Project 13/2014: "**COMPASS Hadron Spectroscopy**"
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Abstract:
For all we know, matter is composed of elementary, seemingly point-like particles – the *quarks* and *leptons*. Quarks are bound into objects called *hadrons* of which protons and neutrons are the most prominent examples.
Quarks interact via the *strong force*, which is described by quantum chromodynamics (QCD). In this theory the strong force is mediate by particles called *gluons*, which, however, carry strong charge themselves, so that the force fields do self-interact. This self-coupling of the strong force fields has an important consequence: It prevents the quarks from leaving the hadrons – an effect called *confinement*. This effect is responsible for 98% of the mass of the visible matter in the universe. But unfortunately up date no one has found a way to solve the QCD equations in the confinement regime. Although it is common believe that QCD is the correct theory, it is still a major open question in particle physics, how exactly quarks and gluons are confined into hadrons.
There are two basic kinds of hadrons: *mesons*, which are bound states of a quark and an antiquark, and *baryons*, which are made of three quarks. All mesons are unstable; the only stable baryon is the proton. By studying the spectrum of excited hadrons, which can be produced at high-energy accelerator facilities like e.g. CERN, one gains more insight into how the strong interaction behaves in the confinement regime.
If QCD is correct, one expects that the hadron spectrum does not only contain ordinary mesons (quark-antiquark) and baryons (three quarks) but also highly excited hadrons that have contribution from the gluon fields (*hybrids*) or ones that consist entirely out of gluons (*glueballs*). Also *multi-quark states* with four or more quarks are not excluded by QCD. All of these states have very short lifetimes of the order of 10-24 sec and can therefore only be measured via their decay products. The most interesting, highly excited hadrons prefer to decay into final states with many particles. The extraction of the hadron states from the measured kinematic distribution of these multi-body final-states is computationally very demanding and employs elaborate methods, called *partial-wave analysis* (PW A).
The COMPASS experiment at CERN is part of a worldwide effort in better determining the spectrum of mesons and baryons, carried out at several accelerator laboratories. COMPASS focuses in particular on finding evidence for the existence or non-existence of hybrid and glueball states and performs precision measurements of disputed and also known mesons decaying into three, four, and five pions in order to constrain models and lattice QCD calculations.
This proposal consists of four subprojects corresponding to a total of about 560,000 core-h of computing time. The projects address the extraordinary computing needs which result from the demanding analysis method and the large size of the COMPASS data sets. Three of the proposed subprojects will try to develop and establish new analysis methods in order to overcome various shortcomings of the established approaches. Two projects are more focused on development, while the other two require significant computing resources from the start.