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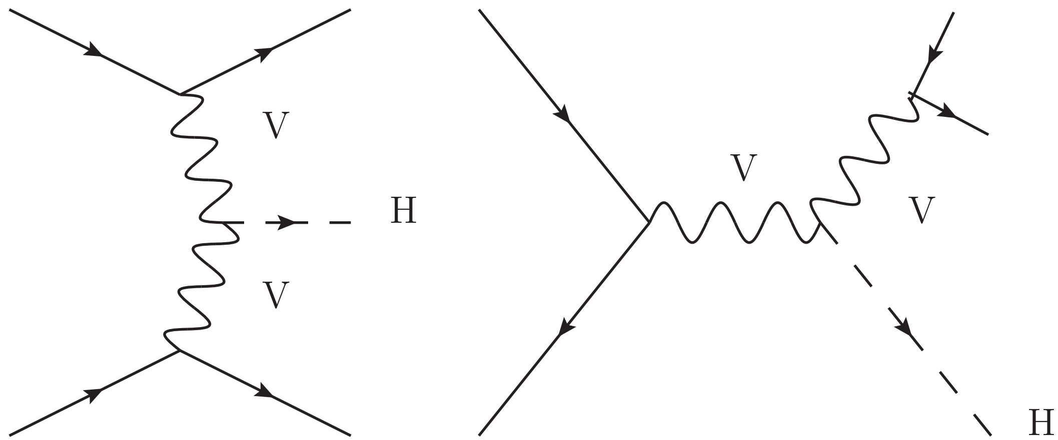



# Parton-Shower Effects in Higgs Production via Vector-Boson Fusion

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

**26.07.2021, Johannes Scheller**

EPS-HEP2021
Online Conference

# Outline

- The VBF-H Process
- Setup of the Calculation & Procedure
- Discussion of Generator-Specific Uncertainties (Example: POWHEG-BOX)
- Comparison of the different generators

# The VBF Approximation

- Consider the process $pp \to Hjj$ at $\mathcal{O}(\alpha_{\mathrm{em}}) = 3$ and $\mathcal{O}(\alpha_{\mathrm{s}}) = 0$ (plus NLO corrections)
- VBF approximation: neglect $s$-channel contributions, as well as interference between $t$- and $u$-channel
- No color exchange between quark lines
- Distinct experimental signature (low jet activity between tagging jets)
- Valid up to the percent level within appropriate cuts (!)
- Theory uncertainties dominating in VBF channel, little knowledge of PS uncertainties

# Setup

- Consider $pp$ scattering at the LHC with $\sqrt{s} = 13\,\text{TeV}$
- 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

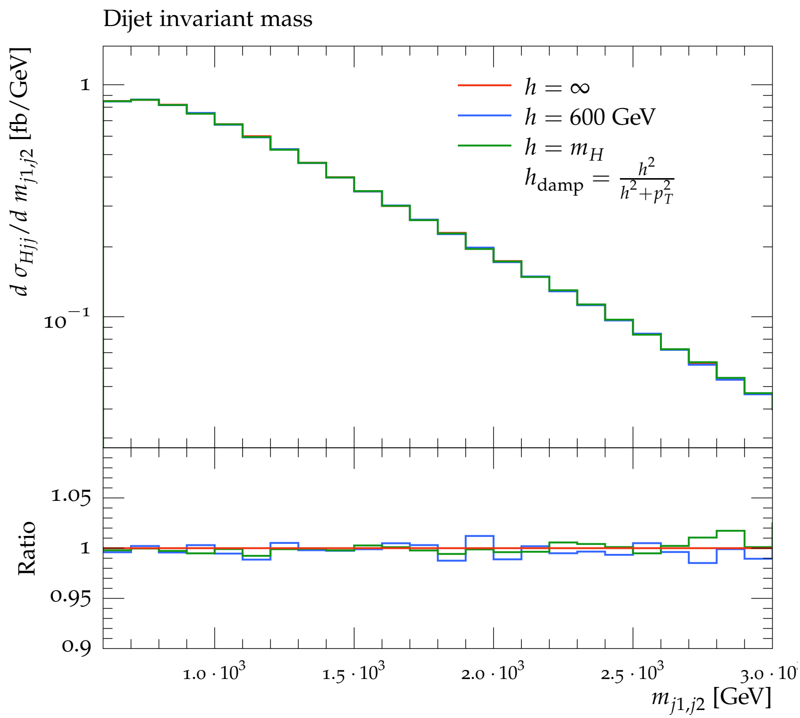
Possible variations:

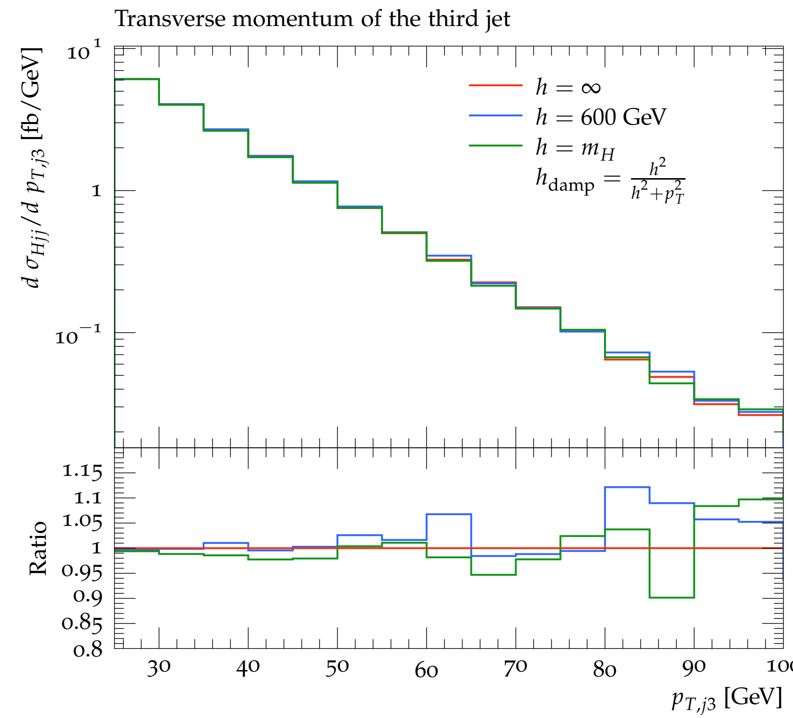
- Generator
- Matching scheme (MC@NLO ($\oplus$) or POWHEG ($\otimes$) style)
- Shower (SMC program, angular vs. dipole)
- Recoil (global vs. local)
- Intrinsic generator variables, scales...

| 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 `hdamp` $= \frac{h^2}{h^2+p_T^2}$
- Nearly no influence of `hdamp` variation

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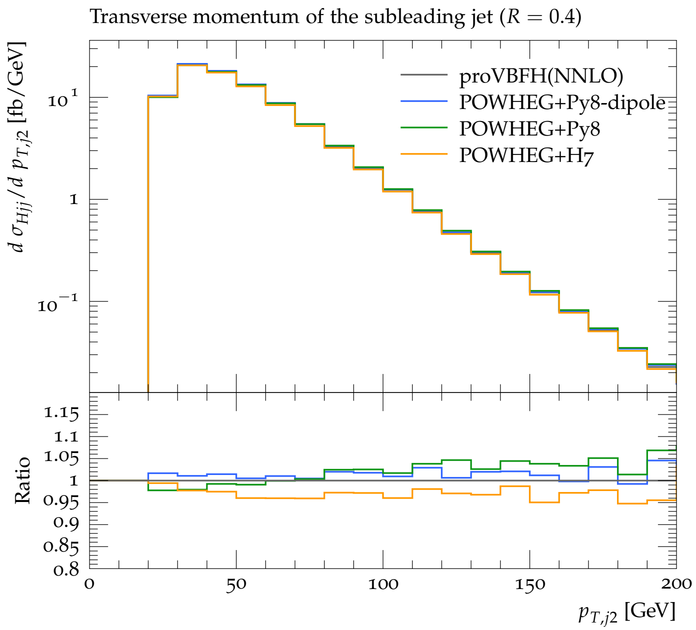
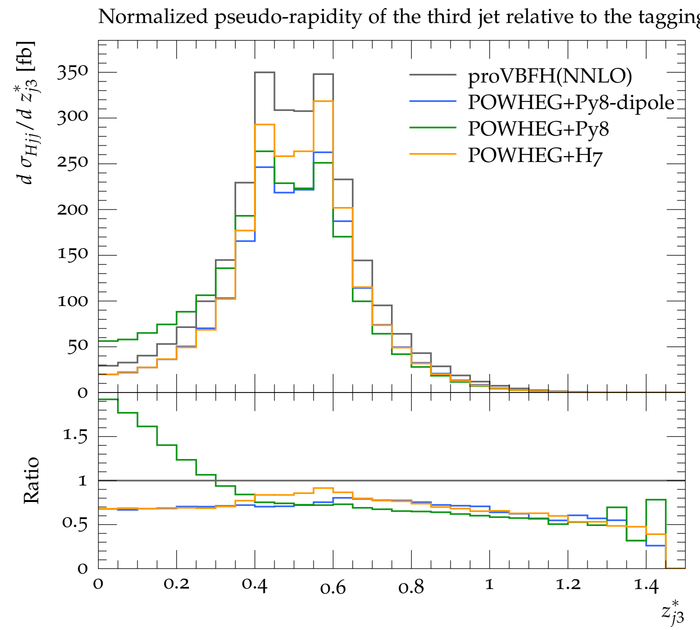
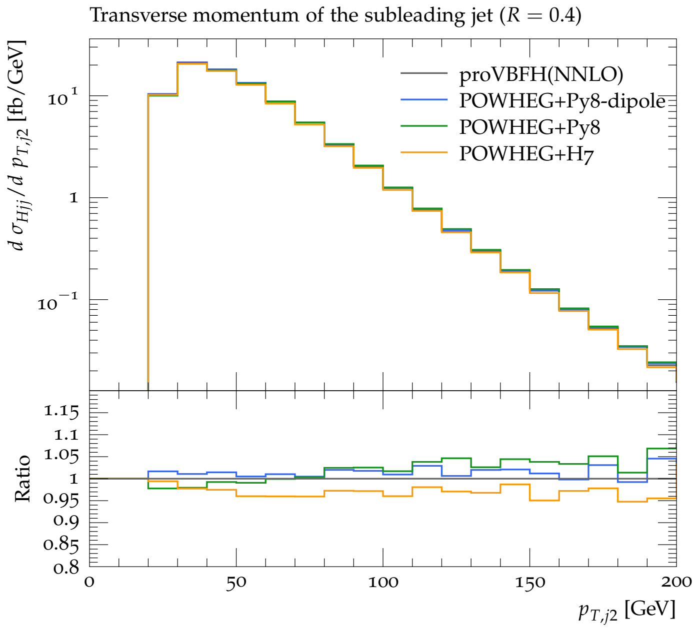
# POWHEG-BOX

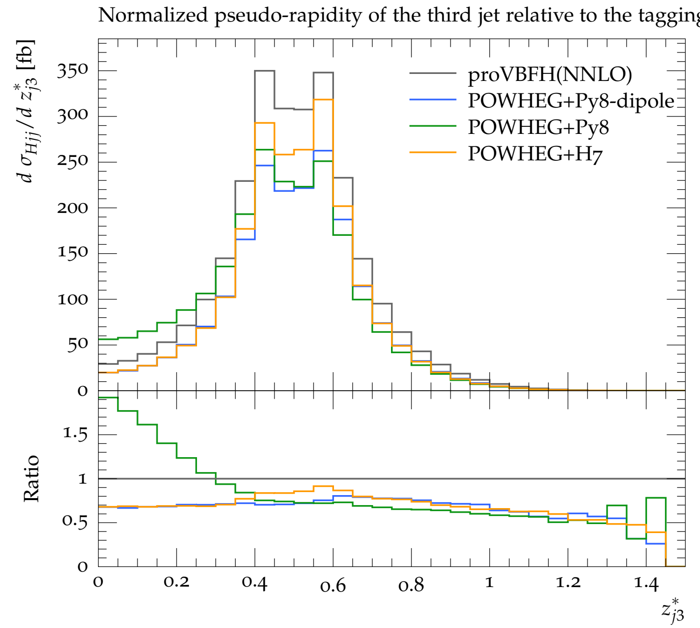



- Matching to HERWIG and PYTHIA8, the latter one with default global recoil and local (dipole) recoil
- Only small differences for hard observables
- Larger differences in third jet observables

# POWHEG-BOX




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

$$z^*_{j3} = \frac{\eta_{j3} - \frac{\eta_{j_1} - \eta_{j_2}}{2}}{|\Delta\eta_{j_1 j_2}|}$$

# 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

# Best Predictions

| generator | matching | SMC | shower recoil | used in comparison |
|---|---|---|---|---|
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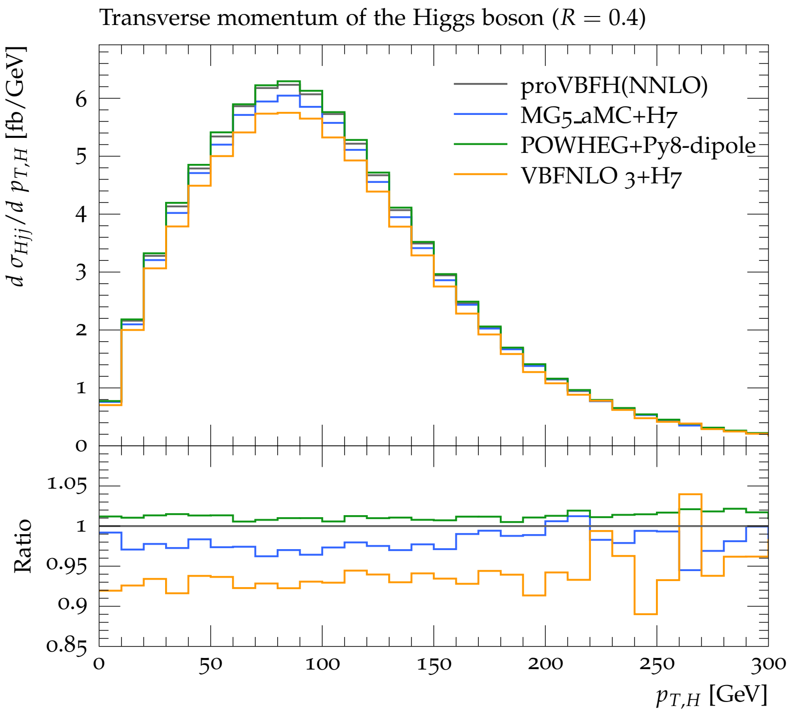
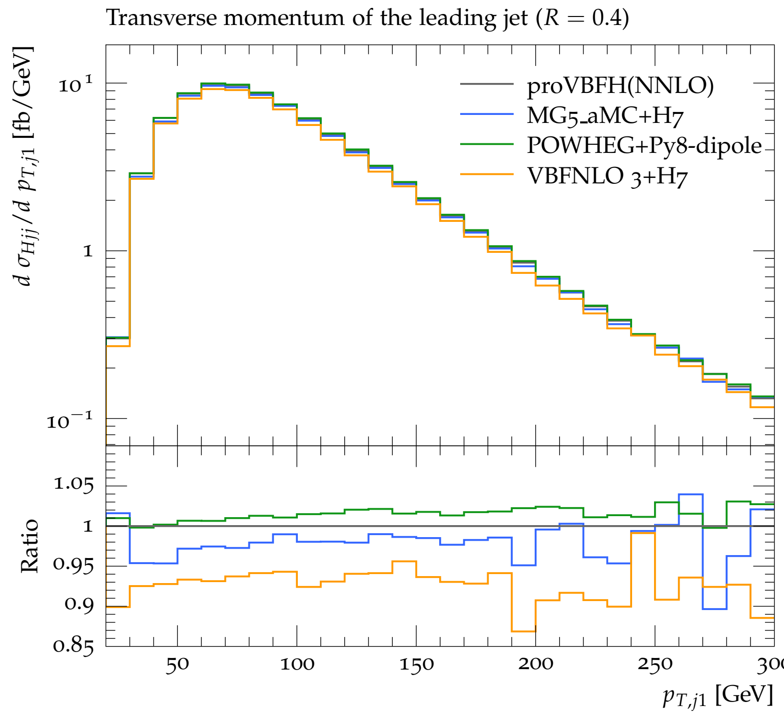
Now: compare 'best' setups, selected based on the results shown before.
We compare to a fixed-order NNLO calculation by proVBFH

# Comparing All Generators

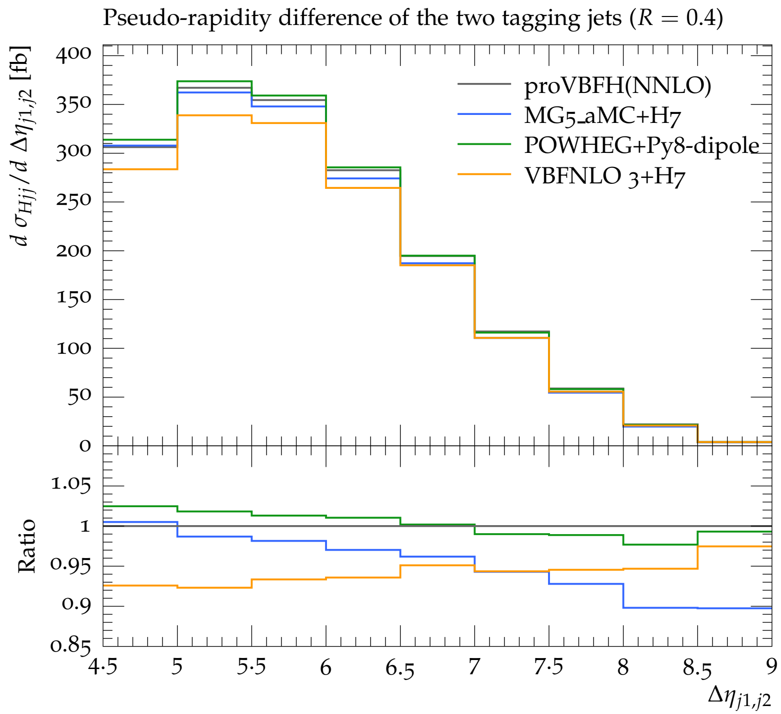


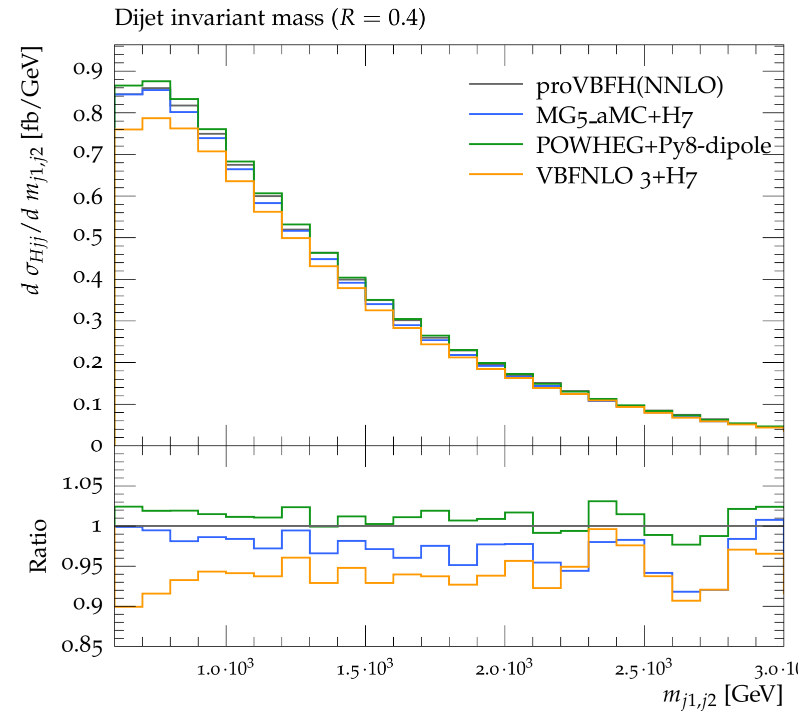




- For very inclusive quantities: nearly only differences in normalization
- Very similar shapes

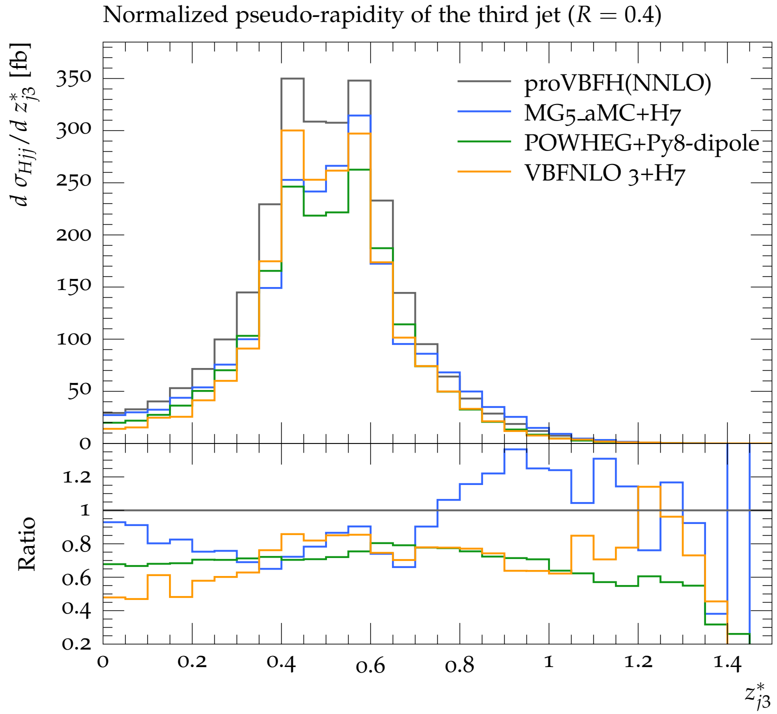
# Comparing All Generators

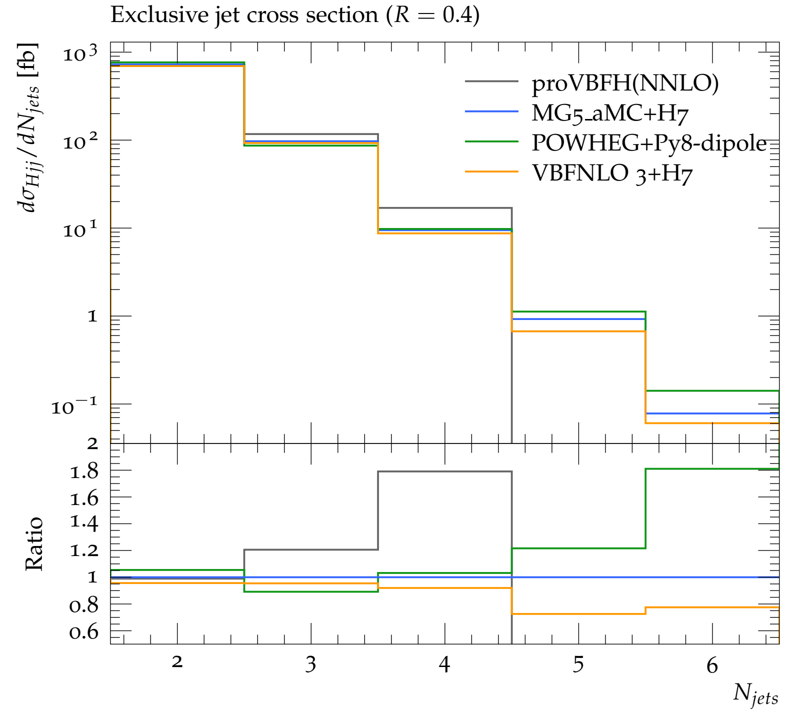



- For typical VBF observables: some shape differences at $\mathcal{O}(10\%)$
- Still dominated by differences in normalization

# Best Predictions: Third Jet Observables




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

# Conclusions and Recommendations

- Comprehensive study of parton shower effects in VBF
- Only small dependence on matching prescription
- More significant differences between different SMCs, mainly in normalization
- Uncertainties of third jet observables at $\sim 20\%$
- Possible future studies: include MPI/UE, study radius dependence, comprehensive study of $H+3J$
- See also: 2105.11399 and 2106.10987

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# Thank you!

Questions?

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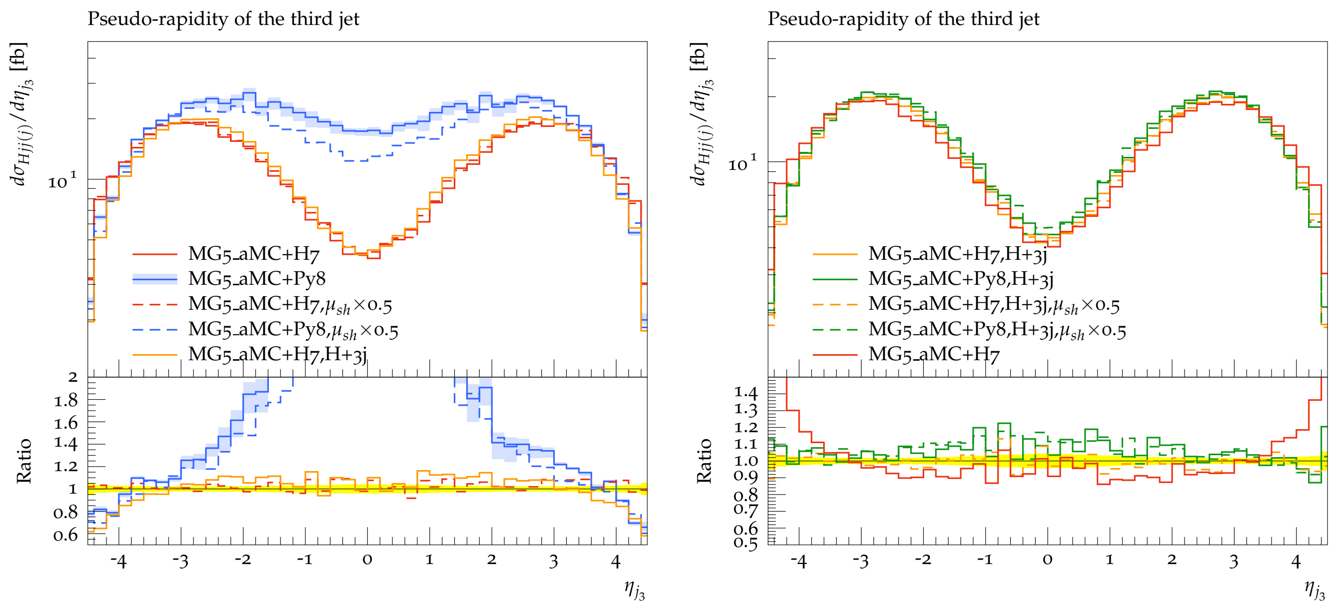
# Backup: MG5_aMC and the Pythia8 Recoil Schemes




- 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!