of upper limit). The expression for w is lengthy and will not be written here.

To obtain the function $P(E_0,E)$, it is necessary to specify the details of reaction (1). It turns out that for the particular reactions and energies considered here, the probability of obtaining low-energy Λ^0 particles (<70 Mev) is greatest when no "additional" particles are produced in reaction (1). With the neglect, then, of "additional" particles, the Λ^0 energy E in the Σ frame can be expressed as a unique function of the incident particle energy E_0 and the angle θ^* of the Λ^0 particle in the center-of-mass frame,

$$E=A(E_0)+C(E_0)\cos\theta^*, \quad (3)$$

where the functions $A(E_0)$ and $C(E_0)$ are lengthy, but easily obtained by standard methods of collision kinematics. Then

$$P(E_0,E)=u(\cos\theta^*)/C(E_0), \quad (4)$$

where $u(\cos\theta^*)d(\cos\theta^*)$ gives the angular distribution of Λ^0 production in the center-of-mass system; $\cos\theta^*$ is to be expressed here as a function of E, by means of Eq. (3).

We consider in the first place the case of isotropic Λ^0 production $[u(\cos\theta^*)=\frac{1}{2}]$. The results for four possible reactions are shown in Fig. 1, where the probability for producing Λ^0 particles below 70

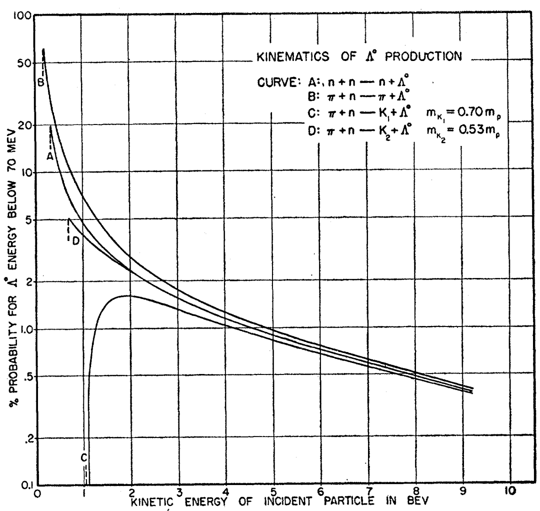

FIG. 1. Probability for Λ^0 energy less than 70 Mev in the laboratory frame, expressed as a function of the incident particle energy in the target-nucleon rest frame (for the large energies involved, this does not differ appreciably from the incident particle energy in the laboratory frame). These results are for the case of isotropic Λ^0 production. In curve C, the mass of the K meson is taken to be 1300 m_e; in curve D, 970m_e.

Mev in the laboratory frame is plotted against the energy of the incident particle in the target-nucleon rest frame. The curves begin at the respective threshold energies; at large energies they coincide and go as E_0^{-1}. Only for reactions A and B is it possible to obtain probabilities larger than 10 percent and then only very near threshold.

Several explanations may be suggested to account for the large fraction of low-energy Λ^0 particles. Consider an anisotropy of the form

$$u(\cos\theta^*)=\tfrac{1}{2}(n+1)|\cos^n\theta^*|.$$

It can then be shown from Eqs. (2) and (4) that

$$P_n(E_0,<E')<(n+1)P_0(E_0,<E').$$

Thus to explain our observed results, on the basis of anisotropy and assuming Λ^0's to be produced well above threshold in the cosmic-ray beam, we require $n>6$.

Alternately, one might consider Λ^0 production to result from a multiple process, or cascade, in which π's or nucleons produce π's which in turn produce Λ^0's at energies near threshold. However, the Brookhaven results[2] indicate that Λ^0's produced by 1.5-Bev π's (i.e., near threshold energy) also show a strong backward peaking in the center-of-mass system.

* Supported by the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

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Small-Angle Neutron-Proton Scattering at 90 Mev*

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THE relative neutron-proton differential cross section has been measured for several angles near zero degrees. This range of angles has been difficult to investigate because of the very short range of the recoil protons. Previously published work,[1-5] done by measurement of proton recoils, has not covered these angles. However, some cloud-chamber experiments are currently in progress at this laboratory[6] in which recoil protons are employed in this range.

The neutron beam was obtained by stripping 190-Mev deuterons on a $\frac{1}{2}$-in. beryllium target in the 184-inch Berkeley cyclotron. A steel shielding block 6 ft long×6 in. high×3 in. thick was placed close to the beam on the same side as the counters to reduce background.

The target was of liquid hydrogen contained in a cylindrical vessel of 5.6-in. diameter with axis vertical. The beam dimensions at the target were 3 in. high×1 in. wide. A bismuth fission counter was employed as a beam monitor.

Scattered neutrons were counted at small angles to the neutron beam. Figure 1 shows the neutron counter, which consisted of the

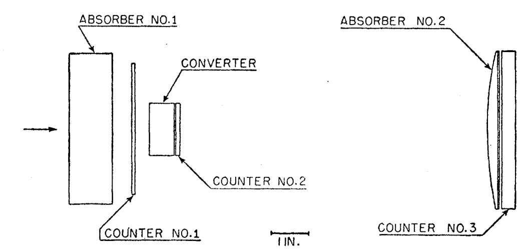

FIG. 1. Arrangement of components of neutron counter.

following components, listed in the order that they would be traversed by a scattered particle: (a) absorber number 1, 25 g cm^{-2} of copper to prevent protons from reaching the scintillation counters directly; (b) scintillation counter number 1, made of plastic scintillant 4.0 in.×3.5 in.×0.080 in. thick; (c) the converter, 1.74 g cm^{-2} of polyethylene; (d) scintillation counter number 2, a liquid counter with active volume 2.2 in.×1.4 in. ×0.118 in. thick; (e) absorber number 2, which was from 1.0 to 1.8 g cm^{-2} of copper plus a shaped aluminum absorber of maximum thickness 1.8 g cm^{-2}; (f) scintillation counter number 3, made of plastic scintillant 6.6 in.×4.2 in.×0.4 in. thick. The distance from the center of the target to the center of the converter was 48 in. for the range of the laboratory scattering angle Θ from 18.5° to 5.0° and 70 in. for the range of 5.0° to 2.5°.

The neutrons actually counted were those that were "converted" in the polyethylene converter or in counter number 2. The term "converted neutron" refers to a neutron that yields a high-energy proton by n-p scattering or nuclear interaction. These recoil protons were counted in coincidence in counters 2 and 3. In order to reject charged particles originating in other

TABLE I. Experimental data for neutron-proton scattering at 90 Mev. θ is the scattering angle in the center-of-mass system. Column I gives the ratio of the differential cross section in the center-of-mass system at the angle θ to that at 36°. Column II gives the absolute differential cross section obtained by normalizing to the results of Hadley *et al.* (see reference 1). The errors listed are the standard deviations of the counting statistics.

θ	I Relative cross section	II Absolute cross section (10^{-27} cm²/steradian)
5.1	1.70±0.14	12.9±1.2
10.3	1.58±0.06	12.0±0.7
20.8	1.36±0.05	10.3±0.6
36.0	1.00	7.6±0.4

processes, counter 1 was connected in anticoincidence. Only events detected in counters 2 and 3 but not 1 were counted.

The thickness of absorber 2 determined the minimum energy which a scattered neutron could have and still be counted. In the present work the minimum energy was adjusted at each scattering angle to be [(60 Mev) $\cos^2\Theta$]. Therefore, a neutron in the beam must have had at least 60 Mev in order to have been counted after scattering, since otherwise the proton yielded at the converter would have had insufficient range to reach counter 3. The shaped portion of absorber number 2 was thickest in the center and was shaped so that to good approximation the minimum neutron energy to count would be independent of the angle with which the recoil proton emerged from the converter. To determine the shape of the absorber we assumed that most of the recoil protons were from n-p scattering processes in the converter. In order to ascertain whether the relative differential cross sections were particularly sensitive to the value of the minimum energy for detection of the scattered neutrons, a measurement was made with this minimum energy increased to 66 Mev. The results were in agreement with those obtained for the 60-Mev minimum within the uncertainty of the counting statistics.

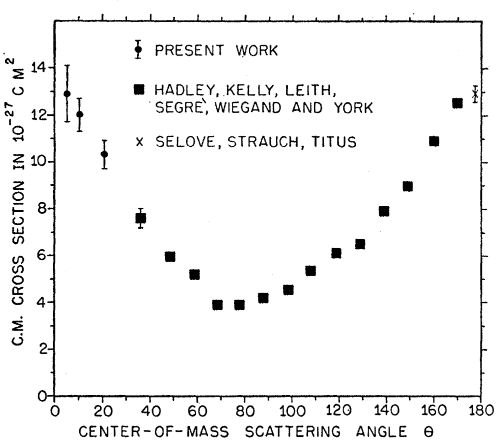

FIG. 2. Differential neutron-proton cross section in the center-of-mass system in 10^{-27} cm²/steradian.

The results are tabulated in Table I. Figure 2 shows the data in their relation to prior work, indicating a marked similarity of the differential cross section in the region of 0° to that in the region of 180°.

Thanks are due Dr. Martin O. Stern for initial studies of background and design of the neutron collimator.

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Additional Properties of Isotopes of Elements 99 and 100

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A SHORT-LIVED alpha activity was previously reported to elute at the element-100 position.[1] This activity was observed, a few hours after column separation, to be in equilibrium[1] with an element-99 parent which decayed with a longer (∼2-day) half-life. Preliminary data obtained from irradiations in the Argonne pile indicated that an MTR irradiation of 10^4 alpha counts/minute of the 6.6-Mev element-99 isotope would produce several hundred 7.2-Mev alpha counts/minute of element 100.

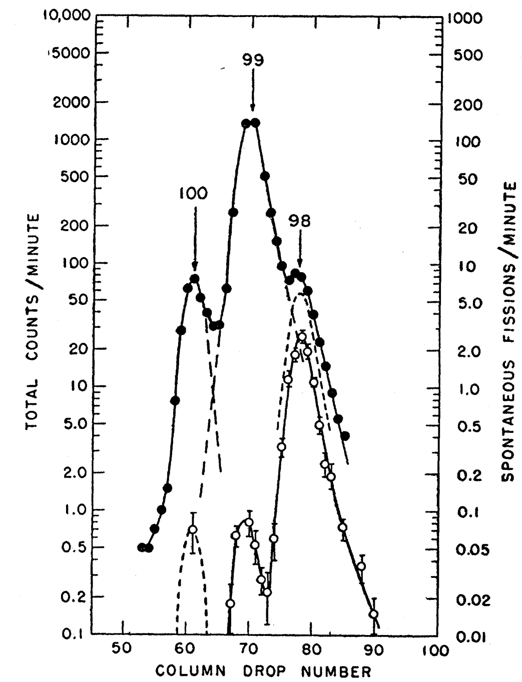

FIG. 1. The solid points represent the total counts/minute (alphas plus spontaneous fissions) from each drop at the time of removal from the cation column. The dashed curves outline the individual element separations as determined by alpha-pulse analysis and spontaneous fission measurements. The open circles represent the spontaneous fission activity as a function of drop number. The value at drop 61 is a result of a spontaneous fission activity measurement immediately after column elution. The other spontaneous fission measurements were made more than 12 hours after column elution, and therefore isotope 100^{254} was in approximate equilibrium with its element-99 parent causing the spontaneous fissions on the element-99 drops.

This note describes the results obtained from a four-day irradiation of an element-99 fraction with californium impurity in the Materials Testing Reactor (MTR) at Arco, Idaho to produce the following reaction:[2]

$$99^{253}(n,\gamma)99^{254} \xrightarrow{\beta^-} 100^{254}.$$

The separation of elements 98, 99, and 100 has been discussed previously and the degree of separation in this experiment is shown in Fig. 1. The peak of the 7.2-Mev alpha activity of element 100 eluted from the cation resin column on drop 61, while the peak of elements 99 and 98 eluted on drops 69–70 and 78, respectively.

The 7.2-Mev alpha-emitting isotope of element 100 decayed with a 3.3±0.2 hour half-life (Fig. 2) measured both by total and by spontaneous fission activity. The ratio of 7.2-Mev alpha