Herwig++ Development '13 - '16

Simon Plätzer – for the Herwig team

IPPP, Department of Physics, Durham University &
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at the
MCnet Network Meeting| CERN, 24 November 2016

The team over the years

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Andreas Papaefstathiou
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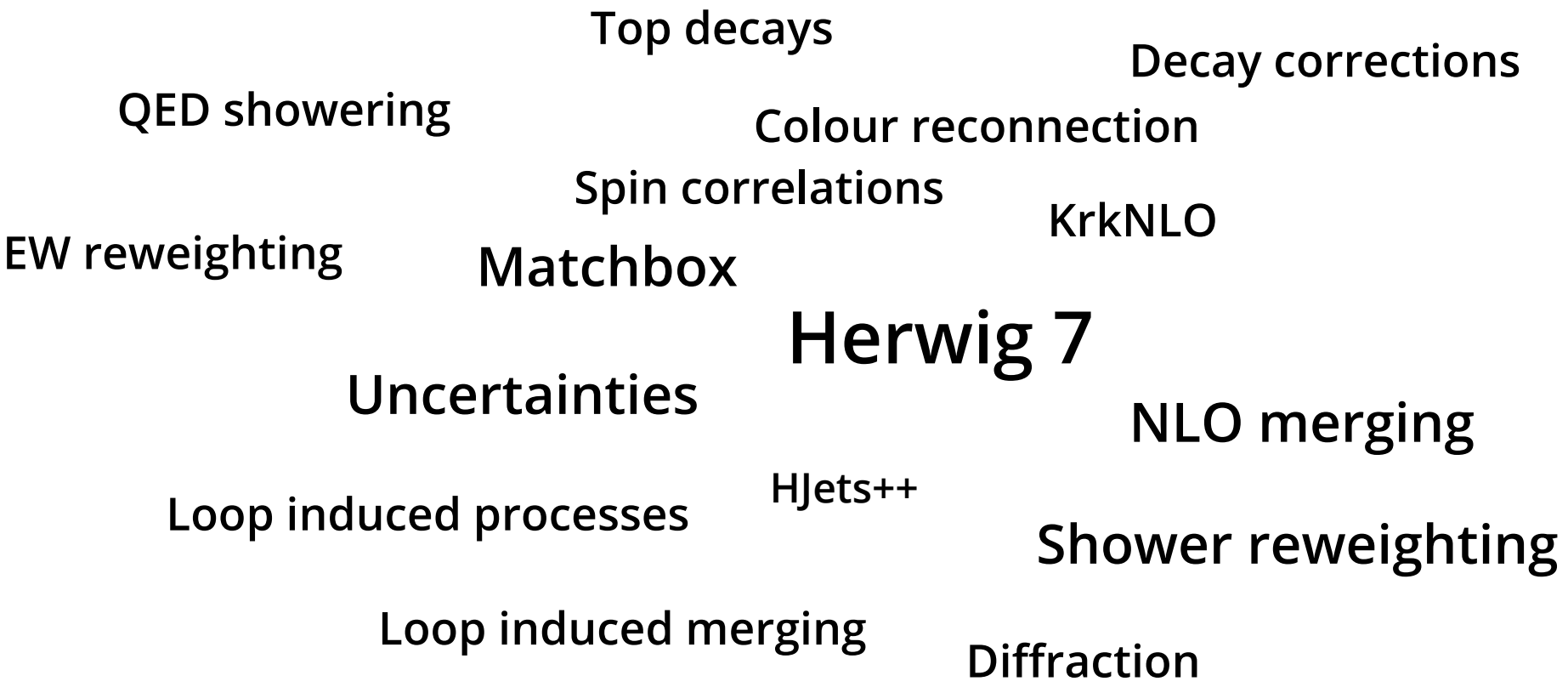
Peter Schichtel
Alex Schofield
Malin Sjödahl
Christian Röhr
Thomas Schuh
Michael Seymour
Andrzej Siodmok
Alix Wilcock
Benjamin Zimmermann

Tag cloud



Impossible to cover everything in 20 minutes, just a small selection.

The Herwig Event Generator

Herwig++ has seen a ten-year development to meet a milestone intended to succeed the FORTRAN HERWIG program.

This milestone evolved over time as the experimental and phenomenological needs did.

On top of its first definition (= at least as good as HERWIG), **precision has become the key goal**

Herwig++ 3.0 → Herwig 7.0

Herwig 7 – Core Features

[Bellm, Gieseke, Grellscheid, Plätzer, M. Rauch, Reuschle, Richardson, Schichtel, Seymour, Siodmok, Wilcock, Fischer, Harrendorf, Nail, Papaefstathiou, D. Rauch – EPJ C 76 (2016) 196]

NLO matched to parton showers as default for the hard process.

→ Fully automated, only linking external codes to calculate amplitudes.
→ Run in a single program, no event files to move around.
→ Subtractive (MC@NLO-type) and multiplicative (POWHEG-type) matching.

Two showers: Angular-ordered and dipole shower.

Spin correlations and QED radiation in angular ordered shower.

Facilities for **parton shower uncertainties.**
Improved kinematics reconstruction.

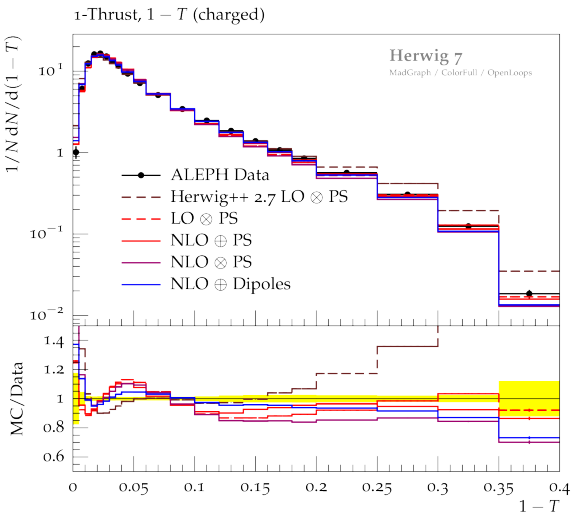
Vastly improved documentation, usage and installation.

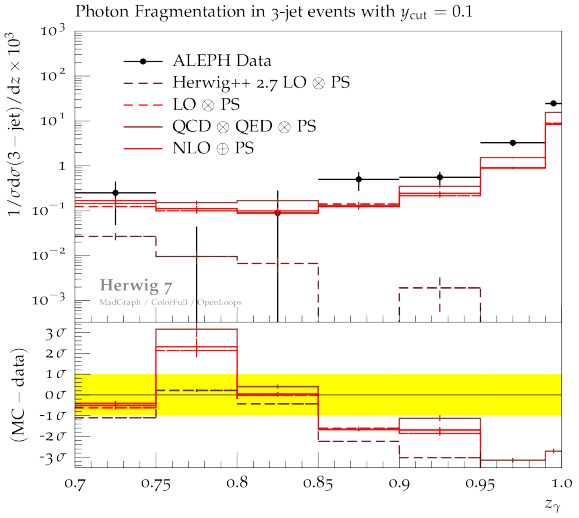
New tunes taking NLO matching into account + much, much more …

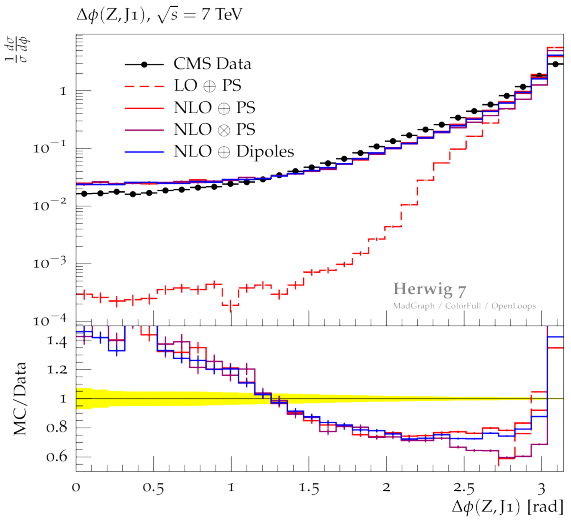
Herwig 7 – Sample Results

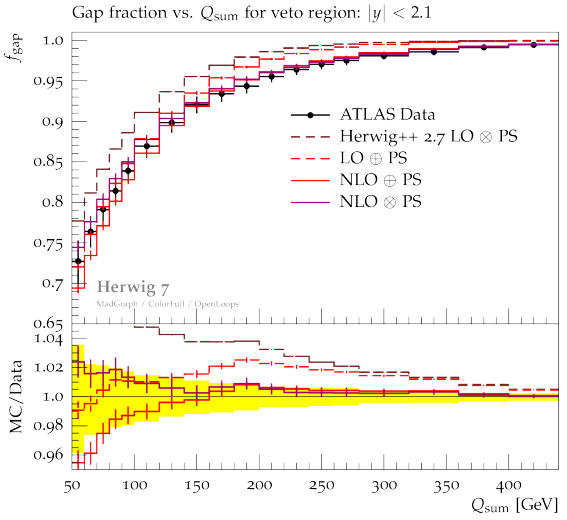
[amplitudes built-in or from MG5aMC and OpenLoops]

From LEP …







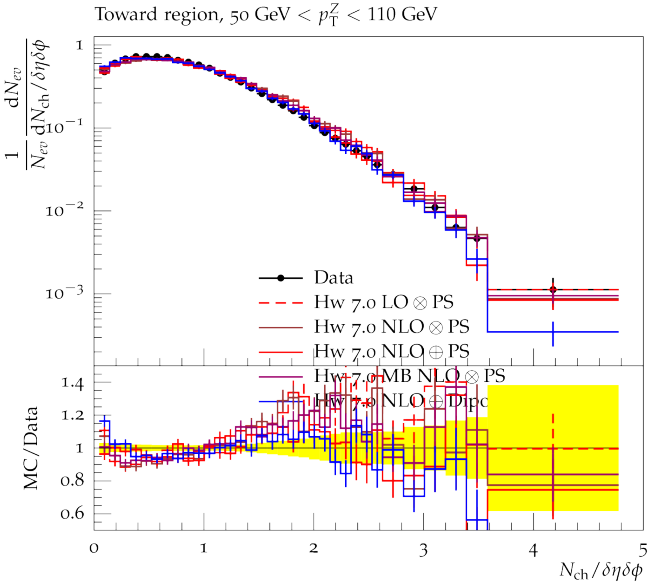


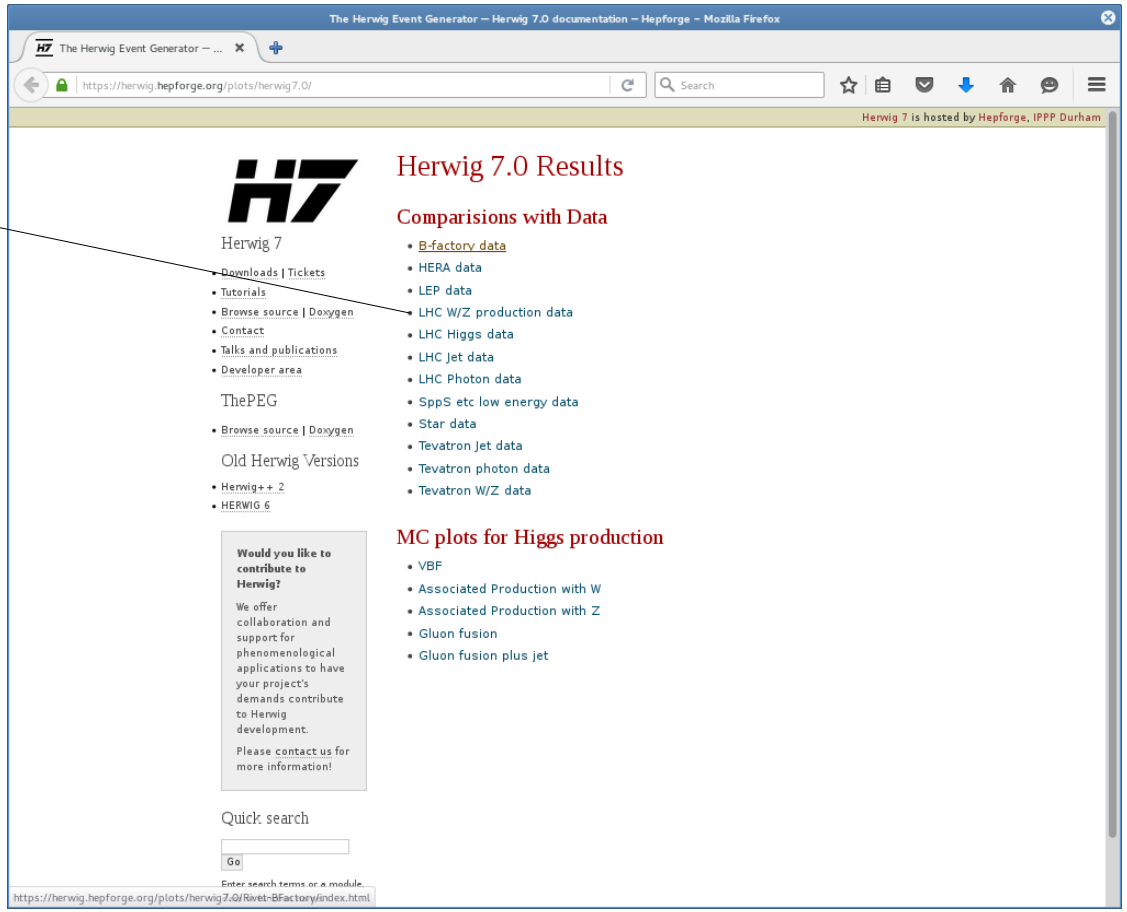
… to LHC.

Herwig 7 – Extensive Validation against Data

[amplitudes built-in or from MG5aMC and OpenLoops]

Routinely run all available Rivet analyses.
All processes simulated at NLO using the available options.
Stability and data description crucial for release quality standards.

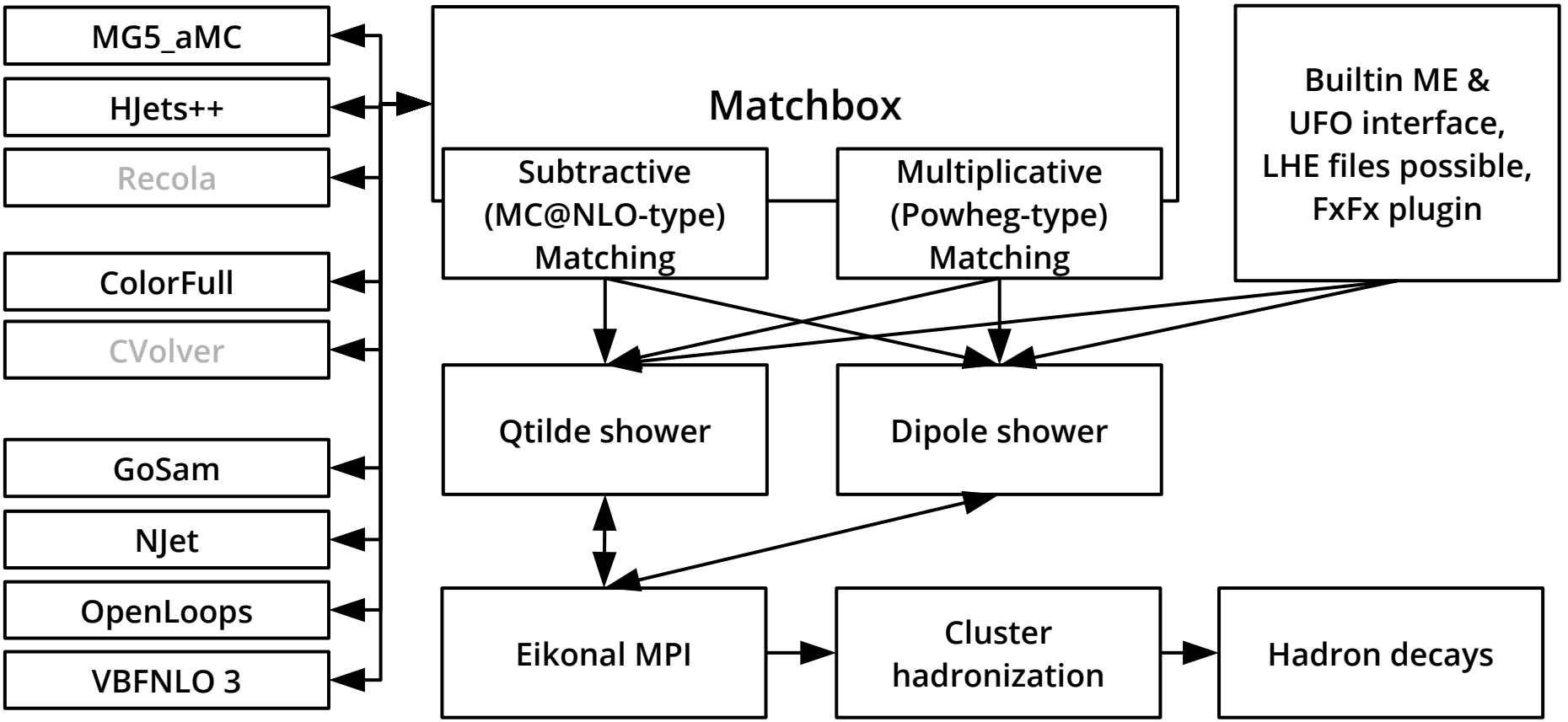




Technology

Herwig 7 – Under the Hood

Use run-time interfaces to external codes to evaluate amplitudes.
Automatically build up fixed-order or matched NLO cross sections.



Output: HepMC, Rivet, built-in analyses.

Fixed-order Calculations

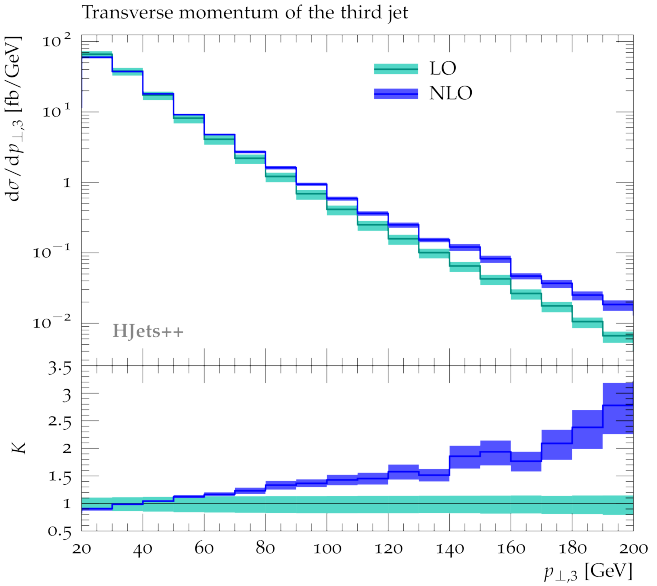
Matrix element input at run time mainly through external libraries.

→ Subprocess bookkeeping internally
→ Automated CS dipole subtraction, including quark masses
→ Several phase space generators and integrators

Flexible **cuts and scale choices**, easy to extend.

Extensive validation e.g. vs MCFM

Performs state of the art calculations, e.g. VBF H + 3 jets



[Campanario, Figy, Plätzer, Sjödahl – Phys.Rev.Lett. 111 (2013) no.21]

Shower reweighting

[Bellm, Plätzer, Richardson, Siodmok, Webster – Phys.Rev. D94 (2016) no.3]

On-the fly shower reweighting available for both shower's scale variations.

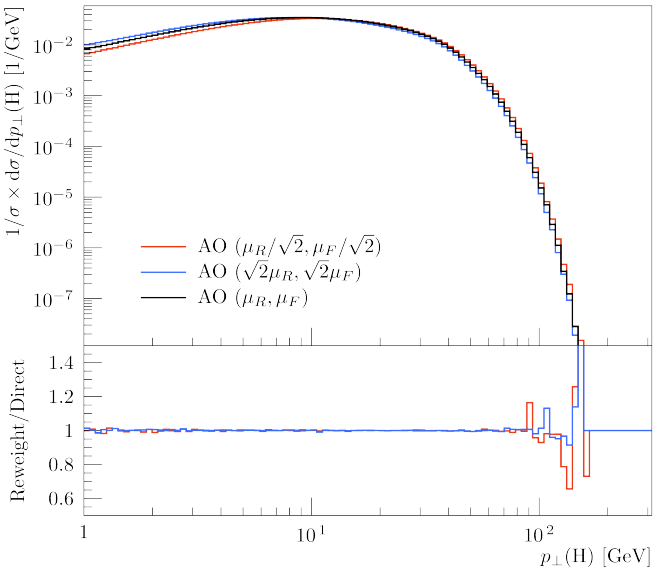
Fills HepMC multi-weight vectors, dedicated validation and performance studied.

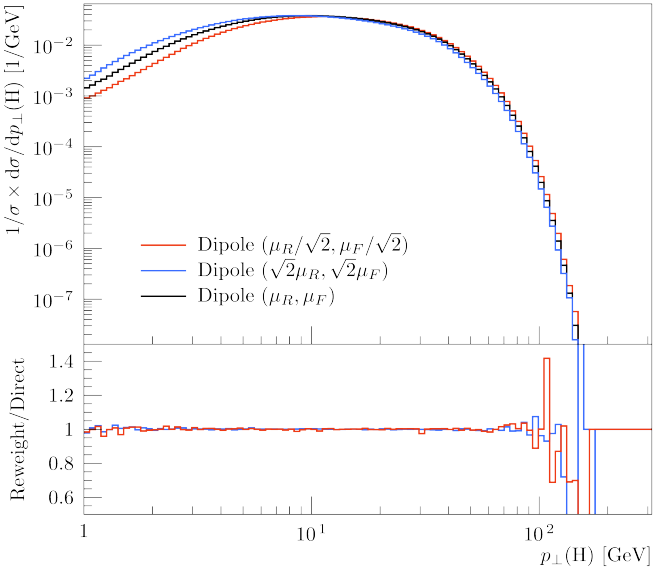
Tested with Rivet 3 beta.

Workhorse:

Weighted version of the “Sudakov veto algorithm” allowing for an unprecedented shower flexibility.

More applications to follow.





Towards Uncertainties

Uncertainty Benchmarks

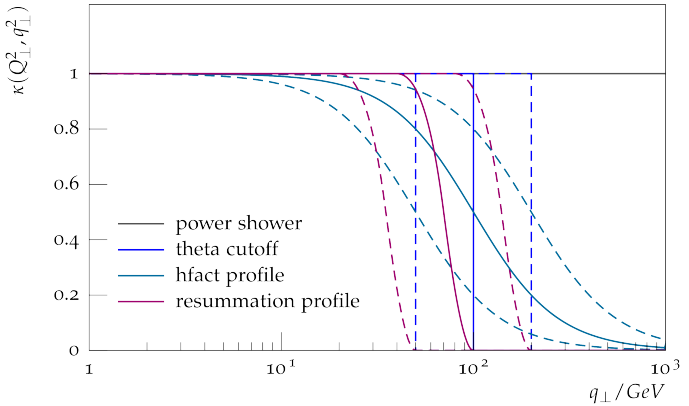
[Bellm, Nail, Plätzer, Schichtel, Siodmok – arXiv:1605.01338, to appear in EPJ C]

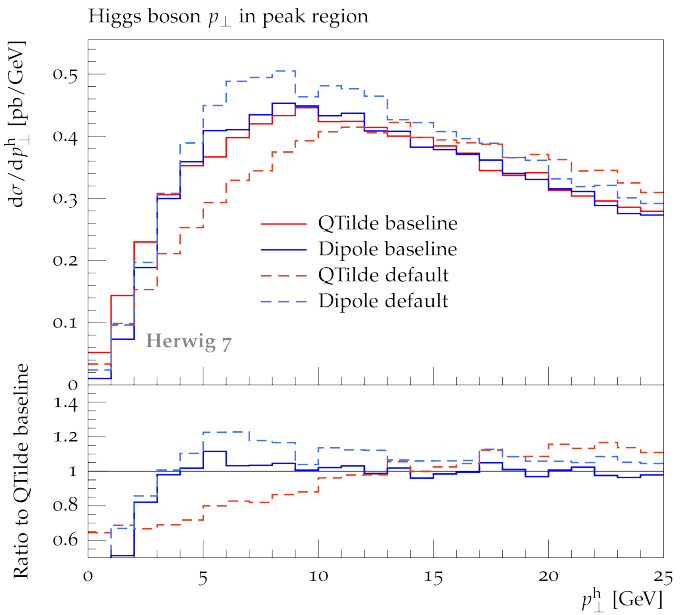
Resummation needs to be cut off at a typical hard scale → veto on hard emissions, region to be filled by matching.

Resummation properties are heavily influenced by the way resummation is being switched off.

Study scale variations in angular ordered and Dipole showers at a benchmark setting where we observe absolutely comparable resummation properties:

Hard veto scales, factorization/renormalization scales in the shower and hard process.





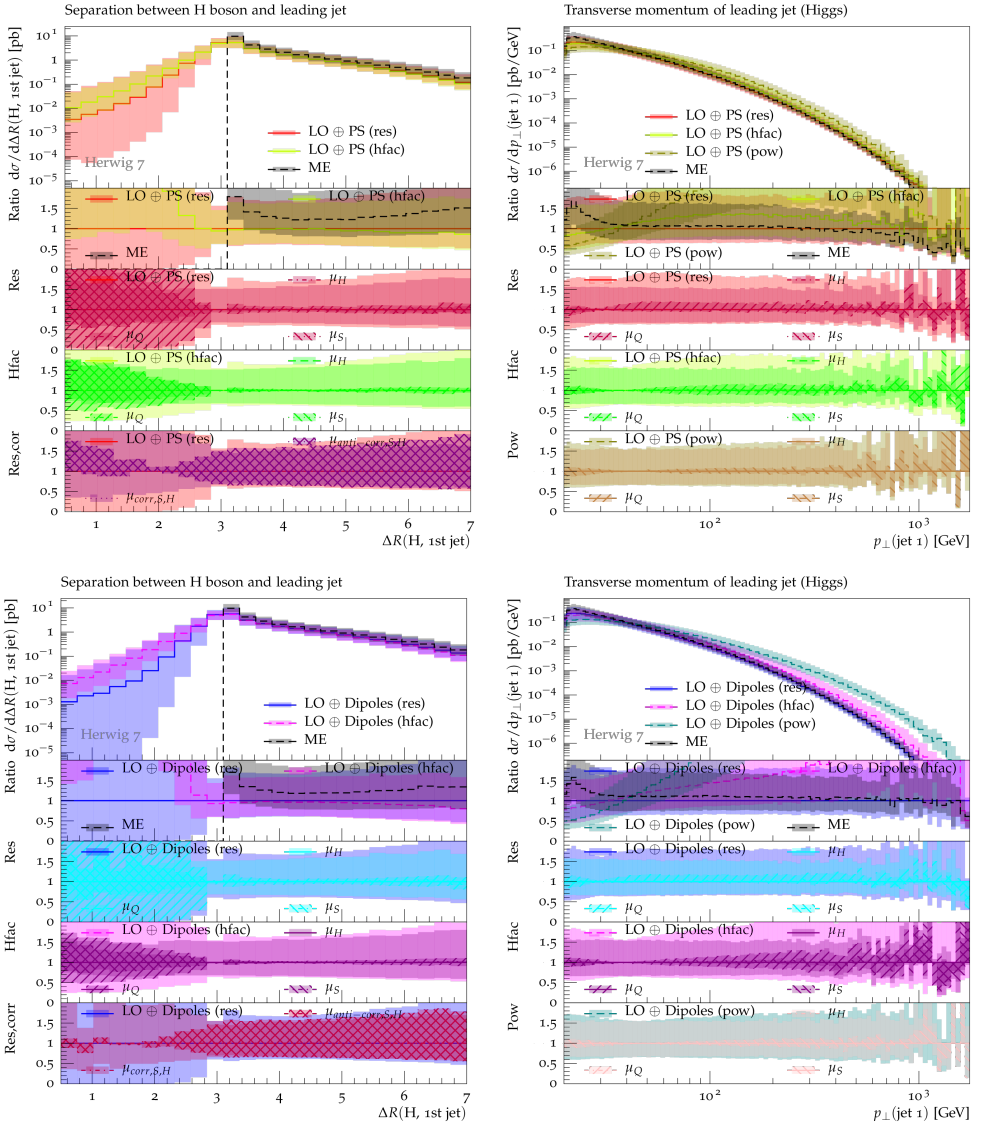
Uncertainty Benchmarks

[Bellm, Nail, Plätzer, Schichtel, Siodmok – arXiv:1605.01338, to appear in EPJ C]

Choice of the hard veto scale is crucial to reproduce hard process input: typically average transverse momenta of hard objects.

Controllable uncertainties can only be established by narrow, smeared versions of a theta function, confirming simple LL arguments.

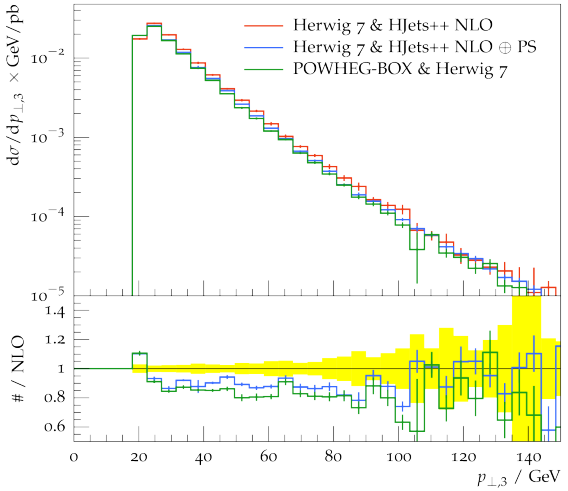
We can now check the impact of higher order improvements.



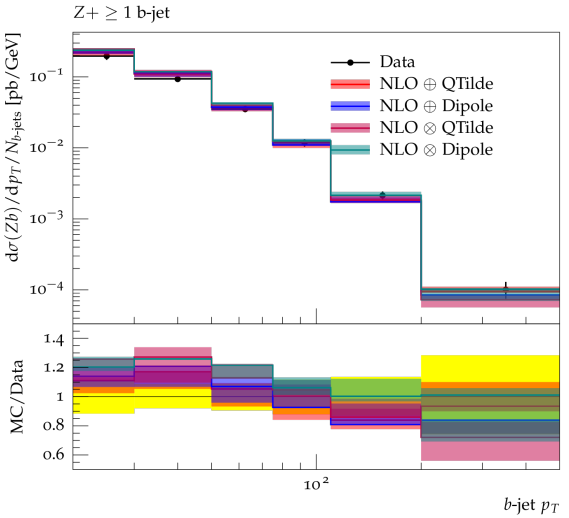
Phenomenology Applications

YR4 and Les Houches Contributions

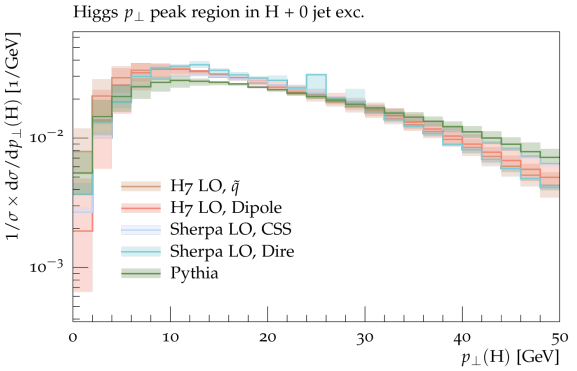
EW H+3jets NLO+PS



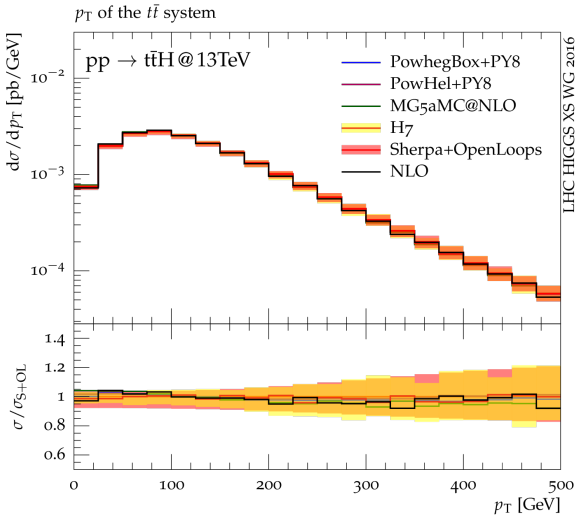
Z+b jets NLO+PS



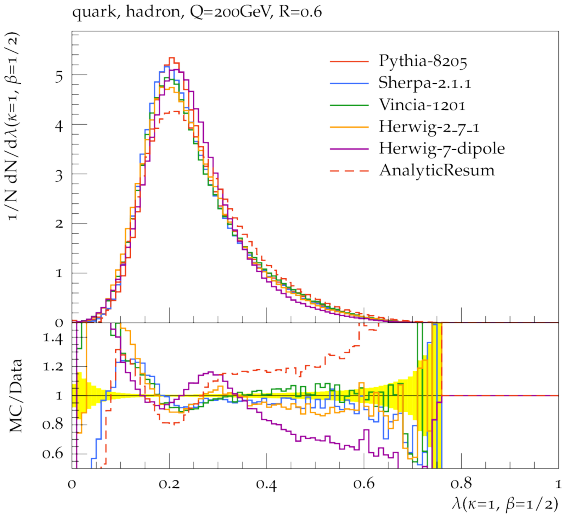
shower uncertainties



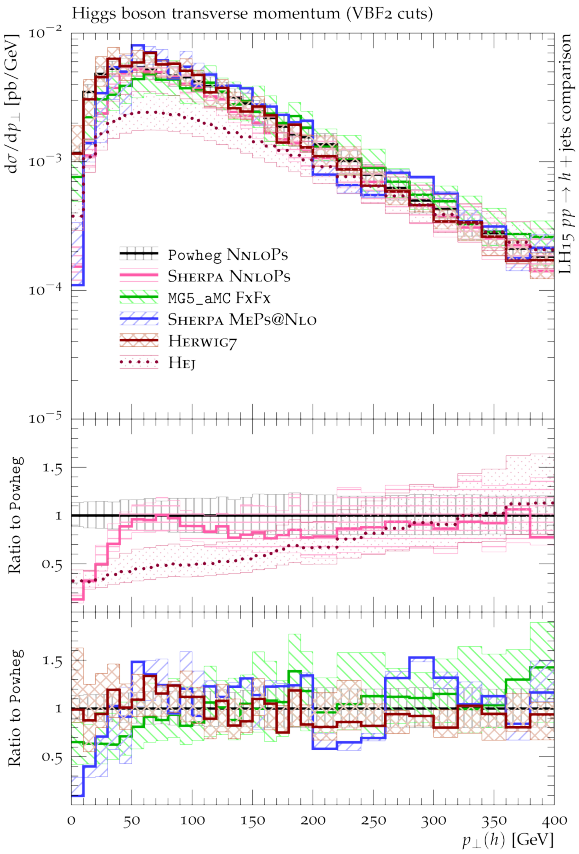
ttH NLO+PS



q/g tagging



ggh NLO merged



(s)tops and squarks

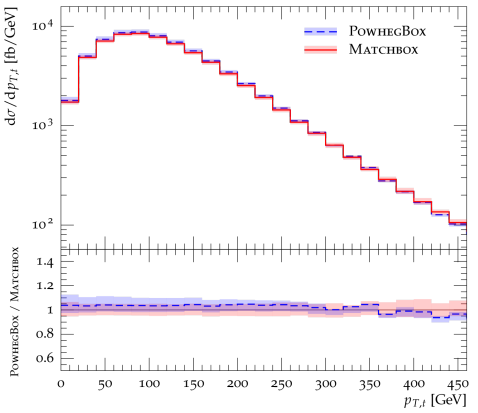
[Wilcock, Plätzer, Richardson – PhD Thesis Wilcock]

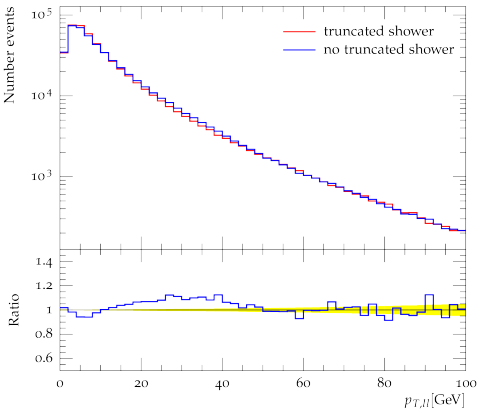
Validation and systematics of Powheg-type matchings in Matchbox.

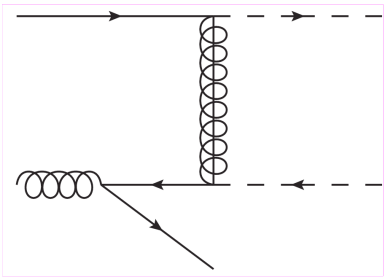
The Herwig 7 setup is unique to address effects of truncated showering for all processes.

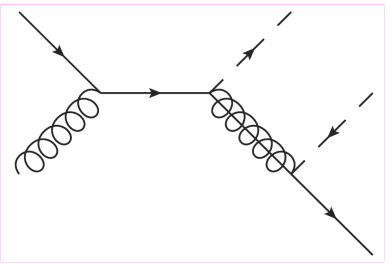
Further application to squark pair production.

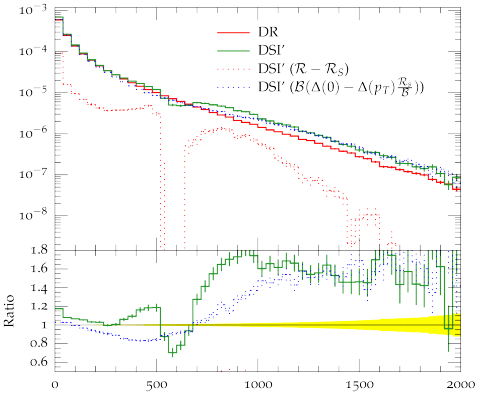
Non-stop production yields resonant contributions in real emission.











WW pairs

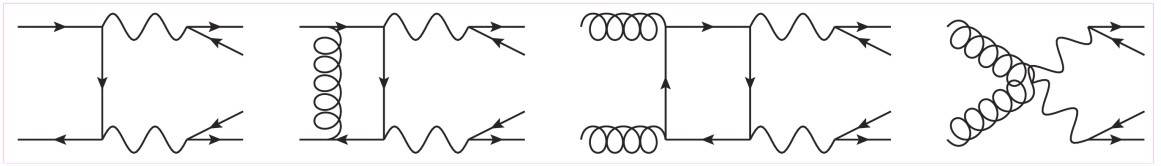
[Bellm, Gieseke, Greiner, Heinrich, Plätzer, Reuschle, v. Soden-Fraunhofen – JHEP 1605 (2016) 106]

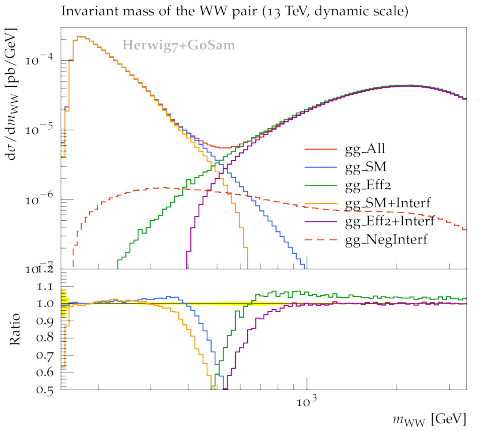
Use Herwig 7 + GoSam to investigate various effects in pp → WW using an improved narrow width approximation.

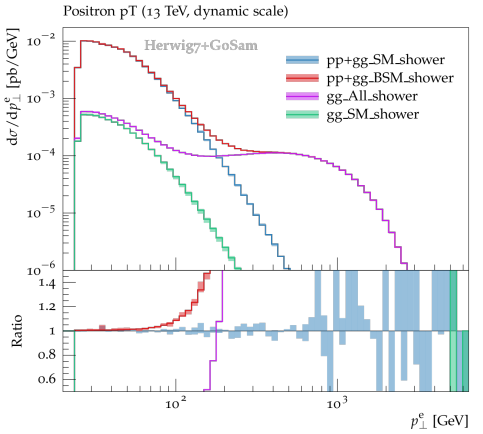
Test of Matchbox's amplitude interfaces for loop-induced processes.

→ Quark initiated channels at NLO
→ Gluon loop induced processes
→ Higher-dimensional operators

All at fixed order and combined with showers, including quantifying the SM/BSM interference.



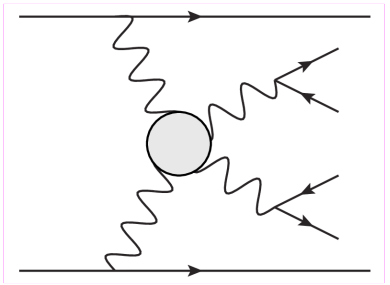


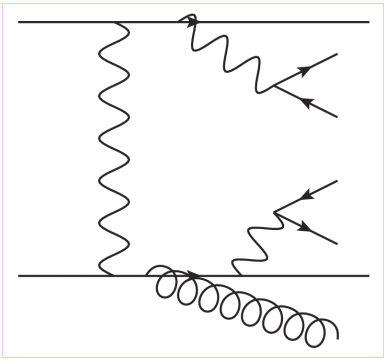


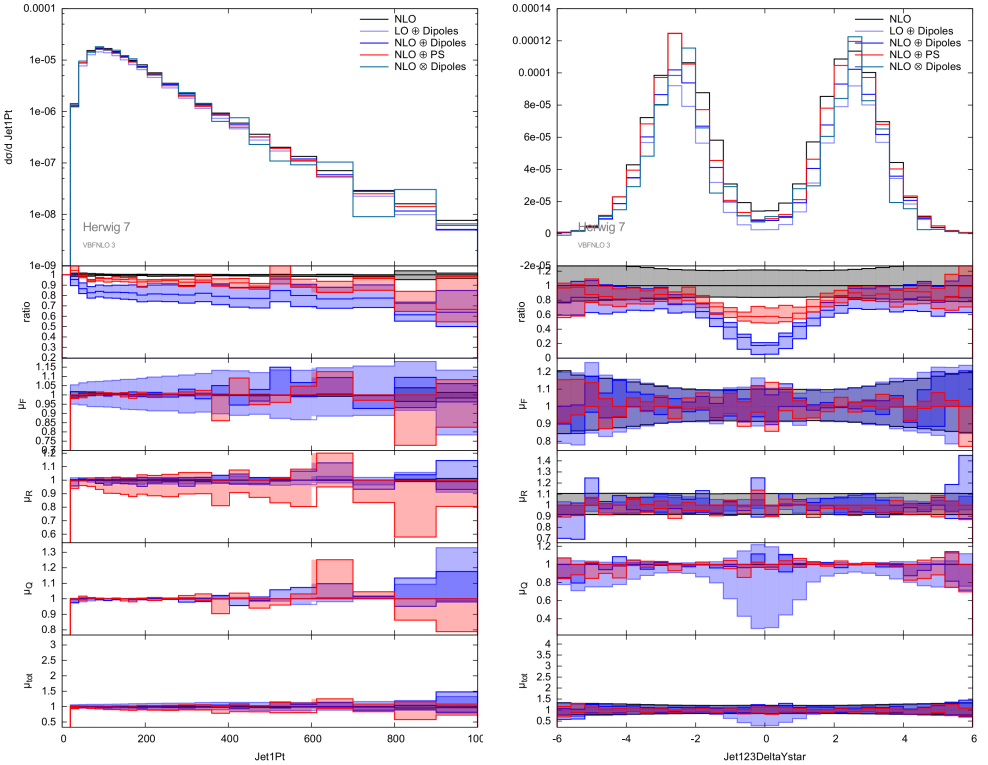
VBF WW → leptons

[Rauch, Plätzer – arXiv:1605.07851]

Herwig 7 + VBFNLO 3 makes several out of VBFNLO's process library available.
First use case: NLO matching systematics in VBF WW production.







Herwig 7.1

Defining milestone is making the **NLO multijet merging** available with at least one of the showers. [Bellm, Gieseke, Plätzer]

There are a number of other functionality which are under current development:

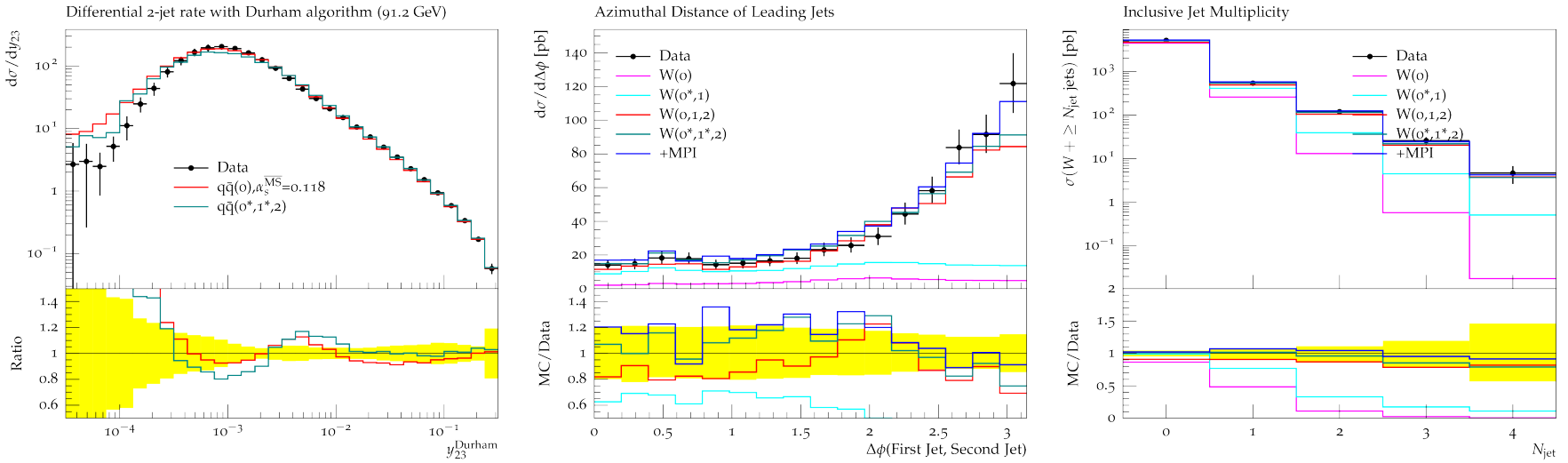
→ Colour matrix element corrections for arbitrary processes [Thoren & Plätzer]
→ Top decays in the dipole shower [Webster & Plätzer, Richardson]
→ UFO for Matchbox [Bellm, Grellscheid]
→ Several shower hooks for other packages, e.g. KRKNLO [Plätzer, Richardson]
→ Improvements in heavy quark fragmentation [Richardson]

Herwig 7.1 – NLO Multijet Merging

[Bellm, Plätzer & Gieseke – PhD thesis Bellm]

NLO multijet merging with the dipole shower, inspired by "unitary" merging algorithms. [Plätzer '12 and Lönnblad, Prestel '12]

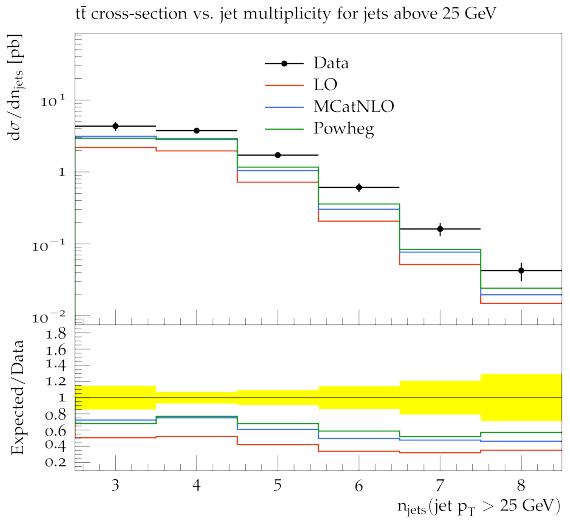
- → **Based on Matchbox infrastructure**
- → **No strict unitarization, only cancel log-enhanced contributions**
- → **Catching cross section changes due to finite real emission contributions**
- → **Standard subtractive matching below merging scale**

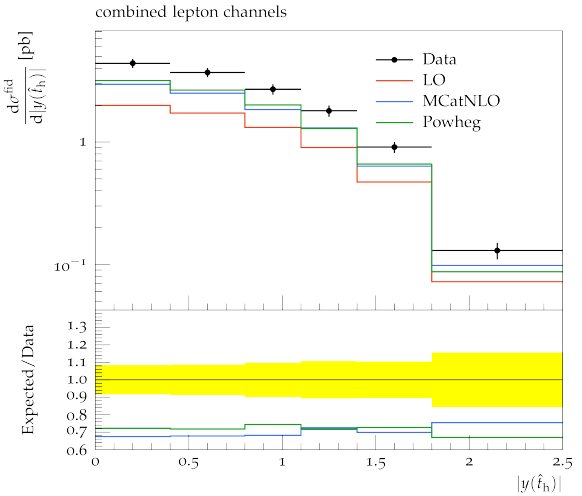


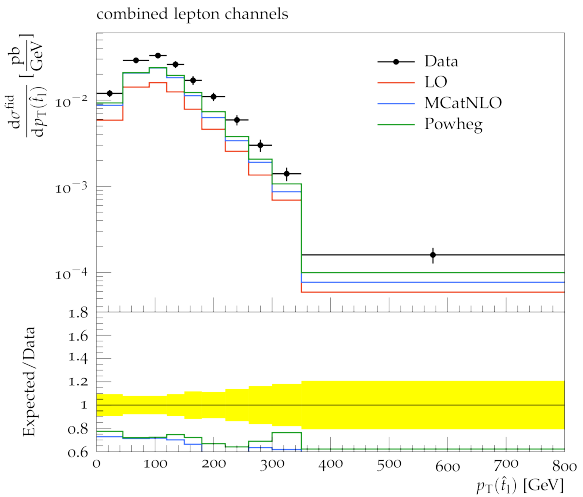
Herwig 7.1 – Top decays for all showers @ NLO

[Webster & Richardson, Plätzer]

Massive kinematics in dipole shower revisited, extended to cover decay systems similar to FF kinematics preserving the mass of the decaying object.







NNLO K factor missing towards data, more extensive studies underway.

Herwig 7.1 – Diffraction

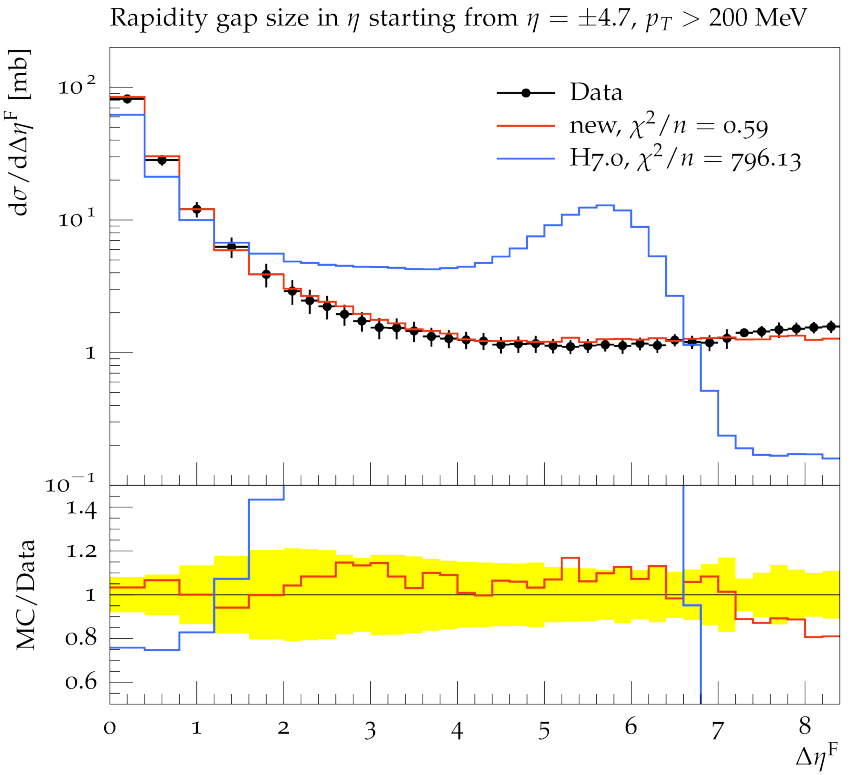
[Gieseke, Kirchgaesser, Loshaj]

Diffraction has not yet been extensively addressed in Herwig.

New developments on soft diffraction and soft MPI.

Long-standing problem of gaps by exploding clusters removed.

Closely related to colour reconnection.



Summary – Take home messages?

Matchbox (N)LO machinery inside Herwig laid the basis for a number of improvements, leading to the Herwig 7 release.

Detailed control at this level is required for all of matching, merging and uncertainty efforts which are underway.

Complemented by continuously improving showers, maintaining of two shower modules at a level that they are as comparable yet as different as possible to help quantifying the accuracy.

All activities backed up by phenomenology effort for stress-testing and quality control.

Will assess the possibilities for this to be a working model for the road ahead. (The things we aim at aren't getting any simpler ...).

Thank you!