V + jets at NLO+PS+FxFx/UNLOPS in MG5_aMC

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Motivations

- Phenomenological motivation: have an MG5_aMC simulation at NLO+PS+merging for this crucial class of processes at the LHC, in realistic experimental setups. A very important but so far missing piece of prediction.
- Validation of FxFx with modern showers Herwig++ and Pythia8: a warmup for NLO+PS+merging within our framework for Run II, in parallel with the experiments.
- Assessment of merging systematics by comparing different showers and merging schemes: crucial towards NLO+PS+merging as the new standard of accuracy.
- Validation of the MG5_aMC UNLOPS interface for Pythia8.

Setup

- $\ell^+\ell^- + X$ and $\ell\nu_\ell + X$ @ LHC 7 TeV; $X = 0, 1, 2$ jets, $\ell^\pm = \{e^\pm, \mu^\pm\}$, $\ell = \{\ell^+, \ell^-\}$.
- 15M events per process per shower for FxFx, 10M NLO and LO (up to 3 jets) per process per merging scale for UNLOPS. 5M per process per shower for inclusive.
- Merging scales considered: 15, 25, 45 GeV, to well asses merging systematics.
- Central scales and PDFs: $\mu = \frac{1}{2}\sum_i m_{T,i}$, NNPDF23_nlo_as_0119.
- Generation cuts: $m_{\ell^+\ell^-} > 40$ GeV, $p_T(j) > 8$ GeV for FxFx; $p_T(j) >$ merging scale for UNLOPS.
- Rivet analyses to compare with ATLAS and CMS data.

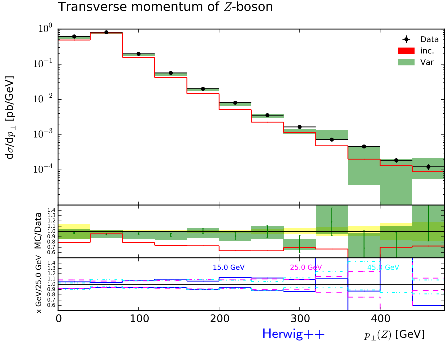
Status of the project

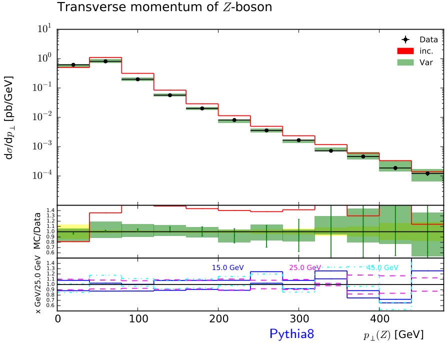
- Herwig++/FxFx results available for Z + jets and W + jets.
- Pythia8/FxFx result available for Z + jets, close to completion for W + jets.
- Pythia8/UNLOPS events produced for both processes, at the beginning of the showering phase.

Z + jets

Z + jets with FxFx: ATLAS_2013_I1230812

$\mathcal{L} = 4.6\ \text{fb}^{-1}$, $p_T(j) > 30$ GeV, $|y(j)| < 4.4$.

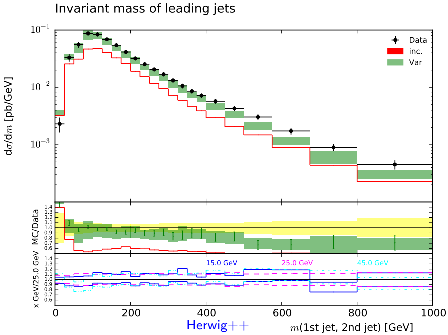


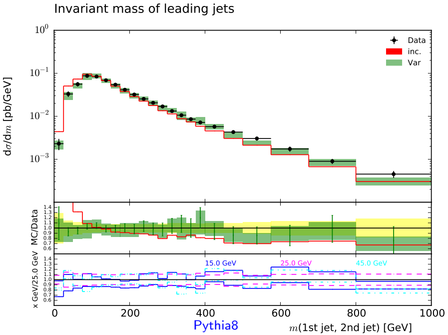


- LO observable in the inclusive case, discrepancy Hw++ vs Py8 up to medium $p_T(Z)$.
- Stabilisation and shower insensitivity when including FxFx.
- Theoretical uncertainty constant at least up to 300 GeV.
  Inclusively, it would increase dramatically starting from $\mathcal{O}(M_Z)$.

Z + jets with FxFx: ATLAS_2013_I1230812

$\mathcal{L} = 4.6\ \text{fb}^{-1}$, $p_T(j) > 30$ GeV, $|y(j)| < 4.4$.

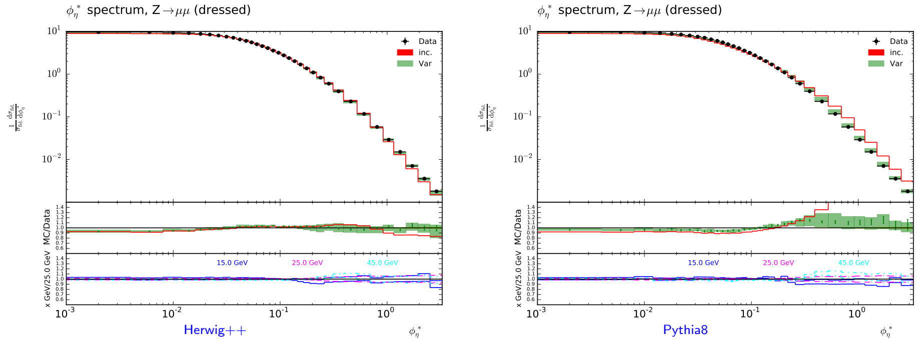




- Herwig++ much softer than data inclusively, slightly softer with FxFx.
- Pythia8 closer to data wrt Herwig++ both inclusively and with FxFx.
- Comparison among different showers important to assess systematics.

Z + jets with FxFx: ATLAS_2012_I1204784, angular correlations

$\mathcal{L} = 4.6\ \text{fb}^{-1}$, $p_T(\ell) > 20$ GeV, $|y(\ell)| < 2.4$.

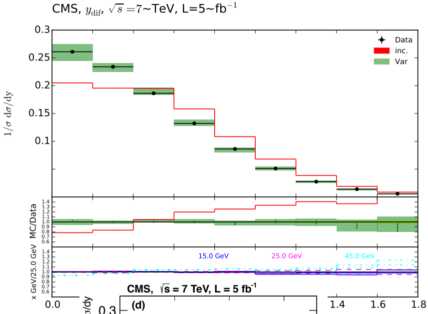


- ϕ^*_η only depends on lepton directions, not momenta: similar to $p_T(Z)$ with better resolution. $\phi^*_\eta < 1$ probes $p_T(Z)$ up to ~ 100 GeV.
  'Dressed' means recombined with radiated photons within $\Delta R = 0.1$.

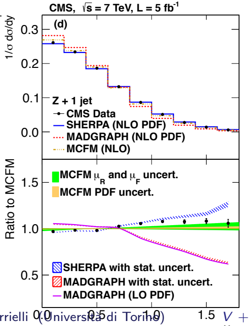
- Good description already at the inclusive level (except large ϕ^*_η for Pythia8, see $p_T(Z)$). Stabilisation with FxFx against shower change and merging-scale variations.

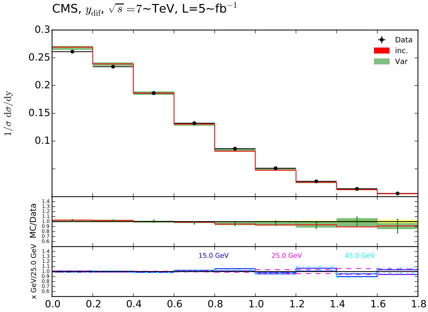
Z + jets with FxFx: CMS_2013_I1258128, exclusive $Z + 1$ jet

$\mathcal{L} = 5.0$ fb^{-1}, $p_T(j) > 30$ GeV, $|\eta(j)| < 2.4$.



Herwig++



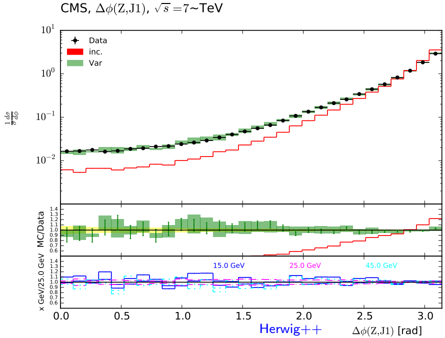


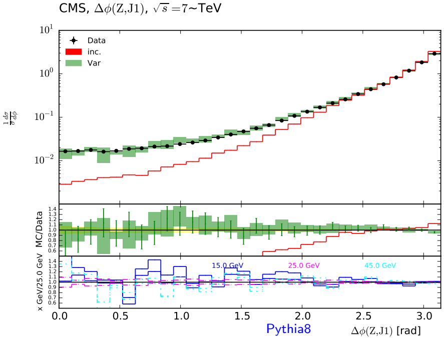
Pythia8

- Herwig++ flat at small $y_{dif} = |y(Z) - y(j)|$: shower initial conditions deplete the central region. Pythia8 populates it more already inclusively.
- Shower much less relevant after merging, still larger systematics for Herwig++.

Z + jets with FxFx: CMS_2013_I1209721

$\mathcal{L} = 5.0\ \text{fb}^{-1}$, $p_T(j) > 50$ GeV, $|\eta(j)| < 2.5$.



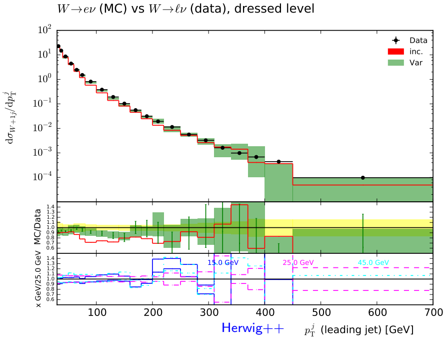


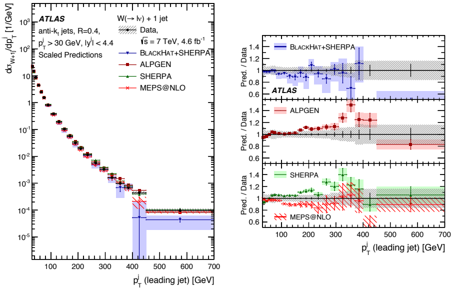
- $\Delta\phi < \pi$ filled by shower and higher orders, hence expected improvement wrt inclusive due to FxFx.
- Slightly larger Pythia8 systematics, driven by the lowest merging scale.

W + jets

W + jets with FxFx: ATLAS_2014_I1319490

$\mathcal{L} = 4.6$ fb^{-1}, $p_T(j) > 30$ GeV, $|y(j)| < 4.4$.



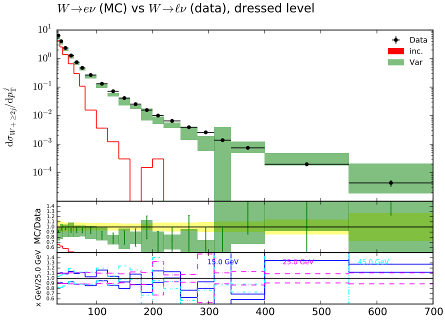


ATLAS paper

- Rivet analysis provided by ATLAS.
- $p_T^{j_1}$ in W + 1 jet events: already decently described at the inclusive level.
- Merged prediction of comparable to other generators.

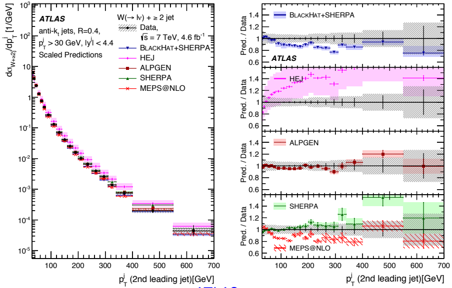
W + jets with FxFx: ATLAS_2014_I1319490

$\mathcal{L} = 4.6\ \text{fb}^{-1}$, $p_T(j) > 30$ GeV, $|y(j)| < 4.4$.



p_T^j (2nd leading jet) [GeV]

Herwig++

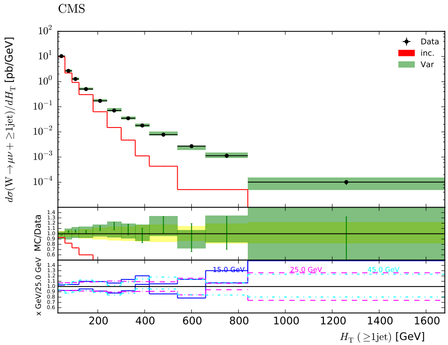


ATLAS paper

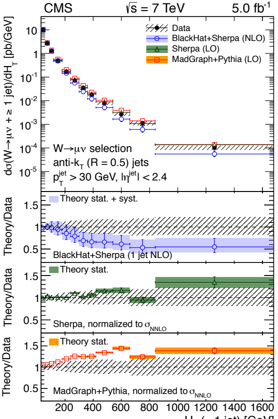
- Inclusive prediction unreliable, since second jet solely generated by the showers.
- Agreement of the merged prediction comparable to (or slightly worse than) other generators. Will be interesting to see Pythia8, which is slightly closer to data than Herwig++ in Z + jets.

W + jets with FxFx: CMS_2014_I1303894, $W \to \mu\nu_\mu$

$\mathcal{L} = 5.0\ \text{fb}^{-1}$, $p_T(j) > 30$ GeV, $|\eta(j)| < 2.4$.



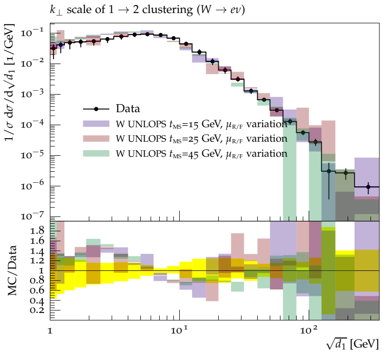
Herwig++

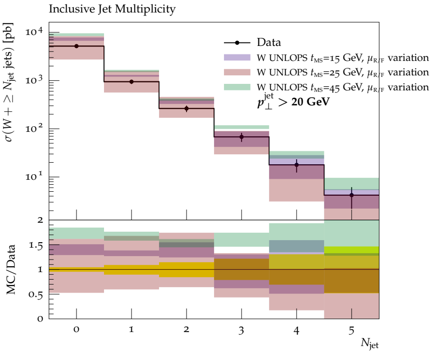


CMS paper

- Rivet analysis provided by CMS.
- Good description of data at large H_T, slightly closer to data than other generators.

W + jets with UNLOPS, very preliminary





- Left panel: ATLAS_2013_I1217867.
- Right panel: ATLAS_2012_I1083318.
- Only a small fraction of available events showered so far: expected to be a very interesting comparison with FxFx.

Conclusions

- First FxFx comparisons to data. Good agreement with data for most observables. Few features ascribed to sizeably different shower behaviours.
- Enhanced insensitivity to underlying shower when including merging: in most cases differences Herwig++ vs Pythia8 lie in the uncertainty band, with visible improvement wrt inclusive.
- Small merging-scale dependence in general, with marginal exceptions driven by the lowest scale.

To do

- Complete showering Pythia8/FxFx W + jets.
- Complete Pythia8/UNLOPS for Z and W + jets.
- Possible related projects: $t\bar{t}$ + jets, ...

Thank you for your attention