

Exploring improvements to the fitting of the strong coupling constant through means of jet substructure techniques

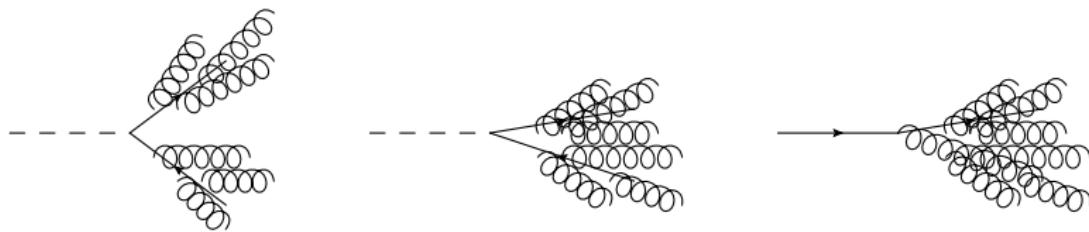
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Boosted particles

- LHC energy much larger than heavy particle masses
- Massive particles predominately produced boosted ($p_T \gg m$)
- Harder to distinguish from QCD jets



Non-perturbative contributions

Many effects cannot be described by perturbation theory:

- Hadronization effects
- Multi-parton interactions
- Pile-up

Jet substructure

- Many jet substructure techniques developed; **Grooming** and Tagging
- Created with the purpose of distinguishing signal from background
- Removes soft wide-angle radiation
- Can also help reduce non-perturbative corrections

mMDT & Soft drop

Main technique we will deal with is soft drop:

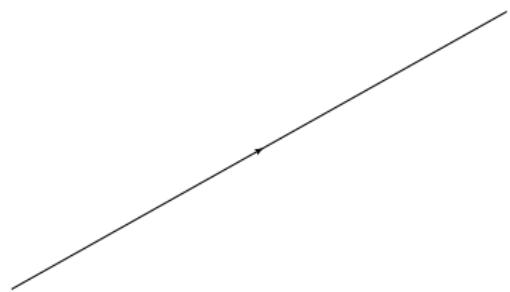
$$\frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}} > z_c \left(\frac{\Delta R_{12}}{R} \right)^\beta$$

Makes use of Cambridge/Aachen clustering.

Reduces to modified Mass Drop Tagger (mMDT) for $\beta = 0$

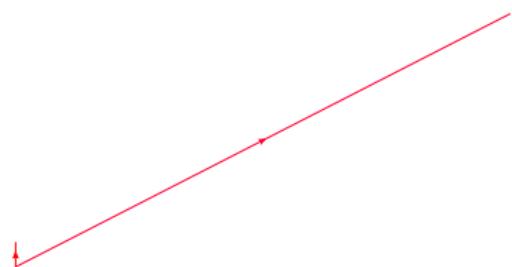
Full Soft drop

- 1) Decluster the last step
- 2) Check the soft drop condition for this splitting
- 3) If it fails drop the softest and repeat
- 4) If it passes finish the grooming



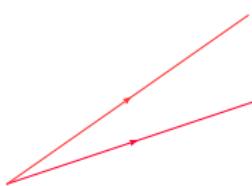
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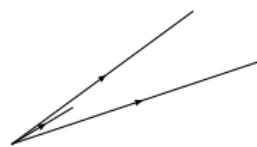
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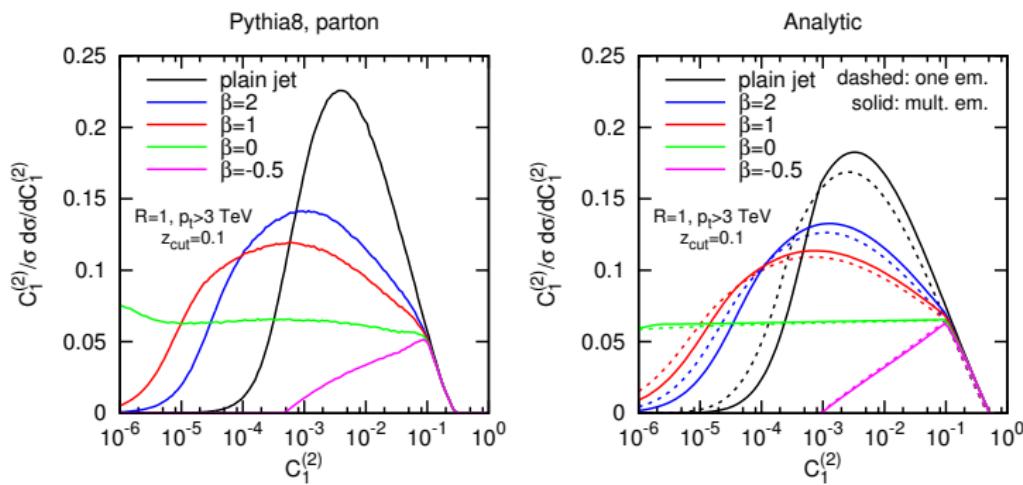
Need for resummation

For boosted jets, great separation of scales $p_T \gg m$ leads to large logarithms:

$$\log \left(\frac{m_J^2}{p_T^2 R^2} \right)$$

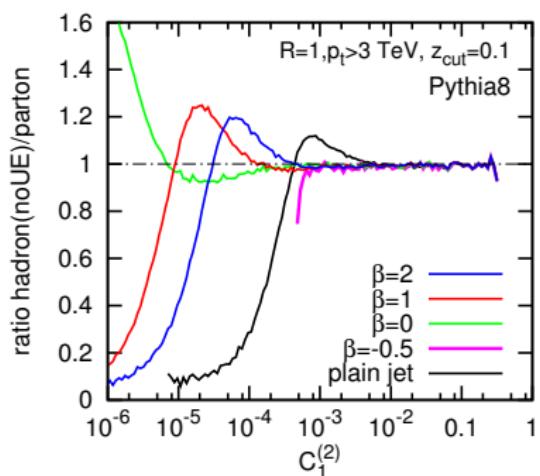
Large logarithms need to be resummed

Analytic computations



[Larkoski, Marzani, Soyez, Thaler; '14]

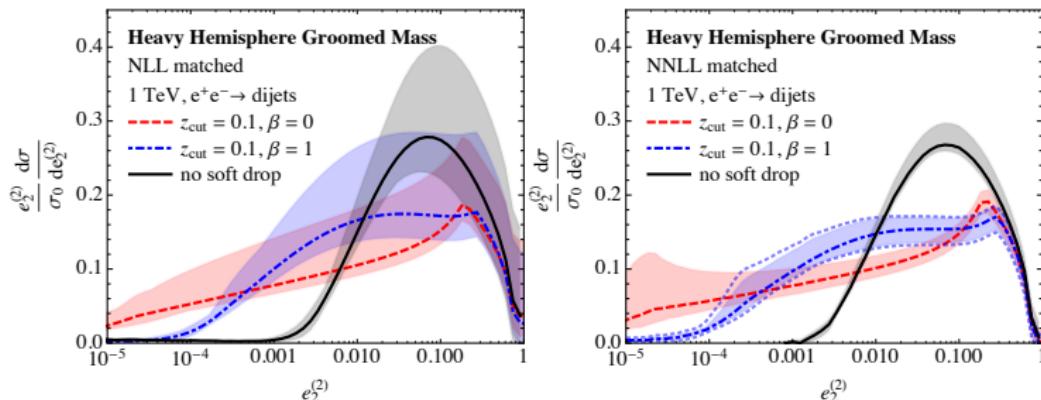
Reduction in NP corrections



[Larkoski, Marzani, Soyez, Thaler; '14]

Computation at NNLL accuracy

- Computation of soft drop using SCET at NNLL accuracy
[Frye, Larkoski, Schwartz, Yan; '16]
- Approximated for $e_2^{(2)} \ll z_{cut}$

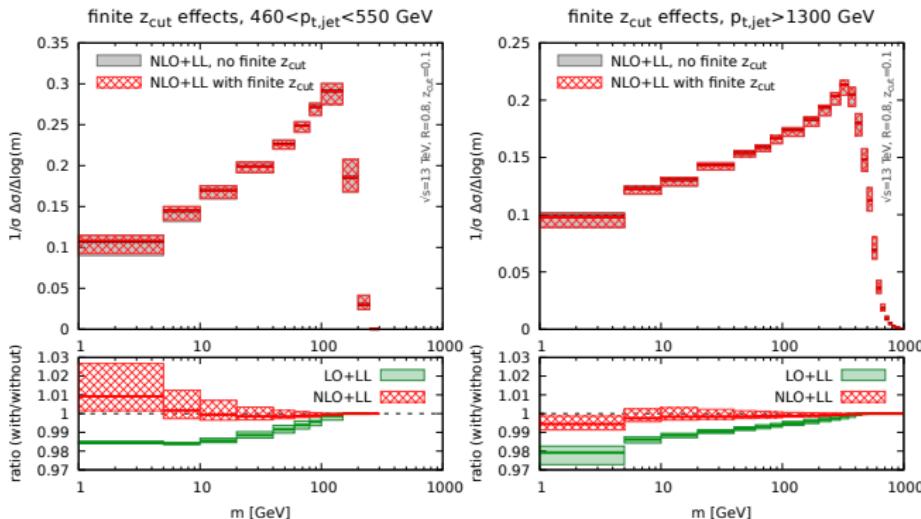


- Significant reduction in uncertainty
- Values remain comparable

Finite z_{cut} effects

Continued calculation in dQCD including finite z_{cut} effects

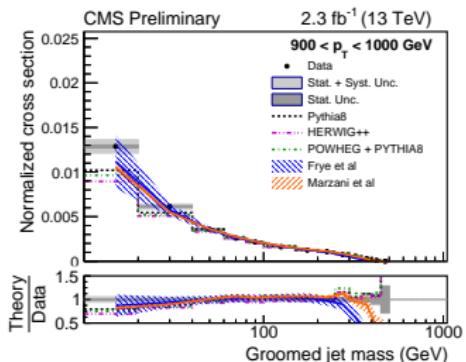
[Marzani, Schunk, Soyez; '17]:



Percent level corrections for $z_{\text{cut}} = 0.1$, but can be larger for other values

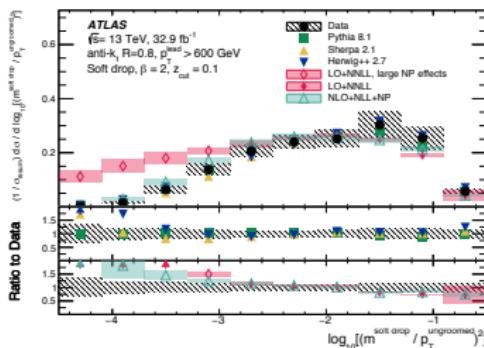
Measurements

Recent comparison to LHC data:



[CMS; '17]

Good agreement with Data



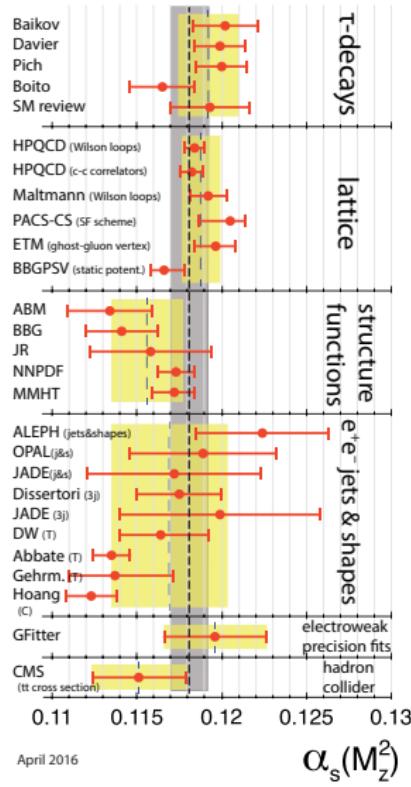
[ATLAS; '17]

The importance of α_s

- Jet physics of great importance to the LHC
- Higher order perturbative corrections shown to be important scale with higher powers of α_s
- Higgs boson production scales as α_s^2

An accurate measurement of α_s is necessary for precision LHC measurements

α_s Measurement

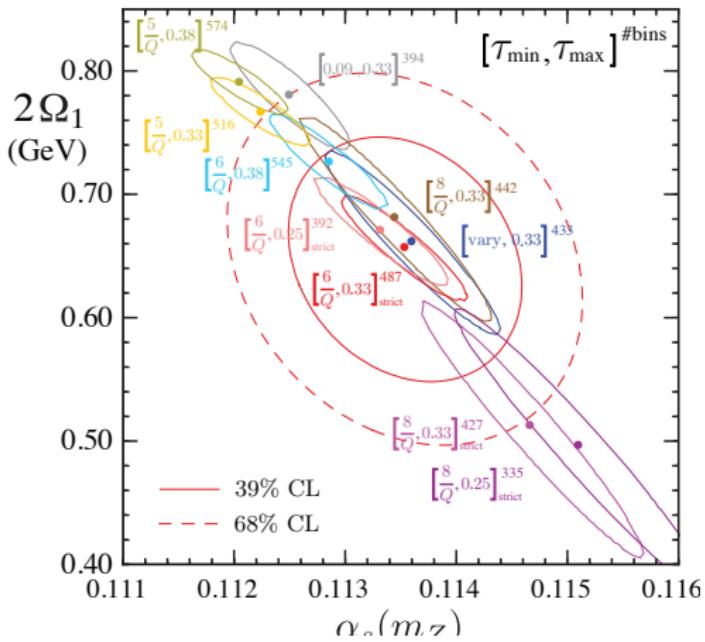


April 2016

$$\alpha_s(M_z^2)$$

[Particle Data Group; 16]

NP contributions



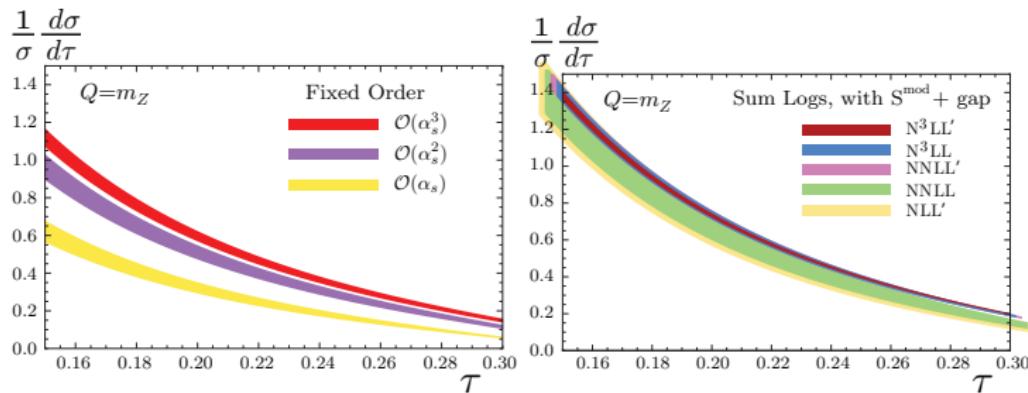
[Abbate, Fickinger, Hoang, Mateu, Stewart; 10]

Thrust

$$\tau = 1 - T = \min_{\vec{n}} \left(1 - \frac{\sum_i |\vec{n} \cdot \vec{p}_i|}{\sum_i |\vec{p}_i|} \right)$$

Minimize for thrust axis \vec{n}

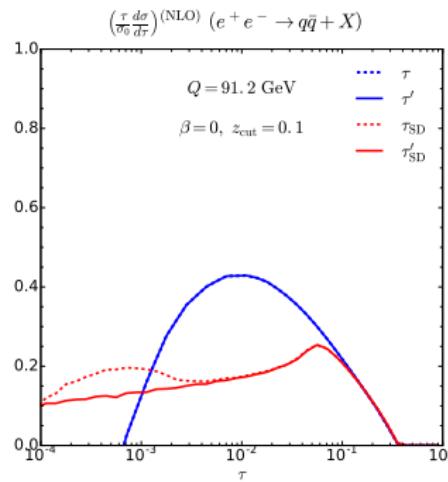
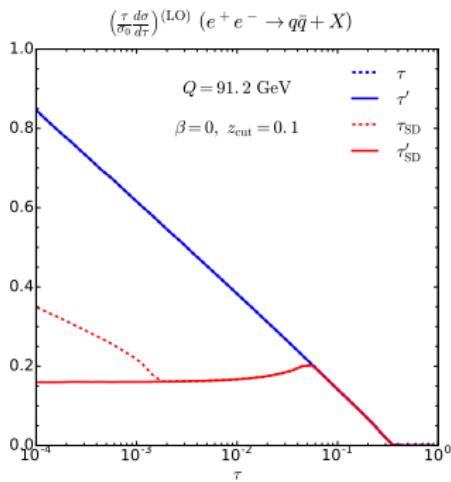
[Abbate, Fickinger, Hoang, Mateu, Stewart; 10]



SD Distribution

Hemisphere jets at an e^+e^- collider \rightarrow Different soft drop condition:

$$\frac{\min [E_i, E_j]}{E_i + E_j} > z_{\text{cut}} (1 - \cos \theta_{ij})^{\beta/2}$$



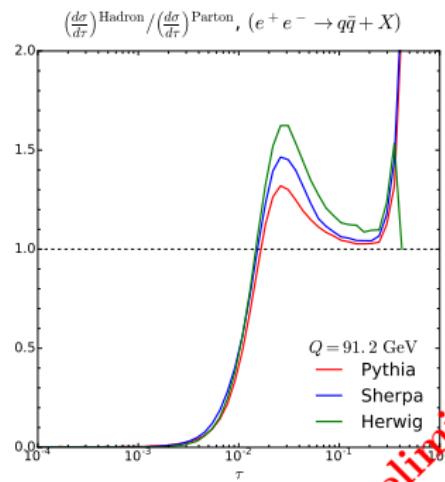
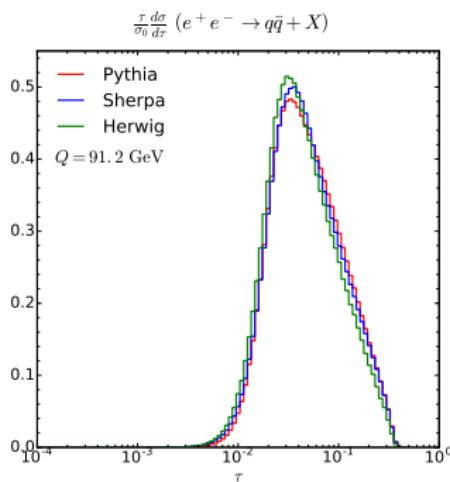
Alternative definition

- Separation into two jets at the hand of thrust axis pre-softdrop
- After softdrop each hemisphere will have its own axis
- Each thrust axis is the jet axis

$$T'_{\text{SD}} = \frac{\sum_{i \in \mathcal{H}_{\text{SD}}^L} |\vec{n}_L \cdot \vec{p}_i|}{\sum_{i \in \mathcal{E}_{\text{SD}}} |\vec{p}_i|} + \frac{\sum_{i \in \mathcal{H}_{\text{SD}}^R} |\vec{n}_R \cdot \vec{p}_i|}{\sum_{i \in \mathcal{E}_{\text{SD}}} |\vec{p}_i|}$$

MC studies

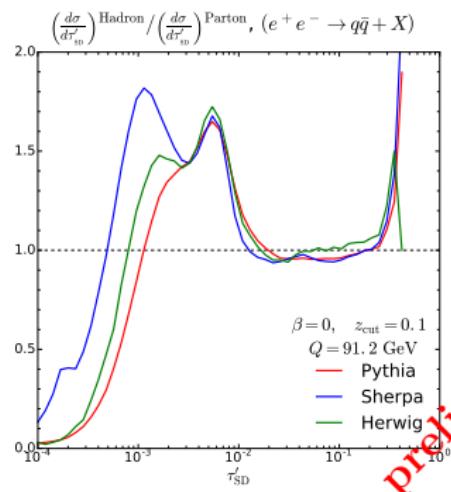
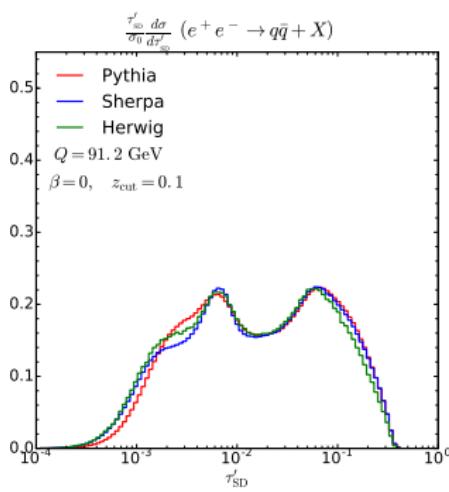
[Baron, Marzani, VT; In preparation]



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MC studies with soft drop

[Baron, Marzani, VT; In preparation]

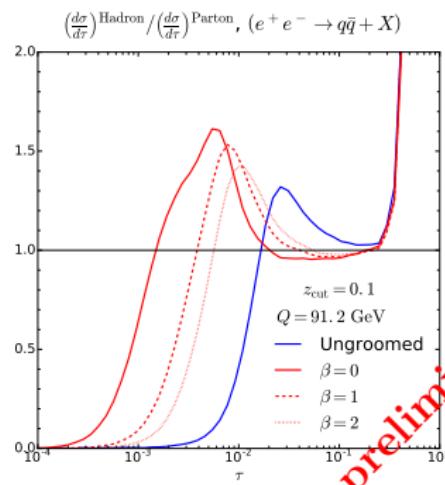
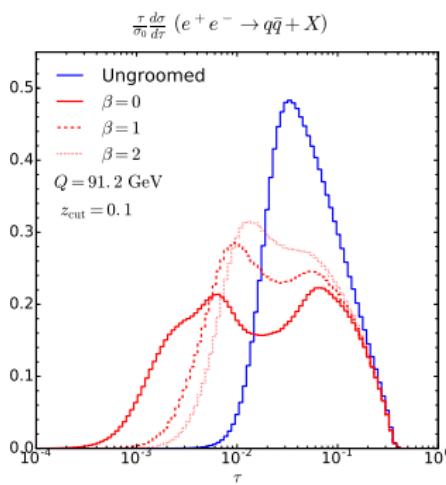


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Reduction in non perturbative corrections.

z_{cut} & β values

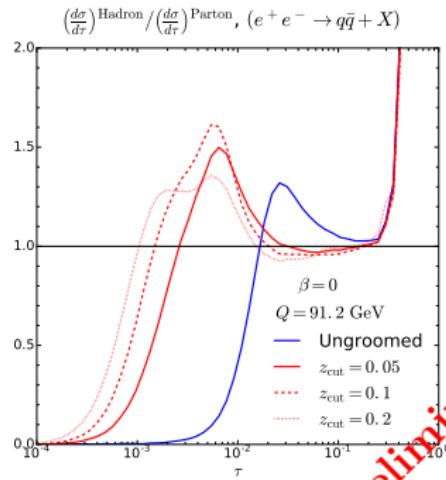
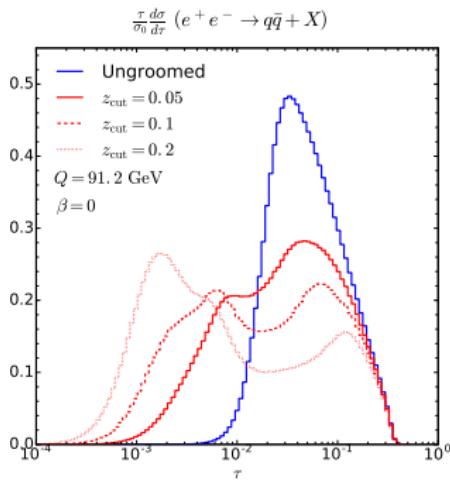
[Baron, Marzani, VT; In preparation]



Different values of β do not offer improvement

z_{cut} & β values

[Baron, Marzani, VT; In preparation]



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Smaller values of z_{cut} offer more data in the relevant region with only a slight increase in non-perturbative corrections.

Analytic computation

Additional calculation for contributions where $\tau \sim z_{\text{cut}}$ at NLL' accuracy:

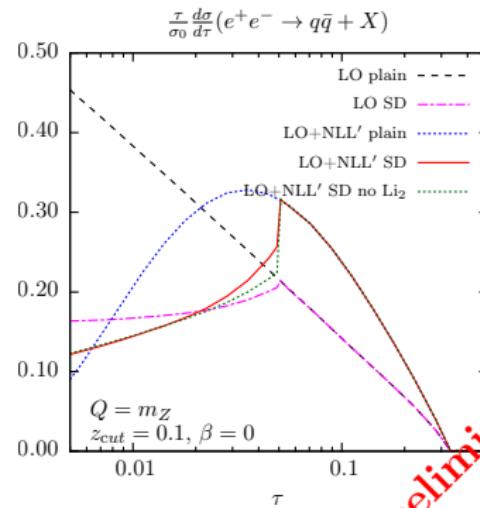
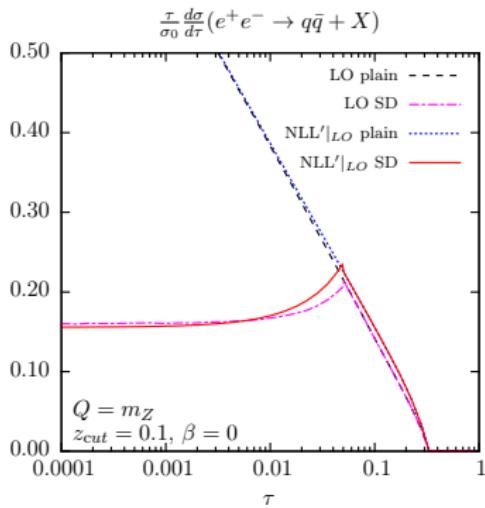
$$\frac{\alpha_s}{\pi} C_F (\beta + 2) \operatorname{Li}_2 \left[\frac{1}{2} \left(\frac{2\tau}{z_{\text{cut}}} \right)^{\frac{2}{\beta+2}} \right]$$

Can be neglected for $\tau \ll z_{\text{cut}}$, but offers a constant contribution near the transition point $\tau = z_{\text{cut}}/2$.

Additional corrections for the end-point of the resummation and expansion.

Resummation results

[Baron, Marzani, VT; In preparation]

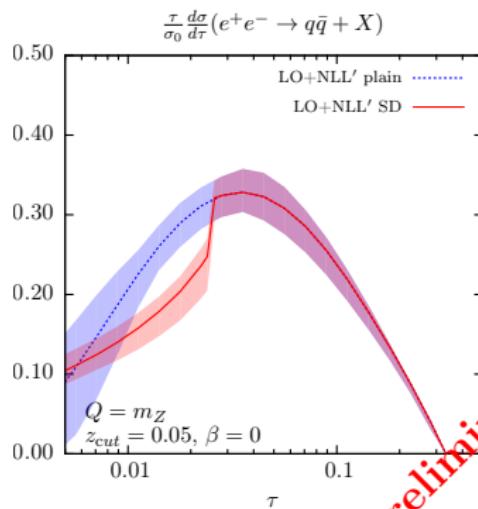
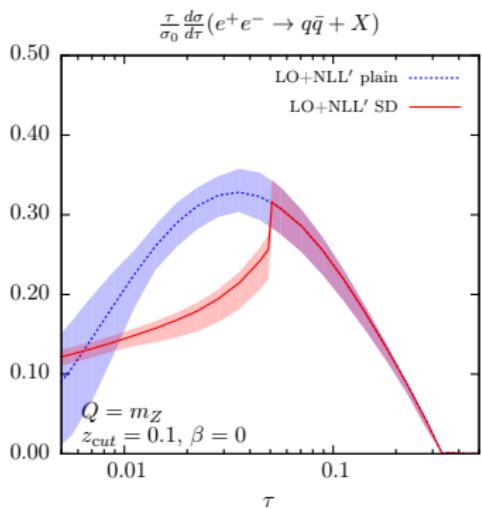


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- Expansion offers a good approximation for fixed order
- Transition corrections are important for thrust

Resummation results

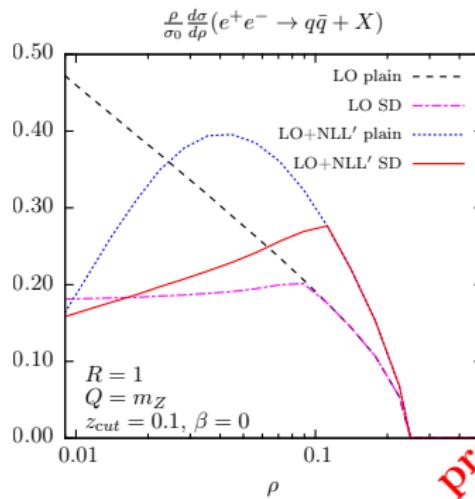
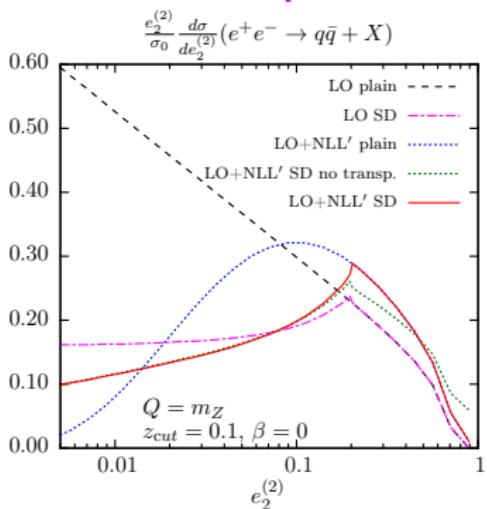
[Baron, Marzani, VT; In preparation]



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Alternative observables

[Baron, Marzani, VT; In preparation]



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Other observables allow for a reduction in transition point effects.

Summary

Conclusions

- Soft drop can help reduce dependence on non-perturbative corrections for thrust
- Could help break degeneracy between non-perturbative contributions and α_s in fit
- Significant transition point effects that will need to be taken into account at NNLL accuracy
- Other observables could reduce the transition point effects

Summary

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- Soft drop can help reduce dependence on non-perturbative corrections for thrust
- Could help break degeneracy between non-perturbative contributions and α_s in fit
- Significant transition point effects that will need to be taken into account at NNLL accuracy
- Other observables could reduce the transition point effects

Thank you for your attention