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8.41 Horizontally Polarized Deuteron Beam at RCNP and Measurements of the Tensor Analyzing Power A_{xz} at 56 MeV

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The tensor analyzing power A_{xz} is a useful observable to investigate the tensor interaction and the D-state components of d, t, ^{3}He and α-particles in the deuteron scatterings and transfer reactions. The measurements of A_{xz} are performed most effectively using a polarized deuteron beam which has a spin quantization axis of 45° with respect to the incident beam direction. One method to get such a polarized beam is to use a solenoid magnet followed by a bending magnet after acceleration. For deuterons, we need a strong magnetic field because of the small value of the magnetic moment: in the case of 56 MeV deuterons, a solenoid magnetic field of 28 kG·m and a dipole magnetic field of 81.7 kG·m is needed to align the spin axis at an angle of 45° to the beam direction in the horizontal plane. Another method is to rotate the spin axis with a Wien filter prior to acceleration. This method is less expensive than the former one. This is the usual way in tandem Van de Graaff accelerators: up to date, most of the measurements of A_{xz} have been carried out in the energy region of $E_d \lesssim 20$ MeV. Until recently this method has not been applied to cyclotrons. The first successful attempt to accelerate horizontally polarized beams at RCNP was already reported in ref. 1). Since then we have made efforts to increase the intensity of horizontally polarized deuterons. Similar method has also been successfully applied at IUCF to accelerate horizontally polarized proton beams[2)].

The RCNP polarized ion source is of an atomic beam type[1)]. The ion beam is vertically injected into the cyclotron through the axial injection line. The spin direction of the D^+ beam is rotated into the horizontal plane by a Wien filter installed just downstream the ion source. In this system, a magnetic field of 2.08 kG and an electric field of 2.04 kV/cm are needed to rotate the spin of a 10 keV D^+ beam by 90°.

When the beam polarized in the horizontal plane is accelerated by the cyclotron, the spin precesses a large number of times during acceleration. For 56 MeV deuterons the spin precession angle is 53.1° per turn in the cyclotron. If a single turn extraction is achieved, the extracted ions are expected to have a same spin precession angle. Even in the condition of a few-turns extraction, the distinction of the turn numbers makes it possible to determine the spin precession angle for each turn. In the "Polarization Tagging Method" described in ref. 1), the spin precession angle for each turn was determined by means of a beam pulsing and a TOF techniques. The observed spin precession angle differed by 53° for one turn, as expected, and no serious depolarization was found[1)]. Using the Polarization Tagging Method the tensor analyzing power A_{xz} was measured for the ^{1}H+d elastic scattering at 56 MeV. It was found that this scattering was useful as a monitor of horizontal beam polarization because of large values of A_{xz} and the cross section[1,3)].

With the Polarization Tagging Method we could select the turn with a large beam polarization ($2p_{zz}\sin\beta\cos\beta \sim 0.7$), but the beam intensity was limited to a very small value (less than 1 nA on target) because of the acceleration of pulse selected beam. In order to measure A_{xz} for other nuclei, it is desired to increase the beam intensity without seriously reducing the beam polarization. For this purpose, it is essential to accelerate and extract the beam from the cyclotron with a constant turn number. The diagnostic to achieve a single turn (or few turns) extraction was carried out by the same method as used in the Polarization Tagging Method: pulsed beam was injected into the cyclotron and the distribution of the turn number of the extracted beam was observed using the TOF technique. By adjusting the parameters of the cyclotron, the turn number of the extracted beam was restricted and a few turns extraction was achieved: the most sensitive parameters were the dee voltage and the magnetic field at the extraction region. After we have achieved a few turns extraction, the beam pulsing system in the injection line was turned off. Since the admixture of turn numbers was very small (less than three turns), the final polarization was expected to have a fairly large value.

The monitoring of horizontal polarization and the measurements of A_{xz} were carried out by the following method. The scattering cross section induced by polarized deuterons with a definite spin axis in the horizontal plane is written as[4]

$$\sigma(\theta) = \sigma_0(\theta)[1\mp p_{zz}\sin\beta\cos\beta A_{xz}+{}^{1}\!/\!_{4}p_{zz}\{\sin^2\beta(A_{xx}-A_{yy})+(3\cos^2\beta-1)A_{zz}\}], \qquad (1)$$

where β is the angle between the spin axis and the incident beam direction, and the minus (plus) sign corresponds to the left (right) detector. In the experimental condition where an admixture of turn numbers exists, the quantities $\sin\beta\cos\beta$, $\sin^2\beta$ and $\cos^2\beta$ in eq.(1) should be replaced by the weighted means, $\Sigma w_i \sin\beta_i \cos\beta_i/\Sigma w_i$, etc. Here w_i and β_i are the beam intensity and the angle of the spin axis, respectively, of the extracted beam with i-th turn number. The A_{xz} was measured using two detectors placed at symmetric angles at the left and right sides to the beam direction in the horizontal plane. Two polarization states (p_z, p_{zz}) = (1/3,1) and (1/3,-1) were used, which were switched every second. We get four countings N_L^+, N_L^-, N_R^+ and N_R^- from the left and right detectors, and with positive (p_{zz}=1) and negative (p_{zz}=-1) tensor polarizations. From these countings the tensor analyzing power A_{xz} is obtained by the equation

$$A_{xz}\cdot 2p_{zz}\overline{\sin\beta\cos\beta} = \frac{N_L^- - N_L^+}{N_L^- + N_L^+} + \frac{N_R^+ - N_R^-}{N_R^+ + N_R^-} \quad . \qquad (2)$$

The quantity $2p_{zz}\,\overline{\sin\beta\cos\beta}$ in eq.(2) means a weighted mean of the horizontal polarization, and it is monitored continuously using the ^{1}H+d elastic scattering at the beam polarimeter downstream the scattering chamber.

An example of the dependence of the horizontal polarization on the dee voltage is shown in fig. 1. The maximum value of $2p_{zz}\overline{\sin\beta\cos\beta}$ was 0.64 and the beam intensity was 20 to 60 nA on target. Using the method described above, the tensor analyzing power A_{xz} has been measured for the elastic scattering on several targets ranging from ^{4}He to ^{208}Pb [ref. 4)]. A long term variation of the horizontal polarization in such an experiment is shown in fig. 2. A fine readjustment of the dee voltage was made several times to maintain large values of horizontal polarization (0.4~0.6). Compared with the Polarization Tagging Method, the figure of merit for the measurement of A_{xz} was largely improved.

References

1) K. Hatanaka et al., Nucl. Instr. and Meth. 217 (1983) 397.
2) E.J. Stephenson et al., Proc. 10th Int. Conf. on cyclotrons and their applications, East Lansing, Michigan, 1984, p.337.
3) K. Hatanaka et al., Nucl. Phys. A426 (1984) 77.
4) K. Nisimura et al., Nucl. Phys. A432 (1985) 378;
N. Matsuoka et al., contribution to this conference.

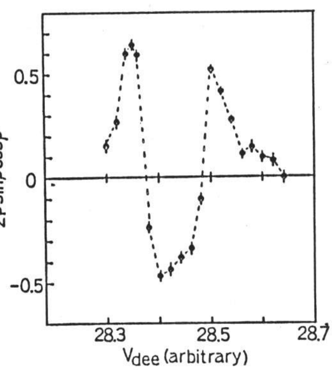

Fig. 1. Horizontal polarization as a function of dee voltage.

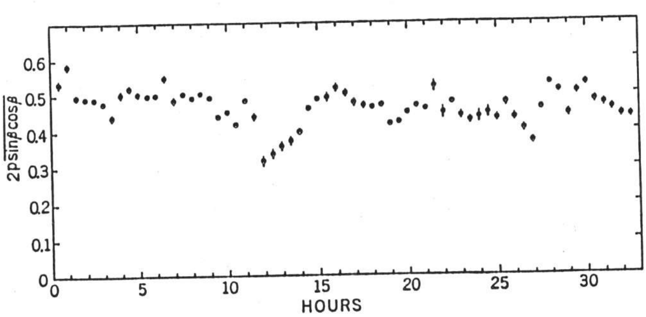

Fig. 2. An example of long term variation of horizontal polarization in an experiment.