

Studies of charm and beauty jet quenching with ALICE detector and machine learning

All the matter surrounding us is made of atoms. Atom is a system of nucleus and cloud of electrons around it. Then, nucleus consists of nucleons (protons and neutrons) and they are made of three quarks, which are kept together by the so called strong nuclear forces. In each atom, more than 99.9% of its mass is inside the nucleus. Interestingly, mass of the nucleus is not equal to sum of masses of its constituents, because of forces which bind the nucleons together and therefore lower the overall mass of the system. The difference is small (below 1%), it is however extremely important – it allows to obtain energy by merging small nuclei into medium ones (nuclear fusion happening on the Sun) and by breaking apart large nuclei (existing nuclear power plants). Situation is similar on the deeper level: mass of the nucleon is not equal to mass of three quarks, most of its mass (contrary to situation in nucleus) comes from interactions between quarks – they are called strong interactions for the reason. Strong interactions are responsible for 95% of the mass of observed matter, the remaining 5% is explained by famous Higgs mechanism.

Strong interactions have one counterintuitive property – their strength rises with distance. It means that, when quarks are very close to each other, they become free, the interactions between them vanish. To make it happen, one has to bring nuclear matter to state of huge temperature and/or density. Here the Large Hadron Collider enters. Collisions of heavy ions of lead moving with velocities close to the speed of light, which happen there, can for small fraction of second create conditions sufficient to free quarks. Matter behaves then in a way differing completely from anything we can observe in everyday life (and in most of laboratories). This peculiar state of matter is called quark-gluon plasma (QGP) and beyond great accelerators, it exists in the cores of neutron stars. Similar state could have been created in first fractions of seconds after the Big Bang. Behavior of QGP is determined by strong forces, that is why its properties allow as to better understand these interactions.

Studies of QGP relies mainly on measurements of properties of particles produced in heavy ion collisions and comparison them to particles created in collisions of protons, when QGP is not created and particles traverse only vacuum. In our project we want to measure how much energy is lost by various types of quarks. Some quarks are even 1000 times heavier than other and understanding of dependence of strength of their interactions with QGP on their mass is one of our main targets.

One of the challenges is the fact, that heavy quarks are produced much less frequently than the light ones. In order to separate ones from the others and obtain a pure sample of each type, we will utilize state-of-the-art machine learning methods, which proved to be very effective in similar tasks both in industrial and scientific applications.

Our research will for sure contribute significantly to development of our understanding of strong interactions and properties of QGP. What practical applications it will bring? It is important, but very difficult question. Nevertheless, history teaches us, that technological progress would not be possible without conducting of fundamental research. You cannot simply come up with an idea to build nuclear power plant without knowledge of atom's construction and (precise!) masses of the nuclei. Similarly, you cannot come up with an idea to (*insert here the future invention granted with Noble Prize*) without understanding of strong interactions. Humanity faces many challenges and there are next yet to come. Focusing only on solving ad hoc problems would be glaring shortsightedness.

Apart from the idea that understanding of mechanisms of the Nature is a beautiful goal in itself...