In our project we wish to shed light on a number of problems concerning the structure of hadrons that can be studied at an Electron-Ion Collider (EIC).

Such accelerators use highly energetic electron beams to investigate the structure of matter at distances 100 thousand times shorter than the size of an atom. Physicists describe the electromagnetic interaction of electrons with the protons and nuclei as being mediated by very short wavelength photons – the quanta of the electromagnetic field.

The very short wavelength fields violently disrupt the constituents of the proton and as the result of the interaction many particles are produced and the proton itself is destroyed. These constituents are the quarks and gluons, and the task of theorists is to draw conclusions on how the proton is built up from these constituents just from analysing at which angles and with which energies the measured newly particles have been produced.

One of the most intensely studied subjects in strong interaction physics is the production of quarkonia, the bound states of a heavy quark and antiquark. Especially the charm-anticharm ($c\bar{c}$) bound states of quarks, charmonia play an important role. The pattern of enhancement and suppression of quarkonia has been suggested as one of the important probes of the quark-gluon plasma phase. This physics is currently studied in high energy nucleus-nucleus collisions at the LHC. In reactions happening at electron ion colliders, the production of quarkonia tells as about the electrically neutral constituents of the proton – the gluons.

There is another type of processes which has most intriguing properties: sometimes, despite its interaction with the highly energetic electromagnetic wave, the proton stays intact, and it is rather the photon which is converted into matter! Only quantum mechanics can explain these peculiar events. As the intensity of particles has an angular distribution like a diffraction pattern from optics, these processes are called diffractive particle production.

The teams from Rzeszów and Kraków which realize this project are experts in the theoretical description of these diffractive interactions. They also tell us about how gluons are distributed in the proton. If one swaps the proton to a nuclear target, one can learn about the gluons inside a nucleus. This is of great interest, as it is supposed, that gluons and quarks in a nucleus don't belong to the individual protons which make up the nucleus, but some of the gluons are shared by two or more protons or neutrons.

Recently, the decision has been taken to build an EIC at Brookhaven National Laboratory in the USA. At this collider, collisions of electrons and protons as well as electrons and nuclei will be studied in a broad range of center of mass energies $\sqrt{s}$, with $20 < \sqrt{s} < 140$ GeV. This collider will have a luminosity about 1000 times higher than the previous accelerator HERA (Hadron-Elektron-Ringanlage) which operated in Hamburg between 1992-2007.

Apart from its large luminosity, the EIC will also accelerate light and heavy nuclei, and it will be the first polarized electron-hadron collider ever.

We want to capitalize on all these opportunities in our grant. We wish to study the theoretical description, and numerical simulation, of a broad range of processes occuring in such a scattering.