The Higgs transverse momentum distribution

Emanuele A. Bagnaschi (DESY Hamburg)

B9 Higgs meeting
DESY
11 July 2016
Hamburg

Talk structure

Introduction

The gluon fusion process

Matching scales determination in gluon fusion

Standard Model

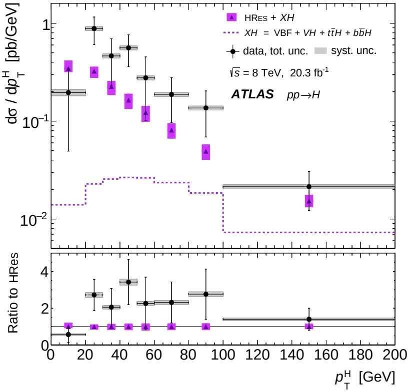
BSM Phenomenology

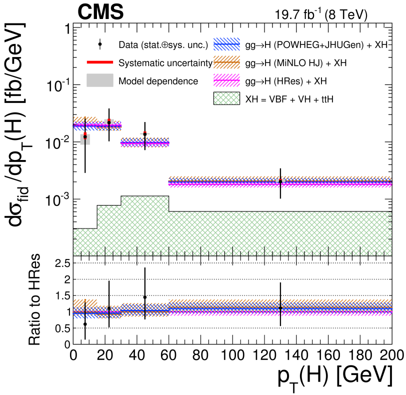
Analytic resummation vs POWHEG vs MC@NLO in the SM and in the 2HDM

H+jets

Conclusions

Why p_T^H?

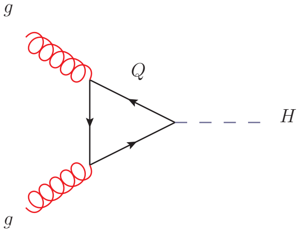


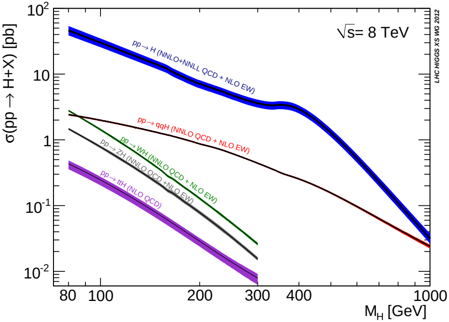


- Discovery of the Higgs at LHC RUN-1.
- First-level characterization through inclusive rates.
- As integrated-luminosity increases, interesting to look at differential observables.

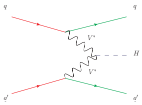
Higgs production channels at the LHC

Gluon fusion

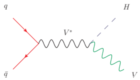




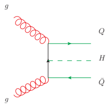
Vector Boson Fusion (VBF)



Higgs Strahlung



Quark associated production

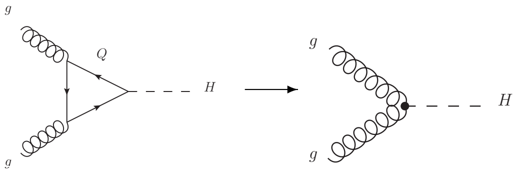


Heavy Quark Effective Field Theory (HQEFT)

In the limit $m_{top} \to \infty$ we can construct an effective Lagrangian for the interaction of the Higgs boson with the gluons

$$\mathscr{L}_{eff} = \frac{\alpha_s}{12\pi} \frac{H}{v} (1+\Delta)\,\mathrm{Tr}\left[G^a_{\mu\nu} G^a_{\mu\nu} \right]$$

In this theory the heavy quark loop shrinks to a point vertex, simplifying the calculations

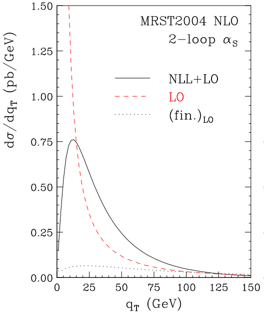


Validity conditions

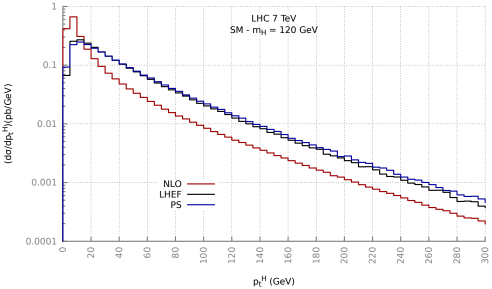
- Total cross section, $m_H < 2m_{top}$
- Kinematic variables, as p_T^H, less than m_{top}
- No strongly coupled light particles running in the loop (e.g. bottom quark in the THDM/MSSM for large $\tan\beta$)

p_T^H distribution in the SM

- The Higgs acquires a transverse momentum due to the recoil against QCD radiation
- At fixed order, the p_T^H distribution diverges in the limit $p_T^H \to 0$
- The physical behaviour is restored by resumming the divergent $\log\left(\frac{p_T^H}{m_H}\right)$ terms, either analytically or numerically (i.e. through a Parton Shower).
- problem: match the resummed and fixed order calculation



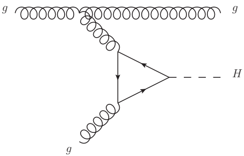
(a) HqT (Bozzi Catani De Florian Grazzini,arXiv:hep-ph/0508068)



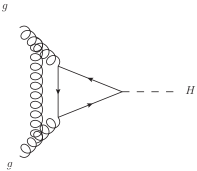
(b) POWHEG (EAB,Degrassi,Slavich,Vicini, arXiv:hep-ph/1111.2854)

Theoretical results

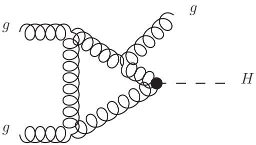
- LO-QCD: [Georgi Glashow Machacek Nanopoulous] (1978).
- NLO-QCD - HQEFT : [Dawson] (1991), [Djouadi Graudenz Spira Zerwas] (1992).
- NLO-QCD - exact: [Spira Djouadi Graudenz Zerwas] (1995), [Aglietti Bonciani Degrassi Vicini] (2007), [Anastasiou Beerli Bucherer Daleo Kunstz] (2007).
- NNLO-QCD - HQEFT : [Anastasiou, Melnikov] (2002), [Harlander Kilgore] (2002), [Ravindran Smith Van Neerven] (2003).
- N3LO-QCD - HQEFT: [Anastasiou, Gehrmann, Kilgore and many others] (2013-2015).



(a) NLO real full



(b) NLO virt full



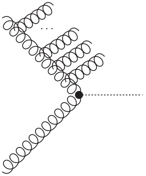
(c) NNLO real HQEFT

Examples of Feynman diagrams contributing to the process at various orders

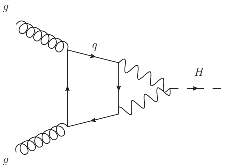
Theoretical results

- NNLO-QCD + finite top mass effects: [Marzani Ball Del Duca Forte Vicini] (2008), [Harlander Ozeren] (2009), [Pak Rogal Steinhauser] (2009), [Harlander Mantler Marzani Ozeren] (2009).
- NNLO-QCD + soft gluon resummation NNLL-QCD: [Catani De Florian Grazzini Nason] (2003), [Mach Vogt] (2005), [Idilbi Ji Yuan] (2006), [Ravindran Smith Van Neerven] (2007).
- NLO-EW : [Djouadi Gambino] (2004), [Aglietti Bonciani Degrassi Vicini] (2004), [Degrassi Maltoni] (2004), [Actis Passarino Sturm Uccirati] (2008).
- mixed NLO EWxQCD: [Anastasiou Boughezal Petriello] (2009).
- p_T resummation in QCD: [Catani, Grazzini et al] (2003-2015).
- Jet-veto studies: [Banfi Salam Zanderighi Monni] (2012).
- SCET studies: [Mantry, Petriello] (2010), [Becher,Neubert](2013).

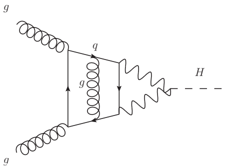
- More work on the p_T at higher-orders: [Caola et al], [Monni et al] (2016).



(a) Soft-gluon emission



(b) NLO EW



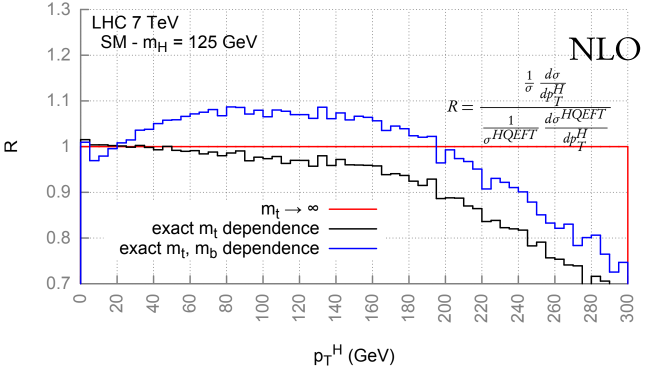
(c) NLO EWxQCD

Available codes

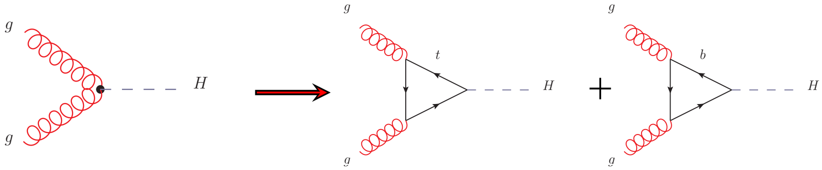
- HIGLU, Fehip - NLO full theory
- ggh@nnlo, HNNLO - NNLO-QCD HQEFT
- iHixs - NNLO-QCD HQEFT, NLO-EW,NLO-EW-QCD
- Pythia/Herwig - PS LO HQEFT
- HqT - (NNLO+NNLL) - QCD HQEFT
- HRES - MC NNLO+NNLL QCD (full theory@NLO)
- SusHi/ MoreSuShi / SusHi Bento - N3LO QCD HQEFT+SM
- CuTe - HQEFT, NNLO+NNLL
- MC@NLO/POWHEG - MC NLO + PS full theory
- HNNLOPS, MiNLO merging.
- aMC@NLO with FxFx merging

Mass effects in p_T^H distribution in the SM

- The emitted parton can resolve the internal structure of the quark loop if the p_T^H is large enough (mass effects start at $p_T^H > 150$ GeV for the top loop and $p_T^H > 10$ GeV for the bottom one).
- Unique way to include mass effects at fixed order (NLO) – good agreement also numerically between different codes.
- Could be used to characterize Higgs couplings to quarks (e.g MSSM – see YR2 and YR3 and arXiv:hep-ph/1111.2854 and many others before and after).



A problem of three scales



- The inclusion of the bottom quark adds a mass scale that is much lower with respect to the others (m_b and m_t).
- We can always rewrite the full amplitude as

$$|\mathcal{M}(t+b)|^2 = |\mathcal{M}(t)|^2 + |\mathcal{M}(b)|^2 + \left[|\mathcal{M}(t+b)|^2 - |\mathcal{M}(t)|^2 - |\mathcal{M}(b)|^2\right].$$

- One should introduce separate resummation scales for the top (Q_t), the bottom (Q_b) and the interference (Q_{int}) contributions and rewrite the formula for the total cross section as

$$\sigma(t+b) = \sigma(t, Q_t) + \sigma(b, Q_b) + [\sigma(t+b, Q_{\mathrm{int}}) - \sigma(t, Q_{\mathrm{int}}) - \sigma(b, Q_{\mathrm{int}})].$$

- We extend the same reasoning to differential distributions.

SM and 2HDM phenomenology

A prescription for the choice of the relevant scales is especially important when the bottom is dominant.

Partonic collinear analysis

- Based on the idea that the resummation should be applied when the collinear limit is a good approximation.
- Parton-level analysis of the behavior of the squared matrix elements.

Large-p_T matching

- Assume that we want to recover the NLO behavior sufficiently fast.
- Hadronic-level analysis (positivity, NLO matching) of the transverse momentum distribution.

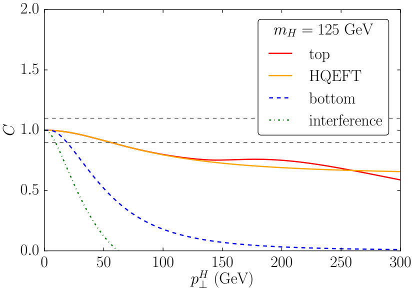
Analytic Resummation

- `HRes` by Grazzini et al.
- `MoRe-SusHi` by Harlander et al.

Monte Carlo event generators

- The `POWHEG-BOX` `gg_H_2HDM` generator (Bagnaschi et al).
- The `MadGraph5_aMC@NLO` generator based on `SusHi` (M. Wiesemann).

Collinear behavior of the $gg \to Hg$ amplitudes

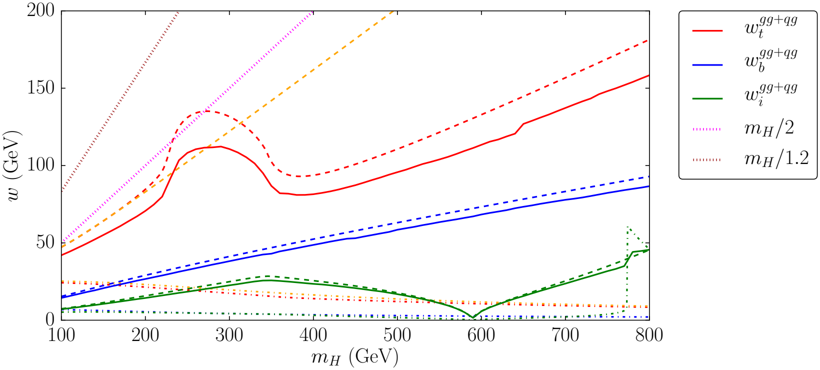


$$C \equiv \frac{|\mathcal{M}_{gg\to Hg}(s,p_T^H,m_Q)|^2}{\left|\mathcal{M}^{div}_{gg\to Hg}(s,p_T^H,m_Q)/p_T^H\right|^2}$$

Relative deviation from the collinear limit.

- The p_T^H at which the deviation reach $\overline{C} = 0.9/1.1$ gives us our preferred value for the factor h.
- We choose a value of $s = s_{\text{min}} + s_{\text{soft}}$ close to the production threshold. Larger values should be PDF suppressed.
- $s_{\text{min}} = m_H^2 + 2(p_T^H)^2 + 2p_T^H\sqrt{(p_T^H)^2 + m_H^2}$.
- s_{soft} is used to move away from the soft divergence.
- Analogous study for the qg channel yields much lower scales.

The scales vs the Higgs mass

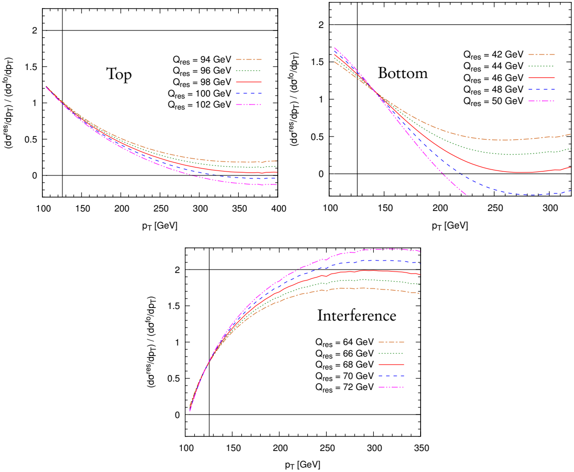


- Combination of the two channels using a differential weights.
- Manifest effect of the top threshold.
- Monotonous line for HQEFT and the bottom since no relevant scales are crossed.
- For heavy Higgs masses, our scales lower than the extrapolation of the "canonical" ones ($m_H/2$, $m_H/1.2$), currently used for a light Higgs.

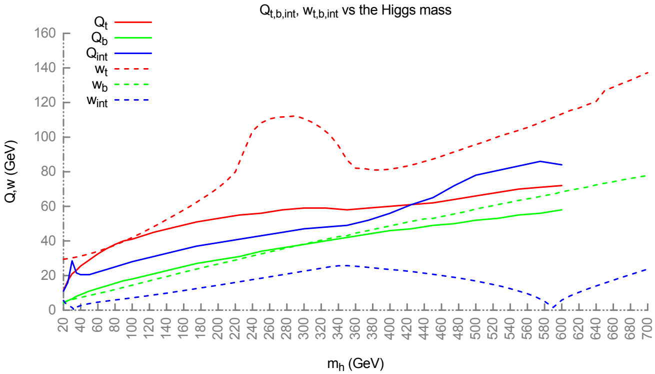
High-p_T matching , example for $m_h = 125$ GeV

- Decomposition of the cross section in three contributions:

$$\sigma(t+b) = \sigma(t, Q_t) + \sigma(b, Q_b) + \sigma(\text{interference}, Q_{int})$$

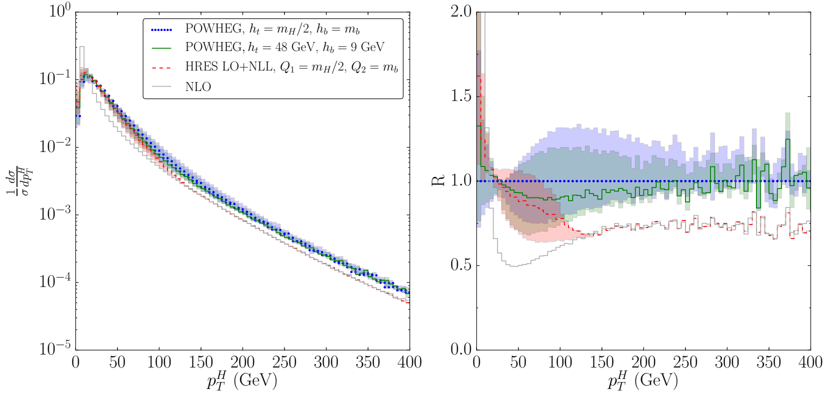


Comparison of the scale sets



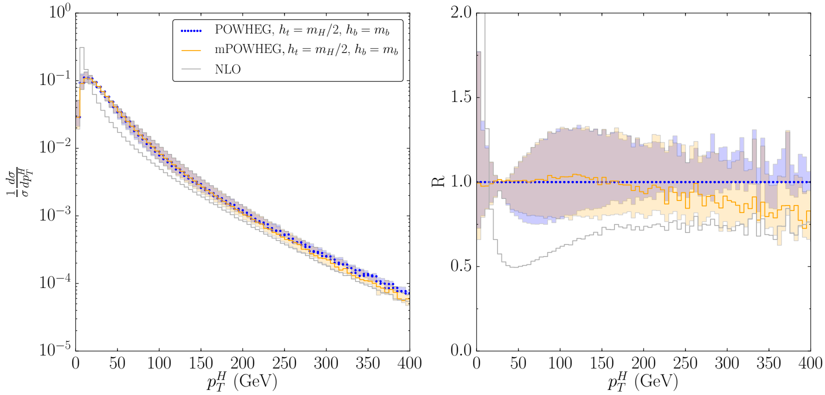
- Similar behavior for the bottom scale.
- Different behavior (especially around the two-top threshold), though compatible, for the top quark contribution.
- Opposite behavior for the interference scale when the interference terms goes to zero.

The SM



- `HRes` recovers the fixed order distribution at $\mathcal{O}(m_b)$ with a forced matching.
- Difference in the intermediate region due to different matching and possibly due to the structure of the `POWHEG` Sudakov form factor.

POWHEG high-p_T tail



- Change the default shower scale choice in **POWHEG**, by capping it at the same value used for h.
- Tail of the distribution goes over the fixed order results.

The Two Higgs-doublet model

Coupling	Type I	Type II	Lepton specific	Flipped
λ_u^h	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
λ_d^h	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$
λ_u^H	$\sin\alpha/\sin\beta$	$\sin\alpha/\sin\beta$	$\sin\alpha/\sin\beta$	$\sin\alpha/\sin\beta$
λ_d^H	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$
λ_u^A	$\cot\beta$	$\cot\beta$	$\cot\beta$	$\cot\beta$
λ_d^A	$-\cot\beta$	$\tan\beta$	$-\cot\beta$	$\tan\beta$

- Two Higgs doublets. Enlarged physical spectrum: $h/H/A$ and $H^{\pm}$.
- Rescaled couplings to quarks. Change in the relative weight of the quarks in the gluon fusion process (e.g. bottom contribution larger than the top).
- If the bottom quark coupling to the Higgs is enhanced, the bottom annihilation process can be the dominant one.

Comparison of the hadronic predictions

We show the comparison of the results obtained with

Analytic resummation (NLO+NLL),

NLO+PS POWHEG (NLO+LL),

NLO+PS MC@NLO (NLO+LL).

- 2HDM scenario B (hep-ph/1312.5571):

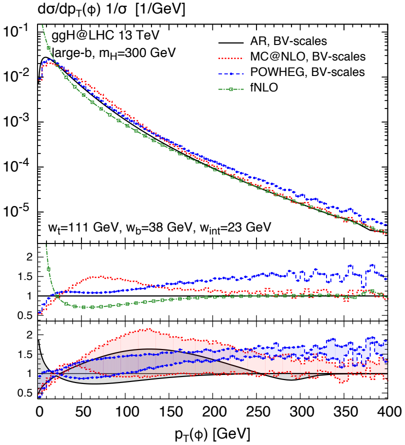
  $\tan\beta = 50$, $\sin(\beta-\alpha) = 0.999$, $m_h = 125$ GeV, $m_H = 300$ GeV, $m_A = 270$ GeV.

- 2HDM large-top scenario

  $\tan\beta = 1$, $\sin(\beta-\alpha) = 0.999$, $m_h = 125$ GeV, $m_H = 300$ GeV, $m_A = 270$ GeV.

- We have considered the shape of the distribution (i.e. $1/\sigma\, d\sigma/dp_T$) for h, H and A production.
- Uncertainty band computed by varying **only** the matching scale using the rescaling-factor combination $\{Q_t/2,\ Q_t,\ 2\cdot Q_t\} \times \{Q_b/2,\ Q_b,\ 2\cdot Q_b\} \times \{Q_i/2,\ Q_b,\ 2\cdot Q_i\}$ and then taking the envelope of the results.
- A more complete study, considering also different scenarios, is available in hep-ph/1510.08850

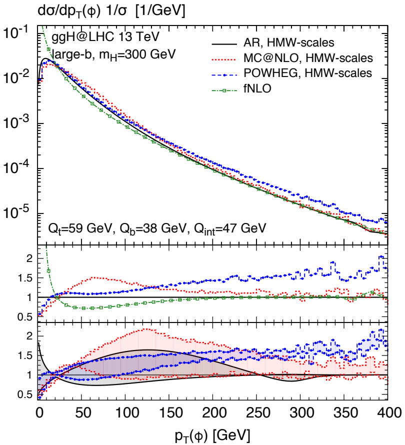
Scenario B – Matching uncertainty



BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Bottom dominated scenario.
- Comparison at fixed scales (**BV**) of the different tools.
- Same behavior of the MCs up to 25 GeV. In the intermediate region POWHEG is flatter, then the two curves cross at $p_T \simeq 150$ GeV.
- Overlap of the uncertainty bands.
- Different shape of the POWHEG vs MC@NLO band understood to be due to the very different distribution of the shower scale.

Scenario B – Matching uncertainty

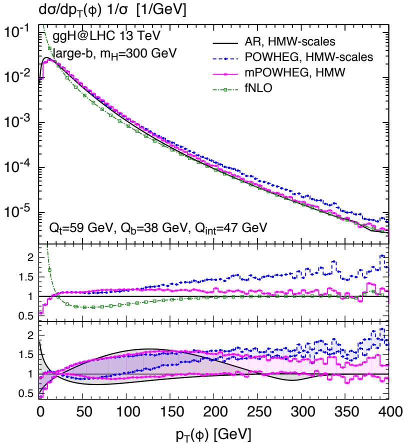


BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Bottom dominated scenario.
- Comparison at fixed scales (**HMW**) of the different tools.
- Same behavior of the MCs up to 25 GeV. In the intermediate region POWHEG is flatter, then the two curves cross at $p_T \simeq 150$ GeV.
- Overlap of the uncertainty bands.
- Different shape of the POWHEG vs MC@NLO band understood to be due to the very different distribution of the shower scale.

Understanding the high-p_T tail in POWHEG

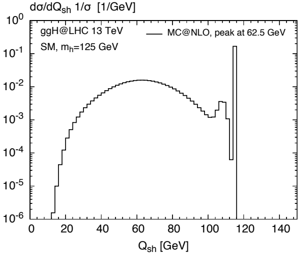
- High-pt tail behavior enhanced in the case of bottom dominated models.
- Changing the default prescription for the shower scale (mPOWHEG) allow for the recovery of the fixed order at high-pt.

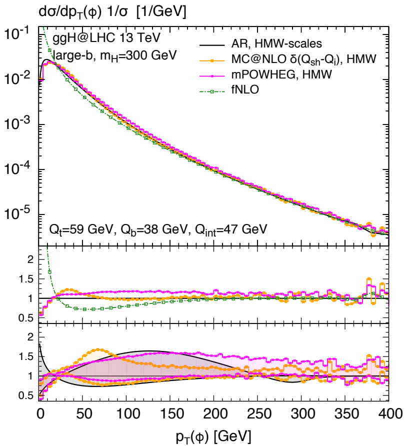


Sensitivity to the shower scale choice in aMC@NLO

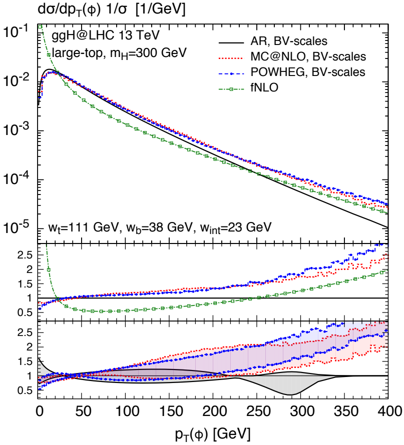
In the default aMC@NLO implementation, the shower scale is chosen as

- S-events: it uses a probability density distribution, which depends on the kinematic of the event, and that results in relatively low scales.
- H-events: the scale is taken equal to the maximum of the distribution for the S-events.
- Probe the sensitivity to these choices by using instead a δ-function distribution.





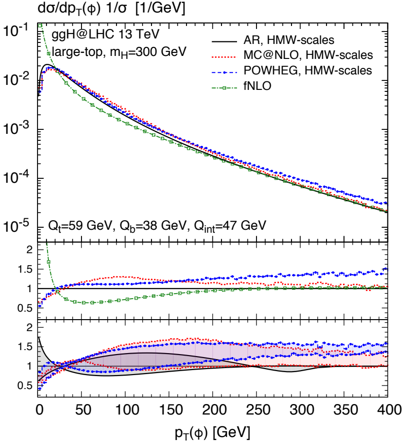
H, large t scenario – Matching uncertainty



BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Top dominated scenario.
- Comparison at fixed scales (**BV**) of the different tools.
- Very compatible behavior of the central predictions between the two MC
- Overlap of the uncertainty bands.
- Very similar shape of the uncertainty band for the MCs.

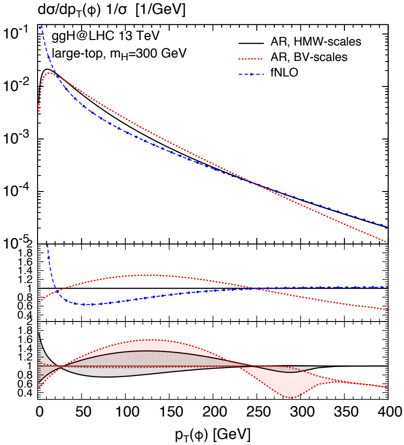
H, large t scenario – Matching uncertainty



	BV		HMW	
	Scale	Value [GeV]	Scale	Value [GeV]
	w_t	111	Q_t	59
	w_b	38	Q_b	38
	w_{int}	23	Q_{int}	47

- Top dominated scenario.
- Comparison at fixed scales (**HMW**) of the different tools.
- Very compatible behavior of the central predictions between the two MC
- Overlap of the uncertainty bands.
- Very similar shape of the uncertainty band for the MCs.

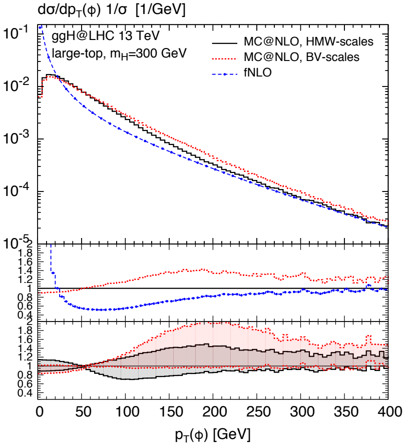
H, large t – Scale sensitivity



BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Top dominated scenario.
- Fixed tool (**AR**), all scales compared.
- Different scales for the top quark.
- Deviation of the central value predictions.

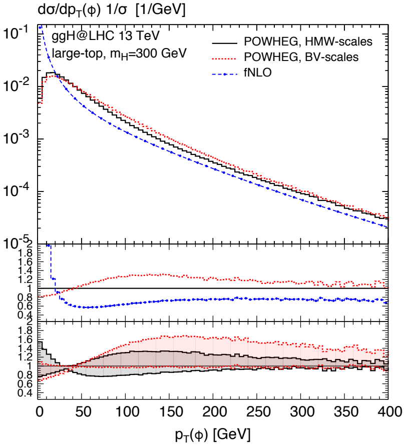
H, large t – Scale sensitivity



BV		**HMW**	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Top dominated scenario.
- Fixed tool (MC@NLO), all scales compared.
- Different scales for the top quark.
- Deviation of the central value predictions.

H, large t – Scale sensitivity



BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Top dominated scenario.
- Fixed tool (POWHEG), all scales compared.
- Different scales for the top quark.
- Deviation of the central value predictions.

H+jets: theoretical results

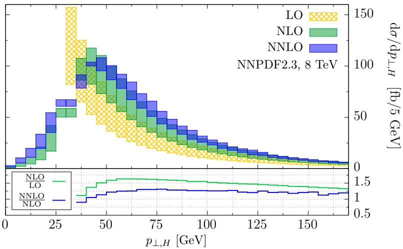
Fixed order:

- H+J NLO-QCD: [De Florian, Grazzini, Kunszt 1999, Ravindran, Smith, Van Neerven 2002, Glosser, Schmidt 2002].
- H+J NLO-QCD with finite m_t effects: [Harlander, Neumann, Ozeren, Wiesemann 2012].
- H+J NNLO-QCD: [Boughezal, Caola, Melnikov, Petriello, Schulze] (2013), [Gehrmann et al](2016).
- Pheno-analysis in `GoSam`,HQEFT, H+1,2,3J @ NLO-QCD, [Greiner at al 2015].

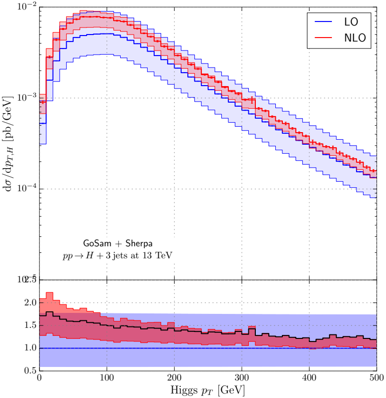
Merged-samples generators:

- HNNLOPS: SM+HQEFT [Nason et al].
- aMC@NLO with FxFx merging [Frixione et al].

Recent H+jets computation

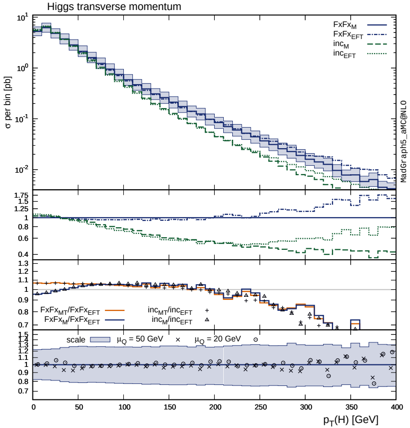


Higgs+1 Jet at LO,NLO and NNLO in the HQEFT [Caola et al].
The jet is defined with $p_{\perp,cut} = 30$ GeV and anti-k_T with $\Delta R = 0.3$.

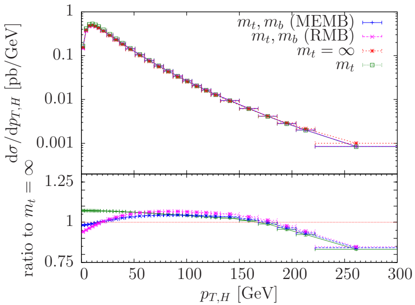


Higgs+3 jets at NLO in the HQEFT [Greiner et al].

Merged-sample generators



Merged sample `FxFx` with aMC@NLO.



Predictions from HNNLOPS, comparison of HQEFT vs inclusion of the mass effects in the SM.

Conclusions

- Inclusive Higgs production in gluon fusion available up to NLO-QCD in the complete SM; estimation of mass effects at higher orders through expansions/approximations;
- Predictions in the HQEFT available up to N3LO.
- H+1 Jet computed up to NNLO-QCD in the HQEFT.
- H+n Jet (n up to 3) predictions up to NLO-QCD in the HQEFT through automated computations.
- Matched computation NLO+PS available in all the major frameworks.
- Merged samples including SM mass effects both in the `MiNLO` and `FxFx` frameworks.
- Uncertainty estimation in the matched predictions important.
- Scale settings for the complete SM not trivial.

Backup slides

Matching in an analytic resummation framework

The master formula for the analytic matching is given by

$$\frac{d\sigma}{dp_\perp^2} = \int \frac{d\Phi_B}{dp_\perp^2}(B+\hat{V}_{\text{fin}})\mathscr{F}_{\text{NLL}}(Q_{\text{res}}) + \int \frac{d\Phi}{dp_\perp^2} R\otimes\Gamma - \int \frac{d\Phi_B}{dp_\perp^2} B\,\mathscr{F}_{\text{NLO}}(Q_{\text{res}}),$$

with

$$\mathscr{F}_{\text{NLL}}(Q_{\text{res}}, p_\perp) = \frac{m_\phi^2}{S}\int_0^\infty db\,\frac{b}{2}J_0(bp_\perp)\mathscr{S}(\alpha_s,\tilde{L})$$
$$\times\sum_{i,j}\int dz_1\,dz_2\left[\delta_{z_1}\delta_{z_2} + \frac{\alpha_s(b_0/b)}{\pi}C_{gi}^{(1)}(z_1)\delta_{z_2} + \frac{\alpha_s(b_0/b)}{\pi}\delta_{z_1}C_{gj}^{(1)}(z_2)\right]\Gamma_{ij}(b_0/b, z_1, z_2),$$

with $\mathscr{S}(\alpha_s,\tilde{L}) = \exp\left\{\tilde{L}g^{(1)}(\alpha_s\tilde{L}) + g^{(2)}(\alpha_s\tilde{L})\right\}$,

- Additive matching. Remove explicitly the terms that are double counted.
- $\tilde{L} = \ln(b^2 Q_{\text{res}}^2/b_0^2 + 1)$
- The scale Q_{res} determines the $p_\perp$-range where the resummation is applied.

Matching in an NLO+PS framework

$$d\sigma = d\Phi_B \bar{B}^s(\Phi_b)\left[\Delta^s(p_\perp^{\min}) + d\Phi_{R|B}\frac{R^s(\Phi_R)}{B(\Phi_B)}\Delta^s(p_T(\Phi))\right] + d\Phi_R R^f(\Phi_R)$$

$$\bar{B}^s = B(\Phi_b) + \left[V(\Phi_b) + \int d\Phi_{R|B}\hat{R}^s(\Phi_{R|B})\right]$$

$$\Delta(\bar{\Phi}_B, p_T) = \exp\left\{-\int d\Phi_{\rm rad}\frac{R^s(\bar{\Phi}_B, \Phi_{\rm rad})}{B(\Phi_1)}\theta(k_T - p_T)\right\}$$

MC@NLO

$$R^s \propto \frac{\alpha_s}{t}P_{ij}(z)B(\Phi_B) \;\;,\;\; R^f = R - R^s$$

- The Sudakov form factor is the one from the P.S., i.e. it uses the collinear splitting function in the exponent.
- The full matrix element appears only in the regular contribution.

POWHEG

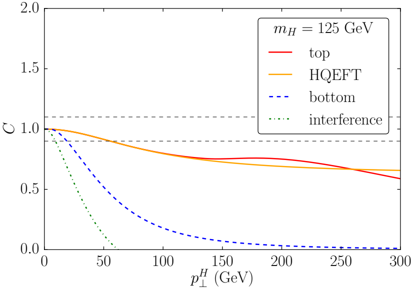
$$R^s = \frac{h^2}{h^2 + p_T^2}R \;\;,\;\; R^f = \frac{p_T^2}{h^2 + p_T^2}R$$

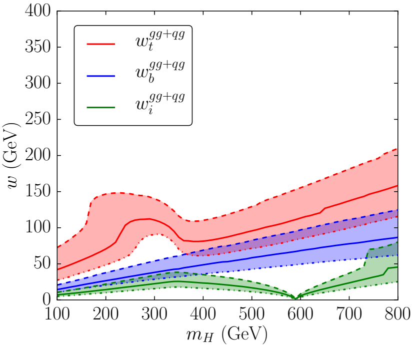
- hfact controls high order effects
- At low p_T R goes into collinear factorization and the Sudakov regains the splitting function in the exponent.

The two approaches differs by higher order terms.

Dependence on the auxiliary parameters

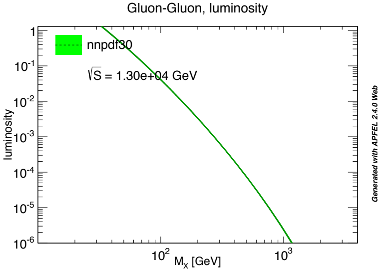
- Sensitivity to the choice of $\overline{C}$.
- It represents how much we allow collinear factorization to be broken.
- Band width comparable with the standard variation interval $[w_i/2, 2\, w_i]$.

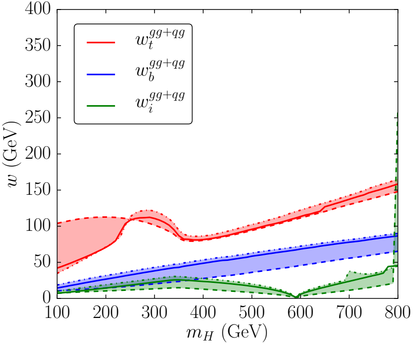




Dependence on the auxiliary parameters

- Sensitivity to the value of s_{soft}.
- Less dependence than on $\overline{C}$. Smaller than the standard uncertainty width.

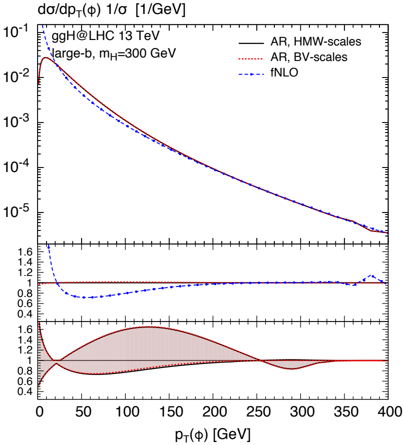




High-p_T matching

- Starts from the consideration that we want to recover the NLO description in the high-p_T region.
- The resummation scale Q is then the maximum scale such that this expectation is true.
- For Higgs masses up to $m_h = 300$ GeV, Q is the maximum scale for which the p_T-distribution is within $[0, 2]\ d\sigma/dp_T^2$ in the range $[m_\phi, p_T^{max}]$ (p_T^{max} is chosen case by case).
- For Higgs mass larger than 800 GeV, due to numerical instabilities, the criteria is changed to requiring that $|[d\sigma^{res}/dp_T^2]/d\sigma/dp_T^2] - 1| = 1/2$ at $p_T = 700$ GeV.
- $Q_0 = Q^{max}/2$, while the uncertainty interval is given by $[Q_0/2, 2Q_0]$.

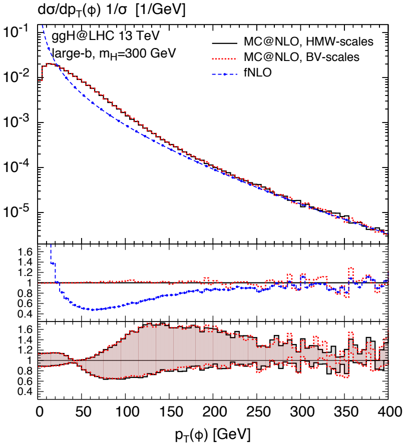
Scenario B – Scale sensitivity



BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Bottom dominated scenario.
- Fixed tool (**AR**), all scales compared.
- Same scale for the bottom quark.
- Scenario is bottom dominated, the bands are practically identical.

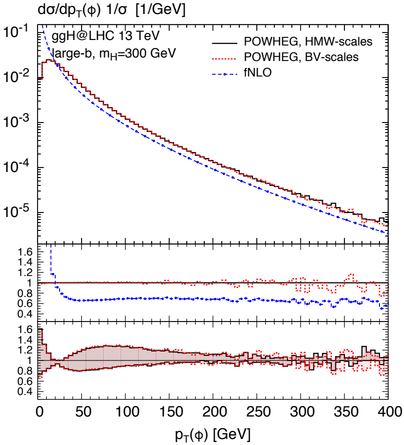
Scenario B – Scale sensitivity



BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Bottom dominated scenario.
- Fixed tool (MC@NLO), all scales compared.
- Same scale for the bottom quark.
- Scenario is bottom dominated, the bands are practically identical.

Scenario B – Scale sensitivity



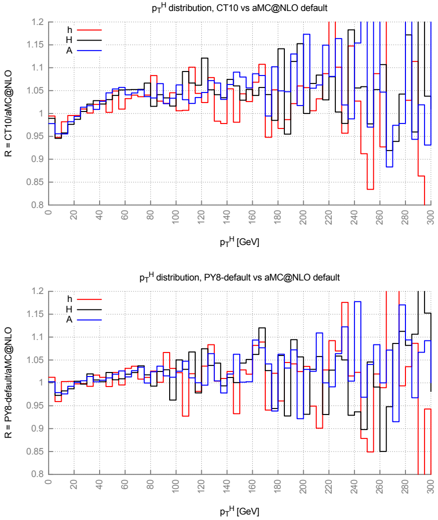
BV		HMW	
Scale	Value [GeV]	Scale	Value [GeV]
w_t	111	Q_t	59
w_b	38	Q_b	38
w_{int}	23	Q_{int}	47

- Bottom dominated scenario.
- Fixed tool (POWHEG), all scales compared.
- Same scale for the bottom quark.
- Scenario is bottom dominated, the bands are practically identical.

Simulation parameters

Simulation setup		2HDM	
Parameter	**Value**	**Parameter**	**Value**
$\sqrt{s}$	13 TeV	$M_h[GeV]$	125
PDF	MSTW2008nlo68cl	$M_H[GeV]$	300
m_t [GeV]	172.5	$M_A[GeV]$	270
m_b [GeV]	4.74	$M_{H^\pm}[GeV]$	335
μ_r	m_ϕ	$M_{12}^2[GeV^2]$	1798
μ_f	m_ϕ	$\tan\beta$	50
Shower	Pythia 8	$\sin(\beta-\alpha)$	0.999001
Tune	aMC@NLO default	λ_6	0
Number of events	1000000	λ_7	0
		α	0.0247

Pythia 8 tune sensitivity



- Compared Pythia8 default, CT10 tune and the default tune of aMC@NLO.
- The distortion in the shape is independent of the Higgs type.
- At most ±5%.