Title
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Spin polarization of ^{43}Ti produced through the projectile fragmentation process in ^{46}Ti on C collisions at 116 MeV/nucleon has been observed as a function of fragment momentum by means of beta-decay asymmetry. From the momentum dependence of the fragment polarization, it was concluded that negative angle deflection of the ^{43}Ti fragment due to the nuclear attractive potential is the main reaction path in the case of light targets.

1. INTRODUCTION

For hyperfine interaction studies detected by nuclear radiations, it is very important to get a variety of probe nuclei in a wide range of elements. The projectile fragmentation process in high energy heavy ion collisions provides us with such probe nuclei with high productivity. Combined with a suitable polarization technique, this production technique can be an excellent source of such probe nuclei, since by the conventional β-NMR detection they can be easily studied. We have been studying magnetic moments of $f_{7/2}$-shell mirror nuclei, using such a combined technique. Since the creation of polarization through the collision is an important part of the method, a clear understanding of the mechanism is crucial for its further extension.

The polarization of projectile-like fragments has been studied experimentally by many scientists in the energy range from 10 to 100 MeV/nucleon [1-3]. The projectile fragmentation process itself together with the experimental polarizations has been qualitatively explained fairly well by a simple fragmentation model [4]. Fragment polarization was found to be an excellent measure of the deflection angle [2][3], changing from positive to negative as function of this angle. Although positive angle deflection due to the Coulomb potential was confirmed from these studies in the case of heavy targets such as Au, the sign is not clear yet in the case of light targets. A study has been carried out at intermediate energies with lighter fragments [5], but not at high energies.

In the present experiment, the spin polarization of the projectile fragment ^{43}Ti(I^{π}=7/2$^-$, $T_{1/2}$=0.50 sec) has been measured detecting asymmetric beta-ray emission from the fragment produced in the ^{46}Ti on C collision at a high incident energy of about 100 MeV/nucleon to study the sign of the deflection angle with a light target.

2. EXPERIMENTAL PROCEDURE

The experimental method is essentially the same as in a previous experiment on the fragment polarization [3]. The ^{43}Ti nuclei were produced through the projectile fragmentation of ^{46}Ti at an effective energy of 116 ± 8 MeV/nucleon on a 260 mg/cm^2 thick C target. The ^{43}Ti nuclei emerging from the target into a certain deflection angle θ_L were purified and momentum analyzed by a fragment separator set in Beam line 44 at the Bevatron of Lawrence Berkeley Laboratory. After a suitable energy degradation, the ^{43}Ti nuclei were implanted into a Pt foil held at 90 K and located in a strong external magnetic field H_0= 6.9 kOe to maintain the polarization created in the collision. Polarization of the ^{34}Ti was measured by detecting asymmetric beta-ray emission. For reliable determination of the polarization, the spin ensemble was inverted by the Adiabatic Fast Passage(AFP) NMR technique and the beta-ray asymmetry was compared with that without inversion.

3. RESULTS AND DISCUSSION

Prior to the polarization measurement, production cross sections and the angular distributions of the ^{43}Ti fragment were measured for both Au and C targets. The observed cross section was significantly smaller for a Au target than that for the C target by a factor of 3. This target mass dependence cannot be reproduced by simple fragmentation models like the abrasion-ablation model [6] where the production cross-section should increase with the target mass due to the increase of the target-nucleus radius. A new mechanism like immediate Coulomb breakup of the produced ^{43}Ti at the collision has to be taken into account, besides the usual abrasion-ablation process, to explain this reduced cross section for heavier targets. This target mass dependence provides crucial information for determining the target material to get the best production conditions.

As typically shown in the lower part of Fig. 1, momentum distributions of the fragments were Gaussian with a widths consistent with the theoretical ones due to the Fermi momentum only (Goldhaber model [7]). On the other hand, the observed angular distributions, reflecting the transverse momentum distributions, were wider than those form the Goldhaber model for both Au and C targets as shown in Fig. 2. For the Au target, this broadening is explained well by the orbital deflection due to the Coulomb potential. For the C target, however, the distribution was even wider than the classical grazing angle. Therefore, the stronger deflection due to the attractive nuclear potential is suggested in the case of the light target.

In order to study the deflection mechanism, we measured the spin polarization of the ^{43}Ti in the ^{46}Ti on C collision, which reflects the sign of the deflection angle. The sign of the deflection distinguishes deflection by the nuclear potential from the Coulomb deflection. The spin polarization has been measured as a function of the fragment momentum as shown in Fig. 1. The sign of the polarization parallel to the vector $p_i \times p_f$ is defined to be positive, where p_i and p_f are the momentum vectors of the incoming and the outgoing particles. The polarization was very close to zero on the low momentum side and has a negative finite value around the optimum momentum at which the yield was maximum. The optimum momentum is smaller by 5 MeV/c/nucleon than the momentum corresponding to the beam velocity shown by an arrow.

This observed trend in its momentum dependence of the fragment polarization was the reverse of that observed for the fragments produced in the ^{40}Ca on Au collision [3], where the polarization increases with momentum as predicted for a positive angle deflection. So, the present trend in polarization suggests dominance of the negative angle deflection due to the attractive nuclear potential. However, compared with the theoretical calculation based on the simple fragmentation model [4] shown by the broken line, there seems to be an additional energy dumping for the component of negative deflection, which seems reasonable because of the longer interaction time for the component.

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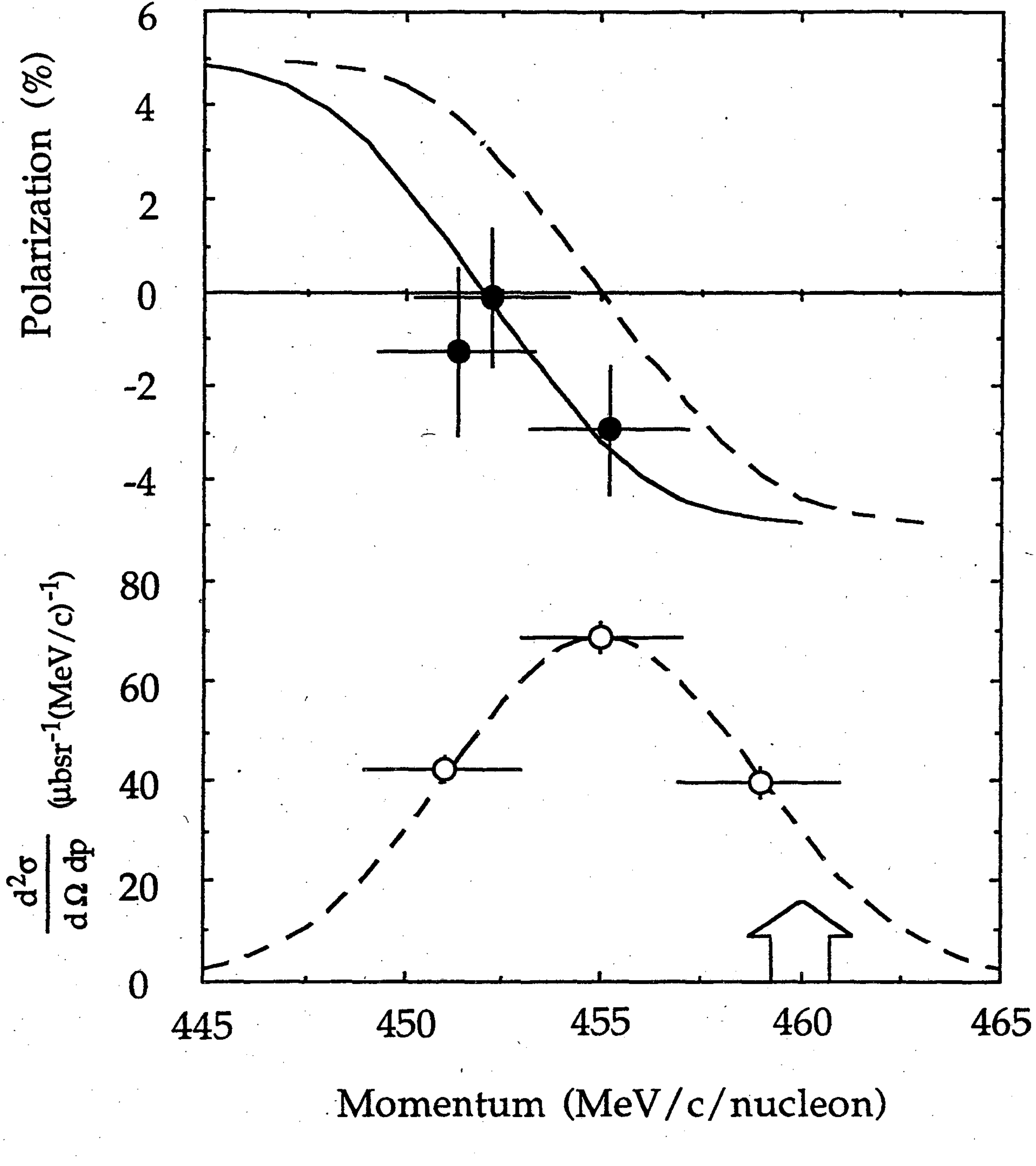

Fig. 1. Momentum dependence of spin polarization of ^{43}Ti.

The arrow indicates the momentum corresponding to the beam velocity. The broken line is the polarization predicted by a simple model multiplied by 1/20. The solid line is the same curve shifted by 3 MeV/c/nucleon to lower momentum side. Lower part of the figure is the momentum distribution of ^{43}Ti.

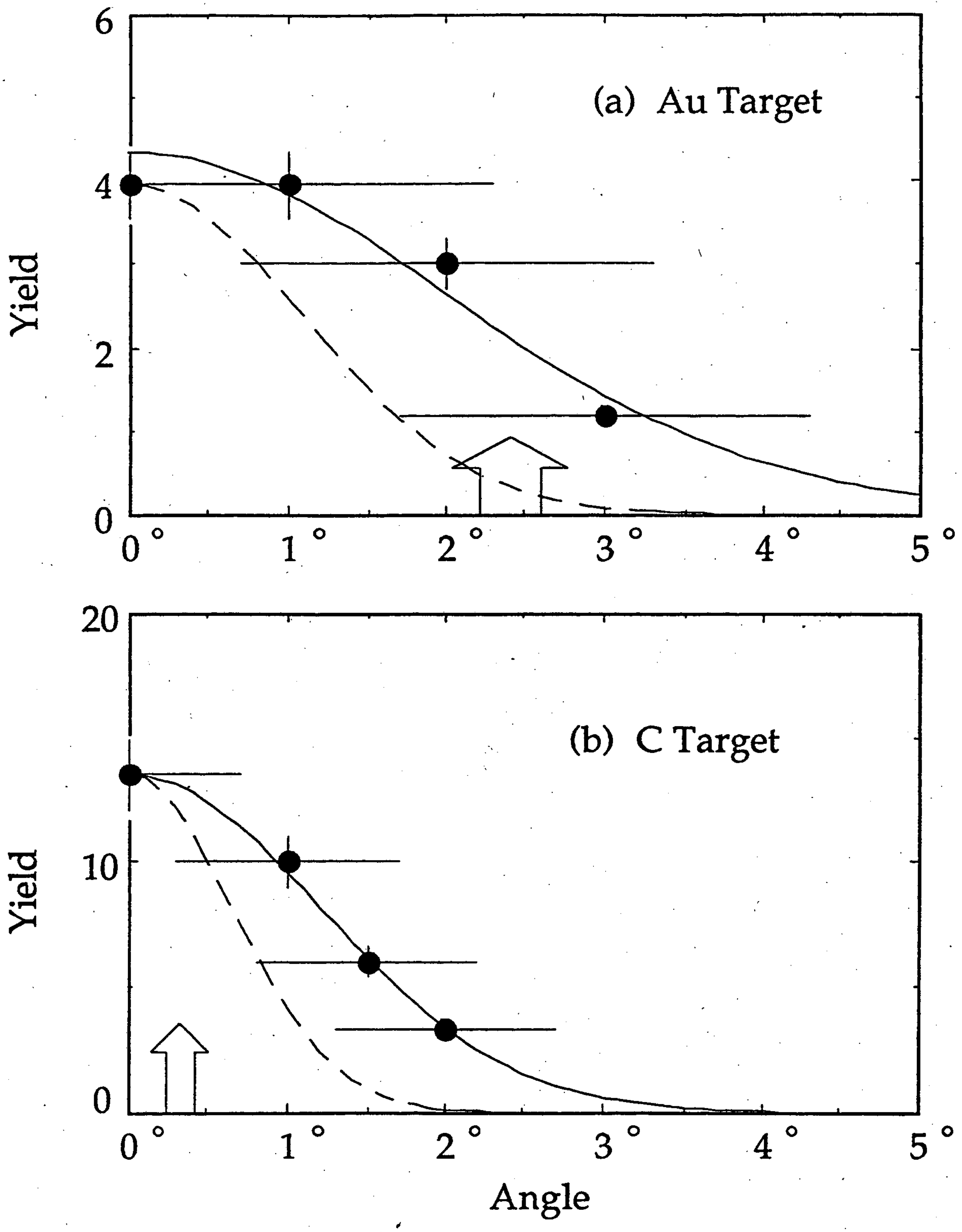

Fig. 2. Angular distribution of ^{43}Ti.

The solid curves are Gaussian distributions best fit to the data. The broken ones are the theoretical predictions from the Goldhaber model. In the calculation, the width of the angular window and the multiple scattering were also taken into account. The arrows indicate grazing angles.

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