The motivation behind this proposal is grounded in a quest for understanding fundamental and emergent aspects of matter. To gain information about matter one studies collisions of particles at the highest available energies. At present, the largest energies are available in collisions of hadrons at the Large Hadron Collider (LHC) located at CERN in Geneva. The constituents of hadrons are quarks, and gluons, commonly called partons, and the actual interaction during collisions takes place between partons. The most direct access to partons is provided by final states called jets which are collimated sprays of hadronized partons. By calculating cross sections which give probabilities for the production of jets, and comparing them to experimental findings, we investigate directly the partonic nature of nucleons (protons, neutrons). A lot is already known about the nature of the partons in nucleons and the common knowledge that stems from recent studies suggests that the higher the energy the more partons are contained within protons. This number will eventually saturate at more extreme conditions, so that the appropriately defined probability for interactions is not larger than one. More extreme conditions at the LHC can be achieved in collisions of protons with lead and lead with lead. The theoretical description of proton-lead collisions is a bit more complex than proton-proton collisions. This is because nucleons are confined in nuclei, so their distribution is affected by forces binding nucleons into nuclei. However, the final state resembles very much the proton proton final state, i.e. after the collision one has conversion of partons into hadrons, or production of electroweak particles. The situation gets more complicated when one collides lead with lead. In such a collision one forms a fireball in which everything melts into a new, extreme state of matter the quark-gluon plasma. This state of matter consists of interacting quarks and gluons and has properties similar to a liquid with low viscosity. After the fireball cools, the individual quarks and gluons recombine into ordinary matter that speeds away in all directions. In such a collision of heavy ions similarly to p–p case, jets can be produced. However, these jets show a difference from those produced in simpler collisions. In the experiments at RHIC and LHC the researchers observed that jets can be quenched. Theoretical understanding of these measurements is challenging, however, and is one of the most important problems in the theory of strong interactions i.e. quantum chromodynamics (QCD). The application of QCD to hadron collisions relies on so called factorization theorems, which enable to decompose the cross section into the product of two basic objects: a short-distance, process dependent, fixed order part characterizing hard parton-parton scattering and parton density functions. Using these objects, and Monte Carlo simulations one can calculate cross sections for various processes which make up the subject of the project.
The project is undertaken since we are still lacking the complete picture of high energy scatterings, and the present frameworks, while working well in their domain of applicability cannot be extended further. The prominent example of the need for further developments in the physics of high energy collisions are:

- parton saturation. Theoretical calculations within QCD suggest that the gluon density in hadrons of any type should saturate i.e. there should be suppression of low momentum particles, and enhancement of high momentum. There are indications from e–p Deep Inelastic Scattering and RHIC experiments that saturation occurs in Nature, but more evidence is needed to claim a discovery;
- di-jet asymmetry which point at strong quenching of jets traversing quark gluon plasma. The open problem is to what extend the initial state of partons determine the observed asymmetry;
- the ridge problem. In 2010 the CMS experiment observed a correlation extending along several units in rapidity between any two produced low momentum particles, and at small azimuthal angle between them. This finding is not explained by any fundamental theory.

The first objective of the proposal is to use the recently formulated framework called ITMD to learn more about the still uncovered dynamics of partonic content of nuclei by calculating cross sections for electroweak observables in p–Pb, and Pb–Pb collisions. Such observables are perfect probes since they are color neutral and therefore can tell us a lot about the partonic content of heavy ions. Furthermore such processes will allow to constrain the parton densities, in order to eventually shed more light on the saturation problem.

The second objective of the proposal is to understand how the interplay of initial structure of hadrons (studied in the previous part) with plasma affects the property of final state jets. To achieve the goal, generalization of ITMD accounting for medium effects like jet quenching will be proposed.