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LONGITUDINAL DEVELOPMENT OF ELECTROMAGNETIC SHOWER PRODUCED BY 5 AND 9 GeV POSITRONS IN LEAD GLASS

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A hodoscope system of total absorption Čerenkov counters is being developed on the spectrometer HYPERON [1]. Each separate block of the detector is a prism of lead glass TF-1-000* 100x100x350 mm^3. To one end of the prism a photomultiplier FEU-110 is glued.

This paper presents experimental results obtained in measurements of the longitudinal development of the electromagnetic shower in such block, necessary for the data handling [2].

Measurements in the Beam

To registrate the Čerenkov radiation emitted by particles of the electromagnetic shower at different depths, a measuring counter C_m (Fig.1) has been made. The counter is a 100x100x25 mm^3 lead-glass block with a FEU-110 glued to a face of the counter by the optical glue. The photomultiplier is wrapped up in several layers of μ-metal against fringe magnetic fields. The radiator is wrapped up in aluminised mylar and black paper.

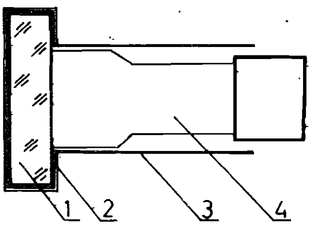


Fig.1. Measuring counter.
1 - Radiator of lead glass TF-1-000.
2 - Aluminised mylar and black paper.
3 - Magnet screen.
4 - FEU-110 and HV divider.

The measurements were carried out at the positive beam of the IHEP accelerator at 5 and 9 GeV/c beam momenta. The equipment lay-out is given in Fig.2. The beam positrons were identified by threshold Čerenkov counters C1÷C5. The size of used beam zone was constrained by scintillator counters S1÷S4 and was 20x20 mm^2 on C_m.

The signal from the measuring counter was transferred to the 8-bits ADC KA-008 [4] and was read in the computer and recorded on the magnetic tape.

During the measurements K TF-1-000 glass blocks (K=0,1,...,18) of the same size as the radiator C_m were placed in front of the counter close to it. Consequently, the counter C_m detected the Čerenkov radiation emitted by charged particles of the shower at the depth from t-1 to t radiation length, where t=K+1. For each value of K $2.5\cdot10^3$ triggers were recorded. Measurements were carried out for several hours; the time drift of the photomultiplier amplitude was negligible.

* The characteristics of glass TF-1-000 are analogous to those of glass SF-5 [3]. The radiation length of glass TF-1-000 is 25 mm.

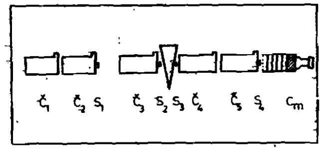


Fig.2. Equipment lay-out in the beam.

Analysis of Experimental Data

In the amplitude spectra at $t \leq 11$ a distinct signal from the electromagnetic shower and the exponentially decreasing background in the region of small amplitudes are seen (Fig.3). The background could originate due to the shower development starting in the air or in matter behind the last positron-selecting Čerenkov counter, occasional coincidences, admixture of signals from other particles in the triggering signal.

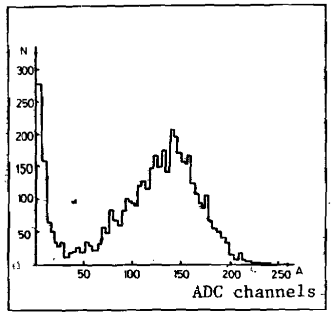


Fig.3. Amplitude Spectrum C_m at K=5 for E=9 GeV.

The signal from the shower for $t \leq 11$ is well described with the Gauss distribution. For larger t the Gauss distribution degrades to the exponential distribution.

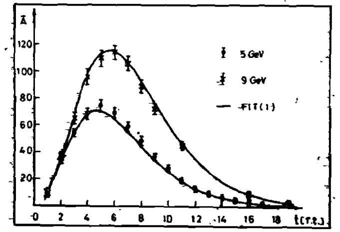
Spectra of amplitudes for $t \leq 11$ radiation lengths were fitted by the sum of the exponential distribution and Gauss distribution. It turned out that the exponential background does not change within the errors for all t region. The background, determined in this way independently for 5 and 9 GeV measurements, was subtracted from all amplitude distributions for all t. Then the mean value of amplitudes $\bar{A}(t,E)$ was found for every spectrum for each t. The obtained values $\bar{A}(t,E)$ are presented in Fig.4. The indicated errors include statistical ones and ten percent systematic errors due to the limited transversal size of the measuring counter (4t), containing about 95% of the lateral shower profile [3], and to the absence of backscattering material behind C_m, a few percent [4].

The data were parametrised by the least squares method [7] using a function [5,8,9]

$$\bar{A}(t,E) = A_0 E \frac{1}{N_0} t^p \exp(-ct) \qquad (1)$$

$$N_0 = \int_0^\infty t^p \exp(-ct)\,dt = \frac{P!}{c^{P+1}}$$

Fig.4. Longitudinal development of the electromagnetic shower in lead glass TF-1-000.



where the power index p depends on the energy of the primary particle:

$$p = a + b\ln E, \quad [E] = \text{GeV} \qquad (2)$$

This choice of the function ensures the normalization of the data, i.e.

$$\frac{1}{A_0} \int_0^\infty A(t,E)\,dt = E.$$

From the simultaneous fitting of the data for 5 and 9 GeV the following values of the parameters were obtained:

$$A_0 = (508.6 \pm 8.8)\ \text{GeV}^{-1}$$
$$a = 1.12 \pm 0.14$$
$$b = 0.924 \pm 0.075$$
$$c = 0.562 \pm 0.019$$

with $\chi^2/NDF = 1.06$.

The position of the maximum of cascade curve (1), $t_{max} = \frac{p}{c}$ is shown in the second column of the Table. The t_{max} calculated by the formula

$$t_{max} = 1.01\,(\ln E/\varepsilon_{cr} - 1)$$

[10] (approximation B) for $\varepsilon_{cr} = 15.8$ MeV [3] are given in the third column of the Table. The fourth column shows the value of t_{max} obtained by Monte-Carlo calculations [5] for γ-quanta (0.5 t subtracted)*.

Table

E[GeV]	$t_{max} = P/c$	$t_{max} = 1.01(\ln E/\varepsilon_{cr} - 1)$	$t^{\gamma}_{max} - 0.5$
5	4.64±0.31	4.76	5.46
9	5.61±0.33	5.40	6.14

* According to [10] (approximation B) t_{max} (primary positron) = t^{γ}_{max} (primary γ-quantum) - 0.5.

Conclusions

The data were obtained on the longitudinal development of the electromagnetic shower in lead glass TF-1-000 produced by 5 and 9 GeV positrons by Čerenkov radiation of the shower particles. The results are well described by function (1) with the constant exponential decrease C and the power index p which linearly depends on the logarithm of the primary particle energy.

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Бицадзе Г.С. и др. E1-86-87

Продольное развитие электромагнитного ливня, вызванного позитронами с энергией 5 и 9 ГэВ в свинцовом стекле

С целью изучения продольного развития электромагнитного ливня в свинцовом стекле ТФ-1-000 был изготовлен специальный счетчик. Измерения проводились на пучке позитронов с энергиями 5 и 9 ГэВ. Энерговыделение ливня, регистрируемое по черенковскому излучению, измерено на глубинах от 1 до 19 радиационных длин. Приведены результаты аппроксимации экспериментальных данных функцией

$$\bar{A}(t,E) = A_0 E \frac{1}{N_0} t^p \exp(-ct),$$

определены положения максимума каскадной кривой.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Longitudinal Development of Electromagnetic Shower Produced by 5 and 9 Positrins in Lead Glass

With the aim of studying a longitudinal development of electromagnetic shower in lead glass TF-1-000 a special counter has been designed. Measurements were performed on the 5 and 9 GeV positron beam. The shower energy deposition has been registered by the Čerenkov radiation measured at the 1 to 19 radiation lenghts. The results of experimental data fitting by function

$$\bar{A}(t,E) = A_0 E \frac{1}{N_0} t^p \exp(-ct),$$

are presented, and the place of cascade curve maximum is defined.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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