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**Elastic Scattering of Polarized Tritons by ^9Be and ^{12}C :
Analyzing Powers and Differential Cross Sections**



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ELASTIC SCATTERING OF POLARIZED TRITONS BY ${}^9\text{Be}$ AND ${}^{12}\text{C}$: ANALYZING POWERS AND DIFFERENTIAL CROSS SECTIONS

by

P. A. Schmelzbach, R. A. Hardekopf,
R. F. Haglund, Jr., and G. G. Ohlsen

ABSTRACT

Analyzing power and differential cross-section results are presented in graphical and numerical form for the ${}^9\text{Be}(t,t){}^9\text{Be}$ and ${}^{12}\text{C}(t,t){}^{12}\text{C}$ elastic scattering at 15- and 17-MeV bombarding energy.



I. INTRODUCTION

This report presents tabulations and graphs of ${}^9\text{Be}(t,t){}^9\text{Be}$ and ${}^{12}\text{C}(t,t){}^{12}\text{C}$ elastic scattering data obtained recently at the Los Alamos Scientific Laboratory tandem Van de Graaff facility. These measurements are part of an extensive investigation of the triton optical potential performed at this Laboratory.

II. EXPERIMENTAL EQUIPMENT

The polarized tritons were produced by the recently completed polarized triton source.¹ Two pairs of counter telescopes were mounted in the supercube scattering chamber² and triton mass identification was performed on-line by the computer.³ Targets of thicknesses 2 mg cm^{-2} for ${}^9\text{Be}$ and 1.9 mg cm^{-2} for ${}^{12}\text{C}$ were used in this experiment. The angular resolution was $\pm 0.4^\circ$.

III. EXPERIMENTAL RESULTS

The experimental results for ${}^9\text{Be}(t,t){}^9\text{Be}$ elastic scattering are listed in Tables I to IV and angular distributions are shown on Figs. 1 and 2. For the

${}^{12}\text{C}(t,t){}^{12}\text{C}$ scattering, the numerical values are given in Tables V to VIII and the angular distributions are shown on Figs. 3 and 4.

The overall relative error of the cross sections is 3%. The ${}^{12}\text{C}(t,t){}^{12}\text{C}$ elastic scattering cross section has been normalized by interpolation to the previous measurements of Keaton et al.⁴ The accuracy of this normalization is not expected to be better than 10% to 15%.

Since the geometry was used in both experiments, a rough normalization of the ${}^9\text{Be}(t,t){}^9\text{Be}$ cross-section data was first made by comparing the thicknesses of the ${}^9\text{Be}$ and ${}^{12}\text{C}$ targets. This normalization was allowed to float during an optical model analysis of these data. The uncertainty of the final normalization is estimated to be $\pm 15\%$.

The absolute calibration of the analyzing power data is better than 2%. The relative errors given in the tables include a contribution of 0.005 quadratically added to the statistical error in order to take into account such effects as beam wander and errors in the setting of the gates.

No corrections for finite geometry or multiple scattering effects have been applied to the present data.

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TABLE I
THE DIFFERENTIAL CROSS SECTION FOR
 $^9\text{Be}(t,t)^9\text{Be}$
ELASTIC SCATTERING AT 15 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mb/sr)	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mb/sr)
15.00	19.99	937.72	75.00	93.93	2.02
17.50	23.30	562.04	80.00	99.31	1.59
20.00	26.60	259.54	85.00	104.54	1.12
22.50	29.89	120.80	90.00	109.61	1.02
25.00	33.17	31.05	95.00	114.53	1.27
26.25	34.80	13.50	100.00	119.30	1.73
27.50	36.43	7.12	105.00	123.91	2.28
30.00	39.67	11.95	110.00	128.38	2.75
32.50	42.90	23.45	115.00	132.70	2.81
35.00	46.11	29.96	120.00	136.89	2.74
37.50	49.30	30.48	125.00	140.95	2.80
40.00	52.47	24.73	130.00	144.89	2.85
42.50	55.62	18.44	135.00	148.72	3.13
45.00	58.74	11.51	137.50	150.06	3.39
47.50	61.84	6.92	140.00	152.45	3.61
50.00	64.91	3.71	142.50	154.28	3.94
52.50	67.96	2.29	145.00	156.09	4.18
55.00	70.97	1.76	147.50	157.88	4.48
57.50	73.96	1.95	150.00	159.66	4.59
60.00	76.91	2.19	152.50	161.41	4.83
62.50	79.83	2.41	155.00	163.15	4.94
65.00	82.72	2.46	157.50	164.88	5.04
70.00	88.39	2.41	160.00	166.59	5.08

The overall relative error is $\pm 3\%$.

TABLE II
THE DIFFERENTIAL CROSS SECTION FOR
 ${}^9\text{Be}(t,t){}^9\text{Be}$
ELASTIC SCATTERING AT 17 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mb/sr)	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mb/sr)
15.00	19.99	870.94	82.50	101.94	0.87
17.50	23.30	465.92	85.00	104.54	0.83
20.00	26.60	218.94	87.50	107.09	0.82
22.50	29.89	60.83	90.00	109.61	0.80
25.00	33.17	9.09	92.50	112.09	0.89
27.50	36.43	7.82	95.00	114.53	1.09
30.00	39.67	21.86	97.50	116.94	1.31
32.50	42.90	31.05	100.00	119.30	1.54
35.00	46.11	31.96	102.50	121.63	1.77
37.50	49.30	26.58	105.00	123.91	1.97
40.00	52.47	18.02	107.50	126.17	2.13
42.50	55.62	10.33	110.00	128.38	2.23
45.00	58.74	5.04	112.50	130.56	2.24
47.50	61.84	2.33	115.00	132.70	2.24
50.00	64.91	1.41	117.50	134.81	2.12
52.50	67.96	1.58	120.00	136.89	2.18
55.00	70.97	1.99	125.00	140.95	2.25
57.50	73.96	2.57	130.00	144.89	2.60
60.00	76.91	2.94	135.00	148.72	3.14
62.50	79.83	2.89	140.00	152.45	3.59
65.00	82.72	2.71	145.00	156.09	4.02
67.50	85.58	2.41	147.50	157.88	4.30
70.00	88.39	2.07	150.00	159.66	4.62
72.50	91.18	1.68	152.50	161.41	4.88
75.00	93.93	1.41	155.00	163.15	5.09
77.50	96.64	1.19	157.50	164.88	5.43
80.00	99.31	1.02	160.00	166.59	5.84

The overall relative error is $\pm 3\%$.

TABLE III

THE ANALYZING POWER A_y FOR ${}^9\text{Be}(\bar{t},t){}^9\text{Be}$
ELASTIC SCATTERING AT 15 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y
15.00	19.99	0.039	0.008	75.00	93.93	0.109	0.009
17.50	23.30	0.053	0.007	80.00	99.32	0.109	0.010
20.00	26.60	0.057	0.009	85.00	104.54	0.129	0.014
22.50	29.89	0.073	0.007	90.00	109.61	0.108	0.011
25.00	33.17	0.057	0.010	95.00	114.53	0.099	0.011
26.25	34.80	-0.032	0.013	100.00	119.30	0.066	0.011
27.50	36.43	-0.174	0.011	105.00	123.91	0.037	0.010
30.00	39.67	-0.079	0.011	110.00	128.38	0.015	0.008
32.50	42.90	0.040	0.011	115.00	132.70	0.034	0.011
35.00	46.11	0.105	0.010	120.00	136.89	0.069	0.011
37.50	49.30	0.134	0.010	125.00	140.95	0.122	0.011
40.00	52.47	0.196	0.007	130.00	144.89	0.197	0.011
42.50	55.62	0.261	0.007	135.00	148.72	0.252	0.011
45.00	58.74	0.331	0.007	137.50	150.06	0.264	0.011
47.50	61.84	0.377	0.008	140.00	152.45	0.263	0.010
50.00	64.91	0.401	0.009	142.50	154.28	0.266	0.010
52.50	67.96	0.246	0.009	145.00	156.09	0.279	0.010
55.00	70.97	-0.052	0.013	147.50	157.88	0.267	0.010
57.50	73.96	-0.189	0.012	150.00	159.66	0.268	0.010
60.00	76.91	-0.201	0.009	152.50	161.41	0.266	0.010
62.50	79.83	-0.158	0.012	155.00	163.15	0.258	0.010
65.00	82.72	-0.067	0.009	157.50	164.88	0.231	0.010
70.00	88.39	0.040	0.008	160.00	166.59	0.212	0.010

TABLE IV

THE ANALYZING POWER A_y FOR ${}^9\text{Be}(\dot{t},t){}^9\text{Be}$
ELASTIC SCATTERING AT 17 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y
15.00	19.99	0.028	0.007	82.50	101.94	-0.001	0.012
17.50	23.30	0.046	0.007	85.00	104.54	-0.023	0.012
20.00	26.60	0.067	0.006	87.50	107.09	-0.027	0.010
22.50	29.89	0.063	0.009	90.00	109.61	0.016	0.010
25.00	33.17	0.051	0.012	92.50	112.09	0.038	0.013
27.50	36.43	-0.094	0.011	95.00	114.53	0.047	0.012
30.00	39.67	-0.030	0.009	97.50	116.94	0.068	0.011
32.50	42.90	0.007	0.007	100.00	119.30	0.050	0.010
35.00	46.11	0.046	0.007	102.50	121.63	0.051	0.011
37.50	49.30	0.083	0.007	105.00	123.91	0.039	0.010
40.00	52.47	0.136	0.006	107.50	126.17	0.005	0.012
42.50	55.62	0.233	0.010	110.00	128.38	-0.021	0.012
45.00	58.74	0.321	0.007	112.50	130.56	-0.037	0.012
47.50	61.84	0.421	0.011	115.00	132.70	-0.027	0.012
50.00	64.91	0.233	0.011	117.50	134.81	-0.037	0.012
52.50	67.96	-0.046	0.010	120.00	136.89	-0.041	0.012
55.00	70.97	-0.148	0.010	125.00	140.95	0.042	0.012
57.50	73.96	-0.135	0.009	130.00	144.89	0.146	0.012
60.00	76.91	-0.103	0.011	135.00	148.72	0.246	0.012
62.50	79.83	-0.056	0.011	140.00	152.45	0.277	0.012
65.00	82.72	-0.030	0.011	145.00	156.09	0.308	0.010
67.50	85.58	0.014	0.012	147.50	157.88	0.319	0.013
70.00	88.39	0.046	0.013	150.00	159.66	0.295	0.012
72.50	91.18	0.068	0.009	152.50	161.41	0.299	0.013
75.00	93.93	0.067	0.010	155.00	163.15	0.277	0.013
77.50	96.64	0.061	0.011	157.50	164.88	0.271	0.013
80.00	99.31	0.032	0.012	160.00	166.59	0.242	0.012

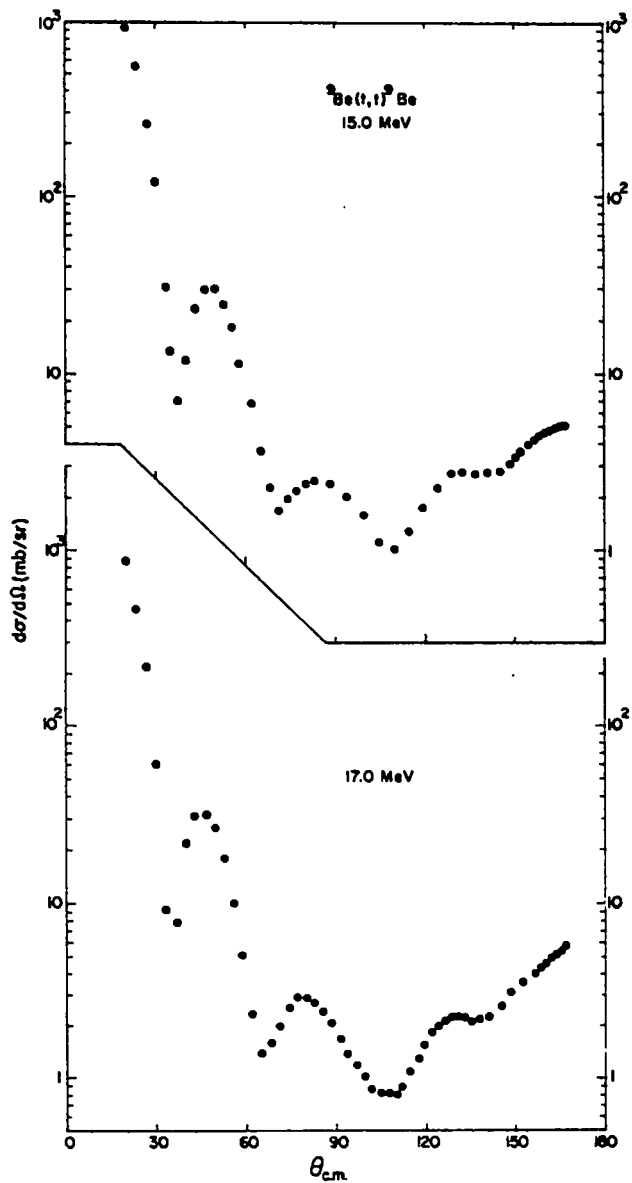


Fig. 1.

The differential cross section for ${}^9\text{Be}(t,t){}^9\text{Be}$ elastic scattering at 15 and 17 MeV.

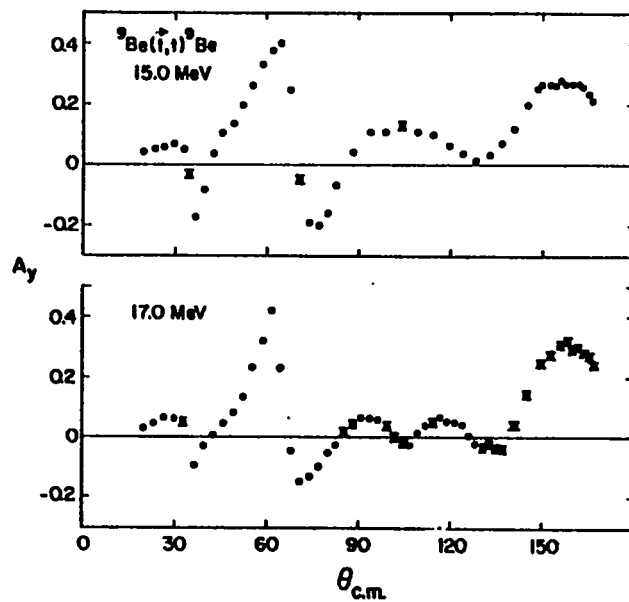


Fig. 2.

The analyzing power for ${}^9\text{Be}(t,t){}^9\text{Be}$ elastic scattering at 15 and 17 MeV.

TABLE V
THE DIFFERENTIAL CROSS SECTION FOR
 $^{12}\text{C}(t,t)^{12}\text{C}$
ELASTIC SCATTERING AT 15 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mb/sr)	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mg/sr)
17.50	21.85	464.05	87.50	102.09	0.67
20.00	24.95	217.91	90.00	104.60	0.45
21.25	26.50	125.42	92.50	107.09	0.33
22.50	28.04	84.50	95.00	109.55	0.32
25.00	31.12	16.00	97.50	111.97	0.39
26.25	32.67	4.67	100.00	114.38	0.43
27.50	34.19	3.02	102.50	116.75	0.43
28.75	35.72	5.64	105.00	119.09	0.34
30.00	37.25	10.93	107.50	121.41	0.22
32.50	40.29	21.37	110.00	123.70	0.14
35.00	43.32	26.30	112.50	125.97	0.12
37.50	46.34	24.67	115.00	128.21	0.22
40.00	49.33	19.03	117.50	130.42	0.43
42.50	52.32	12.89	120.00	132.61	0.62
45.00	55.28	8.34	122.50	134.27	0.67
47.50	58.22	5.64	125.00	136.91	1.28
50.00	61.14	4.63	127.50	139.03	1.86
52.50	64.05	4.31	130.00	141.13	2.27
55.00	66.93	4.10	132.50	143.21	2.56
57.50	69.78	3.51	135.00	145.27	2.60
60.00	72.62	2.64	137.50	147.30	2.49
62.50	75.43	1.68	140.00	149.32	2.18
65.00	78.21	0.97	142.50	151.32	1.77
67.50	80.98	0.62	145.00	153.31	1.39
70.00	83.71	0.67	147.50	155.28	1.02
72.50	86.42	0.94	150.00	157.24	0.92
75.00	89.10	1.21	152.50	159.18	0.81
77.50	91.75	1.43	155.00	161.11	1.20
80.00	94.38	1.45	157.50	163.03	1.89
82.50	96.98	1.26	157.50	163.03	1.89
85.00	99.55	0.98	160.00	164.94	2.90

The overall relative error is $\pm 3\%$.

TABLE VI
THE DIFFERENTIAL CROSS SECTION FOR
 $^{12}\text{C}(t,t)^{12}\text{C}$
ELASTIC SCATTERING AT 17 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mg/sr)	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	$\frac{d\sigma}{d\Omega}$ (mb/sr)
20.00	24.95	203.41	92.50	107.09	1.13
22.50	28.04	59.92	95.00	109.55	1.29
25.00	31.12	7.85	97.50	111.97	1.39
27.50	34.19	3.67	100.00	114.38	1.46
30.00	37.25	14.55	102.50	116.75	1.37
32.50	40.29	23.13	105.00	119.09	1.17
35.00	43.32	24.80	107.50	121.40	0.88
37.50	46.34	20.47	110.00	123.70	0.67
40.00	49.33	14.00	112.50	125.97	0.43
42.50	52.32	8.40	115.00	128.21	0.34
45.00	55.28	4.97	117.50	130.42	0.46
47.50	58.22	3.66	120.00	132.61	0.73
50.00	61.14	3.81	122.50	134.77	1.18
52.50	64.05	4.43	125.00	136.91	1.59
55.00	66.93	4.61	127.50	139.03	2.03
57.50	69.78	4.24	130.00	141.13	2.33
60.00	72.62	3.26	132.50	143.21	2.44
62.50	75.43	2.02	135.00	145.27	2.34
65.00	78.21	0.90	137.50	147.30	1.89
67.50	80.98	0.26	142.50	151.32	1.15
70.00	83.71	0.09	145.00	153.31	0.71
72.50	86.42	0.24	147.50	155.28	0.29
75.00	89.10	0.60	150.00	157.24	0.22
77.50	91.75	0.96	152.50	159.18	0.31
80.00	94.38	1.19	155.00	161.11	0.76
82.50	96.98	1.25	157.50	163.03	1.33
85.00	99.55	1.24	160.00	164.95	1.67
90.00	104.60	1.08			

The overall relative error is $\pm 3\%$.

TABLE VII

THE ANALYZING POWER A_y FOR $^{12}\text{C}(\bar{t},t)^{12}\text{C}$
ELASTIC SCATTERING AT 15 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y
17.50	21.85	0.034	0.006	87.50	102.09	-0.302	0.014
20.00	24.95	0.027	0.006	90.00	104.60	0.237	0.012
21.25	26.50	0.030	0.007	92.50	107.09	0.785	0.012
22.50	28.04	0.002	0.006	95.00	109.55	0.899	0.011
25.00	31.12	-0.229	0.010	97.50	111.97	0.682	0.012
26.25	32.67	-0.581	0.015	100.00	114.38	0.453	0.012
27.50	34.19	-0.779	0.012	102.50	116.75	0.343	0.013
28.75	35.72	-0.181	0.010	105.00	119.09	0.378	0.014
30.00	37.25	0.038	0.009	107.50	121.41	0.608	0.016
32.50	40.29	0.174	0.007	110.00	123.70	0.879	0.014
35.00	43.32	0.221	0.007	112.50	125.97	0.221	0.019
37.50	46.34	0.260	0.007	115.00	128.21	-0.692	0.013
40.00	49.33	0.310	0.006	117.50	130.42	-0.949	0.009
42.50	52.32	0.344	0.009	120.00	132.61	-0.962	0.009
45.00	55.28	0.256	0.010	122.50	134.27	-0.948	0.010
47.50	58.22	-0.078	0.012	125.00	136.91	-0.911	0.012
50.00	61.14	-0.501	0.013	127.50	139.03	-0.892	0.006
52.50	64.05	-0.794	0.008	130.00	141.13	-0.874	0.006
55.00	66.93	-0.920	0.007	132.50	143.21	-0.854	0.006
57.50	69.78	-0.951	0.006	135.00	145.27	-0.831	0.007
60.00	72.62	-0.937	0.006	137.50	147.30	-0.778	0.007
62.50	75.43	-0.906	0.007	140.00	149.32	-0.733	0.008
65.00	78.21	-0.806	0.008	142.50	151.32	-0.647	0.008
67.50	80.98	-0.652	0.010	145.00	153.31	-0.486	0.009
70.00	83.71	-0.614	0.007	147.50	155.28	-0.162	0.011
72.50	86.42	-0.687	0.008	150.00	157.24	0.286	0.011
75.00	89.10	-0.739	0.007	152.50	159.18	0.750	0.014
77.50	91.75	-0.766	0.007	155.00	161.11	0.647	0.012
80.00	94.38	-0.752	0.009	157.50	163.03	0.450	0.012
82.50	96.98	-0.693	0.009	160.00	164.94	0.288	0.010
85.00	99.55	-0.564	0.011				

TABLE VIII

THE ANALYZING POWER A_y FOR $^{13}\text{C}(\ddagger,t)^{13}\text{C}$
ELASTIC SCATTERING AT 17 MeV

θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y	θ_{Lab} (deg)	$\theta_{\text{c.m.}}$ (deg)	A_y	ΔA_y
20.00	24.95	0.085	0.006	92.50	107.09	0.070	0.009
22.50	28.04	0.051	0.007	95.00	109.55	-0.172	0.009
25.00	31.12	-0.200	0.013	97.50	111.97	-0.366	0.008
27.50	34.19	0.184	0.018	100.00	114.38	-0.493	0.008
30.00	37.25	0.375	0.010	102.50	116.75	-0.565	0.008
32.50	40.29	0.379	0.008	105.00	119.09	-0.585	0.008
35.00	43.32	0.430	0.008	107.50	121.40	-0.561	0.009
37.50	46.34	0.462	0.009	110.00	123.70	-0.413	0.014
40.00	49.33	0.478	0.010	112.50	125.97	-0.244	0.018
42.50	52.32	0.476	0.012	115.00	128.21	-0.197	0.020
45.00	55.28	0.301	0.016	117.50	130.42	-0.510	0.017
47.50	58.22	-0.062	0.019	120.00	132.61	-0.743	0.012
50.00	61.14	-0.293	0.011	122.50	134.77	-0.887	0.009
52.50	64.05	-0.343	0.011	125.00	136.91	-0.929	0.007
55.00	66.93	-0.315	0.011	127.50	139.03	-0.937	0.006
57.50	69.78	-0.325	0.009	130.00	141.13	-0.958	0.006
60.00	72.62	-0.365	0.010	132.50	143.21	-0.949	0.006
62.50	75.43	-0.421	0.012	135.00	145.27	-0.925	0.007
65.00	78.21	-0.558	0.008	137.50	147.30	-0.914	0.008
67.50	80.98	-0.770	0.012	140.00	149.32	-0.852	0.008
70.00	83.71	0.312	0.019	142.50	151.32	-0.758	0.010
72.50	86.42	0.751	0.017	145.00	153.31	-0.631	0.013
75.00	89.10	0.522	0.012	147.50	155.28	-0.339	0.018
77.50	91.75	0.418	0.011	150.00	157.24	-0.116	0.021
80.00	94.38	0.415	0.010	152.50	159.18	-0.207	0.017
82.50	96.98	0.455	0.010	155.00	161.11	-0.427	0.014
85.00	99.55	0.478	0.008	157.50	163.03	-0.533	0.011
87.50	102.10	0.464	0.009	160.00	164.95	-0.545	0.011
90.00	104.60	0.317	0.009				

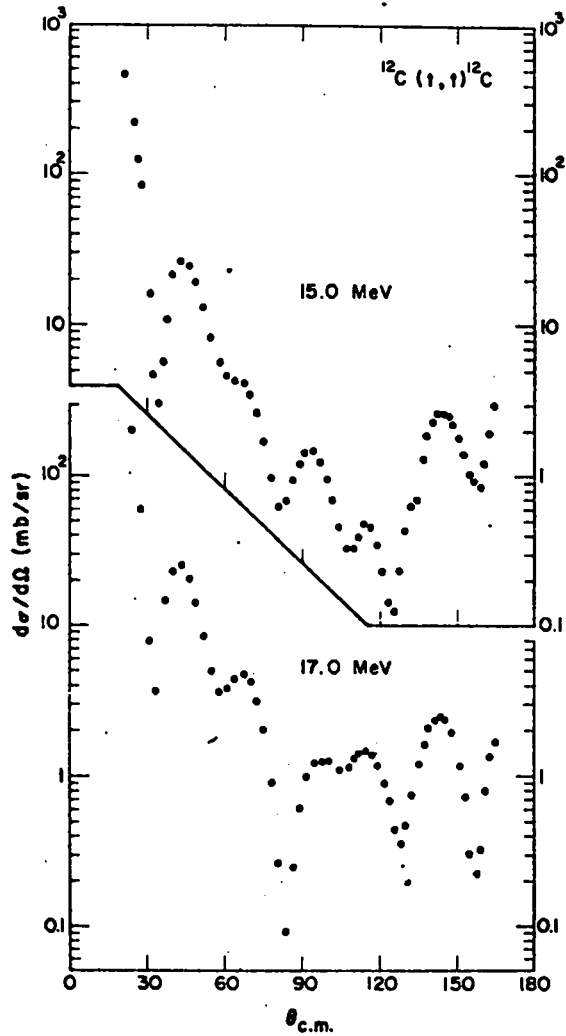


Fig. 3.
The differential cross section for $^{12}\text{C}(t,t)^{12}\text{C}$ elastic scattering at 15 and 17 MeV.

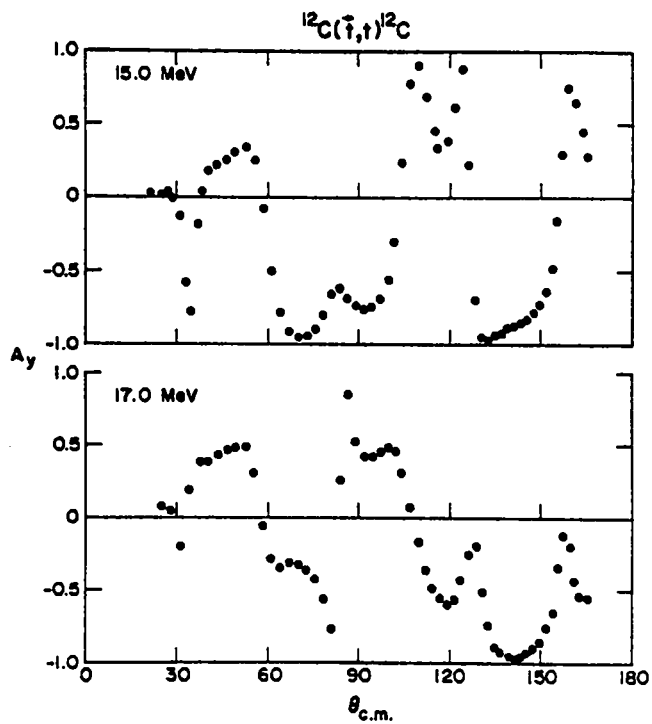


Fig. 4.
The analyzing power for $^{12}\text{C}(t,t)^{12}\text{C}$ elastic scattering at 15 and 17 MeV.