MadGraph5_aMC@NLO

Theory perspectives on tt+jets and tt+HF production

Rikkert Frederix

CERN theory group

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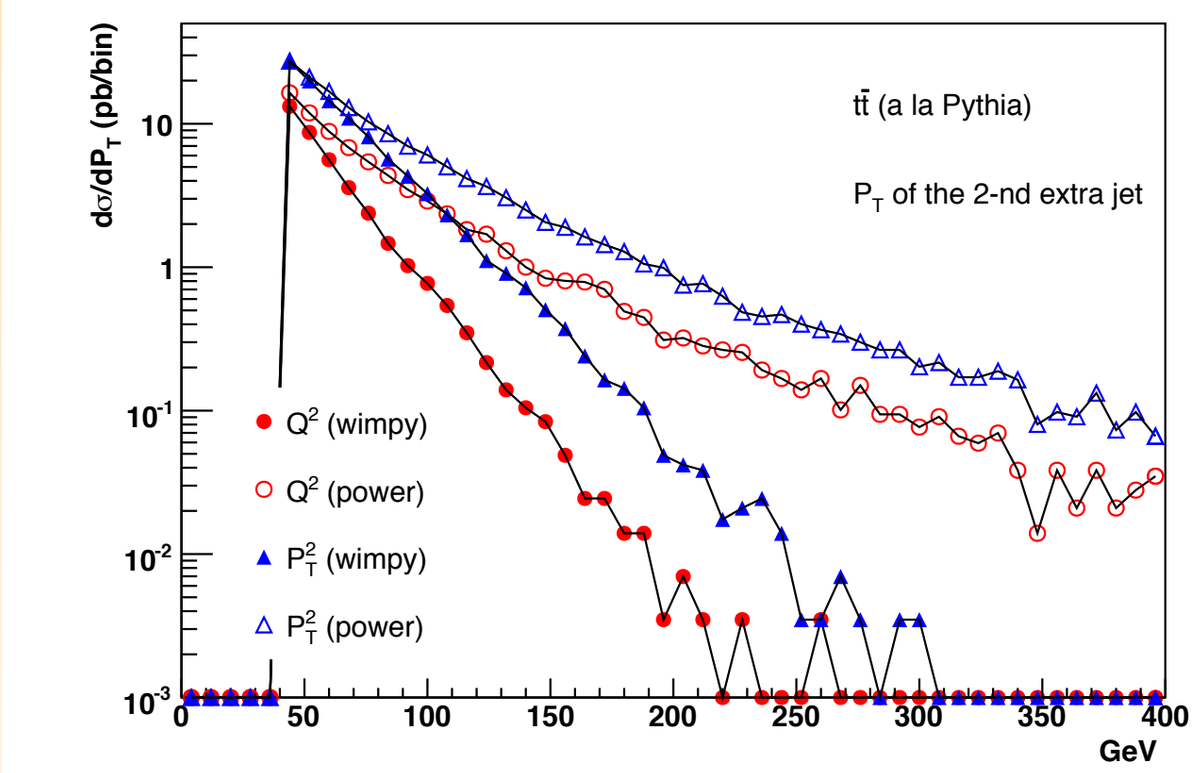
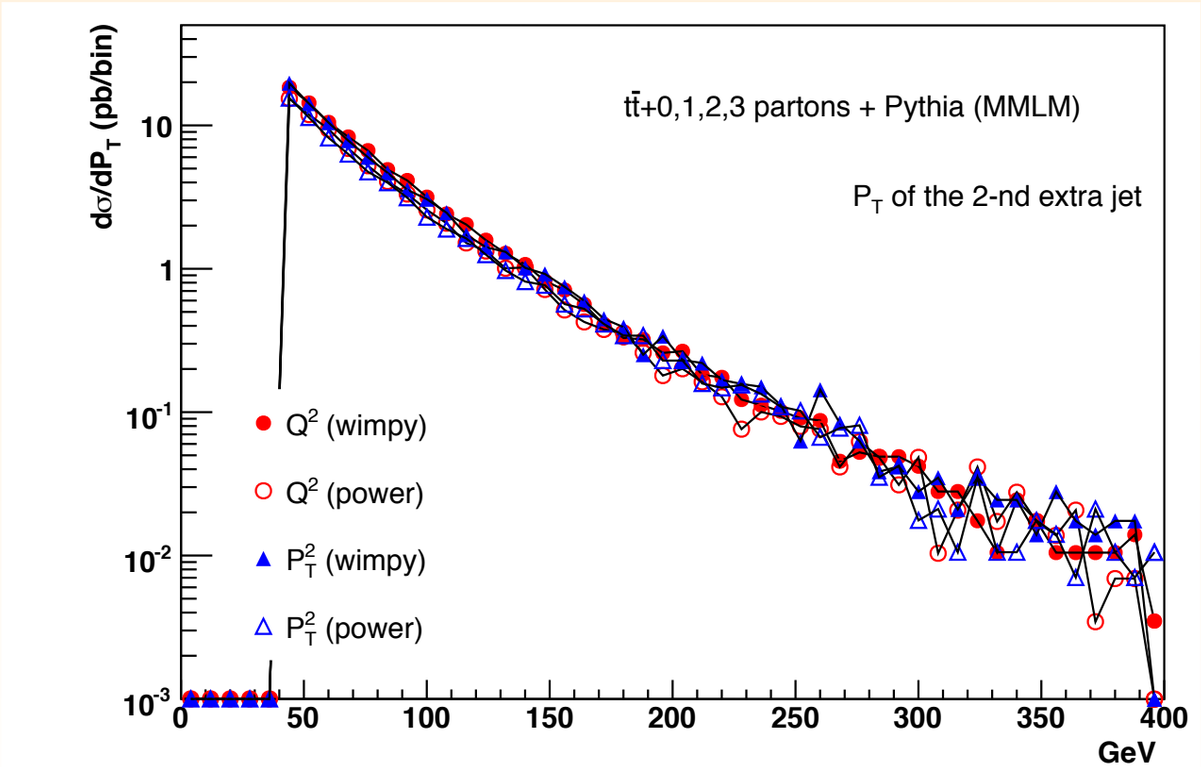
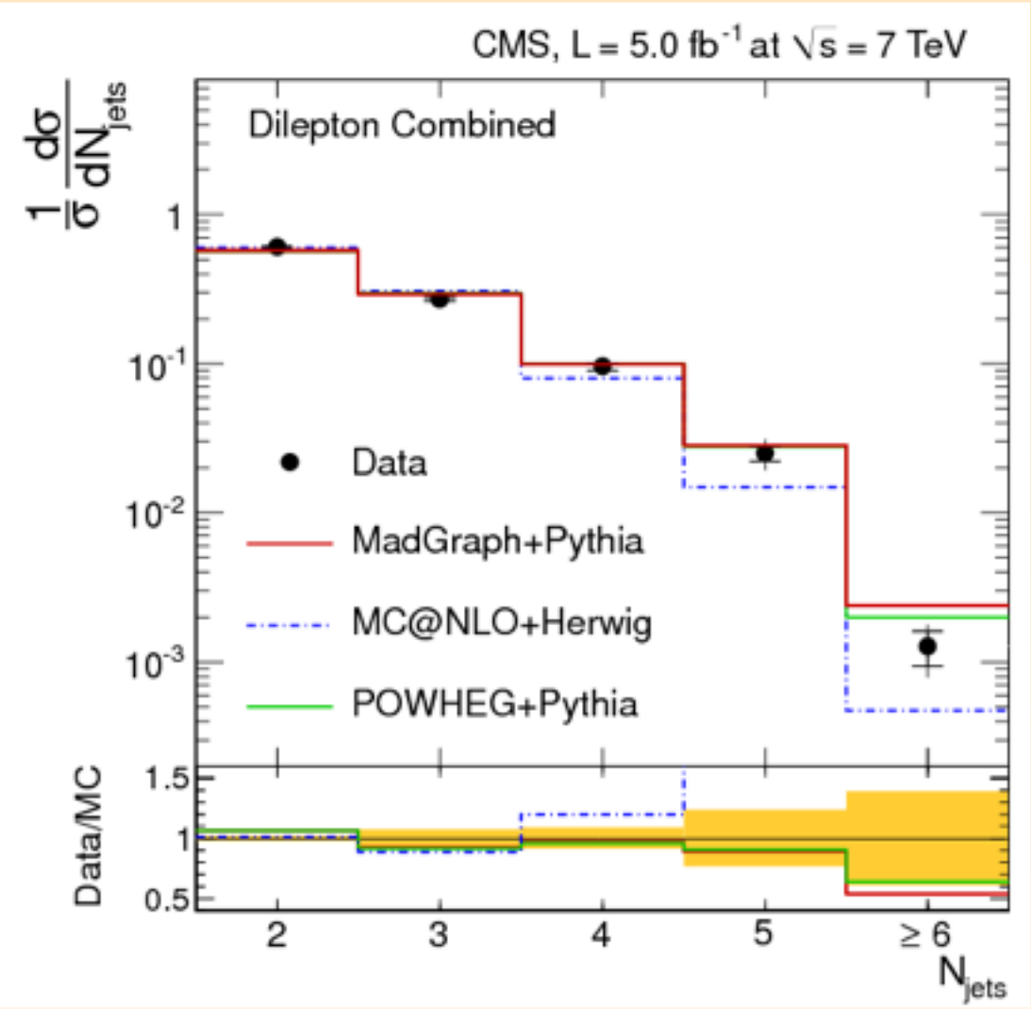
Need for merging

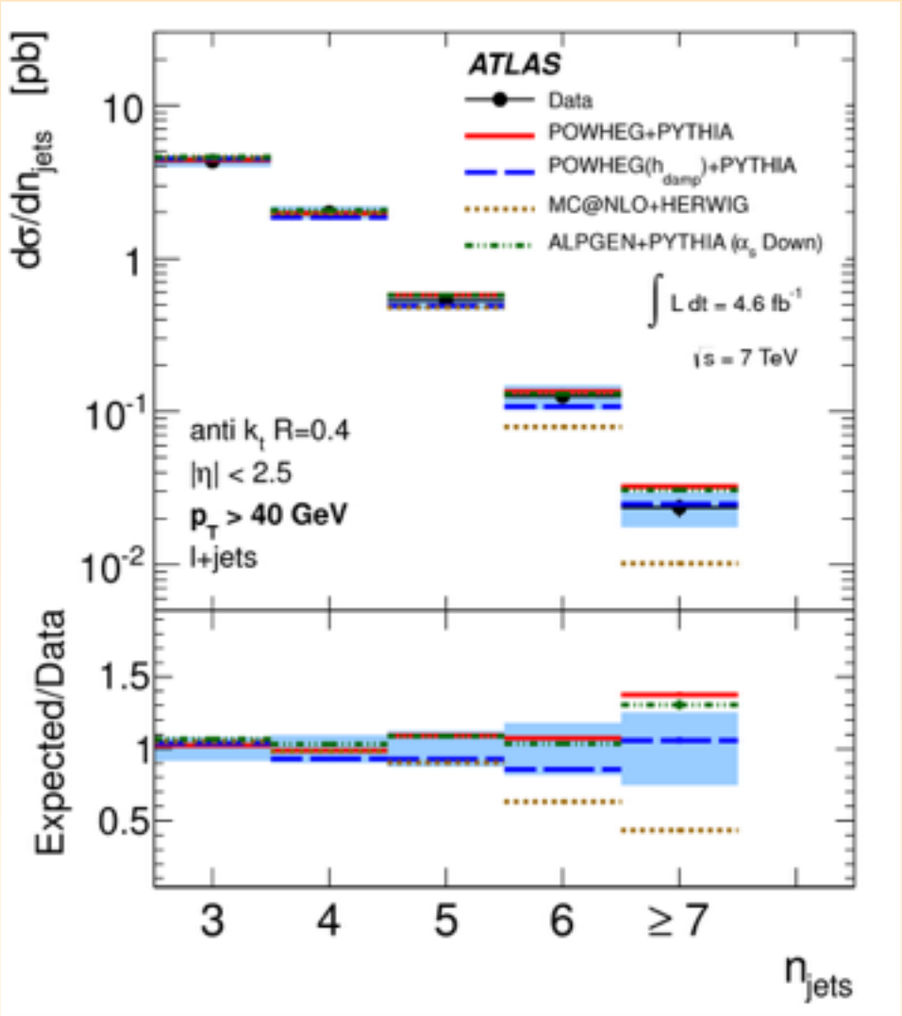
- Without multi-jet merging, jets that are produced in association with the top quark pair, cannot be described with high precision
- Variation is large, and could easily span orders of magnitude





Need for merging





- However, in current measurements there are still comparisons made with non-merged results
- Statements are made that "POWHEG (with h_{damp}) describes the data best", which cannot be concluded without taking the MC uncertainties into account

Merging at NLO

- In MadGraph5_aMC@NLO, we have tried to make it as simple as possible
  - ./bin/mg5_aMC
  - generate p p > t t~ [QCD] @0
  - add process p p > t t~ j [QCD] @1
  - add process p p > t t~ j j [QCD] @2
  - output
  - launch
  - In the run_card, set the ickkw parameter to
    - **3** to activate FxFx merging (tested with herwig6, herwig++ & pythia8) or
      see http://amcatnlo.web.cern.ch/amcatnlo/FxFx_merging.htm for more details
    - **4** to activate UNLOPS merging (pythia8)

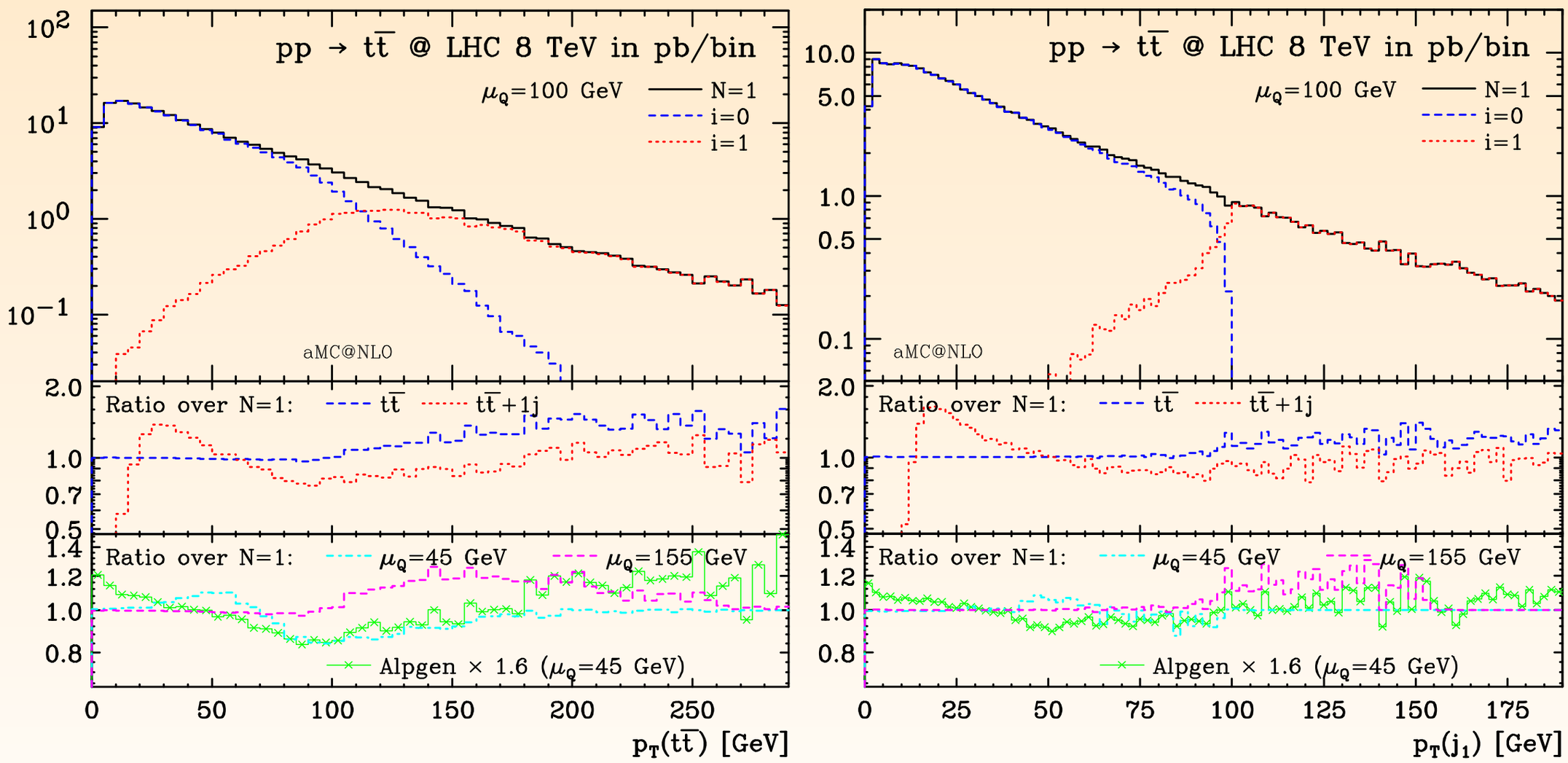
MG5_aMC features

- Event weights to include scale & PDF uncertainties event-by-event at no extra cost
- Decays with MadSpin: spin correlations included
- LHEF events are independent from the merging scale
  - Only shower needs to be rerun to estimate merging scale systematics
- FxFx merging with Herwig++ and Pythia8 allows for study of the MC dependence
- FxFx can be compared to UNLOPS merging for Pythia8

Merging scale

✦ Check that your results are "independent" from the merging scale

RF & Frixione: JHEP 1212 (2012) 061



✦ These plots are for ttbar+0/1j @ NLO; ttbar+2j @NLO is a tough calculation but can be included to improve the description of 2-jet observables

REMARKS

- Dependence on the merging scale much smaller as in LO merging methods
- However, its dependence is non-zero. Moreover:
  - There is no theorem that tells you what this scale should be
  - The scale cannot be taken too large: one looses formally NLO accuracy in exclusive observables
  - The scale cannot be taken too small: one looses formally NLO accuracy in inclusive observables
- Always vary it at least so that both sides of the analyses' jet definition are covered
  - e.g. if jets are defined with 40 GeV p_T, vary the merging scale from below to above 40 GeV.

Heavy Flavour

- Not obvious how to separate ttbar+HF predictions from ttbar +light jet production
- Simplest method: use 4-flavour scheme predictions
  - Do not include the b-quark in the definition of the proton nor the matrix-element jets
  - Generate a separate sample using ttbb matrix elements, which contributes to ttbar, ttbar+b-jet and ttbar+2b-jets

4FS: possible issues

- Introduces a logarithm ($\log[m_b^2/Q^2]$) in the perturbative series which might spoil its convergence
  - Probably okay for b quarks
  - Probably not okay for c quarks
- Parton shower uses 5 flavours (or even 6): mismatch between 4FS matrix element predictions and what is used in the parton shower
  - Also a problem in the 5FS, because in the 5FS bottom quarks are massless in the matrix elements
- No completely satisfactory solution

Summary

- MadGraph5_aMC@NLO can be used for the simulation of ttbar+jets and ttbb
  - For ttbar+jets, FxFx merging can be used
    - Use a large variation of the merging scale: in general from below to above the jet definition
  - For ttbar+HF, use the ttbb process (4 flavour scheme)
  - No ideal solution for ttcc. Best treated as part of ttbar+jets