Supplement to OPTMAN code, manual Version 10 (2008)

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A coupled-channel code to calculate nuclear cross sections, OPTMAN, has been improved after OPTMAN version 8 was published as JAERI-Data/code 2005-002. The most important addition is the inclusion of dispersive relationships between imaginary and real parts of the optical potential within a Lane consistent formalism. The obtained CCOM potentials allow for the description of nucleon induced reactions up to 200 MeV, including (p,n) reactions with excitation of isobaric analog states. Relativistic corrections consistent with those used in the ECIS06 code are also added.

Keywords: NUCLEAR REACTIONS σ_{tot}, direct (n,n), (n,n'), (p,p), (p,p'), (p,n'), $\sigma_{p,nonel}$, OPTMAN, Soft-rotator and Rigid-rotator Model, Collective level structure, Coupled-channels Method, Lane consistency, Coulomb correction, Isobaric analog states, ISTC B-1319, Theory, Numerical Algorithms, Inputs-outputs.

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OPTMAN コードマニュアル, Version 10 (2008)

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チャンネル結合理論に基づいて原子核の断面積を計算するコード OPTMAN が改良されたのでマニュアルを更新する。重要な変更点はポテンシャルの虚数部と実数部を関係付ける分散関係をレーンモデルに基づいて導入した点である。これによって核子エネルギーで 200 MeV 程度までの断面積を計算することが可能である。また (p,n) アイソバリックアナログ状態への断面積の計算アルゴリズムと、ECIS06 と同様の相対論的補正を導入した。

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1 Introduction

For more than twenty years, an original coupled-channels optical model code OPTMAN[1] has been developed at the Joint Institute of Energy and Nuclear Research to investigate nucleon-nucleus interaction mechanisms and as a basic tool for nuclear data evaluation for reactor design and other applications. Results of such activities for e.g., ^{235}U, ^{239}Pu, ^{236}U, ^{233} U, ^{238}Pu etc., were included in evaluated Nuclear Data Library BROND [2] of former Soviet Union. In addition to standard rigid rotator and harmonic vibrator coupling schemes encoded in widely-used JUPITER [3] and ECIS [4] codes, level-coupling schemes based on a non-axial soft-rotator model are included for the even-even nuclei in OPTMAN. This allows accounting of stretching of soft nuclei by rotations, which results in change of equilibrium deformations for excited collective states compared with that of the ground state. This is a critical point for reliable predictions [5, 6, 7] of the cross-sections based on the coupled-channels method.

OPTMAN had been developed over many years, and used for evaluation of reactor oriented nuclear data. So, originally it was written considering only neutrons as the projectile with possible upper incident energy of about 20MeV[5, 6, 7]. 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 ISTC Project CIS-03-95, financial party of which was Japan. In 1997, the OPTMAN code was installed at Nuclear Data Center of Japan Atomic Energy Research Institute and an active collaboration started. After that time, many new options were added to the code following demands from a broad range of applications: power reactors, shielding design, radiotherapy, transmutations of nuclear wastes, and stellar nucleosynthesis.

Calculations with OPTMAN are now possible both for neutrons and protons as the projectile, and the upper incident nucleon energy is extended to at least 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 with account of nuclear volume conservation. The OPTMAN is now 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 can be also applied very successfully even to light nuclei, for example, ^{12}C[11, 12] and ^{28}Si[13], and medium vibrational nuclei such as ^{52}Cr [14], ^{56}Fe [15, 16] and ^{58}Ni [17]. Later, energy dependence of the optical potential has been continuously improved guided by physical principles. Such features as the high-energy saturation behavior consistent with Dirac phenomenology, Elton and Madland relativistic corrections, and properties stemming from the nuclear matter theory had been taken into consideration. Therefore, OPTMAN already had capabilities applicable for analyses of nucleon interaction with light, medium and heavy nuclei for a wide energy

range, which will be crucially important to fulfill many nuclear data demands.

However, as the code, especially the mathematical algorithms were not described in detail before, and it were still a “black box” for most of the users, it were decided to undertake a complete modernization of the code. During 2001-2004 years currently available theoretical approaches and some new, more accurate advanced mathematical solutions and algorithms had been included in the code. They have resulted in a user-friendly code for complex coupled-channels optical model calculations. A complete OPTMAN code’s manual [1], giving details of the soft-rotator model, physical ideas and computation algorithms developed and incorporated into modernized code, description of input and output files, allowing easy running, understanding and using of OPTMAN outputs had been published in 2005. That manual covered the activity performed under the Project Agreement B-521 with the International Science and Technology Center (Moscow). The Financing Party for the Project was Japan.

After 2004 the main efforts in the development of the OPTMAN code were devoted to the improvement of the optical model formalism. We managed to incorporate dispersion relationships between imaginary and real parts of the optical potential [18], that allow to decrease significantly the number of optical parameters used, making them more physically grounded, that leads to the much better description of experimental data and accurate predictions of small differences in the total cross section along the given isotopic chain [19, 20].

We also extended the OPTMAN code allowing for calculations of the (p,n) cross sections with excitation of isobaric analog states and therefore, making possible to derive Lane consistent potentials including a new Coulomb correction [21]. Finally relativistic generalization used in the OPTMAN code had been made completely consistent with the one used in the latest versions of the ECIS [22] code.

All this modernization of OPTMAN code had been carried within activity performed under the Project Agreement B-1319 with the International Science and Technology Center (Moscow). The Financing Parties for the Project were Japan and European Union, job was requested by JAEA and IAEA.

2 New Options of OPTMAN Code

New developments of the OPTMAN code follow. From now on we will refer to the previous code’s manual [1] as a *MANUAL*.

2.1 Dispersive Optical Potential Incorporated in OPTMAN Code

In this subsection we describe optical potential form used in OPTMAN when dispersive relations between real and imaginary parts of the potential are taken into account. For the non-dispersive potential formulae Eqs. (89)-(93) of the *MANUAL* can be used.

We consider that dispersive potential depending of energy can be written as

$$\begin{aligned} V(r,R(\theta',\varphi'),E) = & -\left\{V_{HF}(E)+\Delta V_R^{Coul}(E)\right\}\times f_{WS}(r,R_R(\theta',\varphi'))+ \\ & -\left[\Delta V_V(E)+\Delta V_V^{Coul}(E)+iW_V(E)\right]f_{WS}(r,R_V(\theta',\varphi')) \\ & -\left[\Delta V_D(E)+\Delta V_D^{Coul}(E)+iW_D(E)\right]g_{WS}(r,R_D(\theta',\varphi')) \\ & +\left(\frac{\hbar}{m_\pi c}\right)^2\left[V_{so}(E)+\Delta V_{so}(E)+iW_{so}(E)\right]\times\frac{1}{r}\frac{d}{dr}f_{WS}(r,R_{so})\left(\hat{\sigma}\cdot\hat{L}\right) \\ & +V_{Coul}(r,R_c(\theta',\varphi')) \end{aligned} \quad (1)$$

where the first term is the real smooth, so called Hartree-Fock (HF), volume potential. Successive complex-valued terms are the volume, surface and spin-orbit potentials, all containing the corresponding dispersive contributions $\Delta V_V(E), \Delta V_D(E)$ and $\Delta V_{so}(E)$. It is known that the energy dependence of the depth $V_{HF}(E)$ is due to the replacement of a microscopic nonlocal HF potential by a local equivalent. For a Gaussian non-locality, $V_{HF}(E)$ is a linear function of E for large negative E and is an exponential for large positive E. Following Mahaux and Sartor [23], the energy dependence of the smooth HF part of the nuclear mean field is taken as that found by Lipperheide [24], accounting the isospin dependence [25]: $V_{HF}(E) = V_R^{DISP}\left[1+(-1)^{Z'+1}\frac{C_{viso}}{V_R^{DISP}}\frac{N-Z}{A}\right]\exp(-\lambda_R(E-E_F))$. Apart from the standard prescription for the Coulomb correction already discussed as Eq. (94) in *MANUAL*, a new procedure has been now incorporated, which will be discussed in a later section. Similar Coulomb correction terms $\Delta V_V^{Coul}(E)$ and $\Delta V_D^{Coul}(E)$ are also calculated for volume $\Delta V_V(E)$ and surface $\Delta V_D(E)$ dispersive contributions to the real potential. The geometrical form factors are given as

$$f_{WS}(r,R_i(\theta',\varphi')) = \left\{1+\exp\left[\frac{r-R_i(\theta',\varphi')}{a_i}\right]\right\}^{-1}, \qquad i=R,V,so \quad (2)$$

$$g_{WS}(r,R_D(\theta',\varphi')) = -4a_D\frac{d}{dr}f(r,R_D(\theta',\varphi'))$$

where $R_i(\theta',\varphi')$ denotes the deformed radii with the deformations considered, while spin-orbit potential is considered to be not deformed. The Coulomb potential $V_{Coul}(r,R_c(\theta',\varphi'))$ was calculated using a multipole expansion of a charged ellipsoid with uniform charge density within the Coulomb radius R_c and zero outside as suggested by Bassel *et al.* [26]. The spherical term of the Coulomb potential was calculated by taking account of the diffuseness of the charge density distribution of the form $f_c = \left[1+\exp\left(r-R_c^0\right)/a_c\right]^{-1}$ [27].

In our formulation of the OMP in Eq.(1) the geometrical parameters of the Hartree-Fock potential R_R and a_R are in general different from the geometrical parameters R_V, a_V, R_D, a_D of the volume and surface absorptive potentials; but the real and imaginary spin-orbit terms share the same R_{so} and a_{so} parameters. Therefore the volume dispersive contribution has different geometry (determined by R_V and a_V) from the real smooth volume potential (determined by R_R and a_R). As a result we have two separate volume contributions to the potential (as can be seen in the first and second line of Eq.(1)), effectively giving us more flexibility for the fitting of the experimental data. The present optical potential includes relativistic corrections as discussed by Elton [28] and explained in our recent paper [18].

It is useful to represent the variation of surface $W_D(E)$ and volume absorption potential $W_V(E)$ depth with energy in functional forms suitable for the dispersive optical model analysis. A commonly used energy dependence for the imaginary-surface term has been suggested by Delaroche *et al.* [29],

$$W_D(E) = A_D \frac{(E-E_F)^2}{(E-E_F)^2 + WID_D^2} \exp(-\lambda_D(E-E_F)). \tag{3}$$

An alternative energy dependence for the imaginary-surface term has been used by Charity *et al.* [30],

$$W_D(E) = A_D \left[\frac{(E-E_F)^2}{(E-E_F)^2 + WID_D^2} - \frac{(E-E_F-E_{SHIFT})^2}{(E-E_F-E_{SHIFT})^2 + WID2_D^2} \Theta(E-E_F-E_{SHIFT}) \right], \tag{4}$$

where $\Theta(X)$ is Heaviside's step function, being non-zero if $X > 0$. One can see that contrary to Delaroche *et al.* [29] and *MANUAL* formulae (90) for which surface potential term had been decreasing exponentially, now as an option, it can decrease as the difference of two Breit-Wigner terms with the same height, but shifted by energy which could allow a better fit in some cases.

The isospin dependence of the surface and volume potential terms (the Lane term [25]) was considered in imaginary surface $W_D(E)$ and volume $W_V(E)$ potentials as follow,

$$A_{D,V} = W_{D,V}^{DISP} \left[1 + (-1)^{Z'+1} \frac{C_{wiso,wviso}}{W_{D,V}^{DISP}} \frac{N-Z}{A} \right]. \tag{5}$$

An energy dependence for the imaginary volume term has been suggested in studies of nuclear matter theory by Brown and Rho [31]:

$$W_V(E) = A_V \frac{(E-E_F)^2}{(E-E_F)^2 + (WID_V^{DISP})^2}. \tag{6}$$

The assumption that the imaginary potential $W(E)$ is symmetric about $E' = E_F$ is plausible for small values of $|E' - E_F|$. However, as was pointed out by Mahaux and Sartor [23] this approximate symmetry no longer holds for large values of $|E' - E_F|$. In fact the influence of the nonlocality of the imaginary part of the microscopic mean field will produce an increase of the empirical imaginary potential $W(E')$ at large positive E' and approaches zero at large negative E' [32, 33].The

DOM analysis of neutron scattering on ^{27}Al [34] and ^{232}Th [18] showed the importance of the non-local contribution to describe total cross-section σ_T data for energies above 100 MeV using a non-symmetric version of the volume absorptive potential for large positive and large negative energies. Following Mahaux and Sartor [23], we assume that the absorption strengths are only modified outside some fixed energy interval around the Fermi energy $[E_F - E_a, E_F + E_a]$. They used $E_a = 60$ MeV, however this value is fairly arbitrary [23] and we will use it as a fitting parameter. Let us assume that the non-local imaginary potential to be used in the dispersive integral is denoted by $\widetilde{W}_v(E)$, then we can write [35]

$$\widetilde{W}_V(E) = W_V(E) - W_V(E)\frac{(E_F - E - E_a)^2}{(E_F - E - E_a)^2 + E_a^2}, \text{ for } E < E_F - E_a, \tag{7}$$

and

$$\widetilde{W}_V(E) = W_V(E) + \alpha\left[\sqrt{E} + \frac{(E_F + E_a)^{3/2}}{2E} - \frac{3}{2}\sqrt{(E_F + E_a)}\right], \text{ for } E > E_F + E_a. \tag{8}$$

These functional forms are chosen in such a way that the function and its first derivative are continuous at $E' = |E_F - E_a|$. At large negative energies the volume absorption decreases and goes asymptotically to zero. On the contrary, at large positive energies nucleons sense the "hard core" repulsive region of the nucleon-nucleon interaction and $\widetilde{W}_V(E)$ diverges like $\alpha\sqrt{E}$. Using a model of a dilute Fermi gas hard-sphere the coefficient α was estimated to be equal to 1.65 MeV$^{1/2}$ by Mahaux and Sartor[33], assuming that the Fermi momentum k_F is equal to 1.36 fm^{-1}and that the radius of the repulsive hard core is equal to 0.4 fm. However, as pointed out by Charity *et al* [30], the value of this quantity is not constrained theoretically and they obtained α values ranging from 0 to 2.2 MeV$^{1/2}$. With some other assumptions α can be as small as 0.3, so we decided to keep this parameter adjustable.

2.1.1 Dispersive corrections

In a dispersive relation treatment, the real potential strength consists of the Hartree-Fock term $V_{HF}(\mathbf{r}, E)$ which varies slowly with energy, and a correction term $\triangle V(\mathbf{r}, E)$ calculated using a dispersion relation. Under favorable conditions of analyticity in the complex E-plane the real part ΔV can be constructed from the knowledge of the imaginary part W on the real axis through the dispersion relation

$$\Delta V(\mathbf{r}, E) = \frac{\mathcal{P}}{\pi}\int_{-\infty}^{\infty}\frac{W(\mathbf{r}, E')}{E' - E}dE', \tag{9}$$

where we have now explicitly indicated the radial and energy dependence of these quantities and $\mathcal{P}$ means that the principal value of the integral should be taken. To simplify the problem, the geometry of the imaginary terms of the OMP are usually assumed to be energy-independent. They are expressed in terms of a Woods-Saxon function $f_{WS}(r, R_i(\theta', \varphi'))$ or its derivative $g_{WS}(r, R_i(\theta', \varphi'))$.

In such case the radial functions factorize out of the integrals and the energy-dependence is completely accounted for by two overall multiplicative strengths $\Delta V(E)$ and $W(E)$. Both of these factors contain, we note, volume and surface contributions. The dispersive treatment employed in this work to calculate dispersive contributions $\Delta V_V(E)$, $\Delta V_D(E)$ and $\Delta V_{so}(E)$ was described in detail in ref. [18], so we refer interested readers to these contributions. Details of numerical and analytical methods incorporated in the OPTMAN code to calculate dispersive contributions are thoroughly described in original references [36, 37, 38]

2.2 Changes in Relativistic Generalization of Non-Relativistic Schrödinger Equation Consistent with One used in ECIS Code

The OPTMAN code already included relativistic generalization and in the present version we decided to make it consistent with what is coded in the ECIS [4] code. Let us define that the total relativistic energy of the projectile E_p^t is

$$E_p^t = E_p + m_p c^2,$$

so we can determine the relativistic factor γ for projectile

$$\gamma = \frac{E_p + m_p c^2}{m_p c^2},$$

and its momentum as

$$p_p^2 c^2 = E_p^{t2} - m_p^2 c^4 = (\gamma^2 - 1) m_p^2 c^4.$$

Assuming an interacting target at rest with mass M, the total energy of the interacting system is

$$E_{tot} = E_p + m_p c^2 + M c^2 = \gamma m_p c^2 + M c^2.$$

Now we can determine the velocity of the *CM* (center-of-mass) in the laboratory frame

$$V_{CM} = \frac{p_p c^2}{E_{tot}},$$

so that using relativistic factor γ

$$V_{CM}^2 = \left(\frac{p_p c^2}{E_{tot}}\right)^2 = \frac{(\gamma^2 - 1) m_p^2 c^6}{(\gamma m_p c^2 + M c^2)^2} = \frac{(\gamma^2 - 1) m_p^2 c^2}{(\gamma m_p + M)^2}.$$

Using Lorentz transformations, we can easily find momentum p of interacting particle and target (they are opposite and equal in *CM*), assuming that the momentum of the target in Lab.system vanishes

$$p = \frac{V_{CM}/c^2 M c^2}{\sqrt{1 - V_{CM}^2/c^2}} = \frac{V_{CM} M}{\sqrt{1 - V_{CM}^2/c^2}},$$

and

$$\begin{aligned} p^2 &= \frac{V_{CM}^2 M^2}{1 - V_{CM}^2/c^2} = \frac{(\gamma^2-1)m_p^2c^2}{(\gamma m_p + M)^2} M^2/(1 - \frac{(\gamma^2-1)m_p^2c^2}{(\gamma m_p + M)^2 c^2}) \\ &= \frac{(\gamma^2-1)m_p^2c^2M^2}{(2\gamma m_p M + M^2 + m_p^2)}. \end{aligned}$$

Relativistic interacting particle wave number is $k^2 = \left(\frac{p}{\hbar}\right)^2$, so energies of interacting particle and target in the *CM* system are

$$\begin{aligned} E_{p,CM}^2 &= p^2c^2 + m_p^2c^4 = m_p^2c^4 \frac{\gamma^2M^2 + 2\gamma m_p M + m_p^2}{2\gamma m_p M + M^2 + m_p^2}, \\ E_{M,CM}^2 &= p^2c^2 + M^2c^4 = M^2c^4 \frac{\gamma^2 m_p^2 + 2\gamma m_p M + M^2}{2\gamma m_p M + M^2 + m_p^2}. \end{aligned}$$

Above we considered $p = p_p = p_M$ in the *CM*; in the OPTMAN code we use these energies instead of masses in reduced mass formulae:

$$\frac{E_{p,CM}E_{M,CM}}{E_{p,CM} + E_{M,CM}} = m_p M c^2 \frac{\sqrt{[\gamma^2M^2 + 2\gamma m_p M + m_p^2][\gamma^2 m_p^2 + 2\gamma m_p M^2 + M^2]/[2\gamma m_p M + M^2 + m_p^2]}}{\left\{m_p\sqrt{\gamma^2M^2 + 2\gamma m_p M + m_p^2} + M\sqrt{\gamma^2 m_p^2 + 2\gamma m_p M + M^2}\right\}}. \quad (10)$$

So we found necessary formulas for incident particle wave number and reduced mass of the particle + zero velocity target in terms of relativistic factor γ and masses in relativistic case. The corresponding energy of the system E_{CM} in the *CM* system is

$$\begin{aligned} E_{CM} &= E_{p,CM} + E_{M,CM} \\ &= \frac{m_pc^2[\gamma^2M^2 + 2\gamma m_p M + m_p^2]^{1/2} + Mc^2[\gamma^2 m_p^2 + 2\gamma m_p M + M^2]^{1/2}}{\left[2\gamma m_p M + M^2 + m_p^2\right]^{1/2}}. \end{aligned}$$

The kinetic energy E is equal to the *CM* energy minus the rest mass of the components:

$$\begin{aligned} E &= E_{CM} - m_pc^2 - Mc^2 \\ &= \Big\{m_pc^2([\gamma^2M^2 + 2\gamma m_p M + m_p^2]^{1/2} - [2\gamma m_p M + M^2 + m_p^2])^{1/2} \\ &\quad + Mc^2\,([\gamma^2 m_p^2 + 2\gamma m_p M + M^2]^{1/2} - [2\gamma m_p M + M^2 + m_p^2])^{1/2}\Big\}/[2\gamma m_p M + M^2 + m_p^2]^{1/2}. \end{aligned}$$

Following Elton's suggestions [28], we can multiply optical potential strengths (except for the spin-orbit and Coulomb terms) by a factor $K(E)$, as a relativistic optical potential generalization arising from the reduction of the Dirac equation to the corresponding Schroedinger equation for non-relativistic target and relativistic projectile. Elton suggests $K(E)$ to be $E/(M_pc^2)$. Therefore, the factor grows without limit as the projectile kinetic energy E grows. We defined this factor as suggested by Madland [39], namely $K(E) = 2E/(E + M_pc^2)$, which saturates at 2 as incident energy grows, and allows easier fitting of experimental data. This factor is optional and controlled by the input key `MEREL` (see below).

2.3 Lane consistency of the OMP and excitation of the Isobaric Analog States (IAS)

An isospin-dependent coupled channel optical model potential, can be used to predict quasi-elastic (p,n) scattering to the isobaric analogue states (IAS) of the target nucleus; being such exercise the best test of the quality of the isovector part of the optical potential. It has been pointed out by Lane [25] that the optical model potential can be written in a charge-independent form. The extent to which we can state that a derived optical model potential is *Lane-consistent* can be established from the basic Lane equations [25]:

$$
\begin{aligned}
V_{pp} &= V_0 + \frac{N-Z}{4A}V_1, \\
V_{nn} &= V_0 - \frac{N-Z}{4A}V_1, \\
V_{pn} &= \frac{\sqrt{N-Z}}{2A}V_1,
\end{aligned}
\tag{11}
$$

where V_0 and V_1 are the isocalar and isovector components of the potential with the Coulomb interaction switched off, respectively. In such way one is able to calculate the charge-exchange channels in a (p,n) reaction (to the *elastic IAS* and excited states of the rotational band of the residual nucleus).

An accurate calculation of the nucleon scattering from deformed nuclei must include the coupling to the low-lying collective states. A very successful computational method to account for the importance of the multistep processes is the coupled-channel (CC) method using Tamura's formalism [3], which permits an exact solution of the Lane CC equations. The Coulomb displacement energy, Δ_C, between the ground state and its corresponding IAS is well approximated by the empirical relation [40], $\Delta_C = 1.444Z/A^{1/3} - 1.13$ MeV, with Z being equal the average charge of the target and residual nuclei in the reaction. As an example for actinide targets, the value of Δ_C is about 20 MeV. The coupling form-factors for the charge-exchange calculations are defined as

$$
\begin{aligned}
&< \nu; 0^+_{IAS}|V(\tau,\vec{r})|\pi; 0^+_{gs} > \\
&=< \nu|\mathcal{T}|\pi >< 0^+_{IAS}|V_1^{diag}(r)|0^+_{gs} > \\
&= \frac{\sqrt{(N-Z)}}{2A} < 0^+_{IAS}|V_1^{diag}(r)|0^+_{gs} >,
\end{aligned}
\tag{12}
$$

for the "quasi-elastic" $0^+_{gs} \rightarrow 0^+_{IAS}$ excitation of the IAS, as a particular case of

$$
\begin{aligned}
&< \nu; I^+(\text{residual})|V(\tau,\vec{r})|\pi; I^+(\text{target}) > \\
&=< \nu|\mathcal{T}|\pi >< I^+(\text{residual})|V_1(\vec{r})(|I^+(\text{target}) > \\
&= \frac{\sqrt{(N-Z)}}{2A} < I^+(\text{residual})|V_1(\vec{r})|I^+(\text{target}) >,
\end{aligned}
\tag{13}
$$

for the coupling between analog states of both rotational bands, and

$$
\begin{aligned}
&< \nu; I^{+\prime}(\text{residual})|V(\tau,\vec{r})|\pi; I^{+}(\text{target}) > \\
&=< \nu|\mathcal{T}|\pi >< I^{+\prime}(\text{residual})|V_1^{coupl}(\vec{r})(|I^{+}(\text{target}) > \\
&= \frac{\sqrt{(N-Z)}}{2A} < I^{+\prime}(\text{residual})|V_1^{coupl}(\vec{r})|I^{+}(\text{target}) >,
\end{aligned} \tag{14}
$$

for the coupling between $I' \neq I$ states. In these expressions $\mathcal{T}$ is the isospin operator, ν and π represent the entrance and exit isospin states of projectile and ejectile, respectively, and $V_1^{diag}(r)$ and $V_1^{coupl}(\vec{r})$ are the usual spherical and deformed components of the isovector potential, as defined in the Tamura's *canonical* work [3]. These expression have been implemented into the OPTMAN code allowing to directly calculate the quasi-elastic scattering cross-section or to consider existing IAS scattering data during the optical potential fitting. In this way the isovector component of the potential is much better constrained.

By the moment calculations of IAS excitations in OPTMAN are possible for coupling built on rigid rotator wave functions (rotational model) only, but it will be also possible for soft rotator option of OPTMAN soon.

2.4 Lane Consistent Coulomb Correction Option

The Coulomb correction used for incident charged particles are well established. In the OPTMAN code, the Coulomb correction is applied for incident protons to account for the change of the interacting proton energy due to the Coulomb repulsion by nucleus. In the previous OPTMAN versions such corrections were assumed either as an energy-independent constant to be added to the real potential or as the value proportional to the derivative of the real potential:

$$\Delta V_R^{Coul}(E) = -C_{Coul}\frac{ZZ'}{A^{1/3}}\frac{d}{dE}(V_R(E)). \tag{15}$$

One can see, that such correction is just the first term of Taylor expansion of the proton potential accounting for the Coulomb repulsion, assuming that the "effective" interacting energy of the proton is $E - C_{Coul}\frac{ZZ'}{A^{1/3}}$. It should be noted that constant e^2 in our definition is included in constant C_{Coul}. In fact, the term $C_{Coul}\frac{ZZ'}{A^{1/3}}$ is an estimation of the kinetic energy loss of the incident proton in the interaction region due to the Coulomb repulsion[41]. Indeed, the optical potential at this "effective" energy becomes

$$V(E - C_{Coul}\frac{ZZ'}{A^{1/3}}) = V(E) - C_{Coul}\frac{ZZ'}{A^{1/3}}\frac{d}{dE}(V_R(E)) + ... \tag{16}$$

Above formula (16) is a generalization of the previously used Coulomb correction, which considers such corrections in all orders. It has been included in the OPTMAN code by using the "effective"

energy $E - C_{Coul}\frac{ZZ'}{A^{1/3}}$ for incident protons instead of the physical incident energy E. The constant C_{Coul} is an adjustable constant meant to account for the "effective" radius of interaction of proton in nucleus. It is expected to be near one. It should be noted that full Coulomb correction as defined by [16] is a pre-condition to the exact Lane consistency of the derived OMP.

3 Changes in OPTMAN Code Inputs Due to New Options

We describe changes in the input data of OPTMAN code following *MANUAL* notations [1]. Units of the data are MeV, fm, barn and amu (Carbon units). Data have card image form and we'll show below only those Records changed due to new options, the other Records will not be described.

3.1 Description of the Input Records, that had been Changed

- Record 2 - FORMAT(16I2)

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

  Two new switches `MEDIS` and `MERIP` describing the models options had been added.

  - `MEJOB` = 1 - optical calculations, = 2 - adjustment of optical potential parameters;
  - `MEPOT` = 1 -rotational model potential, =2 - potential expanded by derivatives (must be used for soft-rotor potentials);
  - `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 growing ;
  - `MESOL` = 1 - code will choose which method of coupled channels system solution for a certain J^{π} should be used to reduce calculation time, = 2 - exact solution, =3 - solution using iterations, with spherical solutions as zero approximation, $>$3 - solution using iterations, with exact coupled channels solution with the 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.[42]), = 4 - rigid hexadecapole deformations in the most general case [42] ;

- 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[43] , =2 - common case[44] , 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 the derivative of real potential dependence (*MANUAL* Eq. (94)), = 1 - Coulomb correction is energy independent and applied to real potential, =2 - Lane consistent Coulomb correction with "effective" interacting proton energy equal $E - C_{Coul}\frac{ZZ'e^2}{A^{1/3}}$ (Eq. (16)), applied to real and imaginary potentials, excluding SO potential, =3 - same change of "effective" interacting proton energy as for MECUL=2, is applied only to real potential;
- MERZZ = 0 - charge radius is considered constant, = 1 - charge radius is considered energy dependent (*MANUAL* Eq. (96));
- MERRR = 0 - real potential radius is considered constant, = 1 - charge radius is considered energy dependent (*MANUAL* Eq. (95));
- MEDIS = 0 - without account of dispersion relationships between real and imaginary potential terms, = 1 - with account of dispersion relationships between all real and imaginary potentials terms, =2 - with account of dispersion relationships between all real and imaginary potentials terms, excluding SO potential;
- MERIP = 0 - for CS calculation option (MEJOB = 1) potential parameters are read only at one energy and the potential is calculated for all other energies analytically, =1 - for CS calculation option (MEJOB = 1) code reads potential blocks for each requested energy, this option is used in the RIPL [45] interface. If MEJOB = 2 (adjustment) MERIP is not used.

- Record 8 - FORMAT(E12.7,4I2) for MEHAM = 1, FORMAT(E12.7,7I2) for MEHAM $>$ 1

Characteristics of nuclear levels, NCA(I) -partition level characteristic is added.

(EL(I), JO(I), NPO(I), KO(I), NCA(I), I=1,NUR) - Cards 8a, 8b, .. for MEHAM =1

(EL(I), JO(I), NPO(I), NTU(I), NNB(I), NNG(I), NNO(I), NCA(I), I=1,NUR) - Cards 8a, 8b, .. for MEHAM > 1

- EL(I) -energy of the Ith level;
- 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) - key determining partitions: = 0 for levels of interacting nuclei, =1 - for isobaric analog levels of $A(N-1, Z+1)$ excited in $p + A(N, Z) \rightarrow n' + A(N-1, Z+1)$ reaction.

- Record 10 - FORMAT(6E12.7)

Optical potential parameters, for details see Section 6 of the MANUAL. New potential parameters are added to the card 10i and one more card 10j is added to the potential input card

VR0, VR1, VR2, VR3, VRLA, ALAVR - card 10a

- 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 10b

- 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 10c

- 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 10d

- 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 10e

- 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 10f

- 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 10g

- 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 10h

- 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, WDISO, EA, WDSHI, WDWID2 - card 10i

- CISO - constant for real potential isospin term C_{viso};
- WCISO - constant for imaginary surface potential isospin term C_{wiso};
- WDISO - constant for imaginary volume potential isospin term C_{wviso}
- EA - energy constant E_a at which symmetry of volume absorption potential is broken;
- WDSHI - energy shift constant E_{SHIFT} for surface potential formulae;
- WDWID2 - width of the second Breit-Wigner component in the imaginary surface potential

ALFNEW,VRD - card 10j

- ALFNEW - non-locality constant α in Eq.(7,8);
- VRD - constant not in use by the moment, will be used to create bottle-neck shape of the real potential at high incident energies

This block of potential parameter cards should be repeated NST times if MERIP = 1, as than these parameters for each energy should be created by RIPL interface.

Below are the changes in input cards that are used when potential parameters adjustment is desired (MEJOB = 1).

- Record 12 - FORMAT(6I2)

  Input of flags that determine which parameters will be adjusted; if NPJ(I) = 1 the chosen parameters will be adjusted. The number of the parameters to be adjusted must not exceed 20. The adjustment of optical model parameters WDSHI,WDWID2,ALFNEW and VRD is added in this code's version. Please note that the sequence of inputted flags follows the sequence of optical potential parameters for users convenience. Please also note that comparing with *MANUAL* version NPJ(51) was changed to NPJ(56). We show below the sequence of all NPJ(I) with adjusted parameters.

  (NPJ(I), I=1,64) cards 12a,...12k

  - 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_{wviso} adjustment WDISO;
- NPJ(52) - flag for energy constant E_a at which symmetry of volume absorption potential is broken adjustment EA;
- NPJ(53) - flag for energy shift constant E_{SHIFT} for surface potential formulae adjustment WDSHI;
- NPJ(54) - flag for width of the second BW component in imaginary shape potential adjustment WDWID2;
- NPJ(55) - flag for constant α in Eq.(7,8) adjustment ALFNEW;
- NPJ(56) - flag for constant that later, will be used to create bottle shape of the real potential at high incident energy adjustment VRD;
- NPJ(57) - flag for equilibrium deformation β_{20} for non-axial Hamiltonian model adjustment BET0;
- NPJ(58) - flag for equilibrium deformation β_{30} for non-axial Hamiltonian adjustment BET3;
- NPJ(59) - flag for rigid deformation β_4 for non-axial Hamiltonian model adjustment BET4;
- NPJ(60) - flag for rotational model axial rigid deformation β_{20} adjustment BET(2);
- NPJ(61) - flag for rotational model axial rigid deformation β_{40} adjustment BET(4);
- NPJ(62) - flag for rotational model axial rigid deformation β_{60} adjustment BET(6);
- NPJ(63) - flag for nuclear softness $\mu_{\beta_3} = \mu_\epsilon$ adjustment AMUO;
- NPJ(64) - flag for nuclear softness μ_{γ_0} adjustment AMG0.

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

This is the last card in input.

3.2 Example of Input File

We discuss a test input for a rigid rotator case with potential adjustment. Differences between adjustment and cross section calculations options and between rigid and soft rotator options of the code are the same as in the previous version of the code and are well described in *MANUAL*.

3.2.1 Input for the Rigid-rotator Model

Here one can find a description of an actual input file that was used for adjustment of ^{181}Ta optical model parameters, which is attached below.

- Card 1 - text information about code running.
- Card 2 - defines that a run with adjustment of optical potential parameters (MEJOB=2) for rigid-rotator CC-model (MEPOT=1) is given; the rotational model nuclear Hamiltonian will be used to determine coupling (MEHAM=1); output will be the shortest possible (MEPRI=0); code will use accurate ten channels coupled solution as zero approximation for iteration method for coupled equations system solution (MESOL=10); switches MESHA, MESHO, MEHAO are set to zero, but will be ignored as MEPOT=1; energy dependence of optical potential in different channels caused by energy losses due to levels excitation will be ignored in this run (MEAPP=0); MEVOL is set zero, but will be ignored as MEPOT=1; relativistic generalization will be taken into account by relativistic kinematics, but potential would not be multiplied by $K(E)$ factor (MEREL=2); Coulomb correction will be taken by using "effective energy decrease due to proton repulsion by nuclei for a real potential only (MECUL=3); Coulomb and real potential radii will be considered energy independent (MERZZ= MERRR=0); with account of dispersion relationships between all real and imaginary potentials terms (MEDIS=1); MERIP=1 key is ignored as (MEJOB=2).
- Card 3 - defines that eight levels are coupled (NUR=8); potential will be adjusted using experimental data at one energy point simultaneously (NST=1); the highest order L for radius deformation expansion is chosen to be equal 6 (NPD=6); resulting optical potential will be expanded up to Y_{80} spherical harmonic (LAS=8); MTET is set zero, but will be ignored as MEJOB=2, waves with angular momentum greater than 50 will be ignored (LLMA=50); coupling of no more than 100 equations will be taken into account, other ignored (NCMA=100); no more than 100 J^{π} states ordered by increasing J will be taken into consideration (NSMA=100); coupled equations will be ordered one by one, starting with the first level, then the second and so on (KODMA=0).
- Card 4 - one energy, as it was stated in Card 3 (NST=1), in which adjustment of optical potential to experimental data will be organized in the code.
- Card 5 - one MCHAE(I) flag (NST=1 in Card 3), in our case equal 1 (experimental data for incident proton).
- Cards 6-13 - excitation energies and quantum numbers of the height levels (NUR=8 in Card 3) that should be coupled first four levels are from ^{181}Ta GS rotational band (NCA(1-4)=0) and

four levels from fifth to eighth are isobaric analog states of ^{181}W (NCA(5-8)=1).

- Card 14 - quantities of incident particle and interacting nucleus.
- Cards 15-24 - starting set of optical potential parameters, even in case some values of the potential are equal to zero their radii and diffuseness must be set non-zero.
- Card 25 - β_2 , β_4 and β_6 as defined by NPD=6 on Card 3.
- Cards 26 -36 - NPJ(I) values; in our case only NPJ(49), NPJ(55) and NPJ(61) are equal 1: CISO , a constants and β_{40} deformation are to be adjusted in this run.

Next cards 37-55 apply to the experimental data used for adjustment at the first energy point.

- Card 37 - information about experimental data at the first experimental energy point (E_n=27 MeV), that will be used in optical parameters adjustment; total cross section is not used in adjustment at this energy point (NT(1)=0); reaction cross section is not used in adjustment at this energy (NR(1)=0); no experimental integral scattering cross section with excitation of a group of levels will be used for adjustment (NGN(1)=0), while one group of angular distributions (NGD(1)=1); strength functions S_0 and S_1 will not be adjusted at this energy (NSF1(1)=NSF2(1)=0).
- Card 38 - total and reaction cross sections and their errors at first energy; as NT(1) and NR(1) are equal to zero so this card is blank.
- Card 39 - information about experimental angular distributions: initial and final excited levels of the group and number of experimental angles (NID(1,K)=5, NFD(1,K)=8, MTD(1,K)=32, K=1); in our case NID and NFD do not coincide, it means that experimental angular distributions present excitation of a group of levels from fifth to eighth (isobaric analog states levels.
- Cards 40-55 - experimental angular distributions as angle, data, error. .
- Card 56 -three values of absolute accuracies for adjusted parameters as defined by NPJ(I) in Cards 26-36.
- Card 57 - zero (initial χ^2 is unknown).

The actual rigid-rotator input file for adjustment of ^{181}Ta optical model parameters using experimental angular distribution of emitted neutrons in the $p + {}^{181}Ta \rightarrow n' + {}^{181}W$ reaction

```
 Ta-181  rigid -dispersive
0201010010000000000020300000101
0080010060080000050100100000   NUR NST NPD LAS MTET LLMA NCMA NSMA KODMA
 0.270000+02
01
0.0000000-0007+10700     LEVELS OF Ta-181
0.1362660-0009+10700     EL(I),JO(I),NPO(I),KO(I),NCA(I)
0.30162  -0011+10700
0.49519  -0013+10700
1.7630000+0107+10701     IOS LEVELS OF W-181
1.7796266+0109+10701     EL(I),JO(I),NPO(I),KO(I),NCA(I)
1.7931620+0111+10701
1.8125190+0113+10701
 1.00866520  .5000000-00 .1810000+03 .7300000+02-.6819980+01-.6517450+01
-.0000000+02 .0000000+00 .0000000+00 .1080000+01 .5030000+02 .9130000-02
 .0000000+01-.0000000-00 .0000000+01 .2213500+02 .1469000+02 .0961000-01
 .0000000+01-.0000000-00 .0000000+01 .1076000+02 .8384000+02 .0000000+01
 .6040000+01 .0050000000 .0000000+01-.0000000-00 -3.10 0      160.
 .1239450+01 .00         .1000000+03 2.00        .6295000-00 .0000000-03
 .1240000+01 .5085000-00 .0000000-02 .1077100+01 .6870000+00 .0000000-02
 .1000000+01 .1000000+01 .0000000-00 .1129300+01 .5900000-00-.0000000-02
 .1062600+01 .00         .1000000+01 .640         1.3300     .1000000+01
 .2100000+02 .2940000+02 .0000000+03 052.0        500000.    .0
 1.080000+00 .0
 0.251000+00-0.07900E-00-0.50000E-01
000000000000
000000000000
000000000000
000000000000
000000000000
000000000000
000000000000
010000000000
010000000000
01000000
000000010000      p,n data from here !!!!!!!!
 .0000000+01 .0000000-01 .0000000-00 .0000000-00      27MeV, No total
050832
 2.50000E+00 1.46000E-03 3.65000E-04 7.90000E+00 1.82000E-03 4.55000E-04
 1.61000E+01 2.10000E-03 5.25000E-04 2.44000E+01 2.30000E-03 5.75000E-04
 3.26000E+01 2.40000E-03 6.00000E-04 3.83000E+01 1.59000E-03 3.97500E-04
 4.66000E+01 1.03000E-03 2.57500E-04 5.50000E+01 8.90000E-04 2.22500E-04
 6.24000E+01 7.40000E-04 1.85000E-04 7.16000E+01 6.10000E-04 1.52500E-04
 8.57000E+01 2.30000E-04 5.75000E-05 9.94000E+01 2.30000E-04 5.75000E-05
 1.16100E+02 1.30000E-04 3.25000E-05 1.29900E+02 1.09000E-04 2.72500E-05
```

```
47   1.46400E+02 1.40000E-04 3.50000E-05 1.60200E+02 1.17000E-04 2.92500E-05
48   8.60000E+00 2.01000E-03 2.61300E-04 1.66000E+01 1.54000E-03 1.54000E-04
49   1.67000E+01 1.30000E-03 5.20000E-04 2.41000E+01 2.54000E-03 2.03200E-04
50   3.16000E+01 2.31000E-03 1.84800E-04 3.21000E+01 2.09000E-03 2.09000E-04
51   4.55000E+01 9.50000E-04 1.23500E-04 5.35000E+01 9.60000E-04 1.34400E-04
52   5.41000E+01 6.90000E-04 1.10400E-04 6.10000E+01 8.90000E-04 8.90000E-05
53   6.90000E+01 5.20000E-04 8.84000E-05 7.01000E+01 5.90000E-04 8.85000E-05
54   8.24000E+01 4.20000E-04 1.09200E-04 9.95000E+01 3.80000E-04 9.12000E-05
55   1.13400E+02 2.80000E-04 7.00000E-05 1.28900E+02 1.90000E-04 7.60000E-05
56   .2000000-03 .2000000-03 .100000-03
57  0.0
```

3.3 Running the Code OPTMAN and Description of Output Files

For describing the test of the OPTMAN code we took the same soft-rotator ^{12}C non-dispersive potential input, that has been used in *MANUAL* calculations (see pages 58-59 of *MANUAL*). To allow running with the new version of the code we needed to add keys `MEDIS=0` and `MERIP=0` in the second line of input and add several new potential parameters to the last card (`WDISO=0.0` - imaginary volume isovector term equal zero,`EA=52` - ignored in case of non-dispersive calculations, `WDSHI=500` - allowing to use exponential decrease of surface imaginary potential, and ignoring the alternative formulation for it,`WDWID2=0` - not used) of old potential and add one more card in potential description (`ALFNEW=1.65,VRD=0.0`), which both have not been used by the code, as it is not dispersive case, but should be inputted . As one runs the code it will first ask the name of the input file and, after it will be read, the code asks to give the name for the output file, in which all the calculated information will be stored. While running, eleven more files are created by the code: CR-SECT, TRANSME, GNASH, ANG-DIST, ANG-POL, OPTMAN.CS, OPTMAN.ANG, OPTMAN.ICS, OPTMAN.TL, OPTMAN.LEG and ANGL-DIS.YW. First five have been described in *MANUAL*, and here we just repeat this description for users convenience. The file CR-SECT contains one line for each calculated energy. Line starts with a value of energy, and then follow total cross sections, reaction cross sections and level excitation cross sections ordered by their excitation energies (in case calculations are made for protons total and elastic cross-sections being infinity include contribution of nuclear amplitude only). The file TRANSME contains nucleon transmission coefficients for each calculated energy to be used for the code STAPRE [46] . For each calculated energy the first line indicates incident energy and $l_{\max}$ - maximum angular momentum for which nucleon transmission coefficients are available for this energy, and then lines with $l_{\max}+1$ transmissions follow ordered by growing angular momentum starting with $T_{l=0}$ by six in a line. As the calculated transmission coefficients are intended to be used for the code STAPRE [46] they are aver-

aged over J dependence and depend only on angular momentum l. Many zero value higher angular momentum transmissions are outputted by code, it is convenient for STAPRE code calculations. The file GNASH contains nucleon transmission coefficients for each calculated energy to be used for the code GNASH [47] . For each energy the first line indicates the energy and $l_{\max}$ - maximum angular momentum for which nucleon transmission coefficients are available for this energy, and according with the GNASH format lines with transmissions: first $T_{l=0,j=1/2}$, than pares $T_{l,j=l-1/2}$, $T_{l,j=1/2}$ follow ordered by growing angular momentum up to $l_{\max}$ by six in a line. The file ANGL-DIST contains calculated angular distributions for all excited levels for energies described by Record 5 at angles distinguished by Record 7 of input file. The file ANGLE-DIST consists of NST block: the first card of the block indicated incident energy and type of the particle, than follow MTET lines with first angle and than angular distributions for excited levels in order following the order of levels input. The file ANGL-POL gives polynomial expansion for angular distributions determined by *MANUAL* Eqs. (87,88). This file consists of NST blocks. Each block starts with line describing incident energy and numbers of coefficients in expansions LKK=NL and LCOUL=ML (see *MANUAL* Eqs. (87,88). Second line of the block gives total cross sections, reaction cross sections and level excitation cross sections ordered by their excitation energies, than for each excited level follow NL of $a_L(E)$ coefficients six in line and for elastically scattered protons ML pares of Re$b_L(E)$ and Im$b_L(E)$ coefficients. When one runs optical parameter adjustment files CR-SECT, TRANSME, GNASH, ANGL-DIST and ANGL-POL are organized but are blank. When one runs optical calculations code's option with MTET=0 input files ANGL-DIST,ANGL-POL are also blank. New files OPTMAN.CS, OPTMAN.ANG, OPTMAN.ICS, OPTMAN.TL and OPTMAN.LEG are the files create to be used by the EMPIRE nuclear data evaluation system [48], which are compatible with ECIS output files and are described in ECIS manual. The file ANGDIS-YW is similar to the previously created ANGL-DIST and is being used for some specific purposes. Below we present these files for a run in which optical calculations of ^{12}C cross sections are organized, as well as the appropriate input file. User can compare input file demonstrated here with the one in *MANUAL* for the same case to see the necessary changes. Small changes in calculated values of outputted files, compared with the *MANUAL* ones are due to the new relativistic generalization applied here, which is now completely consistent with the one used in the ECIS code.

INPUT file

```
1  C-12   OCTUPOLE CALCULATION bet3=ksi*bet2
2  0102050001040202000010001010000
3   0.42825E+01 0.27943E+01 0.11860E+00 0.32107E+00 0.16400E+00 0.12600E+00
4   0.14694E+00 0.21419E-03 0.52045E+00 0.24200E+00 0.21005E-01 0.83263E+00
5   0.35000E+00 0.22130E+00 0.00000E+00 0.17221E+01 0.00000E+00
6  00500200400404005010010000l
```

```
 7   .2090000+02 .3970000+02
 8  0001
 9   .1000000+01 .5000000+01 .1000000+02 .1500000+02 .1800000+02 .2100000+02
10   .2400000+02 .2700000+02 .3000000+02 .3300000+02 .3600000+02 .3900000+02
11   .4200000+02 .4500000+02 .4800000+02 .5100000+02 .5400000+02 .5600000+02
12   .5900000+02 .6200000+02 .6500000+02 .7000000+02 .7500000+02 .8000000+02
13   .8500000+02 .9000000+02 .9500000+02 .1000000+03 .1050000+03 .1100000+03
14   .1150000+03 .1200000+03 .1250000+03 .1300000+03 .1350000+03 .1400000+03
15   .1500000+03 .1600000+03 .1700000+03 .1800000+03
16   .0000000-0000+10100000000
17   .4440000+0104+10100000000
18   .9640000+0106-10100000100
19   .7650000+0100+10101000000
20   .1780000+0204+10200000000
21   1.00866520  .5000000-00 .1200000+02 .6000000+01-.1183500+02-.8950000+01
22  -.3094000+02-.0000000-00 .0002381+00 .3000000-06 .8630000+02 .4532000-02
23   .0000000+01-.0000000-00 .0000000+01 .9530000+01 .1533000+02 .1755000-01
24   .0000000+01-.0000000-00 .0000000+01 .1909000+02 .9429000+02 .0000000+01
25   .7840000+01 .0030000000 .0000000+01-.0000000-00 -3.100      160.
26   .1150000+01 .10         .5000000+02 2.          .5190000-00 .2600000-02
27   .1072600+01 .4460000-00 .0000000-02 .1039700+01 .4570000+00 .0000000-02
28   .1000000+01 .1000000+01 .0000000-00 .1086300+01 .6050000-00-.0000000-02
29   .1145300+01 .00         .1000000+01 .680         1.1000     .1000000+01
30   .1300000+02 .3000000+02 .0000000+03 52.00        500.       .0
31  1.65         .0
```

OUTPUT file

```
 1  C-12   OCTUPOLE CALCULATION bet3=ksi*bet2
 2         INTERACTION OF PARTICLE, HAVING SPIN = 0.50
 3                     WITH NUCLEI  A=  12.0000000
 4                      COUPLED CHANNELS METHOD
 5       RELATIVISTIC KINEMATICS AND POTENTIAL DEPENDENCE
 6        OPTICAL POTENTIAL WITHOUT DISPERSIVE RELATIONSHIPS
 7       COULOMB CORRECTION PROPORTIONAL REAL POTENTIAL DER-VE
 8                  CHARGE RADIUS IS ENERGY DEPENDENT
 9                  REAL RADIUS IS ENERGY DEPENDENT
10             WITH AC. NONAXIAL GEXADECAPOLE DEFORMATIONS
11
12             HAMILTONIAN 5PA0      POTENTIAL EXPANDED  BY      BET0
13             WITH AC. NONAXIAL OCTUP0LE      SOFT    DEFORMATIONS
14
15                  NUMBER OF COUPLED LEVELS=  5     NPD = 4
16                 NUMBER OF TERMS IN POTENTIAL EXPANSION=    4
17
18
19                  ENERGY     LEVEL'S SPIN*2    NTU        NNB        NNG         NNO         NPO
20
```

```
21      1          0.0000000E+00          0          1          0          0          0          1
22      2          0.4440000E+01          4          1          0          0          0          1
23      3          0.9640000E+01          6          1          0          0          1         -1
24      4          0.7650000E+01          0          1          1          0          0          1
25      5          0.1780000E+02          4          2          0          0          0          1
26
27                          PARAMETERS OF HAMILTONIAN
28       HW=     4.28250   AMB0= 2.79430   AMG0= 0.11860   GAM0= 0.32107   BET0= 0.16400
29       BET4=   0.12600   BB42= 0.14694   GAMG= 0.00021   DELG= 0.52045
30       BET3=   0.24200   ETO=  0.02100   AMUO= 0.83263   HWO= 0.35000    BB32= 0.22130
31       GAMDE=  0.00000   DPAR=  1.7221   GSHAPE= 0.00000
32
33
34   IO1=  1 IO2=  1 NNT=  1  FOLAR=  0.0000000D+00 ANU1=  0.7043448D+00  ANU2=  0.7043448D+00
35   IO1=  1 IO2=  1 NNT=  2  FOLAR=  0.6440039D+01 ANU1=  0.7043448D+00  ANU2=  0.7043448D+00
36   IO1=  1 IO2=  2 NNT=  1  FOLAR=  0.2536337D+01 ANU1=  0.7043448D+00  ANU2=  0.2543514D+01
37   IO1=  1 IO2=  2 NNT=  2  FOLAR=  0.0000000D+00 ANU1=  0.7043448D+00  ANU2=  0.2543514D+01
38   IO1=  2 IO2=  2 NNT=  1  FOLAR=  0.0000000D+00 ANU1=  0.2543514D+01  ANU2=  0.2543514D+01
39   IO1=  2 IO2=  2 NNT=  2  FOLAR=  0.1826384D+02 ANU1=  0.2543514D+01  ANU2=  0.2543514D+01
40   JU1= 1 JU2= 1 NNT= 1 FOV(JU1,JU2,NNT)=  0.3397700D+01  ANU1=  0.6449750D+00  ANU2=  0.6449750D+00
41   JU1= 1 JU2= 1 NNT= 2 FOV(JU1,JU2,NNT)=  0.1353617D+02  ANU1=  0.6449750D+00  ANU2=  0.6449750D+00
42   JU1= 1 JU2= 1 NNT= 3 FOV(JU1,JU2,NNT)=  0.6079694D+02  ANU1=  0.6449750D+00  ANU2=  0.6449750D+00
43   JU1= 1 JU2= 1 NNT= 4 FOV(JU1,JU2,NNT)=  0.3006270D+03  ANU1=  0.6449750D+00  ANU2=  0.6449750D+00
44   JU1= 1 JU2= 2 NNT= 1 FOV(JU1,JU2,NNT)=  0.3478151D+01  ANU1=  0.6449750D+00  ANU2=  0.7977824D-01
45   JU1= 1 JU2= 2 NNT= 2 FOV(JU1,JU2,NNT)=  0.1400784D+02  ANU1=  0.6449750D+00  ANU2=  0.7977824D-01
46   JU1= 1 JU2= 2 NNT= 3 FOV(JU1,JU2,NNT)=  0.6277322D+02  ANU1=  0.6449750D+00  ANU2=  0.7977824D-01
47   JU1= 1 JU2= 2 NNT= 4 FOV(JU1,JU2,NNT)=  0.3064995D+03  ANU1=  0.6449750D+00  ANU2=  0.7977824D-01
48   JU1= 1 JU2= 3 NNT= 1 FOV(JU1,JU2,NNT)=  0.3667907D+01  ANU1=  0.6449750D+00  ANU2=  0.7969259D-02
49   JU1= 1 JU2= 3 NNT= 2 FOV(JU1,JU2,NNT)=  0.1677113D+02  ANU1=  0.6449750D+00  ANU2=  0.7969259D-02
50   JU1= 1 JU2= 3 NNT= 3 FOV(JU1,JU2,NNT)=  0.8411341D+02  ANU1=  0.6449750D+00  ANU2=  0.7969259D-02
51   JU1= 1 JU2= 3 NNT= 4 FOV(JU1,JU2,NNT)=  0.4547311D+03  ANU1=  0.6449750D+00  ANU2=  0.7969259D-02
52   JU1= 1 JU2= 4 NNT= 1 FOV(JU1,JU2,NNT)=  0.1368376D+01  ANU1=  0.6449750D+00  ANU2=  0.2446976D+01
53   JU1= 1 JU2= 4 NNT= 2 FOV(JU1,JU2,NNT)=  0.1082197D+02  ANU1=  0.6449750D+00  ANU2=  0.2446976D+01
54   JU1= 1 JU2= 4 NNT= 3 FOV(JU1,JU2,NNT)=  0.7238643D+02  ANU1=  0.6449750D+00  ANU2=  0.2446976D+01
55   JU1= 1 JU2= 4 NNT= 4 FOV(JU1,JU2,NNT)=  0.4740800D+03  ANU1=  0.6449750D+00  ANU2=  0.2446976D+01
56   JU1= 1 JU2= 5 NNT= 1 FOV(JU1,JU2,NNT)=  0.3589556D+01  ANU1=  0.6449750D+00  ANU2=  0.2785297D-02
57   JU1= 1 JU2= 5 NNT= 2 FOV(JU1,JU2,NNT)=  0.1724151D+02  ANU1=  0.6449750D+00  ANU2=  0.2785297D-02
58   JU1= 1 JU2= 5 NNT= 3 FOV(JU1,JU2,NNT)=  0.9031816D+02  ANU1=  0.6449750D+00  ANU2=  0.2785297D-02
59   JU1= 1 JU2= 5 NNT= 4 FOV(JU1,JU2,NNT)=  0.5078508D+03  ANU1=  0.6449750D+00  ANU2=  0.2785297D-02
60   JU1= 2 JU2= 2 NNT= 1 FOV(JU1,JU2,NNT)=  0.3586025D+01  ANU1=  0.7977824D-01  ANU2=  0.7977824D-01
61   JU1= 2 JU2= 2 NNT= 2 FOV(JU1,JU2,NNT)=  0.1459821D+02  ANU1=  0.7977824D-01  ANU2=  0.7977824D-01
62   JU1= 2 JU2= 2 NNT= 3 FOV(JU1,JU2,NNT)=  0.6540952D+02  ANU1=  0.7977824D-01  ANU2=  0.7977824D-01
63   JU1= 2 JU2= 2 NNT= 4 FOV(JU1,JU2,NNT)=  0.3166611D+03  ANU1=  0.7977824D-01  ANU2=  0.7977824D-01
64   JU1= 2 JU2= 3 NNT= 1 FOV(JU1,JU2,NNT)=  0.3800098D+01  ANU1=  0.7977824D-01  ANU2=  0.7969259D-02
65   JU1= 2 JU2= 3 NNT= 2 FOV(JU1,JU2,NNT)=  0.1733502D+02  ANU1=  0.7977824D-01  ANU2=  0.7969259D-02
66   JU1= 2 JU2= 3 NNT= 3 FOV(JU1,JU2,NNT)=  0.8590071D+02  ANU1=  0.7977824D-01  ANU2=  0.7969259D-02
67   JU1= 2 JU2= 3 NNT= 4 FOV(JU1,JU2,NNT)=  0.4554697D+03  ANU1=  0.7977824D-01  ANU2=  0.7969259D-02
68   JU1= 2 JU2= 4 NNT= 1 FOV(JU1,JU2,NNT)=  0.1455094D+01  ANU1=  0.7977824D-01  ANU2=  0.2446976D+01
69   JU1= 2 JU2= 4 NNT= 2 FOV(JU1,JU2,NNT)=  0.1080186D+02  ANU1=  0.7977824D-01  ANU2=  0.2446976D+01
70   JU1= 2 JU2= 4 NNT= 3 FOV(JU1,JU2,NNT)=  0.6984171D+02  ANU1=  0.7977824D-01  ANU2=  0.2446976D+01
71   JU1= 2 JU2= 4 NNT= 4 FOV(JU1,JU2,NNT)=  0.4429782D+03  ANU1=  0.7977824D-01  ANU2=  0.2446976D+01
72   JU1= 2 JU2= 5 NNT= 1 FOV(JU1,JU2,NNT)=  0.3708943D+01  ANU1=  0.7977824D-01  ANU2=  0.2785297D-02
73   JU1= 2 JU2= 5 NNT= 2 FOV(JU1,JU2,NNT)=  0.1767531D+02  ANU1=  0.7977824D-01  ANU2=  0.2785297D-02
74   JU1= 2 JU2= 5 NNT= 3 FOV(JU1,JU2,NNT)=  0.9103598D+02  ANU1=  0.7977824D-01  ANU2=  0.2785297D-02
75   JU1= 2 JU2= 5 NNT= 4 FOV(JU1,JU2,NNT)=  0.4998478D+03  ANU1=  0.7977824D-01  ANU2=  0.2785297D-02
76   JU1= 3 JU2= 3 NNT= 1 FOV(JU1,JU2,NNT)=  0.4650767D+01  ANU1=  0.7969259D-02  ANU2=  0.7969259D-02
77   JU1= 3 JU2= 3 NNT= 2 FOV(JU1,JU2,NNT)=  0.2364654D+02  ANU1=  0.7969259D-02  ANU2=  0.7969259D-02
78   JU1= 3 JU2= 3 NNT= 3 FOV(JU1,JU2,NNT)=  0.1289822D+03  ANU1=  0.7969259D-02  ANU2=  0.7969259D-02
```

```
 JU1= 3 JU2= 3 NNT= 4 FOV(JU1,JU2,NNT)=  0.7459344D+03  ANU1=  0.7969259D-02  ANU2=  0.7969259D-02
 JU1= 3 JU2= 4 NNT= 1 FOV(JU1,JU2,NNT)=  0.3176693D+01  ANU1=  0.7969259D-02  ANU2=  0.2446976D+01
 JU1= 3 JU2= 4 NNT= 2 FOV(JU1,JU2,NNT)=  0.2092894D+02  ANU1=  0.7969259D-02  ANU2=  0.2446976D+01
 JU1= 3 JU2= 4 NNT= 3 FOV(JU1,JU2,NNT)=  0.1356776D+03  ANU1=  0.7969259D-02  ANU2=  0.2446976D+01
 JU1= 3 JU2= 4 NNT= 4 FOV(JU1,JU2,NNT)=  0.8938593D+03  ANU1=  0.7969259D-02  ANU2=  0.2446976D+01
 JU1= 3 JU2= 5 NNT= 1 FOV(JU1,JU2,NNT)=  0.4816125D+01  ANU1=  0.7969259D-02  ANU2=  0.2785297D-02
 JU1= 3 JU2= 5 NNT= 2 FOV(JU1,JU2,NNT)=  0.2551115D+02  ANU1=  0.7969259D-02  ANU2=  0.2785297D-02
 JU1= 3 JU2= 5 NNT= 3 FOV(JU1,JU2,NNT)=  0.1443104D+03  ANU1=  0.7969259D-02  ANU2=  0.2785297D-02
 JU1= 3 JU2= 5 NNT= 4 FOV(JU1,JU2,NNT)=  0.8626245D+03  ANU1=  0.7969259D-02  ANU2=  0.2785297D-02
 JU1= 4 JU2= 4 NNT= 1 FOV(JU1,JU2,NNT)=  0.4940767D+01  ANU1=  0.2446976D+01  ANU2=  0.2446976D+01
 JU1= 4 JU2= 4 NNT= 2 FOV(JU1,JU2,NNT)=  0.2992855D+02  ANU1=  0.2446976D+01  ANU2=  0.2446976D+01
 JU1= 4 JU2= 4 NNT= 3 FOV(JU1,JU2,NNT)=  0.1981755D+03  ANU1=  0.2446976D+01  ANU2=  0.2446976D+01
 JU1= 4 JU2= 4 NNT= 4 FOV(JU1,JU2,NNT)=  0.1380222D+04  ANU1=  0.2446976D+01  ANU2=  0.2446976D+01
 JU1= 4 JU2= 5 NNT= 1 FOV(JU1,JU2,NNT)=  0.3838257D+01  ANU1=  0.2446976D+01  ANU2=  0.2785297D-02
 JU1= 4 JU2= 5 NNT= 2 FOV(JU1,JU2,NNT)=  0.2517325D+02  ANU1=  0.2446976D+01  ANU2=  0.2785297D-02
 JU1= 4 JU2= 5 NNT= 3 FOV(JU1,JU2,NNT)=  0.1655250D+03  ANU1=  0.2446976D+01  ANU2=  0.2785297D-02
 JU1= 4 JU2= 5 NNT= 4 FOV(JU1,JU2,NNT)=  0.1113186D+04  ANU1=  0.2446976D+01  ANU2=  0.2785297D-02
 JU1= 5 JU2= 5 NNT= 1 FOV(JU1,JU2,NNT)=  0.5108385D+01  ANU1=  0.2785297D-02  ANU2=  0.2785297D-02
 JU1= 5 JU2= 5 NNT= 2 FOV(JU1,JU2,NNT)=  0.2815616D+02  ANU1=  0.2785297D-02  ANU2=  0.2785297D-02
 JU1= 5 JU2= 5 NNT= 3 FOV(JU1,JU2,NNT)=  0.1650190D+03  ANU1=  0.2785297D-02  ANU2=  0.2785297D-02
 JU1= 5 JU2= 5 NNT= 4 FOV(JU1,JU2,NNT)=  0.1018772D+04  ANU1=  0.2785297D-02  ANU2=  0.2785297D-02

               POTENTIAL   PARAMETERS   V(R)

VR0=-30.940     VR1= 0.0000     VR2= 0.0002381  RR= 1.1500     AR0= 0.5190     AR1= 0.0026
WD0= 0.0000     WD1= 0.0000     VR3= 0.0000003  RD= 1.0726     AD0= 0.4460     AD1= 0.0000
WC0= 0.0000     WC1= 0.0000                     RC= 1.0397     AC0= 0.4570     AC1= 0.0000
                                                RW= 1.0000     AW0= 1.0000     AW1= 0.0000
VSO= 7.8400                                     RS= 1.0863     AS0= 0.6050     AS1= 0.0000
ALF= 1.0000     ANEU= 1.0087                    RZ= 1.1453     AZ0= 0.6800
BNDC=   0.00    WDA1= 0.0000    WCA1= 0.0000    CCOUL= 1.1000     CISO= 13.000    WCISO= 30.000
WS0= 0.0000     WS1= 0.0000     VRLA=86.3000    ALAVR= 0.00453    WCBW=19.0900    WCWID=94.2900
WDBW= 9.5300    WDWID=15.3300   ALAWD= 0.0175   EFERMN=-11.835    EFERMP= -8.950  ALASO= 0.0030
PDIS= 2.0000    WSBW=-3.1000    WSWID= 160.00   RRBWC= 0.1000     RRWID= 50.00    RZBWC= 0.0000
RZWID= 1.0000   EA= 52.00000    WDISO=  0.000   WDSHI= 500.00     WDWID2=   0.00  ALFNEW= 1.650
VRD=   0.000

                            NUCLEUS CHARGE =  6.0000


 SPHERICAL VOLUME INTEGRALS OF REAL POTENTIAL F-FACTORS AND DERIVATIVES:
 VIR0=   8.625  VIR1=  19.696  VIR2=  16.714  VIR3=   5.472  CBET0=   1.000
 SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WC) F-FACTORS AND DERIVATIVES:
 WIC0=   6.132  WIC1=  15.117  WIC2=  13.501  WIC3=   4.471  CBETC=   0.893
 SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WD) F-FACTORS AND DERIVATIVES:
 WID0=  11.922  WID1=  21.532  WID2=  10.714  WID3=   0.080  CBETD=   0.498
 SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WW) F-FACTORS AND DERIVATIVES:
 WIW0=   0.000  WIW1=   0.000  WIW2=   0.000  WIW3=   0.000  CBETW=   0.000

  POTENTIAL VALUES FOR INCIDENT ENERGY=  20.900000 MeV:

  VR=  43.727   VRDC(DWv)=   0.000   DWs=   0.000   Wv=   2.053
  Ws=   4.400   VSO=   7.107   DVSO=   0.000   WSO=  -0.125
  VHF=   0.000   VCUL=   0.000   VCULC=   0.000   RELPOT=   1.011


ORB. MOMENT             TRANSITIONS            SR                 SI
```

0	0.5737846069	-0.2536359445	-0.4370581955
1	0.5374276509	-0.4786559860	-0.3214959692
2	0.6352215737	-0.3613472888	-0.0780649826
3	0.5547320159	0.2268952102	0.3438143496
4	0.1286411602	0.8842311291	0.2237765843
5	0.0161530565	0.9873378258	0.0504127033
6	0.0023943416	0.9983776698	0.0114224488
7	0.0002735766	0.9998513790	0.0024095287
8	0.0000196752	0.4705782607	0.0001341173
9	0.0000000000	0.0000000000	0.0000000000
10	0.0000000000	0.0000000000	0.0000000000
11	0.0000000000	0.0000000000	0.0000000000
12	0.0000000000	0.0000000000	0.0000000000
13	0.0000000000	0.0000000000	0.0000000000
14	0.0000000000	0.0000000000	0.0000000000
15	0.0000000000	0.0000000000	0.0000000000
16	0.0000000000	0.0000000000	0.0000000000
17	0.0000000000	0.0000000000	0.0000000000
18	0.0000000000	0.0000000000	0.0000000000
19	0.0000000000	0.0000000000	0.0000000000
20	0.0000000000	0.0000000000	0.0000000000
21	0.0000000000	0.0000000000	0.0000000000

ANGULAR DISTRIBUTIONS OF SCATTERED PARTICLES

0.100E+01	0.109E+01	0.165E-01	0.240E-02	0.204E-02	0.126E-03
0.500E+01	0.106E+01	0.162E-01	0.241E-02	0.194E-02	0.125E-03
0.100E+02	0.967E+00	0.154E-01	0.241E-02	0.164E-02	0.124E-03
0.150E+02	0.833E+00	0.142E-01	0.241E-02	0.123E-02	0.121E-03
0.180E+02	0.740E+00	0.135E-01	0.242E-02	0.959E-03	0.119E-03
0.210E+02	0.643E+00	0.129E-01	0.242E-02	0.703E-03	0.117E-03
0.240E+02	0.547E+00	0.123E-01	0.242E-02	0.476E-03	0.114E-03
0.270E+02	0.454E+00	0.119E-01	0.243E-02	0.292E-03	0.111E-03
0.300E+02	0.368E+00	0.115E-01	0.244E-02	0.159E-03	0.108E-03
0.330E+02	0.292E+00	0.112E-01	0.246E-02	0.822E-04	0.105E-03
0.360E+02	0.226E+00	0.110E-01	0.248E-02	0.581E-04	0.101E-03
0.390E+02	0.171E+00	0.108E-01	0.251E-02	0.813E-04	0.975E-04
0.420E+02	0.127E+00	0.105E-01	0.254E-02	0.143E-03	0.939E-04
0.450E+02	0.925E-01	0.102E-01	0.259E-02	0.231E-03	0.902E-04
0.480E+02	0.666E-01	0.976E-02	0.263E-02	0.335E-03	0.866E-04
0.510E+02	0.481E-01	0.925E-02	0.267E-02	0.443E-03	0.831E-04
0.540E+02	0.355E-01	0.866E-02	0.271E-02	0.545E-03	0.797E-04
0.560E+02	0.297E-01	0.823E-02	0.274E-02	0.605E-03	0.775E-04
0.590E+02	0.240E-01	0.754E-02	0.277E-02	0.680E-03	0.745E-04
0.620E+02	0.209E-01	0.683E-02	0.279E-02	0.732E-03	0.717E-04
0.650E+02	0.194E-01	0.611E-02	0.279E-02	0.758E-03	0.692E-04
0.700E+02	0.188E-01	0.500E-02	0.277E-02	0.747E-03	0.658E-04
0.750E+02	0.186E-01	0.407E-02	0.271E-02	0.675E-03	0.636E-04
0.800E+02	0.178E-01	0.336E-02	0.262E-02	0.563E-03	0.625E-04
0.850E+02	0.160E-01	0.289E-02	0.250E-02	0.433E-03	0.626E-04
0.900E+02	0.137E-01	0.263E-02	0.236E-02	0.308E-03	0.639E-04
0.950E+02	0.110E-01	0.253E-02	0.222E-02	0.207E-03	0.664E-04
0.100E+03	0.839E-02	0.252E-02	0.207E-02	0.142E-03	0.698E-04
0.105E+03	0.617E-02	0.255E-02	0.193E-02	0.118E-03	0.740E-04
0.110E+03	0.447E-02	0.260E-02	0.179E-02	0.131E-03	0.789E-04
0.115E+03	0.330E-02	0.261E-02	0.166E-02	0.171E-03	0.843E-04
0.120E+03	0.260E-02	0.259E-02	0.153E-02	0.227E-03	0.900E-04

```
     0.125E+03     0.224E-02  0.252E-02  0.140E-02  0.284E-03  0.957E-04
     0.130E+03     0.212E-02  0.242E-02  0.127E-02  0.333E-03  0.101E-03
     0.135E+03     0.213E-02  0.227E-02  0.114E-02  0.368E-03  0.107E-03
     0.140E+03     0.221E-02  0.210E-02  0.101E-02  0.388E-03  0.112E-03
     0.150E+03     0.250E-02  0.171E-02  0.777E-03  0.399E-03  0.122E-03
     0.160E+03     0.292E-02  0.135E-02  0.586E-03  0.410E-03  0.129E-03
     0.170E+03     0.337E-02  0.109E-02  0.461E-03  0.433E-03  0.133E-03
     0.180E+03     0.356E-02  0.100E-02  0.418E-03  0.447E-03  0.134E-03

 NEUTRON ENERGY = 20.900000
 TOTAL  CR-SECT.=  1.388248
 REACTION CR-SECT. =  0.385556
 TOTAL DIRECT CR-SECT.(ELASTIC + DIR.LEV EXCIT.) =  1.002692

   NMAX                CR-SECT. OF LEVEL EXCITATION
     1                          0.909358
     2                          0.061491
     3                          0.025713
     4                          0.005039
     5                          0.001092

                              STRENGTH  FUNCTIONS
 SF0=  0.1997542E-04        SF1=  0.2036385E-04        SF2=  0.2953541E-04

  SPHERICAL VOLUME INTEGRALS OF REAL POTENTIAL F-FACTORS AND DERIVATIVES:
  VIR0=   8.683  VIR1=  19.106  VIR2=  15.798  VIR3=   5.132  CBET0=   1.000
  SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WC) F-FACTORS AND DERIVATIVES:
  WIC0=   6.132  WIC1=  15.117  WIC2=  13.501  WIC3=   4.471  CBETC=   0.893
  SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WD) F-FACTORS AND DERIVATIVES:
  WID0=  11.922  WID1=  21.532  WID2=  10.714  WID3=   0.080  CBETD=   0.498
  SPHERICAL VOLUME INTEGRALS OF IMAGINARY (WW) F-FACTORS AND DERIVATIVES:
  WIW0=   0.000  WIW1=   0.000  WIW2=   0.000  WIW3=   0.000  CBETW=   0.000

   POTENTIAL VALUES FOR INCIDENT ENERGY=  39.700000 MeV:

   VR=  39.714   VRDC(DWv)=   0.000   DWs=   0.000   Wv=   4.014
   Ws=   3.691   VSO=   6.775   DVSO=   0.000   WSO=  -0.262
   VHF=   0.000   VCUL=   0.831   VCULC=   0.000   RELPOT=   1.021


 ORB. MOMENT              TRANSITIONS            SR                  SI

     0                 0.5906007098       -0.4897811171       -0.2914561701
     1                 0.5900982415       -0.5634083289        0.0091432975
     2                 0.6110135297       -0.4348204717        0.2344173454
     3                 0.5819856530       -0.0588710831        0.4037901075
     4                 0.3566833447        0.5014775551        0.4680959806
     5                 0.1085472180        0.8851663631        0.2544105027
     6                 0.0249843609        0.9783258493        0.0940408379
     7                 0.0056572024        0.9958405169        0.0326444816
     8                 0.0011868145        0.9992743424        0.0110129421
     9                 0.0002459203        0.9998661185        0.0036090923
    10                 0.0000515024        0.9999729892        0.0011223856
    11                 0.0000106250        0.9999944683        0.0003191821
    12                 0.0000020932        0.9999989229        0.0000811183
    13                 0.0000004219        0.9999997863        0.0000183648
    14                 0.0000000778        0.9999999609        0.0000037438
```

15	0.0000000128	0.9999999936	0.0000006981	
16	0.0000000019	0.4848484839	0.0000000425	
17	0.0000000000	0.0000000000	0.0000000000	
18	0.0000000000	0.0000000000	0.0000000000	
19	0.0000000000	0.0000000000	0.0000000000	
20	0.0000000000	0.0000000000	0.0000000000	
21	0.0000000000	0.0000000000	0.0000000000	
22	0.0000000000	0.0000000000	0.0000000000	
23	0.0000000000	0.0000000000	0.0000000000	
24	0.0000000000	0.0000000000	0.0000000000	
25	0.0000000000	0.0000000000	0.0000000000	

ANGULAR DISTRIBUTIONS OF SCATTERED PARTICLES

0.100E+01	0.597E+04	0.851E-02	0.984E-03	0.319E-02	0.482E-03
0.500E+01	0.549E+01	0.830E-02	0.102E-02	0.290E-02	0.479E-03
0.100E+02	0.781E+00	0.784E-02	0.111E-02	0.214E-02	0.471E-03
0.150E+02	0.746E+00	0.762E-02	0.126E-02	0.124E-02	0.462E-03
0.180E+02	0.664E+00	0.776E-02	0.138E-02	0.781E-03	0.457E-03
0.210E+02	0.554E+00	0.813E-02	0.153E-02	0.439E-03	0.453E-03
0.240E+02	0.438E+00	0.867E-02	0.172E-02	0.235E-03	0.448E-03
0.270E+02	0.330E+00	0.926E-02	0.195E-02	0.160E-03	0.444E-03
0.300E+02	0.238E+00	0.973E-02	0.220E-02	0.188E-03	0.438E-03
0.330E+02	0.165E+00	0.997E-02	0.248E-02	0.279E-03	0.429E-03
0.360E+02	0.110E+00	0.987E-02	0.274E-02	0.395E-03	0.417E-03
0.390E+02	0.709E-01	0.941E-02	0.298E-02	0.502E-03	0.401E-03
0.420E+02	0.446E-01	0.862E-02	0.315E-02	0.578E-03	0.381E-03
0.450E+02	0.281E-01	0.759E-02	0.325E-02	0.610E-03	0.357E-03
0.480E+02	0.185E-01	0.644E-02	0.325E-02	0.599E-03	0.330E-03
0.510E+02	0.133E-01	0.529E-02	0.317E-02	0.550E-03	0.300E-03
0.540E+02	0.108E-01	0.422E-02	0.300E-02	0.475E-03	0.270E-03
0.560E+02	0.999E-02	0.360E-02	0.284E-02	0.418E-03	0.250E-03
0.590E+02	0.932E-02	0.280E-02	0.257E-02	0.329E-03	0.221E-03
0.620E+02	0.886E-02	0.218E-02	0.226E-02	0.246E-03	0.194E-03
0.650E+02	0.833E-02	0.174E-02	0.195E-02	0.176E-03	0.169E-03
0.700E+02	0.703E-02	0.129E-02	0.144E-02	0.990E-04	0.135E-03
0.750E+02	0.540E-02	0.109E-02	0.102E-02	0.692E-04	0.110E-03
0.800E+02	0.377E-02	0.101E-02	0.702E-03	0.731E-04	0.926E-04
0.850E+02	0.244E-02	0.940E-03	0.489E-03	0.917E-04	0.818E-04
0.900E+02	0.150E-02	0.849E-03	0.359E-03	0.109E-03	0.751E-04
0.950E+02	0.943E-03	0.723E-03	0.287E-03	0.114E-03	0.707E-04
0.100E+03	0.661E-03	0.579E-03	0.249E-03	0.105E-03	0.672E-04
0.105E+03	0.543E-03	0.437E-03	0.225E-03	0.852E-04	0.637E-04
0.110E+03	0.498E-03	0.314E-03	0.204E-03	0.609E-04	0.597E-04
0.115E+03	0.467E-03	0.221E-03	0.181E-03	0.386E-04	0.553E-04
0.120E+03	0.422E-03	0.158E-03	0.155E-03	0.228E-04	0.503E-04
0.125E+03	0.359E-03	0.124E-03	0.126E-03	0.156E-04	0.451E-04
0.130E+03	0.283E-03	0.112E-03	0.994E-04	0.165E-04	0.399E-04
0.135E+03	0.207E-03	0.116E-03	0.759E-04	0.232E-04	0.349E-04
0.140E+03	0.141E-03	0.127E-03	0.578E-04	0.332E-04	0.305E-04
0.150E+03	0.728E-04	0.151E-03	0.388E-04	0.563E-04	0.241E-04
0.160E+03	0.973E-04	0.156E-03	0.360E-04	0.798E-04	0.218E-04
0.170E+03	0.166E-03	0.146E-03	0.386E-04	0.100E-03	0.222E-04
0.180E+03	0.202E-03	0.139E-03	0.399E-04	0.109E-03	0.228E-04

PROTON ENERGY = 39.700000
TOTAL CR-SECT.= 1.021217
REACTION CR-SECT. = 0.272251

```
311   REACTION CR-SECT. incl. LEVELS =  0.317651
312
313     NMAX                 CR-SECT. OF LEVEL EXCITATION
314       1                           0.703566
315       2                           0.028443
316       3                           0.012605
317       4                           0.002521
318       5                           0.001832
319
320                                STRENGTH  FUNCTIONS
321   SF0=  0.1491828E-04        SF1=  0.1559499E-04        SF2=  0.1787253E-04
```

CR-SECT file

```
 1   2.09000E+01 1.38825E+00 3.85556E-01 9.09358E-01 6.14911E-02 2.57128E-02 5.03850E-03 1.09154E-03
 2   3.97000E+01 1.02122E+00 2.72251E-01 7.03566E-01 2.84426E-02 1.26046E-02 2.52092E-03 1.83165E-03
```

TRANSME file

```
 1  0.209000E+02 21
 2   0.57378461 0.53742765 0.63522157 0.55473202 0.12864116 0.01615306
 3   0.00239434 0.00027358 0.00001968 0.00000000 0.00000000 0.00000000
 4   0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
 5   0.00000000 0.00000000 0.00000000 0.00000000
 6  0.397000E+02 25
 7   0.59060071 0.59009824 0.61101353 0.58198565 0.35668334 0.10854722
 8   0.02498436 0.00565720 0.00118681 0.00024592 0.00005150 0.00001062
 9   0.00000209 0.00000042 0.00000008 0.00000001 0.00000000 0.00000000
10   0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
11   0.00000000 0.00000000
```

GNASH file

```
 1  0.209000E+02 50
 2   0.5738E+00 0.5698E+00 0.7133E+00 0.5212E+00 0.5831E+00 0.4032E+00
 3   0.8737E-01 0.6684E+00 0.1617E+00 0.1447E-01 0.2287E-02 0.1755E-01
 4   0.2486E-02 0.2974E-03 0.4181E-04 0.2527E-03 0.0000E+00 0.0000E+00
 5   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 6   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 7   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 8   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 9   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
```

```
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.397000E+02 50
  0.5906E+00 0.6115E+00 0.6722E+00 0.5794E+00 0.5702E+00 0.5582E+00
  0.2766E+00 0.5999E+00 0.4207E+00 0.9128E-01 0.2504E-01 0.1229E+00
  0.2494E-01 0.6318E-02 0.1476E-02 0.5079E-02 0.9298E-03 0.3456E-03
  0.8219E-04 0.1562E-03 0.2361E-04 0.1927E-04 0.4287E-05 0.2698E-05
  0.6780E-07 0.8762E-06 0.1612E-06-0.3181E-16 0.8511E-16 0.2641E-07
  0.3847E-08 0.2618E-16 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
```

ANG-DIST file

```


  NEUTRON ENERGY = 20.900000
      0.100E+01      0.109E+01  0.165E-01  0.240E-02  0.204E-02  0.126E-03
      0.500E+01      0.106E+01  0.162E-01  0.241E-02  0.194E-02  0.125E-03
      0.100E+02      0.967E+00  0.154E-01  0.241E-02  0.164E-02  0.124E-03
      0.150E+02      0.833E+00  0.142E-01  0.241E-02  0.123E-02  0.121E-03
      0.180E+02      0.740E+00  0.135E-01  0.242E-02  0.959E-03  0.119E-03
      0.210E+02      0.643E+00  0.129E-01  0.242E-02  0.703E-03  0.117E-03
      0.240E+02      0.547E+00  0.123E-01  0.242E-02  0.476E-03  0.114E-03
      0.270E+02      0.454E+00  0.119E-01  0.243E-02  0.292E-03  0.111E-03
      0.300E+02      0.368E+00  0.115E-01  0.244E-02  0.159E-03  0.108E-03
      0.330E+02      0.292E+00  0.112E-01  0.246E-02  0.822E-04  0.105E-03
      0.360E+02      0.226E+00  0.110E-01  0.248E-02  0.581E-04  0.101E-03
```

15	0.390E+02	0.171E+00	0.108E-01	0.251E-02	0.813E-04	0.975E-04
16	0.420E+02	0.127E+00	0.105E-01	0.254E-02	0.143E-03	0.939E-04
17	0.450E+02	0.925E-01	0.102E-01	0.259E-02	0.231E-03	0.902E-04
18	0.480E+02	0.666E-01	0.976E-02	0.263E-02	0.335E-03	0.866E-04
19	0.510E+02	0.481E-01	0.925E-02	0.267E-02	0.443E-03	0.831E-04
20	0.540E+02	0.355E-01	0.866E-02	0.271E-02	0.545E-03	0.797E-04
21	0.560E+02	0.297E-01	0.823E-02	0.274E-02	0.605E-03	0.775E-04
22	0.590E+02	0.240E-01	0.754E-02	0.277E-02	0.680E-03	0.745E-04
23	0.620E+02	0.209E-01	0.683E-02	0.279E-02	0.732E-03	0.717E-04
24	0.650E+02	0.194E-01	0.611E-02	0.279E-02	0.758E-03	0.692E-04
25	0.700E+02	0.188E-01	0.500E-02	0.277E-02	0.747E-03	0.658E-04
26	0.750E+02	0.186E-01	0.407E-02	0.271E-02	0.675E-03	0.636E-04
27	0.800E+02	0.178E-01	0.336E-02	0.262E-02	0.563E-03	0.625E-04
28	0.850E+02	0.160E-01	0.289E-02	0.250E-02	0.433E-03	0.626E-04
29	0.900E+02	0.137E-01	0.263E-02	0.236E-02	0.308E-03	0.639E-04
30	0.950E+02	0.110E-01	0.253E-02	0.222E-02	0.207E-03	0.664E-04
31	0.100E+03	0.839E-02	0.252E-02	0.207E-02	0.142E-03	0.698E-04
32	0.105E+03	0.617E-02	0.255E-02	0.193E-02	0.118E-03	0.740E-04
33	0.110E+03	0.447E-02	0.260E-02	0.179E-02	0.131E-03	0.789E-04
34	0.115E+03	0.330E-02	0.261E-02	0.166E-02	0.171E-03	0.843E-04
35	0.120E+03	0.260E-02	0.259E-02	0.153E-02	0.227E-03	0.900E-04
36	0.125E+03	0.224E-02	0.252E-02	0.140E-02	0.284E-03	0.957E-04
37	0.130E+03	0.212E-02	0.242E-02	0.127E-02	0.333E-03	0.101E-03
38	0.135E+03	0.213E-02	0.227E-02	0.114E-02	0.368E-03	0.107E-03
39	0.140E+03	0.221E-02	0.210E-02	0.101E-02	0.388E-03	0.112E-03
40	0.150E+03	0.250E-02	0.171E-02	0.777E-03	0.399E-03	0.122E-03
41	0.160E+03	0.292E-02	0.135E-02	0.586E-03	0.410E-03	0.129E-03
42	0.170E+03	0.337E-02	0.109E-02	0.461E-03	0.433E-03	0.133E-03
43	0.180E+03	0.356E-02	0.100E-02	0.418E-03	0.447E-03	0.134E-03
44						
45						
46						
47	PROTON ENERGY = 39.700000					
48	0.100E+01	0.597E+04	0.851E-02	0.984E-03	0.319E-02	0.482E-03
49	0.500E+01	0.549E+01	0.830E-02	0.102E-02	0.290E-02	0.479E-03
50	0.100E+02	0.781E+00	0.784E-02	0.111E-02	0.214E-02	0.471E-03
51	0.150E+02	0.746E+00	0.762E-02	0.126E-02	0.124E-02	0.462E-03
52	0.180E+02	0.664E+00	0.776E-02	0.138E-02	0.781E-03	0.457E-03
53	0.210E+02	0.554E+00	0.813E-02	0.153E-02	0.439E-03	0.453E-03
54	0.240E+02	0.438E+00	0.867E-02	0.172E-02	0.235E-03	0.448E-03
55	0.270E+02	0.330E+00	0.926E-02	0.195E-02	0.160E-03	0.444E-03
56	0.300E+02	0.238E+00	0.973E-02	0.220E-02	0.188E-03	0.438E-03
57	0.330E+02	0.165E+00	0.997E-02	0.248E-02	0.279E-03	0.429E-03
58	0.360E+02	0.110E+00	0.987E-02	0.274E-02	0.395E-03	0.417E-03
59	0.390E+02	0.709E-01	0.941E-02	0.298E-02	0.502E-03	0.401E-03
60	0.420E+02	0.446E-01	0.862E-02	0.315E-02	0.578E-03	0.381E-03

61	0.450E+02	0.281E-01	0.759E-02	0.325E-02	0.610E-03	0.357E-03
62	0.480E+02	0.185E-01	0.644E-02	0.325E-02	0.599E-03	0.330E-03
63	0.510E+02	0.133E-01	0.529E-02	0.317E-02	0.550E-03	0.300E-03
64	0.540E+02	0.108E-01	0.422E-02	0.300E-02	0.475E-03	0.270E-03
65	0.560E+02	0.999E-02	0.360E-02	0.284E-02	0.418E-03	0.250E-03
66	0.590E+02	0.932E-02	0.280E-02	0.257E-02	0.329E-03	0.221E-03
67	0.620E+02	0.886E-02	0.218E-02	0.226E-02	0.246E-03	0.194E-03
68	0.650E+02	0.833E-02	0.174E-02	0.195E-02	0.176E-03	0.169E-03
69	0.700E+02	0.703E-02	0.129E-02	0.144E-02	0.990E-04	0.135E-03
70	0.750E+02	0.540E-02	0.109E-02	0.102E-02	0.692E-04	0.110E-03
71	0.800E+02	0.377E-02	0.101E-02	0.702E-03	0.731E-04	0.926E-04
72	0.850E+02	0.244E-02	0.940E-03	0.489E-03	0.917E-04	0.818E-04
73	0.900E+02	0.150E-02	0.849E-03	0.359E-03	0.109E-03	0.751E-04
74	0.950E+02	0.943E-03	0.723E-03	0.287E-03	0.114E-03	0.707E-04
75	0.100E+03	0.661E-03	0.579E-03	0.249E-03	0.105E-03	0.672E-04
76	0.105E+03	0.543E-03	0.437E-03	0.225E-03	0.852E-04	0.637E-04
77	0.110E+03	0.498E-03	0.314E-03	0.204E-03	0.609E-04	0.597E-04
78	0.115E+03	0.467E-03	0.221E-03	0.181E-03	0.386E-04	0.553E-04
79	0.120E+03	0.422E-03	0.158E-03	0.155E-03	0.228E-04	0.503E-04
80	0.125E+03	0.359E-03	0.124E-03	0.126E-03	0.156E-04	0.451E-04
81	0.130E+03	0.283E-03	0.112E-03	0.994E-04	0.165E-04	0.399E-04
82	0.135E+03	0.207E-03	0.116E-03	0.759E-04	0.232E-04	0.349E-04
83	0.140E+03	0.141E-03	0.127E-03	0.578E-04	0.332E-04	0.305E-04
84	0.150E+03	0.728E-04	0.151E-03	0.388E-04	0.563E-04	0.241E-04
85	0.160E+03	0.973E-04	0.156E-03	0.360E-04	0.798E-04	0.218E-04
86	0.170E+03	0.166E-03	0.146E-03	0.386E-04	0.100E-03	0.222E-04
87	0.180E+03	0.202E-03	0.139E-03	0.399E-04	0.109E-03	0.228E-04

ANG-POL file

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 1     EN=   20.900   LKK= 16   LCOUL=  0
 2   2.09000E+01 1.38825E+00 3.85556E-01 9.09358E-01 6.14911E-02 2.57128E-02 5.03850E-03 1.09154E-03
 3
 4                LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
 5                  ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 6     0.7236444E-01  0.5856492E-01  0.4359487E-01  0.3064064E-01  0.2004334E-01  0.1102915E-01
 7     0.4910092E-02  0.1812372E-02  0.6086285E-03  0.1845791E-03  0.5168079E-04  0.1260924E-04
 8     0.2571940E-05  0.4288946E-06  0.6065312E-07  0.5987911E-08
 9
10                LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
11                  ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
12     0.4893306E-02  0.1859738E-02  0.7033964E-03  0.1801537E-03 -0.1117703E-03 -0.1458413E-04
13     0.6033732E-04  0.5668852E-04  0.2931499E-04  0.1127401E-04  0.3805886E-05  0.1069167E-05
14     0.2616600E-06  0.4785041E-07  0.7018580E-08  0.6662893E-09
15
16                LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
17                  ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
```

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 0.2046161E-02  0.3529176E-03 -0.1346601E-03 -0.2652838E-04 -0.1485108E-08  0.1308584E-04
 0.4757761E-05 -0.8550424E-06 -0.1120968E-05 -0.4991774E-06 -0.1993302E-06 -0.5435987E-07
-0.1188290E-07 -0.2006546E-08 -0.2632848E-09 -0.2161875E-10

             LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
               ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 0.4009511E-03  0.5381315E-04  0.2113663E-04 -0.2369844E-04  0.2347598E-04  0.5741010E-04
 0.3419885E-04  0.9867403E-05  0.4557760E-05  0.1267224E-05  0.3536885E-06  0.8368380E-07
 0.1724356E-07  0.2461749E-08  0.2916871E-09  0.2406994E-10

             LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
               ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 0.8686176E-04 -0.3504770E-05  0.8932224E-05  0.9562821E-06 -0.1666646E-06 -0.5083541E-07
 0.4903044E-08  0.6371851E-09  0.1080125E-09  0.1020842E-10  0.9459343E-12  0.7785877E-13
 0.4900660E-14  0.2347191E-15  0.1004641E-16  0.3073881E-18

 EN=   39.700   LKK= 32   LCOUL= 17
3.97000E+01 1.02122E+00 2.72251E-01 7.03566E-01 2.84426E-02 1.26046E-02 2.52092E-03 1.83165E-03

             LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
               ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 0.5598798E-01  0.5074457E-01  0.4284439E-01  0.3433034E-01  0.2611217E-01  0.1844517E-01
 0.1185086E-01  0.6848544E-02  0.3594070E-02  0.1744406E-02  0.7982288E-03  0.3483327E-03
 0.1458440E-03  0.5866221E-04  0.2260938E-04  0.8320790E-05  0.2919245E-05  0.9773950E-06
 0.3130308E-06  0.9608660E-07  0.2825816E-07  0.7945747E-08  0.2133602E-08  0.5455996E-09
 0.1320229E-09  0.2997540E-10  0.6316940E-11  0.1219742E-11  0.2124699E-12  0.3259838E-13
 0.4178419E-14  0.3762704E-15

             LEGENDRE COEFFICIENTS FOR  SCATTERED PROTONS
               ANGULAR DISTRIBUTIONS - COULOMB AMPLITUDE
-0.5329607E-05  0.2724234E-04 -0.8424545E-05  0.2731975E-04 -0.7764765E-05  0.2542598E-04
-0.4043458E-05  0.2032444E-04  0.1452678E-05  0.1242014E-04  0.2210252E-05  0.4600765E-05
 0.9878467E-06  0.1462332E-05  0.3641806E-06  0.4790582E-06  0.1257265E-06  0.1578749E-06
 0.4086036E-07  0.5188394E-07  0.1241434E-07  0.1635135E-07  0.3430490E-08  0.4723129E-08
 0.8457065E-09  0.1218796E-08  0.1853447E-09  0.2800696E-09  0.3659081E-10  0.5786558E-10
 0.6614075E-11  0.1091870E-10  0.3810165E-12  0.6769627E-12

             LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
               ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 0.2263392E-02  0.1460025E-02  0.6737818E-03  0.1618302E-03 -0.8769747E-04 -0.1819126E-03
-0.1410000E-03 -0.4008538E-04  0.2540215E-04  0.4211670E-04  0.3300129E-04  0.1901077E-04
 0.8405557E-05  0.2446360E-05  0.1313958E-07 -0.5207376E-06 -0.3885188E-06 -0.1830124E-06
-0.6194802E-07 -0.1350774E-07 -0.2310001E-10  0.1757144E-08  0.1083614E-08  0.4511116E-09
 0.1504731E-09  0.4225555E-10  0.1016230E-10  0.2100226E-11  0.3707529E-12  0.5486393E-13
 0.6476804E-14  0.5108695E-15

             LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
               ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 0.1003039E-02  0.5300818E-03  0.8737568E-04 -0.1194362E-03 -0.1343310E-03 -0.5849834E-04
 0.8217083E-05  0.2319584E-04  0.1335915E-04  0.3594827E-05 -0.7882556E-06 -0.1578205E-05
-0.1149896E-05 -0.6060559E-06 -0.2559891E-06 -0.8898399E-07 -0.2556876E-07 -0.5977355E-08
-0.1062793E-08 -0.1048700E-09  0.1461403E-10  0.1094271E-10  0.3410178E-11  0.7540120E-12
 0.1231391E-12  0.1279214E-13 -0.1053389E-15 -0.4179632E-15 -0.1150545E-15 -0.2050942E-16
-0.2642750E-17 -0.2141415E-18

             LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
               ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 0.2006087E-03  0.1086488E-03  0.5642774E-04  0.2164884E-04  0.1608478E-04  0.1187074E-04
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 76     0.2341582E-04  0.3228098E-04  0.2758898E-04  0.1711844E-04  0.9261094E-05  0.4449792E-05
 77     0.1969907E-05  0.8147737E-06  0.3161590E-06  0.1148564E-06  0.3897304E-07  0.1235672E-07
 78     0.3672258E-08  0.1027123E-08  0.2709612E-09  0.6742394E-10  0.1580305E-10  0.3483977E-11
 79     0.7183827E-12  0.1373959E-12  0.2410329E-13  0.3821297E-14  0.5370573E-15  0.6500135E-16
 80     0.6395858E-17  0.4295177E-18
 81
 82                LEGENDRE COEFFICIENTS FOR  SCATTERED NUCLEONS
 83                  ANGULAR DISTRIBUTIONS - NUCLEAR AMPLITUDE
 84     0.1457584E-03  0.7087144E-04  0.2677219E-04  0.6858640E-05 -0.3044164E-05 -0.4037173E-05
 85    -0.1106796E-05  0.3141728E-06  0.6018783E-06  0.3531678E-06  0.1648211E-06  0.6759515E-07
 86     0.2670557E-07  0.1020991E-07  0.3666891E-08  0.1211379E-08  0.3684126E-09  0.1045432E-09
 87     0.2806741E-10  0.7169551E-11  0.1737758E-11  0.3969828E-12  0.8483983E-13  0.1682128E-13
 88     0.3065229E-14  0.5084441E-15  0.7599398E-16  0.1011545E-16  0.1180852E-17  0.1179210E-18
 89     0.9545002E-20  0.5223029E-21
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OPTMAN.CS file

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 1  <CROSS-S.>      1.01  20.90000     12.00    0    3
 2   0.13882485E+04
 3   0.10026924E+04
 4   0.38555610E+03
 5  <CROSS-S.>      1.01  39.70000     12.00    0    1
 6   0.74896559E+03
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OPTMAN.ANG file

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 1  <ANG.DIS.>       1.01  20.90000     12.00    0    5
 2       1  0.0+   0   40
 3     1.0  0.10873E+04
 4     5.0  0.10568E+04
 5    10.0  0.96686E+03
 6    15.0  0.83318E+03
 7    18.0  0.74017E+03
 8    21.0  0.64317E+03
 9    24.0  0.54650E+03
10    27.0  0.45392E+03
11    30.0  0.36842E+03
12    33.0  0.29213E+03
13    36.0  0.22629E+03
14    39.0  0.17132E+03
15    42.0  0.12698E+03
16    45.0  0.92463E+02
17    48.0  0.66620E+02
18    51.0  0.48101E+02
19    54.0  0.35497E+02
20    56.0  0.29703E+02
21    59.0  0.23991E+02
```

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22    62.0  0.20870E+02
23    65.0  0.19412E+02
24    70.0  0.18784E+02
25    75.0  0.18587E+02
26    80.0  0.17758E+02
27    85.0  0.16044E+02
28    90.0  0.13652E+02
29    95.0  0.10972E+02
30   100.0  0.83859E+01
31   105.0  0.61725E+01
32   110.0  0.44727E+01
33   115.0  0.33040E+01
34   120.0  0.25978E+01
35   125.0  0.22415E+01
36   130.0  0.21171E+01
37   135.0  0.21279E+01
38   140.0  0.22110E+01
39   150.0  0.24982E+01
40   160.0  0.29218E+01
41   170.0  0.33657E+01
42   180.0  0.35638E+01
43      2  2.0+   0   40
44     1.0  0.16531E+02
45     5.0  0.16226E+02
46    10.0  0.15369E+02
47    15.0  0.14221E+02
48    18.0  0.13515E+02
49    21.0  0.12865E+02
50    24.0  0.12305E+02
51    27.0  0.11852E+02
52    30.0  0.11499E+02
53    33.0  0.11224E+02
54    36.0  0.10992E+02
55    39.0  0.10763E+02
56    42.0  0.10499E+02
57    45.0  0.10170E+02
58    48.0  0.97564E+01
59    51.0  0.92524E+01
60    54.0  0.86637E+01
61    56.0  0.82320E+01
62    59.0  0.75425E+01
63    62.0  0.68268E+01
64    65.0  0.61133E+01
65    70.0  0.50006E+01
66    75.0  0.40652E+01
67    80.0  0.33600E+01
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 68    85.0  0.28917E+01
 69    90.0  0.26305E+01
 70    95.0  0.25251E+01
 71   100.0  0.25175E+01
 72   105.0  0.25547E+01
 73   110.0  0.25955E+01
 74   115.0  0.26122E+01
 75   120.0  0.25902E+01
 76   125.0  0.25243E+01
 77   130.0  0.24164E+01
 78   135.0  0.22723E+01
 79   140.0  0.21004E+01
 80   150.0  0.17148E+01
 81   160.0  0.13509E+01
 82   170.0  0.10949E+01
 83   180.0  0.10035E+01
 84      3  3.0-   0   40
 85     1.0  0.24046E+01
 86     5.0  0.24061E+01
 87    10.0  0.24098E+01
 88    15.0  0.24138E+01
 89    18.0  0.24161E+01
 90    21.0  0.24187E+01
 91    24.0  0.24227E+01
 92    27.0  0.24292E+01
 93    30.0  0.24399E+01
 94    33.0  0.24561E+01
 95    36.0  0.24789E+01
 96    39.0  0.25086E+01
 97    42.0  0.25446E+01
 98    45.0  0.25858E+01
 99    48.0  0.26298E+01
100    51.0  0.26739E+01
101    54.0  0.27150E+01
102    56.0  0.27391E+01
103    59.0  0.27682E+01
104    62.0  0.27865E+01
105    65.0  0.27920E+01
106    70.0  0.27702E+01
107    75.0  0.27096E+01
108    80.0  0.26152E+01
109    85.0  0.24952E+01
110    90.0  0.23592E+01
111    95.0  0.22159E+01
112   100.0  0.20718E+01
113   105.0  0.19307E+01
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114   110.0  0.17938E+01
115   115.0  0.16605E+01
116   120.0  0.15293E+01
117   125.0  0.13989E+01
118   130.0  0.12687E+01
119   135.0  0.11394E+01
120   140.0  0.10126E+01
121   150.0  0.77731E+00
122   160.0  0.58629E+00
123   170.0  0.46131E+00
124   180.0  0.41777E+00
125      4  0.0+   0   40
126     1.0  0.20446E+01
127     5.0  0.19409E+01
128    10.0  0.16431E+01
129    15.0  0.12267E+01
130    18.0  0.95881E+00
131    21.0  0.70252E+00
132    24.0  0.47560E+00
133    27.0  0.29172E+00
134    30.0  0.15948E+00
135    33.0  0.82195E-01
136    36.0  0.58132E-01
137    39.0  0.81325E-01
138    42.0  0.14266E+00
139    45.0  0.23113E+00
140    48.0  0.33500E+00
141    51.0  0.44296E+00
142    54.0  0.54492E+00
143    56.0  0.60541E+00
144    59.0  0.68016E+00
145    62.0  0.73189E+00
146    65.0  0.75839E+00
147    70.0  0.74689E+00
148    75.0  0.67542E+00
149    80.0  0.56299E+00
150    85.0  0.43283E+00
151    90.0  0.30786E+00
152    95.0  0.20691E+00
153   100.0  0.14214E+00
154   105.0  0.11784E+00
155   110.0  0.13065E+00
156   115.0  0.17117E+00
157   120.0  0.22663E+00
158   125.0  0.28401E+00
159   130.0  0.33296E+00
```

```
160   135.0  0.36769E+00
161   140.0  0.38759E+00
162   150.0  0.39950E+00
163   160.0  0.41004E+00
164   170.0  0.43332E+00
165   180.0  0.44671E+00
166      5  2.0+   0   40
167     1.0  0.12570E+00
168     5.0  0.12518E+00
169    10.0  0.12358E+00
170    15.0  0.12096E+00
171    18.0  0.11893E+00
172    21.0  0.11658E+00
173    24.0  0.11394E+00
174    27.0  0.11104E+00
175    30.0  0.10790E+00
176    33.0  0.10458E+00
177    36.0  0.10111E+00
178    39.0  0.97522E-01
179    42.0  0.93878E-01
180    45.0  0.90221E-01
181    48.0  0.86601E-01
182    51.0  0.83068E-01
183    54.0  0.79675E-01
184    56.0  0.77514E-01
185    59.0  0.74460E-01
186    62.0  0.71672E-01
187    65.0  0.69192E-01
188    70.0  0.65841E-01
189    75.0  0.63582E-01
190    80.0  0.62502E-01
191    85.0  0.62633E-01
192    90.0  0.63949E-01
193    95.0  0.66374E-01
194   100.0  0.69786E-01
195   105.0  0.74030E-01
196   110.0  0.78932E-01
197   115.0  0.84305E-01
198   120.0  0.89967E-01
199   125.0  0.95744E-01
200   130.0  0.10148E+00
201   135.0  0.10703E+00
202   140.0  0.11229E+00
203   150.0  0.12153E+00
204   160.0  0.12856E+00
205   170.0  0.13296E+00
```

```
 180.0  0.13446E+00
<ANG.DIS.>      1.01  39.70000     12.00    0    5
     1  0.0+   0   40
   1.0  0.59705E+07
   5.0  0.54908E+04
  10.0  0.78120E+03
  15.0  0.74650E+03
  18.0  0.66405E+03
  21.0  0.55361E+03
  24.0  0.43761E+03
  27.0  0.33008E+03
  30.0  0.23837E+03
  33.0  0.16516E+03
  36.0  0.11005E+03
  39.0  0.70878E+02
  42.0  0.44614E+02
  45.0  0.28105E+02
  48.0  0.18467E+02
  51.0  0.13313E+02
  54.0  0.10823E+02
  56.0  0.99897E+01
  59.0  0.93205E+01
  62.0  0.88627E+01
  65.0  0.83253E+01
  70.0  0.70323E+01
  75.0  0.53966E+01
  80.0  0.37728E+01
  85.0  0.24379E+01
  90.0  0.15032E+01
  95.0  0.94338E+00
 100.0  0.66079E+00
 105.0  0.54305E+00
 110.0  0.49806E+00
 115.0  0.46703E+00
 120.0  0.42236E+00
 125.0  0.35869E+00
 130.0  0.28291E+00
 135.0  0.20655E+00
 140.0  0.14094E+00
 150.0  0.72779E-01
 160.0  0.97280E-01
 170.0  0.16606E+00
 180.0  0.20160E+00
    2  2.0+   0   40
   1.0  0.85118E+01
   5.0  0.82978E+01
```

```
252    10.0  0.78382E+01
253    15.0  0.76158E+01
254    18.0  0.77609E+01
255    21.0  0.81348E+01
256    24.0  0.86737E+01
257    27.0  0.92565E+01
258    30.0  0.97348E+01
259    33.0  0.99707E+01
260    36.0  0.98705E+01
261    39.0  0.94060E+01
262    42.0  0.86154E+01
263    45.0  0.75887E+01
264    48.0  0.64415E+01
265    51.0  0.52889E+01
266    54.0  0.42246E+01
267    56.0  0.35959E+01
268    59.0  0.27992E+01
269    62.0  0.21840E+01
270    65.0  0.17374E+01
271    70.0  0.12931E+01
272    75.0  0.10940E+01
273    80.0  0.10070E+01
274    85.0  0.94036E+00
275    90.0  0.84853E+00
276    95.0  0.72345E+00
277   100.0  0.57928E+00
278   105.0  0.43707E+00
279   110.0  0.31431E+00
280   115.0  0.22067E+00
281   120.0  0.15830E+00
282   125.0  0.12415E+00
283   130.0  0.11227E+00
284   135.0  0.11555E+00
285   140.0  0.12691E+00
286   150.0  0.15087E+00
287   160.0  0.15631E+00
288   170.0  0.14610E+00
289   180.0  0.13924E+00
290      3  3.0-   0   40
291     1.0  0.98393E+00
292     5.0  0.10159E+01
293    10.0  0.11100E+01
294    15.0  0.12598E+01
295    18.0  0.13812E+01
296    21.0  0.15333E+01
297    24.0  0.17217E+01
```

```
298    27.0  0.19473E+01
299    30.0  0.22037E+01
300    33.0  0.24760E+01
301    36.0  0.27419E+01
302    39.0  0.29751E+01
303    42.0  0.31500E+01
304    45.0  0.32461E+01
305    48.0  0.32518E+01
306    51.0  0.31654E+01
307    54.0  0.29951E+01
308    56.0  0.28425E+01
309    59.0  0.25699E+01
310    62.0  0.22644E+01
311    65.0  0.19476E+01
312    70.0  0.14437E+01
313    75.0  0.10199E+01
314    80.0  0.70236E+00
315    85.0  0.48860E+00
316    90.0  0.35894E+00
317    95.0  0.28723E+00
318   100.0  0.24889E+00
319   105.0  0.22519E+00
320   110.0  0.20445E+00
321   115.0  0.18125E+00
322   120.0  0.15468E+00
323   125.0  0.12648E+00
324   130.0  0.99373E-01
325   135.0  0.75921E-01
326   140.0  0.57815E-01
327   150.0  0.38754E-01
328   160.0  0.35982E-01
329   170.0  0.38557E-01
330   180.0  0.39943E-01
331      4  0.0+   0   40
332     1.0  0.31887E+01
333     5.0  0.29017E+01
334    10.0  0.21400E+01
335    15.0  0.12427E+01
336    18.0  0.78140E+00
337    21.0  0.43925E+00
338    24.0  0.23481E+00
339    27.0  0.16019E+00
340    30.0  0.18773E+00
341    33.0  0.27923E+00
342    36.0  0.39525E+00
343    39.0  0.50245E+00
```

```
 42.0  0.57788E+00
 45.0  0.61022E+00
 48.0  0.59858E+00
 51.0  0.54985E+00
 54.0  0.47546E+00
 56.0  0.41799E+00
 59.0  0.32911E+00
 62.0  0.24610E+00
 65.0  0.17635E+00
 70.0  0.99013E-01
 75.0  0.69250E-01
 80.0  0.73137E-01
 85.0  0.91696E-01
 90.0  0.10850E+00
 95.0  0.11373E+00
100.0  0.10489E+00
105.0  0.85209E-01
110.0  0.60931E-01
115.0  0.38552E-01
120.0  0.22783E-01
125.0  0.15610E-01
130.0  0.16468E-01
135.0  0.23191E-01
140.0  0.33230E-01
150.0  0.56308E-01
160.0  0.79751E-01
170.0  0.10046E+00
180.0  0.10935E+00
   5  2.0+   0   40
 1.0  0.48170E+00
 5.0  0.47873E+00
10.0  0.47094E+00
15.0  0.46183E+00
18.0  0.45690E+00
21.0  0.45257E+00
24.0  0.44846E+00
27.0  0.44382E+00
30.0  0.43765E+00
33.0  0.42893E+00
36.0  0.41680E+00
39.0  0.40071E+00
42.0  0.38054E+00
45.0  0.35660E+00
48.0  0.32957E+00
51.0  0.30043E+00
54.0  0.27033E+00
```

```
390    56.0  0.25029E+00
391    59.0  0.22110E+00
392    62.0  0.19378E+00
393    65.0  0.16906E+00
394    70.0  0.13481E+00
395    75.0  0.10962E+00
396    80.0  0.92565E-01
397    85.0  0.81773E-01
398    90.0  0.75127E-01
399    95.0  0.70740E-01
400   100.0  0.67214E-01
401   105.0  0.63685E-01
402   110.0  0.59735E-01
403   115.0  0.55258E-01
404   120.0  0.50334E-01
405   125.0  0.45144E-01
406   130.0  0.39923E-01
407   135.0  0.34941E-01
408   140.0  0.30481E-01
409   150.0  0.24109E-01
410   160.0  0.21772E-01
411   170.0  0.22206E-01
412   180.0  0.22803E-01
```

OPTMAN.ICS file

```
 1  <INE.C.S.>      1.01  20.90000     12.00    0    4
 2   0.61491105E+02
 3   0.25712818E+02
 4   0.50385012E+01
 5   0.10915372E+01
 6  <INE.C.S.>      1.01  39.70000     12.00    0    4
 7   0.28442630E+02
 8   0.12604566E+02
 9   0.25209230E+01
10   0.18316537E+01
```

OPTMAN.TL file

```
 1  <TLJ     >      1.01  20.90000     12.00    0   16
 2    0.5 +    1
 3    1   0   0.5   5.7378461D-01
```

```
 4    1.5 +    1
 5    1   2   1.5   7.1334591D-01
 6    2.5 +    1
 7    1   2   2.5   5.8313868D-01
 8    3.5 +    1
 9    1   4   3.5   8.7373406D-02
10    4.5 +    1
11    1   4   4.5   1.6165536D-01
12    5.5 +    1
13    1   6   5.5   2.2870480D-03
14    6.5 +    1
15    1   6   6.5   2.4863075D-03
16    7.5 +    1
17    1   8   7.5   4.1809846D-05
18    0.5 -    1
19    1   1   0.5   5.6979255D-01
20    1.5 -    1
21    1   1   1.5   5.2124520D-01
22    2.5 -    1
23    1   3   2.5   4.0323268D-01
24    3.5 -    1
25    1   3   3.5   6.6835652D-01
26    4.5 -    1
27    1   5   4.5   1.4472244D-02
28    5.5 -    1
29    1   5   5.5   1.7553733D-02
30    6.5 -    1
31    1   7   6.5   2.9739545D-04
32    7.5 -    1
33    1   7   7.5   2.5273519D-04
34  <TLJ     >      1.01  39.70000     12.00    0   31
35    0.5 +    1
36    1   0   0.5   5.9060071D-01
37    1.5 +    1
38    1   2   1.5   6.7224853D-01
39    2.5 +    1
40    1   2   2.5   5.7019019D-01
41    3.5 +    1
42    1   4   3.5   2.7661760D-01
43    4.5 +    1
44    1   4   4.5   4.2073594D-01
45    5.5 +    1
46    1   6   5.5   2.5037786D-02
47    6.5 +    1
48    1   6   6.5   2.4938568D-02
49    7.5 +    1
```

```
    1    8    7.5    1.4760093D-03
    8.5 +     1
    1    8    8.5    9.2975241D-04
    9.5 +     1
    1   10    9.5    8.2186264D-05
   10.5 +     1
    1   10   10.5    2.3607990D-05
   11.5 +     1
    1   12   11.5    4.2874804D-06
   12.5 +     1
    1   12   12.5    6.7800821D-08
   13.5 +     1
    1   14   13.5    1.6115521D-07
   14.5 +     1
    1   14   14.5    8.5105837D-17
   15.5 +     1
    1   16   15.5    3.8466296D-09
    0.5 -     1
    1    1    0.5    6.1145569D-01
    1.5 -     1
    1    1    1.5    5.7941952D-01
    2.5 -     1
    1    3    2.5    5.5815178D-01
    3.5 -     1
    1    3    3.5    5.9986105D-01
    4.5 -     1
    1    5    4.5    9.1284953D-02
    5.5 -     1
    1    5    5.5    1.2293244D-01
    6.5 -     1
    1    7    6.5    6.3177864D-03
    7.5 -     1
    1    7    7.5    5.0791914D-03
    8.5 -     1
    1    9    8.5    3.4558767D-04
    9.5 -     1
    1    9    9.5    1.5621959D-04
   10.5 -     1
    1   11   10.5    1.9272893D-05
   11.5 -     1
    1   11   11.5    2.6977274D-06
   12.5 -     1
    1   13   12.5    8.7616063D-07
   14.5 -     1
    1   15   14.5    2.6414880D-08
   15.5 -     1
```

```
96    1  15  15.5   2.6175853D-17
```

OPTMAN.LEG

```
 1  <LEGENDRE>      1.01  20.90000     12.00    0    5
 2      1   16 COUPLED LEVEL, NUMBER OF VALUES
 3      1    0    7.2364437268D-02
 4      1    1    5.8564916552D-02
 5      1    2    4.3594871585D-02
 6      1    3    3.0640641116D-02
 7      1    4    2.0043336199D-02
 8      1    5    1.1029154493D-02
 9      1    6    4.9100920395D-03
10      1    7    1.8123723722D-03
11      1    8    6.0862853319D-04
12      1    9    1.8457905391D-04
13      1   10    5.1680789259D-05
14      1   11    1.2609243978D-05
15      1   12    2.5719399628D-06
16      1   13    4.2889464056D-07
17      1   14    6.0653118851D-08
18      1   15    5.9879111272D-09
19      2   16 COUPLED LEVEL, NUMBER OF VALUES
20      2    0    4.8933061531D-03
21      2    1    1.8597380079D-03
22      2    2    7.0339639725D-04
23      2    3    1.8015373390D-04
24      2    4   -1.1177027850D-04
25      2    5   -1.4584126582D-05
26      2    6    6.0337318908D-05
27      2    7    5.6688520974D-05
28      2    8    2.9314991472D-05
29      2    9    1.1274013955D-05
30      2   10    3.8058863883D-06
31      2   11    1.0691670409D-06
32      2   12    2.6166002281D-07
33      2   13    4.7850413911D-08
34      2   14    7.0185797767D-09
35      2   15    6.6628931248D-10
36      3   16 COUPLED LEVEL, NUMBER OF VALUES
37      3    0    2.0461608574D-03
38      3    1    3.5291760177D-04
39      3    2   -1.3466006335D-04
40      3    3   -2.6528381269D-05
```

```
41      3    4   -1.4851076140D-09
42      3    5    1.3085843653D-05
43      3    6    4.7577614262D-06
44      3    7   -8.5504239255D-07
45      3    8   -1.1209677508D-06
46      3    9   -4.9917740300D-07
47      3   10   -1.9933022862D-07
48      3   11   -5.4359873705D-08
49      3   12   -1.1882900960D-08
50      3   13   -2.0065458118D-09
51      3   14   -2.6328478998D-10
52      3   15   -2.1618754055D-11
53      4   16 COUPLED LEVEL, NUMBER OF VALUES
54      4    0    4.0095114597D-04
55      4    1    5.3813153943D-05
56      4    2    2.1136626613D-05
57      4    3   -2.3698437268D-05
58      4    4    2.3475977527D-05
59      4    5    5.7410102724D-05
60      4    6    3.4198853087D-05
61      4    7    9.8674028411D-06
62      4    8    4.5577598936D-06
63      4    9    1.2672243782D-06
64      4   10    3.5368848489D-07
65      4   11    8.3683796220D-08
66      4   12    1.7243557721D-08
67      4   13    2.4617489546D-09
68      4   14    2.9168709366D-10
69      4   15    2.4069942819D-11
70      5   16 COUPLED LEVEL, NUMBER OF VALUES
71      5    0    8.6861758548D-05
72      5    1   -3.5047701379D-06
73      5    2    8.9322244359D-06
74      5    3    9.5628207382D-07
75      5    4   -1.6666460404D-07
76      5    5   -5.0835412517D-08
77      5    6    4.9030444034D-09
78      5    7    6.3718509893D-10
79      5    8    1.0801246490D-10
80      5    9    1.0208419009D-11
81      5   10    9.4593426970D-13
82      5   11    7.7858767077D-14
83      5   12    4.9006596556D-15
84      5   13    2.3471913763D-16
85      5   14    1.0046406941D-17
86      5   15    3.0738809080D-19
```

ANGL-DIS.YW

```
 1   20.900000 40  5
 2   0.100000E+01 0.108726E+01 0.165310E-01 0.240460E-02 0.204458E-02 0.125697E-03
 3   0.500000E+01 0.105681E+01 0.162261E-01 0.240608E-02 0.194089E-02 0.125180E-03
 4   0.100000E+02 0.966861E+00 0.153692E-01 0.240978E-02 0.164307E-02 0.123577E-03
 5   0.150000E+02 0.833177E+00 0.142210E-01 0.241381E-02 0.122667E-02 0.120957E-03
 6   0.180000E+02 0.740173E+00 0.135154E-01 0.241609E-02 0.958808E-03 0.118927E-03
 7   0.210000E+02 0.643174E+00 0.128647E-01 0.241874E-02 0.702524E-03 0.116579E-03
 8   0.240000E+02 0.546501E+00 0.123050E-01 0.242268E-02 0.475604E-03 0.113939E-03
 9   0.270000E+02 0.453916E+00 0.118516E-01 0.242923E-02 0.291715E-03 0.111036E-03
10   0.300000E+02 0.368416E+00 0.114990E-01 0.243992E-02 0.159481E-03 0.107905E-03
11   0.330000E+02 0.292125E+00 0.112240E-01 0.245614E-02 0.821951E-04 0.104581E-03
12   0.360000E+02 0.226286E+00 0.109918E-01 0.247890E-02 0.581318E-04 0.101105E-03
13   0.390000E+02 0.171325E+00 0.107627E-01 0.250856E-02 0.813251E-04 0.975224E-04
14   0.420000E+02 0.126981E+00 0.104988E-01 0.254464E-02 0.142664E-03 0.938780E-04
15   0.450000E+02 0.924628E-01 0.101698E-01 0.258578E-02 0.231126E-03 0.902207E-04
16   0.480000E+02 0.666197E-01 0.975644E-02 0.262980E-02 0.334999E-03 0.866006E-04
17   0.510000E+02 0.481013E-01 0.925239E-02 0.267392E-02 0.442956E-03 0.830684E-04
18   0.540000E+02 0.354969E-01 0.866369E-02 0.271499E-02 0.544917E-03 0.796747E-04
19   0.560000E+02 0.297028E-01 0.823196E-02 0.273911E-02 0.605408E-03 0.775138E-04
20   0.590000E+02 0.239909E-01 0.754245E-02 0.276818E-02 0.680158E-03 0.744602E-04
21   0.620000E+02 0.208705E-01 0.682676E-02 0.278646E-02 0.731895E-03 0.716723E-04
22   0.650000E+02 0.194125E-01 0.611327E-02 0.279200E-02 0.758385E-03 0.691921E-04
23   0.700000E+02 0.187836E-01 0.500058E-02 0.277016E-02 0.746889E-03 0.658406E-04
24   0.750000E+02 0.185870E-01 0.406518E-02 0.270960E-02 0.675424E-03 0.635819E-04
25   0.800000E+02 0.177584E-01 0.336000E-02 0.261518E-02 0.562990E-03 0.625025E-04
26   0.850000E+02 0.160444E-01 0.289170E-02 0.249522E-02 0.432834E-03 0.626332E-04
27   0.900000E+02 0.136525E-01 0.263050E-02 0.235923E-02 0.307862E-03 0.639493E-04
28   0.950000E+02 0.109719E-01 0.252508E-02 0.221593E-02 0.206906E-03 0.663737E-04
29   0.100000E+03 0.838593E-02 0.251749E-02 0.207183E-02 0.142135E-03 0.697856E-04
30   0.105000E+03 0.617254E-02 0.255474E-02 0.193073E-02 0.117836E-03 0.740303E-04
31   0.110000E+03 0.447266E-02 0.259549E-02 0.179382E-02 0.130645E-03 0.789319E-04
32   0.115000E+03 0.330403E-02 0.261224E-02 0.166050E-02 0.171167E-03 0.843053E-04
33   0.120000E+03 0.259780E-02 0.259017E-02 0.152930E-02 0.226627E-03 0.899671E-04
34   0.125000E+03 0.224149E-02 0.252431E-02 0.139887E-02 0.284012E-03 0.957440E-04
35   0.130000E+03 0.211711E-02 0.241637E-02 0.126868E-02 0.332957E-03 0.101479E-03
36   0.135000E+03 0.212789E-02 0.227225E-02 0.113936E-02 0.367691E-03 0.107034E-03
37   0.140000E+03 0.221098E-02 0.210037E-02 0.101260E-02 0.387588E-03 0.112291E-03
38   0.150000E+03 0.249824E-02 0.171485E-02 0.777314E-03 0.399496E-03 0.121526E-03
39   0.160000E+03 0.292177E-02 0.135090E-02 0.586289E-03 0.410036E-03 0.128560E-03
40   0.170000E+03 0.336567E-02 0.109490E-02 0.461315E-03 0.433318E-03 0.132961E-03
41   0.180000E+03 0.356375E-02 0.100346E-02 0.417768E-03 0.446710E-03 0.134458E-03
```

```
39.700000 40  5
0.100000E+01 0.597054E+04 0.851176E-02 0.983933E-03 0.318872E-02 0.481695E-03
0.500000E+01 0.549081E+01 0.829776E-02 0.101589E-02 0.290170E-02 0.478727E-03
0.100000E+02 0.781204E+00 0.783821E-02 0.111004E-02 0.214000E-02 0.470945E-03
0.150000E+02 0.746499E+00 0.761579E-02 0.125976E-02 0.124272E-02 0.461832E-03
0.180000E+02 0.664046E+00 0.776093E-02 0.138116E-02 0.781403E-03 0.456904E-03
0.210000E+02 0.553607E+00 0.813484E-02 0.153335E-02 0.439254E-03 0.452568E-03
0.240000E+02 0.437610E+00 0.867365E-02 0.172171E-02 0.234810E-03 0.448458E-03
0.270000E+02 0.330076E+00 0.925646E-02 0.194727E-02 0.160195E-03 0.443816E-03
0.300000E+02 0.238366E+00 0.973484E-02 0.220367E-02 0.187733E-03 0.437651E-03
0.330000E+02 0.165156E+00 0.997070E-02 0.247596E-02 0.279227E-03 0.428934E-03
0.360000E+02 0.110055E+00 0.987053E-02 0.274185E-02 0.395248E-03 0.416801E-03
0.390000E+02 0.708776E-01 0.940597E-02 0.297507E-02 0.502453E-03 0.400711E-03
0.420000E+02 0.446141E-01 0.861541E-02 0.314997E-02 0.577883E-03 0.380540E-03
0.450000E+02 0.281048E-01 0.758869E-02 0.324614E-02 0.610218E-03 0.356595E-03
0.480000E+02 0.184668E-01 0.644155E-02 0.325181E-02 0.598580E-03 0.329568E-03
0.510000E+02 0.133130E-01 0.528894E-02 0.316541E-02 0.549855E-03 0.300434E-03
0.540000E+02 0.108229E-01 0.422457E-02 0.299508E-02 0.475461E-03 0.270327E-03
0.560000E+02 0.998969E-02 0.359589E-02 0.284248E-02 0.417993E-03 0.250291E-03
0.590000E+02 0.932049E-02 0.279916E-02 0.256987E-02 0.329108E-03 0.221098E-03
0.620000E+02 0.886265E-02 0.218402E-02 0.226440E-02 0.246103E-03 0.193776E-03
0.650000E+02 0.832526E-02 0.173744E-02 0.194758E-02 0.176346E-03 0.169057E-03
0.700000E+02 0.703230E-02 0.129310E-02 0.144370E-02 0.990134E-04 0.134806E-03
0.750000E+02 0.539663E-02 0.109402E-02 0.101992E-02 0.692496E-04 0.109622E-03
0.800000E+02 0.377282E-02 0.100701E-02 0.702360E-03 0.731366E-04 0.925653E-04
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0.900000E+02 0.150318E-02 0.848527E-03 0.358935E-03 0.108501E-03 0.751267E-04
0.950000E+02 0.943375E-03 0.723450E-03 0.287228E-03 0.113731E-03 0.707398E-04
0.100000E+03 0.660792E-03 0.579280E-03 0.248893E-03 0.104891E-03 0.672143E-04
0.105000E+03 0.543048E-03 0.437072E-03 0.225193E-03 0.852093E-04 0.636854E-04
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0.135000E+03 0.206545E-03 0.115547E-03 0.759210E-04 0.231910E-04 0.349411E-04
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0.150000E+03 0.727793E-04 0.150870E-03 0.387541E-04 0.563084E-04 0.241091E-04
0.160000E+03 0.972802E-04 0.156307E-03 0.359815E-04 0.797514E-04 0.217716E-04
0.170000E+03 0.166059E-03 0.146102E-03 0.385568E-04 0.100461E-03 0.222061E-04
0.180000E+03 0.201605E-03 0.139242E-03 0.399432E-04 0.109350E-03 0.228033E-04
```

3.4 Other Minor Changes

We had made some additional minor changes for users convenience. If the potential adjustment option of the OPTMAN code is used then the user is able to see the individual χ^2 value for each experimental data point used in adjustment, and calculated values compared with experimental ones with appropriate errors (In the previous version only global χ^2 for each run was outputted).

4 Conclusions

Following the ISTC B-1319 project's Working Plan we extended OPTMAN code's options by including the possibility of accounting dispersive relationships between imaginary and real parts of optical potential used. We also developed theoretical approaches and computational algorithms allowing predictions of isobaric analog states excitations in $p + A(N, Z) \rightarrow n' + A(N - 1, Z + 1)$ reactions to test the Lane consistency of the potential and improve isovector potential fits. A new Lane consistent approach to define the Coulomb correction of proton optical potential has been proposed. Incorporation of relativistic generalization algorithm identical to one used in the ECIS code, now allows to get the same computational results for the two codes with identical inputs. New output files now allow to use them as inputs for the EMPIRE evaluation system.

Physical and mathematical ideas of the work have been developed in close cooperation among the Collaborating Parties, which are Japan and European Union and with support from the International Atomic Energy Agency (IAEA) Nuclear Data Section. The present version of modernized OPTMAN code was employed to derive regional nuclear optical potentials applicable up to 200 MeV incident nucleon energies for actinides $(90 \leq Z \leq 98)$, Ta $-$ W $-$ Hf nuclei and also a number of local potentials for nuclei as ^{55}Mn, ^{103}Ru, ^{197}Au, etc, these derived high-quality dispersive optical potentials are already being used for high energy file evaluation in a cooperative work with our Collaborating Parties and the IAEA Nuclear Data Section. All these potentials are included in the latest version of the RIPL (Reference Input Parameter Library) library, which is an international database maintained by the IAEA.

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