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Higgs Physics & Shower Uncertainties with Herwig 7

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at the
HXSWG Shower Uncertainties Meeting
CERN | 27 June 2019

cost
EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

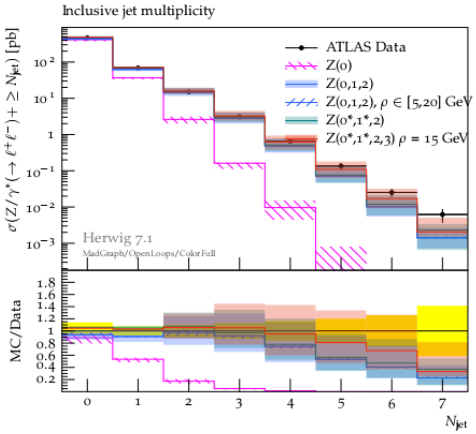
MCnet

Herwig 7 Major Milestones

Herwig 7.0 series

[Herwig collaboration – Eur.Phys.J. C76 (2016) 665]

- NLO matching for angular ordered and dipole shower
- MC@NLO-type and Powheg-type algorithms
- Matchbox central [Plätzer, Bellm, Rauch, Reuschle, Wilcock – unpublished]



Herwig 7.1 series

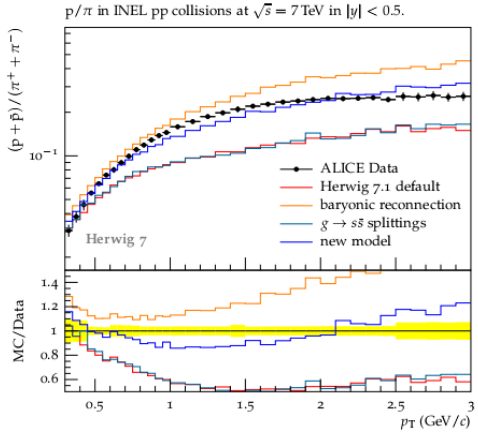
[Herwig collaboration – arXiv:1705.06919]

- Shower variations and reweighting

  [Bellm, Nail, Plätzer, Schichtel, Siodmok – EPJ C76 (2016) 665]
  [Bellm, Plätzer, Richardson, Siodmok, Webster – PhysRev D94 (2016) 4028]
- NLO multijet merging with the dipole shower

  [Plätzer – JHEP 1308 (2013) 114]
  [Bellm, Gieseke, Plätzer – EPJ C78 (2018) 244]
- Colour reconnection and soft model improvements

  [Gieseke, Loshaj, Kirchgaesser – EPJ C77 (2017) 156]
  [Gieseke, Kirchgaesser, Plätzer – EPJ C78 (2018) 99]



Quantifying shower uncertainties

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[Bellm, Nail, Plätzer, Schichtel, Siodmok – EPJ C76 (2016) 665]

Hard to assign from first principles in lack of a systematic expansion.
Overall uncertainty budget of event generator predictions still unknown.

Start with perturbative part, at LO and possibly NLO matched.
Different algorithms in same framework crucial for cross checks.

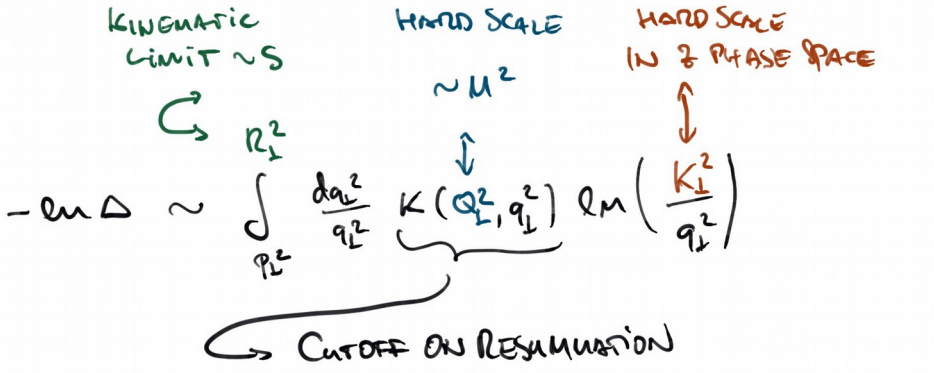
Scale variations indicative of uncertainties, but not at face value:

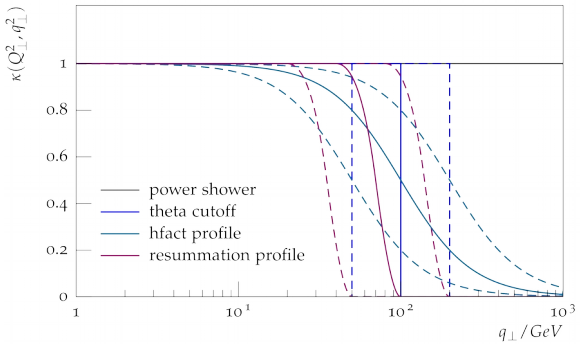
- Renormalization and factorization scales of hard process
- Arguments of running coupling and PDF in shower evolution:
  Constraining these is a strong statement about accuracy, not clear a priori
- Hard veto scale of the shower:
  Not necessarily 'starting' scale: soft end of evolution for AO showers
- Dynamics of the hard veto scale:
  Not the hard process factorization scale, different functional form preferred

Confront with theoretical expectations: hard process input, phase space regions for which showers need to be unreliable, improvements through matching, …

Quantifying shower uncertainties

[Bellm, Nail, Plätzer, Schichtel, Siodmok – EPJ C76 (2016) 665]

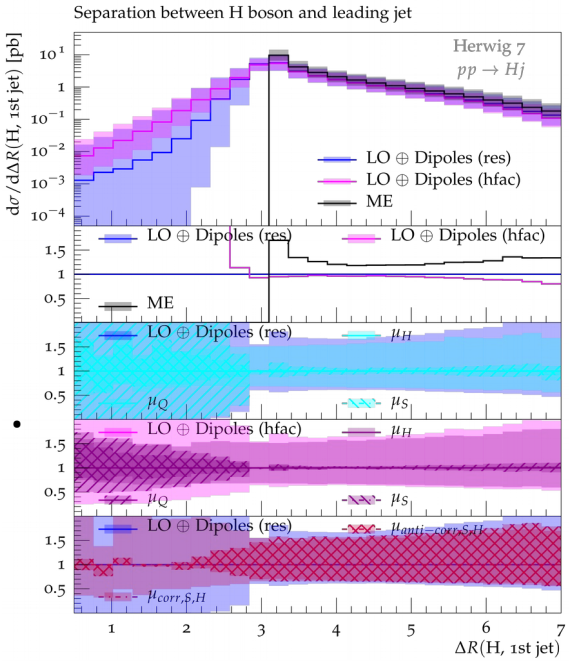


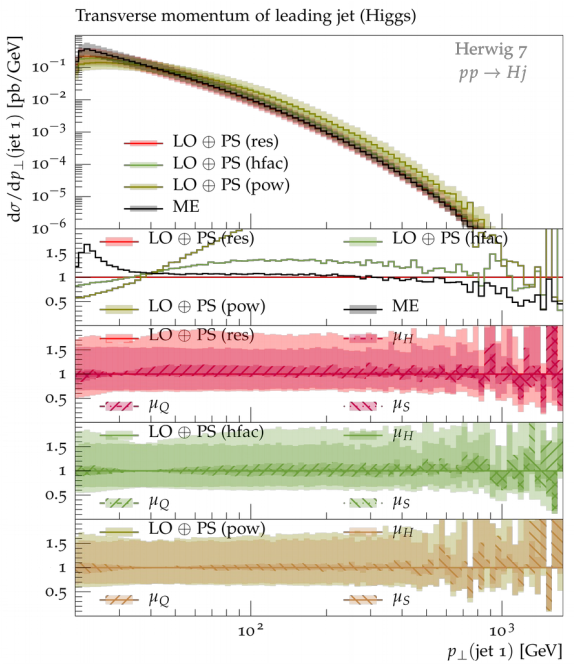


Fast cutoff of the resummation is crucial to produce 'controllable' uncertainties:

Need to reflect reliability of showering and to preserve relevant hard process properties .

Comparable between the two shower algorithms.





Shower reweighting

[Bellm, Plätzer, Richardson, Siodmok, Webster – PRD 94 (2016) 034028]

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

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

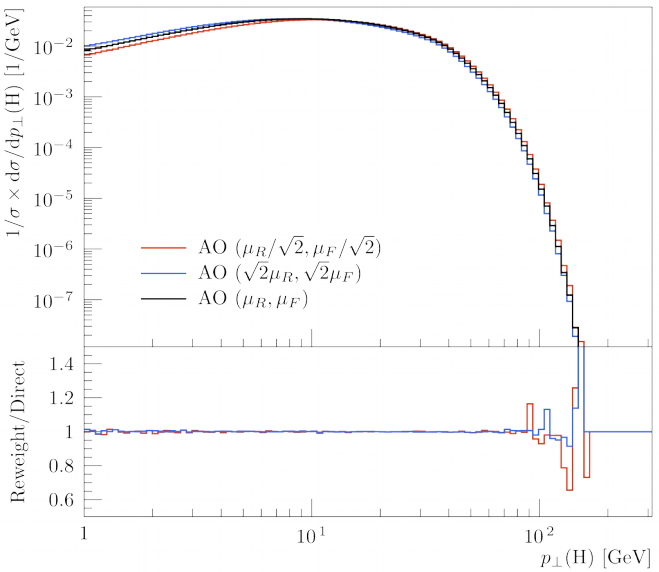
Weighted version of the "Sudakov veto algorithm" allowing for an unprecedented shower flexibility.

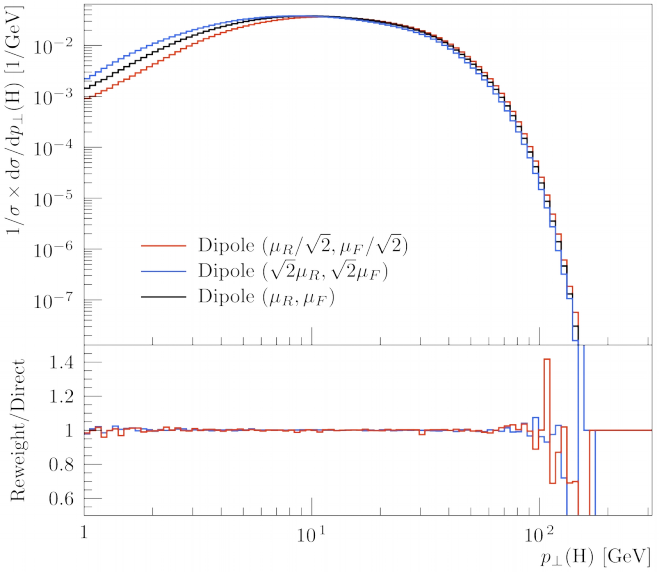
$$S_R = \Delta_R(\mu|Q)\delta(q-\mu) + R(q)\Delta_R(q|Q)\theta(\mu < q < Q)$$

$$w_{\text{veto}} = \frac{1-\frac{P}{R}}{1-\epsilon} \qquad w_{\text{accept}} = \frac{P}{\epsilon\, R}$$

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

Not always bound to be more efficient!





Some applications in Higgs & related final states

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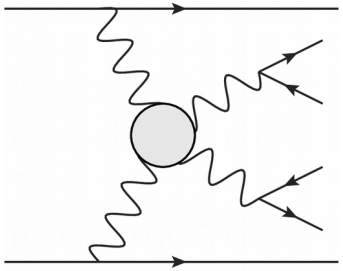
VBS and VBF

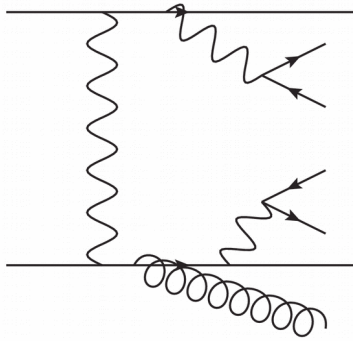
[Rauch, Plätzer – EPJ C77 (2017) 293]
[Rauch et al. For VBSCAN study – EPJ C78 (2018) 671]

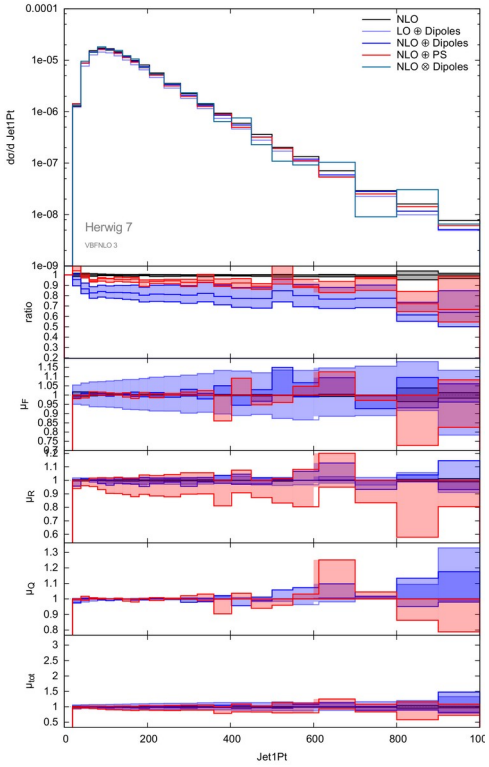
VBFNLO 3 has a native interface to Herwig 7 / Matchbox.

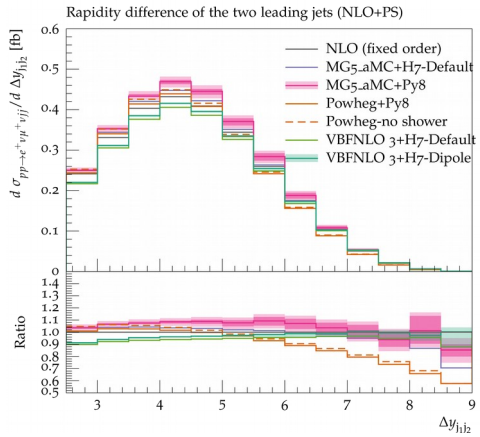
VBS and VBF available, several other processes in validation phase.

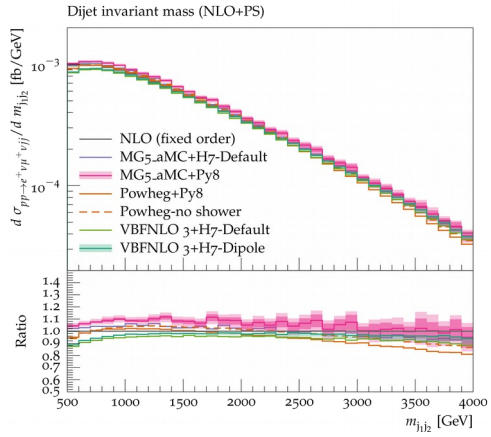
Detailed study of shower effects, matching systematics, multijet merging.





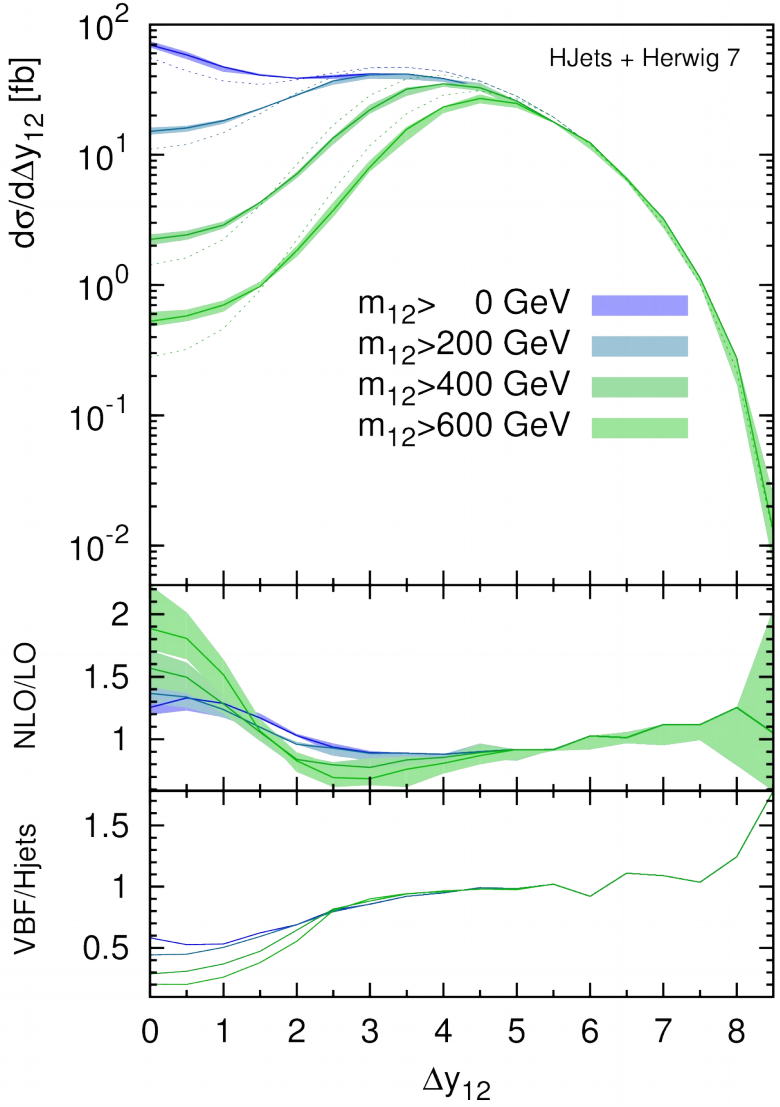




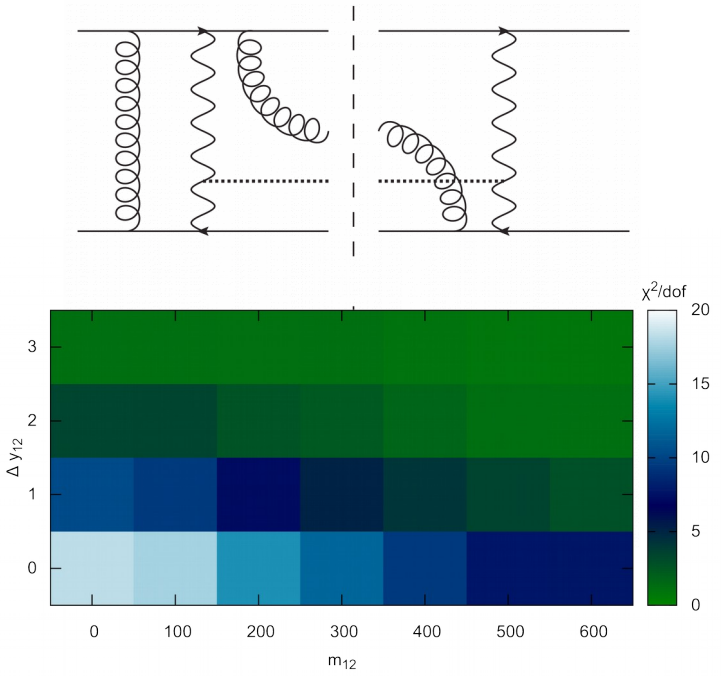


VBS and VBF

[Campanario, Figy, Plätzer, Sjödahl – PRL 111 (2013) 211802]
[Campanario, Figy, Plätzer, Rauch, Schichtel, Sjödahl – PRD 98 (2018) 033]



HJets library provides full Higgs plus 2 and 3 jet electroweak production at NLO QCD, no VBF approximation.



Shower variations and matching systematics in progress, some results in YR 4.

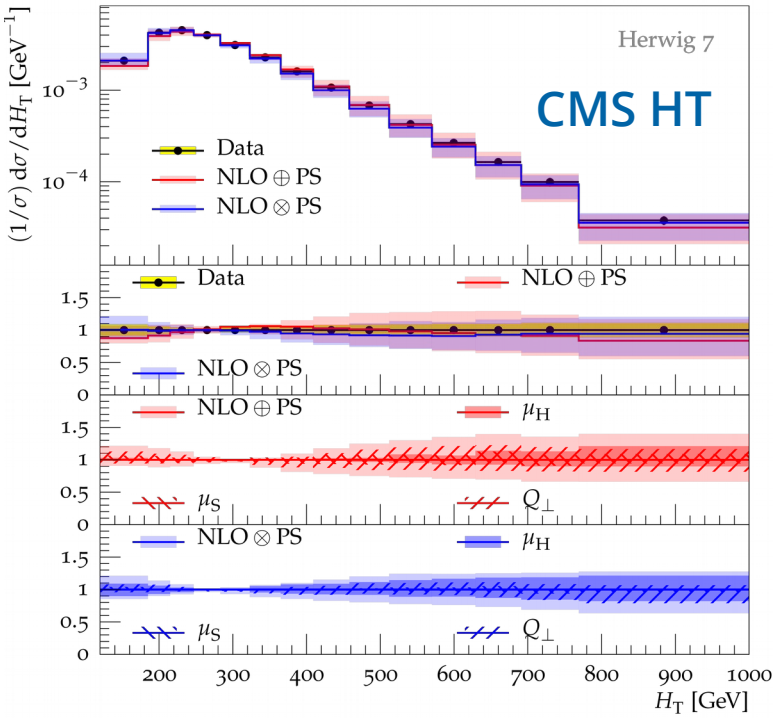
More NLO Matching Systematics & Uncertainties

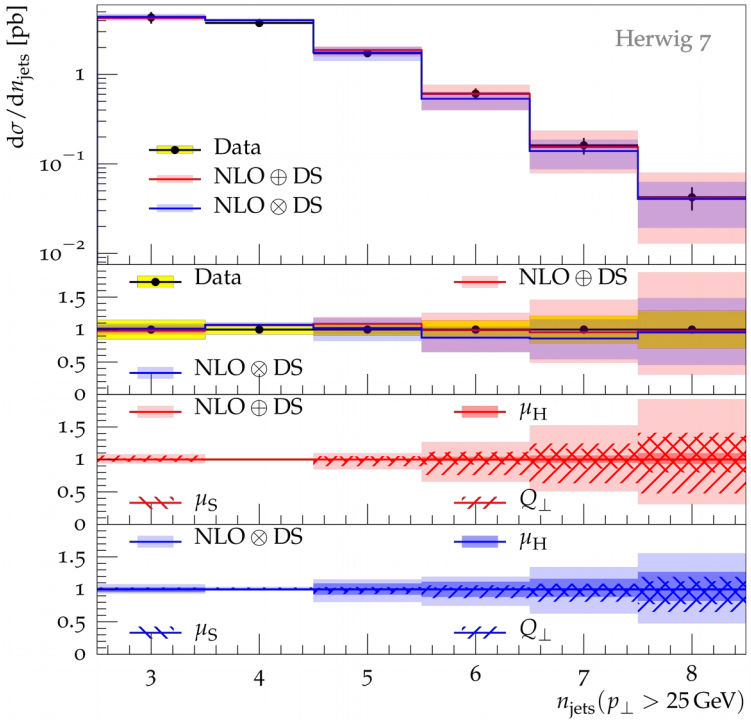
[Cormier, Plätzer, Reuschle, Richardson, Webster – arXiv:1810.06493]

Revised treatment of massive quark evolution in dipole shower, and evolution of decay systems. Matching now available for **production and decays**, and angular ordered and dipole shower.

Study NLO matching in detail using Herwig shower modules and Matchbox.

ATLAS jet multis



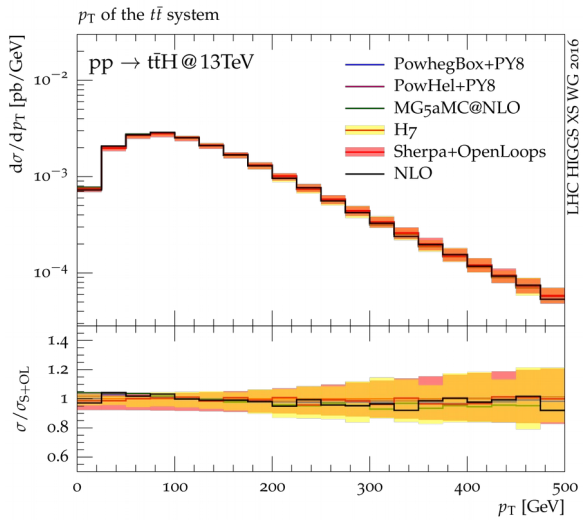


ggF, ttH, …

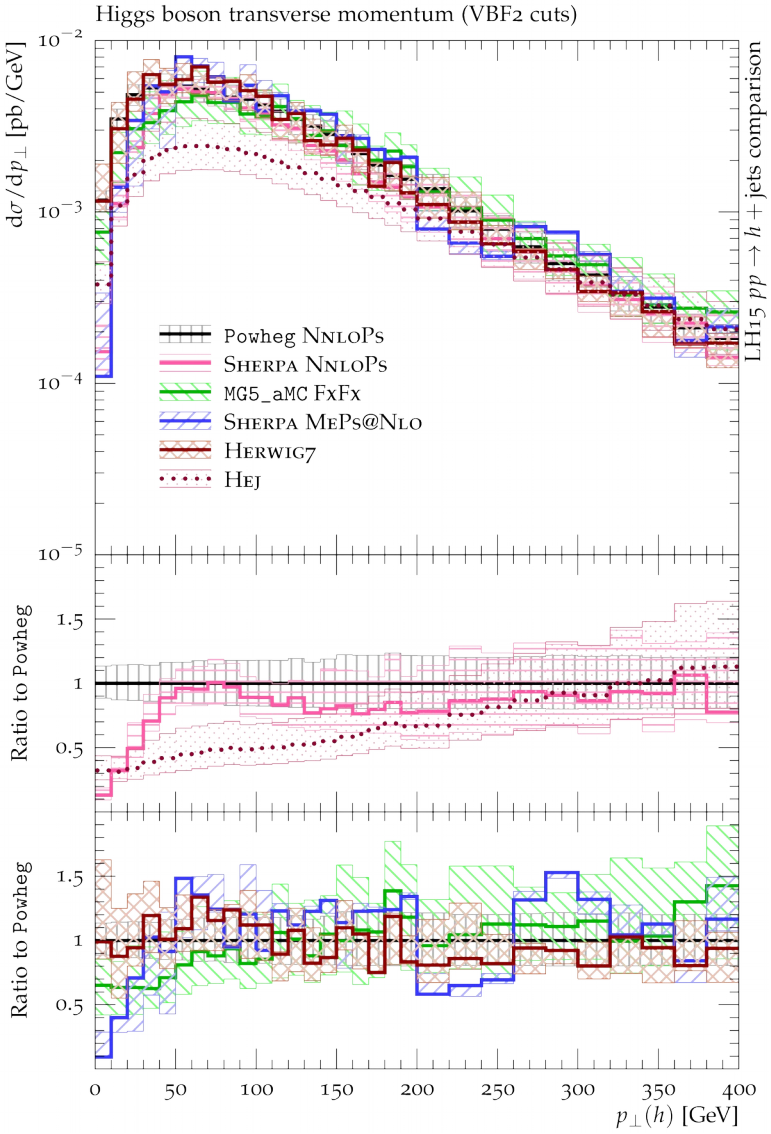
Herwig 7 well capable of including other relevant background/signal processes.

- Gluon fusion with additional jets studied in multi-jet merged setup

- ttH studied at NLO+PS, involved in ttbb benchmarks



[Gieseke, Plätzer, Podskubka, Reuschle for HXSWG YR4]



[Bellm, Plätzer, Schichtel for Les Houches '15]

Some processes require a bit of tweaking beyond the default input cards, please get in touch with us!

Thank you!

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