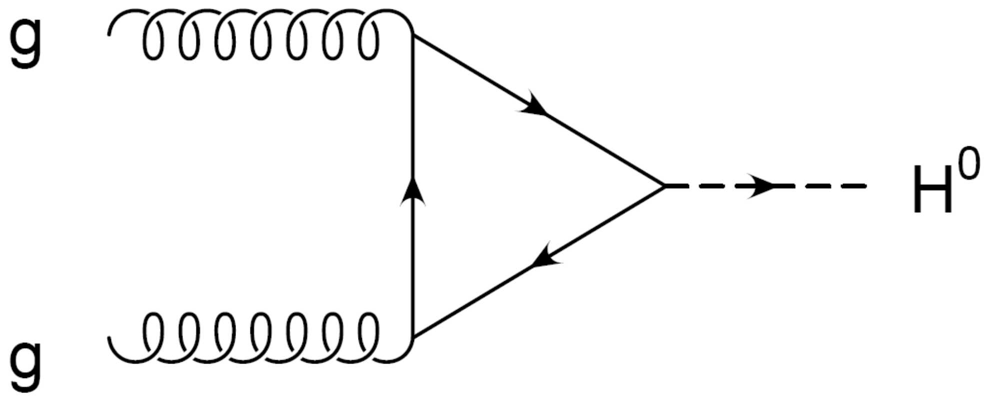
(Validation) Studies of Monte Carlo generators in gluon-fusion Higgs boson production for Run 2



Kathrin Becker
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Higgs (N)NLO MC and Tools workshop, 17.12.14

What do we want for Run 2 with respect to gluon-fusion simulation?

Modeling of gluon-fusion Higgs boson production is important

- for the measurements of the process (often jet-binned, making use of the kinematics of the production)
- as a background for the VBF measurements/searches

Thus, we want the most precise description of

- the kinematics of the Higgs boson
- the jet-binned cross sections
- the kinematics of the additional jets

And a correct and well defined estimation of the uncertainties of the predictions

Generators on the market

Default ggF sample in Run 1:

Powheg (gg_H-quark-mass-effects)+Pythia8, NLO precision, $p_T(H)$ was reweighted to NNLO+NNLL precision (HRes)

Available generators

- PowhegBOX:
  - HJ(J) MINLO (validated samples in Run 1)
  - **ggH@NNLOPS**
  - interfaced to Pythia8
- SHERPA 2.1.1 MEPS@NLO
  - **H+0,1,2 jets @NLO**
- MadGraph5_aMC@NLO (FxFx merging)
  - **H+0,1,2 jets @NLO**
  - interfaced to Herwig++ and Pythia8

In this talk…

- First look at the PowhegBox NNLOPS prediction and the effect of scale variations
- Very first look at SHERPA MEPS@NLO
- Sadly no studies yet on Madgraph5_aMC@NLO
- Studies done in 8 TeV

- All studies shown are in their very first steps and by no means complete
- Aim is to present you the first impression, that we’ve gotten and to discuss with you proper settings as well as uncertainty prescriptions

Powheg NNLOPS Settings

√s	8 TeV
m_H	125.4 GeV
m_t, m_b	172.5 GeV, 4.75 GeV
$\mu=\mu_R=\mu_F$	m_H (HNNLO & core in MiNLO)
ME & PS/UE PDF set	CT10nnlo & CT10
Shower / tune / main31	Pythia 8 / AU2 / Powheg std.

- NNLOPS is the most advanced ggF prediction from Powheg-BOX
- It combines the previously most advanced ggF prediction “MiNLO HJ” with HNNLO, which is an NNLO accurate analytical calculation
- LHE files produced after consulting settings closely with Keith Hamilton (via Dag Gillberg and Florian Bernlochner)

- NNLOPS is supposed to achieve NNLO accuracy in fully inclusive observables and NLO accuracy in Higgs+1 jet production

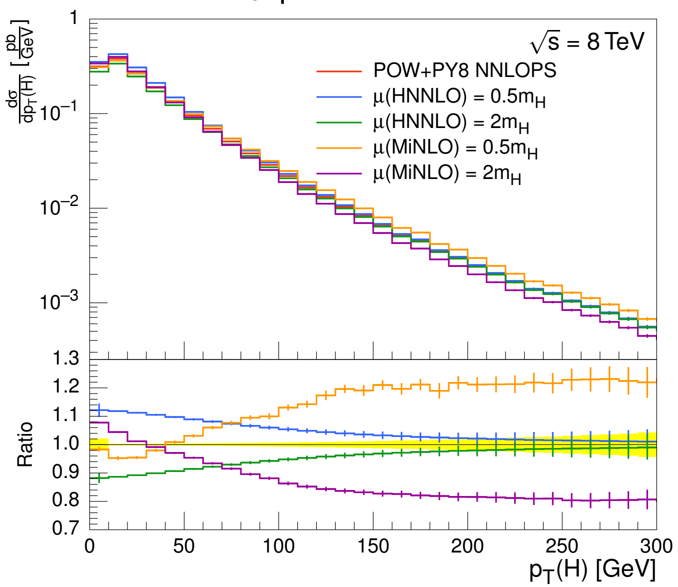
Scale variations with NNLOPS

- Variations of the renormalization and factorization scales in HNNLO and in PowhegBox HJ MiNLO
- Varied by a factor of 0.5 and 2 for $\mu=\mu_R=\mu_F$
- Effect on total cross section is driven by the scale in HNNLO

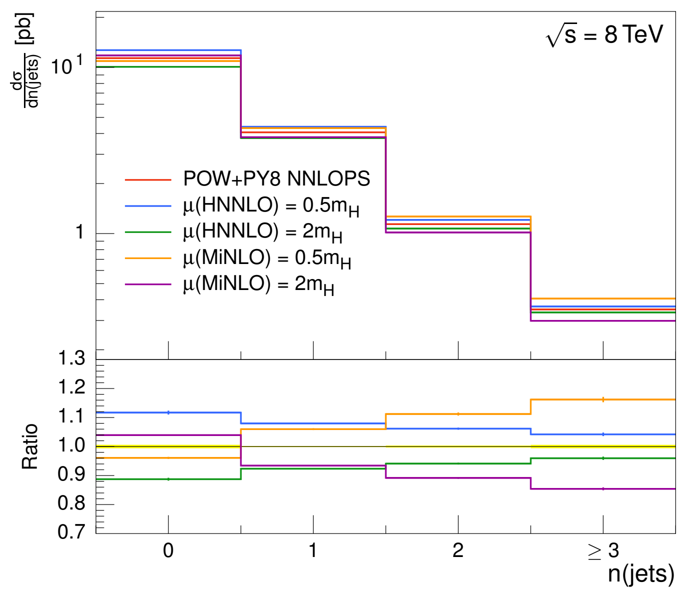
Scale HNNLO	Scale MiNLO	Cross section [pb]
m_H	$\mu_{\text{def.}}$(MINLO)	16.91
$0.5 \cdot m_H$	$\mu_{\text{def.}}$(MINLO)	18.65
$2.0 \cdot m_H$	$\mu_{\text{def.}}$(MINLO)	15.24
m_H	$0.5 \cdot \mu_{\text{def.}}$(MINLO)	16.90
m_H	$2.0 \cdot \mu_{\text{def.}}$(MINLO)	16.91

Scale variations with NNLOPS

$p_T(H)$



Njets



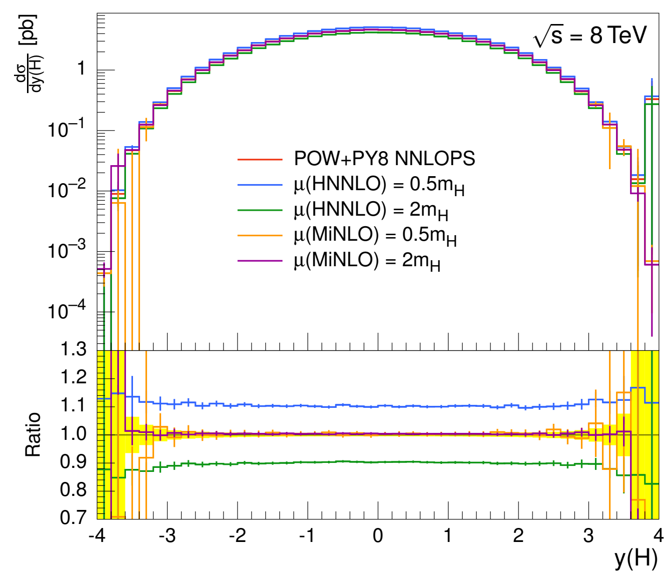
Normalized to the generator cross section

Effect from MiNLO scale dominates for large $p_T(H)$ and higher jet bins

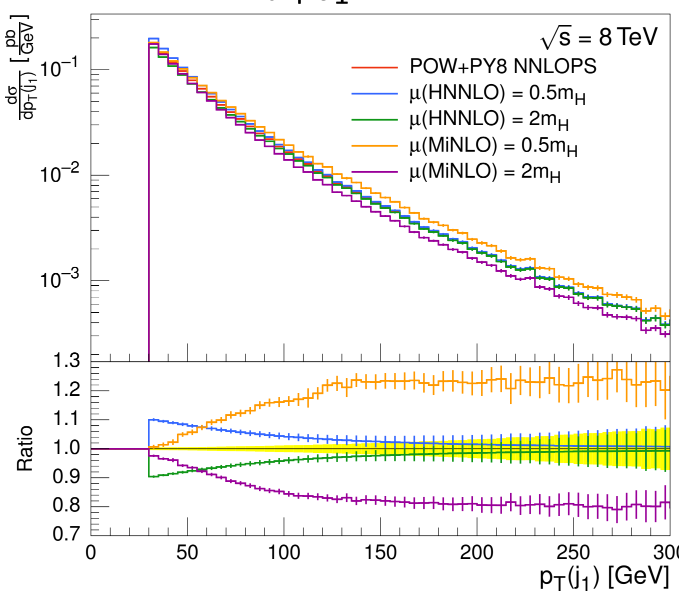
Scale Variation	no cut	0 jets	≥ 1 jet	1 jet	≥ 2 jets	$p_T(H) < 20$ GeV	$p_T(H) > 100$ GeV
μ(NNLO)							
$0.5 \cdot m_H$	10%	12%	8%	9%	6%	12%	4%
$2 \cdot m_H$	-10%	-11%	-7%	-7%	-4%	-12%	-4%
μ(MINLO)							
$0.5 \cdot \mu_{def.}$(MINLO)	~0.0%	-4%	8%	7%	12%	-3%	18%
$2 \cdot \mu_{def.}$(MINLO)	~0.0%	4%	-8%	-6%	-12%	6%	16%

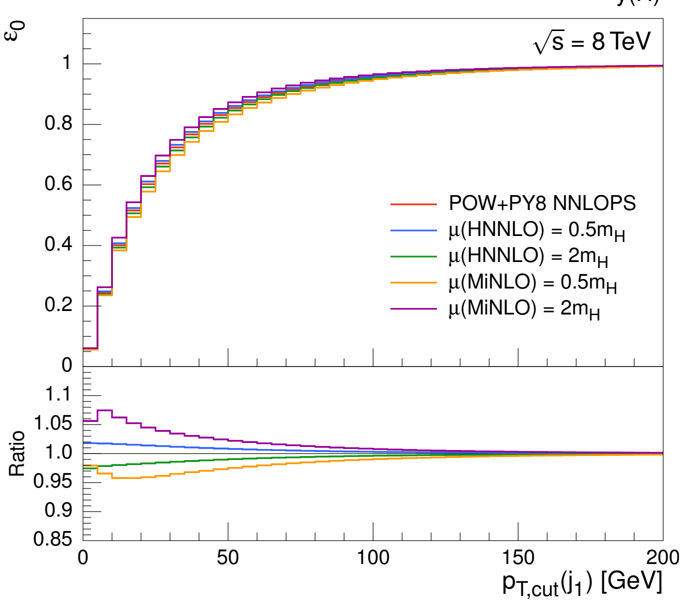
Scale variations with NNLOPS

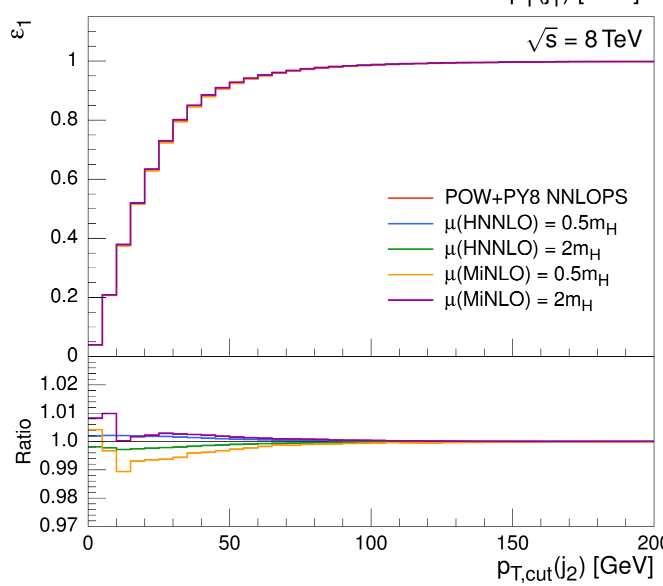
y(H)



$p_T(j_1)$



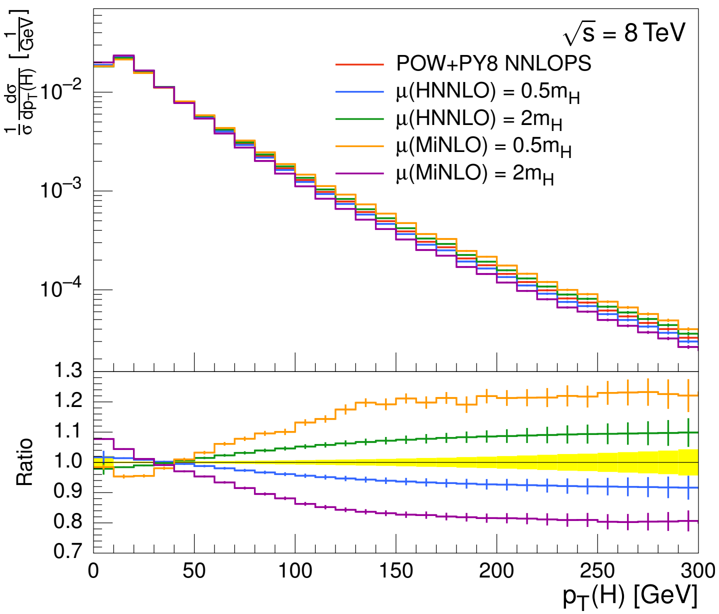


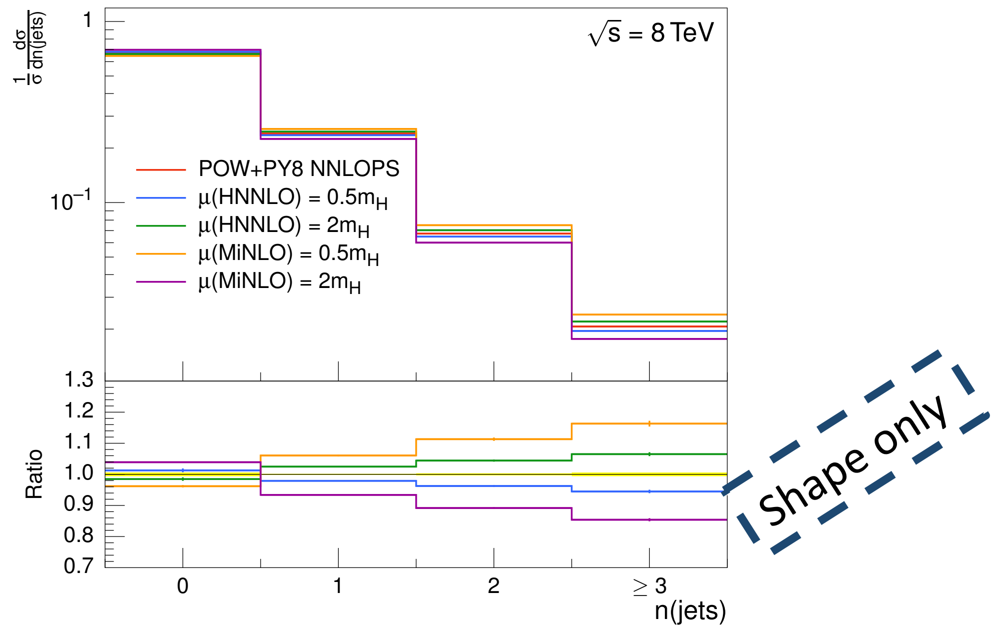


Normalized to the generator cross section

In jet properties, especially in the tails -> large effect from MiNLO scale

Scale variations with NNLOPS

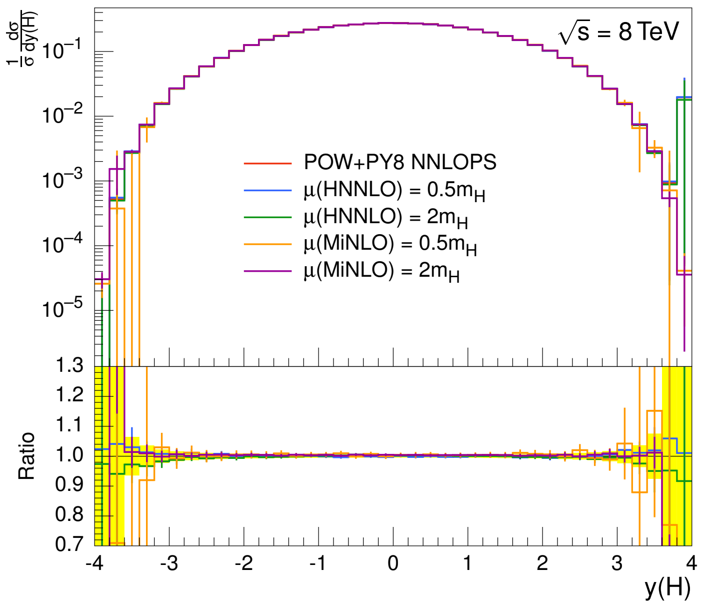


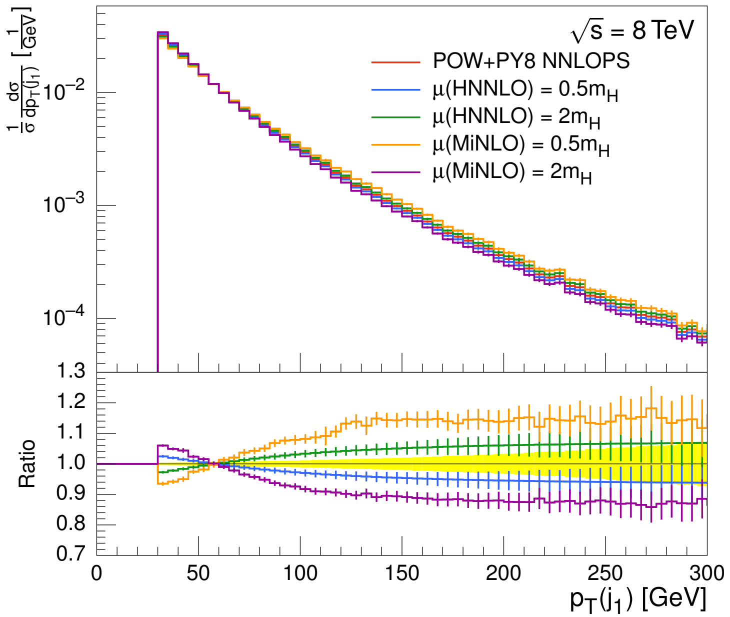


Scale Variation	0 jets	≥ 1 jet	1 jet	≥ 2 jets	$p_T(H) < 20$ GeV	$p_T(H) > 100$ GeV
μ(NNLO)						
$0.5 \cdot m_H$	1%	-2%	-2%	-4%	2%	-6%
$2 \cdot m_H$	-2%	4%	3%	6%	-2%	-7%
μ(MINLO)						
$0.5 \cdot \mu_{def.}$(MINLO)	-4%	8%	7%	12%	-3%	18%
$2 \cdot \mu_{def.}$(MINLO)	4%	-8%	-6%	-12%	6%	16%

Scale variations with NNLOPS

y(H)



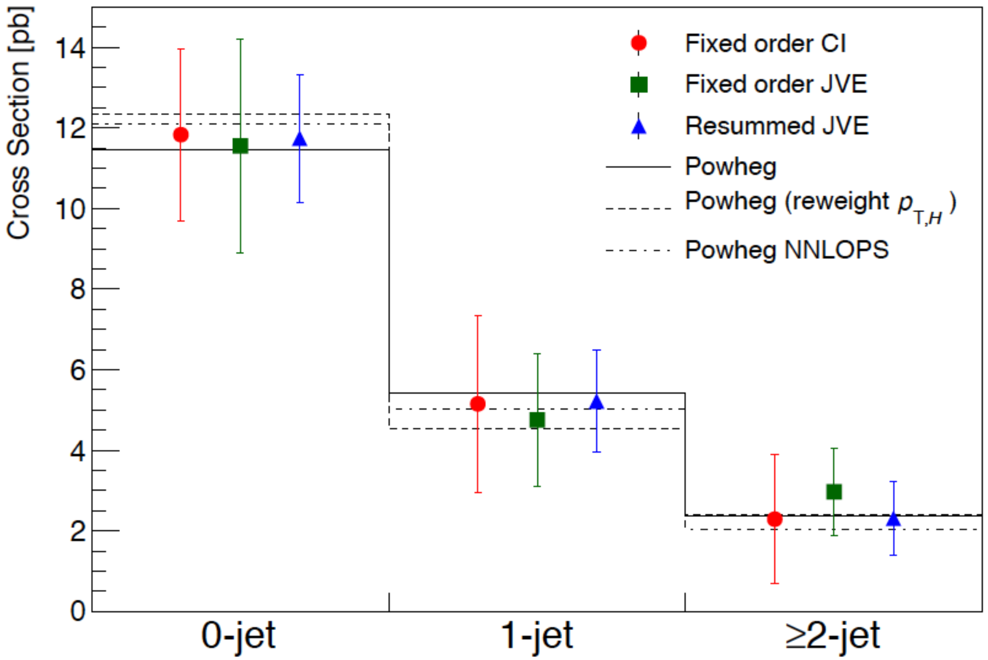


p_T(j1)

Shape only

- Uncertainty on kinematic shapes are larger from the MiNLO contribution

Comparison with Calculations



- All predictions are normalized to an inclusive cross section of 19.27 pb
- Powheg NNLOPS compared to the Run 1 default Powheg
- Fixed Order CI is a jet binned calculation using HNNLO following the combined inclusive prescription
- Fixed order (Resummed) JVE is a jet binned calculation using JetVheto following the jet veto efficiency prescription
- Good agreement is observed

Sherpa MEPS@NLO Settings

√s	8 TeV
m_H	125.0 GeV
m_t, m_b	172.5 GeV, 4.75 GeV
μ Core	Higgs (m_H and $p_T(j)$)
Q cut	20 GeV
PDF	CT10

- The inclusive, H+1 jet and H+2 jets processes are calculated at NLO accuracy and matched to the parton shower using the MEPS@NLO method.
- H+3 jets are calculated at leading order and merged on top
- The integration used was performed by Frank Siegert

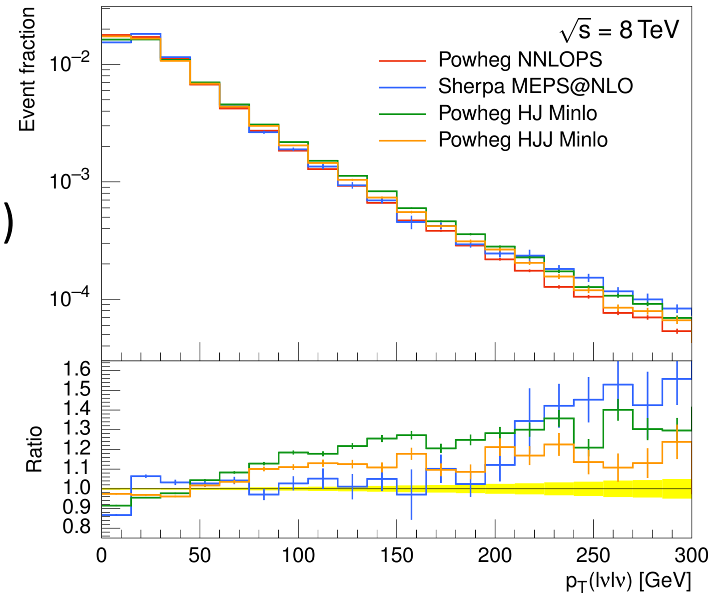
Samples for comparison

Generator	Powheg HJ MiNLO	Powheg HJJ MiNLO
√s	8 TeV	8 TeV
m_H	125.4 GeV	125.0 GeV
m_t, m_b	172.5 GeV, 4.75 GeV	172.5 GeV, 4.75 GeV
$\mu=\mu_R=\mu_F$	m_H (core in MiNLO)	m_H (core in MiNLO)
ME & PS/UE PDF set	CT10nnlo & CT10	CT10
Shower / tune / main31	Pythia 8 / AU2 / Powheg std.	Pythia8 / AU2 / Powheg std.

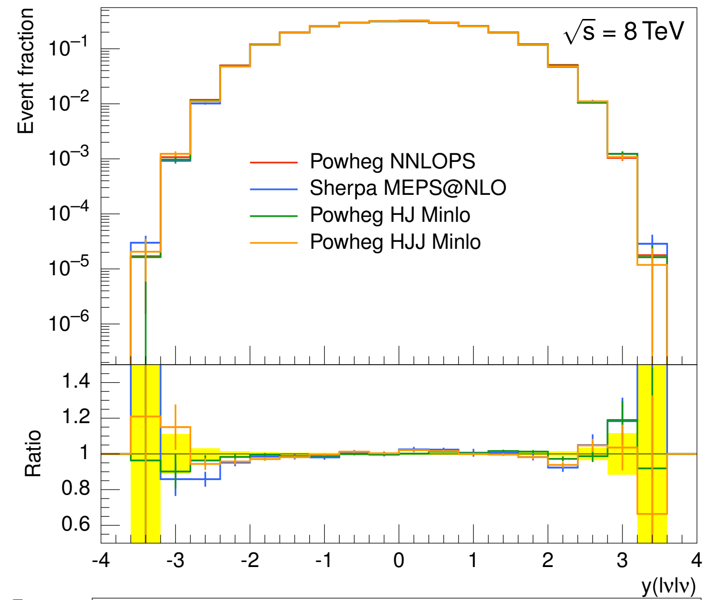
- all samples decay the Higgs to WW->lνlν and are passed through the same Rivet routing for a dilepton+jets selection and plot making

Reconstructed Higgs boson and decay products

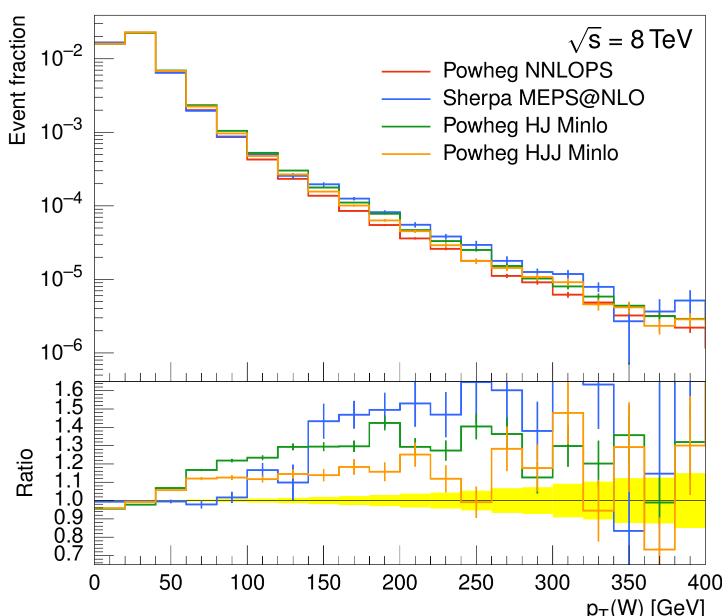
$p_T(l\nu l\nu)$



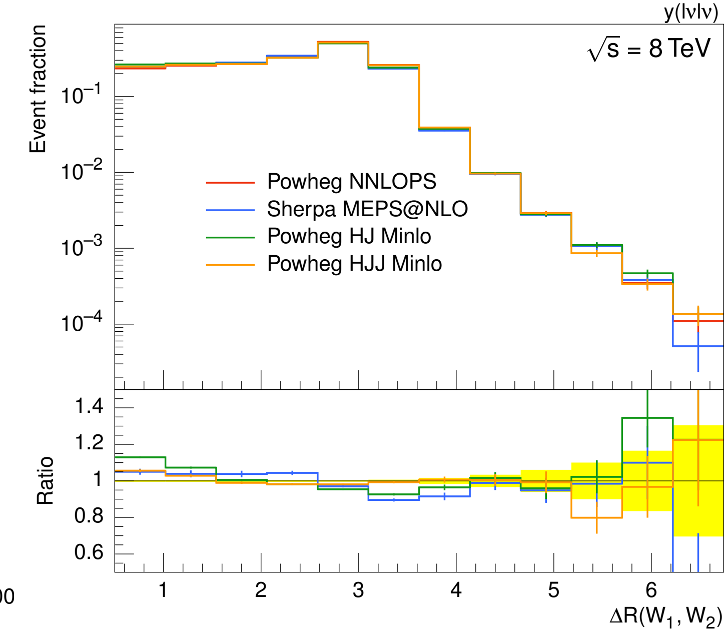
$y(l\nu l\nu)$



$p_T(l\nu)$

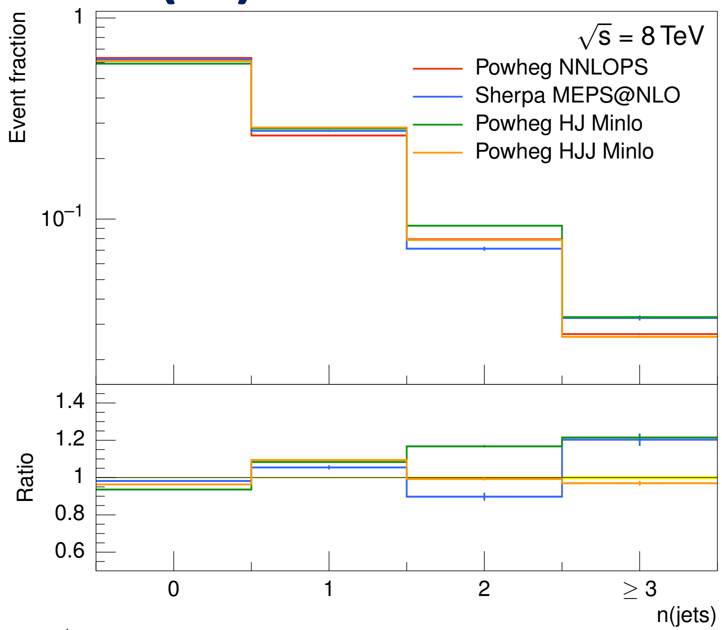


$\Delta R(W_1,W_2)$

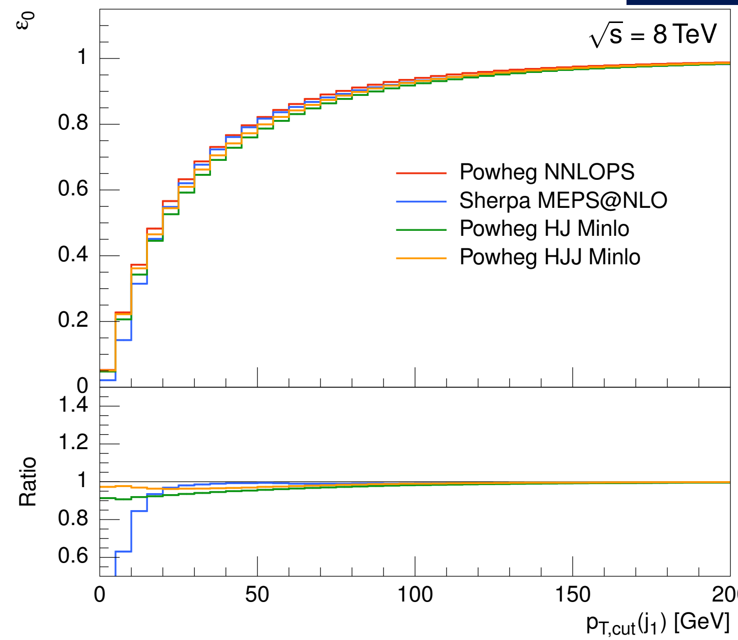


Jets (1)

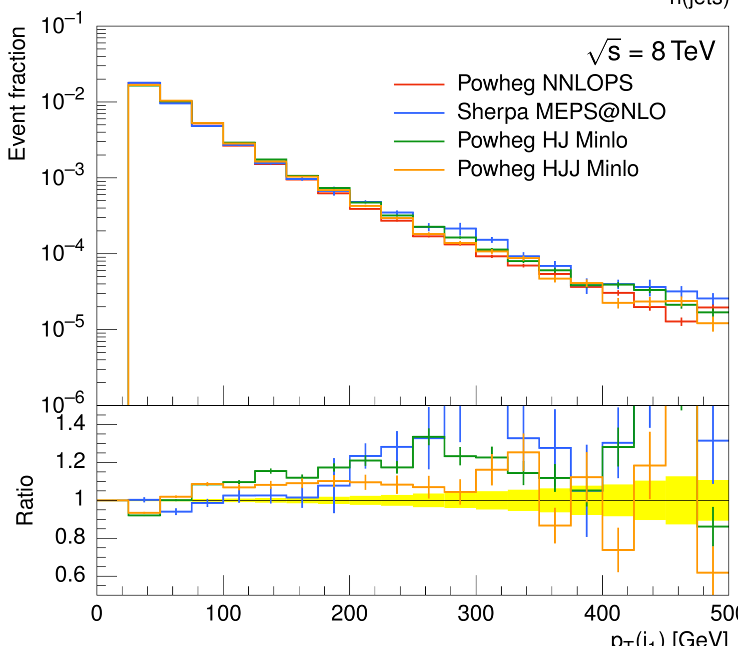
Njets



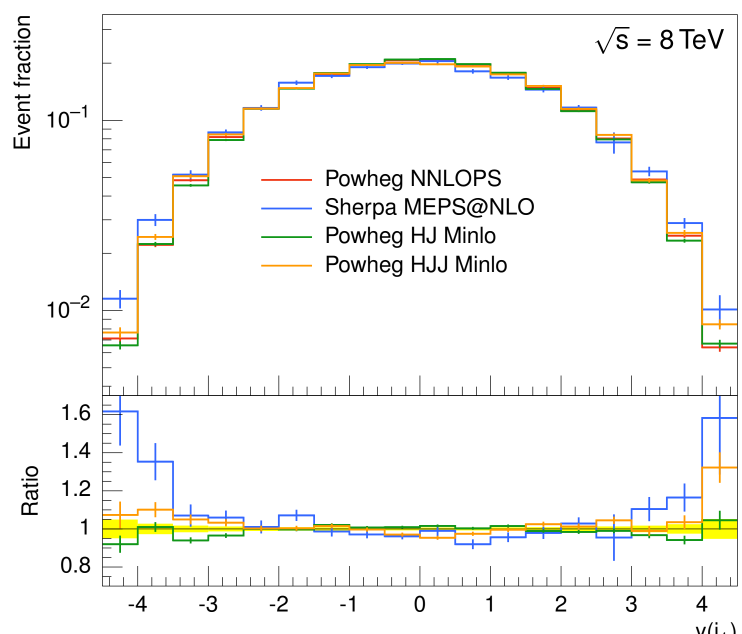
jet veto eff.



$p_T(j_1)$



$y(j_1)$



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Jets (2)

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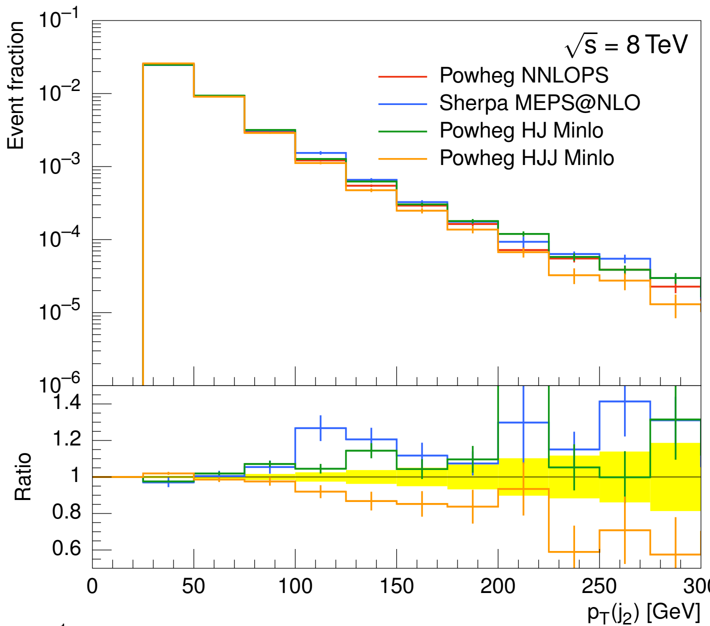
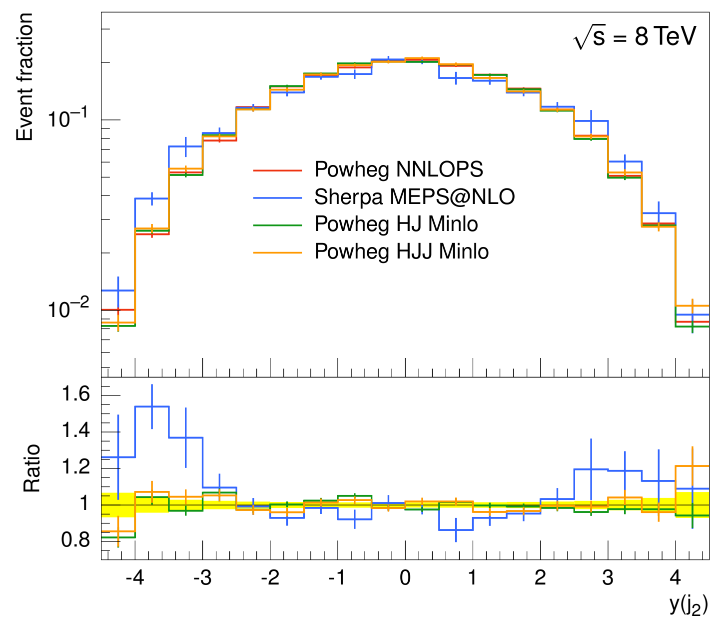
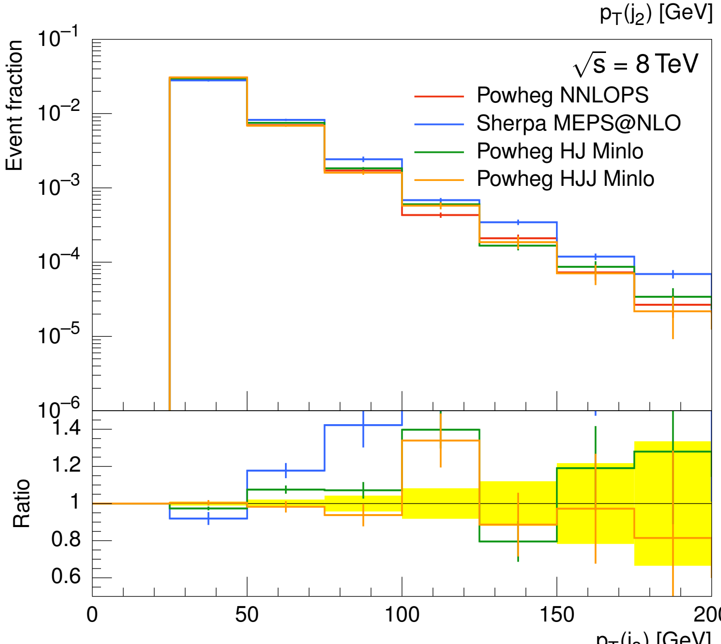
$p_T(j_2)$

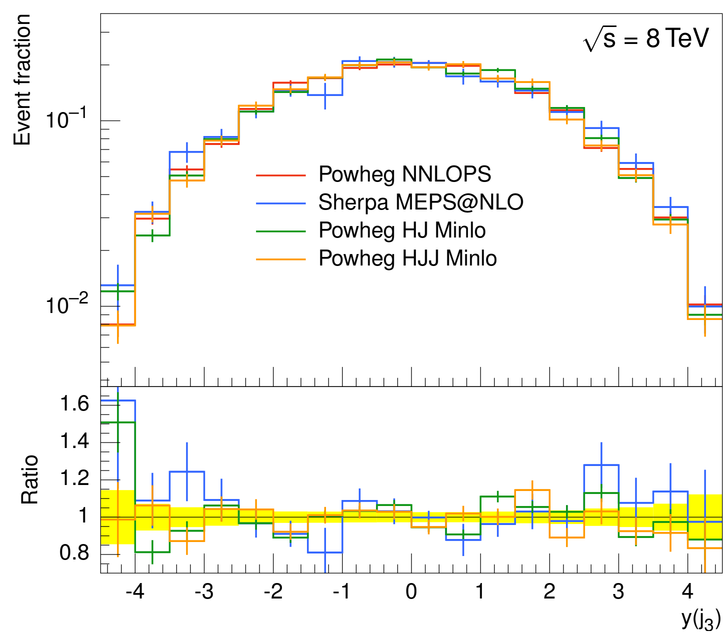




$y(j_2)$

$p_T(j_3)$



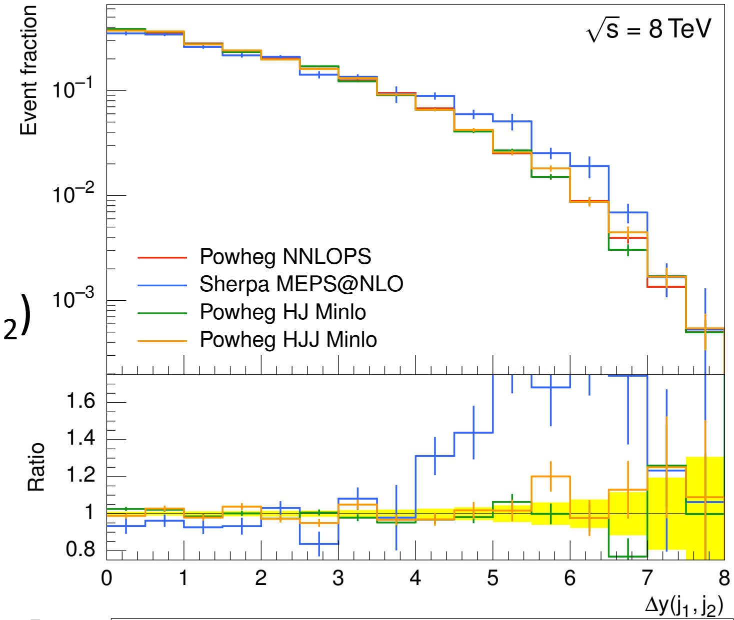


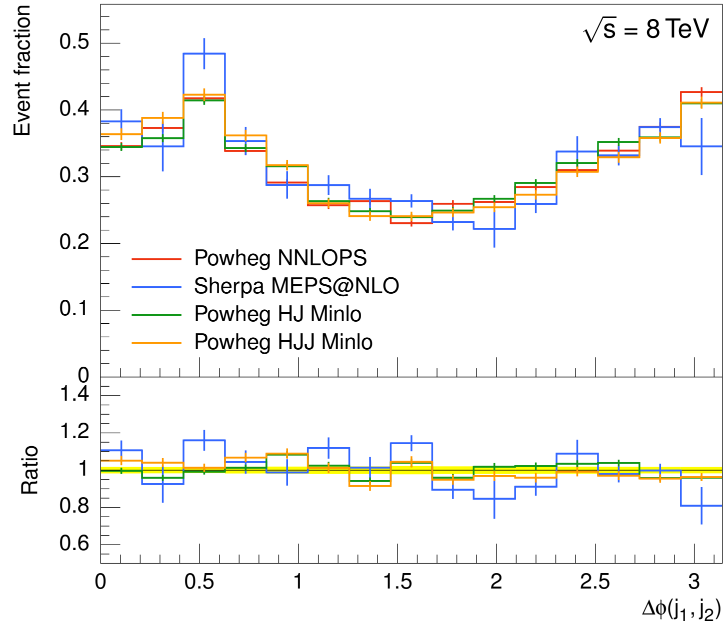
$y(j_3)$

Sherpa jets are more forward -> known and being investigated

Dijet variables

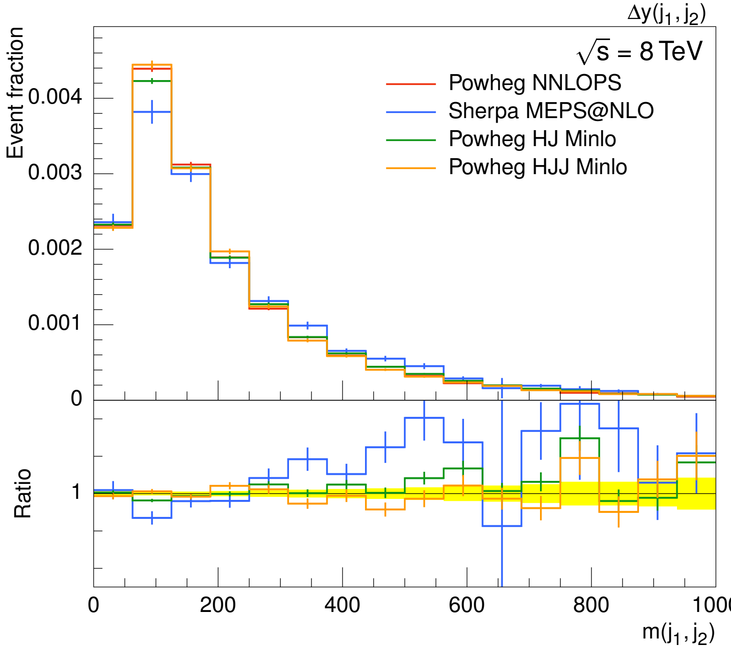
$\Delta y(j_1,j_2)$

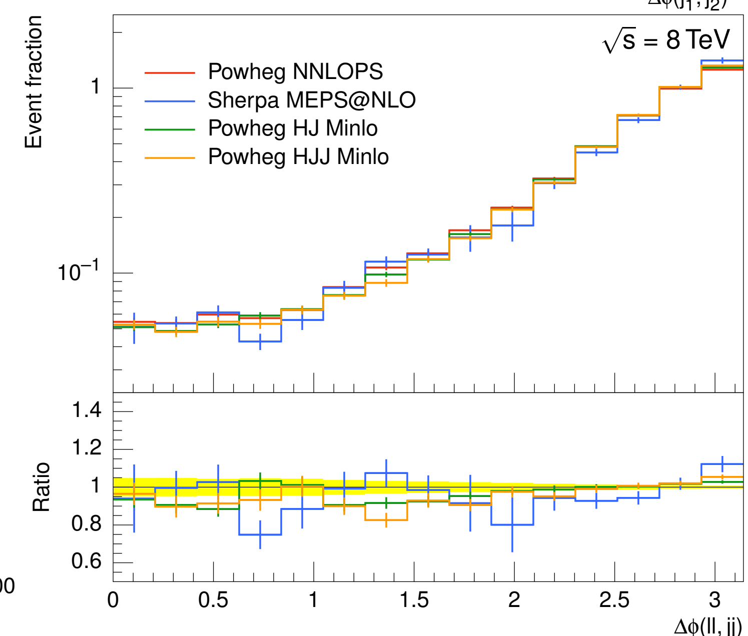




$\Delta\phi(j_1,j_2)$

$m(j_1j_2)$

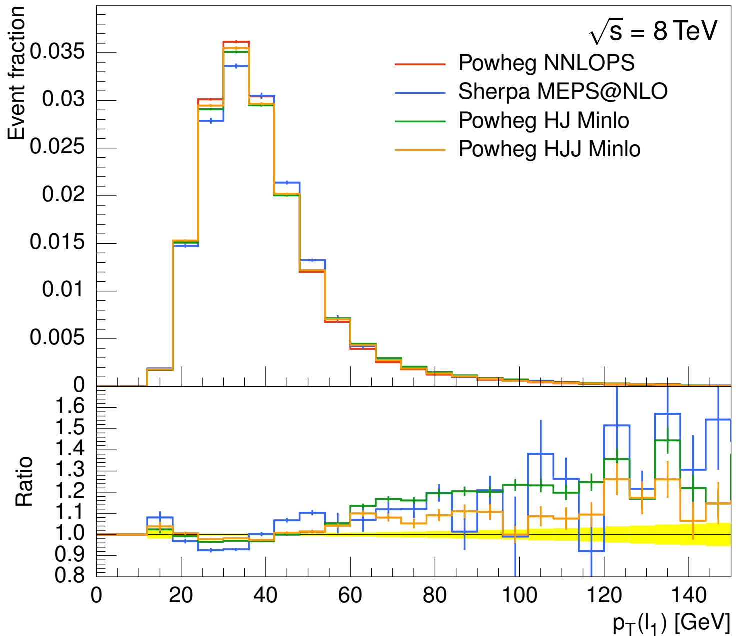




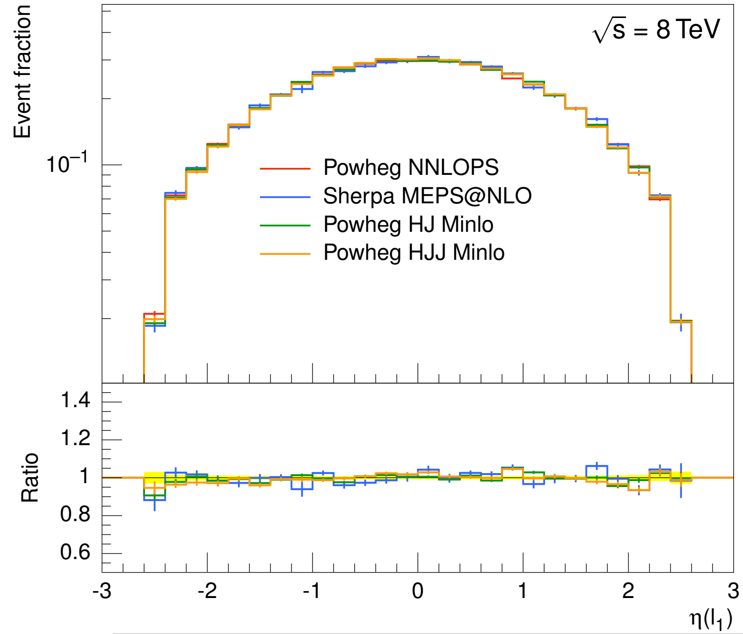
$\Delta\phi(l_1l_2,j_1j_2)$

Leptons

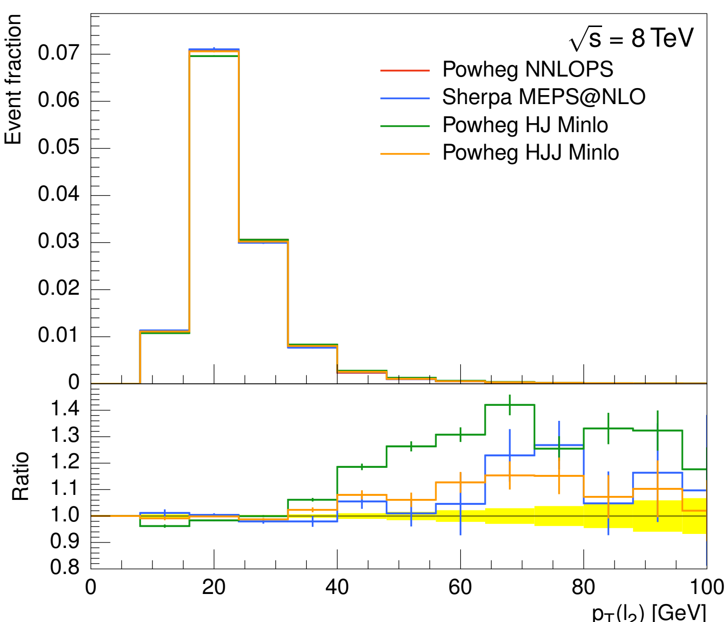
$p_T(l_1)$



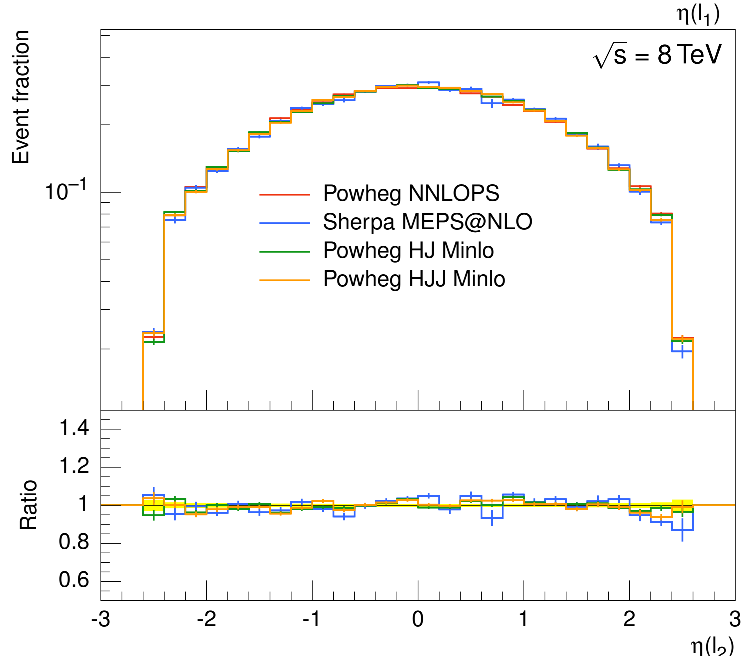
$\eta(l_1)$



$p_T(l_2)$

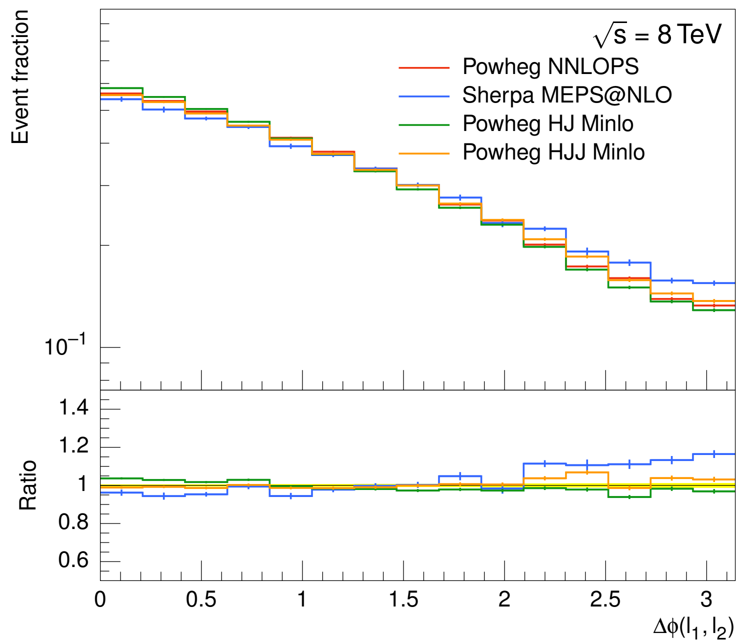


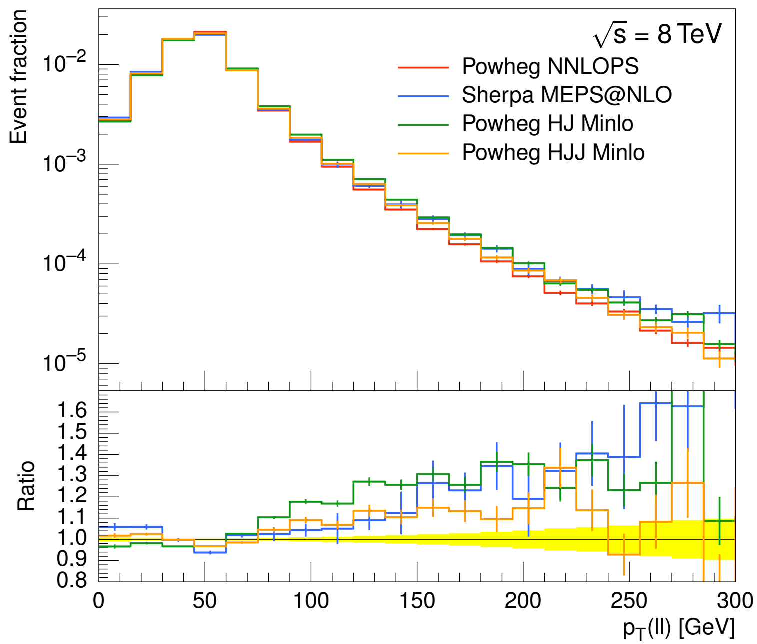
$\eta(l_2)$



Dilepton variables

$\Delta\phi(l,l)$





$p_T(ll)$

- All-over PowhegBox NNLOPS behaves as expected: $p_T(H)$ is softer and the 0-jet fraction is larger
- We observe more jet activity in high jetbins and harder jet p_T distributions with Sherpa
- Basic properties and angles between physics objects look as expected

Benchmark comparisons

- Benchmark number so quantify the comparison

	POWHEG NNLOPS	POWHEG HJ MINLO	POWHEG HJJ MINLO	SHERPA MEPS@NLO
$f(p_T(WW) < 20\ \mathrm{GeV})$	$36.4 \pm 0.2\%$	$33.8 \pm 0.1\%$	$35.5 \pm 0.1\%$	$33.0 \pm 0.3\%$
$f(p_T(WW) > 100\ \mathrm{GeV})$	$8.39 \pm 0.04\%$	$10.37 \pm 0.05\%$	$9.53 \pm 0.07\%$	$9.6 \pm 0.2\%$
$f(\lvert y(WW)\rvert < 1)$	$59.7 \pm 0.2\%$	$59.9 \pm 0.1\%$	$60.5 \pm 0.2\%$	$60.4 \pm 0.5\%$
$f(\lvert y(WW)\rvert > 2)$	$5.00 \pm 0.05\%$	$4.89 \pm 0.04\%$	$4.79 \pm 0.05\%$	$4.6 \pm 0.1\%$

	POWHEG NNLOPS	POWHEG HJ MINLO	POWHEG HJJ MINLO	SHERPA MEPS@NLO
$\epsilon_0(30\ \mathrm{GeV})$	$63.3 \pm 0.2\%$	$59.2 \pm 0.2\%$	$61.0 \pm 0.2\%$	$61.9 \pm 0.4\%$
$\epsilon_0(25\ \mathrm{GeV})$	$56.6 \pm 0.2\%$	$52.6 \pm 0.2\%$	$54.5 \pm 0.2\%$	$54.8 \pm 0.4\%$
$f(1\mathrm{jet})$	$26.05 \pm 0.09\%$	$28.21 \pm 0.09\%$	$28.5 \pm 0.1\%$	$27.5 \pm 0.3\%$
$f(2\mathrm{jet})$	$7.94 \pm 0.05\%$	$9.27 \pm 0.05\%$	$7.88 \pm 0.06\%$	$7.1 \pm 0.2\%$

Error includes only MC stat.

Small differences reflect differences seen in plots.
All over nice consistency between all samples.

To-do list

- PowhegBox NNLOPS
  - central scale choice
  - uncertainty on the reweighting?
  - investigate shower parameters for Pythia8: main31? damping? shower PDF set? merging?
- Sherpa MEPS@NLO
  - investigate scale choices as well as Qcut
- include Madgraph5_aMC@NLO

Conclusions

- I presented an overview of studies with updated MC generators in Higgs-boson production via gluon fusion
- These studies are still incomplete and will need to be continued and extended
- We are very grateful in any kind of feedback from the community.

Thank you for your attention!

BACK-UP

Truth Selection

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- 2 dressed opposite charged leptons (electrons or muons)
- Dressed with photons within a ΔR cone of 0.1 around their direction.
- Electrons: $p_T > 15$ GeV, $|\eta| < 2.47$
- Muons: $p_T > 15$ GeV, $|\eta| < 2.4$

- Jets clustered from all particles except for leptons, photons, and neutrinos not originating from a hadron decay
- FastJet with Anti-Kt 0.4
- Jets: $p_T > 30$ GeV, $|y| < 4.4$

- W reconstructed from selected lepton and a suitable neutrino with mass constraint 10 GeV < m(W) < 120 GeV
- If two W's are reconstructed, the Higgs boson is recontructed from them