New tools and parton showers for Higgs theoretical predictions

LHCp 2020

Matthew Lim

26 May 2020

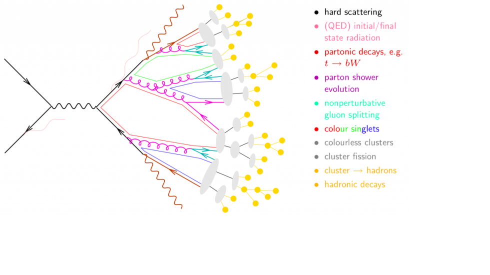
Università degli Studi di Milano-Bicocca

Outline of talk

- Motivation for high precision event generators
- NNLOPS for Higgs processes via the MiNLO approach
- The Geneva method and the *VH* process

Matching fixed order to parton shower

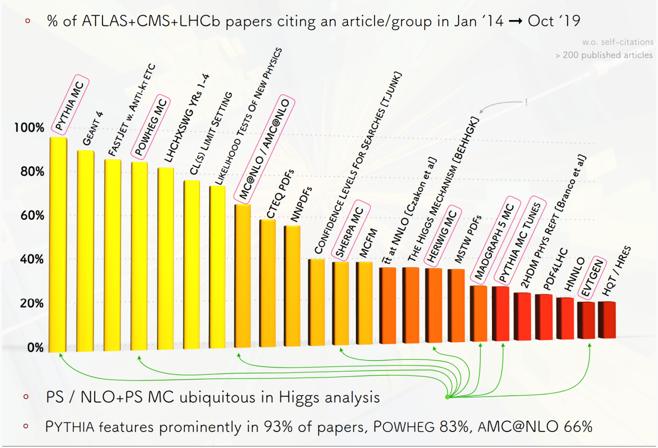
- Fixed order calculations provide us with an accurate description of a hard scattering process.
- Typically complexity of calculation limits number of final state particles to be ≤ 5 at NNLO.



- In a hadron collider experiment, we do not observe single coloured partons but several jets with high partonic multiplicity.
- The parton shower approximation can 'colour in' the outline of our FO prediction to provide a realistic prediction for a collider event.

NLO+PS approaches

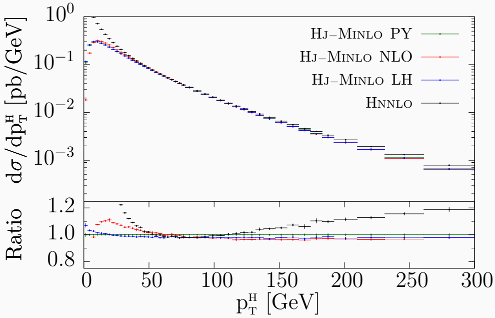
- First understood how to combine fixed order NLO with PS consistently with the **POWHEG** and **MC@NLO** methods.



Slide by K. Hamilton

Higgs production via the MiNLO approach

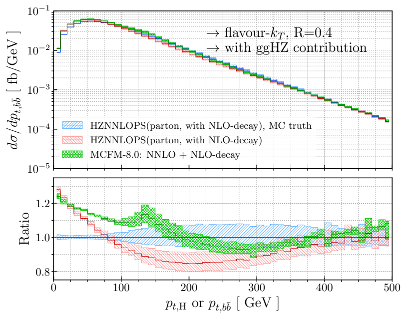
- Start with a `POWHEG` NLO accurate generator for $H + j$ production with additional Sudakov factors to stabilise low p_T^H behaviour.
- Extend NLO accuracy to cover inclusive H production, where the jet has been fully integrated over.
- Obtain full NNLO accuracy by reweighting events to NNLO H rapidity distribution.

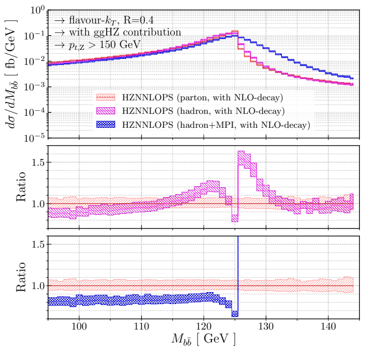


arXiv:1309.0017, K. Hamilton, P. Nason, E. Re, G. Zanderighi

Higgsstrahlung via the MINLO approach

- Approach above also applied to *WH* and *ZH* production.
- Latter also includes decay $H \to b\bar{b}$.
- Reweighting more challenging here in a multi-dimensional case.

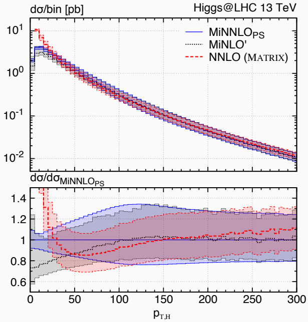


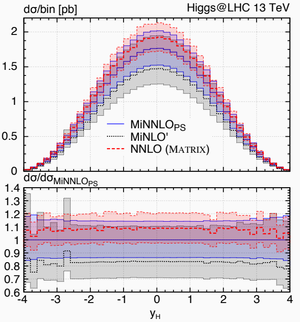


arXiv:1804.08141, W. Astill, W. Bizon, E. Re, G. Zanderighi

The MiNNLO method and H production

- MiNLO reweighting to NNLO poses technical limitations for processes with complex final states.
- In the MiNNLO method, NNLO corrections generated directly and no reweighting required.
- Made possible by connection with the momentum space q_T resummation formula.





arXiv:1908.06987, P. Monni, P. Nason, E. Re, M. Wiesemann, G. Zanderighi

The Geneva method

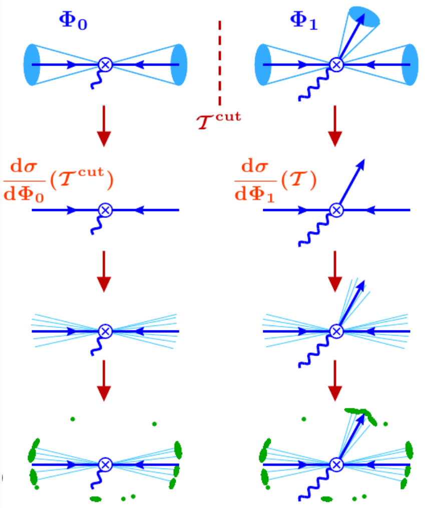
The Three Jewels:

- Geneva produces fully differential fixed order calculations at NNLO;
- By resumming large logarithms at NNLL′, it provides precise predictions over the whole phase space;
- These are matched to a parton shower to produce realistic events (which can further be hadronised, MPI effects included).

The method is fully general and relies on technology imported from Soft Collinear Effective Theory (SCET).

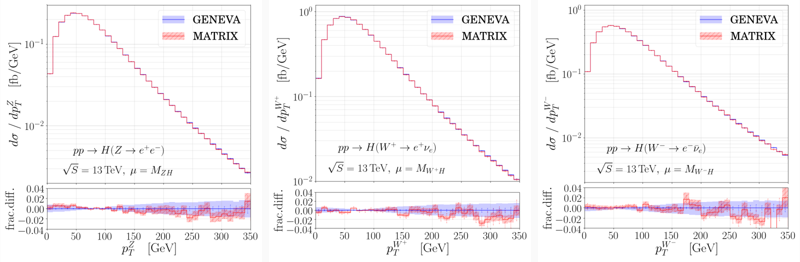
Geneva in a nutshell

1. Design IR-finite definition of events, based e.g. on resolution parameters $\mathcal{T}_0^{\mathrm{cut}}$.
2. Associate differential cross-sections to events such that 0-jet events are (N)NLO accurate and $\mathcal{T}_0$ is resummed at NNLL' accuracy.
3. Shower events imposing conditions to avoid spoiling NNLL' accuracy reached at step 2.
4. Hadronise, add multi-parton interactions (MPI) and decay without further restrictions.



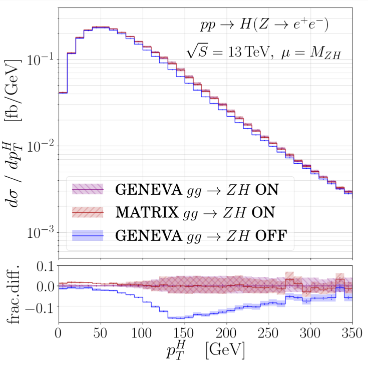
Higgsstrahlung with GENEVA

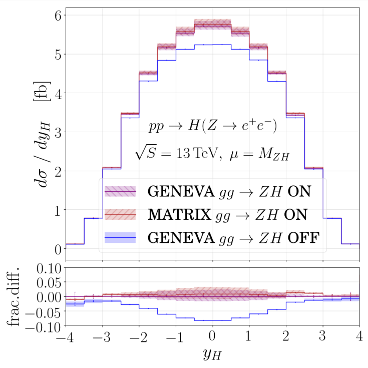
- Most complex final state considered so far using the GENEVA method;
- We consider initially only production of a stable Higgs.
- Validation of inclusive distributions at NNLO performed by comparison with the FO code MATRIX.



arXiv:1909.02026, S. Alioli, A. Broggio, S. Kallweit, MAL, L. Rottoli

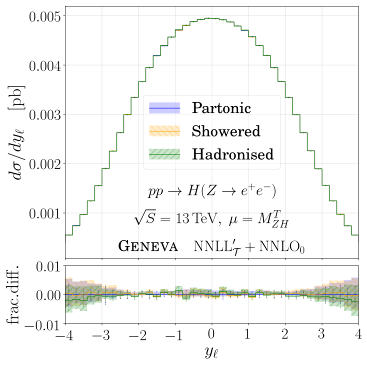
- We include the gluon fusion channel only at fixed order.
- Important at the LHC – up to 20% effect on differential distributions.
- Large scale uncertainties as process is included effectively only at LO.

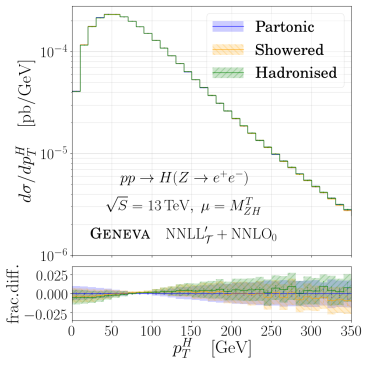




Results – inclusive distributions

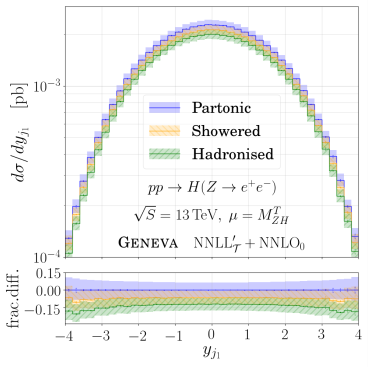
- Shower with PYTHIA8, which also takes care of hadronisation effects and MPI.
- Shower changes shape of distributions very little for inclusive distributions.

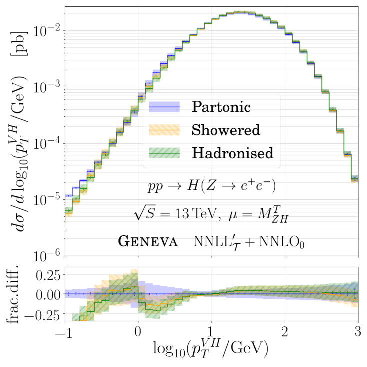




Results – exclusive distributions

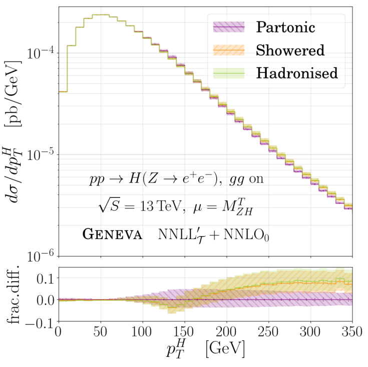
- Larger changes in exclusive cases (sensitive to resummation).
- Resummation only being provided at (N)LL by shower.

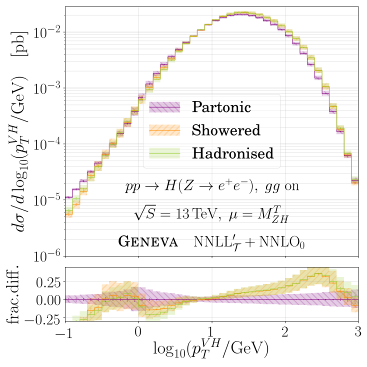




Results – gg channel

- gg channel more sensitive to parton shower (colour effect).
- Effects on H p_T begin at $\sim$ 100 GeV.





Upcoming in GENEVA

- Only considered a stable Higgs thus far – possible to include decays, hadronic cases now being implemented.
- Higgs production in gluon fusion currently also work in progress.
- Other colour singlet processes to follow, e.g. diphoton, diboson, p_T resummation...

Conclusions

- Matching fixed order predictions to parton shower is vital to provide realistic predictions at high accuracy for Higgs physics at the LHC.
- At NNLO, there are different ways in which this can be achieved including the MiNLO and Geneva methods.
- We have recently implemented the VH process in Geneva , matching NNLL' resummed calculations to NNLO to parton shower for a stable Higgs.
- Full production and decay for VH in the narrow width approximation is to follow, as well as implementation of other colour singlet processes.
- Further discussion possible at link below - thanks!

https://zoom.us/j/97238341532?pwd=NnpBbEJuV3pEbW1QVFAxdkdGVEZvQT09