III-8-4. Lecture on Future Prospect

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Professor Rossi has summarized the progress made in the study of two very important aspects of the cosmic radiation during the past two years, and the prospects for the future. He has been particularly concerned with the contributions of cosmic radiation to space physics; and the study of the particles of the very greatest energy giving rise to the extensive air showers which have such an important bearing on theories of the way the cosmic rays are generated. I want to deal very briefly with two aspects complementary to those which he has discussed; namely the nuclear constitution of the primary cosmic radiation, and the studies of nuclear collisions at very high energies.

Let me begin with one or two general remarks. For a long time we have, in these particular fields, been in great need of decisive experiments. The situation has been rather similar to that in the late 1930's when the relation between the hard and soft components was unknown, and many experiments with counters and absorbers were made with a growing complexity of design. The phenomena were so complicated, and precise information was so lacking, that many alternative arguments could be sustained. It was like walking on a bog with no sure ground; the further you went on, the deeper you seemed to sink. We seem to be emerging from a somewhat similar situation. The keynote for the future should be the design and execution of decisive experiments, for we now have the means to carry them out. We should try and make sure that people are all working on experiments which will yield significant results; and that no body is frittering away his energy on trivial or useless experiments.

When I say that we are emerging from a difficult period, I don't want to suggest that the way forward will be particularly smooth and easy. We all know what severe constraints upon experiment are put by the low intensity of cosmic radiation, especially of the heavy nuclei in it, but I think we have been able to distinguish in this conference a fairly clear programme which will give important and significant information.

In both the aspects of the cosmic radiation to which I have referred very considerable progress has been reported here. We can now be certain that, at least at the low-energy end of the spectrum, the light elements lithium, beryllium and boron make an appreciable contribution, about 18%, to the flux of nuclei with Z greater than two. We also have an impression of the general trend of the charge-spectrum in higher values of Z, but our information is approximate only. We need to develop methods of charge determination which give us a clear resolution throughout the observed spectrum, and which allow us to begin to resolve the isotopic constitution not only for hydrogen but for heavier elements. By making experiments with satellites, and using improved detectors based on solid-state and other devices, this is now rapidly becoming within the bounds of technical possibility. We need also to make a serious attack on the constitution of the primary radiation up to much higher energies, because of its bearing both on the problem of the origin of cosmic rays, and on the extensive air showers.

In the study of high-energy interactions also, important advances have been reported. Progress in this field has been very slow because of the difficulty of making precise measurements of the energy of the particles making interactions and of the secondary particles which they produce; and of establishing the nature of the particles. This situation has now been improved with the introduction of new methods, especially the total ionization calorimeter in Moscow. In addition, the fragmentation of heavy nuclei in emulsion provides us with pencils of nucleons all of the same, or very nearly the same, energy; the "jets" produced in turn by the interactions of the individual nucleons of such a pencil give, in favorable cases, a much more reliable measurement of their common velocity, than do isolated interactions.

We shall have the great stimulus that we have already seen how the interpretation of the observations can lead to speculations of very great interest on the structure of the nucleons, and of the processes whereby the π-mesons and other particles are created in nucleon-nucleon collisions. We are here beginning to be able to penetrate into a new domain of the material universe, and we are already encouraged to think that studies of cosmic radiation will have a very valuable contribution to make; perhaps even a contribution of decisive importance. It will be very important to continue experiments of the above types precisely, because they can provide decisive information, even although the work is very arduous. In this work we are being forced more and more to work in collaboration in order to make a useful contribution. In many fields, isolated workers can obtain results of only small statistical weight, which cannot, in the absence of common procedures for the reduction of the information, be readily compared with those of others. Of course, not all scientists find themselves well adapted by temperament to work in collaboration. Some are allergic to collaboration and prefer to work alone; they often make a valuable contribution by doing so. It is not that we want everybody in a particular field to work in the same or a similar way. Our experience here has repeatedly emphasised how valuable it is to have different approaches and methods bearing on the same problem. But more and more decisive experiments are demanding cooperation on an international scale and we may be sure that this tendency will continue.

This problem of promoting effective collaboration, especially in areas which are newly developing their scientific experience and traditions, is an important one for the cosmic-ray commission. It can help to bring isolated scientists into stimulating contact with some of the main growing points of science in situation in which they would otherwise feel alone.

Another promising field is the study of the γ-radiation in the atmosphere, and that arising from nuclear interactions. It is now possible to determine the energy of individual γ-rays, at 10^3 Bev and more, with a precision of about 10%. The results of several methods appear, at least, in some important respect, to be in satisfactory accord, and we begin to have confidence in them. This work also must be actively pursued in order to improve the precision of the measurements, and to resolve some outstanding points of difference, which have been clearly definite in this Conference.

But cooperation has now got to the point where for all these experiments, there are experienced and growing bodies of experimenters. In work with emulsion it is important to provide the international teams of collaborators with the best possible exposures to facilitate the work. This is being done by the ICEF group on a very considerable scale and this type of collaboration could be extended to include other experiments in addition to those with homogeneous stacks. The performance of balloons has been greatly improved so that we can now expose heavy loads at great altitudes, sometimes for days: for several purposes, the longer the exposure at low geomagnetic latitudes, the greater the amount of information contained in the stack, and the more profitable the work of examination. The studies of high-energy nuclear interactions are important not only for their contribution to some of the most fundamental problem of physics. They are also important from two other points of view. We have seen that they have a bearing on the μ-meson spectrum to be expected from the interactions of primary nucleons with a given energy distribution. Further it has been suggested that the charge distribution among the most energetic μ-mesons may depend on the nature of the processes which contribute to the highest energy π-mesons emerging from the interactions. From this point of view, therefore, studies of the high-energy interactions by means of Wilson Chambers and emulsions are closely complementary to studies of the extensive air showers and of the penetrating component at great depths underground. Another proposal which may contribute to making more attractive such arduous experiments at great depths is due to Markov. He suggests that they could allow the observation of the interactions of very energetic neutrinos which have traversed the main mass of the earth.

The second aspect of the study of high-energy interactions is their bearing on the physical programme which it will be possible to undertake if a new generation of accelerators is constructed. When the 25-30 Bev accelerators were under design and construction, it was possible to be assured that they would open up a very valuable field of investigation. We could be confident that we should be able to produce homogeneous beams of π- and K-mesons with sufficient intensity to make fundamental experiments. It is difficult to have any similar assurance in respect of work with a machine generating protons with an energy of 300 to 1000 Bev, and from this point of view any contribution towards knowledge of the results of high-energy interactions through studies of cosmic radiation could be very important.

I have spoken on the one hand of the bearing of the studies of high-energy interactions on the observations of extensive air showers and μ-mesons, and on the other hand of its contribution to high-energy nuclear physics carried out by machine. Of course this is not a one-way traffic. In particular, I think those of us who attended the discussions on "jets" will have been greatly impressed by the contributions to the understanding of our problems made by authors who have made good use of new information becoming available through work with the machines. It is clear, I think, that we have not paid sufficient attention to this important possibility in the past, and that we should not fail to do so in the future.

Let me, in conclusion, turn for a moment to the work of the cosmic ray commission of IUPAP and the question of its future activities. The experience of this Conference has served to emphasise to us all the immense range of contributions which cosmic ray is making to the development of science. Whole new subjects are coming into existence in which the study of cosmic rays plays an essential part. The great success of this Conference serves to demonstrate that, in spite of these many fields of interest, we can still cover them successfully in a single conference of this type; and that there are great advantages to be gained by bringing together experts from the different special fields. We therefore propose to organize similar conference in the future though perhaps not so widely ranging as this one in which we were working jointly with the experts on geophysical phenomena and earth storms.

But it is one of the functions of IUPAP and its commissions to contribute to the development of science in regions where it is not yet flourishing. In this connection, we are not yet certain that the best way to help is to promote the organization of such a large conference as the present one in such regions. The organization of such a conference is a very severe strain on resources requiring the continuous work of many able people for long periods. We are inclined to think that in some regions it would be better to arrange conferences rather narrower in scope, involving rather fewer people, and that the scientists attending from abroad should spend some time in the region after the conference in giving lectures and taking part in discussions.