Interaction of hadrons at superhigh energies (School at Nor-Amberd, Armenian SSR, 30 September–5 October 1985)

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A school with the title "Hadron interactions at superaccelerator energies" was held at the Nor-Amberd high-altitude station of the Erevan Physics Institute in the fall of 1985. This meeting resumed, after a 10-year interruption, the traditional Nor-Amberd schools well known in this country and abroad. Organized for the first time in 1961 on the initiative of A. I. Alikhanyan, these schools played an important role in the development of high energy physics. The broad range of problems discussed, an opportunity to obtain immediate information about the latest achievements, lively and fruitful discussions—all this invariably attracted to the work of the schools both leading Soviet and foreign scientists and young scientists. The international character of the school contributed to strengthening the cooperation of scientists from different countries and to popularization of achievements of Soviet science.

In his opening words the scientific director of the school S. G. Matinyan emphasized that the 1985 school, while continuing the traditionally broad range of the program, is at the same time oriented to a large extent to the physics of cosmic rays, and, first of all, to the large scale ANI experiment that is under preparation jointly by the Erevan Physics Institute and the P. N. Lebedev Physics Institute of the Academy of Sciences of the USSR (FIAN).

The presentation of S. I. Nikol'skiĭ was devoted to the investigation of extensive atmospheric showers (EAS) and hadrons with primary energies of 5–1000 TeV at the high-altitude experimental Tien-Shan station of the FIAN. It was emphasized in the presentation that the nature of the dependence of the form of the shower accompanying the leading hadrons in the EAS on their energy, apparently, cannot be explained by assuming constancy of the inelasticity coefficient of nucleons and unchanging composition of primary cosmic radiation. In the relations between various EAS components with primary energies of 20–600 TeV, contradiction is observed with the model using the monotonic extrapolation of accelerator data. The experiments can be explained by assuming violation of scaling in the fragmentation part of the spectrum of secondary nucleons.

A comparison was made in the presentation of A. P. Garyaka and É. A. Mamidzhanyan of experimental results for cosmic rays with accelerator data and with various theoretical models.

Several presentations were devoted to the largest of all experiments that are under preparation now, i.e., the ANI complex. Participants of the conference had a chance to learn about the progress in the construction work for this experiment during a visit to the Aragats high-altitude experimental station. In the report presented jointly by the Erevan Physics Institute and FIAN (S. V. Ter-Antonyan), three independent methods of measuring the cross-section σ_{pA}^{in} for inelastic proton interaction with air atom nuclei were proposed. It was shown that by using all suggested methods it will be possible, within 3–5 years, to achieve an accuracy in determination of σ_{pA}^{in} not worse than 5% for energies $E > 10^3$ TeV.

In order to determine the energy of the primary particles that cause atmospheric showers, the ANI installation will be using together with other techniques optical (Cherenkov and scintillation) radiation from EAS. The special features of recording this type of radiation in showers with high (10^{11}–10^{15} eV) and superhigh ($> 10^{15}$ eV) energies were discussed in the presentation of A. T. Avundzhyan and F. A. Agaronyan.

It is planned to establish a center for the collection and systematization of experimental data within the ANI experiment. The structure and general principles of this center were described in the presentation of A. A. Chilingaryan.

The research methods that will be used in the future on the installation ANI and now being tested on the smaller model installations—"Hadron" in Tien-Shan and "Maket" on Aragatz. S. B. Shaulov reported in his presentation on the commissioning of the "Hadron" installation.

Extensive experience has been accumulated in our country with x-ray-emulsion chambers in connection with the experimental project "Pamir." The main attention in the experiment is at present devoted to the so-called superfamilies, i.e., to the families with the highest possible energies ($\Sigma E\gamma > 10^3$ TeV). Experimental results on registration probabilities of superfamilies, the description of "Halo" and causes of its origin, the events with multiple formation of "Halos" and their alignment along a straight line have been reported in the presentations of V. M. Maksimenko and S. A. Slavatinskiĭ, and also of T. L. Asatiani and L. É. Genina. The authors presented the data on the azimuthal anisotropy for all energy-selected γ-quanta of superfamilies and their correlation with the "Halo" alignment. It is shown that the superfamily data indicate a rather large scaling violation which, however, is smaller than in the CKP-type models.

Yu. A. Smorodin has analyzed in his presentation miniclusters—the narrow groups of particles observed in gamma-hadron families. The author also discussed the possibility of explaining these groups by the sequential decay of D*-mesons, the first stages of which proceed with small transverse momenta.

The results of the recently completed cosmic ray experiments were summarized in a number of lectures presented at the conference. The results on the cross-sections of inelastic proton and pion interactions in lead and carbon obtained at energies of 0.5–5 TeV in the "Pion" experiment (G. V. Karagezyan) were presented. The correlation between the measured cross-section for hadron interaction in the ionizing

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calorimeter "Pion" and the intensity of the accompanying shower was discussed (M. I. Keropyan). The results on the partial inelasticity coefficients K_γ for protons and pions in iron have been analyzed (S. O. Sokhoyan), as well as the characteristics of the albedo particles generated by the interaction of charged and neutral hadrons in cosmic radiation with the nuclei of lead and iron (G. T. Oganyan).

V. I. Yakovlev summarized the preliminary results of the analysis of the so-called "Tien-Shan effect", i.e., the cascades with an anomalously small absorption in matter. The major conclusion of the authors is that these cascades are connected with the formation of "charmed" particles that carry away a significant amount of energy of the primary hadron. The cross-section for the formation of such particles, for energies above 10 TeV, is estimated to be 3.5 ± 0.4 millibarn/nucleon.

"Charmed" particles can serve as a source of the "fast" or "direct" muons, that at large energies can exceed in intensity the usual muons formed during the decay of pions and kaons. From this point of view the presentation of Yu. N. Vavilov was interesting. He analyzed the intensity of horizontal EAS. An intensity estimate of muons with energy above 100 TeV given in this presentation gives $(2.7–3.0)\cdot 10^{-8}\mathrm{m}^{-2}\mathrm{c}^{-1}\mathrm{Sr}^{-1}$.

Yu. M. Kotlyarevskiĭ, basing his presentation on the results from the Tskhara-Tskharo installation, has discussed the special features of multiple particle production in different nuclear targets.

The presentation of A. P. Garyaka and A. G. Arutyunov were devoted to the modeling of cascade processes in the atmosphere. In the first of these reports a method for calculation of average spatial and energy characteristics of different components of EAS was presented. The second presentation reported on the calculation of the average energy spectra for EAS components initiated by photons.

The most attention in theoretical presentations was devoted to the description of hadron-hadron interactions based on the quark-gluon model.

A. B. Kaĭdalov has discussed in his presentation an approach based on the $1/N$-expansion in QCD and the string model. The model reproduces well the experimental data on the behavior of total and elastic interaction cross-section and on the multiplicity of charged particles. For moderate energies, an approximate KNO-scaling occurs. The data obtained on the ISR and SPS-colliders are described successfully. K. A. Ter-Martirosyan presented the predictions for total cross-sections and hadron multiplicity for future accelerators based on the supercritical pomeron model.

Two presentations were devoted to the development of the quark-gluon string model for description of hadron-nuclear interactions. Yu. M. Shabel'skiĭ demonstrated the inclusive spectra of different particles generated in hA-collisions, that were calculated using this model. In the work of A. D. Erlykin these spectra were used to make calculations concerning the passage of cosmic rays through the atmosphere. The comparison of these calculations with existing experimental data shows generally a satisfactory agreement with the predications of this model, although at very high energies (abve 10^{15} eV) a somewhat larger degree of scaling violation is required.

Calculations of inclusive generation characteristics of "charmed" particles and antiprotons based on the same model were given in the presentation of O. I. Piskunova. It was shown that the model describes qualitative specifics of the spectra, mostly the central generation of D-mesons and fragmentation character of the Δ_c spectrum. The results of calculations of $\bar{p}$-spectra were used for a discussion of the nature of radiation from Cygnus X-3. Sh. S. Eremyan has considered the problems of renormalization of the intercept and of the pomeron generation threshold for the Regge field theory and has shown that for critical and superficial regimes one obtains the same asymptotic behavior of the intercept.

P. G. Badalyan discussed, within the framework of the multiparton recombination model, the inclusive spectra of P,Π,K fragmentation into barion resonances with small transverse momenta.

B. Z. Kopeliovich and N. N. Nikolaev have discussed the asymptotics of nucleon-nucleon cross-sections within the framework of perturbative QCD concepts. At moderately high energies the two-gluon exchange satisfactorily reproduces the constant part of the total cross-section. With an increase of the energy the contribution of poles with $j - 1 = \Delta > 0$ becomes dominant, with Δ_{ef} growing with an energy increase. It is shown that the data on the absorption of CR in the atmosphere for $E \sim 10^5$–10^6 TeV require that $\sigma_{pp}^{tot} \sim 160$–$200$ mbarns and this asymptotically gives $\Delta_{ef} \sim 0.25$–0.35.

The detailed analysis of experimental data on hadron-nuclear cross-sections presented by N. N. Nikolaev has shown that the cross-section for the interaction of hadrons with bound nucleons systematically exceeds, by 5–10%, the cross-section for the interaction with free nucleons. This is interpreted as a QCD enhancement of the cross-section for scattering by multiquark clusters and an indication of the existence of such clusters additional to the EMC effect.

I. I. Roĭsen has presented a QCD-approach to the description of double diffractive dissociation processes with large momentum transfer involving interaction of high energy hadrons and discussed its connection with the Regge phenomenology. It was shown that the relative contribution of such processes grows logarithmically with the energy. The following possible experimental consequences of this fact were discussed—a positive correlation between longitudinal and transverse momenta of secondary hadrons at high speeds and the growth of their inclusive distribution in the case of large transverse momenta, and also the asymmetry of EAS in the target plane and, in particular, the appearance of aligned events.

E. V. Shuryak has considered the problem of transverse flying apart of matter when the phase transition "hadrons-quark-gluon plasma" is crossed. The correlations $\langle p_\perp \rangle$ and particle density discovered in cosmic ray and accelerator experiments were interpreted by the author as a demonstration of plasma "explosion."

M. G. Ryskin has emphasized the important role

played by semihard processes at high energies. There are reasons to believe that already at present the formation of a quark-gluon plasma is being observed in collider experiments and in cosmic rays. However, in contrast to the usually proposed equilibrium case, thermodynamic equilibrium in a plasma is not attained because of the small number of collisions between partons.

Considerable interest was also attracted by the review papers on more general subjects (A. A. Petrukhin, "Development of optical and acoustic DUMAND," A. D. Linde, "The Inflationary Universe," V. A. Tsarev, "Neutrino geophysics," K. A. Ter-Martirosyan, "Supergravitation and superpartners") and by the materials of international conferences presented by A. B. Kaĭdalov and É. A. Mamidzhanyan.

A review of the work on the development of detectors for accelerators and colliders of the next generation was presented by T. L. Asatiani. V. A. Ivanov considered the questions of muon spectroscopy for muons with an energy larger than 1 TeV. At the methodological section of the school M. V. Anokhin gave an interesting presentation on a new method of extracting information from spark detectors using fiber optics lightguides that provide a coordinate accuracy of approximately 200 microns. V. D. Volovik in a presentation on the possibility of combining the ionization and neutrino calorimeters has demonstrated that such a combination will make it possible to increase the accuracy of energy measurement, to have reliable measurements of the partial coefficient of inelasticity K_γ for each event, to determine cases of largest energy transfer to hadron or electron-photon components, to determine the fraction of energy spent on nuclear interactions, etc. The group of K. M. Avakyan has presented a report on the hodoscopic module of proportional counters using aluminum tubes of rectangular cross section constructed at ErFI (Erevan Physics Institute). The amplitude spectra of signals from ^{55}Fe and ^{119}Sn sources given in the presentation indicate the good energy resolution and high efficiency of the developed module that can be used in many hodoscopic installations of the ANI complex. The section also considered the proposal by the group of authors from the Erevan Physics Institute and the Scientific-Research Institute of Nuclear Physica of Moscow State University, presented by G. L. Bashidzhagyan, concerning the search for large-mass particles at the ANI complex. It is proposed to use for this work scintillating dectors with a rapid readout of information for determining the longitudinal structure of EAS. By positioning a group of such detectors above a calorimeter and supplementing them by Cherenkov counters, it is possible to obtain additional information on the delayed particles in EAS and to evaluate their masses and flux.

According to the unanimous opinion of all the participants in the school, the resumption and regular conducting in the future of the Nor-Amberd schools will undoubtedly be useful for better communication among physicists working on accelerators and with cosmic rays, and for the concentration of efforts on the construction of the ANI complex.

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