Jet-bin uncertainties using jet-fractions

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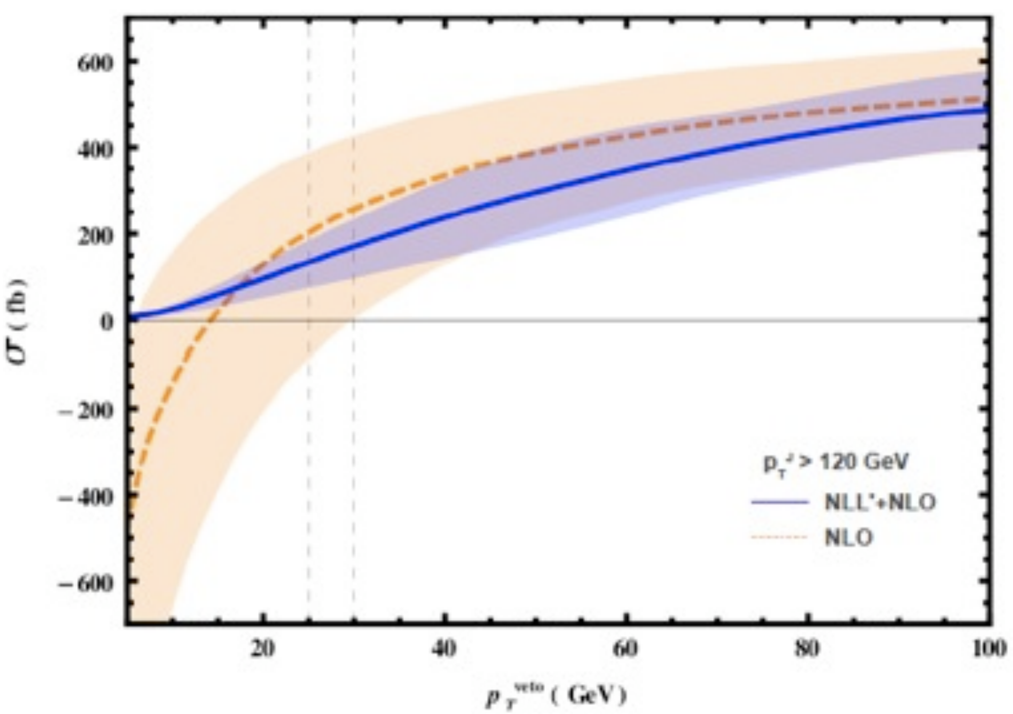
Exclusive jet fractions

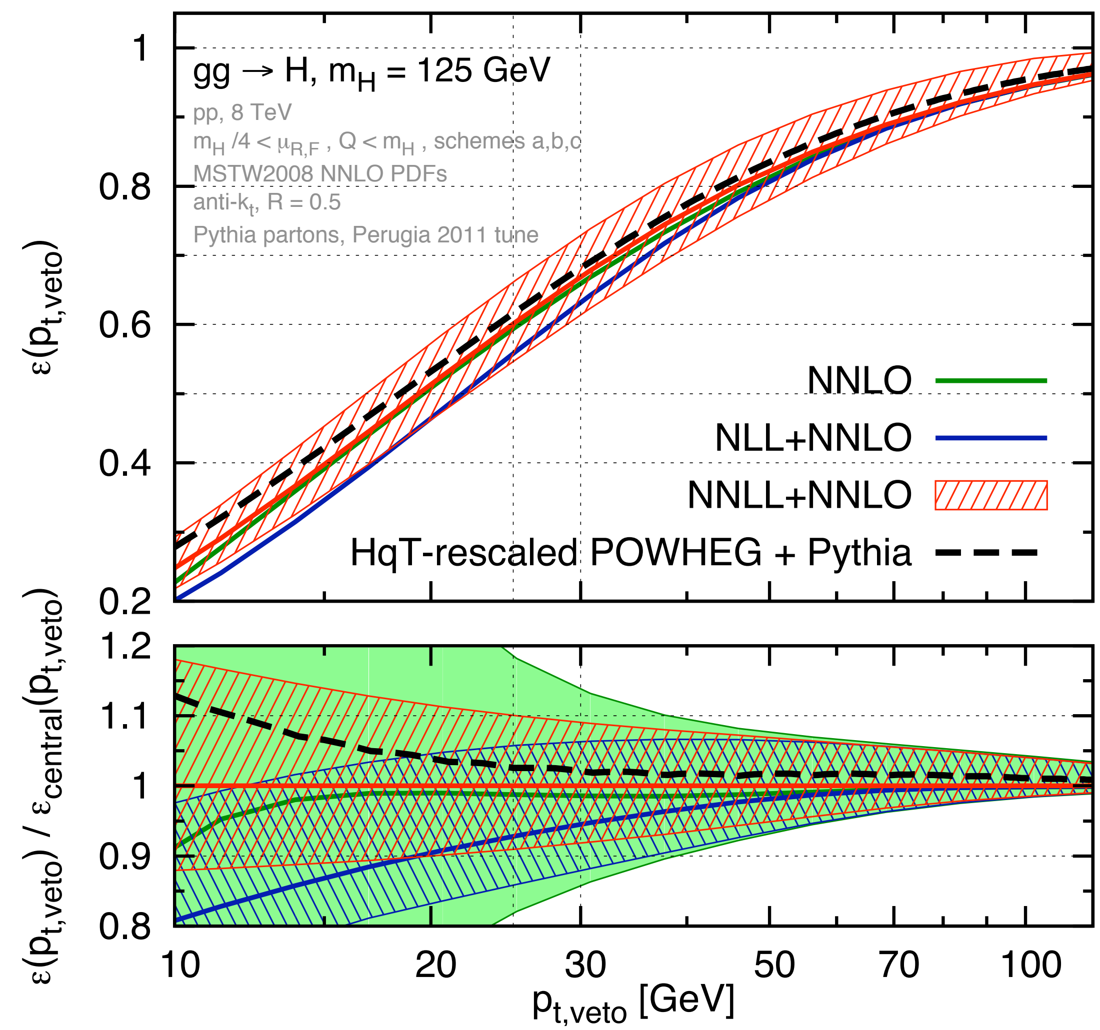
- Scale variation in fixed-order exclusive n-jet cross sections can underestimate the theory uncertainty

- Recently resummed predictions for the 0-jet and (part of) the 1-jet cross section were made available. They provide us with a more reliable assessment of the error

Exclusive 1-jet cross section [Liu, Petriello]



Exclusive 0-jet efficiency [Banfi, PFM, Salam, Zanderighi]



- We need a flexible and general prescription to treat uncertainties in all jet bins which allows one to include resummed results whenever they are available

The efficiency method

- One possible solution is to use jet-veto efficiencies

- *e.g.* in the 0-jet bin:

$$\sigma_{0-\text{jet}} = \sigma_{\text{tot}} \times \epsilon(p_{t,\text{veto}})$$
$$\sigma_{\geq 1-\text{jet}} = \sigma_{\text{tot}} \times [1 - \epsilon(p_{t,\text{veto}})]$$

large K-factor — large logarithms

- We estimate uncertainties by assuming that σ_{tot} and $\epsilon(p_{t,\text{veto}})$ are uncorrelated

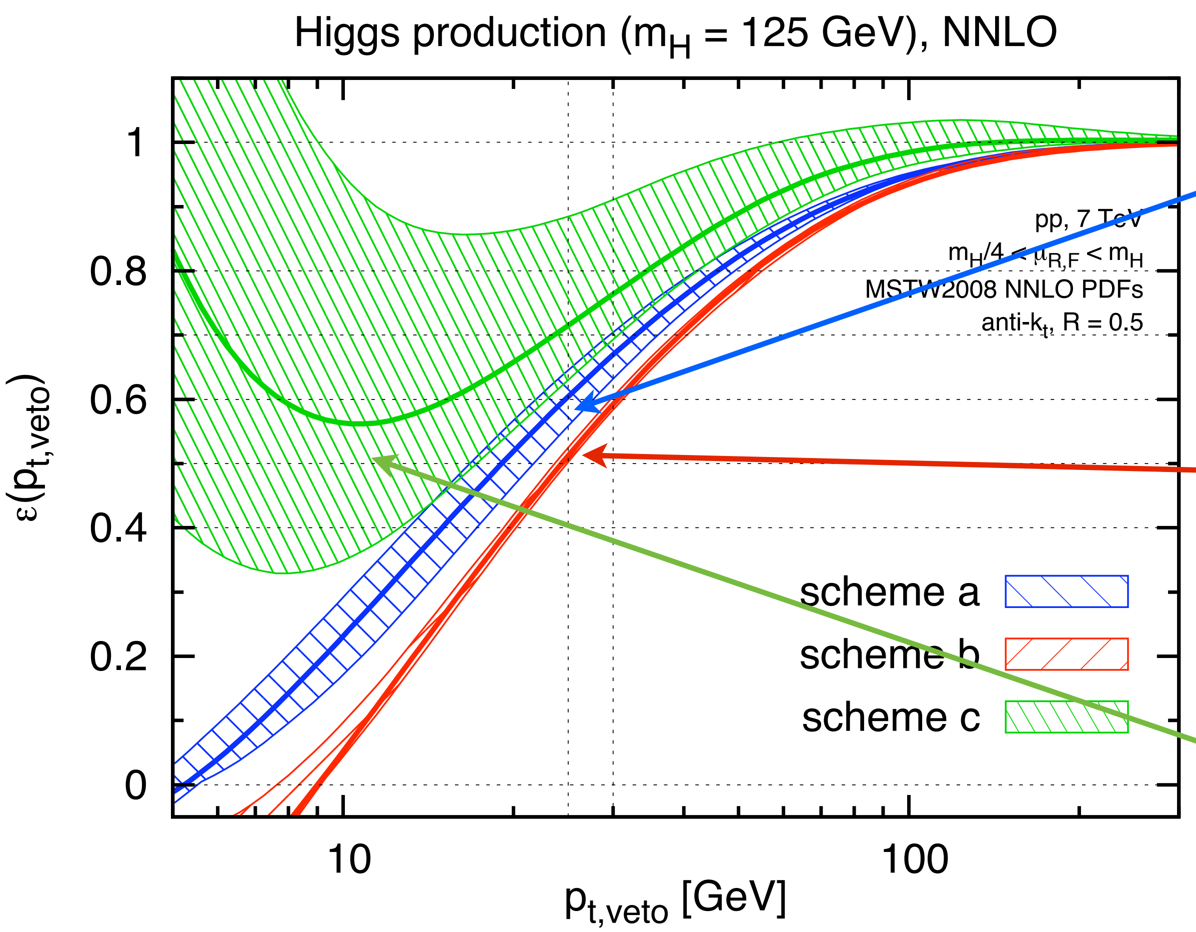
- Uncertainties in σ_{tot} reflect our ignorance of higher order (NNNLO) terms: they correlate $\sigma_{0-\text{jet}}$ and $\sigma_{\geq 1-\text{jet}}$

- Uncertainties in $\epsilon(p_{t,\text{veto}})$ are partially related to missing logs $\alpha_s^n \ln^{2n}(m_H/p_{\text{t,veto}})$ of Sudakov origin: they anticorrelate $\sigma_{0-\text{jet}}$ and $\sigma_{\geq 1-\text{jet}}$

The efficiency method

- At $\mathrm{N^nLO}$, one can define $\mathrm{n}+1$ schemes for the efficiency, that differ by subleading terms

- e.g. NNLO fixed-order:



$$\epsilon^{(a)}(p_{\rm t,veto}) = \frac{\sigma^{\rm NNLO}_{0-\rm jet}}{\sigma^{\rm NNLO}_{\rm tot}}$$

$$\epsilon^{(b)}(p_{\rm t,veto}) = 1 - \frac{\sigma^{\rm NLO}_{\geq 1-\rm jet}}{\sigma^{\rm NLO}_{\rm tot}}$$

$\epsilon^{(c)}(p_{t,\rm veto})$ = strict fixed order expansion

- Resummed predictions can be included (extra slides). NNLL + NNLO predictions can be obtained with the public code JetVHeto (http://jetvheto.hepforge.org). Finite-mass effects due to top and bottom now included up to NNLL (tests ongoing); matching formulae to NNNLO implemented (FO results available soon).

Covariance matrix

- The covariance matrix can be expressed as a sum of a fully correlated and a fully anticorrelated terms

$$\mathrm{Cov}_{\mathrm{BMSZ}}[\sigma_{0-\mathrm{jet}},\sigma_{\geq 1-\mathrm{jet}}] = \begin{pmatrix} \epsilon^2\Delta^2\sigma_{\mathrm{tot}} & \epsilon(1-\epsilon)\Delta^2\sigma_{\mathrm{tot}} \\ \epsilon(1-\epsilon)\Delta^2\sigma_{\mathrm{tot}} & (1-\epsilon)^2\Delta^2\sigma_{\mathrm{tot}} \end{pmatrix} + \begin{pmatrix} \sigma^2_{\mathrm{tot}}\Delta^2\epsilon & -\sigma^2_{\mathrm{tot}}\Delta^2\epsilon \\ -\sigma^2_{\mathrm{tot}}\Delta^2\epsilon & \sigma^2_{\mathrm{tot}}\Delta^2\epsilon \end{pmatrix}$$

- It can be expressed in a "Stewart-Tackmann" form

$$\mathrm{Cov}[\sigma_{0-\mathrm{jet}},\sigma_{\geq 1-\mathrm{jet}}] = \begin{pmatrix} \Delta^2\sigma_{\mathrm{tot}} + \Delta^2\sigma_{\geq 1-\mathrm{jet}} & -\Delta^2\sigma_{\geq 1-\mathrm{jet}} \\ -\Delta^2\sigma_{\geq 1-\mathrm{jet}} & \Delta^2\sigma_{\geq 1-\mathrm{jet}} \end{pmatrix} + (1-\epsilon)\Delta^2\sigma_{\mathrm{tot}} \begin{pmatrix} -2 & 1 \\ 1 & 0 \end{pmatrix}$$

ST-like result

$\mathrm{Corr}[\sigma_{\geq 1-\mathrm{jet}},\sigma_{\mathrm{tot}}]$
(zero in the ST method)

Warning: inclusive-bin uncert. are not evaluated as in ST !!

Numbers at the LHC

- Results for LHC@8TeV, R=0.5
- Total cross section from Higgs cross-section WG: $\sigma_{\rm tot} = 19.52 \pm 1.46\,\mathrm{pb}$
- Large uncertainties at fixed-order

Fixed-order

$p_{\rm t,veto}$	$\epsilon(p_{\rm t,veto})$	$\sigma_{0-\rm jet}[\rm pb]$	$\sigma_{\geq 1-\rm jet}[\rm pb]$
25 GeV	$0.593 \pm 0.110\ (\pm 19\%)$	$11.58 \pm 2.32\ (\pm 20\%)$	$7.94 \pm 2.23\ (\pm 28\%)$
30 GeV	$0.658 \pm 0.094\ (\pm 14\%)$	$12.84 \pm 2.07\ (\pm 16\%)$	$6.68 \pm 1.90\ (\pm 28\%)$

- Uncertainties sensibly reduced when including resummation

Fixed-order + Resummation

$p_{\rm t,veto}$	$\epsilon(p_{\rm t,veto})$	$\sigma_{0-\rm jet}[\rm pb]$	$\sigma_{\geq 1-\rm jet}[\rm pb]$
25 GeV	$0.601 \pm 0.057\ (\pm 9\%)$	$11.73 \pm 1.43\ (\pm 12\%)$	$7.79 \pm 1.26\ (\pm 16\%)$
30 GeV	$0.667 \pm 0.058\ (\pm 9\%)$	$13.03 \pm 1.49\ (\pm 11\%)$	$6.49 \pm 1.22\ (\pm 19\%)$

1-jet bin

- The same method can be applied to higher-multiplicities

- *e.g.* exclusive 1-jet fraction

$$\sigma_{0-\mathrm{jet}} = \epsilon\, \sigma_{\mathrm{tot}} \quad \sigma_{1-\mathrm{jet}} = \epsilon_1 (1-\epsilon)\sigma_{\mathrm{tot}} \quad \sigma_{\geq 2-\mathrm{jets}} = (1-\epsilon_1)(1-\epsilon)\sigma_{\mathrm{tot}}$$

- Uncertainty in the 1-jet efficiency is obtained as described for the 0-jet bin, using all the possible schemes at a given order

- The covariance matrix is obtained considering $\sigma_{\mathrm{tot}}, \epsilon, \epsilon_1$ as uncorrelated

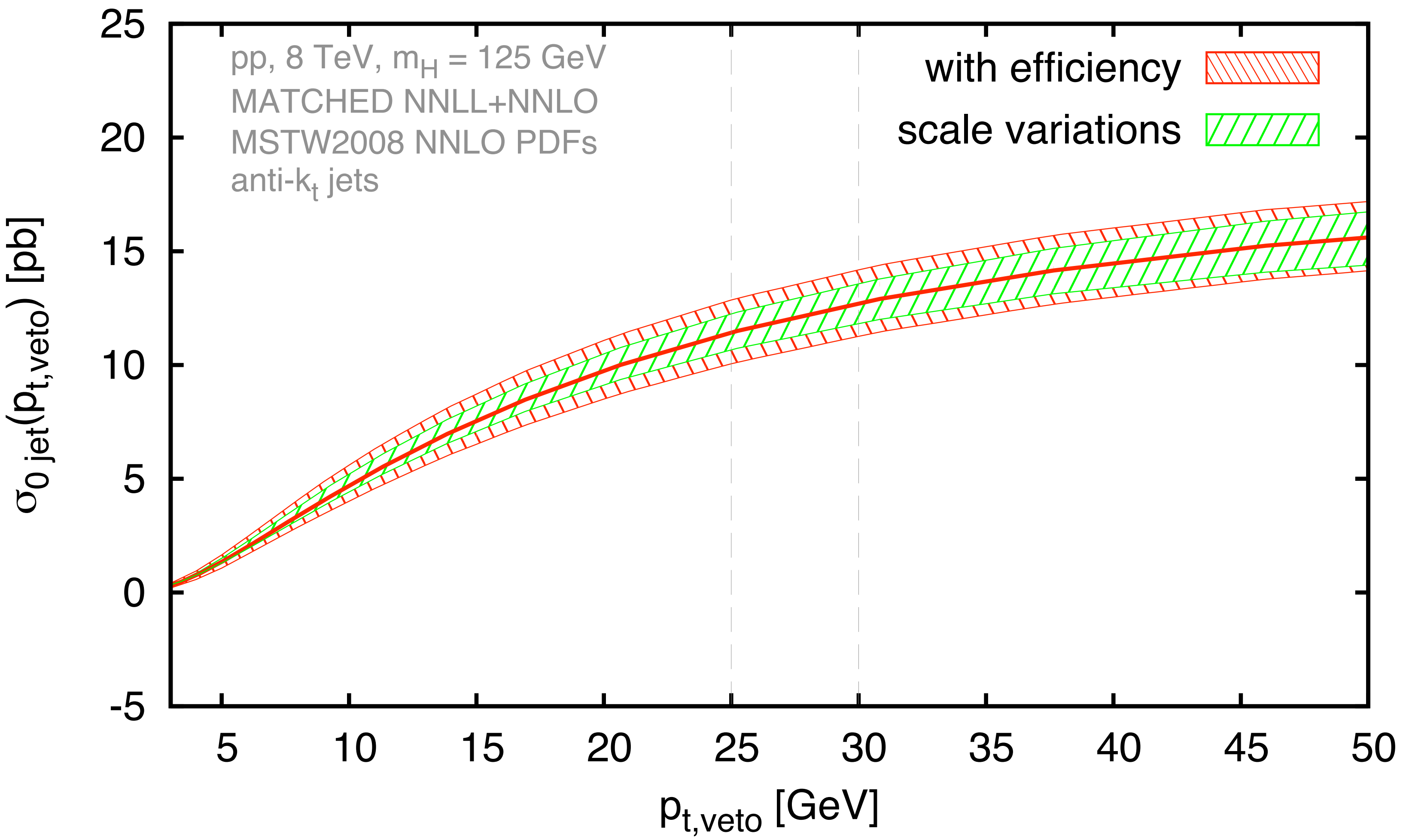
- If resummation is not available, the method reduces to its fixed-order version

Extra slides

Uncertainties in the 0-jet cross section

- Use resummation (with or without efficiencies) to obtain predictions for the exclusive 0-jet cross section

Green band obtained using the matching-scheme (a) for the cross-section. Uncertainties are obtained by varying renormalisation, factorisation and resummation scales.

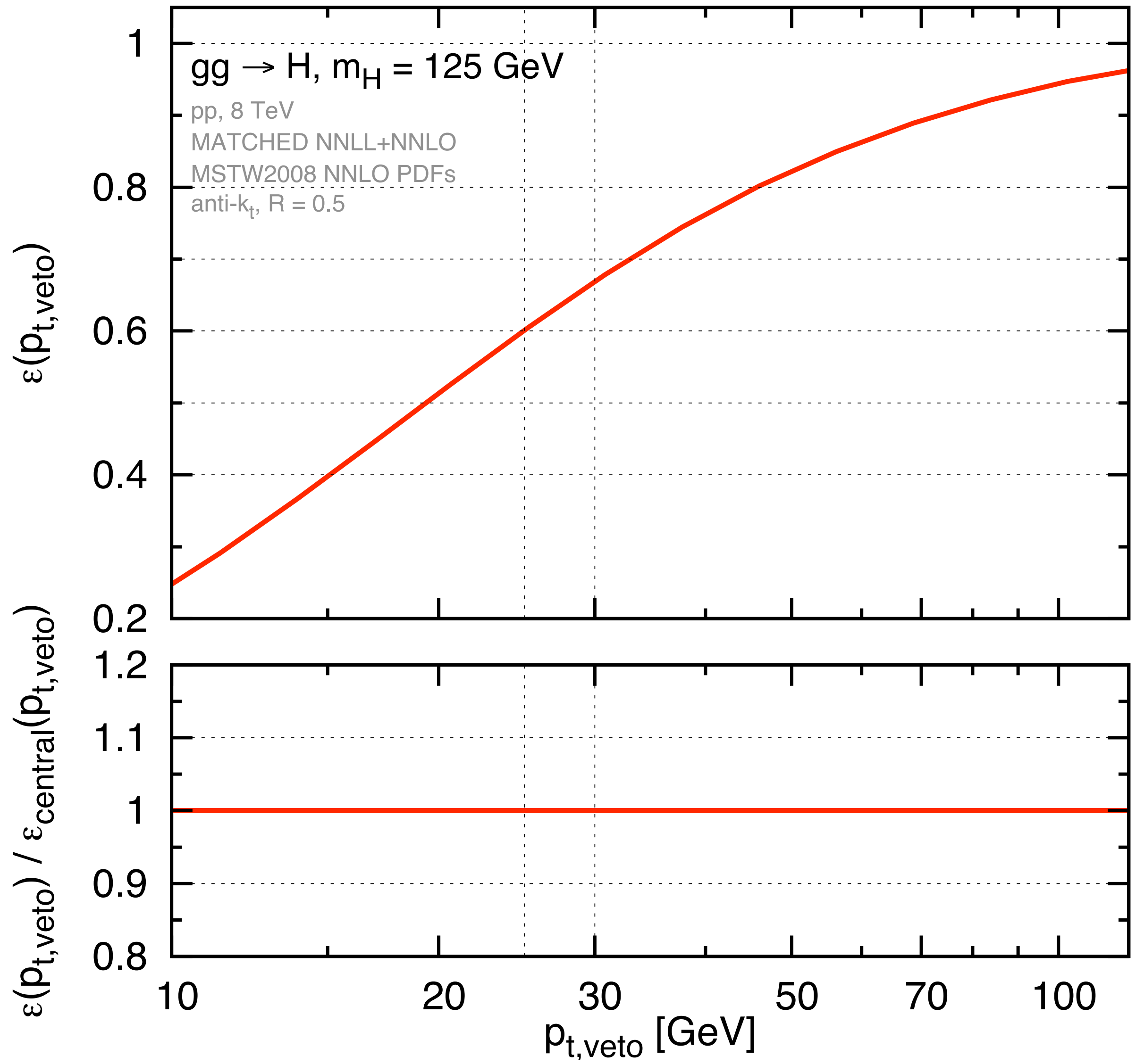


- Small difference mainly due to matching scheme uncertainty in efficiency method. Robust uncertainty estimate $\sim 10\% - 11\%$. Efficiency method more conservative!

Resummation uncertainties

- Central value: scheme (a) with

$$\mu_R = \mu_F = Q = M/2$$



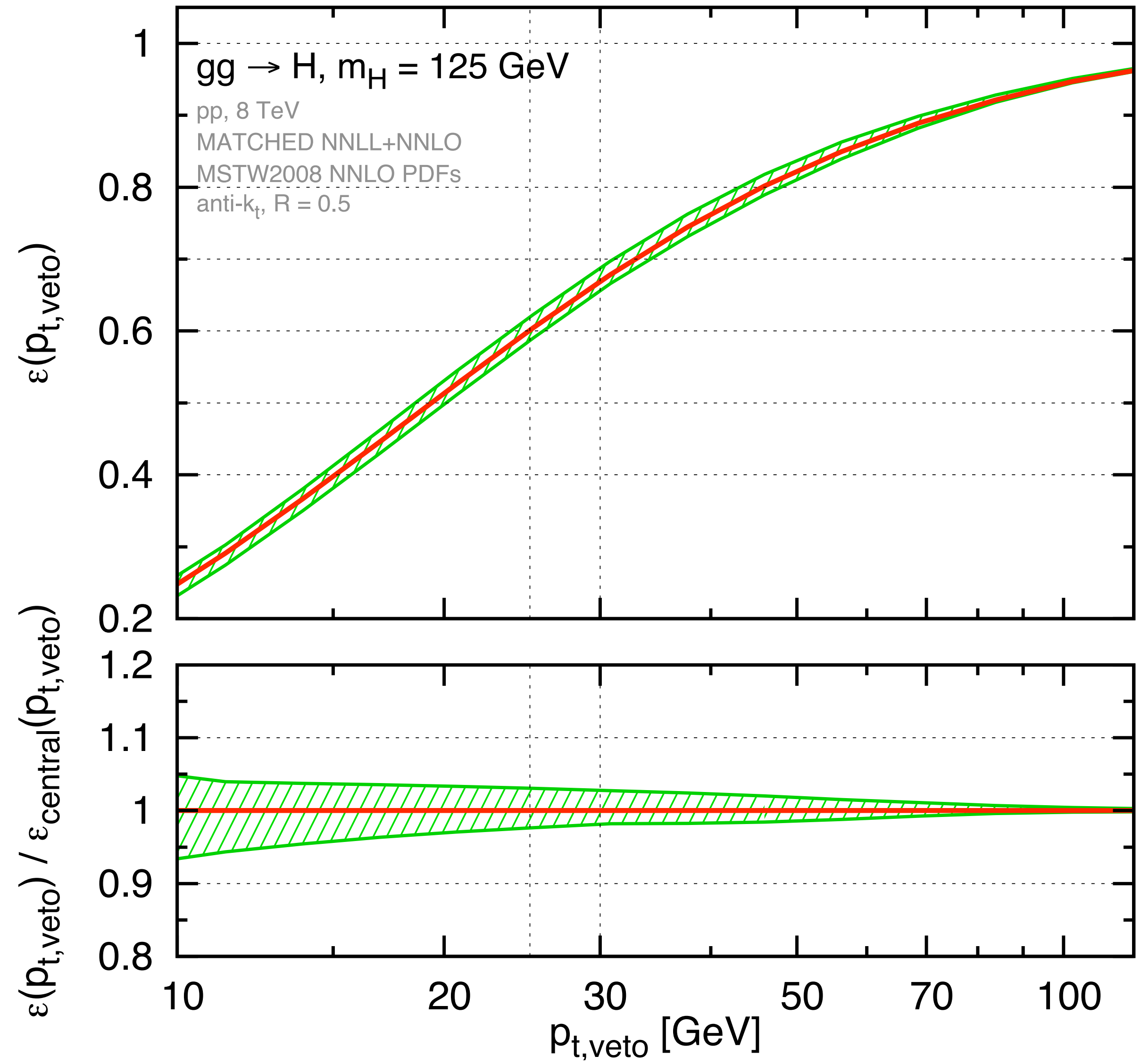
Resummation uncertainties

- Central value: scheme (a) with

$$\mu_R = \mu_F = Q = M/2$$

- μ_R and μ_F variations

$$\frac{M}{4} \leq \mu_R, \mu_F \leq M \qquad \frac{1}{2} \leq \frac{\mu_R}{\mu_F} \leq 2$$



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- Resummation scale (Q) variation

i.e.

$$\ln \frac{M}{p_{t,veto}} \to \ln \frac{Q}{p_{t,veto}}$$

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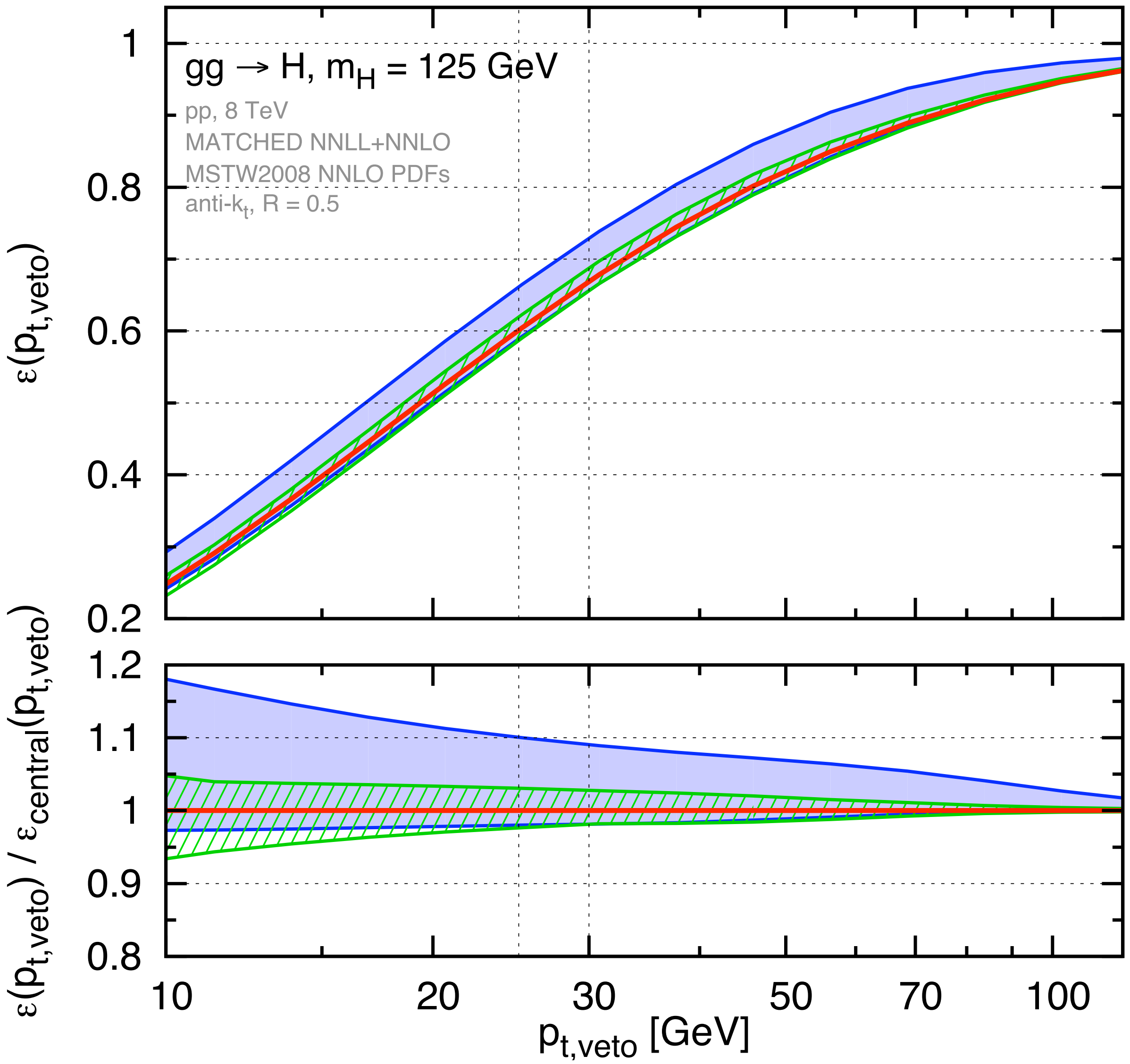

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- Schemes (b) and (c) with

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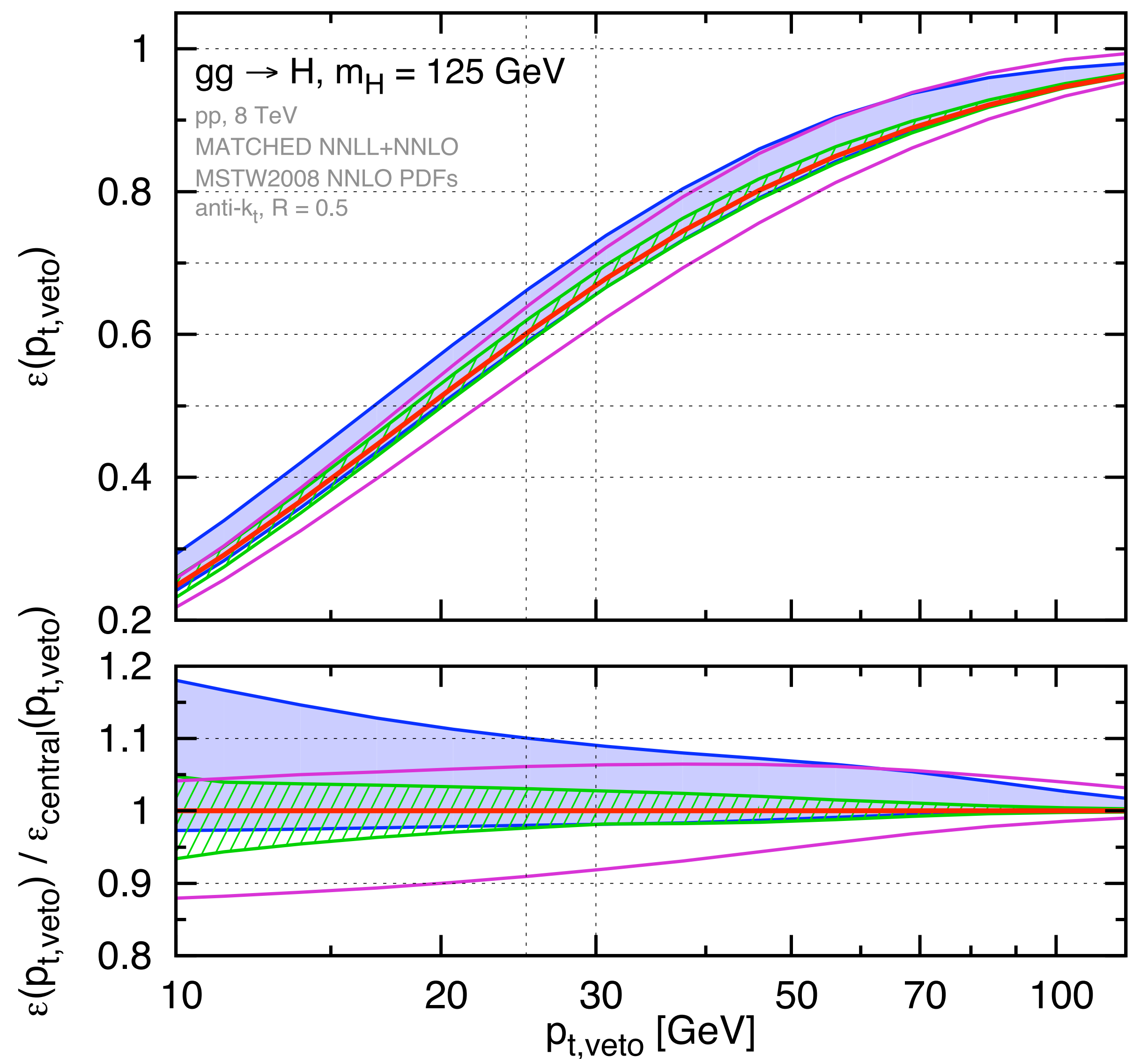

Resummation uncertainties

Total uncertainty = envelope

- Central value: scheme (a) with

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