High-energy resummation for the background to weak boson fusion

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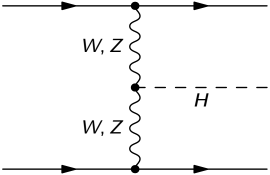
Andersen, Hapola, AM, Smillie; JHEP 1709 (2017) 065; arXiv:1706.01002
Andersen, Hapola, Heil, AM, Smillie; JHEP 1808 (2018) 090; arXiv:1805.04446
Andersen, Cockburn, Heil, AM, Smillie; arXiv:18??.?????

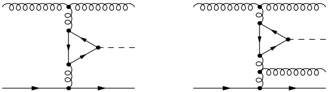
Higgs production in weak-boson fusion



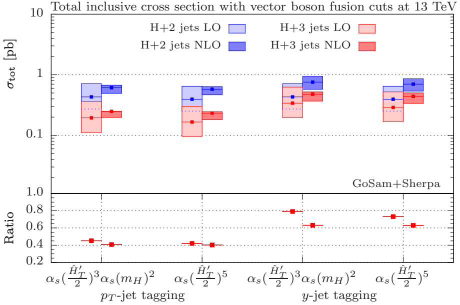
- Second largest channel for Higgs production
- Direct probe of couplings to weak bosons
- Widely separated jets
  $\hookrightarrow$ WBF cuts: $y_{j_1 j_2} > 2.8$, $m_{j_1 j_2} > 400\,\text{GeV}$
- Known at NNLO: $\sim 5\%$ correction

  [Cacciari, Dreyer, Karlberg, Salam, Zanderighi 2015; Cruz-Martinez, Gehrmann, Glover, Huss 2018]
- Gluon-fusion background with major uncertainty

Gluon fusion background



- LO with full mass dependence for $H + 2, 3$ jets: $\sim 2\%$ correction to $m \to \infty$ [Greiner, Höche, Luisoni, Schönherr, Winter 2016]
- $H + 2, 3$ jets with $m \to \infty$ known at NLO: large contribution from higher multiplicities [Cullen et al. 2013]



plot from [Greiner, Höche, Luisoni, Schönherr, Winter, Yundin 2015]

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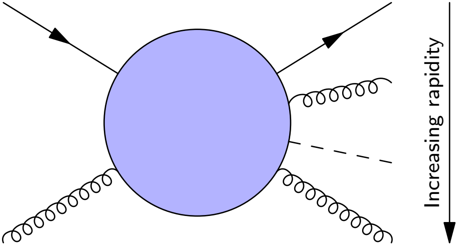
High energy limit:

- Outgoing invariant masses $\gg$ t-channel momenta
- Large rapidity separations
- Dominated by FKL configurations

[Fadin, Kuraev, Lipatov 1975–1977]

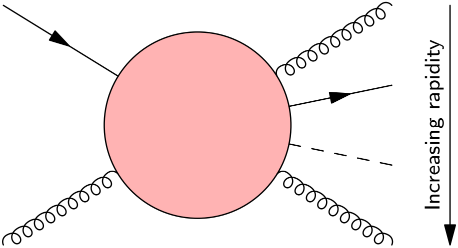


Single t-channel gluon exchange possible

Multi-Regge kinematics for H+jets

High energy limit:

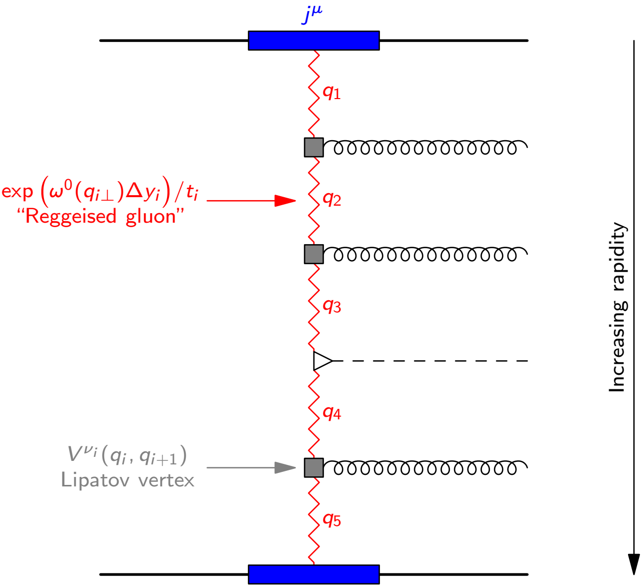
- Outgoing invariant masses $\gg$ t-channel momenta
- Large rapidity separations
- Non-FKL configurations suppressed



No single t-channel gluon exchange possible

High Energy Jets (HEJ) resummation

Matrix element [Andersen, Del Duca, Smillie, White 2008–2010]



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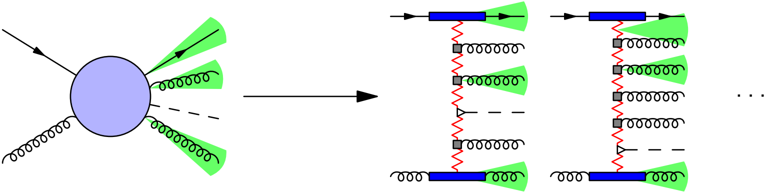
Matching to leading order



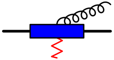
Fixed-order FKL event
MadGraph, Sherpa, . . .
$\sim |\mathcal{M}_{\mathrm{LO}}|^2$

Resummation events
Keep Higgs + jet rapidities, shift jet $p_\perp$
$\sim |\mathcal{M}_{\mathrm{HEJ}}|^2$

Final resummation event weight $\sim \frac{|\mathcal{M}_{\mathrm{LO}}|^2 |\mathcal{M}_{\mathrm{HEJ}}|^2}{|\mathcal{M}_{\mathrm{HEJ,\,LO}}|^2}$

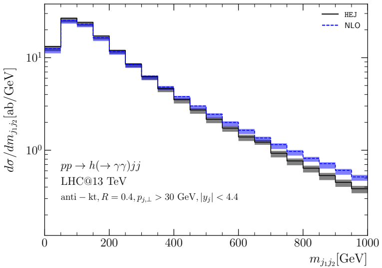
High Energy Jets (HEJ) resummation

Improvements

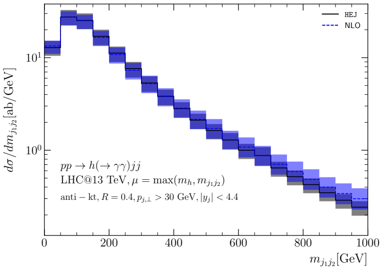
- High-multiplicity (> 4 jets) input events in HEJ approximation
  $\hookrightarrow$ Matching factor $\frac{|\mathcal{M}_{\text{HEJ, LO}}|^2 |\mathcal{M}_{\text{HEJ}}|^2}{|\mathcal{M}_{\text{HEJ, LO}}|^2} = |\mathcal{M}_{\text{HEJ}}|^2$
- Subleading corrections beyond FKL
  e.g. unordered emissions $j_{\text{uno}} =$ 
- Finite quark-mass effects

Results

Invariant mass distribution



$\mu = H_T/2$



$\mu = \max(m_{j_1j_2}, m_h)$

σ_{HEJ} rescaled to σ_{NLO}

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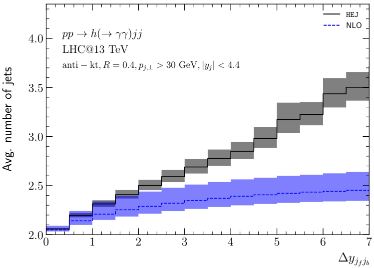
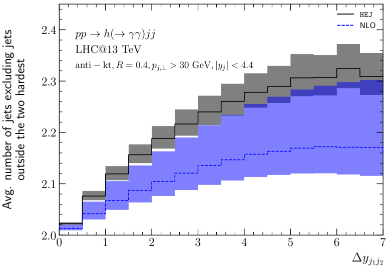
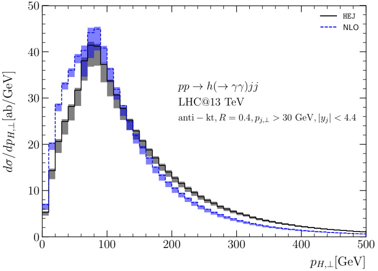
Jet multiplicity

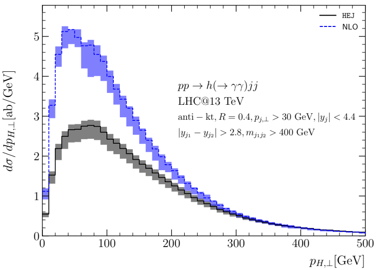




Higgs transverse momentum distribution



inclusive



WBF cuts

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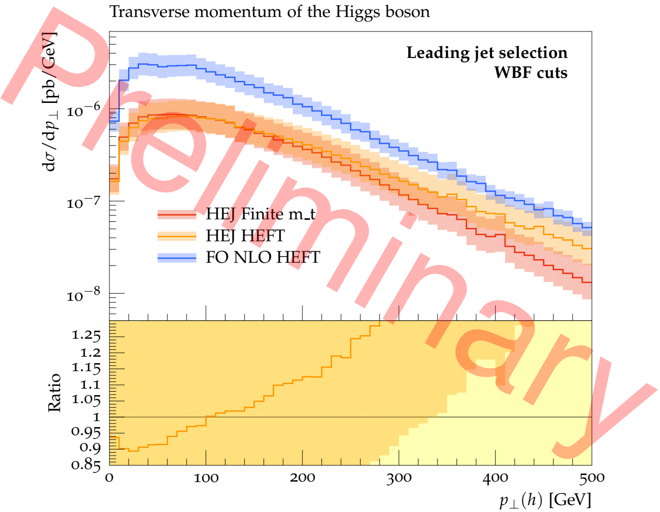
Higgs transverse momentum distribution

Quark mass effects



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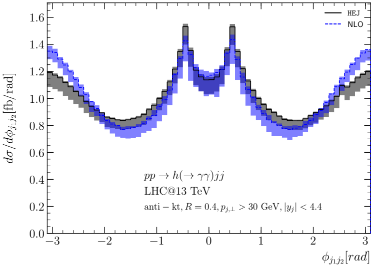
Angular separation



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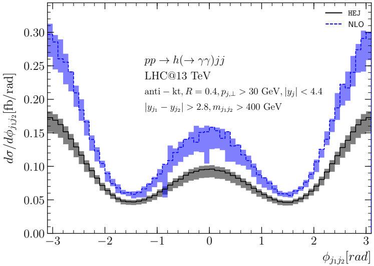

WBF cuts

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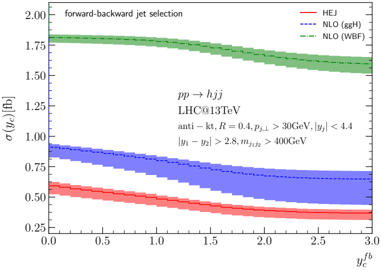
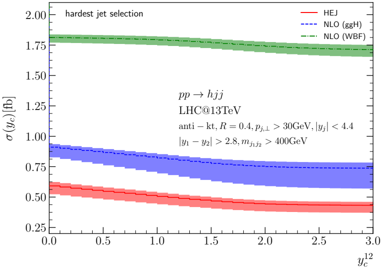
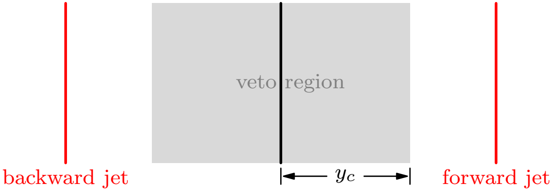
Jet veto efficiency

[Rainwater, Szalapski, Zeppenfeld 1996]







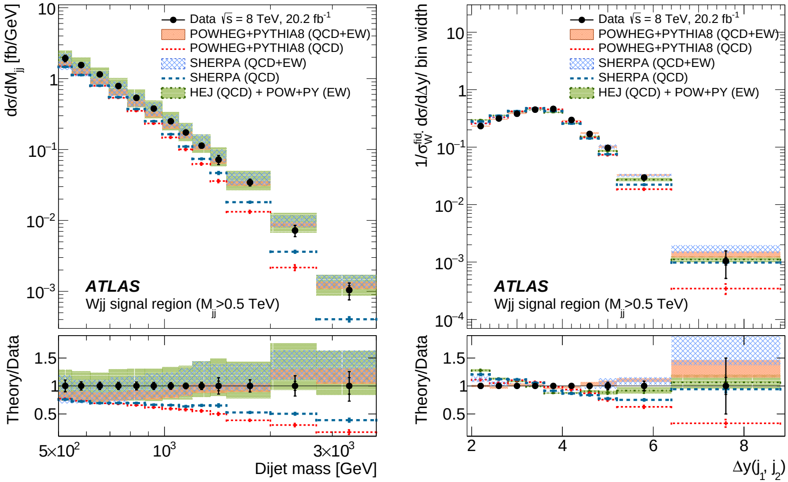
Conclusion

- Need good prediction for $H+$ jets in WBF region *now*
- High-energy resummation has significant effects
- Work in progress:
  - NLO matching at event level
  - Combination with parton shower [Andersen, Brooks, Lönnblad 2017]
- Benchmark HEJ processes: W, Z/γ + jets

Backup

Comparison for $W + jets$

[arXiv:1703.04362]



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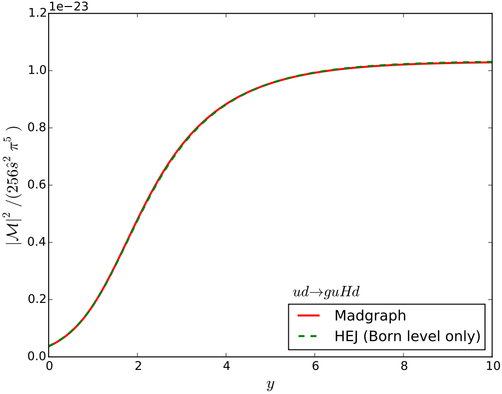
Comparison to leading-order matrix element



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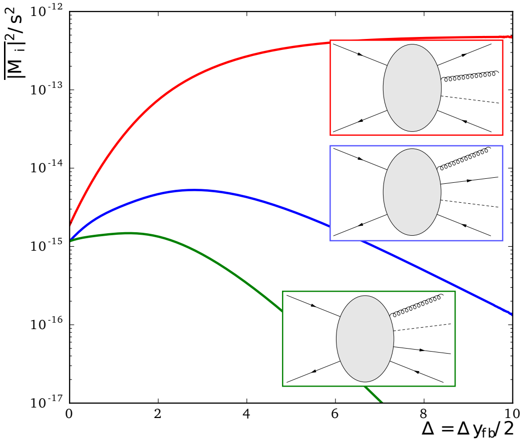
Scaling of matrix element



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