$pp \to H + n$ jets with SHERPA

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Multijet merging at NLO – MEPS@NLO

- extension of CKKW-type multijet merging to NLO accuracy

  Lavesson, Lönnblad JHEP12(2008)070

  Höche, Krauss, MS, Siegert arXiv:1207.5030

  Gehrmann, Höche, Krauss, MS, Siegert arXiv:1207.5031

- implement resummation of parton shower through Sudakov weights, remove overlap of $\mathcal{O}(\alpha_s)$ terms with NLO calculation through modified vetoed truncated shower

$\Rightarrow$ construct inclusive sample where the first few jet multiplicities are calculated at NLO (supplemented by higher multiplicities at LO) while resumming the hierarchy of the emission scales of each individual jet up to a resummation scale (starting scale of the parton shower)

- scales need to be set according to parton shower histories to retain parton shower resummation properties

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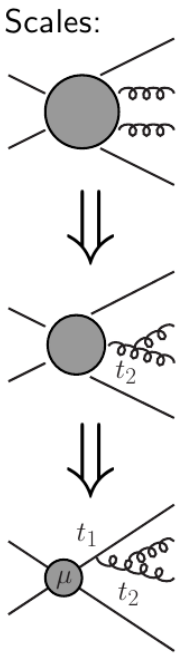

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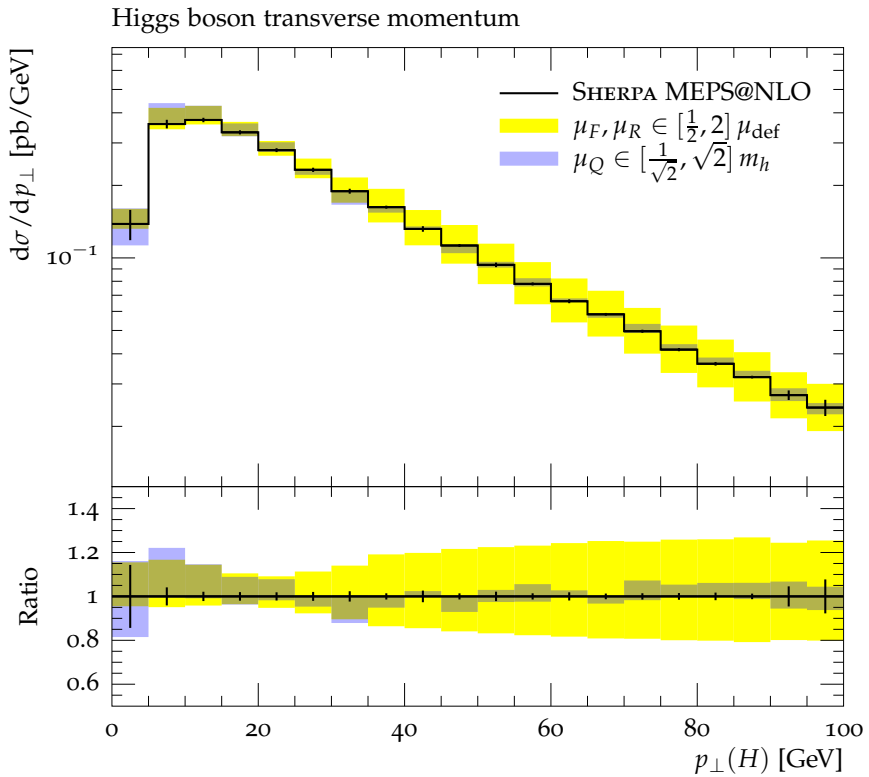
Inclusive distributions

- describe Higgs production in association with (multiple) jets
- fixed order cross sections for $pp \to H + \text{n jet} + X$ decrease only by factor 1.5-2 per jet multiplicity (depending on jet cut)
  $\Rightarrow$ need to describe higher jet multiplicities with an accuracy as high as possible, otherwise a substantial part of the events are not adequately described
- use MEPS@NLO for Higgs production through gluon fusion, i.e.
  - describe $pp \to H + X$ and $pp \to H + \text{jet} + X$ at NLO
  - supplement with LO matrix elements for $pp \to H + 2\text{jets} + X$ and $pp \to H + 3\text{jets} + X$
- perturbative uncertainties through variations μ_R, μ_F, μ_Q, $[Q_{\text{cut}}, N_{\text{max}}]$
- effective ggH-vertex calculated in $m_t \to \infty$ limit, can also do finite m_t if as an effective theory vertex (no internal corrections)
- $ggh \propto \alpha_s^2 \to \mu_R$-dependence
  (dominant contribution to NLO μ_R dependence)

Inclusive distributions

Setup: $pp \to H+$jets (ggF)

- purely perturbative calculation (no hadronisation, MPI, etc.)
- 0,1 jets @ NLO
  2,3 jets @ LO
  $Q_{\text{cut}} = 20$ GeV, $N_{\text{max}} = 3$
- customary perturbative scale variations
  $\mu_{R/F} \in [\frac{1}{2}, 2]\,\mu_{\text{def}}$
  $\mu_Q \in [\frac{1}{\sqrt{2}}, \sqrt{2}]\,m_h$
- variation of merging parameter $Q_{\text{cut}} \in \{15, 20, 30\}$ GeV and max. ME multi $N_{\text{max}} \in \{1, 2, 3\}$
- inclusive calculation
  $\to$ scales of each jet-multiplicity subsample not independent

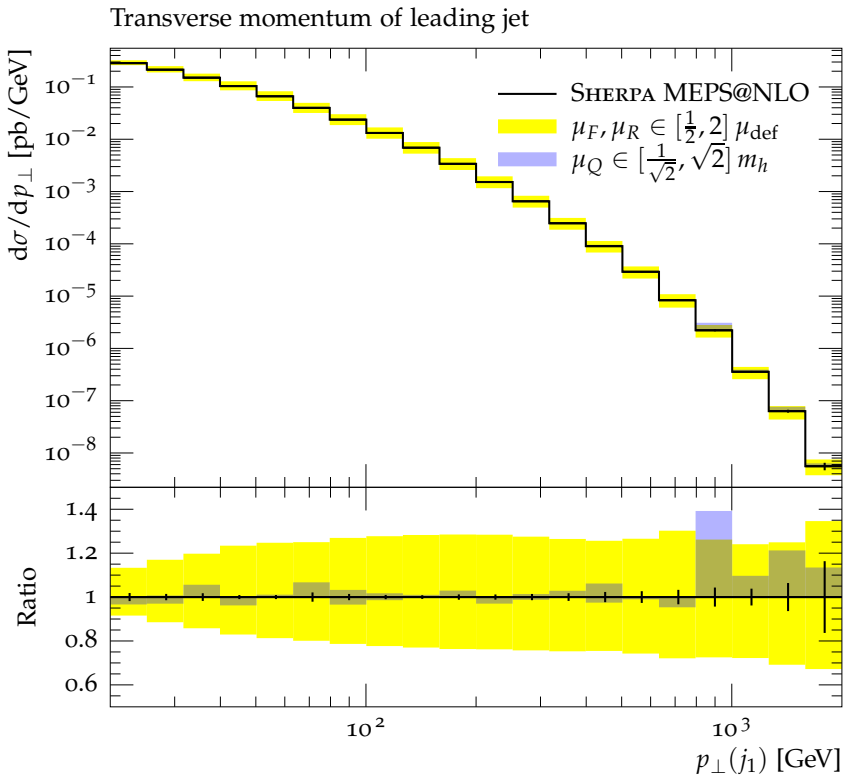


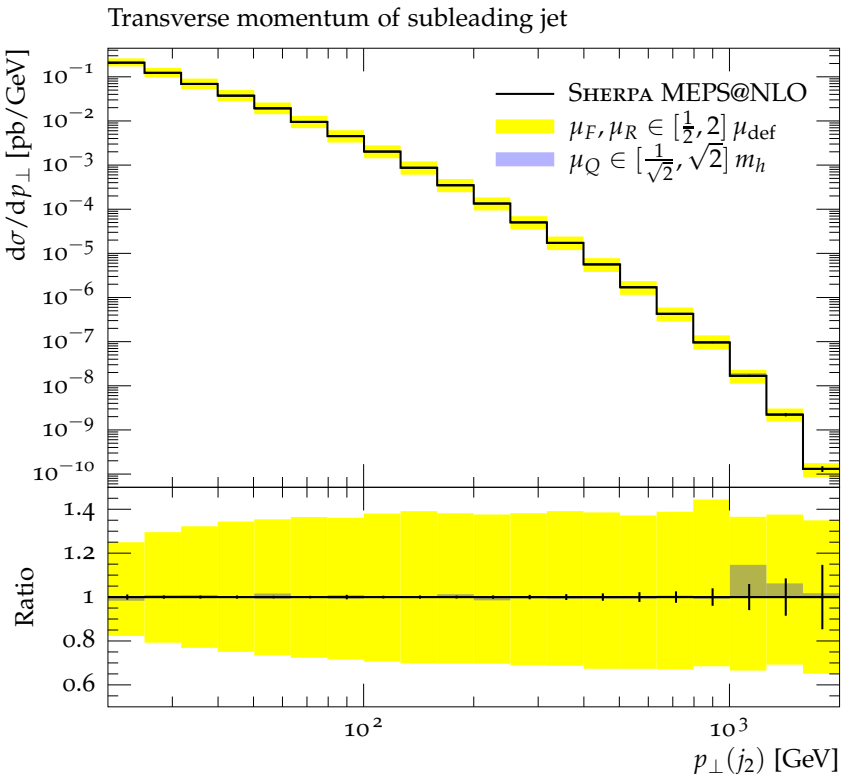
- inclusive cross section

  $\sigma = 15.2\ ^{+2.5\ +1.0\ +0.3\ +0.2}_{-1.5\ -0.4\ -0.0\ -1.0}$ pb

  $\mu_{R/F}$-, μ_Q-, Q_{cut}-, N_{max} var.
  N_{max} large due to inclusion of new initial states

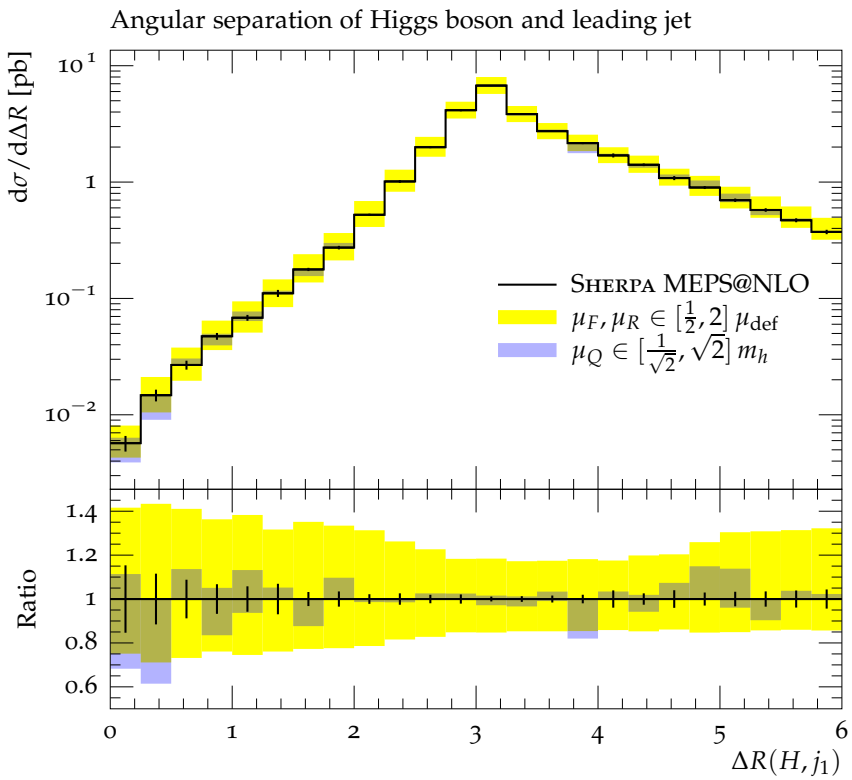
Inclusive distributions

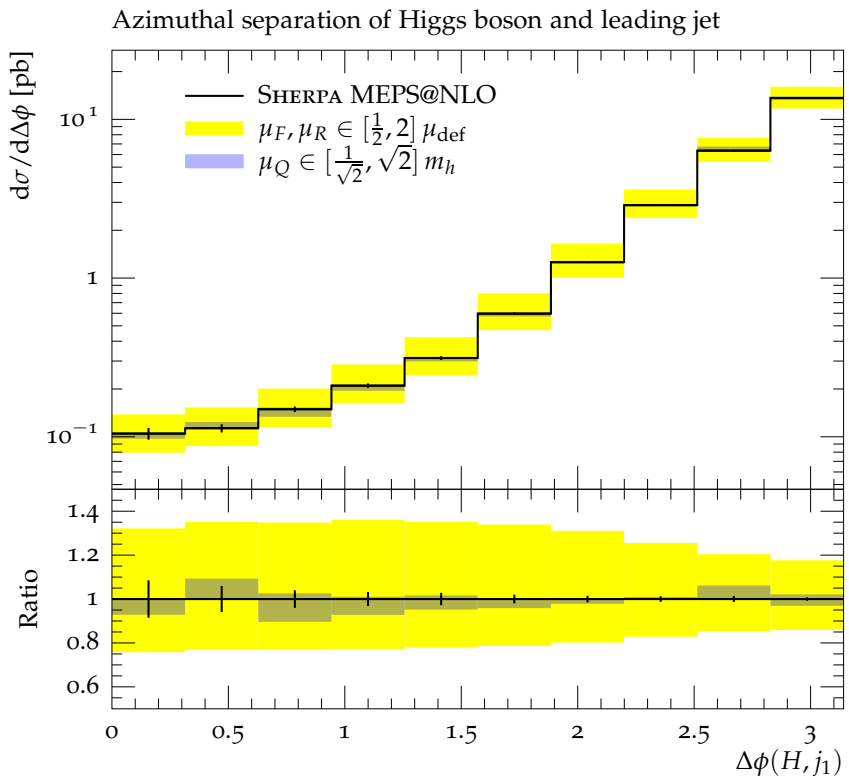




- transverse momenta of leading jets
- only small resummation scale dependence
- bulk of scale dependence comes from μ_R-dependence of effective vertex

Inclusive distributions

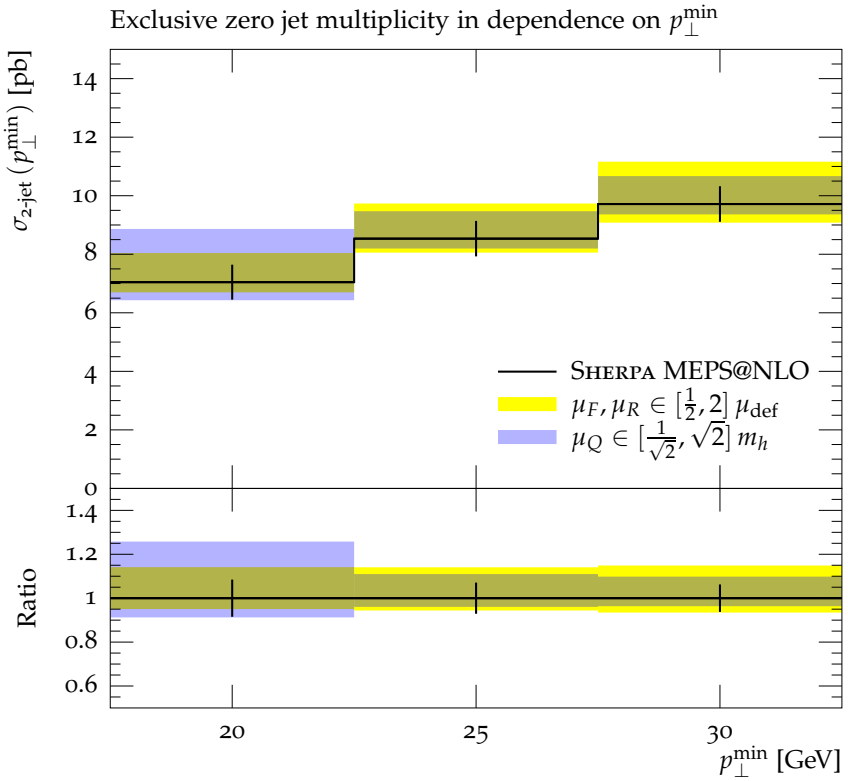




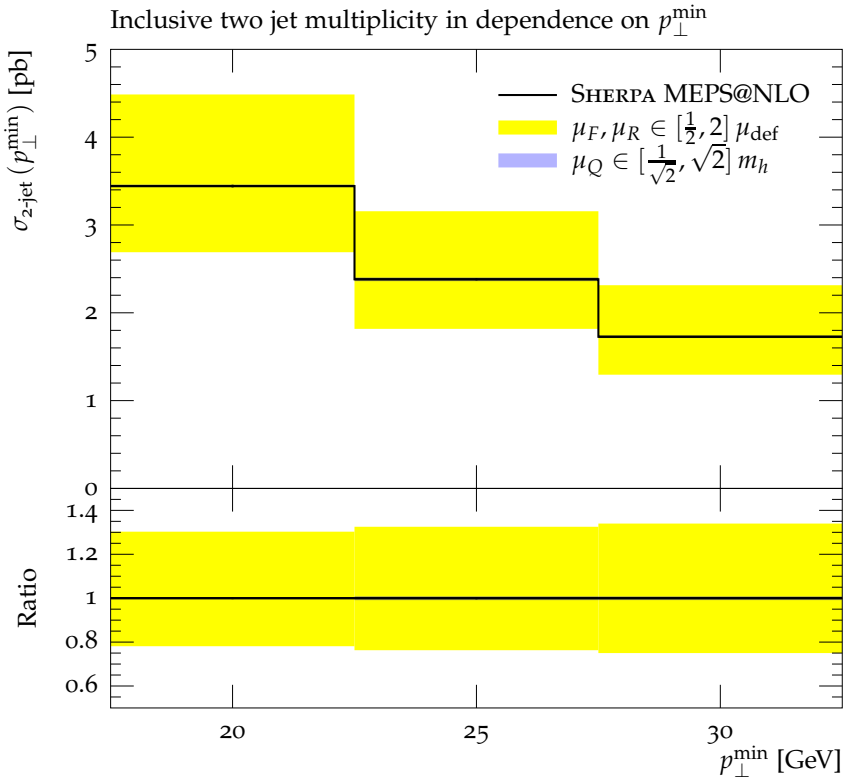
- angular correlations of leading jet and Higgs
- shape rather stable against variation

Jet multiplicities

exclusive 0-jet multiplicity



inclusive 2-jet multiplicity



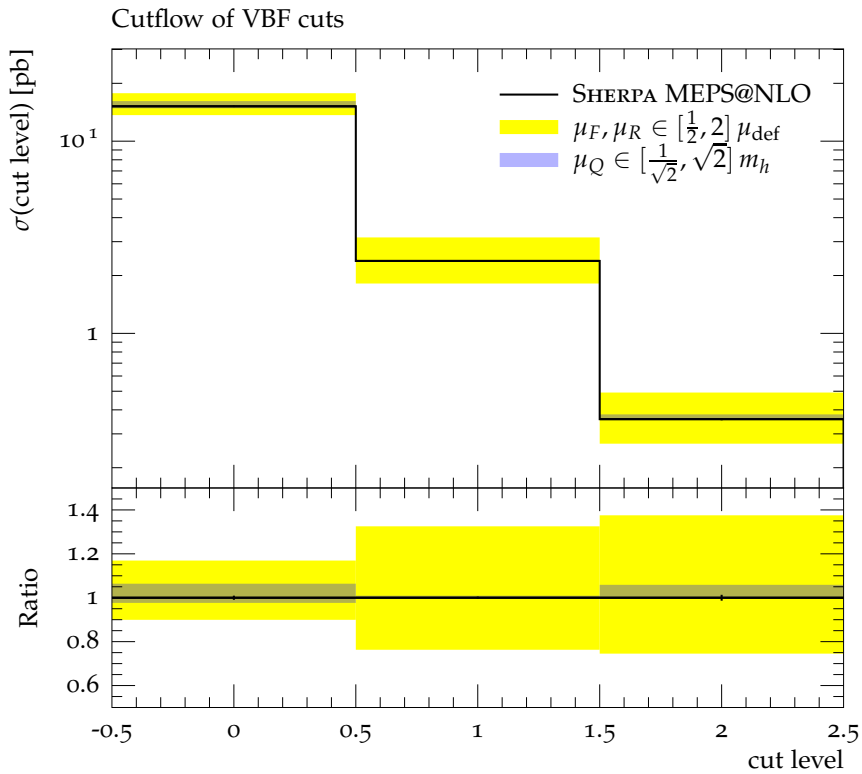
- Determined from inclusive sample
  → common scale choice
  → correlated variations
  → needs improved resummation

Distribution after VBF cuts

Common cuts:

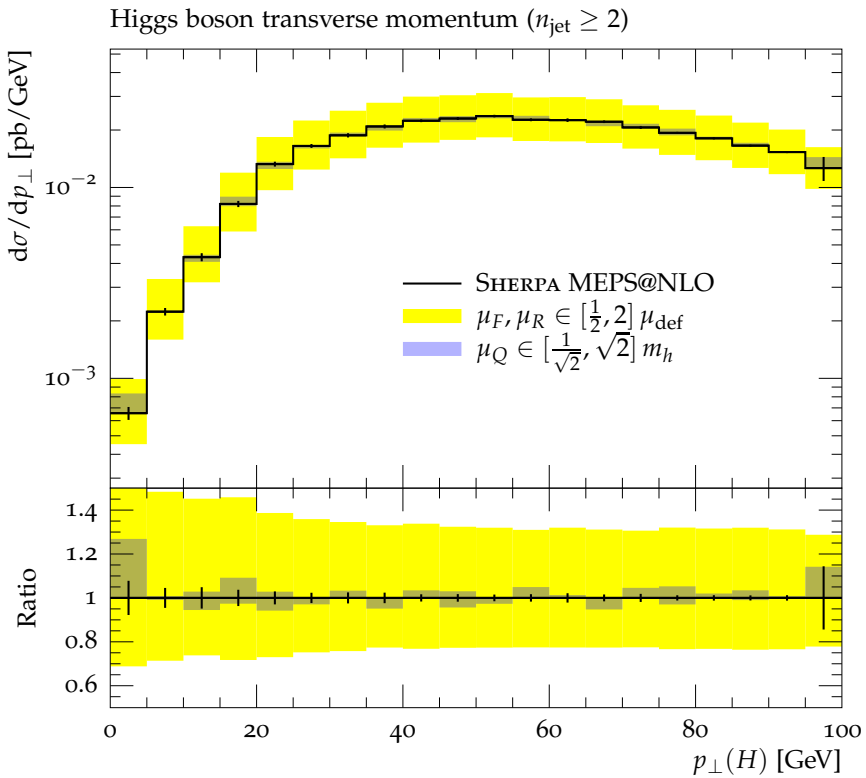
- at least two jets with $|\eta_{\text{jet}}| < 5$, anti-kt $R = 0.4$, $p_\perp > 25$ GeV
- topological cuts:
  $\Delta y_{\text{jet}_1\text{jet}_2} > 2.8$
  $m_{\text{jet}_1\text{jet}_2} > 400$ GeV
- hardest jets are tagging jets

- 2-jet topologies currently only described at LO in inclusive sample (plan to move to NLO for final report)
  $\rightarrow$ large uncertainties



Distribution after VBF cuts

w/o topological cuts



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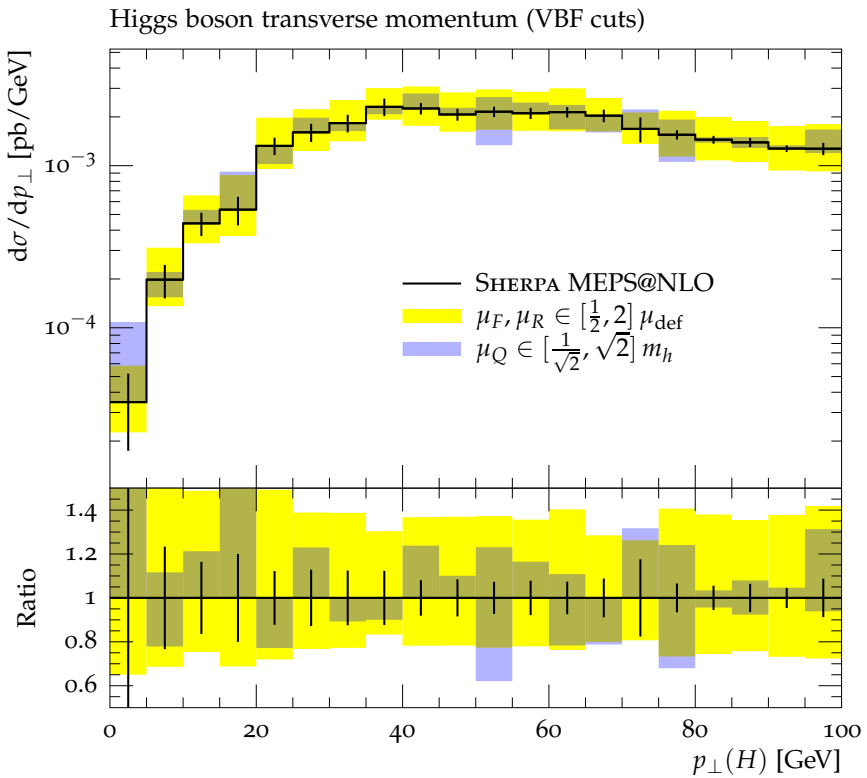

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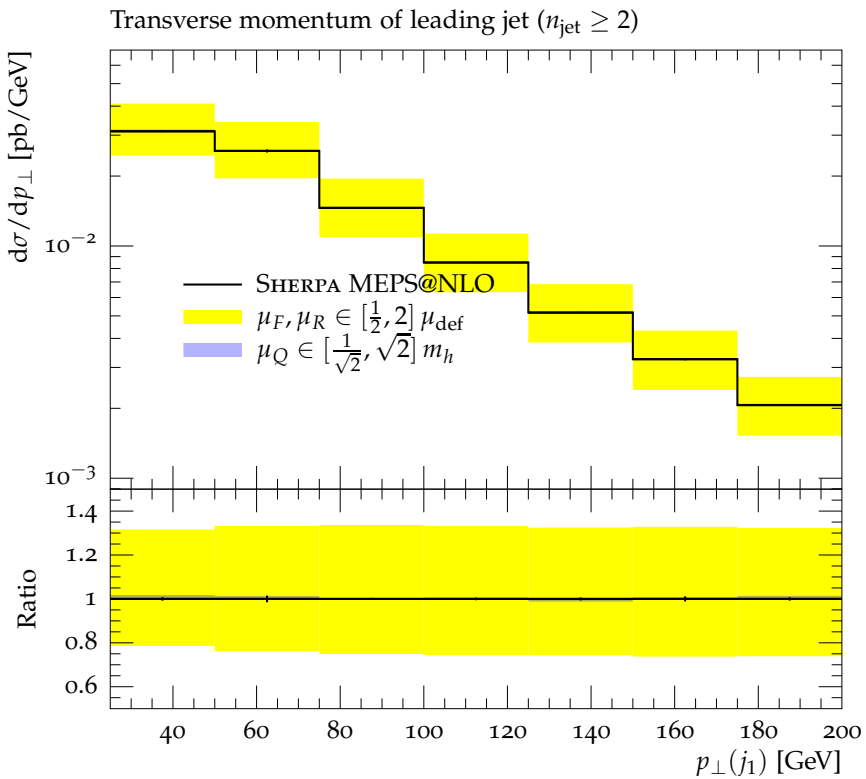

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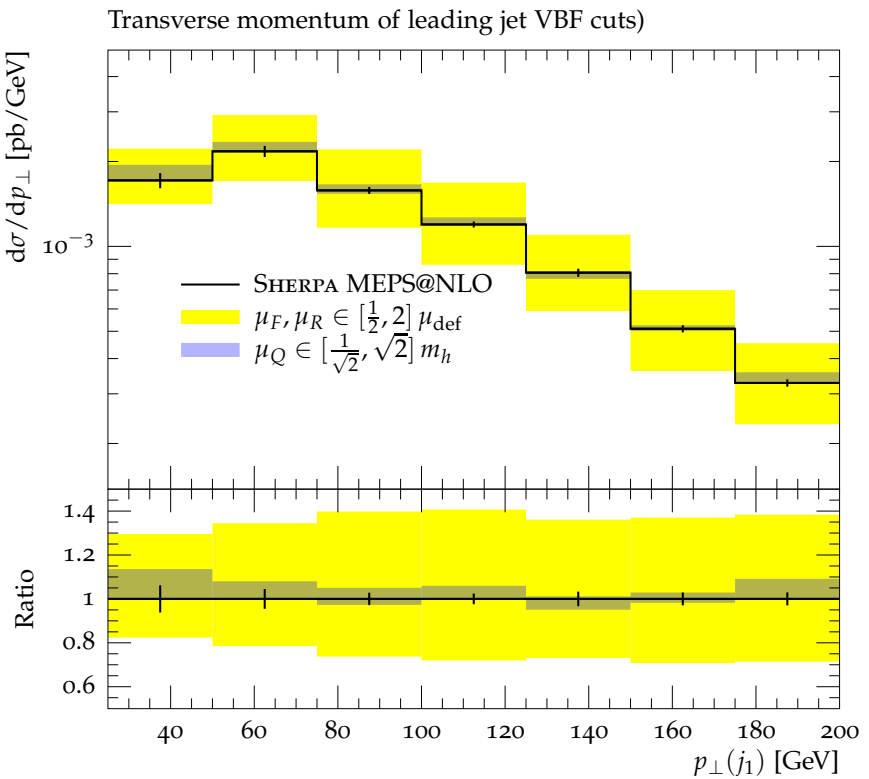

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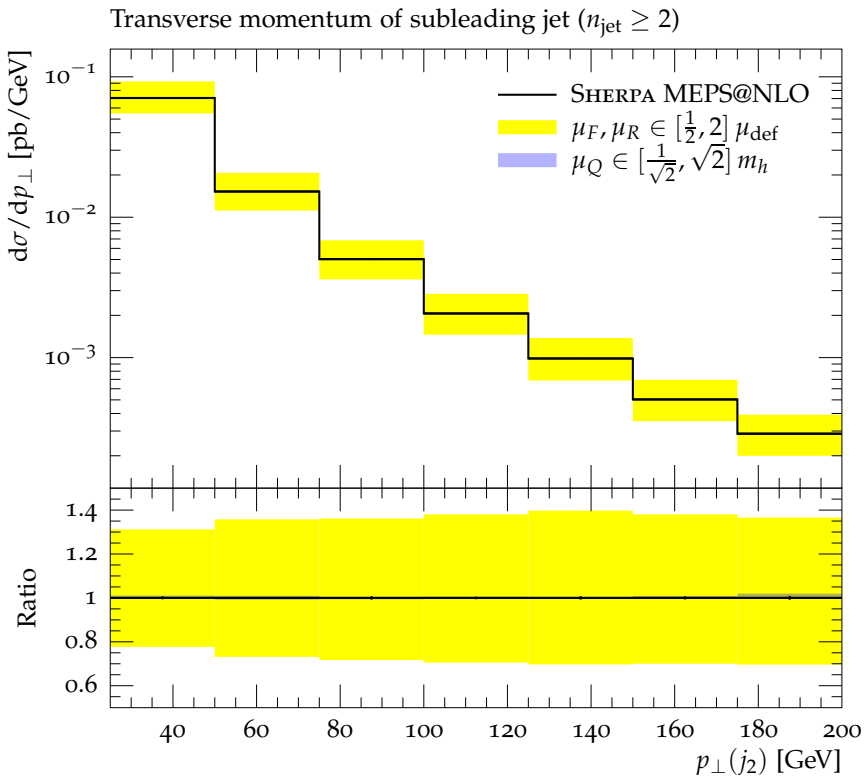

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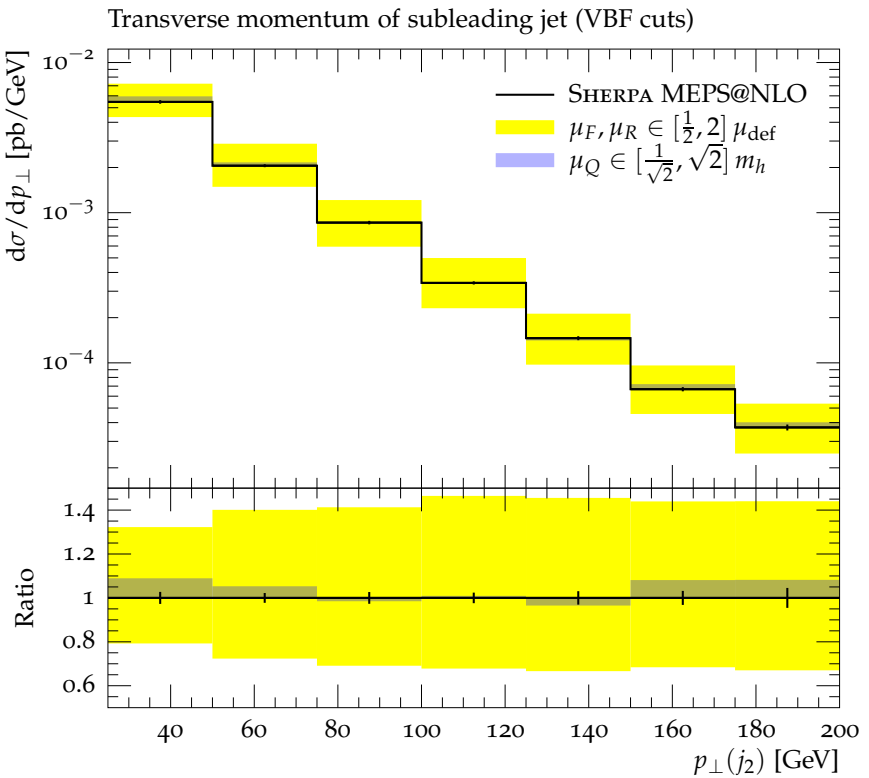

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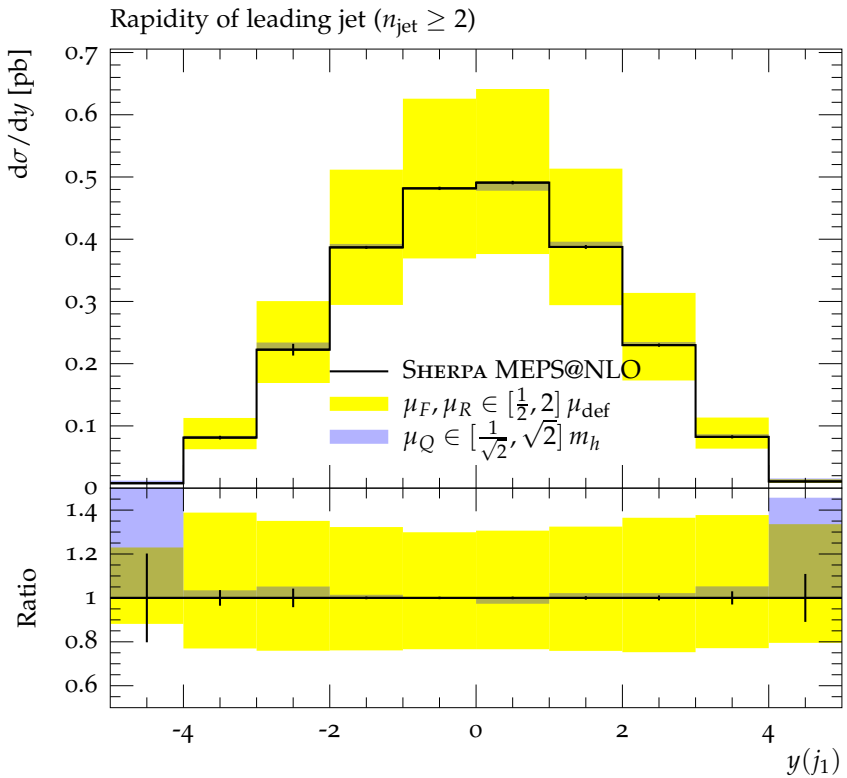

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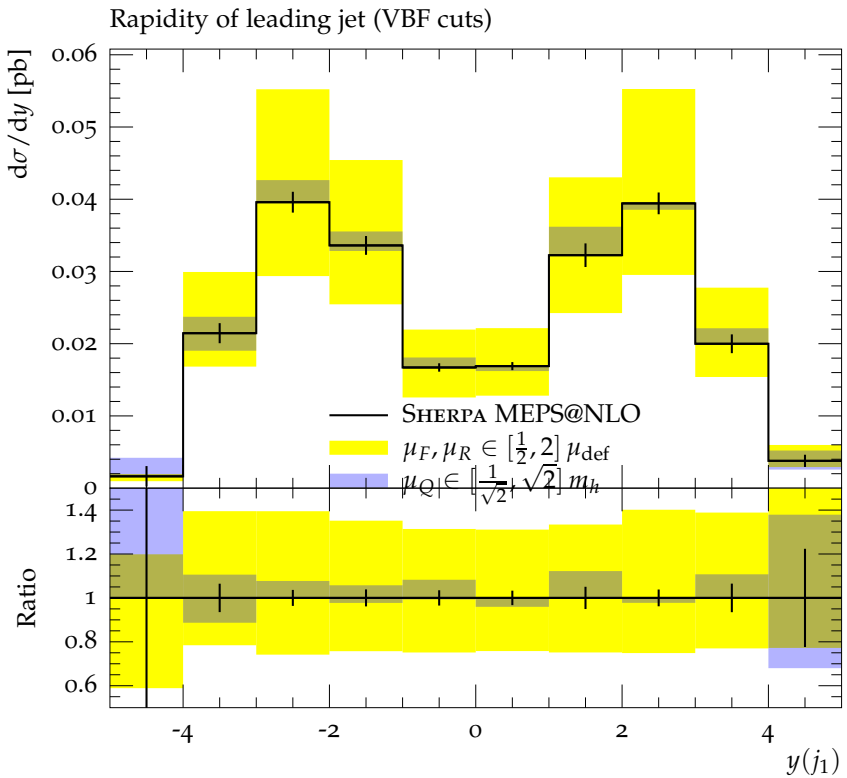

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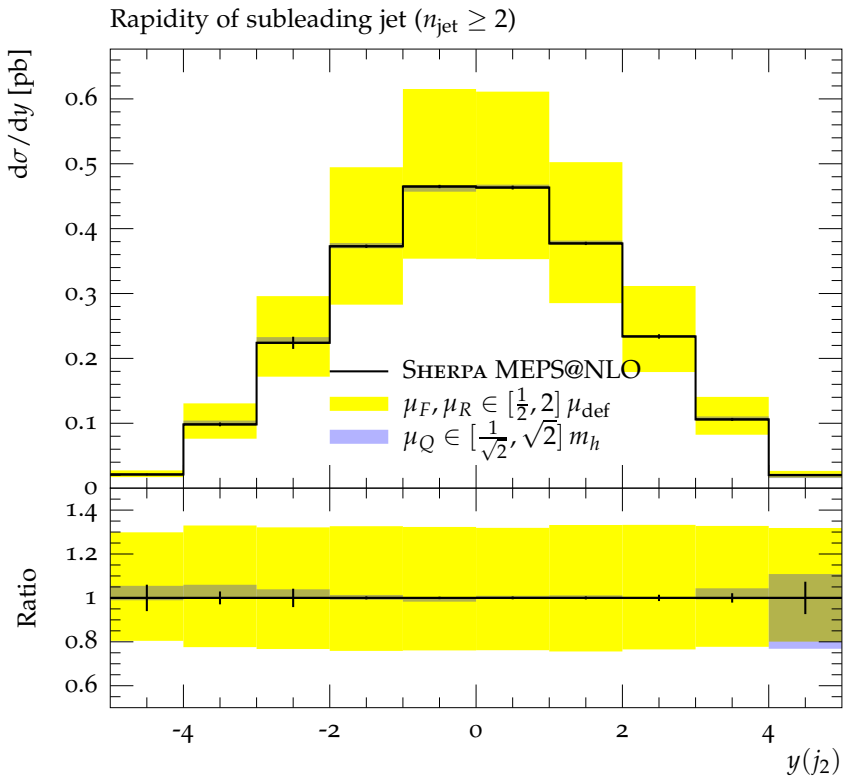

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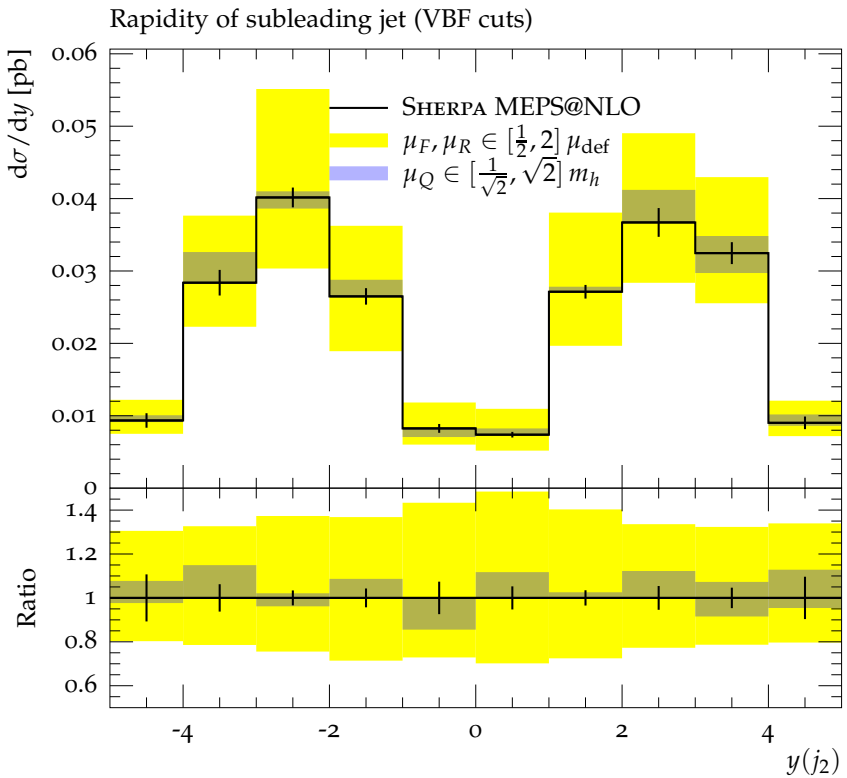

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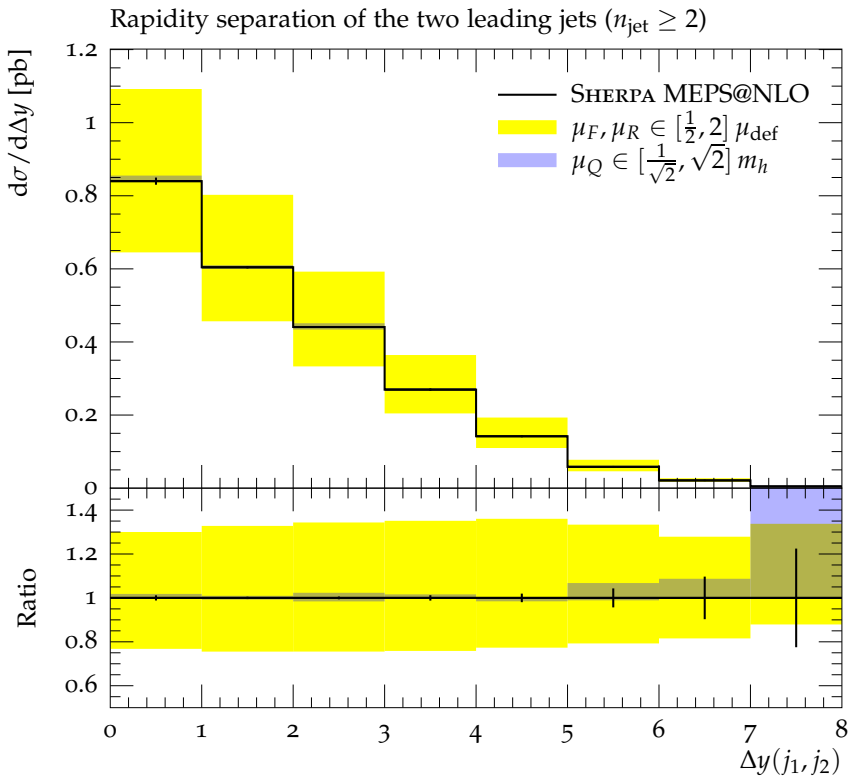

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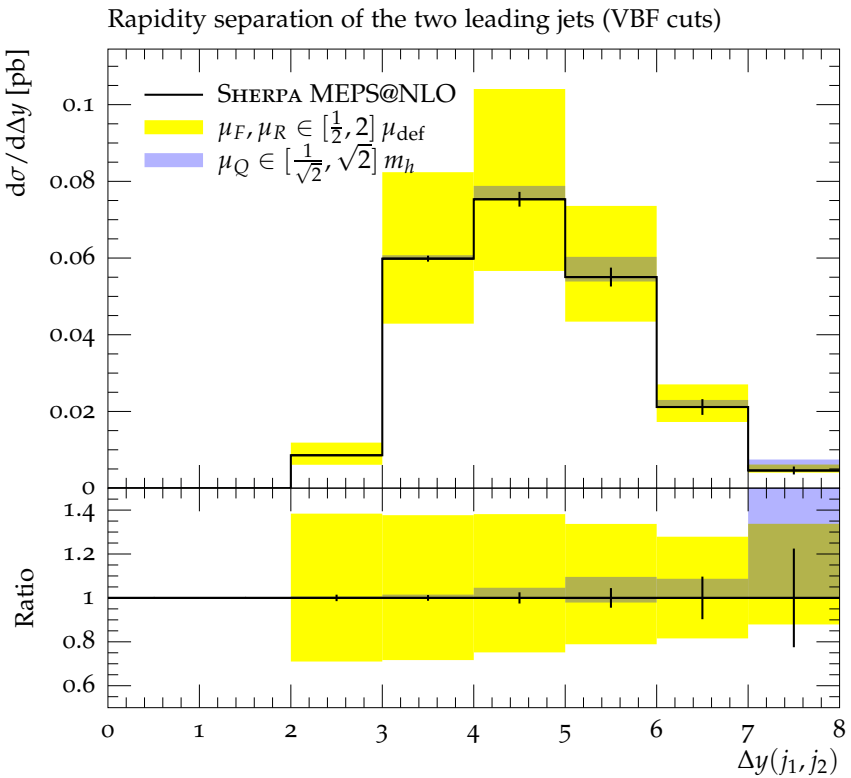

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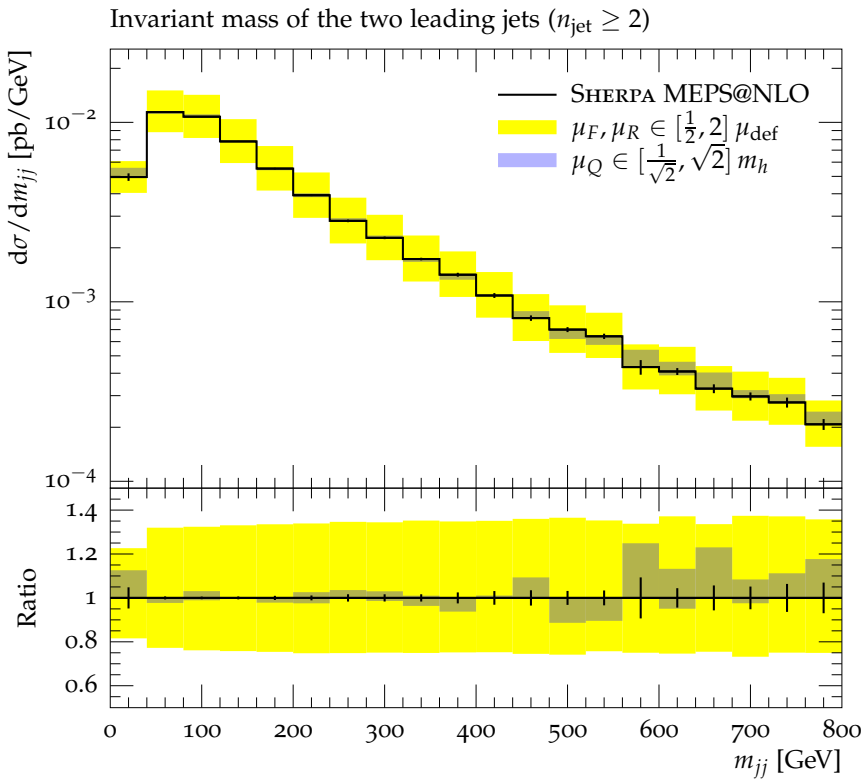

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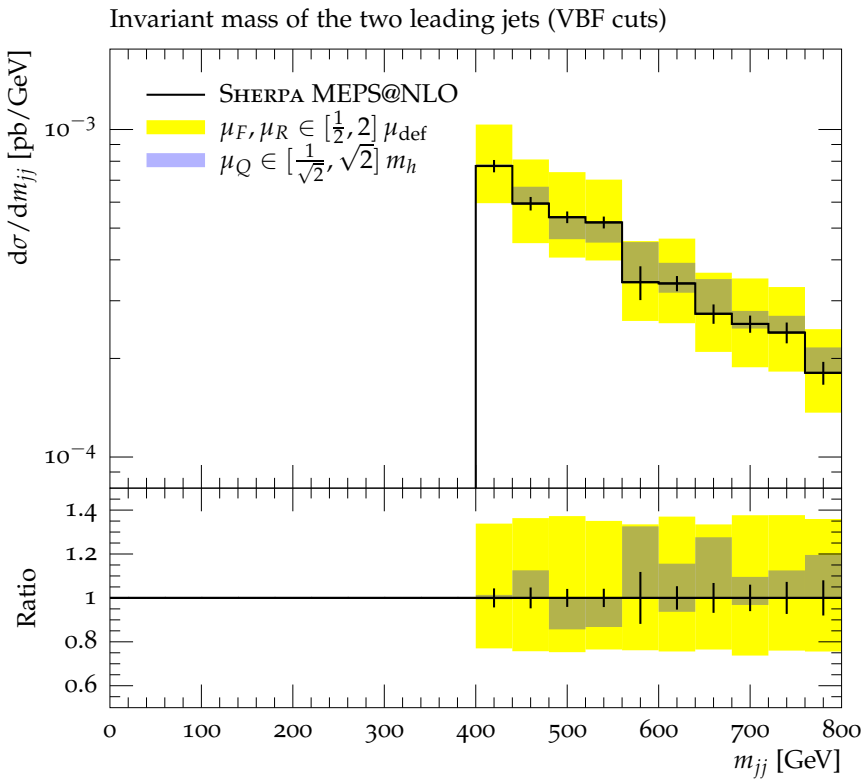

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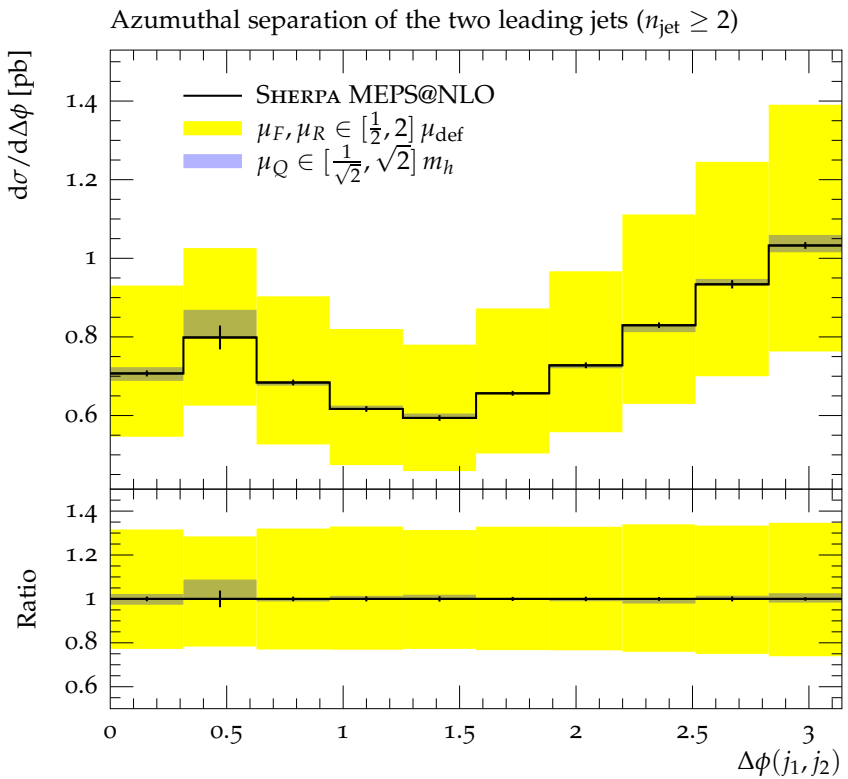

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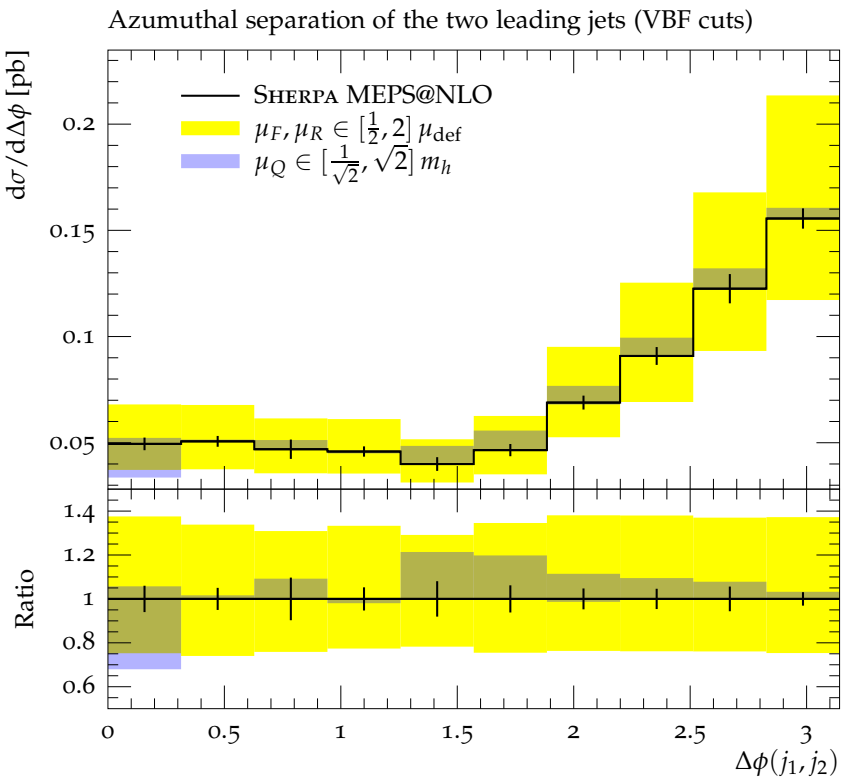

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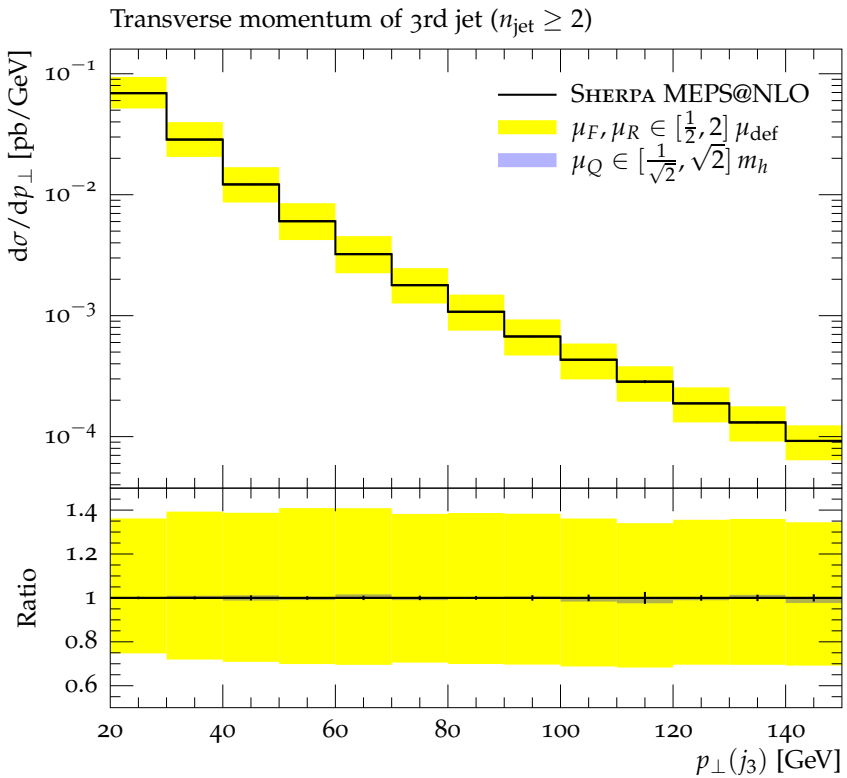

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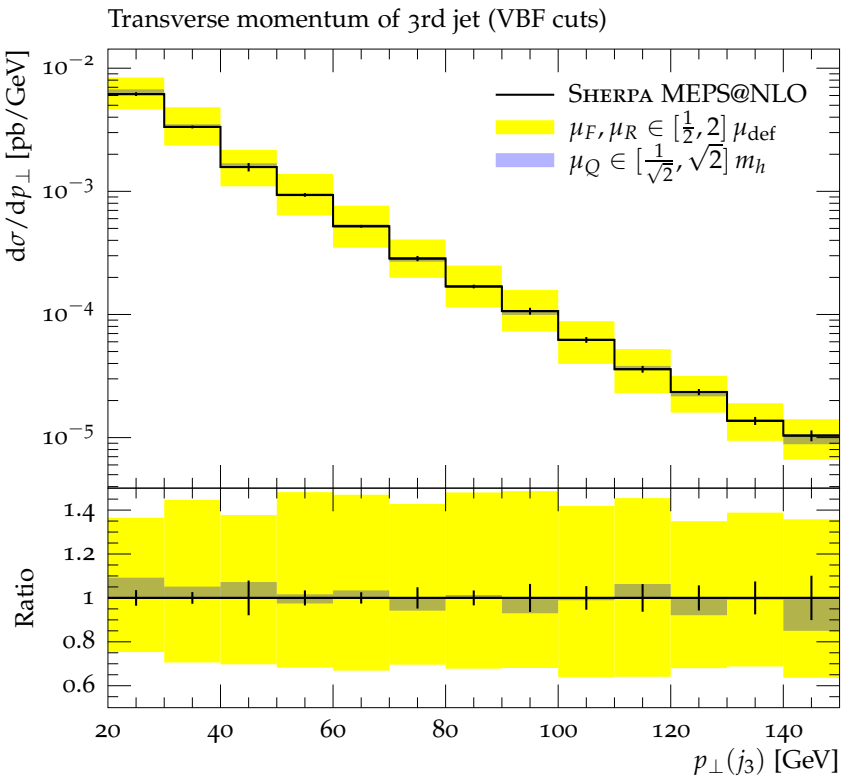

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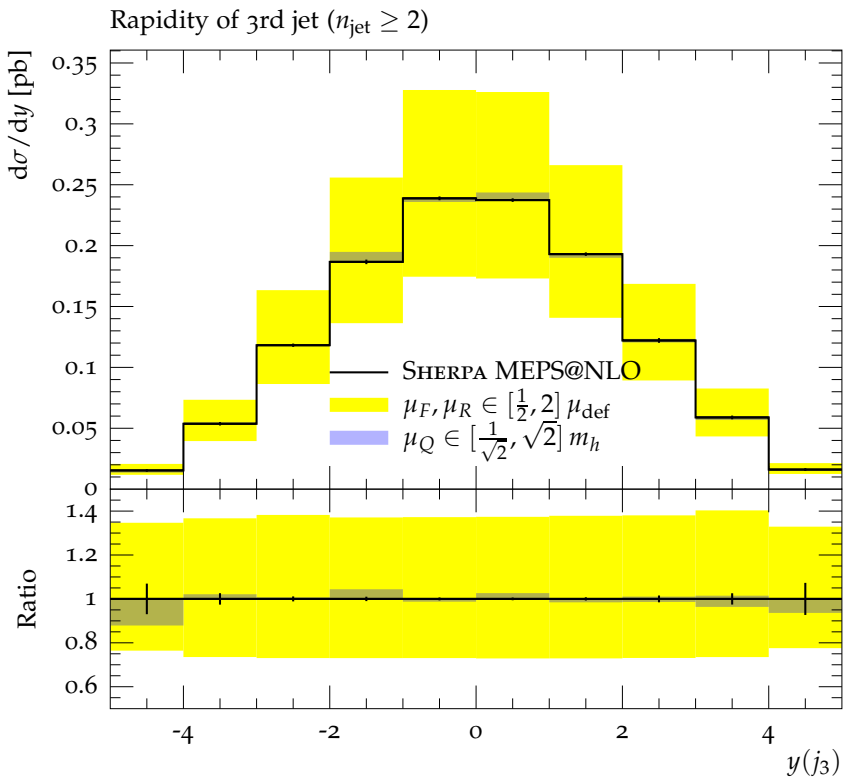

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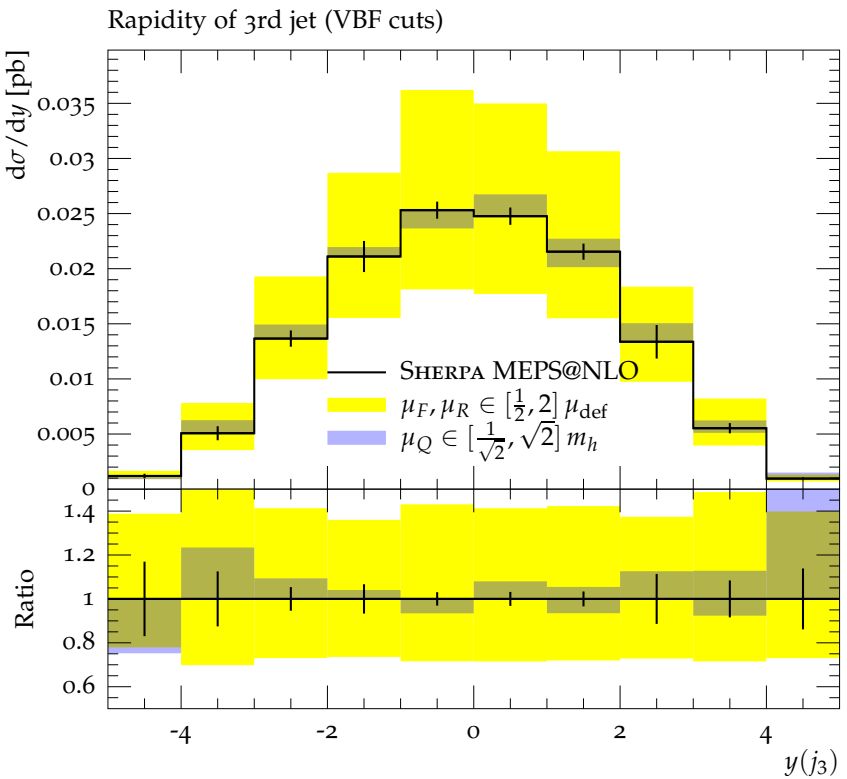

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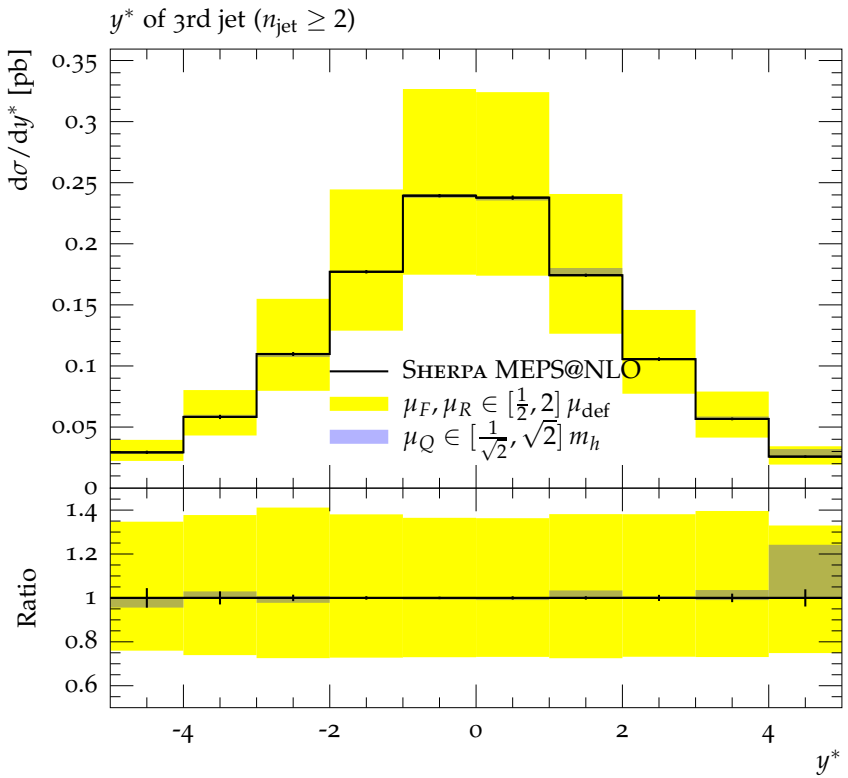

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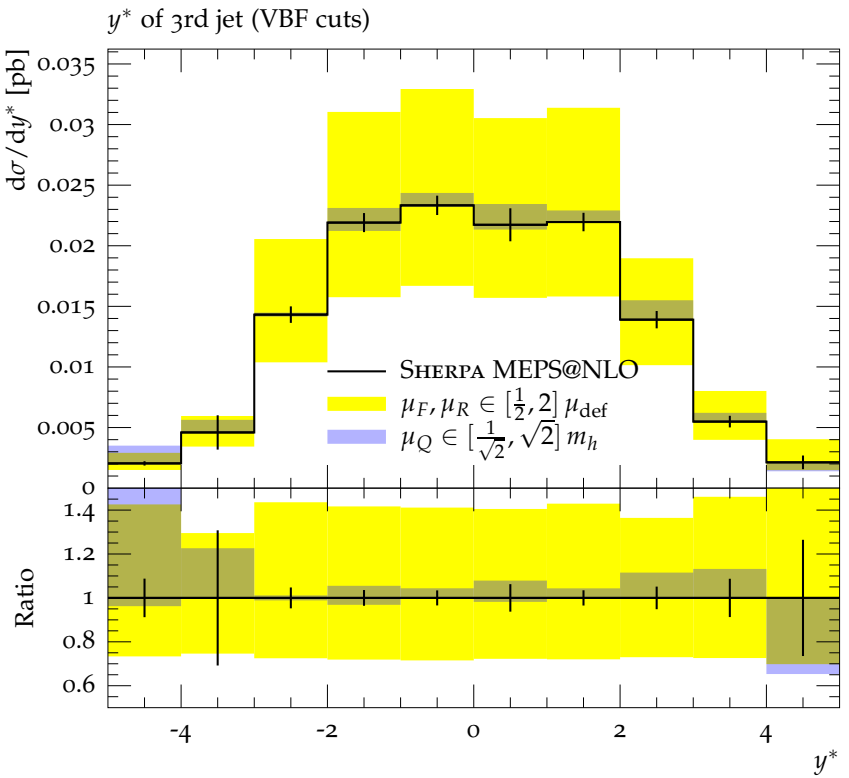
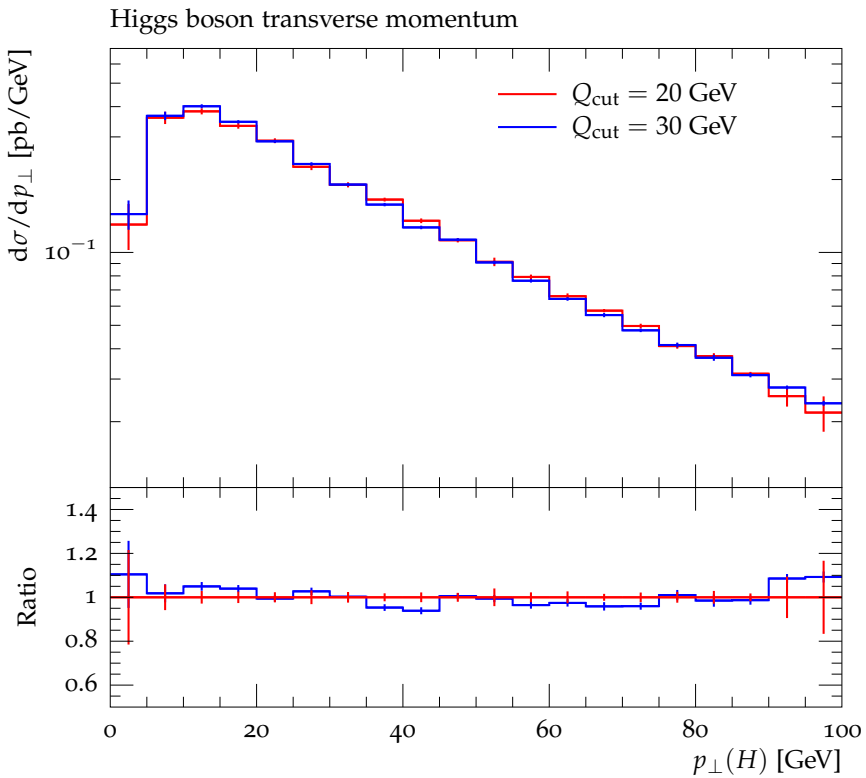
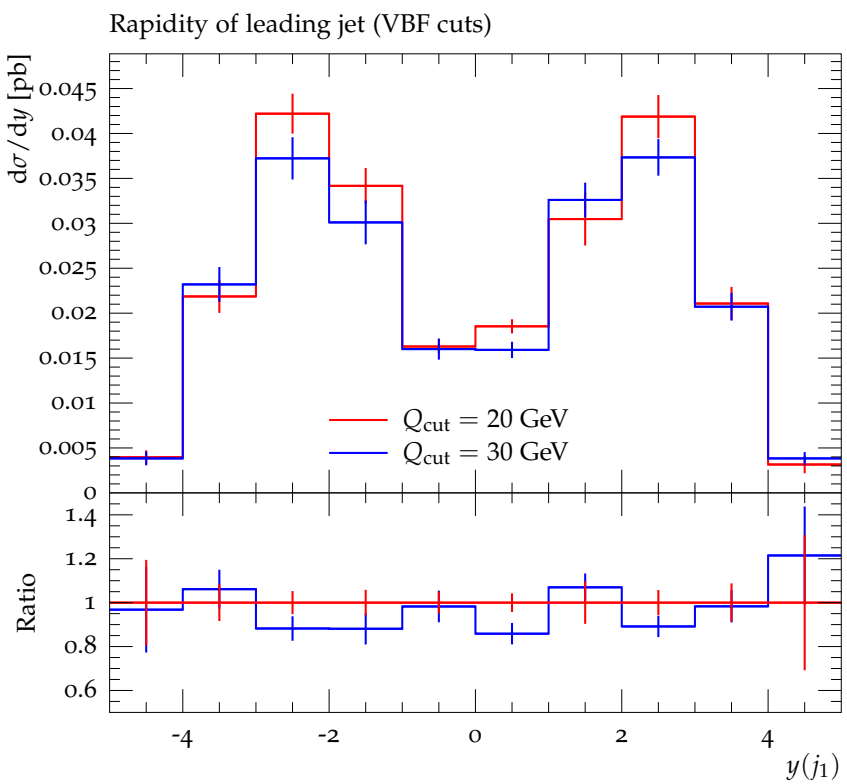


Variation of Q_{cut}

inclusive observables



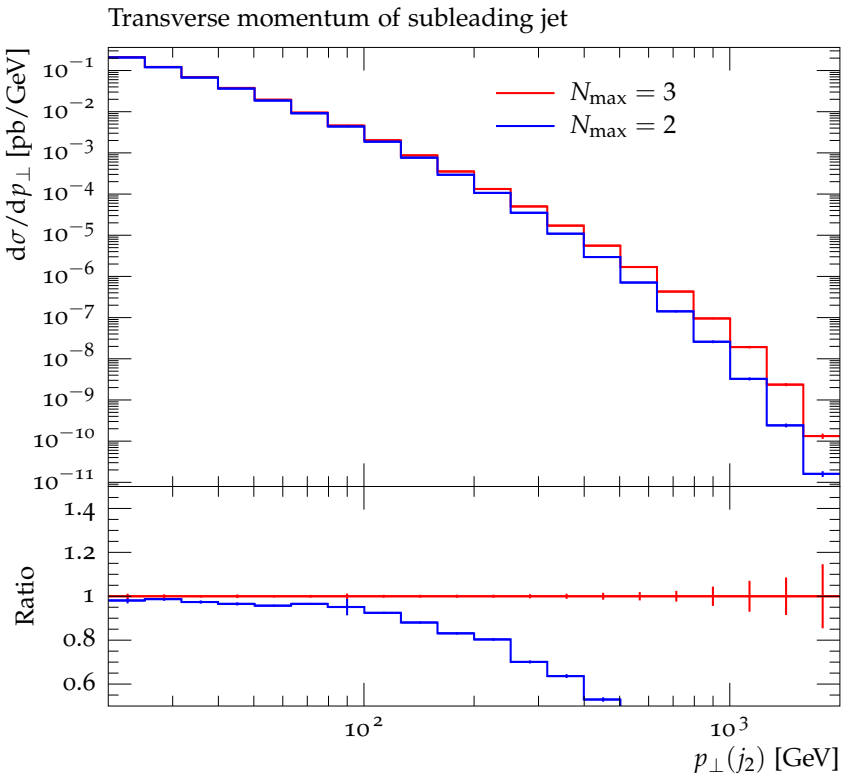
VBF-lie topologies



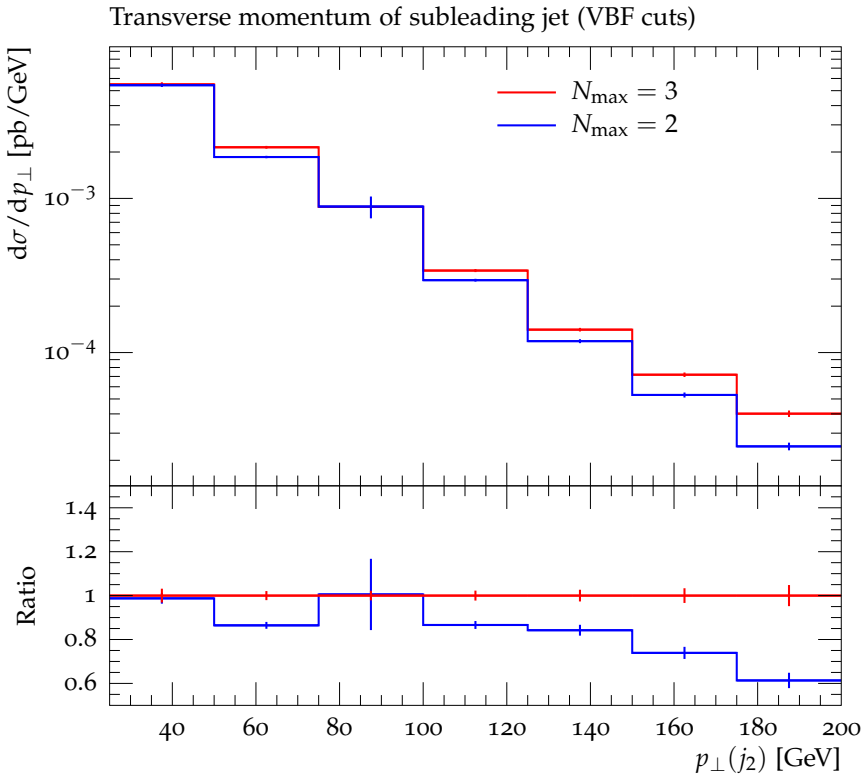
- very small residual Q_{cut} dependence, formally of $\mathcal{O}(\frac{1}{N_C^2}\,\alpha_s^2 L^3)$

Variation of N_{max}

inclusive observables



VBF-like topologies



- second jet receives sizeable contributions from 3 parton matrix element $\rightarrow$ accurate description of VBF-like topologies need at least a third jet at LO

Conclusions

Preliminary results

- first results with MEPS@NLO for $pp \to H+$ jets
- reasonable uncertainties for inclusive observables
- VBF-topologies are currently only described at LO $\Rightarrow$ move to NLO
- NLO description of multileg final states and resummation of scale hierarchies at the same time
  $\Rightarrow$ needed for multiscale processes

Plans for YR3

- 0,1,2 @ NLO, 3,(4) @ LO ($pp \to H + 2$jets virtual from GoSam)
- full theoretical uncertainty estimate (perturbative & non-perturbative)
- include analysis on certain decay channels, e.g. $h \to \gamma\gamma$
- fiducial/acceptance/isolation cuts

Thank you for your attention!