HIGGS AT LARGE PT – UPDATED PREDICTIONS
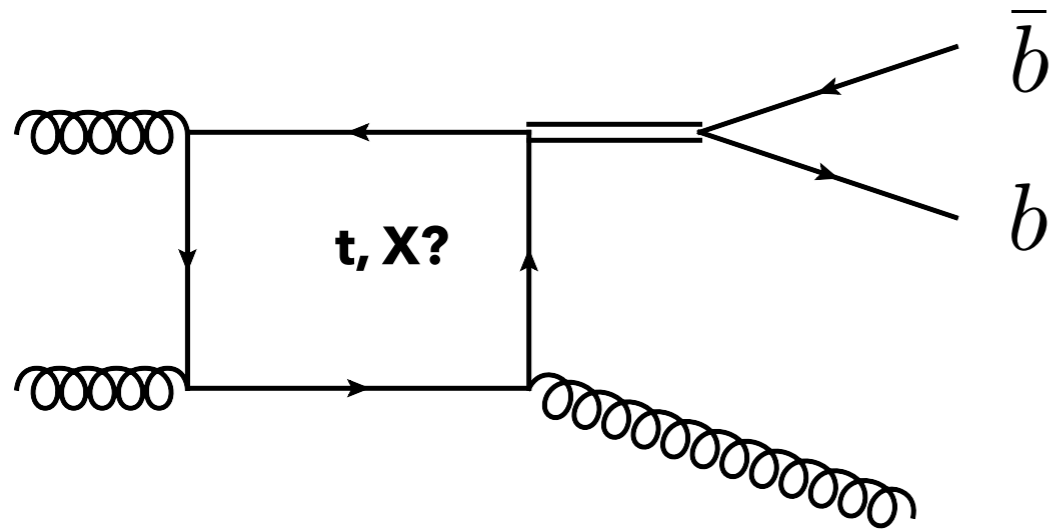
BERNHARD MISTLBERGER

WITH: ALEXANDER KARLBERG, STEPHEN JONES, HAIDER ABIDI AND JONATHON LANGFORD

SLAC

$\bar{b}$

b
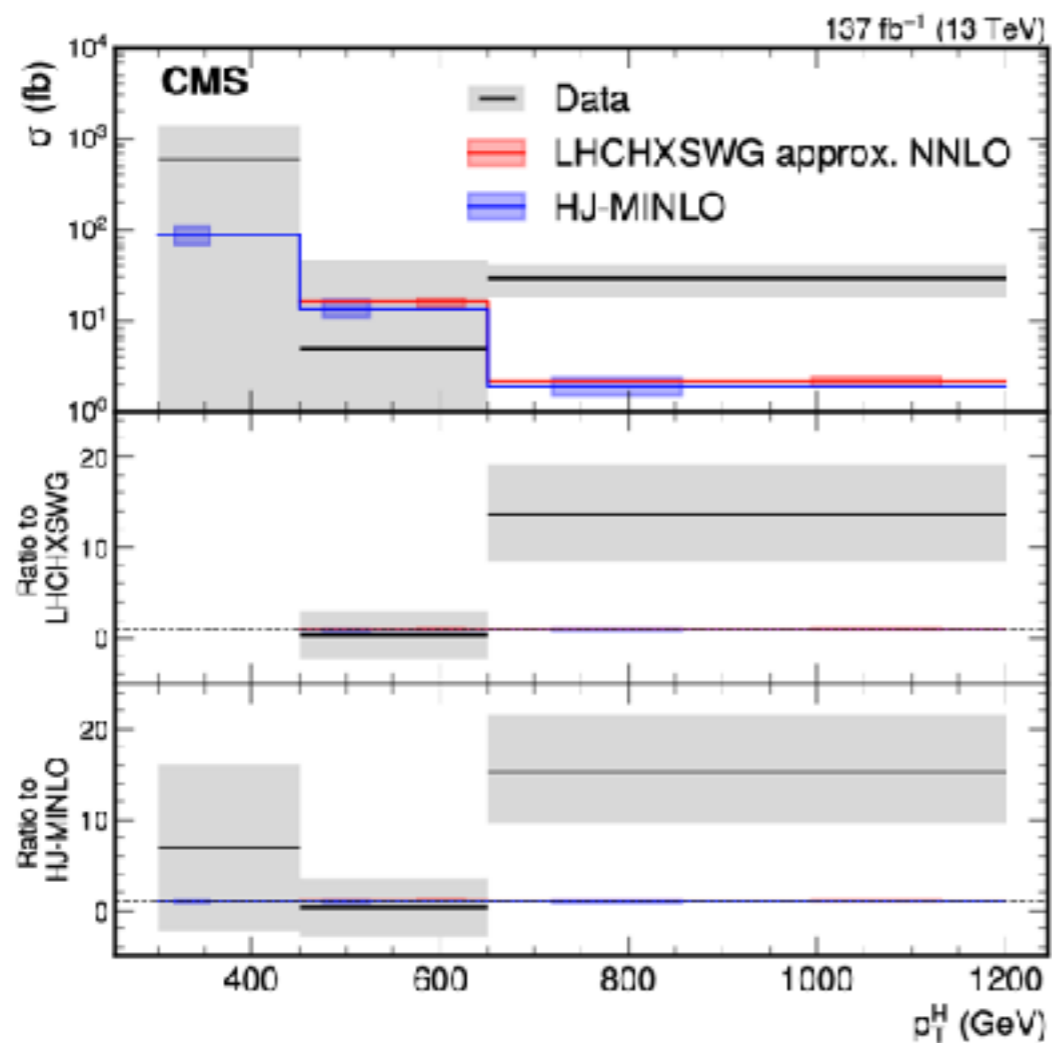
t, X?

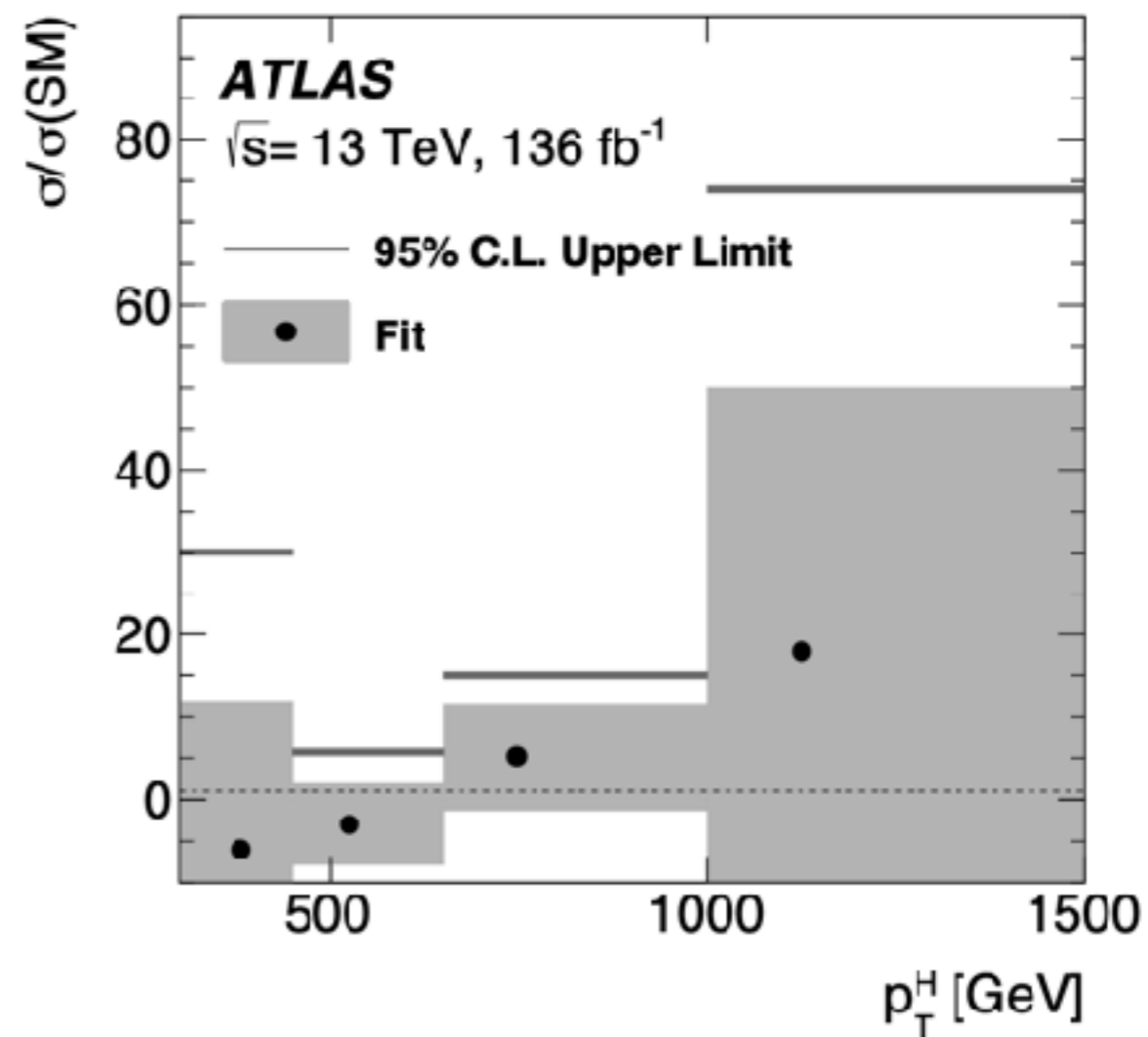▸ Look at very boosted Higgs bosons recoiling against a jet.

$$p_T > 450 GeV$$

▸ Decay to $b\bar{b}$

▸ Sensitive to internal structure of the top quark loop!

▸ Excellent knowledge of pT - spectrum important!

▸ Complicated to derive precise predictions: LO box with massive top quark.

ATLAS AND CMS PRESENTED RECENT ANALYSIS

1709.05543
2006.13251

1906.11005
2111.08340

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,[f] 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,[1][b,n] E. Vryonidou,[e] C. Wever.[o]
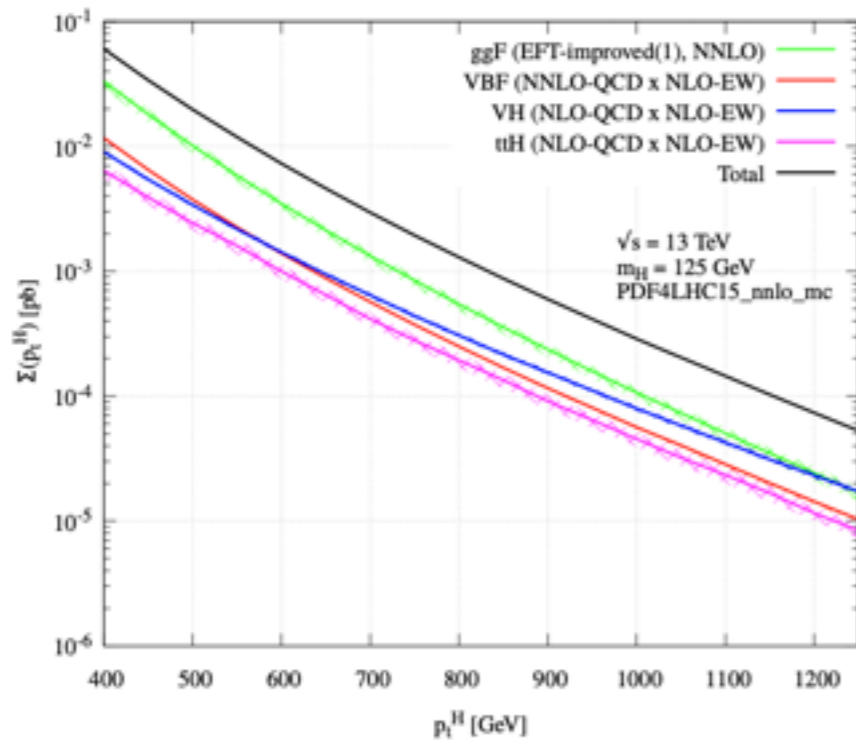
https://arxiv.org/pdf/2005.07762.pdf

TODAY: ▸ Further Extensions

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

STATUS:

▸ QCD predictions for four production mechanism. ggF only ~50%.

$p_\perp^{cut}[GeV]$	$\Sigma_{ggF}^{NNLO\ approximate}_{quad.unc.}(p_\perp^{cut})$ [fb]	$\Sigma_{VBF}^{NNLO}(p_\perp^{cut})$ [fb]	$\Sigma_{VH}^{NLO}(p_-^{cut})$ [fb]	$\Sigma_{ttH}^{NLO}(p_\perp^{cut})$ [fb]
400	$33.30^{10.89\%}_{-12.91\%}$	$14.23^{+0.15\%}_{-0.19\%}$	$11.16^{+4.12\%}_{-3.68\%}$	$6.89^{+12.62\%}_{-12.97\%}$
450	$18.08^{10.78\%}_{-12.79\%}$	$8.06^{+0.24\%}_{-0.23\%}$	$6.87^{+4.6\%}_{-3.49\%}$	$4.24^{+12.84\%}_{-13.15\%}$
500	$10.17^{10.67\%}_{-12.74\%}$	$4.75^{+0.33\%}_{-0.29\%}$	$4.39^{+4.43\%}_{-4.04\%}$	$2.66^{+12.85\%}_{-13.22\%}$
550	$5.87^{10.54\%}_{-12.60\%}$	$2.90^{+0.34\%}_{-0.36\%}$	$2.87^{+4.44\%}_{-3.74\%}$	$1.76^{+14.23\%}_{-13.93\%}$
600	$3.48^{10.35\%}_{-12.49\%}$	$1.82^{+0.41\%}_{-0.39\%}$	$1.91^{+5.22\%}_{-4.71\%}$	$1.11^{+12.99\%}_{-13.4\%}$
650	$2.13^{10.23\%}_{-12.45\%}$	$1.17^{+0.49\%}_{-0.39\%}$	$1.30^{+4.67\%}_{-4.28\%}$	$0.72^{+12.6\%}_{-13.26\%}$
700	$1.32^{10.03\%}_{-12.32\%}$	$0.77^{+0.57\%}_{-0.45\%}$	$0.90^{+4.15\%}_{-5.4\%}$	$0.47^{+11.42\%}_{-12.74\%}$
750	$0.84^{10.05\%}_{-12.31\%}$	$0.51^{+0.69\%}_{-0.56\%}$	$0.62^{+5.15\%}_{-4.66\%}$	$0.32^{+11.53\%}_{-12.84\%}$
800	$0.54^{9.91\%}_{-12.24\%}$	$0.35^{+0.71\%}_{-0.6\%}$	$0.44^{+5.64\%}_{-4.13\%}$	$0.22^{+11.42\%}_{-13.3\%}$

▸ ggF uncertainties at 10% at NNLO

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

GLUON FUSION QCD CORRECTIONS:
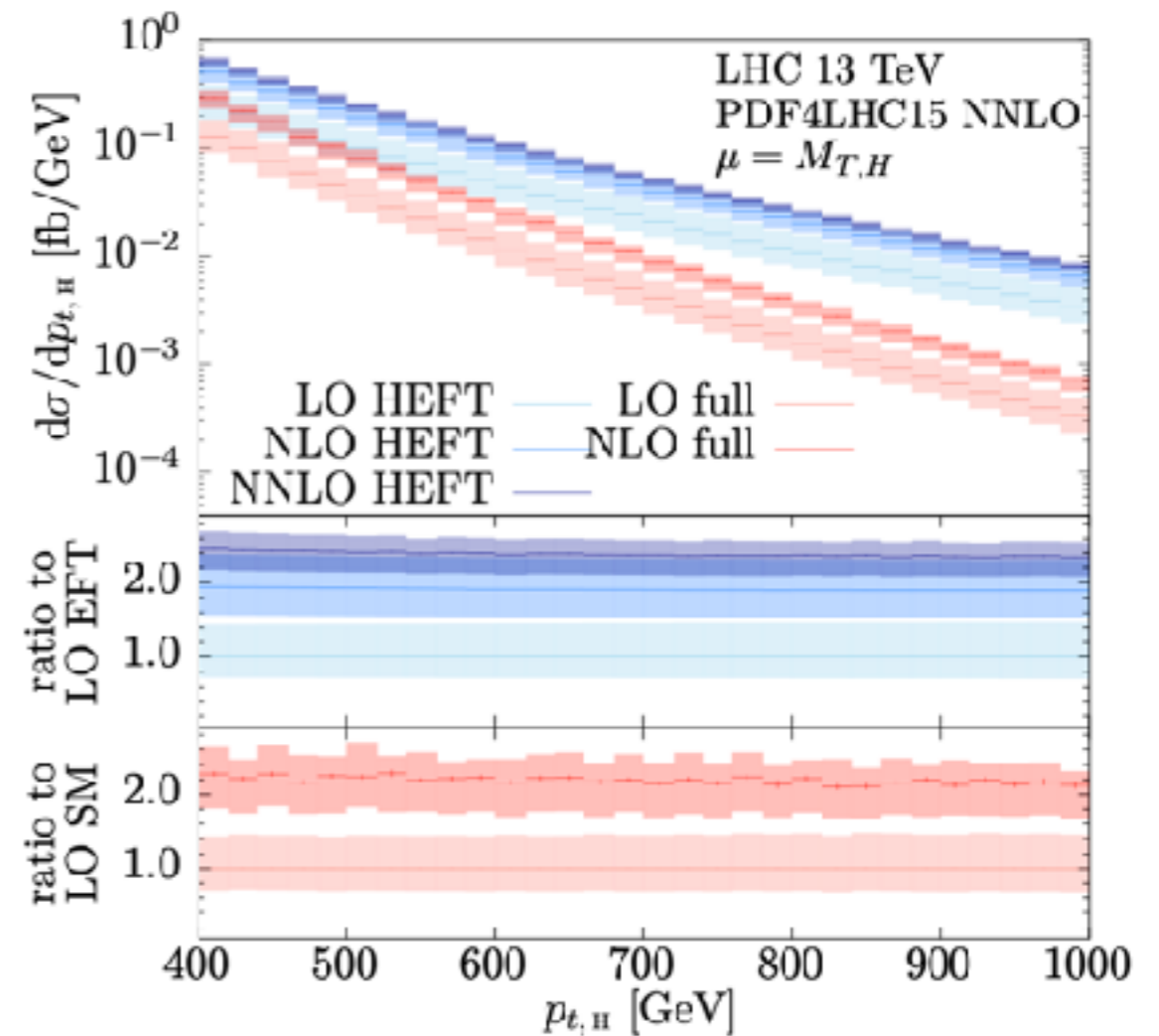
▸ EFT and full QCD (finite top quark mass) deviate substantially starting from pt ~ 200 GeV

▸ Corrections at NLO for pt:
Theoretically
very challenging
due to finite quark masses.

https://arxiv.org/pdf/1802.00349.pdf

https://arxiv.org/pdf/1801.08226.pdf

▸ Rescaled NNLO-EFT:

$$\Sigma^{\text{EFT-improved (1), NNLO}}(p_\perp^{\text{cut}}) \equiv \frac{\Sigma^{\text{SM, NLO}}(p_\perp^{\text{cut}})}{\Sigma^{\text{EFT, NLO}}(p_\perp^{\text{cut}})} \Sigma^{\text{EFT, NNLO}}(p_\perp^{\text{cut}})$$

https://arxiv.org/pdf/1607.08817.pdf

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

STATUS:

$p_\perp^{\mathrm{cut}}$[GeV]	VBF	VH	$t\bar{t}H$
400	−17.80%	−19.05%	−6.95%
450	−19.43%	−20.83%	−7.75%
500	−21.05%	−22.50%	−8.49%
550	−22.34%	−24.07%	−9.11%
600	−23.73%	−25.56%	−9.91%
650	−25.03%	−26.98%	−10.67%
700	−26.29%	−28.30%	−11.37%
750	−27.35%	−29.60%	−11.94%
800	−28.42%	−30.83%	−12.51%

▸ Electroweak corrections for 3 / 4 production mechanisms.

▸ EWK gave sizable corrections!

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

COMPARISON OF PARTON SHOWERS:

$p_\perp^{cut}$	NNLO$_{quad.unc.}^{approximate}$ [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	$18.1^{+10.8\%}_{-12.8\%}$	$16.1^{+22\%}_{-21\%}$	$17.1^{+31\%}_{-25\%}$

- ▸ Good agreement with fixed order for LO accurate PS.

- ▸ Some recommendations on best practice.

FUTURE UPDATED NOTE

RUN 3 IS COMING!

Predictions and measurements for a Higgs boson at large transverse momentum are difficult but very interesting. Due to the particular complexity and not publicly accessible inputs providing explicit information in a combined effort from the theory community is useful.

We would like to propose an extension of the current public note to include several updates useful for the next years of LHC studies.

To make this a reality a concerted effort and support will be necessary.

FUTURE UPDATED NOTE

PROPOSED UPDATES:

ENERGY

▸ New Centre of Mass Energy: 13.6 TeV
Unify input settings and derive predictions for the upcoming run.

RANGE

▸ More Data! 300 fb^-1
Sensitivity to the pT distribution up to 1.2 TeV.

Currently, most of our predictions for cumulative cross sections do not range to 1.25 TeV. We should extend the information provided.

▸ **Jonas Lindert's talk on non-ggF channels**

PDF

▸ New Parton distribution functions are on the horizon:
PDF4LHC21 vs now PDF4LHC15

PROPOSED UPDATES: MASS

▸ Top quark mass scheme uncertainty?

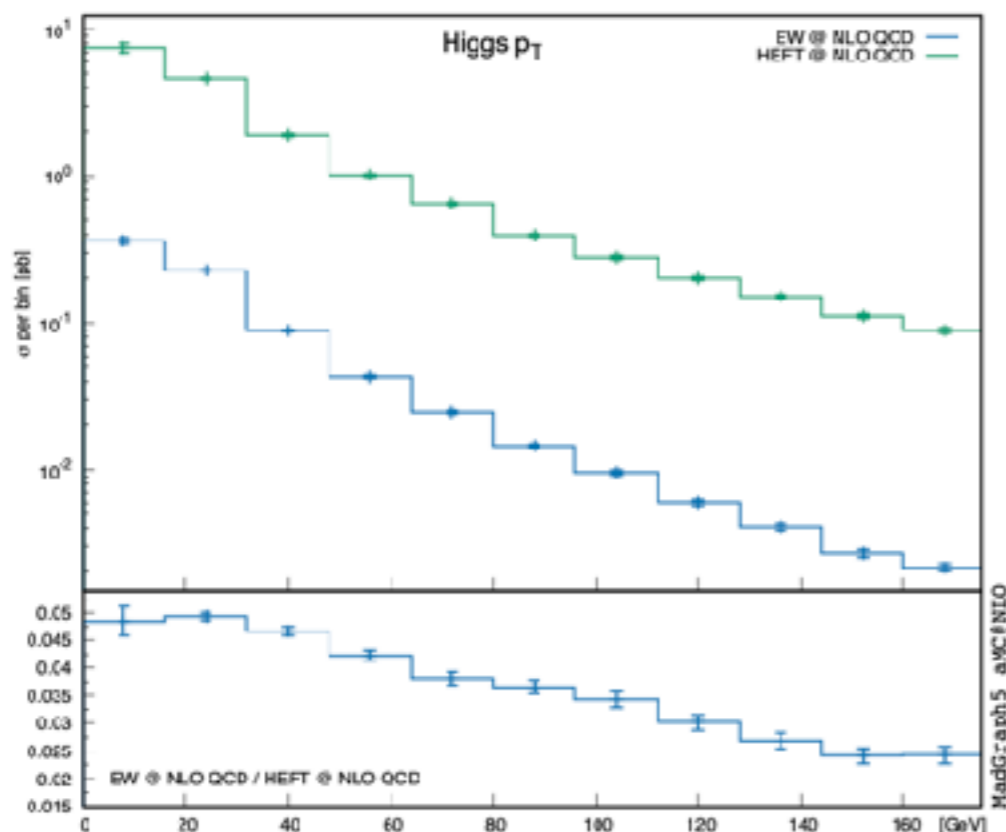$$M_{OS} \qquad \text{vs.} \qquad M_{\overline{\text{MS}}}$$

▸ Currently, no uncertainty is included.
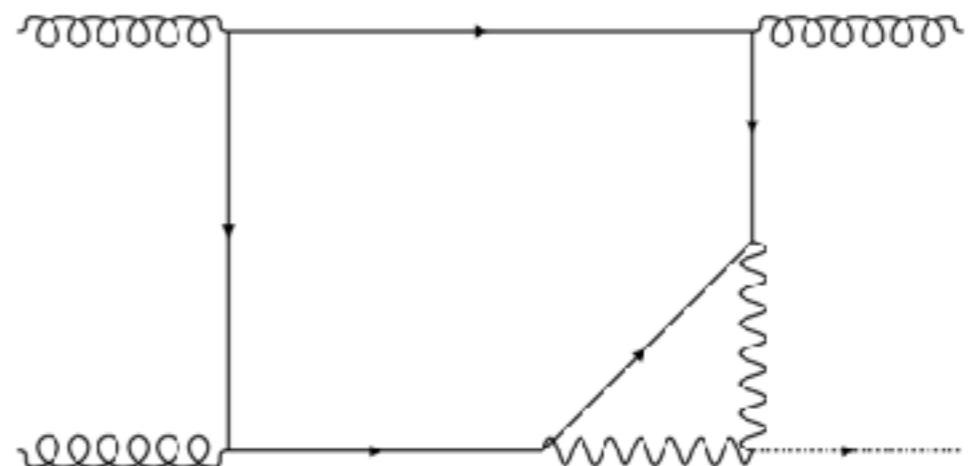
‣ **Stephen Jones' talk on mass uncertainties**

PROPOSED UPDATES: EWK

▸ Electroweak corrections for ggF:
  EWK effects for other channels were large and negative, O(20%).

▸ Leading EWK effects in ggF are very complicated to compute and
  are now available

https://arxiv.org/pdf/2010.09451.pdf

▸ Large PT has not been computed.

▸ Amounts to LO type computation
 with very complicated amplitude.

PROPOSED UPDATES: PARTON SHOWERS

▸ Reliable parton shower predictions for this observable are not easy to generate. Previously, we recommended generators that are NLO accurate in the ggF EFT and contain the top quark mass dependence at LO.

▸ We would propose to include:

    ✳ List of generators that are suitable and **contact people** to help with their usage.

    ✳ Explicit benchmark points for validation purposes.

▸ Interest from exp. to look into two-jet observables.

    ✳ What generator could handle ggF HJJ at NLO at large p_T?

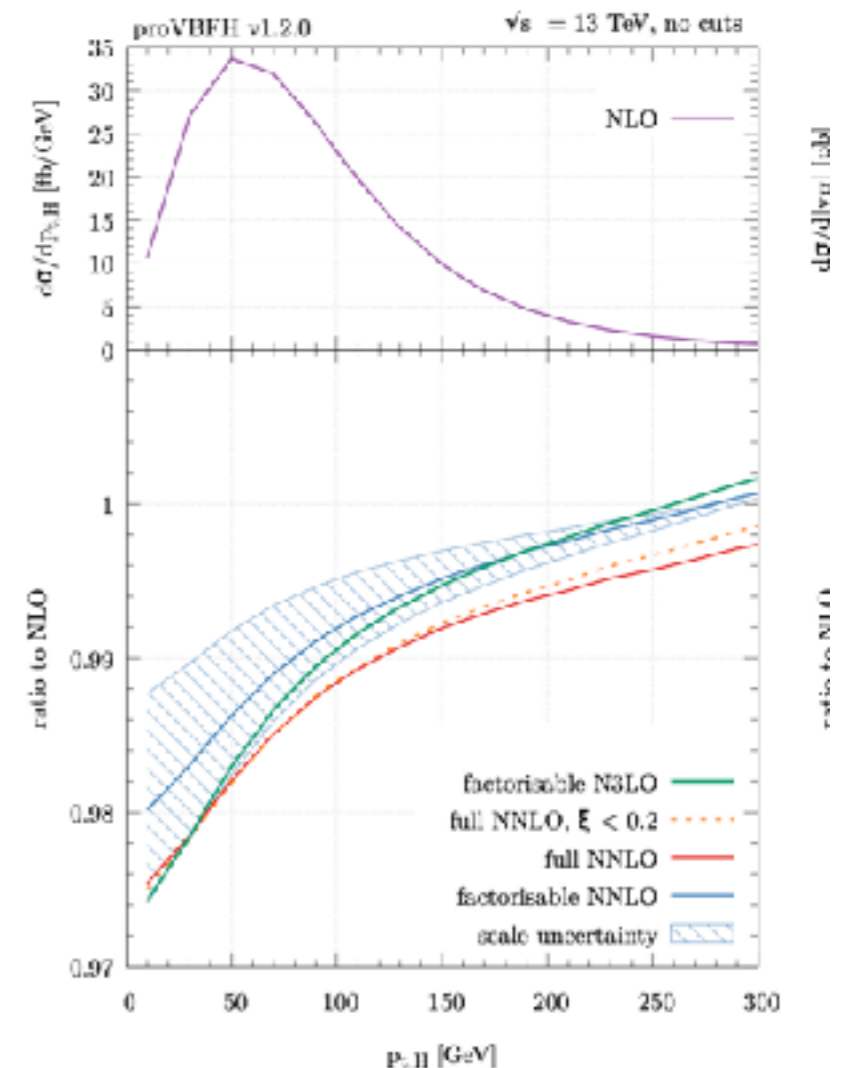   ✳ What recommendation can we give to perform analysis?

PROPOSED UPDATES: NON–FACTORISABLE

▸ VBF predictions delivered in the "fused DIS" approximation.

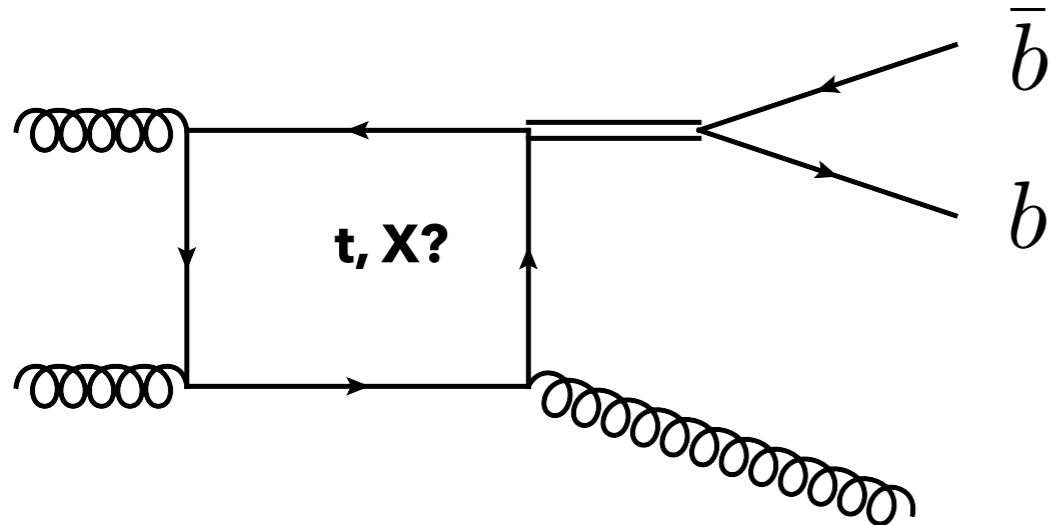▸ Recently, approximation of non-factorizable corrections in VBF

https://arxiv.org/pdf/2005.11334.pdf
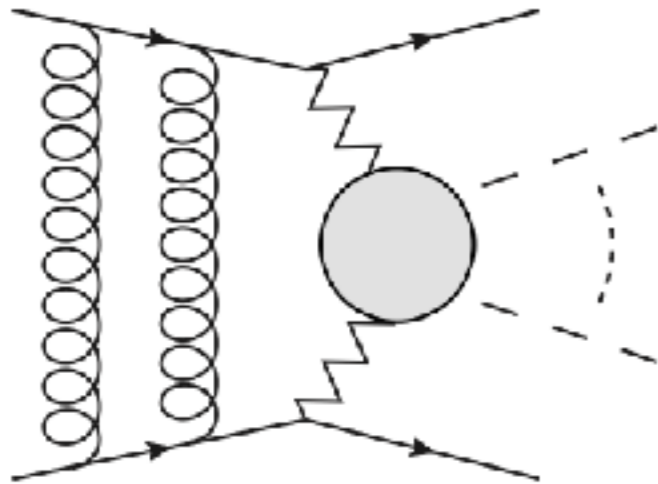
▸ Will this be a problem at large pT?

▸ Discussion?

PROPOSED UPDATES: SUMMARY

Predictions and measurements for a Higgs boson at large transverse momentum are difficult but very interesting. Due to the particular complexity and not publicly accessible inputs providing explicit information in a combined effort from the theory community is useful.

We would like to propose an extension of the current public note to include several updates useful for the next years of LHC studies.

To make this a reality a concerted effort and support will be necessary.

❧ 13.6 TeV

❧ PDF4LHC21

❧ Extend pT range to 1.25 TeV

❧ QCD / Electroweak corrections for ggF

❧ Mass scheme uncertainty for NLO QCD ggF

❧ Parton Showers: HJ and HJJ

❧ Non-factorizable corrections in VBF

❧ ...

▸ Updated note by this summer?