Comparison of tools for VBS simulation: status and future plans

Marco Zaro

In collaboration with
Michele Grossi, Alexander Karlberg, Mathieu Pellen, Giovanni Pellicioli,
Michael Rauch, Vincent Rothe, Christopher Schwan, Pascal Stienemeier

Nikhef

NWO
Netherlands Organisation
for Scientific Research

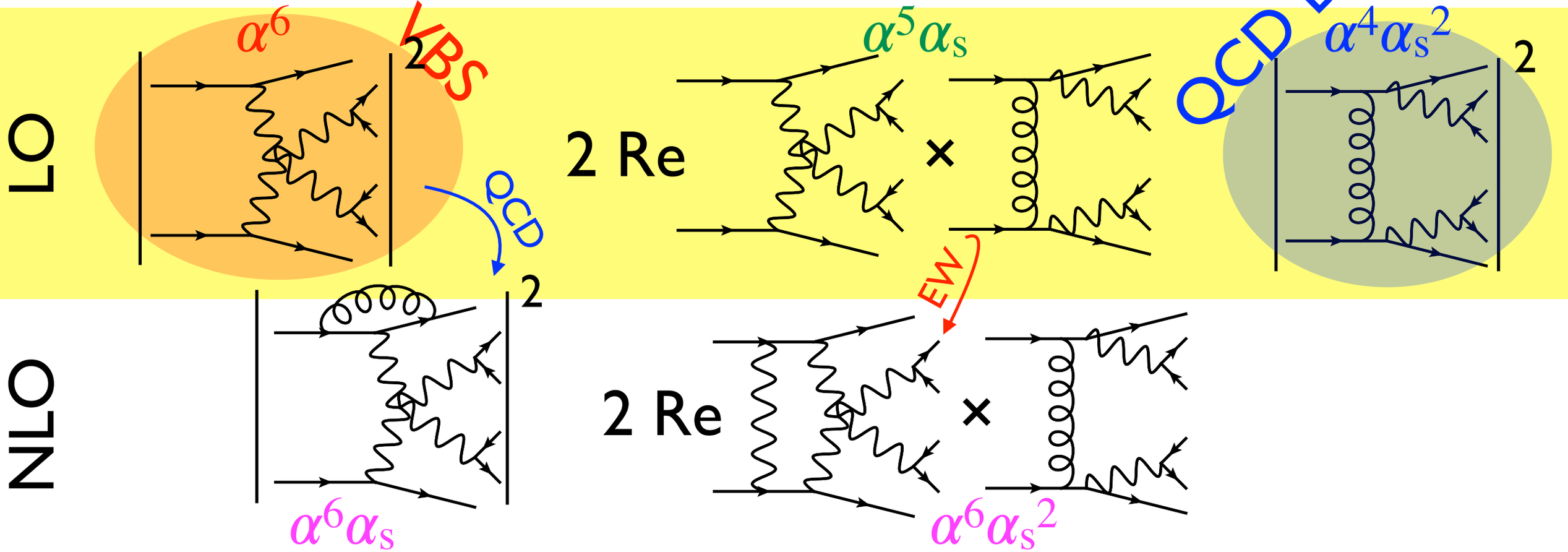
Plan

- Compare the various tools/generators that can be used for VBS simulations
- Comparison are performed at different levels of complexity: LO, NLO QCD, NLO QCD+PS, NLO EW, …
- Process to consider: $pp \to e^+\mu^+\nu\nu jj$
- We do not just want to check that generators agree; we want to see if/how the different approximations that are used have an impact on the phenomenological results

Anatomy of radiative corrections in VBS

More in Mathieu's talk

- The production of two vector bosons and two jets can proceed via different order combinations



Setup, cuts and parameters

- Couplings, masses and widths

$$G_\mu = 1.16637 \times 10^{-5}\,\mathrm{GeV}$$

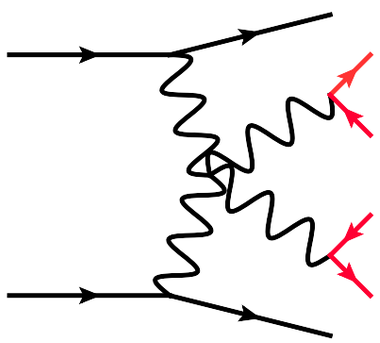
$$\alpha = \frac{\sqrt{2}}{\pi} G_\mu M_\mathrm{W}^2 \left(1 - \frac{M_\mathrm{W}^2}{M_\mathrm{Z}^2}\right)$$

$$\begin{aligned} m_\mathrm{t} &= 173.21\,\mathrm{GeV}, & \Gamma_\mathrm{t} &= 0\,\mathrm{GeV}, \\ M_\mathrm{Z}^\mathrm{OS} &= 91.1876\,\mathrm{GeV}, & \Gamma_\mathrm{Z}^\mathrm{OS} &= 2.4952\,\mathrm{GeV}, \\ M_\mathrm{W}^\mathrm{OS} &= 80.385\,\mathrm{GeV}, & \Gamma_\mathrm{W}^\mathrm{OS} &= 2.085\,\mathrm{GeV}, \\ M_\mathrm{H} &= 125.0\,\mathrm{GeV}, & \Gamma_\mathrm{H} &= 4.07 \times 10^{-3}\,\mathrm{GeV} \end{aligned}$$

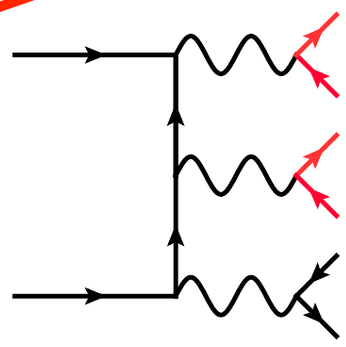
- NNPDF 3.0 PDFs $\alpha_s(M_Z)=0.118$, $\mu^2_{R/F}=p_T(j_1) \cdot p_T(j_2)$
- Selection cuts:
  - At least two (anti-k_T,R=0.4) jets with p_T>30 GeV, |y|<4.5, with jet-lepton distance ΔR_{jl}>0.3
  - The two hardest jet must have Δy>2.5, m_{jj}>500 GeV
  - Two leptons with p_T>20 GeV, |y|<2.5, E_T^{miss}>40 GeV
  - Lepton-lepton distance: ΔR_{ll}>0.3

People and code comparison

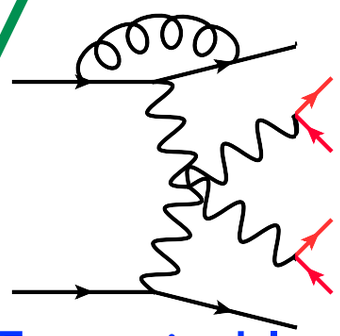
Contact person	Code	$\mathcal{O}(\alpha^6)$ $\lvert s\rvert^2/\lvert t\rvert^2/\lvert u\rvert^2$	$\mathcal{O}(\alpha^6)$ interf.	Non-res.	NF QCD	EW corr. to $\mathcal{O}(\alpha^5\alpha_s)$
A. Karlberg	POWHEG	t/u	No	Yes	No	No
M. Pellen	RECOLA+MOCANLO	Yes	Yes	Yes	Yes	Yes
M. Rauch	VBFNLO	Yes	No	Yes	No	No
C. Schwan	BONSAY	t/u	No	Yes, virt. No	No	No
M. Zaro	MG5_aMC	Yes	Yes	No virt.	No	No
V. Rothe	WHIZARD	Yes	Yes	Yes	Yes	Yes



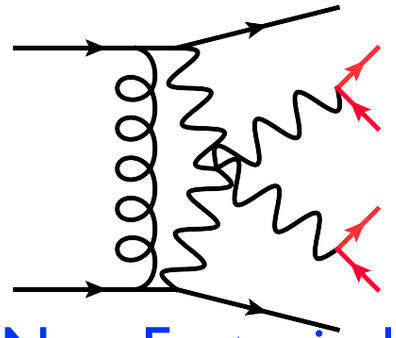
t-channel



s-channel

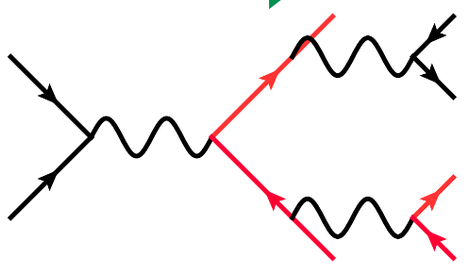


Factorizable QCD corr.



Non-Factorizable QCD corr.

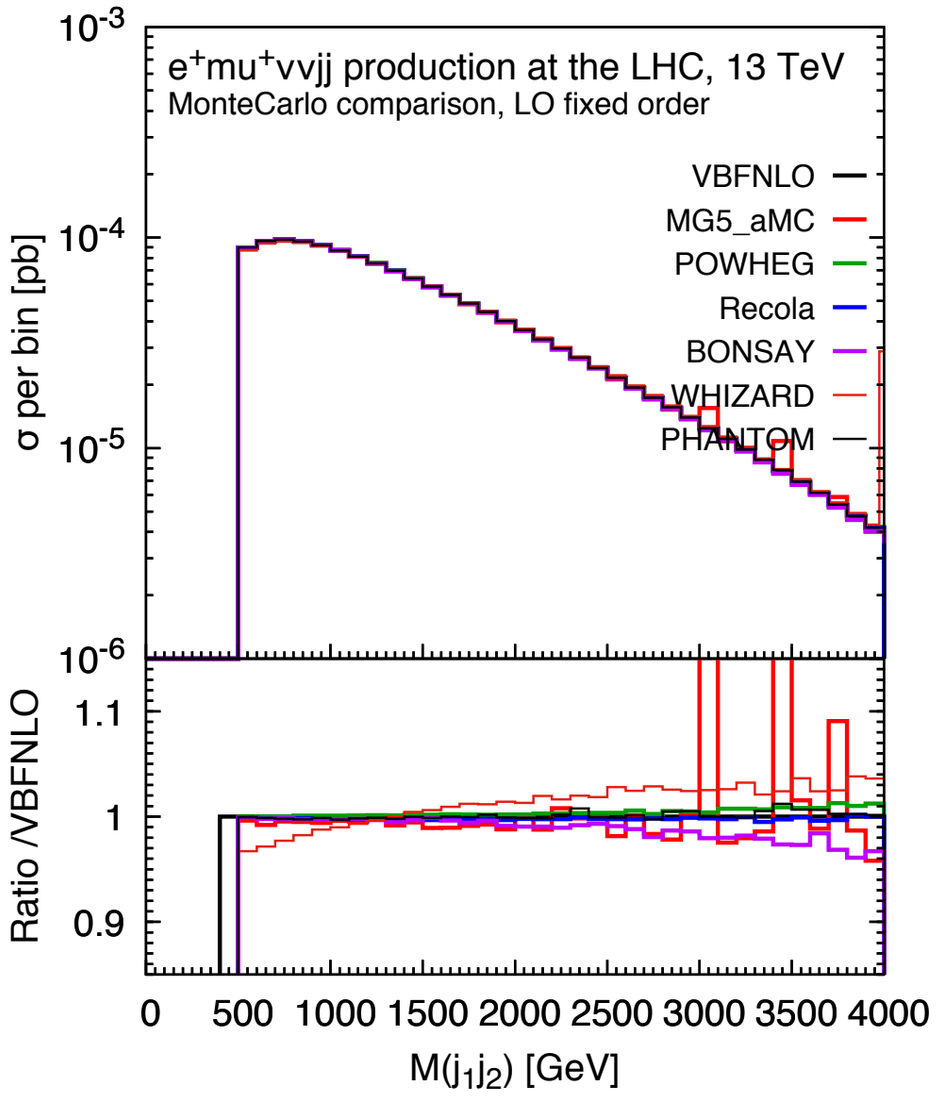
+Phantom
(LO only, full ME)

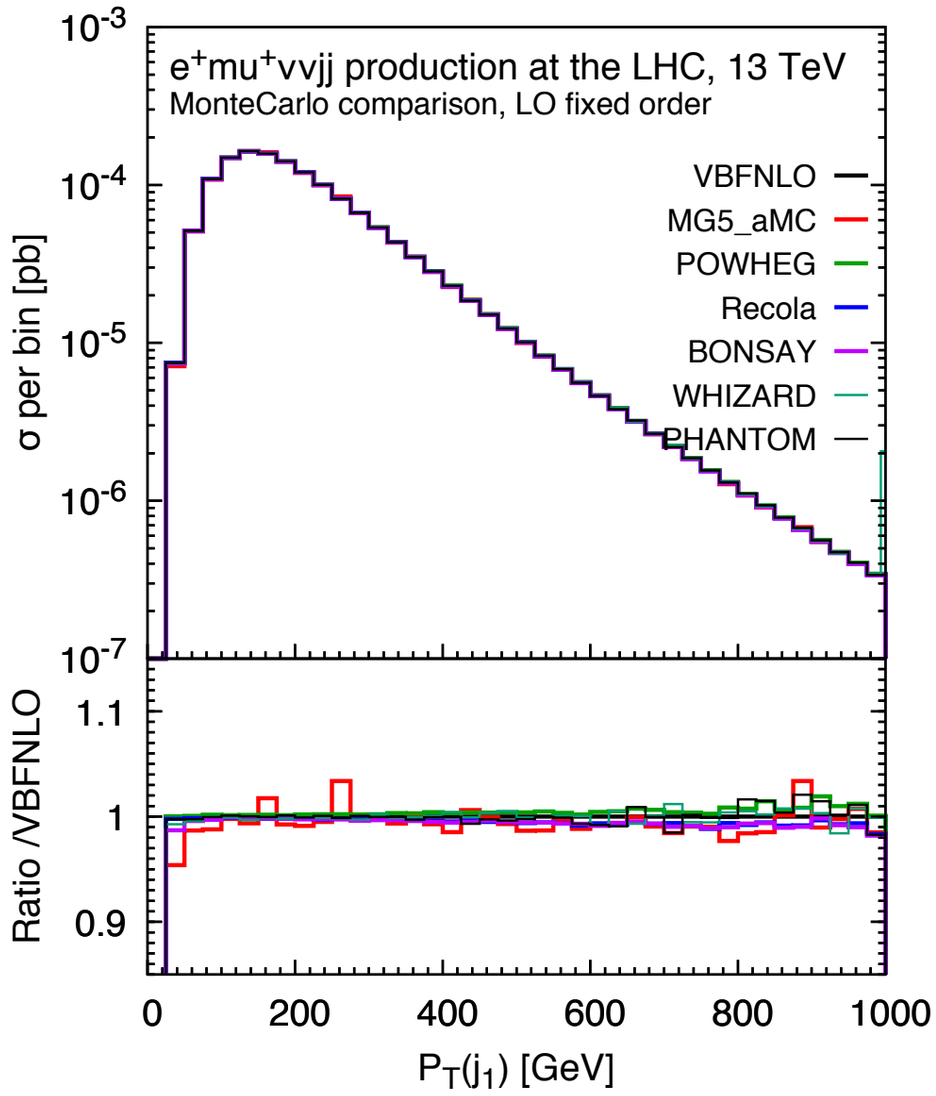


Off-shell and non resonant

Comparison at LO

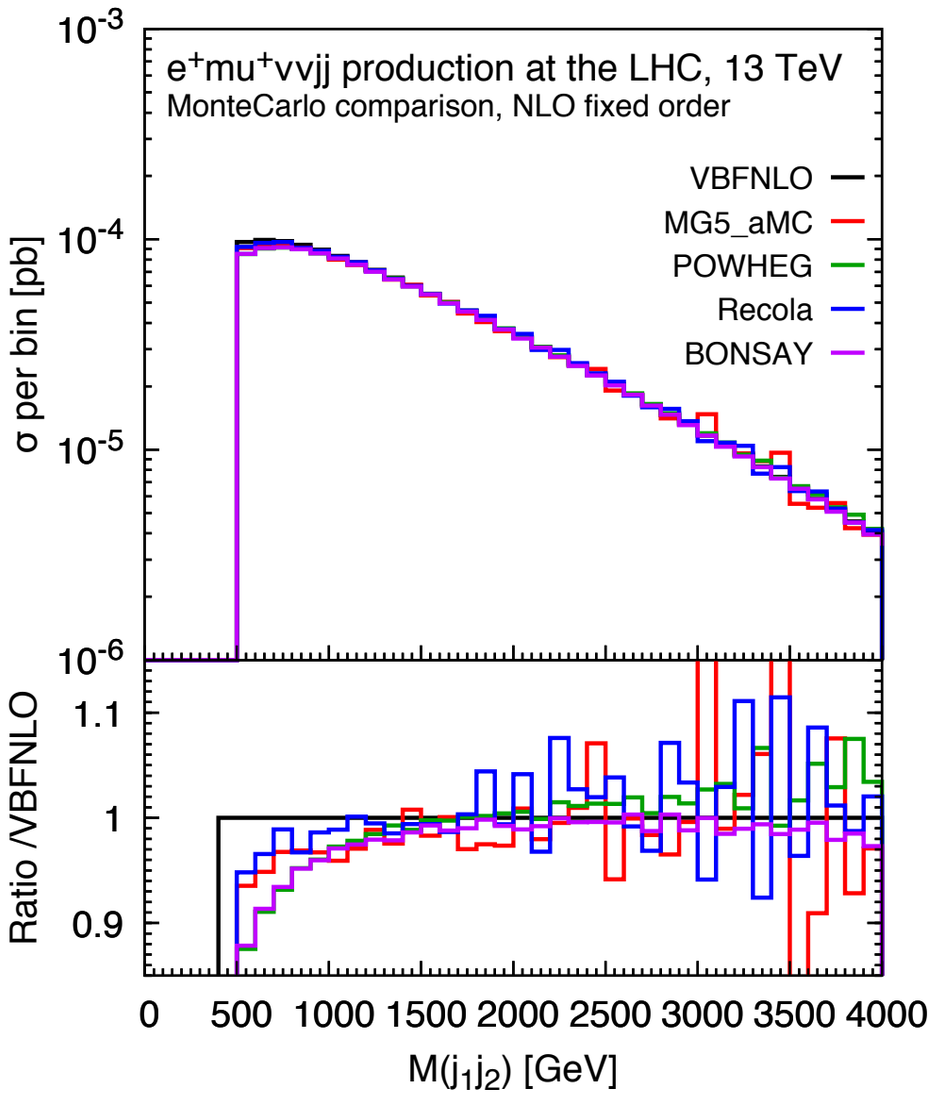
- Agreement at the 1% level among tools at LO (to be improved)

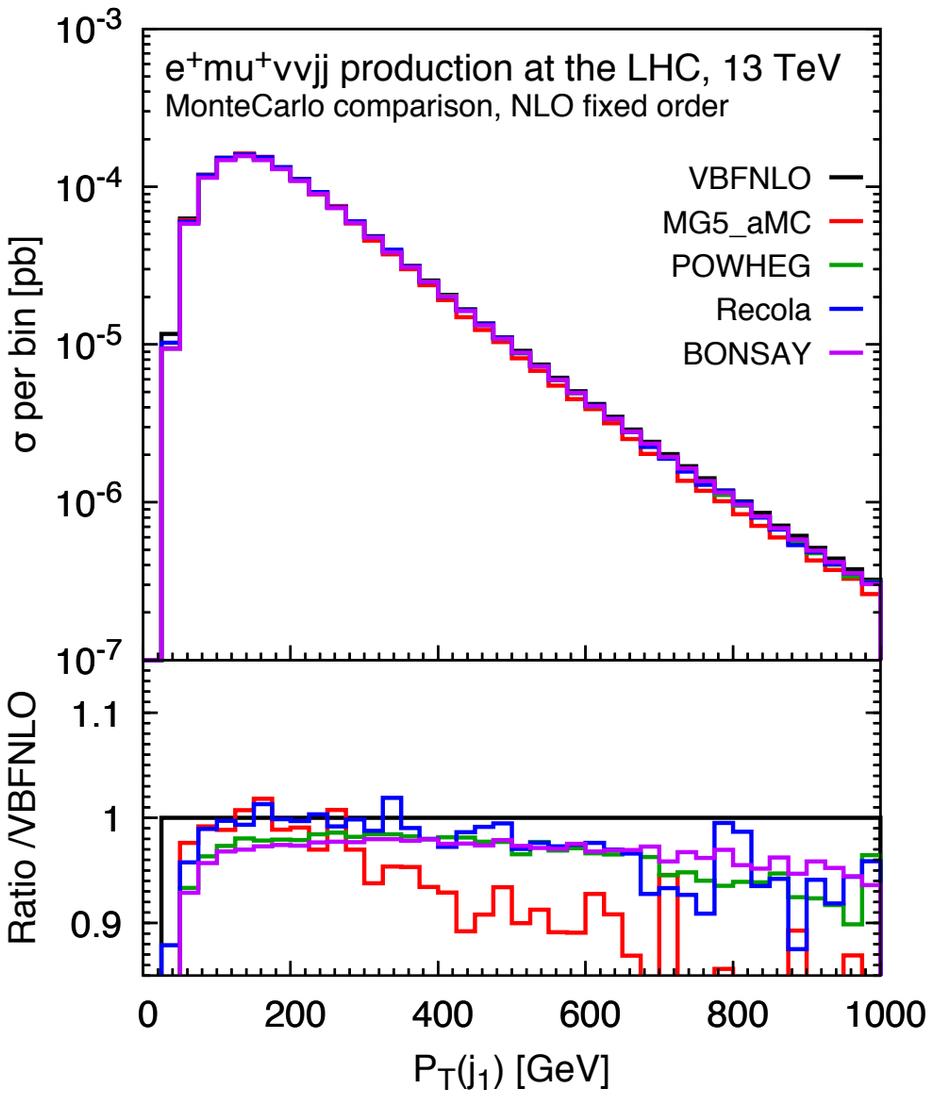




Comparison at NLO QCD

- Different contributions included or not by the various tools give larger (~10%) discrepancies at NLO

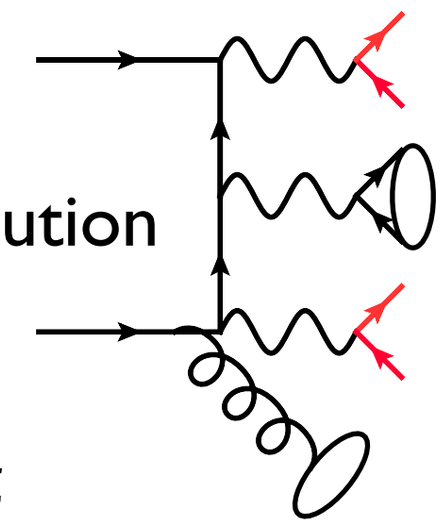




Comparison at NLO QCD

Code	$\mathcal{O}(\alpha^6)$ $\lvert s\rvert^2$/ $\lvert t\rvert^2/\lvert u\rvert^2$	$\mathcal{O}(\alpha^6)$ interf.	Off-shell	NF QCD	EW corr. to $\mathcal{O}(\alpha^5\alpha_s)$
POWHEG	t/u	No	Yes	No	No
Recola	Yes	Yes	Yes	Yes	Yes
VBFNLO	Yes	No	Yes	No	No
BONSAY	t/u	No	Yes, virt. No	No	No
MG5_aMC	Yes	Yes	No virt.	No	No

- Bonsay and Powheg are equivalent
- VBFNLO adds the s-channel diagrams
- MG5_aMC includes interferences and part of NF QCD
- Recola also includes EW corrections to the $\alpha^5\alpha_s$ contribution



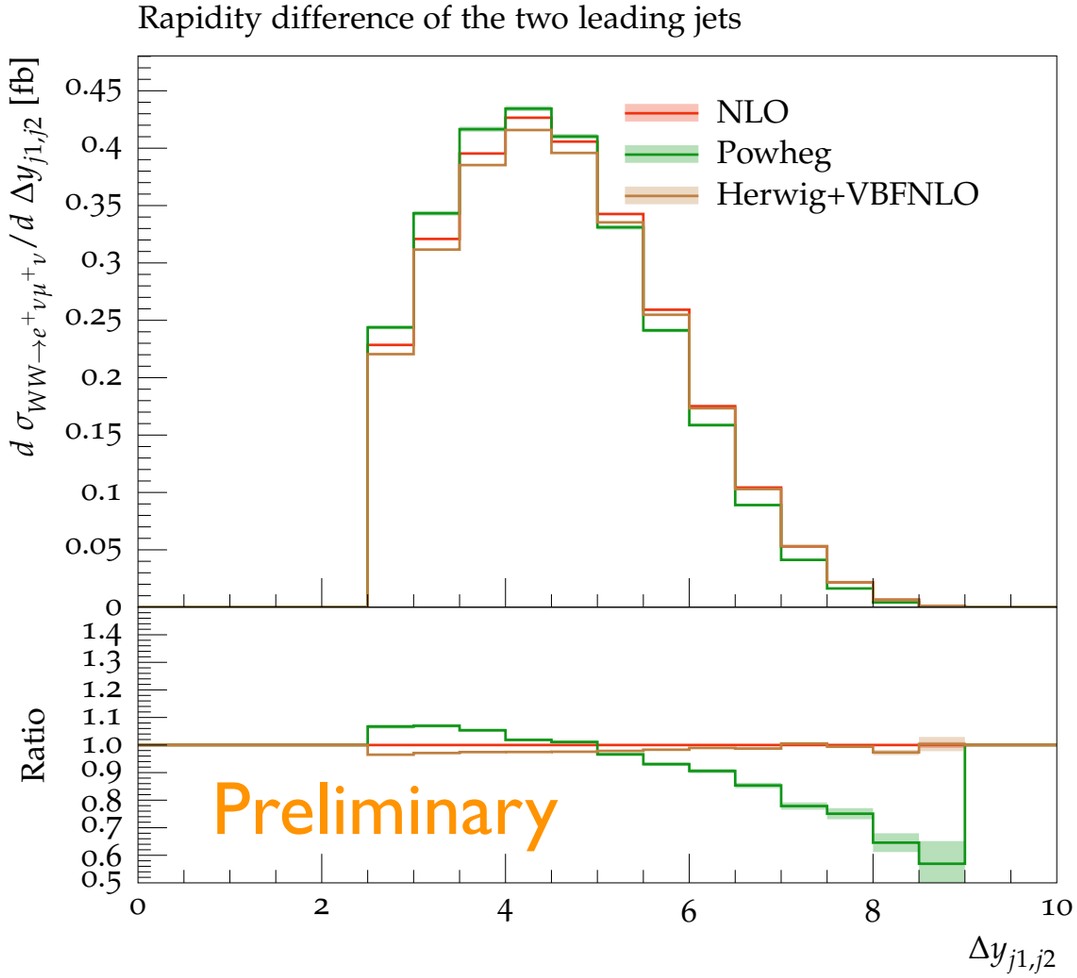
Remember: s-channels are less-suppressed at NLO because extra radiation can give extra jets

Comparison at NLO+PS

- Work in this direction has just started!
- The plan is to compare predictions from
  - Powheg+PY8
  - MG5_aMC@NLO+(PY8, HW++)
  - VBFNLO+Herwig7 (matching both in the Powheg and MC@NLO scheme)
- Predictions are done after hadronization (no MPI)
- Try to use common shower-parameters (not always possible with different showers / matching schemes)

Comparison at NLO+PS

- Matching to parton shower adds further dependence on the matching scheme and on the given parton-shower used.



Conclusions & Outlook

- LO and NLO comparison is at quite an advanced stage, differences among tools are negligible or understood
- NLO+PS adds larger discrepancies, to be investigated
- We profited of this week together to advance with the comparison and set the basis for the future work, including drafting a paper