Calibration of the effective analyzing power for a ^{3}He polarimeter at 443 MeV

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Spin dependent interactions between complex nuclei are subjects of great interest because they are closely related to nuclear structures and reaction mechanisms. Recently, theoretical investigations based on microscopic folding models including the spin dependent ^{3}He-nucleus interactions have been reported [1]. Calculations at intermediate energies showed that the spin-orbit interactions affected significantly the cross sections of elastic scattering and predicted large vector analyzing powers even at forward angles. We have measured the induced polarization parameters of ^{3}He particles elastically scattered from several nuclei [2] for an unpolarized ^{3}He beam of $E_{^3\mathrm{He}}$=443 MeV by employing the double scattering method. A ^{3}He focal plane polarimeter (FPP) of the Grand Raiden spectrometer was calibrated for the experiment. Here, we are reporting results of the FPP calibration.

The calorimeter was newly installed downstream of MWPC4 in order to measure the total energy of ^{3}He particles scattered by the analyzer. The calorimeter consisted of three stacks of plastic scintillators CL1,2,3, thick enough to stop all ^{3}He particles. The first plane CL1 was horizontally segmented by six 15 mm thick plastic scintillators of 100 mm width and 600 mm length. The following planes CL2 and CL3 were vertically segmented by seven and five plastic scintillators, respectively. Each scintillator had the size of 1000 mm length, 100 mm width and 50 mm thickness. The PMTs were installed on both ends of the scintillators via light guides.

In order to calibrate the effective analyzing power of the FPP, the absolute magnitude of the polarization of the incoming ^{3}He beam before the analyzer has to be known. In this experiment, the polarization was measured by the double scattering method under the time reversal invariance condition, where the polarization is equivalent to the analyzing power [3]. The measurement was performed for ^{3}He+^{12}C elastic scattering at $\theta = 7°$ in the laboratory frame, where the double folding model calculations predicted a large analyzing power [4]. A 30 mg/cm^2 thick carbon foil and a carbon sheet with a thickness of 2 mm (375 mg/cm^2) were used as polarizer and analyzer, respectively. The energy resolution of the calorimeter was not good enough to separate elastic scattering events from inelastic events in the second scattering process. Therefore, the absolute polarization was determined from the asymmetry including transitions to the ground and first exited states in the scattering from the polarizer. The absolute magnitude of the polarization was determined to be $P_y = 0.547 \pm 0.018\ ^{+0.019}_{-0.020}$. The second term represents the statistical error, while the third term is the systematic error. The systematic error arose mainly from the uncertainty in selecting the ^{3}He energies of the second scattering, because inelastic scattering events were not completely separated from elastic scattering events.

With the absolute polarization P_y known, the effective analyzing power of the FPP can be derived by

$$A_y^{eff} = \frac{1}{P_y}\varepsilon = \frac{1}{P_y}\frac{\int_L \sigma(\theta_2,\phi_2)d\Omega - \int_R \sigma(\theta_2,\phi_2)d\Omega}{\int_L \sigma(\theta_2,\phi_2)d\Omega + \int_R \sigma(\theta_2,\phi_2)d\Omega} = 0.232 \pm 0.010 \ {}^{+0.017}_{-0.015}, \quad (1)$$

where the first and second uncertainties represent the statistical and systematic ones, respectively. The systematic uncertainties were estimated from those in the absolute polarization value. The effective analyzing power depends on the energy of the incident ^{3}He particles at the center position of the analyzer which was calculated with the simulation code GEANT. Open circles in Fig. 1 show the results of the double folding model calculation for the integrated analyzing power A_y of ^{3}He+^{12}C elastic scattering [4]. The energy dependence of the effective analyzing power was measured by inserting an aluminum plate downstream of the MWDC2 in order to change the ^{3}He energy in the analyzer. It was assumed that the ^{3}He polarization does not change in the aluminum degrader. The experimental results are shown in Fig. 1 as closed circles. We assumed a linear energy dependence of the analyzing power for inclusive and elastic scattering as predicted by the double folding model. The experimental data were fitted by the least-squares method with a linear function, which is shown in Fig. 1. The result of this calibration was utilized to measure the induced polarization of ^{3}He scattering off ^{12}C, ^{58}Ni, and ^{90}Zr nuclei [2]. Figure 2 shows the experimental results of the induced polarization of ^{3}He+^{12}C elastic scattering. The dashed line indicates the center of mass angle corresponding to the scattering angle of 7° in the laboratory frame, where the absolute polarization value was determined in the present work. The polarization has the maximum value near 7°.

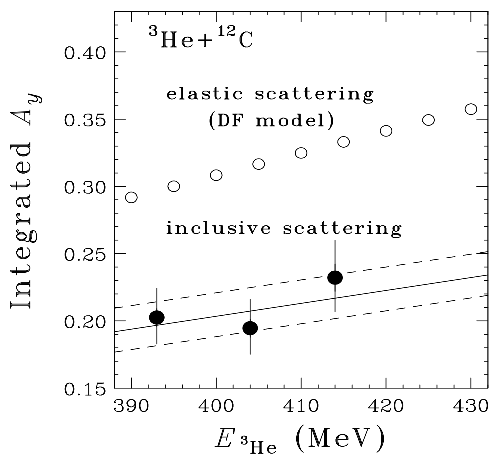

Fig. 1: Calculated (open circles) and measured (closed circles) integrated analyzing power A_y. The solid line represents the linear expression of the data. Dashed lines show the systematic uncertainties in the fitting procedure.

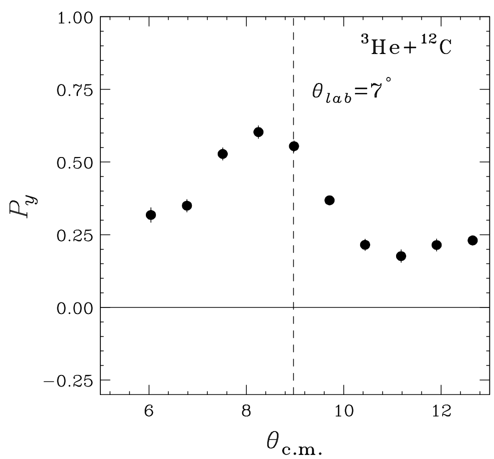

Fig. 2: Induced polarization of ^{3}He elastic scattering from ^{12}C at $E_{^3\mathrm{He}}$=443 MeV, measured with the focal plane polarimeter calibrated in this work.

References

[1] Y. Sakuragi and M. Katsuma, Nucl. Instrum. Methods Phys. Res. A **402**, 347 (1998).
[2] J. Kamiya *et al.*, Phys. Rev. C (to be published).
[3] G.G. Ohlsen, Rep. Prog. Phys. 35 (1972) 717.
[4] M. Katsuma, unpublished.