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8.29 Cross Sections and Analyzing Powers for p-^{12}C Elastic Scattering

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In order to estimate the effective analyzing power of the polarimeter MUSASHI[1], angular distributions of cross sections σ and analyzing powers A_y for proton elastic scattering from a natural carbon target were measured for the angular range $10^\circ < \theta_l < 80^\circ$ at energies of 35, 40, 45, 50, 55, 60, 65, 70, 80 and 84 MeV. The polarized beams were provided by the 230 cm AVF cyclotron at RCNP. The beam intensity was typically 10 nA and the beam spot was 2 mm wide and 2 mm high on target. The beam polarization was monitored continuously using a carbon analyzer and was about 80 %. The target thickness was 40 mg/cm^2. Protons scattered from the carbon target were detected with NaI(Tl) scintillation counters which were placed on both side of the beam. The overall energy resolution was about 1 MeV FWHM. The cross sections were corrected for the efficiency reduction caused by proton induced nuclear reactions in NaI(Tl) detectors[2]:

$$e = 1.002954 - 0.000615Ep. \qquad (1)$$

A part of the results is shown in Fig. 1.

A fitting of two-dimentional B-spline functions to the measured data was performed as a function of the laboratory angle θ_l and energy Ep for the angular range $40^\circ < \theta_l < 70^\circ$ and the energy range 35 MeV < Ep < 84 MeV. The B-spline functions used were as follows[3]:

$$S(\theta_l, Ep) = \sum_{i=-m+1}^{l-1} \sum_{j=-m+1}^{n-1} C_{i,j} \, N_{i,m+1}(\theta_l) N_{j,m+1}(Ep). \qquad (2)$$

$N_{i,m+1}(x)$ is the polynomial of degree m and $C_{i,j}$ are the coefficients to be calculated. Assuming that each of data has 2 % error, χ^2 of σ and A_y of fit are 1.6 and 0.15, respectively. A part of the results of the fit is shown in Fig. 2. The effective analyzing power of the polarimeter MUSASHI is calculated using the above fitted B-spline

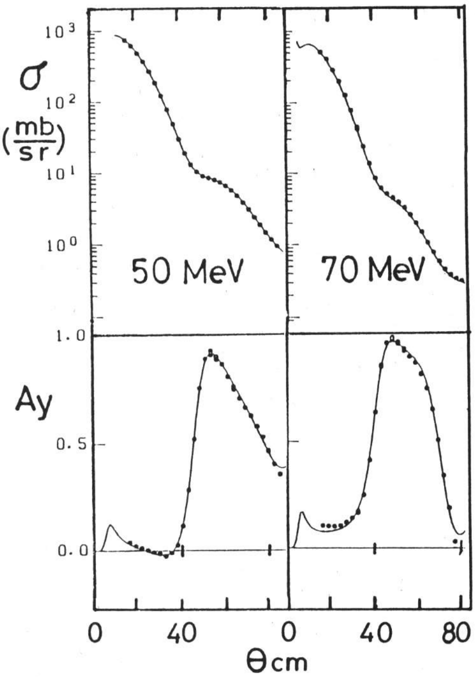

Fig. 1. σ and A_y at 50 and 70 MeV. The solid curves are results of the optical model calculations with the parameters listed in Table 1.

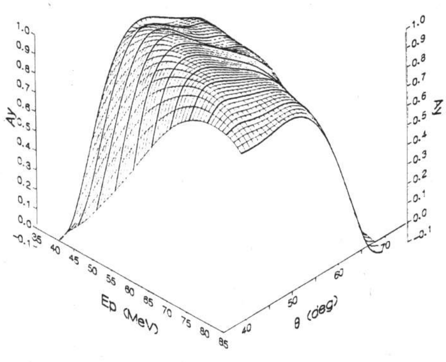

Fig. 2. Two-dimensional B-spline fit to A_y.

function and is shown in Fig. 3.

The experimental data have been also analyzed with the optical model using the automatic search code ECIS79 of Raynal[4]. The following optical potential is used :

$$U(r) = V_{Coul}(r) - V_R f(r; r_R, a_R)$$

$$-iW_v f(r; r_{W_v}, a_{W_v}) + 4a_{W_s} W_s i \frac{d}{dr} f(r; r_{W_s}, a_{W_s})$$

$$+V_{ls} \left(\frac{\hbar}{m_\pi c}\right)^2 \frac{1}{r} \frac{d}{dr} f(r; r_{ls}, a_{ls}) (\sigma \cdot L) \qquad (3)$$

where

$$f(r; r_o, a_o) = (1 + exp((r - r_o)/a_o))^{-1}. \qquad (4)$$

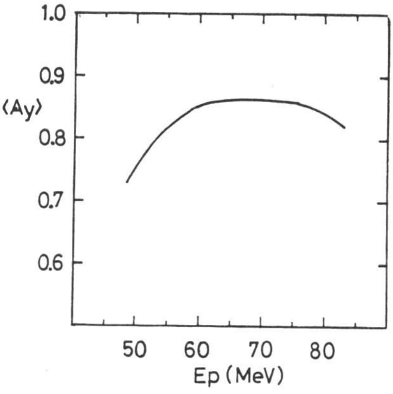

Fig. 3. The effective analyzing power of the polarimeter MUSASHI vs. incident proton energy.

In the first place, at each energy, σ and A_y were fitted varying all parameters except for r_c and r_R. The best fit parameters are shown in Table 1 and the solid curves in Fig. 1. are the predictions of these parameters.

Table 1 Best fit optical potential parameters. r_c = 1.3 , r_R = 1.16

Ep	V_R (MeV)	a_R (fm)	W_v (MeV)	r_{Wv} (fm)	a_{Wv} (fm)	W_s (MeV)	r_{Ws} (fm)	a_{Ws} (fm)	V_{ls} (MeV)	r_{ls} (fm)	a_{ls} (fm)	χ^2/N
35	44.129	0.629	3.713	0.757	0.012	6.354	1.282	0.472	7.800	1.047	0.492	2.41
40	43.786	0.629	4.868	0.721	0.528	5.693	1.308	0.468	7.852	1.052	0.487	0.12
45	39.344	0.647	18.793	0.246	0.568	4.501	1.312	0.521	6.996	1.008	0.538	0.11
50	38.339	0.662	7.360	0.670	0.573	4.263	1.377	0.466	7.014	1.020	0.535	0.13
55	36.164	0.670	6.264	0.913	0.458	4.002	1.437	0.438	7.005	0.997	0.549	0.27
60	34.680	0.683	6.190	0.779	0.039	5.107	1.301	0.483	6.848	0.989	0.556	0.46
65	32.312	0.682	11.197	0.669	0.375	5.104	1.328	0.462	6.562	0.953	0.529	0.53
70	31.210	0.686	8.273	0.783	0.039	5.456	1.265	0.495	6.688	0.938	0.550	0.51
80	28.689	0.701	8.709	0.858	0.153	5.315	1.305	0.429	6.175	0.931	0.555	0.82
84	27.460	0.689	9.471	0.841	0.044	5.807	1.258	0.470	6.144	0.916	0.552	0.88

Excellent fits have been obtained. Secondly, we tried to find an optical potential parameter set which had linear energy dependence and reproduced the experimental data well for an energy region as wide as possible. At present, for an energy range 40 MeV < Ep < 70 MeV, the following result was found ,

$$\begin{aligned} V_R &= 55.113 - 0.3385Ep, & r_R &= 1.16, & a_R &= 0.5715 + 0.00176Ep \\ W_v &= 0.332 + 0.149Ep, & r_{W_v} &= 0.7, & a_{W_v} &= 0.45 \\ W_s &= 4.8, & r_{W_s} &= 1.35, & a_{W_s} &= 0.45 \\ V_{ls} &= 8.597 - 0.0293Ep, & r_{Vls} &= 1.167 - 0.00308Ep, & a_{Vls} &= 0.54 \end{aligned} \qquad (5)$$

Further work to expand the energy region of this analysis is now in progress. We will perform measurements at energies below 35 MeV and utilize the polarimeter MUSASHI for lower energy.

References

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