Polarization Calibration of Spin-Exchange-Type Polarized ^{3}He Target

K. Itoh[1], Y. Shimizu[2], T. Uesaka[3], T. Wakui[3], T. Kawabata[3], Y. Tameshige[2], Y. Sakemi[2], A. Tamii[2], H. Yoshida[2], K. Fujita[2], T. Wakasa[4], T. Kudoh[4], H. Ohira[4] T.Adachi[5] and K. Hatanaka[2]

[1]*Department of Physics, Saitama University, Saitama, Saitama 338-8570, Japan*
[2]*Research Center for Nuclear Physics(RCNP), Ibaraki, Osaka 567-0047, Japan*
[3]*Center for Nuclear Study(CNS), University of Tokyo, Wako, Saitama 351-0198, Japan*
[4]*Department of Physics, Kyusyu University, Hakozaki, Fukuoka 812-8581, Japan*
[5]*Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan*

A spin-exchange-type polarized ^{3}He target was developed at RCNP.In the target system, the cell containing ^{3}He gas has the so-called "double-cell" structure. This structure consists of a target cell and an optically pumping cell, connected to each other through a pipe with an inner diameter of 10 mm. ^{3}He nuclei in the pumping cell are polarized via spin exchange with polarized Rb atoms. The polarized ^{3}He nuclei diffuses into the target cell.

The polarization of ^{3}He nuclei in the target cell is monitored by the adiabatic-fast-passage(AFP)-NMR method, which provides a relative polarization value. On the other hand, the polarization of ^{3}He nuclei in the pumping cell is obtained by measuring the frequency shift of the Rb electron spin resonance (ESR)[1]. The ESR method provides the absolute polarization value. If the difference in ^{3}He polarization between the pumping cell and the target cell is sufficiently small, the AFP-NMR signal can be calibrated by measuring the ESR frequency shift. To compare the polarization in the target cell with that in the pumping cell, the absolute polarization of ^{3}He in the target cell has recently been measured via the $^3\vec{\mathrm{He}}(\vec{p},\pi^+)^4$He reaction, simultaneously with the ESR measurement.

For the case of $\vec{\frac{1}{2}}^+ + \vec{\frac{1}{2}}^+ \rightarrow 0^- + 0^+$, one can show from the parity conservation that the polarization correlation coefficient takes $C_{y,y}$=+1 [2]. In this case, the target polarization P_y^T is written as

$$P_y^T = \frac{1}{P_y^B}\frac{\sigma_{\uparrow\uparrow}+\sigma_{\downarrow\downarrow}-\sigma_{\uparrow\downarrow}-\sigma_{\downarrow\uparrow}}{\sigma_{\uparrow\uparrow}+\sigma_{\downarrow\downarrow}+\sigma_{\uparrow\downarrow}+\sigma_{\downarrow\uparrow}}, \quad (1)$$

where P_y^B is the beam polarization and σ is the cross section for respective combinations of the spin direction. The first and second subscripts indicate the spin directions of the beam and the target, respectively. Thus, the absolute ^{3}He polarization in the target cell can be directly deduced if the beam polarization is known.

The experiment was performed at the Research Center for Nuclear Physics (RCNP), Osaka University, using a polarized proton beam. The beam energy was 392 MeV, the beam intensity was 20 nA, and the beam polarization was about (70±2)%. The beam polarization was monitored using beam-line polarimeters.The pions were momentum analyzed using the high-resolution magnetic spectrometer Grand Raiden, and detected using two plastic scintillation counters and two vertical drift chambers (VDCs).

Spin-dependent cross sections were deduced after subtracting background events mainly due to the cell materials. The absolute target polarization was obtained from the spin-dependent cross sections using Eq. (1). The direction of the beam polarization was reversed every second, and the direction of the target polarization was reversed every 2 hours. The polarization of the ^{3}He target was measured by the AFP-NMR method once per hour. The mean coefficient of proportionality was deduced to be $(6.68\pm0.58)\times10^{-4}$ mV^{-1}.

The calibrations of the polarization obtained from the ESR frequency shift have been performed before and after the $^3\vec{\mathrm{He}}(\vec{p},\pi^+)^4$He reaction. The mean coefficient of proportionality was deduced to be $(4.85 \pm 0.03)\times10^{-4}$ mV^{-1}.

The results of the two different calibration measurements do not agree within the error bar. The re-examination of the systematic error in the ESR frequency measurements and the analysis of the $^3\vec{\mathrm{He}}(\vec{p},\pi^+)^4$He measurement are in progress.

References

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