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The halo and the high energy jet in stratospheric STRANA superfamily with $E_0 > 10^{16}$ eV

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Abstract: Gamma-hadron superfamily STRANA with $E_0 > 10^{16}$ eV and unusual features was detected by emulsion chamber at the board of stratospheric balloon. In the center of the family there was found a halo. The halo and the high energy jet producing it in the chamber are analyzed here.

Introduction

In 1975 in the emulsion balloon experiment at 30 km altitude there was detected a unique CR gamma-hadron family STRANA with energy > 10^{16} eV [see about experiment and installation in V.I.Osedlo, A.K.Managadze et al, *Anisotropic and alignment effects in STRANA superfamily with E_0 > 10^{16} eV* // Proc. of 30 ICRC. Merida 2007].

In addition to striking alignment effect the superfamily is unique because of the leading particle interacting once more in the chamber in 12th layer of target block. It is worth to note that no track of the particle was identified in upper 12 layers, that indicates that this particle is not heavier than He nucleus. A narrow bunch of secondaries appeared to be the result of this interaction, the jet developed rapidly, was detected as tracks in nuclear emulsions and produced a large diffuse spot — halo — in the center of the family in X-ray films of the calorimeter.

Jet from the leading particle

Lateral distribution of tracks in the jet (see an example in Fig. 1) was measured and analyzed for many emulsion layers in target. Experimental lateral distribution was obtained counting numbers of tracks per area unit in scaled sketches of the jet from the field of vision of immersion microscope.

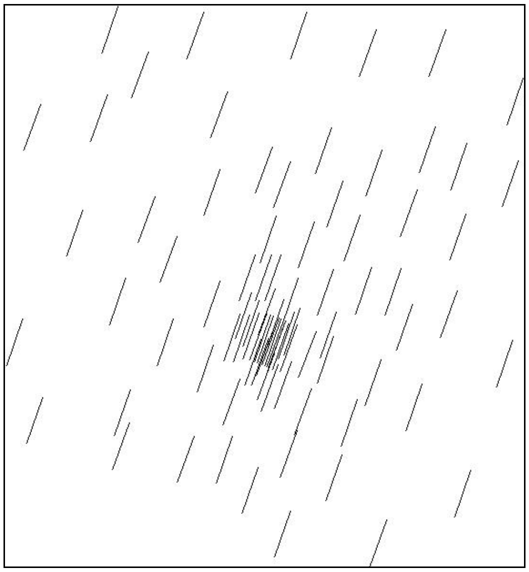
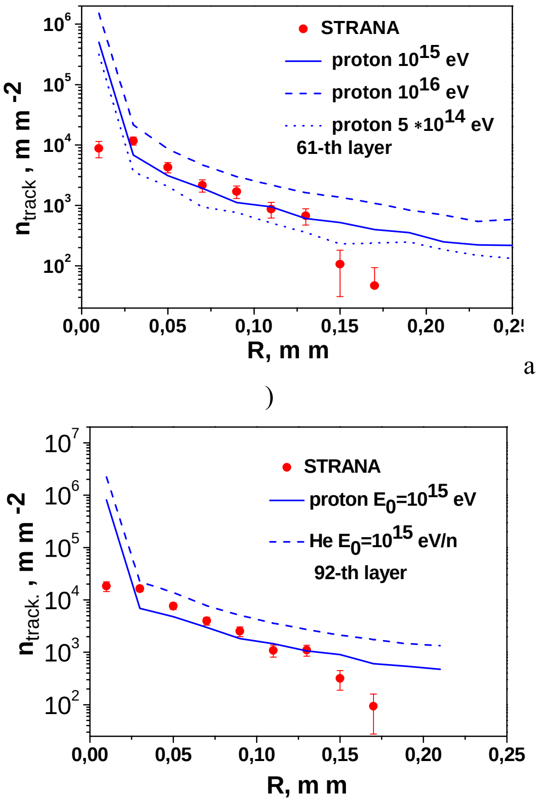


Figure 1: Schematic view of the jet in nuclear emulsion.

For comparison special simulations of such jet development in a chamber were made. In the simulations there was used program system ECSim [1], describing nuclear-electromagnetic cascade advancing through stratified body of emulsion chamber. In the program QGSJET interaction model was incorporated. For the analysis cascades from protons and from He nuclei with various energy were simulated. Output characteristic was a lateral distribution of charged particles density (mainly electrons and positrons) at every registration level in the chamber. The comparison of calculated and experimental distributions in jet for 2 observation levels (as examples) is presented in Fig. 2.



a
)

b)

Figure 2: Comparison of experimental lateral distributions in the jet with calculated ones in detection level № 61 (a) and № 92 (b).

As one can see in Fig. 2 the jet from the leading particle can be described well by cascade from a nucleon with energy (1÷2)×10^{15} eV. The analysis picture in other detection layers is similar.

Halo in the STRANA superfamily

Halo phenomenon observed earlier only in mountain experiments is detected for the first time in a pure interaction registered at stratospheric altitude [2]. For halo formation the concentration of significant energy flux on relatively small film area is necessary. When produced inside chamber by a high energy hadron the large dark spot can be formed by secondaries scatter due to nuclear-electromagnetic development in chamber, a hadron halo never occurs so large as an electromagnetic one. In view of that the study of the central fragment is especially interesting. Development of the halo in the calorimeter is shown in Fig. 3. In Table 1 there are given halo area in every detection layer.

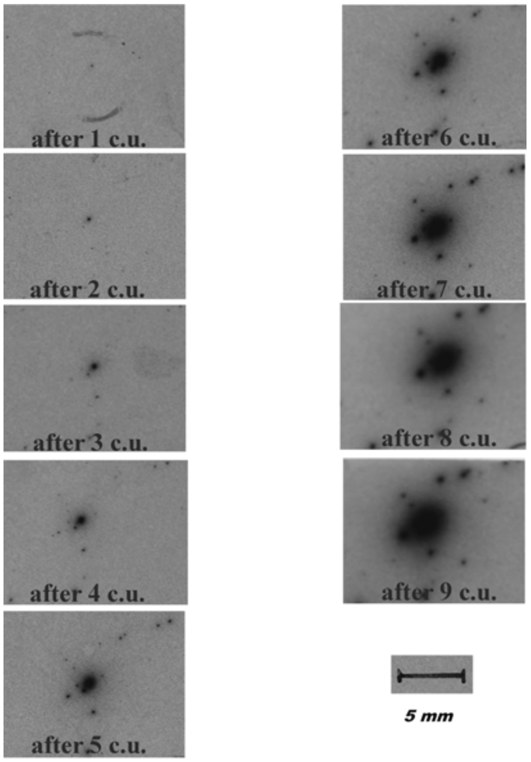
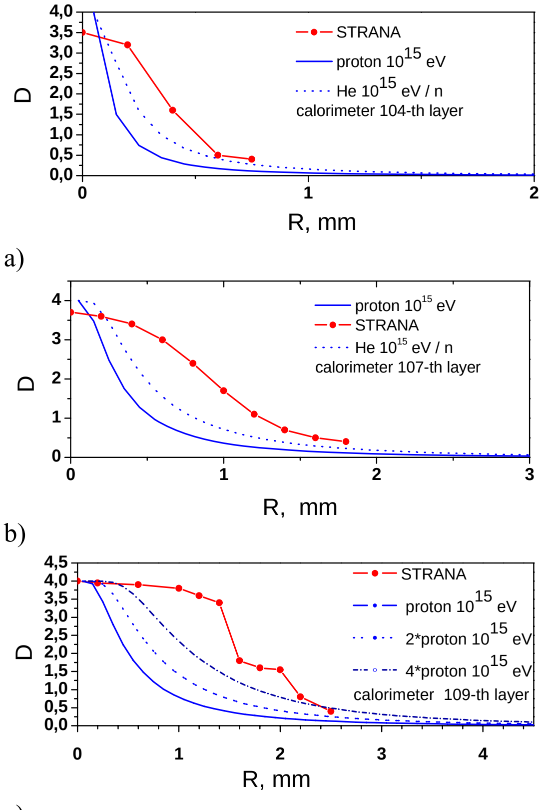


Figure 3: Halo development in X-ray layers of the calorimeter.

The halo in every film was measured with optical system [3]. After obtaining the darkness matrix it is possible to construct a lateral distribution of the halo in all calorimeter layers (Fig.4). The comparison of experimental distributions were made with simulated ones with use of QGSJET model and ECSim program. The transition in calculations from electron density n to local darkness value D was made according to formula $D = D_\infty(1 - e^{-ns})$, where $D_\infty = 4$, s stands for emulsion grain area.



a)

b)

c)

Figure 4: Comparison of darkness lateral distribution in the experimental halo with calculations.

In Fig. 4 one can see that the lateral distributions of the experimental halo are not described completely by calculated curves neither for primary proton, nor for He nucleus, but have wider distributions. In Fig. 4c besides calculated distributions from one proton and from one He nucleus with $E_0 = 10^{15}$ eV there are presented also curves from two and four protons (as if the jet was formed by the bunch of nucleon group), but even such hypothesis cannot describe the experiment. In this Fig. 4c there is seen well that neighboring hadrons give their contributions to the halo too. Besides, as we know from halo study [4], low energy gamma-quanta (even with energy < 2 TeV, that is less than the film threshold) fallen upon the chamber from air and not detected individually may contribute in halo. Such component presence is possible in this superfamily.

Table 1: Halo area S in calorimeter layers at darkness level $D=0.5$.

Layer number	Pb thickness, mm	Halo area, mm^2
1	5	0,12
2	10	0,4
3	15	0,9
4	20	1,5
5	25	3,7
6	30	5,1
7	35	8,6
8	40	12,9
9	45	19

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