# NUCLEON-INDUCED FISSION CROSS-SECTIONS CALCULATIONS AND DEVELOPMENT OF TRANSMUTATION-ACTIVATION DATA LIBRARY FOR TRANSITIVE ENERGY REGION 20-200 MEV

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**Abstract**

The results of a new approach for fission cross-sections at transitive energies are presented and it is shown that the calculations describe experimental data well for both neutron and proton induced fission. The development of the approach and corresponding code system for the calculations of independent and cumulative yields of residual nuclei and fission fragments are discussed and preliminary results are presented.

## 1. Introduction

Nuclear fission of heavy nuclei induced by nucleons at transitive energy region 20-200 MeV is one of the main reaction channels (the fission cross-sections for actinide region can reach value 0.8-0.9 of the reaction cross-section). The accurate knowledge of fission probability for different fission chances allows also defining yields of fission products (fission fragment yields and neutrons emitted from fragment). These data added by particle and isotope yields from other reaction channels (direct and pre-equilibrium emission of nucleons, evaporation of nucleons and light nuclei) give us the possibility to develop the nuclear data necessary for the evaluation of activation of the Pb-Bi target of the accelerator driven systems as well as the data on the fission of fuel and transmutation of actinide radioactive waste.

The energy region 20-200 MeV is the transitive region from the well-investigated low energy region to intermediate energy nucleon-induced reactions. It is well-known that for energies of incoming particles up to 10-20 MeV the mechanism of reaction is defined by the competition between fission and particle evaporation from compound nucleus and fission cross-sections and yields of reaction products are well-reproduced by the statistical models. For higher energies the contributions from the direct and pre-equilibrium reaction stages arise which is used to describe in the framework of intranuclear cascade and exciton models, correspondingly.

In the given work, the new model approach and computer code is developed where the main properties of nucleon-induced reactions on heavy nuclei at transitive energies are calculated in the unified scheme on the base of reliable and detailed description of all main stages of the reaction.

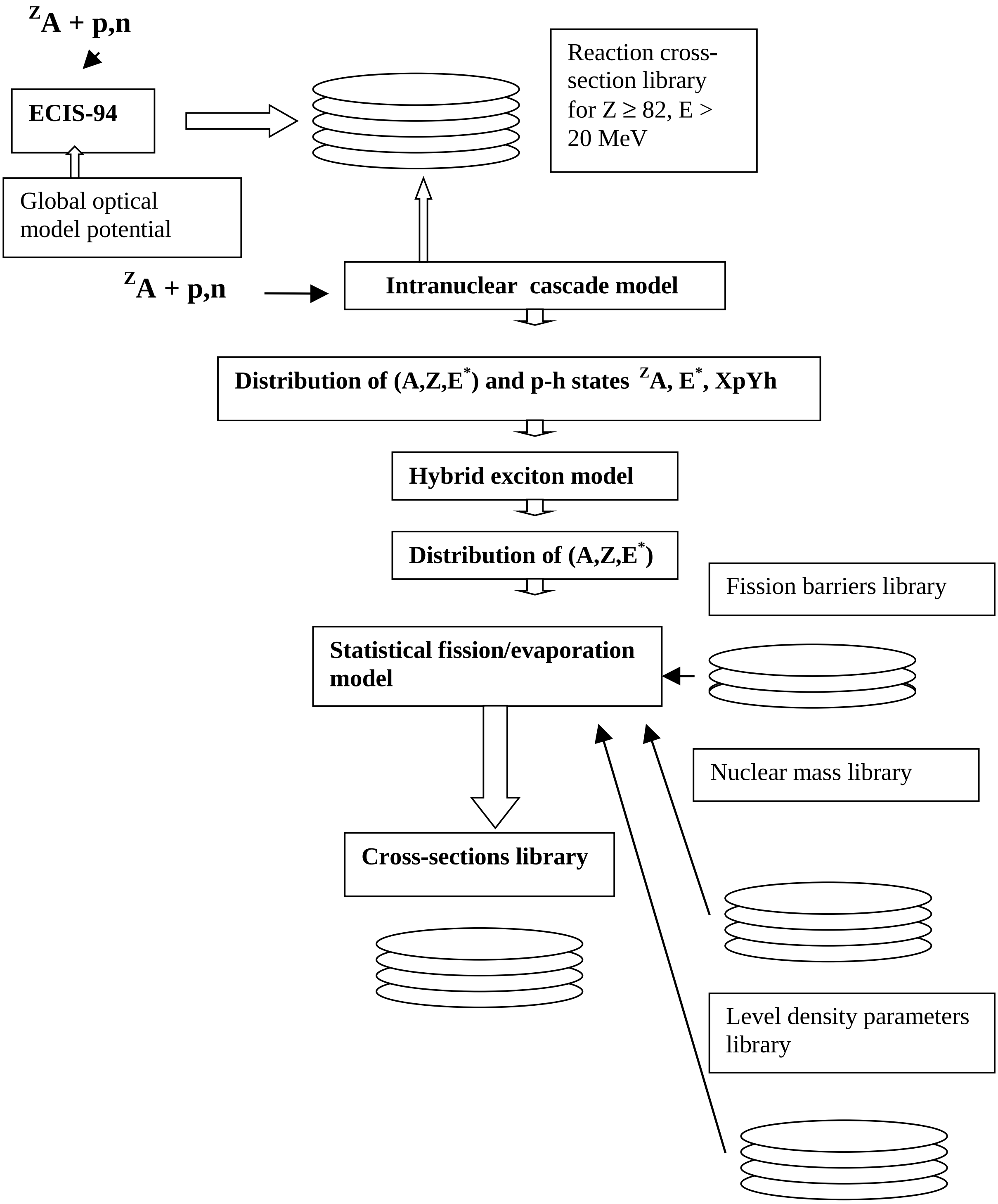
## 2. The model approach

The scheme of new code is shown in the Figure 1. We use for entrance model simulation the coupled channel method in Raynal's version (code ECIS [1]). The deformation of target nucleus in the ground state as well as the 3 lowest excited levels are taken into account in the calculations. The global optical model potential for all nuclei from Pb up to Cf for transitive nucleon energies has been developed by ours early [2]. For all these nuclei and beam energies the reaction cross-section data library has been developed which is further used in the cross-section calculation of secondary reactions.

The intranuclear cascade model in Dubna version [3] has been included in the code for the description of the direct stage of the reaction. The chains of primary and secondary cascades lead to the emission of fast nucleons and the population of residual nuclei in the different nuclear states characterised by mass and charge numbers, excitation energy and number of excitons (A,Z,E*,XpYh distribution) which serve as the input data for the pre-equilibrium processes. The decay of excited states on the pre-equilibrium reaction stage leads again to the particle emission and distribution of excited nuclei (A,Z,E* distribution). The hybrid exciton model with Monte Carlo simulation [4] has been used for the calculation of this reaction stage.

The last stage of statistical decay has been described in the framework of a detailed statistical model based on the well-known code STAPRE [5] for each of the nuclei formed in the previous stages of the reaction. The statistical part of reaction calculations contains a lot of parameters and special efforts have been made in order to reduce the number of fitted parameters and to raise the predictive ability of the code. The new data libraries for the level density parameters, fission barriers, nuclear masses have been developed and included in the calculation scheme [2].

Figure 1. **Scheme of the new code**



## 3. Results and perspectives

On the base of the developed code system, the systematic calculations of proton and fission cross-sections for the nuclei from Pb to Pu have been carried out for transitive energies of incoming particles. Some results of these calculations are presented in the Figures 2 and 3 in comparison with the experimental data. It can be seen from the figures that our calculations describe the experimental data rather well without any fitting of the model parameters. The preliminary results on the isotope and neutron production are shown in the Figures 4 and 5. The calculations have been done within the framework of the same approach. The agreement with the experimental data is quite satisfactory for these data, too.

It is necessary for the fission product yields calculation to include in the code the model of fission fragment production probability. Such a model should be used at each fission chance for each fissioning nuclei formed at direct+pre-equilibrium stages of the reaction. At present we are working out the statistical model of fission fragment yields in Fong's approximation [6].

Figure 2. **The proton-induced fission cross-section of $^{208}$Pb**

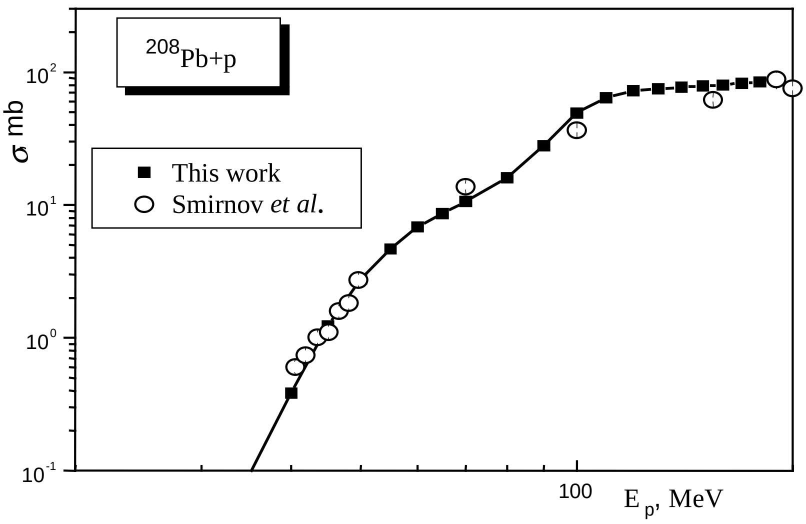


Figure 3. **Neutron-induced fission cross-sections of actinides in comparison with experimental data**

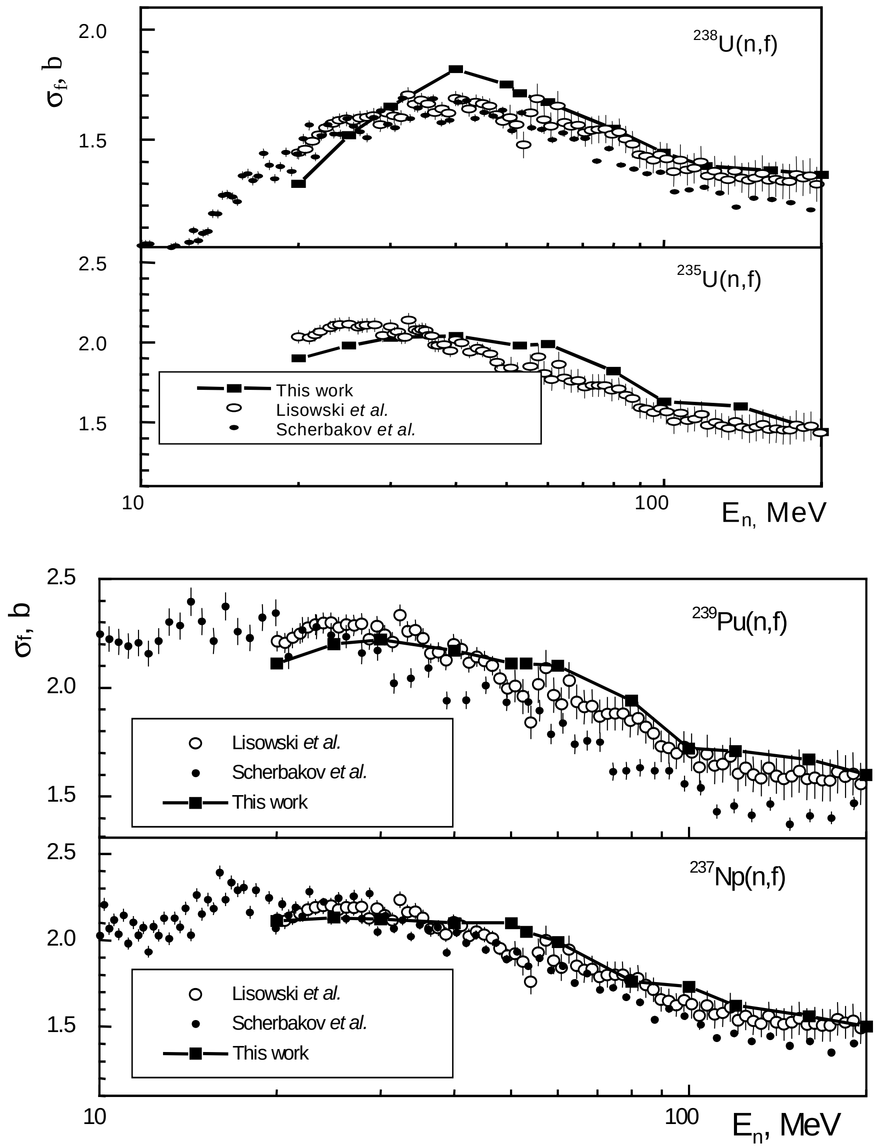


Figure 4. **Yields of U isotopes in the reaction $^{238}$U (1GeV) + p in comparison with the experimental data**

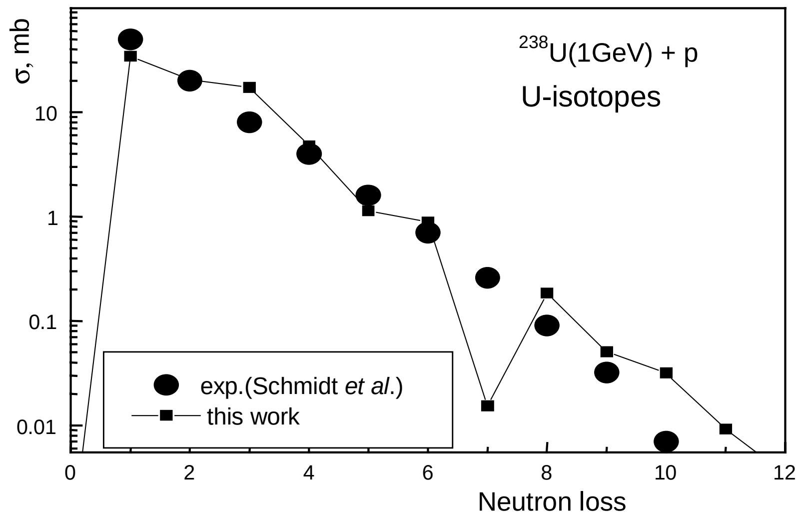
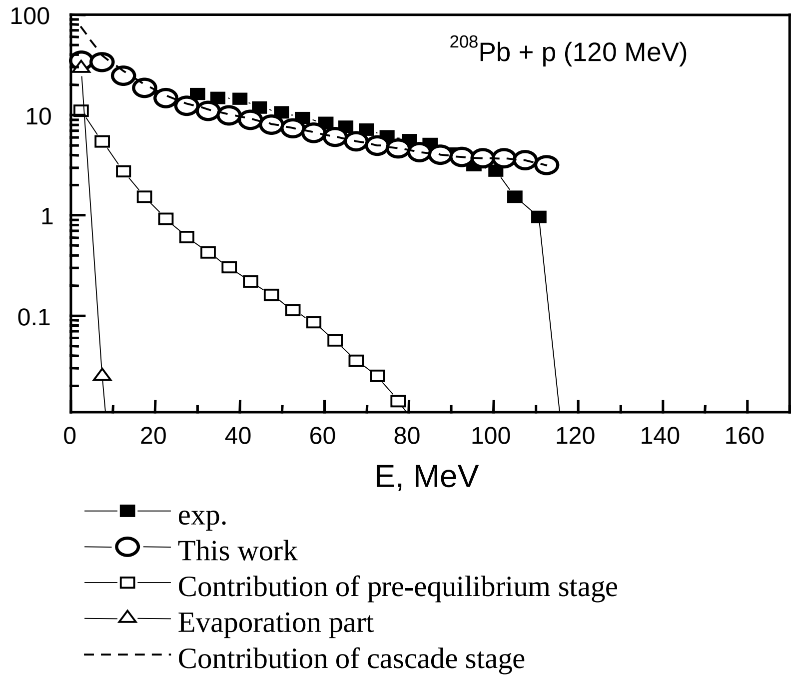



Figure 5. **Neutron spectra from reaction Pb + p**



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