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Transverse Momentum Resummation for t-channel single top quark production at the LHC

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Abstract: We study the soft gluon radiation effects for the t-channel single top quark production at the LHC. By applying the transverse momentum dependent factorization formalism, the large logarithms about the small total transverse momentum of the single-top plus one-jet final state system, are resumed to all orders in the expansion of the strong interaction coupling at the accuracy of NLL. We compare the singular behavior of resummation calculation to fixed order prediction at the small $q_\perp$ region, and find a perfect agreement. The phenomenological importance of the resummation effect at the LHC is also demonstrated.

Qing-Hong Cao , Peng Sun, Bin Yan, C.-P. Yuan and Feng Yuan work in progress

Single top quark production

Edmond L. Berger, Q.-H. Cao, I. Low,PRD80(2009)074020
Q-H. Cao, Bin Yan, J-H Yu, C. Zhang, arxiv:1504.03785;
Q-H. Cao, Bin Yan, PRD92(2015)no.9 094018
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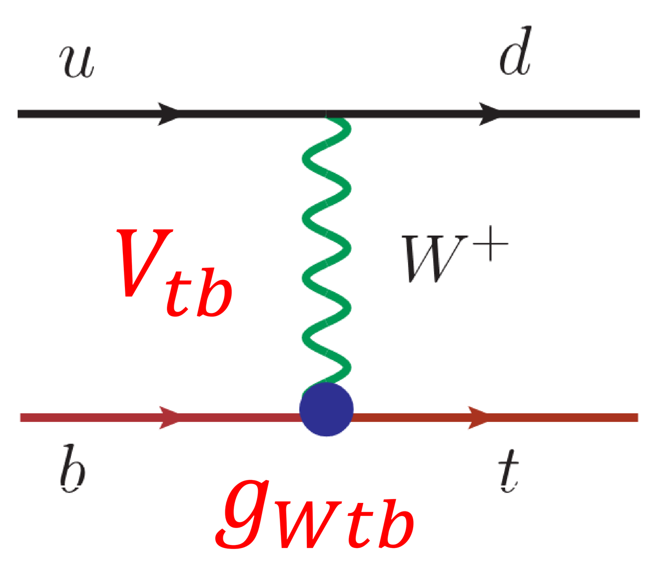
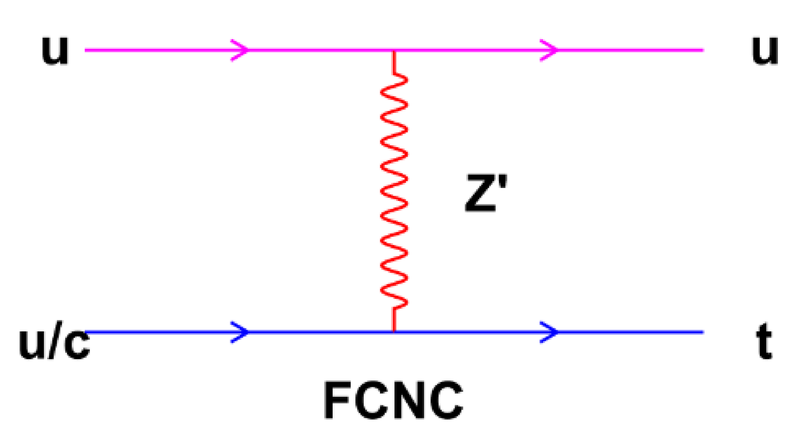
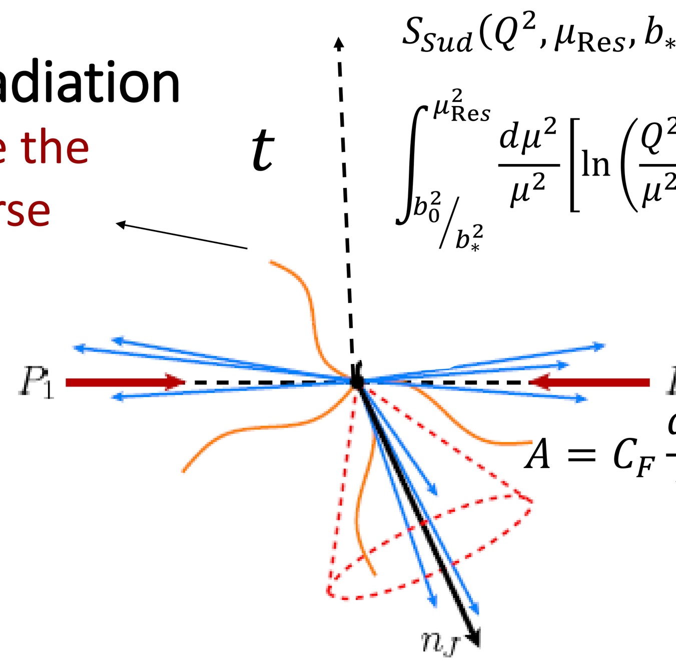




Soft gluon radiation

This will change the system transverse momentum.

$$\ln\frac{q_\perp^2}{Q^2}$$



$$S_{Sud}(Q^2,\mu_{Res},b_*)=\int_{b_0^2/b_*^2}^{\mu_{Res}^2}\frac{d\mu^2}{\mu^2}\left[\ln\left(\frac{Q^2}{\mu^2}\right)A + B + D_1\ln\frac{Q^2-m_t^2}{P_{J\perp}^2R^2} + D_2\ln\frac{Q^2-m_t^2}{m_t^2}\right]$$

$$A = C_F\frac{\alpha_s}{\pi},\ B = -2C_F\frac{\alpha_s}{\pi},\ D_1 = D_2 = C_F\frac{\alpha_s}{2\pi}$$

Resummation Formalism

$$\frac{d^4\sigma}{dy_t dy_J dP_{J\perp}^2 d^2q_\perp} = \sum_{ab}\left[\int\frac{d^2\vec{b}}{(2\pi)^2}e^{-i\vec{q}_\perp\cdot\vec{b}}W_{ab\to tJ}(x_1,x_2,b) + Y_{ab\to tJ}\right]$$

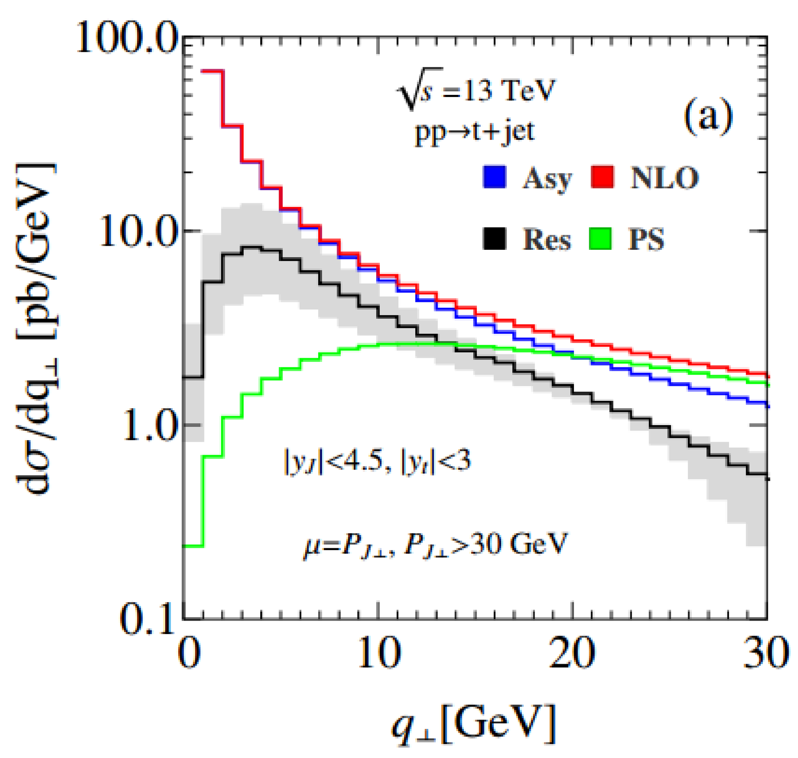
W-piece:

$$x_1 f_a\left(x_1,\frac{b_0}{b^*}\right)x_2 f_b\left(x_2,\frac{b_0}{b^*}\right)\ e^{-S_{Sud}(Q^2,\mu_{Res},b_*)}e^{-F_{NP}(Q^2,b)}$$

$$\mathrm{Tr}\left[\mathbf{H}_{ab\to tJ}(\mu_{Res})\exp\left[-\int_{b_0/b_*}^{\mu_{Res}}\frac{d\mu}{\mu}\gamma^{s\dagger}\right]\mathbf{S}_{ab\to tJ}(b_0/b_*)\exp\left[-\int_{b_0/b_*}^{\mu_{Res}}\frac{d\mu}{\mu}\gamma^{s}\right]\right]$$

Hard function   Soft function   Anomalous dimension

Results: Pythia ≠ Resummation

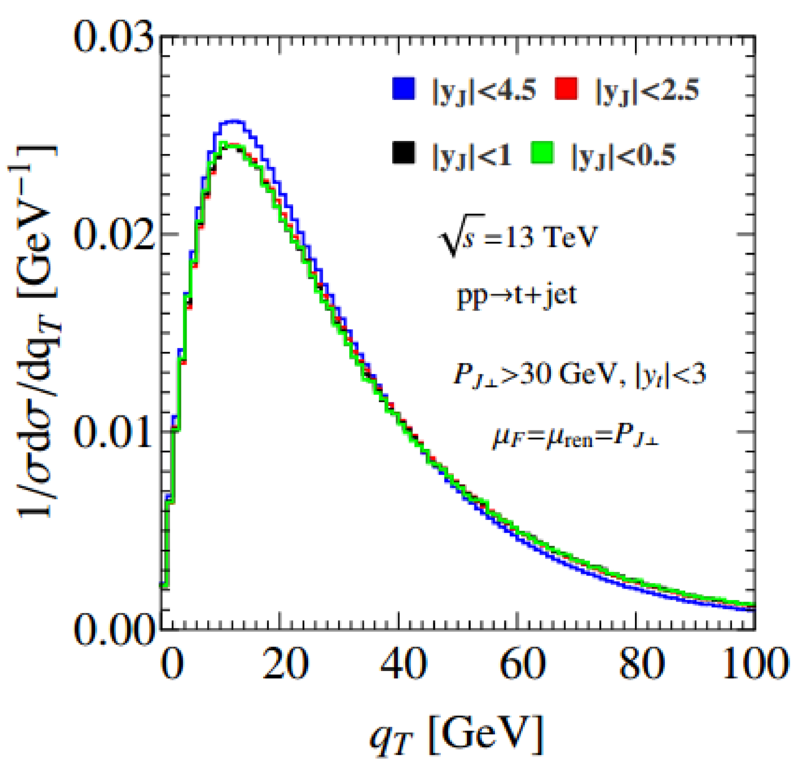


1.The singular behavior of asymptotic result is agree with NLO prediction at the small $q_\perp$ region;

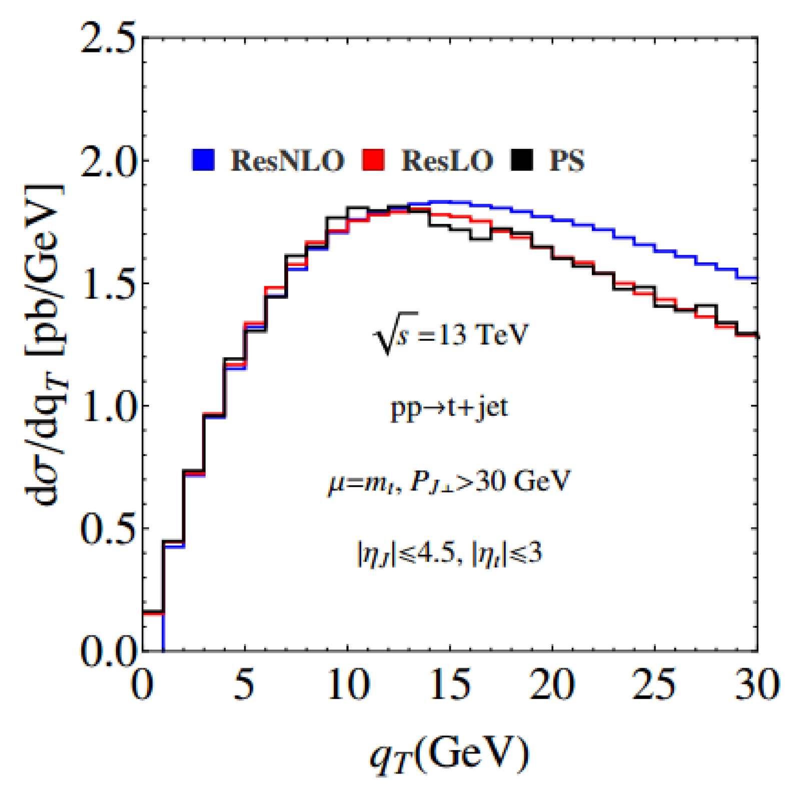
2. The parton shower sudakov peak is much larger than our resummation result;

3. The difference is from the correlation between the initial state and final state soft gluon radiation.

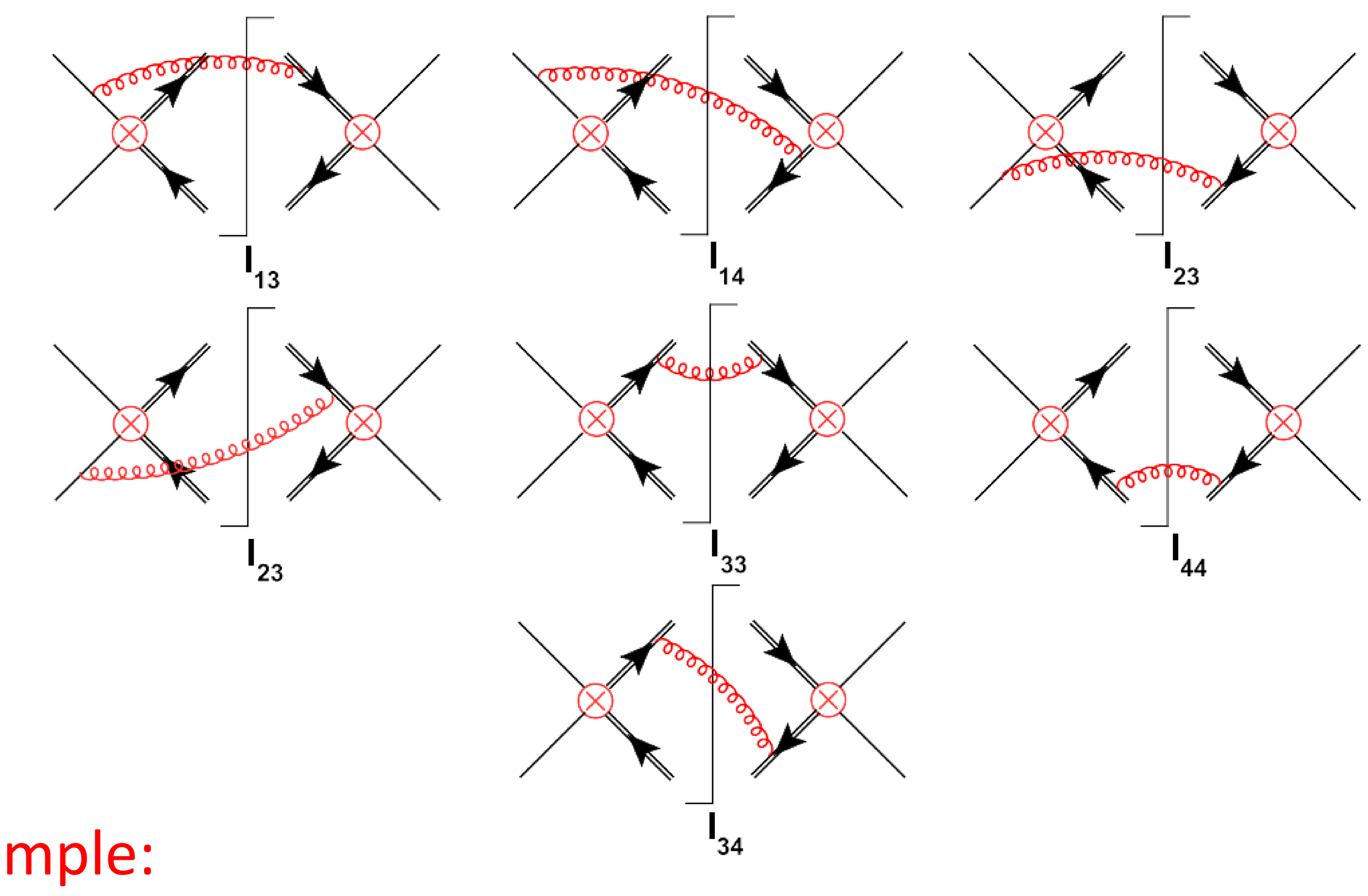
Parton shower



Turn off $\ln\frac{-\hat{t}}{s}$



Soft function and anomalous dimension



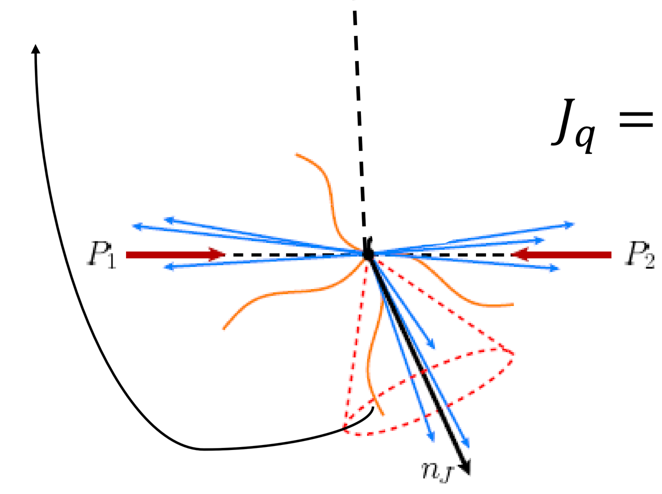
Example:

$$\gamma^{S}_{ub\to dt} = \frac{\alpha_s}{\pi}\begin{bmatrix} C_F T & C_F/C_A\,U \\ U & \frac{1}{2}(C_A - 2/C_A)U - \frac{1}{2C_A}T\end{bmatrix}$$

$$T = \ln\left(\frac{-\hat{t}}{\hat{s}}\right) + \ln\left(\frac{-(\hat{t}-m_t^2)}{\hat{s}-m_t^2}\right) \qquad U = \ln\left(\frac{-\hat{u}}{\hat{s}}\right) + \ln\left(\frac{-(\hat{u}-m_t^2)}{\hat{s}-m_t^2}\right)$$

Jet function:

Collinear gluon radiation



$$J_q = \frac{\alpha_s C_F}{2\pi\Gamma(1-\varepsilon)}\left[\frac{1}{\varepsilon^2} + \frac{1}{\varepsilon}\left(\frac{3}{2} - \ln\frac{P_{J\perp}^2R^2}{\mu_{Res}^2}\right) + I_q\right]$$