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Short description of "**Non-Perturbative QCD and Hadron Physics I**" course @ IPM

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Hadrons are bound states of the strongly interacting quarks and gluons. The quantum field theory of this fundamental interaction is "quantum chromodynamics (QCD)". QCD has two main properties: asymptotic freedom and confinement. The asymptotic freedom has been analytically proven. However, we have no analytic proof for the confinement yet but it has been widely accepted that the QCD is a confining theory since it explains the failure of the free quark searches. The best laboratory to search for the properties of QCD is hadron physics as hadrons contain both the perturbative and non-perturbative aspects of QCD. Investigation of different properties of hadrons will help us not only understand their internal quark-gluon organizations but also gain valuable knowledge on the perturbative and non-perturbative natures of QCD as one of the known four fundamental interactions of nature.

In this course we aim to cover the non-perturbative QCD and its application in hadron physics. After a brief introduction to perturbative QCD and dynamics of the quarks and gluons we will introduce some non-perturbative QCD-based tools to calculate the hadronic properties. The hadrons are divided into two main categories: the standard hadrons (mesons and baryons) and non-conventional or exotic hadrons (tetraquarks, pentaquarks, meson/baryon molecules, hybrids, glueballs, etc), which will be covered in some details. One of the most applicable, powerful and attractive non-perturbative tools in hadron physics is the "QCD sum rule". We will discuss this method in details and introduce the traditional SVZ and light cone QCD sum rules. We will apply this method to calculate some parameters of both the standard and exotic hadrons in vacuum as well as the hot and dense medium.

Outline of the course:

1. Introduction to perturbative QCD: quarks and gluons **2 sessions**

2. The standard and non-conventional hadrons (exotics) **1 session**

3. Non-perturbative methods in QCD: QCD sum rules **2 sessions**
   - SVZ sum rules
   - Light-Cone sum rules
4. Determination of the interpolating currents for the standard and exotic hadrons **1 session**
5. Calculation of the mass, residue and other spectroscopic parameters of hadrons : **12 sessions**
   - B meson in vacuum
   - Nucleons in hot and dense medium
   - X(3872): tetraquark
6. Mathematica-based programming methods and numerical analyses **2 sessions**
7. Weak decays of hadrons: **6 sessions**
   - Semileptonic decay of B to D meson: form factors
   - Anomalies in B meson decays
   - Λ_b to Λ semileptonic decays
8. Radiative decays of hadrons and their multipole moments **3 sessions**
9. Strong decays of hadrons: the strong coupling constants **3 sessions**

Note:

This is a four-credit advanced PhD course. Background knowledge of quantum field theory and particle physics will be useful. The evaluation and grading will be based on homeworks and one take-home exam. The lectures will be 14:00-16:00, Wednesday and Thursday, in Farmanieh Building and they will start on 12 Mehr 1396 (04 October 2017).