# Generator Issues

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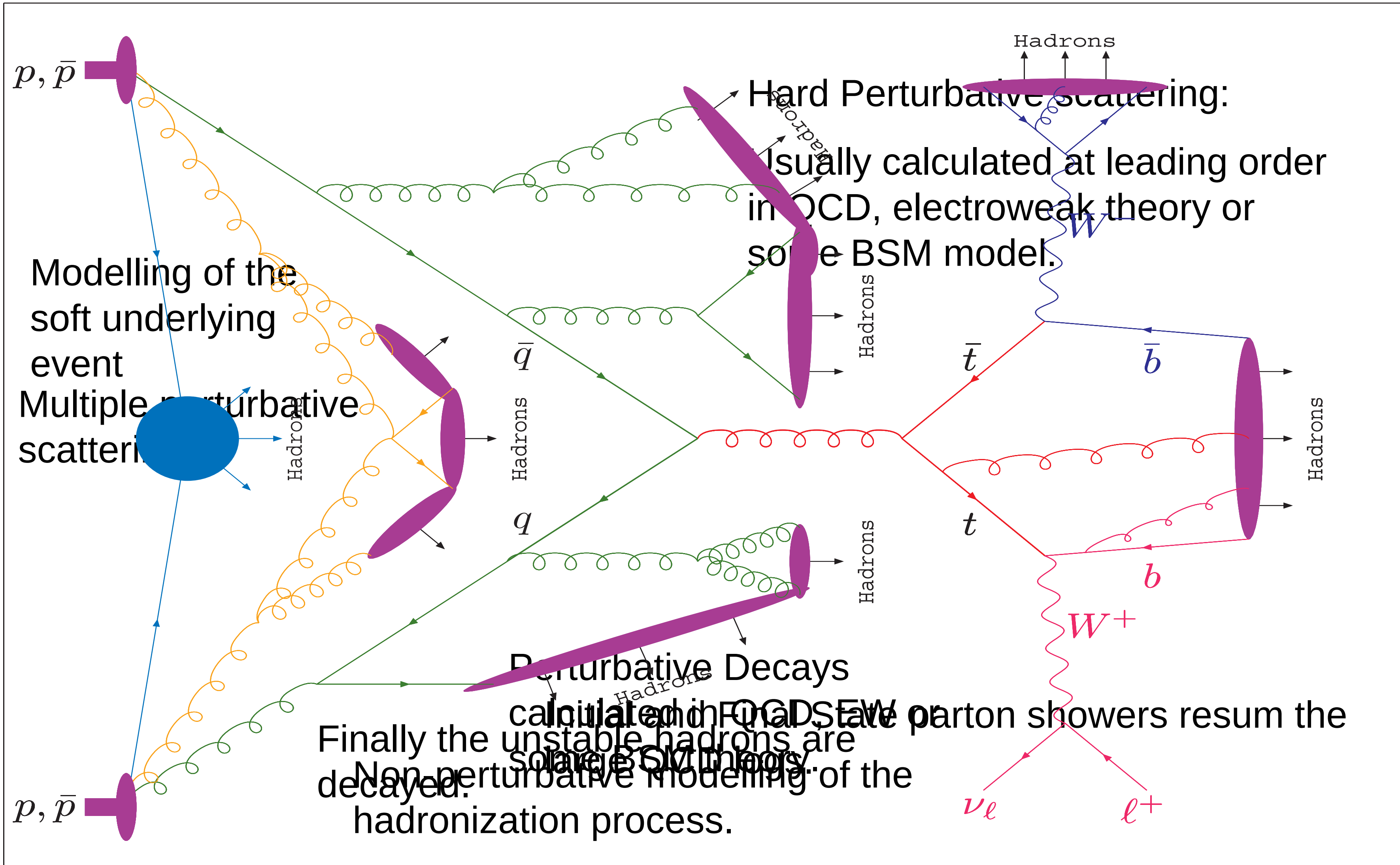
# Summary

- Introduction
- Basics of Event Generation
- Improvements to Parton Shower
- Matching Issues
- Hadronization
- Underlying Event
- New Physics
- Summary

# Introduction

- Monte Carlo event generators are essential both experimental analyses of real data and studies and predictions for future experiments.
- It is important that these simulations are as accurate as possible and both experimentalists and theorists understand the approximations and uncertainties involved.
- There was a lot of discussion of issues of interest to both phenomenologists and experimentalists in the first session, hopefully there'll be more during this session.

# A Monte Carlo Event




Hard Perturbative scattering:

Usually calculated at leading order in QCD, electroweak theory or some BSM model.

Modelling of the soft underlying event

Multiple perturbative scattering.

Perturbative Decays calculated in QCD, EW or some BSM theory.

Initial and Final State parton showers resum the large QCD logs.

Finally the unstable hadrons are decayed.

Non-perturbative modelling of the hadronization process.

# Monte Carlo Event Generators

- The different event generators
  - PYTHIA (P. Skands)
  - HERWIG (M. Gigg, S. Moretti, P. Richardson)
  - SHERPA

  use different approximations or models for the different stages of the event.
- However the overall strategy is the same.

# Matrix Element Generators

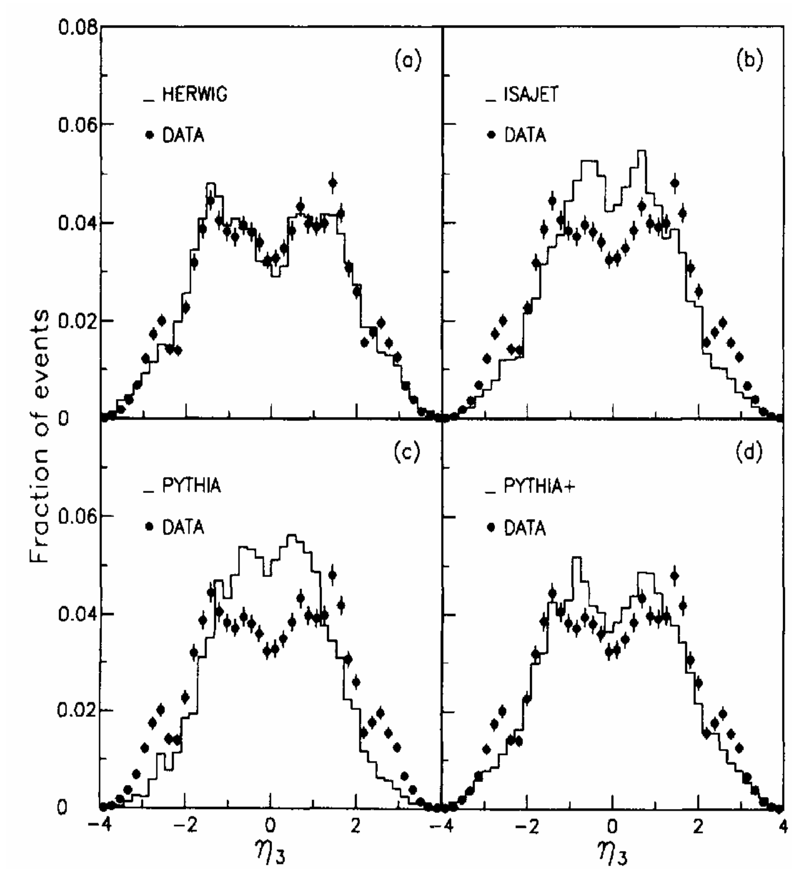
- It has become more common to use matrix element generators for the hard process
  - MADGRAPH (Herquet)
  - ALPGEN (Piccinini)
  - COMPHEP/CALCHEP (Boos)
  - SHERPA

# Shower Improvements

- There have been a number of developments in recent years.
  - Herwig++ Shower algorithm, improved Lorentz invariance and treatment of mass effects.
  - PYTHIA $p_T$ ordered algorithm allows full ordering of event in $p_T$.
- These are the only improvements which are implemented and available.

# Shower Improvements

- One issue with the new shower algorithms is the extent to which colour coherence effects are included.
- Look at the results with the new generation of shower algorithms.
- Richardson, Schumann, Skands



# Shower Improvements

- There are a lot of other ideas being worked on
  - Various approaches based on the dipole/antenna subtraction terms used in NLO calculations (Skands, Giele, Schumann)
  - SCET approach (Schwartz)
  - Quantum Interference (Soper, Nagy)

# Shower Improvements

- Some of these ideas may be useful but need concrete implementations so they can be compared with data.
- The only true test of a Monte Carlo algorithm is comparison with data.

# Matching

- Much of the work in the last 5 years has been on matching parton shower simulations with fixed-order matrix element calculations.
- A number of approaches have emerged a both leading and next-to-leading order.
- I’ll start with the leading order approaches

# LO Matching: General Idea

- Parton Shower (PS) simulations use the soft/collinear approximation:
  - Good for simulating the internal structure of a jet;
  - Can't produce high $p_T$ jets.
- Matrix Elements (ME) compute the exact result at fixed order:
  - Good for simulating a few high $p_T$ jets;
  - Can't give the structure of a jet.
- We want to use both in a consistent way, i.e.
  - ME gives hard emission
  - PS gives soft/collinear emission
  - Smooth matching between the two.
  - No double counting of radiation.
- All the schemes involve matching between the matrix element and parton shower at some scale.

# Two approaches

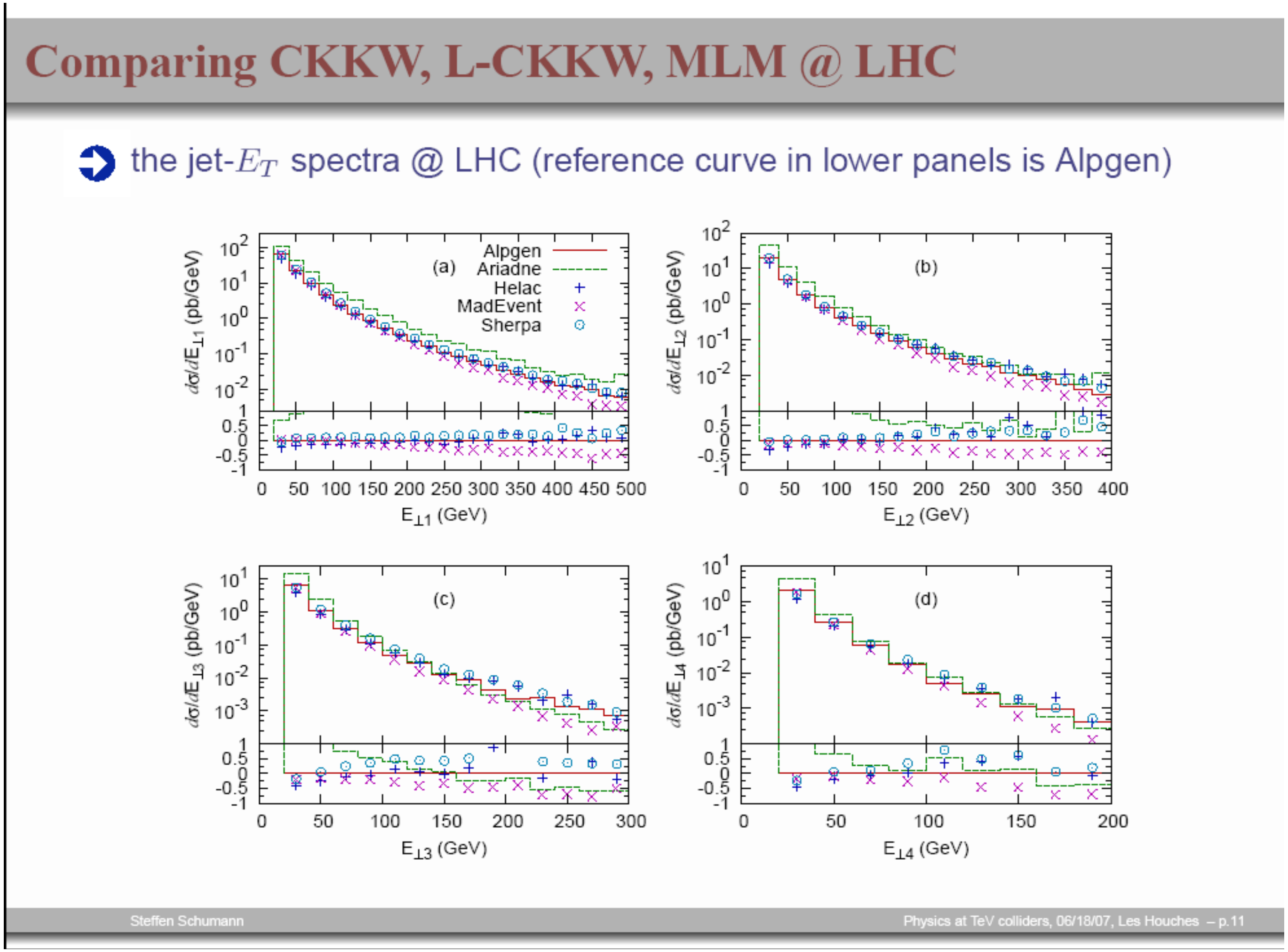
## CKKW

- Simulate N jet partonic state.
- Apply weight factors for probability that no jets emitted above matching scale.
- Generate shower vetoing radiation above the matching scale.
- The weight factors ensure the different samples can be added.

## MLM

- Simulate partonic N jet state.
- Generate parton shower.
- Require that all the jets above the matching scale after the shower have an associated pre-shower parton.
- For each N the shower doesn't add any more jets.
- Rejection ensures that samples with different numbers of jets can be summed

# Comparing CKKW and MLM Approaches arXiv:0706.2569



# Hadronization

- One issue for both the new generation of C++ generators and generators with matrix element matching is tuning.
- The parameters of both the parton shower and hadronization were tuned using LEP data and this needs to be done for the new programs.
- Historically this was done by the LEP collaborations.
- For the new generation of programs will need to be done by Cedar/JetWeb, MCnet, Tevatron and LHC experiments.

# NLO Matching

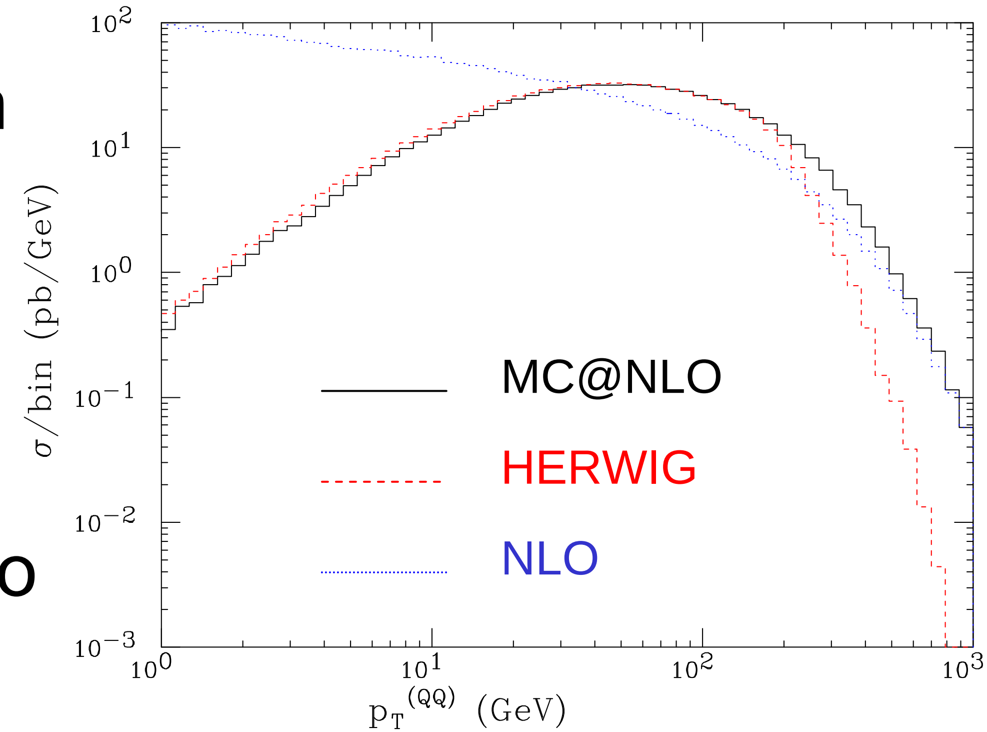
- Here we get the correct NLO rate and the first hardest emission correct.
- A lot of theoretical work.
- However only one (two?) approaches with concrete implementations.
  - MC@NLO
  - Nason approach
- MC@NLO is now available for a number of processes and is the most thoroughly worked out.

# NLO Matching

- The Nason approach has been used for ZZ (Nason and Ridolfi) and $e^+e^-$ (Gieseke, Latunde-Dada and Webber)
- Still need to see examples using all parts of the approach.
- Also only relatively simple cases still need to understand how it will work for e.g. top pair production.

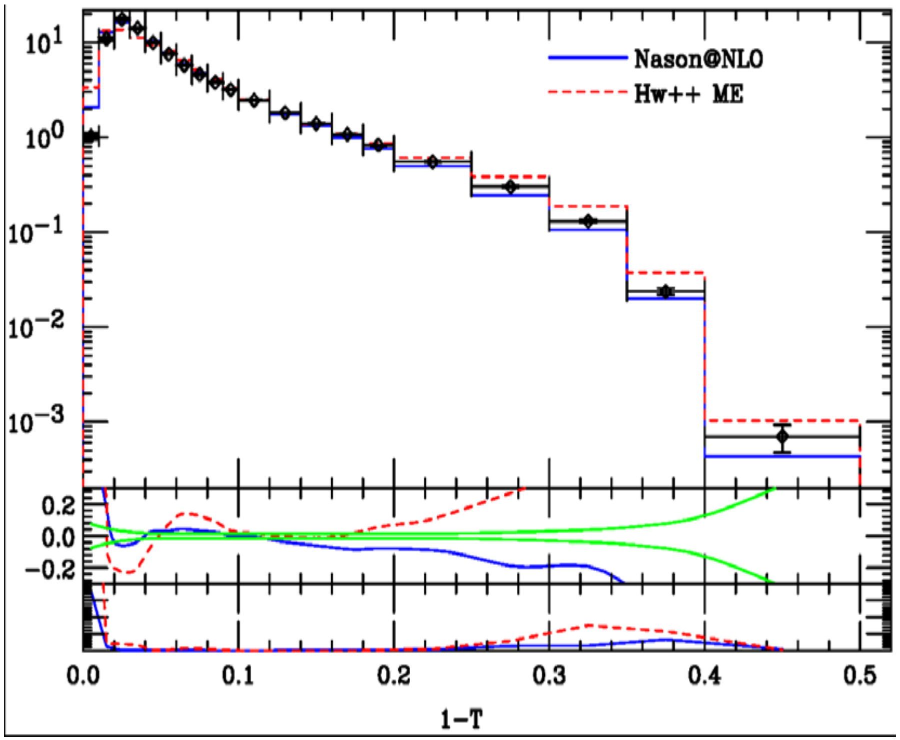
# MC@NLO

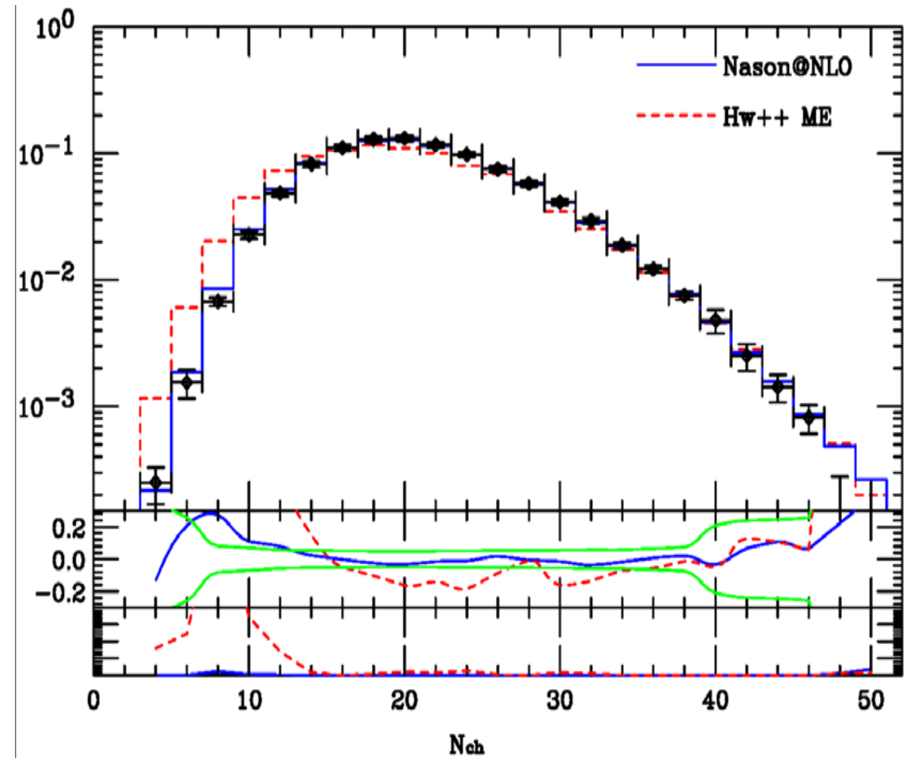
- Idea is to include the hardest emission as in a NLO calculation and get the total cross section to NLO accuracy.
- Rigorous calculation so no new parameters, just the normal ones in the event generator.




S. Frixione, P. Nason and B.R. Webber, JHEP 0308(2003) 007, hep-ph/0305252.

# Nason Approach to MC@NLO

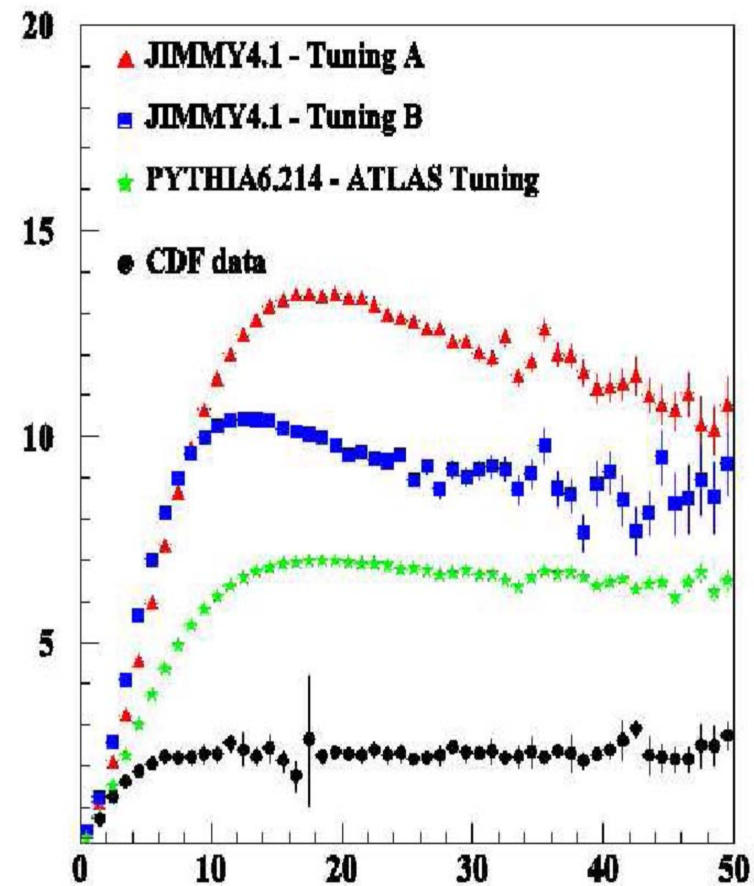



hep-ph/0612281 Oluseyi Latunde-Dada, Stefan Gieseke, Bryan Webber

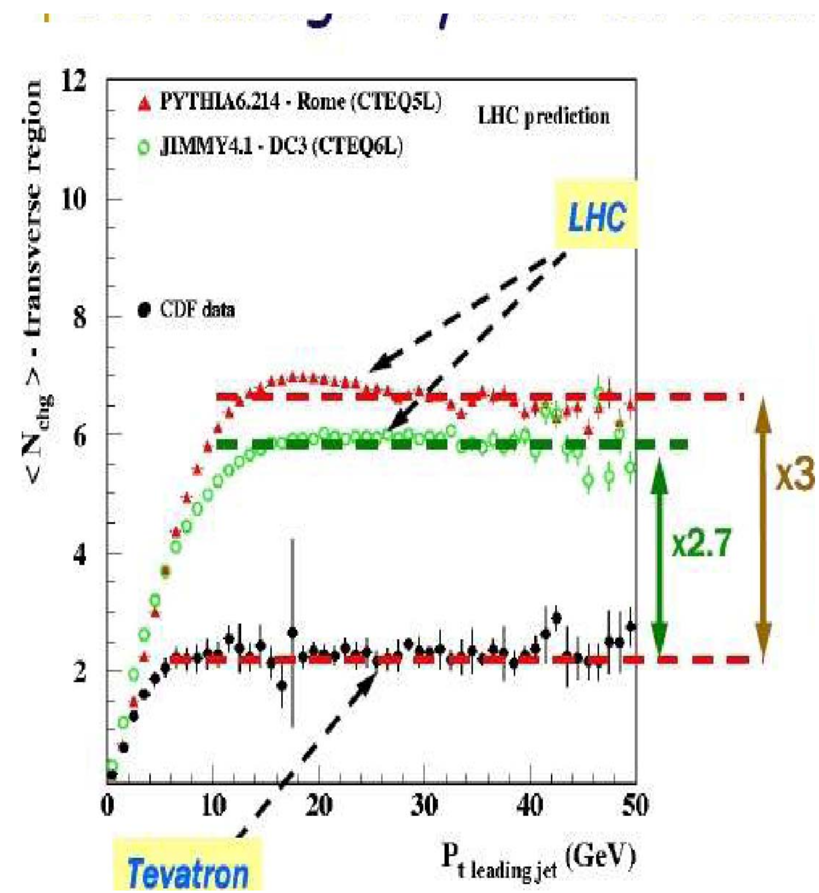
# Underlying Event

- There has been a lot of good work at the Tevatron studying the underlying event.
- Key question is how does this extrapolate to the LHC and what early measurements to we need to tune the models at LHC energies.



# Underlying Event

- Better agreement between HERWIG and PYTHIA in recent ATLAS tunes.
- However, had to change the JIMMY model to make it more PYTHIA-like.
- A lot of work in the first session.



# Les Houches Guidebook

- Plan to update the 2003 Les Houches guidebook.
- Include the new generation of simulations.
- Improvements in matching and underlying event modelling

arXiv:hep-ph/0403045 v2 5 Mar 2004

**Les Houches Guidebook to Monte Carlo Generators for Hadron Collider Physics**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**Abstract**

Recently the collider physics community has seen significant advances in the formalisms and implementations of event generators. This review is a primer of the methods commonly used for the simulation of high energy physics events at particle colliders. We provide brief descriptions, references, and links to the specific computer codes which implement the methods. The aim is to provide an overview of the available tools, allowing the reader to ascertain which tool is best for a particular application, but also making clear the limitations of each tool.


*Compiled by the Working Group on Quantum ChromoDynamics and the Standard Model for the Workshop "Physics at TeV Colliders", Les Houches, France, May 2003.*

May 23, 2006

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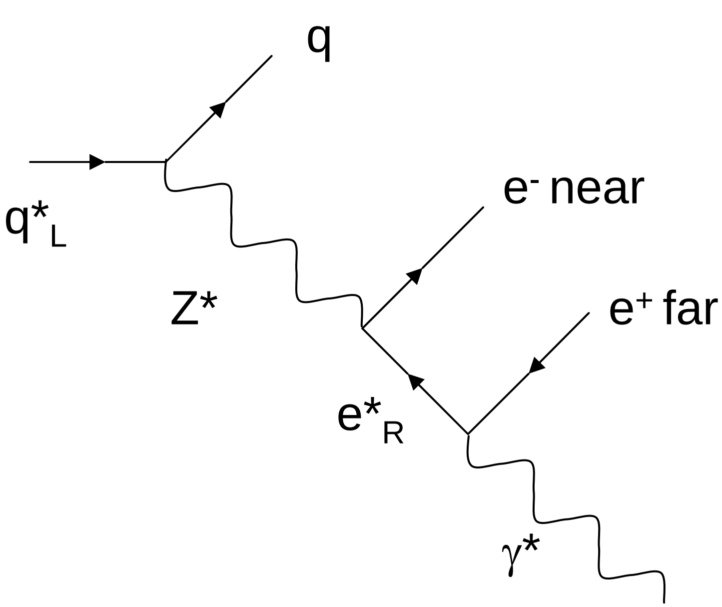
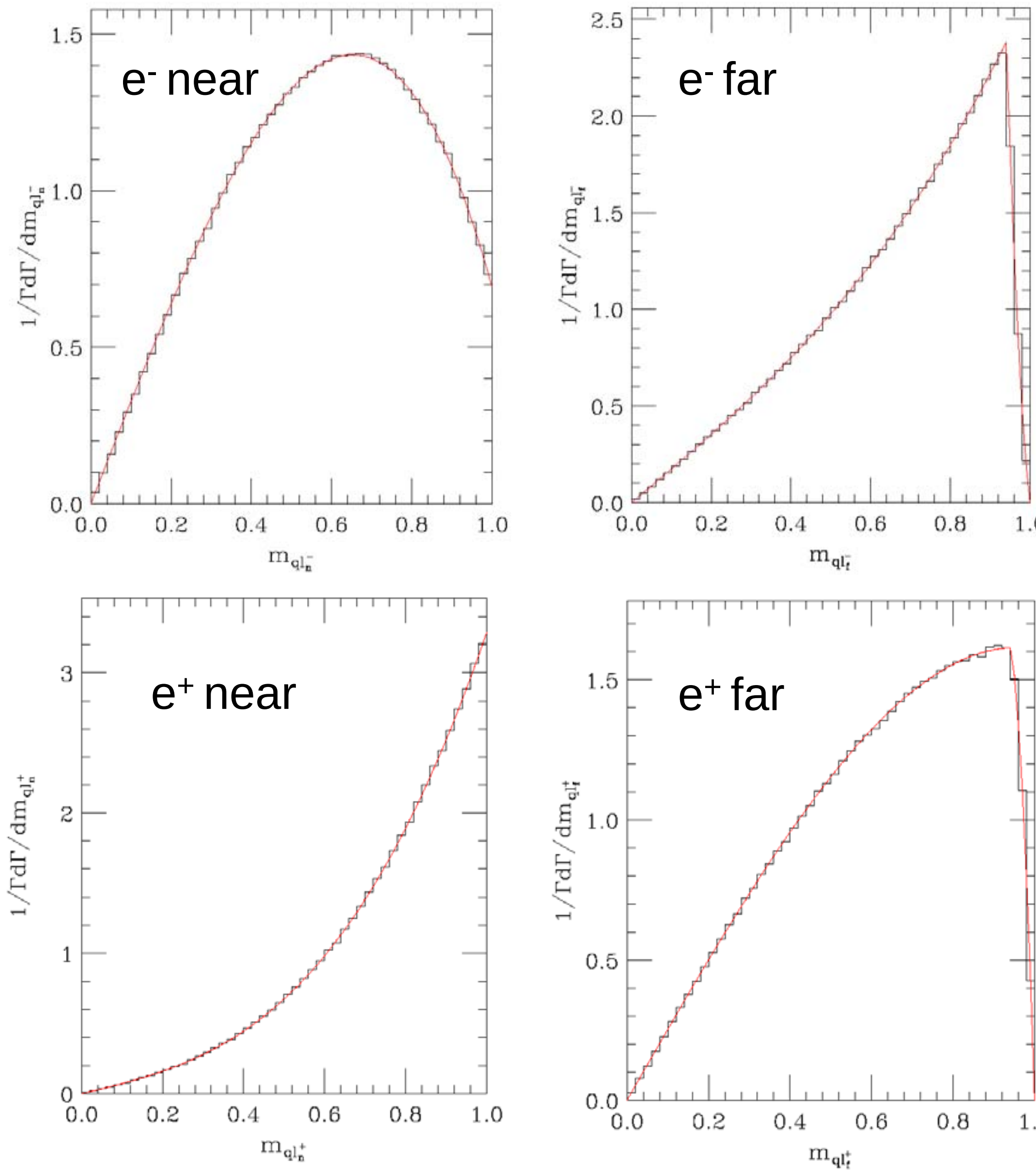
# BSM

- Traditionally the requests here have been for more models in HERWIG/PYTHIA.
- We now have a lot of tools in which adding new models is easier.
- I’m not sure what we need here?
- One question is how reliable are the improved narrow-width approximations used in the event generators.

# UED

## Look at the decay



# BSM

- One project with the BSM group on off-shell effects.
- Other major issue is SHLA2, useful discussion which should be ready for the proceedings.

hep-ph/07mmnnn
FERMILAB-PUB-07-036-T

## SUSY Les Houches Accord 2

B.C. Allanach, C. Balázs, G. Bélanger, F. Boudjema, D. Choudhury, K. Desch, U. Ellwanger, P. Gambino, R. Godbole, J. Guasch, M. Guchait, S. Heinemeyer, C. Hugonie, T. Hurth, S. Kraml, S. Kreiss, J. Lykken, M. Mangano, F. Moortgat, S. Moretti, S. Penaranda, T. Plehn, W. Porod, A. Pukhov, P. Richardson, M. Schumacher, L. Silvestrini, P. Skands, P. Slavich, M. Spira, G. Weiglein, P. Wienemann

*List of affiliations.*

June 18, 2007

**Abstract**

The SUSY Les Houches Accord provides a common interface that conveys spectral and decay information between various computer codes used in supersymmetric analysis problems, such as spectrum calculators, decay packages, Monte-Carlo programs, dark matter evaluators, and SUSY fitting programs. Here, we propose extensions of the conventions of the first SUSY Les Houches Accord to include various generalisations: violation of CP, *R*-parity and flavour as well as the simplest next-to-minimal supersymmetric standard model (NMSSM).

### 1 Introduction

Supersymmetric extensions of the Standard Model rank among the most promising and well-explored scenarios for New Physics at the TeV scale. Given the long history of supersymmetry and the number of both theorists and experimentalists working in the field, several different conventions for defining supersymmetric theories have been proposed over the years, many of which have come into widespread use. At present, therefore, there is not one unique definition of supersymmetric theories that prevails. Rather, different conventions are adopted by different groups for different applications. In principle, this is not a problem. As long as everything is clearly and completely defined, a translation can always be made between two sets of conventions, call them A and B.

However, the proliferation of conventions does have some disadvantages. Results obtained by different authors or computer codes are not always directly comparable. Hence, if author/code A wishes to use the results of author/code B in a calculation, a consistency check of all the relevant conventions and any necessary translations must first be made – a tedious and error-prone task.

To deal with this problem, and to create a more transparent situation for non-experts, the original SUSY Les Houches Accord (SLHA1) was proposed [1]. This accord uniquely defines a set of conventions for supersymmetric models together with a common interface between codes. The most essential fact is not what the conventions are in detail (they largely

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# MCnet

- MCnet is an EU network consisting of all the general purpose event generator authors.
- The projects involved are Herwig++, Pythia, SHERPA, ThePEG.
- Nodes are Karlsruhe, CERN, Lund, Durham( +Cambridge) and UserLink based at UCL.

# MCnet

- The main aims of the network are
  - To train the user community through 4 annual schools, first one April 2007 (Durham) and a large number of three month visiting positions at the nodes.
  - To train a new generation of event generator authors via a number of postdoc and PhD positions.
  - To tune, making use of the expertise of the UserLink node, the new Monte Carlo generators.

# MCnet

- The postdocs and PhDs will mainly be involved in development and tuning.
- The visiting studentships will provide
  - Mechanism for significant involvement on specific problems/analyses if needed.
  - A wider pool of knowledge which we hope will reduce the need for support in the long term.
- Equally we hope the schools will produce a more knowledgeable user community.

# MCnet

- Recently the generator authors collectively agreed, as part of the MCnet program, to release the code under the GPL.
- However this does not address all our concerns about abuse of the codes.
- So we have a agreed a set of guidelines for the use of event generators, making modifications etc.

# Summary

- There are a lot of areas of Monte Carlo simulation of interest to both theorists and experimentalists.
- We had a lot of useful discussions in the first session.
- Hopefully we will have lots more in this one.