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8.32 Neutron Polarimeter for the $(\vec{p},\vec{n})$ Experiment at RCNP

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The measurement of the polarization transfer coefficient D_{NN} is very useful for the nuclear structure study since D_{NN} values are very sensitive to the transferred spin (ΔS) and angular momentum (ΔL). Here we report on the neutron polarimeter with a simple configuration which is being used for the polarization transfer experiments at RCNP[1].

Fig. 1 shows the general scattering geometry used in the polarimeter. The target is bombarded by the polarized beam from the AVF cyclotron at RCNP. Neutrons produced at the reaction angle $\theta_{lab}=0°$ can travel 4-10 meter flight path to the scatterer of the polarimeter.

The neutron polarimeter presently consists of six detectors and it utilizes the analyzing power of n-p scattering from the hydrogen nuclei in the scatterer. The scatterer is a liquid scintillation detector (NE213) 12.7 cm diameter and 12.7 cm high. Scattered neutrons are detected with two sets (left and right) of "side detectors" positioned at 30° with respect to the incident neutron beam. The side detector angle (30°) was chosen because the analyzing power of the n-p scattering is large for a wide range of energies (40-80 MeV). A fast coincidence between the scatterer and each neutron detector is made. Side detectors are consisted of two detectors, a liquid scintillation detector (NE213) 12.7 cm diameter and 12.7 cm high followed by a plastic scintillation detector 12.7 cm diameter and 12.7 cm high. In left side a large size liquid scintillation detector (NE213) 20.3 cm diameter and 12.7 cm high is also added as a side detector to increase a polarimeter efficiency. The distance from the center of the scatterer to the center of closest neutron detector is about 26 cm. The distance between the scatterer and the plastic neutron detector is about 40 cm. In the liquid scintillation detectors the n-γ discrimination is made. In case of the plastic scintillation detector the neutron events are selected from the γ-ray background by using the flight time difference between the scatterer and the plastic detector.

In the off-line analysis a threshold is set to the recoil proton pulse height output in the scatterer to select roughly the neutron scattering angle which is related to the precoil proton energy E_R by $E_R = E_n \cdot \sin^2\theta_n$ where E_n is the incident neutron energy and θ_n the neutron scattering angle. In the case of E_n = 60 MeV, for example, E_R is 15 MeV for θ_n = 30°.

The scattering asymmetry is defined as

$$\varepsilon = (U-D)/(U+D)$$

where U and D are the counts in the neutron detector for the incident beam spin direction of Up and Down, respectively. The asymmetry is related to the polarization transfer coefficient D_{NN} at 0° by

$$\varepsilon = \langle A\rangle \cdot P_p D_{NN}(0°),$$

where $\langle A\rangle$ is the effective analyzing power of the polarimeter, and P_p is the polarization of the incident proton beam.

The value of $\langle A\rangle$ of the polarimeter is deduced by using the neutrons whose polarization is known. Polarized neutrons by the $^6Li(\vec{p},\vec{n})^6Be$ reaction at 65 MeV was used for this purpose. The polarization of the neutrons was estimated from the D_{NN} value[2] for the $1^+ \to 0^+$ transition in the $^6Li(\vec{p},\vec{p}')^6Li$ reaction at 65 MeV by using the analogue relation. The value of $\langle A\rangle$ at 60 MeV was found to be 0.13±0.01. This value is about a half of expected value which is calculated by assuming the n-p single scattering alone[3]. The neutron double scattering effect due to the finite size of the scatterer is estimated and it is found that the value of <A> is reduced about 20% for the relevant neutron energy. There is another reduction from the $^{12}C(n,np)$ reaction. Note that carbon is one of the constituents in the liquid scintillator. Although there is no polarization data for the $^{12}C(\vec{n},np)$ reaction, very rough estimate is made and it gives about 25% reduction factor to the value of <A>. Thus the large reduction of the effective analyzing power seems to be explained by a neutron double scattering and the contribution from the $^{12}C(n,np)$ reaction process. The values of <A> other than 60 MeV are deduced from model calculations which take into account the reduction factors mentioned above. Our preliminary D_{NN} value for the $D(\vec{p},\vec{n})2p$ reaction at 50, 65 and 80 MeV deduced from the present <A> values is consistent with the results at SIN[4].

The scattering efficiency of this neutron polarimeter is an order of 10^{-4} at 60 MeV with an effective analyzing power of 0.13. Based on our results one can roughly estimate that a neutron polarimeter utilizing the analyzing power of n-p scattering has a better figure of merit than that utilizing the analyzing power of n-α scattering for the neutrons of $E_n > 50$ MeV.

References

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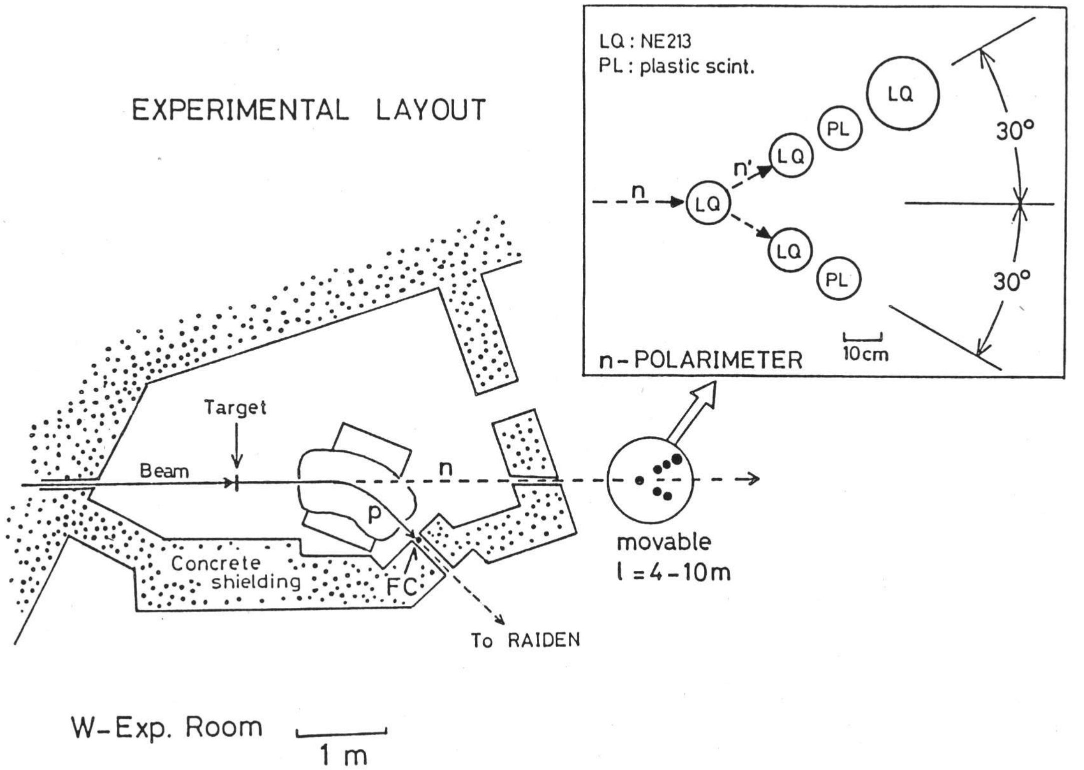

Fig. 1. The polarimeter geometry at RCNP.