One-jettiness resummation for color singlet plus jet production at hadron colliders

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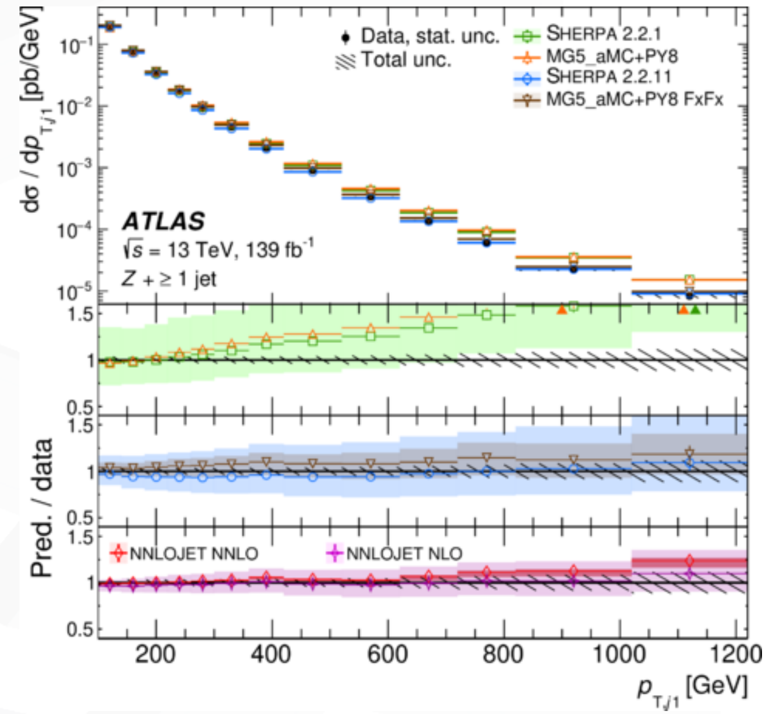
Motivation

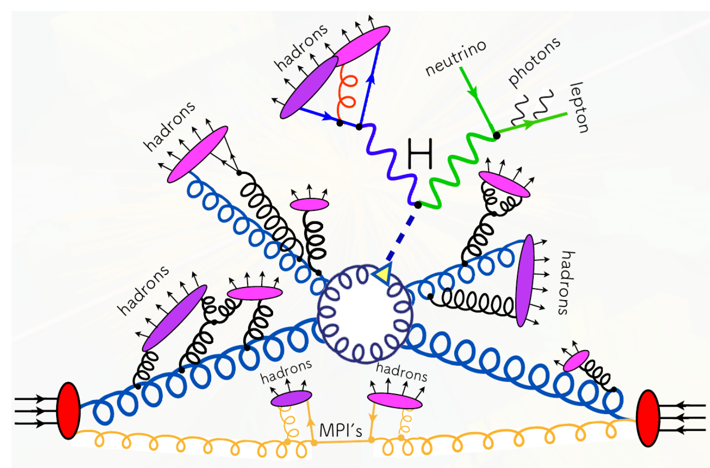
The production $V+j$ is a standard candle at the LHC, high precision expected from experiments.

Theoretical predictions must include NNLO corrections to keep up with experimental uncertainties

Fixed-order predictions fail to capture the complexity of multi-particle final states and do not include resummation nor nonpertubative effects.

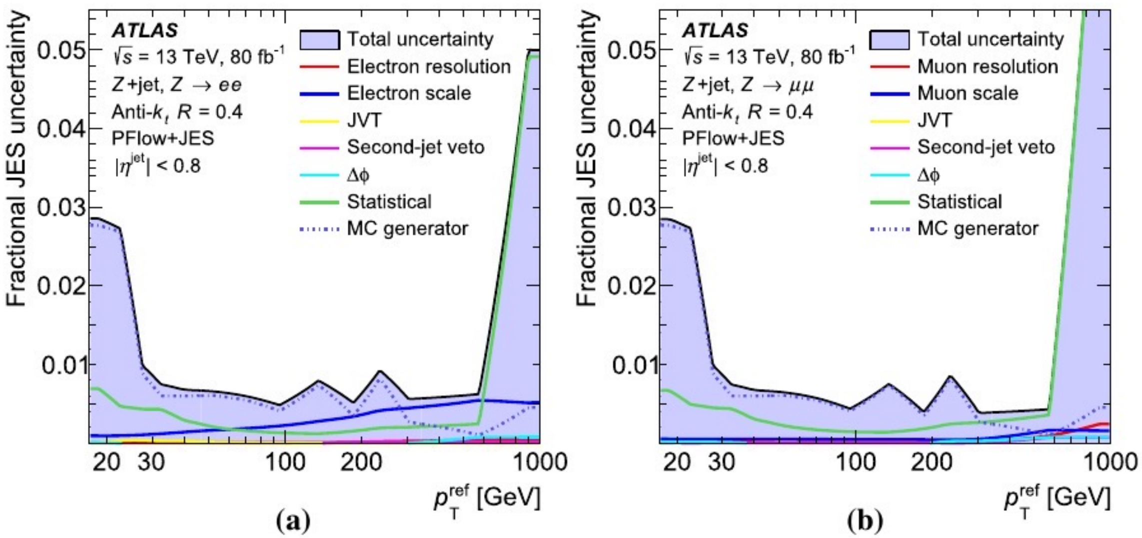
Shower Monte Carlo are therefore essential tools for phenomenology. They must include state-of-the-art theoretical predictions to reduce the associated uncertainties.





Why is accuracy important for SMC ?

SMC are often used to extrapolate theoretical predictions to fid. regions



SMCs are already the dominant source of uncertainty for Jet Energy Scale.

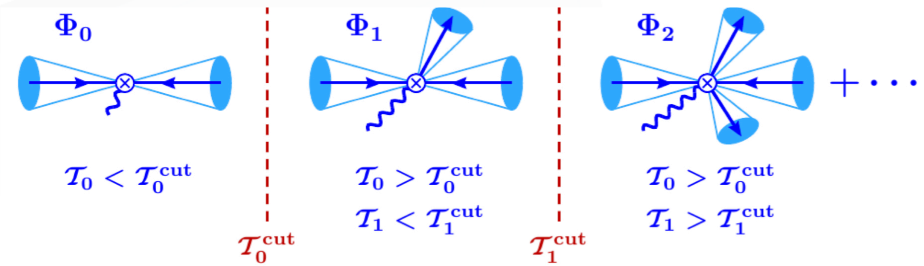
Everything involving jets is affected !

State-of-the-art for SMC is the inclusion of NNLO corrections, matched to the parton shower.

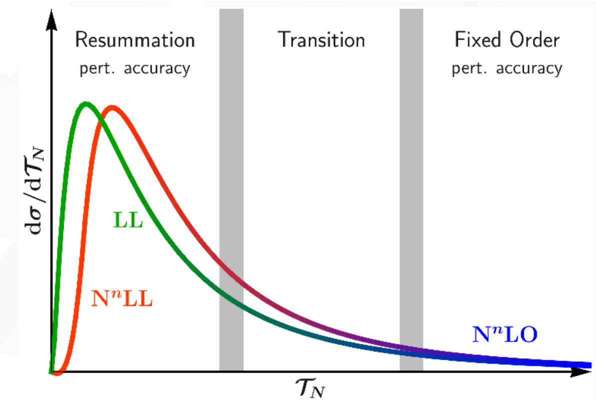
Unfortunately, no NNLO+PS yet available for final states with jets in hadronic collisions.   Our goal is to fill this gap, starting from Z+1 jet.

The Geneva method

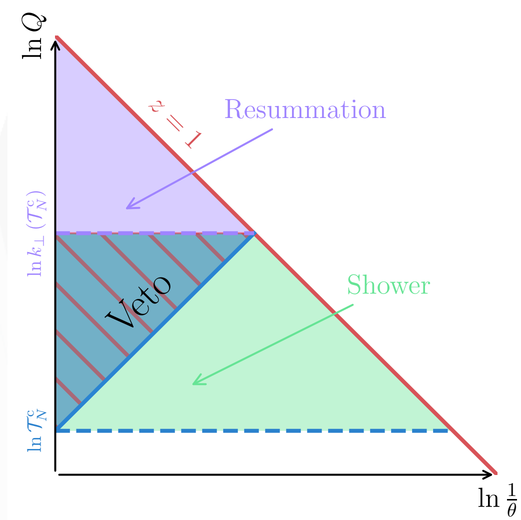
- Monte Carlo fully-differential event generation at higher-orders (NNLO)

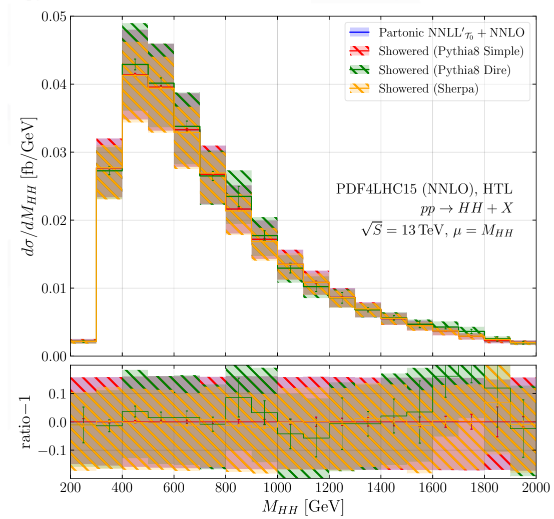


- Resummation plays a key role in the defining the events in a physically sensible way



- Results at partonic level can be further evolved by different shower matching and hadronization models





Resolution parameters for N extra emissions

- The key idea is the introduction of a resolution variable r_N that measure the hardness of the $N+1$-th emission in the Φ_N phase space.

- For color singlet production one can have $r_0 = q_T, p_T^j, k_T$-ness,….

- N-jettiness is a valid resolution variable: given an M-particle phase space point with $M \geq N$

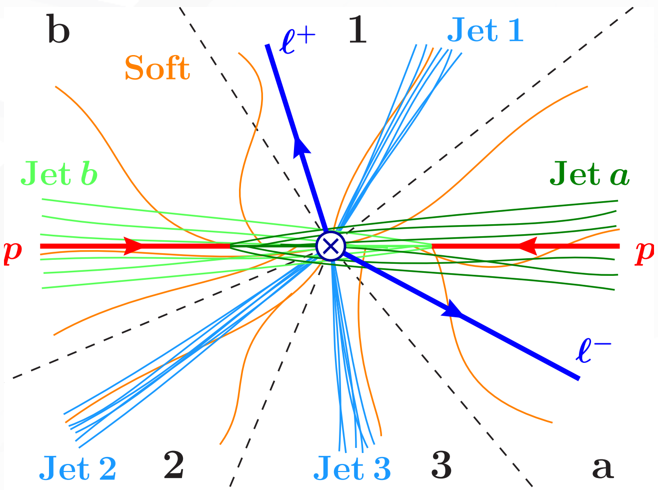
$$\mathcal{T}_N(\Phi_M) = \sum_k \min\{\hat{q}_a \cdot p_k, \hat{q}_b \cdot p_k, \hat{q}_1 \cdot p_k, \ldots, \hat{q}_N \cdot p_k\}$$

- The limit $\tau_N \to 0$ describes a N-jet event where the unresolved emissions are collinear to the final state jets/initial state beams or soft

- For color-singlet final states, it reduces to 0-jettiness

$$\mathcal{T}_0 = \sum_k |\vec{p}_{kT}| \, e^{-|\eta_k - Y|}$$

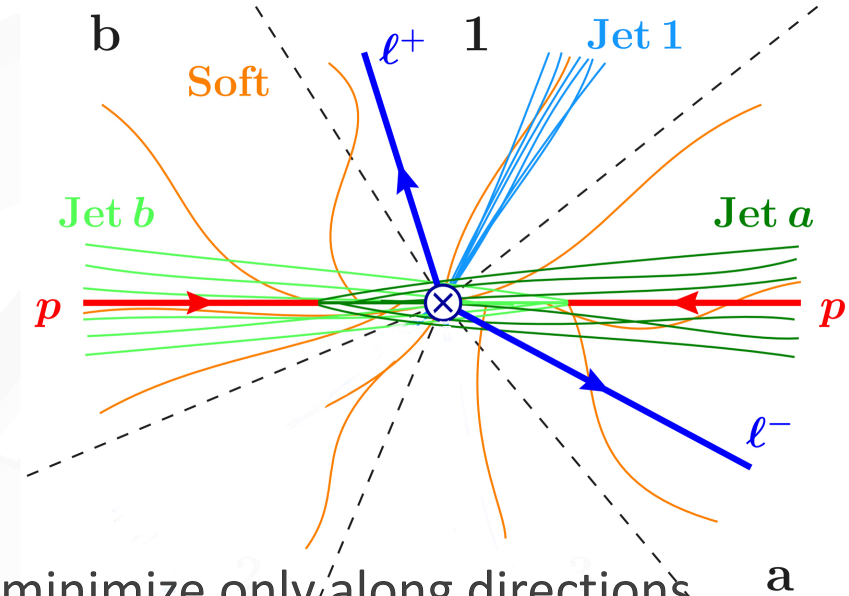
[Stewart, Tackmann,Waalewijn `09,`10]



- When an extra jet is present 1-jettiness used for r_1

$$\mathcal{T}_1 = \sum_k \min\left\{\frac{2q_a \cdot p_k}{Q_a}, \frac{2q_b \cdot p_k}{Q_b}, \frac{2q_J \cdot p_k}{Q_J}\right\}$$

One-jettiness definitions



- Focus of color-singlet plus jet production

$$\mathcal{T}_1 = \sum_k \min\{\frac{2q_a \cdot p_k}{Q_a}, \frac{2q_b \cdot p_k}{Q_b}, \frac{2q_J \cdot p_k}{Q_J}\}$$

- To remove energy-dependence and minimize only along directions $Q_i = 2E_i$'s must be frame-dependent

$$\hat{\mathcal{T}}_1 = \sum_k \min\{\frac{\hat{n}_a \cdot \hat{p}_k}{\rho_a}, \frac{\hat{n}_b \cdot \hat{p}_k}{\rho_b}, \frac{\hat{n}_J \cdot \hat{p}_k}{\rho_J}\}$$

- The choice of the ρ_i's determines the frame in which the one-jettiness resummation is performed. We focus on 3 choices: LAB , UB -frame $Y_{Vj} = 0$ and CS-frame $Y_V = 0$

$$\rho_a = e^{\hat{Y}_V}\,,$$
$$\rho_b = e^{-\hat{Y}_V}\,,$$
$$\rho_J = \frac{e^{-\hat{Y}_V}(\hat{p}_J)_+ + e^{\hat{Y}_V}(\hat{p}_J)_-}{2\hat{E}_J}$$

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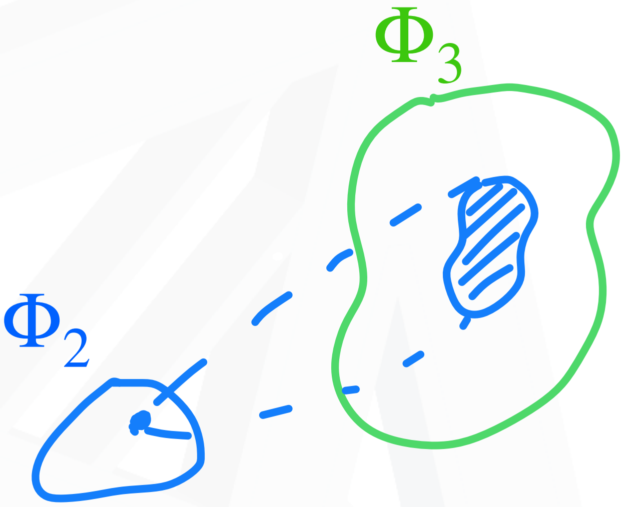
One-jettiness in GENEVA

- For the correct IR definition of an NNLO event weight $\frac{d\sigma^{\rm MC}}{d\Phi_1 d\mathcal{T}_1 dz d\varphi}$ one needs to preserve the resolution parameter when performing the $\Phi_2 \to \Phi_3$ splitting in the NLO_2 calculation, $\mathcal{T}_1$- preserving map required $\mathcal{T}_1(\Phi_2) = \mathcal{T}_1(\Phi_3)$



- Using a jet-algorithm to find the directions or using the exact $\mathcal{T}_1$ definition makes it impractical to find this map. Alternatively, use similar variable that has the same log structure and different $\alpha_s^2\delta(\mathcal{T}_1)$
- We introduce a fully-recursive version of one-jettiness $\mathcal{T}_1^{\rm FR}$ which we use for the fixed-order calculation. The idea is that at each step one finds the closest particles in the one-jettiness metric, merge them and continue. N-jettiness as a clustering procedure.

Issues with $\mathscr{T}_1$ definitions event-by-event

- The LAB and CS frame definition of one-jettiness (even FR) are pretty straightforward, the UB one is not, because the jet that defines the $Y_{Vj} = 0$ frame is not found until all clustering steps have been done

$$
\begin{aligned}
\mathcal{T}_1(\Phi_3) = \min \Bigg\{ & \frac{1}{2}\left(\lambda_{qp_{123}} p^+_{123} + \frac{p^-_{123}}{\lambda_{qp_{123}}}\right) + \sqrt{\frac{1}{4}\left(\lambda_{qp_{123}} p^+_{123} + \frac{p^-_{123}}{\lambda_{qp_{123}}}\right)^2 - m^2_{123}}, \\
& \frac{1}{2}\left(\lambda_{qp_{12}} p^+_{123} + \frac{p^-_{123}}{\lambda_{qp_{12}}}\right) + \sqrt{\frac{1}{4}\left(\lambda_{qp_{12}} p^+_{12} + \frac{p^-_{12}}{\lambda_{qp_{12}}}\right)^2 - m^2_{12}} - \left|\frac{1}{2}\left(\lambda_{qp_{12}} p^+_{3} - \frac{p^-_{3}}{\lambda_{qp_{12}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{13}} p^+_{123} + \frac{p^-_{123}}{\lambda_{qp_{13}}}\right) + \sqrt{\frac{1}{4}\left(\lambda_{qp_{13}} p^+_{13} + \frac{p^-_{13}}{\lambda_{qp_{13}}}\right)^2 - m^2_{13}} - \left|\frac{1}{2}\left(\lambda_{qp_{13}} p^+_{2} - \frac{p^-_{2}}{\lambda_{qp_{13}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{23}} p^+_{123} + \frac{p^-_{123}}{\lambda_{qp_{23}}}\right) - \sqrt{\frac{1}{4}\left(\lambda_{qp_{23}} p^+_{23} + \frac{p^-_{23}}{\lambda_{qp_{23}}}\right)^2 - m^2_{23}} - \left|\frac{1}{2}\left(\lambda_{qp_{23}} p^+_{1} - \frac{p^-_{1}}{\lambda_{qp_{23}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{3}} p^+_{12} + \frac{p^-_{12}}{\lambda_{qp_{3}}}\right) - \left|\frac{1}{2}\left(\lambda_{qp_{3}} p^+_{1} - \frac{p^-_{1}}{\lambda_{qp_{3}}}\right)\right| - \left|\frac{1}{2}\left(\lambda_{qp_{3}} p^+_{2} - \frac{p^-_{2}}{\lambda_{qp_{3}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{2}} p^+_{13} + \frac{p^-_{13}}{\lambda_{qp_{2}}}\right) - \left|\frac{1}{2}\left(\lambda_{qp_{2}} p^+_{1} - \frac{p^-_{1}}{\lambda_{qp_{2}}}\right)\right| - \left|\frac{1}{2}\left(\lambda_{qp_{2}} p^+_{3} - \frac{p^-_{3}}{\lambda_{qp_{2}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{1}} p^+_{23} + \frac{p^-_{23}}{\lambda_{qp_{1}}}\right) - \left|\frac{1}{2}\left(\lambda_{qp_{1}} p^+_{2} - \frac{p^-_{2}}{\lambda_{qp_{1}}}\right)\right| - \left|\frac{1}{2}\left(\lambda_{qp_{1}} p^+_{3} - \frac{p^-_{3}}{\lambda_{qp_{1}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{3}} p^+_{12} + \frac{p^-_{12}}{\lambda_{qp_{3}}}\right) - \left|\frac{1}{2}\left(\lambda_{qp_{3}} p^+_{12} - \frac{p^-_{12}}{\lambda_{qp_{3}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{2}} p^+_{13} + \frac{p^-_{13}}{\lambda_{qp_{2}}}\right) - \left|\frac{1}{2}\left(\lambda_{qp_{2}} p^+_{13} - \frac{p^-_{13}}{\lambda_{qp_{2}}}\right)\right|, \\
& \frac{1}{2}\left(\lambda_{qp_{1}} p^+_{23} + \frac{p^-_{23}}{\lambda_{qp_{1}}}\right) - \left|\frac{1}{2}\left(\lambda_{qp_{1}} p^+_{23} - \frac{p^-_{23}}{\lambda_{qp_{1}}}\right)\right| \Bigg\} .
\end{aligned}
$$

- Consider all possible jet pairings and all possible boosts
- NLO calculation far from trivial. Normal FKS or CS subtractions do not work, a different boost is required for each sector to preserve the correct $\mathscr{T}_1$.
- Similar problems when boosting to rest frame of decaying colored heavy-resonances. [Jezo, Nason` 15]

Resummation of one-jettiness for Z+jet

Factorization formula in the region where $\mathcal{T}_1 \ll Q$ hard scale $\sqrt{s}, M_{\ell^+\ell^-}, M_{T,\ell^+\ell^-}$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Phi_1 \mathrm{d}\mathcal{T}_1} = \sum_{\kappa=\{q\bar{q}g,qgq,ggg\}} H_\kappa(\Phi_1) \int \mathrm{d}t_a \mathrm{d}t_b \mathrm{d}s_J \, B_{\kappa_a}(t_a) B_{\kappa_b}(t_b) J_{\kappa_J}(s_J) \times S_\kappa\left(n_{a,b}\cdot n_J, \mathcal{T}_1 - \frac{t_a}{Q_a} - \frac{t_b}{Q_b} - \frac{s_J}{Q_J}\right)$$

We left the choice of the frame free, keeping in mind the issues for GENEVA.

It is convenient to transform the soft, beam and jet functions in Laplace space to solve the RG equations, the factorization formula is turn into a product.
The color factorizes trivially in soft and hard functions for 3 colored partons.

$$\mathcal{L}\left[\frac{\mathrm{d}\sigma}{\mathrm{d}\Phi_1 \mathrm{d}\mathcal{T}_1}\right] = \sum_\kappa H_\kappa(\Phi_1)\, \tilde{S}_\kappa\left(\ln \frac{\lambda_E^2}{\mu^2}\right) \tilde{B}_{\kappa_a}\left(\ln \frac{Q_a\,\lambda_E}{\mu^2}\right) \tilde{B}_{\kappa_b}\left(\ln \frac{Q_b\,\lambda_E}{\mu^2}\right) \tilde{J}_{\kappa_J}\left(\ln \frac{Q_J\,\lambda_E}{\mu^2}\right)$$

Hard, soft, beam and jet functions

Hard functions known analytically up to 2-loops. [Gehrmann, Tancredi et al. `12, `22]

At NNLL' accuracy include the loop-squared $gg \to Zg$

Beam and jet boundary conditions known up to 3-loop [Mistlberger et al. `20]

[Becher, Bell `10] [Gaunt et al. `14]

We compute the one-loop soft boundary terms as on-the-fly integrals using results in [Jouttenus et al. `11]

$$S^{\kappa\,(1)}_{\mathcal{T}_1,-1} = 2c_s^\kappa\Big[L_{ab}^2 - \frac{\pi^2}{6} + 2(I_{ab,c} + I_{ba,c})\Big] + 2c_t^\kappa\Big[L_{ac}^2 - \frac{\pi^2}{6} + 2(I_{ac,b} + I_{ca,b})\Big]$$
$$+ 2c_u^\kappa\Big[L_{bc}^2 - \frac{\pi^2}{6} + 2(I_{bc,a} + I_{cb,a})\Big]$$

$$I_{ij,m} \equiv I_0\Big(\frac{\hat{s}_{jm}}{\hat{s}_{ij}}, \frac{\hat{s}_{im}}{\hat{s}_{ij}}\Big) \ln\frac{\hat{s}_{jm}}{\hat{s}_{ij}} + I_1\Big(\frac{\hat{s}_{jm}}{\hat{s}_{ij}}, \frac{\hat{s}_{im}}{\hat{s}_{ij}}\Big)$$

Also studied for different jet measures in [Bertolini et al. `17]

The frame-dependent 2-loop contribution $S^{\kappa\,(2)}_{\mathcal{T}_1\,-1}$ is provided by SoftSERVE collaboration (thanks to Bahman Dehnadi), in the form of an 3D interpolation grid in $\{\cos\theta_1, 1/\rho_a, 1/\rho_J\}$ [Bell, Rahn, Talbert `18]

We validated the approach comparing to our one-loop results in different frames

At two-loop it has been validated in the UB frame against the interpolation used in MCFM. [Campbell, Ellis, Mondini, Williams `18] In all other frames genuinely new results!

Resummed formula

We can combine the solutions for the hard, soft, jet and beam functions to obtain

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Phi_1 \mathrm{d}\mathcal{T}_1} = \sum_\kappa \exp\Bigg\{4(C_{\kappa_a}+C_{\kappa_b})K_{\Gamma_{\rm cusp}}(\mu_B,\mu_H) + 4C_{\kappa_J}K_{\Gamma_{\rm cusp}}(\mu_J,\mu_H)$$
$$- 2(C_{\kappa_a}+C_{\kappa_b}+C_{\kappa_J})K_{\Gamma_{\rm cusp}}(\mu_S,\mu_H) - 2C_{\kappa_J}L_J\,\eta_{\Gamma_{\rm cusp}}(\mu_J,\mu_H)$$
$$- 2(C_{\kappa_a}L_B + C_{\kappa_b}L'_B)\eta_{\Gamma_{\rm cusp}}(\mu_B,\mu_H) + \Bigg[C_{\kappa_a}\ln\left(\frac{Q_a^2 u}{st}\right) + C_{\kappa_b}\ln\left(\frac{Q_b^2 t}{su}\right)$$
$$+ C_{\kappa_j}\ln\left(\frac{Q_J^2 s}{tu}\right) + (C_{\kappa_a}+C_{\kappa_b}+C_{\kappa_J})L_S\Bigg]\eta_{\Gamma_{\rm cusp}}(\mu_S,\mu_H) + K_{\gamma_{\rm tot}}\Bigg\}$$
$$\times \tilde{B}_{\kappa_a}(\partial_{\eta_B}+L_B,x_a,\mu_B)\tilde{B}_{\kappa_b}(\partial_{\eta'_B}+L'_B,x_b,\mu_B)\,\tilde{J}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J)$$
$$\times H_\kappa(\Phi_1,\mu_H)\tilde{S}^\kappa_{\mathcal{T}_1}\left(\partial_{\eta_S}+L_S,\mu_S\right)\frac{Q^{-\eta_{\rm tot}}}{\mathcal{T}_1^{1-\eta_{\rm tot}}}\frac{\eta_{\rm tot}\;e^{-\gamma_E\eta_{\rm tot}}}{\Gamma(1+\eta_{\rm tot})} + \mathcal{O}\left(\frac{\mathcal{T}_1}{Q}\right)$$

where we have defined

$$L_H = \ln\left(\frac{Q^2}{\mu_H^2}\right) \qquad L_B = \ln\left(\frac{Q_a Q}{\mu_B^2}\right) \qquad L'_B = \ln\left(\frac{Q_b Q}{\mu_B^2}\right)$$
$$L_J = \ln\left(\frac{Q_J Q}{\mu_J^2}\right) \qquad L_S = \ln\left(\frac{Q^2}{\mu_S^2}\right)$$

$$\eta_{\rm tot} = -2(C_{\kappa_a}+C_{\kappa_b})\eta_{\Gamma_{\rm cusp}}(\mu_B,\mu_J) + 2(C_{\kappa_a}+C_{\kappa_b}+C_{\kappa_J})\eta_{\Gamma_{\rm cusp}}(\mu_S,\mu_J)$$

$$K_{\gamma_{\rm tot}} = -2n_g K_{\gamma_C^g}(\mu_S,\mu_H) + 2(n_g-3)K_{\gamma_C^q}(\mu_S,\mu_H)$$
$$-(n_g - n_g^{\kappa_J})K_{\gamma_J^g}(\mu_J,\mu_B) - n_g K_{\gamma_J^g}(\mu_S,\mu_J)$$
$$+(n_g-2-n_g^{\kappa_J})K_{\gamma_J^q}(\mu_J,\mu_B) + (n_g-3)K_{\gamma_J^q}(\mu_S,\mu_J)$$

Resummation formula up to NNLL' accuracy

Providing

3-loop cusp an. dim

2-loop non cusp

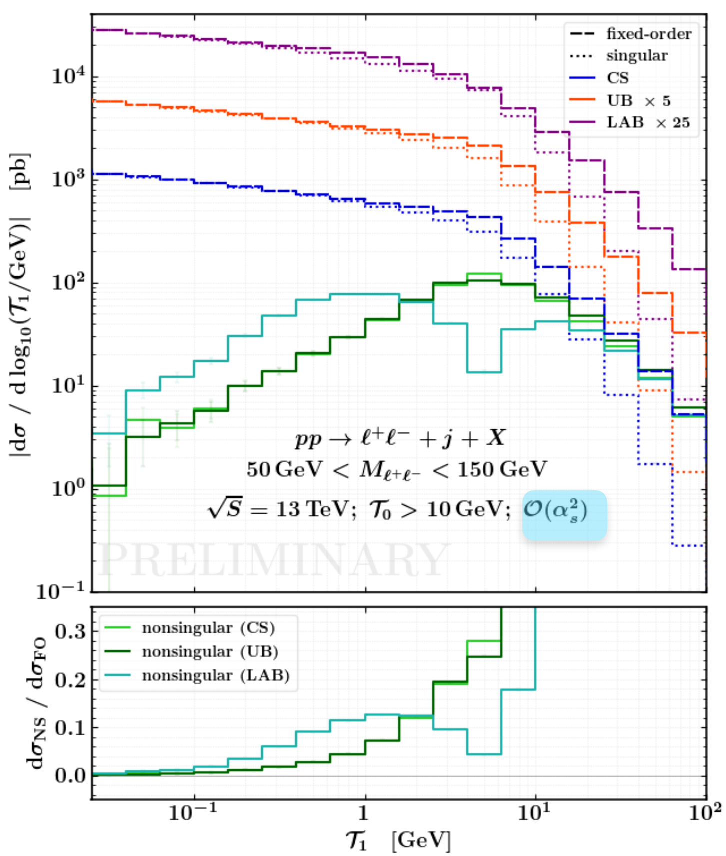
2-loop boundary terms (Hard, Soft, Beam, Jet)

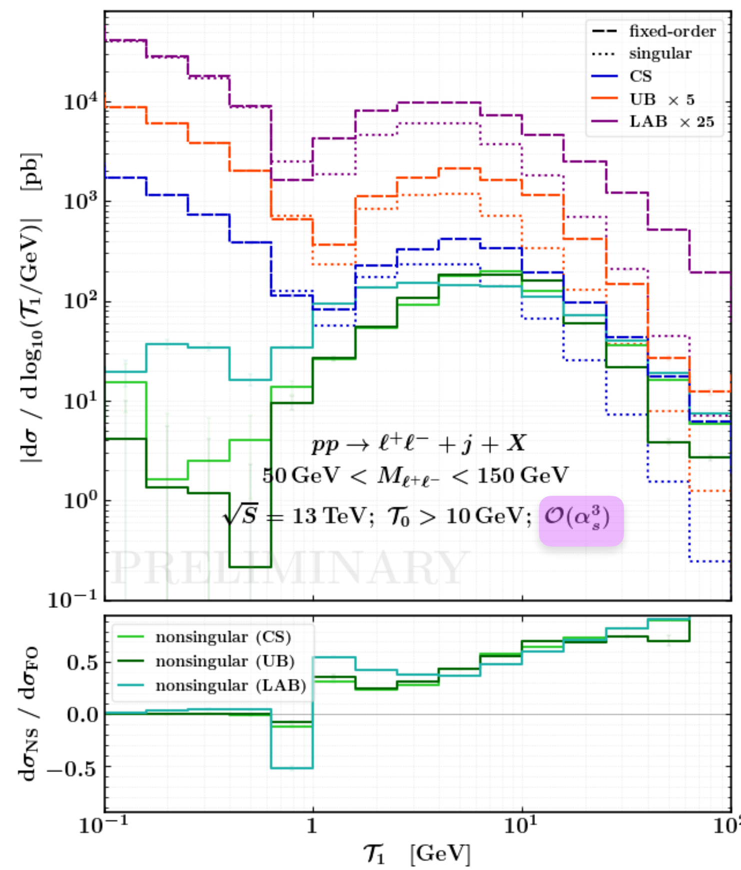
we can reach NNLL' accuracy

$$\frac{d\sigma^{\mathrm{NNLL}'}}{d\Phi_1 d\mathcal{T}_1} = \sum_\kappa \exp\Big\{4(C_{\kappa_a}+C_{\kappa_b})K^{\mathrm{NNLL}}_{\Gamma_{\mathrm{cusp}}}(\mu_B,\mu_H) + 4C_{\kappa_J}K^{\mathrm{NNLL}}_{\Gamma_{\mathrm{cusp}}}(\mu_J,\mu_H)$$
$$- 2(C_{\kappa_a}+C_{\kappa_b}+C_{\kappa_J})K^{\mathrm{NNLL}}_{\Gamma_{\mathrm{cusp}}}(\mu_S,\mu_H) - 2C_{\kappa_J}L_J\,\eta^{\mathrm{NNLL}}_{\Gamma_{\mathrm{cusp}}}(\mu_J,\mu_H)$$
$$- 2(C_{\kappa_a}L_B + C_{\kappa_b}L'_B)\eta^{\mathrm{NNLL}}_{\Gamma_{\mathrm{cusp}}}(\mu_B,\mu_H) + \Big[C_{\kappa_a}\ln\Big(\frac{Q_a^2 u}{st}\Big) + C_{\kappa_b}\ln\Big(\frac{Q_b^2 t}{su}\Big)$$
$$+ C_{\kappa_j}\ln\Big(\frac{Q_J^2 s}{tu}\Big) + (C_{\kappa_a}+C_{\kappa_b}+C_{\kappa_J})L_S\Big]\eta^{\mathrm{NNLL}}_{\Gamma_{\mathrm{cusp}}}(\mu_S,\mu_H) + K^{\mathrm{NNLL}}_{\gamma_{\mathrm{tot}}}\Big\}$$
$$\times \Big\{H^{(0)}_\kappa(\Phi_1,\mu_H)\Big[f_{\kappa_a}(x_a,\mu_B)f_{\kappa_b}(x_b,\mu_B)\Big(1 + \tilde{S}^{\kappa\,(1)}_{\mathcal{T}_1}(\partial_{\eta_S}+L_S,\mu_S) + \tilde{J}^{(1)}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J)$$
$$+ \tilde{S}^{\kappa\,(1)}_{\mathcal{T}_1}(\partial_{\eta_S}+L_S,\mu_S)\,\tilde{J}^{(1)}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J) + \tilde{S}^{\kappa\,(2)}_{\mathcal{T}_1}(\partial_{\eta_S}+L_S,\mu_S) + \tilde{J}^{(2)}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J)\Big)$$
$$+ \Big(\tilde{B}^{(1)}_{\kappa_a}(\partial_{\eta_B}+L_B,x_a,\mu_B)\Big(1 + \tilde{S}^{\kappa\,(1)}_{\mathcal{T}_1}(\partial_{\eta_S}+L_S,\mu_S) + \tilde{J}^{(1)}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J)\Big)$$
$$+ \tilde{B}^{(2)}_{\kappa_a}(\partial_{\eta_B}+L_B,x_a,\mu_B)\Big)f_{\kappa_b}(x_b,\mu_B) + f_{\kappa_a}(x_a,\mu_B)\Big(\tilde{B}^{(2)}_{\kappa_b}(\partial_{\eta'_B}+L'_B,x_b,\mu_B)$$
$$+ \tilde{B}^{(1)}_{\kappa_b}(\partial_{\eta'_B}+L'_B,x_b,\mu_B)\Big(1 + \tilde{S}^{\kappa\,(1)}_{\mathcal{T}_1}(\partial_{\eta_S}+L_S,\mu_S) + \tilde{J}^{(1)}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J)\Big)\Big)\Big]$$
$$+ H^{(1)}_\kappa(\Phi_1,\mu_H)\Big[f_{\kappa_a}(x_a,\mu_B)f_{\kappa_b}(x_b,\mu_B)\Big(1 + \tilde{S}^{\kappa\,(1)}_{\mathcal{T}_1}(\partial_{\eta_S}+L_S,\mu_S) + \tilde{J}^{(1)}_{\kappa_J}(\partial_{\eta_J}+L_J,\mu_J)\Big)$$
$$+ \Big(\tilde{B}^{(1)}_{\kappa_a}(\partial_{\eta_B}+L_B,x_a,\mu_B)f_{\kappa_b}(x_b,\mu_B) + f_{\kappa_a}(x_a,\mu_B)\tilde{B}^{(1)}_{\kappa_b}(\partial_{\eta'_B}+L'_B,x_b,\mu_B)\Big)\Big]$$
$$+ H^{(2)}_\kappa(\Phi_1,\mu_H)f_{\kappa_a}(x_a,\mu_B)f_{\kappa_b}(x_b,\mu_B)\Big\}$$
$$\times \frac{Q^{-\eta^{\mathrm{NNLL}}_{\mathrm{tot}}}}{\mathcal{T}_1^{1-\eta^{\mathrm{NNLL}}_{\mathrm{tot}}}}\,\frac{\eta^{\mathrm{NNLL}}_{\mathrm{tot}}\,e^{-\gamma_E\eta^{\mathrm{NNLL}}_{\mathrm{tot}}}}{\Gamma(1+\eta^{\mathrm{NNLL}}_{\mathrm{tot}})}\,.$$

Nonsingular behavior

- Different $\mathscr{T}_1$ choices have different subleading PC
- Investigated for one-jettiness subtraction at LL NLP [Boughezal, Isgro', Petriello `20]





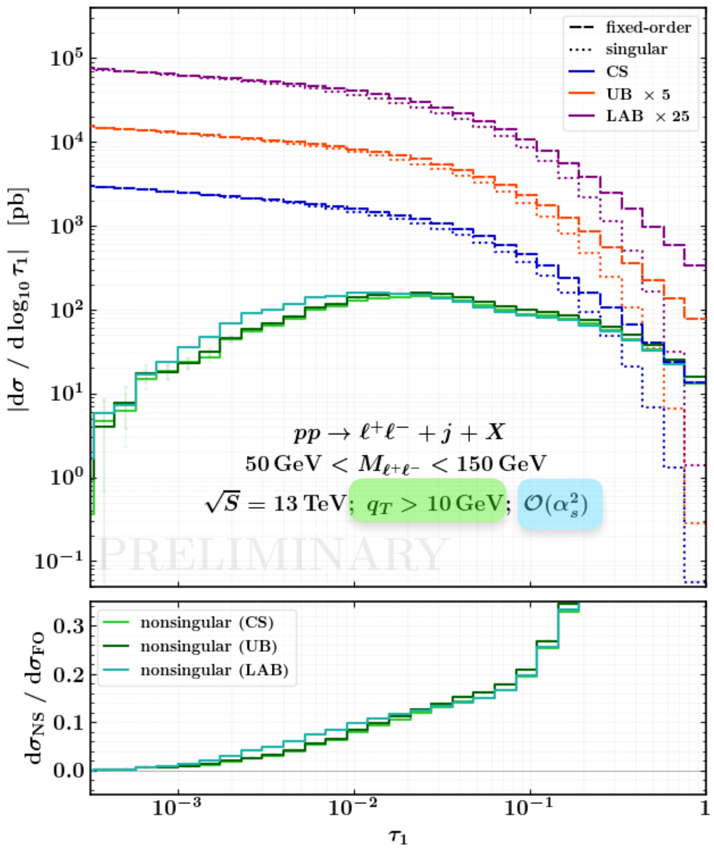
- CS frame as good as UB across different cuts. LAB consistently worse

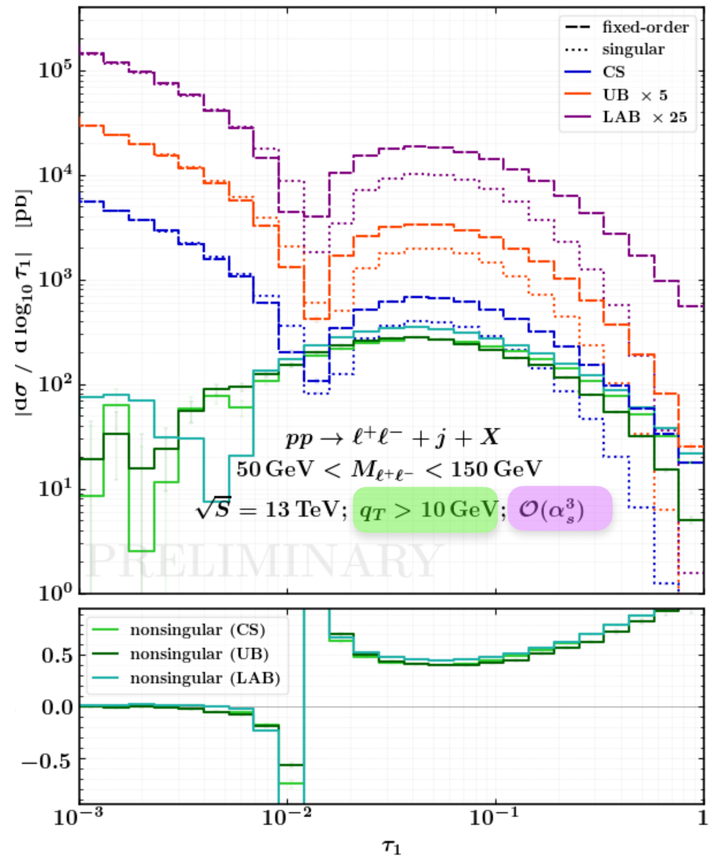
Nonsingular behavior

Dimensionless definition

$$\tau_1 = 2\mathcal{T}_1/\sqrt{M^2_{\ell^+\ell^-} + q_T^2}$$

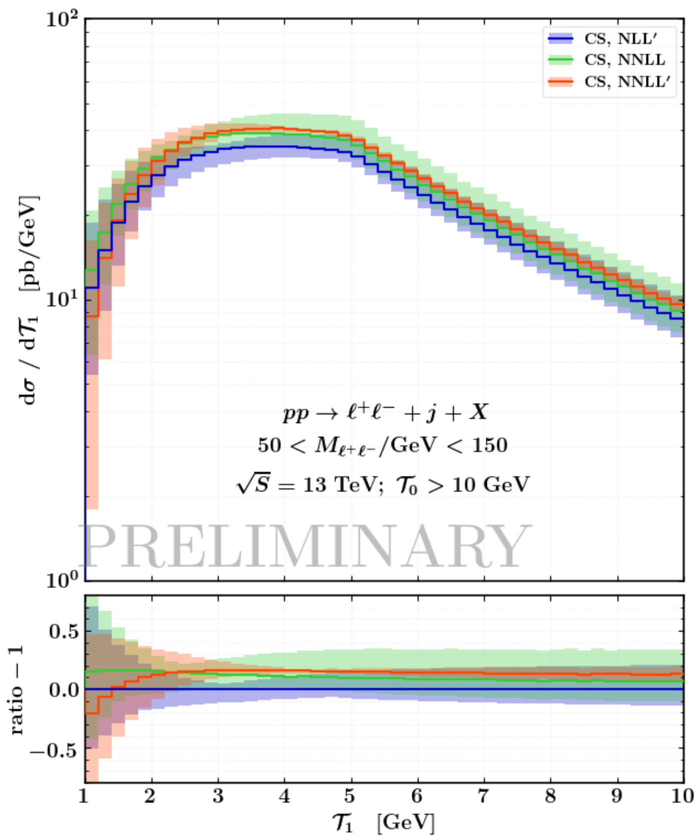
- Reduced differences when cutting on Z boson trans. momentum q_T

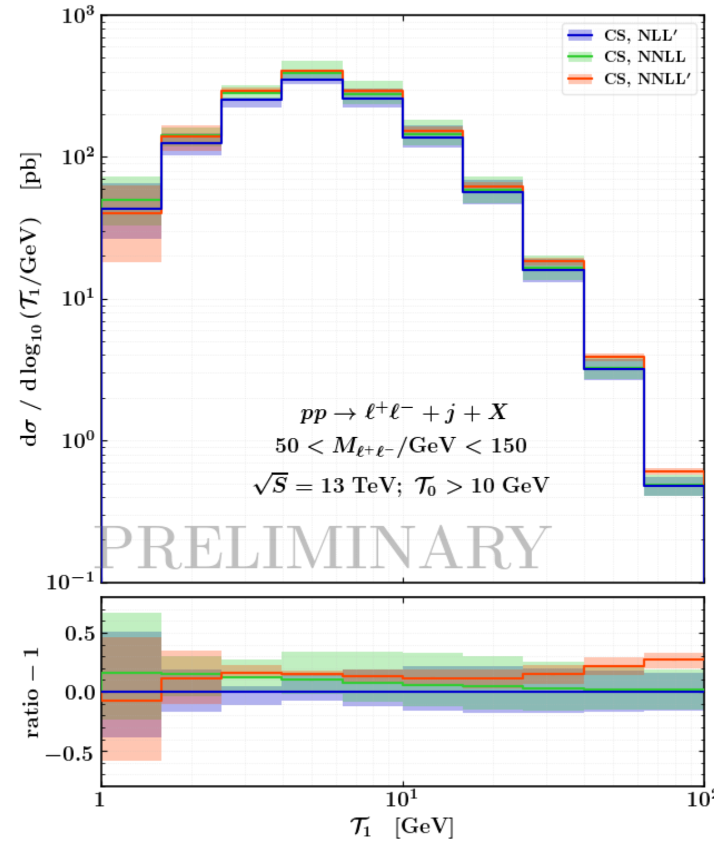




Resummed results

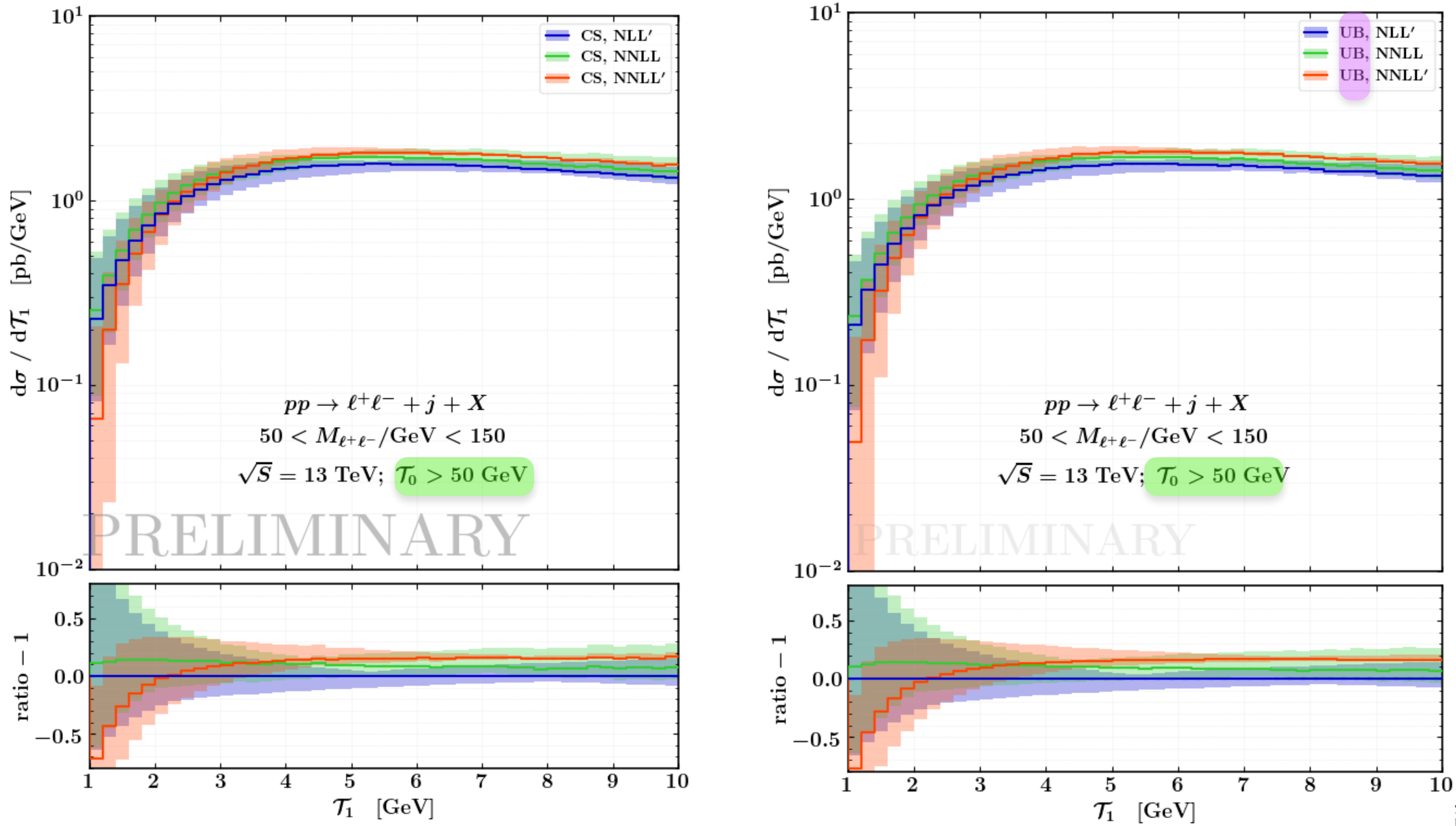
- Using profile scales to switch off resummation at $\mu_H = \sqrt{M^2_{\ell^+\ell^-} + q_T^2}$
- Summing in quadrature profile scales variations and fixed-order ones
- Nice convergence and reduction of theoretical uncertainties





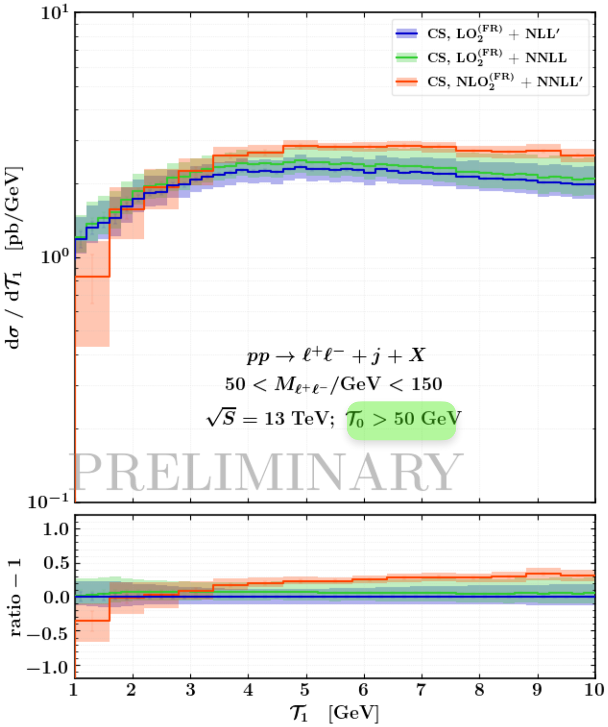
Resummed results

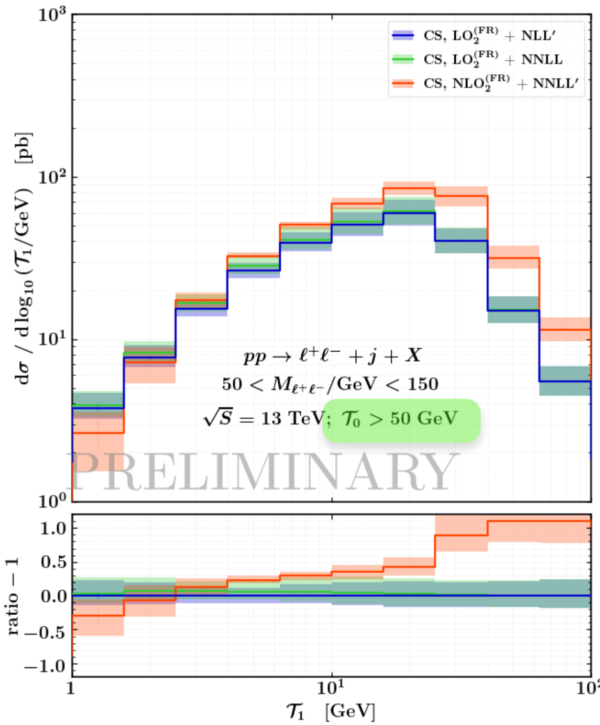
- Similar results for different Born cuts and in the UB frame

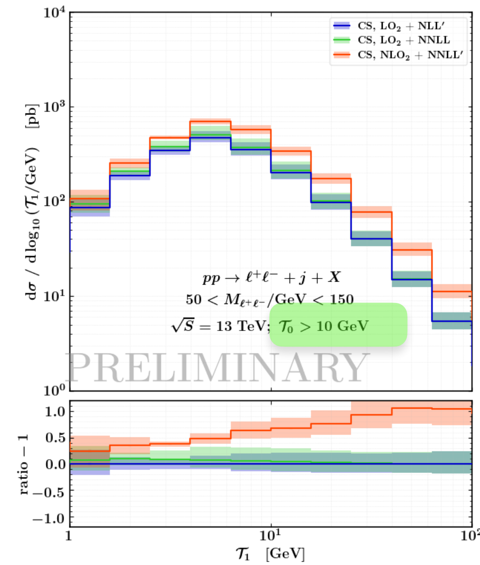


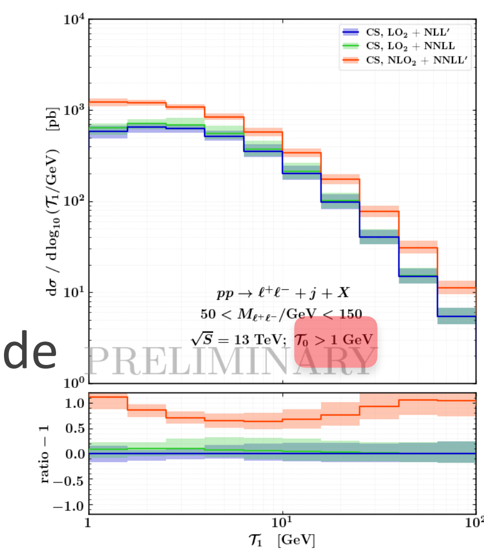
Matched results

$$\frac{d\sigma^{\text{match.}}}{d\Phi_1 d\mathcal{T}_1} = \frac{d\sigma^{\text{res.}}}{d\Phi_1 d\mathcal{T}_1} + \frac{d\sigma^{\text{f.o.}}}{d\Phi_1 d\mathcal{T}_1} - \frac{d\sigma^{\text{res.exp.}}}{d\Phi_1 d\mathcal{T}_1}$$







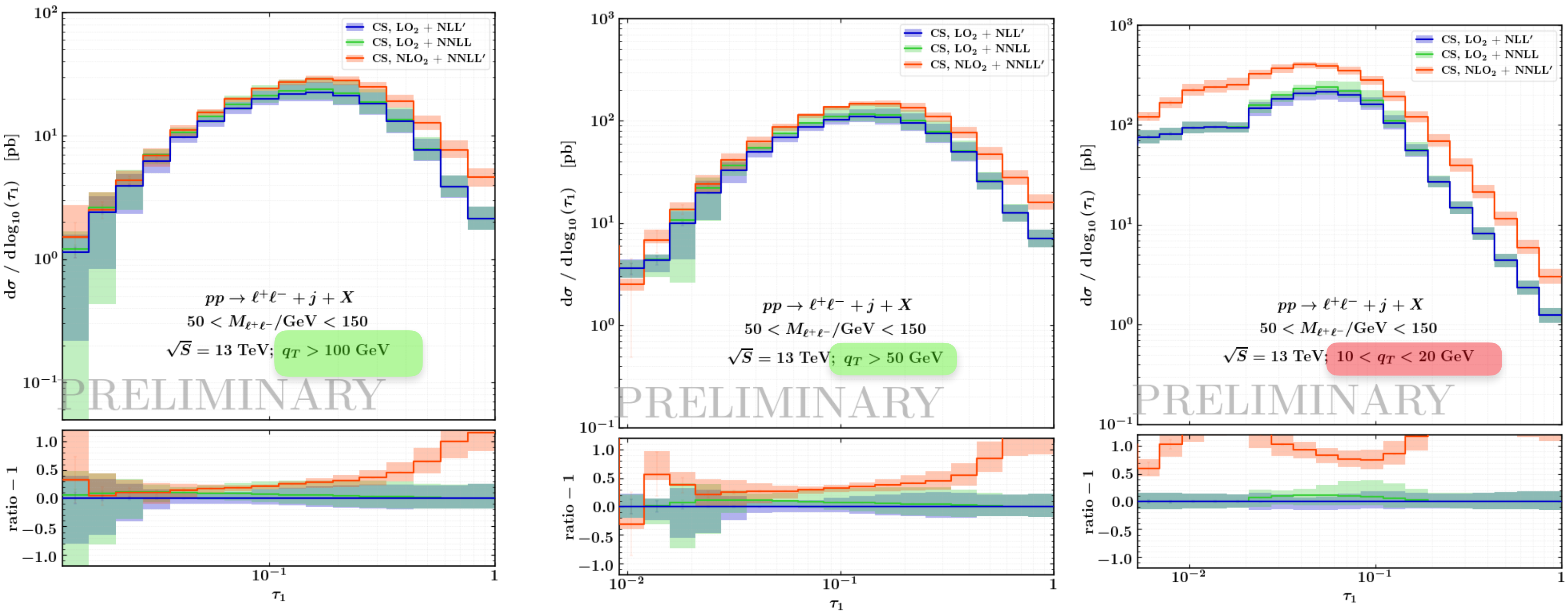


- $\mathcal{O}(\alpha_s^3)$ gives sizable contribution, important to include it for small values of $\mathcal{T}_0$
- Nonsingular divergent for $\mathcal{T}_0 \to 0$. Joint $(\mathcal{T}_0, \mathcal{T}_1)$ resummation required to handle both divergencies

Matched results

Dimensionless definition

$$\tau_1 = 2\mathcal{T}_1 / \sqrt{M^2_{\ell^+\ell^-} + q_T^2}$$



- Similar issues with nonsingular behaviour when $q_T \to 0$

Conclusion and outlook

- The inclusion of state-of-the-art theoretical predictions in SMC generators is mandatory to match the experimental precision and fully exploit the discovery potential of LHC measurements
- GENEVA method allows for interfacing higher-order resummation of resolution variables in event generation with NNLO accuracy and parton showers.
- Implemented one-jettiness resummation to create a NNLO+PS for V+j production.
- Studied different $\mathscr{T}_1$ definitions, performed resummation up to NNLL' and matched to corresponding fixed-order. Observed nice convergence and reduction of theory unc. in presence of an hard jet.
- When jet gets soft/collinear joint resummation is needed to keep nonsingular contributions under control.
- Next step is to complete the GENEVA implementation, including showering interface

Thank you for your attention.