In the broadest sense, the aim of the proposed project is to study the structure of protons and neutrons. In the simplest picture, a proton (and also a neutron) consists of three *quarks*, which are bonded with strong interactions. We do not experience directly strong interactions in everyday life (in contrast to gravity or electromagnetic interactions), but they make protons / neutrons / atomic nuclei stable and thus allow the existence of the Universe as we know it. Quarks (so far) have not revealed the internal structure and we consider them as elementary particles. We know six kinds of quarks, the lightest two build the proton and neutron, while their heavier cousins are formed only in high-energy particle collisions.

The simple picture of a proton as three bonded quarks turns out to be far from physical reality. In the quarks', protons' and neutrons' world, the quantum mechanics plays the key role – it is generalized to the so-called *quantum field theory*. It postulates, that fundamental objects are not elementary particles but quantum fields – for example, a quark is an excitation (oscillation) of a quark field. Interactions are also associated with the quantum fields. The excitation of a strong interaction field is called *gluon*. Different quantum fields couple with each other and interact – for example, the excitation of a quark field can cause excitation of a gluon field which represents the emission of a gluon from a quark. What is more, the gluon can split into 2 gluons or 2 quarks. The reverse process is also possible: 2 gluons can merge into one.

The experimental studies of the proton structure take place in accelerators, where two beams of particles with enormous velocities (and thus energies) collide with each other. The currently largest accelerator – the Large Hadron Collider (LHC), built at CERN laboratory near Geneva, collides (mostly) protons. The energies are so big that thousands of particles can be created in one collision. Reconstructing some of theirs trajectories and energies, physicists gain insight into the structure of protons that collide. The task of theoretical physicists is to calculate the probability of appearance of specific particles in the collisions. Comparing such calculations with experimental results, we learn about dynamics of quarks and gluons at very high energies. So how does the proton looks, when "seen" in the high energy collision? It contains almost only gluons! The three quarks (called valence) that make up the proton at small energy are irrelevant – they are dominated by the sea of gluons and quarks created by their splittings. What's more, with the increasing energy, the density of particles grows – up to the point where it reaches the state of saturation. This phenomenon is still not fully understood and one of the aims of the project is to investigate it's properties.

Due to the complexity of the phenomena we deal with, the basic task for a particle physicist is to determine what final state of collision should be analyzed – among millions or billions collisions only several final states might be interesting. In the proposed project, we intend to perform a theoretical analysis of the production of high-energy photons (quanta of light), leptons (e.g. electrons) and heavy mesons (particles composed of two heavy quarks). As our previous studies have shown, these processes give the opportunity to analyze the structure of protons at high energies, in particular determine the distribution of gluons' momenta in the proton. It should be emphasized, that good understanding of these phenomena is crucial for the searches of New Physics – the hypothetical theories significantly extending our knowledge (e.g. supersymmetry, extra dimensions, dark matter). For this reason, the better we know the strong interactions, the greater chance is to discover a new theory.