

Herwig++

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Introduction

- Current Status
- Plans for the Future

Current Status

- We made a first production release available for hadron-hadron collisions in September 2006.
- All parts of the simulation needed for hadron-hadron collisions were present in that release.
- Some areas, in particular the underlying event, still needed improvement.
- Limited experimental feedback, despite significant experimental pressure to produce this release.

Current Status

- A second hadron-hadron version (2.1) was released on 20 Nov 2007 with major improvements with respect to the previous version.
- Major changes
 - Multiple parton-parton scattering model of the underlying event, based on the FORTRAN JIMMY program.
 - New model of meson and tau decays.
 - Inclusion of BSM physics including the MSSM, UED and RS models.
 - Tuning to LEP, SLD and B-factory data.
- Various other minor improvements.

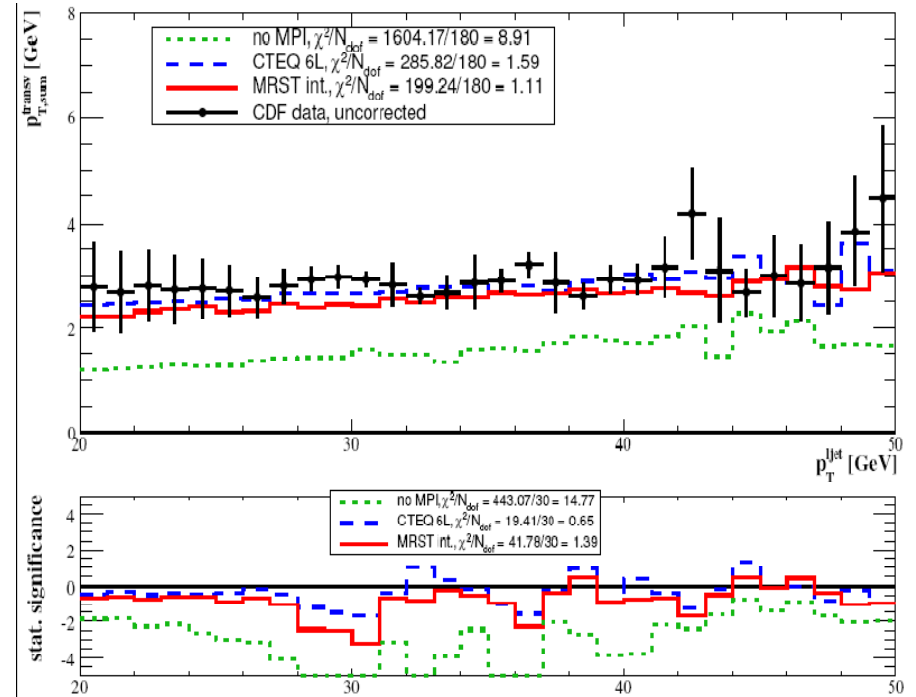
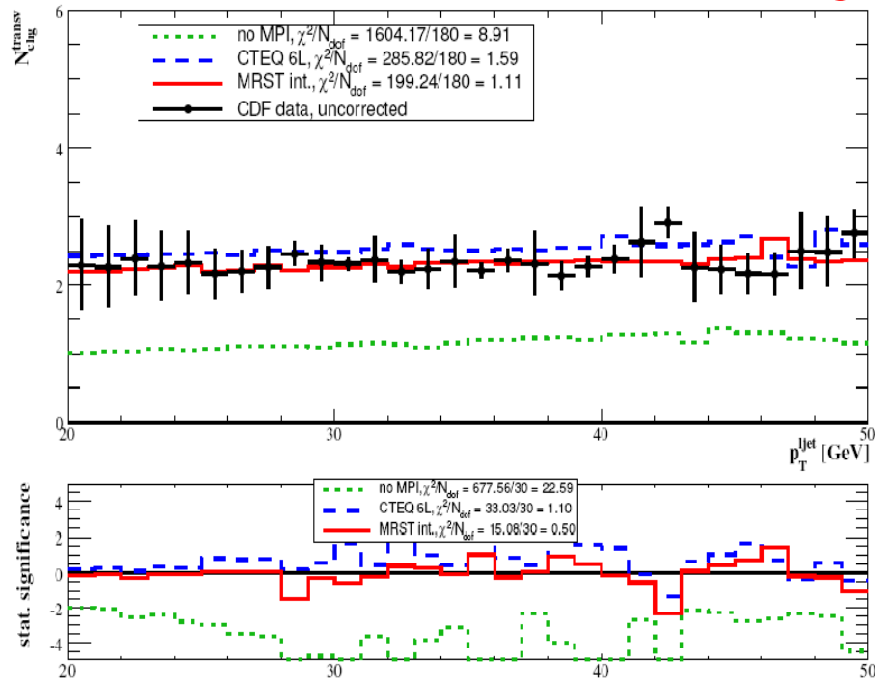
Current Status

- A third hadron-hadron version was released on 18 Apr 2008.
- Major changes
 - New Zh^0 , Wh^0 , $Z+\text{jet}$ and $W+\text{jet}$ hard processes.
 - $gg \rightarrow h^0$ matrix element correction.
- The source code is available from <http://projects.hepforge.org/herwig/> together with wiki and bug tracker.
- In order to improve user support in the first instance all requests for support to herwig@projects.hepforge.org.
- We will open a ticket for all issues and use this for all interactions to improve support and keep a record.

Manual

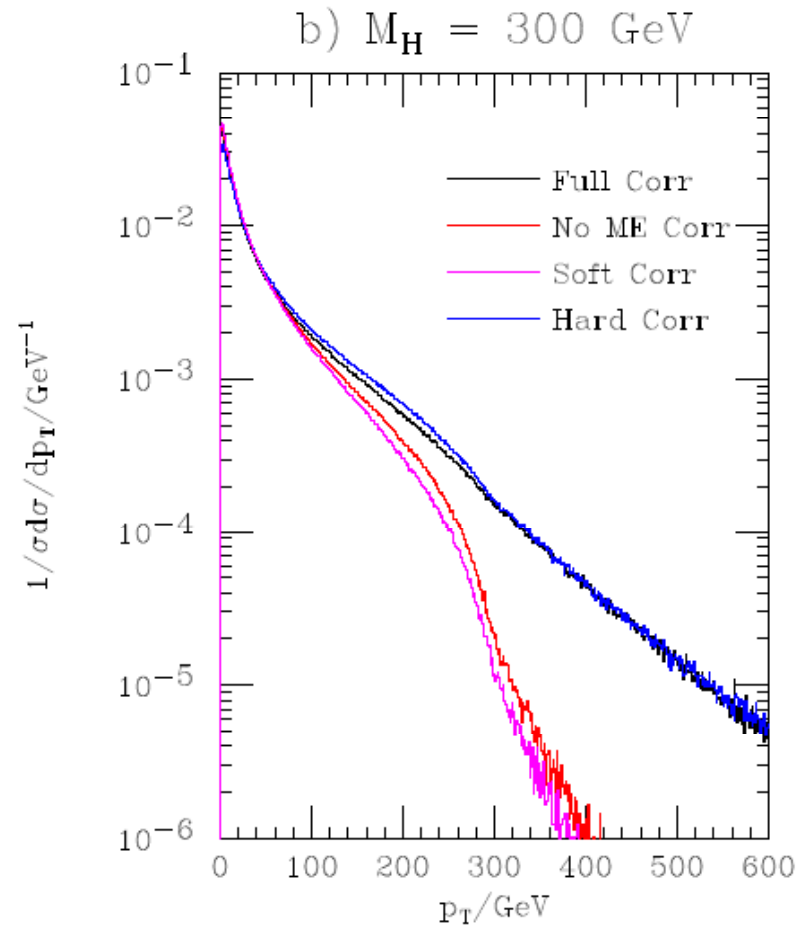
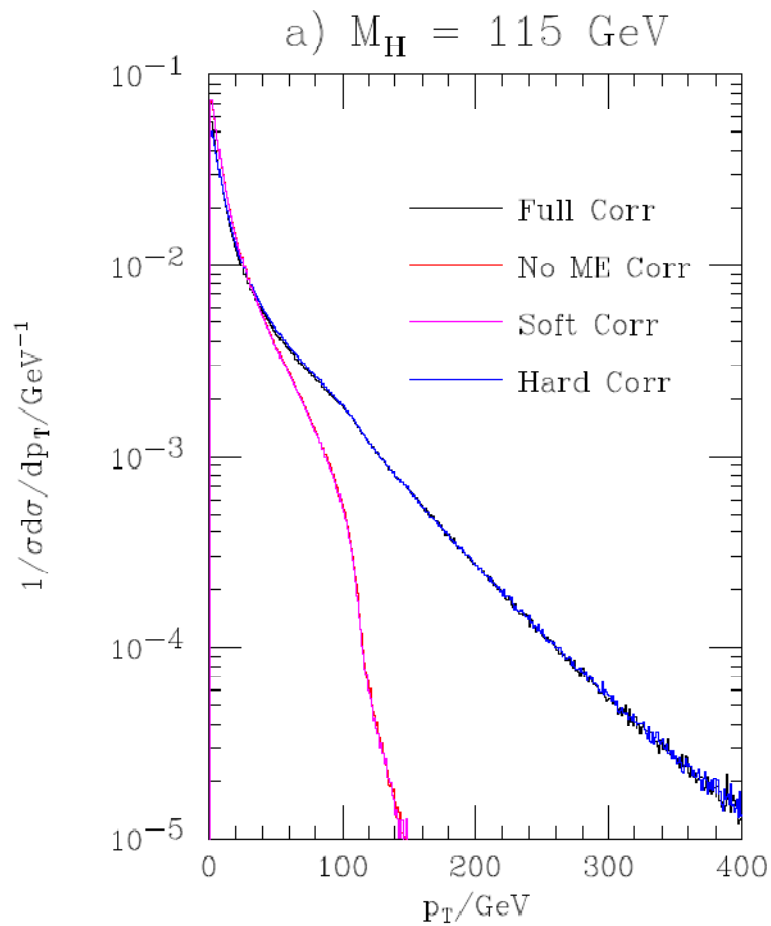
- We (finally) released a full manual [arXiv:0803.0883](https://arxiv.org/abs/0803.0883) in March.
- This contains a full description of the physics together with the overall structure of the code and is designed to supplement the Doxygen documentation of the code and all parameters.
- The PDF of the manual is linked to the Doxygen code and parameter descriptions to make finding things easy.
- There are also a number of examples of using various Herwig++ features in the manual and on the wiki.

Underlying Event



- Major new feature is a multiple scattering model of the underlying event.
- In good agreement with CDF data on the underlying event.
- Talk by M. Bahr on Tuesday.

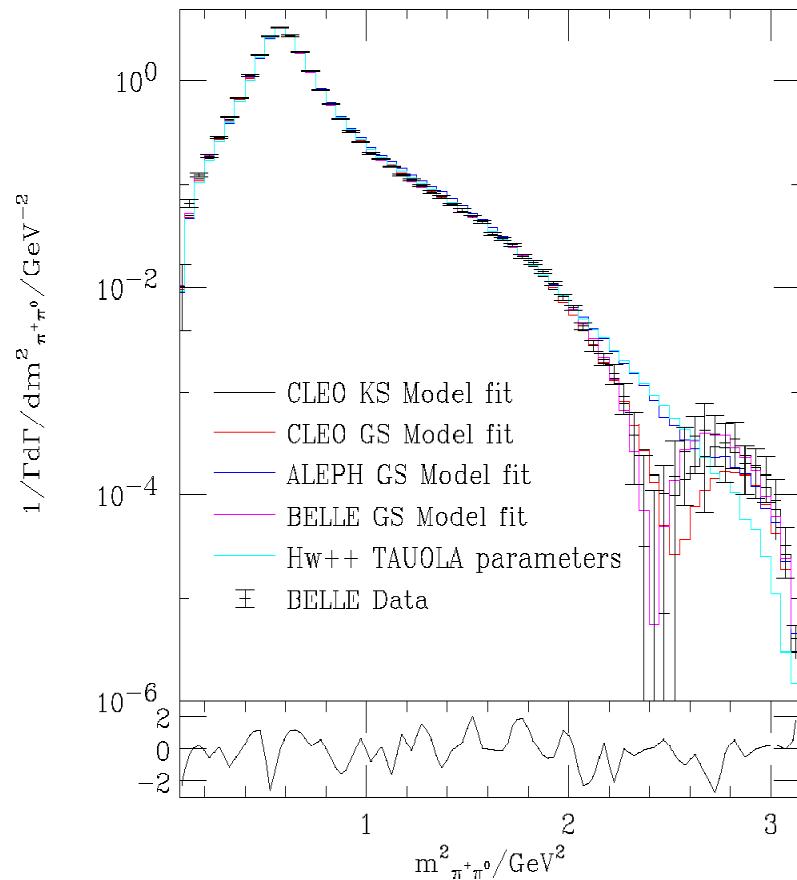
Higgs Matrix Element Correction



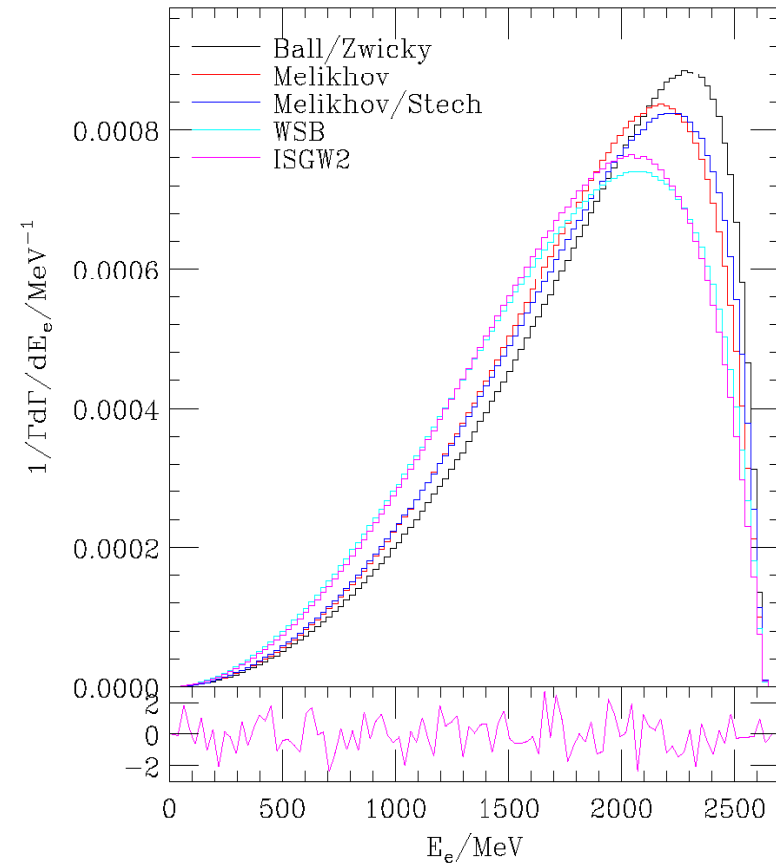
Hadron Decays

- Our new hadronic decay model is now used for meson and tau decays, baryon decays will be added soon.
- The model includes:
 - An update of the particle decay using PDG'06 including a new database to store the information;
 - Spin correlations in all decays, including taus produced in the perturbative stage of the event;
 - A sophisticated treatment of off-shell effects.

Examples of Hadron Decays



Tau Decays, $\tau \rightarrow \rho \nu_\tau$



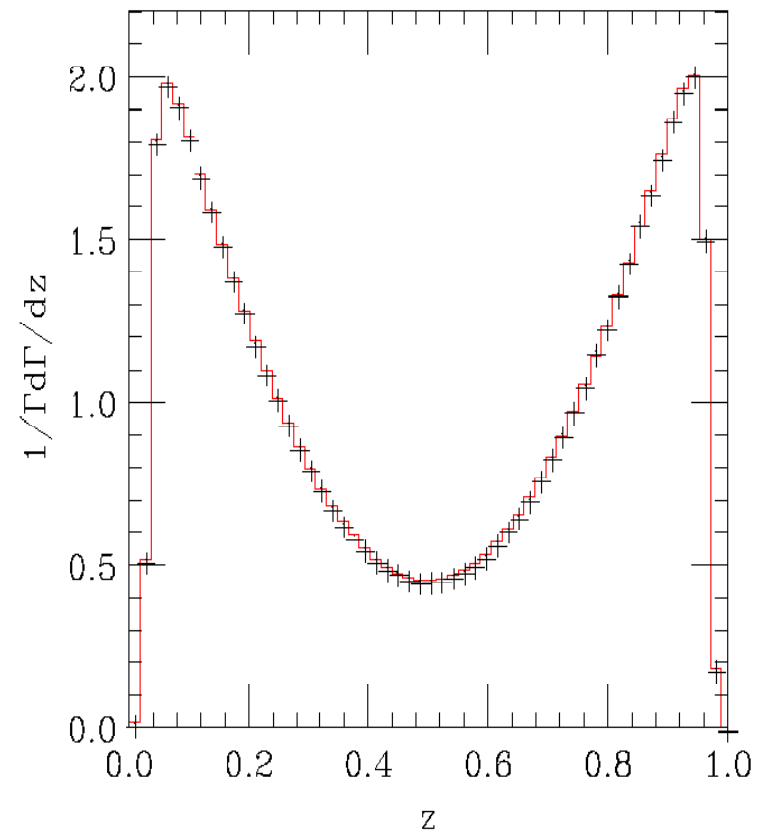
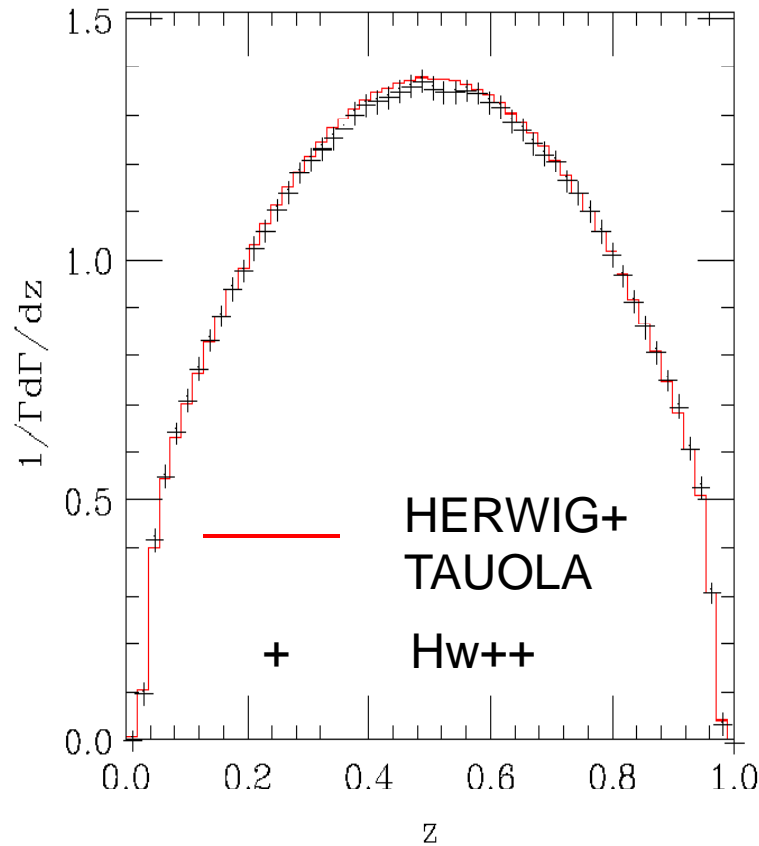
$B \rightarrow \pi e \nu$

Tau Decays

$$\tilde{\tau}^{\pm} \rightarrow \tilde{\chi}_1^0 \tau^{\pm} \rightarrow \tilde{\chi}_1^0 \rho^{\pm} \nu_{\tau} \rightarrow \tilde{\chi}_1^0 \pi^0 \pi^{\pm} \nu_{\tau}$$

Left Handed stau

Right Handed stau



Fraction of visible energy carried by the charged pion

BSM Physics

- New approach for the implementation of BSM physics.
- Rather than hard coding scattering and decay matrix elements have **general** matrix elements for **$2 \rightarrow 2$** and **$1 \rightarrow 2$** processes based on spins.
- **Code** the **Feynman rules** for the different models.
- Makes adding new models and getting the spin correlations right much easier.

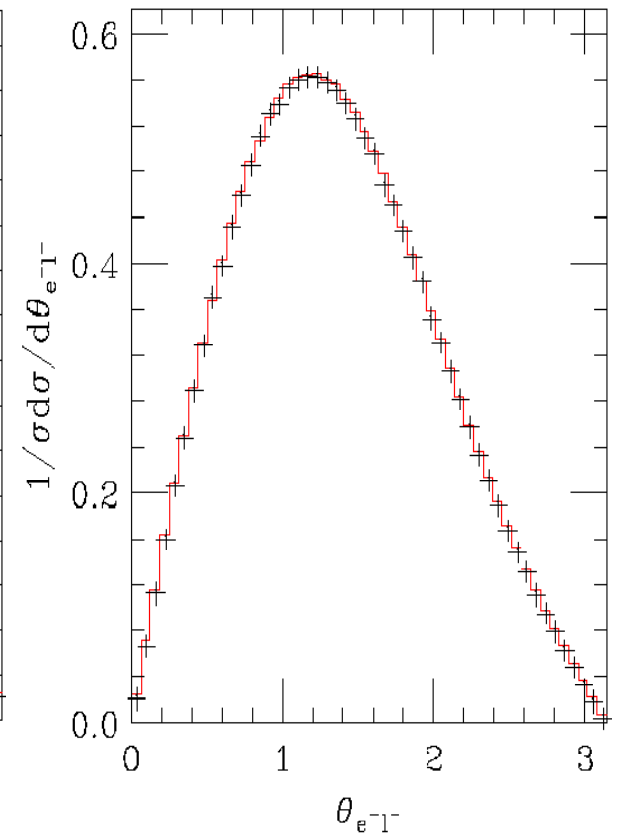
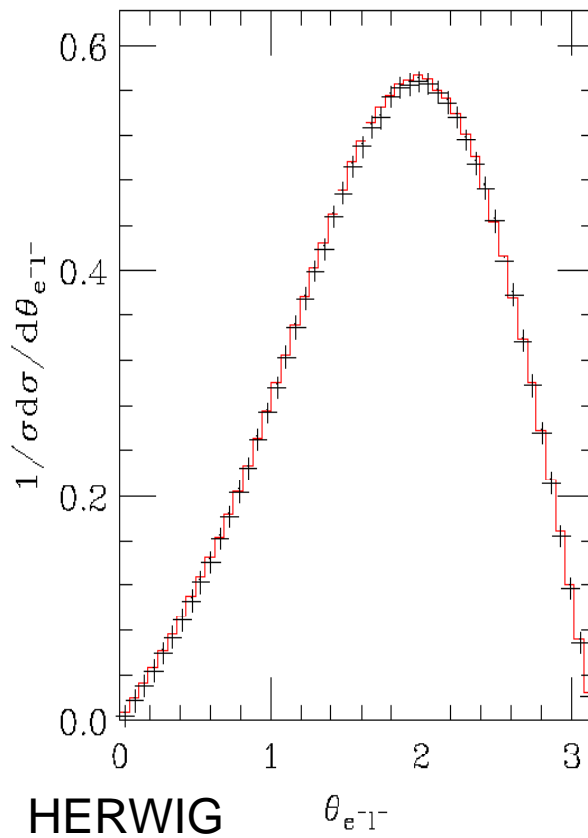
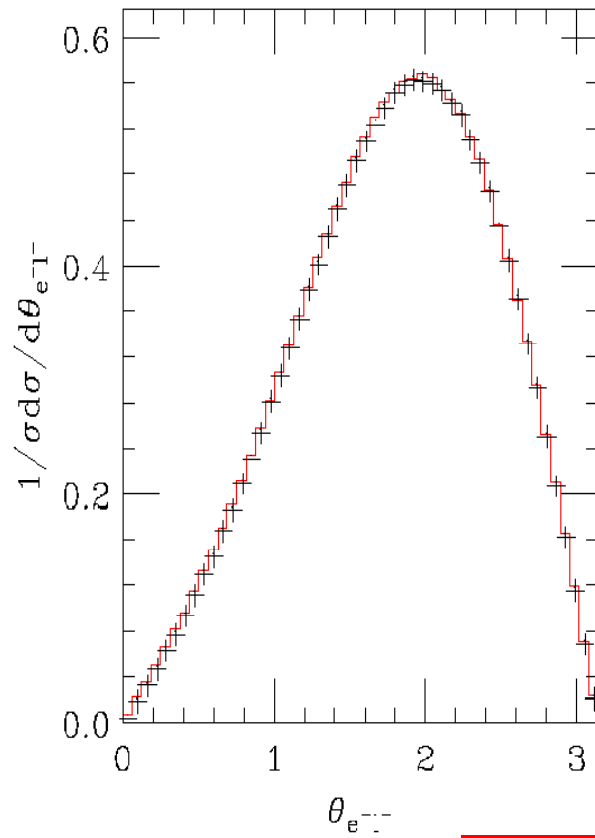
BSM Physics

$$e^+e^- \rightarrow \chi_2^0 \chi_1^0 \rightarrow \tilde{l}_R^+ l^- \chi_1^0$$

Unpolarised

$e_L^- e_R^+$

$e_R^- e_L^+$



HERWIG

θ_{e^-}

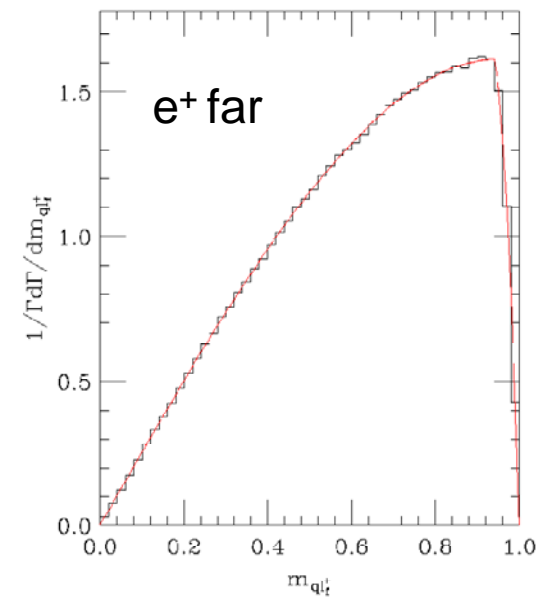
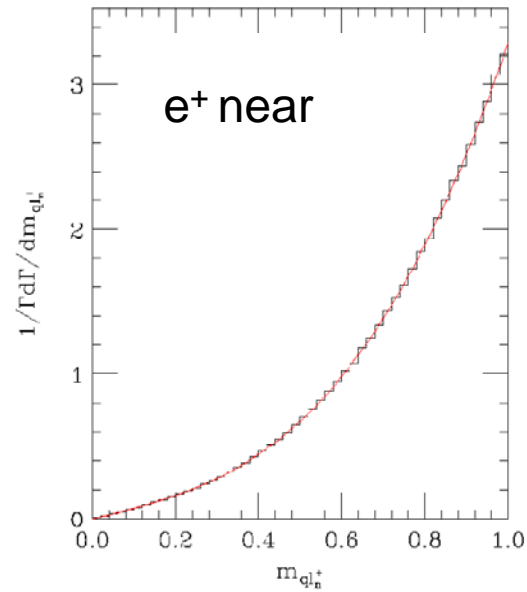
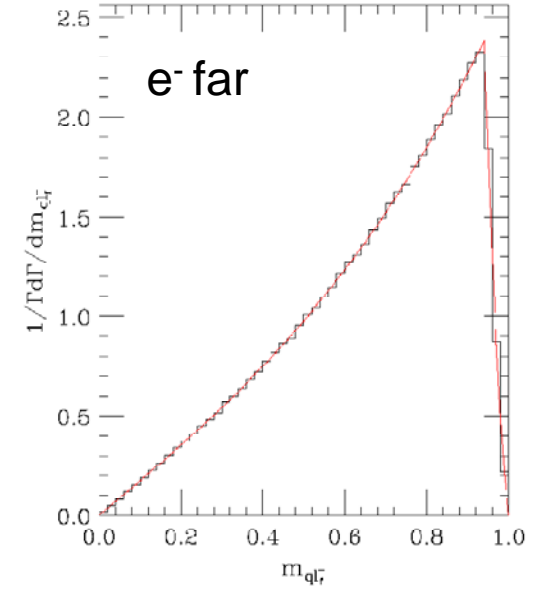
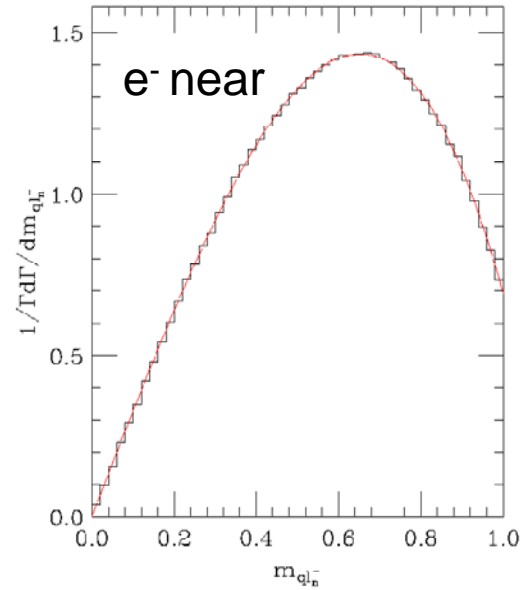
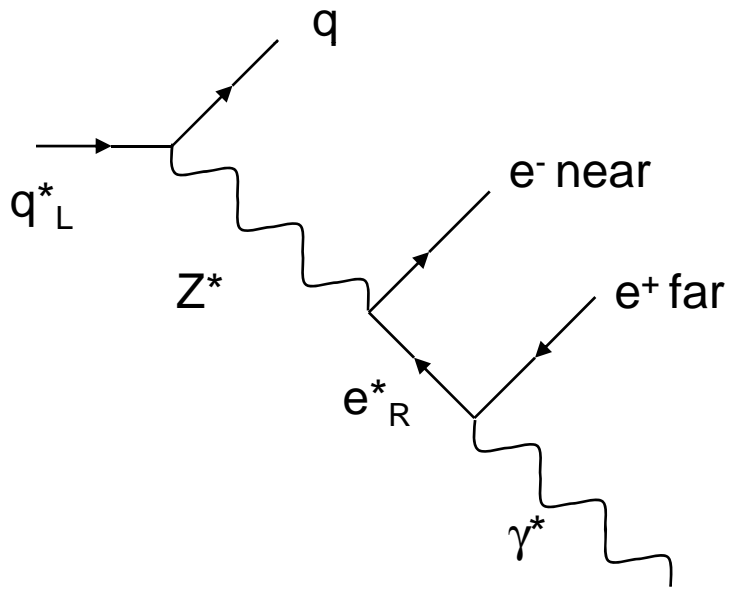
θ_{e^-}

+

Hw++

UED

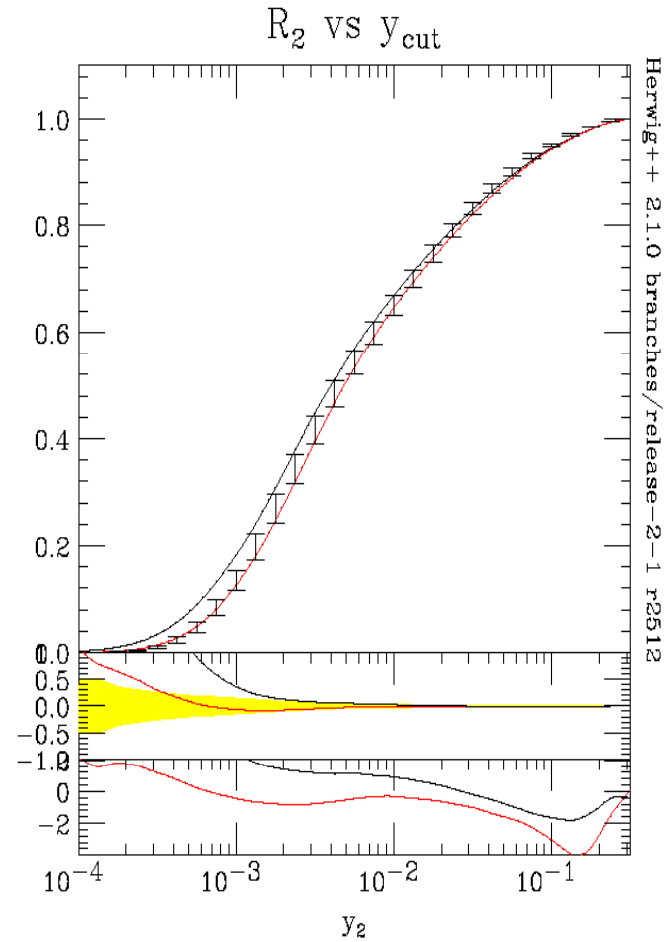
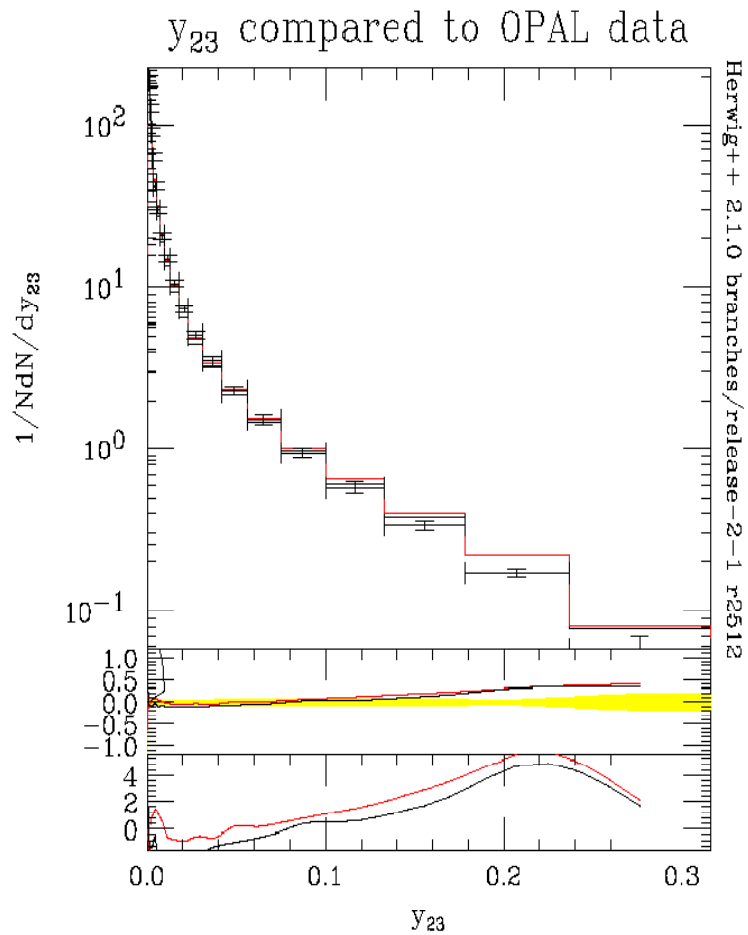
Look at the decay



Tuning

- The parameters of the first Herwig++ release were adjusted to improve the agreement to LEP data, not a real tuning.
- A number of significant improvements have been made since then.
- Did a retuning of the parameters to LEP, SLD and B-factory off-resonance data.
- Randomly selected parameters (2000 points) and minimised about the best set.

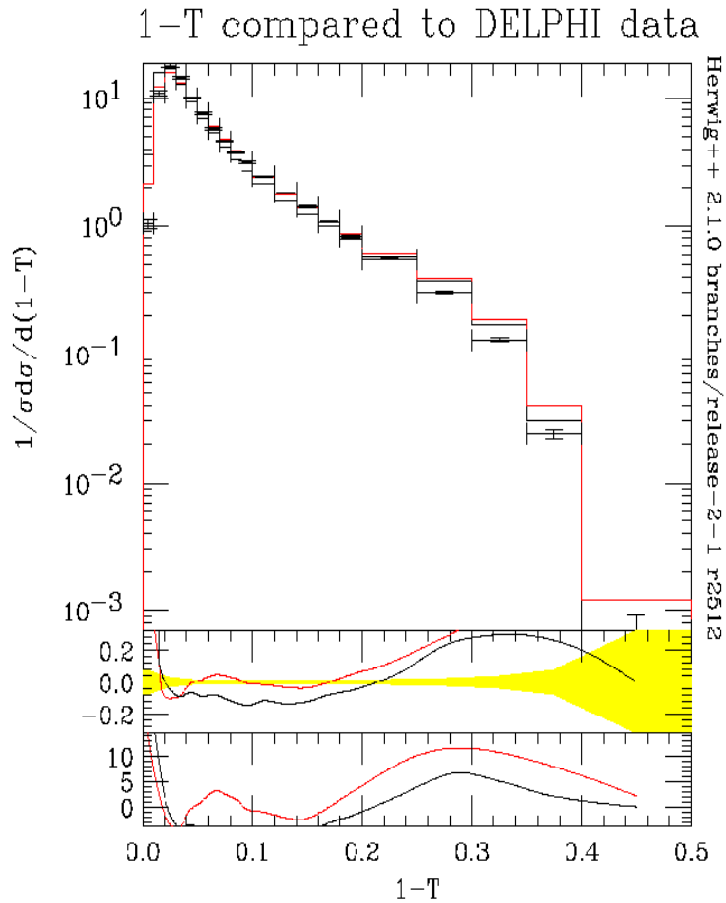
Tuning: Jets



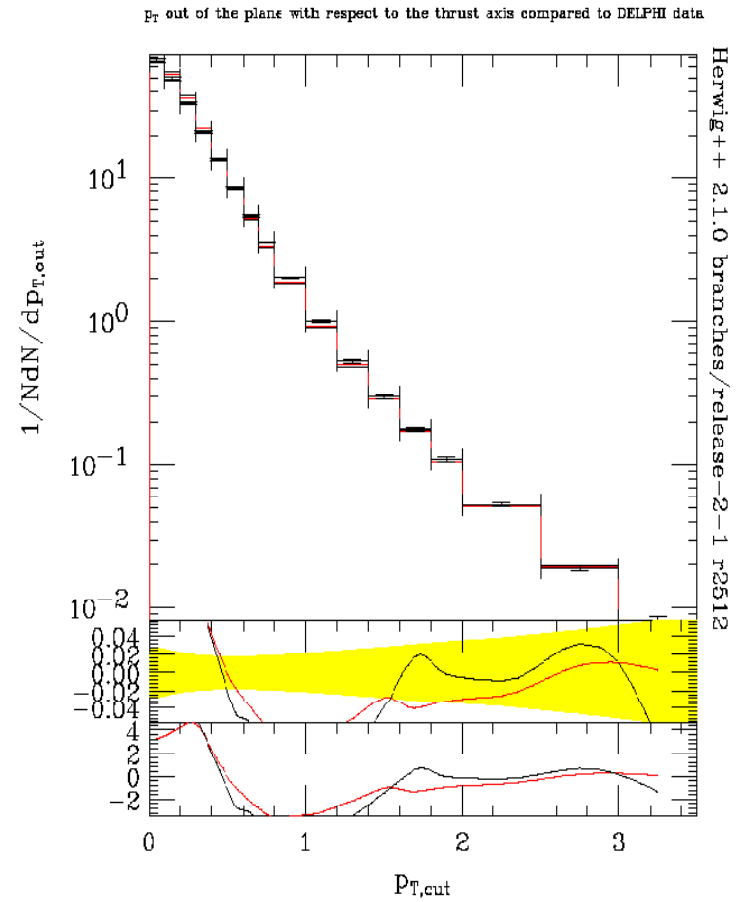
— Before tune

— After Tune

Tuning: Event Shapes

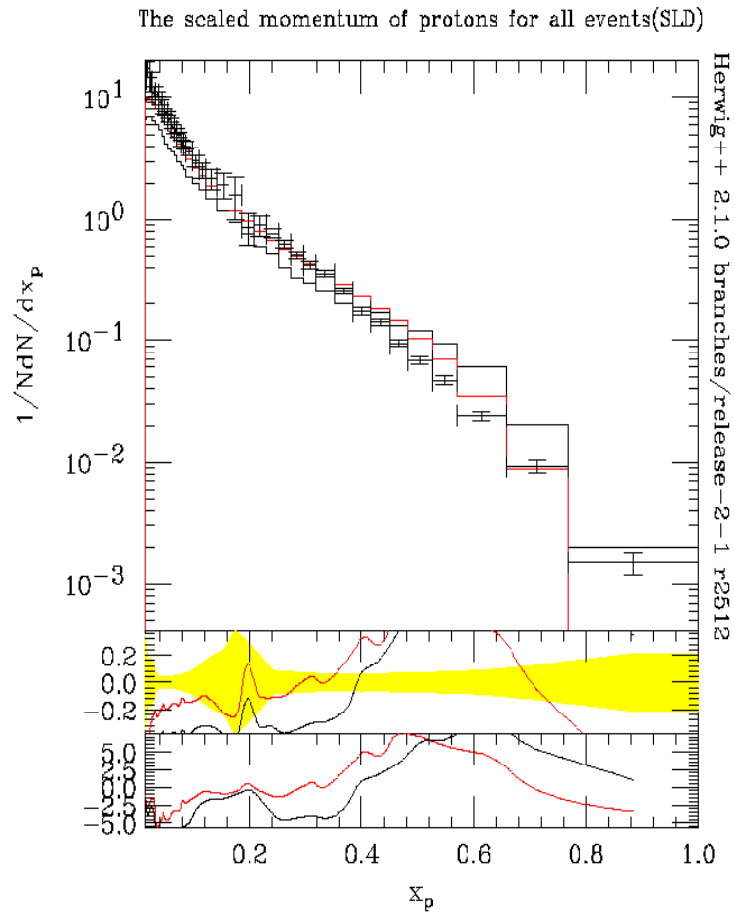


— Before tune

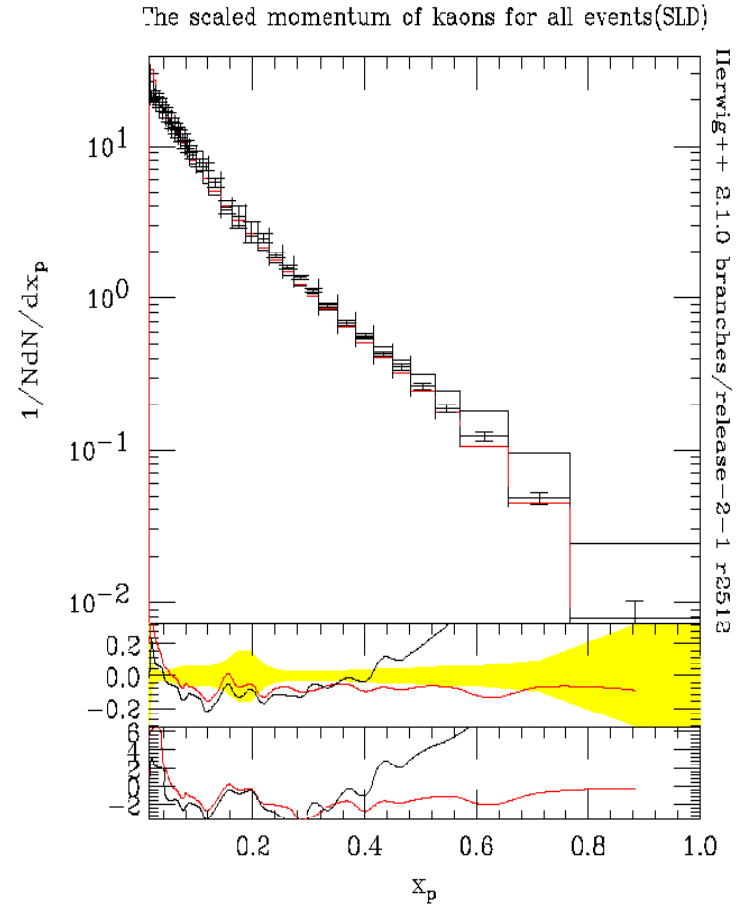


— After Tune

Tuning: Kaons and Protons

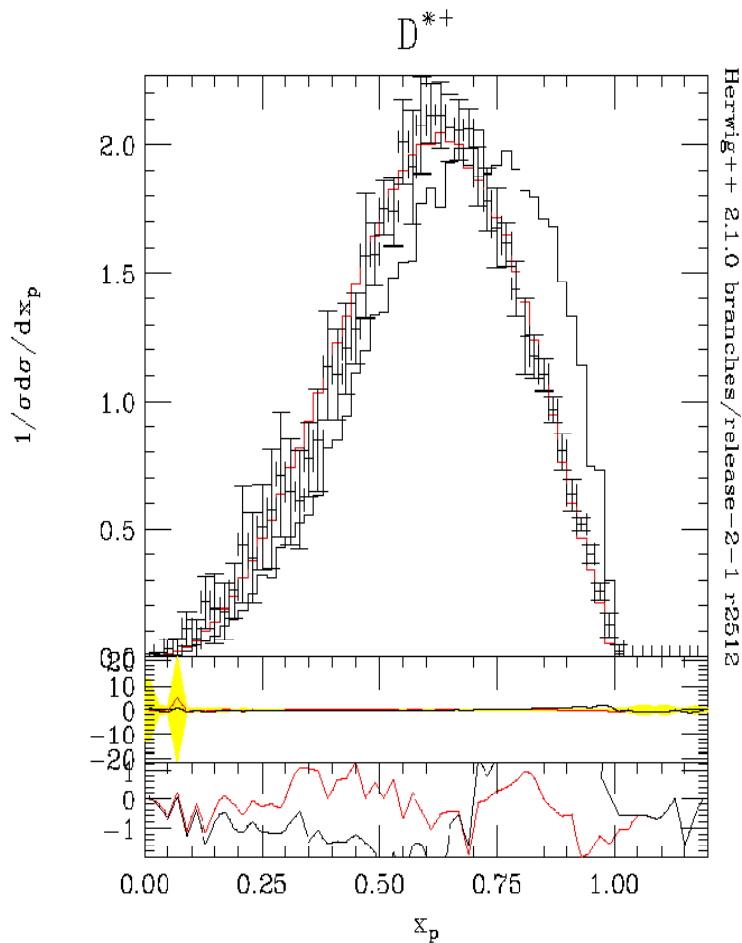


— Before tune

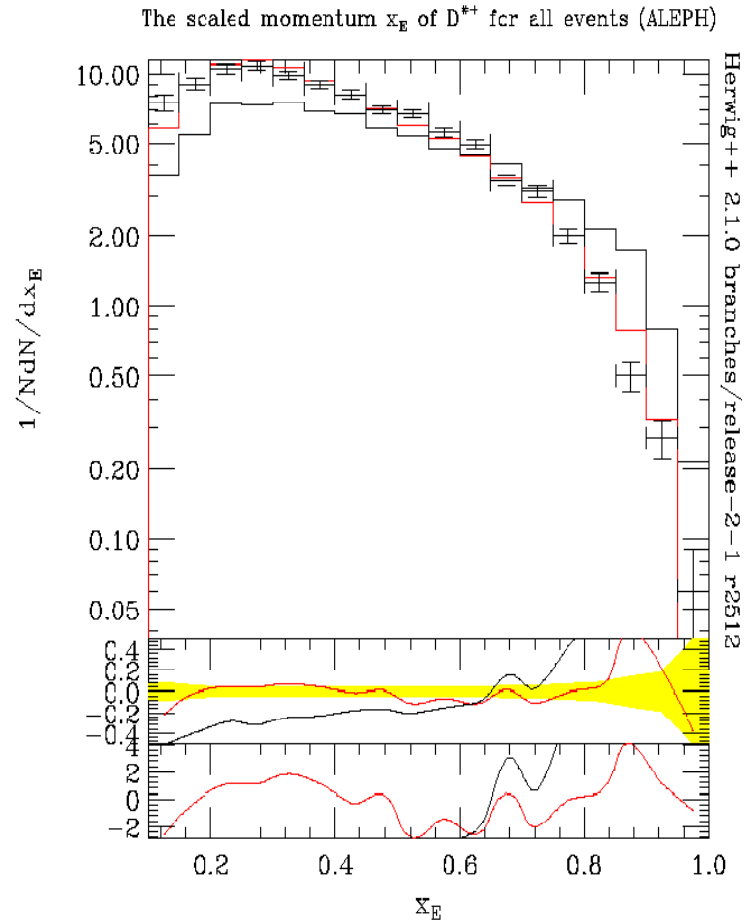


— After Tune

Tuning: Charm Fragmentation



— Before tune



— After Tune

Using Herwig++

- Need to download and install ThePEG and Herwig++ as explained on <http://projects.hepforge.org/herwig/versions.html>
- Has been tested on a wide variety of Linux systems (32 and 64 bit) using gcc 3.4.6, 4.0.4, 4.1.2 and 4.2.2, 4.3.0 and Intel based Macs.
- We use autotools, configure and make for installation.
- Detailed instructions at <http://projects.hepforge.org/herwig/trac/wiki/HerwigInstallation>
- A number of examples for different colliders are provided.

Using Herwig++

- A number of examples are installed in the share directory.
- We have simplified the structure of the input files so that the majority of users should only need to edit one file.
- If you try the LHC example LHC.in
 - `herwig-location/bin/Herwig++ read LHC.in`
- Creates the event generator LHC.run
 - `herwig-location/bin/Herwig++ run LHC.run -N#of-events`
- Runs the event generator.

Using Herwig++

- The hard process can be changed by adding new matrix elements

```
# Drell-Yan Z/gamma
insert SimpleQCD:MatrixElements[0] MEqq2gZ2ff
# Drell-Yan W
# insert SimpleQCD:MatrixElements[0] MEqq2W2ff
# gamma-gamma
# insert SimpleQCD:MatrixElements[0] MEGammaGamma
# gamma+jet
# insert SimpleQCD:MatrixElements[0] MEGammaJet
# gg/qqbar -> Higgs
# insert SimpleQCD:MatrixElements[0] MEHiggs
# higgs+jet
# insert SimpleQCD:MatrixElements[0] MEHiggsJet
# QCD 2-2 scattering
# insert SimpleQCD:MatrixElements[0] MEQCD2to2
# top-antitop production
# insert SimpleQCD:MatrixElements[0] MEHeavyQuark
```

Using Herwig++

- Simple analysis of the events, producing output in topdraw format can be switched on

```
#####  
# Useful analysis handlers for hadron-hadron physics  
#####  
# analysis of W/Z events  
# insert LHCGenerator:AnalysisHandlers 0 /Herwig/Analysis/DrellYan  
# analysis of top-antitop events  
# insert LHCGenerator:AnalysisHandlers 0 /Herwig/Analysis/TTbar  
# analysis of gamma+jet events  
# insert LHCGenerator:AnalysisHandlers 0 /Herwig/Analysis/GammaJet  
# analysis of gamma-gamma events  
# insert LHCGenerator:AnalysisHandlers 0 /Herwig/Analysis/GammaGamma  
# analysis of higgs-jet events  
# insert LHCGenerator:AnalysisHandlers 0 /Herwig/Analysis/HiggsJet
```

Using Herwig++

- Cuts on the particles produced in the hard process can be changed, e.g. p_T and η of photons

```
set PhotonKtCut:MinKT 20.0*GeV
set PhotonKtCut:MinEta -3.
set PhotonKtCut:MaxEta 3.
```

- Switch off parts of the event generation
- Hadron Decays

```
set /Herwig/EventHandlers/LHCHandler:DecayHandler NULL
```

- Multiple scattering

```
set /Herwig/Shower/ShowerHandler:MPI No
```

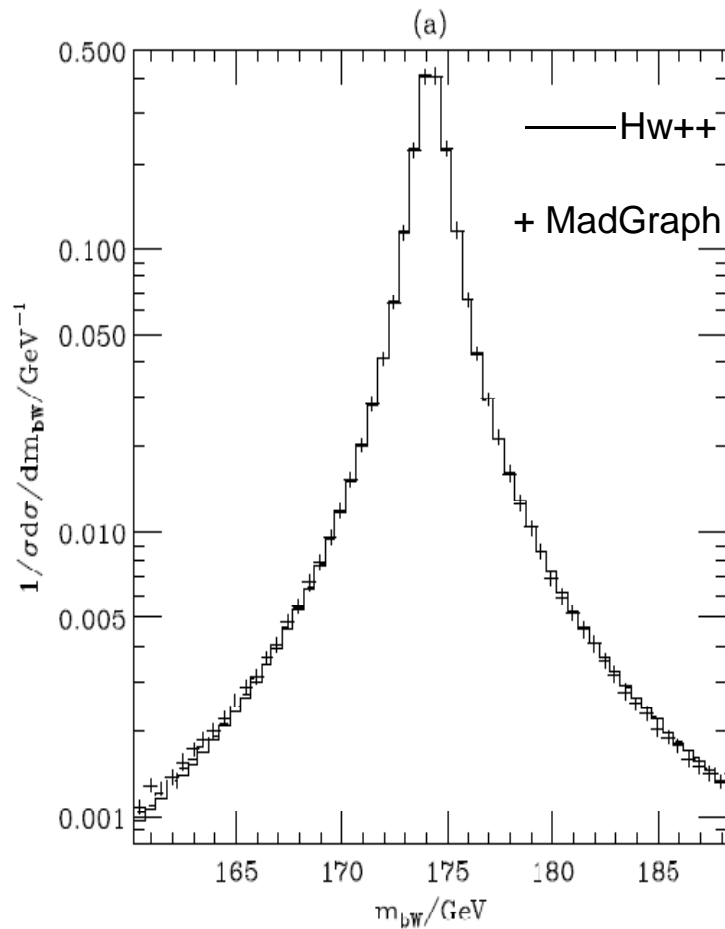

Plans for the Future

- At this point the most important thing is that the program is included in the experimental software and **USED**.
- Experimental feedback is vital to enable us to fix any problems and guide future developments.
- Support for the FORTRAN will decline, there will only be bug fix releases.
- The next bug fix release is likely to be the last.
- User support will be concentrated on the C++, the FORTRAN is a much lower priority.

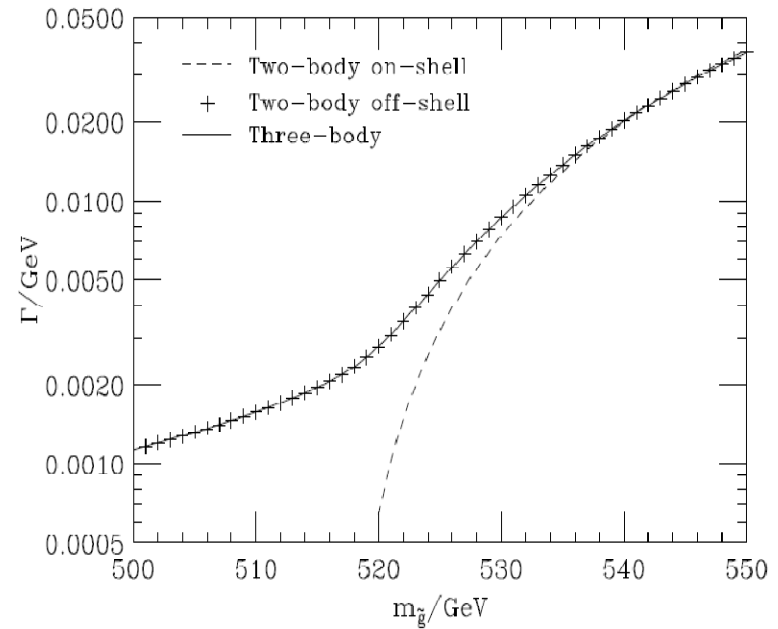
Future Improvements

- We are continuing to work on a number of further improvements
 - CKKW matrix element matching;
 - The multi-scale shower;
 - MC@NLO;
 - The Nason approach to MC@NLO;
 - IVAN soft underlying event model;
 - Improved modelling of baryon decays;
 - Additional new physics models and better simulation of off-shell effects.

Off-shell effects in BSM Physics

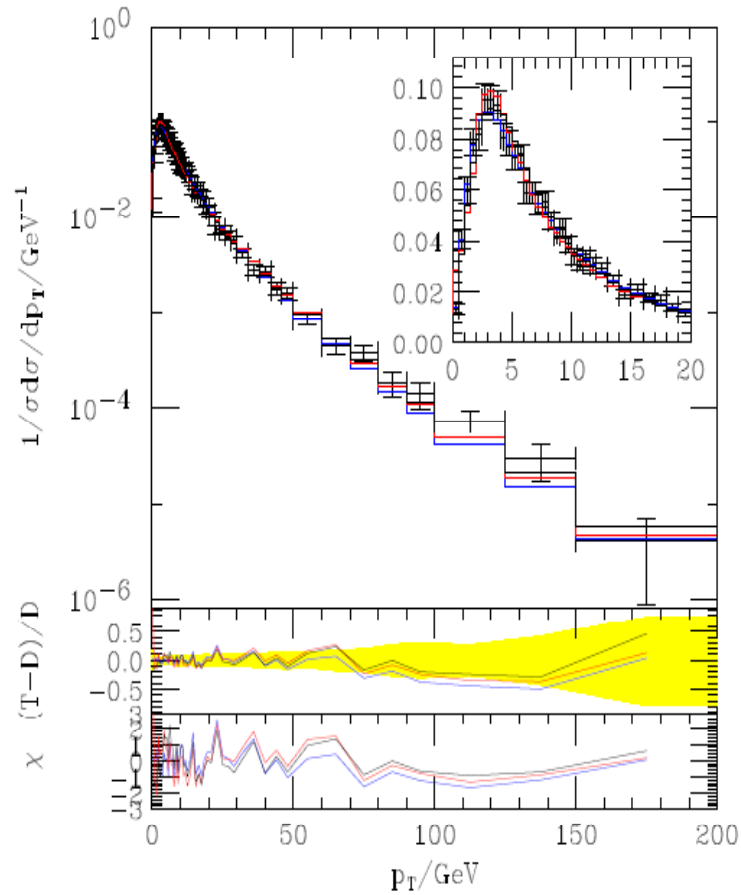


Top mass at the Tevatron

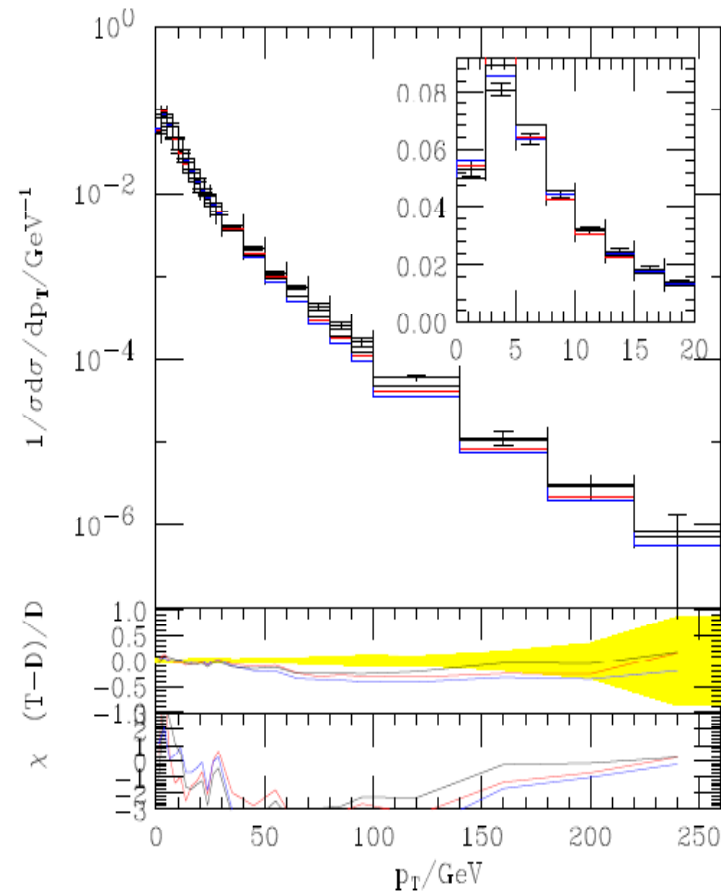


$$\tilde{g} \rightarrow \bar{b} \tilde{b}_1 \rightarrow \tilde{\chi}_2^0 b$$

POWHEG method for Drell-Yan



CDF Run I Z p_T



D0 Run II Z p_T

Herwig++
POWHEG
MC@NLO

Summary

- We have made a lot of progress in the last year.
- Herwig++ is now fully ready for hadron collisions.

PLEASE USE IT

- A comprehensive manual is now available.
- User support available from [*herwig@projects.hepforge.org*](mailto:herwig@projects.hepforge.org)
- Further improvements will follow.