Systematic uncertainties in NLO Monte Carlos - a pilot project

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Disclaimer: This is a pilot project …

… therefore we will

- not aim at solving all problems at the same time;
- focus on the most relevant process class;
- try to address a large variety of issues;
- try to work out some ideas for a systematic procedure that could be used in all other processes.

Aims of the exercise

- Focus on $gg \rightarrow H$, $H \rightarrow \{WW \rightarrow l\nu l\nu, ZZ \rightarrow 4l\}$
- Compare NLO MC implementations

  (i.e. various Powheg realisations & MC@NLO)
- Get a first handle on differences/discrepancies in some important distributions,

  (this will not necessarily lead to a "final result" of how to quantify the uncertainties, but hopefully it will teach us how to assess them systematically)
- Check ways of reweighting with other codes (Hqt)

  (and the associated theoretical uncertainties)
- Transfer of knowledge to the exp. Community

  (how to run these new tools with confidence)

Step I: Fixed order

- MC tools: Powheg-Box, Sherpa, Herwig++

  (if volunteers are found)
- FO tools: HNNLO, HqT (no resum?), MCFM
- Settings:
  - Two Higgs masses: 130 & 160 GeV
  - Jets: Anti-kt with pTmin = 30 GeV, R = 0.4, 0.5, 0.6
  - MSTW2008NNLO for HNNLO, HqT (NNPDF NNLO?)
  - PDF4LHC recommendation for NLO (envelope of MSTW, CT10, NNPDF)
  - Typical scale variation (factor 2), document default choices & cross-check where possible
  - 3 error bands: PDFs and scales alone and both combined
- Observables:
  - σ_{tot}, y^{H}, p_T^{H}, H_T, p_T^{jet}, η^{jet}, $\Delta y_{H,jet}$, $p_T^{leptons}$, $\eta^{leptons}$, $\Delta R_{leptons}$, E_T^{miss}, $\Delta\Phi_{(lepton\ planes)}$
  - F. Siegert has produced a Rivet analysis for the MC codes to feed in.

Step II: After showering

- MC tools: MC@NLO, Powheg-Box, Sherpa, HW++
  (if volunteers are found)
- FO tools: HqT with resummation
- Settings: as in fixed order, but: shower settings?
  - for Powheg-Box (Pythia, Herwig, or both?),
  - MC@NLO (F. Stoeckli has volunteered to run both HW and HW+)
  - vary scale choices in shower (possible in Sherpa)
  - offers possibility to check influence of differing PDFs/alphaS in ME/PS
  - tricky one: Pythia authors unhappy with UE switched off …
  - another tricky one: impact of Pythia tunes.
- Here it becomes a bit harder to see how we can be systematic about systematics.
- Add a few observables: jet veto probability, also: Njets, jet correlations, …
  (Rivet analysis exists, so should not be a problem for the MCs –
  add beam-thrust? Any help from the proponents in implementation?)

Step III: After hadronisation/UE

- Same MC tools.
- Basic idea: quantify impact of non-perturbative stuff.
- Can run Sherpa with two hadronisations, and switch on and off its UE (Pythia not so happy about it);
- Can run Powheg-box with different Pythia tunes .... or with Herwig +- Jimmy.

- I expect that this doesn't change picture drastically,

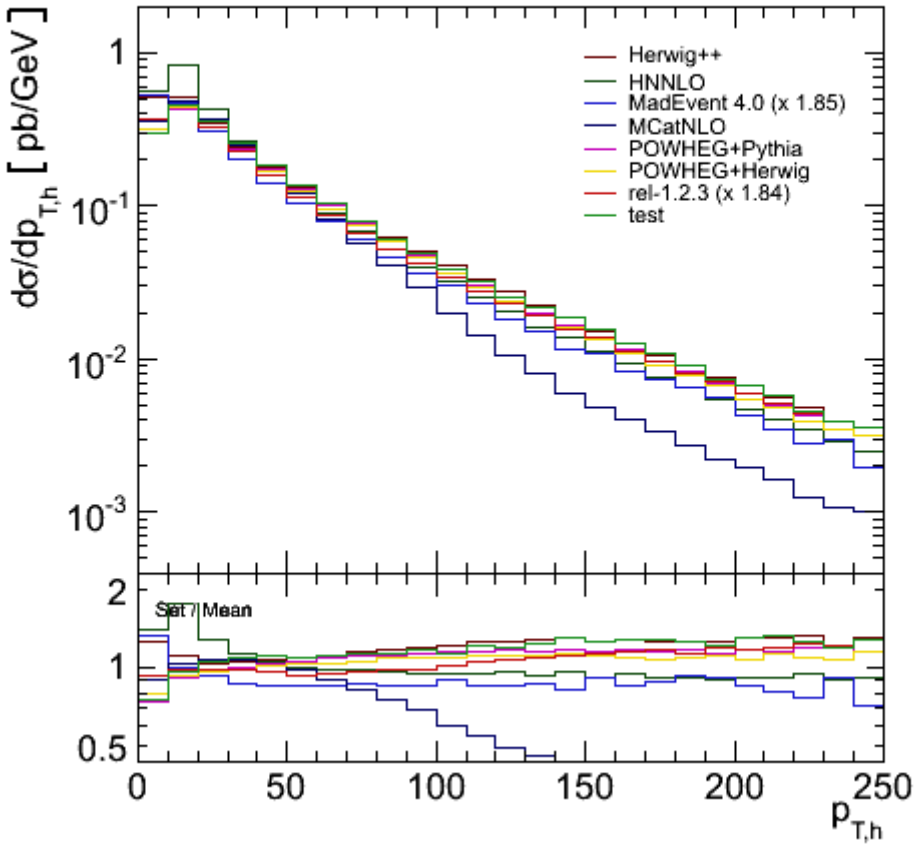
but it is better to check.

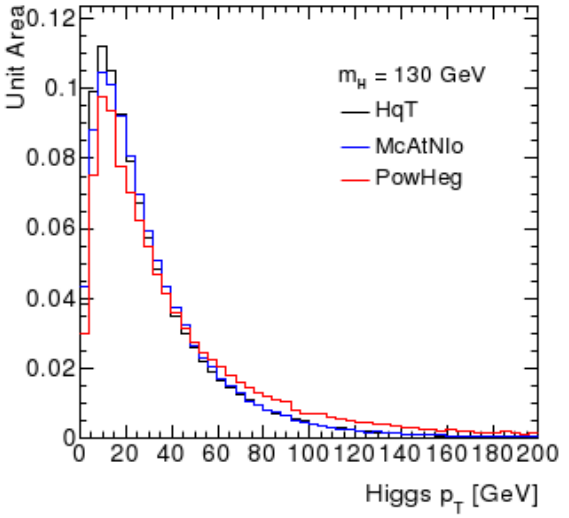
Some general comments:

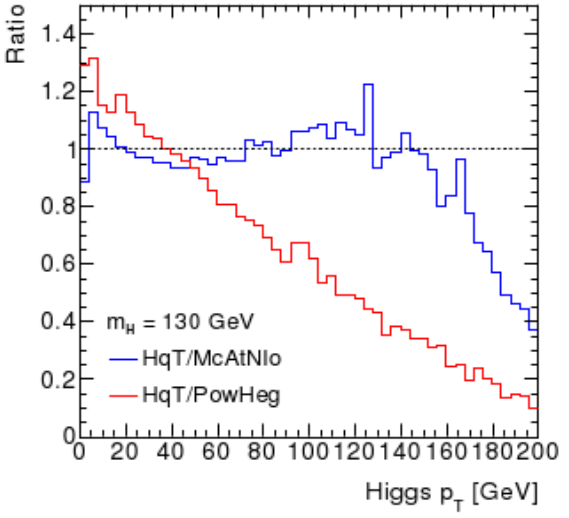
- Such a comparison has never been done in this depth.
- This alone – to my understanding – should be a good enough motivation. These will be publishable results in their own right.
- I expect to learn a lot about the tools themselves. This will help us to understand their systematic strengths and shortcomings much better.
- It will also tell us quite precisely how to assess their uncertainties in a systematic fashion so it is not a game to merely entertain otherwise bored theorists/MC authors.

A puzzle:

(at least for me)

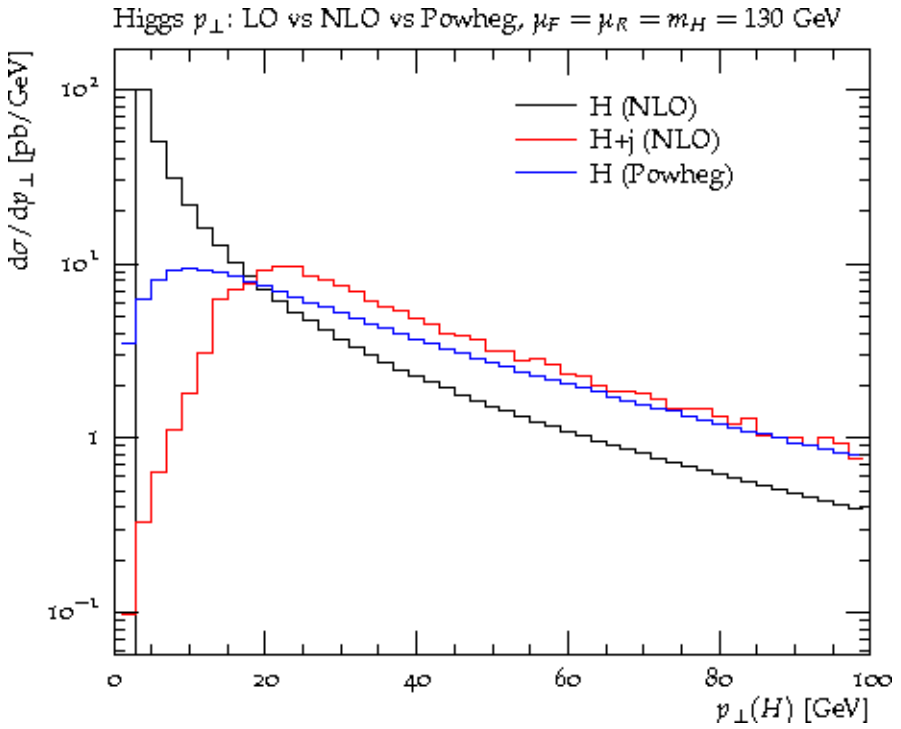


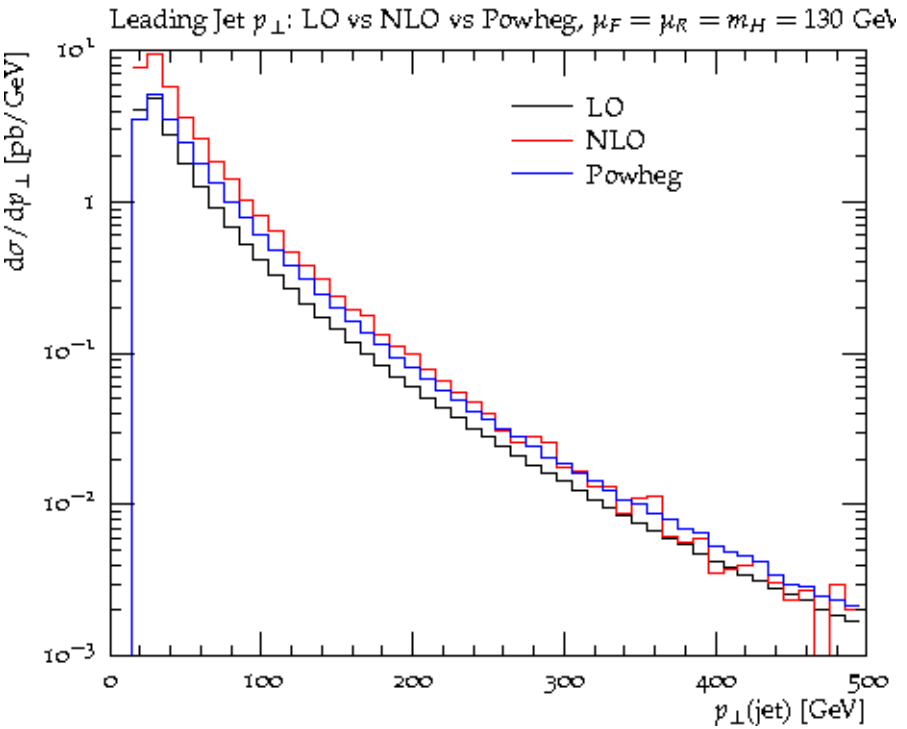




How come, that HqT (NLO + NLL in Higgs pt) does not coincide with Powheg, while HNNLO (NLO in higgs pt) does, within 20% or so?

Compare Powheg (Sherpa) with MCFM





- In Hpt: Good agreement with H+j above ~50 GeV – but in this region there are no more large logs – so don't resum any (i.e. do not use HqT in resum-mode there)!
- In jet pt: at larger pt closer to NLO prediction – this is partially due to the PS allowing for extra radiation, and partially due to exponentiation of “fishy”, non-log terms in the Powheg formalism. Can be cured in MENLOPS … .

A further proposal (for more work ...)

We have all these great theory tools –

- analytical calculations up to NNLO, supplemented with resummation in various observables/logs
- a new generation of MC generators at NLO, sometimes supplemented with ME+PS
- (MENLOPS) technology.

I wonder if

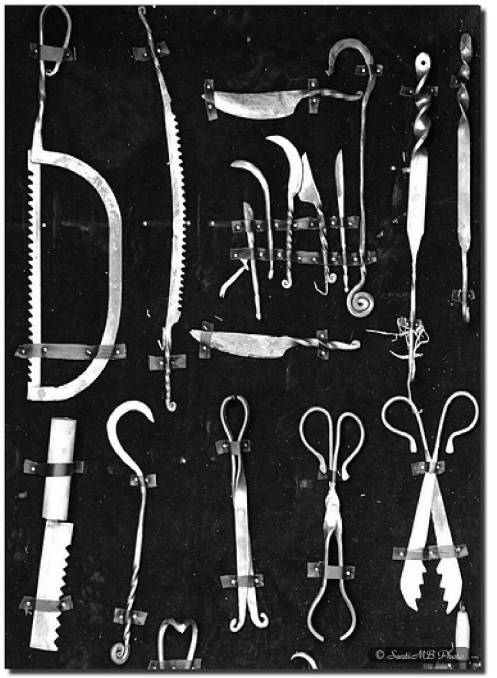
- our shower tools describe different resummation calculations simultaneously, and where the agreement breaks down (at NNLL would be my guess ...)
- there are any observables/distributions (apart from total xsecs), where we find significant, irreconcilable differences between MENLOPS/ME+PS and NNLO;
- it is possible to find scale settings in the MCs such that the related uncertainty bands overlap with the analytical ones, such that we can deduce the systematic uncertainty in this way – this would allow to treat many systematics in a very homogenous way.

I think this would be a very good use of our tools right now and help us trusting them even more.

Final remarks:

I'm fully aware that this is an ambitious plan, given the sheer amount of work and all time-limitations we have.

On the other hand this is a very good project to get many people with different expertise involved – die-hard theorists, MC authors and experimenters. Join the fun!



After all, this is about the tools of our trade and sharpening them ...