Web knowledge base on low-energy nuclear physics

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Abstract. The Web knowledge base on low-energy nuclear physics is described. The project is aimed at developing models and corresponding computing codes for comprehensive theoretical analysis of experimental data on low and intermediate energy nuclear reactions. Accumulated knowledge base experimental data and computational codes are available on web-servers http://nrv.jinr.ru/nrv/ and http://nrv.sun.ac.za/ with free accessibility to any remote user through any web-browser of choice.

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INTRODUCTION

Over the past hundred years progress in nuclear physics has generated a vast amount of the experimental data both on nuclear properties and on reactions induced by nuclear particles. This data currently resides in literature or in special databases. Advances in internet technology has however led to the development of Web based nuclear databases in recent years. These nuclear databases, as a rule, supply users with ordinary text files of tabular information are limited to specific information of a specific type. An example of this is the web-server http://depni.sinp.msu.ru/cdfe supported by the Center for photonuclear experiments data (INP MSU, Moscow) that provides an access to a number of databases on properties of atomic nuclei and their interaction with elementary particles, on giant dipole resonance parameters, on nuclear scientific reference data and others. Part of these databases were adopted from the data-servers in Lawrence Berkeley National Laboratory (http://ie.lbl.gov/) and Brookhaven National Laboratory (http://www.nndc.bnl.gov/), which also provide access through the Internet. Similar data archives were organized on the site of the Nuclear Energy Agency (http://www.nea.fr/dbdata/). V.G.Khlopin Radium Institute in collaboration with the U.S. Department of Energy, where a gamma ray spectra catalog (http://www.atom.nw.ru/ skv/) has been developed. The Nuclear Data group at the Triangle Universities Nuclear Laboratory (http://www.tunl.duke.edu/nucldata/index.shtml) is responsible for the evaluation of light nuclei within the United States Nuclear Data Network and the international Nuclear Structure and Decay Data Evaluators Network.

The databases cited above form part of a long list web based databases currently available.

Certainly cumulative data and its free accessibility assist in the day-to-day work of a modern nuclear physicist. However, variety of data requirements, for example, in the case of planning new experiments results in the work consisting of the following steps. Firstly, a search for available experimental data in the databases. Secondly processing the collected data, in some cases this includes the analysis of the data within appropriate theoretical model. Thirdly, simulation of experiment and choice of effective parameters of the experimental set-ups. Fourthly, when the experiment is completed, the measured data have to be processed and analyzed with the help of the modern physical approaches. All these steps require considerable amount of time, resources and experience.

In order to simplify this work our Web based database system combines databases on nuclear properties and experimental cross sections of nuclear reactions along with computer codes of theoretical models in a unique system which we name the Knowledge Base on Low Energy Nuclear Physics. The system can be accessed on the web-servers http://nrv.jinr.ru/nrv/ (FLNR JINR, Russia) and http://nrv.sun.ac.za/ (Stellenbosch University, South Africa). The nuclear physics Knowledge base adresses the following two problems . (i) Fast and visual access of experimental data on nuclear structure and cross sections of nuclear reactions, a possibility for processing and systematization of these data, their comparison and plotting of the studied regularities. (ii) Analysis of experimental data and modeling of the processes of nuclear dynamics within the modern foolproof codes based on the well-established physical approaches all in a window of a Web-browser. A set of coupled algorithms of nuclear dynamics, experimental data bases on nuclear structure and nuclear reactions, and a system of special net codes for analysis, management, representation and handling of user's queries and obtained results of calculations form altogether what is usually called "knowledge base".

KNOWLEDGE BASE ON LOW ENERGY NUCLEAR PHYSICS

Our Knowledge base differes from the current existing nuclear databases in three distinct ways. (i) In addition to the text information, the Knowledge base contains special programs for graphic representation of data, performs comparative analysis of the data and provides systematics of all kinds over a group of nuclei or the whole nuclear map. (ii) Our databases on the experimental cross sections of nuclear reactions contain the digitized data. Besides significant simplification of their control, this allows one to perform overall processing these data, make graphical comparison of the cross sections with each other and, finally, analyze these data within theoretical models. All these actions are made in the window of any Web-browser without installing any additional computational codes and graphical packages. (iii) The complicated computational programs of modeling the low-energy nuclear dynamics form the main part of the developed system. Taken together with the experimental data on nuclear properties they form the "nuclear knowledge base". As far as we know, for the first time, the complicated computational codes of modeling nuclear dynamics featuring a graphical interface for visual display of data input and graphical representation and also handling of the obtained results in the window of Web-browser, are available in the Internet without a necessity on the part

TABLE 1. Components of the Knowledge base on low energy nuclear physics

Nuclear Map: nucleus property data*	**Nuclear reaction data**	**Nuclear models, Nuclear decay**	**Nuclear reaction models**
Spin, parity, abundance	HI elastic scattering	Shell model	Elastic scattering (Optical mode, Classical model)
Half-life, decay modes	HI complete fusion	Nuclear fission	Inelastic scattering (DWBA)
Nuclear masses	Evaporation residues	Decay of excited nuclei	Heavy-ion fusion (Coupled channel model, Empirical model)
Excited states			Evaporation residues formation (Monte-Carlo)
Metastable states			Driving potential
Nuclear radii			Nuclear reaction kinematics (2-body, 3-body, Q-calculator)
Nuclear radii			
G.s. deformations			
Electro-magnetic properties			

* Most of experimental data are taken from National Nucleur Data Center, http://www.nndc.bnl.gov

of the user to download any of the programs. Beside easiness and convenience of use, this method allows unifying,analysis and processing of the experimental data within the well-established standard models.

The functioning components of the knowledge base are listed in Table 1. Below we give a short description of its main parts.

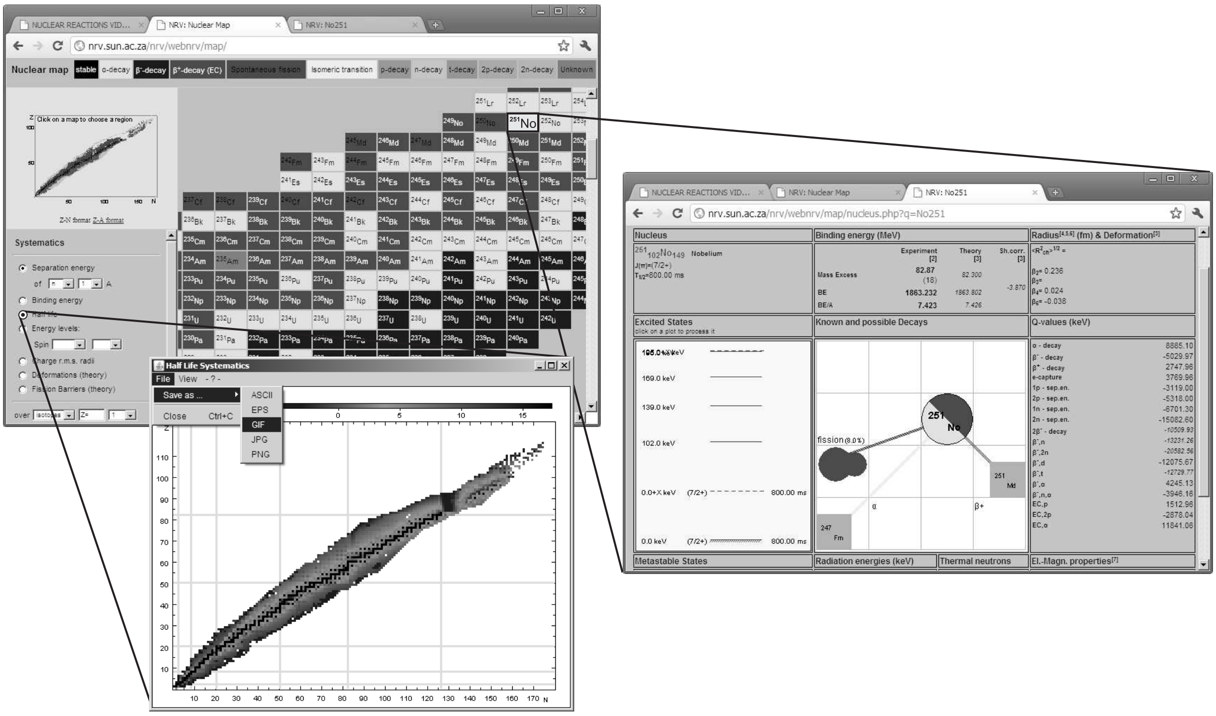

FIGURE 1. Nuclear Map – the databases on properties of an individual atomic nucleus in combination with special software for graphic representation of the data, performing their comparative analysis and obtaining systematizations of all kinds over a group of nuclei or the whole nuclear map.

Nuclear Map and Nuclear Reaction Data

Nuclear Map is a part of the knowledge base combining few databases on all kinds of nucleus properties (see Table 1) adopted from different sources [1, 2, 3, 4, 5, 6, 7]. The Nuclear Map is organized in form of the hypertext table where each cell (colored in correspondence with the main decay branch) represents the web-link to the page with detailed information on the properties of corresponding atomic nucleus. It is demonstrated in Fig. 1 (right side). In particular, on this page user may find the data on spin and parity of the ground state of the nucleus, its binding energy and mass, charge radius and ground state deformations, Q-values of possible decays. Information on observed decay branches (with their probabilities) and structure of excited states are shown also in graphical form (see Fig. 1). Finally, user obtains the data on metastable states, known γ-radiation energies, the capture cross section of thermal neutron, and additional electromagnetic properties (magnetic momentum, transition probabilities and others).

In a number of cases it is necessary to compare certain characteristic over a group of nuclei. This possibility is also realized in the Nuclear Map. With the help of a friendly interface user may send a corresponding query to the Knowledge base. It results in a web-page with the required data in graphical form. In Fig. 1 (at the bottom), in particular, the nuclear half-life systematics is shown over all nuclear map. It is important to mention that data are shown in separate Java window which has its own menu (see Fig. 2) and provides the user with the possibility to process obtained data and, in particular, to save

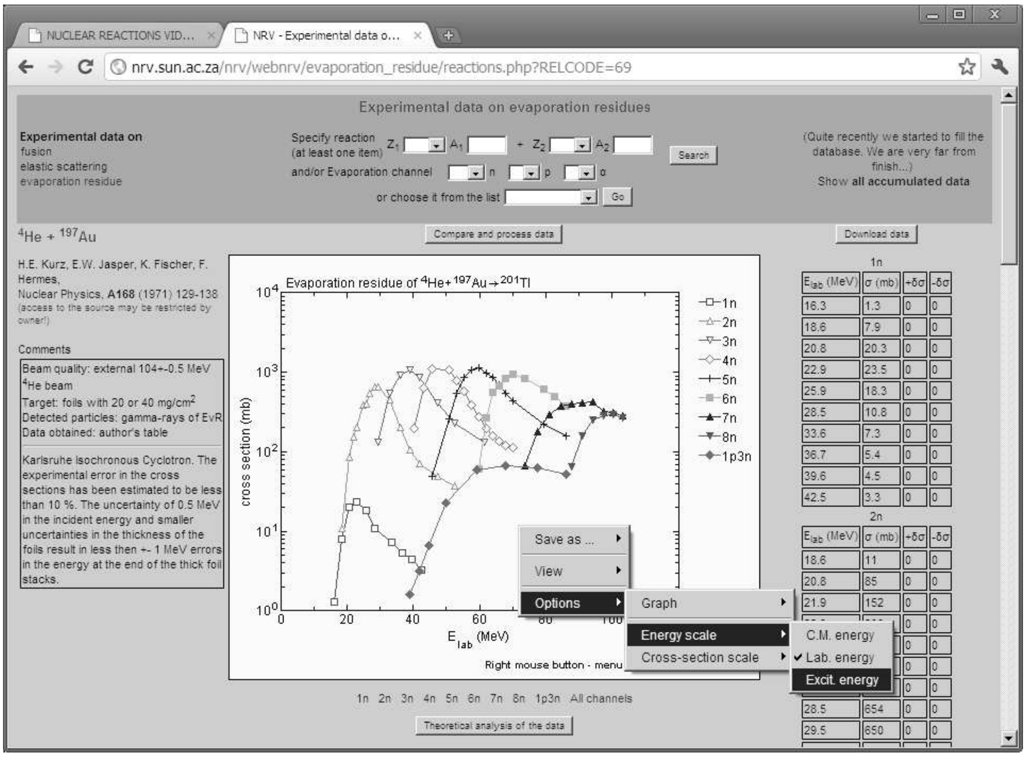

FIGURE 2. Experimental data on cross section of evaporation residue formation in reaction ^{4}He + ^{197}Au → ^{201}Tl. Besides the cross section values the database contains information on authors, original source of the data and details of experimental procedure. All information is downloadable in text or graphical format.

it in textual (ASCII), bitmap (GIF, JPG, PNG) or post-script (EPS) format. The wide use of Java applets makes the Knowledge base handy for the subsequent data processing. The applets allow one to realize just within Web-browser window all the possibilities like an application installed in a user computer.

The Knowledge base also includes databases on the cross sections of nuclear reactions. Among them are (i) the elastic scattering cross sections for the reactions induced by light nuclei (with mass A<20), (ii) the heavy-ion complete fusion cross section and (iii) the evaporation residues cross sections. Last two databases are unique ones. They contain experimental points, reference data and detailed information of the measurement procedure (beam characteristics, target conditions, experimental set-up, measured products and others). The information for these databases were obtained either by digitizing corresponding tables and plots published in main nuclear physical journals or directly from authors. We covered a period of time from 1970 up to present days and keep the databases in up-to-date state. At the moment the databases consist data on more then 1600 reactions, i.e. about 15 000 experimental points. As an example the data on the evaporation residue cross section for the reaction ^{4}He + ^{197}Ag for various channels are shown in Fig. 2.

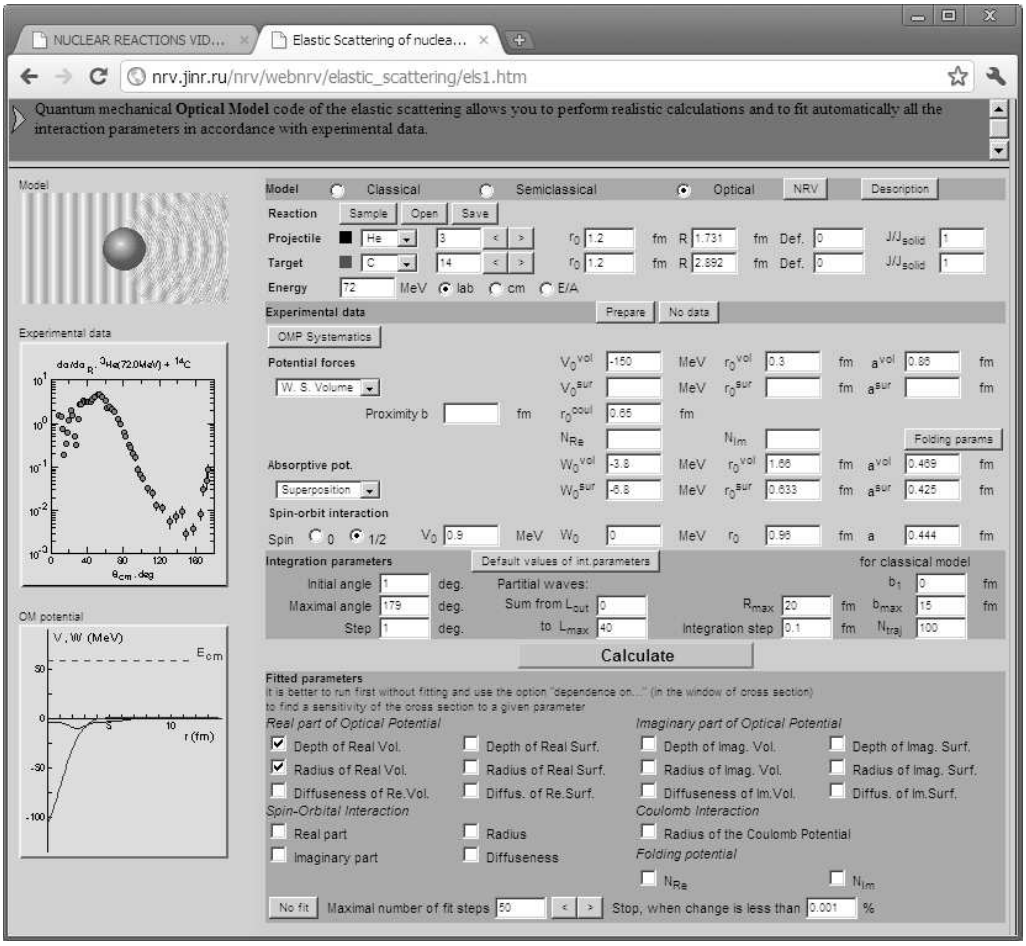

FIGURE 3. Web-form for preparation of the optical model parameters – reaction partners, collision energy, experimental data, optical model potential, integration and fitting parameters.

Nuclear Models and Nuclear Reaction Models

It was mentioned above that one of the main features of the Knowledge base is the possibility to run the computer codes modeling nuclear reaction dynamics. The theoretical models available at the moment in the Web Knowledge base are listed in Table 1. We include on the Knowledge base only the well-established models either coded by us or adopted from the open sources (distributed by author, published or stored in approved code-banks). Originally these codes are the Fortran text supplied with complicated manuals describing the structure of input file. Often the preparation of the input turns out to be difficult even for an experienced user with good knowledge the theoretical approach in detail.

In order to avoid these difficulties we have developed a comprehensible web-form which allows the user to define all input parameters for each theoretical model included to the Knowledge base. As an example such a web-form is shown in Fig. 3. Using this form user may prepare parameters and run the calculation of the differential cross

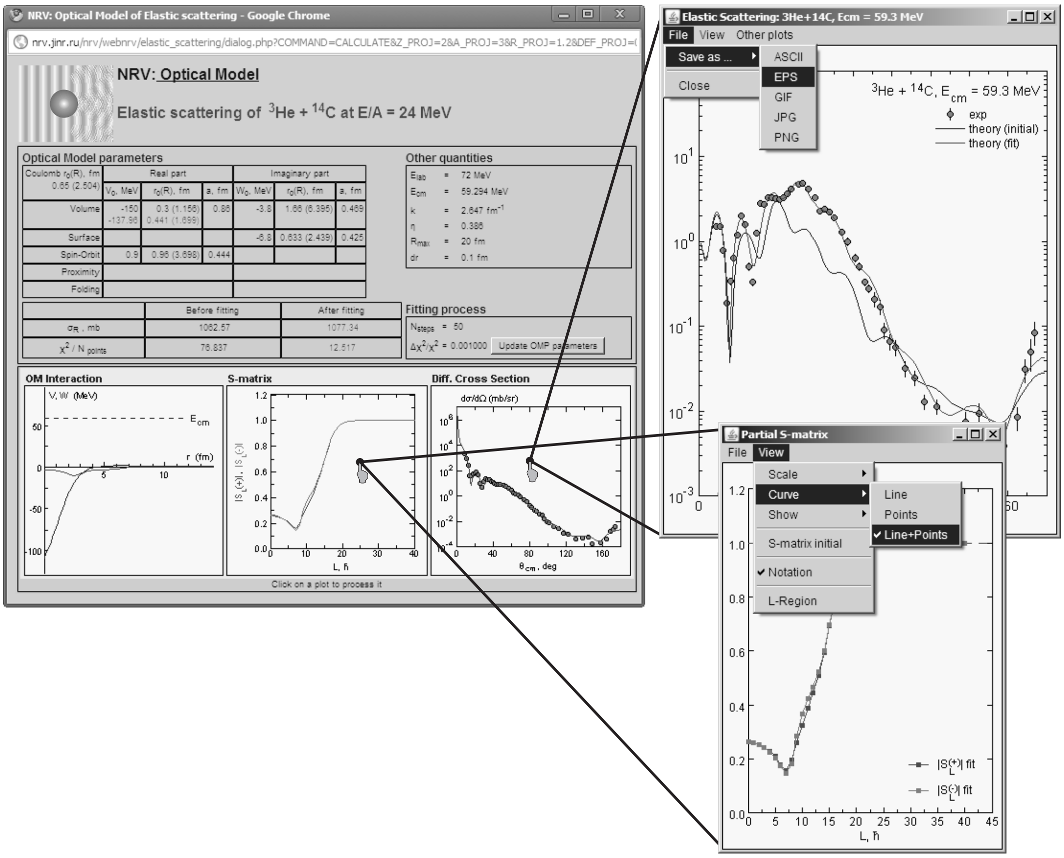

FIGURE 4. Web page with the results of the optical model calculation performed within the Knowledge base for ^{3}He + ^{14}C elastic scattering at the laboratory energy $E = 72$ MeV. Java applets represent data in graphical form and provide additional possibilities to process the obtained results.

section of nuclear elastic scattering. Working with the model user may obtain advices on the optical model parameters based on published systematics or may perform automatic fit in order to find the optimal choice of the parameters. Optionally user may choose different types of the optical potential, such as Woods-Saxon volume or surface potential and their superposition, proximity potential and DDM3Y folding potential. It is possible to request the experimental data on elastic scattering available in the corresponding database of the Knowledge base or to input user's own data. The short theoretical description and main references are also given. The input information is visualized with the help of Java applet incorporated into the web-form (see Fig. 3). Altogether the web-form elements provide friendly interface for parameter preparation and subsequent running the optical model code. Work within all the models of the Knowledge base are organized in the same way.

Basing on the model parameters defined by user the system creates input file and runs the calculation code. All codes of the Knowledge base are run on the sever side only. User does not need to download and to install any executable files on his/her computer. Special services (combination of Java applet and server-side service program) inform user on the calculation progress and show intermediate results. This scheme allows us to run a long-time calculation such as a couple-channel model of heavy-ion fusion, for example, and to be sure in getting the results even after many-hours of computation. Note also that all user's data (input parameters, experimental data and others) are stored on the Knowledge base server in unique directory which is not accessible for other users.

When calculations are completed, the user obtains a final web-page which contains the results in text and graphical representation. In particular, Fig. 4 demonstrates the result of the optical model calculation of elastic scattering for $^{14}C(^{3}He,^{3}He)$ reaction at E_{lab} = 72 MeV. One may see the initial parameters and the fitted ones, the total reaction cross section and some reaction characteristics. Java applets in this web-page give a visual representation of the optical model interaction, elastic S-matrix elements and elastic scattering differential cross section. These Java applets are not static elements. By clicking on the Java applet the user activates a separate Java window with menu including many additional options for processing the obtained results. Particularly, in the Java window showing the elastic scattering cross section the user is able to change the scale of the graph, transform cross section to the laboratory or center of mass system, plot cross section as a ratio to the Rutherford cross section and so on. The S-matrix also can be replotted in different forms and different scales. One of the most important options available in all the Java windows of the Knowledge base is a possibility to save the obtained results to user's hard-disk for further use. As it can be seen in Fig. 4 we realize a possibility to save data both in text and graphical form.

The Knowledge base includes also Java classes for representation of 3-dimensional objects. They are very useful in the case of plotting the multi-dimensional functions like a nucleus-nucleus driving potential, shell-model nucleon wave functions, 3-D total scattering wave function and others. In Fig. 4 (at the left), for instance, the 3-D scattering wave function is shown for $^{3}He + ^{14}C$ elastic scattering at $E_{\rm lab}$ = 72 MeV.

In addition to the obvious scientific application, the Knowledge base has an educational aspect as well. For instance, within the optical model we realize a tool that allows a study of the dependance of the elastic scattering cross section on different parameters of optical potential. By varying the optical model parameters and observing the corresponding changes on the structure of the angular distribution, the student gets a feel of the sensitivity of differerent parametes of the optical potential. In Fig. 5 (at the right) the curves demonstrate the cross section calculated with the optical potentials different by the value of radius of its real part. One can see the shift and stretch of the interference structure of the angular distribution which can be easily related with the change of the size of the scattering field. Thus, basing on the descriptions of theoretical models and on the tools realized in different components of the Knowledge base one may develop a series of practical exercises for students studying nuclear physics.

PERSPECTIVES

Recently a mirror server of the Knowledge base was placed in operation at Stellenbosch University (South Africa). Within this collaboration we are going to develop the Knowledge base in order to give theoretical support to the experimental studies which are planned or already performed in the laboratories of South African institutes, particularly, in the iThemba LABS. Among new components of the Knowledge base it is worth

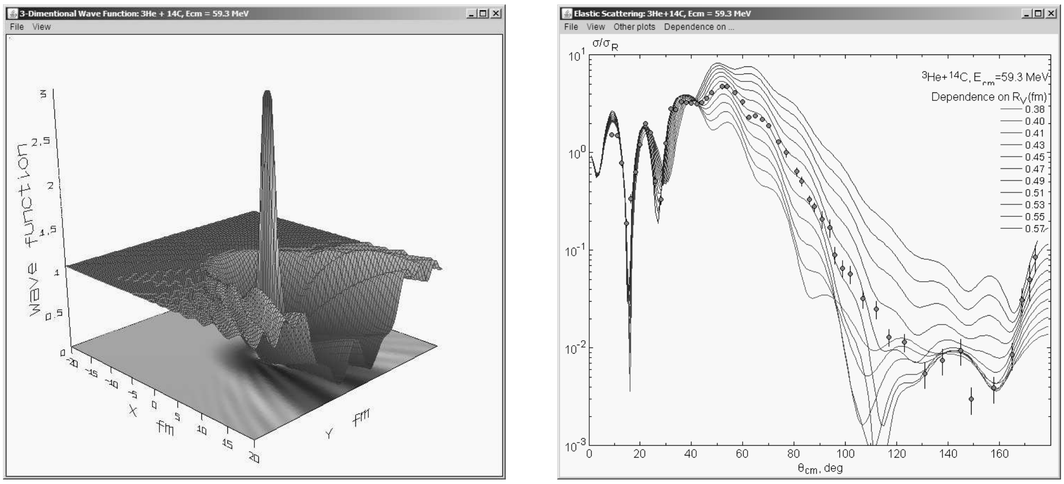

FIGURE 5. (Left) With the help of the optical model code user can calculate, plot and save a 3-D total scattering wave function. The wave function is calculated for ^{3}He + ^{14}C elastic scattering at $E_{\rm lab}$ = 72 MeV. (Right) The optical model code provides the possibility to investigate the influence of the optical model parameters on the elastic scattering angular distribution. In figure the dependence on the radius R_V of the real part of the optical potential is shown for ^{14}C(^{3}He,^{3}He) reaction at $E_{\rm lab}$ = 72 MeV.

mentioning the computer codes for the simulation of nuclear reaction experiments taking into account the detectors loading by the elastic scattering and inelastic events, effects of multiple scattering in a target sample, and providing the information on kinematical properties of future experiments.

We also plan to extend the Knowledge base with the following elements: (i) computer codes for the calculation of energy dependence of reaction cross section, (ii) codes for calculation of the inelastic scattering and transfer reactions in heavy-ion collisions within semiclassical approximation, (iii) codes for the phase shift analysis of resonant scattering of light nuclei, (iv) calculation of radioactive capture cross section at low astrophysical energies, (v) description of properties of different nuclear decay modes, (vi) creation and filling of new databases on nuclear properties, in particularly, databases on reduced transition probabilities $B(E\lambda)$ for heavy ions, and others.

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