeneous structure of chamber gives subsequent reduction of secondary particles.

Introduction.

In this paper we present results of detailed simulations, including the LPM effect, of electromagnetic cascades in lead and lead-scintillator sandwiches which are often used in emulsion chamber experiments. The following processes were taken into account in calculations: pair production, bremsstrahlung including LPM effect with energy dependent cross - sections /Fig.1/, ionisations loss, Compton effect, single and multiple Coulomb scattering, the electron and positron inelastic scattering, photoelectric effect, annihilation of the positron.

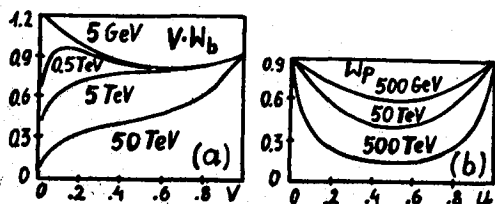


Fig.1.a The product of differential cross-section of bremsstrahlung and  $v$ , where  $v = E/E_0$ .  
b The differential cross-section of pair production, where  $u = E/E_0$ .

The simulations were performed:

- in lead, for primary photons of energy 100 GeV, 10 TeV and 100 TeV and for primary electrons of energy 100 GeV,
- in sandwiches of lead and scintillator: for primary electrons of energy 100 GeV /Tab.1, No.1/, primary photons of energy 10 TeV and 100 TeV /Tab.1, No.2/.

absorber		Pb	Sc	Pb	Sc	Pb	Sc	Pb	Sc	Pb	Pb
thickness of	1	1	.5	.5	.5	.5	.5	.5	.5	.5	.5
aborb. /cm/	2	4	2	1	2	1	90	3	2	1	1

Tab.1 The structure of chambers investigated in our simulation. No.1: this sandwich is similar to that used in FNAL experiment /1/. No.2: this one is similar to the big gamma-hadron detector used in cosmic rays research /for instance Pamir Collaboration /2/ /.

General procedure was following. All particles with energies exceeding certain value of  $k = E_0/E_k$  were followed individually. Particles below  $E_k$  down to the threshold energy were followed using the so-called "thinning" method. The value of  $k$

was usually taken to be 1000 or 100 and the threshold energy was  $2 m_{ec}^2$ .

### Longitudinal and lateral development of the electromagnetic cascades

In the emulsion chamber technique, the energy of an incoming electron or photon is measured by the behaviour of cascade showers near the shower axis. In "core approximation" it is assumed that the lateral structure functions depend on  $E_0 r / K_s$  and  $s$  only and not of separate variables  $E_0$  and  $r$ . In this paper we analyse validity of this statement for wide range of energies and for different structure of chambers. In Fig.2 one can see the transition curves for primary electrons and photons of energy 100 GeV for shower radii 100  $\mu m$  together with the cascades obtained in chamber C1 of FNAL experiment.

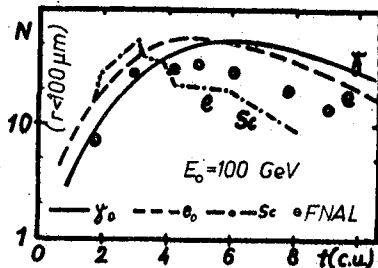


Fig.2 Cascades curves of electrons in photon and electron initiated showers for radius 100  $\mu m$ .

Our results are presented separately for cascade passing only through lead and for cascades initiated in lead-scintillator /sandwich No.1/. As can be seen the introduced scintillator plays important role, giving subsequent reduction of secondary particle numbers. The transition curve obtained for sandwich's structure shows similar tendency as is seen in experiment, i.e. the smaller electron size than in pure lead chamber. We conclude that the agreement with experiment can be achieved by employing as an absorber in our simulations the precise structure of FNAL sandwiches.

Let's compare the shape of transition curves when the energy of primary particles increases.

In Fig.3a we present the transition curves with  $E_{thr}=2m_{ec}^2$  for  $E_0=10$  TeV and  $E_0=100$  TeV for pure lead chamber and for sandwich No.2. Fig.3b gives the transition curves for "core approximation" i.e. for shower radius 100  $\mu m$  and for the same primary energies of particles. For these cascades the LPM effect plays an important role in transition curves as the energy increases giving a deeper position of shower maximum and smaller size at maximum. In Fig.3 one can see that even primary photons of energy 10 TeV can penetrate through all chamber /sandwich No.2/. This effect is stronger when the primary energy of photon increases. The most of EAS experiments have one or more layers of carbon: this enhances the detector capability to discriminate hadrons from photons and electrons. The interesting results of the present simulations is that the number of particles after penetration of



shown in Tab.2 . The value of energy determined from our data changes from a value lower than the energy of primary particle at low  $s$  to the value greater than ones at higher  $s$ . In the other words, our results show that the method of describing lateral distributions of electrons by "core approximation" leads to underestimation of the energy of the primary particle at low value of  $s$  and to overestimation at higher  $s$ .

	$s$	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
<b>a</b>	$t/cm/$	2.9	3.6	4.5	5.3	6.3	7.3	8.5	9.7	11.2	12.8
	$E_e/TeV/$	5.0	7.1	9.2	10.1	12.8	15.0	17.0	22.3	26.6	31.0
<b>b</b>	$t/cm/$	6.6	8.3	10.1	12.0	14.2	16.6	19.2	22.1	25.3	29.0
	$E_e/TeV/$	7.0	21.0	40.0	77.0	107.0	170.0	280.0	370.0	670.0	1000.

Tab.2 The comparison of the energy of primary photon estimated according to "core approximation".  
The energy of primary photon is : a. 10 TeV and b. 100 TeV.

As one can see, these discrepancies depend on the depth of the observation level and on the primary energy of particles.

### Conclusions

1. It was stated that inhomogeneous structure of chamber has an effect on the transition curves. It appeared that numbers of secondary particles / for constant radii and constant primary photon energy / is determined by thickness, the kind of absorbers and their place in sandwiches.
2. It is not possible to describe the lateral distributions of particles with "core approximation" independent of the primary particle energy because the LPM effect plays an important role in transition curves. The method of describing lateral distributions of electrons by the "core approximation" used in chamber experiments lead to underestimation of the primary photon energy at low values of  $s$  and overestimation at higher  $s$ .

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### References

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- [ 2 ] Trudy FIAN, v.154, Moskva 1984