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My project was part of the Future Circular Collider (FCC) design study . The goal of the study is to evaluate the feasibility of constructing the next generation 100 km collider facility with nominal beam energy of 100 TeV. As part of this evaluation, the study aims to determine hardware and software requirements, detectors, and costs for the project. There are three branches of this study (FCC-hh, FCC-eh, and FCC-ee) which focus on different collider facilities that would be housed in the same 100 km tunnel. The FCC-hh is the 100 TeV hadron collider that will define the infrastructure requirements for the project. The FCC-ee is an e+e- collider that would be a first step in the construction of the FCC-hh, and the FCC-eh is an intermediate lepton-hadron collider that is being considered [1]. My project focused on physics of particular interest to the FCC-hh study.

Because the FCC study is still in its very early stages, there is still a very large amount of work to be done in understanding the physics at 100 TeV, as well as the hardware and software that will be needed to make sense of the extremely high data output rates and make precise measurements at such a facility. My project was to fill in some of these gaps by simulating top quark physics at 100 TeV and attempting to use these findings as first looks into the software and hardware requirements of potential detectors. In addition, I was asked to learn about and interface two programs that are commonly used in such simulations, MadGraph 5 [2] and Pythia 8 [3]. This was particularly important since Pythia 8 is a relatively new tool which is expected to become standard in the coming years.

The need for the interface between Madgraph 5 and Pythia 8 arises because of the time consuming nature of the Pythia 8 step. This makes it desirable to be able to generate events with Madgraph 5 and hadronize them with Pythia 8 in a single process which can be decomposed into small jobs and processed on a batch system. This allows the entirety of the event generation to be done with a single command, and it speeds up the process by allowing several computers to generate the desired output in parallel, all without losing any of the computing resources on the user’s personal machine. I was able to accomplish this by writing a script in the Python programming language. After completing this script, I was able to quickly generate top quark pair production events that allowed me to study various aspects of top quark physics at 100 TeV.

I used Delphes on the events generated with the script discussed above to simulate detection software [4]. Because Delphes works using parameters that are provided to determine features like jet radius, I was able to generate output from Delphes that allowed me to study the energy containment of the anti-kT jet finding algorithm used by Delphes [5]. By comparing the energy of jets with various jet radius parameters, I was able to determine how large the jet radius needed to be to capture all of the particles associated to a jet without including particles that were not part of the jet. This data is shown in Figure 1. This is important as a first step toward understanding the software requirements for experiments that might take place on the FCC.

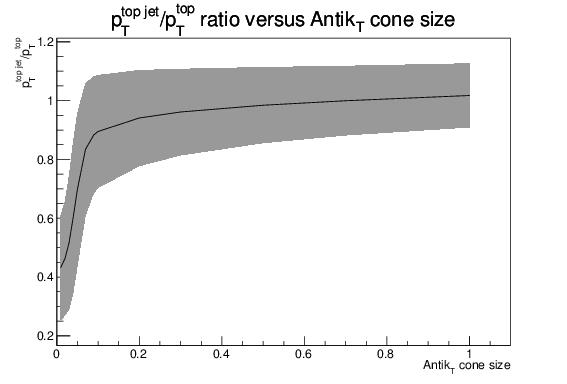


Figure 1. Jet to top pT ratio plateaus for anti-kT cone size above ~0.2.

The data analysis aspect of my project focused on comparing features of boosted tops and high transverse momentum jets in order to understand how these events might be differentiated. In this data analysis, I spent a good deal of time focused on muon production in heavy quark pair production. My advisor and I believed that the fraction of the transverse momentum that a muon receives when the mother particle decays could be used as a benchmark to differentiate the two types of decay. To study this possibility, we analyzed the momentum and multiplicity of muons with large transverse momentum that were produced in W boson decay. By comparing the transverse momentum spectra of the two interactions, we found that, in fact, both multiplicity and momentum could be used as a means of differentiating between top and bottom pair production. This is shown in Figure 2.

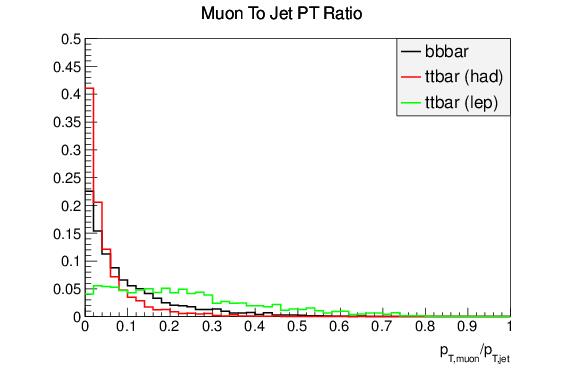


Figure 2. Muon pT as a fraction of jet pT. Leptonic top decay is differentiable from b jet and hadronic top decay.

References

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