Sixth All-Union School on High-Energy Inelastic Interactions (Bakuriani, Georgian SSR, January 20-30, 1978)

A. B. Kaĭdalov and L. A. Ponomarev

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The Sixth All-Union School on High-Energy Inelastic Interactions was held January 20–30, 1978, in Bakuriani. As usual, the lecturers represented the leading centers of research on the physics of elementary particles in both the accelerator and cosmic-ray energy ranges. Specifically, lectures were ready by researchers from the Lebedev Physics Institute, Moscow; the Institute of High-Energy Physics, Serpukhov; the Joint Institute for Nuclear Research, Dubna; the Institute of Theoretical and Experimental Physics, Moscow; the Leningrad Institute of Nuclear Physics; the Institute of Physics of the Academy of Sciences of the Georgian SSR; the Institute of Nuclear Physics of the Siberian branch of the Academy of Sciences of the USSR, Novosibirsk; the Erevan Institute of Physics; and several other institutions.

The topics of primary interest could be discussed extensively and in their various aspects at the School because the participants represented a variety of areas within the general field of the physics of elementary particles: the strong, weak, electromagnetic, and gravitational interactions; quantum field theory; high-energy physics; low-energy physics; nuclear physics, accelerator physics; and cosmic-ray physics. Furthermore, different schools of thought within these specialized areas were represented.

In addition to the treatment of the general questions in lectures or series of lectures, special seminars were arranged for discussing the more specific theoretical and experimental questions of the most current interest.

Strong interactions at high energies attracted much interest at the Sixth Bakuriani School. There were discussions of both "traditional" topics, involving the characteristics of multiple-production processes in the interactions of hadrons with other hadrons and with nuclei, and new problems, involving the spectroscopy of charmonium, the possible existence of heavy quarks and leptons, and the production of hadrons with large transverse momenta.

Recent years have seen much progress in experimental research on high-energy inelastic diffractive processes. The data now available can be used to carry out critical tests of various theoretical models. At the School, diffractive processes were discussed within the framework of the theory of complex angular momenta. The best description of single and double diffractive dissociation and of double-pomeron exchange is given by the Drell–Hiida–Deck model with absorption being taken into account.

The multiperipheral approach explains many characteristic features of the multiple production of hadrons. It was shown in one paper that the model of single-pion exchange not only gives a correct description of the inclusive production of nucleons and Δ isobars but also explains the spin structure of the amplitudes for elastic πN scattering.

An extremely interesting question discussed at the School was the role played by heavy clusters in multiple production. Various correlation methods were examined for analyzing the many-particle final states, and it was pointed out that several of the correlation effects observed experimentally suggest the formation of clusters which decay into three or four particles. The physical nature of clusters was discussed.

One paper dealt with the parton approach to multiple production of hadrons and to reggeon field theory. It was pointed out that high-multiplicity processes ($n \gg \langle n \rangle$) at the energies presently attainable can simulate the interaction of hadrons at asymptotic energies.

There was much interest in the papers with recent results on new particles. Much experimental information has now been acquired on the properties of charmed particles; the D and D^* mesons (consisting of $\bar{c}u$ and $c\bar{d}$ quarks) have been studied most thoroughly. The masses of these mesons have been determined accurately, and several of their decay channels have been studied. The existence of F^+ and F^{*+} mesons ($\overline{cs}$) has been established, and charmed baryons have been observed. The experimental evidence for the heavy lepton τ^+ is becoming progressively more convincing. The experimental probabilities for $\tau^\pm$ decay agree well with theoretical estimates. There was also a discussion of experimental data implying the existence of Y vector mesons with masses $\approx$10 GeV, which may consist of new heavy quarks.

Problems of charmonium spectroscopy (the J/ψ, ψ', and χ mesons) were examined. It was pointed out that our understanding of hadronic interactions can be greatly improved through a study of the properties of charmonium and charmed particles. An analysis of the properties of the charmonium levels confirms the predictions of quantum chromodynamics—the theory of the strong interaction of quarks and gluons. The most difficult problem faced by the theoreticians is interpreting the particles X (2.83) and χ (3.45) which have been observed experimentally. It has been suggested that the X (2.83) meson is not the 1^1S_0 state of charmonium (the η_c meson) and that the η_c meson has a mass of 3.0–3.2 GeV.

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The color description of quark interactions opens up a novel approach to hadron classification and the formulation of selection rules which are a generalization of the Okubo–Zweig–Iizuka rules. One paper dealt with a quantum-chromodynamics string model for baryons and "baryonium" systems (bound states of baryons and antibaryons). Arising in this theory is a new object—the baryon vertex—whose motion must be taken into account in an analysis of quark diagrams. The experimental evidence confirming the existence of baryonium systems was reviewed.

Quantum chromodynamics exhibits short-range asymptotic freedom, so that reactions involving a large momentum transfer can be treated by perturbation theory. The use of quantum chromodynamics to calculate the differential cross sections for hard inclusive reactions was discussed. There were also discussions of reactions which lead to the production of a massive lepton pair with a large transverse momentum in hadron collisions, the inclusive leptoproduction of hadrons with a large transverse momentum, and e^+e^- annihilation resulting in the production of hadrons with a large transverse momentum from opposite hadron streams. The differential cross sections for these processes are expressed in terms of the observed quark distributions in hadrons, and they should fall off slowly with increasing transverse momentum.

A topic of considerable interest for testing of models of hard parton collisions is the inclusive production of hadrons with large transverse momenta in hadron–hadron collisions. Experimental hints of the existence of hadron streams with large transverse momenta were reported. The average stream charge in pp collisions agrees well with the average quark charge in the proton. A question which remains unanswered is why the p_T dependence of the inclusive cross section, $f = Ed^3\sigma/d^3p \sim 1/p_T^8$, is at odds with the prediction of quantum chromodynamics: $f \sim 1/p_T^4$. One possibility is that this behavior will set in at large transverse momenta,[1)] $p_T > 10$ GeV.

Questions related to the production of large-p_T particles in reactions with nuclei were also discussed.

The quark model makes several predictions regarding the interactions of hadrons with nuclei. This approach to the description of the production of fast particles in hadron–hadron collisions, discussed at the School, is extremely promising. In particular, study of the A dependence of the inclusive particle yields in the fragmentation region offers an opportunity for testing the hypothesis that hadrons consist of quarks. These predictions are of special interest in cosmic-ray physics.

Reports of the most recent cosmic-ray results, obtained at energies beyond those obtainable in accelerators, have been standard fare in this series of Schools. Let us summarize the results in this field which were reported at the Sixth School.

1. The cross sections for the inelastic interactions of hadrons with light nuclei continue to increase all the way up to 10 TeV, in accordance with the growth observed in the pp interactions in ISR experiments.

2. Results found at these energies suggest a continued growth of the inclusive cross section for $x \sim 0$. At the same time, the behavior of the average multiplicity remains logarithmic up to ~3 TeV.

3. Several pieces of evidence suggest marked changes in the nature of hadron interactions at $\gtrsim$100 TeV. In this energy range there is a sharp deviation from the scaling of inclusive spectra, and there is a rapid increase in the multiplicity, $\sim\sqrt{E}$. It is also possible that the average transverse momentum of the hadrons increases. To some extent these effects may be related to a change in the composition of the primary cosmic rays (an enrichment in iron nuclei).

An experiment carried out by the "Pamir" collaboration showed that at extremely high energies the hadrons are absorbed in the atmosphere with an anomalously low value absorption range, $\lambda_{abs} \sim \lambda_{interaction}$. The implication is that there are no leader particles near 10^3 TeV.

Interesting results have been obtained by Georgian physicists at the installation of Tskhra-Tskaro. They show that from 50 GeV to 3 TeV the behavior of the normalized secondary-particle multiplicity in reactions in nuclei is universal for all energies and all species of incident particles. The multiplicity distributions indicate a possible separation of the diffractive and multiperipheral mechanisms near 1 TeV. The inelasticity coefficients K increase slightly with increasing atomic number. For pions the value of K is 1.5 times that for nucleons.

Experiments carried out in beams of neutrinos and antineutrinos at energies in the range 2–200 GeV were also reported. The data demonstrate a deviation from scaling. Analysis of the $\mu\mu$ and μe events shows that they correspond to the production of charmed particles followed by a semileptonic decay.

There is presently much interest in the use of the methods of atomic spectroscopy to study neutral currents. Some of the papers discussed an experimental search for an optical activity of the vapor of heavy metals, which would be due to nonparity-conserving neutral currents. One paper dealt with the question of whether the interaction of muons and electrons is universal.

There were also papers and seminars on some general problems of the physics of elementary particles and field theory: the energy-momentum problem in the theory of gravitation, the role of neutrinos in astrophysics, the geometry of the microworld, the properties of solitons in a world of more than one dimension, the calculation of the higher orders of perturbation theory in the various models of quantum field theory, and the channeling of ultrarelativistic particles in

[1)]Recent work has shown that the pion-interaction contribution is important at smaller values of p_T (Russian Editor's note).

crystals.

It can thus be asserted that every one of the most important current problems in the physics of elementary particles was examined at the School. That such a wide range of questions could be discussed was due largely to the excellent organization of the School, for which credit goes to the organizers from the Institute of Physics of the Academy of Sciences of the Georgian SSR.

In summing up the six years of the Bakuriani School on high-energy inelastic interactions, we should point out that this School is now one of the most impressive in the Soviet Union in terms of the range of questions which it covers in the physics of elementary particles.

Translated by Dave Parsons