Proceedings of the VIII International Conference "Distributed Computing and Grid-technologies in Science and Education" (GRID 2018), Dubna, Moscow region, Russia, September 10 - 14, 2018

NRV WEB KNOWLEDGE BASE: SCIENTIFIC AND EDUCATIONAL APPLICATIONS

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The NRV web knowledge base on low-energy nuclear physics has been created in the Joint Institute for Nuclear Research. This knowledge base working through the Internet integrates a large amount of digitized experimental data on the properties of nuclei and nuclear reaction cross sections with a wide range of computational programs for modeling of nuclear properties and various processes of nuclear dynamics which run directly in the browser of a remote user. Today, the NRV knowledge base is both a powerful tool for nuclear physics research and an educational resource. The system is widely used, as evidenced by the large number of user queries to its resources and the number of references to the knowledge base in the articles published in scientific journals. The practical usage of the NRV knowledge base for both scientific and educational applications is demonstrated.

Keywords: web knowledge base, low-energy nuclear physics, nuclear data, nuclear reactions

1. Introduction

The NRV web knowledge base on low-energy nuclear physics [1-3] has been created in the Joint Institute for Nuclear Research under the leadership of Prof. V.I. Zagrebaev. This knowledge base working through the Internet integrates a large amount of digitized experimental data on the properties of nuclei and nuclear reaction cross sections with a wide range of computational programs for modeling of nuclear properties and various processes of nuclear dynamics which run directly in the browser of a remote user. Today, the NRV knowledge base is both a powerful tool for nuclear physics research and an educational resource.

The practical usage of the NRV knowledge base for scientific purposes is demonstrated in detail on the example of the analysis of synthesis of heavy and superheavy nuclei in fusion reactions. The practical usage of the NRV knowledge base for educational purposes illustrated on the example of the analysis of elastic scattering.

2. Analysis of formation of neutron-enriched heavy and superheavy nuclei in fusion reactions

The production and study of heavy and superheavy elements is one of the most important problems in modern nuclear physics. Figure 1 shows the upper part of the map of nuclei. It can be seen that only neutron-deficient nuclei were synthesized for elements heavier than fermium, while the region of heavy neutron-enriched nuclei remains unstudied. This region is highly important for astrophysical research, in particular, for understanding the possibility of formation of superheavy elements in the astrophysical *r*-process.

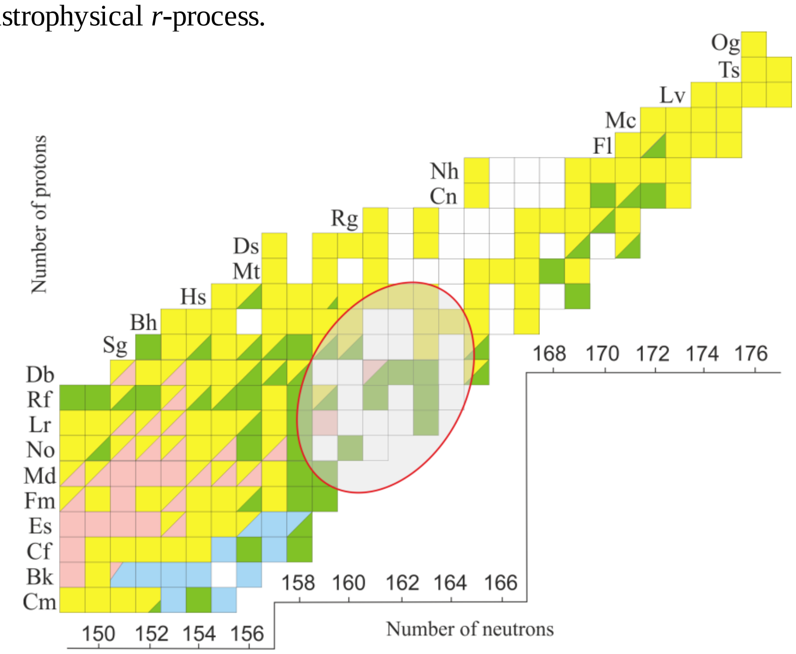

Figure 1. Upper part of the map of nuclei

To reach this region, one can use fusion reactions with more neutron-rich nuclei. For example, in Ref [4] it was proposed to synthesize neutron-enriched isotopes of nuclei with *Z* of 102–108 using fusion reactions of stable (^{22}Ne) and radioactive (^{23}Ne, ^{20}O) neutron-rich projectiles with actinide targets ^{248}Cm, ^{249}Bk, and ^{249}Cf, followed by the evaporation of charged particles (proton or α particle) and neutrons from the compound nucleus. In Ref [4], predictions for the above-mentioned fusion cross sections were made using the NRV web knowledge base on low-energy nuclear physics. Figure 2 shows the results of calculation of cross sections for formation of new isotopes of superheavy elements in the *xn*, *pxn*, and α*xn* evaporation channels of fusion reactions.

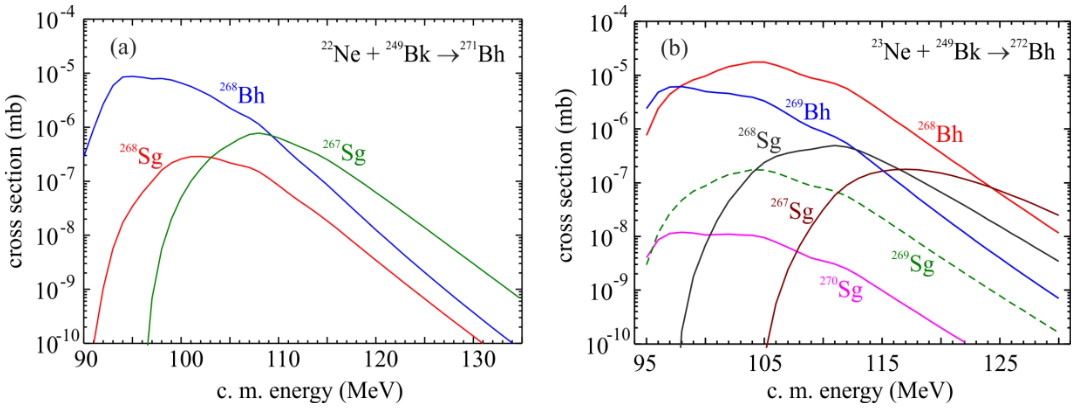

Figure 2. Results of calculation of cross sections for formation of new isotopes of superheavy elements in the *xn*, *pxn*, and α*xn* evaporation channels of fusion reactions performed in Ref [4] using the NRV web knowledge base

The use of the NRV web knowledge base for the analysis of the fusion reaction $^{16}O + {}^{150}Nd$ and calculation of evaporation residues cross sections is illustrated in Figure 3. The left-hand side window shows the web dialog for choosing the parameters of the channel coupling model [5] applied to calculation of the fusion cross section. It should be mentioned that experimental data on nuclear properties available in the knowledge base the can be used to determine the model parameters. This possibility significantly simplifies the use of many theoretical models. In addition, the knowledge base also contains detailed descriptions of the models and parameters used. The right-hand side window shows the results of calculation of evaporation residues. The obtained results may be saved in the text (tabular) or in the graphical formats on the user's computer.

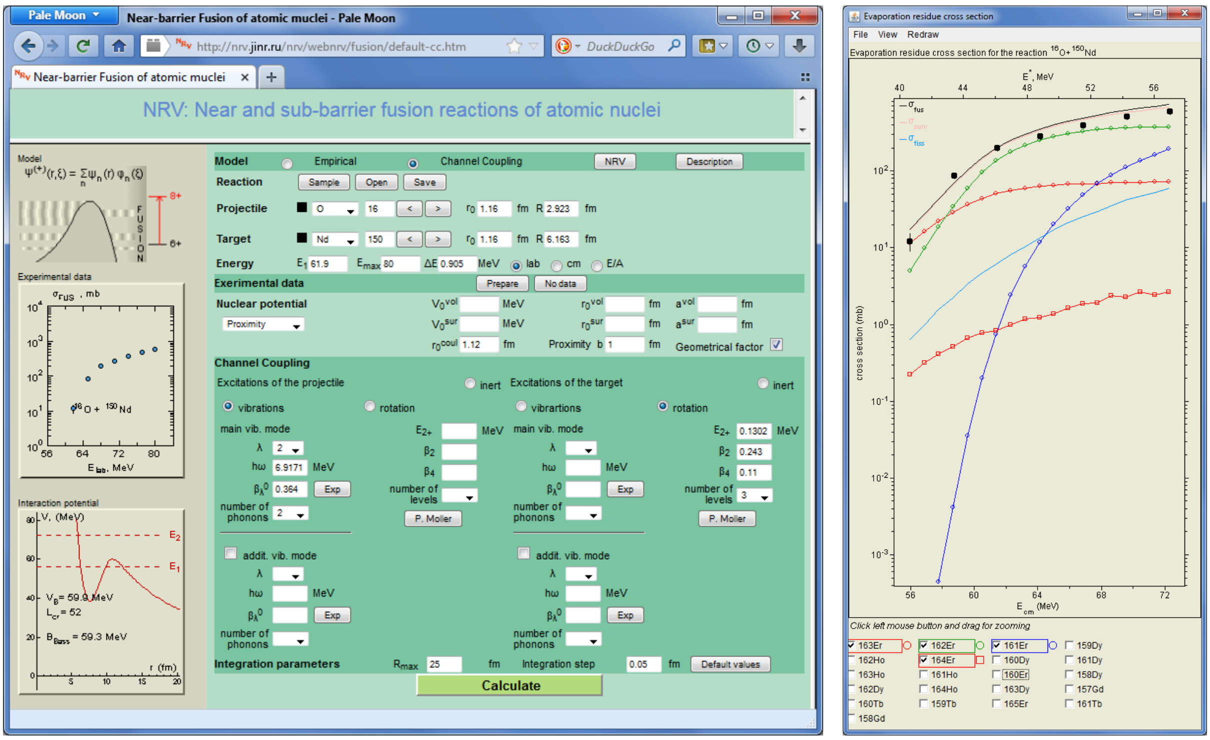

Figure 3. Use of the NRV web knowledge base for the analysis of the fusion reaction $^{16}O + {}^{150}Nd$

In addition to the possibility of performing calculations of fusion and fusion-evaporation cross sections, the NRV web knowledge base contains more than 1600 experimental fusion excitation functions and more than 300 experimental evaporation residues cross sections including references to original papers, which makes it a unique source of information on the current state of research in this field. The experimental databases are constantly updated.

3. Study of elastic scattering of nuclei in optical model

Elastic scattering is one the simplest processes among all channels of nucleus-nucleus collisions, therefore the corresponding section of the NRV web knowledge base is widely used for educational purposes. Students may study the application of both classical mechanics and quantum mechanics to the scattering problem as well as the quasiclassical limit in the transition from light nuclei to heavy nuclei.

Figure 4 shows the web dialog for choosing the parameters of the optical model and starting calculation for the reaction ^{6}Li + ^{28}Si. The results of calculations are shown in Figure 5. It can be seen that with the chosen parameters the optical model code describes the experimental elastic scattering cross section rather well. The NRV web knowledge base contains more than 1200 experimental elastic scattering cross sections.

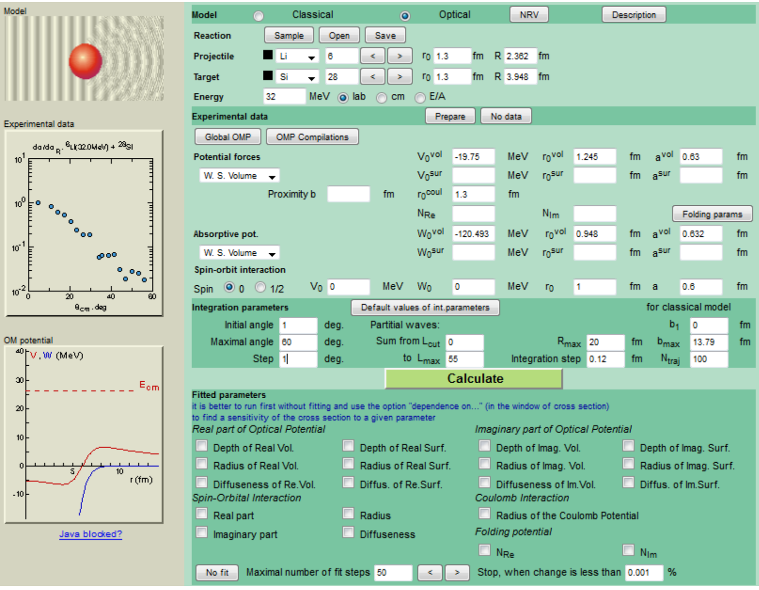

Figure 4. Web dialog for choosing the parameters of the optical model and starting calculation

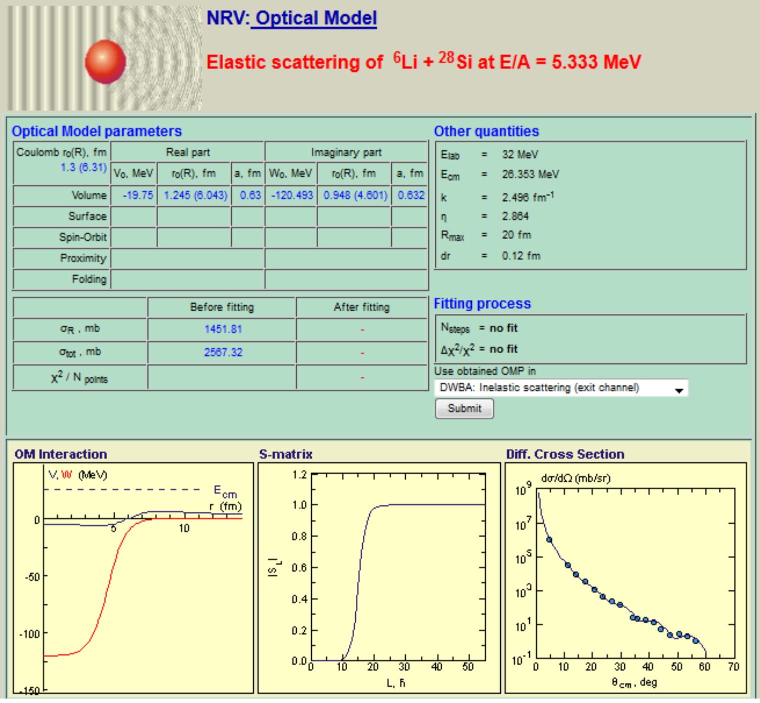

Figure 5. Results of optical model calculation

One of the great advantages of the code is the possibility of automatic fitting of the model parameters, which significantly simplifies its use, especially for unexperienced users.

Due to the wide use of the optical model by Russian-speaking students, tutorial in Russian on the optical model is also available at http://nrv.jinr.ru/nrv/OM-Tutorial.pdf.

For scientific purposes, the optical model of the NRV web knowledge base was successfully used, e.g., in Ref. [6] for studying total cross sections for reactions ^{4,6}He + ^{28}Si and ^{6,7,9}Li + ^{28}Si.

4. Conclusions

In this work, practical usage of the NRV web knowledge base was demonstrated on the example of the analysis of synthesis of heavy and superheavy in fusion reactions and example of the analysis of elastic scattering.

The web knowledge base is an efficient tool for acquisition and development of skills of work with modern theoretical approaches to the description of properties of individual nuclides, modeling of the dynamics of nuclear collisions, as well as the skills of work with experimental data and their systematization. The development of manuals and guidelines for the implementation of practical work may effectively introduce the NRV web knowledge base in the educational process of any university preparing students in the field of nuclear physics.

At present, the NRV web knowledge base is widely used for educational purposes, e.g., by students of Dubna State University (Dubna, Russia), Moscow State University (Moscow, Russia), National Research Nuclear University MEPhI (Moscow, Russia), University of South Africa (South Africa), Karadeniz Technical University (Trabzon, Turkey), L.N. Gumilyov Eurasian National University (Astana, Kazakhstan), and Nazarbayev University (Astana, Kazakhstan). It is also used by students visiting Joint Institute for Nuclear Research for various student practice.

The further development of the NRV knowledge base is planned in the following directions: (1) filling and updating of the existing nuclear databases as well as adding new ones; (2) implementation of new physical models as well as extending the possibilities of the existing ones; (3) modernization of the user interface; (4) preparing new tutorials in Russian and in English.

Acknowledgements

The work was supported by RSA-JINR (Dubna) Cooperation program.

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