DEFENSE PUBLIQUE DE LA DISSERTATION DE DOCTORAT

de M. Lorenzo Cimino, titulaire d'un diplôme de master de l'Université de Mons ainsi que d'une formation doctorale de l'Université de Mons.

Composition du jury :

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Date et lieu de la défense privée
Le mardi 3 septembre 2024 à 14h (salle Pauling/Bâtiment Mendeleïev)

Date et lieu de la défense publique
Le lundi 23 septembre 2024 à 15h (Salle Mirzakhani/Bâtiment De Vinci)

Titre de la dissertation
Study of hybrid baryons in a constituent model of the quantum chromodynamics and prospects for a Large-N extension

Résumé de la dissertation

Since the detection of the first hadrons in the 1950s, extensive efforts have been undertaken, both experimentally and theoretically, to classify and comprehend them. Within the framework of quantum chromodynamics (QCD), the current theory describing the strong interaction, hadrons are understood as bound states of quarks and gluons. QCD describes the interaction between the colour charges of quarks, where confinement dictates that observable states must exhibit colour neutrality. Baryons (comprising three quarks, denoted as qqq) and mesons (formed by a quark-antiquark pair, $q\bar{q}$) are the most prevalent configurations. However, other exotic hadronic states should exist, including hybrid states. These hybrids represent excitations within the gluonic field or the inclusion of a constituent gluon within the system.

In recent years, considerable theoretical and experimental efforts have been dedicated to the study of hybrid mesons. Initially, their identification appears more straightforward, as certain J^{PC} quantum numbers are forbidden in a $q\bar{q}$ configuration but permissible in a $q\bar{q}g$ configuration. Conversely, hybrid baryons lack such a distinctive "smoking gun" signature, as all quantum numbers J^P can be populated by conventional qqq configurations. Theoretical investigations into hybrid baryons have been conducted using various models, including the MIT bag model, flux tube model, QCD sum rules, large-N QCD, and lattice QCD. However, predictions regarding the masses and structures of hybrid baryons differ considerably among these models. On the experimental front, considerable efforts are underway at the Jefferson Laboratory to identify these particles.

This thesis presents a constituent model developed to describe hybrid baryons containing heavy quarks. In our model, the interaction among the three quarks forms a core structure, which subsequently interacts with a gluon. The chosen potential is the funnel one, which combines linear and Coulomb terms for the

long- and short-range interactions, respectively. Initially, we determine the spin-flavour wavefunction based on the Pauli exclusion principle and ensuring that the quark core transforms as a colour octet, as dictated by confinement. This allows the computation of the energy and the wavefunction of the quark core. The interaction between the quark core and the gluon is then modelled using a potential derived from the convolution of the funnel potential, accounting for the spatial extension of the quark core. Masses and wavefunctions of hybrid baryons, with specified J^P quantum numbers, are computed with the two-body helicity formalism of Jacob and Wick.

Another aspect of the thesis focused on the development of the envelope theory (ET), an approximation method for solving the many-body Schrödinger-like equation. The fundamental concept of the ET involves substituting the studied N-body Hamiltonian with an auxiliary Hamiltonian, typically modelled as a N-body harmonic oscillator. This auxiliary Hamiltonian depends on auxiliary parameters determined by energy minimisation. In cases involving identical particles, this minimisation yields a set of three compact equations for determining the approximate spectrum. One notable advantage of this method is its computational efficiency, as its cost remains unaffected by the number of particles involved. The ET finds particular utility in the large-N approach of QCD, where a baryon is conceived as a bound state of N quarks. Extending the ET to accommodate systems with different particles becomes essential for the large-N treatment of hybrid baryons, where the system comprises N quarks and one gluon.