Sub-leading shower effects on top quark distributions

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Work in collaboration with Paolo Nason and Bryan Webber
+ Herwig collaboration

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Outline

- Introduction
- Kinematics Reconstruction
- Final-State Showers
- Herwig 7
- Conclusions

Introduction

- Often we can:
  - improve the description of data by Monte Carlo event generators by varying parameters;
  - assess uncertainties by varying scales and parameters.
- However in Monte Carlo event generators we have often made a number of choices which effect the physics results but are not easily changed.

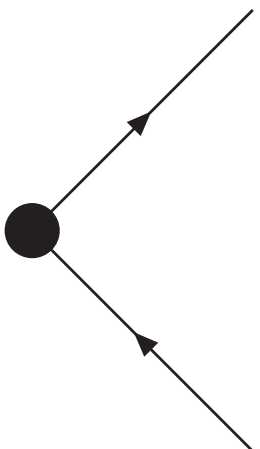
Introduction

- The most obvious are which evolution variable to use and whether to do either:
  - a variant of "dipole" showers with local recoil;
  - single particle emission with a global rescaling to ensure energy and momentum conservation.
- In this talk I'm going to focus on two things we've been looking at recently with Herwig 7:
  1. changing the global rescalings;
  2. reinterpreting the evolution variable for final-state branchings;

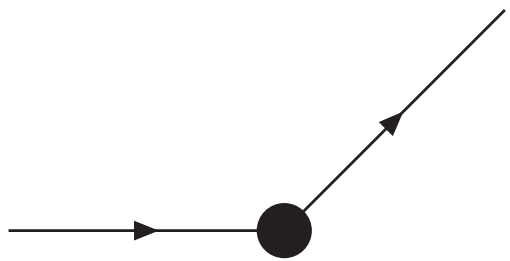
  both of which can have a surprisingly large effect on distributions.

Kinematic Reconstruction

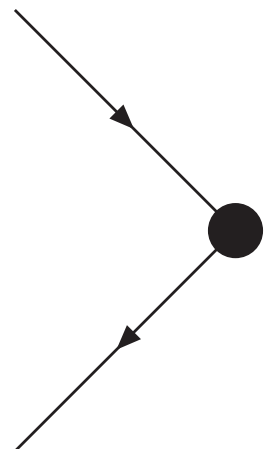
- In order to conserve energy and momenta globally after the parton shower has been generated we rescale the momenta of the jets, imposing some constraints
- The original aim of the improved angular-ordered parton shower in Herwig, Gieseke, Stephens, Webber JHEP 0312 (2003) 045, was to use the colour structure to determine these constraints.



FF, m



IF, q^2



II, $\hat{s}, y$

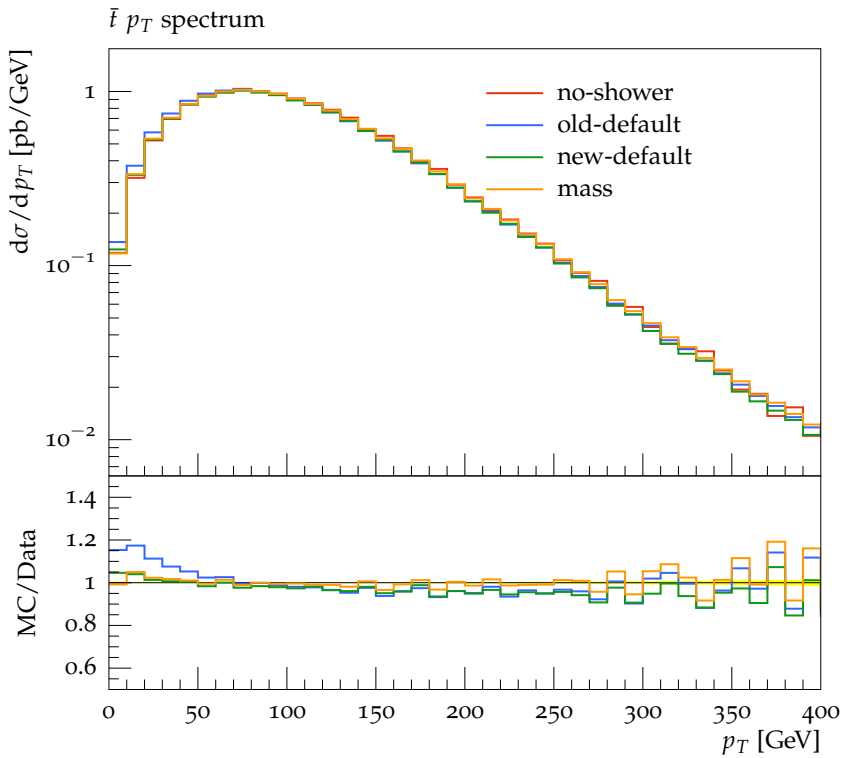
Kinematic Reconstruction

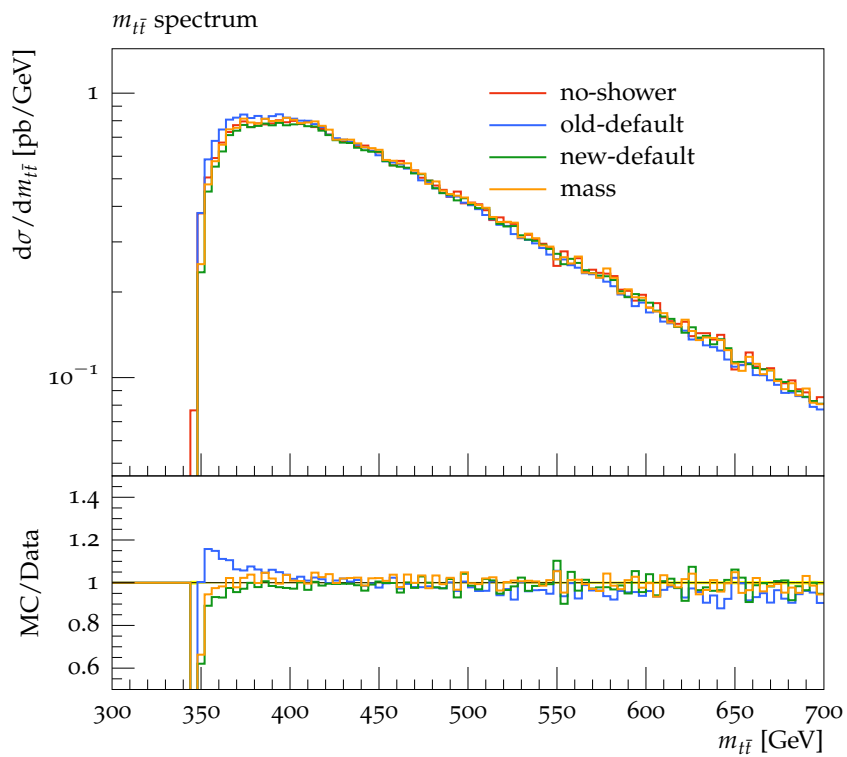
- Used this approach in cases where the process could be split up into colour singlet systems, *e.g.* $e^+e^- \to q\bar{q}$, DIS, Drell-Yan, $q\bar{q} \to t\bar{t}$.
- In processes in hadron collisions where this wasn't possible use the II and the FF methods, same approach as in Herwig 6.
- Some problems pointed out by Bryan Webber and Paolo Nason for $t\bar{t}$ production with extra radiation.
- Use a different treatment of the jet which had radiated the most, special case for top.

Kinematic Reconstruction (PR and Simon Plätzer)

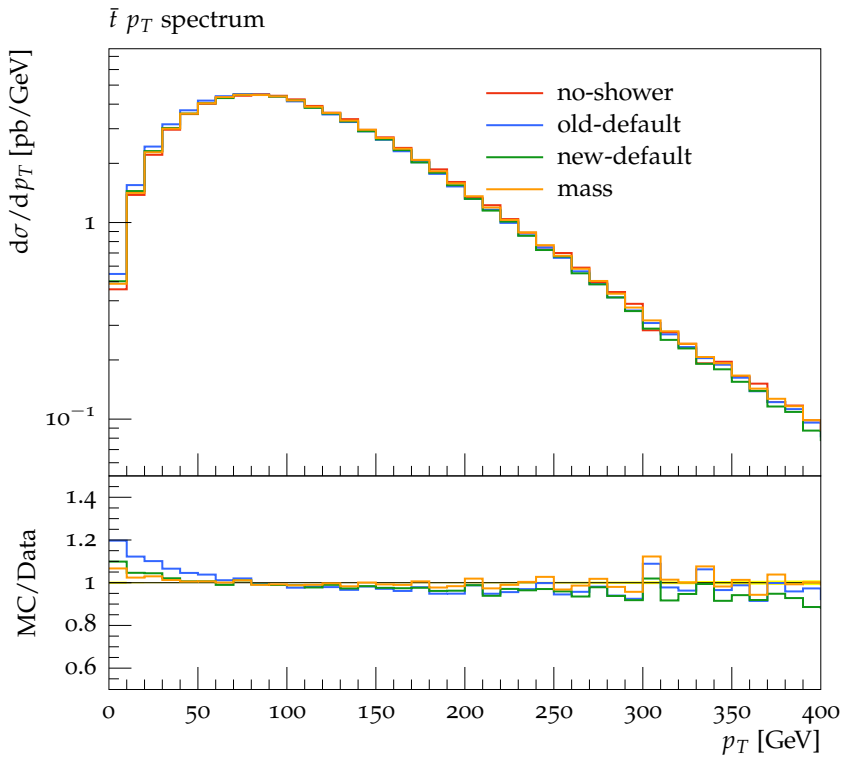
- In general want to make more use of the colour structure so a new approach:
  - Order the partons in terms of which had the hardest parton-shower emission.
  - Reconstruct the 1st parton and let its partner take the recoil, either:
    3. fully reconstructing the partner;
    4. let the unreconstructed parton absorb the recoil.
  - Continue with the unreconstructed parton with the highest shower emission until all the partons are reconstructed.
- More dipole like in structure, more physical in terms of the colour structure, and easier to work out what's going on for matching higher orders.

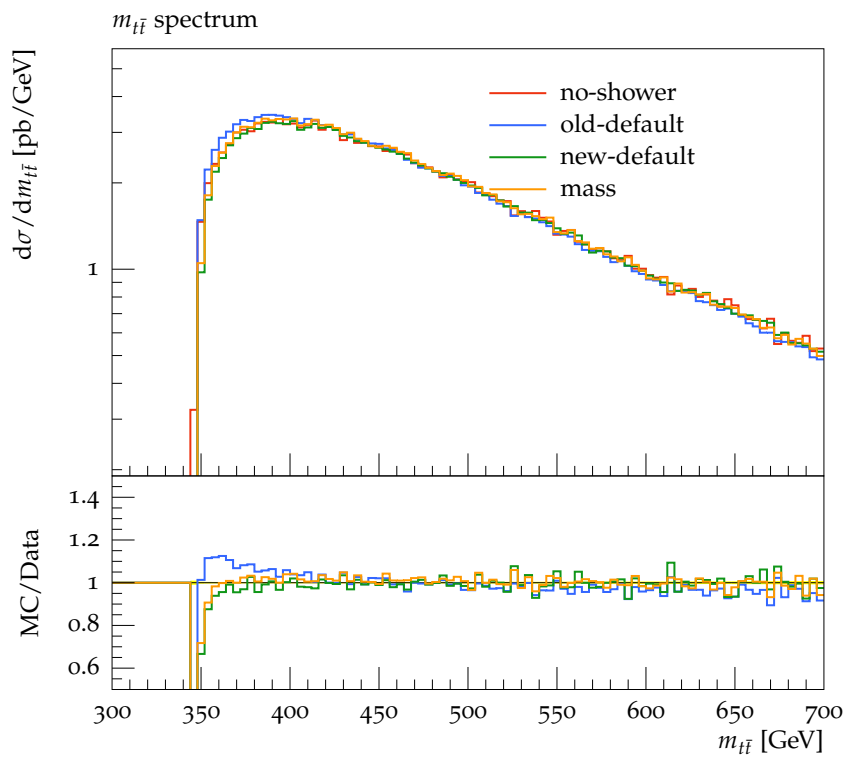
7 TeV (POWHEG-BOX and Herwig7)



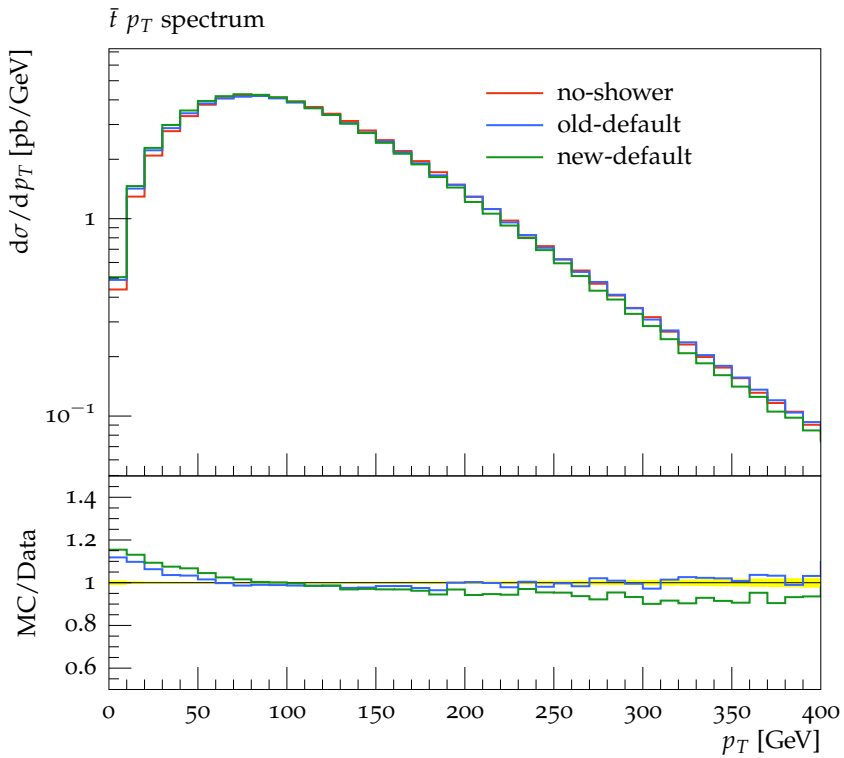


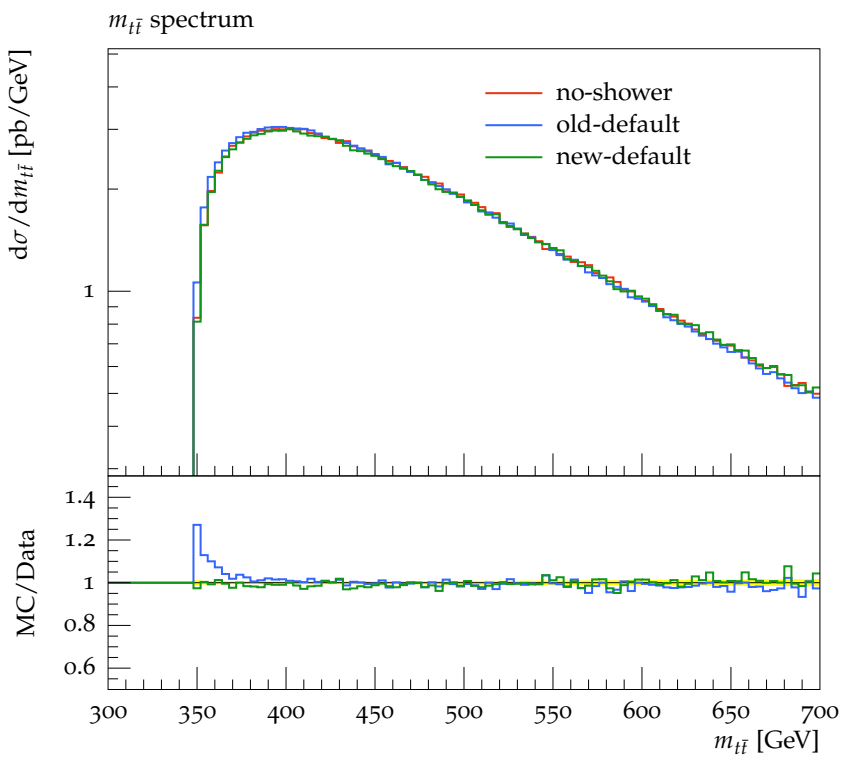
13 TeV (POWHEG-BOX and Herwig7)





13 TeV (Herwig 7.0 preliminary)





Kinematic Reconstruction (PR and Simon Plätzer)

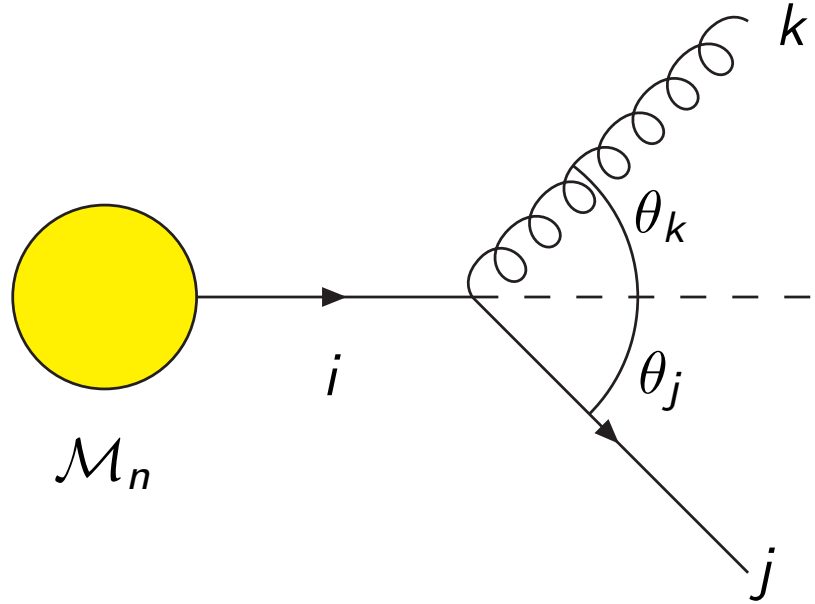
- In also turns out that for one emission our treatment of the FF and IF kinematics is identical to that in the Catani-Seymour Dipoles.
- The II case is not but we have 2 unknowns and need two constraints to obtain them:
  1. Mass of the system;
  2. By default the rapidity of the system.
- Can replace the second constraint:
  - longitudinal momentum;
  - fix the momentum fraction of the initial-state parton which has the softer parton shower emission.
- The 2nd choice reproduces the CS kinematics.

Parton Shower

- We use an evolution variable

$$z(1-z)\tilde{q}^2 = -m_i^2 + \frac{m_j^2}{z} + \frac{m_k^2}{1-z} + \frac{p_T^2}{z(1-z)}$$

- Previously have interpreted this using our cut-off masses to give the p_T of the branching.
- Tend to give too hard emissions, in particular a poor description of the tail of the thrust in e^+e^-.



Parton Shower

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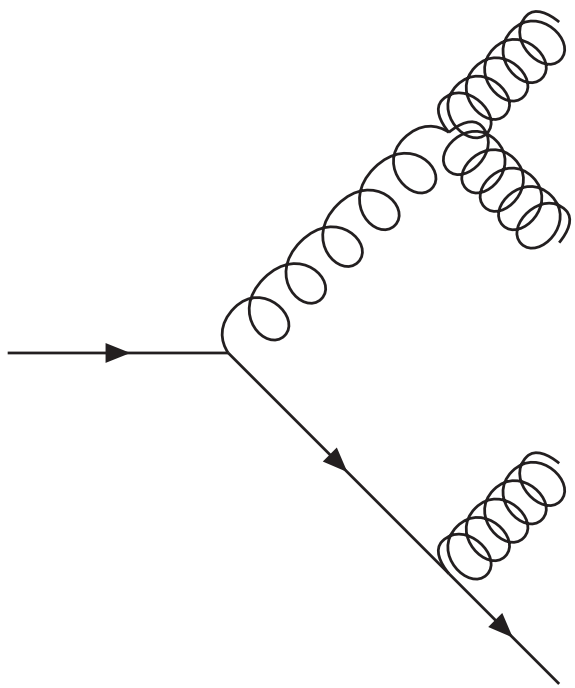
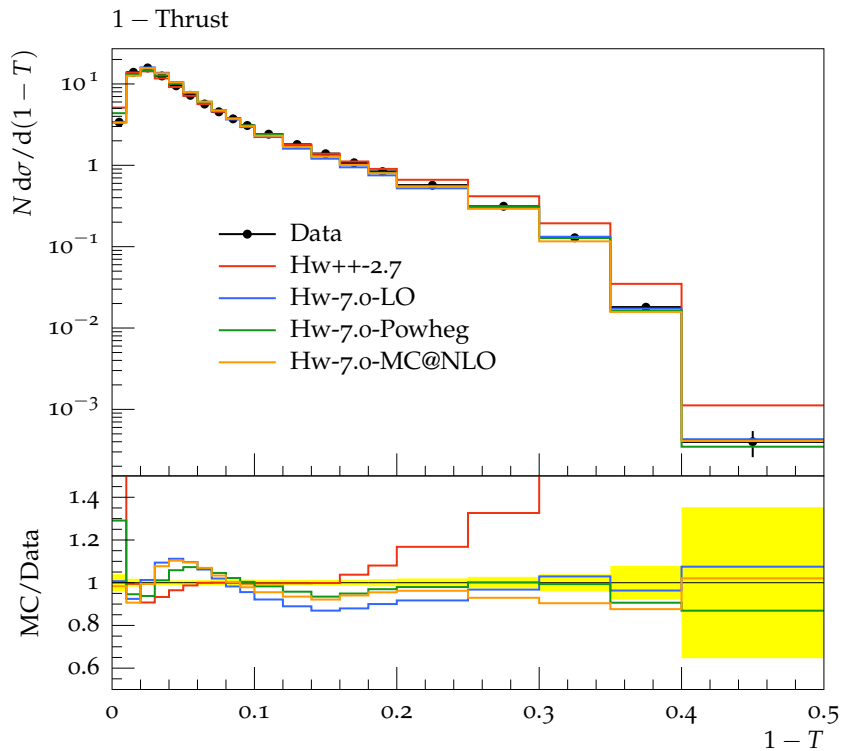
- Instead use the off-shell masses developed by the shower.
- Prevents higher p_T emissions with high virtuality.
- Softens the distribution.



Herwig 7.0 (preliminary)

- Significant improvements in the description of the thrust distribution.



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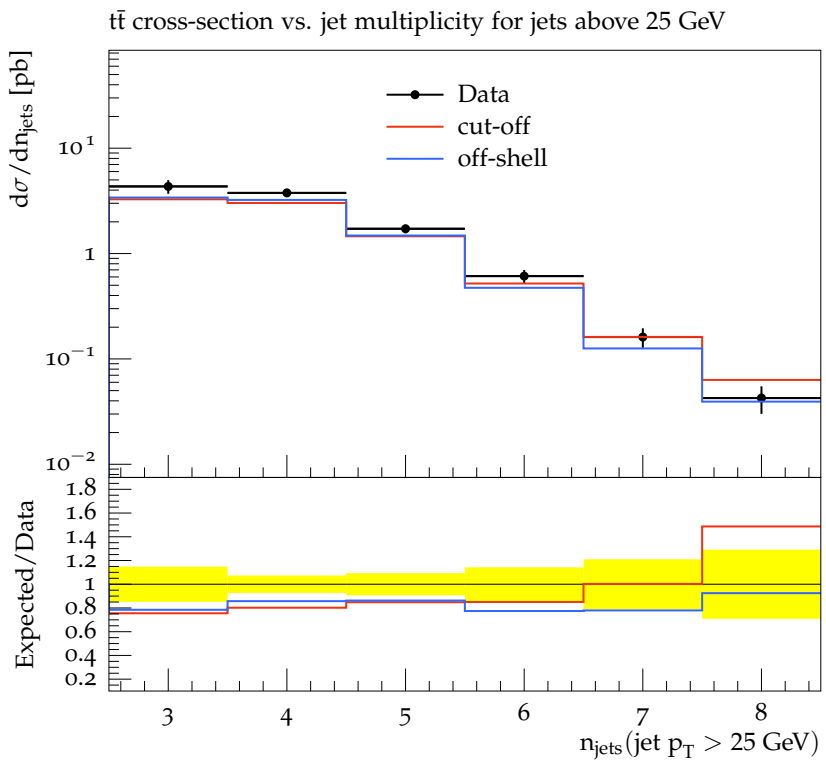
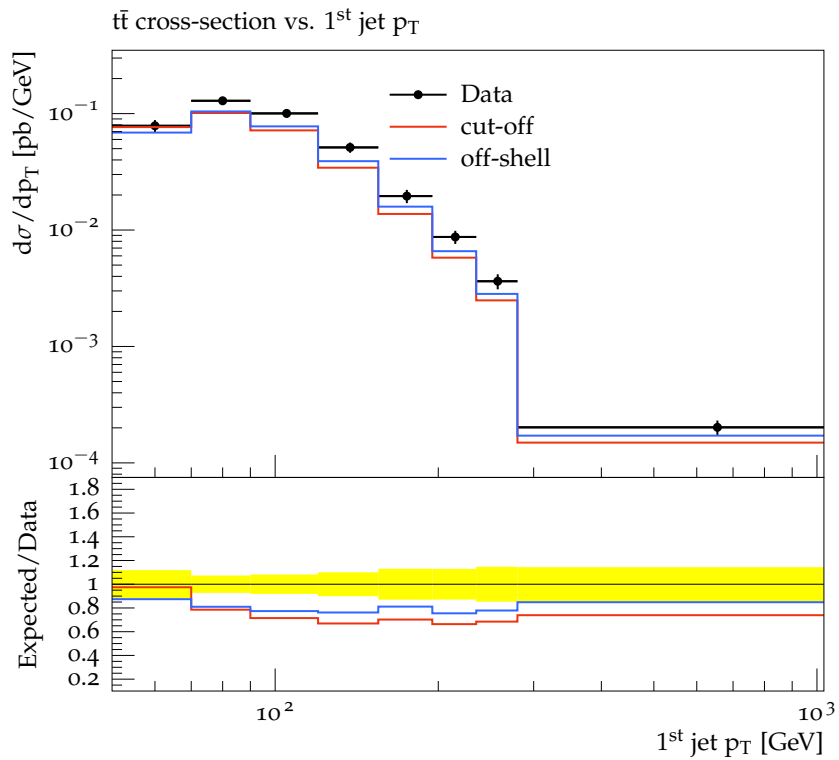
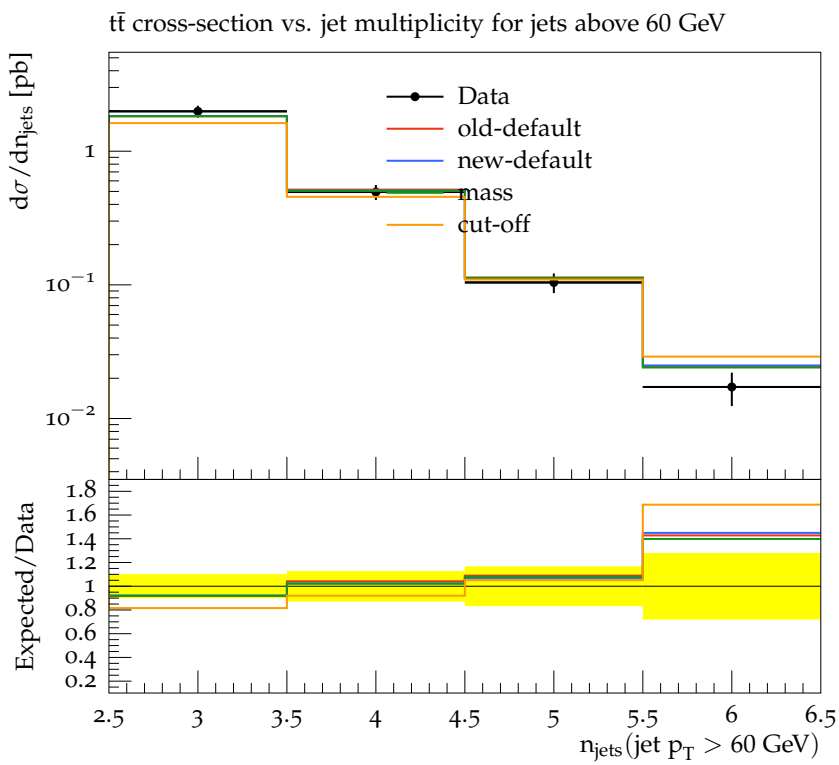
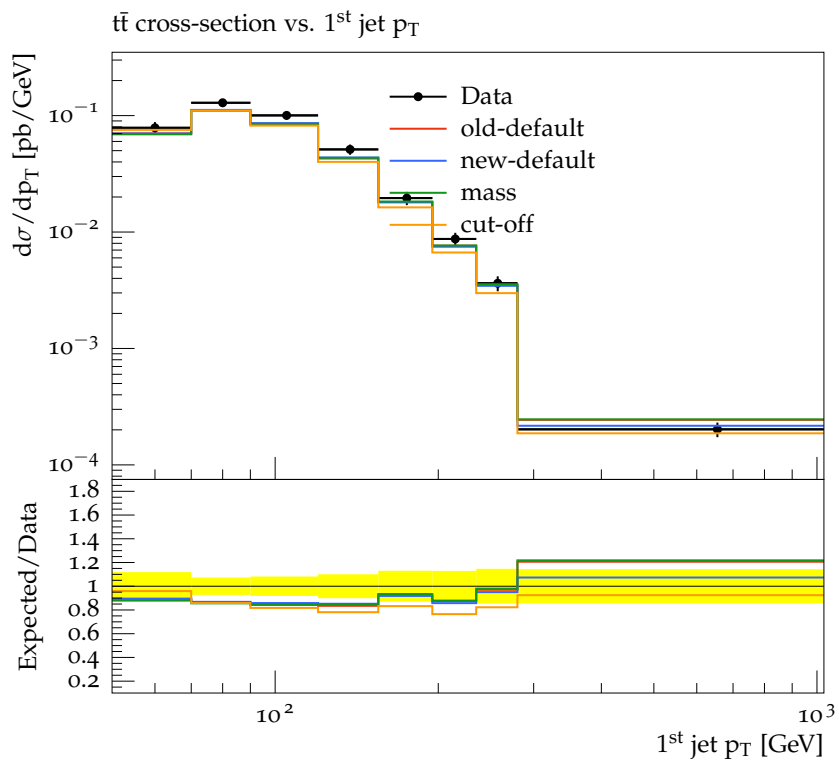




Compared to ATLAS JHEP 1501 (2015) 020.

POWHEG-BOX and Herwig 7.0 (preliminary)





Compared to ATLAS JHEP 1501 (2015) 020.

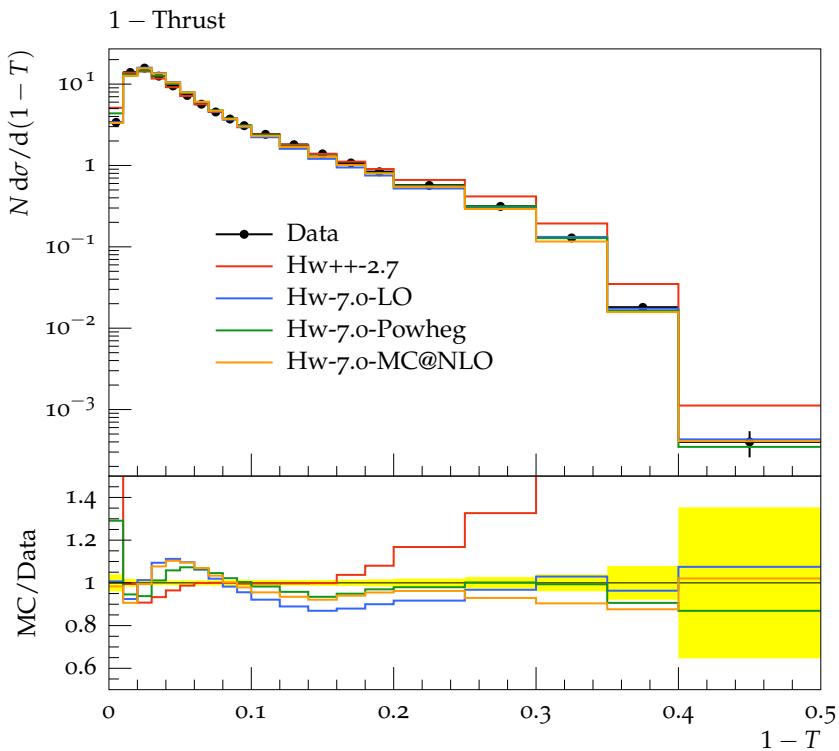
Herwig 7.0 (Herwig++ 3.0)

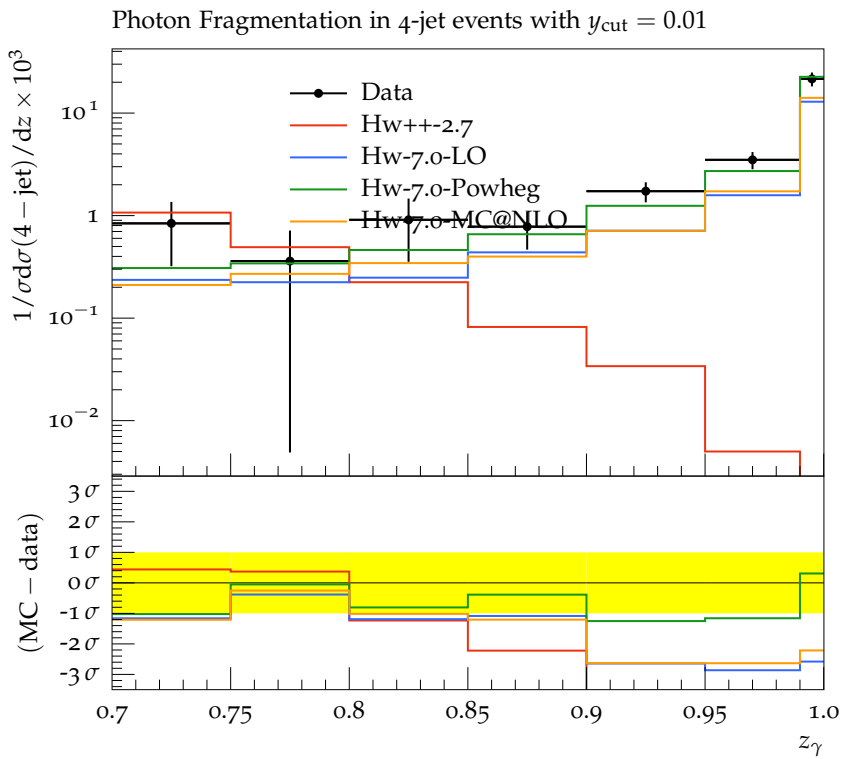
- For the the last 10 years we have been working towards a goal of a release that met a (moving) definition intended to fully replace the FORTRAN HERWIG program.
- Over time that has evolved as the needs of the experimental and phenomenological communities have developed over the last ten years.
- Precision is now the key and matching to higher orders absolutely essential.

Herwig 7.0 (Herwig++3.0)

- There will be a new release in the next few weeks that meets these needs.
- Default is to have NLO matrix elements matched to the parton shower.
- Fully automated, so that users can choose their process and everything is set up for them.
- Both POWHEG and MC@NLO type matching
- Option of two different parton showers, angular-ordered and dipole.
- Much better documentation
- Finally completely replaces FORTRAN HERWIG.

Herwig 7.0 (preliminary)

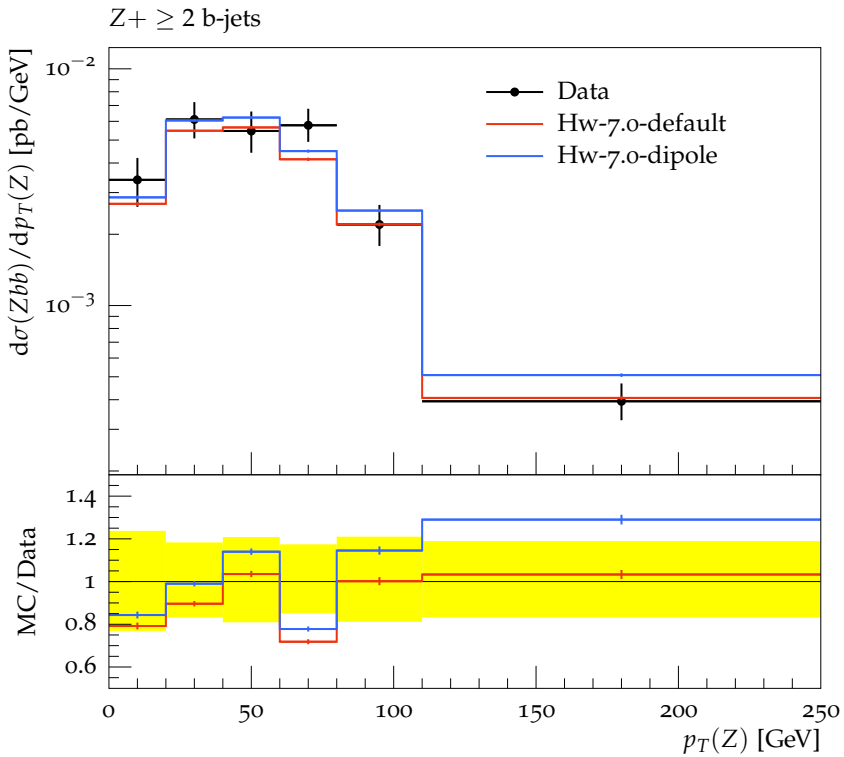


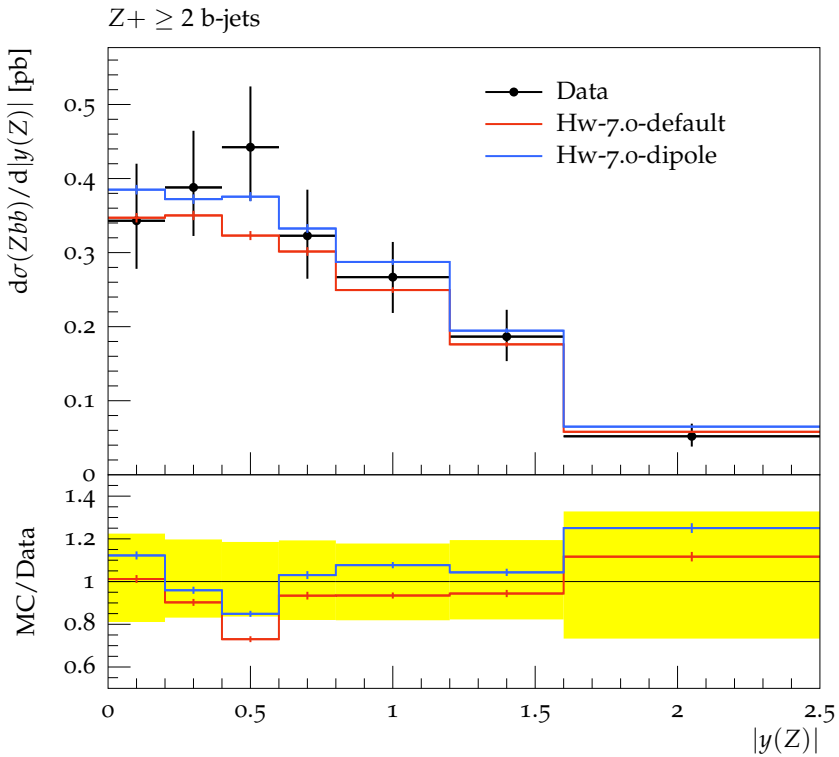


Herwig 7.0 MC@NLO Matching for $e^+e^- \to q\bar{q}$ with matrix element corrections, MC@NLO and Powheg from Z.Phys.C73:11-60,1996 and ALEPH Z.Phys.C69:365-378,1996

Herwig 7.0 NLO (preliminary)

work led by S Plätzer with substantial contributions by J. Bellm, A. Wilcock, M. Rauch, C. Reuschle





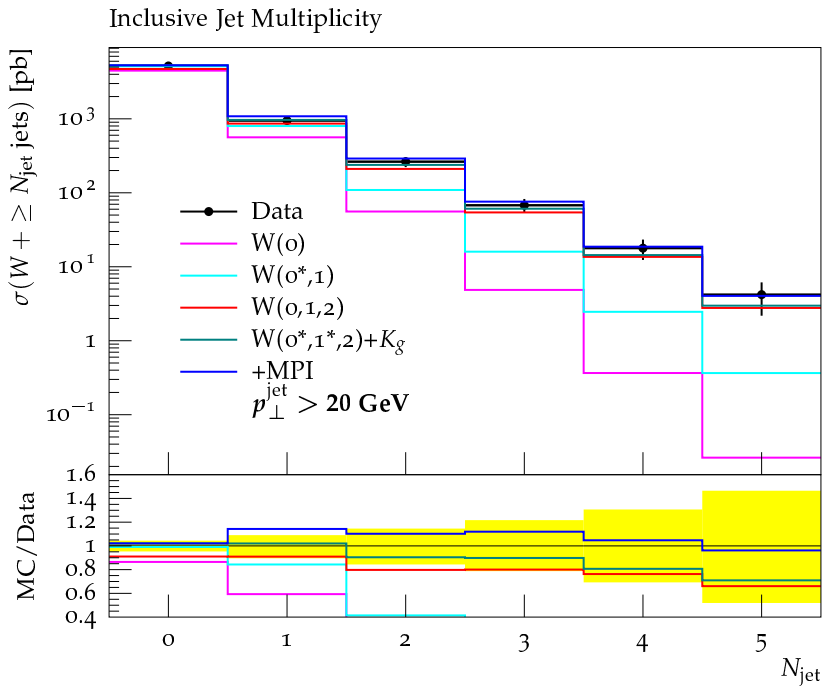
Herwig 7.0 MC@NLO Matching for $Zb\bar{b}$ for the $\tilde{q}$ and dipole showers using Madgraph+OpenLoops for LO and NLO amplitudes, data from ATLAS JHEP 1410 (2014) 141

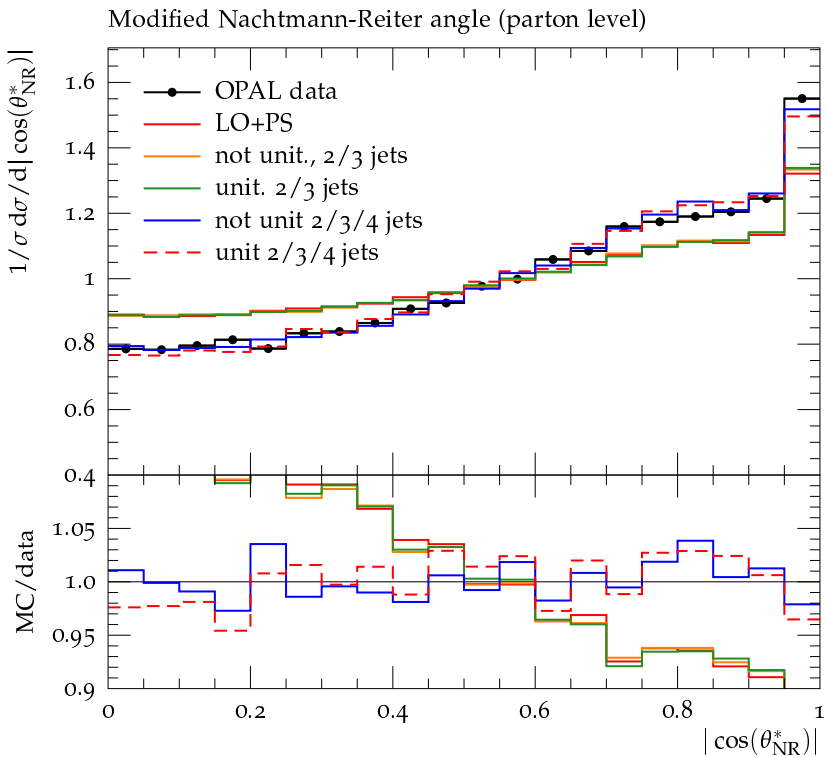
Future of Herwig: Medium Term ($\sim$ 1 year)

- Following the 7.0 release we hope to produce a release including merging multiple higher-order matrix elements in near future building on the work of S. Plätzer & J. Bellm.
- Minor improvements in other areas which were not quite ready for the Herwig7.0 release.
- Given the amount of time taken to develop the simulations it is important that we exploit it to do as much phenomenology as we can during the second run of the LHC.

Herwig: Multi-Jet Merging

J. Bellm & S. Plätzer & S. Gieseke





- Multi-jet NLO merging using MATCHBOX and the BLHA.

Conclusions

- Formally sub-leading changes in the parton shower can have a significant effect on observables.
- Still needs some further work but the new choices which will be available in Herwig 7 are better physically motivated and give improved agreeement with data.
- Herwig 7 will be available soon.