Topic: **Microscopic reaction model for nucleon scattering on light nuclei**

Context:

Nuclear reactions are an essential link for the understanding of the world around us. Their diversity (decays, particle scattering, fission…) and their complexity reflect different dynamical aspects of the many-body problem. The modeling of the mechanisms underlying these physical processes is a major challenge for both the understanding the formation of the universe and some applications. For example, the nuclear scattering reactions on light nuclei such as Li, Be and B, are of interest in astrophysics: a better knowledge of the cross section of the reaction ^{7}Be(n, p)^{7}Li, which is responsible for the disappearance of a large part of ^{7}Be, could help to elucidate the problem of the abundance of Li occuring in cosmological models [1].

Light nuclei are interesting and very special systems. Within them, complex correlations occurs giving rise to very unusual structures, such as halos with one or more nucleons and aggregates of alpha particle type. The existence of such substructures plays an important role during the interaction between the projectile and the target and must have an impact on reaction mechanisms and cross sections.

Objective of the PhD thesis:

The resolution of a (A + 1)-body scattering problem, where A is the mass of the target nucleus, remains too complex to be solved exactly. The reaction models often consider that this problem can be simplified in a two-body problem in which the incident nucleus interacts with the A nucleons of the target via a potential which is complex, the imaginary part allowing the treatment of the absorption. These models are known as the optical model. The effective cross sections are then calculated by solving a radial equation derived from the Schrödinger equation, making use of this complex potential whose parameters are adjusted in order to reproduce some experimental data. Some extensions of this optical model, notably the Continuum Discretized Coupled Channels (CDCC) used in this thesis [2-4], allow to take into account the internal structure of the target, but this structure is introduced phenomenologically by assuming, for example, a structure in two aggregates: the target is described using a relative wave function between the aggregates which is obtained using a potential adjusted to obtain the right binding energy and the right mean square radius.

The objective of this thesis is to extend the CDCC model by introducing ingredients from a microscopic description of the target and of the target-projectile interaction potential. For this purpose, we will use a many-body method developed in the laboratory, the multi-particle-multi-hole configuration mixing method (MPMH)[5-7], which solves exactly or almost exactly the structure of the target, aggregates and from which one can built microscopic optical and transition potentials. Thus, starting from a chiral interaction, we will be able to determine the spectra and the A-body wave functions of the light nuclei.

Outline of the PhD thesis:

During the PhD thesis, the student will therefore have to:

1. calculate the MPMH wave functions of the low-energy states of light nuclei and those of the aggregates that may constitute them;
2. calculate the overlaps between these different wave functions;
3. extract the optical and nucleon-aggregate transition potentials;
4. integrate these overlaps and potentials into the CDCC approach;
5. and finally obtain the cross sections which will be compared to the existing experimental data.

During the thesis, the PhD student will gain expertise in the field of nuclear many-body problem, both on aspects of nuclear structure and reactions. He will collaborate with G. Blanchon and M. Dupuis who are expert of the domain. In addition, the PhD student will benefit from exceptional computing resources from CEA / DAM / DIF. A pre-thesis internship will be possible.

References:

[1] L. Damone et al, Phys. Rev. Lett., vol. 121, p. 042701, 2018.
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[4] P. Chau Huu-Tai, Nuclear Physics A 773 (2006) 56–77.
[5] C. Robin, PhD thesis, Université Paris-Sud 11, 2014.
[6] C. Robin, N. Pillet, D. Pena-Arteaga, and J.-F. Berger, Phys. Rev. C, vol. 93, p. 024302, 2016.
[7] C. Robin, N. Pillet, M. Dupuis, J. Le Bloas, D. Pena-Arteaga, and J.-F. Berger, 2017.

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