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MACROSCOPIC FOLDED FORM FACTORS FOR $^{12}C + ^{12}C$ INELASTIC SCATTERING

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In contrast to the scattering of heavy-ion projectiles from heavy targets, the scattering from "light" heavy-ion targets is sensitive to the nucleus-nucleus interaction throughout the surface region, that is, where there would be appreciable overlap of the static densities. For this reason, the scattering is sensitive to the parameterization of this interaction, and it has not been easy to find simple Woods-Saxon forms which describe the latter case. This is illustrated in Fig. 1 where the angular distributions for scattering of ^{12}C from ^{12}C at E_{lab} = 117.1 MeV are shown. The dashed curves are the result of coupled-channels calculations using a Woods-Saxon optical potential and macroscopic deformed Woods-Saxon form factors for the inelastic scattering. The description is good for the forward angles but fails altogether for the large angles. It is possible to find other Woods-Saxon forms which do better at the large angles, but these lose some quality in the forward angles and depend more strongly on the incident projectile energy than that used here.

Recently it has been found that potentials obtained by folding the static densities of the target and projectile nuclei with a "realistic" nucleon-nucleon interaction improves the overall fit to the elastic scattering angular distributions.[1] Figures 2 to 4 show the result of coupled-channel calculations for the elastic and inelastic scattering using these folded form factors. The transition densities used reproduce the $B(E2:0^+ \rightarrow 2^+)$ values in ^{12}C, as well as the rms radii observed in electron scattering. The nucleon-nucleon interaction is a sum of short-ranged Yukawas which fit the G-matrix elements of the Reid potential.[2] There is an overall normalization factor required in order to reproduce the elastic scattering, and this same factor is applied to

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the inelastic form factors as well. The absorptive potential is phenomenological and chosen energy independent.

The fit to the forward angle scattering in each case is reasonable and the large angle magnitude is increased in better agreement to experiment. This improvement in the large angle prediction is due to the fact that the elastic folded potential is deeper than the Woods-Saxon form in the interior, rather than due to any particular quality of the inelastic form factor. The form factors are compared in Fig. 5, the solid curves corresponding to the folding model and the dashed curves to the Woods-Saxon form. The region of interaction is predominantly between 3 and 6 fm. It is possible to search on a Woods-Saxon-squared form and the best fit parameterization is shown in Fig. 4 as the dotted curves. The result of using this potential is shown in Fig. 1 as the dotted curve.

Finally, we note that DWBA calculations do not satisfactorily reproduce the coupled-channels predictions. The dashed-dotted curves in Figs. 3 and 4 result in first- and second-order DWBA calculations including reorientation matrix elements and, for the mutual excitation of both nuclei, the two-step, sequential excitation. This disagreement is only partially due to the strength of the channel couplings. For the inelastic scattering of ^{12}C from the strongly deformed Nd isotopes, the second-order DWBA reproduces the infinite-order calculation reasonably well.[3] In the latter case, Coulomb scattering dominates, so that only a small number of partial waves contributes to the scattering into a given angle. In this case, the sensitivity to any ℓ dependence which needs to be introduced into an effective elastic one-channel optical potential to account for the coupling to inelastic channels is weak. But for the $^{12}C + {}^{12}C$ case, the Coulomb scattering is relatively less important, and a larger number of partial waves contributes to the scattering amplitude at a given angle. Hence, it is difficult for the ℓ-independent optical potential used in the DWBA calculations here to account completely for the coupled-channels effects.

REFERENCES

1. R. M. Wieland, et al., to be published.
2. G. Bertsch, et al., to be published.
3. L. D. Rickertsen and D. Hillis, to be published.

FIGURE CAPTIONS

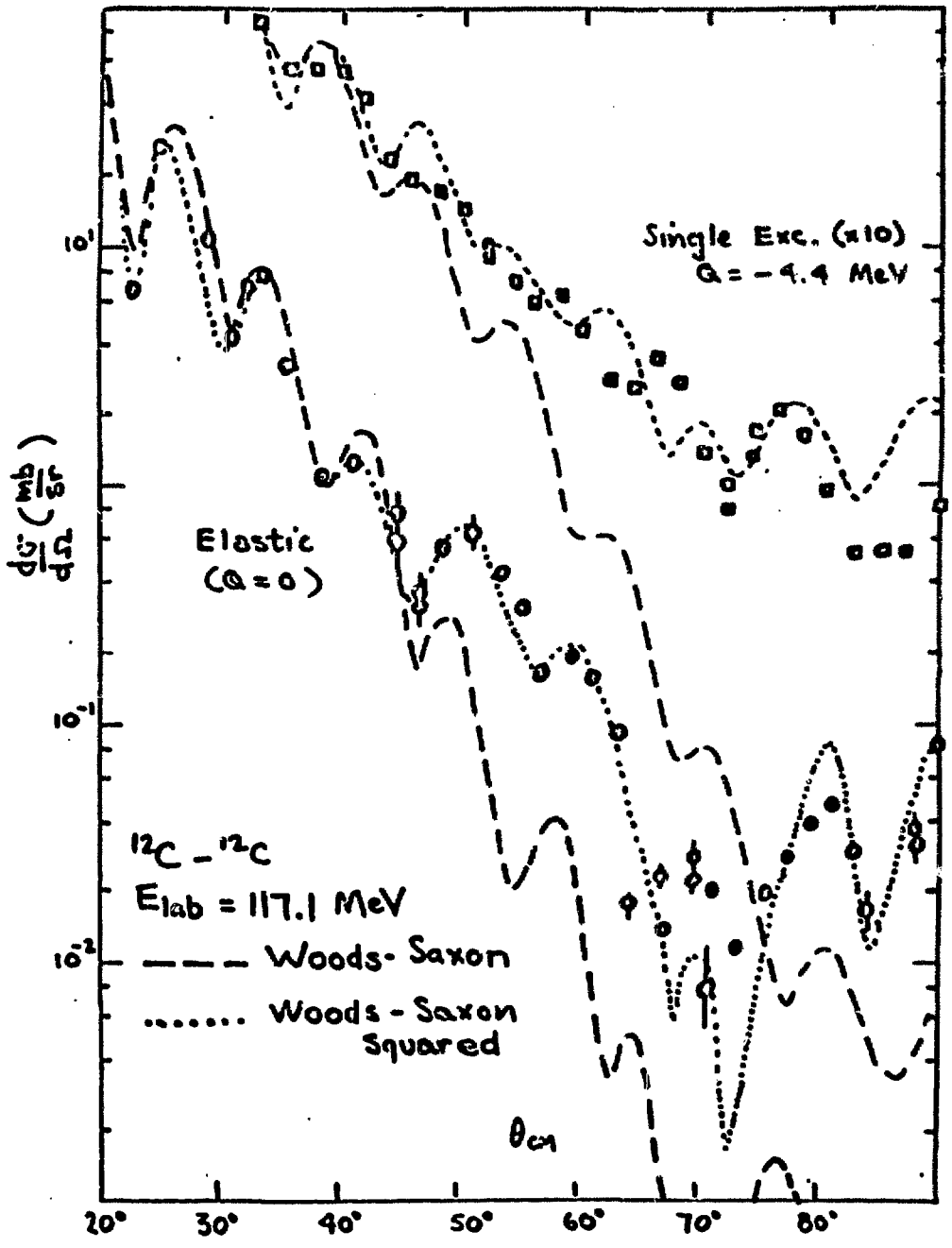
Fig. 1. Scattering of ^{12}C from ^{12}C at E_{lab} = 117.1 MeV. Dashed curve results from using Woods-Saxon parameterization of the deformed optical potential. Dotted curve results from Woods-Saxon-squared parameterization.

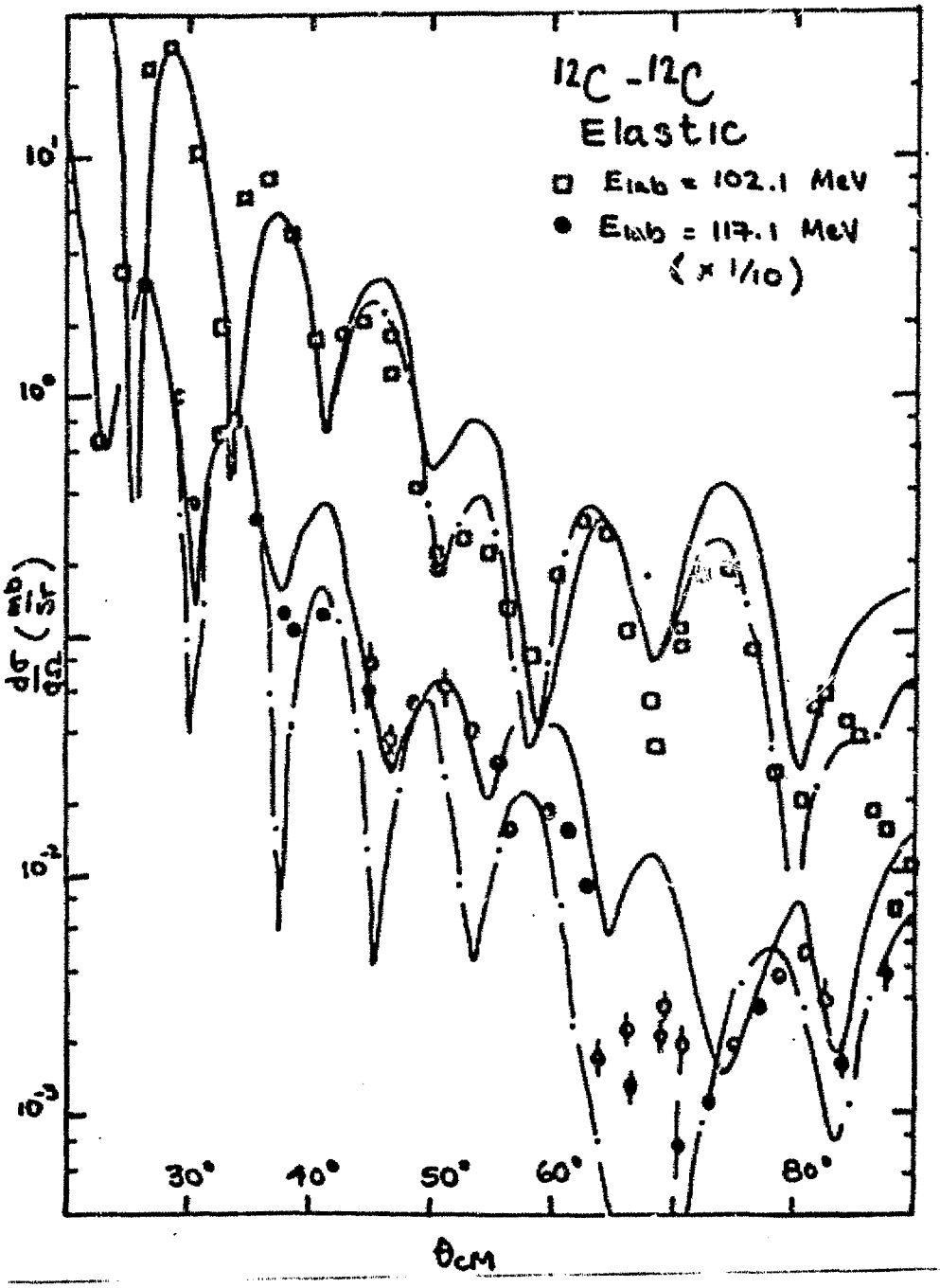
Fig. 2. Elastic scattering of ^{12}C from ^{12}C. Solid curves from coupled-channels calculations using folded real form factors and Woods-Saxon imaginary form factors. Dashed-dotted curves result from one-channel calculations suitably modifying folding and absorptive potentials.

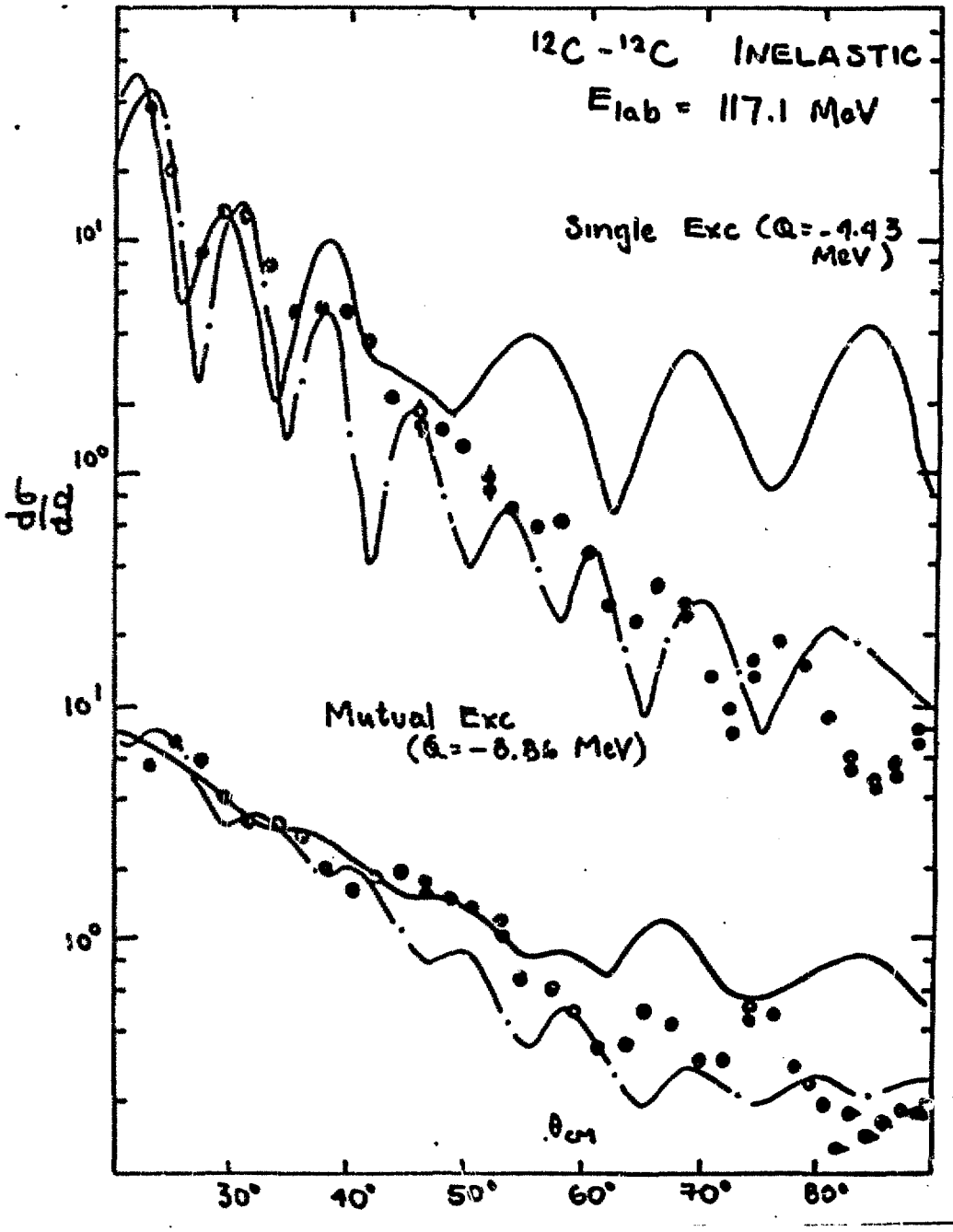
Fig. 3. Inelastic scattering of ^{12}C from ^{12}C. Solid curves as in Fig. 2. Dashed-dotted curves result from DWBA calculations using one-channel potential used for Fig. 2. E_{lab} = 117.1.

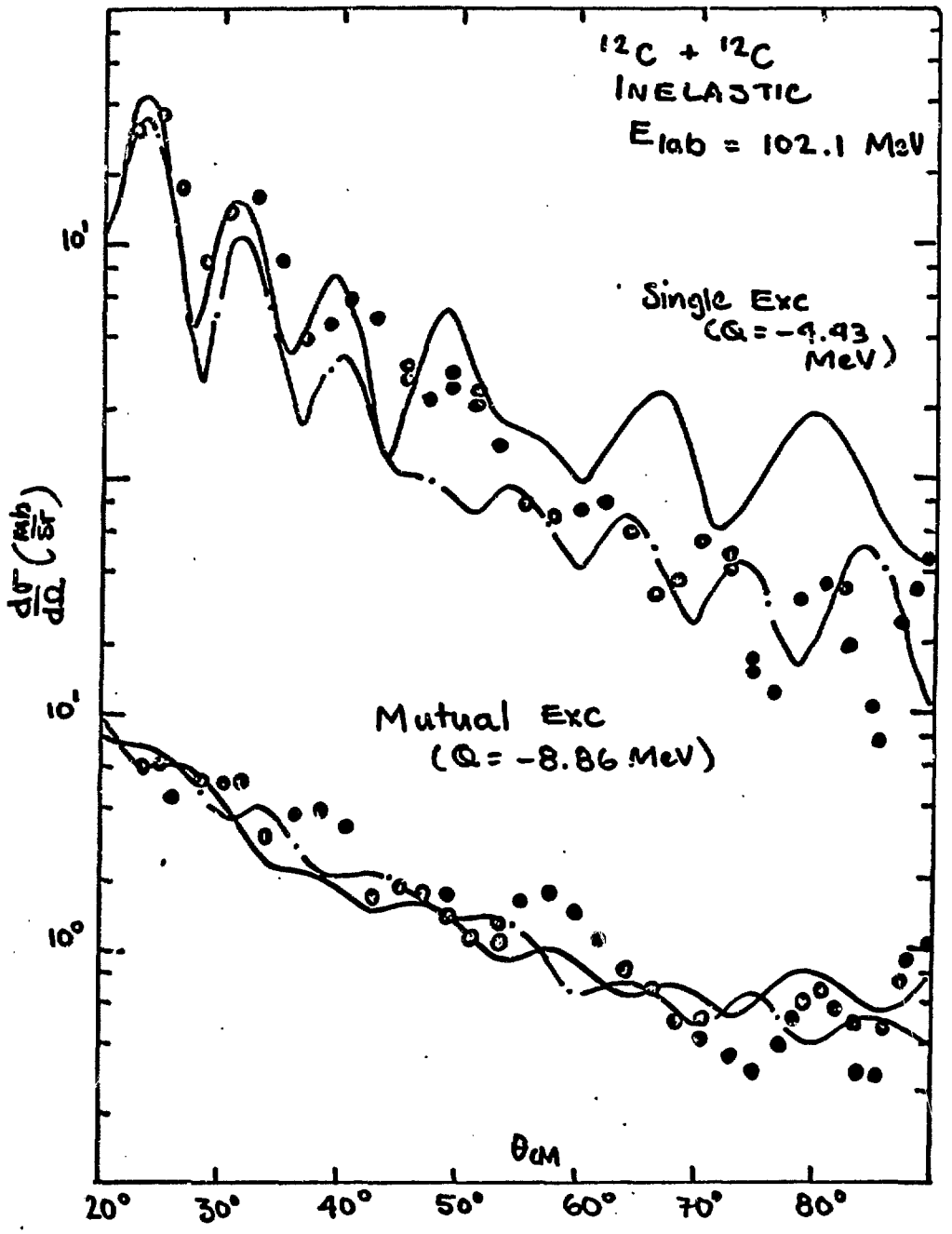
Fig. 4. Inelastic scattering of ^{12}C from ^{12}C. Solid curves as in Fig. 2. Dashed-dotted curves result from DWBA calculations using one-channel potential used for Fig. 2. E_{lab} = 102.1.

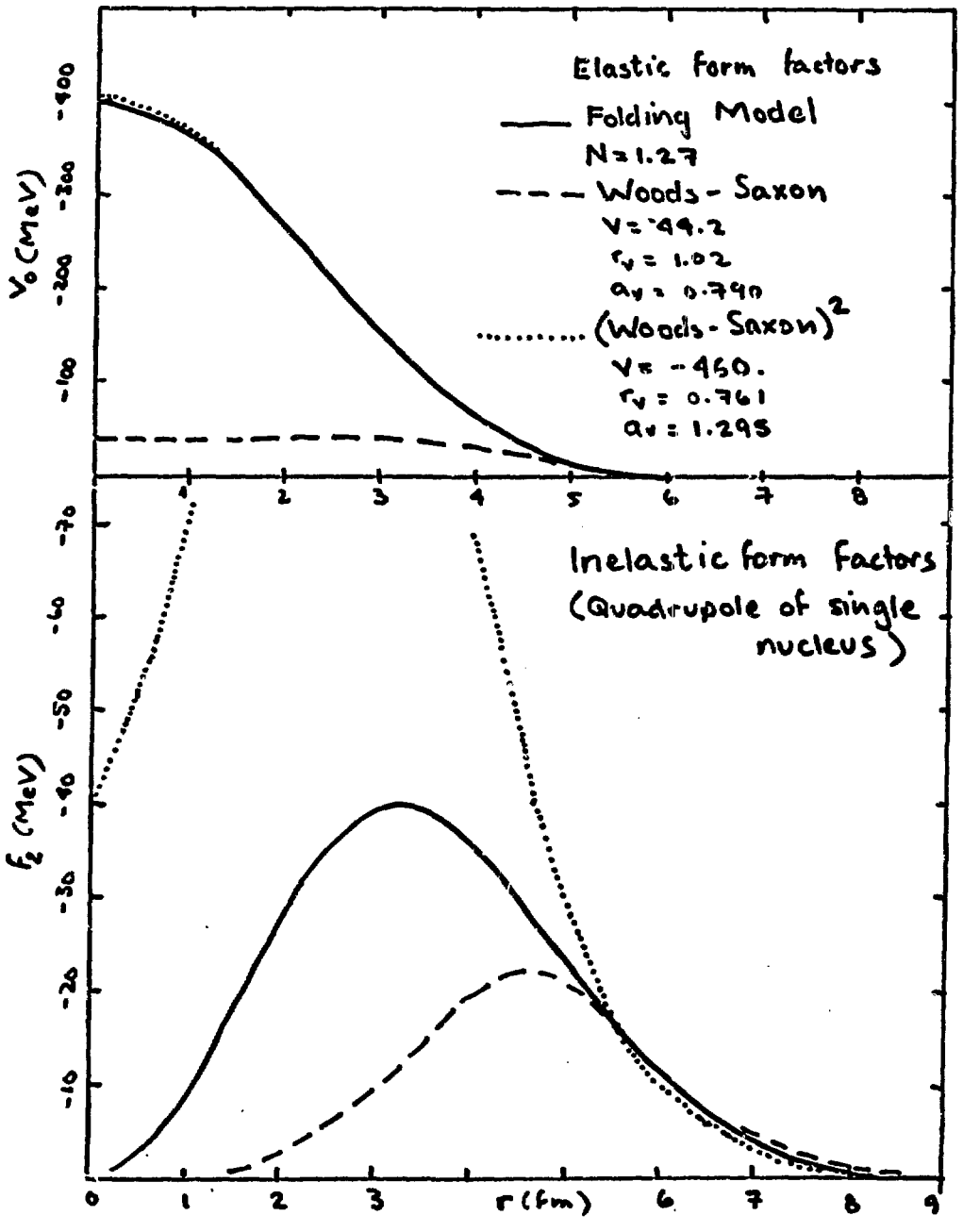
Fig. 5. Upper: Real part of optical potentials. Solid curve is folded potential, dashed curve is Woods-Saxon potential and dotted curve is Woods-Saxon-squared potential. Lower: Real part of inelastic form factors for quadrupole excitation of single nucleus.


Single Exc. (x10)
Q = -4.4 MeV
Elastic
(Q = 0)
$^{12}C - ^{12}C$
E_{lab} = 117.1 MeV
Woods-Saxon
Woods-Saxon Squared
θ_{cm}
$\frac{d\sigma}{d\Omega}$ (mb/sr)
10^1
10^{-1}
10^{-2}
20°
30°
40°
50°
60°
70°
80°


12C - 12C
Elastic
Elab = 102.1 MeV
Elab = 117.1 MeV
(× 1/10)
10¹
10⁰
10⁻¹
10⁻²
dσ/dΩ (mb/sr)
30°
40°
50°
60°
80°
θCM


$^{12}C - ^{12}C$ INELASTIC
E_{lab} = 117.1 MeV
Single Exc (Q=-4.43 MeV)
Mutual Exc (Q=-8.86 MeV)
$\frac{d\sigma}{d\Omega}$
10^1
10^0
10^1
10^0
θ_{cm}
30°
40°
50°
60°
70°
80°


$^{12}C + ^{12}C$
INELASTIC
E_{lab} = 102.1 MeV
Single Exc
(Q = -4.43 MeV)
Mutual Exc
(Q = -8.86 MeV)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
10^1
10^1
10^0
θ_{CM}
20°
30°
40°
50°
60°
70°
80°


Elastic form factors
Folding Model
N=1.27
Woods - Saxon
V=-49.2
r_v = 1.02
a_v = 0.790
(Woods - Saxon)^2
V= -450.
r_v = 0.761
a_v = 1.295
V_0 (MeV)
-400
-300
-200
-100
1
2
3
4
5
6
7
8
Inelastic form Factors
(Quadrupole of single nucleus)
f_2 (MeV)
-70
-60
-50
-40
-30
-20
-10
0
1
2
3
r (fm)
6
7
8
9