# Polarization Measurement in Heavy Ion Scattering



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| journal or publication title | CYRIC annual report |
| volume | 1986 |
| page range | 25-28 |
| year | 1986 |
| URL | http://hdl.handle.net/10097/49321 |

# I. 5 Polarization Measurement in Heavy Ion Scattering

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Experimental investigations of the spin dependence of elastic nucleus-nucleus interaction have been so far restricted to experiments using the polarized Li beam because the production of polarized heavy ion beam with an ion source is very difficult except for alkaloid beam. The first experiments using an ion source for vector polarized $^{6}$Li beam consist of the investigation of the elastic scattering of $^{6}$Li on the target $^{12}$C, $^{16}$O, $^{28}$Si, $^{58}$Ni at $E_{Li}$ = 28.8 MeV.[1] In the energy region of $E_{Li}$ = 20 MeV, compound effects should not be neglected for the light nuclei and one observes an obvious change in the structure of the angular distributions of $\sigma/\sigma_R$ and the asymmetry by changing the bombarding energy from 20 to 22.8 MeV. Furthermore, it has been pointed out by Sakuragi et al.[2] that the breakup effect of $^{6}$Li in these energy region is important for the cross sections and the asymmetries in the elastic scattering.

The polarization of elastically scattered $^{13}$C from the $^{12}$C target was observed by measuring the asymmetry with double scattering experiment.

Unpolarized $^{13}C^{4+}$ ions were accelerated at $E/A \simeq 5$ MeV with the Tohoku AVF cyclotron. Scattered $^{13}$C at angle 8° to the direction of the incident beam were used as the first scattering beam and the second scattering was to left and right at 8°, 9.6°, 11.3°, 22.7°, 24.3° and 25.9°. The doubly scattered $^{13}$C were detected by the counter systems which consist of two 25 μm ΔE surface barrier detectors and a 240 μm position sensitive surface barrier detector. These counter systems have two parallel telescopes $\Delta E_1$-E and $\Delta E_2$-E, i.e. two ΔE-detectors were placed in parallel with the surface of the position sensitive detector. The solid angles of each telescope were defined by three slit apertures and six spectra can be obtained at the same time. These counter systems were installed symmetrically for the secondary beam axis. The polarization product, $P_aP_b$ was calculated from the left-right asymmetry using formula $R = P_aP_b$ , where $P_a$ and $P_b$ are the polarization at the first and second scattering, respectively. For elastic scattering, the analyzing power $A(\theta)$ for an incident polarized beam is equal to the polarization $P(\theta)$ which would occurs at scattering angle $\theta$ for an incident unpolarized beam. This is a consequence of time reversal invariance.

Double scattering experiments have by their nature low count rates and the designer is constantly faced with a compromise between using large geometry and finishing the experiment in a reasonable time. The beam incident on the first target should be considered as the unpolarized beam. Because of the finite size of once scattered beam, and kinematic energy and cross section variations with scattering angle, there will be an effective displacement for the scattered beam with respect to its geometrically defined center. An unphysical asymmetry in the double scattering experiments originates in this effective displacement for the steeply variation of the angular distribution. In order to check these effect, the double scattering experiments with spin-0 projectile are performed on the targets Pb and $^{12}C$ at $E(^{12}C)$ = 65 MeV. The first scattering angle dependences of the first scattering cross sections and the second scattering asymmetries of elastically scattered $^{12}C$ from Pb are shown in Fig. 1. The scattered cross sections indicate the Rutherford scattering cross sections at small angles. The variance of the cross section at $\theta_L = 3°$ is about $2.4 \times 10^5$ b/sr per a degree. The included angles of the first scattering and the second scattering angles are 0.4 and 0.9 degrees, respectively. The effective beam spots on the first and the second targets are 2 × 4 mm and 1 × 7 mm, respectively. Open circles and open triangles indicate the results obtained from the experimental data and simulation calculated by Monte Carlo methods, respectively. The Monte Carlo simulation points reproduce well the experimental data. In the double scattering heavy ion experiments, in particular, the differential cross section variations with energy loss in the target material are important for the unphysical asymmetry of elastically scattered $^{12}C$ from the target. Experimental unphysical asymmetry are within 2±1 % at the first and the second scattering angles of 8°, and the results from the Monte Carlo simulation are within 0±0.5 %. The differential cross sections depend on the incident energy variation by energy loss in the target and these are estimated by the DWBA calculations using the optical model parameters to fit the present angular distribution data at $E(^{12}C)$ = 65 MeV. On the basis of these results, the unphysical asymmetry can be corrected by the Monte Carlo simulation in the double scattering experiments within the framework of the geometry of the present counter system. Fig. 3 shows the left and the right spectra of doubly scattered $^{13}C$ from $^{12}C$ target at $E(^{13}C)$ = 60 MeV, where the first scattering angle $\theta_1 = 8°$ and the second scattering angle $\theta_2 = 8°$. Asymmetries $R(\theta_2)$ at $\theta_1 = 8°$ are shown in Fig. 4 for the $\theta_2 = 8°$, 9.6° and 11.4°. If there is the unphysical asymmetry caused by the steeply variation of the angular distribution, these asymmetries should be negative for decreasing cross sections with angles. Polarization at $\theta_1 = 8°$ obtained from the asymmetry $R(\theta_1 = \theta_2 = 8°)$ is P = (30±4) % at $E(^{13}C)$ = 57 ± 3 MeV.

References

1) Weiss W. et al., Phys. Lett. 61B (1976) 237.

2) Sakuragi Y., Yahiro M. and Kamimura M., Prog. Theor. Phys. 68 (1982) 322.

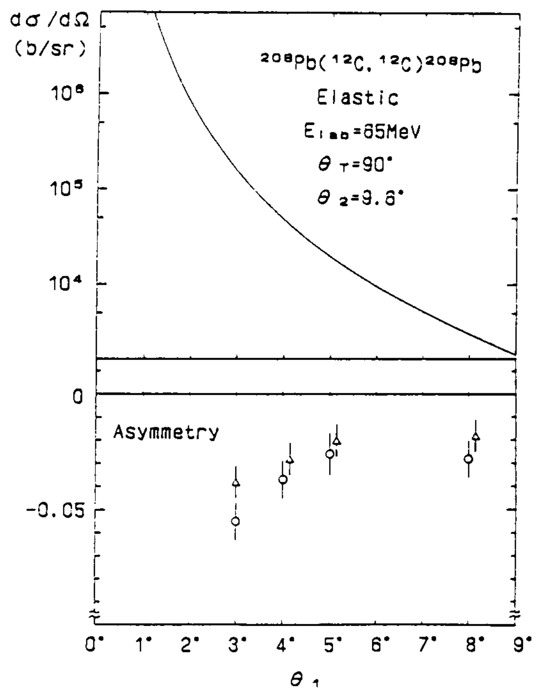


Fig. 1. Cross section curve and second scattering asymmetry of $^{12}C$ scattered elastically from the $P_b$ target.

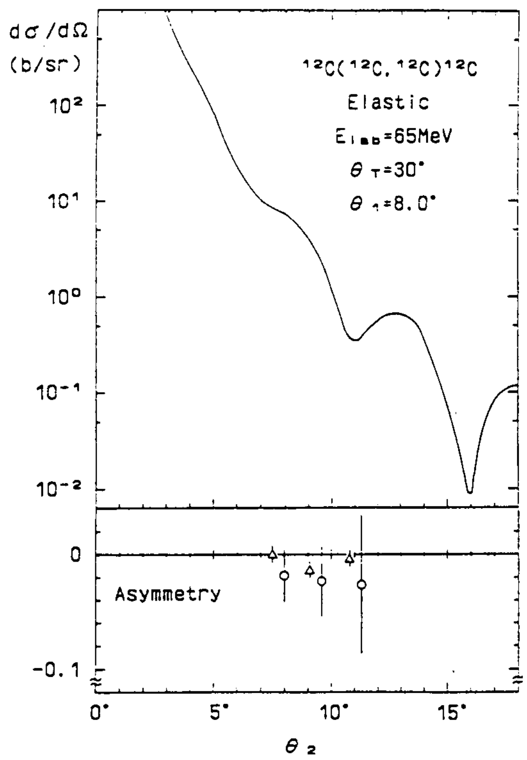


Fig. 2. Cross section curve and second scattering asymmetry of $^{12}C$ scattered from the $^{12}C$ target.

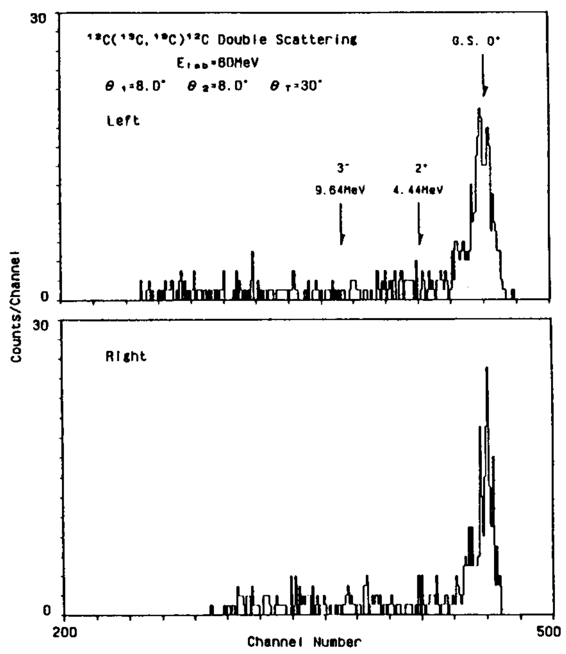


Fig. 3. Left and right spectra of $^{13}C$ scattered from the second $^{12}C$ target.

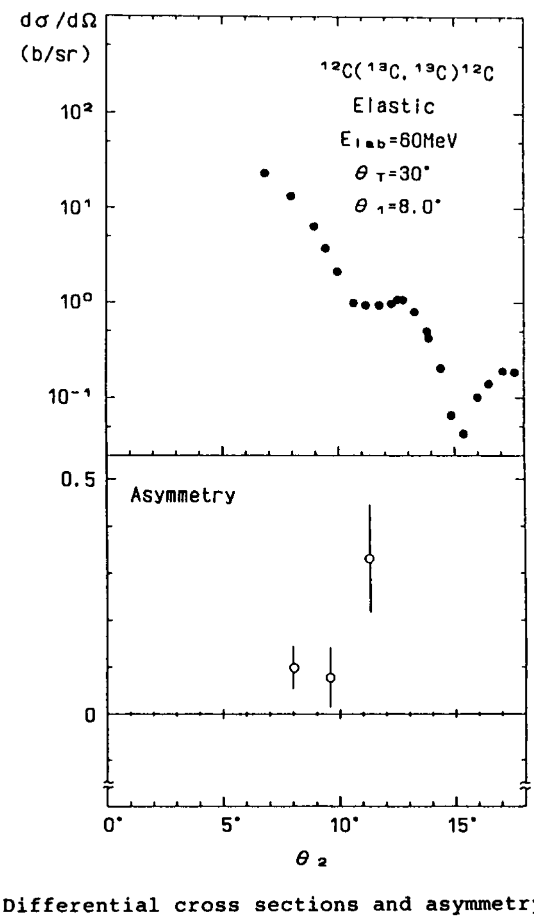


Fig. 4. Differential cross sections and asymmetry of $^{13}C$ from $^{12}C$ target.