Topic: Role of the tensor force in effective approaches – Application to N=Z odd-odd nuclei

Context:

The microscopic world is led by the rules of the strong interaction, one of the four fundamental interactions at the origin of the universe as we know it. This last one is responsible for the quark hadronization in neutrons and protons, which are the only quark bound states. The interaction which acts between nucleons themselves is the long range residue of the strong interaction (of the order of one Fermi!). So it is to nuclear physics what the Van der Waals force is to the condensed matter. Fundamental symmetries make it possible to extract a general form.

In recent years, many studies have been carried out with the aim of linking the strong interaction ("high energy" view point) to the nuclear interaction ("low energy" view point) thanks to the effective field theory. Indeed, the strong interaction theory, the Quantum ChromoDynamic (QCD), is not perturbative at energies typical of nuclear physics.
However, much progress remains to explain the physics of nuclei directly from effective theories inspired by the QCD Lagrangian.

The force within the nucleus is, by definition, a sum of interactions involving a different number of constituents, that is to say from two to A nucleons, the mass of the nucleus. However, there is a hierarchy: the interaction between two nucleons strongly dominates; the one with three nucleons although less intense is also essential for the description of the nuclei. As for interactions between four nucleons and beyond, there is no definitive answer.

The nuclear interaction contains several components allowed by the symmetries of the problem and classified according to their action on the orbitals, the spin and isospin space, for example central terms, spin-orbit terms and tensor terms. The importance of these different terms and their roles vary according to the distance between the nucleons. In general, three domains characterize the nuclear interaction: short, medium and long distance. Unlike the average and the long distance, the nuclear interaction shows a very strong repulsiveness at short distance.

Objective of the PhD thesis:

As a part of the thesis, the doctoral student will focus on the tensor part of the nuclear interaction and its role in determining the properties of the fundamental and excited states of nuclei: deformations, masses and energies of excitation, spin, isospin ... He/She will study, among other things, its impact on the proton-neutron pairing in odd-odd nuclei N = Z. The existence of this type of pairing and its manifestation in the nuclei are important questions in nuclear physics.

Outline of the PhD thesis:

To advance in this ambitious project, the PhD student will use a many-body approach developed in the laboratory for several years, the "multiparticle-multihole configuration mixing". This approach, although very widespread in other areas of physics for which its application is easier, is new in nuclear physics. It has the advantage of taking into account all the correlations present in the nucleus (pairing, rotational and vibrational communities, coupling individual and collective excitations), while keeping / preserving a maximum of fundamental symmetries. In addition, it naturally applies to even-even, odd, and odd-odd nuclei. The first applications of this approach, both for structure and nuclear reactions, have given excellent results.

The proposed subject will be done in collaboration with physicists of the Institute of Nuclear Physics of Orsay (Guillaume Hupin) and the Institute for Nuclear Theory of Seattle (Caroline Robin), who are experts both in the "ab initio" and mean-field and beyond approaches.

During the thesis, the PhD student will gain expertise in the field of nuclear many-body problem, both on aspects of the interaction and methods to solve the many-body problem. In addition, the PhD student will benefit from exceptional computing resources from CEA / DAM / DIF.

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