also has a positive *g* value, we conclude that the hyperfine field at the Co^{57} nuclei is parallel to that at the Fe. This has been found to be negative with respect to the ferromagnetic domain magnetization[10]; hence the field at the Co^{57} is also opposite to the domain field.

It is amusing to consider that the net maximum asymmetry ratio of 1.05 implies that the sublevels of the 14.4-kev state have populations corresponding to a small negative temperature, approximately -5×10^{-3} °K. The negative spin temperature results from the inversion of the sublevel ordering, and its absolute value is a factor of about 20 lower than the temperature of the lattice and the conduction electrons.

Application of the effect as a low-temperature thermometer appears to be a distinct possibility. We are presently conducting a more quantitative study of the temperature dependence; a detailed report on the work will be submitted.

We wish to thank W. Visscher for several important calculations and helpful discussions.

*Work performed under the auspices of the U. S. Atomic Energy Commission.

[1]S. S. Hanna, J. Heberle, C. Littlejohn, G. J. Perlow, R. S. Preston, and D. H. Vincent, Phys. Rev. Letters 4, 177 (1960).
[2]G. K. Wertheim, Phys. Rev. Letters 4, 403 (1960).
[3]O. C. Kistner and A. W. Sunyar, Phys. Rev. Letters 4, 412 (1960).
[4]Proceedings of the Allerton Park Conference on Mössbauer Effect, University of Illinois, Urbana, Illinois, June 5-7, 1960 (unpublished), Sec. 3.
[5]A. C. Gossard and A. M. Portis, Phys. Rev. Letters 3, 164 (1959); M. J. Steenland and H. A. Tolhoek, in Progress in Low Temperature Physics, edited by C. S. Gorter (North Holland Publishing Compnay, Amsterdam, 1957), Vol. 2, p. 326.
[6]W. M. Visscher (private communication).
[7]R. V. Pound and G. A. Rebka, Jr., Phys. Rev. Letters 3, 554 (1959).
[8]R. V. Pound and G. A. Rebka, Jr., Phys. Rev. Letters 4, 274 (1960).
[9]B. D. Josephson, Phys. Rev. Letters 4, 341 (1960).
[10]S. S. Hanna, J. Heberle, G. J. Perlow, R. S. Preston, and D. H. Vincent, Phys. Rev. Letters 4, 513 (1960).

SOURCE OF POLARIZED DEUTERONS AND THE VERIFICATION OF ALIGNMENT WITH THE $T(d,n)He^4$ REACTION

E. Baumgartner, L. Brown, P. Huber, H. Rudin, and H. R. Striebel
Department of Physics, University of Basel, Basel, Switzerland
(Received July 22, 1960)

Interest has developed in recent years in the construction of a source of polarized particles, and several suggestions have been made for its accomplishment.[1] A proposal by Galonsky, Willard, and Welton[2] for using the $T(d,n)He^4$ reaction simplifies the detection of the polarized beam. We have constructed an ion source for polarized deuterons and have confirmed the alignment with this reaction.

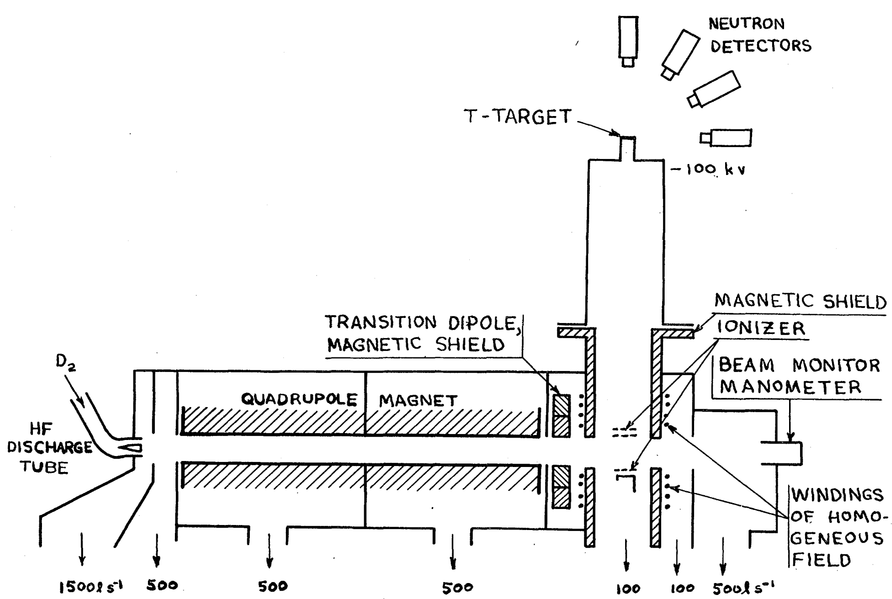

FIG. 1. Schematic diagram of the source.

The course of the particles through the device is shown in Fig. 1. Atoms of deuterium are allowed to diffuse from a high-frequency discharge tube through a region of differential pumping into a strong magnetic quadrupole field. This field is generated by permanent magnets attached to four parallel pole shoes 90 cm long, and has a value of 11 000 gauss at the surface. In this field atoms with strong-field quantum numbers $m_e = 1/2$ and $m_d = +1, 0, -1$ are confined to a circular cylindrical region of 10-mm diameter defined by the pole shoes; the other atoms diverge from the axis. The beam so formed passes into a orienting homogeneous field weak enough to allow strong coupling of electron and nucleus. A small part of it is ionized there by electron bombardment. Deuterons so produced have spin populations of 4/3, 4/3, 1/3 for $m_d = +1, 0, -1$, respectively. The resulting ions are accelerated through 100 kv onto a thick tritium target to produce the desired nuclear reaction. The portion of the atomic beam not ionized finally passes into a beam-receiving compartment where it is pumped away to reduce back diffusion.

The intensity of the atomic beam is measured by placing an ionization manometer in its path; the observed instrument reading is corrected for pressure buildup in the glass cylinder, the ionization cross section of hydrogen, and the divergence of the beam outside the quadrupole field. The measured beam intensity is 8×10^{15} sec^{-1} and the beam pressure at the point of ionization is 1×10^{-6} mm Hg. This manometer serves as the atomic beam monitor during operation.

On leaving the quadrupole field the atoms pass through a homogeneous transition field of about 60 gauss generated by an electromagnet, the ring yoke of which acts as the first magnetic shield between ionization volume and quadrupole magnet. They then pass through an opening in the iron cylinder enclosing the electron gun. Here a magnetic field of 1 gauss or more is maintained by external current windings in a direction perpendicular to the atomic beam axis and parallel to that of the ionic beam. This field is superimposed on the somewhat stronger field formed by the heating current of the tungsten cathode and a compensation winding, forming together a field similar to one produced by Helmholtz coils.

The ions are accelerated without magnetic deflection onto the target. Unpolarized deuterons are obtained by admitting deuterium gas into the ionization compartment. The spin axis is parallel to the ion beam; angular measurements are made relative to this direction. We measured the ratio of reaction cross sections $\sigma(0)/\sigma(\theta)$ for three angles simultaneously with four scintillation detectors by comparing the neutron counting rates produced by deuterons from the atomic beam and from molecular gas admission. A convenient parameter, G, is the population ratio of spin state 0 to the sum of the states +1 and -1. Figure 2 shows the measured distribution and the curves predicted for $G = 4/5$ and for the average value $G = 0.706(\pm 0.014)$. The average value is smaller than 4/5, as one might expect, since the field in the ionization volume is not exactly parallel; we think other sources of depolarization are of less importance. The magnetic shielding and the field from the cathode prevent a controlled change of the direction of the field in the ionizing region; nevertheless, investigations with two neutron detectors showed values of $\sigma(0°)/\sigma(90°)$ about unity, if part of the homogeneous field decreased below 1 gauss. Corrections for the different distributions in the laboratory co-

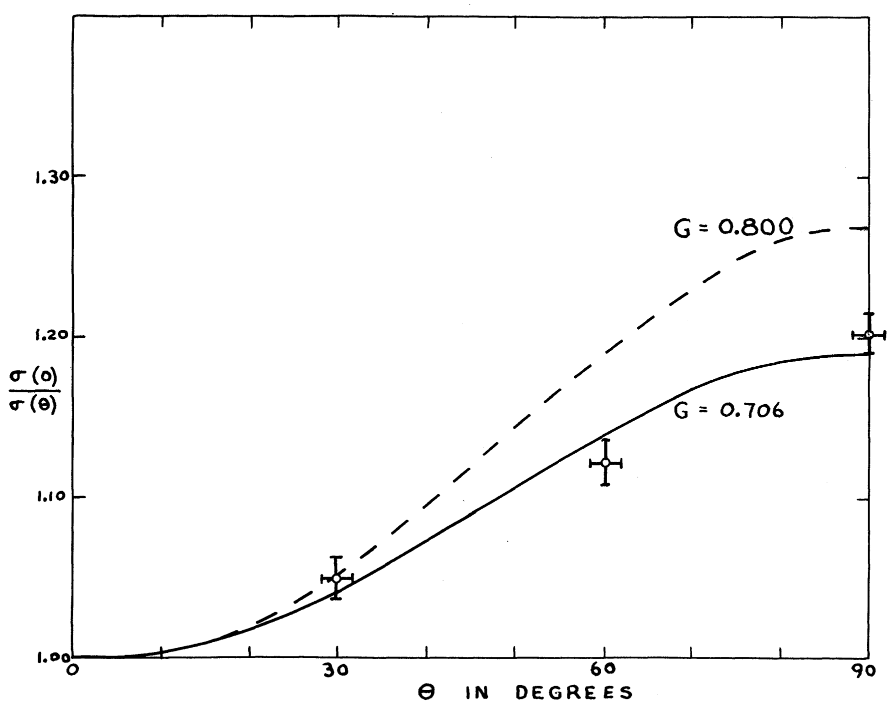

FIG. 2. The ratio of the differential reaction cross section at 0° to the cross section at angle θ is plotted for three measured values. The dashed curve shows the predicted distribution for the maximum possible value of G obtained from the three measured points.

ordinate system for the 100-kev and 50-kev (unpolarized molecular ions) particles are negligible when compared with the resolving power of the neutron detectors.

The current of the polarized beam can be calculated from a knowledge of counting rates, total ion current, partial pressure of deuterium admitted for the unpolarized ions, and the geometry of the electron gun. The current so calculated is 0.01 μa. Typical neutron counting rates are as follows: atomic beam ionized, 700 min^{-1}; residual gas ionized with normal gas admission but no atomic beam, 170 min^{-1}; residual gas ionized without gas admission, 130 min^{-1}; no ionization but accelerating voltage present, 50 min^{-1}.

Investigations of the residual gas ions show the source in its present form is unsuitable for the generation of polarized protons, since about 5 times as many protons originate in the residual gas as in the atomic beam. This is attributed for the most part to the use of rubber seals and oil diffusion pumps; furthermore, no special care has been taken to reduce the residual gas pressure.

[1]A detailed description of the source with an extensive bibliography will soon appear in Helvetica Physica Acta.

[2]A. Galonsky, H. B. Willard, and T. A. Welton, Phys. Rev. Letters 2, 349 (1959).

NEGATIVE PION-PROTON ELASTIC SCATTERING AT 600 TO 750 Mev*

John I. Shonle
Lawrence Radiation Laboratory, University of California, Berkeley, California
(Received July 22, 1960)

The total $\pi^- $-$p$ cross section shows two well-defined peaks, one at 600 Mev and one at 890 Mev (laboratory-system kinetic energy).[1] Peierls[2] has assigned $D_{3/2}$ and $F_{5/2}$, respectively, for the orbital and total angular momentum states based on the photoproduction angular distributions[3] and polarizations of the recoil protons.[4] Landovitz and Marshall[5] suggest that $P_{3/2}$ and $D_{3/2}$ or $D_{5/2}$ assignments are also consistent with the data. Previous π^--p elastic scattering experiments have been made at 425,[6] 460,[7] 600,[7] 770,[7] 810,[8] 925,[9] and 950[10] Mev. These experiments have not led to any definite conclusions, partly because of large energy spreads and low statistics.

This experiment was conceived to try to establish the angular momentum at the peaks from elastic scattering on hydrogen. Negative pions at 610 ± 20, 655 ± 20, and 750 ± 20 Mev were passed through a 30-inch propane bubble chamber operated in a 13-kgauss field.[11] The pions were focused, deflected, and collimated to give a momentum spread of ± 1.5%. The energy spread quoted above comes from energy loss in the chamber. The mean beam momentum was checked by wire orbiting, by measuring the curvature of beam tracks in the bubble chamber, and from kinematics of elastic scattering events with stopping protons. All three methods gave consistent results. Twenty percent of the film was scanned twice. All events were measured on digitized microscopes (most of them on a "Franckenstein") and the data reduced on an IBM 650. A kinematics program gave the events a χ^2 test for elasticity using configuration-dependent errors. Good agreement with the expected χ^2 distribution was found. About 40% of the measured events were elastic.

Tracks entering the scanning region were counted in 4% of the pictures. Corrections were made based on calculated muon contaminations (11.5%) and measured electron contaminations (about 3%), and for interactions reducing track length. The resulting track lengths were checked by counting interactions and checking with the π^--p [1] and π^--C^{12} total cross sections.

The numbers of elastic scattering events found were 539, 1159, and 1008 at 610, 655, and 750 Mev, respectively. Analysis of about 20% more events is still in process, and corrections were made for these assuming they were randomly distributed. Corrections were made for scanning efficiency and azimuthal bias, but not as a function of scattering angle. A correction was made for carbon contamination (about 7%) by using the behavior of the nonelastic tail of the observed χ^2 distribution. For the total elastic scattering cross sections, corrections for small-angle scattering events which were missed were made