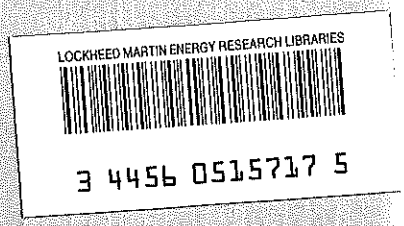

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ORNL-4518
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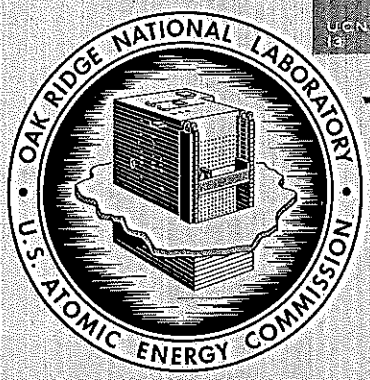
NEUTRON ELASTIC- AND INELASTIC-SCATTERING CROSS SECTIONS FOR Na IN THE RANGE OF 5.4 TO 8.5 MeV

F. G. Perey
W. E. Kinney



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NEUTRON PHYSICS DIVISION

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AUGUST 1970

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NEUTRON ELASTIC- AND INELASTIC-SCATTERING CROSS SECTIONS FOR Na IN THE RANGE OF 5.4 to 8.5 MeV

F. G. Perey and W. E. Kinney

ABSTRACT

We present numerical values for neutron elastic- and inelastic-scattering cross sections for Na for incident energies from 5.4 to 8.5 MeV. In this energy region there exists only one previous measurement, at 7 MeV, for the inelastic scattering to the first excited state. This datum point is consistent with our results. Two ENDF/B evaluations for Na are compared with our data. Both evaluations are in fairly good agreement with the integrated elastic cross sections but give poorer agreement for the differential elastic cross sections. For the inelastic-scattering cross sections, one of the evaluations does not go above 5 MeV and the other, although it reproduces the cross section for the first excited state fairly well fails to reproduce the decrease in the inelastic cross sections as a function of energy for the other levels.

INTRODUCTION

We present neutron elastic and inelastic cross sections for Na from 5.4 to 8.5 MeV. To assist in the evaluation of our data, we briefly discuss our data acquisition and reduction techniques.

For the purposes of discussion, we present our data in graphical form. We compare two ENDF/B evaluated sets of cross sections with our results. Tables of our cross section values are given in an appendix.

DATA ACQUISITION

The data were obtained with conventional time-of-flight techniques. Pulsed (2 MHz), bunched ($\sim$1 nsec full width at half maximum, FWHM) deuterons accelerated by the ORNL Van de Graaff interacted with deuterium in a gas cell to produce neutrons by the $D(d,n)^3He$ reaction. The gas

cells, whose lengths varied from 0.7 to 4 cm and whose pressure was approximately 1.5 atm, gave neutron energy resolutions from 60 to 340 keV, depending on the incident deuteron energy.

The neutrons were scattered from solid right circular cylindrical samples placed approximately 10 cm from the gas cell when the detector angles were greater than 25°. For smaller detector angles the cell-to-sample distance had to be increased to as much as 30 cm in order to shield the detector from neutrons coming directly from the gas cell.

The scattered neutrons were detected by 12.5-cm-diam NE-213 liquid scintillators optically coupled to XP-1040 photomultipliers. The scintillators were normally 2.5 cm thick, but their thickness was increased to 5 cm when the 4-cm gas cell was used. Data were taken with a single detector and later with three detectors simultaneously. Flight paths varied from 4 to 6 m, with the detector angles ranging from 15 to 140°. The gas-cell neutron production was monitored by a time-of-flight system which was a 5-cm-diam by 2.5-cm-thick NE-213 scintillator viewed by a 58-AVP photomultiplier placed about 2 m from the cell at an angle of 55° with the incident deuteron beam.

The flight time of a detected recoil proton event with reference to a beam pulse signal, the pulse height of the recoil proton event, and identification of the detector in the three-detector system were supplied to an on-line PDP-7 computer. The electronic equipment for supplying this information to the computer consisted, for the most part, of standard commercial components. While gamma rays were discriminated against for both the scattered neutron and the monitor detectors, the discrimination was poor below a neutron energy of 700 keV. A digital bias corresponding to

this neutron energy was therefore put into the computer so that two time-of-flight spectra were obtained for each scattered-neutron detector, the spectra corresponding to pulse heights above and below the digital bias. Only the spectra above the bias were used.

The detector efficiencies were measured by ^{1}(n,p) scattering from a thin (6-mm-diam) polyethylene sample and by detecting neutrons coming directly from the gas cell. Both interactions gave results which were in agreement and which yielded efficiency vs energy curves that compared well with calculations.[1]

DATA REDUCTION

We have developed new methods of data reduction which have both simplified the process and made it more reliable. Central to the data reduction process is the use of a light pen with the PDP-7 computer scope display programs to extract peak areas from spectra. The light pen makes a comparatively easy job of separating multiplets and estimating errors in the cross section due to extreme but possible peak shapes. The time-of-flight spectra are transformed into a center-of-mass cross section as a function of excitation energy in the target nucleus before peak stripping is done. This transformation removes kinematic effects and allows easy comparison of spectra taken at different angles or different incident neutron energies. The second effect of the transformation is to make all the peak shapes and widths approximately the same. In the time-of-flight spectrum the width of the peaks is a rapidly varying function of neutron energy since the energy dispersion changes as a function of flight time. Finally, there is communication between the PDP-7 and larger computers

via magnetic tape in order to minimize the bookkeeping and card punching and hence the errors which accompany such operations.

The reduction process starts by normalizing a sample-out to a sample-in time-of-flight spectrum by the ratio of their monitor neutron peak areas, subtracting the sample-out spectrum, and transforming the difference spectrum into a spectrum of cross section (mb/ster/25 keV) vs excitation energy (25 keV/channel). In addition, a spectrum of the variance is computed based on the counting statistics of the initial data.

The transformed spectra are read into the PDP-7 computer from magnetic tape, and the peak stripping is done by means of the light pen. A peak is stripped by drawing a background beneath it and then having the computer calculate the peak area (mb/ster), centroid, and FWHM. The variance spectrum is used to compute a counting statistics variance corresponding to the stripped peak. Peak stripping errors due to uncertainties in the residual background under the peaks or to the tails of imperfectly resolved nearby peaks may be included with the other errors by stripping the peaks several times corresponding to high, low, and best estimates of this background. Although somewhat subjective, the low and high estimates of the cross sections are identified with 95% confidence limits; these together with the best estimate define upper and lower errors due to stripping. Different upper and lower values of the stripping errors are allowed since the upper and lower estimates of the background are rarely symmetric about the best estimate. When a spectrum is completely stripped, the stripping information is written on magnetic tape for additional processing by a larger computer.

Inelastic cross sections are generally sufficiently isotropic so that finite sample corrections can be made at each angle independently of results at other angles. Correction of the elastic cross section, however, must await the reduction of the entire angular distribution before the finite sample effects can be considered. The corrections are performed according to semianalytic recipes whose constants were obtained from fits to Monte Carlo results.[2]

The final error analysis is performed, including uncertainties in the geometrical parameters (scatterer size, gas cell to scatterer distance, flight paths, etc.) and the uncertainties in the finite sample size corrections.

We fit the corrected differential cross sections and integrate the fitted curve to obtain total elastic and inelastic cross sections. We assume that levels higher than the first excited state are isotropic, take a weighted average of the data, and multiply by 4π to obtain the integrated cross section. The computation of the average is an iterative process in that the data points are tested on each round to see whether or not they lie within 3 of their counting-statistical standard deviations of the current average. If a point fails the test, it is ignored on the next round in the computation of a new average.

The ground state and first excited state are fitted by least squares to a Legendre series:

$$\sigma(\mu = \cos\theta) = \sum_{\ell=0}^{L} \frac{2\ell+1}{2} a_\ell P_\ell(\mu),$$

the points being weighted by the inverse of their average total variance. In order to prevent the fit from giving totally unrealistic values outside the angular range of our measurements, we have resorted to the inelegant but workable process of adding three points equally spaced in angle between the largest angle of measurement and 175°. The differential cross sections at the added points are equal to the measured cross section at the largest angle, but they are assigned 50% errors.

As pointed out by Rose[3] if the weight of each point in a least squares fitting is equal to the inverse of its variance, then the variances of the coefficients are equal to the diagonal elements in the least squares inverse matrix. (For the purposes of calculating the errors in the coefficients, the errors of the three added points are reduced to 10%.)

In the case of fitting the elastic cross section, we have included Wick's limit as an additional data point with an error calculated from the total cross section combined with the 7% error which we attribute to the absolute value of our cross sections.

RESULTS

The scattering sample was a solid right circular cylinder of Na having a diameter of 2.5 cm, a height of 2.54 cm, and a mass of 14.48 g. The sample was wrapped in aluminum foil to prevent deterioration.

We first present our differential elastic and inelastic cross sections in graphical form. We then show the comparison of our data for the elastic differential cross sections with two ENDF/B evaluations. Our excitation functions for discrete levels are then compared with the results of the evaluations. We finally give at 8.5 MeV the portion of the continuum spectrum which we have obtained. Numerical values of our cross sections are tabulated in the appendix.

The abbreviations we use, reference numbers, the energies, and energy spreads for the other investigators whose results are also compared with the ENDF/B evaluations are given in Table 1. With the exception of the data ALD7, at 7 MeV, all of the other data are below 4 MeV and were available at the time the evaluations were performed. They are only used as representative data below our energy region and do not comprise all of the data upon which the evaluations are based below 4 MeV.

Differential Cross Sections

Elastic Scattering

The elastic-differential cross sections at 4 energies are shown on Fig. 1 together with the Legendre polynomial fits. At 7.60 MeV we could not find the reason for the large scatter of the measurements between 70 and 90 degrees. The large spread of values is inconsistent with our assigned relative errors for the points and fail to appear in the inelastic cross sections at the same angles.

Inelastic Scattering

The inelastic-differential cross sections are shown on Figs. 2 to 7. There are no marked anisotropies for the differential cross sections, within our experimental errors, except for the first excited state at 0.44 MeV as shown on Fig. 2. Although the Legendre polynomial fits at 6.37 and 7.60 MeV look reasonable for the level at 0.44 MeV, we have no evidence for the cross section being as low as shown on the fit at forward angles at 6.37 MeV. We have not shown the differential cross sections for levels and at energies where the data could only be obtained at less than six angles.

Table 1. The Abbreviations, References, Energies, and Energy Spreads for Other Investigators

Abbreviation	Energy, MeV	Reference
OBNI	2.00 ± 0.05	4
LASL	3.49 ± 0.05 3.75 ± 0.04 4.00 ± 0.03	5
ALD2	2.515 ± 0.03 3.97 ± 0.03	6
ALD7	7.00 ± 0.08	7

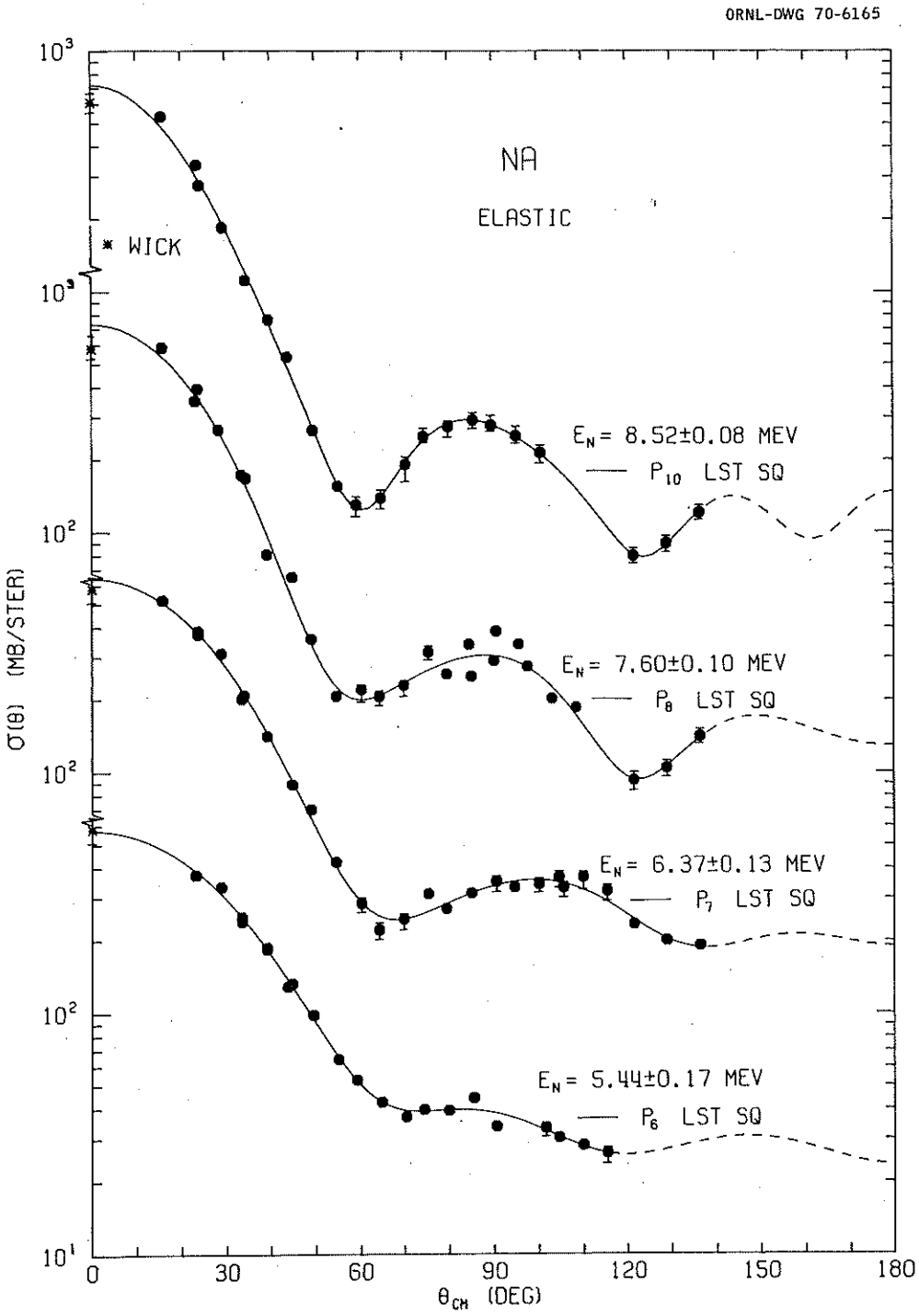
ORNL-DWG 70-6165
NA
ELASTIC
* WICK
E_N = 8.52±0.08 MEV
P_{10} LST SQ
E_N = 7.60±0.10 MEV
P_8 LST SQ
E_N = 6.37±0.13 MEV
P_7 LST SQ
E_N = 5.44±0.17 MEV
P_6 LST SQ
σ(θ) (MB/STER)
θ_{CM} (DEG)
10^3
10^2
10^1
0
30
60
90
120
150
180

Fig. 1

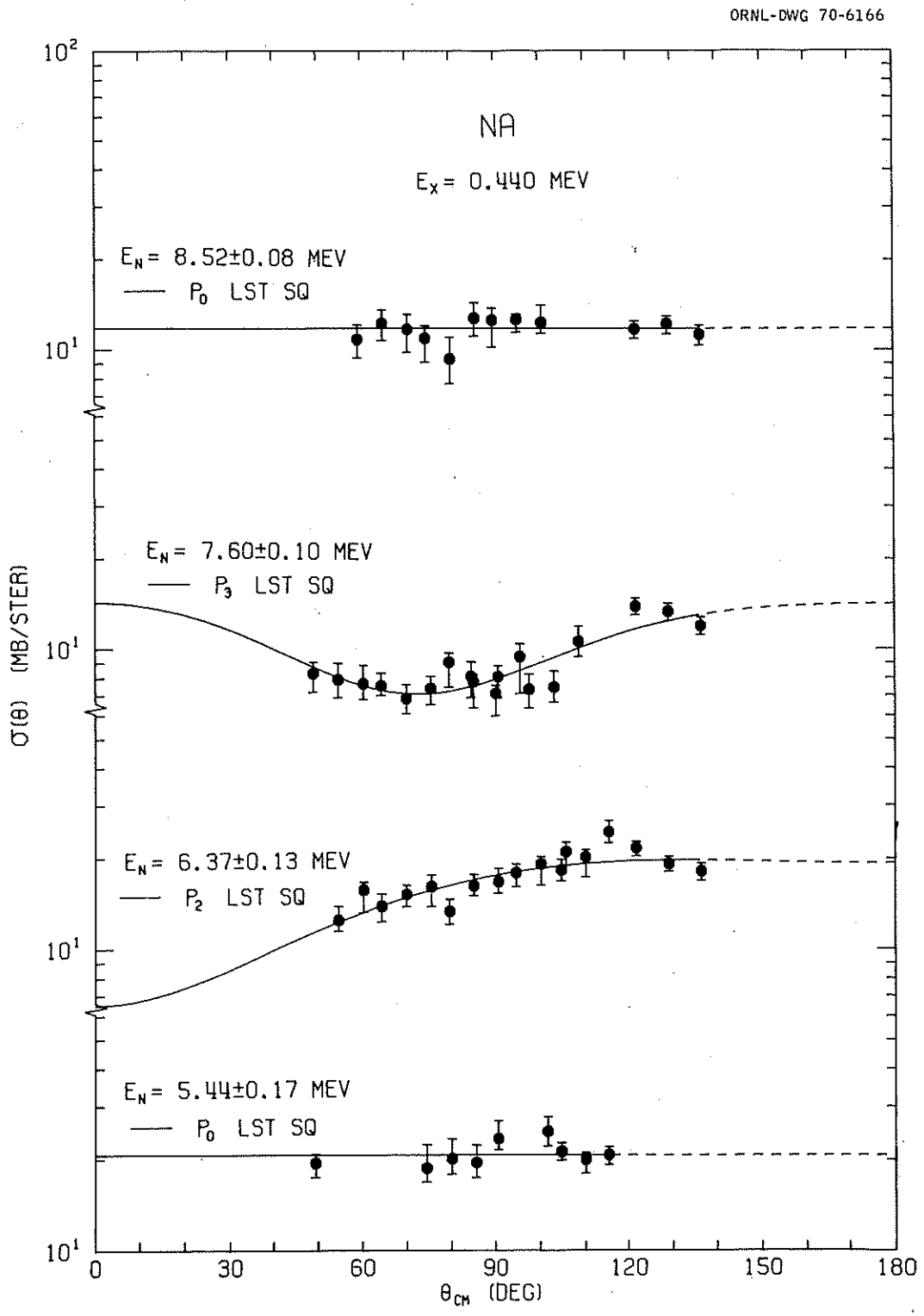
ORNL-DWG 70-6166
NA
E_x = 0.440 MEV
E_N = 8.52±0.08 MEV
P_0 LST SQ
E_N = 7.60±0.10 MEV
P_3 LST SQ
E_N = 6.37±0.13 MEV
P_2 LST SQ
E_N = 5.44±0.17 MEV
P_0 LST SQ
σ(θ) (MB/STER)
10^2
10^1
10^1
10^1
10^1
0
30
60
90
120
150
180
θ_{CM} (DEG)

Fig. 2

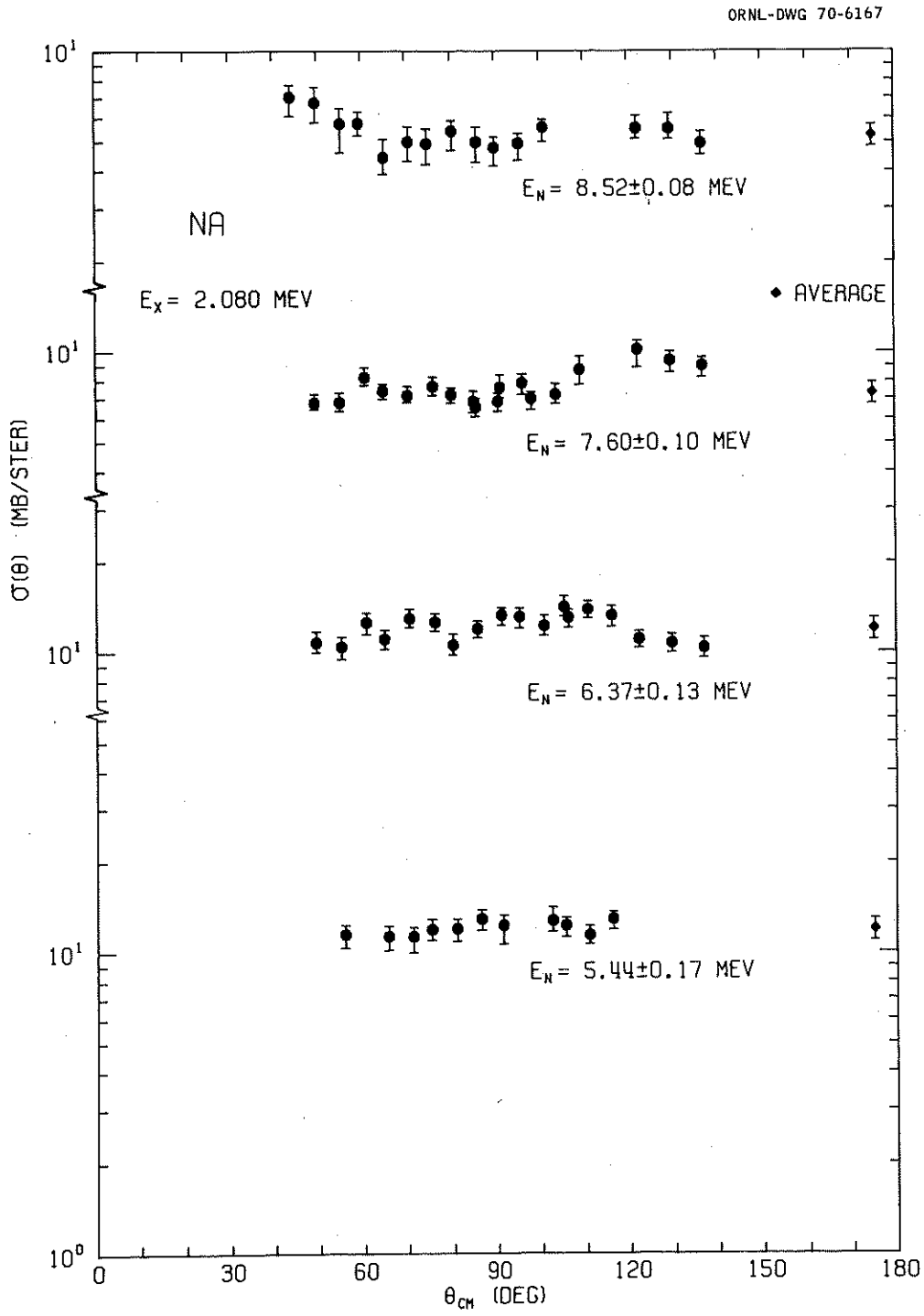
ORNL-DWG 70-6167
NA
E_X = 2.080 MEV
◆ AVERAGE
E_N = 8.52±0.08 MEV
E_N = 7.60±0.10 MEV
E_N = 6.37±0.13 MEV
E_N = 5.44±0.17 MEV
σ(θ) (MB/STER)
θ_{CM} (DEG)
10^1
10^0
0
30
60
90
120
150
180

Fig. 3

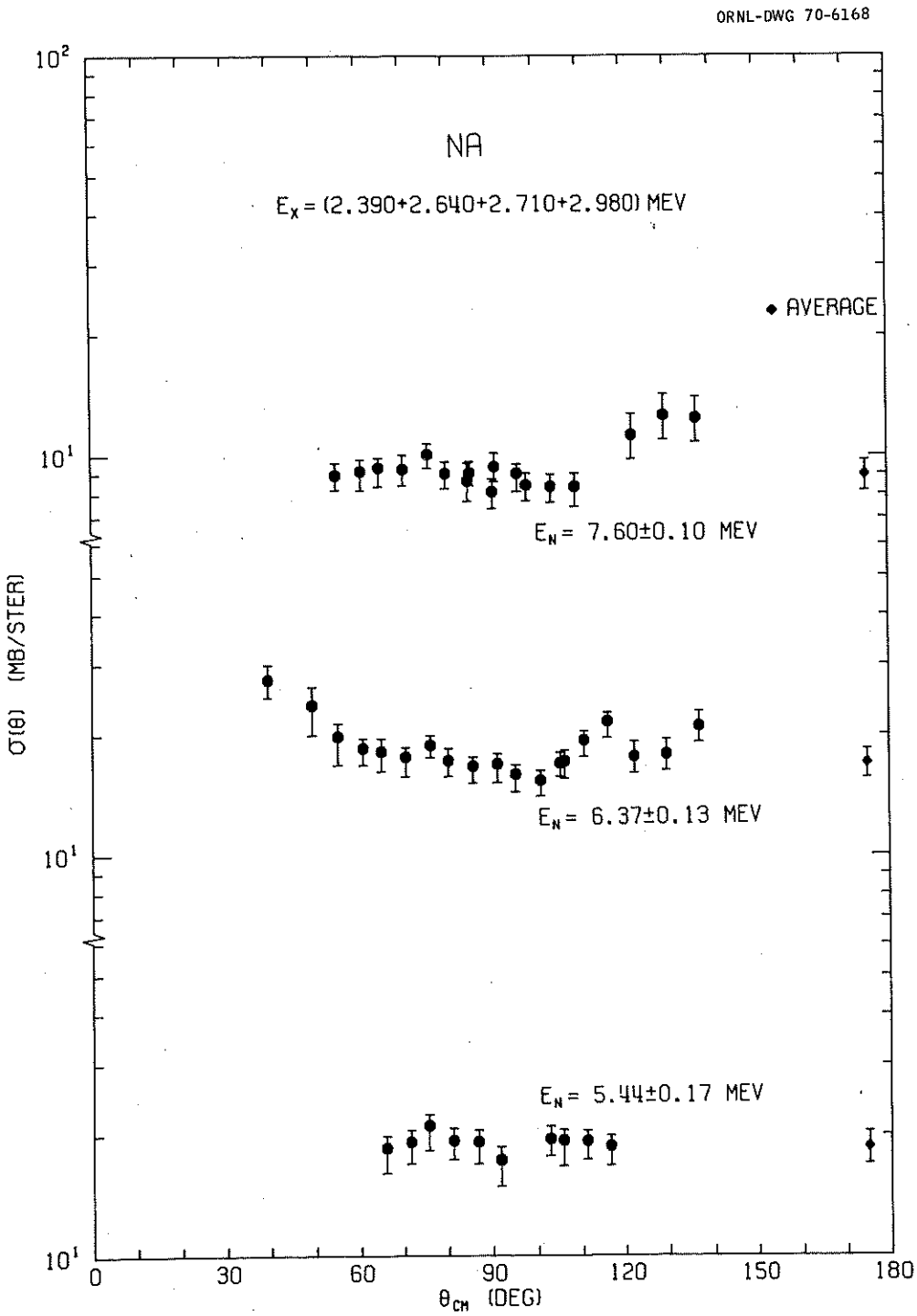
ORNL-DWG 70-6168
NA
E_x = (2.390+2.640+2.710+2.980) MEV
AVERAGE
E_N = 7.60±0.10 MEV
E_N = 6.37±0.13 MEV
E_N = 5.44±0.17 MEV
σ(θ) (MB/STER)
θ_{CM} (DEG)
10^2
10^1
10^1
10^1
0
30
60
90
120
150
180

Fig. 4

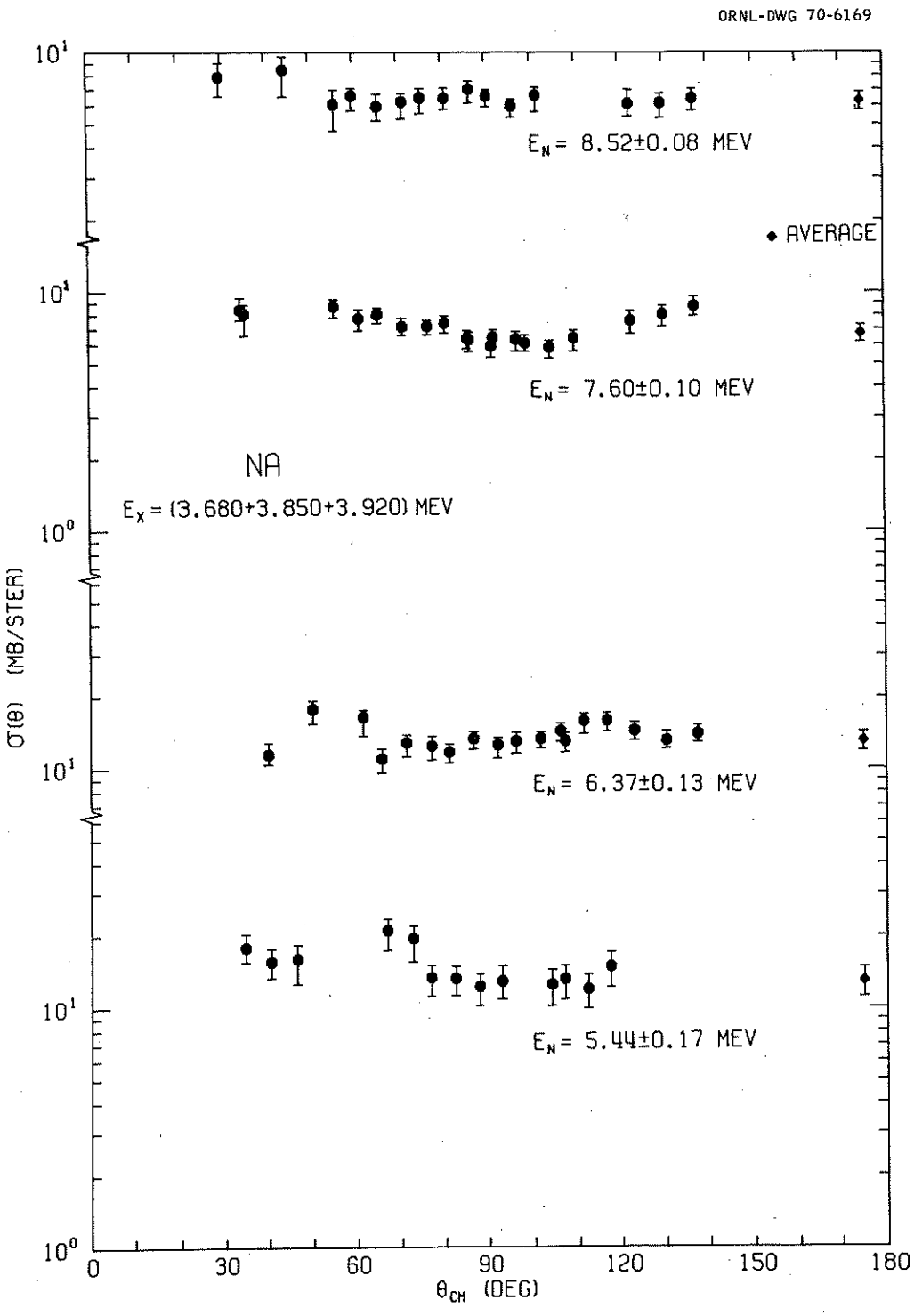
ORNL-DWG 70-6169
E_N = 8.52±0.08 MEV
AVERAGE
E_N = 7.60±0.10 MEV
NA
E_X = (3.680+3.850+3.920) MEV
E_N = 6.37±0.13 MEV
E_N = 5.44±0.17 MEV
σ(θ) (MB/STER)
θ_{CM} (DEG)
0
30
60
90
120
150
180

Fig. 5

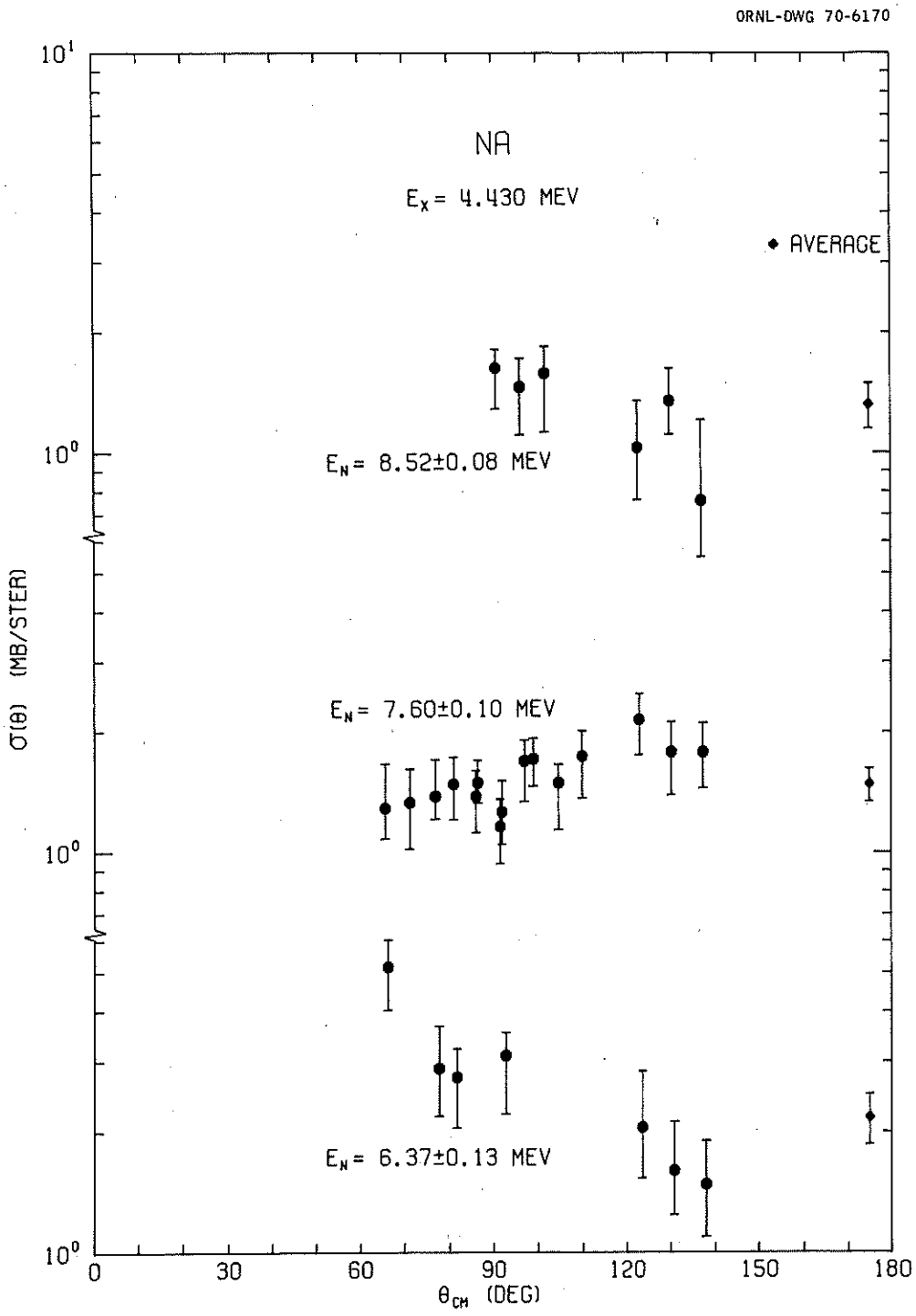
ORNL-DWG 70-6170
NA
E_x = 4.430 MEV
AVERAGE
E_N = 8.52±0.08 MEV
E_N = 7.60±0.10 MEV
E_N = 6.37±0.13 MEV
$\sigma(\theta)$ (MB/STER)
θ_{CM} (DEG)
10^1
10^0
10^0
10^0
0
30
60
90
120
150
180

Fig. 6

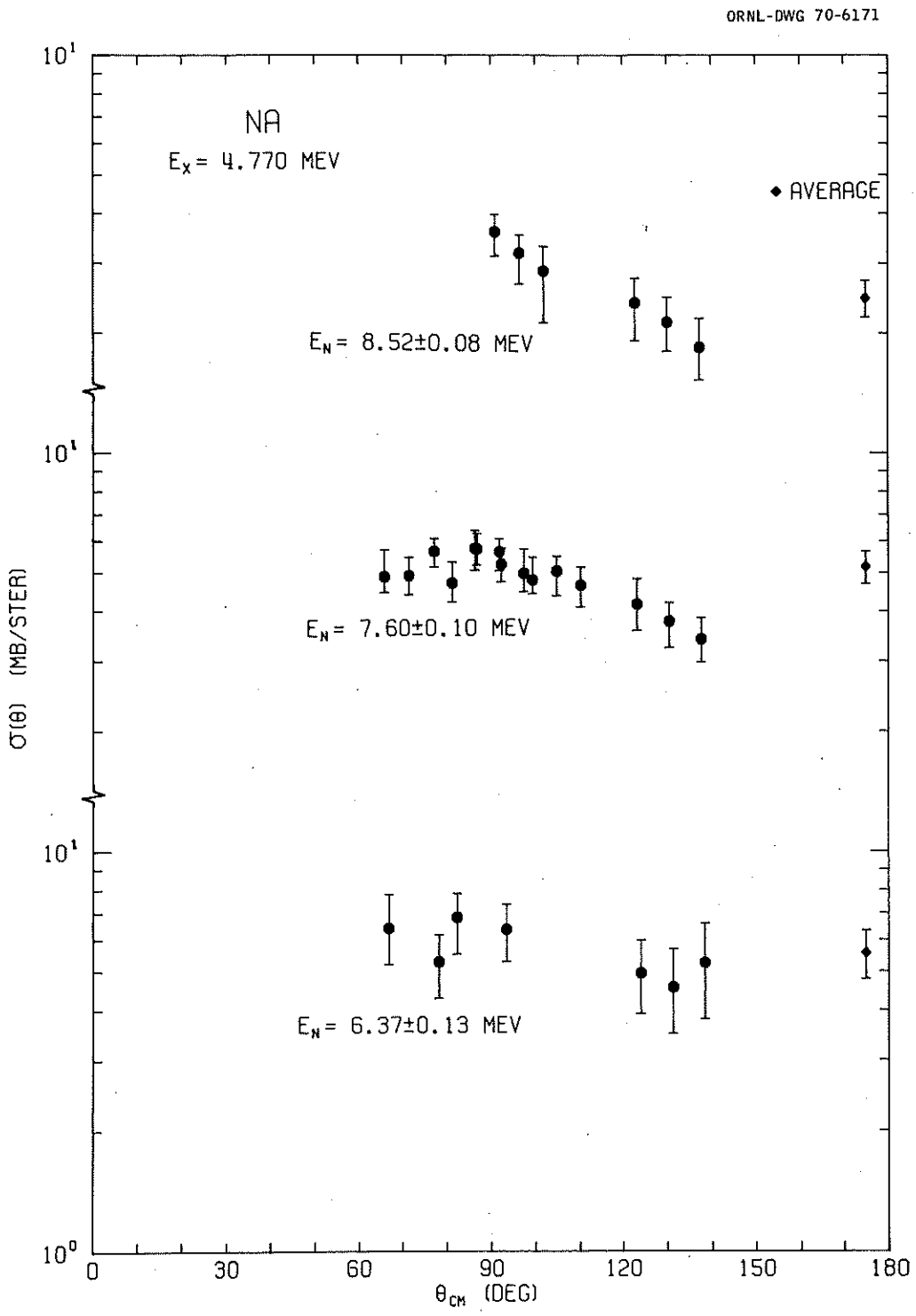
ORNL-DWG 70-6171
NA
E_x = 4.770 MEV
◆ AVERAGE
E_N = 8.52±0.08 MEV
E_N = 7.60±0.10 MEV
E_N = 6.37±0.13 MEV
σ(θ) (MB/STER)
10^1
10^1
10^1
10^0
0
30
60
90
120
150
180
θ_{CM} (DEG)

Fig. 7

Differential Elastic Cross Section Comparison with ENDF/B

There are at present two ENDF/B evaluations for Na. They are identified as material 1059 and material 5001, Tables 2 and 3 give the tape descriptions of the materials. Both of these evaluations give the differential elastic cross sections in the energy range of our measurements.

On Fig. 8 we show the comparison of the data with the angular distributions from material 1059. The general description of the data is fairly good with the minima occurring at slightly too small angles.

On Fig. 9 we show the comparison of the data with the angular distributions from material 5001. In the ENDF/B file the angular distributions are given as values of probability every 0.05 in cosine with a linear interpolation between cosines. This representation causes the broken-line appearance of the ENDF/B distribution when plotted as a function of angle. For this file we normalized the integral to correspond to our measured integrated cross section. For this evaluation as for the previous one, the minima occur at too small angles.

It is evident that the elastic differential cross sections in both fits could be improved in the energy region of our measurements. It should be emphasized, however, that the agreement is remarkably good in view of the fact that no data existed between 4 and 14 MeV when the evaluations were performed.

Integrated Cross Sections as a Function of Energy

All of our differential cross sections integrated over angles are shown on Fig. 10 to 13 together with the data of other investigators indicated in Table 1. The cross sections from the ENDF/B evaluation material 1059 are also shown on Figs. 10 and 11. This evaluation is in

Table 2

SODIUM-23 REF. APDA TECHNICAL MEMORANDUM NO. 42 (JANUARY 13,1967)
MATERIAL= 1059 ZA= 11023. FILE= 1 SECTION= 451

MF#1 GENERAL INFORMATION
ATOMIC MASS GIVEN AS 22.991 FOR NEUTRON MASS OF 1.008986 AMU
MT#453 RADIOACTIVE DECAY DATA-REF. 1
MF#2 RESONANCE PARAMETERS
MT#151 PARAMETERS GIVEN FOR RESONANCES AT 2.85,35.4, AND 53.5KEV
2.85KEV PARAMETERS-REFS. 2,3. 35.4KEV PARAMETERS FROM DATA OF REFS. 4 AND 5 ASSUMING G#7/8. 53.5 KEV PARAMETERS FROM DATA OF REF. 3 USING CAPTURE INTEGRAL FROM REF.4
SPIN INDEPENDENT RADIUS CHOSEN TO GIVE POTENTIAL SCATTERING OF 3.5 BARNS
RESONANCE PARAMETERS TO BE USED ONLY FOR CAPTURE CROSS SECTION ADDITIVE TO SMOOTH DATA OF FILE 3.
MF#3 SMOOTH CROSS SECTIONS
MT#1 TOTAL CROSS SECTION9 .001 TO 400 EV - REF. 6, 400 EV TO .1 MEV CALCULATED SAME AS MT#2, .1 TO .65 MEV - REF. 7, .65 TO 1 MEV - REF. 8,9, 1 TO 2.6 MEV - REF. 8,10,11 2.6 TO 5 MEV - REF. 12,13, 5 TO 15 MEV - REF. 13.
MT#2 ELASTIC SCATTERING OBTAINED BY SUBTRACTING NONELASTIC CROSS SECTION FROM TOTAL CROSS SECTION EXCEPT FROM 400 EV TO .1 MEV. IN THIS ENERGY RANGE,IT IS CALCULATED FROM RESONANCE PARAMETERS OF FILE 2 USING SPIN DEPENDENT RADII OF REF. 14
MT#3 NONELASTIC CROSS SECTION IS SUM OF SEPARATELY EVALUATED COMPONENTS
MT#4 THE INELASTIC CROSS SECTION FOR THE 0.44 MEV LEVEL IS BASED ON REF. 14 FROM 0.8 TO 1.5 MEV. OTHER DATA INCLUDING SEVEN RESOLVED LEVELS WAS OBTAINED FROM REFS. 16 TO 20
MT#16 (N,2N) CROSS SECTION-REF.21
MT#102 0.0253 CAPTURE CROSS SECTION FROM REF. 2 #0.534 BARNS 1.5 EV. TO 65 KEV.- RESONANCE PARAMETER CONTRIBUTION TO BE ADDED TO SMOOTH BACKGROUND (BASED ON REF. 4) CONTAINED IN THIS FILE. 65 KEV. TO 15 MEV.-REFS. 4,22,23.
MT#103 (N,P) - REF. 24
MT#107 (N,ALPHA) -REF. 24
MT#251 UBAR CALCULATED FROM LEGENDRE POLYNOMIALS OF FILE 4.
MT#252 XI CALCULATED FROM LEGENDRE POLYNOMIALS OF FILE 4.
MT#253 GAMMA - REF. 25.
MF#4 LEGENDRE POLYNOMIALS
MT#2 .03 TO .3 MEV. - REF26, .3 TO 1.5 MEV. - REF. 15, 1.5 TO 2.2 MEV. - EXTRAPOLATION BASED ON DATA OF REF. 27,2.5 TO 15 MEV. REFS. 16,28.
MF#5 SECONDARY ENERGY DISTRIBUTIONS
MT#4 NUCLEAR TEMP. FOR MAXWELLIAN DIS. ESTIMATED TO GIVE SAME AVERAGE ENERGY LOSS AS RESOLVED LEVELS AT 4 MEV. AND EXTRAPOLATED TO HIGHER ENERGIES
MT#16 NUCLEAR TEMP. IS GIVEN FOR MAXWELLIAN DISTRIBUTION
MF#7 THERMAL SCATTERING LAW
MT#4 FREE GAS LAW USING FREE ATOM CROSS SECTION # 3.128.-REF. 2

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28. MOORHEAD, T.P., AEEW R 254 (1963)

Table 3

SODIUM--TRANSLATED BY LASL FROM GA EVALUATION (GA-7829, 1967)
MATERIAL= 5001 ZA= 11023. FILE= 1 SECTION= 451

```
PLEASE REFER COMMENTS OR QUESTIONS REGARDING ERRORS IN TRANSLA-
TION OR IN FORMAT, OR CONCERNING THE TRANSLATION CODE (LATEX)
     TO** DONALD J. DUDZIAK, UNIVERSITY OF CALIFORNIA, LOS ALAMOS
          SCIENTIFIC LABORATORY, LOS ALAMOS, NM  87544
ANY COMMENTS REGARDING THE DATA EVALUATION SHOULD BE REFERRED TO
M.K. DRAKE, ET AL, THE AUTHORS OF GA-7829 (NDL-TR-89).  THE PER-
MISSION OF MR. DRAKE TO TRANSLATE HIS EVALUATION IS GRATEFULLY
ACKNOWLEDGED.  TRANSITION PROBABILITY ARRAYS FOR INELASTIC SCAT-
TER(FILE15,OPTION2) WERE TAKEN FROM DIAGRAMS IN GA-7829.  THE
PHOTON FORMAT FOLLOWS LA-3801 (ENDF 111), 1967. FOR MT#15, PHOTON
SPECTRA ARE NORMALIZED. TRANSLATION COMPLETED JULY 1969.
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                    ***** ** ********
** MF#1 **  GENERAL INFORMATION

** MF#3 **  SMOOTH CROSS SECTIONS * 0.01 TO 2.0E+7 EV *
           MT#  1  TOTAL * 0.01 TO 2.0E+7 EV *
           MT#  2  ELASTIC * SAME ENERGY RANGE AS MT#1 *
           MT#  3  NON-ELASTIC * SAME ENERGY RANGE AS MT#1 *
           MT#  4  TOTAL INELASTIC -- (N,N-PRIME)GAMMA
           MT#  5  (N,N-PRIME) TO THE 1ST EXCITED STATE*.4392 MEV
           MT#  6  (N,N-PRIME) TO THE 2ND EXCITED STATE*2.08  MEV
           MT#  7  (N,N-PRIME) TO THE 3RD EXCITED STATE*2.391 MEV
           MT#  8  (N,N-PRIME) TO THE 4TH EXCITED STATE*2.640 MEV
           MT#  9  (N,N-PRIME) TO THE 5TH EXCITED STATE*2.705 MEV
           MT# 10  (N,N-PRIME) TO THE 6TH EXCITED STATE*2.984 MEV
           MT# 11  (N,N-PRIME) TO THE 7TH EXCITED STATE*3.678 MEV
           MT# 12  (N,N-PRIME) TO THE 8TH EXCITED STATE*3.850 MEV
           MT# 13  (N,N-PRIME) TO THE 9TH EXCITED STATE*3.915 MEV
           MT# 14  (N,N-PRIME) TO THE 10TH EXCITED STATE 4.431MEV
           MT# 15  (N,N-PRIME) TO THE CONTINUUM
           MT# 16  (N,2N)          * Q# -12.434 MEV
           MT# 22  (N,N-PRIME)ALPHA * Q# -10.498 MEV
           MT# 28  (N,N-PRIME)P     * Q#  -8.794 MEV
           MT# 51  (N,N-PRIME) TO THE 11TH EXCITED STATE*4.778MEV
           MT# 52  (N,N-PRIME) TO THE 12TH EXCITED STATE*6.27 MEV
           MT# 53  (N,N-PRIME) TO THE 13TH EXCITED STATE*7.11 MEV
           MT# 54  (N,N-PRIME) TO THE 14TH EXCITED STATE*7.79 MEV
           MT#102  (N,GAMMA)
           MT#103  (N,P)      * Q# -3.597 MEV
           MT#107  (N,ALPHA) * Q# -3.880 MEV
           MT#110  PHOTON PRODUCTION (UNIT CROSS SECTION)
           MT#251  MU-BAR (L SYSTEM) * SAME ENERGY RANGE AS MT#1*
** MF#4 **  SECONDARY ANGULAR DISTRIBUTIONS * TABULAR * C SYSTEM
                                * NO TRANSFORMATION MATRICES *
           MT#  2  ELASTIC
           MT#  5  (N,N-PRIME) TO THE  1ST EXCITED STATE
           MT#  6  (N,N-PRIME) TO THE  2ND EXCITED STATE
           MT#  7  (N,N-PRIME) TO THE  3RD EXCITED STATE
           MT#  8  (N,N-PRIME) TO THE  4TH EXCITED STATE
           MT#  9  (N,N-PRIME) TO THE  5TH EXCITED STATE
           MT# 10  (N,N-PRIME) TO THE  6TH EXCITED STATE
           MT# 11  (N,N-PRIME) TO THE  7TH EXCITED STATE
           MT# 12  (N,N-PRIME) TO THE  8TH EXCITED STATE
           MT# 13  (N,N-PRIME) TO THE  9TH EXCITED STATE
           MT# 14  (N,N-PRIME) TO THE 10TH EXCITED STATE
           MT# 51  (N,N-PRIME) TO THE 11TH EXCITED STATE
           MT# 52  (N,N-PRIME) TO THE 12TH EXCITED STATE
           MT# 53  (N,N-PRIME) TO THE 13TH EXCITED STATE
           MT# 54  (N,N-PRIME) TO THE 14TH EXCITED STATE
** MF#5 **  SECONDARY ENERGY DISTRIBUTIONS * ALL LAW1 (TABULAR) *
           MT# 15  (N,N-PRIME) TO THE CONTINUUM
           MT# 16  (N,2N)
           MT# 22  (N,N-PRIME)ALPHA
           MT# 28  (N,N-PRIME)P
** MF#14 **  PHOTON ANGULAR DISTRIBUTIONS * TABULAR
           MT#  5  (N,N-PRIME) TO THE  1ST EXCITED STATE
           MT#  6  (N,N-PRIME) TO THE  2ND EXCITED STATE
           MT#  7  (N,N-PRIME) TO THE  3RD EXCITED STATE (ISO.)
           MT#  8  (N,N-PRIME) TO THE  4TH EXCITED STATE (ISO.)
           MT#  9  (N,N-PRIME) TO THE  5TH EXCITED STATE
           MT# 10  (N,N-PRIME) TO THE  6TH EXCITED STATE
           MT# 11  (N,N-PRIME) TO THE  7TH EXCITED STATE
           MT# 12  (N,N-PRIME) TO THE  8TH EXCITED STATE
           MT# 13  (N,N-PRIME) TO THE  9TH EXCITED STATE
           MT# 14  (N,N-PRIME) TO THE 10TH EXCITED STATE (ISO.)
           MT# 51  (N,N-PRIME) TO THE 11TH EXCITED STATE
           MT# 52  (N,N-PRIME) TO THE 12TH EXCITED STATE (ISO.)
           MT# 53  (N,N-PRIME) TO THE 13TH EXCITED STATE
** MF#15 **  MULTIPLICITIES FOR PHOTON PRODUCTION
           MT#  5  (N,N-PRIME) TO THE  1ST EXCITED STATE* OPTION2
           MT#  6  (N,N-PRIME) TO THE  2ND EXCITED STATE* OPTION2
           MT#  7  (N,N-PRIME) TO THE  3RD EXCITED STATE* OPTION2
           MT#  8  (N,N-PRIME) TO THE  4TH EXCITED STATE* OPTION2
           MT#  9  (N,N-PRIME) TO THE  5TH EXCITED STATE* OPTION2
           MT# 10  (N,N-PRIME) TO THE  6TH EXCITED STATE* OPTION2
           MT# 11  (N,N-PRIME) TO THE  7TH EXCITED STATE* OPTION2
           MT# 12  (N,N-PRIME) TO THE  8TH EXCITED STATE* OPTION2
           MT# 13  (N,N-PRIME) TO THE  9TH EXCITED STATE* OPTION2
           MT# 14  (N,N-PRIME) TO THE 10TH EXCITED STATE* OPTION2
           MT# 15  (N,N-PRIME) TO THE CONTINUUM * OPTION1
           MT# 51  (N,N-PRIME) TO THE 11TH EXCITED STATE* OPTION2
           MT# 52  (N,N-PRIME) TO THE 12TH EXCITED STATE* OPTION2
           MT# 53  (N,N-PRIME) TO THE 13TH EXCITED STATE* OPTION2
           MT#102  (N,GAMMA) * OPTION1
           MT#110  PHOTON PRODUCTION (XS GIVEN AS YIELD)* OPTION1
```

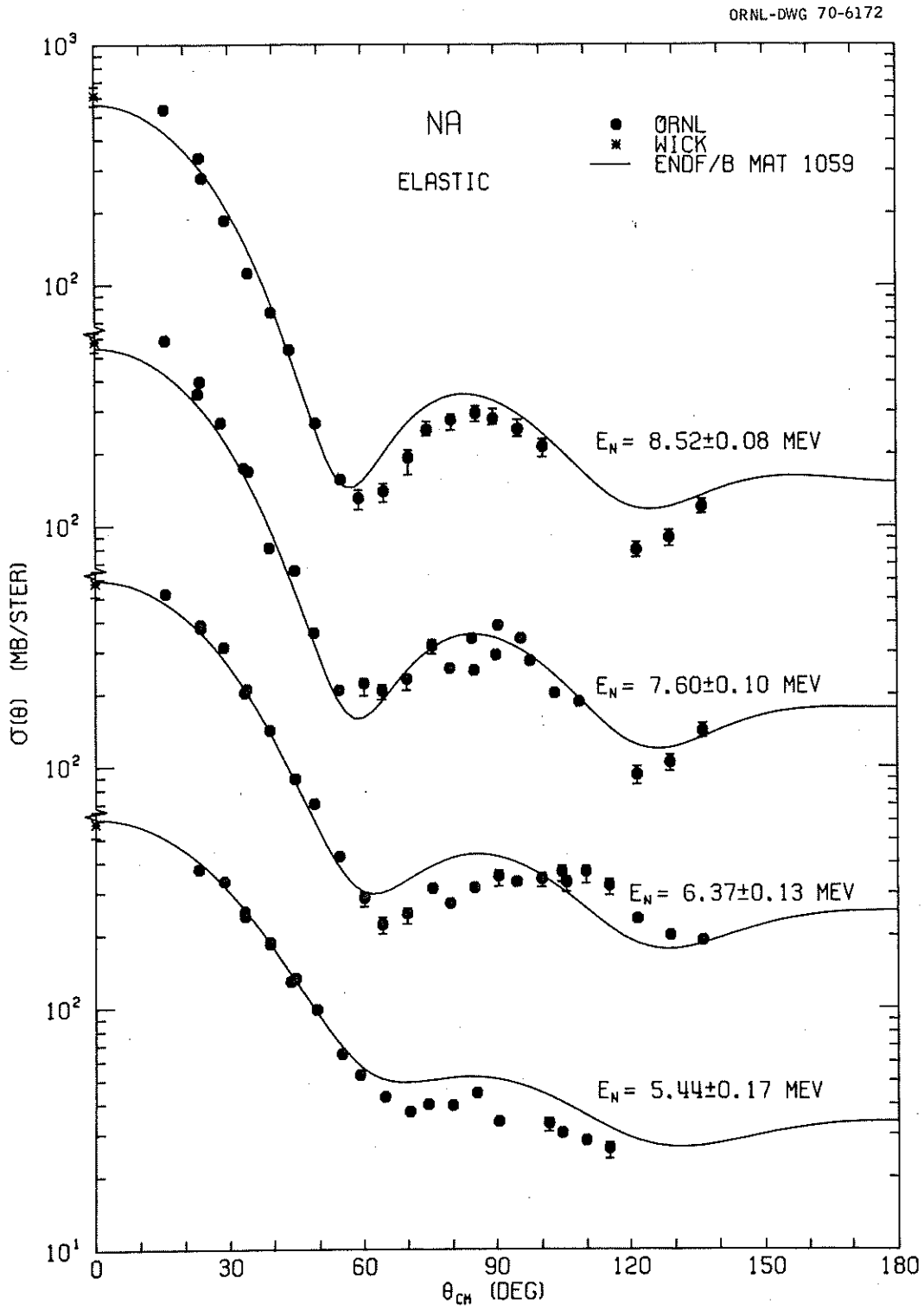
ORNL-DWG 70-6172
NA
ELASTIC
ORNL
WICK
ENDF/B MAT 1059
E_N = 8.52±0.08 MEV
E_N = 7.60±0.10 MEV
E_N = 6.37±0.13 MEV
E_N = 5.44±0.17 MEV
σ(θ) (MB/STER)
θ_{CM} (DEG)
10^3
10^2
10^2
10^2
10^1
0
30
60
90
120
150
180

Fig. 8

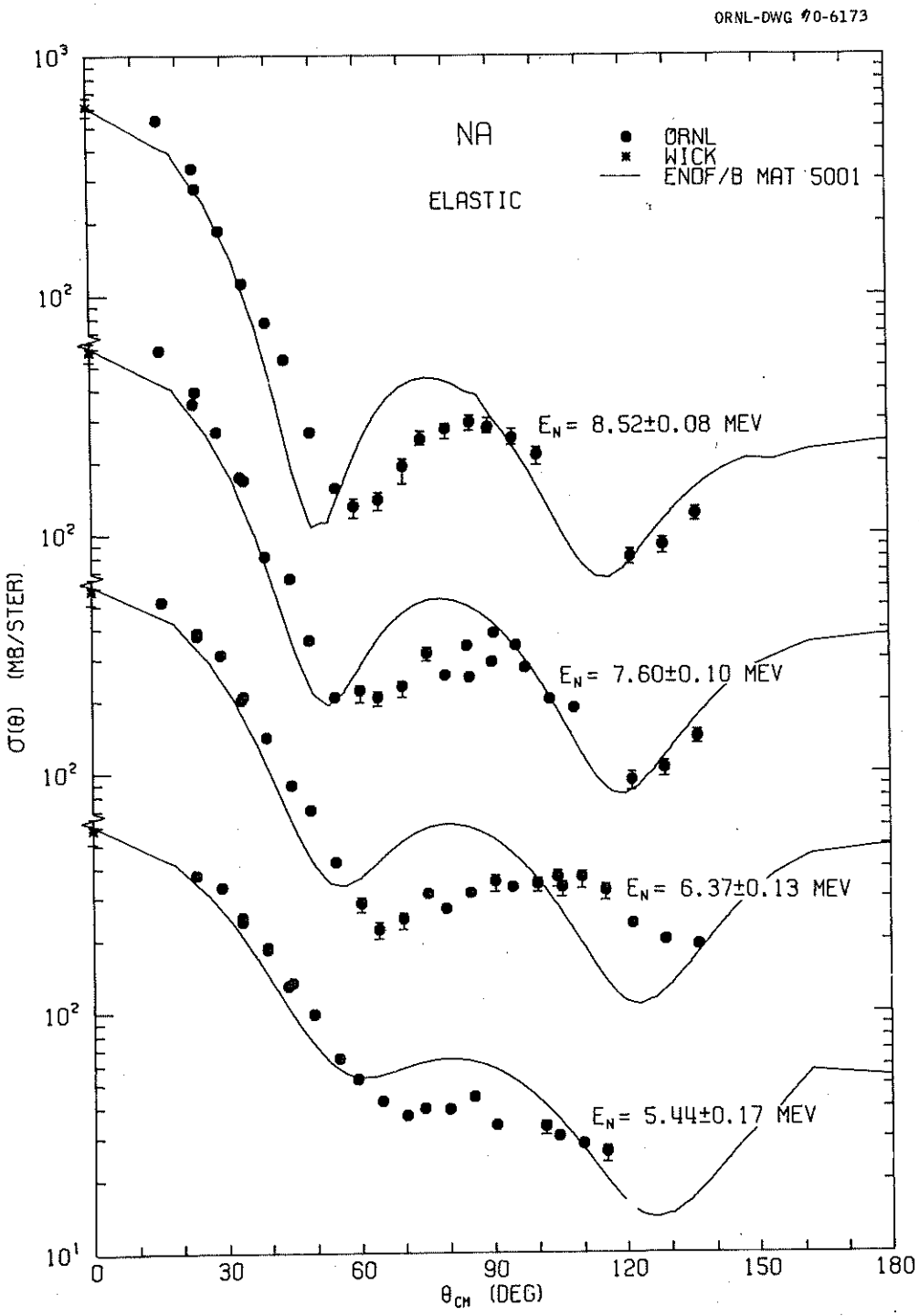
ORNL-DWG 70-6173
NA
ELASTIC
ORNL
WICK
ENDF/B MAT 5001
E_N = 8.52±0.08 MEV
E_N = 7.60±0.10 MEV
E_N = 6.37±0.13 MEV
E_N = 5.44±0.17 MEV
σ(θ) (MB/STER)
θ_{CM} (DEG)
10^3
10^2
10^1
0
30
60
90
120
150
180

Fig. 9

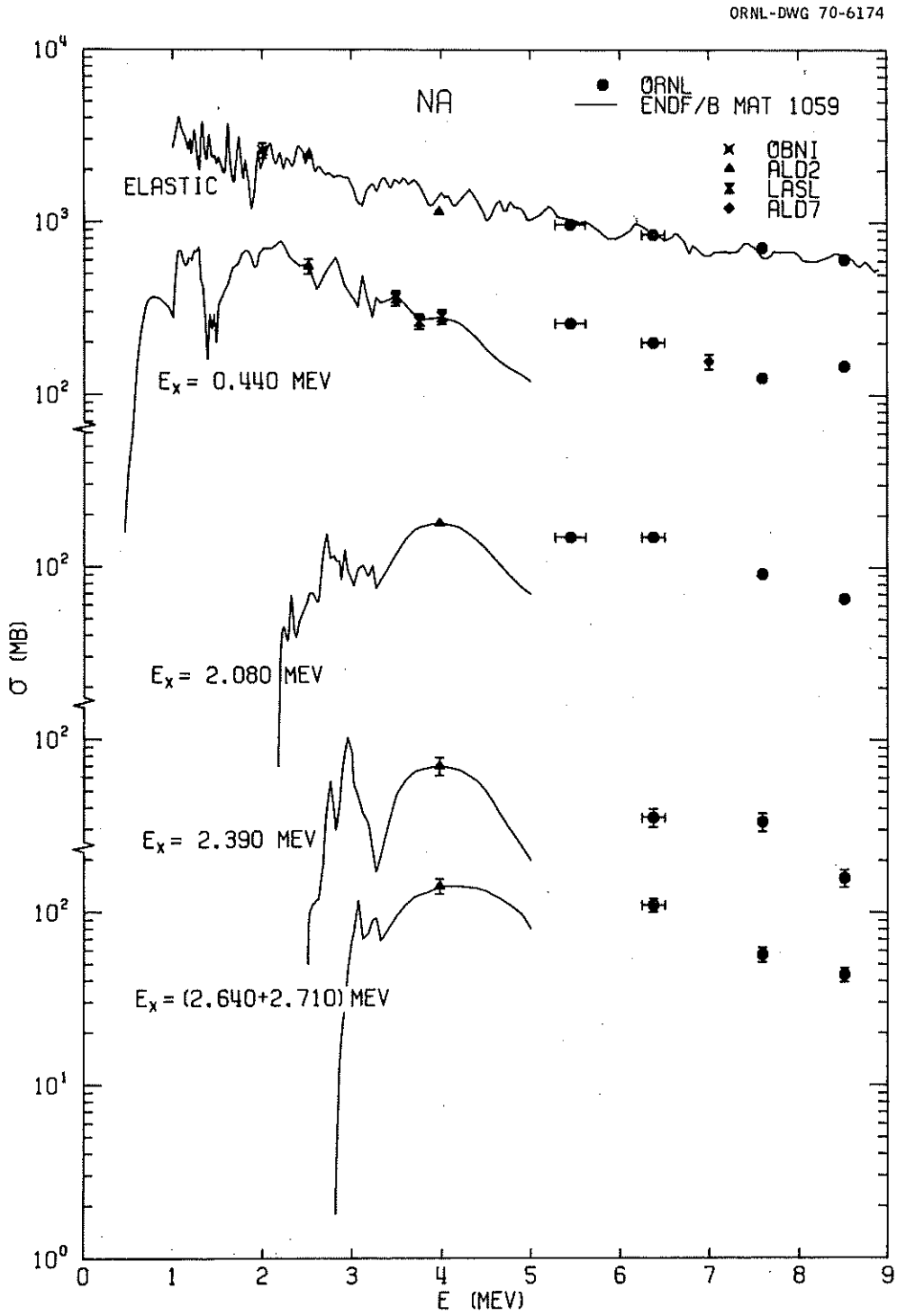
ORNL-DWG 70-6174
NA
ORNL
ENDF/B MAT 1059
ORNL
ALD2
LASL
ALD7
ELASTIC
E_x = 0.440 MEV
E_x = 2.080 MEV
E_x = 2.390 MEV
E_x = (2.640+2.710) MEV
σ (MB)
E (MEV)

Fig. 10

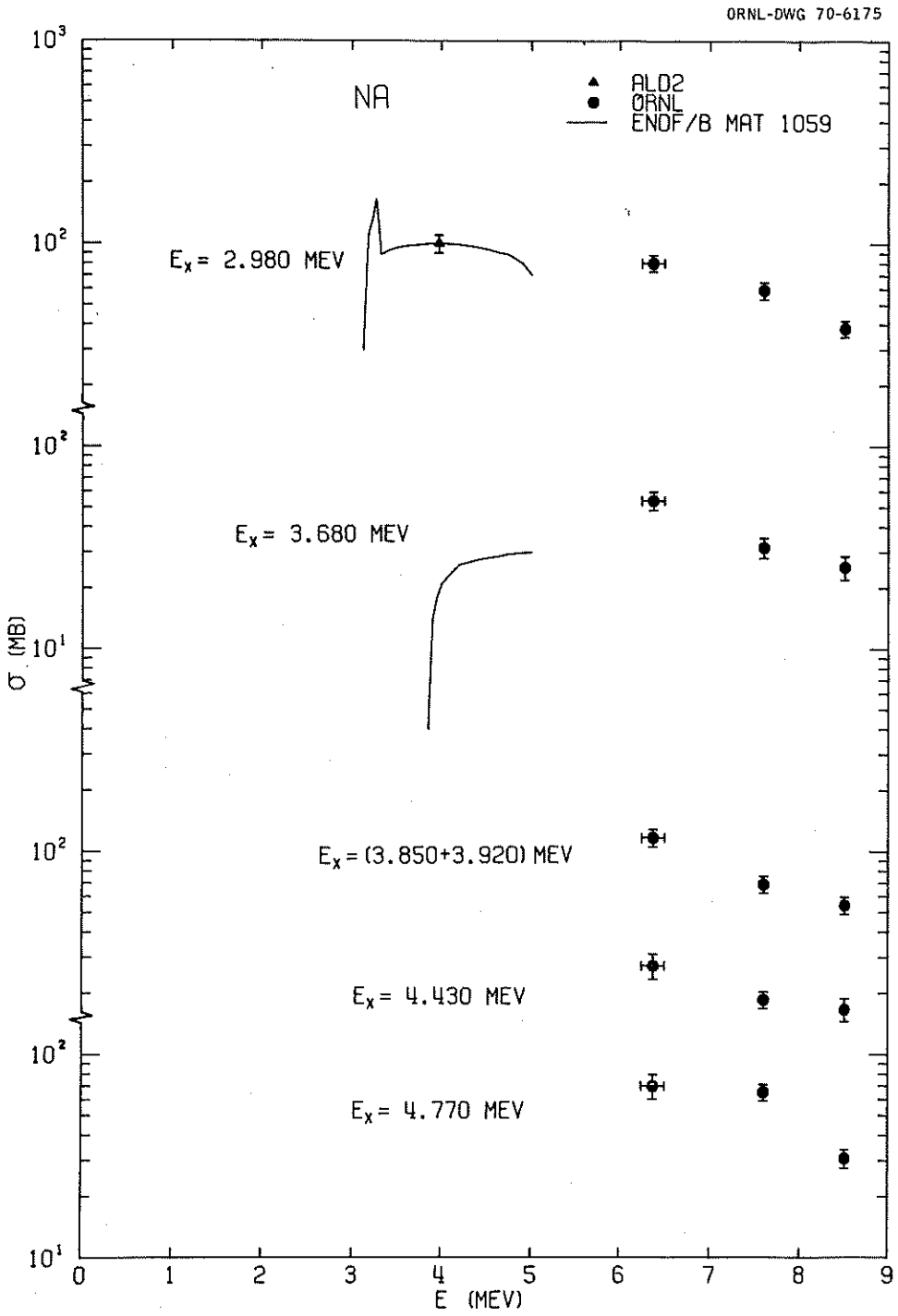
ORNL-DWG 70-6175
NA
ALD2
ORNL
ENDF/B MAT 1059
E_x = 2.980 MEV
E_x = 3.680 MEV
E_x = (3.850+3.920) MEV
E_x = 4.430 MEV
E_x = 4.770 MEV
σ (MB)
E (MEV)

Fig. 11

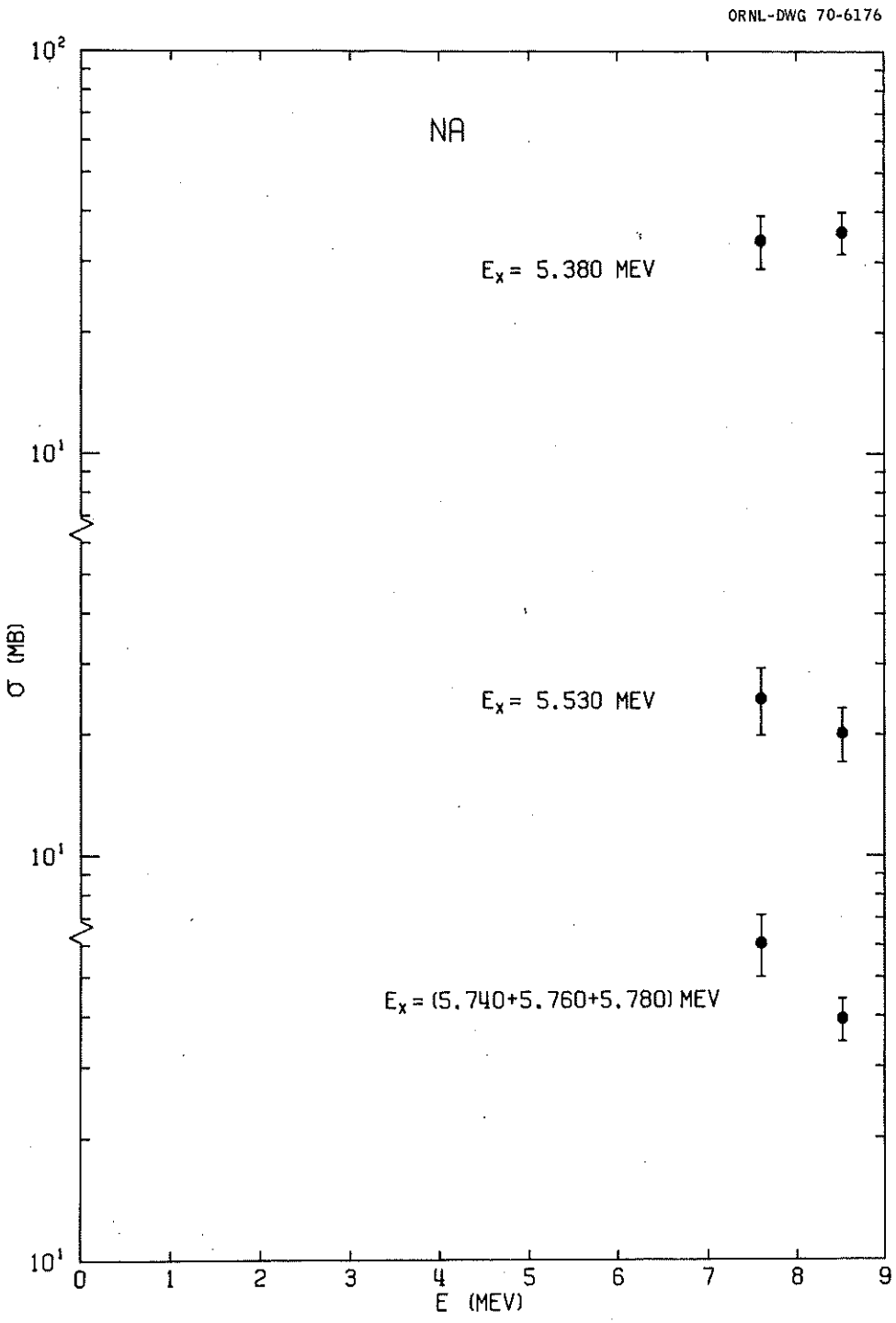
ORNL-DWG 70-6176
NA
E_x = 5.380 MEV
E_x = 5.530 MEV
E_x = (5.740+5.760+5.780) MEV
σ (MB)
E (MEV)
10^2
10^1
10^1
10^1
0
1
2
3
4
5
6
7
8
9

Fig. 12

general agreement with the data for elastic scattering. For the inelastic scattering to discrete levels the evaluation goes only up to a neutron energy of 5 MeV. For an incident neutron energy greater than 5 MeV, an evaporation spectrum using a nuclear temperature is used for inelastic scattering. In view of the data now available above 4 MeV, it is doubtful that the description of the inelastic cross sections would be adequate above this energy.

The cross sections from the ENDF/B evaluation material 5001 are shown with the data on Figs. 14 and 15. There is good agreement with the data for elastic and inelastic scattering to the first level at 0.44 MeV. It is possible that the evaluation for the 0.44 MeV level may be too low by 20 to 30% in the region from 5 to 6 MeV. For the higher excited states there is fair agreement with the data up to 6.5 MeV. However, above 6.5 MeV the evaluation has essentially a constant cross section as a function of energy, whereas the data shows approximately a factor of two reduction in values from 6.5 to 8.5 MeV. This may be necessary in this evaluation to compensate for the fact that up to 9 MeV incident neutron energy only three levels were included between 4.8 and 7.8 MeV to simulate scattering to levels higher than 4.78 MeV. Above 9 MeV this evaluation handles inelastic scattering in terms of a continuum evaporation spectrum.

Continuum Data

Inelastic scattering to levels above the 5.78 MeV levels, at 8.52 MeV incident neutron energy, could not be adequately reduced even in the form of scattering to some individual multiplets. For the 8.52 MeV data inelastic scattering to levels above the 5.78 MeV level was treated as a continuum. The spectra were transformed to cross section per 25 keV of excitation

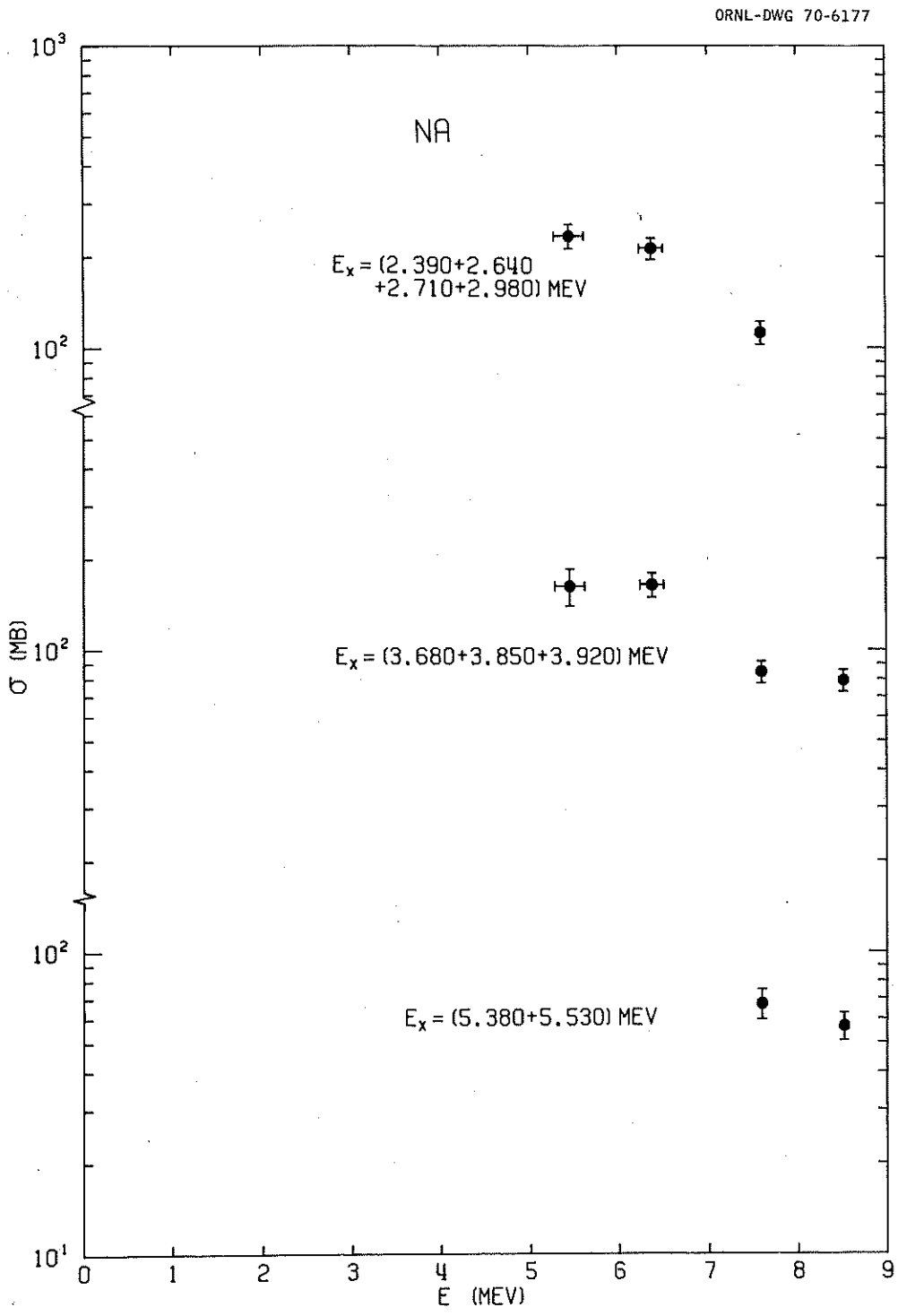
ORNL-DWG 70-6177
NA
E_x = (2.390+2.640 +2.710+2.980) MEV
E_x = (3.680+3.850+3.920) MEV
E_x = (5.380+5.530) MEV
σ (MB)
E (MEV)

Fig. 13

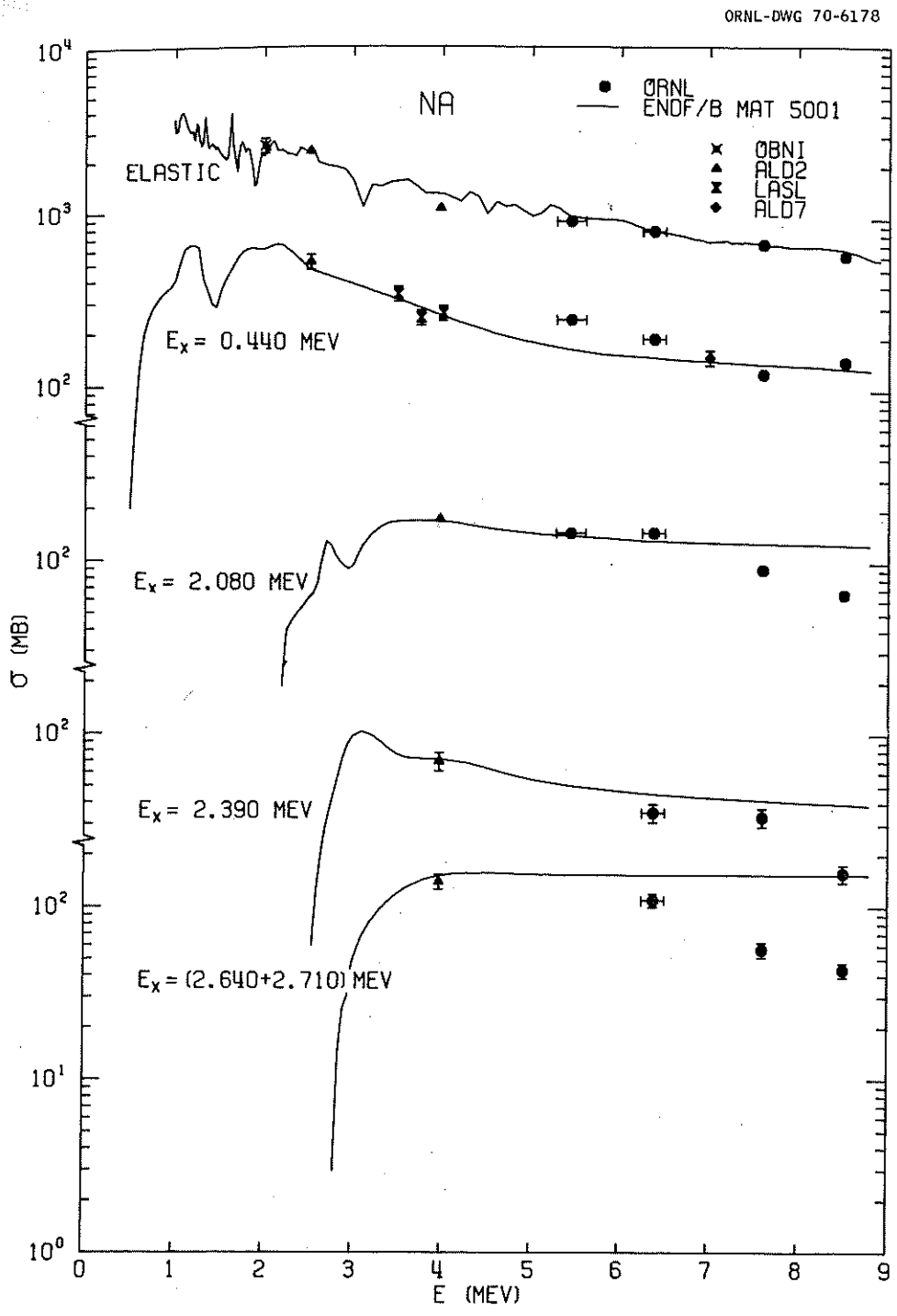
ORNL-DWG 70-6178
NA
ORNL
ENDF/B MAT 5001
OBNI
ALD2
LASL
ALD7
ELASTIC
E_x = 0.440 MEV
E_x = 2.080 MEV
E_x = 2.390 MEV
E_x = (2.640+2.710) MEV
σ (MB)
E (MEV)

Fig. 14

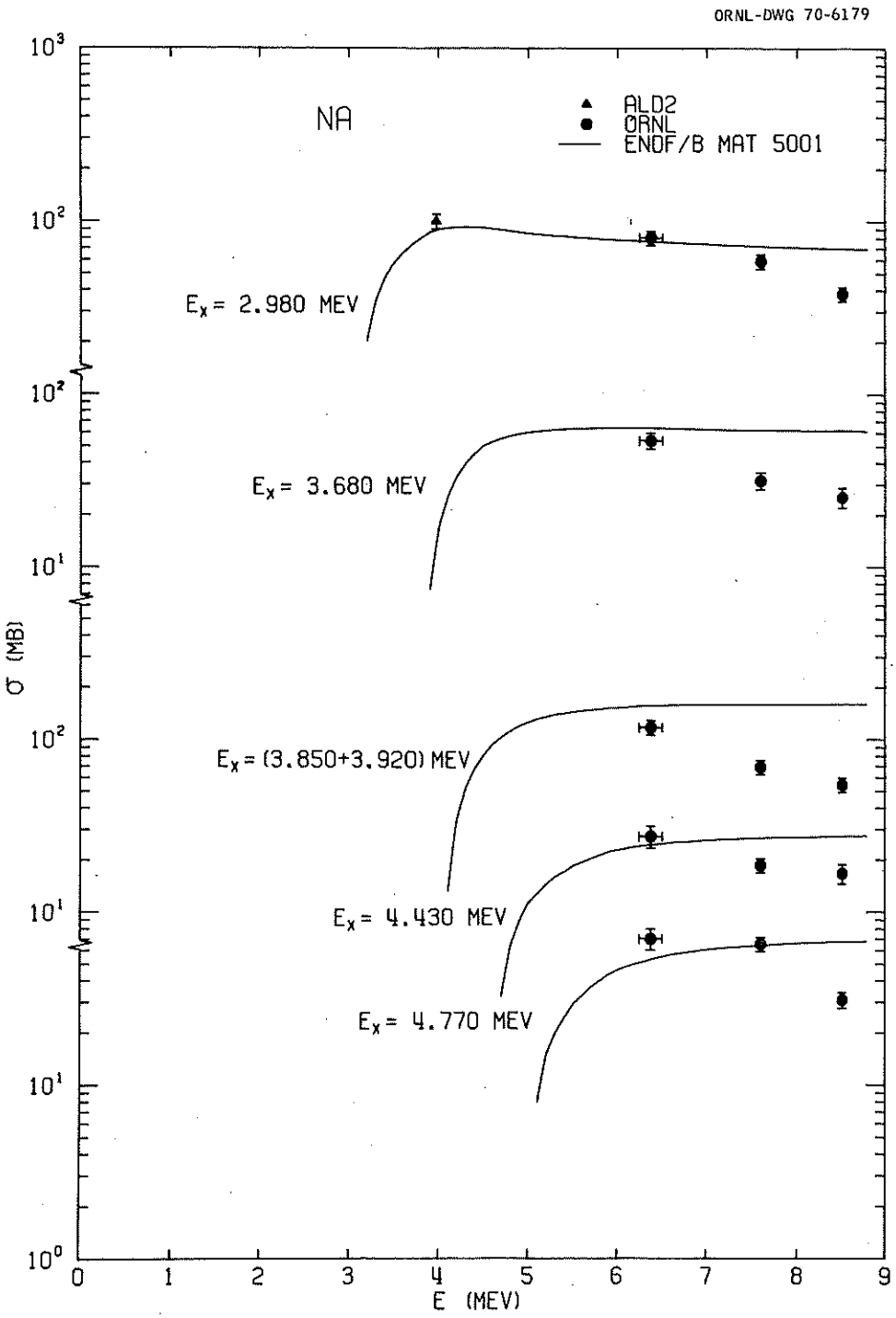
ORNL-DWG 70-6179
NA
ALD2
ORNL
ENDF/B MAT 5001
E_x = 2.980 MEV
E_x = 3.680 MEV
E_x = (3.850+3.920) MEV
E_x = 4.430 MEV
E_x = 4.770 MEV
σ (MB)
E (MEV)

Fig. 15

energy. Our detector bias being 700 keV, the efficiency curve varies very rapidly between 700 keV and 1 MeV. Because we would have had to assign very large errors, due to uncertainties in the efficiency curve for cross sections corresponding to outgoing neutrons below 1 MeV, we have not reduced the data for neutrons below this energy. In our angular range we had no evidence of anisotropic cross sections in the continuum. In an attempt at improving the statistics in the data and in an effort to reduce the quantity of data, we have averaged our continuum data. The weighted average was performed with a weighting factor of the inverse square of the statistical error on each data point. In this report we only present the averaged cross sections for the continuum, they are shown on Fig. 16. The structure observed in the inelastic continuum is typical of what we have obtained for many nuclei in the medium-weight mass region.[8-11] Previous experiments, performed with a much lower energy resolution for the outgoing neutrons, have failed to reveal such structure and led to the belief that the spectra could be adequately represented in terms of a smooth shape characterized by a single parameter, the nuclear temperature. It is obvious from our results that such a simplified picture does not apply in this mass region, and a more elaborate parameterization of the continuum is required to give a satisfactory description of this aspect of inelastic scattering.

CONCLUSIONS

The measurements of elastic- and inelastic-scattering cross sections given in this report are the only data of this kind above 4 MeV for Na. They should provide adequate data to extend the inelastic-scattering evaluations above this energy. The two ENDF/B evaluations for Na have

ORNL-DWG 70-6180

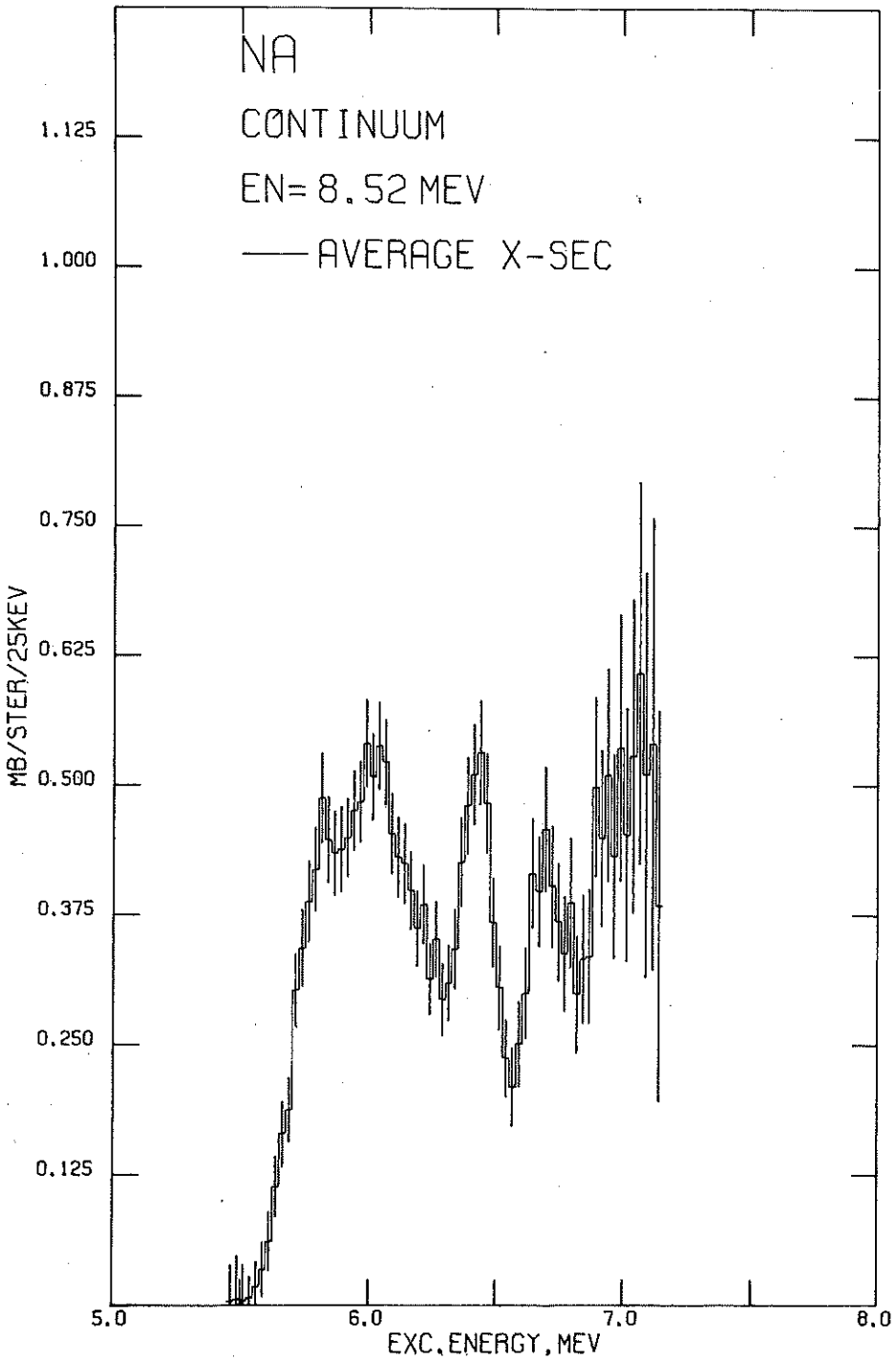

Fig. 16

been compared with our data and found to be adequate for the magnitude of elastic scattering but a little deficient in the shape of the angular distributions. One of the evaluations (material 1059) did not consider inelastic scattering to discrete levels above an incident neutron energy of 5 MeV and it is not clear whether the continuum representation for inelastic scattering above this energy is adequate - it probably is not for many applications. The other evaluation - material 5001 - did represent inelastic scattering as proceeding to discrete levels in our energy region and represented the data fairly well up to 6.5 MeV. Above 6.5 MeV this evaluation fails to reproduce the decrease of the cross sections as a function of energy. This deficiency is probably attributable to the use of only three levels for excitation energies greater than 5.78 MeV.

ACKNOWLEDGMENTS

Numerous persons have contributed to this experimental program at one time or another and we would like to thank them for their contributions. In particular, we would like to acknowledge the help of J. K. Dickens, J. W. McConnell, J. A. Biggerstaff, A. M. Marusak, P. H. Stelson, C. O. LeRigoleur, and M. V. Harlow. We would also like to thank R. Q. Wright of the Computing Technology Center, Union Carbide Corporation, Oak Ridge, for his help in obtaining the ENDF/B cross sections. For assembling the data of other investigators we thank Mrs. C. M. Perey.

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11. F. G. Perey and W. E. Kinney, Neutron Elastic- and Inelastic-Scattering Cross Sections from V in the Energy Range 4.0 to 8.5 MeV, ORNL-4551 (May 1970).

APPENDIX

Tabulated Values of Neutron Elastic- and Inelastic-Scattering Cross Sections for Na in the Energy Range of 5.4 to 8.5 MeV

We tabulate below our values of neutron elastic- and inelastic-scattering cross sections for Na. The tables are arranged by level in order of increasing incident neutron energy. The errors in the differential cross sections are relative and do not include a $\pm 7\%$ error which we attribute to our absolute normalization. The uncertainty in angle is $\pm 1^0$. The integrated cross sections error include the 7% absolute normalization error.

For elastic scattering Wick's limit was used to obtain the zero degree cross section. It was deduced from the total cross section indicated in the table. This total cross section was not measured by us.

The average continuum cross section is given in a table at the end of the appendix. All of the numerical values given in this appendix have been communicated to the National Neutron Cross Section Center, Brookhaven National Laboratory and are also available in the form of BCD magnetic tapes from the Radiation Shielding Information Center, Oak Ridge National Laboratory.

Table AI. A Table of Contents for the Na Neutron Cross Section Tables

Quantity	Page No.
Elastic Scattering	34 - 37
Inelastic Scattering, Na Levels	
E_x = 0.440 MeV	38 - 41
2.080	42 - 43
2.390	44
2.640 + 2.710	45
2.980	46
3.680	47
3.850 + 3.920	48
4.430	49 - 50
4.770	51
5.380	52
5.530	53
2.390 + 2.640 + 2.710 + 2.980	54 - 56
3.680 + 3.850 + 3.920	57 - 59
5.380 + 5.530	60
Continuum	61 - 62

SCATTERING OF 5.44 +OR-0.17 MEV NEUTRONS FROM NA

LEVEL(S) 0.0 MEV KEY(11) 21 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
22.94	374.84	6.1	6.1	50348
28.65	334.86	6.1	6.1	10260
33.32	250.96	6.1	6.1	50336
33.33	239.62	6.1	6.1	50335
39.02	183.60	6.1	6.1	10336
39.03	187.19	6.1	6.1	10335
43.68	128.68	6.2	6.2	50321
44.71	132.77	6.2	6.2	30336
49.34	98.47	4.3	4.7	10321
55.01	64.41	6.3	6.3	30321
59.12	52.87	6.3	6.3	50310
64.74	42.78	6.3	6.3	10310
70.34	37.17	6.3	6.3	30310
74.38	39.86	4.7	5.9	50301
79.94	39.56	5.8	4.3	10301
85.48	44.51	4.7	4.3	30301
90.51	33.89	5.2	6.3	50288
101.49	33.37	5.0	7.8	30288
104.45	30.48	4.8	6.8	50270
109.90	28.34	5.1	6.9	10270
115.31	26.23	5.4	9.4	30270

AVERAGE X-SEC 0.0 MB/STR 1 NOTE

INTEGRATED X-SEC 970.24 MB ERROR 7.2 PER CENT

WICKS LIMIT 580.60 MB/STR ERROR 12.2 PER CENT

TOTAL X-SEC 1.95 B ERROR 5.0 PER CENT

P 6 FIT

L	COEF.	ERROR (O/O)
0	154.41835	1.7
1	79.24251	2.9
2	54.22575	3.5
3	33.08910	4.7
4	18.01288	6.0
5	7.20092	10.8
6	0.61640	84.2

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 0.0 MEV KEY(11) 26 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
15.65	522.59	4.6	5.7	50504
23.46	387.62	4.2	4.8	30504
23.46	376.38	6.1	6.1	10227
28.66	313.44	6.1	6.1	10242
33.33	202.32	6.1	6.1	50320
33.85	209.79	6.1	6.1	10255
39.03	141.37	6.1	6.1	10320
44.71	89.05	6.2	6.2	30320
48.84	70.06	6.2	6.2	50305
54.49	42.47	4.1	7.0	10305
60.13	28.58	5.6	8.3	30305
64.22	22.18	7.0	8.7	50292
69.82	24.61	5.1	9.7	10292
75.40	31.36	4.5	8.0	30292
79.45	27.17	4.7	7.0	50279
84.99	31.58	4.9	6.7	10279
90.51	35.18	5.4	9.6	30279
94.50	33.28	6.0	6.0	50214
99.98	34.37	5.4	7.7	10214
104.45	36.68	5.9	9.1	50267
105.45	33.27	5.1	8.9	30214
109.89	36.74	5.1	10.9	10267
115.31	32.20	5.8	9.1	30267
121.67	23.40	5.7	5.4	50163
129.00	20.02	5.3	5.8	30163
136.28	19.08	6.4	5.6	10163

AVERAGE X-SEC 0.0 MB/STR 1 NOTE

INTEGRATED X-SEC 849.89 MB ERROR 7.1 PER CENT

WICKS LIMIT 579.29 MB/STR ERROR 12.2 PER CENT

TOTAL X-SEC 1.80 B ERROR 5.0 PER CENT

P 7 FIT

L	COEF.	ERROR (O/O)
0	135.26485	1.4
1	73.73717	2.2
2	53.49301	2.7
3	39.62860	2.9
4	23.76869	3.8
5	9.46268	7.3
6	3.46520	14.7
7	1.40926	22.3

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 0.0 MEV KEY(11) 26 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	−	RUN
MULTIPLE SCATTERING CORRECTION DONE				
15.65	588.95	4.0	5.7	50527
22.94	352.06	6.1	6.1	50158
23.46	396.18	4.2	4.6	30527
28.14	267.72	6.1	6.1	50166
33.33	173.49	6.1	6.1	50148
34.37	168.14	6.1	6.1	30153
39.03	80.89	6.2	6.2	10148
44.71	65.09	6.2	6.2	30148
48.83	35.95	4.3	7.3	50121
54.49	20.72	5.2	7.6	10121
60.13	22.14	4.5	11.3	30121
64.22	20.68	5.6	8.2	50127
69.82	23.06	4.4	10.3	10127
75.40	31.71	5.9	7.3	30127
79.45	25.66	4.9	7.6	50133
84.49	34.14	4.3	3.8	50138
84.98	25.07	5.7	5.2	10133
90.01	29.10	4.4	7.7	10138
90.51	38.71	4.5	7.9	30133
95.51	34.09	4.8	7.9	30138
97.50	27.51	5.4	6.9	50143
102.97	20.24	4.1	6.0	10143
108.42	18.60	7.0	4.1	30143
121.67	9.27	7.8	9.2	50098
128.99	10.41	7.6	8.3	30098
136.28	14.12	7.1	6.7	10098

AVERAGE X-SEC 0.0 MB/STR 1 NOTE

INTEGRATED X-SEC 714.50 MB ERROR 7.2 PER CENT

WICKS LIMIT 580.76 MB/STR ERROR 9.2 PER CENT

TOTAL X-SEC 1.65 B ERROR 3.0 PER CENT

P 8 FIT

L	COEF.	ERROR (O/O)
0	113.71600	1.5
1	70.16930	2.2
2	52.60252	2.6
3	39.96288	2.8
4	29.57799	3.0
5	16.36870	4.3
6	6.46512	7.9
7	3.39931	10.6
8	1.17353	19.5

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 0.0 MEV KEY(11) 21 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
15.65	536.33	4.9	5.2	50558
23.46	337.09	5.4	6.3	30558
23.98	276.85	6.1	6.1	30416
29.17	184.89	6.1	6.1	30409
34.37	111.67	6.1	6.1	30403
39.54	76.71	6.1	6.1	30396
43.68	53.58	6.1	6.1	50379
49.35	26.63	6.2	6.2	10379
54.99	15.54	6.3	6.3	30379
59.09	13.02	8.2	10.4	50352
64.71	13.89	7.7	9.9	10352
70.32	19.16	7.2	15.3	30352
74.38	25.05	8.1	5.6	50360
79.94	27.54	5.3	9.5	10360
85.48	29.30	7.2	7.9	30360
89.50	27.87	9.9	5.6	50368
95.00	25.18	9.5	6.9	10368
100.48	21.37	7.4	9.6	30368
121.67	7.97	7.5	7.1	50252
128.99	8.98	7.2	8.3	30252
136.28	12.07	7.2	6.6	10252

AVERAGE X-SEC 0.0 MB/STR 1 NOTE

INTEGRATED X-SEC 610.86 MB ERROR 7.2 PER CENT

WICKS LIMIT 612.20 MB/STR ERROR 9.2 PER CENT

TOTAL X-SEC 1.60 B ERROR 3.0 PER CENT

P10 FIT

L	COEF.	ERROR (O/O)
0	97.22203	1.9
1	60.44531	2.6
2	45.42108	3.2
3	36.24222	3.5
4	27.74580	3.8
5	16.36591	5.6
6	7.42661	9.9
7	4.46945	13.0
8	2.83706	14.9
9	1.34781	23.7
10	0.87184	25.4

SCATTERING OF 5.44 +OR-0.17 MEV NEUTRONS FROM NA

LEVEL(S) 0.440 MEV KEY(21) 9 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
49.42	19.48	7.3	10.2	10321
74.47	18.74	19.7	10.0	50301
80.04	20.14	16.3	11.1	10301
85.58	19.54	14.3	10.7	30301
90.61	23.45	14.7	7.9	50288
101.59	24.77	11.8	10.6	30288
104.55	21.25	6.9	6.3	50270
109.99	19.98	5.4	9.9	10270
115.41	20.73	6.5	7.3	30270

AVERAGE X-SEC 0.0 MB/STR 0 NOTE

INTEGRATED X-SEC 259.97 MB ERROR 7.5 PER CENT

P O FIT

L	COEF.	ERROR(O/O)
0	41.37560	2.7

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL (S) 0.440 MEV KEY (21) 17 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
54.56	12.50	11.2	8.1	10305
60.19	15.73	6.4	15.8	30305
64.29	13.90	9.6	11.1	50292
69.89	15.20	7.3	9.0	10292
75.48	16.15	9.2	14.3	30292
79.53	13.35	9.5	9.4	50279
85.07	16.20	9.2	7.2	10279
90.60	16.74	10.7	8.4	30279
94.60	17.91	7.0	10.1	50214
100.08	19.14	5.9	15.0	10214
104.54	18.30	8.6	8.0	50267
105.53	21.03	7.5	9.8	30214
109.98	20.21	5.7	14.1	10267
115.40	24.51	9.1	8.1	30267
121.76	21.63	5.1	6.0	50163
129.07	19.18	6.0	5.7	30163
136.35	18.12	6.2	6.8	10163

AVERAGE X-SEC 0.0 MB/STR 0 NOTE

INTEGRATED X-SEC 201.53 MB ERROR 7.5 PER CENT

P 2 FIT

L	COEF.	ERROR (O/O)
0	32.07391	2.6
1	-4.25871	14.2
2	-1.26054	35.1

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 0.440 MEV KEY(21) 18 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
48.88	8.29	9.2	13.3	50121
54.55	7.90	13.5	12.7	10121
60.18	7.67	15.2	11.4	30121
64.27	7.55	9.9	7.2	50127
69.88	6.82	11.3	10.8	10127
75.46	7.39	9.5	11.8	30127
79.51	9.03	7.4	17.3	50133
84.55	8.09	11.8	14.9	50138
85.05	7.77	5.3	18.2	10133
90.08	7.10	6.4	15.8	10138
90.58	8.07	8.9	15.0	30133
95.57	9.41	10.4	24.5	30138
97.57	7.32	12.4	13.5	50143
103.04	7.45	13.1	10.9	10143
108.48	10.58	12.1	11.0	30143
121.74	13.85	6.4	6.5	50098
129.05	13.32	6.5	7.0	30098
136.34	11.91	7.1	6.5	10098

AVERAGE X-SEC 0.0 MB/STR 0 NOTE

INTEGRATED X-SEC 125.99 MB ERROR 7.8 PER CENT

P 3 FIT

L	COEF.	ERROR (O/O)
0	20.05170	3.3
1	-1.36402	35.0
2	1.68446	21.4
3	0.60076	42.1

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 0.440 MEV KEY(21) 12 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
59.15	10.83	11.7	13.4	50352
64.77	12.22	11.1	12.2	10352
70.38	11.68	12.1	16.3	30352
74.44	10.90	10.0	16.8	50360
80.00	9.30	18.3	17.3	10360
85.54	12.73	12.5	12.8	30360
89.56	12.54	9.8	18.7	50368
95.06	12.59	4.4	9.3	10368
100.54	12.30	14.5	8.0	30368
121.73	11.68	6.5	6.9	50252
129.05	12.21	6.1	7.5	30252
136.33	11.20	7.4	7.9	10252

AVERAGE X-SEC 0.0 MB/STR 0 NOTE

INTEGRATED X-SEC 147.92 MB ERROR 7.4 PER CENT

P O FIT

L	COEF.	ERROR(O/O)
0	23.54277	2.5

SCATTERING OF 5.44 +OR-0.17 MEV NEUTRONS FROM NA

LEVEL(S) 2.080 MEV KEY(31) 11 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
55.56	11.47	7.3	9.9	30321
65.34	11.29	8.2	10.2	10310
70.98	11.27	7.2	11.7	30310
75.05	11.89	8.1	7.9	50301
80.63	11.97	7.6	9.2	10301
86.19	12.89	7.2	8.4	30301
91.23	12.26	8.1	13.3	50288
102.19	12.73	10.8	8.1	30288
105.15	12.28	6.3	8.4	50270
110.56	11.38	7.5	6.5	10270
115.96	12.90	5.8	7.9	30270

AVERAGE X-SEC 11.89 MB/STR 0 NOTE

INTEGRATED X-SEC 149.42 MB ERROR 8.4 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 2.080 MEV KEY(31) 18 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
49.25	10.76	8.6	7.2	50305
54.93	10.41	7.9	9.1	10305
60.60	12.55	7.6	8.8	30305
64.71	11.03	7.2	7.5	50292
70.34	12.90	7.4	6.5	10292
75.93	12.54	6.9	6.5	30292
79.99	10.54	8.7	7.3	50279
85.54	11.92	6.2	6.6	10279
91.07	13.26	5.6	7.5	30279
95.08	13.07	6.9	8.3	50214
100.54	12.21	8.5	7.0	10214
105.01	14.16	8.6	6.9	50267
105.99	13.03	6.4	7.4	30214
110.42	13.86	6.6	6.6	10267
115.83	13.24	7.2	8.3	30267
122.17	11.04	6.2	6.6	50163
129.45	10.72	7.2	7.0	30163
136.69	10.34	8.1	7.6	10163

AVERAGE X-SEC 11.94 MB/STR 0 NOTE

INTEGRATED X-SEC 150.05 MB ERROR 8.3 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 2.080 MEV KEY(31) 18 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
49.16	6.77	6.9	4.8	50121
54.84	6.79	7.7	6.3	10121
60.50	8.24	7.7	6.1	30121
64.61	7.40	5.5	6.0	50127
70.22	7.15	7.3	5.1	10127
75.82	7.67	7.6	6.6	30127
79.87	7.19	5.4	6.0	50133
84.92	6.83	8.4	7.9	50138
85.42	6.55	6.9	7.1	10133
90.45	6.84	6.5	7.4	10138
90.94	7.61	10.0	7.6	30133
95.95	7.86	7.2	8.2	30138
97.94	6.99	5.4	8.2	50143
103.40	7.22	8.8	6.7	10143
108.84	8.74	10.5	11.0	30143
122.07	10.20	6.8	13.0	50098
129.36	9.38	6.9	8.8	30098
136.61	9.01	6.5	8.6	10098

AVERAGE X-SEC 7.30 MB/STR 0 NOTE

INTEGRATED X-SEC 91.74 MB ERROR 8.1 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 2.080 MEV KEY(31) 15 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
43.93	7.05	9.6	13.6	50379
49.62	6.76	12.6	14.2	10379
55.28	5.74	12.3	19.7	30379
59.42	5.76	9.3	8.9	50352
65.05	4.44	14.7	12.0	10352
70.67	5.00	12.0	13.8	30352
74.74	4.93	11.9	14.6	50360
80.31	5.42	8.5	13.4	10360
85.86	4.99	12.2	14.2	30360
89.88	4.79	8.3	13.1	50368
95.38	4.94	7.7	12.2	10368
100.86	5.59	6.3	10.4	30368
122.01	5.54	9.9	7.7	50252
129.30	5.54	12.2	7.9	30252
136.55	4.95	9.1	8.5	10252

AVERAGE X-SEC 5.24 MB/STR 0 NOTE

INTEGRATED X-SEC 65.83 MB ERROR 8.2 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 2.390 MEV KEY(41) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.27	2.90	14.0	13.8	50163
129.55	2.80	15.2	14.6	30163
136.77	2.65	24.1	17.0	10163

AVERAGE X-SEC 2.82 MB/STR 0 NOTE

INTEGRATED X-SEC 35.41 MB ERROR 12.2 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 2.390 MEV KEY (41) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.15	2.15	16.4	21.9	50098
129.43	3.26	14.1	13.8	30098
136.67	3.05	9.9	19.0	10098

AVERAGE X-SEC 2.66 MB/STR 0 NOTE

INTEGRATED X-SEC 33.43 MB ERROR 12.2 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL (S) 2.390 MEV KEY (41) 6 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
89.96	1.27	21.7	20.4	50368
95.45	1.11	21.7	21.4	10368
100.93	1.18	18.8	19.0	30368
122.07	1.66	19.6	22.8	50252
129.36	1.43	19.3	21.3	30252
136.61	1.18	22.3	22.4	10252

AVERAGE X-SEC 1.25 MB/STR 0 NOTE

INTEGRATED X-SEC 15.75 MB ERROR 11.6 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL (S) 2.640 MEV KEY (52) 3 ANGLES
2.710

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.39	8.22	7.4	8.5	50163
129.65	8.96	7.2	8.5	30163
136.87	9.75	6.7	9.0	10163

AVERAGE X-SEC 8.75 MB/STR 0 NOTE

INTEGRATED X-SEC 109.97 MB ERROR 9.1 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 2.640 MEV KEY (52) 3 ANGLES
2.710

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.24	4.56	10.4	11.7	50098
129.51	4.27	10.2	10.3	30098
136.74	4.85	9.9	11.0	10098
AVERAGE X-SEC	4.51 MB/STR	0 NOTE		

INTEGRATED X-SEC 56.71 MB ERROR 10.0 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL (S) 2.640 MEV KEY (52) 6 ANGLES
2.710

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
90.04	4.06	12.6	11.6	50368
95.54	4.22	14.0	10.1	10368
101.02	4.84	9.9	11.8	30368
122.14	2.85	12.3	12.8	50252
129.43	2.53	14.8	13.2	30252
136.66	2.15	13.5	12.7	10252
AVERAGE X-SEC	3.45 MB/STR	1 NOTE		

INTEGRATED X-SEC 43.39 MB ERROR 9.5 PER CENT

DATA FROM 1 ANGLE (S) EXCLUDED
136.66

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 2.980 MEV KEY(71) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.52	6.50	7.6	9.0	50163
129.77	6.10	8.9	9.0	30163
136.98	6.61	8.1	8.8	10163

AVERAGE X-SEC 6.39 MB/STR 0 NOTE

INTEGRATED X-SEC 80.28 MB ERROR 9.3 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 2.980 MEV KEY(71) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.33	4.53	9.9	10.8	50098
129.59	5.06	10.3	9.8	30098
136.82	4.50	11.1	10.0	10098

AVERAGE X-SEC 4.69 MB/STR 0 NOTE

INTEGRATED X-SEC 58.96 MB ERROR 9.8 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 2.980 MEV KEY(71) 6 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
90.13	2.38	14.6	17.6	50368
95.64	2.71	14.7	17.6	10368
101.11	2.45	14.3	15.6	30368
122.21	3.83	11.3	10.9	50252
129.48	3.33	10.7	10.4	30252
136.72	3.50	9.6	9.4	10252

AVERAGE X-SEC 3.04 MB/STR 0 NOTE

INTEGRATED X-SEC 38.18 MB ERROR 9.2 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL (S) 3.680 MEV KEY(81) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.90	4.08	11.4	11.8	50163
130.14	4.39	15.1	10.5	30163
137.31	4.53	15.6	12.5	10163

AVERAGE X-SEC 4.31 MB/STR 0 NOTE

INTEGRATED X-SEC 54.13 MB ERROR 10.7 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 3.680 MEV KEY(81) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.60	2.43	12.6	23.4	50098
129.84	2.15	18.1	16.9	30098
137.05	3.15	14.7	13.7	10098

AVERAGE X-SEC 2.52 MB/STR 0 NOTE

INTEGRATED X-SEC 31.71 MB ERROR 11.4 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL (S) 3.680 MEV KEY(81) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.40	1.92	25.7	17.8	50252
129.66	2.04	17.9	19.8	30252
136.89	2.03	20.6	15.1	10252

AVERAGE X-SEC 2.01 MB/STR 0 NOTE

INTEGRATED X-SEC 25.32 MB ERROR 13.3 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL (S) 3.850 MEV KEY(92) 3 ANGLES
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
123.08	10.61	8.6	8.5	50163
130.29	8.06	10.1	8.8	30163
137.44	9.21	9.6	9.0	10163

AVERAGE X-SEC 9.30 MB/STR 0 NOTE

INTEGRATED X-SEC 116.81 MB ERROR 10.0 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 3.850 MEV KEY(92) 3 ANGLES
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.70	5.40	9.1	10.1	50098
129.93	5.61	9.7	12.4	30098
137.12	5.49	8.7	8.9	10098

AVERAGE X-SEC 5.48 MB/STR 0 NOTE

INTEGRATED X-SEC 68.82 MB ERROR 9.6 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL (S) 3.850 MEV KEY(92) 3 ANGLES
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
122.48	4.44	10.0	9.8	50252
129.74	3.98	12.1	10.9	30252
136.95	4.43	9.2	9.2	10252

AVERAGE X-SEC 4.32 MB/STR 0 NOTE

INTEGRATED X-SEC 54.28 MB ERROR 9.7 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL (S) 4.430 MEV KEY (111) 7 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
66.15	5.16	17.1	21.9	50292
77.53	2.88	27.6	23.9	30292
81.59	2.74	17.9	25.2	50279
92.74	3.10	14.3	28.5	30279
123.62	2.05	38.4	25.3	50163
130.77	1.60	32.8	22.4	30163
137.89	1.48	28.6	26.0	10163

AVERAGE X-SEC 2.17 MB/STR 0 NOTE

INTEGRATED X-SEC 27.27 MB ERROR 14.4 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 4.430 MEV KEY (111) 15 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
65.54	1.29	29.1	16.2	50127
71.17	1.33	21.5	23.4	10127
76.81	1.38	23.7	12.3	30127
80.88	1.48	17.0	18.5	50133
85.96	1.38	16.0	18.9	50138
86.42	1.49	14.0	10.8	10133
91.50	1.16	17.0	19.3	10138
91.97	1.26	19.9	16.9	30133
96.98	1.69	12.8	20.8	30138
98.97	1.71	12.8	14.5	50143
104.43	1.49	11.4	23.6	10143
109.86	1.74	15.7	21.6	30143
122.99	2.15	15.8	18.6	50098
130.21	1.78	19.1	21.9	30098
137.36	1.78	18.5	18.6	10098

AVERAGE X-SEC 1.48 MB/STR 0 NOTE

INTEGRATED X-SEC 18.56 MB ERROR 9.5 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 4.430 MEV KEY(111) 6 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
90.69	1.63	11.2	21.0	50368
96.18	1.46	18.0	24.0	10368
101.64	1.58	16.8	28.7	30368
122.68	1.03	31.2	26.0	50252
129.93	1.35	20.6	17.6	30252
137.11	0.76	59.5	27.8	10252

AVERAGE X-SEC 1.32 MB/STR 0 NOTE

INTEGRATED X-SEC 16.64 MB ERROR 13.0 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 4.770 MEV KEY(121) 7 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
66.72	6.41	21.6	18.9	50292
78.09	5.28	16.9	18.9	30292
82.20	6.83	14.8	19.1	50279
93.33	6.37	15.5	17.1	30279
124.04	4.94	21.2	20.7	50163
131.23	4.56	24.8	23.4	30163
138.29	5.25	25.7	27.6	10163

AVERAGE X-SEC 5.55 MB/STR 0 NOTE

INTEGRATED X-SEC 69.72 MB ERROR 14.0 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 4.770 MEV KEY(121) 15 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
65.77	4.88	16.9	8.6	50127
71.45	4.91	11.1	10.5	10127
77.09	5.65	7.9	8.6	30127
81.14	4.71	12.7	10.5	50133
86.26	5.75	10.9	11.8	50138
86.72	5.73	9.4	8.8	10133
91.79	5.64	7.9	10.4	10138
92.24	5.24	9.9	9.6	30133
97.28	4.98	15.0	10.1	30138
99.29	4.79	14.0	7.7	50143
104.72	5.04	8.9	13.2	10143
110.13	4.65	10.9	11.9	30143
123.26	4.16	16.0	14.1	50098
130.43	3.77	11.4	14.1	30098
137.56	3.40	13.2	12.4	10098

AVERAGE X-SEC 5.17 MB/STR 1 NOTE

INTEGRATED X-SEC 64.97 MB ERROR 9.4 PER CENT

DATA FROM 2 ANGLE(S) EXCLUDED
137.56
130.43

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 4.770 MEV KEY(121) 6 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
90.90	3.60	10.5	13.2	50368
96.40	3.18	10.9	16.5	10368
101.86	2.86	15.4	25.7	30368
122.84	2.38	15.4	19.7	50252
130.07	2.13	15.6	15.5	30252
137.25	1.84	18.3	17.2	10252

AVERAGE X-SEC 2.45 MB/STR 0 NOTE

INTEGRATED X-SEC 30.74 MB ERROR 10.5 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 5.380 MEV KEY(131) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
123.81	2.76	20.0	18.3	50098
130.95	2.84	23.5	26.6	30098
138.05	2.57	20.7	20.9	10098

AVERAGE X-SEC 2.70 MB/STR 0 NOTE

INTEGRATED X-SEC 33.93 MB ERROR 15.2 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 5.380 MEV KEY(131) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
123.20	3.12	12.8	14.1	50252
130.39	3.03	11.8	15.3	30252
137.53	2.48	15.4	13.2	10252

AVERAGE X-SEC 2.83 MB/STR 0 NOTE

INTEGRATED X-SEC 35.58 MB ERROR 12.0 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 5.530 MEV KEY(141) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
124.06	1.97	28.2	29.4	50098
131.15	1.83	24.7	25.7	30098
138.23	2.19	25.3	28.6	10098

AVERAGE X-SEC 1.96 MB/STR 0 NOTE

INTEGRATED X-SEC 24.57 MB ERROR 19.1 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 5.530 MEV KEY(141) 3 ANGLES

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
123.32	1.20	29.6	33.1	50252
130.52	1.68	22.2	20.0	30252
137.63	1.97	17.3	19.9	10252

AVERAGE X-SEC 1.61 MB/STR 0 NOTE

INTEGRATED X-SEC 20.17 MB ERROR 15.4 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 5.740 MEV KEY(153) 3 ANGLES
5.760
5.780

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
123.49	3.72	14.0	14.9	50252
130.65	3.20	14.1	15.6	30252
137.77	2.79	14.3	17.1	10252

AVERAGE X-SEC 3.13 MB/STR 0 NOTE

INTEGRATED X-SEC 39.35 MB ERROR 12.1 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 5.740 MEV KEY(153) 3 ANGLES
5.760
5.780

ANGLE CM	X-SEC. MB/STR	ERROR(O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
124.34	4.55	19.4	22.8	50098
131.47	5.15	22.2	20.3	30098
138.48	4.86	21.9	21.0	10098

AVERAGE X-SEC 4.82 MB/STR 0 NOTE

INTEGRATED X-SEC 60.60 MB ERROR 17.5 PER CENT

SCATTERING OF 5.44 +OR-0.17 MEV NEUTRONS FROM NA

LEVEL (S) 2.390 MEV KEY(44) 10 ANGLES
2.640
2.710
2.980

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
65.73	18.55	7.0	13.4	10310
71.40	19.21	6.9	11.8	30310
75.49	21.12	6.4	13.2	50301
81.07	19.35	7.4	10.2	10301
86.63	19.23	6.9	11.9	30301
91.68	17.33	7.7	14.1	50288
102.63	19.53	7.5	9.4	30288
105.59	19.38	6.2	13.7	50270
110.97	19.29	6.3	9.9	10270
116.35	18.73	6.3	10.6	30270

AVERAGE X-SEC 18.64 MB/STR 0 NOTE

INTEGRATED X-SEC 234.27 MB ERROR 9.3 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 2.390 MEV KEY(44) 19 ANGLES
2.640
2.710
2.980

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	−	RUN
MULTIPLE SCATTERING CORRECTION DONE				
39.54	27.49	8.9	9.7	10320
49.46	23.75	11.1	16.0	50305
55.17	19.77	7.9	15.1	10305
60.86	18.50	5.6	9.3	30305
64.98	18.16	7.7	10.9	50292
70.60	17.57	5.6	10.8	10292
76.21	18.83	5.6	6.9	30292
80.29	17.21	7.3	8.7	50279
85.83	16.66	5.3	9.2	10279
91.36	16.89	6.0	10.4	30279
95.37	15.90	5.5	9.7	50214
100.83	15.34	5.7	8.8	10214
105.29	16.95	6.3	7.4	50267
106.28	17.14	6.4	9.4	30214
110.70	19.34	5.5	9.0	10267
116.08	21.57	5.2	9.1	30267
122.40	17.62	9.0	9.0	50163
129.60	17.86	9.0	9.0	30163
136.90	21.01	9.0	9.0	10163

AVERAGE X-SEC 16.96 MB/STR 1 NOTE

INTEGRATED X-SEC 213.08 MB ERROR 8.2 PER CENT

DATA FROM 1 ANGLE(S) EXCLUDED
39.54

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL (S) 2.390 MEV KEY (44) 17 ANGLES
2.640
2.710
2.980

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	−	RUN
MULTIPLE SCATTERING CORRECTION DONE				
55.01	8.91	7.2	8.2	10121
60.68	9.12	7.0	10.4	30121
64.79	9.31	5.8	10.3	50127
70.42	9.23	8.6	9.1	10127
76.01	10.05	6.6	7.6	30127
80.07	9.00	7.2	8.3	50133
85.12	8.63	10.7	11.0	50138
85.62	9.04	6.7	7.2	10133
90.65	8.11	7.6	9.2	10138
91.14	9.37	8.2	8.2	30133
96.15	9.01	5.7	9.9	30138
98.15	8.42	7.1	8.7	50143
103.59	8.34	7.2	8.7	10143
109.03	8.35	7.8	10.9	30143
122.20	11.24	13.0	13.0	50098
129.50	12.59	13.0	13.0	30098
136.70	12.40	13.0	13.0	10098

AVERAGE X-SEC 8.93 MB/STR 0 NOTE

INTEGRATED X-SEC 112.26 MB ERROR 8.8 PER CENT

SCATTERING OF 5.44 +OR-0.17 MEV NEUTRONS FROM NA

LEVEL (S) 3.680 MEV KEY (83) 13 ANGLES
3.850
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	−	RUN
MULTIPLE SCATTERING CORRECTION DONE				
34.56	17.84	13.7	13.2	50336
40.44	15.56	13.1	14.9	10336
46.34	16.00	14.3	21.6	30336
66.74	21.01	11.4	17.5	10310
72.61	19.49	12.6	20.4	30310
76.64	13.33	12.7	16.4	50301
82.23	13.22	12.5	15.2	10301
87.81	12.22	12.7	16.7	30301
92.87	12.86	16.0	16.0	50288
103.81	12.46	15.2	18.5	30288
106.72	13.13	13.9	17.6	50270
112.11	11.92	14.8	17.0	10270
117.42	14.82	15.0	18.0	30270

AVERAGE X-SEC 12.89 MB/STR 0 NOTE

INTEGRATED X-SEC 161.96 MB ERROR 14.1 PER CENT

SCATTERING OF 6.37 +OR-0.13 MEV NEUTRONS FROM NA

LEVEL(S) 3.680 MEV KEY(83) 18 ANGLES
3.850
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
39.98	11.45	11.8	9.2	10320
50.00	17.77	8.3	13.2	50305
61.48	16.46	7.0	16.6	30305
65.63	10.99	10.1	12.7	50292
71.28	12.86	7.7	12.9	10292
76.94	12.46	10.1	12.7	30292
81.02	11.74	8.0	9.8	50279
86.53	13.37	6.8	9.7	10279
92.10	12.54	7.5	11.9	30279
96.11	13.02	9.1	11.3	50214
101.56	13.37	6.8	8.8	10214
106.00	14.39	7.6	9.9	50267
106.99	13.06	8.0	10.3	30214
111.38	15.82	7.2	11.6	10267
116.76	15.88	7.6	10.0	30267
123.03	14.43	8.4	9.1	50163
130.23	13.14	9.5	7.8	30163
137.39	14.00	8.5	8.0	10163

AVERAGE X-SEC 13.05 MB/STR 0 NOTE

INTEGRATED X-SEC 164.04 MB ERROR 9.2 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 3.680 MEV KEY(83) 19 ANGLES
3.850
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	−	RUN
MULTIPLE SCATTERING CORRECTION DONE				
33.93	8.44	12.0	9.6	50148
34.98	8.11	8.9	19.2	30153
55.37	8.71	6.9	10.2	10121
61.07	7.75	9.1	11.0	30121
65.21	8.05	6.3	8.0	50127
70.84	7.17	8.5	8.0	10127
76.46	7.19	6.0	7.9	30127
80.52	7.42	7.1	9.1	50133
85.60	6.38	8.3	9.4	50138
86.07	6.32	7.4	11.1	10133
91.11	5.93	8.2	10.3	10138
91.60	6.47	7.5	9.3	30133
96.62	6.33	7.6	10.8	30138
98.61	6.10	7.9	7.9	50143
104.05	5.86	6.8	9.8	10143
109.48	6.41	7.6	12.0	30143
122.67	7.58	9.7	11.8	50098
129.90	8.07	8.6	11.3	30098
137.10	8.73	9.5	9.2	10098

AVERAGE X-SEC 6.70 MB/STR 0 NOTE

INTEGRATED X-SEC 84.21 MB ERROR 8.3 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 3.680 MEV KEY(83) 15 ANGLES
3.850
3.920

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
29.59	7.92	14.2	17.4	30409
44.28	8.48	13.1	23.0	50379
55.73	6.07	14.7	22.4	30379
59.86	6.60	7.5	13.5	50352
65.53	5.95	12.5	13.0	10352
71.18	6.22	8.1	15.0	30352
75.26	6.47	9.3	14.0	50360
80.83	6.44	10.2	10.1	10360
86.39	7.03	8.0	12.4	30360
90.41	6.57	6.4	9.6	50368
95.91	5.97	6.5	10.3	10368
101.38	6.63	7.6	14.7	30368
122.46	6.10	14.5	11.5	50252
129.71	6.15	9.7	13.5	30252
136.93	6.42	9.5	11.1	10252

AVERAGE X-SEC 6.28 MB/STR 0 NOTE

INTEGRATED X-SEC 78.89 MB ERROR 8.4 PER CENT

SCATTERING OF 7.60 +OR-0.10 MEV NEUTRONS FROM NA

LEVEL(S) 5.380 MEV KEY(132) 7 ANGLES
5.530

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
56.39	5.09	16.6	11.6	10121
66.33	5.29	20.0	12.6	50127
72.03	6.02	13.8	12.6	10127
77.70	5.38	11.6	11.4	30127
123.80	4.73	26.0	26.0	50098
130.10	4.67	26.0	26.0	30098
138.00	4.76	26.0	26.0	10098

AVERAGE X-SEC 5.33 MB/STR 0 NOTE

INTEGRATED X-SEC 67.00 MB ERROR 11.5 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA

LEVEL(S) 5.380 MEV KEY(132) 6 ANGLES
5.530

ANGLE CM	X-SEC. MB/STR	ERROR (O/O) +	-	RUN
MULTIPLE SCATTERING CORRECTION DONE				
91.27	5.39	13.5	19.2	50368
96.79	4.19	9.6	13.6	10368
102.25	5.61	10.0	14.9	30368
123.20	4.32	17.0	17.0	50252
130.40	4.71	17.0	17.0	30252
137.50	4.45	17.0	17.0	10252

AVERAGE X-SEC 4.50 MB/STR 0 NOTE

INTEGRATED X-SEC 56.57 MB ERROR 10.5 PER CENT

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA PAGE 1

CONTINUUM X-SEC AVERAGE OF 6 SPECTRA 50 LINES

EN (LAB) MEV	QN MEV	X-SEC MB/STR	ERR MB/STR
2.587	-5.450	0.004	0.035
2.563	-5.475	0.006	0.041
2.539	-5.500	0.004	0.035
2.515	-5.525	0.007	0.020
2.491	-5.550	0.018	0.024
2.467	-5.575	0.034	0.026
2.443	-5.600	0.061	0.028
2.419	-5.625	0.114	0.029
2.395	-5.650	0.165	0.030
2.371	-5.675	0.188	0.031
2.347	-5.700	0.303	0.035
2.323	-5.725	0.343	0.037
2.299	-5.750	0.388	0.039
2.275	-5.775	0.419	0.040
2.251	-5.800	0.488	0.043
2.228	-5.825	0.447	0.042
2.204	-5.850	0.435	0.041
2.180	-5.875	0.438	0.041
2.156	-5.900	0.450	0.038
2.132	-5.925	0.476	0.039
2.108	-5.950	0.484	0.039
2.084	-5.975	0.540	0.042
2.060	-6.000	0.508	0.041
2.036	-6.025	0.538	0.042
2.012	-6.050	0.522	0.041
1.988	-6.075	0.453	0.039
1.964	-6.100	0.431	0.038
1.940	-6.125	0.425	0.039
1.916	-6.150	0.399	0.038
1.892	-6.175	0.362	0.037
1.868	-6.200	0.386	0.038
1.844	-6.225	0.313	0.034
1.820	-6.250	0.352	0.036
1.796	-6.275	0.294	0.035
1.772	-6.300	0.310	0.037
1.748	-6.325	0.343	0.038
1.724	-6.350	0.426	0.043
1.700	-6.375	0.481	0.046
1.676	-6.400	0.511	0.048
1.653	-6.425	0.532	0.050
1.629	-6.450	0.483	0.048
1.605	-6.475	0.368	0.043
1.581	-6.500	0.305	0.040
1.557	-6.525	0.237	0.037
1.533	-6.550	0.210	0.037
1.509	-6.575	0.251	0.040
1.485	-6.600	0.300	0.044
1.461	-6.625	0.415	0.053
1.437	-6.650	0.398	0.053
1.413	-6.675	0.458	0.060

SCATTERING OF 8.52 +OR-0.08 MEV NEUTRONS FROM NA PAGE 2

CONTINUUM X-SEC AVERAGE OF 6 SPECTRA 18 LINES

EN(LAB) MEV	QN MEV	X-SEC MB/STR	ERR MB/STR
1.389	-6.700	0.404	0.058
1.365	-6.725	0.369	0.056
1.341	-6.750	0.338	0.055
1.317	-6.775	0.387	0.062
1.293	-6.800	0.299	0.056
1.269	-6.825	0.333	0.062
1.245	-6.850	0.336	0.065
1.221	-6.875	0.499	0.087
1.197	-6.900	0.449	0.085
1.173	-6.925	0.510	0.103
1.149	-6.950	0.432	0.098
1.125	-6.975	0.537	0.129
1.102	-7.000	0.453	0.122
1.078	-7.025	0.529	0.152
1.054	-7.050	0.609	0.185
1.030	-7.075	0.510	0.195
1.006	-7.100	0.541	0.218
0.982	-7.125	0.384	0.188

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