summarized briefly here. The 90° yields of both γ_0 and γ_1 in this case show considerable, though dissimilar, sharp resonance structure. The envelope of this structure for γ_1 rises steadily for proton energies from 4.0 to 10.4 Mev while that for γ_0 rises and stays relatively constant from 6.0 to 10.4 Mev. If, indeed, the ground state gamma-ray yield falls off at energies above the range presently covered to give a giant resonance envelope, the present measurements indicate that the width of the envelope is at least 4.5 Mev.

Angular distributions of both γ_0 and γ_1 in the $Al^{27}(p, \gamma)Si^{28}$ reaction have been measured at proton energies of about 6.9, 7.2, and 8.4 Mev. All three distributions for γ_0 are fitted by $W(\theta) = 1 + a_2P_2(\cos\theta)$ where a_2 is slightly greater than zero, while those for γ_1 are spherically symmetric within experimental uncertainties. Direct capture processes give rise to a coefficient of $P_2(\cos\theta)$ which is less than or equal to zero and hence the observed positive coefficient for γ_0 suggests that the process cannot be described in this way.

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[*] Seconded from the Atomic Weapons Research Establishment, Aldermaston, England.

[1] Designed and built by High Voltage Engineering Corporation, Burlington, Massachusetts.

[2] Manufactured and canned by the Harshaw Chemical Company.

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NEUTRON ASYMMETRY FROM MU CAPTURE IN MAGNESIUM[*]

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It has been pointed out by many authors[1-4] that a measurement of the angular distribution of neutrons emitted after the capture of polarized μ^- mesons by complex nuclei may give information on the nature of the coupling constants in the process

$$\mu^- + p \rightarrow n + \nu. \qquad (1)$$

A spatial asymmetry with respect to the μ spin direction would also be evidence for parity nonconservation in reaction (1). Until now no such violation has been experimentally observed. A calculation by Primakoff suggests that an asymmetry parameter as large as -0.4 could be expected.[2] In addition to the neutrons from (1), evaporation neutrons would be emitted. Since these would mask an asymmetry, they were discriminated against in the present experiment by detecting only those neutrons with an energy > 5.5 Mev.

A previous attempt to measure this asymmetry was hindered by a large contamination of nuclear de-excitation γ rays.[5] A large number of such γ rays per μ capture has been observed.[6-8] In order to reject these γ rays in this experiment, the neutrons were detected with a sandwich counter consisting of 15 6-in. by 3-in. sheets of 1/8-in. thick plastic scintillator. The adjacent layers were viewed alternately by two phototubes [6 and 7 of Fig. 1 (a)]. Electrons of energy above a certain threshold produced by gamma rays crossing the counter have in general a range sufficient to penetrate more than one layer thus causing a (67) coincidence. It is therefore possible to reject such events because most of the neutrons from μ^- capture produce counts either in 6 only or in 7 only, the range of the proton recoil being short compared to the thickness of a single layer (see Fig. 2).

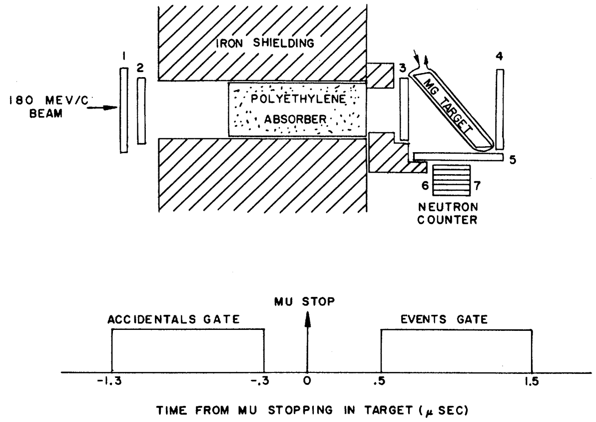

FIG. 1. (a) Experimental arrangement. (b) Timing diagram.

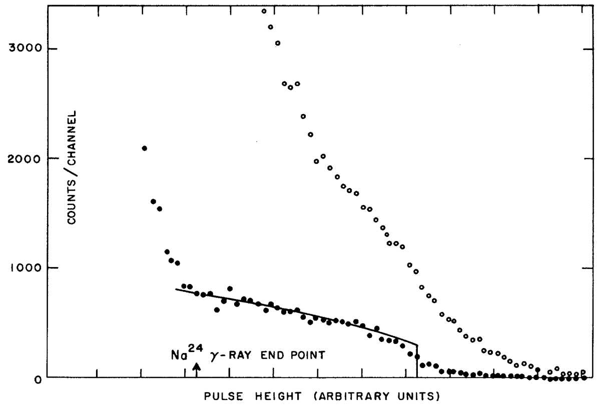

FIG. 2. Proton recoil spectrum from 14.8-Mev neutrons in the presence of a high gamma-ray background. Upper points are without (67) anticoincidence requirement; lower points are with this requirement. Solid line is calculated proton recoil spectrum corrected for loss of protons which penetrate more than one layer of neutron counter.

The γ-ray rejection efficiency of the counter was determined by counting 2.76-Mev (Na^{24}) and 4.43-Mev ($p + C^{12} \rightarrow p + C^{12} + \gamma$) γ rays with a pulse-height threshold of 2.2 Mev, with and without the anticoincidence (67). The γ-ray rejection efficiency was found to be 0.96 for 2.76-Mev and better than 0.98 for 4.43-Mev γ rays. In our counter, an electron of 2.2 Mev gives the same pulse height as a 5.5-Mev proton.[9]

The experimental arrangement is shown in Fig. 1 (a). A neutron event is defined by a count in 6 or 7 in anticoincidence with (a) a count in 5, (b) a (67) coincidence, and (c) a (16) or (17) coincidence to reject neutrons from pion stars in the absorber. The neutron event was delayed 0.3 μsec before triggering two identical 1-μsec wide gates. A stopped μ pulse, $23\bar{4}$, delayed 1.8 μsec was sent to one gate to determine an event, and an undelayed pulse was sent to the other to determine an accidental count [Fig. 1 (b)]. Thus both events and accidentals were measured simultaneously. The outputs of these gates triggered two 100-channel pulse-height analyzers on which was recorded the total energy lost in the neutron counter for events and accidentals.

The neutron asymmetry was measured by precessing the μ^-'s stopped in a magnesium target through 90° by a constant magnetic field which was reversed every 30 minutes. Approximately 27 000 events and 15 000 accidental counts for each direction of the field were recorded. Only accidental counts were observed (a) when the target was removed, (b) when a lithium target was used, and (c) when μ^+'s were stopped in the target.

By removing the (67) anticoincidence requirement on the sandwich counter, γ rays will be counted in addition to neutrons. An increase of 3.8 times was found in the events rate, corrected for accidentals. Combining this with the γ-ray rejection efficiency above yields a negligible contribution to the final result.

To determine the μ^- polarization in the target, electrons from μ decays were recorded under identical conditions except that a (567) coincidence was required. The results are summarized in Table 1 where α is the asymmetry parameter in the assumed $1 + \alpha \cos\theta$ angular distribution. These results seem inconsistent with the significantly large negative value that has been theoretically predicted.

We wish to acknowledge the assistance of Dr. T. Coffin, Dr. H. Gursky, and Dr. D. Tycko. We also want to thank Dr. Lee Lidofsky for the use of the Columbia Van de Graaff for calibrating the neutron counter, and Dr. D. Tycko for assistance in analyzing the data.

Table I. Measured asymmetries in magnesium for neutrons and electrons. Energies refer to threshold set on pulse height of recoil proton.

Particle	$\frac{\text{Counts (field up)} - \text{Counts (field down)}}{\text{Counts (field up)} + \text{Counts (field down)}}$	α
Electrons	-0.036 ± 0.003	-0.33 (Assumed)
Neutrons > 5.5 Mev	$+0.016 \pm 0.012$	$+0.15 \pm 0.11$
Neutrons > 10 Mev	$+0.017 \pm 0.019$	$+0.15 \pm 0.18$
Neutrons > 15 Mev	$+0.040 \pm 0.030$	$+0.37 \pm 0.28$

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PION-PION CORRELATIONS IN ANTIPROTON ANNIHILATION EVENTS*

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We have observed angular correlation effects between pions emitted from antiproton annihilation events. This experiment was carried out with a separated antiproton beam[1] of momentum $p_{\bar{p}} = 1.05$ Bev/c. A total of 2500 annihilation events were observed in 20 000 pictures taken with the Lawrence Radiation Laboratory 30-in. propane bubble chamber.

Pion pairs formed by the charged pions emitted in an antiproton-annihilation event can be considered in two groups: viz., like pairs (in the isotopic-spin state $I=2$) and unlike pairs (in the isotopic-spin states $I=0, 1$, or 2). We searched for correlation effects in these separate groups. Our results show that the distribution of the angles between pions of like charges is strikingly different from the distribution of the angles between pions of unlike charges. The angles between pion pairs were computed in the center of mass of the antinucleon-nucleon system.[2] The results shown in Fig. 1 were obtained from the analysis of the "hydrogenlike" events in which four and six charged pions, respectively, are emitted. We define as "hydrogenlike" those events giving rise to an equal number of positive and negative pions. Events showing visible evaporation prongs are excluded from this sample. The curves shown in Fig. 1 were calculated on the basis of the statistical model, expressed in the Lorentz-invariant phase-space[3] (LIPS) form, for pion production from a nucleon-antinucleon annihilation. This model imposes energy and momentum conservation, but no other constraints. The distribution of the pion-pair angles θ_{12} for an annihilation into n pions of mass μ is[4]

$$\phi_n(\cos\theta_{12}) = \iint p_1 p_2 F_{n-2}(W''^2)\,d\omega_1 d\omega_2,$$

with integration limits from $\omega_1 \geqslant \mu$, $\omega_2 \geqslant \mu$ to max

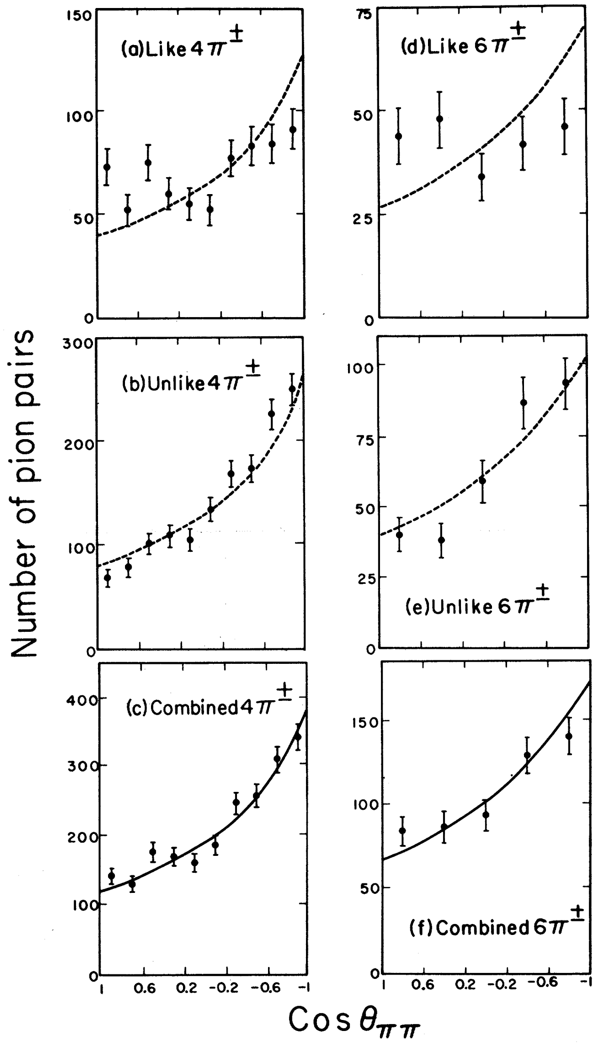

FIG. 1. Distribution of angles between pion pairs as a function of $\cos\theta_{12}$. The curves correspond to calculations on the Lorentz-invariant phase-space (LIPS) model. The deviations of the experimental distribution from the LIPS model are discussed in the text.