Status of Herwig++

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SG, A. Ribon, M. H. Seymour, P. Stephens and B. Webber, JHEP **0402** (2004) 005 [hep-ph/0311208]

SG, D. Grellscheid, A. Ribon, P. Richardson, M.H. Seymour, P. Stephens, B.R. Webber hep-ph/0602069

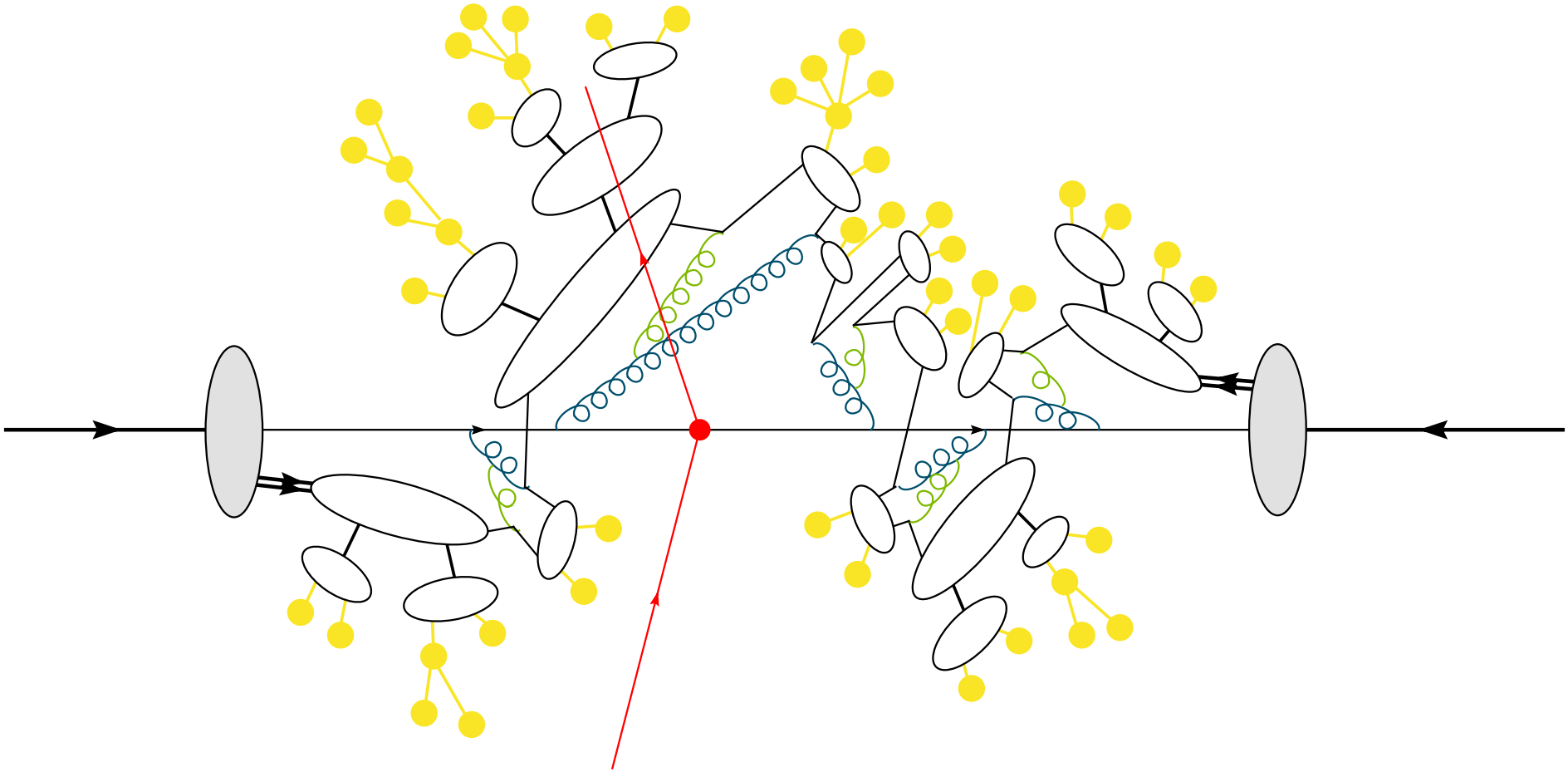
`http://hepforge.cedar.ac.uk/herwig/`

Who and where we are

- Cambridge
  - Bryan Webber, Seyi Latunde–Dada*
- CERN
  - Mike Seymour, Alberto Ribon
- Durham
  - Peter Richardson, David Grellscheid•, Keith Hamilton•, Martyn Gigg*, Jonathon Tully*
- Karlsruhe
  - SG, Manuel Bähr*, Simon Plätzer*
- Kraków
  - Phil Stephens•

* PhD Student
• Postdoc ($\leq$3yr contract)

pp Event Generator



A (simplified) picture of what we are talking about.

Hard interactions in Herwig++

Herwig++ will probably never have a very large library of built–in hard matrix elements.

- Basic ME's included in ThePEG, such as:

$$e^+e^- \longrightarrow q\bar{q}, \text{ partonic } 2 \longrightarrow 2.$$

- We provide our own set of basic processeses, currently

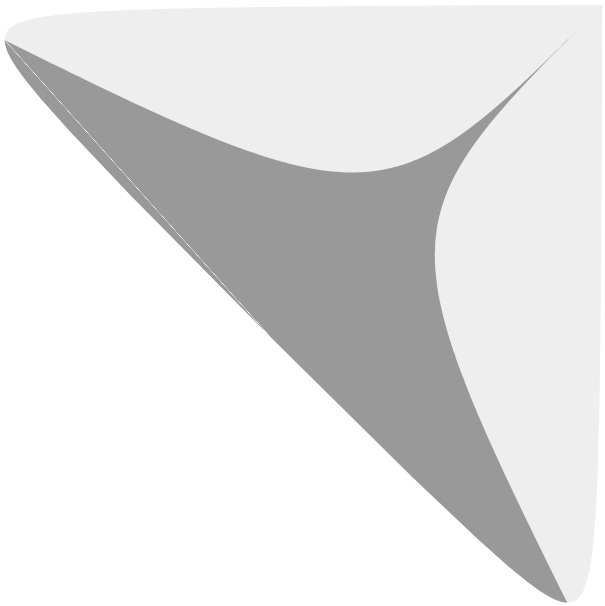
$$e^+e^- \longrightarrow Z^0,\ e^+e^- \longrightarrow q\bar{q},$$
$$\text{QCD } 2 \longrightarrow 2,\ pp \longrightarrow t\bar{t},$$
$$pp \longrightarrow (\gamma, Z^0) \longrightarrow \ell^+\ell^-,\ pp \longrightarrow W^\pm \longrightarrow \ell^\pm\nu_\ell,$$
$$pp \longrightarrow h^0 + \text{jet},\ pp \longrightarrow \gamma + \text{jet},\ pp \longrightarrow \gamma\gamma\ .$$

- LesHouchesFileReader enables to read in and process *any* hard event generated by parton level event generators (MadGraph/MadEvent, AlpGen, CompHEP,...).
- AMEGIC++ will provide arbitrary ME's for multiparton final states via AMEGICInterface.

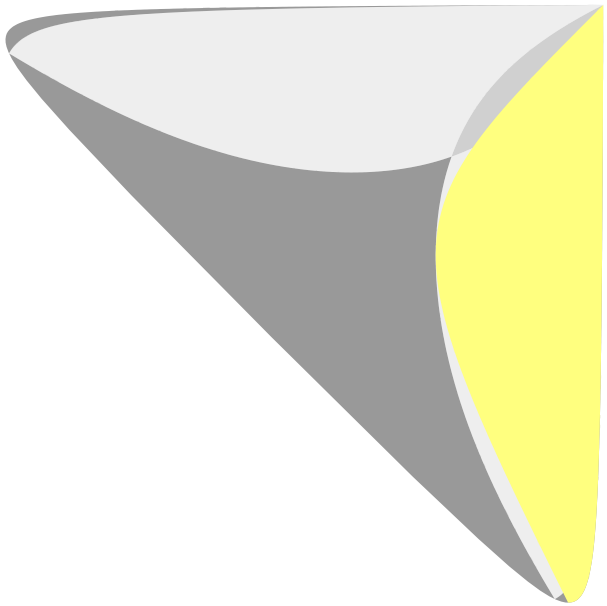
However: HELAS like structures are already implemented for decays and spin correlations $\longrightarrow$ allows us to code simple processes efficiently.

New parton shower variables — HERWIG vs Herwig++

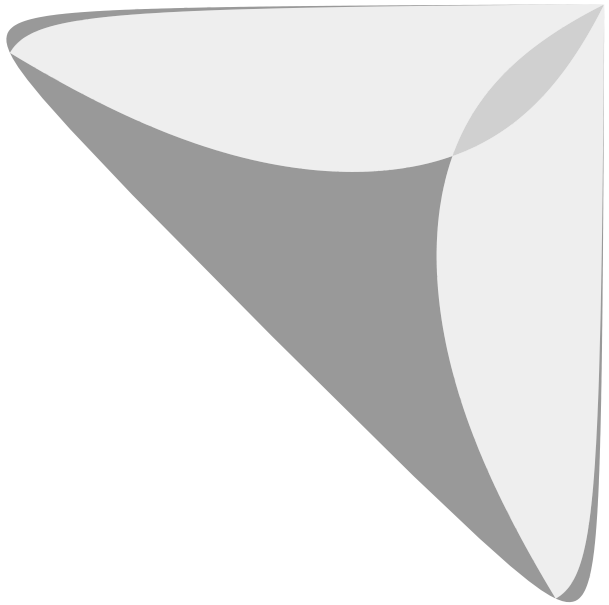
New evolution variables for parton shower evolution in Herwig++ [hep-ph/0311208].
Consider $(x, \bar{x})$ phase space for $e^+e^- \to q\bar{q}g$



Herwig++



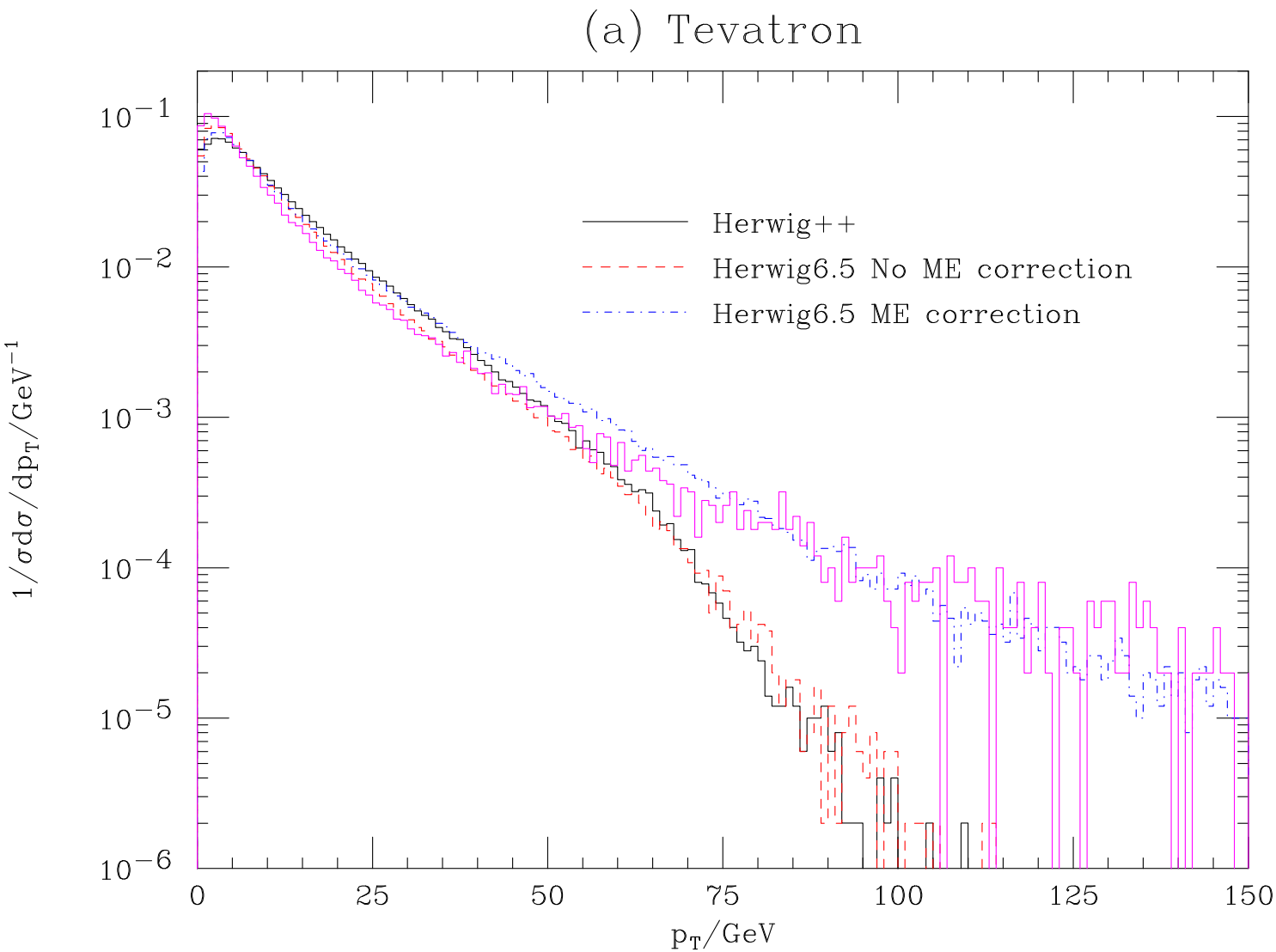
Comparison



HERWIG

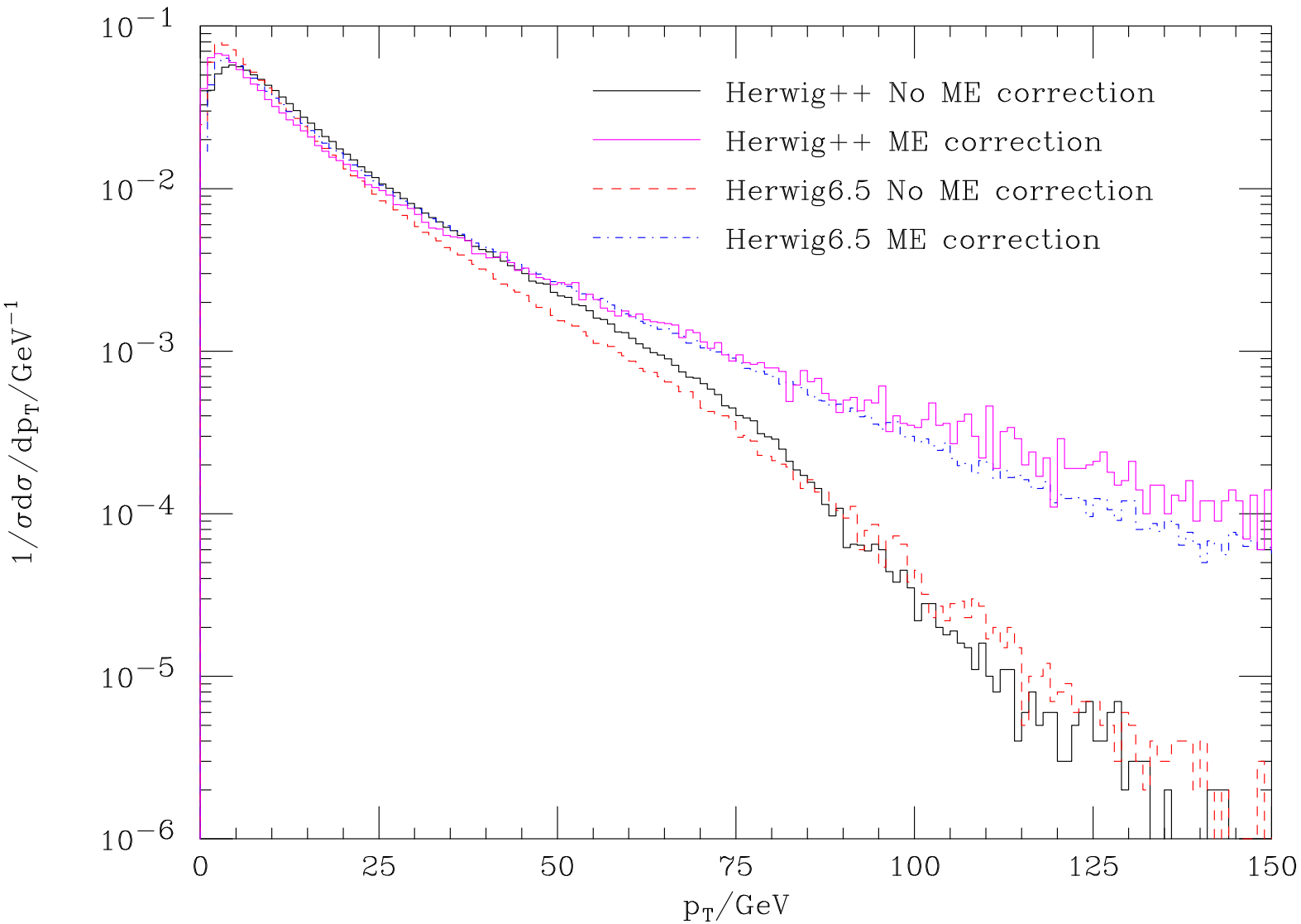
✓ Smooth coverage of soft gluon region.
✓ No overlapping regions in phase space.
✓ Evolution of heavy quarks.

$W^{\pm}$ Boson $p_{\perp}$ distribution (Tevatron)



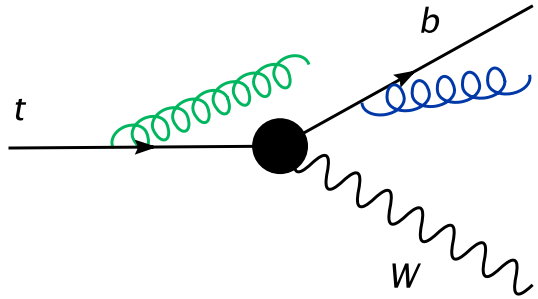
Herwig++ with ME corrections.

Z^0 Boson $p_\perp$ distribution (LHC)

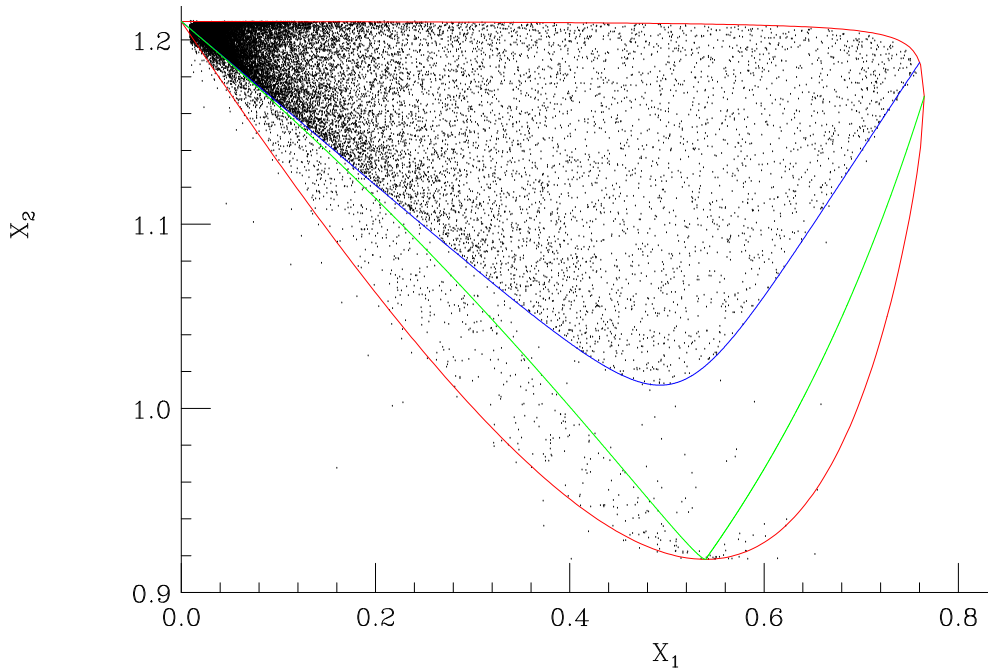


Soft ME Corrections in t Decays

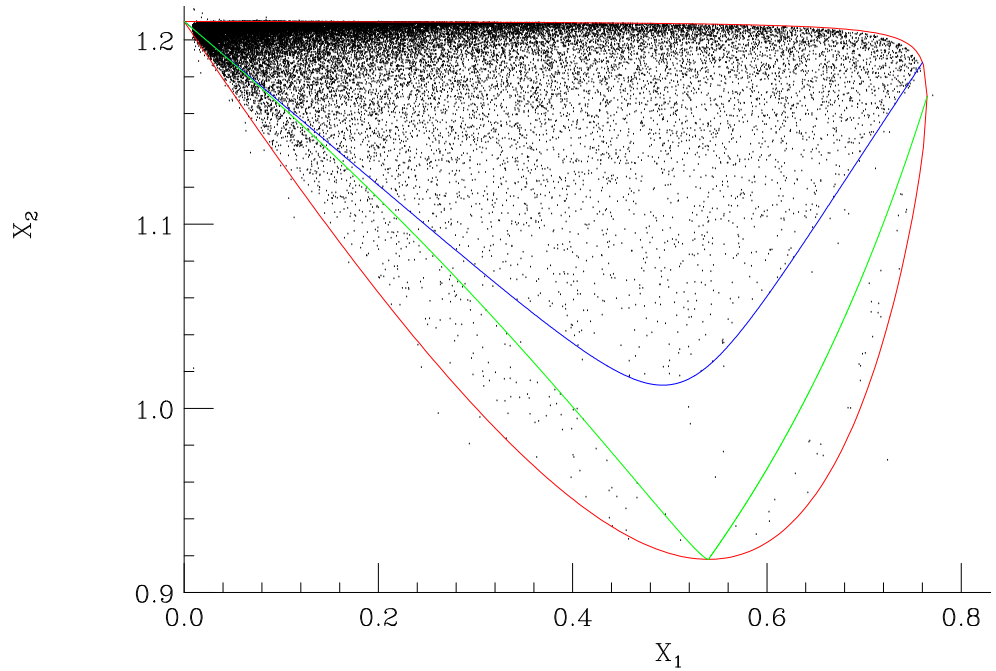
Smooth coverage of soft gluon region from both parton showers. Hard region also filled (not shown here).



$$x_1 = \frac{2q_g \cdot p_t}{m_t^2}\,, \quad x_2 = \frac{2q_W \cdot p_t}{m_t^2}$$



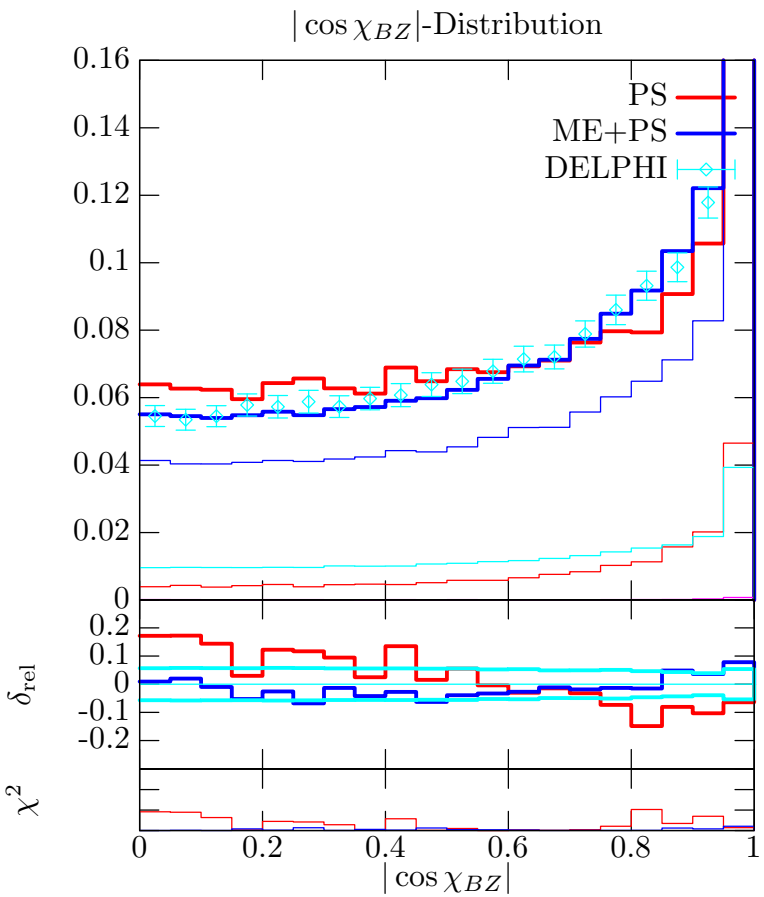
w/o soft ME correction

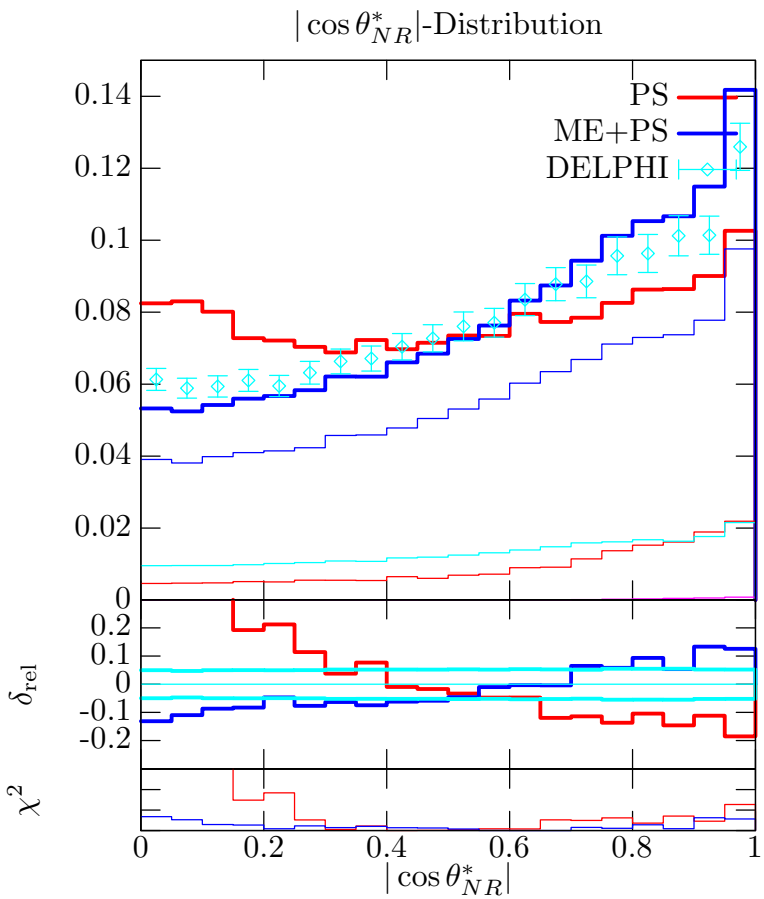


with soft ME correction

Four Jet Angles with ME+PS matching

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

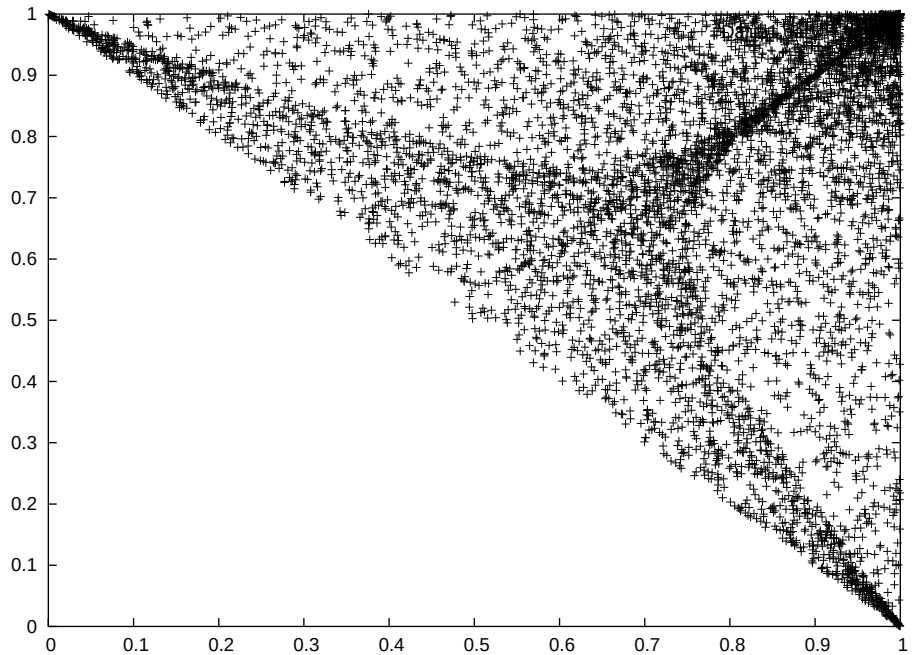


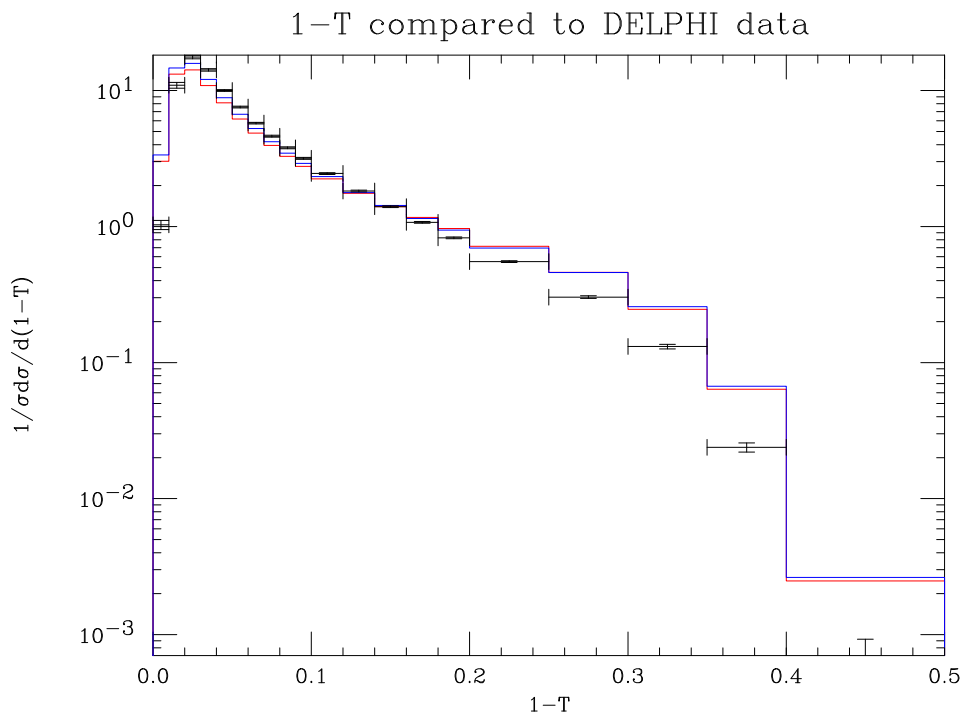


$e^+e^- \longrightarrow$ jets done. Matching for hadronic processes under way. [Simon Plätzer, Diploma Thesis, Karlsruhe]

MC@NLO with Herwig++

Dalitz plot for $e^+e^- \to q\bar{q}g$ events.
Unweighted events in 'dead region' ($w = 1$), counter events ($w = -1$) in shower region.





Results for various events shapes are available. Work for DY under way.
Effect similar to ME correction but histograms normalized to unity (no cross sections).

Cluster hadronization in a nutshell

- Nonperturbative $g \longrightarrow q\bar{q}$ splitting ($q = uds$) isotropically. Here, $m_g \approx 750\,\text{MeV} > 2m_q$.
- Cluster formation, universal spectrum (see below)
- Cluster fission, until

$$M^p < M^p_{\text{max}} + (m_1 + m_2)^p$$

where masses are chosen from

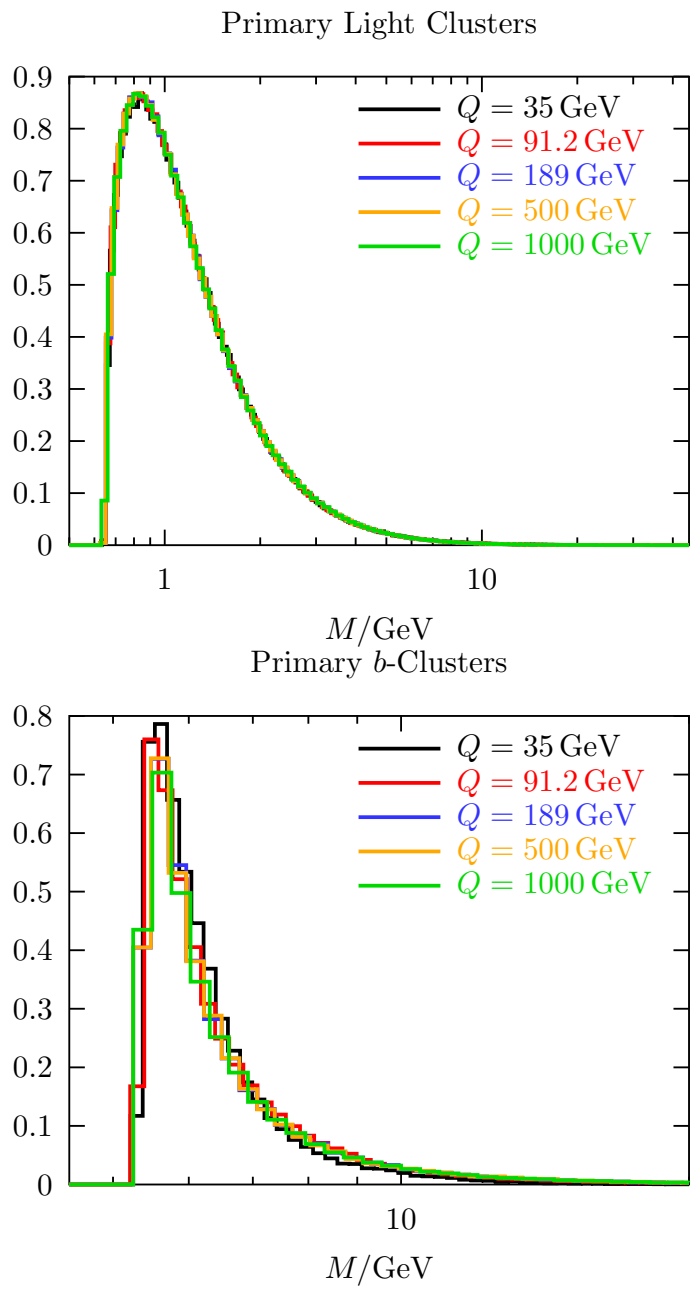
$$M_i = \left[\left(M^P - (m_i + m_3)^P\right) r_i + (m_i + m_3)^P\right]^{1/P},$$

with additional phase space contraints. Constituents keep moving in their original direction.

- Cluster Decay

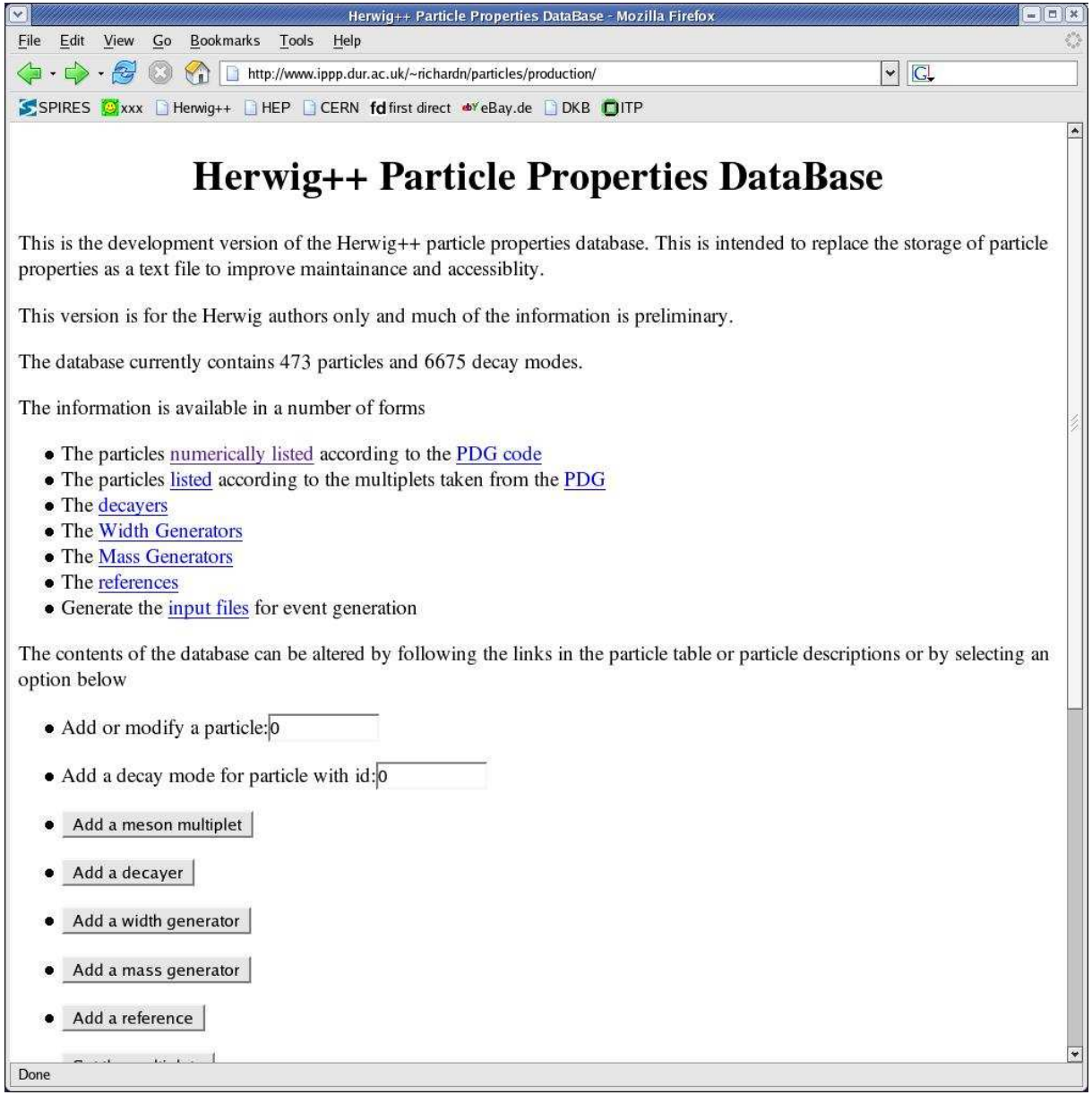
$$P(a_{i,q}, b_{q,j}|i,j) = \frac{W(a_{i,q}, b_{q,j}|i,j)}{\sum_{M/B} W(c_{i,q'}, d_{q',j}|i,j)}.$$

New in Herwig++ Meson/Baryon ratio is parametrized in terms of diquark weight. In HERWIG the sum ran over all possible hadrons.



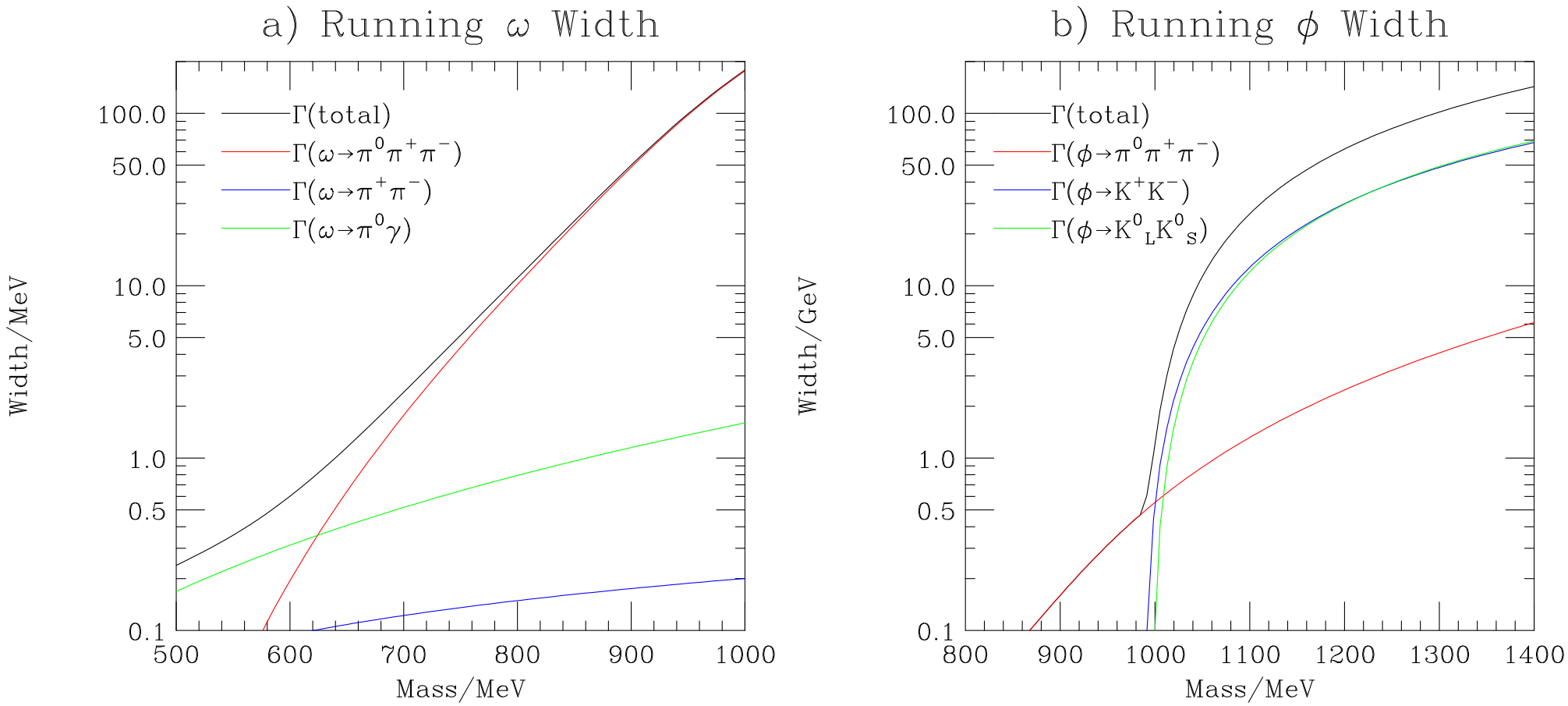
Hadronic Decays

- FORTRAN HERWIG is reproduced with Hw64Decayer using the same Matrix element codes as before.
- *New!* Many new decayers have been developed.
- $\longrightarrow B$ decays.
- Spin correlations included.
- Major effort.
  - a universal database is set up.
  - contains 473 particles and 6675 decay modes at present (at least!).
  - possibility to generate configuration files for different generators.



Running Widths

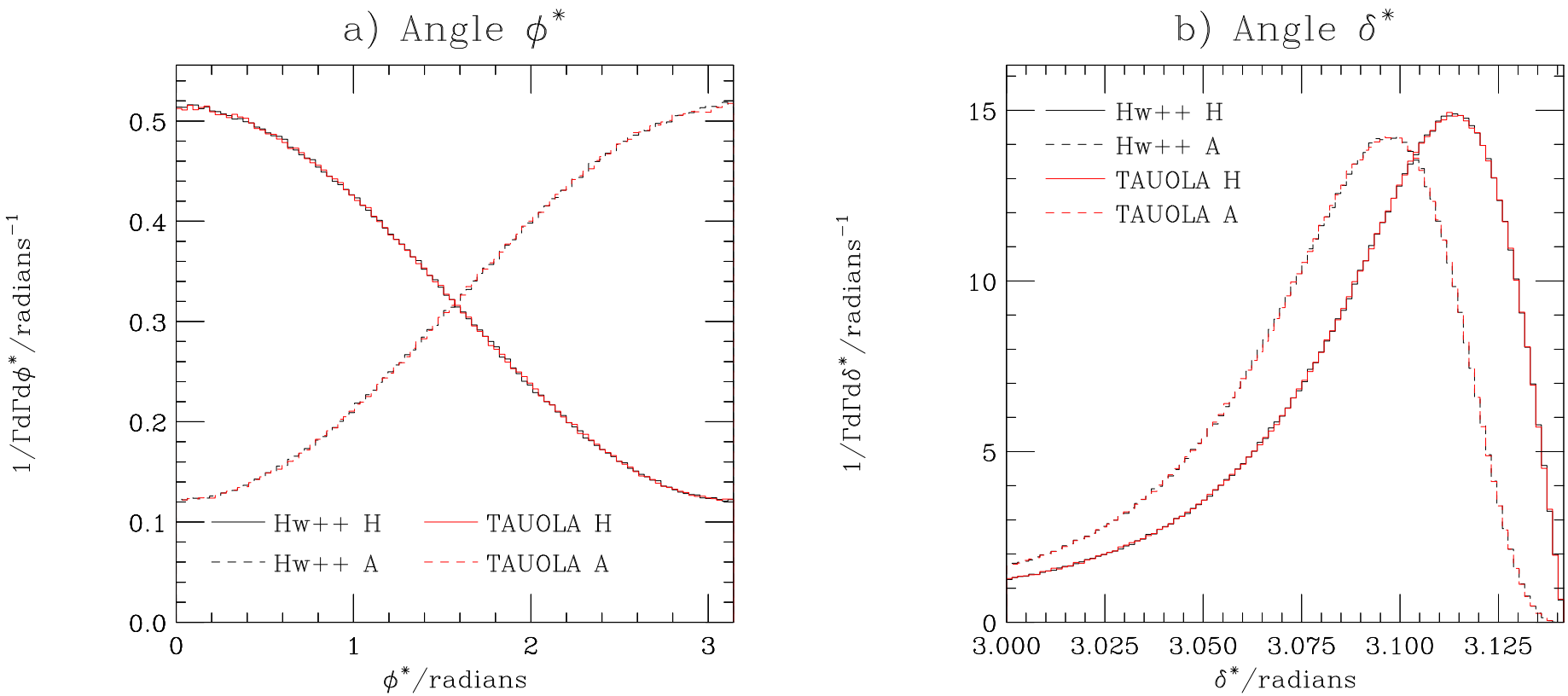
Masses are generated acc to Breit–Wigner like distribution. Subsequent decays will depend on that.



Important for spin correlation algorithm.

Spin Correlations

Use narrow–width approximation for cascade decays. Spin correlations are restored, based upon PR's algorithm.

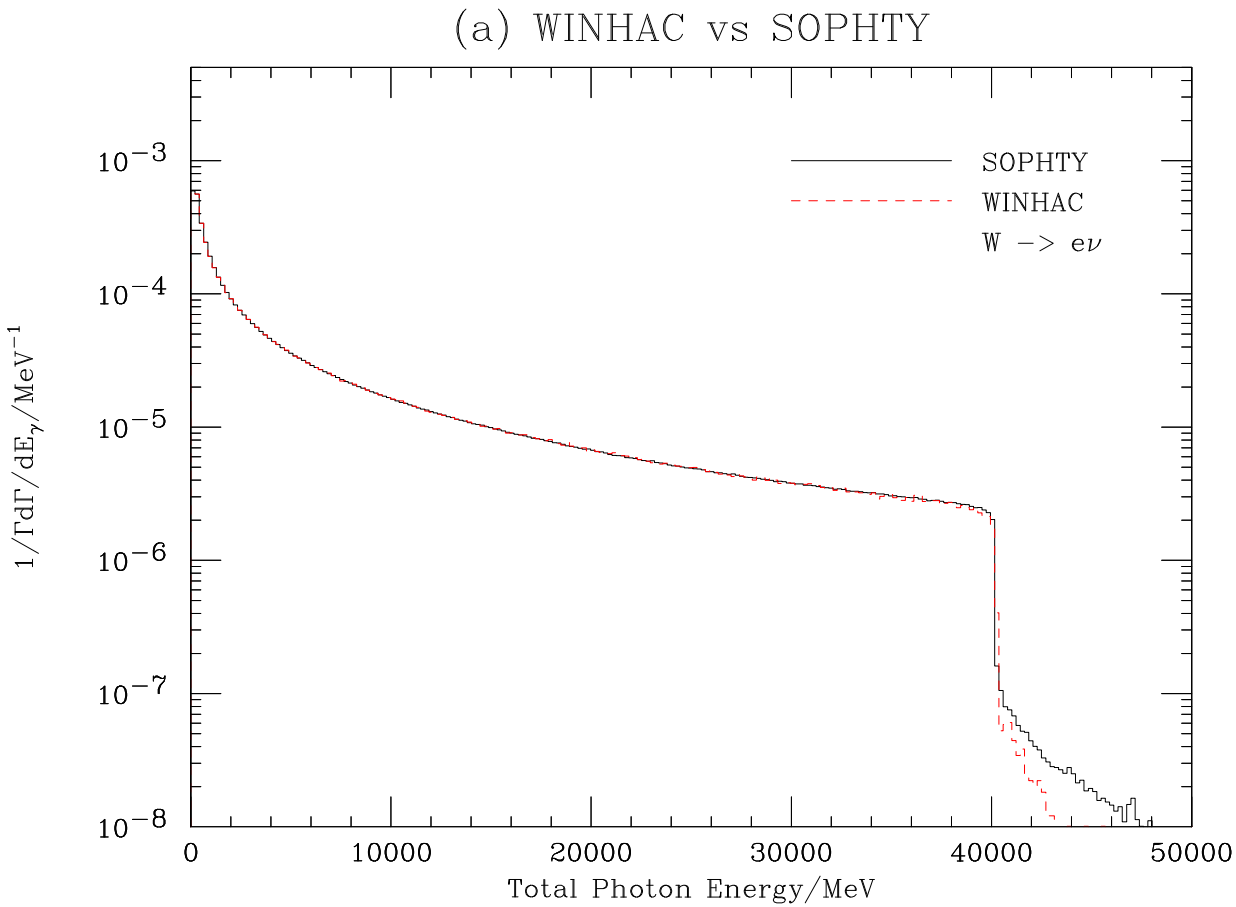


$H, A \to \tau^+\tau^-$, followed by $\tau^\pm \to \pi^\pm\nu_\tau$.

ϕ^* = angle between decay planes of τ's. δ^* = angle between π's in rf of H/A.

Photon Radiation in Decays

New package SOPHTY included in Herwig++. YFS multiple photon radiation with some hard component.



[K. Hamilton, P. Richardson, hep-ph/0603034]

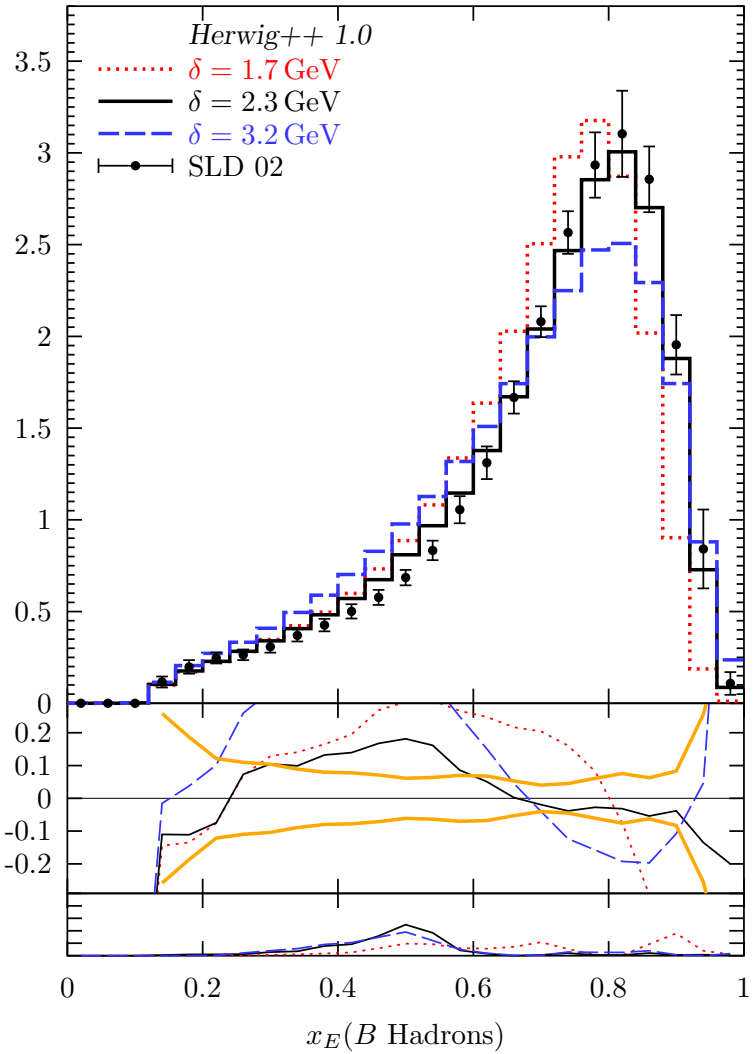
Validation: Herwig++ 1.0

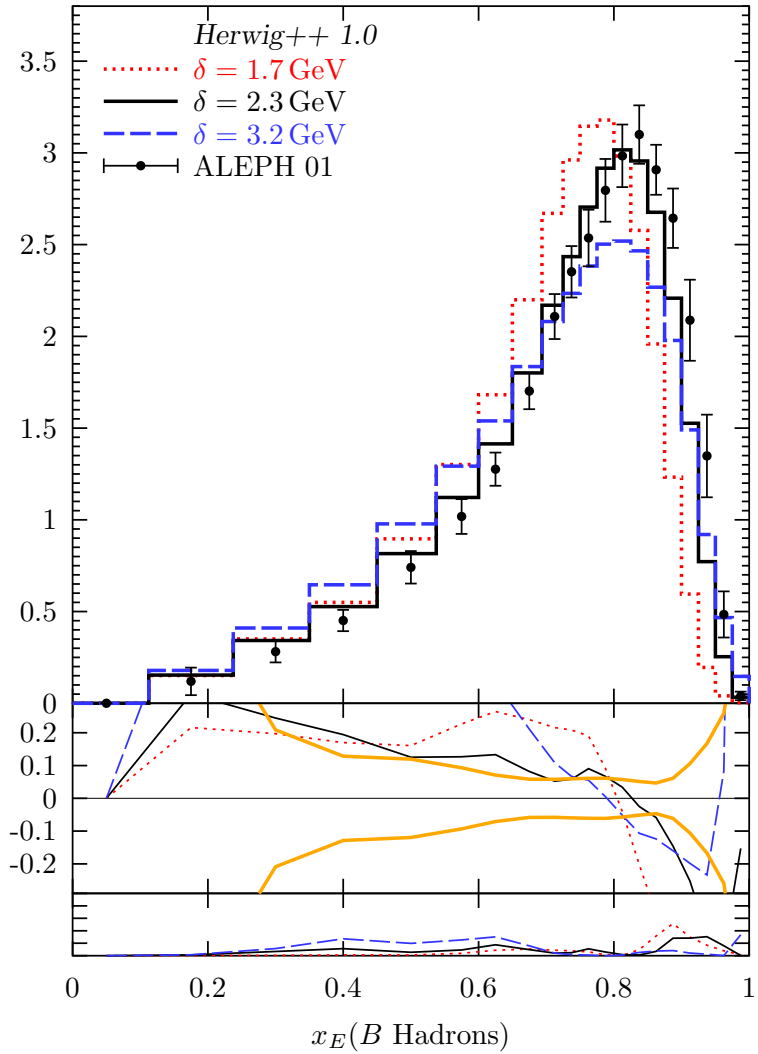
Tested parton shower and hadronization against LEP in great detail [hep-ph/0311208].

- Hadronization against hadron multiplicities. Find some improvements wrt `HERWIG`.
- Single particle distributions $\longrightarrow$ hadronization and shower.
- jets, jets, jets.
- Event shapes.
- B fragmentation funcion (new parton shower).

No global validation against Tevatron data yet! Strategies? $\longrightarrow$ this workshop!

B-fragmentation function



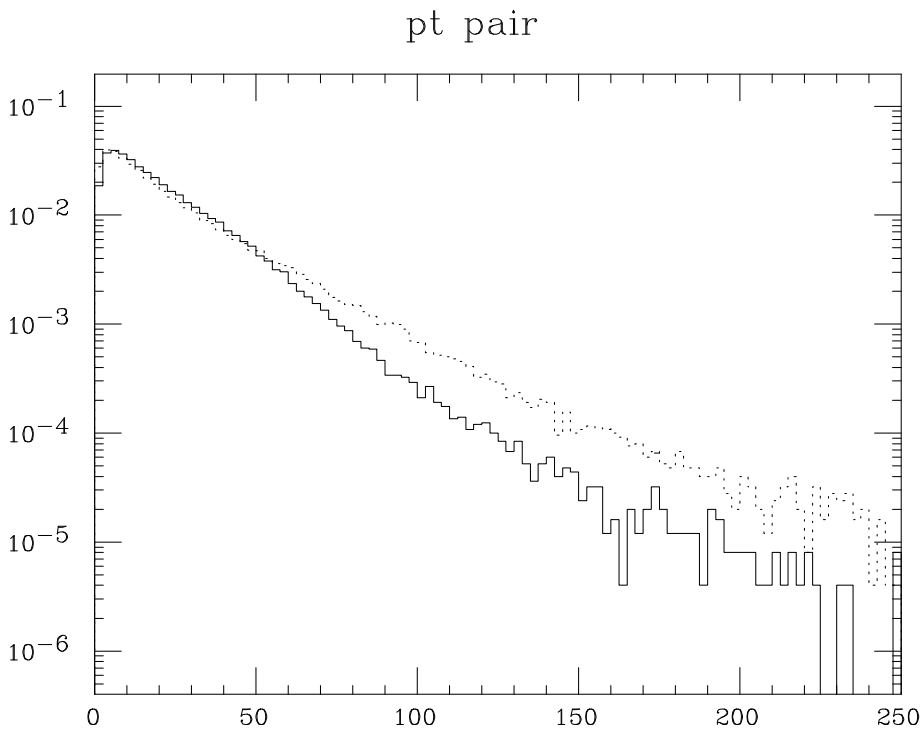


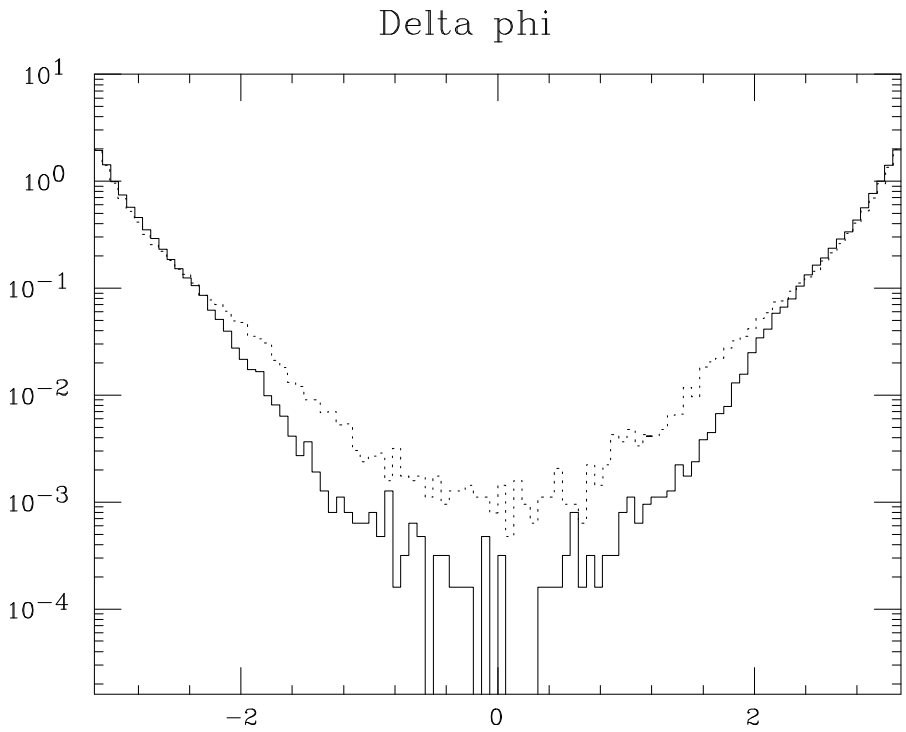
Only parton shower parameters varied

Strong improvement wrt HERWIG, due to new parton shower in Herwig++.

Testing against fHERWIG

Eg γ–pair production. Observables sensitive to shower. $p_\perp/GeV$ of the γ–pair and the azimuthal difference $\Delta\phi$. Very useful cross check.



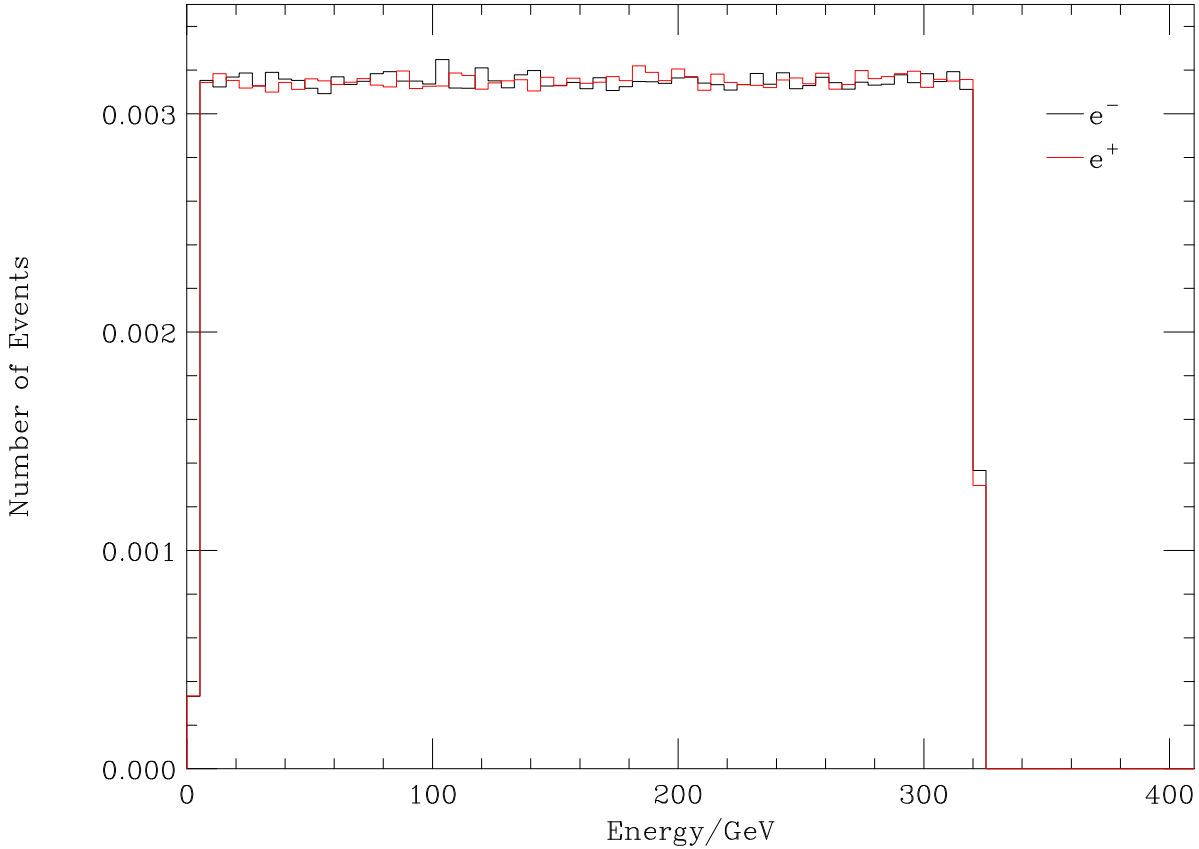


Solid: fHERWIG. Dotted: Herwig++. Herwig++ shower somewhat harder.

This is *only* internal validation. No replacement for validation/tuning efforts by experiments!

SUSY processes

MSSM decays implemented. Some first hard processes as well (e^+e^- and pp).
Example: $e^+e^- \to \tilde{e}_R^+\tilde{e}_R^- \to \chi_1^0\chi_1^0 e^+e^-$ at linear collider. Energy spectra of FS electrons.



[Martyn Gigg]

Currently

Main goal: LHC physics.

In version 2.0β

- $W^{\pm}$, Z^0 production.
- Backward evolution.
- New hadronic decays.

[hep-ph/0602069]

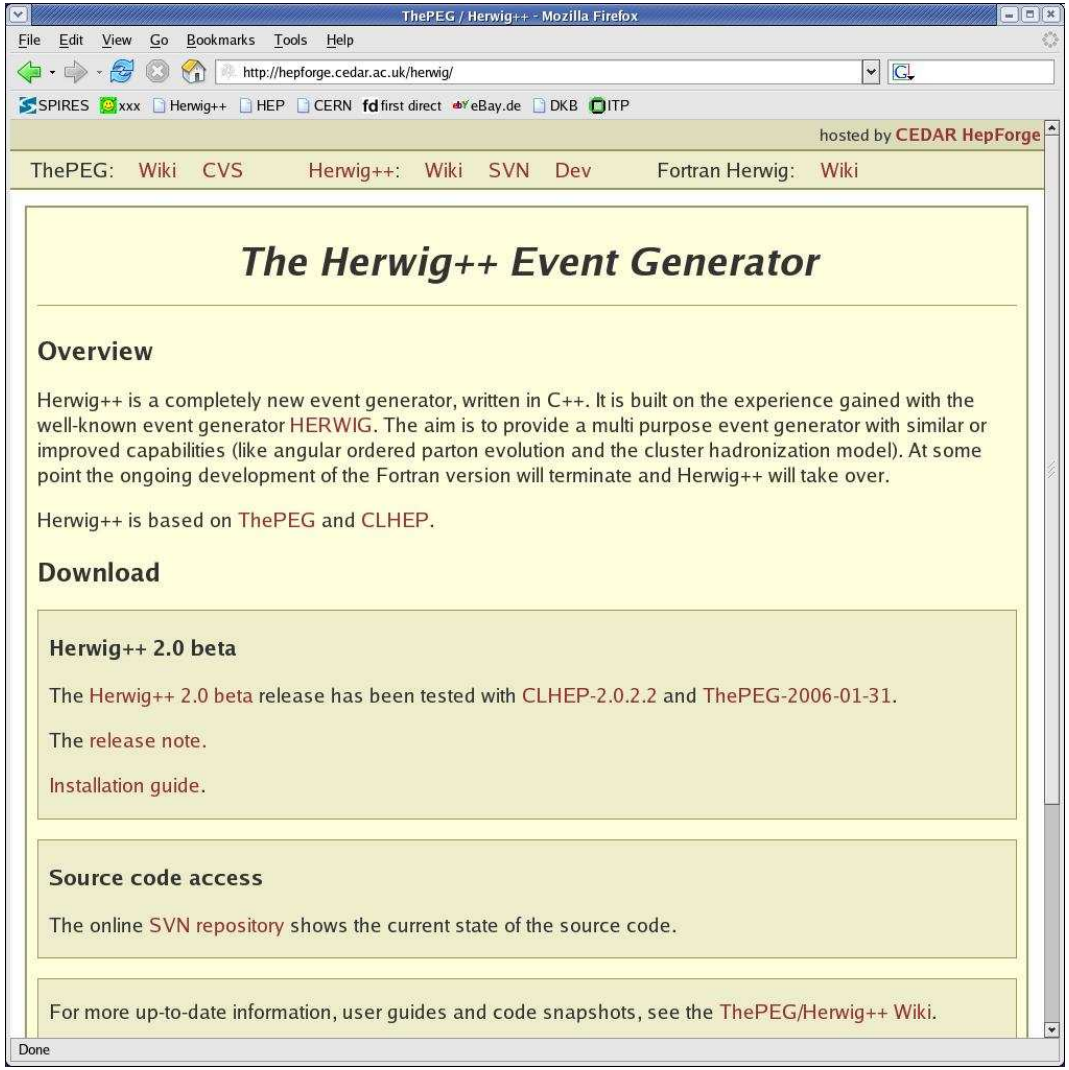
Only available from release of full version 2.0:

- Full timelike showers
- UA5 type underlying event
- Jet production, other hard processes

On `svn` repository. Released soon!

News, Wiki, downloads. . .

http://hepforge.cedar.ac.uk/herwig/



- Need `CLHEP` and `ThePEG`.
- Builds with `autotools`.
- `./configure`, `make`, `make install`.
- Successfully built with `gcc`'s from 3.2.x to 4.1.1.
- Also on OS X.

Summary

- Some useful hard processes available. All the rest as well via LH interface.
- New parton shower working in IS, FS, t–decays, (SUSY particles).
- ME corrections in $e^+e^- \to q\bar{q}g$, DY, t–decay.
- ME+PS matching a la CKKW for $e^+e^- \to \mathrm{jets}$.
- MC@NLO type matching for $e^+e^- \to \mathrm{jets}$.
- pp simulations now possible in Herwig++. Many new features wrt old `HERWIG`.
- Hadronization ready.
- Much improved hadronic decayers.
- Spin correlations.
- Photon radiation in decays.
- First BSM (mostly MSSM) physics included.
- UA5 model for (simple) Underlying Event simulation.

Near Future of Herwig++

- ME+PS matching for hadronic interactions.
- NLO matching(s).
- More sophisticated Underlying event simulation.
- More BSM physics.
- More validation: Tevatron data (HERA photopruduction data?).