Thesis Preliminary Exam Writeup

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The standard model of particle physics, a quantum field theory describing quark and lepton interactions through gauge boson exchange, establishes the theoretical basis for electromagnetic, weak, and strong forces. In this model, partons (quarks and gluons) are constituents of stable hadrons, bound by the strong force mediated by the self-interacting gluon. While the model successfully explains electromagnetic and weak interactions, it does not encompass gravity, dark matter, or neutrino mass, yet it is experimentally verified with great precision.

According to the standard model, quarks carry color charge, but experimentally, a quark has never been observed in isolation. Instead, quarks exist in color-neutral states of mesons and baryons (groups of two and three quarks, respectively), a phenomenon known as color confinement. At great distances, the strong color force grows, forming particle-antiparticle pairs to create a color-neutral composite particle. However, Quantum Chromodynamics (QCD) displays asymptotic freedom, allowing partons to be liberated from strong-force bonds in sufficiently hot and/or dense matter—an essential focus of modern high-energy nuclear physics.

To achieve such a hot and dense state, ultra-relativistic heavy-ion collisions are employed. The first relativistic Pb-Pb collisions in 1984 at the SPS at CERN revealed collective behavior and strangeness enhancement, consistent with Quark-Gluon Plasma (QGP) predictions. Observations of jet quenching at RHIC in 2000 suggested the creation of a hot, dense medium, also in line with QGP expectations. Heavy-ion collisions at the LHC have set new energy records, allowing for experimental estimations of particle yield ratios to determine system temperature and baryon chemical potential, confirming states of efficient energy density for QGP formation. Peripheral collisions exhibit elliptic flow scaling with parton number, further evidence of deconfinement.

Among the experimental tools for QGP studies are jets—collimated sprays of hadrons resulting from high-energy quark or gluon fragmentation during hard scatterings. The hard-scattering cross section of a jet remains unaffected by the medium, enabling comparisons to scaled pp reference for studying medium effects. Features like dijet asymmetry and jet quenching quantify energy loss in the QGP medium, allowing measurement of characteristics such as the QGP transport coefficient. Altered jet shapes in central heavy-ion collisions indicate parton interaction with the medium.

An active area of research in high-energy nuclear physics is the flavor-dependence of partonic energy loss and interactions with the QGP medium. In my thesis, I plan to use data from the CMS detector to isolate jets stemming from the fragmentation of bottom quarks and measure their suppression. The suppression of bottom-quark jets (b-jets) provides insights into how partons of different mass interact with the QGP. Heavy-flavor jets carry unique experimental signatures, and by utilizing the advanced muon-detection system of the CMS and jets from full particle-flow reconstruction, lepton-to-jet tagging is implemented to filter for jets stemming from heavy-flavor fragmentation. This study aims to investigate flavor-dependent medium effects on parton propagation and test model predictions regarding heavy-flavor objects.