EXPERIMENT "PAMIR"-III. COPLANAR EMISSION OF HIGH ENERGY γ-QUANTA AT INTERACTION OF HADRONS WITH NUCLEI OF AIR ATOMS AT ENERGIES ABOVE 10^7 GEV

Collaboration of the Experiment 'Pamir' *

ABSTRACT

At a systematic analysis of large γ-families, detected in X-ray-emulsion chambers, cases of multicore halos have been observed, and among them five events in which the halo is divided into three or four separate cores with their alignment observed in the target diagram (coplanarity of axes of corresponding electron-photon cascades). The halo alignment (tendency to the straight line) leads to the azimuthal asymmetry ("thrust"). The analysis of lateral and momentum distributions of particles in these families shows that they also have "thrust" that correlates with the direction of the halo core alignment.

1. Introduction

Recently halos - diffuse zones of darkening on X-ray films in the central part of large γ-families - are intensively studied in the framework of experiment "Pamir" /1,6/. While scanning on microdensitometers, five standard levels of electron number density (excess over the background) in the range Δn = 0.015-0.16 μm^{-2} are used. The area S_i bounded by the corresponding isodense, and the total number of electrons N_i confined at this area, have been determined for each level /2,3/. For quantitative evaluations a family with halo is defined as the family in which (1) the number of electrons N_3 on the third level of observation (Δn = 0.04 μm^{-2}) satisfies the condition $N_3 \geqslant 2 N_3^{(\gamma)}$, where $N_3^{(\gamma)}$ is the calculated number of electrons for the same level of observation in electron-photon cascades (EPC) from above-threshold γ-e particles of the family; (2) the area $S_3 \geqslant 1$ mm; (3) the number of above-threshold particles providing the first two conditions are fulfiled is > 1.

Analysis of the halo on the third level of observation has shown that its basic characteristics (spatial distribution of energy density, axial symmetry, values N_3, S_3 and their dependence on the depth in the chamber) allow to interpret most of them as a certain stage of the EPC development from the γ-e particle that has been formed with a large value of the Feynman variable ($x \geqslant 0.1$) /2/.

Thus, the presence of halo indicates the production of high energy γ-e particles in atmospheric cascades.

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By the densitometric scanning of ~ 80 γ-families with $\sum E_\gamma \geqslant 250$ TeV 36 events with halo have been detected, and in 15 of them several halos (2-4) are observed (multicore or multiple halos). Each component or core was considered as a separate halo, if the above conditions were satisfied, the number of electrons in it was not less than 5% of N_3, and the distance between the cores exceeded that between the neighboring density level isodenses. In three- and four-core events a quasilinear alignment of halo cores is observed, i.e. coplanarity of axes of corresponding EPC /2,5/.

In the present report we continue investigating the nature of halo, structure of multicore halo, their alignment as well as correlations of the γ-family particles alignment with that of halo.

2. Structure of halo on upper density levels

The study of the halo structure on higher levels ($\Delta h = 0.08$ and 0.16 μm^{-2}) shows that the ratios N_5/N_3 and N_4/N_3 fluctuate not much which should be the case with EPC, and that large (1.5 order) fluctuations of the size of halo at the given energy of families $\sum E_\gamma$ occur at all levels.

In Fig.1 the correlation field of points (N_i/S_i , S_i) for separate halo axes is shown. Crosses denote the results for high energy EPC according to calculations /4/. Small fluctuations ratios and proximity of the experimental mean value to the calculated one support the interpretation of halo as a definite stage of EPC development induced by a high energy quantum.

In the upper part of Fig.1 there are events with large halos which apparently begin to differ essentially from "electromagnetic" ones at the large depths of the chamber.

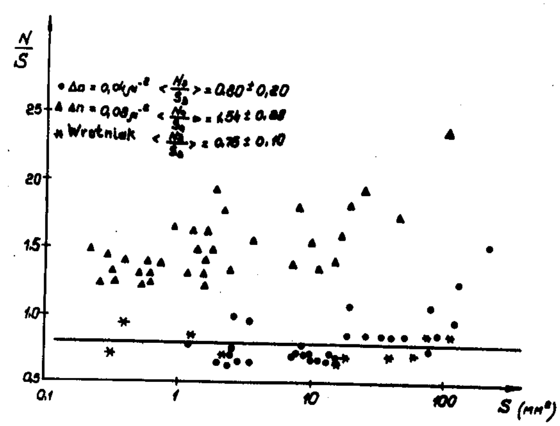

Fig.1

3. "Thrust" of halos and γ-quanta

Densitograms of events with multicore halos and their characteristics are presented in Fig.2a and Table 1, respectively. Each core of such halos may be considered as an event of generation of γ-e particle at a high altitude. Thus nuclear-electromagnetic cascades (NEC) are detected when several such particles are produced. Densitograms show an obvious tendency of halo components to be arranged

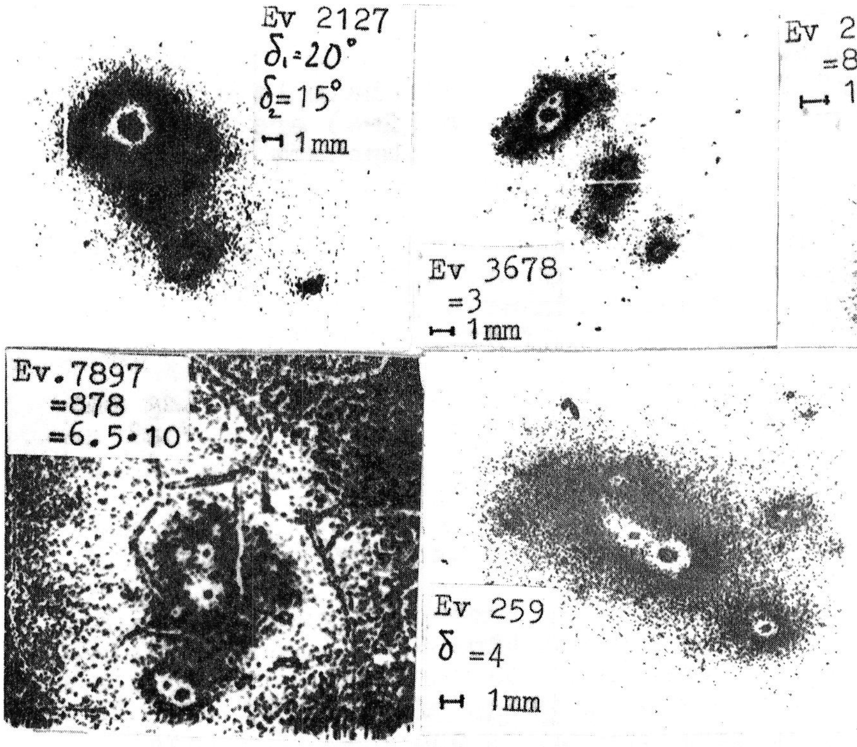

Fig.2a

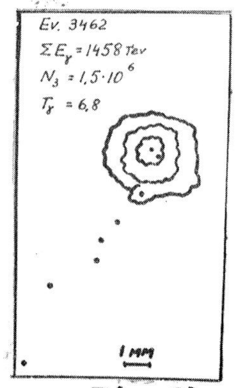

Fig.2b

on the target diagram along one line, i.e. coplanarity of axes of corresponding EPC (alignment). As a quantitative measure of the alignment may serve the angle formed by lines that connect the second in number $N_3^{(i)}$ halo core with the first one and all the others. The estimate, based on experimental values of these angles, shows that the probability of a random imitation of the observed coplanarity in all five events makes $\sim 10^{-4}$.

The alignment of multicore halos leads to asymmetry in the distribution of transverse momenta - "thrust". As a quantitative dimension of "thrust" of halos or particles in families serves the value $T' = \sum_{i \neq k} |Z_{ik} \cos\theta_{ik}| / \sum_{i \neq k} |Z_{ik} \sin\theta_{ik}|$ where $Z_{ik} = R_{ik} E_i E_k / (E_i + E_k)$; E_i, E_k are the energies of i-th and k-th core of the halo or particle, respectively; θ_{ik}, R_{ik} is the difference of azimuthal angles and distances in the plane of traget diagram between appropriate objects. (The value T' by its physical meaning is close to thrust used in analysis of collisions at high energies). Values of T' are plotted in table 2 for halo cores and above-threshold γ-e particles of the family with $f' = E_\gamma / \sum E_\gamma \geq 0.04$. It is seen from table that the "thrust" of γ-quanta in families correlates with that of halos in events with multiple halos.

As far as most low energy γ-quanta come from low altitudes, this cor-

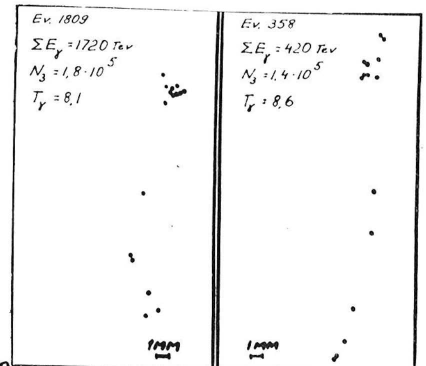

Fig.2b

Table 1. Data on multicore halos

N event	$\sum E_\gamma$, TeV	$N_3/10^5$ S_3, mm	$x=N_3^{(i)}/N_3$, %	$\sum E_\gamma$, TeV in core	T'
275	2350	10.3 14.7	46, 25, 20	525, 678, 230	2.6
259	506	7.5 11.4	76, 12, 6	92, 80, 98	5.6
3678	1638	11.7 16.7	67, 17, 6	564, 248, 120	5.3
2127	1720	7.2 10.4	80, 6, 5,8	375,21,121,141	4.2

Table 2. Mean "thrust" of γ-quanta and halo axes

Number of axes	0	1	2	3	4
Number of events	38	10	10	4	1
Mean "thrust" of halo axes				4.4±1.2	4.2
Mean "thrust" in γ-e particles with	1.4±0.24*)	1.15±0.2*)	6.1±2	2.8±0.6	5.2
$f' \geq 0.04$	2.8±0.4	3.0 ±0.4	6.4±1.9	3.1±0.6	5.2

*) for the arbitrarily chosen direction

relation shows that along with the generation of γ-e particles whose "thrust" is established by halo, at high altitudes other particles (hadrons?) are also generated with "thrust" that provide the conservation of the direction of "thrust" in the further development of NEC in atmosphere.

The "thrust" of quanta occurs not only in events with multicare halos but is observed also ($T' \geq 5$) in some families without or with one halo. Examples of target diagrams of such events are presented in Fig.2b for γ-e particles with $f' \geq 0.04$.

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