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Study of the energy spectrum of cosmic rays obtained at the "Hadron 55" installation located at an altitude of 3340 m.

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"HADRON-55" with scintillation detectors and ionization calorimeters is used for studies in high-energy gamma-astronomy and cosmic ray physics. The "HADRON-55" consists of two parts - the upper gamma block and the lower hadron block. The gamma block absorbs and detects the electron-photon components of cosmic rays, while hadrons are not absorbed when they pass through the gamma block and begins to form particles in the hadron block. Project's main idea is to select events where there is the interaction in gamma block and no interaction in hadron block. Analysis of experiments results on "HADRON-55" accounts for ~ 6% of such events. The peripheral part of "HADRON-55" consists of 8 scintillation detectors placed in 2 circles with radii of 40 and 100 m. Over 4 years, more than 120,000 events with high energy of 10^{15} eV were detected.

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1. Introduction

It is often overlooked that elementary particle physics has come from cosmic ray physics. After the outstanding results of particle physics due to advances in accelerator technology, we again witnessed some interest in studying of ultrahigh-energy cosmic rays. The main research interest in Hadron-55 is directed at studying cosmic rays with energies above 10^{15} eV.

Some years ago started a new cosmic ray experiment at the Tien Shan High Mountain Research Station (TSHMRS) located at an altitude of 3340 m above sea level 45 km far from Almaty city. There we have assembled a new HADRON-55 hybrid setup consisting of a two-storey coordinate scintillation-ionization calorimeter (CSIC) of 55 m^2 in area and a dense array of scintillation detectors which cover the calorimeter itself as well as the adjacent territory [1,2].

Main advantages of the constructed HADRON-55 setup are a possibility to determine the energy of the primary radiation as well as its capability to measure the angular, lateral and longitudinal distribution of secondary particles in the atmosphere and in the lead absorber. It is also very important that the setup makes it possible to study different components of air showers by providing experimentalists with comprehensive information on the studied phenomena [3].

2. The “Hadron 55” setup design

The HADRON-55 (we also call ‘calorimeter’) setup represents a two-tiered coordinate scintillation-ionization calorimeter (CSIC) of 55 m^2 in area and 1050 g/cm^2 deep (Fig. 1) surrounded by a dense array of scintillation detectors which will be extended in future outside the laboratory building and will cover an area of more than 2 km^2. The tiers are spaced vertically by 2.2 meters. The upper deck (called the Gamma-block) contains two rows of ionization chambers (IC) (100 IC in the first row, 138 in the second and filled with argon) under it, which are arranged in mutually perpendicular directions. Beneath them, there is a target lead block of 22 cm (250 g/cm^2) thick in which hadrons of cosmic radiation interact effectively with lead nuclei. The design of the upper tier installation makes it possible to determine the energy of electron-photon component and, in conjunction with the lower tier (Hadron-block) enables experimentalists to reconstruct the particle trajectories. There are also 24 scintillation detectors 0.25 m^2 each which are spread over an area of 324 m^2 at the level of the upper tier.

The lower tier consists of 6 rows (from 3 to 8 rows) of ionization chambers (144 IC in each row), which consists of iron absorber with gaps where IC, neutron and Geiger counters are placed [3]. The Geiger counter is used to detect the muon component of EAS, and the neutron counters are used to detect neutrons. Neutron counters filled with Argon and Helium-3. Series modules are assembled in 6-7 pieces. Total area 54 m^2. The deceleration of neutrons occurs due to a case made of wood. This unit (lower tier) is used to measure the energy of the charged cosmic ray component as well as to determine the particle trajectories. The specific feature of the HADRON-55 setup is that it represents a set of different detectors by allowing a much more detailed study of characteristics of cosmic ray particle interactions.

According to [4] and our calculations [5] the error in determination of interaction energy in an ionization calorimeter of 1,000 g/cm^2 thick containing six levels of registration is about 10%. Therefore the calorimeter’s design has 9 rows of detectors and the total thickness of the absorber is 1033 g/cm^2 that is sufficient for a correct determination of the primary particle energy E_0 with a reasonable accuracy.

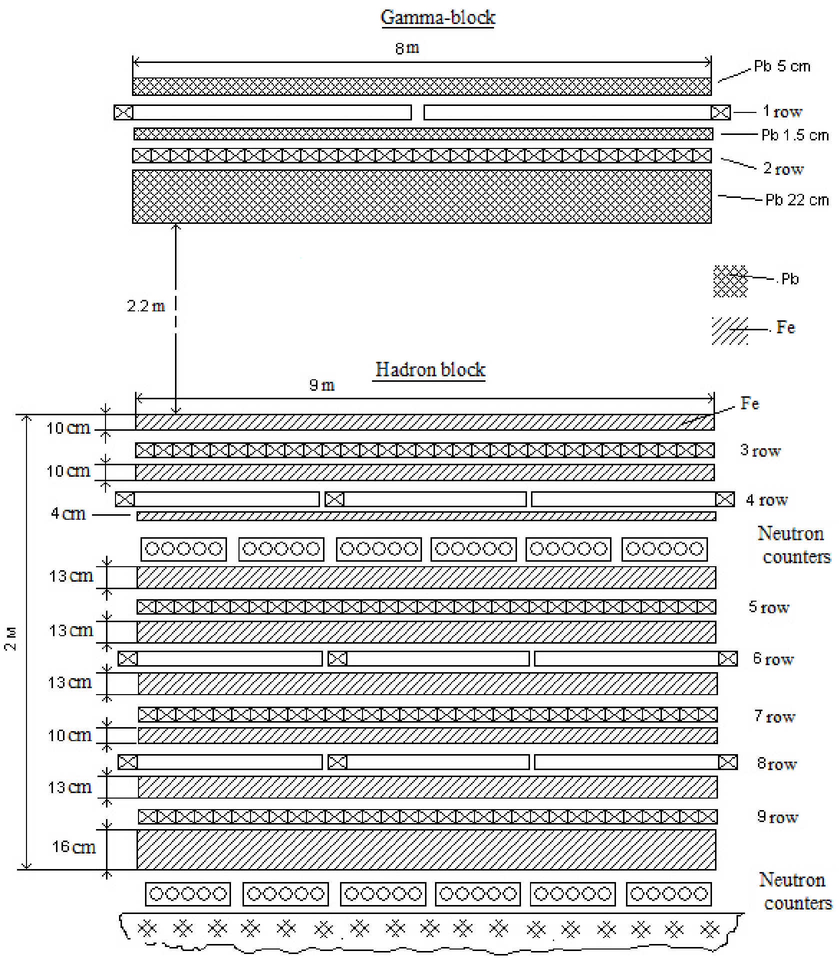
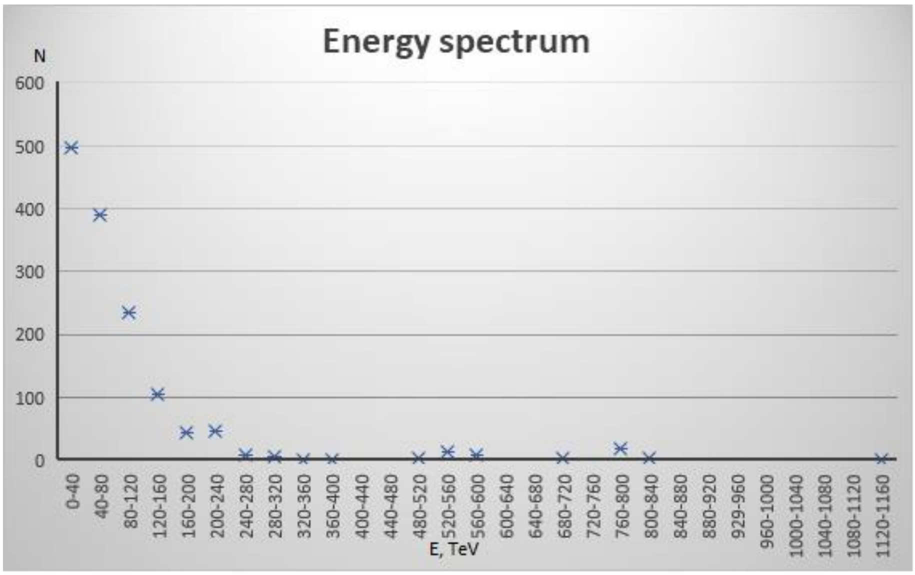


Figure 1. A two-tiered coordinate scintillation-ionization calorimeter of the HADRON-55 setup.

It is envisaged that, in the nearest future, the HADRON-55 setup will work as a part of a new shower array which is now under construction at TSHMRS. This array represents a network of scintillation detectors located on an area of about two km^2. Thus, measurements of the primary particle energy E_0 and determination of their mass should be performed more reliably that makes it possible to solve the problems planned.

3. Results

In order to verify the correct operation of the entire electronics of calorimeter, the adequacy of programs and methods for calculating the energy of primary particles, we calibrated the setup by determining the flux of particles of cosmic rays with an energy of $E_0 \geq 10^{15}$ eV. It is known that the flux of cosmic particles at a given height is a fairly stable and well-studied quantity. Therefore, a comparison of the experimentally measured flux values on a new installation with results obtained on already well-tested plants that have worked stably for a long period allows us to estimate the accuracy of measurements on our plant [6]. It was logical to compare our data with work results of the ionization calorimeter of the Tien-Shan plant of P.N. Lebedev Physical Institute of the Russian Academy of Sciences, located on the same site with our calorimeter. Picture 2 shows energy spectrum of dates from 1.10.2018 to 27.10.2018.



Picture 2. Energy spectrum.

3.1. Conclusion.

Using the methodology for processing data obtained in cosmic rays studies on the HADRON-55 installation searches for similar structures in the data obtained at high-energy accelerators, that is, in the future we can compare this data with the data obtained at particle accelerators.

In addition, the data obtained using HADRON-55 will be used in other experiments conducted at TSHHSS [7-10].

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