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Pre-equilibrium of the Quark-Gluon Plasma

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Collisions of heavy ion nuclei at relativistic speeds (close to the speed of light), sometimes referred to as the "Little Bang", can recreate conditions similar to the early universe. This high-temperature and very dense form of matter, now known as the Quark-Gluon plasma (QGP), is made of the elementary building blocks - quarks and gluons - whose description lies within the Quantum Chromodynamics, a keystone of the Standard Model of Particle Physics. An early signature of the QGP, both theorized and seen in experiments, was "jet quenching". The concept behind quenching is that a highly energetic quark or gluon undergoes significant energy loss due to its interactions when traversing the created QGP medium. The result of its fragmentation and radiation pattern is the development of a jet of final-state particles that carry information about the produced medium.

With the plethora of experimental results, the theory of jet quenching has matured, and the underlying dynamics of in-medium propagation of quarks and gluons is under theoretical control. However, its exploitation as a tool to unveil the inner workings of the Quark-Gluon Plasma is still in its infancy. Currently, Quark-Gluon Plasma is described as the most perfect liquid. But how this macroscopic behaviour emerges from a Quantum Field Theory as QCD is still unknown. This will be the challenge for the upcoming heavy-ion data taking at the Large Hadron Collider and will be the focus of this master thesis.

The main objectives of this thesis are thus:
1) Delve into the theory of jet quenching to understand the high-energy and high-density corners of the QCD phase diagram;
2) Get acquainted with the newly developed jet algorithms that aim to probe the time structure of the QGP that is produced in heavy-ion collisions;
3) Model different Quark-Gluon Plasma evolution profiles within the allowed QCD phase space;
4) Identify the timescale at which the Quark-Gluon Plasma comes to thermal equilibrium
5) Assess the potential use of jets to constrain the pre-equilibrium phase of QGP

If successful, the result will be an impactful publication with an immediate application in current ultra-relativistic heavy-ion experiments (such as LHC) and in determining the future heavy-ion physics program.

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