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

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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, $\sigma_\ell$ the Coulomb phase shift for the $\ell$th partial wave, $\eta_\ell$ the complex amplitude of the $\ell$th outgoing partial wave, $P_\ell(\cos\theta)$ the Legendre polynomial of order $\ell$, and k the relative wave number. The form of $\eta_\ell$ 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 $\eta_\ell$, the parameters L, $\Delta$, 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 $\eta_\ell$ 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

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

where $C_1(I) = \delta_1(I)/\sqrt{2I+1}$, and $\delta_1(I)$ is related to the deformation parameter, $\beta_1(I)$ as $\delta_1(I) = \beta_1(I)R_0$. The quantities in brackets are Clebsch-Gordan coefficients. The derivative of $\eta_\ell$ is to be evaluated at $\bar{\ell} = (\ell+\ell')/2$. For an excitation involving two phonons, the amplitude is given by

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

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, $\Delta$, 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 expression13) 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 $\delta_e$ $(= \beta_e R_e)$. 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 $(\alpha,\alpha')$ data.

$Ni^{58}$

| $\alpha$-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 |

$Ni^{62}$

| $\alpha$-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.

## References

1) For a partial summary of the experimental data see H. Farragi and J. Saudinos, in Nuclear Spectroscopy with Direct Reactions,I: Contributed Papers, Argonne National Laboratory Report ANL-6848, March 1964, p. 137

2) R. Beurtey, P. Catillon, R. Chaminade, M. Crut, H. Farragi, A. Papineau, J. Saudinos and J. Thirion, Compt. Rend. 252 (1961) 1756; J. Phys. Radium 21 (1960) 399

3) H. W. Broek, T. H. Braid, J. L. Yntema and B. Zeidman, Phys. Rev. 126 (1962) 1514

4) B. Buck, Phys. Rev. 127 (1962) 940

5) J. R. Meriwether, A. Bussière de Nercy, B. G. Harvey, and D. J. Horen, Phys. Letters 11 (1964) 299

6) B G. Harvey, E. J.-M. Rivet, A. Springer, J. R. Meriwether, W. B. Jones, J. H. Elliot and P. Darriulat, Nucl. Phys. 52 (1964) 465

7) F. S. Goulding and D. A. Landis, Lawrence Radiation Laboratory, Drawing Number 11 × 198-1P2

8) S. M. Shafroth and G. T. Wood, International Congress of Nuclear Physics, paper C185, Paris, (July 1964)

9) N. Austern and J. S. Blair, to be published

10) A. Springer, Ph.D. Thesis, Lawrence Radiation Laboratory Report UCRL-11681, unpublished

11) G. R. Satchler, private communication

12) Taro Tamura, private communication

13) K. Alder, A. Bohr, T. Huus, B. Mottelson and A. Winther, Rev. Mod. Phys. 28 (1956) 432

## 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 $Ni^{58}$.

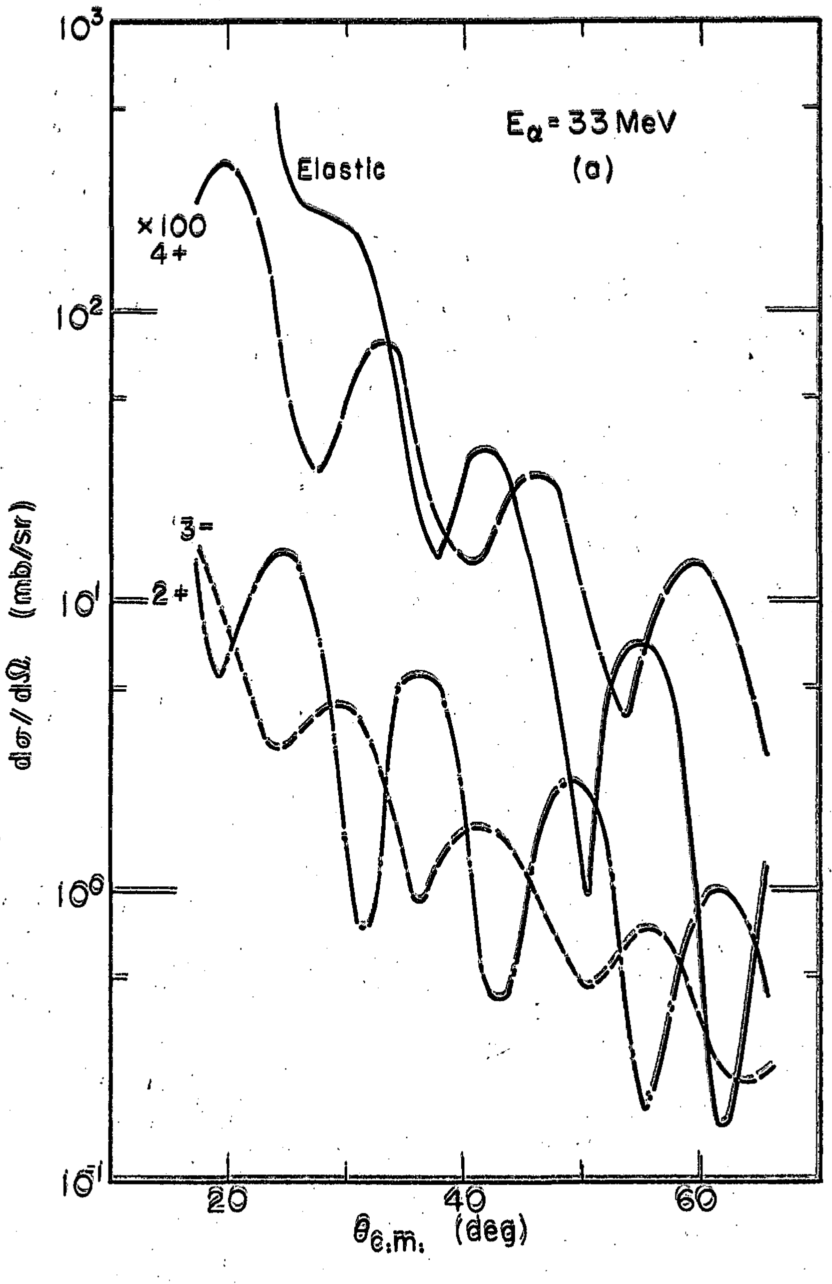
Fig. 2. Variation of the phase of the angular distributions of the inelastic groups relative to that of the elastic group of $Ni^{58}$ as a function of the energy of the incident alpha particles. The spins and parities correspond to the levels at 1.45 MeV (2+), 2.45 MeV (4+) and 4.50 MeV (3-).

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.

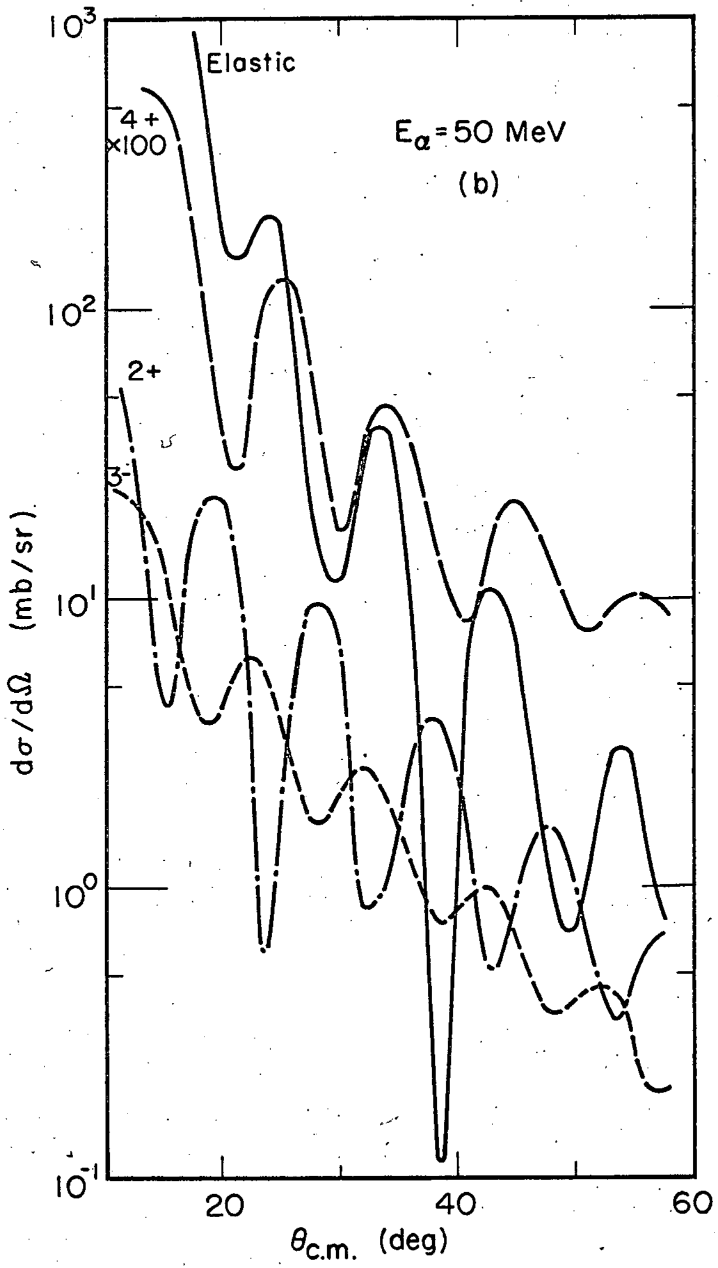
Fig. 5. Austern and Blair model fits to the 1.17 (2+) and 4.50 (3-) MeV Angular distributions from the scattering of 50-MeV alpha particles by $Ni^{58}$. The values for the parameters L, $\Delta$, A, B and D were taken from the fit shown in Fig. 4.

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, $\Delta$, 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.



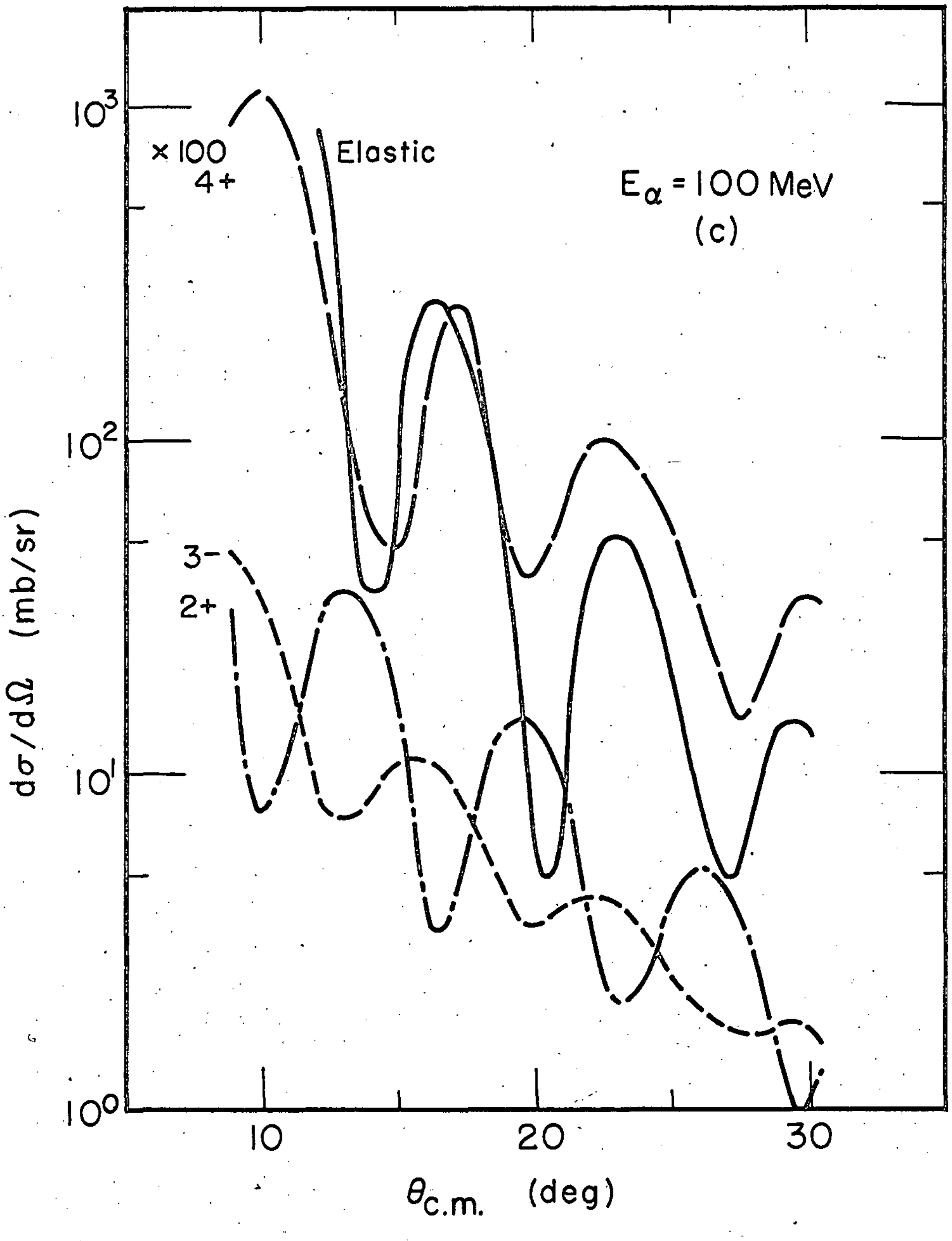
MUB-5175

Fig. 1 (a).



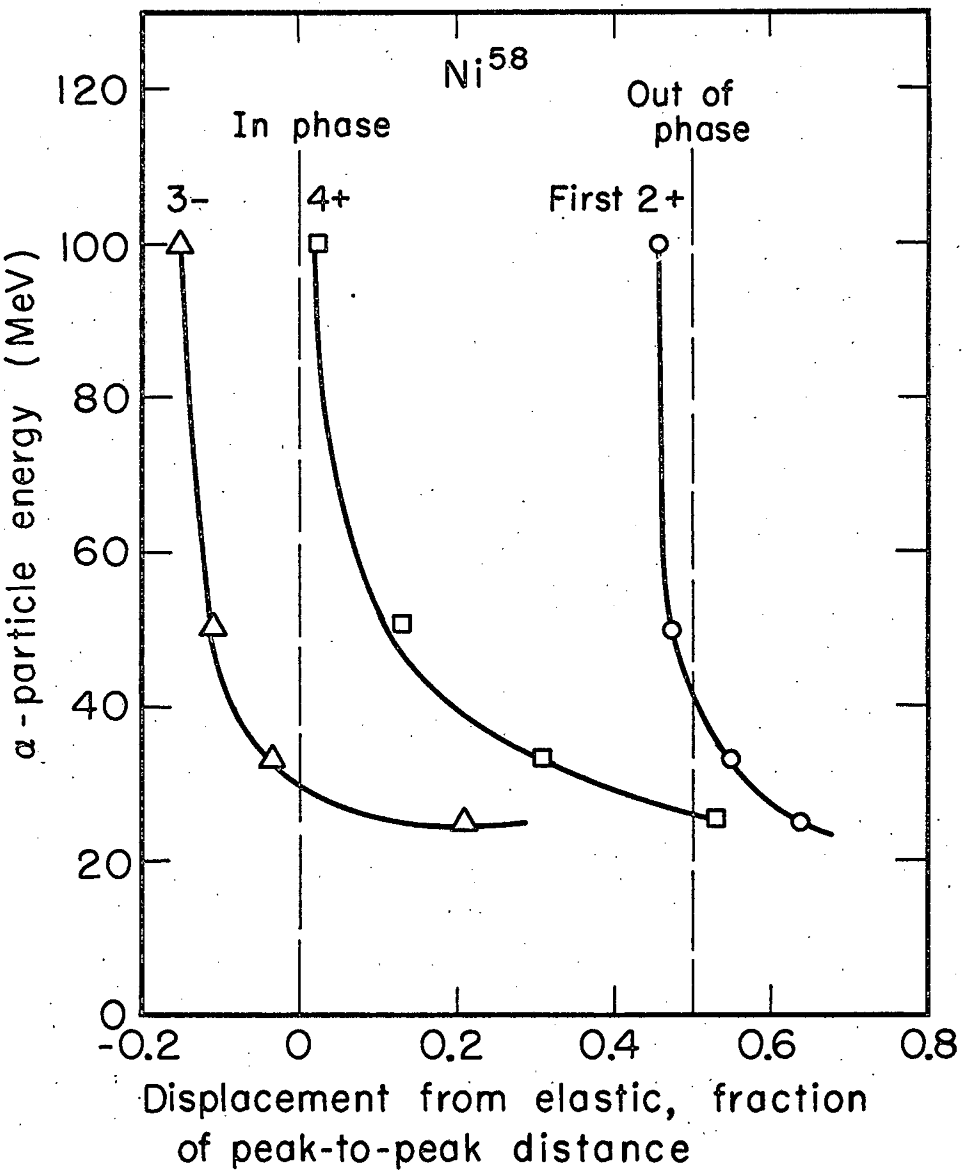
MUB-5176

Fig. 1(b).



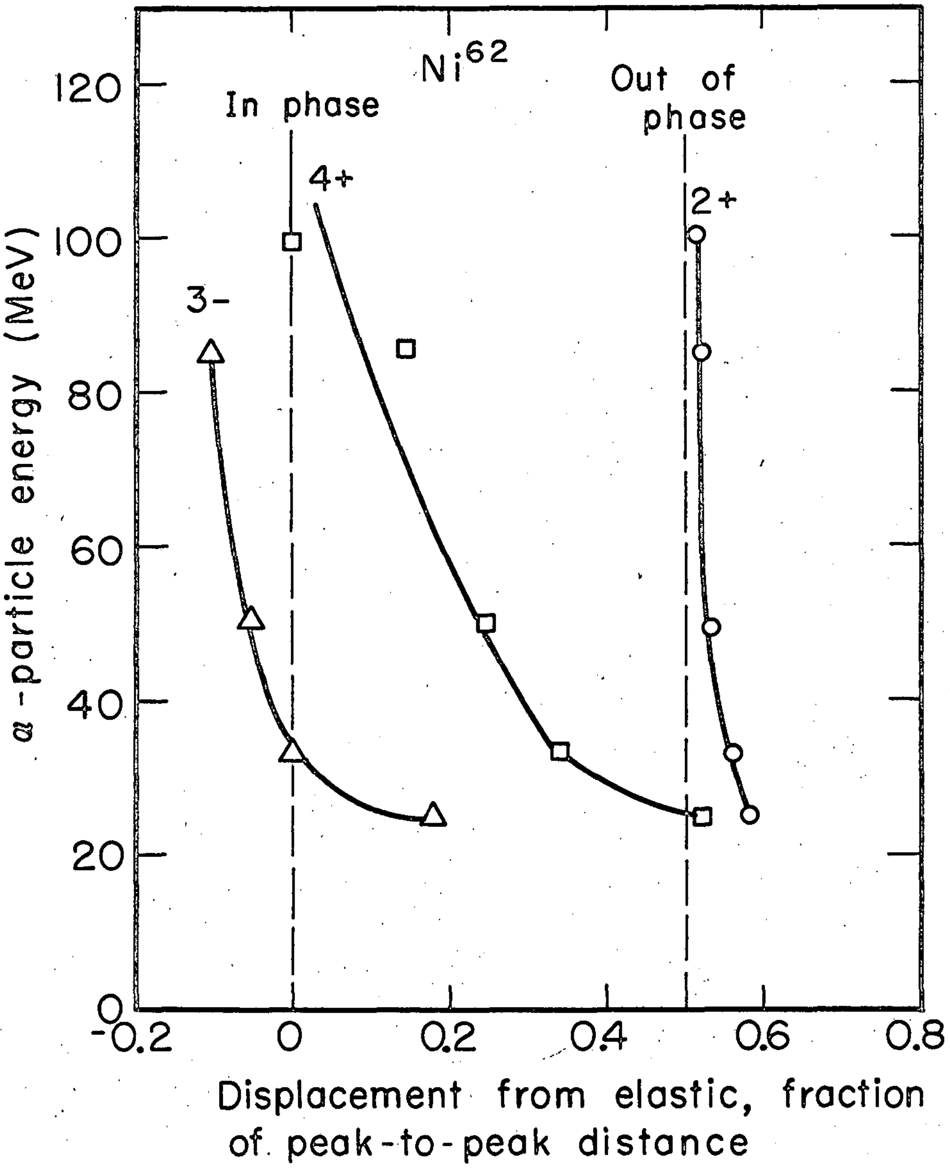
MUB-5177

Fig. 1(c).



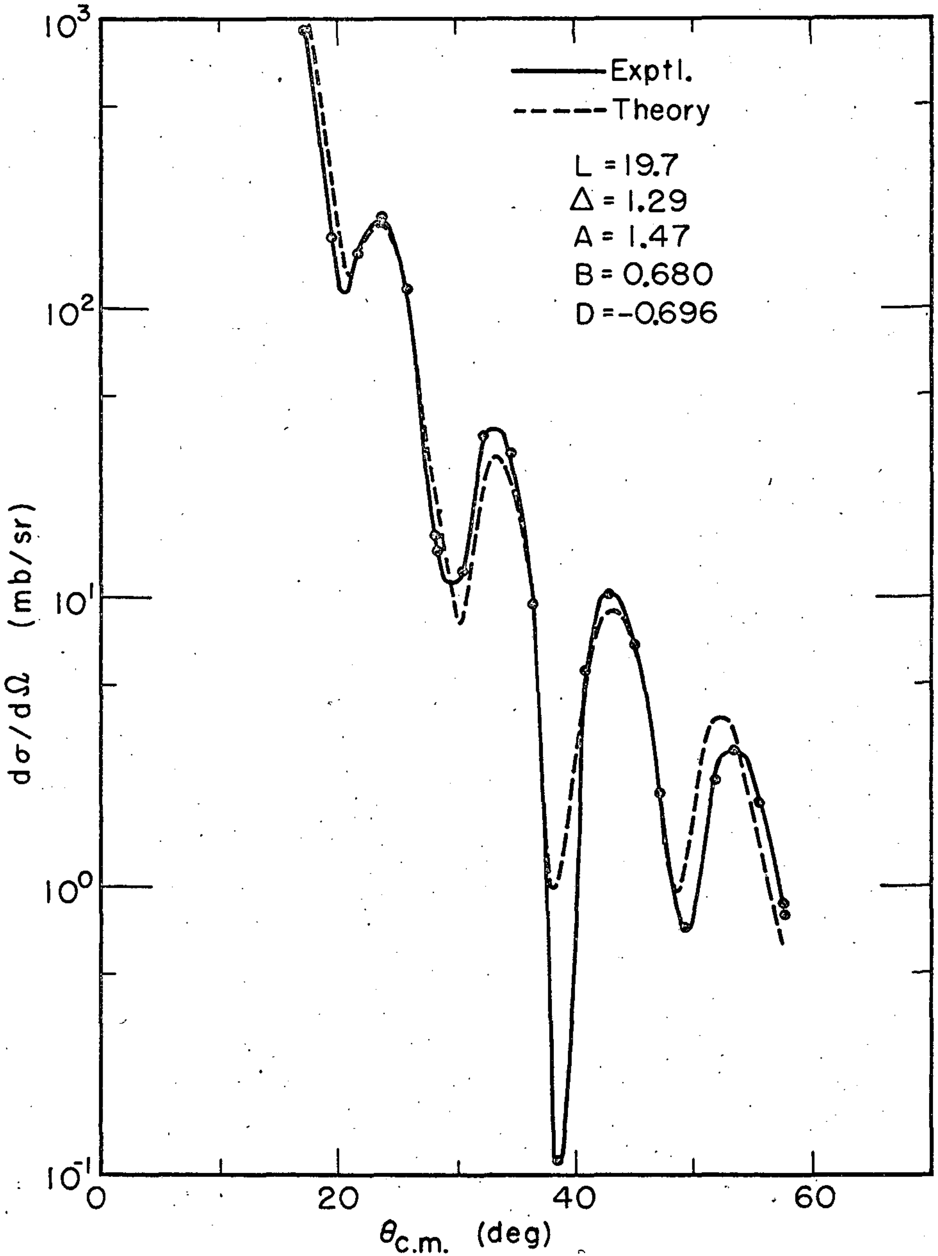
MUB-5178

Fig. 2



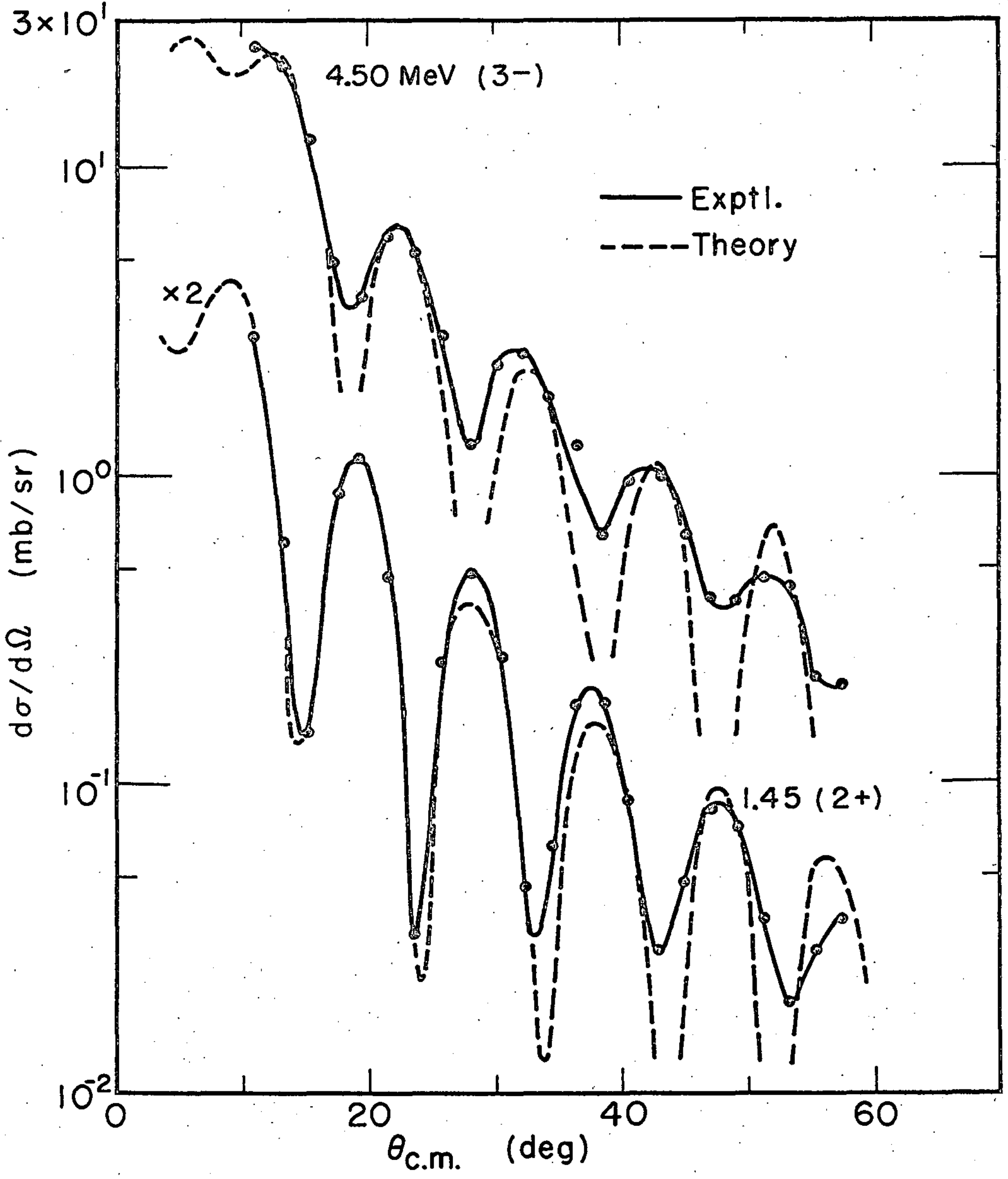
MUB-5179

Fig. 3.



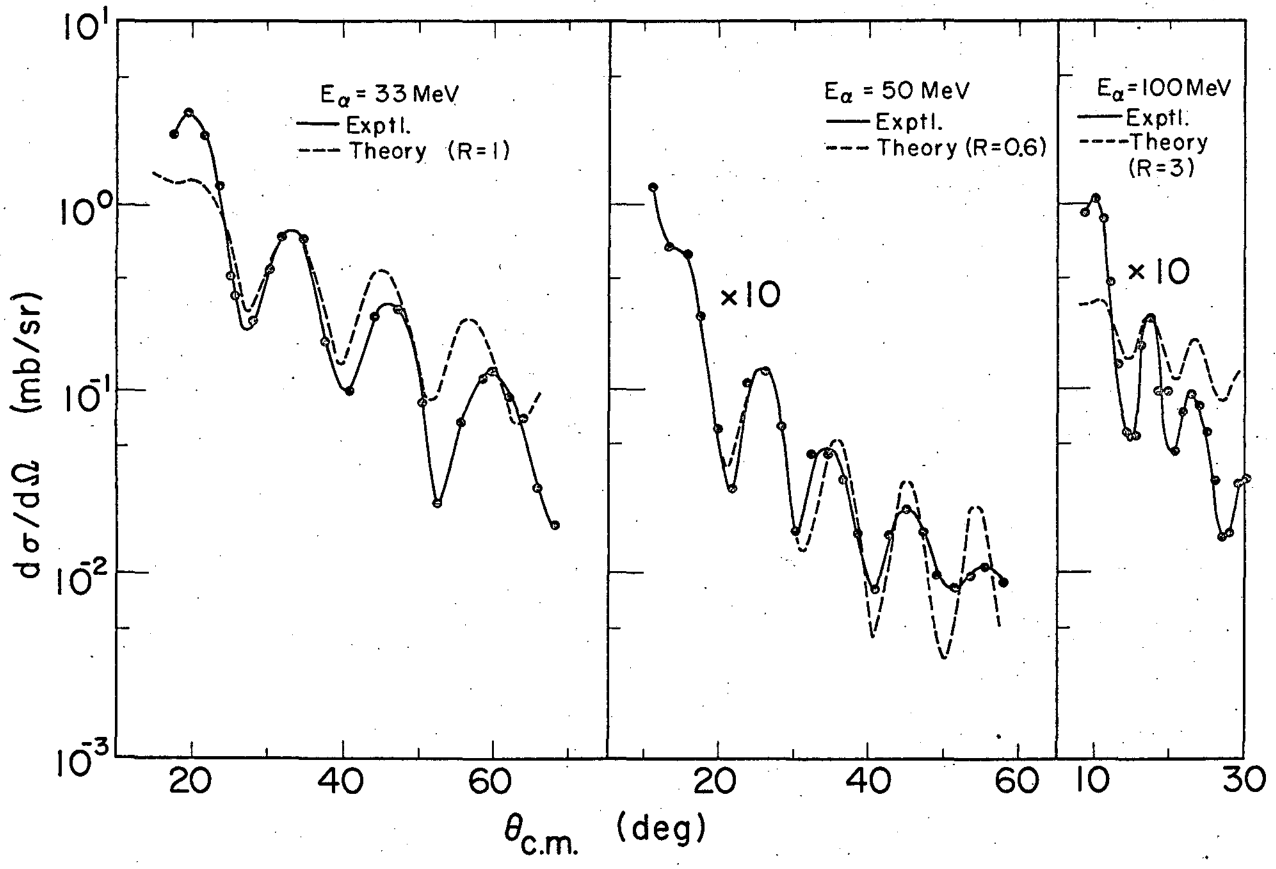
MUB-5180

Fig. 4.



MUB-5181

Fig. 5.



MUB-5182

Fig. 6.

# $Ni^{58}$

## Elastic Cross Sections

$E_\alpha$ = 25 MeV

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

## $Ni^{58}$

### 1.452 MeV 2+ Level

$E_\alpha = 25$ MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha = 25$ MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_{\alpha}$ = 33 MeV

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

## $Ni^{58}$

### 1.452 MeV 2+ Level

$E_\alpha$ = 33 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_{\alpha}$ = 33 MeV

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

* $O^{16}$ included

## $Ni^{58}$

### 4.56 MeV 3- Level

$E_\alpha$ = 33 MeV

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

# $\mathrm{Ni}^{58}$

## Elastic Cross Sections

$E_{\alpha} = 50$ MeV

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

# $Ni^{58}$

## 1.452 MeV 2+ Level

$E_{\alpha}$ = 50 MeV

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

## $Ni^{58}$

## 2.458 MeV 4+ Level

$E_\alpha$ = 50 MeV

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

# $Ni^{58}$

## 4.5 MeV 3- Level

$E_\alpha$ = 50 MeV

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

## $Ni^{58}$

## 3.026 MeV

$E_\alpha$ = 50 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 50 MeV

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

## $Ni^{58}$

### 3.60 MeV

$E_\alpha$ = 50 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 50 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 100 MeV

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

# $Ni^{58}$

## 1.452 MeV 2+ Level

$E_\alpha$ = 100 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 100 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 100 MeV

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

# $Ni^{62}$

## Elastic Cross Sections

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ | $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ |
|---|---|---|---|---|---|---|---|
| 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

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_\alpha$ = 25 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_\alpha$ = 33 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ | $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ |
|---|---|---|---|---|---|---|---|
| 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

$E_\alpha$ = 33 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_\alpha$ = 33 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 33 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 50 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ | $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractinnal Statistical Error | $\sigma/\sigma_{RUTH}$ |
|---|---|---|---|---|---|---|---|
| 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

$E_{\alpha}$ = 50 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_\alpha$ = 50 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 50 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 85 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ | $\theta_{cm}$ (DEG) | $d\sigma/d$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ |
|---|---|---|---|---|---|---|---|
| 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

$E_\alpha$ = 85 MeV

| $\theta_{cm}$ (DEG) | dσ/dΩ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (DEG) | dσ/dΩ (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

$E_\alpha$ = 100 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ | $\theta_{cm}$ (DEG) | $d\sigma/d$ (mb/SR) | Fractional Statistical Error | $\sigma/\sigma_{RUTH}$ |
|---|---|---|---|---|---|---|---|
| 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

$E_\alpha$ = 100 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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

$E_\alpha$ = 100 MeV

| $\theta_{cm}$ (DEG) | $d\sigma/d\Omega$ (mb/SR) | Fractional Statistical Error | $\theta_{cm}$ (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