Simone Alioli

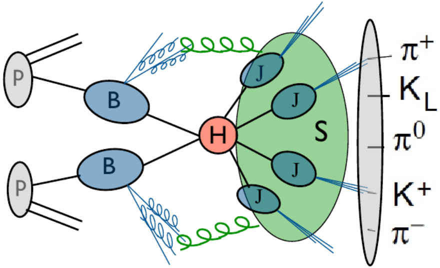
Research interests and activities:

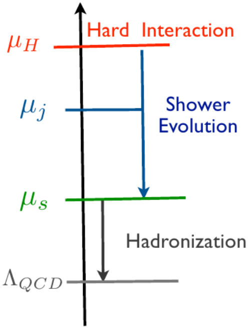
- Precision QCD calculations
- Monte Carlo event generators (POWHEG, GENEVA)
- Resummation
- LHC phenomenology (SM and beyond)

Les Houches Theory Retreat, 5-7 November 2014

GENEVA: quick overview

- Monte Carlo is built on the idea of factorization



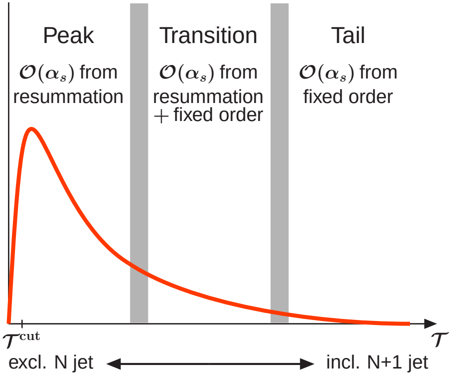


$$d\sigma^{MC} = \text{Hard Interaction} \otimes \underbrace{\boxed{\text{Collinear Evolution} \otimes \text{Soft Radiation}}}_{\text{Parton Shower Evolution}} \otimes \begin{array}{c}\text{PDFs}\\ \text{Hadronization}\\ \text{Underlying Event}\end{array}$$

- Replacing parton-shower evolution with higher order logarithmic resummation from μ_H to $\mu_{\mathbf{B}}, \mu_{\mathbf{J}}, \mu_S$.

3 key ingredients in a single framework:

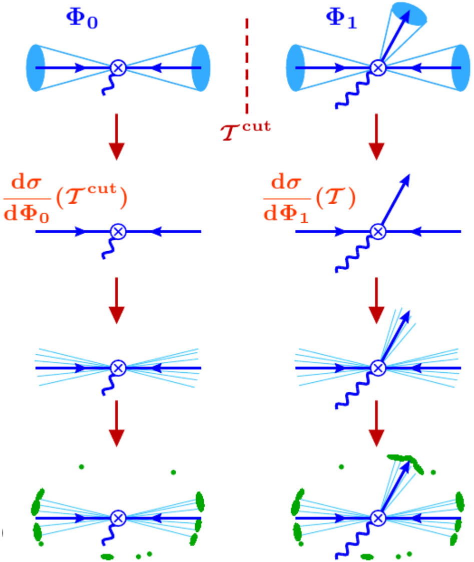
- Fully Exclusive NLO Calculations
  - NLO$_N$, NLO$_{N+1}$, . . .
- Higher-order Resummation (using SCET, but not limited to it)
  - LL$_\mathcal{O}$, NLL$_\mathcal{O}$, NLL'$_\mathcal{O}$, NNLL$_\mathcal{O}$ . . .
- Parton Shower and Hadronization
  - Pythia8, Herwig++, . . .



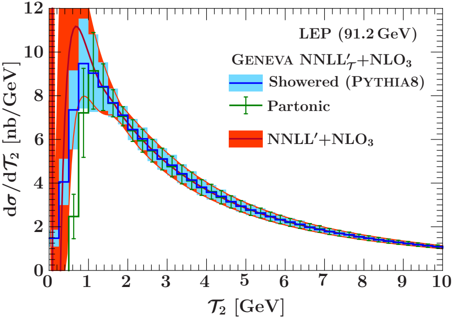
Gives fully exclusive events at the **Next-to-Lowest perturbative accuracy** in both fixed-order perturbation theory and logarithmic resummation of the resolution parameter, including **event-by-event theoretical uncertainties**, and combine it with parton shower and hadronization.

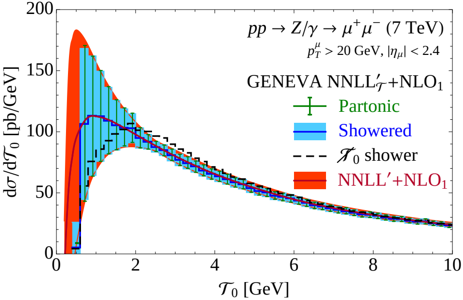
GENEVA workflow:

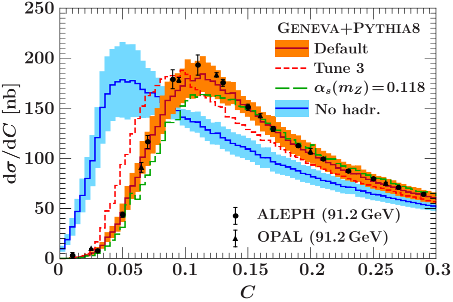
1. Start from an IR-finite NLO definition of events, based on resolution parameters $\mathcal{T}_N^{\mathrm{cut}}$.
2. Associate differential cross-sections to events such that inclusive jet bins are NLO accurate and jet resolution is resummed at NNLL'$_{\mathcal{T}}$
3. Shower events imposing conditions to avoid spoiling higher order logarithmic accuracy reached at step 2
4. Hadronize and decay without restrictions

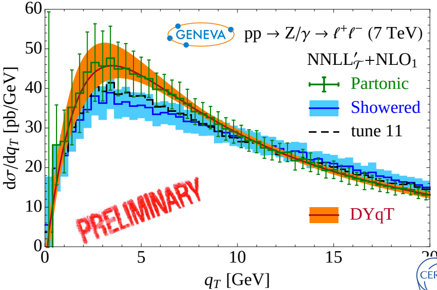


Results for $e^+e^- \to$ jets and $pp \to (Z/\gamma^* \to \ell^+\ell^-)$ + jets



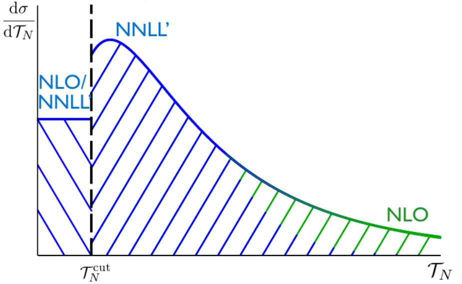






GENEVA @ NNLO+NNLL'$_{\mathcal{T}_0}$

- We have worked out analytically the ingredients (and the recipe) needed to achieve NNLO accuracy in LL accurate SMC. [1311.0286]
- How can we make GENEVA NNLO accurate?



- Inclusive cross section NLO$_0$ accurate
- Perturbative $\mathcal{O}(\alpha_s)$ everywhere
- Logarithms of merging scale ($\mathcal{T}_N^{\text{cut}}$) cancel at NNLL' by construction: merging of NLO$_0$ and NLO$_1$ is a by-product

- With NNLL' resummation, NNLO singular contributions are included

✓ $\frac{d\sigma^C_{\geq N}}{d\Phi_N} \Delta_N(\Phi_N; \mathcal{T}_N^{\text{cut}}) \to \frac{d\sigma^{\text{resummed}}_N}{d\Phi_N}(\mathcal{T}_N^{\text{cut}})$ ✓ $\frac{d\sigma^{C-S}_N}{d\Phi_N}(\mathcal{T}_N^{\text{cut}}) = 0$

✗ $\frac{d\sigma^{B-C}_N}{d\Phi_N}(\mathcal{T}_N^{\text{cut}}) \to \frac{d\sigma^{\text{nonsingular}}_N}{d\Phi_N}(\mathcal{T}_N^{\text{cut}}) \neq \frac{d\sigma^{\text{NNLO ns.}}_N}{d\Phi_N}(\mathcal{T}_N^{\text{cut}})$ (suppr. as $(\mathcal{T}_N^{\text{cut}})^n$)

- Adding NNLO non-singular to GENEVA 0-jet bin we could get NNLO+NNLL'$_{\mathcal{T}_0}$.

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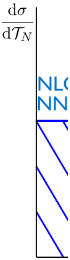

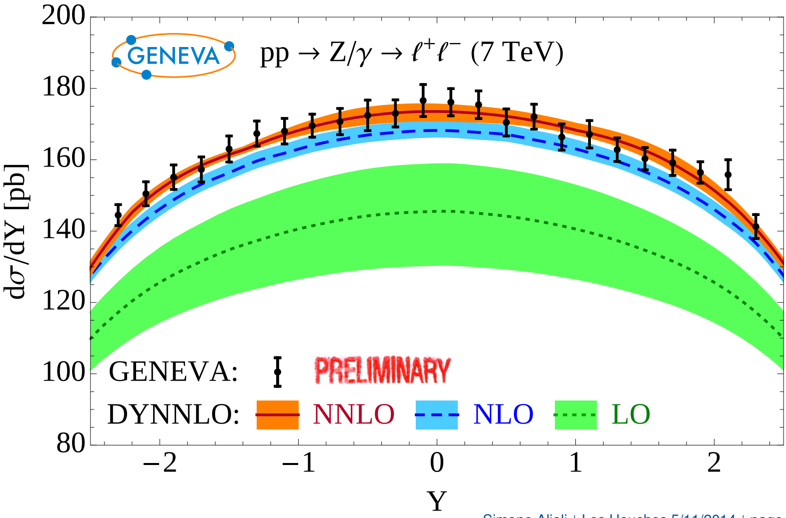

e

$(\mathcal{T}_N^{\rm cut})$

on:

a

- W

- A
N

GENEVA To-Do List:

- Implement other processes : all color singlet (Higgs, Diboson, Higgs pair, . . .) are relatively easy to add.
- Investigate resummation of other resolution parameters: $p_T^{\rm jet}$, E_T, . . .

  What formal precision do we reach?

  Which logarithms do we capture ?
- Include further jet multiplicities, iterating GENEVA procedure
- Interface to different showering algorithms.
- Provide proper tunes to better describe data.

Other recent/ongoing works:

- Jet Veto Clustering Logs at NLO (with J. Walsh) arXiv:1311.5234
  - Many analysises use jet-algorithms to separate backgrounds in excl. jet bins
  - Clustering effects induce a $\log(R)$ dependence in the cross section.

$$U^{(n)}_{\rm clus}(R, p_T^{\rm cut}) = \exp\left[\left(\frac{\alpha_s(p_T^{\rm cut})C_A}{\pi}\right)^n C_n(R) \ln \frac{m_H}{p_T^{\rm cut}}\right],$$

$$\mathrm{C}_n(R) = C_n^{(n-1)} \ln^{n-1} R^2 + \ldots + C_n^{(1)} \ln R^2 + C_n^{(0)}(R)$$

  - At $R = 0.4,\ 0.5$ the first $C_2^{(1)}$ is large and effects are sizeable ($\sim 10\%$ for Higgs production). We have calculated $C_3^{(2)}\ \alpha_s^2 \log^2(R^2)$ and found it to be small.
- FONLL predictions for W + D (with E. Mereghetti) (to appear)
  - Important process to access strange pdf at $x \sim 0.01$. Currently limited by theoretical uncertainty.
  - Fixed-order (MCFM) provides large scale uncertainties.
  - (NLO) Monte Carlo resum only a subset of all contributions enhanced by large $\log(m_c/p_T)$. Flavor excitation and gluon-splitting only included at LO.
  - NLL resummation in the fragmentation function approach helps reducing the theoretical error, especially at high p_T.
  - FONLL combines NLO calculation with full mass effects with NLL resummation of $\log(m_c/p_T)$

Thank you for your attention!