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Abstract

The DISCA code has been originated to obtain reaction cross-sections, energy and angular particle distributions in nuclear reactions induced by incident nucleons and alpha-particles at intermediate energies.

The code implements the advanced intranuclear cascade evaporation model considering the nucleon-cluster interactions. The nuclear model is based on the realistic approximation of the Woods-Saxon nucleon density distribution. The modeling of intranuclear interactions takes into account along with the Pauli principle the number of essential features of nucleon-nucleon and nucleon-cluster interactions resulting from the quantum mechanical consideration of these effects. The model discussed can be applied to the calculation of excitation functions and total and differential nuclear reaction cross-sections over the entire energy range of precompound exciton models application and at the higher energies of incident particles.

DISCA – Code System zur Berechnung von Partikelverteilungen und Wirkungsquerschnitten für Kernreaktionen bei mittleren Energien basierend auf einem fortgeschrittenen intranuklearen Kaskaden Verdampfungsmodell mit vorgeformten Clustern

Zusammenfassung

Der DISCA Code ist entwickelt worden für die Berechnung von Wirkungsquerschnitten und Energie- und Winkelverteilungen von Kernreaktionen mit Nukleonen und Alpha-Teilchen mittlerer Energie.

Der Code implementiert das weiterentwickelte intranukleare Kaskaden Verdampfungsmodell, das die Nukleon-Cluster Wechselwirkung berücksichtigt. Das Kernmodell basiert auf der realistischen Annäherung der Woods-Saxon Nukleonen Dichteverteilung. Die Modellierung der intranuklearen Wechselwirkungen berücksichtigt neben dem Pauli Prinzip eine Reihe wesentlicher Eigenschaften der Nukleon-Nukleon und Nukleon-Cluster Wechselwirkungen, die aus der quantenmechanischen Betrachtung resultieren.

Das diskutierte Modell kann angewendet werden für die Berechnung von Anregungsfunktionen und totalen und differentiellen Wirkungsquerschnitten über den gesamten Energiebereich, für den das Precompound Excitonen Modell gültig ist und für einfallende Teilchen mit höheren Energien.

CONTENTS

page

The DISCA code has been elaborated to study nucleon and α-particle interactions with nuclei at intermediate energies.

The code calculates energy and angular distributions of particles emitted in nuclear reactions, residual nuclei yields, recoil spectra, total nonelastic cross-section for nuclear reactions induced by nucleons and α-particles. The code implements the advanced intranuclear cascade evaporation model with consideration of the nucleon-cluster interactions.

1. History of the code development

The creation of the DISCA code was initiated in 1987. The brief history of the code is described below.

DISCA: creation of general algorithm of the code refers to the works [1,2]. The code has been used for gas production and displacement cross-section calculations for stainless steel components irradiated with neutrons and protons at the energy up to 150 MeV [3] and for the creation of the BISERM-1 data library [4-7]

DISCA-2 or DISCA-S: the code algorithm, the routines for *n-n* interactions and particle evaporation simulation have been improved. The code has been used for the calculations of radioactive nuclide production cross-sections [8,9] and the cross-section evaluation for the BISERM-2 library [10,11].

DISCA-3: the code algorithm has been completely rewritten, the simulation of the α-particle knock-out and pick-up processes was included in the code [12]

DISCA-3D: the code was extended to describe the deuteron interactions with nuclei [13], the interactions with light nuclei and to perform simple calculations for thick targets.

DISCA-C/05 is the current version of the code realized in April, 2005. The parameters of the model were optimized. The code was used for helium production cross-section calculation for tungsten and tantalum isotopes [14].

2. Description of the model

2.1 Model of the nucleus

In the calculations the nucleus is broken up into concentric regions (zones) with uniform density. The number of zones is defined by the code parameter KZONESC (Sect.7). The position of nuclear zones is defined according to the Woods-Saxon expression

$$\rho(r) = \frac{\rho_0}{1+\exp[(r-c)/a_d]}, \qquad (1)$$

where $c=1.07\ A^{1/3}$ fm, $a_d=0.545$ fm, $\rho_0 = 0.17$ fm^{-3}.

The momentum distribution for nucleons for each zone is defined according to the Fermi gas model. Fermi momentum and energy are

$$p_{ni}^F = \left(3\pi^2 \mathbf{h}^3 \rho_{ni}\right)^{1/3} \qquad (2)$$

$$T_{ni}^F = \left(p_{ni}^F\right)^2 / 2m \qquad (3)$$

where index "n" relates to nucleon, and ρ_i is the nucleon density in i-th zone.

It is supposed that besides of nucleons the nucleus consists of preformed clusters: tritons, ^{3}He nuclei and α-particles. The maximum kinetic energy of the clusters (Fermi energy) and their potentials are defined by

$$T_{\alpha i}^F = 4T_{ni}^F, \quad T_{ti}^F = T_{hi}^F = 3T_{ni}^F, \qquad (4)$$

$$U_{\alpha i} = T_{ni}^F + B_\alpha, \quad U_{ti} = T_{ti}^F + B_t, \quad U_{hi} = T_{hi}^F + B_h, \qquad (5)$$

where $T_{\alpha i}^F, T_{ti}^F, T_{hi}^F$ are Fermi energy for α-particles, tritons and ^{3}He, correspondingly, B_{xi} is the separation energy calculated using table of experimental nuclide masses, U_{xi} is the potential for considered type of the particles.

The value of U_{xi} in Eq(4),(5) is in agreement with the real part of optical potential obtained in Refs.[15,16] from data for α-particle elastic scattering on nuclei.

According to Ref.[17] the momentum distributions for tritons, ^{3}He and α-particles are taken as

$$N_\alpha(\mathbf{p}_\alpha)\,d\mathbf{p}_\alpha \propto p^8\,dp\,d\Omega, \tag{6}$$

$$N_t(\mathbf{p}_t)\,d\mathbf{p}_t = N_h(\mathbf{p}_h)\,d\mathbf{p}_h \propto p^6\,dp\,d\Omega \tag{7}$$

2.2 Definition of the point of intranuclear interaction and partner characteristics

The method proposed to define the point of the interaction and partner characteristics is discussed in Refs.[12,13]. Let us consider a particle moving with kinetic energy T inside the nucleus. Probability of interaction per unit length is equal to

$$Q(\mathbf{r}) = \sum_x \rho_x(\mathbf{r})\,\sigma_x^{eff}(T), \tag{8}$$

where the summing is performed over all particles inside the nucleus, ρ_x is the density of particles of type "x", σ_x^{eff} is the effective cross-section for interaction of the considered particle and a particle of the x-type.

The cross-section σ_x^{eff} is defined as follows

$$\sigma_x^{eff}(T) = (1/v)\int v_{rel}\,\sigma_x(\mathbf{p},\mathbf{p}_x)\,N_x(\mathbf{p}_x)\,d\mathbf{p}_x\,, \tag{9}$$

where v is the absolute value of the velocity and **p** is the momentum of the considered particle corresponding to the energy T, v_{rel} is the relative velocity for two particles in the coordinate system with the motionless x-particle, $\sigma_x(\mathbf{p},\mathbf{p}_x)$ is the interaction cross-section, which depends on the absolute value and direction of momentums of colliding particles.

The numerical calculation of Q value, Eq.(8) is noticeable simplified taking into account that the effective cross-section value σ_x^{eff} calculated using Eq.(9) at different T values is close to the value of the cross-section for interaction of the considered particle with a motionless partner (particle of x-type) $\sigma_x^{eff}(T) \cong \sigma_x(T) = \sigma_x(\mathbf{p},\mathbf{p}_x = 0)$.

Fig.1 shows the ratio $\sigma_x^{eff}(T) = (1/v)\int v_{rel}\,\sigma_x(\mathbf{p},\mathbf{p_x})\,N_x(\mathbf{p_x})\,d\mathbf{p_x} / \sigma_x(T)$ calculated for nucleon-nucleon and nucleon-α interactions at different nucleon kinetic energy T.

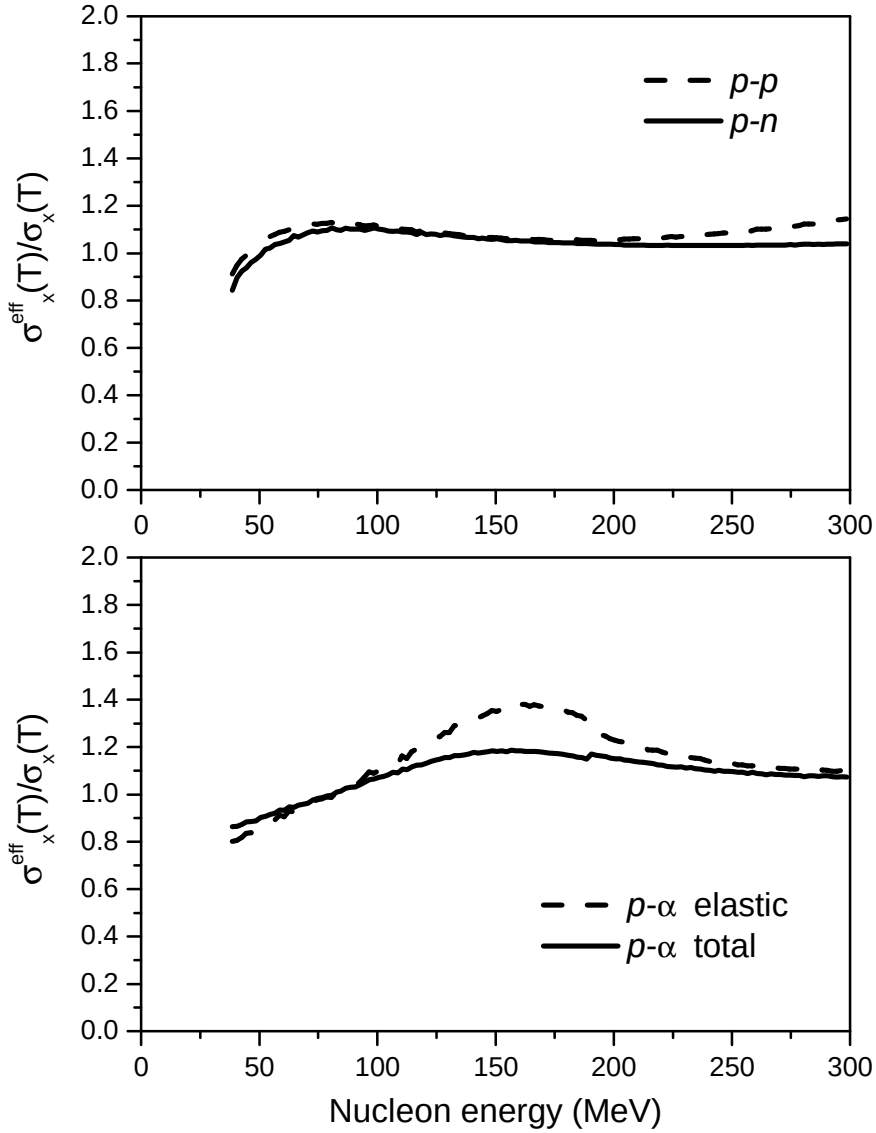

Fig.1 The ratio of the effective cross-section for nucleon-nucleon and nucleon-α interactions inside a nucleus and the cross-section corresponding to the motionless partner.

Data shown in Fig.1 correspond to the central nuclear zone with the biggest value of T^F_n, where the difference between $\sigma_x^{eff}(T)$ and $\sigma_x(T)$ is maximal. One can see that the ratio of cross-sections is close to unity. Therefore, the probability of interaction of the considered particle with the particles of the nucleus can be calculated using the following approximation

$$Q(\mathbf{r}) = \sum_x \rho_x(\mathbf{r})\,\sigma_x(T) \tag{10}$$

The particle range (L) in nuclear matter is defined by

$$\int_0^L Q(\mathbf{r})\,dl = -\ln\xi, \tag{11}$$

where ξ is the random number from the interval [0,1].

For a nucleus with constant density zones Eq.(11) is written as

$$\sum Q_i(\mathbf{r}_i)\,\Delta l_i = -\ln\xi, \tag{12}$$

where Q_i is the probability of particle interaction with nuclear matter in the i-th zone, Δl_i is the length of the trajectory part in the i-th zone.

The point of the interaction is defined using Eq.(12) as follows.

The random number ξ is sampled in the interval [0,1]. For the considered particle with momentum **p**, located in the point with the radius-vector **r**, the distance for the nearest zone boundary Δl is calculated according to the momentum direction. The value of the sum, Eq.(12) is increased by the $Q(\mathbf{r})\,\Delta l$ value. If the resulting value $\sum Q_i(\mathbf{r}_i)\,\Delta l_i$ is much larger then $-\ln\xi$, than the particle is shifted by a distance corresponding to the rigorous equality of Eq.(12). In this case, the particle coordinates correspond to the point of interaction with an intranuclear cluster or nucleon. If $\sum Q_i(\mathbf{r}_i)\,\Delta l_i < -\ln\xi$, the particle crosses the zone boundary. According to its new momentum direction, a new distance for the zone boundary is calculated, the sum, Eq.(12) is increased by the new $Q(\mathbf{r})\,\Delta l$ value again etc, until an equality Eq.(12) is fulfilled.

After the definition of the point of interaction, the type of partner and its momentum are obtained by the Monte Carlo method. Note that the partner characteristics are defined only once, in contrast with the repeated random choice of the partner type and momentum, as used in Refs.[5,6].

The partner type is defined according to the relation between the items in Eq.(10) for the calculation of the probability Q. The interaction of the considered particle with nucleons, α-, t- and ^{3}He-clusters is taken into account. The partner momentum is defined according to the distribution $(v_{rel}/v)\sigma_x(\mathbf{p},\mathbf{p}_x)N_x(\mathbf{p}_x)d\mathbf{p}_x$.

The efficiency of the algorithm for momentum definition is based on the following property of the distribution

$$\int (v_{rel}/v)\,\sigma_x(\mathbf{p},\mathbf{p_x})\,N_x(\mathbf{p_x})\,d\Omega_{\mathbf{x}} \;\cong \sigma_x(\mathbf{p},\mathbf{p_x}=0)\int N_x(\mathbf{p_x})\,d\Omega_{\mathbf{x}}\;, \qquad (13)$$

According to Eq.(13) the result of integration does not depend from the absolute value of $\mathbf{p}_x$ and the value p_x can be independently chosen at random based on the $N_x(p_x)$ distribution. To obtain the momentum direction the following expression is used

$$\int (v_{rel}/v)\,\sigma_x(\mathbf{p},p_x)\,d\Omega_{\mathbf{x}} = \xi\,\sigma_x(T)\,, \qquad (14)$$

where ξ is the random number, T is the kinetic energy of primary (considered) particle corresponding to the momentum **p**, and the absolute value p_x is defined according to the $N_x(p_x)$ distribution.

2.3 Probability of intranuclear interaction

For a proton moving inside the nucleus with kinetic energy T, the probability of interaction with nuclear matter is

$$Q_i = \rho_i\left[\varphi_n\sigma^{pn}(T)+\varphi_p\sigma^{pp}(T)+\varphi_\alpha\sigma^{p\alpha}(T)+\sigma^{pt}_{p-u}(T)\right], \qquad (15)$$

where ρ_i is the nucleon density for the i-th zone, σ^{pn} and σ^{pp} are cross-sections for interactions with intranuclear neutron and proton, correspondingly, $\sigma^{p\alpha}$ is the cross-

section for interaction with a "preformed" α-cluster, σ^{pt}_{p-u} is the cross-section for the "pick-up" processes combining the proton and a "preformed" triton to form of the α-particle, φ_n, φ_p, φ_α are relative numbers of neutrons, protons and α-clusters in the nucleus, correspondingly.

Typical values of φ_α obtained from the analysis of experimental α-particle spectra are from 0.05 to 0.1. Values of φ_n and φ_p depend from the total number of nucleons in nuclei and φ_α value.

A similar equation describes the neutron moving inside the nucleus.

For excited α-particle, the elastic scattering and break-up processes at the interactions with intranuclear nucleons are considered. For calculating the nucleon-nucleon interaction cross-sections, the following approximation formulas from Ref.[18] are used

$$\sigma^{pn}(T) = \begin{cases} -5057.4/T^2 + 9069.2/T + 6.9466, & T \le 40 \text{ MeV} \\ 239380.0/T^2 + 1802.0/T + 27.147, & 40 < T \le 400 \text{ MeV} \\ 34.5, & 400 < T \le 800 \text{ MeV} \end{cases} \quad (16)$$

$$\sigma^{pp}(T) = \begin{cases} -1174.8/T^2 + 3088.5/T + 5.3107, & T \le 40 \text{ MeV} \\ 93074.0/T^2 - 11.148/T + 22.429, & 40 < T \le 310 \text{ MeV} \\ 887.37/T + 0.05337T + 3.5475, & 310 < T \le 800 \text{ MeV} \end{cases} \quad (17)$$

where the cross-sections are given in millibarns.

For calculating nucleon-α interaction cross-sections, the approximation formulas obtained in Ref.[12] are used. These were obtained on the basis of experimental and evaluated data from Refs.[19,20] at energies above 14 MeV and the BROND-2 data for low energies. The total and elastic scattering cross-sections for nucleon-α interaction are calculated as follows

$$\sigma^{p\alpha}(T)=\begin{cases}6754.8T^2-1608.5T+778.94, & T \le 1.125\ \text{MeV}\\ 7467.2/T^{1.6089}-51.109T+1773.7, & 1.125 < T \le 20\ \text{MeV}\\ 5230.0/T^{0.43473}+1.2270T-658.81, & 20 < T \le 190\ \text{MeV}\\ 3425.3/T+0.073484T+74.410, & 190 < T \le 1000\ \text{MeV}\end{cases} \quad (18)$$

$$\sigma_{el}^{p\alpha}(T)=\begin{cases}6754.8T^2-1608.5T+778.94, & T \le 1.125\ \text{MeV}\\ 7466.4/T^{1.6338}-53.939T+1815.2, & 1.125 < T \le 20\ \text{MeV}\\ 10182.0/T^{0.76746}+0.68190T-282.56 & 20 < T \le 190\ \text{MeV}\\ 4833.8/T+0.036414T-2.9546 & 190 < T \le 1000\ \text{MeV}\end{cases} \quad (19)$$

where $\sigma^{p\alpha}$ is the total cross-section and $\sigma_{el}^{p\alpha}$ is the elastic scattering cross-section in millibarns.

The energy dependence of the pick-up cross-section $\sigma_{p-u}^{pt}(T)$ is defined according to the form-factor $F_{1,3}$ calculated in Ref.[21] corresponding to formation of the α-particle from three nucleons with energy below the Fermi energy and one nucleon with energy above the Fermi energy. The cross-section is

$$\sigma_{p-u}^{pt}(T)=\varsigma\left[-1{,}011\times10^{-6}\varepsilon^3+1{,}748\times10^{-4}\varepsilon^2-1{,}128\times10^{-2}\varepsilon+0{,}275742\right]/(R\rho_i), \quad (20)$$

where $\varepsilon = T - T_{ni}^F$ ($\varepsilon < 67$ MeV), $R = 1.25\ A^{1/3}$, ς is the fitting parameter, which typical value is equal to 14.

To obtain the momentum of the particles after interactions, the angular distribution for nucleon-nucleon scattering is parameterized as

$$\sigma(\theta) = A(T) + B(T)\cos^n\theta, \quad (21)$$

where the coefficients A(T) and B(T) and the "n" values are defined in Ref.[22].

The angular distributions for elastic nucleon-α scattering are calculated according to Ref.[23] as

$$\sigma(\theta) = C(\theta)\exp\left(-k(\theta)\sqrt{T}\right), \quad (22)$$

where θ is the angle in CM system and C(θ) and k(θ) are parameters, which do not depend on the primary nucleon energy.

The values of C(θ) and k(θ) tabulated in Ref.[32] are approximated by polynomials

$$C(\theta) = 1.4447\times10^{-6}\theta^3 + 1.0774\times10^{-4}\theta^2 - 8.87098\times10^{-2}\theta + 6.7415 \qquad (23)$$

and

$$\begin{aligned} k(\theta) &= 4.0\times10^{-3}\theta, \quad \text{if } \theta < 30^\circ \\ k(\theta) &= -1.4519\times10^{-10}\theta^5 + 6.6868\times10^{-8}\theta^4 - 1.0539\times10^{-5}\theta^3 + \\ &\quad + 6.1054\times10^{-4}\theta^2 - 3.8739\times10^{-3}\theta - 7.7636\times10^{-2}, \quad \text{if } 30^\circ \le \theta \le 165^\circ \\ k(\theta) &= 0.36889, \quad \text{if } \theta > 165^\circ \end{aligned} \qquad (24)$$

where angle θ is given in degrees.

2.4 Pauli principle and limitation on orbital particle momenta

In the simulation of intranuclear interactions, the Pauli principle is taken into account as well for nucleon-nucleon as for nucleon-α collisions. The check provides that the kinetic energy of interacting particles is never below the Fermi energy. Also, the restriction on the orbital momenta of nucleons discussed in Ref.[24] is considered.

Finite nuclear sizes impose restrictions on the orbital momenta of the interacting nucleons. According to Ref.[25], the orbital momenta *l* of nucleons colliding within a square potential well should not exceed the product of asymptotic nucleon momentum and nucleus radius: $l \le p_a R$, where p_a is the linear momentum the nucleon would have outside the nucleus and R is the nucleus radius. This restriction on *l* results from the fact that the nucleus has no states below the centrifugal barrier [25]. For a nuclear model with the multi-region density, the restriction on the orbital momenta of nucleons colliding in the i-th zone has the following form [24,25]

$$l \le p_{i+1} R_i, \qquad (25)$$

where *l* is the angular momentum of the nucleon with momentum p_i in the i-th zone, p_{i+1} is the momentum the nucleon would have in the i+1-th zone (the regions are

numbered beginning from the nucleus center), and R_i is the radius of the i-th zone in which the two nucleons collide. The relationship between p_i and p_{i+1} is derived from the following relation between corresponding values of the nucleon kinetic energy T_i and T_{i+1}

$$T_{i+1} = T_i - T_i^F + T_{i+1}^F, \qquad (26)$$

where T_i^F is the Fermi energy in the i-th zone. If the i-zone has the maximum radius, then $T_{i+1}^F = -B_b$, where B_b is the binding energy of the nucleon or α-particle in the nucleus.

Restriction, Eq.(25) on orbital momenta leads to a reduced total number of intranuclear interactions and to an increased emission of high energy particles from the nucleus. The calculations show [24] that use of Eq.(25) along with the Pauli principle results in a much better reproduction of the experimental data for low and intermediate primary particle energies.

Fig.2 illustrates how the restriction on orbital momenta used in modeling nucleon-nucleon interactions affects the accuracy of the calculation of double-differential cross-sections. The calculated spectrum for 19 MeV neutrons produced by irradiation of ^{93}Nb with 26 MeV neutrons is shown in Fig.2. The calculations were performed with and without checking of Eq.(25) for intranuclear interactions. In both calculations the effects of the refraction and reflection of the nucleon momentum at the boundary of nuclear regions were taken into account. The total reaction cross-section was normalized to the same value of the cross-section, obtained by the optical model. Fig.2 shows that a more accurate description of intranuclear processes leads to a better agreement between the calculations and experimental data [26].

2.5 Distortion of particle trajectory inside the nucleus

When the nucleon moves in a non-uniform nuclear potential well its path is distorted and the distortion is simulated by describing the refraction and reflection of the nucleon momentum at the boundary of nuclear regions.

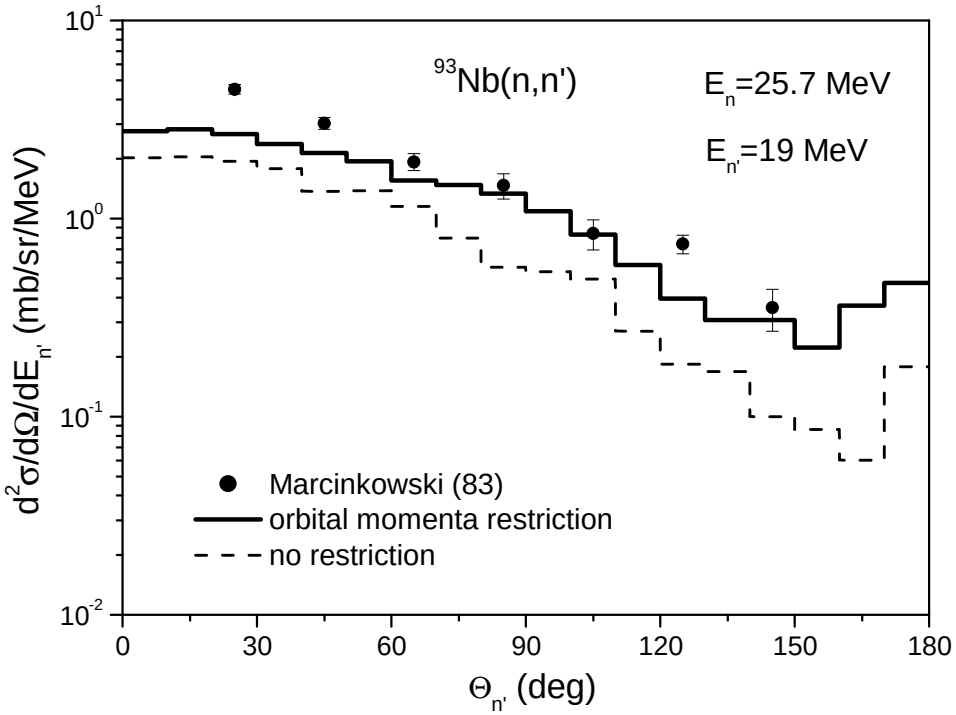

Fig.2 Double-differential cross-section for 19 MeV neutrons emitted in the reaction ^{93}Nb(n,n') induced by 25.7 MeV neutrons. Calculations are carried with the checking of Eq.(25) for nucleon-nucleon interactions (solid line) and without the checking (dashed line). The refraction and reflection of the nucleon momentum at the nuclear zone boundaries are taken into account. Experimental data are taken from Ref.[26].

The problem of describing refraction and reflection processes has been discussed long before [22,27]. In Ref.[27] it was shown that these effects when included in the model algorithm deteriorate the level of agreement between calculated and

experimental data. The neglecting of refraction and reflection is the default (recommended) option for calculations using the Bertini and ISABEL codes from MCNPX package [28]. However, it was proved [22] that the classical interpretation of refraction and reflection effects was quite justified and cannot be used as a basis for disregarding these effects.

A solution of the problem was given in Ref.[25] where it was pointed out that the calculations in Ref.[27] did not take into account the effect associated with the restriction on orbital momenta of interacting nucleons, Eq.(25). As shown in Ref.[25] and confirmed by the DISCA calculations, taking into account refraction and reflection and meeting condition Eq.(25) the agreement between calculations and experimental data in the intermediate energy range is noticeably improved.

The effects of refraction and reflection of particle momentum on the boundary of two nuclear zones is considered in all DISCA simulations.

2.6 Cut-off energy

The cutoff energy T_{cut} is a parameter of the intranuclear cascade model and presents the minimal energy of the fast particle emitted from the nucleus [22]. When the kinetic energy T of a particle residing in the potential well meets the condition

$$T^F < T < T^F + B + T_{cut}, \qquad (27)$$

where B is a binding energy, it is generally accepted, that the particle is absorbed by the nucleus and its further movement is not observed.

From the calculations performed [24] it follows that the best results are obtained if the cut-off energy for neutrons and protons is assumed to be equal to zero, and penetration through the Coulomb barrier for protons is simulated.

In modeling the cascade process for protons approaching the nucleus with energies less than the Coulomb potential, the tunnel effect is considered in the

following way. The probability of penetrating through the Coulomb barrier is as follows [24]

$$D = \exp\left(-2\frac{R}{\mathbf{D}(V_p)}\left[(V_p/\varepsilon)^{1/2}\arccos(\varepsilon/V_p)^{1/2} - (1-\varepsilon/V_p)^{1/2}\right]\right), \qquad (28)$$

where ε is the energy of proton outside the nucleus, V_p is the Coulomb potential, $\mathbf{D}(V_p)$ is the de Broglie wave length of the proton at the energy V_p equal to $4.5 \cdot V_p^{-1/2}$ fm.

By generating a random number and using Eq.(28) for the proton with the energy $0 < \varepsilon < V_p$ one can find whether the proton is absorbed or emitted from the nucleus. If the under-barrier effect is taken into consideration the smooth dependence of the proton nonequilibrium spectrum on the energy of the outgoing particle is described (Fig.3). In the pre-equilibrium exciton model similar energy dependence for the calculated spectrum is observed when calculating the inverse reaction cross-section for protons via the optical model describing the proton absorption and scattering in a realistic potential well.

2.7 Particle evaporation

The description of the particle evaporation by the intranuclear cascade evaporation model is linked to the problem of developing an efficient algorithm to simulate this process by the Monte Carlo method. The efficiency of the algorithm ensuring the speed of the computer code often implies that the particle evaporation widths are calculated through analytical formulas rather than by means of numerical integration. Old versions of the DISCA code preceding DISCA-3 used the analytical expression for calculating of the particle emission probability. New versions starting from DISCA-3 implement the method described in Ref.[29] (“single width integration”).

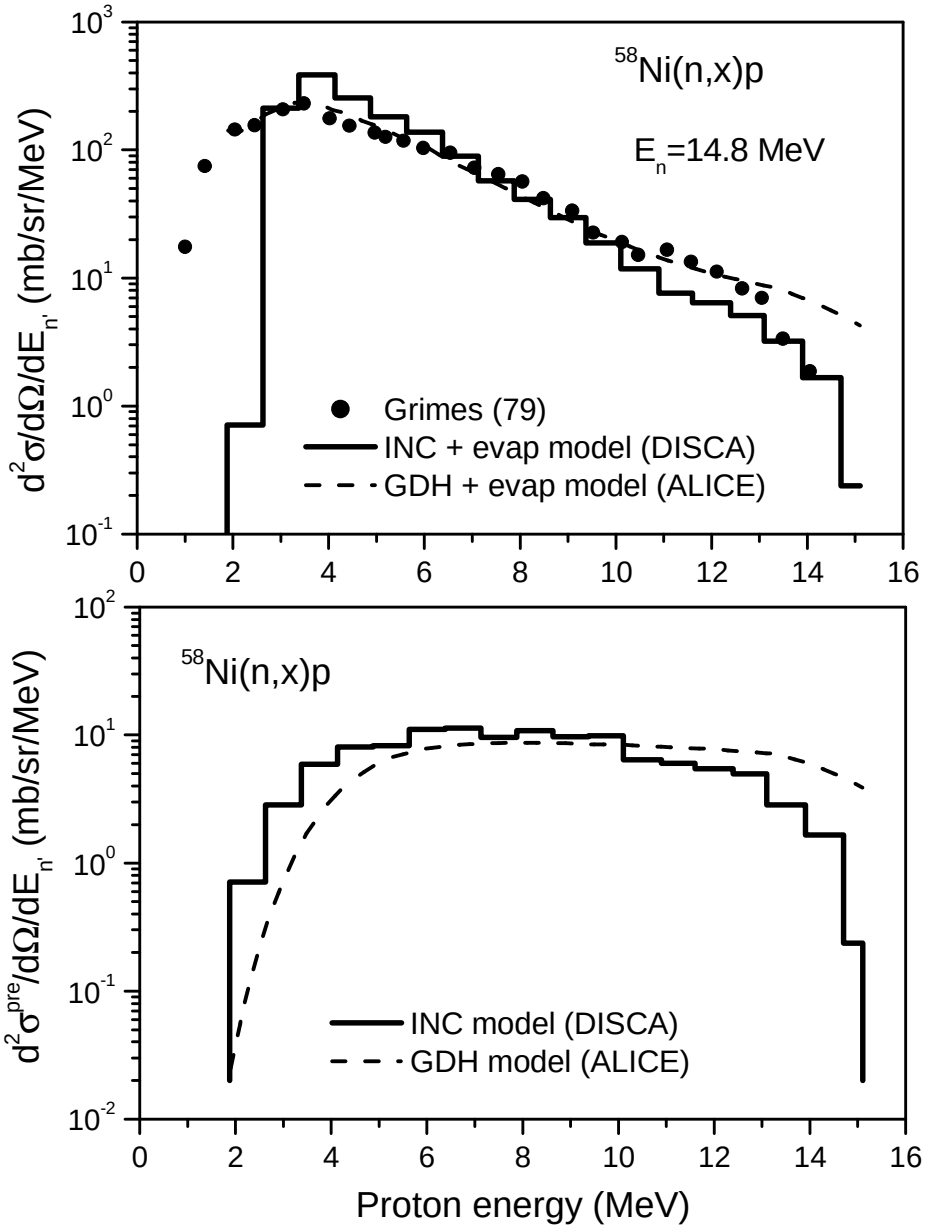

Fig.3 Proton energy distribution for the ^{58}Ni(n,x)p reaction induced by 14.8 MeV neutrons calculated using the intranuclear cascade evaporation model by the DISCA code (histogram) and using the geometry dependent hybrid exciton and evaporation model [28,29] by the ALICE (dashed line). Upper figure shows the sum of the non-equilibrium and evaporation spectrum, bottom figure shows the calculated non-equilibrium spectrum. Experimental data (circle) are taken from Ref.[30].

The probability of evaporation of the x-type particle from the excited nucleus is obtained by the Weisskopf formula

$$W_x \propto \int (2S_x + 1)\mu_x \varepsilon_x \sigma_{inv}(\varepsilon_x)\rho(U)d\varepsilon_x , \qquad (29)$$

where S_x, μ_x, ε_x are the particle spin, reduced mass and kinetic energy, correspondingly, σ_{inv} is the inverse reaction cross-section, $\rho(U)$ is the level density for the residual nucleus with the excitation energy U.

Instead of the crude approximation for $\rho(U)$ used in several codes [31] $\rho(U) = C\exp(2\sqrt{aU})$, where C is a constant, and "a" is the level density parameter, the nuclear level density is calculated according to the Fermi gas model

$$\rho(U) = (1/12)\pi^{1/2} a^{-1/4} U^{-5/4} \exp(2\sqrt{aU}) \qquad (30)$$

at the high excitation energy U and by the "constant temperature" model at low energy of excitation. The inverse reaction cross-sections are calculated using phenomenological formulas from Ref.[32], which approximate the results of optical model calculations. Evaporation is considered for neutrons, protons, deuterons, tritons, ^{3}He nuclei and α-particles.

2.8 Binding energies

The particle binding energies are calculated using the experimental masses of nuclei. If experimental data are absent, the formula of Myers, Swiatecki, Lysekil [29] is used to obtain the particle separation energy for residual nuclei (Z,N) with $Z - Z_C \leq 9$ and $N - N_C \leq 22$, where Z_C and N_C are numbers of protons and neutrons in initial compound nucleus. The algorithm of the calculation is taken from Ref.[29]. The binding energies for other nuclei are calculated using the Cameron formula [22]. The calculations for tritons and ^{3}He are always performed according to Cameron [22].

2.9 Total nonelastic interaction cross-section

The cross-section of nonelastic interaction of the primary particle with a nucleus (σ_{non}) is calculated internally by the code or estimated using the data for nucleons from Ref.[33] and for α-particles from Ref.[19] or calculated by approximating formulas [32].

The input variable INFS0 (Sect.7) defines what type of the nonelastic cross-section is used for the total normalization of the calculated residual nuclei yields and particle distributions.

The total cross-section of the interaction of an incident nucleon with a nucleus is calculated by the code as $\sigma_{tot} = \pi(R_{max} + \mathbf{D})^2$, where R_{max} is the radius of the outmost nuclear zone, $\mathbf{D}$ is the wavelength of the incident nucleon. The nonelastic reaction cross-section σ_{non} is defined as $\sigma_{non} = \sigma_{tot}(N/N_{tot})$, where N is the number of events resulting to nucleus excitation and N_{tot} is the total number of events.

Fig.4 shows the σ_{non} cross-section calculated using the DISCA code and obtained by the optical model with different set of the optical potentials. As can be seen from Fig.4 the calculations by the DISCA code are in agreement with the σ_{non} values obtained using the optical model.

2.10 Simulation of atomic displacements in materials

The DISCA code calculates the displacement cross-section for nonelastic interactions of incident particles with nuclei. The cross-section is calculated by the formula

$$\sigma_d(E_p) = \sum_i \int_{E_d}^{T_i^{max}} \frac{d\sigma(E_p, Z_T, A_T, Z_i, A_i)}{dT_i} \nu(T_i, Z_T, A_T, Z_i, A_i) dT_i \quad , \qquad (31)$$

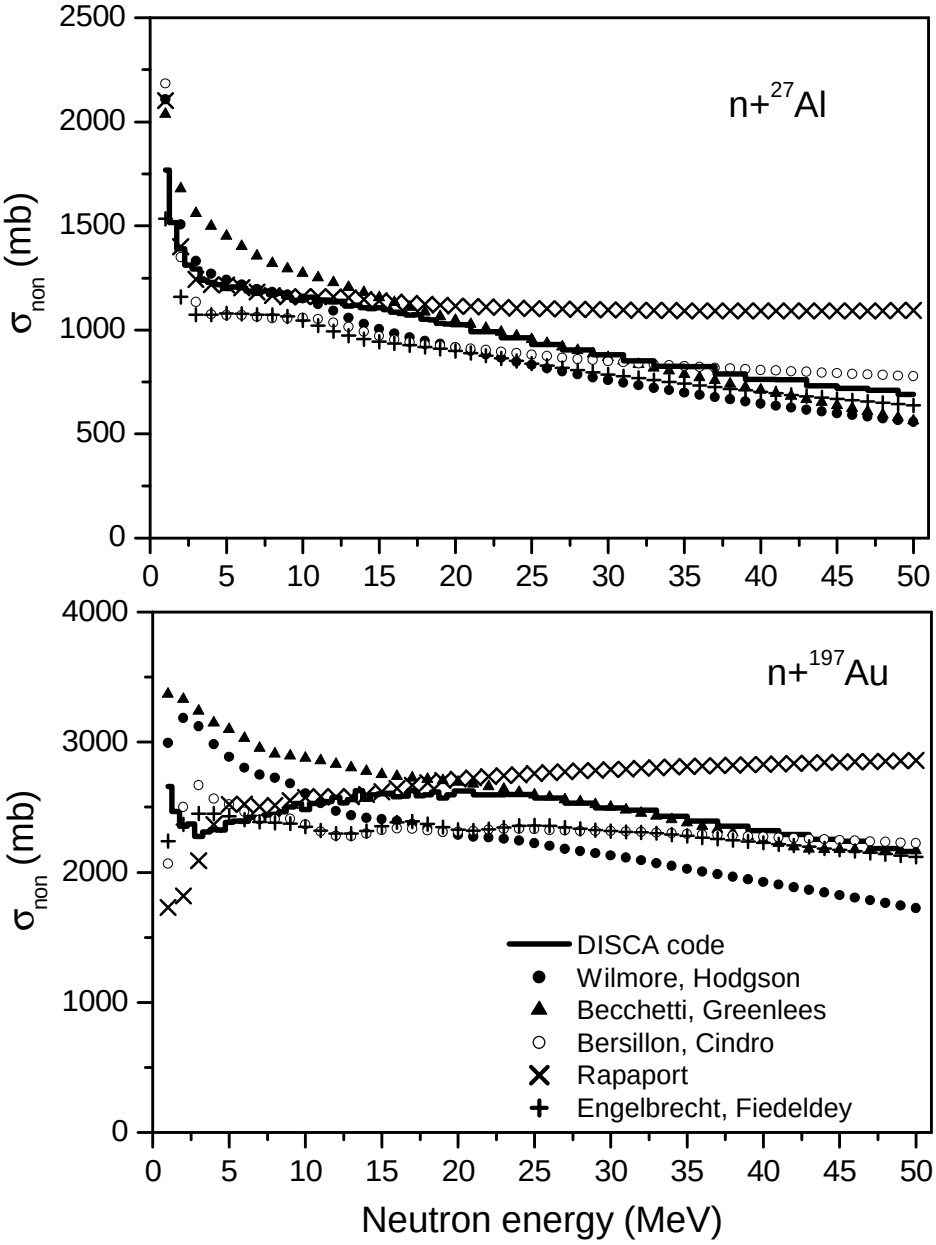

Fig.4 Total nonelastic interaction cross-section for ^{27}Al and ^{197}Au irradiated with neutrons, calculated by the DISCA code (histogram) and using the optical model [34] with potentials: Wilmore-Hodgson (dark circle), Becchetti-Greenlees (triangle), Bersillon-Cindro (open circle), Rapaport (cross), Engelbrecht-Fiedeldey (plus).

where E_p is the incident proton energy, $d\sigma/dT_i$ is the cross-section of energy transfer to recoil atom, Z_i and A_i are the atomic number and the mass number of the recoil atom, correspondingly, Z_T and A_T are the same for the target material, $\nu(T_i)$ is the number of Frenkel pairs produced by PKA with the kinetic energy T_i, T_i^{max} is the maximal energy of the PKA spectrum, E_d is effective threshold displacement energy, the summing is for all recoil atoms produced in the irradiation.

The number of defects produced by the PKA in material $\nu(T)$ is calculated according to the NRT approach [35] with the value of "k" parameter defined according to Robinson [36]

$$\nu(T) = \eta \frac{0.8}{2E_d} T_{dam}(T), \tag{32}$$

$$T_{dam}(T) = \frac{T}{1 + k\left(3.4008\,\varepsilon^{1/6} + 0.40244\,\varepsilon^{3/4} + \varepsilon\right)}, \tag{33}$$

$$k = \frac{32}{3\pi}\left(\frac{m_e}{M_T}\right)^{1/2} \frac{(A_i + A_T)^{3/2} Z_i^{2/3} Z_T^{1/2}}{A_i^{3/2}(Z_i^{2/3} + Z_T^{2/3})^{3/4}}, \tag{34}$$

$$\varepsilon = \left[A_T T/(A_i + A_T)\right]\left[a/(Z_i Z_T e^2)\right], \tag{35}$$

$$a = a_0 (9\pi^2/128)^{1/3}\left(Z_i^{2/3} + Z_T^{2/3}\right)^{-1/2}, \tag{36}$$

where η is the defect production efficiency [37], m_e is the mass of an electron, M_T is the mass of the target atom, a_0 is the Bohr radius, "e" is the electron charge; the kinetic energy T of the recoil atom is taken in keV.

In the DISCA calculations the η value is taken equal to unity. Subroutine DEFINE_ED contains the data for the effective threshold displacement energy E_d used for the σ_d computation.

3. Energy range of the model applicability

3.1 Low energy limit

As follows from the comparison of the DISCA calculations and experimental data the discussed intranuclear cascade evaporation model can be used for the calculation of total and differential cross-sections of nuclear reactions over the entire energy range in which pre-equilibrium exciton models are applicable, i.e. at energies above several mega electron-volts [24]. The applicability of the model at relatively low energies is due to the fact that the model algorithm takes into account the factors discussed above in Sect. 2.3 and 2.4.

The agreement between cross-sections calculated using the intranuclear cascade model discussed and those obtained by the hybrid exciton model [28,29] testifies to similarity of both approaches as noted in Ref.[38]. Both models are semi-classical and regard the dynamics of the non-equilibrium process as a series of quasi-free nucleon-nucleon interactions. The comparison of results of calculations with experimental data proves that the approximation of the intranuclear cascade model in which nucleons are assumed to follow quasi-classical paths is “not less reasonable” as the assumption of the hybrid exciton model concerning equal probabilities of configurations with a certain number of excitons and a transition from “n” to “n+2” exciton state as a result of interaction of the “leading” particle with the nucleons. The roughness of both approaches appears to be quite comparable.

The formal applicability criterion of the model applicability is the smallness of the incident particle wavelength compared to its free path length Λ within the nucleus [24]

$$\frac{\mathbf{D}}{\Lambda} = \frac{W}{E}\left(\frac{1+V}{E}\right)^{-1/2} << 1, \qquad (37)$$

where V and W are, respectively, the real and imaginary parts of the optical potential regarded as a square well, and E is the primary particle energy.

Taking into account the typical relation between the values of W and V values [24], condition Eq.(37) is actually met at energies above several mega electron-volts.

3.2 High energy limit

At present time, the model discussed does not suppose the nonelastic nucleon-nucleon interactions. For this reason the current version of the DISCA code is used for the simulations at the projectile energy up to 600-800 MeV.

4. Peculiarities of simulation of the non-equilibrium a-particle emission from nuclei

The calculations show that the knock-out of preformed α-particle resulting from elastic nucleon-α interaction plays the secondary role in the forming of the non-equilibrium α-particle emission distribution at medium energies of the α-spectrum. The energy distribution of α-particles calculated using the knock-out model (ζ=0 in Eq.(15),(20)) has a "hole" at the medium part of the spectrum, which is characteristic also of the calculations using the pre-equilibrium exciton model. Fig.5 shows the difference between experimental data [39] and the α-particle spectrum calculated by the pre-equilibrium exciton model [40] and intranuclear cascade model taking into account the knock-out of α-particles by the fast nucleons and neglecting the pick-up process.

In spite of the secondary role of the knock-out process in the non-equilibrium α-particle emission, the elastic nucleon interaction with preformed α-clusters has a noticeable effect on the nucleon emission at large emission angles. Fig.6 shows the double differential cross-section for protons emitted from the ^{90}Zr(p,p') reaction induced by 80 MeV protons. The calculations are performed with and without consideration of the α-particle knock-out in nuclear reaction. The pick up of the ^{3}He

or triton cluster forming α-particle was not considered in both cases (ζ=0). It can be seen from Fig.6 that the agreement with experimental data [41] is substantially improved with the consideration of the processes of the interaction of nucleons with α-clusters of the nucleus.

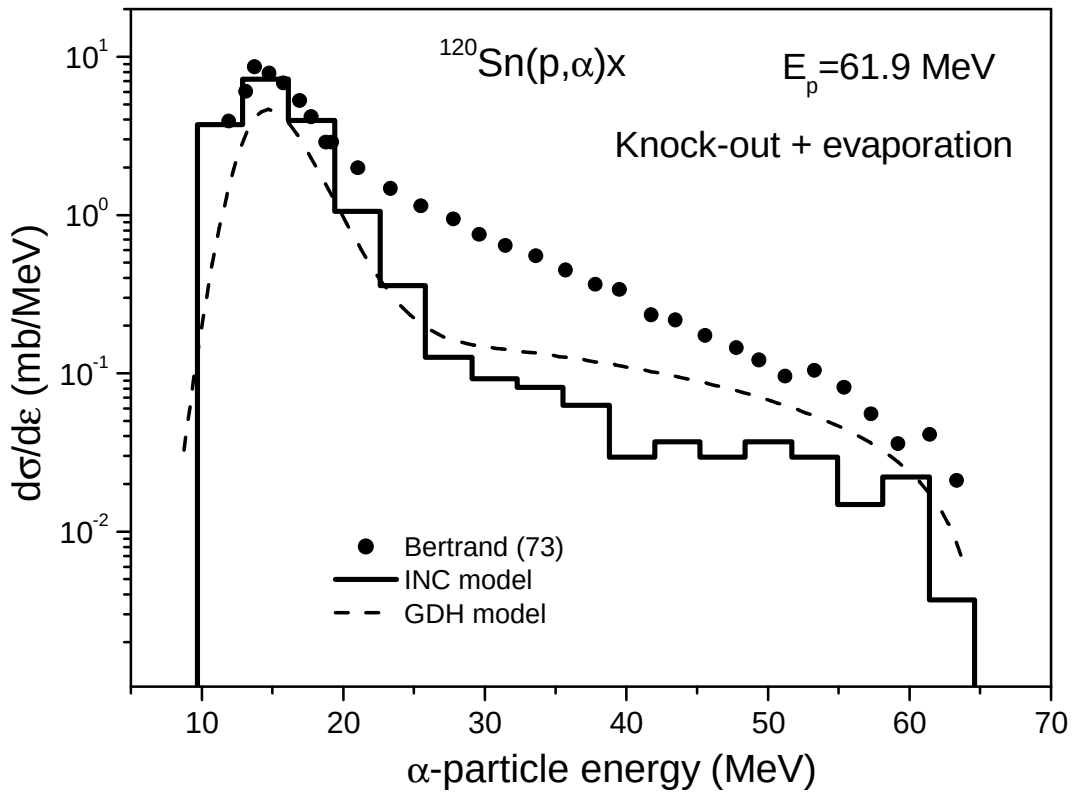

Fig.5 Contribution of the knock-out process and the evaporation in the energy distribution of α-particles emitted from the ^{120}Sn(p,α)x reaction induced by 61.9 MeV protons. Calculations are performed using the DISCA code (histogram) and the modified ALICE code [40] (dashed line). Experimental data are from Ref.[39].

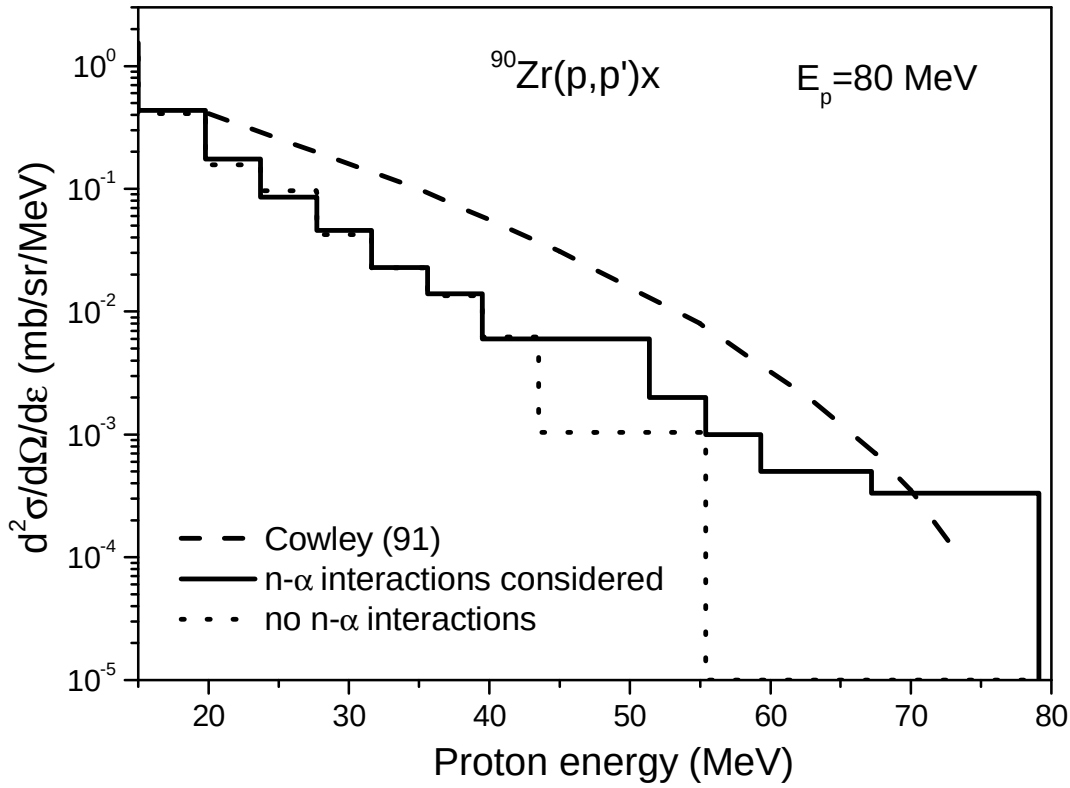

Fig.6 Double differential cross-section for protons emitted from the ^{90}Zr(p,p')x reaction induced by 80 MeV protons. Calculations are performed using the DISCA code with (solid histogram) and without (dashed histogram) consideration of the elastic nucleon-α interactions. Experimental data (dashed line) are from Ref.[41].

The experimental α-particle spectra from nucleon induced reaction at energies up to hundreds MeV are correctly described considering three basic mechanisms of the α-particle emission in nuclear reactions: the knock-out, pick-up and evaporation. Fig.7 shows the contribution of the different processes in the ^{209}Bi(p,α)x reaction induced by 90 MeV protons.

Next figure (Fig.8) shows the role of the nuclear regions with low density on the forming of the non-equilibrium α-particle spectrum. The calculations are performed assuming that the α-particles are formed only in the nuclear region with the density lower than $0.1 \cdot \rho_0$, where ρ_0 is the density of nucleons in the center of nucleus, and considering the α-particle formation in total nuclear volume. Fig.8 show that the calculated α-particle spectrum is formed mainly from intranuclear interactions in nuclear region with low density $\rho \leq 0.1 \cdot \rho_0$.

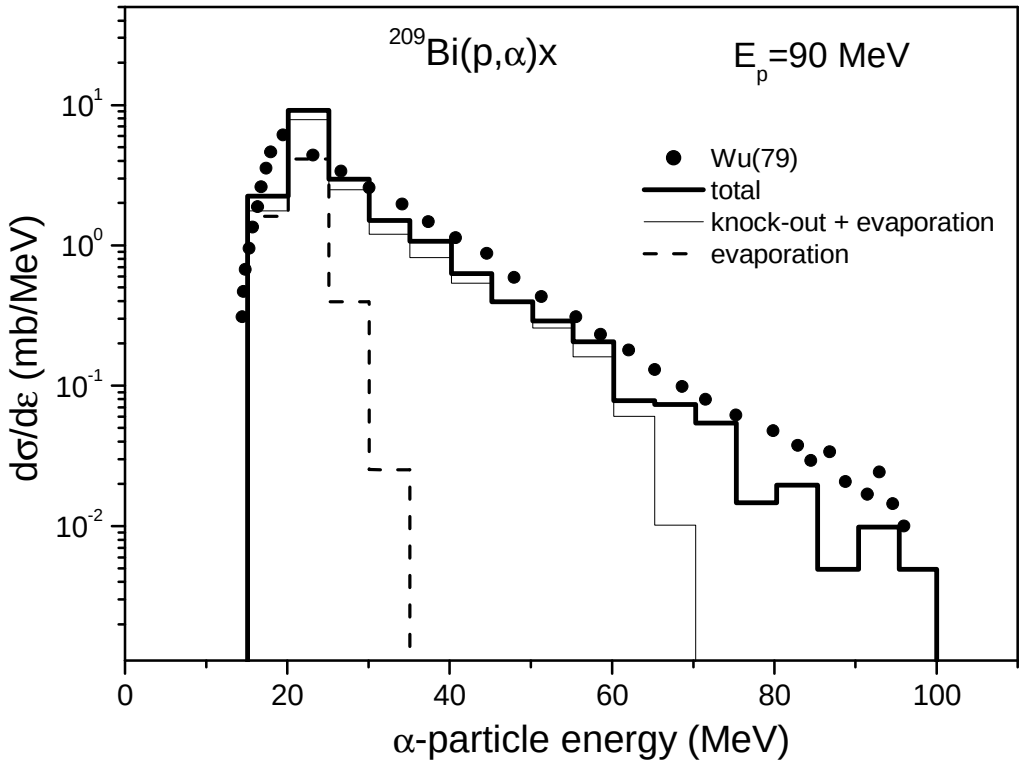

Fig.7 Contribution of the different processes in the of α-particle emission from the ^{209}Bi(p,α)x reaction induced by 90 MeV protons. Calculations are performed using the DISCA code (histograms). Experimental data are from Ref.[42].

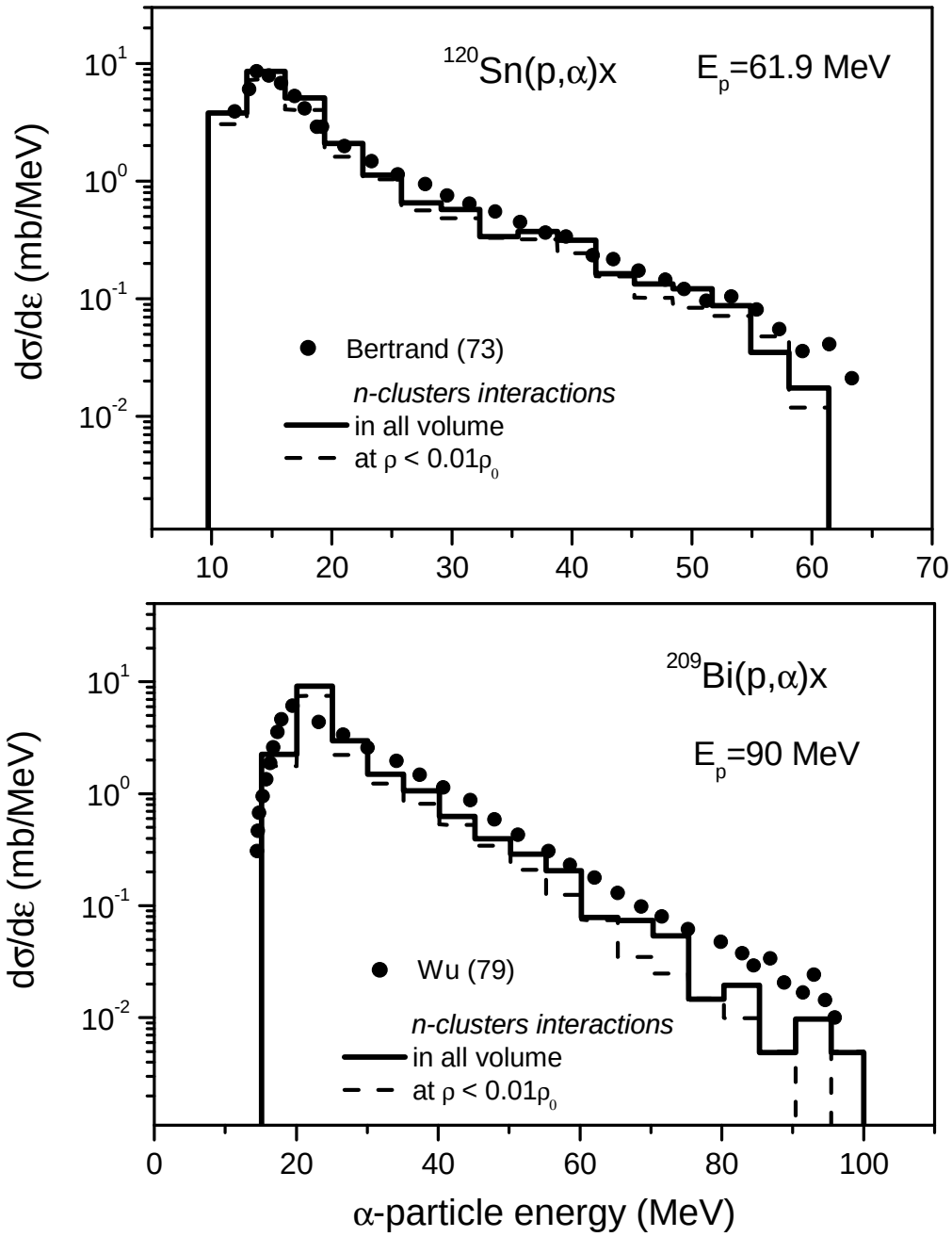

Fig.8 The α-particle emission spectrum calculated taking into account nucleon and preformed clusters (t, ^{3}He, α) interactions in all nuclear volume (solid histogram) and in the region with low density (dashed histogram). Experimental data are from Refs.[39,42].

Fig.9 shows an influence of the cluster momentum distribution on the calculated value of the α-particle emission spectrum for medium nuclei. Calculations were performed using Eq.(4)-(7) and simple approximations for the cluster momentum distributions and Fermi energies

$$N_x(\mathbf{p}_x)\,d\mathbf{p}_x \propto p^2\,dp\,d\Omega, \tag{37}$$

and

$$T^F_{\alpha i} = T^F_{ti} = T^F_{hi} = T^F_{ni}, \tag{38}$$

where symbol "x" refers to the α-particle, triton, ^{3}He and nucleon.

It is seen from Fig.9 that the use of the approximation equations Eq.(37),(38) instead of Eq.(4)-(7) results at the proton energy 62 MeV to the simple redefinition of the ζ value, Eq.(20). For 500 MeV protons the simulation of the cluster momentum distribution according to Eq.(37),(38) distorts high energy part of the calculated α-spectrum.

5. Examples of DISCA calculations

The applicability of the model for calculations at low projectile energies is illustrated by the data in Fig.10-12. The examples of calculated energy and angular α-particle distributions are shown in Fig.13-16.

Fig.17,18 demonstrate an importance of the consideration of the non-equilibrium α-particle emission to describe excitation functions of (p,xnypzα) reactions. Fig.19 shows the non-equilibrium component of the α-particle production cross-section for ^{197}Au. For the comparison the results obtained by the ALICE/ASH code is also shown. It is seen that despite of the difference of the models the knock-out contribution and the total non-equilibrium α-production cross-sections are close.

Many other examples of the DISCA code application can be found in Refs.[1-14, 24, 31, 38, 45-48].

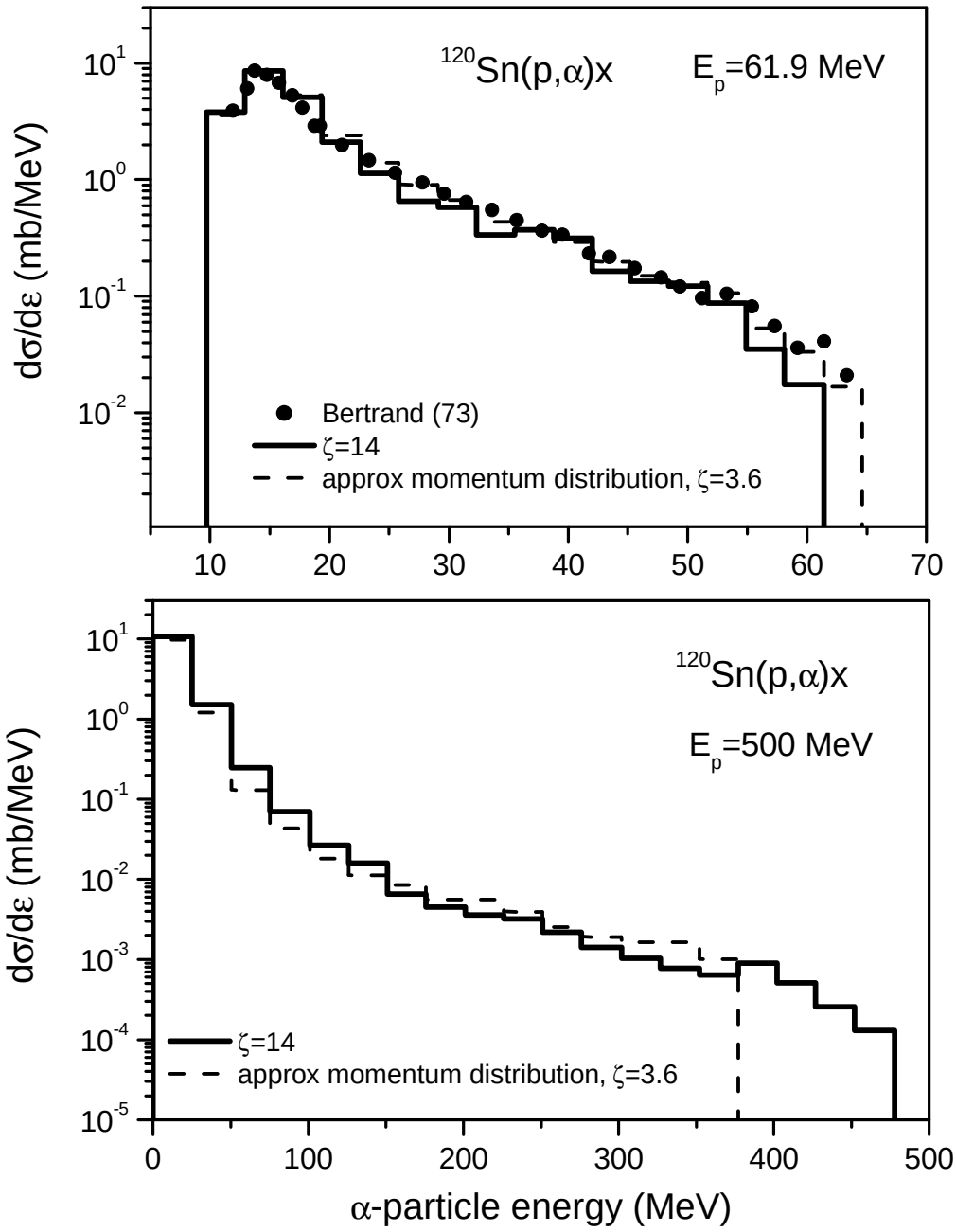

Fig.9 The α-particle emission spectrum calculated using Eq.(4)-(7) (solid histogram) and approximation expressions Eq.(37),(38) (dashed histogram) at different value of the ζ value. Experimental data are from Ref.[39].

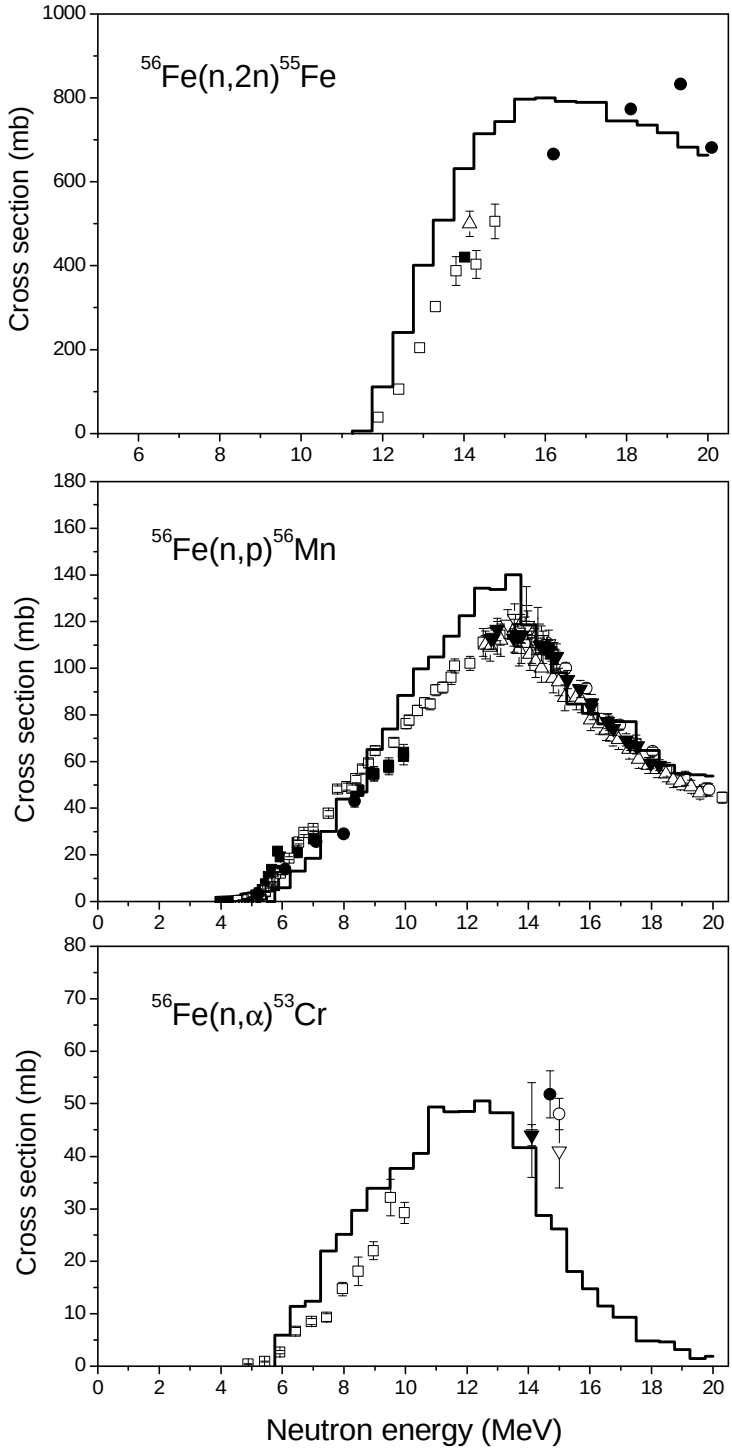

Fig.10 Neutron induced reaction cross-section for ^{56}Fe calculated using the DISCA code (histogram) at primary energies below 20 MeV. Experimental data are from EXFOR.

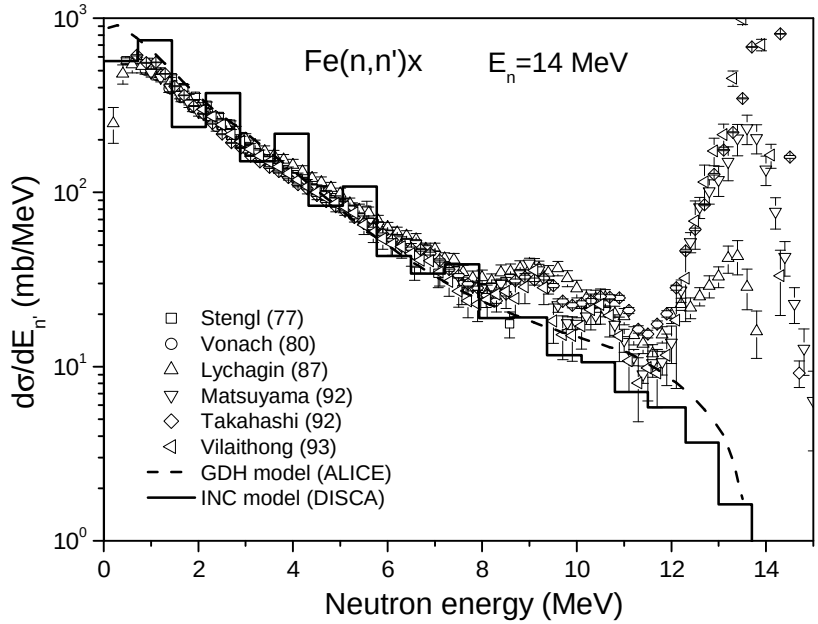

Fig.11 Neutron emission spectrum for the Fe(n,n')x reaction induced by 14 MeV neutrons calculated by the intranuclear cascade evaporation model using the DISCA code (histogram) and by the GDH model using the ALICE code [29] (dashed line). Experimental data are from EXFOR.

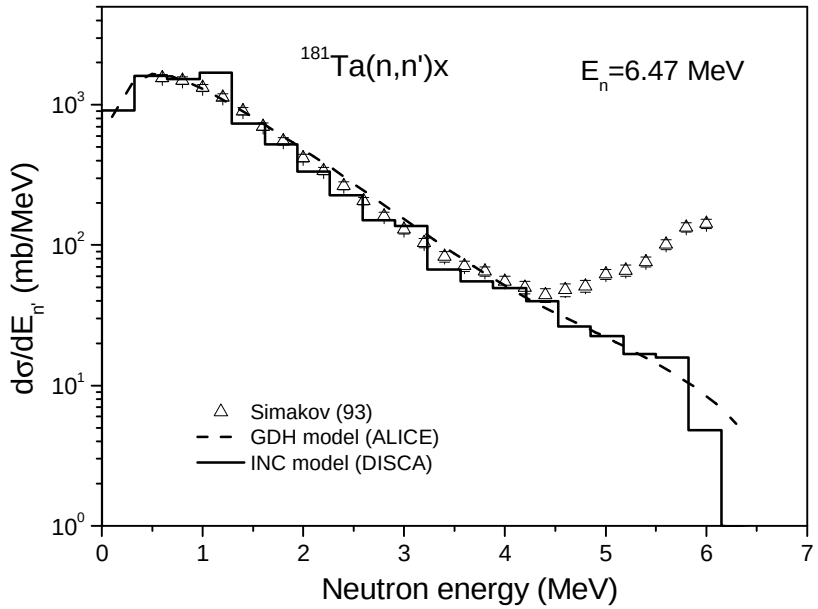

Fig.12 Neutron emission spectrum for the ^{181}Ta(n,n')x reaction induced by 6.47 MeV neutrons calculated using the DISCA code (histogram) and the ALICE code [29] (dashed line). Experimental data are from EXFOR.

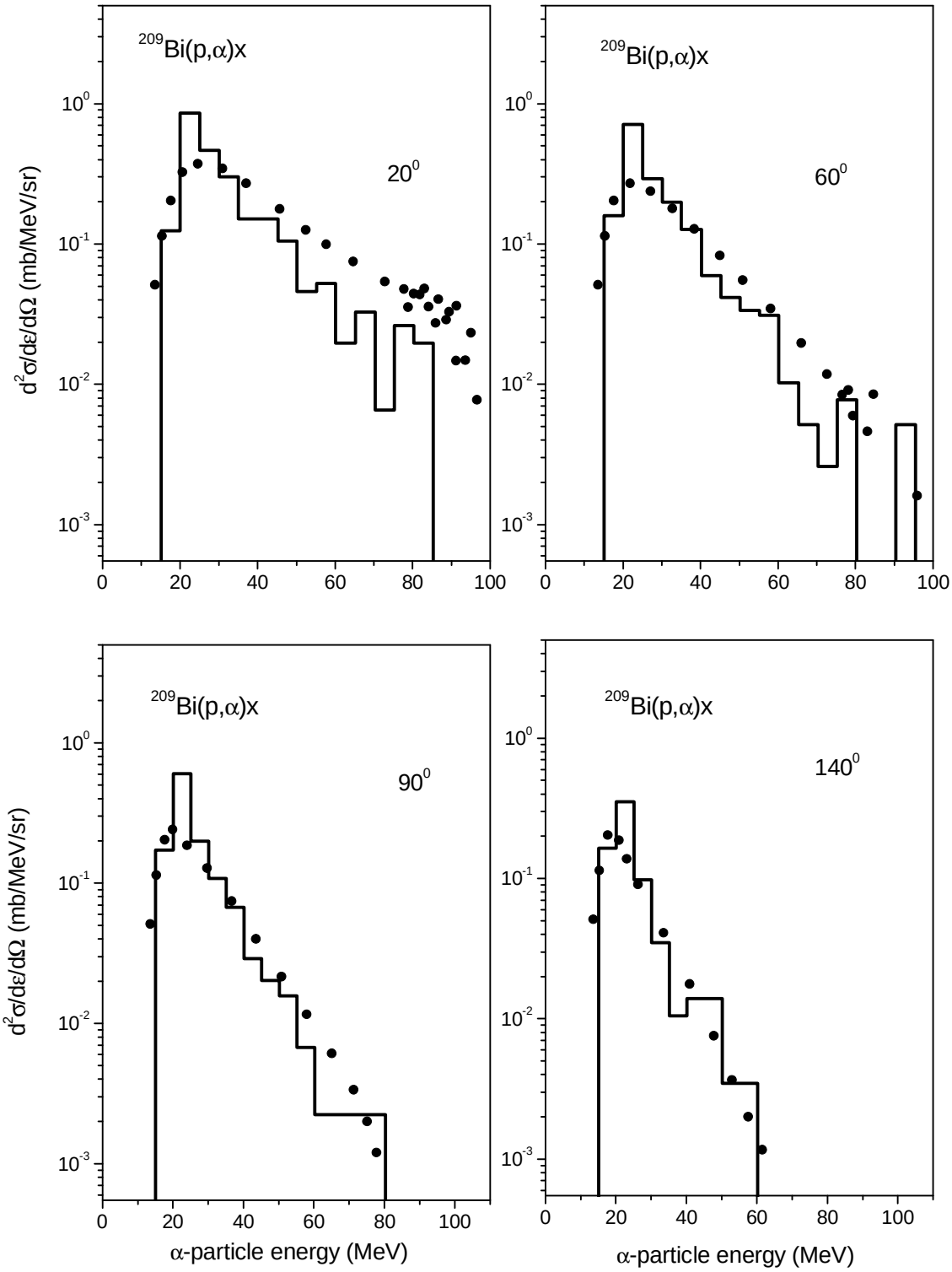

Fig.13 Calculated double differential cross-section for α-particles emitted from ^{209}Bi irradiated with 90 MeV protons. Experimental data (circle) are from Ref.[42].

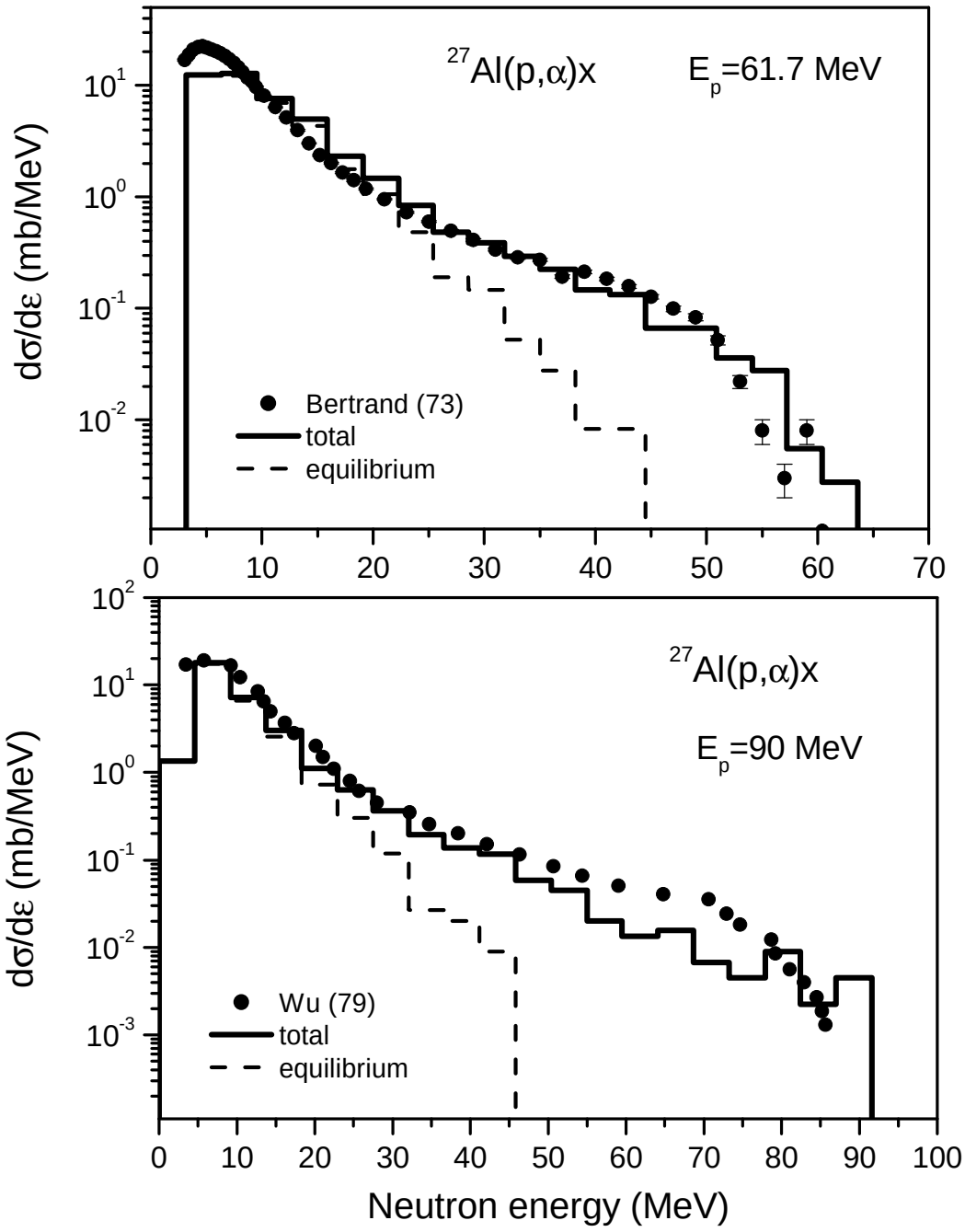

Fig.14 Energy distribution of α-particles from the ^{27}Al(p,α)x reaction induced by 61.7 and 90 MeV protons calculated using the DISCA code. Experimental data are from Refs.[39,42].

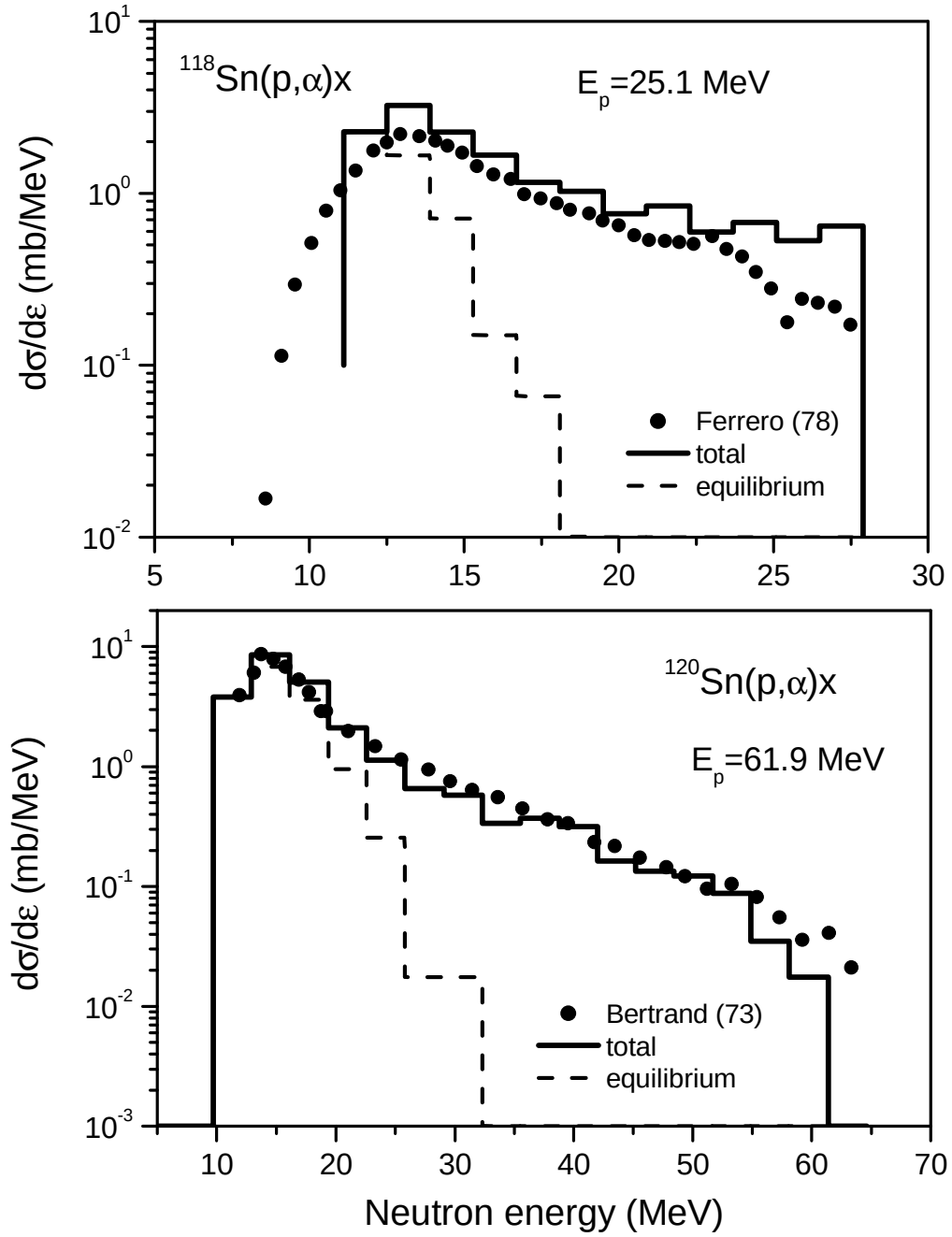

Fig.15 Energy distribution of α-particles from the ^{118}Sn(p,α)x reaction induced by 25.1 MeV protons and from the ^{120}Sn(p,α)x reaction induced by 61.9 MeV protons calculated using the DISCA code. Experimental data are from Refs.[39,43].

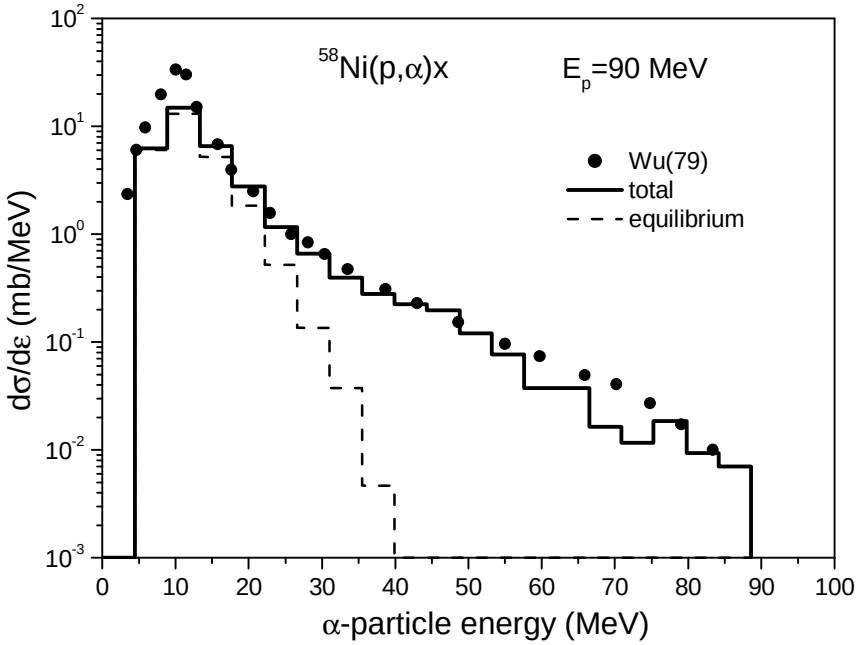

Fig.16 Energy distribution of α-particles from the ^{58}Ni(p,α)x reaction induced by 90 MeV protons calculated using the DISCA code. Experimental data are from Ref.[42].

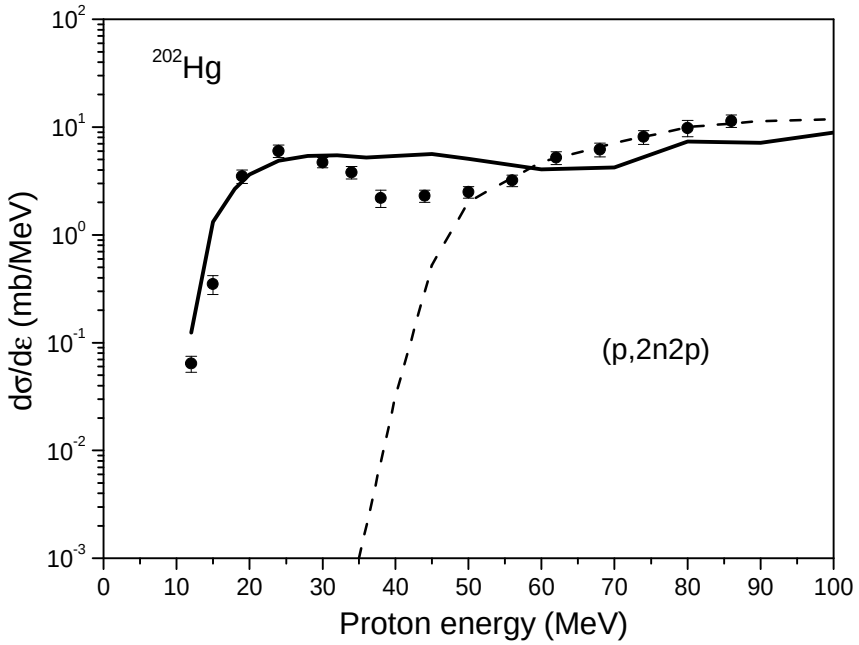

Fig.17 Excitation function of the (p,2n2p) reaction for ^{202}Hg calculated using the DISCA code with (solid line) and without (dashed line) consideration of nucleon-cluster interactions. Experimental data are from Ref.[44].

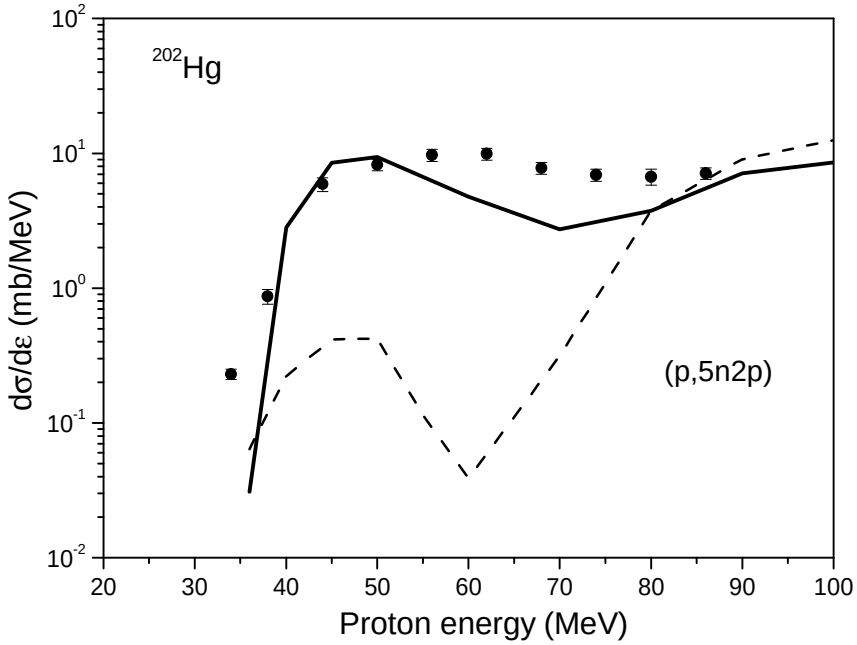

Fig.18 Excitation function of the (p,5n2p) reaction for ^{202}Hg calculated using the DISCA code with (solid line) and without (dashed line) consideration of nucleon-cluster interactions. Experimental data are from Ref.[44].

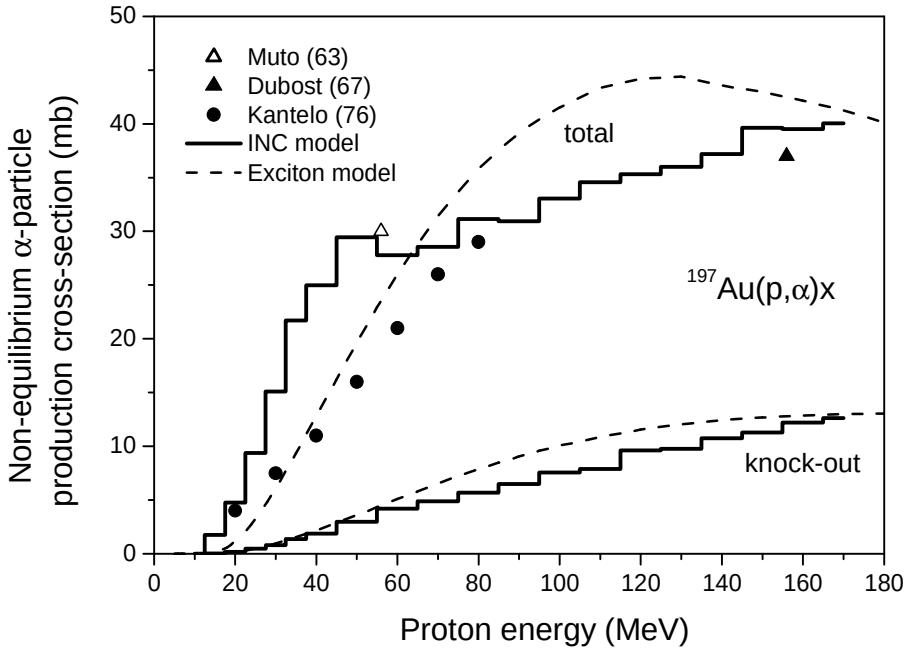

Fig.19 Production cross-section for non-equilibrium α-particles calculated using the DISCA code (φ_α=0.06, ζ=14) (solid line) and the ALICE/ASH code (dashed line). The parameters of the pre-equilibrium exciton model from the ALICE/ASH code were obtained from the analysis [14] of availbale experimental α-particle emission spectra. Experimental data are from Refs.[44,51,52].

6. Computer compatibility

The DISCA code is written in FORTRAN. The code uses a random number generator, which can be different for different FORTRAN compilers. The current version of the code uses the GNU FORTRAN built-in random number generator RAND. To substitute it by the other one it is necessary to check the FUNCTION RANDOM in the code.

7. Input data file

The structure of the input data reflects historical stages in the DISCA code development. New features were introduced in the code keeping the possibility to use the same input structure for old and new versions of the code. In particular, it simplifies the comparison of the calculations performed using the DISCA-C code and DISCA-S code, which implement different models for intranuclear interactions. The description of the input is given below.

Card 1. Name of output files NAMRD: “NAMRD.XXX”. Format is (A8).

Card 2. The title of the task described in 72 characters including blank spaces.

Card 3. Parameters INFBIG, INFS0, INFSCR, INFDOS,I NFDEN, INFSEP

Parameter INFBIG defines the size of printed information about details of the calculation. The value is from 0 to 3. Recommended: INFBIG = 0 or 1.

INFS0 defines the type of the cross-section for nonelastic interactions (σ_{non}) used for overall normalization of the results obtained. INFS0 = 1: the σ_{non} value is calculated using the Barashenkov data Ref.[33]; INFS0 = 2: the nonelastic cross-

section is calculated internally by the DISCA code; INFS0 = 3: the σ_{non} value is taken from the input file (*Card 10*); INFS0 = 4: the nonelastic cross-section is evaluated by the analytical expressions from Ref.[49] obtained using the results of optical model calculations. INFS0=4 is valid for nucleon incident energy up to 50 MeV. For incident α-particles INFS0 is set to 1. Recommended: INFS0 = 1.

INFSCR is the screen printing option for each Monte Carlo event proceeded. INFSCR = 1: yes, = 0: no.

INFDOS is not used in the present version of the code.

INFDEN defines the calculation of the non-equilibrium component of the triton and ^{3}He production cross-section according to the "nuclear bond breakdown" model from Ref.[50]. INFDEN=10: the calculations performed; INFDEN=0: no. Recommended: INFDOS = 10.

INFSEP is the option for the separate printing of the cross-sections calculated for a number of reactions (in addition to NAMRD.LIB file). INFSEP = 0 : no printing; INFSEP = 1: print cross-sections for reactions identified by the number of neutrons, protons and α-particles escaped. In this case the next lines of the input file must contain the number of particles. For example, for reactions (n,2n), (n,np2α), (n,4n2p) three lines must be supplied: 2 0 0; 1 1 2; –4 2 0, and the minus sign for the last line means the end of the reaction list. INFSEP = 2 is as =1, but reactions are identified by Z and A for residual nucleus. For example, for reactions producing ^{55}Fe and ^{54}Mn nuclei two lines must be added: 26. 55.; –25. 54. No more than cross-sections for 100 reactions are printed separately. Full information about the cross-sections obtained is written in the NAMRD.LIB file (Sect.8). If the INFSEP parameter is increased by 10, the file NAMRD.ALP will be created (see below). Recommended value of INFSEP is 10, 11 or 12.

Cards group 4 *(exact number depends from the number of reactions introduced according to the INFSEP parameter).* Cards contain angles and energies of secondary particles for printing double differential cross-sections.

Nine emission angles in degrees are read for each secondary particle by Format (1X,9F6.1) for the calculation of the double differential cross-section $d^2\sigma d\Omega^{-1}d\varepsilon^{-1}$ ($mb\cdot MeV^{-1}\cdot sr^{-1}$), which depends from the particle emission energy. Five energy intervals (MeV) are read by Format (1X, 5(F6.1,1X,F5.1)) for the double differential cross-section ($mb\cdot MeV^{-1}\cdot sr^{-1}$) calculation, which depends from the particle emission angle. The first symbol in each line ("N", "P" or "A") identifies the outgoing particle.

Data are presented for various outgoing particles in arbitrary order. Some particle types can be omitted. Note, that angles and energies introduced relate to the laboratory coordinate system. The double differential cross-sections are calculated for selected angles ± DCEN, where the value of DCEN is defined in subroutine INIDAT.

Card 5. Parameters FIALPH, XPARDE, FICAP, MZONA, KZONESC

FIALPH is the relative number of α-clusters in the nucleus. It is the φ_α parameter from Eq.(15). The typical FIALPH value is from 0.05 to 0.1.

XPARDE defines the value of the level density parameter for equilibrium states: a = A/XPARDE, where A is the atomic mass number. The typical XPARDE value is from 7 to 10.

FICAP defines the probability of the triton and ^{3}He cluster pick-up, which results to the α-particle formation. It is the ζ parameter from Eq.(20). The typical value is about 14.

MZONA defines the number of the nuclear zone, beginning with which the nucleon-clusters interactions are considered. The nuclear zones are counted from the center of the nucleus. The MZONA value depends from the value of the KZONESC parameter. The typical value is from 1 to 5 for the division of nucleus on ten concentric regions (KZONESC=0).

KZONESC defines the number of nuclear zones with constant density in the nucleus approximating Wood-Saxon density distribution. KZONESC = 0 or 1: the nucleus is subdivided on 10 zones. The division of the Wood-Saxon density distribution is defined by the A1(i) array values in the subroutine INIDAT. The most remote zone corresponds to the nuclear density 0.01 of the density at the center of the nucleus. KZONESC = 2: the nucleus is subdivided on 33 zones. The division is defined by the A2(i) array in the subroutine INIDAT. The most remote zone corresponds to the nuclear density 10^{-5} of the density at the center. Recommended: KZONESC=0.

Card 6. The number of Monte Carlo events, KHIST. The KHIST value corresponds to elastic and nonelastic interactions of the incident particle with the nucleus.

Card 7. Values MPARIN, Z, AN

MPARIN defines the type of the projectile. MPARIN = 1: incident particle is neutron; = 2: proton; = 3: α-particle.

Z and AN are atomic number and atomic mass number of the target nucleus.

Card 8. The kinetic energy of projectile, T0 in MeV

Card 9. The use of this and next cards relates to old input structure of the code. New energy on this *Card* will continue the calculations. If no real value is found on the *Card*, the input value is interpreted as IDOPCS value from the old input of the DISCA code. IDOPCS defines the reading of the nonelastic cross-section used for overall normalization of the results of calculations (see below).

Card 10. The card is used in the case if no incident particle energy is found on the *Card 9.*

The *Card* allows to read the nonelastic reaction cross-section CSABS (barn) used for overall normalization of the results.

Card 11. Parameter ICONT. The card is used in the case if no incident particle energy is found on the *Card 9*.

ICONT defines if the calculations continue for new incident energy and new IDOPCS value. Recommended: omit *Card 10* and *Card 11*.

Example of the INPUT file

Table 1 shows an example of the DISCA code input. The task consists in the simulation of the p+^{27}Al interaction at two proton incident energies equal to 62 and 90 MeV.

The nucleus is subdivided on ten concentric nuclear zones. The relative number of α-clusters, φ_α is equal to 0.05, the pick-up coefficient ζ is equal to 14. The simulation of the nucleon-cluster interactions is performed starting from fifth nuclear zone. The production cross-section for ^{22}Na, ^{24}Na and ^{26}Al is printed separately. Total number of Monte Carlo events for each incident energy is equal 200,000. The output file name is DISCAL27.

The energy and angular distribution will be printed for secondary neutrons, protons and α-particles. The double differential cross-section for neutrons escaped is calculated at 30^0, 60^0, 120^0 etc angles and for the outgoing energy intervals: from 17.5 to 22.5 MeV, from 37.5 to 42.5 MeV, from 57.5 to 62.5 MeV etc.

Table 1

```
DISCAl27
  Proton induced reaction for Al-27
0  1  1  0  10  12
 11  22
 11  24
-13  26
N  30.0  60.0 120.0 150.0 145.0 155.0 160.0 170.0 175.0
   17.5- 22.5  37.5- 42.5  57.5- 62.5  77.5- 82.5  95.0-105.0
P  20.0  30.0  45.0  60.0  75.0  90.0 105.0 120.0 140.0
   17.5- 22.5  37.5- 42.5  57.5- 62.5  77.5- 82.5  95.0-105.0
A  20.0  30.0  45.0  60.0  75.0  90.0 105.0 120.0 140.0
   55.0- 65.0  80.0- 90.0 100.0-120.0 110.0-140.0 200.0-300.0
0.05  9.0  14.0  5   1
200000
2  13. 27.
62.
90.
```

8. Output data files

The results of calculations are written in several output files. The name of files is defined by the character input variable NAMRD (Sect. 7). The brief description of output files is given below.

NAMRD.FUL contains detail information about calculations performed.

Printed:
- calculation options;
- cross-sections for reactions selected by the input parameter INFSEP;
- cross-sections for nonelastic interactions (barn) used for the particle production and displacement cross-section normalization;
- displacement cross-section (barn);
- neutron, proton, α-particle, deuteron, triton and ^{3}He production cross-sections (barn);
- energy and angular distributions of emitted particles in tables and in graphs. Units are mb/MeV for particle spectra and mb/MeV/sr for double differential cross-sections. Data are in the laboratory coordinate system.
- recoil spectrum (mb/MeV)

NAMRD.SHO contains information about the nonelastic cross-section, displacement cross-section and the particle production cross-sections.

NAMRD.LIB contains calculated cross-sections for all open reaction channels.

Printed: Z and A of the target nucleus, the energy of the projectile, the type of the projectile, the cross-section of nonelastic interactions (mb) used for the normalization of cross-sections printed, the origin of the nonelastic cross-

section (single character), number of chemical elements in the file (in brackets), the name of the code, number of Monte Carlo events corresponding to the nonelastic interactions, Z of the residual nucleus, number of isotopes (in brackets), A of the residuals, the production cross-sections (mb).

NAMRD.MLT contains information about particles emitted on the cascade and evaporation stages of the reaction.

Printed: details of the α-particle, triton and ^{3}He production, average energy of the excitation of residual nuclei formed after the cascade stage (MeV), multiplicity of neutrons, protons and α-particles emitted during the cascade and equilibrium stage of the reaction (dimensionless).

NAMRD.NNN, NAMRD.PPP and **NAMRD.AAA** contain neutron, proton and α-particle energy and angular distributions, respectively. The energy of ejectile is given in MeV. Spectra are given in mb/MeV and double-differential cross-sections are in mb/MeV/sr.

Printed: First column: the outgoing particle energy; second column: the non-equilibrium spectrum; third column: the evaporation spectrum; fourth: the total spectrum; columns 5-13: double differential cross-sections depending from the outgoing particle energy given in the first column; column 14: the angle of the particle emitted (degrees); columns 15-19: double differential cross-sections depending from the emission angle of the outgoing particle printed in 14 column. Energies and angles are given in the laboratory coordinate system.

NAMRD.ALP includes calculated non-equilibrium and total production cross-sections for α-particles (mb). Cross-sections are normalized on the

nonelastic cross-section printed in NAMRD.FUL and NAMRD.SHO files.

9. Publications relating to the DISCA code

The DISCA code has been used for

- the residual nuclei yields calculation in Refs.[9,12,24,31,46,47]
- the calculation of the energy and angular distribution of secondary particles in nuclear reactions in Refs.[12,24,38]
- simulation of deuteron interaction with nuclei in Ref.[13]
- the damage cross-section calculation in Refs.[1-5,7,10-12,45,48]
- the helium and tritium production calculation in Refs.[3,4,6-8,10-12,14,45].

REFERENCES

1. Konobeyev A.Yu., Korovin Yu.A., Sosnin V.N., Some Specific Features and Assumptions Related to Neutron Radiation Damage and Displacement Cross Sections Calculation at Neutron Energies above 10 MeV, *Transactions of Byelorussian Academy of Sciences, Phys. and Energ. Series (Vestsi Akademii Navuk BSSR. Ser. Fiz.-Energ. Navuk)*, **1** (1989) 3; Calculation of Neutron Displacement Cross Sections for Iron at Energies from 10 to 40 MeV**,** *Ibidem***, 2** (1989) 9.
2. Konobeyev A.Yu., Korovin Yu.A., Sosnin V.N., Radiation Damage in Muon Catalyzed Hybrid Reactors, *Kerntechnik*, **55** (1990) 358.
3. Konobeyev A.Yu., Cross-Sections for Calculations of Radiation Damage, Gas Production and Radioactive Nuclide Accumulation Rates at the Energies of Incident Particles up to 150 MeV, Institute of Nuclear Power Engineering, Obninsk, June 1990.
4. Korovin Yu.A., Konobeyev A.Yu., Sosnin V.N., BISERM, Neutron and Proton Data Library for Evaluation of Irradiation Effects in Structural Materials in the Energy Range up to 800 MeV, *Fusion Technology*, **20** (1991) 883.
5. Konobeyev A.Yu., Korovin Yu.A., Sosnin V.N., Neutron Displacement Cross Sections for Structural Materials below 800 MeV, *J. Nucl. Mat.*, **186** (1992) 117.
6. Konobeyev A.Yu., Korovin Yu.A., Helium Production Cross Sections in Structural Materials Irradiated by Protons and Neutrons at Energies up to 800 MeV, *J. Nucl. Mat.*, **195** (1992) 286.
7. Konobeyev A.Yu., Korovin Yu.A., Sosnin V.N., A Nuclear Data Library for Structural Material Radiation Damage Calculation at High Energies, *Kerntechnik*, **57** (1992) 188.
8. Konobeyev A.Yu., Korovin Yu.A., Tritium Production in Materials from C to Bi Irradiated with Nucleons of Intermediate and High Energies, *Nucl. Instr. and Meth.*, **B82** (1993) 103.
9. Artisyuk V.V., Konobeyev A.Yu., Korovin Yu.A., Nucleon Induced Reaction Cross-Sections for Strontium and Cesium at Energies 1 MeV to 10 GeV, *Kerntechnik*, **58** (1993) 174.
10. Korovin Yu.A., Stankovsky A.Yu., Konobeyev A.Yu., Pereslavtsev P.E., BISERM-2. Nuclear Data Library for Evaluation of Radiation Effects in Materials Induced by Neutrons of Intermediate Energies, IAEA-NDS-203, March 1997.

11. Korovin Yu.A., Konobeyev A.Yu., Pereslavtsev P.E., Stankovsky A.Yu., Broeders C., Broeders I., Fischer U., von Möllendorf U., Wilson P., Woll D., Evaluation and Test of Nuclear Data for Investigation of Neutron Transport, Radiation Damage and Processes of Activation and Transmutation in Materials Irradiated by Intermediate and High Energy Particles, Reffo, G. (Hrsg.), Proc. Int. Conf. on Nuclear Data for Science and Technology, Trieste, May, 19-24, 1997, Bologna, Ital. Phys. Soc., Part 1, p.851.
12. Konobeyev A.Yu., Elaboration of Methods for Nuclear Reaction Cross-Section Calculation and Creation Nuclear Data Libraries in Intermediate Energy Region, JINR, Dubna, March 1997.
13. Konobeyev A.Yu., Korovin Yu.A., Pereslavtsev P.E., Fischer U., von Möllendorff U., Development of Methods for Calculation of Deuteron-Lithium and Neutron-Lithium Cross-Sections for Energies up to 50 MeV, *Nucl. Sci. Eng.*, **139** (2001) 1.
14. Broeders C.H.M., Konobeyev A.Yu., Evaluation of ^{4}He production cross-section for tantalum, tungsten and gold irradiated with neutrons and protons at the energies up to 1 GeV, *Nucl. Instr. and Meth.*, **B234** (2005) 387.
15. Singh P.P., Schwandt P., *Nucleonika*, **21** (1976) 451.
16. Put L.W., Paans A.M.J., *Phys. Lett.*, **49B** (1974) 266.
17. Ferrero A., Gadioli E., Gadioli Erba E. et al., *Z. Phys.*, **A293** (1979) 123.
18. Chen K., Fraenkel Z., Friedlander G., Grover J.R., Miller J.M., Shimamoto Y., *Phys. Rev.*, **166** (1968) 949.
19. Barashenkov V.S., Polanski A. Electronic Guide for Nuclear Cross Sections, JINR, Laboratory of Computing Techniques and Automation, Dubna, 1993.
20. Barashenkov V.S. Cross-Sections for Interaction of Particles and Nuclei with Nuclei, JINR, Dubna, 1993.
21. Iwamoto A., Harada K., *Phys. Rev.*, **C26** (1982) 1821.
22. Barashenkov V.S., Toneev V.D. Interaction of High Energy Particles and Atomic Nuclei with Nuclei, Atomizdat, Moscow, 1972; [Engl. transl.: FTD-ID (RS) T-1069-77, July 1977].
23. Ostroumov V.I., Filov R.A., *Sov. J. Experim. Theor. Phys.*, **37** (1959) 643.
24. Konobeyev A.Yu., Korovin Yu.A., Application of the Intranuclear Cascade Evaporation Model, *Kerntechnik*, **63** (1998) 124.
25. Bunakov, V.E., Nesterov, M.M., Tarasov, N.A., *Bulletin of the Academy of Sciences of the USSR. Physical Series*, **41(10)** (1977) 168; *Izvestiya Akademii Nauk SSSR. Seriya Fizicheskaya*, **41** (1977) 2187.

26. Marcinkowski A., Finlay, R.W., Randers-Pehrson G., Brient C.E., Kurup R., Mellema S., Meigooni A., Tailor R., *Nucl. Sci. Eng.*, **83** (1983) 13.

27. Bertini H.W., Harp G.D., Bertrand F.E., *Phys. Rev*. **C10** (1974) 2472.

28. Blann M., Vonach H.K., *Phys. Rev.*, **C 28** (1983) 1475.

29. Blann M., ALICE-91: Statistical Model Code System with Fission Competition, RSIC Code Package PSR-146.

30. Grimes S.M., Haight R.C., Alvar K.R., Barschall H.H., Borchers R.R., *Phys. Rev*., **C19** (1979) 2127.

31. International Codes and Model Intercomparison for Intermediate Energy Activation Yields, NSC/DOC(97)-1, Jan. 1997, http://www.nea.fr/html/science/docs/1997/nsc-doc97-1/

32. Chatterjee A., Murthy K.H.N., Gupta S.K., Optical Reaction Cross Sections for Light Projectiles, INDC(IND)- 27/GJ, 1980.

33. Barashenkov V.S. Nucleon-Nucleus Cross-Sections, JINR, Dubna, R2-89-770, 1989.

34. Bersillon O., Centre d'Etudes de Bruyeres-le-Chatel, CEA-N-2227, NEANDC (FR)220"L", INDC(E) 49/L, Oct. 1981.

35. Norgett M.J., Robinson M.T., Torrens I.M., *Nucl. Eng. Des*., **33** (1975) 50.

36. Robinson M.T., *J. Nucl. Mater*., **216** (1994) 1.

37. Broeders C.H.M., Konobeyev A.Yu., *J. Nucl. Mater*. **328** (2004) 197.

38. Shubin Yu.N., Lunev V.P., Konobeyev A.Yu., Korovin Yu.A., Comparison between Preequilibrium and Intranuclear Cascade Models at Intermediate Energies. In: Intermediate Energy Nuclear Data: Models and Codes, Proc. Specialists' Meeting. Issy-Les-Moulineaux, France, June 1994, OECD, p.35.

39. Bertrand F.E., Peelle R.W., *Phys. Rev*. **C8** (1973) 1045.

40. Konobeyev A.Yu., Lunev V.P., Shubin Yu.N., Pre-Equilibrium Emission of Clusters, *Acta Physica Slovaca*, **45** (1995) 705.

41. Cowley A. A., van Kent A., Lawrie J. J., Förtsch S. V., Whittal D. M., Pilcher J. V., Smit F. D., Richter W. A., Lindsay R., van Heerden I. J., Bonetti R., Hodgson P. E., *Phys. Rev*., **C43** (1991) 678.

42. Wu J.R., Chang C.C., Holmgren H.D., *Phys. Rev*., **C19** (1979) 698.

43. Ferrero A.M., Iori I., Molho N., Zetta L. (p,α) Reactions on: Nb, Ag, Sn, Ho, Tm from ~ 20 to ~ 44 MeV Incident Proton Energy, Instituto Nazionale di Fisica Nucleare, Milano, INFN/BE-78/6, 1978.

44. Kantelo M.V., Hogan J.J., *Phys. Rev.*, **C13** (1976) 1095.

45. Konobeyev A.Yu., Korovin Yu.A., Sosnin V.N., The Code DIDACS/88 for Calculation of Displacement Cross Sections, Hydrogen, Helium and Long-Lived Radionuclide Production Cross Sections for Structural Materials Irradiated with Nucleons at Energy up to 200 MeV, *Atomnaya Energiya* (*Soviet Atomic Energy*), **71** (1991) 168.

46. Korovin Yu.A., Konobeyev A.Yu., Pereslavtsev P.E., Comparison of Different Approaches for Nucleon Induced Reaction Cross-Section Calculation for Nonstable Long-Lived Fission Products at the Intermediate and High Energies, Yasuda, H. (Hrsg.), Emerging Nuclear Energy Systems (ICENES'93): Proc of the 7th Int. Conf., Makuhari, Japan, Sept. 20-24, 1993, p.444, Singapore, World Scientific, 1994.

47. Korovin Yu.A., Konobeyev A.Yu., Pereslavtsev P.E., Calculation of Proton Induced Reaction Cross Sections For Zirconium Isotopes at Intermediate and High Energies, *Voprosy Atomnoi Nauki i Techniki (Problems of Nuclear Science and Technology), Series: Nuclear Data*, **1** (1994) 81.

48. Konobeyev A.Yu., Konobeev Yu.V., Korovin Yu.A., Nuclear Data to Study Damage in Materials under Irradiation by Nucleons with Energies up to 25 GeV, *J. Nucl. Sci. Technol.*, **Suppl. 2**, (2002) 1236.

49. Chatterjee A., Murthy K.H.N., Gupta S.K., Optical reaction cross sections for light projectiles, INDC(IND)- 27/GJ, 1980.

50. Denisov F.P., Mekhedov V.N., Nuclear Reactions at High Energies, Atomizdat, Moscow, 1972.

51. Muto J., Iton H., Okano K., Shiomi N., Fukuda K., Omori Y., Kinara M., *Nucl. Phys.* **47** (1963) 19.

52. Dubost H., Gatty B., Lefort M., Peter J., Tarrago X., *J. de Physique* **28** (1967) 257.

The text of the DISCA code

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                                         *
*                                                      Version: 2005      *
*                                                                         *
*  DISCA-C/05                                                             *
*                                                                         *
*                                                                         *
* Intranuclear cascade evaporation model with clusters                    *
*                                                                         *
*                                                                         *
*                                                                         *
*                                                                         *
*                                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      CHARACTER NAMRD*8, IDPA*1, NAMPAR(3)*1, C80*80
      REAL*8 INFGEN
      COMMON/DATINI/RA,T0,W0 /NPROL/NPROL/KHIST/KHIST
      COMMON/CSABS/CSABS,FIALP2 /INFGEN/INFGEN(9) /IWRI/IWRI
      COMMON/EOUT/SPE(19,5,3),PI(19),EOUT1(5,3),EOUT2(5,3),MSPE
      COMMON/SPEFUL/ANGLIM(9,2,3),ANGSUM(21,9,3),ANGCEN(9,3),DCEN,MANG
      COMMON/TEMP2/BONNE /XPARAM/XPARAM,FIALPH /NREJ/REFR,NREJ
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/EVA/PARALP,PARPRO /INFDIS/INFDIS,INFOUP(3)
      COMMON/MAIIPR/IPR /AN/AN  /INF/INFBIG,INFS0
      COMMON/IDOPCS/IDOPCS /MPARIN/MPARIN /MAX/MAXNEU,MAXPRO
      COMMON/INF001/INFKAL /INF002/INFDOS
      COMMON/INF003/INFDEN /INF004/KHIST0 /INFBON/IBOND
      COMMON/INF005/INFDM /INFSEP/KSEP(100,4),INFSEP,JSEPM
      COMMON/LIB91/WINLIB(100,250),INFLIB
      COMMON/K1996/K1996 /FICAP/FICAP,MZONA
      DATA NAMPAR/1HN,1HP,1HA/
C
C Input data file
C
      Open(5,file='disca.dat')
C
C  INPUT CARD 1
C**************
C---------------------------------------------------------------------
C
C   NAMRD: Name of output files Namrd.XXX
C---------------------------------------------------------------------
            Read(5,111)Namrd
111         Format(a8)
C
      CALL OPEN_OUTPUT_FILES(NAMRD)
C
C
C Define general options for calculations
C
```

```
      CALL OPTIONS(IPR,BONNE,IWRI,INFKAL)
C
C  INPUT CARD 2
C**************
C-----------------------------------------------------------------------
C
C   INFGEN(): Text from 72 symbols will be printed in output file
C-----------------------------------------------------------------------
          READ(5,1900)(INFGEN(I),I=1,9)
C
C
C  INPUT CARD 3
C**************
C-----------------------------------------------------------------------
C
C     INFBIG       : defines the bulk of the printed results of
C                    calculation
C              = 0  : most appropriate information will printed; the
C                    arrays of COMMON Block MASOUT are not used in
C                    counting of events
C              = 1  : additional information about options and parameters
C                    of calculation
C              = 2  : printing of the lumped cross-sections and displa-
C                    cement cross-sections for reactions (1988)
C              = 3  : the same as =2, but detail information for
C                    reactions (1988)
C Recommended: INFBIG=0
C
C     INFS0        : defines the type of nonelastic cross-section
C                    used for normalization of the cross-sections
C                    and particle spectra obtained
C              = 1  : data taken from Barashenkov, JINR, R2-89-770,
C                    1989 (Subr BARASH)
C              = 2  : nonelastic cross-section is calculated by the code
C                    using the INC model
C              = 3  : data taken from input file (unit=5) is used
C              = 4  : nonelastic cross-section is calculated according
C                    to Chatterjee A. et al, IAEA,INDC(IND)- 27/GJ, 1980
C                    Valid only for incident particle energies below
C                    50 MeV. For primary alpha-particles INFS0 is turned
C                    to 1.
C Recommended: INFS0=1
C
C     INFSCR       : screen printing option for each Monte Carlo event
C                    proceeded, = 1  yes,  = 0 no.
C Recommended: INSCR=1
C
C     INFDOS       : defines the Coulomb potential calculations for inve-
C                    rse reaction cross-sections (not used since 1996)
C              = 0  : Coulomb potential is taken according to M.Blann
C              = 1  : Coulomb potential is calculated according to
C                    V.M.Bychkov et al, 1982
C Recommended: INFDOS=0
C
C     INFDEN       : level density parameter calculation
C              = 0  : a=A/XPARDE,  ( XPARDE defined below )
C              = 1-4: not used since 1996
C If INFDEN increased by 10, the non-equilibrium component of the triton,
C and He-3 production cross-section is calculated according to the
```

```
C "nuclear bond breakdown" model of  F.P.Denisov, V.N. Mekhedov,
C "Nuclear Reactions at High Energies", Atomizdat, Moscow 1972, p.112
C Recommended: INFDOS=10
C
C     INFSEP       : option for printing of cross-sections for separate
C                    reactions
C             = 0  : no printing
C             = 1  : print cross-sections for reactions identified by
C                    the number of neutrons, protons and alphas escaped.
C                    For example for reactions (n,6np2a),(n,2n10p) one
C                    should insert two lines with
C                     6 1 2
C                    -2 10 0
C                    (minus means the end of reaction list ( < 100 )
more than 100)
C             = 2  : as =1, but reaction is identified by Z and A for
C                    residual nucleus. For example, for reactions
C                    resulting to nuclides 26. 55. and 25. 54. one should
C                    insert
C                     26. 55.
C                    -25. 54.
C If INFSEP increased by 10, the alpha particle production cross-section
C and its non-equilibrium component will printed in file NAMRD.ALP
C Recommended: INFSEP=10, 11 or 12
C
C-----------------------------------------------------------------------
          READ(5,*)INFBIG,INFS0,INFSCR,INFDOS,INFDEN,INFSEP
C
          INFLIB=0
          IF(INFSEP.GE.10) INFLIB=1
          IF(INFSEP.GE.10) INFSEP=INFSEP-10
      IF(INFSEP.EQ.1) CALL INSEP
      IF(INFSEP.EQ.2) CALL INSEP2
      INFDM=0
      IF(INFDEN.GE.10)INFDM=1
      IF(INFDEN.GE.10)INFDEN=INFDEN-10
C
C INPUT CARD GROUP 4 (or depends from number of reactions by INFSEP)
C*******************
C-----------------------------------------------------------------------
C
C Read angles and energies to store characteristics of secondary particles
C
C    The double differential cross-sections are calculated for selected
C angles +/- DCEN (DCEN defined in Subr INIDAT) and selected energy ranges.
C    The first symbol in each line identifies an outgoing particle. Use
C N,P and/or A only.
C    Nine angles (degrees) are read for each secondary particle by format
C (1X,9F6.1) for the double differential cross-section d^2S/dOdE calcula-
C tion depending from particle emission energy (mb/MeV/sr) and five energy
C intervals (MeV) by format (1X, 5(F6.1,1X,F5.1)) for the double differen-
C tial cross-section calculation depending from emission angle (mb/MeV/sr)
C Example
CN   5.0  20.0  40.0  60.0  80.0 100.0 120.0 140.0 160.0
C   40.0- 50.0  80.0- 90.0 100.0-120.0 110.0-140.0 200.0-300.0
CP   5.0  20.0  40.0  60.0  80.0 100.0 120.0 140.0 160.0
C   40.0- 50.0  80.0- 90.0 100.0-120.0 110.0-140.0 200.0-300.0
C
C Note. Angles and energies relate to LCS system. Data can be introduced
```

```
C for different particles in arbitrary order. Any particle types can be
C omitted.
C-----------------------------------------------------------------------
C
          INFDIS   =0
          INFOUP(1)=0
          INFOUP(2)=0
          INFOUP(3)=0
                    MANG=9
                    MSPE=5
2900    READ(5,3001)IDPA
3001    FORMAT(A1)
        DO 3100 MP=1,3
        IF(IDPA.EQ.NAMPAR(MP) ) GOTO 3300
3100    CONTINUE
        GOTO 4500
3300        BACKSPACE 5
            INFOUP(MP)=1
            READ(5,5000)(ANGCEN(ICEN,MP),ICEN=1,9)
5000        FORMAT(1X,9F6.1)
            READ(5,5001)(EOUT1(LL,MP),EOUT2(LL,MP),LL=1,5)
5001        FORMAT(1X, 5(F6.1,1X,F5.1) )
            GOTO 2900
4500    BACKSPACE 5
        IF(INFOUP(1).EQ.1.OR.INFOUP(2).EQ.1.OR.INFOUP(3).EQ.1)INFDIS=1
        IF(INFDIS.EQ.0)PRINT 3200
C
C
C INPUT CARD 5
C*************
C-----------------------------------------------------------------------
C
C     FIALPH       : the relative number of alpha-clusters in nucleus.
C                    Typical FIALPH values are from 0.05 to 0.1
C
C     XPARDE       : defines level density parameter for equilibrium
C                    states, a = A/XPARDE. (XPARDE =8...10)
C
C     FICAP        : defines the pick-up probability for t ar He-3
C                    cluster resulting to alpha-particle formation.
C                    FICAP is about 14.
C
C     MZONA        : number of nuclear zone, beginning with which the
C                    non-equilibrium effects with alpha clusters are
C                    considered. The zones are counted from center of
C                    the nucleus. (MZONA depends from KZONESC value)
C                    Typical value is 1...5 for ten nuclear zones
C                    (KZONESC=0)
C
C     KZONESC      : defines number of zones with constant density in
C                    the nucleus approximating Wood-Saxon density distri-
C                    bution
C         = 0 or 1 : 10 zones. The division of the density distribution
C                    is defined by A1( ) array in Subr INIDAT. The most
C                    remote zone corresponds to the nuclear density 0.01
C                    of the density at the center.
C         = 2      : 33 zones. The division is defined by A2( ) array
C                    in Subr INIDAT. The most remote zone corresponds to
C                    the nuclear density 1.E-05 of the density at the
```

```
C                    center.
C Recommended: KZONESC=0
C
C---------------------------------------------------------------------
           READ(5,*)FIALPH,XPARDE,FICAP,MZONA,KZONESC
C
       XPARAM=1./XPARDE
                                      FI=FIALPH
C
C
C IBOND defines the method of the particle binding energy calculation
C        = 3 : the separation energy for neutrons, protons, deuterons
C              and alpha-particles is calculated using the table of
C              experimental masses and MSL-formula (M.Blann, Report
C              LLL(USA), UCID19614(1982)) for nuclei with
C              Z - Z(compound) < 9 and N - N(COMPOUND) < 22. For other
C              cases the Cameron formula is used.
C        = 2 : use the Cameron formula
C        = 1 : not used since 1993
C If IBOND  < 0   : test printing for selected ABS(IBOND) option
C
      IBOND=3
      IBONDS=IABS(IBOND)
C
C PARALP and PARPRO are normalization coefficients for "old"
C Dostrovsky et al formulas for inverse cross-sections
C (See also Barashenkov, Toneev, "Interaction...",1972, p.413)
          PARALP=1.
          PARPRO=1.
C
C
C INPUT CARD 6
C*************
C---------------------------------------------------------------------
C
C     KHIST  :  the number of Monte Carlo events
C
C---------------------------------------------------------------------
          READ(5,*)KHIST
C
      KHIST0=KHIST
C
C
C INPUT CARD 7
C*************
C---------------------------------------------------------------------
C
C     MPARIN defines projectile
C            = 1   : incident particle is neutron
C            = 2   : proton
C            = 3   : alpha-particle
C
C     Z and AN  are atomic number and atomic mass number for target
C               nucleus
C
C---------------------------------------------------------------------
          READ(5,*)MPARIN,Z,AN
C
      IF(MPARIN.eq.3) INFS0=1
```

```
      IF(INFSEP.EQ.2) CALL INSEP3(MPARIN,Z,AN)
1811      IF(AN.GT.219..AND.INFDEN.EQ.2) STOP
C
                                      FIALPH=FI
C
C
C INPUT CARD 8
C*************
C-----------------------------------------------------------------------
C
C     T0 is the energy of projectile (MeV)
C
C-----------------------------------------------------------------------
          READ(5,*)T0
C
C
C INPUT CARD 9
C*************
C-----------------------------------------------------------------------
C
C The use of this and following cards relates as to old input of the
C code, as to new one.
C
C Simply, put new energy on this CARD in real format to continue
C calculations or put nothing to stop calculations after the finish
C of simulations with T0 energy.
C
C If no real value is found on this CARD, the variable is interpreted
C as IDOPCS value from old input (1987-1995) of the DISCA code.
C    IDOPCS defines the reading of the nonelastic cross-section used
C            for normalization from input file (unit=5)
C            = 1   : yes
C            = 0   : no
C
C-----------------------------------------------------------------------
C Try to find new energy
                                        IDOPCS=0
                                        ICONT=0
          READ(5,'(a80)',END=1819)C80
          DO IC80=1,80
          IF(C80(IC80:IC80).eq.'.')THEN
                                    BACKSPACE 5
                                    READ(5,*)TMP
                                    IF(TMP.ne.0.0) ICONT=1
                                    BACKSPACE 5
                                    GOTO 1819
                                    ENDIF
          ENDDO
          BACKSPACE 5
          READ(5,*)IDOPCS

C
        IF(IDOPCS.NE.1)GOTO 1818
C
C
C INPUT CARD 9A  (Old DISCA format. Read comment to CARD 9)
C*************
C-----------------------------------------------------------------------
C
```

```
C     CSABS is the nonelastic reaction cross-section (barn)
C           (only for IDOPCS=1)
C-----------------------------------------------------------------------
          READ(5,*)CSABS
C
1818  continue
C
C
C
C INPUT CARD 9B  (Old DISCA format. Read comment to CARD 9)
C**************
C-----------------------------------------------------------------------
C
C     ICONT defines the continuation of the calculations for new incident
C           energy and new IDOPCS value
C
C            = 1   : new energy
C            = 0   : end of calculations
C
C-----------------------------------------------------------------------
          READ(5,*)ICONT
C
1819  IF(INFLIB.EQ.1)  CALL ZERLIB
      PRINT 1987,T0,BONNE,KHIST,XPARAM
         IF(IBONDS.LT.1.OR.IBONDS.GT.3)GOTO 97
         IF(INFBIG.GT.1.AND.INFS0.EQ.0)INFS0=1
         IF(INFS0.EQ.3.AND.IDOPCS.EQ.0)INFS0=1
         IF(INFKAL.NE.1.OR.T0.LE.60.)GOTO 100
           IF(IWRI.NE.0)WRITE(IWRI,1830)T0
           WRITE(IPR,1830)T0
           PRINT 1830,T0
           STOP
97                IF(IWRI.NE.0)WRITE(IWRI,1840)IBOND
                  WRITE(IPR,1840)IBOND
                  PRINT 1840,IBOND
                  STOP
100   GOTO(101,102,103),IBONDS
101          MAXNEU=13
             MAXPRO=9
             STOP
102     CALL PRECAM
           GOTO 104
103     CALL PRECAM
        CALL PRELYM
104   CONTINUE
           CALL ZERO1
           CALL INIDAT(KZONESC)
           CALL MASDAT
           CALL DENS
            IIII=-1
      KHIST=KHIST0
      DO 10 I=1,KHIST
            ISTOR=I
            IF(INFSCR.NE.1)GOTO 6
            ICCC=I/500
            IF(ICCC.NE.IIII)PRINT 2000,I
            IF(ICCC.NE.IIII)IIII=ICCC
C
C Label 10 is for normal end of MC history, Label 8 means too many reflec-
```

```
C tions (more than REFR), Label 40 means the dimension of arrays in not
C sufficient to proceed KHIST events
C
    6  CALL MODEL(IXX)
       GOTO(8,10,40),IXX
    8 NREJ=NREJ+1
   10 CONTINUE
   20 CALL OUTPUT
*           PRINT *,'K1996 = ',K1996
           IF(ICONT.EQ.1)GOTO 1811
      STOP
   40 KHIST=ISTOR
      GOTO 20
C
 1830 FORMAT(1X,'Old Kalbach,Mann parametrization is not valid for '
     +' T0 =',G12.5)
 1840 FORMAT(1X,'Incorrect IBOND number  ',I6)
 1987 FORMAT(1X,' T0=',F7.1,' BONNE=',F5.3,' KHIST=',I6/1X,' XPARAM=',
     +F7.3)
 1900 FORMAT(9A8)
 2000 FORMAT(1X,'******* EVENT ',I6)
 3200 FORMAT(1X,60('*')/1x,10x,'Characteritics of secondary particl',
     +'es are not stored'/1x,60('*'))
      END
**********************************************************************
*                SUBROUTINE A1B1B2                                   *
**********************************************************************
      SUBROUTINE A1B1B2
      COMMON/FIGA1B/T1(16),BA1(16),BB1(16),BB2(9),BB3(8)
      COMMON/ACTA1B/TREST /A1BNPD/S(4),PAR1 /AUXIL/ICOU1,ICOU2
        ICOU1=ICOU1+1
      I=1
   10 I=I+1
      IF(I.LE.16)GOTO 12
        I=16
        ICOU2=ICOU2+1
        GOTO 20
   12 IF(TREST-T1(I))20,20,10
   20 IF(I-9)40,40,30
   30 BBB=BB3(I-8)
      AAA=BB3(I-9)
      PAR1=0.14285714
      GOTO 50
   40 BBB=BB2(I)
      AAA=BB2(I-1)
      PAR1=0.2
   50 D2=T1(I)
      D1=T1(I-1)
      DT=D2-D1
      A1=TREST*(BA1(I)-BA1(I-1))/DT+(D2*BA1(I-1)-D1*BA1(I))/DT
      B1=TREST*(BB1(I)-BB1(I-1))/DT+(D2*BB1(I-1)-D1*BB1(I))/DT
      BB=TREST*(BBB-AAA)/DT+(D2*AAA-D1*BBB)/DT
      SUM=2.*A1+0.25*B1+PAR1*BB
      S(1)=A1/SUM
      S(2)=S(1)+0.25*B1/SUM
      S(3)=S(2)+S(1)
      S(4)=S(3)+PAR1*BB/SUM
      RETURN
      END
```

```
************************************************************************
*                  SUBROUTINE ACTIN                                    *
************************************************************************
      SUBROUTINE ACTIN(IKS)
      COMMON/FIGA1B/T1(16),BA1(16),BB1(16),BB2(9),BB3(8)
      COMMON/K/K /JACT/JACT
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/NDIM/NPAR  /PARTNR/PPX,PPY,PPZ,PP,MX
      COMMON/TYPACT/L,L7 /ACTA1B/TREST
      COMMON/ACTSCI/PINX1,PINY1,PINZ1,WPX,RK3,RK4,GAMMA,SK2,VC2,VCX,
     *VCY,VCZ,MPX
      COMMON/URAND1/IYG
      IF(L.NE.6) GOTO 1
      CALL PICKUP(IKS)
      RETURN
    1 MPX=MX
      WPX=WM(MX)
      WPX2=WPX*WPX
      EP=SQRT(PP*PP+WPX2)
      E1=E+EP
      VCX=(PX+PPX)/E1
      VCY=(PY+PPY)/E1
      VCZ=(PZ+PPZ)/E1
      SK1=PX*VCX+PY*VCY+PZ*VCZ
      VC2=VCX*VCX+VCY*VCY+VCZ*VCZ
      GAMMA=1./SQRT(1.-VC2)
      EE=((GAMMA-1.)*SK1/VC2)-E*GAMMA
      PINX=PX+EE*VCX
      PINY=PY+EE*VCY
      PINZ=PZ+EE*VCZ
      EIN=GAMMA*(E-SK1)
      TREST=(E*EP-PX*PPX-PY*PPY-PZ*PPZ)/WPX-WP
      CALL ANGLE(QSIN,QCOS,FISIN,FICOS)
      IF(ABS(PINZ)-1.E-06)10,20,20
   10 BX=0.
      BY=0.
      BZ=400.
      GOTO 30
   20 BX=400.
      BY=400.
      BZ=-400.*(PINX+PINY)/PINZ
   30 B=SQRT(BX*BX+BY*BY+BZ*BZ)
      PO2=PINX*PINX+PINY*PINY+PINZ*PINZ
      EPIN=SQRT(PO2+WPX2)
      RK0=QSIN/B
      RK1=RK0*FICOS*SQRT(PO2)
      RK2=RK0*FISIN
      PINX1=RK1*BX+RK2*(PINY*BZ-PINZ*BY)+QCOS*PINX
      PINY1=RK1*BY+RK2*(PINZ*BX-PINX*BZ)+QCOS*PINY
      PINZ1=RK1*BZ+RK2*(PINX*BY-PINY*BX)+QCOS*PINZ
      SK2=PINX1*VCX+PINY1*VCY+PINZ1*VCZ
      RK3=GAMMA*EIN
      RK4=GAMMA*EPIN
      TB1=RK3+GAMMA*SK2-WP
      TP1=RK4-GAMMA*SK2-WPX
      CALL PAULI(TB1,TP1,IKS)
      RETURN
      END
************************************************************************
```

```
*                FUNCTION ANGKAL                                        *
*************************************************************************
      FUNCTION ANGKAL(QCOS,E1)
C QCOS is cos required
      DIMENSION P(30)
C P(1) value corresp to polynomial P(0)
      LMAX=9
      CALL LEGEN(QCOS,P)
C M=1 --- BKAL(0,E1)=1 ,P(1) -polynomial of (0) = 1
      S=1.
      DO 10 M=2,LMAX
10    S=S+BKAL((M-1),E1)*P(M)
      ANGKAL=S
      RETURN
      END
*************************************************************************
*                 SUBROUTINE ANGLE                                      *
*************************************************************************
      SUBROUTINE ANGLE(QSIN,QCOS,FISIN,FICOS)
      COMMON/FIGA1B/T1(16),BA1(16),BB1(16),BB2(9),BB3(8)
      COMMON/TYPACT/L,L7
      COMMON/ACTA1B/TREST
      COMMON/URAND1/IYG
      GOTO(10,20,30,40,40),L
   10 CALL NPDRAW(QCOS,FI)
      QSIN=SQRT(ABS(1.-QCOS*QCOS))
      FISIN=SIN(FI)
      FICOS=COS(FI)
      RETURN
   20 CALL PPDRAW(QCOS,FI)
      QSIN=SQRT(ABS(1.-QCOS*QCOS))
      FISIN=SIN(FI)
      FICOS=COS(FI)
      RETURN
* N-A interaction
   30 T = TREST
      CALL NADRAW(T,QCOS,FI)
      QSIN=SQRT(ABS(1.-QCOS*QCOS))
      FISIN=SIN(FI)
      FICOS=COS(FI)
      RETURN
* A-N interaction
   40 T = TREST/4.
      CALL NADRAW(T,QCOS,FI)
      QSIN=SQRT(ABS(1.-QCOS*QCOS))
      FISIN=SIN(FI)
      FICOS=COS(FI)
      RETURN
      END
*************************************************************************
*                 SUBROUTINE AUXANG                                     *
*************************************************************************
      SUBROUTINE AUXANG
C Angular distributions acording to Kalbach, Mann phenomenology
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/MAIIPR/IPR /URAND1/IYG
          R=1.
          EKAL=TW
          RMAX=ANGKAL(R,EKAL)
```

```
       DO 100 I=1,100
C   Argument  QCOS=2.*X-1.
       C1=2.*RANDOM(0)-1.
C   Function
       C2=RMAX*RANDOM(0)
       RF=ANGKAL(C1,EKAL)
       IF(RF.GE.C2) GOTO 200
100    CONTINUE
       WRITE(IPR,150)RMAX,RF,C1,C2
150    FORMAT(1X,'Error: COS can not be obtained in Subr AUXANG'/
     * 1X,'RMAX=',G12.5,' RF=',G12.5/' C1=',G12.5,' C2=',G12.5)
       STOP
200    QCOS=C1
       QSIN=SQRT(1.-QCOS*QCOS)
       FI=6.283*RANDOM(0)
          P=SQRT(TW*(TW+938.92635))
          PWZ=P*QCOS
          PWX=P*QSIN*COS(FI)
          PWY=P*QSIN*SIN(FI)
       RETURN
       END
*********************************************************************
*               SUBROUTINE BARASH                                   *
*********************************************************************
      SUBROUTINE BARASH(TEST,MPAR9,A9,T9,CSNON)
*
* Evaluated nonelastic cross-sections (mb)
* Data taken from Barashenkov,JINR, R2-89-770,1989
* MPAR=1 : neutron incident; = 2 : proton
* IF TEST .ne. 0 : test printingœ
* A : Atomic mass number of target nucleus
* CSP(ENERGY,ATOMIC MASS) : proton cross-sections
* CSN(ENERGY,ATOMIC MASS) : neutron cross-sections
*
      DIMENSION CSP(46,12),CSN(46,12),ENERGY(46)
      DIMENSION CSPAL(46),CSPSI(46),CSPCA(46),CSPFE(46),CSPCU(46),
     1          CSPMO(46),CSPCD(46),CSPSN(46),CSPW(46),CSPPB(46),
     2          CSPU(46),CSPNA(46)
      DIMENSION CSNAL(46),CSNSI(46),CSNCA(46),CSNFE(46),CSNCU(46),
     3          CSNMO(46),CSNCD(46),CSNSN(46),CSNW(46),CSNPB(46),
     4          CSNU(46),CSNNA(46)
      DIMENSION RIDENT(12)
      DIMENSION AELEM(12)
      DIMENSION PPN(6),PPP(6)
      EQUIVALENCE (CSP(1),CSPNA(1)
     +),    (CSP(47),CSPAL(1)),(CSP(93),CSPSI(1)),(CSP(139),CSPCA(1)
     +),    (CSP(185),CSPFE(1)),(CSP(231),CSPCU(1)),(CSP(277),CSPMO(1)
     +),    (CSP(323),CSPCD(1)),(CSP(369),CSPSN(1)),(CSP(415),CSPW(1)
     +),    (CSP(461),CSPPB(1)),(CSP(507),CSPU(1))
      EQUIVALENCE (CSN(1),CSNNA(1)
     +),    (CSN(47),CSNAL(1)),(CSN(93),CSNSI(1)),(CSN(139),CSNCA(1)
     +),    (CSN(185),CSNFE(1)),(CSN(231),CSNCU(1)),(CSN(277),CSNMO(1)
     +),    (CSN(323),CSNCD(1)),(CSN(369),CSNSN(1)),(CSN(415),CSNW(1)
     +),    (CSN(461),CSNPB(1)),(CSN(507),CSNU(1))
C PROTON INDUCED REACTION
      DATA AELEM/ 23., 27.,  28., 40.,  55.9, 63.6,  96.,  112.6, 118.8,
     #           183.9, 207.3, 238./
      DATA ENERGY/14.,  15.,  16.,  17.,  18., 19.,  20.,  22.,
     $       25.,  27.,  30.,  33.,  35.,  37.,  40.,  45.,
```

```
$       50.,  55.,  60.,  65.,  70.,  80.,  90., 100., 120.,
$      140., 150., 160., 180., 200., 250., 300., 350., 400.,
$      500., 600., 700., 800., 900.,1000., 1500., 2000., 3000.,
$      5000., 7000., 10000./
 DATA RIDENT/'NA','AL','SI','CA','FE','CU','MO',
+     'CD','SN',' W','PB',' U'/
 DATA CSPNA/600.,  617.,  638.5, 660., 665., 670.,   675.,  680.,
$           680.,  670.,
$           650.,  605.,  575.,  565.,  550.,  525.,  490.,  470.,
$           450.,  435.,  420.,  385.,  367.,  360.,  350.,  350.,
$           350.,  345.,  347.,  350.,  350.,  350.,  356.,  364.,
$           384.,  392.,  400.,  408.,  410.,  420.,  408.,  412.,
$           420.,  411.,  409.,  407./
 DATA CSNNA/960.,  930.,  910.,  890.,  867.3, 844.67,  822.,
$           790.,  750.,  725.,
$           686.,  646.4, 620.,  612.,  600.,  575.,  540.,  518.5,
$           497.,  473.5, 450.,  414.,  390.,  380.,  372.,  364.,
$           360.,  355.,  354.,  350.,  350.,  350.,  356.,  364.,
$           384.,  392.,  400.,  408.,  410.,  420.,  408.,  412.,
$           420.,  411.,  409.,  407./
 DATA CSPAL/650.,  682.,  690.,  715.,  726.67, 738.33,
$           750.,  762.,  750.,  740.,
$           720.,  681.,  655.,  640.,  617.,  575.,  540.,  505.,
$           470.,  462.5, 455.,  432.,  420.,
$           408.,  400.,  403.,  403.,  408.,  406.,  404.,  400.,
$           402.,  404.,  408.,  424.,  438.,  448.,  450.,  454.,
$           456.,  472.,  480.,  466.,  456.,  452.,  448./
 DATA CSNAL/1000., 990.,  975.,  950.,  935.,  920.,
$           905.,  875.,  825.,  800.,
$           762.,  718.8, 690.,  674.8, 652.,  610.,  570.,  532.5,
$           495.,  487.5, 480.,  456.,  444.,
$           432.,  420.,  420.,  420.,  420.,  410.,  410.,  400.,
$           402.,  404.,  408.,  424.,  438.,  448.,  450.,  454.,
$           456.,  472.,  480.,  466.,  456.,  452.,  448./
 DATA CSPSI/670.,  700.,  725.,  750.,  760.,  770.,
$           780.,  780.,  770.,  757.,
$           735.,  708.,  690.,  668.,  635.,  585.,  570.,  530.,
$           490.,  482.5,
$           475.,  460.,  446.,  431.,  423.,  425.,  425.,
$           425.,  425.,  422.,  422.,  412.,  416.,  422.,  440.,
$           460.,  472.,  476.,  479.,  480.,  492.,  496.,  488.,
$           472.,  472.,  464./
 DATA CSNSI/1060., 1035., 1015., 990., 971.67, 953.33,
$           935.,  900.,  860.,  830.,
$           790.,  751.,  725.,  701.,  665.,  630.,  600.,  560.,
$           520.,  512.,
$           504.,  486.,  470.,  456.,  444.,  432.,  432.,
$           432.,  418.,  418.,  415.,  412.,  416.,  422.,  440.,
$           460.,  472.,  476.,  479.,  480.,  492.,  496.,  488.,
$           472.,  472.,  464./
 DATA CSPCA/770., 800., 823., 850., 866.67, 883.3,
$           900., 925., 935., 920., 895.,
$           859., 835., 821., 800., 750., 715., 678., 640., 622.5,
$           605., 590., 588., 573.,
$           555., 543., 540., 540., 540., 535., 530., 530., 540.,
$           550., 570., 595., 610., 615., 620., 622., 629., 630.,
$           620.,  612.,  607.,  592./
 DATA CSNCA/1240.,1225.,1200.,1180.,1161.67, 1143.3,
$           1125.,1090.,1045.,1020.,980.,
```

```
$           947., 925., 907., 880., 825., 770., 725., 680., 660.,
$           640., 620., 615., 600.,
$           580., 565., 560., 560., 560., 550., 535., 530., 540.,
$           550., 570., 595., 610., 615., 620., 622., 629., 630.,
$           620.,  612.,  607.,  592./
 DATA CSPFE/900., 960.,1015.,1070.,1076.67,1083.3,
$          1090.,1115.,1120.,1115.,1080.,
$          1045.,1025.,1000., 960., 900., 885., 865., 790., 777.5,
$           765.,
$           740., 720., 700., 697., 697., 697., 697., 695., 690.,
$           688., 690., 712., 705., 735., 750., 765., 775., 780.,
$           795., 810., 813., 810., 784., 757., 743./
 DATA CSNFE/1440.,1433.,1411.5,1390.,1368.3, 1346.67,
$          1325.,1280.,1260.,1215.,1180.,
$          1140.,1110.,1080.,1040., 990., 955., 920., 885.,860.,
$           835.,
$           800., 780., 765., 750., 725., 720., 720., 710., 700.,
$           700., 700., 712., 705., 735., 750., 765., 775., 780.,
$           795., 810., 813., 810., 784., 757., 743./
 DATA CSPCU/935.,1000.,1030.,1060.,1103.3,1146.67,
$          1190.,1220.,1250.,1240.,1210.,
$          1150.,1130.,1115.,1050., 985., 950., 890., 870., 845.,
$           820.,
$           800., 785., 780., 770., 750., 745., 740., 735., 735.,
$           745., 760., 762., 770., 795., 810., 825., 830., 840.,
$           848., 870., 870., 868., 840., 825., 810./
 DATA CSNCU/1540.,1535.,1517.5,1500.,1481.67,1463.3,
$          1445.,1407.,1380.,1330.,1300.,
$          1285.,1270.,1240.,1190.,1090.,1010., 940., 920., 890.,
$           860.,
$           835., 820., 810., 800., 780., 775., 770., 760., 760.,
$           758., 765., 765., 770., 795., 810., 825., 830., 840.,
$           848., 870., 870., 868., 840., 825., 810./
 DATA CSPMO/1025.,1080.,1135.,1190.,1253.3,1316.67,
$           1380.,1440.,1495.,1475.,1420.,
$           1350.,
$           1310.,1300.,1290.,1250.,1200.,1170.,1130.,1112.5,
$           1095.,1060.,
$           1040.,1022.,1020.,1016.,1016.,1016.,1016.,1012.,1005.,
$           1005.,1005.,1010.,1060.,1085.,1100.,1110.,1120.,1127.,
$           1150.,1160.,1140.,1100.,1085.,1080./
 DATA CSNMO/1790.,1775.,1757.5,1740.,1720.,1700.,
$           1680.,1640.,1580.,1550.,1510.,
$           1460.,
$           1440.,1418.,1380.,1330.,1280.,1240.,1200.,1177.5,
$           1155.,1140.,
$           1110.,1110.,1080.,1065.,1050.,1050.,1025.,1020.,1015.,
$           1020.,1022.,1026.,1060.,1085.,1100.,1110.,1120.,1127.,
$           1150.,1160.,1140.,1100.,1085.,1080./
 DATA CSPCD/1020., 1100., 1162.5,1225.,1290.,1365.,1440.,1520.,
$           1575.,1560.,1518.,1460.,1420.,1412.,1400.,1365.,1340.,
$           1300.,1280.,1260.,1200.,1190.,1160.,6*1125., 3*1120.,
$           1118.,1146.,1180.,1220.,1240.,1250.,1260.,1265.,1270.,
$           1275.,1250.,2*1222.,1220./
 DATA CSNCD/1920.,1910.,1895.,1880.,1860.,1850.,1840.,1800.,1760.,
$           1720.,1675.,1630.,1600.,1568.,1520.,1465.,1420.,1390.,
$           1340.,1310.,1280.,1275.,1235.,1225.,1200.,3*1170.,
$           1165.,1145.,1140.,1140.,1135.,1160.,1180.,
$                           1220.,1240.,1250.,1260.,1265.,1270.,
```

```
     $           1275.,1250.,2*1222.,1220./
      DATA CSPSN/1020.,1080.,1175.,1270.,1335.,1400.,1465.,1505.,1610.,
     $           1610.,1550.,1535.,1500.,1476.,1440.,1407.,1370.,1340.,
     $           1300.,1285.,1260.,1230.,1215.,1200.,1180.,1170.,1170.,
     $           1165.,1165.,
     $           1170.,1165.,1165.,1183.,1195.,1240.,1270.,1285.,
     $           1300.,1300.,1310.,1320.,1320.,1290.,3*1240./
      DATA CSNSN/1945.,1940.,1922.5,1905.,1890.,1875.,1860.,1830.,1780.
     $          ,1755.,1717.,1680.,1645.,1615.,1570.,1500.,1455.,1410.,
     $           1370.,1340.,
     $           1320.,1290.,1285.,1260.,1240.,1235.,1212.,1200.,
     $           2*1200.,2*1190.,1200.,1210.,1240.,1270.,1285.,1300.,
     $                 1300.,1310.,1320.,1320.,1290.,3*1240./
      DATA CSPW / 950.,1020.,1130.,1240.,1400.,1480.,1560.,1670.,1760.,
     $           1830.,1850.,1855.,1870.,1858.,1840.,1800.,1770.,1740.,
     $           1715.,1680.,1670.,1650.,1620.,1610.,6*1600.,1595.,
     $           1585.,1595.,1615.,1640.,1700.,1720.,1730.,1740.,1750.,
     $           1780.,1780.,1750.,1740.,1735.,1710./
      DATA CSNW /2440.,2400.,2385.,2370.,2350.,2330.,2310.,2270.,2220.,
     $           2195.,2150.,2100.,2070.,2046.,2010.,1945.,1900.,1850.,
     $           1820.,1780.,1760.,1730.,1720.,1680.,1680.,1660.,1660.,
     $           1650.,1650.,1640.,1640.,1612.,1615.,1625.,1640.,
     $                                  1700.,1720.,1730.,1740.,1750.,
     $           1780.,1780.,1750.,1740.,1735.,1710./
      DATA CSPPB/ 900.,1060.,1130.,1200.,1310.,1420.,1515.,1620.,1750.,
     $           1800.,1915.,1984.,2030.,2002.,1960.,1940.,1910.,1860.,
     $           1840.,1810.,1780.,1770.,1760.,1740.,1720.,1725.,1740.,
     $           1740.,1730.,1720.,1700.,1710.,1720.,1730.,1740.,1815.,
     $           1835.,1860.,1890.,1895.,1920.,1920.,1890.,1850.,1835.,
     $           1830./
      DATA CSNPB/2580.,2550.,2527.5,2505.,2483.5,2462.,2460.,2435.,2380.
     $          ,2355.,2280.,2220.,2180.,2176.,2170.,2130.,2080.,2035.,
     $           1980.,1960.,1940.,1900.,1870.,1840.,1800.,1800.,1800.,
     $           1780.,1760.,1760.,1740.,1730.,1725.,1740.,
     $           1785.,1815.,1835.,1860.,1890.,
     $           1895.,1920.,1920.,1890.,1850.,1835.,1830./
      DATA CSPU / 800., 900.,1000.,1100.,1200.,1300.,1410.,1510.,1680.,
     $           1800.,2000.,2120.,2200.,2152.,2080.,2060.,2025.,2100.,
     $           2030.,2030.,2030.,2000.,3*1960.,1940.,1925.,1920.,
     $           1905.,1890.,1860.,1880.,1910.,1930.,1945.,1985.,2010.,
     $           2040.,2070.,2080.,2090.,2095.,2080.,2063.,2060.,2050./
      DATA CSNU /2820.,2770.,2735.,2700.,2680.,2660.,2645.,2620.,2580.,
     $           2550.,2515.,2476.,2450.,2426.,2390.,2320.,2260.,2225.,
     $           2200.,2170.,2140.,2080.,2060.,2040.,2000.,1980.,1965.,
     $           1960.,1930.,1920.,1890.,1905.,1920.,1945.,1970.,
     $                                                    1985.,2010.,
     $           2040.,2070.,2080.,2090.,2095.,2080.,2063.,2060.,2050./
      DATA PPN,PPP/6*1HN,6*1HP/
      IF(TEST.NE.0.) GOTO 5000
        A=A9
        T0=T9
        MPARIN=MPAR9
                          ISMALL = 0
C
        IF(A.GT.AELEM(12).OR.A.LE.0.)              GOTO 10000
        IF(A.GE.AELEM(1) ) GOTO 44
        PRINT 3000
        ISMALL = 1
        A = AELEM(1)
```

```
        ASM = A9
44          IF(T0.LT.ENERGY(1)  )                   GOTO 20000
            IF(T0.GT.ENERGY(46)) PRINT 4000,ENERGY(46)
            IF(T0.GT.ENERGY(46)) T0 = ENERGY(46)
C
        DO  50 I=1,12
        IF(A.LE.AELEM(I)) GOTO 100
50      CONTINUE
        GOTO 10000
C
100     IA1=I-1
        IF(I.EQ.1)IA1=1
        IA2=I
C
        DO  150 I=1,46
        IF(T0.LE.ENERGY(I)) GOTO 200
150     CONTINUE
        GOTO 20000
C
200     IE1=I-1
        IF(I.EQ.1)IE1=1
        IE2=I
           IF(MPARIN.EQ.2)GOTO 201
              CS11=CSN(IE1,IA1)
              CS12=CSN(IE1,IA2)
              CS21=CSN(IE2,IA1)
              CS22=CSN(IE2,IA2)
              GOTO 202
201                CS11=CSP(IE1,IA1)
                   CS12=CSP(IE1,IA2)
                   CS21=CSP(IE2,IA1)
                   CS22=CSP(IE2,IA2)
C
202           IF(IE1.EQ.IE2) CSMIN=CS11
              IF(IE1.EQ.IE2) CSMAX=CS12
              IF(IE1.EQ.IE2) GOTO 400
C
                  E1=ENERGY(IE1)
                  E2=ENERGY(IE2)
        CS1=CS11
        CS2=CS21
              RR=E2-E1
              AAA=(CS2-CS1)/RR
              BBB=(CS1*E2-E1*CS2)/RR
        CSMIN = AAA * T0 + BBB
C
        CS1=CS12
        CS2=CS22
              RR=E2-E1
              AAA=(CS2-CS1)/RR
              BBB=(CS1*E2-E1*CS2)/RR
        CSMAX = AAA * T0 + BBB
C
400         IF(IA1.EQ.IA2) CSNON=CSMIN
            IF(IA1.EQ.IA2) GOTO 555
               A1=AELEM(IA1)
               A2=AELEM(IA2)
              RR=A2-A1
              AAA=(CSMAX-CSMIN)/RR
```

```
             BBB=(CSMIN*A2-A1*CSMAX)/RR
        CSNON = AAA * A  + BBB
555     IF(ISMALL.EQ.0) RETURN
        CSNON = CSNON * ( (ASM/A)**0.66666666 )
        RETURN
C
C TEST PRINTING
5000     PRINT 5010,(RIDENT(I),I=1,6)
5010     FORMAT(/1X,'  E,MEV ',4X,6(8X,A2,7X))
         PRINT 5011,(AELEM(I),I=1,6)
5011     FORMAT(1X,   8X,     4X,6(6X,F6.2,5X))
         PRINT 5014,(PPN(II),PPP(II),II=1,6)
5014     FORMAT(1X,   8X,     4X,6(3X,A1,3X, 3X,A1,3X, 3X))
         PRINT 5012
5012     FORMAT(120('-'))
         DO 8000 II=1,46
8000     PRINT 5020,ENERGY(II),(CSN(II,JJ),CSP(II,JJ),JJ=1,6)
5020     FORMAT(1X,F8.1,4X,6(2F7.1,3H I ))
         PRINT 5015
5015     FORMAT(120('='))
         PRINT 5010,(RIDENT(I),I=7,12)
         PRINT 5011,(AELEM(I),I=7,12)
         PRINT 5014,(PPN(II),PPP(II),II=1,6)
         PRINT 5012
         DO 9000 II=1,46
9000     PRINT 5020,ENERGY(II),(CSN(II,JJ),CSP(II,JJ),JJ=7,12)
         STOP
C
10000    PRINT 1000,A
1000     FORMAT(1X,'SUBROUTINE BARASH: NO INFORMATION ABOUT A =',G12.5)
         STOP
20000    PRINT 2000,T0
         WRITE(1,2000)T0
         WRITE(8,2000)T0
         CSNON=0.
         RETURN
2000     FORMAT(1X,'SUBROUTINE BARASH: NO INFORMATION FOR ENERGY = ',
     $  G12.5/ 1X,' CSNON =0.')
3000     FORMAT(1X,'Attention !'/1X,' For low atomic numbers ',
     $  ' SUBR BARASH gets approximated cross-sections'//)
4000     FORMAT(//1X,' Attention !'/1X,'BARASH: Cross-section is taken ',
     $  ' at the energy = ',G14.7//)
         END
*********************************************************************
*              SUBROUTINE BINDEN                                    *
*********************************************************************
      SUBROUTINE BINDEN(ZEE,AMASS,NZ,NA,AP,AT,ZP,ZT,QVAL,M3,MP)
* taken from Blann code ALICE
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24)
      DIMENSION EXCES(4),RES(4),ERR(4)
      DATA TAB/4H TAB/
      IZEE=ZEE+.1
      IMASS=AMASS+.1
      IAP=AP+.1
      IAT=AT+.1
      IZP=ZP+.1
      IZT=ZT+.1
      INP=IAP-IZP
      INT=IAT-IZT
```

```
      IRET=0
      N=IMASS-IZEE
      CALL MASS(IZP,INP,EXCES(1),ERR(1),IRET)
      CALL MASS(IZT,INT,EXCES(2),ERR(2),IRET)
      CALL MASS(IZEE,N,EXCES(3),ERR(3),IRET)
      IF(IRET.GT.0) GO TO 10
      IF(QVAL.NE.0.)GO TO 10
      QVAL=-EXCES(3)+EXCES(2)+EXCES(1)
cccc  WRITE(6,4)
    4 FORMAT(//,20X,'*****************************************'//)
cccc  WRITE(6,5)QVAL
cccc  WRITE(6,4)
5     FORMAT(20X,' QVAL USED (CALCULATED FROM MASS TABLE) = ',F5.1)
10    IRET=0
      CALL MASS(0,1,EXCES(1),ERR(1),IRET)
      CALL MASS(1,0,EXCES(2),ERR(2),IRET)
      CALL MASS(2,2,EXCES(3),ERR(3),IRET)
      CALL MASS(1,1,EXCES(4),ERR(4),IRET)
      IF(IRET.GT.0) RETURN
cccc  WRITE(6,6)
6     FORMAT(30X,'BINDING ENERGIES CALCULATED FROM MASS TABLE',
     1 ' WHERE POSSIBLE.')
cccc  IF(MP.EQ.0)WRITE(6,7)
7     FORMAT(35X,'PAIRING REMOVED FROM MASSES IN TABLE')
cccc  IF (MP.EQ.0.AND.MC.EQ.1) WRITE(6,8)
    8 FORMAT (35X,'SHELL CORRECTION REMOVED FROM MASSES IN TABLE')
      DO 65 IZ=1,NZ
      DO 65 IA=1,NA
      IZZ=IZEE-IZ+1
      INN=IMASS-IZEE-IA+1
      IZZ1=IZZ-1
      INN1=INN-1
      INN2=INN-2
      IZZ2=IZZ-2
      IRET=0
      CALL MASS(IZZ,INN,XMASS,ERR(1),IRET)
      CALL MASS(IZZ,INN1,RES(1),ERR(1),IRET)
      IF(M3.GE.2)CALL MASS(IZZ1,INN,RES(2),ERR(2),IRET)
      IF(M3.GE.3)CALL MASS(IZZ2,INN2,RES(3),ERR(3),IRET)
      IF(M3.EQ.4)CALL MASS(IZZ1,INN1,RES(4),ERR(4),IRET)
      IF(IRET.GT.0) GO TO 65
      IF(MP.NE.0)GO TO 55
      XMASS=XMASS+PAIR(IZ,IA)
      RES(1)=RES(1)+PAIR(IZ,IA+1)
      RES(2)=RES(2)+PAIR(IZ+1,IA)
      RES(3)=RES(3)+PAIR(IZ+2,IA+2)
      RES(4)=RES(4)+PAIR(IZ+1,IA+1)
   55 DO 60 I=1,M3
60    BE(IZ,IA,I)=-XMASS+EXCES(I)+RES(I)
      SYMB(IZ,IA)=TAB
65    CONTINUE
      RETURN
      END
*********************************************************************
*               FUNCTION BKAL(M,E1)                                 *
*********************************************************************
          FUNCTION BKAL(M,E1)
          RM=FLOAT(M*(M+1))
          AL=0.036+0.0039*RM
```

```
            BL=92.-90./SQRT(RM)
            BKAL=FLOAT(2*M+1)/(1.+EXP(AL*(BL-E1)))
            RETURN
            END
*********************************************************************
*                  BLOCK DATA                                       *
*********************************************************************
      BLOCK DATA
      COMMON/DATEVA/GP,GD,GT,GHE,GAL,GAMP,GAMD,GAMT,GAMHE,GAMAL,CP,CD,
     *CT,CHE,CAL,VP,VD,VT,VHE,VAL,QN,QP,QD,QT,QHE,QAL
      COMMON/FIGA1B/T1(16),BA1(16),BB1(16),BB2(9),BB3(8)
      COMMON/DATCAM/CAMN(130),CAMP(130),MAXN,MAXP
      COMMON/DOSTRO/RKPD(6),RKAD(6),CPD(6),CAD(6),ZD(6)
      COMMON/DATREN/RL0N,RL1N,RM0N,RM1N,RN0N,RN1N,RN2N
      COMMON/DATREP/P0P,P1P,P2P,RL0P,RL1P,RM0P,RM1P,RN0P,RN1P,RN2P
      COMMON/SHEL2/DWA(220)
      COMMON/DATREA/P0A,P1A,P2A,RL0A,RL1A,RM0A,RM1A,RN0A,RN1A,RN2A
C
      DATA GAMP,GAMD,GAMT,GAMHE,GAMAL/2*1., 2*3., 2./
      DATA T1/ 0.,  40.,  80.,  120.,  160.,  200.,  240.,
     *280.,  300.,  320.,  360.,  400.,  440.,  480.,  520.,  560./
      DATA BA1/1592., 12., 5.2, 3.3, 2.3, 2., 1.9, 1.8, 1.75,
     * 1.7, 1.5, 1.4, 1.3, 1.2, 1.1, 1./
      DATA BB1/ 0., 7.,  8.1,  6.6,  3.9,  11*3.6/
      DATA BB2/0.,  7.,  8.3,  9.,  7.7,  6.5,  6.2,  6.,  5.8071425/
      DATA BB3/8.1299995,  7.8,  7.4,  7.,  6.7,  6.4,  6.1,  5.8/
C
C     CAMN/CAMP : corrections for nuclei with neutrons/protons number
C     equal to array number
      DATA CAMN/-8.4, -12.9, -8.0, -11.9, -9.2, -12.5, -10.8, -13.6,
     * -11.2, -12.2,
     * -12.81, -15.40, -13.07, -15.80, -13.81, -14.98,
     * -12.63, -13.76, -11.37,  -12.38,  -9.23,  -9.65, -7.64,  -9.17,
     * -8.05, -9.72,  -8.87,  -10.76,  -8.64,  -8.89,  -6.60,  -7.13,
     * -4.77, -5.33,  -3.06,  -3.79,  -1.72,  -2.79, -0.93,  -2.19,
     *  -0.52, -1.90, -0.45,  -2.20,  -1.22,  -3.07, -2.42,  -4.37,
     * -3.94, -6.08, -4.49, -4.5, -3.14, -2.93, -1.04, -1.36, 0.69,
     * 0.21, 2.11, 1.33,
     * 3.29, 2.46, 4.30, 3.32, 4.79, 3.62, 4.97, 3.64,
     * 4.63, 3.07, 4.06, 2.49, 3.30, 1.46, 2.06, 0.51, 0.74,-1.18,
     *-1.26,-3.54,-3.97,-5.26,-4.18,-3.71,-2.10,-1.70,-0.08,-0.18,
     * 0.94, 0.27, 1.13, 0.08, 0.91, 0.31, 0.49,-0.78, 0.08,-1.15,
     *-0.23,-1.41,-0.42,-1.55,-0.55,-1.66,-0.66,-1.73,-0.75,-1.74,
     *-0.78,-1.69,-0.78,-1.60,-0.75,-1.46,-0.67,-1.26,-0.51,-1.04,
     *-0.53,-1.84,-2.42,-4.52,-4.76,-6.33,-6.76,-7.81,-5.80,-5.37,
     *-3.63,-3.35/
      DATA CAMP/ 20.8, 15.8, 21.0, 16.8, 19.8, 16.5, 18.8, 16.5,
     *  18.5, 17.2,
     *  18.26,  15.05,  16.01,  12.04,  13.27,  11.09,
     *  12.17,  10.26,  11.04,  8.41,  9.79,  7.36,  8.15,  5.63, 5.88,
     *  3.17,  3.32,  0.82,  1.83,  0.97,  2.33,  1.27,  2.92, 1.61,
     *  2.91,  1.35,  2.40,  0.89,  1.74,  0.36,  0.95, -0.65,  -0.04,
     *  -1.73, -0.96, -2.87, -2.05, -4.05, -3.40, -5.72, -3.75, -4.13,
     * -2.42, -2.85, -1.01, -1.33, 0.54, -0.02, 1.74, 0.75,
     * 2.24, 1.00, 1.98, 0.79, 1.54, 0.39, 1.08, 0.00, 0.78,-0.35, 0.58,
     *-0.55, 0.59,-0.61, 0.59,-0.35, 0.32,-0.96,-0.52,-2.08,-2.46,-3.64,
     *-1.55,-0.96, 0.97, 0.88, 2.37, 1.75, 2.72, 1.90, 2.55, 1.46, 1.93,
     * 0.86, 1.17, 0.08,-0.39,-0.76,-0.39,-1.51,-1.17,-2.36,-1.95,-3.06,
     *-2.62,-3.55,-2.95,-3.75,-3.07,-3.79,-3.06,-3.77,-3.05,-3.78,-3.12,
```

```
     *-3.90,-3.35,-4.24,-3.86,-4.92,-5.06,-6.77,-7.41, 9.18,-10.16,
     *-11.12,-9.76,-9.23,-7.96,-7.65/
C                                      1000. is simply "big" number
      DATA ZD/10., 20., 30., 50., 70., 1000./
      DATA RKPD/ 0.42, 0.58, 0.68, 0.77, 0.8, 0.8/
      DATA CPD/ 0.5, 0.28, 0.2, 0.15, 0.1, 0.1/
      DATA RKAD/ 0.68, 0.82, 0.91, 0.97, 0.98, 0.98/
      DATA CAD/ 3*0.1, 0.08, 0.06, 0.06/
C  CHATTERJEE COMPILATION
C        NEUTRONS WILMORE
         DATA RL0N,RL1N,RM0N,RM1N,RN0N,RN1N,RN2N/
     *31.05,-25.91,342.4,21.89,0.223,0.673,617.4/
C        PROTONS BECCHETTI
         DATA P0P,P1P,P2P,RL0P,RL1P,RM0P,RM1P,RN0P,RN1P,RN2P/
     *15.72,9.65,-449.0,0.00437,-16.58,244.7,0.503,273.1,-182.4,-1.872/
C        ALPHA-PARTICLES HUIZENGA
         DATA P0A,P1A,P2A,RL0A,RL1A,RM0A,RM1A,RN0A,RN1A,RN2A/
     *10.95,-85.2,1146.,0.0643,-13.96,781.2,0.29,-304.7,-470.,-8.58/
      DATA DWA/22*0.0,
     * -0.6, -0.7, -0.8, -0.9, -1.8, -2.0, -2.9, -2.4, -2.3, -1.6, -1.3,
     * -1.0, -0.8, -0.4, -0.3,  0.1,  0.5,  0.8,  1.4,  2.0,  1.8,  1.5,
     *  1.4,  1.3,  0.8,  0.3, -0.0, -0.8, -1.5, -1.6, -1.7, -1.8, -1.8,
     * -1.8, -2.4, -2.0, -1.7, -1.6, -1.6, -1.3, -0.7, -0.6, -0.2,  0.0,
     *  0.9,  0.8,  1.2,  1.5,  1.8,  2.0,  2.4,  1.8,  2.4,  2.0,  1.7,
     *  2.4,  2.4,  1.8,  1.2,  0.4, -0.1, -0.3,  0.5, -0.9, -2.0, -1.7,
     * -2.4, -2.4, -2.0, -1.6, -1.1, -0.7, -0.2, -0.2, -0.2, -0.1,  0.7,
     *  1.2,  1.8,  0.1,  0.8,  1.1,  1.5,  1.6,  0.5,  0.7,  1.1,  1.2,
     *  1.2, -0.0,  0.3,  0.2,  0.4,  0.3,  0.3, -0.7, -0.0, -1.1, -0.6,
     * -0.7, -1.0, -1.6, -2.0, -1.7, -1.5, -2.2, -2.3, -3.1, -2.6, -3.2,
     * -2.6, -3.3, -4.2, -2.4, -4.1, -3.8, -4.1, -3.7, -3.2, -2.9, -2.2,
     * -2.4, -1.8, -0.6, -0.4,  0.1,  0.2,  0.3, -0.1, -0.5, -0.7, -1.1,
     * -1.4, -1.7, -2.0, -2.1, -2.1, -2.3, -2.5, -2.2, -2.5, -2.7, -3.0,
     * -3.2, -3.4, -3.1, -3.2, -3.4, -3.5, -3.3, -3.7, -3.1, -3.4, -3.5,
     * -3.4, -3.2, -3.5, -3.2, -3.5, -3.7, -3.4, -3.4, -3.4, -3.2, -3.0,
     * -2.9, -2.5, -2.8, -3.0, -3.3, -3.7, -4.3, -4.8, -5.4, -6.0, -6.8,
     * -7.1, -8.1, -8.7, -9.2, -9.6,-10.5,-11.3,-12.2,-12.0,-12.7,-12.1,
     *-11.2,-10.6,-10.0, -9.4, -8.8, -8.2, -7.6, -7.0, -6.4, -5.8, -5.2/
c      RETURN
       END
************************************************************************
*                  BLOCK DATA C                                        *
************************************************************************
      BLOCK DATA C
C Written by Barashenkov, Polanski
C     NUCLEUS-NUCLEUS CROSS-SECTION PARAMETERS
      COMMON/CX/CX(38)
      DATA  CX/2.07,560.,0.8,0.426,
     *           100.,-2.05,1.9,
     *           200.,0.07,0.87,
     *           20.,-1.55,2.1,
     *           700.,-1.01,1.08,
     *           400.,-0.59,0.94,
     *        2.45,225.,-2.25,2.,
     *           100.,-4.61,3.18,
     *           185.,-3.,2.4,
     *           185.,-3.,2.4,
     *           185.,-4.77,3.18,
     *           185.,-4.77,3.18/
      END
```

```
************************************************************************
*                  FUNCTION CAMERO                                     *
************************************************************************
      FUNCTION CAMERO(RN,Z)
* Defect mass calculation. Barashenkov, Toneev "Interaction of particles
* and nuclei", 1972, Atomizdat (error on p.419 corrected)
      A=RN+Z
      A13=A**0.333333333
      A23=A13*A13
      A43=A23*A23
      Z43=Z**(4./3.)
      AZ=((A-2.*Z)/A)**2
      RMOB=A*(8.367+31.4506*AZ)-(0.783*Z+17.0354*A)
      RMPOW=A23*(25.8357-44.2355*AZ)*((1.-0.62025/A23)**2)
      RMK=0.779*(Z*(Z-1.)/A13)*(1.-1.5849/A23+1.2273/A+1.5772/A43)
      RMEX=-0.4328*(Z43/A13)*(1.-0.57811/A13-0.14518/A23+0.49597/A)
      CAMERO=RMOB+RMPOW+RMK+RMEX
      RETURN
      END
************************************************************************
*                  SUBROUTINE CFUN                                     *
************************************************************************
      SUBROUTINE CFUN
      COMMON/CFUMAS/CF /TR2CFU/REC /EDEFF/Ed
      COMMON/QBOCFU/NSUMN,NSUMP /AN/AN /MPARIN/MPARIN
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
         AP=1.
         IF(MPARIN.eq.3) AP=4.
         Z2=Z-FLOAT(NSUMP)+1.+(MPARIN-1)
         A2=AN-FLOAT(NSUMN+NSUMP)+2.+AP
         Z1=Z
         A1=AN
      CALL NRT_COEFF(Z1,Z2,A1,A2,ANRT,BNRT,GNRT)
      EDkeV=Ed
* NRT
      TT=REC*1000.
      If(TT.lt.EDkeV) then
                      CF=0.0
                      Return
                      Endif
       If(TT.lt.2.*EDkeV) TT=2.*EDkeV
       CF=(0.8/(2.*EDkeV))*TT/
     + (1.+ANRT*TT+BNRT*(TT**0.75)+GNRT*(TT**0.16666666666))
       RETURN
       END
************************************************************************
*                  SUBROUTINE CHECK1                                   *
************************************************************************
      SUBROUTINE CHECK1(G,T1,W1,IGEN,M1)
* limitation on orbital momenta according to Bunakov
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/ACTSCI/PIN1,PIN2,PIN3,WPX,RK3,RK4,GAMMA,SK2,VC2,VCX,
     *VCY,VCZ,MPX
      COMMON/SCIMEM/WPM,PXM,PYM,PZM,PM,TM,EM,XM,YM,ZM,RM,JINM,MM
      COMMON/IMOM/IMOM
      IF(IMOM.EQ.0)RETURN
C
      IF(G)1,1,2
    1 RK=RK4-(GAMMA-1.)*SK2/VC2
```

```
      GOTO 3
    2 RK=RK3+(GAMMA-1.)*SK2/VC2
    3 CONTINUE
    4 PX5=G*PIN1+RK*VCX
      PY5=G*PIN2+RK*VCY
      PZ5=G*PIN3+RK*VCZ
      P5=SQRT(PX5*PX5+PY5*PY5+PZ5*PZ5)
      T5=T1
      RORM=ORBIT(PX5,PY5,PZ5,X,Y,Z)
      CALL QUES(RORM,T5,W1,JIN,M1,IGEN)
      RETURN
C
      END
**********************************************************************
*                 SUBROUTINE CHESEP                                  *
**********************************************************************
      SUBROUTINE CHESEP
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/EVAMAS/NEVAN,NEVAP,NEVAD,NEVAT,NEVAHE,NEVAAL
      COMMON/INFSEP/KSEP(100,4),INFSEP,JSEPM
        DO 100 J=1,JSEPM
        IF(KSEP(J,1).NE.
     +  (NPREN+NEVAN+NEVAD+2*NEVAT+NEVAHE+2*(NEVAAL+NPREA))) GOTO 100
        IF(KSEP(J,2).NE.
     +  (NPREP+NEVAP+NEVAD+NEVAT+2*NEVAHE+2*(NEVAAL+NPREA))) GOTO 100
        KSEP(J,4)=KSEP(J,4)+1
100     CONTINUE
      RETURN
      END
**********************************************************************
*                 SUBROUTINE CHOPAR                                  *
**********************************************************************
      SUBROUTINE CHOPAR(JZ,SXX)
      COMMON/DAINT/PF(33,4),RO1(33),RZON(33),FIG
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/PARTNR/PPX,PPY,PPZ,PP,MX
      COMMON/TYPACT/L,L7 /QPARX/QPROT,QNEUT,QPROT2,QNEUT2
      COMMON/BOND1/QBON(200,200,6) /TFERMI/TF(34,4)
      COMMON/RNUCL/RNUCL /XPARAM/XPARAM,FIALPH
      COMMON/FICAP/FICAP,MZONA
      COMMON/URAND1/IYG
C
C Types of inetractions: L = 1  N-P  or  P-N
C                        L = 2  N-N  or  P-P
C                        L = 3  Elastic scattering NUCELON-ALPHA
C                        L = 4  Elastic scattering ALPHA-NUCLEON
C                        L = 5  Decay of ALPHA-PARTICLE in N-A interaction
C                        L = 6  NUCLEON-T  or  NUCLEON-HE-3
C                        L = 7  Decay of ALPHA-PARTICLE in A-N interaction
C
      MX = 0
      L  = 0
      L7 = 0
                      QNEUTX=QNEUT
                      QPROTX=QPROT
      IF(JZ.GE.MZONA) QNEUTX=QNEUT2
      IF(JZ.GE.MZONA) QPROTX=QPROT2
C
      IF(M.EQ.3) GOTO 300
```

```
C
      CALL CSPPPN(T,SPP,SPN)
      CALL CSPANA(T,SPA,1)
C "+QBON" because FLM coefficients are shifted on Q
       TT = T - QBON(1,1,6) - TF(JZ,M)        +  QBON(1,1,6)
       IF(TT.LT.0.0) TT = 0.0
       CSCAPT = 0.1 *
     # (-1.011E-06*(TT**3) + 0.0001748*TT*TT - 0.01128*TT+0.275742)
       CSCAPT = CSCAPT/( RNUCL * RO1(JZ) )
       IF(CSCAPT.LT.0.0) CSCAPT =0.0
       CSCAPT = CSCAPT*FICAP
C
      GOTO(4,5),M
C   NEUTRON
    4 QPAR1=QNEUTX
      QPAR2=QPROTX
      GOTO 6
C   PROTON
    5 QPAR1=QPROTX
      QPAR2=QNEUTX
    6 SPP=SPP*QPAR1
      SPN=SPN*QPAR2
C + CSCAPT due to introduction of D,HE3 in calculstions
                 STOT=SPN+SPP
      IF(JZ.GE.MZONA) STOT=SPN+SPP+SPA+CSCAPT
      SXX = STOT
      YY=STOT * RANDOM(0)
      IF(YY-SPP)10,10,20
C   INTERACTION WITH THE SAME TYPE
   10 MX=M
      L=2
      RETURN
   20 IF(YY-(SPN+SPP))100,100,200
  100 L=1
      IF(M-1)30,30,40
C  INTERACTION NEUTRON-----PROTON
   30 MX=M+1
      RETURN
C  INTERACTION PROTON-----NEUTRON
   40 MX=M-1
      RETURN
  200 IF(YY-(SPN+SPP+SPA))110,110,210
C  INTERACTION NUCLEON-----ALPHA
  110 MX = 3
C DEFINE TYPE OF INTERACTION (ELASTIC-NONELASTIC)
      CALL CSPANA(T,SEL,2)
                If(SPA.lt.SEL) SPA = SEL
      YY=SPA * RANDOM(0)
      IF(YY-SEL)103,103,105
C ELASTIC INTERACTION N-A
  103 L=3
      RETURN
C DECAY OF ALPHA
C NO DECAY DUE TO PAULI
  105 L=3
      RETURN
C  INTERACTION NUCLEON-----T,HE3
  210 MX = 4
      L = 6
```

```
      RETURN
C
C PROJECTILE IS ALPHA-PARTICLE
  300 T4 = T/4.
          FI = FIALPH
          FIALPH = 1.
      CALL CSPANA(T4,STOT,1)
      CALL CSPANA(T4,SEL,2)
                If(STOT.lt.SEL) STOT = SEL
          FIALPH = FI
      SXX = STOT
      YY=STOT * RANDOM(0)
      IF(YY-SEL)1004,1004,1005
C ELASTIC INTERACTION A-N
 1004 L=4
      GOTO 1007
C DECAY OF ALPHA-PARTICLE
 1005 L=7
      L7 = 1
C
C DEFINE PARTNER
 1007 YY = (QPROTX+QNEUTX) * RANDOM(0)
      IF(YY-QPROTX)1000,1000,2000
 1000 MX=2
C  INTERACTION ALPHA-----PROTON
      RETURN
 2000 MX=1
C  INTERACTION ALPHA-----NEUTRON
      RETURN
      END
**********************************************************************
*                  SUBROUTINE COULCH                                 *
**********************************************************************
      SUBROUTINE COULCH(VP,VA,IPAR,AEFF,ZEFF,
     + P11P,RL11P,RM11P,RN11P,ECOP,P11A,RL11A,RM11A,RN11A,ECOA)
C Calculate Coulomb potential for protons and neutrons for inverse
C reaction cross-sections according to Chatterjee (see Block data also)
         IPAR=0
         ECO2=ECOP*ECOP
         B=-2.*P11P*ECOP+RL11P-RN11P/ECO2
         C=P11P*ECO2+RM11P+2.*RN11P/ECOP
C Discriminant of square equation
             D=B*B-4.*P11P*C
             IF(D.LT.0.) GOTO 80
             SQD=SQRT(D)
         ES1=0.5*(-B+SQD)/P11P
         ES2=0.5*(-B-SQD)/P11P
             IF(P11P)10,20,30
10       VP=AMIN1(ES1,ES2)
         GOTO 40
20       WRITE(8,21)P11P
21       FORMAT(1X,'ERROR: SUBROUTINE COULCH  P11P=',E12.5)
          STOP
30       VP=AMAX1(ES1,ES2)
C the same for alpha-particles
40       ECO2=ECOA*ECOA
         B=-2.*P11A*ECOA+RL11A-RN11A/ECO2
         C=P11A*ECO2+RM11A+2.*RN11A/ECOA
C Discriminant of square equation
```

```
            D=B*B-4.*P11A*C
            IF(D.LT.0.) GOTO 80
            SQD=SQRT(D)
         ES1=0.5*(-B+SQD)/P11A
         ES2=0.5*(-B-SQD)/P11A
            IF(P11A)50,60,70
50       VA=AMIN1(ES1,ES2)
           GOTO 75
60       WRITE(8,61)P11A
61       FORMAT(1X,'ERROR:   SUBROUTINE COULCH  P11A=',E12.5)
           STOP
70       VA=AMAX1(ES1,ES2)
75       RETURN
  80    WRITE(8,1080)ZEFF,AEFF
1080    FORMAT(1X,'FOR ZEFF=',F6.1,' AEFF=',F6.1,' BLANN SHARP CUT',
     +  'OFF CR SECT IS TAKEN')
        IPAR=1
        RETURN
        END
*************************************************************************
*                 SUBROUTINE CROZON                                     *
*************************************************************************
      SUBROUTINE CROZON(J1,J2,WM,P1,T,M)
      COMMON/TFERMI/TF(34,4)
      T=T+TF(J2,M)-TF(J1,M)
      P1=SQRT(T*(T+2.*WM))
      RETURN
      END
*************************************************************************
*                 FUNCTION CSCHAT                                       *
*************************************************************************
      FUNCTION CSCHAT(T0,MPARIN)
C Inverse cross-sections according to Chatterjee A., Murthy K.H.N.,
C Gupta  S.K. Optical reaction cross sections for light projectiles
C Report IAEA,INDC(IND)- 27/GJ, 1980.
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/AN/AN
      COMMON/DATREN/RL0N,RL1N,RM0N,RM1N,RN0N,RN1N,RN2N
      COMMON/DATREP/P0P,P1P,P2P,RL0P,RL1P,RM0P,RM1P,RN0P,RN1P,RN2P
            GOTO(1,2,3),MPARIN
C  NEUTRONS
1       AN13=AN**0.333333333
        AN23=AN13*AN13
        RL11N=RL0N/AN13+RL1N
        RM11N=RM0N*AN13+RM1N*AN23
        RN11N=RN0N*AN23*AN23+RN1N*AN23+RN2N
      CSCHAT=0.001*(RL11N*T0+RM11N+RN11N/T0)
         RETURN
C  PROTONS
2     AP=AN
      ECOP=1.44*Z/(1.5*(AP**0.3333333333))
      EC2=ECOP*ECOP
         AM=AP**RM1P
         P11P=P0P+P1P/ECOP+P2P/EC2
         RL11P=RL0P*AP+RL1P
         RM11P=RM0P*AM
         RN11P=AM*(RN0P+RN1P*ECOP+RN2P*EC2)
C   EKSI=AMAX1(T0,ECOP)  CE‰—AC T0 BCEƒ„A > ECOP
       EKSI=T0
```

```
      CS=P11P*((T0-EKSI)**2)+RL11P*T0+RM11P+RN11P*(2.-T0/EKSI)/EKSI
      CSCHAT=0.001*CS
        RETURN
C NO CALCULATIONS FOR ALPHA INCIDENT
3       CSCHAT=0.0
        RETURN
        END
*********************************************************************
*                SUBROUTINE CSPANA                                  *
*********************************************************************
      SUBROUTINE CSPANA(T,SPA,ITYPE)
* Nucleon-alpha interaction cross-sections (fm**2)
* Data are correct only for T < 1 GeV
C ITYPE=1 total, =2 elastic
      COMMON/XPARAM/XPARAM,FI
      GOTO(1,2),ITYPE
C Total
1     IF(T-1.125)30,30,10
   10 IF(T-20.)  40,40,20
   20 IF(T-190.)50,50,60
C
   30 SPA=6754.8*(T**2)  -1608.5*T + 778.94
      SPA=0.1*FI*SPA
      RETURN
C
   40 SPA=7467.2/(T**1.6089) -51.109*T + 1773.7
      SPA=0.1*FI*SPA
      RETURN
C
   50 SPA=5230.0/(T**0.43473) + 1.2270*T  -658.81
      SPA=0.1*FI*SPA
      RETURN
C
   60 SPA= 3425.3/T + 0.073484* T  +  74.410
      SPA=0.1*FI*SPA
      RETURN
C
C Elastic
2     IF(T-1.125)300,300,100
  100 IF(T-20.)  400,400,200
  200 IF(T-190.)500,500,600
C
  300 SPA=6754.8*(T**2)  -1608.5*T + 778.94
      SPA=0.1*FI*SPA
      RETURN
C
  400 SPA=7466.4/(T**1.6338) -53.939*T + 1815.2
      SPA=0.1*FI*SPA
      RETURN
C
  500 SPA=10182.0/(T**0.76746) + 0.68190*T  -282.56
      SPA=0.1*FI*SPA
      RETURN
C
  600 SPA=  4833.8/T + 0.036414* T  -2.9546
      SPA=0.1*FI*SPA
      RETURN
      END
*********************************************************************
```

```
*                 SUBROUTINE CSPPPN                                     *
*************************************************************************
      SUBROUTINE CSPPPN(T,SPP,SPN)
* Nucleon-nucleon interaction cross-sections (fm**2)
      IF(T-40.)30,30,10
   10 IF(T-310.)40,40,20
   20 IF(T-400.)50,50,60
C
   30 SPN=-505.74/T**2+906.92/T+0.69466
      SPP=-117.42/T**2+308.85/T+0.53107
      RETURN
C
   40 SPN=23938./T**2+180.2/T+2.7147
      SPP=9307.4/T**2-1.1148/T+2.2429
      RETURN
C
   50 SPN=23938./T**2+180.2/T+2.7147
      SPP=88.737/T+.005337*T+.35475
      RETURN
C
   60 SPN=3.45
      SPP=88.737/T+.005337*T+.35475
      RETURN
      END
*************************************************************************
*                  SUBROUTINE DEFINE_ED                                 *
*************************************************************************
       SUBROUTINE DEFINE_ED
C Effective threshold damage energy Ed (eV)
C Data are from NJOY, except global value (NJOY: 25 eV)
       COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB  /EDEFF/Ed
       Ed=40.
       IZ=Ifix(Z+0.0001)
       If(IZ.eq. 4) Ed=31.
       If(IZ.eq. 6) Ed=31.
       If(IZ.eq.12) Ed=25.
       If(IZ.eq.13) Ed=27.
       If(IZ.eq.14) Ed=25.
       If(IZ.eq.20) Ed=40.
       If(IZ.ge.22.and.IZ.le.29) Ed=40.
       If(IZ.eq.40) Ed=40.
       If(IZ.eq.41) Ed=40.
       If(IZ.eq.42) Ed=60.
       If(IZ.eq.47) Ed=60.
       If(IZ.eq.73) Ed=90.
       If(IZ.eq.74) Ed=90.
       If(IZ.eq.79) Ed=30.
       If(IZ.eq.82) Ed=25.
C --> keV
       Ed=Ed/1000.
       Return
       End
*************************************************************************
*                  SUBROUTINE DENS                                      *
*************************************************************************
      SUBROUTINE DENS
* Level density calculation (idea of M.Blann)
      DOUBLE PRECISION POW,SQ11,EE,PT,UCLA
      COMMON/LAB10/POW(6,10000) /LAB3/SIG(6,2000)
```

```
      COMMON/LAB4/UCLA(6,2000) /INCR/ED
      COMMON/DATINI/RA,T0,W0
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/AN/AN /BOND1/QBON(200,200,6)
      COMMON/MPARIN/MMM /JMAX1/TENED,JMAX
      COMMON/XPARAM/XPARAM,FIALPH
      DIMENSION RD(6)
        IF(MMM.le.2) MPARIN=MMM
        IF(MMM.eq.3) MPARIN=6
      ED=0.5
C
C                1-N, 2-P, 3-D, 4-T, 5-HE3, 6-A
C
      DO 6 I=1,2000
      DO 6 K=1,6
  6   UCLA(K,I)=0.
         ZEFF=Z
         AEFF=AN
      XMAX= T0+QBON(1,1,MPARIN)
      If(QBON(1,1,6).lt.0.0) XMAX= T0+QBON(1,1,MPARIN)-QBON(1,1,6)
      IMAX=INT(XMAX/ED+1.)
      IF(IMAX.GT.2000)Print 30000
      IF(IMAX.GT.2000)IMAX=2000
      PLD=1./XPARAM
      M3 = 6
C Inverse reaction cross-sections
      CALL SIGICH(ZEFF,AEFF)
      AMASS=AEFF
C This value corresponds to 150 MeV energy for total equilibrium spectra
      QJMAX=FLOAT(150)/ED
      JMAX=INT(QJMAX)
      IF(JMAX.GT.2000)JMAX=2000
      TENED=10.*ED
      RR=AMASS/PLD
      SOR=SQRT(RR*100.)
C
C Level density parameters for particles channels POW(I)
      RD(1)=(AMASS-1.)/PLD
      RD(2)=(AMASS-1.)/PLD
      RD(3)=(AMASS-2.)/PLD
      RD(4)=(AMASS-3.)/PLD
      RD(5)=(AMASS-3.)/PLD
      RD(6)=(AMASS-4.)/PLD
C
      DO 7050 L=1,M3
      DO 7050 IB=1,10000
      BJ=DFLOAT(IB)/10.-.05
      SQ=2.*SQRT(RD(L)*BJ)-SOR
      SQ11=SQ
 7050 POW(L,IB)=(1./(1.+BJ**1.25))*DEXP(SQ11)
C Energy to join Fermi gas and constant temperature
      EX=2.
      TEN=10.*EX+0.05
      IT=INT(TEN)
      IF=IT-1
      DO 7047 L=1,M3
      TEMP=SQRT(EX/RD(L))
      D=EXP((EX)/TEMP)
      CQ1=POW(L,IT)/D
```

```
      DO 7048 IB=1,IF
      EE=0.10*DFLOAT(IB)-0.05
      POW(L,IB)=CQ1*DEXP((EE)/TEMP)
7048  CONTINUE
7047  CONTINUE
         Print *,'Level density calculated...'
      DO 4000 KJ=1,M3
      PRINT *,KJ
      DO 1000  I=1,IMAX
      EMAX=FLOAT(I-1)*ED
      M=INT(EMAX/ED+1.0001)
      IF(M-JMAX)415,415,410
  410 M=JMAX
  415 IF(M-1)430,420,420
  430 Print *,'M < 1'
      Goto 1000
  420 PT=0.0
          BI=10.*EMAX+0.05
          IB=INT(BI)
          If(IB.gt.10000) IB = 10000
          IF(IB.LE.0) GO TO 1000
      DO 435 L=1,M
      IF(IB.LT.1)GO TO 435
      PT=PT+POW(KJ,IB)*SIG(KJ,L)
      BI=BI-TENED
      IB=BI
  435 CONTINUE
      UCLA(KJ,I) = PT
 1000 Continue
 4000 Continue
      Return
30000 Format(//1x,60('Ä')/1x,5x,'ATTENTION!  IMAX is REDEFINED'
     # /1x,60('Ä'))
      End
*********************************************************************
*                 SUBROUTINE DISTPA                                 *
*********************************************************************
      SUBROUTINE DISTPA(JZ)
      COMMON/DAINT/PF(33,4),RO1(33),RZON(33),FIG
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/PARTNR/PPX,PPY,PPZ,PP,MX
      COMMON/DATCHO/RMP
      COMMON/TYPACT/L,L7
      COMMON/URAND1/IYG
      COMMON/k1996/k1996
      COMMON/XPARAM/XPARAM,FIALPH
C
C Types of interactions:  L = 1  N-P or P-N
C                         L = 2  N-N or P-P
C                         L = 3  Elastic NUCLEON-ALPHA
C                         L = 4  Elastic ALPHA-NUCLEON
C                         L = 5  Decay of ALPHA in N-A interaction
C                         L = 6  NUCLEON-T OR NUCLEON-HE-3
C                         L = 7  Decay of ALPHA in A-N interaction
C
C Temporarily: no averaging,  L=5 is considered by SEL:
C For L=6 cross-sectios are taken the same for all T or HE-3
       GOTO(1,2,3,4,5,106,7),L
1      CALL CSPPPN(T,SPP,SYY)
```

```
       GOTO 8
2      CALL CSPPPN(T,SYY,SPN)
       GOTO 8
3      CALL CSPANA(T,SYY,2)
       GOTO 8
4      T4 = T/4.
       FI = FIALPH
       FIALPH = 1.
       CALL CSPANA(T4,SYY,2)
       FIALPH = FI
       GOTO 8
5      CALL CSPANA(T,STOT,1)
       CALL CSPANA(T,SEL,2)
                SYY = STOT-SEL
                If(SYY.lt.0.0) SYY = 0.0
       GOTO 8
7      T4 = T/4.
       FI = FIALPH
       FIALPH = 1.
       CALL CSPANA(T4,STOT,1)
       CALL CSPANA(T4,SEL,2)
                SYY = STOT-SEL
                If(SYY.lt.0.0) SYY = 0.0
       FIALPH = FI
C
8      UU=RANDOM(0)
       IF(UU.ge.1.0) UU=0.99999
       RKSI = SYY * INT( 10.*UU + 1.0 )
106                PFM=PF(JZ,MX)
C
             VX = PX/WP
             VY = PY/WP
             VZ = PZ/WP
             V  = P /WP
       WPP=WM(MX)
       CALL WERO(PFM,PP,MX)
C
      KSS =0
9       SUM = 0.
        DO 900 II=1,15
C
      QCOS=1.-2.*RANDOM(0)
      FI=6.283185*RANDOM(0)
      QSIN=SQRT(ABS(1.-QCOS**2))
      CC=PP*QSIN
      PPX=CC*COS(FI)
      PPY=CC*SIN(FI)
      PPZ=PP*QCOS
      EP=SQRT(PP*PP+WPP*WPP)
      TRE=((E*SQRT(PP*PP+WPP*WPP)-PX*PPX-PY*PPY-PZ*PPZ)/WPP)-WP
             VXP = PPX/WPP
             VYP = PPY/WPP
             VZP = PPZ/WPP
        VV = SQRT((VXP-VX)**2 +(VYP-VY)**2 +(VZP-VZ)**2 )/V
C
C DEFINE CROSS-SECTION
C
       GOTO(10,20,30,40,50,60,70),L
10     CALL CSPPPN(TRE,SPP,SZZ)
```

```
       GOTO 800
20     CALL CSPPPN(TRE,SZZ,SPN)
       GOTO 800
30     CALL CSPANA(TRE,SZZ,2)
       GOTO 800
40     T4 = TRE/4.
       FI = FIALPH
       FIALPH = 1.
       CALL CSPANA(T4,SZZ,2)
       FIALPH = FI
       GOTO 800
50     CALL CSPANA(TRE,STOT,1)
       CALL CSPANA(TRE,SEL,2)
                SZZ = STOT-SEL
                If(SZZ.lt.0.0) SZZ = 0.0
       GOTO 800
60     RETURN
70     T4 = TRE/4.
       FI = FIALPH
       FIALPH = 1.
       CALL CSPANA(T4,STOT,1)
       CALL CSPANA(T4,SEL,2)
                SZZ = STOT-SEL
                If(SZZ.lt.0.0) SZZ = 0.0
       FIALPH = FI
C
800    SUM = SUM + SZZ * VV
C                                1  2  3  4   5  6   7
           If(SUM.ge.RKSI) GOTO(99,99,99,99,905,99,907),L
900    Continue
C
950    k1996 = k1996+1
                           GOTO(99,99,99,99,905,99,907),L
99    RETURN
C----------------------------L=5----------------------------------
C REDEFINITION OF PARTNER TYPE FOR ALPHA-DECAY (L=5)
905   PP=PP/4.
      PPX=PPX/4.
      PPY=PPY/4.
      PPZ=PPZ/4.
      TP = (PP**2)/(2.*WM(1))
      CALL CSPPPN(TP,SPP,SPN)
      YY=(SPN+SPP) * RANDOM(0)
      IF(YY-SPP)11,11,22
C  INTERACTION WITH THE SAME TYPE
   11 MX=M
      L=2
      RETURN
   22 L=1
      IF(M-1)33,33,44
C  INTERACTION NEUTRON----PROTON
   33 MX=M+1
      RETURN
C  INTERACTION PROTON-----NEUTRON
   44 MX=M-1
      RETURN
C----------------------------L=7----------------------------------
C REDEFINITION OF TYPE OF INCIDENT PARTICLE FOR ALPHA-DECAY (L=7)
907   CALL MEMDEC(1)
```

```
      WP = WP/4.
      PX = PX/4.
      PY = PY/4.
      PZ = PZ/4.
      P  = P /4.
      T  = T /4.
      E  = E /4.
      CALL CSPPPN(T,SPP,SPN)
      YY=(SPN+SPP) * RANDOM(0)
      IF(YY-SPP)111,111,222
C  INTERACTION WITH THE SAME TYPE
  111  M=MX
       L=2
       RETURN
  222  L=1
       IF(MX-1)333,333,444
C  INTERACTION NEUTRON----PROTON
  333  M=MX+1
       RETURN
C  INTERACTION PROTON----NEUTRON
  444  M=MX-1
       RETURN
       END
**********************************************************************
*                SUBROUTINE EVAPAR                                   *
**********************************************************************
      SUBROUTINE EVAPAR
      COMMON/DATEVA/GP,GD,GT,GHE,GAL,GAMP,GAMD,GAMT,GAMHE,GAMAL,CP,CD,
     *CT,CHE,CAL,VP,VD,VT,VHE,VAL,QN,QP,QD,QT,QHE,QAL
      COMMON/EVATR2/WEIG,VX,VY,VZ
      COMMON/EVAMAS/NEVAN,NEVAP,NEVAD,NEVAT,NEVAHE,NEVAAL
      COMMON/TR1EVA/EXCIT,WMAI /URAND1/IYG
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/SUM90/ER90,KER90
      COMMON/INFDIS/INFDIS,INFOUP(3)
      DIMENSION WIDTH(6),TAUX(6)
      WEIG=WMAI
                   ER90=ER90+EXCIT
                   KER90=KER90+1
    1 CALL QBOND(EXCIT,WIDTH,TAUX,KEY)
         IF(KEY.EQ.0) RETURN
      CC=RANDOM(0)
      DO 2 KX = 1,6
      IF(CC.LE.WIDTH(KX)) GOTO 3
    2 CONTINUE
      PRINT 1000,WIDTH,CC
      STOP
    3 GOTO(11,22,33,44,55,66),KX
C N
   11 NEVAN=NEVAN+1
      CALL FLIG(1,TAUX(1),E)
      WPAR=WM(1)
      WEIG = WEIG - WPAR
      EXCIT = TAUX(1) - E
      IF(INFOUP(1).EQ.1)CALL MEMEQU(E,1)
      GOTO 200
C P
   22 NEVAP=NEVAP+1
      CALL FLIG(2,TAUX(2),E)
```

```
      WPAR=WM(2)
      WEIG = WEIG - WPAR
      EXCIT = TAUX(2) - E
      IF(INFOUP(2).EQ.1)CALL MEMEQU(E,2)
      GOTO 200
C D
   33 NEVAD=NEVAD+1
      CALL FLIG(3,TAUX(3),E)
      WPAR=WM(5)
      WEIG = WEIG - WPAR
      EXCIT = TAUX(3) - E
      GOTO 200
C T
   44 NEVAT=NEVAT+1
      CALL FLIG(4,TAUX(4),E)
      WPAR=WM(4)
      WEIG = WEIG - WPAR
      EXCIT = TAUX(4) - E
      GOTO 200
C HE3
   55 NEVAHE=NEVAHE+1
      CALL FLIG(5,TAUX(5),E)
      WPAR=WM(4)
      WEIG = WEIG - WPAR
      EXCIT = TAUX(5) - E
      GOTO 200
C A
   66 NEVAAL=NEVAAL+1
      CALL FLIG(6,TAUX(6),E)
      WPAR=WM(3)
      WEIG = WEIG - WPAR
      EXCIT = TAUX(6) - E
      IF(INFOUP(3).EQ.1)CALL MEMEQU(E,3)
  200 V=VELOC(WPAR,WEIG,E)
      CC=RANDOM(0)
      QCOS=1.-2.*CC
      QSIN=SQRT(ABS(1.-QCOS*QCOS))
      CC=RANDOM(0)
      FI=6.2831852*CC
      VX=VX+V*QSIN*COS(FI)
      VY=VY+V*QSIN*SIN(FI)
      VZ=VZ+V*QCOS
      GOTO 1
C
 1000 FORMAT(1X,'CONTROL SUBR EVAPAR:'/1X,6G12.5/1X,G12.5)
      END
**********************************************************************
*                  FUNCTION FC                                       *
**********************************************************************
      FUNCTION FC(T,B)
C Written by Barashenkov, Polanski
      COMMON /FH/AMP,AMT,AP,AT,B0,R0
C     CMS ENERGY
      TC=T*AMT/(AMP+AMT)
      X=(TC-B)/1.2
      IF(X.GT.5) GO TO 1
      D=1.+EXP(X)
      FC=ALOG(D)/TC
      RETURN
```

```
  1   FC=X/TC
      RETURN
      END
*********************************************************************
*                  FUNCTION FHS                                     *
*********************************************************************
      FUNCTION FHS(IS,E,C)
C Written by Barashenkov, Polanski
C     CALCULATION OF HIGH-ENERGY TOTAL (IS=2) AND
C     INELASTIC (IS=1) CROSS-SECTIONS
C      E - LAB. KINETIC ENERGY OF PROJECTILE(MEV)
      COMMON/FH/AM      P,AMT,AP,AT,B0,R0
C     SQUARED PROJECTILE CMS MOMENTUM
      PPC=AMT*AMT*E*(E+2.*AMP)/((AMP+AMT)**2+2.*AMT*E)
C     DE BROGLE WAVE LANGTH
      AL=1.41*140./SQRT(PPC)
      EC=SQRT(PPC+AMP*AMP)-AMP
C     COULOMB BARRIER
      B=B0/R0/(AP+AT+AL)
      FHS=31.416*1.21*(1.-B/EC)*(AP+AT+1.85*AP*AT/(AP+AT)
     *+AL-C)**2*IS
      RETURN
      END
*********************************************************************
*                SUBROUTINE FLIG                                    *
*********************************************************************
      SUBROUTINE FLIG(KJ,TAUX,E)
      DOUBLE PRECISION UCLA,WTOT,PT,POW
      COMMON/URAND1/IYG  /MAIIPR/IPR
      COMMON/LAB10/POW(6,10000)
      COMMON/LAB3/SIG(6,2000)
      COMMON/LAB4/UCLA(6,2000)
      COMMON/INCR/ED
      COMMON/JMAX1/TENED,JMAX
      E=0.
      M=INT(TAUX/ED+1.)
      EMAX=FLOAT(M-1)*ED
            CC=RANDOM(0)
            WTOT = CC*UCLA(KJ,M)
      IF(M-JMAX)415,415,410
  410 M=JMAX
  415 IF(M-1)430,420,420
  430 RETURN
C
  420    PT=0.0
         BI=10.*EMAX+0.05
         IB=INT(BI)
         If(IB.gt.10000) IB = 10000
         IF(IB.LE.0) RETURN
C
      DO 435 L=1,M
      IF(IB.LT.1)GO TO 435
      PT=PT+POW(KJ,IB)*SIG(KJ,L)
      IF(PT.GE.WTOT) GOTO 500
      BI=BI-TENED
      IB=BI
  435 CONTINUE
      PRINT *,'BAD INTEGRAL: ',PT,' < ',WTOT,' CC=',CC
  500 E=FLOAT(L)*ED - ED/2.
```

```
      RETURN
      END
*********************************************************************
*                 SUBROUTINE GRAPH                                  *
*********************************************************************
      SUBROUTINE GRAPH(Y,F,N3,IALOG)
* IALOG.ne.0 : logarithmic scale for function (Y)
      COMMON/MAIIPR/IPR1
      DIMENSION Y(N3),F(N3),F1(150)
      INTEGER A1(40),B1,C1,D1,D2,D3,D4,D5,D6
      DATA B1,C1,D1,D2,D5,D6/1H*,1H ,1H!,1H-,1HI,1H./
      IF(N3.GT.150)STOP
      N1=1
      W=F(1)
      DO 1 L=1,N3
      IF(ABS(W).GT.ABS(F(L)))GOTO 1
      W=F(L)
    1 CONTINUE
      IF(W.NE.0.)GOTO 70
      WRITE(IPR1,41)
   41 FORMAT(1X,' SUBR GRAPH: MAXIMAL FUNCTION VALUE IS EQUAL TO ZERO')
      RETURN
   70 IF(IALOG.NE.0)GOTO 199
      WRITE(IPR1,60)
   60 FORMAT(/3X,'Agrument    Function   ',4X,4('.........!'))
      T=40./ABS(W)
      DO 300 I=1,N3
  300 F1(I)=F(I)
      GOTO 7
  199 WMIN=1.E+10
      DO 200 I=1,N3
      IF(F(I).NE.0..AND.F(I).LT.WMIN)WMIN=F(I)
  200 CONTINUE
      IMAX=-8
  210 IF(W.LE.10.**IMAX)GOTO 220
      IMAX=IMAX+1
      GOTO 210
  220 IMIN=IMAX
  230 IF(WMIN.GE.10.**IMIN)GOTO 240
      IMIN=IMIN-1
      GOTO 230
  240 R10=10.**IMIN
      IF(IMIN.EQ.IMAX)GOTO 250
      WW1=FLOAT(IMIN)
      WW=FLOAT(IMAX-IMIN)
      R20=10.**IMAX
      WRITE(IPR1,62)R10,R20
   62 FORMAT(1X,5X,'LOGARITHMICAL SCALE FOR FUNCTION'
     1/3X,23X,E8.2,32X,E8.2)
      GOTO 260
  250 WW1=ALOG10(WMIN)
      WW=ALOG10(WMAX)-ALOG10(WMIN)
  260 DO 270 I=1,N3
      FF=F(I)
      IF(FF.EQ.0.)FF=R10
  270 F1(I)=ALOG10(FF)-WW1
      WRITE(IPR1,63)
   63 FORMAT(/3X,'Agrument    Function   ',4X,4('.........'))
      T=40./WW
```

```
    7 CONTINUE
      DO 3 I=1,N3
      X=F1(I)
      N=INT(X*T)
      IF(I.EQ.N3)GOTO 105
      IF(I.EQ.N1*10)GOTO 107
      D4=C1
      GOTO 108
  105 D4=D6
      GOTO 108
  107 D4=D2
      N1=N1+1
  108 N2=1
      DO 4 J1=1,40
      IF(J1.EQ.20)GOTO 110
      IF(J1.EQ.1.OR.J1.EQ.40)GOTO 24
      D3=D4
      GOTO 25
   24 D3=D5
   25 CONTINUE
      GOTO 111
  110 D3=D1
      N2=N2+1
  111 CONTINUE
      IF(J1.EQ.N)GOTO 101
      A1(J1)=D3
      GOTO 102
  101 A1(J1)=B1
  102 CONTINUE
    4 CONTINUE
      WRITE(IPR1,61)Y(I),F(I),A1
   61 FORMAT(G12.5,1X,1PE12.5,5X,40A1)
    3 CONTINUE
      RETURN
      END
*********************************************************************
*                   SUBROUTINE INIDAT                               *
*********************************************************************
      SUBROUTINE INIDAT(KZONESC)
      COMMON/DATINI/RA,T0,W0  /DAINT/PF(33,4),RO1(33),RZON(33),FIG
      COMMON/DATCHO/RMP /TFERMI/TF(34,4)
      COMMON/DATEVA/GP,GD,GT,GHE,GAL,GAMP,GAMD,GAMT,GAMHE,GAMAL,CP,CD,
     *CT,CHE,CAL,VP,VD,VT,VHE,VAL,QN,QP,QD,QT,QHE,QAL
      COMMON/K/K /DATOUT/SGEOM,FOUT
      COMMON/DATTR1/QNN,QPP /URAND1/IYG  /DATPAU/BONCUT(3)
      COMMON/EMEM/EMEM0(21),EMEM(21),RMEM(21,3),RMEM0(21,3),HMEM
      COMMON/RNUCL/RNUCL/CSABS/CSABS,FIALP2
      COMMON/EOUT/SPE(19,5,3),PI(19),EOUT1(5,3),EOUT2(5,3),MSPE
      COMMON/TEMP2/BONNE/NREJ/REFR,NREJ/MM/RMASS
      COMMON/QPARX/QPROT,QNEUT,QPROT2,QNEUT2 /BOND1/QBON(200,200,6)
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/ALIBLI/ALINPK(6),BLINPK(6),ALINPC(6),BLINPC(6),
     *ALINAK(6),BLINAK(6),ALINAC(6),BLINAC(6)
      COMMON/DOSTRO/RKPD(6),RKAD(6),CPD(6),CAD(6),ZD(6)
      COMMON/QNNN/QNNN /MAIIPR/IPR /AN/AN /INF/INFBIG,INFS0
      COMMON/EMEM91/EMEMT(21),RMEMT(21),HMEMT
      COMMON/SPEFUL/ANGLIM(9,2,3),ANGSUM(21,9,3),ANGCEN(9,3),DCEN,MANG
      COMMON/XPARAM/XPARAM,FIALPH /MPARIN/MPARIN
      DIMENSION A1(10),A2(33),A(33)
```

```
C
C  Number of zones (K)
C  Values to approximate Woods-Saxon distribution
C 1.0 corresponds to the center of the nucleus
C 10 zones
      DATA A1/ 0.9, 0.8, 0.5, 0.3, 0.2, 0.1,  0.075, 0.05, 0.025, 0.01/
C 33 zones
      DATA A2/
     *  0.98, 0.95,  0.90, 0.85,  0.80, 0.75, 0.70,  0.60,  0.50, 0.40,
     *  0.30, 0.20,  0.10, 0.08,  0.06,  0.04, 0.02, 0.01, 0.008, 0.006,
     *  0.004, 0.002, 0.001, 8.e-4, 6.e-4, 4.e-4, 2.e-4, 1.e-4, 8.e-5,
     *  6.e-5, 4.e-5, 2.e-5, 1.e-5/
                            If(KZONESC.eq.0) KZONESC=1
                            If(KZONESC.lt.1.or.KZONESC.gt.2) goto 2000
C
C KZONESC =1 : 10 zones;  = 2 :  33 zones
       If(KZONESC.eq.1) then
       K=10
       Do i=1,K
       A(i)=A1(i)
       Enddo
                       else
       K=33
       Do i=1,K
       A(i)=A2(i)
       Enddo
                       endif
       AM=AN
C  QPROT2,QNEUT2  are for zones with alpha-particles
      QPROT=Z/AN
      QNEUT=(AN-Z)/AN
         QPROT2=(Z-2.*FIALPH*AN)/(AN-3.*FIALPH*AN)
         QNEUT2=(AN-Z-2.*FIALPH*AN)/(AN-3.*FIALPH*AN)
C Recalculation FIALPH
      FIALP2=FIALPH
      FIALPH=FIALPH*AN/(AN-3.*FIALPH*AN)
      ONE=QPROT2+QNEUT2+FIALPH
      print *,'ONE=',ONE
      RMASS=1./(1.+AM)
C Effective nucleus radius
      RNUCL=1.25*(AM**0.3333333333)
C Nuclear density
      DATA AA/0.545/,RO/0.17/
      R=1.07*(AN**0.333333333)
      X1=(3.*(3.1415926**2))**0.333333333
      PARTFM=0.5*(20.7214+20.74998)*(X1**2)
      PARPFM=197.3285*X1
C
      RMP=0.5*(938.2796+939.5731)
      PRINT 69
      IF(INFBIG.GT.0)WRITE(IPR,69)
C
C PF(I,M), TF(I,M):
C M = 1   neutron
C M = 2   proton
C M = 3   alpha-particle
C M = 4   He-3, triton
       DO 1 I=1,K
          RO1(I)=A(I)*RO
```

```
          ROPRO=RO1(I)*QPROT
          RONEU=RO1(I)*QNEUT
          RZON(I)=R+AA*ALOG((1.-A(I))/A(I))
          PF(I,2)=PARPFM*(ROPRO**0.333333333)
          TF(I,2)=PARTFM*(ROPRO**0.666666666)
          PF(I,1)=PARPFM*(RONEU**0.333333333)
          TF(I,1)=PARTFM*(RONEU**0.666666666)
          TFEFF=QPROT*TF(I,2)+QNEUT*TF(I,1)
          PFEFF=SQRT(2.*RMP*TFEFF)
             TF(I,3) = 4.* TFEFF
             PF(I,3) = SQRT(2.*WM(3)*TF(I,3))
          TF(I,4) = 3.* TFEFF
          PF(I,4) = SQRT(2.*WM(4)*TF(I,4))
          PRINT 70,I,RZON(I),RO1(I),
     *    PF(I,2),PF(I,1),PF(I,3),TF(I,2),TF(I,1),TF(I,3),PFeff,TFeff
          IF(INFBIG.GT.0)WRITE(IPR,70)I,RZON(I),RO1(I),
     *    PF(I,2),PF(I,1),PF(I,3),TF(I,2),TF(I,1),TF(I,3),PFeff,TFeff
C TF and PF for neutrons and protons
          PF(I,1)=PFEFF
          TF(I,1)=TFEFF
              PF(I,2)=PFEFF
              TF(I,2)=TFEFF
    1  CONTINUE
   69 FORMAT(1X,'ZONE RADIUS  DENS ',
     *' PF(P) PF(N)  PF(A) TF(P) TF(N) TF(A) PF(Eff) TF(Eff)')
   70 FORMAT(1X,1x,I2,1x, F7.2,  F7.4, 2F6.1, F7.1, 3F6.1, 2F8.2)
C Number of division for free particle path (not used)
      FIG=3.
      FOUT=FIG
C Woods-Saxon nucleus radius
      RA=RZON(K)
C Mass of incident particle
                       W0=939.5731
        IF(MPARIN.EQ.2)W0=938.2796
        IF(MPARIN.EQ.3)W0=4.0026033*931.4812
C
C For Dostrovsky inverse cross-section ( Barashenkov, Toneev Book,1972 p.413)
C Dostrovsky coeff = ALINAK * Z + BLINAK
          DO 555 I=2,6
         ZZ=ZD(I)-ZD(I-1)
              ALINPK(I)=(RKPD(I)-RKPD(I-1))/ZZ
              BLINPK(I)=-ALINPK(I)*ZD(I-1)+RKPD(I-1)
                ALINPC(I)=(CPD(I)-CPD(I-1))/ZZ
                BLINPC(I)=-ALINPC(I)*ZD(I-1)+CPD(I-1)
         ALINAK(I)=(RKAD(I)-RKAD(I-1))/ZZ
         BLINAK(I)=-ALINAK(I)*ZD(I-1)+RKAD(I-1)
           ALINAC(I)=(CAD(I)-CAD(I-1))/ZZ
555      BLINAC(I)=-ALINAC(I)*ZD(I-1)+CAD(I-1)
C  See also BLOCK DATA
C
C Geometrical cross-section
      SGEOM=(3.1415926E-02)*((RA+4.552/SQRT(T0))**2)
        QN=QBON(1,1,1)
        QP=QBON(1,1,2)
      TF(K+1,1)=-QN
      TF(K+1,2)=-QP
      TF(K+1,3)=-QBON(1,1,6)
      TF(K+1,4)=-0.5*( QBON(1,1,4)+QBON(1,1,5) )
C Redefinition of this value for neutron and proton
```

```
      TF(K+1,1)=QNEUT*TF(K+1,1)+QPROT*TF(K+1,2)
      TF(K+1,2)=TF(K+1,1)
C
       QNN=QN
       QPP=QP
           QNNN=QN
           IF(MPARIN.EQ.2)QNNN=QP
           IF(MPARIN.EQ.3)QNNN=QBON(1,1,6)
C
C Coulomb potential for protons and alphas
C             VP=0.1*Z+0.8
C             VP=1.44*Z/RNUCL
C best value
              VP=1.0 *Z/RNUCL
CC Zr (N,P) reaction
CC    VP=(  Z-FLOAT(MPARIN-2)  )*1.15/( 1.6 + 1.21*( AN**.3333+1.))
CC    VP=0.1*Z-0.2
      VAL=0.21*Z+2.5
      PRINT 600,VP,VAL
C
C Cut-off parameter BONCUT(1)-neutrons, (2)-protons, (3)-alpha
      BONCUT(1)=-TF(K+1,1)+BONNE
      BONCUT(2)=-TF(K+1,2)+VP+BONNE
      BONCUT(3)=-TF(K+1,3)+VAL+BONNE
      PRINT 1999,QN,QP,BONCUT(1),BONCUT(2),BONCUT(3),TF(K+1,1),BONNE,VP
        IF(QN.GT.-TF(K+1,1))BONCUT(1)=QN+BONNE
        IF(QP.GT.-TF(K+1,2))BONCUT(2)=QP+VP+BONNE
      PRINT 1999,QN,QP,BONCUT(1),BONCUT(2),BONCUT(3),TF(K+1,1),BONNE,VP
 1999 FORMAT(1X,' QN=',F6.2,' QP=',F6.2,' BONCUT(1)=',F6.2,' (2)=',
     *F6.2,' (3)=',F6.2,' TF(max)=',F6.2,' BONNE=',F6.2,' VP=',F6.2)
C
C=====================================================================
C Arrays and auxilarily for calculation energy spectra
C EMEM: evaporation spectrum, EMEM0: non-equilibrium spectrum
C EMEM=EMEM0. EMEMT: recoil spectrum
      EMEM0(1)=0.
      RMEM0(1,1)=0.
      RMEM0(1,2)=0.
      RMEM0(1,3)=0.
            QBMIN = QBON(1,1,MPARIN)
       IF(MPARIN.eq.3) QBMIN =QBON(1,1,6)
            If(QBMIN.gt.QBON(1,1,1)) QBMIN = QBON(1,1,1)
            If(QBMIN.gt.QBON(1,1,2)) QBMIN = QBON(1,1,2)
            If(QBMIN.gt.QBON(1,1,6)) QBMIN = QBON(1,1,6)
         HMEM=( T0+QBON(1,1,MPARIN)-QBMIN )/20.
         IF(MPARIN.eq.3) HMEM=( T0+QBON(1,1,6)-QBMIN )/20.
         EMEM(1)=0.
         RMEM(1,1)=0.
         RMEM(1,2)=0.
         RMEM(1,3)=0.
                HMEMT=(9.*T0/AN)+0.2
        IF(MPARIN.eq.3)  HMEMT=0.3*T0 ! rather arbitrary
                HMEMT=HMEMT/20.
            EMEMT(1)=0.
            RMEMT(1)=0.
      DO 567 NU=2,21
      EMEM0(NU)=EMEM0(NU-1)+HMEM
        EMEM(NU)=EMEM(NU-1)+HMEM
          EMEMT(NU)=EMEMT(NU-1)+HMEMT
```

```
      RMEM0(NU,1)=0.
      RMEM0(NU,2)=0.
      RMEM0(NU,3)=0.
         RMEM(NU,1)=0.
         RMEM(NU,2)=0.
         RMEM(NU,3)=0.
  567       RMEMT(NU)=0.
            EMEMT(21)=(9.*T0/AN)+3.0
C
C Arrays for calcualtion total angular distribution
      QPI=3.1415926/18.
      QAN=0.
      PI(1)=1.
      DO 597 IQAN =1,19
      DO 597 IQAN2=1,5
      DO 597 IQAN3=1,3
  597 SPE(IQAN,IQAN2,IQAN3)=0.
         DO 598 IQAN=2,19
         QAN=QAN+QPI
  598    PI(IQAN)=COS(QAN)
C
C Arrays for calcualtion of inclusive particle spectra
C ANGCEN is array for angles (9)
C DCEN is the angular bin for angles  ANGCEN +/- DCEN
           DCEN = 4.
      QPI=3.1415926/180.
            DO 1014 MP = 1,3
      DO 1012 ICEN=1,9
         QAN1= ANGCEN(ICEN,MP) - DCEN
         QAN2= ANGCEN(ICEN,MP) + DCEN
      IF(QAN1.LT.0.0)   QAN1 =0.0
      IF(QAN2.GT.180.0) QAN2 =180.0
      ANGLIM(ICEN,1,MP) = COS(QAN1*QPI)
      ANGLIM(ICEN,2,MP) = COS(QAN2*QPI)
      DO 1011 NU=1,21
1011  ANGSUM(NU,ICEN,MP) = 0.0
1012  CONTINUE
1014       CONTINUE
C=======================================================================
  600 FORMAT(1X,10X,'VP=',F6.1,' VAL=',F6.1)
C REFR is the maximal number of reflections for current MC history
      REFR=100.
      PRINT 731,TF(K+1,1)
      IF(INFBIG.GT.0)WRITE(IPR,731)TF(K+1,1)
  731 FORMAT(1X,' Average binding energy ',E12.5)
C
C Define effective threshold damage energy
      CALL DEFINE_ED(Z)
C
      RETURN
 2000 Print 2001,KZONESC
      Write(IPR,2001)KZONESC
 2001 Format(' Parameter KZONESC =',i5,' is not valid')
      STOP
      END
**********************************************************************
*                 SUBROUTINE INIPAR                                  *
**********************************************************************
      SUBROUTINE INIPAR
```

```
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/K/K /DATINI/RA,T0,W0 /MAIIPR/IPR /MPARIN/MPARIN
      COMMON/URAND1/IYG
      WP=W0
      CC=RANDOM(0)
      RK=RA*SQRT(CC)
      Z=-RA*SQRT(1.-CC)
      UU=6.2831852*RANDOM(0)
      X=RK*COS(UU)
      Y=RK*SIN(UU)
      R=RA
      T=T0
      JIN=K
      PX=0.
      PY=0.
      P=SQRT(T**2+2.*WP*T)
      PZ=P
         M=MPARIN
      CALL TRANS(K+1,K,ITR9)
                  IF(ITR9.NE.0)  GOTO 10
      E=T+WP
      RETURN
   10 WRITE(IPR,20)
   20 FORMAT(1X,'ERROR IN INIPAR (REFLECTION AT THE ENTRANCE ',
     1'IN NUCLEUS)')
      STOP
      END
**********************************************************************
*                  SUBROUTINE INSEP                                  *
**********************************************************************
      SUBROUTINE INSEP
      COMMON/INFSEP/KSEP(100,4),INFSEP,JSEPM
      COMMON/MAIIPR/IPR /IWRI/IWRI
C JSEPM is maximal number of reactions required
C If INFSEP=1 and input contains 0 0 0, no calculations
         I=0
77       I=I+1
         IF(I.GT.100)GOTO 3000
      READ *,IN,IP,IA
            KSEP(I,1)=IABS(IN)
            KSEP(I,2)=IABS(IP)
            KSEP(I,3)=IABS(IA)
            JSEPM=I
      IF((IABS(IN)+IABS(IP)+IABS(IA)).EQ.0) INFSEP=0
      IF(INFSEP.EQ.0) RETURN
      IF(IN.LT.0.OR.IP.LT.0.OR.IA.LT.0) RETURN
      GOTO 77
3000  WRITE(IPR,4000)
      IF(IWRI.NE.0)WRITE(IWRI,4000)
4000  FORMAT(1X,' SUBR INSEP.  NUMBER OF REACTIONS REQUIRED > 100')
      STOP
      END
**********************************************************************
*                  SUBROUTINE INSEP2                                 *
**********************************************************************
      SUBROUTINE INSEP2
      COMMON/INFSEP/KSEP(100,4),INFSEP,JSEPM
      COMMON/SEPSEP/RSEP2(100,2),JSEPM2
      COMMON/MAIIPR/IPR
```

```
      COMMON/IWRI/IWRI
C JSEPM is maximal number of reactions required
C If INFSEP=2 and input contains 0 0 0, no calculations
         I=0
77       I=I+1
         IF(I.GT.100)GOTO 3000
      READ *,ZZZ,AAA
            RSEP2(I,1)=ABS(ZZZ)
            RSEP2(I,2)=ABS(AAA)
            JSEPM2=I
      IF((ABS(ZZZ)+ABS(AAA)).EQ.0.) INFSEP=0
      IF(INFSEP.EQ.0) RETURN
      IF(ZZZ.LT.0..OR.AAA.LT.0.) RETURN
      GOTO 77
3000  WRITE(IPR,4000)
      IF(IWRI.NE.0)WRITE(IWRI,4000)
4000  FORMAT(1X,'SUBR INSEP2. NUMBER OF REACTIONS REQUIRED >  100')
      STOP
      END
************************************************************************
*                   SUBROUTINE INSEP3                                  *
************************************************************************
      SUBROUTINE INSEP3(MM,ZZ,AA)
      COMMON/INFSEP/KSEP(100,4),INFSEP,JSEPM
      COMMON/SEPSEP/RSEP2(100,2),JSEPM2
      COMMON/MAIIPR/IPR /IWRI/IWRI
      MPARIN=MM
      Z=ZZ
      AN=AA
          ZCOMP=Z+FLOAT(MPARIN)-1.
          ACOMP=AN+1.
           IF(MPARIN.eq.3)  ZCOMP=Z+2.
           IF(MPARIN.eq.3)  ACOMP=AN+4.
        DO 10 I=1,JSEPM2
        TOT=ACOMP-RSEP2(I,2)
        ZI=ZCOMP-RSEP2(I,1)
        RNI=TOT-ZI
                 IN=RNI+0.01
                 IP=ZI+0.01
                 IA=0
            KSEP(I,1)=IN
            KSEP(I,2)=IP
10          KSEP(I,3)=IA
            JSEPM=JSEPM2
        RETURN
      END
************************************************************************
*                  SUBROUTINE INTPOP                                   *
************************************************************************
      SUBROUTINE INTPOP(IKS,INT9)
      COMMON/DAINT/PF(33,4),RO1(33),RZON(33),FIG
      COMMON/K/K /NDIM/NPAR
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/PARTNR/PPX,PPY,PPZ,PP,MX
      COMMON/TYPACT/L,L7 /QSUM/QSUM /BOND1/QBON(200,200,6)
      COMMON/URAND1/IYG /INFDIS/INFDIS,INFOUP(3)
      COMMON/JACT/JACT /MAIIPR/IPR
                              INT9=0
```

```
      J1=JIN
C
      CC=RANDOM(0)
C
      X1=ALOG(CC)
   10 CONTINUE
      J3=J1-1
      IF(J3)12,12,14
   12 RZJ0=0.
      GOTO 16
   14 RZJ0=RZON(J3)
   16 CONTINUE
      RZONX=RZON(J1)
      CALL ZONWAY(RZONX,RZJ0,J1,J3,J2,SLINE)
   20 CONTINUE
        IF(J1.GT.K)GOTO 1985
      CALL CHOPAR(J1,SXX)
                  IF(MX.eq.0 .or. L.eq.0) GOTO 1995
      PATH=1./(RO1(J1)*SXX)
CCCCC      DSL=PATH/FIG
      DSL=PATH
      IF(SLINE-DSL)30,30,40
   30 D1=SLINE
      GOTO 50
   40 D1=DSL
   50 X1=X1+D1/PATH
      HH=D1/P
                 X=X+HH*PX
                 Y=Y+HH*PY
                 Z=Z+HH*PZ
      R=SQRT(X*X+Y*Y+Z*Z)
      SLINE=SLINE-D1
      IF(X1)60,52,150
   52 IF(SLINE)200,53,150
   53 DELTA=0.001
      GOTO 200
   60 CONTINUE
      IF(ABS(SLINE)-0.0001)70,70,20
   70 IF(J1-J2)80,80,140
   80 J2=J1+1
      IF(J2-K)140,140,90
   90 CONTINUE
      CALL TRANS(J1,J2,ITR9)
                   IF(ITR9.NE.0)  GOTO 250
      IF(J1-K)10,10,95
   95            PWX=PWX+PX
                 PWY=PWY+PY
                 PWZ=PWZ+PZ
                 TW=TW+T
      IF(M.NE.3)  QSUM=QBON(NPREN+2*NPREA+1,NPREP+2*NPREA+1,M)+QSUM
      IF(M.EQ.3)  QSUM=QBON(NPREN+2*NPREA+1,NPREP+2*NPREA+1,6)+QSUM
C
           IF(INFDIS.EQ.1.AND.JACT.NE.0)CALL MEMPRE(M,PX,PY,PZ,T)
C
      IF(M-2)101,102,103
  101 NPREN=NPREN+1
      GOTO 111
  102 NPREP=NPREP+1
      GOTO 111
```

```
  103 NPREA=NPREA+1
C
  111 CONTINUE
      IF(NPAR)112,112,114
  112 IKS=-1
      RETURN
  114 IKS=0
      RETURN
  140 CONTINUE
      CALL TRANS(J1,J2,ITR9)
                  IF(ITR9.NE.0)  GOTO 250
  145         E=T+WP
      GOTO 10
  150 DELTA=PATH*X1
  200 HH=DELTA/P
                 X=X-HH*PX
                 Y=Y-HH*PY
                 Z=Z-HH*PZ
                 R=SQRT(X**2+Y**2+Z**2)
      IKS=1
      JIN=J1
      CALL DISTPA(J1)
      RETURN
  250                    INT9=1
                         RETURN
C
C
 1985 PRINT 1986,J1,K
      WRITE(IPR,1986)J1,K
 1986 FORMAT(1X,' INTPOP  FALSE  J1=',I4,' K=',I4)
      STOP
 1995 PRINT 1996,M,MX,L
      WRITE(IPR,1996)M,MX,L
 1996 FORMAT(1X,' ERROR IN CHOPAR: M=',I5,' MX=',I5,' L=',I5)
      STOP
      END
*********************************************************************
*               SUBROUTINE LEGEN                                    *
*********************************************************************
        SUBROUTINE LEGEN(X,P)
        DIMENSION P(30)
        P(1)=1.
        P(2)=X
        DO 1 M=1,7
        RM=FLOAT(M)
    1   P(M+2)=((2.*RM+1.)*X*P(M+1)-RM*P(M))/(RM+1.)
        RETURN
        END
*********************************************************************
*                 SUBROUTINE LIBGEN                                 *
*********************************************************************
      SUBROUTINE LIBGEN
      COMMON/MPARIN/MPARIN /QBOCFU/NSUMN,NSUMP /AN/AN
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/LIB91/WINLIB(100,250),INFLIB
              A1=1.+AN-FLOAT(NSUMN+NSUMP)+2.
              Z1=FLOAT(MPARIN-1)+Z-FLOAT(NSUMP)+1.
        IF(MPARIN.eq.3)   A1=4.+AN-FLOAT(NSUMN+NSUMP)+2.
        IF(MPARIN.eq.3)   Z1=2.+Z-FLOAT(NSUMP)+1.
```

```
      IAA=A1+0.01
      IZZ=Z1+0.01
      IF(IAA.GT.250.OR.IZZ.GT.100) GOTO 1000
      WINLIB(IZZ,IAA)=WINLIB(IZZ,IAA)+1.
      RETURN
1000  WRITE(12,2000)IAA , IZZ
      WRITE(1,2000)IAA , IZZ
      PRINT 2000,IAA , IZZ
2000  FORMAT(1X,' SUBR. LIBGEN : IAA=',I6,' IZZ=',I6,' EXCEED LIMIT')
      STOP
      END
*********************************************************************
*                 SUBROUTINE LIBOUT                                 *
*********************************************************************
      SUBROUTINE LIBOUT(CSNON,RRR)
      REAL*8 ITYP(3),ICS(4)
      COMMON/MAIIPR/IPR  /IWRI/IWRI /MPARIN/MPARIN
      COMMON/DATINI/RA,T0,W0  /AN/AN
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/KHIST/KHIST /LIB91/WINLIB(100,250),INFLIB
      COMMON/INF/INFBIG,INFS0
      DIMENSION CSNON(4),LA(8),CC(8)
C B=BARASH,G=GEOMETRY,O=OPTICAL,C=CHATTERJEE
      DATA ICS/'B','G','O','C'/
      DATA ITYP/' NEUTRON','  PROTON','   ALPHA'/
C Output unit
      M=12
      ITZ=Z+0.01
      ITA=AN+0.01
      IPZ=MPARIN-1
      IPA=1
         IF(MPARIN.eq.3) IPZ=2
         IF(MPARIN.eq.3) IPA=4
C
      REASUM=RRR
C Define nonelastic cross-section
            ICSN=INFS0
            CRSNON=1000.*CSNON(ICSN)
            CRSTMP=CRSNON/REASUM
C
C Form file
        WRITE(M,1000)
1000    FORMAT('1',79('*'))
        KHISTN=REASUM+0.001
        IZSUP=ITZ+IPZ
        IASUP=ITA+IPA
            ISUMAL=0
            DO 50 LLLZ=1,IZSUP
            ISUMZ=0
            DO 20 MMMA=1,IASUP
            IF(WINLIB(LLLZ,MMMA).GE.1.E-04)ISUMZ=1
            IF(ISUMZ.EQ.1)GOTO 25
20          CONTINUE
25          IF(ISUMZ.EQ.1) ISUMAL=ISUMAL+1
50          CONTINUE
C Header
        WRITE(M,1001)ITZ,ITA, T0,ITYP(MPARIN),CRSNON,ICS(ICSN),
     %               ISUMAL,KHISTN
1001    FORMAT(I3,I4,F8.1,' MEV',A8,F9.1,A1,'   (',I2,'Z)',
```

```
     %      3X,'   DISCA',I7)
           DO 500 I=1,IZSUP
           IZ=IZSUP-I+1
           ISUMZ=0
           DO 200 JJ=1,IASUP
           IF(WINLIB(IZ,JJ).GE.1.E-04)ISUMZ=ISUMZ+1
200        CONTINUE
           IF(ISUMZ.EQ.0) GOTO 500
           WRITE(M,1500)IZ,ISUMZ
1500       FORMAT(I3,'      (',I3,'A)')
                           JJJ=0
           DO 300 JA=1,IASUP
           JM=IASUP-JA+1
           WW=WINLIB(IZ,JM)   *   CRSTMP
           IF(WW.LT.1.E-04) GOTO 300
           JJJ=JJJ+1
           IF(JJJ.GT.8) GOTO 7000
           LA(JJJ)=JM
           CC(JJJ)=WW
           IF(JJJ.NE.8) GOTO 300
               WRITE(M,2000)(LA(J11),J11=1,8)
               WRITE(M,2001)(CC(J11),J11=1,8)
2000           FORMAT(4X,I3,7(7X,I3))
2001           FORMAT(8E10.3)
            DO 299 LL=1,8
            LA(LL)=-10
299         CC(LL)=-10.
               JJJ=0
300         CONTINUE
                IF(JJJ.NE.0)  WRITE(M,2000)(LA(J11),J11=1,JJJ)
                IF(JJJ.NE.0)  WRITE(M,2001)(CC(J11),J11=1,JJJ)
500        CONTINUE
C
      RETURN
7000       WRITE(M,7001)
7001       FORMAT(1X,' ERROR IN SUBR LIBOUT ')
           STOP
      END
*********************************************************************
*               SUBROUTINE LYMASS                                   *
*********************************************************************
      SUBROUTINE LYMASS(ZEE,AMASS,NZ,NA,MC,MP,AP,AT,ZP,ZT,QVAL)
* taken from Blann code ALICE
      DIMENSION EM(10),XK(10),Y(2),F(2),XMS(24,11), EMP(10)
      DIMENSION XQ(30)
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24)
      COMMON/SF/M3,KPLT
      DATA BLANK,FOR,RINP/4H    ,4H MSL,4H INP/
      DO 1 I=1,11
      DO 1 K=1,24
      SYMBP(I,K)=BLANK
      SYMB(I,K)=BLANK
      PAIR(I,K)=0.
      DO 1 L=1,4
      BE(I,K,L)=0.
    1 CONTINUE
      DEL=0.
      IF(MP.EQ.0.)DEL=2.
      IF(MP.EQ.3.)DEL=1.
```

```
C
C  ABOVE STATEMENTS DEFINE PAIRING TREATMENT
      IBIND=0
      IF(MC.LT.10) GO TO 6
      IBIND = 1
      MC=MC-10
    6 EM(1)=0.0
      EM(2)=2.0
      EM(3)=8.0
      EM(4)=14.0
      EM(5)=28.0
      EM(6)=50.0
      EM(7)=82.0
      EM(8)=126.0
      EM(9)=184.0
      EM(10)=258.0
      CAY1=1.15303
      CAY3=200.0
      CAY4=11.0
      CAY5=8.07144
      CAY6=7.28899
      GAMMA=1.7826
      A1=15.4941
      A2=17.9439
      A3=0.7053
      D=0.444
      C=5.8
      SMALC=0.325
      PVAL=0.
      DO 15 I=1,10
      EMP(I)=EM(I)**(5.0/3.0)
   15 CONTINUE
      DO 20 I=1,9
      XK(I)=0.6*(EMP(I+1)-EMP(I))/(EM(I+1)-EM(I))
   20 CONTINUE
      RZ=.863987/A3
      L=0
      Z=1.0
   25 KZ=ZEE
      KA=AMASS
      IF(QVAL.EQ.0..AND.PVAL.EQ.0.)GO TO 30
      GO TO 35
   30 NNZ=3
      NNA=1
      GO TO 90
   35 NNZ=NZ+2
      NNA=NA+2
cccc     WRITE (6,36)
   36 FORMAT (1H1,53X,'MASS OPTIONS'/)
      IF (MC.EQ.1.AND.MP.NE.0) MC=0
cccc     IF(IBIND.EQ.1)WRITE(6,86)
   86 FORMAT(20X,' EXPERIMENTAL MASSES ARE USED WHERE TABUL'
     1,'ATED;LIQUID DROP VALUES OTHERWISE.')
cccc     IF(MC.EQ.0) WRITE(6,70)
cccc     IF(MC.EQ.1) WRITE(6,65)
cccc     IF (MC.EQ.2) WRITE (6,70)
   50 Continue
cccc   IF(MP.EQ.0)WRITE(6,75)
cccc   IF(MP.EQ.1)WRITE(6,80)
```

```
cccc   IF(MP.EQ.3)WRITE(6,81)
   81 FORMAT(' NORMAL PAIRING SHIFT WITH ODD-EVEN REFERENCE POINT')
   65 FORMAT(40X,'LIQUID DROP WITHOUT SHELL CORRECTION TERM')
   70 FORMAT(41X,'LIQUID DROP WITH SHELL CORRECTION TERM')
   75 FORMAT(21X,'WITHOUT PAIRING, I.E. LEVEL DENSITY PAIRING ',
     1 'SHIFT ABSORBED IN BINDING ENERGIES')
   80 FORMAT(10X,'WITH PAIRING, LEVEL DENSITY PAIRING SHIFT',
     1 ' CALC. FROM MSL FORMULA AND APPLIED IN BACKSHIFTED',
     2 ' CONVENTION')
cccc      IF (MP.EQ.2) WRITE(6,85)
   85 FORMAT (20X,'MSL SHELL CORRECTION TERM INCLUDED IN LEVEL ',
     1 'DENSITY GROUND STATE SHIFT')
   90 DO 215 JZ=1,NNZ
      DO 215 JA=1,NNA
      IF(QVAL.EQ.0..AND.PVAL.EQ.0.)GO TO 95
      GO TO 115
   95 IF(JZ-2)100,105,110
  100 Z=ZEE
      A=AMASS
      IA=A
      IZ=Z
      N=IA-IZ
      UN=AMASS-ZEE
      GO TO 125
  105 Z=ZT
      A=AT
      IA=A
      IZ=Z
      N=IA-IZ
      UN=AT-ZT
      GO TO 125
  110 Z=ZP
      A=AP
      IZ=Z
      IA=A
      N=IA-IZ
      UN=AP-ZP
      GO TO 125
  115 IA=KA+2-JA-JZ
      IZ=KZ+1-JZ
      N=IA-IZ
  120 Z=IZ
      UN=N
      A=IA
  125 A3RT=A**(1.0/3.0)
      A2RT=SQRT(A)
      A3RT2=A3RT**2.0
      ZSQ=Z**2.0
      SYM=((UN-Z)/A)**2
      ACOR=1.0-GAMMA*SYM
      PARMAS=CAY5*UN+CAY6*Z
      VOLNUC=-1.0*A1*ACOR*A
      SUFNUC=A2*ACOR*A3RT2
      COULMB=A3*ZSQ/A3RT
      FUZSUR=-1.0*CAY1*ZSQ/A
      ODDEV=-1.0*(1.0+2.0*(N/2)-UN+2.*(IZ/2)-Z)/SQRT(A)*CAY4
      PAIR(JZ,JA)=-ODDEV
      SYMBP(JZ,JA)=FOR
      IF(MP.EQ.0)ODDEV=0.
```

```
      IF(MP.EQ.0)GO TO 11
   10 PAIR(JZ,JA)=(2.0*(N/2)-UN+2.0*(IZ/2)-Z+DEL)/SQRT(A)*CAY4
      SYMBP(JZ,JA) = FOR
   11 CONTINUE
      IF(SYM.GT.0.4)WTERM=0.
  130 WTERM=0.
      WOTNUC=PARMAS+COULMB+FUZSUR+ODDEV+WTERM
      SMASS=WOTNUC+VOLNUC+SUFNUC
      XMS(JA,JZ)=SMASS
      XQ(JZ)=SMASS
  135 CONTINUE
      C2=(SUFNUC+WTERM)/(A**(2.0/3.0))
      X=COULMB/(2.0*(SUFNUC+WTERM))
  140 BARR=0.0
  145 Y(1)=UN
      Y(2)=Z
      DO 165 J=1,2
      DO 150 I=1,9
      IF (Y(J)-EM(I+1)) 160,160,150
  150 CONTINUE
  155 STOP
  160 F(J)=XK(I)*(Y(J)-EM(I))-.6*(Y(J)**(5./3.)-EMP(I))
  165 CONTINUE
      S=(2.0/A)**(2.0/3.0)*(F(1)+F(2))-SMALC*A**(1./3.)
      EE=2.*C2*D**2*(1.0-X)
      FF=.42591771*C2*D**3*(1.+2.*X)/A3RT
      SSHELL=C*S
      V=SSHELL/EE
      EPS=1.5*FF/EE
      IF(EE*(1.-3.*V).LE.0.0) GO TO 170
      QCALC=0.0
      THETA=0.0
      SHLL=SSHELL
      GO TO 210
  170 TO=1.0
  175 DO 180 IPQ=1,10
      T=TO-(1.-EPS*TO-V*(3.-2.*TO**2)*EXP(-TO**2))/(-EPS+V*(10.*TO-4.
     1 *TO**3)*EXP(-TO**2))
      IF (T.LE.0.0) GO TO 190
      IF (ABS(T-TO) .LT.0.0001) GO TO 185
      TO=T
  180 CONTINUE
      GO TO 200
  185 IF (2.*EE*(1.-2.*EPS*T-V*(3.-12.*T**2+4.*T**4)*EXP(-T**2))
     1 .GT.0.0) GO TO 205
  190 DO 195 I=1,20
      TO=FLOAT(I)/10.
      GL=EE*(1.-EPS*TO-V*(3.-2.*TO**2)*EXP(-TO**2))
      IF (GL.GE.0.0) GO TO 175
  195 CONTINUE
  200 CONTINUE
      GO TO 215
  205 THETA=T
      ALPHA0=D*SQRT(5.)/A**(1./3.)
      ALPHA=ALPHA0*THETA
      SIGMA=ALPHA*(1.+ALPHA/14.)
      QCALC=.004*Z*(RZ*A3RT)**2*(EXP(2.*SIGMA)-EXP(-SIGMA))
      SHLL=EE*T**2-FF*T**3+SSHELL*(1.-2.*T**2)*EXP(-T**2)
  210 IF(MC.NE.1.OR.MP.NE.0) GO TO 211
```

```
    PAIR(JZ,JA)=PAIR(JZ,JA)-SHLL
    SHLL = 0.
211 CMASS=SMASS+SHLL
    XMS(JA,JZ)=CMASS
    IF(MP.EQ.2) PAIR(JZ,JA)=PAIR(JZ,JA)-SHLL
    XQ(JZ)=CMASS
215 CONTINUE
    IF(QVAL.EQ.0..AND.PVAL.EQ.0.)GO TO 220
    GO TO 240
220 IF(ZP-20.)225,225,230
225 IF(AP.EQ.01..AND.ZP.EQ.01.)XQ(3)=7.29
    IF(AP.EQ.01..AND.ZP.EQ.00.)XQ(3)=8.07
    IF(AP.EQ.02..AND.ZP.EQ.01.)XQ(3)=13.14
    IF(AP.EQ.03..AND.ZP.EQ.01.)XQ(3)=14.95
    IF(AP.EQ.03..AND.ZP.EQ.02.)XQ(3)=14.93
    IF(AP.EQ.04..AND.ZP.EQ.02.)XQ(3)=2.43
    IF(AP.EQ.06..AND.ZP.EQ.03.)XQ(3)=14.09
    IF(AP.EQ.07..AND.ZP.EQ.03.)XQ(3)=14.91
    IF(AP.EQ.09..AND.ZP.EQ.04.)XQ(3)=11.35
    IF(AP.EQ.10..AND.ZP.EQ.05.)XQ(3)=12.05
    IF(AP.EQ.11..AND.ZP.EQ.05.)XQ(3)=8.67
    IF(AP.EQ.12..AND.ZP.EQ.06.)XQ(3)=0.
    IF(AP.EQ.13..AND.ZP.EQ.06.)XQ(3)=3.13
    IF(AP.EQ.14..AND.ZP.EQ.07.)XQ(3)=2.86
    IF(AP.EQ.15..AND.ZP.EQ.07.)XQ(3)=0.10
    IF(AP.EQ.16..AND.ZP.EQ.08.)XQ(3)=-4.74
    IF(AP.EQ.17..AND.ZP.EQ.08.)XQ(3)=-.81
    IF(AP.EQ.18..AND.ZP.EQ.08.)XQ(3)=-.78
    IF(AP.EQ.19..AND.ZP.EQ.09.)XQ(3)=-1.49
    IF(AP.EQ.20..AND.ZP.EQ.10.)XQ(3)=-7.04
    IF(AP.EQ.21..AND.ZP.EQ.10.)XQ(3)=-5.73
    IF(AP.EQ.22..AND.ZP.EQ.10.)XQ(3)=-8.03
    IF(AP.EQ.23..AND.ZP.EQ.11.)XQ(3)=-9.53
    IF(AP.EQ.24..AND.ZP.EQ.12.)XQ(3)=-13.93
    IF(AP.EQ.25..AND.ZP.EQ.12.)XQ(3)=-13.19
    IF(AP.EQ.26..AND.ZP.EQ.12.)XQ(3)=-16.21
    IF(AP.EQ.27..AND.ZP.EQ.13.)XQ(3)=-17.2
    IF(AP.EQ.28..AND.ZP.EQ.14.)XQ(3)=-21.49
    IF(AP.EQ.29..AND.ZP.EQ.14.)XQ(3)=-21.89
    IF(AP.EQ.30..AND.ZP.EQ.14.)XQ(3)=-24.44
    IF(AP.EQ.31..AND.ZP.EQ.15.)XQ(3)=-24.44
    IF(AP.EQ.32..AND.ZP.EQ.16.)XQ(3)=-26.01
    IF(AP.EQ.33..AND.ZP.EQ.16.)XQ(3)=-26.58
    IF(AP.EQ.34..AND.ZP.EQ.16.)XQ(3)=-29.93
    IF(AP.EQ.36..AND.ZP.EQ.16.)XQ(3)=-30.66
    IF(AP.EQ.35..AND.ZP.EQ.17.)XQ(3)=-29.01
    IF(AP.EQ.37..AND.ZP.EQ.17.)XQ(3)=-31.77
    IF(AP.EQ.36..AND.ZP.EQ.18.)XQ(3)=-30.23
    IF(AP.EQ.38..AND.ZP.EQ.18.)XQ(3)=-34.72
    IF(AP.EQ.40..AND.ZP.EQ.18.)XQ(3)=-35.04
    IF(AP.EQ.39..AND.ZP.EQ.19.)XQ(3)=-33.80
    IF(AP.EQ.40..AND.ZP.EQ.19.)XQ(3)=-33.53
    IF(AP.EQ.41..AND.ZP.EQ.19.)XQ(3)=-35.55
    IF(AP.EQ.40..AND.ZP.EQ.20.)XQ(3)=-34.85
    IF(AP.EQ.42..AND.ZP.EQ.20.)XQ(3)=-38.54
    IF(AP.EQ.43..AND.ZP.EQ.20.)XQ(3)=-38.40
    IF(AP.EQ.44..AND.ZP.EQ.20.)XQ(3)=-41.46
    IF(AP.EQ.46..AND.ZP.EQ.20.)XQ(3)=-43.14
    IF(AP.EQ.48..AND.ZP.EQ.20.)XQ(3)=-44.22
```

```
  230 PVAL=XQ(2)+XQ(3)-XQ(1)
cccc    WRITE(6,235)PVAL
  235 FORMAT(/41X,' QVAL FROM MYERS SWIATECKI MASS FORMULA = ',F8.3)
      GO TO 25
  240 DO 245 JZ=1,NZ
      DO 245 JA=1,NA
      SYMB(JZ,JA) = FOR
      BE(JZ,JA,1)=8.07+XMS(JA+1,JZ)-XMS(JA,JZ)
      BE(JZ,JA,2)=7.29+XMS(JA,JZ+1)-XMS(JA,JZ)
      BE(JZ,JA,4)=13.3+XMS(JA+1,JZ+1)-XMS(JA,JZ)
  245 BE(JZ,JA,3)=2.42+XMS(JA+2,JZ+2)-XMS(JA,JZ)
      IF(IBIND.EQ.1) CALL BINDEN(ZEE,AMASS,NZ,NA,AP,AT,ZP,ZT,
     1   QVAL,M3,MP)
cccc      IF(QVAL.EQ.0.)WRITE(6,235)PVAL
      IF(QVAL.EQ.0.)QVAL=PVAL
      IF(MC.NE.2) GO TO 260
  250 DO 255 IZ=1,NNZ
      DO 255 IA=1,NNA
      READ(5,270)BE1,BE2,BE3,BE4,PDEL
      IF(BE1.EQ.0.) GO TO 400
      BE(IZ,IA,1)=BE1
      BE(IZ,IA,2)=BE2
      BE(IZ,IA,3)=BE3
      BE(IZ,IA,4)=BE4
      SYMB(IZ,IA)=RINP
  400 IF(PDEL.EQ.0.) GO TO 255
      PAIR(IZ,IA)=PDEL
      SYMBP(IZ,IA)=RINP
  255 CONTINUE
cccc      WRITE (6,275)
  260 Continue
cccc  WRITE(6,280)
      DO 265 IZ=1,NNZ
      MZ=ZEE+1-IZ
      DO 265 IA=1,NNA
      MA=AMASS+2-IA-IZ
cccc   WRITE(6,285)MZ,MA,(BE(IZ,IA,K),K=1,4),SYMB(IZ,IA),
cccc     1 PAIR(IZ,IA),SYMBP(IZ,IA)
      IF(MP.LE.0)PAIR(IZ,IA)=0.
      PAIR(IZ,IA)=10.*PAIR(IZ,IA)
  265 CONTINUE
cccc  WRITE (6,268)
  268 FORMAT (1H1)
      RETURN
  270 FORMAT(5F10.5)
  275 FORMAT (20X,'SOME BINDING ENERGIES OR LEVEL DENSITY GROUND ',
     * 'STATE SHIFTS PROVIDED BY USER')
  280 FORMAT (/30X,'BINDING ENERGIES AND LEVEL DENSITY GROUND ',
     * 'STATE SHIFTS USED'//22X,' IZ = Z-INDEX OF NUCLEUS,',
     * ' IA = A-INDEX OF NUCLEUS IN PROGRAM ISOTOPE TABLE'/32X,
     * 'MSL = CALCULATED BY MYERS SWIATECKI LYSEKILL MASS FORMULA'/
     * 32X,'TAB = TAKEN FROM 1971 MASS TABLE'/32X,'INP = PROVIDED',
     * ' BY USER'/32X,'ABE = ABSORBED IN BINDING ENERGY'//
     * 10X,'  IZ  IA     NEUTRON      PROTON      ALPHA     ',
     * 'DEUTERON    SOURCE    GS SHIFT  SOURCE'/)
  285 FORMAT(10X,2I4,2X,4(F10.5,2X),3X,A4,3X,F10.5,3X,A4)
      END
**********************************************************************
*                SUBROUTINE MASDAT                                   *
```

```
*********************************************************************
* Only nucleon and alpha projectile is assumed
      SUBROUTINE MASDAT
      COMMON/MASTR1/W(21,21)
      COMMON/AN/AN
      COMMON/MPARIN/MPARIN
            AM=AN
            If(MPARIN.eq.3) AM=AN+3.
      DO 2 I=1,21
      DO 1 J=I,21
      W(I,J)=(AM-FLOAT(I-1)-FLOAT(J-2))*931.5016
      W(J,I)=W(I,J)
    1 CONTINUE
    2 CONTINUE
      RETURN
      END
*********************************************************************
*               SUBROUTINE MASS                                     *
*********************************************************************
      SUBROUTINE MASS(MZ,N,EXCES,ERRR,IRET)
* taken from Blann code ALICE
C     FINDS MASS EXCESS (EXCES, IN MEV) AND ERROR (ERRR) FROM 1971
C     WAPSTRA GOVE MASS TABLE UP TO 199PT, FROM 1977(?) TABLE UP TO 256E
C     ERRR=500. MEANS MASS IS FROM SYSTEMATICS
C     ERRR=+0.  MEANS STABLE NUCLIDE
C     PIONS IN MASS TABLE HAVE HAD Z ELECTRONS ADDED TO BE CONSISTENT
C     WITH REST OF THE ATOMIC MASS TABLE
      DATA NT/ 1755/
      NZNO=MZ*1000+N
      NL=((MZ/10)*2-4)*100
      IF(NL.LE.0) NL=1
      DO 11 J=NL,NT
      IF(IZATAB(J).EQ.NZNO) GO TO 12
   11 CONTINUE
      IRET=IRET+1
      RETURN
   12 EXCES=ZAMASS(J)
      ERRR=ERRMAS(J)
      RETURN
      END
      FUNCTION IZATAB(J)
C     TABLE OF ZA (1000*Z + A)
      DIMENSION ITABLE(1800),
     1 I1(54),I1A(46),I2(54),I2A(46),I3(54),I3A(46),I4(54),I4A(46),
     2 I5(54),I5A(46),I6(54),I6A(46),I7(54),I7A(46),I8(54),I8A(46),
     3 I9(54),I9A(46),I10(54),I10A(46),I11(54),I11A(46),
     4 I12(54),I12A(46),I13(54),I13A(46),I14(54),I14A(46),
     5 I15(54),I15A(46),I16(54),I16A(46),I17(54),I17A(46),
     6 I18(54),I18A(46)
      EQUIVALENCE (I1(1),ITABLE(1)),(I2(1),ITABLE(101)),
     1(I3 (1),ITABLE(201 )),(I4 (1),ITABLE( 301)),(I5 (1),ITABLE( 401)),
     2(I6 (1),ITABLE( 501)),(I7 (1),ITABLE( 601)),(I8 (1),ITABLE( 701)),
     3(I9 (1),ITABLE( 801)),(I10(1),ITABLE( 901)),(I11(1),ITABLE(1001)),
     4(I12(1),ITABLE(1101)),(I13(1),ITABLE(1201)),(I14(1),ITABLE(1301)),
     5(I15(1),ITABLE(1401)),(I16(1),ITABLE(1501)),(I17(1),ITABLE(1601)),
     6(I18(1),ITABLE(1701))
      EQUIVALENCE (I1A(1),ITABLE(55)),(I2A(1),ITABLE(155)),
     1 (I3A (1),ITABLE(255 )),(I4A (1),ITABLE( 355)),
     2 (I5A (1),ITABLE(455 )),(I6A (1),ITABLE( 555)),
```

```
3 (I7A (1),ITABLE(655 )),(I8A (1),ITABLE( 755)),
4 (I9A (1),ITABLE(855 )),(I10A(1),ITABLE( 955)),
5 (I11A(1),ITABLE(1055)),(I12A(1),ITABLE(1155)),
6 (I13A(1),ITABLE(1255)),(I14A(1),ITABLE(1355)),
7 (I15A(1),ITABLE(1455)),(I16A(1),ITABLE(1555)),
8 (I17A(1),ITABLE(1655)),(I18A(1),ITABLE(1755))
 DATA I1/
1  -999,     0,   999,     1,     4,  1000,  1001,  1002,  1004,
2  2001,  2002,  2003,  2004,  2006,  3002,  3003,  3004,  3005,
3  3006,  3007,  3008,  4001,  4002,  4003,  4004,  4005,  4006,
4  4007,  4008,  5002,  5003,  5004,  5005,  5006,  5007,  5008,
5  5009,  5010,  6002,  6003,  6004,  6005,  6006,  6007,  6008,
6  6009,  6010,  6011,  7003,  7004,  7005,  7006,  7007,  7008/
 DATA I1A/
1  7009,  7010,  7011,  7012,  8003,  8004,  8005,  8006,  8007,
2  8008,  8009,  8010,  8011,  8012,  9005,  9006,  9007,  9008,
3  9009,  9010,  9011,  9012,  9013,  9014, 10005, 10006, 10007,
4 10008, 10009, 10010, 10011, 10012, 10013, 10014, 11007, 11008,
5 11009, 11010, 11011, 11012, 11013, 11014, 11015, 11016, 12007,
6 12008/
 DATA I2/
1 12009, 12010, 12011, 12012, 12013, 12014, 12015, 12016, 13009,
2 13010, 13011, 13012, 13013, 13014, 13015, 13016, 13017, 13018,
3 14009, 14010, 14011, 14012, 14013, 14014, 14015, 14016, 14017,
4 14018, 15011, 15012, 15013, 15014, 15015, 15016, 15017, 15018,
5 15019, 15020, 16011, 16012, 16013, 16014, 16015, 16016, 16017,
6 16018, 16019, 16020, 16021, 16022, 17013, 17014, 17015, 17016/
 DATA I2A/
1 17017, 17018, 17019, 17020, 17021, 17022, 17023, 18013, 18014,
2 18015, 18016, 18017, 18018, 18019, 18020, 18021, 18022, 18023,
3 18024, 18025, 18026, 18027, 18028, 19015, 19016, 19017, 19018,
4 19019, 19020, 19021, 19022, 19023, 19024, 19025, 19026, 19027,
5 19028, 20015, 20016, 20017, 20018, 20019, 20020, 20021, 20022,
6 20023/
 DATA I3/
1 20024, 20025, 20026, 20027, 20028, 20029, 20030, 21019, 21020,
2 21021, 21022, 21023, 21024, 21025, 21026, 21027, 21028, 21029,
3 22019, 22020, 22021, 22022, 22023, 22024, 22025, 22026, 22027,
4 22028, 22029, 22030, 23021, 23022, 23023, 23024, 23025, 23026,
5 23027, 23028, 23029, 23030, 23031, 24021, 24022, 24023, 24024,
6 24025, 24026, 24027, 24028, 24029, 24030, 24031, 24032, 25023/
 DATA I3A/
1 25024, 25025, 25026, 25027, 25028, 25029, 25030, 25031, 25032,
2 25033, 26023, 26024, 26025, 26026, 26027, 26028, 26029, 26030,
3 26031, 26032, 26033, 26034, 26035, 27025, 27026, 27027, 27028,
4 27029, 27030, 27031, 27032, 27033, 27034, 27035, 27036, 27037,
5 28025, 28026, 28027, 28028, 28029, 28030, 28031, 28032, 28033,
6 28034/
 DATA I4/
1 28035, 28036, 28037, 28038, 28039, 29029, 29030, 29031, 29032,
2 29033, 29034, 29035, 29036, 29037, 29038, 29039, 29040, 30029,
3 30030, 30031, 30032, 30033, 30034, 30035, 30036, 30037, 30038,
4 30039, 30040, 30041, 30042, 31032, 31033, 31034, 31035, 31036,
5 31037, 31038, 31039, 31040, 31041, 31042, 31043, 31044, 32033,
6 32034, 32035, 32036, 32037, 32038, 32039, 32040, 32041, 32042/
 DATA I4A/
1 32043, 32044, 32045, 32046, 32047, 33936, 33937, 33938, 33939,
2 33940, 33941, 33942, 33943, 33944, 33945, 33946, 33947, 33948,
3 34037, 34038, 34039, 34040, 34041, 34042, 34043, 34044, 34045,
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4 34046, 34047, 34048, 34049, 34050, 35038, 35039, 35040, 35041,
5 35042, 35043, 35044, 35045, 35046, 35047, 35048, 35049, 35050,
6 35051/
 DATA I5/
1 35052, 36038, 36039, 36040, 36041, 36042, 36043, 36044, 36045,
2 36046, 36047, 36048, 36049, 36050, 36051, 36052, 36053, 36054,
3 36055, 37042, 37043, 37044, 37045, 37046, 37047, 37048, 37049,
4 37050, 37051, 37052, 37053, 37054, 37055, 37056, 38043, 38044,
5 38045, 38046, 38047, 38048, 38049, 38050, 38051, 38052, 38053,
6 38054, 38055, 38056, 38057, 39044, 39045, 39046, 39047, 39048/
 DATA I5A/
1 39049, 39050, 39051, 39052, 39053, 39054, 39055, 39056, 39057,
2 39058, 40045, 40046, 40047, 40048, 40049, 40050, 40051, 40052,
3 40053, 40054, 40055, 40056, 40057, 40058, 40059, 40060, 40061,
4 41046, 41047, 41048, 41049, 41050, 41051, 41052, 41053, 41054,
5 41055, 41056, 41057, 41058, 41059, 41060, 41061, 41061, 42046,
6 42047/
 DATA I6/
1 42048, 42049, 42050, 42051, 42052, 42053, 42054, 42055, 42056,
2 42057, 42058, 42059, 42060, 42061, 42062, 43048, 43049, 43050,
3 43051, 43052, 43053, 43054, 43055, 43056, 43057, 43058, 43059,
4 43060, 43061, 43062, 43063, 44049, 44050, 44051, 44052, 44053,
5 44054, 44055, 44056, 44057, 44058, 44059, 44060, 44061, 44062,
6 44063, 44064, 45050, 45051, 45052, 45053, 45054, 45055, 45056/
 DATA I6A/
1 45057, 45058, 45059, 45060, 45061, 45062, 45063, 45064, 45065,
2 46051, 46052, 46053, 46054, 46055, 46056, 46057, 46058, 46059,
3 46060, 46061, 46062, 46063, 46064, 46065, 46066, 47052, 47053,
4 47054, 47055, 47056, 47057, 47058, 47059, 47060, 47061, 47062,
5 47063, 47064, 47065, 47066, 47067, 47068, 47069, 48053, 48054,
6 48055/
 DATA I7/
1 48056, 48057, 48058, 48059, 48060, 48061, 48062, 48063, 48064,
2 48065, 48066, 48067, 48068, 48069, 48070, 48071, 49053, 49054,
3 49055, 49056, 49057, 49058, 49059, 49060, 49061, 49062, 49063,
4 49064, 49065, 49066, 49067, 49068, 49069, 49070, 49071, 49072,
5 49073, 49074, 49075, 50053, 50054, 50055, 50056, 50057, 50058,
6 50059, 50060, 50061, 50062, 50063, 50064, 50065, 50066, 50067/
 DATA I7A/
1 50068, 50069, 50070, 50071, 50072, 50073, 50074, 50075, 50076,
2 50077, 50078, 51054, 51055, 51056, 51057, 51058, 51059, 51060,
3 51061, 51062, 51063, 51064, 51065, 51066, 51067, 51068, 51069,
4 51070, 51071, 51072, 51073, 51074, 51075, 51076, 51077, 51078,
5 51079, 51080, 51081, 51082, 52055, 52056, 52057, 52058, 52059,
6 52060/
 DATA I8/
1 52061, 52062, 52063, 52064, 52065, 52066, 52067, 52068, 52069,
2 52070, 52071, 52072, 52073, 52074, 52075, 52076, 52077, 52078,
3 52079, 52080, 52081, 52082, 52083, 53060, 53061, 53062, 53063,
4 53064, 53065, 53066, 53067, 53068, 53069, 53070, 53071, 53072,
5 53073, 53074, 53075, 53076, 53077, 53078, 53079, 53080, 53081,
6 53082, 53083, 53084, 54062, 54062, 54063, 54064, 54065, 54066/
 DATA I8A/
1 54067, 54068, 54069, 54070, 54071, 54072, 54073, 54074, 54075,
2 54076, 54077, 54078, 54079, 54080, 54081, 54082, 54083, 54084,
3 54085, 54086, 55068, 55069, 55070, 55071, 55072, 55073, 55074,
4 55075, 55076, 55077, 55078, 55079, 55080, 55081, 55082, 55083,
5 55084, 55085, 55086, 55087, 56069, 56070, 56071, 56072, 56073,
6 56074/
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 DATA I9/
1 56075, 56076, 56077, 56078, 56079, 56080, 56081, 56082, 56083,
2 56084, 56085, 56086, 56087, 56088, 57070, 57071, 57072, 57073,
3 57074, 57075, 57076, 57077, 57078, 57079, 57080, 57081, 57082,
4 57083, 57084, 57085, 57086, 57087, 57088, 57089, 58073, 58074,
5 58075, 58076, 58077, 58078, 58079, 58080, 58081, 58082, 58083,
6 58084, 58085, 58086, 58087, 58088, 58089, 58090, 59075, 59076/
 DATA I9A/
1 59077, 59078, 59079, 59080, 59081, 59082, 59083, 59084, 59085,
2 59086, 59087, 59088, 59089, 59090, 59091, 60076, 60077, 60078,
3 60079, 60080, 60081, 60082, 60083, 60084, 60085, 60086, 60087,
4 60088, 60089, 60090, 60091, 60092, 61078, 61079, 61080, 61081,
5 61082, 61083, 61084, 61085, 61086, 61087, 61088, 61089, 61090,
6 61091/
 DATA I10/
1 61092, 61093, 62079, 62080, 62081, 62082, 62083, 62084, 62085,
2 62086, 62087, 62088, 62089, 62090, 62091, 62092, 62093, 62094,
3 63080, 63081, 63082, 63083, 63084, 63085, 63086, 63087, 63088,
4 63089, 63090, 63091, 63092, 63093, 63094, 63095, 63096, 63097,
5 64080, 64081, 64082, 64083, 64084, 64085, 64086, 64087, 64088,
6 64089, 64090, 64091, 64092, 64093, 64094, 64095, 64096, 64097/
 DATA I10A/
1 64098, 65081, 65082, 65083, 65084, 65085, 65086, 65087, 65088,
2 65089, 65090, 65091, 65092, 65093, 65094, 65095, 65096, 65097,
3 65098, 65099, 66082, 66083, 66084, 66085, 66086, 66087, 66088,
4 66089, 66090, 66091, 66092, 66093, 66094, 66095, 66096, 66097,
5 66098, 66099, 66100, 67082, 67083, 67084, 67085, 67086, 67087,
6 67088/
 DATA I11/
1 67089, 67090, 67091, 67092, 67093, 67094, 67095, 67096, 67097,
2 67098, 67099, 67100, 67101, 67102, 67103, 68082, 68083, 68084,
3 68085, 68086, 68087, 68088, 68089, 68090, 68091, 68092, 68093,
4 68094, 68095, 68096, 68097, 68098, 68099, 68100, 68101, 68102,
5 68103, 68104, 68105, 69082, 69083, 69084, 69085, 69086, 69087,
6 69088, 69089, 69090, 69091, 69092, 69093, 69094, 69095, 69096/
 DATA I11A/
1 69097, 69098, 69099, 69100, 69101, 69102, 69103, 69104, 69105,
2 69106, 69107, 70083, 70084, 70085, 70086, 70087, 70088, 70089,
3 70090, 70091, 70092, 70093, 70094, 70095, 70096, 70097, 70098,
4 70099, 70100, 70101, 70102, 70103, 70104, 70105, 70106, 70107,
5 70108, 71084, 71085, 71086, 71087, 71088, 71089, 71090, 71091,
6 71092/
 DATA I12/
1 71093, 71094, 71095, 71096, 71097, 71098, 71099, 71100, 71101,
2 71102, 71103, 71104, 71105, 71106, 71107, 71108, 71109, 72085,
3 72086, 72087, 72088, 72089, 72090, 72091, 72092, 72093, 72094,
4 72095, 72096, 72097, 72098, 72099, 72100, 72101, 72102, 72103,
5 72104, 72105, 72106, 72107, 72108, 72109, 72110, 72111, 73090,
6 73091, 73092, 73093, 73094, 73095, 73096, 73097, 73098, 73099/
 DATA I12A/
1 73100, 73101, 73102, 73103, 73104, 73105, 73106, 73107, 73108,
2 73109, 73110, 73111, 73112, 73113, 74091, 74092, 74093, 74094,
3 74095, 74096, 74097, 74098, 74099, 74100, 74101, 74102, 74103,
4 74104, 74105, 74106, 74107, 74108, 74109, 74110, 74111, 74112,
5 74113, 74114, 74115, 75092, 75093, 75094, 75095, 75096, 75097,
6 75098/
 DATA I13/
1 75099, 75100, 75101, 75102, 75103, 75104, 75105, 75106, 75107,
2 75108, 75109, 75110, 75111, 75112, 75113, 75114, 75115, 75116,
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3 76093, 76094, 76095, 76096, 76097, 76098, 76099, 76100, 76101,
4 76102, 76103, 76104, 76105, 76106, 76107, 76108, 76109, 76110,
5 76111, 76112, 76113, 76114, 76115, 76116, 76117, 76118, 76119,
6 77094, 77095, 77096, 77097, 77098, 77099, 77100, 77101, 77102/
 DATA I13A/
1 77103, 77104, 77105, 77106, 77107, 77108, 77109, 77110, 77111,
2 77112, 77113, 77114, 77115, 77116, 77117, 77118, 77119, 77120,
3 77121, 78095, 78096, 78097, 78098, 78099, 78100, 78101, 78102,
4 78103, 78104, 78105, 78106, 78107, 78108, 78109, 78110, 78111,
5 78112, 78113, 78114, 78115, 78116, 78117, 78118, 78119, 78120,
6 78121/
 DATA I14/
1 78122, 78123, 79098, 79099, 79100, 79101, 79102, 79103, 79104,
2 79105, 79106, 79107, 79108, 79109, 79110, 79111, 79112, 79113,
3 79114, 79115, 79116, 79117, 79118, 79119, 79120, 79121, 79122,
4 79123, 79124, 79125, 80097, 80098, 80099, 80100, 80101, 80102,
5 80103, 80104, 80105, 80106, 80107, 80108, 80109, 80110, 80111,
6 80112, 80113, 80114, 80115, 80116, 80117, 80118, 80119, 80120/
 DATA I14A/
1 80121, 80122, 80123, 80124, 80125, 80126, 81102, 81103, 81104,
2 81105, 81106, 81107, 81108, 81109, 81110, 81111, 81112, 81113,
3 81114, 81115, 81116, 81117, 81118, 81119, 81120, 81121, 81122,
4 81123, 81124, 81125, 81126, 81127, 81128, 81129, 82103, 82104,
5 82105, 82106, 82107, 82108, 82109, 82110, 82111, 82112, 82113,
6 82114/
 DATA I15/
1 82115, 82116, 82117, 82118, 82119, 82120, 82121, 82122, 82123,
2 82124, 82125, 82126, 82127, 82128, 82129, 82130, 82131, 82132,
3 83106, 83107, 83108, 83109, 83110, 83111, 83112, 83113, 83114,
4 83115, 83116, 83117, 83118, 83119, 83120, 83121, 83122, 83123,
5 83124, 83125, 83126, 83127, 83128, 83129, 83130, 83131, 83132,
6 83133, 84109, 84110, 84111, 84112, 84113, 84114, 84115, 84116/
 DATA I15A/
1 84117, 84118, 84119, 84120, 84121, 84122, 84123, 84124, 84125,
2 84126, 84127, 84128, 84129, 84130, 84131, 84132, 84133, 85134,
3 85111, 85112, 85113, 85114, 85115, 85116, 85117, 85118, 85119,
4 85120, 85121, 85122, 85123, 85124, 85125, 85126, 85127, 85128,
5 85129, 85130, 85131, 85132, 85133, 85134, 85135, 86114, 86115,
6 86116/
 DATA I16/
1 86117, 86118, 86119, 86120, 86121, 86122, 86123, 86124, 86125,
2 86126, 86127, 86128, 68129, 86130, 86131, 86132, 86133, 86134,
3 86135, 86136, 87115, 87116, 87117, 87118, 87119, 87120, 87121,
4 87122, 87123, 87124, 87125, 87126, 87127, 87128, 87129, 87130,
5 87131, 87132, 87133, 87134, 87135, 87136, 87137, 87138, 87139,
6 87140, 88116, 88117, 88118, 88119, 88120, 88121, 88122, 88123/
 DATA I16A/
1 88124, 88125, 88126, 88127, 88128, 88129, 88130, 88131, 88132,
2 88133, 88134, 88135, 88136, 88137, 88138, 88139, 88140, 88141,
3 88142, 89120, 89121, 89122, 89123, 89124, 89125, 89126, 89127,
4 89128, 89129, 89130, 89131, 89132, 89133, 89134, 89135, 89136,
5 89137, 89138, 89139, 89140, 89141, 89142, 89143, 90123, 90124,
6 90125/
 DATA I17/
1 90126, 90127, 90128, 90129, 90130, 90131, 90132, 90133, 90134,
2 90135, 90136, 90137, 90138, 90139, 90140, 90141, 90142, 90143,
3 90144, 90145, 91131, 91132, 91133, 91134, 91135, 91136, 91137,
4 91138, 91139, 91140, 91141, 91142, 91143, 91144, 91145, 91146,
5 91147, 92134, 92135, 92136, 92137, 92138, 92139, 92140, 92141,
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     6 92142, 92143, 92144, 92145, 92146, 92147, 92148, 93136, 93137/
      DATA I17A/
     1 93138, 93139, 93140, 93141, 93142, 93143, 93144, 93145, 93146,
     2 93147, 93148, 93149, 94138, 94139, 94140, 94141, 94142, 94143,
     3 94144, 94145, 94146, 94147, 94148, 94149, 94150, 94151, 94152,
     4 95139, 95140, 95141, 95142, 95143, 95144, 95145, 95146, 95147,
     5 95148, 95149, 95150, 95151, 95152, 95153, 96140, 96141, 96142,
     6 96143/
      DATA I18/
     1 96144, 96145, 96146, 96147, 96148, 96149, 96150, 96151, 96152,
     2 96153, 96154, 97141, 97142, 97143, 97144, 97145, 97146, 97147,
     3 97148, 97149, 97150, 97151, 97152, 97153, 97154, 97155, 98142,
     4 98143, 98144, 98145, 98146, 98147, 98148, 98149, 98150, 98151,
     5 98152, 98153, 98154, 98155, 98156, 99144, 99145, 99146, 99147,
     6 99148, 99149, 99150, 99151, 99152, 99153, 99154, 99155, 99156/
      DATA I18A/
     1 99157,     0,     0,     0,     0,     0,     0,     0,     0,
     2     0,     0,     0,     0,     0,     0,     0,     0,     0,
     3     0,     0,     0,     0,     0,     0,     0,     0,     0,
     4     0,     0,     0,     0,     0,     0,     0,     0,     0,
     5     0,     0,     0,     0,     0,     0,     0,     0,     0,
     6     0/
      IZATAB=ITABLE(J)
      RETURN
      END
      FUNCTION ZAMASS(J)
C
C     MASS EXCESS IN MEV.
C
      DIMENSION AMASS(1800),
     1 A1 (54),A2 (54),A3 (54),A4 (54),A5 (54),A6 (54),A7 (54),
     2 A8 (54),A9 (54),A10(54),A11(54),A12(54),A13(54),A14(54),
     3 A15(54),A16(54),A17(54),A18(54),
     4 A1A(46),A2A(46),A3A(46),A4A(46),A5A(46),A6A(46),A7A(46),
     5 A8A(46),A9A(46),A10A(46),A11A(46),A12A(46),A13A(46),
     6 A14A(46),A15A(46),A16A(46),A17A(46),A18A(46)
      EQUIVALENCE (A1(1),AMASS (1)),(A2(1),AMASS (101)),
     1(A3 (1),AMASS (201 )),(A4 (1),AMASS ( 301)),(A5 (1),AMASS ( 401)),
     2(A6 (1),AMASS ( 501)),(A7 (1),AMASS ( 601)),(A8 (1),AMASS ( 701)),
     3(A9 (1),AMASS ( 801)),(A10(1),AMASS ( 901)),(A11(1),AMASS (1001)),
     4(A12(1),AMASS (1101)),(A13(1),AMASS (1201)),(A14(1),AMASS (1301)),
     5(A15(1),AMASS (1401)),(A16(1),AMASS (1501)),(A17(1),AMASS (1601)),
     6(A18(1),AMASS (1701))
      EQUIVALENCE (A1A(1),AMASS (55)),(A2A(1),AMASS (155)),
     1 ( A3A(1),AMASS ( 255)),( A4A(1),AMASS ( 355)),
     2 ( A5A(1),AMASS ( 455)),( A6A(1),AMASS ( 555)),
     3 ( A7A(1),AMASS ( 655)),( A8A(1),AMASS ( 755)),
     4 ( A9A(1),AMASS ( 855)),(A10A(1),AMASS ( 955)),
     5 (A11A(1),AMASS (1055)),(A12A(1),AMASS (1155)),
     6 (A13A(1),AMASS (1255)),(A14A(1),AMASS (1355)),
     7 (A15A(1),AMASS (1455)),(A16A(1),AMASS (1555)),
     8 (A17A(1),AMASS (1655)),(A18A(1),AMASS (1755))
      DATA A1/
     1139.06700,134.97500,140.08900,  8.07169, 32.28676,  7.28922,
     2 13.13626, 14.95038, 33.78999, 14.93173,  2.42494, 11.39000,
     3 17.59730, 31.61300, 11.68000, 14.08750, 14.90859, 20.94750,
     4 24.95540, 34.10000, 41.70000, 34.92304, 18.37500, 15.77029,
     5  4.94180, 11.34840, 12.60810, 20.17700, 24.94999, 27.94000,
     6 22.92230, 12.41569, 12.05230,  8.66795, 13.37040, 16.56200,
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7 24.60000, 29.70000, 35.10000, 28.91200, 15.70270, 10.65019,
8  0.00000,  3.12527,  3.01995,  9.87350, 13.69299, 17.56000,
9 40.23163, 25.44999, 17.34400,  5.34570,  2.86382,   .10180/
 DATA A1A/
1  5.68350,  7.87100, 13.27400, 16.35000, 50.59094, 32.97922,
2 23.10600,  8.00859,  2.86110, -4.73668,  -.80700,  -.78250,
3  3.33230,  3.80000, 34.32074, 17.66000, 10.69300,  1.95180,
4   .87280, -1.48610,  -.01570,  -.04600,  2.82800,  3.36000,
5 42.65895, 24.66971, 16.47999,  5.31900,  1.75210, -7.04170,
6 -5.73120, -8.02510, -5.15000, -5.94800, 25.57849, 12.97999,
7  6.84000, -2.18300, -5.18290, -9.52900, -8.41670, -9.35600,
8 -6.85300, -5.98000, 32.71106, 17.74000/
 DATA A2/
1 10.91100,  -.39900, -5.47240,-13.93130,-13.19149,-16.21339,
2-14.58470,-15.01700, 18.05000,  6.77000,  -.04900, -8.91230,
3-12.20880,-17.19500,-16.84880,-18.21300,-15.89000,-15.56000,
4 23.93176, 10.76000,  3.82400, -7.14300,-12.38539,-21.49110,
5-21.89329,-24.43130,-22.94790,-24.09100, 10.57867,   .21000,
6 -7.15400,-16.94999,-20.20390,-24.43960,-24.30420,-26.33700,
7-24.83000,-24.93600, 17.55025,  4.45666, -3.16000,-14.06200,
8-18.99800,-26.01429,-26.58599,-29.92919,-28.84560,-30.66589,
9-26.90700,-26.86300,  4.88808, -7.20000,-13.26299,-21.00239/
 DATA A2A/
1-24.43840,-29.01300,-29.52180,-31.76150,-29.80000,-29.80200,
2-27.54000, 11.18168, -2.15889, -9.40000,-18.37900,-23.04939,
3-30.23049,-30.94740,-34.71440,-33.24000,-35.03919,-33.06610,
4-34.42000,-31.98000,-32.76000,-29.72700,-29.73200, -1.69218,
5-11.25000,-17.31700,-24.79840,-28.79200,-33.80529,-33.53410,
6-35.55830,-35.02140,-36.58200,-35.80500,-36.61100,-35.42600,
7-35.70400,  4.74011, -6.44739,-13.14400,-22.02299,-27.28300,
8-34.84570,-35.13710,-38.53810,-38.39900/
 DATA A3/
1-41.46359,-40.80630,-43.13800,-42.34300,-44.22200,-41.29200,
2-39.57800,-20.52099,-28.64100,-32.10700,-36.17900,-37.81400,
3-41.06309,-41.75840,-44.32890,-44.49500,-46.55200,-44.54500,
4-15.80000,-25.12100,-29.34100,-37.54800,-39.00070,-44.12579,
5-44.92919,-48.48559,-48.55729,-51.43359,-49.73900,-49.47000,
6-23.85400,-31.90000,-37.07140,-42.00480,-44.47020,-47.95610,
7-49.21670,-52.19740,-51.43690,-51.86100,-49.93000,-19.47600,
8-31.24000,-34.62500,-42.81600,-45.38800,-50.25500,-51.44600,
9-55.41500,-55.28380,-56.93230,-55.12100,-55.26600,-31.01700/
 DATA A3A/
1-37.72000,-42.62460,-48.24000,-50.70500,-54.68650,-55.55700,
2-57.71000,-56.90870,-57.62000,-56.06000,-26.75500,-35.79100,
3-40.23200,-48.33390,-50.94200,-56.25170,-57.47840,-60.60940,
4-60.18380,-62.15510,-60.67000,-61.43500,-59.03000,-37.03100,
5-44.06400,-48.00200,-54.01240,-56.04120,-59.34700,-59.84720,
6-62.23570,-61.65560,-62.92000,-61.53000,-61.86300,-60.11000,
7-29.63200,-40.71200,-45.35000,-53.90800,-56.10400,-60.23500,
8-61.16260,-64.47920,-64.22700,-66.75190/
 DATA A4/
1-65.52150,-67.10930,-65.13390,-66.06000,-63.20000,-51.66800,
2-56.36300,-58.35200,-61.98180,-62.80500,-65.58740,-65.43180,
3-67.26480,-66.25980,-67.30200,-69.42000,-65.94000,-48.43700,
4-54.19300,-56.58000,-61.11500,-62.22200,-66.00640,-65.91410,
5-68.89450,-67.87670,-70.00430,-68.41620,-69.55970,-67.33200,
6-68.13100,-56.72000,-58.93400,-62.65500,-63.71900,-66.87600,
7-67.08500,-69.32300,-68.90600,-70.13810,-68.58760,-69.74000,
8-67.92000,-68.54000,-56.36000,-61.61700,-62.45000,-66.69800,
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9-67.09750,-70.55950,-69.90300,-72.58070,-71.29320,-73.42240/
 DATA A4A/
1-71.84100,-73.21230,-71.16000,-71.78000,-69.39000,-63.13000,
2-64.33800,-67.89400,-68.23000,-70.95400,-70.85870,-73.02970,
3-72.28620,-73.91700,-72.76000,-73.69000,-71.76000,-72.59000,
4-62.89000,-67.63000,-68.21400,-72.21300,-72.16490,-75.25460,
5-74.60140,-77.02680,-75.93390,-77.75700,-76.38700,-77.58700,
6-75.44000,-75.92000,-63.51000,-65.21000,-69.15500,-70.15000,
7-73.23690,-73.45300,-76.07410,-75.88530,-77.97400,-77.50300,
8-79.01800,-77.73000,-78.67000,-75.96000/
 DATA A5/
1-74.20000,-62.11000,-64.05000,-69.15000,-70.23700,-74.14700,
2-74.44300,-77.89600,-77.68000,-80.59100,-79.98700,-82.43320,
3-81.47260,-83.26130,-80.70000,-79.70000,-76.56000,-74.89000,
4-71.50000,-70.92000,-72.10000,-75.42000,-76.19400,-78.94900,
5-79.75300,-82.15960,-82.73830,-84.59260,-82.60400,-81.71000,
6-79.30000,-78.00000,-75.02000,-73.05000,-71.62000,-75.59000,
7-76.69900,-80.63980,-81.09600,-84.50940,-84.86610,-87.90760,
8-86.19600,-85.92790,-83.68400,-82.92000,-79.95000,-78.74000,
9-75.54000,-72.20000,-73.69000,-77.83600,-79.23600,-82.98400/
 DATA A5A/
1-84.28900,-87.68560,-86.47390,-86.34900,-84.83400,-84.25400,
2-82.26000,-81.23600,-78.63000,-76.83000,-72.94000,-77.94000,
3-79.48400,-83.61000,-84.85100,-88.76260,-87.89350,-88.45690,
4-87.14370,-87.26310,-85.66600,-85.42600,-82.93390,-81.27300,
5-78.36000,-77.09000,-72.90000,-74.28000,-76.41000,-80.98000,
6-82.65200,-86.63200,-86.45300,-87.20710,-86.36430,-86.78850,
7-85.60900,-85.60500,-83.51000,-82.86000,-80.19000,-79.40000,
8-76.20000,-76.20000,-71.81000,-75.01000/
 DATA A6/
1-80.16500,-82.18800,-86.80840,-86.80900,-88.40990,-87.71339,
2-88.79590,-87.54020,-88.11090,-85.95600,-86.18510,-83.50400,
3-83.60000,-80.50000,-80.19000,-76.59000,-78.86000,-83.62300,
4-84.15000,-86.01200,-85.86000,-87.19500,-86.52000,-87.32800,
5-85.85000,-86.32500,-84.60000,-84.90000,-82.79000,-82.53000,
6-79.82000,-77.42000,-82.56900,-83.45000,-86.07300,-86.04000,
7-88.22300,-87.62020,-89.22190,-87.95570,-89.10020,-87.25300,
8-88.09400,-85.93000,-86.32300,-83.71000,-83.71000,-78.45000,
9-79.63000,-82.55000,-83.16600,-85.56800,-85.59200,-87.40200/
 DATA A6A/
1-86.77800,-88.01600,-86.94400,-87.84700,-86.36200,-86.86000,
2-85.03000,-85.11000,-82.94000,-77.75000,-81.37000,-82.16300,
3-85.19000,-85.41200,-87.92700,-87.46300,-89.41100,-88.41300,
4-89.90200,-88.37300,-89.52600,-87.60600,-88.34000,-86.02000,
5-86.28000,-76.13000,-77.89000,-81.01000,-82.36700,-84.78000,
6-85.31100,-87.07800,-86.92800,-88.40800,-87.60500,-88.72150,
7-87.45550,-88.22400,-86.58000,-87.03500,-85.01000,-84.91000,
8-82.42000,-75.48000,-79.47000,-80.38000/
 DATA A7/
1-84.01000,-84.28000,-87.13020,-86.99100,-89.24800,-88.53900,
2-90.34640,-89.25160,-90.57690,-89.04490,-90.01420,-88.09000,
3-88.71500,-86.40800,-86.70400,-84.21000,-69.67000,-73.78000,
4-75.51000,-79.18000,-80.39000,-83.50000,-84.10000,-86.52000,
5-86.42000,-88.42600,-87.98900,-89.34200,-88.58400,-89.54100,
6-88.24800,-88.92900,-87.45000,-87.71400,-85.49000,-85.82000,
7-83.24000,-83.42000,-80.83000,-65.88000,-70.91000,-72.58000,
8-77.09000,-78.20000,-82.00000,-82.72000,-85.82400,-85.91800,
9-88.64800,-88.31700,-90.56500,-90.02700,-91.52180,-90.39260/
 DATA A7A/
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1-91.64830,-90.06160,-91.09430,-89.20270,-89.93560,-87.80900,
2-88.22900,-85.89000,-86.01300,-83.51000,-83.40000,-63.18000,
3-65.69000,-70.10000,-72.20000,-76.02000,-77.62000,-81.02000,
4-81.85000,-84.41900,-84.87000,-86.99700,-87.02000,-88.64000,
5-87.95300,-89.48300,-88.41400,-89.58990,-88.32560,-89.21910,
6-87.61420,-88.26200,-86.33900,-86.70800,-84.70000,-84.59100,
7-82.35000,-82.09000,-79.59000,-79.00000,-60.05000,-65.29000,
8-67.42000,-72.12000,-73.62000,-77.65000/
 DATA A8/
1-78.52000,-82.17000,-82.46000,-85.46000,-85.15000,-87.65000,
2-87.18900,-89.40200,-88.59000,-90.30380,-89.16200,-90.51410,
3-89.02730,-90.06490,-88.28900,-88.98890,-87.00400,-87.34540,
4-85.19100,-85.19300,-82.90000,-82.57000,-77.78000,-71.32000,
5-73.47000,-76.96000,-78.16000,-80.84000,-81.55000,-83.99000,
6-84.10000,-86.22000,-86.16000,-87.96000,-87.35400,-88.87930,
7-87.91400,-88.98140,-87.73510,-88.50300,-86.88800,-87.44320,
8-85.69800,-85.86000,-83.97000,-83.77600,-79.42000,-76.81000,
9-73.66000,-73.66000,-74.77000,-78.25000,-79.00000,-81.90000/
 DATA A8A/
1-82.43000,-85.06000,-85.29000,-87.45000,-87.14000,-89.16500,
2-88.31700,-89.86010,-88.69400,-89.88010,-88.41400,-89.27840,
3-87.66000,-88.12300,-86.50200,-86.42300,-82.21300,-80.07000,
4-75.98000,-73.24000,-81.09000,-81.55000,-84.07000,-84.16000,
5-86.22700,-85.95300,-87.59000,-86.85700,-88.05900,-87.17900,
6-88.08700,-86.90600,-87.65900,-86.35600,-86.56100,-82.87000,
7-80.78000,-77.54000,-74.87000,-71.07000,-79.57000,-82.36000,
8-82.73000,-85.25000,-85.15000,-87.29700/
 DATA A9/
1-86.71900,-88.45100,-87.57200,-88.96500,-87.86800,-88.90400,
2-87.73400,-88.27400,-84.92600,-83.24100,-79.97000,-77.77000,
3-74.01000,-71.80000,-77.73000,-78.45000,-81.15000,-81.60000,
4-83.76000,-83.74000,-85.67000,-85.25500,-86.83000,-86.03000,
5-87.23000,-86.48000,-87.18600,-84.27600,-82.96900,-79.97000,
6-78.21040,-74.90000,-72.91000,-69.44000,-79.46000,-82.34000,
7-82.37000,-84.75000,-84.53000,-86.46200,-86.03000,-87.53600,
8-86.91100,-88.04200,-85.39900,-84.48700,-81.59300,-80.40300,
9-77.11000,-75.74000,-72.23000,-70.68000,-78.55000,-80.95000/
 DATA A9A/
1-81.26000,-83.28000,-83.09900,-84.79900,-84.65400,-85.98000,
2-83.75200,-83.03800,-80.71900,-79.59900,-76.82000,-75.43000,
3-72.48000,-71.38000,-68.66000,-78.80000,-79.28000,-81.80000,
4-82.00000,-84.18000,-84.17500,-85.91600,-83.97000,-83.71600,
5-81.40400,-80.89800,-78.12900,-77.38100,-74.37700,-73.66200,
6-70.89900,-70.12600,-77.50000,-78.28000,-80.45000,-81.10000,
7-82.90100,-81.34000,-81.23400,-79.42100,-79.02300,-76.85200,
8-76.04600,-73.53000,-73.36500,-71.35000/
 DATA A10/
1-70.74000,-68.45000,-76.05000,-79.05000,-79.42200,-81.90400,
2-80.59600,-80.94700,-79.24800,-79.31700,-77.11800,-77.03390,
3-74.55300,-74.74900,-72.54400,-72.45100,-70.19300,-69.35900,
4-74.42000,-75.57700,-77.87600,-77.07500,-77.48600,-76.21700,
5-76.36000,-74.71900,-74.62900,-72.86300,-73.34700,-71.71300,
6-71.81800,-70.07200,-69.46100,-67.25000,-65.92000,-63.53000,
7-71.88000,-72.88000,-75.88000,-75.15800,-76.20700,-75.07200,
8-75.72800,-74.16500,-74.69100,-73.10600,-73.69100,-72.06500,
9-72.52400,-70.82100,-70.68000,-68.55300,-67.93400,-65.49400/
 DATA A10A/
1-64.29000,-67.78000,-70.56000,-70.59000,-71.37500,-71.06000,
2-71.55700,-70.87100,-71.31000,-70.29000,-71.22000,-70.22000,
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3-70.75700,-69.44000,-69.50300,-67.81300,-67.44500,-65.69000,
4-64.67000,-62.59000,-67.79000,-67.48000,-69.10000,-68.55200,
5-70.05700,-69.09000,-70.35600,-69.12100,-70.49100,-69.39400,
6-70.38400,-69.13800,-69.64800,-68.02700,-68.15100,-66.35100,
7-65.93400,-63.57700,-62.56300,-61.58000,-62.00000,-63.50000,
8-63.67000,-64.83200,-64.59800,-65.82000/
 DATA A11/
1-65.39000,-66.89000,-66.40700,-67.44000,-66.72800,-67.21000,
2-65.98100,-66.34200,-64.95500,-64.87300,-63.04400,-62.29800,
3-60.20000,-58.75000,-56.39000,-57.90000,-58.20000,-60.43000,
4-60.25000,-62.40000,-62.01000,-63.69000,-62.99000,-64.91000,
5-64.34000,-65.93000,-65.16100,-66.29900,-65.13400,-65.91800,
6-64.50100,-64.90400,-63.26800,-62.96800,-60.89900,-60.09100,
7-57.70000,-56.48000,-53.42000,-50.90000,-51.93000,-53.90000,
8-54.49000,-56.31000,-56.69000,-58.19000,-58.31000,-60.14000,
9-60.13000,-61.64000,-61.60000,-62.71700,-61.95600,-62.93600/
 DATA A11A/
1-61.86900,-62.52100,-61.27000,-61.25100,-59.77300,-59.19000,
2-57.36900,-56.21500,-53.87000,-52.28000,-49.34000,-47.30000,
3-50.01000,-50.42000,-53.07000,-53.21000,-55.31000,-55.14000,
4-57.33900,-57.14000,-59.30000,-59.02000,-60.86000,-60.18400,
5-61.60900,-60.56600,-61.54900,-60.34400,-60.74100,-59.28300,
6-59.23900,-57.53500,-56.93390,-54.68100,-53.48500,-50.97500,
7-49.47000,-42.69000,-43.93000,-46.31000,-47.11000,-48.94000,
8-49.53000,-51.64000,-52.20000,-54.22000/
 DATA A12/
1-54.46000,-56.18000,-56.11000,-57.50000,-57.19000,-58.07400,
2-57.30100,-57.89000,-56.74000,-56.84500,-55.56200,-55.14900,
3-53.37000,-52.37100,-50.17000,-49.10000,-46.47000,-39.05000,
4-42.18000,-42.74000,-45.23000,-45.54000,-48.20000,-48.62000,
5-51.06000,-51.08000,-53.41000,-53.20000,-55.19000,-54.70000,
6-56.10000,-55.29000,-56.34000,-55.25000,-55.76000,-54.54200,
7-54.55900,-52.86800,-52.42200,-50.45000,-49.76600,-47.38900,
8-45.90000,-43.21900,-41.52000,-42.46000,-44.88000,-45.61000,
9-47.80000,-48.19000,-50.10000,-50.10000,-51.59000,-51.34000/
 DATA A12A/
1-52.35000,-51.76000,-52.34000,-51.46000,-51.71000,-50.51000,
2-50.33100,-48.84000,-48.41200,-46.40300,-45.25900,-42.63700,
3-41.38000,-38.58000,-37.78000,-40.61000,-41.40000,-43.99000,
4-44.30000,-46.60000,-46.59000,-48.54000,-48.35000,-49.86000,
5-49.34000,-50.46000,-49.71000,-50.42000,-49.23000,-49.65000,
6-48.22500,-48.20800,-46.32700,-45.66700,-43.34500,-42.47500,
7-39.87000,-38.63400,-35.44000,-33.70000,-34.99000,-37.50000,
8-38.40000,-40.69000,-41.24000,-43.15000/
 DATA A13/
1-43.46000,-45.04000,-44.96000,-46.11000,-45.76000,-46.54000,
2-45.86000,-46.43000,-45.34800,-45.77100,-44.06000,-43.77400,
3-41.88100,-41.18100,-38.98300,-37.94200,-35.49000,-34.46000,
4-29.60000,-32.60000,-33.49000,-36.14000,-36.75000,-39.06000,
5-39.34000,-41.36000,-41.41000,-42.96000,-42.74000,-43.96000,
6-43.40000,-44.25000,-43.37000,-44.15800,-42.75900,-42.95800,
7-41.18400,-41.10100,-38.95200,-38.67400,-36.36200,-35.85000,
8-33.36700,-32.39700,-29.85000,-25.23000,-26.62000,-29.30000,
9-30.37000,-32.74000,-33.58000,-35.59000,-35.96000,-37.64000/
 DATA A13A/
1-37.86000,-39.10000,-38.95000,-39.97000,-39.44000,-40.26000,
2-39.12700,-39.68000,-38.26800,-38.45000,-36.62000,-36.67200,
3-34.79900,-34.49900,-32.49400,-31.85100,-29.46000,-28.41000,
4-25.51000,-20.84000,-24.00000,-24.97000,-27.85000,-28.68000,
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5-31.07000,-31.65000,-33.68000,-33.85000,-35.59000,-35.48000,
6-36.94000,-36.46000,-37.50000,-36.78000,-37.72800,-36.55000,
7-37.29300,-35.67200,-36.25600,-34.43800,-34.73390,-32.78600,
8-32.63500,-30.41400,-29.90600,-27.40600/
 DATA A14/
1-26.60000,-23.74000,-21.19000,-22.41000,-24.75000,-25.63000,
2-27.64000,-28.18000,-30.01000,-30.22000,-31.73000,-31.69000,
3-32.87000,-32.49000,-33.41000,-32.87600,-33.87000,-32.76800,
4-33.36000,-32.25600,-32.57200,-31.16200,-31.15000,-29.59100,
5-29.10400,-27.30000,-26.40000,-23.86000,-22.98000,-20.20000,
6-12.65000,-15.93000,-16.80000,-19.86000,-20.79000,-23.21000,
7-23.69000,-26.04000,-26.14000,-28.35000,-28.06000,-29.88000,
8-29.21000,-30.96000,-30.48000,-31.97400,-31.02000,-32.20600,
9-31.05600,-31.84600,-30.73500,-30.96400,-29.55700,-29.51400/
 DATA A14A/
1-27.67200,-27.36500,-25.27700,-24.70300,-22.29900,-20.95500,
2-15.83000,-16.90000,-19.11000,-19.86000,-21.93000,-22.29000,
3-24.02000,-24.16000,-25.67000,-25.59000,-27.02000,-26.81000,
4-27.85000,-27.35000,-28.33900,-27.50000,-28.08000,-27.06000,
5-27.18500,-25.98800,-25.76900,-24.35300,-23.83700,-22.26900,
6-21.04100,-16.76800,-13.65000, -9.25100,-11.74000,-14.33900,
7-14.94000,-17.51000,-17.86000,-20.22000,-20.23000,-22.29000,
8-22.07000,-23.81000,-23.55000,-25.15000/
 DATA A15/
1-24.63000,-25.90000,-25.98000,-26.16000,-25.32700,-25.94200,
2-24.79400,-25.11700,-23.77700,-23.79500,-22.46300,-21.79500,
3-17.62400,-14.73800,-10.49190, -7.56200, -3.14000,  -.18500,
4 -9.87000,-10.85000,-15.05000,-13.67000,-15.56400,-15.98000,
5-17.68000,-17.76000,-19.41000,-19.30000,-20.61000,-20.46000,
6-21.41000,-21.04000,-21.60000,-20.82000,-21.07000,-20.03390,
7-20.05800,-18.87900,-18.26800,-14.80100,-11.86500, -8.13500,
8 -5.24300, -1.20900,  1.71000,  5.97000, -8.31000,-10.81000,
9-11.06000,-13.21000,-13.23000,-15.07000,-15.05000,-16.74000/
 DATA A15A/
1-16.41000,-17.78000,-17.36000,-18.25000,-17.57600,-18.19000,
2-17.15000,-17.47500,-16.37300,-15.96300,-12.44400,-10.38100,
3 -6.63390, -4.47900,  -.54000,  1.76900,  5.96000,  8.35460,
4 -4.05000, -6.03000, -6.67000, -8.47000, -8.67000,-10.52000,
5-10.52000,-11.97000,-11.97000,-12.96000,-12.73000,-13.31000,
6-12.64000,-12.88800,-11.97600,-11.63500, -8.62500, -6.58900,
7 -3.38900, -1.26200,  2.23700,  4.38200,  8.99000, 10.53000,
8 14.20000, -3.74000, -3.95000, -5.88000/
 DATA A16/
1 -6.00000, -7.77000, -7.60000, -8.97000, -8.69000, -9.56000,
2 -8.94000, -9.60800, -8.76100, -8.66600, -5.70600, -4.32800,
3 -1.17900,   .24500,  3.64900,  5.21200,  8.83070, 10.59900,
4 14.38000, 16.37000,  3.16000,  1.23000,   .87000, -1.04000,
5 -1.18000, -2.65000, -2.77000, -3.76000, -3.64000, -4.22000,
6 -3.69000, -3.55600,  -.96500,   .30900,  2.97500,  4.30700,
7  7.05000,  8.61700, 11.47000, 13.26500, 16.33800, 18.38230,
8 21.71000, 23.79000, 27.46000, 29.58000,  6.28000,  5.98000,
9  3.96000,  3.70000,  1.93000,  1.97000,   .61000,   .78000/
 DATA A16A/
1  -.11000,   .29000,   .09000,  2.53100,  3.28500,  5.88100,
2  6.66400,  9.37700, 10.26300, 12.95700, 14.32100, 17.23480,
3 18.81300, 21.98730, 23.66570, 27.18500, 28.94100, 32.72000,
4 34.56000,  9.12000,  8.86000,  7.40000,  7.18000,  6.17000,
5  6.14000,  5.95000,  7.98000,  8.70100, 10.83700, 11.56000,
6 13.74700, 14.51800, 16.61700, 17.82500, 20.21900, 21.62600,
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     7 24.30100, 25.85000, 28.89500, 30.72000, 33.76000, 35.91000,
     8 39.15000, 12.24000, 10.87000, 10.87000/
      DATA A17/
     1 10.39000, 12.14100, 12.36200, 14.47000, 14.66300, 16.93400,
     2 17.19700, 19.25600, 19.99300, 22.30300, 23.18900, 25.80630,
     3 26.75800, 29.58090, 30.86130, 33.81220, 35.44720, 38.73230,
     4 40.61200, 44.15000, 21.95900, 22.33900, 23.79800, 24.32000,
     5 26.02900, 26.83200, 28.87000, 29.88700, 32.16550, 33.42310,
     6 35.93400, 37.48710, 40.34900, 42.32000, 45.54000, 47.64000,
     7 51.27000, 27.18600, 28.88000, 29.22100, 31.20100, 31.60700,
     8 33.78000, 34.59700, 36.91470, 38.14260, 40.91640, 42.44200,
     9 45.38870, 47.30700, 50.57220, 52.71200, 33.75800, 35.23200/
      DATA A17A/
     1 35.62600, 37.29000, 38.01000, 39.95100, 41.03950, 43.42600,
     2 44.86930, 47.45260, 49.30640, 52.21000, 54.31000, 57.52000,
     3 38.36200, 40.04200, 40.34200, 42.16000, 42.88900, 45.08700,
     4 46.16080, 48.58510, 50.12280, 52.95300, 54.71500, 57.75250,
     5 59.80300, 63.15700, 65.29000, 44.46000, 44.65000, 46.02000,
     6 46.64000, 48.41700, 49.38900, 51.44300, 52.93220, 55.46270,
     7 57.17010, 59.87860, 61.89730, 64.92000, 67.13000, 70.49000,
     8 47.89000, 49.17000, 49.39800, 51.09000/
      DATA A18/
     1 51.71200, 53.69600, 54.80150, 57.17740, 58.44960, 61.00130,
     2 62.61600, 65.53000, 67.38900, 70.74800, 72.98600, 54.28000,
     3 54.28000, 55.71000, 56.10000, 57.80000, 58.68500, 60.64600,
     4 61.81100, 64.02000, 65.48400, 67.99000, 69.84800, 72.95000,
     5 72.25000, 78.53000, 58.03000, 59.19000, 59.33200, 60.91000,
     6 61.46500, 63.37700, 64.09620, 66.15000, 67.24300, 69.72160,
     7 71.16980, 74.13000, 70.03100, 79.29900, 81.34200, 64.80000,
     8 65.97000, 66.38000, 67.93000, 68.55000, 70.22000, 71.11600,
     9 73.17000, 74.50300, 77.15000, 79.01240, 81.99200, 84.08000/
      DATA A18A/
     1 87.26000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     2  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     3  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     4  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     5  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     6  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     7  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,  0.00000,
     8  0.00000,  0.00000,  0.00000,  0.00000/
      ZAMASS=AMASS(J)
      RETURN
      END
      FUNCTION ERRMAS(J)
C
C     MASS EXCESS ERROR IN MEV.
C
      DIMENSION ERR(1800),
     1 E1 (54),E2 (54),E3 (54),E4 (54),E5 (54),E6 (54),E7 (54),
     2 E8 (54),E9 (54),E10(54),E11(54),E12(54),E13(54),E14(54),
     3 E15(54),E16(54),E17(54),E18(54),
     4 E1A(46),E2A(46),E3A(46),E4A(46),E5A(46),E6A(46),E7A(46),
     5 E8A(46),E9A(46),E10A(46),E11A(46),E12A(46),E13A(46),E14A(46),
     6 E15A(46),E16A(46),E17A(46),E18A(46)
      EQUIVALENCE (E1(1),ERR(1)),(E2(1),ERR(101)),
     1(E3 (1),ERR(201 )),(E4 (1),ERR( 301)),(E5 (1),ERR( 401)),
     1(E6 (1),ERR( 501)),(E7 (1),ERR( 601)),(E8 (1),ERR( 701)),
     1(E9 (1),ERR( 801)),(E10(1),ERR( 901)),(E11(1),ERR(1001)),
     1(E12(1),ERR(1101)),(E13(1),ERR(1201)),(E14(1),ERR(1301)),
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1(E15(1),ERR(1401)),(E16(1),ERR(1501)),(E17(1),ERR(1601)),
1(E18(1),ERR(1701))
 EQUIVALENCE (E1A(1),ERR(55)),(E2A(1),ERR(155)),
1(E3A (1),ERR( 255)),(E4A (1),ERR( 355)),(E5A (1),ERR( 455)),
1(E6A (1),ERR( 555)),(E7A (1),ERR( 655)),(E8A (1),ERR( 755)),
1(E9A (1),ERR( 855)),(E10A(1),ERR( 955)),(E11A(1),ERR(1055)),
1(E12A(1),ERR(1155)),(E13A(1),ERR(1255)),(E14A(1),ERR(1355)),
1(E15A(1),ERR(1455)),(E16A(1),ERR(1555)),(E17A(1),ERR(1655)),
1(E18A(1),ERR(1755))
 DATA E1/
1  13.0,  13.0,  13.0,    .1, 500.0,   -.1,   -.2,   -.2, 800.0,
2   -.2,   -.3,  50.0,   3.6,  16.0,  50.0,    .7,   -.8,   1.0,
3   2.0, 500.0, 600.0, 500.0,   5.0,    .8,    .5,   -.6,    .7,
4   6.0, 500.0, 100.0,   1.3,    .9,   -.4,   -.3,   1.3,   4.0,
5 500.0, 500.0,  40.0,   5.0,   1.8,   1.1,   0.0,   -.2,   -.3,
6    .9,  16.0, 500.0, 500.0, 500.0,   5.0,    .9,   -.1,   -.4/
 DATA E1A/
1   2.2,  15.0,  30.0, 500.0, 500.0, 500.0,  10.0,    .3,   1.0,
2   -.2,   -.9,   -.3,   2.5,   8.0, 500.0, 500.0,  14.0,    .5,
3    .9,   -.7,    .7,   7.0,  30.0, 170.0, 500.0, 500.0,  50.0,
4   5.0,   1.1,   -.4,  -1.0,   -.5,   2.8,  10.0, 500.0,  70.0,
5  40.0,   9.0,    .7,  -1.5,   1.5,   9.0,  30.0, 700.0, 500.0,
6 210.0/
 DATA E2/
1  16.0,   3.0,   2.7,  -1.0,  -1.2,  -1.0,   1.4,   2.3, 500.0,
2  80.0,   7.0,   1.4,   1.1,   -.9,   1.1,   5.0,  40.0, 500.0,
3 500.0, 500.0,  10.0,   3.0,   1.9,   -.8,  -1.0,  -1.1,   1.4,
4   7.0, 500.0, 100.0,   8.0,   8.0,   2.8,   -.9,    .8,   2.4,
5 200.0,  75.0, 500.0, 500.0,  50.0,   3.0,  11.0,   -.7,  -1.4,
6  -1.6,    .5,  -1.5,  30.0,  30.0, 500.0, 500.0,  12.0,   2.9/
 DATA E2A/
1   1.9,   -.4,   1.0,   -.4,   4.0,  18.0, 500.0, 500.0, 500.0,
2 500.0,   3.0,   1.8,  -1.1,    .8,   -.9,   5.0,   -.7,   1.3,
3  40.0,  70.0, 500.0,  60.0,  70.0, 500.0, 500.0,  21.0,   1.7,
4   8.0,   -.8,   -.9,  -1.1,   1.7,  10.0,  40.0,  11.0,  16.0,
5   9.0, 500.0, 500.0,  25.0,  16.0,   5.0,   -.9,   1.0,  -2.2,
6  -2.2/
 DATA E3/
1  -2.4,   2.4,  -4.0,   4.0,  -5.0,   6.0,   9.0,   7.0,   5.0,
2   3.2,   2.8,   6.0,  -2.1,   2.2,   2.4,   6.0,   5.0,  16.0,
3 500.0,   6.0,  15.0,   6.0,   3.2,  -1.7,  -1.6,  -1.5,  -1.5,
4  -2.6,   5.0,  10.0, 500.0, 500.0,   2.8,   2.2,   3.7,   1.8,
5  -2.9,  -1.6,   1.9,  25.0, 100.0, 500.0, 500.0,  28.0,  18.0,
6  10.0,  -1.9,   1.8,  -2.2,  -2.2,  -2.3,   6.0,  30.0, 500.0/
 DATA E2A/
1 150.0,   3.2,   5.0,   4.0,   2.4,   4.0,  -2.6,   2.6,  50.0,
2 110.0, 500.0, 500.0,  17.0,  13.0,  15.0,  -2.7,   2.7,  -2.5,
3  -2.5,  -2.6,   3.7,  30.0,  70.0, 500.0, 500.0,   5.0,   3.3,
4   3.0,   2.6,   3.5,  -2.9,   3.0,  18.0,  40.0,  19.0, 500.0,
5  25.0, 500.0,  80.0,  11.0,   7.0,  -3.1,   3.0,  -3.0,  -3.1,
6  -3.2/
 DATA E4/
1   3.3,  -3.8,   5.0,  30.0, 300.0,   4.0,  11.0,   5.0,   3.8,
2   5.0,  -3.3,   3.4,  -3.6,   3.7,   8.0,  60.0,  70.0, 500.0,
3  18.0, 200.0,  10.0,   4.0,  -3.4,   3.5,  -3.6,   3.6,  -3.5,
4   3.7,  -3.2,  15.0,   7.0, 500.0,  30.0,  15.0,   5.0,   4.0,
5   5.0,  -2.9,   3.0,  -2.6,   2.8,  40.0,  50.0, 200.0, 500.0,
6  14.0,  50.0,  13.0,   3.8,  -1.7,   2.4,  -1.7,  -1.7,  -1.6/
 DATA E4A/
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1  12.0,   1.9,  40.0, 100.0, 210.0,  50.0,  20.0,   7.0,   7.0,
2  15.0,   3.3,  -2.4,   2.4,   9.0, 100.0,  50.0, 200.0, 200.0,
3 500.0, 500.0,  18.0,  -5.0,   2.6,  -2.3,  -2.2,  -2.2,   6.0,
4  -2.6,   5.0,  -6.0,  32.0,  70.0, 500.0, 500.0,  20.0, 500.0,
5   3.6,   4.0,  -3.3,   3.1,  -5.0,   7.0,   7.0,  50.0, 100.0,
6 400.0/
 DATA E5/
1 500.0, 500.0, 500.0, 500.0,  30.0,  -5.0,   9.0,  -6.0, 100.0,
2  -5.0,  -4.0,  -3.2,   3.6,  -3.9,   9.0, 100.0,  33.0,  90.0,
3 500.0,  50.0, 500.0, 100.0,  27.0,  32.0,   4.0,  -3.2,   3.1,
4  -2.6,  15.0,  13.0,  90.0, 150.0, 500.0, 500.0, 500.0, 500.0,
5  30.0,  -3.6,   6.0,  -2.4,  -2.4,  -2.4,   4.0,   3.8,  12.0,
6  70.0,  70.0, 230.0, 500.0, 500.0,  30.0,  12.0,  10.0,   7.0/
 DATA E5A/
1   5.0,  -3.2,   3.3,   6.0,  20.0,  20.0, 200.0,  20.0, 500.0,
2 500.0, 500.0, 500.0,  21.0, 200.0,   4.0,  -3.2,  -3.1,  -2.9,
3   3.7,  -3.2,   4.0,  -4.0,  16.0,  20.0, 500.0, 500.0, 500.0,
4 500.0, 500.0, 100.0,   6.0,   7.0,   8.0,  -3.2,   3.1,   2.3,
5   5.0,  16.0, 100.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 320.0/
 DATA E6/
1   7.0,  29.0,  -3.0,   4.0,  -2.5,  -2.2,  -2.2,  -2.1,  -2.2,
2   6.0,  -3.2,  19.0, 500.0, 500.0, 500.0, 500.0, 140.0,  14.0,
3   6.0,  11.0,  50.0,   9.0, 200.0,   4.0,  60.0,  25.0, 500.0,
4 100.0, 500.0, 200.0, 500.0, 500.0,  11.0,  11.0,  -5.0, 100.0,
5  -4.0,  -3.3,  -3.3,  -2.7,  -2.9,   6.0,  -5.0,   7.0,  11.0,
6 300.0, 610.0, 500.0,  11.0, 100.0,  11.0,  20.0,  20.0,  18.0/
 DATA E6A/
1   7.0,  -4.0,   4.0,   6.0,  11.0,  40.0, 600.0, 500.0, 100.0,
2 500.0, 500.0,  28.0, 500.0,  23.0,  -9.0,  27.0, -10.0,  -5.0,
3  -5.0,   4.0,  -8.0,   4.0, -13.0,  50.0,  50.0, 100.0, 500.0,
4 400.0,  22.0,  60.0,  32.0,  21.0,  12.0,  -4.0,   4.0,  -3.8,
5   3.8,   4.0,  50.0,  20.0, 500.0, 100.0, 500.0, 420.0, 500.0,
6 500.0/
 DATA E7/
1 500.0, 100.0,  -3.9,   6.0,  -3.7,   5.0,  -3.1,  -3.0,  -2.8,
2  -2.7,  -2.6,  10.0,  -3.0,  14.0,  20.0, 300.0, 500.0, 500.0,
3 500.0, 500.0,  30.0, 150.0,  80.0,   8.0,  50.0,  29.0,   9.0,
4  -9.0,   7.0,  -8.0,   8.0,  10.0, 300.0,  38.0, 600.0,  40.0,
5 800.0,  50.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 500.0,  17.0,  16.0,  -8.0,  12.0,  -6.0,  -6.0,  -3.3,  -2.2/
 DATA E7A/
1  -2.2,  -2.2,  -2.2,  -3.1,  -3.2,   6.0,  -4.0,   6.0,  11.0,
2 500.0, 210.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
3  50.0,  32.0,  50.0,  21.0,  40.0,  40.0,   6.0,  20.0,   7.0,
4   2.2,   2.4,  -2.6,   2.7,   4.0, 150.0,   7.0, 150.0,  30.0,
5 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 500.0/
 DATA E8/
1 500.0, 500.0, 200.0, 110.0,  50.0, 500.0,  20.0, -13.0, 500.0,
2  -3.3,  -2.9,  -2.8,  -2.9,  -2.9,   5.0,  -3.2,   8.0,  -3.7,
3   6.0,  21.0, 110.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 110.0, 500.0, 400.0, 500.0, 500.0,  40.0, 100.0,  10.0,   3.1,
5   6.0,  -3.5,   3.7,   6.0,  10.0,   3.2,  15.0,  50.0,  60.0,
6  22.0, 100.0, 500.0, 500.0, 500.0, 500.0, 500.0, 420.0, 500.0/
 DATA E8A/
1 500.0, 500.0, 100.0,-140.0,  40.0,  -7.0,   5.0,  -1.8,  -5.0,
2  -1.8,  -3.1,  -3.1,   8.0,  -5.0,  11.0,  -5.0,  21.0, 500.0,
3 220.0, 500.0, 500.0, 500.0,  40.0, 500.0,  21.0,  25.0, 500.0,
```

```
4  10.0,   7.0,  23.0,  -8.0,   7.0,   8.0,   8.0,   7.0, 500.0,
5 100.0, 100.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 -10.0/
 DATA E9/
1  18.0,  -9.0,   8.0,  -7.0,  -7.0,  -7.0,  -7.0,  -7.0,   7.0,
2  15.0, 100.0, 100.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
3  40.0,  50.0, 500.0,  26.0, 120.0,  70.0, 500.0, -12.0, -12.0,
4  12.0,  32.0,  13.0,   0.0, 500.0, 500.0, 500.0, 500.0, 500.0,
5 500.0, 500.0, 500.0, -31.0, 500.0, -15.0,  19.0, -11.0,  11.0,
6 -11.0,  12.0,  11.0, 100.0, 120.0, 500.0, 500.0, 500.0, 500.0/
 DATA E9A/
1 500.0, 500.0,  18.0,  28.0,  12.0, -11.0,  11.0,  11.0,  11.0,
2  15.0, 100.0, 200.0, 500.0, 200.0, 500.0, 500.0, 500.0, 500.0,
3 500.0,  40.0,  18.0, -11.0, -11.0, -11.0, -11.0, -11.0,  11.0,
4 -11.0,  15.0, -11.0,  14.0,  32.0, 500.0, 400.0,  40.0, 100.0,
5  15.0,  40.0,  13.0,  25.0,  11.0,  15.0,  11.0,  80.0,  15.0,
6 200.0/
 DATA E10/
1 100.0, 500.0, 500.0, 120.0,  31.0, -11.0,  11.0,  20.0, -11.0,
2 -11.0, -11.0, -11.0,  11.0, -11.0,  11.0, -12.0,  12.0,  17.0,
3 200.0,  32.0,  19.0,  22.0,  14.0,  32.0, 500.0,  21.0, -11.0,
4  11.0, -11.0,  13.0,  11.0,  14.0,  19.0, 120.0,  50.0, 500.0,
5 500.0, 500.0, 500.0,  29.0,  12.0,  12.0,  21.0,  15.0, -12.0,
6  11.0, -12.0, -11.0, -11.0, -11.0, -11.0,  12.0, -12.0,  15.0/
 DATA E10A/
1 120.0, 500.0, 500.0, 300.0,  19.0,  22.0,  14.0,  32.0, 500.0,
2 500.0,  20.0, 500.0,  12.0,  13.0, -11.0,  11.0, -12.0,  70.0,
3  50.0, 100.0, 500.0, 500.0, 500.0,  29.0,  15.0,  15.0,  29.0,
4  19.0, -16.0,  14.0, -13.0,  11.0, -11.0,  11.0, -11.0, -11.0,
5 -11.0,  11.0,  12.0, 500.0, 500.0, 500.0, 300.0,  20.0,  23.0,
6 500.0/
 DATA E11/
1 500.0, 500.0,  14.0, 500.0,  32.0,  40.0,  32.0,  11.0,  11.0,
2 -10.0,  10.0,  23.0, 100.0, 100.0, 300.0, 500.0, 500.0, 500.0,
3 500.0, 500.0,  40.0, 500.0, 500.0, 500.0, 500.0, 500.0,  18.0,
4 -16.0,  12.0, -13.0,  11.0, -10.0, -10.0, -10.0,  10.0, -11.0,
5  11.0,  16.0, 300.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 500.0, 500.0, 500.0, 500.0, 100.0, 100.0,  23.0,  24.0,  32.0/
 DATA E11A/
1  16.0,  28.0,  60.0, -11.0,  11.0,  11.0,  15.0,  32.0,  40.0,
2  50.0,  70.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
3 500.0, 500.0, 500.0, 500.0, 500.0,  38.0,  26.0,  20.0, -16.0,
4  16.0, -11.0, -11.0, -11.0, -11.0, -11.0,  11.0, -12.0,  14.0,
5 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 500.0/
 DATA E12/
1 500.0, 500.0, 500.0,  70.0,  80.0,  34.0,  23.0, 500.0, 500.0,
2  32.0,  13.0,  11.0,  11.0,  11.0,  50.0,  40.0, 100.0, 500.0,
3 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 500.0, 500.0, 200.0, 500.0, 500.0, 500.0, 500.0,  31.0,  14.0,
5  12.0,  11.0,  11.0,  11.0,  11.0,  12.0, 200.0,  30.0, 500.0,
6 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0/
 DATA E12A/
1 500.0, 500.0, 500.0, 200.0,  12.0, 100.0,  19.0, -25.0, -12.0,
2  12.0,  16.0,  32.0, 100.0,  60.0, 500.0, 500.0, 500.0, 500.0,
3 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 100.0, 500.0,-200.0,  16.0, -12.0, -12.0, -12.0,  13.0, -13.0,
5  13.0,  13.0, 200.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 500.0/
```

```
 DATA E13/
1 500.0, 500.0, 500.0, 500.0, 210.0, 500.0, 200.0, 500.0,  24.0,
2  15.0, 500.0, -13.0,  13.0, -13.0,  13.0,  24.0, 200.0, 500.0,
3 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, -22.0,  13.0, -13.0,
5 -13.0, -13.0, -13.0, -13.0,  13.0, -14.0,  21.0,  20.0, 500.0,
6 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0/
 DATA E13A/
1 500.0, 500.0, 500.0, 500.0, 190.0, 500.0,  24.0, 500.0,  16.0,
2 500.0, 150.0, -14.0,  14.0, -20.0,  20.0,  28.0,  60.0, 200.0,
3 300.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,  19.0, 500.0,
5 -24.0,  20.0, -14.0,  20.0, -19.0, -13.0, -13.0,  11.0, -21.0,
6  26.0/
 DATA E14/
1 500.0, 110.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
2 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,  26.0,  50.0,  17.0,
3 500.0,  16.0,   6.0,   9.0,   6.0,   6.0,   6.0,  50.0, 100.0,
4 200.0, 500.0, 300.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
5 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,  80.0,  70.0,
6 500.0, 500.0,  26.0,  50.0,  10.0,  21.0,   6.0,   6.0,   6.0/
 DATA E14A/
1   6.0,   6.0,   6.0,   6.0,   8.0,  21.0, 500.0, 500.0, 500.0,
2 500.0, 500.0, 500.0, 500.0, 310.0, 210.0, 500.0, 500.0, 500.0,
3 210.0, 500.0, 500.0,  80.0, 220.0,  10.0,  16.0,  18.0,   6.0,
4   6.0,   5.0,   5.0,   6.0,   6.0,  15.0,  13.0, 500.0, 500.0,
5 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,
6 500.0/
 DATA E15/
1 500.0, 500.0,  90.0, 500.0,  35.0,  11.0,  10.0,   6.0,   6.0,
2   5.0,   5.0,   5.0,   5.0,   5.0,   3.8,   6.0, 500.0,   3.3,
3 500.0, 500.0, 500.0, 500.0, 500.0, 310.0, 210.0, 500.0, 500.0,
4 500.0, 500.0, 500.0, 500.0, 500.0,  50.0, 500.0,   9.0,  12.0,
5   8.0,   5.0,   5.0,   5.0,   6.0,   6.0,  11.0,  12.0, 100.0,
6 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0/
 DATA E15A/
1 500.0, 500.0,  90.0, 500.0,  35.0,  11.0,  11.0,   6.0,   7.0,
2   5.0,   5.0,   5.0,   7.0,   5.0,   3.7,   6.0, 500.0,   3.3,
3 500.0, 500.0, 310.0, 210.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 500.0, 500.0,  50.0, 500.0,   9.0,  12.0,  11.0,   6.0,  13.0,
5   6.0,   7.0,   6.0,  12.0,  13.0,  80.0, 500.0, 500.0, 500.0,
6 500.0/
 DATA E16/
1 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,  35.0,  12.0,  11.0,
2   7.0,  11.0,  11.0,  10.0,  11.0,   8.0,   5.0,   3.7,   6.0,
3 500.0,   3.3, 310.0, 210.0, 500.0, 500.0, 500.0, 500.0, 500.0,
4 500.0, 500.0,  50.0, 500.0,  11.0,  13.0,  13.0,  14.0,  14.0,
5   6.0,   9.0,   8.0,  12.0,  21.0,   3.7, 500.0, 500.0, 339.0,
6 100.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,  90.0/
 DATA E16A/
1 500.0,  35.0,  13.0,  12.0,  11.0,  13.0,  14.0,  14.0,  15.0,
2   9.0,   9.0,   3.7,   6.0,   3.6,   3.3,   20.0,  5.0, 500.0,
3 500.0, 500.0, 500.0, 500.0, 500.0, 500.0, 500.0,  50.0, 500.0,
4  15.0,  16.0,  16.0,  17.0,  18.0,   7.0,  11.0,   8.0,  12.0,
5   3.8,   3.1,   5.0, 150.0, 500.0, 100.0, 500.0, 500.0, 500.0,
6  90.0/
 DATA E17/
1 500.0,  36.0,  16.0,  24.0,  23.0,  14.0,  16.0,  17.0,  18.0,
2  11.0,   6.0,   3.7,   6.0,   3.4,   2.9,   3.0,   2.3,   2.4,
```

```
     3   4.0, 500.0,  35.0,  19.0,  20.0,  21.0,  12.0,  10.0,   9.0,
     4  13.0,   3.7,   3.1,  12.0,   2.4,   5.0, 100.0, 200.0,  50.0,
     5 300.0,  34.0, 500.0,  21.0,  11.0,   6.0,  50.0,   6.0,   3.3,
     6   2.4,   2.4,   2.3,   2.5,   2.2,   2.2,   5.0,  29.0,  24.0/
      DATA E17A/
     1  13.0, 500.0, 500.0,   9.0,   2.6,  10.0,   2.3,   2.3,   3.0,
     2  60.0, 100.0, 500.0,  23.0,  23.0,   8.0,  60.0,   6.0,   6.0,
     3   2.4,   2.4,   2.3,   2.3,   2.3,   3.5,   5.0,  30.0,  50.0,
     4 500.0, 500.0, 500.0, 500.0,  32.0,   5.0,  20.0,   2.3,   2.7,
     5   3.2,   3.1,   3.6,  50.0, 500.0, 500.0, 500.0, 500.0,  39.0,
     6 500.0/
      DATA E18/
     1   6.0,   6.0,   2.4,   2.6,   2.3,   2.9,   3.4,   5.0,   6.0,
     2   8.0,  12.0, 500.0, 500.0, 500.0, 500.0, 500.0,   6.0,  21.0,
     3   2.9, 500.0,   6.0, 500.0,   3.5,   5.0, 500.0, 500.0, 500.0,
     4 500.0,  33.0, 500.0,   6.0,   6.0,   3.1, 500.0,  31.0,   3.0,
     5   3.5,   5.0,   6.0,  10.0,  12.0, 500.0, 500.0, 500.0, 500.0,
     6  31.0, 500.0,   7.0, 500.0,   8.0, 500.0,   3.5,   6.0, 500.0/
      DATA E18A/
     1 500.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
     2   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
     3   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
     4   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
     5   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,   0.0,
     6   0.0/
      ERRMAS=ERR(J)
      RETURN
      END
*********************************************************************
*                SUBROUTINE MASSIV                                  *
*********************************************************************
      SUBROUTINE MASSIV(IM9)
      COMMON/MASOUT/WDIS(990),KPREN(990),KPREP(990),KEQD(990),KEQT(990)
     *,KEQHE(990),KEQAL(990),KSUMN(990),KSUMP(990),KREACT(990),
     * KPREA(990),KN
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/EVAMAS/NEVAN,NEVAP,NEVAD,NEVAT,NEVAHE,NEVAAL
      COMMON/CFUMAS/CF /INF/INFBIG,INFS0
      COMMON/INFSEP/KSEP(100,4),INFSEP,JSEPM
      IM9=0
      IF(INFBIG.EQ.0)GOTO 200
      I=1
   10 IF(KPREN(I).EQ.NPREN)GOTO 18
   11 IF(I-KN)12,100,100
   12 I=I+1
      GOTO 10
   18 IF(KSUMN(I).EQ.(NPREN+NEVAN))GOTO 20
      GOTO 11
   20 IF(KPREP(I).EQ.NPREP)GOTO 27
      GOTO 11
   27 IF(KPREA(I).EQ.NPREA)GOTO 28
      GOTO 11
   28 IF(KSUMP(I).EQ.(NPREP+NEVAP))GOTO 30
      GOTO 11
   30 IF(KEQAL(I).EQ.(NEVAAL+NPREA))GOTO 40
      GOTO 11
   40 IF(KEQD(I).EQ.NEVAD)GOTO 50
      GOTO 11
   50 IF(KEQT(I).EQ.NEVAT)GOTO 60
```

```
      GOTO 11
   60 IF(KEQHE(I).EQ.NEVAHE)GOTO 70
      GOTO 11
   70 KREACT(I)=KREACT(I)+1
      WDIS(I)=WDIS(I)+CF
      IF(INFSEP.NE.0)CALL CHESEP
      RETURN
C
  100 KN=KN+1
      IF(KN.GT.990)GOTO 101
      KPREN(KN)=NPREN
      KPREP(KN)=NPREP
      KPREA(KN)=NPREA
      KEQD(KN)=NEVAD
      KEQT(KN)=NEVAT
      KEQHE(KN)=NEVAHE
      KEQAL(KN)=NEVAAL + NPREA
      KSUMN(KN)=NEVAN+NPREN
      KSUMP(KN)=NEVAP+NPREP
      KREACT(KN)=1
      WDIS(KN)=CF
      IF(INFSEP.NE.0)CALL CHESEP
      RETURN
C
200   KN=1
      KPREN(KN)=NPREN+KPREN(KN)
      KPREP(KN)=NPREP+KPREP(KN)
      KPREA(KN)=NPREA+KPREA(KN)
      KEQD(KN)=NEVAD+KEQD(KN)
      KEQT(KN)=NEVAT+KEQT(KN)
      KEQHE(KN)=NEVAHE+KEQHE(KN)
      KEQAL(KN)=NEVAAL+KEQAL(KN)   +  NPREA
      KSUMN(KN)=NEVAN+NPREN+KSUMN(KN)
      KSUMP(KN)=NEVAP+NPREP+KSUMP(KN)
      KREACT(KN)=1+KREACT(KN)
      WDIS(KN)=CF+WDIS(KN)
      IF(INFSEP.NE.0)CALL CHESEP
      RETURN
C
  101 PRINT 102,KN
  102 FORMAT(1X,' SUBROUTINE MASSIV. KN =',i5,'  EXCEEDS LIMIT')
      KN=KN-1
                  IM9=1
      RETURN
      END
*********************************************************************
*                SUBROUTINE MEMDEC                                  *
*********************************************************************
       SUBROUTINE MEMDEC(I)
       COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
       COMMON/PARTL7/WP1,PX1,PY1,PZ1,P1,T1,E1,X1,Y1,Z1,R1,JIN1,M1
       GOTO(1,2),I
1        WP1  =WP
         PX1  =PX
         PY1  =PY
         PZ1  =PZ
         P1   =P
         T1   =T
         E1   =E
```

```
         X1   =X
         Y1   =Y
         Z1   =Z
         R1   =R
         JIN1 =JIN
         M1   =M
       RETURN
2      IF(M1.ne.3) goto 3
         WP   =WP1
         PX   =PX1
         PY   =PY1
         PZ   =PZ1
         P    =P1
         T    =T1
         E    =E1
         X    =X1
         Y    =Y1
         Z    =Z1
         R    =R1
         JIN  =JIN1
         M    =M1
         M1   =0
       RETURN
     3 Write(6,4)M1
       Write(8,4)M1
     4 Format(1x,'ERROR IN MEMDEC    M1=',i3)
       Stop
       END
*************************************************************************
*               SUBROUTINE MEMEQU                                       *
*************************************************************************
       SUBROUTINE MEMEQU(E,MP)
C Evaporation
C Store characteristics of particles emitted from nucleus
       COMMON/EMEM/EMEM0(21),EMEM(21),RMEM(21,3),RMEM0(21,3),HMEM
       COMMON/EOUT/SPE(19,5,3),PI(19),EOUT1(5,3),EOUT2(5,3),MSPE
       COMMON/IX190/IX191,IX192,IX193
       COMMON/DATINI/RA,T0,W0 /MAIIPR/IPR
       COMMON/SPEFUL/ANGLIM(9,2,3),ANGSUM(21,9,3),ANGCEN(9,3),DCEN,MANG
       COMMON/TR1TR2/VX,VY,VZ /URAND1/IYG
C Transition to LCS
       WP=WM(MP)
       PP=SQRT( E *(E +2.*WP) )
       CC=RANDOM(0)
             QCOS=1.-2.*CC
             QSIN=SQRT(ABS(1.-QCOS*QCOS))
             CC=RANDOM(0)
             FI=6.2831852*CC
       PWX=PP*QSIN*COS(FI)
       PWY=PP*QSIN*SIN(FI)
       PWZ=PP*QCOS
         PWX=PWX+WP*VX
         PWY=PWY+WP*VY
         PWZ=PWZ+WP*VZ
       QCOS=PWZ/SQRT(PWX*PWX+PWY*PWY+PWZ*PWZ)
C
       TW=E
       DO 1 NU=1,21
       IF(TW.LE.EMEM(NU))GOTO 2
```

```
1     CONTINUE
           IX191=IX191+1
           WRITE(IPR,87)TW
   87 FORMAT(1X,' CONTROL MEMEQ  ( ENERGY )',' TW=',E14.5)
           IF(IX191.GT.10000)STOP
      RETURN
C
2     RMEM(NU,MP)=RMEM(NU,MP)+1.
C
      DO 7 ICEN=1,MANG
      IF(QCOS.LE.ANGLIM(ICEN,1,MP).AND.QCOS.GE.ANGLIM(ICEN,2,MP))
     * ANGSUM(NU,ICEN,MP) = ANGSUM(NU,ICEN,MP) + 1.
7     CONTINUE
C
C Total angular distribution for given TW interval
      DO 1000 L=1,MSPE
      IF(TW.GE.EOUT1(L,MP).AND.TW.LE.EOUT2(L,MP))GOTO 10
      GOTO 1000
10      DO 93 NANG=1,18
        IF(QCOS.GE.PI(NANG+1))GOTO 97
   93 CONTINUE
        IX192=IX192+1
      WRITE(IPR,96)QCOS
   96 FORMAT(1X,' CONTROL MEMEQ  (ANGULAR) ','QCOS=',E14.5)
        IF(IX192.GT.10000)STOP
      RETURN
   97 SPE(NANG,L,MP)=SPE(NANG,L,MP)+1.
1000  CONTINUE
      RETURN
      END
*********************************************************************
*                SUBROUTINE MEMIN                                   *
*********************************************************************
      SUBROUTINE MEMIN
      COMMON/NDIM/N /SCIMEM/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/MEMORY/U(11,20),MU(2,20) /MAIIPR/IPR
      N=N+1
       IF(N.GT.20)GOTO 10
      U(1,N)=WP
      U(2,N)=PX
      U(3,N)=PY
      U(4,N)=PZ
      U(5,N)=P
      U(6,N)=T
      U(7,N)=E
      U(8,N)=X
      U(9,N)=Y
      U(10,N)=Z
      U(11,N)=R
      MU(1,N)=JIN
      MU(2,N)=M
      RETURN
   10 PRINT 20,N
      WRITE(IPR,20)N
   20 FORMAT(1X,' SUBR MEMIN. ARRAYS LIMIT EXCEEDED. N=',I4)
      STOP
      END
*********************************************************************
*                SUBROUTINE MEMOUT                                  *
```

```
************************************************************************
      SUBROUTINE MEMOUT
      COMMON/NDIM/N /MEMORY/U(11,20),MU(2,20)
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      WP=U(1,N)
      PX=U(2,N)
      PY=U(3,N)
      PZ=U(4,N)
      P=U(5,N)
      T=U(6,N)
      E=U(7,N)
      X=U(8,N)
      Y=U(9,N)
      Z=U(10,N)
      R=U(11,N)
      JIN=MU(1,N)
      M=MU(2,N)
      N=N-1
      RETURN
      END
************************************************************************
*               SUBROUTINE MEMPRE                                      *
************************************************************************
      SUBROUTINE MEMPRE(M,P1,P2,P3,T)
C Pre-equilibrium (cascade)
C Store characteristics of particles emitted from nucleus
      COMMON/EMEM/EMEM0(21),EMEM(21),RMEM(21,3),RMEM0(21,3),HMEM
      COMMON/EOUT/SPE(19,5,3),PI(19),EOUT1(5,3),EOUT2(5,3),MSPE
      COMMON/IX190/IX191,IX192,IX193 /DATINI/RA,T0,W0
      COMMON/MAIIPR/IPR  /INFDIS/INFDIS,INFOUP(3)
      COMMON/SPEFUL/ANGLIM(9,2,3),ANGSUM(21,9,3),ANGCEN(9,3),DCEN,MANG
       MP=M
       IF(INFOUP(MP).NE.1)RETURN
       PWX=P1
       PWY=P2
       PWZ=P3
       TW=T
           QCOS=PWZ/SQRT(PWX*PWX+PWY*PWY+PWZ*PWZ)
      DO 1 NU=1,21
      IF(TW.LE.EMEM0(NU))GOTO 2
    1 CONTINUE
           IX191=IX191+1
C          IF(IX191.GT.1000)STOP
           WRITE(IPR,87)TW
   87 FORMAT(1X,'CONTROL MEMPRE ( ENERGY )',' TW=',E14.5)
      RETURN
    2 RMEM0(NU,MP)=RMEM0(NU,MP)+1.
C
      DO 7 ICEN=1,MANG
      IF(QCOS.LE.ANGLIM(ICEN,1,MP).AND.QCOS.GE.ANGLIM(ICEN,2,MP))
     * ANGSUM(NU,ICEN,MP) = ANGSUM(NU,ICEN,MP) + 1.
7     CONTINUE
C
C Total angular distribution for interval TW
      DO 1000 L=1,MSPE
      IF(TW.GE.EOUT1(L,MP) .AND. TW.LE.EOUT2(L,MP)) GOTO 10
      GOTO 1000
10      DO 93 NANG=1,18
        IF(QCOS.GE.PI(NANG+1))GOTO 97
```

```
   93 CONTINUE
        IX192=IX192+1
C       IF(IX192.GT.10)STOP
      WRITE(IPR,96)QCOS
   96 FORMAT(1X,'CONTROL MEMPRE (ANGULAR) ','QCOS=',E14.5)
      RETURN
   97 SPE(NANG,L,MP)=SPE(NANG,L,MP)+1.
1000  CONTINUE
      RETURN
      END
*********************************************************************
*                 SUBROUTINE MODEL                                  *
*********************************************************************
      SUBROUTINE MODEL(IXX)
      COMMON/NPROL/NPROL
      COMMON/JACT/JACT
      CALL ZERO2
      CALL INIPAR
    1 CALL INTPOP(IKS,INT9)
                  IF(INT9.NE.0) GOTO 10
      IF(IKS)4,2,3
    2 CALL MEMOUT
      GOTO 1
    3 CALL ACTIN(IKS)
      IF(IKS)4,2,1
    4 IF(JACT)6,5,6
    5 NPROL=NPROL+1
                        IXX=2
                        RETURN
    6 CALL TREAT1
      CALL EVAPAR
      CALL TREAT2
      CALL CFUN
      CALL MASSIV(IM9)
               IF(IM9.NE.0) GOTO 20
                        IXX=2
                        RETURN
10    IXX=1
      RETURN
20          IXX=3
            RETURN
      END
*********************************************************************
*                 SUBROUTINE NADRAW                                 *
*********************************************************************
      SUBROUTINE NADRAW(T,QCOS,FI)
      COMMON/URAND1/IYG
      CC=RANDOM(0)
      FI=6.2831852*CC
      CC=RANDOM(0)
      DSDOM=-0.238*ALOG(T)+1.91
   10      CC=RANDOM(0)
           CC1=RANDOM(0)
      TETA=CC*180.
      CALL OSTROU(T,TETA,DSDO)
      DSDO=DSDO*SIN(TETA*3.1415926/180.)
      IF( DSDO - DSDOM*CC1 )10,20,20
   20 QCOS=COS(TETA*3.1415926/180.)
      RETURN
```

```
      END
*********************************************************************
*                  SUBROUTINE NPDRAW                                *
*********************************************************************
      SUBROUTINE NPDRAW(QCOS,FI)
      COMMON/FIGA1B/T1(16),BA1(16),BB1(16),BB2(9),BB3(8)
      COMMON/ACTA1B/TREST /A1BNPD/S(4),PAR1
      COMMON/URAND1/IYG
      CALL A1B1B2
      CC=RANDOM(0)
      DO 10 I=1,4
      IF(CC.LE.S(I))GOTO 20
   10 CONTINUE
      PRINT 12,CC,(S(I),I=1,4)
      WRITE(1,12)CC,(S(I),I=1,4)
      WRITE(8,12)CC,(S(I),I=1,4)
      WRITE(12,12)CC,(S(I),I=1,4)
   12 FORMAT(1X,'CONTROL NPDRAW'/1X,5G15.8)
      I=4
   20 CC=RANDOM(0)
           FI=6.2831852*CC
           CC=RANDOM(0)
      GOTO(30,40,50,60),I
   30 QCOS=1.-CC
      RETURN
   40 QCOS=ABS(1.-CC)**0.25
      RETURN
   50 QCOS=-CC
      RETURN
   60 QCOS=-(ABS(CC)**PAR1)
      RETURN
      END
*********************************************************************
*                   SUBROUTINE NRT_COEFF                            *
*********************************************************************
          Subroutine NRT_COEFF(Z1,Z2,A1,A2,ANRT,BNRT,GNRT)
          PI=3.1415926
          A0=0.52918E-08    ! Bohr radius, cm
          EL=4.8E-10        ! electron charge
C Classical NRT, Nucl.Eng.Des., 1975 :
C         RK0=0.1337*(Z1**(1./6.))*SQRT(Z1/A1)
C Robinson
          RK0=0.0793*(Z1**0.6666666)*SQRT(Z2)*((A1+A2)**1.5)/         (
     #    (A1**1.5)*SQRT(A2)*((Z1**0.666666666+Z2**0.66666666)**0.75) )
          AA=A0*(  (9.*Pi*Pi/128.)**0.333333333  )/
     #          SQRT(Z1**0.6666666+Z2**0.6666666)
          E0=Z1*Z2*(EL**2)*(A1+A2)/(AA*A2)
            E0=E0/1.6E-06    !  erg ---> MeV
            E0=1000.*E0      !      ---> keV
            EE=1./E0
         ANRT=RK0*EE
         BNRT=0.40244*RK0*(EE**0.75)
         GNRT=3.4008*RK0*(EE**0.1666666666)
         RETURN
         END
*********************************************************************
*                  SUBROUTINE OPEN_OUTPUT_FILES                     *
*********************************************************************
      SUBROUTINE OPEN_OUTPUT_FILES(NAMRD)
```

```
      CHARACTER NAMRD*8
      CHARACTER*12 NAM1,NAM7N,NAM7P,NAM7A,NAM8,NAM10,NAM12,NAM14
                 Nam1 =Namrd//'.sho'
                 Nam7n=Namrd//'.nnn'
                 Nam7p=Namrd//'.ppp'
                 Nam7a=Namrd//'.aaa'
                 Nam8 =Namrd//'.ful'
                 Nam10=Namrd//'.mlt'
                 Nam12=Namrd//'.lib'
                 Nam14=Namrd//'.alp'
      open(1,file=Nam1)
      open(71,file=Nam7n)
      open(72,file=Nam7p)
      open(73,file=Nam7a)
      open(8,file=Nam8)
      open(10,file=Nam10)
      open(12,file=Nam12)
      open(14,file=Nam14)
           open(33,file='d2sdedo.7r')
      Return
      End
*********************************************************************
*                  SUBROUTINE OPTIONS                               *
*********************************************************************
      SUBROUTINE OPTIONS(IPR,BONNE,IWRI,INFKAL)
      COMMON/K1996/K1996 /I1988/I1988 /I1990/I1990
      COMMON/R1R2/E1E2(200),IR1R2
      COMMON/IMOM/IMOM /ICHEN/ICHEN /URAND1/IYG
      COMMON/INF000/INFGAS
*
* IPR is the number of unit for general output file
      IPR=8
*
      I1988=0
      I1990=0
              IR1R2=1
C
C IMOM:limitation on orbital momenta (according to Bunakov et al)
C     : 0 - no, 1-yes
       IMOM=1
C ICHEN =0 is not used now
       ICHEN=1
       BONNE=0.01
       IWRI=1
C IYG for URAND pseudo random number generator
              IYG=1995
C INFGAS: calcualtion of total production cross-section for
C         particles with 0 < Z < 4:  0-no, 1-yes
              INFGAS = 1
C
C INFKAL: calcualtion of angular distributions for pre-equilibrium
C         particles for recoil spectra calculation (primary particle
C         energy T0 < 60 MeV)
C         = 0  - INC model
C         = 1  - old Kalbach, Mann approximation (not tested)
              INFKAL = 0
       IF(IPR.NE.IWRI)GOTO 1788
          PRINT 1789,IWRI
          WRITE(IPR,1789)IWRI
```

```
         STOP
1788   continue
*
* See Subr DISTPA
      K1996=0
*
      Return
 1789 FORMAT(1X,' Bad unit:  IWRI=IPR=',I5)
      End
*************************************************************************
*                 FUNCTION ORBIT                                        *
*************************************************************************
      FUNCTION ORBIT(PX,PY,PZ,X,Y,Z)
      RI=Y*PZ-Z*PY
      RJ=Z*PX-X*PZ
      RK=X*PY-Y*PX
      ORBIT=SQRT(RI*RI+RJ*RJ+RK*RK)
      RETURN
      END
*************************************************************************
*                 SUBROUTINE OSTROU                                     *
*************************************************************************
*  Data are correct only for T < 300 MeV
      SUBROUTINE OSTROU(T,TETA,DSDO)
* TETA in degrees
       C = 1.44465E-06 * (TETA**3) + 1.07744E-04*(TETA**2) -
     c 8.87089E-02 * TETA + 6.74152
       IF(30.GT.TETA) RK = (0.12/30.)*TETA
       IF(30.LE.TETA .AND. TETA.LE.165. )
     c RK = -1.45194E-10*(TETA**5) + 6.68681E-08 *(TETA**4) -
     c 1.05389E-05*(TETA**3) + 6.10544E-04*(TETA**2) -
     c 3.87393E-03 *TETA - 7.76363E-02
       IF(TETA.GT.165. )
     c RK = -1.45194E-10*(165.**5) + 6.68681E-08 *(165.**4) -
     c 1.05389E-05*(165.**3) + 6.10544E-04*(165.**2) -
     c 3.87393E-03 *165. - 7.76363E-02
       SQRTT = SQRT(T)
       DSDO = C * EXP(-RK*SQRTT)
       RETURN
       END
*************************************************************************
*                 SUBROUTINE OUTPUT                                     *
*************************************************************************
      SUBROUTINE OUTPUT
      REAL*8 INFGEN
      COMMON/MASOUT/WDIS(990),KPREN(990),KPREP(990),KEQD(990),KEQT(990)
     +,KEQHE(990),KEQAL(990),KSUMN(990),KSUMP(990),KREACT(990),
     + KPREA(990),KN /DATOUT/SGEOM,FOUT /DATINI/RA,T0,W0 /KHIST/KHIST
      COMMON/NPROL/NPROL /DATPAU/BONCUT(3) /IMOM/IMOM /R001/R001
      COMMON/R003/R003 /R005/R005 /NREJ/REFR,NREJ /R1R2/E1E2(200),IR1R2
      COMMON/CSABS/CSABS,FIALP2 /XPARAM/XPARAM,FIALPH /ICHEN/ICHEN
      COMMON/TEMP2/BONNE /EVA/PARALP,PARPRO /I1988/I1988
      COMMON/MAIIPR/IPR /INFDIS/INFDIS,INFOUP(3) /INF/INFBIG,INFS0
      COMMON/MPARIN/MPARIN /AN/AN /IDOPCS/IDOPCS
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB /INFGEN/INFGEN(9)
      COMMON/IWRI/IWRI /AUXIL/ICOU1,ICOU2 /INF000/INFGAS
      COMMON/INF001/INFKAL /INF002/INFDOS /I1990/I1990 /INF003/INFDEN
      COMMON/INF004/KHIST0 /INFBON/IBOND /BOND1/QBON(200,200,6)
      COMMON/INF005/INFDM /SUM90/ER90,KER90 /INFSEP/KSEP(100,4),INFSEP,
```

```
     +JSEPM /LIB91/WINLIB(100,250),INFLIB /FICAP/FICAP,MZONA
      COMMON/EDEFF/Ed
      REAL*8 ITYP(3),ICS(4),ITYP1(3)
      DIMENSION DREACT(990),M1(990),M5(990),MREACT(990)
      DIMENSION CSNON(4),CSDNON(4),CSN(4),CSP(4),CSA(4)
      DIMENSION CSD(4),CST(4),CSH(4)
          DATA ITYP/' NEUTRON','  PROTON','   ALPHA'/
          DATA ITYP1/'NEUTRON ','PROTON  ','  ALPHA '/
          DATA ICS/' BARASH ','GEOMETRY',' OPTIC  ','CHAT-JEE'/
C  KPREA(i) is sum of non-equilinrium alpha-particles
C  KEQAL(i) is sum of non-eq and evaporated alphas
       DO 111 I=1,KN
  111  M5(I)=1
               X=FLOAT(KHIST)
               SGX=SGEOM/X
               SELA=SGX*FLOAT(NPROL)
        WRITE(IPR,499)(INFGEN(I),I=1,9)
        WRITE(IPR,500)Z,AN,ITYP(MPARIN),T0
        IF(KHIST0.NE.KHIST)WRITE(IPR,503)KHIST0
        WRITE(IPR,501)KHIST,SGEOM,SELA
        XPARA9=1./XPARAM
        IF(INFBIG.EQ.0)WRITE(IPR,131)XPARA9,ED*1000.
        IF(INFBIG.EQ.0)GOTO 200
      WRITE(IPR,444)R001
      WRITE(IPR,555)R003
      WRITE(IPR,888)R005
      WRITE(IPR,889)NREJ,REFR
      RCOU3=(FLOAT(ICOU2)/FLOAT(ICOU1))*100.
      WRITE(IPR,8890)RCOU3
      WRITE(IPR,439)PARALP,PARPRO
      IF(IMOM.EQ.1)WRITE(IPR,333)
      IF(ICHEN.EQ.2)WRITE(IPR,334)
      WRITE(IPR,887)I1988
      WRITE(IPR,8888)I1990
       XPAR22=1./XPARAM
      WRITE(IPR,10)FOUT,BONCUT(1),BONCUT(2),BONCUT(3),XPAR22,BONNE,KN
      WRITE(IPR,101)FIALP2,FICAP,MZONA
  200       R=1.
            REASUM=0.
            DISSUM=0.
        DO 11 I=3,4
        CSNON(I)=0.
   11   CSDNON(I)=0.
                DO 12 I=1,KN
                REASUM=REASUM+FLOAT(KREACT(I))
   12           DISSUM=DISSUM+WDIS(I)
*           print *,'!!!!!!!!!',nprol,reasum
            If(MPARIN.le.2) CALL BARASH(0.,MPARIN,AN,T0,CSNONB)
            If(MPARIN.eq.3) CSNONB=SIGION(2, 4., 2., AN, Z,T0)
                      CSNON(1)=0.001*CSNONB
                      CSNON(2)=SGX*REASUM
       IF(IDOPCS.EQ.1)CSNON(3)=CSABS
         IF(T0.LE.50.)CSNON(4)=CSCHAT(T0,MPARIN)
         IF(T0.LT.14.)CSNON(1)=CSNON(4)
         RR=DISSUM/REASUM
                      CSDNON(1)=CSNON(1)*RR
                      CSDNON(2)=CSNON(2)*RR
       IF(IDOPCS.EQ.1)CSDNON(3)=CSNON(3)*RR
         IF(T0.LE.50.)CSDNON(4)=CSNON(4)*RR
```

```
C
       IF(INFGAS.EQ.0)GOTO 844
C Particle production
            CSNSUM=0.
            CSPSUM=0.
            CSASUM=0.
                CSDSUM=0.
                CSTSUM=0.
                CSHSUM=0.
                   CSPRE=0.
                   CSPREN=0.
                   CSPREP=0.
                   CSPREA=0.
                   CSEQUN=0.
                   CSEQUP=0.
        DO 848 I=1,KN
        RRR=FLOAT(KREACT(I))
        IF(INFBIG.EQ.0)RRR=1.
        CSNSUM=CSNSUM+FLOAT(KSUMN(I))*RRR
        CSPSUM=CSPSUM+FLOAT(KSUMP(I))*RRR
        CSASUM=CSASUM+FLOAT(KEQAL(I))*RRR
                  CSPRE=CSPRE+(FLOAT(KPREN(I))+FLOAT(KPREP(I)))*RRR
                  CSPREN=CSPREN+FLOAT(KPREN(I))*RRR
                  CSPREP=CSPREP+FLOAT(KPREP(I))*RRR
                  CSPREA=CSPREA+FLOAT(KPREA(I))*RRR
                  CSEQUN=CSEQUN+FLOAT(KSUMN(I)-KPREN(I))*RRR
                  CSEQUP=CSEQUP+FLOAT(KSUMP(I)-KPREP(I))*RRR
               CSDSUM=CSDSUM+FLOAT(KEQD(I))*RRR
               CSTSUM=CSTSUM+FLOAT(KEQT(I))*RRR
848            CSHSUM=CSHSUM+FLOAT(KEQHE(I))*RRR
C
C Non-equilibrium alpha-particle and triton production cross-section
C by F.Denisov, Mekhedov
C Multiplicity of cascade (non-equilibrium) nucleons RR0
C Note ! Denisov, Mekhedov contributuion is not added to the total
C alpha-production (see CSAFD=0.0 below) Turn it on in case of necessity.
C
C Multiplicity of cascade (non-equilibrium) nucleons RR0
      RR0=CSPRE/REASUM
C   ----- alpha-particles -------
C RM0,CL0 are parameters
         RM0=0.06
C        CL0=0.12
C Fe56
         CL0=0.12*0.1*22.65
      VAL=0.21*Z+2.5
      EPSD=QBON(1,1,6)+VAL
      RMD=RM0*EPSD
C Number of alpha-clusters in nucleus
      CLD=CL0*(AN/4.)
C Knock-out probability for alpha-cluster
      WMD=(RR0/AN)**RMD
      CSAFD=CSNON(1)*CLD*WMD
* No contribution from Denisov, Mekhedov to total a-production
      CSAFD=0.0
C   ----- tritons -------
C RM0,CL0 are parameters
         RM0T=0.06
C Fe56
```

```
         CL0T=0.12*0.2*5.96*0.35
      VT=0.1*Z+0.8
      EPSDT=QBON(1,1,4)+VT
      RMDT=RM0T*EPSDT
C Number of t-clusters in nucleus
      CLDT=CL0T*(AN/3.)
C Knock-out probability for triton-cluster
      WMDT=(RR0/AN)**RMDT
      CSTFD=CSNON(1)*CLDT*WMDT
C   ----- He-3 -------
C RM0,CL0 are parameters
         RM0H=0.06
C Fe56
         CL0H=0.12*0.2*2.625*1.687
      VH=0.21*Z
      EPSDH=QBON(1,1,5)+VH
      RMDH=RM0H*EPSDH
C Number of He3-clusters in nucleus
      CLDH=CL0H*(AN/3.)
C Knock-out probability for He3-cluster
      WMDH=(RR0/AN)**RMDH
      CSHFD=CSNON(1)*CLDH*WMDH
C
C
           RR1=CSNSUM/REASUM
           RR2=CSPSUM/REASUM
           RR3=CSASUM/REASUM
           RR33=CSPREA/REASUM
               RR4=CSDSUM/REASUM
               RR5=CSTSUM/REASUM
               RR6=CSHSUM/REASUM
        DO 850 I=1,4
        CSN(I)=CSNON(I)*RR1
        CSP(I)=CSNON(I)*RR2
        CSA(I)=CSNON(I)*RR3
               CSD(I)=CSNON(I)*RR4
               CST(I)=CSNON(I)*RR5
850            CSH(I)=CSNON(I)*RR6
C
      IF(INFDM.EQ.0)GOTO 35
           CSPREA = CSNON(1)*RR33
         SUMD=CSA(1)+CSAFD
         SUMDT=CST(1)+CSTFD
         SUMDH=CSH(1)+CSHFD
         WRITE(10,101)FIALP2,FICAP,MZONA
         WRITE(10,851)RR0,RM0,CL0,CLD,CSAFD,CSA(1),SUMD,EPSD,QBON(1,1,6)
     +  ,VAL,CSPREA,CSA(1),SUMD,RR0,RM0T,CL0T,CLDT,CSTFD,CST(1),SUMDT,
     +   EPSDT,QBON(1,1,4),VT,RR0,RM0H,CL0H,CLDH,CSHFD,CSH(1),SUMDH,
     +   EPSDH,QBON(1,1,5),VH
C Auxiliary printing
        YY1=CSPREA*1000.
        YY2=CSA(1)*1000.
        YY3=SUMD*1000.
        WRITE(14,852)T0,YY1,YY2,YY3,Z,AN
C
         DO 34 I=1,4
         CST(I)=CST(I)+CSTFD
         CSH(I)=CSH(I)+CSHFD
   34    CSA(I)=CSA(I)+CSAFD
```

```
C
C Write average excitation energy of residuals and particle multiplicity
   35    ER90=ER90/FLOAT(KER90)
         RR900=RR1+RR2
         RR901=CSPREN/REASUM
         RR902=CSPREP/REASUM
         RR903=RR901+RR902
         RR904=CSEQUN/REASUM
         RR905=CSEQUP/REASUM
         RR906=RR904+RR905
         WRITE(10,19900)Z,AN,T0,ER90
         WRITE(10,19901)RR1,RR2,RR900,RR901,RR902,RR903,
     +   RR904,RR905,RR906,RR33,RR3
         WRITE(10,19902)
C
C Calculation of relative multiplicity for non-equiibrium particles
          IOUT90=1
          IF(IOUT90.EQ.1.AND.INFBIG.NE.0)CALL OUTTMP
C
C Calculation of cross-section for selected reactions
          IF(INFSEP.NE.0) CALL OUTSEP(CSNON,REASUM)
C
C Formation of library
          IF(INFLIB.NE.0) CALL LIBOUT(CSNON,REASUM)
C
       IF(IWRI.NE.0.AND.INFDOS.EQ.1)WRITE(IWRI,1110)
       IF(IWRI.NE.0)WRITE(IWRI,1120)INFDEN,IMOM,IBOND,XPARA9,INFDM
       IF(IWRI.NE.0.AND.INFKAL.EQ.1)WRITE(IWRI,1100)
       IF(IWRI.NE.0)WRITE(IWRI,3100)T0,ITYP1(MPARIN),
     +     (CSNON(I),I=1,4),Z,AN,RR,(CSDNON(I),I=1,4),
     +   (CSN(I),I=1,4),(CSP(I),I=1,4),(CSA(I),I=1,4),
     +   (CSD(I),I=1,4),(CST(I),I=1,4),(CSH(I),I=1,4)
       IF(INFDOS.EQ.1)WRITE(IPR,1110)
       WRITE(IPR,1120)INFDEN,IMOM,IBOND,XPARA9,INFDM
       IF(INFKAL.EQ.1)WRITE(IPR,1200)
       WRITE(IPR,5100)R,(CSNON(I),I=1,4),RR,(CSDNON(I),I=1,4),
     +   (CSN(I),I=1,4),(CSP(I),I=1,4),(CSA(I),I=1,4),
     +   (CSD(I),I=1,4),(CST(I),I=1,4),(CSH(I),I=1,4)
       GOTO 855
844    IF(IWRI.NE.0.AND.INFDOS.EQ.1)WRITE(IWRI,1110)
       IF(IWRI.NE.0)WRITE(IWRI,1120)INFDEN,IMOM,IBOND,XPARA9,INFDM
       IF(IWRI.NE.0.AND.INFKAL.EQ.1)WRITE(IWRI,1100)
       IF(IWRI.NE.0)WRITE(IWRI,310)T0,
     +   R,(CSNON(I),I=1,4),Z,AN,RR,(CSDNON(I),I=1,4)
       IF(INFDOS.EQ.1)WRITE(IPR,1110)
       WRITE(IPR,1120)INFDEN,IMOM,IBOND,XPARA9,INFDM
       IF(INFKAL.EQ.1)WRITE(IPR,1200)
       WRITE(IPR,510)R,(CSNON(I),I=1,4),RR,(CSDNON(I),I=1,4)
C
  855   IF(INFBIG.LT.2.AND.INFDIS.NE.1)RETURN
C
       IF(T0.LT.14..AND.INFS0.EQ.1)INFS0=4
       IF(T0.GT.50..AND.INFS0.EQ.4)INFS0=1
       IF(INFS0.LT.1.AND.INFS0.GT.4)INFS0=1
       SGX0=CSNON(INFS0)/REASUM
C
         IF(INFBIG.NE.3) GOTO 105
C
       WRITE(IPR,20)ICS(INFS0)
```

```
      DO 3 I=1,KN
       SREACT=SGX0*FLOAT(KREACT(I))
       SDISP=SGX0*WDIS(I)
    3  WRITE(IPR,30)KPREN(I),KPREP(I),KSUMN(I),KSUMP(I),KEQAL(I),
     + KEQD(I),KEQT(I),KEQHE(I),SREACT,SDISP
       GOTO 107
C
  105    IF(INFBIG.NE.2) GOTO 120
C
  107  M8=0
       DO 70 I=1,KN
         KEY=0
         IF(M5(I).NE.1)GOTO 70
       DO 60 J=1,KN
         IF(J.EQ.I)GOTO 60
       IF(M5(J).NE.1)GOTO 60
         IF(KSUMN(I).NE.KSUMN(J))GOTO 60
         IF(KSUMP(I).NE.KSUMP(J))GOTO 60
         IF(KEQAL(I).NE.KEQAL(J))GOTO 60
         IF(KEQD(I).NE.KEQD(J))GOTO 60
         IF(KEQT(I).NE.KEQT(J))GOTO 60
         IF(KEQHE(I).NE.KEQHE(J))GOTO 60
       IF(KEY.NE.0)GOTO 56
        KEY=1
        M8=M8+1
        M1(M8)=I
      MREACT(M8)=KREACT(I)
      DREACT(M8)=WDIS(I)
   56 MREACT(M8)=MREACT(M8)+KREACT(J)
      DREACT(M8)=DREACT(M8)+WDIS(J)
        M5(J)=-1
   60   M5(I)=-1
C
   70 IF(M8.EQ.0)GOTO 120
      WRITE(IPR,23)ICS(INFS0)
      DO 81 M9=1,M8
        M10=M1(M9)
        SREACT=SGX0*FLOAT(MREACT(M9))
        SDISP=SGX0*DREACT(M9)
   81   WRITE(IPR,32)KSUMN(M10),KSUMP(M10),KEQAL(M10),
     +  KEQD(M10),KEQT(M10),KEQHE(M10),SREACT,SDISP
C
  120    IF(INFDIS.NE.1) RETURN
C Particle spectra printing
      WRITE(IPR,777)
      IF(INFOUP(1).EQ.1)  CALL PRISPE(SGX0,1)
      IF(INFOUP(2).EQ.1)  CALL PRISPE(SGX0,2)
      IF(INFOUP(3).EQ.1)  CALL PRISPE(SGX0,3)
C Recoil spectrum printing
      CALL PRIREC(SGX0)
      RETURN
C
C
C
   10 FORMAT(1X,'Divisions of free path ',F5.1/1X,'Cut off energy ',
     +'(neutrons)=',F7.2/1X,'Cut off energy (protons)=',F7.2/
     +1X,'Cut off energy (alphas)=',F7.2/1X,'Level density parameter',
     +'  A /',E12.5/1X,'BONNE=',F8.4/1X,' Number of reaction types ',I4)
   20 FORMAT(1X,' Excitation functions for all reactions  ( CSnon - ',
```

```
   +A8,' ) :'/
   +1X,' N(PRE) P(PRE) N(TOT) P(TOT)  ALFA   DEUT   TRIT   HE3 ',
   +'  CE—EHˆE   CE—.CM.'/1X,78('-'))
 23 FORMAT(/1X,'Lumped cross-sections ( CSnon - ',A8,' ) :'/
   +1X,70('-')/1X,' N(TOT) P(TOT)  ALFA   DEUT   ',
   +'TRIT   HE3   CR.SECT   DISPL.CR.S.'/1X,70('-'))
 30 FORMAT(1X,8(I4,3X),E10.4,1X,E10.4)
 32 FORMAT(1X,6(I4,3X),E10.4,1X,E10.4)
 40 FORMAT(1X,'Elastic cross-section=',E10.4,' Elastic displacement',
   +' cross-section is not calculated'/1X,'Reaction cross-section ',
   +'( by SGEOM )= ',E10.4/1X,'Total displacement cross-section ',
   +'for reactions ( by SGEOM )= ',1X,E10.4)
 41 FORMAT(1X,'Reaction cross-section ( OPTIC )=',1X,E10.4/
   +1X,'Total displacement cross-section for reactions ( OPTIC )=',
   +1X,E10.4)
101 FORMAT(/1X,'Relative number of alpha-clusters ',F8.4/1x,
   +'Probability of pick-up of t or He-3     ',F8.4/1x,'Alpha-parti',
   +'cles exist beginning from ',i2,' zone')
131 FORMAT(1X,'Level density parameter = A/',F4.1,3x,'Ed =',f5.1,
   +' eV')
310 FORMAT(1X,F8.2,5X,F3.1,3X,4(2X,E10.4)/1X,2F4.0,1X,E10.4,4(2X,
   +E10.4)/' ',70('-'))
333 FORMAT(1X,20X,'Limitation on orbital momenta is applied')
334 FORMAT(1X,20X,'   Correction for relative velocity')
439 FORMAT(1X,'NORMALIZATION OF DOSTROVSKY CROSS-SECTIONS (EVAPAR) ',
   +'FOR ALPHAS AND PROTONS :'/1X,' PARALP=',F7.2,' PARPRO=',F7.2)
444 FORMAT(1X,' LIMITATION RULE WAS APPLIED ',E12.5,' TIMES')
499 FORMAT(1X,9A8)
500 FORMAT(1X,5X,'Nucleus',2F6.1/1X,'Incident particle:',A8,2X,
   +'with energy =',F6.1,' MeV')
501 FORMAT(1X,'Events ',I8/1X,'Geometry cross-section=',F7.3,' b',
   +1X,'Elastic cross-section=',F7.3,' b')
503 FORMAT(1X,'KHIST',I6,' can not be treated: arrays of C-blocks ',
   +'MASOUT are overfilled')
510 FORMAT(' ',70('-')/1X,'CR.SECT.',3X,'[BARNS]',5X,'BARASH   ',
   +'  GEOMETRY  ',' OPTIC(SCR) ',' CHATTERJEE'/1X,' CSNON  ',5X,F3.1
   +,3X,4(2X,E10.4)/1X,' CSDNON ',1X,E10.4,4(2X,E10.4)/' ',70('-'))
555 FORMAT(1X,' REFLECTION TOOK PLACE ',E12.5,' TIMES')
667 FORMAT(1X,10(E10.3))
777 FORMAT(//' GRAPHS '///' Energy distributions :  Energy(i-1) ',
   +'to E(i) -- Function(i)'/' Angular distributions:  Angle(i) ',
   +'to Angle(i+1) -- Function(i)')
851 FORMAT(/1X,' Alpha-particles :'/1X,'RR0=',F6.1,' M0=',F5.3,' N0=',
   +F5.3,' CLD=',F5.1,' CSD=',F5.3,' CSA=',F5.3,' SUM=',F5.3/1X,
   +' EPSD =',F7.1,' QBON(1,1,6)=',F7.1,' VAL=',F7.1/1X,F9.5,
   +' Production cross-sect for non-eq alphas [b] ',
   +'(CSnon-Barashenkov)'/1X,F9.5,' Total product cross-secti',
   +'on for alphas without Denisov-Mekhedov correction (CSnon-B)'
   +/1X,F9.5,' Total product cross-section for a-particles ',
   +' + D-M correction (CSnon-B)'//1X,'   Tritons    :'/1X,'RR0=',
   +F6.1,' M0=',F5.3,' N0=',F5.3,' CLD=',F5.1,' CSD=',F5.3,' CST=',
   +F5.3,' SUM=',F5.3/1X,' EPSD =',F7.1,' QBON(1,1,4)=',F7.1,' VT ='
   +,F7.1//1X,'   He-3       :'/1X,'RR0=',F6.1,' M0=',F5.3,' N0=',
   +F5.3,' CLD=',F5.1,' CSD=',F5.3,' CSH=',F5.3,' SUM=',F5.3/1X,
   +' EPSD =',F7.1,' QBON(1,1,5)=',F7.1,' VH =',F7.1)
852 FORMAT(1x,f8.2,3G12.5,2F6.1,'   T0, Alpha(mbarn):Pre, Pre+',
   +'Eq, Pre+Eq+Denisov')
887 FORMAT(1X,' DIMENSION FOR AT WAS EXCEEDED ',I8,' TIMES')
888 FORMAT(1X,' PAULI PRINCIPLE WAS APPLIED ',E12.5,' TIMES')
```

```
  889 FORMAT(1X,' REJECTED EVENTS ',I7,',MAXIMAL NUMBER OF',
     +' REFLECTIONS',F7.1)
 1100 FORMAT(1X,' Angular distributions have been calculated by ',
     * 'Kalbach, Mann formulas')
 1110 FORMAT(1X,' Coulomb potential for inverse reactions:  VP=0.1*',
     +'Z+0.8, VA=2.*VP')
 1120 FORMAT(1X,'INFDEN=',I3,' IMOM=',I3,' IBOND=',I3,' XPARDE =',F5.1,
     + ' INFDM=',I3)
 1200 FORMAT(1X,70('#')/1X,' Angular distributions have been calcul',
     + 'ated by Kalbach, Mann formulas'/1X,70('#'))
 3100 FORMAT(1X,F8.2,1X,A8,2X,4(2X,E10.4)/1X,2F4.0,1X,E10.4,4(2X,E10.4)
     +/1X,' NEUTRON PRODUCTION',4(2X,E10.4)/1X,'  PROTON PRODUCTION',
     +4(2X,E10.4)/1X,'   ALPHA PRODUCTION',4(2X,E10.4)
     +/1X,'     H-2 PRODUCTION',4(2X,E10.4)/1X,'     H-3 PRODUCTION',
     +4(2X,E10.4)/1X,'    HE-3 PRODUCTION',4(2X,E10.4)/' ',70('-'))
 5100 FORMAT(' ',70('-')/1X,'CR.SECT.',3X,'[BARNS]',5X,'BARASH   ',
     +'  GEOMETRY  ',' OPTIC(SCR) ',' CHATTERJEE'/1X,' CSNON  ',5X,
     +F3.1,3X,4(2X,E10.4)/1X,' CSDNON ',1X,E10.4,4(2X,E10.4)
     +/1X,' NEUTRON PRODUCTION',4(2X,E10.4)/1X,'  PROTON PRODUCTION',
     +4(2X,E10.4)/1X,'   ALPHA PRODUCTION',4(2X,E10.4)/1X,'     H-',
     +'2 PRODUCTION',4(2X,E10.4)/1X,'     H-3 PRODUCTION',4(2X,E10.4)
     +/1X,'    HE-3 PRODUCTION',4(2X,E10.4)/' ',70('-'))
 8890 FORMAT(1X,' PROBABILITY TO OVERLOAD ENERGY ( > 500 )',F6.0,' %')
 8888 FORMAT(1X,' CURRENT CHARGE WAS LOWER THAN ',
     +'PERMISSIBLE ',I8,' TIMES')
C T(X) is the sum for nucleons in X-process
19900 FORMAT(1X,65('-')/' Task'/1X,'Z= ',F6.1,' A= ',F6.1,' T0= ',
     +F6.1//' Average energy of excitation after cascade stage =',
     +f9.3,' MeV'/)
19901  FORMAT(1X,'Particle multiplicity:'/1X,
     + ' N(SUM) P(SUM) T(SUM) N(PRE) P(PRE) T(PRE) ',
     + 'N(EQU) P(EQU) T(EQU) A(PRE) A(SUM without D-M)'
     +  /1X,11F7.3)
19902 FORMAT(/34('='),'end',34('='))
      END
**********************************************************************
*                 SUBROUTINE OUTSEP                                  *
**********************************************************************
      SUBROUTINE OUTSEP(CSNON,RRR)
      REAL*8 ICS(4)
      COMMON/MAIIPR/IPR /IWRI/IWRI /INFSEP/KSEP(100,4),INFSEP,JSEPM
      COMMON/MPARIN/MPARIN /DATINI/RAAAAA,T0,W0
      COMMON/SEPSEP/RSEP2(100,2),JSEPM2 /INF/INFBIG,INFS0
      DIMENSION CSNON(4)
      DATA ICS/' BARASH ','GEOMETRY',' OPTIC  ','CHAT-JEE'/
      DATA RN,RP,RA/1HN,1HP,1HA/
      REASUM=RRR
C Define CSnon
           ICSN=INFS0
        WRITE(IPR,900)ICS(ICSN)
        IF(IWRI.NE.0)WRITE(IWRI,900)ICS(ICSN)
        RI=RN
        IF(MPARIN.EQ.2)RI=RP
        IF(MPARIN.EQ.3)RI=RA
C Cross-section in mb
      DO 100 J=1,JSEPM
      CS=1000.*FLOAT(KSEP(J,4))*CSNON(ICSN)/REASUM
      IF(INFSEP.EQ.1)
     CWRITE(IPR,1000)RI,KSEP(J,1),KSEP(J,2),KSEP(J,3),CS
```

```
      IF(IWRI.NE.0.AND.INFSEP.EQ.1)
     CWRITE(IWRI,1000)RI,KSEP(J,1),KSEP(J,2),KSEP(J,3),CS
      IF(INFSEP.EQ.2)
     CWRITE(IPR,2000)RI,KSEP(J,1),KSEP(J,2),KSEP(J,3),CS,RSEP2(J,1),
     C               RSEP2(J,2)
      IF(IWRI.NE.0.AND.INFSEP.EQ.2)
     CWRITE(IWRI,2000)RI,KSEP(J,1),KSEP(J,2),KSEP(J,3),CS,RSEP2(J,1),
     C               RSEP2(J,2)
 100  CONTINUE
 900  FORMAT(1X,'Cross-section for selected reactions (CSnon:',A8,')')
1000  FORMAT(1X,'( ',A1,',',I2,'n',I2,'p',I2,'a )',G12.5,' mb')
2000  FORMAT(1X,'( ',A1,',',I2,'n',I2,'p',I2,'a )',G12.5,' mb',
     C '   Residual  ',F6.1,F7.1)
      RETURN
      END
*********************************************************************
*                 SUBROUTINE OUTTMP                                 *
*********************************************************************
      SUBROUTINE OUTTMP
C Relative multiplicity of pre-equlibrium (cascade) particles
      REAL*8 R1(2)
      COMMON/MASOUT/WDIS(990),KPREN(990),KPREP(990),KEQD(990),KEQT(990)
     *,KEQHE(990),KEQAL(990),KSUMN(990),KSUMP(990),KREACT(990),
     * KPREA(990),KN /MAIIPR/IPR  /IWRI/IWRI
      DIMENSION TOT(4)
      DATA R1/'NEUTRONS',' PROTONS'/
      IF(IWRI.NE.0)WRITE(IWRI,1000)
      WRITE(IPR,1000)
                DO 18 I0=1,4
18              TOT(I0)=0.
      DO 400 J1=1,2
50       DO 100 I=1,KN
            RRR=FLOAT(KREACT(I))
         GOTO(81,82),J1
81          SUMX=FLOAT(KSUMN(I))
            PREX=FLOAT(KPREN(I))
            GOTO 90
82          SUMX=FLOAT(KSUMP(I))
            PREX=FLOAT(KPREP(I))
90    TOT(1)=TOT(1)+SUMX*RRR
         IF(PREX.EQ.0)GOTO 100
      TOT(2)=TOT(2)+RRR*PREX
      IF(PREX.GE.2.)TOT(3)=TOT(3)+RRR*(PREX-1.)
      IF(PREX.GE.3.)TOT(4)=TOT(4)+RRR*(PREX-2.)
100      CONTINUE
       PRETOT=100.*TOT(2)/TOT(1)
       PREGE2=100.*TOT(3)/TOT(1)
       PREGE3=100.*TOT(4)/TOT(1)
       IF(IWRI.NE.0)WRITE(IWRI,2000)R1(J1),PRETOT,PREGE2,PREGE3
400    WRITE(IPR,2000)R1(J1),PRETOT,PREGE2,PREGE3
1000   FORMAT(1X,'Multiplicity of precompound particles of this type ',
     * 'to'/1X,16X,'all partiles of this type in %'/1X,8X,
     * 7X,'TOTAL',14X,'>2',14X,'>3')
2000   FORMAT(1X,A8,3G16.2)
       RETURN
       END
*********************************************************************
*                 SUBROUTINE PAULI                                  *
*********************************************************************
```

```
      SUBROUTINE PAULI(TB1,TP1,IKS)
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/SCIMEM/WPM,PXM,PYM,PZM,PM,TM,EM,XM,YM,ZM,RM,JINM,MM
      COMMON/NDIM/NPAR  /MEMORY/U(11,20),MU(2,20)
      COMMON/ACTSCI/PIN1,PIN2,PIN3,WPX,RK3,RK4,GAMMA,SK2,VC2,VCX,
     *VCY,VCZ,MPX /DATPAU/BONCUT(3) /TFERMI/TF(34,4)
      COMMON/JACT/JACT /R005/R005 /TYPACT/L,L7
      DIMENSION TT(2)
      IF(TB1-TF(JIN,M))10,20,20
   10 IKS=1
      IF(L7.EQ.1) CALL MEMDEC(2)
      IF(IGEN.EQ.1)RETURN
      R005=R005+1.
      RETURN
   20 IF(TP1-TF(JIN,MPX))10,30,30
   30 TT(1)=TF(JIN,M)+BONCUT(M)
      TT(2)=TF(JIN,MPX)+BONCUT(MPX)
C
C
      IF(TB1.GT.TT(1))GOTO 50
C TB1 < TT(1)
            IF(M.EQ.2)              CALL PROZR(TB1,TT(1),JIN,KEY,M)
            IF(M.EQ.2.AND.KEY.EQ.1)   GOTO 50
      IF(TP1.GT.TT(2))GOTO 60
C TP1 < TT(2)
            IF(MPX.EQ.2)            CALL PROZR(TP1,TT(2),JIN,KEY,MPX)
            IF(MPX.EQ.2.AND.KEY.EQ.1) GOTO 60
           IGEN=2
           CALL CHECK1(1.,TB1,WP,IGEN,M)
           IF(IGEN.EQ.1)GOTO 10
           IGEN=2
           CALL CHECK1(-1.,TP1,WPX,IGEN,MPX)
           IF(IGEN.EQ.1)GOTO 10
33    IF(NPAR.GT.0)GOTO 40
      IKS=-1
      JACT=1
      RETURN
   40 IKS=0
      RETURN
   50 IF(TP1.GT.TT(2))GOTO 70
C TP1 < TT(2)
            IF(MPX.EQ.2)              CALL PROZR(TP1,TT(2),JIN,KEY,MPX)
            IF(MPX.EQ.2.AND.KEY.EQ.1) GOTO 70
           IGEN=2
           CALL CHECK1(-1.,TP1,WPX,IGEN,MPX)
           IF(IGEN.EQ.1)GOTO 10
      IGEN=2
      CALL SCILSK(0,1.,TB1,WP,IGEN,M)
      IF(IGEN.EQ.1)GOTO 10
      IKS=3
      JACT=1
      RETURN
   60      IGEN=2
           CALL CHECK1(1.,TB1,WP,IGEN,M)
           IF(IGEN.EQ.1)GOTO 10
      IGEN=2
      CALL SCILSK(0,-1.,TP1,WPX,IGEN,MPX)
      IF(IGEN.EQ.1)GOTO 10
      IKS=3
```

```
      JACT=1
      RETURN
   70      IGEN=2
           CALL CHECK1(-1.,TP1,WPX,IGEN,MPX)
           IF(IGEN.EQ.1)GOTO 10
      IGEN=2
      CALL SCILSK(0,1.,TB1,WP,IGEN,M)
      IF(IGEN.EQ.1)GOTO 10
      IGEN=2
      CALL SCILSK(1,-1.,TP1,WPX,IGEN,MPX)
      IF(IGEN.EQ.1)GOTO 10
      CALL MEMIN
      IKS=3
      JACT=1
      RETURN
      END
*********************************************************************
*                 SUBROUTINE PICKUP                                 *
*********************************************************************
      SUBROUTINE PICKUP(IKS)
C Energy conservation
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/PARTNR/PPX,PPY,PPZ,PP,MX
      COMMON/NDIM/NPAR
      COMMON/DATPAU/BONCUT(3)
      COMMON/TFERMI/TF(34,4)
      COMMON/JACT/JACT
      COMMON/R005/R005
      DIMENSION TT(2)
C
      T2 = (PP**2)/(2.*WM(MX))
C
C Alpha-particle characteristics
      WP1 = WM(3)
      M1 = 3
C Auxiliary values
         PX11 = PX + PPX
         PY11 = PY + PPY
         PZ11 = PZ + PPZ
         P11 =  SQRT(PX11**2+PY11**2+PZ11**2)
      T1  = T + T2
      P1  = SQRT(T1**2+2.*WP1*T1)
      PX1 = PX11*(P1/P11)
      PY1 = PY11*(P1/P11)
      PZ1 = PZ11*(P1/P11)
      E1=T1+WP1
C
      TB1 = T1
      IF(TB1-TF(JIN,M1))10,20,20
   10 IKS=1
      RETURN
   20 TT(1)=TF(JIN,M1)+BONCUT(M1)
      IF(TB1.GT.TT(1))GOTO 50
C TB1 < TT(1)
      IF(NPAR.GT.0)GOTO 40
      IKS=-1
      JACT=1
      RETURN
   40 IKS=0
```

```
      RETURN
   50 CONTINUE
C Prohibition on angular momentum
           IGEN=2
      RORM=ORBIT(PX1,PY1,PZ1,X,Y,Z)
      CALL QUES(RORM,T1,WP1,JIN,M1,IGEN)
           IF(IGEN.EQ.1)GOTO 10
C Creation of alpha-particle
      WP = WP1
      PX = PX1
      PY = PY1
      PZ = PZ1
      P  = P1
      T  = T1
      E  = E1
      M  = M1
      IKS=3
      JACT=1
      RETURN
      END
*********************************************************************
*                 SUBROUTINE PPDRAW                                 *
*********************************************************************
      SUBROUTINE PPDRAW(QCOS,FI)
      COMMON/URAND1/IYG
      CC=RANDOM(0)
      QCOS=1.-2.*CC
      CC=RANDOM(0)
      FI=6.2831852*CC
      RETURN
      END
*********************************************************************
*                 SUBROUTINE PRECAM                                 *
*********************************************************************
      SUBROUTINE PRECAM
C Binding energy according to Cameron (Barashenkov, Tonnev, 1972,
C pp.418-419)
       COMMON/AN/AN /BOND1/QBON(200,200,6)
       COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
       COMMON/MPARIN/MPARIN /INFBON/IBOND
       COMMON/DATCAM/CAMN(130),CAMP(130),MAXN,MAXP
       COMMON/MAIIPR/IPR /MAX/MAXNEU,MAXPRO
       REAL*8 RMAS(6),RAT,IP90(6)
       DIMENSION ATO(200,200),RMASM(6),NN(6),NP(6)
       DATA RMAS/ 0.008 665 27, 0.007 825 22, 0.014 102 22,
     c 0.016 049 71, 0.016 029 68, 0.002 603 3/
       DATA RAT/931.5016/
C RMAS is mass defect in at. units
C
C RMAS:  1     2     3     4     5     6
C--------N-----P-----D-----T---HE-3----A--  particle
C  J     1     2     3     4     5     6
C-----------------------------------------
C  NN    1     0     1     2     1     2
C  NP    0     1     1     1     2     2
C-----------------------------------------
      DATA NN/ 1, 0, 1, 2, 1, 2/,NP/ 0, 3*1, 2*2/
      DATA IP90/8H NEUTRON,8H  PROTON,8HDEUTERON,8H  TRITON,8H    HE-3,
     c8H   ALPHA/
```

```
C
C MAXN/MAXP is the dimension of CAMN/CAMP array (see corresp BLOCK DATA),
C which is equal to maximal permissible number of neutrons/prootons in
C target nucleus
C
C MAXNEU and MAXPRO are dimensions of QBON array
      MAXN=130
      MAXP=130
C L11N/L11P is minimal number of neutrons/protons in nucleus, for which
C corrections to Cameron formula are available
        L11N=1
        L11P=1
        IF(MAXN.LT.200.AND.MAXP.LT.200)GOTO 7
        WRITE(IPR,700)MAXN,MAXP
        STOP
7         IZNUCL=Z
          INNUCL=AN-Z
      IF(MPARIN.EQ.1)INNUCL=INNUCL+1
      IF(MPARIN.EQ.2)IZNUCL=IZNUCL+1
           IF(MPARIN.EQ.3)INNUCL=INNUCL+2
           IF(MPARIN.EQ.3)IZNUCL=IZNUCL+2
         IF(INNUCL.LE.MAXN)GOTO 10
         WRITE(IPR,800)INNUCL,MAXN
      STOP
10       IF(IZNUCL.LE.MAXP)GOTO 20
         WRITE(IPR,900)IZNUCL,MAXP
         STOP
C  INNUCL-L11N is the number of neutrons emitted, +1 : array dimension
C  ATO is more than this amount on 1,i.e. ATO(1,1) means 0 emitted
20      DO 80 I=L11N,INNUCL
        RN=FLOAT(I)
            DO 70 J=L11P,IZNUCL
            RZ=FLOAT(J)
            INN1=INNUCL-I+1
            IZN1=IZNUCL-J+1
            IF(INN1.LE.200.AND.IZN1.LE.200)GOTO 65
            WRITE(IPR,1000)INN1,IZN1
              STOP
65          ATO(INN1,IZN1)=CAMERO(RN,RZ)+CAMN(I)+CAMP(J)
70          CONTINUE
80       CONTINUE
            LMAXN=(INNUCL-L11N+1)-2
            LMAXP=(IZNUCL-L11P+1)-2
       MAXNEU=LMAXN
       MAXPRO=LMAXP
          IF(LMAXN.GT.5.AND.LMAXP.GT.5)GOTO 90
          WRITE(IPR,1100)LMAXN,LMAXP
              STOP
90        DO 92 I=1,6
92        RMASM(I)=RAT*RMAS(I)
            DO 200 IN=1,LMAXN
            DO 100 IZ=1,LMAXP
               AT1=ATO(IN,IZ)
            DO 95 NUCL=1,6
               AT2=ATO(IN+NN(NUCL),IZ+NP(NUCL))
95             QBON(IN,IZ,NUCL)=AT2+RMASM(NUCL)-AT1
100         CONTINUE
200         CONTINUE
            IF(IBOND.GT.0)RETURN
```

```
C TEST
            IF(IBOND.EQ.-3)RETURN
          WRITE(1,499)
          WRITE(6,499)
          WRITE(8,499)
            INM=MIN0(12,MAXNEU)
            IZM=MIN0(12,MAXPRO)
          DO 300 NUCL=1,6
            WRITE(1,500)IP90(NUCL)
            WRITE(6,500)IP90(NUCL)
            WRITE(8,500)IP90(NUCL)
          DO 300 IZ=1,IZM
            WRITE(1,600)IZ,(QBON(IN,IZ,NUCL),IN=1,INM)
            WRITE(6,600)IZ,(QBON(IN,IZ,NUCL),IN=1,INM)
300         WRITE(8,600)IZ,(QBON(IN,IZ,NUCL),IN=1,INM)
            STOP
499   FORMAT(1X,'TEST FOR BINDING ENERGIES'/
     c       1X,'CAMERON FORMULAS FOR ALL NUCLIDES'/1X,72(1H-))
500   FORMAT(/1X,A8/1X,'IZ   IN-----> NEUTRON NUMBER DECREASED')
600   FORMAT(1X,I2,12F6.1)
700   FORMAT(1X,'ERROR IN PRECAM: DIMENSION OF QBON, ATO, CAMN/CAMP',
     c' ARE NOT CONSISTENT. CHANGE QBON AND ATO DIMENSIONS IN ALL CODE')
800   FORMAT(1X,'ERROR IN PRECAM: PERMISSIBLE AMOUNT IS EXCEEDED FOR:'/
     c1X,5X,I5,' > ',I5/
     c1X,'NEUTRONS IN TARGET NUCLEUS. ADD NEW CAMN AND CAMP DATA (SEE'/
     c1X,'CORRESPONDING BLOCK DATA) AND CHANGE DIMENSION OF THESE '/
     c1X,'ARRAYS IN ALL CODE AND MAXN AND MAXP VALUES IN PRECAM (!)')
900   FORMAT(1X,'ERROR IN PRECAM: PERMISSIBLE AMOUNT IS EXCEEDED FOR:'/
     c1X,5X,I5,' > ',I5/
     c1X,'PROTONS IN TARGET NUCLEUS. ADD NEW CAMN AND CAMP DATA (SEE'/
     c1X,'CORRESPONDING BLOCK DATA) AND CHANGE DIMENSION OF THESE '/
     c1X,'ARRAYS IN ALL CODE AND MAXN AND MAXP VALUES IN PRECAM  (!)')
1000  FORMAT(1X,'ERROR IN PRECAM: DIMENSION OF ARRAY EXCEEDED    '/1X,
     c' ATO  INNUCL-I+1=',I5,' > 200  ^  IZNUCL-J+1=',I5,' > 200')
1100  FORMAT(/1X,'****** SUBROUTINE PRECAM *******'/1X,' TOO SMALL',
     c' NUMBER OF CASCADES WILL BE SIMULATED  ',I5,' AND ',I5//
     c' CALL AUTHORS OF DISCA  (AND LOOK IN THEIR EYES).'//)
      END
**********************************************************************
*                SUBROUTINE PRELYM                                   *
**********************************************************************
      SUBROUTINE PRELYM
C CALCULATION OF BINDING ENERGIES USING MASS TABLE AND MSL-FORMULA
C FOR NEUTRONS, PROTONS, DEUTERONS AND ALPHA-PARTICLES FOR RESIDUAL
C NUCLEI FORMED AFTER ESCAPE OF NOT MORE THAN 9 PROTONS AND 22 NEUTRONS.
C FOR OTHER NUCLEI THE CALCUALTION IS PERFORMD USING CAMERON FORMULA
C (SEE SUBR.PRECAM)
      COMMON/AN/AN /BOND1/QBON(200,200,6)
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
      COMMON/MPARIN/MPARIN /MAIIPR/IPR
      COMMON/MAX/MAXNEU,MAXPRO /INFBON/IBOND
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24)
      COMMON/SF/M3,KPLT /LYM2/ILYM
      COMMON/LYM3/PAIRP(11,24),PAIRE(11,24),ILYM2
      REAL*8 IP90(6)
      DATA IP90/8H NEUTRON,8H  PROTON,8HDEUTERON,8H  TRITON,8H    HE-3,
     c8H   ALPHA/
            NZ=MIN0(9,MAXPRO)
            NA=MIN0(22,MAXNEU)
```

```
        AT=AN
        ZT=Z
          AP=1.
          ZP=0.
            IF(MPARIN.EQ.2)ZP=1.
            IF(MPARIN.EQ.3)THEN
                           ZP=2.
                           AP=4.
                           ENDIF
      ZEE=ZP+ZT
      AMASS=AP+AT
           MC=10
           MP=3
           QVAL=0.
      ILYM=0
      ILYM2=0
      KPLT=0
      M3=4
      CALL LYMASS(ZEE,AMASS,NZ,NA,MC,MP,AP,AT,ZP,ZT,QVAL)
C  BE(11,24,K)   K=1-N, 2-P, 3-A, 4-D
      DO 200 NUCL=1,6
          IF(NUCL.EQ.1.OR.NUCL.EQ.2)KPART=NUCL
          IF(NUCL.EQ.3)KPART=4
          IF(NUCL.EQ.4.OR.NUCL.EQ.5)GOTO 200
          IF(NUCL.EQ.6)KPART=3
      DO 100 IZ=1,NZ
      DO 100 IN=1,NA
100       QBON(IN,IZ,NUCL)=BE(IZ,IN,KPART)
200   CONTINUE
      IF(IBOND.GT.0)RETURN
C TEST
         WRITE(1,499)NZ,NA
         WRITE(6,499)NZ,NA
         WRITE(8,499)NZ,NA
           INM=MIN0(12,MAXNEU)
           IZM=MIN0(12,MAXPRO)
         DO 300 NUCL=1,6
           WRITE(1,500)IP90(NUCL)
           WRITE(6,500)IP90(NUCL)
           WRITE(8,500)IP90(NUCL)
         DO 300 IZ=1,IZM
           WRITE(1,600)IZ,(QBON(IN,IZ,NUCL),IN=1,INM)
           WRITE(6,600)IZ,(QBON(IN,IZ,NUCL),IN=1,INM)
300        WRITE(8,600)IZ,(QBON(IN,IZ,NUCL),IN=1,INM)
           STOP
499   FORMAT(1X,'TEST FOR BINDING ENERGIES'/
     c1X,'M.BLANN CALCULATION FOR NZ=',I4,' NA=',I4
     c/1X,'OTHER NUCLIDES ARE OBTAINED BY CAMERON FORMULAS'
     c/1X,72(1H-))
500   FORMAT(/1X,A8/1X,'IZ   IN-----> NEUTRON NUMBER DECREASED')
600   FORMAT(1X,I2,12F6.1)
      END
**********************************************************************
*                 SUBROUTINE PRIREC                                  *
**********************************************************************
      SUBROUTINE PRIREC(SGX0)
* Printing of reacoil spectra in separate file
      COMMON/EMEM91/EMEMT(21),RMEMT(21),HMEMT
      COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
```

```
      COMMON/AN/AN /DATINI/RA,T0,W0 /MAIIPR/IPR
      DIMENSION EKE(21)
C --> mb
      SGX1=SGX0*1000.
               SUM = 0.0
               EKE(1) = EMEMT(1)
               DO 122 NU=2,21
122            EKE(NU)=(  EMEMT(NU-1) + EMEMT(NU)  ) / 2.
      RMEMT(1)=RMEMT(1)*SGX1/HMEMT
      DO 121 NU=2,21
      RMEMT(NU)=RMEMT(NU)*SGX1/(EMEMT(NU)-EMEMT(NU-1))
121            SUM=SUM+RMEMT(NU)
               SUM=SUM*HMEMT
      WRITE(IPR,22200)
22200 FORMAT(/1X,'RECOIL SPECTRUM (LINEAR SCALE) ')
      CALL GRAPH(EKE,RMEMT,21,0)
      Write(33,2000)T0,SUM,Z,AN
2000  Format(f6.1,e12.5,t40,
     c  'NEUTRON ENERGY AND SUM OF RECOIL SPECTRUM FOR TARGET ',2f6.1)
* Attention ! Last energy is not treated
                     MMAX = 21
         Write(33,2010)MMAX
2010     Format(i7,t40,'NUMBER OF KE INTERVALS FOR SPECTRUM')
         Write(33,2011)(EKE(I),I=1,MMAX)
2011     Format(10f7.3)
         Write(33,2012)(RMEMT(I),I=1,MMAX)
2012     Format(1pe10.3,7e10.3)
       RETURN
       END
**********************************************************************
*                 SUBROUTINE PRISPE                                  *
**********************************************************************
      SUBROUTINE PRISPE(SGX0,MP)
      COMMON/DATINI/RA,T0,W0
      COMMON/EMEM/EMEM0(21),EMEM(21),RMEM(21,3),RMEM0(21,3),HMEM
      COMMON/EOUT/SPE(19,5,3),PI(19),EOUT1(5,3),EOUT2(5,3),MSPE
      COMMON/MAIIPR/IPR /MPARIN/MPARIN /AN/AN
      COMMON/SPEFUL/ANGLIM(9,2,3),ANGSUM(21,9,3),ANGCEN(9,3),DCEN,MANG
      REAL*8 ITYP(3)
      DIMENSION ANGTMP(21), GR1(19), XSTE(150),YSTE(150),PRITMP(150,23)
C dimension of EOUT1,2(I,) = EMEAN
      DIMENSION RTMP(21),EMEAN(5)
C IU is unit for printing (see open in main routine)
      IU = 70 + MP
C PRITMP is array for histogram presentation
          DATA ITYP/' NEUTRON','  PROTON','   ALPHA'/
               DO 1 I=1,150
               XSTE(I)=0.0
               YSTE(I)=0.0
               DO 1 J=1,23
1              PRITMP(I,J)=0.0
      IF(MP.NE.3) WRITE(IPR,221)ITYP(MP)
      IF(MP.EQ.3) WRITE(IPR,222)
C---------------------------------------------------------------------
C Energy distribution
       SS1=0.
       SSS=0.
C --> mb
        SGX1=SGX0*1000.
```

```
      DO 121 NU=1,21
        SSS=SSS+RMEM0(NU,MP)
        RMEM0(NU,MP)=RMEM0(NU,MP)*SGX1/HMEM
        RMEM(NU,MP)=RMEM(NU,MP)*SGX1/HMEM
        SS1=SS1+RMEM0(NU,MP)+RMEM(NU,MP)
121     CONTINUE
      WRITE(IPR,220)
220   FORMAT(/1X,'NON-EQUILIBRIUM SPECTRUM DS/DE ------------->')
             DO 700 NU=1,21
700          RTMP(NU) = RMEM0(NU,MP)
             CALL GRAPH(EMEM0,RTMP,21,2)
             DO 1700 NU=1,21
             If(RTMP(NU).eq.0.0) RTMP(NU) = 1.E-13
1700         Continue
        SSS=SGX1*SSS
        WRITE(IPR,670)SSS
670     FORMAT(1X,'C“MMA ',G12.5)
C NSTE is the number of points obtained < 150
        CALL STEP93(EMEM0,RTMP,21,XSTE,YSTE,150,NSTE,1)
        DO 2 I=1,NSTE
        PRITMP(I,1) = XSTE(I)
2       PRITMP(I,2) = YSTE(I)
             DO 701 NU=1,21
701          RTMP(NU) = RMEM(NU,MP)
      WRITE(IPR,2210)
2210  FORMAT(/1X,'EQUILIBRIUM SPECTRUM DS/DE ------------->')
      CALL GRAPH(EMEM,RTMP,21,2)
             DO 1701 NU=1,21
             If(RTMP(NU).eq.0.0) RTMP(NU) = 1.E-13
1701         Continue
        CALL STEP93(EMEM ,RTMP ,21,XSTE,YSTE,150,NSTE,1)
        DO 3 I=1,NSTE
3       PRITMP(I,3) = YSTE(I)
        DO 987 NU=1,21
987     RMEM0(NU,MP)=RMEM0(NU,MP)+RMEM(NU,MP)
             DO 702 NU=1,21
702          RTMP(NU) = RMEM0(NU,MP)
C
C Total spectrum
      IF(MP.NE.3) WRITE(IPR,22100)ITYP(MP)
22100 FORMAT(/1X,'TOTAL SPECTRUM - "',A8,' PRODUCTION"')
      IF(MP.EQ.3) WRITE(IPR,22101)
22101 FORMAT(/1X,'TOTAL SPECTRUM - ALPHA PRODUCTION"')
            CALL GRAPH(EMEM0,RTMP,21,2)
             DO 1702 NU=1,21
             If(RTMP(NU).eq.0.0) RTMP(NU) = 1.E-13
1702         Continue
        CALL STEP93(EMEM0,RTMP,21,XSTE,YSTE,150,NSTE,1)
        DO 4 I=1,NSTE
4       PRITMP(I,4) = YSTE(I)
C
C---------------------------------------------------------------------
C Inclusive spectra :
      DO 1000 ICEN=1,MANG
      WRITE(IPR,888)ITYP(MP),ANGCEN(ICEN,MP),DCEN
           PI180=3.1415926/180.
      PPP0=DCEN
      QAN1 = ANGCEN(ICEN,MP)-DCEN
      IF(QAN1.LT.0.0) PPP0= ANGCEN(ICEN,MP)
```

```
      QAN1 = ANGCEN(ICEN,MP)+DCEN
      IF(QAN1.GT.180.0) PPP0= 180.0-ANGCEN(ICEN,MP)
      PPP0=PPP0+DCEN
           PPP= PPP0*(3.1415/180.)*2.*3.1415
           ANG=PI180*ANGCEN(ICEN,MP)
      DO 322 NU=1,21
322   ANGTMP(NU)=0.0
      DO 323 NU=1,21
        ANGTMP(NU)     =ANGSUM(NU,ICEN,MP)*SGX1/HMEM
323     ANGTMP(NU)     =ANGTMP(NU)     /(PPP*SIN(ANG) )
      CALL GRAPH(EMEM0,ANGTMP,21,2)
             DO 1323 NU=1,21
             If(ANGTMP(NU).eq.0.0) ANGTMP(NU) = 1.E-13
1323         Continue
        CALL STEP93(EMEM0,ANGTMP,21,XSTE,YSTE,150,NSTE,1)
        DO 5 I=1,NSTE
5       PRITMP(I,4+ICEN) = YSTE(I)
1000    CONTINUE
C
      DO 2000 L=1,MSPE
C-----------------------------------------------------------------------
C Total angular distribution
      WRITE(IPR,777)EOUT1(L,MP),EOUT2(L,MP)
      EOUEOU=1./(EOUT2(L,MP)-EOUT1(L,MP))
      GR1(1)=0.
      DO 97 NANG=2,19
   97 GR1(NANG)=GR1(NANG-1)+10.
      PI180=3.1415926/18.
        PPP=(3.1415/18.)*2.*3.1415
      SPE(19,L,MP)=0.
      ANG=0.
      DO 99 NANG=1,18
      ANG=ANG+PI180
      ANG2=ANG - 5.*3.1415926/180.
   99   SPE(NANG,L,MP)=SGX1*SPE(NANG,L,MP)*EOUEOU/(PPP*SIN(ANG2))
           DO 703 NANG=1,19
703        RTMP(NANG) = SPE(NANG,L,MP)
           CALL GRAPH(GR1,RTMP,19,2)
               DO 1703 NU=1,21
               If(RTMP(NU).eq.0.0) RTMP(NU) = 1.E-13
1703           Continue
        CALL STEP93(GR1  ,RTMP  ,19,XSTE,YSTE,150,NSTE1,2)
        DO 6 I=1,NSTE1
        IF(L.EQ.1) PRITMP(I,13+L) = XSTE(I)
6       PRITMP(I,14+L) = YSTE(I)
2000  CONTINUE
C-----------------------------------------------------------------------
        DO 49 I=1,5
49      EMEAN(I) = 0.5*(EOUT1(I,MP)+EOUT2(I,MP))
C
C PRITMP printing
      WRITE(IU,7001)T0
7001  Format(1X,'" T0=',f7.1,' "')
      WRITE(IU,7000)(ANGCEN(I,MP),I=1,9),(EMEAN(II),II=1,5)
7000  FORMAT(1X,5X,'"E"',6X,'"NEQ"',5X,'"EQ"',6X,'"TOT"'1X,
     # 9(2X,'"',F5.1,'ø"'), 2X,'" TETA "',  5(2X,'"',F6.1,'"'))
      DO 50 I=1,NSTE
      IF(I.GT.20)WRITE(IU,5000)(PRITMP(I,NN),NN=1,19)
5000  FORMAT(1X,1PE10.2,18E10.2)
```

```
      IF(I.EQ.1)WRITE(IU,5001)(PRITMP(I,NN),NN=1,19),ITYP(MP)
5001  FORMAT(1X,1PE10.2,18E10.2,'   EMITTED PARTICLE: ',A8)
      IF(I.EQ.2)WRITE(IU,5002)(PRITMP(I,NN),NN=1,19)
5002  FORMAT(1X,1PE10.2,18E10.2,'  "A": ENERGY FOR COLUMNS "B"-"M" ')
      IF(I.EQ.3)WRITE(IU,5003)(PRITMP(I,NN),NN=1,19)
5003  FORMAT(1X,1PE10.2,18E10.2,'  "B":DS/DE(PRE), "C":(EQ), "D":(TOT)')
      IF(I.EQ.4)WRITE(IU,5004)(PRITMP(I,NN),NN=1,19)
5004  FORMAT(1X,1PE10.2,18E10.2,'  "E"-"M": D2S/DExDO')
      IF(I.EQ.5)WRITE(IU,5005)(PRITMP(I,NN),NN=1,19),ANGCEN(1,MP)
5005  FORMAT(1X,1PE10.2,18E10.2,'  "E":',0PF6.1)
      IF(I.EQ.6)WRITE(IU,5006)(PRITMP(I,NN),NN=1,19),ANGCEN(2,MP)
5006  FORMAT(1X,1PE10.2,18E10.2,'  "F":',0PF6.1)
      IF(I.EQ.7)WRITE(IU,5007)(PRITMP(I,NN),NN=1,19),ANGCEN(3,MP)
5007  FORMAT(1X,1PE10.2,18E10.2,'  "G":',0PF6.1)
      IF(I.EQ.8)WRITE(IU,5008)(PRITMP(I,NN),NN=1,19),ANGCEN(4,MP)
5008  FORMAT(1X,1PE10.2,18E10.2,'  "H":',0PF6.1)
      IF(I.EQ.9)WRITE(IU,5009)(PRITMP(I,NN),NN=1,19),ANGCEN(5,MP)
5009  FORMAT(1X,1PE10.2,18E10.2,'  "I":',0PF6.1)
      IF(I.EQ.10)WRITE(IU,5010)(PRITMP(I,NN),NN=1,19),ANGCEN(6,MP)
5010  FORMAT(1X,1PE10.2,18E10.2,'  "J":',0PF6.1)
      IF(I.EQ.11)WRITE(IU,5011)(PRITMP(I,NN),NN=1,19),ANGCEN(7,MP)
5011  FORMAT(1X,1PE10.2,18E10.2,'  "K":',0PF6.1)
      IF(I.EQ.12)WRITE(IU,5012)(PRITMP(I,NN),NN=1,19),ANGCEN(8,MP)
5012  FORMAT(1X,1PE10.2,18E10.2,'  "L":',0PF6.1)
      IF(I.EQ.13)WRITE(IU,5013)(PRITMP(I,NN),NN=1,19),ANGCEN(9,MP)
5013  FORMAT(1X,1PE10.2,18E10.2,'  "M":',0PF6.1)
      IF(I.EQ.14)WRITE(IU,5014)(PRITMP(I,NN),NN=1,19)
5014  FORMAT(1X,1PE10.2,18E10.2,'  "N"-"S": D2S/DExDO FOR E1-E2')
      IF(I.EQ.15)WRITE(IU,5015)(PRITMP(I,NN),NN=1,19)
5015  FORMAT(1X,1PE10.2,18E10.2,'  "N":  ANGLES FOR COLUMNS "O"-"S" ')
      IF(I.EQ.16)WRITE(IU,5016)(PRITMP(I,NN),NN=1,19),EOUT1(1,MP),
     +                         EOUT2(1,MP)
5016  FORMAT(1X,1PE10.2,18E10.2,'  "O":',0PF7.1,'-',F7.1,' ŒEV')
      IF(I.EQ.17)WRITE(IU,5017)(PRITMP(I,NN),NN=1,19),EOUT1(2,MP),
     +                         EOUT2(2,MP)
5017  FORMAT(1X,1PE10.2,18E10.2,'  "P":',0PF7.1,'-',F7.1,' MEV')
      IF(I.EQ.18)WRITE(IU,5018)(PRITMP(I,NN),NN=1,19),EOUT1(3,MP),
     +                         EOUT2(3,MP)
5018  FORMAT(1X,1PE10.2,18E10.2,'  "Q":',0PF7.1,'-',F7.1,' MEV')
      IF(I.EQ.19)WRITE(IU,5019)(PRITMP(I,NN),NN=1,19),EOUT1(4,MP),
     +                         EOUT2(4,MP)
5019  FORMAT(1X,1PE10.2,18E10.2,'  "R":',0PF7.1,'-',F7.1,' MEV')
      IF(I.EQ.20)WRITE(IU,5020)(PRITMP(I,NN),NN=1,19),EOUT1(5,MP),
     +                         EOUT2(5,MP)
5020  FORMAT(1X,1PE10.2,18E10.2,'  "S":',0PF7.1,'-',F7.1,' MEV')
50    CONTINUE
C
C*********************************************************************
  221 FORMAT(/72('=')/1X,10X,'EMISSION SPECTRA FOR  ',A8,
     +'S   (MB/MEV...)')
  222 FORMAT(/72('=')/1X,10X,'EMISSION SPECTRA FOR ALPHA-PARTICLE',
     +'S (MB/MEV...)')
  777 FORMAT(/1X,10X,'TOTAL ANGULAR DISTRIBUTION FOR ENERGY RANGE:'/1X,
     +2X,'EOUT1=',F6.1,2X,'EOUT2=',F6.1)
  888 FORMAT(/1X,A8,':  ','INCLUSIVE SPECTRUM FOR ANGLE ',
     +F6.1,'  +/- ',F6.1)
      RETURN
      END
*********************************************************************
```

```
*               SUBROUTINE PROZR                                        *
**********************************************************************
      SUBROUTINE PROZR(TP,TT,JIN,KEY,M)
C Sub-barrier proton penetration
      COMMON/DAINT/PF(33,4),RO1(33),RZON(33),FIG
      COMMON/TFERMI/TF(34,4) /RNUCL/RNUCL /K/KF
      COMMON/URAND1/IYG
      KEY=0
      T=TP-TF(JIN,M)+TF(KF+1,M)
      IF(T.LE.0.)RETURN
      B=TT-TF(JIN,M)+TF(KF+1,M)
      STB=SQRT(T/B)
         GAMMA = ( ACOS(STB)/STB ) - SQRT(1.-T/B)
         G = -2.*RNUCL/(4.5/SQRT(B))
      D=EXP(G*GAMMA)
      O=RANDOM(0)
      IF(O.LE.D) KEY=1
      RETURN
      END
**********************************************************************
*                SUBROUTINE QBOND                                     *
**********************************************************************
       SUBROUTINE QBOND(EXCIT,WIDTH,TAUX,KEY)
       DOUBLE PRECISION UCLA,RELX
       COMMON/BOND1/QBON(200,200,6)
       COMMON/EVAMAS/NEVAN,NEVAP,NEVAD,NEVAT,NEVAHE,NEVAAL
       COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
       COMMON/INIQBO/Z,CKA,CKB,RPA,RPB,RALA,RALB
       COMMON/I1988/I1988 /QBOCFU/NSUMN,NSUMP
       COMMON/MAX/MAXNEU,MAXPRO /AN/AN
       COMMON/LAB4/UCLA(6,2000) /INCR/ED
       DIMENSION RELX(6),WIDTH(6),TAUX(6)
       KEY=0
       NSUMN=1+NPREN+NEVAN+NEVAD+2*NEVAT+NEVAHE+2*(NEVAAL+NPREA)
       NSUMP=1+NPREP+NEVAP+NEVAD+NEVAT+2*NEVAHE+2*(NEVAAL+NPREA)
       IF(NSUMN.GT.MAXNEU.OR.NSUMP.GT.MAXPRO)GOTO 100
C
C 1-N, 2-P, 3-D, 4-T, 5-HE3, 6-A
C  QN =QBON( , ,1)   QP=QBON( , ,2)   QD=QBON( , ,3)
C  QT =QBON( , ,4)   QHE=QBON( , ,5)  QAL=QBON( , ,6)
C
        DO 1 K = 1,6
        RELX(K) = 0.0
        TAUX(K) = EXCIT - QBON(NSUMN,NSUMP,K)
        IX   =INT(TAUX(K)/ED+1.)
C to avoid overloading
        IF(IX.gt.2000) IX = 2000
        IF(IX.lt.1) goto 1
        RELX(K) = UCLA(K,IX)
    1   CONTINUE
        DO 2 K=2,6
    2   RELX(K) = RELX(K-1)+RELX(K)
        IF(RELX(6).eq.0.D+00) RETURN
        KEY = 1
C normalize on 1
        DO 3 K=1,6
C "+1.E-04" is to avoid cycling
    3   WIDTH(K) = (RELX(K)/RELX(6)) + 1.D-04
        RETURN
```

```
  100   I1988=I1988+1
        RETURN
        END
*********************************************************************
*                 SUBROUTINE QUES                                   *
*********************************************************************
      SUBROUTINE QUES(RORM,T,W,JIN,M,IGEN)
      COMMON/TFERMI/TF(34,4) /RNUCL/RNUCL  COMMON/R001/R001
      COMMON/MASTR1/WN(21,21) /DATINI/RA,T0,W0
      COMMON/DAINT/PF(33,4),RO1(33),RZON(33),FIG
      COMMON/DATTR1/QNN,QPP /MPARIN/MPARIN/K/KF
C                            no check ?
                  IF(M.EQ.3) goto 3
C Asymptotic energy must be lower than EMAX
                  TA=T+TF(KF+1,M)-TF(JIN,M)
      IF(M.EQ.1.AND.MPARIN.EQ.1) EMAX = T0
      IF(M.EQ.1.AND.MPARIN.EQ.2) EMAX = T0 + QPP - QNN
      IF(M.EQ.2.AND.MPARIN.EQ.1) EMAX = T0 + QNN - QPP
      IF(M.EQ.2.AND.MPARIN.EQ.2) EMAX = T0
         IF(TA.LE.EMAX) GOTO 3
         IGEN=1
         RETURN
3     TX=T-TF(JIN,M)+TF(JIN+1,M)
         IF(TX.LT.0.0    ) RETURN
      PX=SQRT(TX*(TX+2.*W))
         IF(RORM.GT.(PX*RZON(JIN)) )IGEN=1
      IF(IGEN.EQ.1)R001=R001+1.
      RETURN
      END
*********************************************************************
*                 FUNCTION RANDOM                                   *
*********************************************************************
       FUNCTION RANDOM(NO ARGUMENTS)
*
* random number generator
*
**** GNU Fortran pseudo random generator:
****
****
****      RANDOM=RAND(0)
**
**
** WATCOM Fortram pseudo random number generator
** generator is initialized in Subroutine OPTIONS
**
      Common/urand1/iyg
      RANDOM=URAND(iyg)
**
      Return
      End
*********************************************************************
*               SUBROUTINE REGR1                                    *
*********************************************************************
       SUBROUTINE REGR1(X1,X2,Y1,Y2,A,B)
       RR=X2-X1
       A=(Y2-Y1)/RR
       B=(Y1*X2-X1*Y2)/RR
       RETURN
       END
```

```
************************************************************************
*                  SUBROUTINE SCILSK                                   *
************************************************************************
      SUBROUTINE SCILSK(I,G,T1,W1,IGEN,M1)
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/ACTSCI/PIN1,PIN2,PIN3,WPX,RK3,RK4,GAMMA,SK2,VC2,VCX,
     +VCY,VCZ,MPX
      COMMON/SCIMEM/WPM,PXM,PYM,PZM,PM,TM,EM,XM,YM,ZM,RM,JINM,MM
      COMMON/IMOM/IMOM
      IF(G)1,1,2
    1 RK=RK4-(GAMMA-1.)*SK2/VC2
      GOTO 3
    2 RK=RK3+(GAMMA-1.)*SK2/VC2
    3 IF(I)4,4,50
    4 PX5=G*PIN1+RK*VCX
      PY5=G*PIN2+RK*VCY
      PZ5=G*PIN3+RK*VCZ
      P5=SQRT(PX5*PX5+PY5*PY5+PZ5*PZ5)
      T5=T1
      IF(IMOM.EQ.0)GOTO 21
      RORM=ORBIT(PX5,PY5,PZ5,X,Y,Z)
      CALL QUES(RORM,T5,W1,JIN,M1,IGEN)
      IF(IGEN.EQ.1)RETURN
   21 PX=PX5
      PY=PY5
      PZ=PZ5
      P=P5
      T=T5
      WP=W1
      E=T+W1
      M=M1
      RETURN
   50 PX5=-PIN1+RK*VCX
      PY5=-PIN2+RK*VCY
      PZ5=-PIN3+RK*VCZ
      P5=SQRT(PX5*PX5+PY5*PY5+PZ5*PZ5)
      T5=T1
      IF(IMOM.EQ.0)GOTO 121
      RORM=ORBIT(PX5,PY5,PZ5,X,Y,Z)
      CALL QUES(RORM,T5,W1,JIN,MPX,IGEN)
      IF(IGEN.EQ.1)RETURN
  121 PXM=PX5
      PYM=PY5
      PZM=PZ5
      PM=P5
      TM=T5
      WPM=W1
      EM=T1+W1
      XM=X
      YM=Y
      ZM=Z
      RM=R
      JINM=JIN
      MM=MPX
      RETURN
      END
************************************************************************
*                  SUBROUTINE SIGICH                                   *
************************************************************************
```

```
      SUBROUTINE SIGICH(ZEFF,AEFF)
      COMMON/LAB3/SIG(6,2000)/DATREN/RL0N,RL1N,RM0N,RM1N,RN0N,RN1N,RN2N
      COMMON/DATREP/P0P,P1P,P2P,RL0P,RL1P,RM0P,RM1P,RN0P,RN1P,RN2P
      COMMON/DATREA/P0A,P1A,P2A,RL0A,RL1A,RM0A,RM1A,RN0A,RN1A,RN2A
      COMMON/INCR/ED
* IPAR =0 Chatterjee compilation, =1 Blann inverse cross-section
* IPARR=0 minimum printing
        IPAR=0
        IPARR=0
C 1-N, 2-P, 3-D, 4-T, 5-HE3, 6-A
  2     IF(IPAR.EQ.1)WRITE(8,290)
      DO 6 I=1,2000
      DO 6 K=1,6
  6   SIG(K,I)=0.
C NEUTRON
         AN=AEFF-1.
         AN13=AN**0.333333333
         AN23=AN13*AN13
         RL11N=(RL0N/AN13+RL1N)
         RM11N=RM0N*AN13+RM1N*AN23
         RN11N=(RN0N*AN23*AN23+RN1N*AN23+RN2N)
C PROTON
         AP=AEFF-1.
         ZP=ZEFF-1.
         ECOP=1.44*ZP/(1.5*(AP**0.3333333333))
         EC2=ECOP*ECOP
         AM=AP**RM1P
         P11P=P0P+P1P/ECOP+P2P/EC2
         RL11P=RL0P*AP+RL1P
         RM11P=RM0P*AM
         RN11P=AM*(RN0P+RN1P*ECOP+RN2P*EC2)
C ALPHA
         AA=AEFF-4.
         ZA=ZEFF-2.
         ECOA=2.88*ZA/(1.5*(AA**0.3333333333)+1.2)
         EC2=ECOA*ECOA
         AM=AA**RM1A
         P11A=P0A+P1A/ECOA+P2A/EC2
         RL11A=RL0A*AA+RL1A
         RM11A=RM0A*AM
         RN11A=AM*(RN0A+RN1A*ECOA+RN2A*EC2)
      RP=1.21*((AEFF-1.)**.3333+1.)
      RD=1.21*((AEFF-2.)**.3333+1.260)
      RA=1.21*((AEFF-4.)**.3333+1.587)
           CONRP=31.42*RP*RP
           CONRA=31.42*RA*RA
           CONRD=31.42*RD*RD
      VD=(ZEFF-1.)*1.32/(RD+1.6)
C
      IF(IPAR.EQ.0)    CALL COULCH(VP,VA,IPAR,AEFF,ZEFF,
     +P11P,RL11P,RM11P,RN11P,ECOP,P11A,RL11A,RM11A,RN11A,ECOA)
      IF(IPAR.EQ.1)VP=(ZEFF-1.)*1.15/(RP+1.6)
      IF(IPAR.EQ.1)VA=(ZEFF-2.)*2.64/(RA+1.6)
         RMP=1.-1./AEFF
         RMD=3.-6./AEFF
         RMT=3.-9./AEFF
         RMH=3.-9./AEFF
         RMA=2.-8./AEFF
C •EPEHOPMˆPOBKA CE—EHˆ‰ „‹Ÿ HE‰TPOHOB •Pˆ •HEPƒˆˆ < 1 M•B
```

```
      RCH=1.
      IF(IPAR.EQ.0) RCH = ( RL11N+RM11N+RN11N ) /
     +                    ( 31.42*(RP+3.4/SQRT(1.+.5))**2 )
      DO 10 IK=1,2000
      EI=FLOAT(IK)*ED-ED/2.
         E1=EI
         IF(E1.GT.50.)E1=50.
C N
      IF(IPAR.EQ.1)SIG(1,IK)=31.42*(RP+3.4/SQRT(EI+.5))**2
      IF(IPAR.EQ.0.AND.EI.GE.1.)SIG(1,IK)=RL11N*E1+RM11N+RN11N/E1
      IF(IPAR.EQ.0.AND.EI.LT.1.)SIG(1,IK)=
     +                           RCH * ( 31.42*(RP+3.4/SQRT(EI+.5))**2 )
        IF(SIG(1,IK).LT.0.)IPAR=1
        IF(SIG(1,IK).LT.0.)GOTO 2
C D
      IF(VD.GE.EI) GO TO 11
      SIG(3,IK) = CONRD*(1.-VD/EI)
C P
   11 IF(VP.GE.EI)GO TO 10
      IF(IPAR.EQ.1)SIG(2,IK)=CONRP*(1.-VP/EI)
      EKSI=AMAX1(E1,ECOP)
      IF(IPAR.EQ.0)SIG(2,IK)=
     +P11P*((E1-EKSI)**2)+RL11P*E1+RM11P+RN11P*(2.-E1/EKSI)/EKSI
        IF(SIG(2,IK).LT.0.)IPAR=1
        IF(SIG(2,IK).LT.0.)GOTO 2
C A
      IF(VA.GE.EI) GO TO 10
      IF(IPAR.EQ.1)SIG(6,IK)=CONRA*(1.-VA/EI)
      EKSI=AMAX1(E1,ECOA)
      IF(IPAR.EQ.0)SIG(6,IK)=
     +P11A*((E1-EKSI)**2)+RL11A*E1+RM11A+RN11A*(2.-E1/EKSI)/EKSI
        IF(SIG(6,IK).LT.0.)IPAR=1
        IF(SIG(6,IK).LT.0.)GOTO 2
10    CONTINUE
C D=T, HE3 = A
      DO 20 IK=1,2000
      SIG(4,IK)=SIG(3,IK)
   20 SIG(5,IK)=SIG(6,IK)
      IF(IPARR.eq.0) goto 151
      DO 150 K=1,6
      GO TO (201,202,203,204,205,206),K
  201 WRITE(7,211) RCH
  211 FORMAT(/,38X,'CHAT-BLANN NEUTRON INVERSE CROSS SECTIONS'
     +,'  ( ',G12.5,' )'/)
      GO TO 135
  202 WRITE(7,222)
  222 FORMAT(//38X,'CHATTERJEE PROTON INVERSE CROSS SECTIONS'/)
      GO TO 135
  203 WRITE(7,233)
  233 FORMAT(//37X,'SHARP CUTOFF DEUTERON INVERSE CROSS SECTIONS'/)
      GO TO 135
  204 WRITE(7,244)
  244 FORMAT(//37X,'SHARP CUTOFF TRITON=D INVERSE CROSS SECTIONS'/)
      GO TO 135
  205 WRITE(7,255)
  255 FORMAT(//37X,'CHATTERJEE HE3=ALPHA INVERSE CROSS SECTIONS'/)
      GO TO 135
  206 WRITE(7,266)
  266 FORMAT(//39X,'CHATTERJEE ALPHA INVERSE CROSS SECTIONS'/)
```

```
  135 WRITE(7,145) (SIG(K,JE),JE=1,2000)
  145 FORMAT ( 1H ,10F7.0)
  150 CONTINUE
  151 DO 200 K=1,2000
      EI=(FLOAT(K)*ED-ED/2.)*ED
      SIG(1,K)=SIG(1,K)*EI*RMP
      SIG(2,K)=SIG(2,K)*EI*RMP
      SIG(3,K)=SIG(3,K)*EI*RMD
      SIG(4,K)=SIG(4,K)*EI*RMT
      SIG(5,K)=SIG(5,K)*EI*RMH
 200  SIG(6,K)=SIG(6,K)*EI*RMA
      RETURN
  290 FORMAT(1X,'FOR Z TREATED BLANN SHARP CUTOFF APPROX. IS USED')
      END
*********************************************************************
*                  FUNCTION SIGION                                  *
*********************************************************************
      FUNCTION SIGION(ISS,A1,Z1,A2,Z2,T)
C Written by Barashenkov, Polanski
C     FOR CALCULATION OF NUCLEUS-NUCLEUS TOTAL(ISS=1)
C     AND INELASTIC(ISS=2) CROSS SECTIONS
C     A1,Z1 - PROJECTILE MASS AND CHARGE NUMBERS (A1>1)
C     A2,Z2 - THE SAME FOR TARGET NUCLEUS(3<A2<240)
C     T - LAB. KINETIC ENERGY OF PROGECTALE (1 MEV/NUCLEON< T <1 TEV/NUCLEON)
      COMMON/CX/CX(38)
      COMMON /FH/AMP,AMT,AP,AT,B0,R0
      IS=3-ISS
      IF(IS.LE.0) RETURN
      IF(A1.LT.1.0.OR.A1.GT.240.0.OR.A2.LT.3.0.OR.A2.GT.240.) GO TO 101
      IF(ABS(Z1).LT.1.0) GO TO 101
      IF(T.LT.1.0) GO TO 101
      SIGION=0.
      TP=T/A1
      AP=A1**0.333333
      AT=A2**0.333333
      AMP=A1*930.63
      AMT=A2*930.63
C     PARAMETER FOR CALCULATION OF NUCLEAR RADIUS
      R0=1.4
      IF(ABS(A1-4.) .LT. 0.1) R0=1.3
      B0=1.44*Z1*Z2
      I=1
       IF(IS.EQ.2) I=20
C     SELECTION OF PROJECTILE
C     HEAVY ION
      IF(A1.GT.4.1) N=I
C     ALFA,HELION,TRITON
      IF(A1.GT.2.1 .AND. A1.LT.4.1) N=I+6
C     DEUTERON
      IF(A1.LT.2.1) N=I+12
C     HIGH-ENERGY CROSS-SECTION
C     SELECTION OF PROJECTILE ENERGY
      IF(TP.LT.CX(N+1)) K=2
      IF(TP.LT.CX(N+4)) K=5
C     CROSS-SECTION PARAMETERS
      C=CX(I)
      IF(TP.LT.CX(N+1)) C=CX(N+K)+CX(N+K+1)*LOG10(TP)
      CP=CX(N+5)+CX(N+6)
      IF(TP.LT.10.) GO TO 1
```

```
C     HIGH-ENERGY CROSS-SECTION
      SIGION=FHS(IS,T,C)
      RETURN
C     CALCULATION OF LOW-ENERGY CROSS-SECTION
C     NORMALIZATION OF HIGH-ENERGY CROSS-SECTION
 1     SH10=FHS(IS,10.*A1,CP)
      R0=1.45
      IF(ABS(A1-4.).LT. 0.1) R0=1.4
C     RENORMALIZED COULOMB BARRIER
      B=B0/R0/(AP+AT)
C     LOW-ENERGY CROSS-SECTION
      SIGION=SH10*FC(T,B)/FC(10.*A1,B)
      IF(SIGION) 101,100,100
  101 WRITE(6,1001)
 1001 FORMAT(' ERROR IN INPUT OF PARAMETERS OF FUNCTION SIGION')
  100 CONTINUE
      RETURN
      END
*********************************************************************
*                 SUBROUTINE STEP93                                 *
*********************************************************************
C Histograms
          SUBROUTINE STEP93(E,CS,ND1,ERES,CSRES,ND2,JMAX,LL)
C If LL = 1 - energy distributions
C    LL = 2 - angular distributions
C ND2 must be < 150
          DIMENSION E(ND1),CS(ND1),ERES(ND2),CSRES(ND2)
          N = ND1
            N1 = N - 1
            ERES(1) = E(1)
            CSRES(1) = CS(1)
                                    J=2
          DO 300 I=1,N1
          GOTO(1,2),LL
1         ERES(J) = E(I)
          CSRES(J) = CS(I+1)
              ERES(J+1) = E(I+1)
              CSRES(J+1) = CS(I+1)
          GOTO 3
2         ERES(J) = E(I+1)
          CSRES(J) = CS(I)
              ERES(J+1) = E(I+1)
              CSRES(J+1) = CS(I+1)
3         J = J+2
          IF(J.GT.150)then
                      PRINT 10000
                      WRITE(8,10000)
                      RETURN
                      endif
300       CONTINUE
          GOTO(11,22),LL
11        ERES(J) = E(N)
          CSRES(J) = 1.0E-13
          JMAX=J
          RETURN
22        JMAX=J-2
          RETURN
10000     FORMAT(1X,' STEP93:  Dimension of arrays exceeded.  ','
     c    No histograms ')
```

```
          END
************************************************************************
*                  SUBROUTINE TRANS                                    *
************************************************************************
      SUBROUTINE TRANS(J1,J2,ITR9)
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      COMMON/R003/R003 /R008/R008 /NREJ/REFR,NREJ
                       ITR9=0
      T7=T
      CALL CROZON(J1,J2,WP,P1,T7,M)
      QCOS=(PX*X+PY*Y+PZ*Z)/(P*R)
      QSIN=SQRT(ABS(1.-QCOS*QCOS))
      QSIN1=QSIN*P/P1
      IF(QSIN1-1.)20,10,10
C Reflection
   10 RK1=-2.*P*QCOS/R
      R003=R003+1.
      R008=R008+1.
      IF(R008.GT.REFR) THEN
                       ITR9=1
                       RETURN
                       ENDIF
      GOTO 30
   20 J1=J2
      T=T7
                     RK1=0.
      If(QCOS.ne.0.0)RK1=((P1*QCOS/ABS(QCOS))*SQRT(ABS(1.-QSIN1**2))-
     *P*QCOS)/R
      P=P1
   30     PX=PX+X*RK1
          PY=PY+Y*RK1
          PZ=PZ+Z*RK1
      RETURN
      END
************************************************************************
*                  SUBROUTINE TREAT1                                   *
************************************************************************
      SUBROUTINE TREAT1
      COMMON/MASTR1/WN(21,21) /DATINI/RA,T0,W0
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/TR1EVA/EXCIT,WMAI /TR1TR2/VAICX,VAICY,VAICZ
      COMMON/QSUM/QSUM /URAND1/IYG
      COMMON/QNNN/QNNN /MAIIPR/IPR /INF001/INFKAL
      N1 = NPREN + 2*NPREA + 1
      N2 = NPREP + 2*NPREA + 1
         IF(N1.GT.21.OR.N2.GT.21)GOTO 100
      WMAI=WN(N1,N2)
      PZ0=SQRT(T0*(T0+2.*W0))
C
      IF(INFKAL.EQ.1)CALL AUXANG
      EXCIT=QNNN-QSUM+
     *T0-TW-(PWX*PWX+PWY*PWY+(PWZ-PZ0)**2)/(2.*WMAI)
      VAICX=-PWX/WMAI
      VAICY=-PWY/WMAI
      VAICZ=(PZ0-PWZ)/WMAI
      RETURN
100   WRITE(IPR,101)N1,N2
101   FORMAT(1X,'ERROR IN SUBROUTINE TREAT1: '/1X,' N1  OR',
     +'  N2 EXCEED MAXIMUM '/1X,' N1=',I5,' N2=',I5)
```

```
       STOP
       END
*********************************************************************
*                SUBROUTINE TREAT2                                  *
*********************************************************************
      SUBROUTINE TREAT2
      COMMON/TR1TR2/V1,V2,V3 /EVATR2/W,VX,VY,VZ /MAIIPR/IPR
      COMMON/TR2CFU/RECOIL /INFDIS/INFDIS,INFOUP(3)
      COMMON/EMEM91/EMEMT(21),RMEMT(21),HMEMT
      COMMON/LIB91/WINLIB(100,250),INFLIB
C
      IF(INFLIB.EQ.1) CALL LIBGEN
      RECOIL=W*0.5*((V1+VX)**2+(V2+VY)**2+(V3+VZ)**2)
      IF(INFDIS.EQ.0)RETURN
C Recoil spectrum
      DO 10 NU=1,21
      IF(RECOIL.LE.EMEMT(NU))GOTO 50
   10 CONTINUE
           WRITE(IPR,20)RECOIL
   20      FORMAT(1X,' CONTROL SUBR TREAT2.   RECOIL=',G12.5)
           RETURN
   50 RMEMT(NU)=RMEMT(NU)+1.
      RETURN
      END
*********************************************************************
*                FUNCTION VELOC                                     *
*********************************************************************
      FUNCTION VELOC(WPAR,W0,E)
      VELOC=SQRT(2.*WPAR*E/(W0*(W0+WPAR)))
      RETURN
      END
*********************************************************************
*                SUBROUTINE WERO                                    *
*********************************************************************
      SUBROUTINE WERO(PFM,PP,MX)
      COMMON/BOND1/QBON(200,200,6)
      COMMON/URAND1/IYG
      GOTO(1,1,3,4),MX
C
C NEUTRON, PROTON
    1 IPOWER = 2
      PFMAX = PFM**IPOWER
C
   10    CC=RANDOM(0)
         CC1=RANDOM(0)
      GGG=PFM*CC
      IF( (GGG**IPOWER) - PFMAX*CC1 )10,20,20
   20 PP=GGG
      RETURN
C
C ALPHA-PARTICLE
    3 IPOWER = 8
      PFMAX = PFM**IPOWER
  100    CC=RANDOM(0)
         CC1=RANDOM(0)
      GGG=PFM*CC
      IF( (GGG**IPOWER) - PFMAX*CC1 )100,200,200
  200 PP=GGG
      RETURN
```

```
C
C TRITON, HE-3
4     IPOWER = 6
      PFMAX = PFM**IPOWER
 1000    CC=RANDOM(0)
         CC1=RANDOM(0)
      GGG=PFM*CC
      IF( (GGG**IPOWER) - PFMAX*CC1 )1000,2000,2000
 2000 PP=GGG
      RETURN
      END
*********************************************************************
*                 FUNCTION WM                                       *
*********************************************************************
      FUNCTION WM(M)
C  1 - N
C  2 - P
C  3 - A
C  4 - T, HE3
C  5 - D
      WM=938.2796
      GOTO(1,2,3,4,5),M
1     WM=939.5731
      RETURN
2     WM=938.2796
      RETURN
3     WM=3726.
      RETURN
4     WM=2794.5
      RETURN
5     WM=1863.
      RETURN
      END
*********************************************************************
*                   SUBROUTINE ZERLIB                               *
*********************************************************************
      SUBROUTINE ZERLIB
      COMMON/LIB91/WINLIB(100,250),INFLIB
      DO 1 I=1,100
      DO 1 J=1,250
1     WINLIB(I,J)=0.
      RETURN
      END
*********************************************************************
*                   SUBROUTINE ZERO1                                *
*********************************************************************
      SUBROUTINE ZERO1
      COMMON/MASOUT/WDIS(990),K1(990),K2(990),K3(990),K4(990),
     +K5(990),K6(990),K7(990),K8(990),K9(990),K10(990),KN
      COMMON/NPROL/NPROL /R001/R001 /R003/R003
      COMMON/R005/R005 /IX190/IX191,IX192,IX193
      COMMON/NREJ/REFR,NREJ /AUXIL/ICOU1,ICOU2
      COMMON/SUM90/ER90,KER90
      COMMON/INFSEP/KSEP(100,4),INFSEP,JSEPM
      DO 10 I=1,990
      WDIS(I)=0.
      K1(I)=0
      K2(I)=0
      K3(I)=0
```

```
      K4(I)=0
      K5(I)=0
      K6(I)=0
      K7(I)=0
      K8(I)=0
      K9(I)=0
   10 K10(I)=0
      KN=0
      NPROL=0
      R001=0.
      R003=0.
      R005=0.
      IX191=0
      IX192=0
      IX193=0
      NREJ=0
      ICOU1=0
      ICOU2=0
      ER90=0.
      KER90=0
      DO 100 I=1,100
100   KSEP(I,4)=0
      RETURN
      END
*********************************************************************
*                SUBROUTINE ZERO2                                   *
*********************************************************************
      SUBROUTINE ZERO2
      COMMON/INTTR1/PWX,PWY,PWZ,TW,NPREN,NPREP,NPREA
      COMMON/EVATR2/WEIG,VX,VY,VZ /EVAMAS/N1,N2,N3,N4,N5,N6
      COMMON/JACT/JACT /NDIM/NPAR /MEMORY/U(11,20),MU(2,20) /R008/R008
      COMMON/IZET/IZET /QSUM/QSUM /QBOCFU/NSN,NSP
      PWX=0.
      PWY=0.
      PWZ=0.
      TW=0.
      VX=0.
      VY=0.
      VZ=0.
         NPREN=0
         NPREP=0
         NPREA=0
             NSN=0
             NSP=0
      N1=0
      N2=0
      N3=0
      N4=0
      N5=0
      N6=0
      JACT=0
      DO 2 I=1,11
      DO 1 J=1,20
    1 U(I,J)=0.
    2 CONTINUE
      DO 3 I=1,20
      MU(1,I)=0
    3 MU(2,I)=0
      NPAR=0
```

```
      R008=0.
      IZET=0
      QSUM=0.
      RETURN
      END
*********************************************************************
*                SUBROUTINE ZONWAY                                  *
*********************************************************************
      SUBROUTINE ZONWAY(RZJ1,RZJ0,J1,J3,J2,SLINE)
      COMMON/PARTIC/WP,PX,PY,PZ,P,T,E,X,Y,Z,R,JIN,M
      IF(R-1.E-06)2,2,8
    2 SLINE=RZJ1
      RETURN
    8 QCOS=(PX*X+PY*Y+PZ*Z)/(R*P)
      IF(QCOS)10,20,20
   10 D1=-1.
      J2=J3
      RRJ=RZJ0
      GOTO 30
   20 D1=1.
      J2=J1
      RRJ=RZJ1
   30 DD=(RRJ**2)-(1.-(QCOS**2))*(R**2)
      IF(DD)50,50,70
   50 CONTINUE
      OOO=RRJ-RZJ1
      IF(OOO)20,60,20
   60 CONTINUE
      SLINE=0.
      RETURN
   70 CONTINUE
      SLINE=-R*QCOS+D1*SQRT(DD)
      RETURN
      END
```