Meetings and Conferences

ALL-UNION CONFERENCE ON COSMIC-RAY PHYSICS

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AN All-union Conference on Cosmic-Ray Physics was held in Alma Ata October 12-18, 1966. About 300 delegates from the various scientific centers of the Soviet Union took part in the Conference, and also ten physicists from Poland, Czechoslovakia, Hungary and the German Democratic Republic.

During the six days of the Conference there were 16 review and invited reports (each 30 minutes long with 30 minutes discussion) in the plenary sessions, and about 150 original communications (each ten minutes in length with five minutes discussion) in two parallel sessions on nuclear physics and cosmic physics. On the last day of the Conference the morning sessions were conducted in three sections which discussed questions of apparatus and experimental technique.

The delegates had the opportunity to become acquainted with the work of the Tian' Shan' High-Altitude Scientific Station for Cosmic-ray Research, located at an altitude of 3200 m in the mountains near Alma Ata.

In what follows we will attempt to describe briefly the main directions of research reported at the Conference.

1. NUCLEAR PHYSICS RESEARCH

One of the most important questions in the interaction of elementary particles at superhigh energies presently inaccessible with accelerators is the energy dependence of the total cross section for nuclear interactions. Interesting experimental data have been obtained from the satellites Proton-1 and Proton-2. The cross section for inelastic interaction of protons with carbon nuclei was measured in the energy region from 2×10^{10} to 10^{12} eV. It was observed that the cross section increases by roughly 15—20% in this interval and then remains constant. The value obtained at 2×10^{10} eV agrees with the data obtained previously in accelerators for 10—20 BeV (210—220 mb), but is about 15% smaller than the result of repeated measurements made recently by Cocconi's group at CERN (254 ± 7 mb for 20 BeV). Therefore, if the recent CERN measurements, which apparently were made very carefully, are correct, the cross section is constant from 10^{10} to 10^{12} eV.

From the theoretical point of view the question of the preasymptotic rise in the cross section was studied in terms of several models for the kernel of the Bethe-Salpeter equation. It was shown that the possibility of a rise in the cross section in the energy range 10^{10}–10^{14} eV may be due to the formation in this energy region of fireballs, i.e., short-lived states with a mass of 3–5 BeV/c^2 with zero baryon number and without definite spin value.

The question of the formation of fireballs and the uniqueness of interpretation of the available experimental data on them was one of the most acute and controversial subjects in the Conference. It was shown that while formation of a single fireball in the energy region of ~ 20 BeV is improbable, the process is already important at $\sim 10^{11}$ eV, and at $\sim 10^{12}$ eV two fireballs are formed in an appreciable fraction of events. From a theoretical point of view, fireballs can be formed in peripheral processes. However, it is necessary here to separate clearly the nucleon-nucleon and nucleon-nuclear interactions. In particular, two peaks can appear in the angular distribution of secondary particles in the latter, even if the nucleon-nucleon interaction has a "central," hydrodynamical nature but the incident nucleon, and then an energetically emitted secondary meson, interact successively with two nucleons of the same nucleus.

Closely connected with the question of fireballs is the problem discussed at the Conference of separating central and peripheral inelastic nucleon-nucleon collisions. Two new methods were proposed which could help in the solution of this problem—separation on the basis of the squared four-momentum transfer, and a method utilizing the correlation between the inelasticity coefficients of clusters moving forward and backward in the center-of-mass system. The experimental data on the role of statistical processes (at accelerator energies) and hydrodynamical processes (at higher energies) were also discussed. Indications of the existence of hydrodynamical processes follow, in particular, from the production of very energetic neutral π mesons. The problem of separating coherent and diffraction events was also discussed.

Certain contradictions in the experimental data in the superhigh energy region can be successfully explained if we use the hypothesis, reported at the Conference, of the existence of a passive state in which a nucleon can exist for period of $\sim 10^{-10}$ sec after a nuclear interaction. However, the number of objections raised during the discussion shows that this hypothesis must be subjected to serious examination.

We should also mention the interesting although preliminary data (obtained by the ionization calorimeter and cloud chamber methods) on the angular asymme-

try, observed in a number of events, in emission of secondary neutral and charged mesons in nuclear interactions of nucleons and mesons with energies of hundreds of BeV. Also deserving of attention are the data on large values of transverse momenta (about 1 BeV/c) of secondary nucleons which, as a rule, are the energetically emitted particles at energies above 10^{12} eV. Unfortunately the accuracy in determining the particle energies in these events (observed in very large stacks of emulsions) is still insufficient to obtain definitive results.

Everything we have mentioned above refers to the inelastic interactions of particles. It is well known that the study of elastic interactions in cosmic rays encounters serious technical difficulties. At the Conference an apparatus design was described which would permit obtaining data on the elastic interaction of particles in the region from 30 to 700 BeV.

The theory of elastic and weakly inelastic processes (with formation of a small number of particles) at these energies was discussed in detail, based on consideration of poles in the orbital angular momentum plane. It was shown that, both in this theory and on the basis of several models employing the Bethe-Salpeter equation, we can expect that the asymptotic energy region lies rather high and begins at energies of $\sim 10^{13}$—10^{14} eV.

The search for quarks in cosmic rays was discussed with great interest at the Conference. At the present time the upper limit for the flux of quarks in cosmic rays is 1.5×10^{-9} cm^{-2} sr^{-1} sec^{-1} for the charge $\frac{1}{3}e$ and 1.4×10^{-9} cm^{-2} sr^{-1} sec^{-1} for the charge $\frac{2}{3}e$. It was reported that apparatus is being built which will allow this limit to be reduced by an order of magnitude. We will not discuss this problem in detail here, since it is discussed elsewhere in this journal (see p. 256).

Experiments with extensive air showers and the penetrating (muon) component of cosmic rays form a separate division. Serious arguments were advanced favoring the idea that the recently observed groups of penetrating particles (at depths of ~ 40 m of water equivalent) cannot be explained by the already known processes of development of extensive showers. Interesting discussions were also carried on on the possible appearance at energies of $(3—4) \times 10^{13}$ eV of an additional process (the so called "gammaization") which provides a substantial ($\sim 80\%$) fraction of the energy released to the electron-photon component of extensive showers.

Detection of the radio-frequency radiations of extensive showers at a wavelength of ≈ 10 m has revealed a number of important and in part unexpected properties of this radiation, in particular, its coherent nature, polarization, and considerably higher intensity than predicted theoretically.

Finally, there was discussion of the work at Yakutsk on construction of a giant installation for detection of showers of record-breaking size. The urgency of this experiment is due, first of all, to the necessity of verifying the theoretical prediction of a sharp drop in the primary energy spectrum at energies of $\sim 10^{20}$ eV resulting from interaction of the primary cosmic radiation with the residual thermal radio-frequency radiation in the Metagalaxy.

2. COSMIC PHYSICS INVESTIGATIONS

A number of new results were reported on investigation of primary cosmic rays. Among these we will mention first the absolute measurements in balloon flights of the intensity of protons with a given magnetic rigidity R. The value obtained, $I(R > 17\ BV) = 75 \pm 5$ protons/m^2-sec-sr, is in good agreement with the estimate of the energy carried into the atmosphere by cosmic rays at the corresponding geomagnetic latitude, and turns out to be substantially smaller than the values usually given in the literature. An accurate value of this intensity is important for plotting the spectrum of primary cosmic rays in the energy region from 10^{10} to 10^{14}—10^{15} eV.

Considerable interest was evoked by the preliminary results on measurement of the primary spectrum in the energy region 10^{10}—10^{14} eV in satellites of the Proton series. These included measurement of the spectrum of the total radiation in the energy region 5×10^{10}—10^{14} eV. In this energy region the integral spectrum of all particles turned out to follow a power law with a single exponent $\gamma = 1.73 \pm 0.1$. This region of the spectrum had not previously been studied in detail and, although extrapolation from the geomagnetic region to the region of energies of extensive air showers led to a similar value of γ, the existence of a nonmonotonic relation ("breaks") in this region of the spectrum could not be ruled out.

Preliminary data from Proton-1 and Proton-2 indicated a substantial quantity of nuclei heavier than iron in the primary cosmic-ray flux, up to elements with $Z = 48$. Improvement of these data can shed new light on the nature of the sources and acceleration of cosmic rays.

Extended measurements of the variations in the intensity of extensive air showers in the energy region 10^{14}—10^{15} eV, carried out at Yakutsk, have provided the best estimate at the present time of the maximum possible anisotropy of cosmic rays in this energy region. It is less than 0.1%.

An important contribution to the solution of the problem of the primary electrons was provided by the measurements made at the Dolgoprudnyĭ branch of FIAN (Physics Institute, Academy of Sciences, U.S.S.R.) of the electron intensity in the energy region above 3 BeV. These studies established reliably for the first time the electron spectrum in this energy region and also the presence of electrons with energies up to 80--100 BeV.

In the field of theory of the origin of cosmic rays or, more accurately, the astrophysics of cosmic rays

and related subjects, we will mention the following results.

As the result of an extremely time consuming study, improved values were obtained for the fragmentation parameters for different groups of nuclei, and in particular for nickel nuclei, by impregnation of photographic emulsions bombarded by a proton beam of a given energy. The improvement of these parameters has an importance of the first degree for analysis of the mechanisms of production and the nature of the motion of cosmic rays in the interstellar medium.

Significant development has occurred in theoretical studies in the field of neutrino astrophysics, which at the present time is beginning to become a major new direction of experimental study of processes in the universe.

Analysis of the interaction of cosmic rays of superhigh energy with the residual thermal radiation in the universe allowed estimation of an upper limit of the cosmic-ray energy spectrum. This limit is due to pion photoproduction processes and is $(3—5) \times 10^{19}$ eV.

The existing hypotheses on the origin of cosmic rays were analyzed, and arguments were presented in favor of the stationary galactic model and against the metagalactic model. The bases of these arguments are as follows: The low energy density of relativistic particles in metagalactic space compared to that observed in the galaxy (there are now direct data for electrons from x-ray astronomy); the presence in the galaxy of electrons with energies up to 100 BeV which rapidly lose energy as the result of magnetic bremsstrahlung (synchrotron radiation) and Compton scattering and, consequently, could not have been produced in the distant past; data on the composition in the low energy region, on the relative abundance of elements and isotopes absent in the sources but observed in cosmic rays, and data on the isotopic composition of beryllium and the "cosmic" age of meteorites. All of these data are difficult to reconcile with the hypothesis of generation of cosmic rays in a single event, for example, an explosion of a galactic nucleus. They argue in favor of the stationary or quasistationary production of cosmic rays in the galaxy (see UFN 88, 485 (1966)).

Many reports were devoted to the problem of cosmic rays in the solar system, and particularly to questions of the production of solar cosmic rays, their propagation in the interplanetary magnetic fields, and the modulation of galactic cosmic rays.

A transition to a strict, quantitative analysis of the experimental data is characteristic of this direction of research. On the one hand, this applies to estimation of the reliability of separation of the various harmonics in the variations of cosmic rays. On the other hand, quantitative theories of the observed variations are being intensively developed. We can mention here the theoretical interpretation, suggested at the Conference, of cases of the preferential increase in intensity of heavy nuclei produced in active regions in the sun. The experimental data agree satisfactorily with the idea of a preferential "escape" of heavy ions in the statistical acceleration of particles.

We should particularly mention studies giving a theoretical analysis of the diffusion of energetic particles in chaotic magnetic fields, and the development of the theory of modulation of galactic cosmic rays in the solar system. This theory allows us to connect such observed parameters as the velocity of the solar wind, the structure of the interplanetary magnetic field, the frequency spectrum of its inhomogeneities, and others, with the amplitude of the variations and the degree and direction of anisotropy of cosmic rays at the Earth. Important consequences of this theory are the determination of the size of the region of modulation, the connection of the modulation with the sun's activity and to the relative delay of the former, and the possibility of the re-establishment of the primary spectrum of galactic cosmic rays beyond the limits of the solar system.

In addition to these investigations of a generalizing nature, a number of new experimental results were presented on specific cases of the increase of cosmic ray intensity in various energy intervals, including measurements at large distances from the Earth.

Translated by C. S. Robinson