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# Update on VBF parton shower studies

Simon Plätzer

Particle Physics, University of Vienna

at the  
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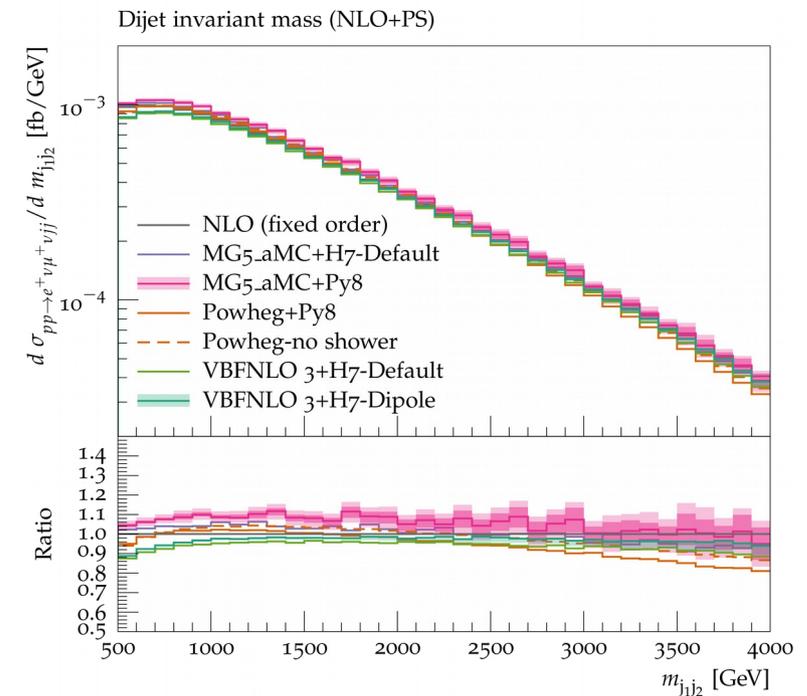
Parton shower and soft QCD effects addressed in detail for VBS → get VBF at a similar level.

No first-principles approach to shower uncertainties → **comparison of different algorithms is vital.**

- Coherence approaches
- Recoil strategies
- Variation in hard scales
- Matching paradigms
  
- Impact of VBF approximation
- Tight versus loose setups, jet radius dependence

## Outline:

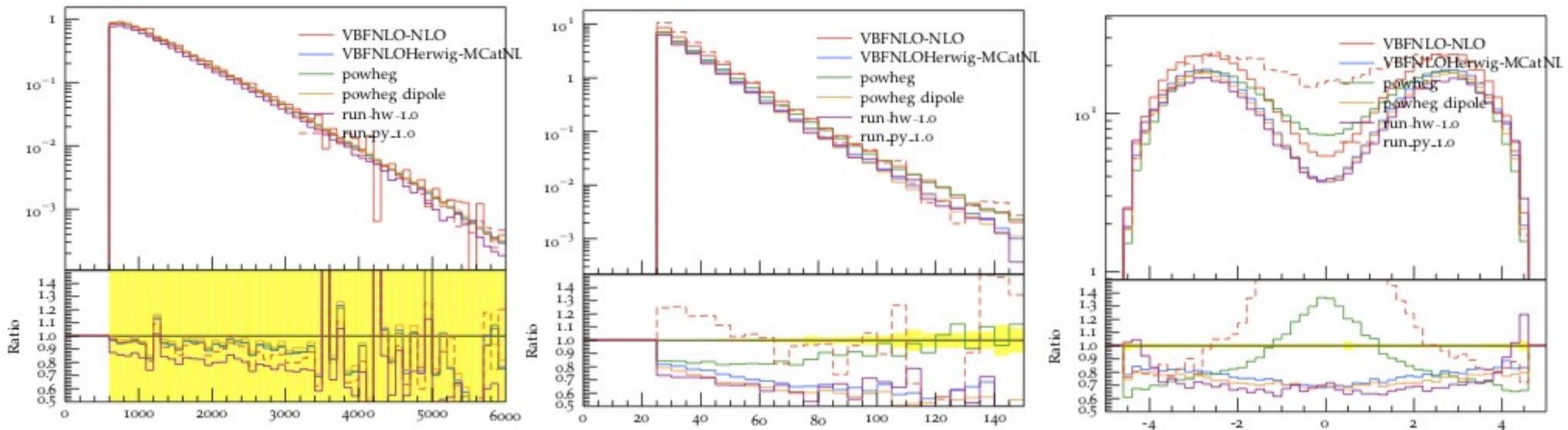
- Current status of the study and prospects for results, shower comparisons
- Shower variations, impact of VBF approximation, ...



[Rauch et al. For VBSCAN study – EPJ C78 (2018) 671]

In-depth comparison of:

- Herwig 7 Matchbox, MG5\_aMC and POWHEG based hard process for H+ 2 jets
- Herwig 7 and Pythia 8 showers, study **variations after all issues have been understood**



- Pythia dipole recoil improves description with respect to NLO, non-dipole recoil even problematic if first emission matched, dipole recoil not yet supported in MG5\_aMC
- Herwig angular ordered shower consistently lower cross sections, not for dipole shower

KINEMATIC LIMIT  $\sim S$   
HARD SCALE  $\sim M^2$   
HARD SCALE IN  $z$  PHASE SPACE

$$- \ln \Delta \sim \int_{P_2}^{P_1} \frac{dq_{\perp}^2}{q_{\perp}^2} K(Q_{\perp}^2, q_{\perp}^2) \ln \left( \frac{K_{\perp}^2}{q_{\perp}^2} \right)$$

↕  
CUTOFF ON RESUMMATION

Hard veto scale is one of the main sources of shower variations

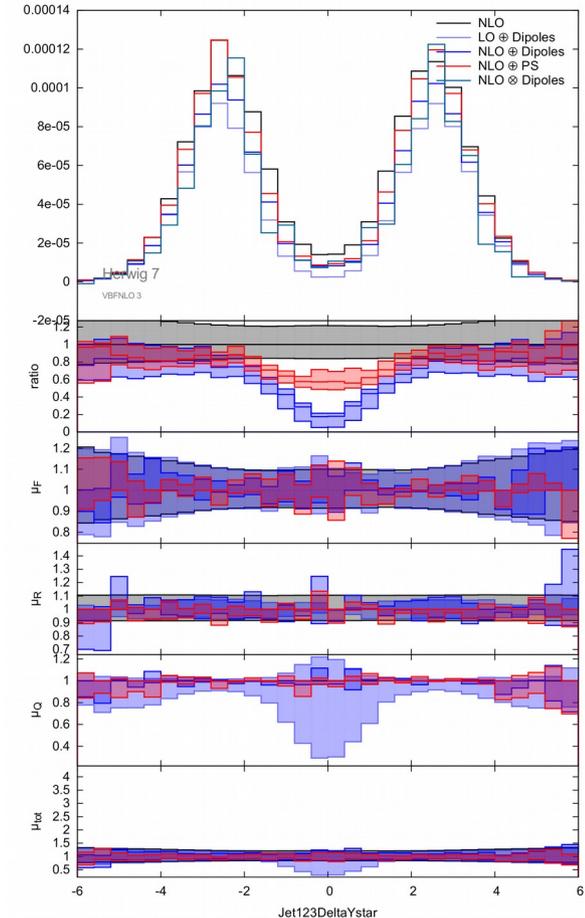
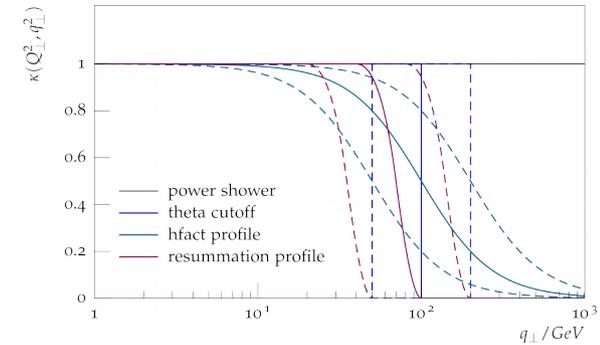
- Herwig profile scales, Powheg hdamp parameter, hard scale selection in MG5\_aMC:

Probes phasespace where shower becomes unreliable, significant improvements through matching with NLO.

[Bellm, Nail, Plätzer, Schichtel, Siodmok – EPJ C76 (2016) 665]

[Rauch, Plätzer – EPJ C77 (2017) 293]

**Impact on jets** is in **hardness of emissions, jet multiplicities.**



[Jäger, Karlberg, Plätzer, Scheller, Zaro – work in progress]

Assess impact of VBF approximation:

- Herwig 7 provides interfaces to **VBFNLO** and **HJets**:  
Full calculation available for H+2jet and H+3jet production at NLO QCD

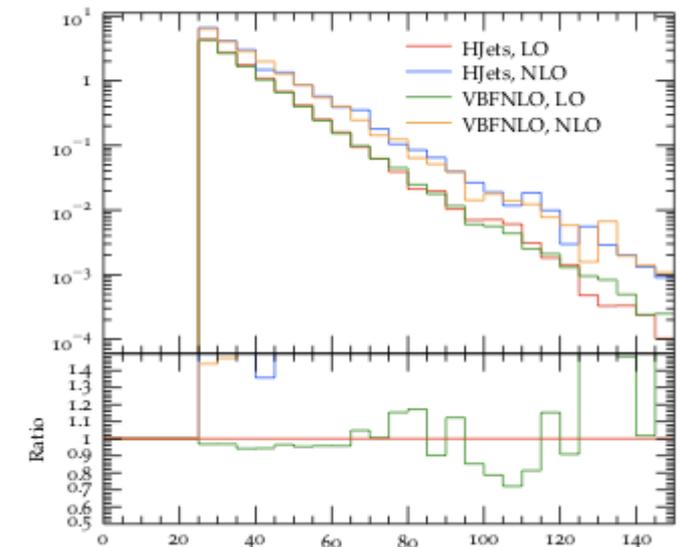
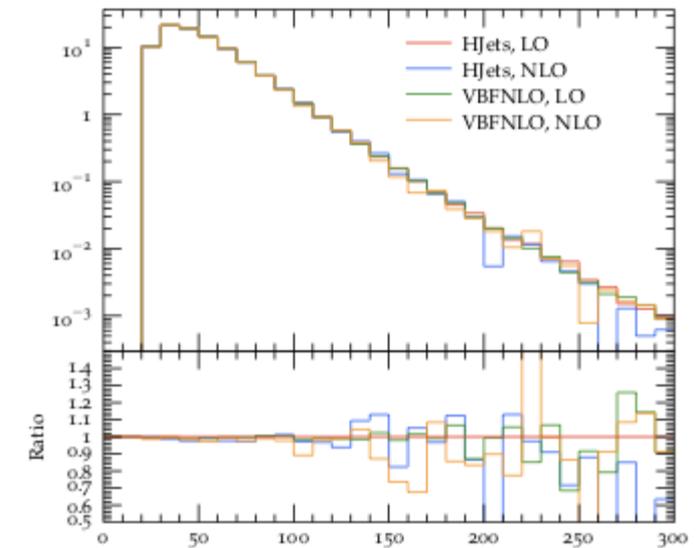
[Campanario, Figy, Plätzer, Sjö Dahl – PRL 111 (2013) 211802]

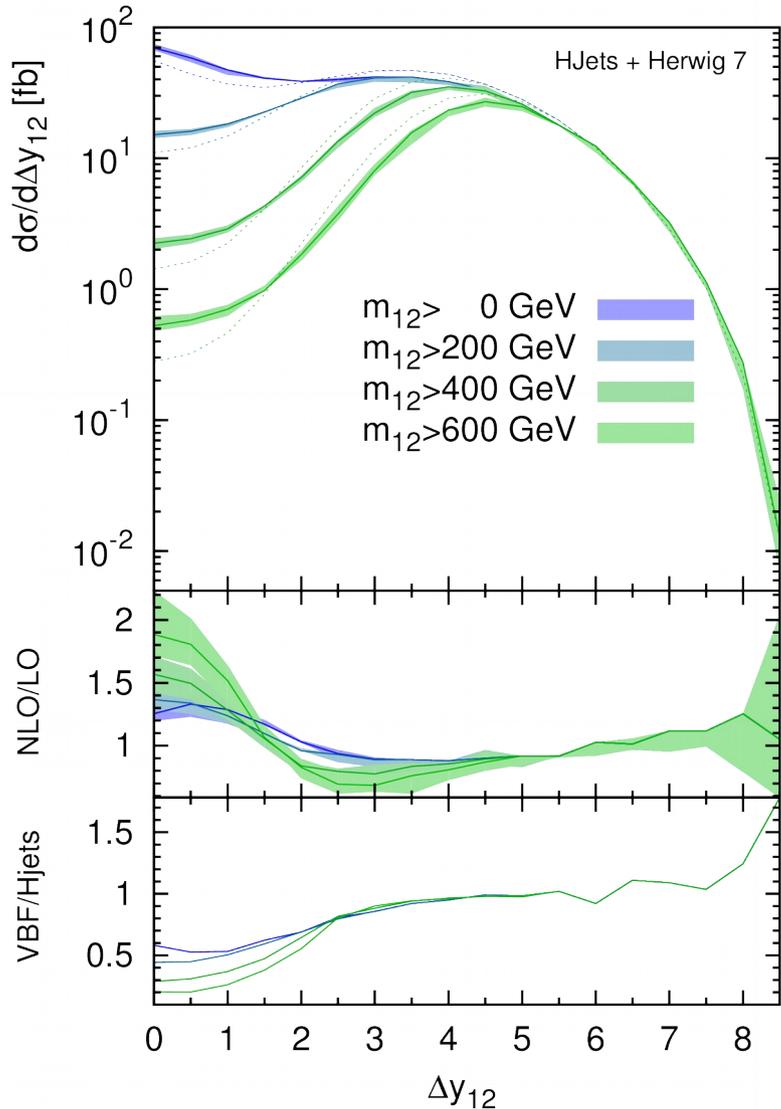
- Can compare fixed-order and NLO+PS
- Comparison outside of tight VBF selection requires additional s-channel component together with VBF approximated result

Little impact for tight VBF selection, more significant changes in inclusive selections.

Combination of VBF approximated calculations with “VH”:

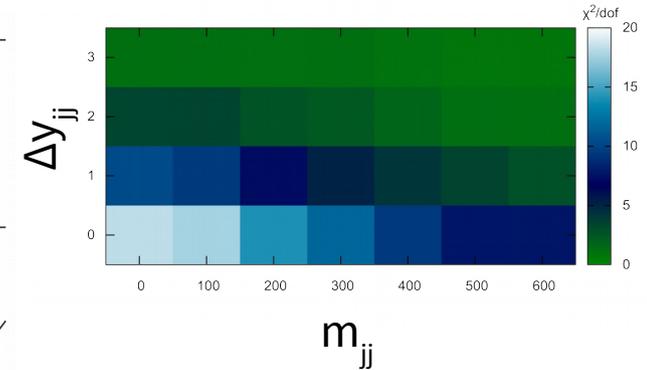
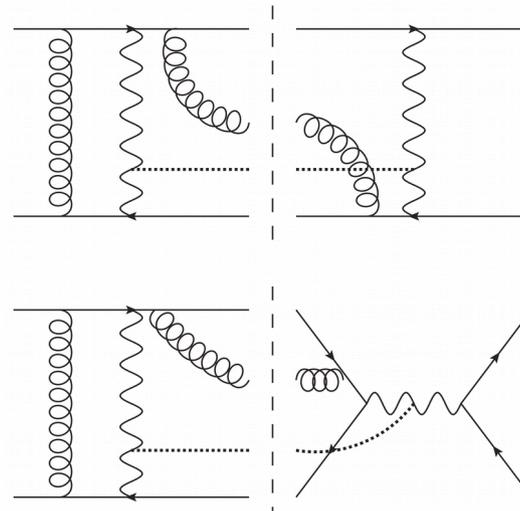
- Neglecting the interference alone includes off-shell VH contributions which can be large
- Estimate using full calculation with veto on W/Z masses in jet invariant masses





Outside of tight VBF selection: **presence and mixing of different colour flows** changes large-angle (soft) radiation pattern.

Shower initial conditions even more delicate, including presence of matching.



summary of 3<sup>rd</sup> jet observables vs VBF approximation

Detailed study of parton showers and matching in progress for VBF Higgs production.

No a priori recipe to assign parton shower uncertainties, calls for comparison of different algorithms and variations therein – matching required for proper modeling of hard jets.

Matching paradigms and hard scale variations, impact of jet radii, VBF selection and VBF approximation, prediction of third-jet properties, ...

Thank you!