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TEST OF ISOTOPIC SPIN CONSERVATION FROM AN EXPERIMENT LIMIT ON $\sigma(d + d \rightarrow He^4 + \pi^0)$

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The reaction

$$d + d \to He^4 + \pi^0 \qquad (1)$$

has been looked for at the 184-inch cyclotron at Berkeley. This reaction is of interest because it is forbidden by the conservation of isotopic spin, I, since the three heavy particles all have I-spin = 0 and the I-spin of the ordinary π_1^0 (member of the I-spin triplet π_1^+, π_1^0, π_1^-) is 1. Therefore Reaction (1), which is a strong interaction, would require a change in I-spin of +1. The incident deuteron kinetic energy in the laboratory system for this experiment was 460 Mev. Previous efforts at observing Reaction (1) have obtained limits for the total cross section of 7×10^{-32} cm^2 at 460 Mev[1] and 2×10^{-32} cm^2 at 400 Mev.[2]

We obtain an apparent center-of-mass-system differential angular cross section of $18\pm2.3\times10^{-34}$ cm^2/steradian at θc.m.=90 deg. For reasons given below, we consider this value to be an upper limit for Reaction (1); the data are consistent with no π^0 production. Within the limits of the impulse approximation used to calculate the expected cross section for (1) if isotopic spin need not be conserved,[3] we conclude that isotopic spin is at least 93.5% conserved. We also looked for the reaction

$$d + d \to He^4 + \gamma . \qquad (2)$$

An apparent cross section for (2) is ~~$5.2\pm1.8\times10^{-32}$ cm~~ $48\pm10\times10^{-34}$ cm^2/steradian at θc.m.=65 deg. This also is to be treated as an upper limit; our data are consistent with no γ

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production from Reaction (2).

Figure 1 shows the laboratory-system kinematics for Reaction (1) for incident deuterons of 460 Mev kinetic energy and $M(\pi^0) = 135.0$ Mev. The kinematics for Reaction (2) are also shown, dotted. Slits of lead were placed between the target and the first quadrupole to fix the lab angle of the alpha particle at 8.7±.6 deg. (indicated in Fig. 1) and to prevent the magnetic channel from seeing the deuteron beam as it passed through the windows of the gaseous target.

Two alpha momentum settings were used: 1275±75 Mev/c, which was sensitive to the production of a neutral particle with a mass of from 120 to 155 Mev, and 1427±40 Mev/c, which was sensitive to a mass of from 0 to 110 Mev. The momentum intervals quoted above were defined by the deliberately broad magnetic channel acceptance (±6%) and by the energy loss in the deuterium target.

Figure 2 shows the experimental arrangement used to focus and identify the alpha particles. The target had 1/32-in.-thick aluminum entrance and exit windows 6 in. in diameter. It was filled to a gas pressure of 25 atm at liquid nitrogen temperatures. Hydrogen and deuterium fillings were alternated during the experiment. The alpha-particle beam passed entirely through a vacuum except for regions near the target and in the vicinity of the counters.

The counters were constructed of 0.020-in.-thick plastic scintillator to minimize energy loss and multiple scattering. Alpha particles were identified by means of time of flight and range (i.e., $T_1T_2T_3T_4\overline{A_1}$) and $\frac{dE}{dx}$ (i.e., lower-level discrimination of the pulse height on T_3 and T_4). All counter pulses were recorded on a four-gun oscilloscope. The electronics was tuned up by means of an alpha-particle beam from the cyclotron, and consistency checks were made periodically through the run.

The cross section for deuterons on carbon,

$\frac{d\sigma}{d\Omega}(d + C \rightarrow He^4 + \text{residue})$, was also measured by using the CH_2-H_2 subtraction technique. The result is $2.3 \times 10^{-30} cm^2$/steradian-Mev/c for alpha particles of 1060 Mev/c momentum (lab) and an angle of 8-2/3 deg. With the CH_2 target we could show that our electronics did not saturate even though the production cross section for alpha particles and the background of deuterons were larger than with the deuterium target in place.

Our data runs were cycled among four settings: He^4 momentum set at 1275 Mev/c to observe Reaction (1) and then at 1427 Mev/c to observe Reaction (2), first with a deuterium target and then with a hydrogen target.

Table I. Counts per 10^{13} incident deuterons

$p(He^4)$	D_2	H_2	Target empty
1275 Mev/c (π^0)	31.4±.85	22.7±.73	16.5±1.08
1427 Mev/c (γ)	33.9±1.07	24.2±.88	

Table I presents our data with their statistical errors. Since no alpha particles can come from d-p collisions, the hydrogen data were treated as background and subtracted from the deuterium data to yield the net He^4 signal from d-d collisions. This signal is now to be considered as an upper limit because any contamination of the deuteron beam with alpha particles would give us a net positive yield. This was shown by using an alpha-particle beam from the cyclotron under the conditions listed in Table I. At both momenta the α-d inelastic scattering yielded 1.48±.03 times as many alpha counts as did α-p scattering. Alpha contamination of the deuteron beam could explain the observed net positive difference in alpha-particle yield between the deuterium and hydrogen targets. Further data (not shown in Table I) at different momenta give us additional information on the background. These data are consistent with zero yield from Reaction (1), but the errors are large. We find, therefore, no evidence of the nonconservation of isotopic spin.

To get a firm upper limit for Reaction (1) we assumed that the counts in Table I for D_2 target minus those from H_2 target were due entirely to Reaction (1). The limit for the differential scattering cross section in the center-of-mass system obtained in this manner is $d\sigma_{c.m.}/d\Omega \leqslant (18 \pm 2.3) \times 10^{-34}$ cm^2/steradian at 90 deg (c.m.). Comparing this with the theoretical prediction[3] for the cross section $d\sigma^T/d\Omega = 380 \times 10^{-34}$ cm^2/steradian, based on the assumption that isotopic spin need not be conserved, we find that isotopic spin is at least 93.5% conserved with a 97% confidence level (two standard deviations in one direction. The standard deviation of 0.9% was a composite of experimental errors quoted here plus errors on experimental quantities as reflected in the calculation of Ref. 3). The limit obtained for Reaction (2), mentioned previously, was obtained in this same manner from the data in Table I.

We should like to thank Mr. James Carroll and Mr. William Bowman as well as Mr. Richard Eandi, Mr. Dale Dickinson, and Mr. Donald Hagge for help throughout the experiment; Professor Moyer for discussions, and Mr. James Vale and the cyclotron crew for their cooperation.

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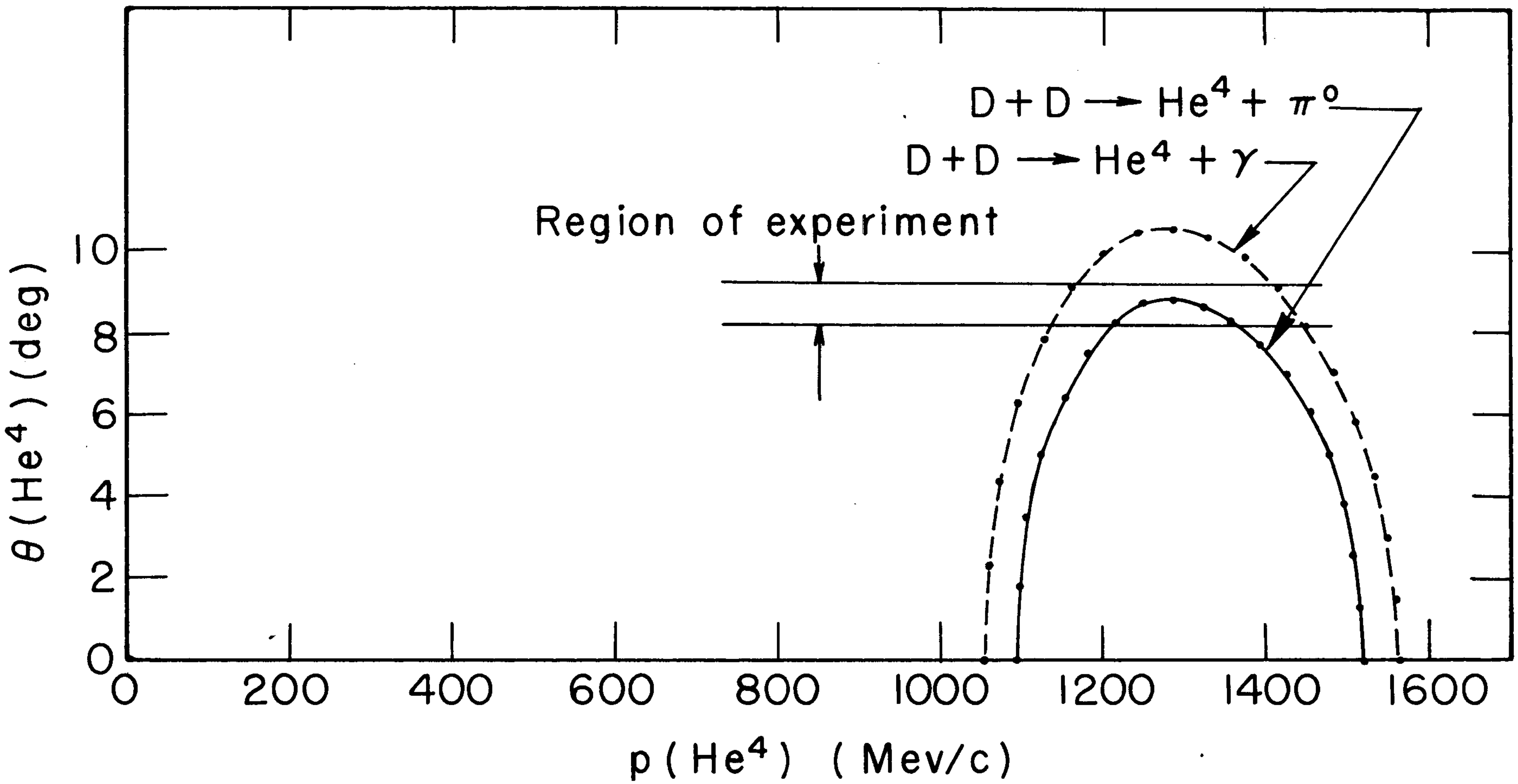
3. K. R. Greider, accompanying Physical Review Letter.

LEGENDS

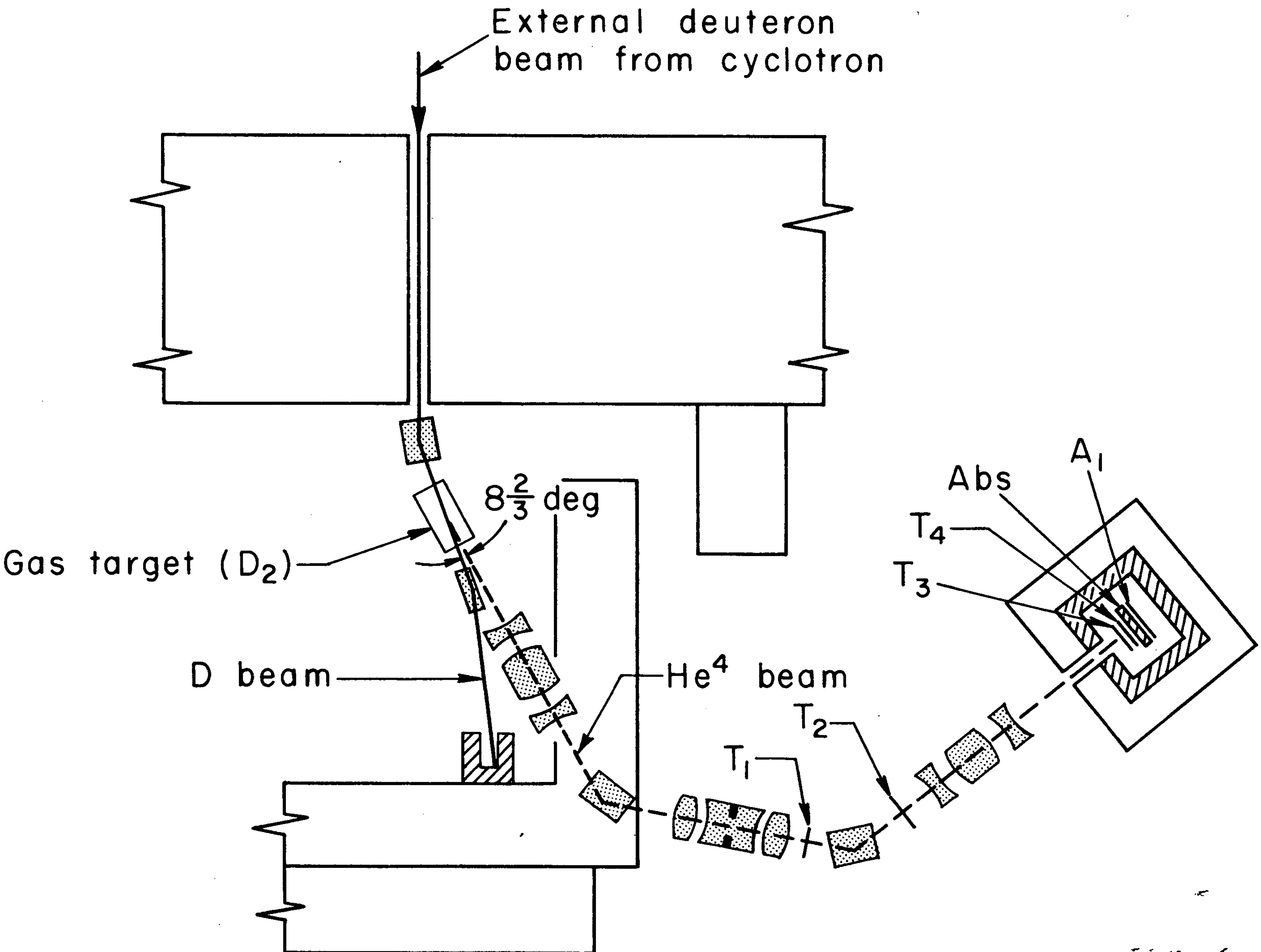
Fig. 1. Angle vs momentum of He^4 (lab).

Fig. 2. Experimental arrangement.

ANGLE vs MOMENTUM OF He^4 IN THE LAB



EXPERIMENTAL ARRANGEMENT



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