Shower Variations with Herwig

[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]
[Bellm, Plätzer, Richardson, Siodmok, Webster – Phys.Rev. D94 (2016) no.3]

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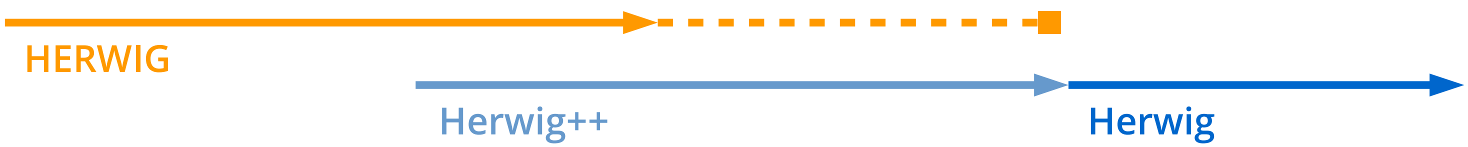
at
Les Houches | 7 June 2017

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

Shower Algorithms

Need to have too systematically different algorithms to validate uncertainties

"QTilde" [Gieseke, Stephens, Webber – JHEP 0312 (2003) 045]

→ "Traditional" angular ordered shower: default shower

→ QED, spin correlations, shower variations, decays

→ Truncated showering for Powheg-type matching

"Dipole" [Plätzer, Gieseke – JHEP 1101 (2011) 024]

→ Dipole-type evolution, ordered in dipole pt

→ Extensive shower variations, decays

→ Working horse for NLO multijet merging

Uncertainties/Variations

[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]

Classify sources of uncertainties.
Has now been generally accepted (see Marek's talk):

→ (Numerical – statistical convergence)

→ Parametric – quantities taken from measurements or fits
→ Algorithmic – discrete choices: kinematics, evolution variable
→ Perturbative – a priori arbitrary scales

→ (Phenomenological – goodness of fit measures)

Focus on perturbative part:
Scales in the game: R/F hard process, R/F shower, hard shower scale.

Uncertainties/Variations

[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]

Aim at evaluating event generator uncertainties in a global prescription

→ Need to evaluate uncertainties of building blocks one at a time.
→ Then pin down cross feed, making minimal assumptions.

Start with the perturbative part: Parton showers – at leading order!
Then check if matching algorithms exhibit the expected improvement.

Shower scale variations not a priori clear to serve as estimating an order
one term in the next (logarithmic) order – logarithmic accuracy mostly unclear.

Rather constrain by demanding **controllable** uncertainties:

→ Small/large where showers are expected to be reliable/unreliable.
→ Consistent between two systematically different algorithms.
→ Not to mess around with hard process input.

Logarithmic structure

[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]

Look at generic Sudakov exponent:

KINEMATIC LIMIT $\sim S$

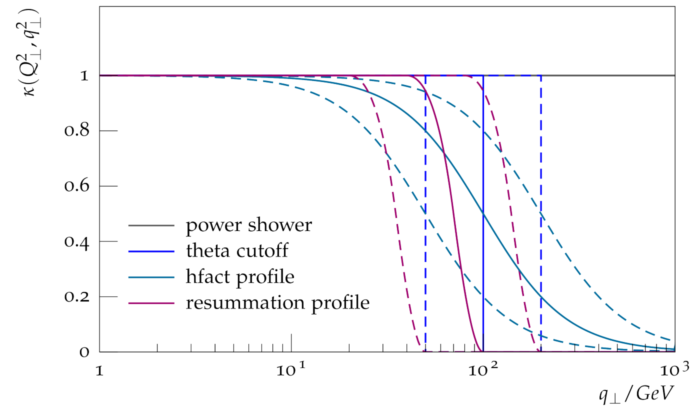
HARD SCALE $\sim M^2$

HARD SCALE IN z PHASE SPACE

$$-\ln\Delta \sim \int_{p_\perp^2}^{k_\perp^2} \frac{dq_\perp^2}{q_\perp^2} \underbrace{K(Q_\perp^2, q_\perp^2)}_{\text{CUTOFF ON RESUMMATION}} \ln\left(\frac{K_\perp^2}{q_\perp^2}\right)$$

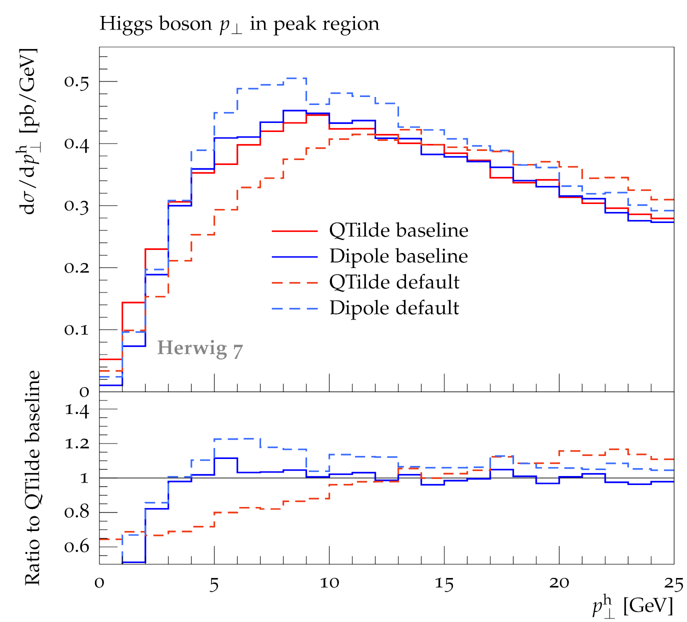
Uncertainty Benchmarks with Herwig 7

[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]



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.



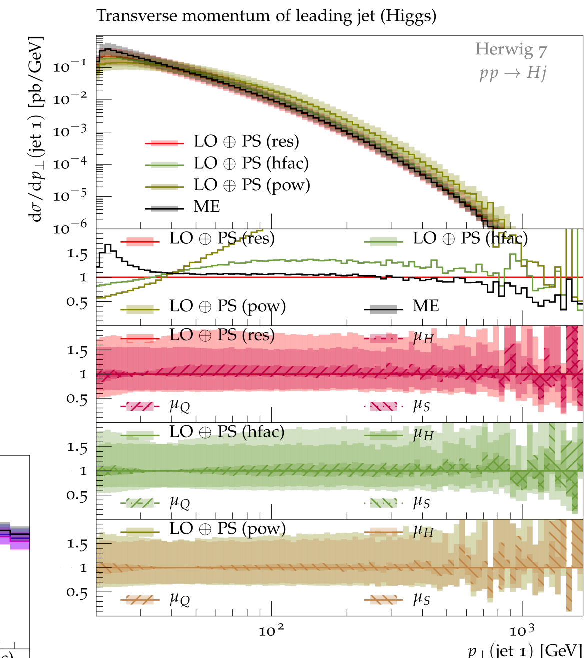
Study scale variations in angular ordered and Dipole showers at a benchmark setting where we observe absolutely comparable resummation properties:

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

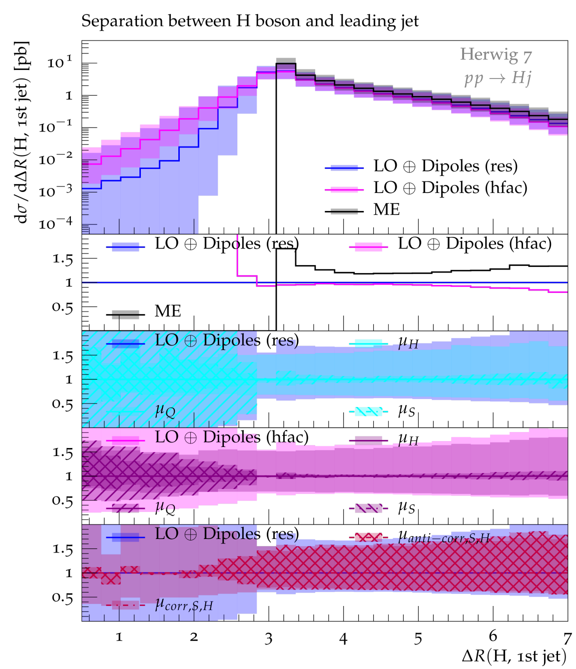
Uncertainty Benchmarks with Herwig 7

[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]

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.

At LO explore the full set of scale variations hard + shower.

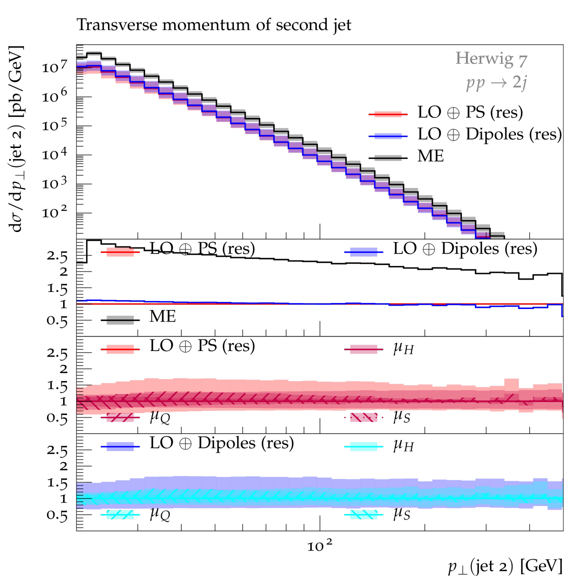
Uncertainty Benchmarks – Jets

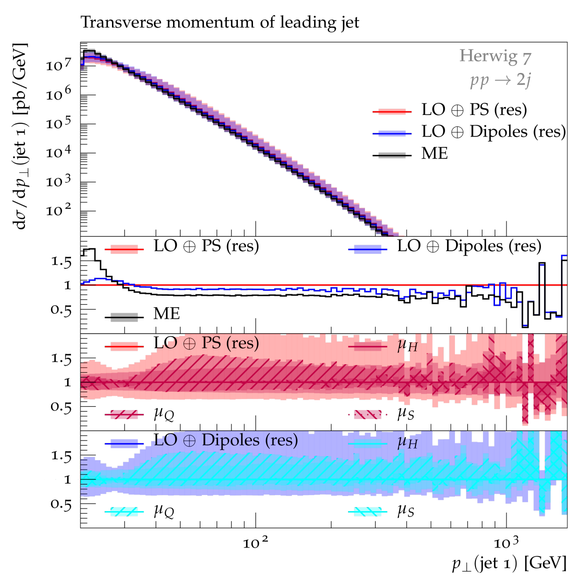
[Bellm, Nail, Plätzer, Schichtel, Siodmok – Eur.Phys.J. C76 (2016) 665]

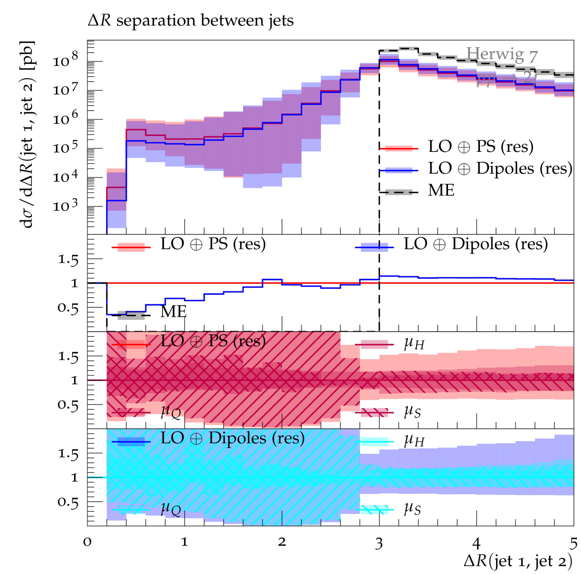
Choice of hard shower scale is crucial.

Again reliable and comparable results across showers:

→ Variations are reasonable, resummation profile as default.







[Amplitudes provided by MG5_aMC + ColorFull]

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.

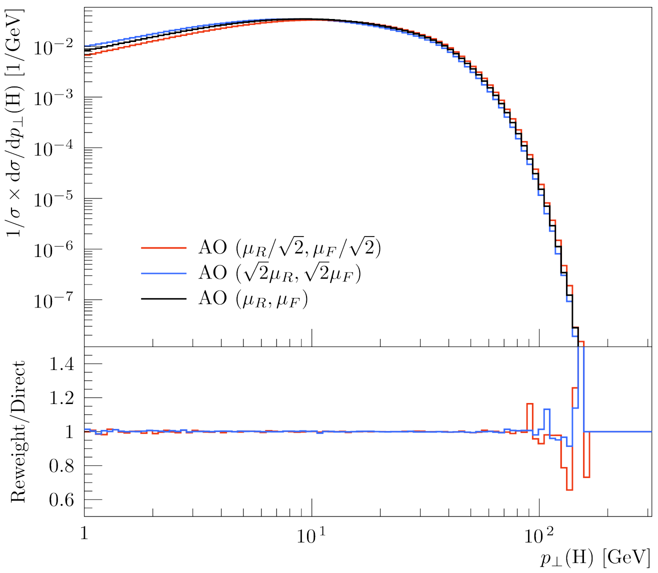
Fills HepMC multi-weight vectors, dedicated validation and performance studied.

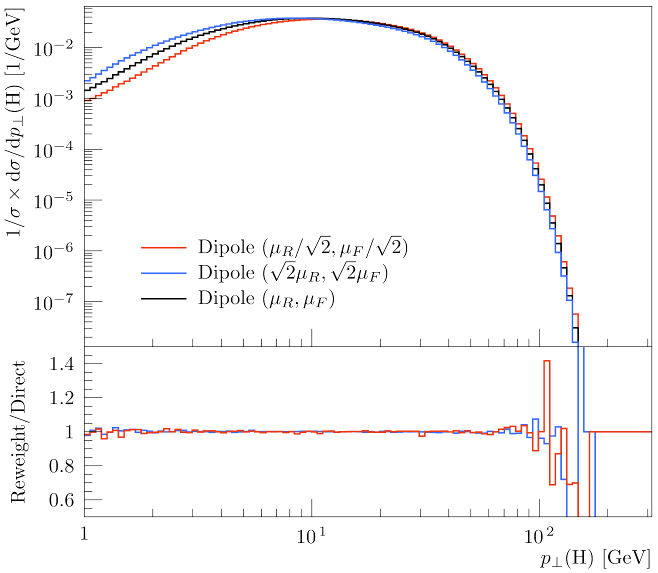
Tested with Rivet 3 beta.

Workhorse:

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

More applications to follow, can also deal with negative "probabilities".





Thank you!