HVJ AND $gg \to HZ$ WITH THE POWHEG BOX

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- HVJ production
- $gg \to HZ$ production
- Conclusions

HVJ: the original code

The original code (Luisoni, Nason, C.O., Tramontano, arXiv:1306.2542) was generated using two interfaces:

- ✓ to MadGraph 4, built in collaboration with Frederix, that automatically builds the codes to compute the Born, Born color- and spin-correlated amplitudes, the real amplitude and the Born color structure in the limit of large number of colors. This is done just once and for all, when a new process is implemented in the POWHEG BOX.

- ✓ to GoSam (Cullen, Greiner, Heinrich, Luisoni, Mastrolia, Ossola, Reiter, Tramontano), built in collaboration with Luisoni and Tramontano , that writes automatically the code for the computation of the finite part of the virtual contributions.

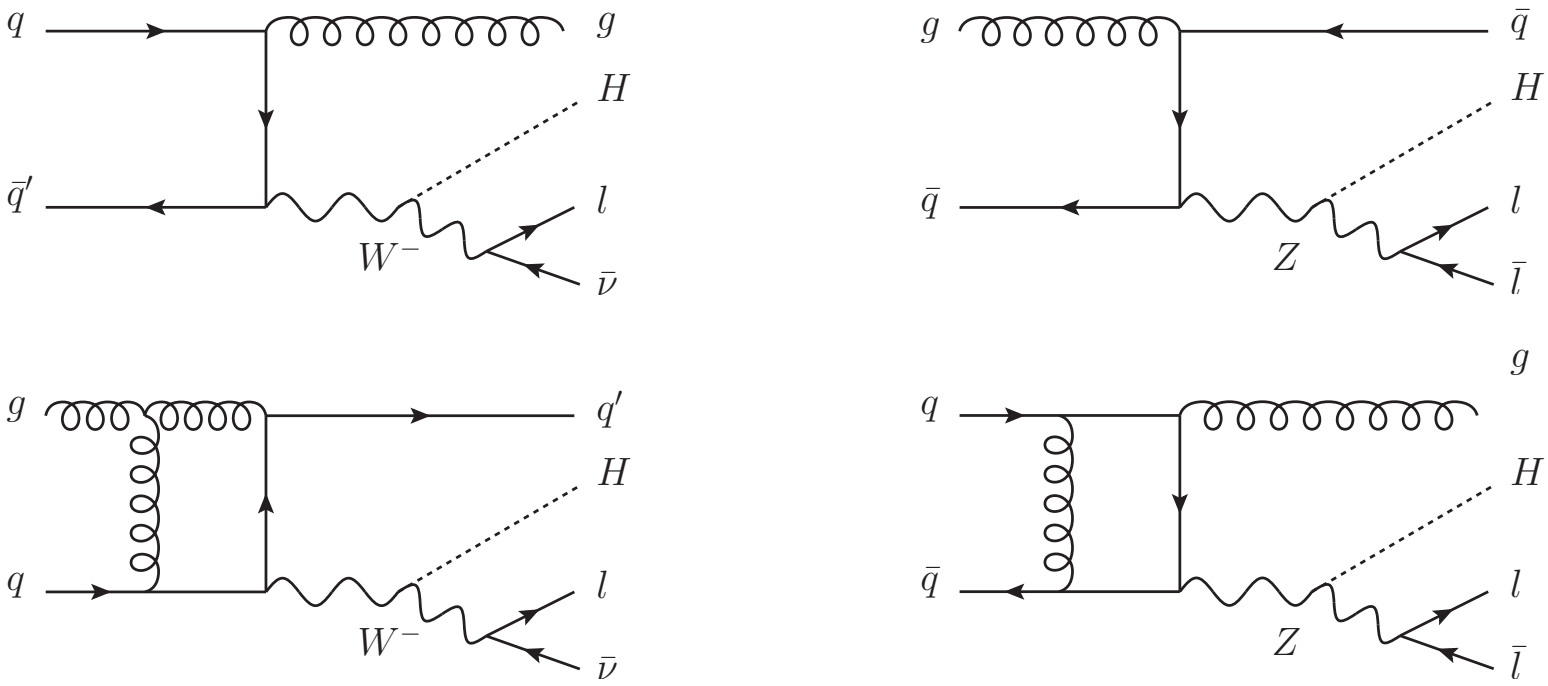
HVJ: the new code

- ✓ In the new code, the virtual contributions have been computed analytically. The resulting code is much faster.

- ✓ We have added the possibility of having not only top quarks in the loop diagrams but also bottom massive quarks

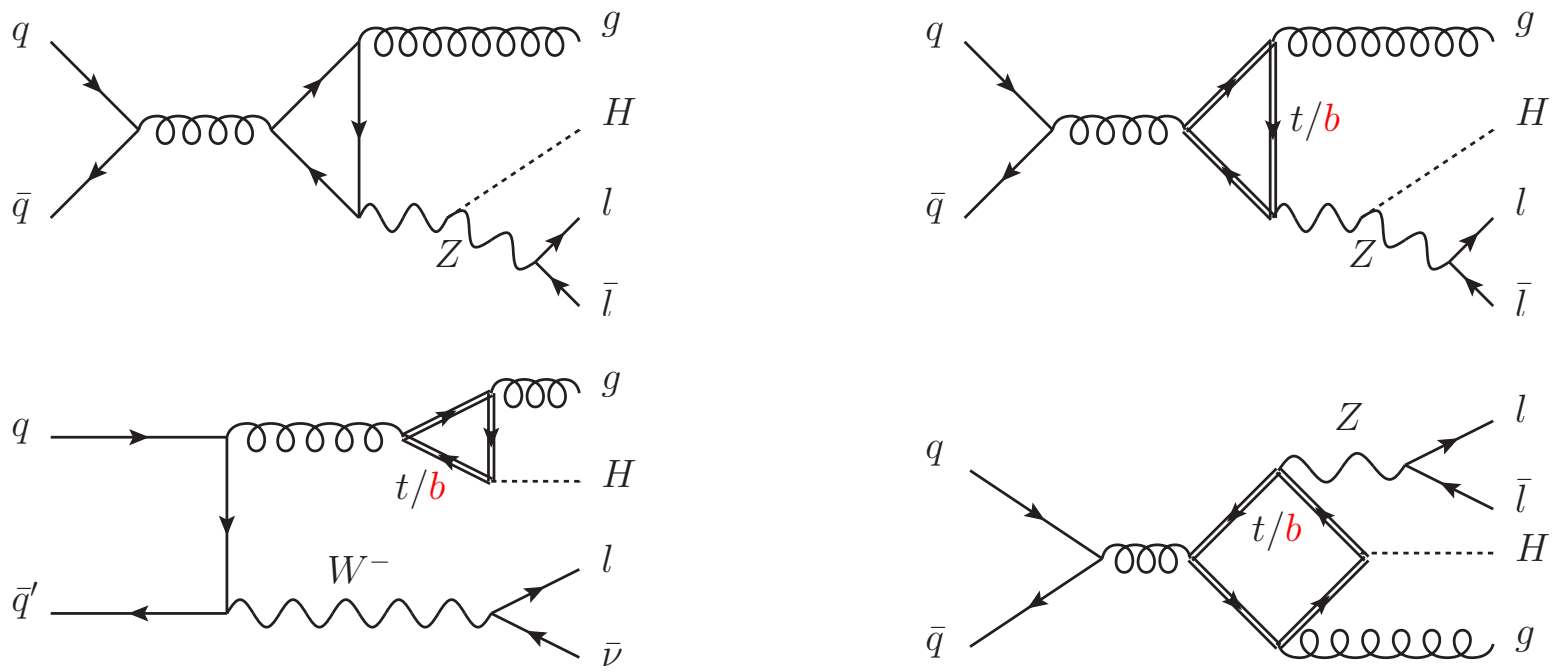
This work has been done in collaboration with Federico Granata.

HVJ: virtual diagrams



- virtual contribution (1): Higgs-Strahlung type diagrams with no closed fermion loop

HVJ: virtual diagrams



- virtual contribution (2): Higgs-Strahlung type diagrams with closed fermion loop. Only in Z production. Due to Furry theorem, only the difference between the axial current with massive top and massless/massive bottom survives
- virtual contribution (3): Higgs boson coupled directly to the massive top or bottom quark
- These last two contributions are finite

Running time

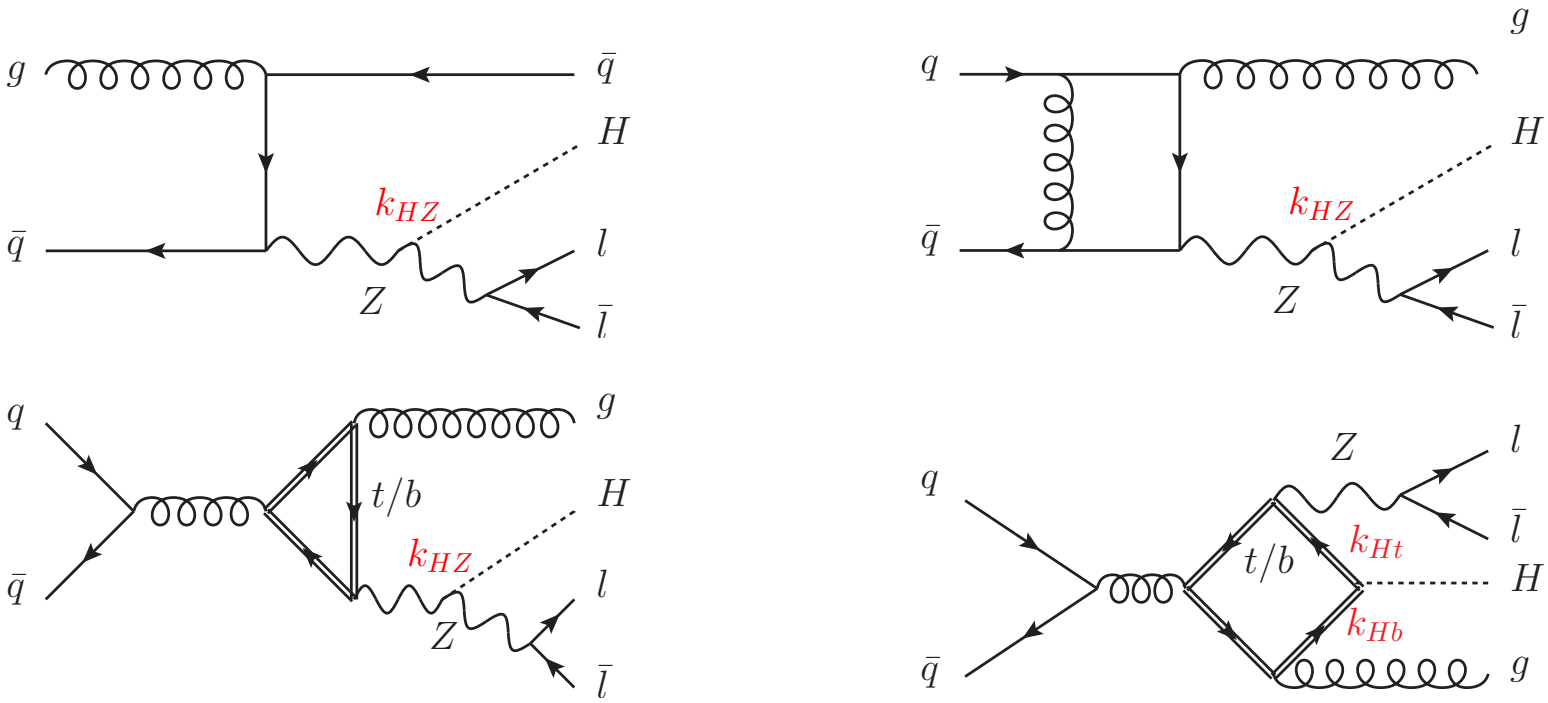
Full NLO calculation: first and second stage in POWHEG (i.e. x-grids and NLO differential cross sections/histograms)

$m_H = 125$ GeV, LHC@8 TeV, `bornktmin` 0.26

`ncall1` 50000 2 times
`ncall2` 50000 2 times

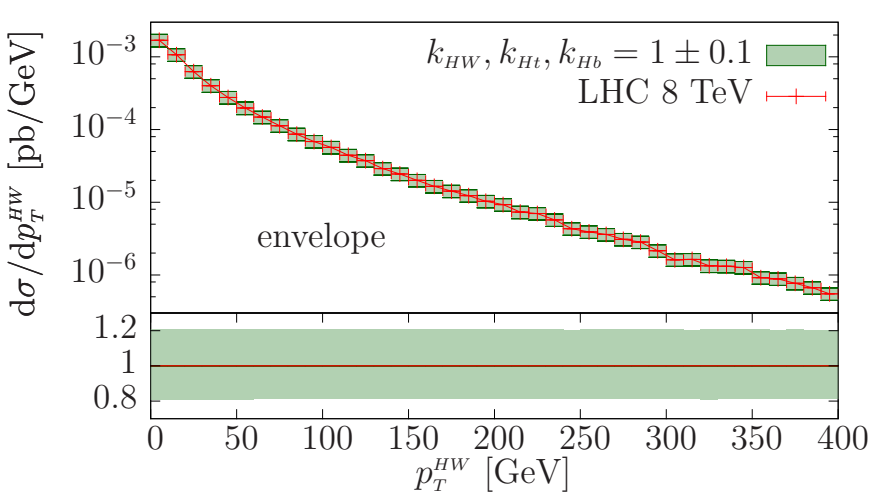
	HW^-j			HW^+j			HZJ		
	analytic	GoSam	GS/an	analytic	GoSam	GS/an	analytic	GoSam	GS/an
no top quark	8 m 20 s	25 m 40 s	3.1	8 m 12 s	25 m 36 s	3.1	10 m 38 s	4 h 45 m	27
top quark	8 m 21 s	26 m 23 s	3.2	8 m 13 s	26 m 13 s	3.2	14 m 03 s	5 h 28 m	23

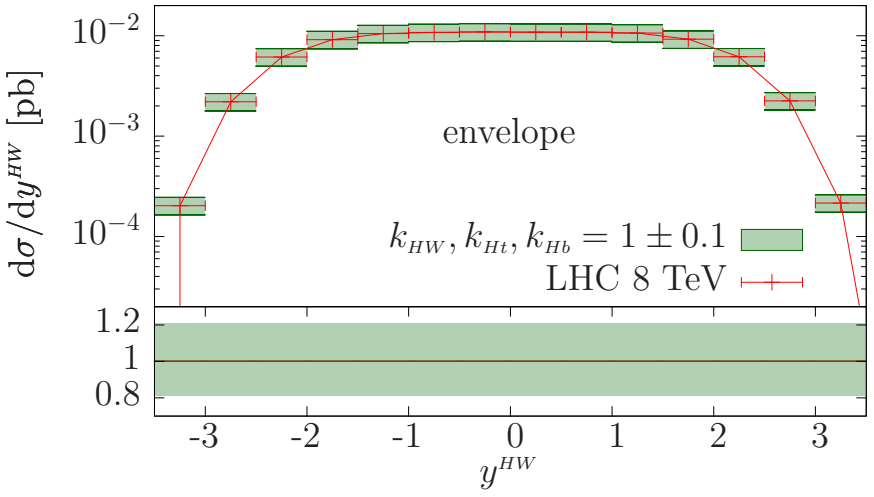
HVJ: anomalous couplings

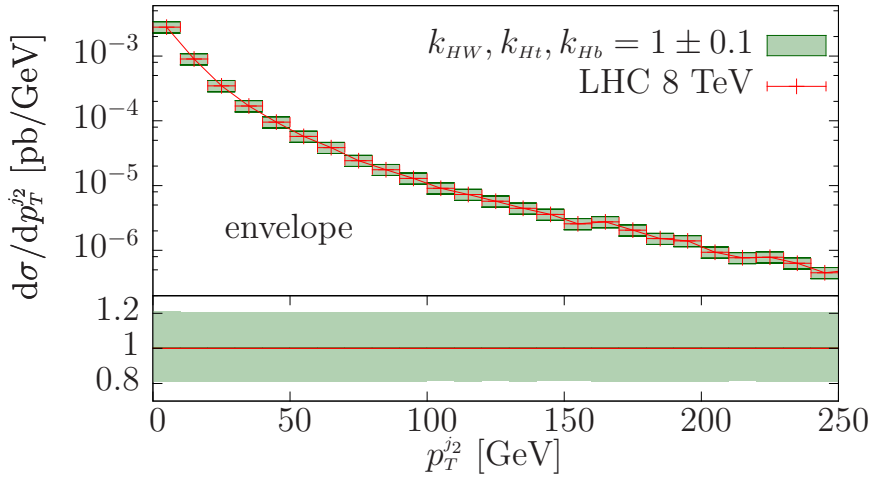


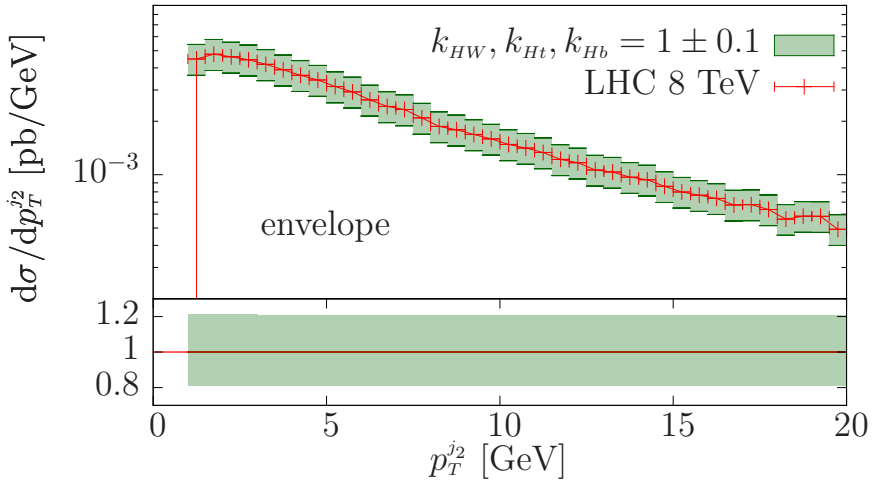
- We have added the possibility of varying the Higgs boson couplings to W, Z, t and b: $k_{HW}, k_{HZ}, k_{Ht}, k_{Hb}$.
- The calculation of the weights associated with the events with different anomalous couplings can be performed using the reweighting tool in the POWHEG BOX V2.
  No need to compute everything from scratch.

HWJ: anomalous couplings



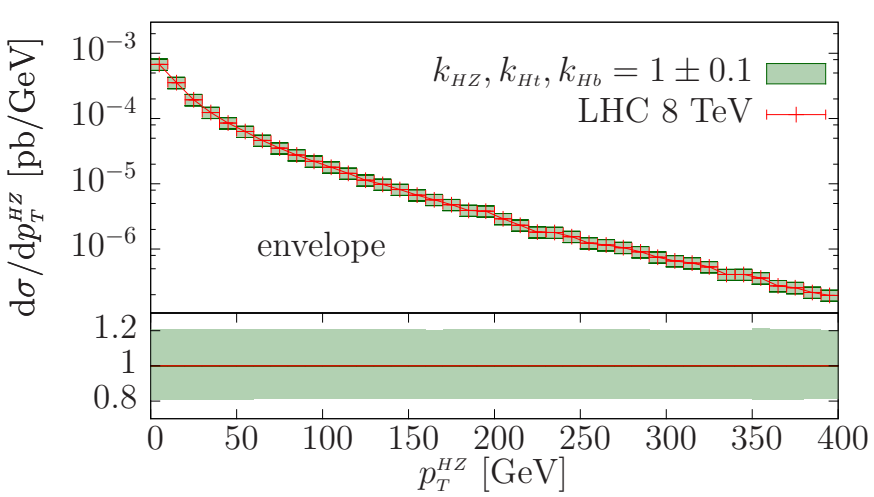


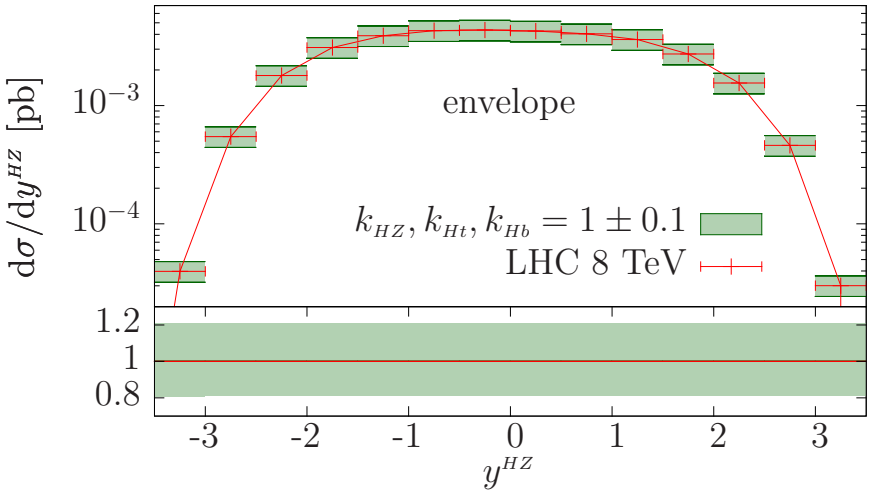


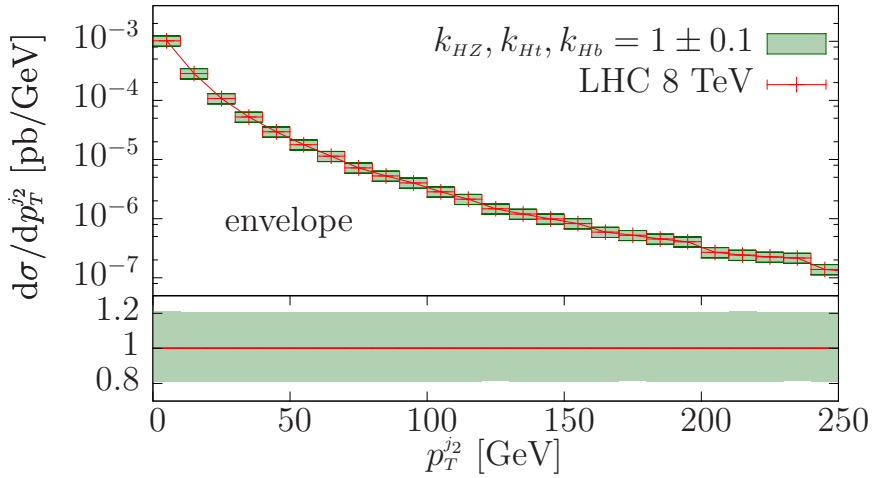


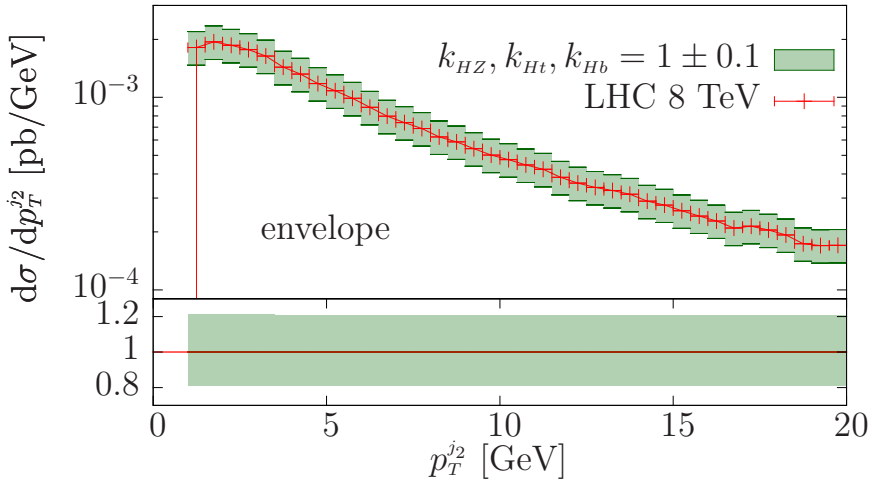
- k_{HW}, k_{Ht}, $k_{Hb} = 1 \pm 0.1$
- dominated by the variation of $k_{HW}^2 = 0.81 \div 1.21$

HZJ: anomalous couplings



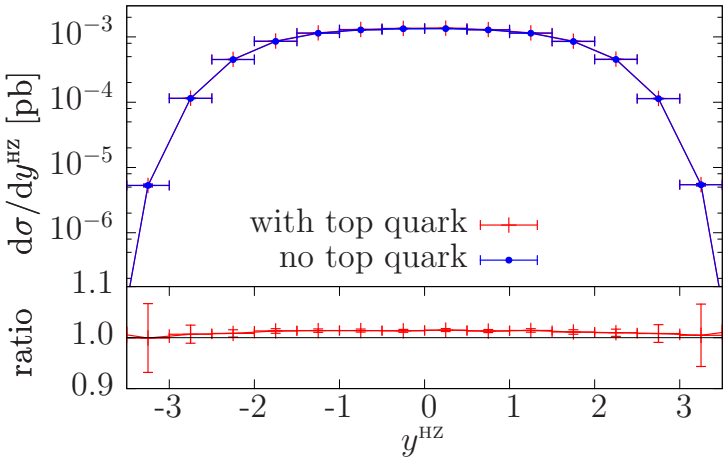


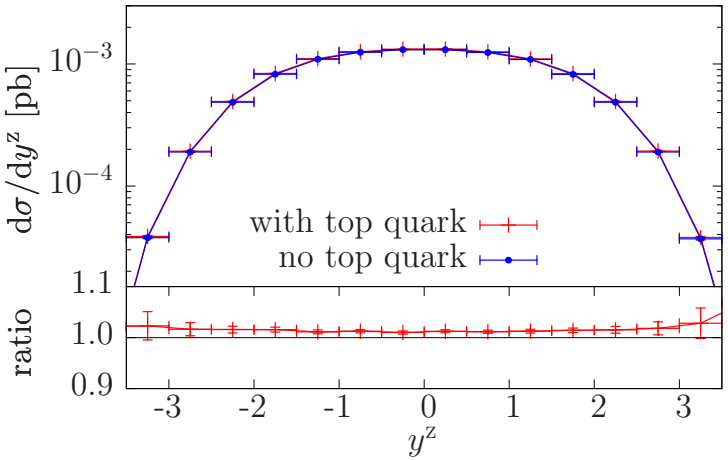


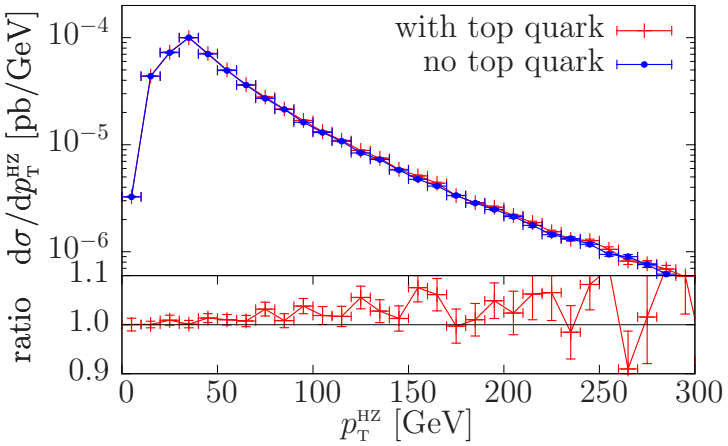


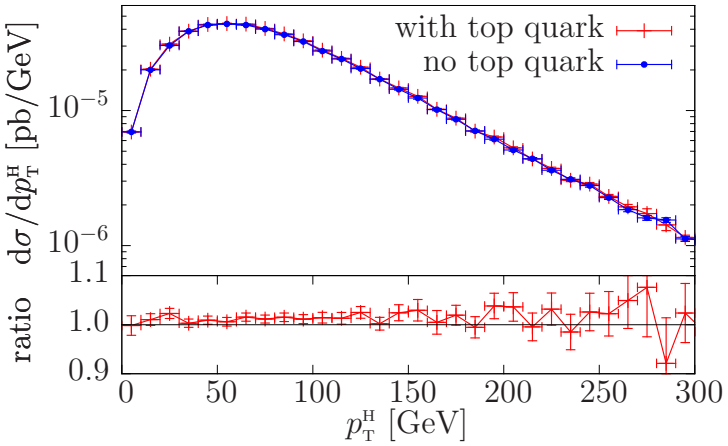
- k_{HZ}, k_{Ht}, $k_{Hb} = 1 \pm 0.1$
- same conclusions as for HWj production

NLO with and without the top quark



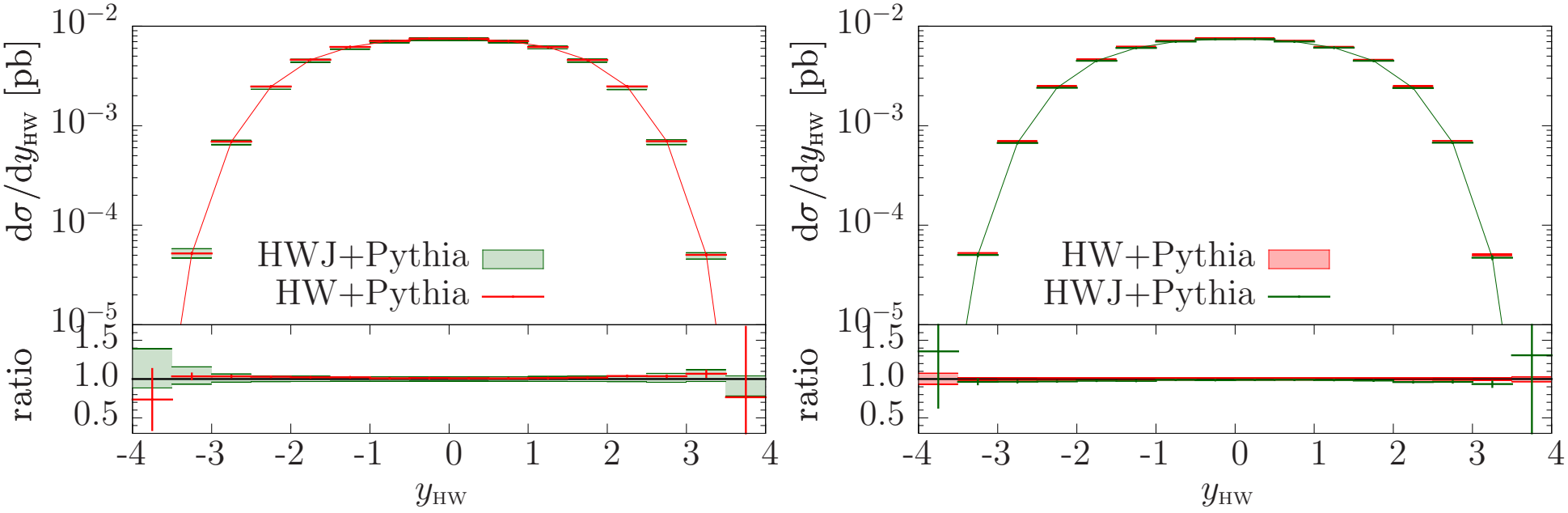






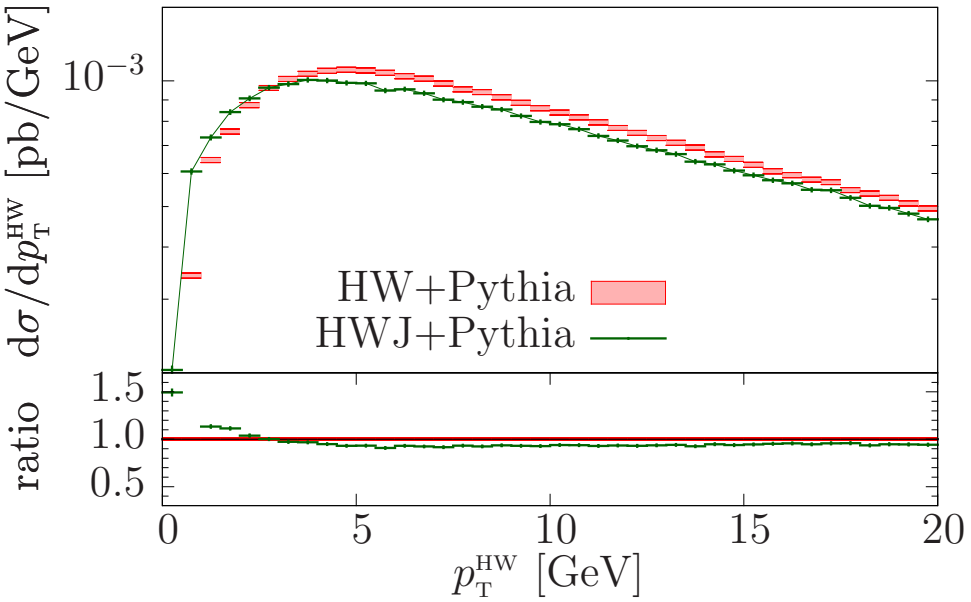
- Differences of less than 1–2% for almost all distributions.
- Only p_T^{HZ} displays larger differences, but at larger p_T, where MiNLO suppression is absent.
- the POWHEG BOX flags `massivetop` and `massivebottom` are used to include or exclude the virtuals (2) and (3)

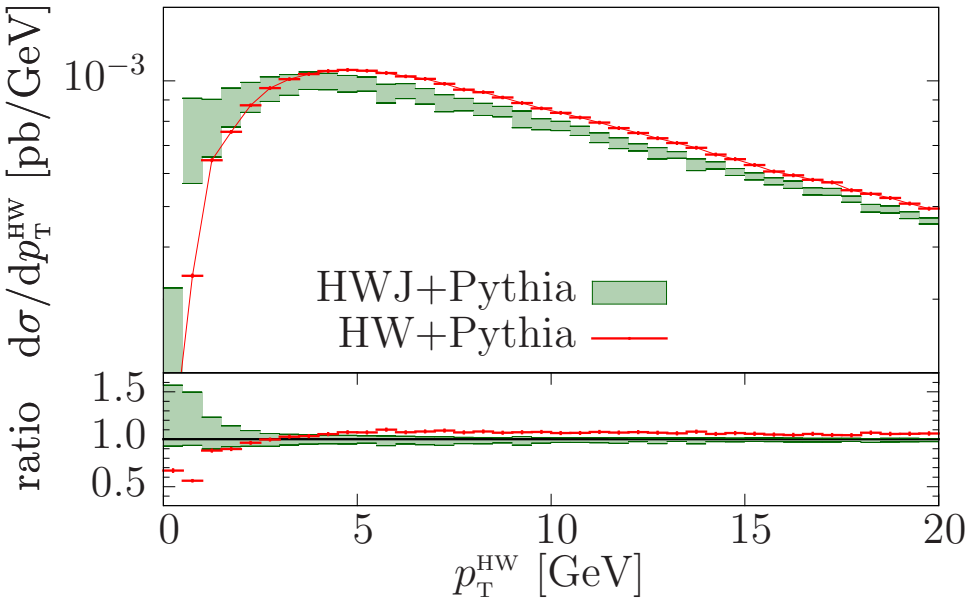
HWJ-MiNLO



- *HW*, *HZ*, *HWj* and *HZj* production (plus decay of the vector bosons): see Luisoni, Nason, C.O., Tramontano, arXiv:1306.2542
- the rapidity of the HV system is the only NLO quantity in HV production. It is then the best place to make the comparison with the HVJ-MiNLO results
- Scale-variation bands from varying μ_R and μ_F by a factor of 2 around their central values
- Results for W^- production at 8 TeV, $m_{\rm H} = 125$ GeV. Very narrow scale-variation bands

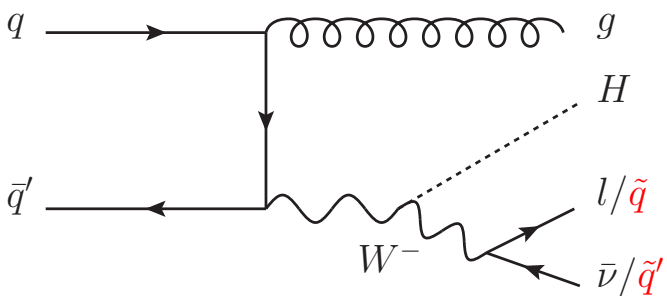
HWJ-MiNLO

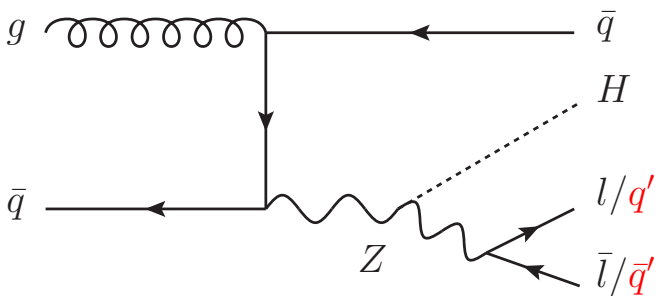




- The Sudakov peak is around 5 GeV: very close to the hadronization scales.
- It is then sensitive to any non-perturbative parameter in the showering program, and to the tuning.

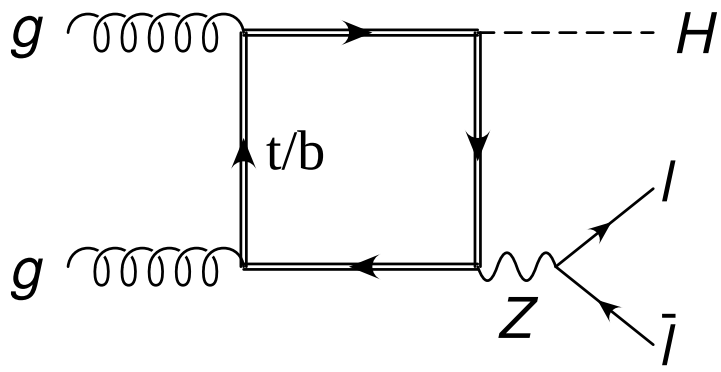
HVJ: hadronic and inclusive decays





- We have added the possibility of having hadronic and inclusive decay of the vector bosons, together with the previous leptonic decay.
- NLO corrections to the hadronic decay products are not computed by POWHEG
- They are only taken into account by multiplying the tree-level hadronic widths by a factor $1 + \alpha_s(m_V)/\pi$

$gg \to HZ$ production: no news



- Born, real and interference of virtual corrections with Born
- We have added to the POWHEG BOX the square of the LO contribution to $gg \to HZ$ production (through a massive t/b loop) as a separate generator. This is a LO generator, NOT a NLO one
- $Z \to l\bar{l}$ and $Z \to \nu\bar{\nu}$. No hadronic decay in the current version.

Conclusions

- ✓ The new code will be released in a few days. Same repositories as the previous codes

  `POWHEG-BOX-V2/User-Processes-V2/HWJ`
  `POWHEG-BOX-V2/User-Processes-V2/HZJ`

- ✓ The previous `GoSam` code will still be in place. A user can choose to do runs with the previous numeric code, automatically generated by `GoSam`, or with the new analytic one.

- ✓ Instructions on how to run version 2 of the POWHEG BOX can be found under the directory

  `POWHEG-BOX-V2/Docs`

- ✓ Instructions on how to run HWj and HZj can be found under the directory

  `POWHEG-BOX-V2/HWJ/Docs`
  `POWHEG-BOX-V2/HZJ/Docs`

- ✓ See `http://powhegbox.mib.infn.it` for the list of available processes and papers to quote.