EXPERIMENT "PAMIR"-IV. ANALYSIS OF SUPERFAMILY WITH HALO OF ELECTROMAGNETIC NATURE DETECTED IN DEEP XEC

Collaboration of Experiment "Pamir"*

1. Introduction. The family Pb2-11 was detected in the multilayer lead XEC with total thickness of 100 c.u. exposed at the Pamirs. Each lead layer was 1 cm thick, the first registering layer being located under 2 cm of Pb($\simeq$4 c.u.). The family comprised a narrow group of gamma-rays which near the maximum of cascade development($\simeq$14 c.u.) produced a dark spot of optical density $D \gtrsim .4$ over area $S \simeq 25\,mm^2$. The narrow group of gamma-rays was traced up to 14th layer corresponding to 30 c.u. Deeper in the chamber, for the space of 70 c.u. no hadron cascade was observed. Thus, the pure electromagnetic halo could be assumed.

Preliminary results of the analysis of the family Pb2-11 has been presented in /1/. We consider here in more detail the methods of estimation of energy of primary particle and height of nuclear interaction responsible for the observed halo.

2. Longitudinal and lateral characteristics of halo. To determine ΣE_γ released in the halo, the area of halo was scanned by two instruments at various depths in lead. From the measured optical densities we inferred the density of number of secondary electrons n(r) and subsequently the total number of particles N(4mm) within a circle of radius 4 mm. When determining ΣE_γ, restriction of the scanned area should be regarded. The ratio of the total number of secondary electrons in lead to the particle number within a circle of 4 mm, K(4 mm), was calculated for maximum of an electron-photon cascade(EPC) induced by primary gamma-ray and electron with various energies E_γ. The value of K(4mm) weakly depends on E_γ and is equal to 24. Thus, $\Sigma E_\gamma = K(4mm) \cdot \beta \cdot \int_0 N(4mm) \cdot t dt$, where β=7.5 MeV. After taking into account the scattering of shower particles within a gap, the total energy was found to be ΣE_γ=560 and 610 TeV, respectively, for two scanning instruments.

In /2,3/, the EPC from one or few high-energy gamma-rays have been shown to dominate halo production. To evaluate the height ($t_{a/2}$) and the energy (E_0) of the primary interaction producing the halo, experimental characteristics of halo were compared with the characteristics calculated in /2,3/ for air-lead EPC induced by high-energy gamma-ray. The Table below lists the interaction parameters used in three calculational versions.

The choice of the best version of calculations was made by comparison of experimental and calculated lateral

---

* Full list of authors see in HE 1.2-12. The author of this paper is also Zatsepin G.T., Institute of Nuclear Research, Academy of Sciences of the USSR, Moscow

distributions for 9 depths in the chamber, because the comparison on a single depth turned out to be insufficient. As an example the distribution n(r) for three depths are plotted in Fig.1. The best agreement of experimental and calculated distributions is obtained for version II.

If lateral distribution in the halo at various depths are available, the transition curve for the halo longitudinal development within circles of various radii in the chamber can be obtained. Fig.2 presents the experimental and calculated transition curves for a circle of radius 4 mm. The best agreement is also achieved for version II.

Table

Versions of calculations	I	II	III
E_o, TeV	100	700	1400
τ_{a1z}, c.u.	3	3	9
n_γ	7	1	1

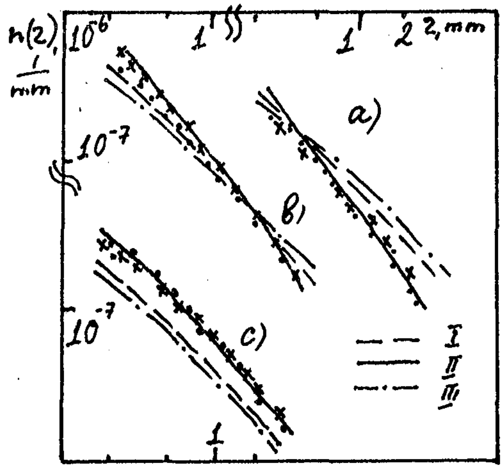

Fig.1. Lateral distributions n(r) for the depths in XEC equal to 8 c.u.(a), 14 c.u.(b) and 20 c.u.(c). Experimental data is observed with scanning systems of University of Tokyo (.) and P.N.Lebedev Physical Institute (x). Curves present results of three versions of calculations listed in Table

3. Lateral and energy distributions of individual gamma-rays in the halo

To obtain the characteristics of individual particles in the halo, spots from them were photometered at a depth of 6 c.u. taking into account overlapping /4,5/.

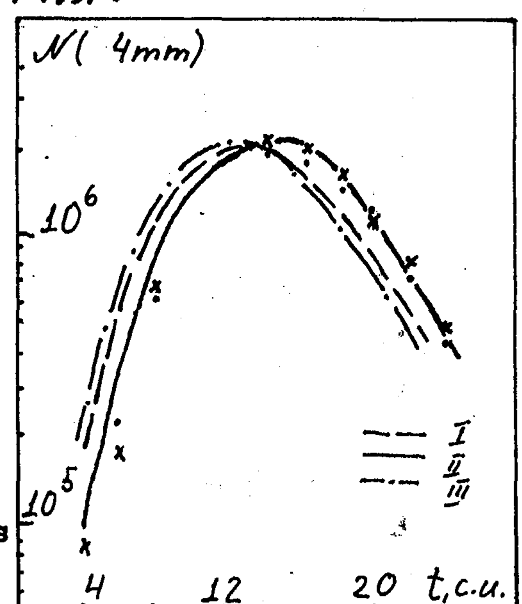

Fig.2. Transition curve N(4mm). Symbols are the same as in Fig.1.

Fig.3 presents the experimental energy spectrum of gamma-rays in the halo and calculated spectra for three versions of calculations and for version II with E_o=1000 TeV. The best description of experimental data gives version II with E_o = 1000 TeV.

Experimental lateral characteristics and multiplicities obtained for gamma-rays within halo area for two different threshold(4 TeV and 10 TeV) were compared with calculated ones/6/ and thus the values E_o=1000 TeV and $\tau_{a1z} \approx$ 3-5 c.u.

were obtained.

Distribution of the relative transverse momentum z_{ik} for gamma-rays in the halo and for all gamma-rays in the family are shown in Fig.4. The distribution for all gamma-rays has two maxima. The first maximum corresponding to the component with momentum $p_{em} \sim 2 \cdot 10^7$ eV/c, i.e. typical value for Coulomb scattering of electrons in the EPC, is caused mainly by gamma-rays in halo. The second maximum is caused by the component with characteristic nuclear transverse momentum $p_{nucl} \sim 2 \cdot 10^8$ eV/c. The height of nuclear interaction(τ_{air}) derived frOm the dependence $z_{ik}(\tau_{air})$/7/ is equal to $\tau_{air} \simeq 5$ c.u. both for gamma-rays in the halo and for all particles in the family.

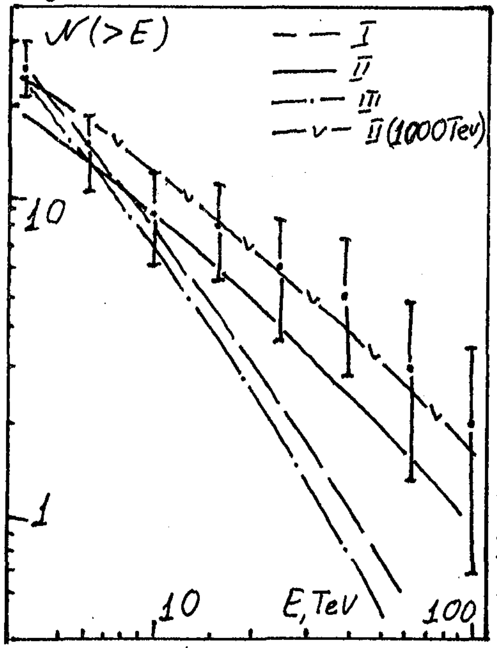

Fig.3. Experimental and calculated energy spectrum of gamma-rays in the halo. Calculations are made for three versions listed in Table and for version II with E_0= 1000 TeV

The same analysis was also applied to the integral distribution of relative transverse momenta of particles with respect to the direction of the particle with the highest energy (z_{i0}), and obtained estimation of the height is $\tau_{air} \simeq$ 4 c.u. also both for gamma-rays in halo and for all particles.

4.Conclusion. Summarizing the results of the analysis, we can infer that the observed halo is caused by the EPC induced by a single gamma-ray with energy $E_0 \sim 1000$ TeV and production height τ_{air} 3-5 c.u. The family is due to the nuclear interaction which has occurred at a height of 3-5 c.u. above the XEC.

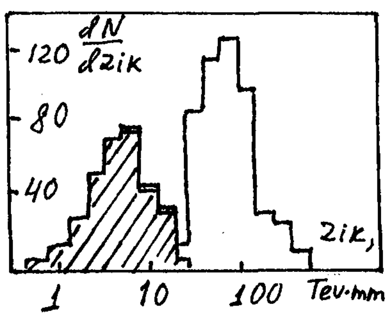

Fig.4.Distribution of z_{ik} for gamma-rays in halo(dashed) and for all gamma-rays in the family

It is important that the values of E_0 and τ_{air} obtained by analysing the halo development in the chamber and by analysing the lateral and energy distributions of family particles are in a good agreement.

Thus, the information on the longitudinal and lateral characteristics of electromagnetic halo allows estimation of the parameters of primary interaction producing the halo.

Energy of the primary interaction E_{int} can be obtained as a sum of energy of gamma-rays and hadrons outside halo/1/ and above estimated energy of halo equal to 700-1000 TeV, and the result is E_{int} 1200-1500TeV.

The transfer of the large energy fraction into the electromagnetic component is an important feature of the family. The observed event can be treated as detection of the charge exchange process $\pi^{\pm}\rightarrow\pi^{0}$ with Feynman variable $x \simeq .6\pm.1$.

References

1. Borisov A.S. et al. - Proc. of Int. Symp. on Cosmic Ray and Particle Physics, Tokyo, 1984, p.3-29.
2. Fedorova G.F., Managadze A.K.- Proc. 18th ICRC, 1983, v.5, p.466-469.
3. Ivanenko I.P., Managadze A.K., Roganova T.M., Osipova L.A. - Proc. 15th ICRC, 1977, v.7, p.267-280.
4. Aminava T.P., Lazareva T.V., Managadze A.K. - Acta Univ. Łodz. ZNUL, 1980, ser.II, v.32, p.199-216.
5. Ivanenko I.P., Managadze A.K., Roganova T.M. - Proc. 15th ICRC, 1977, v.7, p.280-284.
6. Adachy A. et al. - Prog. Theor. Phys., Suppl., 1964, v.32, p.154-191.
7. Baradzey L.T., Smorodin Yu.A., Solopov E.A. Preprint NN 103, 104, M.: FIAN, 1974.