To understand the production processes of chemical elements that took place during the Big Bang, the burning phases of stars or at the end of a star's life a detailed knowledge about the underlying nuclear physics processes is necessary. In particular, the cross sections and reaction rates of nuclear reactions that happen within the various astrophysical scenarios have a huge impact on the abundances of the chemical elements. For nuclear reactions that are not accessible experimentally, either because they involve unstable nuclei or they cannot be reached at astrophysical relevant energies, robust and reliable theoretical extrapolations obtained by means of the Hauser-Feshbach statistical model are required. Among the most important ingredients related to nuclear physics for those calculations are the nuclear level density (NLD), the γ-ray strength function (γ-SF) and the particle-nucleus optical-model potentials (OMPs).

The present cumulative thesis comprises six publications in peer-reviewed journals. The thesis reports on four nuclear reactions that have been measured, aiming not only at extending the experimental database of measured cross sections, but also at constraining the statistical nuclear physics properties in atomic nuclei around the A ≈ 100 mass region. The nuclear reactions investigated by means of in-beam γ-ray spectroscopy in this thesis are the ^{107}Ag(p, γ)^{108}Cd, ^{109}Ag(p, γ)^{110}Cd and ^{93}Nb(p, γ)^{94}Mo reactions while the ^{96}Mo(p, n)^{96m,g}Tc reaction has been measured using the activation technique. In addition, within the scope of this thesis the experimental setup that is used for cross-section measurements relevant for nuclear astrophysics has been revised. The new target chamber as well as methodical improvements allow to measure even very small reaction cross sections in the nb region.

The radiative proton capture experiments on the stable silver isotopes ^{107,109}Ag provided the first set of measured cross sections over a wide range of energies for the respective reactions. In addition to the total cross sections, in the case of ^{107}Ag(p, γ)^{108}Cd partial cross sections have been extracted for the first time allowing to directly investigate the γ-SF in ^{108}Cd. The ^{93}Nb(p, γ)^{94}Mo reaction cross sections have been measured as this reaction can affect the overall abundance of the neutron-deficient nucleus ^{94}Mo and at present no satisfying agreement between experimental results and statistical model calculations is obtained. Primary γ rays emitted by the excited compound nucleus and partial cross sections have been used to constrain the γ-SF in ^{94}Mo. In addition, comprehensive nuclear physics information about previously unknown levels, γ-ray transitions and their intensities were found. For the first time the individual ^{96}Mo(p, n)^{96m,g}Tc cross sections have been measured for the ground state and metastable state at astrophysical relevant energies. Additionally, the ^{96m}Tc → ^{96}Mo decay intensity has been remeasured by means of offline, time-resolved γ-ray spectroscopy and showed to be two times higher than previously reported.

Since the studied (p, γ) reactions are mostly sensitive to the NLD and γ-SF, a new strategic approach has been worked out to test the predictive power of theoretical models for those properties. It was found that for the NLD microscopic models that are based on firm physical grounds provide much more reliable predictions compared to simple phenomenological models. The results for the γ-SF in ^{108}Cd and ^{94}Mo extracted by means of the primary γ-ray analysis are in good agreement with recent microscopic calculations for the electric and magnetic dipole strength function.