E. L. Feĭnberg. *Cosmic rays and elementary-particle physics.* When we consider the question as to the expediency of broad pursuit of further research into the nature and the laws of interaction and transformation of the particles in cosmic rays, we are confronted immediately with three new questions:

1. Since we have in the cosmic radiation a weak and uncontrollable source and it is seldom possible to determine all the necessary parameters in a single experiment, *can we trust* the results obtained in cosmic rays? Half a century of experience has taught us that *all* the results obtained in cosmic rays by various investigators have invariably been correct and have been confirmed when it became possible to test them on accelerators. Errors, sometimes sensational, have always been made by individual groups (or laboratories) but have been tracked down by the investigators themselves.

2. *Should attention be paid* to results obtained in cosmic-ray physics? It can be seen in a number of examples how failure to consider cosmic-ray data has allowed erroneous ideas to persist for many years in particle physics, to be abandoned only when their error, and the correctness of the cosmic-ray data, were demonstrated in accelerator experiments.

Initially (during the 1950s and early 1960s), for example, only small average multiplicities were accessible to accelerator experiments, and attempts were made to explain the multiple-production process as the excitation and subsequent decay of colliding nucleons as a result of exchange of some particle or Regge pole. Only after moving to higher energies and high multiplicities was it understood that this is a highly particular process. Then the simple multiperipheral comb with a scaling distribution of the inclusive cross section was used as a basis. Not until the mid-1970s did an accelerator experiment show that not even this is correct for the basic group of generated (pionizing) particles: neither the plateau required by this model, nor the energy-independence of its height, nor the predicted increase in the width of this plateau with energy exists. The picture became increasingly similar to that obtained for this range from cosmic rays over twenty years earlier: a "multiperipheral chain" with a small (averaging 2–4 for energies up to several TeV) number of teeth, some of which were heavy clusters (fireballs). It was understood why scale invariance should characterize only the fragmentation (fastest) products, and not the numerically preponderant component. This is also in exact agreement with what had long been established in cosmic rays (nonlogarithmic increase of multiplicity with energy, etc.).

3. *What can be expected* at this time from further cosmic-ray research? Extremely important results and suggestions pertaining to the interaction of hadrons in the superaccelerator range are already available, especially for hadron energies of 10^{12}–10^{15} eV (in the lab system) and sometimes up to 10^{18} eV. Transfer of the "center of gravity" of research to the 10^{15}–10^{17} eV range is a priority matter.

The main general result is that up to energies of the order of magnitude of 10^{14} eV there are no cardinal changes in the principal characteristics of the multiple-production process—they remain much the same as those known for lower energies. However, new features appear above that energy. Apparently, the multiplicity begins to increase with energy not only faster than the logarithm, but even faster than $E^{1/4}$, and perhaps even as $E^{1/2}$. This pertains to the most numerous, pionization part. Fragmentation particles, on the other hand, are generated in numbers smaller than those predicted by scale invariance, which begins to fail here. Then there begins an admixing of processes in which particles with very large transverse momenta are generated (momenta tens of times larger than the average transverse momentum over the entire preceding energy range). At first, such processes account for about one percent of all collisions, but when the energy rises to 10^{15}–10^{16} eV, their fraction increases, perhaps to ten percent (data from multicore extensive air showers, from x-ray-emulsion experiments, which show families of gamma quanta spaced widely across the film, etc.).

Note should also be taken of the "Tien Shan anomaly:" in the ionization calorimeter, avalanches from hadrons and shower hadron cores are damped normally (in accordance with the nucleus-nucleus cross section known for lower energies) only at energies up to about 10^{14} eV. At higher energies, however, they are damped much more slowly (as if they now included many particles that interact less strongly than known hadrons, although this is not, of course, the only possible explanation).

Finally, we need hardly mention the totally incomprehensible events (from the Brazilian-Japanese collaboration) known as "Centaurs," in which about a hundred hadrons are generated, but with no pions at all, in a total about-face from hadron processes of the usual type. Although only two of the five recorded events may be considered absolutely "pure" and not amenable to conventional explanation, they are evidence of some sort of fundamentally new phenomenon. All these cases were observed in the energy range 10^{15}–10^{16} eV, and the momentum distribution of the hadrons (nucleons?) was such as to indicate that they were products of isotropic decay of an object with a mass of the order of magnitude of 200 GeV.

Therefore, although *exhaustive* study of the particles is possible *only* with the aid of accelerators (while some of the most important aspects of cosmic-ray physics are totally inaccessible), the development of large-scale research using the methods of cosmic-ray physics in the superaccelerator range promises much and, es-

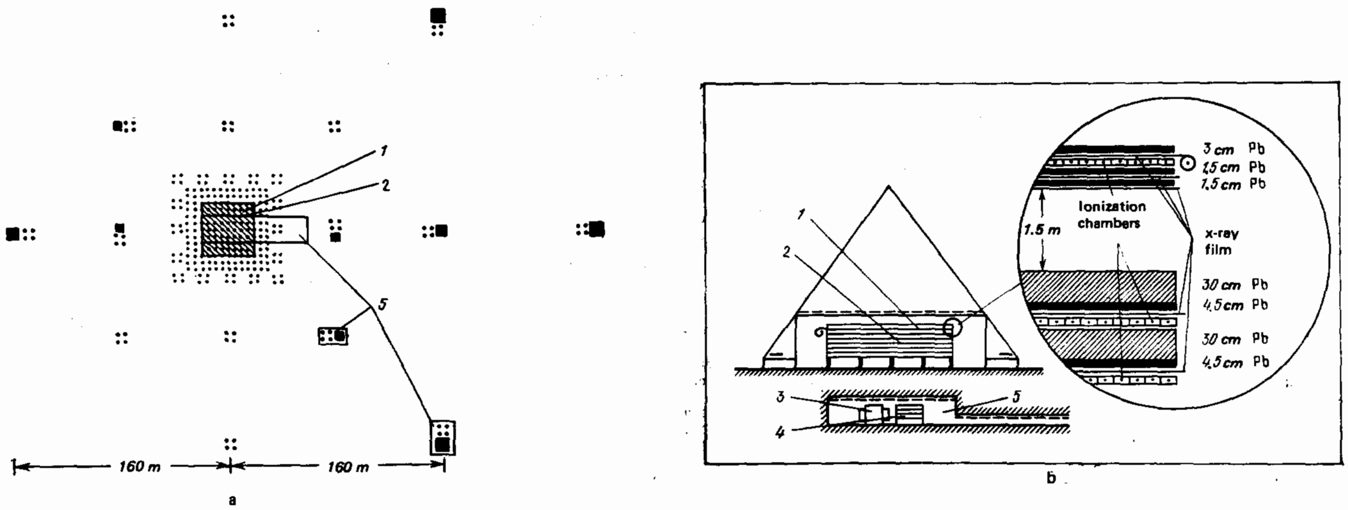

FIG. 1. Plan of ANI facility (a) and section (b) through its center. 1—x-ray emulsion chamber to cord hadrons and γ quanta with energies of several TeV and higher. One layer of the x-ray film moves to permit comparison of γ quanta from the air with extensive air showers; 2—ionization calorimeter for measurement of the energies of the electron-photon and hadron components of EAS. Area $S = 40\times40 = 1600$ m^2; 3—high-energy-muon magnetic spectrometer; 4—multilayer muon-interaction detector; 5) underground laboratories for cording munons with energies above 10 GeV; the dashes and dots represent scintillation detectors for determination of the angular and spatial characteristics of EAS accompanying high-energy γ-quanta and hadrons; the dark squares are gas-discharge counters.

pecially when we consider its low cost as compared to accelerator experiments, must be characterized as promising and necessary.

V. V. Avakyan, A. Ts. Amatuni, T. S. Asatiani, A. D. Erlykin, A. K. Kulichenko, É. A. Mamidzhanyan, S. G. Matinyan, S. I. Nikol'skiĭ, V. A. Romakhin, and E. I. Tukish. *Plan for an experiment to study hadron collisions at energies of 10^3–10^6 TeV.* The experimental hadron-research installation (ANI) is designed to cover a broad range of primary cosmic-ray nucleon energies: 10^3–10^6 TeV. The lower limit of this range is dictated by past experiments, the existence of other scientific facilities, and, most importantly, by experiments being planned for the next few years and beyond with colliding proton-antiproton beams, with particle energies of 0.27 to 3 TeV in each beam.

The upper limit of the energy range to be spanned in this hadron-interaction experiment is determined by the energy spectrum of the primary cosmic radiation and the realistic effective areas of the detectors used in the system.

The nature of cosmic-ray experiments on the one hand and the complexity of the multiple-production event to be studied on the other make it urgently necessary to consider the information yield of the experiment. This is not to question the possibility of a relatively large information yield of this experiment as compared to others, but to face the task of securing, in a single experiment, the most complete information accessible to contemporary techniques on multiple-generation processes at 10^4–10^6 TeV.

The solution of this problem is to be sought in a complex approach to the recording of cascade showers and groups of high-energy γ quanta, electrons, hadrons, and muons. The facility can be divided into three sections on the basis of the criteria used to choose the physical quantities for recording and subsequent processing (see figure).

Firstly, all extensive air showers with primary energies above $2 \cdot 10^3$ TeV are recorded as their cores pass through x-ray-emulsion chambers combined with an ionization calorimeter, area 1600 m^2, at the center of the installation. The possibility of studying composition and structure of the cores of EAS with primary energies above 10^4 TeV makes this facility unique.

Secondly, all groups of γ quanta and electrons or hadrons with 10-TeV total energies are recorded. Analysis of these groups at the high spatial-energetic resolution of the x-ray-emulsion chambers, in combination with information on the total energy flux at the observing level (ionization calorimeter) and the energy of the primary particle (EAS), has hitherto been carried out only for methodological purposes.

Thirdly, high-energy muons generated in inelastic collisions of hadrons and nuclei at energies above 10^3 TeV are recorded also with simultaneous information on the entire nuclear cascade in the atmosphere.

The above selection criteria exhaust all the possible results of incidence of primary protons and nuclei with energies above 10^3 TeV at the top of the atmosphere. However, a wide variety of narrower samples of events of interest can be taken during later statistical computer processing. All recording and processing functions will be automated, and the results stored in databank form. The computer will also make systematic quality-control tests of the performance of the numerous and varied modules of the detection system (see Fig. 1).

In conclusion, we list the parameters and characteristics of the inelastic collision event between hadrons and nuclei of air atoms that can be investigated, directly or indirectly: effective cross section for inelastic collision, multiplicity and composition of secondary particles, energy spectrum of secondary particles (fragmentation part), inelasticity coefficient for nucleons, secondary-particle transverse-momentum distribution, and correlation between parameters of the multiple-generation event.

Translated by R. W. Bowers