Submitted to Nuclear Instruments and Methods (as a Letter)

IS THE $^{12}C(\vec{d}, d_o)$ REACTION A GOOD POLARIZATION STANDARD?

J. Arvieux, J. Birchall, H. E. Conzett,
W. Dahme, W. Haeberli and R. M. Larimer

January 1974

Prepared for the U. S. Atomic Energy Commission
under Contract W-7405-ENG-48

DISCLAIMER

IS THE $^{12}C(\vec{d},d_o)$ REACTION A GOOD POLARIZATION STANDARD?[†]

J. Arvieux[††], J. Birchall, H. E. Conzett, W. Dahme[‡], W. Haeberli[‡‡], and R. M. Larimer

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

January 1974

Abstract

The suitability of $\vec{d}$-^{12}C elastic scattering as a deuteron polarization analyzer is examined.

[†]Work performed under the auspices of the U. S. Atomic Energy Commission.

[††]Present address: Institut des Sciences Nucléaires - Cedex 257 - 38044 GRENOBLE - France.

[‡]Present address: Sektion Physik - Univ. München - D-8046 Garching - Germany.

[‡‡]Department of Physics - University of Wisconsin - Madison, Wisconsin.

There has been a great development of polarized-ion sources associated with different kinds of accelerators, ranging from very low energy electrostatic generators up to the 12-GeV Argonne ZGS synchrotron. The widening of the energy range at which polarized beams are available emphasizes the need for good polarization standards which can be used to calibrate the polarized beams. Usually one relies on double-scattering experiments which give, for spin 1/2 particles, an absolute value of the polarization. For deuterons such an experiment would usually give an ambiguous answer, because the effects of the tensor polarizations, T_{2q}, are difficult to separate from that of the vector polarization iT_{11}. Hopefully, there are a few reactions in which the T_{2q} are small compared to iT_{11} so that an absolute value of the vector polarization can be derived. One such reaction is the $^4He(\vec{d},d)^4He$ elastic scattering at an incident beam energy E_d = 11.5 MeV and laboratory scattering angle θ_L = 88°, at which a double-scattering experiment has been done at Los Alamos[1]). The result from this experiment is in good agreement with a later result which was achieved with a polarized beam from the Los Alamos Lamb-shift polarized-ion source, whose polarization was determined by the quench ratio method[2]). An independent measurement of iT_{11} at E_d = 11.5 MeV, θ_L = 87.8° was made at Zurich[3]). Their absolute calibration of the tensor polarization of the deuteron beam was made via the $^{16}O(\vec{d},\alpha)^{14}N^*(2.31)$ reaction[4]), and the theoretical ratio between vector and tensor polarization in the beam was then used to provide the absolute vector polarization value. The agreement between the values from the two laboratories is very good, and this point can now be used as a deuteron vector polarization calibration standard. The value we have adopted is $iT_{11}(E_d$ = 11.5 MeV, θ_L = 88°) = -0.360±0.009 which is the weighted mean value between the Zurich result, iT_{11} = -0.362±0.009, and the Los Alamos result, iT_{11} = -0.356±0.013. This value has been used at Berkeley[5]) to normalize an angular distribution of iT_{11} in $^4He(\vec{d},d)^4He$ scattering at 15 MeV and the agreement with 15-MeV data from Los Alamos[6]) is excellent. At Berkeley the vector analyzing power iT_{11} has been measured at energies up to 45 MeV.

The 15 MeV $^4He(\vec{d},d)^4He$ data have been also used in Grenoble to calibrate a ^{12}C polarimeter from 20 to 30 MeV[7]), which has then been used to study the $^4He(\vec{d},d)^4He$ scattering between 20 and 30 MeV[8]). A comparison of preliminary data from Berkeley and Grenoble has shown very good agreement for the 20 and 30 MeV data but there was a 10% discrepancy at E_d = 25 MeV. The possibility exists that the 25 MeV ^{12}C calibration experiment could be the source of the discrepancy. If one looks at the $^{12}C(\vec{d},d_o)$ analyzing power angular distributions, one sees that the first maximum value of $|iT_{11}|$ is $iT_{11}(E_d = 20.4$ MeV, $\theta_L = 40°) = -0.287$ and $iT_{11}(E_d = 25.2$ MeV, $\theta_L = 45°) = -0.711$. This rapid variation with energy has been attributed[9]) to compound nucleus effects in ^{14}N at excitation energies around 30 MeV where a broad resonance has been observed in photonuclear scattering[10]). Rapid variations of iT_{11} are then likely to occur around E_d = 25 MeV, and, thus, small beam energy differences between the ^{12}C calibration run and the $^4He(\vec{d},d)^4He$ experiment could explain the discrepancy between the Berkeley and Grenoble data.

To check this possibility we have measured iT_{11} in $^{12}C(\vec{d},d_o)$ elastic scattering at E_d = 20, 25 and 30 MeV near the first maximum of iT_{11}. Near 25 MeV the incident energy was varied by steps of a few hundred keV. The experiment was done at the Berkeley 88" Cyclotron. The purely vector polarized deuteron beam (intensity up to 100 nA, polarization of the order of 82 per cent of the maximum possible $iT_{11} = \sqrt{3}/3$) was sent onto a gas target cell filled with one atmosphere of ^4He located in a first scattering chamber. The beam energy, measured with an analyzing magnet was 30.00±0.05 MeV. Two telescopes set symmetrically left and right at $\theta_L = 90°$ detected and identified the scattered deuterons. The measured asymmetry, combined with the previously established value[5]) of the analyzing power, $iT_{11}(E_d = 30\text{ MeV}, \theta_L = 90°) = -0.321\pm0.010$, served to monitor the beam polarization, which was very stable and changed by less than 3 per cent during the course of the experiment. The unscattered beam was then sent into a second scattering chamber after having passed through aluminum energy degraders and a set of defining slits. There the beam was incident on a 15 mg/cm^2 ^{12}C target, and the asymmetry was measured by two telescopes set symmetrically left and right at angles θ_L. In order to eliminate instrumental asymmetries, alternate runs were taken with the sign of the beam polarization reversed. The results of our vector analyzing power measurements are given in table 1. The given errors include both statistical and systematic uncertainties. The overall normalization uncertainty is 2.9 per cent. The 29.5 MeV result agrees well with the value measured at Grenoble, $iT_{11}(E_d = 29.5\text{ MeV}, \theta_L = 44°) = -0.713\pm0.050$, which included the normalization uncertainty. Near 25 MeV there is a strong variation of iT_{11} with energy changes of a few hundred keV (see fig. 1). These values must be compared with the Grenoble value $iT_{11}(E_d = 25.2\text{ MeV}, \theta_L = 47°) = -0.711\pm0.050$. Although the agreement is satisfactory, the higher precision of the present data clearly shows that $^{12}C(\vec{d},d_o)$ elastic scattering is not a good reaction for a polarimeter around 25 MeV. A similar effect is observed at 20 MeV where there is a significant difference between our value and the Grenoble value, $iT_{11}(E_d = 20.4\text{ MeV}, \theta_L = 40°) = -0.287\pm0.018$, which can also be attributed to the difference in beam energies for the two experiments.

In conclusion, $^{12}C(\vec{d},d_o)^{12}C$ elastic scattering is suitable as a polarization standard at 30 MeV, but should be used with caution below this energy because of rapid variations of the analyzing power with angle and energy. A much more detailed survey of the analyzing powers in $^{12}C(\vec{d},d_o)$ scattering below 30 MeV is required before it can be used with confidence as a standard polarization analyzer in that energy region. The $^{4}He(\vec{d},d)^{4}He$ elastic scattering exhibits a smooth dependence with angle and energy over a wide range from 15 to 45 MeV, and thus is more suitable as a polarization standard, although iT_{11} is smaller than for the $^{12}C(\vec{d},d_o)$ reaction.

References

1) V. S. Starkovitch, Thesis, LASL Report LA-4191, July 1969, unpublished; G. G. Ohlsen, V. S. Starkovitch, W. G. Simon, and E. M. Bernstein, Phys. Letters 28B (1969) 404.

2) V. S. Starkovitch and G. G. Ohlsen, Polarization Phenomena in Nuclear Reactions, ed. by H. H. Barschall and W. Haeberli (Univ. of Wisconsin Press, Madison, 1971), p. 581; LASL Report LA-4465 MS, July 1970, unpublished.

3) V. König, W. Grüebler, A. Ruh, R. E. White, P. A. Schmelzbach, R. Risler, and P. Marmier, Nucl. Phys. A166 (1971) 393; W. Grüebler, V. König, P. A. Schmelzbach, and P. Marmier, Nucl. Phys. A134 (1969) 686.

4) B. A. Jacobsohn and R. M. Ryndin, Nucl. Phys. 24 (1961) 505.

5) Ch. Leemann, H. E. Conzett, W. Dahme, J. Macdonald, and J. P. Meulders, Bull. Am. Phys. Soc. 17 (1972) 562, and to be published.

6) R. A. Hardekopf, D. D. Armstrong, L. L. Catlin, P. W. Keaton, Jr., and G. P. Lawrence, LASL Report LA-5051, October 1972, unpublished.

7) G. Perrin, Nguyen Van Sen, A. Fiore, and J. Arvieux, Nucl. Instr. Methods 101 (1972) 603.

8) A. Fiore, J. Arvieux, Nguyen Van Sen, G. Perrin, R. Darves-Blanc, J. C. Gondrand, and F. Merchez, Proceedings of the International Conference on Few Particle Problems in the Nuclear Interaction, ed. by I. Slaus, S. A. Moszkowski, R. P. Haddock, and W. T. H. Van Oers (North-Holland Publishing Co., Amsterdam, 1972), p. 620.

9) G. Perrin, Nguyen Van Sen, J. Arvieux, A. Fiore, J. L. Durand, R. Darves-Blanc, J. C. Gondrand, F. Merchez, and C. Perrin, Nucl. Phys. A193 (1972) 215.

10) J. M. Loiseaux, J. M. Maison, and M. Langevin, J. Physique 28 (1967) 11.

E_d	θ_L	iT_{11}	$\Delta(iT_{11})$
29.56	43	- 0.659	0.021
	44	- 0.710	0.016
	45	- 0.704	0.016
	46	- 0.669	0.015
24.9	46	- 0.712	0.017
	47	- 0.745	0.015
	48	- 0.747	0.024
	49	- 0.684	0.016
24.2	46	- 0.677	0.014
	47	- 0.727	0.013
	48	- 0.728	0.016
	49	- 0.660	0.017
23.9	46	- 0.633	0.011
	47	- 0.663	0.015
	48	- 0.656	0.017
	49	- 0.621	0.014
19.8	40	- 0.255	0.006

Table 1 : Vector analyzing power iT_{11} in $^{12}C(\vec{d},d_o)$. E_d is the incident energy in MeV, θ_L the laboratory angle in degrees, and $\Delta(iT_{11})$ includes the statistical and systematic uncertainties, but does not include an overall normalization uncertainty of 2.9 per cent.

Figure Caption

Fig. 1. Vector analyzing power, iT_{11}, in $^{12}C(\vec{d},d_o)$ as a function of θ_L, the angle in the lab. system for incident energies E_d near 25 MeV. The solid curves serve only to guide the eye.

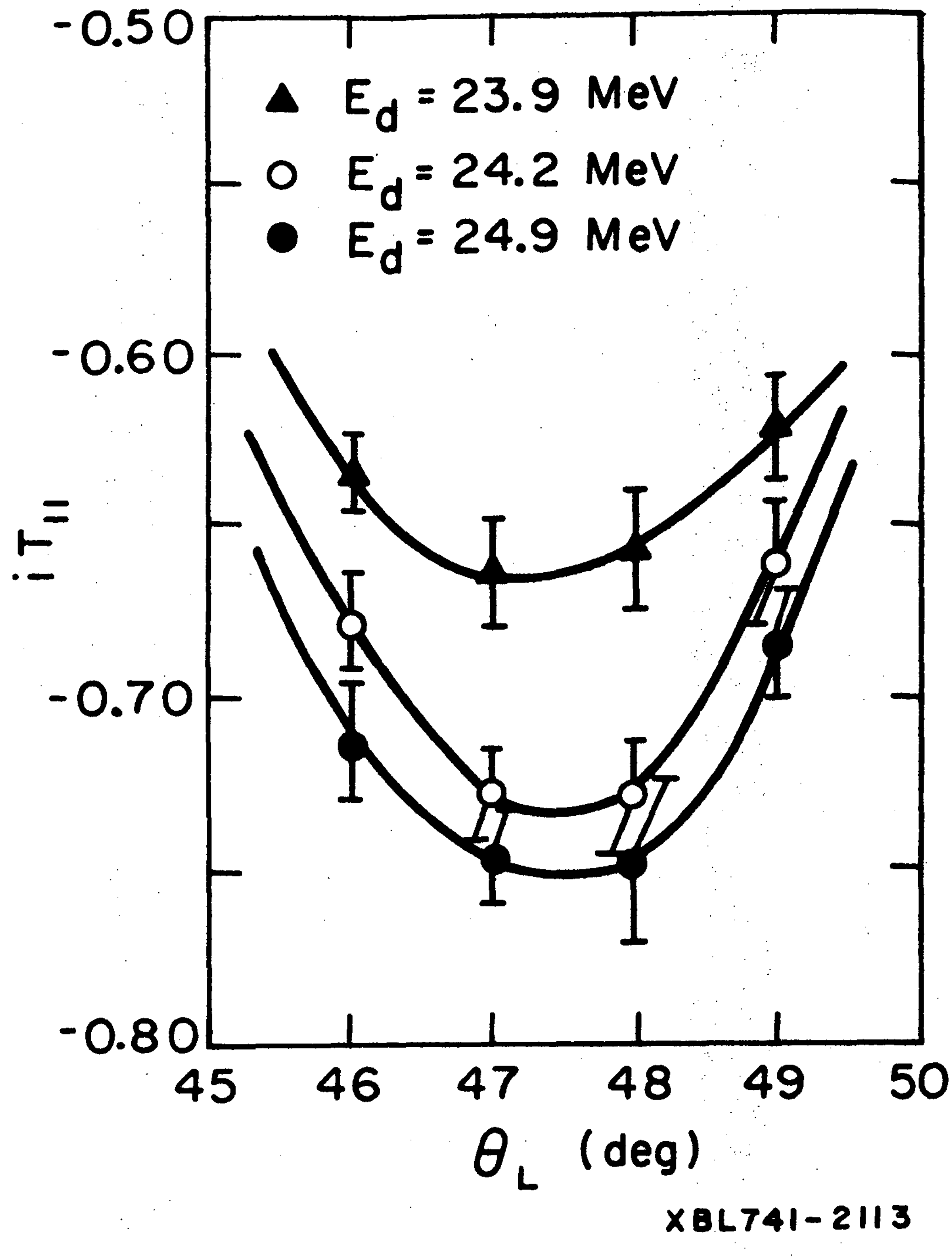
-0.50
-0.60
-0.70
-0.80
E_d = 23.9 MeV
E_d = 24.2 MeV
E_d = 24.9 MeV
iT_{11}
45
46
47
48
49
50
θ_L (deg)
XBL741-2113

Fig. 1

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720