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Abstract. The main motivations for hadron spectroscopy in general and in particular for hybrid meson spectroscopy will be reviewed. The HASPECT (HAdron SPEctroscopy CenTer) project will be presented and discussed.

1. Introduction
Quantum Chromodynamics (QCD) describes the interactions of the fundamental degrees of freedom, quarks and gluons carrying the color charge, that give origin to the hadrons. Hadrons are bound states, and their properties are determined by interactions that are genuinely non-perturbative in nature. In particular, hadron masses originates mainly from gluonic self-interactions, in a way that only allows objects neutral with respect to the color charge to
exist as physical, asymptotic states, and this still not completely clear phenomenon is known as confinement. As a consequence, the elementary colored degrees of freedom of the underlying theory only manifest themselves indirectly in the physical spectrum which is built from composite colorless hadrons.

On one side quark models have provided for years the main tools for studying the spectrum and the structure of the hadrons, but they lack a strict connection with QCD elementary degrees of freedom, since working with constituent degrees of freedom there are dynamical degrees of freedom not taken into account, on the other side recent developments in lattice simulations and effective-field-theory methods (considering in this category also QCD in physical gauge, chiral effective theories, etc. etc.) have opened new possible insight for investigations of hadron properties rooted deeply in non perturbative QCD. Mesons, being the simplest hadronic bound systems, are the ideal laboratory to study the non perturbative behavior of QCD, understand the role of the gluons inside hadrons in the generation of the hadron masses, and to investigate the origin of color confinement. To perform such studies, it is important to measure the meson spectrum and decays with precise determination of resonance masses and properties, looking for rare meson states and for unconventional mesons with exotic quantum numbers, i.e. that can not be obtained only starting from a quark and an antiquark. In fact, one of the most interesting part of the present and future investigation of the hadron spectrum is linked with the phenomenology of the low-energy gluons and thus regards the mapping of gluonic excitations, that may manifest themselves either as in hybrid states (states with both quarks and gluons as active or effective valence degrees of freedom) or in glue balls (states formed from gluons only). For that task the accuracy of the present and next-generation hadron spectroscopy experiments (JLab, BESS, FAIR, CERN and BELLE) will allow for the identification also of those more elusive hadronic resonances, for which either a reliable determination of their parameters has still not been completed or their existence could not be unambiguously established before. In parallel and encoded as necessary condition for the achievement of this challenge is the development of new analysis methods incorporating into partial-waves analyses all the possible theoretical constraints. This will give the possibility of a reaction-independent determination of the pole position and residues that define a certain resonance. This is one of the goals of the HASPECT group, a strict collaboration between experimentalists and theoreticians, developing dedicated strategies and analysis methods for the Jlab12 MesonEx experiment, in strict contact with other analysis groups of other experiments.

Finally, we remind that even New Physics claims in the Standard Model and Beyond the Standard Model still need a high precision era of knowledge of the non perturbative QCD dynamics mapping program, that has still to be completed by those already cited and next coming laboratories. If there are strong interaction observables involved in an analysis claim for New Physics beyond the Standard Model, one has first to be sure to have under control all the pieces linked with non perturbative strong interaction if involved.

2. Hybrids

Hybrids, i.e states that contain both quark and gluon excitations, have been studied in various models [1, 2, 3, 4, 5, 6] but recent lattice simulations [7, 8, 9, 10, 11, 12] have generated a greater expectation, in particular also for light hybrid mesons[12]. Moreover, on the experimental side, in recent years several new states, in particular in the charmonium spectrum, have been discovered, probably including a hybrid resonance, the $Y(4260)$, discovered by Babar [13]. Conventional heavy quarkonia are well described by non-relativistic QCD, thus one can expect that hybrids containing heavy quarks could be treated in a similar way, i.e. by considering gluon excitations in presence of slow quarks. Moreover, in physical gauge, the dynamical gluons can be separated from the instantaneous Coulomb-type forces that act between color charges, thus while the non-abelian Coulomb potential is expected to be responsible for binding and confinement,
the remaining, transverse gluon excitations could bring contribution to the spectrum. In the non-relativistic, physical gauge QCD the lowest mass charmonium hybrid multiplet has been predicted to be composed by those states $J^{PC} = 1^{--}$: $(0; 1; 2)^{--} [15]$. This four state hybrid multiplet identified in physical gauge calculations, has been recently identified also in lattice simulations $[10, 11, 12]$, both in the heavy $[10, 11]$ and light quark sectors $[12]$, moreover it includes an exotic state (a state with exotic quantum numbers) with $J^{PC} = 1^{-+}$. In the non-relativistic, physical gauge QCD the lowest mass charmonium hybrid multiplet can be explained as due to a color-octet $c\bar{c}$ pair with $J_q^{P_c} = 0^{-+}$ or $1^{--}$ corresponding to the total quark-antiquark spin with $S_q = 0$ and $S_q = 1$, respectively, coupled to a single physical, transverse gluon with predicted quantum numbers $J^{PC}_g = 1^{+-} [14, 15]$; the unusual positive parity of the physical gluon originates from the non-abelian nature of the Coulomb interactions as explained in Refs. $[14, 15]$.

3. Photoproduction of hybrid and exotic mesons
Phenomenological models indicate that the photon may be more effective in producing exotic hybrids in diffractive production on a proton target than, for example, the pion. In the fact, the photon carries spin one and it can fluctuate into a qq pair with spins aligned. When a $c\bar{c}$ pair with $S = 1$ is excited into a hybrid, the production of exotic quantum numbers is expected to be favored. Phenomenological studies also indicate that exotic mesons can be produced with photon probes with cross sections comparable to ordinary mesons$[17, 18]$. In this respect, there will be dedicated experiments at Jlab: Gluex and MesonEx. They will use real and quasi-real photo-production on a proton target to investigate the meson spectrum in the energy range of few GeVs, looking for exotic and hybrid states, using Partial Wave Analysis to determine their mass and properties.

4. Amplitude analysis
Going back to the days of the S-matrix approaches, it was assumed that S-matrix analyticity together with requirements of crossing-symmetry and unitarity could provide constraints sufficient for computing the scattering amplitude: Regge theory determining the asymptotic behavior and dispersion techniques used to generate dynamical equations for the scattering amplitude. These general requirements from the S-matrix theory were found to be insufficient to unambiguously determine hadronic amplitudes, and $c\bar{c}$ pair later on, these ambiguities could be traced to the existence of QCD bound states. Even after 40 years of hadron physics we are still far from being able to construct hadronic amplitudes from first principles. The identification of new resonances and analysis of their properties can only be successful if there is a combined effort involving experimental analysis, theory and phenomenology. This is particularly pressing since in recent years new hadron resonances that seem to escape the established phenomenology have been found in both light and heavy quark sectors, and numerous experimental efforts in hadron spectroscopy have been started. The goal of a meson spectroscopy program is to identify resonances measuring their decay products. A resonance is formally described as a pole in the production amplitude with definite angular momentum and isospin. In practice, resonances are numerous, often broad and overlapping each other: only for a narrow and well-isolated state, the resonant structure can be identified by looking at the invariant mass spectrum of the decay products. The identification of a precise state requires the extraction of the corresponding waves from the measured distributions. This task is performed via the Partial Wave Analysis (PWA): the cross section of the process is parametrized as a coherent sum of different amplitudes with definite quantum numbers. The cross section is then fitted to the data to extract amplitudes. Fits can be performed as a function of the invariant mass of the measured decay products and other relevant kinematic variables to derive information on the dependence of the amplitudes on these variables. A resonance is uniquely characterized by its pole and residues, the position of
the pole being universal, its residues depending on the decay channel in question. The problem in the precision determination of these parameters is that the experiments are limited to real, physical values of the energy. Only when a resonance is well isolated from the others and also far from thresholds, one can use simple expressions like Breit Wigner amplitudes that provide, in a limited region, a very good approximation to the result one would obtain from dispersion theory, but mathematically, in principle, are Dispersion Relations the tools to provide a rigorous way of analytically continuing amplitudes from the physical regime into the complex plane, giving us the possibility of unambiguously extracting the pole parameters of the resonance.

The cases where the distance of the resonance pole to the real axis is smaller than its distance to any other singularity, or where there is just one threshold cut nearby, have been already studied and their properties have been well established during the years. Nowadays we are trying to understand the complicated part of the spectrum, where this ideal situation does not occur and resonances are wide, with poles relatively deep in the complex plane. The effects of overlapping resonances and proximity to more than one threshold due to many possible decay channels require more elaborate techniques.

5. Conclusions
Meson Spectroscopy is a powerful tool to answer to fundamental questions in QCD, as the origin of color confinement and the role of gluons inside hadrons. Mesons are the simplest quark bound system and, therefore, the ideal laboratory to study the strong force at the non-perturbative energy scale of few GeVs. In particular, unconventional mesons would be the best experimental evidence of the active role of gluons in hadron dynamics. In this respect, from an experimental side there will be dedicated experiments at Jlab, FAIR, BESS, BELLE and CERN. In particular, at Jlab two complementary experiments will run: the Gluex and the MesonEx experiment. New high statistics and precise data need an adequate analysis and this will be task of the Haspect Center. Beyond providing a deeper understanding of the inner workings of non perturbative QCD, a theoretical control over hadronic final-state interactions is also essential for the hunt of physics beyond the Standard Model.

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