b-jet shape analysis using the Rivet software package

Project Outline

Luke Pomfrey

Project Supervisors:
Prof. Jon Butterworth and Dr. Ben Waugh

Monday 20th October, 2008

Abstract

This project aims to investigate the shape and angular distribution of b-quark jets in $p\bar{p}$ collisions using Monte-Carlo based computer simulations. The `Rivet`[1] software framework will be used to model the collisions, with the `AGILe`[2] generator interface, and `GENSER`[3] Monte-Carlo simulation programs. The simulated results will then be compared against actual data (obtained from the Tevatron at FNAL) in order to tune the Monte-Carlo programs for the LHC.

1 Introduction

1.1 Monte-Carlo methods

Monte-Carlo methods are a way to model complex physical situations that contain a degree of improbability and/or randomness using statistical sampling. They are important for data analysis in HEP experiments.

A MC approach generally follows a pattern comprising the following steps[4]:

1. Define a domain of possible inputs.
2. Generate inputs randomly from the domain and perform a deterministic computation on them.
3. Aggregate the individual results of the inputs into the final result.

A simple example of a Monte-Carlo method for approximating the value of π is as follows[4]:

1. Draw a unit square and inscribe a circle within it. (Defining the domain of inputs.)
2. Scatter some grains of rice within the square. (Generating the random inputs.)
3. The proportion of objects within the circle, as compared to those within the square, should be approximately $\frac{\pi}{4}$. Count the number of grains of rice in the circle (performing the computation, i.e. testing hether the grain of rice is in the circle) and multiply by four.
4. Then, divide by the total number of grains of rice in the square to get an approximation of π. (Aggregating the results to get a final output.)

Another general overview of the MC method, in terms of it's original realisation and use, can be found in [5]. Originally performed by hand, computers have allowed MC methods to reach much higher levels of complexity and accuracy.

The MC programs that will be used in this project will be from CERN's `GENSER` library[3], and include `Herwig`[6, 7], and `Pythia6`[8].

1.2 Generator tuning

Computational based MC event generators have a number of free parameters in them. These parameters cannot be determined by studying the underlying theory but must be varied to make the MC output data match the experimental data. By varying these free parameters the MC generator can be tuned to accurately describe experimental data.

In this project the generators will be tuned to get their output to closely follow measured values for b-quark jet shapes from the Tevatron in order to increase their effectiveness in predicting events at the LHC.

`Professor`, written in Python, is an application written to ease and automate the tuning of MC generator parameters.[9] This type of software could possibly be used in the project.

1.3 Rivet and AGILe

`Rivet` (or "Robust Independent Validation of Experiment and Theory") is a toolkit written in C++ for the validation of MC event generators (such as `Herwig` and `Pythia`).[1] It is a replacement for `HZTool/HZSteer`.

On a basic level, `Rivet` allows the user to setup the variables of an accelerator collision (e.g. beam particles, particle momenta, detector variables, resultant partons of interest, etc.) and then run the analysis using one of many MC generators (using `AGILe`).

`Rivet` can take input from multiple generators, using `AGILe`, to produce MC histograms which can then be compared against real data histograms. It's object-oriented base allows the user to write "plugins" for the computation of simulated data for many collision/detector/experiment scenarios.[1]

`AGILe` (or "A Generator Interface Library") is an object oriented interfac for MC generators written in C++.[2] It is used by `Rivet` as a generator interface layer.

2 Project aims and avenues of investigation

This project will perform computational analyses of $p\bar{p}$ collisions in the Tevatron CDF detector, using `Rivet` and the above mentioned MC generators, in order to study the shape and angular distribution of b-quark jets. The simulated data will then be compared to experimental data in order to enable further tuning of the MC generators used so that they may be used more accurately in simulations for the LHC detectors (ATLAS *et al.*).

2.1 Known MC generator deficiencies

The `Rivet` analysis used will be the one described in [10]. It is known that the `Pythia` and `Herwig` generators are not sufficiently tuned to perfectly reproduce experimental data from these types of collisions when looking at b-jet shapes in that the measured b-jet shapes are broader than those simulated (possibly due to the underestimation of b-jets resulting from gluon splitting).[10] It is also known that the `Pythia` simulation data is closer to the experimental data then the `Herwig` data.[10] This is likely due to the algorithmic and physics differences in the `Pythia` and `Herwig` code. This is an avenue that could be investigated in the project.

2.2 Possible search for the Higgs boson

Another possible avenue of investigation, after the MC generators have been tuned, could be the investigation into jet substructure to search for the Higgs boson.

Whilst Higgs boson decays to $b\bar{b}$ are widely considered a poor search mechanism for the Higgs boson, it has been shown that with effective jet-reconstruction and decomposition they may be a promising search avenue for a Higgs boson with mass ~ 120 GeV.[11]

References

[1] Rivet (Robust Independent Validation of Experiment and Theory). Web:. `http://projects.hepforge.org/rivet/`.

[2] AGILe (A Generator Interface Library). Web:. `http://projects.hepforge.org/agile/`.

[3] CERN Generator Support Subproject (GENSER). Web:. `http://lcgapp.cern.ch/project/simu/generator/`.

[4] Wikipedia. Monte Carlo method — Wikipedia, The Free Encyclopedia, 2008. [Online; accessed 12-October-2008].

[5] N. Metropolis. The beginning of the Monte-Carlo methods. *Los Alamos Science*, pages

125–130, 1987. http://library.lanl.gov/la-pubs/00326866.pdf.

[6] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber. HERWIG 6.5: an event generator for Hadron Emission Reactions With Interfering Gluons (including supersymmetric processes). 2001. arXiv:hep-ph/0011363v3.

[7] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber. Herwig 6.5 release note. 2005. arXiv:hep-ph/0210213v2.

[8] PYTHIA 6.4. Web:. http://projects.hepforge.org/pythia6/.

[9] Professor (PROcedure For Estimating SySTematic errORs). Web:. http://projects.hepforge.org/professor/.

[10] E. Nurse *et al.* Measurement of b-jet Shapes in Inclusive Jet Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV. 2008. arXiv:hep-ex/0806.1699v3.

[11] J. M. Butterworth and A. R. Davison. Jet substructure as a new Higgs search channel at the LHC. 2008. arXiv:hep-ph/0802.2470v2.