Generator Issues

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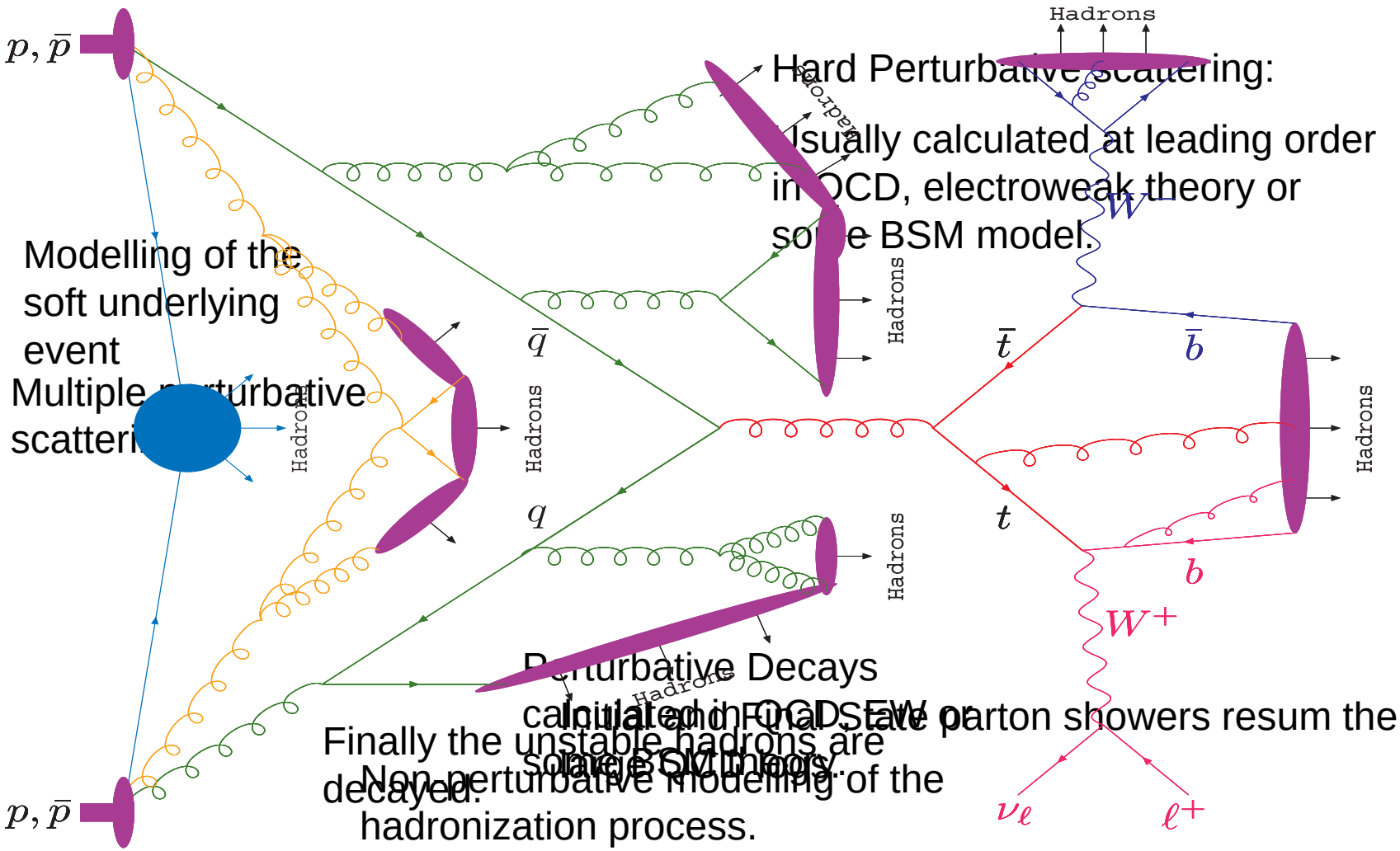
Summary

- 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.
- Hopefully there will be a lot of discussion of issues of interest to both phenomenologists and experimentalists here.

A Monte Carlo Event



Monte Carlo Event Generators

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

  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, Frederix)
  - ALPGEN (Piccinini, Pittau)
  - COMPHEP/CALCHEP (Boos, Pukhov)
  - SHERPA (Schumann)

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

- 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)
  - Various forward evolution ideas for initial-state radiation.
  - Complex weights (Soper, Nagy)
  - Others???

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.

Shower Questions

- So a number of possible questions have been raised for discussion and hopefully some work.
  - Uncertainties, how to assess them particularly for ISR.
  - $1/N_c^2$
  - Non-global soft logs
  - NLL
  - Infrared cut-off
  - Others?

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.

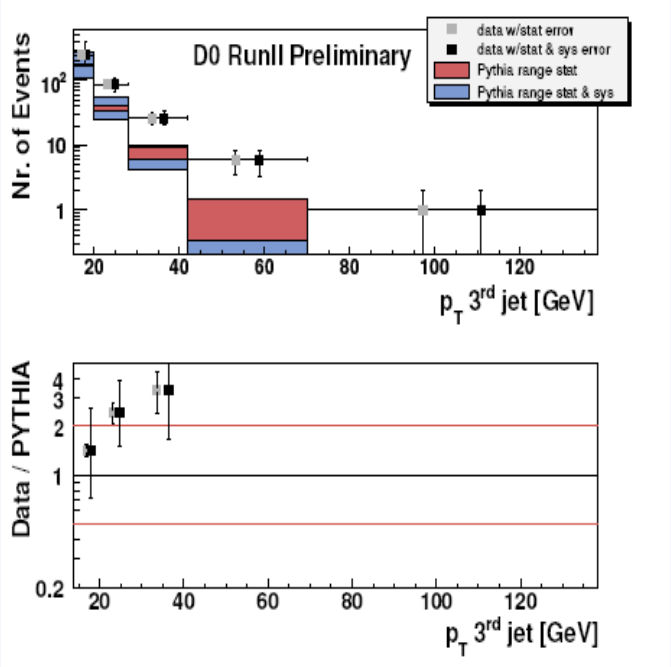
MLM

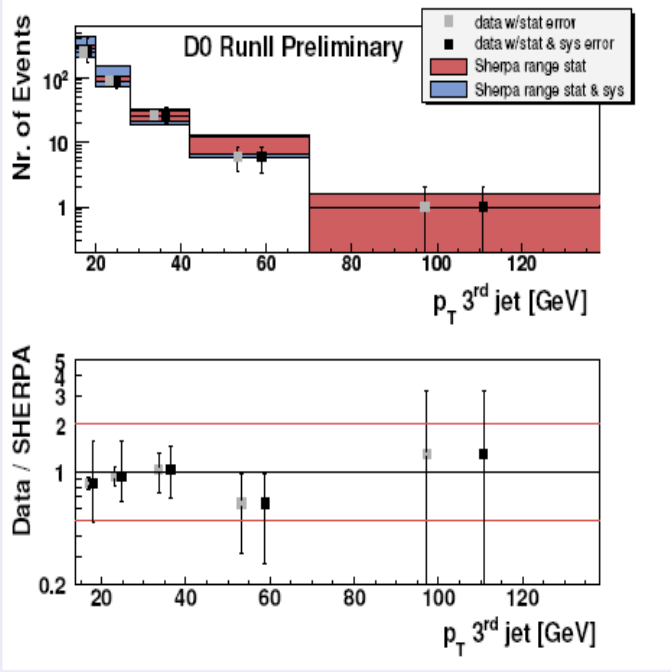
- Simulate partonic N jet state.
- Generate parton shower.
- Require that all the jets above the matching scale after the shower have an associated pre-shower parton.
- For each N the shower doesn't add any more jets.
- Rejection ensures that samples with different numbers of jets can be summed

CKKW results for Z +jets

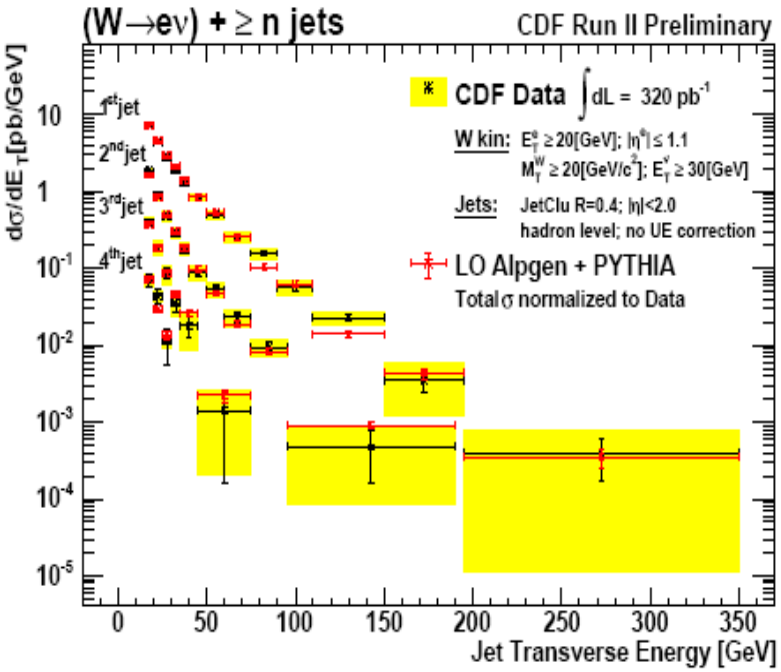
Jet spectra (3rd jet) in $p\bar{p} \rightarrow Z + X$ @ Tevatron

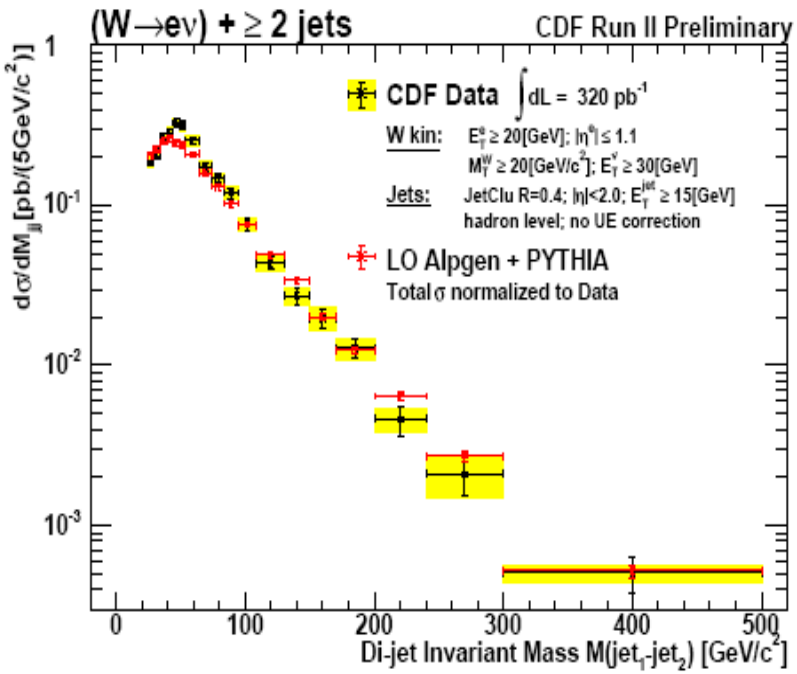
(D0-Note 5066)





MLM Method for W+jets





LO Matching

- So there are people here who have worked on both approaches
  - ALPGEN (Piccinini, Pittau)
  - MADGRAPH (Herquet, Frederix)
  - SHERPA (Schumann)
  - HERWIG (Richardson)

LO Matching

- Again the issues are
  - Differences between different approaches (a lot of work here)
  - How to access the uncertainties.

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

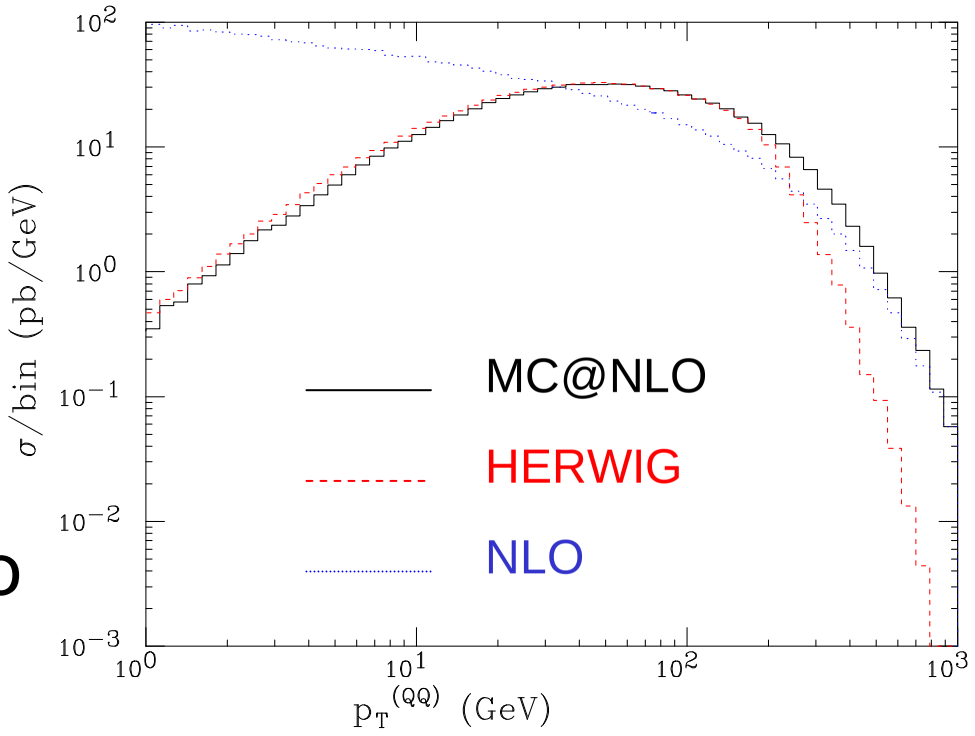
- Here we get the correct NLO rate and the first hardest emission correct.
- A lot of theoretical work.
- However only one (two?) approaches with concrete implementations.
  - MC@NLO
  - Nason approach
- MC@NLO is now available for a number of processes and is the most thoroughly worked out.

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.

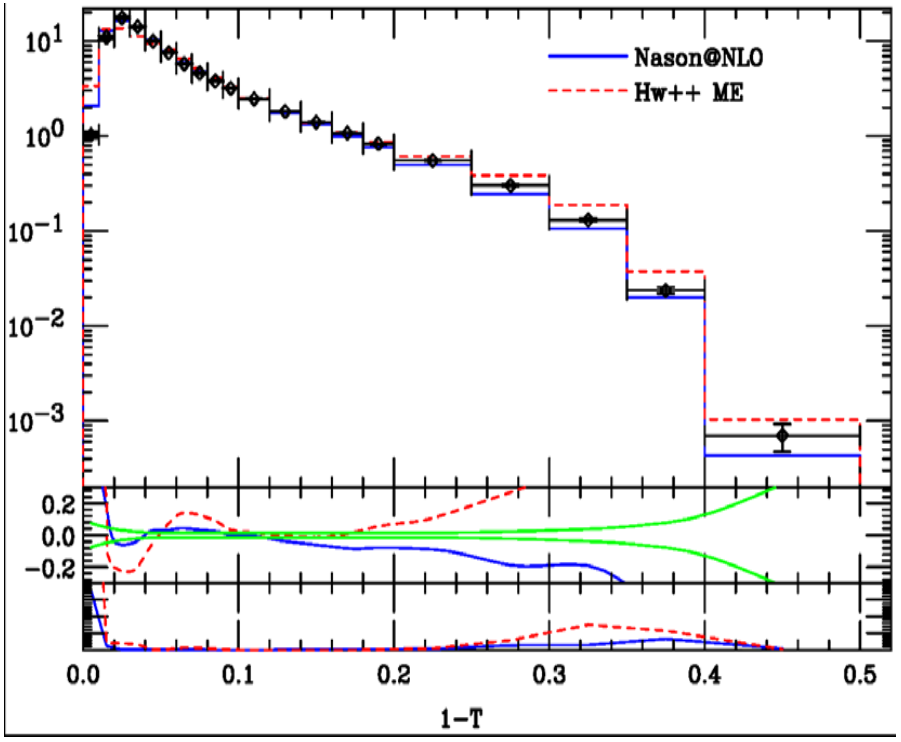
MC@NLO

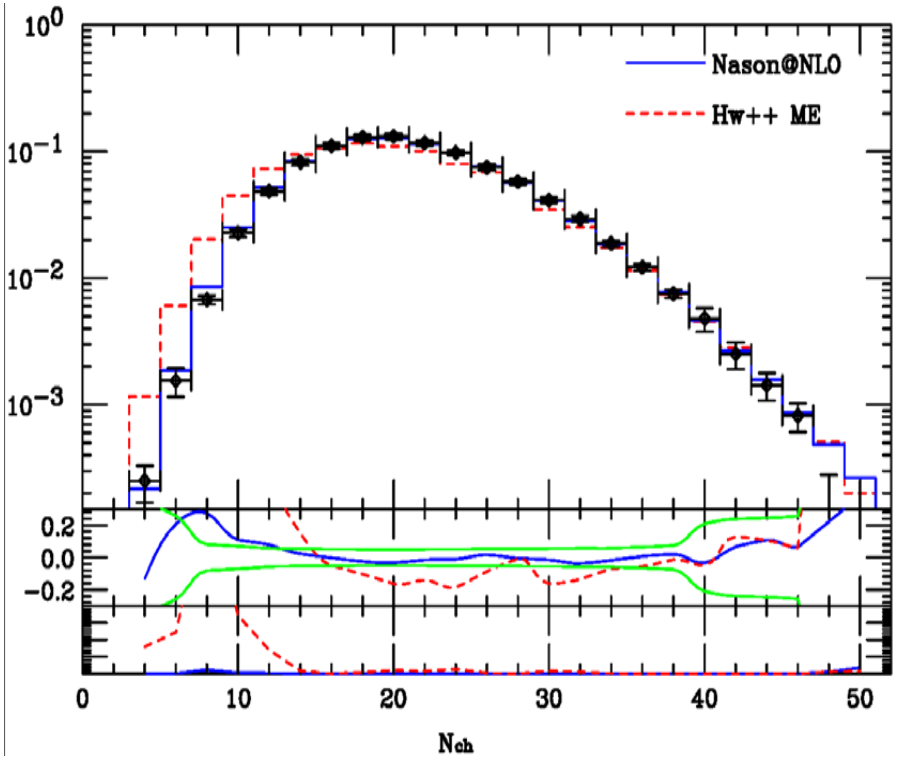
- Idea is to include the hardest emission as in a NLO calculation and get the total cross section to NLO accuracy.
- Rigorous calculation so no new parameters, just the normal ones in the event generator.



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

Nason Approach to MC@NLO

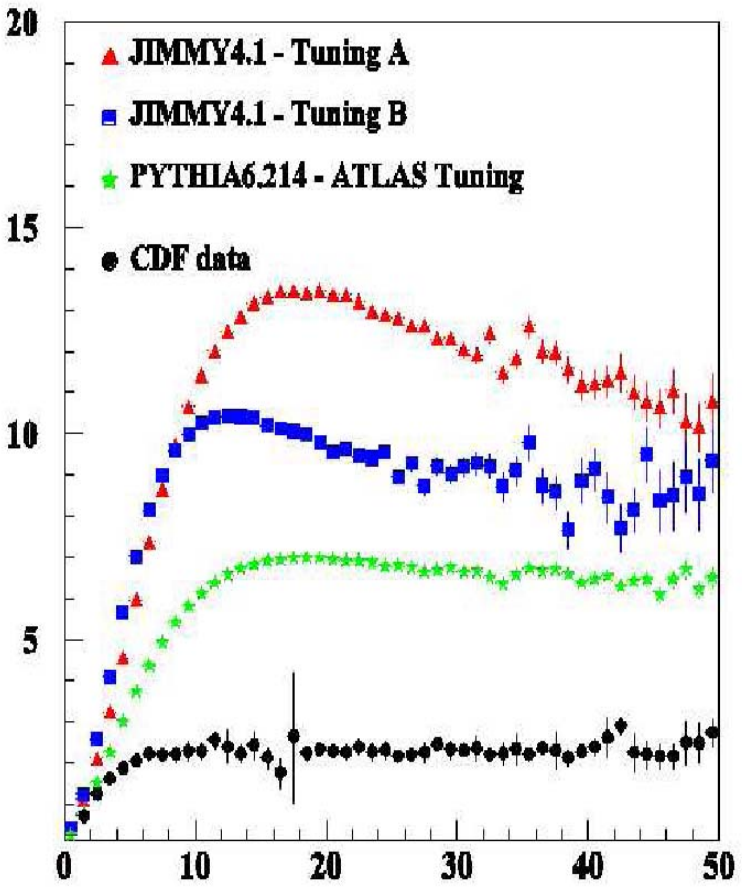




hep-ph/0612281 Oluseyi Latunde-Dada, Stefan Gieseke, Bryan Webber

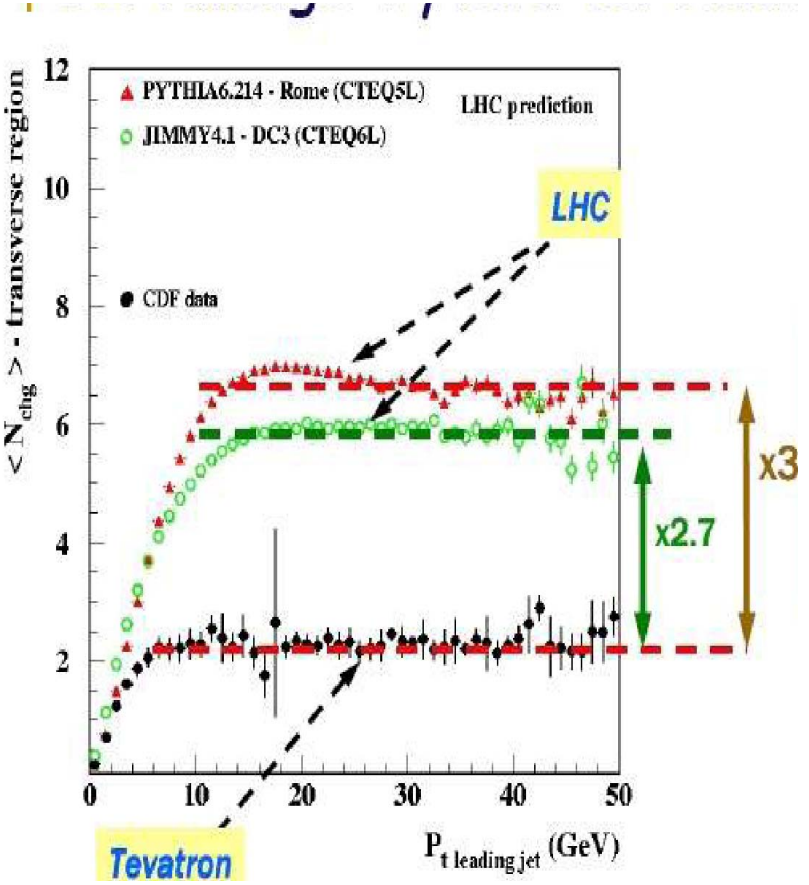
Underlying Event

- 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.

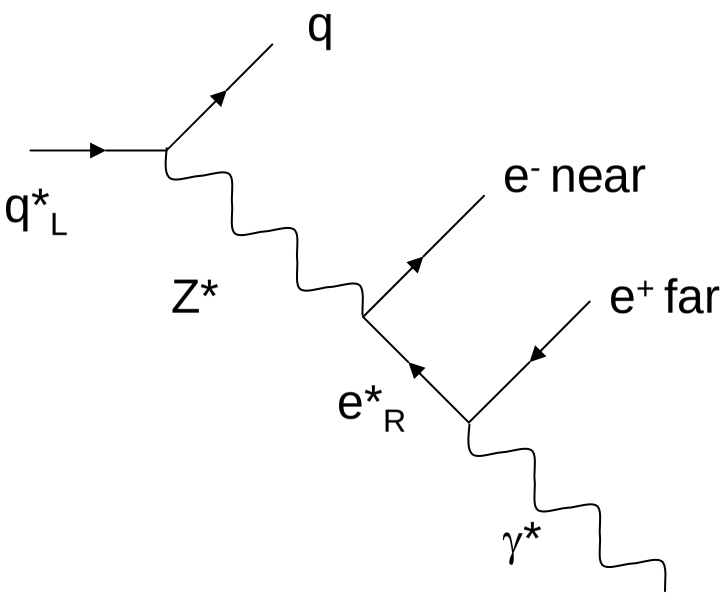


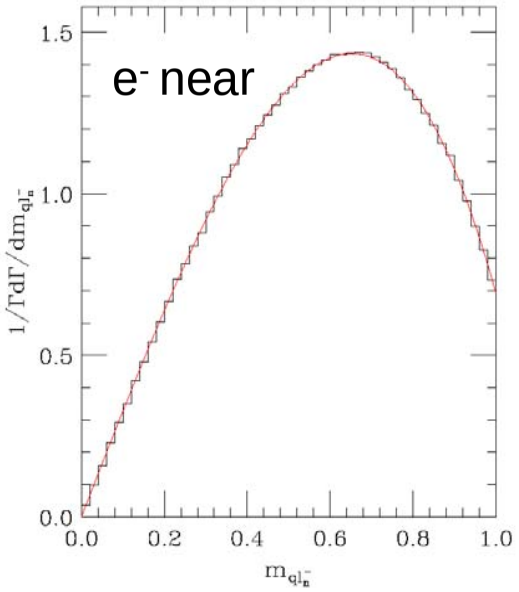
BSM

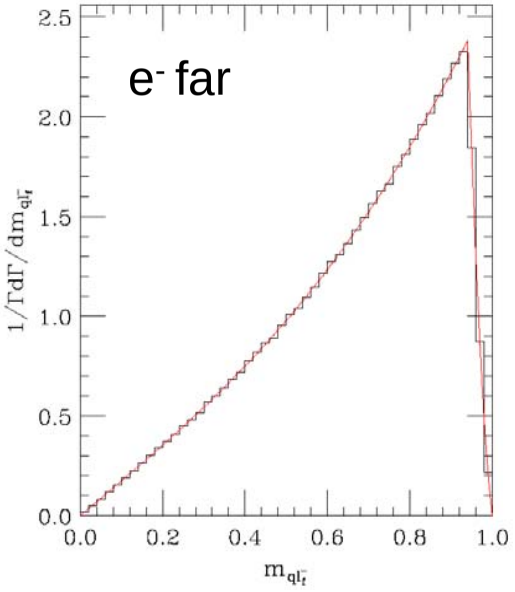
- Traditionally the requests here have been for more models in HERWIG/PYTHIA.
- We now have a lot of tools in which adding new models is easier.
- I'm not sure what we need here?
- One question is how reliable are the improved narrow-width approximations used in the event generators.

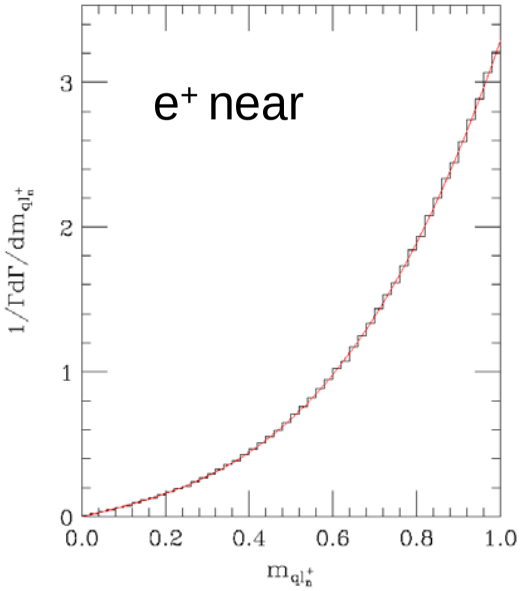
UED

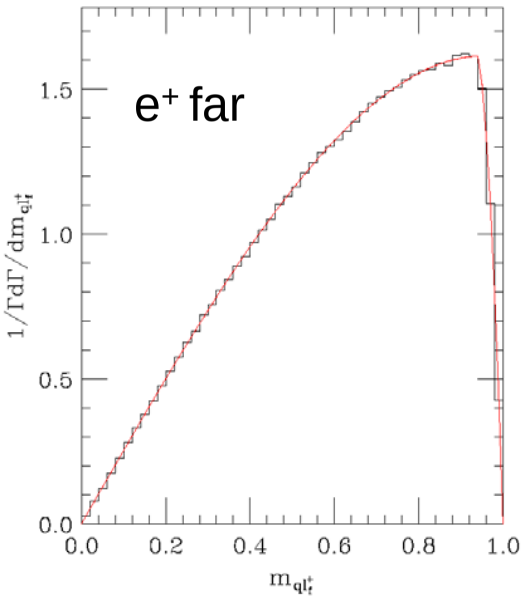
Look at the decay











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.
- Should have a discussion here about these.

Summary

- There are a lot of areas of Monte Carlo simulation of interest to both theorists and experimentalists.
- Hopefully we will have lots of useful discussions.