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E.M.BOJAKHCHYAN, I.A.KEROPYAN, N.I.NIKITIN

SOME DATA ON FLUCTUATION OF ENERGY LOSS IN A SHOWER DETECTOR

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YEREVAN PHYSICS INSTITUTE

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Yerevan 1979

To detect high-energy electrons and photons, the total-absorption spectrometers are widely used, mainly the three types: a big size $NaJ(T\ell)$ scintillation spectrometers described by R.Khofstadter et al. [1,2], the Cerenkov lead-glass spectrometers [3,4] and lead-scintillation sandwiches [5,6]. The resolution typical for these devices at 1GeV energy is equal to 2, 10 and 22%, respectively (FWHM). Being considerably inferior to the continuum in energy resolution, the lead-scintillation detectors have some preferences: they are more accessible, easy to be made, and it is easy to satisfy the condition of total absorption of shower in them by means of increasing of the thickness.

1. Construction

Four identical moduli of the lead-scintillation detector were designed for separate detection of two photons. The channel for detection the one photon consists of two moduli placed one by another. Each of them contains 10 plates of plastic scintillator of (450 x 350 x 10) mm size. The scintillator's plates coupled by a glue contact on both sides with short lightguides of 100 mm height (Fig.1). In order to reach the best contact of the lightguides and scintillators, the latters were combined into a packet and their buttends were processed from the lightguides side. Gluing of the lightguide together with the packet was performed by epoxy pitch ED-5 at once. The packet's thickness is 15 cm, which corresponds to the diameter of the photocathode used PMT-49Б in order to provide a better homogeneity of the light collection over the laminated medium depth. The lead sheets of 4 mm thickness, served as converters in order to cause the electron-photon showers, were put down into the gaps between the scintillator's plates. The total thickness of the converter is about 7 rad.len.. The module was scanned from the both sides by photomultipliers which were fixed to the lightguides on an optical contact by attracting rubbers with the total force ~ 6 kg.

The photomultipliers were supplied by two stable-voltage sources. One of the sources joined up in usual way, provided the total supply, and the second one stabilized voltage between the anode and the last dynode. The necessity of this is connected with the noticeable change of the amplitude of the signal in the output of the photomultiplier with increasing the pulse load. The increase of the load results in the decrease of the difference of voltage, mainly between the last dynode and the anode. Although the voltage on the last dynode gap does not affect both the amplification factor and the electron avalanche collection on the anode in a wide range of values, the released voltage distributing among other dynodes results in the increase of the signal amplitude on the output of the photomultiplier. In Fig.2 the result of the voltage stabilization on the last dynode is shown. The output signal amplitude at single loading was 1 v and the current through divider was 1 ma. The small increase within a few percents is explained by the same effect on the last but one (etc.) dynode gap.

2. Preliminary Calibration

The moduli calibration was performed with the secondary electron beam of the Yerevan Synchrotron. The photons of the primary beam formed and purified from the charged component, were converted to the electron-positron pairs in a thin lead target. The electrons of certain energy were separated by a deflecting magnet and through the collimator (2.5 x 2.5) cm hit on the shower detector. The electron energy during the calibration varied from 0.7 to 4 GeV. The beam monochromaticity was ±1%.

The photomultiplier signals were summed by blocks and then they came to the general mixer. All the mixing circuits were passive. The summarized signal from one (two, three) moduli through the amplifier came to the analyzer. All the photomultiplier's voltage was equal, and the amplitudes flattening was done at the output passive attenuators. At the initial stage the two output amplitudes of each module were flattened. Then the flattening of the signal amplitudes between them was done, for which the signals of both the first and the second moduli came to the mixer through the attenuators and the amplitudes spectrum was measured by the analyzer dependence on the attenuation either in the first or in the second shoulder. The amplitude spectrum width determined at a half-high sum of the two moduli, and the optical attenuation was chosen by the curve's minimum. The amplitudes were flattened with the accuracy not worse than ±1db. In Fig.3 is shown the curve of the dependence of the resolution on the amplitudes ratio of the first and the second moduli signals.

3. The Results

In Fig.4 is given the behaviour of the straggling shower's energy (E_{res}) after the laminar medium containing 7 rad.len. of lead at the increase of the electron energy. The data are obtained by the comparison of the pulse amplitudes of the sum of three and one moduli of the shower detector assuming the losses after the three moduli unessential. The share of the shower losses increases following the electron energy as power dependence E_e :

$$\frac{E_{res}}{E_e} = K E_e^{\alpha}$$

where $K = 0.15$ and $\alpha = 0.36$. Correspondingly the energy dependences of the amplitude differ from the linear dependence. The deviation from the linearity can be compensated for not very large energy intervals by choosing the width of the additional converter in front of the detector, since the shower energy share absorbed by the front converter decreases, while the non-detected residue increases as the electron energy grows.

The total amplitude of the two and three moduli practically increases linearly with the energy growth, since the losses are small: the addition of the third module results in increasing of the amplitude by (3 ÷ 4)%. One can assume that in three blocks the shower is fully absorbed, and the energy resolution is determined by the internal properties of the detector, that is: laminarity and uniformity of the medium, the converter's material, the identity of the light-collection conditions from different plates, etc. In Fig.6 the resolution is given for the two and three moduli. The third module yields the insignificant improvement up to 1%. The variation of the resolution well agrees with the electron energy as power dependence

$$\frac{\Delta A}{A} \simeq 26/\sqrt{E}\ (\%)$$

The fluctuation curve is close to the normal distribution (to the energy 1 GeV corresponds the root-mean-square deviation σ equalled to 12%).

The amplitude fluctuations of the output signal of one module are shown in Fig.7 by crosses (the absorber's thickness is 7 rad.len.). The are essentially larger than those for the two and three moduli in Fig.6, which takes place on account of the loss fluctuations. Supposing that

$$(\sigma A/A)^2 = (\sigma A/A)_{in}^2 + (\sigma E_{res}/E_{abs})^2 ,$$

where $(\sigma A/A)_{in} = (12/E_{abs})\,\%$ are the fluctuations determined by the internal properties of the medium, we obtain the values of $\sigma E_{res}/E_{abs}$ given in Fig.7 by circles. These values are the limit lower resolution for the seven rad.len. of the given laminar medium. The share of the fluctuation losses increases with the growing of the electron energy.

The relative fluctuations $\sigma E_{res}/E_{res}$ of the losses of the shower's energy can be extracted from these data. As is seen in Fig.8, they are well described by the dependence of the form:

$$\sigma E_{res}/E_{res} = 35\, E_{res}^{-0,3}\ (\%)$$

where E_{res} is measured in GeV-s.

To this relation correspond the fluctuations of the number of particles N in the share of the shower beyond the detector

$$\sigma N/N \sim N^{-0,3}$$

assuming that their average energy does not depend on E_{res} . Anyhow (due to the growing of the average energy of the particles at increasing of E_{res}) the fluctuation dependence must not be weaker than the given one - the magnitude of power in module $\geqslant 0.3$.

The dependence of the detector's characteristics on the input place of the particles was checked at 3.5 GeV electron energy. In Fig.9 are given the curves of the resolution variation and of the amplitude in two perpendicular directions relative to the detector's centre. Both the amplitude and resolution remain constant all over area except for the region of about 5 cm at the detector's edges, determined by the transverse dimensions of the shower and the cross section of the incoming electron beam.

In conclusion the authors should like to express their gratitude to Dr. V.M.Kharitonov for his constant attention and assistance in the work.

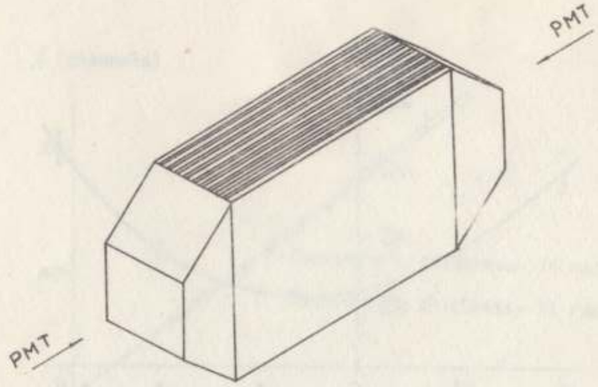

Fig. 1

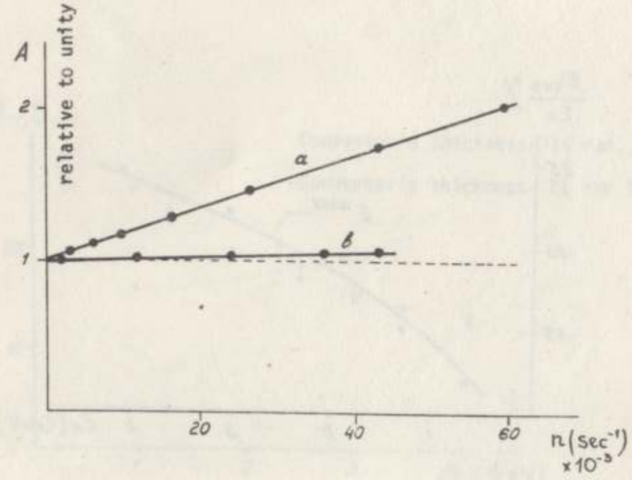

Fig. 2

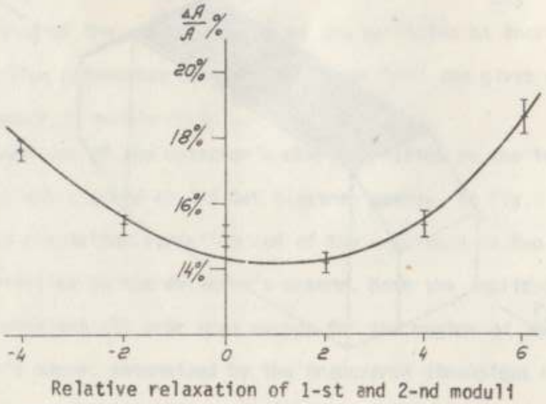

Fig. 3

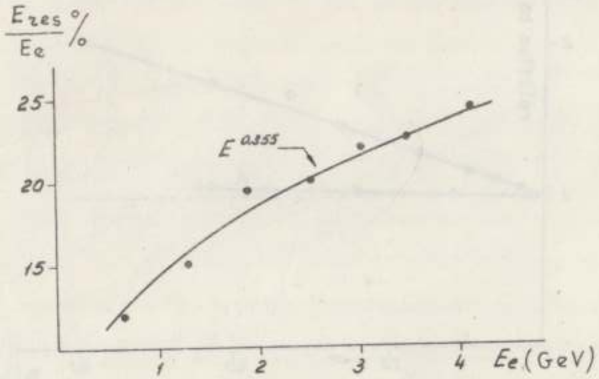

Fig. 4

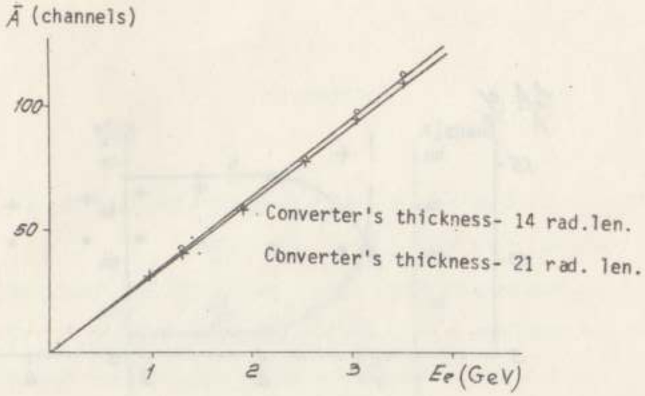

Fig. 5

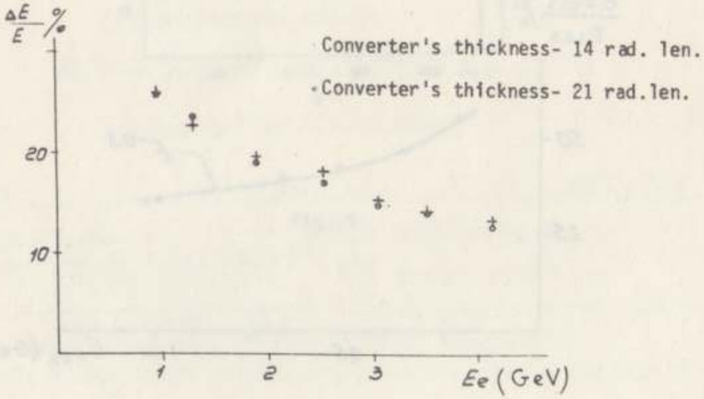

Fig. 6

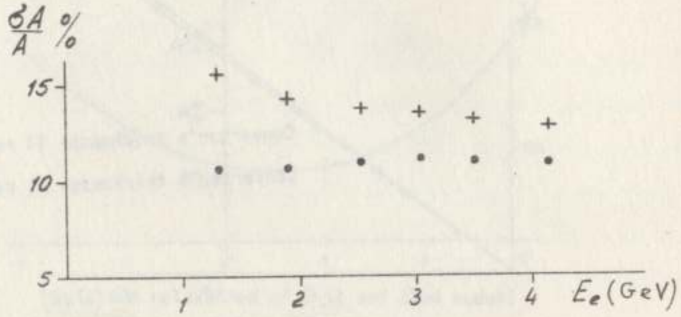

Fig. 7

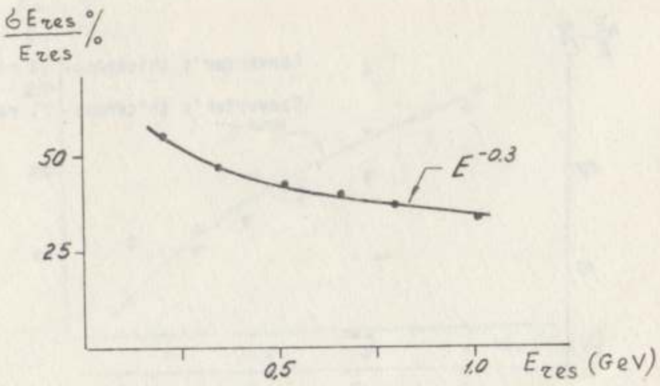

Fig. 8

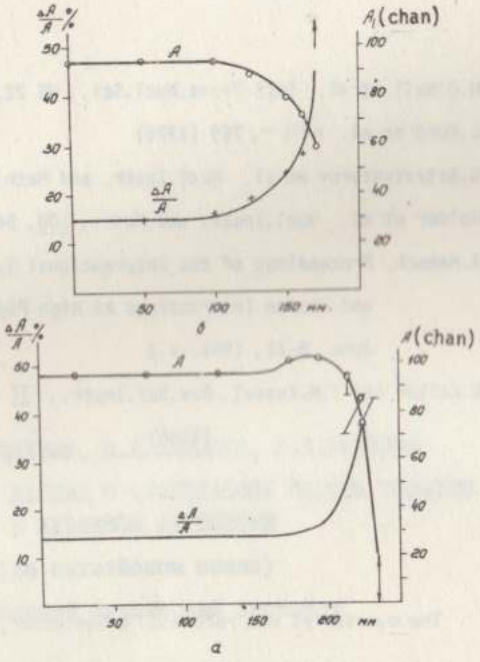

Fig. 9

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НЕКОТОРЫЕ ДАННЫЕ О ФЛУКТУАЦИЯХ ПОТЕРЬ ЭНЕРГИИ
В ЛИВНЕВОМ ДЕТЕКТОРЕ
(на английском языке)
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