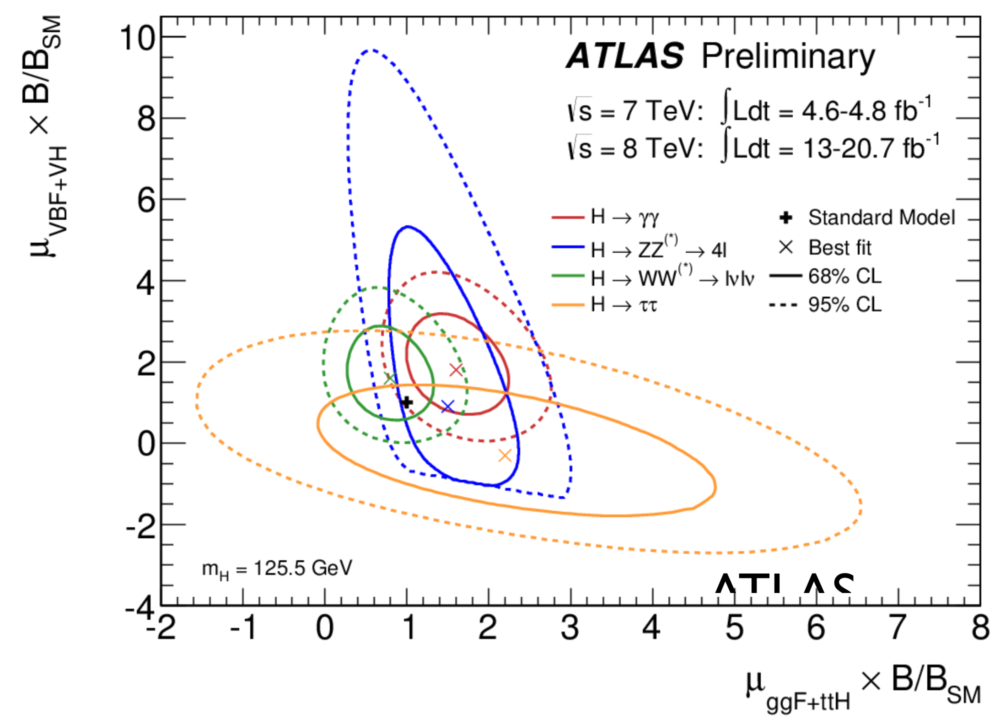
Weak corrections to ttH production at hadron colliders

Marco Zaro, LPTHE-UPMC
based on Frixione, Hirschi, Pagani, Shao, MZ, arXiv:1407.0823

LHCPhenoNet final meeting
Berlin, November 24th, 2014

Motivation

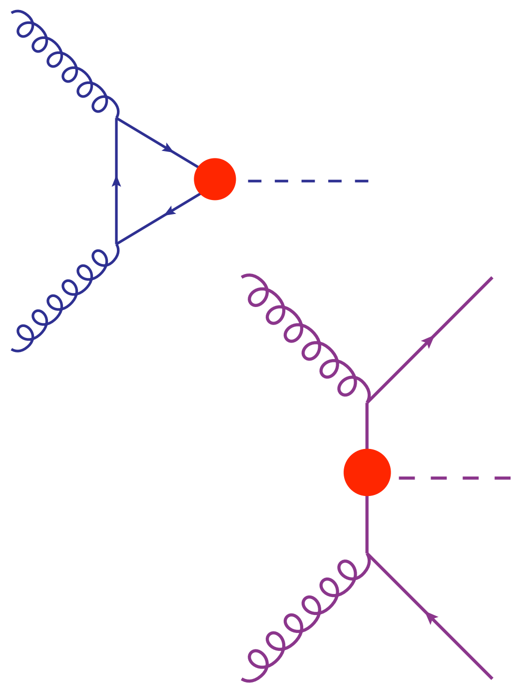
- Since the discovery of the Higgs boson candidate at the LHC, lots of efforts have been put into the determination of its properties and couplings
- Non-SM effects can lead to deviations in the coupling strengths
- No deviation observed so-far, substantial improvements in exp accuracy expected for LHC run II

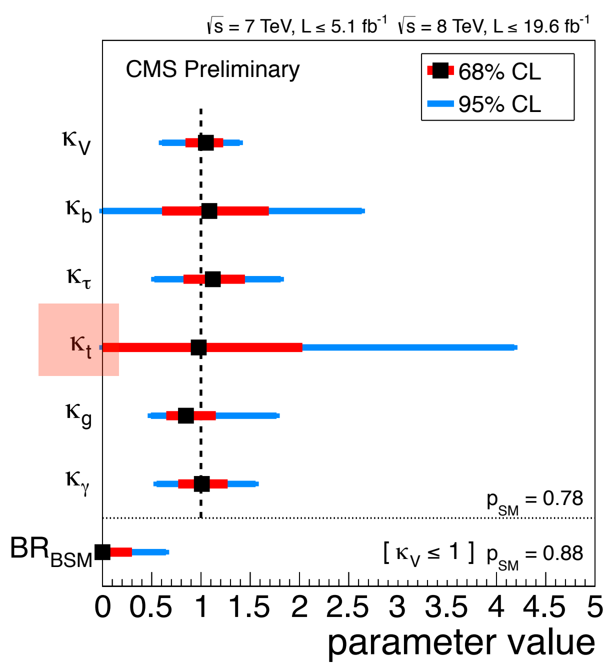


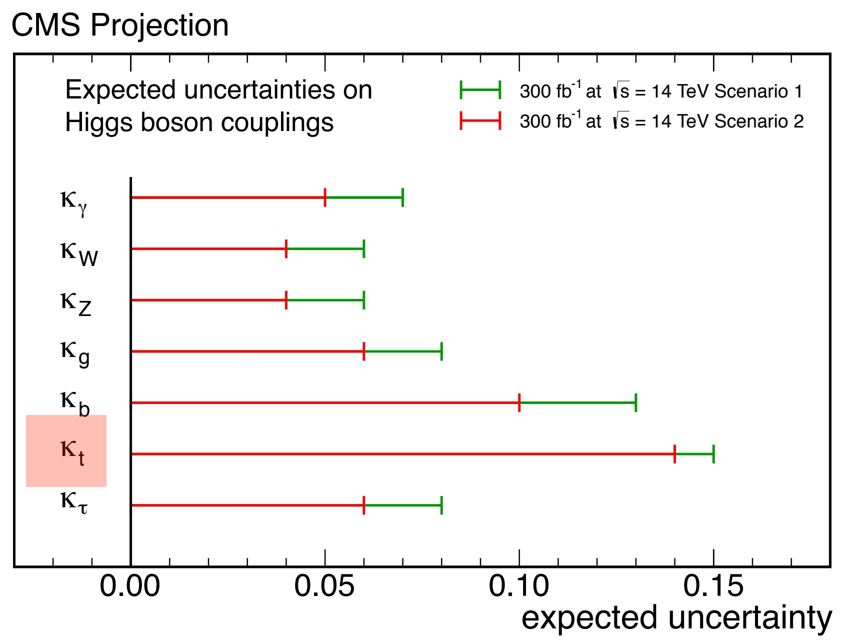
Need for accurate predictions!

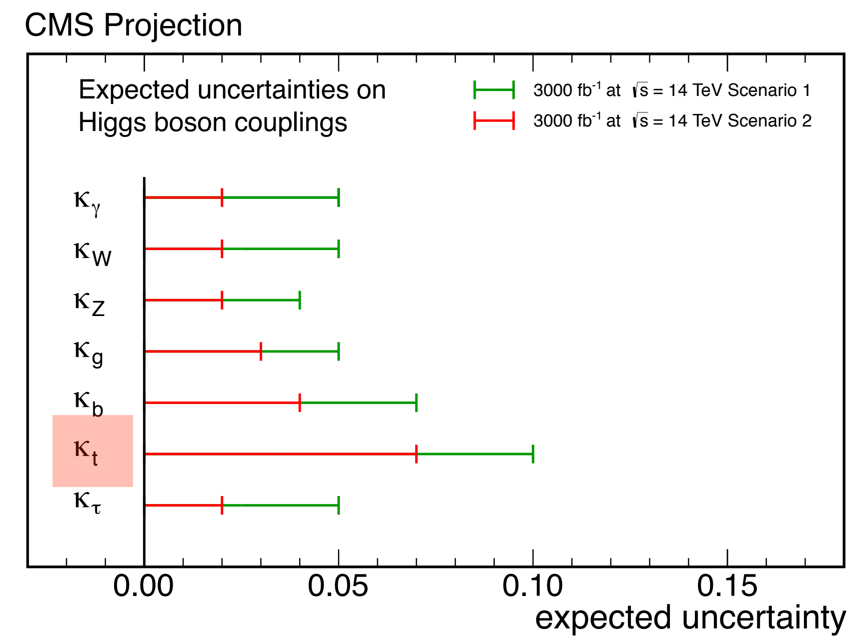
The top Yukawa coupling

- One crucial parameter to be measured is the top Yukawa
- It can be extracted looking at Higgs production in ggF (indirectly) and in ttH (directly)
- Expected to be measured at 15 (10%) at 300(3000) fb-1



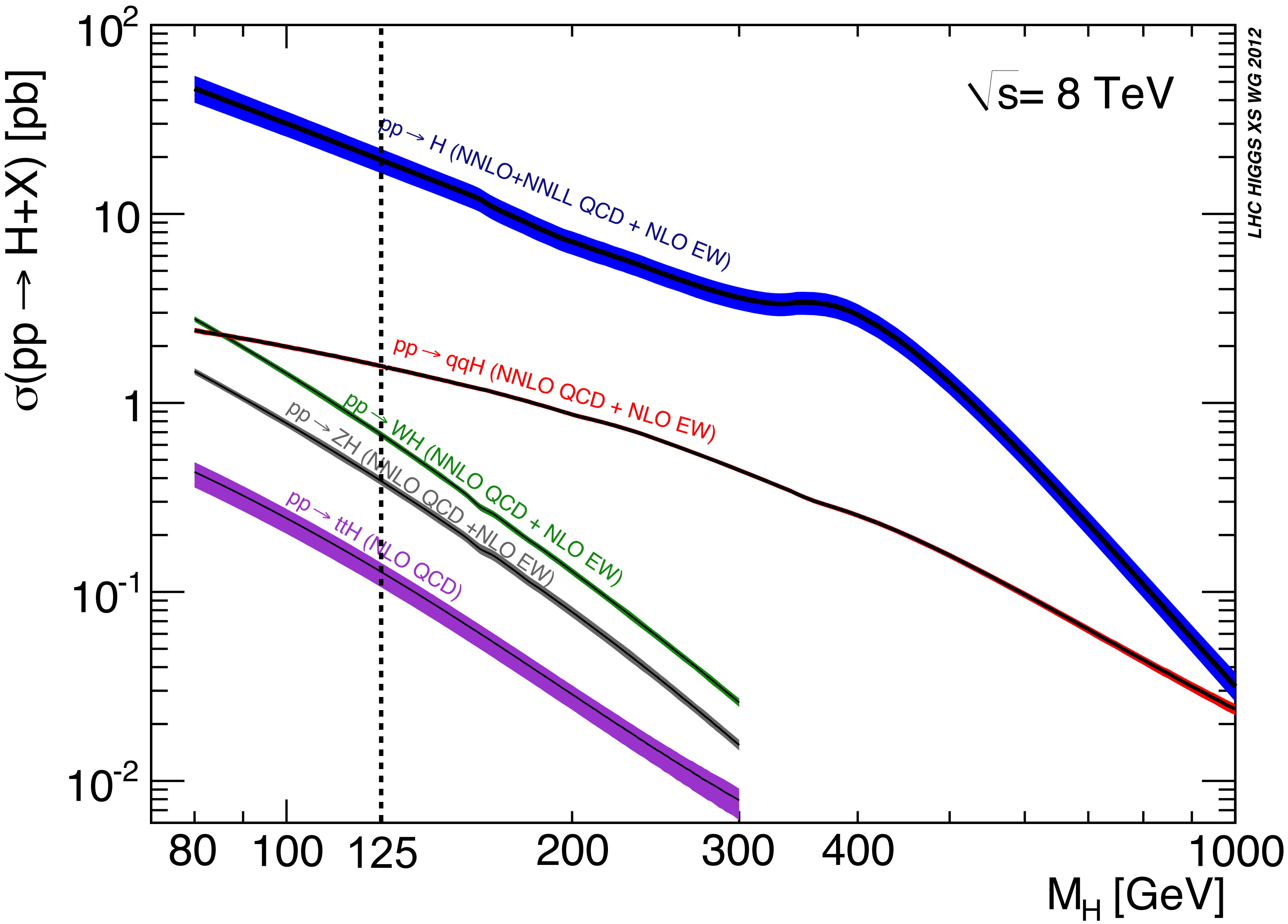


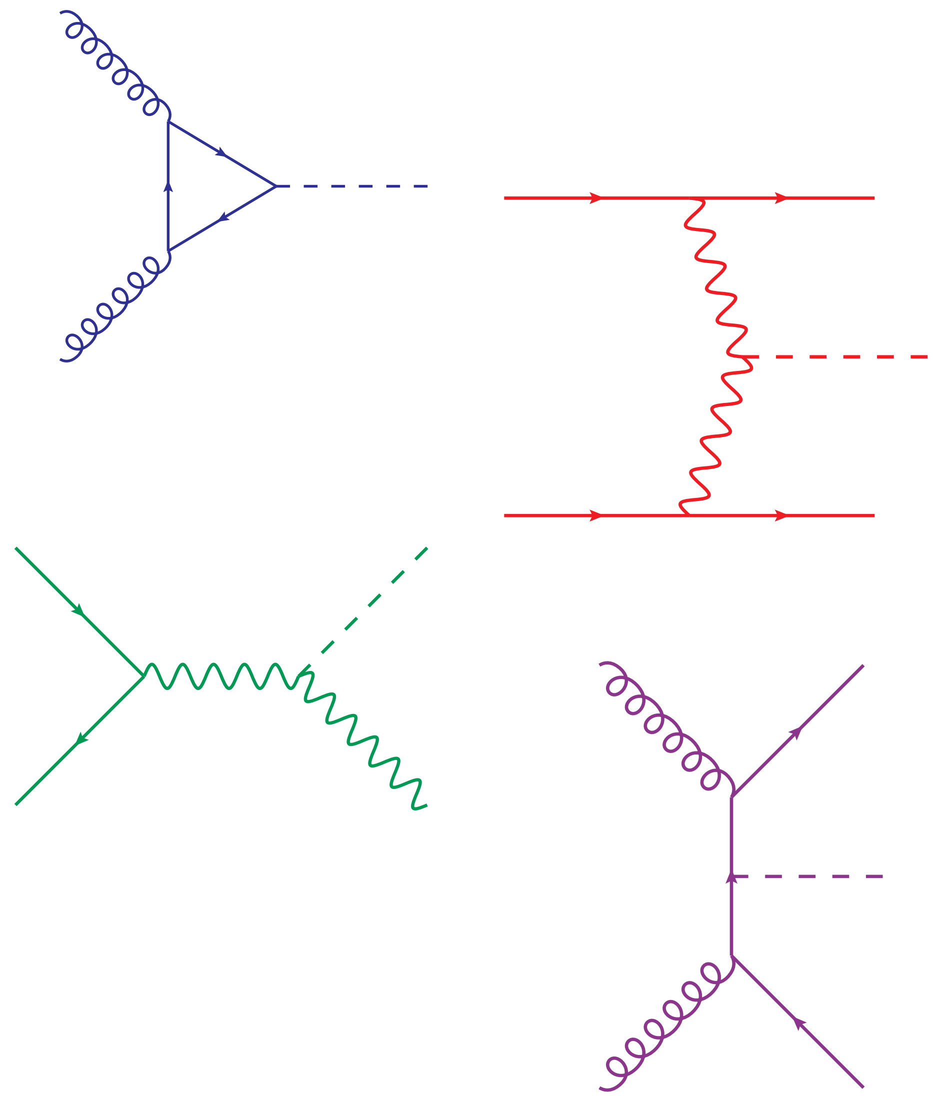




State-of-the-art predictions for Higgs production at the LHC

(circa June 2014)



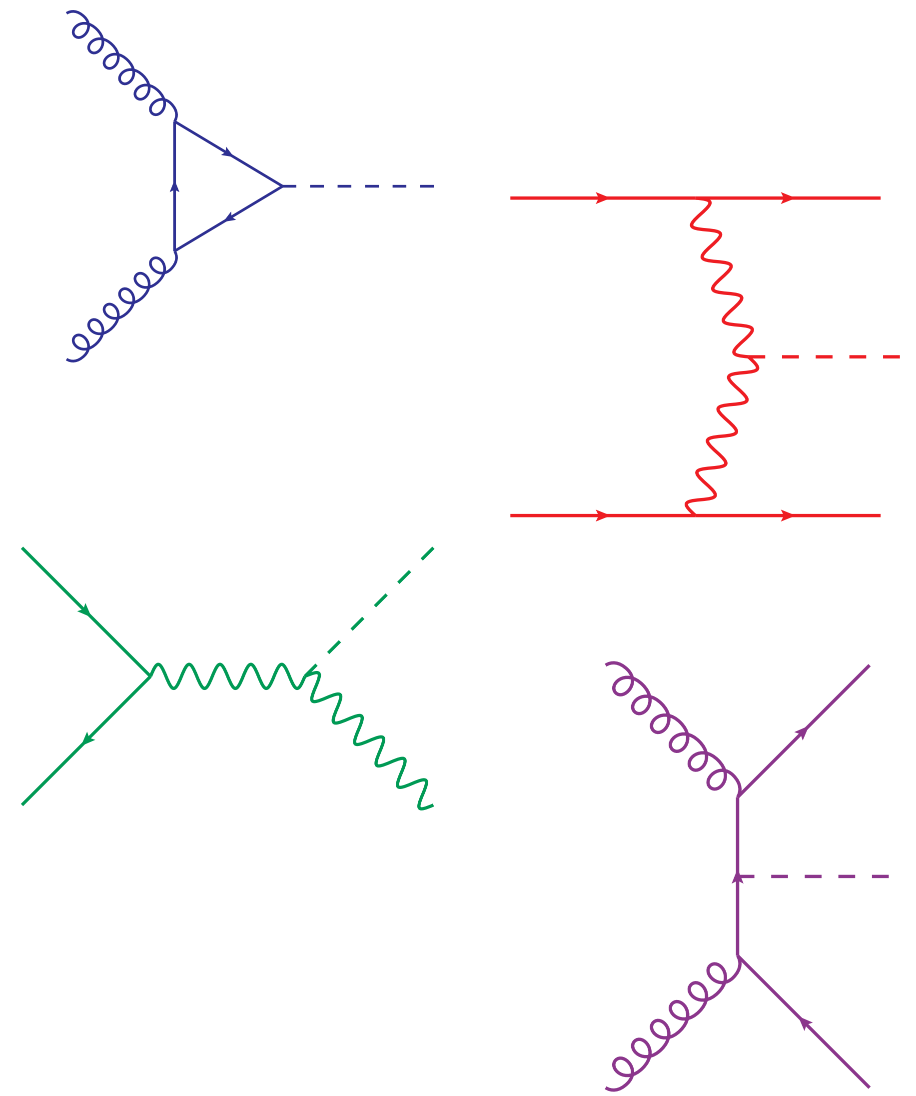


rather poor accuracy for ttH compared to other production channels

State-of-the-art predictions for Higgs production at the LHC

(circa June 2014)

- Electroweak corrections known for all Higgs production channels but ttH
  - ggH: Djouadi, Gambino, hep-ph/9406432, Degrassi, Maltoni, hep-ph/0407249, Aglietti, Bonciani, Degrassi, Vicini, hep-ph/0610033, Actis, Passarino, Sturm, Uccirati, arXiv:0809.1301
  - VBF: Ciccolini, Denner, Dittmaier, arXiv:0707.0381 & 0710.4749
  - VH: Ciccolini, Dittmaier, Kramer, hep-ph/0306234



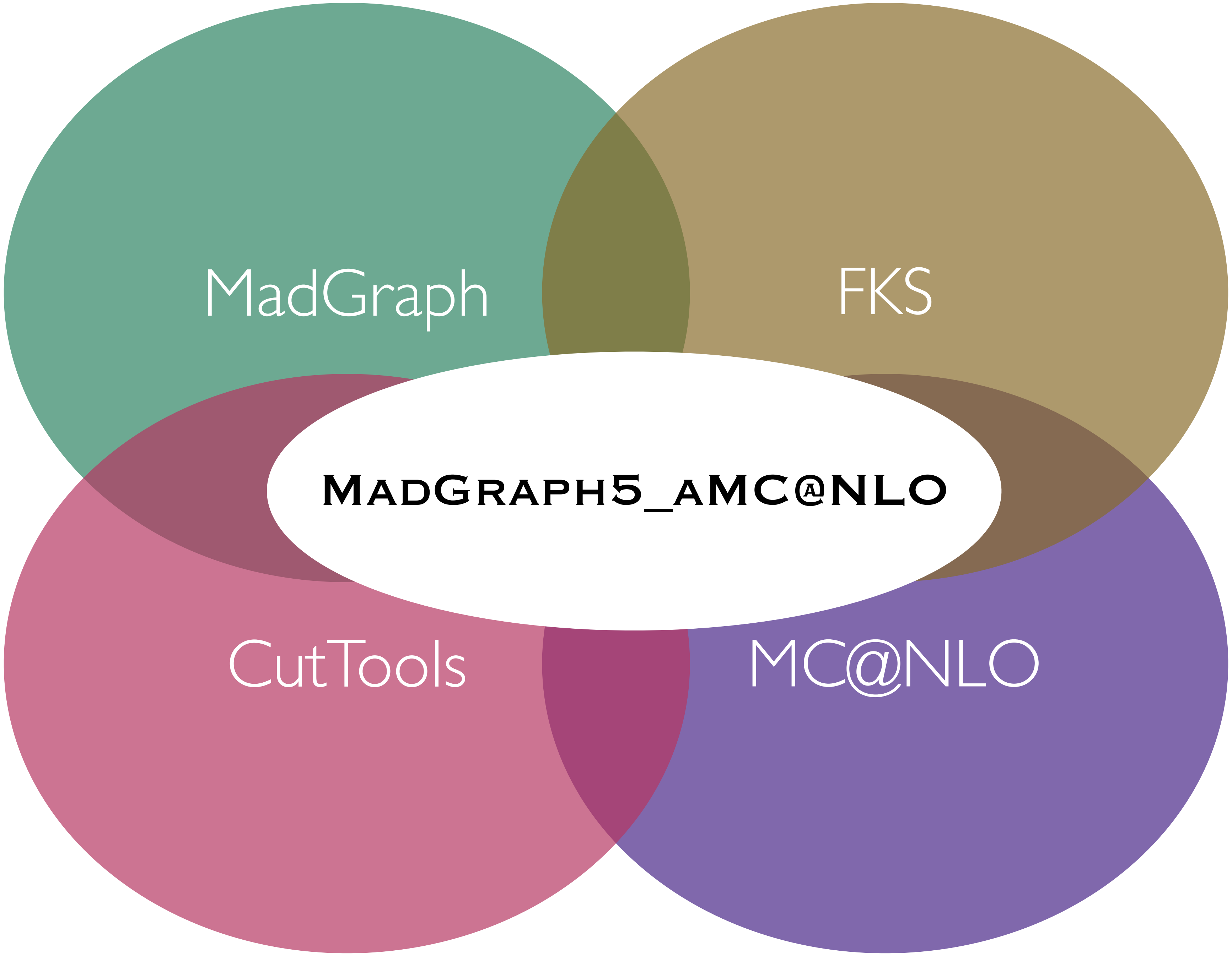
rather poor accuracy for ttH compared to other production channels

Weak corrections to ttH

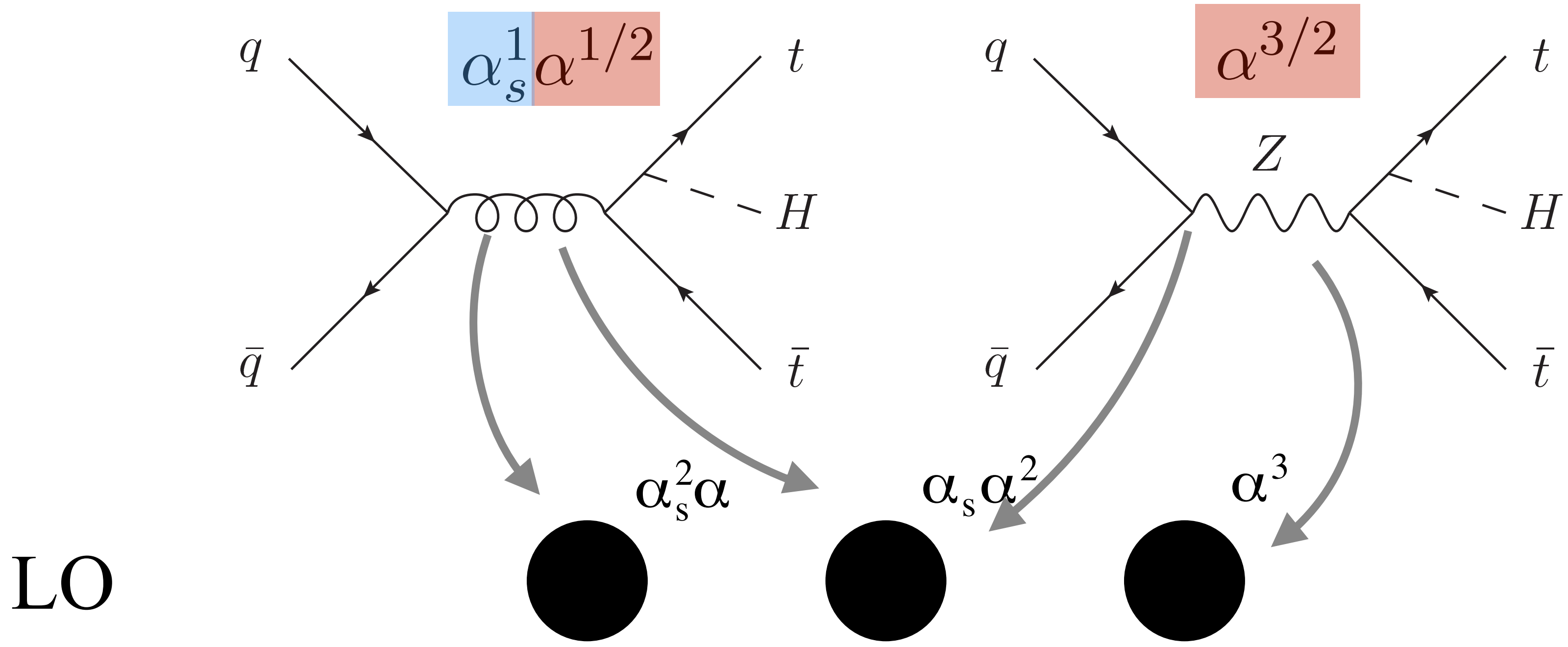
- Computation of corrections of weak origin to ttH
- Why only weak?
  - Lazy guy motivation: Weak corrections are simpler than full EW corrections, particularly for IR singularities
  - Learning guy motivation: use weak corrections to learn about how to compute full EW corrections (and how to automate them)
  - Pheno motivation I: Weak corrections are supposed to be the dominant part of full EW: they contain Sudakov logs
  - Pheno motivation II: Weak corrections spoil the y_t^2 dependence of the cross-section, intro ducting dependence on g_{hvv}, λ_{hhh}

MadGraph5_aMC@NLO

Alwall, Frederix, Frixione, Maltoni, Mattelaer, Shao, Stelzer, Torrielli, Hirschi, MZ arXiv:1405.0301



Structure of EW corrections: 1) coupling orders



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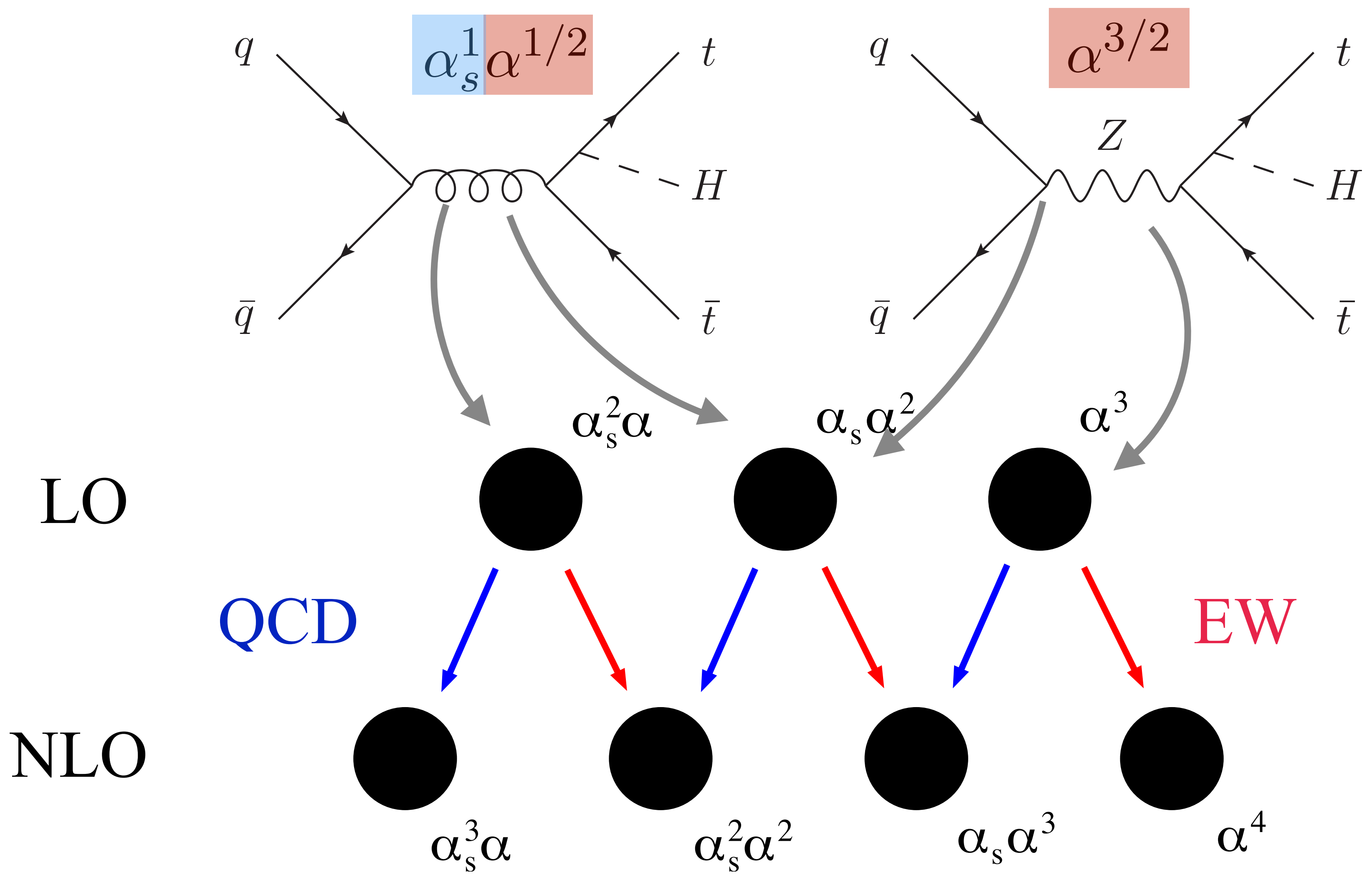

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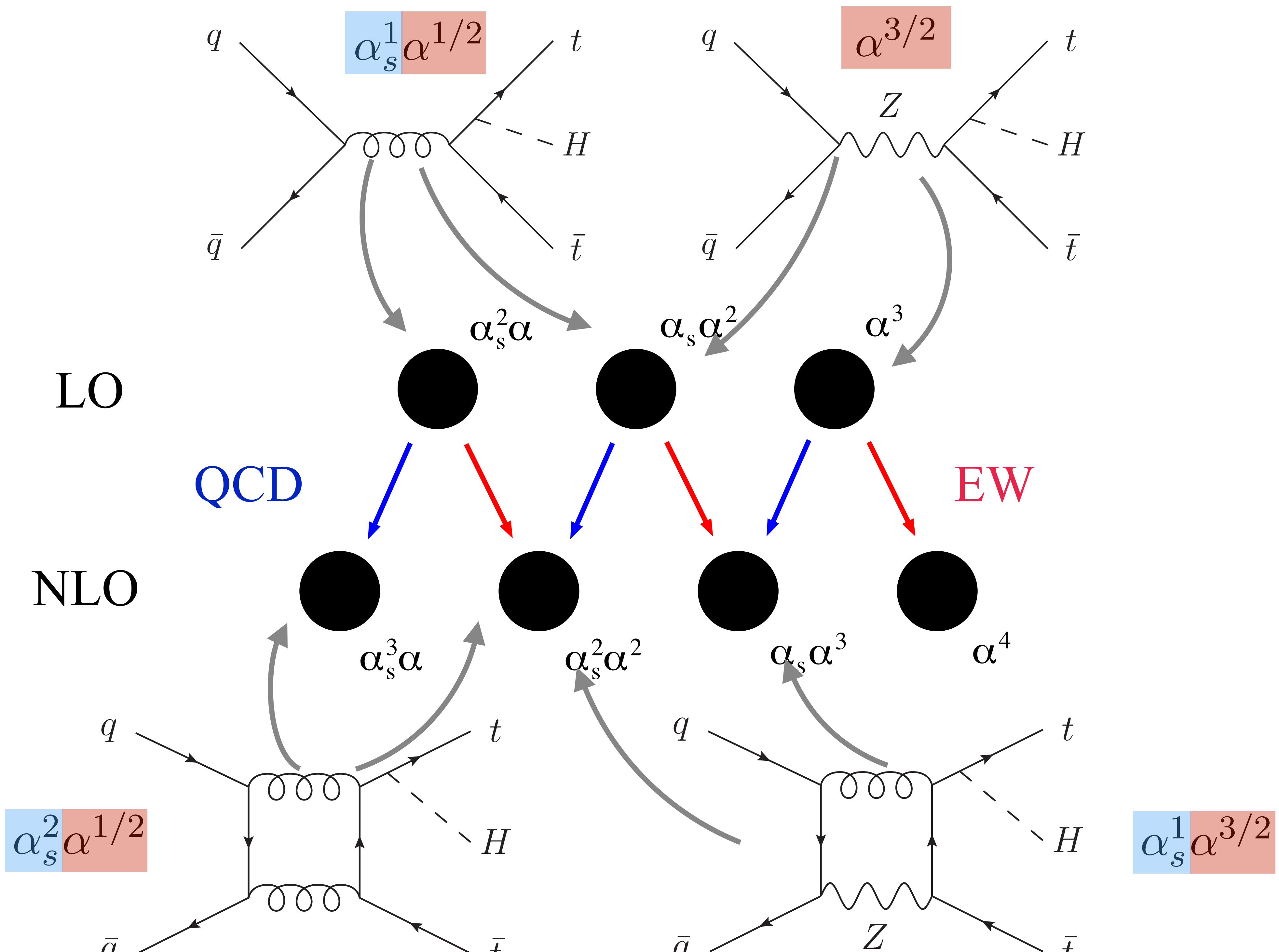

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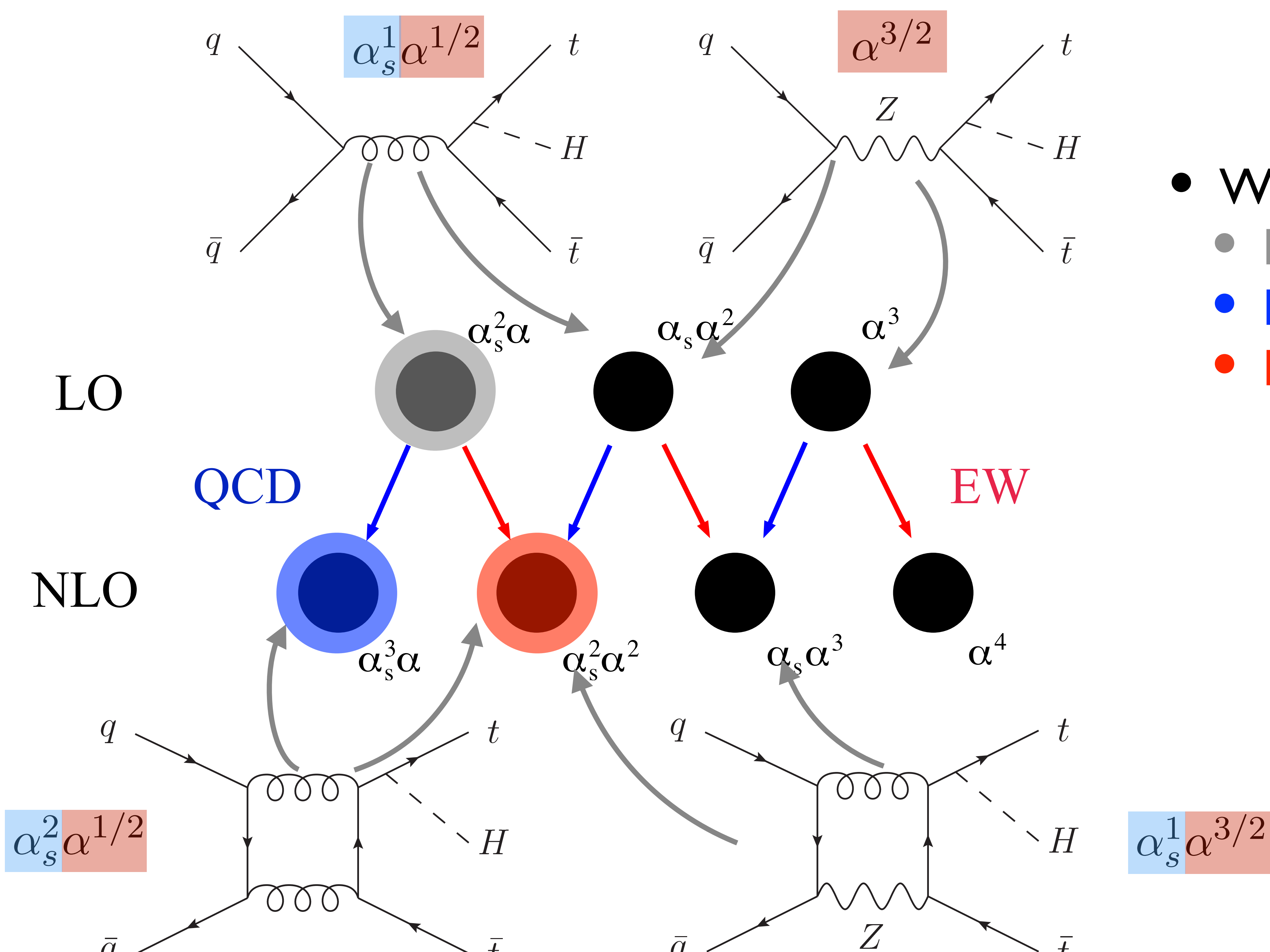
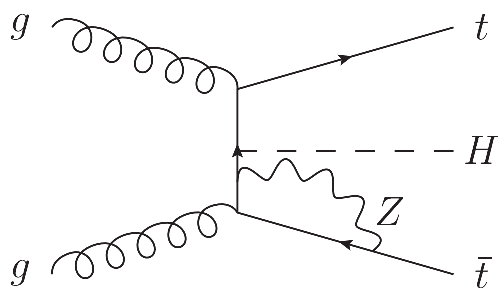


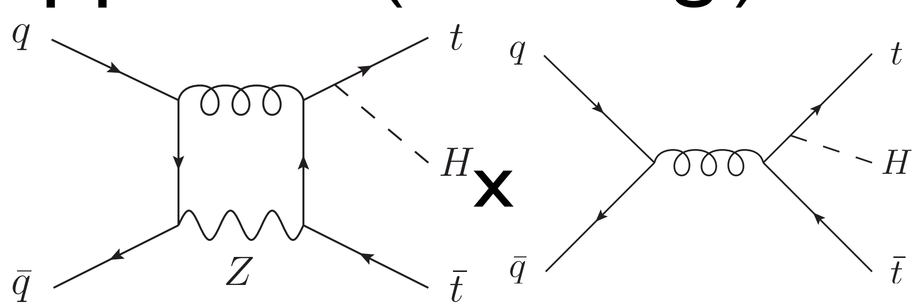
- We are used to call
  - LO
  - NLO QCD
  - NLO EW

Structure of EW corrections: 2) partonic subchannels & IR structure

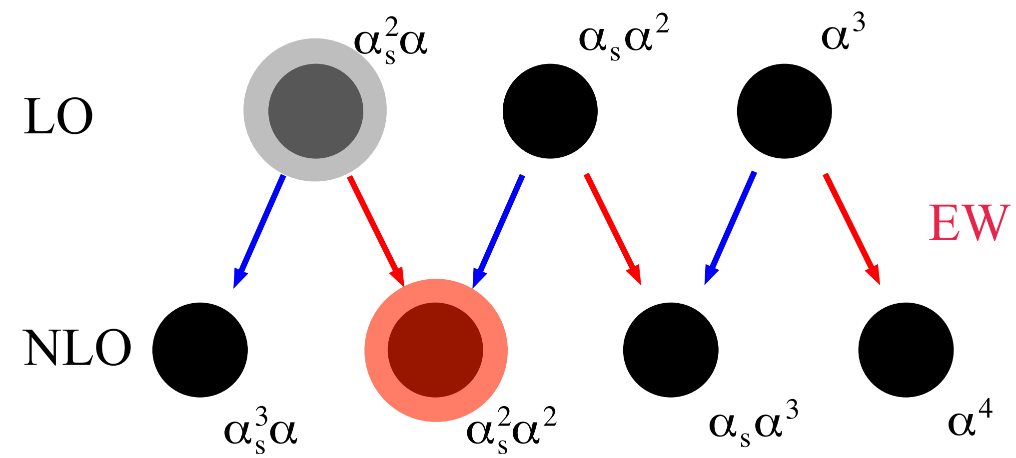
- Virtual corrections
  - gg→t$\bar{\text{t}}$H (finite)



  - q$\bar{\text{q}}$→t$\bar{\text{t}}$H (soft sing.)



- Real corrections
  - q$\bar{\text{q}}$→t$\bar{\text{t}}$Hg (soft sing)
  - q$\bar{\text{g}}$→t$\bar{\text{t}}$Hq (finite)



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Structure of EW corrections: 2) partonic subchannels & IR structure

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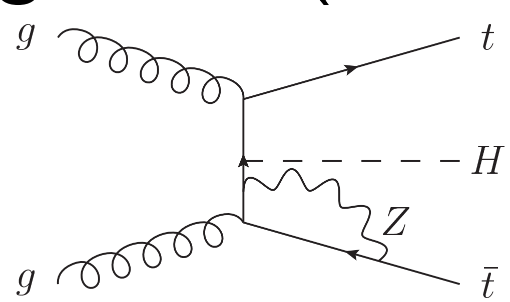
  - $gg \to t\bar{t}H$ (finite)



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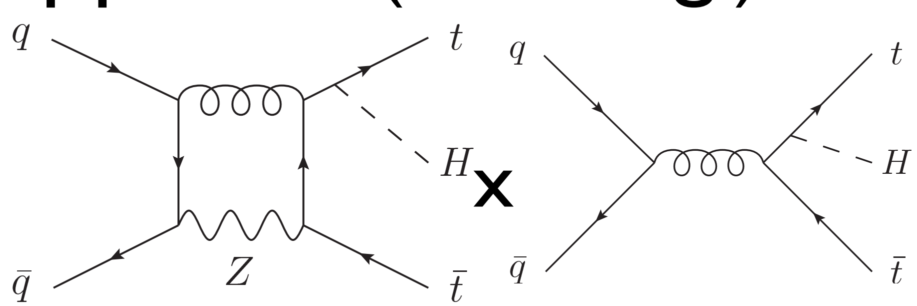

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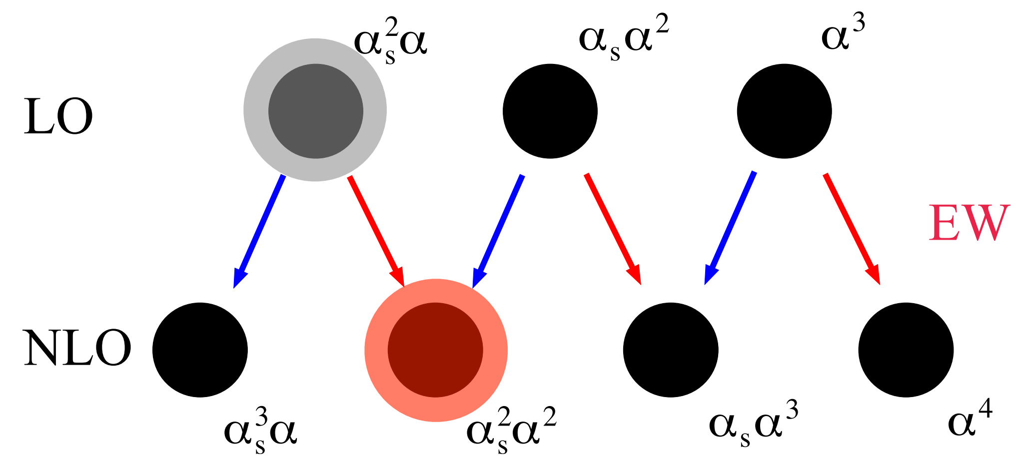

- Heavy boson radiation
  - $pp \to t\bar{t}HV$ (finite, but $O(\boldsymbol{\alpha_s}^2\boldsymbol{\alpha}^2)$) V=W,Z,H

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- Setup:
  - Weak corrections computed in the $\alpha(M_Z)$-scheme (G_μ also available)
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  - MSTW 2008 NLO pdfs
  - Ren/Fact scales set to

$$\mu = \frac{H_T}{2}$$

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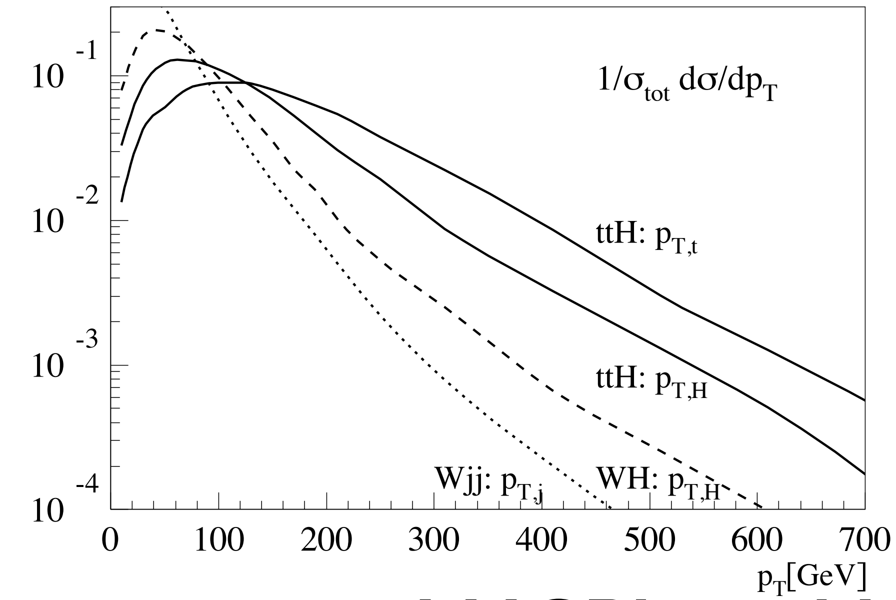
  - Boosted analysis
    - S/B enhanced in boosted regimes Plehn, Salam, Spannowsky, arXiv:0910.5472



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    - S/B enhanced in boosted regimes Plehn, Salam, Spannowsky, arXiv:0910.5472
    - Apply boosted cuts
    $$p_T(t,\bar{t},H) > 200\text{GeV}$$
    - Sudakov logs relevant in boosted region

Inclusive rates

NLO corrections (boosted regime in brackets)

$\delta_{\rm NLO}(\%)$	8 TeV	13 TeV	100 TeV
QCD	$+25.6^{+6.2}_{-11.8}$ $(+19.6^{+3.7}_{-11.0})$	$+29.3^{+7.4}_{-11.6}$ $(+23.9^{+5.4}_{-11.2})$	$+40.4^{+9.9}_{-11.6}$ $(+39.1^{+9.7}_{-10.4})$
weak	-1.2 (-8.3)	-1.8 (-8.2)	-3.0 (-7.8)

Heavy boson radiation

$\delta_{\rm HBR}(\%)$	8 TeV	13 TeV	100 TeV
W	$+0.42(+0.74)$	$+0.37(+0.70)$	$+0.14(+0.22)$
Z	$+0.29(+0.56)$	$+0.34(+0.68)$	$+0.51(+0.95)$
H	$+0.17(+0.43)$	$+0.19(+0.48)$	$+0.25(+0.53)$
sum	$+0.88(+1.73)$	$+0.90(+1.86)$	$+0.90(+1.70)$

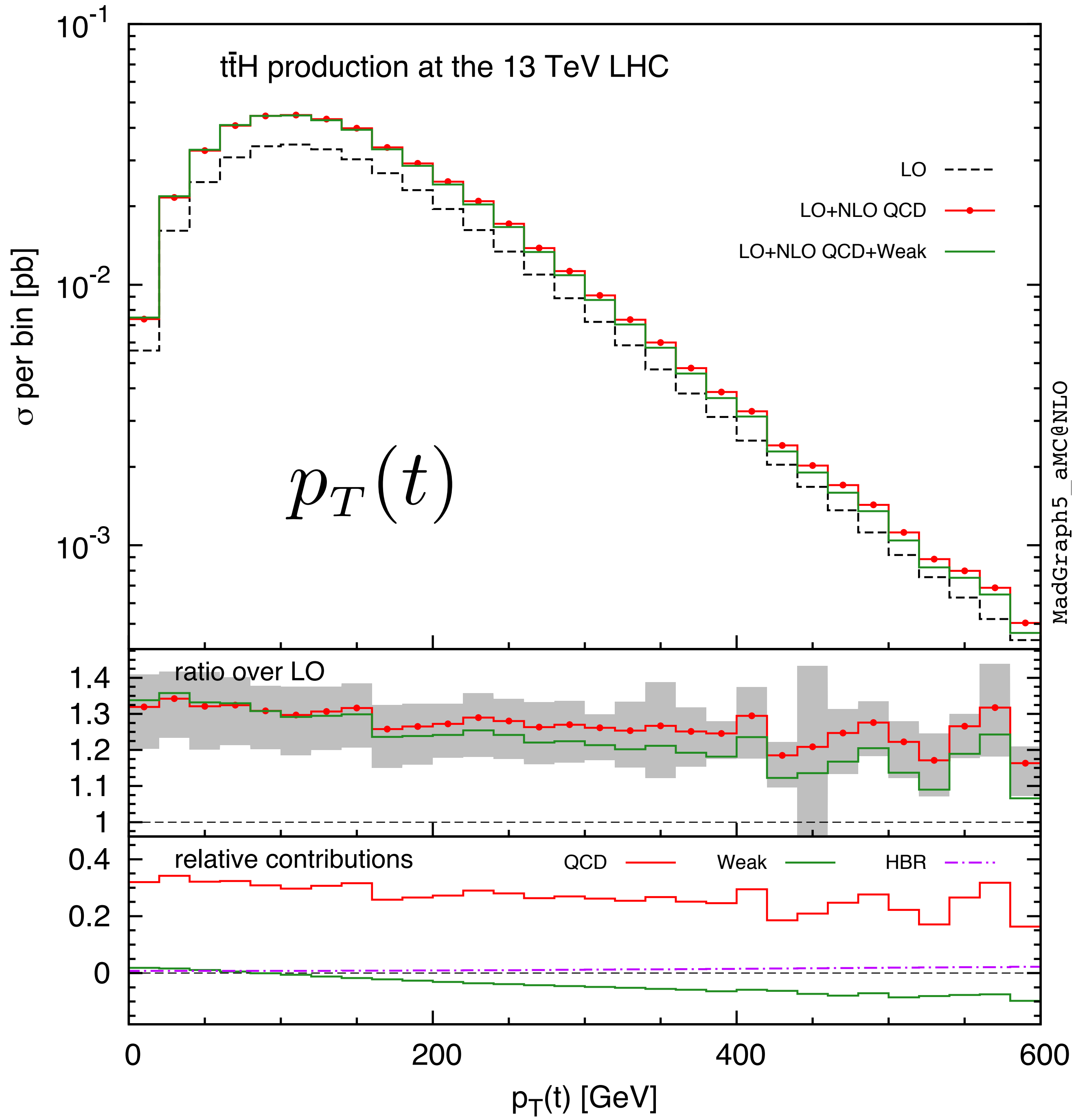
Corrections per partonic subchannel

$\delta_{\rm NLO}(\%)$	8 TeV	13 TeV	100 TeV
gg	-0.67 (-2.9)	-1.12 (-4.0)	-2.64 (-6.8)
$u\bar{u}$	-0.01 (-3.2)	-0.15 (-2.3)	-0.10 (-0.5)
$d\bar{d}$	-0.55 (-2.2)	-0.52 (-1.9)	-0.23 (-0.5)

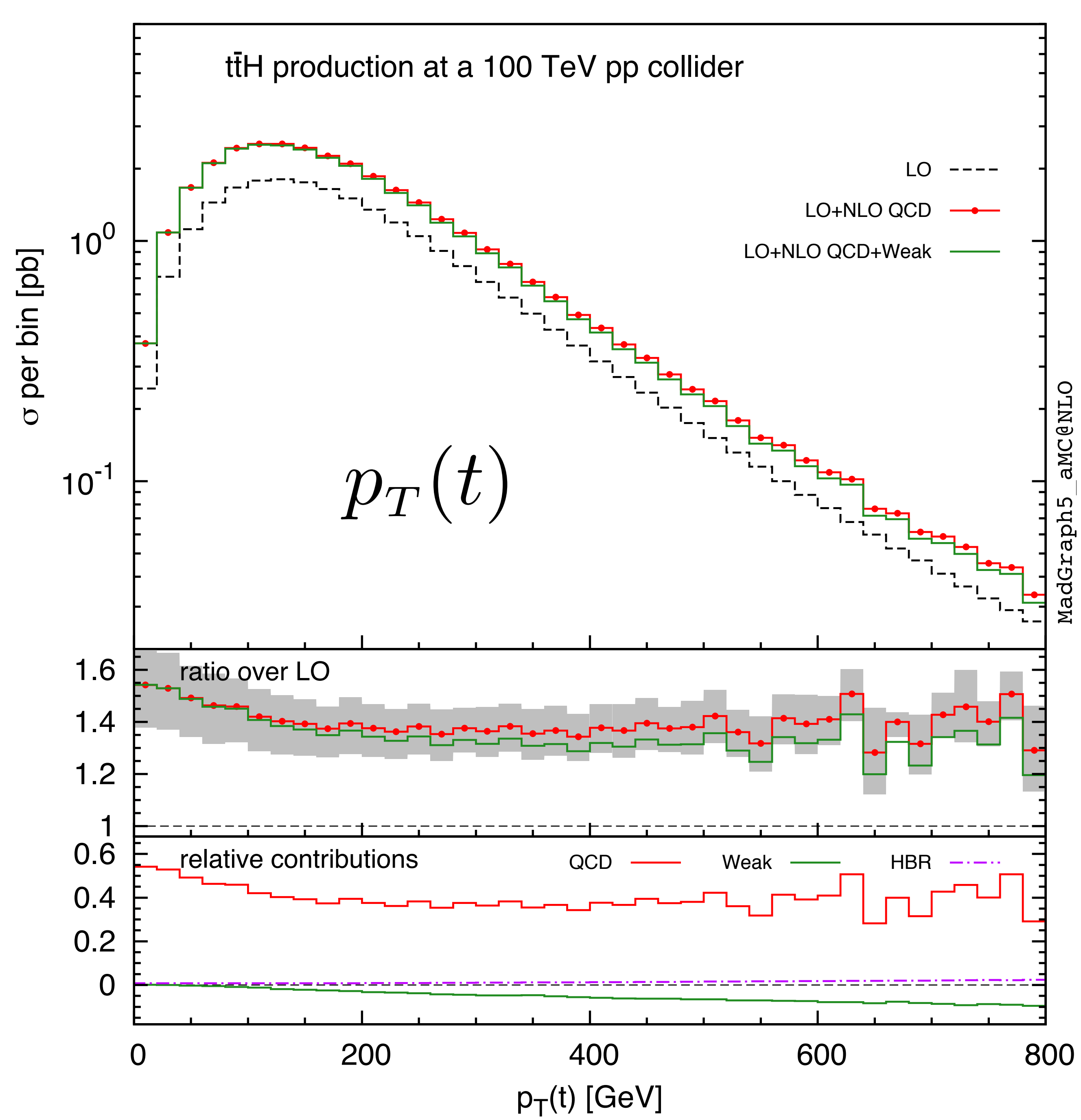
- Weak corrections are quite small, but can become important in boosted kinematics
- HBR compensates Sudakov logs only partially
  - differences in PS and PDFs
  - Final state not a EW singlet

Manohar, Shotwell, Bauer, Turczyk, arXiv:1409.1918

Differential distributions

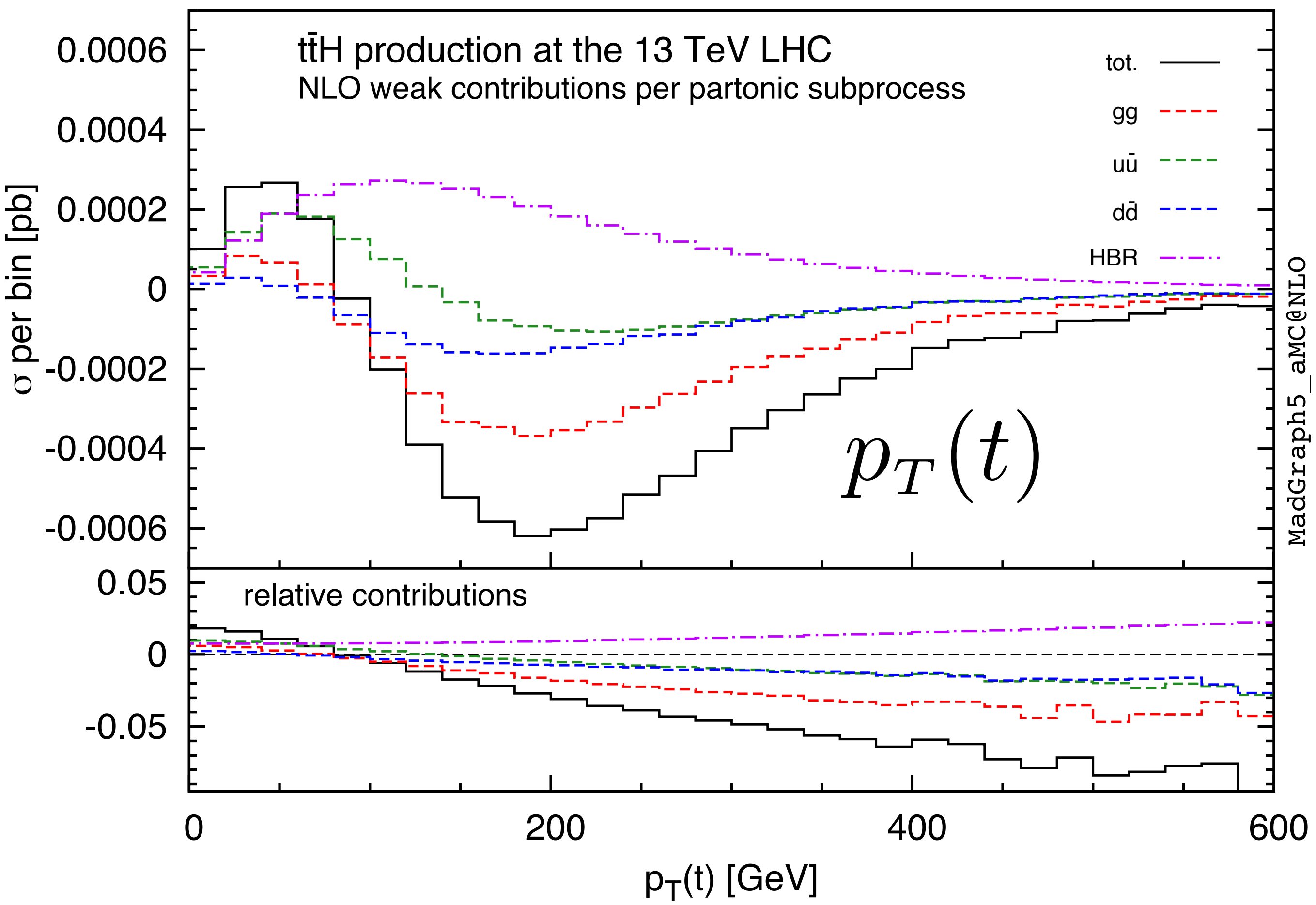


13 TeV

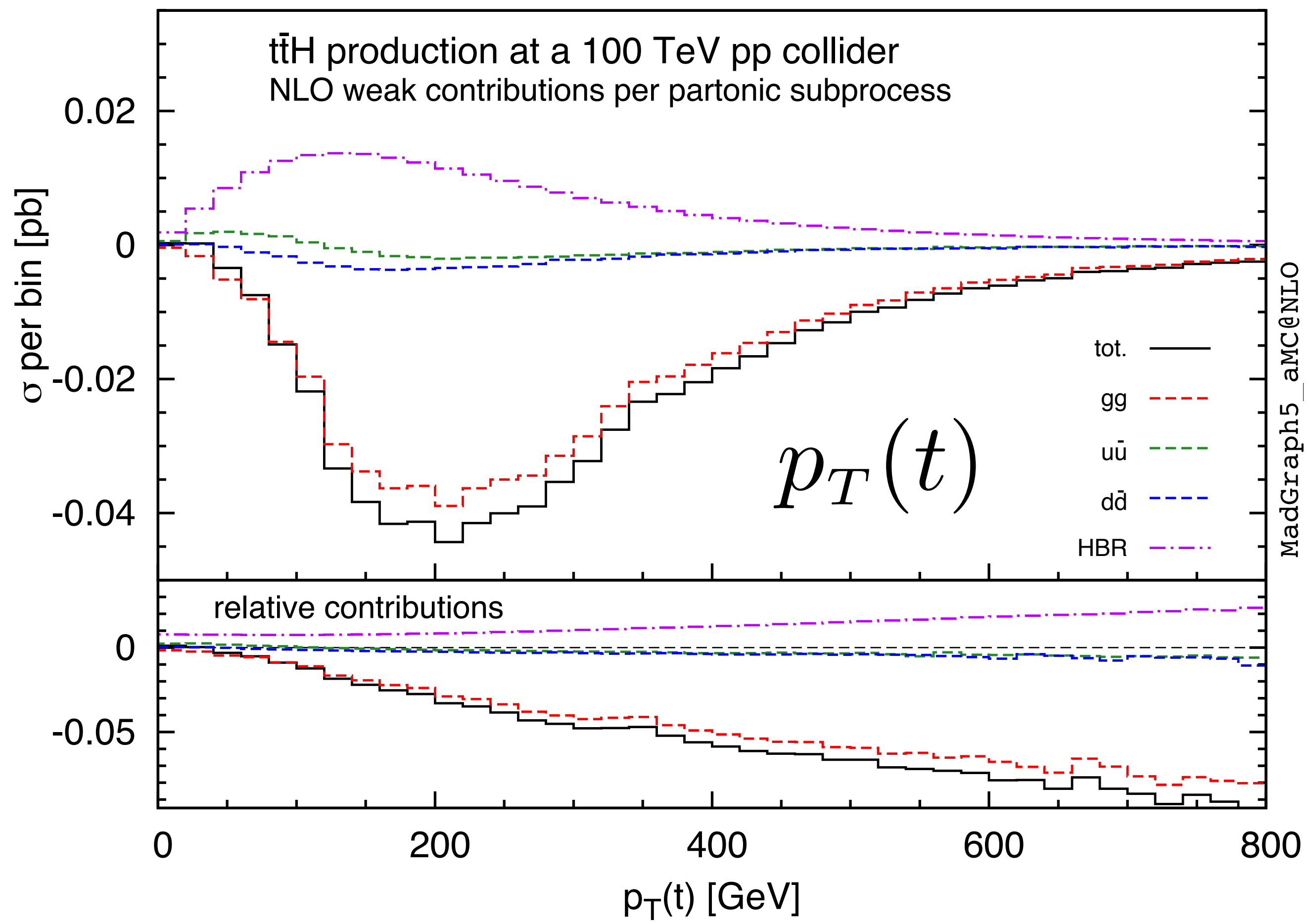


100 TeV

Partonic subprocesses

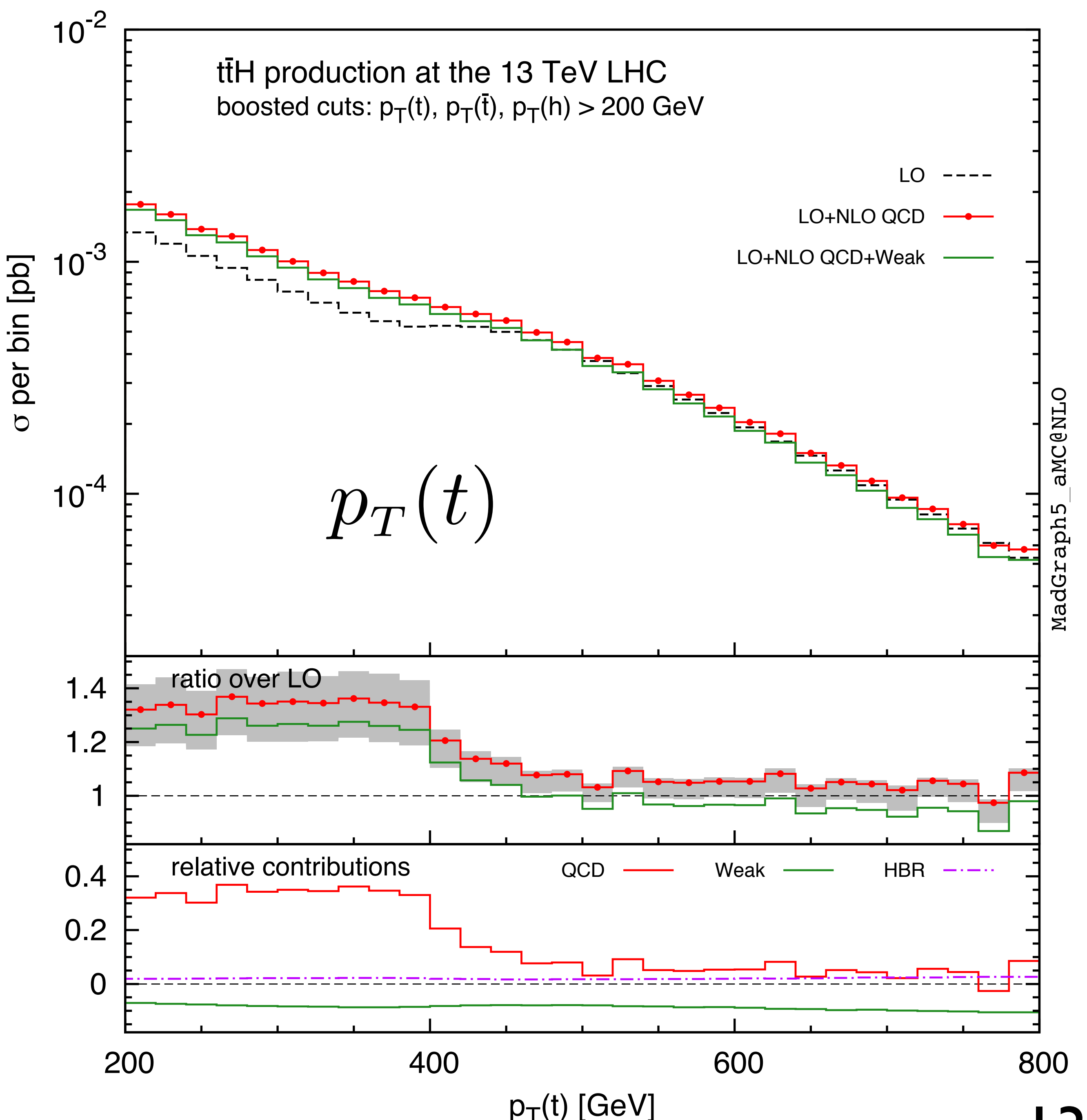


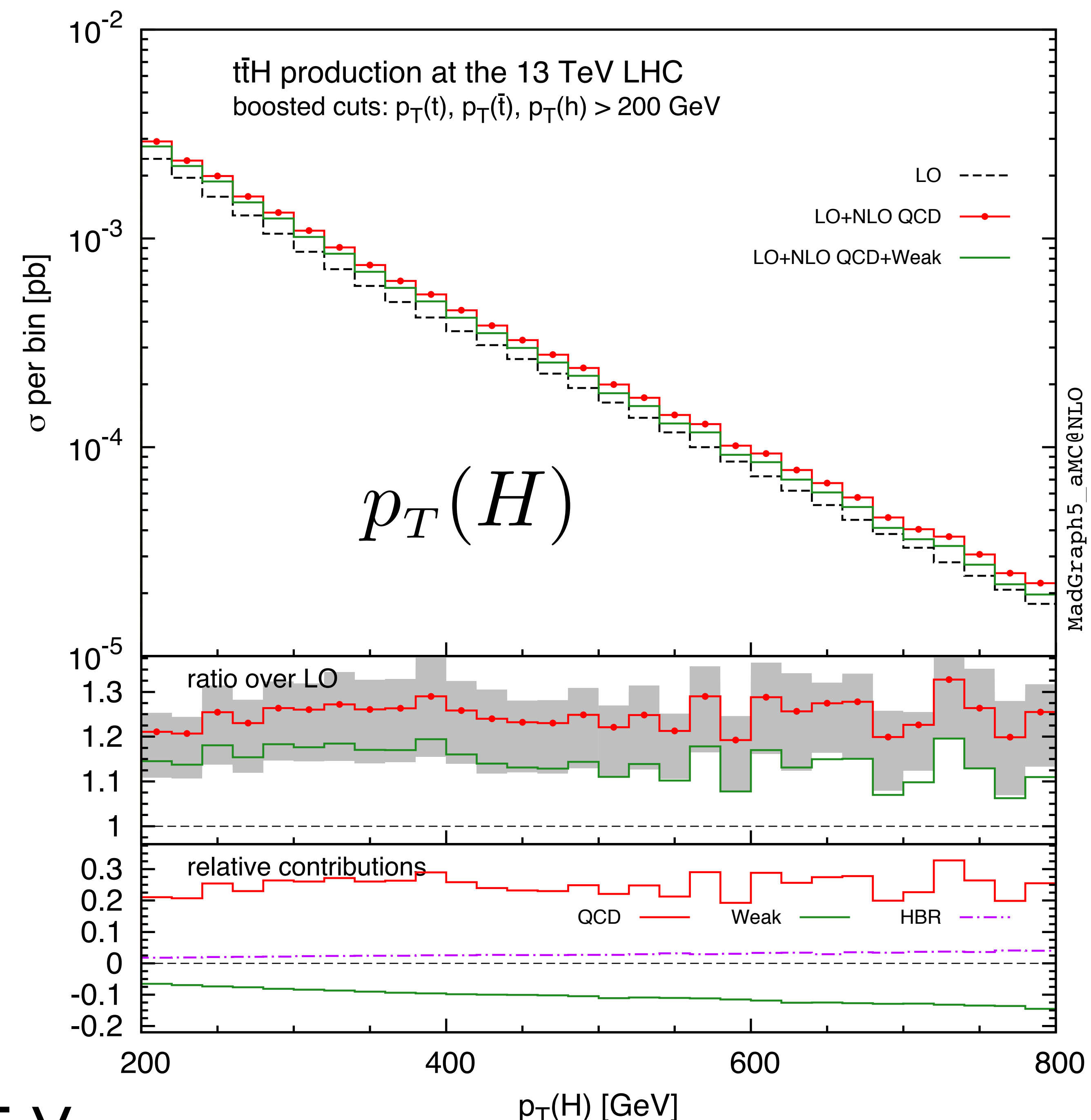
13 TeV



100 TeV

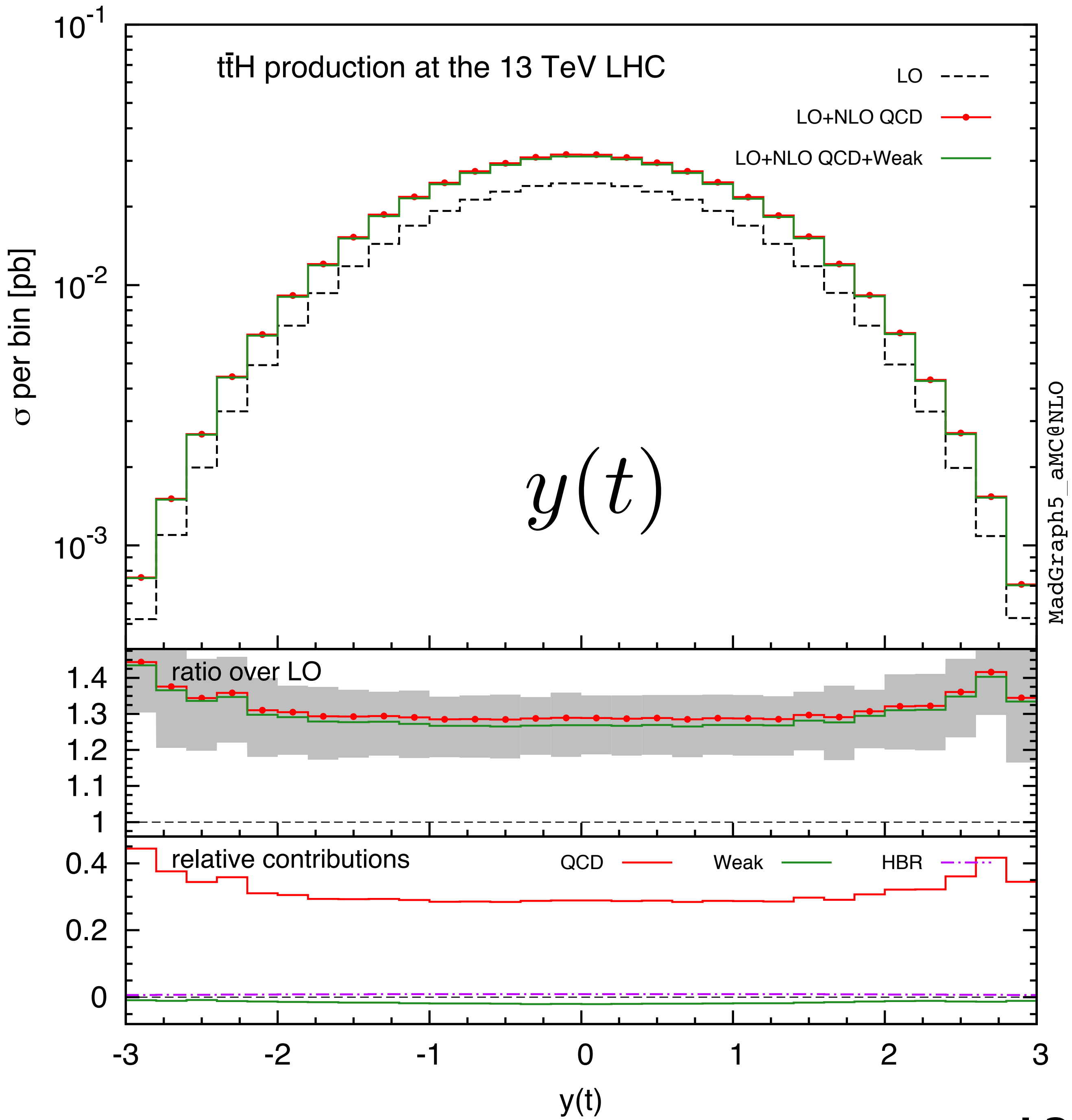
Boosted kinematics

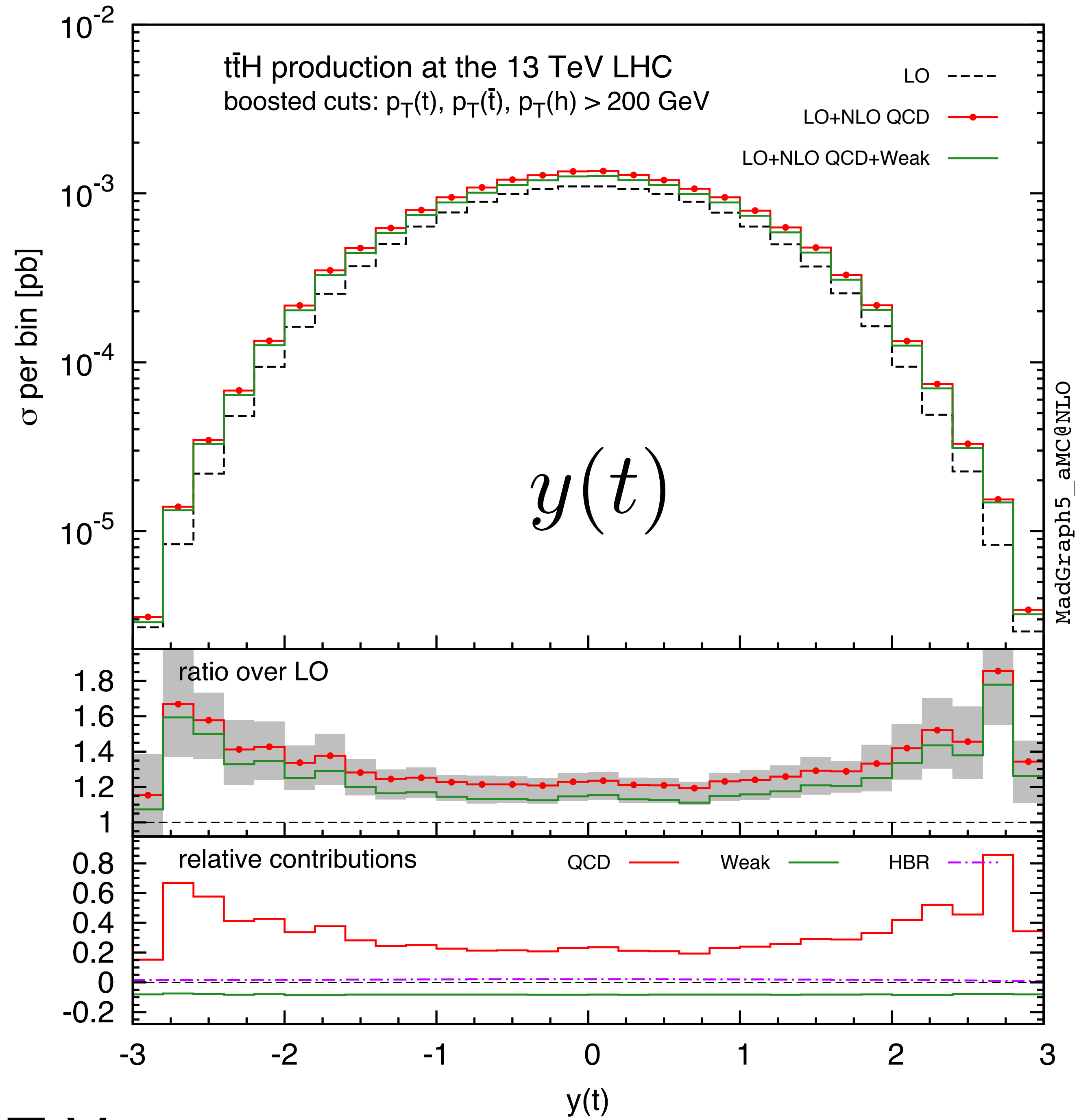




13 TeV

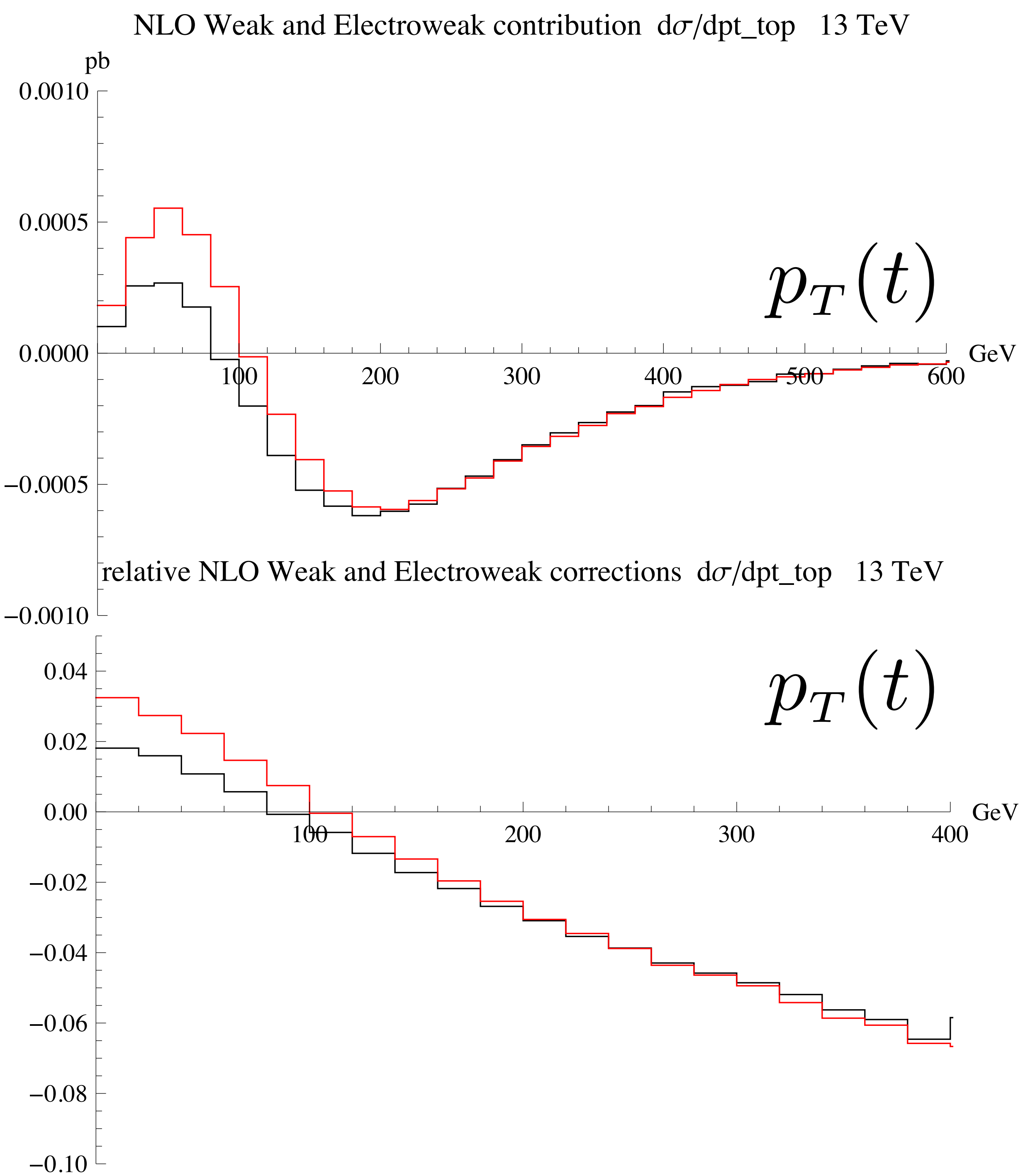
Boosted vs unboosted





13 TeV

Weak vs Electroweak (preliminary)



Weak (-1.8 %)

ElectroWeak (-1.3 %)

Very preliminary results: initial states with photons are missing.

Conclusions

- Automation of EW corrections in MadGraph5_aMC@NLO in progress
- First pheno study: weak corrections to ttH
- Weak corrections can be sizeable, in particular in boosted regions (important for searches)
- HBR effects studied, partial compensation of Sudakov logs
- Computation of EW corrections quite advanced
- More to come…