The search for primary particle tracks in nucleon-nucleus interactions with gamma ray energy $\Sigma E_\gamma \geq 3$ TeV registered in stratospheric X-ray emulsion chambers using data of the RUNJOB experiment

I.S. Zayarnaya[a] and T.A. Irkhina

P.N. Lebedev Physical Institute of RAS, 53 Leninskiy Prospekt, Moscow 119991, Russia

Abstract. We present here the result of a retreatment of data from the RUNJOB (RUssia-Nippon JOint Balloon) experiment of nucleon-nucleus interactions registered in stratospheric X-ray emulsion chambers (REC) using a new method for searching and tracing of galactic particles in nuclear emulsions. In about halfcof these interactions (~ 50) recorded in REC RUNJOB'96-3B, RUNJOB'97-6A and RUNJOB'99-11A,B with energy released in the electromagnetic component $\Sigma E_\gamma \geq 3$ TeV and $\Sigma E_\gamma \geq 5$ TeV respectively, single charged particle tracks are not found within the search area defined individually by the particle track location accuracy. The absence of primary proton tracks is consistent with the original treatment of the RUNJOB experimental data.

There is a difference in the zenith angular distribution for two groups of events in which a single charged particle track is observed or absent. The average penetration depth of the primary particles in REC to the interaction vertex in the zenith angle range from 60° to 79° differs by a factor two for these groups.

1. Introduction

The Russian-Japanese balloon experiments RUNJOB have been conducted from 1995 to 1999 for the purpose of studying the elemental composition and energy spectra of galactic cosmic rays in the energy range ~ 10–10^3 TeV/particle using stratospheric emulsion chambers exposed at an atmospheric depth $\sim 10\,\mathrm{g/cm^2}$ in long duration flights (130–170 hr). The structure of REC RUNJOB'97 is shown in Fig. 1. As a result of the experimental data processing it was noted that the primary protons are identified in about half of the events related to the nucleon-nucleus interactions [1]. The single charged particle tracks are detected by nuclear emulsion with close to 100% efficiency (it is based on tracing the secondary $\pi^\pm$ mesons as well as primary protons through the emulsion layers). To explain a large number of unfound primary particles in the events related to nucleon-nucleus interactions, a detailed investigation of methodical reasons for this experimental fact was conducted [2].

As a result of this work we did not succeed in explaining why there are a lot of unfound single charged particle tracks by the method of searching and tracing of primary particles in the emulsion layers. For the analysis it was necessary to increase the statistics of events on account of low-energy nucleon-nucleus interactions registered in the REC and not included in the final primary proton spectrum in the RUNJOB experiment [3]. To be able to make a retreatment of these events we proposed a new method of searching and tracing of particles in the REC nuclear emulsions [4].

In this method as well as in the original one, the background nuclei are used as fiducials for locating the primary particle track. The results of the search for primary particle tracks in all nucleon-nucleus interactions registered in the RUNJOB'96-3B, RUNJOB'97-6A and RUNJOB'99-11A,B chambers with total electromagnetic energy $\Sigma E_\gamma \geq 3$ TeV and $\Sigma E_\gamma \geq 5$ TeV respectively by the two methods fully coincide, i.e., in about half of the events related to proton events the primary particle tracks are not found within the search area determined by the primary track location accuracy [5]. Figure 2 shows the deviation distribution of measured coordinates of the primary particle from the respective predicted ones for nucleon-nucleus and nucleus-nucleus interactions registered in the X-ray emulsion chambers using the new method. The measurement accuracy σ for the primary particle track location is near 31 microns.

2. The angular analysis of nucleon-nucleus interactions with found and absent primary particle tracks

In this work we analyzed 50 events registered in REC RUNJOB'96-3B, RUNJOB'97-6A and RUNJOB'99-11A,B with gamma ray energy $\Sigma E_\gamma \geq 3$ TeV and $\Sigma E_\gamma \geq 5$ TeV respectively at the zenith angle θ cut $\tan\theta \leq 5$ and related to the nucleon-nucleus interactions in the RUNJOB experiment. In each X-ray emulsion chamber the primary single charged particle track is not found in about half of the interactions. Figure 3 shows the zenith angle distribution for two groups of events in which the primary particle is observed or is not found. The graphs show that

[a] e-mail: zayar@sci.lebedev.ru

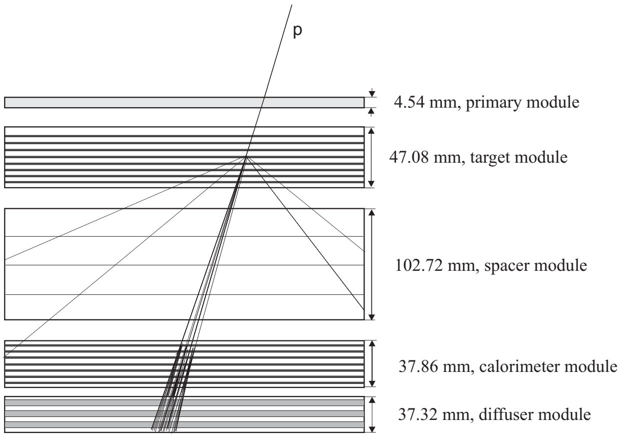

Figure 1. The structure of REC RUNJOB'97.

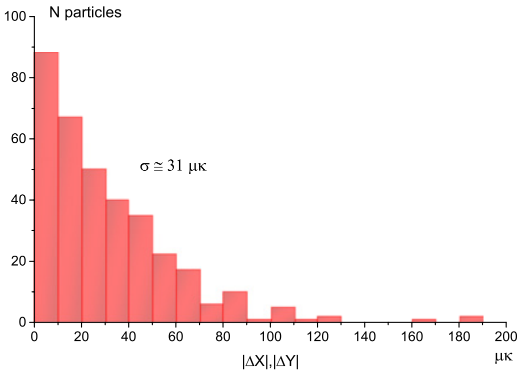

Figure 2. Deviation distribution of the measured co-ordinates of primary particles from the respective predicted ones.

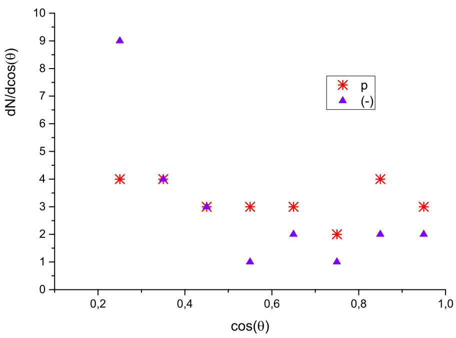

Figure 3. Zenith angle, θ, distribution for two groups of events: with observed primary proton track ($*$) and unfound ones ($\triangle$).

the zenith angle distribution for the group with observed proton track is nearly isotropic, that is not contrary to the expected zenith angle distribution of protons at the chamber exposure level ($\sim 10\,\mathrm{g/cm^2}$).

At the same time, an increased number of events with an unfound primary single charged particle track are observed in the zenith angle range $\theta > 60°$. It is interesting to note that the mean penetration depth, Λ, of primary particles within the REC from the first emulsion layer to the layer above the interaction vertex differs by a factor two for these groups in the zenith angle range from 60° to 79°. In units of mean free path length for a proton in the group with an observed proton track $<\Lambda(p)>= 0.18 \pm 0.12$, whereas for the group with an absent charged particle track $<\Lambda(-)>= 0.37 \pm 0.16$. Since the statistics of the studied interactions is low, we can only discuss about a possible indication of a distinction in the nature of the primary particles in the two groups of events.

3. Conclusion

According to the reprocessing of galactic particle interactions detected by REC RUNJOB'96-3B, RUNJOB'97-6A and RUNJOB'99-11A,B and related to the nucleon-nucleus interactions with gamma ray energy $\Sigma E_\gamma \geq 3\,\mathrm{TeV}$ and $\Sigma E_\gamma \geq 5\,\mathrm{TeV}$ respectively using a new method of searching and tracing of the primary particles in the REC nuclear emulsion plates the primary proton tracks are not observed in about half of the events. The absence of single charged particle tracks within the search area for the primary particle is consistent with the original processing of the RUNJOB experiment data. The nucleon flux incident on REC may include the secondary neutrons from the interaction of the primary cosmic rays with the residual atmosphere above the exposed installation ($\sim 10\,\mathrm{g/cm^2}$). According to calculations [6], their proportion in the flux of secondary particles is about 4% which is much smaller than the experimental relative number of events with absent proton track within the search area. To clarify the nature of the primary particle in the events related to nucleon-nucleus interactions in the RUNJOB experiment further processing and analysis of experimental data is required.

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