Except for the lightest ones, the chemical elements building up our universe are produced in stars at different stages of stellar evolution through various nucleosynthetic processes. The chemical elements heavier than iron are mainly produced by neutron induced nuclear reactions, however, there are a few dozens of heavy, proton rich isotopes which cannot be created this way. These are the so-called p-isotopes and their general production mechanism is referred to as the astrophysical p-process. The p-process is one of the least known processes of nucleosynthesis, the model calculations are not able to reproduce well the abundances of p-isotopes observed in nature. One reason for this failure can be the insufficient knowledge of the nuclear physics background of the models. P-process model calculations involve huge reaction networks and the rates of the reactions are necessary inputs for the calculations. Therefore, the experimental determination of the reaction rates from reaction cross section measurements is very important.

The main goal of this project was to investigate charged particle induced reactions in the mass and energy range of the p-process. The experimental database available for the p-process shows a severe lack of
data for alpha-induced cross sections in the mass region of the heavy p-isotopes. Therefore special emphasis was put on nuclear reaction studies in this region. The measured cross sections can be compared with the predictions of statistical model calculations which are typically used to obtain reaction rates for p-process network calculations. Since statistical model calculations can be carried out using different nuclear physics inputs resulting in different cross sections, the comparison with experimental data can also help select the best nuclear physics input parameters.

Calculations show that one of the most important and most uncertain nuclear input parameter of the calculations is the alpha-nucleus optical potential. This quantity can directly be studied experimentally with high precision elastic alpha-scattering experiments. To study the optical potentials by scattering experiments is the second main goal of the project.

In order to reach the above goals significant technical and methodological improvements have been made supported by the ERC Starting Grant. High efficiency gamma-detectors as well as modern nuclear electronics instruments have been installed in order to make the planned cross section measurements possible. The scattering chamber used for elastic alpha-scattering experiments has been substantially upgraded and a new target chamber for in-beam cross section measurements has been designed, built and tested. A completely new technique, the characteristic X-ray detection based activation method for p-process experiments has been developed and successfully applied to several reactions. Feasibility studies of activation experiments have been made in an underground laboratory. Technically very challenging storage ring experiments and gamma-induced reaction studies have been initiated. When the data analysis necessitated, high precision decay half-life measurements were carried out on certain radioactive isotopes.

With the activation method the cross sections of about two dozens of nuclear reactions relevant for the p-process were measured. Elastic alpha-scattering experiments were carried out on nine isotopes. In all cases the experimental results have been compared with the prediction of statistical model calculations using different nuclear physics input parameters and the astrophysical consequences have been drawn. For proton induced reactions a modification of the proton optical potential is recommended. In the case of alpha-induced reactions the general observation is that the calculations overestimate the measured cross sections, so a reduction of the relevant reaction rates on network calculations is recommended. However, the available alpha-induced reaction cross sections do not show a clear picture, therefore, further measurements are highly necessary. Based on the scattering experiments, a new global alpha-nucleus optical potential is suggested for astrophysical applications. This potential will be further developed in the future.

With our measurements we could give a significant contribution to the better understanding of the production of heavy, proton rich isotopes of the universe. Further details about the project and about the dissemination of the results can be found on the website of the project: http://w3.atomki.hu/~gyurky/ERC/

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