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PEGASUS : A PREEQUILIBRIUM AND MULTI-STEP EVAPORATION CODE FOR NEUTRON CROSS SECTION CALCULATION

June 1999

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PEGASUS: A Preequilibrium and Multi-Step Evaporation Code for Neutron Cross Section Calculation

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(Received May 12, 1999)

The computer code PEGASUS was developed to calculate neutron-induced reaction cross sections on the basis of the closed form exciton model preequilibrium theory and the multi-step evaporation theory. The cross sections and emitted particle spectra are calculated for the compound elastic scattering, (n,γ), (n,n'), (n,p), (n,α), (n,d), (n,t), (n,^{3}He), (n,2n), (n,n'p), (n,n'α), (n,n'd), (n,n't), (n,2p) and (n,3n) reactions. The double differential cross sections of emitted particles are also calculated. The calculated results are written on a magnetic disk in the ENDF format. Parameter files and/or systematics formulas are provided for level densities, mass excess, radiation widths and inverse cross sections so that the input data to the code are made minimum.

Keywords: Neutron-induced Reactions, Computer Code, PEGASUS, Preequilibrium Theory, Multi-step Evaporation Theory, Cross Sections, Particle Spectra, Angular Distributions

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JAERI－Data/Code 99－031

PEGASUS：前平衡理論と多段階蒸発理論による中性子反応断面積計算コード

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（1999年5月12日受理）

PEGASUS は励起子模型前平衡理論及び多段階蒸発理論による中性子反応断面積を計算するために開発したコードである。ガンマ線スペクトル及び、核分裂過程は考慮していない。断面積と放出粒子スペクトルを複合核弾性散乱、(n,γ), (n,n'), (n,p), (n,α), (n,d), (n,t), (n,^{3}He), (n,2n), (n,n'p), (n,n'α), (n,n'd), (n,n't), (n,2p), (n,3n)反応について計算する。また、核子放出の二重微分断面積も計算する。結果は ENDF フォーマットで磁気ディスクに出力される。レベル密度、質量欠損、放射捕獲幅、逆反応断面積を格納したパラメータファイルや、これらの系統性式を用意しており、計算の入力データは極く少なくて済む。

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1. Introduction

The computer code PEGASUS [§] was developed to calculate neutron-induced reaction cross sections, emitted particle spectra and angular distributions on the basis of the closed form exciton model preequilibrium theory and multi-step evaporation theory. Gamma-ray spectra are not calculated. The fission process is not taken into account.

PEGASUS calculates the cross sections and emitted particle spectra for compound elastic scattering, (n,γ), (n,n'), (n,p), (n,α), (n,d), (n,t), (n,^{3}He), (n,2n), (n,n'p), (n,n'α), (n,n'd), (n,n't), (n,2p) and (n,3n) reactions. The calculated results are written on a magnetic disk in the ENDF format.

PEGASUS was originally written in BASIC and was converted to FORTRAN. The present report describes the FORTRAN version of PEGASUS. Calculation formulas are given in Chapter 2. The program structure and functions of subroutines are described in Chapter 3. In Chapter 4 described are parameter files that contain evaluated level density parameters, mass excess and the inverse reaction cross sections for charged particles. Certain systematics formulas for the level densities, Kalbach's constants and radiation widths are built in the code. These data files and the built-in systematics minimize the input data to the code. The input data format is given in Chapter 5. The output in the ENDF format is explained in Chapter 6. The sample calculations are described in Chapter 7. In Appendix, a special version of ELIESE-3[1)] and the auxiliary code SIGINVF are described, which are used to prepare the inverse reaction cross section file.

Though simplified in theory, the calculated result agrees well with that of a more sophisticated code such as GNASH[2)] when the excitation energies are not very low. PEGASUS has been used for efficient and quantitative estimation of the above-mentioned reaction cross sections and the emitted particle spectra. Since PEGASUS does not treat particle emissions more than 3 particles, its use is limited to incident neutron energies below about 20 MeV.

[§] PEGASUS was developed by S.Iijima who is one of authors of the present report. Other authors aided him to improve the code, to make parameter files and to complete this report. Chapters 2 and 3 of this report are based on the manuscript written by S.Iijima. While S.Iijima should be the first author, the order of authors are changed for convenience' sake because of editorial procedure in JAERI.

2. Calculation Formulas

In the following, symbols such as $Q_{n,x}$ are often abbreviated as Q_x omitting the index n, which stands for neutrons, for the sake of simplification.

2.1 The First Stage Reaction Cross Sections

The differential cross sections for the first stage (n,x) reactions are written as the sum of the direct, preequilibrium and equilibrium processes. Ignoring the direct reaction process, we write the cross section as

$$\sigma_{n,x}(E_n,\varepsilon_x)=\sigma_{n,x}^{pre}(E_n,\varepsilon_x)+\left(1-\frac{\sigma_{tot}^{pre}(E_n)}{\sigma_c(E_n)}\right)\sigma_{n,x}^{eq}(E_n,\varepsilon_x), \tag{2.1}$$

where E_n is the relative kinetic energy of incident neutrons, ε_x the energy of the emitted particle x in the center-of-mass system, σ_c the compound (or composite) nucleus formation cross section. The cross section via preequilibrium process, $\sigma_{n,x}^{pre}(E_n,\varepsilon_x)$, is calculated with the closed form exciton model up to the equilibrium exciton number n neglecting the "coming-back" transitions. The "strength left" to the equilibrium process, $\left(1-\sigma_{tot}^{pre}(E_n)/\sigma_c(E_n)\right)$, is equal to the so-called depletion factor $D(n,E_c)$ given later as Eq. (2.16). The quantity $\sigma_{tot}^{pre}(E_n)$ is the total cross section of the preequilibrium process. The equilibrium process $\left(\sigma_{n,x}^{eq}(E_n,\varepsilon_x)\right)$ is calculated with the evaporation theory.

In the following, we first give the expressions for the evaporation process, and next the preequilibrium process.

2.1.1 Cross Sections for the First Stage Evaporation Process

The first stage evaporation cross sections in Eq. (2.1) are given by

$$\sigma_{n,x}^{eq}(E_n,\varepsilon_x)=\sigma_c(E_n)g_x(E_c,\varepsilon_x)\Big/\sum_y\Gamma_y(E_c), \tag{2.2}$$

where E_c the excitation energy of the compound nucleus and the suffix c denotes the

compound nucleus. The width $\Gamma_x(E_c)$ and spectrum $g_x(E_c,\varepsilon_x)$ of a particle x are expressed by

$$\Gamma_x(E_c)=\int_0^{\varepsilon_c^{\max}} d\varepsilon_x g_x(E_c,\varepsilon_x) \quad \text{(MeV)}, \tag{2.3}$$

and

$$g_x(E_c,\varepsilon_x)=C_x\varepsilon_x\sigma_{inv}^{(x)}(\varepsilon_x)\rho_x(U)/\rho_c(E_c)\ , \tag{2.4}$$

where

$C_x = 0.244(2s_x+1)\dfrac{\mu_x}{m_n}$ ($b^{-1}MeV^{-1}$),

m_n = neutron mass,

μ_x = reduced mass of the reaction channel x,

s_x = spin of the particle x,

$U = E_n + Q_x - \varepsilon_x$, excitation energy of a residual nucleus,

$\varepsilon_c^{\max} = E_n + Q_x$, the maxinum values of U,

Q_x = Q-value of the (n,x) reaction,

$\sigma_{inv}^{(x)}$ = inverse reaction cross section for the (n,x) reaction,

ρ_c, ρ_x = level densities of compound and residual nuclei, respectively.

The inverse reaction cross sections for charged particles should be calculated elsewhere and must be supplied to PEGASUS as a data file which will be described in Chapter 4. The inverse reaction cross sections for neutrons $\sigma_{inv}^{(n)}(E_n)$ that are the same as the compound nucleus formation cross section $\sigma_c(E_n)$ in Eqs.(2.1) and (2.2) are taken either from another data file or from the systematics formula of Pearlstein[3], i.e.,

$$\sigma_{inv}^{(n)}=\pi\times\left(0.12A^{1/3}+0.21\right)^2 \quad \text{(barns)}\ . \tag{2.5}$$

The level densities are expressed by the composite formula given by Gilbert and Cameron.[4] The total observable level density is given as

$$\rho(E)=C\exp(E/T) \qquad (E \leqq E_x), \tag{2.6a}$$

$$\rho(E)=\frac{\exp\left(2\sqrt{aU}\right)}{12\sqrt{2}\sigma a^{1/4}U^{5/4}} \qquad (E \geqq E_x), \tag{2.6b}$$

where U = E – Δ, Δ the pairing energy, σ^2 (= $0.146\sqrt{aU}A^{2/3}$) the spin cutoff factor, and a the level density parameter. The pairing energies are adopted from the table given by Gilbert and Cameron.[4] The smooth continuity of the level density formulas (2.6a) and (2.6b) at $U_x = E_x - \Delta$ gives the relations

$$x \equiv \sqrt{aU_x} = \frac{1}{2}\left[aT + \sqrt{(aT)^2 - 6aT}\right] \tag{2.7a}$$

and

$$CT\exp(\Delta/T) = \frac{\exp(x)}{1.447A^{1/3}x(x-3/2)} . \tag{2.7b}$$

In the code, a level density parameter file is used, which contains the mass excess data and the values of a and T. The values of C and U_x (or E_x) are determined from the values of a and T using Eqs. (2.7a) and (2.7b). Note that Eqs. (2.7a) and (2.7b) do not have solutions when aT<6.

For the calculation of the spectra of particles emitted from the second and third stage reactions, the level density of the residual nucleus is often approximated in the code by

$$\rho(E-\varepsilon) \approx \rho(E)\exp(-\varepsilon/\theta), \tag{2.8}$$

where

$$\theta^{-1} = T^{-1}, \qquad \text{when } E < E_x,$$

$$\theta^{-1} = \sqrt{a/U} - \frac{3}{2}U, \qquad \text{when } E \geq E_x. \tag{2.9}$$

In the case of the (n,n') process, the ground state of the target nucleus is represented by the delta function in the level density formula to take account of the compound elastic scattering at low incident energies. The compound elastic and the inelastic neutron widths are then given by

$$\Gamma_{nn}(E_c) = C_n E_n \sigma_{inv}^{(n)}(E_n)/\rho_c(E_c), \tag{2.10}$$

and

$$\Gamma_{nn'}(E_c) = \int_0^{E_n - E_1} d\varepsilon_n g_n(E_c, \varepsilon_n), \tag{2.11}$$

where E_1 is the energy above which the levels may be described by the constant temperature form. It is either specified by input or determined from the constant temperature form of the level density by

$$\int_0^{E_1} \rho_n(E)dE = 1, \tag{2.12a}$$

i.e.

$$E_1 = T\ln\left(1+\frac{1}{CT}\right). \tag{2.12b}$$

As to the γ-ray emission, the inverse reaction cross section for photons $\sigma_\gamma(\varepsilon_\gamma)$ is given by the Brink-Axel formula for the giant dipole resonance. The radiative strength function is

$$\frac{\Gamma_\gamma(E_c)}{D(E_c)} = \frac{1}{\pi^2}\int_{E_n}^{E_c} d\varepsilon_\gamma k_\gamma^2 \sigma_\gamma(\varepsilon_\gamma)\rho_c(E_c-\varepsilon_\gamma).$$

The quantity k_γ is the wave number of the γ-ray channel. Assuming $\sigma_\gamma(\varepsilon_\gamma) \propto \varepsilon_\gamma^2$ and approximating the level density by the constant temperature form, we obtain

$$\Gamma_\gamma(E_c) \approx \Gamma_\gamma(Q_\gamma)\frac{G(E_c/T_c)-G(E_n/T_c)}{G(Q_\gamma/T_c)}, \tag{2.13}$$

where

$$G(x) = \frac{1}{4!}\int_0^x x^4 \exp(-x)dx = 1-\sum_{m=0}^{4}\frac{x^m}{m!}\exp(-x).$$

The value of $\Gamma_\gamma(Q_\gamma)$ at the neutron binding energy is either input or given from the systematics in the code.

2.1.2 Preequilibrium Cross Sections

The preequilibrium cross section is given[5)] by

$$\sigma_{n,x}^{pre}(E_n,\varepsilon_x)=\sigma_c(E_n)\sum_{n=n_0}^{\bar{n}}W_x(n,E_c,\varepsilon_x)\tau(n,E_c), \tag{2.14}$$

where n = p + h : number of excitons,

p, h = number of particles and holes,

$\bar{n} = \sqrt{2g_cE_c}$: equilibrium exciton number,

g_c = single particle level density (MeV^{-1}),

$W_x(n,E_c,\varepsilon_x)$: emission rate ($MeV^{-1}sec^{-1}$) of a particle x,

$\tau(n,E_c)$: life time of the exciton state n (sec).

The initial exciton number n_0 is taken as 3 (2 particle 1 hole state). The single particle level density g of the composite or residual nuclei is calculated from the corresponding level density parameter a as $g = (6/\pi^2)a$.

In the closed form approximation, the exciton life time is written by

$$\tau(n,E_c)=D(n,E_c)/\lambda_n^+(E_c), \tag{2.15}$$

where

$$D(n,E_c)=\prod_{m=n_0}^{n}\frac{\lambda_m^+(E_c)}{\lambda_m^+(E_c)+W(m,E_c)}. \tag{2.16}$$

The quantities $D(n,E_c)$ and λ_n^+ $(=\lambda_{n\to n+2})$ are the depletion factor and the transition rate, respectively. Note that $D(\bar{n},E_c)=1-\sigma_{tot}^{pre}(E_n)/\sigma_c(E_n)$. This is equal to the terminology "strength left (to the equilibrium process)" used in GNASH output. The total emission rate $W(n,E_c)$ is given by

$$W(n,E_c)=\sum_x\int d\varepsilon_x W_x(n,E_c,\varepsilon_x). \tag{2.17}$$

The transition rates between the exciton states due to the two body interaction are given by

$$\lambda_n^+ \equiv \lambda_{n\to n+2}=(2\pi/\hbar)|M|^2 g_c(g_cE_c)^2/2(n+1), \tag{2.18}$$

$$\lambda_n^0 \equiv \lambda_{n\to n} = (2\pi/\hbar)|M|^2 g_c(g_c E_c)(3n-2)/4, \tag{2.19}$$

$$\lambda_n^- \equiv \lambda_{n\to n-2} = (2\pi/\hbar)|M|^2 g_c ph(n-2)/2, \tag{2.20}$$

and

$$|M|^2 = \frac{K}{A_c^3 E_c}, \tag{2.21}$$

where K is Kalbach's constant.[6)]

In the present code, only the n→n+2 transition rate is considered for the cross section calculation. The n→n transition rate is taken into account only in the calculation of the angular distributions.

Kalbach's constant is estimated by comparing Eq. (2.21) with the expression for transition rate by Kawai and Kikuchi[7)]

$$\lambda_{1\to 3}(E) = \upsilon\rho\sigma = 1.4\times 10^{21}E - 6\times 10^{18}E^2 \quad (\mathrm{sec}^{-1}),$$

where v is the nucleon velocity, ρ the density of nuclear matter, σ the nucleon-nucleon scattering cross section, and E is in unit of MeV. Jahn reported that from the analysis of the cross section Kawai-Kikuchi's expression had better be multiplied by a factor ranging from 0.1 to 0.25 to reproduce the cross sections.[8)] Hence, ignoring the term proportional to E^2 and comparing with the expression (2.18), we obtain a rough estimate:

$$K\times(g_c/A_c)^3 \approx 0.1 \quad (\pm 50\%)\ . \tag{2.22}$$

If $a_c = A_c/8$ (MeV^{-1}) is assumed, K is 230 MeV^3 which is independent of the mass number. In the code, either the value of K is input or the Eq. (2.22) is used by the option.

The particle emission rate is obtained from the principle of detailed balance[9)]:

$$W_x(n, E_c, \varepsilon_x) = \frac{C_x \varepsilon_x \sigma_{inv}^{(x)}(\varepsilon_x)\omega_R^*(U)}{\hbar\omega_c(n, E_c)}, \tag{2.23}$$

where U : excitation energy of the residual nucleus,

ω_c : exciton state density of composite nucleus,

ω_R^* : exciton state density of residual nucleus multiplied by the probability to pickup the particle x.

Ericson[10] gave the exciton state density as

$$\omega(p,h,E)=g\frac{\left[g(E-\Delta)-A_{ph}\right]^{p+h-1}}{p!h!(p+h-1)!}, \tag{2.24}$$

where Δ is the pairing correction and A_{ph} is the Pauli correction. The Pauli correction is expressed as

$$A_{ph}=ph-\frac{1}{4}\left[p(p+1)+h(h+1)\right] \qquad \text{(Anzaldo[11])}, \tag{2.25a}$$

and

$$A_{ph}=\frac{1}{4}\left(p^2+h^2+p-3h\right) \qquad \text{(Williams[9])}. \tag{2.25b}$$

The formula of Anzaldo is used in PEGASUS. If $A_{ph} < 0$, then A_{ph} is set to 0.

The state density of the residual nucleus after nucleon emission is calculated by the expression of Cline[12]:

$$\omega_R^*(U)=R_x(p)\omega_R(p-1,h,U), \tag{2.26}$$

where $R_x(p)$ is the combinational factor of Cline, which expresses the probability that a particle x is extracted from the state of the particle number p. This is given by

$$R_\beta(p)=\sum_{i=0}^{p-p_\alpha}\left(\frac{Z}{A}\right)^i\left(\frac{N}{A}\right)^{p-p_\alpha-i}\times\frac{(p-p_\alpha)!}{i!(p-p_\alpha-i)!}\frac{(\pi_\alpha+i)!}{\pi_\beta!(\pi_\alpha+i-\pi_\beta)!}$$
$$\times\frac{(p-\pi_\alpha-i)!}{\nu_\beta!(p-\pi_\alpha-i-\nu_\beta)!}\Big/\frac{p!}{p_\beta!(p-p_\beta)!}, \tag{2.27}$$

where p_α (= $\pi_\alpha + \nu_\alpha$), π_α and ν_α are the number of nucleons, protons and neutrons in the incident particle, respectively. In the same way, p_β (= $\pi_\beta + \nu_\beta$), π_β and ν_β are the number of

nucleons, protons and neutrons in the outgoing particle, respectively. In the case of neutron incident and nucleon emission reactions, Eq. (2.27) becomes

$$R_n(p)=\sum_{i=0}^{p-1}\left(\frac{Z}{A}\right)^i\left(\frac{N}{A}\right)^{p-1-i}\frac{(p-1)!(p-i)}{(p-1-i)!i!p} \tag{2.28a}$$

for neutron emission, and

$$R_p(p)=1-R_n(p) \tag{2.28b}$$

for proton emission. When Z = N, approximate values are, $R_n(p)$ = 3/4 (p=2), 2/3 (p=3), 5/8 (p=4), and 1/2 for large p values.

The state density of the residual nucleus after cluster particle emission is calculated with the expression by Iwamoto, Harada and Sato[13]:

$$\omega_R^* = \gamma_x \sum_{l,m} F_{lm}(\varepsilon_x^*)\omega_R(p-l,h,U), \tag{2.29}$$

where $F_{lm}(\varepsilon_x^*)$ is the normalized cluster formation factor and γ_x an adjustable parameter. Kinetic energy (ε_x) of the emitted cluster at the outside of nucleus is converted to its kinetic energy (ε_x^*) in the nucleus by subtracting the reaction Q-value, i.e. $\varepsilon_x^* = \varepsilon_x - Q_x$.

The cluster formation factor is the probability of forming a cluster x (number of nucleons = l+m) with the kinetic energy ε_x^* from l nucleons above Fermi surface and m below Fermi surface. It does not depend on a target nucleus. Iwamoto et al. made a table of $F_{lm}(\varepsilon_x^*)$ as a function of the kinetic energy of the cluster particle in nuclei ε_x^* ranging from −10 to 100 MeV.[14] The cluster formation factors $F_{lm}(\varepsilon_x^*)$ are normalized to unity when summed over l and m. In the present code, these were fitted by polynomials:

$$F_{lm}(\varepsilon_x^*)=b_0+b_1\varepsilon_x^*+b_2(\varepsilon_x^*)^2 \quad (\varepsilon_x^* \text{ in MeV}). \tag{2.30}$$

The values of coefficients are given in Table 1. Fitting was made in the range of ε_x^* = 0 – 30 MeV with relative error within 2% (except when F_{lm} is very small). When ε_x^* is small, Eq. (2.30) gives small negative values. In such cases, F_{lm} is set to zero in the code.

The absolute value of the cluster emission is adjusted by an input factor γ_x in Eq. (2.29), which ranges from about 0.1 to 0.5.

2.2 Second Stage Reaction Cross Sections

All second stage reactions are described by the evaporation process. Including the competition with the emission of γ-rays, for the double differential energy spectrum, we obtain

$$\sigma_{n,xy}(E_n,\varepsilon_x,\varepsilon_y)=\hat{\sigma}_{n,x}(E_n,\varepsilon_x)g_{xy}(E_n,\varepsilon_x,\varepsilon_y)\Big/\sum_z \Gamma_{xz}(E_n,\varepsilon_x), \tag{2.31}$$

where $\hat{\sigma}_{n,x}$ is the cross section of the first stage process, Γ_{xz} the emission width of particle z (and γ) from the daughter of the (n,x) reaction, whose excitation energy is $U = E_n + Q_x - \varepsilon_x$.

For particle emission the emission width is written by

$$\Gamma_{xy}(E_n,\varepsilon_x)=\int_0^U d\varepsilon_y g_{xy}(E_n,\varepsilon_x,\varepsilon_y), \tag{2.32}$$

and

$$g_{xy}(E_n,\varepsilon_x,\varepsilon_y)=C_y\varepsilon_y\sigma_{inv}^{(y)}(\varepsilon_y)\rho_{xy}(U-\varepsilon_y)/\rho_x(U). \tag{2.33}$$

For γ-ray emission, the width is estimated using Eq. (2.13):

$$\Gamma_{x\gamma}(E_n,\varepsilon_x)\approx\Gamma_{x\gamma}(Q_\gamma)\frac{G((E_n+Q_x-\varepsilon_x)/T_x)}{G(Q_\gamma/T_x)}, \tag{2.34}$$

where $\Gamma_{x,\gamma}(Q_\gamma)$ is the radiation width of the (n,x) reaction daughter at the neutron binding energy Q_γ.

From Eq. (2.31), the cross section is

$$\sigma_{n,xy}(E_n)=\int_0^{E_n+Q_{xy}} d\varepsilon_x\hat{\sigma}_{n,x}(E_n,\varepsilon_x)\frac{\Gamma_{xy}(E_n,\varepsilon_x)}{\sum_z \Gamma_{xz}(E_n,\varepsilon_x)}. \tag{2.35}$$

The spectra of the first and second emitted particles are, respectively,

$$\sigma_{n,xy}^{(1)}(E_n,\varepsilon_x)=\hat{\sigma}_{n,x}(E_n,\varepsilon_x)\frac{\Gamma_{xy}(E_n,\varepsilon_x)}{\sum_z \Gamma_{xz}(E_n,\varepsilon_x)} \tag{2.36}$$

and

$$\sigma_{n,xy}^{(2)}(E_n,\varepsilon_y)=\int_0^{E_n+Q_{xy}-\varepsilon_y} d\varepsilon_x \sigma_{n,xy}^{(1)}(E_n,\varepsilon_x)\Bigg[\varepsilon_y \sigma_{inv}^{(y)}(\varepsilon_y)\exp(-\varepsilon_y/T_{xy})$$

$$\Big/\int_0^{E_n+Q_{xy}-\varepsilon_x} d\varepsilon\varepsilon\sigma_{inv}^{(y)}(\varepsilon)\exp(-\varepsilon/T_{xy})\Bigg], \tag{2.37}$$

where T_{xy} is the temperature of the residual nucleus of the (n,xy) reaction, In deriving Eq. (2.37), the approximated level density Eq. (2.8) was used. For an efficient computation of the double integration in Eq. (2.37), the following intermediate integrals are computed and stored:

$$I_1^{(xy)}(E)\equiv\int_0^E d\varepsilon\varepsilon\sigma_{inv}^{(y)}(\varepsilon)\exp(-\varepsilon/T_{xy}) \tag{2.38}$$

and

$$I_2^{(xy)}(E)\equiv\int_0^E d\varepsilon\,\sigma_{n,xy}^{(1)}(E_n,\varepsilon)/I_1^{(xy)}(E_n+Q_{xy}-\varepsilon). \tag{2.39}$$

The equation (2.37) is computed with the interpolation of these integrals.

Calculation of the (n,yx) process is performed in the same way. The spectra of the first particle from the (n,xy) and that of the second particle from the (n,yx) reactions are added to construct the spectrum of the particle x associated with the (n,xy)+(n,yx) reaction.

2.3 (n,3n) Reaction Cross Sections

In the third stage process, only the (n,3n) reaction is considered. Competition between emissions of γ-rays and charged particles is ignored. As in the case of the (n,xy) reaction, the (n,3n) cross section and the first, second and third neutron spectra are expressed by

$$\sigma_{n,3n}(E_n)=\int_0^{E_n+Q_{3n}} d\varepsilon_1 \sigma_{n,3n}^{(1)}(E_n,\varepsilon_1), \tag{2.40}$$

$$\sigma^{(1)}_{n,3n}(E_n,\varepsilon_1) \approx \sigma^{(1)}_{n,2n}(E_n,\varepsilon_1)\frac{F_{2n}(E_n+Q_{3n}-\varepsilon_1)}{F_{2n}(E_n+Q_{2n}-\varepsilon_1)}, \tag{2.41a}$$

$$\begin{aligned}\sigma^{(2)}_{n,3n}(E_n,\varepsilon_2) \approx & \left(\varepsilon_2/T^2_{2n}\right)\exp(-\varepsilon_2/T_{2n}) \\ & \times\int_0^{E_n+Q_{3n}-\varepsilon_2} d\varepsilon_1\, \sigma^{(1)}_{n,2n}(E_n,\varepsilon_1)/F_{2n}(E_n+Q_{2n}-\varepsilon_1)\end{aligned} \tag{2.41b}$$

and

$$\sigma^{(3)}_{n,3n}(E_n,\varepsilon_3) \approx \frac{1}{N}\left(\varepsilon_3/T^2_{3n}\right)\exp(-\varepsilon_3/T_{3n})(E_n+Q_{3n}-\varepsilon_3)^2, \tag{2.41c}$$

where

$$\begin{aligned}F_x(E) &= \int_0^E d\varepsilon \frac{\varepsilon}{T_x^2}\exp(-\varepsilon/T_x) \\ &= 1-\left(1+\frac{E}{T_x}\right)\exp(-E/T_x).\end{aligned} \tag{2.42}$$

The quantity T_x is the temperature parameter of the residual nucleus of the (n,x) process. In deriving Eq. (2.41c), a crude approximation was made to put $F_{3n}(E_n+Q_{3n}-\varepsilon_1-\varepsilon_2)$ as a constant in the integrals over ε_1 and ε_2. The normalization factor N is determined so that the Eq. (2.41c) is equal to the (n,3n) cross section.

2.4 Angular Distributions of Neutrons and Protons

The nucleon emissions from the preequilibrium process have generally forward peaked angular distributions. The energy-angle double differential cross sections are calculated for neutron and proton emissions. Clusters are assumed to be emitted isotropically. The emissions from the evaporation process are also isotropic. Therefore, the double differential cross section of the first stage reaction is written by

$$\hat{\sigma}_{n,x}(E_n,\varepsilon_x,\Omega) = \hat{\sigma}^{pre}_{n,x}(E_n,\varepsilon_x,\Omega) + \frac{1}{4\pi}D(\bar{n},E_c)\hat{\sigma}^{eq}_{n,x}(E_n,\varepsilon_x). \tag{2.43}$$

Expanding Eq.(2.43) with the Legendre polynomials, the following relations are hold:

$$\hat{\sigma}_{n,x}(E_n,\varepsilon_x,\Omega) = \hat{\sigma}_{n,x}(E_n,\varepsilon_x)\sum_l \frac{2l+1}{4\pi} f_l(E_n,\varepsilon_x)P_l(\cos\theta) \tag{2.44}$$

and

$$\hat{\sigma}_{n,x}^{pre}(E_n,\varepsilon_x,\Omega)=\hat{\sigma}_{n,x}^{pre}(E_n,\varepsilon_x)\sum_l \frac{2l+1}{4\pi}B_l(E_n,\varepsilon_x)P_l(\cos\theta), \tag{2.45}$$

where

$$f_0(E_n,\varepsilon_x)=B_0(E_n,\varepsilon_x)=1, \tag{2.46a}$$

and

$$f_l(E_n,\varepsilon_x)=B_l(E_n,\varepsilon_x)\frac{\hat{\sigma}_{n,x}^{pre}(E_n,\varepsilon_x)}{\hat{\sigma}_{n,x}(E_n,\varepsilon_x)} \quad (l\geqq 1). \tag{2.46b}$$

The neutron and proton angular distributions of the preequilibrium process are calculated by the theory of Mantzouranis et al.[15] and Akkermans et al.[16] assuming an infinite refraction of the incident neutrons at the nuclear surface. The preequilibrium cross section is written according to the generalized form Eq. (2.14) as

$$\hat{\sigma}_{n,x}^{pre}(E_n,\varepsilon_x,\Omega)=\sigma_c(E_n)\sum_{n=3}^{\bar{n}}W_x(n,E_c,\varepsilon_x)\tau(n,E_c,\Omega). \tag{2.47}$$

Expansion of the exciton life time with the Legendre polynomials and comparison with Eq. (2.45) give

$$\begin{aligned}\hat{\sigma}_{n,x}^{pre}(E_n,\varepsilon_x,\Omega)=\sigma_c(E_n)\sum_l \frac{2l+1}{4\pi}\\ \times\left[\sum_{n=3}^{\bar{n}}W_x(n,E_c,\varepsilon_x)\tau_l(n,E_c)\right]P_l(\cos\theta)\end{aligned} \tag{2.48}$$

and

$$B_l(E_n,\varepsilon_x)=\sum_{n=3}^{\bar{n}}W_x(n,E_c,\varepsilon_x)\tau_l(n,E_c)\Big/\sum_{n=3}^{\bar{n}}W_x(n,E_c,\varepsilon_x)\tau_0(n,E_c). \tag{2.49}$$

According to Mantzouranis et al., $\tau_l(n,E_c)$ is

$$\tau_l(n,E_c)=\frac{D_l(n,E_c)}{\lambda_n^+(E_c)}, \tag{2.50}$$

where

$$D_l(n,E_c)=\mu_l^{(n-n_0+2)/2}\prod_{m=n_0}^{n}\frac{\lambda_m^+}{\lambda_m^+ + (1-\mu_l)\lambda_m^0 + W(m,E_c)}. \tag{2.51}$$

The quantity n_0 in Eq.(2.51) is assumed to be 1, which corresponds to infinite refraction of an incident neutron at the nuclear surface. W(m = 1, E_c) is taken as zero. The transition λ_n^0 rate was included to take account of the effect of the multiple scattering of excitons in a nucleus. The μ_l is the eigenvalue of the two-nucleon scattering angular distribution in the nucleus. Assuming the free and isotropic scattering in the center-of-mass frame of two colliding nucleons and an infinite mass of the target nucleus, μ's are expressed by

$$\mu_0 = 1,\ \mu_1 = 2/3,\ \mu_2 = 1/4,\ \mu_3 = 0,\ \mu_4 = -1/24,\ \mu_5 = 0,\ \text{etc.} \tag{2.52}$$

It is sufficient to take $l_{max} = 2$.

In the second and third stage reactions, the angular anisotropy is considered only for the emission of the first particle. The second and third particles are assumed to be emitted isotropically.

It is noted that for practical purpose the transition rate λ_m^0 can be neglected in Eq. (2.51). Further, if we assume that the particle emission from the n = 3 state is predominant, the Legendre coefficient is approximated by $B_l = B_0\mu_l^2$. We then obtain

$$\hat{\sigma}_{n,x}(E_n,\varepsilon_x,\Omega)=\frac{1}{4\pi}\left[\hat{\sigma}_{n,x}(E_n,\varepsilon_x)+\hat{\sigma}_{n,x}^{pre}(E_n,\varepsilon_x)\sum_{l=1}^{l_{max}}(2l+1)\mu_l^2 P_l(\cos\theta)\right]. \tag{2.53}$$

This approximation is valid with a good accuracy and the result agrees well with the Kalbach-Mann systematics[17] of the double differential cross sections.

2.5 Cross Sections, Particle Spectra and Angular Distributions for Individual and Composite Reactions

Expressions of the cross sections, particle spectra and angular distributions given in sections 2.1 through 2.4 are rearranged to obtain those for the individual and the composite

reactions, decomposing the first cross section into the sum of the one particle emission process and the second cross sections:

$$\sigma_1(n,n') = \sigma(n,n') + \sigma_2(n,nx),$$
$$\sigma_1(n,p) = \sigma(n,p) + \sigma_2(n,px),$$
$$\sigma_1(n,\alpha) = \sigma(n,\alpha) + \sigma_2(n,\alpha x),$$
$$\text{etc.} \tag{2.54}$$

The suffices 1 and 2 denote the first and second stages, respectively. Since the third stage reaction is considered only for (n,3n), the 2nd stage cross sections are the same as the individual reaction cross sections for 2-particle emissions except for (n,3n), i.e.

$$\sigma_2(n,np) = \sigma(n,np),$$
$$\sigma_2(n,n\alpha) = \sigma(n,n\alpha),$$
$$\sigma_2(n,2n) = \sigma(n,2n) + \sigma(n,3n),$$
$$\text{etc.} \tag{2.55}$$

Thus, all cross sections of individual reactions are determined from the cross sections for each stage of reactions using the above relations. The particle spectra and angular distributions of individual reactions are calculated in the similar manner.

On the other hand, the particle production cross sections (or the composite reaction cross sections) are given by, for example,

$$\sigma(n,xn) = \sigma(n,n) + \sigma^{(1)}(n,2n) + \sigma^{(2)}(n,2n) + \sigma^{(1)}(n,np) + \sigma^{(2)}(n,pn) + \sigma^{(1)}(n,n\alpha) + \sigma^{(2)}(n,\alpha n) + \ldots\ldots \tag{2.56}$$

The superficies (1) and (2) denote the first and second particles, respectively. The composite energy spectra and the angular distributions are constructed in the similar way. It should be noted that the first particle denoted by the superfix (1) has the angular anisotropy, while the second particle emission is isotropic.

3. Program Structure, Functions of Subroutines and Important Variables

3.1 Program Flow and Functions of Subroutines

Figure 1 shows program flow of PEGASUS. MAIN program sets the constants, reads input data and prepares the inverse cross sections and the level density parameters by referring the inverse reaction cross section and level density parameter files. After processing these data, cross sections are calculated at each incident neutron energy point and finally the results are written on the logical unit 10 in the ENDF format.

Functions of subroutines are as follows. FUNCTION type subroutines are denoted by an asterisk.

APARA*

calculates the level density parameter *a* from the systematics formula given in Table 2. This function is called when the value of *a* parameter is not found in the level-density-parameter file.

BFILE

stores the calculated results tentatively in data arrays in order to make them output in the ENDF format.

BFOUT

writes the data stored in the subroutine BFILE on the logical unit 10 in the ENDF format. Subroutines CONT, TAB1, TAB2, END and FLOATC are called from BFOUT.

CLUSTR

computes the cluster particle emission rates by using the tables prepared by Iwamoto et al.[13)]

DENS*

computes the level densities of the Gilbert-Cameron type.

ECSI

is called from BFOUT to perform integration of particle spectra with the ENDF interpolation rule.

ENPREP, NBM

insert reaction threshold energies into a table of incident neutron energies where cross sections are calculated.

ERICSN

computes the exciton state densities.

FMASS*

calculates the mass excess from the formula given in Ref. 19 when the mass excess is not found in the level density parameter file.

GPARA*

calculates radiation widths from Table 3 when the radiation width is not specified by input data.

INTER

makes interpolation between two data points.

LDCONT

determines C and E_x of Eq. (2.6) from a and T using the continuity condition given in Eq. (2.7).

NUCLEON

computes the preequilibrium nucleon emission rates.

PEGINN

interpolates the neutron inverse cross section at the incident neutron energy points. The data are interpolated in the logarithm scale of cross sections and the linear scale of energies. If the neutron energy is lower than the first energy of the given inverse cross section, the cross section is extrapolated by assuming that the cross section has the form of 1/v.

PEGINV

interpolates the inverse cross sections at the integration energy meshes up to 25 MeV. The same interpolation method as that in PEGINN is adopted. For the interpolation below the first energy point of the given inverse cross section, the cross sections of 10^{-20} barn at 0 MeV is assumed.

REDUCE

reduces the number of data points of spectrum data.

SIMPSN

calculates integration by means of the Simpson method.

3.2 Important Constants and Variables

Important constants

1) Particle and reaction indices, I and IX = IC(IA, IB):

Emitted particles are represented with the following numbers:

I	particle
0	γ-ray
1	neutron
2	proton
3	α
4	d
5	t
6	^{3}He

By using these particle identification numbers, reactions and reaction products are specified by the index IX = IC(IA, IB), where IA and IB denote the types of the first and second emitted particles, respectively. These indices are defined as follows.

IC(0,0) = 0;	(n,γ),	IC(1,0) = 1;	(n,n'),
IC(2,0) = 2;	(n,p),	IC(3,0) = 3;	(n,α),
IC(4,0) = 4;	(n,d),	IC(5,0) = 5;	(n,t),
IC(6,0) = 6;	(n,^{3}He),	IC(1,1) = 7;	(n,2n),
IC(2,1) = 8;	(n,pn),	IC(3,1) = 9;	(n,αn),
IC(1,2) = 10;	(n,np),	IC(1,3) = 11;	(n,nα),
IC(2,2) = 12;	(n,2p),	IC(4,1) = 13;	(n,dn),
IC(5,1) = 14;	(n,tn),	IC(1,4) = 15;	(n,nd),
IC(1,5) = 16;	(n,nt).		

For the (n,3n) reaction, IX is set to 17 specially. For other reactions not listed above, IC(IA,IB) is set to zero.

2) LCMAX(I)

The maximum numbers of l in the cluster formation factor F_{lm} of Eq. (2.29) are set in LCMAX. The subscript "I" indicates the emitted particle type. For example,

LCMAX(3) = 4, LCMAX(4) = 2, LCMAX(5) = 3, and LCMAX(6) = 3.

3) LMAX

Maximum order of the Legendre coefficients of angular distributions (=2).

4) NPMAXO

Maximum number of particle excitons (=10). (Number of excitons is $\leq$ 19.)

5) XMU(L)

Eigenvalue μ_l given by Eq. (2.52). For examples,

XMU(1)= μ_0 = 1,XMU(2)= μ_1 = 2/3, and XMU(3)= μ_2 = 1/4.

Important variables

In the followings, the subscript IX (= IC(IA,IB)) is used to designate the reaction, IA the first emitted particle, IB the second emitted particle, and I the emitted particle or the reaction product of the first stage reaction. The subscript J is the index for the emitted particle energy.

1) AS(IX), TS(IX), CS(IX), EX(IX)

Level density parameters of a residual nuclide produced by the reaction IX.

AS : *a* parameter,

TS : nuclear temperature,

CS : normalization constant,

EX : energy where the constant temperature model is connected to the Fermi gas model.

2) BN(IX)

The Q-value (MeV) of the reaction IX with inverse sign.

3) COEFF(IX)

C_x (=0.244(2s_x + 1) μ_x/m_n) ($b^{-1}MeV^{-1}$) in Eq. (2.4).

4) DN(NP)

D(n,E_c), the depletion factor of Eq. (2.16).

5) DNMAX

DN(NPMAX) = D(n,E_c).

6) FL(L,J)

$F_{lm}(\varepsilon_J^*)$: The cluster formation factor given in Eq. (2.30).

7) G(IX)

$(6/\pi^2)$AS(IX), the single particle level density.

8) GB(IX)

$\Gamma_y(E_c)$, a particle emission width of Eq. (2.2).

9) GTOT

Total width = Sum of GB(IX).

10) GW(IX,J)

Particle emission width $\Gamma_{xy}(E_n,\varepsilon_j)$ of Eq. (2.32).

11) GINT1(IX,J)

Intermediate integral of Eq. (2.38).

12) GINT2(IX,J)

Intermediate integral of Eq. (2.39).

13) GT(IA,J)

Sum of GW(IX,J) over different second emitted particles, $\sum_z \Gamma_{xz}(E_n,\varepsilon_x)$ appearing in the denominator of Eq. (2.31).

14) MSQ

$|M|^2$ in Eqs. (2.18) ~ (2.20).

15) NP

Exciton particle number (NP = 2 ~ NPMAX).

16) TAU(NP)

$\tau(n,E_c)$, the exciton life time of Eq. (2.15).

17) TP, TP0

$\lambda_n^+(E_c)$ and $\lambda_n^0(E_c)$, the transition rate of Eqs. (2.18) and (2.19).

18) SIG1(I,J)

The first stage particle spectrum,

19) SIGEQ(I,J)

The first stage equilibrium particle spectrum,

20) SIGRR(I,J)

The first stage preequilibrium particle spectrum,

21) SPEC1(IX,J), SPEC2(IX,J), SPEC3(J)

The first, second and third particle spectra for the reaction IX, respectively.

22) W(I,J,NP)

$W_x(n,E_c,\varepsilon_J)$, the preequilibrium emission rate of the particle I of Eqs. (2.14) and (2.23).

23) WB(I,NP)

$W_x(n,E_c)$, the energy-integrated preequilibrium emission rate of the particle I.

24) WN(NP)

The preequilibrium total emission rate of Eq. (2.17).

25) XEQ(I)

$\hat{\sigma}_{n,x}^{eq}(E_n)$

26) XPR(I)

$\hat{\sigma}_{n,x}^{pre}(E_n)$.

27) XS(IX,KE)

The reaction cross section of IX at the neutron energy KE.

4. Built-in Data and Parameter Files

4.1 Built-in Data

Systematics of radiation widths at the neutron binding energies is based on the data compiled by Mughabghab et al.[18] and given in Function GPARA as listed in Table 3.

The mass formula of Uno, Yamada and Ando[19] is given in Function FMASS which provides the mass excess as a function of Z and A. This formula is used when the mass excess is not found in the level-density-parameter file described in the next section.

The systematics of the level density parameter a of the Fermi gas model is given in Table 2. It is built in Function APARA as a function of mass numbers A and neutron numbers N. The temperature T of the constant temperature model is estimated as

$$T = 65/A \text{ (MeV)} \qquad A < 100,$$
$$T = 0.65 - 0.00242\,(A - 100) \text{ (MeV)} \qquad A \geq 100.$$

The upper and lower limits of T are fixed to 2.5 and 0.4 MeV, respectively. Pairing energies are adopted from the table by Gilbert and Cameron[4]. Since the data for the nuclei with Z and N less than 12 are not given by Gilbert and Cameron, the values at Z and N = 12 are used for the nuclei with smaller Z and N than 12.

An a priori estimation of Kalbach's constant given in Eq. (2.22) is used.

4.2 Level Density Parameter File

Nuclear mass excess and level density parameters should be prepared in the level-density-parameter file with the following format:

Col.	format	
1 - 6	A6	Nuclide name (ex. FE-56)
7 - 10	I4	Atomic number
11 - 15	I5	Mass number
16 - 19	F4.1	Spin
20	A1	Parity (+ or −), or blank in the case of parity unknown, or N in the case of spin

		and parity unknown.
21 - 30	E10.3	Mass excess + 1.0 (U)
31 - 40	E10.3	*a* parameter
41 - 50	E10.3	Temperature T
51 - 60	E10.3	C of Eq. (2.6)
61 - 70	E10.3	E_x

Figure 2 is an example of the level-density-parameter file. The presently prepared level-density-parameter file contains the mass excess data for about 2000 nuclides, and level density parameters for about 350 nuclides in a fission product mass region. The mass excess data were taken from the table of Wapstra and Bos.[20] The parameter *a* and temperature T were determined[21] from the average s-wave resonance level spacing data[18] and cumulative plot of low-lying level data in ENSDF[22] by using the code LEVDENS.[23] If the mass excess is not given in the file, the mass formula of Uno, Yamada and Ando[19] is used. If $a = 0$ and/or $T = 0$, the systematics formulas for *a* and T are used. Figures 3 and 4 show the plots of *a* and T parameters mainly in the fission product mass region, respectively. If the parameters C and E_x in Eq. (2.6) are not given in the level density file, they are calculated in PEGASUS from the values of *a* and T using the continuity condition in Eq. (2.7).

4.3 Inverse Reaction Cross Section File

The inverse reaction cross sections of the compound nucleus formation are read from the files. The inverse reaction cross sections for charged particles are read from the logical unit 1, and those for neutrons from the logical unit 3. A set of the inverse reaction cross section is read with the following two list direct read statements:

```
READ (NT,*)    TYPE, Z, A, JEMAX3
READ (NT,*)    (EII(J), SINV(J), J = 1, JEMAX3)
```

where NT = 1 for charged particles and NT = 3 for neutrons. The variable TYPE is one of 'NN', 'PN', 'AN', 'DN', 'TN', 'HE3N' which represent the reactions of (n,n), (p,n), (α,n), (d,n), (t,n), and (^{3}He,n). The atomic number Z and mass number A are those of the residual nucleus of the reaction specified by "TYPE". The variable EII is an array of energies (MeV)

of the particle in the center-of-mass system and SINV is the inverse reaction cross section (mill-barns).

An inverse reaction cross section file for charged particles was prepared[24] for target nuclei from Z=4 to 83 using the special version of spherical optical model code ELIESE-3[1] and the following optical potential parameters:

particle	optical potential parameters
proton	Perey[25]
α	Huizenga and Igo[26]
d	Lohr and Haeberi[27]
t	Becchetti and Greenlees[28]
^{3}He	Becchetti and Greenlees[28]

Figure 5 shows a part of the inverse reaction cross section file for the charged particles. The special version of ELIESE-3, named ELIESE-3I, is described in Appendix. For neutrons, users are recommended to make their own files using appropriate sets of optical potential parameters and ELIESE-3I.

The inverse reaction cross section file for the charged particles contains the data of several important isotopes for each atomic number. The charged particle cross sections in the file are given for the compound nuclei of neutron-induced reactions of the most abundant isotopes for each element with Z = 4 – 83. For example, for Z=26, the cross sections given in the file are those of the ^{56}Mn(p,n)^{57}Fe, ^{53}Cr(α,n)^{57}Fe, ^{55}Mn(d,n)^{57}Fe, ^{54}Mn(t,n)^{57}Fe and ^{54}Cr(^{3}He,n)^{57}Fe reactions, because ^{57}Fe is the compound nucleus of neutron-induced reaction with the most abundant isotope ^{56}Fe of Z = 26. Figure 6 shows those cross sections forming ^{57}Fe.

Retrieval of the cross sections from the file is made first by searching TYPE and the atomic number Z of the residual nucleus after emission of particles, and next by searching the nearest value of mass number A. For example, in the case of the above-mentioned Fe, the cross section of ^{56}Mn(p,n)^{57}Fe is used for calculation of the (n,p) cross sections of all the Fe isotopes. If TYPE or the atomic number under search is not found in the file, the inverse reaction cross sections for the charged particle are set to zero. When the inverse reaction cross section for the neutron is not given in the file on the logical unit 3, the formula of Pearlstein[3], Eq. (2.5), is used.

5. Input Data Format

In this chapter, the format of input data which are read from the logical unit 5 is described. A set of input data consists of six kinds of data as described here. In a job, more than one set of input data can be given.

1) Control data

Col.	Symbol	Format	Description
1 - 5	ZT	I5	Atomic number of the target nucleus.
6 - 10	AMT	I5	Mass number of the target nucleus.
11 - 15	MATNO	I5	MAT number for output in the ENDF format. If MATNO = 0, no output is made in the ENDF format. If MATNO > 0, the cross sections and energy distributions of emitted neutrons are written in the ENDF format on the logical unit 10.
16 - 20	YP0	I5	Option for the compound nucleus formation cross sections for neutrons. YP0 = 0: the compound nucleus formation cross section is assumed to be constant, and is calculated from $\sigma_{comp} = \pi\left(0.12A^{1/3} + 0.21\right)^2$. YP0 ≠ 0: the compound nucleus formation cross section is read from the logical unit 3. In this case, the compound nucleus formation cross section must be prepared in the same format as the inverse cross sections.
21 - 25	YP1	I5	Option for printing the inverse cross sections YP1 = 0: No output is made. YP1 ≠ 0: The inverse cross sections are printed out.

26 - 30	YP2	I5	Option for printing the first stage cross sections YP2 = 0: No output YP2 ≠ 0: output is made.
31 - 35	YP3	I5	Option for printing particle spectra YP3 = 0: No output YP3 ≠ 0: output is made.
36 - 40	YP4	I5	Option for printing the first stage emitted particle spectra YP4 = 0: No output YP4 ≠ 0: output is made.
41 - 45	YP5	I5	Option for printing angular distributions YP5 = 0: No output YP5 ≠ 0: output is made.
46 - 50	NSPECT	I5	In the case where YP3, YP4 or YP5 is not equal to zero, spectra and/or angular distributions are printed out at every energy interval of secondary particle (DE × NSPECT), where DE is an energy mesh for integration given in the next input data. If NSPECT is zero, NSPECT is assumed to be 2.

2) Parameters

Col.	Symbol	Format	Description
1 - 10	KME	E10.3	Kalbach's constant (MeV^3) in Eq. (2.21). If KME < 0, KME is estimated as $KME = 0.1 / (g_c / A_c)^3$, where $g_c = (6/\pi^2)a_c$, a_c and A_c are the level density parameter and mass number of the composite nucleus (see Eq. (2.22)). If KME = 0, the preequilibrium process is not considered in the calculation.
11- 20	GAMMA	E10.3	An adjustable parameter γ_x for the cluster formation factor in Eq. (2.29).

21 - 30	DE	E10.3	Energy mesh for integration (MeV). If DE < 0.1, DE is assumed to be 0.125 MeV. The value of DE must satisfy that E2MAX/DE ≤ 250, where E2MAX is the maximum energy of emitted particles. If given DE does not satisfy this condition, DE is automatically increased to satisfy this condition.
31 - 40	GG	E10.3	Radiation width (eV) at the neutron binding energy. If GG = 0.0, it is determined by using the systematics given in Table 3.
41 - 50	ETHINL	E10.3	Threshold energy (MeV) of the continuum inelastic scattering. If ETHINL < 0.0, it is regarded as a Q-value.

3) Incident neutron energies

3-1) Number of neutron energy points

Col.	Symbol	Format	Description
1 - 5	KEMAXI	I5	Number of incident neutron energies. If KEMAXI ≤ 0, the calculation is made at the following 25 energies. 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 13.5, 14.0, 14.5, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0 (MeV) Calculations are also made at the threshold energies of the reactions. The sum of KEMAXI and the number of the threshold energies must be less than or equal to 62.

3-2) Incident neutron energies

This input is not needed in the case of KEMAXI ≤ 0.

Col.	Symbol	Format	Description
1 - 70	ENI	7E10.3	Incident neutron energies (MeV) in the laboratory system.

4) Incident neutron energies where output of spectra and angular distributions is made to the logical unit 6 (a line-printer).

4-1) Number of incident energy points

Col.	Symbol	Format	Description
1 – 5	ISPMXI	I5	Number of incident energy points where output of spectra and angular distributions is made. If ISPMXI < 0, the output is not made. If ISPMXI = 0, the output is made at the following 5 energy points. 1.0, 5.0, 10.0, 15.0, 20.0 (MeV)

4-2) Incident neutron energies

This input is not needed in the case of ISPMXI ≤ 0.

Col.	Symbol	Format	Description
1 - 70	ENSPEC	7E10.3	Energies (MeV) where spectra and angular distributions are output. The energies given in this input must be included in the energies given in Input 3.

5) Angles

This input is not needed in the case of ISPMXI ≤ 0.

5-1) Number of angles

Col.	Symbol	Format	Description
1 - 5	IANGI	I5	Number of angles where angular distributions are calculated. If IANGI < 0, no calculation is

made, If IANGI = 0, calculation is performed at the following 9 angles.

0.0, 30.0, 60.0, 80.0, 90.0, 100.0, 120.0, 160.0, 180.0

IANGI must be less than 11.

5-2) Angles

This input is not needed in the case of IANGI ≤ 0.

Col.	Symbol	Format	Description
1 - 70	THETA	7E10.3	Angles (degrees.)

6) Level density parameters

The level density parameters are read from the logical unit 2. However, if needed, they can be modified by the following input.

6-1) Number of nuclides

Col.	Symbol	Format	Description
1 – 5	IOP1	I5	Number of nuclides whose level density parameters are replaced with the following input.

6-2) Level density parameters

If IOP1 = 0, this input is not needed. This input must be repeated IOP1 times.

Col.	Symbol	Format	Description
1 - 5	Z	I5	Atomic number
6 - 10	A	I5	Mass number
11 - 20	ASS	E10.3	*a* parameter (MeV^{-1})
21 - 30	TSS	E10.3	Temperature T(MeV)

6. Output in ENDF format

In the case where MATNO of the input data is not equal to zero, the calculated cross sections and energy distributions of emitted neutrons are written in the ENDF format on the logical unit 10. In the output, the following MT numbers are used.

MT =	2	compound elastic scattering
	16	(n,2n) reaction
	17	(n,3n) reaction
	22	(n,nα) reaction
	28	(n,np) reaction
	32	(n,nd) reaction
	33	(n,nt) reaction
	91	continuum inelastic scattering
	102	(n,γ) reaction
	103	(n,p) reaction
	104	(n,d) reaction
	105	(n,t) reaction
	106	(n,^{3}He) reaction
	107	(n,α) reaction
	111	(n,2p) reaction
	999	sum of cross sections of MT = 16, 17, 22, 28, 32, 33, 103, 104, 105, 106, 107 and 111.

The cross section of MT=22 is the sum of the (n,nα) and (n,αn) cross sections. In the same way, MT=28 the sum of (n,np) and (n,pn) cross sections, MT=32 the sum of the (n,nd) and (n,dn) cross sections, and MT=33 the sum of the (n,nt) and (n,tn) cross sections.

For the reactions with a positive Q-value, except the compound elastic scattering and (n,γ) reaction, the cross section of 0.0 barn is assumed at 10^{-5} eV. In the case of a negative Q-value, the threshold energy is calculated from the Q-value. For the continuum inelastic scattering, the threshold energy is given in the input data.

Interpolation schemes of cross sections (MF=3) are determined as follows:

reactions (MT)	interpolation
2, 102	4 (log σ is linearly interpolated in E)
16, 17	2 (σ is linearly interpolated in E)
others	2 for the first energy interval and 4 for the other energy intervals

The present version of PEGASUS does not make output of the angular distributions in the ENDF format.

The energy distributions (MF=5) are given for the neutrons emitted from the (n,n'), (n,2n), (n,3n), (n,nα), (n,np), (n,nd) and (n,nt) reactions. As to the distributions at the threshold energies, a triangle distribution from the emitted neutron energy of 0 to 2 eV with a peak at 1 eV is assumed. However, integral tests revealed that a very narrow spectrum caused an unacceptable central spectrum of reactors.[29] The energy distribution at the threshold energy should be modified when they are adopted in an evaluated nuclear data file.

All the energy distributions are given in a tabular form. They start with 0.0 at 0 MeV and end with 0 at the maximum emitted neutron energy. Interpolation scheme of 2 (linear-linear) is adopted for the first and last energy intervals and 4 (log-linear) for the other energy intervals. The number of data points of each distribution is automatically reduced to the number enough to represent the calculated distribution within 1%.

7. JCL and Examples

7.1 JCL

PEGASUS uses the following logical units.

1. Inverse reaction cross sections for charged particles (the inverse reaction cross section file)
2. Level density parameters (the level density parameter file)
3. Inverse reaction cross sections for neutrons
5. Input data
6. Output
10. Output in the ENDF format

For the users of the JAERI computer system GS8400 whose OS is MSP, a cataloged procedure has been prepared in J2608.PROCLIB.CNTL(PEGASUS). Figure 7 shows the cataloged procedure of PEGASUS. In this procedure, the inverse reaction cross section file (J2608.SGINVPS.DATA) for charged particles and the level density parameter file (J2608.LDPDATA.DATA) are allocated to the logical unit 1 and 2, respectively. Core size needed for the calculation with PEGASUS is about 1.3 M bytes.

7.2 Examples

1) Example 1

An example of JCL (Job Control Language) and input data shown in Fig. 8 is the calculation of the following problem.

Target : ^{144}Nd

ENDF format output : required. The MAT number is 4399.

Compound nucleus formation cross section : given in the file of "J2608.J32ND144.DATA(SCOMP)"

Kalbach's constant : 25.0

Cluster formation factor : 0.3

Energy mesh for integration : 0.125 MeV

Radiative capture width : systematics built in PEGASUS

Threshold energy of the continuum inelastic scattering: 1.82953 MeV

Incident neutron energies : the following 22 points,

0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 14.5, 15, 16, 17, 18, 19, 20 (MeV)

The output of this example is given in Fig. 9, and the data in the ENDF format written in FT10F001 are partly listed in Fig. 10. The CPU time consumed was 10.6 sec with GS8400 at JAERI.

The calculated (n,2n) cross section is compared with experimental data in Fig. 11. All cross sections are shown in Fig.12.

2) Example 2

In this example, some options are changed from Example 1 as follows;

Printing of particle spectra : yes

Printing of angular distributions : yes

The input data are changed only in the first control data record as follow;

```
60  144 6044    1    0    0    1    0    1    4
```

An example of the calculated particle spectra and angular distributions at 14 MeV is shown in Fig. 13.

Acknowledgments

We appreciate Dr. A. Iwamoto and late Dr. K. Harada for providing us with the table of cluster formation factors and instructive discussions. We are thankful to Mr. Y. Ando of Toshiba Nuclear Engineering Laboratory for the mass formula program of Uno, Ando and Yamada, and to Mr. M. Kawasaki of Century Research Center for making the inverse reaction cross section file and for modification of ELIESE-3I. We own the members of Fission Product Nuclear Data Working Group of Japanese Nuclear Data Committee for evaluation of level density parameters. We also appreciate Dr. Y. Nakajima for careful reading of the manuscript and his valuable comments.

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Table 1 Coefficients of Polynomial Approximation for $F_{lm}(\varepsilon_x^*)$

	F_{lm}	b_0	b_1	b_2	comment
d	$F_{1,1}$	+0.99846	−0.02521	$+1.34\times10^{-4}$	
	$F_{2,0}$	$+1.54\times10^{-3}$	+0.02521	-1.34×10^{-4}	
	Sum	+1.0000	0.0	0.0	
t	$F_{1,2}$	+0.57860	−0.01990	$+2.08\times10^{-4}$	
	$F_{2,1}$	+0.42246	+0.01973	-3.26×10^{-4}	
	$F_{3,0}$	-1.191×10^{-3}	$+1.92\times10^{-4}$	$+1.18\times10^{-4}$	$F_{3,0}$ (< 4 MeV) = 0
	Sum	+0.9999	$+1.5\times10^{-5}$	$+4.4\times10^{-7}$	
^{3}He	$F_{1,2}$	+0.57500	−0.02143	$+2.33\times10^{-4}$	
	$F_{2,1}$	+0.42614	+0.02126	-3.75×10^{-4}	
	$F_{3,0}$	-1.36×10^{-3}	$+2.03\times10^{-4}$	$+1.41\times10^{-4}$	$F_{3,0}$ (< 4 MeV) = 0
	Sum	+0.9998	$+3.3\times10^{-5}$	-9.5×10^{-7}	
α	$F_{1,3}$	+0.28144	−0.01113	$+1.34\times10^{-4}$	
	$F_{2,2}$	+0.61409	$+1.96\times10^{-3}$	-1.74×10^{-4}	
	$F_{3,1}$	+0.10408	$+9.39\times10^{-3}$	$+1.61\times10^{-5}$	
	$F_{4,0}$	$+4.31\times10^{-4}$	-2.27×10^{-4}	$+2.31\times10^{-5}$	$F_{4,0}$ (< 8 MeV) = 0
	Sum	+1.0000	-7.0×10^{-6}	-2.0×10^{-8}	

Table 2 Systematics of level density parameter a

$$a = A\frac{C_1(N-N_1)+C_2(N_2-N)}{N_2-N_1}+C_3 \quad (\mathrm{MeV}^{-1})$$

A: Mass Number

N: Neutron Number

N	N_1	N_2	C_1	C_2	C_3
$N \le 17$	1	17	0.0	0.0	4.0
$18 \le N \le 27$	18	27	0.15	0.15	0.0
$28 \le N \le 41$	28	41	0.193	0.122	0.0
$42 \le N \le 49$	42	49	0.155	0.187	0.0
$50 \le N \le 59$	50	59	0.185	0.104	0.0
$60 \le N \le 81$	60	81	0.114	0.182	0.0
$82 \le N \le 88$	82	88	0.166	0.100	0.0
$89 \le N \le 98$	89	98	0.124	0.171	0.0
$99 \le N \le 116$	99	116	0.123	0.123	0.0
$117 \le N \le 126$	117	126	0.041	0.116	0.0
$127 \le N \le 139$	127	139	0.154	0.058	0.0
$140 \le N \le 146$	140	146	0.124	0.141	0.0
$147 \le N$	147	200	0.120	0.120	0.0

Table 3 Systematics of radiation widths

Mass Number (A)	Γ_γ (eV)
≤ 30	3.5
50	0.37
90	0.17
110	0.10
140	0.07
150	0.07
160	0.12
165	0.12
180	0.06
195	0.12
205	2.0
210	0.065
≥ 220	0.035

For any mass number, values of Γ_γ given in this table are interpolated by assuming $\log(\Gamma_\gamma)$ is linear in mass number A.

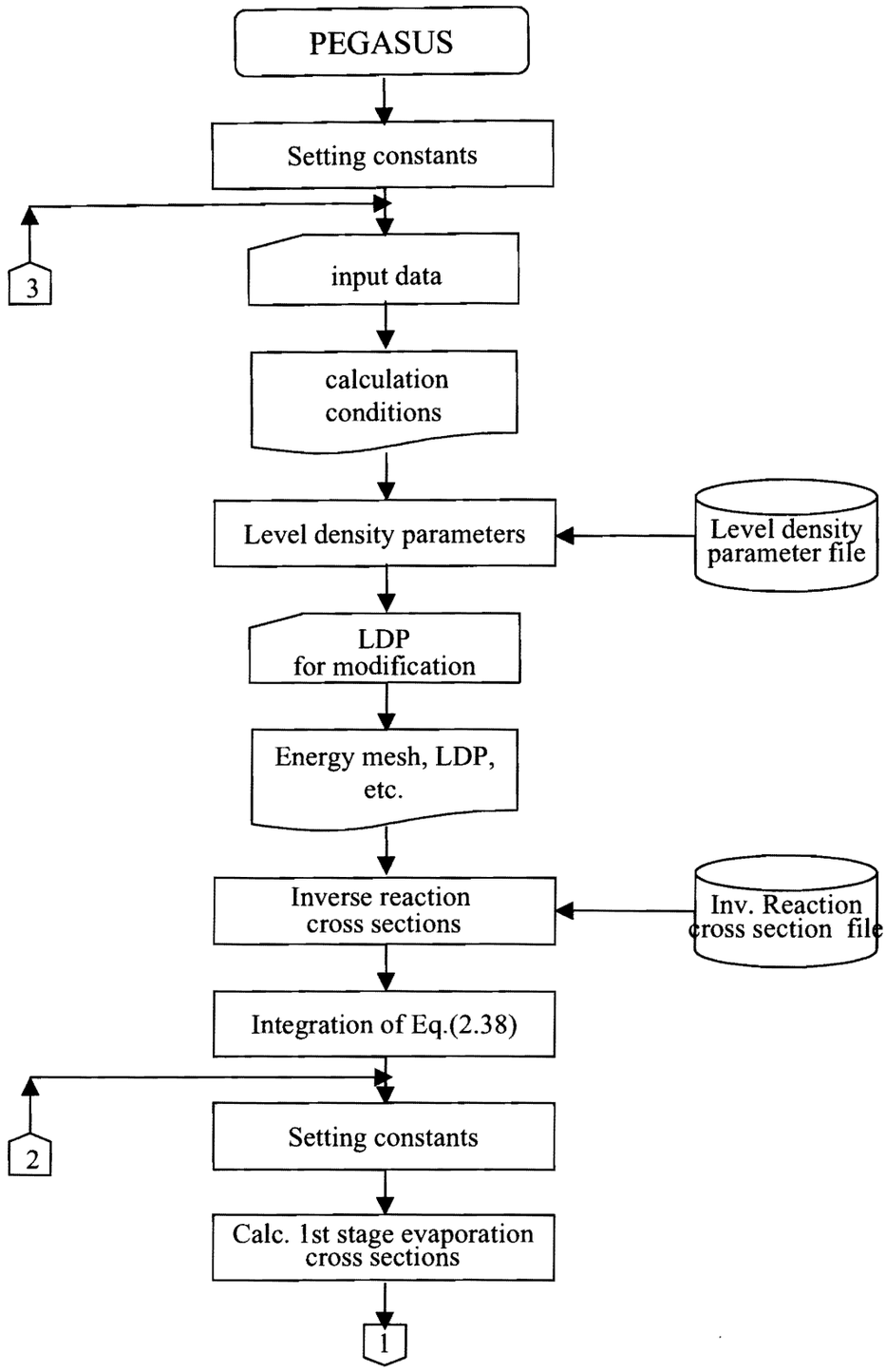

Fig.1(1) Flowchart of PEGASUS

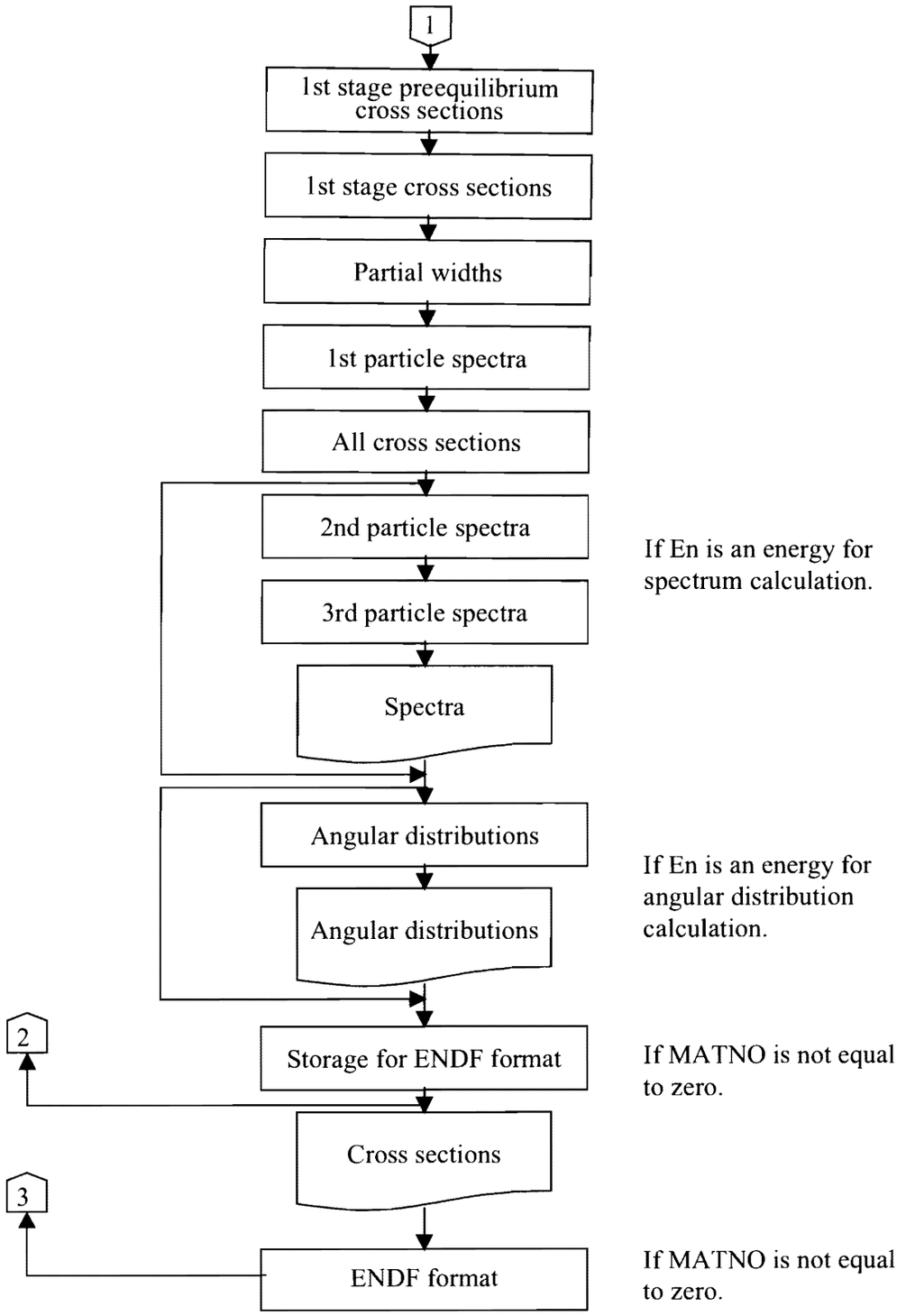

Fig.1(2) Flowchart of PEGASUS

```
AS- 71  33   71 2.5-0.92711446
AS- 72  33   72 2.0-0.92675053
AS- 73  33   73 1.5-0.92383373
AS- 74  33   74 2.0-0.9239296011.320      0.9475
AS- 75  33   75 1.5-0.9215955212.500      0.951
AS- 76  33   76 2.0-0.9223934813.300      0.786
AS- 77  33   77 1.5-0.9206488813.000      0.844
AS- 78  33   78 2.0-0.9219110311.500      0.750
AS- 79  33   79 1.5-0.9208589712.900      0.823
AS- 80  33   80 1.0+0.9226410411.500      0.725
AS- 81  33   81 1.5-0.92201839
AS- 82  33   82 1.0+0.92464855
AS- 83  33   83 1.5-0.92490620
AS- 84  33   84 0.0-0.92897490
SE- 67  34   67     N0.94945795
SE- 68  34   68 0.0+0.94184659
SE- 69  34   69     N0.93955996
SE- 70  34   70 0.0+0.93388095
SE- 71  34   71 1.5-0.93227065
SE- 72  34   72 0.0+0.92711339
SE- 73  34   73 4.5+0.9267752214.040      0.825
SE- 74  34   74 0.0+0.9224771112.900      0.862
SE- 75  34   75 2.5+0.9225240213.910      0.850
SE- 76  34   76 0.0+0.9192065813.150      0.890
SE- 77  34   77 0.5-0.9199077114.380      0.800
SE- 78  34   78 0.0+0.9173039612.870      0.875
SE- 79  34   79 3.5+0.9184965514.120      0.800
SE- 80  34   80 0.0+0.9165204913.340      0.813
SE- 81  34   81 0.5-0.9179915513.680      0.749
SE- 82  34   82 0.0+0.9167086812.590      0.798
SE- 83  34   83 4.5+0.9190446913.810      0.750
SE- 84  34   84 0.0+0.91847357
SE- 85  34   85 2.5+0.92209353
SE- 86  34   86 0.0+0.92392928
BR- 69  35   69     N0.94995178
BR- 70  35   70     N0.94509940
BR- 71  35   71     N0.93935598
BR- 72  35   72 3.0 0.93673656
BR- 73  35   73 1.5-0.93164800
BR- 74  35   74 0.0-0.92990350
BR- 75  35   75 1.5-0.92575536
BR- 76  35   76 1.0-0.92452724
BR- 77  35   77 1.5-0.92137265
BR- 78  35   78 1.0+0.9211402313.940      0.757
BR- 79  35   79 1.5-0.9183361612.930      0.869
BR- 80  35   80 1.0+0.9185283213.180      0.795
BR- 81  35   81 1.5-0.9162900012.900      0.831
BR- 82  35   82 5.0-0.9168031512.660      0.690
BR- 83  35   83 1.5-0.9151638613.240      0.783
BR- 84  35   84 2.0-0.91652296
BR- 85  35   85 1.5-0.9155449711.000      0.700
BR- 86  35   86 2.0-0.91845425
BR- 87  35   87 1.5-0.92033294
BR- 88  35   88 1.0-0.92368237
KR- 71  36   71     N0.95008060
KR- 72  36   72 0.0+0.94216865
KR- 73  36   73     N0.93882995
KR- 74  36   74 0.0+0.93341933
KR- 75  36   75     +0.93112197
KR- 76  36   76 0.0+0.92581870
```

Fig.2(1) An example of the level-density-parameter file

```
KR- 77  36   77 2.5+0.9245991713.590      0.825
KR- 78  36   78 0.0+0.9203973513.220      0.869
KR- 79  36   79 0.5-0.9200871013.690      0.840
KR- 80  36   80 0.0+0.9163748112.050      0.835
KR- 81  36   81 3.5+0.9165787815.030      0.730
KR- 82  36   82 0.0+0.9134827113.190      0.781
KR- 83  36   83 4.5+0.9141337014.830      0.670
KR- 84  36   84 0.0+0.91150643 9.970      0.960
KR- 85  36   85 4.5+0.9125371410.240      0.890
KR- 86  36   86 0.0+0.91061422 9.052      0.8686
KR- 87  36   87 2.5+0.91335818 9.400      0.886
KR- 88  36   88 0.0+0.91445103
KR- 89  36   89 2.5+0.91756321
KR- 90  36   90 0.0+0.91929161
KR- 91  36   91 2.5+0.92295236
KR- 92  36   92 0.0+0.92576502
KR- 93  36   93 0.5+0.93030608
RB- 75  37   75     N0.93826098
RB- 76  37   76 1.0 0.93493302
RB- 77  37   77 1.5-0.93010211
RB- 78  37   78 0.0+0.92797651
RB- 79  37   79 2.5+0.92392928
RB- 80  37   80 1.0+0.92250148
RB- 81  37   81 1.5-0.91900712
RB- 82  37   82 1.0+0.91818264
RB- 83  37   83 2.5-0.91520466
RB- 84  37   84 2.0-0.9143834011.060      0.806
RB- 85  37   85 2.5-0.9117996211.900      0.869
RB- 86  37   86 2.0-0.9111781510.020      0.850
RB- 87  37   87 1.5-0.90918352 8.806      0.941
RB- 88  37   88 2.0-0.91132383 9.801      0.8185
RB- 89  37   89 1.5-0.91227391
RB- 90  37   90 1.0-0.9145787911.790      0.722
RB- 91  37   91 1.5-0.91629644
RB- 92  37   92 0.0-0.91935602
RB- 93  37   93 2.5-0.92171780
RB- 94  37   94 3.0-0.92543223
RB- 95  37   95 2.5 0.92855622
RB- 96  37   96 2.0+0.93261418
SR- 77  38   77 2.5 0.93777789
SR- 78  38   78 0.0+0.93145476
SR- 79  38   79 1.5-0.92972637
SR- 80  38   80 0.0+0.92443384
SR- 81  38   81 0.5-0.92328516
SR- 82  38   82 0.0+0.91841238
SR- 83  38   83 3.5+0.91762011
SR- 84  38   84 0.0+0.91342903
SR- 85  38   85 4.5+0.9129416411.340      0.910
SR- 86  38   86 0.0+0.9092732711.200      0.890
SR- 87  38   87 4.5+0.9088902310.300      0.861
SR- 88  38   88 0.0+0.90562486 9.160      0.751
SR- 89  38   89 2.5+0.90745803 9.380      0.820
SR- 90  38   90 0.0+0.90774605 9.940      0.853
SR- 91  38   91 2.5+0.9101815810.900      0.810
SR- 92  38   92 0.0+0.91101250
SR- 93  38   93 3.5+0.91381658
SR- 94  38   94 0.0+0.91523364
SR- 95  38   95 0.5+0.91933455
SR- 96  38   96 0.0+0.92155677
SR- 97  38   97 0.5+0.92584017
```

Fig.2(2) An example of the level-density-parameter file (continued)

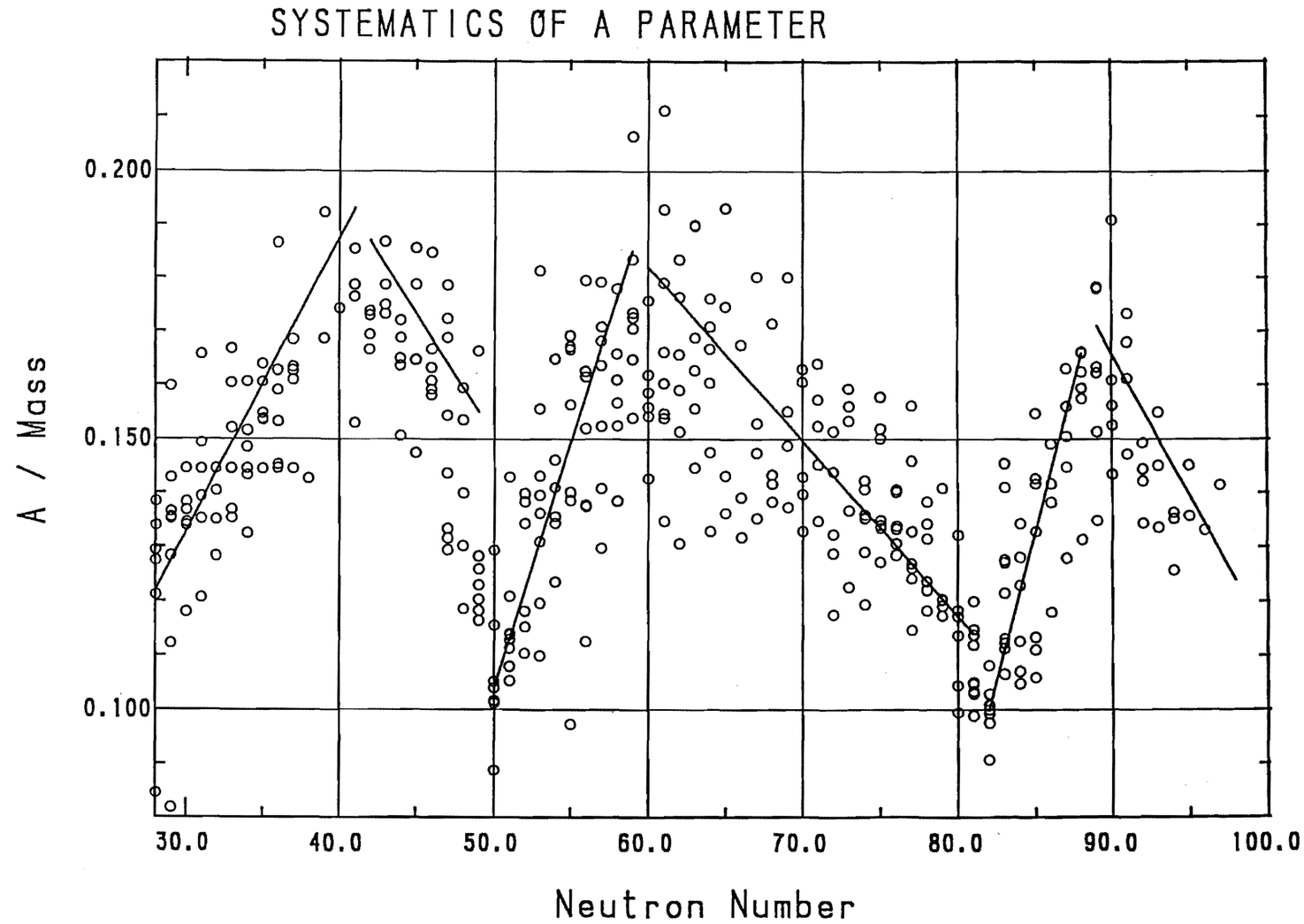

Fig.3 Systematics of *a* parameter

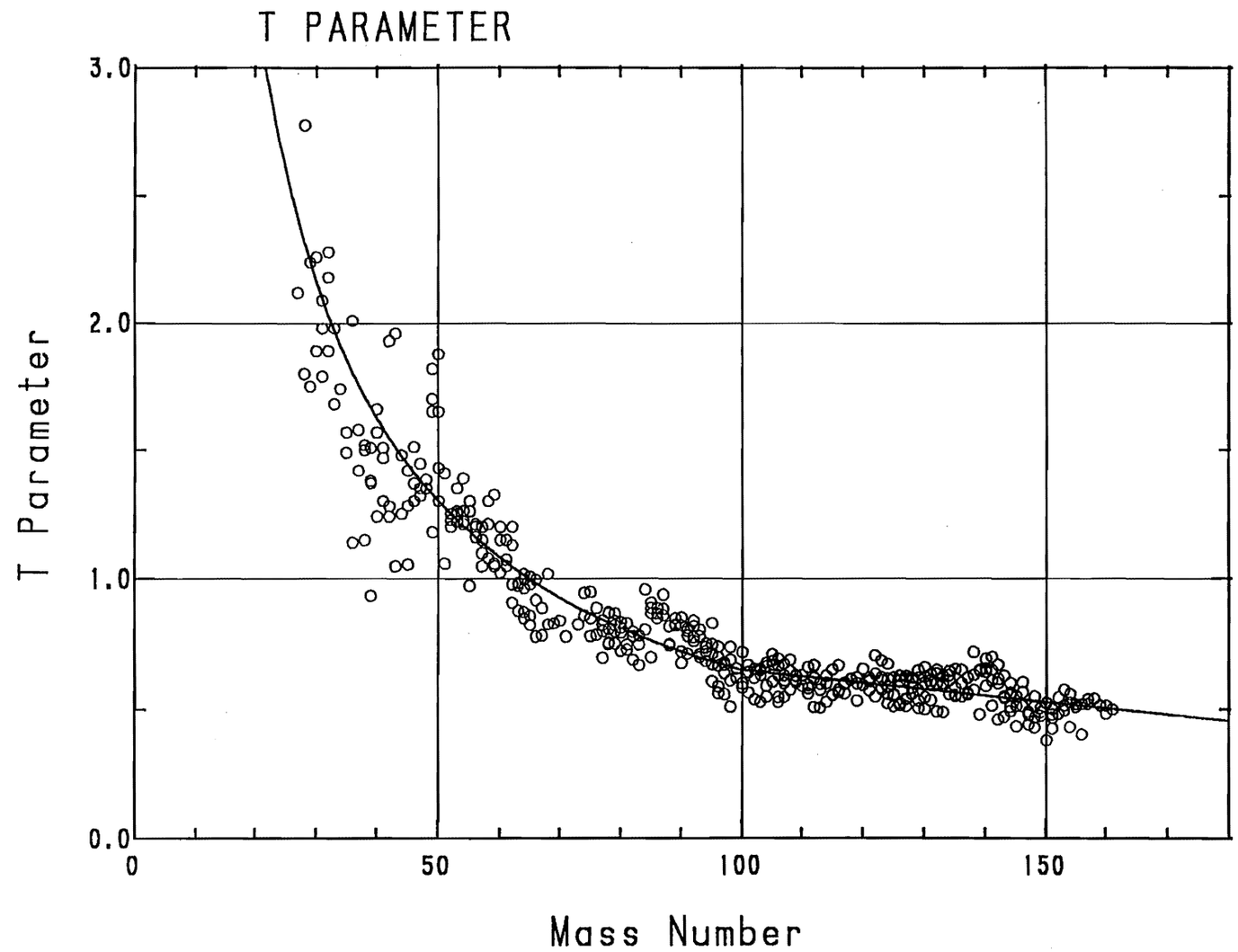

Fig.4 Systematics of Temperature T

```
'PN'      4  11    25 11    BE11 + P (EN=0.05MEV)  REF. OF PEREY.
  0.0500  5.7933E-02        0.1000  4.0637E+00      0.2000  6.3657E+01
  0.4000  2.9387E+02        0.6000  4.5231E+02      0.8000  5.3222E+02
  1.0000  5.7597E+02        1.2500  6.1124E+02      1.5000  6.3845E+02
  1.7500  6.6199E+02        2.0000  6.8312E+02      2.5000  7.1917E+02
  3.0000  7.4704E+02        3.5000  7.6700E+02      4.0000  7.7960E+02
  5.0000  7.8738E+02        6.0000  7.8182E+02      7.0000  7.7305E+02
  9.0000  7.5948E+02       12.0000  7.3166E+02     15.0000  6.8890E+02
 18.0000  6.4999E+02       22.0000  6.1097E+02     30.0000  5.5074E+02
 40.0000  4.9547E+02
'AN'      3   8    26 21    LI 8 + A (EN=0.5 MEV)  REF. OF H.I
  0.5000  2.9734E+01        1.0000  3.8125E+02      1.2000  5.5204E+02
  1.4000  6.9223E+02        1.6000  7.5832E+02      1.8000  7.7262E+02
  2.0000  7.7007E+02        2.5000  7.6932E+02      3.0000  7.7858E+02
  3.5000  7.8482E+02        4.0000  7.8426E+02      5.0000  7.8188E+02
  6.0000  8.4651E+02        7.0000  9.3012E+02      8.0000  9.1065E+02
 10.0000  8.5824E+02       12.0000  7.5228E+02     14.0000  7.2900E+02
 16.0000  8.3135E+02       18.0000  7.4943E+02     20.0000  6.6342E+02
 23.0000  6.5869E+02       26.0000  6.2216E+02     30.0000  5.6462E+02
 35.0000  5.2443E+02       40.0000  4.8571E+02
'DN'      4  10    25 31    BE10 + D (EN=0.05MEV)  REF. OF L.H.
  0.0500  5.8308E-04        0.1000  2.3778E-01      0.2000  1.2820E+01
  0.4000  1.5345E+02        0.6000  3.6727E+02      0.8000  5.5452E+02
  1.0000  6.9600E+02        1.2500  8.2091E+02      1.5000  9.0747E+02
  1.7500  9.6939E+02        2.0000  1.0145E+03      2.5000  1.0726E+03
  3.0000  1.1062E+03        3.5000  1.1267E+03      4.0000  1.1389E+03
  5.0000  1.1492E+03        6.0000  1.1505E+03      7.0000  1.1473E+03
  9.0000  1.1352E+03       12.0000  1.1138E+03     15.0000  1.0932E+03
 18.0000  1.0745E+03       22.0000  1.0526E+03     30.0000  1.0168E+03
 40.0000  9.8254E+02
'TN'      4   9    25 41    BE 9 + T (EN=0.05MEV)  REF. OF B.G.
  0.0500  5.6660E-05        0.1000  6.6770E-02      0.2000  7.5255E+00
  0.4000  1.4509E+02        0.6000  4.0230E+02      0.8000  6.3731E+02
  1.0000  8.1480E+02        1.2500  9.7253E+02      1.5000  1.0816E+03
  1.7500  1.1571E+03        2.0000  1.2100E+03      2.5000  1.2748E+03
  3.0000  1.3073E+03        3.5000  1.3229E+03      4.0000  1.3303E+03
  5.0000  1.3329E+03        6.0000  1.3243E+03      7.0000  1.3103E+03
  9.0000  1.2747E+03       12.0000  1.2257E+03     15.0000  1.1810E+03
 18.0000  1.1390E+03       22.0000  1.0887E+03     30.0000  1.0024E+03
 40.0000  9.0278E+02
'HE3N'    3   9    26 51    LI 9 + HE3 (EN=0.5 MEV)  REF. OF B.G.
  0.5000  3.9683E+01        1.0000  4.0997E+02      1.2000  5.7237E+02
  1.4000  7.1053E+02        1.6000  8.2412E+02      1.8000  9.1655E+02
  2.0000  9.9176E+02        2.5000  1.1264E+03      3.0000  1.2117E+03
  3.5000  1.2674E+03        4.0000  1.3048E+03      5.0000  1.3476E+03
  6.0000  1.3663E+03        7.0000  1.3729E+03      8.0000  1.3726E+03
 10.0000  1.3615E+03       12.0000  1.3445E+03     14.0000  1.3253E+03
 16.0000  1.3057E+03       18.0000  1.2861E+03     20.0000  1.2673E+03
 23.0000  1.2402E+03       26.0000  1.2145E+03     30.0000  1.1823E+03
 35.0000  1.1450E+03       40.0000  1.1102E+03
'PN'      5  12    25 11    B 12 + P (EN=0.05MEV)  REF. OF PEREY.
  0.0500  1.4373E-03        0.1000  3.6034E-01      0.2000  1.4547E+01
  0.4000  1.3685E+02        0.6000  2.8731E+02      0.8000  3.9272E+02
  1.0000  4.5863E+02        1.2500  5.1169E+02      1.5000  5.5001E+02
  1.7500  5.8155E+02        2.0000  6.0920E+02      2.5000  6.5625E+02
  3.0000  6.9353E+02        3.5000  7.2181E+02      4.0000  7.4179E+02
  5.0000  7.6182E+02        6.0000  7.6553E+02      7.0000  7.6365E+02
  9.0000  7.5863E+02       12.0000  7.3584E+02     15.0000  6.9640E+02
 18.0000  6.6097E+02       22.0000  6.2475E+02     30.0000  5.6574E+02
 40.0000  5.1130E+02
```

Fig.5(1) An example of the inverse reaction cross section file

```
'AN'      4   9    26 21    BE 9 + A (EN=0.5 MEV)  REF. OF H.I
  0.5000  1.9282E+00        1.0000  1.0370E+02      1.2000  1.8245E+02
  1.4000  2.6286E+02        1.6000  3.3500E+02      1.8000  3.9416E+02
  2.0000  4.4094E+02        2.5000  5.2719E+02      3.0000  6.0704E+02
  3.5000  6.8728E+02        4.0000  7.4463E+02      5.0000  8.2059E+02
  6.0000  9.8538E+02        7.0000  9.6281E+02      8.0000  8.6395E+02
 10.0000  7.8683E+02       12.0000  7.7823E+02     14.0000  8.8816E+02
 16.0000  7.9036E+02       18.0000  7.0374E+02     20.0000  7.1885E+02
 23.0000  7.0681E+02       26.0000  6.3280E+02     30.0000  6.0813E+02
 35.0000  5.5252E+02       40.0000  5.1687E+02
'DN'      5  11    25 31    B 11 + D (EN=0.05MEV)  REF. OF L.H.
  0.0500  3.9620E-06        0.1000  9.4082E-03      0.2000  1.7562E+00
  0.4000  5.2242E+01        0.6000  1.8884E+02      0.8000  3.5548E+02
  1.0000  5.0683E+02        1.2500  6.5653E+02      1.5000  7.6755E+02
  1.7500  8.5037E+02        2.0000  9.1305E+02      2.5000  9.9799E+02
  3.0000  1.0504E+03        3.5000  1.0845E+03      4.0000  1.1071E+03
  5.0000  1.1319E+03        6.0000  1.1428E+03      7.0000  1.1463E+03
  9.0000  1.1429E+03       12.0000  1.1287E+03     15.0000  1.1121E+03
 18.0000  1.0960E+03       22.0000  1.0761E+03     30.0000  1.0426E+03
 40.0000  1.0095E+03
'TN'      5  10    25 41    B 10 + T (EN=0.05MEV)  REF. OF B.G.
  0.0500  1.6817E-07        0.1000  1.5817E-03      0.2000  7.7211E-01
  0.4000  4.3313E+01        0.6000  1.9651E+02      0.8000  4.0476E+02
  1.0000  5.9855E+02        1.2500  7.9035E+02      1.5000  9.3179E+02
  1.7500  1.0353E+03        2.0000  1.1119E+03      2.5000  1.2144E+03
  3.0000  1.2757E+03        3.5000  1.3134E+03      4.0000  1.3371E+03
  5.0000  1.3600E+03        6.0000  1.3648E+03      7.0000  1.3614E+03
  9.0000  1.3434E+03       12.0000  1.3082E+03     15.0000  1.2720E+03
 18.0000  1.2378E+03       22.0000  1.1962E+03     30.0000  1.1231E+03
 40.0000  1.0445E+03
'HE3N'    4  10    26 51    BE10 + HE3 (EN=0.5 MEV)  REF. OF B.G.
  0.5000  3.2031E+00        1.0000  1.3786E+02      1.2000  2.5515E+02
  1.4000  3.8289E+02        1.6000  5.0548E+02      1.8000  6.1558E+02
  2.0000  7.1139E+02        2.5000  8.9485E+02      3.0000  1.0190E+03
  3.5000  1.1046E+03        4.0000  1.1650E+03      5.0000  1.2404E+03
  6.0000  1.2809E+03        7.0000  1.3027E+03      8.0000  1.3135E+03
 10.0000  1.3177E+03       12.0000  1.3104E+03     14.0000  1.2977E+03
 16.0000  1.2828E+03       18.0000  1.2666E+03     20.0000  1.2504E+03
 23.0000  1.2260E+03       26.0000  1.2021E+03     30.0000  1.1714E+03
 35.0000  1.1350E+03       40.0000  1.1002E+03
'PN'      6  14    25 11    C 14 + P (EN=0.05MEV)  REF. OF PEREY.
  0.0500  2.6779E-05        0.1000  2.4881E-02      0.2000  2.5398E+00
  0.4000  4.7320E+01        0.6000  1.3883E+02      0.8000  2.3261E+02
  1.0000  3.1025E+02        1.2500  3.8667E+02      1.5000  4.4840E+02
  1.7500  5.0086E+02        2.0000  5.4643E+02      2.5000  6.2022E+02
  3.0000  6.7449E+02        3.5000  7.1302E+02      4.0000  7.3934E+02
  5.0000  7.6761E+02        6.0000  7.7922E+02      7.0000  7.8553E+02
  9.0000  7.8980E+02       12.0000  7.6498E+02     15.0000  7.2847E+02
 18.0000  6.9959E+02       22.0000  6.6632E+02     30.0000  6.0553E+02
 40.0000  5.5031E+02
'AN'      5  11    26 21    B 11 + A (EN=0.5 MEV)  REF. OF H.I
  0.5000  3.3817E-02        1.0000  1.1515E+01      1.2000  3.5354E+01
  1.4000  8.1436E+01        1.6000  1.5319E+02      1.8000  2.4439E+02
  2.0000  3.3965E+02        2.5000  5.4819E+02      3.0000  7.4762E+02
  3.5000  8.5323E+02        4.0000  8.7832E+02      5.0000  9.0089E+02
  6.0000  8.8121E+02        7.0000  8.7723E+02      8.0000  9.3255E+02
 10.0000  9.9101E+02       12.0000  9.2930E+02     14.0000  8.7496E+02
 16.0000  9.0104E+02       18.0000  9.4439E+02     20.0000  8.3965E+02
 23.0000  8.2520E+02       26.0000  7.9865E+02     30.0000  7.3517E+02
 35.0000  6.8786E+02       40.0000  6.4482E+02
```

Fig.5(2) An example of the inverse reaction cross section file (continued)

```
'DN'      6  13    25 31    C 13 + D (EN=0.05MEV)  REF. OF L.H.
  0.0500  2.1602E-08        0.1000  3.1843E-04     0.2000  2.1491E-01
  0.4000  1.6077E+01        0.6000  8.9143E+01     0.8000  2.1542E+02
  1.0000  3.5766E+02        1.2500  5.1941E+02     1.5000  6.5023E+02
  1.7500  7.5264E+02        2.0000  8.3275E+02     2.5000  9.4566E+02
  3.0000  1.0182E+03        3.5000  1.0671E+03     4.0000  1.1011E+03
  5.0000  1.1418E+03        6.0000  1.1632E+03     7.0000  1.1738E+03
  9.0000  1.1798E+03       12.0000  1.1731E+03    15.0000  1.1607E+03
 18.0000  1.1469E+03       22.0000  1.1291E+03    30.0000  1.0973E+03
 40.0000  1.0649E+03
'TN'      6  12    25 41    C 12 + T (EN=0.05MEV)  REF. OF B.G.
  0.0500  3.2116E-10        0.1000  2.7699E-05     0.2000  6.4348E-02
  0.4000  1.1003E+01        0.6000  8.4021E+01     0.8000  2.3491E+02
  1.0000  4.1609E+02        1.2500  6.2442E+02     1.5000  7.9171E+02
  1.7500  9.2066E+02        2.0000  1.0197E+03     2.5000  1.1572E+03
  3.0000  1.2434E+03        3.5000  1.2990E+03     4.0000  1.3360E+03
  5.0000  1.3769E+03        6.0000  1.3943E+03     7.0000  1.3998E+03
  9.0000  1.3928E+03       12.0000  1.3662E+03    15.0000  1.3351E+03
 18.0000  1.3039E+03       22.0000  1.2644E+03    30.0000  1.1935E+03
 40.0000  1.1161E+03
'HE3N'    5  12    26 51    B 12 + HE3 (EN=0.5 MEV)  REF. OF B.G.
  0.5000  2.0572E-01        1.0000  3.6341E+01     1.2000  9.2538E+01
  1.4000  1.7666E+02        1.6000  2.7825E+02     1.8000  3.8510E+02
  2.0000  4.8844E+02        2.5000  7.0813E+02     3.0000  8.6965E+02
  3.5000  9.8648E+02        4.0000  1.0719E+03     5.0000  1.1833E+03
  6.0000  1.2479E+03        7.0000  1.2868E+03     8.0000  1.3104E+03
 10.0000  1.3319E+03       12.0000  1.3354E+03    14.0000  1.3303E+03
 16.0000  1.3208E+03       18.0000  1.3089E+03    20.0000  1.2956E+03
 23.0000  1.2745E+03       26.0000  1.2530E+03    30.0000  1.2245E+03
 35.0000  1.1895E+03       40.0000  1.1558E+03
'PN'      7  16    25 11    N 16 + P (EN=0.05MEV)  REF. OF PEREY.
  0.0500  4.7267E-07        0.1000  1.6409E-03     0.2000  4.2642E-01
  0.4000  1.5704E+01        0.6000  6.4362E+01     0.8000  1.3359E+02
  1.0000  2.0637E+02        1.2500  2.9180E+02     1.5000  3.6912E+02
  1.7500  4.3862E+02        2.0000  5.0029E+02     2.5000  5.9939E+02
  3.0000  6.6859E+02        3.5000  7.1443E+02     4.0000  7.4397E+02
  5.0000  7.7562E+02        6.0000  7.9144E+02     7.0000  8.0195E+02
  9.0000  8.0874E+02       12.0000  7.8576E+02    15.0000  7.5827E+02
 18.0000  7.3580E+02       22.0000  7.0280E+02    30.0000  6.4204E+02
 40.0000  5.8631E+02
'AN'      6  13    26 21    C 13 + A (EN=0.5 MEV)  REF. OF H.I
  0.5000  1.0174E-03        1.0000  2.2414E+00     1.2000  1.0605E+01
  1.4000  3.4097E+01        1.6000  8.1933E+01     1.8000  1.5385E+02
  2.0000  2.3615E+02        2.5000  4.2378E+02     3.0000  5.6760E+02
  3.5000  6.5529E+02        4.0000  7.1676E+02     5.0000  8.4408E+02
  6.0000  9.3483E+02        7.0000  1.0341E+03     8.0000  1.0732E+03
 10.0000  9.9199E+02       12.0000  1.0150E+03    14.0000  1.0454E+03
 16.0000  1.0009E+03       18.0000  9.5152E+02    20.0000  9.9598E+02
 23.0000  9.3826E+02       26.0000  9.0225E+02    30.0000  8.6333E+02
 35.0000  8.1169E+02       40.0000  7.6211E+02
'DN'      7  15    25 31    N 15 + D (EN=0.05MEV)  REF. OF L.H.
  0.0500  1.0727E-10        0.1000  9.9024E-06     0.2000  2.4263E-02
  0.4000  4.5349E+00        0.6000  3.8300E+01     0.8000  1.1998E+02
  1.0000  2.3615E+02        1.2500  3.9221E+02     1.5000  5.3299E+02
  1.7500  6.5018E+02        2.0000  7.4539E+02     2.5000  8.8467E+02
  3.0000  9.7732E+02        3.5000  1.0414E+03     4.0000  1.0870E+03
  5.0000  1.1441E+03        6.0000  1.1763E+03     7.0000  1.1945E+03
  9.0000  1.2104E+03       12.0000  1.2121E+03    15.0000  1.2041E+03
 18.0000  1.1931E+03       22.0000  1.1773E+03    30.0000  1.1476E+03
 40.0000  1.1160E+03
```

Fig.5(3) An example of the inverse reaction cross section file (continued)

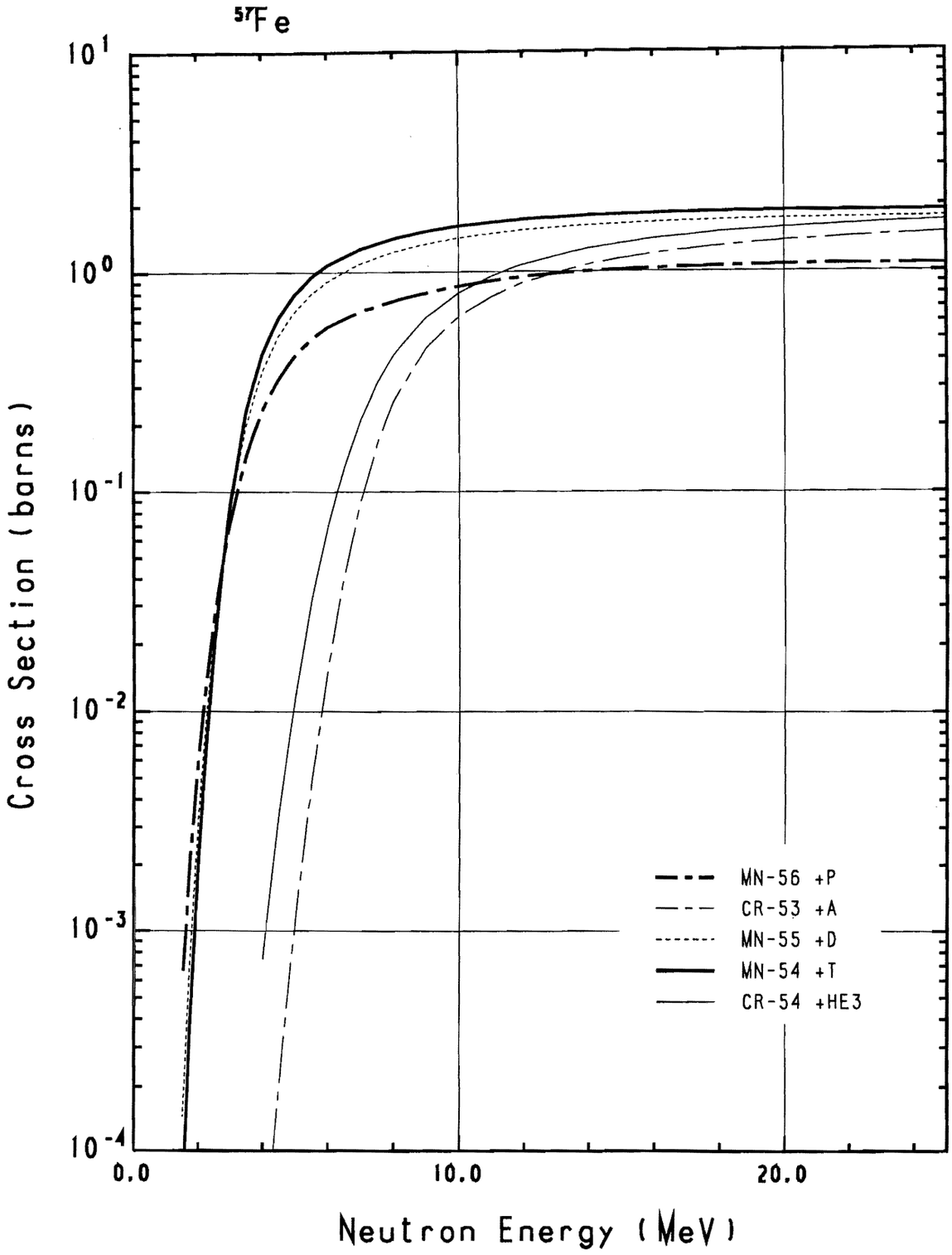

Fig.6 Inverse cross sections to ^{57}Fe

```
//PEGASUS  PROC SYSOUT='*',ERR=0,ITR13=0,PNM=PEGASUS                    00010005
//*********************************************************************00020000
//*     PEGASUS                                                         00030014
//*                          COMP. OPT. = AUTODBL(DBLPAD)               00040004
//*********************************************************************00050000
//PEGASUS   EXEC PGM=&PNM,COND=(4,LT),                                  00060003
//         PARM='FLIB(ERRCUT=&ERR,ITR13=&ITR13)'                        00070000
//STEPLIB  DD DSN=J2608.LOADD.LOAD,DISP=SHR                             00080007
//SYSPRINT DD SYSOUT=&SYSOUT                                            00090000
//FT05F001 DD DDNAME=SYSIN                                              00100000
//FT06F001 DD SYSOUT=&SYSOUT                                            00110000
//FT02F001 DD DSN=J2608.LDPDATA.DATA,DISP=SHR,LABEL=(,,,IN)             00120004
//FT01F001 DD DSN=J2608.SGINVPS.DATA,DISP=SHR,LABEL=(,,,IN)             00130012
```

Fig.7 Cataloged procedure of PEGASUS

```
//JOBPROC DD DSN=J2608.PROCLIB.CNTL,DISP-SHR
// EXEC  PEGASUS
//FT03F001 DD DSN=J2608.J32ND144.DATA(SCOMP),DISP=SHR,LABEL=(,,,IN)
//FT10F001 DD DSN=J2608.PEGND144.DATA,DISP=(NEW,CATLG),UNIT=TSSWK,
//         SPACE=(TRK,(10,10),RLSE),DCB=(DSORG=PS)
//SYSIN DD *
   60  144 6044    1    0    0    0    0    0
     25.0    0.3       0.125              1.82953
   22
   0.5      1.0      2.0      3.0      4.0      5.0      6.0
   7.0      8.0      9.0      10.0     11.0     12.0     13.0
   14.0     14.5     15.0     16.0     17.0     18.0     19.0
   20.0
   11
    1.0      2.0      4.0      6.0      8.0      10.0     12.0
   14.0     16.0     18.0     20.0
    9
    0.0     30.0     60.0     80.0    100.0    120.0    140.0
   160.0    180.0
    0
//
```

Fig.8 JCL and input data of Example 1

```
*********************************************************************

                PEGASUS FOR THRESHOLD CROSS SECTION CALCULATION
                    EVAPORATION AND PRE-EQUILIBRIUM THEORY

                            NAIG   S. IIJIMA
                      JAERI  T. SUGI AND T. NAKAGAWA
                          OSAKA UNIV.  T. NISHIGORI
                JNDC   S.W.G. ON NUCLEAR DATA FOR GAS PRODUCTION

                            REVISED FEB. 20, 1987

*********************************************************************


DATE = 99-03-01

 TARGET = ND-144  Z=  60  A = 144

         OPTION FOR SIG-COMP (0=     2.2113, ELSE= INPUT)---= 1
         OPTION FOR PRINT OF SIG-INV (0= NO, ELSE=YES)-------= 0
         OPT. PRINT OF 1-ST STAGE SIG.(0= NO, ELSE=YES)------= 0
         OPTION FOR PRINT OF SPETRA (0= NO, ELSE=YES)--------= 0
         OPT. PRINT OF 1-ST STAGE SPECTRA(0= NO, ELSE=YES)---= 0
         OPTION FOR PRINT OF ANGULAR DIST(=0 : NO, ELSE=YES)= 0

     KALBACH CONST =   25.0 MEV**3  SINGLE PARTICLE LDP=AS(I)*6/PI**2
     CLUSTER FORMATION FACTOR = IWAMOTO/HARADA (ADJUSTMENT PARAMETER =  0.3000 )
     GAMMA-WIDTH (GG) =  7.000D-02 EV
     E-THRESHOLD FOR SPECT. OF INEL. NEUTRONS = 1.830D+00 MEV
     ENERGY INTEGRATION MESH INTERVAL (DE) = 0.125 MEV IN C.M. SYSTEM
     INCIDENT NEUTRON ENERGIES (MEV)
            0.50    1.00    2.00    3.00    4.00    5.00    6.00    7.00    8.00    9.00
           10.00   11.00   12.00   13.00   14.00   14.50   15.00   16.00   17.00   18.00
           19.00   20.00
     ENERGIES FOR SPECTRUM AND ANG. DIST. CALC. (MEV)
            1.00    2.00    4.00    6.00    8.00   10.00   12.00   14.00   16.00   18.00
           20.00
     ANGLES FOR ANGULAR DISTRIBUTION CALCULATION (DEG)
            0.0    30.0    60.0    80.0   100.0   120.0   140.0   160.0   180.0
     ENERGY INTERVAL FOR SPECTRA/ANG.DIST. PRINT (MEV) =  0.250
```

Fig. 9(1) Output to FT06F001 from Example 1

LEVEL DENSITY PARAMETERS

NUCL.	Z	A	WEIGHT(U)	REACTION	Q(N,X)	A(/MEV)	T(MEV)	C(/MEV)	EX(MEV)	PAIRING	MM	SYST
ND-145	60	145	144.91258	COMPOUND	5.760D+00	2.054D+01	5.120D-01	2.465D+00	4.869D+00	1.180D+00		
ND-144	60	144	143.91010	(N,N')	0.0	1.771D+01	5.640D-01	4.792D-01	5.691D+00	1.940D+00		
PR-144	59	144	143.91331	(N,P)	-2.214D+00	1.600D+01	6.000D-01	1.045D+01	3.744D+00	0.0		
CE-141	58	141	140.90828	(N,ALP)	7.346D+00	1.714D+01	5.150D-01	7.134D-01	3.957D+00	1.170D+00		
PR-143	59	143	142.91083	(N,D)	-5.665D+00	1.500D+01	6.280D-01	2.607D+00	4.558D+00	7.600D-01		
PR-142	59	142	141.91005	(N,T)	-6.830D+00	1.595D+01	6.150D-01	1.201D+01	3.974D+00	0.0		
CE-142	58	142	141.90925	(N,TAU)	-6.067D+00	1.600D+01	6.000D-01	4.210D-01	5.674D+00	1.930D+00		
ND-143	60	143	142.90982	(N,2N)	-7.822D+00	1.826D+01	4.710D-01	5.220D-01	3.613D+00	1.180D+00		
PR-143	59	143	142.91083	(N,PN')	-7.975D+00	1.500D+01	6.280D-01	2.607D+00	4.558D+00	7.600D-01		
CE-140	58	140	139.90544	(N,AN')	1.913D+00	1.413D+01	6.541D-01	3.376D-01	5.852D+00	2.020D+00		
PR-143	59	143	142.91083	(N,N'P)	-7.975D+00	1.500D+01	6.280D-01	2.607D+00	4.558D+00	7.600D-01		
CE-140	58	140	139.90544	(N,N'A)	1.913D+00	1.413D+01	6.541D-01	3.376D-01	5.852D+00	2.020D+00		
CE-143	58	143	142.91239	(N,2P)	-8.647D+00	1.900D+01	5.500D-01	2.613D+00	5.094D+00	1.170D+00		
PR-142	59	142	141.91005	(N,DN')	-1.302D+01	1.595D+01	6.150D-01	1.201D+01	3.974D+00	0.0		
PR-141	59	141	140.90766	(N,TN')	-1.268D+01	1.400D+01	6.500D-01	1.810D+00	4.559D+00	8.500D-01		
PR-142	59	142	141.91005	(N,N'D)	-1.302D+01	1.595D+01	6.150D-01	1.201D+01	3.974D+00	0.0		
PR-141	59	141	140.90766	(N,N'T)	-1.268D+01	1.400D+01	6.500D-01	1.810D+00	4.559D+00	8.500D-01		
ND-142	60	142	141.90773	(N,3N)	-1.395D+01	1.288D+01	6.710D-01	2.250D-01	5.526D+00	2.030D+00		

SYST: ** = LDP'S WERE DETERMIBNED FROM SYSTEMATICS, *** = MASS WAS ALSO DETERMINED FROM SYSTEMATICS.

```
 INVERSE SIG FOUND NN   60 144
*INVERSE CROSS SECTION NOT FOUND FOR P    59 144
      AND SUBSTITUTED FROM          P    59 142
*INVERSE CROSS SECTION NOT FOUND FOR A    58 141
      AND SUBSTITUTED FROM          A    58 139
*INVERSE CROSS SECTION NOT FOUND FOR D    59 143
      AND SUBSTITUTED FROM          D    59 141
*INVERSE CROSS SECTION NOT FOUND FOR T    59 142
      AND SUBSTITUTED FROM          T    59 140
*INVERSE CROSS SECTION NOT FOUND FOR HE-3 58 142
      AND SUBSTITUTED FROM          HE-3 58 140
```

Fig. 9(2) Output to FT06F001 from Example 1(Continued)

ND-144 CROSS SECTION SUMMARY KALBACH CONSTANT = 25.0 MEV**3

E(MEV)	COMP-ELST	SIG(N,N')	SIG(N,P)	SIG(N,A)	SIG(N,2N)	SIG(N,NP)	SIG(N,PN)	SIG(N,NA)	SIG(N,AN)	SIG(N,D)	SIG(N,T)	SIG(N,HE3)
0.500	2.560D+00	5.828D-02	0.0	2.078D-07	0.0	0.0	0.0	0.0	2.327D-14	0.0	0.0	0.0
1.000	2.541D+00	6.102D-02	0.0	9.329D-07	0.0	0.0	0.0	0.0	1.358D-13	0.0	0.0	0.0
2.000	9.408D-01	1.499D+00	0.0	7.148D-06	0.0	0.0	0.0	4.271D-10	3.345D-12	0.0	0.0	0.0
2.229	6.856D-01	1.763D+00	0.0	9.903D-06	0.0	0.0	0.0	6.145D-10	6.189D-12	0.0	0.0	0.0
3.000	2.311D-01	2.246D+00	3.653D-22	2.507D-05	0.0	0.0	0.0	2.715D-09	6.358D-11	0.0	0.0	0.0
4.000	5.020D-02	2.448D+00	1.857D-18	5.814D-05	0.0	0.0	0.0	3.077D-08	1.134D-09	0.0	0.0	0.0
5.000	1.004D-02	2.492D+00	5.962D-15	1.025D-04	0.0	0.0	0.0	4.452D-07	1.909D-08	0.0	0.0	0.0
5.704	3.107D-03	2.492D+00	1.697D-12	1.376D-04	0.0	0.0	0.0	3.128D-06	1.486D-07	0.0	0.0	0.0
6.000	1.887D-03	2.490D+00	1.831D-11	1.561D-04	0.0	0.0	0.0	7.135D-06	3.259D-07	3.787D-27	0.0	0.0
6.109	1.567D-03	2.487D+00	4.308D-11	1.615D-04	0.0	0.0	0.0	9.948D-06	4.499D-07	1.462D-26	0.0	0.0
6.878	4.223D-04	2.460D+00	2.309D-08	2.271D-04	0.0	0.0	0.0	7.085D-05	2.639D-06	1.917D-23	0.0	2.450D-27
7.000	3.439D-04	2.456D+00	6.453D-08	2.436D-04	0.0	0.0	0.0	9.038D-05	3.315D-06	5.233D-23	1.625D-28	4.622D-27
7.877	8.109D-05	2.423D+00	1.135D-05	4.069D-04	0.0	0.0	0.0	4.772D-04	1.316D-05	8.641D-20	6.063D-24	2.298D-25
8.000	6.654D-05	2.419D+00	1.598D-05	4.388D-04	0.0	0.0	0.0	5.739D-04	1.551D-05	2.299D-19	1.968D-23	3.872D-25
8.031	6.340D-05	2.415D+00	1.738D-05	4.662D-04	2.791D-03	0.0	0.0	5.899D-04	1.591D-05	2.977D-19	3.658D-23	4.391D-25
8.708	2.227D-05	2.074D+00	7.338D-05	7.614D-04	3.392D-01	5.582D-23	3.335D-23	9.217D-04	3.610D-05	8.526D-17	2.025D-20	6.997D-24
9.000	1.436D-05	1.850D+00	1.201D-04	9.464D-04	5.619D-01	6.271D-22	4.635D-22	9.435D-04	4.856D-05	9.115D-16	2.764D-19	2.292D-23
10.000	3.361D-06	1.286D+00	4.696D-04	2.000D-03	1.120D+00	1.307D-18	3.395D-18	9.030D-04	1.239D-04	3.849D-12	3.453D-15	1.298D-21
11.000	8.399D-07	9.969D-01	1.312D-03	3.703D-03	1.398D+00	2.377D-15	2.381D-14	8.868D-04	2.895D-04	1.050D-08	4.066D-11	7.879D-20
12.000	2.226D-07	8.394D-01	2.918D-03	5.957D-03	1.543D+00	3.918D-12	2.055D-10	8.690D-04	6.704D-04	1.242D-05	4.610D-07	5.867D-18
12.767	8.100D-08	7.452D-01	4.719D-03	7.756D-03	1.594D+00	1.157D-09	2.246D-07	8.222D-04	1.251D-03	1.065D-04	1.157D-05	1.922D-16
13.000	5.985D-08	7.216D-01	5.360D-03	8.290D-03	1.603D+00	6.240D-09	2.037D-06	8.052D-04	1.504D-03	1.683D-04	2.183D-05	5.978D-16
13.107	5.211D-08	7.114D-01	5.667D-03	8.572D-03	1.606D+00	1.237D-08	5.481D-06	7.980D-04	1.632D-03	2.044D-04	2.862D-05	9.544D-16
14.000	1.677D-08	6.294D-01	8.502D-03	1.019D-02	1.632D+00	4.215D-07	1.115D-04	7.292D-04	3.116D-03	8.362D-04	1.721D-04	8.230D-14
14.047	1.583D-08	6.281D-01	8.664D-03	1.037D-02	1.630D+00	4.715D-07	1.201D-04	7.326D-04	3.200D-03	8.939D-04	1.836D-04	9.229D-14
14.500	9.107D-09	5.927D-01	1.029D-02	1.092D-02	1.643D+00	9.427D-07	2.655D-04	6.973D-04	4.299D-03	1.540D-03	3.741D-04	1.012D-12
15.000	5.008D-09	5.596D-01	1.214D-02	1.152D-02	1.610D+00	1.593D-06	5.396D-04	6.690D-04	5.663D-03	2.583D-03	7.168D-04	1.290D-11
16.000	1.555D-09	5.006D-01	1.568D-02	1.221D-02	1.409D+00	3.024D-06	1.645D-03	6.211D-04	8.932D-03	5.851D-03	1.956D-03	2.291D-09
17.000	5.127D-10	4.549D-01	1.883D-02	1.233D-02	1.206D+00	4.496D-06	3.856D-03	5.923D-04	1.305D-02	1.091D-02	4.087D-03	8.110D-08
18.000	1.747D-10	4.139D-01	2.109D-02	1.212D-02	1.058D+00	5.997D-06	7.392D-03	5.721D-04	1.748D-02	1.765D-02	7.098D-03	8.005D-07
19.000	6.101D-11	3.757D-01	2.242D-02	1.158D-02	9.519D-01	7.644D-06	1.208D-02	5.565D-04	2.205D-02	2.562D-02	1.078D-02	4.232D-06

Fig. 9(3) Output to FT06F001 from Example 1(Continued)

20.000	2.186D-11	3.411D-01	2.304D-02	9.852D-03	8.714D-01	9.579D-06	1.765D-02	5.450D-04	2.654D-02	3.387D-02	1.465D-02	1.841D-05

E(MEV)	SIG(N,2P)	SIG(N,ND)	SIG(N,DN)	SIG(N,NT)	SIG(N,TN)	SIG(N,3N)	SIG(N,XN)	SIG(N,XP)	SIG(N,XA)	SIG(N,G)	SIG-C
0.500	0.0	0.0	0.0	0.0	0.0	0.0	2.618D+00	0.0	2.078D-07	1.238D-01	2.742D+00
1.000	0.0	0.0	0.0	0.0	0.0	0.0	2.602D+00	0.0	9.329D-07	1.548D-01	2.757D+00
2.000	0.0	0.0	0.0	0.0	0.0	0.0	2.440D+00	0.0	7.149D-06	1.457D-01	2.586D+00
2.229	0.0	0.0	0.0	0.0	0.0	0.0	2.448D+00	0.0	9.904D-06	1.297D-01	2.578D+00
3.000	0.0	0.0	0.0	0.0	0.0	0.0	2.477D+00	3.653D-22	2.507D-05	8.007D-02	2.557D+00
4.000	0.0	0.0	0.0	0.0	0.0	0.0	2.499D+00	1.857D-18	5.817D-05	3.379D-02	2.532D+00
5.000	0.0	0.0	0.0	0.0	0.0	0.0	2.502D+00	5.962D-15	1.030D-04	1.177D-02	2.514D+00
5.704	0.0	0.0	0.0	0.0	0.0	0.0	2.495D+00	1.697D-12	1.409D-04	5.127D-03	2.501D+00
6.000	0.0	0.0	0.0	0.0	0.0	0.0	2.491D+00	1.831D-11	1.635D-04	3.556D-03	2.495D+00
6.109	0.0	0.0	0.0	0.0	0.0	0.0	2.489D+00	4.308D-11	1.719D-04	3.098D-03	2.492D+00
6.878	0.0	0.0	0.0	0.0	0.0	0.0	2.461D+00	2.309D-08	3.006D-04	1.155D-03	2.462D+00
7.000	0.0	0.0	0.0	0.0	0.0	0.0	2.456D+00	6.453D-08	3.373D-04	9.877D-04	2.458D+00
7.877	0.0	0.0	0.0	0.0	0.0	0.0	2.424D+00	1.135D-05	8.973D-04	3.242D-04	2.425D+00
8.000	0.0	0.0	0.0	0.0	0.0	0.0	2.419D+00	1.598D-05	1.028D-03	2.780D-04	2.420D+00
8.031	0.0	0.0	0.0	0.0	0.0	0.0	2.421D+00	1.738D-05	1.072D-03	2.676D-04	2.419D+00
8.708	0.0	0.0	0.0	0.0	0.0	0.0	2.753D+00	7.338D-05	1.719D-03	1.176D-04	2.415D+00
9.000	1.268D-49	0.0	0.0	0.0	0.0	0.0	2.975D+00	1.201D-04	1.938D-03	8.303D-05	2.414D+00
10.000	1.813D-44	0.0	0.0	0.0	0.0	0.0	3.528D+00	4.696D-04	3.027D-03	2.604D-05	2.410D+00
11.000	2.317D-40	0.0	0.0	0.0	0.0	0.0	3.795D+00	1.312D-03	4.880D-03	8.514D-06	2.401D+00
12.000	2.022D-36	0.0	0.0	0.0	0.0	0.0	3.927D+00	2.918D-03	7.497D-03	2.890D-06	2.393D+00
12.767	2.233D-33	0.0	0.0	0.0	0.0	0.0	3.934D+00	4.719D-03	9.830D-03	1.272D-06	2.353D+00
13.000	1.671D-32	0.0	0.0	4.663D-30	2.149D-27	0.0	3.929D+00	5.362D-03	1.060D-02	9.954D-07	2.340D+00
13.107	5.557D-32	0.0	0.0	3.407D-29	1.246D-26	0.0	3.926D+00	5.673D-03	1.100D-02	8.897D-07	2.334D+00
14.000	1.434D-28	2.726D-26	2.120D-23	1.815D-25	2.168D-22	0.0	3.897D+00	8.614D-03	1.403D-02	3.525D-07	2.285D+00
14.047	2.669D-28	5.387D-26	3.417D-23	2.103D-25	3.715D-22	0.0	3.893D+00	8.784D-03	1.430D-02	3.359D-07	2.282D+00
14.500	1.053D-26	2.189D-24	3.294D-21	1.110D-23	2.909D-20	6.111D-03	3.902D+00	1.056D-02	1.591D-02	2.130D-07	2.270D+00
15.000	9.100D-25	1.438D-22	4.213D-19	6.211D-22	3.553D-18	5.465D-02	3.951D+00	1.268D-02	1.785D-02	1.297D-07	2.258D+00
16.000	3.139D-21	6.316D-19	5.342D-15	1.789D-18	4.623D-14	2.787D-01	4.165D+00	1.733D-02	2.176D-02	4.895D-08	2.235D+00
17.000	9.601D-18	2.324D-15	8.283D-11	5.155D-15	5.556D-10	5.182D-01	4.438D+00	2.269D-02	2.597D-02	1.914D-08	2.242D+00
18.000	2.379D-14	8.651D-12	1.208D-06	1.222D-11	4.242D-06	6.987D-01	4.651D+00	2.848D-02	3.017D-02	7.651D-09	2.254D+00
19.000	1.624D-11	1.896D-09	1.915D-04	4.494D-10	9.904D-05	8.287D-01	4.801D+00	3.451D-02	3.419D-02	3.112D-09	2.262D+00
20.000	3.115D-10	1.351D-08	1.239D-03	2.421D-09	6.363D-04	9.288D-01	4.917D+00	4.071D-02	3.694D-02	1.288D-09	2.269D+00

Fig. 9(4) Output to FT06F001 from Example 1(Continued)

```
6.01440+ 4 1.42674+ 2          0          99          0          06044 3  2    1
0.0     + 0 0.0    + 0          0           0          2         336044 3  2    2
         2          2         33           4                       6044 3  2    3
1.00000- 5 0.0    + 0 5.00000+ 5 2.55971+ 0 1.00000+ 6 2.54124+ 06044 3  2    4
2.00000+ 6 9.40778- 1 2.22905+ 6 6.85556- 1 3.00000+ 6 2.31082- 16044 3  2    5
4.00000+ 6 5.02021- 2 5.00000+ 6 1.00356- 2 5.70423+ 6 3.10710- 36044 3  2    6
6.00000+ 6 1.88659- 3 6.10936+ 6 1.56654- 3 6.87835+ 6 4.22258- 46044 3  2    7
7.00000+ 6 3.43927- 4 7.87693+ 6 8.10922- 5 8.00000+ 6 6.65413- 56044 3  2    8
8.03054+ 6 6.33974- 5 8.70779+ 6 2.22672- 5 9.00000+ 6 1.43602- 56044 3  2    9
1.00000+ 7 3.36131- 6 1.10000+ 7 8.39871- 7 1.20000+ 7 2.22552- 76044 3  2   10
1.27674+ 7 8.10027- 8 1.30000+ 7 5.98529- 8 1.31069+ 7 5.21132- 86044 3  2   11
1.40000+ 7 1.67684- 8 1.40470+ 7 1.58289- 8 1.45000+ 7 9.10722- 96044 3  2   12
1.50000+ 7 5.00827- 9 1.60000+ 7 1.55511- 9 1.70000+ 7 5.12704-106044 3  2   13
1.80000+ 7 1.74655-10 1.90000+ 7 6.10135-11 2.00000+ 7 2.18559-116044 3  2   14
                                                                    6044 3  0   15
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 16   16
0.0     + 0-7.82210+ 6          0           0          1         206044 3 16   17
        20          2                                               6044 3 16   18
7.87693+ 6 0.0    + 0 8.00000+ 6 0.0    + 0 8.03054+ 6 2.79106- 36044 3 16   19
8.70779+ 6 3.39200- 1 9.00000+ 6 5.61934- 1 1.00000+ 7 1.12045+ 06044 3 16   20
1.10000+ 7 1.39830+ 0 1.20000+ 7 1.54307+ 0 1.27674+ 7 1.59359+ 06044 3 16   21
1.30000+ 7 1.60266+ 0 1.31069+ 7 1.60607+ 0 1.40000+ 7 1.63200+ 06044 3 16   22
1.40470+ 7 1.63024+ 0 1.45000+ 7 1.64297+ 0 1.50000+ 7 1.61025+ 06044 3 16   23
1.60000+ 7 1.40867+ 0 1.70000+ 7 1.20553+ 0 1.80000+ 7 1.05762+ 06044 3 16   24
1.90000+ 7 9.51905- 1 2.00000+ 7 8.71355- 1                         6044 3 16   25
                                                                    6044 3  0   26
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 17   27
0.0     + 0-1.39492+ 7          0           0          1          86044 3 17   28
         8          2                                               6044 3 17   29
1.40470+ 7 0.0    + 0 1.45000+ 7 6.11061- 3 1.50000+ 7 5.46477- 26044 3 17   30
1.60000+ 7 2.78685- 1 1.70000+ 7 5.18175- 1 1.80000+ 7 6.98728- 16044 3 17   31
1.90000+ 7 8.28704- 1 2.00000+ 7 9.28803- 1                         6044 3 17   32
                                                                    6044 3  0   33
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 22   34
0.0     + 0 1.91309+ 6          0           0          2         336044 3 22   35
         2          2         33           4                       6044 3 22   36
1.00000- 5 0.0    + 0 5.00000+ 5 2.32708-14 1.00000+ 6 1.35849-136044 3 22   37
2.00000+ 6 4.30436-10 2.22905+ 6 6.20656-10 3.00000+ 6 2.77892- 96044 3 22   38
4.00000+ 6 3.19081- 8 5.00000+ 6 4.64329- 7 5.70423+ 6 3.27613- 66044 3 22   39
6.00000+ 6 7.46141- 6 6.10936+ 6 1.03981- 5 6.87835+ 6 7.34927- 56044 3 22   40
7.00000+ 6 9.36935- 5 7.87693+ 6 4.90378- 4 8.00000+ 6 5.89367- 46044 3 22   41
8.03054+ 6 6.05764- 4 8.70779+ 6 9.57760- 4 9.00000+ 6 9.92062- 46044 3 22   42
1.00000+ 7 1.02693- 3 1.10000+ 7 1.17631- 3 1.20000+ 7 1.53937- 36044 3 22   43
1.27674+ 7 2.07357- 3 1.30000+ 7 2.30927- 3 1.31069+ 7 2.43031- 36044 3 22   44
1.40000+ 7 3.84476- 3 1.40470+ 7 3.93217- 3 1.45000+ 7 4.99607- 36044 3 22   45
1.50000+ 7 6.33221- 3 1.60000+ 7 9.55294- 3 1.70000+ 7 1.36388- 26044 3 22   46
1.80000+ 7 1.80491- 2 1.90000+ 7 2.26111- 2 2.00000+ 7 2.70894- 26044 3 22   47
                                                                    6044 3  0   48
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 28   49
0.0     + 0-7.97465+ 6          0           0          2         186044 3 28   50
         2          2         18           4                       6044 3 28   51
8.03054+ 6 0.0    + 0 8.70779+ 6 8.91761-23 9.00000+ 6 1.09056-216044 3 28   52
1.00000+ 7 4.70161-18 1.10000+ 7 2.61900-14 1.20000+ 7 2.09444-106044 3 28   53
1.27674+ 7 2.25748- 7 1.30000+ 7 2.04317- 6 1.31069+ 7 5.49312- 66044 3 28   54
1.40000+ 7 1.11945- 4 1.40470+ 7 1.20594- 4 1.45000+ 7 2.66461- 46044 3 28   55
1.50000+ 7 5.41200- 4 1.60000+ 7 1.64800- 3 1.70000+ 7 3.86054- 36044 3 28   56
1.80000+ 7 7.39782- 3 1.90000+ 7 1.20924- 2 2.00000+ 7 1.76644- 26044 3 28   57
                                                                    6044 3  0   58
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 32   59
0.0     + 0-1.30156+ 7          0           0          2         106044 3 32   60
```

Fig. 10(1) Output of Example 1 in the ENDF format

```
          2           2          10           4                       6044 3 32   61
1.31069+ 7 0.0     + 0 1.40000+ 7 2.12266-23 1.40470+ 7 3.42190-236044 3 32   62
1.45000+ 7 3.29607-21 1.50000+ 7 4.21404-19 1.60000+ 7 5.34299-156044 3 32   63
1.70000+ 7 8.28338-11 1.80000+ 7 1.20781- 6 1.90000+ 7 1.91522- 46044 3 32   64
2.00000+ 7 1.23924- 3                                             6044 3 32   65
                                                                  6044 3  0   66
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 33   67
0.0     + 0-1.26786+ 7         0           0          2         126044 3 33   68
          2           2          12           4                       6044 3 33   69
1.27674+ 7 0.0     + 0 1.30000+ 7 2.15399-27 1.31069+ 7 1.24973-266044 3 33   70
1.40000+ 7 2.16986-22 1.40470+ 7 3.71696-22 1.45000+ 7 2.91058-206044 3 33   71
1.50000+ 7 3.55313-18 1.60000+ 7 4.62334-14 1.70000+ 7 5.55606-106044 3 33   72
1.80000+ 7 4.24209- 6 1.90000+ 7 9.90369- 5 2.00000+ 7 6.36285- 46044 3 33   73
                                                                  6044 3  0   74
6.01440+ 4 1.42674+ 2          0          99          0          06044 3 91   75
0.0     + 0 0.0     + 0        0           0          2         336044 3 91   76
          2           2          33           4                       6044 3 91   77
1.00000- 5 0.0     + 0 5.00000+ 5 5.82800- 2 1.00000+ 6 6.10198- 26044 3 91   78
2.00000+ 6 1.49912+ 0 2.22905+ 6 1.76293+ 0 3.00000+ 6 2.24571+ 06044 3 91   79
4.00000+ 6 2.44833+ 0 5.00000+ 6 2.49213+ 0 5.70423+ 6 2.49238+ 06044 3 91   80
6.00000+ 6 2.48958+ 0 6.10936+ 6 2.48697+ 0 6.87835+ 6 2.46047+ 06044 3 91   81
7.00000+ 6 2.45605+ 0 7.87693+ 6 2.42329+ 0 8.00000+ 6 2.41861+ 06044 3 91   82
8.03054+ 6 2.41464+ 0 8.70779+ 6 2.07401+ 0 9.00000+ 6 1.84982+ 06044 3 91   83
1.00000+ 7 1.28571+ 0 1.10000+ 7 9.96939- 1 1.20000+ 7 8.39414- 16044 3 91   84
1.27674+ 7 7.45161- 1 1.30000+ 7 7.21559- 1 1.31069+ 7 7.11419- 16044 3 91   85
1.40000+ 7 6.29402- 1 1.40470+ 7 6.28093- 1 1.45000+ 7 5.92681- 16044 3 91   86
1.50000+ 7 5.59578- 1 1.60000+ 7 5.00569- 1 1.70000+ 7 4.54912- 16044 3 91   87
1.80000+ 7 4.13901- 1 1.90000+ 7 3.75718- 1 2.00000+ 7 3.41113- 16044 3 91   88
                                                                  6044 3  0   89
6.01440+ 4 1.42674+ 2          0          99          0          06044 3102   90
0.0     + 0 0.0     + 0        0           0          2         336044 3102   91
          2           2          33           4                       6044 3102   92
1.00000- 5 0.0     + 0 5.00000+ 5 1.23811- 1 1.00000+ 6 1.54817- 16044 3102   93
2.00000+ 6 1.45743- 1 2.22905+ 6 1.29725- 1 3.00000+ 6 8.00658- 26044 3102   94
4.00000+ 6 3.37937- 2 5.00000+ 6 1.17659- 2 5.70423+ 6 5.12704- 36044 3102   95
6.00000+ 6 3.55603- 3 6.10936+ 6 3.09821- 3 6.87835+ 6 1.15507- 36044 3102   96
7.00000+ 6 9.87697- 4 7.87693+ 6 3.24200- 4 8.00000+ 6 2.77981- 46044 3102   97
8.03054+ 6 2.67599- 4 8.70779+ 6 1.17555- 4 9.00000+ 6 8.30301- 56044 3102   98
1.00000+ 7 2.60417- 5 1.10000+ 7 8.51371- 6 1.20000+ 7 2.89002- 66044 3102   99
1.27674+ 7 1.27242- 6 1.30000+ 7 9.95401- 7 1.31069+ 7 8.89673- 76044 3102  100
1.40000+ 7 3.52484- 7 1.40470+ 7 3.35918- 7 1.45000+ 7 2.13018- 76044 3102  101
1.50000+ 7 1.29711- 7 1.60000+ 7 4.89486- 8 1.70000+ 7 1.91414- 86044 3102  102
1.80000+ 7 7.65116- 9 1.90000+ 7 3.11171- 9 2.00000+ 7 1.28833- 96044 3102  103
                                                                  6044 3  0  104
6.01440+ 4 1.42674+ 2          0          99          0          06044 3103  105
0.0     + 0-2.21353+ 6         0           0          2         296044 3103  106
          2           2          29           4                       6044 3103  107
2.22905+ 6 0.0     + 0 3.00000+ 6 3.65267-22 4.00000+ 6 1.85743-186044 3103  108
5.00000+ 6 5.96214-15 5.70423+ 6 1.69713-12 6.00000+ 6 1.83138-116044 3103  109
6.10936+ 6 4.30832-11 6.87835+ 6 2.30872- 8 7.00000+ 6 6.45277- 86044 3103  110
7.87693+ 6 1.13490- 5 8.00000+ 6 1.59758- 5 8.03054+ 6 1.73837- 56044 3103  111
8.70779+ 6 7.33820- 5 9.00000+ 6 1.20149- 4 1.00000+ 7 4.69606- 46044 3103  112
1.10000+ 7 1.31174- 3 1.20000+ 7 2.91780- 3 1.27674+ 7 4.71867- 36044 3103  113
1.30000+ 7 5.36013- 3 1.31069+ 7 5.66739- 3 1.40000+ 7 8.50241- 36044 3103  114
1.40470+ 7 8.66384- 3 1.45000+ 7 1.02901- 2 1.50000+ 7 1.21369- 26044 3103  115
1.60000+ 7 1.56822- 2 1.70000+ 7 1.88280- 2 1.80000+ 7 2.10867- 26044 3103  116
1.90000+ 7 2.24178- 2 2.00000+ 7 2.30443- 2                       6044 3103  117
                                                                  6044 3  0  118
6.01440+ 4 1.42674+ 2          0          99          0          06044 3104  119
0.0     + 0-5.66453+ 6         0           0          2         256044 3104  120
```

Fig. 10(2) Output of Example 1 in the ENDF format (continued)

```
          2           2          25           4                       6044 3104  121
5.70423+ 6 0.0     + 0 6.00000+ 6 3.78664-27 6.10936+ 6 1.46196-266044 3104  122
6.87835+ 6 1.91663-23 7.00000+ 6 5.23289-23 7.87693+ 6 8.64077-206044 3104  123
8.00000+ 6 2.29894-19 8.03054+ 6 2.97674-19 8.70779+ 6 8.52644-176044 3104  124
9.00000+ 6 9.11512-16 1.00000+ 7 3.84871-12 1.10000+ 7 1.05002- 86044 3104  125
```

Skipped

```
1.40000+ 7 1.65565+ 0 1.40470+ 7 1.65440+ 0 1.45000+ 7 1.67746+ 06044 3999  192
1.50000+ 7 1.69873+ 0 1.60000+ 7 1.73425+ 0 1.70000+ 7 1.78735+ 06044 3999  193
1.80000+ 7 1.83976+ 0 1.90000+ 7 1.88601+ 0 2.00000+ 7 1.92822+ 06044 3999  194
                                                                 6044 3  0  195
                                                                 6044 0  0  196
6.01440+ 4 1.42674+ 2          0           0           1          06044 5 16  197
0.0     + 0 0.0     + 0          0           1           1          26044 5 16  198
          2           2                                             6044 5 16  199
7.87693+ 6 1.00000+ 0 2.00000+ 7 1.00000+ 0                         6044 5 16  200
0.0     + 0 0.0     + 0          0           0           1          76044 5 16  201
          7           2                                             6044 5 16  202
0.0     + 0 7.87693+ 6          0           0           1          36044 5 16  203
          3           2                                             6044 5 16  204
0.0     + 0 0.0     + 0 1.00000+ 0 1.00000+ 0 2.00000+ 0 0.0     + 06044 5 16  205
0.0     + 0 1.00000+ 7          0           0           3         126044 5 16  206
          2           2         11           4          12          26044 5 16  207
0.0     + 0 0.0     + 0 1.25000+ 5 8.57881- 7 2.50000+ 5 9.12985- 76044 5 16  208
3.75000+ 5 9.07596- 7 5.00000+ 5 8.64706- 7 6.25000+ 5 7.94733- 76044 5 16  209
7.50000+ 5 7.08136- 7 1.00000+ 6 5.26989- 7 1.37500+ 6 3.09150- 76044 5 16  210
1.62500+ 6 2.04629- 7 1.87500+ 6 1.05307- 7 2.00000+ 6 0.0     + 06044 5 16  211
0.0     + 0 1.20000+ 7          0           0           3         166044 5 16  212
          2           2         15           4          16          26044 5 16  213
0.0     + 0 0.0     + 0 1.25000+ 5 5.11499- 7 2.50000+ 5 5.95695- 76044 5 16  214
3.75000+ 5 6.29186- 7 5.00000+ 5 6.32101- 7 6.25000+ 5 6.09973- 76044 5 16  215
7.50000+ 5 5.69393- 7 1.00000+ 6 4.64124- 7 1.87500+ 6 1.90317- 76044 5 16  216
2.25000+ 6 1.37364- 7 2.75000+ 6 9.60064- 8 3.37500+ 6 6.49656- 86044 5 16  217
3.50000+ 6 5.89167- 8 3.62500+ 6 5.18576- 8 3.87500+ 6 2.99566- 86044 5 16  218
4.00000+ 6 0.0     + 0                                              6044 5 16  219
0.0     + 0 1.40000+ 7          0           0           3         206044 5 16  220
          2           2         19           4          20          26044 5 16  221
0.0     + 0 0.0     + 0 1.25000+ 5 4.39017- 7 2.50000+ 5 5.21166- 76044 5 16  222
3.75000+ 5 5.55062- 7 5.00000+ 5 5.60580- 7 6.25000+ 5 5.42851- 76044 5 16  223
7.50000+ 5 5.07959- 7 1.00000+ 6 4.15348- 7 1.75000+ 6 1.94418- 76044 5 16  224
2.12500+ 6 1.39819- 7 2.50000+ 6 1.06791- 7 2.87500+ 6 8.62188- 86044 5 16  225
3.37500+ 6 6.98123- 8 4.00000+ 6 5.81611- 8 5.12500+ 6 4.45957- 86044 5 16  226
5.37500+ 6 4.03917- 8 5.50000+ 6 3.74786- 8 5.62500+ 6 3.35213- 86044 5 16  227
5.87500+ 6 1.89431- 8 6.00000+ 6 0.0     + 0                      6044 5 16  228
0.0     + 0 1.60000+ 7          0           0           3         236044 5 16  229
          2           2         22           4          23          26044 5 16  230
0.0     + 0 0.0     + 0 1.25000+ 5 3.66675- 7 2.50000+ 5 4.17527- 76044 5 16  231
3.75000+ 5 4.40132- 7 5.00000+ 5 4.46350- 7 6.25000+ 5 4.35931- 76044 5 16  232
7.50000+ 5 4.12022- 7 1.00000+ 6 3.46207- 7 1.50000+ 6 2.33793- 76044 5 16  233
1.87500+ 6 1.80863- 7 2.25000+ 6 1.32584- 7 2.62500+ 6 1.03314- 76044 5 16  234
3.00000+ 6 8.55306- 8 3.50000+ 6 7.17040- 8 4.12500+ 6 6.22373- 86044 5 16  235
5.37500+ 6 5.25610- 8 6.62500+ 6 4.45474- 8 7.12500+ 6 3.98093- 86044 5 16  236
7.37500+ 6 3.60487- 8 7.50000+ 6 3.33489- 8 7.62500+ 6 2.96200- 86044 5 16  237
7.87500+ 6 1.56168- 8 8.00000+ 6 0.0     + 0                      6044 5 16  238
0.0     + 0 1.80000+ 7          0           0           3         326044 5 16  239
          2           2         31           4          32          26044 5 16  240
0.0     + 0 0.0     + 0 1.25000+ 5 4.06194- 7 2.50000+ 5 4.40394- 76044 5 16  241
3.75000+ 5 4.50414- 7 5.00000+ 5 4.47628- 7 6.25000+ 5 4.28333- 76044 5 16  242
7.50000+ 5 3.94346- 7 8.75000+ 5 3.51515- 7 1.00000+ 6 3.06307- 76044 5 16  243
```

Fig. 10(3) Output of Example 1 in the ENDF format (continued)

```
1.37500+ 6 1.85790- 7 1.87500+ 6 9.19817- 8 2.12500+ 6 6.76166- 86044 5 16  244
2.25000+ 6 5.94415- 8 2.37500+ 6 5.34298- 8 2.50000+ 6 4.93580- 86044 5 16  245
2.62500+ 6 4.70355- 8 2.75000+ 6 4.63035- 8 2.87500+ 6 4.70204- 86044 5 16  246
3.00000+ 6 4.90560- 8 3.25000+ 6 5.64841- 8 3.62500+ 6 7.19086- 86044 5 16  247
3.75000+ 6 7.60142- 8 3.87500+ 6 7.78106- 8 4.87500+ 6 6.84504- 86044 5 16  248
7.62500+ 6 5.37085- 8 8.75000+ 6 4.62305- 8 9.12500+ 6 4.23466- 86044 5 16  249
9.37500+ 6 3.82913- 8 9.50000+ 6 3.53184- 8 9.62500+ 6 3.11539- 86044 5 16  250
9.87500+ 6 1.51624- 8 1.00000+ 7 0.0    + 0                     6044 5 16  251
0.0    + 0 2.00000+ 7          0          0          3          366044 5 16  252
         2          2         35          4         36           26044 5 16  253
0.0    + 0 0.0    + 0 1.25000+ 5 4.36818- 7 2.50000+ 5 4.62585- 76044 5 16  254
3.75000+ 5 4.68217- 7 5.00000+ 5 4.64373- 7 6.25000+ 5 4.44255- 76044 5 16  255
7.50000+ 5 4.08443- 7 8.75000+ 5 3.62857- 7 1.00000+ 6 3.14565- 76044 5 16  256
1.25000+ 6 2.23386- 7 1.75000+ 6 1.02640- 7 2.87500+ 6 1.66274- 86044 5 16  257
3.12500+ 6 1.16545- 8 3.25000+ 6 1.00436- 8 3.37500+ 6 8.90949- 96044 5 16  258
3.50000+ 6 8.19718- 9 3.62500+ 6 7.86888- 9 3.75000+ 6 7.90216- 96044 5 16  259
3.87500+ 6 8.28851- 9 4.00000+ 6 9.03231- 9 4.12500+ 6 1.01529- 86044 5 16  260
4.37500+ 6 1.36338- 8 5.12500+ 6 3.70363- 8 5.37500+ 6 4.95068- 86044 5 16  261
5.62500+ 6 6.22805- 8 5.75000+ 6 6.73085- 8 5.87500+ 6 6.99196- 86044 5 16  262
9.12500+ 6 5.60720- 8 1.03750+ 7 4.88586- 8 1.10000+ 7 4.33840- 86044 5 16  263
1.12500+ 7 3.99771- 8 1.13750+ 7 3.76240- 8 1.15000+ 7 3.45267- 86044 5 16  264
1.16250+ 7 3.01723- 8 1.18750+ 7 1.32876- 8 1.20000+ 7 0.0    + 06044 5 16  265
                                                                 6044 5  0  266
6.01440+ 4 1.42674+ 2          0          0          1           06044 5 17  267
0.0    + 0 0.0    + 0          0          1          1           26044 5 17  268
         2          2                                              6044 5 17  269
1.40470+ 7 1.00000+ 0 2.00000+ 7 1.00000+ 0                       6044 5 17  270
0.0    + 0 0.0    + 0          0          0          1           46044 5 17  271
         4          2                                              6044 5 17  272
0.0    + 0 1.40470+ 7          0          0          1           36044 5 17  273
         3          2                                              6044 5 17  274
0.0    + 0 0.0    + 0 1.00000+ 0 1.00000+ 0 2.00000+ 0 0.0    + 06044 5 17  275
0.0    + 0 1.60000+ 7          0          0          3          156044 5 17  276
         2          2         14          4         15           26044 5 17  277
0.0    + 0 0.0    + 0 1.25000+ 5 6.82653- 7 2.50000+ 5 9.72782- 76044 5 17  278
3.75000+ 5 1.06294- 6 5.00000+ 5 1.03819- 6 6.25000+ 5 9.49126- 76044 5 17  279
7.50000+ 5 8.27581- 7 8.75000+ 5 6.94272- 7 1.00000+ 6 5.62179- 76044 5 17  280
1.12500+ 6 4.38247- 7 1.25000+ 6 3.27028- 7 1.37500+ 6 2.30056- 76044 5 17  281
1.50000+ 6 1.47919- 7 1.75000+ 6 3.21156- 8 1.87500+ 6 0.0    + 06044 5 17  282
0.0    + 0 1.80000+ 7          0          0          3          186044 5 17  283
         2          2         17          4         18           26044 5 17  284
0.0    + 0 0.0    + 0 1.25000+ 5 3.74733- 7 2.50000+ 5 5.66728- 76044 5 17  285
3.75000+ 5 6.53716- 7 5.00000+ 5 6.75370- 7 6.25000+ 5 6.57006- 76044 5 17  286
7.50000+ 5 6.15463- 7 1.00000+ 6 5.04619- 7 1.50000+ 6 3.01797- 76044 5 17  287
2.00000+ 6 1.80172- 7 2.75000+ 6 8.91076- 8 3.00000+ 6 6.66694- 86044 5 17  288
3.12500+ 6 5.56255- 8 3.25000+ 6 4.45728- 8 3.37500+ 6 3.35914- 86044 5 17  289
3.50000+ 6 2.29487- 8 3.75000+ 6 5.21159- 9 3.87500+ 6 0.0    + 06044 5 17  290
0.0    + 0 2.00000+ 7          0          0          3          246044 5 17  291
         2          2         23          4         24           26044 5 17  292
0.0    + 0 0.0    + 0 1.25000+ 5 3.09281- 7 2.50000+ 5 4.74949- 76044 5 17  293
3.75000+ 5 5.53761- 7 5.00000+ 5 5.77340- 7 6.25000+ 5 5.66462- 76044 5 17  294
7.50000+ 5 5.35136- 7 1.00000+ 6 4.46148- 7 1.37500+ 6 3.12155- 76044 5 17  295
2.00000+ 6 1.67665- 7 2.37500+ 6 1.22662- 7 2.75000+ 6 9.57974- 86044 5 17  296
3.12500+ 6 7.96594- 8 3.75000+ 6 6.41227- 8 4.37500+ 6 5.18207- 86044 5 17  297
4.62500+ 6 4.57266- 8 4.87500+ 6 3.81905- 8 5.00000+ 6 3.37681- 86044 5 17  298
5.12500+ 6 2.88918- 8 5.25000+ 6 2.36043- 8 5.37500+ 6 1.80194- 86044 5 17  299
5.50000+ 6 1.23615- 8 5.75000+ 6 2.62542- 9 5.87500+ 6 0.0    + 06044 5 17  300
                                                                 6044 5  0  301
6.01440+ 4 1.42674+ 2          0          0          1           06044 5 22  302
```

Fig. 10(4) Output of Example 1 in the ENDF format (continued)

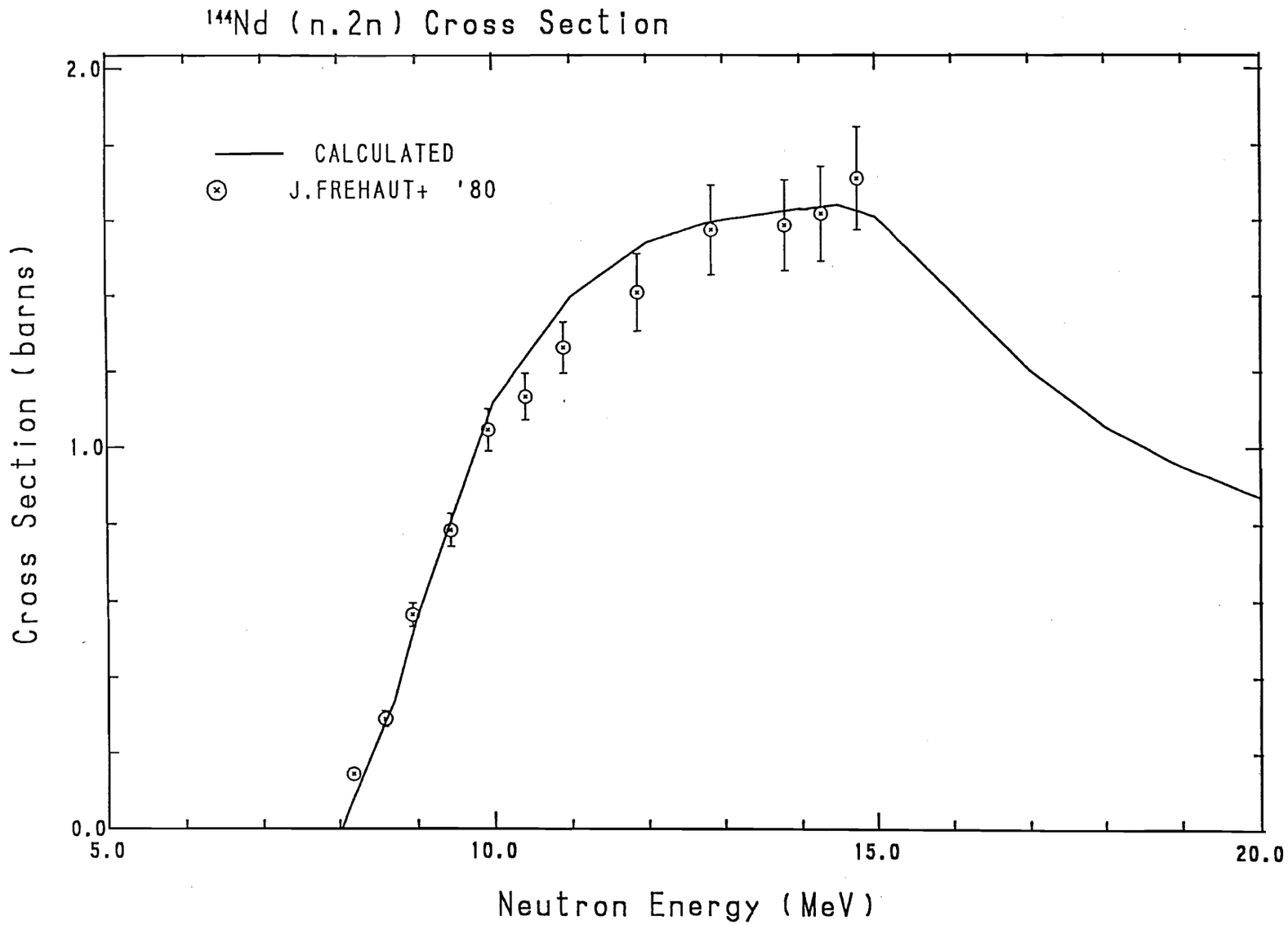

Fig.11 ^{144}Nd(n,2n) reaction cross section

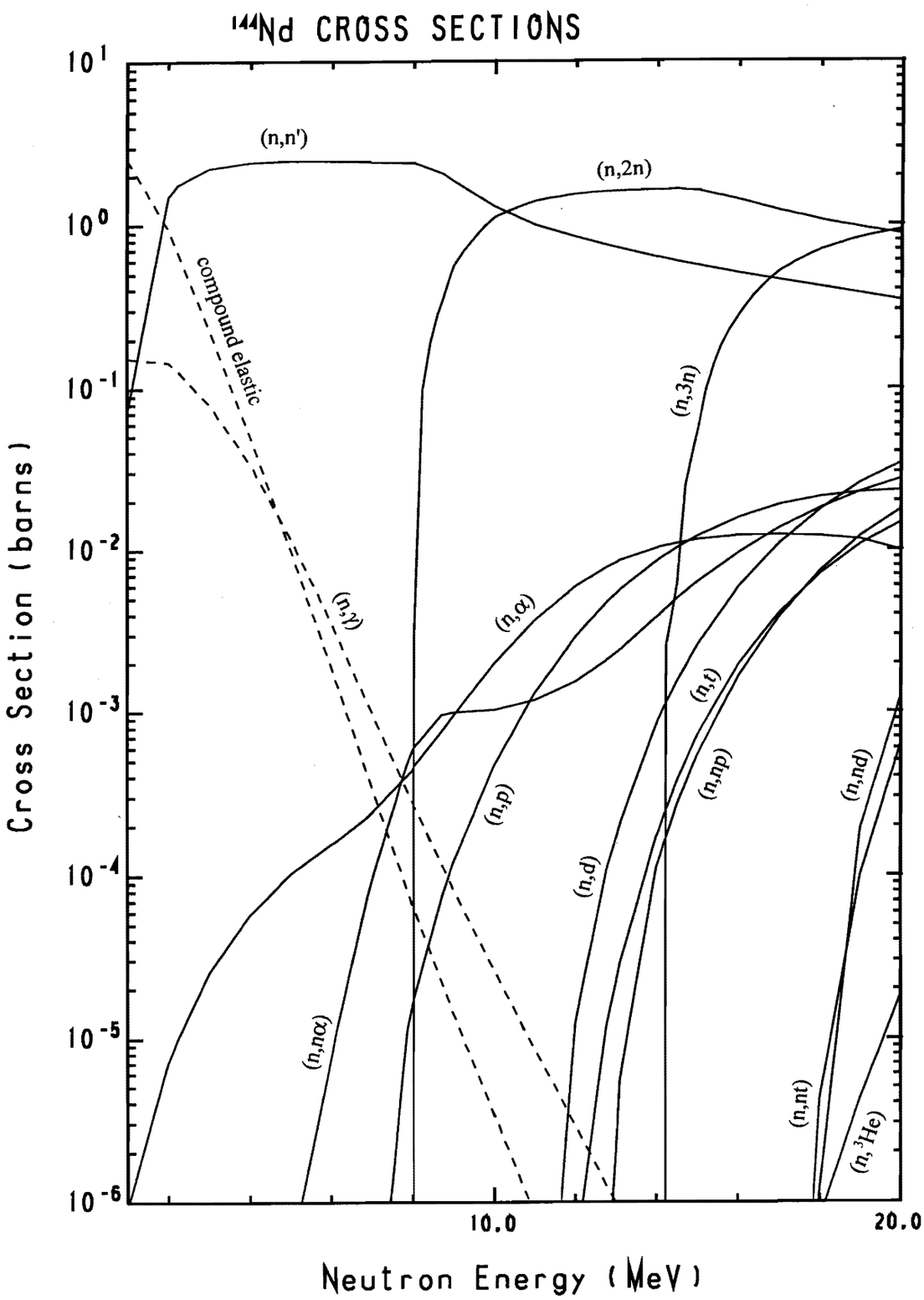

Fig.12 All threshold reaction cross sections of ^{144}Nd

ND-144 NEUTRON EMISSION SPECTRA FOR EN = 14.000 MEV (LAB) 13.903 MEV (C.M.)

EPS	(N,N')	(N,2N)-1	(N,2N)-2	(N,N'P)	(N,PN')	(N,N'A)	(N,AN')	(N,N'D)	(N,DN')	(N,N'T)	(N,TN')
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.000D-01	6.160D-04	3.752D-01	1.682D+00	5.420D-07	1.032D-04	8.779D-05	3.279D-03	6.279D-27	5.323D-25	4.509D-26	1.129D-23
1.000D+00	1.143D-03	4.677D-01	1.057D+00	1.073D-07	5.137D-06	1.235D-04	1.433D-03	0.0	0.0	4.795D-28	1.281D-26
1.500D+00	1.611D-03	4.287D-01	4.868D-01	2.121D-09	2.221D-08	1.300D-04	5.528D-04	0.0	0.0	0.0	0.0
2.000D+00	2.172D-03	3.663D-01	2.020D-01	4.005D-11	1.055D-10	1.279D-04	2.031D-04	0.0	0.0	0.0	0.0
2.500D+00	2.947D-03	3.125D-01	7.943D-02	7.581D-13	5.308D-13	1.238D-04	7.332D-05	0.0	0.0	0.0	0.0
3.000D+00	3.995D-03	2.686D-01	2.943D-02	1.421D-14	2.725D-15	1.159D-04	2.525D-05	0.0	0.0	0.0	0.0
3.500D+00	5.488D-03	2.353D-01	1.028D-02	2.657D-16	1.409D-17	1.065D-04	8.356D-06	0.0	0.0	0.0	0.0
4.000D+00	7.726D-03	2.101D-01	3.345D-03	4.937D-18	7.192D-20	9.583D-05	2.595D-06	0.0	0.0	0.0	0.0
4.500D+00	1.139D-02	1.898D-01	9.787D-04	9.070D-20	3.504D-22	8.650D-05	7.593D-07	0.0	0.0	0.0	0.0
5.000D+00	1.865D-02	1.695D-01	2.348D-04	1.628D-21	1.506D-24	8.127D-05	2.024D-07	0.0	0.0	0.0	0.0
5.500D+00	3.962D-02	1.375D-01	3.559D-05	3.063D-23	4.370D-27	9.364D-05	4.972D-08	0.0	0.0	0.0	0.0
6.000D+00	1.301D-01	3.684D-02	6.392D-07	0.0	0.0	1.525D-04	1.078D-08	0.0	0.0	0.0	0.0
6.500D+00	1.563D-01	0.0	0.0	0.0	0.0	8.170D-05	2.009D-09	0.0	0.0	0.0	0.0
7.000D+00	1.455D-01	0.0	0.0	0.0	0.0	2.998D-05	3.175D-10	0.0	0.0	0.0	0.0
7.500D+00	1.342D-01	0.0	0.0	0.0	0.0	9.258D-06	4.066D-11	0.0	0.0	0.0	0.0
8.000D+00	1.223D-01	0.0	0.0	0.0	0.0	2.195D-06	3.762D-12	0.0	0.0	0.0	0.0
8.500D+00	1.105D-01	0.0	0.0	0.0	0.0	4.713D-07	3.016D-13	0.0	0.0	0.0	0.0
9.000D+00	9.786D-02	0.0	0.0	0.0	0.0	1.003D-07	2.379D-14	0.0	0.0	0.0	0.0
9.500D+00	8.424D-02	0.0	0.0	0.0	0.0	2.106D-08	1.846D-15	0.0	0.0	0.0	0.0
1.000D+01	6.959D-02	0.0	0.0	0.0	0.0	4.348D-09	1.408D-16	0.0	0.0	0.0	0.0
1.050D+01	5.376D-02	0.0	0.0	0.0	0.0	8.749D-10	1.055D-17	0.0	0.0	0.0	0.0
1.100D+01	3.673D-02	0.0	0.0	0.0	0.0	1.664D-10	7.748D-19	0.0	0.0	0.0	0.0
1.150D+01	1.834D-02	0.0	0.0	0.0	0.0	2.575D-11	5.575D-20	0.0	0.0	0.0	0.0
1.200D+01	2.117D-07	0.0	0.0	0.0	0.0	1.099D-16	3.918D-21	0.0	0.0	0.0	0.0
1.250D+01	8.978D-08	0.0	0.0	0.0	0.0	2.355D-17	2.651D-22	0.0	0.0	0.0	0.0
1.300D+01	3.802D-08	0.0	0.0	0.0	0.0	9.447D-18	1.733D-23	0.0	0.0	0.0	0.0
1.350D+01	0.0	0.0	0.0	0.0	0.0	0.0	1.082D-24	0.0	0.0	0.0	0.0
1.400D+01	0.0	0.0	0.0	0.0	0.0	0.0	6.316D-26	0.0	0.0	0.0	0.0
1.450D+01	0.0	0.0	0.0	0.0	0.0	0.0	3.318D-27	0.0	0.0	0.0	0.0
1.500D+01	0.0	0.0	0.0	0.0	0.0	0.0	1.378D-28	0.0	0.0	0.0	0.0
1.550D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.663D-30	0.0	0.0	0.0	0.0
1.600D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.650D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Fig. 13(1) Output of Example 2

1.700D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.750D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.800D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.850D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.900D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.950D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.000D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.050D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.100D+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	6.294D-01	1.632D+00	1.632D+00	4.215D-07	1.115D-04	7.292D-04	3.116D-03	2.726D-26	2.120D-23	1.815D-25	2.168D-22

EPS	(N,3N)-1	(N,3N)-2	(N,3N)-3	N-SPECTRUM
0.0	0.0	0.0	0.0	0.0
5.000D-01	0.0	0.0	0.0	2.061D+00
1.000D+00	0.0	0.0	0.0	1.527D+00
1.500D+00	0.0	0.0	0.0	9.178D-01
2.000D+00	0.0	0.0	0.0	5.708D-01
2.500D+00	0.0	0.0	0.0	3.951D-01
3.000D+00	0.0	0.0	0.0	3.021D-01
3.500D+00	0.0	0.0	0.0	2.512D-01

Skipped

2.000D+01	0.0	0.0	0.0	0.0
2.050D+01	0.0	0.0	0.0	0.0
2.100D+01	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	

ND-144 PROTON AND ALPHA SPECTRA FOR EN = 14.000 MEV (LAB) 13.903 MEV (C.M.)

EPS	(N,P)	(N,PN')	(N,N'P)	(N,2P)-1	(N,2P)-2	P-SPECTRUM	(N,A)	(N,AN')	(N,N'A)	A-SPECTRUM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.000D-01	2.266D-26	3.026D-23	5.722D-22	1.088D-30	8.840D-29	6.025D-22	8.758D-24	3.340D-20	7.802D-16	7.803D-16

Fig. 13(2) Output of Example 2 (continued)

1.000D+00	4.224D-24	4.368D-21	4.349D-20	2.729D-30	6.786D-29	4.786D-20	1.172D-22	4.187D-19	7.014D-15	7.014D-15
1.500D+00	6.015D-22	4.835D-19	2.633D-18	5.212D-30	4.478D-29	3.117D-18	1.175D-21	3.915D-18	4.728D-14	4.729D-14
2.000D+00	7.788D-20	4.908D-17	1.439D-16	8.984D-30	2.835D-29	1.930D-16	1.046D-20	3.238D-17	2.834D-13	2.834D-13
2.500D+00	9.763D-18	4.853D-15	7.351D-15	1.480D-29	1.763D-29	1.221D-14	8.728D-20	2.496D-16	1.592D-12	1.592D-12
3.000D+00	1.225D-15	4.810D-13	3.548D-13	2.385D-29	1.077D-29	8.370D-13	6.986D-19	1.837D-15	8.586D-12	8.588D-12
3.500D+00	1.574D-13	4.841D-11	1.612D-11	3.777D-29	6.356D-30	6.469D-11	5.436D-18	1.306D-14	4.502D-11	4.504D-11
4.000D+00	2.122D-11	4.962D-09	6.783D-10	5.786D-29	3.470D-30	5.662D-09	4.143D-17	9.042D-14	2.299D-10	2.300D-10
4.500D+00	3.133D-09	5.166D-07	2.521D-08	7.985D-29	1.567D-30	5.450D-07	3.110D-16	6.122D-13	1.100D-09	1.100D-09
5.000D+00	5.670D-07	5.427D-05	7.297D-07	5.977D-29	3.290D-31	5.557D-05	2.308D-15	4.067D-12	5.045D-09	5.049D-09
5.500D+00	4.005D-06	1.269D-04	2.623D-07	0.0	0.0	1.312D-04	1.699D-14	2.656D-11	2.257D-08	2.259D-08
6.000D+00	2.685D-04	0.0	0.0	0.0	0.0	2.685D-04	1.242D-13	1.708D-10	9.889D-08	9.906D-08
6.500D+00	4.853D-04	0.0	0.0	0.0	0.0	4.853D-04	9.048D-13	1.083D-09	4.248D-07	4.259D-07
7.000D+00	7.876D-04	0.0	0.0	0.0	0.0	7.876D-04	6.574D-12	6.772D-09	1.787D-06	1.794D-06
7.500D+00	1.164D-03	0.0	0.0	0.0	0.0	1.164D-03	4.773D-11	4.182D-08	7.348D-06	7.390D-06
8.000D+00	1.581D-03	0.0	0.0	0.0	0.0	1.581D-03	3.466D-10	2.552D-07	2.939D-05	2.964D-05
8.500D+00	1.983D-03	0.0	0.0	0.0	0.0	1.983D-03	1.536D-09	9.388D-07	6.868D-05	6.962D-05
9.000D+00	2.297D-03	0.0	0.0	0.0	0.0	2.297D-03	5.628D-09	2.832D-06	1.233D-04	1.262D-04
9.500D+00	2.445D-03	0.0	0.0	0.0	0.0	2.445D-03	1.748D-08	7.215D-06	1.618D-04	1.690D-04
1.000D+01	2.364D-03	0.0	0.0	0.0	0.0	2.364D-03	4.680D-08	1.593D-05	1.445D-04	1.605D-04
1.050D+01	1.983D-03	0.0	0.0	0.0	0.0	1.983D-03	1.045D-07	2.966D-05	1.360D-04	1.657D-04
1.100D+01	1.372D-03	0.0	0.0	0.0	0.0	1.372D-03	2.318D-07	5.554D-05	1.494D-04	2.052D-04
1.150D+01	4.302D-04	0.0	0.0	0.0	0.0	4.302D-04	4.311D-07	8.825D-05	1.439D-04	2.326D-04
1.200D+01	0.0	0.0	0.0	0.0	0.0	0.0	8.138D-07	1.439D-04	1.402D-04	2.849D-04
1.250D+01	0.0	0.0	0.0	0.0	0.0	0.0	1.376D-06	2.122D-04	1.181D-04	3.316D-04
1.300D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.440D-06	3.287D-04	9.758D-05	4.287D-04
1.350D+01	0.0	0.0	0.0	0.0	0.0	0.0	4.071D-06	4.748D-04	6.865D-05	5.475D-04
1.400D+01	0.0	0.0	0.0	0.0	0.0	0.0	7.396D-06	7.220D-04	4.535D-05	7.747D-04
1.450D+01	0.0	0.0	0.0	0.0	0.0	0.0	1.342D-05	1.002D-03	2.319D-05	1.039D-03
1.500D+01	0.0	0.0	0.0	0.0	0.0	0.0	3.163D-05	1.425D-03	8.944D-06	1.466D-03
1.550D+01	0.0	0.0	0.0	0.0	0.0	0.0	1.323D-04	1.710D-03	1.319D-06	1.844D-03
1.600D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.349D-03	0.0	0.0	2.349D-03
1.650D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.526D-03	0.0	0.0	2.526D-03
1.700D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.696D-03	0.0	0.0	2.696D-03
1.750D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.837D-03	0.0	0.0	2.837D-03
1.800D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.917D-03	0.0	0.0	2.917D-03
1.850D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.579D-03	0.0	0.0	2.579D-03
1.900D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.153D-03	0.0	0.0	2.153D-03
1.950D+01	0.0	0.0	0.0	0.0	0.0	0.0	1.616D-03	0.0	0.0	1.616D-03

Fig. 13(3) Output of Example 2 (continued)

2.000D+01	0.0	0.0	0.0	0.0	0.0	0.0	9.440D-04	0.0	0.0	9.440D-04
2.050D+01	0.0	0.0	0.0	0.0	0.0	0.0	4.922D-08	0.0	0.0	4.922D-08
2.100D+01	0.0	0.0	0.0	0.0	0.0	0.0	2.040D-08	0.0	0.0	2.040D-08
TOTAL	8.502D-03	1.115D-04	4.215D-07	1.434D-28	1.434D-28	8.614D-03	1.019D-02	3.116D-03	7.292D-04	1.403D-02

ND-144 NEUTRON ANGULAR DISTRIBUTIONS FOR EN = 14.000 MEV (LAB) 13.903 MEV (C.M.)

EPS	SIG(0.0)	SIG(30.0)	SIG(60.0)	SIG(80.0)	SIG(100.0)	SIG(120.0)	SIG(140.0)	SIG(160.0)	SIG(180.0)	TOTAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.000D-01	1.692D-01	1.683D-01	1.662D-01	1.645D-01	1.630D-01	1.617D-01	1.609D-01	1.604D-01	1.603D-01	2.061D+00
1.000D+00	1.308D-01	1.293D-01	1.254D-01	1.223D-01	1.195D-01	1.173D-01	1.159D-01	1.150D-01	1.148D-01	1.527D+00
1.500D+00	8.521D-02	8.317D-02	7.805D-02	7.407D-02	7.044D-02	6.759D-02	6.568D-02	6.463D-02	6.430D-02	9.178D-01
2.000D+00	5.980D-02	5.737D-02	5.130D-02	4.660D-02	4.234D-02	3.902D-02	3.681D-02	3.561D-02	3.523D-02	5.708D-01
2.500D+00	4.769D-02	4.492D-02	3.804D-02	3.273D-02	2.793D-02	2.423D-02	2.178D-02	2.046D-02	2.006D-02	3.951D-01
3.000D+00	4.167D-02	3.866D-02	3.116D-02	2.540D-02	2.022D-02	1.624D-02	1.364D-02	1.226D-02	1.183D-02	3.021D-01
3.500D+00	3.859D-02	3.540D-02	2.746D-02	2.138D-02	1.594D-02	1.179D-02	9.097D-03	7.676D-03	7.245D-03	2.512D-01
4.000D+00	3.683D-02	3.351D-02	2.529D-02	1.900D-02	1.340D-02	9.159D-03	6.432D-03	5.006D-03	4.577D-03	2.213D-01
4.500D+00	3.564D-02	3.224D-02	2.386D-02	1.747D-02	1.180D-02	7.525D-03	4.801D-03	3.392D-03	2.970D-03	2.022D-01
5.000D+00	3.459D-02	3.117D-02	2.275D-02	1.634D-02	1.068D-02	6.434D-03	3.751D-03	2.375D-03	1.966D-03	1.885D-01
5.500D+00	3.349D-02	3.010D-02	2.174D-02	1.540D-02	9.813D-03	5.651D-03	3.039D-03	1.711D-03	1.320D-03	1.773D-01
6.000D+00	3.225D-02	2.892D-02	2.072D-02	1.453D-02	9.081D-03	5.045D-03	2.529D-03	1.262D-03	8.915D-04	1.671D-01
6.500D+00	3.069D-02	2.747D-02	1.957D-02	1.360D-02	8.377D-03	4.521D-03	2.134D-03	9.415D-04	5.951D-04	1.564D-01
7.000D+00	2.893D-02	2.586D-02	1.833D-02	1.266D-02	7.701D-03	4.059D-03	1.818D-03	7.074D-04	3.870D-04	1.455D-01
7.500D+00	2.696D-02	2.408D-02	1.699D-02	1.167D-02	7.029D-03	3.632D-03	1.554D-03	5.315D-04	2.384D-04	1.342D-01
8.000D+00	2.479D-02	2.212D-02	1.556D-02	1.063D-02	6.351D-03	3.227D-03	1.325D-03	3.967D-04	1.319D-04	1.223D-01
8.500D+00	2.257D-02	2.011D-02	1.411D-02	9.605D-03	5.696D-03	2.853D-03	1.131D-03	2.944D-04	5.724D-05	1.105D-01
9.000D+00	2.010D-02	1.791D-02	1.253D-02	8.501D-03	5.012D-03	2.480D-03	9.522D-04	2.146D-04	6.419D-06	9.786D-02
9.500D+00	1.739D-02	1.548D-02	1.081D-02	7.316D-03	4.291D-03	2.102D-03	7.856D-04	1.528D-04	-2.508D-05	8.424D-02
1.000D+01	1.442D-02	1.283D-02	8.947D-03	6.041D-03	3.530D-03	1.715D-03	6.266D-04	1.055D-04	-4.055D-05	6.959D-02
1.050D+01	1.118D-02	9.941D-03	6.922D-03	4.666D-03	2.718D-03	1.313D-03	4.711D-04	6.948D-05	-4.276D-05	5.376D-02
1.100D+01	7.650D-03	6.803D-03	4.733D-03	3.187D-03	1.853D-03	8.908D-04	3.158D-04	4.192D-05	-3.449D-05	3.673D-02
1.150D+01	3.825D-03	3.401D-03	2.365D-03	1.592D-03	9.244D-04	4.434D-04	1.562D-04	1.946D-05	-1.863D-05	1.834D-02
1.200D+01	1.685D-08	1.685D-08	1.685D-08	1.685D-08	1.685D-08	1.685D-08	1.685D-08	1.685D-08	1.685D-08	2.117D-07
1.250D+01	7.145D-09	7.145D-09	7.145D-09	7.145D-09	7.145D-09	7.145D-09	7.145D-09	7.145D-09	7.145D-09	8.978D-08
1.300D+01	3.025D-09	3.025D-09	3.025D-09	3.025D-09	3.025D-09	3.025D-09	3.025D-09	3.025D-09	3.025D-09	3.802D-08

Fig. 13(4) Output of Example 2 (continued)

Appendix 1

ELIESE-3I

Auxiliary Computer Code

for Calculation of Inverse Reaction Cross Sections

1. Introduction

The computer code ELIESE-3[1)] was developed by S. Igarasi in order to calculate nuclear cross sections with the optical model and statistical model. The special version of ELIESE-3, ELIESE-3I, was made to calculate the compound nucleus formation cross sections of n, p, t, d and ^{3}He induced reactions, by giving several sets of optical potential parameters. The output is further translated by the code SIGINVF into the form that can be read with PEGASUS as the inverse cross sections. SIGINVF is described in Appendix 2.

2. Input data

Detailed description of input data to ELIESE-3 is given in Ref. 1. Here only the input data needed in ELIESE-3I are described in the order of input.

2.1 Title card

Col.	Symbol	Format	Description
1 - 5	NLEVEL	I5	Number of discrete levels. This should be 1.
16 - 75	TITLE		Arbitrary title of a job.

2.2 Integer data card #1

Col.	Symbol	Format	Description
1 - 2	NCNTL	I2	= 1
3 - 5	NDATA	I3	Number of floating point data cards.
6 - 10	NKIND	I5	Designation of an incident particle.
			NKIND = 1 : neutron
			NKIND = 2 : charged particle with spin of 1/2
			NKIND = 3 : charged particle with spin of 0
			NKIND = 4 : charged particle with spin of 1
11 - 15	NUMBER	I5	= 1

16 - 20	NIMAG	I5	Selection for the imaginary part of the optical potential.

NIMAG	volume part	surface part
1	none	Gaussian
2	none	der. Woods-Saxon
3	Woods-Saxon	none
4	Woods-Saxon	Gaussian
5	Woods-Saxon	der. Woods-saxon

21 - 25	NOUTPT	I5	= 0
26 - 30	NCHAGT	I5	Atomic number of the target nucleus.
31 - 35	NMASST	I5	Mass number of the target nucleus.
36 - 40	NCHAGI	I5	Charge number of the incident particle.
41 - 45	NMASSI	I5	Mass number of the incident particle.

2.3 Integer data card #2

Col.	Symbol	Format	Description
41 – 45	NLVFIX	I5	Control for the input data; whether floating-point data for the previous energy point are used or not. If NVLFIX is 1, the floating-point data for the previous energy point are used. NLVFIX should be 1, except for the first and last incident energies.

2.4 Floating-point data cards

Floating-point data are identified by specifying their own addresses in the input data. Input data are given in the columns from 11 to 60. The address of the first input data of each input record is specified in the columns from 6 to 10. The following floating-point data are needed for ELIESE-3I.

Address	Symbol	Description
1	EMTARG	Mass of the target nucleus in u.

2	EMIN	Mass of the incident particle in u.
3	SPIN	Spin and parity of the incident particle. For example, −2.5 for the case of $5/2^-$.
4	SEPAR	Separation energy of the particle (MeV).
5	EIN	Energy of the incident particle (MeV).
6	R0	Radius parameter r_0 of the real potential (fm).
7	RI	Radius parameter r_v of the imaginary volume type potential (fm).
8	RS	Radius parameter r_s of the imaginary surface type potential (fm).
9	RSO	Radius parameter r_{so} for the spin-orbit force (fm).
10	RC	Coulomb radius parameter r_c (fm).
11	A0	Diffuseness parameter a_0 for the real potential (fm).
12	AI	Diffuseness parameter a_v for the imaginary volume type potential (fm).
13	B	Diffuseness parameter b for the imaginary surface type potential (fm).
14	ASO	Diffuseness parameter a_{so} for the spin-orbit force (fm).
16	V	Constant term of the real potential (MeV).
17	WI	Constant term of the imaginary volume type potential (MeV).
18	WS	Constant term of the imaginary surface type potential (MeV).
19	VSO	Constant term of the spin-orbit potential (MeV).
20	WSO	Constant term of the imaginary part of the spin-orbit potential (MeV).
21 ~ 25	VE ~ WSOE	Coefficients of E for each potential.
26 ~ 30	VSE ~ WSOSE	Coefficients of E^2 for each potential.
31	VSYM	Coefficient of the symmetric term of the real potential (MeV).
32	VCOUL	Coulomb potential.

In the case where NLVFIX is 1 and their values are the same as those for the previous

energy point, their columns can be left blank.

3. Optical potential parameters

The following potential sets are built in ELIESE-3I. Those parameters are selected by specifying NKIND, NIMAG, NCHAGI and NMASSI values of the integer data card #1, as listed in Table A1. In the following equations, Z stands for the atomic number and A the mass number.

proton (Perey[24])

$V = 53.3 - 0.55E + 27(N-Z)/A + 0.4(Z/A^{1/3})$ (MeV)

$W_s = 13.5$ (MeV)

$V_{so} = 7.5$ (MeV)

$r_0 = 1.25$ (fm), $a_0 = 0.65$ (fm)

$r_s = 1.25$ (fm), $a_s = 0.47$ (fm)

$r_{so} = 1.25$ (fm), $a_{so} = 0.47$ (fm)

$r_c = 1.25$ (fm)

α (Huizenga and Igo[25])

$V = 50$ (MeV),

W_v = Huizenga and Igo gave a table of W_v values. In ELIESE-3I, a value of W_v is calculated by linear interpolation or extrapolation of the given values as a function of neutron number N,

$R_0 = 1.17A^{1/3} + 1.77$ (fm), $a_0 = 0.576$ (fm)

$R_v = 1.17A^{1/3} + 1.77$ (fm), $a_v = 0.576$ (fm)

$R_c = 1.17A^{1/3}$ (fm)

The number "n" needed to calculate the coulomb potential is given as

$$n = 1.627 \times A^{1/3}.$$

deuteron (Lohr and Haeberi[26])

$V = 91.13 + 2.2(Z/A^{1/3})$ (MeV)

$W_s = 218/A^{2/3}$ (MeV)

$V_{so} = 7.0$ (MeV)

$r_0 = 1.05$ (fm), $a_0 = 0.86$ (fm)

r_s = 1.43 (fm), a_s = 0.50 + 0.013$A^{2/3}$ (fm)

r_{so} = 0.75 (fm), a_{so} = 0.5 (fm)

r_c = 1.3 (fm)

triton (Becchetti and Greenlees[27])

V = 165.0 – 0.17E – 6.4(N-Z)/A (MeV)

W_s = 46.0 – 0.33E – 110(N-Z)/A (MeV)

V_{so} = 2.5 (MeV)

r_0 = 1.20 (fm), a_0 = 0.72 (fm)

r_s = 1.40 (fm), a_s = 0.84 (fm)

r_{so} = 1.20 (fm), a_{so} = 0.72 (fm)

r_c = 1.30 (fm)

^{3}He (Becchetti and Greenlees[27])

V = 151.9 – 0.17E + 50(N-Z)/A (MeV)

W_s = 41.7 – 0.33E + 44(N-Z)/A (MeV)

V_{so} = 2.5 (MeV)

r_0 = 1.20 (fm), a_s = 0.72 (fm)

r_s = 1.40 (fm), a_s = 0.88 (fm)

r_{so} = 1.20 (fm), a_{so} = 0.72 (fm)

r_c = 1.30 (fm)

neutron (Iijima and Kawai[30])

Potential parameters were determined to reproduce the measured total cross sections of fission product nuclides.

4. JCL and example

Input data are read from the logical unit of 9, and calculated results are written on the logical unit of 10. The messages from ELIESE-3I are listed on the logical unit of 6. Scratch files are allocated to the logical units of 8, 27, 28 and 29.

The cataloged procedure listed in Fig. A1 is prepared in "J2608.PROCLIB.CNTL (ELIESE3I)". A typical example of input data is shown in Fig. A2. Figure A3 shows the results written on the logical unit 10 that can be used by PEGASUS as the compound

nucleus formation cross section. Figure A4 is output to the logical unit 6.

This example uses a core size of 670 k bytes, and CPU time of 0.6 sec.

Table A1 Selection of optical potentials

NCHAGI	NMASSI	NKIND	NIMAG	potential
1	1	2	−2	Perey potential[24] for proton
1	2	4	−2	Lohr-Haeberli potential[26] for deuteron
1	3	2	−3	Becchetti-Greenlees potential[27] for triton
2	3	2	−3	Becchetti-Greenlees potential[27] for ^{3}He
2	4	3	−3	Huizenga-Igo potential[25] for α
0	1	1	2	Iijima-Kawai potential[A1] for neutron

Appendix 2

SIGINVF

Auxiliary Computer Code

to make An Inverse Reaction Cross Section File

This is a small program to change the format of ELESE-3I output to the input of PEGASUS. The cataloged procedure is prepared in "J2608.PROCLIB.CNTL(SIGINVF)". It is listed in Fig.A5. No input data for control are needed. The output data file of ELIESE-3I must be allocated on the logical unit of 1, and the output from SIGINVF on the logical unit of 2.

Typical JCL of ELIESE-3I and SIGINVF are as follows:

```
// EXEC ELIESE3I
//FT06F001 DD DCB=(RECFM=FBA,BLKSIZE=137),SYSOUT=*
//FT08F001 DD DUMMY
//FT10F001 DD UNIT=WK10,DSN=&&SGINV,DISP=(,PASS),
//  DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200),SPACE=(TRK,(20,10),RLSE)
//FT27F001 DD DUMMY
//FT28F001 DD DUMMY
//FT29F001 DD DUMMY
//FT09F001 DD *
```

Input data to ELIESE-3I

```
// EXEC SIGINVF
//FT01F001 DD DSN=&&SGINV,DISP=(OLD,DELETE)
//FT02F001 DD DSN=J2608.FPND144.DATA,DISP=(SHR,KEEP,KEEP)
//   DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200),SPACE=(TRK,(10,5),RLSE)
//FT06F001 DD DCB=(RECFM=FBA,BLKSIZE=137),SYSOUT=*
```

Examples of the output of SIGINVF are shown in Figs.5 and A6.

```
//ELIESE3I PROC SYSOUT='*',ERR=0,ITR13=0                                00010000
//*********************************************************************00020000
//*     ELIESE3I  (TRANSMISSION COEFFICIENT FOR PEGASUS)                00030009
//*                        COMP. OPT. = AUTODBL(DBLPAD)                 00040004
//*********************************************************************00050000
//ELIESE3I  EXEC PGM=ELIESE3I,COND=(4,LT),                              00060000
//        PARM='FLIB(ERRCUT=&ERR,ITR13=&ITR13)'                         00070000
//STEPLIB  DD DSN=J2608.LOADC.LOAD,DISP=SHR                             00080000
//SYSPRINT DD SYSOUT=&SYSOUT                                            00090000
//FT05F001 DD DDNAME=SYSIN                                              00100000
//FT06F001 DD SYSOUT=&SYSOUT,                                           00110002
//         DCB=(RECFM=FBA,LRECL=137,BLKSIZE=19043)                      00120002
//FT08F001 DD DSN=&&FT08,UNIT=VIO,SPACE=(TRK,(100,20)),DCB=(DSORG=PS)   00130007
//FT10F001 DD DSN=&&FT10,UNIT=VIO,SPACE=(TRK,(100,20)),DCB=(DSORG=PS)   00140007
//FT27F001 DD DUMMY                                                     00150001
//FT28F001 DD DUMMY                                                     00160001
//FT29F001 DD DUMMY                                                     00170001
```

Fig.A1 Cataloged procedure of ELIESE-3I

```
//FT09F001 DD *                                                          00001500
   1              ND144+ N'  (EN=0.01MEV)                                00000100
 1 7    1    1    2    0   60  144    0    1    2   -1    0    0    0    00000200
                                           0                             00000300
        1 143.910   1.00867   +0.5                0.01                   00000400
        6 1.2817+ 0 0.0    + 0 1.4431+ 0 1.2918+ 0
       11 6.0000- 1 0.0    + 0 4.5000- 1 6.0000- 1
       16 4.7940+ 1 0.0    + 0 9.1300+ 0 7.0000+ 0 0.0    + 0
       21 0.0    + 0 0.0    + 0 0.0    + 0 0.0    + 0 0.0    + 0
       36 0.0        +0.0
       51 -1.0       1.0                                                  00001000
   1              EN=0.025MEV                                            00001100
 1 1                                                                      00001200
                                           1                             00001300
        5 0.025                                                          00001400
   1              EN=0.05 MEV                                            00001500
 1 1                                                                      00001600
                                           1                             00001700
        5 0.05                                                           00001800
   1              EN=0.075MEV                                            00001900
 1 1                                                                      00002000
                                           1                             00002100
        5 0.075                                                          00002200
   1              EN=0.1  MEV                                            00002300
 1 1                                                                      00002400
                                           1                             00002500
        5 0.1                                                            00002600
   1              EN=0.2  MEV                                            00002700
 1 1                                                                      00002800
                                           1                             00002900
        5 0.2                                                            00003000
   1              EN=0.4  MEV                                            00003100
 1 1                                                                      00003200
                                           1                             00003300
        5 0.4                                                            00003400
   1              EN=0.6  MEV                                            00003500
 1 1                                                                      00003600
                                           1                             00003700
        5 0.6                                                            00003800
   1              EN=0.8  MEV                                            00003900
 1 1                                                                      00004000
                                           1                             00004100
        5 0.8                                                            00004200
   1              EN=1.0  MEV                                            00004300
 1 1                                                                      00004400
                                           1                             00004500
        5 1.0                                                            00004600
   1              EN=1.25 MEV                                            00004700
 1 1                                                                      00004800
                                           1                             00004900
        5 1.25                                                           00005000
   1              EN=1.5  MEV                                            00005100
 1 1                                                                      00005200
                                           1                             00005300
        5 1.5                                                            00005400
   1              EN=1.75 MEV                                            00005500
 1 1                                                                      00005600
                                           1                             00005700
        5 1.75                                                           00005800
   1              EN=2.0  MEV                                            00005900
```

Fig.A2(1) An example of input data to ELIESE-3I

```
1  1                                                                    00006000
                                                   1                    00006100
        5 2.0                                                           00006200
   1              EN=3.0  MEV                                           00006300
1  1                                                                    00006400
                                                   1                    00006500
        5 3.0                                                           00006600
   1              EN=4.0  MEV                                           00006700
1  1                                                                    00006800
                                                   1                    00006900
        5 4.0                                                           00007000
   1              EN=5.0  MEV                                           00007100
1  1                                                                    00007200
                                                   1                    00007300
        5 5.0                                                           00007400
   1              EN=6.0  MEV                                           00007500
1  1                                                                    00007600
                                                   1                    00007700
        5 6.0                                                           00007800
   1              EN=8.0  MEV                                           00007900
1  1                                                                    00008000
                                                   1                    00008100
        5 8.0                                                           00008200
   1              EN=10.0 MEV                                           00008300
1  1                                                                    00008400
                                                   1                    00008500
        5 10.0                                                          00008600
   1              EN=12.0 MEV                                           00008700
1  1                                                                    00008800
                                                   1                    00008900
        5 12.0                                                          00009000
   1              EN=14.0 MEV                                           00009100
1  1                                                                    00009200
                                                   1                    00009300
        5 14.0                                                          00009400
   1              EN=16.0 MEV                                           00009500
1  1                                                                    00009600
                                                   1                    00009700
        5 16.0                                                          00009800
   1              EN=18.0 MEV                                           00009900
1  1                                                                    00010000
                                                   1                    00010100
        5 18.0                                                          00010200
   1              EN=20.0 MEV                                           00010300
1  1                                                                    00010400
                                                   1                    00010500
        5 20.0                                                          00010600
   1              EN=22.0 MEV                                           00010700
1  1                                                                    00010800
                                                   1                    00010900
        5 22.0                                                          00011000
   1              EN=25.0 MEV                                           00011100
1  1                                                                    00011200
                                                   1                    00011300
        5 25.0                                                          00011400
/*                                                                      00006700
```

Fig.A2(2) An example of input data to ELIESE-3I (continued)

```
   ND144+ N'  (EN=0.01MEV)                                    000 60144 0 1
 0.0100    1.2274D+04
 0.0250    7.5579D+03
 0.0500    5.2858D+03
 0.0750    4.3405D+03
 0.1000    3.8147D+03
 0.2000    2.9863D+03
 0.4000    2.7278D+03
 0.6000    2.7569D+03
 0.8000    2.7759D+03
 1.0000    2.7564D+03
 1.2500    2.7047D+03
 1.5000    2.6511D+03
 1.7500    2.6103D+03
 2.0000    2.5842D+03
 3.0000    2.5563D+03
 4.0000    2.5317D+03
 5.0000    2.5134D+03
 6.0000    2.4944D+03
 8.0000    2.4179D+03
10.0000    2.4094D+03
12.0000    2.3922D+03
14.0000    2.2797D+03
16.0000    2.2322D+03
18.0000    2.2551D+03
20.0000    2.2704D+03
22.0000    2.2229D+03
25.0000    2.1388D+03
```

Fig.A3 An example of output from ELIESE-3I

```
ND144+ N' (EN=0.01MEV)                                  000                                          PAGE   1

                    TARGET    INCIDENT       PMESH =2.5000D-01 (FERMI)    MAXIMUM ANGULAR MOMENTUM     2
  MASS ......... 143.91     1.008670       PMESHC=2.5000D-01 (FERMI)    CLASSICAL CUT-OFF MOMENTUM   0
  MASS NO.  ..... 144        1              CMESH =2.5115D-01 (FERMI)    WAVE NUMBER ............     0.021891
  ATOMIC NO.  ...  60        0              CMESHC=0.0        (FERMI)    COULOMB PARAMETER (YETA)     0.0

  CMS ENERGY  ...    0.010000 (MEV)
  LAB ENERGY  ...    0.010070 (MEV)         SEPARATION ENERGY  ...    0.0    (MEV)

  INCIDENT PARTICLE  ..... NEUTRON

  IMAGINARY POTENTIAL FORM                                  NON-LOCAL PARAMETER = 0.0  (          L-S TERM          )
      INTERNAL  ........... SURFACE ABSORPTION ONLY
      SURFACE  ............ DIFF. WOODS-SAXON


POTENTIAL PARAMETER

  FORM PARAMETER    . WELL DEPTH PARAMETER (MEV)
       (FERMI)
  RO = 1.282     V   = 47.94     WI   =  0.0     WS   =  9.13     VSO   =  7.00     WSO   =  0.0     VSYM =  0.0
  RI = 0.0
  RC = 0.0       VE  =  0.0      WIE  =  0.0     WSE  =  0.0      VSOE  =  0.0      WSOE  =  0.0     VCOUL=  0.0
  RS = 1.443
  RSO= 1.292     VESO=  0.0      WIESO=  0.0     WSESO=  0.0      VSOESO=  0.0      WSOESO=  0.0
  AO = 0.600
  A1 = 0.0       VRE = 47.94     WIMI =  0.0     WIMS =  9.13     VSPO  =  1.14     WSPO  =  0.0     VSYMM=  0.0
  B  = 0.450
  ASO= 0.600


LEVEL DENSITY PARAMETER
  EC =  0.0       A =  0.0      SGM=  0.0      EPR=  0.0      NOM=     0.0
  ET =  0.0

  TOTAL CROSS SECTION  ......  1.9654D+04 (MILLI-BARN)
  SHAPE ELASTIC CROSS SECTION  7.3809D+03 (MILLI-BARN)
  REACTION CROSS SECTION  ...  1.2274D+04 (MILLI-BARN)
```

Fig.A4(1)　An example of output to the logical unit of 6 from ELIESE-3I

```
EN=0.025MEV                                    000                                    PAGE   0

 TOTAL CROSS SECTION  ......  1.4441D+04 (MILLI-BARN)
 SHAPE ELASTIC CROSS SECTION  6.8831D+03 (MILLI-BARN)
 REACTION CROSS SECTION  ...  7.5579D+03 (MILLI-BARN)

EN=0.05 MEV                                    000                                    PAGE   0

 TOTAL CROSS SECTION  ......  1.1626D+04 (MILLI-BARN)
 SHAPE ELASTIC CROSS SECTION  6.3407D+03 (MILLI-BARN)
 REACTION CROSS SECTION  ...  5.2858D+03 (MILLI-BARN)

EN=0.075MEV                                    000                                    PAGE   0

 TOTAL CROSS SECTION  ......  1.0290D+04 (MILLI-BARN)
 SHAPE ELASTIC CROSS SECTION  5.9492D+03 (MILLI-BARN)
 REACTION CROSS SECTION  ...  4.3405D+03 (MILLI-BARN)

EN=0.1  MEV                                    000                                    PAGE   0

 TOTAL CROSS SECTION  ......  9.4562D+03 (MILLI-BARN)
 SHAPE ELASTIC CROSS SECTION  5.6416D+03 (MILLI-BARN)
 REACTION CROSS SECTION  ...  3.8147D+03 (MILLI-BARN)

EN=0.2  MEV                                    000                                    PAGE   0

 TOTAL CROSS SECTION  ......  7.8370D+03 (MILLI-BARN)
```

(Skipped)

```
EN=25.0 MEV                                    000                                    PAGE   0

 TOTAL CROSS SECTION  ......  5.3480D+03 (MILLI-BARN)
 SHAPE ELASTIC CROSS SECTION  3.2092D+03 (MILLI-BARN)
 REACTION CROSS SECTION  ...  2.1388D+03 (MILLI-BARN)

'N'   Z=  60 A= 144 ENERGY POINT=   27 COPY END.
```

Fig.A4(2)　An example of output to the logical unit of 6 from ELIESE-3I

```
//SIGINVF  PROC SYSOUT='*'                                          00000100
//*********************************************************************00000200
//*     SIGINVF                                                     00000300
//*********************************************************************00000400
//SIGINVF   EXEC PGM=SIGINVF,COND=(4,LT),                           00000500
//STEPLIB  DD DSN=J2608.LOADC.LOAD,DISP=SHR                         00000600
//SYSPRINT DD SYSOUT=&SYSOUT                                        00000700
//FT05F001 DD DDNAME=SYSIN                                          00000800
//FT06F001 DD SYSOUT=&SYSOUT,                                       00000900
//         DCB=(RECFM=FBA,LRECL=137,BLKSIZE=19043)                  00001000
```

Fig.A5 Cataloged procedure of SIGINVF

```
'N'      60 144    27 11     ND144+ N'  (EN=0.01MEV)
  0.0100  1.2274E+04      0.0250  7.5579E+03      0.0500  5.2858E+03
  0.0750  4.3405E+03      0.1000  3.8147E+03      0.2000  2.9863E+03
  0.4000  2.7278E+03      0.6000  2.7569E+03      0.8000  2.7759E+03
  1.0000  2.7564E+03      1.2500  2.7047E+03      1.5000  2.6511E+03
  1.7500  2.6103E+03      2.0000  2.5842E+03      3.0000  2.5563E+03
  4.0000  2.5317E+03      5.0000  2.5134E+03      6.0000  2.4944E+03
  8.0000  2.4179E+03     10.0000  2.4094E+03     12.0000  2.3922E+03
 14.0000  2.2797E+03     16.0000  2.2322E+03     18.0000  2.2551E+03
 20.0000  2.2704E+03     22.0000  2.2229E+03     25.0000  2.1388E+03
```

Fig.A6 An example of output from SIGINVF