Contribution ID: **3**

Type: **not specified**

Microscopic description of fission for the r-process in neutron-star mergers ejecta

Tuesday, 2 July 2019 09:35 (35 minutes)

Nuclear fission is known to be of fundamental importance in many applications, for example for energy production applications, such as nuclear power reactors or nuclear waste recycling. In astrophysics, nuclear fission plays a significant role during the rapid neutron-capture process (r-process) of stellar nucleosynthesis by recycling the matter during the neutron irradiation occurring in a neutron star merger ejecta [1,2]. The recent observation of gravitational waves and its optical counterpart from a binary neutron-star merger proves that such events can provide a viable site for the production of heavy (and potentially super-heavy) nuclei by the r-process nucleosynthesis. During the r-process, heavy neutron-rich nuclei are produced and decay or fission. A reliable description of nuclear fission is needed to explain the fission of such heavy neutron-rich nuclei.

The description the nuclear fission is a theoretical challenge because the many-body problem has to be solved with an interaction between nucleons that is known in a phenomenologically way only. In addition of these static considerations there are dynamical effects which leads to the splitting of the nucleus. There are four major aspects that need to be described during the fission process, namely i) the fissioning nucleus formation, ii) the fission barrier penetration and transmission, iii) the fission fragment formation, and iv) the fission fragment de-excitation. Fissioning nucleus can be formed by neutron (neutron-induced fission), gamma capture (photofission), or beta decay (beta-delayed fission). The fission barrier can be crossed by tunnel effect like in spontaneous fission or be crossed over if the nucleus is sufficiently excited like in neutron/gamma-induced fission. When the barrier is crossed, nucleus can be splitted in many ways with different probabilities, called the fission yields. Finally fission fragments de-excite mainly by neutron and gamma evaporation.

All these aspects have to be properly and microscopically described for nucleosynthesis applications since they involve exotic neutron-rich nuclei that cannot be produced experimentally. The most recent theoretical and computational developments need to be considered for a reliable estimate. In the present paper, we will describe our effort to provide updated state-of-the-art models for the description of the fission process by exotic neutron-rich nuclei.
Concerning the fission path, new calculations have been performed, based on newly computed potential energy surfaces (PES) on the basis of Gogny HFB-calculations with beyond-mean-field corrections [3]. Results for all the 500 even-even nuclei from Th to Ds lying between the proton and the neutron drip lines will be compared with predictions obtained within the Skyrme-HFB or liquid-drop approaches. Moreover, through the determination of the inertia tensor at each point of the PES, the least action path can be determined and spontaneous fission half-lifes deduced and compared with available experimental data [4]. Based on these new non-trivial fission paths, all fission transmission coefficients have to be computed considering competition between fission and others possible channels to deduce fission cross sections. Recent results along those lines will be presented
Finally we will present the scission-point model, called SPY [5], developed to estimate yields and kinetic energies of the fission fragments. To improve the description of the fissioning system at the scission point, microscopic state densities, proton and neutron distributions as well as potential energy surfaces of each fragments are now considered within the mean-field approach. We will show that these new developments have a significant impact on the predictions of fission yields and fragment excitation energies. Implications for the r-process nucleosynthesis will be discussed.

[1] S. Goriely et al, Phys. Rev. Lett 111, 242502 (2013)

[2] S. Goriely, Eur. Phys. J. A 51, (2015)
[3] N. Dubray et al, Phys. Rev. C 77, 014310 (2008)
[4] J.-F. Lemaître et al, Phys. Rev. C 98, 024623 (2018)
[5] J.-F. Lemaître et al, Phys. Rev. C 99, 034612 (2019)

Primary author: Dr LEMAÎTRE, jean-françois (université libre de Bruxelles)

Co-authors: Dr GORIELY, Stéphane (Université Libre de Bruxelles); Dr HILAIRE, Stéphane (CEA / DAM ILE-DE-FRANCE); Dr DUBRAY, Noel (CEA / DAM ILE-DE-FRANCE)

Presenter: Dr LEMAÎTRE, jean-françois (université libre de Bruxelles)

Session Classification: Session