ENERGY SPECTRUM OF CASCADES GENERATED BY MUONS IN BAKSAN UNDERGROUND SCINTILLATION TELESCOPE

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ABSTRACT

Spectrum of cascades generated by cosmic ray muons underground is presented.The mean zenith angle of the muon arrival is $\bar{\theta}=35°$,the depth $\sim 1000 hg/cm^2$. In cascades energy range >700 Gev the measured spectrum is in agreement with the sea-level integral muon spectrum index $\gamma=3.0$.Some decrease of this exponent has been found in the range >4000 Gev.

1.Introduction. General description of the Baksan Underground Telescope is given in ref. (1).The experiment (2) using the Telescope as a calorimeter to study muon induced electromagnetic and hadronic cascades is in progress now.New experimental data are available and analysed here.

2.Experimental details. The 4 scintillation layers structure, the large total thickness($\sim$25 radiation lengths) and big area ($>200\ m^2$) (1,2) enable to record muon-nucleus interactions with energy transfer up to $\sim$20 Tev.The 4 scintillation layers are separated by 0.8 m or 144 g/cm^2 of absorber (low radioactive minerals mostly olivine,with $\bar{Z}\approx 14$ and $\bar{A}\approx 27$ placed on 8 mm iron sheet being used for support.The layer of 23.4g/cm^2 of liquid scintillator is formed by 400(or 576 for top layer) individual detectors,30x70x70 cm^3 each.There is 2.5 m air gap between scintillators and iron sheet at the ceiling.Total thickness corresponding to one layer is 8.2 radiation lengths and a distance between the layers is 3.6 m.

Energy release is measured by logarithmic charge-to-time converters in every detector.The converters thresholds were adjusted to 500 Mev(10 r.p. - relativistic particles),using a pulsed X-ray sourse.These thresholds and converters slopes (22% per 1 step or 10 μs) were examined by ON-LINE computer monitor program permanently.Special low-level trigger ($\geqslant$7r.p. in any scintillator layer) is used for this purpose.Counting rate of each detector with 500 Mev threshold is only 0.3 h^{-1}. We use weekly the accumulated monitor information to check every detector and to repair or adjust it if required.The main trigger is produced in a case,when the energy release in any horizontal scintillator layer is $\geqslant$50 r.p.(2.5 Gev). By this trigger all available information,associated with the event will be recorded on the magnetic tape and the 10-beam oscilloscope screen will be photographed.The oscilloscope is used to visualize each scintillator layer's pulse for π-μ-e decays recording. Further data processing is carried out by OFF-LINE computer selecting events of given energy. Only cascade with axes crossing no less than 3 horizontal layers have been included in the analysis. Mean zenith angle due to such a selection equals to $\bar{\theta}=35°$.

3. Results. Data accumulated during a 11640^h run of the experiment are shown in fig.1. Solid curves represent calculated cascade size spectra obtained in following assumptions:

i) all kinds of μ-A interactions can be expressed in analitical form as in ref.(3);

ii) muon see-level spectrum is purely power law and underground at our depth it has a form:

$$dN(E_\mu)/dE_\mu \sim (200+E_\mu)^{-\gamma-1}, \qquad E_\mu \text{ in Gev}$$

and $\gamma=2.8$ or $\gamma=3.0$.

To obtain the total cascade energy from visible one (released in scintillators) cascade curves (4,5) for homogeneous matter were used, assuming uniform cascades production and observed angular distribution of the cascade axes.

These cascades curves have been corrected for transition effect, geometrical configuration and a loss because of 10 r.p.(500 Mev) energy threshold by Monte-Carlo cascade simulations. The correction factor ($\sim$20%) does not depend on cascade energy. The correction for the loss due to finite detectors energy thresholds, though small, was made individually for each event using low energy 0.25 r.p. integral discriminators installed in each detector. Monte-Carlo simulation showed that the mean energy release in the interval $0.25\text{r.p.} < E < 10\text{r.p.}$ is 1.6r.p.. Finally, we have the transition factor from visible energy, released in scintillator, to the mean total energy. For electron-photon cascade and hadronic cascade these factors are slightly different, correspondingly 8.6 and 9.7, but practically do not depend on cascade energy for $E_c > 700$Gev.

4. Conclutions. Some excess of the experimental relative to calculated cascades spectrum can be seen in fig.1 in the energy range >4000 Gev. But, this is not statistically well established being less than 2σ effect. Note that the spectrum is presented in integral form, so the points are not statistically independent. Actually the point at $\sim$8000 Gev (6 events) is responsible for all excess. At lower energy in the range 1÷4 Tev the best fit is obtained for integral muon spectrum at the surface as E_μ^{-3}. This exponent $\gamma=3$ deviates from the most popular exponent $\gamma=2.8$ (6). One can hope that future experiments will clarify the situation and probably explain the small differenses, which traditionally are arising in different experiments dealing with muon induced cascades and muon spectra.

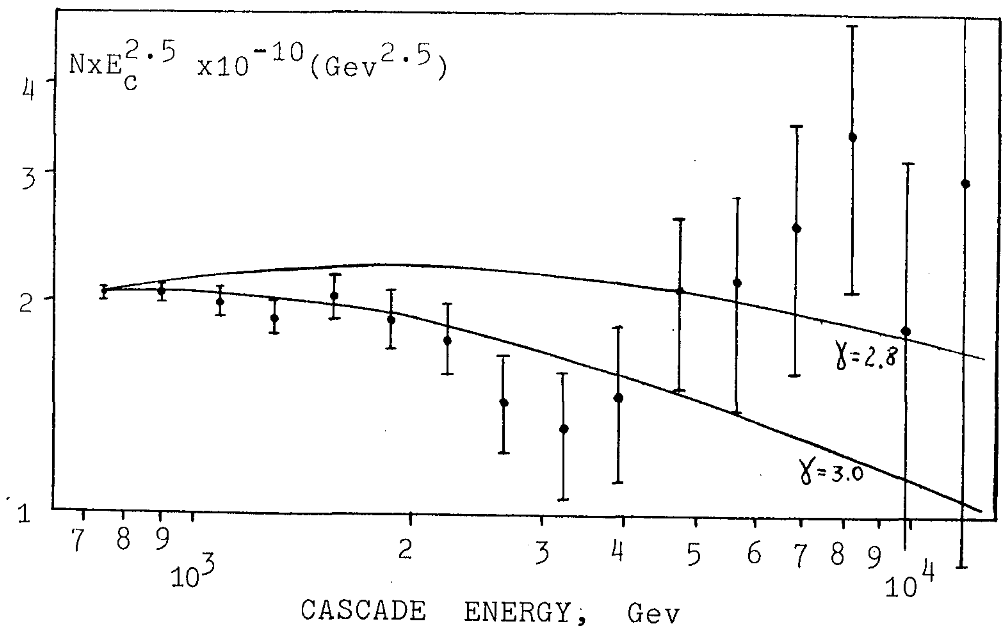

Fig.1. Cascades size spectrum.

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