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Sensitivity of r-nuclide distributions to the choice of nuclear mass model

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The astrophysical r-process of nucleosynthesis is widely considered to explain the production of stable and neutron-rich isotopes beyond the iron peak. Taking place at temperatures above 1 GK and very high densities, it is believed to occur in extreme astrophysical scenarios (e.g., [1, 2]), such as supernova explosions or neutron star and black hole collisions. In order to study stellar nuclear
reactions computer simulations are commonly used. Simulation models of the r-process depend on a very large number of nuclear parameters. Thus, this nucleosynthesis mechanism poses great interest to both astrophysics and nuclear physics.

One of the most important parameters that impacts calculation of the neutron capture rates is the masses of participating nuclei, especially in the little-studied exotic isotope regions of the nuclide chart. Most of such masses were obtained not experimentally, but from theoretical models. For some isotopes different models predict significantly different values, which brings uncertainties to r-process calculations.

It was found in the first part of our research [3], that theoretical r-process yeilds of some isotopes are strongly dependent on the choice of the nuclear mass model. In this study different nuclear mass models were used to create a number of reaction rate libraries, analogous to the REACLIB [4]. Reaction rates and their cross sections calculation was performed using the TALYS package [5].

Following nuclear mass models were considered by us in this scope: the macro-microscopic models FRDM [6] and WS4 [8], the Skyrme interaction-based HFB mass model [7], and our mass evaluation based on local mass relations [9]. The latter is based on a phenomenological approach, assuming that the residual neutron-proton interaction energy behaves smoothly as a function of the mass number.

These reaction rates libraries were subsequently used to carry out simulations of the r-process. For this purpose we have used a nuclear reaction network of about 7000 isotopes and corresponding reactions with macroscopic conditions. Our implementation is based on the SkyNet modular nuclear reaction network library [10].

Final mass distributions of the nucleosynthesis products were obtained in an r-process scenario at 1.2 GK and the sensitivity of the calculation to the choice of the nuclear mass model was estimated. Comparison of the results of different models in the interval $A = 60 \div 220$ was performed. Obtained r-process isotopes yields show the differences of the considered mass models.

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