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ENERGY SPECTRA OF COSMIC RAYS ABOVE 2 TEV AS MEASURED BY THE "SOKOL" APPARATUS

I.P.Ivanenko, V.Ya.Shestoperov, L.O.Chikova, I.M.Fateeva, L.A.Khein, D.M.Podorozhnyi, I.D.Rapoport, G.A.Samsonov, V.A.Sobinyakov, A.N.Turundaevskyi, I.V.Yashin

Institute of Nuclear Physics, Moscow State University, Moscow, 119899, Russia

ABSTRACT

Results on the energy spectra and charge composition of the primary cosmic rays at energies above 2 TeV measured onboard satellite by the "SOKOL" apparatus are presented. New data are included increasing the overall statistics by more than 50 percent. Analysis of the charge composition at different energies reveals the tendency to the decrease of the proton fraction in the cosmic radiation. We confirm our previous conclusion on the statistically significant difference in the ratio of the measured proton to helium fluxes over that measured at 10-100 GeV energies, which also implies non-identical energy spectra of those components.

In (Ivanenko 1988,1990) we presented the energy spectra of cosmic ray nuclei measured onboard the "COSMOS 1543" and "COSMOS 1713" satellites. The primary particle energy was measured by a calorimeter of depth 5.5 λ_p and charge was measured by solid-state Cerenkov detectors. Details of the experimental setup may be found in (Vernov 1981).

The data in (Ivanenko 1988,1990) included particles with trajectories crossing the top and the bottom of the calorimeter. A continuation of the experimental data analysis enabled us to add particles with trajectories escaping the calorimeter from its side, (with the additional requirement that the cascades in the calorimeter develop over the depth not less than 3.5 λ_p).We also corrected the procedure of the energy determination, which resulted for previously published data in the average energy increase of about 5%.

Since the effective calorimeter depth for additional events diminishes the energy threshold grows. We use thus the new data at somewhat higher energies than the old ones, namely, at E>5TeV for protons, at E>4TeV for He nuclei and at E>3TeV for heavier nuclei. The overall increase of statistics at these energies amounts to more than 50%.

The differential energy spectra of protons and all particles are shown in Fig.1. Results of (Asakimori 1991, Linsley 1983, Ryan 1972, Zatcepin 1990) are also presented. A power approximation of our data at energies above 5 TeV looks for protons:

$$dI/dE=(1.49\pm0.11)\cdot10^{-1}\cdot E^{-(2.85\pm0.14)}(m^2\cdot sr\cdot s\cdot TeV)^{-1}$$

and for all particles:

$$dI/dE=(2.77\pm0.12)\cdot10^{-1}\cdot E^{-(2.68\pm0.07)}(m^2\cdot sr\cdot s\cdot TeV)^{-1}$$

Fig.2 shows our spectra of He, M, H and VH nuclei together with results of (Asakimori 1991, Engelmann 1990, Meyer 1991, Ryan 1972, Simon 1980). Our data can be described by the power law with the indexes: $\gamma_{He}=2.64\pm0.12$, $\gamma_M=2.58\pm0.07$, $\gamma_H=2.49\pm0.07$ and $\gamma_{VH}=2.62\pm0.08$.

Table 1 presents the charge composition of cosmic rays as derived from our data. Table 2 lists the ratios of the different cosmic ray components.

TABLE 1 The charge composition of cosmic rays.

E(TeV)	p	He	M	H	VH	M+H+VH
>2.5	39±3	27±2	13±1	10±1	11±1	34±2
>5	37±3	28±2	14±2	9±1	12±2	35±3
>10	31±5	30±4	14±3	13±3	12±3	39±5

TABLE 2 The ratios of integral fluxes of different cosmic ray components.

E(TeV)	p/He	p/M+H+VH	He/M+H+VH
>2.5	1.44±0.15	1.14±0.11	0.79±0.07
>5	1.32±0.14	1.06±0.12	0.80±0.09
>10	1.03±0.21	0.79±0.16	0.77±0.14

It follows from the presented results that the proton spectrum is steeper than the spectra of other nuclei. The helium spectrum does not exhibit statistically significant difference from the heavier nuclei spectra.

The ratio of the proton flux to that of helium nuclei is given at energies near 60 GeV per nucleon in (Ryan 1972) as 26±3 and in the energy range 20-100 GeV per nucleon in (Webber 1987) as 24±3. It follows from our data that at energies above 5 TeV per particle the P/He ratio is 1.32±0.14. Provided the He nuclei index equals to 2.64, this corresponds to the value of the ratio at fixed energy per nucleon 12.8±2.1. The JACEE group gives a close value for this ratio at energies above 10 TeV per nucleon: 12.2±2.1. Henceforth, the difference of the proton to helium ratio in the two energy intervals separated by about two order of magnitude is far beyond the statistical uncertainty.

A pronounced decrease in the P/He ratio agree well with the model of the cosmic ray acceleration presented in (Silbeberg 1990). According to this model cosmic ray composition at high energy derives from the composition of the stellar wind of presupernova stars, including Wolf-Rayet stars featured with poor hydrogen abundance.

We can state on the basis of the analyzed experimental data that in order to come to definite conclusions on the behavior of the proton and helium spectra, in view of their important astrophysical implications, it is desirable not only to increase statistics at energies above several TeV per nucleon but to measure with high precision the spectra in above 100 GeV per nucleon.

REFERENCES

Asakimori K. et al: 1991,Proc 22 ICRC,2,57

Engelmann J.J. et al: 1990,Astron. Astroph.,233,96

Ivanenko I.P. et al: 1988,JETP Lett.,48,510

Ivanenko I.P. et al: 1990,Proc 21 ICRC,3,77

Linsley J.: 1983,Proc 18 ICRC,12,135

Meyer P. et al: 1991,Proc 22 ICRC,2,21

Ryan M.J. et al: 1972,Phys.Rev.Lett.,28,985

Silbeberg R., Tsao C.N.: 1990,Ap.J.Lett.,352,49

Simon M. et al: 1980,Ap.J.,239,712

Vernov S.N. et al: 1981,Proc 17 ICRC,8,49

Webber W.R. et al: 1987,Proc 20 ICRC,2,463

Zatcepin V.I. et al: 1990,Proc 21 ICRC,3,81

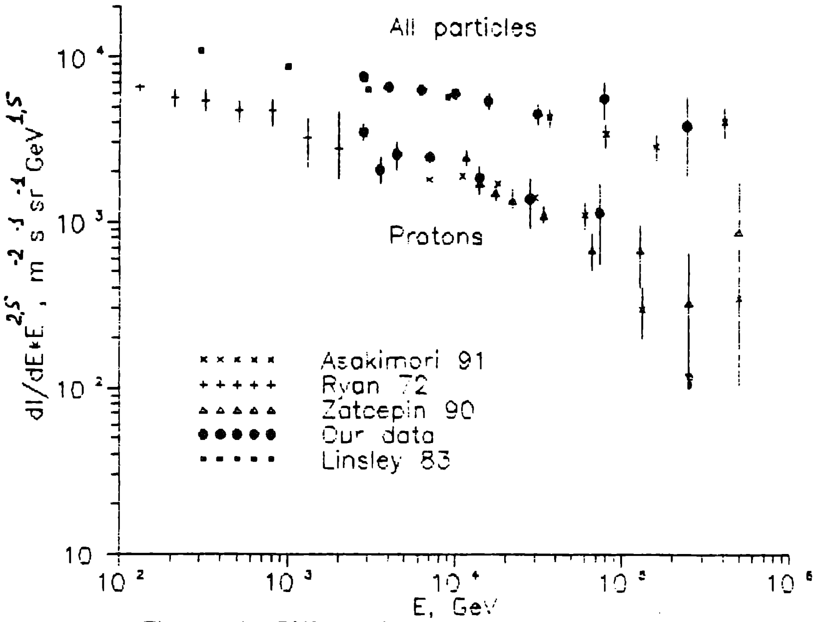

Figure 1. Differential energy spectra of protons and all particles

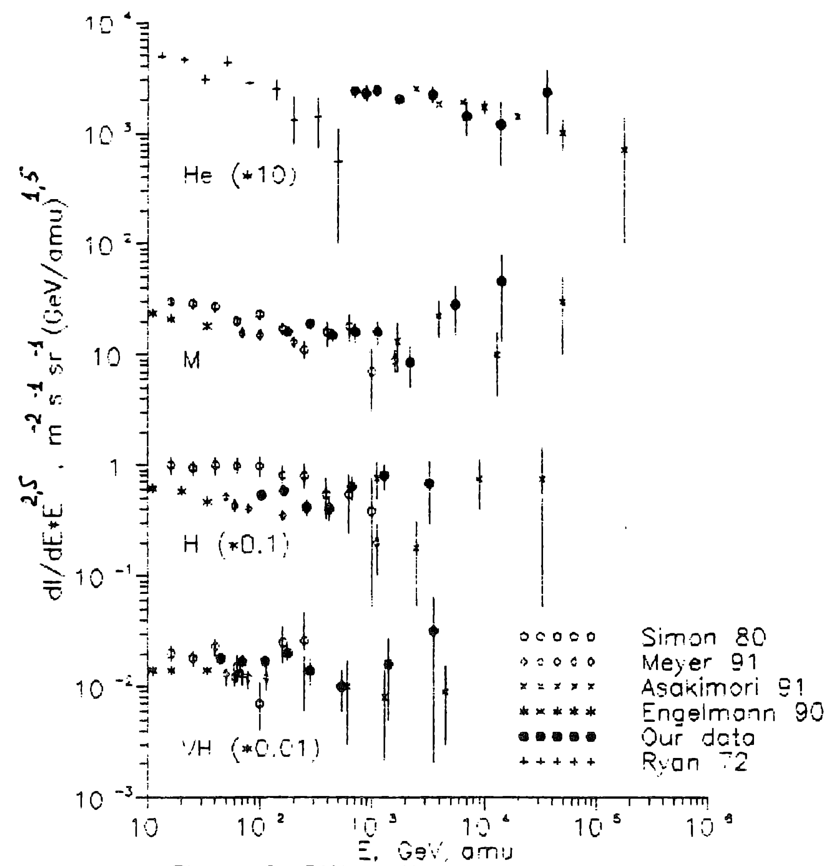

Figure 2. Differential energy spectra of He, M, H and VH nuclei