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aMC@NLO studies

TOPLHCWG meeting, CERN, 19/4/2013

With R. Frederix and A. Papanastasiou

What aMC@NLO is

A single framework for the computation of:

A. Hard events at the NLO or LO, to be subsequently showered

B. Infrared-safe observables at the NLO or LO

As in MadGraph (whose platform is used by aMC@NLO) there is no pre-defined list of processes: all is generated/computed on the fly

The code is modular: the use of third-party results for virtual matrix elements is straightforward (but not mandatory)

A.

- At the NLO, the matching formalism is the same as in MC@NLO. Currently HW6, HW++, and PY6 (Q^2; p_T is ISR-only) are supported. PY8 is under validation
- At the LO, it is the same as MadEvent (however, ME only interfaced to PY)
- In both cases, as is customary, MCs must be seen as plugins. aMC@NLO contains (lots of) utilities to shower hard events right after their generation, but this is not mandatory
- Hard event files are fully LHA compliant

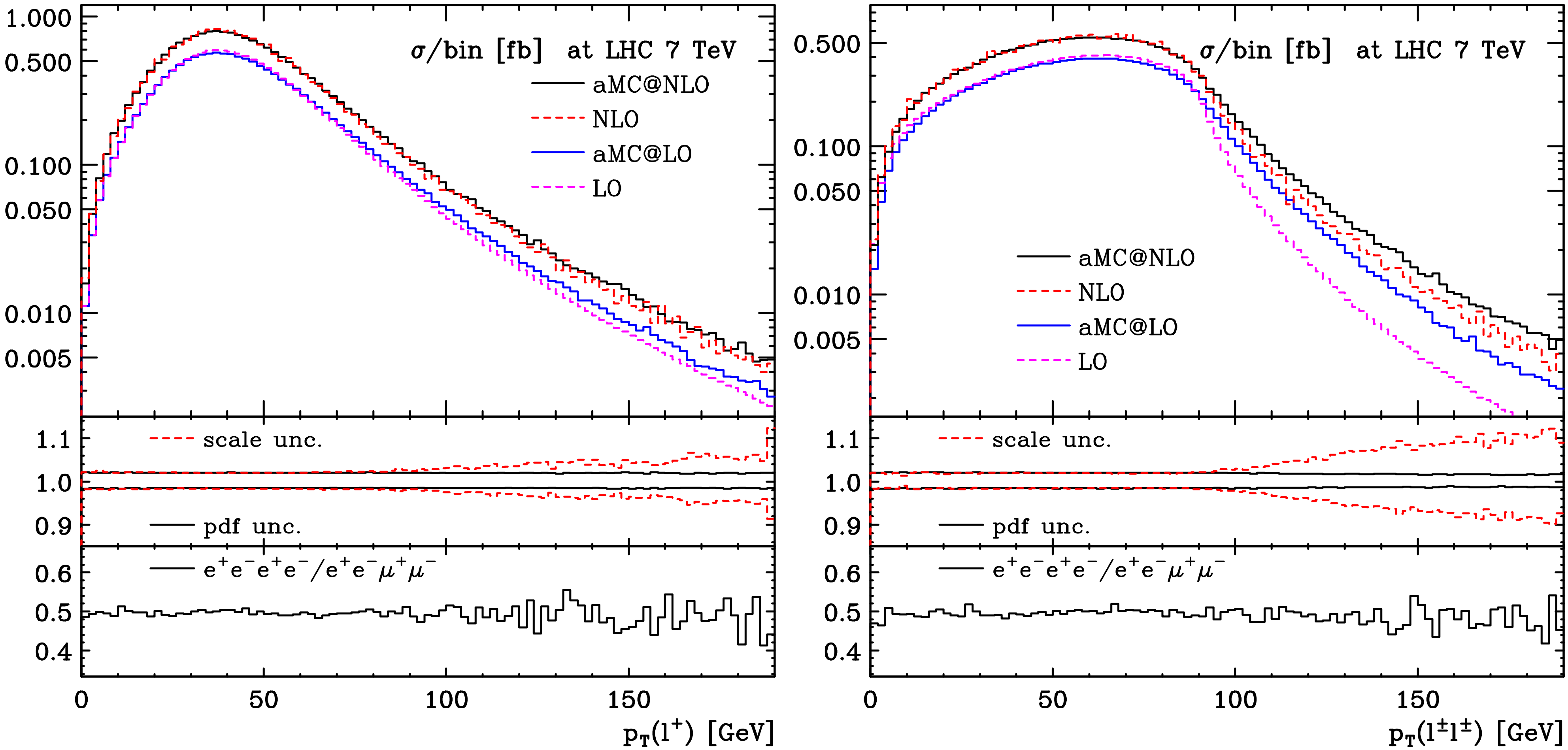
B.

- This is the analogue of BlackHat+Sherpa or MCFM

  (no event generation, only histograms of IR-safe observables)

- Plots have to be produced on-the-fly (may change if needed)

Typical results



From arXiv:1110.4738

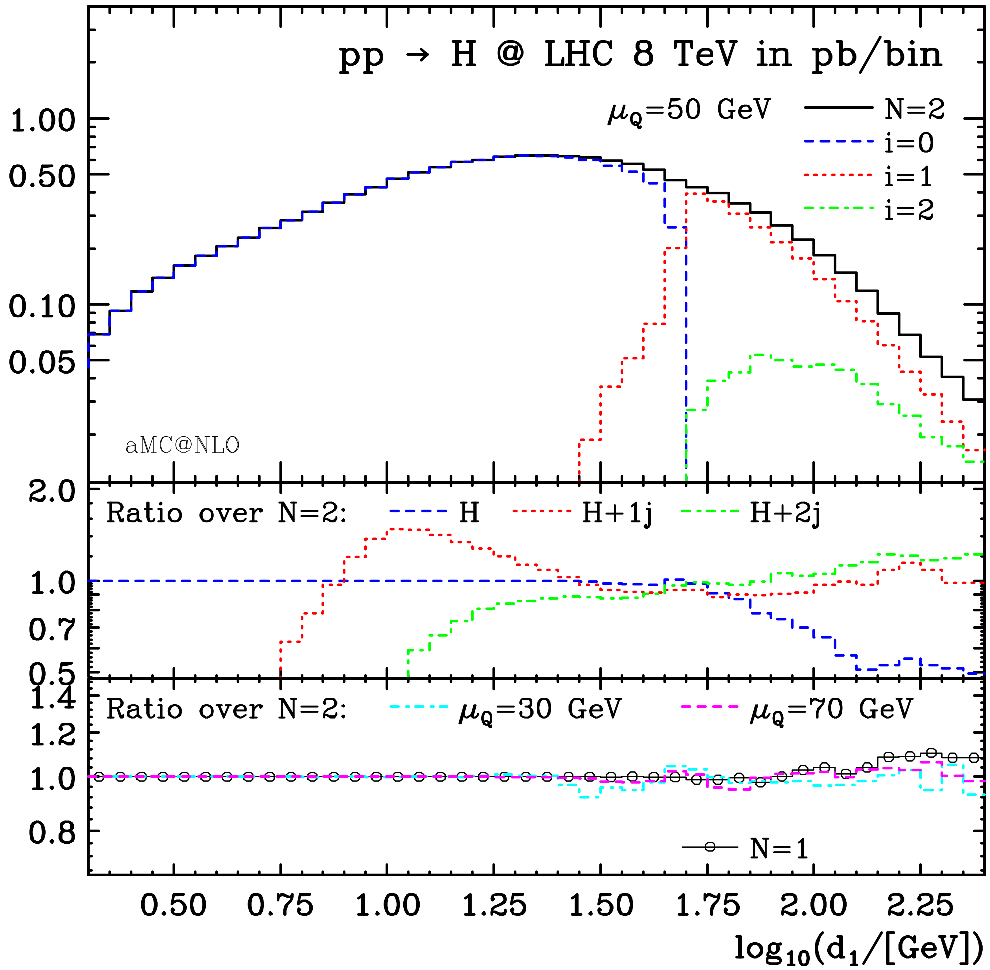
Note: scale and PDF uncertainty bands come at no extra CPU cost: one just reweights the "central" results

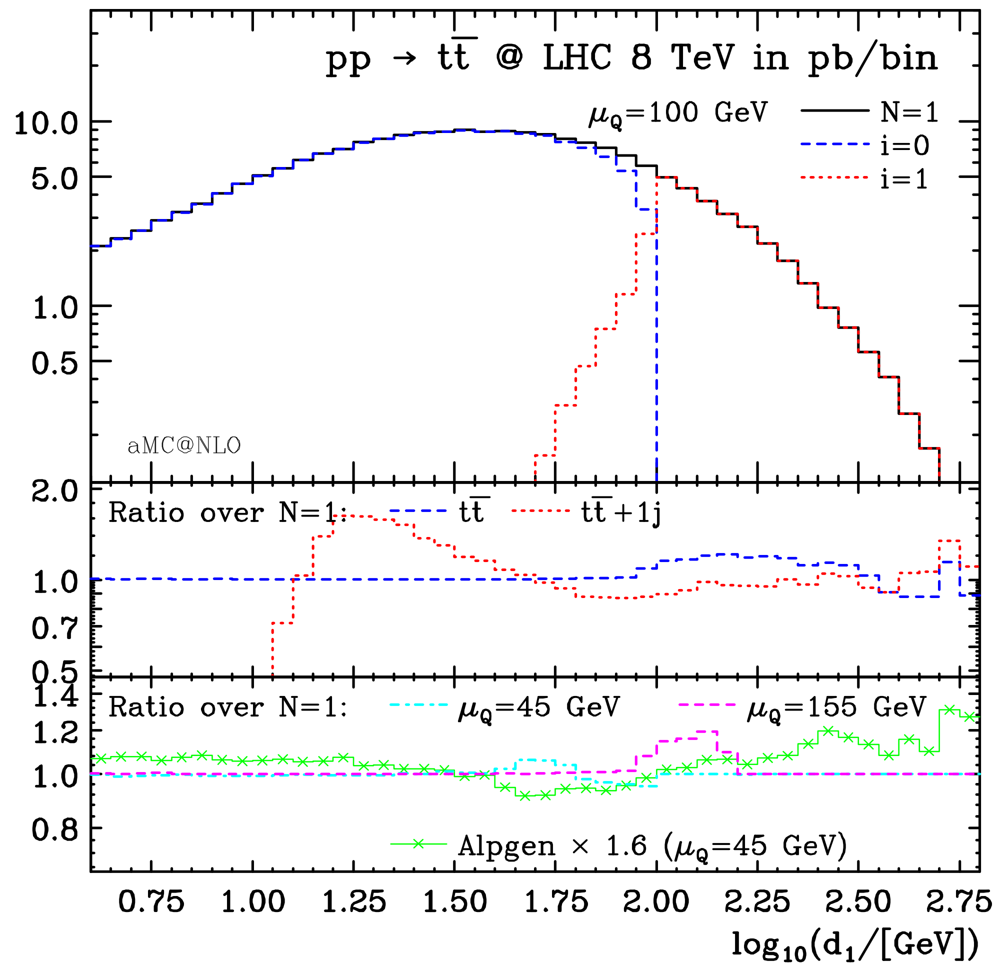
FxFx merging (1209.6215)

- The i-parton sample receives contributions from the same matrix elements that enter the i-jet cross section at the NLO
- The i-parton cross section is basically the MC@NLO one, times a suitable combination of damping factors defined with a (smooth) function $D(\mu)$, which allow one to distinguish ME-dominated, MC-dominated, and intermediate regions
- $D(\mu)$ can also be chosen to be sharp, in which case

$$D(\mu) = \Theta\left(\mu_Q - \mu\right)$$

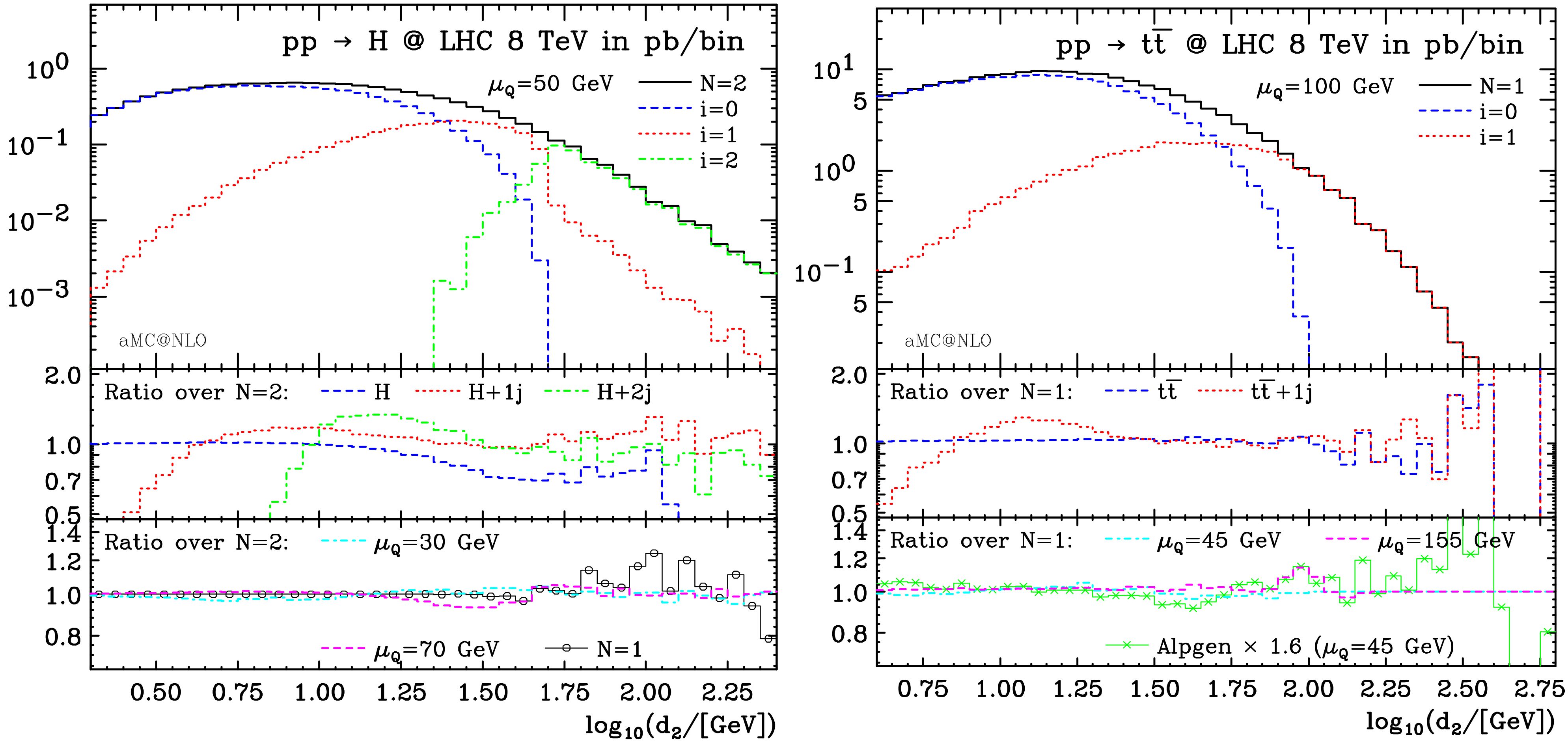
  with μ_Q the merging scale
- The above is further supplemented by a CKKW-like procedure





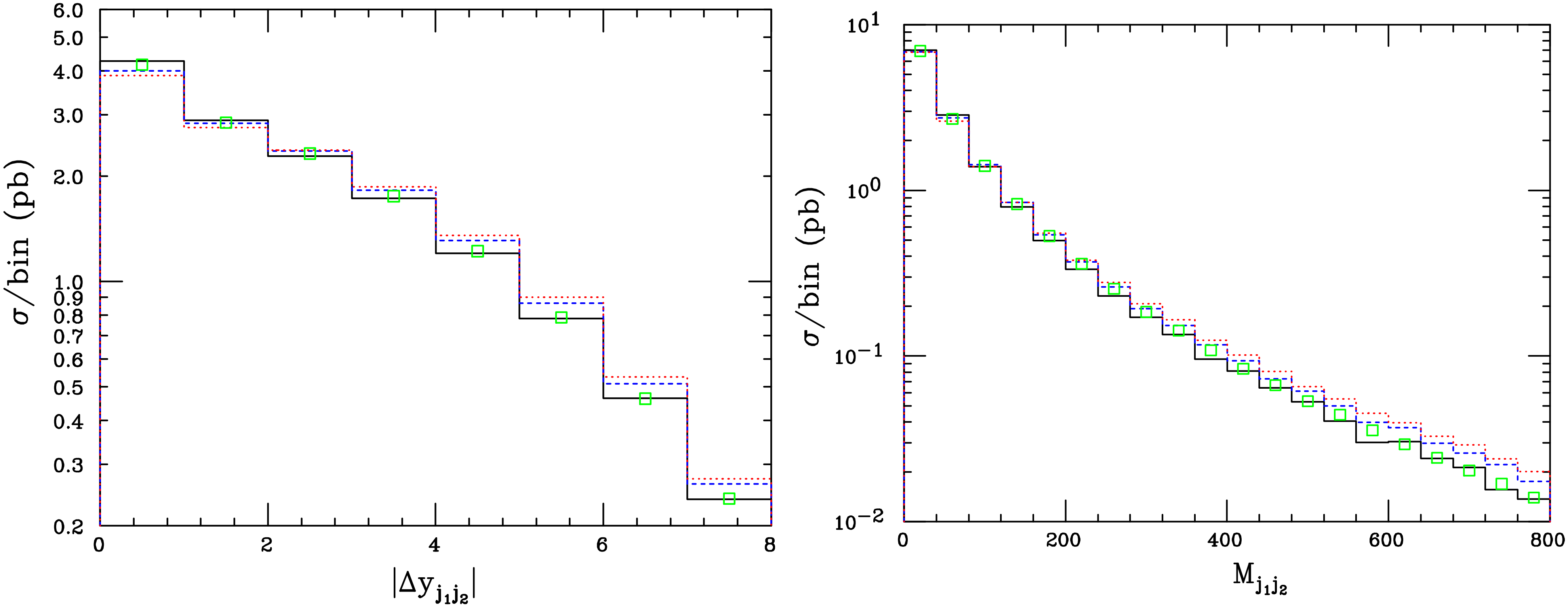
From arXiv:1110.4738

$0 \longrightarrow 1$ rates in H^0 and $t\bar{t}$ production



From arXiv:1110.4738

$1 \to 2$ rates in H^0 and $t\bar{t}$ production



$$gg \longrightarrow H^0$$

$\mu_Q = 30$ GeV, $\mu_Q = 50$ GeV, $\mu_Q = 70$ GeV,
Alpgen ≤ 3 partons (rescaled) merging 30 GeV

NLO merging techniques are very new – we have a lot to learn

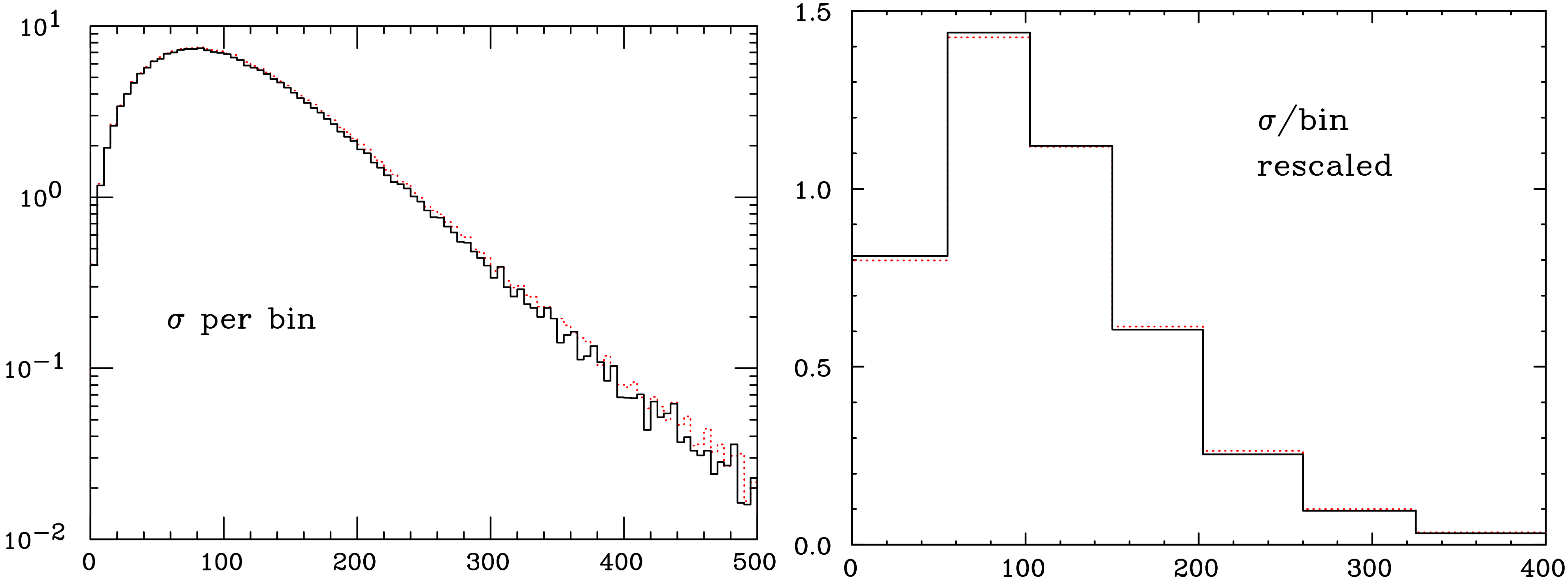
So far, we are happy with FxFx. In particular, we see small changes in observables supposedly well described at the lowest multiplicity

(in spite of *not* imposing unitarity)

It is therefore interesting to check what happens in $t\bar{t}$ production, the case study being that of the two following observables:

- top p_T (one measurement had more data at low p_T than NLO-based results)
- gap fractions (agreement within errors (3-4%) with MC@NLO, data being lower than MC@NLO at low-p_T and central rapidities)

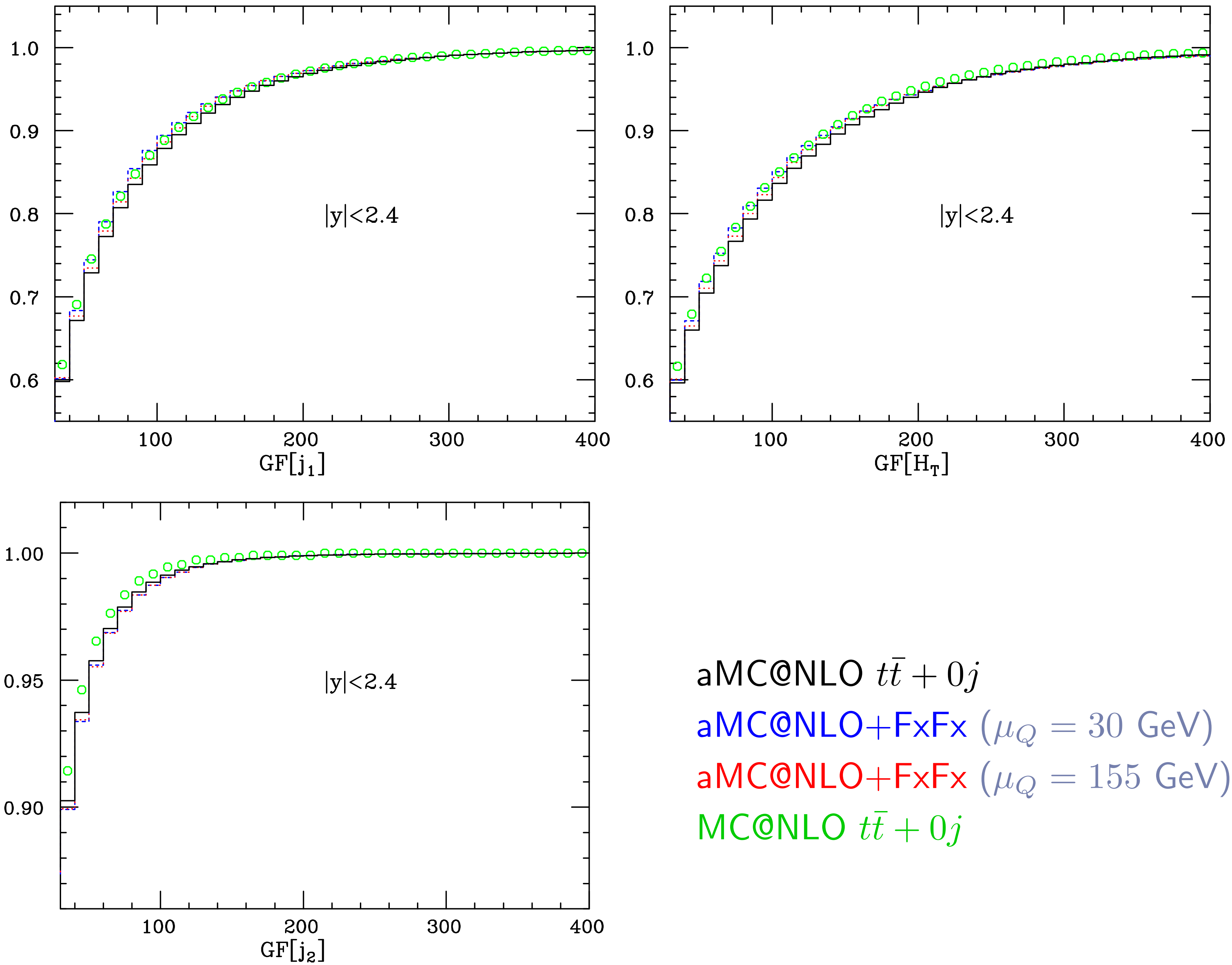
What follows is a theory vs theory comparison – the results are at 8 TeV, but the patterns must be the same at 7 TeV



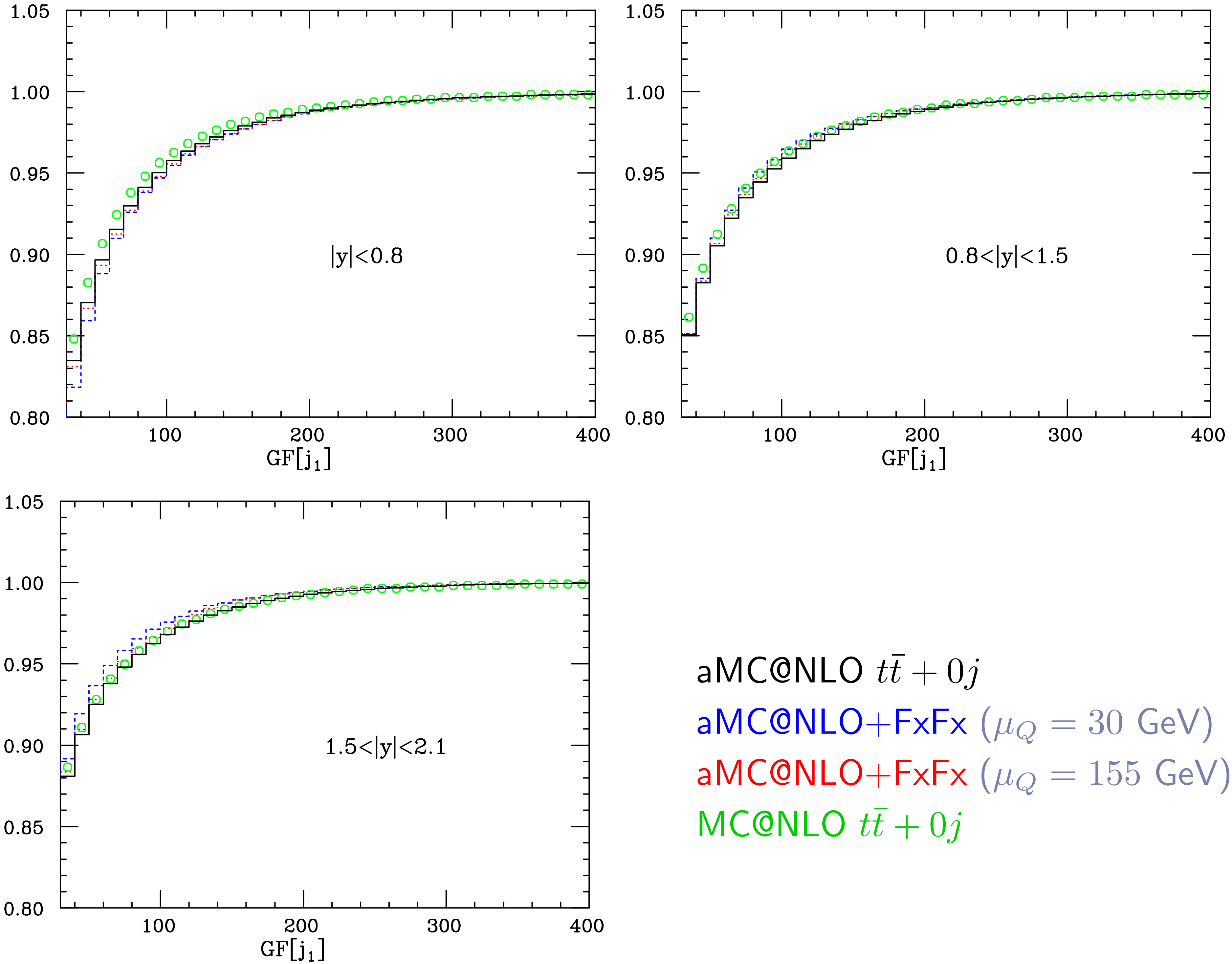
p_T of top

aMC@NLO FxFx merged $(\mu_Q = 100$ GeV$)$

aMC@NLO $t\bar{t} + 0j$



|y|<2.4
GF[j1]
|y|<2.4
GF[HT]
|y|<2.4
GF[j2]
aMC@NLO $t\bar{t}+0j$
aMC@NLO+FxFx ($\mu_Q = 30$ GeV)
aMC@NLO+FxFx ($\mu_Q = 155$ GeV)
MC@NLO $t\bar{t}+0j$



1.05
1.00
0.95
0.90
0.85
0.80
100
200
300
400
GF[j1]
|y|<0.8
0.8<|y|<1.5
1.5<|y|<2.1
aMC@NLO $t\bar{t}+0j$
aMC@NLO+FxFx ($\mu_Q = 30$ GeV)
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- Hence, it looks like aMC@NLO is closer to data than MC@NLO. But: *a)* it is within uncertainties; *b)* the analysis must be done exactly as that of the experiments

Γ_t effects in t-channel single top

We are now done with implementing the Complex Mass Scheme in aMC@NLO, which is a way to deal with unstable particles particularly suited to automated approaches

The idea is that of comparing results with those obtained in the Narrow Width Approximation; for "inclusive" observables, one expects effects suppressed by Γ_t/m_t

With CMS, we deal with

$$pp \longrightarrow W^+ j_b j$$

and apply cuts so as to have a fair comparison with NWA (MCFM).

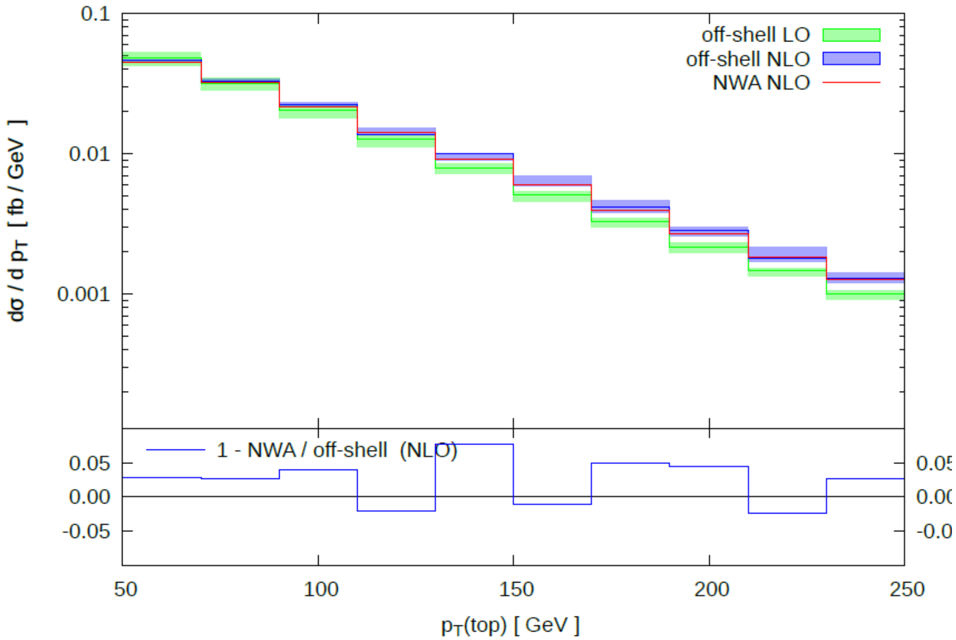
What follows does not include shower

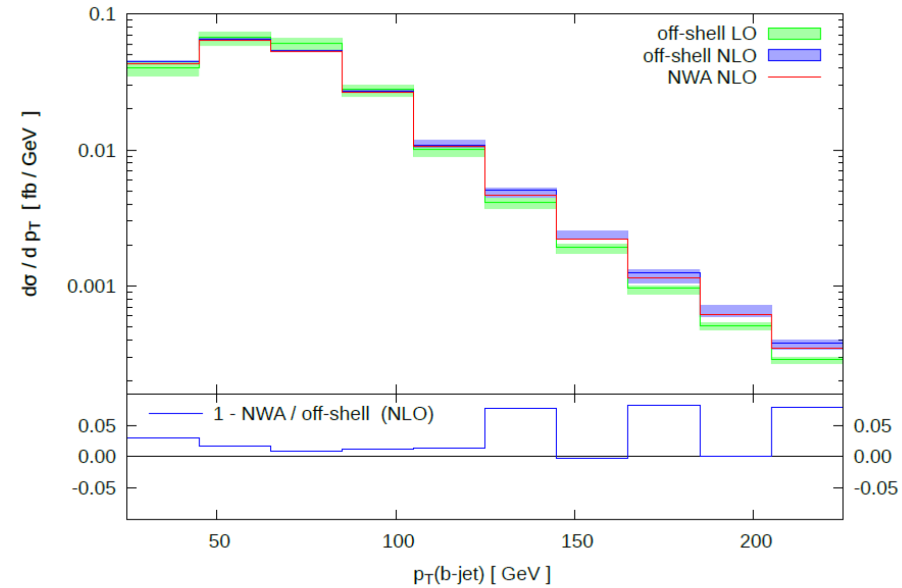
Note: we are considering a $\alpha^3(1+\alpha_S)$ cross section

This is a well-defined operation only thanks to the fact that the Born-level interference of EW (e^3) and QCD (eg_S^2) amplitudes vanishes

In turn, this happens only with $V_{tb}=1$

In a fully general case, one must treat the problem in the context of a mixed QED-QCD perturbative expansion (which is most likely a waste of time, given that complications are due to contributions which are quite strongly suppressed)



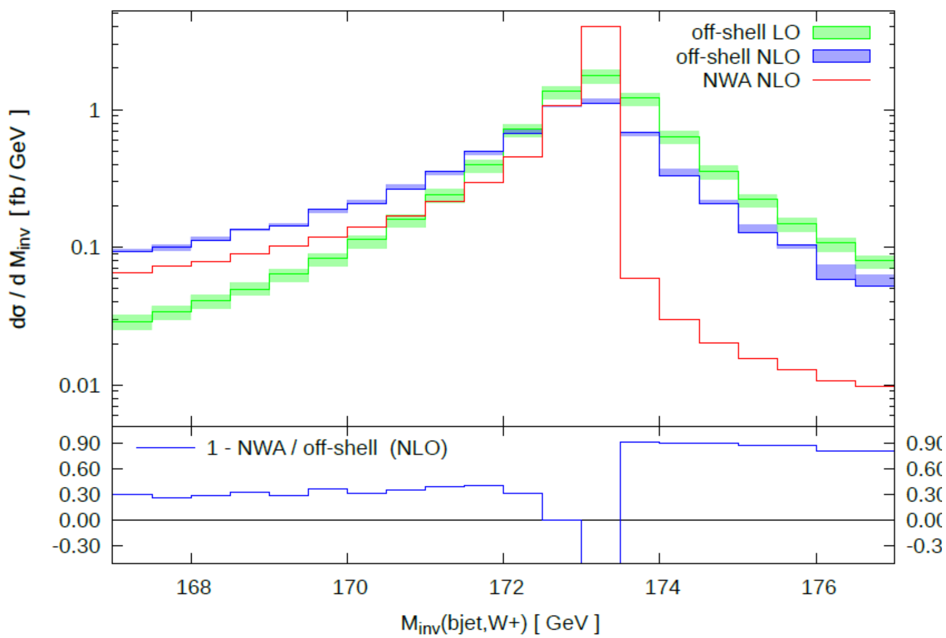


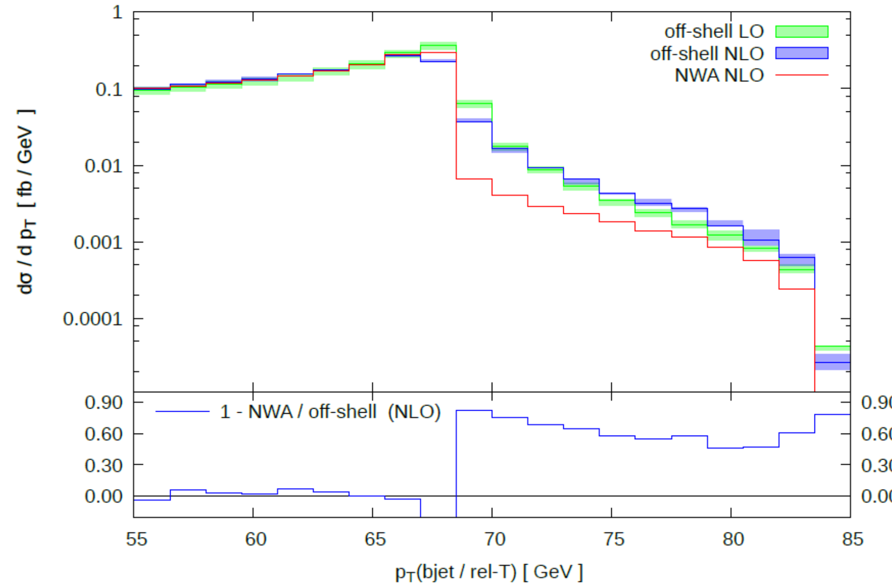
Γ_t-insensitive observables

$$p_T(j_b) \geq 25 \text{ GeV} \qquad p_T(j) \geq 25 \text{ GeV}$$

$$|j_b| < 4.5 \qquad |j| < 4.5 \qquad 140 \leq M(W^+ j_b) \leq 200 \text{ GeV}$$

Effects similar as for total rates ($\sim 1.5\%$ there)





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- Within cuts, NWA is in general an excellent approximation – note that not only Γ_t effects are neglected there, but also all non-factorizable corrections
- Γ_t- sensitive observables show a dramatic behaviour. This is something to be kept in mind e.g. for m_t extractions
- We observe a pattern fully analogous to that found by Denner *et al* (see e.g. 1208.5018) in $t\bar{t}$ production