Features of parameters of gamma-ray families formed from AA-interactions at superhigh energies above $10^{16}$ eV

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Abstract. Different lateral and energetic characteristics of gamma-ray families produced in nucleus-nucleus (AA) interactions of primary cosmic rays (PCR) are studied. Primary mass composition analysis performed on the basis of “Pamir” Collaboration X-ray emulsion chambers (XREC) data by using of selection criteria of gamma-ray families originating from AA-interactions above 10 PeV. Experimental data are compared with results of MC0 algorithm based on quark-gluon string model (QGSM). Among seven considered variables, only two lateral parameters, $R_{1E}$ and $\rho$, are not described by the MC0 model.

1. Introduction

For the PCR mass composition determination it was proposed a method of comparison the energy dependence of the fraction of registered events, satisfied to the definite selection criteria, with a model, simulated on different assumptions on the PCR composition. As a result, it was shown that “Pamir” experimental data are in agreement with a supposition about a “normal” PCR composition slowly enriched by heavy nucleus at energies above $10^{16}$ eV.

Families were subjected to the electromagnetic “decascading” procedure. Pairs of $\gamma$-rays satisfying the condition $Z_{ik} < Z_0 = 10$ TeV·mm (where $Z_{ik} = R_{ik}(1/E_i+1/E_k)^{-1}$, $R_{ik}$ is a distance between $i$th and $k$th particles with energies $E_i$ and $E_k$) were united into “initial” gamma-rays. Thus, the observable $\gamma$-ray families are transformed into “initial” gamma-ray families with number $n_{in}$ of “initial” $\gamma$-rays.

Experimental data [1] are compared with QGSM-based MC0 model [2] that gives a good description of both the accelerator data and cosmic ray results in the energy region $E_0 < 10$ PeV. Gamma-ray families were with simulated the MC0 model on the assumption that the PCR composition is “normal” (28% $p$, 18% $\alpha$, …, 27% Fe) at lower energies and enriched by heavy nucleus with slowly increasing energy in the region $E_0 > 10^{16}$ eV.

2. Experimental data and calculation

“Pamir” experimental data consisted of $N_0 = 807$ families with energies $\Sigma E_\gamma = 100$-2000 TeV, number of particles $n_\gamma \geq 4$ and $\gamma$-ray energies $E_\gamma \geq 4$ TeV, selected within a circle of radius $R_0 = 20$ cm, have been analyzed.

In order to select the gamma-ray families mainly initiated by primary AA-interactions, the following family characteristic is used:

$$\chi_R = \Sigma E_\gamma / R_t,$$

where $R_t = \Sigma R_{in}$, $R_{in}$ is distance of “initial” gamma-rays from the family center.

The gamma-ray families mainly (~ 75% of events) produced by primary nuclei (A-families) are selected according to the criterion $\chi_R < 0.46 \overline{\chi}_R$, where $\overline{\chi}_R$ is the average value of the parameter (1). A-families are considered with the use of lateral parameters $R_{1E}$, $\overline{R}_{in} = \Sigma R_{in} / n_{in}$, $D = \Delta n_{in} / n_{in}$, $\rho = R_{1E} / \overline{R}_{in}$ and energetic characteristics $\bar{E}_{in} = \Sigma E_{in} / n_{in}$, $d = n_\gamma / n_{in}$, $\Gamma = E_{\max} / \Sigma E_i$. Here $R_{1E}$ is the
distance of an “initial” gamma-ray with the maximal energy in the family, $E_{\text{max}}$, from the family center; $\Delta n_{\text{in}}$ is number of “initial” gamma–rays placed at the distance $R_i < 20$ mm from the family center. Results of simulation are presented in the following table.

### Table. Lateral and energetic parameters of the “initial” $\gamma$-ray families.

| Lateral parameters | Energetic parameters |
|--------------------|----------------------|
| $<\bar{R}_{\text{in}}>$ (mm) | $<\bar{E}_{\text{in}}>$ (TeV) |
| $D$ | $\bar{R}_{1E}$ (mm) | $\bar{\rho}$ | $\bar{\Gamma}$ |
| Experiment | Model |
| 51±4 | 48±1.5 | 0.33±0.03 | 0.33±0.01 | 31±2 | 20±1 | 0.59±0.04 | 0.41±0.01 | 14±1 | 12±0.3 | 1.4±0.1 | 1.4±0.03 | 0.43±0.04 | 0.43±0.01 |

3. Results

According to the table, only averaged values of the experimental lateral characteristics $\bar{R}_{1E}$ and $\bar{\rho}$ have poor agreement with the MC0 model. These discrepancies can be seen in the figure. Solid lines are predicted by MC0 model, points present experimental data.

![Figure](image)

**Figure.** Distributions of characteristics $R_{1E}$ (left) and $\rho$ (right).

According to the figure, a considerable fraction of events with $R_{1E} > 35$ mm and $\rho > 0.6$ is observed in the experiment. These results can point to some strong increase of the transverse momentum of most energetic particles in AA-interactions at the energies above $10^{16}$ eV.

References

[1] Yuldashbaev T S and Nuritdinov Kh 1999 *Nucl. Phys. B (Proc. Suppl.)* **75**A 153

[2] Fedorova G F and Muchamedshin R A 1994 *Bull. Soc. Sci. Lettr. Lodz, Ser. Rech. Def.* **XVI** 137