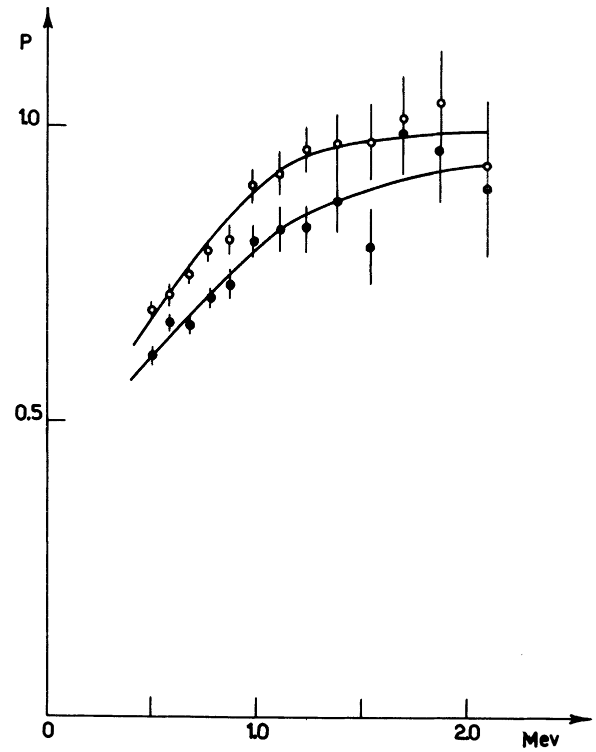

FIG. 1. Circular polarization of external bremsstrahlung quanta from Y^{90} β-rays, produced in unmagnetized (upper curve) and magnetized iron (lower curve).

Mev) the percentage decrease of polarization appears to be nearly constant against E and equal to about 10%. At higher energies the statistical errors prevent a significant conclusion, but the results are not in conflict with the reasonable assumption that the magnetic perturbation vanishes at the high-energy end of the spectrum.

Although a quantitative account of the effect cannot be given at present, the existence of a magnetic perturbation on circular polarization of EB is not surprising. It must not be forgotten that in magnetized iron the β particles are subject to strong inhomogeneous electric and magnetic fields varying on a microscopic scale, which are able to produce electron depolarization. If this hypothesis is correct, the superficial magnetic structure (thickness less than 0.2 mm) of the iron target should play an important role.

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S-WAVE DETECTOR OF DEUTERON POLARIZATION AND 14-Mev POLARIZED-NEUTRON SOURCE

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(Received March 9, 1959)

Recently a great deal of interest[1] has been expressed in the development of polarizing ion sources for use in accelerators. In this connection a convenient analyzer for the resulting polarized beams would be most useful. It is well known that in both scattering and reactions induced by polarized s-wave protons the angular distribution of the scattered protons, or of any reaction product, is isotropic[2] just as they would be for unpolarized s-wave protons.[3] The purpose of this Letter is to point out that the fact that isotropy does not necessarily follow for a reaction induced by polarized s-wave deuterons[4] may enable one to use, for example, the $T(d,n)He^4$ reaction as a sensitive detector of the polarization of a deuteron beam. This reaction will then also serve as a source of polarized, 14-Mev neutrons.

The different results obtained for proton and deuteron beams may be ascribed to the fact that the spin projection has only two possible values for the proton, but three for the deuteron. We have for the d-T resonance ($E_{max}=107$ kev, $l_d=0$, $J=3/2^+$, $l_n=2$)[5] the following partial cross sections[6]:

$$\left(\frac{d\sigma}{d\Omega}\right)^{+1}_{3/2,\,1/2}=\left(\frac{d\sigma}{d\Omega}\right)^{+1}_{1/2,\,-1/2}=\left(\frac{d\sigma}{d\Omega}\right)^{-1}_{-3/2,\,-1/2}=\left(\frac{d\sigma}{d\Omega}\right)^{-1}_{-1/2,\,1/2}$$

$$=\tfrac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)^{0}_{1/2,\,-1/2}=\tfrac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)^{0}_{-1/2,\,1/2}=3K\sin^2\theta\cos^2\theta,$$

$$\left(\frac{d\sigma}{d\Omega}\right)^{+1}_{3/2,\,-1/2}=\left(\frac{d\sigma}{d\Omega}\right)^{-1}_{-3/2,\,1/2}=3K\sin^4\theta,$$

$$\left(\frac{d\sigma}{d\Omega}\right)^{+1}_{1/2,\,1/2}=\left(\frac{d\sigma}{d\Omega}\right)^{-1}_{-1/2,\,-1/2}=\tfrac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)^{0}_{1/2,\,1/2}=\tfrac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)^{0}_{-1/2,\,-1/2}$$

$$=\tfrac{1}{3}K(9\cos^4\theta-6\cos^2\theta+1),$$

where $K=|U|^2/16k^2$ is independent of angle, U is the relevant element of the collision matrix, and k is the deuteron wave number. The superscripts on the cross sections are the magnetic quantum numbers of the deuterons; the subscripts are those of the channel spins referred to the beam axis,[7] the first subscript for the d-T channel (channel spin 1/2 does not contribute to this resonance reaction since $J=3/2$ and $l_d=0$) and the other for the n-He^4 channel. The cross section for a deuteron beam polarized with $m_d=+1$ is

$$\sum_{a,b}\left(\frac{d\sigma}{d\Omega}\right)^{+1}_{a,b}=\tfrac{2}{3}K(3\sin^2\theta+2);$$

if $m_d=-1$ we get the same result, and if $m_d=0$ we get $\frac{4}{3}K(3\cos^2\theta+1)$. The differential cross section for an unpolarized beam, which is the average of the above three cross sections, is $8K/3$; isotropic, as it must be.[3] The equality of the $m_d=\pm1$ cross sections is a consequence of reflection invariance of the nuclear interaction. Similarly, for a proton beam $m_p=+\frac{1}{2}$ and $-\frac{1}{2}$ give equal cross sections. These are isotropic for s-waves, since an unpolarized beam, which can be represented as an equal mixture of $m_p=\pm\frac{1}{2}$, gives isotropy.[3]

Thus, we see that the angular distribution of the neutrons or alpha particles in the d-T reaction is determined by the alignment (mean value of $m_d^{\,2}$) rather than the polarization (mean value of m_d). If one were attempting experimentally to produce a pure $m_d=+1$ beam, for example, the major impurity would most likely be $m_d=0$. Then the alignment and polarization would be equal. Figure 1 is a set of angular distributions resulting from various mixtures of $m_d=+1$ and 0 in the deuteron beam.

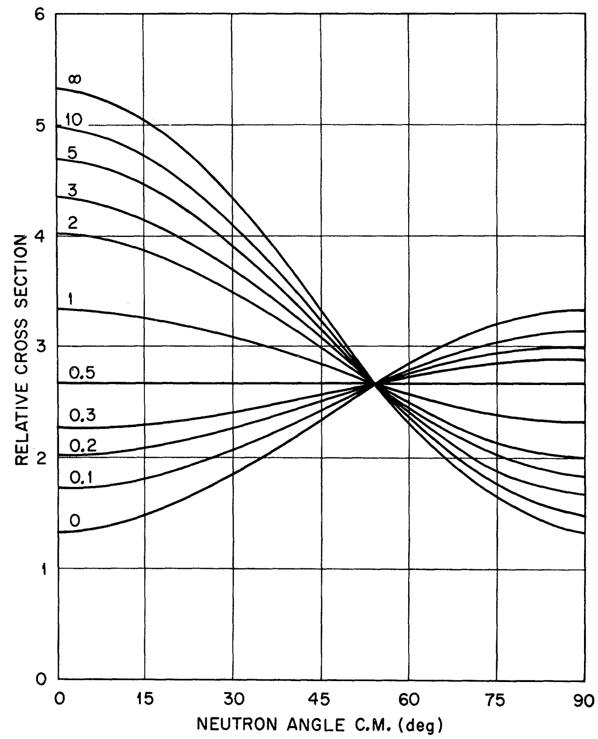

FIG. 1. Angular distributions of neutrons from the T(d,n)He^4 resonance reaction for polarized beams of deuterons containing a mixture of $m_d=+1$ and 0. The label on each curve is the ratio of the $m_d=0$ component to the $m_d=+1$ component.

The main advantage of attempting to produce beams of polarized deuterons rather than polarized protons is that s-waves and, therefore, low voltages are sufficient to produce anisotropy. In our T(d,n)He^4 example the cross section has its maximum at only 107 kev. In addition, this cross section at the maximum is very large (5 barns for an unpolarized beam) and the width is 140 kev. This scheme obviates the need for a pressurized electrostatic generator. With a low-voltage, open-air accelerator there need be no limitation on the size of the polarizing apparatus and the easy accessibility of such apparatus has many obvious advantages. If convenient, the polarity of the accelerator may even be reversed so that the polarizer and ion source are at ground potential. As an example of the rapidity of determination of the polarization, consider the following conditions for a pure $m_d=+1$ beam, where the neutrons from a thick Zr-T target are detected at 90°: deuteron energy = 200 kev, deuteron current = 1 millimicroampere, detector solid angle = 1 % of sphere (half-angle = 12°), and

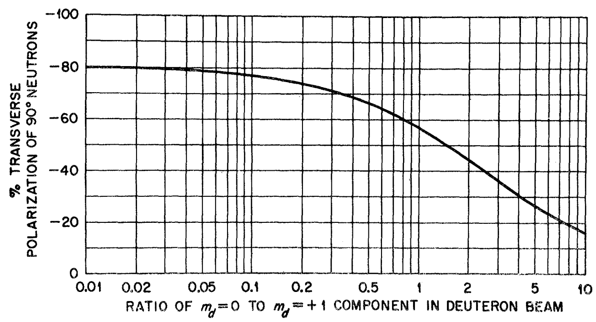

FIG. 2. Polarization of neutrons produced at 90° in the $T(d,n)He^4$ resonance reaction by a polarized deuteron beam. The direction of polarization is opposite to the beam direction in the scattering plane, hence transverse to the neutron direction.

detector efficiency = 20%. The resulting count rate is ~300/sec.

Reference to the partial cross sections listed above shows that the 14-Mev neutrons produced in the d-T reaction are, in general, polarized. The $m_d = \pm 1$ deuterons produce equal and opposite neutron polarizations and the $m_d = 0$ deuterons no polarization. Figure 2 shows the polarization of the neutrons at 90° as a function of the contamination of an $m_d = +1$ beam by $m_d = 0$. The direction of polarization is opposite to the beam direction in the scattering plane, hence transverse to the neutron direction. It is, of course, essential to the use of the neutrons in a subsequent nuclear process that the neutron polarization be transverse. By examination of the neutron angular distribution and polarization, it therefore appears that the complete polarization state of the deuteron beam can be determined.

It should be pointed out that the analogous $He^3(d,p)$ reaction may be an even more convenient one for determining the polarization state of the deuteron. This reaction would, in addition, produce 14-Mev polarized protons.

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RESONANCES IN THE π-HYPERON SYSTEM

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(Received March 30, 1959)

The scattering matrix for the charge symmetric π-Σ-Λ interaction[1] has been investigated in the Chew-Low approximation. The Σ-Λ relative parity was assumed to be even. In the case of global symmetry ($g_{\Sigma\Sigma\pi} = \pm g_{\Sigma\Lambda\pi}$) we obtain the familiar Chew-Low equations for the π-nucleon system; the π-nucleon states of isotopic spin $T=\frac{3}{2}$ and $T=\frac{1}{2}$ corresponding now to the π-hyperon states $T=2$ and $T=0$, respectively. The scattering amplitude for the two $T=1$ states ($\Sigma\pi$ and $\Lambda\pi$) can be written as a linear combination of the amplitudes in the $T=2$ and $T=0$ states. The effective range in the $T=2$, $J=\frac{3}{2}$ state is positive, and if the coupling constant and cutoff energy are comparable to the π-nucleon values we get the analog of the famous π-nucleon $T=\frac{3}{2}$, $J=\frac{3}{2}$ resonance. In the limits $g_{\Sigma\Lambda\pi} \ll g_{\Sigma\Sigma\pi}$ and $g_{\Sigma\Lambda\pi} \gg g_{\Sigma\Sigma\pi}$, the effective range also turns out to be positive in the $T=2$, $J=\frac{3}{2}$ state. In addition the effective range is positive in the $T=0$, $J=\frac{1}{2}$ state for the case $g_{\Sigma\Lambda\pi} \ll g_{\Sigma\Sigma\pi}$ and in the $T=1$, $J=\frac{1}{2}$ ($\Sigma\pi$) and $T=1$, $J=\frac{3}{2}$ ($\Lambda\pi$) states in the case $g_{\Sigma\Lambda\pi} \gg g_{\Sigma\Sigma\pi}$.