Nuclear observables for nucleosynthesis processes

RESPONSABLES: KAMILA SIEJA ET FREDERIC NOWACKI
IPHC 23 RUE DU LOESS, 67037 STRASBOURG
TEL : 03 88 10 61 67 ; E-MAIL : KAMILA.SIEJA@IPHC.CNRS.FR
TEL : 03 88 10 61 96 ; E-MAIL : FREDERIC.NOWACKI@IPHC.CNRS.FR

Abstract:
The heavy elements, beyond ^{56}Fe, are produced in the so-called *rapid neutron capture* nucleosynthesis process (*r-process*) which takes place during cataclysmic events like supernovea explosions or neutron stars collisions. The recent observations by LIGO and VIRGO of the optical *kilonova* signal confirmed that the neutron-star mergers are possible sites for this nucleosynthesis process. Its theoretical simulation remains however challenging and the reproduction of the elemental abundances in the Universe is not yet satisfactory. One of the uncertainties of astrophysical models is the nuclear structure input necessary to describe nucleosynthesis processes, e.g. masses, half-lives, nucleon capture rates, fission barriers.

To describe the r-process the knowledge of e.g. neutron-capture cross section is needed for about 5000 nuclids. The measurements of the neutron-capture cross sections are possible only in stable and long-lived nuclei. Thus astrophysics models and other applications (e.g. reactors physics) rely on theoretical predictions, which are often based on simple phenomenological models of gamma-ray strength functions and level densities, being basic ingredients of statistical calculations of neutron-capture rates. Recently, thanks to the calculations within the large-scale shell-model, it was possible to examine structure effects appearing at low energy in the gamma strength functions in different regions of nuclei [1-2] and incorporate those to other models [3-4]. However, further systematic shell model studies in neutron-rich nuclei are necessary to constrain global models and to test the limits of applicability of statistical description of the radiative neutron capture processes.

During the PhD thesis the candidate will also have to perform new nuclear structure calculations, relevant for nucleosynthesis and the description of the first r-process peak. These include mass systematics, Gamow-Teller and first forbidden beta decay calculations for isotopic chains with atomic number Z larger than Z=28 (Nickel). Such developments will be based on actual state-of-the-art structure calculations [5,6] extended to the relevant needed observables. These calculations will be used as benchmark for the r-process calculations under conditions of neutron-star mergers and the associated electromagnetic transients.

This work will be done in collaboration with CEA-DAM Bruyères-le-Châtel, ULB Bruxelles and GSI Darmstadt.

[1] K. Sieja, Phys. Rev. Lett. 119, 052502, 2017.
[2] K. Sieja, Phys. Rev. C98, 064312, 2018.
[3] K. Sieja and S. Goriely, arXiv :1911.08184 [nucl-th].
[4] S. Goriely, S. Hilaire, S. Peru and K. Sieja, Phys. Rev. C98 (2018) 014327.
[5] F. Nowacki, E. Caurier, A. Poves, and B. Bounthong, Phys. Rev. Lett. 117 (2016) 272501.
[6] R. Taniuchi et al., Nature Physics 569 (2019) 53.