A Search for Very High Energy Muons ($E_\mu > 100$ TeV) in EAS Around the Knee

Valery B. Petkov[1], Aleksey G. Bogdanov[2], Musa M. Boliev[1], Sergey N. Karpov[1], Viktor V. Kindin[2], Rostislav P. Kokoulin[2], Konstantin G. Kompaniets[2], Yuri F. Novoseltsev[1], Rita V. Novoseltseva[1], Anatoly A. Petrukhin[2], Aleksandr V. Radchenkov[1], Anna V. Shalabaeva[2], Vladimir I. Volchenko[1], Aleksey F. Yanin[1], Igor I. Yashin[2], Aleksey N. Zaichenko[1]
(1) Institute for Nuclear Research of RAS, Baksan Neutrino Observatory, Neutrino, 361609, KBR, Russia
(2) Moscow Engineering Physics Institute, Moscow 115409, Russia

Abstract

A possible explanation of the "knee" in the extensive air shower (EAS) spectrum is a change of hadron-hadron interactions. One of such scenarios suggests a threshold production of new heavy particles or states of matter at the knee energy. If the appearance of the knee is related to these new objects, their decays should give considerable rise to very high energy muons, whose energy is not measured with existing EAS arrays without using special detectors for muon energy determination. In order to check this hypothesis, simultaneous evaluation of muon energy and the energy of EAS is required. The experiment to search for such muons in EAS was started at Baksan Neutrino Observatory in September 2002. The energy of muons in our experiment is estimated by means of the Baksan Underground Scintillation Telescope (BUST), and the EAS electromagnetic component is measured by the "Andyrchy" array, which is located straight above the BUST.

1. Introduction

Despite the fact that the knee in the shower size spectrum was first observed more than 40 years ago [1] the nature of the knee is still a puzzle. The astrophysical interpretation (the steepening of the primary cosmic ray spectrum) seems to be the most natural now. Reasons for such steepening can be found both in acceleration and in propagation processes. Alternative interpretation is a change in the hadronic interaction properties. One of such scenarios suggests a threshold production of new heavy particles or states of matter at the knee energy [2-3]. Decays of these new objects (for example, new metastable chromodynamically–charged particles [4]) should give considerable rise of very high energy (VHE) muon intensity. We consider a possibility to check experi-

pp. 57–60

mentally this hypothesis by means of simultaneous determination of muon energy (BUST) and the energy of EAS ("Andyrchy" EAS array).

2. Experiment

"Andyrchy" EAS array [5] is located on the slope of the mountain Andyrchy above BUST and consists of 37 plastic scintillation detectors of 1 m^2 each with the thickness of scintillator of 5 cm. Each scintillator is viewed by one PMT. The distance between the detectors is about 40 m in projection to the horizontal plane, the maximum vertical distance is about 150 m. The overall area of the installation is about $4.5 \cdot 10^4$ m^2. The central detector is located straight above the BUST and the corresponding vertical distance is 360 m. The altitude above sea level is 2060 m (atmospheric depth 800 g/cm^2). The shower trigger is produced when 4 or more detectors are fired within 3 μs. The trigger rate is about 9 s^{-1}. The shower size N_e is measured in the range $5.7 \leq lg(N_e) \leq 7.2$ for near vertical ($\sec\theta \leq 1.05$) events. The knee position is at $lg(N_e)_{knee} = 6.26$ [6].

BUST [7] is situated in an excavation at the effective depth 850 hg/cm^2. It is a four-flour building with (16 m $\times$ 16 m $\times$ 11 m) dimensions. 3150 liquid scintillator detectors cover entirely all four horizontal and four vertical layers of the installation. Each of the detectors has dimensions 0.7 m $\times$ 0.7 m $\times$ 0.3 m. The construction of the telescope allows to determine the number of passing muons (1-200), their coordinates (with 0.7 m accuracy) and direction of their arrival (with 1.5 degree accuracy). Coincidence trigger rate of BUST and "Andyrchy" is about 0.1 s^{-1}. The threshold energy for muons for the directions considered in this work is 230 GeV. The detectors of BUST have 10 MeV threshold for coordinate measurements and 500 MeV for energy deposition measurements [8, 9].

The experiment to search for VHE muons in EAS was started in September 2002, after energy deposition measurement system of BUST was recovered. The information presented hereafter was collected during 789 hr of joint BUST and "Andyrchy" operation.

3. Events selection

In the following analysis we have used coincidence events with shower size $lg(N_e) \geq 5.7$ and, certainly, one or more muons that pass through the telescope. The number of such events amounted to 1040, including 127 with estimated EAS size above the knee. Among them, only in 38 events four scintillation detectors in the telescope (or more) have energy deposit $\geq$ 500 MeV (5 events correspond to EAS above the knee). The telescope response for three samples of such events is presented in Fig.1. Two of them (left and center) are for EAS sizes below and one (right) higher than the knee position.

Because VHE muons pass through the matter with a significant continuous

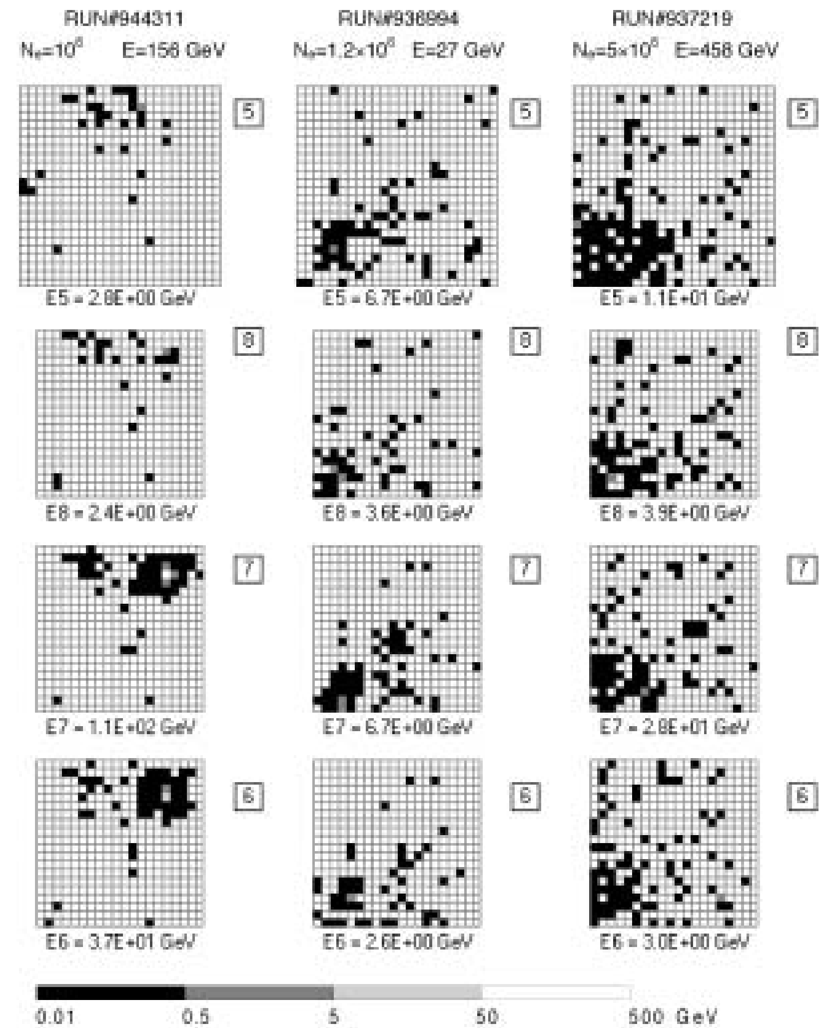

Fig. 1. Selected events from EAS below and higher the knee.

energy deposition, subsequent selection was that at least one muon must pass through 4 horizontal planes and fire three or four BUST detectors with energy deposition $\geq$ 500 MeV. After that, the number of remaining events is equal to 6. No such events were found above the knee.

Preliminary results of the experiment show that the problem of reliable selection of VHE muons is rather complicated. However, we hope that the detailed analysis of high statistics material which will be obtained in the nearest future, and the further study of simulated events [10] will allow to find necessary approaches to the solution of this task.

4. Acknowledgments

The work was supported by the Russian Foundation for Basic Research (RFBR grants 03-02-16198 and 03-02-06611) and by the Federal Program "Integration" (projects I0586/920 and I0803/930).

5. References

1. Kulikov G.V., Khristiansen G.B. 1959, Sov. Phys. JETP 8, 41
2. Petrukhin A.A. 1999, Proc. XIth Rencontres de Blois "Frontiers of Matter" (The Gioi Publ., Vietnam, 2001), 401
3. Petrukhin A.A. 2001, Proc. 24th ICRC 5, 1768
4. Petkov V.B., Lalakulich O.D., Vereshkov G.M. 2003, Physics of Atomic Nuclei, 66, 523
5. Alexeyev E.N. et al. 1993, Proc. 23rd ICRC 2, 474
6. Petkov V.B. et al. 2003, "EAS high energy muon component around the knee: simultaneous surface and underground measurements at Baksan", these Proceedings
7. Alexeyev E.N. et al. 1979, Proc. 16th ICRC 10, 276
8. Andreyev Yu.M. et al. 1981, Proc. of 17th ICRC 7, 67
9. Bakatanov V.N. et al. 1991, Proc. of 22nd ICRC 2, 77
10. Petkov V.B. et al. 2003, "Possibility to search for VHE muons with Baksan Underground Scintillation Telescope", these Proceedings