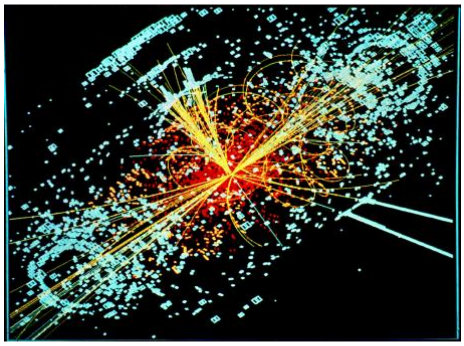
Ball picking in the Search of Dark Matter

Dark matter, a mystery taking up about 30 percent of the mass energy existence in the universe, remains hidden despite our current technologies. Astronomy observations suggested the existence of dark matter and dark energy. We now believe that they are responsible for the very being of our galaxies. The normal matter we know of is as tiny as only five percent of the whole mass of the universe and it cannot provide enough gravity for galaxies to form their current structures. But we still do not know what the "invisible" mysteries are. Are they composed of new particles unknown to us? Or are these theories just another "aether" of our age? To answer these questions, many theories have been forwarded and experiments have been conducted. Among these attempts, particle physicists are curious about the particle composition of dark matter particles. Now most of the related experiments are based on the Large Hadron Collider at CERN, which is the largest collider in the world. Fancy pictures of this experiments can be found everywhere on the Internet, among which Plot 1 is a very popular one. This collider can also keep track of outcoming particles, as are shown in plot 2. My thesis will also be focused on the data analysis for one of those experimental searches for Dark Matter.

Plot 1: Inside the LHC. Plot source: Ref. 1



Plot 2: A collision happening inside the LHC
Plot source: Ref. 2

My thesis will be working on one part of a dark matter search. The search is based on a theoretical model that the dark matter particle can be mediated by a light resonance. The resonance is created with a radiation and will decay into two quarks. The radiation can be either a photon or a gluon. Gluons and quarks are particles that give similar features in detectors. In the case of the radiation being a gluon, the detector will be collecting three similar objects, two from the resonance decay products and one from the radiation. The detector cannot tell the radiated gluon from the quarks. However, only the two quarks can be reconstructed into the resonance of interest. Mixing these three particles will broaden the resonance distribution peak, affecting the sensitivity of the search. The main task here is to pick the right pair of objects for the resonance reconstruction.

So this can be simplified into a ball-picking problem: three balls in a dark box, two of which are red while one is blue, and the task is to pick the two red ones from the box. Relying on the pure probability of this choice will lead to the chance of only one third being correct, which is too low to be used in analysis. So we need to cast some light into the box to help making a better choice. The "light" in our case are variables applied to identify the gluon and quarks. In my thesis, different variables will be tested first with simulation data, trying to give hints on how to pick the quarks. With the data collected from simulations, we will be able to identify gluons and quarks for real data. This will greatly improve the accuracy for making the object pair choice. Once the most useful variables are found, more light will be casted into the box. In this way, the choices are made more and more accurate, thus improving the sensitivity of the search.

This research will not only help with this dark matter search, the methods applied here can also provide reference for future searches for ISR related searches. Some light resonance characteristics may also be useful for future studies. Hopefully, with this research, people will find some insights with other black-box problems.

Reference:

[1] Inside the Large Hadron Collider. https://www.flickr.com/photos/cizauskas/15329609917

[2] CMS Higgs-event. https://commons.wikimedia.org/wiki/File:CMS_Higgs-event.jpg