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Polarization Monitors for ^{7}Li and ^{23}Na*)

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With the development of polarized ^{7}Li and ^{23}Na beams at the Heidelberg MP-Tandem[1)] it has become important to find suitable polarimeters for these beams. The polarization of the atomic beam in the ion source has been measured by laser induced fluorescence in a strong magnetic field[2)]. At low energies the ion beam polarization can be determined by beam foil spectroscopy[3)]. However, partial depolarization of the beam during acceleration and transport to the experimental areas makes it necessary to monitor the polarization after acceleration[4)]. A polarimeter requires a scattering or reaction for which the analyzing powers can be calculated or measured by an independent method. For pure Coulomb excitation of the polarized projectile the analyzing powers and polarization transfer coefficients are calculable[5)]. For reactions with the spin structures $3/2+1/2 \rightarrow 0+0$ the second rank tensor analyzing power T_{20} =-1 at 0^0 and 180^0 [5)].

Back angle Coulomb excitation of ^{23}Na to the first excited state at E_x=0.44 MeV from a ^{208}Pb target has been calculated to give second rank tensor analyzing powers around T_{20}=0.65. In order to obtain a reasonable counting rate thick targets are required. This makes it necessary to use particle gamma coincidences to identify the inelastic events. Annular parallel plate avalanche counters were used to detect the backscattered excited ^{23}Na nuclei at laboratory angles between 137^0 and 161^0 in coincidence with 0.44 MeV γ rays detected by a pair of NaI counters placed close to the target. This method of measuring the alignment (2nd rank tensor polarization) of the ^{23}Na beams has been used for energies up to 84 MeV. At higher energies the nuclear force also plays a role in the scattering and the polarimeter has to be calibrated with an absolute monitor such as the p(^{23}Na,α)^{20}Ne$_{g.s.}$ reaction at zero degrees.

Coulomb excitation can also be used to measure the first and third rank polarization components of the beam. To do this one needs to replace the annular detectors with detectors sensitive to the azimuthal scattering angle. By using forward angle scattering one can also go to higher beam energies at the expense of lower analyzing powers (T_{20}) and a higher ratio of elastic to inelastic events. In all cases one must be aware to the anisotropy of the decay gamma distribution due to the polarization of the excited ^{23}Na nuclei. Although the polarization transfer is calculable for Coulomb excitation it is not easy to determine the distribution of the gamma rays. This is due to partial depolarization of the excited Na by hyperfine interaction with electrons. Thus one must carefully choose the angles of the particle and gamma counters to minimize systematic errors.

The reactions ^{1}H(^{7}Li, α)α and ^{1}H(^{23}Na, α)^{20}Ne$_{g.s.}$ at 0^0 have also been used to measure the tensor polarization t_{20} of the beams. In both cases a tantalum foil placed after the target was used to stop the direct beam hitting the detector. Polyethylene $(CH_2)_n$ targets were used for both ^{7}Li and ^{23}Na measurements. Due to the high reaction Q-value in case of ^{7}Li the α-peak of interest is well separated from a continuous α background making this a useful polarimeter. For Na the lower reaction Q-value and the high projectile to target mass ratio couple to give low energy α's which sit on a continuous background from competing reactions with both the carbon in the target and the tantalum beam stop (Fig.1). This background problem and the resonance nature of the cross section limits the usefulness of this reaction. However, at lower energies the results from this polarimeter agree well with those from Coulomb excitation.

The ^{1}H(^{7}Li, α,α) reaction can also be used to measure the first and third rank polarization of the beam if the corresponding proton analyzing power is close to its absolute maximum[6]. This is the case for proton energies from 6 to 10 MeV[7] and at proton energies of 12.3 and 14.3 MeV[8]. Hence the odd rank beam polarization of a ^{7}Li beam should be determinable to within an absolute error of the order of 5% for energies from 42-100 MeV.

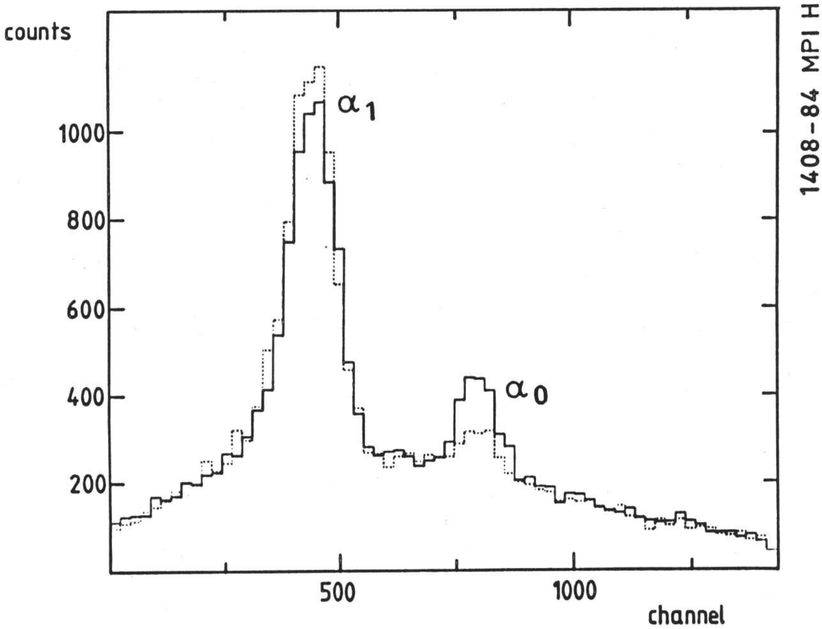

Fig. 1) Zero degree α-spectrum for 90 MeV ^{23}Na incident on a 500 μg/sq cm polyethylene foil + a 50 μm Tantalum beam stop. The dashed and solid lines are for positive and negatively tensor polarized ^{23}Na. α_o and α_1 denote the peaks corresponding to the 0^+ ground state and 2^+ first excited state in ^{20}Ne.

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