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DESCRIPTION OF PRINTED OUTPUT FROM INTRANUCLEAR CASCADE CALCULATION

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Abstract

This report gives a detailed description of the printed output sheets from the intranuclear cascade calculation described in ORNL-3383.

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Introduction

This report gives detailed explanations of the printed output that is available from the intranuclear cascade calculation. It is intended for use by those persons who will obtain and run the cascade code itself and by those persons who are interested only in the output of the many cases which have been run and are on file.

It will be assumed that the reader is familiar with the intranuclear cascade calculation as described in ORNL-3383.[1] However, a brief explanation of the type of output that the cascade code itself produces is given here.

When an incident particle makes a collision, a cascade develops inside the nucleus. The cascade code results are written on a primary output tape. All the important data for a case are printed in a series of records, which comprise one file on the primary output tape. The first record describes the case, the intermediate records contain the results of the cascade reaction, and the last record briefly summarizes the results of the cascade calculation. There is one file per case, a case consisting of a specific type of incident particle with a given energy bombarding a target nucleus; for example, a neutron with an energy of 200 Mev incident on an aluminum target. A sufficient number of histories are run to provide good statistics.

The intermediate records contain data pertaining to the escaping cascade particles for each incident particle that makes a collision.* For each escaping cascade particle the type of particle, its energy, its direction cosines with respect to the incident-particle direction, and the point inside the nucleus from which it made its last collision (the x, y, and z coordinates of the point of last collision) are recorded. A record is also made when the incident particle makes a collision and no particles escape from the nucleus, but in this case the record contains only a zero. Hence there is one record of some type for every incident particle that makes a collision.

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1. H. W. Bertini, Monte Carlo Calculations on Intranuclear Cascades, ORNL-3383 (1962).

*Note: No record is made if the incident particle goes right through the nucleus.

To make full use of the output, analysis codes must be written which will organize the raw data in the intermediate records of the primary output tape into suitable forms. This report concerns three such codes: analysis codes I and II, which were written for this purpose, and an existing evaporation code[2] which was slightly modified (by Dresner) to use the primary output tape as a source of input data.

Analysis code I is somewhat rigid in its application. It was written concurrently with the cascade code and was an attempt to secure as much information from the cascade code as was feasible at any one time. This code contains all the data pertaining to the nucleus which remains after the cascade process is completed (referred to as the "residual" nucleus) and data pertaining to the escaping cascade particles themselves. In general, the distributions produced by this code are normalized to 1.

Analysis code II is more flexible in its application. It was written after completion of the cascade code and was meant primarily to provide comparisons of the results of the cascade code with available experimental data. This code contains data pertaining to the escaping cascade particles themselves but none on the residual nucleus. The distributions available from this code are given in terms of absolute cross sections [millibarns/(steradian-Mev), millibarns/steradian, etc.].

The evaporation code consists of two parts: the first part, an analysis of the cascade code primary output tape only to the extent of calculating input information for an evaporation subroutine -- that is, the A, Z, and excitation energy of the residual nucleus; and the second part, which is Dresner's code made to operate as a subroutine. The output from this code therefore represents results of the evaporation reactions which follow the cascade.

Each page of the output from the above three codes is displayed in this report on a right-hand page. Explanations of the terms which are not obvious are given on facing pages. One case is used as an example of the output: a 200-Mev neutron incident on an aluminum target whose mass number, A, is 27 and whose atomic number, Z, is 13, with 2500 incident particles analyzed.

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2. L. Dresner, EVAP -- A Fortran Program for Calculating the Evaporation of Various Particles from Excited Compound Nuclei, ORNL CF-61-12-30.

Analysis Code I

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Analysis Code I: Statement of Backward Momentum

One of the quantities calculated for some of the initial angular distributions is the ratio of the value of the distribution integrated over the forward direction to that integrated over the backward direction. When the value of the integral over the backward direction is zero, this ratio should be infinite, but the code prints out a zero. Consequently, the statement on the facing page is printed for the purpose of notifying the user that, in some of the first angular distributions that follow, the values for the distribution in the backward direction were zero.

THE BACKWARD MOMENTUM FROM ONE OF THE FIRST HISTOGRAMS IS □

Analysis Code I: Input Information

The facing page contains the input information used by analysis code I. It contains the input information punched into the cards used by the code, the information on the first record in the primary output tape from the cascade code, and the information on the last record in the primary output tape. Pertinent items of calculated information from the last record are (1) the geometric cross section of the target, (2) the inelastic cross section for the specified case, and (3) the cutoff energy used in the cascade calculation. The cutoff energy is the energy below which no particles are allowd to escape from the nucleus in the cascade phase.

INPUT

FROM CARDS

USED FILE 5 INCIDENT PARTICLE NEUT INCIDENT KINETIC ENERGY 200.000 MEV

TOTAL NUMBER OF INCIDENT PARTICLES 2500 TARGET SYMBOL AL

SIZE OF HISTOGRAMS FOR OUTGOING K.E. 25 FOR PROT, 25 FOR NEUT, 25 FOR PI+, 25 FOR PIO, 25 FOR PI-.

CROSS SECTIONS WERE CALCULATED FOR AS MANY AS 9 EMITTED PARTICLE COMBINATIONS.

21.000 MEV INTERVAL WAS USED IN CALCULATING HISTOGRAM FOR N(E*)DE FOR TOTAL REACTION

DELTAS FOR OUTGOING KINETIC ENERGY DISTRIBUTION IN MEV

	-.6 MU -.4 0 (K.E.) 100	-.1 MU +.1 0 (K.E.) 100	+.4 MU +.6 0 (K.E.) 100	+.9 ML +.95 0 (K.E.) 200	+.95 MU +1.0 0 (K.E.) 200
PROTONS	40.0000	40.0000	20.0000	20.0000	10.0000
NEUTRONS	40.0000	40.0000	20.0000	20.0000	10.0000
PI+	40.0000	40.0000	20.0000	20.0000	10.0000
PIO	40.0000	40.0000	20.0000	20.0000	10.0000
PI-	40.0000	40.0000	20.0000	20.0000	10.0000

D # DELTA, RESPECTIVE ENERGY INTERVALS OF HISTOGRAMS

OUTGOING COMBINATIONS	10000	01000	11000	20000	21000	12000	02000	22000	13000
INTERVAL FOR N(E*)DE IN MEV	21.000	21.000	21.000	21.000	21.000	21.000	21.000	21.000	21.000

FROM RECORD 1

2500 INCIDENT NEUT HIT AL TARGET WITH 27.000 MASS AND 13.000 ATOMIC NUMBER AT 200.000MEV.

FROM RECORD N

THERE WERE 964. INCIDENT PARTICLE COLLISIONS CREATING 964 ESCAPING PARTICLE RECORDS. THE GEOMETRIC CROSS SECTION WAS 1028.2133824 MB. THE INELASTIC CROSS SECTION WAS 596.4772709 MB. THE CUT OFF ENERGY WAS 1.6374597 MEV.

Analysis Code I: General

The first line of the output in this example and in all subsequent examples specifies the case. The line should read in full: neutrons incident on aluminum; the incident-particle kinetic energy is 200 Mev; mass number A is 27; atomic number Z is 13; there were 2500 incident-particle histories; and a 1.6-Mev cutoff energy was used.

The second line gives the momentum and the excitation energy of the compound nucleus. The momentum is simply the momentum of incident particle, in units of Mev/c; the excitation energy of the compound nucleus is the kinetic energy of the incident particle plus the binding energy of the most loosely bound nucleon.

The third line gives information on the mass of the residual nucleus. In the cascade calculation the number of nucleons in the nucleus is not reduced by the number of emitted cascade particles; consequently, it is possible that there may have been more particles emitted than there were nucleons in the initial nucleus. This line records how many times the number of cascade particles escaping was the same as the number of nucleons in the initial nucleus (that is, the mass of the residual nucleus was zero) and how many times there were more cascade particles escaping than there were initial nucleons in the nucleus (that is, the mass of the residual nucleus was minus). The cutoff energy, also given on the third line, is as described before.

The fourth line gives the number of times (zero in this case) that there were more than nine cascade particles emitted. (This is referred to later under "Analysis Code I: Cascade-Particle-Emission Cross Sections.")

Next on the page is a table giving the average number of cascade particles of the specified types that are emitted, the variance of the number distribution, the average kinetic energy, in Mev, of the cascade particles emitted, and the variance of the energy distribution. The averages refer to the average value per incident-particle collision.

The second table on the page consists of data pertaining to the residual nucleus which results from the cascade. Under the column "OUTGOING COMBINATION," the notation "TOTAL CASCADE" refers to those quantities calculated for all cascade events, and the five-digit numbers below "TOTAL CASCADE" refer to particular combinations of emitted cascade particles, the first digit referring to the number of protons emitted, the second digit to number of neutrons emitted, and the last three digits to number of π^+, π^0, and π^- emitted, respectively. The quantities to the right of the first column refer to the cascade nucleus for these events.

The column titles "CO," "C1," "ARM," "AREE," and "ARR" are defined at the bottom of the page. "CO" is the average value of the component of the residual momentum of the nucleus which is parallel to the incoming particle direction, and the printed quantity is in units of the momentum of the compound nucleus. "C1" is the average value of the component of the residual nucleus which is perpendicular to the direction of the incoming particle and is also given in units of the momentum of the compound nucleus. "ARM" is the average momentum for all directions of the residual nucleus, in units of Mev/c. "AREE" refers to the average residual excitation energy which remains after the cascade is completed. "AAR" refers to the average mass of the residual nucleus at the completion of the cascade.

It will be noted that all the entries for the emission of cascade pions in the first table are zero. This is because the present calculation ignores the production of pions for incident nucleons.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

MOMENTUM OF COMPOUND NUCLEUS 645.003777MEV/C EXCITATION ENERGY OF COMPOUND NUCLEUS 206.915216MEV

THE MASS OF THE RESIDUAL NUCLEUS WAS ZERO 0 TIMES, WAS MINUS 0 TIMES CUT OFF ENERGY 1.637460MEV

FOR 0 INCIDENT PARTICLE COLLISIONS THERE WERE MORE THAN 9 OUT GOING PARTICLES

EMITTED CASCADE PARTICLES

	PROTONS	NEUTRONS	PI+	PI0	PI-
AVERAGE NO.	0.9719917E 00	0.1543568E 01	0.	0.	0.
VARIANCE	0.8135309E 00	0.7958196E 00	0.	0.	0.
AV. K.E. (MEV)	0.5129998E 02	0.6772408E 02	0.	0.	0.
VARIANCE	0.3086170E 04	0.3467183E 04	0.	0.	0.

RESIDUAL NUCLEUS

OUTGOING COMBINATION	CO	CI	ARM	AREE	AAR
TOTAL CASCADE	0.2206824	0.2681468	244.0574074	35.1190605	25.4844396
10000	0.1417622	0.2731096	201.9379387	27.2017293	27.0000000
01000	0.1623787	0.3225370	238.8455200	28.4902108	27.0000000
11000	0.1413007	0.2152710	183.7389965	21.9739401	26.0000000
20000	0.2860668	0.3378481	308.4163628	41.6664295	26.0000000
21000	0.2729495	0.3013383	279.2158470	43.5731163	25.0000000
12000	0.2611375	0.2844086	273.6498451	40.4716101	25.0000000
02000	0.1325011	0.2075313	175.7122974	19.1740172	26.0000000
22000	0.3504765	0.3312624	327.7129784	55.6910400	24.0000000
13000	0.3672144	0.3082573	326.8819733	59.3421202	24.0000000

CO # (SUM OF PARALLEL RESIDUAL MOMENTUM/NUMBER OF INCIDENT PARTICLE COLLISIONS)/MOMENTUM OF COMPOUND NUCLEUS

CI # (SUM OF PERPENDICULAR RESIDUAL MOMENTUM/NUMBER OF INCIDENT PARTICLE COLLISIONS)/MOMENTUM OF COMPOUND NUCLEUS

ARM # AVERAGE RESIDUAL MOMENTUM IN MEV/C

AREE # AVERAGE RESIDUAL EXCITATION ENERGY IN MEV

AAR # AVERAGE MASS OF RESIDUAL NUCLEUS FOR TOTAL CASCADE
AAR # MASS OF RESIDUAL NUCLEUS FOR DESIGNATED OUTGOING COMBINATIONS

Analysis Code I: Angular Distributions of Residual Nuclei

This example contains the angular distributions of the residual nuclei which result from the cascade. These include the angular distributions for the total cascade and for all combinations of the emitted particles listed on the previous page. The angular distributions are given in terms of

$$\frac{\text{fraction of the total events which occur in } \Delta\mu}{\Delta\mu},$$

where μ is the cosine of the angle with respect to the incident-particle direction. The numbers on lines 3 and 4, that is, -0.9000000E 00, etc., and 0.1000000E-00, etc., refer to the middle of the interval along the μ scale, which ranges from -1 to 1.*

The numbers on the two lines immediately below "TOTAL CASCADE" refer to the angular distribution of the residual nucleus which results from the cascade for all cascade events. Note that these numbers appear in the same columns as the set of numbers above them specifying the center of the interval along the μ scale. This means that for the first entry on the first line, 0.3630705E-01, the $\Delta\mu$ interval ranges from -1 to -0.8; for the second entry it ranges from -0.8 to -0.6, for the third from -0.6 to -0.4, etc. For the first entry on the second line, 0.4045643E-00, the interval ranges from 0 to 0.2; for the second entry it ranges from 0.2 to 0.4, etc. Therefore these two lines of numbers specify a histogram of the angular distribution of the residual nucleus after the completion of the cascade.

On the same line with "TOTAL CASCADE" the entry "RATIO OF FORWARD/BACKWARD" followed by a number is simply the sum of the distribution in the forward direction divided by the sum of the distribution in the backward direction. It will be zero if the denominator of the ratio is zero. When this occurs, the statement "THE BACKWARD MOMENTUM FROM ONE OF THE FIRST HISTOGRAMS IS 0" will be printed as the first page of the outputs from this code.

The remainder of the page gives the angular-distribution data for various combinations of emitted cascade particles and their histograms. For example, the first combination is for one proton, zero neutron, zero π^+, zero π^0, and zero π^-, and the histogram is constructed in the same manner as that for total cascade.

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*Note: When the numbers which appear in the output contain an "E" both on this page and on succeeding pages, the numbers following the E refer to the power of 10 by which the number itself is to be multiplied. A blank space following the E indicates a positive exponent. A minus sign following the E indicates a negative exponent. If a minus sign precedes the entire number, the number itself is negative; otherwise it is positive.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ANGULAR DISTRIBUTION OF THE CASCADE NUCLEUS (FRACTION IN DELTA MU)/(DELTA MU)

-0.9000000E 00 -0.7000000E 00 -0.5000000E 00 -0.3000000E-00 -0.1000000E-00
0.1000000E-00 0.3000000E-00 0.5000000E 00 0.7000000E 00 0.9000000E 00

TOTAL CASCADE RATIO OF FORWARD /BACKWARD 0.8836735E 01
0.3650705E-01 0.1141079E-00 0.8298755E-01 0.1192946E-00 0.1556017E-00
0.4045643E-00 0.7883817E 00 0.1068465E 01 0.1120332E 01 0.1109958E 01

1 PROTONS 0 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.
0. 0. 0. 0. 0.
0.1351351E 01 0.1081081E 01 0.2027027E 01 0.4054054E-00 0.1351351E-00

0 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.
0. 0. 0. 0. 0.
0.6435644E 00 0.2178218E 01 0.1782178E 01 0.2475247E-00 0.1485148E-00

1 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.4973684E 01
0.8810573E-01 0.1541850E-00 0.1541850E-00 0.1982379E-00 0.2422907E-00
0.4185022E-00 0.6607929E 00 0.1211454E 01 0.1035242E 01 0.8370044E 00

2 PROTONS 0 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.
0. 0. 0. 0. 0.
0.8620690E 00 0.5172414E 00 0.1206897E 01 0.1379310E 01 0.1034483E 01

2 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.1800000E 02
0. 0.6578947E-01 0. 0.1973684E-00 0.
0.1315789E-00 0.7894737E 00 0.9868421E 00 0.1250000E 01 0.1578947E 01

1 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.6214286E 01
0. 0.1980198E-00 0.1980198E-00 0.1485148E-00 0.1485148E-00
0.3465346E-00 0.2970297E-00 0.7425742E 00 0.1485148E 01 0.1435644E 01

0 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.4612903E 01
0.8620690E-01 0.2298851E-00 0.1436782E-00 0.1724138E-00 0.2586207E-00
0.4310345E-00 0.8620690E 00 0.8333333E 00 0.1120690E 01 0.8620690E 00

2 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.1950000E 02
0. 0.2439024E-00 0. 0. 0.
0.2439024E-00 0.3658537E-00 0.8536585E 00 0.1951219E 01 0.1341463E 01

1 PROTONS 3 NEUTRONS 0 PI+ 0 PI0 0 PI- RATIO OF FORWARD /BACKWARD 0.3400000E 02
0. 0. 0. 0.1428571E-00 0.
0.2857143E-00 0.1428571E-00 0.5714286E 00 0.1857143E 01 0.2000000E 01

Analysis Code I: Excitation-Energy Distributions of Residual Nuclei

This example gives the excitation-energy distributions of the residual nuclei resulting from the cascade. The distributions are expressed as the fraction of all events leaving the nucleus with excitation energy in a particular energy interval divided by that energy interval. Again, the excitation-energy distributions are given for the "TOTAL CASCADE" and for the events in which only particular combinations of the emitted particles occur. These particular combinations of emitted particles are the same as those defined on the preceding two pages. The # sign is to be interpreted as an = sign.

The two lines immediately below the title specify the ΔE intervals for all the histograms. The DEA value refers to the interval for the total-cascade histogram, the DEB value to the interval for the histogram for the combination of one proton, zero neutron, zero π^+, zero π^0, and zero π^-, the DEC value to the interval for the next combination of particles shown on the page, and so forth. For each separate histogram, the ΔE interval remains constant. In the examples shown here, the intervals are the same for all the histograms; that is, they are all equal to 21 Mev. However, this is by choice and they need not be the same.

The notation "(SUM OVER HISTOGRAM)x(DEX)" and the numbers following this notation are related to the range of the excitation-energy spectrum over which the histogram is being constructed and how many times excitation energies occur beyond this range. The code is set up so that the ΔE interval for each histogram is selected as an input number. A histogram is constructed for ten ΔE intervals, and so the range of the histogram is from 0 to 10 x ΔE. If, for example, one is interested in the excitation-energy distribution toward the low-energy end of the spectrum only, one could specify a small ΔE and obtain a histogram from 0 to 10 x ΔE, but the range for that histogram would be much smaller than the range of available excitation-energy values. The number immediately following the notation "(SUM OVER HISTOGRAM)x(DEX)" represents the fraction of the entire excitation-energy spectrum that is being examined. If the number is 1, the range of the histogram that was selected by specifying the ΔE covers the entire range of possible excitation-energy values. If the number is less than 1, excitation energies may occur beyond the range of the histogram. The extent to which this happens is given by the number preceding the notation "OFL." This number specifies the number of "overflows," which is the number of times that excitation energies occur beyond the range specified by 10 x ΔE. If the "SUM OVER HISTOGRAM x (DEX)" is 1, there should always be a zero overflow.

The 10 entries for each of the histograms are values for the 10 energy intervals in successive order. That is, under "TOTAL CASCADE" the first entry (0.2010472E-01) is the value for the energy interval 0 - 21 Mev, the second entry (0.1165777E-01) is the value for the interval 21 - 42 Mev, the third entry for the interval 42 - 63 Mev, and so forth. In this example corresponding entries for the other histograms are for the same energy intervals, <u>but only because</u> in this case the widths of the energy intervals designated for each histogram are equal.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

EXCITATION ENERGY DISTRIBUTION OF THE CASCADE RESICUAL NUCLEUS (FRACTION PER UNIT EN.) (DE#DELTA E(MEV))

DEA IS 0.2100000E 02 DEB IS 0.2100000E 02 DEC IS 0.2100000E 02 DED IS 0.2100000E 02 DEE IS 0.2100000E 02
DEF IS 0.2100000E 02 DEG IS 0.2100000E 02 DEH IS 0.2100000E 02 DEI IS 0.2100000E 02 DEJ IS 0.2100000E 02

TOTAL CASCADE (SUM OVER HISTOGRAM)X(DEA) 0.1000000E 01 0 OFL

0.2010472E-01	0.1165777E-01	0.7854179E-02	0.3852993E-02	0.2222881E-02
0.1136139E-02	0.5927682E-03	0.1481921E-03	0.4939735E-04	0.

1 PROTONS 0 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEB) 0.1000000E 01 0 OFL

0.2187902E-01	0.1415701E-01	0.9009009E-02	0.2574003E-02	0.
0.	0.	0.	0.	0.

0 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEC) 0.1000000E 01 0 OFL

0.2168788E-01	0.1461575E-01	0.8958039E-02	0.4714757E-03	0.9429514E-03
0.	0.4714757E-03	0.	0.4714757E-03	0.

1 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DED) 0.1000000E 01 0 OFL

0.3020768E-01	0.9859450E-02	0.4615062E-02	0.1468429E-02	0.8391022E-03
0.2097755E-03	0.4195511E-03	0.	0.	0.

2 PROTONS 0 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEE) 0.1000000E 01 0 OFL

0.1642036E-01	0.1477832E-01	0.6568144E-02	0.3284072E-02	0.3284072E-02
0.1642036E-02	0.	0.1642036E-02	0.	0.

2 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEF) 0.1000000E 01 0 OFL

0.1253133E-01	0.1691729E-01	0.6892231E-02	0.5012531E-02	0.3132832E-02
0.1253133E-02	0.1879699E-02	0.	0.	0.

1 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEG) 0.1000000E 01 0 OFL

0.1225857E-01	0.1604017E-01	0.1084394E-01	0.5657709E-02	0.1885903E-02
0.4714757E-03	0.	0.4714757E-03	0.	0.

0 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEH) 0.1000000E 01 0 OFL

0.3338807E-01	0.7662835E-02	0.3010400E-02	0.1368363E-02	0.1094691E-02
0.5473454E-03	0.5473454E-03	0.	0.	0.

2 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEI) 0.1000000E 01 0 OFL

0.4645761E-02	0.1277584E-01	0.1626016E-01	0.6968641E-02	0.4645761E-02
0.2322880E-02	0.	0.	0.	0.

1 PROTONS 3 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)X(DEJ) 0.1000000E 01 0 OFL

0.2721088E-02	0.6802721E-02	0.2040816E-01	0.1088435E-01	0.4081633E-02
0.2721088E-02	0.	0.	0.	0.

Analysis Code I: Description of Momentum-Distribution Histograms

The facing page contains a brief description of three momentum-distribution histograms which follow.

DESCRIPTION OF THE FOLLOWING MOMENTUM DISTRIBUTIONS

THE FIRST GROUP OF NUMBERS BELOW THE TITLES SPECIFY THE MIDPOINTS OF THE MOMENTUM INTERVALS.

THE MOMENTUM IS THE NUMBER INDICATED (MEV/C).

THE SUBSEQUENT GROUPS OF NUMBERS ARE THE FRACTION OF THE TOTAL IN EACH INTERVAL DIVIDED BY DELTA P.

Analysis Code I: Momentum Distributions of Residual Nuclei

The distribution of the magnitude of the momentum of the cascade residual nucleus is given on the facing page. The first set of numbers below the title refers to the midpoints of the momentum intervals, in units of Mev/c, for which the distributions have been calculated. For example, the midpoint of the first interval occurs at 0.3225019E 02 Mev/c (i.e., at 32.25 Mev/c), with the total width of the interval being twice that value. The midpoint of the second interval is 0.9675056E 02 Mev/c, and so on.

The heading "TOTAL CASCADE" means, as before, that the numerical entries on the next two lines refer to the residual nucleus for all combinations of the emitted cascade particles. The headings below "TOTAL CASCADE," also as before, specify the particular particle combinations to which the numerical entries below the headings apply. The entries themselves represent the fraction of events which occur in each momentum interval divided by the width of the interval. Each entry is aligned to fall in the same column with the entry which specifies the midpoint of the momentum interval to which it applies. For example, in the histogram headed "1 PROTONS 1 NEUTRONS 0 PI+ 0 PIO 0 PI-," the third entry in the first line (0.2936840E-02) applies to the momentum interval whose midpoint is 0.1612509E 03, as indicated in the third entry in the first line in the first set of numbers on the page.

On the same line with each histogram heading is the notation "(SUM OVER HISTOGRAM) (DELTA P)." This notation and the numbers following have the same meaning as those pertaining to the excitation-energy distributions described previously, except, of course, that here they refer instead to momentum distributions. Also, the user has no choice in selecting the ranges of momentum distributions, since they are estimated in the code and therefore will not be large enough in some cases. The notations and corresponding numbers here are meant to show how much of the entire distribution is represented.

```
NEUT   ON AL        INC. K.E. (MEV) IS   200.0   A IS   27.   Z IS  13.   2500 INC. HISTORIES        1.6 MEV CUTOFF EN.

                    THE MOMENTUM DISTRIBUTION OF THE CASCADE RESIDUAL NUCLEUS

 0.3225019E 02  0.9675056E 02  0.1612509E 03  0.2257513E 03  0.2902517E 03  0.3547521E 03  0.4192524E 03
        0.4837528E 03  0.5482532E 03  0.6127536E 03  0.6772539E 03  0.7417543E 03  0.8062547E 03  0.8707550E 03

          TOTAL CASCADE                    (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.9810486E-03  0.2846649E-02  0.2846649E-02  0.2492829E-02  0.2235504E-02  0.1656525E-02  0.9488831E-03
        0.6111450E-03  0.4824829E-03  0.1929932E-03  0.1447449E-03  0.3216553E-04  0.1608276E-04  0.1608276E-04

1 PROTONS   0 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.                0.6285318E-02  0.2933149E-02  0.2095106E-02  0.2514127E-02  0.4190212E-03  0.
        0.                0.1257064E-02  0.              0.              0.              0.              0.

0 PROTONS   1 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.3070056E-03  0.2456045E-02  0.3684068E-02  0.3223559E-02  0.3070056E-02  0.1074520E-02  0.6140113E-03
        0.4605085E-03  0.4605085E-03  0.              0.1535028E-03  0.              0.              0.

1 PROTONS   1 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.1912361E-02  0.4302813E-02  0.2936840E-02  0.2595347E-02  0.1707465E-02  0.1024479E-02  0.4097917E-03
        0.3414931E-03  0.1365972E-03  0.1365972E-03  0.              0.              0.              0.

2 PROTONS   0 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.5346133E-03  0.1603840E-02  0.2673066E-02  0.1603840E-02  0.2138453E-02  0.3207680E-02  0.5346133E-03
        0.1069226E-02  0.5346133E-03  0.5346133E-03  0.5346133E-03  0.5346133E-03  0.              0.

2 PROTONS   1 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.6117915E-03  0.1223583E-02  0.2455960E-02  0.3059958E-02  0.3263955E-02  0.1427980E-02  0.1019986E-02
        0.2159887E-03  0.6117915E-03  0.4079943E-03  0.              0.2039972E-03  0.              0.

1 PROTONS   2 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.9210169E-03  0.1535028E-02  0.2609548E-02  0.2609548E-02  0.1995537E-02  0.2609548E-02  0.1842034E-02
        0.7675141E-03  0.3070056E-03  0.1535028E-03  0.1535028E-03  0.              0.              0.

0 PROTONS   2 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.1603840E-02  0.4903623E-02  0.3564088E-02  0.2049351E-02  0.1871146E-02  0.6237155E-03  0.5346133E-03
        0.2673066E-03  0.8910221E-04  0.              0.              0.              0.              0.

2 PROTONS   2 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.3781411E-03  0.1512564E-02  0.2268847E-02  0.2268847E-02  0.1134423E-02  0.3025129E-02  0.1134423E-02
        0.1890705E-02  0.7562822E-03  0.3781411E-03  0.3781411E-03  0.              0.              0.3781411E-03

1 PROTONS   3 NEUTRONS   0 PI+   0 PI0   0 PI-   (SUM OVER HISTOGRAM)(DELTA P)    0.1000000E 01     0 OFL
 0.                0.4429653E-03  0.2214826E-02  0.2214826E-02  0.2657792E-02  0.3986688E-02  0.8859306E-03
        0.1328896E-02  0.1328896E-02  0.4429653E-03  0.              0.              0.              0.
```

Analysis Code I: Perpendicular-Momentum Distributions of Residual Nuclei

This example is for the component of the momentum of the residual nucleus resulting from the cascade that is perpendicular to the direction of the incident particles. Its format is the same as that for the example on the preceding page.

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THE PERPENDICULAR MOMENTUM DISTRIBUTION OF THE CASCADE RESIDUAL NUCLEUS

0.3225019E 02 0.9675066E 02 0.1612509E 03 0.2257513E 03 0.2902517E 03 0.3547521E 03 0.4192524E 03
0.4837528E 03 0.5482532E 03 0.6127536E 03 0.6772539E 03 0.7417543E 03 0.8062547E 03 0.8707550E 03

TOTAL CASCADE				(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.2315918E-02	0.3763367E-02	0.3554291E-02	0.2637573E-02	0.1801270E-02	0.8523865E-03	0.4181519E-03	
0.1286621E-03	0.3216553E-04	0.	0.	0.	0.	0.	
1 PROTONS	0 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.4192212E-03	0.7123361E-02	0.2095106E-02	0.2514127E-02	0.2095106E-02	0.	0.1257064E-02	
0.	0.	0.	0.	0.	0.	0.	
0 PROTONS	1 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.4605085E-03	0.2763051E-02	0.3991073E-02	0.3837571E-02	0.2609548E-02	0.1074520E-02	0.6140113E-03	
0.1535028E-03	0.	0.	0.	0.	0.	0.	
1 PROTONS	1 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.3612826E-02	0.4712604E-02	0.2868542E-02	0.2522153E-02	0.1434271E-02	0.3414931E-03	0.2048958E-03	
0.	0.	0.	0.	0.	0.	0.	
2 PROTONS	0 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.2138453E-02	0.3207680E-02	0.2138453E-02	0.5346133E-03	0.3207680E-02	0.3207680E-02	0.5346133E-03	
0.5346133E-03	0.	0.	0.	0.	0.	0.	
2 PROTONS	1 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.1631977E-02	0.2855960E-02	0.4283940E-02	0.3059958E-02	0.2243962E-02	0.4079943E-03	0.6119915E-03	
0.4079943E-03	0.	0.	0.	0.	0.	0.	
1 PROTONS	2 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.1680631E-02	0.3070056E-02	0.4451582E-02	0.3070056E-02	0.1975537E-02	0.6140113E-03	0.4605085E-03	
0.1535028E-03	0.	0.	0.	0.	0.	0.	
0 PROTONS	2 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.3920477E-02	0.4276955E-02	0.4831525E-02	0.2049351E-02	0.8910221E-03	0.3564088E-03	0.1782044E-03	
0.	0.	0.	0.	0.	0.	0.	
2 PROTONS	2 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.2268847E-02	0.2268847E-02	0.2268847E-02	0.3403270E-02	0.2268847E-02	0.2268847E-02	0.	
0.3781411E-03	0.3781411E-03	0.	0.	0.	0.	0.	
1 PROTONS	3 NEUTRONS	0 PI+	0 PI0	0 PI-	(SUM OVER HISTOGRAM)	(DELTA P)	0.1000000E 01	0 OFL
0.1328496E-02	0.2657792E-02	0.4427653E-02	0.3100757E-02	0.1771861E-02	0.1771861E-02	0.4429653E-03	
0.	0.	0.	0.	0.	0.	0.	

Analysis Code I: Parallel (and Antiparallel) Momentum Distributions of Residual Nuclei

The examples on the facing page and on page 23 show the distribution of the component of momentum of the residual nucleus resulting from the cascade that is parallel (or antiparallel) to the incident-particle direction. The numbers on the four lines immediately below the title refer to the midpoints of the momentum intervals and are in units of Mev/c. The plus and minus signs preceding these numbers indicate that the components of momentum are parallel or antiparallel to the incident-particle direction, respectively.

Here again the distributions are given for the total cascade and for the combinations of emitted cascade particles used previously. The numerical entries for the histograms represent the fraction of events which occurs in each momentum interval divided by the momentum interval. As before, the midpoints of the momentum intervals in which the various histogram entries fall are indicated in a corresponding position in the first set of numbers on the page, the only difference being that here each set of numbers covers four lines instead of two lines. As a result, the line on which the entry falls as well as the column in which it falls must be considered. For example, the first nonzero entry under "TOTAL CASCADE" is 0.4824829E-04. Since it appears on the second line of the histogram, it falls within the interval whose midpoint is indicated on the second line of the same column in the first set of numbers on the page; that is, it falls within the interval whose midpoint is -0.1612509E 03 (-161.25 Mev/c).

The notation "(SUM OVER HISTOGRAM)(DELTA P)" and "OFL" have the same meaning as in the previous momentum distributions. The notation "UFL," indicating "underflow," refers to the number of events that occur whose momenta lie below the range of values specified.

(continued on page 22)

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THE PARALLEL MOMENTUM DISTRIBUTION OF THE CASCADE RESIDUAL NUCLEUS

-0.8707550E 03	-0.8062547E 03	-0.7417543E 03	-0.6772539E 03	-0.6127536E 03	-0.5482532E 03	-0.4837528E 03
-0.4192524E 03	-0.3547521E 03	-0.2902517E 03	-0.2257513E 03	-0.1612509E 03	-0.9675056E 02	-0.3225019E 02
0.3225019E 02	0.9675056E 02	0.1612509E 03	0.2257513E 03	0.2902517E 03	0.3547521E 03	0.4192524E 03
0.4837528E 03	0.5482532E 03	0.6127536E 03	0.6772539E 03	0.7417543E 03	0.8062547E 03	0.8707550E 03

TOTAL CASCADE (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.4824829E-04	0.2090759E-03
0.3699036E-02	0.3296967E-02	0.2267670E-02	0.1913849E-02	0.9649659E-03	0.7880555E-03	0.4503174E-03
0.2734070E-03	0.1125793E-03	0.6433106E-04	0.6433106E-04	0.3216553E-04	0.	0.

1 PROTONS 0 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.7542382E-02	0.2933149E-02	0.3352170E-02	0.4190212E-03	0.4190212E-03	0.8380424E-03	0.
0.	0.	0.	0.	0.	0.	0.

0 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.6293616E-02	0.5065593E-02	0.2302542E-02	0.7675141E-03	0.4605085E-03	0.3070056E-03	0.
0.3070056E-03	0.	0.	0.	0.	0.	0.

1 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.4917500E-02	0.3619826E-02	0.1912361E-02	0.1434271E-02	0.4097917E-03	0.1365972E-03	0.2731944E-03
0.1365972E-03	0.6829861E-04	0.	0.	0.	0.	0.

2 PROTONS 0 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.3207680E-02	0.5346133E-02	0.1603840E-02	0.1069226E-02	0.1603840E-02	0.5346133E-03	0.1069226E-02
0.	0.5346133E-03	0.	0.5346133E-03	0.	0.	0.

2 PROTONS 1 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.2039972E-03	0.6119915E-03
0.1631977E-02	0.3671949E-02	0.3059958E-02	0.3875946E-02	0.8159887E-03	0.6119915E-03	0.2039972E-03
0.4079943E-03	0.2039972E-03	0.	0.	0.2039972E-03	0.	0.

Analysis Code I: Parallel (and Antiparallel) Momentum Distributions (cont.)

The parallel-momentum distributions of the residual nucleus are sometime given over two pages of output, as in the example on the facing page and the preceding page. The numbers giving the midpoints of the momentum intervals and the entries for the total cascade histogram are the same, but the combinations of particles are different.

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THE PARALLEL MOMENTUM DISTRIBUTION OF THE CASCADE RESIDUAL NUCLEUS

-0.8707550E 03 -0.8062547E 03 -0.7417543E 03 -0.6772539E 03 -0.6127536E 03 -0.5482532E 03 -0.4837528E 03
-0.4192524E 03 -0.3547521E 03 -0.2902517E 03 -0.2257513E 03 -0.1612509E 03 -0.9675056E 02 -0.3225019E 02
0.3225019E 02 0.9675056E 02 0.1612509E 03 0.2257513E 03 0.2902517E 03 0.3547521E 03 0.4192524E 03
0.4837528E 03 0.5482532E 03 0.6127536E 03 0.6772539E 03 0.7417543E 03 0.8062547E 03 0.8707550E 03

TOTAL CASCADE (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.4824829E-04	0.2090759E-03	0.1318787E-02
0.3699336E-02	0.3276967E-02	0.2267670E-02	0.1913849E-02	0.9649659E-03	0.7880555E-03	0.4503174E-03	
0.2734073E-03	0.1125793E-03	0.6433106E-04	0.6433106E-04	0.3216553E-04	0.	0.	

1 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.1535028E-03	0.6140113E-03	0.1381525E-02
0.1995537E-02	0.1381525E-02	0.3223559E-02	0.2456045E-02	0.1688531E-02	0.1535028E-02	0.6140113E-03	
0.3773056E-03	0.1535028E-03	0.	0.	0.	0.	0.	

0 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.1782044E-03	0.2583964E-02
0.4633315E-02	0.4276905E-02	0.1247431E-02	0.1871146E-02	0.3564088E-03	0.8910221E-04	0.2673066E-03	
0.	0.	0.	0.	0.	0.	0.	

2 PROTONS 2 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.3781411E-03	0.3781411E-03
0.2269947E-02	0.1512564E-02	0.3025129E-02	0.1512564E-02	0.1890705E-02	0.1890705E-02	0.1890705E-02	
0.	0.	0.3781411E-03	0.3781411E-03	0.	0.	0.	

1 PROTONS 3 NEUTRONS 0 PI+ 0 PI0 0 PI- (SUM OVER HISTOGRAM)(DELTA P) 0.1000000E 01 0 OFL 0 UFL

0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.4429653E-03
0.8859306E-03	0.1328896E-02	0.3543722E-02	0.3100757E-02	0.2657792E-02	0.1771861E-02	0.8859306E-03	
0.4429653E-03	0.4429653E-03	0.	0.	0.	0.	0.	

Analysis Code I: Cascade-Particle-Emission Cross Sections

The example on the facing page gives all nonzero values of the cross sections for the emission of various combinations of emitted cascade particles in which the sum of the total emitted particles is less than or equal to nine. On the output sheet shown on page 9 , fourth line, it was noted that there were zero incident-particle collisions in which there were more than nine outgoing particles; therefore, there are no nonzero cross-section values for the emission of more than nine particles, and the data on the facing page include all the cross-section values for the case of 200-Mev neutrons incident on aluminum.

The five-digit entries in columns 1, 3, 5, and 7 specify the various combinations of emitted cascade particles. For example, in the first entry, 35000, the first digit represents the number of cascade protons emitted, the second digit the number of cascade neutrons, the third the number of π^+, the fourth the number of π^0, and the fifth the number of π^-. The cross section for this event, given in column 2, is 0.41128555E-00 millibarn (0.41 mb).

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CROSS SECTIONS (MB) FOR VARIOUS COMBINATIONS OF EMITTED CASCADE PARTICLES

1ST NO.	IS NO. OF PROTONS EMITTED	2ND	IS NO. OF NEUTRONS	3RD	IS NO. OF PI+	4TH	IS NO. OF PI0	5TH	IS NO. OF PI-
35000	0.41128555E-00	34000	0.82257110E 00	43000	0.82257110E 00	15000	0.12338566E 01		
24000	0.41128555E-00	33000	0.24677133E 01	42000	0.82257110E 00	05000	0.41128555E-00		
14000	0.28789988E 01	23000	0.78144254E 01	32000	0.37015699E 01	41000	0.12338566E 01		
04000	0.20564277E 01	13000	0.14394994E 02	22000	0.16862707E 02	31000	0.86369964E 01		
40000	0.82257110E 00	03000	0.18507849E 02	12000	0.41539840E 02	21000	0.31257701E 02		
30000	0.57579976E 01	02000	0.71563685E 02	11000	0.93361819E 02	20000	0.11927281E 02		
01000	0.41539840E 02	10000	0.15217565E 02						

Analysis Code I: Cascade-Particle Energy Spectra for μ = 1.00 to 0.95

The facing page and the four pages of output which follow are examples of data for the energy spectra of the cascade particles emitted within particular angular intervals, the interval being specified by the values of μ, the cosine of the angle measured with respect to the incident-particle direction. In the example on the facing page, μ ranges from 1.00 to 0.95, as indicated in the title. This corresponds to an angular interval from 0° to $18^{\circ}12'$, which is noted parenthetically below the title. On the following four pages of output, the values of μ are 0.95 to 0.90, 0.60 to 0.40, 0.10 to -0.10, and -0.40 to -0.60.

The energy spectra are given in terms of N(E), which is defined, but incorrectly, in the fourth line on the page. The correct definition is: N(E) is the fraction of the total number of particles of the specified type that have been emitted in the angular interval $\Delta\mu$ with energies that lie within ΔE divided by $\Delta\mu\Delta E$.

Values of N(E) are given for each of the five types of particles being emitted as a function of E. In each case E specifies the midpoint of the energy interval, in Mev. The total width of the interval is indicated by the number following the notation "DELTA E(MEV)" above each set of data. It will be noted that the energy spectra given on the facing page and on the following output page have been divided into 10 uniform energy intervals, whereas those given on the next three output pages are divided into 20 uniform intervals.

As an aid in reading these data, refer to the table of data headed "PROTONS." The midpoint of the first ΔE interval in the histogram is 5.0 Mev, with the interval covering all energies between 0 and 10 Mev. The value of N(E) for protons in this energy interval is 0.244E-00 (0.244). The midpoint of the second ΔE interval is 15 Mev, and the interval covers the range 10 to 20 Mev. The N(E) value for the second interval is 0.178E-00, and so forth.

At the bottom of the column an N value is given. As defined near the right-hand top of the page, N is the sum of the values of N(E) multiplied by $\Delta\mu \times \Delta E$. In the example shown here, N is equal to 1, which means that the entire width of the energy range for this particular angular interval has been spanned.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRA OF CASCADE PARTICLES WITH MU FROM 1.00 TO 0.95
(THETA FROM 0 DEG. 0 MIN. TO 18 DEG. 12 MIN.)

N(E) IS (FRACTION OF PARTICLES IN DELTA MU)/(DELTA MU)(DELTA E)

E(MEV) IS CENTER OF INTERVAL N IS (SUM OVER N(E))(DELTA MU)(DELTA E)

PROTONS DELTA E(MEV) 10.0		NEUTRONS DELTA E(MEV) 10.0		PI+ DELTA E(MEV) 10.0		PI0 DELTA E(MEV) 10.0		PI- DELTA E(MEV) 10.0	
E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)
5.0	0.244E-00	5.0	0.177E-00	5.0	0.	5.0	0.	5.0	0.
15.0	0.178E-00	15.0	0.145E-00	15.0	0.	15.0	0.	15.0	0.
25.0	0.444E-01	25.0	0.484E-01	25.0	0.	25.0	0.	25.0	0.
35.0	0.889E-01	35.0	0.323E-01	35.0	0.	35.0	0.	35.0	0.
45.0	0.	45.0	0.484E-01	45.0	0.	45.0	0.	45.0	0.
55.0	0.444E-01	55.0	0.645E-01	55.0	0.	55.0	0.	55.0	0.
65.0	0.889E-01	65.0	0.161E-01	65.0	0.	65.0	0.	65.0	0.
75.0	0.222E-01	75.0	0.161E-01	75.0	0.	75.0	0.	75.0	0.
85.0	0.667E-01	85.0	0.161E-01	85.0	0.	85.0	0.	85.0	0.
95.0	0.	95.0	0.484E-01	95.0	0.	95.0	0.	95.0	0.
105.0	0.222E-01	105.0	0.161E-01	105.0	0.	105.0	0.	105.0	0.
115.0	0.222E-01	115.0	0.323E-01	115.0	0.	115.0	0.	115.0	0.
125.0	0.444E-01	125.0	0.484E-01	125.0	0.	125.0	0.	125.0	0.
135.0	0.667E-01	135.0	0.161E-01	135.0	0.	135.0	0.	135.0	0.
145.0	0.667E-01	145.0	0.968E-01	145.0	0.	145.0	0.	145.0	0.
155.0	0.667E-01	155.0	0.177E-00	155.0	0.	155.0	0.	155.0	0.
165.0	0.156E-00	165.0	0.806E-01	165.0	0.	165.0	0.	165.0	0.
175.0	0.267E-00	175.0	0.242E-00	175.0	0.	175.0	0.	175.0	0.
185.0	0.244E-00	185.0	0.371E-00	185.0	0.	185.0	0.	185.0	0.
195.0	0.267E-00	195.0	0.306E-00	195.0	0.	195.0	0.	195.0	0.
N IS	1.000E 00	N IS	1.000E 00	N IS	0.	N IS	0.	N IS	0.

Analysis Code I: Cascade-Particle Energy Spectra for μ = 0.95 to 0.90

See page 26 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRA OF CASCADE PARTICLES WITH MU FROM 0.95 TO 0.90
(THETA FROM 18 DEG. 12 MIN. TO 25 DEG. 51 MIN.)

N(E) IS (FRACTION OF PARTICLES IN DELTA MU)/(DELTA MU)(DELTA E)

E(MEV) IS CENTER OF INTERVAL N IS (SUM OVER N(E))(DELTA MU)(DELTA E)

PROTONS		NEUTRONS		PI+		PI0		PI-	
DELTA E(MEV)	20.0	DELTA E(MEV)	20.0	DELTA E(MEV)	20.0	DELTA E(MEV)	20.0	DELTA E(MEV)	20.0
E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)
10.0	0.288E-00	10.0	0.147E-00	10.0	0.	10.0	0.	10.0	0.
30.0	0.137E-01	30.0	0.441E-01	30.0	0.	30.0	0.	30.0	0.
50.0	0.548E-01	50.0	0.221E-01	50.0	0.	50.0	0.	50.0	0.
70.0	0.685E-01	70.0	0.515E-01	70.0	0.	70.0	0.	70.0	0.
90.0	0.411E-01	90.0	0.588E-01	90.0	0.	90.0	0.	90.0	0.
110.0	0.274E-01	110.0	0.588E-01	110.0	0.	110.0	0.	110.0	0.
130.0	0.822E-01	130.0	0.956E-01	130.0	0.	130.0	0.	130.0	0.
150.0	0.192E-00	150.0	0.213E-00	150.0	0.	150.0	0.	150.0	0.
170.0	0.219E-00	170.0	0.206E-00	170.0	0.	170.0	0.	170.0	0.
190.0	0.137E-01	190.0	0.103E-00	190.0	0.	190.0	0.	190.0	0.
210.0	0.	210.0	0.	210.0	0.	210.0	0.	210.0	0.
230.0	0.	230.0	0.	230.0	0.	230.0	0.	230.0	0.
250.0	0.	250.0	0.	250.0	0.	250.0	0.	250.0	0.
270.0	0.	270.0	0.	270.0	0.	270.0	0.	270.0	0.
290.0	0.	290.0	0.	290.0	0.	290.0	0.	290.0	0.
310.0	0.	310.0	0.	310.0	0.	310.0	0.	310.0	0.
330.0	0.	330.0	0.	330.0	0.	330.0	0.	330.0	0.
350.0	0.	350.0	0.	350.0	0.	350.0	0.	350.0	0.
370.0	0.	370.0	0.	370.0	0.	370.0	0.	370.0	0.
390.0	0.	390.0	0.	390.0	0.	390.0	0.	390.0	0.
N IS	1.000E 00	N IS	0.100E 01	N IS	0.	N IS	0.	N IS	0.

Analysis Code I: Cascade-Particle Energy Spectra for $\mu = 0.60$ to 0.40

See page 26 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRA OF CASCADE PARTICLES WITH MU FROM 0.60 TO 0.40
(THETA FROM 53 DEG. 8 MIN. TO 66 DEG. 25 MIN.)

N(E) IS (FRACTION OF PARTICLES IN DELTA MU)/(DELTA MU)(DELTA E)

E(MEV) IS CENTER OF INTERVAL N IS (SUM OVER N(E))(DELTA MU)(DELTA E)

PROTONS		NEUTRONS		PI+		PIO		PI-	
DELTA E(MEV)	20.0	DELTA E(MEV)	20.0	DELTA E(MEV)	20.0	DELTA E(MEV)	20.0	DELTA E(MEV)	20.0
E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)
10.0	0.997E-01	10.0	0.830E-01	10.0	0.	10.0	0.	10.0	0.
30.0	0.456E-01	30.0	0.426E-01	30.0	0.	30.0	0.	30.0	0.
50.0	0.456E-01	50.0	0.340E-01	50.0	0.	50.0	0.	50.0	0.
70.0	0.287E-01	70.0	0.447E-01	70.0	0.	70.0	0.	70.0	0.
90.0	0.186E-01	90.0	0.287E-01	90.0	0.	90.0	0.	90.0	0.
110.0	0.676E-02	110.0	0.106E-01	110.0	0.	110.0	0.	110.0	0.
130.0	0.338E-02	130.0	0.532E-02	130.0	0.	130.0	0.	130.0	0.
150.0	0.169E-02	150.0	0.106E-02	150.0	0.	150.0	0.	150.0	0.
170.0	0.	170.0	0.	170.0	0.	170.0	0.	170.0	0.
190.0	0.	190.0	0.	190.0	0.	190.0	0.	190.0	0.
N IS	1.000E 00	N IS	1.000E 00	N IS	0.	N IS	0.	N IS	0.

Analysis Code I: Cascade-Particle Energy Spectra for μ = 0.10 to -0.10

See page 26 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRA OF CASCADE PARTICLES WITH MU FROM 0.10 TO -0.10
(THETA FROM 84 DEG. 16 MIN. TO 95 DEG. 44 MIN.)

N(E) IS (FRACTION OF PARTICLES IN DELTA MU)/(DELTA MU)(DELTA E)

E(MEV) IS CENTER OF INTERVAL N IS (SUM OVER N(E))(DELTA MU)(DELTA E)

PROTONS		NEUTRONS		PI+		PI0		PI-	
DELTA E(MEV)	40.0	DELTA E(MEV)	40.0	DELTA E(MEV)	40.0	DELTA E(MEV)	40.0	DELTA E(MEV)	40.0
E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)
20.0	0.107E-00	20.0	0.108E-00	20.0	0.	20.0	0.	20.0	0.
60.0	0.149E-01	60.0	0.168E-01	60.0	0.	60.0	0.	60.0	0.
100.0	0.298E-02	100.0	0.	100.0	0.	100.0	0.	100.0	0.
140.0	0.	140.0	0.	140.0	0.	140.0	0.	140.0	0.
180.0	0.	180.0	0.	180.0	0.	180.0	0.	180.0	0.
220.0	0.	220.0	0.	220.0	0.	220.0	0.	220.0	0.
260.0	0.	260.0	0.	260.0	0.	260.0	0.	260.0	0.
300.0	0.	300.0	0.	300.0	0.	300.0	0.	300.0	0.
340.0	0.	340.0	0.	340.0	0.	340.0	0.	340.0	0.
380.0	0.	380.0	0.	380.0	0.	380.0	0.	380.0	0.
N IS	0.100E 01	N IS	0.100E 01	N IS	0.	N IS	0.	N IS	0.

Analysis Code I: Cascade-Particle Energy Spectra for μ = -0.40 to -0.60

See page 26 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRA OF CASCADE PARTICLES WITH MU FROM -0.40 TO -0.60
(THETA FROM 113 DEG. 35 MIN. TO 126 DEG. 54 MIN.)

N(E) IS (FRACTION OF PARTICLES IN DELTA MU)/(DELTA MU)(DELTA E)

E(MEV) IS CENTER OF INTERVAL N IS (SUM OVER N(E))(DELTA MU)(DELTA E)

PROTONS		NEUTRONS		PI+		PI0		PI-	
DELTA E(MEV)	40.0	DELTA E(MEV)	40.0	DELTA E(MEV)	40.0	DELTA E(MEV)	40.0	DELTA E(MEV)	40.0
E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)	E(MEV)	N(E)
20.0	0.116E-00	20.0	0.125E-00	20.0	0.	20.0	0.	20.0	0.
60.0	0.862E-02	60.0	0.	60.0	0.	60.0	0.	60.0	0.
100.0	0.	100.0	0.	100.0	0.	100.0	0.	100.0	0.
140.0	0.	140.0	0.	140.0	0.	140.0	0.	140.0	0.
180.0	0.	180.0	0.	180.0	0.	180.0	0.	180.0	0.
220.0	0.	220.0	0.	220.0	0.	220.0	0.	220.0	0.
260.0	0.	260.0	0.	260.0	0.	260.0	0.	260.0	0.
300.0	0.	300.0	0.	300.0	0.	300.0	0.	300.0	0.
340.0	0.	340.0	0.	340.0	0.	340.0	0.	340.0	0.
380.0	0.	380.0	0.	380.0	0.	380.0	0.	380.0	0.
N IS	0.103E 01	N IS	0.100E 01	N IS	0.	N IS	0.	N IS	0.

Analysis Code I: Energy Spectrum of Emitted Cascade Protons for All Angles

The data on the facing page and on the following four pages of output are for the energy spectra of the cascade particles emitted in all directions and are, respectively, for protons, neutrons, π^+, π^0, and π^-.

In each case the energy range is 0 to 0.2000000E 03 Mev (200 Mev), as specified on the line immediately below the title, and the overflow value is zero. This indicates that there were no events in which cascade particles were emitted beyond the 200-Mev range.

The values of the histograms themselves as a function of K.E. are given under the entry N(E). As defined in the fourth line, K.E. is the midpoint of the (kinetic) energy interval, in Mev, and N(E) is the fraction of the total number of emitted protons which occur in the ΔE interval divided by ΔE. The interval width is constant at all energies for each distribution. For example, for the emitted cascade protons, the value of the histogram of the energy spectrum for the first energy interval, in this case from 0 to 8 Mev, is 0.2961579E-01. This is the fraction of all the emitted cascade protons which were emitted into the energy interval 0 to 8 Mev divided by 8 Mev.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRUM OF EMITTED CASCADE PROTONS

0 TO 0.2000000E 05 MEV 0 OFL

K.E. IS THE CENTER OF THE ENERGY INTERVAL IN MEV N(E) IS THE FRACTION OF TOTAL NUMBER OF EMITTED PROTONS /DELTA E

K.E.	N(E)	K.E.	N(E)	K.E.	N(E)	K.E.	N(E)
4.00	0.2961579E-01	60.00	0.3868730E-02	108.00	0.2267876E-02	156.00	0.2801494E-02
12.00	0.2014408E-01	68.00	0.3201708E-02	116.00	0.2401281E-02	164.00	0.2134472E-02
20.00	0.1267343E-01	76.00	0.2267876E-02	124.00	0.1734258E-02	172.00	0.2267876E-02
28.00	0.6403415E-02	84.00	0.3201708E-02	132.00	0.2001067E-02	180.00	0.2668090E-02
36.00	0.4402348E-02	92.00	0.2134472E-02	140.00	0.1600854E-02	188.00	0.6670224E-03
44.00	0.6403415E-02	100.00	0.1600854E-02	148.00	0.2801494E-02	196.00	0.1467449E-02
52.00	0.4268943E-02						

Analysis Code I: Energy Spectrum of Emitted Cascade Neutrons for All Angles

See page 36 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRUM OF EMITTED CASCADE NEUTRONS

0 TO 0.2000000E 03 MEV 0 OFL

K.E. IS THE CENTER OF THE ENERGY INTERVAL IN MEV N(E) IS THE FRACTION OF TOTAL NUMBER OF EMITTED NEUTRONS/DELTA E

K.E.	N(E)	K.E.	N(E)	K.E.	N(E)	K.E.	N(E)
4.00	0.2200941E-01	60.00	0.3276210E-02	108.00	0.4032258E-02	156.00	0.3864247E-02
12.00	0.1335645E-01	68.00	0.4620296E-02	116.00	0.3276210E-02	164.00	0.2352151E-02
20.00	0.7896506E-02	76.00	0.3612231E-02	124.00	0.3024194E-02	172.00	0.3024194E-02
28.00	0.6720430E-02	84.00	0.3864247E-02	132.00	0.2520161E-02	180.00	0.3192204E-02
36.00	0.5712366E-02	92.00	0.3864247E-02	140.00	0.2856183E-02	188.00	0.2268145E-02
44.00	0.4783307E-02	100.00	0.4032258E-02	148.00	0.4032258E-02	196.00	0.1428091E-02
52.00	0.5376344E-02						

Analysis Code I: Energy Spectrum of Emitted Cascade π^+ for All Angles

See page 36 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRUM OF EMITTED CASCADE PI+

0 TO 0.2000000E 03 MEV 0 OFL

K.E. IS THE CENTER OF THE ENERGY INTERVAL IN MEV N(E) IS THE FRACTION OF TOTAL NUMBER OF EMITTED PI+ / DELTA E

K.E.	N(E)	K.E.	N(E)	K.E.	N(E)	K.E.	N(E)
4.00	0.	60.00	0.	108.00	0.	156.00	0.
12.00	0.	68.00	0.	116.00	0.	164.00	0.
20.00	0.	76.00	0.	124.00	0.	172.00	0.
28.00	0.	84.00	0.	132.00	0.	180.00	0.
36.00	0.	92.00	0.	140.00	0.	188.00	0.
44.00	0.	100.00	0.	148.00	0.	196.00	0.
52.00	0.						

Analysis Code I: Energy Spectrum of Emitted Cascade π^{o} for All Angles

See page 36 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRUM OF EMITTED CASCADE PIO

0 TO 0.2000000E 03 MEV 0 OFL

K.E. IS THE CENTER OF THE ENERGY INTERVAL IN MEV N(E) IS THE FRACTION OF TOTAL NUMBER OF EMITTED PIO / DELTA E

K.E.	N(E)	K.E.	N(E)	K.E.	N(E)	K.E.	N(E)
4.00	0.	60.00	0.	108.00	0.	156.00	0.
12.00	0.	68.00	0.	116.00	0.	164.00	0.
20.00	0.	76.00	0.	124.00	0.	172.00	0.
28.00	0.	84.00	0.	132.00	0.	180.00	0.
36.00	0.	92.00	0.	140.00	0.	188.00	0.
44.00	0.	100.00	0.	148.00	0.	196.00	0.
52.00	0.						

Analysis Code I: Energy Spectrum of Emitted Cascade π^- for All Angles

See page 36 for description of facing page.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ENERGY SPECTRUM OF EMITTED CASCADE PI-

0 TO 0.2000000E 03 MEV 0 OFL

K.E. IS THE CENTER OF THE ENERGY INTERVAL IN MEV N(E) IS THE FRACTION OF TOTAL NUMBER OF EMITTED PI- / DELTA E

K.E.	N(E)	K.E.	N(E)	K.E.	N(E)	K.E.	N(E)
4.00	0.	60.00	0.	108.00	0.	156.00	0.
12.00	0.	68.00	0.	116.00	0.	164.00	0.
20.00	0.	76.00	0.	124.00	0.	172.00	0.
28.00	0.	84.00	0.	132.00	0.	180.00	0.
36.00	0.	92.00	0.	140.00	0.	188.00	0.
44.00	0.	100.00	0.	148.00	0.	196.00	0.
52.00	0.						

Analysis Code I: Angular Distributions of Emitted Cascade Particles for All Energies

The data on the facing page are for the angular distribution of all the emitted cascade particles for all energies. MU (μ) is the cosine of the angle of emission measured with respect to the incident-particle direction, and the series of numbers under MU specify the center of the cosine interval, which ranges from 1 to -1. The numbers under the columns "PROTON," "NEUTRON," "PI+," "PIO," and PI-" give the fraction of all the particles of the specified type emitted into each $\Delta\mu$ interval divided by $\Delta\mu$. Therefore, the sum of the numbers under each column specifying the type of cascade particle multiplied by $\Delta\mu$ should be 1. For emitted cascade protons, for example, the value of the histogram of the angular distribution for the μ interval from 1 to 0.95 (midpoint is 0.975) is 0.1921024E 01; etc.

NEUT ON AL INC. K.E. (MEV) IS 200.0 A IS 27. Z IS 13. 2500 INC. HISTORIES 1.6 MEV CUTOFF EN.

ANGULAR DISTRIBUTION OF EMITTED CASCADE PARTICLES

(FRACTION IN EACH INTERVAL)/(DELTA MU)

MU IS COSINE THETA AND SPECIFIES THE CENTER OF THE INTERVAL

MU	PROTON	NEUTRON	PI+	PI0	PI-
0.975	0.1921024E 01	0.1666667E 01	0.	0.	0.
0.925	0.1558164E 01	0.1827957E 01	0.	0.	0.
0.875	0.1472785E 01	0.1841398E 01	0.	0.	0.
0.825	0.1067236E 01	0.1491935E 01	0.	0.	0.
0.775	0.1216649E 01	0.1223118E 01	0.	0.	0.
0.725	0.9391676E 00	0.1290323E 01	0.	0.	0.
0.675	0.7470651E 00	0.1169355E 01	0.	0.	0.
0.625	0.6830309E 00	0.1088710E 01	0.	0.	0.
0.575	0.8119993E 00	0.1034946E 01	0.	0.	0.
0.525	0.1024546E 01	0.8198925E 00	0.	0.	0.
0.475	0.6189968E 00	0.5913979E 00	0.	0.	0.
0.425	0.7043757E 00	0.7123656E 00	0.	0.	0.
0.375	0.4055496E-00	0.7392473E 00	0.	0.	0.
0.325	0.4902285E-00	0.5510753E 00	0.	0.	0.
0.275	0.2988260E-00	0.3763441E-00	0.	0.	0.
0.225	0.5763074E 00	0.4166667E-00	0.	0.	0.
0.175	0.5549526E 00	0.3494624E-00	0.	0.	0.
0.125	0.4482391E-00	0.3091398E-00	0.	0.	0.
0.075	0.3842349E-00	0.2688172E-00	0.	0.	0.
0.025	0.5122732E 00	0.2822581E-00	0.	0.	0.
-0.025	0.4055496E-00	0.3360215E-00	0.	0.	0.
-0.075	0.4909285E-00	0.2150538E-00	0.	0.	0.
-0.125	0.4268943E-00	0.2016127E-00	0.	0.	0.
-0.175	0.2134472E-00	0.1209677E-00	0.	0.	0.
-0.225	0.1280683E-00	0.1344086E-00	0.	0.	0.
-0.275	0.2561366E-00	0.1344086E-00	0.	0.	0.
-0.325	0.2561366E-00	0.1344086E-00	0.	0.	0.
-0.375	0.1921025E-00	0.5376344E-01	0.	0.	0.
-0.425	0.1067236E-00	0.1075269E-00	0.	0.	0.
-0.475	0.1494130E-00	0.1075269E-00	0.	0.	0.
-0.525	0.1280683E-00	0.5376344E-01	0.	0.	0.
-0.575	0.2347719E-00	0.8064516E-01	0.	0.	0.
-0.625	0.1280683E-00	0.1344086E-01	0.	0.	0.
-0.675	0.1067236E-00	0.5376344E-01	0.	0.	0.
-0.725	0.6403415E-01	0.6720430E-01	0.	0.	0.
-0.775	0.2134472E-01	0.2688172E-01	0.	0.	0.
-0.825	0.6403415E-01	0.2688172E-01	0.	0.	0.
-0.875	0.6403415E-01	0.4032258E-01	0.	0.	0.
-0.925	0.8537887E-01	0.	0.	0.	0.
-0.975	0.4268943E-01	0.4032258E-01	0.	0.	0.

Analysis Code II

Page No.

Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 0 - 30° and 30 - 60° as a Function of Energy 50

Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 0 - 30° and 30 - 60° Integrated Over Energy 52

Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 60 - 120° and 120 - 180° as a Function of Energy 56

Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 60 - 120° and 120 - 180° Integrated Over Energy 58

Differential Cross Section for Emission of Cascade Protons with Restricted Energy Values as a Function of Angle 60

Cross Sections for the Emission of 1 to 15 Protons into Various Energy Intervals 62

Ratio of Number of Protons Emitted on First Collision to Total Number of Emitted Particles of the Same Type as the Incident Particle; Cross Section for the Emission of Two Protons as a Function of the Angle Between Them 64

Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 0 - 30° and 30 - 60° as a Function of Energy 66

Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 0 - 30° and 30 - 60° Integrated Over Energy 68

Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 60 - 120° and 120 - 180° as a Function of Energy 70

Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 60 - 120° and 120 - 180° Integrated Over Energy 72

Differential Cross Section for Emission of Cascade Neutrons with Restricted Energy Values as a Function of Angle 74

Cross Sections for the Emission of 1 to 15 Neutrons into Various Energy Intervals 76

Ratio of Number of Neutrons Emitted on First Collision to Total Number of Emitted Particles of the Same Type as the Incident Particle 78

Analysis Code II: Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 0 - 30° and 30 - 60° as a Function of Energy

The data for analysis code II somewhat overlap those for analysis code I, but the titles in code II are more explanatory. The page numbers for these output sheets are not in sequence and so are to be ignored.

The titles and values which specify the case on the top of the facing page and on all the following examples should read in full: INCIDENT PARTICLE, Neutrons; INCIDENT LABORATORY KINETIC ENERGY (MEV), 200; TARGET SYMBOL, Aluminum with an A of 27 and a Z of 13; NUMBER OF INCIDENT PARTICLES, 2500; CUTOFF ENERGY (MEV), 1.64; GEOMETRIC CROSS SECTION (MILLIBARNS), 1028.2; and NUMBER OF INCIDENT-PARTICLE COLLISIONS, 964. One could calculate the total inelastic cross section from these data by multiplying the geometric cross section by the ratio of incident-particle collisions to the number of incident particles.

The first type of data in the output is the differential cross section for the emission of cascade protons into various angular intervals, $d^2\sigma/(d\Omega\ dE)$, in units of millibarns/(steradian-Mev) [mb/(sr-Mev)]. The first of the two sets of data on this page refers to protons emitted in the laboratory angular interval of 0 to 30° for 20 energy intervals, each having a 10-Mev width. Immediately below each of the 20 energy intervals is the value of $d^2\sigma/(d\Omega\ dE)$ for that interval. For example, the value of the differential cross section for protons emitted with energies between 20 and 30 Mev (interval 2) is 1.1238 mb/(sr-Mev).

The next set of values is for cascade protons emitted into an angular interval of 30 to 60°, and the values are to be interpreted as above.

PAGE 1

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
PROTON	0. TO 30.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1.2215E 00	1.1238E 00	2.9315E-01	3.4201E-01	2.4429E-01	3.9087E-01	3.4201E-01	2.4429E-01
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
2.9315E-01	1.4658E-01	9.7717E-02	1.9543E-01	2.4429E-01	5.3745E-01	5.8630E-01	9.7717E-01
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
9.7717E-01	9.7717E-01	5.8630E-01	5.8630E-01				

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
PROTON	30.00 TO 60.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1.3234E 00	7.1534E-01	5.3651E-01	3.2190E-01	3.7555E-01	3.7555E-01	1.7884E-01	2.3249E-01
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
2.6825E-01	1.9672E-01	1.7884E-01	3.9344E-01	1.7884E-01	1.0730E-01	1.6095E-01	1.4307E-01
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
5.3651E-02	1.7884E-02	1.7884E-02	0.				

Analysis Code II: Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 0 - 30° and 30 - 60° Integrated Over Energy

In the example on the facing page the fourth line, which reads in full THE SUM OF $d\sigma/(d\Omega\ dE) \times dE = 0.1041 \times 10^3$ MILLIBARNS/STERADIAN FOR CASCADE PROTONS WITH θ FROM 0 to 30°, means that the histogram in the preceding example has now been integrated over energy to provide the differential cross section for emission of protons into the angular interval from 0 to 30° with any energy. The line below gives the average energy of the protons emitted into this angular interval. The next two lines give the same quantities for the angular interval from 30 to 60°.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.1041E 03 MB/STERADIAN FOR CASCADE PROTON WITH THETA FROM 0. TO 30.00 DEG

AVERAGE ENERGY EQUALS 0.103920E 03 MEV FOR CASCADE PROTON WITH THETA FROM 0. TO 30.00 DEG

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.5776E 02 MB/STERADIAN FOR CASCADE PROTON WITH THETA FROM 30.00 TO 60.00 DEG

AVERAGE ENERGY EQUALS 0.539783E 02 MEV FOR CASCADE PROTON WITH THETA FROM 30.00 TO 60.00 DEG

Pages like the facing one containing this or a similar number and no other information are to be ignored.

777777

Analysis Code II: Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 60 - 120° and 120 - 180° as a Function of Energy

In the example here, cross sections are given for the emission of protons into the laboratory angular interval 60 to 120° and 120 to 180°. The interpretation is the same as for the example on page 51.

PAGE 1

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
PROTON	60.00 TO 120.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
8.7059E-01	5.8258E-01	2.8802E-01	1.0473E-01	1.8983E-01	8.5096E-02	6.5458E-02	5.2367E-02
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
5.2367E-02	2.6183E-02	0.	1.3092E-02	6.5458E-03	0.	0.	0.
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
0.	0.	0.	0.				

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
PROTON	120.00 TO 180.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
4.0584E-01	1.3092E-01	2.6183E-02	1.3092E-02	0.	0.	0.	0.
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
0.	0.	0.	0.	0.	0.	0.	0.
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
0.	0.	0.	0.				

Analysis Code II: Differential Cross Section for Emission of Cascade Protons Within Angular Intervals 60 - 120° and 120 - 180° Integrated Over Energy

Here the histogram in the example on page 57 is integrated over energy for the emission of protons into the angular interval 60 to 120° and 120 to 180°, with the average energy of the protons emitted into these angular intervals. The interpretation for this page is the same as that on page 52.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	TARGET A	TARGET Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.2337E 02 MB/STERADIAN FOR CASCADE PROTON WITH THETA FROM 60.00 TO 120.00 DEG

AVERAGE ENERGY EQUALS 0.233753E 02 MEV FOR CASCADE PROTON WITH THETA FROM 60.00 TO 120.00 DEG

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.5760E 01 MB/STERADIAN FOR CASCADE PROTON WITH THETA FROM 120.00 TO 180.00 DEG

AVERAGE ENERGY EQUALS 0.886364E 01 MEV FOR CASCADE PROTON WITH THETA FROM 120.00 TO 180.00 DEG

Analysis Code II: Differential Cross Section for Emission of Cascade Protons with Restricted Energy Values as a Function of Angle

In this example of the differential cross sections for a specified type of emitted particle (protons in this case), the particles have restricted energy values ranging from 0 to 40, 40 to 160, and 160 to 200 Mev, and the cross-section values are given as a function of angle ranging from 0 to 180°.

PAGE 3

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	TARGET A	TARGET Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

DSIGMA / DOMEGA

(MB / STERADIAN)

TYPE OF CASCADE PARTICLE PROTON — FOR THE ENERGY INTERVAL (MEV) 0 TO 40

LABORATORY ANGLE FROM 0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
3.039E 01	2.978E 01	2.854E 01	2.186E 01	2.281E 01	1.043E 01	7.627E 00	4.147E 00	2.171E 00

TYPE OF CASCADE PARTICLE PROTON — FOR THE ENERGY INTERVAL (MEV) 40 TO 160

LABORATORY ANGLE FROM 0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
3.365E 01	4.184E 01	2.510E 01	9.628E 00	4.147E 00	1.003E 00	0.	0.	0.

TYPE OF CASCADE PARTICLE PROTON — FOR THE ENERGY INTERVAL (MEV) 160 TO 200

LABORATORY ANGLE FROM 0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
5.427E 01	6.765E 00	2.460E-01	0	0.	0.	0.	0.	0.

Analysis Code II: Cross Sections for the Emission of 1 to 15 Protons into Various Energy Intervals

The facing page is an example of output data for the cross section in millibarns for the emission of K particles (K = 0, 1, 2,...,15) of a given type for various energy intervals. In this case the emitted particle is a proton and the energy intervals range from 0 to 200 Mev. With the exception of K = 0 the definitions for these events are given in terms of a few examples. The value beneath the K = 1 entry gives the cross section for the emission of 1 cascade proton whose energy lies within the interval 0 to 40 Mev. If one proton is emitted with energy within the interval under consideration, it is counted as a contribution independent of the number of particles of the other types emitted along with it. The cross section under the K = 2 column is for the emission of 2 protons with energies lying within the interval 0 to 40 Mev. There are provisions for calculating cross sections up to K = 15 for each energy interval. The following similar sets of data are for energy intervals of 40 to 160 Mev and 160 to 200 Mev.

In the past, in all but a few cases, the cross sections for the emission of zero particles (K = 0) in each energy interval were calculated incorrectly with this version of the code. When the energy intervals taken together span the range of energies available to the cascade particle under consideration and when the intervals do not overlap (as here, where 0 - 40, 40 - 160, 160 - 200 Mev are used), then the sum of the cross sections for all K values in each energy interval should be the same for all the intervals. This can be used as a test to determine whether the K = 0 cross sections have been calculated correctly.

One obtains contributions to the K = 0 cross section when none of the particles of the specified type that are found in a record of the primary output tape have energies within the given energy interval. If there are no particles of the specified type found in the record, there is no contribution to the K = 0 (or to any other value of K) cross section.

The data for the cross sections in which $K \neq 0$ are useful for comparison with the results with data available from photographic emulsions, that is, the track-number distributions for tracks of various energies.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

CROSS SECTIONS (MB) FOR THE EMISSION OF K PARTICLES OF SPECIFIED TYPE INTO ENERGY INTERVALS INDICATED

(CONTRIBUTIONS TO K EQUAL ZERO ARE MADE ONLY WHEN PARTICLES OF SPECIFIED TYPE ARE EMITTED BUT ARE NOT IN THE ENERGY INTERVALS INDICATED)

EMITTED PARTICLE PROTON ENERGY INTERVAL (MEV) 0 TO 40

K EQUALS 0	1	2	3	4	5	6	7
9.7475E 01	1.1681E 02	3.7427E 01	8.6370E 00	2.0564E 00	0.	0.	0.
8	9	10	11	12	13	14	15
0.	0.	0.	0.	0.	0.	0.	0.

EMITTED PARTICLE PROTON ENERGY INTERVAL (MEV) 40 TO 160

K EQUALS 0	1	2	3	4	5	6	7
0.	1.1187E 02	9.0483E 00	4.1129E-01	0.	0.	0.	0.
8	9	10	11	12	13	14	15
0.	0.	0.	0.	0.	0.	0.	0.

EMITTED PARTICLE PROTON ENERGY INTERVAL (MEV) 160 TO 200

K EQUALS 0	1	2	3	4	5	6	7
0.	2.8379E 01	0.	0.	0.	0.	0.	0.
8	9	10	11	12	13	14	15
0.	0.	0.	0.	0.	0.	0.	0.

Analysis Code II: Ratio of Number of Protons Emitted on First Collision to Total Number of Emitted Particles of the Same Type as the Incident Particle; Cross Section for the Emission of Two Protons as a Function of the Angle Between Them

The first entry on the facing page is the number of particles of a given type emitted on the first incident-particle collision divided by the number of particles of the incident-particle type emitted. In this case, it represents the ratio of the number of protons emitted on the first collision to the total number of neutrons emitted. The entry 0.2412 means that there are ~25% as many protons emitted on the first collision as there are total neutrons emitted.

The entries PION ABSORPTION CROSS SECTION and PION CHARGE EXCHANGE CROSS SECTION would have values only if incident pions were used. The pion absorption cross section is the cross section for the event in which a pion is incident and no pion escapes. The pion charge-exchange cross section is the cross section in which a charged pion is incident and a π^0 is emitted.

The angular distribution data given near the bottom of the page apply for the case in which two protons, no pions, and any number of neutrons are emitted. The entries below the angular intervals are the cross sections, in mb/sr, for the emission of two protons in angular intervals from 0 to 180°.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

NO. OF TIMES SPECIFIED PARTICLE IS EMITTED ON THE FIRST INC. PARTICLE COLLISION DIVIDED BY THE NO. OF TIMES THE INC. PARTICLE TYPE IS EMITTED	PION ABSORPTION CROSS SECT. (MB)	PION CHARGE EXCHANGE CROSS SECT. (MB)
PROTONS 0.24120E-00		

ANGULAR DISTRIBUTION OF TWO CASCADE PROTONS AS A FUNCTION OF THE ANGLE, X, BETWEEN THEM.

DSIGMA / DOMEGA (MB / STERADIAN)

(REACTIONS CONTRIBUTE WHEN THERE ARE NO PIONS, ONLY TWO PROTONS, AND ANY NUMBER OF NEUTRONS EMITTED)

X FROM 0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
0.3256E 01	0.5277E 01	0.4675E 01	0.5215E 01	0.7728E 01	0.5817E 01	0.4921E 01	0.4900E 01	0.1085E 01

Analysis Code II: Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 0 - 30° and 30 - 60° as a Function of Energy

The example on the facing page and those that follow contain information which is identical in form to that obtained for cascade protons (see page 50) except that it applies to cascade neutrons.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
NEUTRON	0. TO 30.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1.3192E 00	8.3060E-01	5.8630E-01	3.4201E-01	2.4429E-01	2.9315E-01	4.8859E-01	2.9315E-01
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
3.9087E-01	4.3973E-01	3.9087E-01	6.8402E-01	9.7717E-01	6.8402E-01	1.2703E 00	2.0032E 00
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
1.3192E 00	2.1986E 00	1.6612E 00	1.1238E 00				

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
NEUTRON	30.00 TO 60.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1.6989E 00	9.1206E-01	6.6169E-01	7.1534E-01	6.4381E-01	7.6899E-01	5.5439E-01	6.2592E-01
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
7.1534E-01	8.7629E-01	7.6699E-01	5.9016E-01	3.7555E-01	5.3651E-01	4.4709E-01	2.8614E-01
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
1.6095E-01	7.1534E-02	3.5767E-02	3.5767E-02				

Analysis Code II: Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 0 - 30° and 30 - 60° Integrated Over Energy

See page 52 for explanation relating to this type of output.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.1754E 03 MB/STERADIAN FOR CASCADE NEUTRON WITH THETA FROM 0. TO 30.00 DEG

AVERAGE ENERGY EQUALS 0.123106E 03 MEV FOR CASCADE NEUTRON WITH THETA FROM 0. TO 30.00 DEG

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.1148E 03 MB/STERADIAN FOR CASCADE NEUTRON WITH THETA FROM 30.00 TO 60.00 DEG

AVERAGE ENERGY EQUALS 0.689720E 02 MEV FOR CASCADE NEUTRON WITH THETA FROM 30.00 TO 60.00 DEG

Analysis Code II: Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 60 - 120° and 120 - 180° as a Function of Energy

See page 50 for explanation relating to this type of output.

PAGE 1

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
NEUTRON	60.00 TO 120.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
1.0735E 00	5.6949E-01	3.7311E-01	2.5529E-01	2.1601E-01	7.8550E-02	1.7019E-01	9.8187E-02
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
3.2729E-02	5.8912E-02	3.9275E-02	1.9637E-02	0.	6.5458E-03	0.	0.
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
0.	0.	0.	0.				

(DSIGMA/(DOMEGA X DE) (MB)/(STERADIAN-MEV)

TYPE OF CASCADE PARTICLE	LAB. ANGULAR INTERVAL (DEG)	NO. OF ENERGY INTERVALS	DELTA E (MEV)
NEUTRON	120.00 TO 180.00	20	10.0000

INTERVAL 1	INTERVAL 2	INTERVAL 3	INTERVAL 4	INTERVAL 5	INTERVAL 6	INTERVAL 7	INTERVAL 8
3.1420E-01	5.2366E-02	2.6183E-02	0.	0.	0.	0.	0.
INTERVAL 9	INTERVAL 10	INTERVAL 11	INTERVAL 12	INTERVAL 13	INTERVAL 14	INTERVAL 15	INTERVAL 16
0.	0.	0.	0.	0.	0.	0.	0.
INTERVAL 17	INTERVAL 18	INTERVAL 19	INTERVAL 20				
0.	0.	0.	0.				

Analysis Code II: Differential Cross Section for Emission of Cascade Neutrons Within Angular Intervals 60 - 120° and 120 - 180° Integrated Over Energy

See page 52 for explanation relating to this type of output.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.2991E 02 MB/STERADIAN FOR CASCADE NEUTRON WITH THETA FROM 60.00 TO 120.00 DEG

AVERAGE ENERGY EQUALS 0.268381E 02 MEV FOR CASCADE NEUTRON WITH THETA FROM 60.00 TO 120.00 DEG

SUM OF DSIG/(DOMEGA X DE) X DE EQUALS 0.3927E 01 MB/STERADIAN FOR CASCADE NEUTRON WITH THETA FROM 120.00 TO 180.00 DEG

AVERAGE ENERGY EQUALS 0.766667E 01 MEV FOR CASCADE NEUTRON WITH THETA FROM 120.00 TO 180.00 DEG

Analysis Code II: Differential Cross Section for Emission of Cascade Neutrons With Restricted Energy Values as a Function of Angle

See page 60 for explanation relating to this type of output.

PAGE 3

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

DSIGMA / DOMEGA

(MB / STERADIAN)

TYPE OF CASCADE PARTICLE NEUTRON — FOR THE ENERGY INTERVAL (MEV) 0 TO 40

LABORATORY ANGLE FROM	0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
	3.690E 01	3.129E 01	4.158E 01	3.590E 01	2.205E 01	1.023E 01	4.921E 00	2.639E 00	3.256E 00

TYPE OF CASCADE PARTICLE NEUTRON — FOR THE ENERGY INTERVAL (MEV) 40 TO 160

LABORATORY ANGLE FROM	0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
	5.101E 01	9.801E 01	6.446E 01	1.785E 01	3.393E 00	6.017E-01	0.	0.	0.

TYPE OF CASCADE PARTICLE NEUTRON — FOR THE ENERGY INTERVAL (MEV) 160 TO 200

LABORATORY ANGLE FROM	0 - 20 DEG	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180
	8.249E 01	2.563E 01	4.921E-01	0.	0.	0.	0.	0.	0.

Analysis Code II: Cross Sections for the Emission of 1 to 15 Neutrons into Various Energy Intervals

See page 62 for explanation relating to this type of output.

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

CROSS SECTIONS (MB) FOR THE EMISSION OF K PARTICLES OF SPECIFIED TYPE INTO ENERGY INTERVALS INDICATED

(CONTRIBUTIONS TO K EQUAL ZERO ARE MADE ONLY WHEN PARTICLES OF SPECIFIED TYPE ARE EMITTED BUT ARE NOT IN THE ENERGY INTERVALS INDICATED)

EMITTED PARTICLE NEUTRON ENERGY INTERVAL (MEV) 0 TO 40

K EQUALS 0	1	2	3	4	5	6	7
1.6904E 02	1.3614E 02	4.1951E 01	1.1105E 01	3.2903E 00	1.2339E 00	0.	0.
8	9	10	11	12	13	14	15
0.	0.	0.	0.	0.	0.	0.	0.

EMITTED PARTICLE NEUTRON ENERGY INTERVAL (MEV) 40 TO 160

K EQUALS 0	1	2	3	4	5	6	7
0.	1.7480E 02	5.0999E 01	8.2257E-01	0.	0.	0.	0.
8	9	10	11	12	13	14	15
0.	0.	0.	0.	0.	0.	0.	0.

EMITTED PARTICLE NEUTRON ENERGY INTERVAL (MEV) 160 TO 200

K EQUALS 0	1	2	3	4	5	6	7
0.	6.0048E 01	0.	0.	0.	0.	0.	0.
8	9	10	11	12	13	14	15
0.	0.	0.	0.	0.	0.	0.	0.

Analysis Code II: Ratio of Number of Neutrons Emitted on First Collision to Total Number of Emitted Particles of the Same Type as the Incident Particle

See page 64 for explanation relating to this type of output.

PAGE 5

INCIDENT PARTICLE	INC. LAB. K.E.(MEV)	TARGET SYMB.	A	Z	NO. OF INC. PARTICLES	CUTOFF EN.(MEV)	GEOMETRIC X-SEC.(MB)	NO. OF INC. PART. COLLISIONS
NEUT	200	AL	27	13	02500	1.64	1028.2	00964

	NO. OF TIMES SPECIFIED PARTICLE IS EMITTED ON THE FIRST INC. PARTICLE COLLISION DIVIDED BY THE NO. OF TIMES THE INC. PARTICLE TYPE IS EMITTED	PION ABSORPTION CROSS SECT. (MB)	PION CHARGE EXCHANGE CROSS SECT. (MB)
NEUTRONS	0.45094E-00		

Evaporation Code

Page No.

Case Description and Average Number of Particles Evaporated per Inelastic Event..... 82

Distribution of Residual Nuclei Following Evaporation..... 84

Moments of Energy Distributions for Evaporation Particles and Normalized Evaporation Neutron Spectrum..... 86

Normalized Evaporation Proton Spectrum..... 88

Normalized Evaporation Spectra for Deuterons, Tritons, He^3, and Alpha Particles..... 90

Evaporation Code: Case Description and Average Number of Particles Evaporated per Inelastic Event

The case number in the upper right-hand corner of the facing sheet and on all following sheets represents an A of 27, a Z of 13, a kinetic energy of 200 Mev, and the type of incident particle — the figure 1 indicating neutron; 2, proton; 3, π^+; and 4, π^-.

The information in the upper left-hand corner is self-explanatory, except that the symbol # should be read as an = sign.

This page also gives the average number of particles evaporated per inelastic event for each of the particles specified.

CASE NUMBER 27 13 200 1

A# 27
Z# 13
KINETIC ENERGY (MEV)# 200.00
NEUT
GEOMETRIC CROSS SECTION (MB)# 1028.21
CUTOFF ENERGY (MEV)# 1.64
2500 CASE HISTORIES
INELASTIC CROSS SECTION (MB) 396.48

AVERAGE EVAPORATION YIELD PER INELASTIC EVENT

NEUTRONS	PROTONS	DEUTERONS	TRITONS	HE3	ALPHAS
0.7593361	0.7987552	0.1224066	0.0145228	0.0663900	0.2645228

Evaporation Code: Distribution of Residual Nuclei Following Evaporation

The radiochemical cross sections on the facing page are for the reaction involving both the cascade calculation and the evaporation calculation. The column under A is the mass number of the final residual nucleus; the column under Z is the atomic number of the residual nucleus; the column headed "NUMBER OF NUCLEI" refers to the number of nuclei which remained with a corresponding A and Z value after the cascade and evaporation phase have been completed; and the cross section in the last column is the value for obtaining a particular A and Z as a final residual nucleus. For example, given a 200-Mev neutron striking an aluminum target with an A of 27 and a Z of 13, the cross section for obtaining a residual nucleus with an A of 23 and a Z of 12 after the cascade and the evaporation phase have been completed is 0.41 millibarn.

CASE NUMBER 27 13.200 1

DISTRIBUTION OF RESIDUAL NUCLEI FOLLOWING EVAPORATION

A	Z	NUMBER OF NUCLEI	CROSS SECTION (MB)
27	13	31	12.75
	12	12	4.94
26	13	117	48.12
	12	108	44.42
25	13	3	1.23
	12	133	54.70
	10	1	0.41
24	12	86	35.37
	11	12	4.94
	10	6	2.47
23	12	1	0.41
	11	45	18.51
	9	2	0.82
22	11	27	11.10
	9	4	1.65
21	11	2	0.82
	10	25	10.28
	9	75	30.85
20	10	4	1.65
	8	88	36.19
19	9	1	0.41
	7	11	4.52
18	9	13	5.35
	7	40	16.45
17	8	21	8.64
	6	11	4.52
16	8	28	11.52
	6	3	1.23
15	8	3	1.23
	7	7	2.88
	6	1	0.41
14	7	5	2.06
	6	4	1.65
	5	1	0.41
13	6	4	1.65
	5	1	0.41
12	6	20	8.23
8	4	2	0.82
7	4	1	0.41
4	2	5	2.06

Evaporation Code: Moments of Energy Distributions for Evaporation Particles and Normalized Evaporation Neutron Spectrum*

The first table on the facing page gives the first, second, and third moments of the energy distributions for the specified evaporation particles (neutrons, protons, etc.).

The next table gives the values of the normalized evaporation neutron spectrum; that is, the entries represent the fraction of the total number of neutrons that were evaporated into particular energy intervals divided by the width of the interval. The interval width is the same for all intervals and is equal to 0.1 Mev. The values for ten successive intervals are listed on each line. The lower limit of every tenth interval is listed under "E", 0 being the lower limit for the first interval, 1 the limit for the eleventh interval, 2 the limit for the twenty-first interval, etc. The histogram is normalized such that the sum of all the values of the histogram multiplied by the energy interval, 0.1 Mev, should give 1.

If the histogram constructed from this table or tables of some other type is sporadic, one can regroup and construct a new histogram with wider energy intervals. This regrouping may lose some of the details, but it will also indicate the trends more clearly.

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*Note: There are no angular distributions for the evaporation particles, since it is assumed that they are evaporated isotropically in the center-of-mass system of the excited nucleus.

CASE NUMBER 27 13 200 1

MOMENTS OF THE ENERGY DISTRIBUTIONS FOR THE FOLLOWING EVAPORATION PARTICLES

	NEUTRONS	PROTONS	DEUTERONS	TRITONS	HE3	ALPHAS
1ST MOM.	4.33285E 00	6.23789E 00	7.61015E 00	8.09739E 00	7.89871E 00	7.67045E 00
2ND MOM.	3.71421E 01	6.12568E 01	9.67539E 01	1.03309E 02	8.72982E 01	7.40946E 01
3RD MOM.	4.82287E 02	8.41125E 02	1.86519E 03	1.89287E 03	1.37129E 03	8.96309E 02

NORMALIZED EVAPORATION NEUT SPECTRUM
(E SPECIFIES THE LOWER ENERGY LIMIT OF THE INTERVAL IN MEV)

E										
0	0.164835	0.178571	0.192308	0.192308	0.192308	0.178571	0.109890	0.151099	0.192308	0.247253
1	0.178571	0.178571	0.192308	0.164835	0.219780	0.164835	0.192308	0.219780	0.096154	0.151099
2	0.164835	0.151099	0.178571	0.164835	0.178571	0.206044	0.151099	0.082418	0.109890	0.123626
3	0.178571	0.192308	0.137363	0.109890	0.096154	0.109890	0.109890	0.096154	0.096154	0.109890
4	0.123626	0.054945	0.054945	0.068681	0.123626	0.082418	0.096154	0.013736	0.041209	0.041209
5	0.027473	0.068681	0.027473	0.041209	0.041209	0.027473	0.054945	0.068681	0.013736	0.082418
6	0.041209	0.068681	0.054945	0.013736	0.068681	0.068681	0.096154	0.013736	0.041209	0.054945
7	0.041209	0.013736	0.096154	0.041209	0.027473	0.027473	0.109890	0.	0.068681	0.027473
8	0.041209	0.082418	0.013736	0.041209	0.054945	0.027473	0.054945	0.013736	0.027473	0.041209
9	0.013736	0.027473	0.027473	0.	0.027473	0.041209	0.027473	0.027473	0.	0.041209
10	0.013736	0.027473	0.041209	0.041209	0.	0.013736	0.027473	0.	0.027473	0.
11	0.013736	0.	0.013736	0.027473	0.013736	0.	0.041209	0.041209	0.041209	0.041209
12	0.	0.013736	0.027473	0.013736	0.013736	0.013736	0.	0.013736	0.	0.
13	0.	0.	0.	0.013736	0.041209	0.013736	0.	0.027473	0.	0.
14	0.013736	0.	0.013736	0.	0.013736	0.	0.	0.013736	0.041209	0.
15	0.	0.	0.013736	0.013736	0.	0.	0.	0.013736	0.013736	0.
16	0.	0.	0.	0.	0.	0.	0.013736	0.013736	0.013736	0.
17	0.	0.	0.	0.	0.	0.	0.013736	0.	0.	0.013736
18	0.	0.	0.013736	0.	0.013736	0.	0.	0.013736	0.	0.
19	0.013736	0.	0.013736	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.013736	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.013736	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Evaporation Code: Normalized Evaporation Proton Spectrum

The facing page contains the values for the proton spectrum, and its format is identical to that for the neutron energy spectrum given on the preceding page.

CASE NUMBER 27 13 200 1

NORMALIZED EVAPORATION PROTON SPECTRUM
(E SPECIFIES THE LOWER ENERGY LIMIT OF THE INTERVAL IN MEV)

E										
0	0.	0.	0.	0.	0.	0.	0.	0.013072	0.013072	0.052288
1	0.013072	0.039216	0.065359	0.130719	0.143791	0.143791	0.065359	0.117647	0.169935	0.196078
2	0.156863	0.222222	0.156863	0.130719	0.183007	0.261438	0.169935	0.091503	0.117647	0.183007
3	0.196078	0.052288	0.156863	0.104575	0.091503	0.065359	0.143791	0.130719	0.104575	0.104575
4	0.143791	0.156863	0.117647	0.130719	0.130719	0.117647	0.104575	0.104575	0.065359	0.091503
5	0.130719	0.052288	0.039216	0.130719	0.078431	0.104575	0.117647	0.117647	0.065359	0.065359
6	0.052288	0.117647	0.183007	0.091503	0.091503	0.078431	0.091503	0.052288	0.026144	0.091503
7	0.013072	0.052288	0.052288	0.039216	0.078431	0.039216	0.117647	0.052288	0.052288	0.065359
8	0.117647	0.039216	0.091503	0.039216	0.091503	0.026144	0.091503	0.026144	0.026144	0.013072
9	0.026144	0.013072	0.091503	0.013072	0.039216	0.026144	0.013072	0.039216	0.026144	0.052288
10	0.013072	0.039216	0.039216	0.065359	0.039216	0.039216	0.026144	0.	0.039216	0.013072
11	0.039216	0.026144	0.039216	0.013072	0.026144	0.013072	0.013072	0.039216	0.039216	0.013072
12	0.026144	0.013072	0.	0.026144	0.	0.013072	0.	0.026144	0.026144	0.
13	0.026144	0.026144	0.	0.026144	0.026144	0.013072	0.026144	0.	0.026144	0.
14	0.026144	0.026144	0.013072	0.026144	0.	0.	0.	0.026144	0.	0.
15	0.013072	0.013072	0.	0.026144	0.026144	0.013072	0.	0.013072	0.026144	0.013072
16	0.039216	0.	0.	0.026144	0.013072	0.026144	0.013072	0.026144	0.013072	0.013072
17	0.	0.	0.	0.	0.	0.	0.013072	0.013072	0.026144	0.013072
18	0.	0.	0.	0.	0.	0.	0.	0.	0.013072	0.013072
19	0.	0.	0.013072	0.013072	0.	0.013072	0.	0.	0.013072	0.
20	0.013072	0.	0.	0.	0.013072	0.013072	0.	0.	0.	0.013072
21	0.	0.	0.013072	0.	0.	0.	0.	0.	0.	0.013072
22	0.013072	0.	0.013072	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.026144	0.	0.013072	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.013072

Evaporation Code: Normalized Evaporation Spectra for Deuterons, Tritons, He^3, and Alpha Particles

The format for the energy spectra given here for the specified particles is the same as that of the two preceding examples except for the interval width being larger — 0.5 Mev for each histogram.

NORMALIZED EVAPORATION DEUT SPECTRUM
(E SPECIFIES THE LOWER ENERGY LIMIT OF THE INTERVAL IN MEV)

E										
0	0.	0.	0.033898	0.067797	0.203390	0.050847	0.169492	0.033898	0.135593	0.101695
5	0.169492	0.135593	0.101695	0.067797	0.016949	0.033898	0.067797	0.050847	0.067797	0.050847
10	0.033898	0.067797	0.	0.	0.050847	0.	0.050847	0.016949	0.	0.
15	0.033898	0.016949	0.	0.	0.	0.016949	0.016949	0.016949	0.	0.016949
20	0.016949	0.016949	0.	0.	0.	0.	0.	0.	0.016949	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.016949	0.
30	0.	0.	0.	0.	0.	0.016949	0.	0.	0.	0.
35	0.	0.	0.	0.016949	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

NORMALIZED EVAPORATION TRITON SPECTRUM
(E SPECIFIES THE LOWER ENERGY LIMIT OF THE INTERVAL IN MEV)

E										
0	0.	0.	0.	0.	0.015152	0.030303	0.	0.	0.045455	0.
5	0.	0.	0.	0.	0.015152	0.015152	0.015152	0.015152	0.	0.015152
10	0.	0.	0.015152	0.	0.015152	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.015152	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

NORMALIZED EVAPORATION HE3 SPECTRUM
(E SPECIFIES THE LOWER ENERGY LIMIT OF THE INTERVAL IN MEV)

E										
0	0.	0.	0.	0.	0.	0.	0.030612	0.051020	0.081633	0.061224
5	0.030612	0.010204	0.061224	0.030612	0.040816	0.020408	0.030612	0.051020	0.020408	0.020408
10	0.	0.020408	0.	0.010204	0.010204	0.010204	0.	0.010204	0.	0.
15	0.	0.	0.	0.010204	0.	0.	0.	0.	0.	0.010204
20	0.010204	0.	0.	0.	0.	0.	0.	0.	0.	0.010204
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.010204
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

NORMALIZED EVAPORATION ALPHA SPECTRUM
(E SPECIFIES THE LOWER ENERGY LIMIT OF THE INTERVAL IN MEV)

E										
0	0.	0.	0.	0.008869	0.008869	0.008869	0.026608	0.084257	0.093126	0.062084
5	0.115299	0.075388	0.075388	0.044346	0.066519	0.013304	0.044346	0.057650	0.048780	0.035477
10	0.035477	0.022173	0.044346	0.035477	0.013304	0.013304	0.008869	0.022173	0.008869	0.004435
15	0.004435	0.008869	0.013304	0.004435	0.004435	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.004435	0.	0.004435	0.004435
25	0.	0.004435	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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