Popular Science Summary

Probing Charm Production in Proton-Proton Collisions

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When ions are heated up to extreme temperatures they undergo a phase transition into so called quark-gluon plasma (QGP), an extraordinary type of matter in which the fundamental particles building up protons and neutrons move more or less freely. It is believed that the early universe was made up of this hot and dense mixture, so by studying the behaviour of this fluid we can learn more about how the building blocks of our universe were once formed. To understand the quark-gluon plasma, we must first understand the basic building blocks of matter. The fact that matter is made up of atoms and that these in turn consist of protons, neutrons and electrons is something most people learn about in high school. But in fact, protons and neutrons can be split into even smaller elementary particles called quarks. There are three pairs of quarks - up and down, strange and charm, and top and bottom. Protons are made up of one down and two up quarks, but more exotic particles are made up of other combinations of two or three of these quarks and their corresponding antiparticles.

When nuclei collide at very high energies, they can create conditions similar to those in the early universe. This is done at particle accelerators such as the Large Hadron Collider (LHC) at CERN, producing so called "little Bangs". The droplet of QGP which is formed in these collisions exists for a very short time, before decaying into showers of particles that are detected and analysed. Many theoretical predictions for properties of the QGP have been proposed and confirmed by experiments, such as the abundances and spatial distributions of the produced particles. However, recently signatures previously attributed to QGP were also found in proton-proton collisions. This was a big shock to the high-energy physics community since the QGP was not expected to form in collisions of smaller particles – there simply is not enough time. As researchers, we want to understand what is going on in these collisions and this thesis hopes to contribute to a small piece of this puzzle.

The particles produced in the collision are spread out in space around the collision point. By considering the relative positions of these particles, we can determine at what time in between collision and detection they are produced, which in turn gives clues about the production mechanisms, i.e. how they are produced. In this work, so called charmed particles are considered. These are exotic particles that include a charm (or anti-charm) quark and one or two other quarks, most often the up and down quarks. The proton-proton collisions are simulated using a model called Pythia, which is a Lund-based theoretical model often used in high-energy physics. It simulates the produced particles, their propagation towards the detectors and their decay into new particles. All of this information is in the analysis used to find the spatial distribution of the charmed particles in a so called three-particle correlation. In essence, this is a topological map which tells you the probability to find the protons and other charmed particles, if you have a charmed baryon at the origin. The results of this work may in future research be compared to experimental data to enable the evaluation of the theoretical models describing proton-proton collisions.