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ResBos2: Status Update

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LHC EW Precision Sub-Group Meeting

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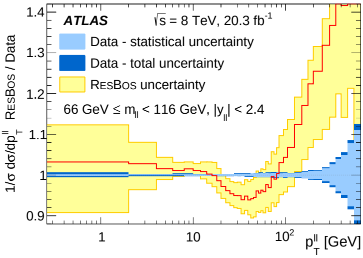
Outline

- Motivation for ResBos2
- CSS vs CFG Formalisms
- N^3LL Accuracy
- Current Status on Transverse Momentum Distributions
- Future Goals

Motivations for ResBos2

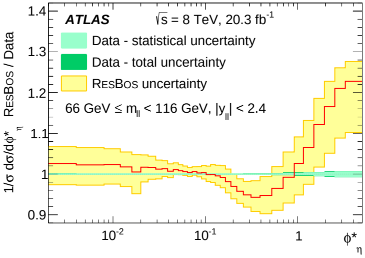
- Understand errors introduced by q_T resummation scheme choice
- Improve agreement with Drell-Yan data



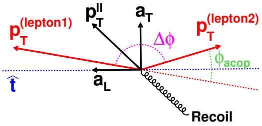
ATLAS, 1512.02192v2

Motivation (Cont.)

$$\phi_\eta^* = \tan\left(\frac{\pi - \Delta\phi}{2}\right)\sqrt{1 - \tanh\left(\frac{\eta_1 - \eta_2}{2}\right)} \approx \frac{Q_T}{Q}\sin\phi_{CS}$$



ATLAS, 1512.02192v2



Vesterinen and Wyatt et al., arXiv:1010.0262

CSS vs. CFG Formalism

Hard Factor:

- CSS: $\sigma = \sigma_0 \times (1)$
- CFG: $\sigma = \sigma_0 \times \left(1 + \frac{\alpha_s}{\pi} H^{(1)} + ...\right)$

Theoretical Scales:

- Canonical Scale: $C_1 = b_0$, $C_2 = 1$, $C_3 = b_0$
- Factorization Scale (PDFs): μ_F
- Renormalization Scale (Couplings): μ_R

CSS vs. CFG (Cont.)

All Orders Conversion

$$A^{CSS} = A^{CFG}$$

$$B^{CSS} = B^{CFG} - \beta\left(\alpha_s\right)\frac{d\ln H\left(\alpha_s\right)}{d\ln\alpha_s}$$

$$C^{CSS} = \left[H\left(\alpha_s\right)\right]^{1/2} C^{CFG}$$

B^3 for Drell-Yan

CSS

$$B^{(3)} = 114.982 - 11.2737 n_f + 0.321798 n_f^2$$

$$B^{(1)}_{n_f=5} = -2 \quad B^{(2)}_{n_f=5} = 1.9 \quad B^{(3)}_{n_f=5} = 66.66$$

$$\frac{B^{(3)} \frac{\alpha_s}{\pi}}{B^{(2)}} = 1.32$$

CFG

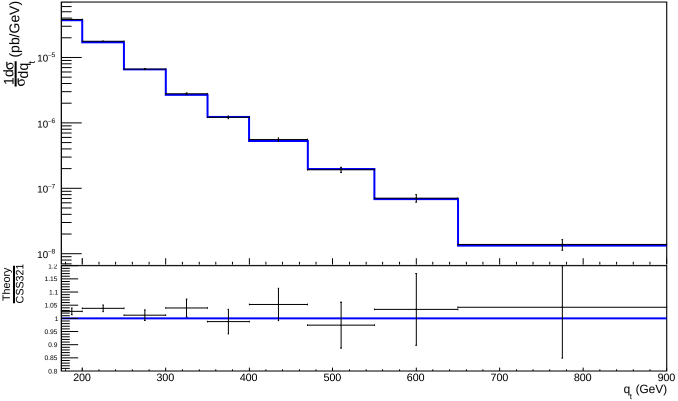
$$B^{(3)} = -16.185 - 0.011592 n_f + 0.11379 n_f^2$$

$$B^{(1)}_{n_f=5} = -2 \quad B^{(2)}_{n_f=5} = -0.488 \quad B^{(3)}_{n_f=5} = -13.38$$

$$\frac{B^{(3)} \frac{\alpha_s}{\pi}}{B^{(2)}} = 1.03$$

HuaXing Zhu, et al. arXiv:1604.01404

High q_T Scale Choice



Theory vs. Data at high q_T with scale choice of

$$\mu = M_T = \sqrt{M_Z^2 + q_T^2}$$

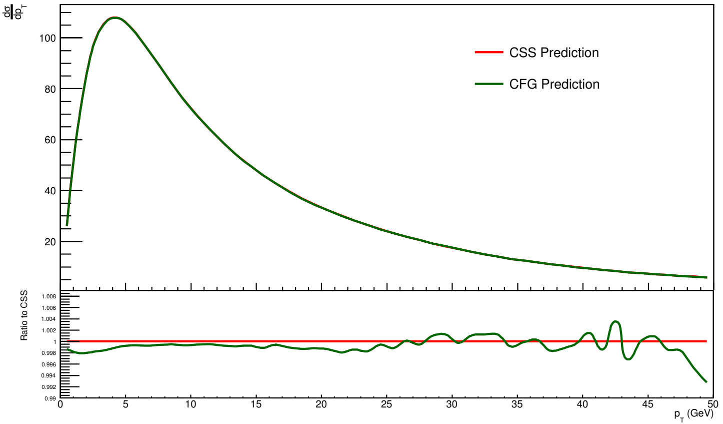
Asymptotic Expansion

$$\frac{d\sigma}{dq_t^2}_A = \sigma \sum_{i,j} \sum_{n,m} \left(\frac{\alpha_s\left(\mu\right)}{\pi}\right)^n {}_nC_m^{(ij)} \ln^m \left(\frac{Q^2}{q_T^2}\right)$$

First term that is different between the CSS and CFG Formalism in the asymptotic expansion is:

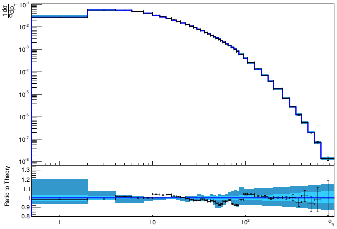
$$\frac{d\sigma}{dq_t^2}_A \subset \alpha_s^4 \ln\left(\frac{Q^2}{Q_T^2}\right)\left[A^{(4)} f_i f_j + \left(A^{(1)}\left(C^{(3)} \otimes f_i\right) f_j + A^{(1)}\left(C^{(3)} \otimes f_j\right) f_i\right)\right]$$

CSS/CFG Comparison

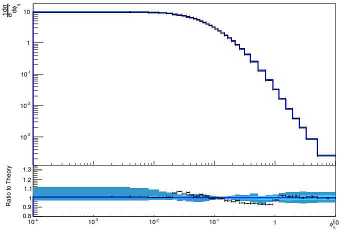


CSS P_T and ϕ^*_η Distributions

Transverse Momentum



ϕ^*_η



Light blue is PDF Uncertainty. Dark blue is scale uncertainty plus PDF uncertainty. Scale uncertainty is given by: $C_1 = 0.5(2)b_0$, $C_2 = 2(0.5)$, $C_3 = 0.5(2)b_0$, $\mu_F = 0.5(2)\mu_0$, $\mu_R = 0.5(2)\mu_0$. A total of 7 scale variations are used.

Transverse Momentum Ratio Study

Setup:

- LHC 8TeV
- Compare both NNLL + NNLO and N3LL + NNLO
- Including PDF uncertainties

Cuts:

- $p_T^l > 25$ GeV
- $|y^l| < 2.5$
- $|y^{(W/Z)}| < 2.5$

Cuts Z Only:

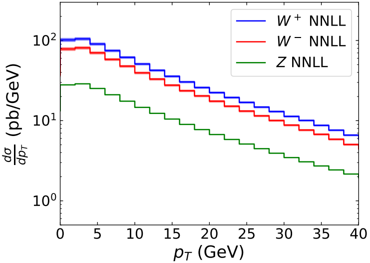
- 66 GeV $< |M_{ll}| <$ 116 GeV

Cuts W Only:

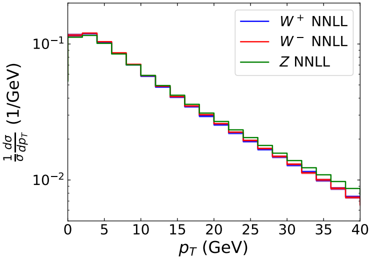
- $\not{E}_T > 25$ GeV
- 50 GeV $< M_T = \sqrt{2 p_T \not{E}_T (1 - \cos\theta)} <$ 300 GeV

Transverse Momentum at NNLL + NNLO

Transverse Momentum

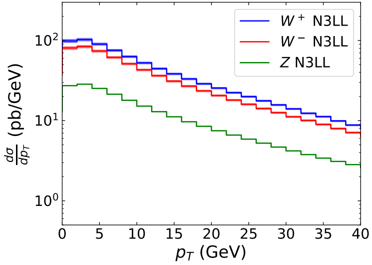


Transverse Momentum Shape

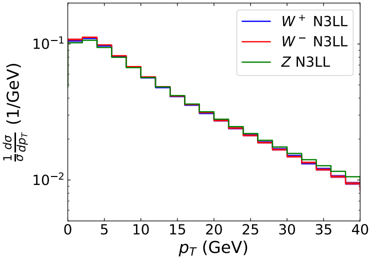


Transverse Momentum at N3LL + NNLO

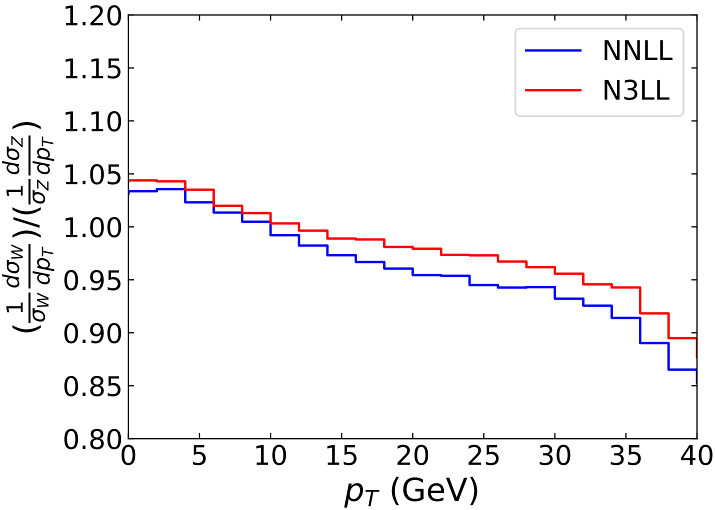
Transverse Momentum



Transverse Momentum Shape



Transverse Momentum Ratio



Conclusion

- Resolve predictions for both p_T and ϕ^*_η for the ResBos predictions
- Study uncertainty induced by scheme choice
- ResBos2 merges old ResBos code with Legacy code (no need for privately made grid files)
- Comparison of Results at NNLL + NNLO and N3LL + NNLO for transverse momentum distributions

Future Steps

- Matching to NNLO $Z + j$
- New Non-pert fit for each scale choice
- Detailed study of relationship between scale uncertainties for Drell-Yan and $W^{\pm}$
- Make the ResBos2 Code public