Combining Resummed Jet Bin Predictions

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see

Radja Boughezal, Xiaohui Liu, Frank Petriello, Frank Tackmann, and JW - 1312.4535
Iain Stewart, Frank Tackmann, JW, Saba Zuberi - 1307.1808
Xiaohui Liu, Frank Petriello - 1210.1906, 1303.4405

Outline

1. A general uncertainty parameterization
    - ***No assumptions needed*** for a single channel measurement
    - Not tied to any particular theory prediction
    - Covariance matrix ⇔ nuisance parameters used in fits
2. Overview of our results using this uncertainty parameterization
    - 0-jet resummed results (NNLL'+NNLO)
    - 1-jet resummed results (NLL'+NLO + higher orders)
    - Comparison to fixed order

Uncertainties, 2-by-2 case, General Parameterization

$$C = C_{\mathrm{y}} + C_{\mathrm{cut}}$$

covariance matrix in terms of yield and migration components

0, ≥1 jet case [parameterization currently used for ST]

$$C_{\mathrm{y}} = \begin{pmatrix} (\Delta_0^{\mathrm{y}})^2 & \Delta_0^{\mathrm{y}}\Delta_{\geq 1}^{\mathrm{y}} \\ \Delta_0^{\mathrm{y}}\Delta_{\geq 1}^{\mathrm{y}} & (\Delta_{\geq 1}^{\mathrm{y}})^2 \end{pmatrix}$$

100% correlated

↓

yield
nuisance parameter κ_{y}

$$C_{\mathrm{cut}} = \begin{pmatrix} \Delta_{\mathrm{cut}}^2 & -\Delta_{\mathrm{cut}}^2 \\ -\Delta_{\mathrm{cut}}^2 & \Delta_{\mathrm{cut}}^2 \end{pmatrix}$$

100% anti-correlated

↓

0, ≥1 migration
nuisance parameter κ_{cut}

$(\Delta_0^{\mathrm{y}}\,,\ \Delta_{\geq 1}^{\mathrm{y}})$

uncertainty amplitudes

$(\Delta_{\mathrm{cut}}\,,\ -\Delta_{\mathrm{cut}})$

Uncertainties, 2-by-2 case, Specific Results

fixed order S-T assumption: $\Delta_{\rm cut} = \Delta^{\rm FO}_{\geq 1} \quad (\Rightarrow \ \Delta^{\rm y}_{\geq 1} = 0)$

$$C^{\rm ST}_{\rm y} = \begin{pmatrix} \Delta^2_{\rm tot} & 0 \\ 0 & 0 \end{pmatrix} \qquad C^{\rm ST}_{\rm cut} = \begin{pmatrix} (\Delta^{\rm FO}_{\geq 1})^2 & -(\Delta^{\rm FO}_{\geq 1})^2 \\ -(\Delta^{\rm FO}_{\geq 1})^2 & (\Delta^{\rm FO}_{\geq 1})^2 \end{pmatrix}$$

JVE assumption: $\sigma_{\rm tot}, \ \epsilon_0 = \sigma_0/\sigma_{\rm tot}$ uncorrelated $\left(\frac{\Delta^2_0}{\sigma^2_0} = \frac{\Delta^2_{\rm tot}}{\sigma^2_{\rm tot}} + \frac{\Delta^2_{\epsilon_0}}{\epsilon^2_0} \right)$

$$C^{\rm JVE}_{\rm y} = \Delta^2_{\rm tot} \begin{pmatrix} \epsilon^2_0 & \epsilon_0(1-\epsilon_0) \\ \epsilon_0(1-\epsilon_0) & (1-\epsilon_0)^2 \end{pmatrix} \qquad C^{\rm JVE}_{\rm cut} = \begin{pmatrix} \sigma^2_{\rm tot}\Delta^2_{\epsilon_0} & -\sigma^2_{\rm tot}\Delta^2_{\epsilon_0} \\ -\sigma^2_{\rm tot}\Delta^2_{\epsilon_0} & \sigma^2_{\rm tot}\Delta^2_{\epsilon_0} \end{pmatrix}$$

resummed 0-jet results from STWZ (1307.1808):
all 3 uncertainties estimated using scale variations in factorization theorem

$$\Delta^{\rm y}_0 = \Delta_{\mu 0} \qquad \Delta^{\rm y}_{\geq 1} = \Delta_{\mu \geq 1} \qquad \Delta_{\rm cut} = \Delta_{\rm resum}$$

Uncertainties, 3-by-3 case, General Parameterization

$$C = C_{\rm y} + C^{01}_{\rm cut} + C^{12}_{\rm cut}$$

yield and migration components analogous to 2-by-2 case

$$C_{\rm y} = \begin{pmatrix} (\Delta^{\rm y}_0)^2 & \Delta^{\rm y}_0\Delta^{\rm y}_1 & \Delta^{\rm y}_0\Delta^{\rm y}_{\geq 2} \\ \Delta^{\rm y}_0\Delta^{\rm y}_1 & (\Delta^{\rm y}_1)^2 & \Delta^{\rm y}_1\Delta^{\rm y}_{\geq 2} \\ \Delta^{\rm y}_0\Delta^{\rm y}_{\geq 2} & \Delta^{\rm y}_1\Delta^{\rm y}_{\geq 2} & (\Delta^{\rm y}_{\geq 2})^2 \end{pmatrix} \longrightarrow$$

yield nuisance parameter uncertainty amplitude

$$\kappa_{\rm y} : (\Delta^{\rm y}_0\,,\ \Delta^{\rm y}_1\,,\ \Delta^{\rm y}_2)$$

$$C^{01}_{\rm cut} = \begin{pmatrix} \Delta^2_{0\,\rm cut} & -\Delta^2_{0\,\rm cut} \\ -\Delta^2_{0\,\rm cut} & \Delta^2_{0\,\rm cut} \end{pmatrix} \rightarrow \begin{pmatrix} \Delta^2_{0\,\rm cut} & -(1-\rho)\Delta^2_{0\,\rm cut} & -\rho\,\Delta^2_{0\,\rm cut} \\ -(1-\rho)\Delta^2_{0\,\rm cut} & (1-\rho)^2\Delta^2_{0\,\rm cut} & \rho(1-\rho)\Delta^2_{0\,\rm cut} \\ -\rho\,\Delta^2_{0\,\rm cut} & \rho(1-\rho)\Delta^2_{0\,\rm cut} & \rho^2\Delta^2_{0\,\rm cut} \end{pmatrix}$$

0, ≥1 jet basis

[can write as a sum of 2-by-2 anti-correlated terms between each pair of jet bins]

$$\kappa_{01} : (\Delta_{0\,\rm cut}\,,\ -(1-\rho)\Delta_{0\,\rm cut}\,,\ -\rho\,\Delta_{0\,\rm cut})$$

$$C^{12}_{\rm cut} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \Delta^2_{1\,\rm cut} & -\Delta^2_{1\,\rm cut} \\ 0 & -\Delta^2_{1\,\rm cut} & \Delta^2_{1\,\rm cut} \end{pmatrix} \longrightarrow$$

$$\kappa_{12} : (0\,,\ \Delta_{1\,\rm cut}\,,\ -\Delta_{1\,\rm cut})$$

Uncertainties, 3-by-3 case, General Parameterization

- Parameterization is general and can be used with anyone's predictions
  - Correlations between jet bins must be provided

Uncertainties, 3-by-3 case, Specific Results

- This parameterization effectively already used for ST implementation
  - fixed order S-T assumptions: $\Delta_{0\,\mathrm{cut}} = \Delta^{\mathrm{FO}}_{\geq 1}\,, \quad \Delta_{1\,\mathrm{cut}} = \Delta^{\mathrm{FO}}_{\geq 2}$

$$(\Rightarrow \quad \Delta^{\mathrm{y}}_1 = \Delta^{\mathrm{y}}_{\geq 2} = 0\,,\ \Delta^{\mathrm{y}}_0 = \Delta_{\mathrm{tot}}\,,\ \rho = 0)$$

- Can also be implemented for JVE
  - JVE assumptions: $\sigma_{\mathrm{tot}},\ \epsilon_0 = \sigma_0/\sigma_{\mathrm{tot}},\ \epsilon_1 = \sigma_1/\sigma_{\geq 1}$ uncorrelated

$$(\Rightarrow \quad \Delta^{\mathrm{y}}_0 = \delta_{\mathrm{tot}}\sigma_0\,,\ \Delta^{\mathrm{y}}_1 = \delta_{\mathrm{tot}}\sigma_1\,,\ \Delta^{\mathrm{y}}_{\geq 2} = \delta_{\mathrm{tot}}\sigma_{\geq 2}\,,$$
$$\Delta_{0\,\mathrm{cut}} = \delta_{\epsilon_0}\sigma_0\,,\ \Delta_{1\,\mathrm{cut}} = \delta_{\epsilon_1}\sigma_1\,,\ \rho = 1 - \epsilon_1)$$

- We will see that resummed 0+1 jet results will give predictions for all 6 parameters in the 3-by-3 case $(\Delta^{\mathrm{y}}_0\,, \Delta^{\mathrm{y}}_1\,, \Delta^{\mathrm{y}}_{\geq 2}\,,\ \Delta_{0\,\mathrm{cut}}\,, \Delta_{1\,\mathrm{cut}}\,, \rho)$

- Nuisance parameters correspond to physical uncertainty sources - justified to use the same nuisance parameters $(\kappa_{\mathrm{y}}\,, \kappa_{01}\,, \kappa_{12})$ across different analyses

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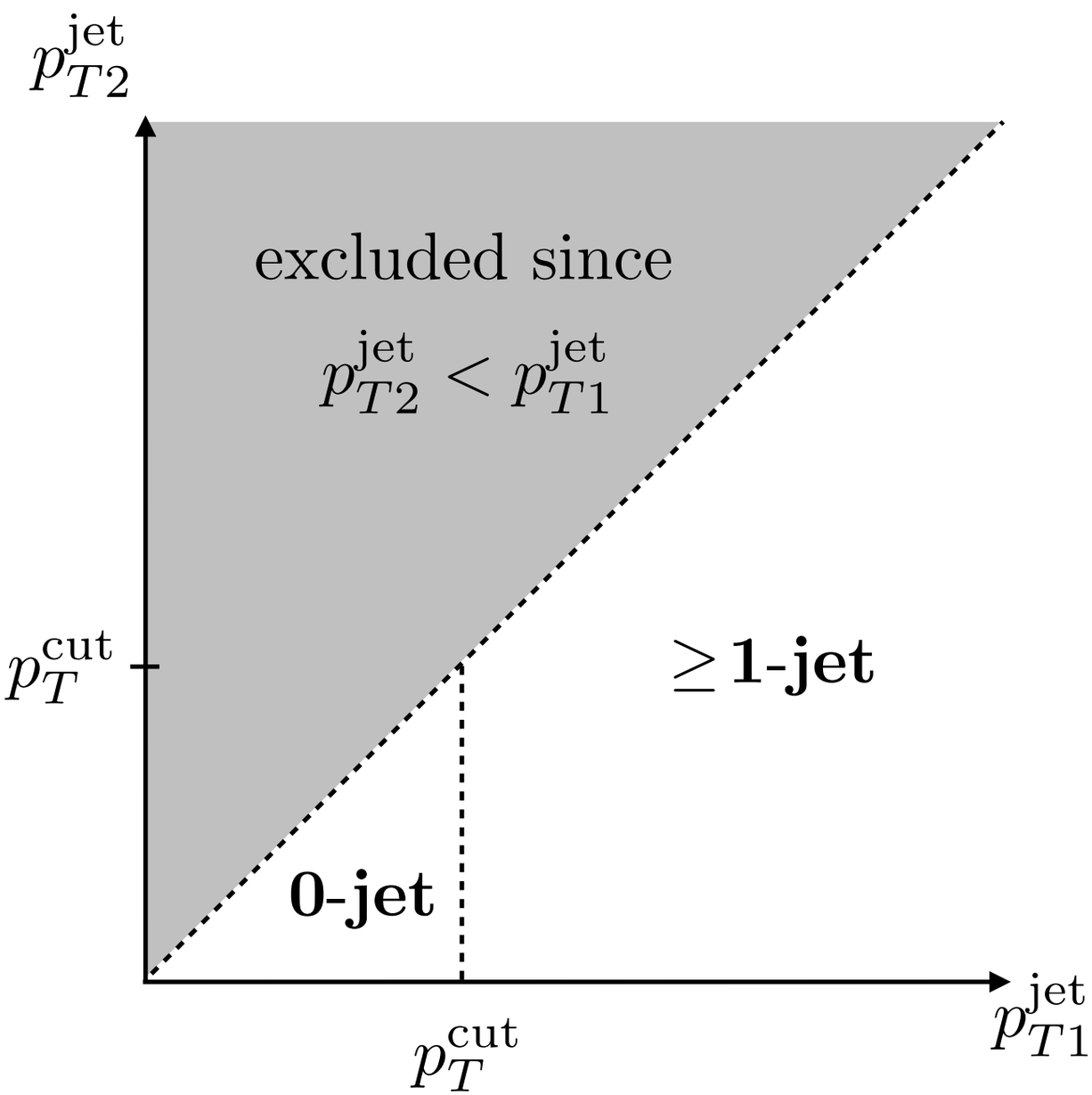
0-jet Resummation

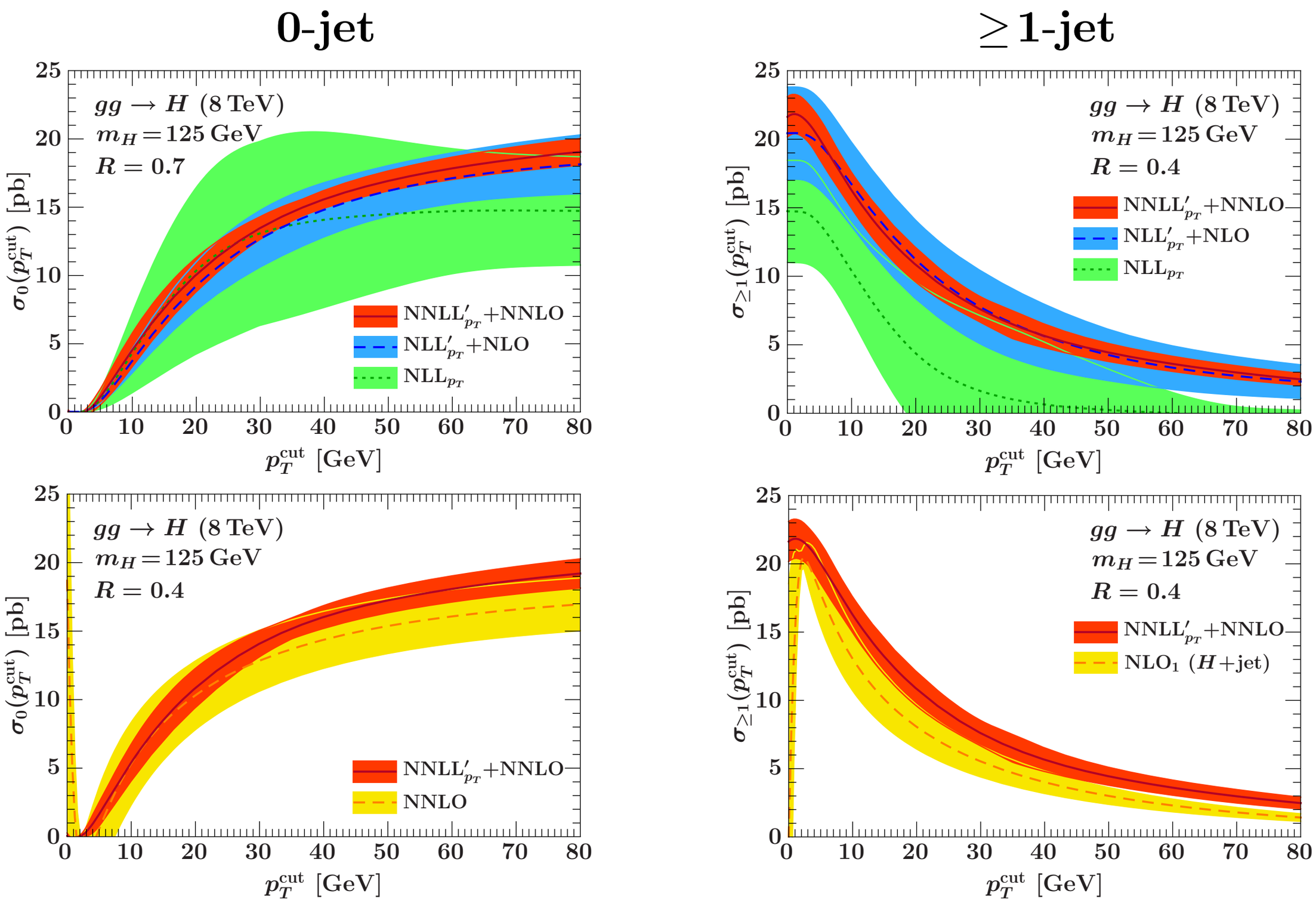


veto on leading jet p_T
divides the cross section into
0-jet and inclusive 1-jet bins

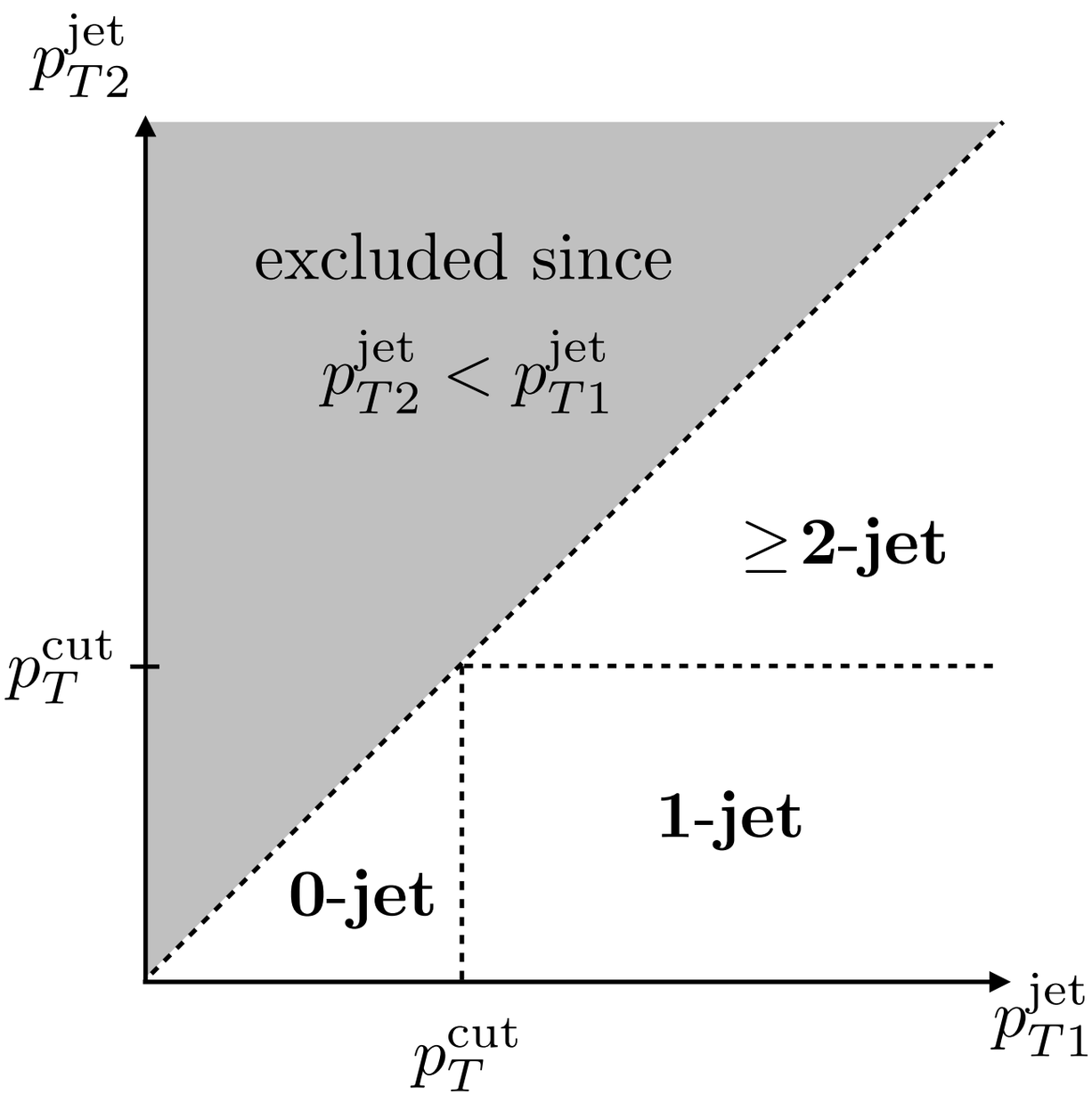
total inclusive cross section
lets us relate 0-jet and
inclusive 1-jet rates

0-jet Resummation

Stewart, Tackmann, JW, Zuberi, 1307.1808



1-jet Resummation



exclusive 1-jet cross section is a two-scale problem: differential in leading jet p_T and a veto on 2nd leading jet p_T

direct prediction of 1-jet rate with resummation can be performed in high leading jet p_T regime

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low leading jet p_T regime with resummation uses the inclusive 1-jet rate

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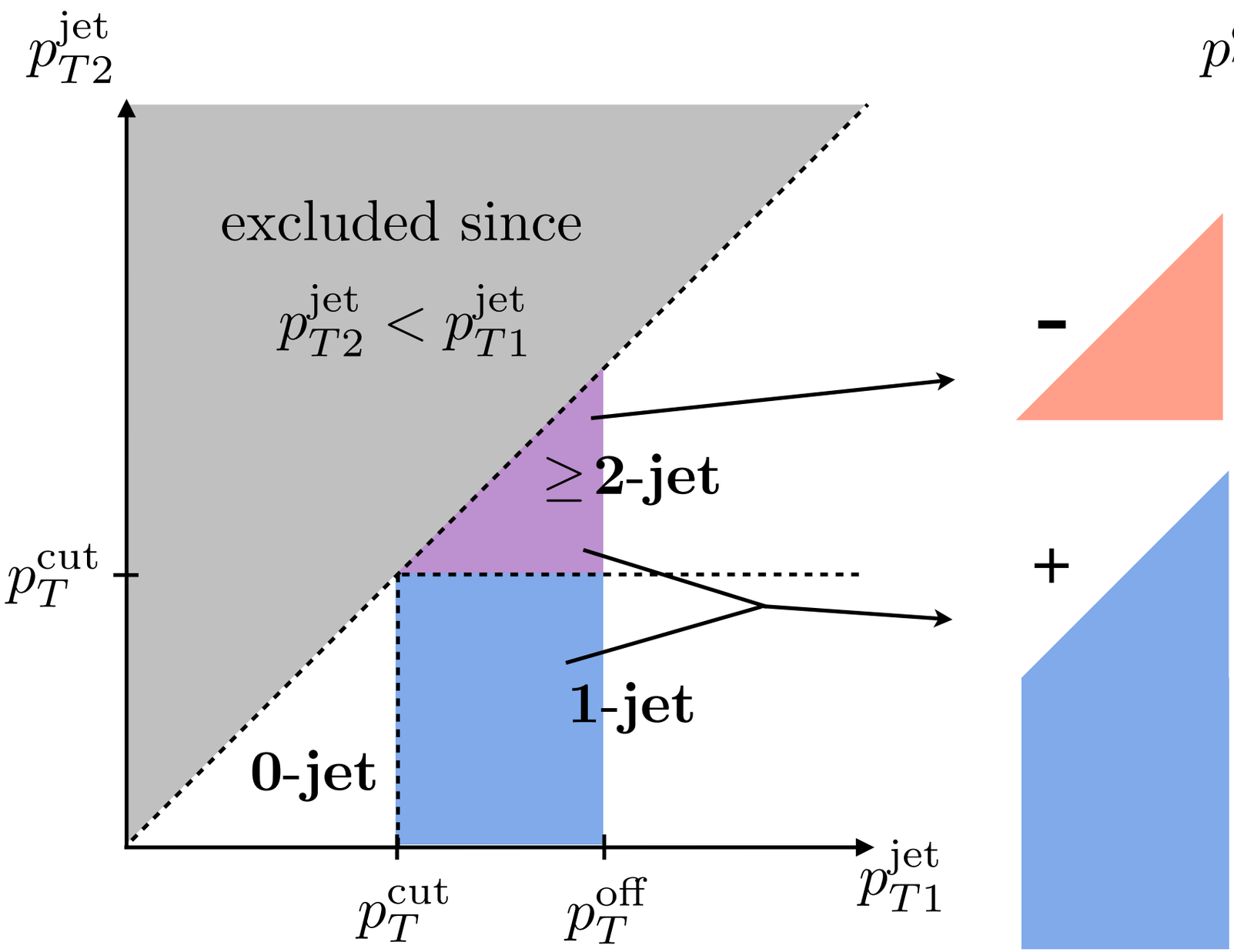
1-jet Resummation, Low Jet p_T Regime

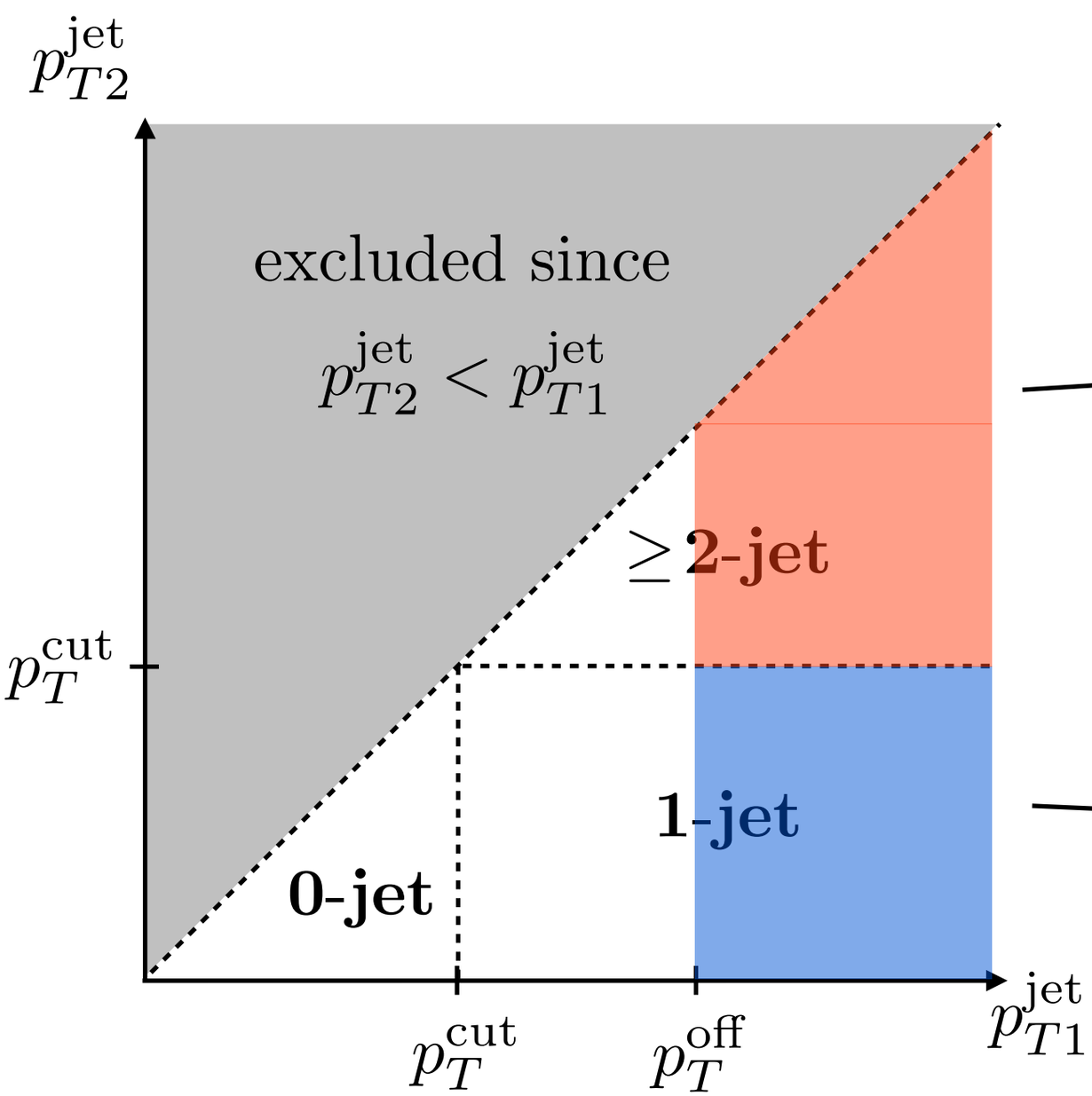
$$p_T^{\rm cut} < p_{T1}^{\rm jet} < p_T^{\rm off} \ :$$



≥2-jet fixed order contribution
[corrects ≥1-jet rate to exclusive 1-jet rate]

≥1-jet resummed contribution

1-jet Resummation, High Jet p_T Regime



$p_T^{\rm off} < p_{T1}^{\rm jet}$:

≥2-jet fixed order contribution

1-jet resummed contribution

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1-jet Resummation

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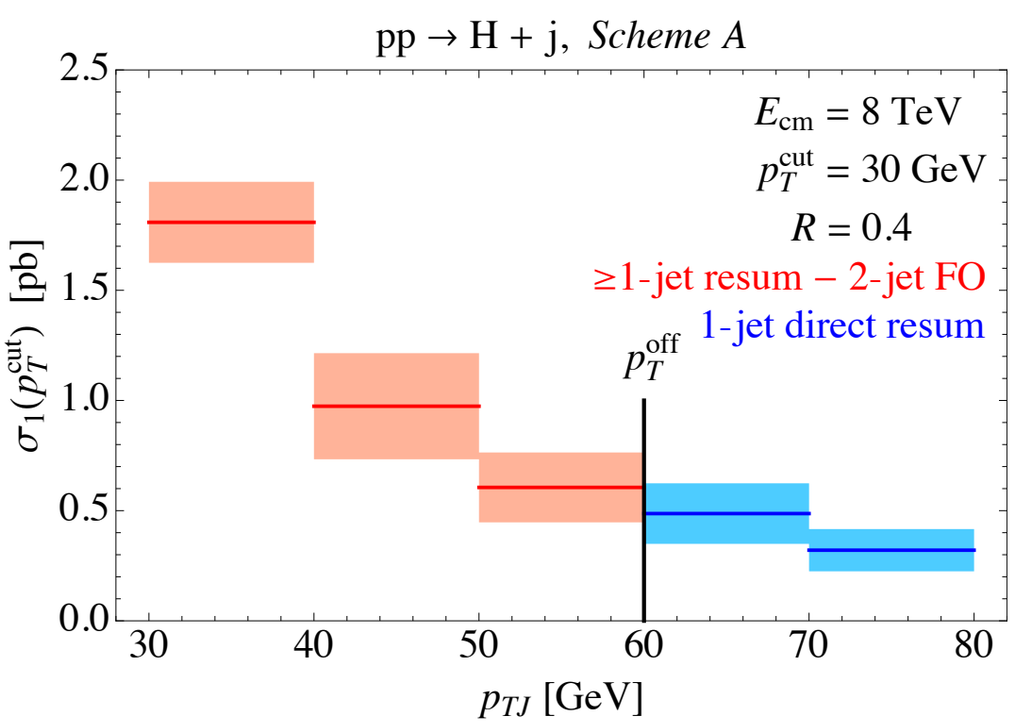
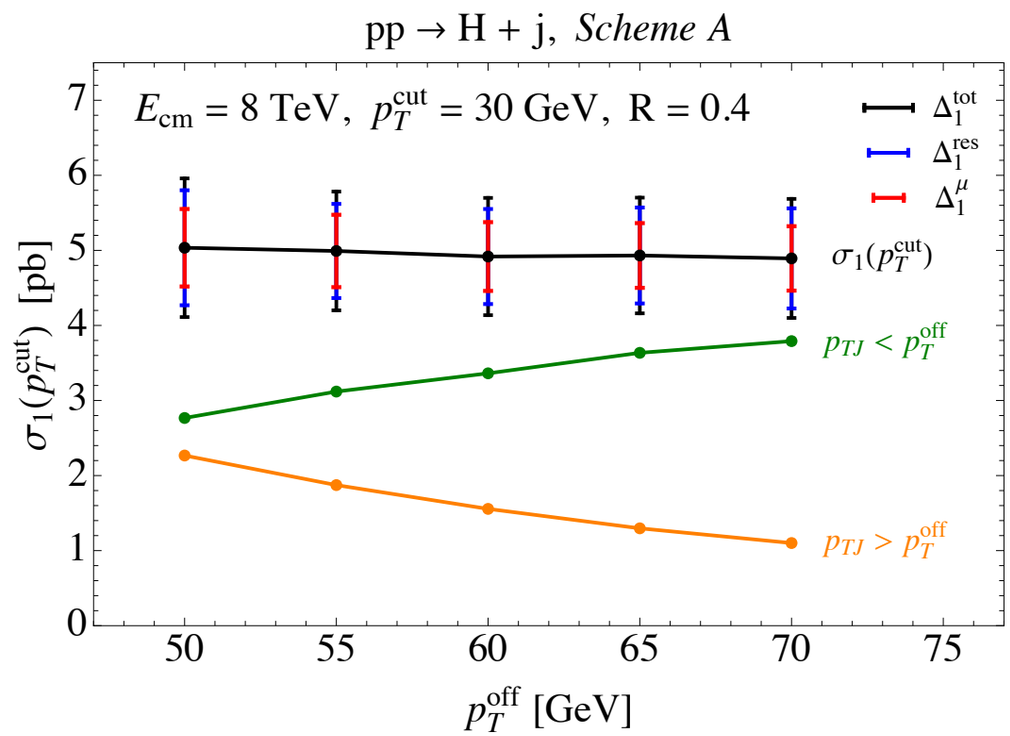
relation for exclusive 1-jet cross section in bin [p_T^{cut}, p_T^{off}]:

$$\sigma_1([p_T^{\rm cut}, p_T^{\rm off}]; p_T^{\rm cut}) = \underbrace{[\sigma_0(p_T^{\rm off}) - \sigma_0(p_T^{\rm cut})]}_{\text{0-jet (1-jet inclusive) terms}} + \underbrace{[\sigma_{\geq 2}(p_T^{\rm off}, p_T^{\rm cut}) - \sigma_{\geq 2}(p_T^{\rm cut}, p_T^{\rm cut})]}_{\text{2-jet inclusive terms}}$$



smooth matching between direct and indirect approaches



matching scale dependence mild over a reasonable range

Combined Result

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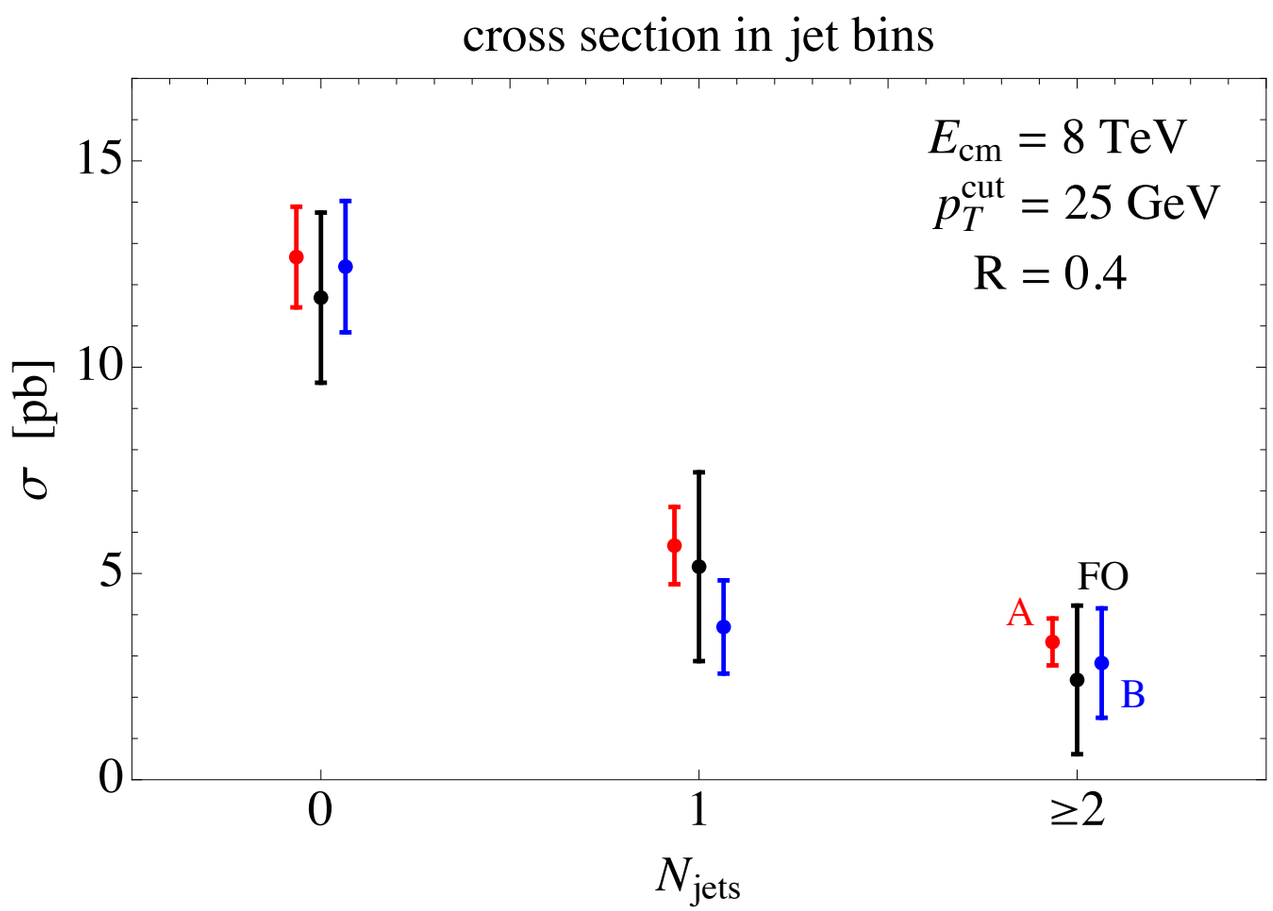

scheme A has our primary results

scheme A: π^2 resummation, H + 1j NNLO virtuals

scheme B: no π^2 resummation, H + 1j @ NLO

uncertainties reduced over fixed order by a factor of ~2

fully predict correlations between jet bins

$$C^{\rm ATLAS} = \begin{pmatrix} 1.49 & -0.39 & 0.20 \\ -0.39 & 0.88 & -0.04 \\ 0.20 & -0.04 & 0.32 \end{pmatrix} \ {\rm pb}^2$$

basis of 0, 1, 2+ jet rates can determine the uncertainty for any observable depending on these rates

Uncertainties

uncertainty amplitudes for nuisance parameters:

$$\kappa_{\rm y} : (\Delta_0^{\rm y}\,,\ \Delta_1^{\rm y}\,,\ \Delta_2^{\rm y})$$

$$\kappa_{01} : (\Delta_{0\,\rm cut}\,,\ -(1-\rho)\Delta_{0\,\rm cut}\,,\ -\rho\,\Delta_{0\,\rm cut})$$

$$\kappa_{12} : (0\,,\ \Delta_{1\,\rm cut}\,,\ -\Delta_{1\,\rm cut})$$

we can estimate these uncertainties in our combined resummed results

$$\Delta_0^{\rm y} = \Delta_{\mu 0}(p_T^{\rm cut}) = 0.87 \text{ pb}$$

$$\Delta_1^{\rm y} = \Delta_{\mu 1}(p_T^{\rm cut}) = 0.30 \text{ pb}$$

$$\Delta_{\geq 2}^{\rm y} = \Delta_{\rm tot} - \Delta_0^{\rm y} - \Delta_1^{\rm y} = 0.32 \text{ pb}$$

numbers for

$p_T^{\rm cut} = 25$ GeV, $R = 0.4$

$$\Delta_{0\,\rm cut} = \Delta_0^{\rm resum}(p_T^{\rm cut}) = 0.86 \text{ pb}$$

$$\Delta_{1\,\rm cut} = \left[\Delta_1^{\rm resum}(p_T^{\rm off}, p_T^{\rm cut})^2 + \Delta_{\geq 2}^{\rm FO}(p_T^{\rm off}, p_T^{\rm cut})^2\right]^{1/2} = 0.46 \text{ pb}$$

$$\rho = \Delta_0^{\rm resum}(p_T^{\rm off})/\Delta_0^{\rm resum}(p_T^{\rm cut}) = 0.11$$

The WW Signal Strength

Table 13: Leading uncertainties on the signal strength μ for the combined 7 and 8 TeV analysis.

Category	Source	Uncertainty, up (%)	Uncertainty, down (%)
Statistical	Observed data	+21	−21
Theoretical	Signal yield ($\sigma \cdot \mathcal{B}$)	+12	−9
Theoretical	WW normalisation	+12	−12
Experimental	Objects and DY estimation	+9	−8
Theoretical	Signal acceptance	+9	−7
Experimental	MC statistics	+7	−7
Experimental	W+ jets fake factor	+5	−5
Theoretical	Backgrounds, excluding WW	+5	−4
Luminosity	Integrated luminosity	+4	−4
Total		+32	−29

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rough estimate of reduction in the uncertainty:

$$\Delta_{\mathrm{FO}}^{\mathrm{th,\,y}}\mu = 0.12 \longrightarrow \Delta_{\mathrm{A}}^{\mathrm{th,\,y}}\mu = 0.07$$

reduction by almost a factor of 2

Conclusions

- We propose an uncertainty parameterization that allows for generic correlations between jet bins
  - **Allows anyone's results to be implemented**
  - Physical uncertainty sources connected to nuisance parameters
  - There are no built-in assumptions
    - JVE and fixed order S-T are special cases (have assumptions)
- Our resummed 0/1 jet predictions may be used to compute all entries in the covariance matrix
  - Improves over FO by a factor of ~2 over all jet bins (0, 1, 2+)

Extra Slides