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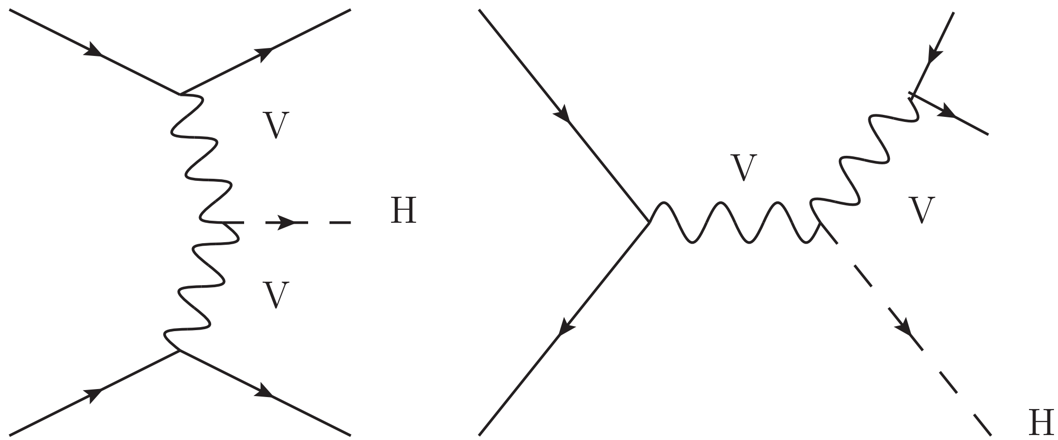


Parton-Shower Effects in Higgs Production via Vector-Boson Fusion

Work done in collaboration with Barbara Jäger, Alexander Karlberg, Simon Plätzer and Marco Zaro (Eur. Phys. J. C 80 (2020) 8, 756)

28.04.2021, Johannes Scheller

SM@LHC 2021

Setup

- Consider the VBF-Higgs process $pp \to Hjj$ at $\mathcal{O}(\alpha_{\text{em}}) = 3$ and $\mathcal{O}(\alpha_s) = 0$ (plus NLO corrections)
- Within VBF approximation
- $\sqrt{s} = 13$ TeV, PDF set: `PDF4LHC15_nnlo_100_pdfas` (`LHAPDF ID=91200`)
- Relatively tight VBF cut set:

$$|y_j| < 4.5, \quad p_{T,j} > 25\,\text{GeV}$$
$$m_{jj} > 600\,\text{GeV}, \quad |\Delta y_{j_1 j_2}| > 4.5, \quad y_{j_1} \cdot y_{j_2} < 0$$

- Jets defined with anti-k_t algorithm ($R = 0.4$)
- no hadronisation or underlying event effects considered!

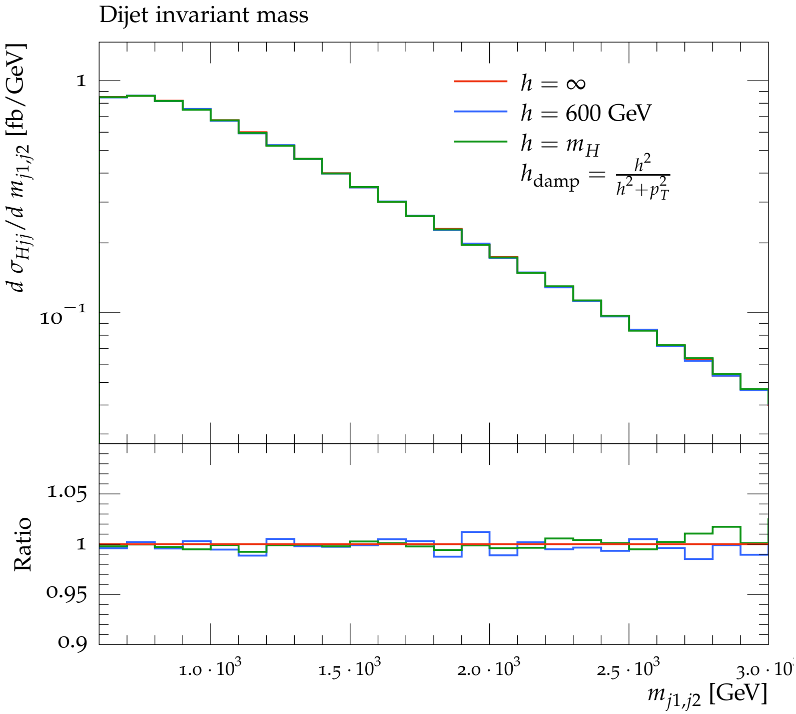
Setup

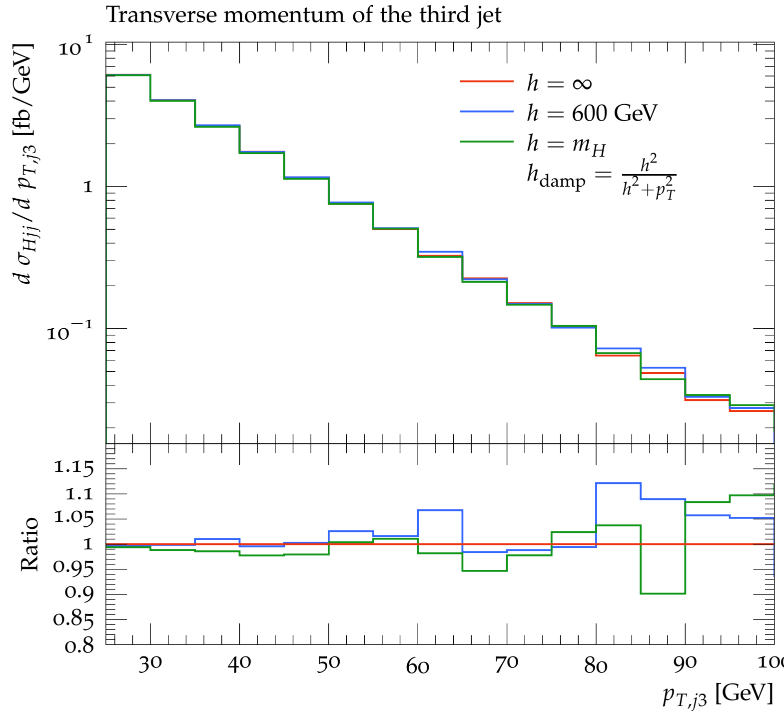
Possible variations:

- Generator
- Matching scheme (MC@NLO ($\oplus$) or POWHEG ($\otimes$) style)
- Shower (SMC program, angular vs. dipole)
- Recoil (global vs. local)
- Intrinsic generator variables, scales...

generator	matching	SMC	shower recoil	used in comparison
VBFNLO+Herwig7/Matchbox	$\oplus$	HERWIG 7.1.5	global ($\tilde{q}$) / local (dipole)	✓($\tilde{q}$)
HJets+Herwig7/Matchbox	$\oplus$	HERWIG 7.1.5	global ($\tilde{q}$) / local (dipole)	
MadGraph5_aMC@NLO 2.6.1	$\oplus$	HERWIG 7.1.2	global	✓
MadGraph5_aMC@NLO 2.6.1	$\oplus$	PYTHIA 8.230	global	
POWHEG-BOX V2	$\otimes$	PYTHIA 8.240	local (dipole)	✓
POWHEG-BOX V2	$\otimes$	PYTHIA 8.240	global	
POWHEG-BOX V2	$\otimes$	HERWIG 7.1.4	global ($\tilde{q}$)	

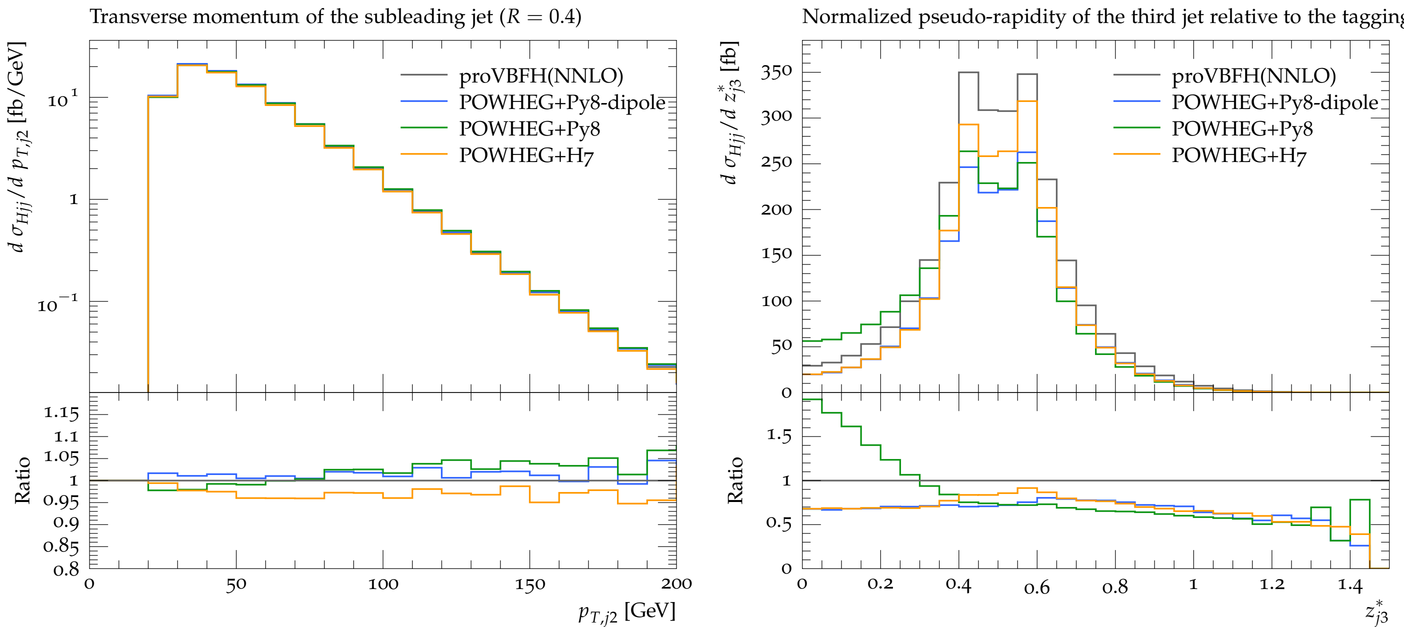
POWHEG-BOX





- Intrinsic uncertainties assessed by variation of SMC and `hdamp` parameter with $\texttt{hdamp} = \frac{h^2}{h^2+p_T^2}$
- Nearly no influence of `hdamp` variation

POWHEG-BOX



- Matching to HERWIG and PYTHIA8, the latter one with default global recoil and local (dipole) recoil
- Only small differences for hard observables
- Larger differences in third jet observables

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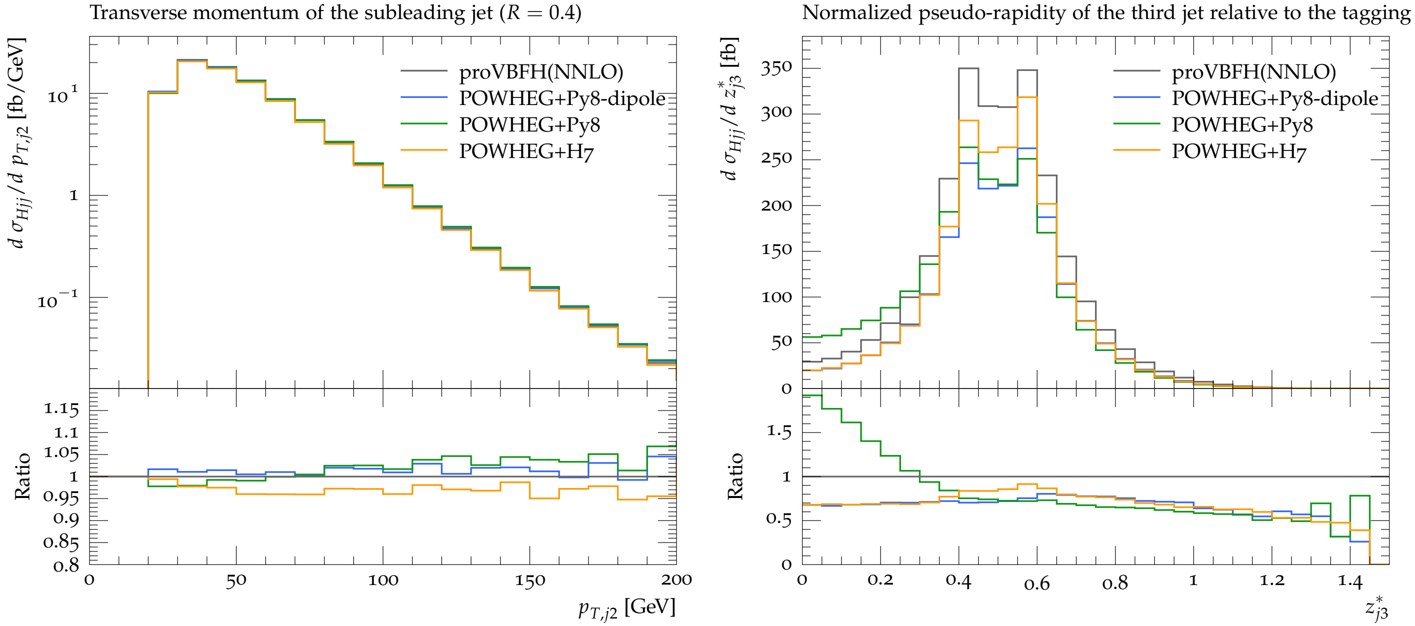
POWHEG-BOX



- Matching to HERWIG and PYTHIA8, the latter one with default global recoil and local (dipole) recoil
- Only small differences for hard observables

$$z^*_{j3} = \frac{\eta_{j3} - \frac{\eta_{j1} - \eta_{j2}}{2}}{|\Delta\eta_{j1j2}|}$$

Best Predictions

generator	matching	SMC	shower recoil	used in comparison
VBFNLO+Herwig7/Matchbox	$\oplus$	HERWIG 7.1.5	global ($\tilde{q}$) / local (dipole)	✓($\tilde{q}$)
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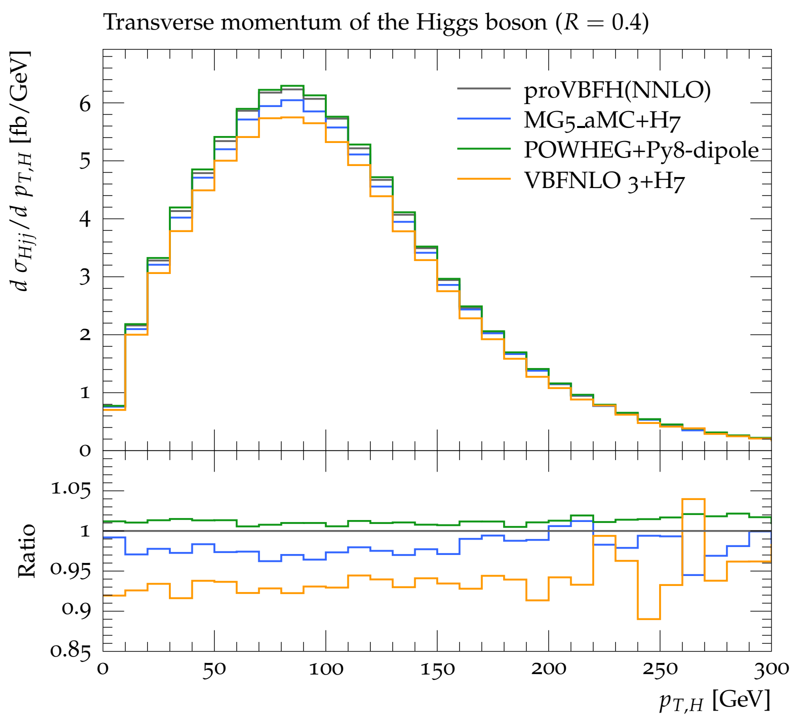
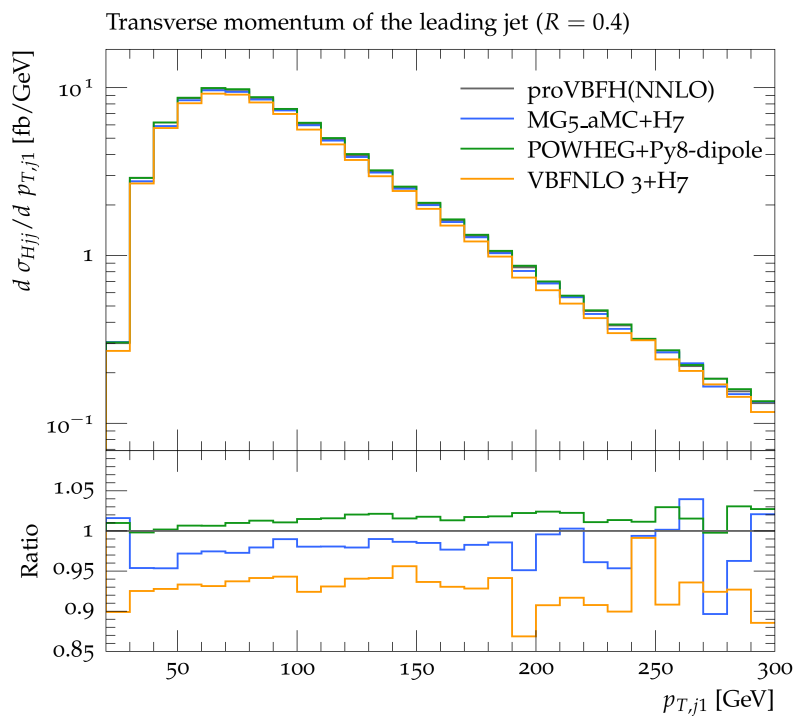
POWHEG-BOX V2	$\otimes$	HERWIG 7.1.4	global ($\tilde{q}$)	

Now: compare 'best' setups, selected based on the results shown before.
We compare to a fixed-order NNLO calculation by proVBFH

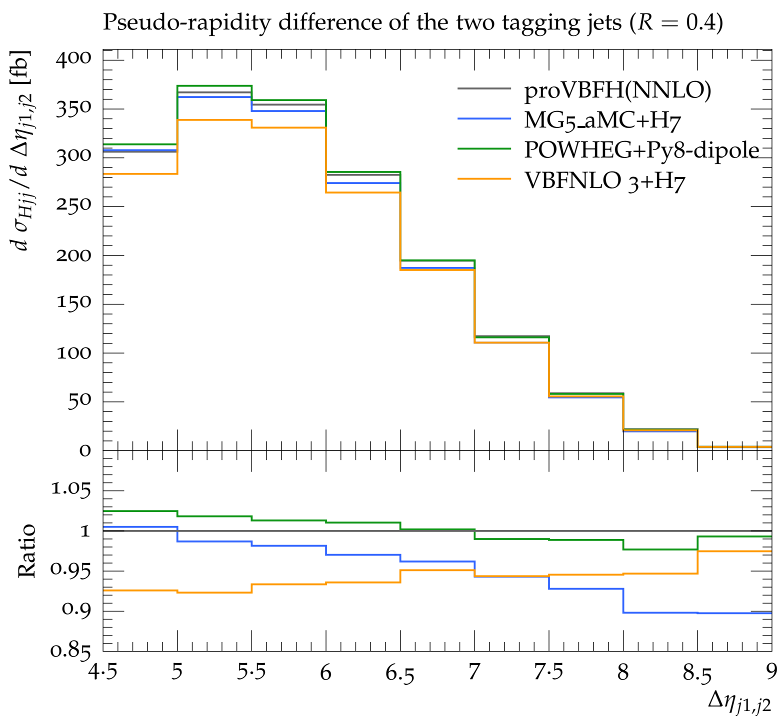
Comparing All Generators

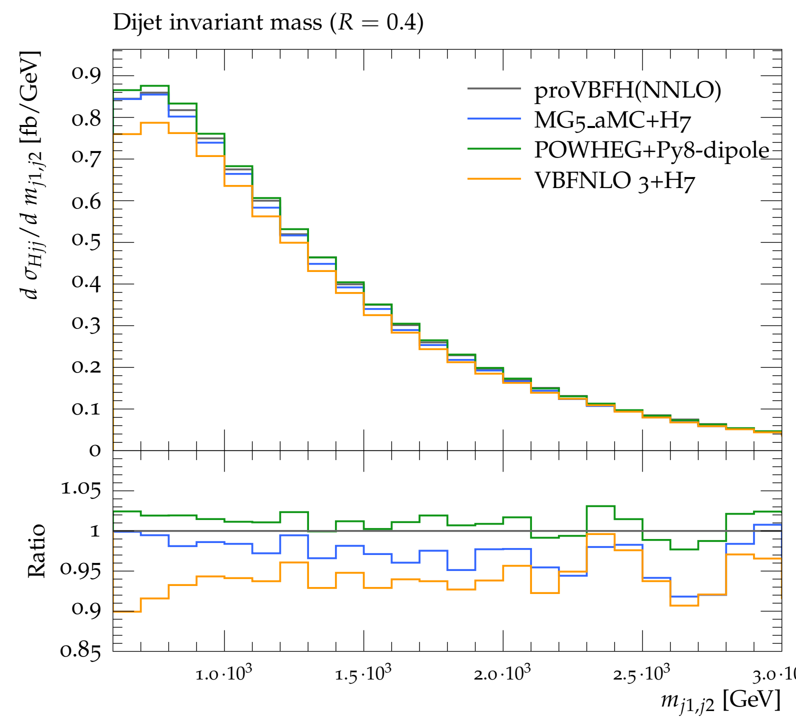




- For very inclusive quantities: nearly only differences in normalization
- Very similar shapes

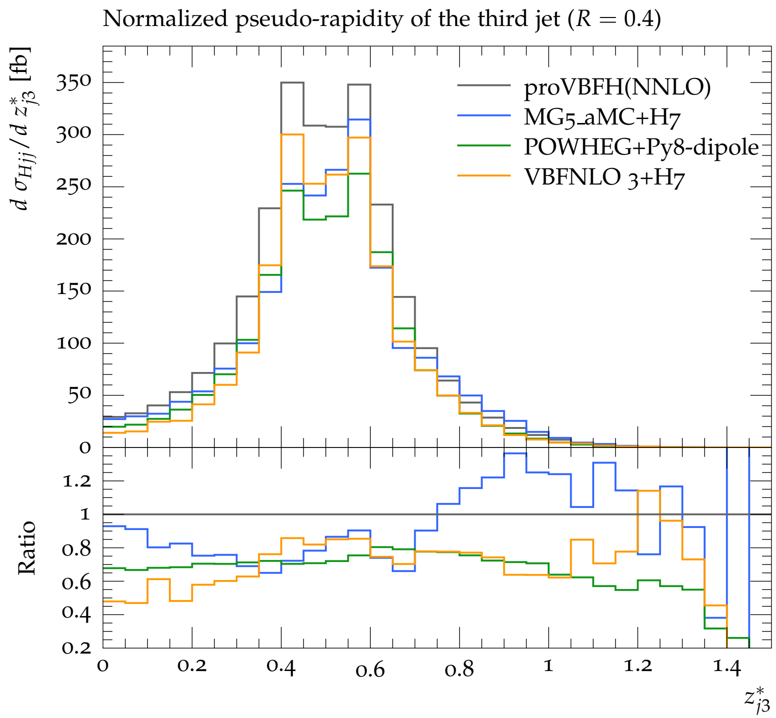
Comparing All Generators

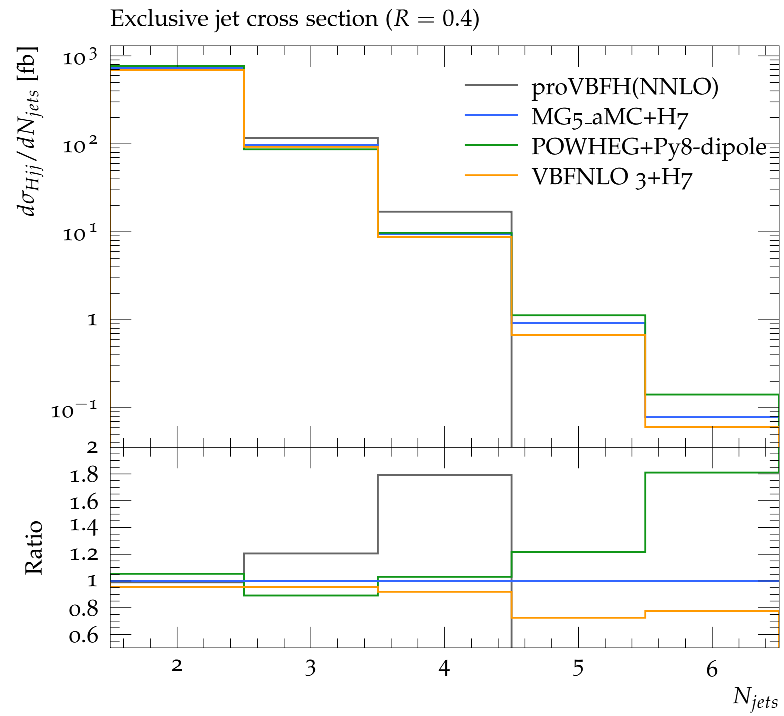




- For typical VBF observables: some shape differences at $\mathcal{O}(10\%)$
- Still dominated by differences in normalization

Best Predictions: Third Jet Observables





- Much larger discrepancies for higher jet multiplicities
- NLO accuracy only for the two hardest jets

Conclusions and Recommendations

- First comprehensive study of parton shower effects in VBF
- Only small dependence on matching prescription
- More significant differences between different SMCs, mainly in normalization
- Prefer local dipole shower over (default) global recoil within `PYTHIA8`
- Uncertainties of third jet observables at $\sim 20\%$
- Possible future studies: include MPI/UE, study radius dependence, comprehensive study of $H + 3J$

Thank you!

Questions?

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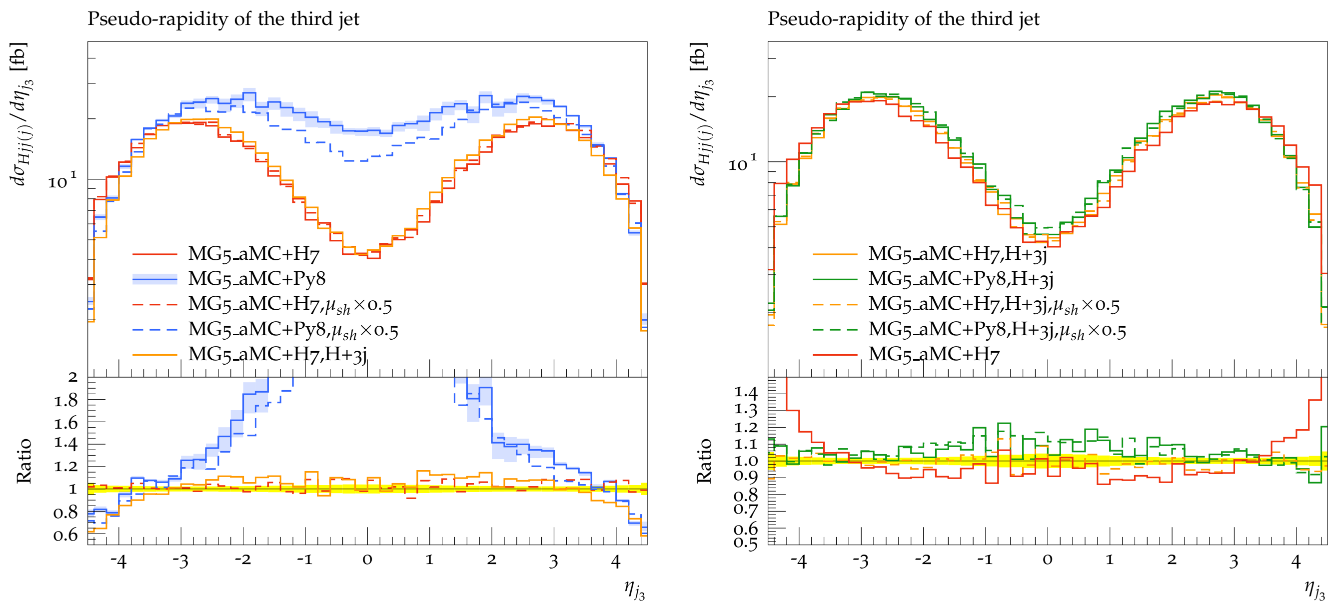
Backup: The Recoil Schemes in Pythia8

- PYTHIA8 offers two different recoil schemes
- (Default) global recoil scheme: valid, if no color flow between IS and FS (e.g. Drell-Yan)
- New dipole approach with local recoil: for processes with initial-final color flow, e.g. DIS
- VBF: no color connection between incoming partons $\Rightarrow$ global distribution of recoil clearly unphysical
- POWHEG-BOX V2 can be interfaced to both recoil schemes, MadGraph5_aMC@NLO only to default scheme

Backup: MG5_aMC and the Pythia8 Recoil Schemes



- Huge discrepancies outside of scale variation, especially in central rapidity region
- Very good agreement with `HERWIG7` results when moving to VBF-$H + 3J$

  $\rightarrow$ `PYTHIA8` matching clearly gives unphysical results!

