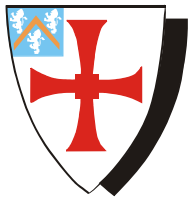

Durham University

New Developments in Herwig++

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Introduction

- Recent Developments
- Current Status
- Plans for the Future

Recent Developments

- A new version of Herwig++, 2.0, was released on the 29th of September.
- This version includes many major developments:
  - Simulation of initial-state radiation;
  - Simulation of the underlying event;
  - Many more hadron-hadron matrix elements;
  - Simulation of initial-state radiation in the decay of heavy particles.

Recent Developments

  - Matrix element correction for Drell-Yan and top decays;
  - Simulation of QED radiation in particle decays.

- This is the first version which can be used for realistic physics studies of hadron-hadron collisions.

New Matrix Elements

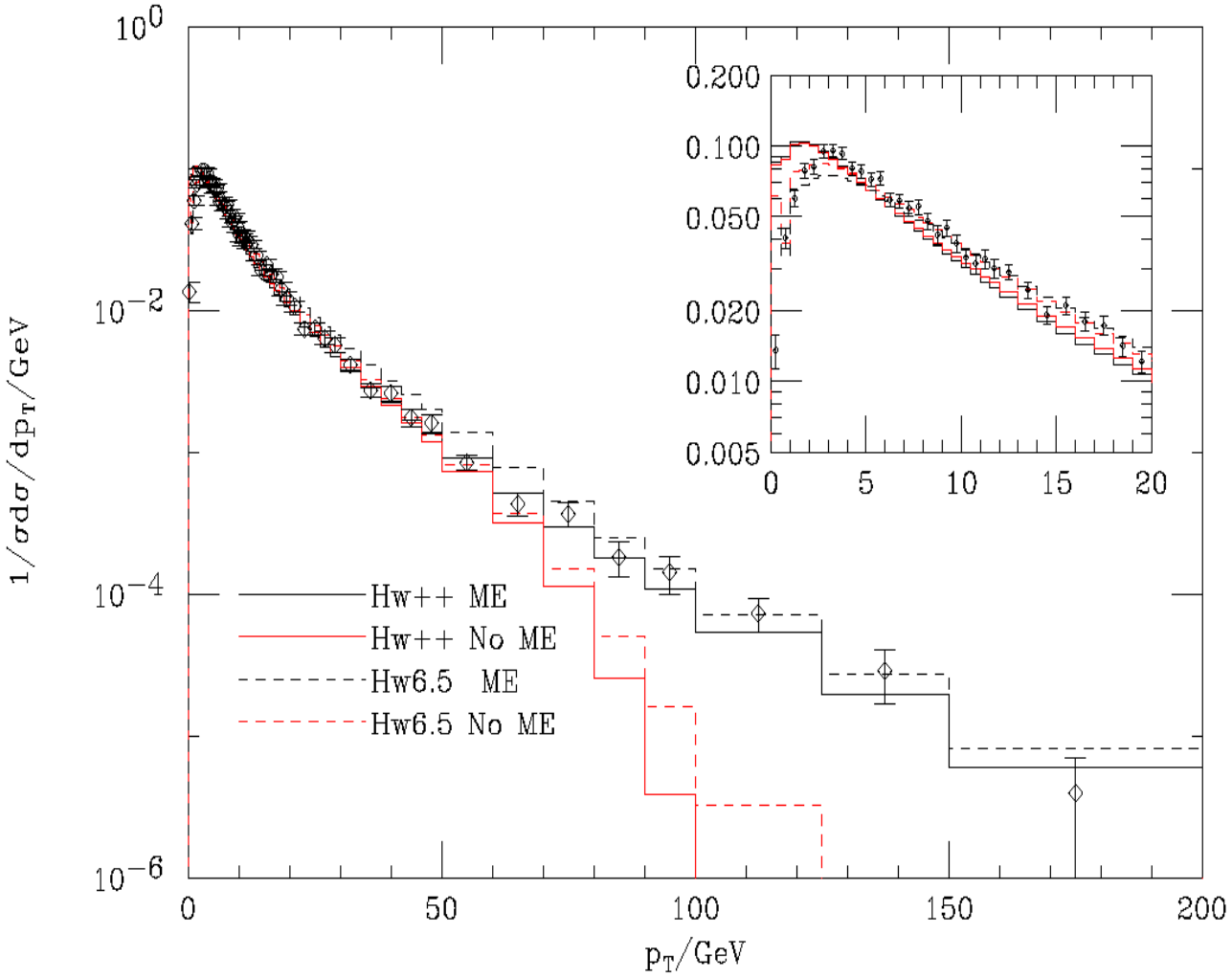
- The matrix elements for:
  - Direct photon pair production;
  - Photon+jet production;
  - Higgs boson production;
  - Higgs boson plus jet production;
  - Heavy quark pair production;
  - QCD 2→2 scattering processes;

  were included.
- Other processes are available using a Les Houches accord interface.

Initial-State Radiation

- The major changes in this version were
  - Simulation of initial-state radiation for processes other than Drell-Yan;
  - Final-State radiation from the partons produced in the initial-state shower;
  - The hard matrix element correction for Drell-Yan W and Z production.

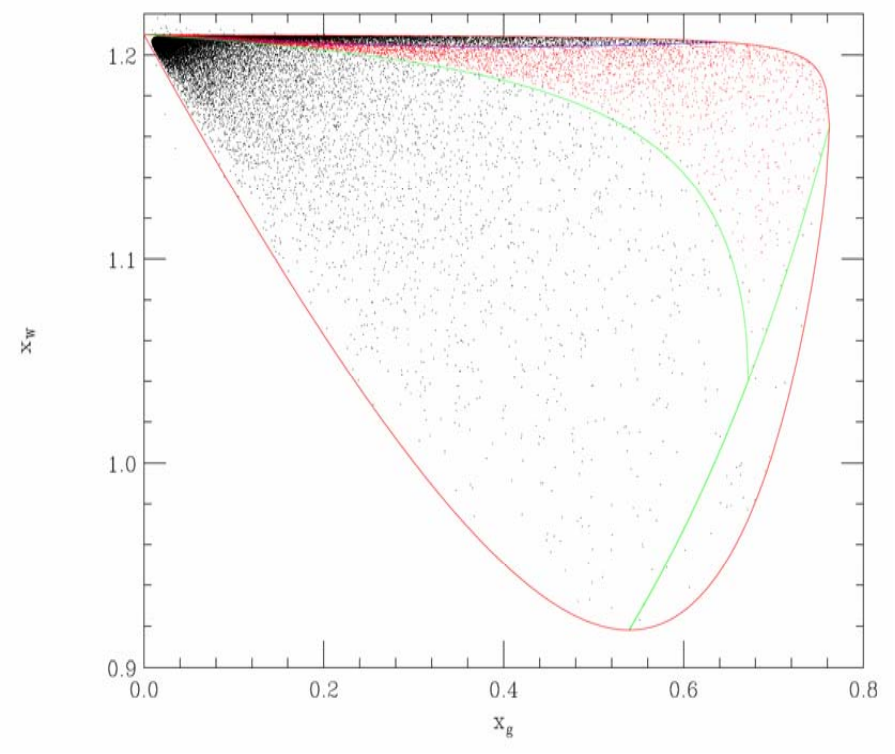
p_T of the Z compared with CDF data

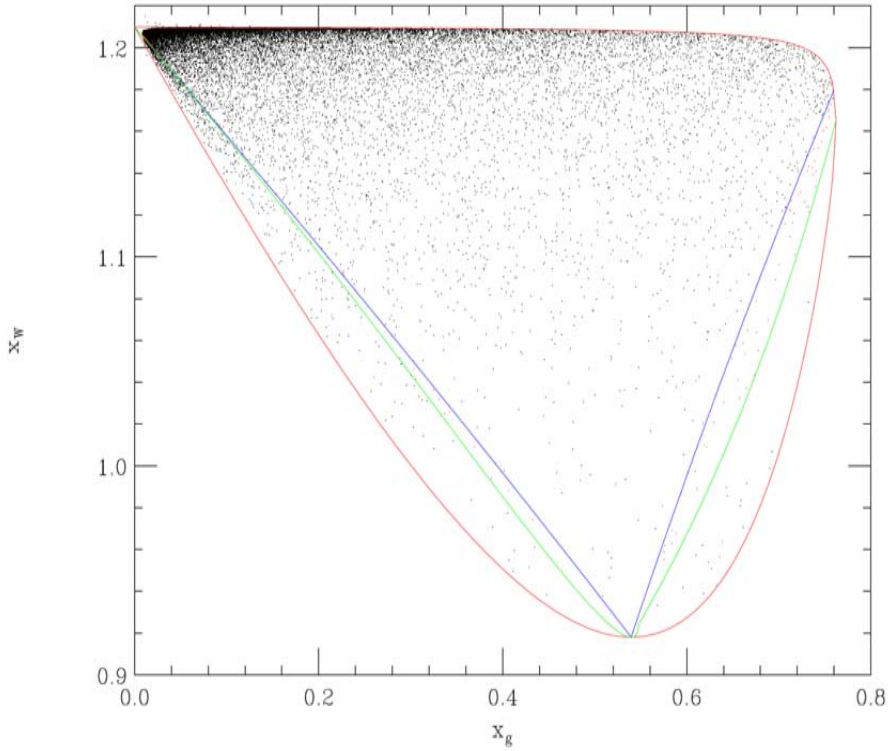


Top Decay Shower

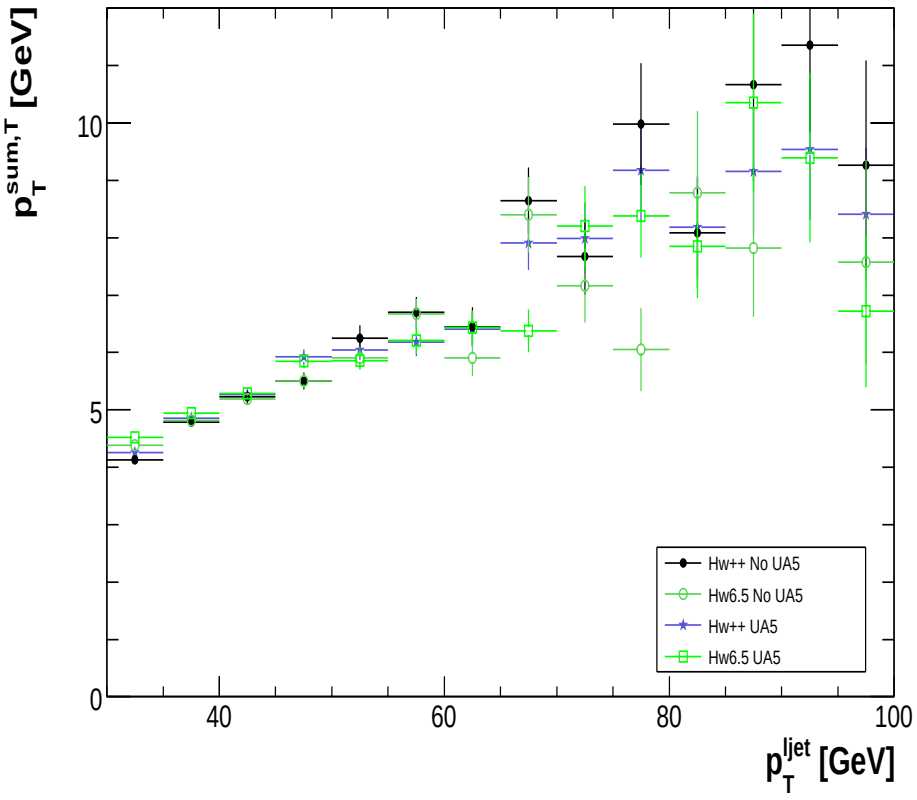
- A key feature of the new parton shower algorithm is the simulation of radiation in particle decays.
- In the new approach the decaying particle emits radiation in its decay to ensure the full soft region is covered.
- However the soft matrix element is required to give smooth coverage in the soft region.

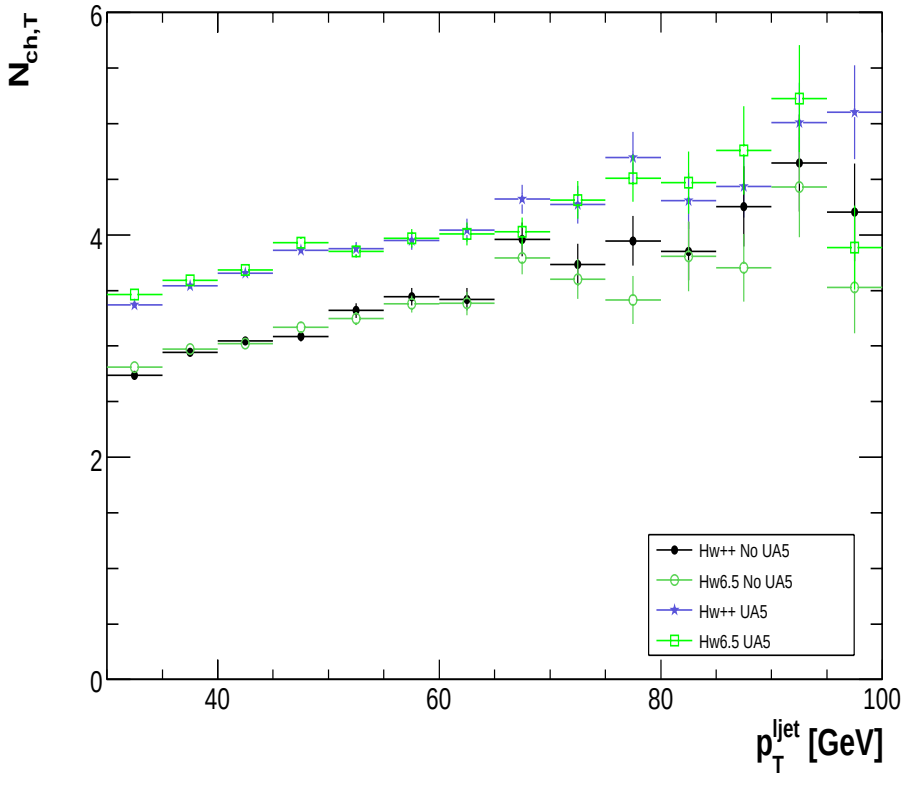
Top Shower and Matrix Element Correction in $t \rightarrow bW^{+}g$





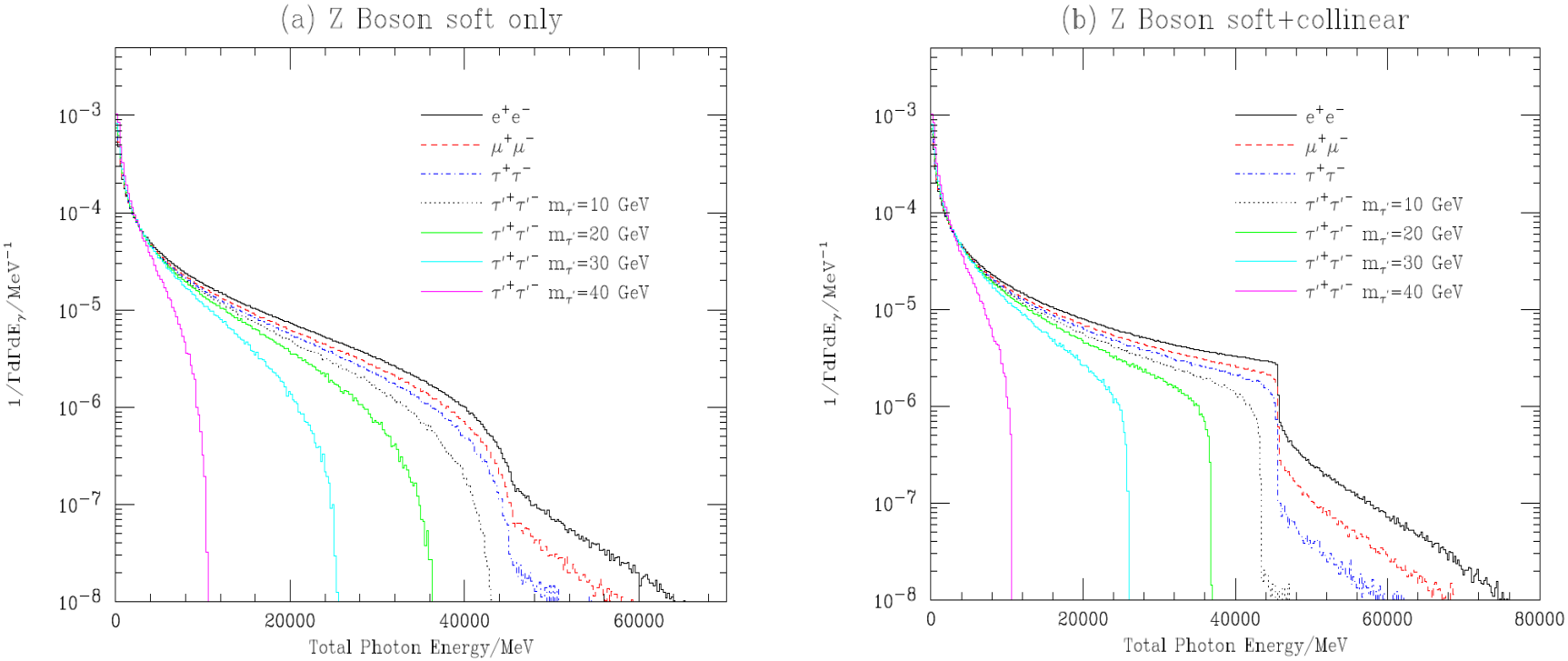
Underlying Event





- Uses the UA5 model as in the FORTRAN program to gives some simulation of the underlying event.

Simulation of QED Radiation



- The FORTRAN program did not simulate QED radiation.
- Recently this was included in the C++ program using the YFS formalism.

K. Hamilton and PR hep-ph/0603034, JHEP 0607:010, 2006.

Bug tracking and Release Strategy

- We are using HEPFORGE for bug tracking and a wiki

  http://hepforge.cedar.ac.uk/herwig/bugtrack/
- Our plan is to release a monthly update which will only contain bug fixes etc.
- There will be less frequent major releases with physics changes to the simulation.

Profiling

- Since the release Vincenzo Innocente of CMS profiled the code and found some simple changes which lead to significant speed increases.
- Building on this with a bit on minor restructuring of one class in the hadronization gives a 30% speed increase.
- A bug-fix release with this change and a number of bug fixes will be released soon.

Plans for the Future

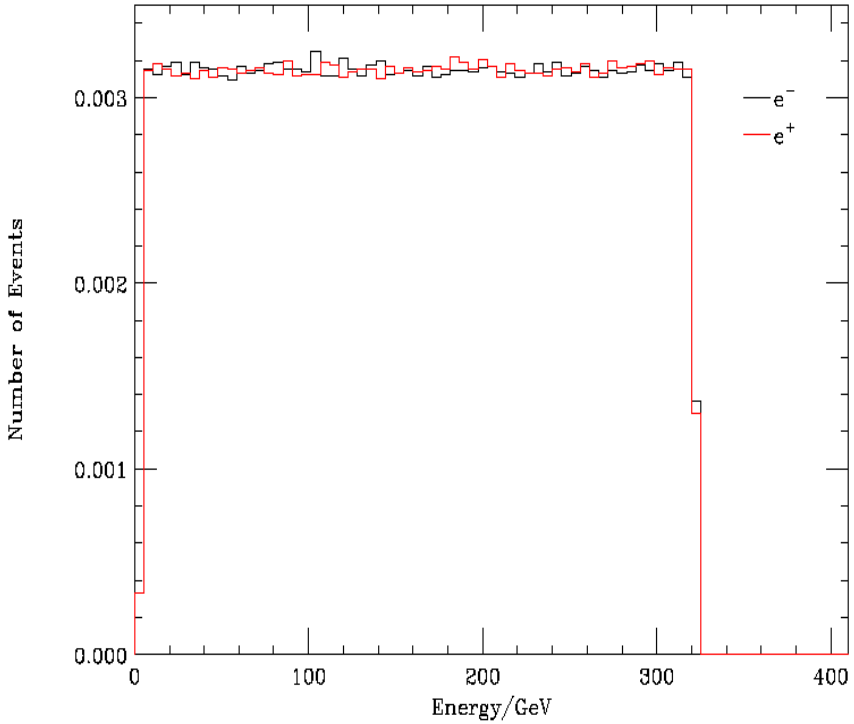
- The 2.0 release gives us a solid foundation on which further developments can build.
- There are a number of features which we still need to include:
  - JIMMY multiple scattering model for the underlying event;
  - different kinematic reconstruction procedures for the shower;
  - BSM Physics;
  - new hadron decay model;
  - spin correlations throughout the simulation.

  In order for the simulation to be as good as, or better than, the FORTRAN for everything.
- There has been a lot of work on the hadron decays and BSM physics.

BSM physics

- The new hard processes are based on a library of classes using the helicity formalism.
- For other BSM models we will automatically generate the decays and hard processes from the Feynman rules (Vertices).
- Using helicity amplitudes throughout will make it easy to add spin correlations.
- My PhD student Martyn Gigg is doing most of the work.

Example SUSY Process

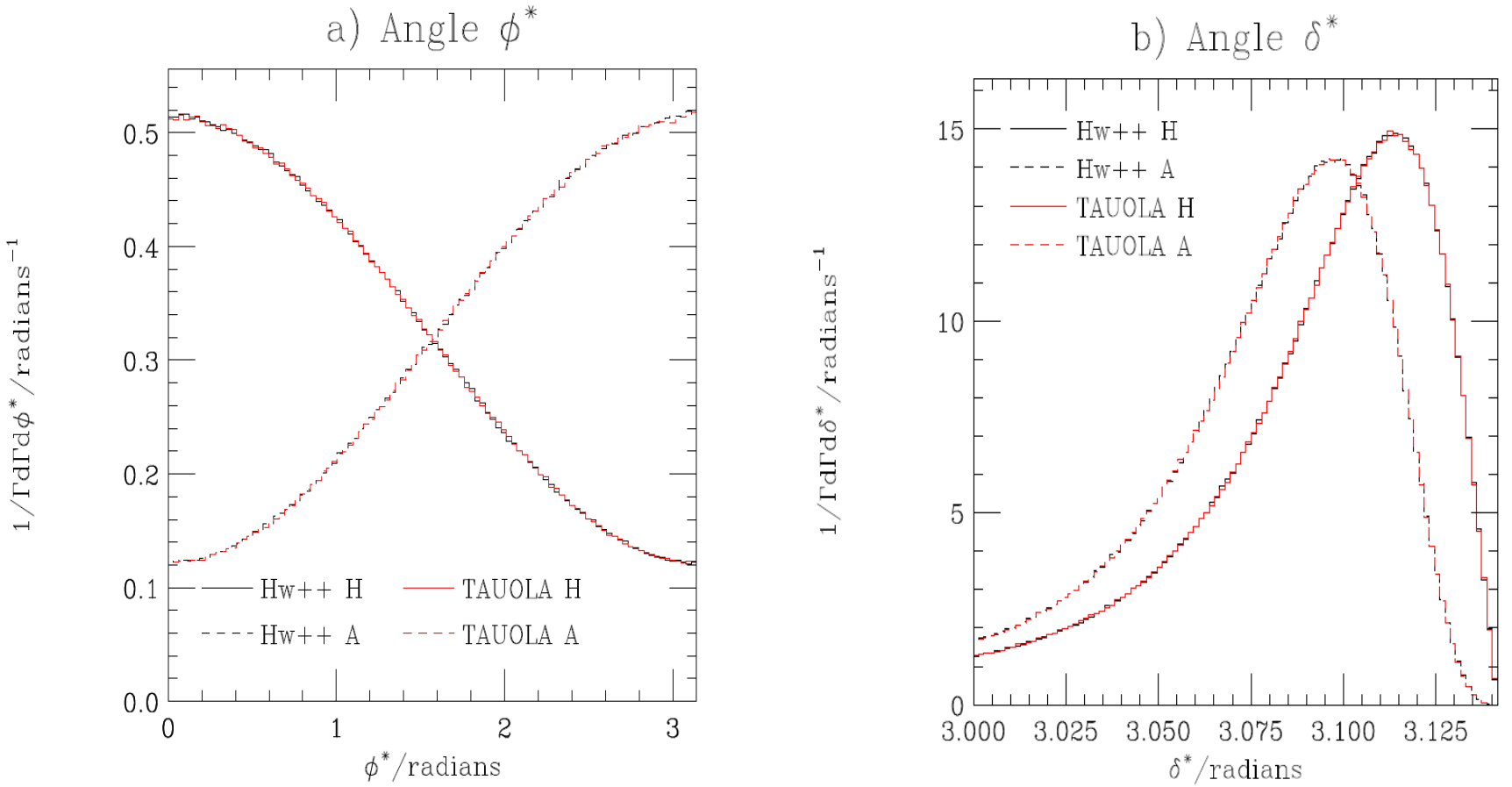


$$e^+e^- \longrightarrow \tilde{e}^+_R\tilde{e}^-_R \longrightarrow \chi^0_1\chi^0_1 e^+e^-$$

Hadron Decays

- We have a wide range of hadron decay matrix elements available, including spin correlations.
- Much of the code is ready it just needs to be full tested.
- Hopefully this will happen in the near future.

Hadron Decays



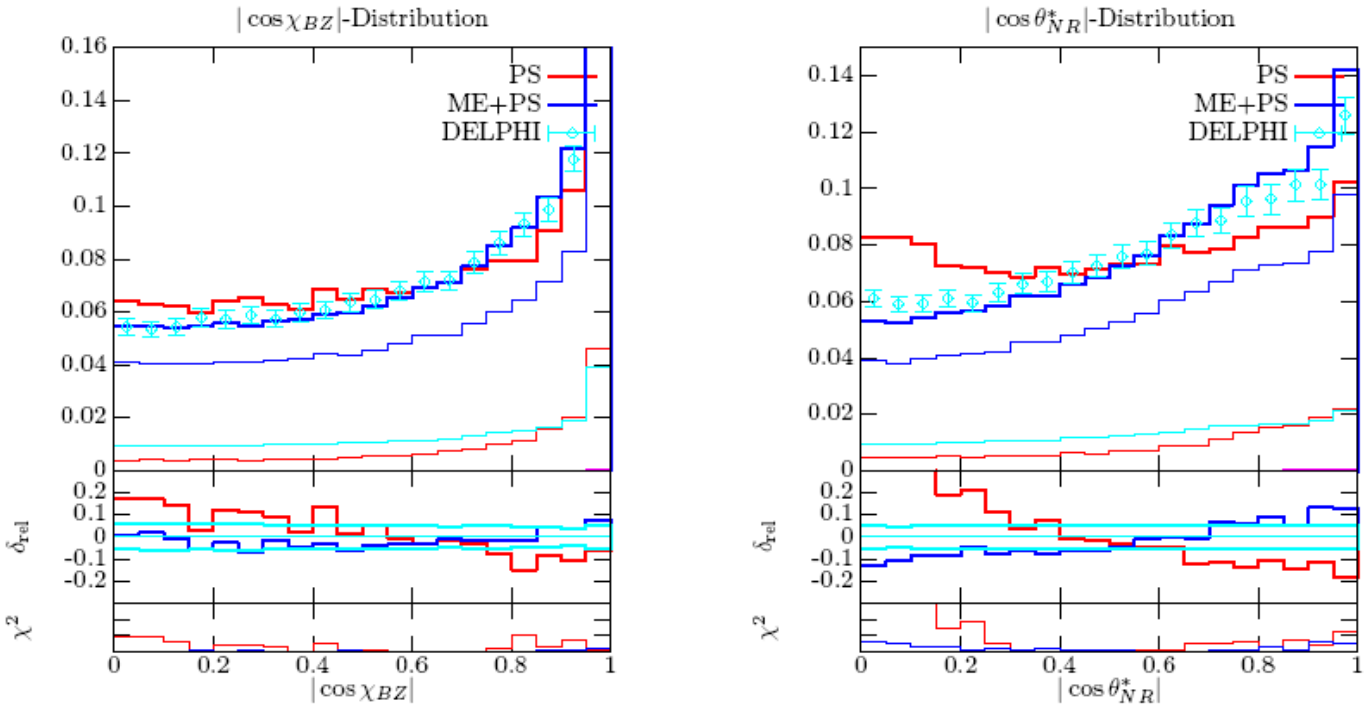
- Spin correlations are also included.
- In the decay $H \to \tau^+\tau^- \to \bar{\nu}_\tau \pi^+ \nu_\tau \pi^-$ the angle between the tau decay planes, ϕ^*, and between the pions, δ^*, depends on whether the parity of the Higgs boson.

Future Shower Improvements

- In addition to the other features one of the main reasons for going to C++ was to allow improvements to the shower algorithm:
  - CKKW matrix element matching;
  - The multi-scale shower;
  - MC@NLO;
  - The Nason approach to MC@NLO.

Four Jet Angles with ME+PS matching

Preliminary results from our ME+PS implementation (CKKW adopted to our parton shower).



$e^+e^- \to$ jets done. Matching for hadronic processes under way. [Simon Plätzer, Diploma Thesis, Karlsruhe]

Summary

- We have made a lot of progress in the last year.
- Herwig++ is now ready for hadron collisions.
- Following this first release for hadron collisions further improvements will now be easier and happen faster.