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Program OPTMAN Version 14 (2013), User's Guide

Coupled-channel optical model code based on rigid- or soft-rotator models, compatible with the EMPIRE nuclear data evaluation system

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Abstract
The users' guide for OPTMAN code version 14 (2013) is presented. All input options are explained with examples. The OPTMAN Code is an optical model solver including rigid and soft-rotator structure models, coupling rotational bands built on vibrational and/or single particle bandheads. Code version 14 is compatible with the EMPIRE nuclear data evaluation system and provides output files equivalent to ECIS06 code outputs. A full Lane consistent and dispersive coupled-channel optical model potential can be used in calculations.

Keywords: NUCLEAR REACTIONS σ_{tot} , (n,n), (n,n'), (p,p), (p,p'), (p,n), $\sigma_{p,nonel}$, OPTMAN, soft-rotator model, rigid-rotor model, rotational-vibrational model, potential search, dispersive potential, Lane consistency, OPTMAN input, OPTMAN user's guide.

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1. INTRODUCTION

For more than thirty years, an original coupled-channel optical model code OPTMAN has been developed at Joint Institute for Energy and Nuclear Research to investigate nucleon-nucleus interaction mechanisms and as a basic tool for nuclear data evaluation. The Code has been broadly used to produce data needed for reactor design and other applications. Results of such activities for ^{235}U, ^{239}Pu, ^{236}U, ^{233}U, ^{238}Pu, etc. were included in BROND [1] evaluated Nuclear Data Library of former Soviet Union. Standard rigid rotator and harmonic vibrator coupling scheme were encoded in widely-used JUPITER [2] and ECIS [3, 4] codes. OPTMAN is the first code to include level-coupling schemes based on a non-axial soft-rotator model for even-even nuclei. The soft-rotator model allows considering the stretching of soft nuclei by rotations, which results in change of equilibrium deformations for excited collective states. This is a critical point for reliable scattering predictions [5, 6, 7], based on the coupled-channel optical model calculations.

Over many years, OPTMAN was developed and used for evaluation of reactor-oriented nuclear data. It was written originally considering only neutrons as the projectile with incident energies up to 20 MeV. In 1995-1998, this code was successfully used as a theoretical base for nuclear data evaluation for minor actinides carried out in the framework of the ISTC Project CIS-03-95, funded by Japan. In 1997 the OPTMAN Code was installed at the Nuclear Data Center of Japan Atomic Energy Research Institute; an active international collaboration started that was initiated by Satoshi Chiba from JAEA (former JAERI). Since then, many new options were added to the Code meeting different data needs for a broad range of applications: power reactors, shielding design, radiotherapy, transmutations of nuclear waste, and nucleosynthesis.

Calculations with OPTMAN are now possible both for neutrons and protons as projectiles, and the upper incident nucleon energy is extended to 150-200 MeV [8]. The current version of soft-rotator model of OPTMAN takes into account the non-axial quadrupole, octupole and hexadecapole deformations, and β_2, β_3 and $\gamma-$vibrations (assuming a constant nuclear volume). With this option, OPTMAN is able to analyze the collective level structure, E2, E3, E4 $\gamma-$transition probabilities and reaction data in a self-consistent manner, which makes results of such analyses more reliable. We have found that this model was flexible enough so that OPTMAN can be applied not only to heavy rotational nuclei [9, 10], but also to very light nuclei, namely ^{12}C [11, 12] and ^{28}Si [13]. Furthermore, OPTMAN has been applied to vibrational nuclei such as ^{52}Cr [14], ^{56}Fe [15, 16] and ^{58}Ni [17]. Later the code had been developed through ISCT Projects B-1319 and B-1805. Since 2004 further development of the OPTMAN Code had been undertaken in close

collaboration with Roberto Capote from IAEA and José M. Quesada from Seville University. The main efforts were devoted to the incorporation of the latest theoretical advances in the formulation and use of phenomenological optical model potentials in the OPTMAN Code. We have included dispersion relationships between imaginary and real parts of the optical potential [18], thus allowing for a significant decrease in the number of optical parameters used in the data fit. Dispersive potentials lead to a much better description of experimental data and accurate predictions of total cross-section differences along the given isotope chain [19, 20].

We also extended the OPTMAN code to calculate direct (p,n) cross sections (quasi-elastic channel) with excitation of isobar-analog states, and derived Lane consistent potentials within a new formalism. Finally, relativistic generalization was made consistent with the one used in the ECIS code [3, 4]. Recent theoretical developments allow coupled-channels calculations with coupling of additional bands with the ground state band, using the axial rigid rotor potential as a zero approximation. Deviations of instant shapes from axial deformations are usually small, which leads to a quick convergence of computational algorithm with additional vibrational bands coupled. So far this option has only been implemented for even-even nuclides; it will be extended in the near future to the coupling of additional rotational bands built on single-particle excitations for odd nuclei.

The theory, computational algorithms, and description of inputs/outputs of the OPTMAN Code were described in a comprehensive manual [21] published in 2005, and a supplement to this manual [22] published in 2008. Many new options have been added to the OPTMAN Code recently. In addition, the OPTMAN Code has been integrated into the EMPIRE nuclear data evaluation system [23]. Therefore, the need has arised to publish an updated User's Guide describing OPTMAN inputs, allowing interested users to work with OPTMAN Code more efficiently.

1.1. Input Data

Input data of the OPTMAN Code are described in this section. Data have the card image form. Units of the data are MeV, fm, barn and n (unified mass unit). Interested readers may find additional information on the theory and computational methods in [21, 22]; for the latest upgrades please refer to [24].

- Record 1 - FORMAT(20A4)

  Any text information that identifies current calculation. It will be printed in the head of output.

- Record 2 - FORMAT(14I2)

  MEJOB, MEPOT, MEHAM, MEPRI, MESOL, MESHA, MESHO, MEHAO, MEAPP, MEVOL, MEREL, MECUL, MERZZ, MERRR,MEDIS,MERIP

  Flags describing the nuclear collective structure model.

  - MEJOB = 1 - optical calculations, = 2 adjustment of optical potential parameters;
  - MEPOT = 1 -rotational model potential, =2 - potential expanded by derivatives;
  - MEHAM = 1 - nuclear Hamiltonian of rotational model, = 2 - not in use yet, = 3 - Davydov-Chaban model, = 4 - Davydov-Philipov model, = 5 - nuclear Hamiltonian with account of γ softness [6, 7] , =6,7 - not in use yet;
  - MEPRI = 0 - short output, additional output as MEPRI is increasing ;
  - MESOL = 1 - code will choose which method of coupled channels system solution for a certain J^π should be used to reduce time of calculations, = 2 - exact solution, =3 - solution using iterations, with spherical solutions as zero approximation, >3 - solution using iterations, with exact coupled channels solution with number of coupled states equal MESOL as zero approximation, MESOL must be less than or equal to 20;
  - MESHA = 1 - rigid hexadecapole deformations are not taken into account, = 2 - with account of axial rigid hexadecapole deformations, = 3 - rigid hexadecapole deformations depending on γ (Ref.[25]), = 4 - rigid hexadecapole deformations in the most general case [25] ;
  - MESHO = 0 - nuclear shape without octupole deformations, = 1 -nuclear shape with axial octupole deformations, = 2 - nuclear shape with non-axial octupole deformations;
  - MEHAO = 0 - nucleus is rigid to octupole deformations, = 1 - nucleus is soft to non symmetric octupole, = 2 - nucleus is soft to symmetric octupole deformations scaled by β_2[5] , = 3 - nucleus is soft to symmetric octupole deformations not scaled by β_2;
  - MEAPP = 0 - solution with the potential dependency on level energy losses in the channel, =1 - quick solution without potential dependency on level energy losses, can be used when energies of levels are much less than particle incident energy;
  - MEVOL = 0 - solution without account of volume conservation, =1 - account of volume conservation in uniform nuclear density approximation[26] , =2 - common case[27] , presenting nuclear density distribution by real potential form factor;

- `MEREL` = 0 - calculations using non-relativistic Schrödinger formalism, =1 -account of relativistic kinematics and potential dependence, =2 - account of relativistic kinematic only, =3 - account of relativistic kinematics and real potential dependence;
- `MECUL` = 0 - solution with Coulomb correction potential proportional to derivative of real potential dependence, = 1 - Coulomb correction is energy independent, = 2 - Lane consistent Coulomb correction with "effective" nuclear potential energy for protons equal to incident energy minus Coulomb displacement energy (CDE), applied both to real and imaginary parts of the potential, = 3 - Coulomb correction with "effective" nuclear potential energy for protons equal to incident energy minus CDE, applied to the real part of the potential only;
- `MERZZ` = 0 - charge radius is considered constant, = 1 - charge radius is considered energy dependent;
- `MERRR` = 0 - real potential radius is considered constant, = 1 - charge radius is considered energy dependent.
- `MEDIS` = 0 - without account of dispersion relations between real and imaginary potentials, = 1 - account of dispersion relations between real and imaginary parts of the potential, =3 - account of dispersion relations between real and imaginary parts of the potential excluding spin-orbit potential;
- `MERIP` = 0 - reads potential one time, then calculates necessary one in each energy point inside OPTMAN, =1 - takes potential from the RIPL interface [28], this is recommended only in case levels energy is much less than incident energy, even in this case gives approximate results.

- Record 3 - FORMAT(6E12.7), cards - 3a, 3b, 3c, not read in this place if `MEJOB=2`

  Parameters of non-axial nuclear Hamiltonian. These cards are read if `MEHAM` > 1. These parameters are detailed described elsewhere [5, 11, 25] .

  `HW`, `AMB0`, `AMG0`, `GAM0`, `BET0`, `BET4` - card 3a

  - `HW` - energy scale factor $\hbar\omega_0$;
  - `AMB0` - nuclear softness μ_{β_2};
  - `AMG0` - nuclear softness μ_{γ_0},

- GAM0 - equilibrium non-axiality $0 < \gamma_0 < \pi/3$ in radians;
- BET0 - equilibrium deformation β_{20}, for a non-axial Hamiltonian;
- BET4 - rigid deformation β_4, for a non-axial Hamiltonian.

BB42, GAMG, DELG, BET3, ET0, AMU0 - card 3b

- BB42 - $a_{42} = B_4/B_2(\beta_4/\beta_{20})^2$, where B_λ - are mass parameters;
- GAMG - parameter of β_4 non-axiality, γ_4;
- DELG - parameter of β_4 non-axiality, δ_4;
- BET3 - if MEHA0 = 2 - BET3=ϵ_0 and $\beta_{30} = \beta_{20}\epsilon_0$ = BET3 * BET0, if MEHA0 = 3 - BET3= equilibrium deformation $\beta_{30} = \epsilon_0$ = BET3;
- ET0 - non-axiality of octupole β_3 deformation η;
- AMU0 - nuclear softness μ_ϵ.

HW0, BB32, GAMDE, DPAR, GSHAPE - card 3c

- HW0 - energy scale for octupole oscillations $\hbar\omega_\epsilon$, used if MEHA0 = 1;
- BB32 - $a_{32} = B_3/B_2(\beta_{30}/\beta_{20})^2$;
- GAMDE - yet not in use;
- DPAR - splitting of energy for the states with different parity in symmetric potential well for octupole oscillations equal δ_n;
- GSHAPE- parameter allowing negative β_2 deformations so that $\cos(\gamma_0 + \text{GHAPE})$ is negative.

- Record 4 - FORMAT(5I.3) this card is read, only for MEJOB=2, for fit of potential parameters option

  Flag defining the fitting details

  MENUC, MEBET, MEIIS, MERES, MELEV

  - MENUC - number of isotopes experimental data of which is used for potential parameters adjustment (MENUC$\leq$10);
  - MEBET - number of isotope deformations of which should beadjusted;

- MEIIS - by the moment not in use;
- MERES - by the moment not in use;
- MELEV - number of level, other than Ground State (GS) band level for an isotope, deformation of which, that couples it with GS level, should be adjusted

- Record 5 - FORMAT(9I3)

  Flags defining details of calculations

  NUR, NST, NPD, LAS, MTET, LLMA, NCMA, NSMA, KODMA

  - NUR - number of coupled levels in optical model calculations (NUR $\leq$ 40). Ignored in case of potential parameters adjustment option (MEJOB = 2), put any value;
  - NST - number of energy points for which optical model calculations will be carried out if MEJOB=1; ignored if MEJOB = 2- potential parameters adjustment option,put any value (NST $\leq$ 50);
  - NPD - the highest multipole Y_{l0} in deformed radii expansion, l_{max} =NPD for rotational model (MEPOT = MEHAM = 1), NPD $\leq$ 8. For non-axial nuclear Hamiltonian models (MEPOT =2, MEHAM $>$ 2), not in use;
  - LAS - the highest multipole Y_{l0} in deformed potential expansion, l_{max}=LAS for rotational model (MEPOT = MEHAM = 1), LAS $\leq$ 8. For non-axial nuclear Hamiltonian models (MEPOT =2, MEHAM $>$ 2), number of potential derivatives for deformed potential expansion, must be no more than 4;
  - MTET - number of angels (in c.m.) for which angular distributions of scattered neutrons will be calculated (used only for MEJOB = 1, for MEJOB = 2 it is not used, put any value), if MTET = 0 angular distributions are not calculated, MTET must be no more than 150;
  - LLMA = maximum angular momentum of scattered neutrons that is taken into account; higher are rejected. LLMA $<$ 90;
  - NCMA - maximum number of coupled equation for certain J^{π}; NCMA $\leq$ 200;
  - NSMA - maximum number of J^{π} states for which coupled channels systems are solved; NSMA $\leq$ 180;

- KODMA - = 0 - coupled equations are ordered one by one, first for the first level, then for the second, etc., = 1 - coupled equations are ordered one by one by growing angular momentum of scattered neutrons, the total number of coupled equations ≤ NCMA.

- Record 6 - FORMAT(20I.3) this cards are read, if only MEJOB=2, for potential parameters adjustment option, MENUC such cards are read.

  Flags defining the fitting for a certain isotope

  NSTIS(I), NURIS(I), MESOIS(I),NRES(I),I,=1, MENUC

  - NSTIS(I) - number of energy points for ith isotope experimental data of which is used for potential parameters adjustment (MENUC≤10);
  - NURIS(I) - number of levels coupled for I-th of isotope;
  - MESOIS(I) - method of coupled equation system solution for ith isotope (MESOL);
  - NRES(I) - by the moment not in use, should be set equal zero.

- Record 7 - FORMAT(6E12.7) this card is read, if only MEJOB=2, for potential parameters adjustment option. WEI(I),I=1, MENUC

  - WEI(I) - relative weight of ith isotope in natural mixture.

Block of records below is read once for MEJOB=1, or MENUC times for MEJOB=2.

- Record 3' - FORMAT(6E12.7), same as above Record 3, cards - 3'a, 3'b, 3'c, not read in this place if MEJOB=1

  Parameters of non-axial nuclear Hamiltonian. These cards are read if MEHAM > 1. In details this parameters are described elsewhere[5, 11, 25]

- Record 8 - FORMAT(6E12.7)

  MEJOB = 1 - energies (EE(I)) in which optical model cross sections are calculated, MEJOB = 2 - energies for experimental points for I-th isotope which will be used for potential adjustment; NST ≤ 50

  (EE(I), I=1,NST) - cards 8a, 8b, ...

- Record 9 - FORMAT(36I2)

  Flags determining charge (in units of electron charge) of the incident particles Z' for which calculations for energy `EE(I)` will be carried out.

  (`MCHAE(I)`, `I`=1,`NST`) - card 9a and for `NST` $>$ 36 - card 9b.

- Record 10 - FORMAT(6E12.7)

  Angles at which angular distributions will be calculated. If `MTET` = 0 or `MEJOB` = 2 these cards are not read, `MTET` must be no more than 150;

  (`TET(I)`, `I`=1,`MTET`) - Cards 10a, 10b, ...

- Record 11 - FORMAT(E12.7,5I2,E12.7) for `MEHAM` = 1, FORMAT(E12.7,7I2) for `MEHAM` $>$ 1

  Characteristics of nuclear levels for I-th isotope

  `(EL(I),JO(I),NPO(I),KO(I),NCA(I),NUMB(I),BETB(I),I=1,NUR)` - Cards 11a, 11b, .. for `MEHAM` =1

  (`EL(I)`, `JO(I)`, `NPO(I)`, `NTU(I)`, `NNB(I)`, `NNG(I)`, `NNO(I)`, `NCA` , `I`=1,`NUR`) - Cards 11a, 11b, .. for `MEHAM` $>$ 1

  - `EL(I)` -energy of the ith level of isotope;
  - `JO(I)` - spin of the level multiplied by two;
  - `NPO(I)` - parity of the level = +1 - for positive, = -1 - for negative;
  - `KO(I)` - K of the levels band multiplied by two;
  - `NTU(I)` - the number of rotational energy solution τ;
  - `NNB(I)` - the number of β_2 oscillation function solution n_{β_2};
  - `NNG(I)` - the number or γ oscillation function solution n_γ;
  - `NNO(I)` - the number of β_3 oscillation function solution n_{β_3};
  - `NCA(I)`- flag =0 for excitations leading to the same isotope, =1 for excitations leading to isobar analog state (IAS) excitation;
  - `NUMB(I)`- flag of the level band, for the GS and IAS band levels should be = 0;
  - `BETB(I)`- deformations of other than GS and IAS levels determining coupling with GS level.

- Record 12 - FORMAT(I3) Necessary only for `MEJOB=1`, nor necessary for `MEJOB=2`.
  - any blank card.
- Record 13 - FORMAT(6E12.7)

  Individual characteristics of interacting incident particle and isotope

  `ANEU`, `ASP`, `AT`, `ZNUC`, `EFERMN`, `EFERMP`
  - `ANEU` - incident particle mass;
  - `ASP` - incident particle spin;
  - `AT` - interacting nuclear mass;
  - `ZNUC` - target nuclear charge Z;
  - `EFERMN` - Fermi energy for neutrons;
  - `EFERMP` - Fermi energy for protons.

Attention !!! End of the BLOCK for each isotope

- Record 14 - FORMAT(6E12.7)

  A-mass and Z- charge independent optical potential parameters.

  `VR0`, `VR1`, `VR2`, `VR3`, `VRLA`, `ALAVR` - card 14a
  - `VR0` - real optical potential V_R constant term V_R^0;
  - `VR1` - real optical potential V_R linear term V_R^1;
  - `VR2` - real optical potential V_R square term V_R^2;
  - `VR3` - real optical potential V_R cubic term V_R^3;
  - `VRLA` - real optical potential V_R exponential term V_R^{DISP};
  - `ALAVR` - real optical potential V_R exponential constant λ_R.

  `WD0`, `WD1`, `WDA1`, `WDBW`, `WDWID`, `ALAWD` - card 14b

- WD0 - imaginary surface potential W_D constant term W_D^0;
- WD1 - imaginary surface potential W_D linear term W_D^1;
- WDA1 - imaginary surface potential W_D linear term W_D^1 for the projectile energies above E_{change} ;
- WDBW - imaginary surface potential W_D term W_D^{DISP};
- WDWID - imaginary surface potential W_D dispersion width WID_D;
- ALAWD - imaginary surface potential W_D exponential constant λ_D.

WC0, WC1, WCA1, WCBW, WCWID, BNDC - card 14c

- WC0 - imaginary volume potential W_V constant term W_V^0;
- WC1 - imaginary volume potential W_V linear term W_V^1;
- WCA1 - imaginary volume potential W_V linear term W_V^1 for the projectile energies above E_{change} ;
- WCBW - imaginary volume potential W_V term W_V^{DISP};
- WCWID - imaginary volume potential W_V dispersion width WID_V;
- BNDC - boundary energy where linear potential slopes change E_{change}.

VS, ALASO, WSO, WS1, WSBW, WSWID - card 14d

- VS - real spin orbit potential V_{SO}^0;
- ALASO - real spin orbit potential V_{SO} exponential constant λ_{so};
- WSO - imaginary spin orbit potential W_{SO} constant term W_{SO}^0;
- WS1 - imaginary spin orbit potential W_{SO} linear term W_{SO}^1;
- WSBW - imaginary spin orbit potential W_{SO} term W_{SO}^{DISP};
- WSWID - imaginary spin orbit potential W_{SO} dispersion width WID_{SO}.

RR, RRBWC, RRWID, PDIS, AR0, AR1 - card 14e

- RR - real potential radius R_R;
- RRBWC - real potential radius R_R dispersion constant C_R;

- RRWID - real potential radius R_R dispersion width WID_R;
- PDIS - dispersion power constant S;
- AR0 - real potential diffuseness a_R constant term a_R^0;
- AR1 - real potential diffuseness a_R linear term a_R^1.

RD, AD0, AD1, RC, AC0, AC1 - card 14f

- RD - imaginary surface potential radius R_D;
- AD0 - imaginary surface potential diffuseness a_D constant term a_D^0;
- AD1 - imaginary surface potential diffuseness a_D linear term a_D^1;
- RC - imaginary volume potential radius R_V;
- AC0 - imaginary volume potential diffuseness a_V constant term a_V^0;
- AC1 - imaginary volume potential diffuseness a_V linear term a_V^1.

RW, AW0, AW1, RS, AS0, AS1 - card 14g

- RW - imaginary Gaussian potential radius R_W;
- AW0 - imaginary Gaussian potential diffuseness a_W constant term a_W^0;
- AW1 - imaginary Gaussian potential diffuseness a_W linear term a_W^1;
- RS - spin orbit potential radius R_{SO};
- AS0 - spin orbit potential diffuseness a_{SO} constant term a_{SO}^0;
- AS1 - spin orbit potential diffuseness a_{SO} linear term a_{SO}^1.

RZ, RZBWC, RZWID, AZ, CCOUL, ALF - card 14h

- RZ - equivalent charged ellipsoid radius R_C;
- RZBWC - equivalent charged ellipsoid radius R_C dispersion constant C_C;
- RRWID - equivalent charged ellipsoid radius R_C dispersion width WID_C;
- AZ - charged ellipsoid radius diffuseness a_Z;
- CCOUL - Coulomb correction constant C_{Coul};
- ALF- mixture coefficient for imaginary volume and Gaussian potentials α.

CISO, WCISO,EA,WDSHI, WDWID2 - card 14i

- CISO - constant for real potential isospin term C_{viso};
- WCISO - constant for imaginary surface potential isospin term C_{wiso};
- EA - energy E_a where volume absorption dependence is modified;
- WDSHI - imaginary surface imaginary potential specific formulae constant;
- WDWID2 - imaginary surface imaginary potential specific formulae constant.

ALFNEW,VRD,CAVR,CARR,CAAR,CARD - card 14k

- ALFNEW - imaginary surface non-locality potential constant α;
- VRD - imaginary surface potential constant;
- CAVR - coefficient of real potential linear dependence of A-mass number ;
- CARR - coefficient of real radius linear dependence of A-mass number;
- CAAR - coefficient of real diffuseness linear dependence of A-mass number;
- CARD - coefficient of imaginary shape potential diffuseness linear dependence of A-mass number.

CAAC - card 15

- CAAC - coefficient of imaginary volume potential diffuseness linear dependence of A-mass number.

- Record 16 - FORMAT(6E12.7)

Input of even axial coefficients of radii deformations $\beta_{\lambda 0}$ from β_{20} to $\beta_{\lambda 0}$, λ=NPD. This Record is read only for axial rotator model (MEHAM = 1). Note that λ is even and no more than 8. For MEJOB=1 one cart is read, while for MEJOB$\geq$1 MENUC such cards are read.

(BET(I), I=2,NPD,2)

---

a. ***This is the LAST card of input for cross section calculations*** MEJOB= 1***. The following cards are used when the fitting of potential parameters is requested.***

- Record 17 - FORMAT(6I2)

  Input of flags that determine which parameters will be adjusted; if `NPJ(I)` = 1 the chosen parameter will be adjusted. Number of parameters to be adjusted must not exceed 20. Please note, that up to `NPJ(50)`for users convenience sequence of inputted flags follows sequence of potential parameters.

  (`NPJ(I)`, `I`=1,69) cards 17a,...17j

  - `NPJ(1)` - flag for real optical potential V_R constant term adjustment `VR0`;
  - `NPJ(2)` - flag for real optical potential V_R linear term adjustment `VR1`;
  - `NPJ(3)` - flag for real optical potential V_R square term adjustment `VR2`;
  - `NPJ(4)` - flag for real optical potential V_R cubic term adjustment `VR3`;
  - `NPJ(5)` - flag for real optical potential V_R exponential term V_R^{DISP}adjustment `VRLA`;
  - `NPJ(6)` - flag for real optical potential V_R exponential exponential constant λ_R adjustment `ALAVR`;
  - `NPJ(7)` - flag for imaginary surface potential W_D constant term adjustment `WD0`;
  - `NPJ(8)` - flag for imaginary surface potential W_D linear term adjustment `WD1`;
  - `NPJ(9)` - flag for imaginary surface potential W_D linear term W_D^1 for particle incident energies above `BNDC`=E_{change} adjustment `WDA1`;
  - `NPJ(10)` - flag for imaginary surface potential W_D dispersion term W_D^{DISP} adjustment `WDBW`;
  - `NPJ(11)` - flag for imaginary surface potential W_D dispersion width term WID_D adjustment `WDWID`;
  - `NPJ(12)` - flag for imaginary surface potential W_D exponential constant λ_D adjustment `ALAWD`;
  - `NPJ(13)` - flag for imaginary volume potential W_V constant term linear term W_V^0 adjustment `WC0`;
  - `NPJ(14)` - flag for imaginary volume potential W_V linear term W_V^1 adjustment `WC1`;
  - `NPJ(15)` - flag for imaginary volume potential W_V linear term W_V^1 for particle incident energies above `BNDC`=E_{change} adjustment `WCA1`;

- NPJ(16) - flag for imaginary surface potential W_V dispersion term W_V^{DISP} adjustment WCBW;
- NPJ(17) - flag for imaginary surface potential W_V dispersion width term WID_V adjustment WCWID;
- NPJ(18) - flag for energy where linear potential slopes change E_{change} adjustment BNDC;
- NPJ(19) - flag for real spin-orbit potential V_{SO} adjustment VS;
- NPJ(20) - flag for real spin-orbit potential V_{SO} exponential constant λ_{so}adjustment ALASO;
- NPJ(21) - flag for imaginary spin-orbit potential W_{SO} constant term W_{SO}^0 adjustment WSO;
- NPJ(22) - flag for imaginary spin-orbit potential W_{SO} linear term W_{SO}^1 adjustment WS1;
- NPJ(23) - flag for imaginary spin-orbit potential W_{SO} dispersion term W_{SO}^{DISP} adjustment WSBW;
- NPJ(24) - flag for imaginary spin-orbit potential W_{SO} dispersion dispersion width WID_{SO} adjustment WSWID;
- NPJ(25) - flag for real potential radius R_R adjustment RR;
- NPJ(26) - flag for real potential radius R_R dispersion constant C_R adjustment RRBWC;
- NPJ(27) - flag for real potential radius R_R dispersion dispersion width WID_R adjustment RRWID;
- NPJ(28) - flag for dispersion power constant S adjustment PDIS;
- NPJ(29) - flag for real potential diffuseness a_R constant term adjustment AR0;
- NPJ(30) - flag for real potential diffuseness a_R linear term a_R^1adjustment AR1;
- NPJ(31) - flag for imaginary surface potential radius R_D adjustment RD;
- NPJ(32) - flag for imaginary surface potential diffuseness a_D constant term adjustment AD0;
- NPJ(33) - flag for imaginary surface potential diffuseness a_D linear term a_D^1 adjustment AD1;
- NPJ(34) - flag for imaginary volume potential radius R_V adjustment RC;

- NPJ(35) - flag for imaginary volume potential diffuseness a_V constant term adjustment AC0;
- NPJ(36) - flag for imaginary volume potential diffuseness a_V linear term a_V^1 adjustment AC1;
- NPJ(37) - flag for Gaussian potential radius R_W adjustment RW;
- NPJ(38) - flag for Gaussian potential radius diffuseness a_W constant term adjustment AW0;
- NPJ(39) - flag for Gaussian potential radius diffuseness a_W linear term a_W^1 adjustment AW1;
- NPJ(40) - flag for spin-orbit potential radius R_{SO} adjustment RS;
- NPJ(41) - flag for spin-orbit potential diffuseness a_{SO} constant term adjustment AS0;
- NPJ(42) - flag for spin-orbit potential diffuseness a_{SO} linear term a_{SO}^1 adjustment AS1;
- NPJ(43) - flag for equivalent charged ellipsoid radius R_C adjustment RZ;
- NPJ(44) - flag for equivalent charged ellipsoid radius R_C dispersion constant C_C adjustment RZBWC;
- NPJ(45) - flag for equivalent charged ellipsoid radius R_C dispersion width WID_C adjustment RZWID;
- NPJ(46) - flag for equivalent charged ellipsoid radius R_C diffuseness a_Z adjustment AZ;
- NPJ(47) - flag for Coulomb correction constant adjustment CCOUL;
- NPJ(48) - flag for mixture coefficient α for imaginary volume and Gaussian potentials adjustment ALF;
- NPJ(49) - flag for real potential isospin constant C_{viso} adjustment CISO;
- NPJ(50) - flag for imaginary surface potential isospin constant C_{wiso} adjustment WCISO;
- NPJ(51) - flag for imaginary volume potential isospin constant C_{wdiso} adjustment WDISO;
- NPJ(52) - flag for energy E_a where volume absorption is modified adjustment EA;
- NPJ(53) - flag for imaginary surface imaginary potential specific formulae adjustment WDSHI;

- NPJ(54) - flag for imaginary surface imaginary potential specific formulae adjustment WDWID2;
- NPJ(55) - flag for surface imaginary potential constant α adjustment ALFNEW;
- NPJ(56) - flag for imaginary potential constant adjustment VRD;
- NPJ(57) - flag for equilibrium deformation β_{20} for non-axial Hamiltonian model adjustment BET0 for MEBET isotope;
- NPJ(58) - flag for equilibrium deformation β_{30} for non-axial Hamiltonian adjustment BET3 for MEBET isotope;
- NPJ(59) - flag for rigid deformation β_4 for non-axial Hamiltonian model adjustment BET4 for MEBET isotope;
- NPJ(60) - flag for rotational model axial rigid deformation β_{20} adjustment BET(2) for MEBET isotope;
- NPJ(61) - flag for rotational model axial rigid deformation β_{40} adjustment BET(4) for MEBET isotope;
- NPJ(62) - flag for rotational model axial rigid deformation β_{60} adjustment BET(6) for MEBET isotope;
- NPJ(63) - flag for nuclear softness $\mu_{\beta_3} = \mu_\epsilon$ adjustment AMUO;
- NPJ(64) - flag for nuclear softness μ_{γ_0} adjustment AMGO;
- NPJ(65) - flag for coefficient of real potential linear dependence of A-mass number adjustment CAVR;
- NPJ(66) - flag for coefficient of real radius linear dependence of A-mass number adjustment CARR;
- NPJ(67) - flag for coefficient of real diffuseness linear dependence of A-mass number adjustments CAAR;
- NPJ(68) - flag for coefficient of surface imaginary radius linear dependence of A-mass number adjustment CARD ;
- NPJ(69) - flag for coefficient of volume imaginary diffuseness linear dependence of A-mass number adjustment CAAC.

Next block of cards will be read for each isotope `MENUC` times and for each isotope for each energy point `EE(I)`, that means `NST` blocks.

- Record 18 - FORMAT(8I2)

  Input of flags determining which experimental data will be used in parameters adjustment (flag = 1 means used in adjustment) for the current energy `EE(I)` .

  `NT(I)`, `NR(I)`, `NGN(I)`, `NGD(I)`, `NSF1(I)`, `NSF2(I)`, `NRAT(I)`, `NNAT(I)`

  - `NT(I)` - flag of total cross section;
  - `NR(I)` - flag of reaction cross section;
  - `NGN(I)` - flag of integral excitation cross section of a group of levels, number of such groups, `NGN(I)` must be no more than 5;
  - `NGD(I)` - flag of angular distributions of scattered neutrons with excitation of a group of levels, number of such groups, `NGD(I)` must be no more than 5;
  - `NSF1(I)` - flag of S_0 strength function;
  - `NSF2(I)` - flag of S_1 strength function;
  - `NRAT(I)`- flag of total ratio. `NRAT (I)` number (this flag is not 1!!!) ratio with which isotope should be calculated
  - `NNAT(I)`- flag of natural isotope mixture total cross section.

- Record 19 - FORMAT(6E12.7)

  Experimental data for total and reaction cross sections and totals ratio for current energy, if flag = 0 may be blank.

  `STE(I)`, `DST(I)`, `SRE(I)`, `DSR(I)`,`RATIO(I)`, `DRAT(I)`

  - `STE(I)` - experimental total cross section;
  - `DST(I)` - experimental total cross section error;
  - `SRE(I)` - experimental reaction cross section;
  - `DSR(I)` - experimental reaction cross section error;
  - `RATIO(I)` - experimental totals ratio;

- DRAT(I)- experimental totals error.

- Record 20 - FORMAT(2E12.7)

  Experimental data for natural isotope mixture total cross section for current energy, if NNAT(I) = 0 Record is not read.

  CSNAT(I), DCSNAT(I)

  - CSNAT(I)- experimental natural mixture cross section;
  - DCSNAT(I)experimental natural mixture cross section error.

- Record 21 - FORMAT(2E12.7)

  Experimental data for strength functions, if NSF1(I) = 0 this Record is not read.

  SE1(I), DS1(I), SE2(I), DS2(I)

  - SE1(I) - experimental S_0 strength function;
  - DS1(I) - experimental S_0 strength function error;
  - SE2(I) - experimental S_1 strength function;
  - DS2(I) - experimental S_1 strength function error.

- Record 22 - FORMAT(2E12.7,2I2), cards 16a, 16b, ...

  Experimental data for integral excitation of groups of levels for current energy, each card is read for the group of excited levels, that means NGN(I) times, if NGN(I) = 0 - these cards are not read. Number of groups must not exceed 5.

  (SNE(I,K), DSN(I,K), NIN(I,K), NFN(I,K), K=1,NGN(I))

  - SNE(I,K) - experimental integral cross section of a group of levels;
  - DSN(I,K) - experimental integral cross section error of a group of levels;
  - NIN(I,K) - the number of the first excited level in a group as specified in Record 8;
  - NFN(I,K) - the number of the last excited level in a group as specified in Record 8.

- Record 20 - FORMAT(15I2)

Description of experimental data for angular distributions of scattered neutron with excitation of a group of levels, if NGD(I) = 0, this Record is not read. Number of groups must not exceed 5.

(NID(I,K), NFD(I,K), MTD(I,K), K =1,NGD(I))

- NID(I,K) - the number of the first excited level in a group as specified in Record 8;
- NFD(I,K) - the number of the last excited level in a group as specified in Record 8;
- MTD(I,K) - number of angles in which experimental angular distributions with excitation of a group of levels exist.

- Record 23 - FORMAT(6E12.7), cards 18a, 18b, ...

  Experimental angular distribution with excitation of a group of levels, this block of cards is read NGD(I) times, if NGD(I)=0, this Record is not read.

  (TED(I,K,L), SNGD(I,K,L), DSD(I,K,L), L=1,MTD(I,K)) Cards 23a, 23b,...

  - TED(I,K,L) - center-of-mass angles for angular distribution in degrees;
  - SNGD(I,K,L) - experimental differential cross section in b/sr;
  - DSD(I,K,L) - experimental differential cross section error in b/sr.

- Record 24 - FORMAT(6E12.7), cards 24a, 24b,...

  Estimated accuracy of parameter adjustment

  (EP(I), I= 1,NV)

  - EP(I) - absolute accuracy for a parameter with ith flag=1, NV is equal to a number of flags=1. Number of flags =1 must not exceed 20.

- Record 25 - FORMAT(E12.7)

  Initial value of χ^2 if known. If equal 0.000000E+00 - will start with the calculation of the initial value χ^2.

This is the last card in input.

1.2. Examples of input files

Here we are presenting two inputs. The first input is for optical model parameters adjustment calculations and deals with the rigid-rotator model, and the second one activates optical model calculations without parameter adjustment.

Rigid-rotator input file for adjustment of the ^{238}U optical model parameters

---

```
U-238/Th-232    RIGID ROTOR MODEL, OMP PARAMETER ADJUSTMENT
02010100200100000000020201010101
002002001000007
009002006008000090150180001     -->  NUR NST NPD LAS mtet LLMA NCMA NSMA KODMA
005019020000002019020000
 .9930000+00 .0070000+00
 .3000000-02 .3387000+01 .4500000+01 .2000000+02 .2600000+02
0000000001
 .0000000-0000+1000000 .2280000+00                                          --->EL(I) JO(I) NPO(I) KO(I), I=1,NUR
 .4491600-0104+1000000 .2280000+00
 .1483800-0008+1000000 .2280000+00
 .3071800-0012+1000000 .2280000+00
 .5181000-0016+1000000 .2280000+00
 .6801100-0002-1000001 .0550000-00
 .7319300-0006-1000001 .0550000-00
 .8266400-0010-1000001 .0550000-00
 .9272100-0000+1000003 .0080000-00
 .9661300-0004+1000003 .0080000-00
 .9663100-0014-1000001 .0550000-00
 .9972300-0000+1000002 .0100000-00
  1037250+0104+1000002 .0100000-00
 .1056380+0108+1000003 .0080000-00
 .1060270+0104+1040004 .0200000-00
 .1150700+0118-1000001 .0550000-00
 .1167990+0108+1040004 .0200000-00
 .1949340+0200+1000100 .2280000+00                                    ---> IAS ground state band 0+ U238
 .1953830+0204+1000100 .2280000+00                                    ---> IAS ground state band 2+
 1.00866520  .5000000-00 .2380000+03 .9200000+02-.5479130+01-.6454370+01
 .2000000-02 .7000000+01
0001
 .0000000-0000+1000000 .2010000+00                                     --->EL(I) JO(I) NPO(I) KO(I), I=1,NUR
 .4936900-0104+1000000 .2010000+00
 .1621200-0008+1000000 .2010000+00
 .3332600-0012+1000000 .2010000+00
```

```
 .5569000-0016+1000000 .2010000+00
 .7144200-0002-1000001 .0570000-00
 .7306000-0000+1000003 .0080000-00
 .7741500-0004+1000003 .0080000-00
 .7744300-0006-1000001 .0570000-00
 .7852500+0004+1040004 .0180000-00
 .8730000+0008+1040004 .0180000-00
 .8838000-0010-1000001 .0570000-00
 .8901000-0008+1000003 .0080000-00
 .1042900+0114-1000001 .0570000-00
 .1078600+0100+1000002 .0100000-00
  1121680+0104+1000002 .0100000-00
 .1249600+0118-1000001 .0570000-00
 .1949340+0200+1000100 .2010000+00                                    ---> IAS ground state band 0+ Th232
 .1953830+0204+1000100 .2010000+00                                    ---> IAS ground state band 2+
 1.00866520  .5000000-00 .2320000+03 .9000000+02-.5611000+01-.6502000+01
-.0000000+02 .0000000+03 .0000000+00 0.000       .5042000+02 .0097700-00
 .0000000+01-.0000000-00 .0000000+01 .1739000+02 .1056000+02 .1296000-01
 .0000000+01-.0000000-00 .0000000+01 .1172000+02 .8217000+02 .0000000+01
 .5620000+01 .0050000000 .0000000+01-.0000000-00 -3.100      160.
 .1248500+01 .00         .1000000+03 2.00        .6410000-00 .0000000-03
 .1173400+01 .6160000-00 .0000000-02 .1265600+01 .6960000+00 .0000000-02
 .1000000+01 .1000000+01 .0000000-00 .1121400+01 .5900000-00-.0000000-02
 .1277100+01 .00         .1000000+01 .647        1.1         .1000000+01
 .1750000+02 .2900000+02 .0         .0550000+03   0.0        0.0
 0.368         0.0        .02920      -.00170    .002180      0.00330
-0.00029
 .2280000+00 .6100000-01-.5700000-02
 .2070000+00 .7300000-01 .0600000-02
000000000000
00000000000000
00000000000000
0000000000000
0000000000000
0000000000000
000000000000
000000000000
000000000000
00000000000000
0100000000000
0000000000000000     NPJ(I)=0, WITHOUT SEARCH
000000000000
000001000101
 .0000000-00 .0000000-00 .0000000-00 .0000000-00
```

```
 .1000000-03 .8700000-05 .2000000-03 .5000000-04   S0,DS0,S1,DS1
 .1134000+02 .1500000-00 1 1          SCATTERING (R'=9.6fm minus .25barn from thermal to 3keV energy) and uncert.
010000030000
 .7951000+01 .8000000-01 .0000000-00 .0000000-00                            SIGTOT, DSIGTOT, 3.387MEV
010118020216030315
 .2010000+02 .2866800+01 .1749000-00 .3010000+02 .1540100+01 .9580000-01  HAOUT, 0+
 .4020000+02 .3096000-00 .2390000-01 .4520000+02 .1443000-00 .1170000-01
 .5020000+02 .2730000-01 .3400000-02 .6020000+02 .3670000-01 .5400000-02
 .6520000+02 .8420000-01 .8200000-02 .8020000+02 .1135000-00 .1220000-01
 .8520000+02 .1052000-00 .9800000-02 .9020000+02 .8700000-01 .8700000-02
 .1002000+03 .3300000-01 .4200000-02 .1052000+03 .2660000-01 .3600000-02
 .1102000+03 .1030000-01 .1900000-02 .1202000+03 .2100000-02 .7000000-03
 .1302000+03 .5400000-02 .1500000-02 .1402000+03 .1410000-01 .2700000-02
 .1501000+03 .2420000-01 .3700000-02 .1601000+03 .3350000-01 .4400000-02
 .4020000+02 .8160000-01 .9700000-02 .4520000+02 .6130000-01 .6600000-02  HAOUT    2+
 .5020000+02 .4530000-01 .6200000-02 .6020000+02 .3590000-01 .5900000-02
 .6520000+02 .4330000-01 .5100000-02 .8020000+02 .5070000-01 .7400000-02
 .8520000+02 .4970000-01 .5800000-02 .9020000+02 .5230000-01 .5800000-02
 .1002000+03 .3010000-01 .4100000-02 .1052000+03 .1980000-01 .3100000-02
 .1102000+03 .1660000-01 .2800000-02 .1202000+03 .9800000-02 .2100000-02
 .1302000+03 .3400000-01 .4600000-02 .1402000+03 .4240000-01 .5200000-02
 .1501000+03 .2780000-01 .3900000-02 .1601000+03 .1930000-01 .3100000-02
 .4020000+02 .2190000-01 .4500000-02 .4520000+02 .2220000-01 .3500000-02 HAOUT    4+
 .5020000+02 .1580000-01 .3500000-02 .6020000+02 .1220000-01 .3300000-02
 .6520000+02 .9900000-02 .2100000-02 .8020000+02 .9000000-02 .2800000-02
 .8520000+02 .9900000-02 .2200000-02 .9020000+02 .1010000-01 .2600000-02
 .1052000+03 .9700000-02 .2200000-02 .1102000+03 .8400000-02 .2000000-02
 .1202000+03 .6800000-02 .1800000-02 .1302000+03 .6600000-02 .1700000-02
 .1402000+03 .4800000-02 .1500000-02 .1501000+03 .3900000-02 .1300000-02
 .1601000+03 .3100000-02 .1100000-02
010000010000
 .7890000+01 .0900000-00 .0000000-00 .0000000-00                                SIGTOT, DSIGTOT,4.5MEV
010450
.1790000E+02.4880000E+01.1464000E+00.2090000E+02.3947000E+01.1184100E+00   SMITH 0+2+4+6
.2090000E+02.3925000E+01.1177500E+00.2580000E+02.2513000E+01.7539000E-01
.2580000E+02.2379000E+01.7137000E-01.2770000E+02.1976000E+01.5928000E-01
.2880000E+02.1620000E+01.4860000E-01.3080000E+02.1315000E+01.3945000E-01
.3080000E+02.1358000E+01.4074000E-01.3570000E+02.6351000E+00.1905300E-01
.3570000E+02.5979000E+00.1793700E-01.3870000E+02.3293000E+00.9879000E-02
.4370000E+02.1248000E+00.3744000E-02.4670000E+02.7192000E-01.2499939E-02
.4670000E+02.7938000E-01.2499676E-02.5160000E+02.4740000E-01.2499876E-02
.5160000E+02.5529000E-01.2500214E-02.5460000E+02.6062000E-01.2499969E-02
.5910000E+02.7805000E-01.2499942E-02.6210000E+02.9118000E-01.2735400E-02
.6210000E+02.8960000E-01.2688000E-02.6710000E+02.1100000E+00.3300000E-02
```

```
.6710000E+02.1072000E+00.3216000E-02.7010000E+02.1080000E+00.3240000E-02
.7470000E+02.1209000E+00.3627000E-02.7760000E+02.1187000E+00.3561000E-02
.7760000E+02.1177000E+00.3531000E-02.8280000E+02.1062000E+00.3186000E-02
.8280000E+02.1140000E+00.3420000E-02.8560000E+02.1048000E+00.3144000E-02
.9000000E+02.8997000E-01.2699100E-02.9300000E+02.7586000E-01.2500346E-02
.9300000E+02.8032000E-01.2500362E-02.9800000E+02.5515000E-01.2499949E-02
.9800000E+02.5457000E-01.2499852E-02.1010000E+03.4502000E-01.2499961E-02
.1056000E+03.3260000E-01.2500094E-02.1085000E+03.2403000E-01.2499120E-02
.1085000E+03.2516000E-01.2499897E-02.1134000E+03.1989000E-01.2500173E-02
.1210000E+03.3219000E-01.2499875E-02.1239000E+03.3769000E-01.2499978E-02
.1289000E+03.4842000E-01.2499925E-02.1365000E+03.5999000E-01.2499783E-02
.1395000E+03.6337000E-01.2499946E-02.1443000E+03.5314000E-01.2500237E-02
.1473000E+03.4316000E-01.2499827E-02.1493000E+03.4082000E-01.2499817E-02
.1542000E+03.2926000E-01.2499974E-02.1572000E+03.2093000E-01.2499042E-02
01010000000002
 .6260000+01 .0700000-00 .2700000+01 .1500000-00.0040700E+00.0010000E+00       SIGTOT,DSIGTOT, 20MEV
000000050000
 .5950000+01 .1000000-00 .0000000-00 .0000000-00                                 26MEV, TOTAL NOT USED
0101220202140303140404061819l6
.8400000E+01.5791349E+03.1505751E+02.1390000E+02.7846572E+02.2040109E+01   HANSEN 0+
.1740000E+02.2997115E+02.7492786E+00.2370000E+02.7352708E+01.8087978E+00
.2590000E+02.3287341E+01.3287341E+00.3160000E+02.1485318E+01.3713295E-01
.3720000E+02.8010805E+00.4806483E-01.4280000E+02.4317878E+00.4317877E-01
.4880000E+02.1981907E+00.1585525E-01.5490000E+02.8862995E-01.7090396E-02
.6050000E+02.5916556E-01.7691523E-02.6380000E+02.5193624E-01.3635537E-02
.6930000E+02.3921355E-01.3137084E-02.7520000E+02.2289467E-01.2518414E-02
.8120000E+02.1324582E-01.2251790E-02.8930000E+02.7582437E-02.8340681E-03
.1004000E+03.5491729E-02.7139248E-03.1102000E+03.2149645E-02.1719716E-03
.1183000E+03.1496915E-02.1197532E-03.1239000E+03.1261602E-02.1261602E-03
.1294000E+03.1241038E-02.9928303E-04.1411000E+03.6837406E-03.1162359E-03
.3900000E+02.2700000E-01.8100000E-02.4300000E+02.2300000E-01.6900000E-02    HANSEN 2+
.5100000E+02.1340000E-01.2680000E-02.5300000E+02.1020000E-01.2346000E-02
.5700000E+02.8700000E-02.1218000E-02.6600000E+02.8100001E-02.1539000E-02
.7100000E+02.7400000E-02.1406000E-02.7600000E+02.4300001E-02.1204000E-02
.8100000E+02.3300000E-02.6930000E-03.9000000E+02.2400000E-02.5040000E-03
.1040000E+03.1700000E-02.4930000E-03.1230000E+03.7700000E-03.1463000E-03
.1270000E+03.9300000E-03.2046000E-03.1510000E+03.4700000E-03.8930000E-04
.3900000E+02.9100001E-03.2730000E-03.4300000E+02.4600000E-03.1012000E-03    HANSEN 4+
.4800000E+02.5600000E-03.1680000E-03.5300000E+02.4500000E-03.1215000E-03
.6000000E+02.3500000E-03.1015000E-03.6600000E+02.4100000E-03.1189000E-03
.7100000E+02.2900000E-03.6090000E-04.7600000E+02.3400000E-03.8160000E-04
.8100000E+02.2500000E-03.5000000E-04.9500000E+02.2500000E-03.5000000E-04
.1020000E+03.2900000E-03.6090000E-04.1230000E+03.1460000E-03.3942000E-04
.1270000E+03.1800000E-03.3960000E-04.1510000E+03.1040000E-03.2704000E-04
```

```
.7100000E+02.8900001E-04.3560000E-04.9300000E+02.5000000E-04.1000000E-04    HANSEN 6+
.1040000E+03.4200000E-04.1008000E-04.1230000E+03.3100000E-04.5890000E-05
.1300000E+03.3600000E-04.1080000E-04.1510000E+03.2600000E-04.4940000E-05
 3.10000E+00 1.98890E-03 3.67350E-04 8.70000E+00 2.18660E-03 4.28370E-04   16 points HansenU8  [ data in C.M. ]
 1.71000E+01 1.50150E-03 2.27830E-04 2.49000E+01 1.24470E-03 3.45300E-04
 3.11000E+01 1.01270E-03 2.93190E-04 3.96000E+01 1.06220E-03 2.56850E-04
 4.79000E+01 7.50340E-04 2.83120E-04 5.34000E+01 8.64770E-04 2.82270E-04    0+ + 2+ + 4+ (p,n)
 6.19000E+01 7.23720E-04 1.83500E-04 7.02000E+01 3.47500E-04 1.09110E-04
 8.42000E+01 4.28100E-04 1.95800E-04 9.83000E+01 2.70300E-04 1.34930E-04
 1.14600E+02 1.45400E-04 1.08020E-04 1.28900E+02 8.04800E-05 9.37000E-05
 1.45700E+02 1.15280E-04 8.37500E-05 1.61300E+02 7.55700E-05 8.04700E-05
000001000101                                                  Th-232 FROM HERE
 .0000000-00 .0000000-00 .0000000-00 .0000000-00                            2 KeV
 .8700000-04 .5000000-05 .1700000-03 .4000000-04     evaluated strength functions S0, S1
 .1141000+02 .1500000-00 1 1                         evaluated Ro (should be calculated at 10KeV)
010000010000
 .6550000+01 .1400000-00 .0000000-00 .0000000-00                              total 7.0 MeV
010512                                                                        n,el  Batchelor  En=7.0 CM 21019 002
 1.50645E+01 3.88728E+00 7.77457E-01 2.00852E+01 2.00360E+00 4.00719E-01       12 Points
 2.51053E+01 5.45692E-01 1.09138E-01 3.01246E+01 4.04946E-01 8.09892E-02
 4.01601E+01 1.62914E-01 3.25827E-02 5.01908E+01 8.85051E-02 1.77010E-02
 6.02157E+01 5.37664E-02 1.07533E-02 7.52406E+01 1.54653E-01 3.09306E-02
 9.02491E+01 8.30008E-02 1.66002E-02 1.05241E+02 4.40996E-02 8.81992E-03
 1.20216E+02 5.92578E-02 1.18516E-02 1.35176E+02 2.71669E-02 5.43338E-03
 .100000E-02 .100000E-04 .100000E-01 .100000E-03 .100000E-03 .100000E-03
0.0
```

Input for ^{238}U optical model cross-section calculations (no fitting)

```
  0.001-200.000 MeV neutron  on 238U - OMP cross section calculation
0101010020010000000020201010100
01905000600809109015018000l     -->     NUR NST NPD LAS mtet LLMA NCMA NSMA KODMA
  .10000E-02  .50000E-02  .10000E-01  .20000E-01  .40000E-01  .70000E-01
  .10000E+00  .20000E+00  .40000E+00  .70000E+00  .10000E+01  .13000E+01
  .15000E+01  .20000E+01  .30000E+01  .40000E+01  .50000E+01  .60000E+01
  .70000E+01  .80000E+01  .10000E+02  .12000E+02  .14000E+02  .16000E+02
  .18000E+02  .20000E+02  .23000E+02  .26000E+02  .30000E+02  .33000E+02
  .36000E+02  .40000E+02  .45000E+02  .50000E+02  .55000E+02  .60000E+02
  .65000E+02  .70000E+02  .75000E+02  .80000E+02  .85000E+02  .90000E+02
  .95000E+02  .10000E+03  .11500E+03  .13000E+03  .15000E+03  .16000E+03
  .18000E+03  .20000E+03
```

```
0000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000
 .1000000+00 .2000000+01 .4000000+01 .6000000+01 .8000000+01 .1000000+02
 .1200000+02 .1400000+02 .1600000+02 .1800000+02 .2011000+02 .2200000+02
 .2400000+02 .2600000+02 .2800000+02 .3000000+02 .3200000+02 .3400000+02
 .3600000+02 .3800000+02 .4000000+02 .4200000+02 .4400000+02 .4600000+02
 .4800000+02 .5000000+02 .5200000+02 .5400000+02 .5600000+02 .5800000+02
 .6000000+02 .6200000+02 .6400000+02 .6600000+02 .6800000+02 .7000000+02
 .7200000+02 .7400000+02 .7600000+02 .7800000+02 .8000000+02 .8200000+02
 .8400000+02 .8600000+02 .8800000+02 .9000000+02 .9200000+02 .9400000+02
 .9600000+02 .9800000+02 .1000000+03 .1020000+03 .1040000+03 .1060000+03
 .1080000+03 .1100000+03 .1120000+03 .1140000+03 .1160000+03 .1180000+03
 .1200000+03 .1220000+03 .1240000+03 .1260000+03 .1280000+03 .1300000+03
 .1320000+03 .1340000+03 .1360000+03 .1380000+03 .1400000+03 .1420000+03
 .1440000+03 .1460000+03 .1480000+03 .1500000+03 .1520000+03 .1540000+03
 .1560000+03 .1580000+03 .1600000+03 .1620000+03 .1640000+03 .1660000+03
 .1680000+03 .1700000+03 .1720000+03 .1740000+03 .1760000+03 .1780000+03
 .1800000+03
 .0000000-0000+1000000 .2240000+00                                          --->EL(I) JO(I) NPO(I) KO(I), I=1,NUR
 .4491600-0104+1000000 .2240000+00
 .1483800-0008+1000000 .2240000+00
 .3071800-0012+1000000 .2240000+00
 .5181000-0016+1000000 .2240000+00
 .6801100-0002-1000001 .0550000-00
 .7319300-0006-1000001 .0550000-00
 .8266400-0010-1000001 .0550000-00
 .9272100-0000+1000003 .0080000-00
 .9661300-0004+1000003 .0080000-00
 .9663100-0014-1000001 .0550000-00
 .9972300-0000+1000002 .0100000-00
  1037250+0104+1000002 .0100000-00
 .1056380+0108+1000003 .0080000-00
 .1060270+0104+1040004 .0200000-00
 .1150700+0118-1000001 .0550000-00
 .1167990+0108+1040004 .0200000-00
 .1949340+0200+1000100 .2240000+00                                  ---> IAS ground state band 0+ U238
 .1953830+0204+1000100 .2240000+00                                  ---> IAS ground state band 2+ U238
000
 1.00866520  .5000000-00 .2380000+03 .9200000+02-.5479130+01-.6454370+01
-.0000000+02 .0000000+03 .0000000+00 0.000       .5042000+02 .0097700-00
 .0000000+01-.0000000-00 .0000000+01 .1739000+02 .1056000+02 .1296000-01
 .0000000+01-.0000000-00 .0000000+01 .1172000+02 .8217000+02 .0000000+01
 .5620000+01 .0050000000 .0000000+01-.0000000-00 -3.100      160.
 .1248500+01 .00         .1000000+03 2.00        .6410000-00 .0000000-03
```

```
 .1173400+01 .6160000-00 .0000000-02 .1265600+01 .6960000+00 .0000000-02
 .1000000+01 .1000000+01 .0000000-00 .1121400+01 .5900000-00-.0000000-02
 .1277100+01 .00         .1000000+01 .647        1.1         .1000000+01
 .1750000+02 .2900000+02 .0         .0550000+03   0.0        0.0
 0.368         0.0        .02920      -.00170    .002180      0.00330
-0.00029       .238+03
 .2280000+00 .6100000-01-.5700000-02
```

1.3. Running the OPTMAN code and short description of output files

As one runs the code the name of the input file will first be asked. Please note, that input files must have the extension "*inp*", but the user must answer typing the name of the file without extension. The OPTMAN Code now can run in a mode compatible with the EMPIRE nuclear data evaluation system [23]. For this, the user needs to set a logical variable `EMPIRE` = .TRUE. in the OPTMAN source file (optmand.f). In this case the OPTMAN code assumes that the input is stored in the input file called *optman.inp*. Users running the OPTMAN Code in stand-alone mode, can use any desired input file name. After having read the input file in stand-alone mode, the Code assigns the same name for output file $*.out$, in which all the calculations will be stored. While running in EMPIRE mode, the following EMPIRE output files are created: *optman.out*, and *ecis*06.*cs*, *ecis*06.*ics*, *ecis*06.*tl*, *ecis*06.*leg*, and *ecis*06.*ang*. Additionally, the following files are always created: CR-SECT, TRANSME, GNASH, ANG-DIST, ANG-POL. The CR-SECT output file contains one line for each calculated energy. Each line starts with a value of the incident projectile energy, followed by the total, elastic, reaction cross section, and level excitation cross sections ordered by their excitation energies. For proton calculations calculated total and elastic cross-sections include only the nuclear contribution. The TRANSME output file contains l-dependent nucleon transmission coefficients for each calculated energy (averaged over J dependence) to be used for the STAPRE Code [29]. The GNASH output file contains nucleon transmission coefficients for each calculated energy in the format used by the GNASH code [30]. The ANGL-DIST (ANG-POL) output files contain calculated angular distributions (polarization) for all excited levels for energies described by Record 5 at angles distinguished by Record 7 of the input file. For a detailed description of the structure of output files please refer to [21]. In the optical-model parameter search (`MEJOB` = 2), the output files CR-SECT, TRANSME, GNASH, ANGL-DIST and ANGL-POL remain empty. If the number of angles (to do calculations) in the

input file is equal zero (`MTET` = 0), then output files ANGL-DIST and ANGL-POL remain empty even for cross-section calculations (`MEJOB` = 1).

2. SUMMARY

The OPTMAN code has been modernized and integrated into the EMPIRE nuclear data evaluation system. New physical and mathematical ideas have been developed through extensive international cooperation. The current version of the modernized OPTMAN Code was used to find the best fit of optical-model parameters for actinides, Zr, Ta, Mg^{24}, Mg^{26}, C^{12}, Si^{28-30} and Cr^{52}. Some of those potentials have already been used successfully for high energy file evaluation in a cooperative work with our collaborators.

The modernized OPTMAN code is now installed in different computers at the IAEA, JAEA Nuclear Data Center, Tokyo Institute of Technology, and Seville University. A special program producing the OPTMAN input has been developed to directly access the RIPL database of optical model potentials [28]. This guide had been written by the authors of the Code with extensive users' feedback. The manual is available through the IAEA Nuclear Data Section web page as INDC(NDS)-0642 document.

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