The hunt for hot nuclear matter

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In particle physics, a jet is a shower of collimated particles generated by a highly energetic quark or gluon. In a lead-lead collision, jets must traverse through quark gluon plasma, altering their energy, track and consistency.

In his dissertation, Tomas Snellman studied whether there are differences in the characteristics of jets between proton-proton and proton-lead collisions. The goal was to determine if quark gluon plasma can be generated in a proton-lead collisions, as then jets would start resembling observations made in lead-lead collisions.

Hot nuclear matter usually means quark gluon plasma (QGP). It is a matter so hot that quarks and gluons are no longer confined to nucleons, i.e., protons and neutrons, but move freely within the plasma. To turn ordinary matter into quark gluon plasma requires temperatures of about 2000 billion Kelvin. These high temperatures can be reached in high energy collisions between atomic nuclei in laboratories, for example at the Large Hadron Collider (LHC).

Tomas Snellman studies particle jets in collisions between protons and lead nuclei, which have been measured at CERN at the ALICE experiment of the LHC.

An important goal in the measurements performed at ALICE was to find out if the characteristics of a proton-lead collision can be explained using only the properties of cold nuclear matter. Cold nuclear matter is simply used to refer to the ordinary state of atomic nuclei, which is cold by the standards of particle physics.

"In the field it has been established that quark gluon plasma is created in lead-lead collisions at LHC. The interesting question is whether this can happen also in proton-lead collisions," Snellman says.

By the scales in particle physics research atomic nuclei are "large." Thus, the ball of colliding matter in a collision between two heavy nuclei is large enough to turn into quark gluon plasma. On the other hand, a single proton is so small, that it was deemed unlikely that QGP would be created.

"However, some proton-lead collisions have shown indications of the creation of QGP. It remains unknown what actually happens in proton-lead collisions."

"In my research, I studied whether jets from either the average proton-lead collision or from an exceptionally active collision differ from jets observed in proton-proton collisions. Changes in the active collisions could provide clear proof of the creation of QGP. However, within the current experimental capabilities, no proof could be found," Snellman explains.

"Thus, the question of QGP in proton-lead collision remains an open one. Certain measurements support the creation of QGP, but especially measurements based on particle jets, like this thesis, see no signs. As the potential QGP droplet would be small in proton-lead collisions, the signals would be weak. This explains a part of the discrepancy, but not all of it. A solution would require a better theoretical understanding of the underlying phenomena, but also on the experimental side we need better control of the biases affecting our measurements so that even a weak signal could be detected," concludes Snellman.

More information: Jet transverse momentum distributions from reconstructed jets in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. jyx.jyu.fi/handle/123456789/64412

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