Comparison of tools for VBS simulation

VBSCan Kick-off Meeting
28-30 June 2017, Split

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Paris - France

In collaboration with
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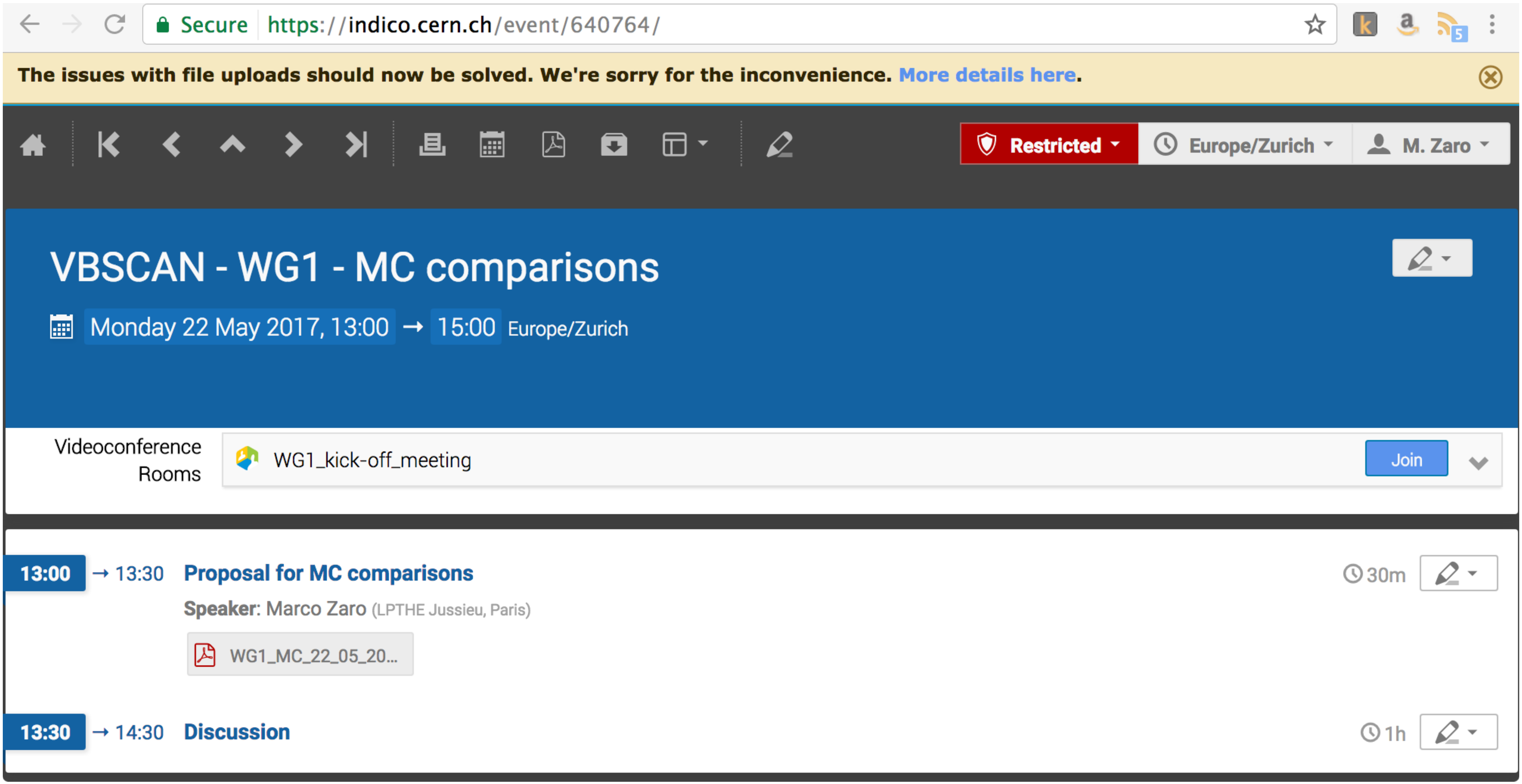
Mathieu Pellen
Michael Rauch
Jurgen Reuter
Christopher Schwan

Working Group Objectives

2. Signal and background processes will be described a significantly better precision than available nowadays, with next-to-leading precision in the strong and electro-weak perturbation theory of the Standard Model.

- Comparative study of the different tools/computer codes related to signal and background processes (both at fixed order and matched with parton showers), assessing the respective strengths and weaknesses. (Month 1-18)
- Set of predictions for the relevant processes including NLO QCD and EW corrections, and recommendations to include the effect of EW corrections (on central values and theoretical uncertainties) in event generators (NLO QCD+PS) used by experimental analyses. (Month 1-48)


Secure https://indico.cern.ch/event/640764/
The issues with file uploads should now be solved. We're sorry for the inconvenience. More details here.
Restricted
Europe/Zurich
M. Zaro
VBSCAN - WG1 - MC comparisons
Monday 22 May 2017, 13:00 → 15:00 Europe/Zurich
Videoconference Rooms
WG1_kick-off_meeting
Join
13:00 → 13:30 Proposal for MC comparisons
30m
Speaker: Marco Zaro (LPTHE Jussieu, Paris)
WG1_MC_22_05_20...
13:30 → 14:30 Discussion
1h

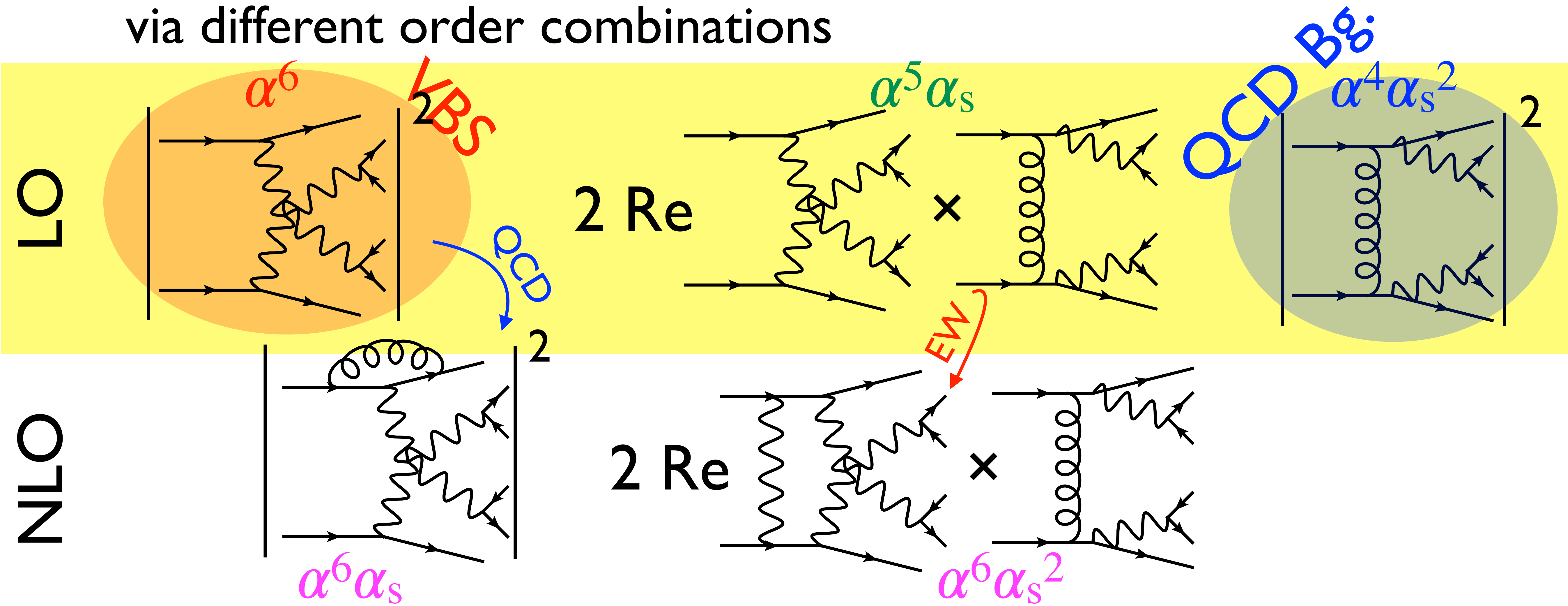
Plan

- 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



- Beware! QCD corrections to VBS are of the same order as EW corrections to the interference!

Setup, cuts and parameters

- Couplings, masses and widths

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

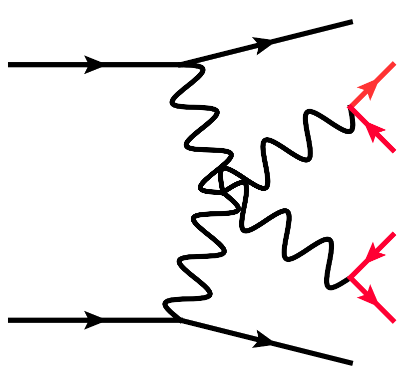
$$\alpha = \frac{\sqrt{2}}{\pi} G_\mu M_\text{W}^2 \left(1 - \frac{M_\text{W}^2}{M_\text{Z}^2}\right)$$

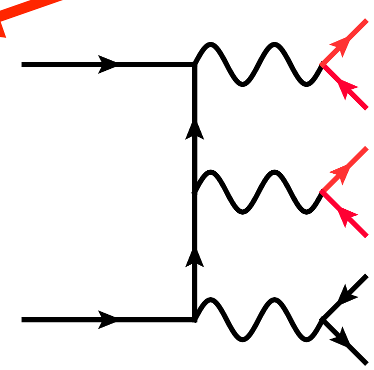
$$\begin{aligned} m_\text{t} &= 173.21\,\text{GeV}, & \Gamma_\text{t} &= 0\,\text{GeV}, \\ M_\text{Z}^\text{OS} &= 91.1876\,\text{GeV}, & \Gamma_\text{Z}^\text{OS} &= 2.4952\,\text{GeV}, \\ M_\text{W}^\text{OS} &= 80.385\,\text{GeV}, & \Gamma_\text{W}^\text{OS} &= 2.085\,\text{GeV}, \\ M_\text{H} &=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

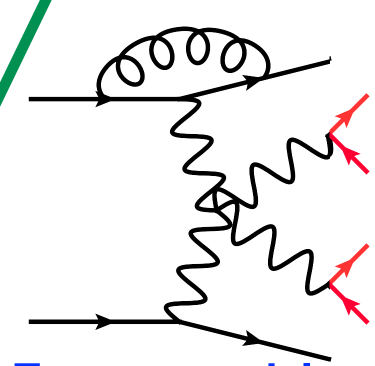
- NNPDF 3.0 PDFs $\alpha_s(M_Z)=0.118$, $\mu_{R/F}=M_W$
- Selection cuts:
  - At least two (anti-k_T,R=0.4) jets with p_T>30 GeV, |y|<4.5
  - The two hardest jet must have $\Delta y>2.5$, $m_{jj}>500$ GeV
  - Two leptons with p_T>20 GeV, |y|<2.5, $E_T^{miss}>40$ GeV
  - Lepton-lepton and jet-lepton distance: $\Delta R_{jl}>0.3$, $\Delta R_{ll}>0.3$
  - Observables:
    - Rate within cuts and in jet-multiplicity bins
    - $m(e^+\mu^+)$, mjj, $p_T(j_{1,2})$, $y(j_{1,2})$, $z(e^+/\mu^+)$

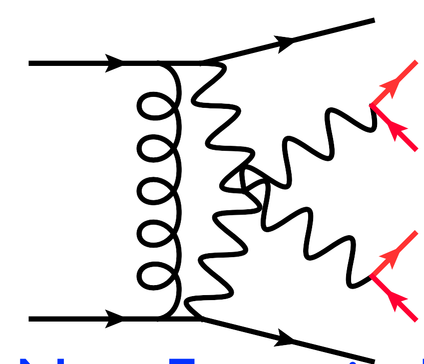
People and code comparison

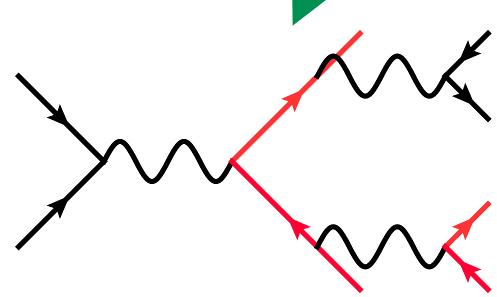
Contact person	Code	$\mathcal{O}(\alpha^6)$ $\lvert s\rvert^2/\lvert t\rvert^2/\lvert u\rvert^2$	$\mathcal{O}(\alpha^6)$ interf.	Off-shell	NF QCD	EW corr. to $\mathcal{O}(\alpha^5\alpha_s)$ *
A. Karlberg	POWHEG	t/u	No	Yes	No	No
M. Pellen	RECOLA	Yes	Yes	Yes	Yes	Yes
M. Rauch	VBFNLO	Yes	No	Yes	No	No
C. Schwan	BONSAY	t/u	No	Yes, virt. No	No	No
M. Zaro	MG5_AMC	Yes	Yes	No virt.	No	No


t-channel


s-channel

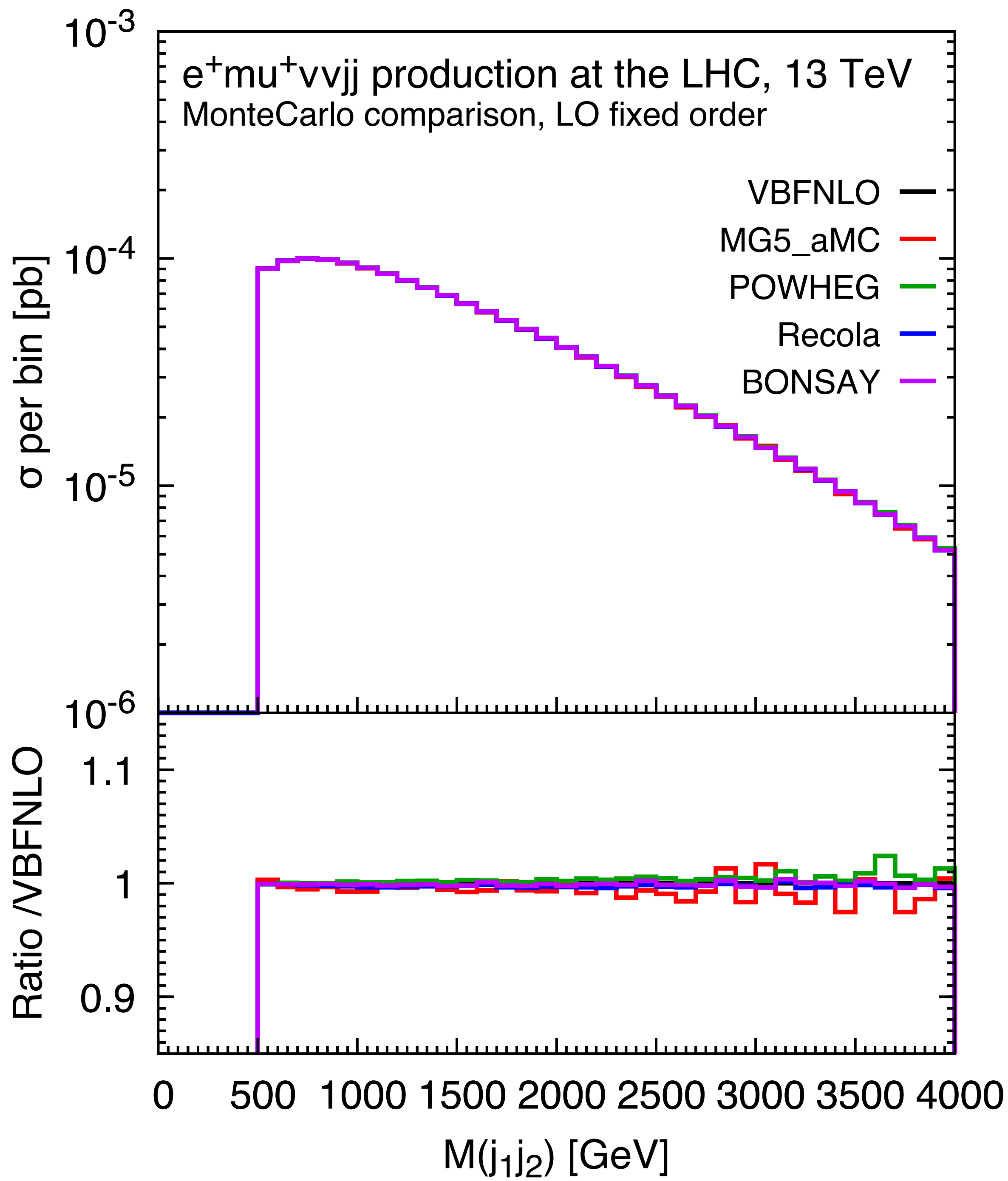

Factorizable QCD corr.

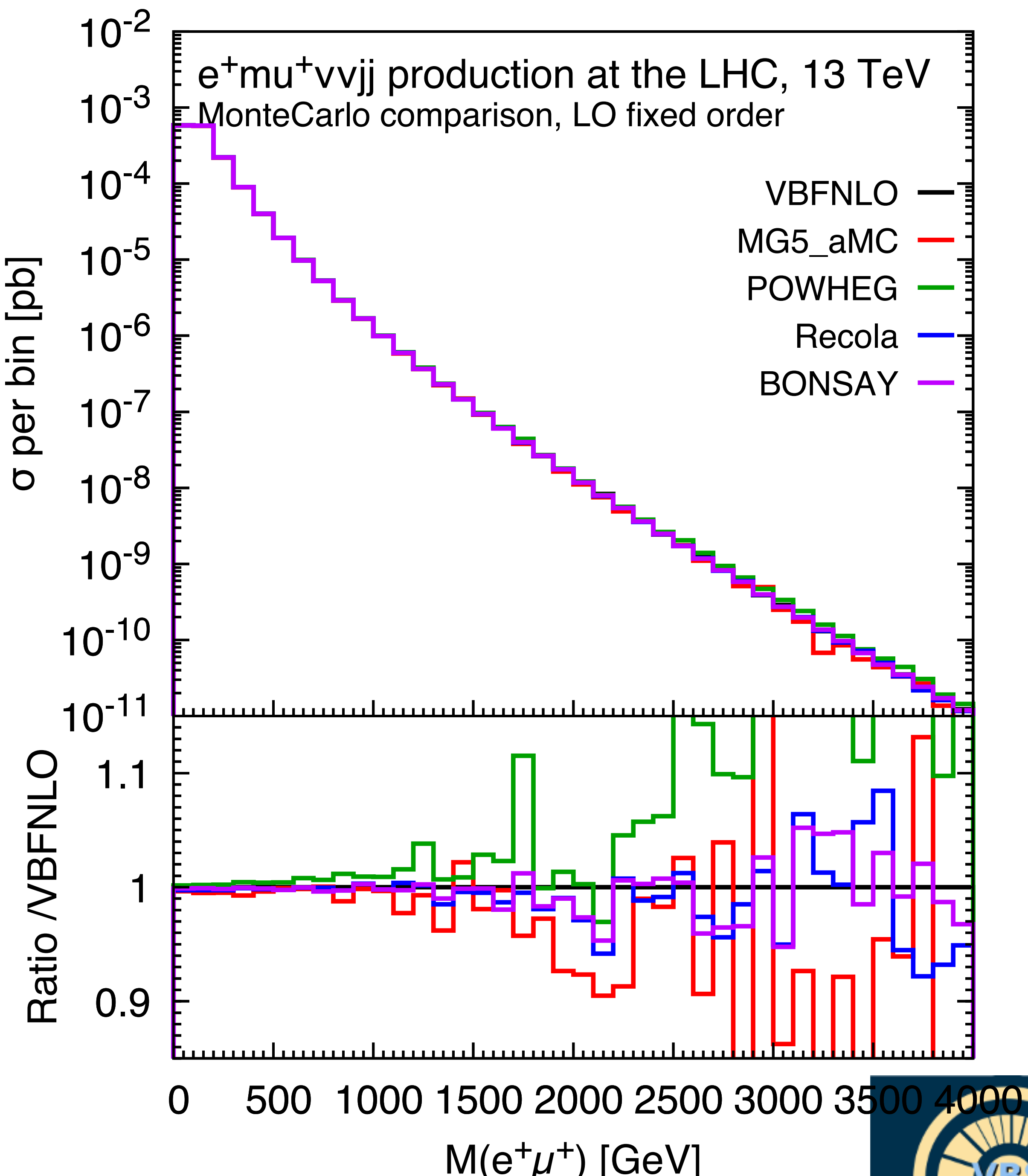

Non-Factorizable QCD corr.


Off-shell and non resonant

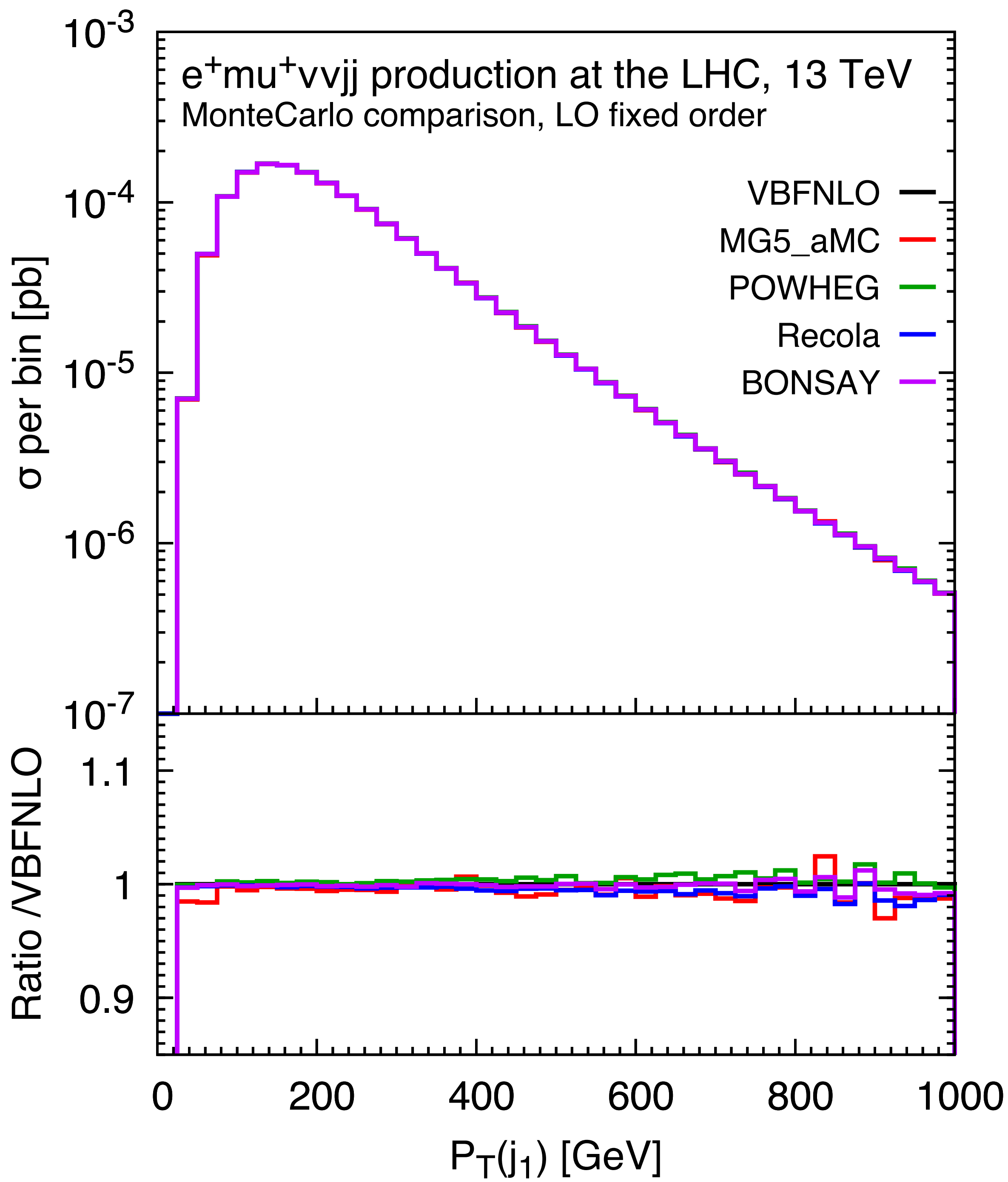
* M. Schoenherr (Sherpa) recently joined

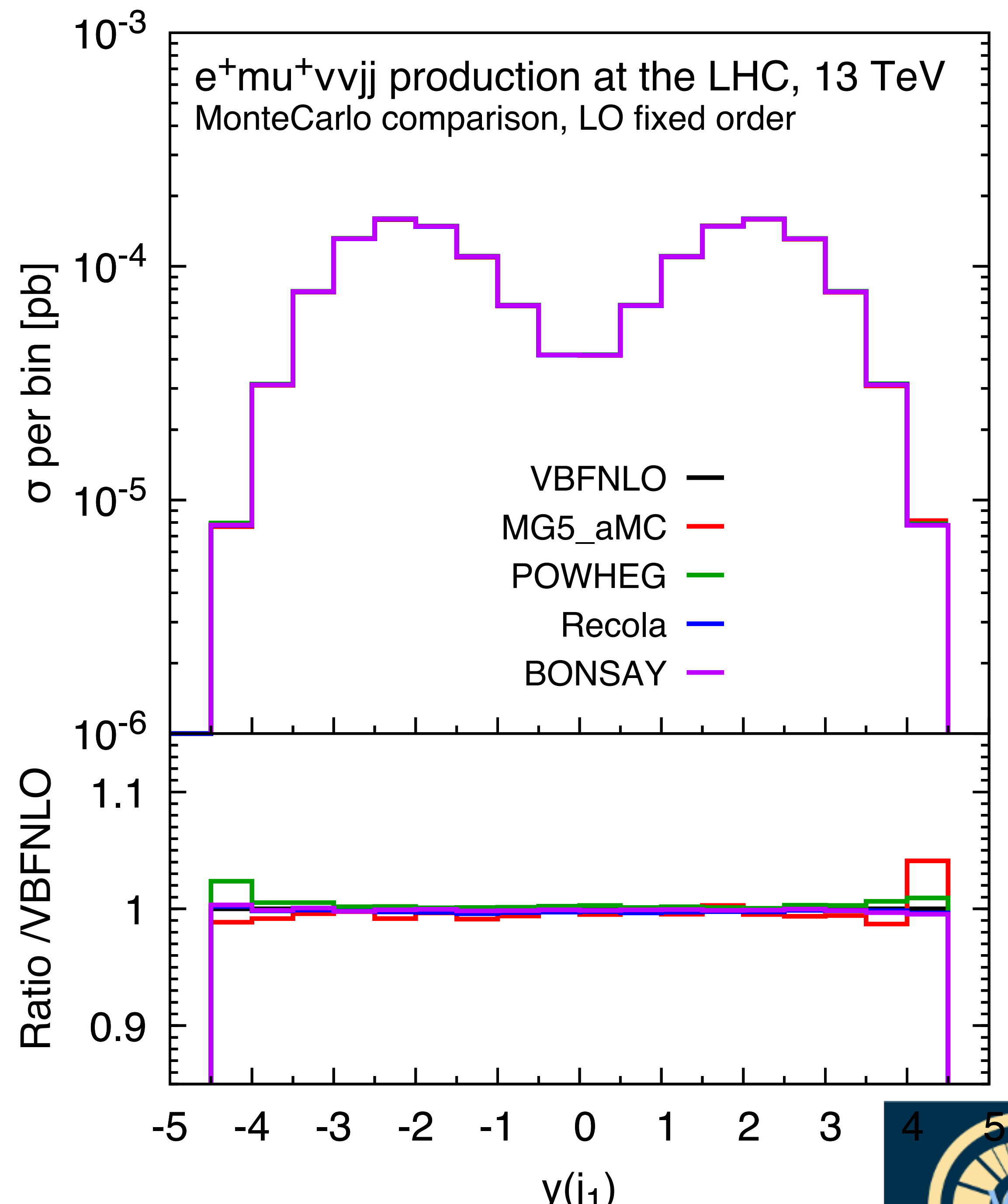
Comparison at LO



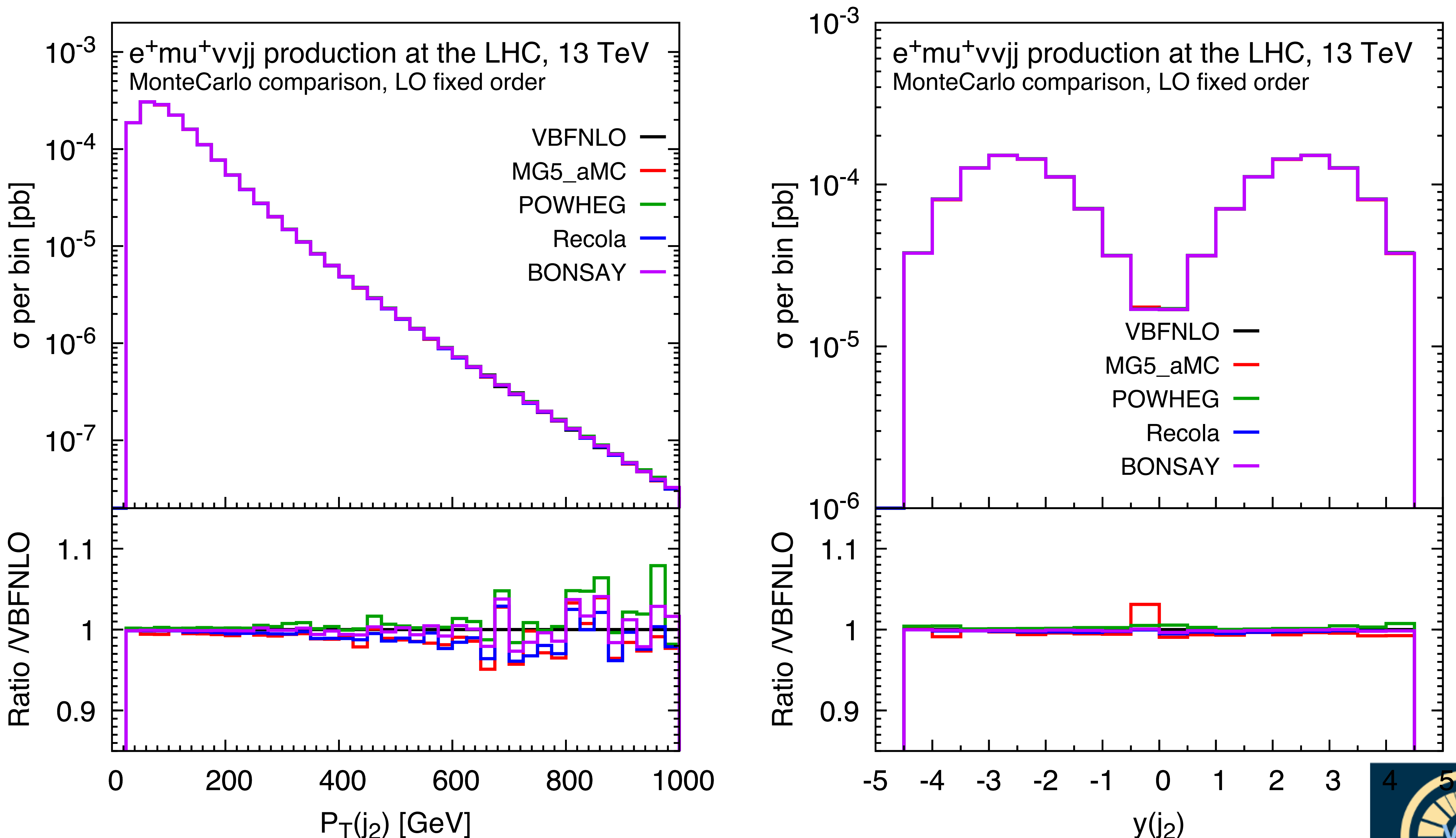


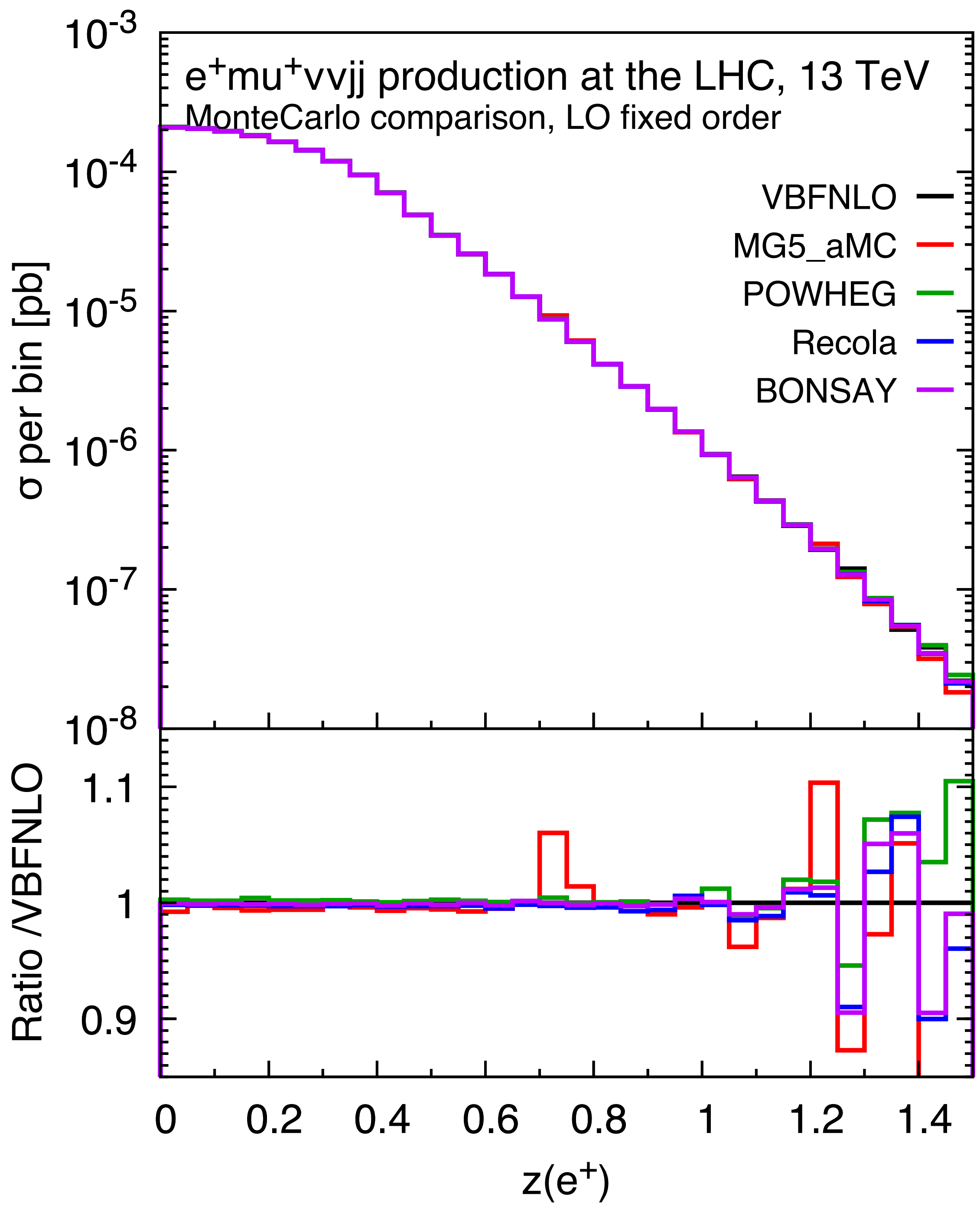
Comparison at LO





Comparison at LO



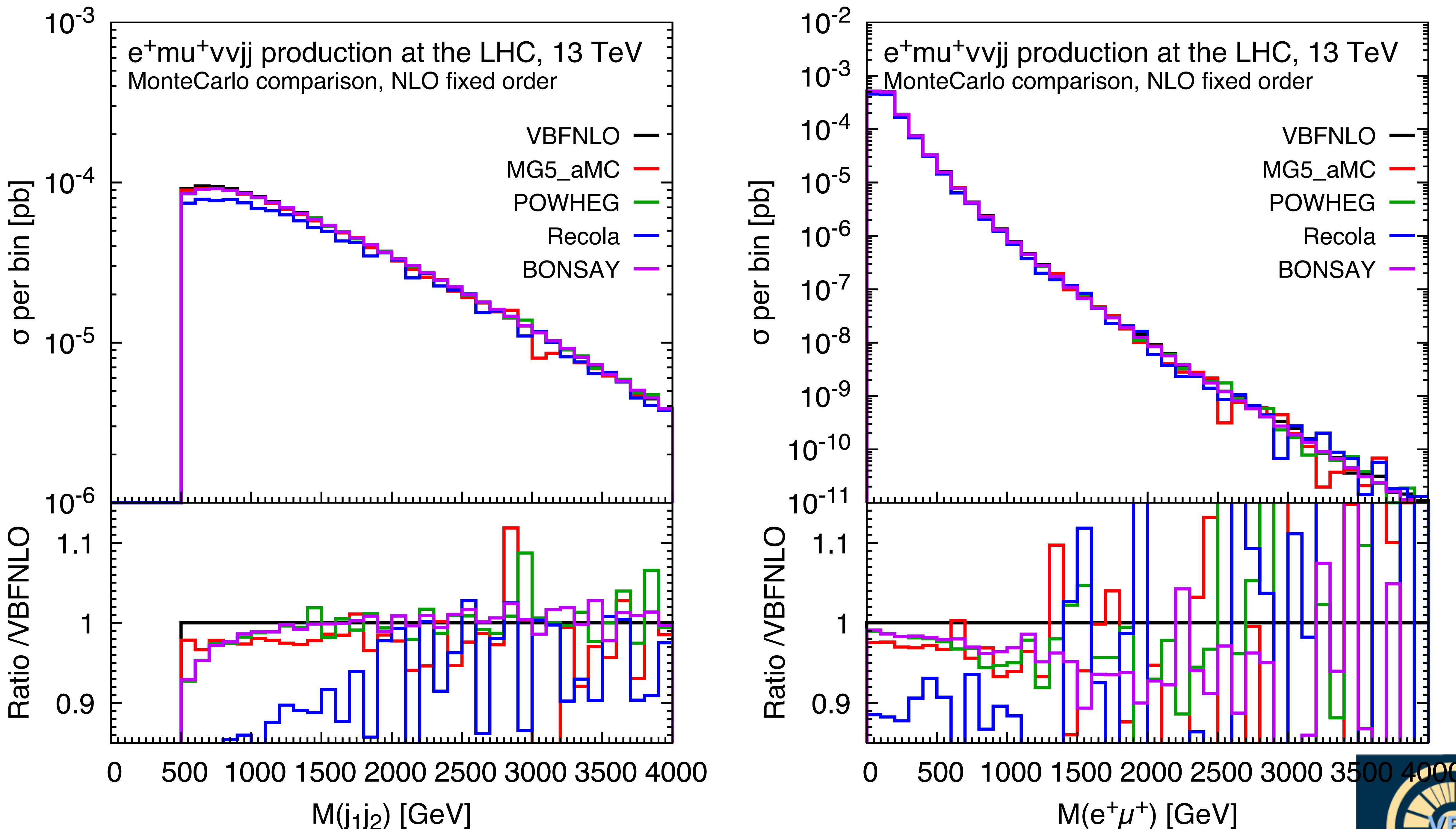


Rates within cuts

Code	σ[fb]
POWHEG	1.5573 ± 0.0003
Recola	1.5503 ± 0.0003
VBFNLO	1.5538 ± 0.0002
BONSAY	1.5524 ± 0.0002
MG5_aMC	1.547 ± 0.001

Bottom line:
hardly any difference is visible at LO
interferences/s-channels/off-shell effects
are negligible

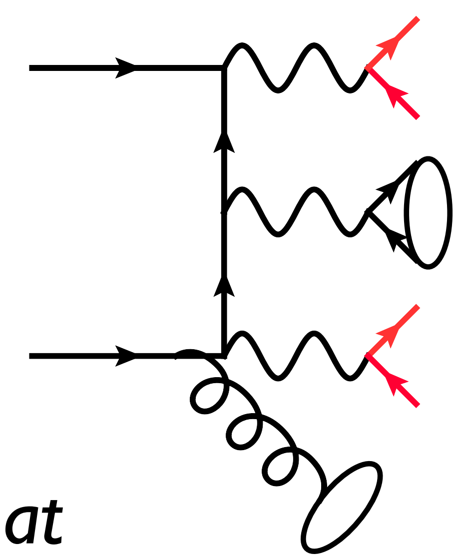
Comparison at NLO QCD



Comparison at NLO QCD: differences between generators

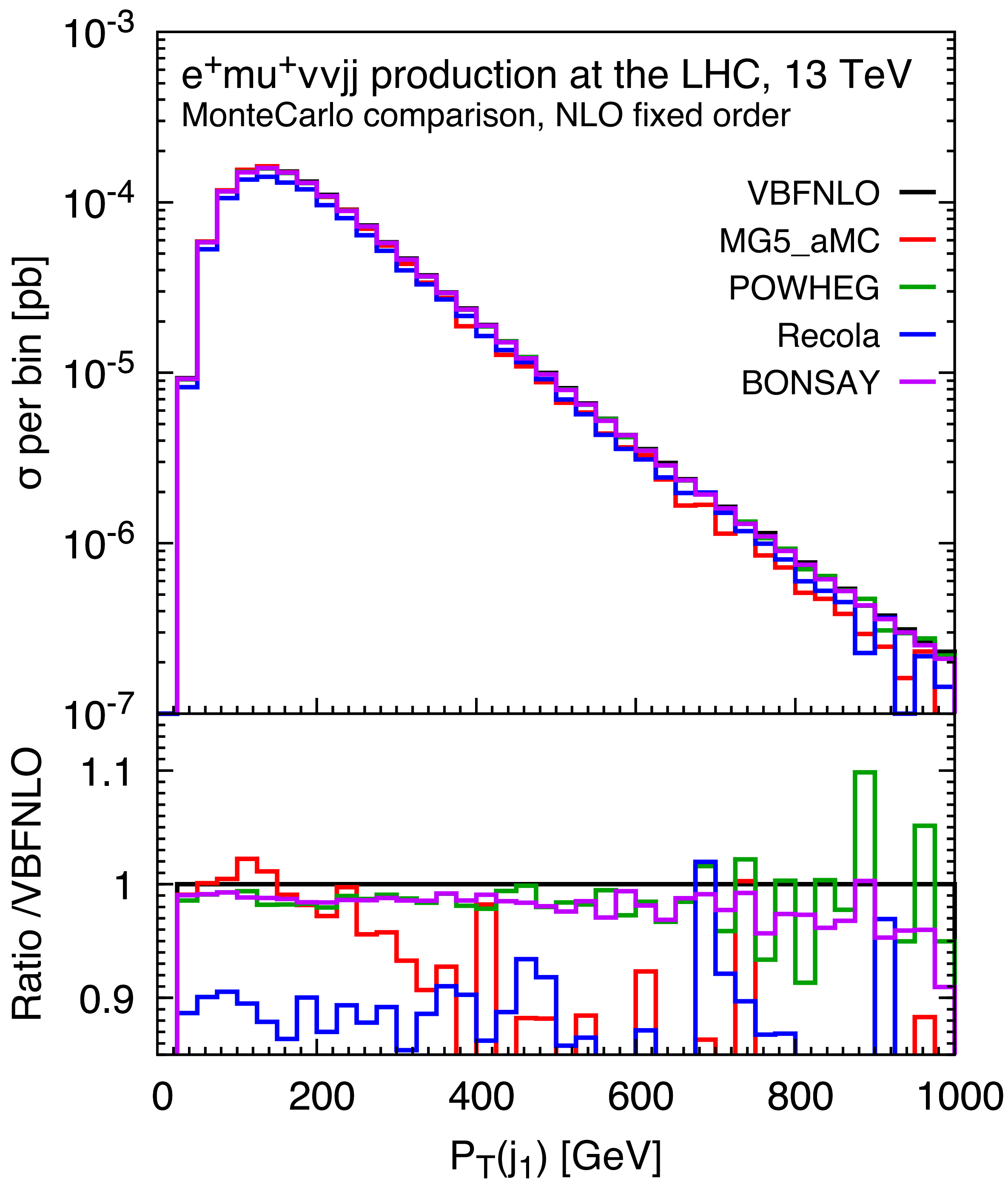
Code	$\mathcal{O}(\alpha^6)$ $\lvert s\rvert^2/\lvert t\rvert^2/\lvert u\rvert^2$	$\mathcal{O}(\alpha^6)$ interf.	Off-shell	NF QCD	EW corr. to $\mathcal{O}(\alpha^5\alpha_s)$
POWHEG	t/u	No	Yes	No	No
RECOLA	Yes	Yes	Yes	Yes	Yes
VBFNLO	Yes	No	Yes	No	No
BONSAY	t/u	No	Yes, virt. No	No	No
MG5_AMC	Yes	Yes	No virt.	No	No

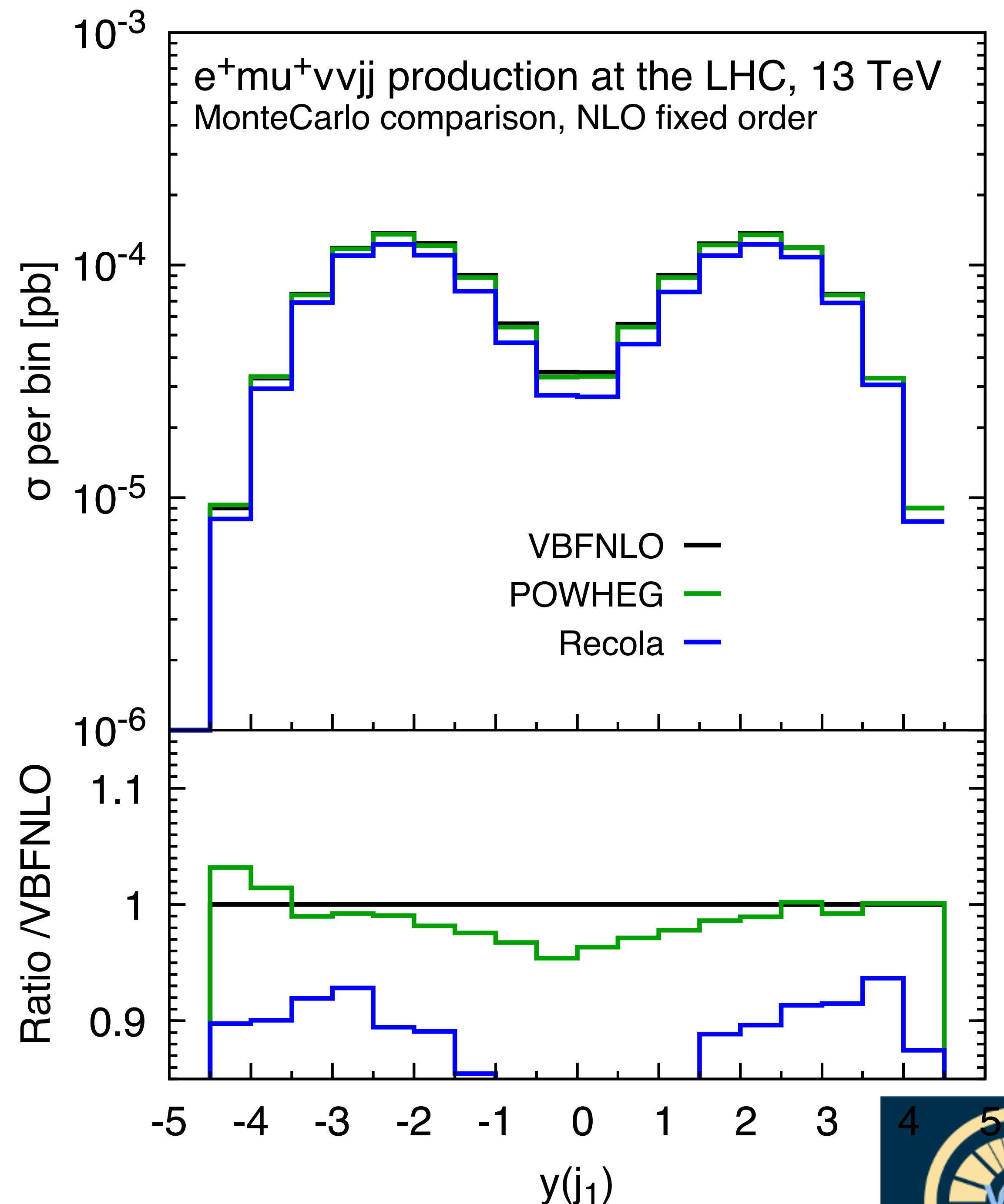
- Bonsay and Powheg are equivalent
- VBFNLO adds the s-channel diagrams
- MG5_aMC includes interferences and part of NF QCD
- Recola also includes EW corrections to the $\alpha^5\alpha_s$ contribution



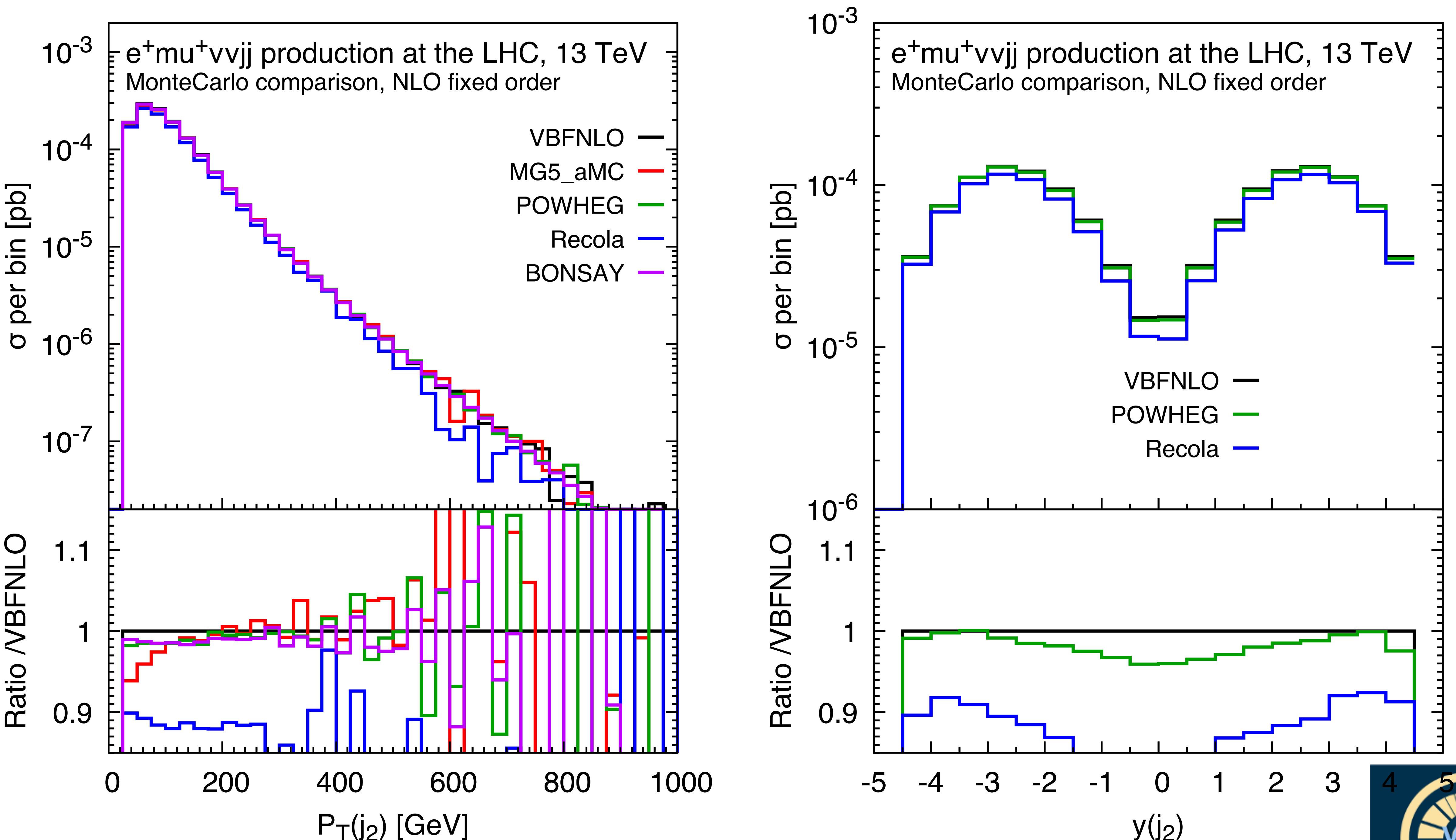
Remember: s-channels are less-suppressed at NLO because extra radiation can give extra jets

Comparison at NLO QCD

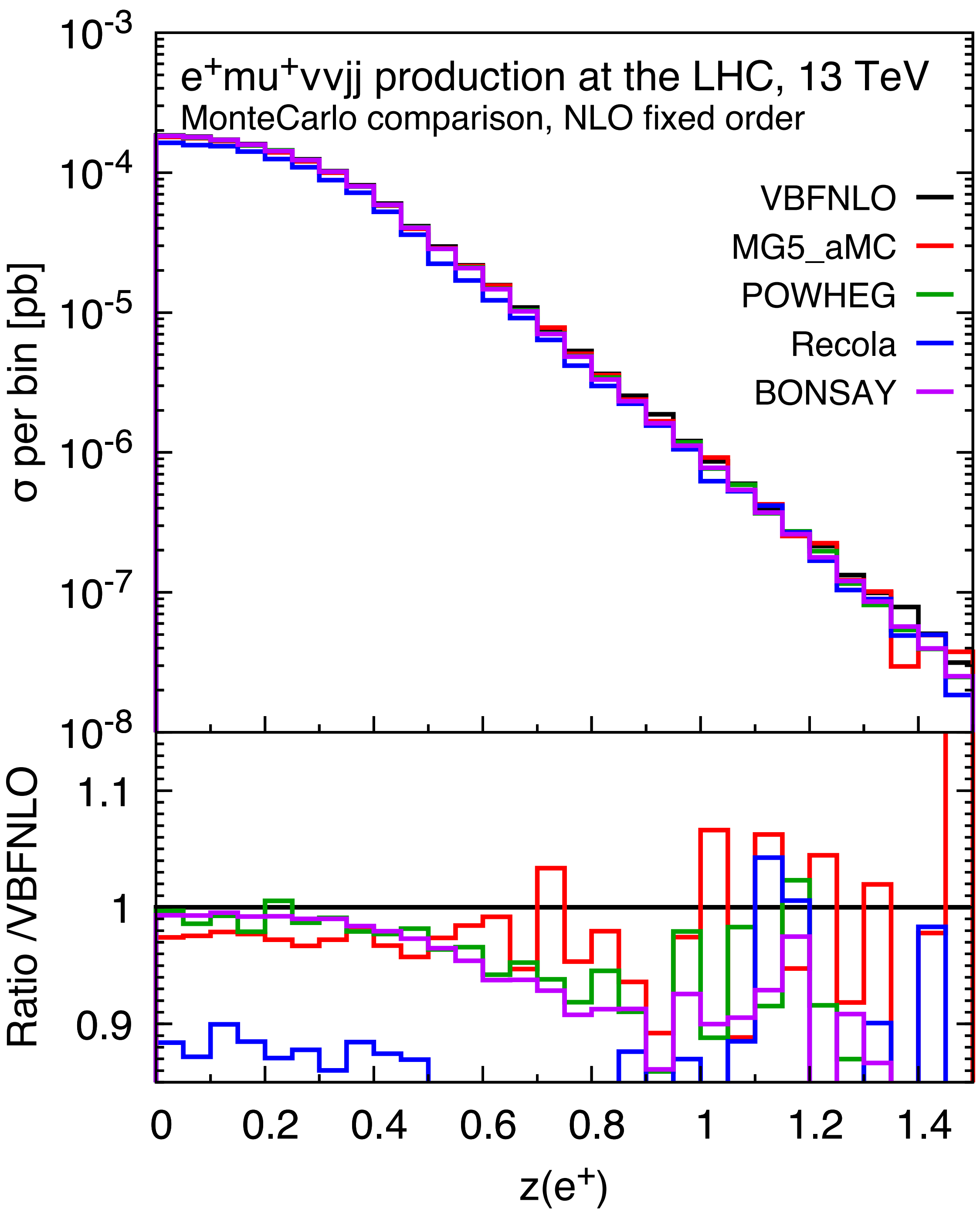




Comparison at NLO QCD



Comparison at NLO QCD



Code	σ[fb]	$\sigma(n_j = 2)$[fb]	$\sigma(n_j = 3)$[fb]
POWHEG	1.334 ± 0.0003	0.808 ± 0.001	0.5260 ± 0.0005
RECOLA	1.197 ± 0.003		
VBFNLO	1.3531 ± 0.0003	0.8264 ± 0.0003	0.5267 ± 0.0001
BONSAY	1.3366 ± 0.0009	0.8199 ± 0.0008	0.51663 ± 0.00007
MG5_aMC	1.318 ± 0.003	0.781 ± 0.004	0.5374 ± 0.0016

Bottom line:
differences between codes start to emerge at NLO
Largest effects (~10%) probably come from EW corrections to the $\alpha^5\alpha_s$ LO term

Conclusions & Outlook

- LO and NLO comparison is at quite an advanced stage, differences among tools are negligible or understood
- Further directions:
  - NLO+PS and EW corrections
  - Use the differences among tools to understand the importance of the various contributions w.r.t. cuts
    (connected to the LesHouches proceedings)
  - …?