

Herwig++ @ higher orders

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– on behalf of the Herwig++ collaboration –



herwig.hepforge.org – release 2.6.x news at [arXiv:1205.4902](https://arxiv.org/abs/1205.4902)

Disclaimer

A survey of recent and ongoing developments in almost every part of the perturbative simulation.

Can't cover all details, but just flash some results.

Will not cover any of the non-perturbative or BSM part, though many improvements are available in 2.6.x.

The title doesn't quite match, but yes we do care about colour coherence ;-)

Outline

NLO matching

- POWHEG matrix elements
- NLO matrix elements for Herwig++
- More showers, more matching, more uncertainties

LO merging

- MLM support
- CKKW with truncated showers

Misc

- Multiscale showering
- First steps towards higher orders in N_c

Summary & plans

POWHEG matrix elements

POWHEG supported since long:

- Handmade, tailored code for several processes.
- Natively integrated with angular ordered shower.
- Featuring full truncated showering.
- Provide ME corrections consistently included in CKKW merging.

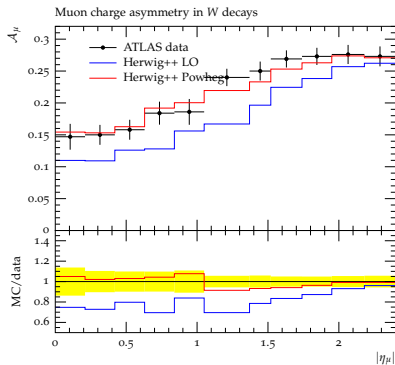
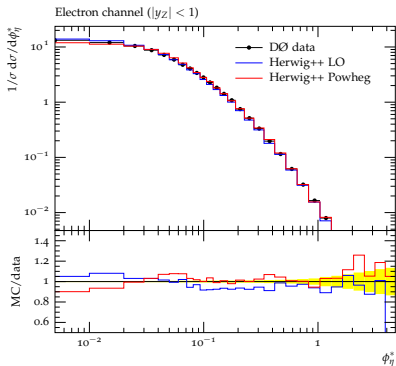
Run as any other built-in matrix element.

A number of processes released or to appear: $ee \rightarrow 2 \text{ jets}$, DIS, $pp \rightarrow (gg, b\bar{b}) \rightarrow H$, $pp \rightarrow Z, W$, $pp \rightarrow ZH, WH$, $pp \rightarrow VV$, $H \rightarrow Q\bar{Q}$, $pp \rightarrow Hjj$ (VBF), $pp \rightarrow \gamma\gamma \dots$

POWHEG matrix elements

[K. Hamilton, J. Tully, P. Richardson – JHEP 0810 (2008) 015]

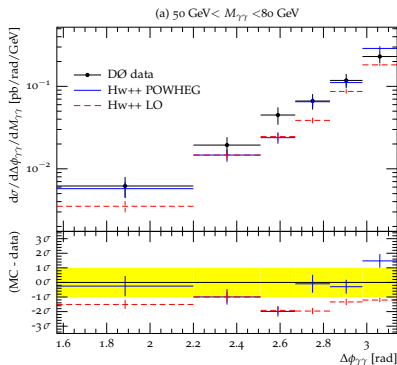
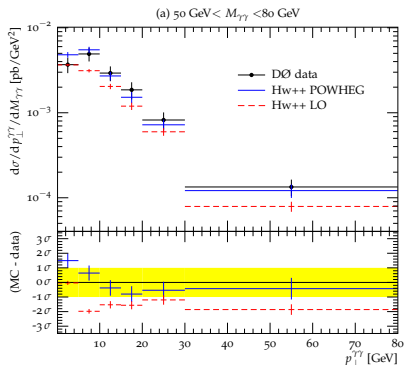
Drell-Yan $pp \rightarrow Z \rightarrow l^+l^-$ at Tevatron Run II, $pp \rightarrow W \rightarrow l\bar{\nu}$ at LHC 7 TeV



POWHEG matrix elements

[L. D'Errico, P. Richardson – JHEP 1202 (2012) 130]

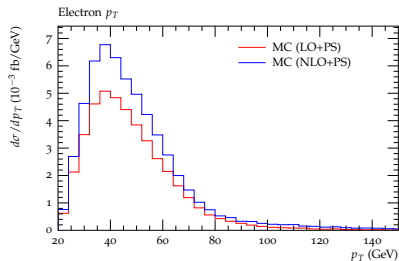
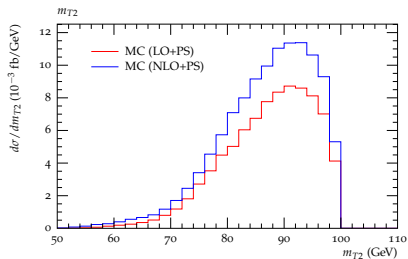
$pp \rightarrow \gamma\gamma$ at Tevatron Run II



POWHEG matrix elements

[I. Fridman Rojas, P. Richardson – arXiv:1208.0279]

$pp \rightarrow \tilde{e}\tilde{e}$ in a simplified model at LHC 8 TeV



(N)LO matrix elements for Herwig++

[SP, S. Gieseke – Eur.Phys.J. C72 (2012) 2187 + work in progress]

Matchbox provides a framework to automatically assemble NLO calculations.
Serves as basis for automated NLO matching and merging.

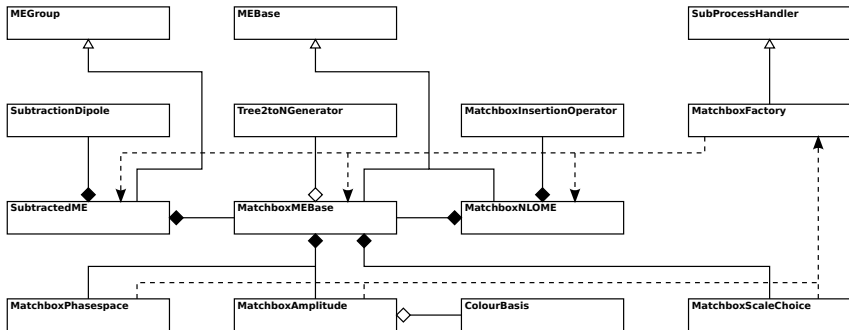
- Automated dipole subtraction.
- Multi-channel phasespace generation.
- Interface external codes at amplitude or $|\mathcal{M}|^2$ level.
- Steering just as plain Herwig++.

Many sideband developments:

More flexible cuts, scale choices, process and diagram generation, ...

No separate codes to run, no intermediate event files.

Matchbox internals



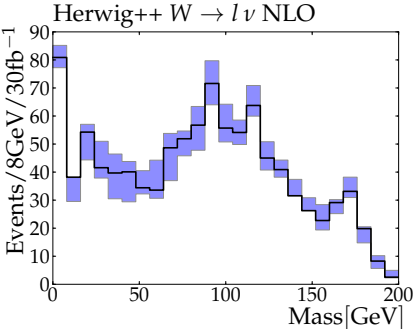
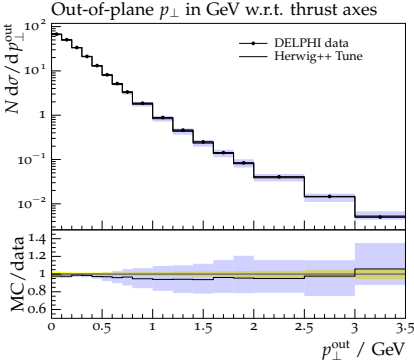
Functionality validated for a range of colliders and processes.

More showers, more matching, more uncertainties.

[P. Richardson, D.E. Winn – arXiv:1207.0380]

Eigentunes for Herwig++ similar to PDF error sets.

Investigate impact on jet substructure analysis (including $H \rightarrow b\bar{b}$ POWHEG).



More showers, more matching, more uncertainties.

[SP, S. Gieseke – JHEP 1101 (2011) 024 & Eur.Phys.J. C72 (2012) 2187]

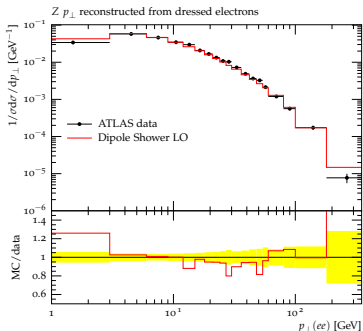
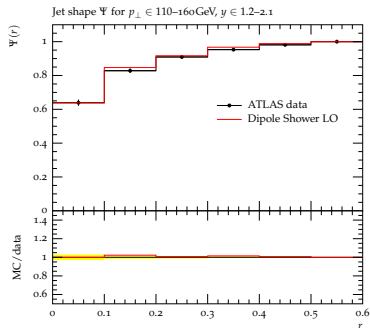
Recently introduced a new dipole-type shower.

- Alternative to check systematics.
- Built-in support for scale variations: μ_R, μ_F, μ_H .
- Eases NLO matching.
- Basis for colour matrix element corrections.

Preliminary tunes available in 2.6.x, need more sophisticated tuning.

More showers, more matching, more uncertainties.

Jets and DY at LHC 7 TeV (no dedicated tune yet)



More showers, more matching, more uncertainties.

Matchbox can perform POWHEG or MC@NLO-type matching to the dipole shower.

- Built-in support for scale variations.
- Uses adaptive sampling of Sudakov-type distributions. [SP – Eur.Phys.J. C72 (2012) 1929]
- Colour matrix element corrections will provide subleading- N_c exact matching.

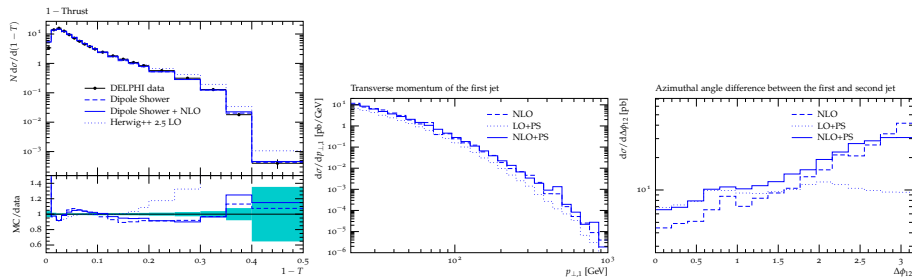
More general ShowerApproximation plugin in preparation.

Matchbox proof of concept.

[SP, S. Gieseke – Eur.Phys.J. C72 (2012) 2187]

Simple e^+e^- /DIS/DY and Z +jet.

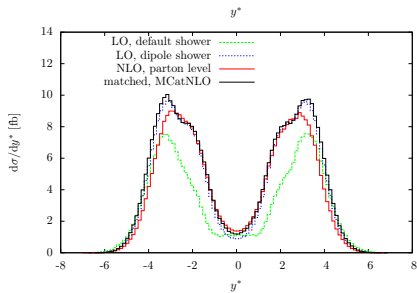
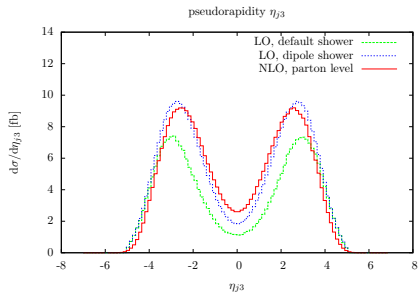
Different tunes for LO and NLO simulations.



Examples: LEP 1 thrust, Z plus one jet at LHC 7 TeV.

VBF Higgs production with Matchbox + VBFNLO.

[K. Arnold, S. Gieseke, SP – work in progress]



LHC 8 TeV with VBF selection cuts.

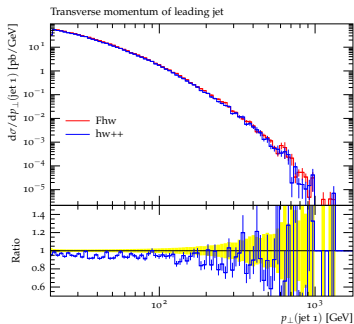
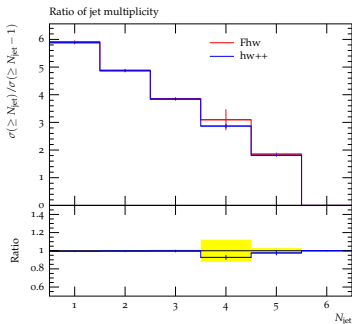
MLM support.

Implementation of ALPGEN interface and MLM support.

Good agreement with `fHERWIG` implementation for all tested processes.

Further validation to come.

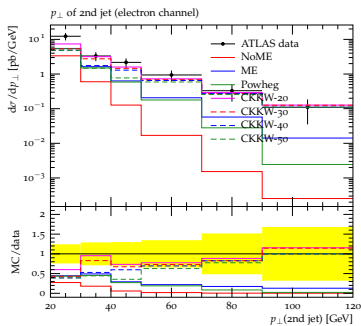
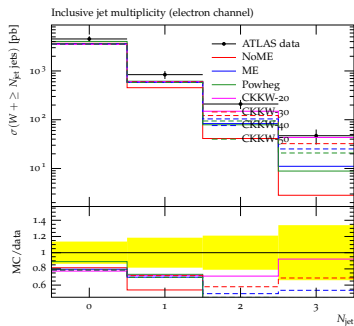
[K. Hamilton, A. Papaefstathiou – arXiv:1205.4902]



CKKW merging.

Modified CKKW merging with full truncated showering.

[K. Hamilton, P. Richardson, J. Tully – JHEP 0911 (2009) 038]



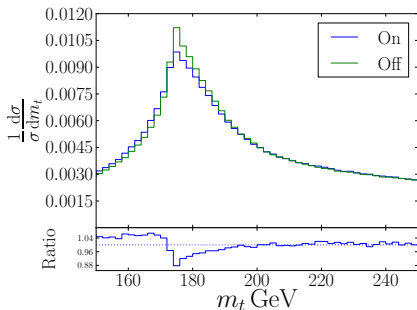
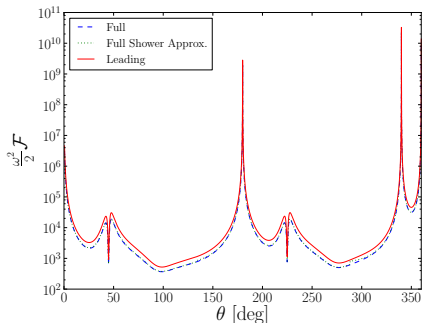
ATLAS W +jets at 7 TeV

Multiscale showering.

Improve shower algorithm for soft gluons in multi-scale problems.

Particularly relevant in decays of heavy coloured particles (masses, widths, IR cutoff).

[P. Richardson, D.E. Winn – in preparation]



Double gluon emission pattern in $gg \rightarrow t\bar{t}$ and impact of correction on the top mass.

First steps towards higher orders in N_c .

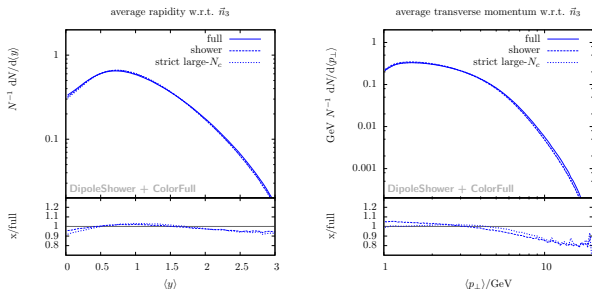
Include virtual colour rearranging terms in shower evolution.

Studied for gaps between jets.

[A. Schofield, M. Seymour – JHEP 1201 (2012) 078]

Correct single emission pattern by full colour correlations.

'Colour matrix element corrections' first studied for LEP. [SP, M. Sjödal – JHEP 1207 (2012) 042]



Relative orientation of soft particles to hard three-jet system very sensitive.

Summary & plans.

Lots of finished and ongoing development in every corner of the perturbative stage.

+ Many improvements in non-perturbative and BSM bits, not covered here.

- Release as far as possible (if not done yet), particularly merging and matching.
- Activities on uncertainties and (N)LO merging ongoing, stay tuned.

Next round of major improvements (2.7.x) expected around easter 2013.

We're well on our way towards Herwig++ 3.0 \equiv Herwig 7, marking the end of fHerwig.

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