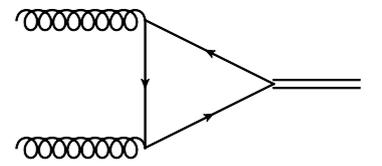


GGF

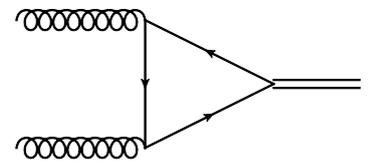
BERNHARD MISTLBERGER

SLAC



CURRENT SUB-WORKING GROUP CONVENERS

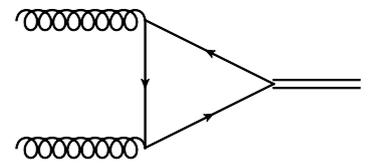
- ▶ Kathrin Becker (ATLAS) kathrin.becker@cern.ch
- ▶ Andrea Massironi (CERN, CMS) andrea.massironi@cern.ch
- ▶ Bernhard Mistlberger (SLAC) bernhard.mistlberger@cern.ch
- ▶ (Pier Monni (CERN, TH) pier.monni@cern.ch)
- ▶ (Emanuele Re (Annecy) emanuele.re@lapth.cnrs.fr)



RECENT DEVELOPMENTS IN THE GGF SUB-GROUP

- ▶ Note on large p_T Higgs boson cross sections
- ▶ Inclusive cross sections for heavy Higgs bosons
- ▶ Heavy flavour effects in PS
- ▶ Uncertainties in STXS

See talk tomorrow by Jonathon Mark Langford and Syed Haider Abidi



NOTE ON LARGE PT HIGGS BOSON CROSS SECTIONS

CERN-TH-2020-074

Precise predictions for boosted Higgs production

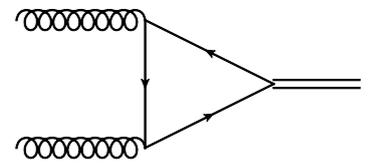
Conveners of the gluon-fusion Working Group:

K. Becker,^a F. Caola,^b A. Massironi,^c B. Mistlberger,^d P. F. Monni.^e

In collaboration with:

**X. Chen,^f S. Frixione,^g T. Gehrmann,^j N. Glover,^h K. Hamilton,ⁱ A. Huss,^{e,h} S. P. Jones,^e
A. Karlberg,^b M. Kerner,^f K. Kudashkin,^j J. M. Lindert,^k G. Luisoni,^l M. L. Mangano,^e S.
Pozzorini,^f E. Re,^m G. P. Salam,^{1b,n} E. Vryonidou,^e C. Wever.^o**

<https://arxiv.org/pdf/2005.07762.pdf>

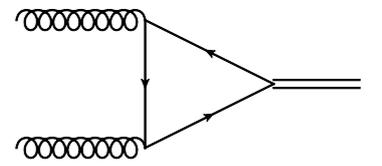


NOTE ON LARGE PT HIGGS BOSON CROSS SECTIONS

- ▶ Predictions for Higgs boson transverse momentum distribution with $p_t > 400$ GeV
- ▶ Comparison of currently best fixed order predictions and MC generators

p_{\perp}^{cut}	NNLO ^{approximate} _{quad.unc.} [fb]	HJ-MINLO [fb]	MG5_MC@NLO [fb]
400 GeV	$33.3^{+10.9\%}_{-12.9\%}$	$29^{+24\%}_{-21\%}$	$31.5^{+31\%}_{-25\%}$
430 GeV	$23.0^{+10.8\%}_{-12.8\%}$	-	$21.8^{+31\%}_{-25\%}$
450 GeV	$18.1^{+10.8\%}_{-12.8\%}$	$16.1^{+22\%}_{-21\%}$	$17.1^{+31\%}_{-25\%}$

<https://arxiv.org/pdf/2005.07762.pdf>



PRODUCING HEAVY SCALAR BOSONS

- ▶ Production Cross Sections similar to Standard Model Higgs

$$m_H \neq m_S$$

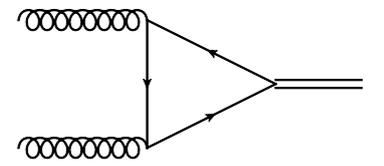
- ▶ Use Standard Model Higgs computations to predict cross section.
Current HXWG Twiki:

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageBSMAt13TeV>

- ▶ Extend range to $m_H=5$ TeV.
- ▶ More comprehensive explanation.

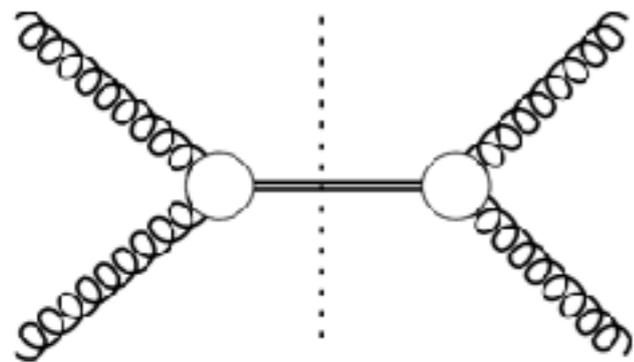
Tools:

- ihixs2 [28]: <https://github.com/dulatf/ihixs>.
- SusHi Bento [3, 29]: <https://sushi.hepforge.org>.
- ggHiggs [30–35]: <https://www.ge.infn.it/~bonvini/higgs/>.
- HNNLO [36]: <http://theory.fi.infn.it/grazzini/codes.html>.

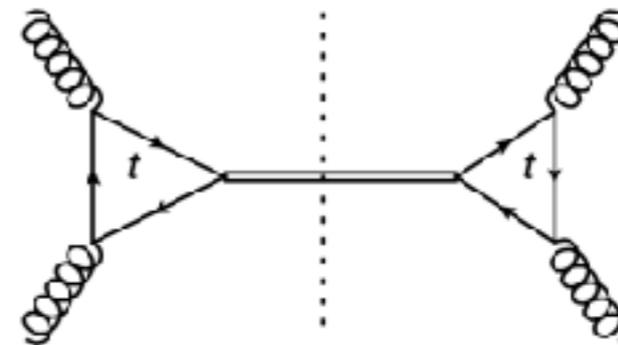


PRODUCING HEAVY SCALAR BOSONS

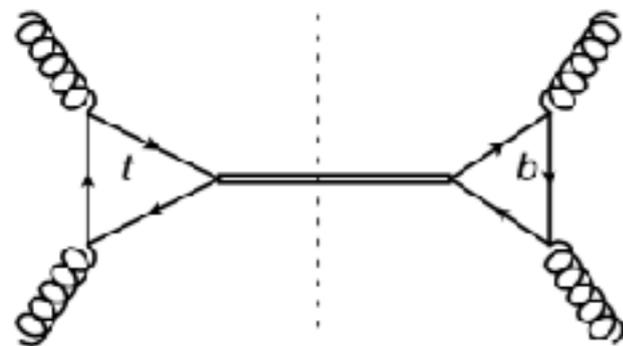
- ▶ Production Cross Sections similar to Standard Model Higgs



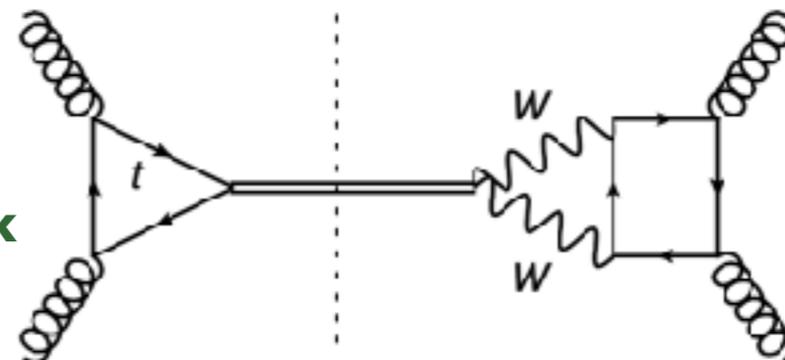
Dim-5 EFT to gluons



Yukawa to top quark

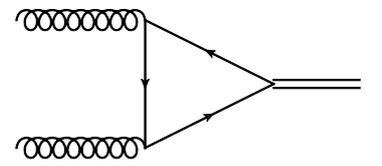


Yukawa to top/bottom quark



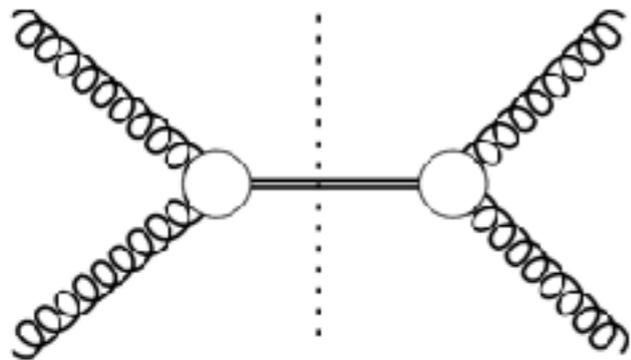
Yukawa to top + EWK boson

$$\sigma_S = \left| \frac{C_S}{C_H} \right|^2 \sigma_{EFF} + y_t^2 K_{31}^{EFF} \sigma_{tt} + y_t y_b \sigma_{tb} + y_t y_c \sigma_{tc} + y_t \lambda_{EWK} K_{30}^{EFF} \sigma_{EWK}.$$



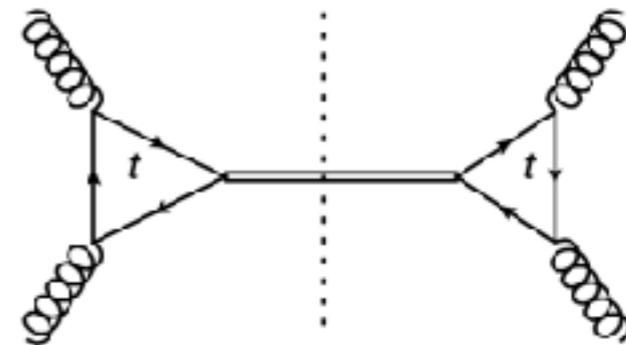
PRODUCING HEAVY SCALAR BOSONS

- ▶ Production Cross Sections similar to Standard Model Higgs



Dim-5 EFT to gluons

Known at **N3LO** in QCD

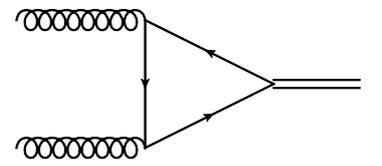


**Yukawa
to top quark**

Known at **NLO** in QCD

- ▶ Heavy top quark EFT works in the limit of infinite top quark mass.

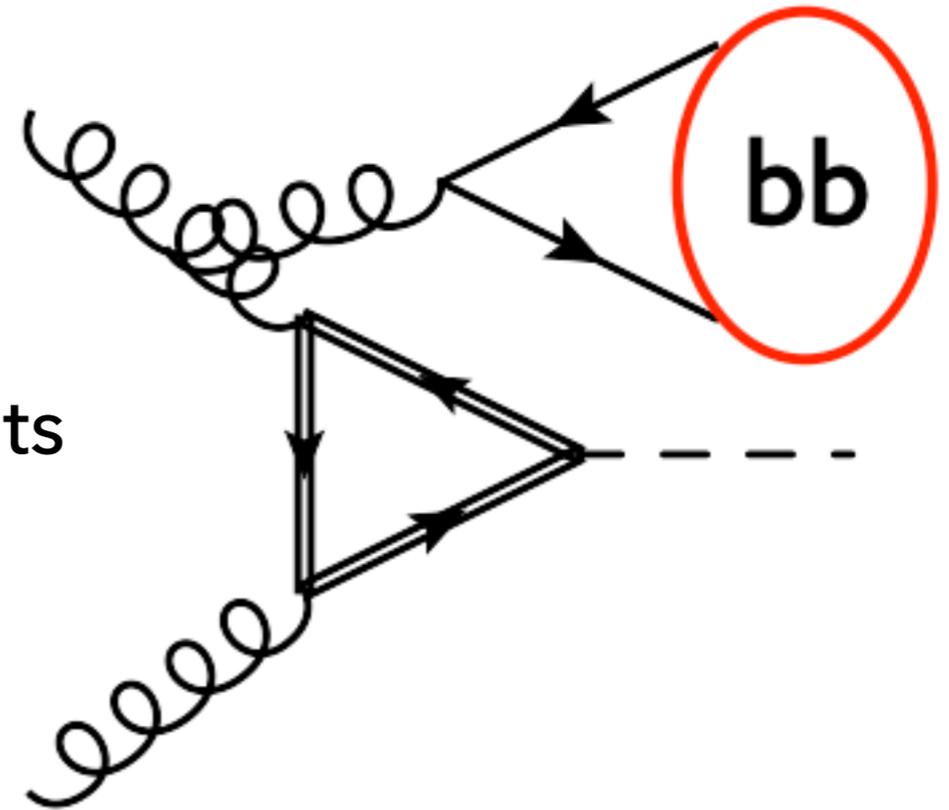
- ▶ Effectively an expansion in $\frac{m_H^2}{4m_t^2}$

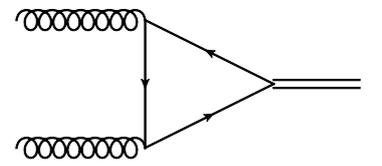


H+HEAVY FLAVOUR

$$gg \rightarrow H + \bar{b}b$$

- ▶ Producing Higgs Boson along side b-jets
- ▶ Background for HH production
- ▶ Background for ttH production
- ▶ Treat quarks massless? (4 vs 5 flavour scheme)
- ▶ PS uncertainties?
- ▶ What is the best prediction for Run II?
- ▶ How do we go beyond YR4?



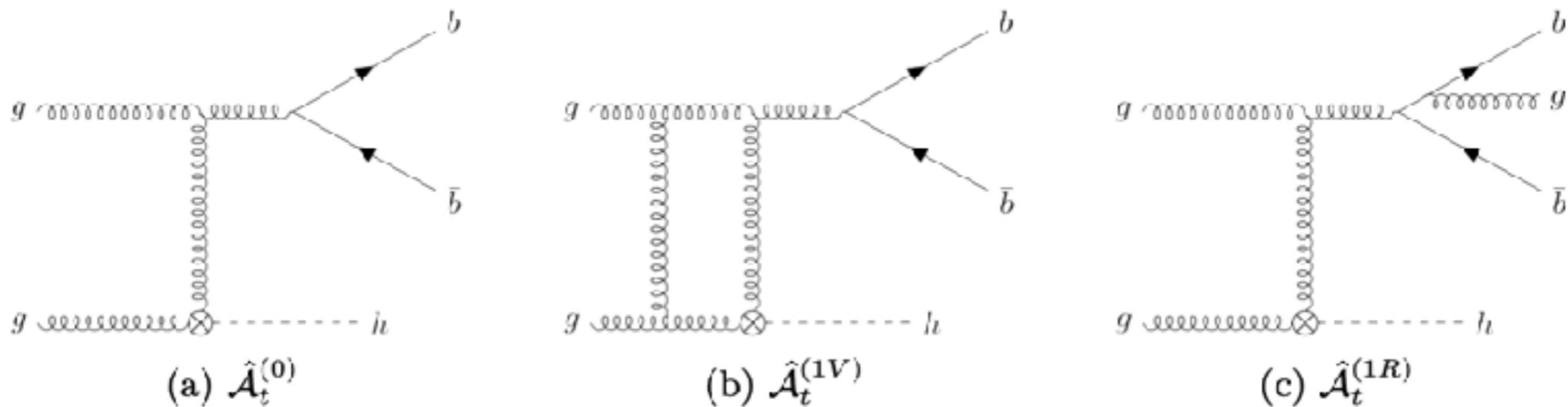


H+HEAVY FLAVOUR

$$gg \rightarrow H + \bar{b}b$$

- ▶ NLO gluon fusion contributions:

[[Deutschmann, Maltoni, Wiesemann, Zaro:1808.01660](#)]



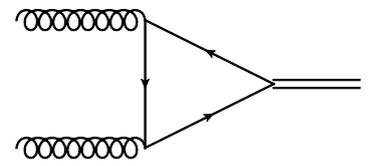
$$\sigma = Y_t^2 \sigma_{tt} + Y_b Y_t \sigma_{tb} + Y_b^2 \sigma_{bb}$$

- ▶ PS for bbH: a lot already exists (see also YR4)

- ▶ Sherpa: [1612.04640](#)

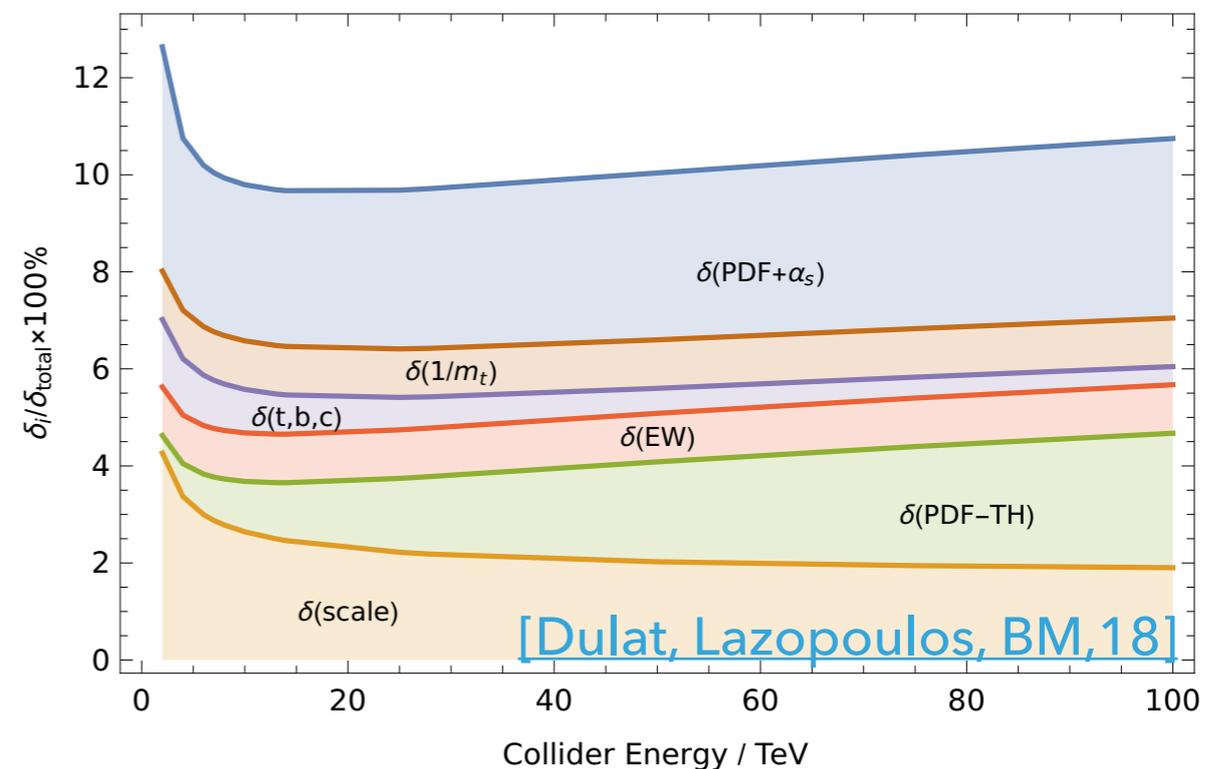
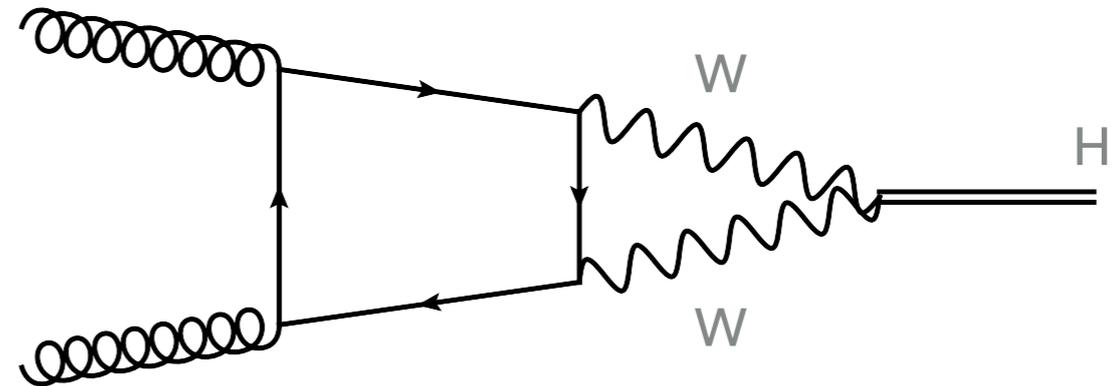
- ▶ Powheg: [1509.05843](#)

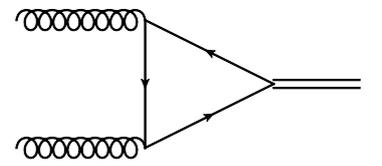
- ▶ MG5: [1409.5301](#)



MIXED QCD ELECTROWEAK CORRECTIONS

- ▶ LO EWK corrections: **2-Loops**
- ▶ Missing NLO-QCD corrections cause 1 % uncertainty on total XS.
- ▶ What is the impact of missing QCD/EWK corrections on differential distributions?
 - ▶ Y ?
 - ▶ PT ?





MIXED QCD ELECTROWEAK CORRECTIONS

- ▶ (Dominant) Light-Quark contributions computed:

[[Becchetti,Bonciani.DelDuca,Hirschi,Moriello,Schweitzer, 2010.09451](#)]

- ▶ Contribution to inclusive cross section:

$$\sigma_{pp \rightarrow H+X}^{(\text{EW,best})} = 2.11 \pm 0.28 \text{ (theory) pb.}$$

- ▶ Reduction of residual uncertainty:

$$\delta(\text{EWK}) \quad 1\% \quad \longrightarrow \quad 0.57\%$$

- ▶ **Very** compatible with previous estimates!

$$\sigma_{\text{EWK}} / \sigma_{\text{NLO-HEFT}}$$

Soft Approx for mixed QCD/EWK:

$$M_W \rightarrow 0$$

$$M_W \rightarrow \infty$$

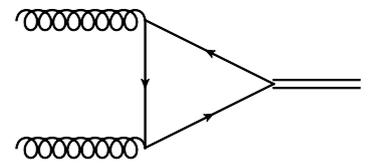
Exact:

5.4% [[Bonetti,Melnikov,Tancredi:1801.10403](#)]

5.4% [[Anastasiou,DelDuca,Furlan,BM,Moriello,Schweitzer,Specchia:1811.11211](#)]

5.2% [[Anastasiou,Boughezal,Petriello: 0811.3458](#)]

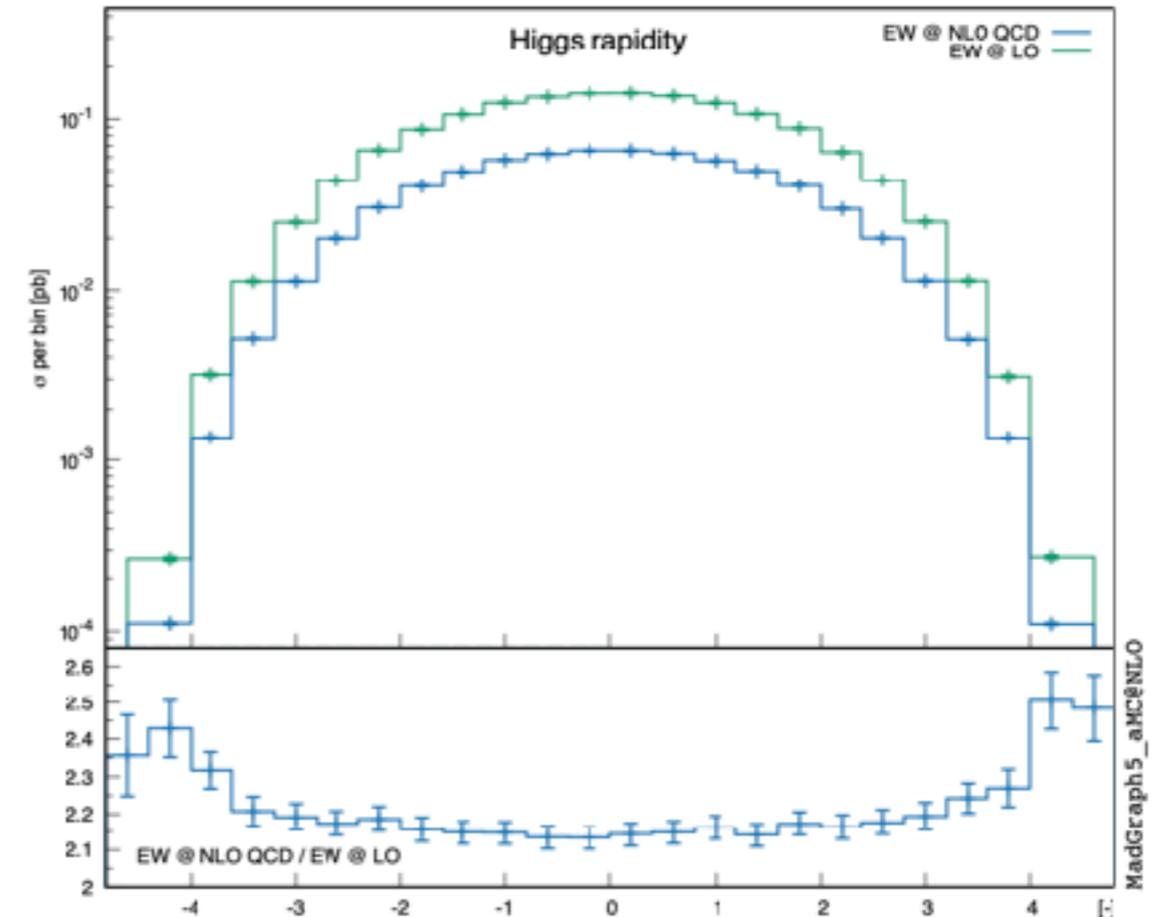
5.1%



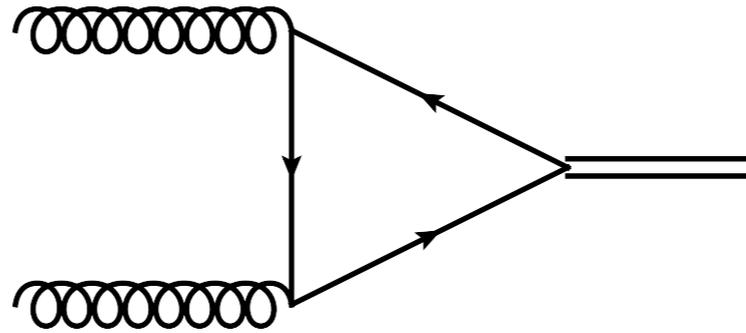
MIXED QCD ELECTROWEAK CORRECTIONS

- ▶ Flat differential K-factor for Rapidity Distribution

[Becchetti,Bonciani,DeDuca,Hirschi,Moriello,Schweitzer, 2010.09451]



- ▶ Currently:
Mixed QCD/EWK amplitudes are interfered with QCD amplitudes in heavy top limit.
- ▶ What happens with full top quark mass QCD amplitudes?
- ▶ Are there sizeable corrections to the transverse momentum distribution, particularly at large top quark mass?



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- ▶ (Emanuele Re (Annecy) emanuele.re@lapth.cnrs.fr)