The Contradiction in the EAS Muon and Hadron Data Beyond the CR Spectrum Break

S.B. Shaulov[1]
(1) P.N. Lebedev Physical Institute, Russian Academy of Sciences, Leninsky prospect 53, Moscow 117924, Russia

Abstract

The comparison of muon numbers in two groups of events: all EAS and EAS with gamma-families and hadrons, shows that problem of CR composition beyond the break becomes much more complicate then usually suggested. $\overline{N_\mu} - N_e$ dependence shows muon abundance for EAS with gamma-families in comparison with average muon number for all EAS. The standard nuclear models predict opposite effect. The E_γ spectra in EAS core become more hard at the same energy area that has be interpreted as increase of proton part in CR beyond CR break . The both effects can't be explained simultaneously by the ordinary nuclear cascades.

1. Introduction

The reason of CR spectrum break stays a mystery despite of a big efforts which were made to resolve this problem. The main point of interest is CR composition at energy area $E > 1$ PeV and particular the proton part in CR. As usually the break in CR spectrum at energy $E \simeq 3$ PeV is connected with break in the spectrum of the proton component. This hypothesis has arisen in the beginning of investigations, when protons has believed to be a dominant component in CR ($\sim 40\%$), as the most simple explanation of the break sharp form. The experimental results, received during the last thirty years, most probably contradict this hypothesis because of the decrease proton part at the energy area 1-1000 TeV [1,2] and more likely value of break magnetic rigidity R=0.1 PV instead of R=3 PV [3]. That case CR spectrum break has be connected with one's in the spectra of Fe group nuclei.

The situation above the CR break is discussed in this work. The analysis of the hadron and muon data in EAS for this area shows the definite contradiction between them which can't be explained in the case of the traditional CR composition. It seems that we are forced to introduce a new processes in the nuclear cascades which are possible to generate EAS with simultaneously hard hadron spectra as in protons one and a large muon number N_μ as in EAS, generated by Fe nuclei.

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2. Methods

The main data about kind of the primary nucleus are contained at the most energetic particles of the EAS core. A few simple conclusions may be drown from it about the method of investigation. The detector spatial resolution has be high enough to distinguish single hadrons (γ-quanta from π^0) in EAS core, the detecting level in the atmosphere has be as high as possible and detecting area has be more then 100 m^2 in order to determined CR composition. The Tien-Shan installation “HADRON” has been created proceeding from these principles. It has included :

- 37 scintillation points in the radius $R \leq 70$ m;

- burst detector consisting of the 4 layers of the ionization chambers on the area 162 m^2: 2 in G-block (criss-cross) and 2 in H-block, divided by 60 cm of gum (Carbon);

- X-ray emulsion chamber on the same area 162 m^2 consisting of G-block (6 cm Pb) and H-block (5cm Pb) under the ionization chambers;

- underground muon hodoscope of Geiger counters with sensitive area ~ 50 m^2 and energy threshold $E_\mu \geq 5$ GeV;

- shower hodoscope at ground level and Cherencov detectors;

The EC has 100 micron spatial resolution which exceeds one's of the ionization calorimeter in $\sim 10^3$ times. It permits to measure the energy of single γ-quanta (π^0) at G-block and charged hadrons at H-block at EAS core. The gum are used as converter charged hadrons at γ-quanta. The detector of this kind has a highest sensitivity to CR composition among another one's. The slope of the integral E_γ spectra at energy area $E_\gamma \geq 2$ TeV changed from $\kappa \simeq 1$ for protons up to $\kappa \simeq 2.5$ for EAS generated by the nuclei of Fe-group and practically don't depended from the interaction characteristics as has been received at [4]. It seems possible to conclude that either this method permits to resolve the problem of CR composition or EAS investigation deep in atmosphere don't gives the sufficient information for it in principle and the only one variant is remained - direct measurements of CR composition out of the atmosphere.

3. Results

The N_e dependencies of $\kappa = \kappa(N_e)$, where κ is a spectral index in $N(> E_\gamma) \sim E_\gamma^{-\kappa}$, and the average muon numbers $\overline{N_\mu}(N_e)$ are compared in this work. Figure 1 shows experimental and calculated [5] values of $\kappa(N_e)$ and Fig.2 $\overline{N_\mu}(N_e)$

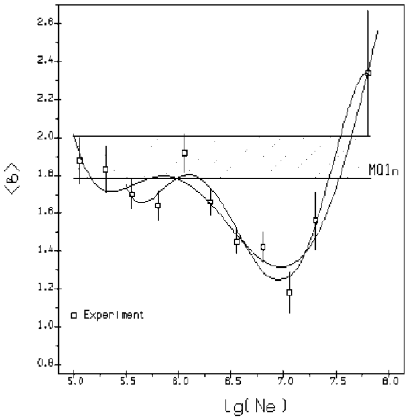

Fig. 1. N_e dependencies for slope b of energy spectra $N(> E_\gamma)$ for experimental data and model one's.

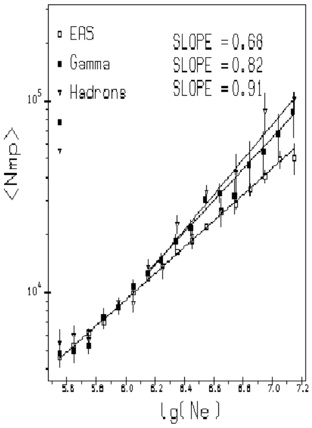

Fig. 2. $\overline{N_\mu}(N_e)$ dependencies for all EAS and EAS with γ-families and hadrons.

for all EAS and EAS with γ-families and hadrons. The visible energy at EC: $\Sigma E_\gamma, \Sigma E_h^\gamma \geq 10$ TeV in all cases.

The local decrease of κ above the break ($N_e^{br} \simeq 1.6 \cdot 10^6$) from 1.8 up to 1.2 may means formally that CR composition at this area consists of the almost pure protons, but Fig.2 shows that muon number $\overline{N_\mu}$ increases more quick at this area for the same events (EAS with γ-families) and $\overline{N_\mu}$ for them are more then one's for all EAS. The model calculations with 40% protons up to break at Fig.1 shows that κ must stay constant for these energies. The slopes α of $\overline{N_\mu}-N_e$ dependencies are as follow: $\alpha^{EAS} = 0.68 \pm 0.01$ for all EAS, $\alpha^\gamma = 0.82 \pm 0.06$ for EAS with γ-families, $\alpha^h = 0.91 \pm 0.08$ for EAS with hadrons. The ratio $\overline{N_\mu^\gamma}/\overline{N_\mu^{EAS}} = 1.5 \pm 0.2$ if averaged in interval $N_e = 2 \cdot 10^6 - 2 \cdot 10^7$ and $\overline{N_\mu^\gamma}/\overline{N_\mu^{EAS}} = 1.4 \pm 0.1$ for $N_e = 3 \cdot 10^6 - 6 \cdot 10^6$.

4. Discussion

The most intrigue fact is a relatively large muon numbers at EAS with γ-families and hadrons comparing with one's for all EAS because of the inverse relationship is expected for any CR nuclei composition. The detecting of the high energy hadrons (γ) in EAS core deep in atmosphere (700 g/cm^2) supposes that a rear fluctuation take place when a relatively small part of primary energy is dissipated above the detector and energy of secondary hadrons is survived. But small dissipated energy means a relatively small muon numbers and $\overline{N_\mu^\gamma} \leq \overline{N_\mu^{EAS}}$ with $E_\mu \sim 5$ GeV. The contradiction, if would confirmed, has a seriously consequences for the whole problem. The N_e-dependence for E_γ spectra shows that protons part in CR increases beyond the CR break that contradicts the usually used model of break with magnetic rigidity R=3 PV too.

5. Conclusions

The both effects can't be explained simultaneously by the characteristics of the ordinary nuclear cascade. If additional CR component is introduced it must differ from any nuclei and the stable particles of the strange quark matter are the first candidate for the role of this component [6,7,8].

6. List of Symbols/Nomenclature

EAS=Extencive Air Shower, EC=X-ray Emulsion Chamber
G-block=EC upper block=6 cm Pb+2 layers of ionization chambers under Pb.
H-block=EC lower block=60 cm of gum+5 cm Pb+2 layers of
ionization chambers under Pb.

7. References

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