

Reweighting Higgs p_T to NNLL(Resummation)+NNLO(Fixed order)

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Higgs $q_T(p_T)$ reweighting

- The QCD correction of the $gg \rightarrow H$ process is up to NLL(Resummation)+NLO(Fixed order) for both McAtNLO(+Herwig) and PowHeg(+Pythia) generators.
- The **HqT** program provides Higgs p_T distributions up to NNLL+NNLO.

<http://theory.fi.infn.it/grazzini/codes.html>

- We are using HqT to reweight Higgs p_T distributions from NLL+NLO to NNLL+NNLO.
- Since the transverse momentum(q_T or p_T) of the Higgs is related to the jet activity. Reweighting the Higgs p_T will change jet multiplicities.
- Three mass points ($m_H = 130, 160, 400$ GeV) are studied in this talk for comparisons between McAtNlo and PowHeg.
- All studies are based on the **parton level truth** information **without** QED radiation corrections for leptons.

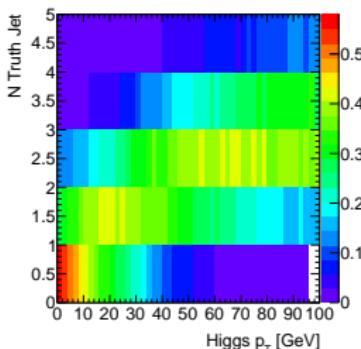
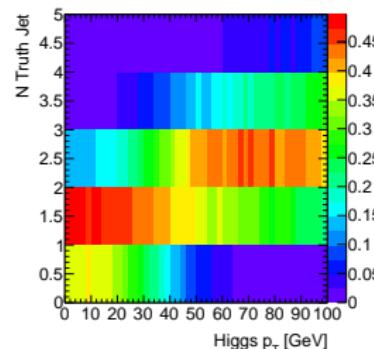
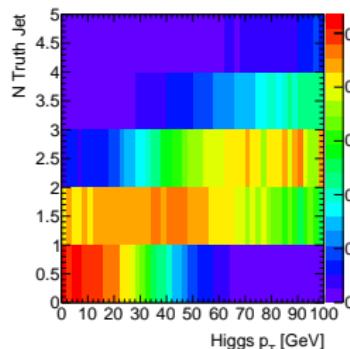
Jet multiplicity versus Higgs p_T

The jet multiplicity ($p_T^{jet} > 25$ GeV and $|\eta| < 4.5$) increases as Higgs p_T .

McAtNlo: $m_H = 130$ GeV

$m_H = 160$ GeV

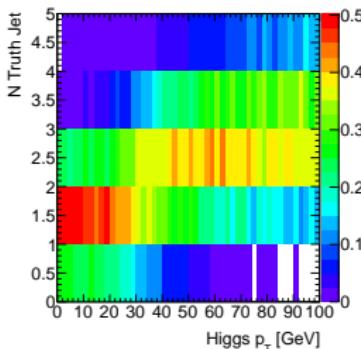
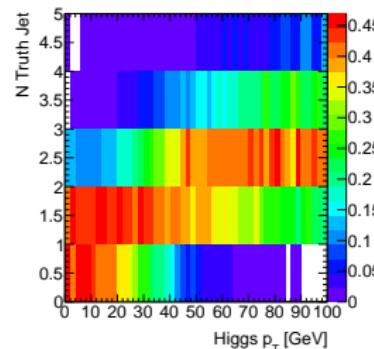
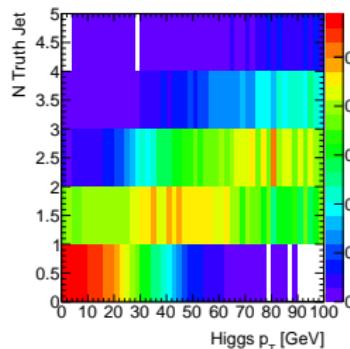
$m_H = 400$ GeV



PowHeg: $m_H = 130$ GeV

$m_H = 160$ GeV

$m_H = 400$ GeV

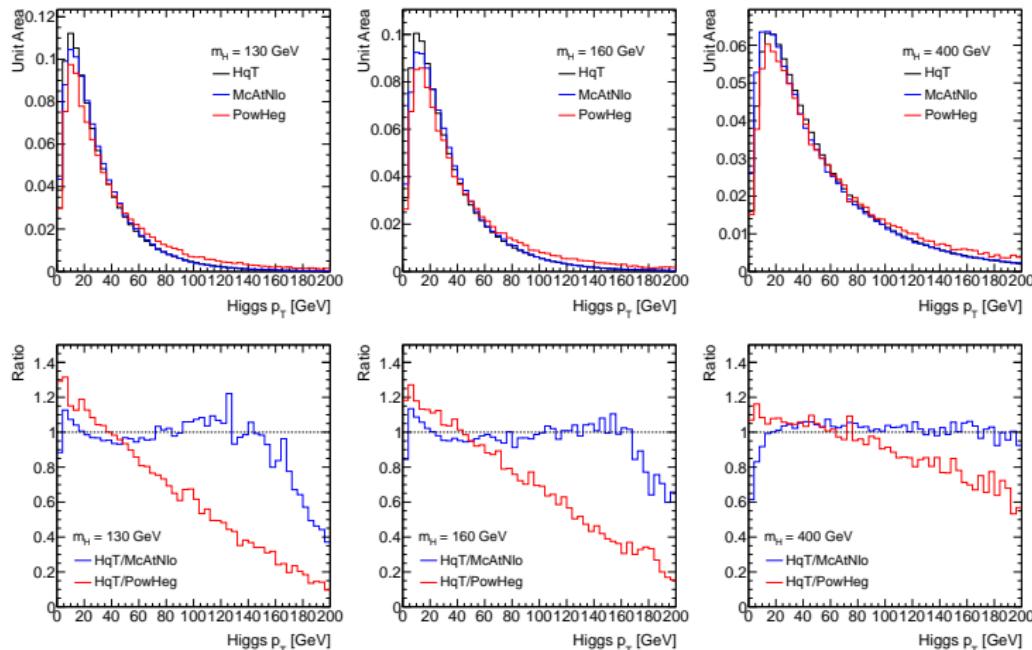


Large difference between McAtNlo and PowHeg at $m_H = 400$ GeV

- The data card for $m_H = 130$ GeV
 - 1 !pp(1) or ppbar (-1) collisions
 - 7d3 ! centre of mass energy
 - 130d0 ! Higgs mass
 - 2 ! order of calculation: NLL+LO (1) NNLL+NLO (2)
 - 92 0 ! pdf, errors MSTW2008 NNLO, nominal eigenvector
 - 3 ! alpha_s nloop
 - 130d0 130d0 ! renormalization and factorization scales
 - 0d0 ! g: NP spearing
 - 1 ! normalization (0) mttop->infinity (1) full mt,mb dependence
 - 1 201 2 ! qtmin qtmax qtbin
- Vary the renormalization and factorization scales to set the scale uncertainty
- Use difference MSTW2008 NNLO eigenvector pairs at 90% C.L. to set PDF uncertainty

Higgs p_T distribution from HqT and new weights

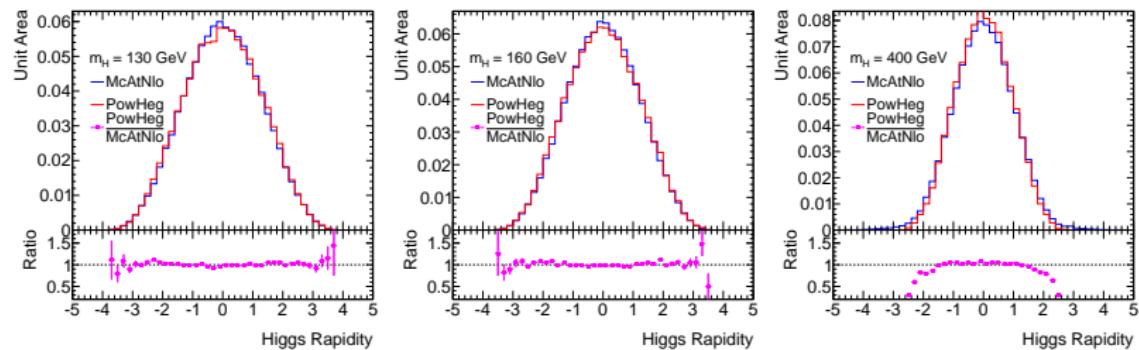
- We normalize the Higgs p_T distributions to unit for all the generators to calculate weights



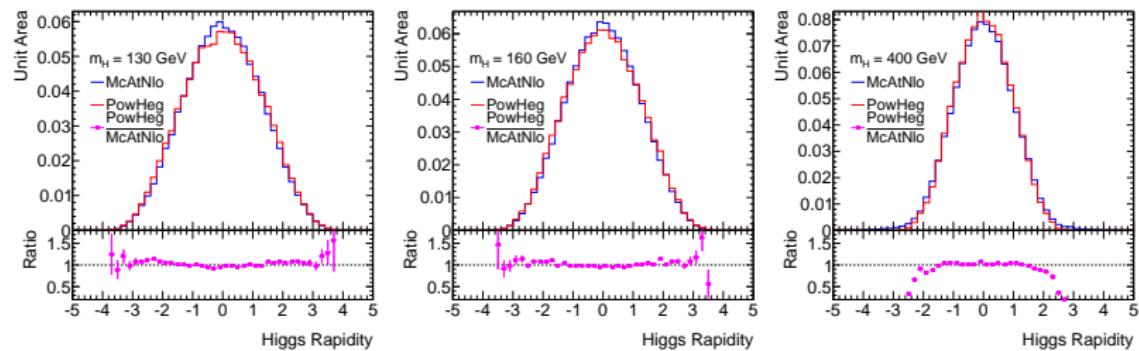
Compared to McAtNlo, PowHeg predicts harder Higgs p_T distribution in the high p_T region

Higgs Rapidity distributions

Compare the Higgs rapidity between McAtNlo and PowHeg
Before reweighting



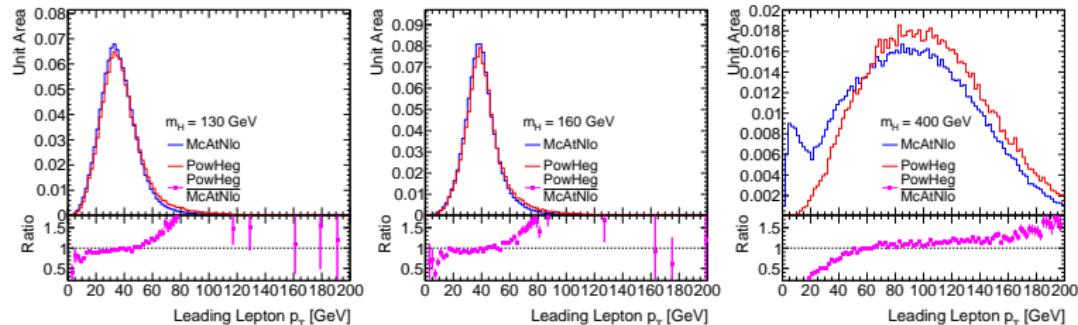
After reweighting



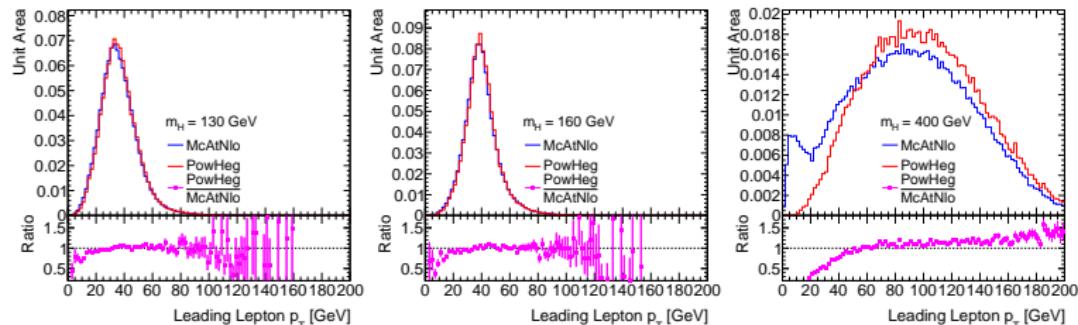
The impact on the Higgs rapidity from p_T reweighting is negligible

Leading Lepton p_T distributions

Before reweighting



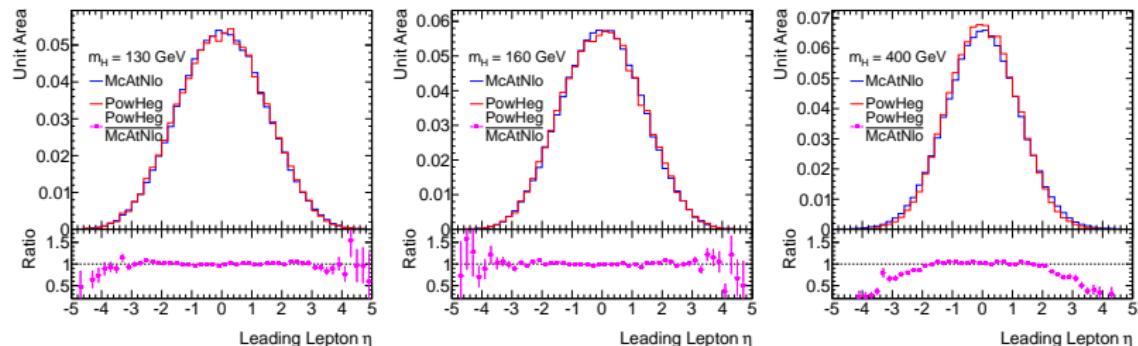
After reweighting



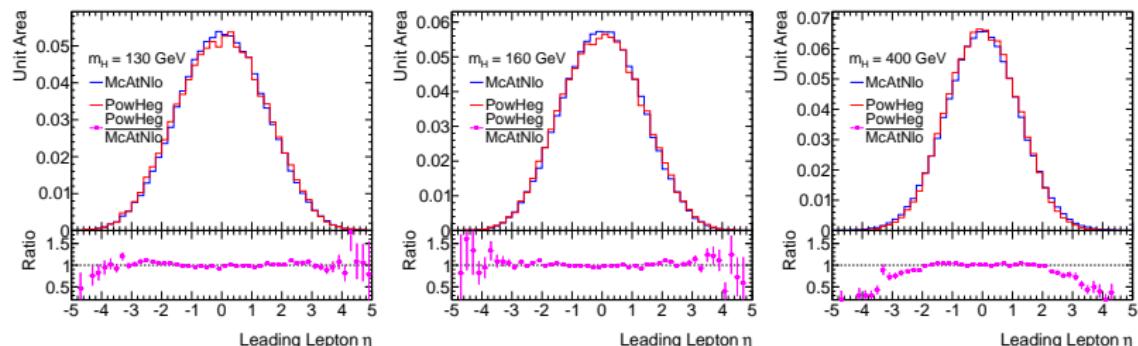
Unexpected leading lepton p_T distribution of McAtNlo with $m_H = 400$ GeV. It has been understood and fixed by the McAtNlo author.

Leading Lepton η distributions

Before reweighting



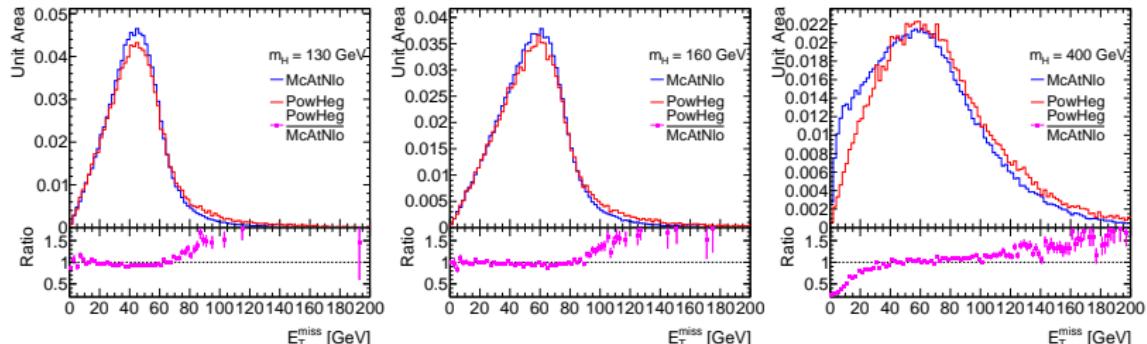
After reweighting



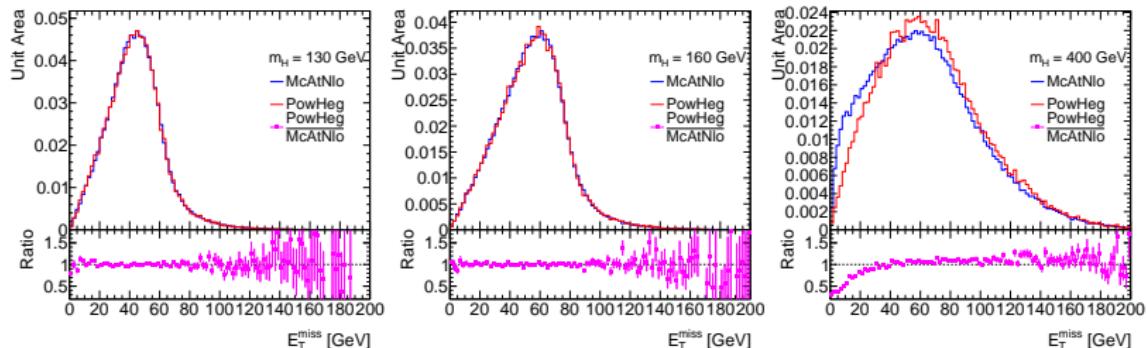
Negligible impact on the lepton η distribution.

$E_T^{miss} = \vec{\nu}_1 + \vec{\nu}_2$ distributions

Before reweighting



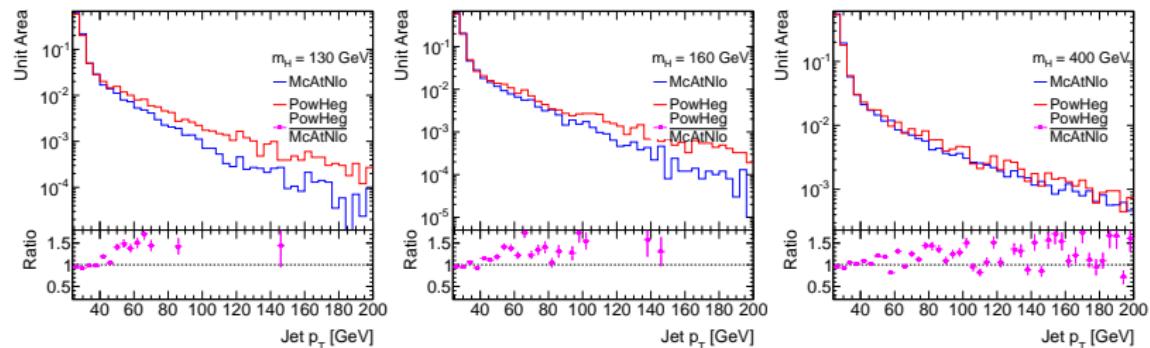
After reweighting



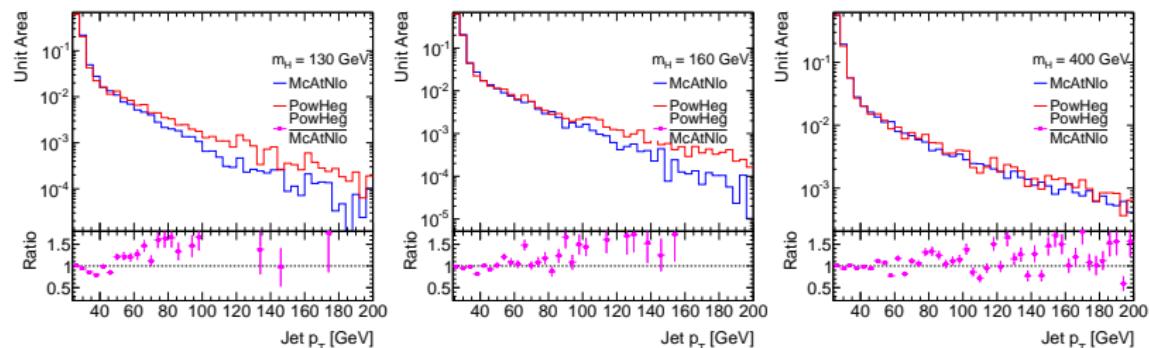
Small corrections on E_T^{miss}

Truth jet p_T distributions

Compare truth jet p_T with $p_T^{jet} > 25 \text{ GeV}$, $|\eta|^{jet} < 4.5$
Before reweighting



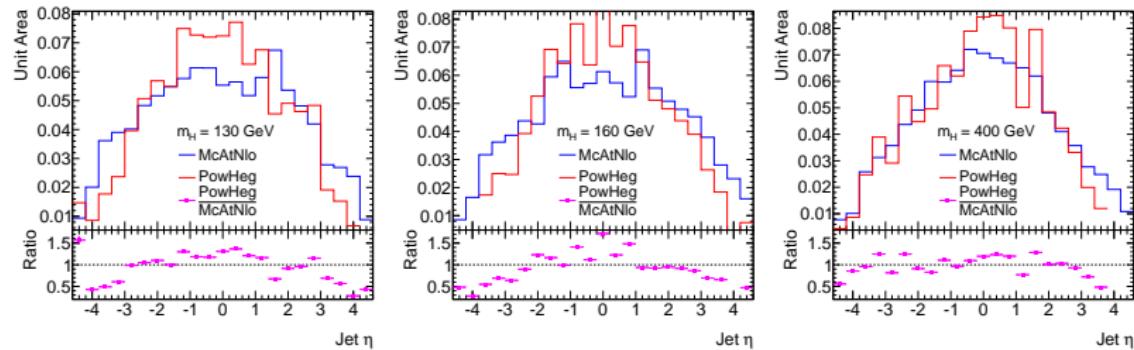
After reweighting



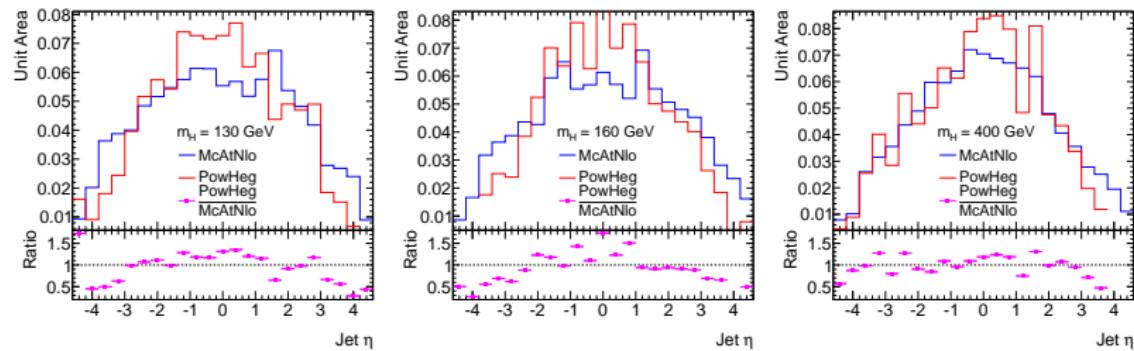
PowHeg has harder jet p_T distributions.

Truth jet η distributions

Compare truth jet η with $p_T^{jet} > 25 \text{ GeV}$, $|\eta|^{jet} < 4.5$
Before reweighting



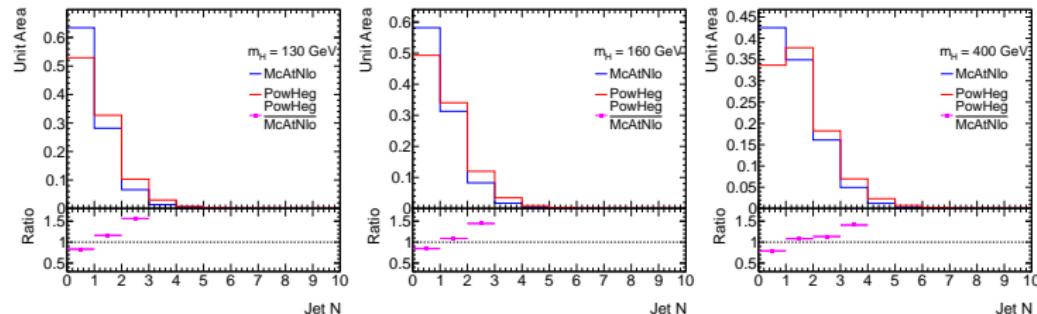
After reweighting



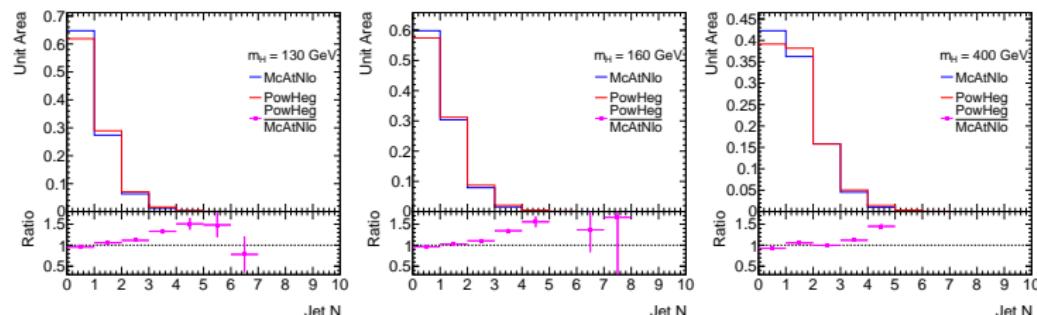
Negligible impact on the jet η distribution.

Truth jet multiplicity distributions

Compare truth jet multiplicity with $p_T^{jet} > 25 \text{ GeV}$, $|\eta|^{jet} < 4.5$
Before reweighting



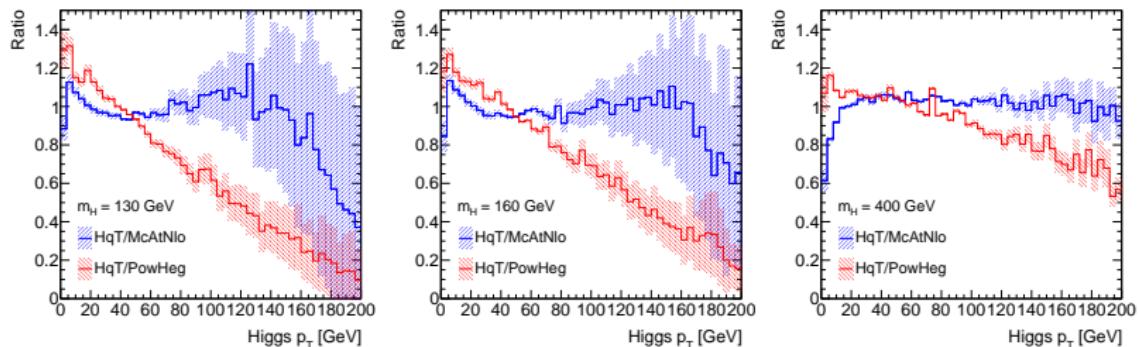
After reweighting



The discrepancy of jet multiplicity distributions between McAtNlo and PowHeg decreases after the Higgs p_T reweighting

Systematic uncertainty from μ_R and μ_F

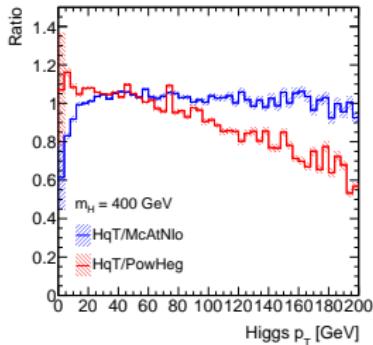
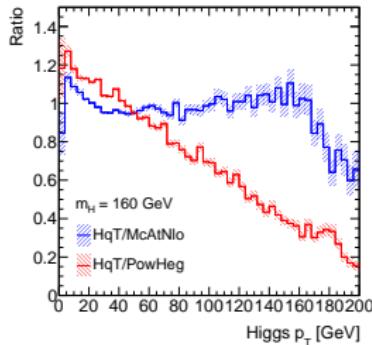
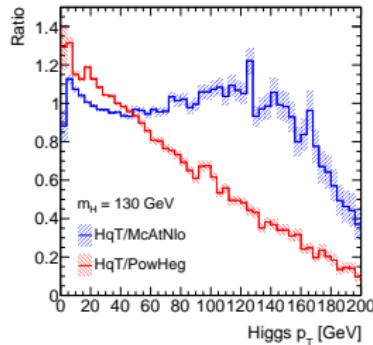
- Vary the μ_R and μ_F in HqT: $\mu_R, \mu_F = \frac{1}{2}m_H, 2m_H$
- Symmetric error band :
Scale Uncertainty = $\text{Max}(\Delta\text{weight}(\mu_R, \mu_F = \frac{1}{2}, 2m_H))$
- The scale uncertainty decreases as the Higgs mass



Systematic uncertainty from PDF

- Use 90% C.L. eigenvector pairs $\{(\vec{x}_1, \vec{x}_2), \dots, (\vec{x}_{39}, \vec{x}_{40})\}$ from NNLO MSTW2008 to set the PDF uncertainty
- Symmetric error band :

$$\text{PDF Uncertainty} = \sqrt{\sum_{n=1}^{n=20} \left(\frac{\text{weight}(\vec{x}_{2n-1}) - \text{weight}(\vec{x}_{2n})}{2} \right)^2}$$



The PDF uncertainty also decreases as the Higgs mass.

Impact on the acceptance

- Study the impact of the Higgs p_T reweighting on the acceptance
- The acceptance requirement consists of several cuts **sequentially** applied on kinematics of leptons, E_T^{miss} and the jet multiplicity.
 - $p_T^{\ell,1} > 20 \text{ GeV}$, $p_T^{\ell,2} > 15 \text{ GeV}$ and $|\eta^\ell| < 2.5$
 - $E_T^{miss} > 30 \text{ GeV}$
 - 0, 1 and 2 Jets with $p_T^{jet} > 25 \text{ GeV}$ and $|\eta^{jet}| < 4.5$

Cut Acc. Eff.	McAtNlo $m_H = 130 \text{ GeV}$			PowHeg $m_H = 130 \text{ GeV}$			McAtNlo $m_H = 160 \text{ GeV}$			PowHeg $m_H = 160 \text{ GeV}$		
	w.o RWT	with RWT	diff.(%)	w.o RWT	with RWT	diff.(%)	w.o RWT	with RWT	diff.(%)	w.o RWT	with RWT	diff.(%)
Lepton cut	0.484	0.482	-0.30	0.522	0.509	-2.50	0.714	0.714	-0.11	0.741	0.738	-0.45
E_T^{miss} cut	0.387	0.385	-0.33	0.414	0.405	-2.07	0.634	0.634	-0.08	0.657	0.656	-0.11
Zero Jet	0.246	0.251	2.22	0.216	0.253	17.14	0.371	0.382	2.82	0.326	0.380	16.59
One Jet	0.106	0.103	-3.24	0.134	0.115	-13.85	0.197	0.191	-3.03	0.220	0.202	-8.21
Two Jet	0.027	0.025	-5.99	0.045	0.029	-35.95	0.052	0.049	-5.20	0.079	0.057	-28.43

- The reweighting changes the zero jet acceptance by 2-3% for McAtNlo and 17% for PowHeg with
- The major correction is on the jet multiplicity, as it is highly related to the Higgs p_T
- After the Higgs p_T reweighting, the McAtNlo and PowHeg acceptance agrees well!

Summary

- Reweighting the Higgs p_T distributions from NLL+NLO to NNLL+NNLO using HqT
- The reweighting uncertainties are from renormalization and factorization scales and PDF
- The McAtNlo and PowHeg have different Higgs p_T distributions in the high p_T region
- After the reweighting, the McAtNlo and PowHeg have the similar acceptance at the truth level
- Will include the comparison to Pythia...