LHCXSWG
ggH report

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Preparatory Meeting of the LHC Higgs Cross Section Working Group
http://indico.cern.ch/event/510558/

Overview

- ~~Inclusive cross section~~
- ~~Jet binned cross section~~

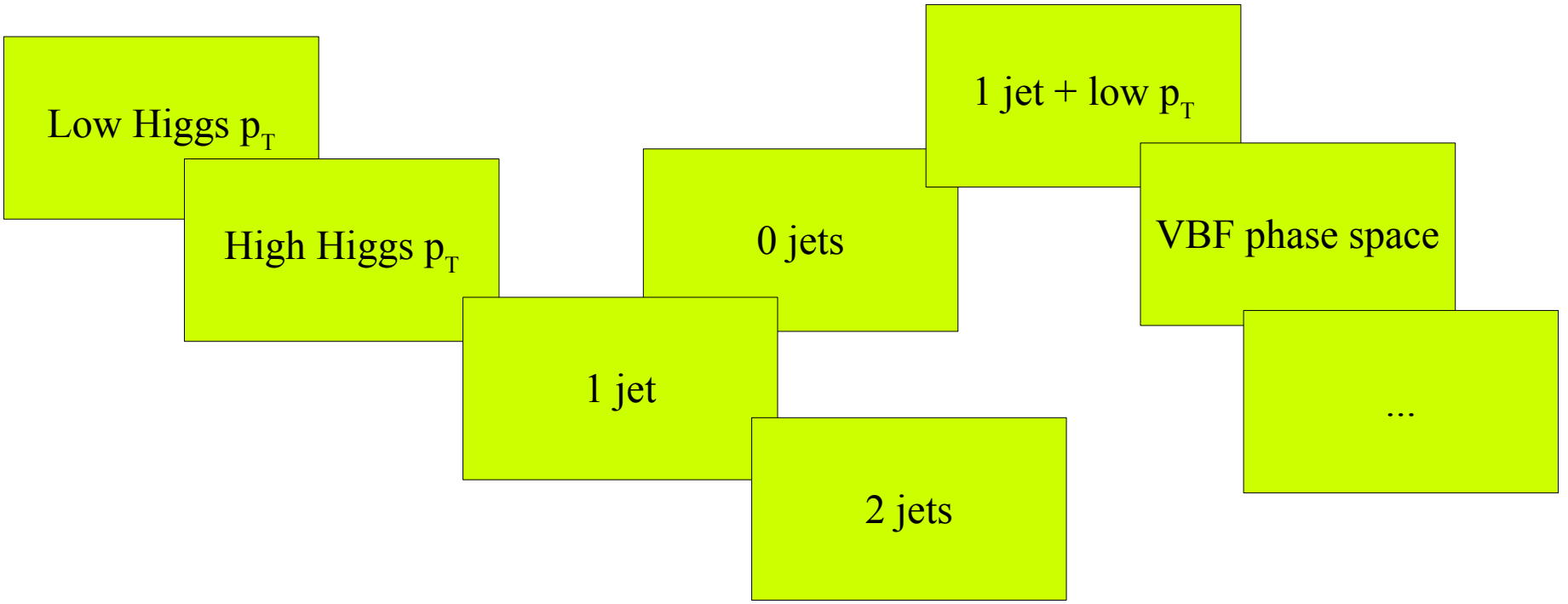
See Chris talk

- Benchmarks for cross sections and differential distributions
- Effects of heavy quarks masses

  - ggF draft for YR4 https://cds.cern.ch/record/2194224

Benchmarks for cross sections and differential dist.

- Comparison of **parton** level code and **hadron** level codes with different accuracy and phase space usability
- From experimental side
  - A lot of analyses exploiting **different phase spaces**
  - Need to **combine** the different analyses to get the best measurement
  - **Accurate modeling** of the differential distributions required



Parton level

- **Parton level** code:
  - **Hres** *D. de Florian, G. Ferrera, M. Grazzini, D. Tommasini, H. Sargsyan*
    - NNLO QCD accuracy, with NNLL QCD resummation for small $p_T H$ and matching to NLO QCD H+1jet at large $p_T H$
  - **CuTe** *T. Becher, M. Neubert, and D. Wilhelm*
    - NNLL QCD resummation at small $p_T H$, and matching to NLO QCD H + 1jet at large $p_T H$
  - **NRV** *D. Neill, I. Z. Rothstein, and V. Vaidya*
    - NNLL resummed accuracy matched to the fixed-order O (α_s^4) computation
  - **MRT** *P. F. Monni, E. Re, P. Torrielli*
    - NNLL for $p_T H$ distribution matched to the NNLO (α_s^5) fixed-order prediction for Higgs+jet
  - **BFGLP** *R. Boughezal, C. Focke, W. Giele, X. Liu, and F. Petriello*
    - H + 1jet at NNLO QCD
  - **CGGJ** *X. Chen, E. W. N. Glover, T. Gehrmann, M. Jacquier*
    - Same as BFGLP
  - **STWZ-BLPTW** *R. Boughezal, X. Liu, F. Petriello, I. W. Stewart, F. J. Tackmann, J. R. Walsh, and S. Zuber*
    - SCET-based resummation for the jet veto at NNLL′ +NNLO
  - **JVE** *A. Banfi, F. Caola, F. A. Dreyer, P. F. Monni, G. P. Salam, G. Zanderighi, and F. Dulat*
    - N^3LO+NNLL+LLR accurate resummation for the jet veto, including heavy quark mass effects up to NLO
  - **Gosam + Sherpa** *G. Cullen, N. Greiner, G. Heinrich, G. Luisoni, P. Mastrolia, G. Ossola, T. Reiter, and F. Tramontano, T. Gleisberg, S. Höche, F. Krauss, M. Schönherr, S. Schumann, F. Siegert and J. Winter*
    - up to two additional jets at NLO QCD accuracy

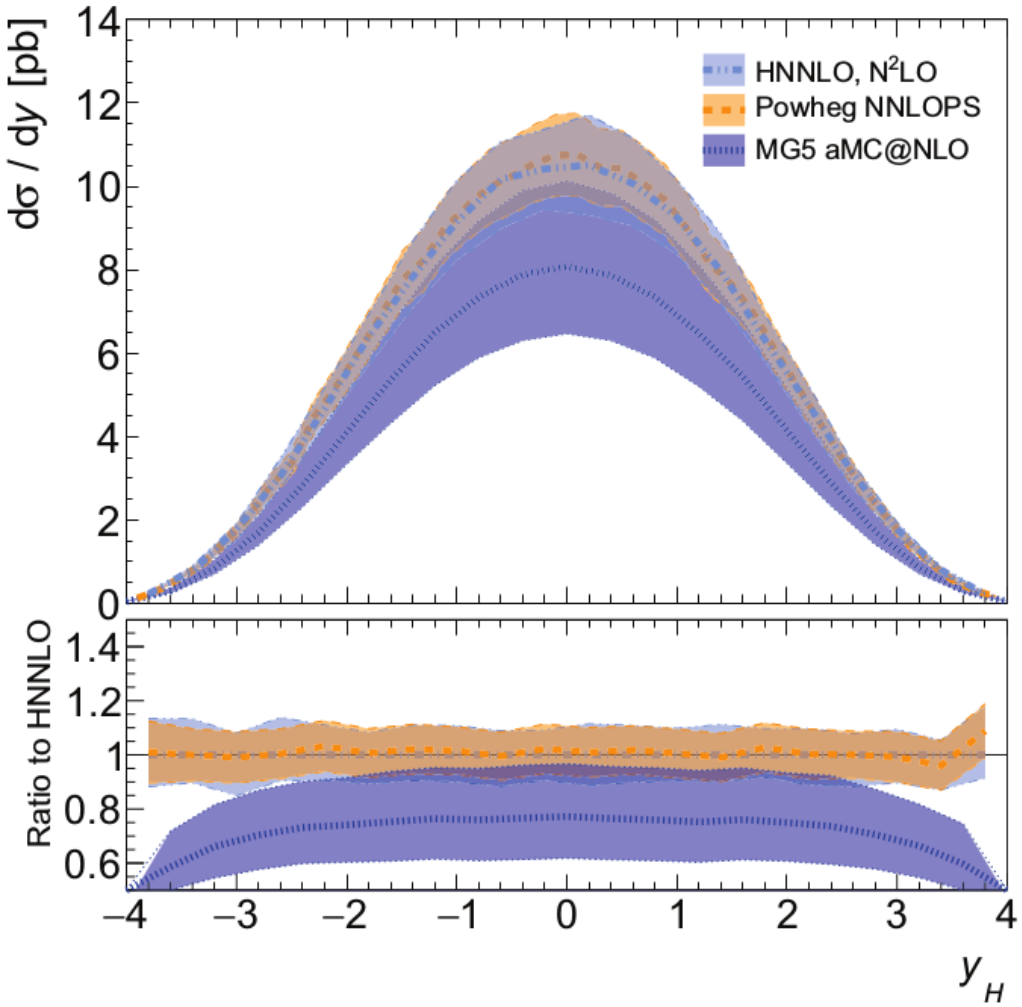
Hadron level

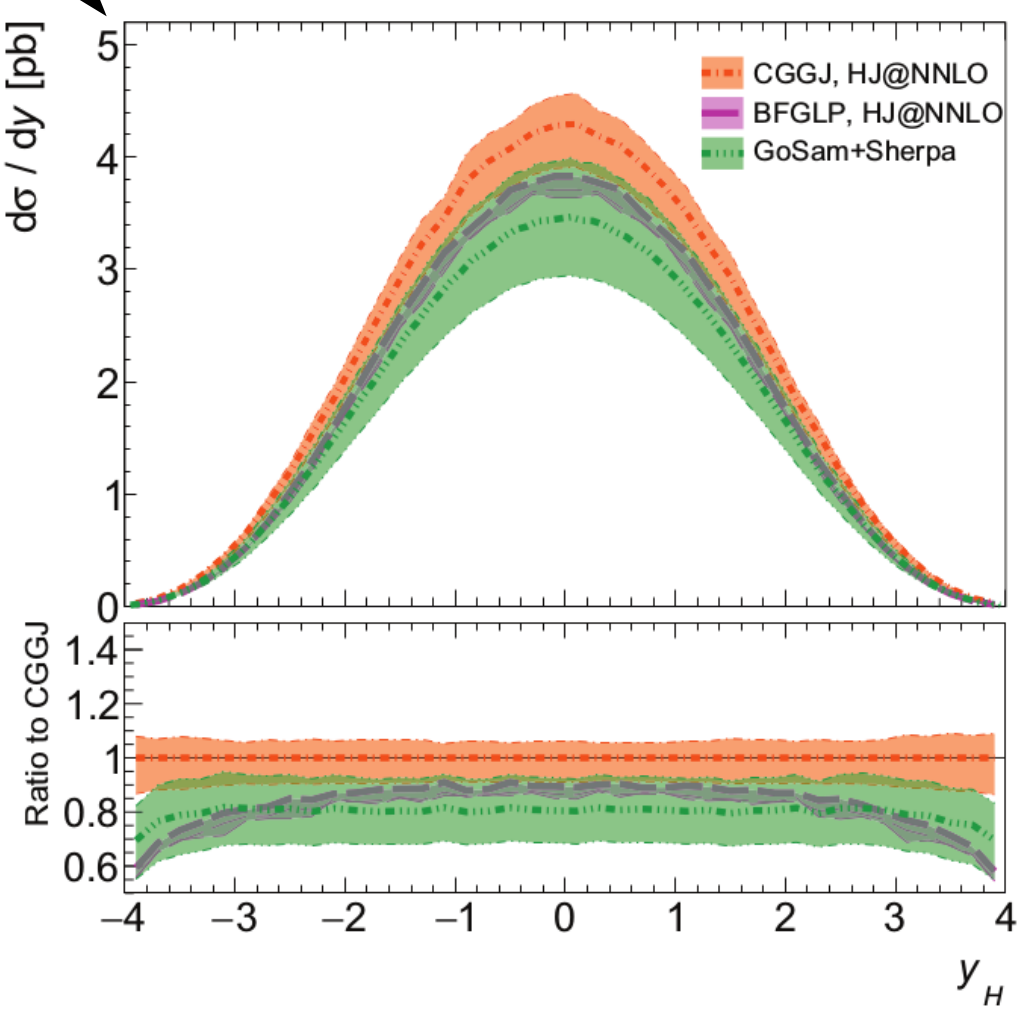
- **Hadron level** code (different scale choices):

  - **MG5_ aMC@NLO** *R. Frederix, S. Frixione, E. Vryonidou, and M. Wiesemann*
    - up to two additional jets at NLO QCD accuracy with the FXFX merging scheme
    - top quark mass included via reweighting of the events
  - **Powheg NNLOPS** *K. Hamilton, P. Nason, E. Re, and G. Zanderighi*
    - NNLO QCD accuracy for inclusive events, and NLO+PS for Higgs+one jet
    - Top and bottom quark mass effects are included up to NLO

Higgs η

- Uncertainty mainly from QCD variation
- **Inclusive** phase space, and after requiring **1 jet**

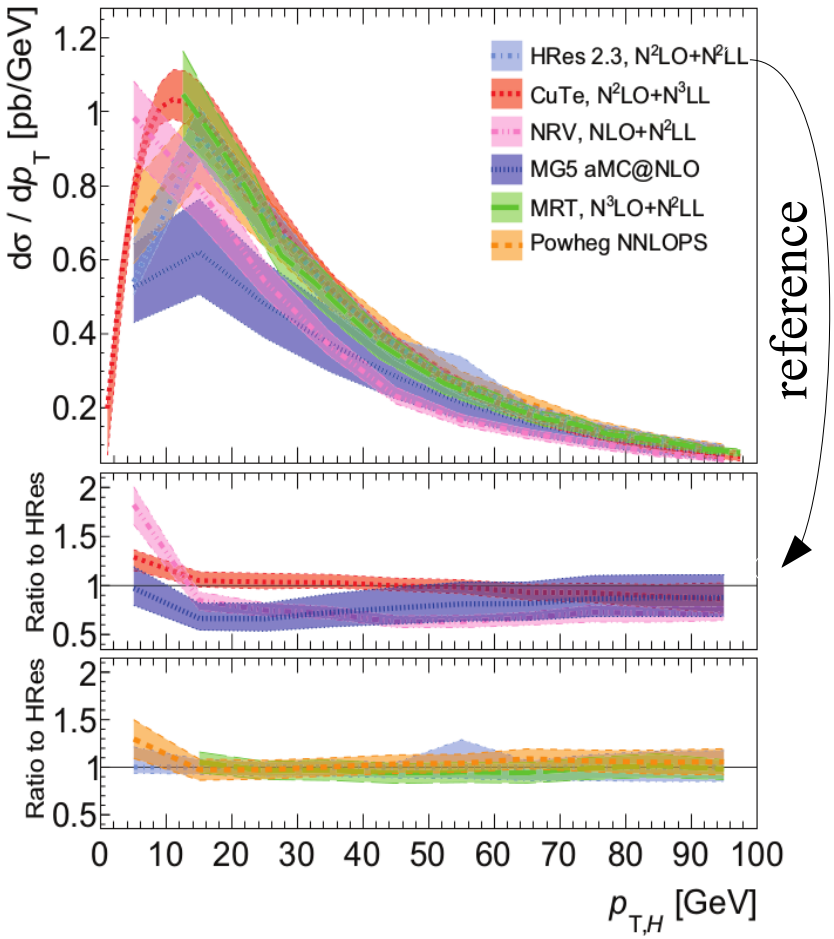




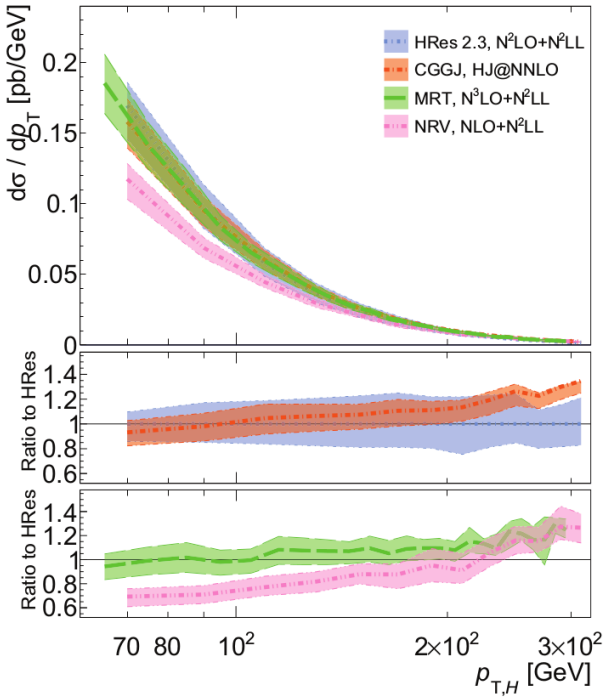
Higgs p_T

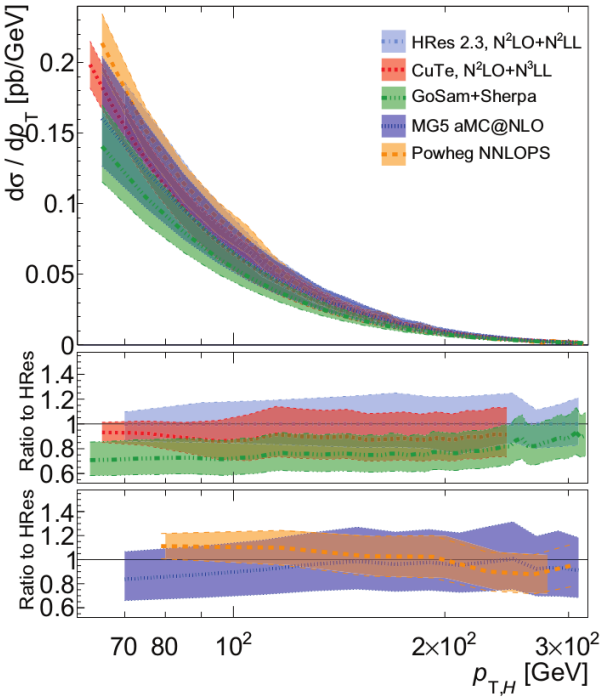
- Uncertainty mainly from QCD variation
- **Low p_TH** region and **high p_TH** region

- Considering MRT as reference
  - Low p_TH: MRT ~ HRes, CuTe, NRV → N^{2}LL
  - High p_TH: MRT ~ CGGJ
  - POWHEG NNLOPS ok low/high
  - MG5_aMC@NLO lower at low p_TH and larger uncertainty



reference

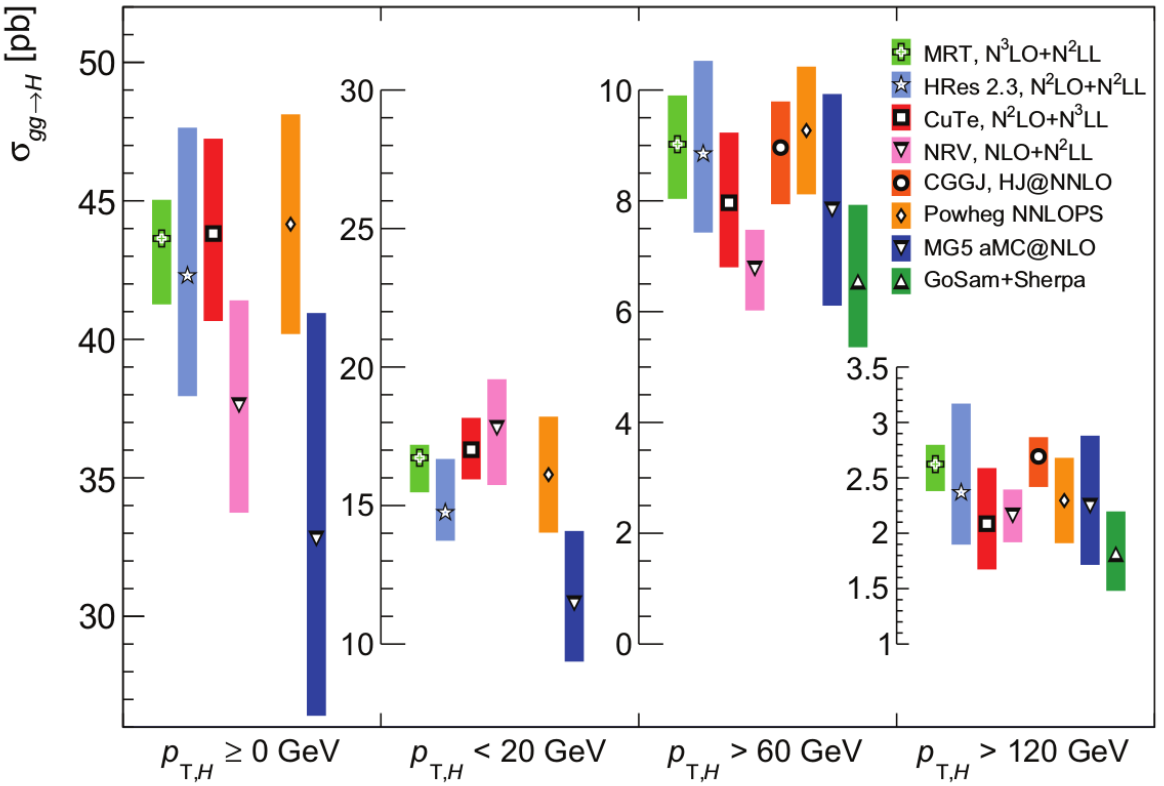




Higgs p_T

- Bins of $p_T H$
- The numbers in italic font have been obtained by using the N^{3}LO cross section with the EW component subtracted, 48.58 − 2.4 = 46.18 pb

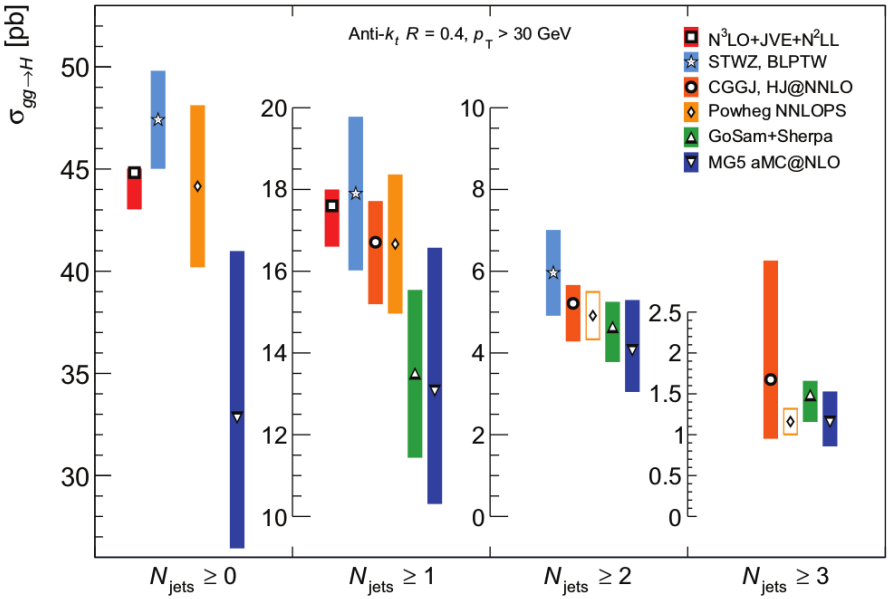
Prediction	$p_{T,H}$ / GeV < 20	> 60	> 120
HRes	34.9%	20.9%	5.60%
CuTe	38.8%	18.2%	4.76%
MRT	38.3%	20.7%	6.00%
NRV	47.3%	18.0%	5.74%
BLPTW	–	–	–
JVE	–	–	–
CGGJ	–	*19.4%*	*5.83%*
GoSam+Sherpa	–	–	–
Powheg NNLOPS	36.5%	21.0%	5.20%
aMCNLO MG5	34.9%	23.9%	6.84%

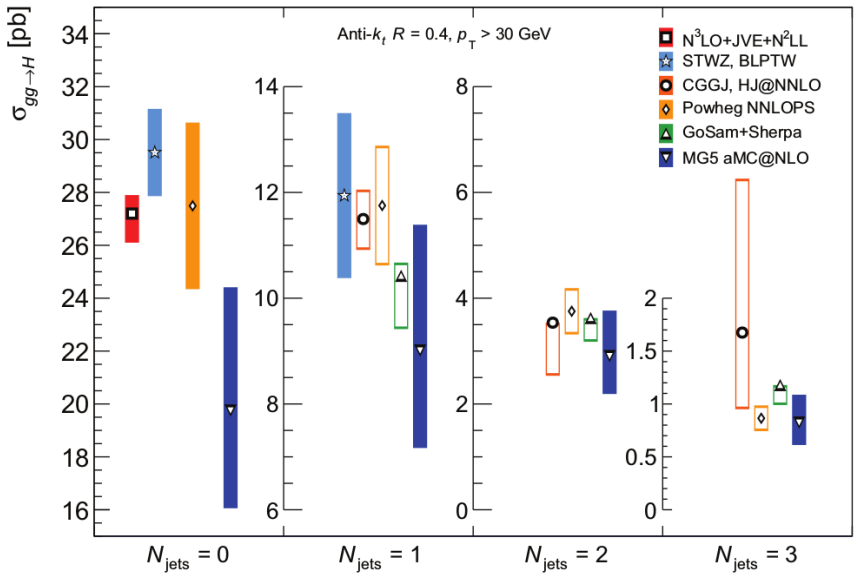


Jets

- **Jets** and jet bin **uncertainty**
- The numbers in italic font have been obtained by using the N^{3}LO cross section with the EW component subtracted, 48.58 − 2.4 = 46.18 pb
- GOSAM +SHERPA use separate predictions for each jet bin: ggF + 1, 2 and 3 jets at NLO
- In all other cases numbers are normalized to their respective predictions

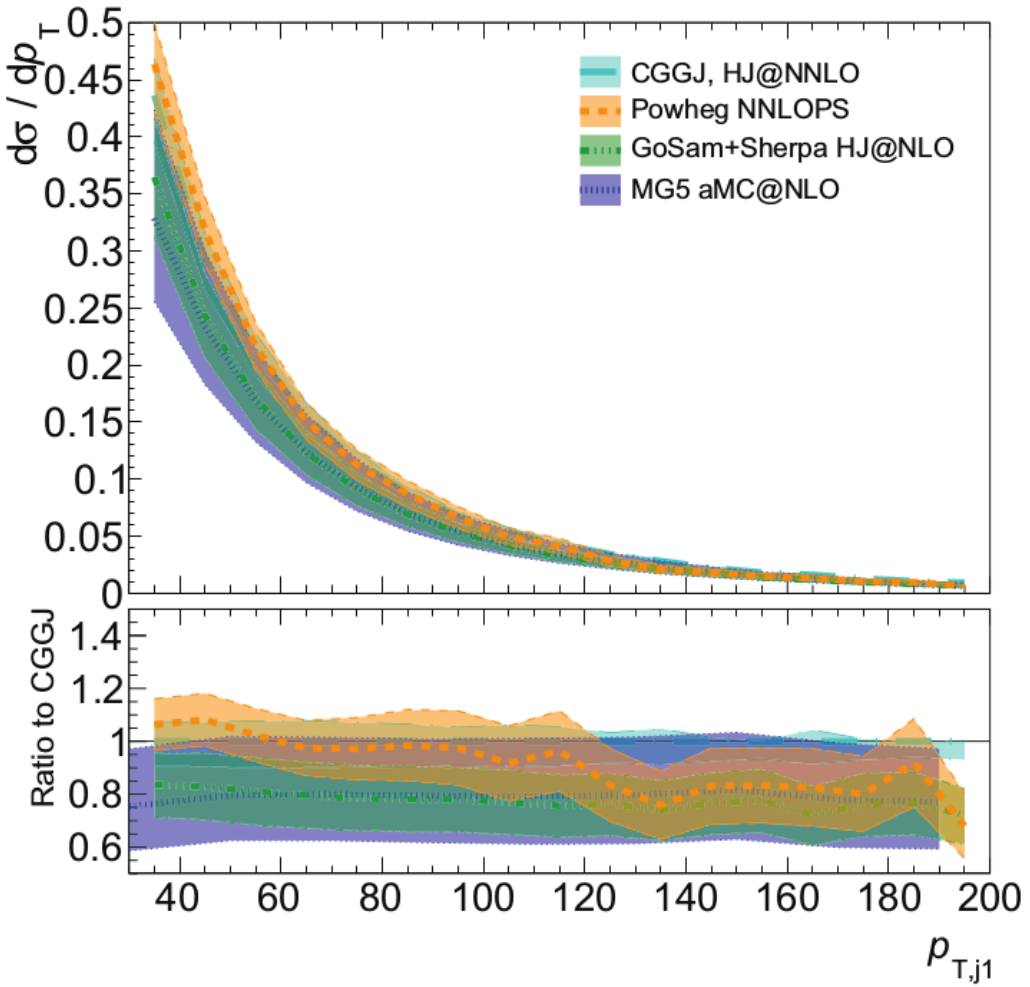
	N_{jets}, $p_{T,j} > 30$ GeV			
Prediction	$= 0$	$= 1$	≥ 2	≥ 3
HRes	–	–	–	–
CuTe	–	–	–	–
MRT	–	–	–	–
NRV	–	–	–	–
BLPTW	62.2%	25.2%	12.6%	–
JVE	60.7%	–	–	–
CGGJ	*63.8%*	*24.9%*	*11.3%*	*3.63%*
GoSam+Sherpa	–	*22.6%*	*10.0%*	*3.22%*
Powheg Nnlops	62.3%	26.6%	11.1%	2.63%
aMCNLO MG5	60.2%	27.5%	12.4%	3.52%

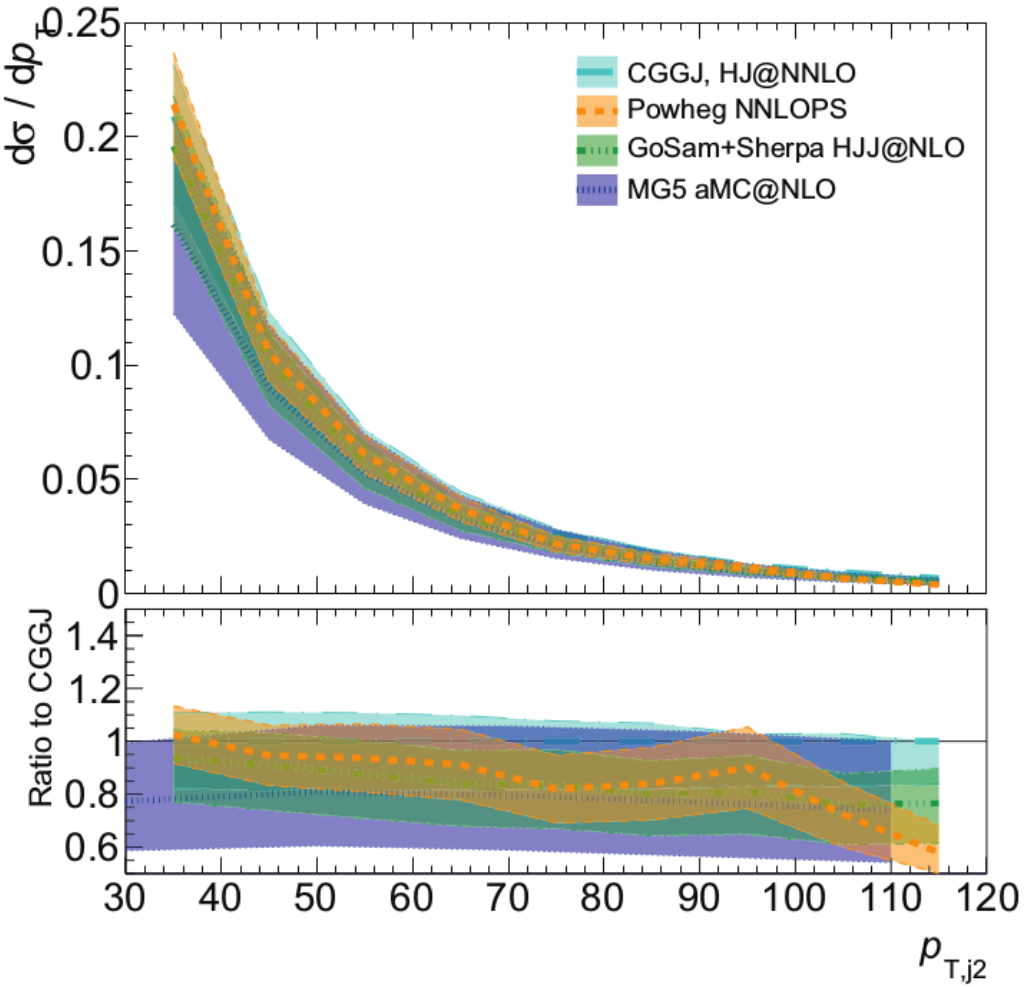




Jets kinematics

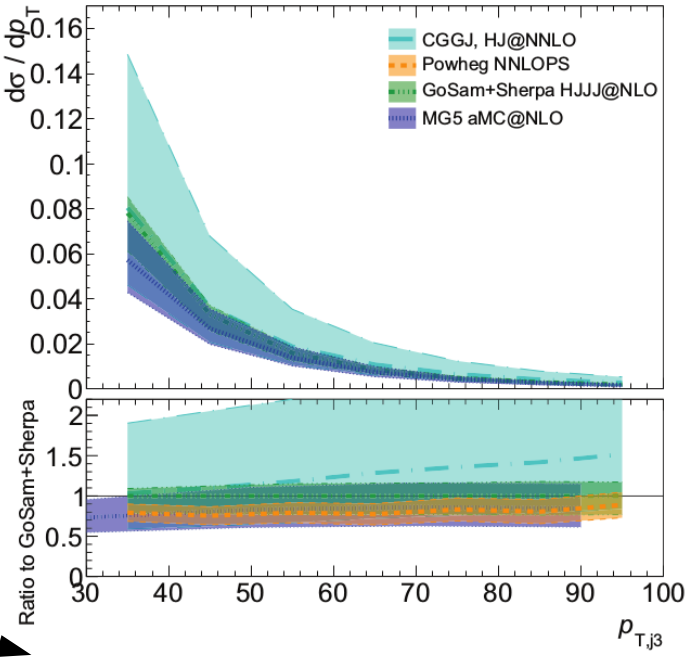
- Leading and sub-leading jet p_T
  - CCGI is NNLO
  - GoSam+Sherpa and MG5_aMC@NLO are LO
  - POWHEG NNLOPS ~ NNLO
  - CCGI, GoSam+Sherpa and MG5_aMC@NLO are NLO
  - POWHEG NNLOPS is LO → uncertainty underestimated, but still prediction in agreement with others

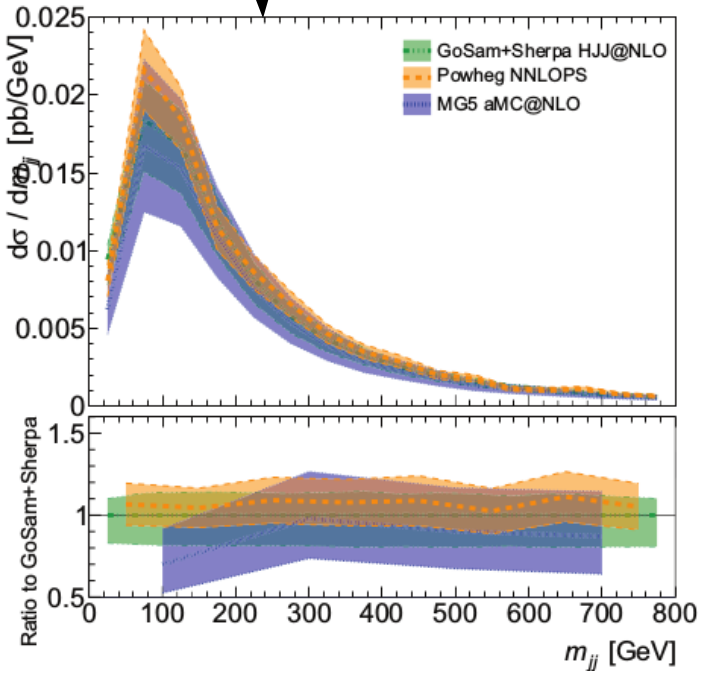


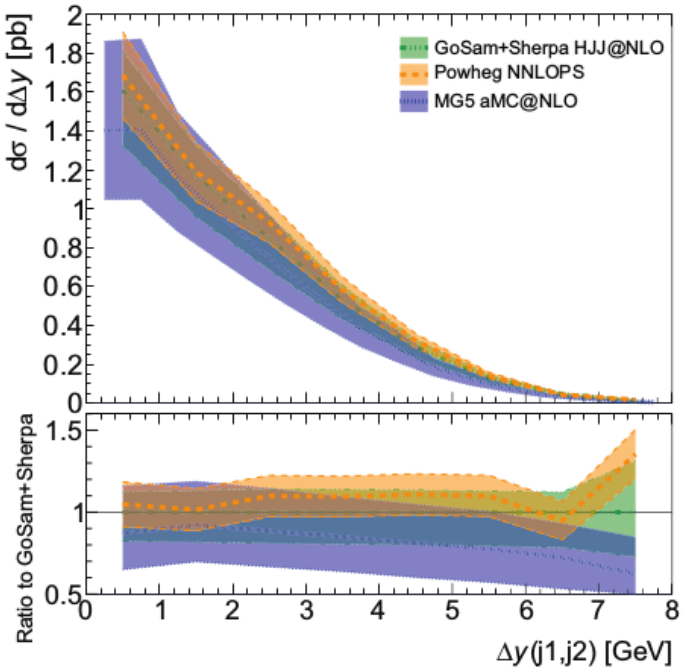


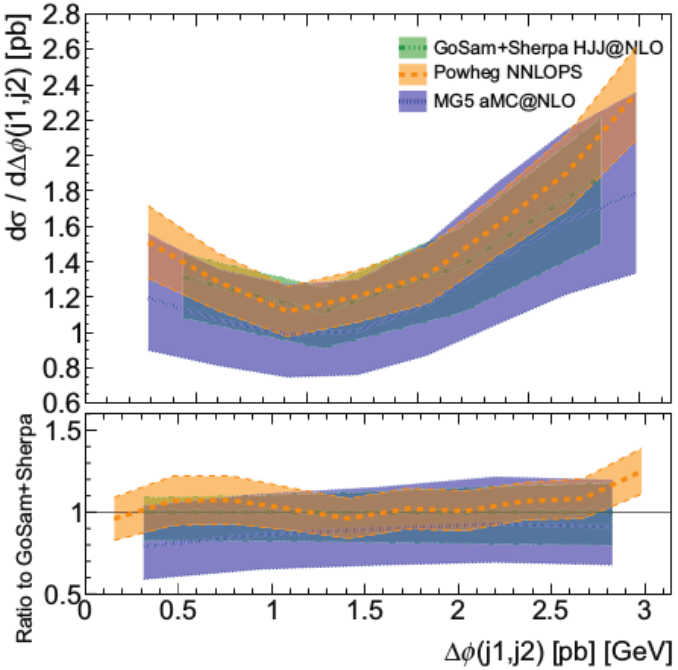
Jets and VBF phase space

- Jets in **VBF** phase space
  - Third jet p_T
  - Kinematics of di-jets
    - $\Delta\phi_{jj}$
    - $\Delta\eta_{jj}$
    - Invariant mass m_{jj}





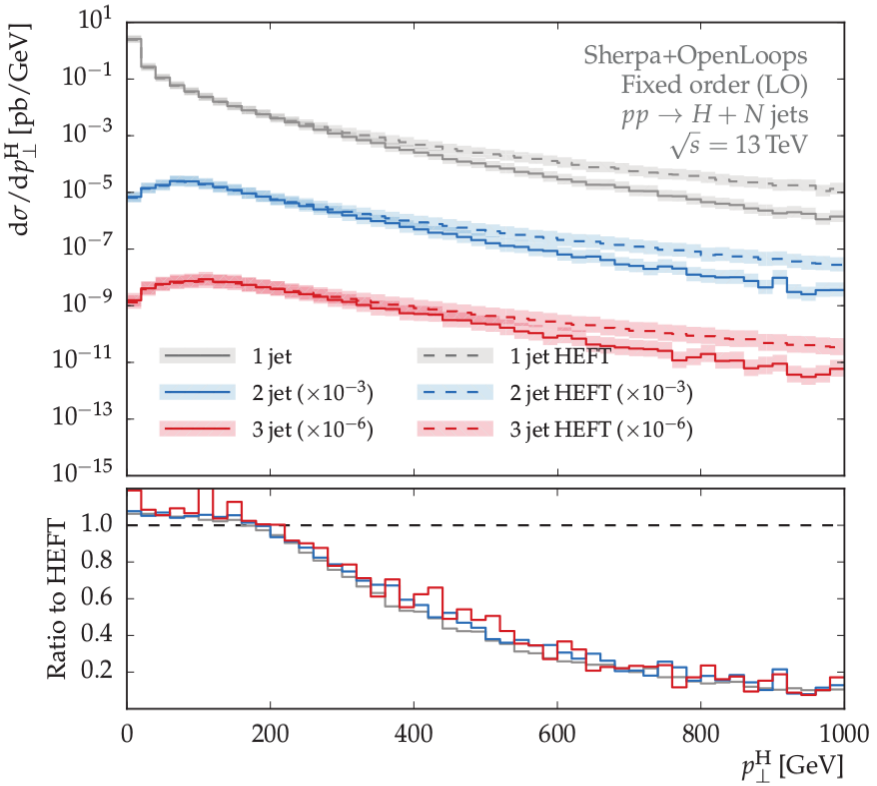




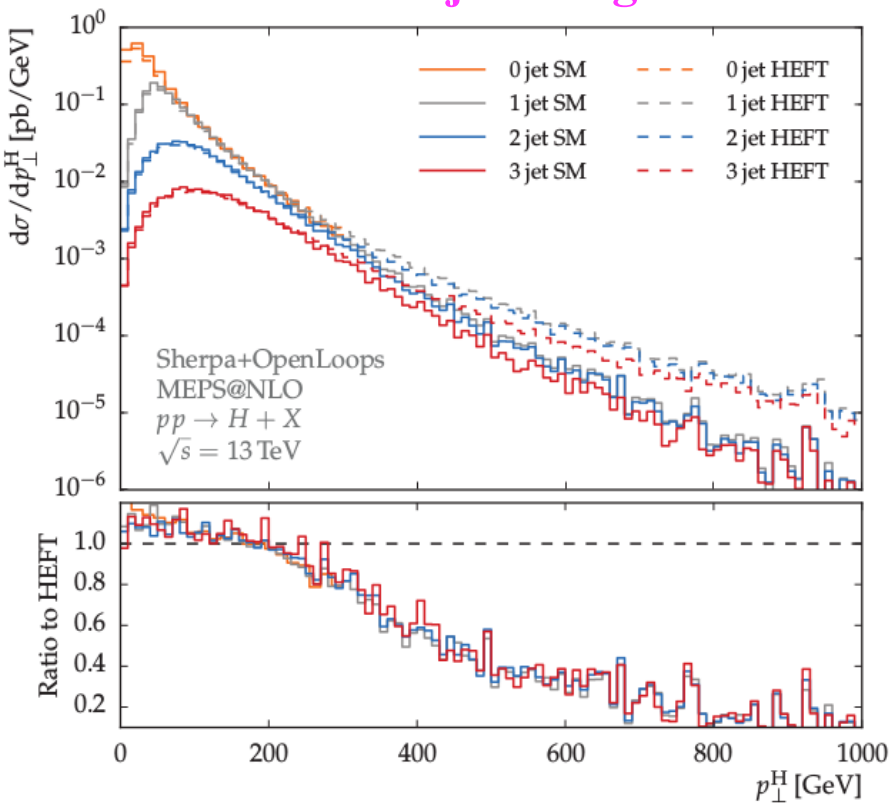
Heavy quark mass effects

- Inclusive cross section depends mildly on Higgs Effective Field Theory (**HEFT**) approach
  - $\mathbf{m_{top} \rightarrow \infty}$
- Differential distributions depend on the m_{top} assumption, e.g. $p_T H \sim m_{top}$
- Proposed new method to include full top mass dependency with one-loop matrix element **OpenLoops** + **Collier**

LO

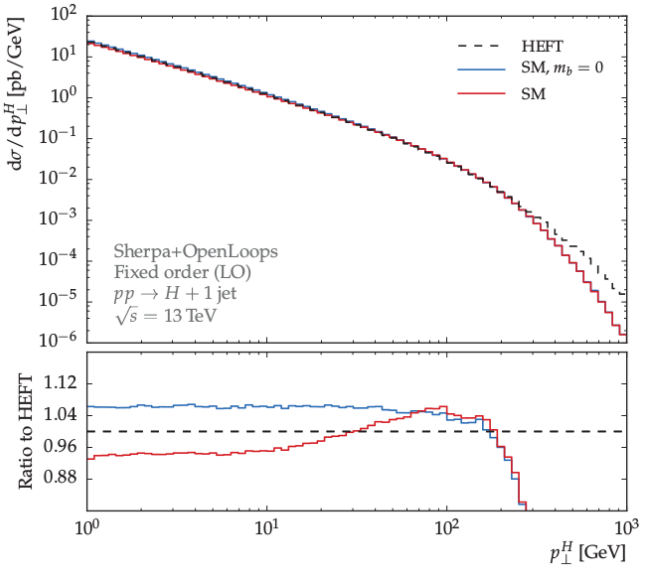


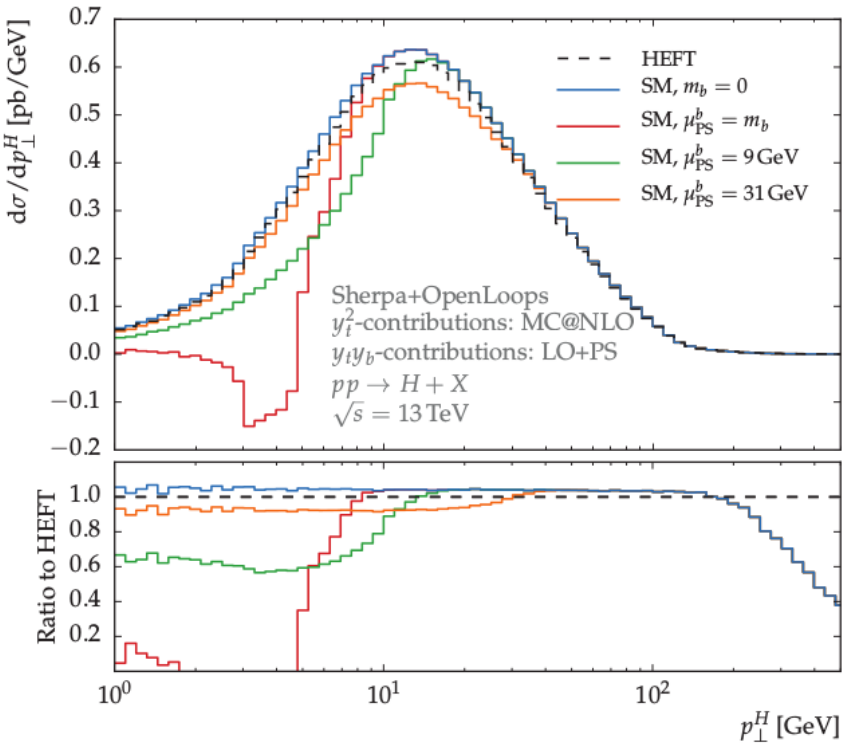
Multijet merged

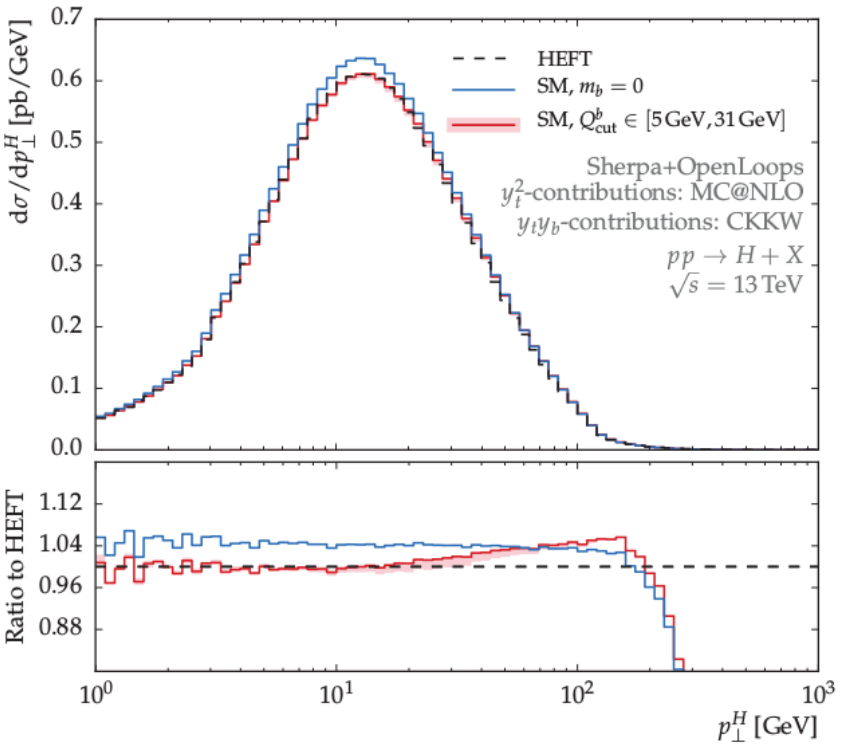


Heavy quark mass effects

- Similar approach for the m_b inclusion
  - Fixed order
  - Fixed order + PS







Summary

ggF draft for YR4 https://cds.cern.ch/record/2194224

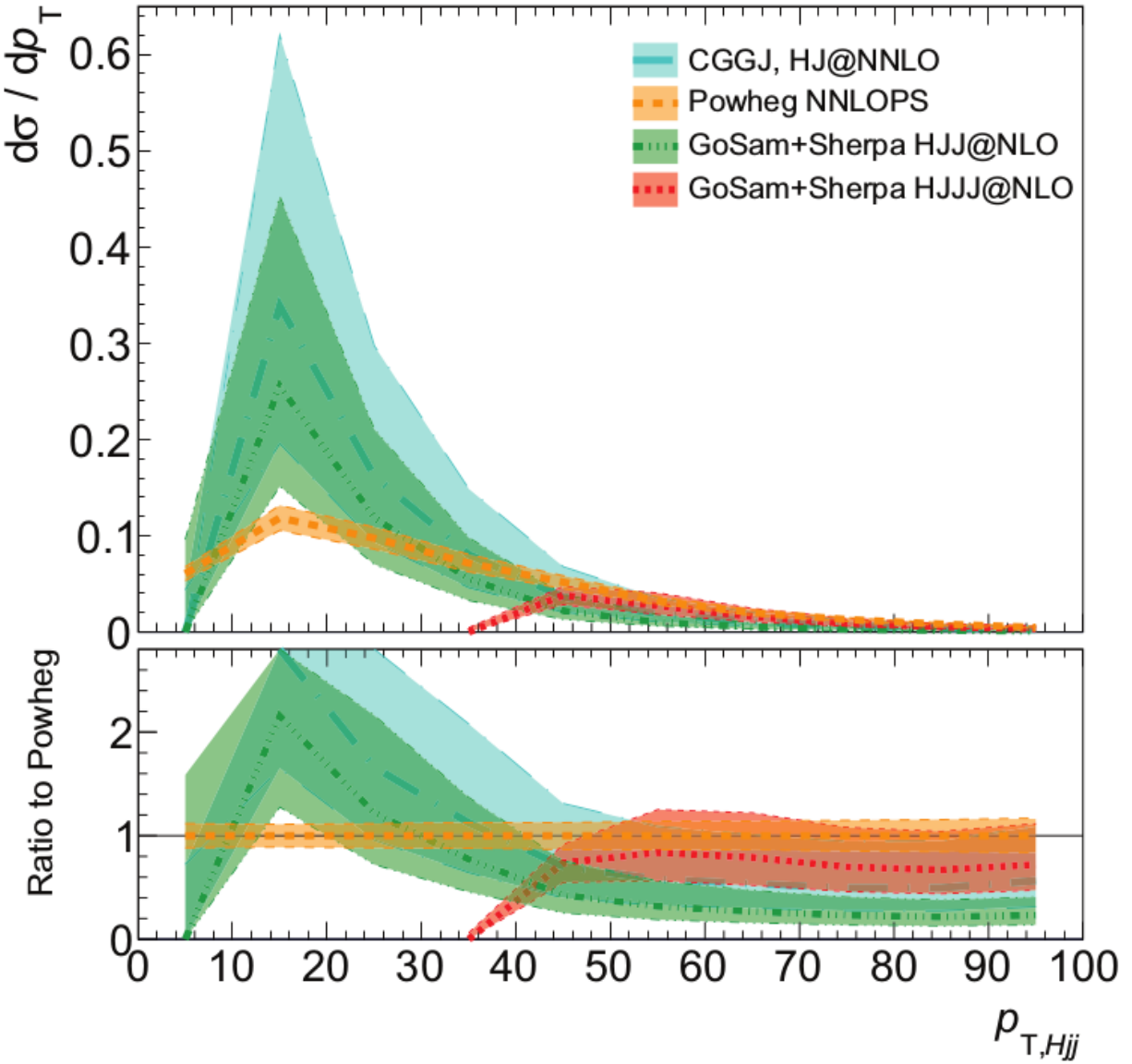
- Inclusive cross section
- Jet binned cross section
- Benchmarks for cross sections and differential distributions
- Effects of heavy quarks masses

- The future:
  - co-ordinate with the **VBF** subgroup in order to run a joint study/benchmark of the signal and background in that channel
  - have a **general public meeting** with a discussion on various sources of theoretical uncertainty
  - discussion on procedures to estimate **correlations in theory uncertainties** in **different phase spaces**
  - produce benchmarks with **common settings**


BACKUP

Jets and VBF phase space

- Jets in VBF phase space
  - p_T of Hjj system
  - HJJJ not reliable at low p_T



VBF phase space

Prediction	$m_{jj} > 400$ GeV, $\Delta y_{jj} > 2.8$ no jet3 veto	$m_{jj} > 400$ GeV, $\Delta y_{jj} > 2.8$ $p_{T,j3} < 30$ GeV	$m_{jj} > 600$ GeV, $\Delta y_{jj} > 4.0$ no jet3 veto	$m_{jj} > 600$ GeV, $\Delta y_{jj} > 4.0$ $p_{T,j3} < 30$ GeV
POWHEG NNLOPS	653^{+86}_{-86} fb	435^{+54}_{-54} fb	283^{+36}_{-36} fb	198^{+24}_{-24} fb
aMCNLO MG5	512^{+152}_{-133} fb	329^{+92}_{-84} fb	214^{+62}_{-57} fb	142^{+39}_{-37} fb
GOSAM+SHERPA HJJ@NLO	610^{+74}_{-120} fb	435^{+0}_{-70} fb	268^{+32}_{-55} fb	195^{+0}_{-31} fb
POWHEG NNLOPS, $k = 1.05$	683^{+90}_{-90} fb	455^{+57}_{-57} fb	296^{+38}_{-38} fb	207^{+25}_{-25} fb
aMCNLO MG5, $k = 1.41$	721^{+214}_{-188} fb	463^{+129}_{-118} fb	302^{+87}_{-80} fb	200^{+55}_{-52} fb

- Predicted cross sections for gg → H with VBF topology
- QCD uncertainties shown for P OWHEG NNLOPS are not valid (the third jet is from the showering)
- The last two rows show result from normalizing the inclusive cross section to 46.18 pb

General idea