MICHIGAN STATE UNIVERSITY

CYCLOTRON LABORATORY

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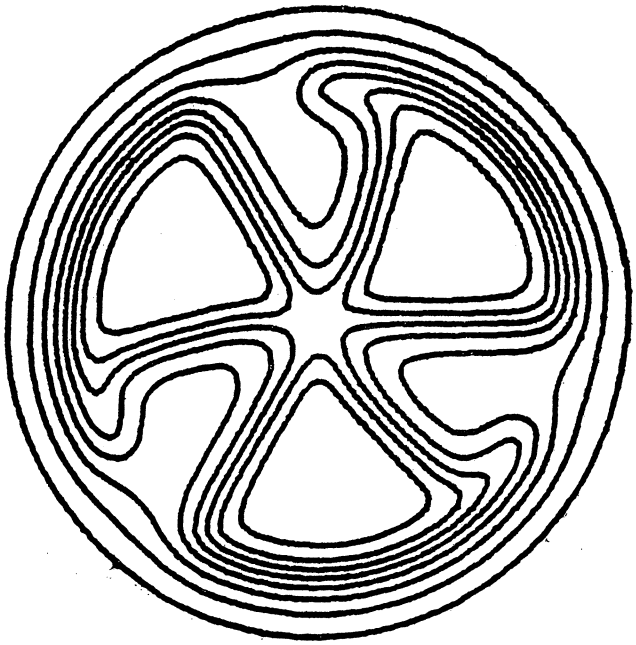

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Is Monopole Core Polarization Important in the Inelastic Excitation of Low Lying 0^+ States?*

Hans-Peter Morsch

Cyclotron Laboratory, Michigan State University
East Lansing, Michigan 48824

ABSTRACT

The monopole transition density between the ground and first excited 0^+ states in ^{28}Si and ^{46}Ti is discussed. Both electron scattering and inelastic ^3He and α scattering support models of the state which use multiparticle-multihole configurations and disagree with macroscopic or 1plh models. Thus we conclude that the giant monopole admixture in the low lying 0^+ states is small.

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Very little is known about 1plh monopole admixtures in low lying states although it enters, at least in part, into several different problems such as the isotope shift and the Nolen-Schiffer anomaly. In general this effect of monopole core polarization is difficult to investigate, and so far only qualitative limits on its coupling strength have been obtained.[1] Recently inelastic monopole transitions to low lying 0^+ states have been measured, and it was found that their angular distributions are particularly sensitive to the interaction form factor,[2,3] thus providing a direct test of the importance of monopole core polarization in the excitation of low lying 0^+ states.

These low lying monopole transitions in the sd and $f_{7/2}$ shell have been analyzed by use of form factors due to n particle-n hole configuration mixing only.[2,3] Although good fits have been obtained, it is important to know whether core polarization, i.e. 1plh excitation through two major shells, should be taken into account, because this would drastically change the spectroscopic information extracted. In particular, this could answer the question as to whether for E0 transitions effective operators in the form of a renormalization of the E0 matrix element should be introduced (similar to those for quadrupole transitions, for example) which would give a better agreement of shell model predictions with experimental E0 matrix elements in the sd shell (see ref. 3).

This is of considerable interest also in connection with the investigation of the nuclear breathing mode which can give information on the compressibility of nuclear matter. Although

no such mode has been found experimentally, it has been the subject of many theoretical investigations, with considerable differences in its predicted excitation energy. However, through the mixing into low lying 0^+ states, information on the breathing mode energy may be obtained from the monopole transitions in question.

In the present study 1p1h form factors are discussed for the excitation of first excited 0^+ states in inelastic α scattering from ^{28}Si and ^{3}He scattering from ^{46}Ti. 1p1h admixtures in the wave functions of ground and excited 0^+ state give rise to two different form factors, one due to 1p1h excitations and the other due to recoupling of 1p1h componenents in ground and excited state. Because the second term employs the overlap of small core polarization components in both channels, in first order its contribution can be neglected. The detailed structure of the 1p1h excitation form factor is given in ref. 4. Its absolute normalization is obtained by adjusting the 1p1h amplitudes to reproduce the experimental E0 matrix elements. This microscopic description of the monopole core polarization is compared with collective models in ref. 5.

1p1h excitations were considered for ^{28}Si from 1p and $1d_{5/2}$ shell nucleons, for ^{46}Ti from 1p, sd and $f_{7/2}$ shell nucleons. Simple $(d_{5/2})^0$ and $(f_{7/2})^6$ wave functions were used for the ground state configurations. Using a more complicated structure, including e.g. for ^{28}Si $2s_{1/2}$ and $1d_{3/2}$ particle components, leads only to minor changes in the 1p1h form factor. Details

of the calculations are the same as in ref. 4. For the calculations of collective model densities (ref 5) ground state densities were used from electron scattering.[6] Only small differences in the form factors were found for the different transition densities of ref. 5.* For ^{28}Si the transition densities are shown in Fig. 1. The microscopic 1p1h form factor (dashed line) is very similar to that from the collective model (dotted line). No change from the usual bound state geometry of r_o=1.25 fm, a_o=0.65 fm was necessary to obtain this close agreement. The transition radius $R_{TR}^2=\langle r^4\rangle_{TR}/\langle r^2\rangle_{TR}$ of the 1p1h density was calculated to be 4.8 fm which yields $R_{TR}/\langle r^2\rangle_{gs}^{1/2}\sim 1.5$, a value which is considerably smaller than that obtained from the systematics of light nuclei in electron scattering[8,9] ($R_{TR}/\langle r^2\rangle_{gs}^{1/2}\sim 2$). Fig. 1 also shows the transition density (solid line) previously obtained in a shell model description using form factors due to n particle-n hole configuration mixing only (ref. 3). This transition density yields $R_{TR}/\langle r^2\rangle_{gs}^{1/2}\sim 2.0$ which is in good agreement with the systematics from electron scattering.

For the calculation of the inelastic form factors an effective nucleon-nucleon interaction of Gaussian form with 1.68 fm range and a volume integral of 446 MeV fm^3 is used. This interaction, which is consistent with interactions describing few nucleon systems,[10] was folded with ^{3}He and α internal wave functions of ref. 11. The experimental E0 matrix element of 6.8 fm^2 for ^{28}Si (ref. 8) is obtained in the 1p1h calculation

*It should be mentioned that these collective model densities are well reproduced by Hartree-Fock transition densities (see ref. 7).

if 1p1h amplitudes of 0.0518 are used. For ^{46}Ti the E0 matrix element has not been measured directly. From our results in ref. 2 an E0 matrix element of about 4 fm^2 is estimated. To produce this value (or equivalently the cross section at small angles) much smaller 1p1h amplitudes of 0.0163 have to be used. The angular distributions calculated by use of these 1p1h amplitudes are shown in Figs. 1 and 2. Also included in the figures are the previously obtained fits using form factors due to n particle-n hole configuration mixing.[2,3]

The results may be summarized as follows: Large differences are found in the calculated transition densities and differential cross sections between form factors due to n particle-n hole configuration mixing and 1p1h form factors, the latter in disagreement with the experimental data. Also in the 1p1h description three times larger 1p1h amplitudes would be necessary for ^{28}Si as compared to ^{46}Ti to reproduce the experimental E0 matrix elements. However, a much stronger monopole coupling strength is not expected for sd shell nuclei as compared to $f_{7/2}$ shell nuclei.

Thus, we conclude that for the transitions in question monopole core polarization is small. This is consistent with results of Zamick[1] who derived similar conclusions from the discussion of particle-hole and particle-particle spectra. Our conclusions are in disagreement with ref. 12, in which the low lying 0^+ excitation is described by a small fraction of the 1p1h monopole state. Compared to low lying quadrupole states, which have fairly large 1p1h admixtures, our results show very different features for the monopole state. This may indicate a higher breathing mode energy

as compared to the energy of the giant quadrupole resonance in agreement with theoretical estimates.[13-17]

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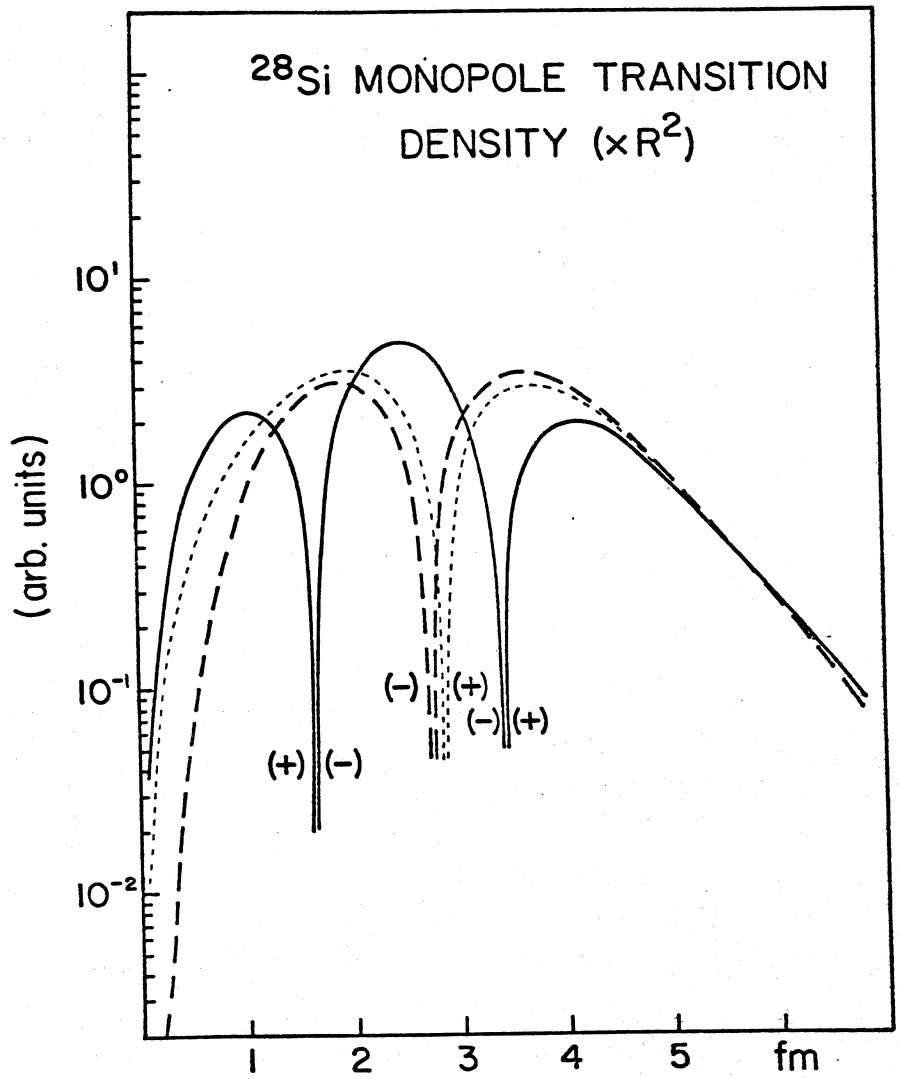
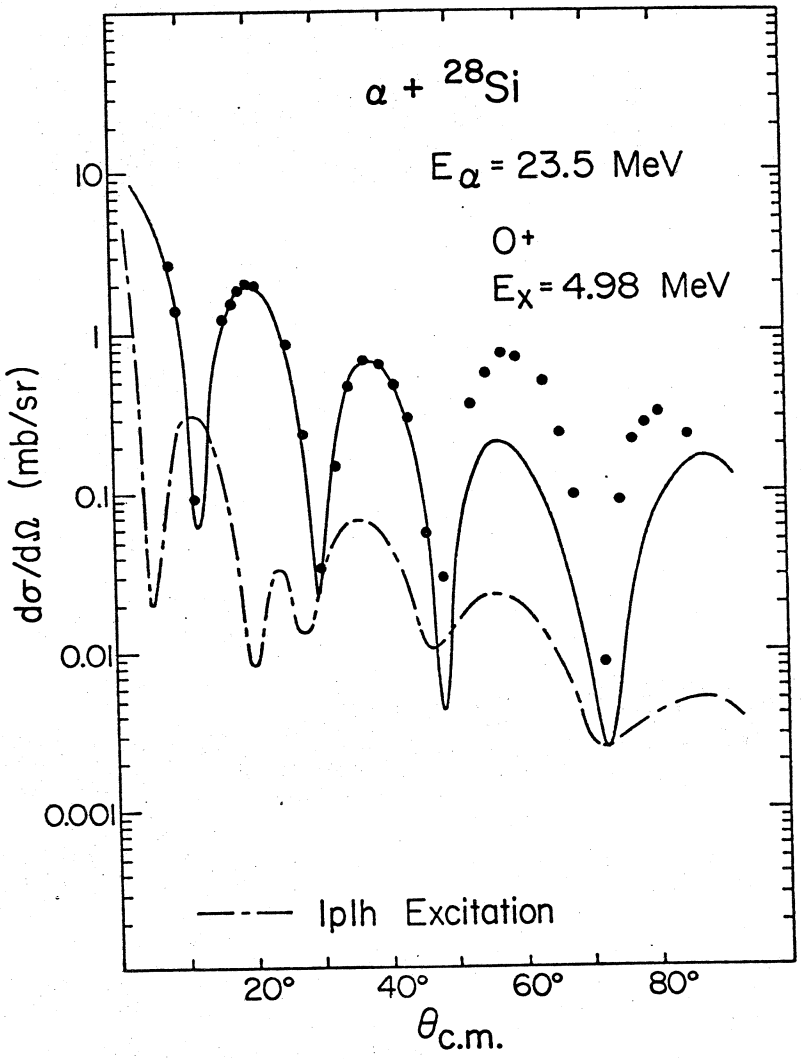
FIGURE CAPTIONS

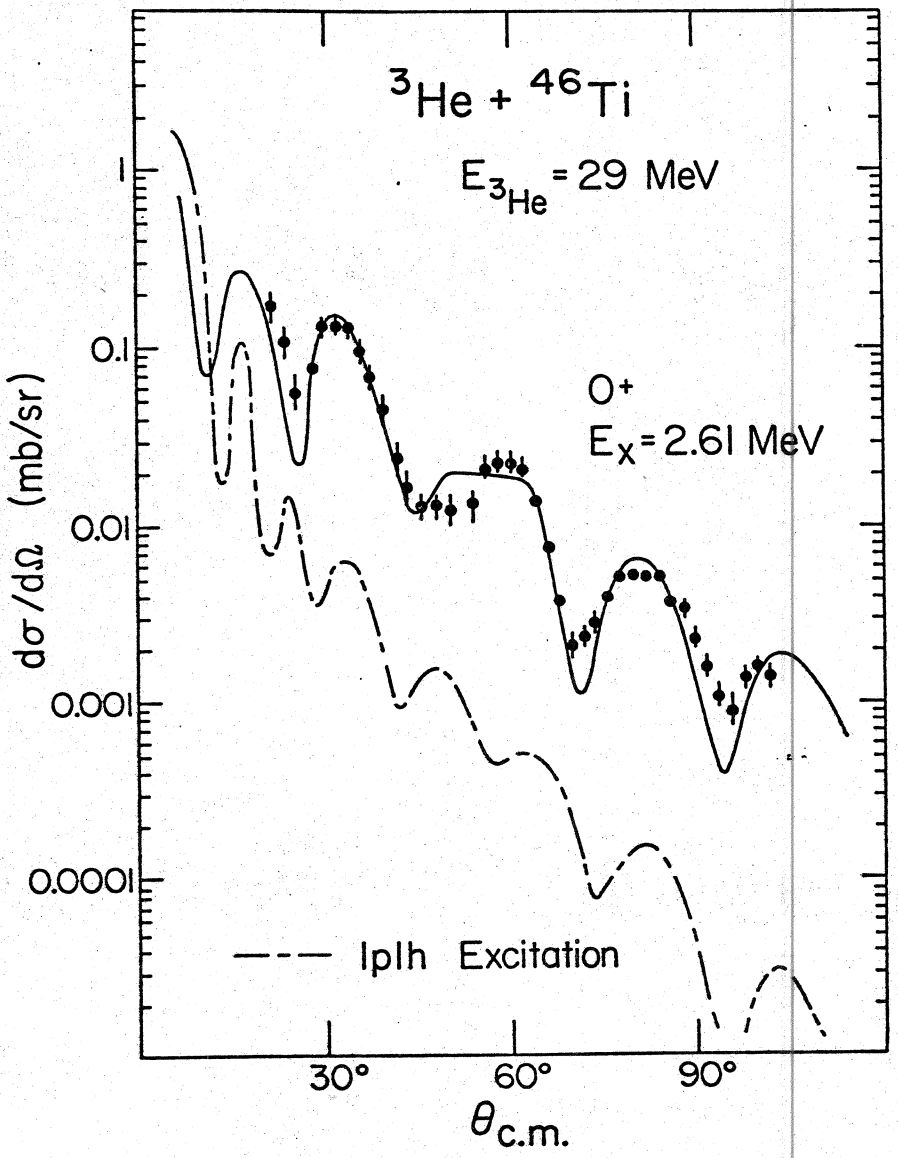
Fig. 1: Monopole transition densities in ^{28}Si, between ground and first excited 0^+ state. The solid line is a shell model density obtained from a fit to inelastic scattering (ref 3) which yields a transition radius consistent with electron scattering. The dashed and dotted curves are 1plh and macroscopic transition densities, respectively; the macroscopic density is that of version 2 in ref. 5.

Fig. 2: Angular distribution for α-scattering from ^{28}Si. The curves are microscopic calculations using form factors due to n particle-n hole configuration mixing (solid line) and 1plh form factors (dot-dashed line).

Fig. 3: Angular distribution for ^{3}He-scattering from ^{46}Ti. The curves represent calculations similar to those in fig. 2.


^{28}Si MONOPOLE TRANSITION
DENSITY (×R^2)
(arb. units)
10'
10°
10^{-1}
10^{-2}
(+)
(−)
(−)
(+)
(−)
(+)
1
2
3
4
5
fm


α + ^{28}Si
E_α = 23.5 MeV
0+
E_x = 4.98 MeV
dσ/dΩ (mb/sr)
10
1
0.1
0.01
0.001
1p1h Excitation
20°
40°
60°
80°
$\theta_{c.m.}$


$^3He + ^{46}Ti$
$E_{^3He} = 29$ MeV
0^+
$E_x = 2.61$ MeV
1p1h Excitation
$d\sigma/d\Omega$ (mb/sr)
1
0.1
0.01
0.001
0.0001
30°
60°
90°
$\theta_{c.m.}$