Multi-Jet Higgsstrahlung Event Analysis

Michael T. Ronan
LBNL, Berkeley, CA 94720, USA

An analysis of multi-jet Higgsstrahlung signal and backgrounds is presented for events generated by Pandora, Pythia and Whizard. The physics generators and fast detector simulation models from the American and European efforts are compared within a common Java framework. A preliminary result on the expected multi-jet Higgs signal is given.

1. Introduction

The golden channel for Higgs production and analysis at a future e^+e^- Linear Collider (LC) is the Higgsstrahlung process, $e^+e^- \rightarrow ZH$. Many measurements of the Higgs properties and studies of the Higgs mechanism for generating particle masses will be performed using events with the Z decaying leptonically to tag the recoil Higgs. In this multi-jet study, the Higgs signal and background are measured in events with both the Z and Higgs decaying hadronically. Multi-jet reconstruction of the Top quark, W and Z bosons and the Higgs are important for fundamental measurements such as the Top Yukawa coupling and the Higgs self-coupling. This analysis is being designed to understand the detector requirements for optimizing jet reconstruction.

Physics generators and detector simulation modules, and the jet analysis discussed in the following section were run in a common Java framework described briefly elsewhere [1]. The event generators are compared in section 3. Comparisons of the detector simulation models are made in presenting results in the following sections. Prelimary predictions for the expected multi-jet Higgsstrahlung signal and background, and the next phase of calculations to be addressed are summarized in the last section.

2. Multi-Jet Higgsstrahlung Analysis

Multi-jet events are selected by a event thrust cut of $|\cos(\theta)| \leq 0.707$. Jets are found using a "JadeE JetFinder" by varying the ycut value in requiring no more than 4 jets. The flavors of the jets are tagged by correlating the reconstructed jets with primary partons by requiring the angle between them to be less than 100 mrad. and the energy to agree within 50%. Jets which are not "correctly" reconstructed are discarded in subsequent analysis. The clean e^+e^- jet environment is evident in the distributions of reconstructed jets from LCD Fast Monte Carlo and TESLA SimDet detector simulations of Whizard Higgsstrahlung events shown in Fig 1.

3. Pandora, Pythia & Whizard Comparisons

In the analysis of multi-jet Higgsstrahlung events from an assumed 500 fb^{-1} sample at 500 GeV, all pairs of jets are combined to find Z candidates. For each Z hadronic decay candidate, the jet-jet mass of the remaining jets from LCD Fast Monte Carlo (FMC) and TESLA SimDet detector simulations are shown in Fig 2a and b, respectively. The distributions display the Higgs signal with a long low mass tail due to semi-leptonic decays and a secondary Z peak due to events in which the Higgs is mis-reconstructed as the Z. Jet mass resolutions of 1.5 and 2.5 GeV for LCD Fast Monte Carlo (FMC) and TESLA SimDet detector simulations, respectively, are obtained from the high mass edge of the distributions. Results for Pandora V2.2, Pythia V6.2 and Whizard V1.22 Monte Carlo event generators are in good agreement. Pythia appears to have a lower normalization in the TESLA SimDet simulations possibly due to a smaller number of Z's reconstructed with the chosen Z mass cuts of 85. to 97.5 GeV.

4. Higgsstrahlung Background Studies

To lowest order, multi-jet backgrounds arise from exclusive processes such as $e^+e^- \rightarrow WW$ and ZZ, and from inclusive processes included in $e^+e^- \rightarrow q\overline{q}$ and $q\overline{q}q\overline{q}$, where gluon emission and photon splitting need to be taken into account. These processes have been studied by comparing predictions from different Monte Carlo calculations.

Multi-jet WW and ZZ backgrounds from Pandora and Whizard simulations are compared using the recoiling FMC Particle jet-jet mass distributions. Fig 3a shows the Higgsstrahlung signal with a low mass tail due in part to ZZ backgrounds and a flat high mass distribution due to WW backgrounds. The disagreement between Pandora and Whizard is largely due to polarization effects included only in Pandora.

The Whizard Monte Carlo system performs full amplitude analysis of multi-fermion processes for different matrix element calculations from CompHEP, MadGraph and O'Mega. Fig 3b displays Whizard

Presented at International Linear Collider Workshop, Jeju Is., Korea, Aug. 26 - 30, 2002

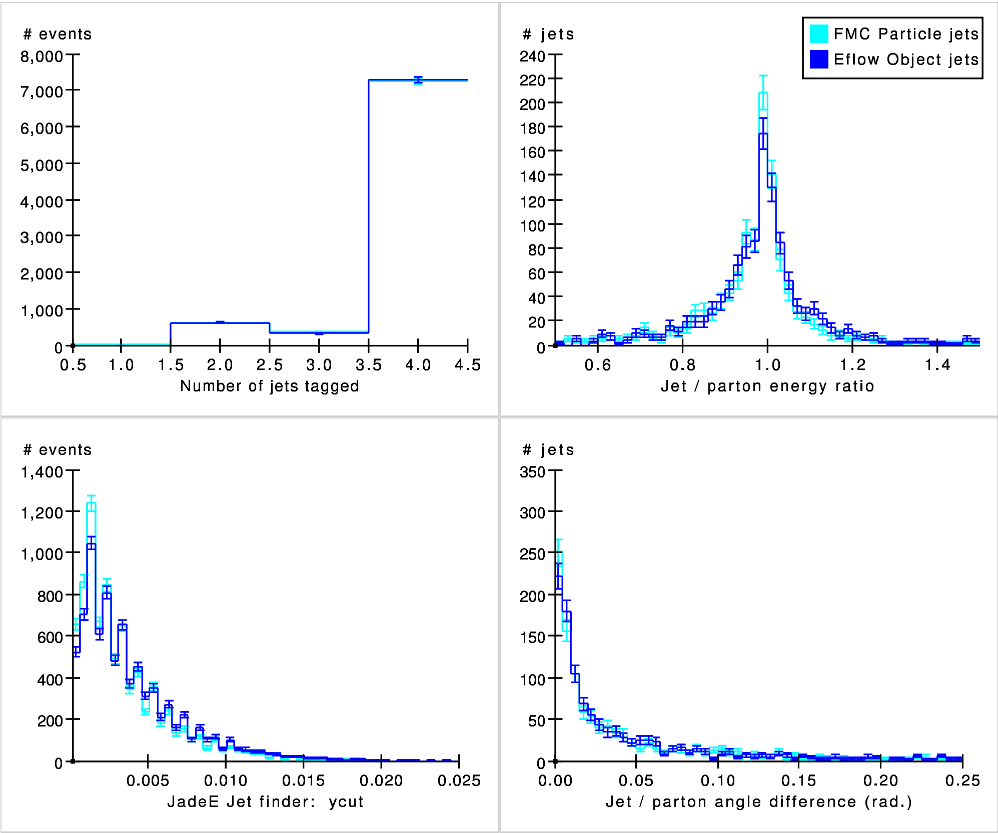

Figure 1: Jet distributions of: (a) number of tagged hadronic jets, (b) ratio of reconstructed jet energy to primary parton energy, (c) JadeE Jet-finder ycut for obtaining no more than 4 jets and (d) angle between reconstructed jets and the closest primary parton.

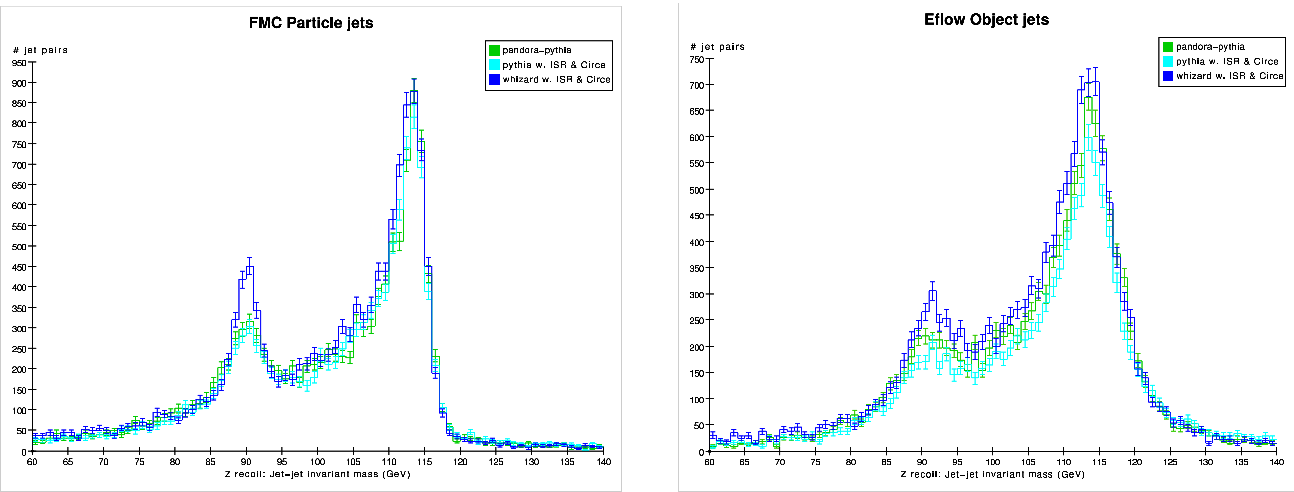

Figure 2: Jet-jet mass distributions: (a) for FMC Particle jets recoiling against a reconstructed Z candidate and (b) for SimDet "Energy-flow" Object jets.

calculation of $e^+e^-\to q\bar{q}q\bar{q}$ for Monte Carlo generator level and FMC detector level simulations. Interference is observed in the region between the W and Z.

5. Whizard: MadGraph Higgsstrahlung Event Analysis

Whizard Higgsstrahlung signal and background distributions based on MadGraph and O'Mega matrix

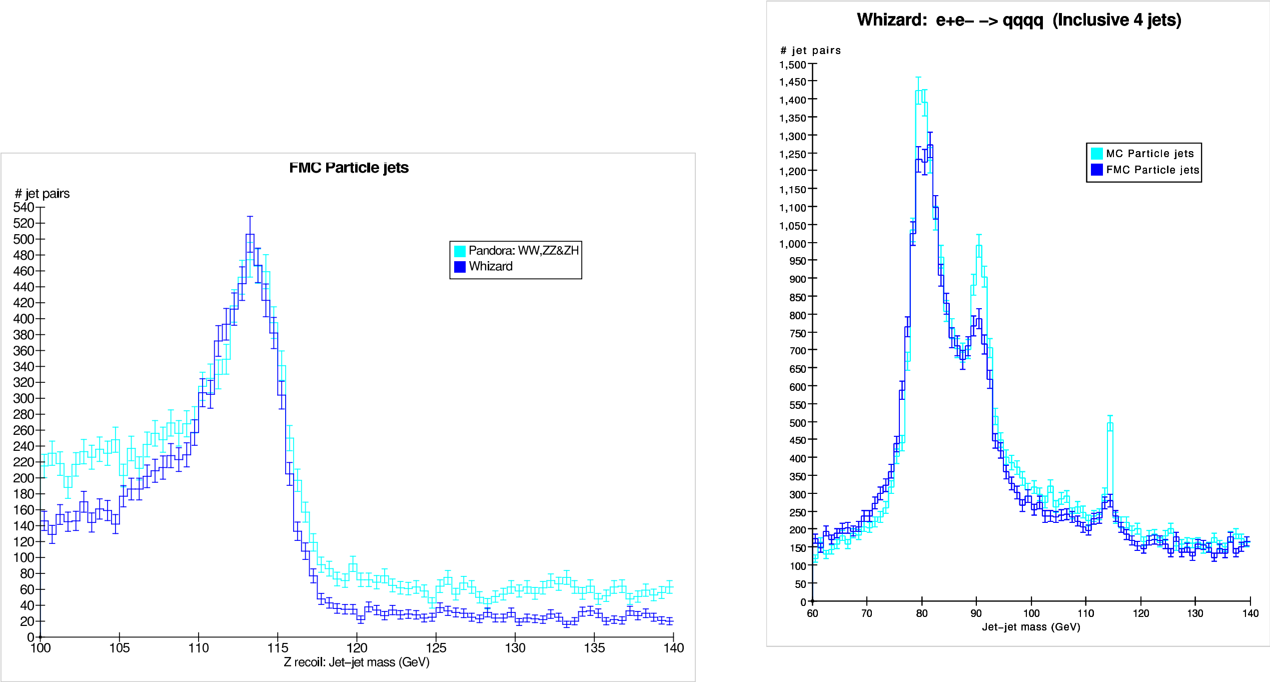

Figure 3: (a) Recoiling FMC Particle jet-jet mass distributions for the Higgsstrahlung signal, and $e^+e^-\to WW$ and ZZ backgrounds from Pandora and Whizard MC simulations and (b) Inclusive jet-jet mass distributions in multi-jet final states from Whizard V1.22 Monte Carlo simulation of $e^+e^-\to q\overline{q}q\overline{q}$ at 500 GeV assuming 500 fb^{-1}.

element calculations are in good agreement. However, differences in background predictions arise from different handelling of the fragmentation process for which the O'Mega simulation is now understood to be incomplete. Fig 4 displays the Higgsstrahlung signal and $e^+e^-\to q\overline{q}$ and $e^+e^-\to q\overline{q}q\overline{q}$ backgrounds using LCD FMC & SimDet detector simulations from Whizard simulations using MadGraph matrix elements. The preliminary background predictions are sensitive to the analysis procedure and might be reduced with an improved multi-jet Higgsstrahlung analysis. The estimated Higgs signal to background ratio also depends strongly on the detector model.

For some analyses, the $q\overline{q}$ and $q\overline{q}q\overline{q}$ backgrounds can be completely suppressed by requiring a pair of b-jets in reconstructing the Higgs, as shown in Fig 4 where the flavour tagging described in Sec. 2 was used for near perfect b-tagging.

6. Summary

Three LC event generators have been tested: Pandora, Pythia and Whizard. Each has some limitations or cautions with the Whizard: MadGraph calculations being the most complete. Two "idealistic" detector simulations, LCD FMC and SimDet, provide estimates of the expected detector performance. Good overall agreement is seen in several different comparisons. The LCD FMC jet-jet mass resolution is significantly better since it assumes "perfect" energy flow. The SimDet simulation is more realistic but may be improved with the development of new techniques to resolve charged and neutral calorimeter clusters.

Acknowledgments

I thank Tim Barklow, Wolfgang Kilian, Stephen Mrenna, Thorsten Ohl and Michael Peskin for useful discussions on the Pandora, Pythia and Whizard Monte Carlo packages, and Tony Johnson for many useful discussions on Java object modeling. [2]

Work supported by the U.S. Department of Energy contract DE-AC03-76SF00098.

References

References

[1] Michael T. Ronan, "Java Physics Generator and Analysis Modules", *Presented at Computing in High Energy and Nuclear Physics, La Jolla, California, March 24 - 28, 2003*, Computational Physics: physics/0306019, LC-Note: LC-TOOL-2003-015, May 2003.

[2] All tools used in this study are available from **http://www.lbl.gov/~ronan/docs/lcstudies**.

Presented at International Linear Collider Workshop, Jeju Is., Korea, Aug. 26 - 30, 2002

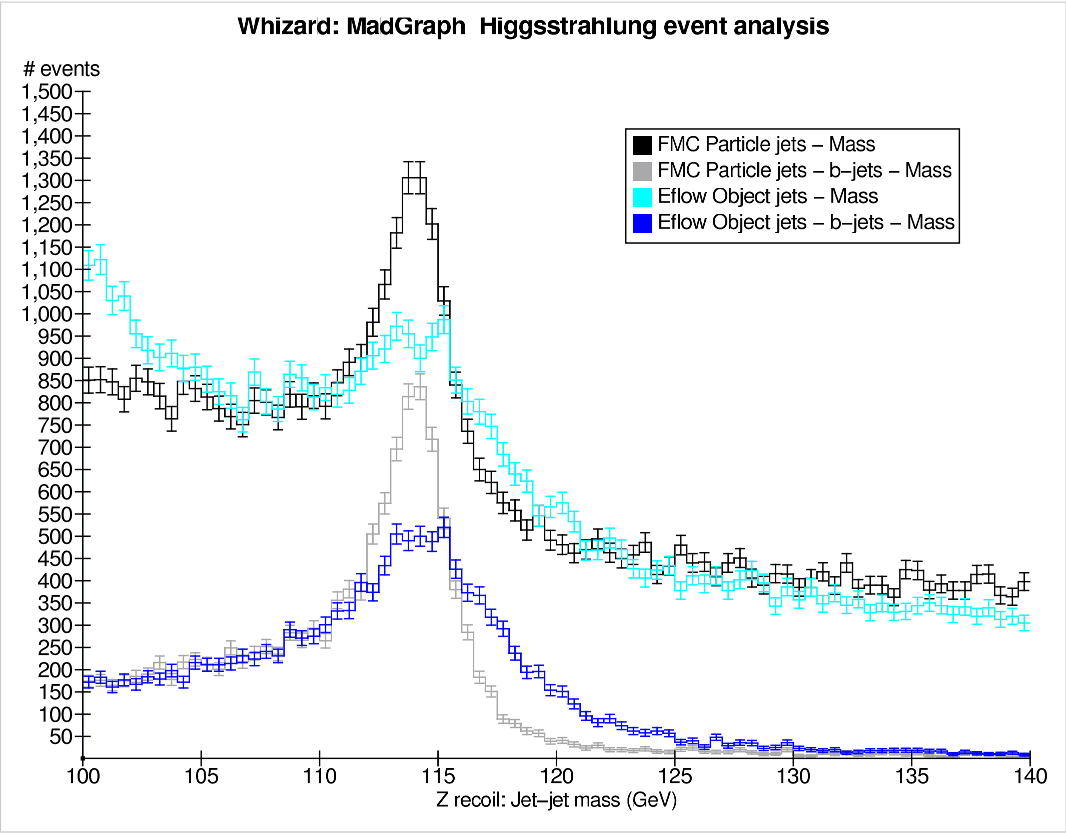

Figure 4: Jet-jet mass recoiling against a reconstructed Z hadronic decay in multi-jet final states.