we should expect to see on the basis of the known $\pi^- + p \rightarrow \Lambda + K^0 + n\pi^0$ background events and the conditions for ambiguity in $K_2{}^0$ vs $\overline{\Lambda}$ decay, we find less than 10^{-6} of an event.

It is also dynamically possible for the reaction $\overline{p} + p \rightarrow \overline{\Lambda} + \Lambda + \gamma$ to give rise to the observed event. This, however, is very unlikely because of the small probability of radiative production with a γ ray of 75 Mev/c.

This experiment would certainly not have been possible without the stimulation and foresight of Professor Luis W. Alvarez. An experiment of this difficulty owes its success to a great many people. Morris Pripstein and Ngyen H. Xuong have contributed long and tiring hours both in the development and in the operation of the antiproton beam. One can hardly overemphasize the indebtedness we owe to the people who built and operated the 72-in. bubble chamber, notably James D. Gow, Paul Hernandez, and Robert Watt. Members of Professor Burton J. Moyer's group contributed to the electronic aspect of the beam development and operation. Our thanks go to Dr. Margaret Alston and Dr. Hugh Bradner and the scanners for their contribution to the experiment. We are greatly indebted to Jon Peter Berge for assistance in the IBM analysis of our events. Finally we wish to thank the Bevatron crew who had the difficult task of producing the high-flux, short-spill beam that was necessary for this bubble chamber experiment.

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π^- CAPTURE IN COMPLEX NUCLEI AND NUCLEAR PAIR CORRELATIONS[*]

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A study was undertaken of the high-energy products of the capture of stopped π^- mesons in complex nuclei; scintillation counters in coincidence were used as detectors of neutrons and protons. By measuring the neutrons it was hoped to establish whether or not π^- capture in complex nuclei involves two nucleons, and if it does, to use the process to study the ratio of neutron-proton pairs to proton-proton pairs in complex nuclei.

Brueckner, Serber, and Watson[1] developed the hypothesis, which was also suggested by Perkins,[2] that low-energy π mesons would preferentially be absorbed by a pair of nucleons in complex nuclei. In the case of π^- absorption the reactions would be

$$\pi^- + p + n \rightarrow n + n, \tag{1a}$$

$$\pi^- + p + p \rightarrow n + p. \tag{1b}$$

Early measurements[3,4] on the interaction of π^+ mesons with carbon supported this hypothesis. Many studies of π^- capture have been made using radiochemical and emulsion techniques[5,6] and Ammiraju and Lederman[7] have made extensive measurements on π^- capture in light nuclei using a cloud chamber. The observations from most of these experiments were interpreted in terms of the two-body model with some modifications. All of these measurements lacked the possibility of observing the ejected neutrons and their angular correlations.

For the present set of measurements the π^- mesons were produced by bombarding beryllium with a bremsstrahlung beam from the MIT synchrotron. Coincidences were observed between two neutron counters in order to study reaction (1a), or between a neutron and a proton (telescope) counter in order to study reaction (1b); the latter experimental arrangement is shown in Fig. 1. For the results reported below, the neutron counters had an efficiency[8] of about 10% for 55-Mev neutrons, and the neutron counters were biased to observe only recoil protons with energies greater than 9 Mev. The proton counter system would accept protons of energy greater than 22 Mev and less than 112 Mev. We stopped π^- mesons in targets made of Li, C, Al, S, Cu, and Pb. Most effort was devoted to obtaining good statistics on the C and Al targets.

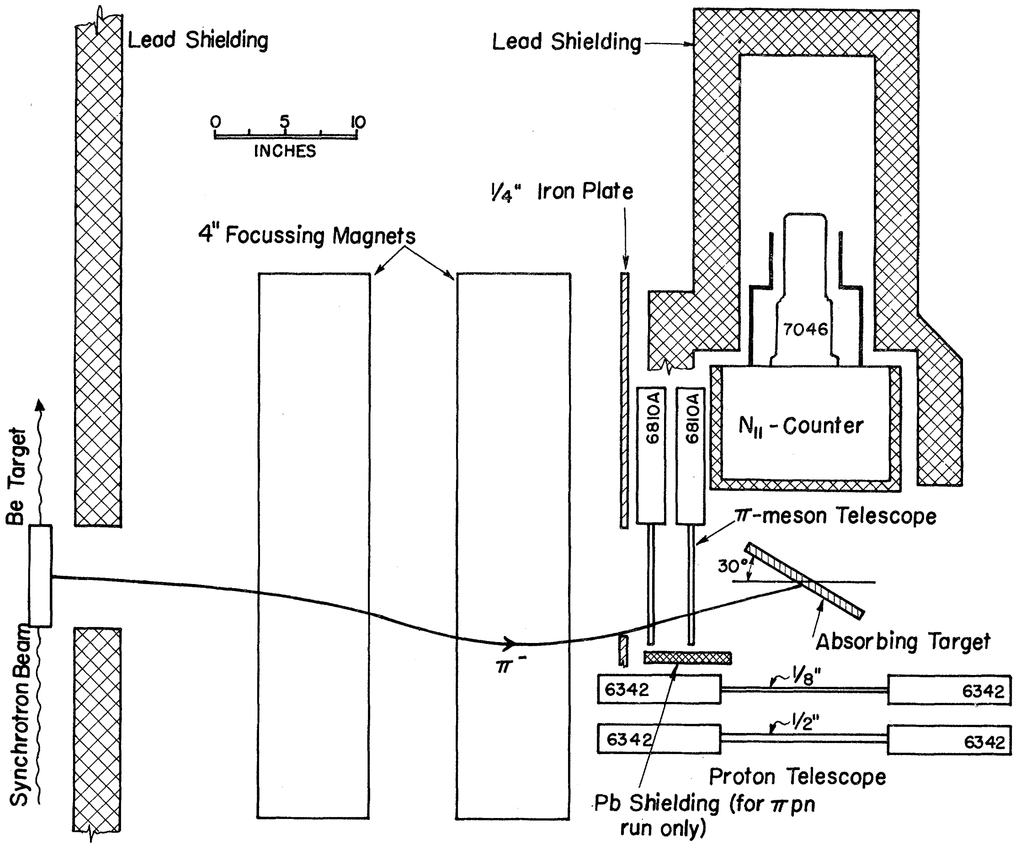

FIG. 1. The experimental arrangement of the apparatus which was used for the π^- + proton + neutron coincidence measurements at 180°. For the π^- + neutron + neutron coincidence measurements a neutron counter replaced the two proton counters so that the solid angle subtended would be approximately the same.

If the capture in a complex nucleus of a stopped π^- meson occurs according to reactions (1a) and (1b) (the two-nucleon model), kinematics requires that the nucleons come off essentially back to back if both nucleons escape from the nucleus without scattering inside the nucleus. The nucleons are not sharply correlated in angle because of the initial Fermi momentum of the pair of capturing nucleons.

In order to test the spatial correlation of the ejected nucleons, measurements were made with the counters at 180° to each other (Fig. 1) and with the counters at 90° to each other. The results for C are given in Table I. One sees in the data the 180° correlation required by the two-body model of Brueckner, Serber, and Watson.[1] The data of the other light elements agree but are not as statistically significant.

If one corrects for the relative probability of detecting the neutrons and protons, one obtains the following values of the ratio of n-n events [reaction (1a)] to n-p events [reaction (1b)]:

$$\text{ratio } (a/b) = 5.0 \pm 1.5 \text{ for carbon;}$$

$$\text{ratio } (a/b) = 3.9 \pm 1.2 \text{ for aluminum.}$$

Due to background subtractions and secondary events contributing more to the proton coincidence runs, we feel these observed ratios are to be taken as lower limits on the ratio of reaction (1a) to (1b). In other words, the capture of π^- mesons is likely to occur much more frequently

Table I. Coincidences as a function of angle.

Target	Neutron-proton coincidences per monitor unit		Neutron-neutron coincidences per monitor unit	
	90°	180°	90°	180°
C	0.8±1.1	4.8±0.7	2±7	25±3

with a neutron-proton pair than with a proton-proton pair. DeSabbata, Manaresi, and Puppi[9] and Tomasini[10] have previously found it necessary to assume this in order to explain data obtained on π^- capture in nuclear emulsions. Ammiraju and Lederman[7] drew the same conclusion from their data on capture in He.

If one assumes that only even angular momentum states are present between pairs of nucleons in complex nuclei (essentially the "Serber mixture of nuclear forces") and if one takes account of the Pauli principle only in the initial states, then the ratios one would expect from simple counting of the initial nucleon states are approximately 4.8 for both carbon and aluminum. If one includes odd angular momentum states, the expected ratios are approximately 2.4 which disagree with the observed ratios. On the above naive basis, one would say that the data are in agreement with the assumption of the "Serber mixture of nuclear forces" inside complex nuclei.

In the above estimates of the expected ratios, all final-state interactions have been neglected. However, it is of interest that the above conclusions are also valid if one takes account of the final states of the two nucleons.

In order to count the final states one has to take a particular model of the π^- capture process. We have assumed that the capture of π^- occurs when the π^- is in a p-state relative to one of the protons. The Pauli principle essentially inhibits some final states but only for reaction (1a), leading to a reduction in the expected ratio. Taking account of the Pauli principle and an angular momentum barrier, we get an expected ratio of about 3.4 for both elements.

In that we consider the observed ratios as lower limits, we have been led into reconsidering the assumptions used in obtaining an expected ratio that is somewhat less than the observed ratios.

In calculating the expected ratio we have neglected the fact that the momentum transfers involved correspond to short interaction distances, namely about 0.4×10^{-13} cm. For these small distances, the phenomenological nucleon-nucleon potentials[11, 12] are much stronger for the triplet states than for the singlet state. The triplet states contribute to only the neutron-proton pairs [reaction (1a)] which would lead to the relative enhancement of the number of neutron-proton pairs at least in the above process. Thus the expected ratio would be in better agreement with the observed ratio if there are relatively fewer proton-proton pairs in the nucleus than the number given by a simple counting and the Pauli principle.

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