High-energy cosmic-ray interactions (*)

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Summary. — The problems under review include unusual results observed in cosmic-ray investigations which were not explained and are now up-to-date.

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1. – Introduction

I would like to present the most interesting and unusual results of the investigations of interactions at the superacceleratory energy region.

The experimental data obtained with accelerators as well as by cosmic-ray methods at energy less than $10^{16}$ eV can be described by quark-gluon-string model [1]. The model based on the QCD theory and the Regge theory was developed by K. Ter-Martirosyan, A. Kaidalov, and Yu. Shabelsky in Russia and by A. Capella in France [2]. But the situation changes at energy above $10^{16}$ eV. At the last International Symposium on High-Energy Cosmic-Ray Interactions (Tokyo, 1994) Prof. Fujimoto said: «There is evidence for existence of a fundamental change in the character of strong interaction above $10^{16}$ eV».

The experimental data presented at this Session were mostly obtained by the X-ray emulsion chamber method. The method was first developed by Japanese physicists and more recently it was widely adopted and improved by Brazilian, Japanese, Russian and Polish physicists together [3].

Now the large-scale experiment is being carried out at the Pamirs and Chacaltaya by the Pamir-Chacaltaya collaboration including Russia, Japan, Poland, Brazil, Bolivia, Uzbekistan, Tadjikistan, and Georgia. Two types of emulsion chambers are used in the experiment: lead chambers made of thin lead plates with X-ray films in between and carbon chambers consisting of thick carbon layers and lead plates interlaid by X-ray

films too. The Pamir carbon chamber is shown in fig. 1. In the upper part of the chamber (γ-block) all high-energy electrons and γ-quanta of extensive air shower (EAS) core are recorded as black spots on the X-ray film. Hadrons of the same EAS produce secondary neutral pions in interactions mainly in carbon block. Then γ-quanta from neutral pion decays generate dark spots on X-ray films mostly in the lower γ-block. We call the totality of all these spots «family». The summary energy of the electron-photon cascades, \( \sum E_\gamma \), and of the hadron ones, \( \sum E_h' \), is the «visible energy» of the family. When this energy is more than 500 TeV we talk about superfamily.

The threshold of cascade registration by the X-ray film is about 4-5 TeV so the real energy range of the observed families is approximately 10–10^5 TeV («visible energy»).

The calculation of a shower development in the atmosphere shows that the primary particle energy is higher than the «visible energy» by a factor of about 20-30 [3].

There are some specific peculiarities with the use of emulsion chambers.

1) By choosing the events with sufficiently high energy, we mainly select interactions of primary protons with air nuclei.

2) We observe the particles mainly from the fragmentation region of the interactions.

3) The experiments with X-ray emulsion chambers have a good space resolution (about 100 μm), but the error in the energy measurement is about (20–40)%.

The following problems were selected for the scientific program of our Special Session:

2. Unusual particles

Professor S. Hasegawa will present the experimental results about the existence of very unusual particles observed earlier in Chacaltaya emulsion chambers and now also