MEASUREMENT OF ANGULAR AND MOMENTUM DISTRIBUTIONS OF CHARGED PARTICLES WITHIN AND AROUND JETS IN Pb+Pb AND *pp* COLLISIONS AT $\sqrt{S_{\mathrm{NN}}} = 5.02$ TeV WITH ATLAS AT THE LHC

BY

AKSHAT PURI

DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Physics
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2019

Urbana, Illinois

Doctoral Committee:

Professor Matthias Grosse Perdekamp, Chair
Professor Anne Marie Sickles, Advisor
Professor Aida El-Khadra
Professor Bryce Gadaway

Abstract

Studies of the fragmentation of jets into charged particles in heavy-ion collisions can help in understanding the mechanism of jet quenching by the hot and dense matter created in such collisions, the quark-gluon plasma. This thesis presents a measurement of the angular distribution of charged particles around the jet axis as measured in Pb+Pb and *pp* collisions collided at a center of mass energy of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The measurement is done using the ATLAS detector at the Large Hadron Collider, and utilizes 0.49 pb^{-1} of Pb+Pb and 25 pb^{-1} of *pp* data collected in 2015. The measurement is performed inside jets reconstructed with the anti-k_t algorithm with radius parameter $R = 0.4$, and is extended to regions outside the jet cone. Results are presented as a function of Pb+Pb collision centrality, and both jet and charged-particle transverse momenta. It was observed that in Pb+Pb collisions there is a broadening of the jet for charged particles with $p_{\mathrm{T}} < 4$ GeV, along with a narrowing for charged particles with $p_{\mathrm{T}} > 4$ GeV. Ratios between the angular distributions in Pb+Pb and *pp* showed an enhancement for particles with $p_{\mathrm{T}} < 4$ GeV in Pb+Pb collisions, with the enhancement increasing up to 2 for $r < 0.3$, and remaining constant for $0.3 < r < 0.6$. Charged particles with $p_{\mathrm{T}} > 4$ GeVshow a growing suppression of up to 0.5 for $r < 0.3$ in Pb+Pb collisions, with the depletion remaining constant for $0.3 < r < 0.6$.

For my Mother, Father, and Brother

Chapter 1

Introduction

The Large Hadron Collider (LHC) at the European Center for Nuclear Research (CERN), is one of the worlds most expensive and complicated machines, and was built with the purpose of accelerating subatomic particles to close to the speed of light and colliding them to study their underlying structure. Detectors around the LHC ring, the biggest of which are ATLAS (A Toroidal LHC ApparatuS), CMS (Compact Muon Solenoid), ALICE (A Large Ion-Collider Experiment), and LHCb (LHC-Beauty), study these collisions and use the debris as a playground to verify and expand the "Standard Model" of particle physics. This thesis will focus on measurements of collisions involving heavy ions, as measured by the ATLAS detector.

Relativistic heavy ion collisions such as those at the LHC provide insight into the interactions between quarks and gluons. These fundamental building blocks of all matter interact via the strong force, the theoretical framework of which is described by Quantum Chromodynamics (QCD). This theory dictates that quarks and gluons are confined, i.e. locked together to form composite particles and cannot exist independently, making their study extremely difficult. Relativistic heavy ion collisions provide an extreme environment where nuclear matter can "melt" and form a deconfined medium that consists of free quarks and gluons. This state of matter, called the Quark Gluon Plasma (QGP) is what existed a few microseconds after the Big Bang, and is what eventually cooled and expanded to form the existing universe.

The quark-gluon plasma (see Refs. [**Roland:2014jsa**, **Busza:2018rrf**] for recent reviews) can be probed by jets, sprays of particles that come from hard scattering processes between the nucleons involved in the collision. These jets are produced early in the collision, and interact with the QGP as they make their way to the detector. Studying the rates and characteristics of these jets in Pb+Pb collisions, and comparing them to similar quantities in *pp* collisions can provide information on the properties of the QGP.

This thesis is split into 4 main chapters. An overview of the LHC and the ATLAS detector is given in Chapter **??**, Chapter **??** will describe the QCD framework that will give context to the measurements discussed, Chapter **??** will describe the work undertaken to become a member of the ATLAS Collaboration, and Chapter **??** will provide a detailed description of the measurement to determine the angular distributions of charged particles in Pb+Pb and *pp* collisions.