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ELECTROMAGNETIC CASCADES PRODUCED BY GAMMA-QUANTA WITH THE ENERGY E_γ=100-3500 MeV. IV. Correlations

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I. INTRODUCTION

The problem of correlations in an electromagnetic cascade process (ECP or e.m. shower) hasn't been practically considered at all in literature, neither experimentally nor theoretically, although some fragmentary aspects in the field were sometimes broached yet. So, for example, as is demonstrated in ref. [1], the correlations between the numbers of shower electrons at high enough energies of initial electrons (10 GeV and more) are such strong that can be used to the considerable improvement of extraction of the electrons from π-meson beam.

In general, the knowledge of the correlations between different characteristics of the ECP created by high energy gamma-quanta (GQ) or electrons in dense media may be regarded from practical point of view as a useful tool for sufficiently trustworthy determination of the energy of primary GQ or electrons, especially when the dimensions of detectors used in an experiment are far from to be large enough as is often the case in practice or when one would like to minimize the dimensions of an apparatus for high energy GQ and or electron registration. Among the possible ECP characteristics being of interest with this regard such are important first of all which can be simply measured by the majority of detectors, viz. the longitudinal and lateral shower electrons ionization loss (IL) deposition. So, the problem may be formulated as follows: how large along the shower axis and broadwise must be an active layer of a calorimeter to register, on the average, a fraction A of the total IL in an e.m. shower produced by a GQ of a given energy?

The aim of this work is to attack the aforesaid problem using the pictures of the 180 l xenon bubble chamber (XeBC) of ITEP (Moscow) [2]. This chamber has relatively large dimensions in units of radiation lengths (RL), 25.7x11x10, and owing to clearly seen electron and positron (later: electron) tracks recorded on a picture it makes possible to get comprehensive enough experimental information about e.m. showers up to some GeV of primary GQ energy E_γ.

As has been mentioned in the first paper [3] of a series, our investigation of the ECP is based on analysis of 908 events of e.m.showers registered in the XeBC and fulfilling the appropriate selection criteria, in particular, 1) the shower axis (SA) is in the picture plane and 2) the minimum risk for a sample of selected showers to be cut off by the chamber [3]. All these 908 events of e.m. showers have been grouped into 22 intervals of primary GQ energy E_γ and the summary projection range of shower electrons (SER) in a picture plane were measured within a square $\Delta t \Delta p$ in step of $\Delta t = 0.6$RL along the SA and $\Delta p = 0.3$RL in its transversal direction. The cut-off energy of shower electrons as 0.5-1.5 MeV. By means of a simple computer simulation of e.m. showers in liquid xenon a conclusion has been drawn /4/ that the SER corresponds with the relevant IL, on the average to about 3%, at least in the central shower region where ~ 90% of the total IL is released.

II. LONGITUDINAL-LATERAL SPREAD

Figs. 1 and 2 display scatter plots of IL in e.m. showers created in liquid xenon by GQ of energy $E_\gamma = 375 \pm 35$ MeV and 3375 ± 125 MeV, respectively, when a fraction A of the total IL is fixed as A = 0.9, 0.8, 0.7 and 0.6. Every marked point (t, p) on the diagrams means that between two parallel planes each perpendicular to the projection plane and separated a distance p from the SA on its both sides whereas the depth of an absorber, measured from the conversion point of a primary GQ, is equal to t, the fraction A of the total shower IL is released. Because any fixed value of S can be obtained by means of different sets of (t, p), the relevant points for some individual event of e.m.shower often form the regular enough sequences, particularly vizualized at higher values of A and E_γ when fluctuations are not so significant. Another remark must be made too, concerning the scatter of (t, p) points, namely as one can see on figs.1 and 2, their collimation increases with decreasing A, especially at higher E_γ, indicating that the main contribution to the fluctuations of IL is caused by the remotest low energy shower electrons. Moreover, the lower is the fraction A the most collimated are the points close by the average dependence of t vs. p shown in figs.1 and 2 by solid lines.

III. AVERAGE LONGITUDINAL-LATERAL CORRELATION

Figs.3 show the dependence between average values of the depth t and width p in the projection plane for e.m. showers produced in liquid xenon by GQ at eight values of energy E_γ: 100, 175, 310, 455, 1125, 1625, 2625 and 3375 MeV. The quoted results refer to four different values of the fraction S of the total IL of shower electrons released within an absorber volume limited to t along the SA and 2·p across it with the SA in the middle. It is necessary to emphasize that each curve has been obtained as averaged over all shower events of a given sample of energy $E_\gamma \pm \Delta E_\gamma$ including some limited number N_γ of events (varied from 11 to 86) and so being an estimation only

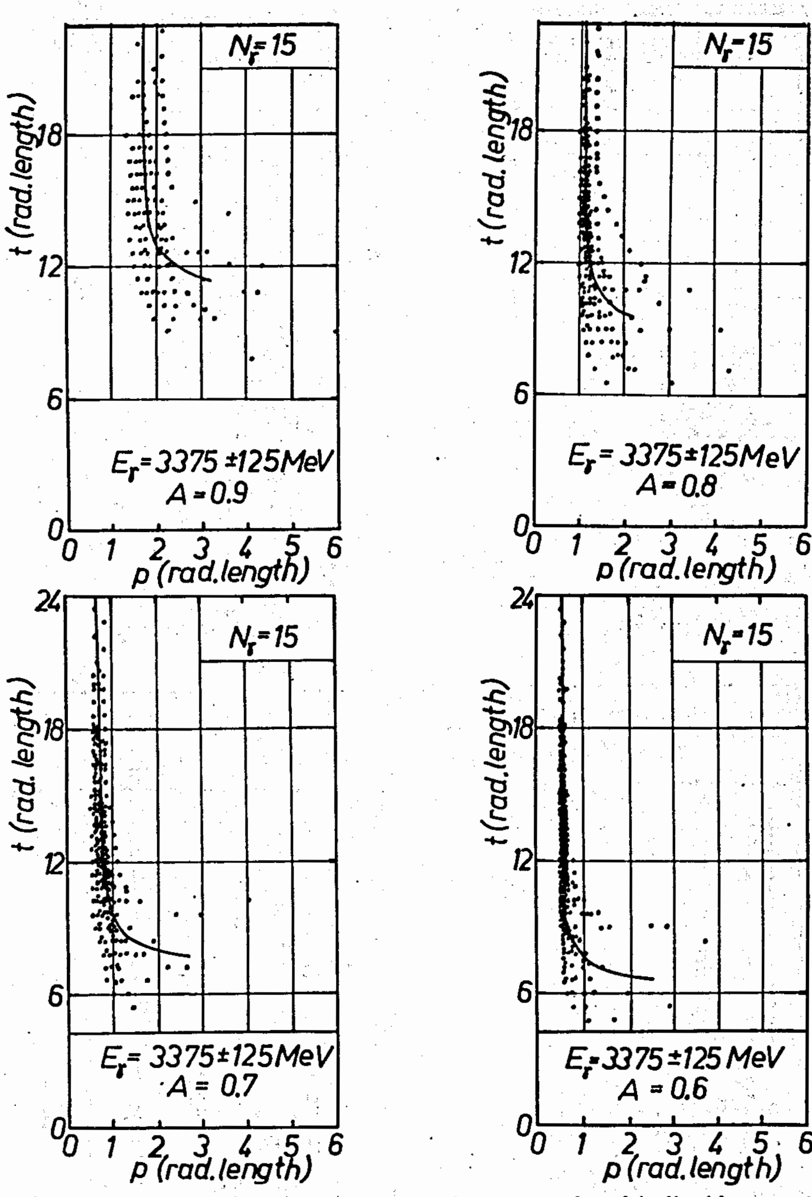

Fig.1. Scatter plots of points (t, p) for e.m. showers produced in liquid xenon by GQ of energy $E_\gamma = 3375 \pm 125$ MeV; t and p are such coordinates measured in the picture plane that within a box of a thickness t along the SA and limited in its lateral direction by two parallel planes each distant p from the SA the fraction A of the total IL is released (t is measured from the conversion point of a primary photon). Solid lines show the t vs.p dependence averaging over all sample including N_γ shower events.

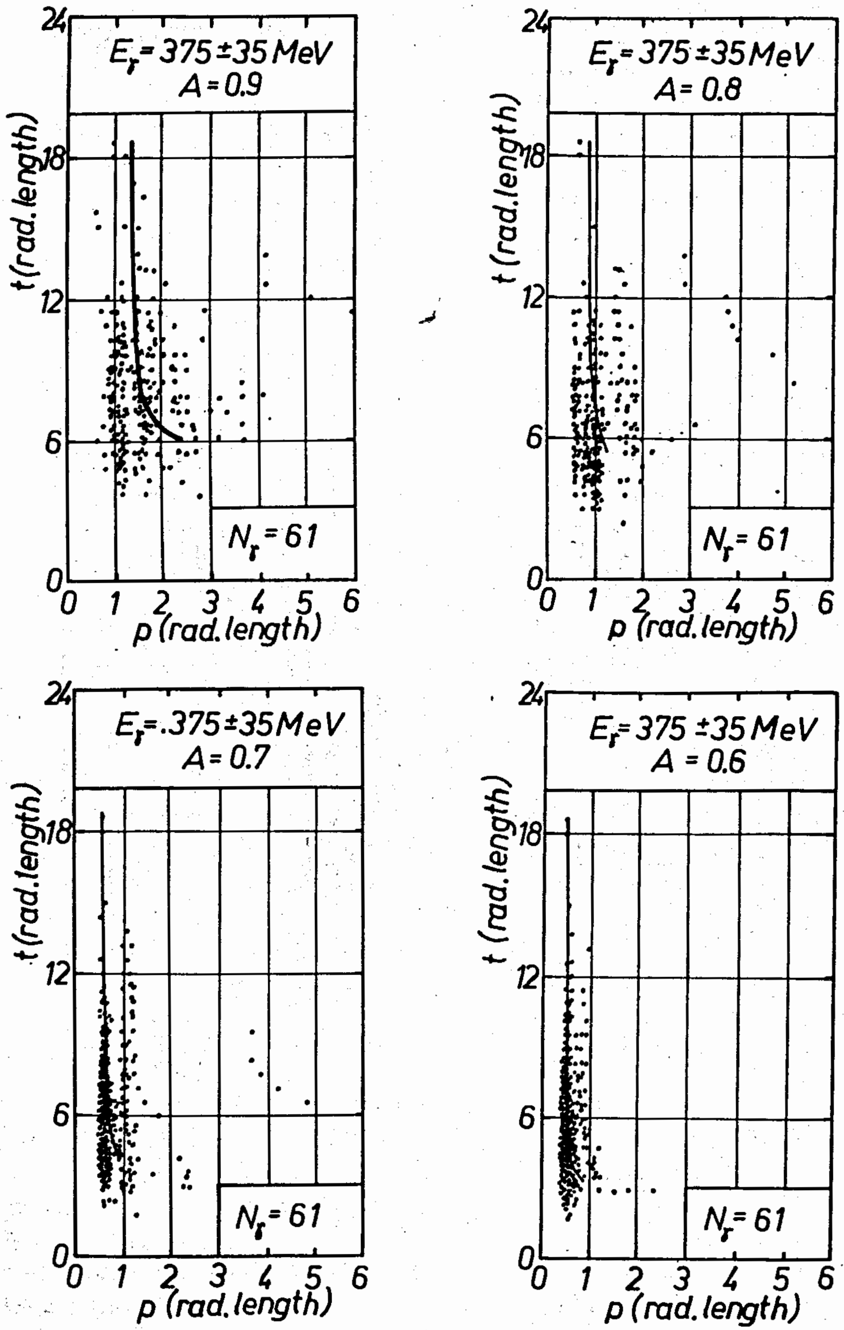

Fig.2. Same as fig.1, for the primary photon energy of 375 ± 35 MeV.

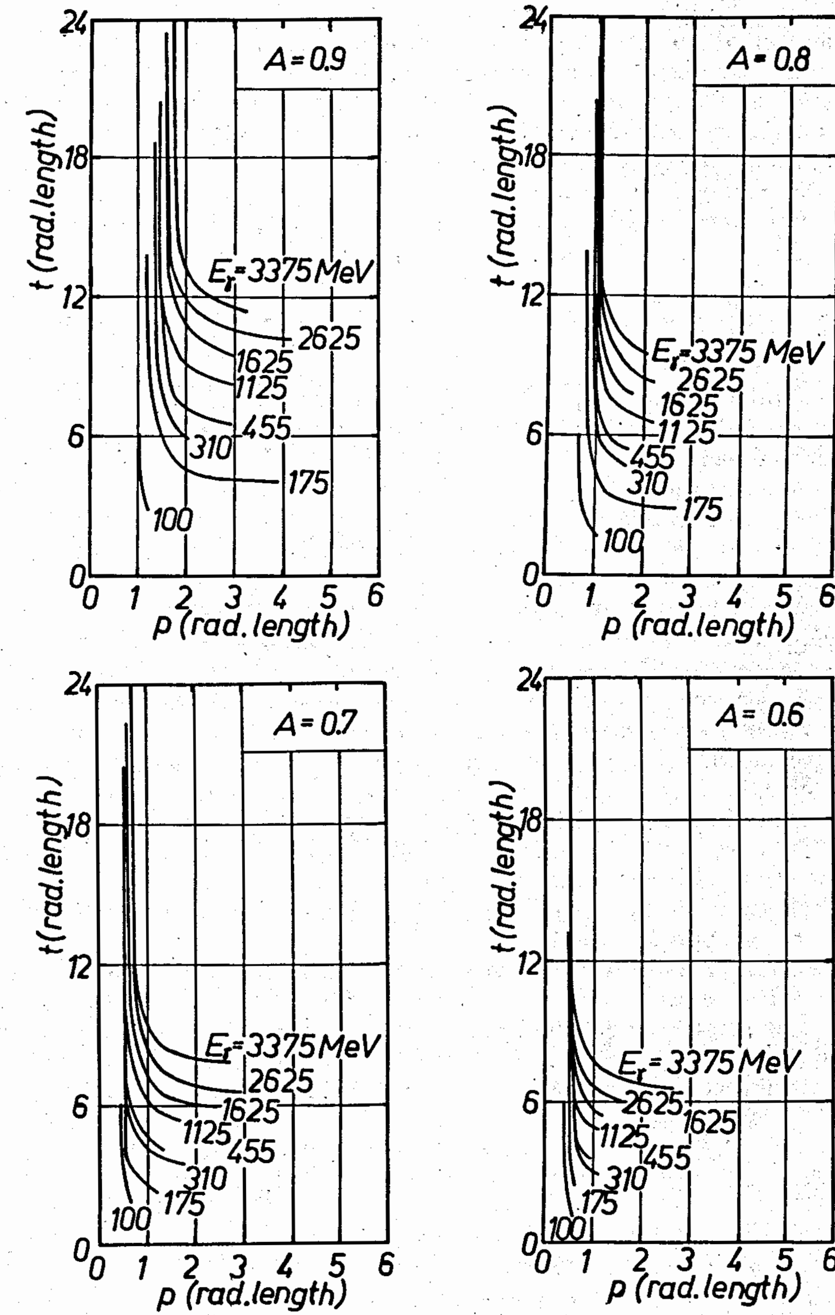

Fig.3. Averaged (t, vs.p) dependence for different A and E_γ (see also fig.1).

of the respective average dependence between t and p at a fixed fraction A of energy E_γ. One can notice that within all analysed interval of energy E_γ = = 100-3375 MeV e.m. showers are to be distinguished with regard to their energy, on the average and to the acceptable degree, only when the dimensions of an active layer of the calorimeter are sufficiently large, viz. at $t > 15$RL and $p \gtrsim 3$Rl, respectively. At lower values of (t, p) it is difficult to infer reliable enough from a measured value of IL what was the energy of a photon initiating shower.

IV. CONCLUSIONS

The results of the investigation of the longitudinal-lateral correlation in e.m. showers induced in liquid xenon by GQ with energies of 100-300 MeV can be summarized as follows:

1. The dimensions (t, p) of an active volume of a calorimeter within which some fixed fraction A of the total shower electron IL is released are submitted to relatively large fluctuations, particularly at A close to unity and at lower E_γ values.

2. The possibility of distinguishing, on the average, between e.m. showers of different total IL turns out reliable enough when the dimensions of active absorbent layers are sufficiently large. For instance, at E_γ = 3375 MeV t and p shouldn't be less than about 15RL and 2-3RL, respectively. At lower energies E_γ these values are correspondingly less. If the maximum dimensions of a calorimeter are inferior to necessary ones it isn't possible to conclude whether the registered IL is produced by a GQ having higher value of energy E_γ but only some low fraction A of its IL is deposited within the layer or quite the reverse. Moreover, from the discussed point of view it seems to be reasonable to use for the total shower energy determination rather sandwichs of independent and relatively thin oblong active layers each heaving a thickness of $\sim$ 1RL instead of thick layers or cylinders.

3. Our results concerning the lateral spread of IL in e.m. showers which are expressed in terms of a distance p from the SA and measured in the picture plane become practically coinciding with the ones expressed by a radial width when p is sufficiently larger viz. at $p \gtrsim$ 2-3RL because e.m. showers are narrow enough in liquid xenon and within the considered interval of energy E_γ.

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