Matter is made out of small atoms. An atom has a nucleus in the middle and electrons which fly around it. The nucleus is made of protons and neutrons. That is not the end yet: a proton and a neutron are made of three even smaller objects, called quarks. Quarks and electrons are elementary particles: to the best of our knowledge they cannot be further divided.

Particle physicists try to answer the following questions concerning quarks: how do they interact with each other? What is the weight of a quark? Quarks are like small lego-blocks, which can combine in different ways. Which combinations are possible and which not?

We know some of the answers but not all of them. Quarks interact with each other by exchanging particles called gluons. As the name tells us, the interaction is very strong, actually so strong that we cannot see an isolated quark (a property called confinement). We know that a quark and an antiquark can combine to form a bound state: many particles of these type, called mesons, have been found. Another possibility is to put three quarks together: in this way we construct a baryon, such as a proton.

More precisely, a quark is a 'colored' object: it can be red, green, or blue. Of course, these are not real colors, yet they offer a useful mathematical analogy, which also gives the name to the theory describing quarks and gluons: Quantum Chromodynamics (QCD). However, contrary to quarks, mesons and baryons are white, i.e. the color charges of quarks inside them neutralize: one has a quark with color and an antiquark with anticolor inside mesons and an equal admixture of red, green, and blue quarks in baryons. Indeed, this is a basic property of all existing bound objects made of quarks which goes at the heart of confinement: these objects are white.

Yet, there can be other possibilities: can one build particles which are made of two quarks and two antiquarks? This is a so-called four-quark state, which also needs to be white. Very recent experiment (LHC-b at Cern and BES-III in 2014) show that these objects exist in nature. A part of this proposal concentrates on the existence of four-quark states and on the way they decay in smaller and conventional quark-antiquark objects. Note, we deal here with very small decay times, of the order of: 10^-22 sec! In this short lifetime the fuzziness of quantum mechanics plays an important role and shall be studied in detail within the framework of the proposed project.

But there is more: gluons themselves, the force carriers, interact with each other. This is a very peculiar property of gluons. Can gluons form white bound states? Computer simulations tell us 'yes'. These hypothetical states are called 'glueballs', that is, balls of gluons. They also represent a possibility which goes beyond the quark-antiquark picture. Up to now the experiments have not found glueballs, but the research goes on. As also the glueballs live very short (also 10^-22 sec), we need to know precisely how they decay in order to find them. In the proposed work, we will calculate many possible decays of glueballs, in order to facilitate their experimental discovery.

In conclusion, the theoretical investigation of novel possibilities for forming bound states of quarks and gluons aims to help our understanding on how elementary particles making the worlds around us work.