Introduction

Method
HELAS
Hard Process
Decays
Spin Correlations
Summary

Plots

Summary

Herwig++ and BSM Physics

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Outline

1. Motivation
2. Method Details
3. Results
4. Summary

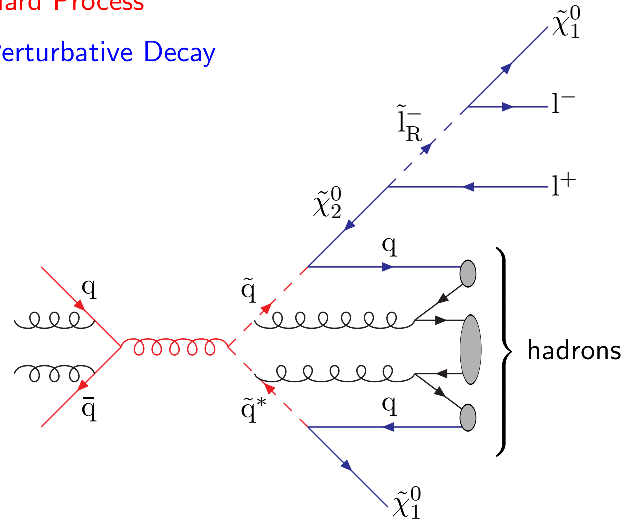
Aim

The usual approach in incorporating new physics models in an event generator is to hard code each one as it is needed. This can be a time consuming process.

We have adopted an approach that is more general and lowers the amount of time needed to implement a new model in Herwig++.

Monte Carlo Event

1. Hard Process
2. Perturbative Decay



HELAS and Vertices

Any vertex has a definite Lorentz structure that can be written down without the exact knowledge of the interacting states.

For example a antifermion-fermion-scalar interaction has the form:

$$ic\bar{\psi}\left[a_L P_L + a_R P_R\right]\psi\,\phi$$

The HELAS procedure then enables us to evaluate either; the vertex as a complex number, or an off-shell wavefunction for one of the particles.

This method is used extensively throughout Herwig++.

Hard Process

For a given process we need to be able to calculate $|\mathcal{M}|^2$.

We have implemented a library of $2 \to 2$ matrix elements that are based on external spins rather than specific processes.

The user specifies the external states when running the program and the diagrams that contribute to that process are calculated automatically.

In addition to calculating the amplitude each class is also responsible for setting up the colour structure of the hard process which is necessary for showering and hadronization.

Perturbative Decays

Any new physics model will contain heavy particles that require methods to decay them until they reach some stable point.

We have again implemented a library capable of all $1 \to 2$ decays with spin correlations included based again on a specific Lorentz structure rather than implementing each by hand.

For SUSY the decay modes are read in, along with the spectrum information, from an SLHA file.

Other models, where no such file is available, have the possible decay modes determined automatically and also require the spectrum to be calculated.

Spin Correlations

As we are not calculating the full $2 \to N$ matrix element we must do a bit amount of extra work in order to take into account the effects of spin throughout the event generation process.

The algorithm, *Richardson hep-ph/0110108*, uses spin density matrices calculated at each stage of the process to keep track of the necessary information to be able to reconstruct the correct behaviour at the end of the event.

Requirements

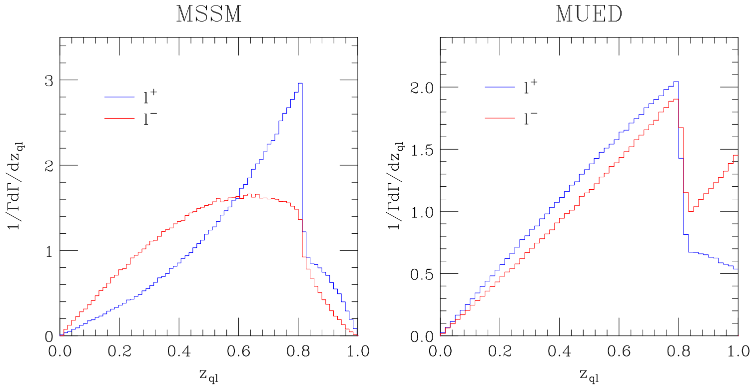
- A set of Feynman rules for the new model;
- A list of all the new states in the model;
- If necessary the information for calculating the particle spectrum.

Currently we have implemented:

- Randall-Sundrum model
- MSSM with CP, R-parity and flavour conservation and
- A minimal UED model with one extra dimension.

Cascade Decays

Recently we have been looking at cascade decays in the MSSM and MUED. Some example plots for SPS points 1a in the MSSM and for $R^{-1} = 500\,\mathrm{GeV}$ and $\Lambda R = 20$ in MUED.

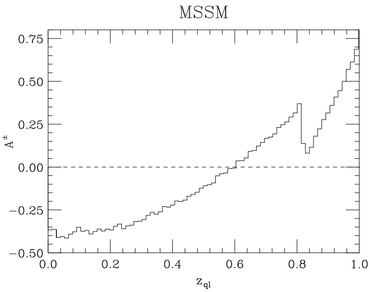


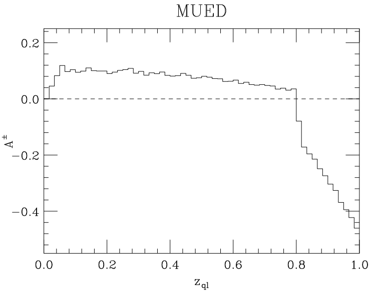
z_{ql} is the rescaled mass variable m_{ql}/m_{max}.

Cascade Decays MUED

A useful quantity is the charge asymmetry, defined as:

$$A^{\pm} = \frac{\frac{dP^{+}}{dz} - \frac{dP^{-}}{dz}}{\frac{dP^{+}}{dz} + \frac{dP^{-}}{dz}}$$



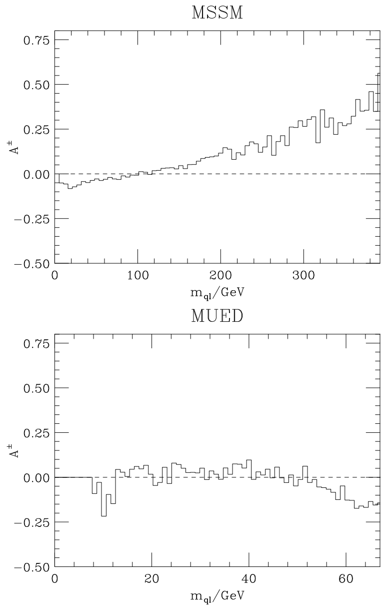


Detector Simulations

Applied a fast-detector simulation to the events to gauge the likelihood of seeing such distributions under experimental conditions. Using the package AcerDet with the following cuts:

- Exactly two leptons with opposite sign;
- At least 4 jets with a p_T of 50 GeV;
- Missing p_T of at least 100 GeV;
- The sum of the jet p_T and missing E_T of at least 400 GeV;
- The invariant mass of the jet + lepton should be less than the maximum allowed by the mass spectrum where the jet is chosen such that $\min(m_{jll})$;
- The dilepton invariant mass to be in the allowed range.

AcerDet Results



Advantages

- Quicker implementation of BSM physics within an event generator
- New model is incorporated within the full event simulation framework not just matrix element generation,
- $2 \rightarrow 2 +$ cascade decays allows for arbitrarily long decay chains including all spin correlation effects within a reasonable amount of time

Summary and Outlook

- Our new approach aids in the implementation of a new physics model in Herwig++.
- The models available in the next release:
  - Randall-Sundrum Model
  - MSSM
  - MUED

Current and future work:

- Incorporating off-shell effects within cascade decays
- More models - NMSSM, 6D SM ...