ELASTIC AND INELASTIC SCATTERING OF PROTONS ON THE UNSTABLE NUCLEI ^{40}S and ^{43}Ar

F. Marechal[a], T. Suomijarvi[a], Y. Blumenfeld[a], A. Azhari, D. Bazin, J. A. Brown, P. D. Cottle[b], M. Fauerbach, T. Glasmacher, S. E. Hirzebruch[a], J. K. Jewell[b], J. H. Kelley[a], K. W. Kemper[b], P. F. Mantica, D. J. Morrissey, L. A. Riley[b], H. Scheit, J. A. Scarpaci[a] and M. Steiner

We have recently studied the structure of neutron rich sulfur isotopes,^{38}S and ^{40}S by using elastic and inelastic proton scattering in inverse kinematics. The first experiment was performed on^{38}S isotope and the results have been reported in ref. 1 and in the NSCL/MSU Annual Report 1996. The second experiment was devoted to the study of ^{40}S but data were also collected for the neutron rich ^{43}Ar isotope which was present as a byproduct in the secondary beam.

The secondary ^{40}S and ^{43}Ar beams were produced by fragmentation of an incident 120 enA ^{48}Ca beam from the K1200 cyclotron on a ^{9}Be production target and analysed and purified by using the A1200 fragment separator. A final intensity of about 2200 pps for the ^{40}S beam at 30 MeV/A and of about 16000 pps for the ^{43}Ar beam at 33 MeV/A was obtained. By using a ToF and ΔE-E measurements an unambiguous identification of the different beam particles was achieved.

The secondary beam was scattered on a 1.6 mg/cm^2 $(CH_2)_n$ target and the angle and energy of recoiling protons were measured with a silicon-strip array. The array consisted of 8 telescopes of 5×5 cm^2 active area. Each telescope comprises a 300 μm silicon strip-detector with 16 vertical strips 3 mm wide backed by a 500 μm thick silicon PIN-diode and a 1 cm thick CsI stopping detector read out by 4 photodiodes. Such detectors allow us to measure protons from about 1 MeV up to 50 MeV. The particle identification in the recoil telescopes was performed either by a time-of-flight measurement for particles stopped in the strip-detector or by a ΔE-E measurement for particles stopped in the Si PIN-diode or the CsI-detector. The telescopes were placed at 29 cm from the target at angles between 61^o and 84^o allowing us to measure the elastic and inelastic scattering to the first excited state over the angular range $\Theta_{C.M.}$=15^o to $\Theta_{C.M.}$=45^o.

A ΔE-E plastic detector was placed at zero degree behind the target in order to select the reaction channel of interest and to give a start for the time-of-flight measurement. The incident angle and the position of the secondary beam on the target was measured event by event by using two Parallel Plate Avalanche Counters (PPAC) placed at 82 cm and 182 cm from the target. Due to the very small intensity of the ^{40}S beam, the maximum momentum acceptance of 3% of the A1200 line was used. In order to correct for the broad momentum distribution, the energy of secondary projectiles was measured event by event by recording the ToF between the scintillator placed after the A1200 and the ΔE-E detector.

The excitation energy spectra measured for ^{40}S and ^{43}Ar are shown in fig. 1. Due to the low energy of the first 2$^+$ state in ^{40}S and the very low statistics, the 2$^+$ state can only be observed in a narrow range around $\Theta_{C.M.}$=30^o where the elastic scattering cross section exhibits a minimum. Therefore, in the case of ^{40}S, the spectrum shown is integrated between 28 and 36^o in the center-of-mass frame. The first 2$^+$ state is observed at 860 keV excitation energy, in good agreement with a previous Coulomb excitation experiment 2. In the spectrum measured for ^{43}Ar, a peak is observed at 1.61 MeV, which probably corresponds to a E2 transition from the ground state J$^\pi$=5/2$^-$ to an excited state J$^\pi$=1/2$^-$. However, no clear spin assignement was obtained from the data. The excitation energy resolution in both cases is of the order of 700 keV which is very similar to that measured for a stable ^{40}Ar beam with the same detection system 1.

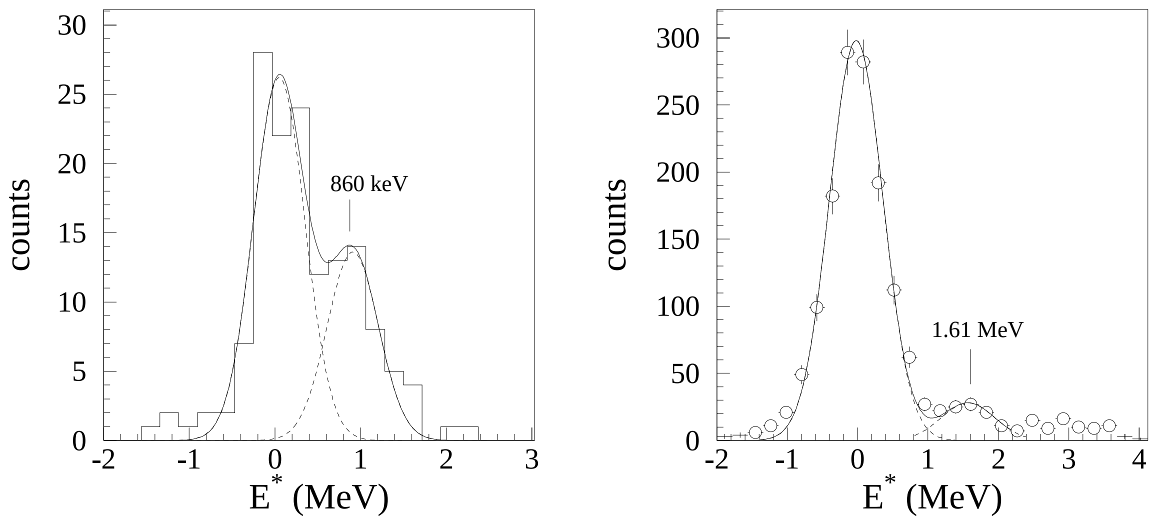

Figure 1: Excitation energy spectra measured for ^{40}S (left) and ^{43}Ar (right). Dashed lines are gaussian fits to the elastic scattering peak and to the first excited state. Solid line is the sum of the two contributions.

The elastic and the 2^+ angular distributions for ^{38}S (from ref. 1) and ^{40}S are shown in fig. 2. In the case of ^{40}S, the very low statistics obtained for the inelastic scattering allowed to extract only two points for the angular distribution. Note that no arbitrary normalization is involved here. Coupled-channels predictions using the Becchetti-Greenlees parameterization 3 are shown (solid line) in comparison with the data. The β_2 values were extracted by normalizing the coupled channel calculation to the 2^+ state cross section. The value obtained for ^{38}S is β_2=0.35±0.04 and for ^{40}S β_2=0.35±0.05. These values are clearly larger that those measured by Coulomb excitation, β_2=0.246±0.016 and β_2=0.284±0.016 2 for ^{38}S and ^{40}S, respectively. Since the proton scattering also probes the neutron transitions contrarily to the Coulomb excitation measurements, these very large β_2-values indicate a strong neutron contribution to the studied transitions.

Particularly interesting information on the isoscalar or isovector character of the 2^+ oscillation is given by the ratio of the neutron and proton multipole matrix elements M_n/M_p 4. This ratio can be obtained by combining the β_2 values measured by electromagnetic and nuclear excitations using the formula derived in ref. 5. This yields M_n/M_p = (1.50±0.20)N/Z and M_n/M_p = (1.25±0.25)N/Z for the 2_1^+ state in ^{38}S and ^{40}S, respectively. For a pure isoscalar collective excitation this ratio is expected to be equal to N/Z and thus these values, clearly larger than N/Z, indicate an isovector contribution to the 2^+ excitation. The large M_n/M_p value for ^{38}S can be qualitatively understood by considering the ^{38}S nucleus as a ^{36}S core plus two valence neutrons forming a neutron skin which drives the oscillation. However, when two more neutrons are added, the M_n/M_p value does not increase as would be expected from this very simple picture. This saturation could be due to core polarisation which becomes important in the case of ^{40}S. In order to better understand the excitation of the first low lying collective states in the sulfur isotopes, microscopic analysis of the data is currently in progress.

In the case of ^{43}Ar, the measured inelastic angular distribution is in good agreement with an E2 transition. A relatively low value of β_2=0.25±0.03 was extracted. This value is comparable with the one reported for the stable ^{40}Ar isotope β_2=0.23±0.01 6. Moreover, it is similar to that measured by Coulomb excitation for the neighboring isotopes ^{42}Ar and ^{44}Ar 2 indicating no significant changes in the structure of argon isotopes when neutrons are added.

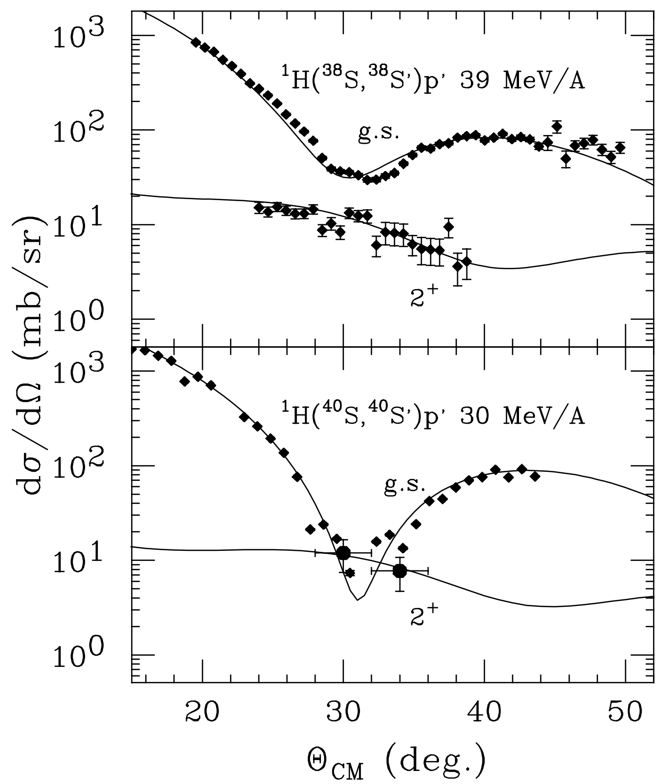

Figure 2: Elastic and 2^+ angular distributions for ^{38}S (top) and ^{40}S (bottom) isotopes. Solid lines correspond to coupled-channel calculations, see text.

a. Institut de Physique Nucleaire, IN_2P_3-CNRS, 91406 Orsay, France
b. Department of Physics, Florida State University, Tallahassee, FL 32306

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