Uncertainties in NLO merging schemes

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September 5th, 2019

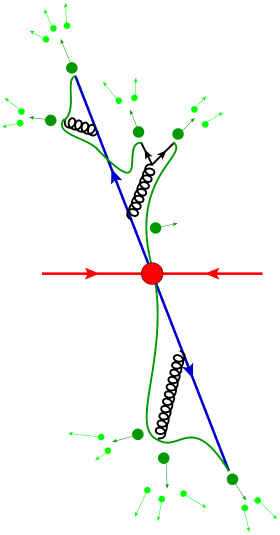
Overview

Introduction: Matching and Merging

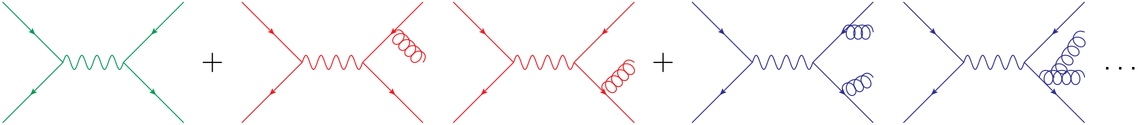
Matching and merging: use additional pQCD input

NLO matching NLO matrix elements → higher fixed order accuracy

Multi-jet merging Higher multiplicity matrix elements → improved radiation pattern



CKKW-L Merging arXiv:hep-ph/0109231 arXiv:hep-ph/0112284

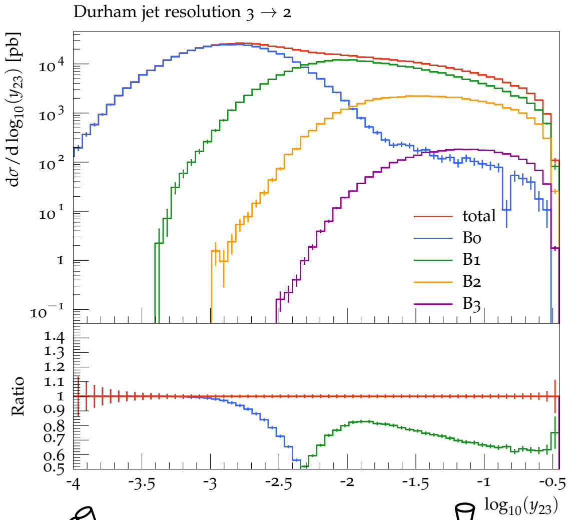


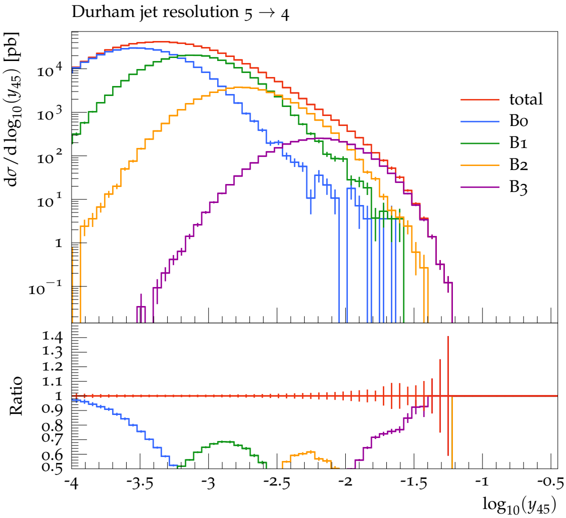
Combine MEs with different multiplicities, avoid overlap by reweighting

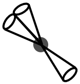
$$\langle \mathcal{O} \rangle = \int d\phi_0 \left\{ \mathcal{O}_0 B_0 w_0 + \int d\phi_1 \mathcal{O}_1 B_1 w_1 + \int d\phi_1 \int d\phi_2 \mathcal{O}_2 B_2 w_2 \right\}$$

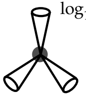
with the weights

$$w_0 = \Pi_0(t_0, t_{MS})\,, \quad w_1 = \Pi_0(t_0, t_1)\frac{\alpha_s(t_1)}{\alpha_s(\mu_R)}\Pi_1(t_1, t_{MS})\,, \quad w_2 = \Pi_0(t_0, t_1)\frac{\alpha_s(t_1)}{\alpha_s(\mu_R)}\Pi_1(t_1, t_2)\frac{\alpha_s(t_2)}{\alpha_s(\mu_R)}$$









All plots generated with MG5_aMC@NLO + Pythia8

arXiv:1405.0301 arXiv:hep-ph/0603175

Unitarized Merging

- Problem with CKKW-L: Procedure might change inclusive cross section
- No-emission probability

$$\Pi_0(t_0, t_1) = 1 - \int_{t_1}^{t_0} dt P(t)$$

  with $P(t)$ shower emission probability, but in general $P(t) \neq B_1(t)/B_0$
- To preserve total cross section: Use $P(t) \to B_1(t)/B_0$ ME corrected shower
- Alternative: Subtract separate ME sample, possible at any multiplicity: UMEPS arXiv:1211.4827

$$B_0 w_0 = B_0 - \int_{t_{MS}}^{t_0} dt B_1(t)$$

UMEPS Merging and Scale Variations

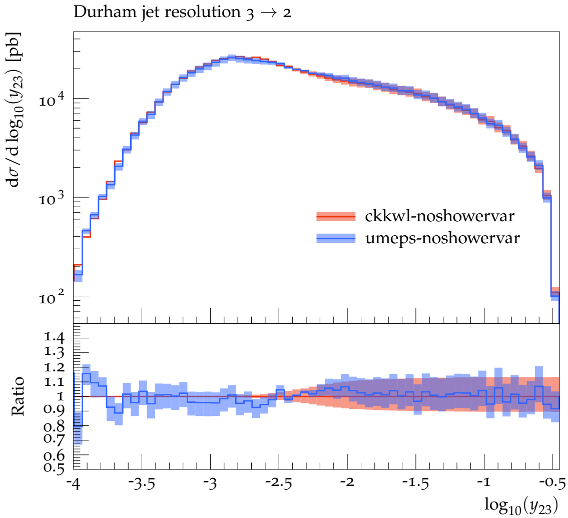
In unitarized multi-jet merging, observables $\mathcal{O}$ are calculated by

$$\langle\mathcal{O}\rangle = \int d\phi_0 \left\{ \mathcal{O}_0 \left[B_0 - \int_s B_{1\to 0} w_1 \right] + \int d\phi_1 \mathcal{O}_1 B_1 w_1 \right\}$$

with weights

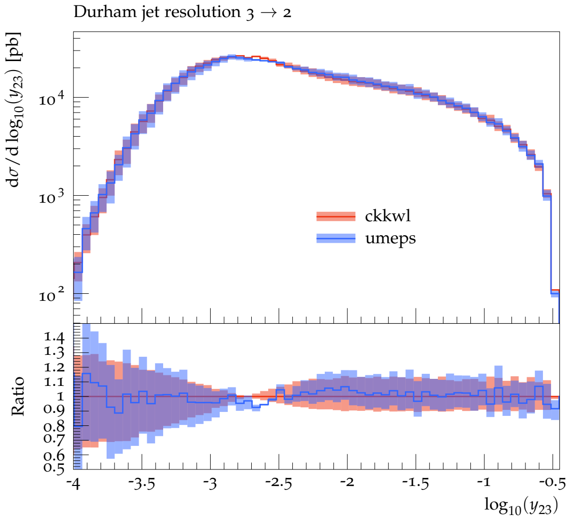
$$w_1 = \Pi_0(t_0, t_1, b) \frac{\alpha_s(bt_1)}{\alpha_s(\mu_R)}$$

Vary $b = 1, 1/2, 2$ in weights and shower (inc. trial shower for Π_i)



No scale variation in attached shower

- CKKW-L no variation below merging scale
- UMEPS variation above and below due to subtraction
- Both shapes sensitive to merging scale



Scale variation in merging and shower

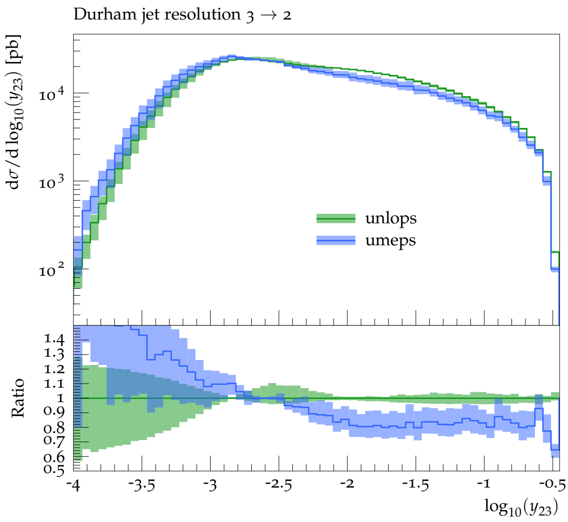
- Both CKKW-L and UMEPS have similar variations above and below merging scale
- Shape dependence on merging scale remains

Scale Variations in UNLOPS

- UNLOPS: Combine NLO matching and UMEPS merging arXiv:1211.7278 arXiv:1211.5467 arXiv:1705.06700
- Subtract $\mathcal{O}(\alpha_s)$ from weights to preserve perturbative accuracy

$$\langle\mathcal{O}\rangle = \int d\phi_0 \left\{ \mathcal{O}_0 \left[\bar{B}_0 - \int_s \bar{B}_{1\to 0} - \int_s B_{1\to 0}(w_1 - w_1|_{\mathcal{O}(\alpha_s)}) \right] + \int d\phi_1 \mathcal{O}_1 \left[\bar{B}_1 + B_1(w_1 - w_1|_{\mathcal{O}(\alpha_s)}) \right] \right\}$$

with weights w_1 as before, but $\bar{B}_i(b)$ with variations as well



NLO merging reduces scale variation band above merging scale

Uncertainty of Unitary NLO Merging Prescription

+1 jet contribution in UNLOPS pure 1st order correction

$$B_1 w_1 + \left[\bar{B}_1 - B_1 w_1|_{\mathcal{O}(\alpha_s)}\right]$$

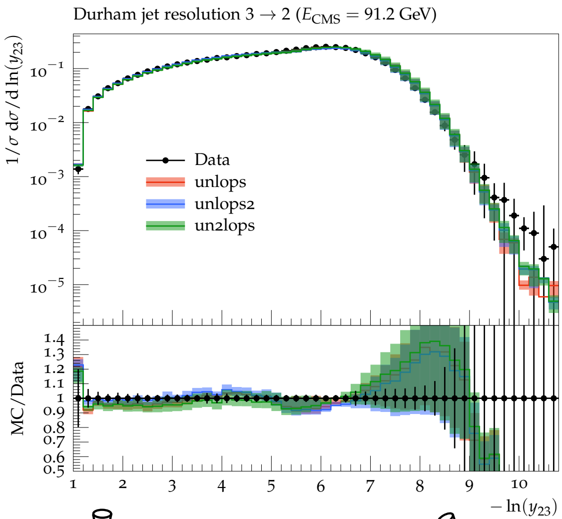
Apply CKKW-L reweighting to perturbative correction:

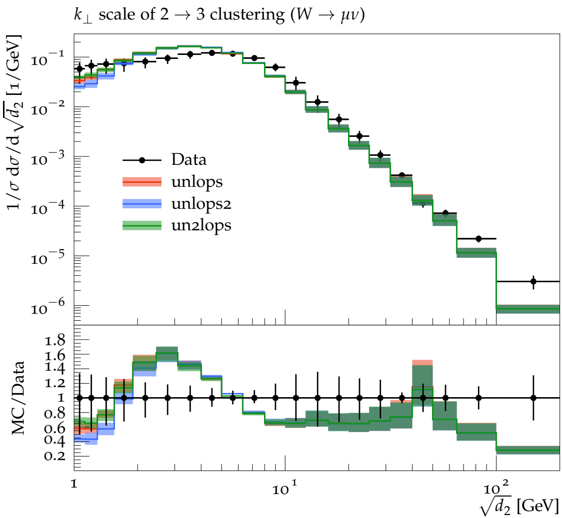
UN2LOPS arXiv:1405.3607

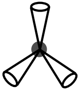
$$B_1 w_1 + \left[\bar{B}_1 - B_1 w_1|_{\mathcal{O}(\alpha_s)}\right] \Pi_0(t_0, t_1, b)$$

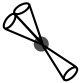
UNLOPS2

$$B_1 w_1 + \left[\bar{B}_1 - B_1 w_1|_{\mathcal{O}(\alpha_s)}\right] \Pi_0(t_0, t_1, b) \frac{\alpha_s(bt_1)}{\alpha_s(\mu_R)}$$









In pp collisions PDF weights are included

Summary

- For consistency: Vary renormalization scale in ME, merging weights and shower simultaneously
- Reweighting more efficient than separate runs
- Some freedom in weighting of perturbative corrections: can be used as uncertainty on merging prescriptions
- Reasonable estimation of merging uncertainties by combining scale and scheme variation