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Study of EAS hadronic component with hadron energy > 50 GeV

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Abstract: An experiment has been performed using Baksan "Carpet-2" Air Shower array. We present here preliminary experimental data for hadrons with energy more than 50 GeV in EAS with $N_e \geq 10^5$ at core distances of (45-55) m, obtained by a new method. The experimental data are compared with results of Monte Carlo simulations using CORSIKA code (HDPM model).

Introduction

In previous Conference Proceedings we published EAS events recorded by "Carpet - 2" array, with cores inside the "Carpet", and accompanied by "jets" with density ≥10 relativistic particles/m^2 in Muon Detector (MD) [1]. These events are explained as cascades in the absorber of muon detector produced by hadrons of a few (or few tens) GeV energy in showers at distances of 45-55 m from an axis. Such explanation is based on results of preliminary calculation of hadron flux in EAS with $N_e \geq 10^5$ particles and on measurement of barometric coefficient for such events in MD. In the present work the results of Monte Carlo calculations for GeV-hadrons that passed through the MD absorber are shown. Also the number of such events as a function of N_e is measured for EAS of size $N_e=10^5 \div 10^6$.

Experimental Set-Up

The "Carpet - 2" array [2] of the Baksan Neutrino Observatory (1700 m a. s. l.) consists of the ground level detector called "Carpet" (200 m^2) and underground muon detector. "Carpet" consists of 400 individual liquid scintillator detectors of 0.5 m^2 each. Energy deposit is measured in each detector for the interval of 1-5000 relativistic particles. Six outside points have 18 scintillator detectors, each of the same type. Four of them are placed in the form of a square at a distance of 30 m from the centre of "Carpet" and the other two are at distance of 40 m. The signals from these detectors are used as stopping pulses in time measurement system to measure delays and reconstruct arrival direction. Muon detector 5x35 m^2 [3] is situated at about 48 m apart from the Carpet's center and consists of 175 plastic scintillator detectors of 1 m^2 each under a soil absorber of 2.5 m thickness (500 g/cm^2) in an underground tunnel attached to its ceiling. Each detector can measure energy deposit in interval of 1÷100 relativistic particles (r. p.). The "Carpet" can measure the shower parameters with good accuracy: $\otimes X=\otimes Y=0.35$ m.; $\otimes N_e/N_e=0.1$; $\otimes s/s = 0.02$ in EAS size interval of $N_e = 10^5 \div 5*10^6$.

Results

Only near vertical showers (sec θ <1.15), with $N_e \geq 10^5$ and cores located inside the "Carpet" (excluding perimeter detectors), accompanied by "jets of particles" with density ≥ 10 r. p. / m^2 in MD were selected for the analysis. This density corresponds to energy deposit of $\varepsilon \geq$ 100 MeV.

Here ε is the total energy deposit in a group of the detectors. A number of detectors in the group should not exceed five. The results of Monte Carlo simulation for single hadrons (protons and π-mesons) interacting in an absorber of 500 g/sm^2 thickness are shown in Fig 1.

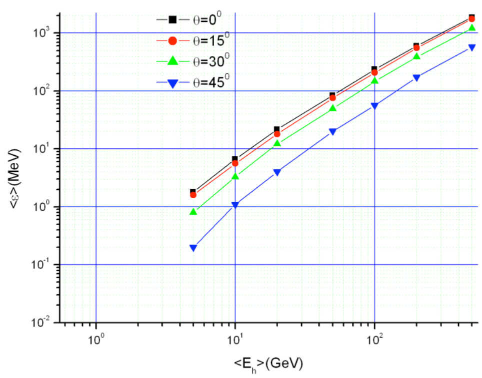

Figure 1: Energy deposit in a detector as a function of hadron energy.

Where <∑> is a mean energy deposit in MD (MeV) from the hadron cascade with energy <E_h> (GeV). Calculations were performed for the four values of zenith angles: 0, 15, 30 and 45 degrees. The same calculation performed for hadrons with $E_h = 5 \div 500$ GeV gives the average size of the hadron cascades in MD of <r> ~ 0.01÷4 m^2. From the results of this calculation it seems reasonable to assume that events in which <∑> ≥ 100 MeV/m^2 are caused by hadrons with E_h> 50 GeV. To confirm the hadronic origin of such events in MD we have calculated a dependence of the number of such cascades in showers on full number of particles in EAS with $N_e = 10^5 \div 10^6$, (figure 2), which was found to be described by a power law: $N_{jet} \sim N_e^a$, where α = 0.89 ± 0.08. Value α =0.8÷0.9 for the dependence of a total number of hadrons on a total number of particles in showers with $N_e = 10^5 \div 10^6$ was obtained in the experiments studying hadrons in EAS at mountain heights [4,5,6]. The number of hadronic cascades was selected in our experiment in a narrow interval for core distances of 45-55 m. However, the law of a dependence of the number of hadrons on EAS size does not contradict the results of other experiments.

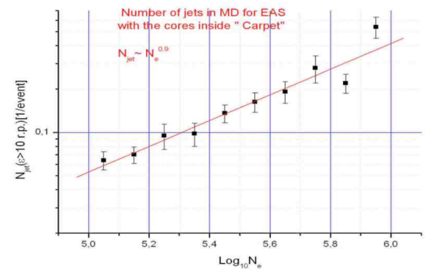

Figure 2: Mean number of hadrons (jets) in MD as a function of EAS size.

We have also estimated the mean number of hadrons of E_h> 50 GeV per one shower. For this purpose the result of our above-stated calculations is used: <E_h> = (<ε> +78.3)/3.8, where <ε> is the total energy deposit of experimental jet (MeV) and <E_h> is the calculated energy of hadron (GeV). The data obtained are compared with the results of Monte Carlo simulations using CORSIKA code (HDPM model). The results of this comparison are shown in figure 3 and confirm also our hypothesis of hadronic origin of jets in MD. It should be noted that at present we can say nothing about primary cosmic ray mass composition. This preliminary estimation is rough enough and in future we plan to obtain energy hadron spectrum.

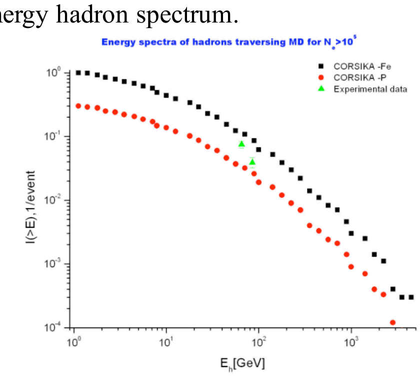

Figure 3: Energy spectra of hadrons traversing the MD for N_e>10^5.

Conclusion

In the present work we have started to study EAS hadronic component using the muon detector (MD) having large continuous area.

This method allows measuring number of EAS hadrons and their energy with good accuracy [1]. In the nearest future we plan to study EAS hadron number spectrum and energy spectrum as well as lateral distribution of hadrons. The proposed method seems to be promising for studying primary cosmic ray mass composition.

Acknowledgments

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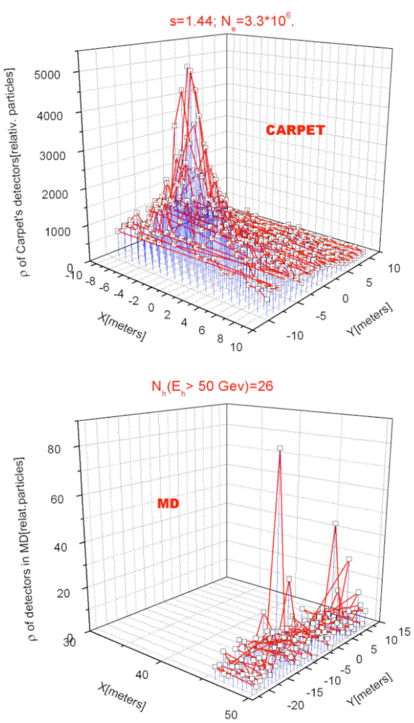

Figure 4: An example of a particular EAS event recorded by “Carpet-2”.

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