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PHASE VARIATION IN THE SCATTERING OF ALPHA PARTICLES BY $Ni^{58,62}$

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January 1965

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Abstract

The scattering of various energy alpha particles by Ni^{58} and Ni^{62} has been studied. It has been found that the phase of the inelastic groups relative to that of the elastic group tends to vary with energy, the most pronounced variation being that arising from excitation of the first 4+ ("two-phonon") level. The data have been compared with the modified diffraction model of Austern and Blair. The theory is moderately successful in fitting the data for excitation of the first 2+ and 3- levels. The variation in phase of the 4+ angular distribution with energy could be reasonably reproduced by considering an admixture of one and two phonon excitations. Nuclear matrix elements and reduced electric transition probabilities for some of the levels in Ni^{58} and Ni^{62} are included.

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1. Introduction

The scattering of medium-energy alpha particles has been investigated both experimentally and theoretically by numerous authors. According to what has come to be known as the Blair phase rule for the inelastic scattering of strongly absorbed particles, the angular distributions for alpha groups corresponding to an even value of angular momentum transfer L should be out of phase with that for the elastic group; whereas those corresponding to odd-L transfer should be in phase with the elastic group. Experimentally, this phase rule has been verified for the excitation of the first 2+ (quadrupole) and 3- (octupole) states in even-even nuclei. However, it has been found that the relative phases for excitation of the first 4+ and second 2+ levels (two-phonon) are in some cases in phase and in other cases out of phase with the elastic group[1]). In particular, the scattering of 43-MeV alpha particles by Ni^{58} has shown that the angular distribution for excitation of the first 4+ level is nearly in phase with that of the elastic group[2,3]). This anomolous phase behavior has been attributed to interference effects between the direct and multiple processes by which the 4+ level can be excited[4]).

With the availability of alpha particles with energies up to about 125 MeV it was considered desirable to investigate the phase relationships as a function of the energy of the incident alpha particles. In this paper are presented the results for the scattering of alpha particles over the energy range of 25 to 100 MeV by Ni^{58} and Ni^{62}. A preliminary report of the results for Ni^{62} has been published elsewhere[5]).

2. Experimental Technique

The Berkeley 88-inch variable energy cyclotron was used to provide incident alpha particles with energies of 25, 33, 50, 85, and 100 MeV. The experimental arrangement has been described elsewhere[6]). The targets consisted of isotopically enriched* Ni^{58} (99.9 percent) and Ni^{62} (99.9 percent), which were oriented at an angle of 45° with respect to the incident beam. The scattered alpha particles were stopped in lithium-drifted silicon detectors of thicknesses from 0.040 to 0.120 inches. For the 100-MeV work, the 0.120-inch detector was oriented at an angle of 45° with respect to the scattered alpha particles. The electronics has been described elsewhere[7]). The overall resolutions obtained in this work varied from about 40 keV FWHM at 25 MeV, to about 200 keV at 100 MeV. In general, data were recorded at one to two degree intervals in the laboratory system, but the length of the interval was varied when considered desirable.

3. Results

In figs. 1a, 1b, and 1c are shown the angular distributions obtained for the scattering of 33-, 50-, and 100-MeV alpha particles by the ground (0+), 1.452-MeV (2+), 2.458-MeV (4+) and 4.50-MeV (3-) states in Ni^{58}. A similar figure showing the results for the scattering of 33-, 50-, and 85-MeV alpha particles by the ground (0+), 1.17-MeV (2+) 2.33-MeV (4+ and 2+ doublet) and 3.77-MeV (3-) states in Ni has already been published[5]). From these data, the fractional displacements of the inelastic maxima relative to the elastic maxima were determined,

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*Obtained from the Stable Isotopes Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

and in figs. 2 and 3 these are shown as a function of the energy of the incident alpha particles.

It is clear from figs. 2 and 3 that the phases for the scattering by the first 2+ and 3- states, relative to that for scattering by the ground state, are fairly independent of energy, whereas the phase for scattering by the 4+ levels changes from nearly out of phase at low alpha energies to essentially in phase at higher energies. As regards the data for the 4+ level in Ni^{62}, it should be noted that no correction has been made for a possible contribution to the angular distributions arising from excitation of the second 2+ level at an energy of 2.303 MeV. However, the fact that the "sharpness" of the oscillations in the angular distributions is fairly independent of energy, leads one to suspect that any such contribution must necessarily be small. Further evidence that might be utilized to justify such a suspicion has been obtained from the work on Ni^{58}. Here, the alpha group which would arise from excitation of the second 2+ level[8] was not observed.

The angular distributions obtained for Ni^{58} and Ni^{62} were compared with the predictions of the diffraction model in a manner suggested by Austern and Blair[9]). These authors have shown how the Drozdov-Blair-Sharp-Wilets diffraction model can be generalized to calculate the cross section for any multipole excitation, as well as to include Coulomb distortion. The form for the elastic-scattering amplitude is

$$f_{e\ell}(\theta) = f_c(\theta) + \frac{i}{2k} \sum_{\ell=0}^{\infty} e^{i\sigma_\ell} (2\ell + 1)(1 - \eta_\ell) P_\ell(\cos\theta), \qquad (1)$$

where $f_c(\theta)$ is the Coulomb amplitude, σ_ℓ the Coulomb phase shift for the ℓth partial wave, η_ℓ the complex amplitude of the ℓth outgoing partial wave, $P_\ell(\cos\theta)$ the Legendre polynomial of order ℓ, and k the relative wave number. The form of η_ℓ was assumed as

$$\eta_\ell = \epsilon + B\Delta\frac{d\epsilon}{d\ell} + i\left(A\Delta\frac{d\epsilon}{d\ell} + D\Delta^2\frac{d^2\epsilon}{d\ell^2}\right) ; \qquad (2)$$

where

$$\epsilon = \left(1 + e^{(L-\ell)/\Delta}\right)^{-1} .$$

Using the above expressions for $f_{e\ell}(\theta)$ and η_ℓ, the parameters L, Δ, A, B and D were determined by least squares fitting to the experimental elastic cross sections with the aid of a search program due to Springer[10]). The η_ℓ so determined were then inserted into the formulae given by Austern and Blair for the excitation of a nucleus with ground state angular momentum zero to an excited state with angular momentum I. For an excitation involving a single phonon the expression for the scattering amplitude is

$$f_{IM;00} = \frac{i}{2}(2I + 1)^{1/2}\, C_1(I) \sum_{\ell\ell'} \Big[i^{\ell-\ell'}(2\ell' + 1)^{1/2}$$
$$e^{i(\sigma_\ell + \sigma_{\ell'})} \langle \ell' I - M_I M_I | \ell 0\rangle \langle \ell' I 00 | \ell 0\rangle \frac{\partial\eta_\ell}{\partial\ell} Y_{\ell'}^{-M_I}(\theta,0)\Big] \qquad (3)$$

where $C_1(I) = \delta_1(I)/\sqrt{2I + 1}$, and $\delta_1(I)$ is related to the deformation parameter, $\beta_1(I)$ as $\delta_1(I) = \beta_1(I)R_o$. The quantities in brackets are Clebsch-Gordan coefficients. The derivative of η_ℓ is to be evaluated at $\bar{\ell} = (\ell+\ell')/2$. For an excitation involving two phonons, the amplitude is given by

$$f_{IM;00} = -\frac{ik}{4}(2I + 1)^{1/2}\, C_2(I) \sum_{\ell\ell'} \Big[i^{\ell-\ell'}(2\ell' + 1)^{1/2}\, e^{i(\sigma_\ell + \sigma_{\ell'})}$$
$$\langle \ell' I - M_I M_I | \ell 0\rangle \langle \ell' I 00 | \ell 0\rangle \frac{\partial^2\eta_\ell}{\partial\ell^2} Y_{\ell'}^{-M_I}(\theta,0)\Big] , \qquad (4)$$

where $C_2(I)$ is a nuclear matrix element involving the square of a coefficient in an expansion of the nuclear radius in terms of spherical harmonics, and is simply related to $C_1(2)$ for rotational and simple vibrational nuclei.

The results of fitting the data for Ni^{58} and Ni^{62} by the procedures outlined above were quite similar. For this reason, figures demonstrating the types of fits so obtained will be presented here only for Ni^{58}. In fig. 4 is shown the fit to the 50-MeV elastic data obtained by use of the expressions given in eqs. (1) and (2). The values of the parameters L, Δ, A, B and D determined by the fitting procedure are listed on the figure. The fits at 50-MeV alpha energy for the levels at 1.45 MeV (2+) and 4.50 MeV (3-) are shown in fig. 5. In each case, the calculated distributions (i.e., by use of eq. (3)) have been normalized to the experimental data at the "first" maximum. From the variation in phase of the angular distribution for excitation of the 4+ level at 2.45 MeV, it was clear that neither the single-phonon expression (eq. (3)) nor the two-phonon expression (eq. (4)) could separately fit the data over the range of alpha particle energies studied in this work. Hence, an effort was made to determined whether the data could be fit by using the sum of eqs. (3) and (4), and a single value for the ratio $R = C_2(I)/C_1(I)$. The best fits obtained for incident alpha particle energies of 33-, 50- and 100-MeV are shown in fig. 6. Here also the experimental and theoretical curves were normalized at the "first" maximum.

From fig. 5, it can be seen that the theory fairly well reproduces the phase of the angular distributions for excitation of the first 2+ and 3- levels, but has difficulty in predicting the fall off of cross sections with increasing angle. For the 4+ level (see fig. 6), the agreement is not nearly so good. We have found that it is not possible to reproduce simultaneously the phase and magnitude of the angular distributions for the 4+ level. These results are comparable with those obtained by preliminary DWB and coupled channel calculations[11,12].

In Table 1 are given the values for the nuclear matrix elements, $C_n(I)$, resulting from the analyses described above. The fact that the values of $C_n(I)$

are relatively independent of the energy of the incident alpha particle is encouraging and would appear to justify the use of the theory noted above. The $C_n(I)$ for the 2+ and 3- levels can be used to calculate reduced electric quadrupole and octupole transition probabilities. This has been done by utilizing the usual collective expression[13]) for the reduced electric transition probability, and the suggestion by Blair that the deformation $\delta_\alpha (= \beta_\alpha R_i)$ as measured by alpha particle scattering should be compared with the electromagnetic value δ_e $(= \beta_e R_e)$. Hence, this leads to the substitution $\beta = \delta_\alpha / R_e$ (or in the terminology given above, $\delta_n(I)/R_e$) in the expression for the reduced transition probability. R_e is the charge radius, and was taken as $1.2 \times 10^{-13}\ A^{1/3}$ cm. The reduced transition probabilities so calculated are also given in Table 1.

The fact that we have observed a level at 3.65 MeV in Ni^{58} and levels at 3.52 and 4.02 MeV in Ni^{62} which also appear to have spin and parity 4+ and cross sections comparable to that for excitation of the first 4+ level, might imply that the 4+ levels are mixed. This would tend to support the assumption of both single and double excitation of these levels. For the simplest form of configuration mixing, the values of $C_1(4)$ and $C_2(4)$ would then depend upon the strength of such mixing. Should such mixing occur, one might expect the phases of the other admixed states to vary with the energy of the incident alpha particles. Although we only have data at 33 and 50 MeV, it appears that this is the case for the 3.65-MeV (probable 4+) level in Ni^{58}.

4. Conclusions

It has been shown here that the phase of the angular distributions of the inelastic groups relative to that of the elastic group varies as a function of the incident alpha particle energy, the most pronounced variation being that arising from excitation of the 4+, "two-phonon" state. The theory of Austern and Blair has been moderately successful in explaining these effects. Whereas the theory has been able to reproduce the phase for the "two-phonon" group, it is unable to fit the fall off of the cross-section with increasing angle. Even with the inclusion of simple configuration mixing, it does not appear that the Austern and Blair model would be successful in simultaneously fitting the phase and slope of the "two-phonon" excitations. It appears that additional experiments, similar to those described in this paper might prove fruitful. In particular, it is suggested that in order to determine the validity of the theories such experiments might be performed on nuclei for which the 4+ state is known to be a pure vibrational or rotational level. Measurements of the angular distributions of inelastically scattered alpha particles as a function of the energy of the incident alpha particle might very well prove to be a means to determine the purity of "two phonon" states.

Acknowledgments

The authors are grateful to Art Springer for a number of enlightening discussions, as well as for making his computer program available to them. We are grateful to Claude Ellsworth for preparing the targets, for the electronic assistance rendered by the group under the direction of Fred Goulding, and of course, to the operating crew of the 88-inch cyclotron.

Table 1.
Nuclear matrix elements and reduced electric transition probabilities for levels in Ni^{58} and Ni^{62} obtained from Austern and Blair model analysis of (α,α') data.

Ni^{58}

α-particle energy (MeV)	1.45 MeV		2.45 MeV		4.50 MeV	
	$C_1(2)^a$	$\frac{B(E2)}{e^2}\downarrow(fm^4)$	$C_1(4)^a$	$C_2(4)^a$	$C_1(3)^a$	$\frac{B(E3)}{e^2}\downarrow(fm^6)$
33	0.37	135	0.063	0.063	0.20	830
50	0.43	179	0.096	0.077	0.24	1080
100	0.35	118	0.037	0.111	0.20	830

Ni^{62}

α-particle energy (MeV)	1.17 MeV		2.33 MeV		3.77 MeV	
	$C_1(2)^a$	$\frac{B(E2)}{e^2}\downarrow(fm^4)$	$C_1(4)^a$	$C_2(4)^a$	$C_1(3)^a$	$\frac{B(E3)}{e^2}\downarrow(fm^6)$
33	0.39	150	.063	.044	0.22	1040
50	0.43	180	.074	.044	0.28	1700
85	0.38	145	.052	.073	0.21	1100
100	0.41	170				

[a]The $C_n(I)$ are given in units of fm.

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Figure Captions

Fig. 1a. Angular distributions for the scattering of 33-MeV alpha particles by the ground, 1.45 (2+, 2.45- (4+) and 4.50- (3-) MeV states of Ni^{58}.

Fig. 1b. Angular distributions for the scattering of 50-MeV alpha particles by the ground, 1.45 (2+), 2.45- (4+) and 4.50- (3-) MeV states of Ni^{58}.

Fig. 1c. Angular distributions for the scattering of 100-MeV alpha particles by the ground, 1.45 (2+), 2.45- (4+) and 4.50- (3-) MeV states of Ni^{58}.

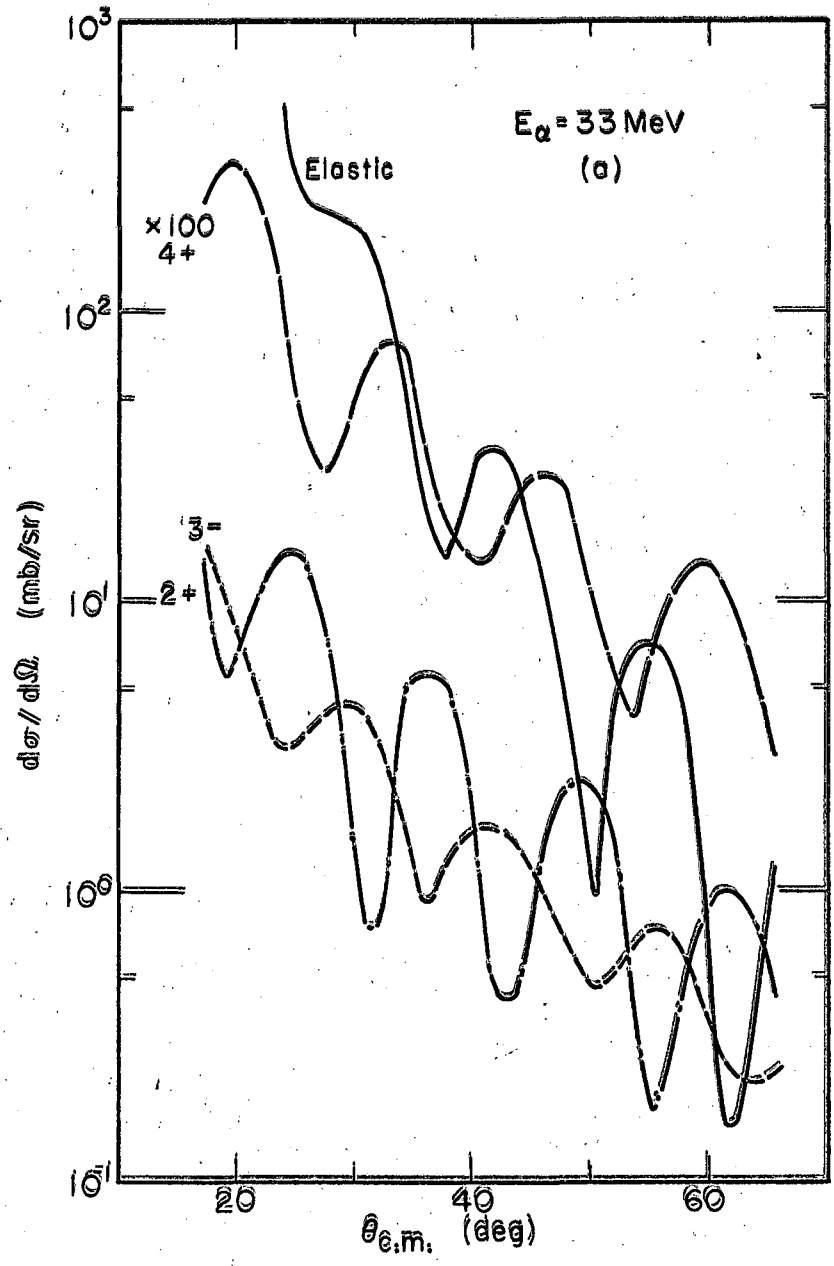
Fig. 2. Variation of the phase of the angular distributions of the inelastic groups relative to that of the elastic group of Ni^{58} as a function of the energy of the incident alpha particles. The spins and parities correspond to the levels at 1.45 MeV (2+), 2.45 MeV (4+) and 4.50 MeV (3-).

Fig. 3. Variation of the phase of the angular distributions of the inelastic groups relative to that of the elastic group of Ni^{62} as a function of the energy of the incident alpha particles. The spins and parities correspond to the levels at 1.17 MeV (2+), 2.33 MeV (4+), and 3.77 MeV (3-).

Fig. 4. Best fit obtained for the elastic scattering cross section of Ni^{58} for an incident alpha particle energy of 50 MeV. The parameters noted on the figure are described in the text.

Fig. 5. Austern and Blair model fits to the 1.17 (2+) and 4.50 (3-) MeV Angular distributions from the scattering of 50-MeV alpha particles by Ni^{58}. The values for the parameters L, Δ, A, B and D were taken from the fit shown in Fig. 4.

Fig. 6. Best fits to the angular distribution of the 2.45- (4+) MeV level of Ni^{58} for incident alpha particle energies of 33, 50 and 100 MeV. The values of the parameters L, Δ, A, B and D were obtained from fits to the elastic data at each energy. The values of R (see the text for definition) obtained from the fits are given in the figure.



MUB-5175

Fig. 1(a).

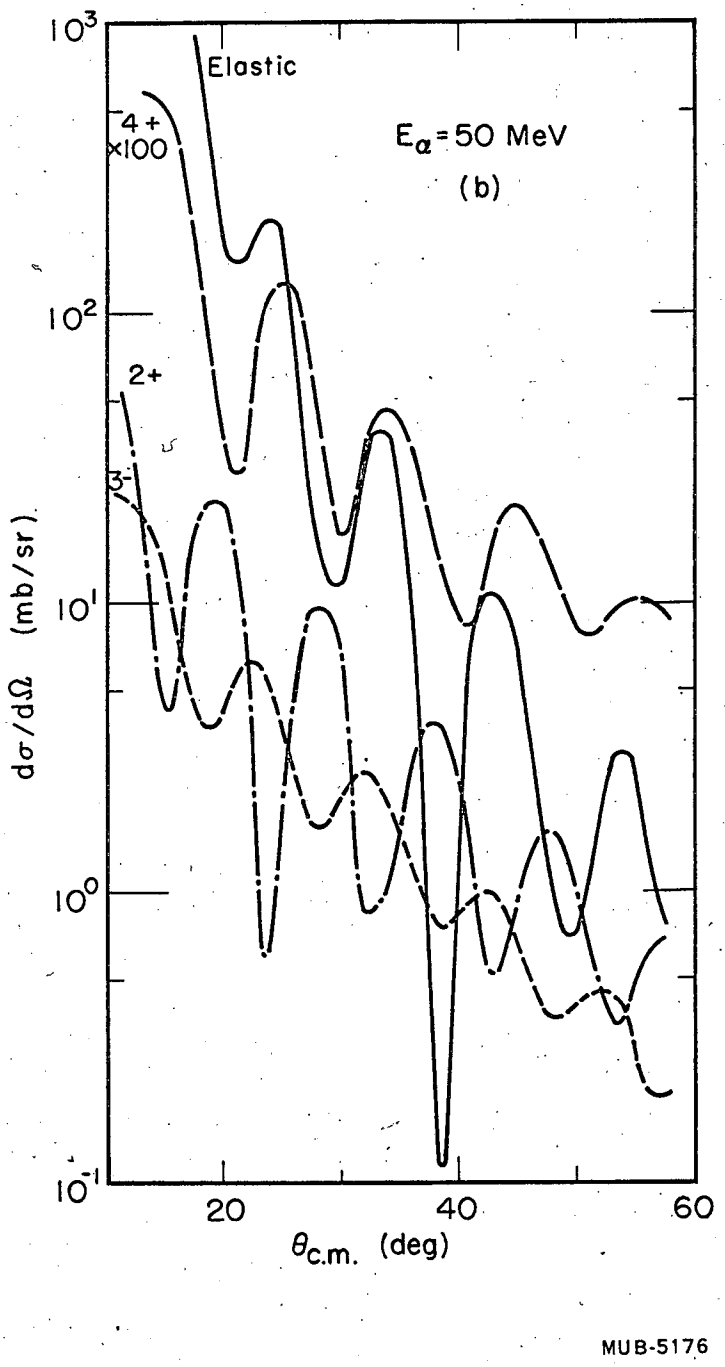
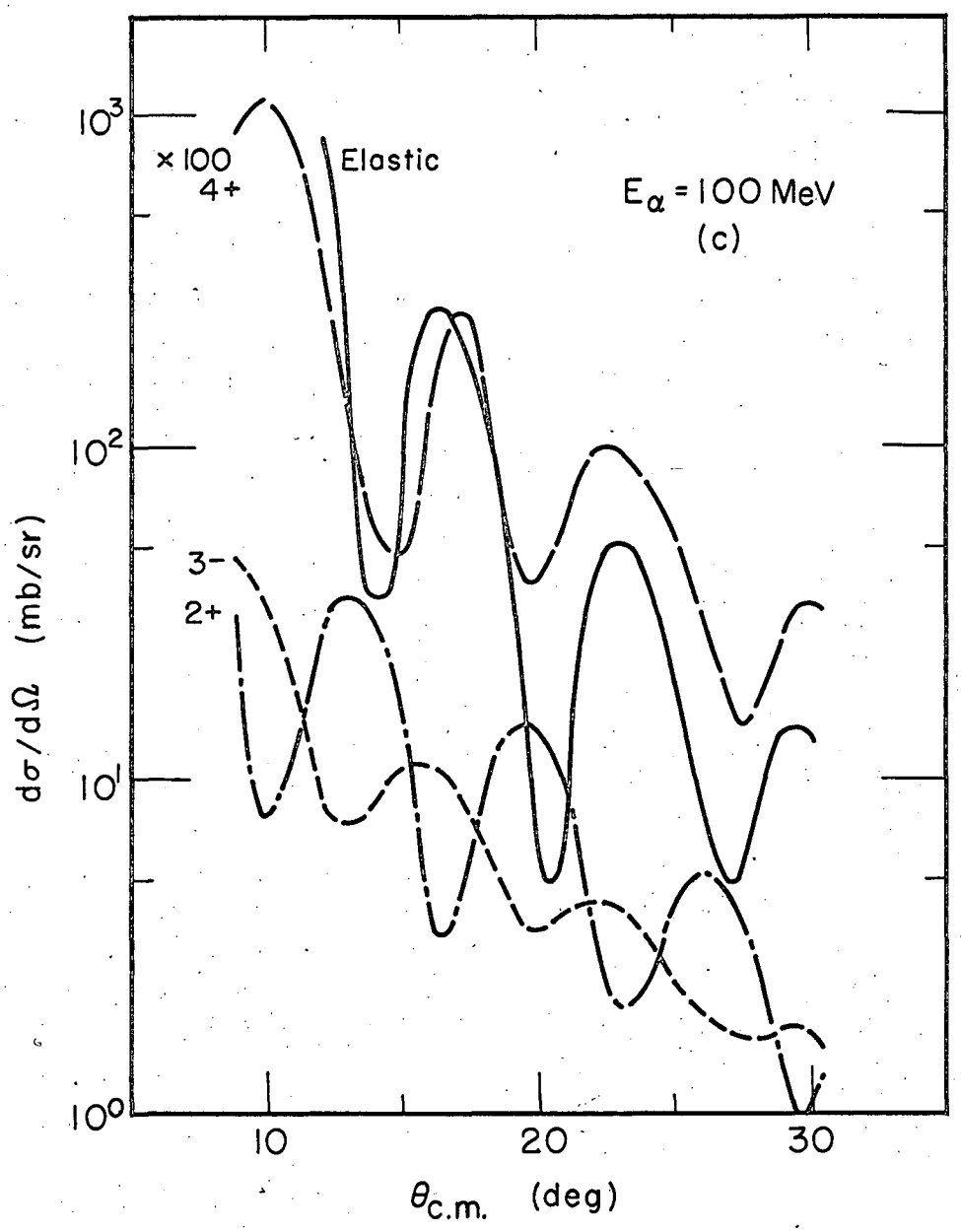
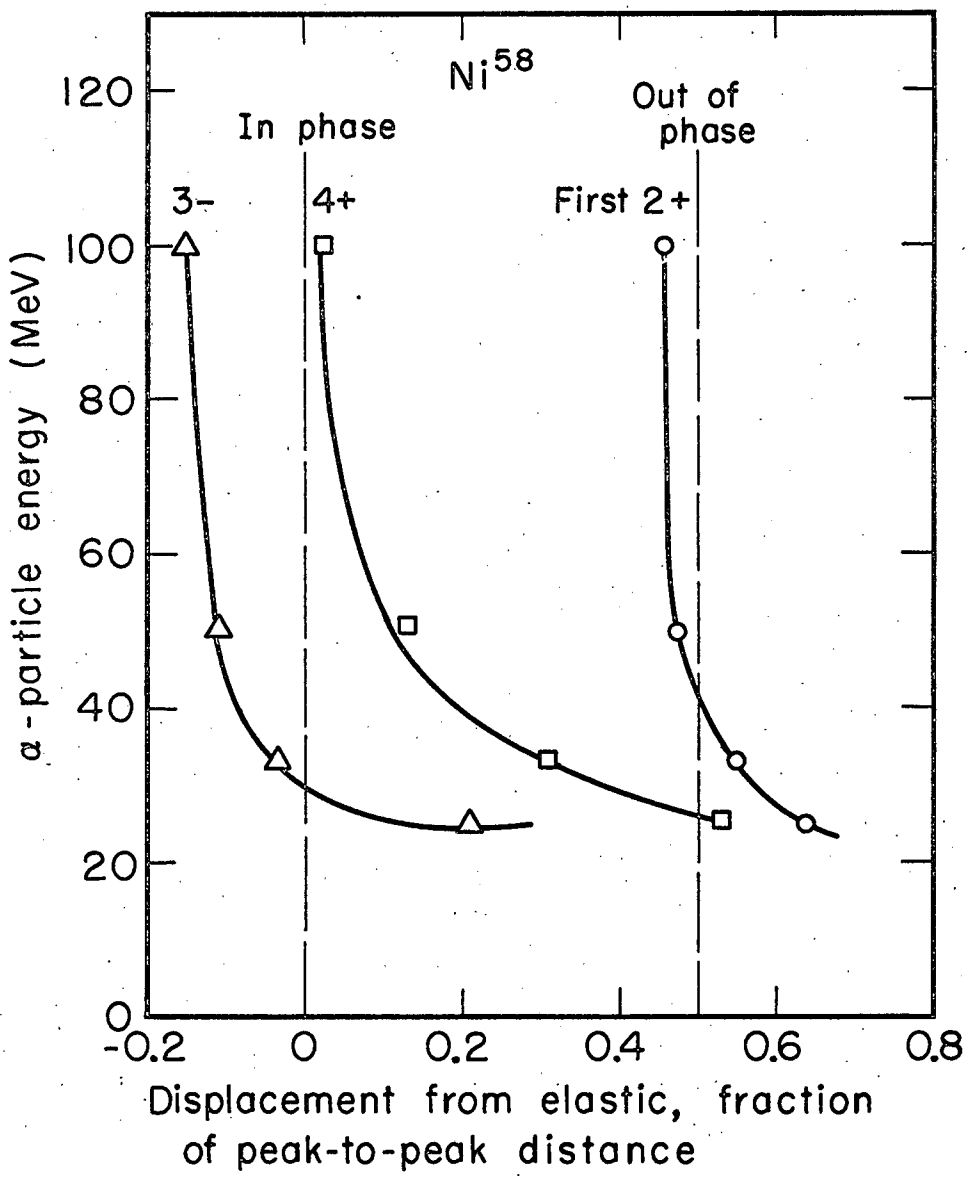

Elastic
4+
×100
E_α = 50 MeV
(b)
2+
3-
10^3
10^2
10^1
10^0
10^{-1}
$d\sigma/d\Omega$ (mb/sr)
20
40
60
$\theta_{c.m.}$ (deg)
MUB-5176

Fig. 1(b).



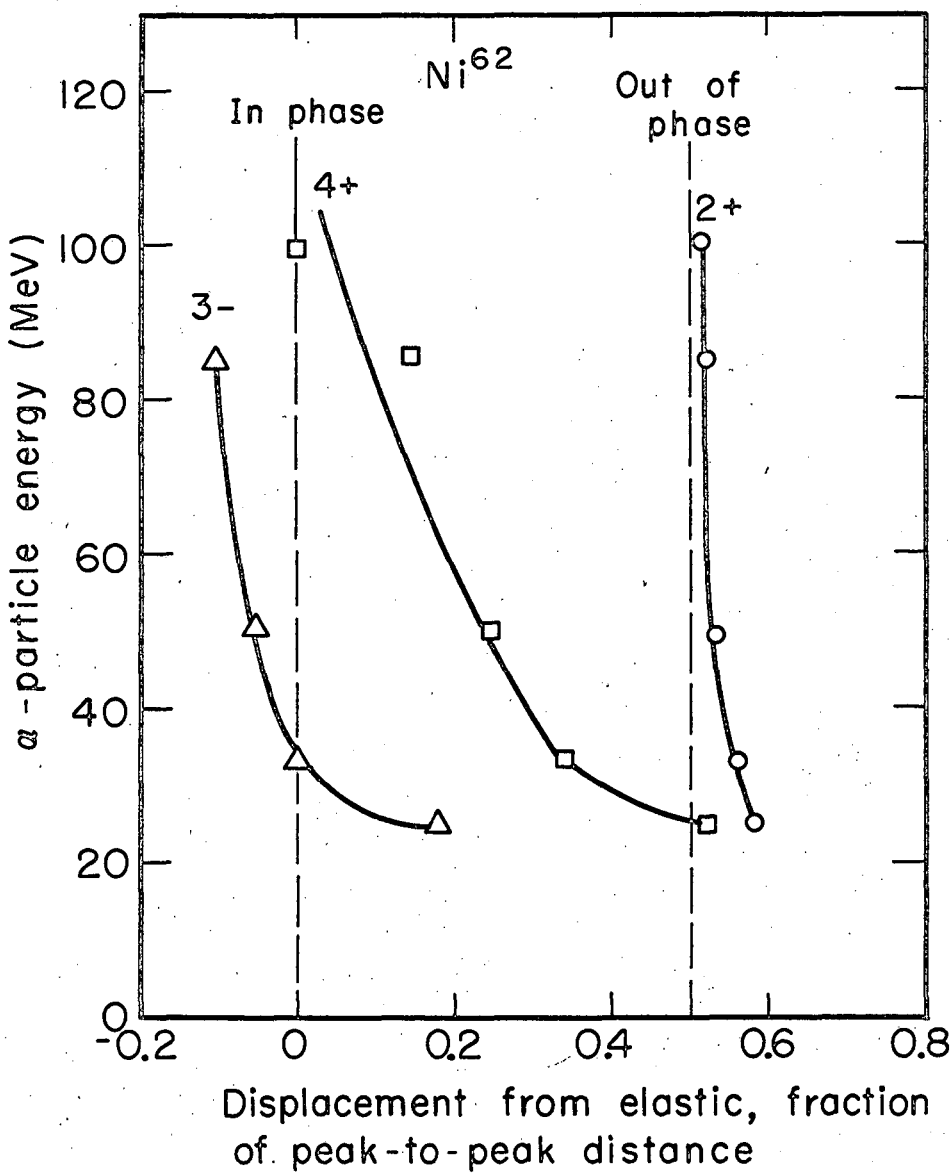
MUB-5177

Fig. 1(c).



MUB-5178

Fig. 2



MUB-5179

Fig. 3.

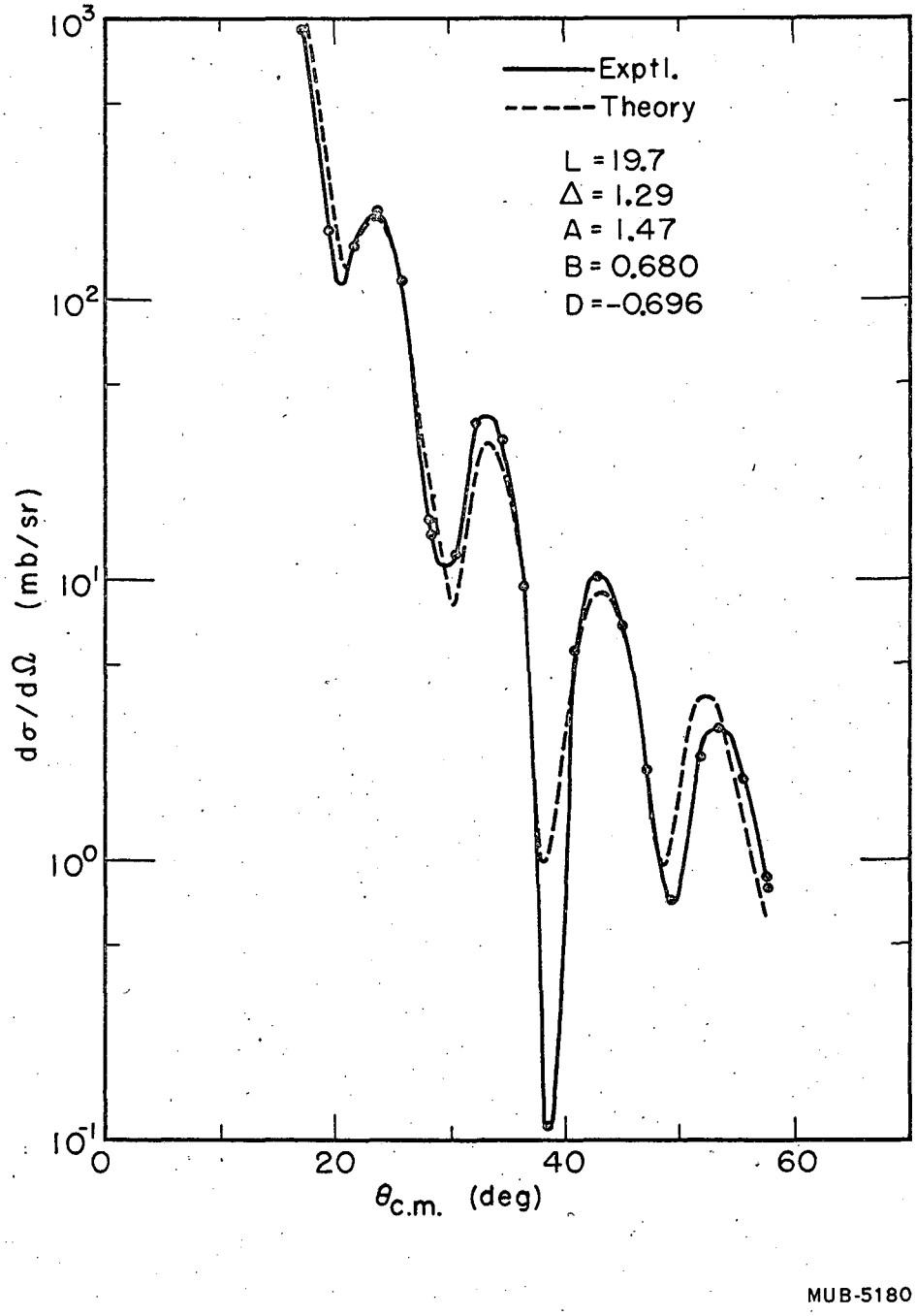

Exptl.
Theory
L = 19.7
Δ = 1.29
A = 1.47
B = 0.680
D = -0.696
10^3
10^2
10^1
10^0
10^{-1}
dσ/dΩ (mb/sr)
0
20
40
60
$\theta_{c.m.}$ (deg)
MUB-5180

Fig. 4.

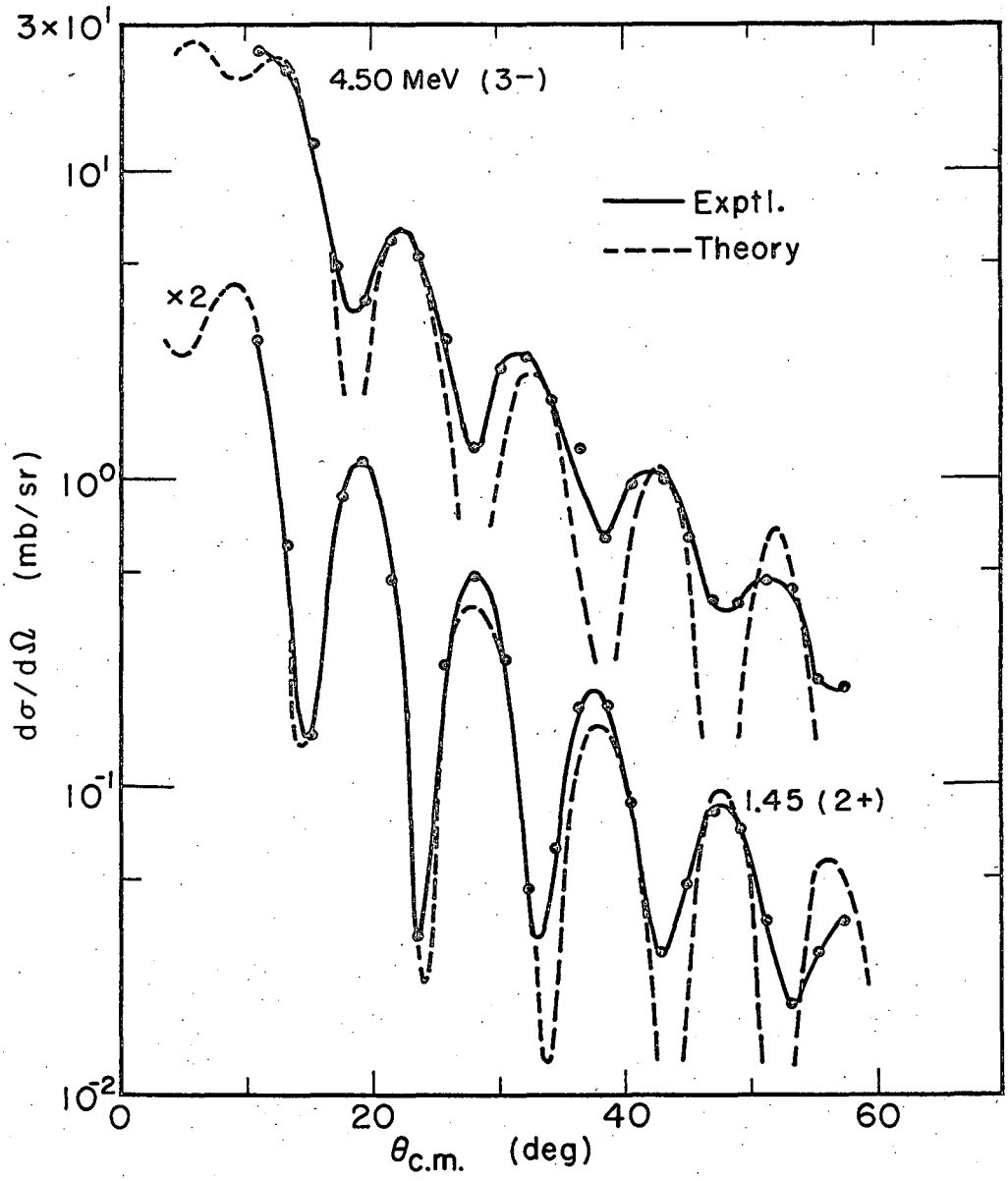
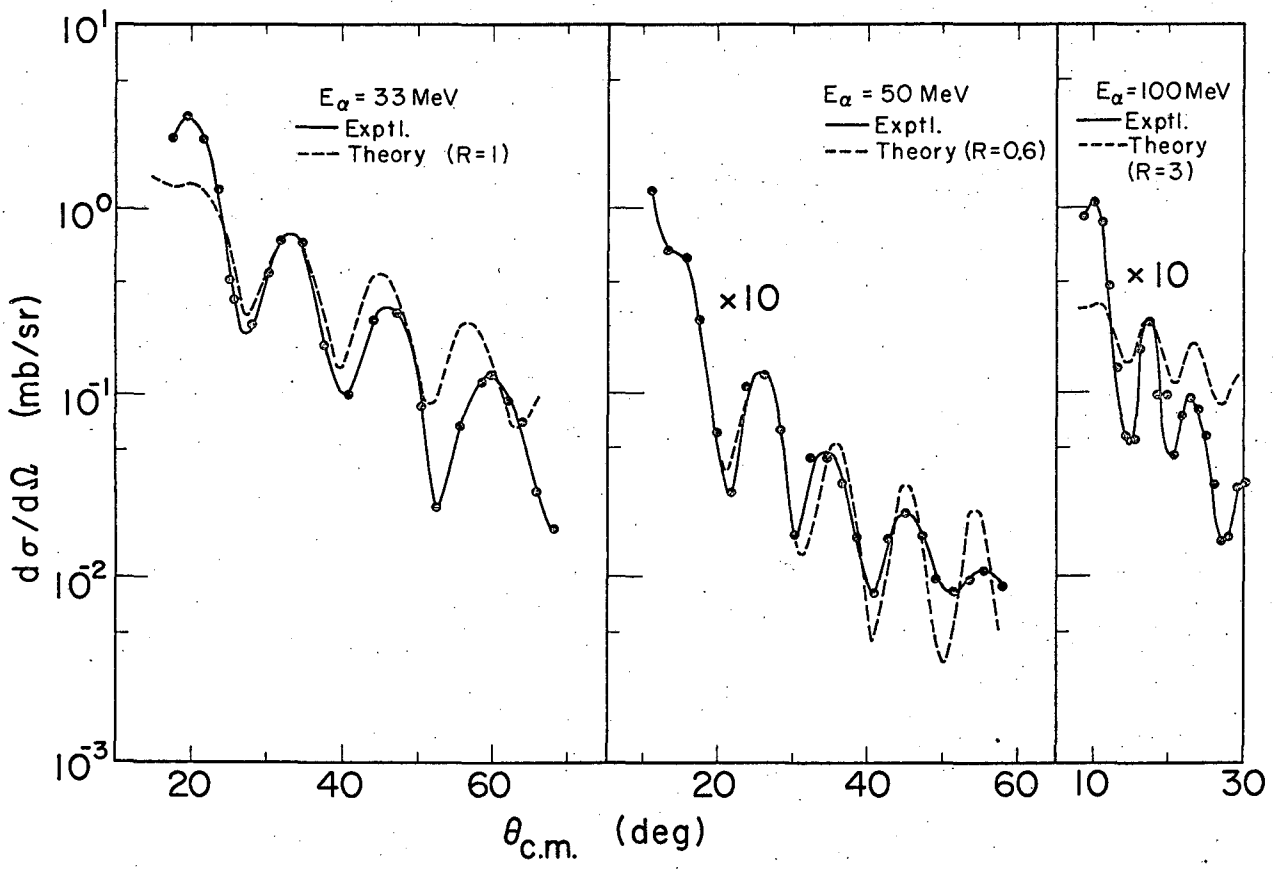

3×10¹
10¹
10⁰
10⁻¹
10⁻²
dσ/dΩ (mb/sr)
4.50 MeV (3−)
Exptl.
Theory
×2
1.45 (2+)
0
20
40
60
θc.m. (deg)
MUB-5181

Fig. 5.



MUB-5182

Fig. 6.

Ni^{58}

Elastic Cross Sections

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
21.7	3174	.010	51.3	25.6	.005
23.9	2147	.013	54.5	14.3	.008
30.2	388	.004	57.5	5.08	.010
32.3	242	.004	59.6	3.41	.013
32.3	255	.004	61.7	5.55	.008
35.5	204	.004	64.8	5.99	.010
38.6	142	.004	67.9	4.19	.009
41.8	62.1	.004	67.9	4.15	.011
45.0	27.5	.006	71.1	1.46	.019
48.1	26.5	.004	74.0	.266	.044

Ni^{58}

1.452 MeV 2+ Level

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
30.3	8.66	.014	54.5	.604	.031
32.4	5.10	.016	57.6	1.37	.021
32.4	6.58	.013	59.7	1.42	.020
35.5	2.33	.021	61.8	1.27	.017
38.7	1.32	.027	64.9	.378	.039
41.9	3.19	.018	68.0	.103	.060
45.1	3.53	.018	71.1	.309	.041
48.2	1.96	.018	74.2	.478	.033
51.4	0.38	.039			

Ni^{58}

2.458 MeV 4+ Level

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
30.3	.556	.054	54.6	.182	.058
32.4	.260	.070	57.7	.152	.063
32.4	.320	.058	59.8	.131	.069
35.6	.340	.056	61.9	.111	.056
41.9	.450	.048	65.0	.038	.20
45.1	.301	.049	68.1	.028	.20
48.3	.096	.077	71.1	.052	.10
51.4	.071	.090	74.3	.037	.20

Ni^{58}

4.56 MeV 3- Level

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
30.4	1.91	.038	48.4	.829	.026
32.5	2.00	.024	51.6	1.13	.023
32.5	2.30	.021	57.9	.579	.031
35.7	2.57	.020	68.3	.432	.029
38.9	2.27	.022	71.4	.308	.041
42.1	1.43	.027	74.2	.248	.046
45.3	.850	.035			

Ni^{58}

3.026 Cross Sections

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractinnal Statistical Error
30.3	.280	.075	59.7	.085	.079
32.4	.264	.063	61.9	.121	.054
35.6	.102	.100	65.0	.049	.103
38.7	.204	.072	68.0	.032	.103
45.1	.234	.068	68.0	.032	.103
48.2	.132	.064	71.1	.032	.146
54.5	.035	.127	74.2	.034	.146
57.7	.075	.085			

Ni^{58}

3.30 Cross Sections

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
30.3	.366	.066	57.7	.057	.100
32.4	.337	.056	59.8	.081	.081
35.6	.195	.073	61.8	.124	.053
38.8	.262	.064	65.0	.071	.088
42.0	.294	.060	68.1	.053	.083
48.3	.202	.052	68.1	.083	.089
51.4	.079	.082	71.2	.044	.127
54.6	.056	.100	74.3	.039	.130

Ni^{58}

Elastic Cross Sections

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.4	3284	.009	43.9	27.3	.004
19.5	2159	.004	47.1	7.06	.009
21.7	1226	.005	50.2	.950	.008
23.8	493	.008	53.4	6.42	.007
25.9	232	.004	55.4	7.38	.007
28.0	202	.004	57.5	5.00	.008
28.0	210.3	.004	59.6	1.36	.016
31.3	174.3	.004	61.7	.159	.046
34.4	55.4	.005	63.8	.300	.033
37.6	14.0	.009	65.8	1.20	.015
40.8	31.7	.004			

Ni^{58}

1.452 MeV 2+ Level

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.4	13.4	.016	44.0	2.450	.034
19.6	5.46	.024	47.2	2.05	.016
21.7	9.41	.013	50.3	2.23	.016
26.0	13.9	.011	53.4	.656	.023
28.1	5.62	.017	55.5	.172	.044
28.1	5.57	.026	57.6	.362	.031
31.3	.743	.050	59.7	.854	.020
34.5	4.98	.016	61.8	.985	.018
37.6	5.31	.017	63.8	.789	.021
40.8	1.45	.019	65.9	.422	.026

Ni^{58}

2.458 MeV 4+ Level

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.4	2.50	.029	44.0	.256	.046
19.6	3.26	.031	47.2	.264	.045
21.7	2.46	.025	50.3	.106	.071
23.9	1.30	.035	53.5	.037	.094
26.0	.421	.061	55.6	.078	.065
28.1	.304	.072	57.7	.120	.052
28.1	.271	.100	59.8	.138	.049
31.3	.689	.052	61.8	.101	.058
34.5	.673	.043	63.9	.055	.077
37.7	.202	.072	66.0	.030	.094
40.9	* .204	.051			

* O^{16} included

Ni^{58}

4.56 MeV 3- Level

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.5	14.2	.015	44.1	1.42	.030
19.6	9.88	.018	47.3	.701	.027
21.8	5.29	.017	50.5	.452	.034
23.9	3.05	.023	53.6	.622	.023
26.0	3.42	.022	55.7	.749	.021
28.2	4.34	.019	57.8	.609	.024
28.2	4.33	.028	59.9	.362	.029
31.4	3.65	.031	62.0	.243	.037
34.6	1.65	.027	64.0	.221	.039
37.8	1.19	.030	66.1	.245	.032
41.0	1.67	.018			

Ni^{58}

Elastic Cross Sections

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.4	917	.004	40.8	5.66	.008
20.0	183	.004	42.9	10.27	.004
21.7	156	.004	45.0	6.74	.004
23.8	212	.004	47.1	2.05	.013
25.9	119	.004	49.2	.712	.015
28.1	16.9	.010	51.3	2.37	.012
28.1	21.5	.007	51.3	2.26	.010
28.1	14.6	.010	53.4	3.00	.009
30.2	12.8	.008	55.5	1.96	.011
32.3	36.6	.005	55.5	2.13	.039
34.4	31.4	.005	57.6	.863	.062
36.5	9.46	.009	57.6	.791	.018
38.7	.113	.060			

Ni^{58}

1.452 MeV 2+ Level

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
11.0	55.6	.007	34.5	1.25	.025
13.1	16.3	.014	36.6	3.57	.015
15.3	4.31	.027	38.7	3.67	.010
17.4	17.5	.014	40.8	1.79	.015
19.5	23.0	.008	42.9	.559	.019
21.9	9.41	.013	45.0	.995	.018
23.8	.613	.050	47.1	1.68	.014
25.9	5.30	.017	49.2	1.47	.011
28.1	9.29	.014	51.3	.719	.018
28.1	10.3	.010	53.4	.393	.025
28.1	9.37	.013	55.5	.567	.021
30.2	5.24	.013	57.6	.734	.018
32.3	.902	.029			

Ni^{58}

2.458 MeV 4+ Level

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
11.0	11.9	.015	34.5	.438	.042
13.2	5.86	.024	36.6	.323	.050
15.3	5.23	.024	38.7	.160	.050
17.4	2.41	.036	40.8	.081	.070
19.6	.623	.050	42.9	.157	.035
21.7	.282	.074	45.1	.220	.038
23.8	1.08	.038	47.2	.161	.044
26.0	1.25	.035	49.3	.096	.041
28.1	.562	.053	51.4	.082	.054
28.1	.720	.036	53.4	.093	.051
28.1	.589	.052	55.6	.107	.047
30.3	.164	.069	57.7	.089	.052
32.4	.441	.042			

Ni^{58}

4.5 MeV 3- Level

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
11.0	24.3	.010	34.5	1.79	.021
13.2	20.8	.013	36.7	1.51	.024
15.3	12.0	.016	38.8	.742	.024
17.4	4.83	.025	40.9	.948	.021
19.6	4.00	.020	43.0	.970	.016
21.7	6.13	.016	45.1	.638	.023
23.9	5.30	.017	47.2	.403	.028
26.0	2.90	.024	49.3	.394	.020
28.1	1.59	.031	51.4	.454	.023
28.1	1.89	.024	53.5	.433	.024
28.1	1.65	.030	55.6	.217	.033
30.3	2.37	.018	57.7	.209	.033
32.4	2.62	.018			

Ni^{58}

3.026 MeV

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
19.7	1.228	.035	40.8	.175	.048
21.8	.751	.045			
26.1	.180	.092	45.1	.031	.110
28.2	.547	.054	47.2	.056	.075
28.2	.630	.041	49.3	.075	.047
30.5	.570	.038	51.4	.050	.080
32.4	.220	.060	51.4	.056	.065
34.4	.068	~.120	53.5	.033	.084
36.6	.150	.072	55.6	.020	~.15
38.7	.230	.042	57.7	.030	.088

Ni^{58}

3.30 MeV

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
19.7	1.70	.030	40.8	.228	.042
21.8	1.05	.038			
26.1	.247	.079	45.1	.039	.090
28.2	.669	.048	47.2	.076	.065
28.2	.685	.039	49.3	.111	.038
30.5	.275	.054	51.4	.084	.063
32.4	.347	.047	51.4	.079	.055
34.6	.055	~.15	53.5	.044	.073
38.7	.239	.041	55.6	.021	~.12
			57.7	.041	.075

Ni^{58}

3.60 MeV

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
19.7	.658	.049			
21.8	.162	.100	45.1	.086	.061
26.1	.572	.053	47.2	.089	.060
28.2	.413	.062	49.3	.066	.050
28.2	.534	.042	51.4	.037	.093
30.5	.193	.064	51.4	.033	.084
32.4	.213	.061	53.5	.036	.080
34.6	.150	.073	55.6	.048	.071
36.6	.220	.060	57.7	.047	.071
38.7	.120	.058			

Ni^{58}

4.8 MeV

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
19.7	1.098	.037	40.9	.117	.059
21.8	.353	.066			
26.1	.955	.041	45.1	.132	.050
28.2	.727	.046	47.2	.159	.045
28.2	.885	.034	49.3	.113	.038
30.3	.299	.051	51.4	.060	.073
32.5	.193	.064	51.4	.069	.059
34.6	.258	.030	53.5	.046	.072
36.7	.398	.045	55.6	.064	.063
38.8	.271	.039	57.7	.076	.057

Ni^{58}

Elastic Cross Sections

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.9	2404	.005	20.6	5.05	.023
9.9	2535	.005	21.7	29.7	.009
11.0	1794	.006	21.7	31.8	.009
12.1	813	.004	22.8	50.4	.005
13.1	194	.004	23.8	42.1	.006
14.2	340	.009	24.9	22.5	.008
15.3	161	.004	26.0	7.65	.024
16.3	251	.004	27.0	4.80	.017
17.4	202	.004	28.1	9.48	.012
18.5	97.5	.004	29.1	14.2	.008
19.6	17.5	.013	30.2	12.8	.010

Ni^{58}

1.452 MeV 2+ Level

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.9	32.2	.009	20.6	10.7	.016
9.9	8.38	.018	21.7	5.26	.023
11.0	12.6	.015	21.7	4.88	.024
12.1	29.8	.010	22.8	2.04	.026
13.2	25.4	.006	23.8	2.57	.023
14.2	28.8	.009	24.9	4.41	.018
15.3	13.1	.010	26.0	5.27	.016
16.3	3.48	.019	27.0	4.32	.018
17.4	5.43	.022	28.1	2.50	.023
18.5	12.5	.010	29.2	1.25	.026
19.6	14.1	.014	30.2	1.28	.032

Ni^{58}

2.458 MeV 4+ Level

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.9	8.97	.018	20.6	.458	.075
9.9	10.9	.016	21.7	.870**	.055
11.0	8.36	.018	21.7	.750**	.060
12.1	3.80	.026	22.8	.955**	.037
13.2	1.38	.030	23.8	.806	.041
14.2	.574	.068	24.9	.582	.048
15.3	.537	.050	26.0	.316	.065
16.4	1.75	.027	27.0	.158	.093
17.4	2.45	.033	28.1	.162	.090
18.5	.977*	.037	29.2	.300	.055
19.6	.960*	.053	30.2	.316	.065

* C^{12}

** O^{16}

Ni^{58}

4.5 MeV 3- Level

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.9	46.3	.008	20.6	3.87	.026
10.0	33.8	.009	21.7	4.21	.025
11.0	21.2	.011	21.7	4.51	.025
12.1	8.87	.018	22.8	4.10	.018
13.2	7.68	.013	23.9	3.43	.020
14.2	9.42	.017	24.9	2.45	.024
15.3	11.2	.011	26.0	2.01	.026
16.4	10.5	.011	27.1	1.73	.027
17.4	7.30	.019	28.1	1.66	.028
18.5	5.02	.017	29.2	1.84	.023
19.6	3.58	.027	30.3	1.59	.029

Ni^{62}

Elastic Cross Sections

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}
21.3	1816	.001	.288	50.8	14.1	.010	.065
25.5	756	.002	.244	52.9	13.5	.010	.072
27.6	482	.002	.195	54.9	7.54	.013	.046
29.7	254	.002	.159	57.0	4.70	.017	.033
31.9	220	.002	.170	59.1	2.75	.021	.022
34.0	144	.004	.143	61.2	2.95	.021	.026
36.1	119	.004	.149	63.2	4.24	.018	.043
38.2	98.2	.004	.153	65.3	5.06	.016	.058
40.3	66.1	.004	.126	67.4	4.77	.014	.062
42.4	29.5	.004	.069	69.4	3.10	.018	.044
44.5	19.4	.008	.054	71.5	1.50	.025	.024
46.6	15.5	.009	.052	73.5	.592	.039	.010
48.7	16.8	.009	.066				

Ni^{62}

1.17 MeV 2+ Level

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
19.2	1.64	.034	50.8	.465	.050
21.3	2.02	.058	52.9	.268	.070
23.4	4.93	.085	55.0	.503	.050
29.8	3.47	.018	57.1	.819	.040
31.9	6.92	.018	59.2	.915	.038
34.0	3.70	.024	61.2	.831	.040
36.1	2.00	.032	63.3	.551	.049
38.2	1.17	.042	65.4	.337	.064
40.4	1.24	.033	67.4	.216	.067
42.5	1.55	.028	69.7	.275	.060
44.6	1.99	.025	71.5	.419	.048
46.7	1.65	.027	73.6	.568	.041
48.8	1.14	.033			

Ni^{62}

2.33 MeV 4+ Level

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
25.7	.454	.068	55.2	.084	.19
27.7	.265	.063	57.3	.107	.11
29.8	.202	.086	59.4	.071	.14
36.3	.150	.096	61.3	.069	.14
40.5	.221	.073	63.5	.048	.16
42.5	.195	.078	65.6	.035	.19
44.5	.158	.089	67.7	.040	.15
48.8	.039	.18	69.7	.054	.13
50.8	.044	.17	71.8	.058	.13
52.9	.052	.15	73.8	.079	.11

Ni^{62}

3.77 MeV 3- Level

E_α = 25 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.1	1.14	.096	44.7	.346	.062
19.3	.650	.058	46.8	.320	.080
21.4	1.09	.068	53.1	.617	.045
23.5	.762	.062	55.2	.415	.056
25.7	1.09	.042	57.3	.291	.068
27.8	.601	.044	59.4	.211	.078
29.9	.384	.064	63.5	.167	.086
32.0	1.11	.043	65.6	.249	.074
34.2	1.38	.038	67.7	.350	.052
36.3	1.40	.038	69.7	.327	.054
38.4	1.37	.038	71.8	.275	.060
40.5	1.04	.034	73.8	.170	.075
42.6	.462	.065			

Ni^{62}

Elastic Cross Sections

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}
8.5	175113	.001	1.25	61.2	.222	.032	.003
10.6	74070	.001	1.27	63.2	.842	.016	.015
12.8	30799	.001	1.12	65.3	2.09	.010	.043
14.9	11744	.001	.786	67.4	2.48	.010	.056
14.9	11338	.001	.802	69.4	1.85	.011	.046
17.02	5233	.001	.591	71.5	.744	.018	.021
19.2	3402	.001	.622	73.5	.091	.050	.003
21.3	1968	.001	.542	75.6	.094	.050	.003
23.4	653	.002	.261	77.6	.472	.016	.017
25.5	384	.002	.216	79.6	.815	.012	.033
27.6	297	.002	.227	81.7	.841	.012	.036
29.8	284	.002	.294	83.7	.609	.014	.029
31.9	200	.004	.270	85.7	.289	.021	.015
31.9	207	.004	.280	87.7	.092	.036	.005
34.0	98.7	.004	.171	89.7	.066	.030	.004
36.1	32.3	.006	.070	91.7	.153	.020	
38.2	26.5	.007	.072	93.7	.266	.015	
40.3	40.4	.004	.135	95.7	.323	.014	
42.4	41.6	.004	.169	95.7	.308	.033	
44.5	26.6	.007	.130	97.7	.281	.014	
46.6	9.13	.011	.053	97.7	.279	.035	
48.7	1.90	.026	.013	99.7	.200	.018	
50.8	4.04	.018	.032	101.7	.105	.026	
50.8	4.92	.004	.040	103.7	.041	.037	
52.9	7.96	.013	.074	105.7	.023	.049	
52.9	9.43	.003	.088	107.6	.037	.039	
54.9	10.00	.003	.106	109.6	.063	.026	
57.02	6.30	.004	.078	111.6	.085	.026	
59.1	2.23	.010	.031	113.5	.079	.027	

Ni^{62}

1.17 MeV 2+ Level

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.3	90.5	.072	63.1	1.11	.015
10.4	26.1	.077	65.2	.629	.018
12.6	38.8	.035	67.2	.190	.035
14.7	53.0	.022	69.3	.111	.050
14.7	44.9	.022	71.3	.306	.027
16.8	21.8	.015	73.4	.469	.022
18.9	4.04	.010	75.4	.505	.022
25.3	26.7	.008	77.5	.359	.018
29.6	3.34	.022	79.5	.179	.026
31.6	1.61	.06	81.5	.074	.040
31.7	1.93	.05	83.5	.087	.036
33.8	6.12	.02	85.6	.172	.026
35.9	9.32	.05	87.6	.485	.023
38.0	7.55	.02	89.6	.251	.016
40.1	3.18	.02	91.6	.217	.017
42.2	.494	.04	93.6	.134	.022
44.3	1.01		95.6	.082	.027
46.4	2.87	.01	95.6	.088	.062
48.5	3.82		97.6	.059	.030
50.6	2.77	.01	97.6	.051	.079
50.6	2.95	.01	99.6	.071	.030
52.7	1.23	.04	101.6	.097	.027
52.7	1.33	.01	103.5	.126	.022
54.8	.308	.01	105.5	.127	.022
57.1	.393	.02	107.5	.112	.023
59.0	.983	.02	109.5	.084	.026
61.0	1.36	.013	111.4	.060	.030

Ni^{62}

2.33 MeV 4+ Level

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
14.7	4.52	.064	61.1	.175	.035
16.8	3.30	.047	63.1	.095	.047
19.0	2.68	.042	65.2	.059	.061
21.1	2.68		67.3	.060	.061
23.2	1.56	.045	69.3	.096	.048
25.3	.989	.040	71.3	.099	.048
27.5	.706	.046	73.4	.085	.052
29.6	.786	.045	75.5	.065	.059
33.8	.921	.042	77.5	.050	.048
35.9	.723	.047	79.6	.039	.055
42.3	.242	.058	81.6	.044	.051
44.3	.325		83.6	.046	.050
46.4	.417	.063	85.6	.051	.048
48.5	.238		87.7	.048	.049
50.6	.083	.140	89.7	.040	.038
50.7	.125	.029	91.7	.032	.043
52.7	.054	.187	93.7	.032	.043
52.8	.064	.041	95.7	.031	.044
54.8	.124	.029	97.7	.035	.041
56.9	.202	.024	99.7	.031	.044
59.0	.220	.031	101.6	.031	.048

Ni^{62}

3.77 MeV 3- Level

E_α = 33 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
14.7	21.4	.029	61.0	.213	.031
16.8	17.8		63.2	.176	.036
19.0	13.4	.019	65.2	.312	.028
21.1	6.07		67.4	.421	.022
23.2	2.60	.011	69.4	.386	.024
25.4	3.79		71.5	.313	.027
27.5	6.15	.017	73.5	.196	.034
29.6	6.98	.016	75.6	.101	.049
31.7	4.88	.031	77.6	.084	.038
31.8	4.74	.031	79.6	.124	.031
33.8	2.05	.027	81.7	.161	.031
36.0	.779	.045	83.7	.151	.029
38.1	1.46	.033	85.7	.136	.029
40.3	2.90	.017	87.7	.174	.037
44.4	1.88		89.8	.064	.031
46.5	.835	.044	91.8	.048	.035
48.6	.249		93.8	.061	.031
50.8	.565	.014	95.8	.074	.028
52.8	.911	.042	97.8	.060	.031
54.9	1.12	.008	99.8	.073	.028
57.0	.897	.011	101.7	.073	.031
59.0	.514	.022			

Ni^{62}

Elastic Cross Sections

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractinnal Statistical Error	σ/σ_{RUTH}
6.3	574000	.001	2.81	27.5	14.7	.001	.025
7.4	115000	.001	1.08	27.6	33.0	.001	.058
8.4	58115	.001	.908	28.7	9.89	.001	.020
9.5	29176	.001	.746	28.9	9.17	.001	.019
10.6	15389	.001	.607	29.6	27.2	.001	.063
11.6	7443	.001	.419	29.8	33.0	.001	.078
12.7	4931	.001	.401	31.8	50.6	.001	.155
13.7	4000	.001	.443	31.8	87.4	.001	.205
14.8	3660	.001	.546	32.8	45.2	.001	.156
15.9	2505	.001	.498	33.9	30.4	.001	.119
16.9	1457	.001	.369	34.0	37.1	.001	.147
17.6	1110	.001	.330	34.9	18.3	.001	.080
18.0	732	.001	.238	35.9	8.98	.001	.044
18.6	497	.001	.184	36.5	1.95	.002	.010
19.0	313	.001	.126	37.2	.681	.003	.004
19.7	195	.001	.090	38.2	3.49	.001	.021
20.2	198	.001	.102	39.3	7.96	.001	.055
21.1	235	.001	.143	40.3	9.65	.001	.074
22.0	258	.001	.186	41.4	9.23	.001	.078
23.3	282	.001	.255	42.4	7.42	.001	.069
23.4	291	.001	.267	43.5	4.71	.001	.048
24.1	237	.001	.244	44.5	1.91	.001	.021
25.0	181	.001	.216	46.6	.355	.003	.005
25.4	131	.001	.165	48.7	1.65	.001	.025
26.1	88.6	.001	.125	50.8	2.36	.001	.044
				52.9	1.37	.001	.029

Ni^{62}

1.17 MeV 2 + Level

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.6	24.7	.017	35.0	2.25	.012
18.6	31.6	.010	35.9	4.46	.011
19.7	28.5	.008	36.5	5.85	.010
20.2	21.4	.011	37.2	4.69	.011
22.0	8.86	.012	38.2	3.71	.010
23.4	2.22	.027	39.3	2.18	.016
24.1	* 1.45	.022	40.3	.862	.019
25.0	4.38	.016	41.4	.518	.021
26.1	8.50	.009	42.4	.724	.021
27.7	12.2	.008	43.5	1.03	.020
28.7	11.2	.006	44.5	1.50	.014
28.9	11.8	.007	46.6	1.60	.012
29.8	5.08	.011	48.7	.832	.016
31.8	3.65	.011	50.8	.288	.026
32.8	.603	.030	52.9	.371	.023
34.0	1.08	.027			

* OXYGEN CONTAMINATION

Ni^{62}

2.33 MeV 4+ Level

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.6	3.10	.055	35.0	.473	.025
18.7	1.89	.044	36.0	.534	.032
19.7	1.25	.036	36.6	.477	.033
22.1	.754	.041	37.2	.232	.048
23.4	.977	.041	38.3	.173	.045
24.1	1.42	.022	39.3	.157	.058
25.0	2.29	.022	40.4	.166	.044
26.1	1.12	.021	41.4	.232	.031
27.7	1.03	.027	42.5	.283	.032
28.8	.633	.024	43.5	.294	.037
29.0	.699	.027	44.6	.242	.033
29.8	* .603	.032	46.7	.168	.037
31.8	* .194	.022	48.8	.103	.044
32.9	.424	.036	50.9	.119	.041
34.0	.552	.038	53.0	.144	.037

* OXYGEN CONTAMINATION

Ni^{62}

3.77 MeV 3- Level

E_α = 50 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
17.6	2.63	.059	35.0	1.10	.017
18.7	2.71	.037	36.0	.651	.028
19.7	5.14	.018	36.6	.463	.034
20.8	8.14	.018	37.2	.663	.028
22.1	9.65	.012	38.3	1.10	.018
23.5	8.98	.014	39.4	1.47	.019
24.1	6.32	.010	40.4	1.23	.017
25.1	3.99	.017	41.5	1.07	.015
26.1	1.70	.020	42.5	.832	.019
27.7	1.02	.027	43.6	.575	.027
28.8	1.27	.017	44.6	.615	.030
29.0	1.44	.019	46.7	.273	.028
29.8	3.44	.014	48.8	.422	.022
31.8	* 7.42	.008	50.9	.481	.020
32.9	2.54	.012	53.0	.300	.026
34.1	1.87	.015			

*

Ni^{62}

Elastic Cross Sections

E_α = 85 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}	θ_{cm} (DEG)	$d\sigma/d$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}
8.5	6966	.004	.330	29.8	9.15	.008	.064
9.6	3834	.004	.294	30.8	14.5	.009	.115
10.6	3666	.004	.417	31.9	12.2	.007	.110
11.7	3083	.004	.512	32.9	9.37	.008	.095
12.8	3386	.004	.818	34.0	5.38	.011	.062
13.9	561	.004	.187	35.1	2.45	.016	.032
14.9	115.4	.007	.051	36.1	1.92	.018	.028
16.0	137.6	.004	.081	37.2	2.82	.015	.045
17.0	241.7	.004	.181	38.2	4.06	.013	.072
18.1	298.8	.004	.297	39.3	5.89	.009	.120
19.2	205	.004	.249	40.3	3.52	.012	.078
20.2	78.7	.007	.118	41.4	2.48	.016	.062
21.3	3.57	.018	.006	42.4	1.63	.019	.044
22.4	12.32	.007	.027	43.5	1.21	.022	.035
23.4	42.3	.004	.112	44.5	1.28	.022	.041
24.5	59.2	.004	.188	45.6	1.37	.022	.049
25.5	48.4	.004	.180	46.6	1.34	.022	.051
26.6	27.8	.004	.122	47.7	1.24	.022	.052
27.7	6.68	.009	.035	47.7	2.18	.022	.091
28.7	2.84	.016	.017	48.7	.90	.026	.041
				52.9	.61	.030	.038

Ni^{62}

3.77 MeV 3- Level

E_α = 85 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
16.0	12.7	.014	32.0	1.60	.020
17.1	12.6	.018	33.0	1.11	.024
18.1	10.5	.019	34.0	.72	.029
19.2	5.44	.027	35.1	.50	.035
21.3	2.47	.022	37.2	.80	.028
22.4	4.47	.011	38.2	.71	.029
23.5	6.15	.010	39.3	1.04	.022
24.5	5.38	.010	40.3	.56	.030
25.6	3.58	.013	41.4	.43	.037
28.8	1.56	.019	42.4	.34	.041
29.8	2.51	.015	44.5	.19	.042
30.9	2.40	.022			

Ni^{62}

Elastic Cross Sections

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}	θ_{cm} (DEG)	$d\sigma/d$ (mb/SR)	Fractional Statistical Error	σ/σ_{RUTH}
8.5	3430	.013	.225	20.2	9.04	.018	.015
9.6	3720	.008	.395	21.3	47.7	.005	.121
10.7	2650	.015	.378	22.4	67	.007	.208
11.7	1270	.004	.297	23.4	54.6	.008	.201
12.8	308	.004	.101	24.5	25.0	.008	.110
13.9	60.6	.010	.027	25.5	5.93	.022	.030
14.9	239	.005	.147	26.6	6.88	.015	.042
16.0	366	.004	.298	27.7	1.46	.010	.010
17.1	294	.004	.312	28.7	1.91	.009	.016
18.1	118	.005	.157	29.8	1.65	.010	.015
19.2	18.5	.013	.031	30.8	10.5	.012	.113
				31.9	5.04	.018	.063

Ni^{62}

1.17 MeV 2+ Level

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.5	45.3	.012	21.3	8.72	.012
9.6	17.6	.019	22.4	3.19	.030
10.7	16.4	.019	23.4	2.52	.034
11.7	47.4	.016	24.5	6.62	.017
12.8	57.4	.010	25.5	8.26	.019
13.9	49.2	.011	26.6	7.09	.015
14.9	21.2	.017	27.7	4.17	.019
17.1	5.38	.027	28.7	2.14	.027
18.1	16.8	.014	29.8	1.70	.029
19.2	22.1	.012	30.8	2.56	.024
20.2	17.7	.013	31.9	3.30	.022

Ni^{62}

2.33 MeV 4+ Level

E_α = 100 MeV

θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error	θ_{cm} (DEG)	$d\sigma/d\Omega$ (mb/SR)	Fractional Statistical Error
8.5	3.43	.042	22.4	~ .91	.058
9.6	14.9	.020	23.4	1.38	.047
10.7	9.79	.025	24.5	.797	.043
11.7	5.03	.049	25.5	.541	.074
12.8	3.27	.043	26.6	.578	.051
13.9	~1.2	.070	27.7	.493	.055
14.9	1.36	.066	28.7	.582	.051
16.0	3.0	.045	29.8	.706	.046
19.2	~ .3	.100	30.8	.687	.047
20.3	<1.56*	.043	31.9	.514	.055
21.3	<1.68*	.027			

* OXYGEN CONTAMINATION

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