Rikkert Frederix

CERN Theory Group Retreat, Les Houches Centre de Physique, France, Nov. 6, 2013

My interests:

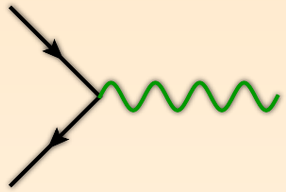
- LHC phenomenology
- Perturbative QCD and higher order corrections applied to collider physics
- Matching and merging fixed order (NLO) calculations to parton showers
- MadGraph5_aMC@NLO

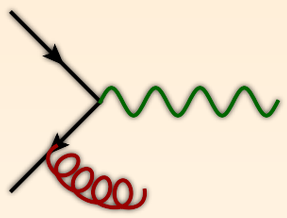
NLO + Parton shower

- NLO:
  - Reduced theoretical uncertainties due to meaningful scale dependence
  - Proper estimate of the PDF uncertainties
  - Description of pure higher order effects (like ttbar Forward-Backward asymmetry)
- Parton shower:
  - Resums logarithms: excellent descriptions when partons are close in phase-space
  - Proper exclusive description of events: can include hadronization
  - Events can be passed through detector simulation
- Combine the two approaches: NLO+PS

Matching NLO to PS: double counting

Parton shower →

Born+Virtual: 

Real emission: 

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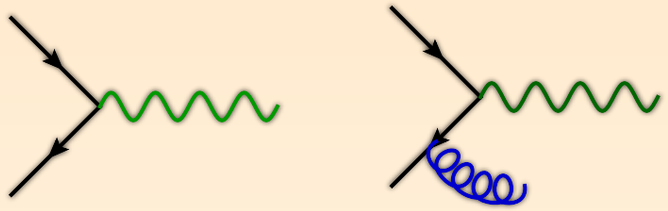
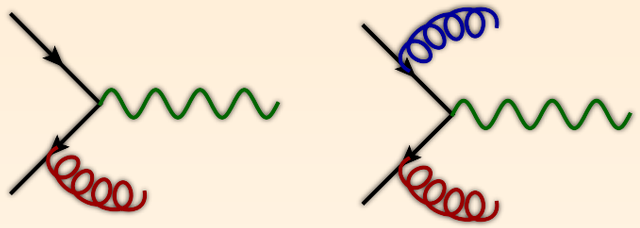


Real emission:



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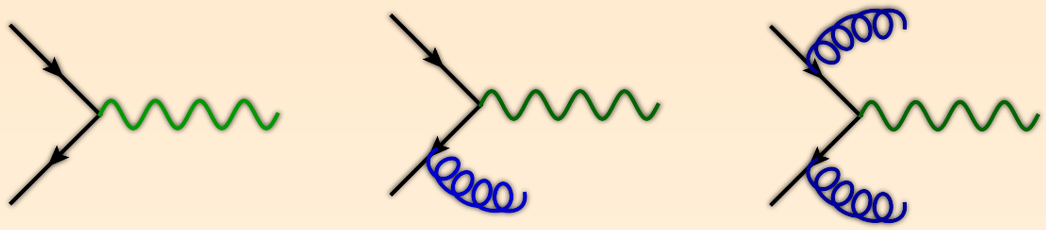

...

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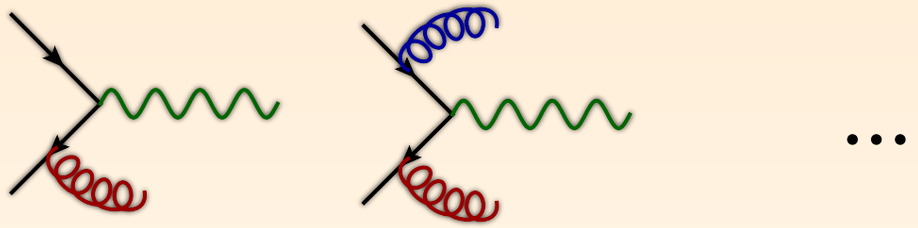

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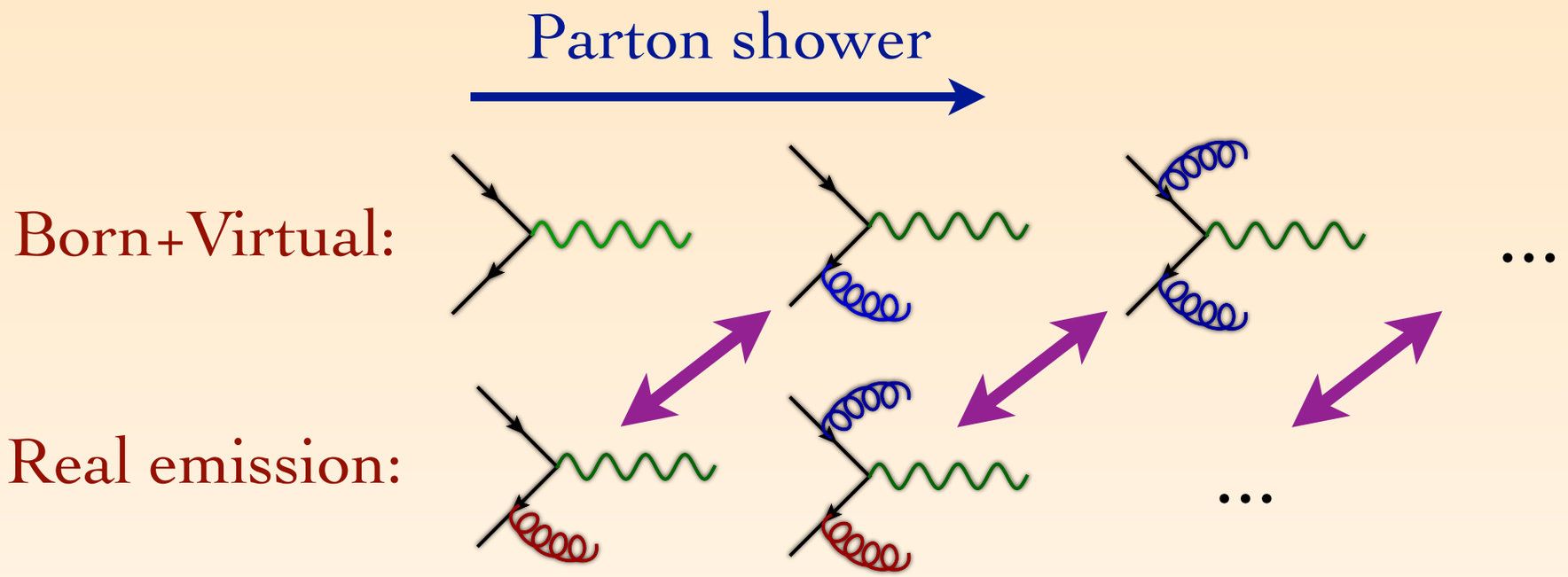
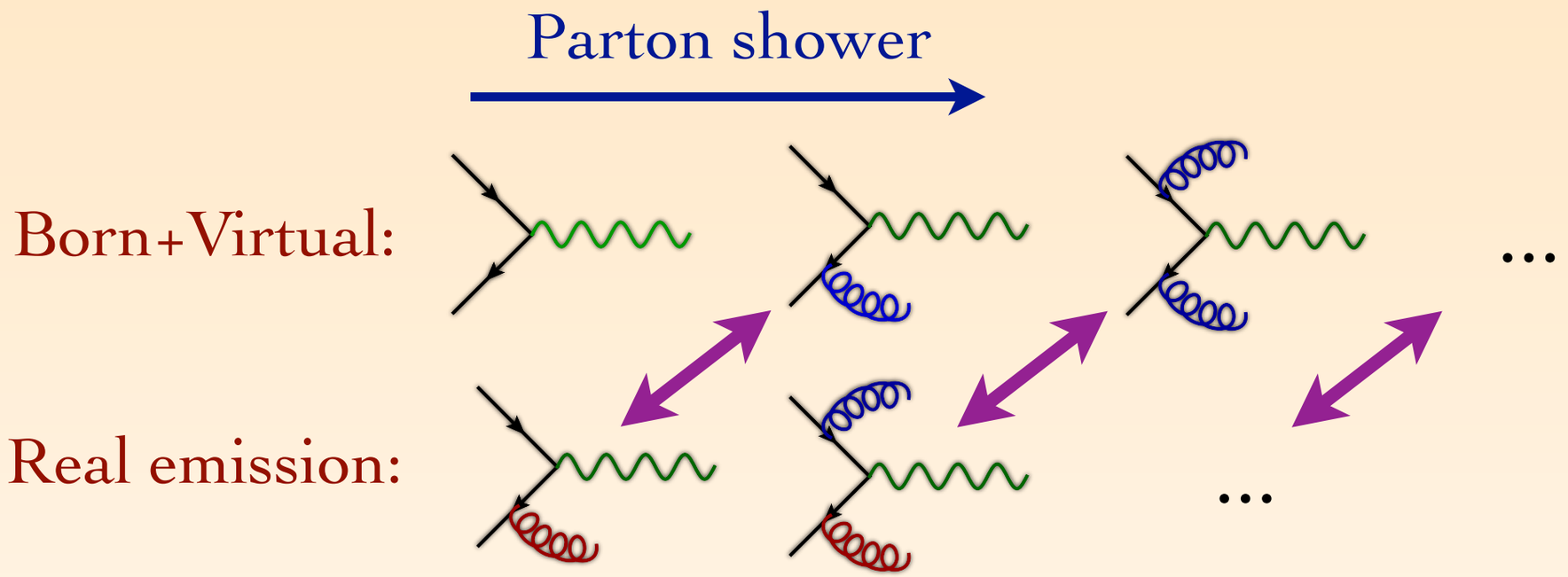


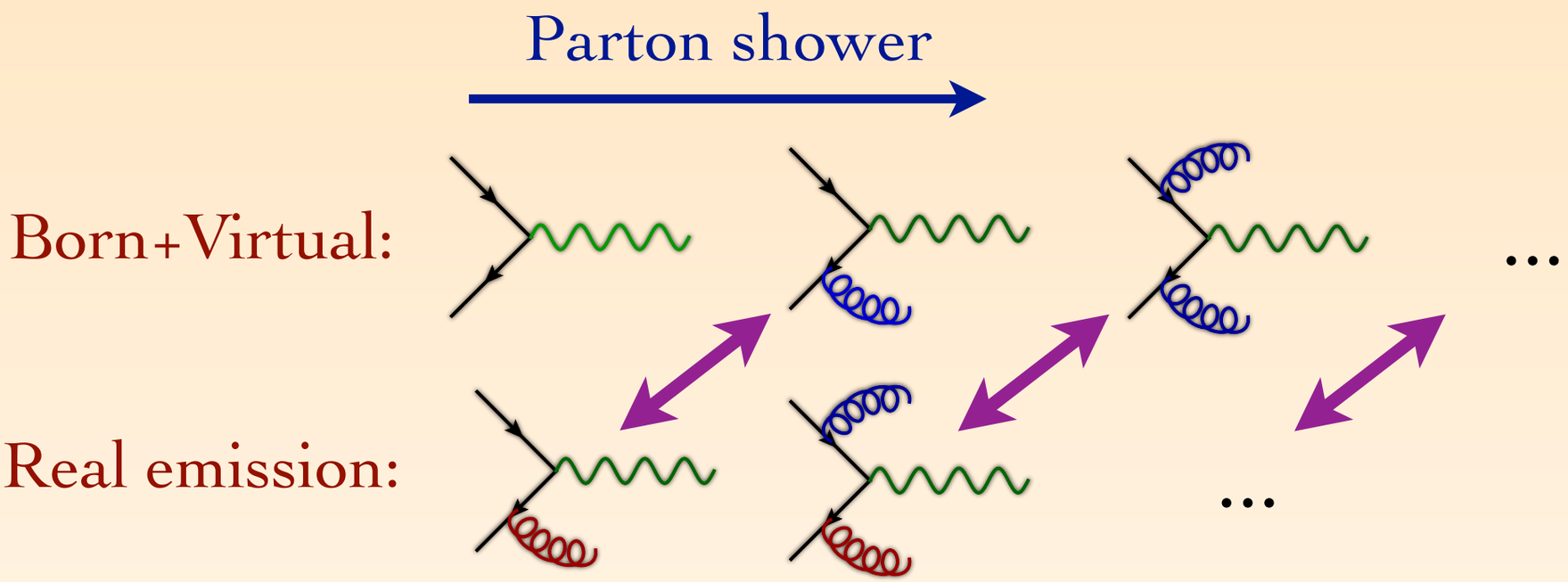
Matching NLO to PS: double counting



- There is double counting between the real emission matrix elements and the parton shower: the extra radiation can come from the matrix elements or the parton shower
- There is also an overlap between the virtual corrections and the Sudakov suppression in the zero-emission probability

MC@NLO PROCEDURE

Frixione & Webber (2002)



$$\frac{d\sigma_{\rm NLOwPS}}{dO} = \left[d\Phi_m (B + \int_{\rm loop} V + \int d\Phi_1 MC) \right] I^{(m)}_{\rm MC}(O)$$
$$+ \left[d\Phi_{m+1} (R - MC) \right] I^{(m+1)}_{\rm MC}(O)$$

- Double counting is explicitly removed by including the "Monte Carlo subtraction terms"

MadGraph5_aMC@NLO

RF, Frixione, Hirschi, Maltoni, Mattelaer, Torrielli, Zaro (paper to appear)

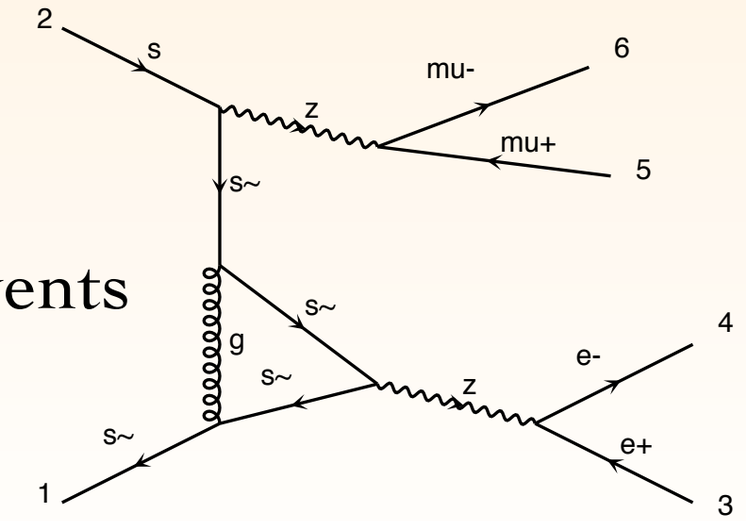
- aMC@NLO ("automatic MC@NLO") is a tool that we have been developing over the last couple of years
- It will be merged with MadGraph5, hence "MadGraph5_aMC@NLO"
- It can generate any SM process at NLO accuracy, including the MC subtraction terms, in a completely automatic way
- It's already build upon the MadGraph5 framework and uses the same syntax as the original leading order code
- Became publicly available last year

http://amcatnlo.cern.ch

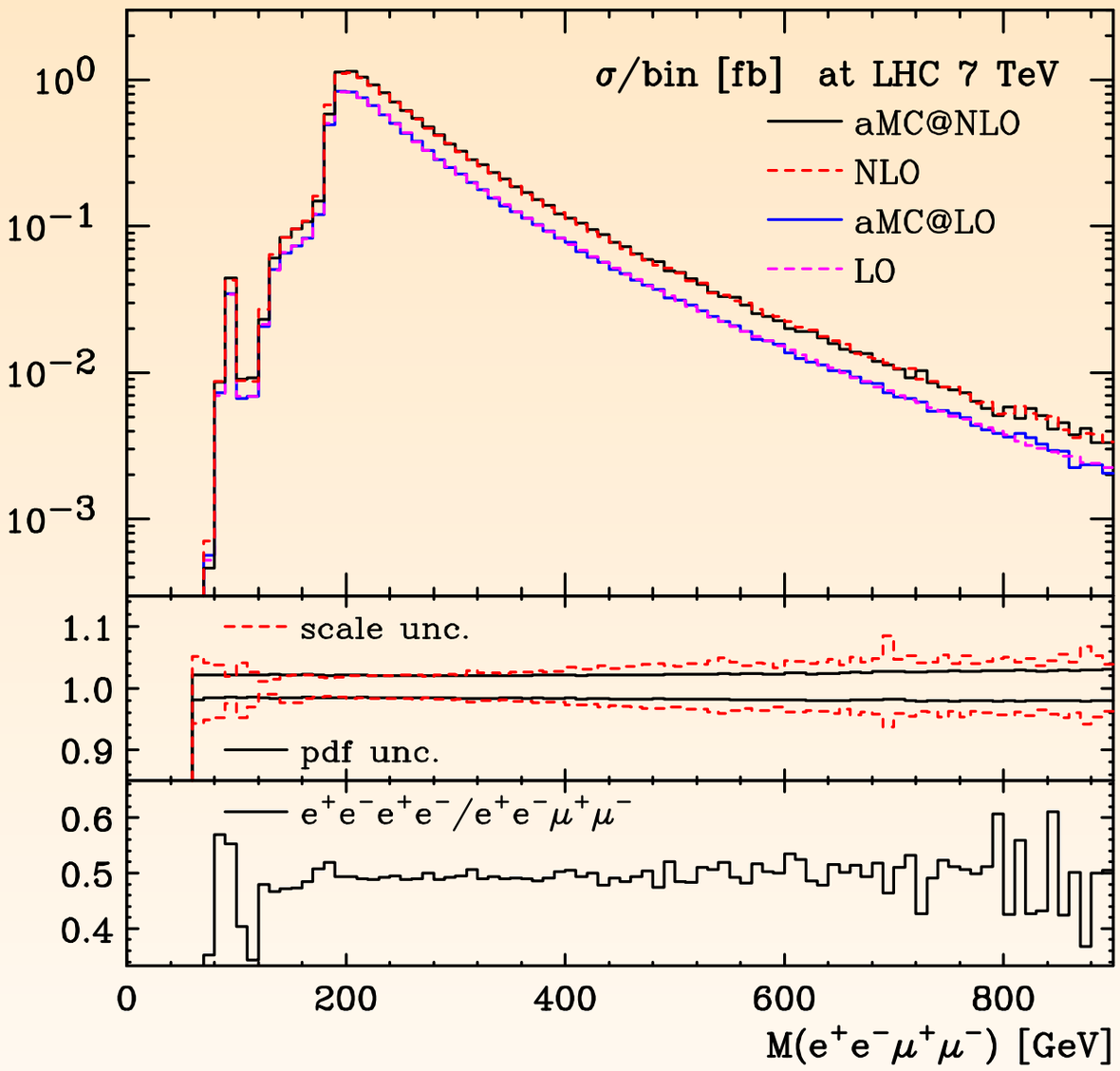
MadGraph5_aMC@NLO: quick guide

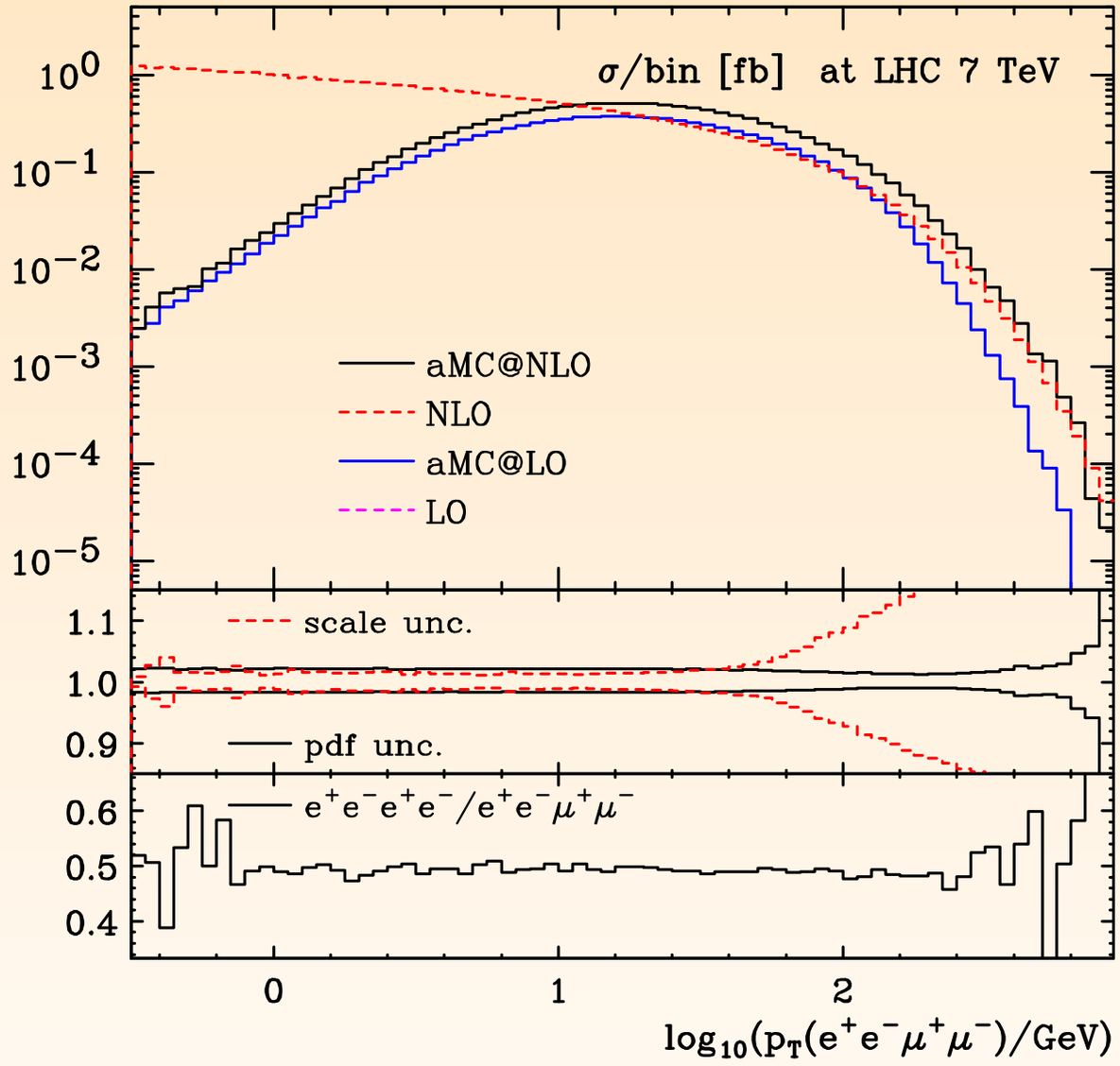
RF, Frixione, Hirschi, Maltoni, Mattelaer, Torrielli, Zaro (paper to appear)

- Open the madgraph python shell:
  `$ ./bin/mg5`
- From the shell generated the requested process:
  `> generate p p > e+ e- mu+ mu- [QCD]`
  (the tag "`[QCD]`" means: do NLO corrections). This generates the process internally in the code
- Output the process and write it to disk:
  `> output my_NLO_eemumu_process`
- And launch the event generation:
  `> launch`
- And wait for the code to generate the NLO events



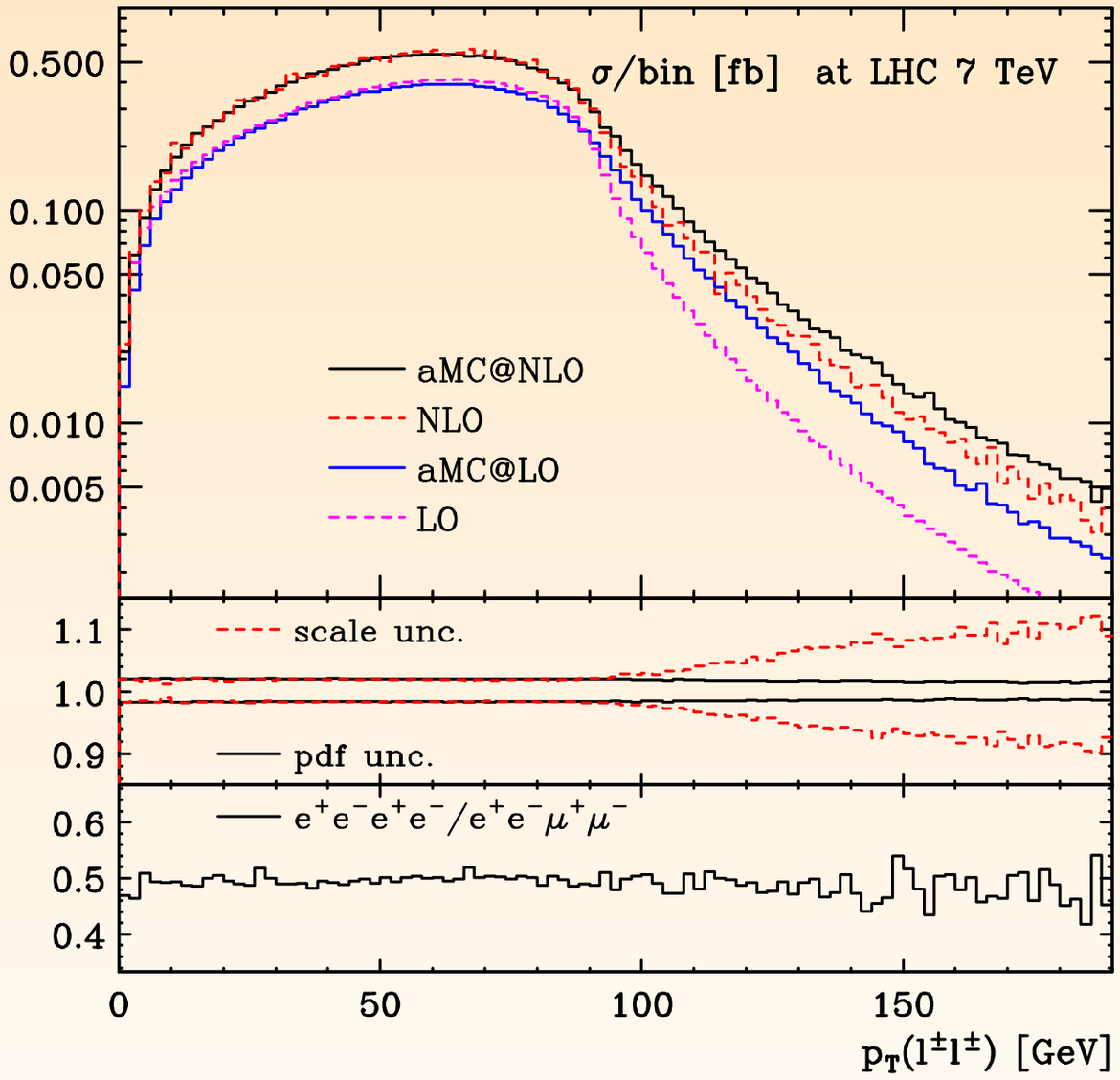
Four-lepton production





- 4-lepton invariant mass is almost insensitive to parton shower effects.
  4-lepton transverse moment is extremely sensitive
- Including scale uncertainties

Four-lepton production



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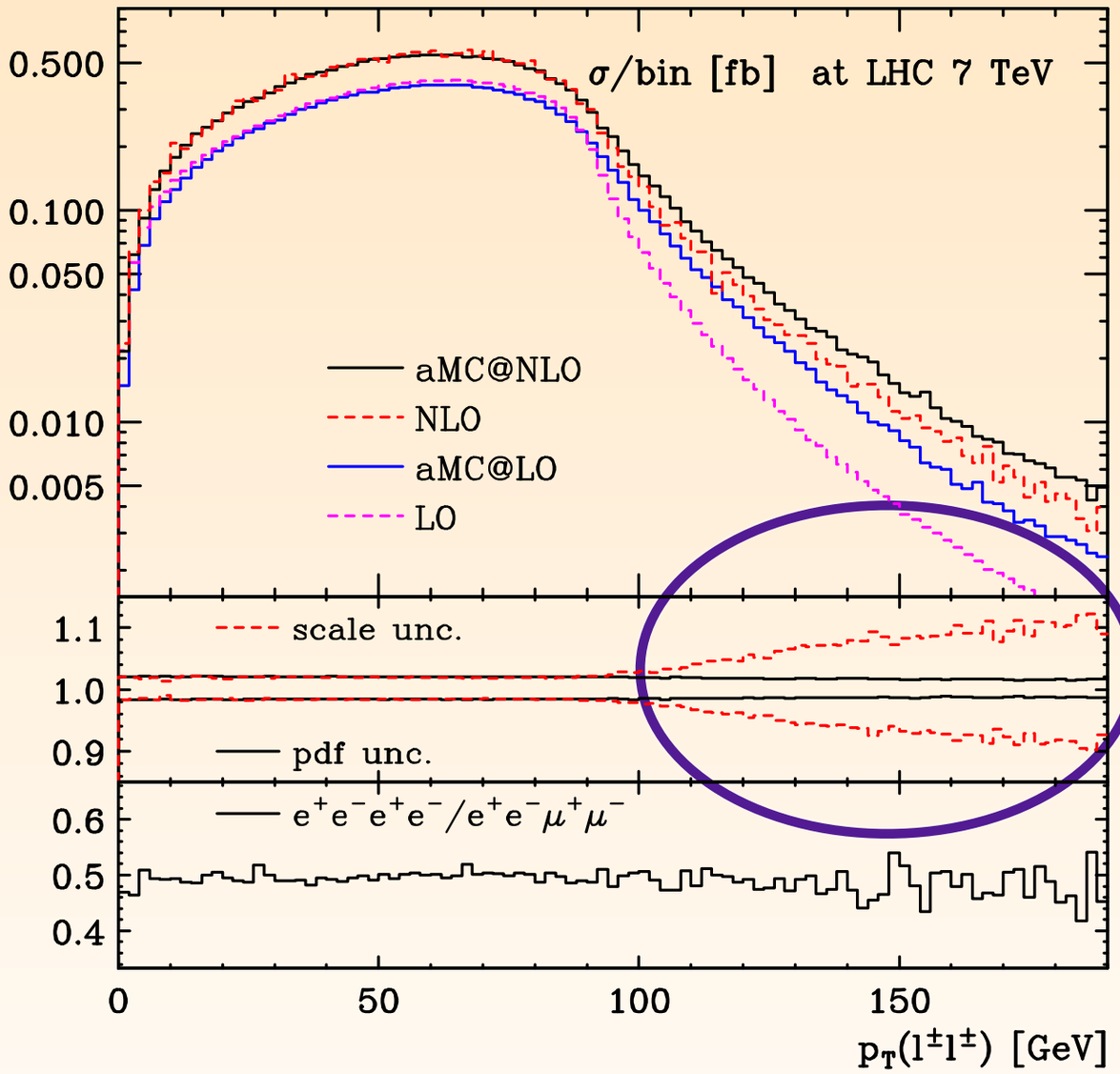
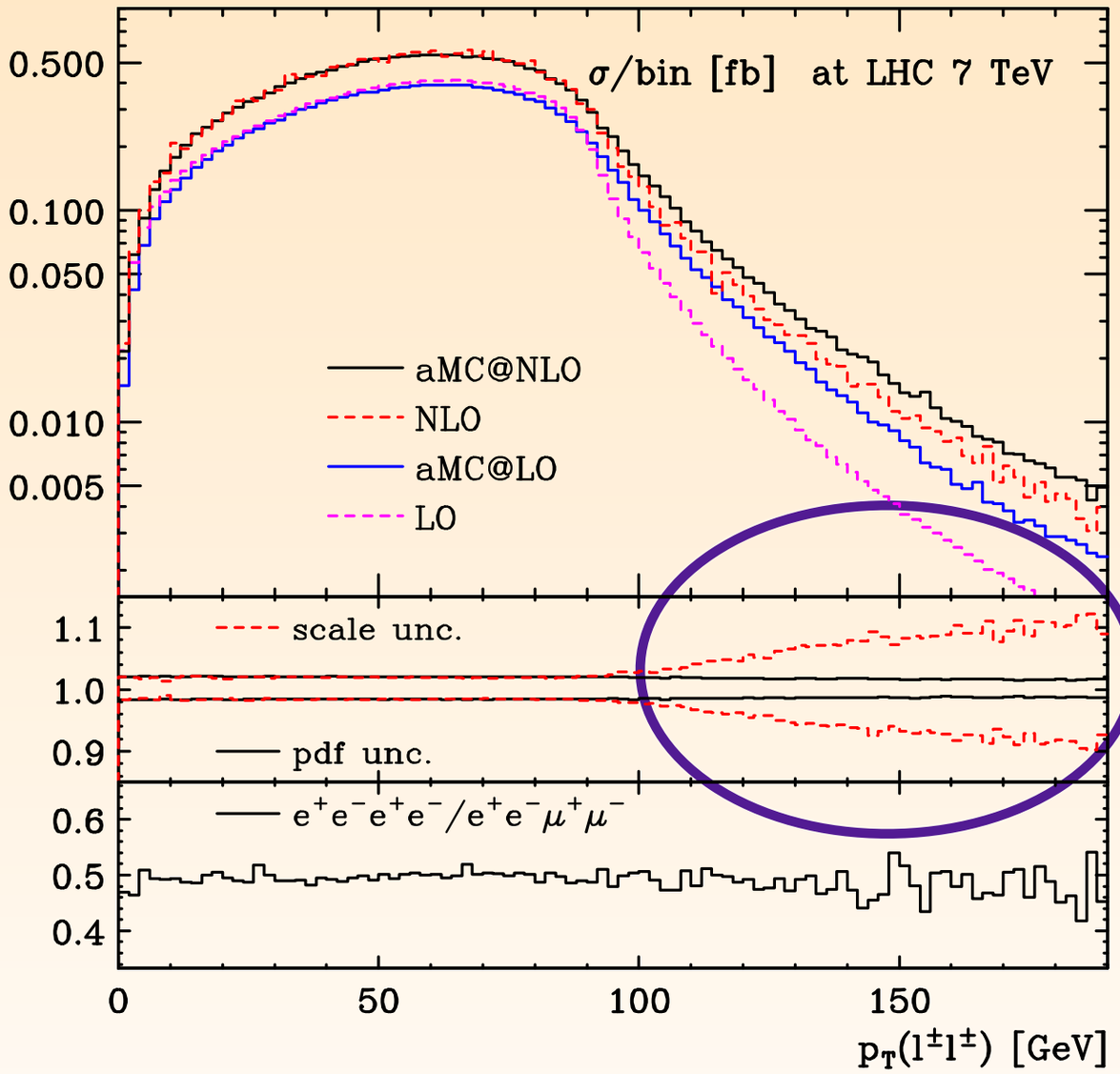


In the tail of the p_T spectrum, there are large theoretical uncertainties. This is no surprise! Here the NLO calculation has actually only LO accuracy, because there must be a hard parton/jet recoiling against the 4-lepton system.

Four-lepton production



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Can we include the NLO corrections to *4* leptons + 1 (hard) jet here?

Exclusive MC@NLO: FxFx merging

RF & Frixione, 2012

$\mathbb{S}$-events: $$\left[d\Phi_m (B + \int_{\text{loop}} V + \int d\Phi_1 MC) \right]$$

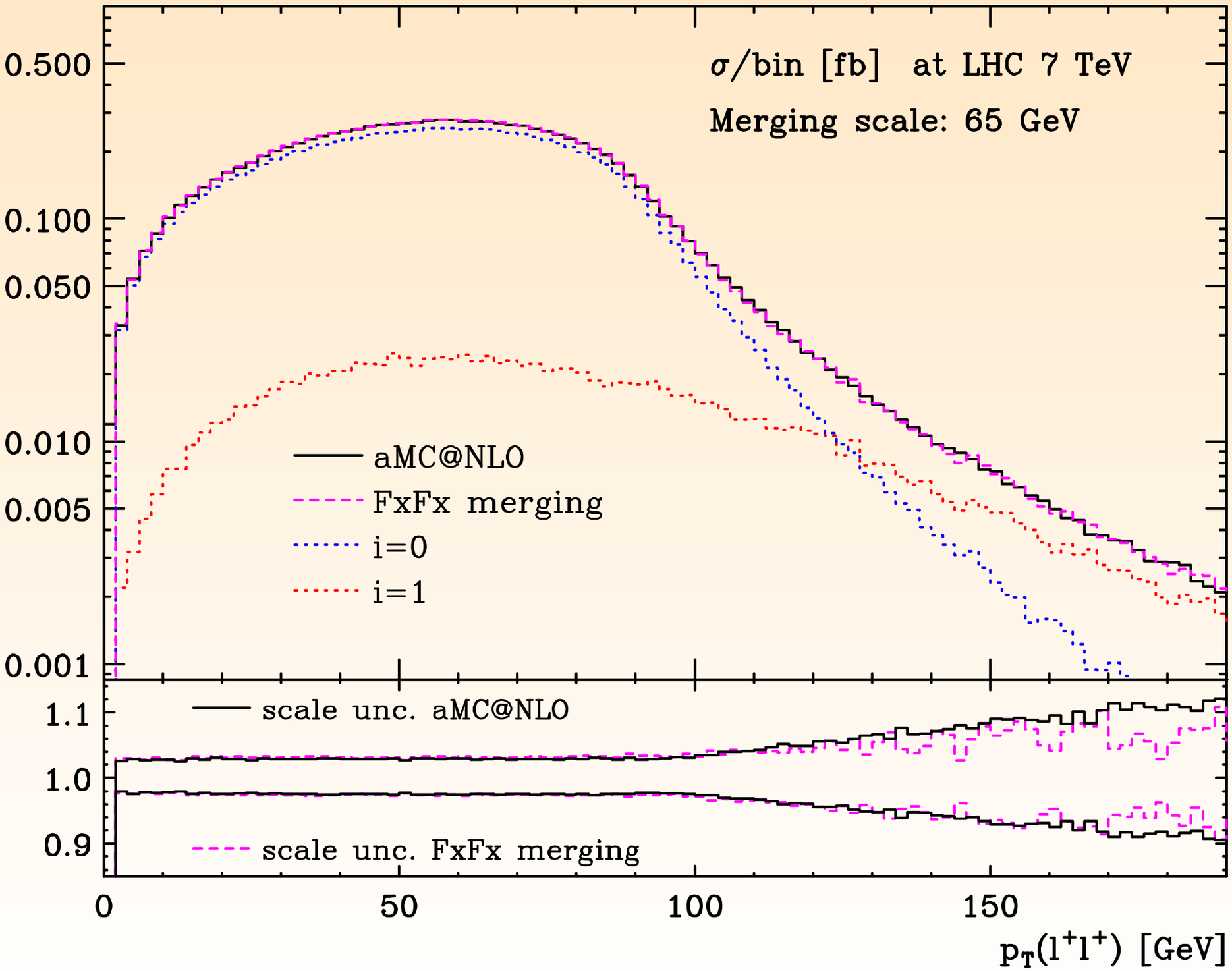
$\mathbb{H}$-events: $$\left[d\Phi_{m+1} (R - MC) \right]$$

Making aMC@NLO predictions exclusive in the number of "jets"

$\mathbb{S}$-events:
$$\left\{ B_n + V_n + \int_0^{Q^c} d\Phi_1 \, \text{MC} - B_n \Delta_n^{(1)}(Q_{\max}, Q^c) \right\} \Theta(k_{T,n}^B - Q^c) \Delta_n(Q_{\max}^B, Q^c)$$

$\mathbb{H}$-events:
$$\left\{ R_{n+1} \Theta(k_{T,n}^R - Q^c) - \text{MC}\, \Theta(k_{T,n}^B - Q^c) \right\} \Theta(Q^c - k_{T,n+1}^R) \Delta_n(Q_{\max}^R, Q^c)$$

Four-lepton production



What is still work in progress...

- aMC@NLO for BSM processes (in particular the ones that need new UV counterterms)
- aMC@NLO for QED or EW corrections
- aMC@NLO for processes with intermediate colored resonances

Conclusions

- I've been working on the aMC@NLO project for the last couple of years.
- The code is being used by both CMS and ATLAS experimentalists, and directly compared to data
- Still some improvements, additions, optimization, etc to do...
- ... but definitely ready to be used

http://amcatnlo.cern.ch

Collider Cross Talk

- The Collider Cross Talk is
  - very informal
  - black-board style
  - joined theory & LHC experiments
  - every week in the theory common room on Thursday morning at 11:00
- I'm one of the managers of the Collider X-talk, mainly responsible for Standard Model Theory
  - If you think you have an interesting subject to discuss, please contact me so that we can try to schedule it