

Popular Scientific Abstract

Scientists have questioned the mysteries of the universe for many years; how did the Big Bang happen? Why is the universe still expanding? And have we discovered all the particles that exist out there? These sort of mysteries can hopefully be solved in the field of particle physics.

Particle physics is the study of particles and their interactions. Particles can be fundamental, like electrons and quarks, or composite, like protons and neutrons, which are made of quarks and gluons. An interaction between particles is mediated by a particle called a mediator. Many particles, composite and fundamental, have been discovered since the 19th century. The fundamental ones have been put together in the Standard Model (SM) of particle physics.

The Large Hadron Collider (LHC) has hosted many particle physics experiments, allowing physicists to discover new particles and study their interactions. Inside the LHC ring, protons are accelerated to collide with each other, allowing quarks inside them to interact with one another and form different kinds of particles. If a newly formed particle is unstable, it will decay into more stable particles, for example, quarks. But quarks are confined by the strong interaction, which prevents them to exist freely. Therefore, a single quark will spontaneously combine with another quark or gluon and form a collimated cone of particles called a jet. The mass of the new particle can then be reconstructed from a mass combination of the resulting two jets (a dijet).

There are questions beyond the Standard Model (BSM) physics that remain unanswered. Theorists have postulated new physics models to solve the mysteries. What is left to be done is for the experimentalists to conduct the experiments to prove those hypotheses right or wrong. Recent experiments at the LHC are dedicated to searches for BSM phenomena. Some examples of particles that have been postulated to exist are a composite quark Q – a massive quark partner – and a dark matter mediator Z' – a particle that mediates interactions between dark matter and SM particles.

This master thesis focuses on searches for Q and Z' , in which each particle decays into a dijet with an additional jet in the system. The mediator mass is reconstructed by a mass combination of its decay products. However, there are three jets in the final states, and only two originate from the BSM particle. Studies of how to choose the right dijet mass for reconstructing the Q and Z masses are presented in Part I. In order to improve the understanding of the phenomena before conducting the real experiment, the studies are done using samples generated by event generators, mimicking events and detector effects observed by the ATLAS detector.

The next step is to use the best mass combination to search for Q and Z' . Only Z' is used in this thesis. Ideally, a prototype of the search using simulated data can be done by following these steps: First, generate processes with SM particles and call them “background”. Second, generate Z' of a certain mass and call them “signals”. Third, compare the difference between the background-only and signal-plus-background. If our analysis highlights a discrepancy, then we can discover a new particle that could be Z' . If there is no discrepancy, then we can constrain the parameters of the theory that includes Z' .

Given the incredible performance of the LHC and the ATLAS detector, searches for BSM particles are promising. It would be a historic breakthrough for the physics society and for mankind if the experimental searches confirm the existence of those particles. But even if nothing is found, we will always learn how to develop the experiments and strategies to answer the fundamental questions of the universe.