NAL PROPOSAL No. 146

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A study of proton-nuclei interactions at energies higher than 100 GeV with visual solid detectors

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July 1971

P R O P O S A L

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TO STUDY WITH THE AID OF VISUAL SOLID DETECTORS :

- Fragment production cross sections and angular distributions in the interactions of protons at energies higher than 100 GeV with different nuclei.

- Elastic and quasi elastic scattering of protons.

- The Pij fragmentation parameters of the heavy ions of the cosmic radiation by the way of inverse reactions (p,N).

I - SCIENTIFIC OBJECTIVES

1.1 Cosmic rays

In order to interpret the charge spectrum of the corpuscular component of the cosmic rays it is absolutely necessary to know the ion mean free path and the particle formation rate after ion fragmentation.

The observed spectrum at the earth level is indeed a deformed spectrum as a result of the interactions of the cosmic rays with the interstellar matter which is essentially constituted of hydrogen.

It is difficult to define unambiguously the traversed path length of primaries from their source to earth. Yet, one can ask the questions : what thickness of matter is traversed on an average by heavy primaries, and what is the chemical composition of primaries at their source ?

As was pointed out (1) the above questions can be answered by the analysis of the light nuclei component. It is known that the light nuclei Li, Be and B are easily destroyed by nuclear reactions at relatively low temperature so that they cannot exist in the hot matter like stellar interior and their cosmic abundance is really small. Thus almost all the light nuclei component in cosmic-rays must be produced through the break-up of the heavier component.

An observation on hydrogen-target break-up has been attempted by looking for the so-called "clean" break-up events in nuclear emulsion. Nearly half of the clean events are real hydrogen collosions but remaining half are due to peripheral collisions with heavier nuclei. One may try to reject the peripheral neutron collisions by examining the charge conservation in the events, but the charge measurement cannot be made as accurate as required.

The following fragmentation parameters in hydrogen (2) should be looked at with large reservation and are compared with those calculated (3) on the basis of theoretical considerations

		Calculated
P_{LL}	$\sim 0,21 \pm 0,17$	
P_{ML}	$\sim 0,41 \pm 0,12$	0,48
P_{MM}	$\sim 0,04 \pm 0,07$	0,25
P_{HL}	$\sim 0,50 \pm 0,18$	0,28
P_{HM}	$\sim -0,02 \pm 0,13$	0,28

In order to obtain more informations on the Pij fragmentation parameters particularly for the H nuclei and to examine the applicability of the simple diffusion equation, considerably greater statistical accuracy will be required than has been obtained up to now.

As known, the fragmentation parameters can be obtained also from an investigation of the reverse process that is the study of the fragments in the reactions induced by protons of high energy on different homogeneous targets. This solves the great difficulties of the direct study of the cosmic ion fragmentation.

The employed targets have a thickness of some microns and should characterize the following cosmic groups classified according to their charges :

L	: 3 - 5
M	: 6 - 9
H	: 10 - 19
VH	: 20 - 28
SH	: > 28

For example, for the H group we can use an aluminium target Al : Z = 13.

1.2 Mechanism of fragmentation of nuclei with very high energy protons

There are a lot of studies on fragmentation in the range of 1 to 30 GeV. The most recent results are these of Katcoff (4) 1968, Poskanzer (5) 1970, Dobrotin (6) 1970.

Very briefly, we can say that the cross sections are of the order of some hundred mb for nuclei of low charge (< 10) and of the order of magnitude of some ten mb for heavy nuclei. Katcoff notes an increase in the cross section by a factor of 2 to 2,5 for nuclei of charge < 10 in the range from 3 to 30 GeV.

However, the cross sections for the production of fragments of charge between 20 and 50 do not change from 3 to 30 GeV.

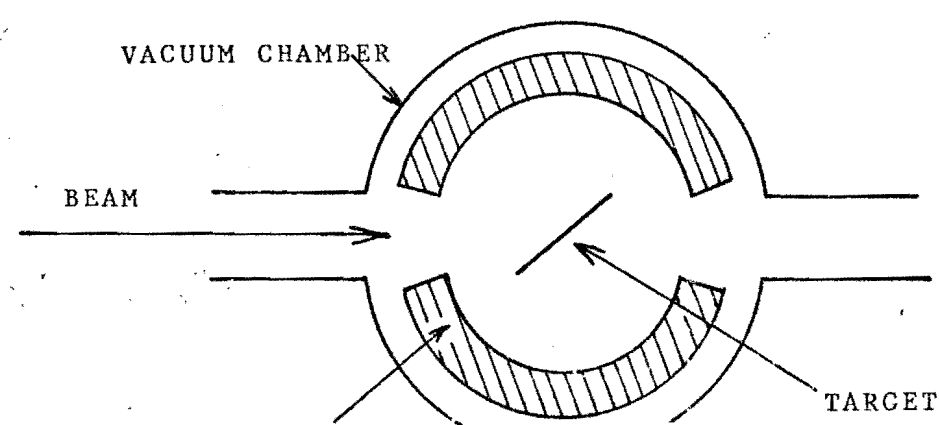
The experiment which is to be undertaken will show us what is the evolution of the cross section of production of fragments from 30 to 200 GeV and greater (7,8). Dobrotin (6) writes that for reactions (P.C.) at 1 000 GeV (cosmic) we have 200 mb and for reactions (P,Fe) we have 700 mb.

Particularly, the laboratory of corpuscular physics of the Nuclear Center of Research of Strasbourg has already made studies of this kind in experiments performed at CERN in the energy region of 20 GeV (Experiment E 52)(9-10-11). This experiment permitted us to become familiar with a great number of important experimental problems ; utilization of plastic detectors and the better exploitation of these detectors according to their selective sensitivity. The problem of radioprotection has been studied meticulously. The results of the discussions in this field, at the "International Congress on protection against accelerator and space radiation" in Geneve in april 1971, showed that during the irradiation of their targets at 200 GeV the dose would be of the same order of magnitude as that during our experiments at 20 GeV at CERN.

In the E 52 experiment, we have studied the interactions (p,N) at 20 GeV. We have obtained the isotopic production ratio d/p, t/d and ${}^{3}_{2}He/{}^{4}_{2}He$. The ratio $\frac{d}{p} \sim \frac{t}{d} \simeq 0,2$ is constant at any kinetic energy of the emitted particle. The results are in good agreement with observations made at other incident energies ; for example, Poskanzer (5) at 5 GeV. The energy spectra of the isotopes of charge 1 are correctly described by the nuclear evaporation theory for energies less than 30 MeV. At higher energies, the ejection of agregates from nucleonic cascade particles would explain the experimental spectra. On the other hand, with the solid state detectors technique, we have studied particles of charge $Z \geqslant 2$. We have put in evidence the rare isotope ${}^{8}_{4}He$. Finally, the exploitation of our experimental results let us believe in the existence of the isotope ${}^{8}_{6}C$. Such results let us hope also to obtain interesting features of reactions at energies higher than 100 GeV.

II - EXPERIMENTAL ARRANGEMENT

2.1 Vacuum chamber



The proton beam interacts with a target situated in the center of a vacuum chamber having roughly 60 cm diameter. The fragments which result from an interaction are detected by means of visual solid detectors placed around the chamber. The fragments enter the detectors at an angle of 30 degrees due to a special configuration arrangement. For this type of detector there is no background due to particles of charge 1 and 2 since it is insensitive to these particles.

2.2 Beam

A total flux of approximately 10^{14} protons is necessary for each exposure because the production cross section decreases rapidly with increasing charge (4).

In order to have a good angular definition we need a pencil beam of about 2 mm diameter.

2.3 Detectors

The various detectors used are chosen according to their different sensitivity to the heavy ions :

- cellulose nitrate
- makrofol
- silver chloride crystals
- glasses

Thus, by counting the number of tracks in two different detectors, it is possible to find the ratio Pij/Pik.

The stacks of detectors will give us the mass and energy spectra. The methodology of plastics has made great progress during recent years, particularly in the field of the registration selective character of the particles which is very important (12).

CONCLUSION

This experiment being done in a new field of high energy is of great interest firstly to the astrophysicists with regard to the problem of cosmic fragmentation and secondly to the nuclear physicists (experimentalists and theoreticians) working in the field of the mechanism of interactions at very high energy.

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