by the former. It can be seen that instead of the steeply falling curve of the aforementioned authors, present data indicate a coefficient of appreciable magnitude at relatively large E/p. This circumstance can be explained by reference to our data on α/p; it is apparent that some multiplication is taking place. If proper allowance for this process is not made, the apparent attachment will be less than the true rate. It thus appears that the quantities α and η cannot be treated independently in regions where they are of comparable magnitude.

Figure 3 shows the attachment cross section plotted against mean electron energy computed from our measurements with the aid of the data of Healey and Kirkpatrick.[6] Previous explanations[5,7] of the maximum at 2 volts have been influenced by its apparent sharpness and have led to the conclusion that the negative ions were molecular. It now seems plausible that the reaction

$$O_2+e\rightarrow O^-+O$$

found by Lozier[8] and Hagstrum[9] with an appearance potential of 3.0 volts and a maximum at 7 volts is responsible for much of the high energy negative ion production. It is still possible that the process postulated by Bradbury[2,5] contributes to the steep rise that occurs at about 1.6 volts.

Further investigations of attachment processes in O_2 and other gases are in progress.

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The Yield of Neutral Mesons from Proton Bombardment of Light Nuclei*

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(Received December 3, 1951)

This experiment was planned in order to study the relative cross sections of various light nuclei for the production of neutral pions by 340-Mev protons.

In particular we wished to measure the yield of π^0's in $p-p$ collisions in order to obtain information about the symmetry properties of the π^0-meson.

If the π^0 is a pseudoscalar meson it cannot be emitted in a P angular momentum state from a $p-p$ collision in an even orbital state, since parity and angular momentum cannot be conserved simultaneously in this case. If the π^0 is emitted in an S state, then, in analogy with π^+-production for which the S state yield is about one-eighth of the P state yield, we should expect the numbers of π^0's from $p-p$ collisions to be about one-eighth of that from $p-n$ collisions. If the π^0 is a scalar meson no such large ratio would be expected.

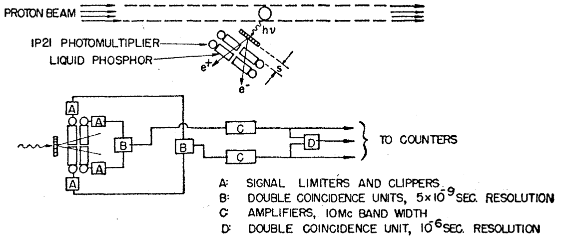

FIG. 1. Apparatus and circuit for detection of high energy photons.

TABLE I. Relative cross sections for neutral meson production by 341-Mev protons. The carbon yield has arbitrarily been given the value 6.00.

Nucleus	Relative cross section
H^1	0.07 ±0.06
H^2	0.85 ±0.20
Be^9	5.01 ±0.12
B^{10}	4.99 ±0.11
B^{11}	5.95 ±0.13
C^{12}	6.00 ±0.16
O^{16}	7.46 ±0.28

No direct comparison of the $p-p$ and $p-n$ π^0-yields could be made using a proton beam, but relative $p-p$ and $p-d$ yields were obtained by subtractions utilizing targets of carbon, polyethylene, heavy water, ordinary water and liquid oxygen. The series Be^9, B^{10}, B^{11}, C^{12} was also studied.

A unique method of identifying a neutral pion would be to detect both of the decay γ-rays in coincidence in the manner used for detection of neutral photomesons,[1] but the unfavorable neutron background conditions associated with proton bombarded targets makes the method infeasible for this experiment. Hence it was necessary to depend on single γ-detection. This is probably a valid measure of the neutral meson yield since the photon spectrum from proton-bombarded targets, which has been measured by Bjorklund, Crandall, Moyer, and York[2] and by Crandall and Panofsky,[3] is nearly consistent with a pure π^0-decay spectrum. The possible reabsorption of a charged or neutral meson within the nucleus in which it is created seems to be not more than a few percent.

The pair spectrometer method of Bjorklund *et al.*[2] was not suitable for comparing yields from different targets because of the uncertainties involved in multiple traversals when viewing internal cyclotron targets.

The photon detector used for this experiment was of the type developed by Hildebrand, Knable, and Leith,[4] in which multiple scattering in a thick converter is used to separate the electron pairs. In this device two scintillation counter telescopes are

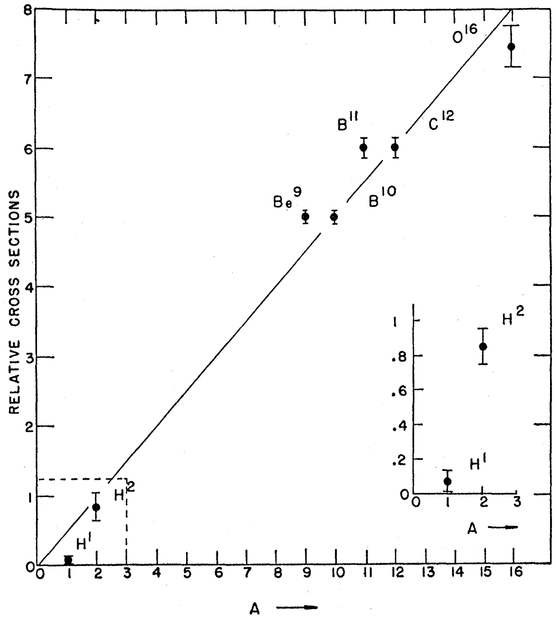

FIG. 2. Relative neutral meson yields.

placed behind the converter and connected in coincidence as shown in Fig. 1, so that whenever the electron and positron are scattered into separate telescopes the event is recorded. The phosphors were thick, so that only photons above 20 Mev could produce pairs with sufficient energy to cause a coincidence of all four counters. This detector has good discrimination against neutrons and charged particles and was thus suitable for use with the external beam in the presence of a high background.

The detector was placed at an angle of 135° to the direction of the proton beam for all these measurements in order to avoid the large flux of neutrons from the target which is present at small angles. The results obtained at this one angle should be a fairly good measure of relative total yields of π^0s, since the angular distribution of photons in the meson's rest frame is isotropic so that the photon yield at one angle in the lab frame receives contributions from mesons emitted in any direction. That the photon yield in a given direction in the laboratory is not strongly affected by conceivable meson angular distributions can be shown by straightforward calculations.

The results are shown in Table I and Fig. 2. The yields shown are relative to the carbon yield which has arbitrarily been given the value 6.00.

The yield from H^1 appears to be suppressed, in accordance with the selection rule discussed above for a pseudoscalar meson. Further measurements using a liquid hydrogen target in place of the carbon and polyethylene targets will be necessary to establish a positive yield from hydrogen or to lower the present upper limit appreciably. The yields from the series Be^9, B^{10}, B^{11}, C^{12}, which differ by the successive addition of a proton, a neutron, and a proton, suggest that only the neutrons in light nuclei contribute appreciably to π^0-production in proton bombardment. However, differences in the nuclear structure of these nuclei may modify this simple inference.

* This work was performed under the auspices of the AEC.
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Neutral V-Particle Decay and the Negative Proton*

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(Received November 28, 1951)

RECENT experimental evidence on neutral V-particles[1] indicates that one variety (denoted here by V^0) decays into a proton and a negative meson (probably pi). The V^0-particles observed thus far are accompanied on the average by several penetrating particles (protons and pi-mesons) and originate in events the total energy of which averages several times 10^{10} ev. Substantially lower energy events seem much less likely to produce V^0-particles, and substantially higher energy events result in penetrating showers of such high density that V^0-particles are hard to identify.

It is reasonable to inquire why it is that a neutral V-particle that decays into a negative proton and a positive meson does not also appear with comparable probability (such a particle will be denoted here by $\bar{V}^0$). V^0 and $\bar{V}^0$ would be expected to have the same rest mass, and indeed to be antiparticles of each other. It can then be argued that they should be produced equally readily, whether they are made independently or as members of antiparticle pairs. The disagreement between this argument and the experimental results to date can be resolved either by supposing that $\bar{V}^0$-particles, and presumably then also negative protons, do not exist, or by supposing that V^0- (or $\bar{V}^0$-) particles can actually be produced singly by some kind of coalescence of a proton (or negative proton) and a negative (or positive) meson. The first supposition would require a drastic revision of the quantum theory of particles as it now exists, and should not be adopted until the evidence for it is unambiguous. The second supposition suffers from the well-known difficulty of reconciling the relatively long lifetime for V^0-decay and the relatively high probability for V^0-production. Apart from this objection, to which we return later, it would account for the experiments in that a $\bar{V}^0$-particle could not then appear unless a negative proton were made as an intermediate step; this would necessitate the simultaneous production of an extra proton or V^0-particle, so that the whole process would require approximately 2 Bev more energy in the center-of-mass system than the appearance of a V^0-particle.

The second supposition can be put in explicit form by making the plausible assumption that there is a conservation law for all particles of nucleonic mass: protons, neutrons, V^0-particles, and other possible particles that decay into protons or neutrons, such as perhaps the charged V-particles. This is a simple extension of the generally accepted conservation law for protons and neutrons only, and may be stated as follows: the difference between the total number of nucleonic particles (protons, neutrons, V^0) and the total number of antinucleonic particles (negative protons, antineutrons, $\bar{V}^0$) is a constant of the motion. This constant is, for example, equal to two if the primary event is the collision of a high energy proton or neutron with a single nuclear proton or neutron. From the point of view of Fermi's statistical treatment of high energy events,[2] an additional restraint is thereby imposed on the system, and a new parameter analogous to the chemical potential in conventional thermodynamics is introduced.

In a two-body encounter, the total number of protons, neutrons, and V^0-particles that emerge should be two unless the energy is so high that antinucleonic particles can be created. As pointed out by Fermi, this will require a primary proton energy greater than about 10^{12} ev, in which case a penetrating shower of high density is produced and antinucleonic particles are difficult or impossible to identify. On the other hand, it is known that several nucleonic particles (including in one instance three neutral V-particles) often emerge from events where the total energy probably does not exceed 10^{11} ev.[3] According to the view adopted here, such events would be regarded as cascade processes that probably take place within a single nucleus.

Sachs[4] has recently suggested that the long V^0-decay lifetime can be understood in terms of the great complexity of the ground and excited states of protons and neutrons (V^0 is supposed to be an excited state of a neutron), which is caused by the presence of many virtual pi-mesons. Such a model can also be used to account qualitatively for the relative ease with which V^0-particles are produced in energetic nuclear encounters, since the high temperature in the small collision volume[2] greatly increases the populations of states which contain large numbers of real and virtual mesons in comparison with the populations of these states for an isolated nucleon or V^0-particle. It seems to us, however, that the essential feature required for an explanation of the apparent lack of reversibility between V^0-formation and decay is independent of the particular model proposed by Sachs, and has to do with the existence of states that connect V^0 and its decay products that are only present with appreciable probability in a region of high temperature.

The writer is greatly indebted to Professors W. B. Fretter, R. B. Leighton, and C. D. Anderson for discussion of their most recent experimental findings.

* Assisted in part by the joint program of the ONR and AEC.

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