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Quark mass effects in $gg \longrightarrow H$ with MC@NLO

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$gg \to H$ in MC@NLO

Up to v4.07 only HEFT results available (Born can retain the exact m_t dependence)

From v4.08 (June 2012), the real and virtual matrix elements have been included that feature the exact m_t *and* m_b dependence

From v4.10 (July 2013), the possibility is given to follow the prescription of Grazzini and Sargsyan (1306.4581) whereby bottom-loop contributions are treated differently w.r.t top-loop ones

Note: aMC@NLO is capable of simulating many more Higgs processes than MC@NLO (see e.g. 1104.5613 [$t\bar{t}H/t\bar{t}A$], 1304.7927 [VBF] or 1306.6464 [$X(J^p)$])

The use of MC@NLO in this specific case is due to the fact that the relevant matrix elements are loop-induced (e.g., the virtuals are two-loop diagrams), and cannot be computed automatically

MC@NLO and HRes

They are quite similar: both use an additive matching approach

Resummation in HRes is performed through analytically-computed Sudakovs, in MC@NLO with parton showers

The analogue of HRes' Q_i in MC@NLO is the shower scale passed to the MC in the LH event file (to be dead sure that there are no sharp-thresold effects, we randomly choose the shower scale in a pre-defined range)

MC@NLO v4.10

IMODEHGG=0, HVQMASS#0, HGGBMASS#0 (same as up to v4.09):

$$\sigma = |\mathcal{A}_t|^2 + 2\Re\left(\mathcal{A}_t\mathcal{A}_b^*\right) + |\mathcal{A}_b|^2$$

$$Q_1 = Q_2 = \mathcal{O}(m_H)$$

IMODEHGG=0, HVQMASS#0, HGGBMASS=0:

$$\sigma = |\mathcal{A}_t|^2$$

$$Q_1 = \mathcal{O}(m_H)$$

IMODEHGG=1, HVQMASS#0, HGGBMASS#0:

$$\sigma = 2\Re\left(\mathcal{A}_t\mathcal{A}_b^*\right) + |\mathcal{A}_b|^2$$

$$Q_2 = \mathcal{O}(m_b)$$

Note: the two runs:

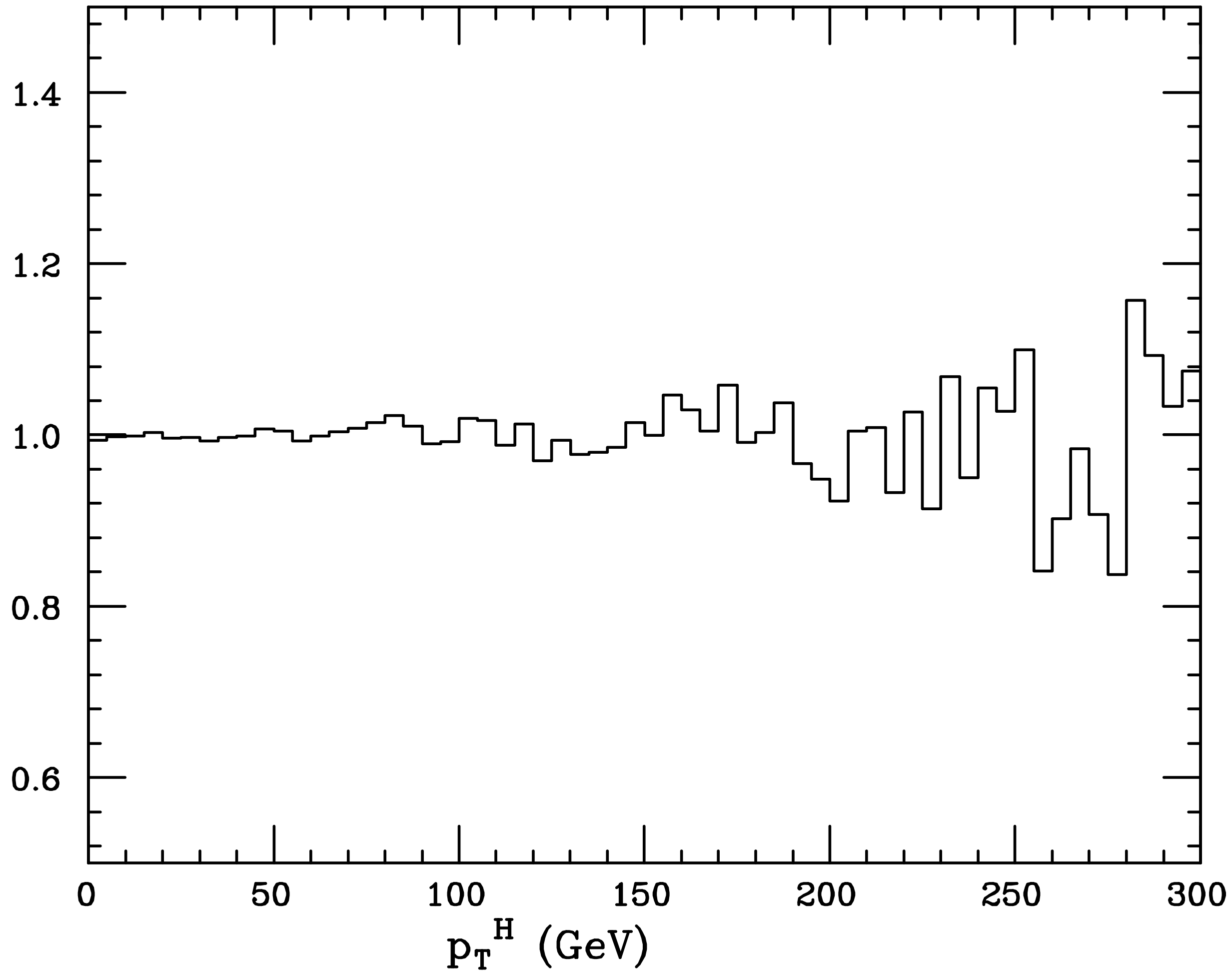
`IMODEHGG=0`, `HVQMASS#0`, `HGGBMASS=0`

`IMODEHGG=1`, `HVQMASS#0`, `HGGBMASS#0`

must both be performed, and the results summed (with their respective cross sections) – always trivial, and particularly so when running with `WGTTYPE=1`

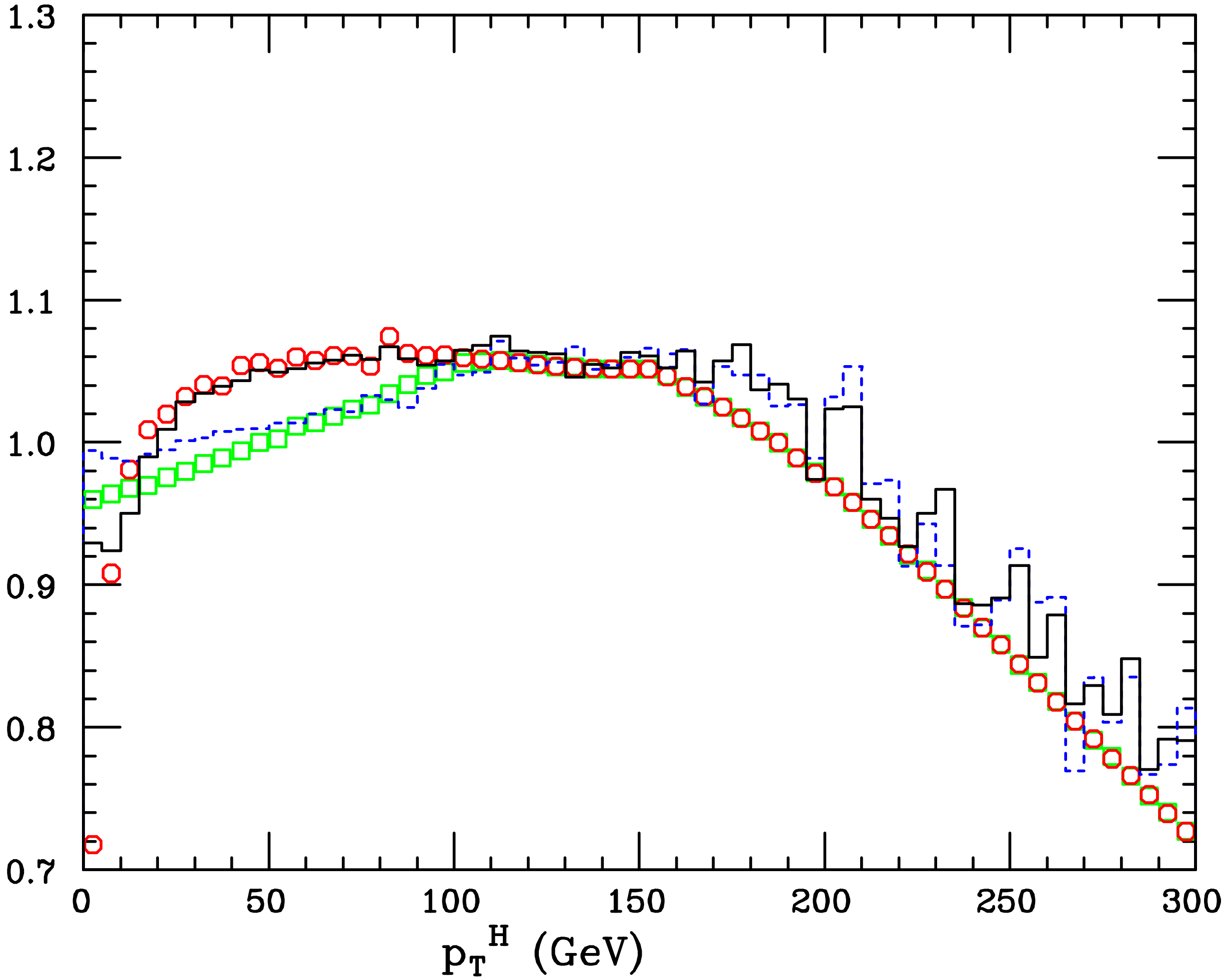
The latter results are unphysical *if taken without the former*

Consistency check



Ratio of the result of v4.09 over that obtained by separating the top and bottom contributions, and showering both with the same shower scales as used in v4.09 $\Longrightarrow$ such a separation works as expected

MC@NLO vs HRES

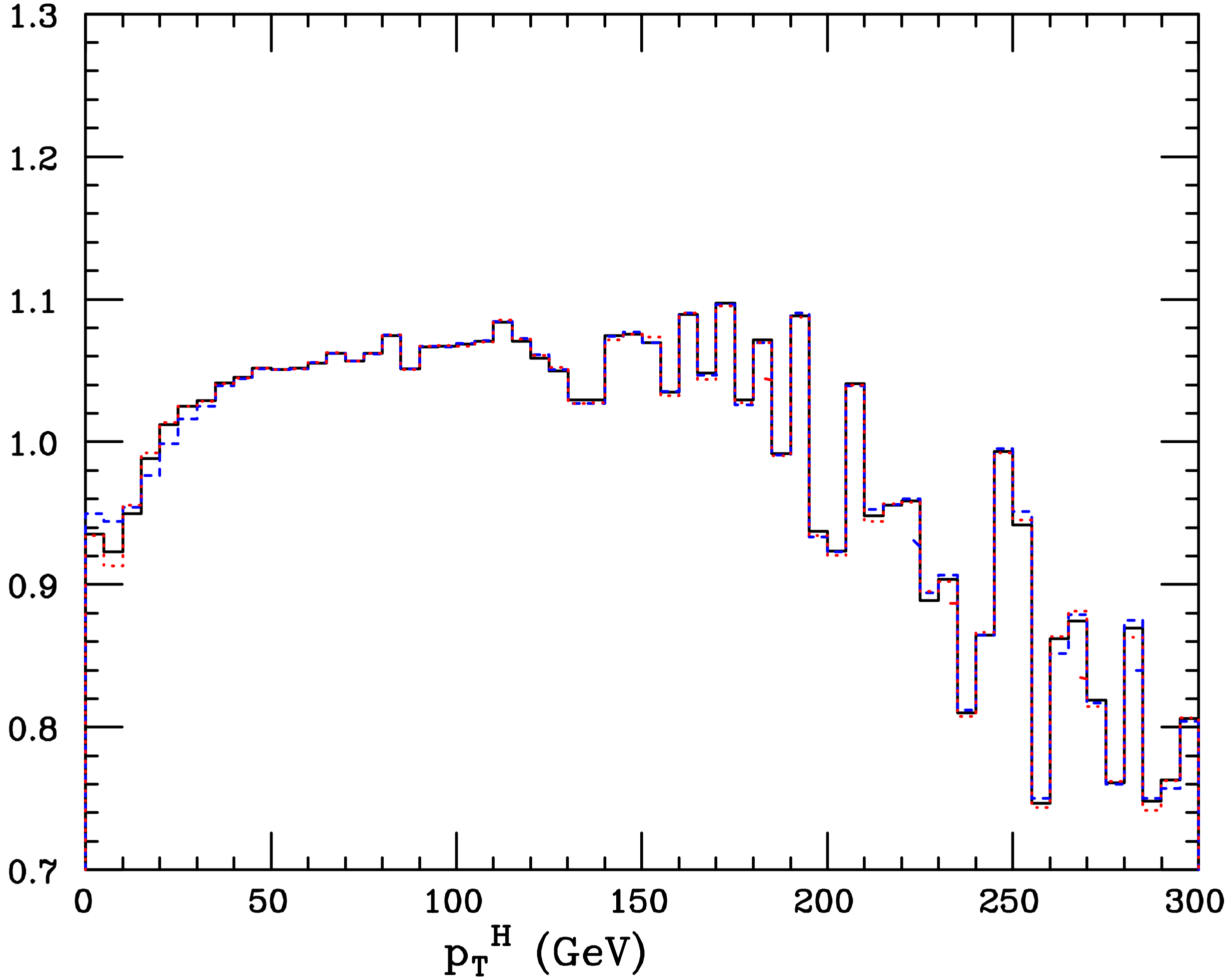


histograms: MC@NLO symbols: HRes

solid and circles: $Q_2 = \mathcal{O}(m_b)$ dashed and boxes: $Q_2 = \mathcal{O}(m_H)$

- Not a tuned comparison with HRes (eg hard scales are different).
  Yet, good agreement except in the first bin
- While the statistics can be improved, the first bin in MCs is always going to be significantly driven by cutoff choices (a universal effect)
- The agreement (including resummation/shower scale (in)dependence) need not be surprising, given the similarities between the two formalisms
- Note, in particular, that the dependence on Q_2 is the same in the whole $m_b \longrightarrow m_H$ range

Shower scale dependence

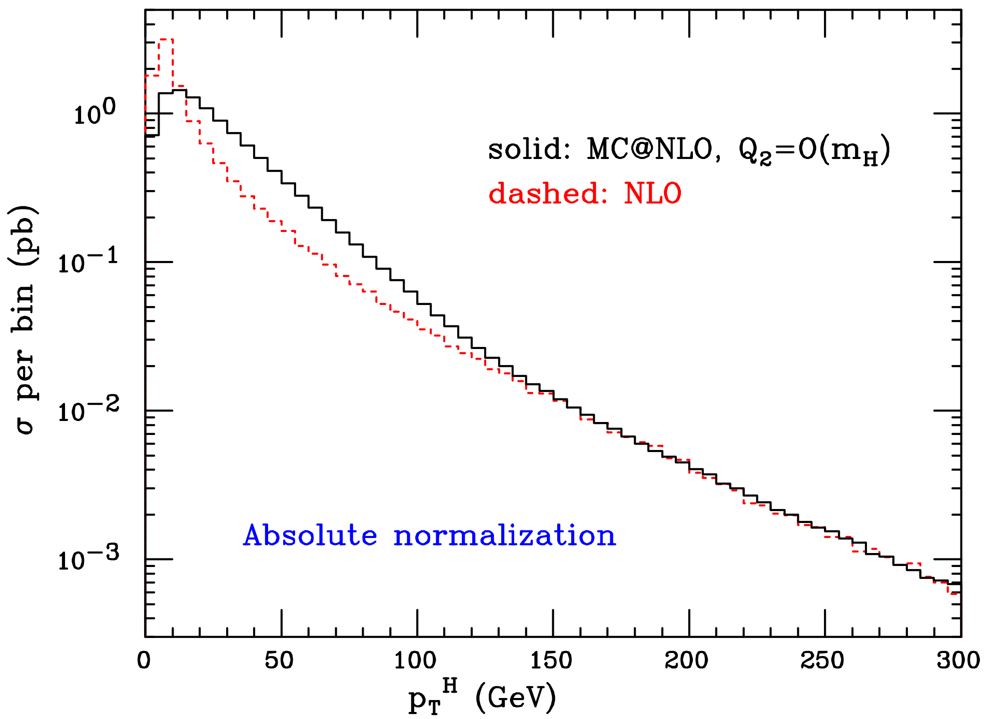


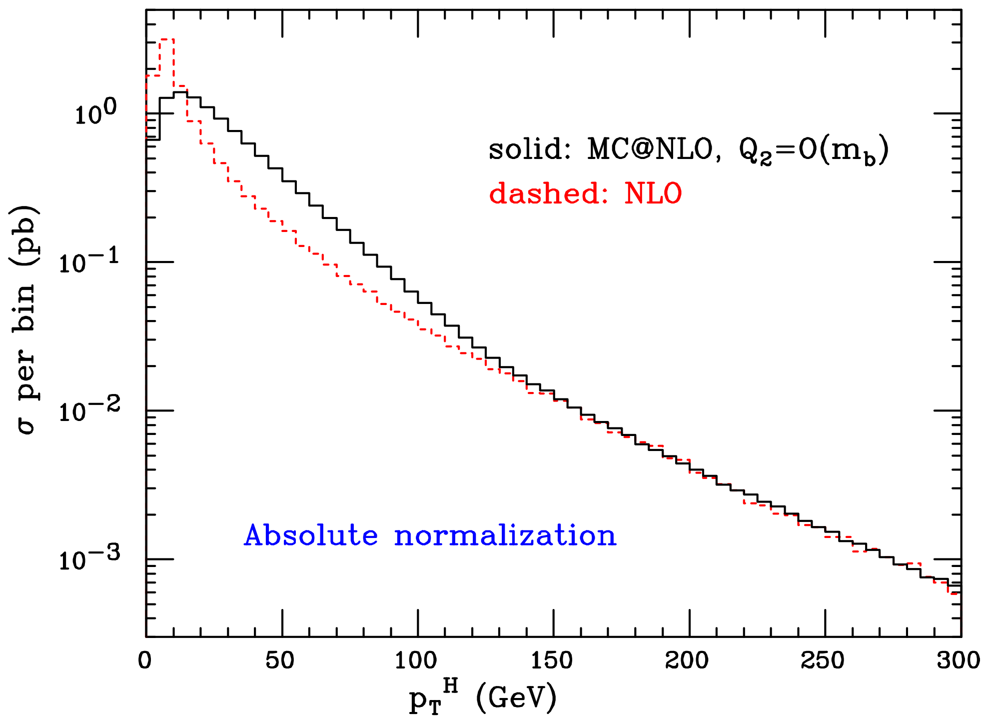
black solid: $5 \leq Q_2 \leq 10$

blue dashed: $5 \leq Q_2 \leq 20$

red dotted: $4 \leq Q_2 \leq 7$

MC@NLO vs NLO





As usual, MC@NLO coincides in shape and normalization with the underlying fixed-order result in regions not dominated by the MC

- Note: the two-run structure can easily be changed, if there is a sufficient interest. The present solution was simply the quickest to implement starting from v4.09
- It is more laborious to port the two-loop matrix elements into aMC@NLO (for matching with Pythia). We will not do this unless strongly encouraged...
- In my opinion, it is not a bad idea to be conservative with theoretical systematics. This is a three-scale problem, and potentially-large logs remain unresummed. Is the $m_b \to 0$ limit smooth?