tierte Experimente von BORGHINI und Mitarb. [11, 23], die in eingefrorenen Lösungen von Porphyrexid in Alkoholen unter Beimischung von wenig Wasser besonders starke Protonenpolarisation fanden.

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Einer von uns (K. G.) dankt der Europäischen Gemeinschaft für ein zweijähriges Euratom-Stipendium und dem Max-Planck-Institut für Chemie in Mainz für die Möglichkeit, die Arbeit zu Ende führen zu können. Herrn Dr. J. HAUPT danken wir für interessante Diskussionsbeiträge.

Cosmic Ray Interactions in Paraffin and Lead

J. P. MUNDRA, D. P. BHATTACHARYYA, and P. K. SENCHAUDHURY

Department of Physics, Presidency College, Calcutta

(Z. Naturforschg. **24 a**, 1541—1543 [1969]; received 21 September 1968)

Nuclear interactions of cosmic rays under paraffin and lead have been studied by means of a counter controlled multiplate cloud chamber. The lead plates inside the chamber served as producer and analyser. A search has been made for the possible transition effect of nuclear interaction in lighter elements using charged components for triggering and to compare it with a previously observed apparent transition effect in graphite for neutron shower using coincidence of neutron counters. The results show a continuous increase of nuclear interaction with increasing thickness of paraffin absorber up to 30.4 gcm^{-2}. A similar rise is also observed under 11.3 gcm^{-2} of Pb.

The nuclear interaction of high energy cosmic ray particles with condensed material has been a subject of study by many workers using different experimental techniques. Some experiments on this line involve direct measurement of moderate energy nucleons released in nuclear disintegrations. In one [1] of such previous investigations [2−8], the simultaneous production of at least two neutrons by nuclear interaction of cosmic ray particles in a producer layer of 2 cm thick lead, was measured under various thickness of graphite and lead as moderator. The detection was done by two layers of B^{10} enriched BF_3 neutron counters in coincidence. A continuous increase of coincidence rate under lead upto 25 cm (282 g cm^{-2}) was observed (integral effect). If one subtracts, however, the coincidence rate due to the nuclear interactions in the moderator layer, it turns out that the one related only to the interactions in the lower-most producer layer decreases monotonously (differential effect). But graphite showed an aparent strong transition effect with a maximum at about only 11 cm (19 g cm^{-2}). By filtering the nuclear-active components of cosmic radiation with solid absorbers, similar transition effects were observed by many earlier workers using emulsion techniques. The transition effect in graphite in the experiment refered to [1] was attributed to reflection of neutrons (albedo effect) in graphite. When the experimental results were corrected for the reflection effect, the frequency of nuclear interactions showed also a monotonous decrease with increasing thickness of graphite absorber. But there were some uncertainty in calculating the reflection factor indirectly from the experimentally observed data on neutrons from Ra-Be source. The energy spectra of neutrons produced by cosmic rays are certainly not the same as that of Ra-Be neutrons. Also there may be additional complications in applying correction for the simultaneous detection of two neutrons. As charged particles are produced along with neutrons in the product of nuclear interactions, it is expected that similar results are also likely to be observed detecting charged components of nuclear interactions. The present investigation has been done to verify

Reprint requests to Prof. Dr. P. K. SEN CHAUDHURY, Department of Physics, Presidency College, *Calcutta 12*, India.

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the above expectation detecting charged components which do not require any correction by the uncertain corection factor as in the case of detecting neutrons.

1. The Experiment

A counter-controlled cloud chamber of diameter 30 cm with three lead plates inside has been utilized for the analysis (Fig. 1). It was operated with a filling of argon and $(75-25)\%$ Ethyl Alcohol-water mixture at a total pressure of 108 cm of Hg. The lead plates

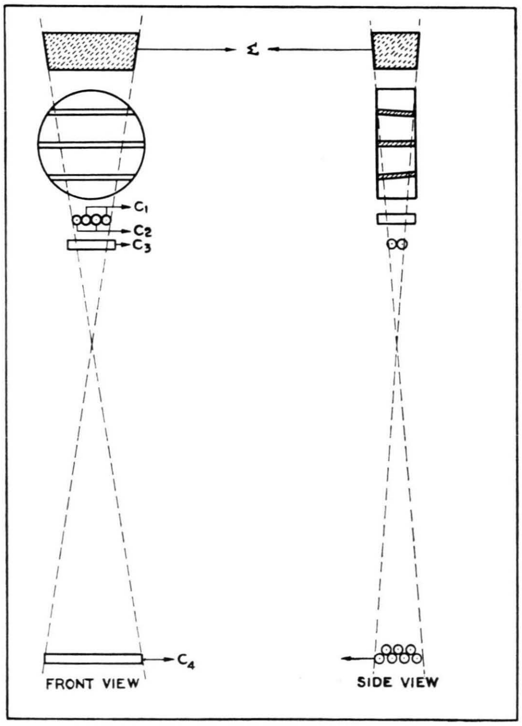

Fig. 1. Scheme of the experimental arrangement.

each 1 cm thick served the purpose of producer layer as well as analyser whereas paraffin and lead placed on the top of the chamber served as moderator or absorber. The experiment was performed in a laboratory room with a roof of 126 g cm^{-2} concrete. The chamber was trigered by a four-fold coincidence (C_1, C_2, C_3, C_4) of a G.M. counter telescope in such a way that both charged and neutral components of cosmic rays could produce interactions inside the chamber. The arrangement was such that at least two charged particles should be produced simultaneously to trigger the four-fold arrangement.

2. Results and Discussion

Stereoscopic photographs of events occuring in the cloud chamber were taken throughout the experiment. The photographs obtained shows (a) Single muons most of which produced knock-on electron to triger the four-fold coincidence. (b) Electromagnetic cascades. (c) Knock-on showers produced by muons. (d) Lateral showers. (e) Nuclear interactions. (f) Blanks. The results for nuclear interactions are sumarised in the Table 1.

	Moderator thickness g cm^{-2}	Actual number of N. I.	No. of N. I. Expressed as % to total events	Rate/hr.
Paraffin	0	9	4.5	0.11 ± 0.03
	6.1	14	6.9	0.14 ± 0.03
	12.2	23	10.1	0.20 ± 0.04
	18.4	17	14.3	0.23 ± 0.05
	30.4	19	20.0	0.24 ± 0.05
Lead	11.3	17	9.0	0.17 ± 0.04

Table 1. Nuclear interactions under various thickness of moderator.

Figure 2 gives a plot of the rate of nuclear interactions versus the thickness of moderator measured in g cm^{-2}. A continuous increase of the rate of n. i. with moderator thickness at least upto 30.4 g cm^{-2} is noticed. Again to see whether the production of nuclear interaction is dependent on nuclear charge of the absorber above the producer layer, observations were made under 11.3 g cm^{-2} lead. The observed n. i. frequency under lead is also plotted in Fig. 2. A similar rise in the n. i. frequency above the background under lead shows that the rate of n. i. is independent of the nuclear charge of the absorber.

The results for n. i. are similar to neutron shower production under graphite observed earlier by SENCHAUDHURY and PFOTZER [1] without correction for neutron reflection, detection efficiency etc. In the present investigation the n. i. frequency under 30.4 g cm^{-2} rises by a factor of about 2.2 over the background whereas the uncorrected neutron shower frequency (SENCHAUDHURY and PFOTZER) rises by a factor of about 1.8.

The statistical error together with an uncertainty of identifying an n. i. against small electromagnetic interaction in the present experiment may account for the difference with the previous result. A rather high percentage of n. i. detected in comparison with electromagnetic interactions etc. may be due to the fact that any cosmic ray to trigger the coincidence arrangement must pass through 3 to 4 radiation

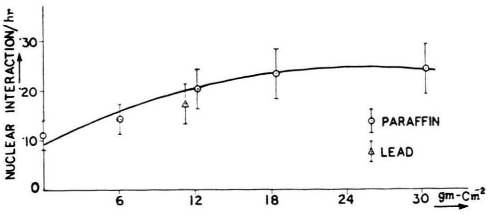

Fig. 2. The rate of nuclear interaction as a function of absorber thickness.

length in the absorser and the roof material above the cloud chamber and as such most of the soft component is filtered off. Further, the detection probability in the last stage of a cascade becomes much less due to the placing of the lowest counter tray at a depth of about 1 metre below the chamber.

BRIDGE and REDIKER [9], REDIKER [10], BOZOKI, FENYVES, and JANOSSY [11] have thoroughly investigated the production of bursts and local penetrating showers in lead and light material by nuclear active component of cosmic rays at sea level and at high altitude. A strong transiton effect with lead absorber above the producer layer of 170 g cm^{-2} rising by a factor of about 2 has been found in their experiments. Bridge and Rediker observed that 50 p. c. of the total number of bursts produced at sea level are caused by the nuclear active component of cosmic-rays. Rediker also found that the observed rate of burst production under oil by nuclear active compoents was much higher than expected according to the mean free path of the nuclear active component. He concluded that the excess is due to the production of pions in the oil. Some of our photographs show the production of such pions in paraffin and lead which subsequently produced n. i. in the lead plates inside the cloud chamber. Besides pion producing nuclear interactions, we also obtained some photographs of n. i. produced by neutral particles inside the chamber plate. These neutral particles may be either primary neutrons or fast secondary neutrons or unstable neutral particles, if any, produced in the moderators layers. There is however, some difference in our experimental arrangement and that of Rediker, Bozoki and others in that in the latter arrangement there must be simultaneous production of at least two penetrating particles passing through at least 170 g cm^{-2} lead whereas in the present experimental arrangement the penetrating particles produced in n. i. pass only through 2 to 4 radiation length to trigger the coincidence arrangement. Therefore comparatively low energy n. i. likely to be mised in the former arrangements are detected in the present experimental arrangement.

3. Conclusion

It becomes apparent from the analysis of experimental results that there is a transition effect of n. i. under paraffin and lead detected by their charged components. The observed rise in n. i. frequency is similar to the initial rise of the rate of neutron showers observed previously by Senchaudhury and Pfotzer without any correction for the reflection factor, the detection efficiency etc. Upto the thickness of absorber presently limited to 30.4 g cm^{-2} paraffin a rise in shower frequency by a factor of 2.2 is observed but it is expected that under still higher thickness of absorber the n. i. frequency will decrease simlar to neutron shower frequency and local penetrating shower frequency observed by others. This will be investigated soon. But already the result of the present experiment seems not to agree with the monotonous decrease of the corrected neutron shower frequency. One of the reasons for this may be that the present experimental arrangement is slightly biased for detecting comparatively higher energy nuclear interaction than that of neutron shower frequency detected earlier. Another reason may be the uncertainty in evaluating the correction factor for neutron reflection in observed neutron coindicences.

Acknowledgment

This work was supported financially by the Government of West Bengal, India. We offer our sincere thanks to Prof. Dr. G. PFOTZER of Max-Planck-Institute of Aeronomie, West Germany for many helpful suggestions.

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