ATLAS EXPERIMENT

LPC Particules pLasmas Univers applicationS
Laboratoire de Physique de Clermont

# Probing the Top-Higgs Quartic interaction

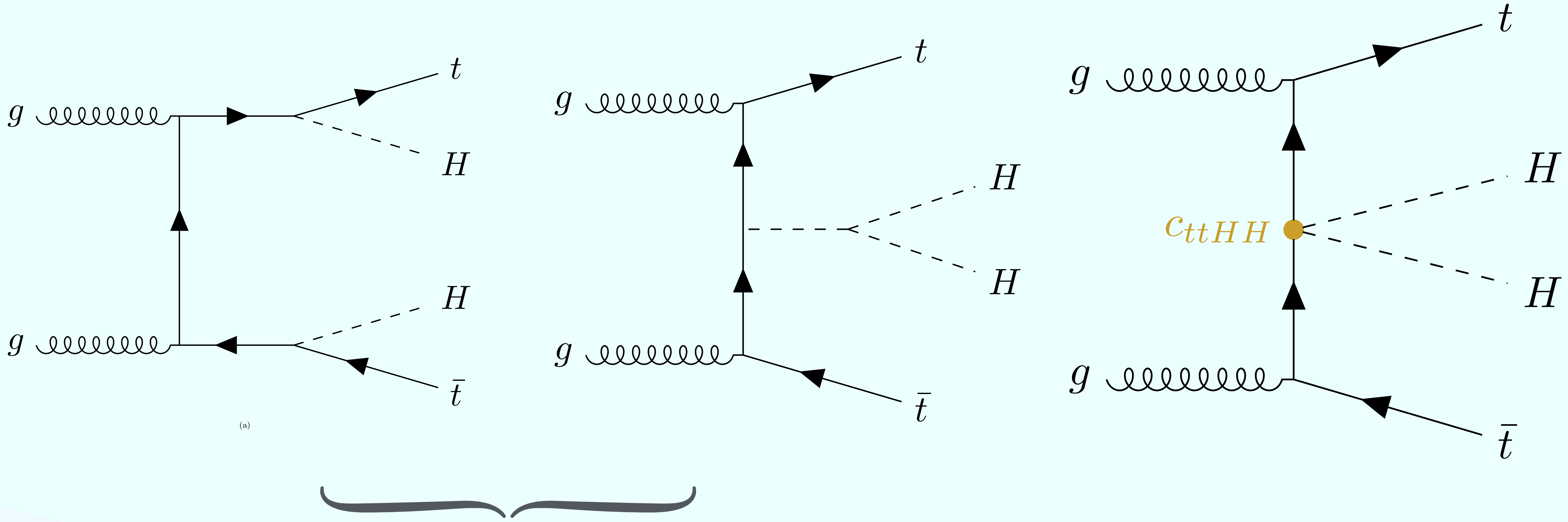
## through an EFT interpretation of ttHH production at ATLAS

arXiv:[2603.13113](2603.13113)

**Adrien Gutierrez-Auriol**, `adrien.auriol@cern.ch`
**26th May, 2026**

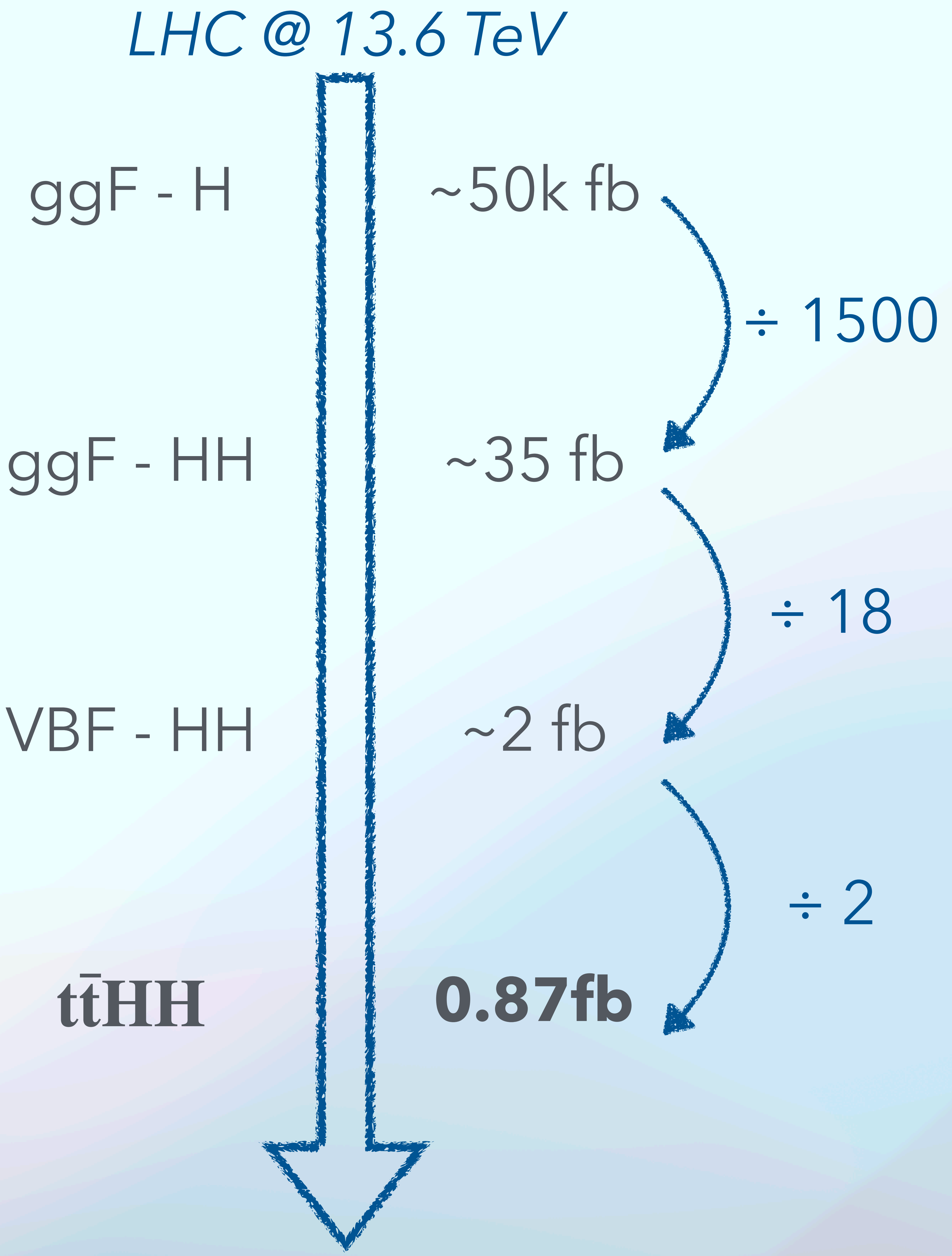
ATLAS EXPERIMENT

# Motivations



SM

- <u>3rd leading</u> HH production mode @ LHC



*LHC @ 13.6 TeV*

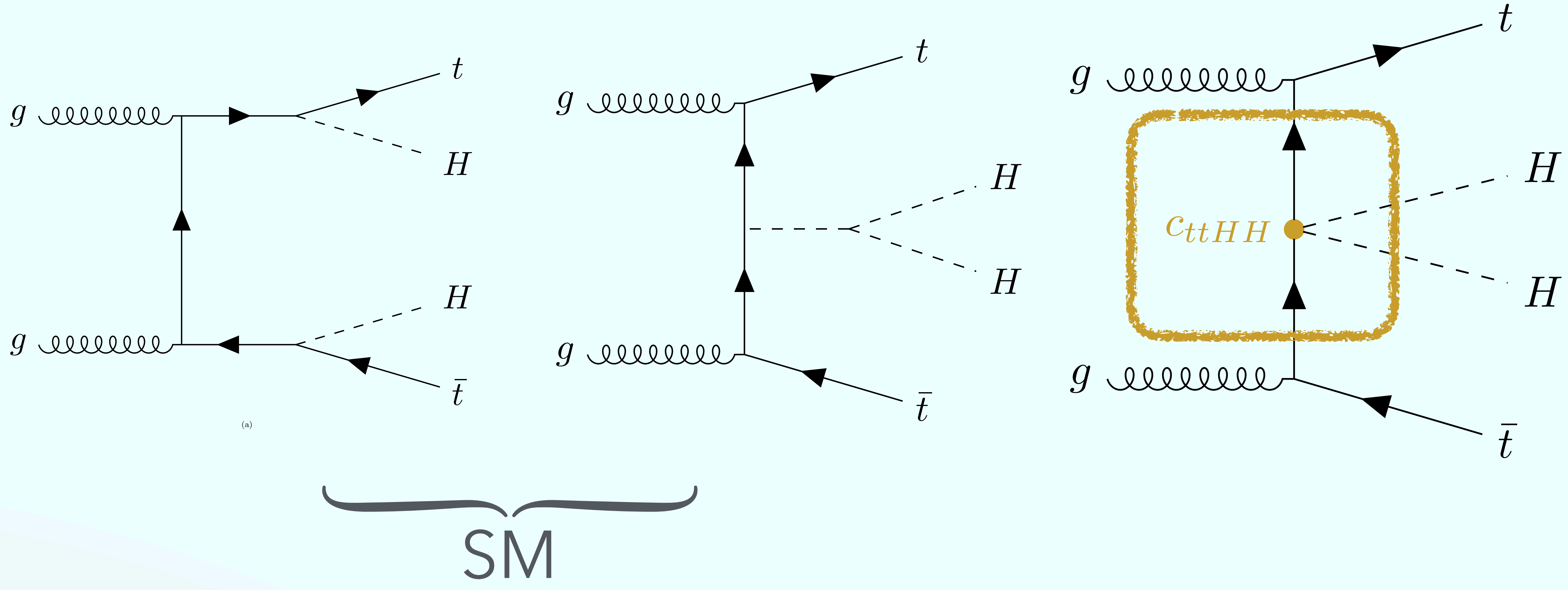
| | |
|---|---|
| ggF - H | ~50k fb |
| ggF - HH | ~35 fb |
| VBF - HH | ~2 fb |
| **$t\bar{t}HH$** | **0.87fb** |

÷ 1500

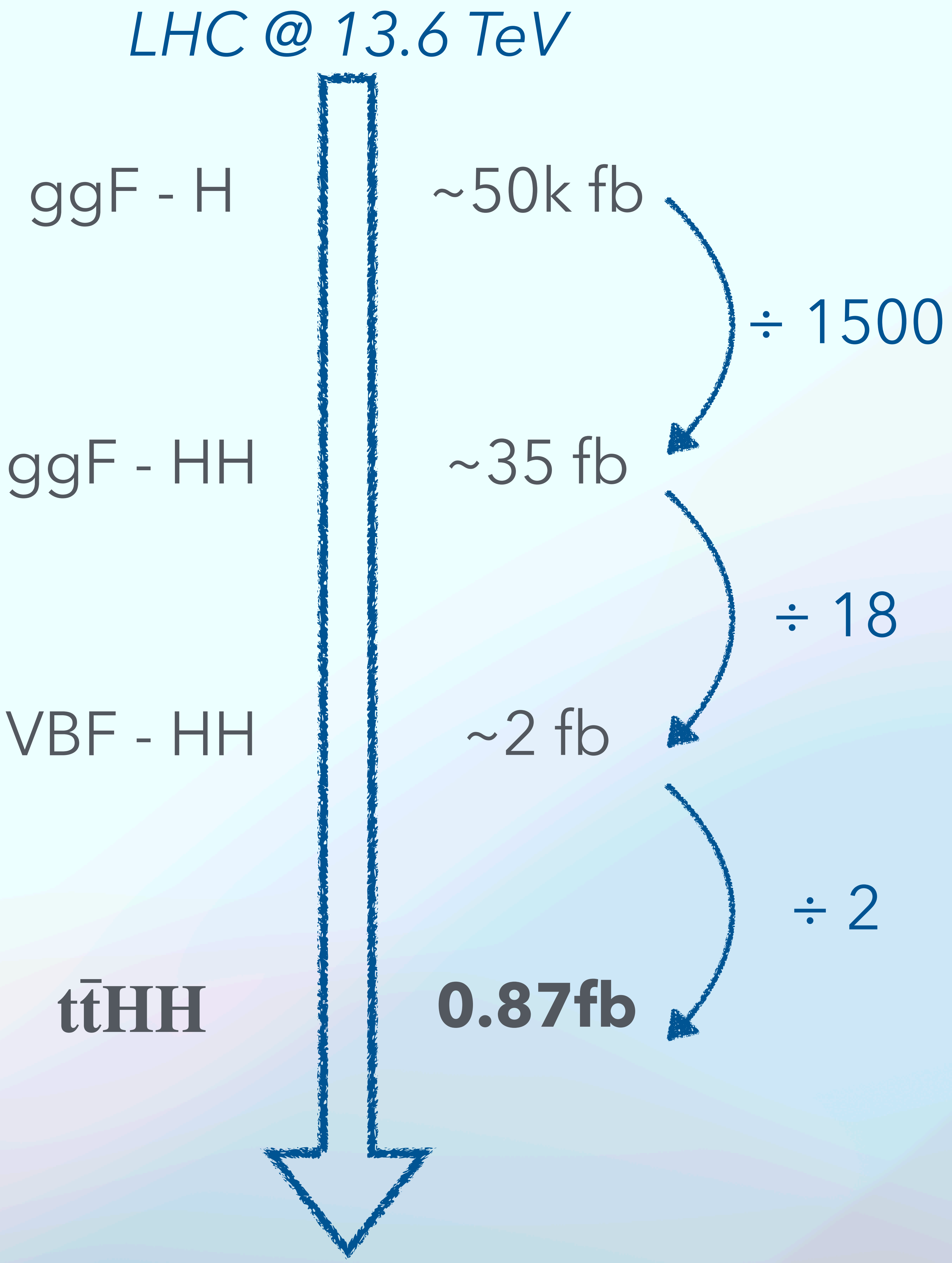
÷ 18

÷ 2

# Motivations



- 3rd leading HH production mode @ LHC
- Gives **direct** access to $t\bar{t}HH$ quartic interaction



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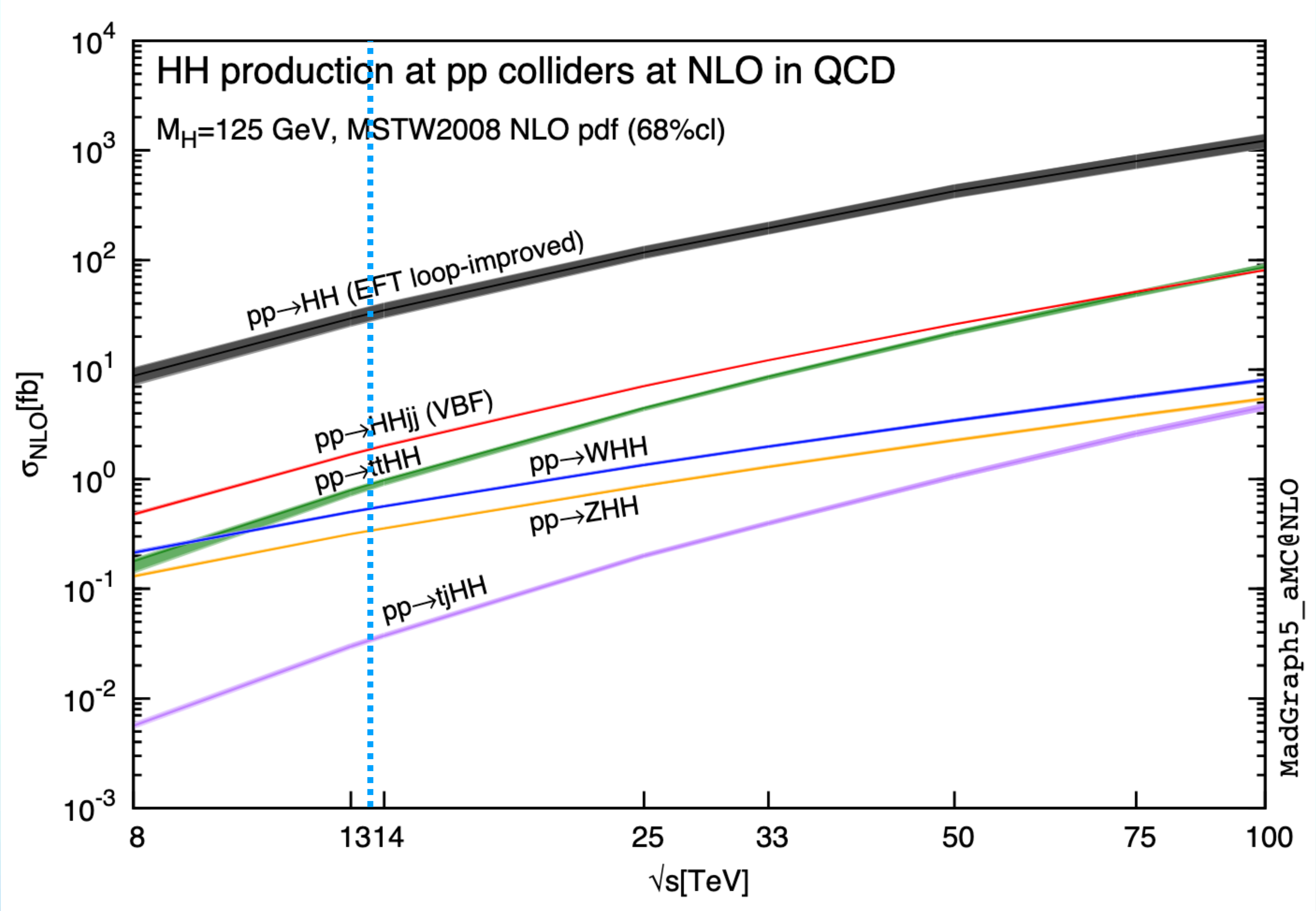
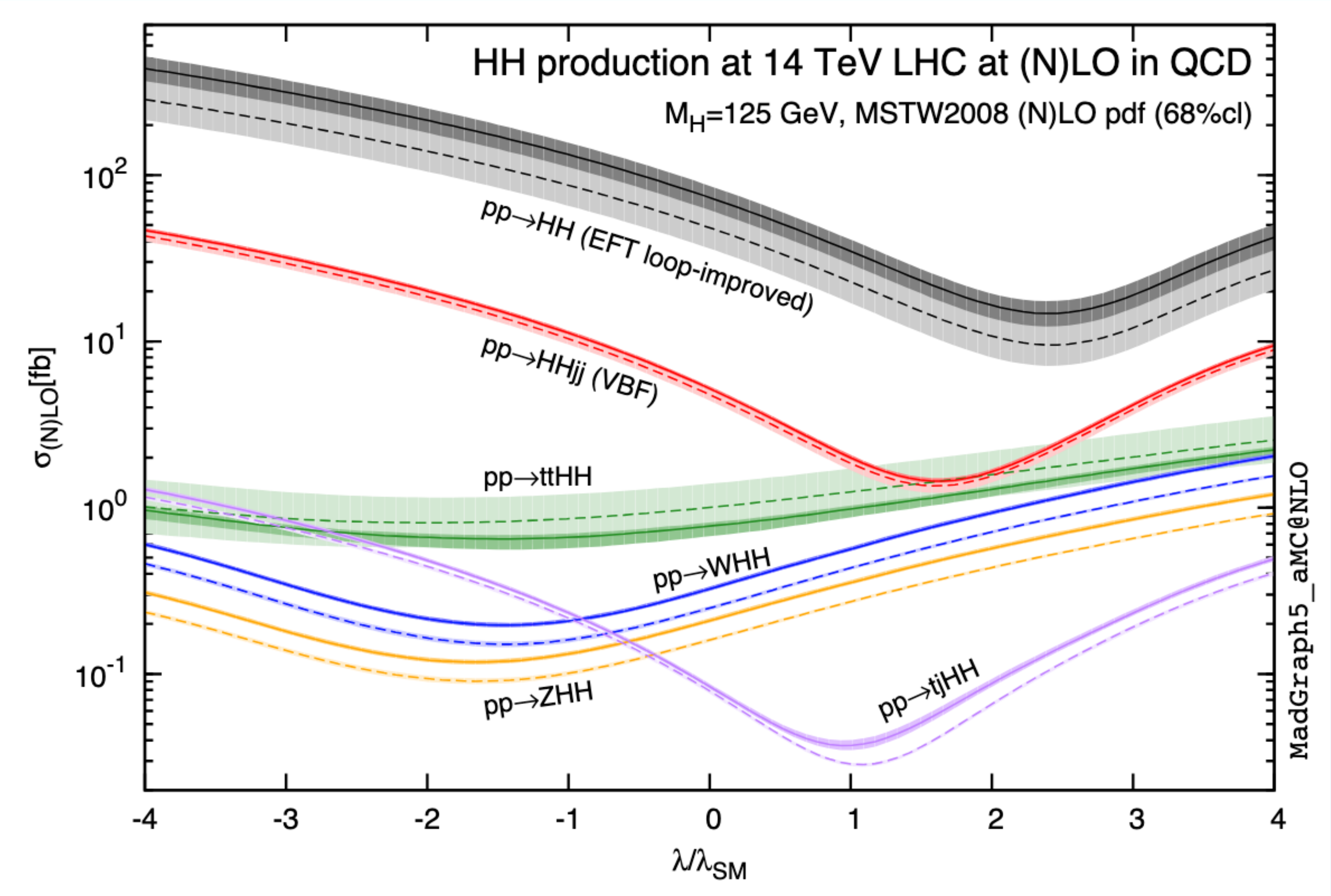
# ttHH production

arXiv:1401.7340

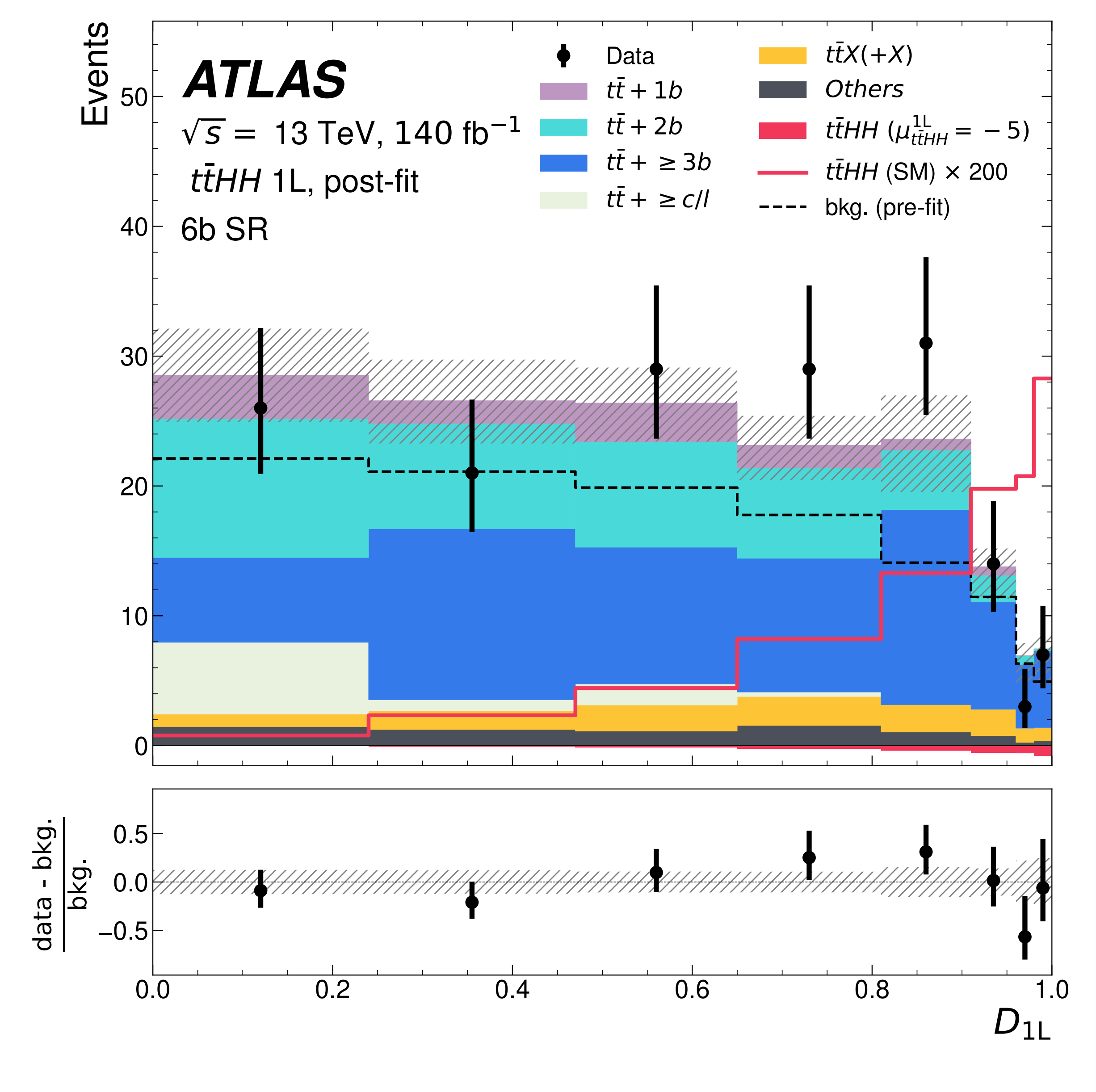
*We stand here*





- Cross-section scales faster with $\sqrt{s}$
- Unique interference pattern dependance on $\kappa_\lambda$

# Strategy

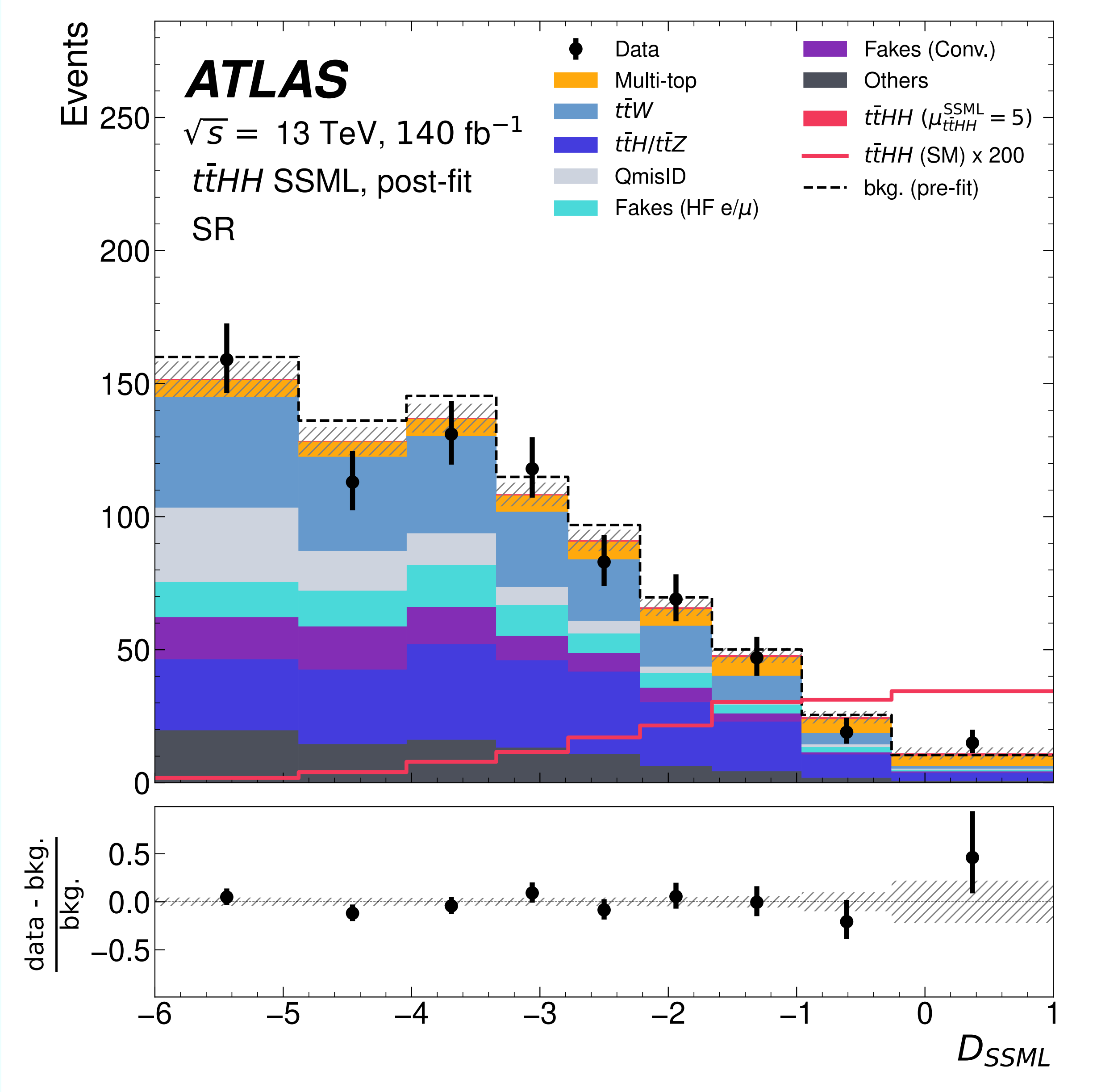


## **Single lep. channel** (1L)

$HH \rightarrow 4b$ and semileptonic $t\bar{t}$

*dom. bkg :* $t\bar{t} + jets$

Obs. limit on $\mu$ : **26** x SM

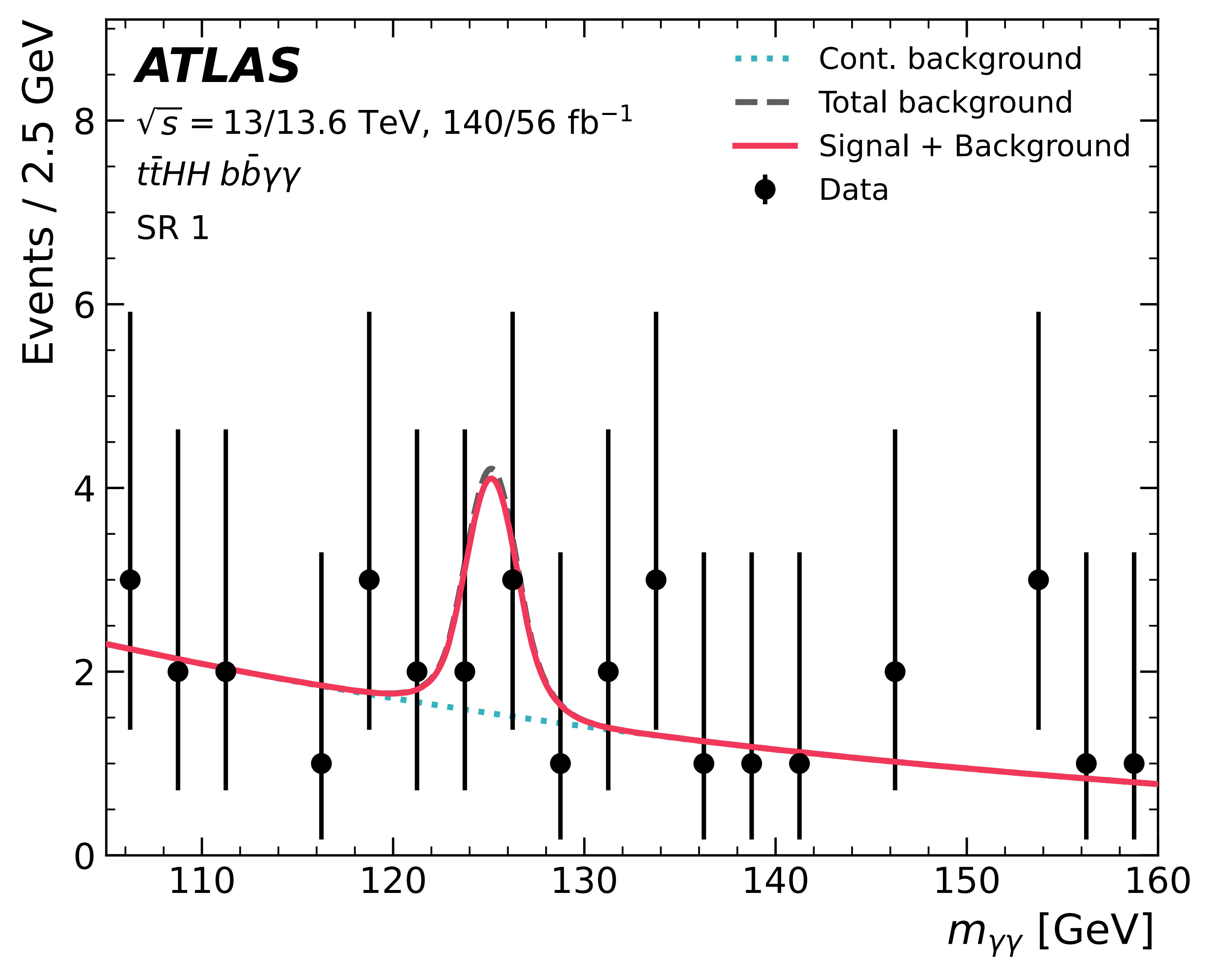


## **Multi-lep. Channel** (ML)

$HH \rightarrow b\bar{b}WW, b\bar{b}\tau\tau, \ldots$

*dom. bkg :* $t\bar{t}W, t\bar{t}t\bar{t}$, *QmidID*

Obs. limit on $\mu$ : **40** x SM



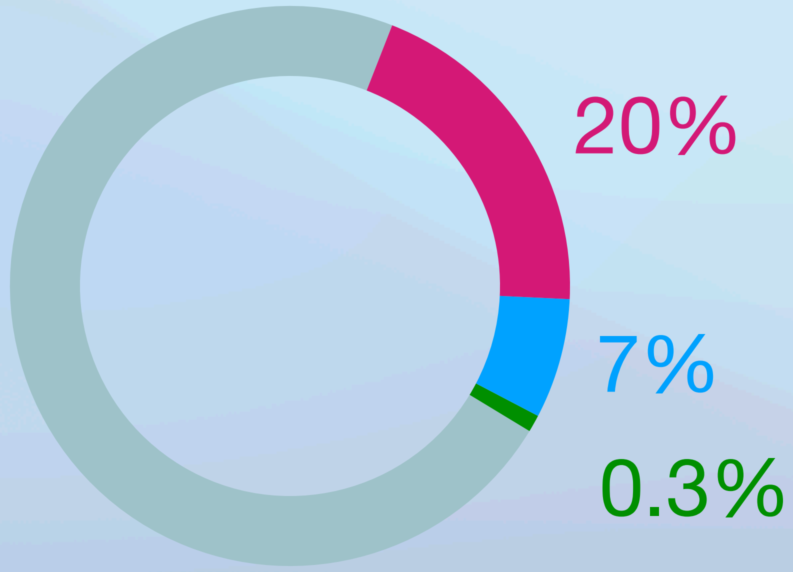
## **$b\bar{b}\gamma\gamma$ channel**

$HH \rightarrow b\bar{b}\gamma\gamma$

*dom. bkg :* $\gamma\gamma + jets$ *continuum*

Obs. limit on $\mu$ : **75** x SM

arXiv:2603.13113

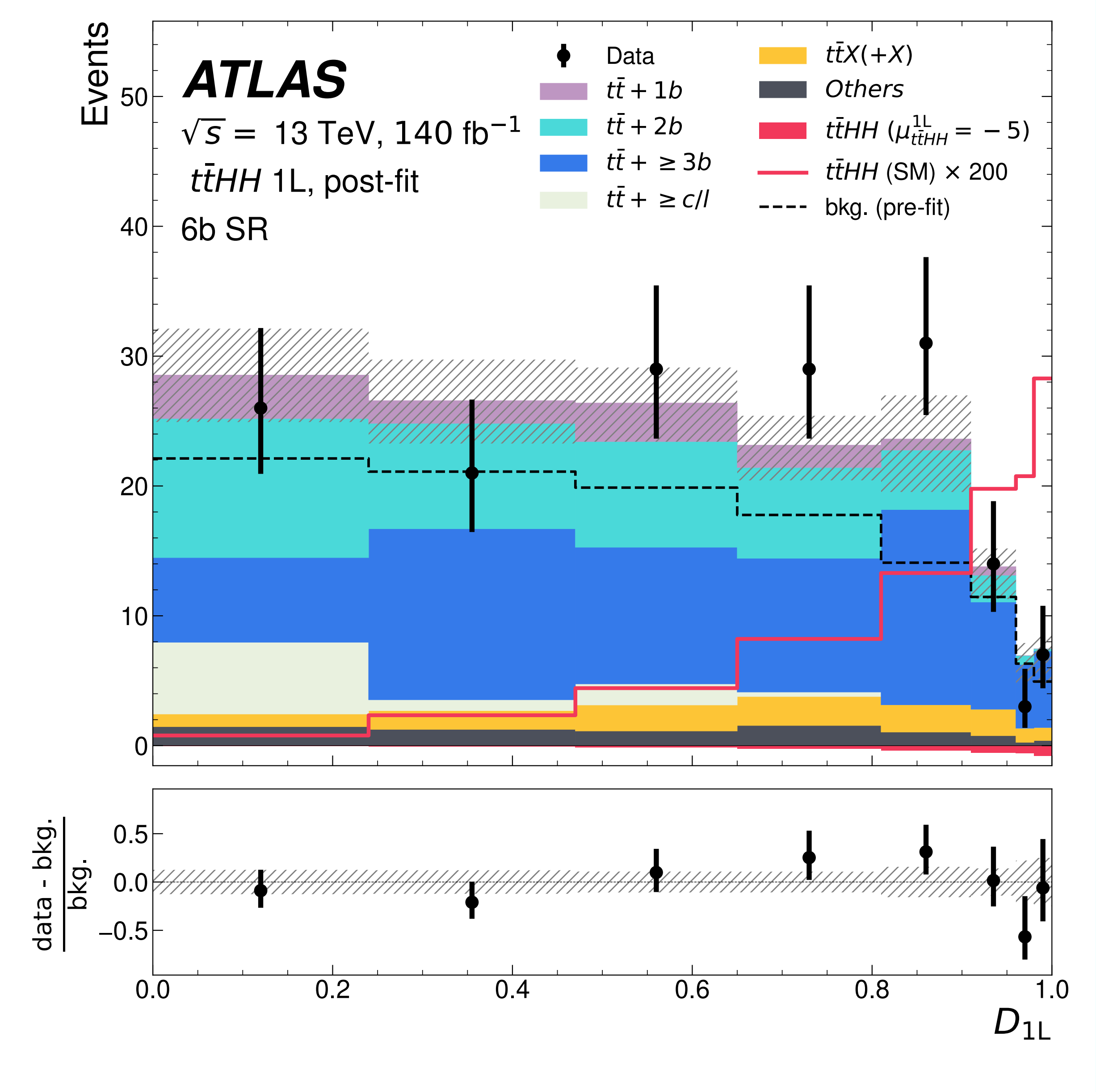


- 1L and ML : Fit Transformer score
- $b\bar{b}\gamma\gamma$ : Fit on $m_{\gamma\gamma}$ after BDT selection

Obs. limit on $\mu$ : **20** x SM

*Adrien Gutierrez-Auriol - Top LHC France 2026*

# Strategy



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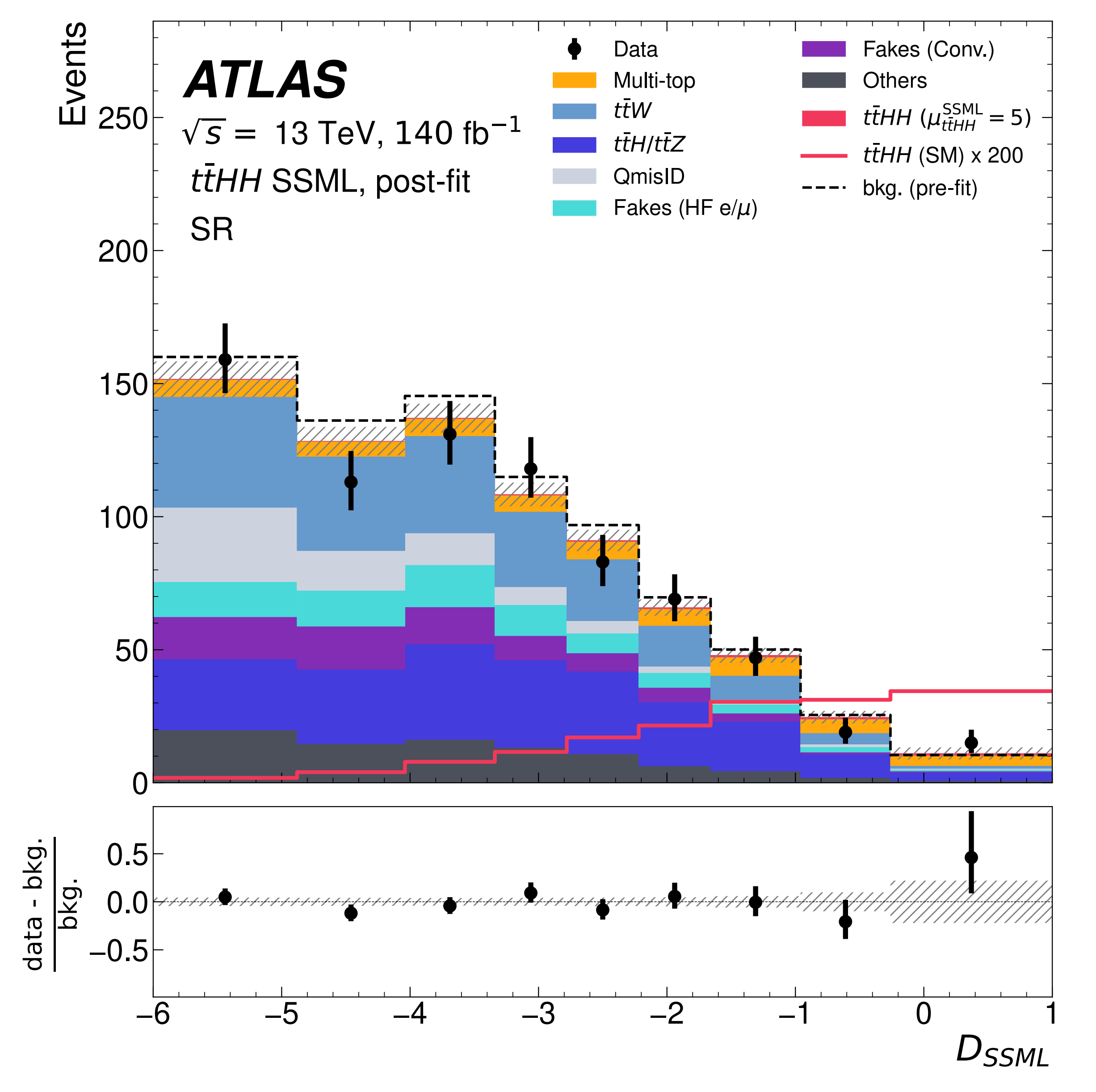

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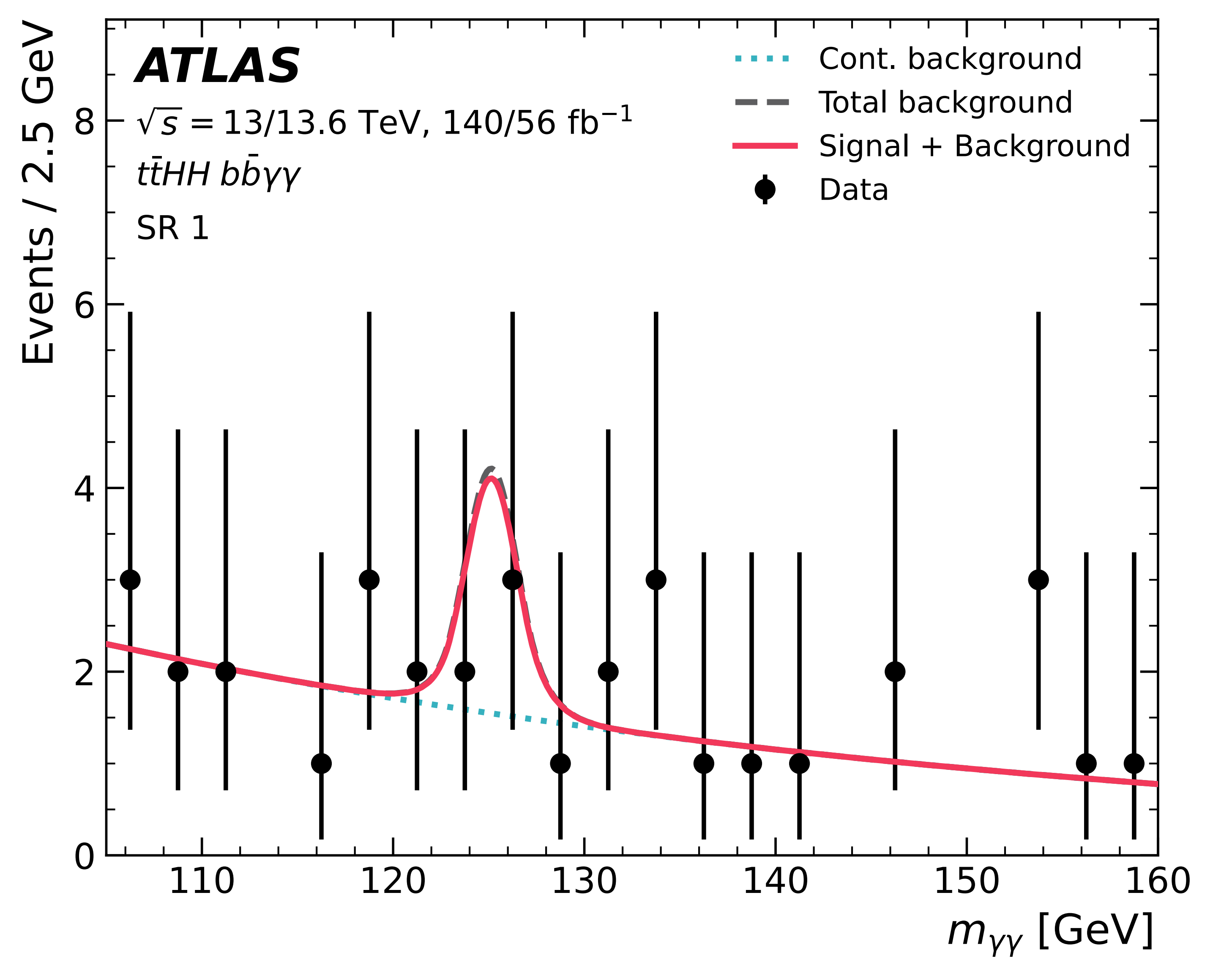

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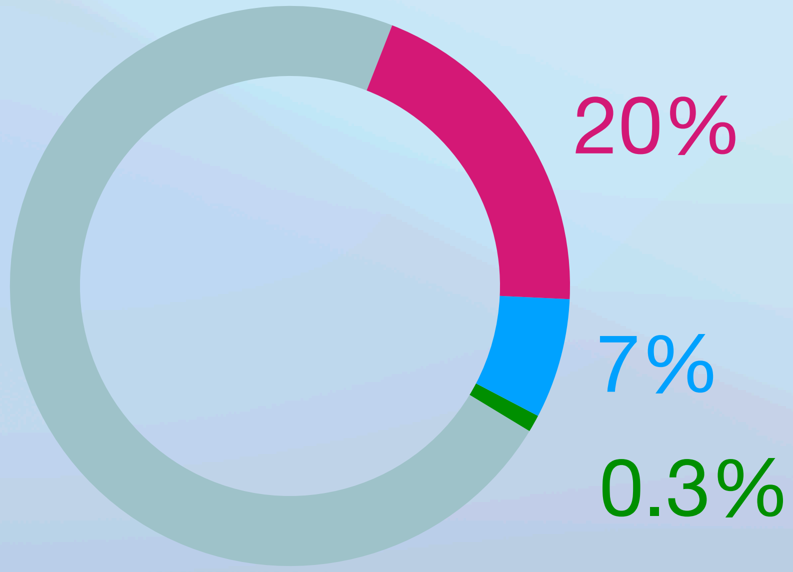

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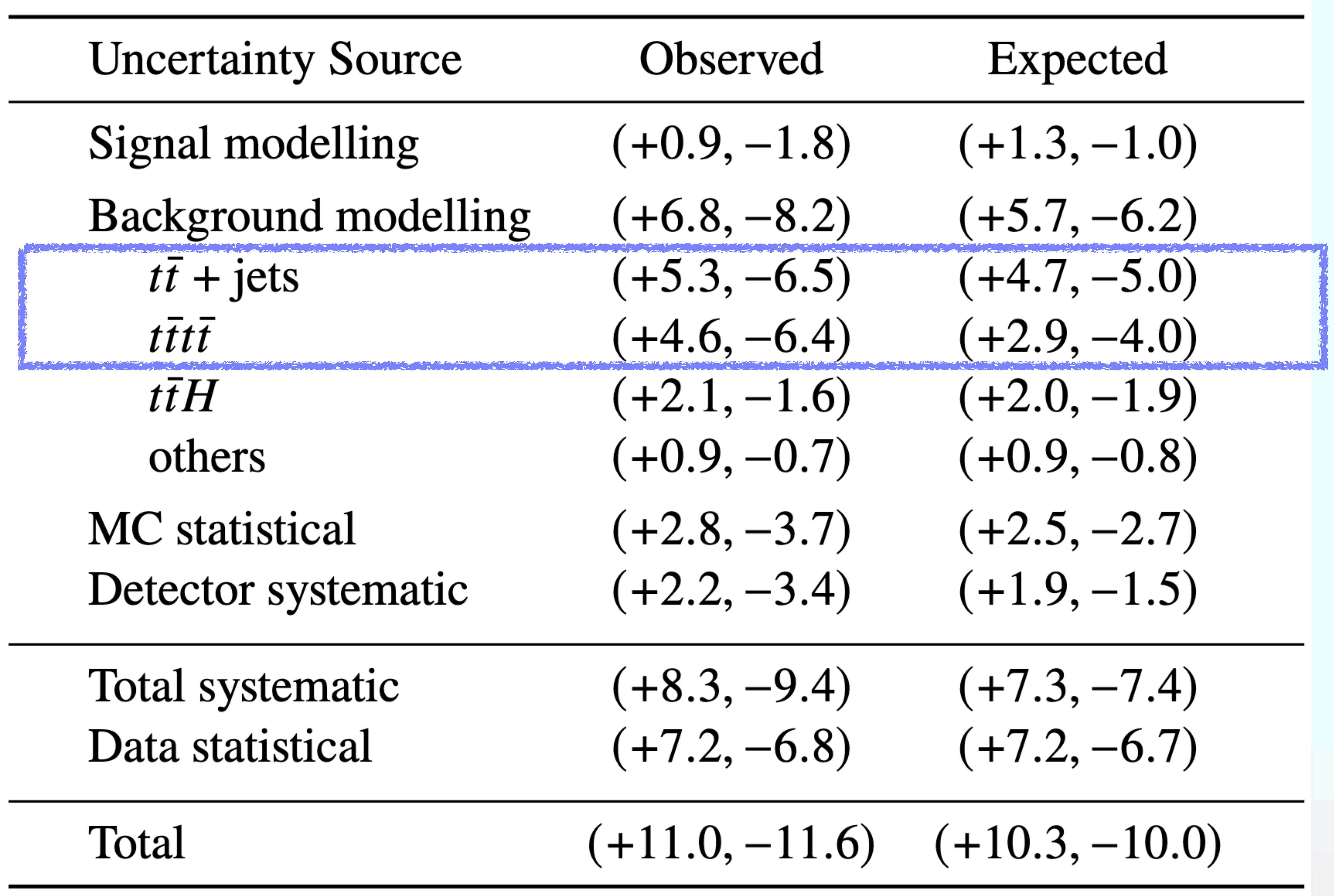
# Limitations



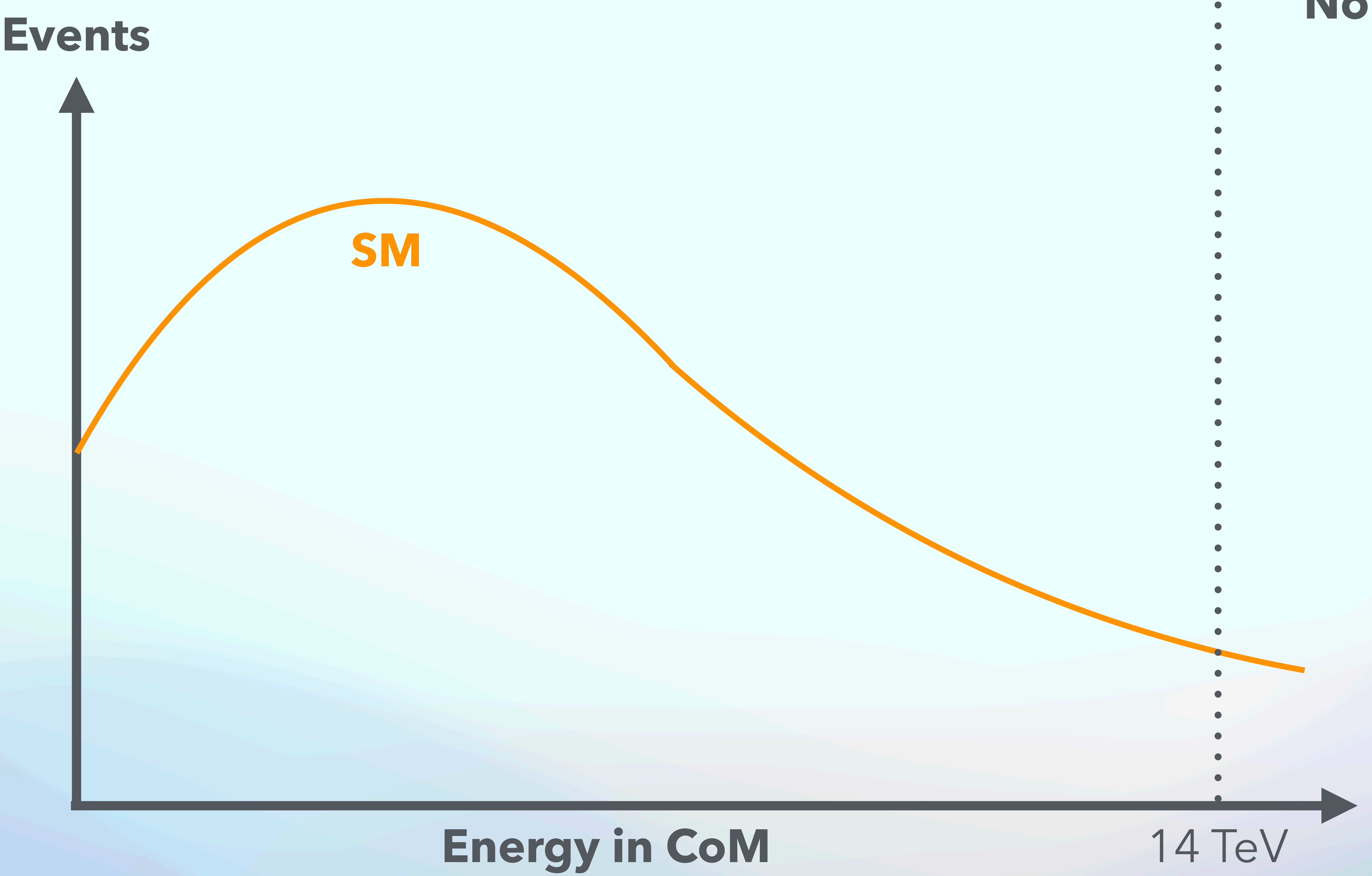
| Uncertainty Source | Observed | Expected |
|---|---|---|
| Signal modelling | (+0.9, −1.8) | (+1.3, −1.0) |
| Background modelling | (+6.8, −8.2) | (+5.7, −6.2) |
| $t\bar{t}$ + jets | (+5.3, −6.5) | (+4.7, −5.0) |
| $t\bar{t}t\bar{t}$ | (+4.6, −6.4) | (+2.9, −4.0) |
| $t\bar{t}H$ | (+2.1, −1.6) | (+2.0, −1.9) |
| others | (+0.9, −0.7) | (+0.9, −0.8) |
| MC statistical | (+2.8, −3.7) | (+2.5, −2.7) |
| Detector systematic | (+2.2, −3.4) | (+1.9, −1.5) |
| Total systematic | (+8.3, −9.4) | (+7.3, −7.4) |
| Data statistical | (+7.2, −6.8) | (+7.2, −6.7) |
| Total | (+11.0, −11.6) | (+10.3, −10.0) |

**Dominant systematic unc.** :
heavy flavour modelling and 4 tops

**Overall** → Balance between stat. and modelling

# Going beyond the SM using an effective approach ?

**No evidence of new physics (NP) at current energy reach!**



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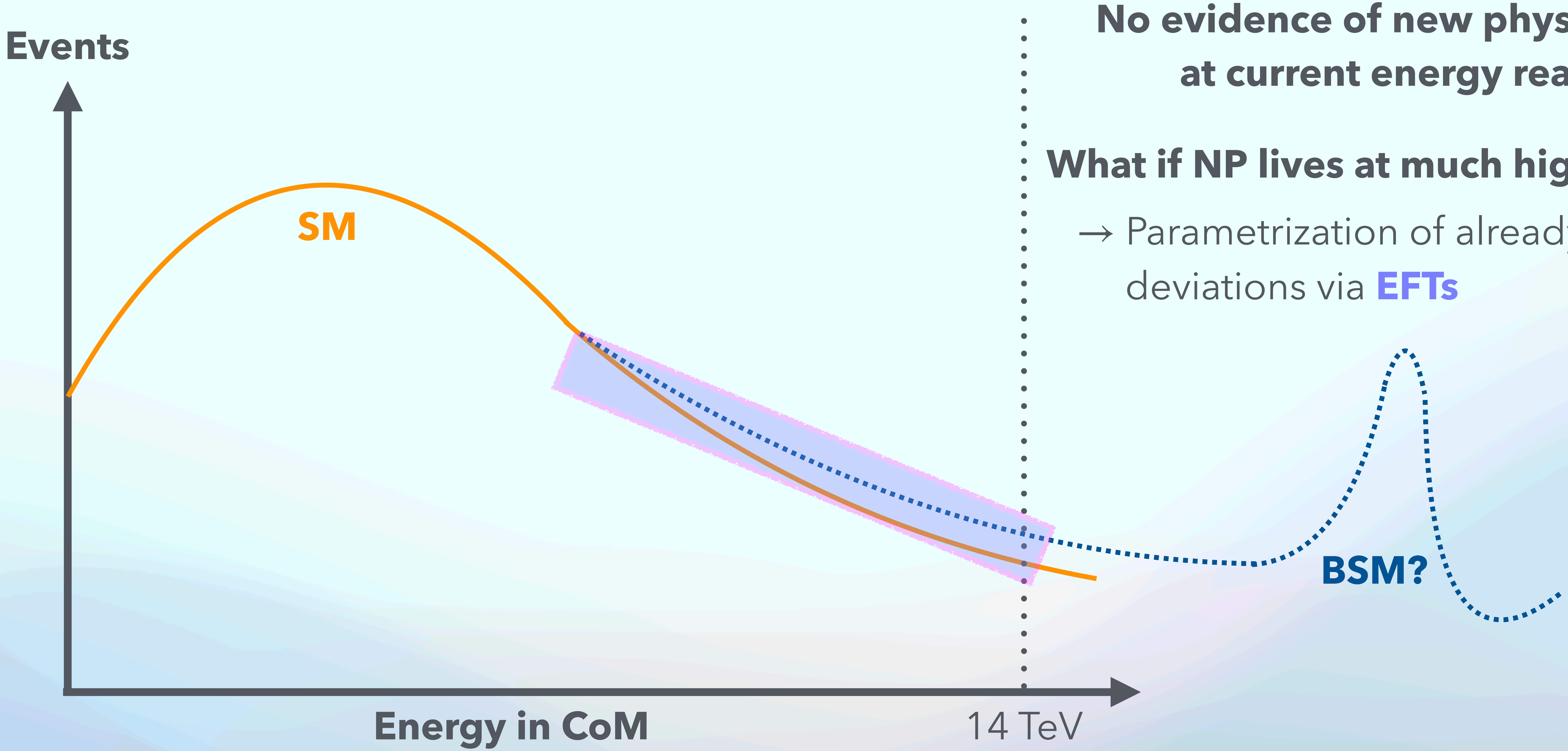

**No evidence of new physics (NP) at current energy reach!**

**What if NP lives at much higher mass?**

→ Parametrization of already existing deviations via **EFTs**

# Recipe of an EFT

*EFT recipe*

**Step 1** : We fix the field content

**Step 2** : We fix the symmetries

**Step 3** : We write an exhaustive list of allowed interactions at a fixed order

# Recipe of an EFT

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# Recipe of an EFT

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$$\rightarrow \mathscr{L}_{\text{SMEFT}} = \mathscr{L}_{\text{SM}} + \sum_{d=5}^{\infty} \sum_i \frac{c_{i,d}}{\Lambda^{d-4}} \mathcal{O}_i^{(d)}$$

*"usual" in LHC analyses*

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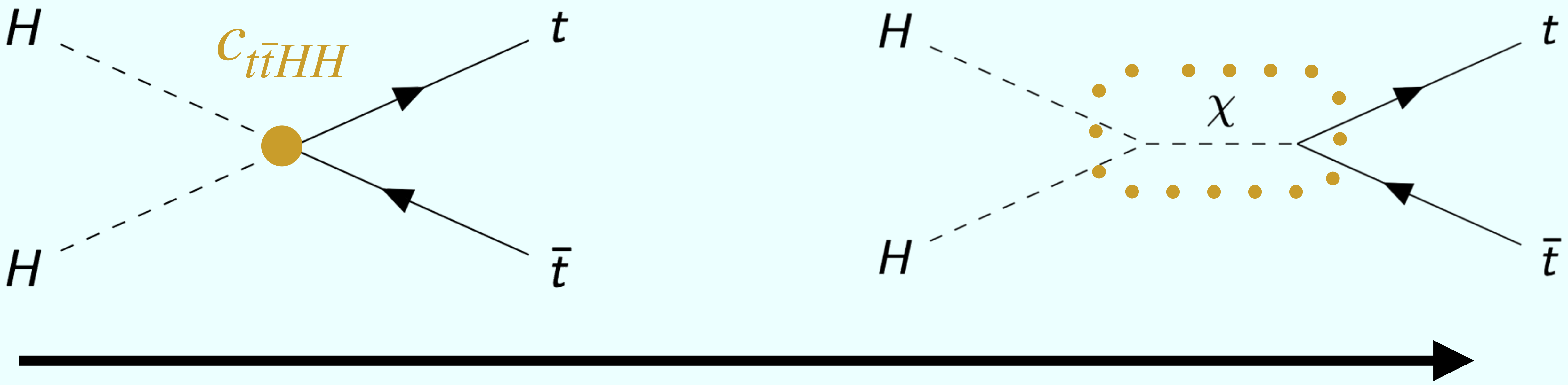
**There are other assumptions that we can make!** *(e.g. for Step 2)*

# Higgs Effective Field Theory



$$E_{LHC} \quad << \quad E \sim \Lambda_{NP}$$

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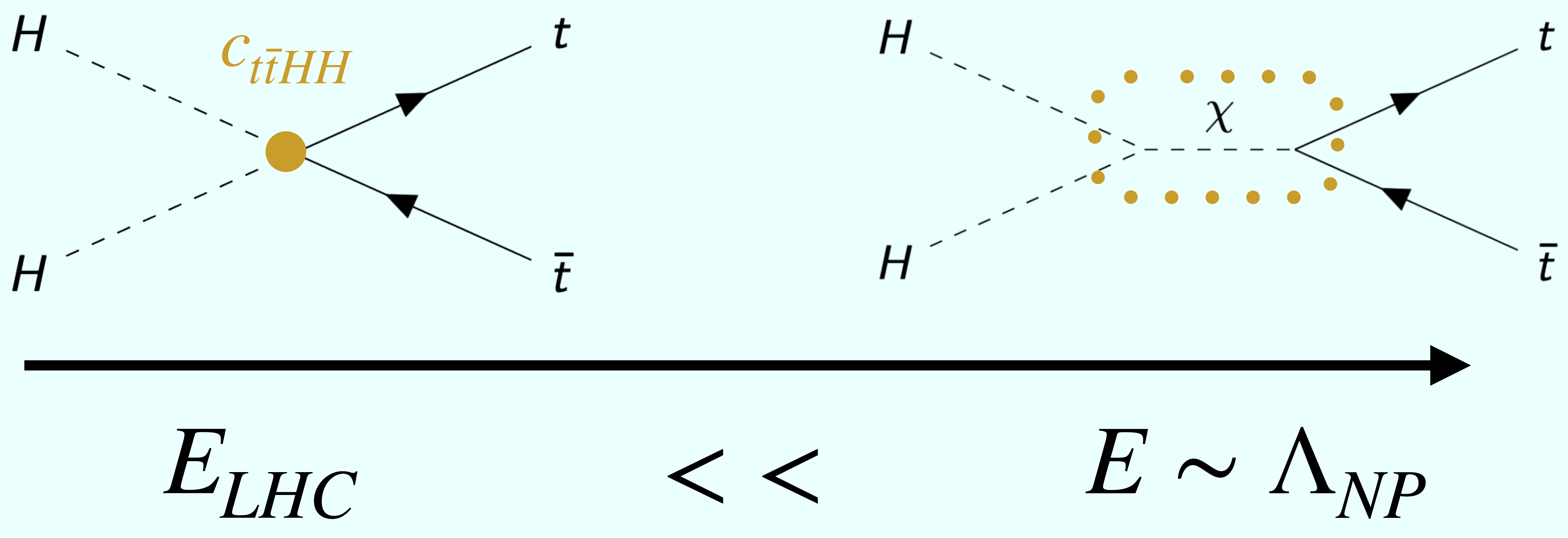

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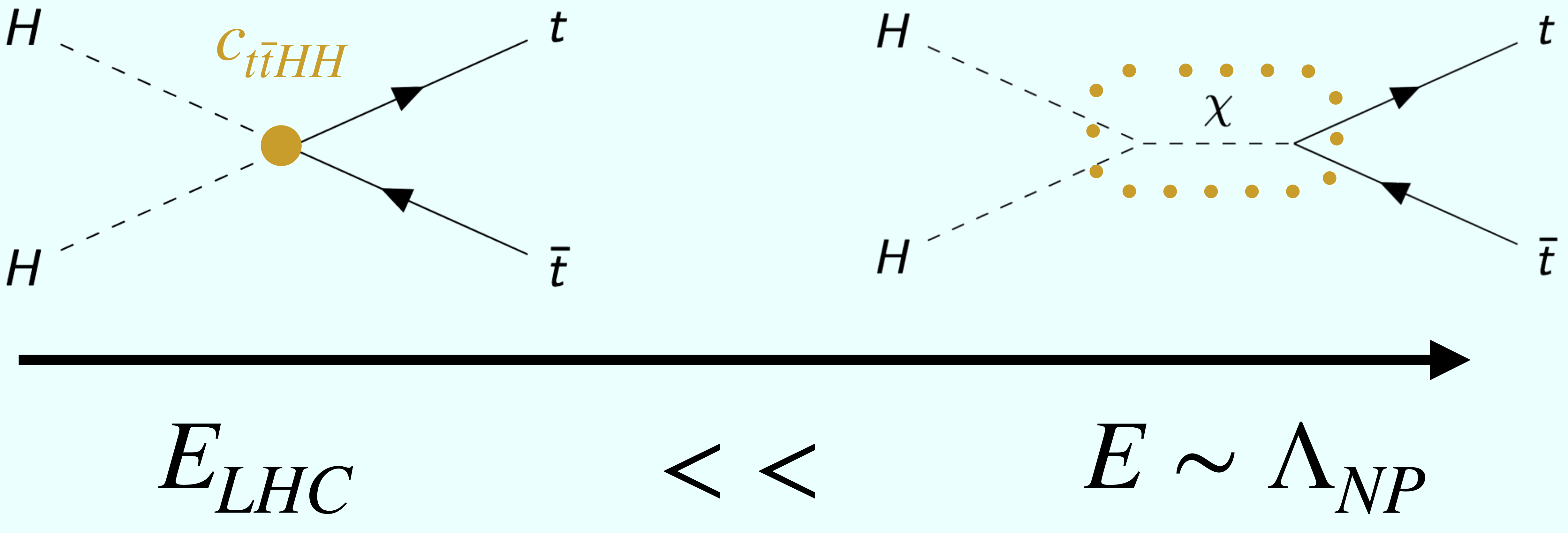

HEFT relaxes the assumption that the physical Higgs boson $h$ is part of a $SU(2)_L$ doublet

→ Higgs properties unconstrained by EWSB pattern

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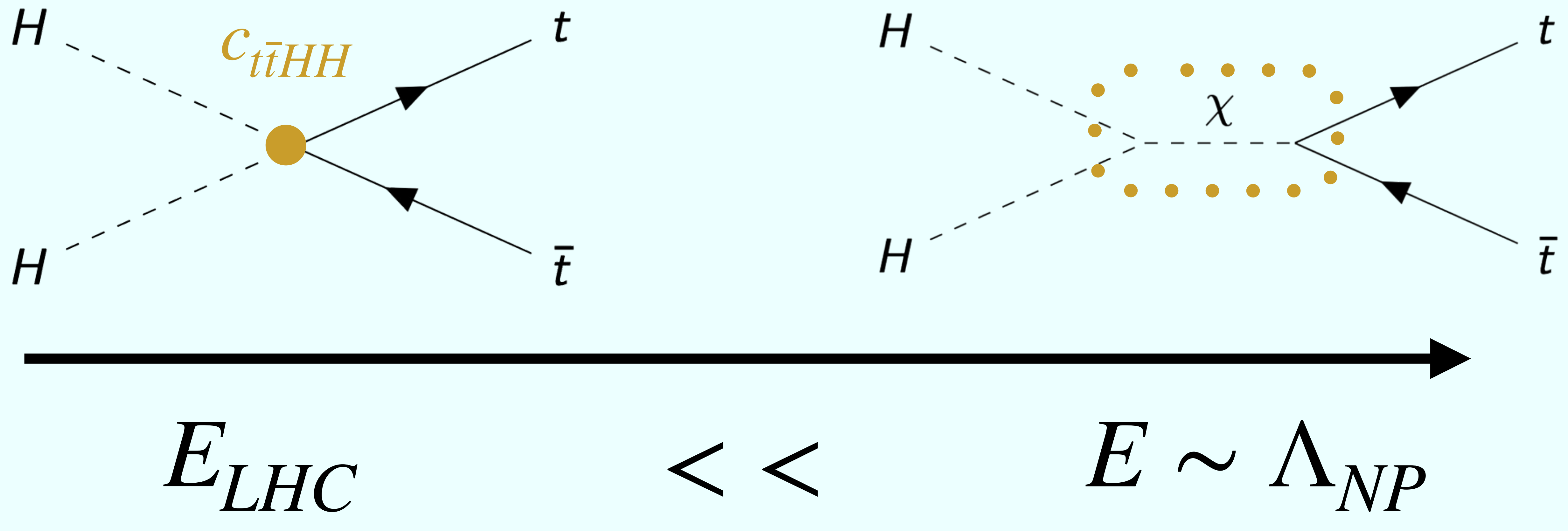

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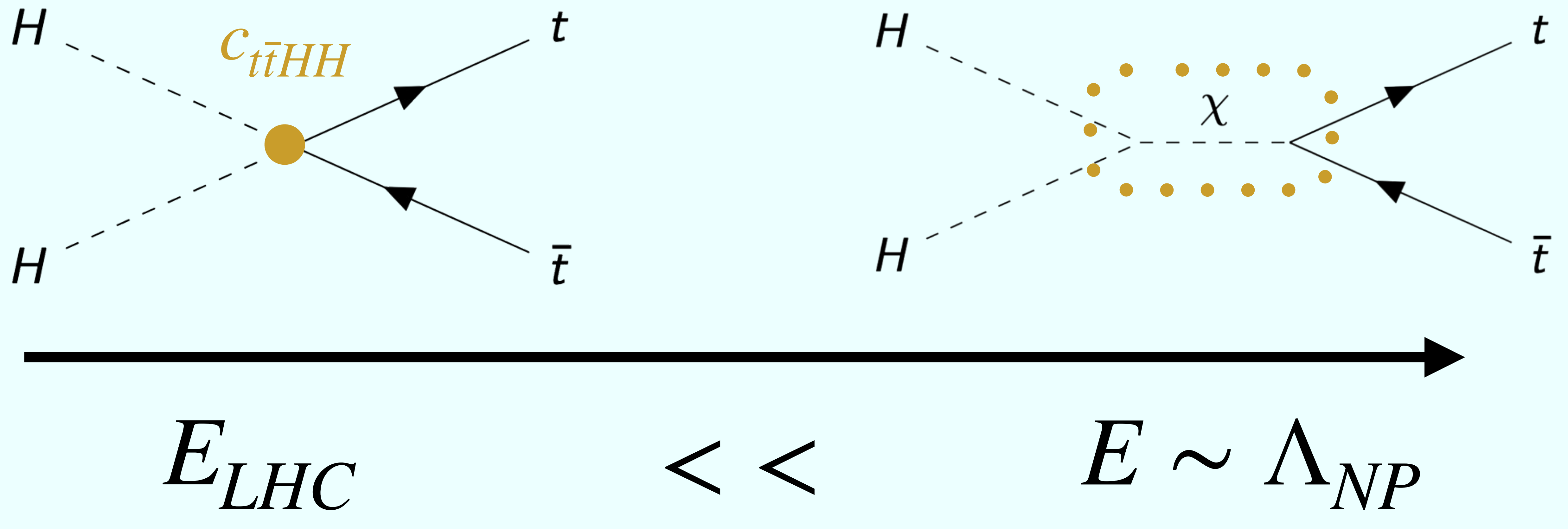

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$$\mathscr{L}_{\text{HEFT}} \supset -m_t\left(c_{t\bar{t}H}\frac{h}{v} + c_{t\bar{t}HH}\frac{h^2}{v^2}\right)t\bar{t} - \kappa_\lambda\frac{m_H^2}{2v}h^3$$

# Strategy and results

Exploit **cross-section dependance** in 1L and ML channels

**Reinterpretation**

$$\mathscr{L}(d\,|\,\mu) \longrightarrow \mathscr{L}(d\,|\,\sigma(\,c_{t\bar{t}HH}\,))$$

# Strategy and results

Exploit **cross-section dependance** in 1L and ML channels

*Acceptance effects covered by 30% unc. on signal yield*

*Shape variations neglected (evaluated to have a small impact)*

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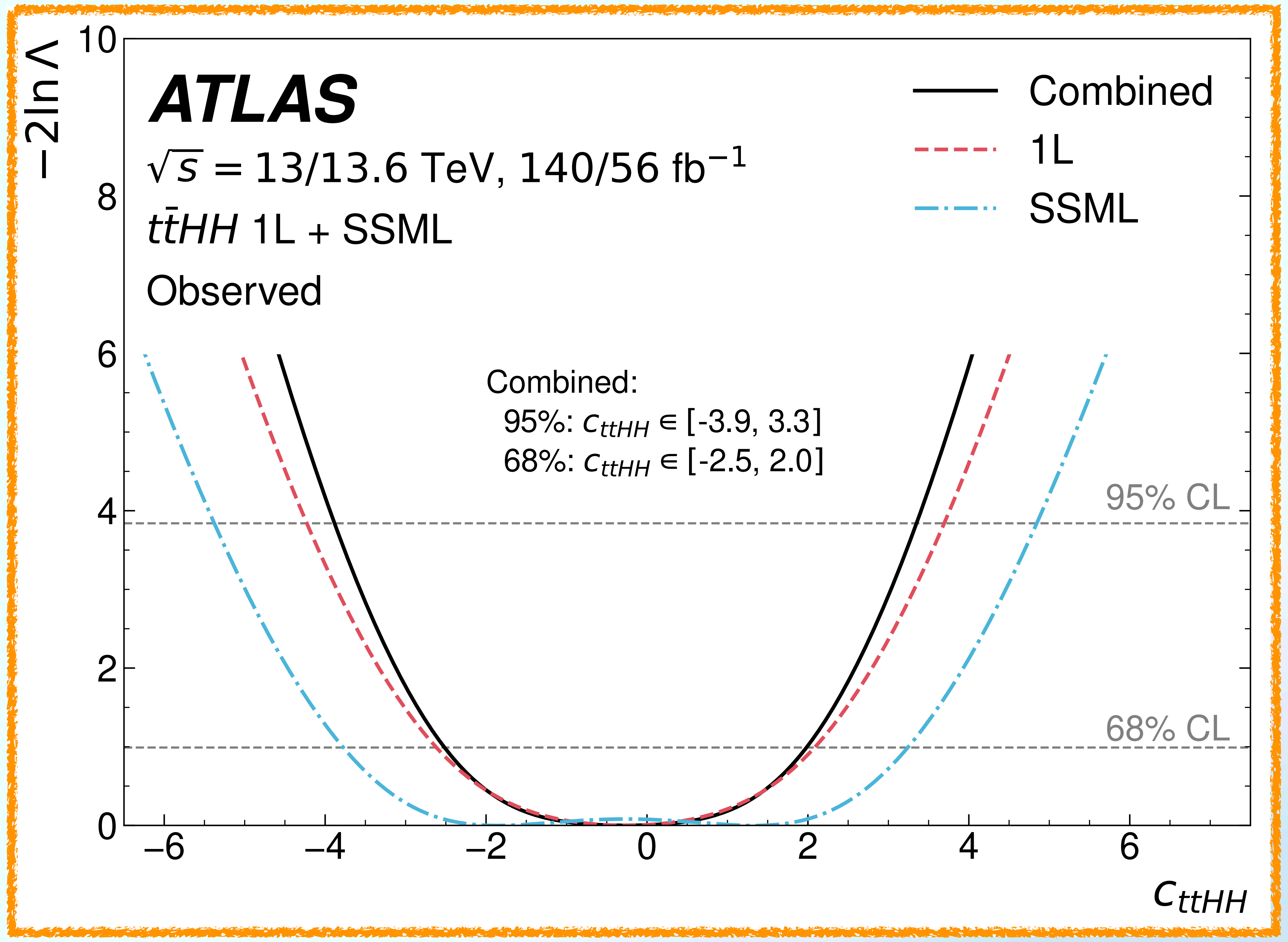


arXiv:2603.13113

*Almost flat likelihood*
*(small degeneracy in ML channel)*
*→ Not sensible to sign*

Exp. : $c_{t\bar{t}HH} \in [-4.1, 3.5]$ @ 95 % CL

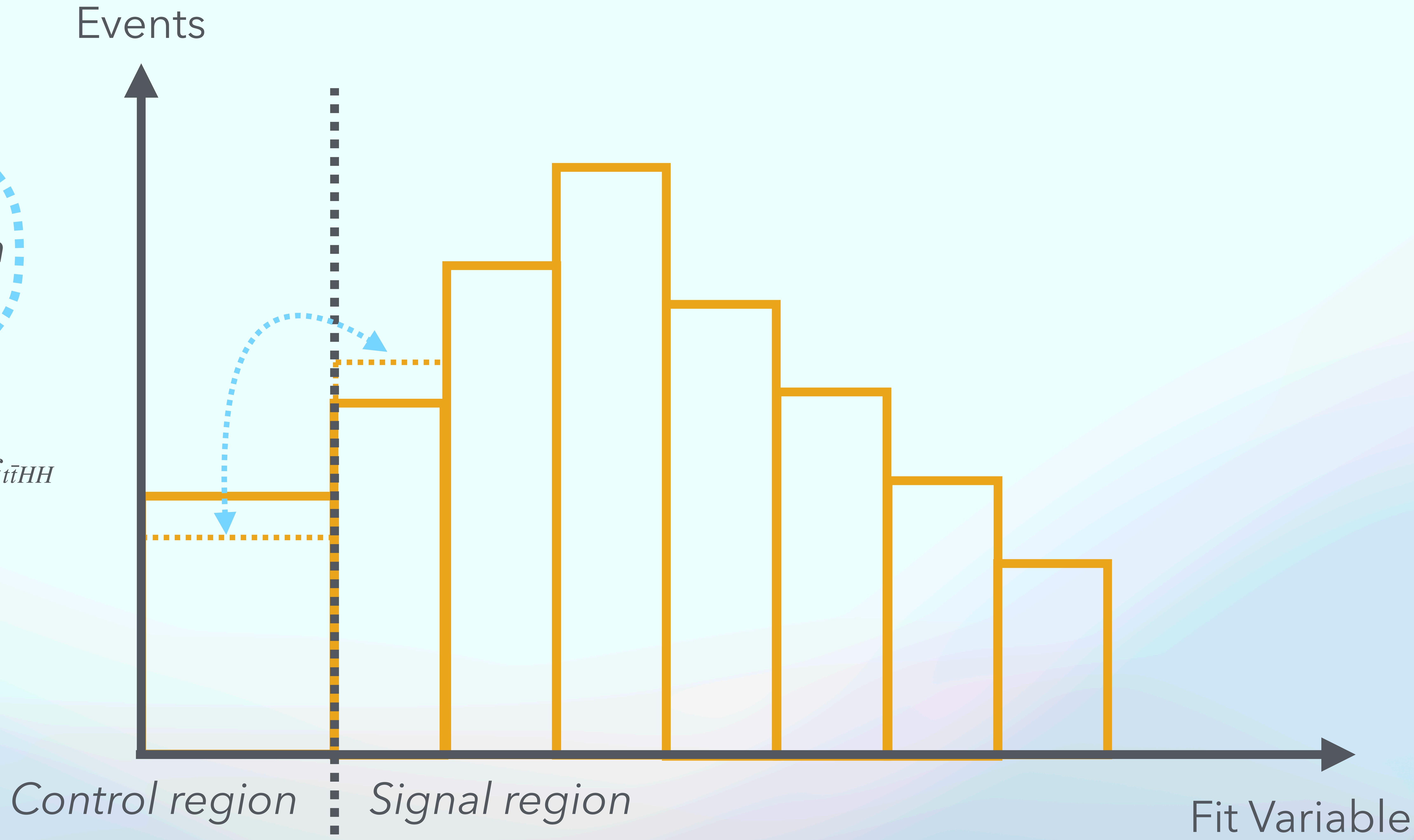
Obs. : $c_{t\bar{t}HH} \in [-3.9, 3.3]$ @ 95 % CL

# What effects do we need to take into account?

*Acceptance effects covered by 30% unc. on signal yield*

*30% is **very** conservative*

*Flat uncertainty for all values of $c_{t\bar{t}HH}$*



# What effects do we need to take into account?

Does the shapes have an impact on the sensitivity?

↓

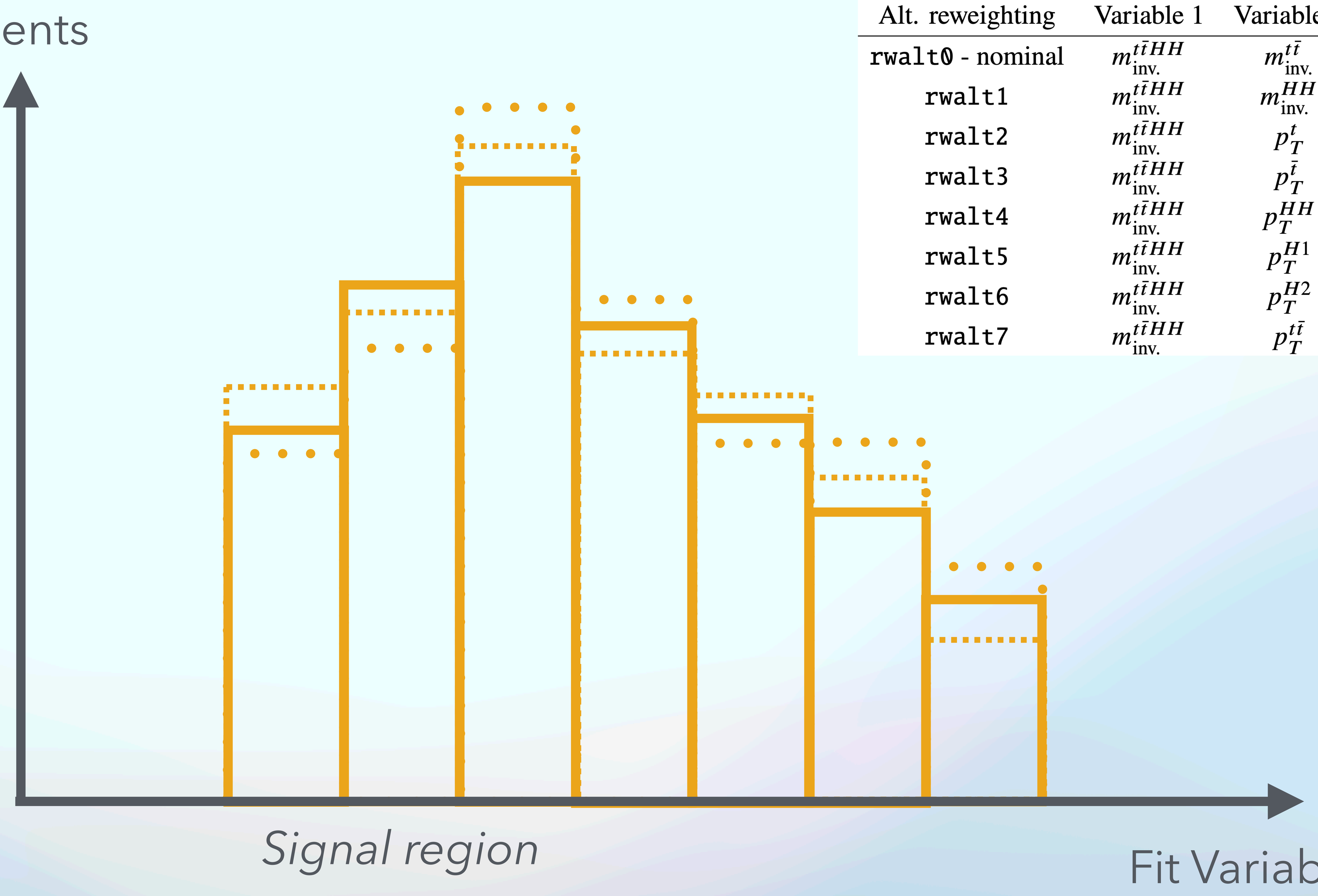
We tested 7 alternative reweightings against no shape variation

↓

*Shape variations neglected (evaluated to have a small impact)*

*At most 10% impact on 95% CL interval*

| Alt. reweighting | Variable 1 | Variable 2 |
|---|---|---|
| `rwalt0` - nominal | $m_{\text{inv.}}^{t\bar{t}HH}$ | $m_{\text{inv.}}^{t\bar{t}}$ |
| `rwalt1` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $m_{\text{inv.}}^{HH}$ |
| `rwalt2` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $p_T^{t}$ |
| `rwalt3` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $p_T^{\bar{t}}$ |
| `rwalt4` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $p_T^{HH}$ |
| `rwalt5` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $p_T^{H1}$ |
| `rwalt6` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $p_T^{H2}$ |
| `rwalt7` | $m_{\text{inv.}}^{t\bar{t}HH}$ | $p_T^{t\bar{t}}$ |



# Outlook of ATLAS analysis

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- **First search** for $t\bar{t}HH$ done by ATLAS
  - → Most stringent **direct limits** on $c_{t\bar{t}HH}$

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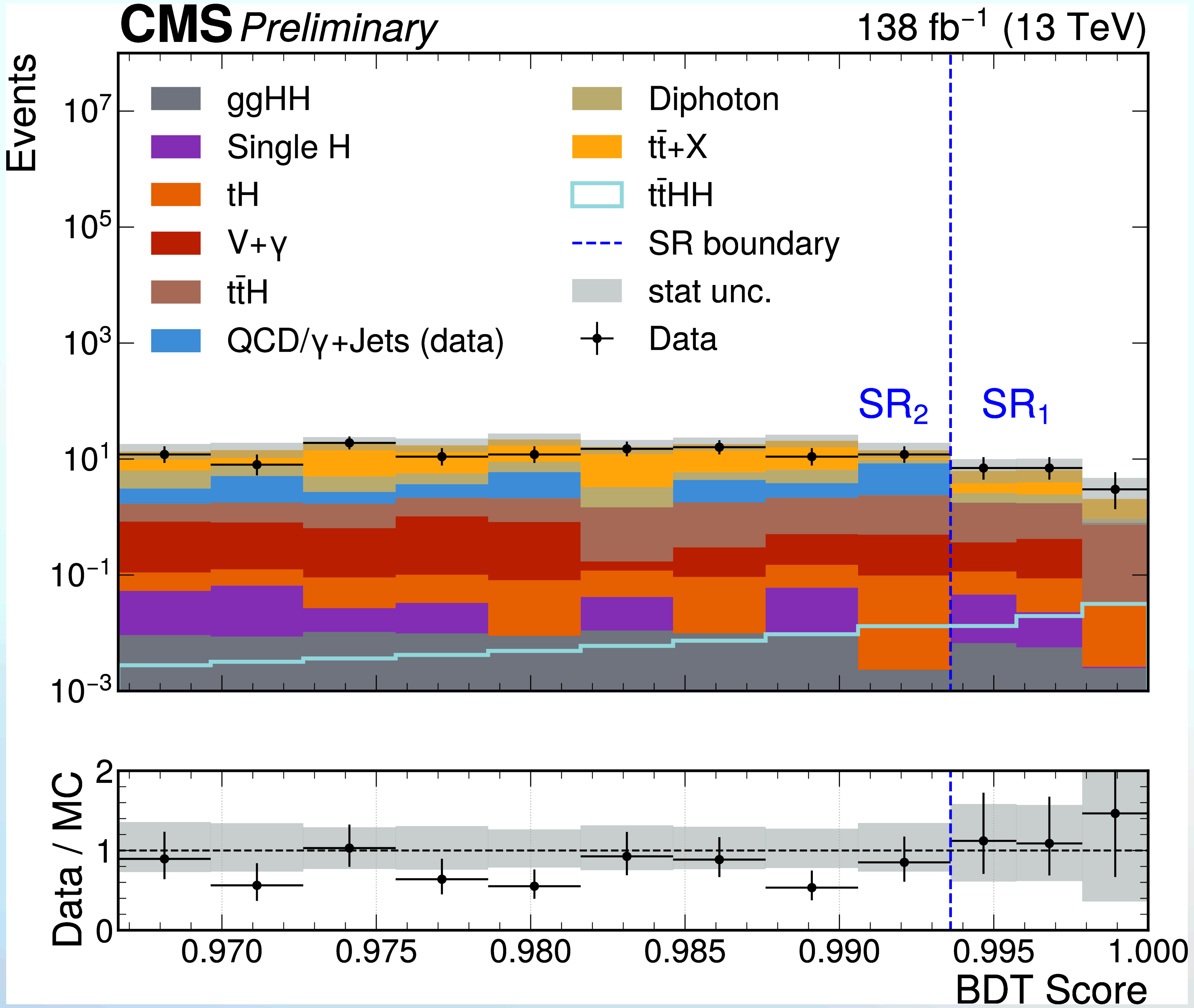
| | **CMS** $t\bar{t}HH$<br>[CMS-PAS-HIG-23-004] | |
|---|---|---|
| Obs. 95% CL limits on $c_{t\bar{t}HH}$ | [-8.0, 7.5] | |

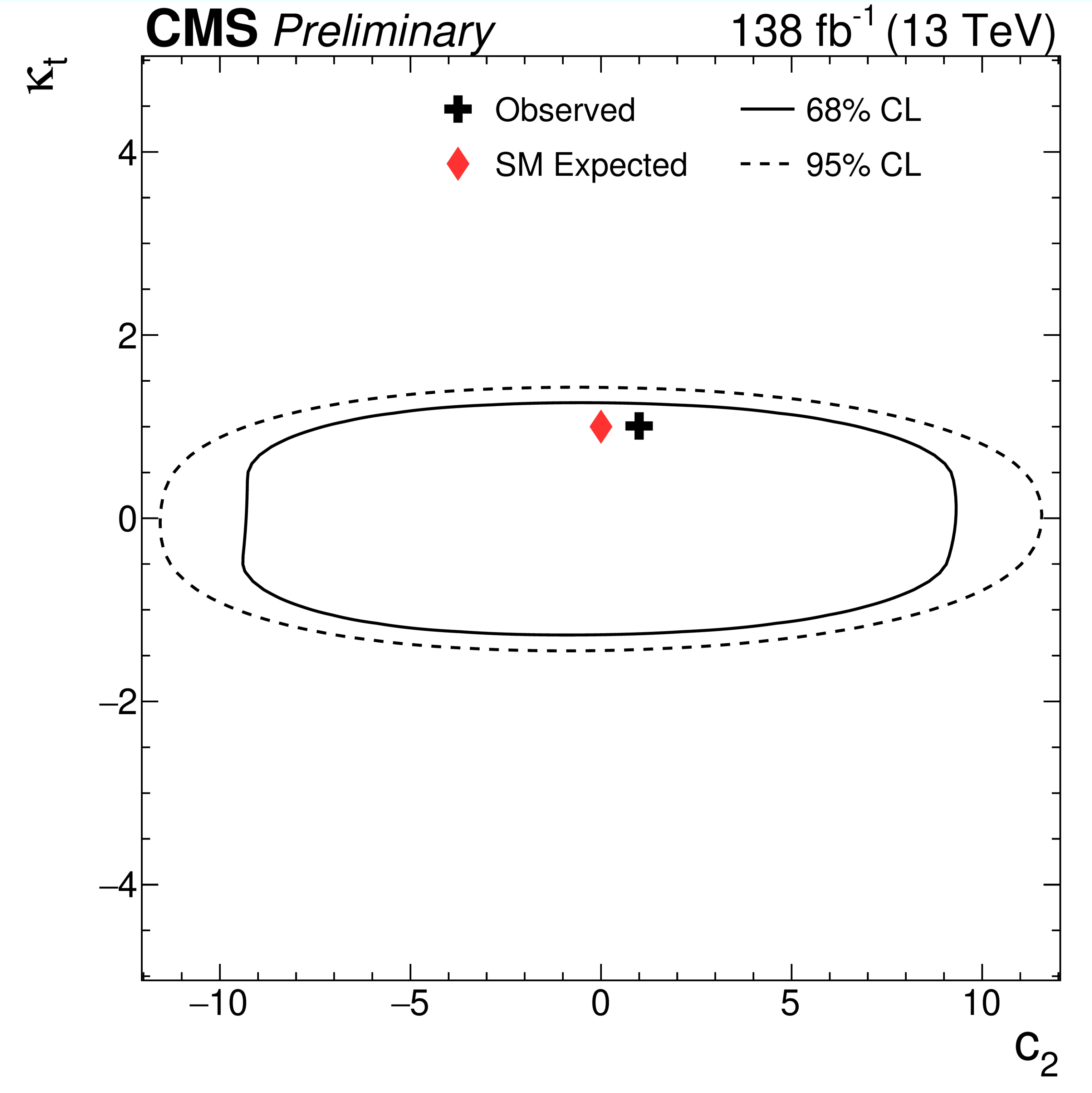
# CMS ttHH analysis (1)

CMS-PAS-HIG-23-004

- **Targets** $\gamma\gamma + X$ with $X \in [b, W^{\pm}, \tau^{\pm}]$ with **Run 2 data**
- Similar modelling strategy as ATLAS (MVA discriminant)
- **Both** $c_{t\bar{t}HH}$ and $c_{tHH}$ probed (called resp. $c_2$ and $\kappa_t$)

*Not $\kappa_\lambda$…*



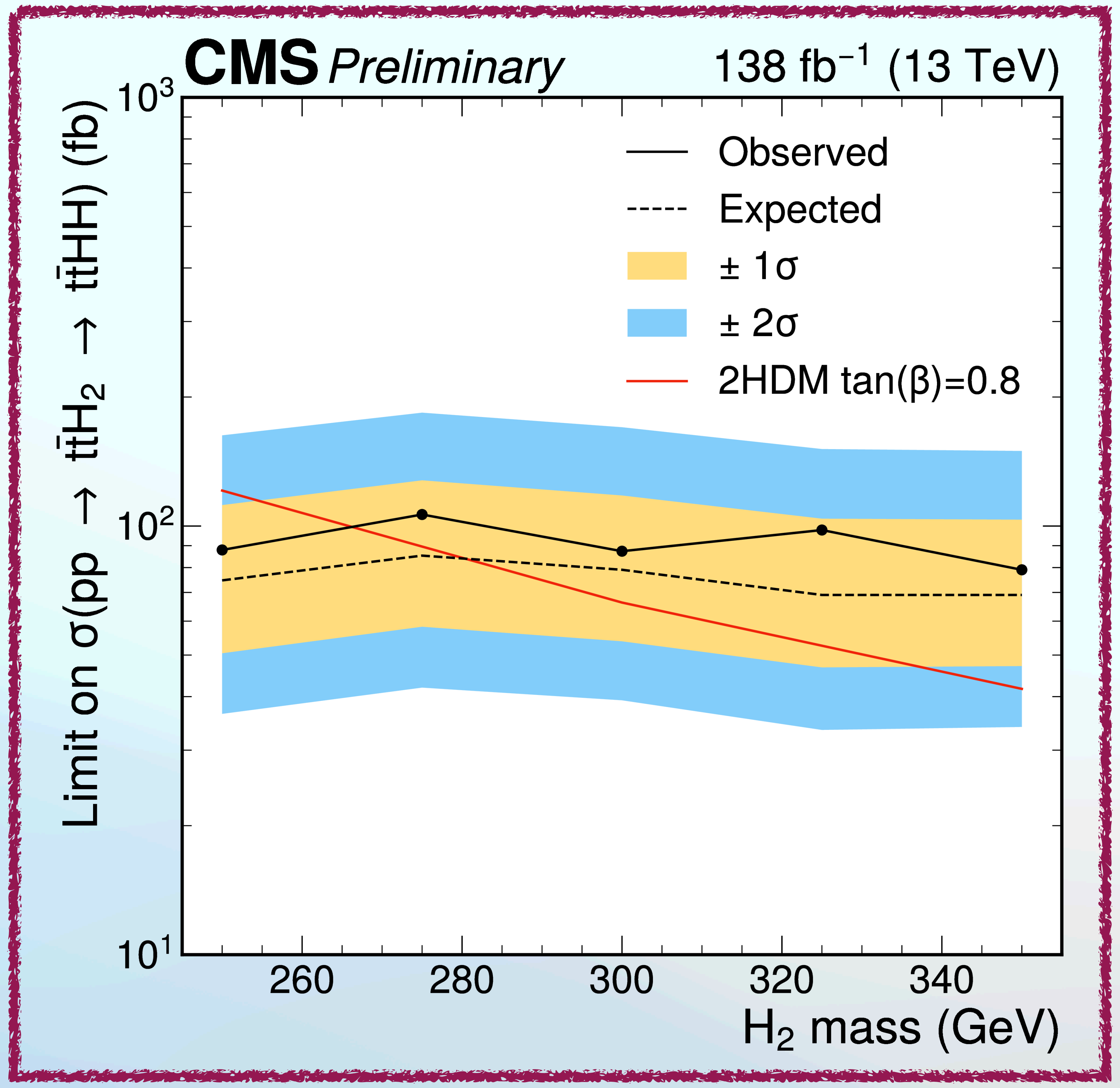


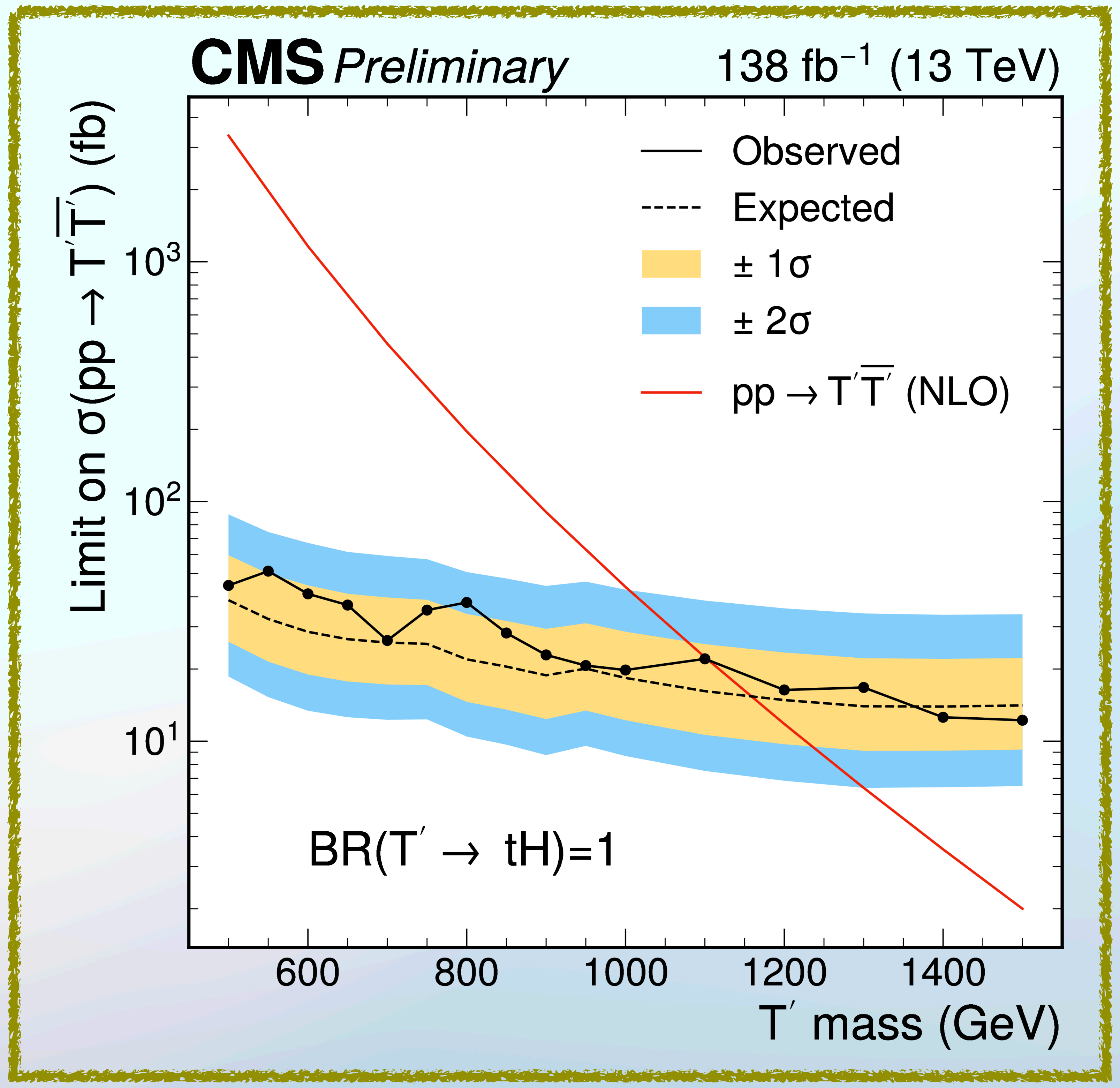
# CMS ttHH analysis (2)

CMS-PAS-HIG-23-004

Limits on **resonant production** of CP-even **heavy neutral scalar** $(H_2)$ in the context of **type-II 2HDM** and **heavy VLQ** $T'$ **pair production** in the $T' \rightarrow tH$ final state

*natural candidate to test HEFT vs. SMEFT*





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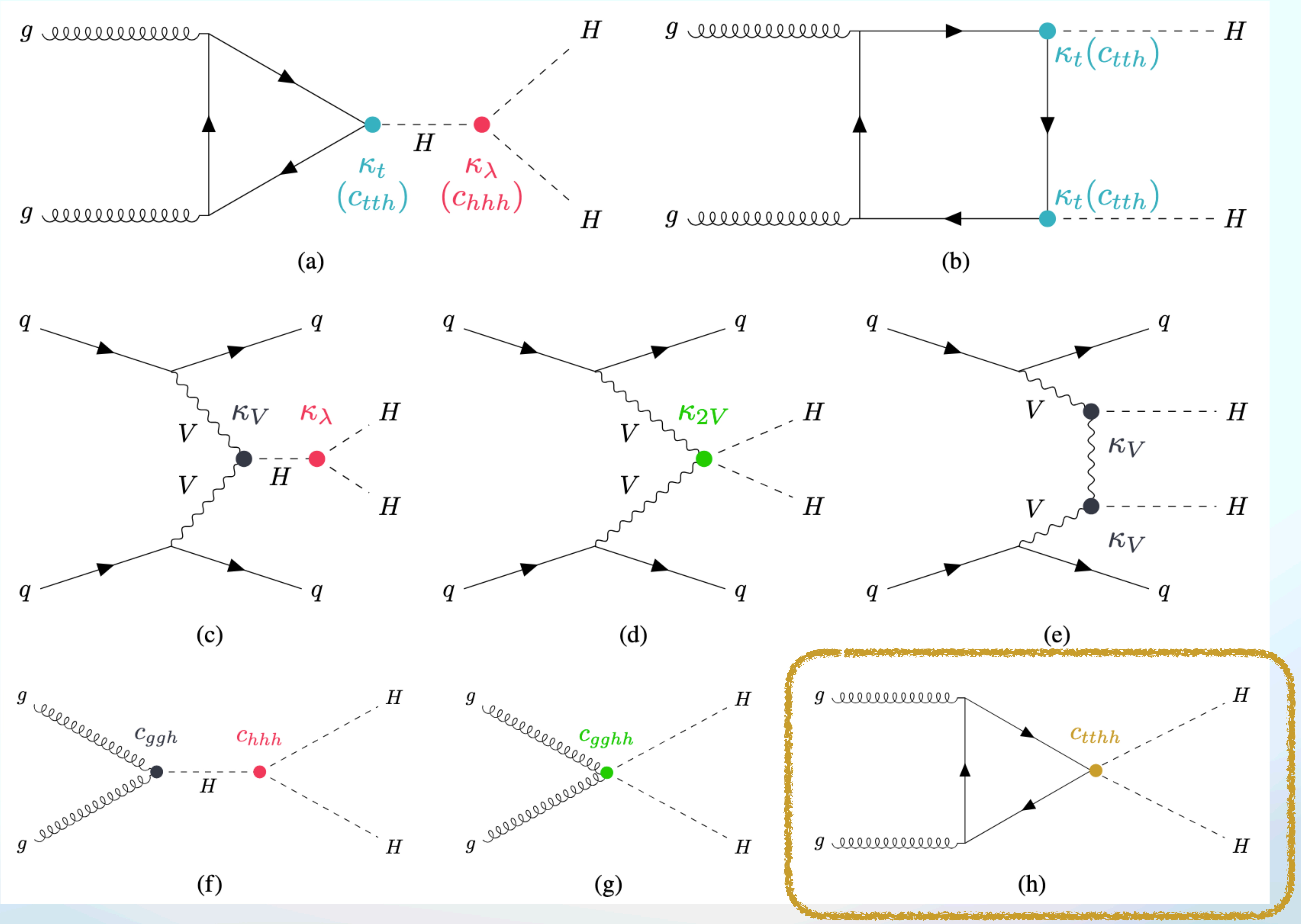
| | **CMS $t\bar{t}HH$**<br>[CMS-PAS-HIG-23-004] | **ATLAS HH comb.**<br>[arXiv:2406.09971] | **CMS HH comb.**<br>[arXiv:2510.07527] |
|---|---|---|---|
| Obs. 95% CL limits on $c_{t\bar{t}HH}$ | [-8.0, 7.5] | [-0.19, 0.7] | [-0.29, 0.59] |

# Comparison with ggF - HH



Parametrised with **more** couplings

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- **First search** for $t\bar{t}HH$ done by ATLAS
  - → Most stringent **direct limits** on $c_{t\bar{t}HH}$
- ggF more sensitive, but parametrised with two additional Higgs-gluon couplings : $c_{ggH}$ and $c_{ggHH}$
  - → In $t\bar{t}HH$, these enter at higher loop order
  - → More challenging in ggF unless further assumptions imposed

| | **CMS $t\bar{t}HH$**<br>[CMS-PAS-HIG-23-004] | **ATLAS HH comb.**<br>[arXiv:2406.09971] | **CMS HH comb.**<br>[arXiv:2510.07527] |
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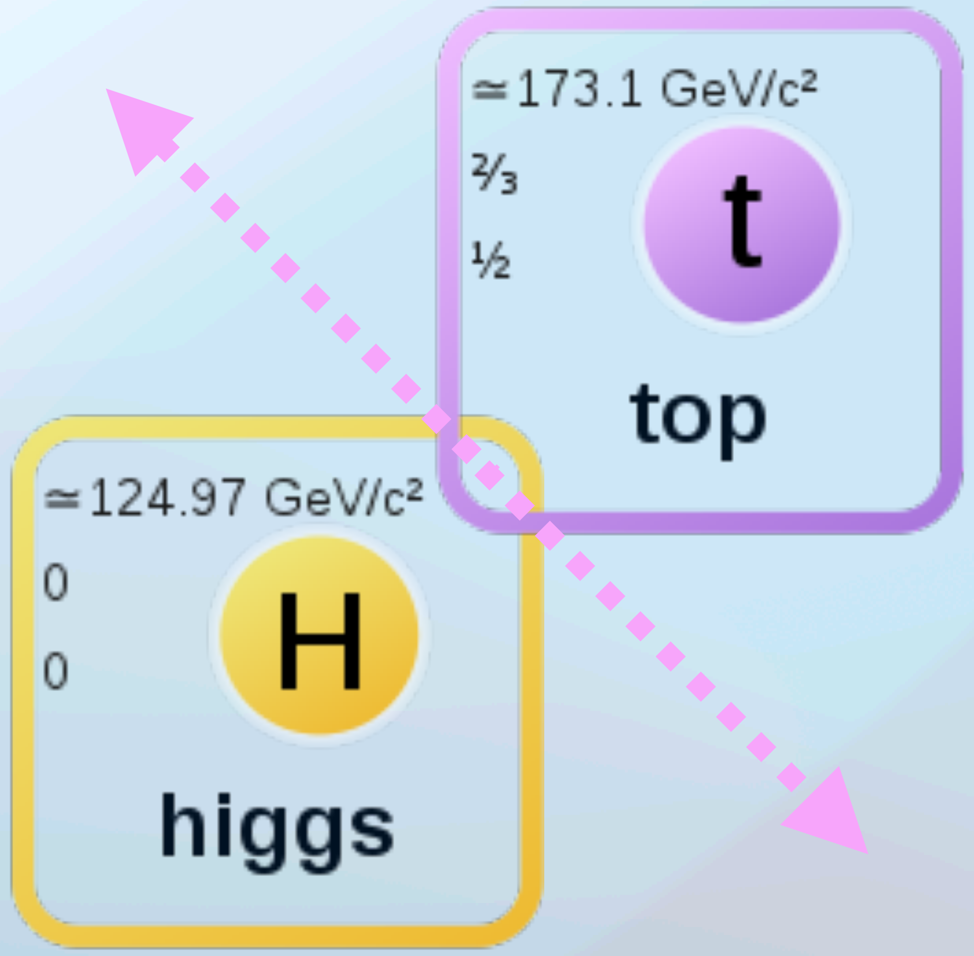
# Conclusion and prospects

$t\bar{t}HH$ is promising but still limited

→ Importance of multi-top processes such as $t\bar{t}t\bar{t}$, $t\bar{t}H$

→ Factor ~2 of size of 95%CL interval by the end of Run 4

*ATLAS internal studies ongoing*



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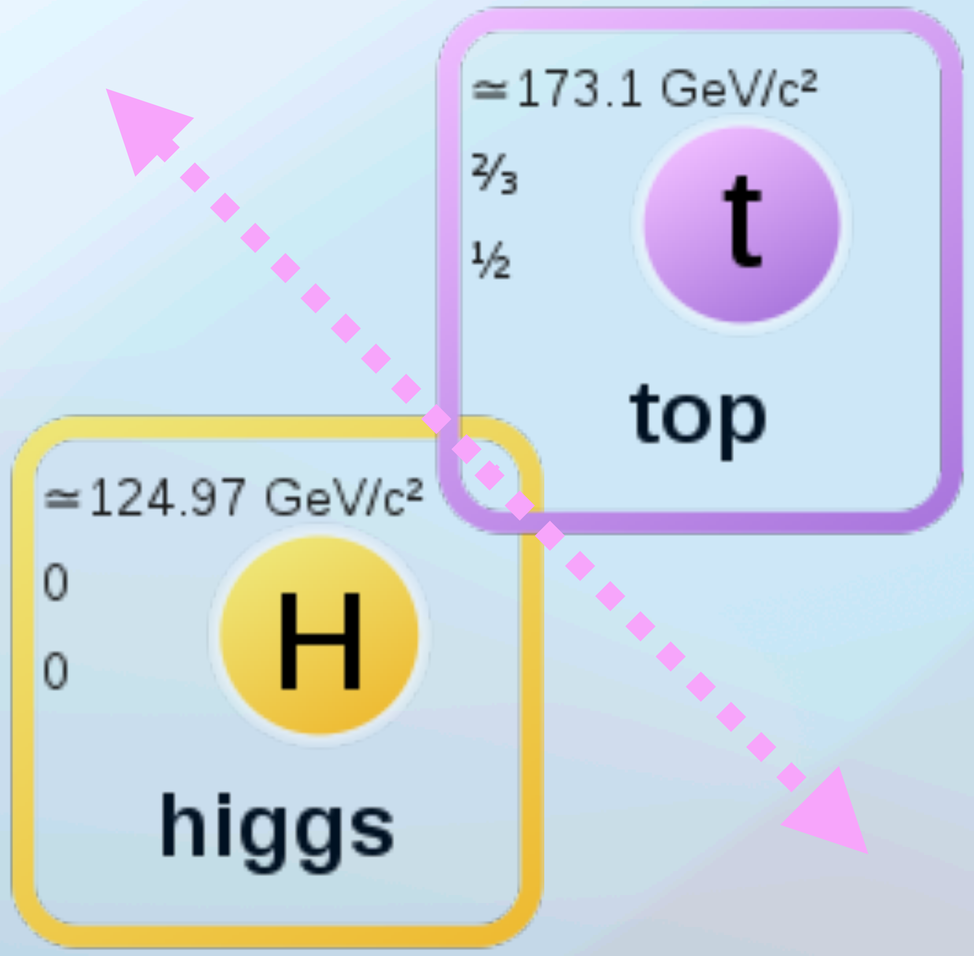
Still **a lot** of room for improvement

→ Combinations, between analysis, and between experiments

→ *Higher order effets* to be taken into account (running of the coeffs)

→ Designing analysis specifically for EFT



# Conclusion and prospects

$t\bar{t}HH$ is promising but still limited

→ Importance of multi-top processes such as $t\bar{t}t\bar{t}$, $t\bar{t}H$

→ Factor ~2 of size of 95%CL interval by the end of Run 4

*ATLAS internal studies ongoing*

Still **a lot** of room for improvement

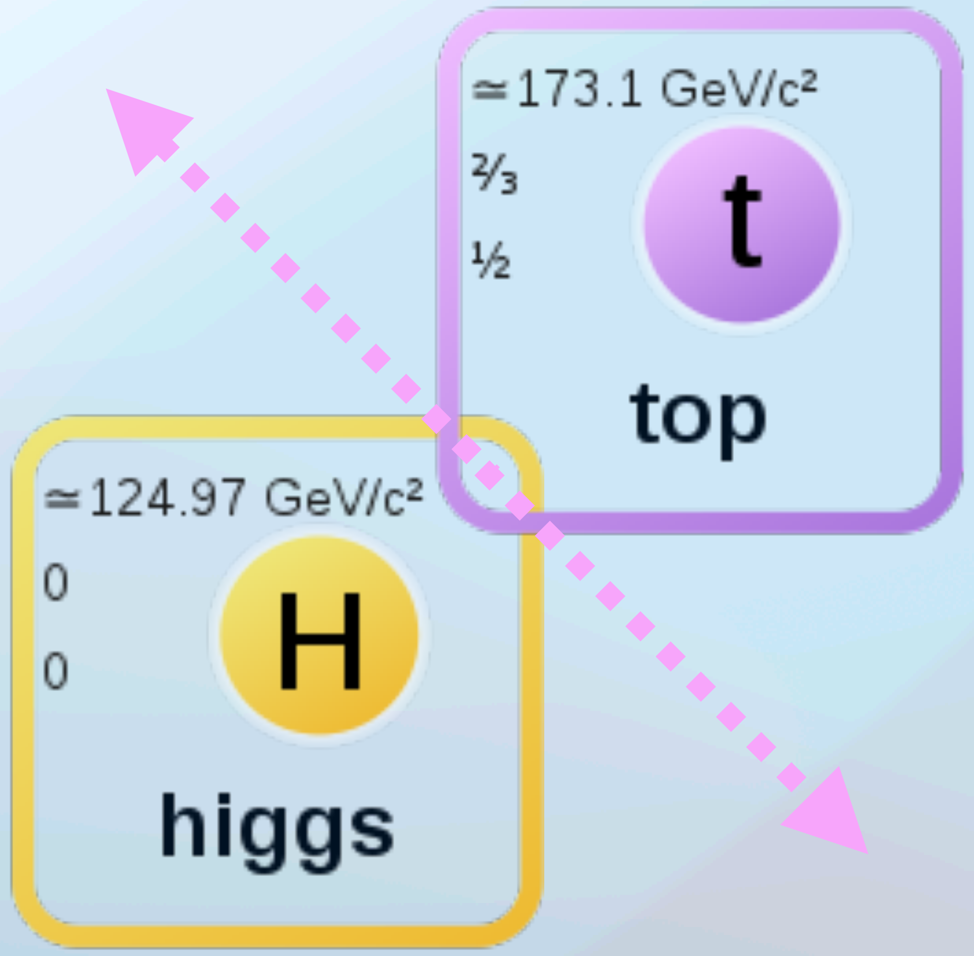
→ Combinations, between analysis, and between experiments

→ *Higher order effets* to be taken into account (running of the coeffs)

→ Designing analysis specifically for EFT

**HEFT** vs. "*traditional*" **SMEFT** interpretion *when relevant*

*What UV model have different predictions in both frameworks?*



# Conclusion and prospects

$t\bar{t}HH$ is promising but still limited

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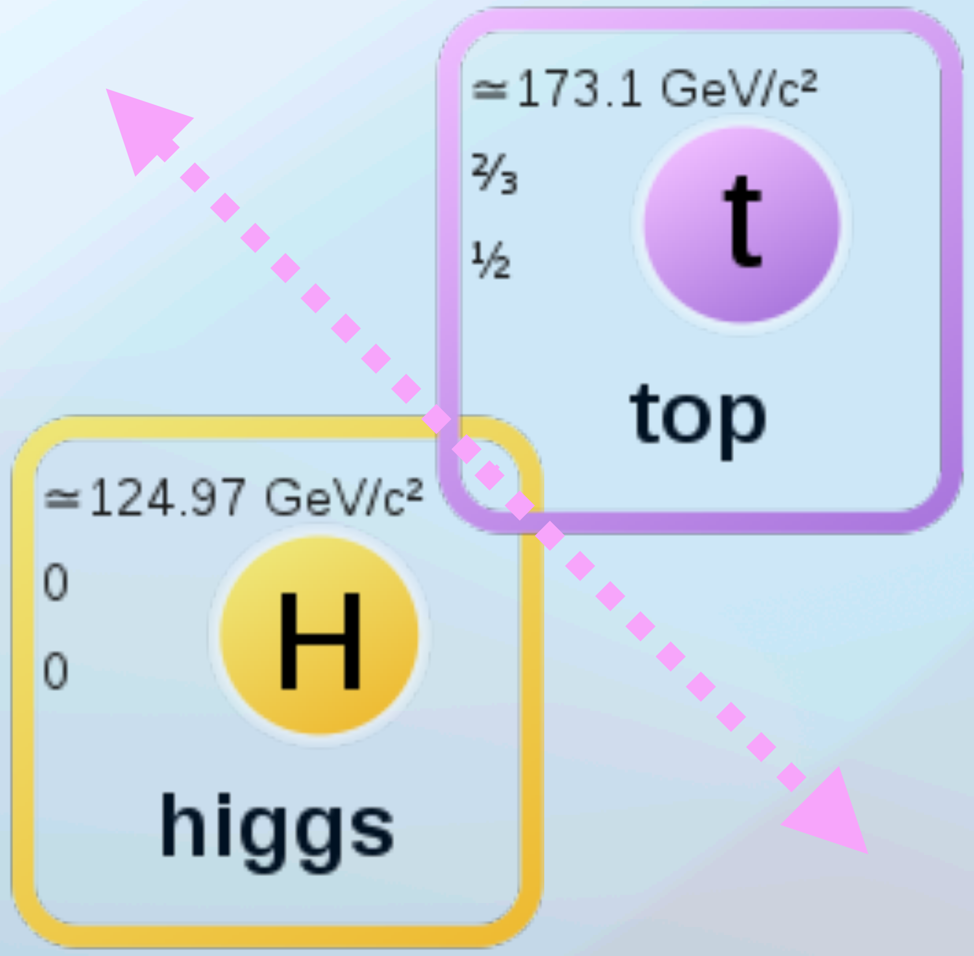
**HEFT** vs. "*traditional*" **SMEFT** interpretion *when relevant*

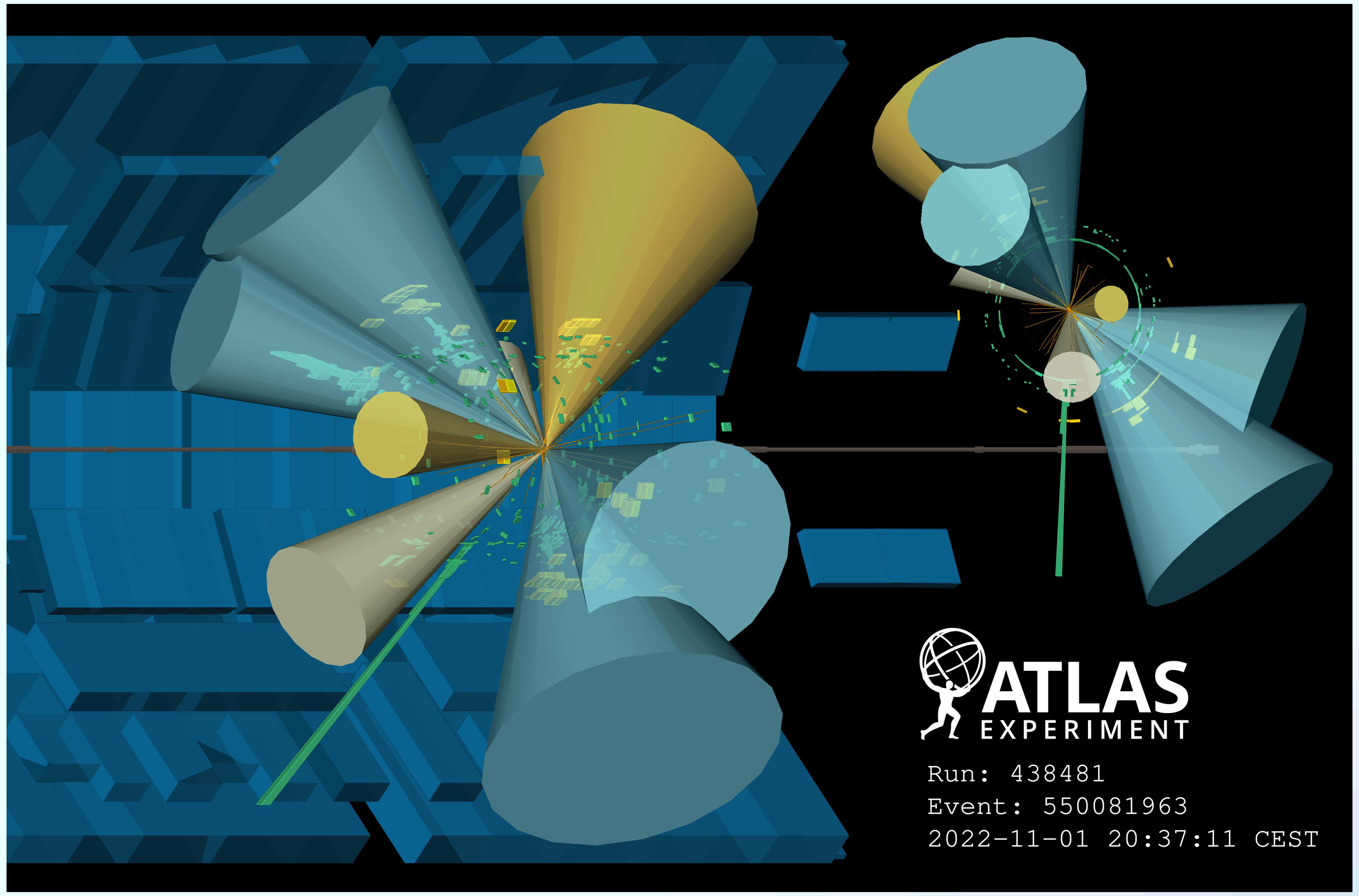
*What UV model have different predictions in both frameworks?*

Top and Higgs sectors are **promissing probes** for exploring EWSB + connexion to heavy NP



# Backup

# Single-lepton channel

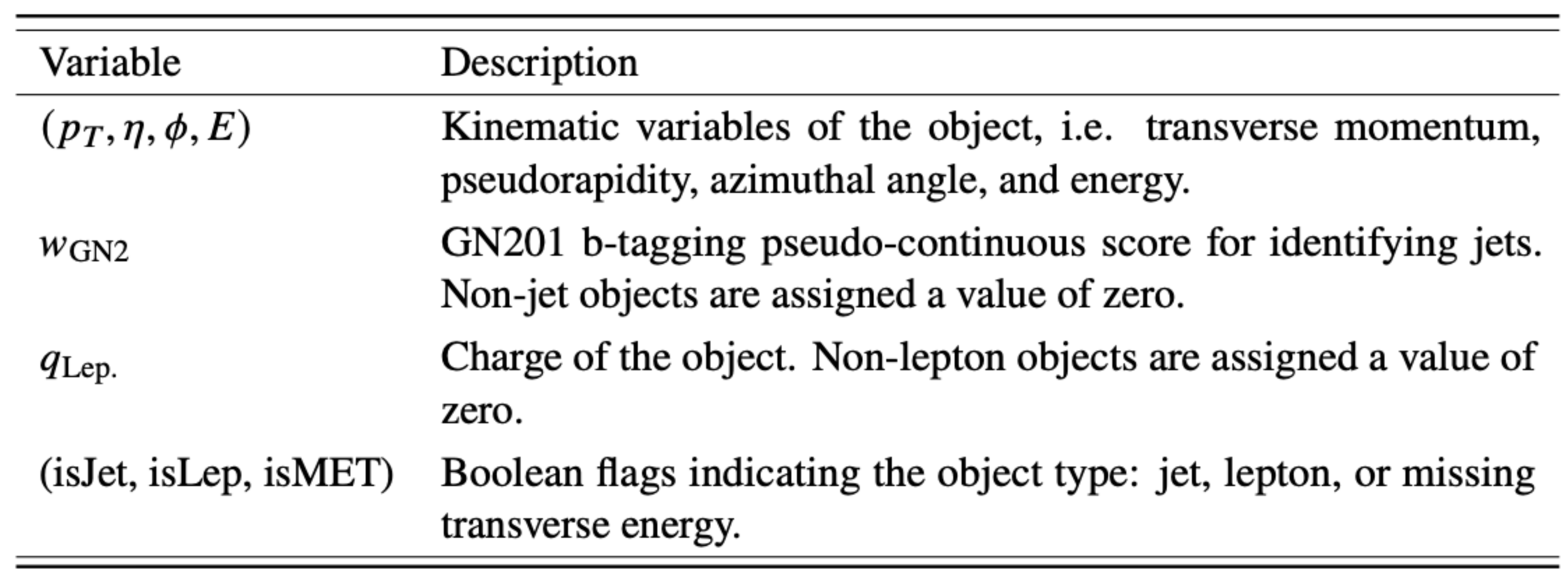


**Single lepton from W and $\geq$ 4 b-tagged jets**

Dominant background : $t\bar{t} + jets$

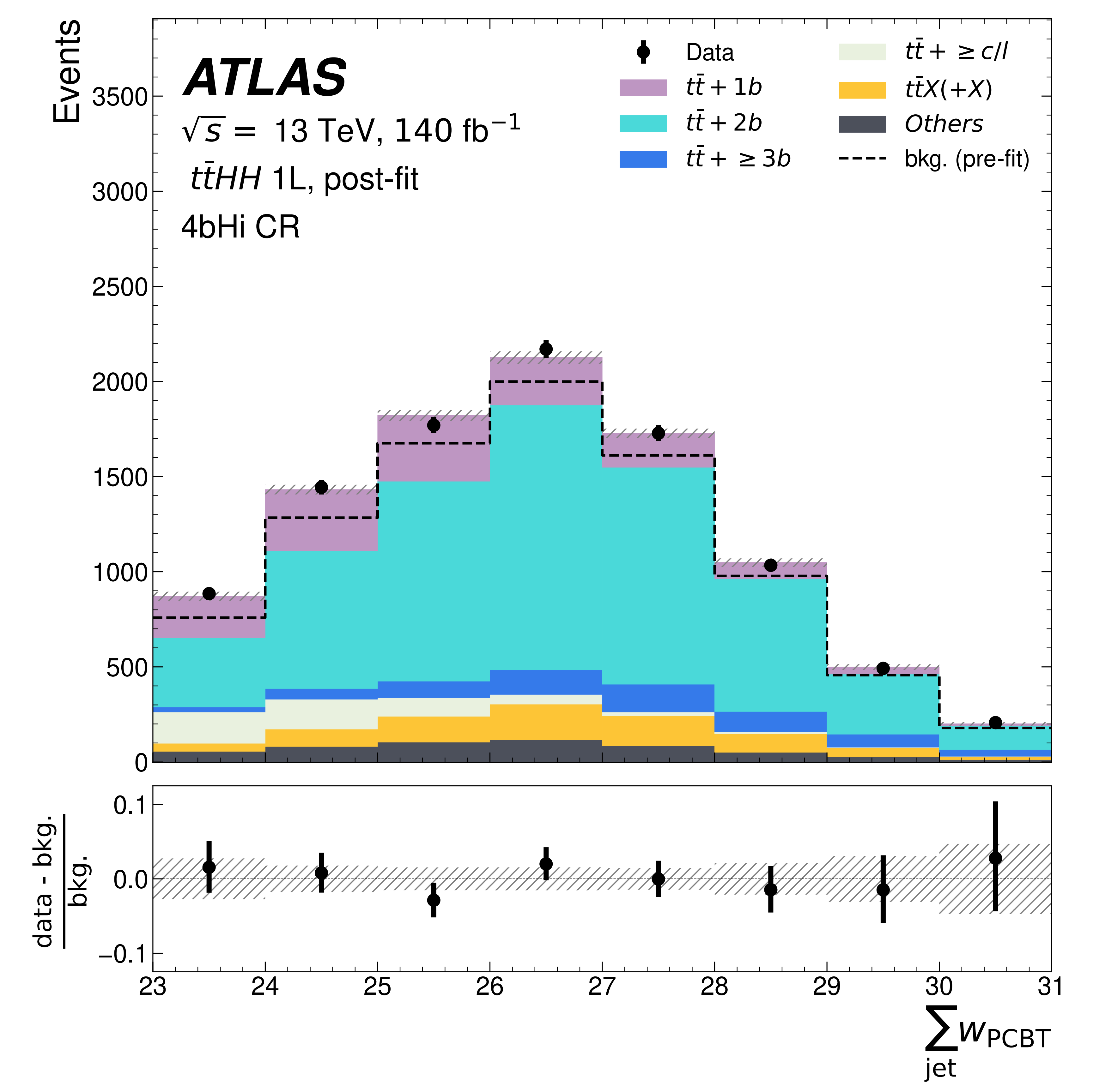
Signal / Background split by jet-multiplicity

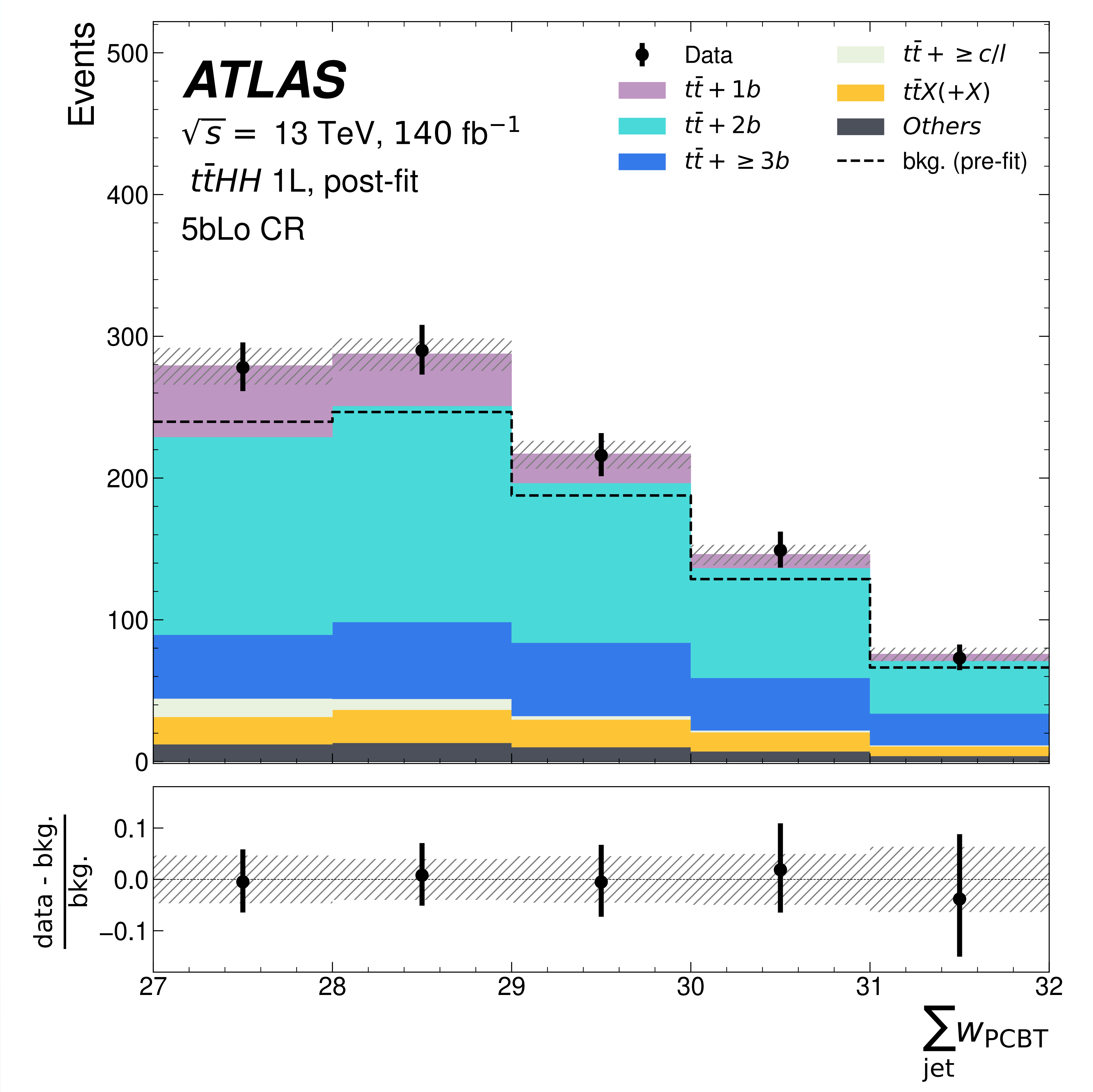
Fit from a GNN score



| Variable | Description |
|---|---|
| $(p_T, \eta, \phi, E)$ | Kinematic variables of the object, i.e. transverse momentum, pseudorapidity, azimuthal angle, and energy. |
| $w_{\mathrm{GN2}}$ | GN201 b-tagging pseudo-continuous score for identifying jets. Non-jet objects are assigned a value of zero. |
| $q_{\mathrm{Lep.}}$ | Charge of the object. Non-lepton objects are assigned a value of zero. |
| (isJet, isLep, isMET) | Boolean flags indicating the object type: jet, lepton, or missing transverse energy. |

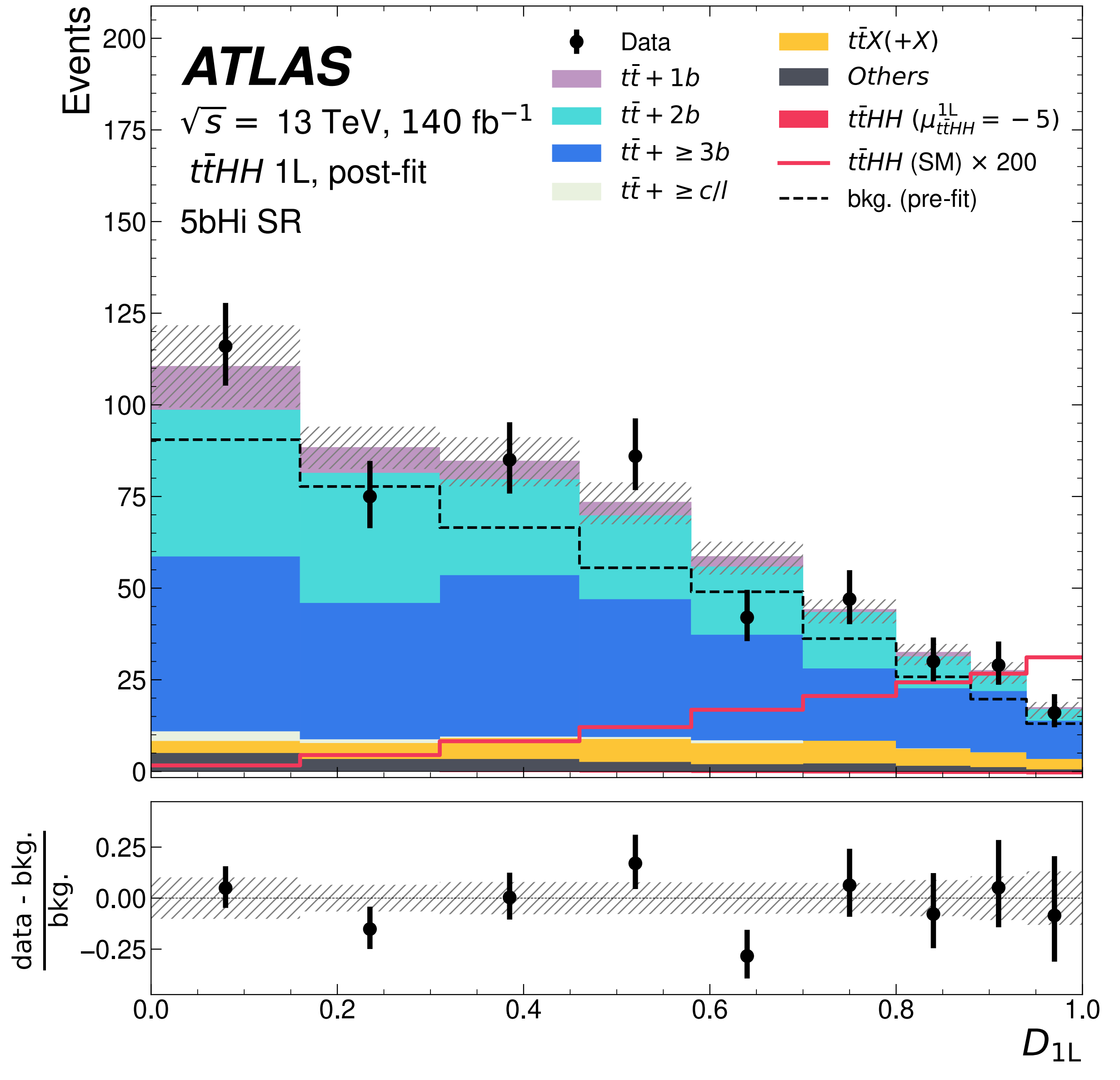
# 1L Run 2 CR distributions

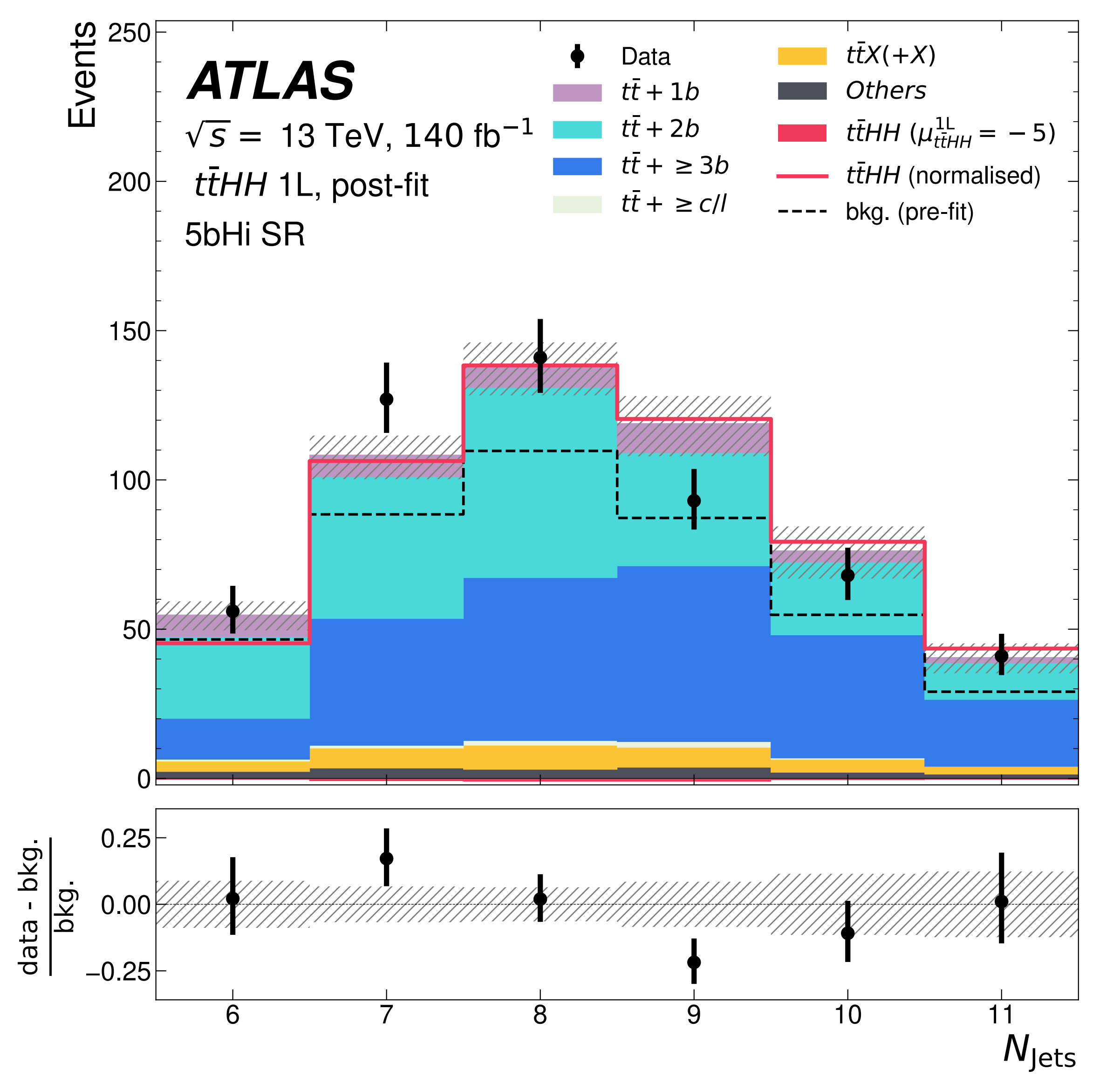


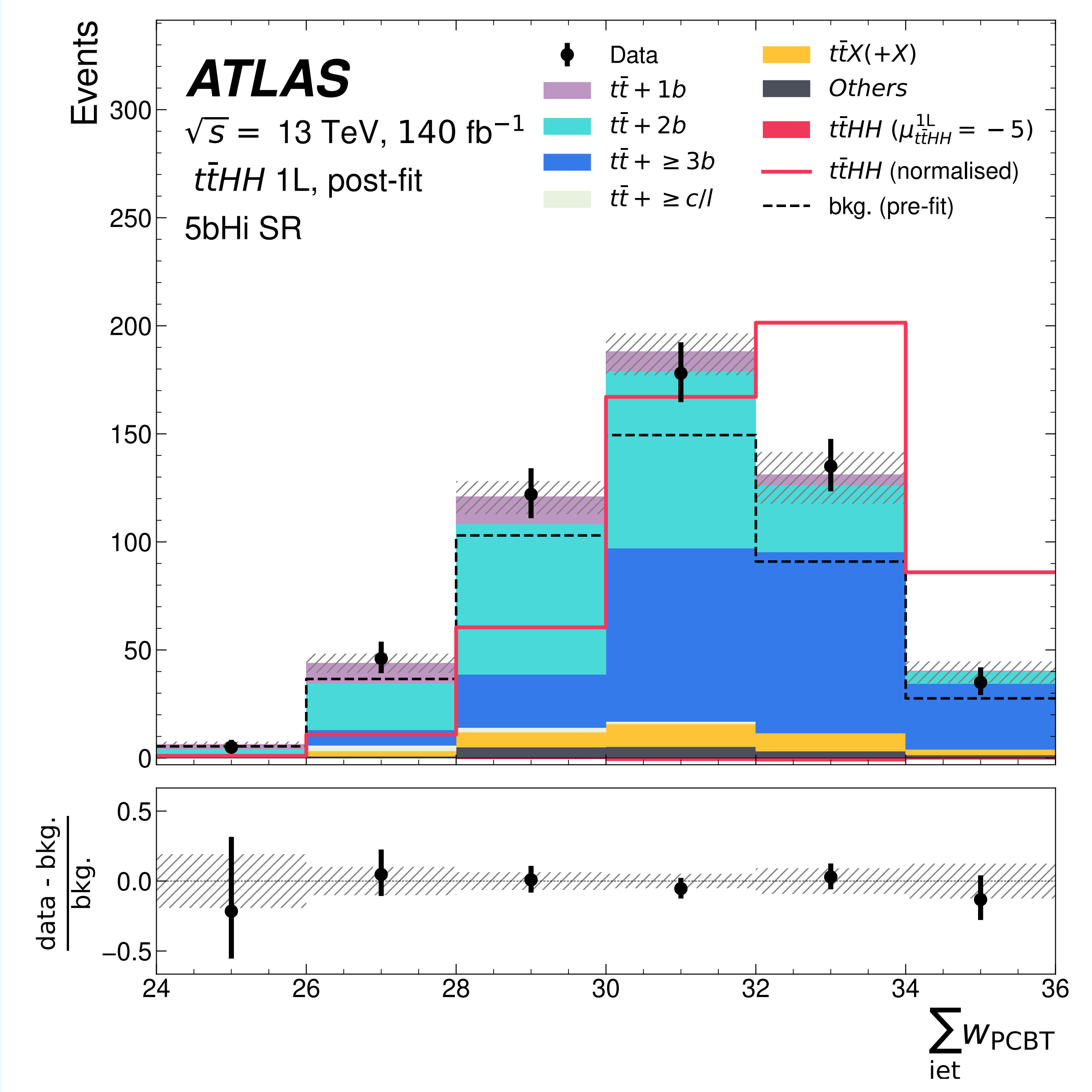


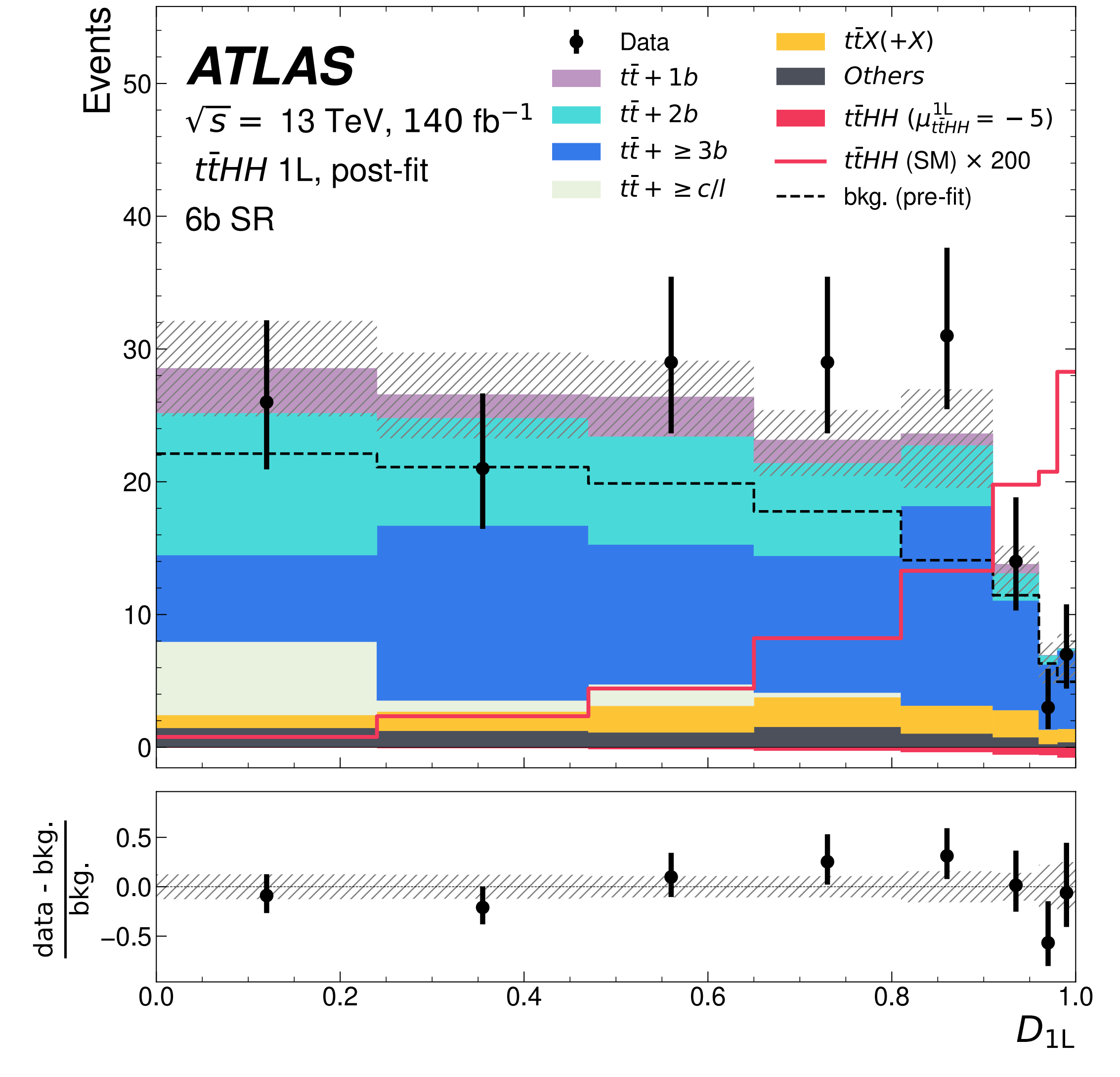
- Signal defined by jet multiplicity
- Well understood background

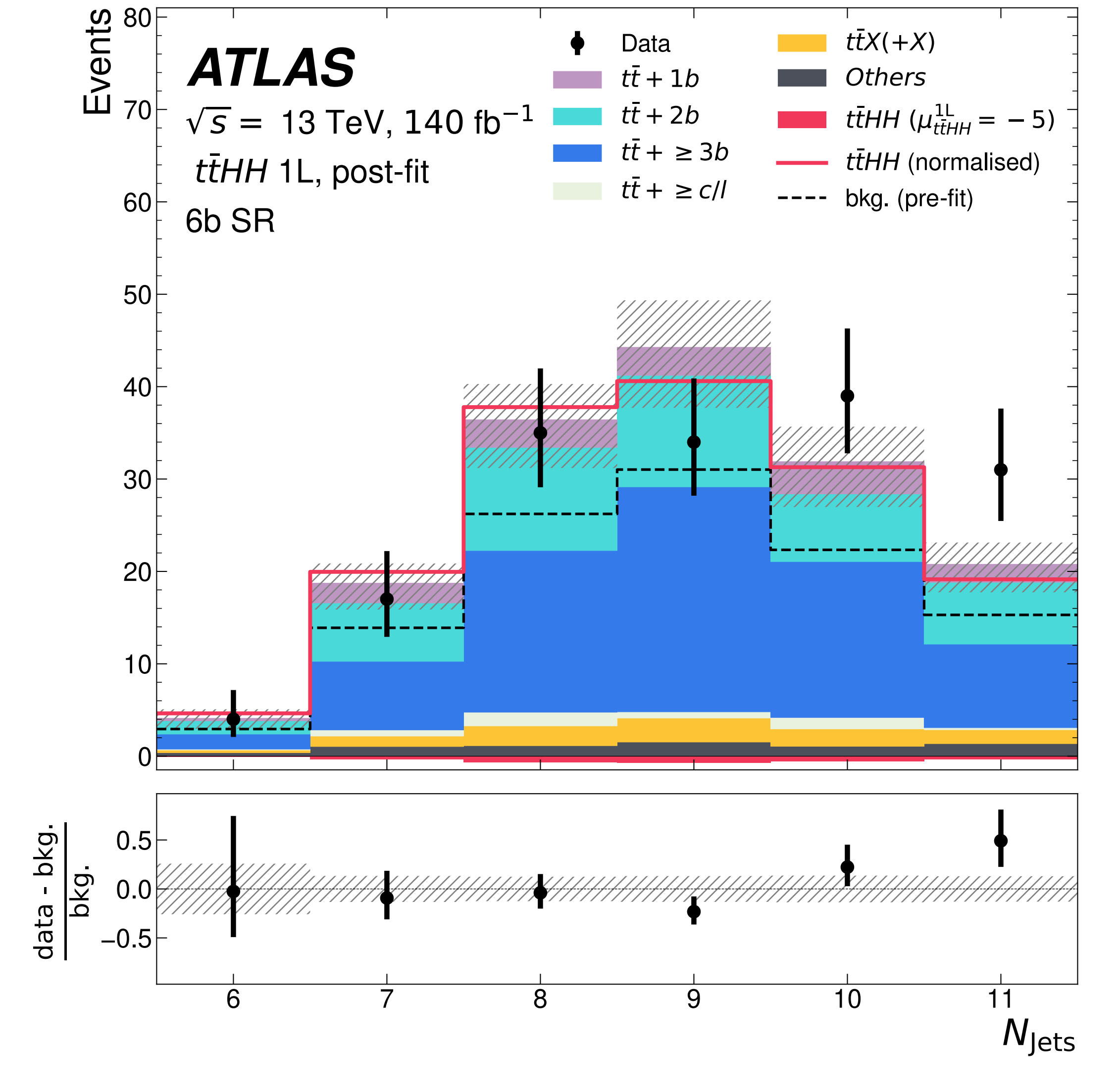
# 1L Run 2 SR distributions

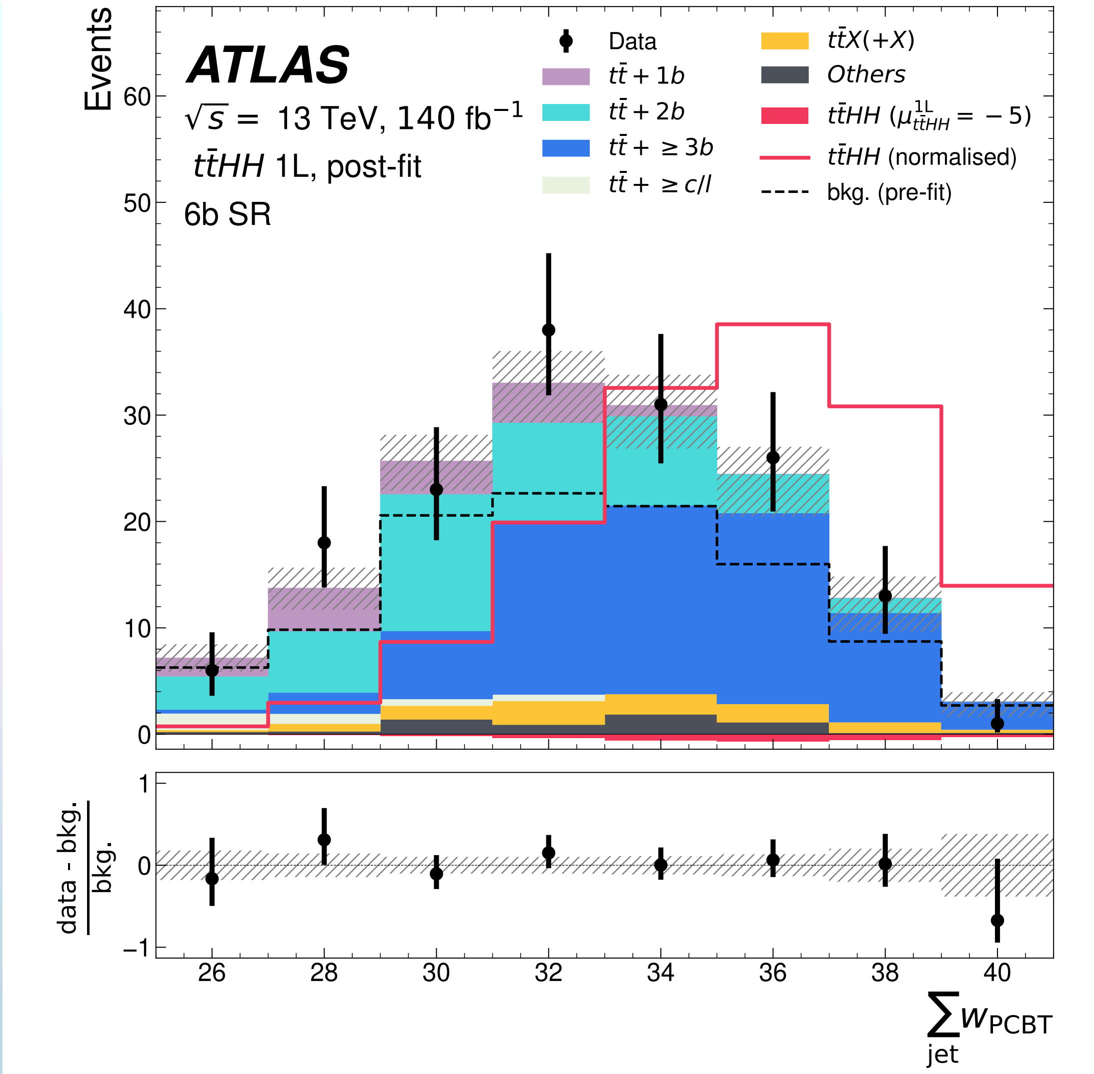




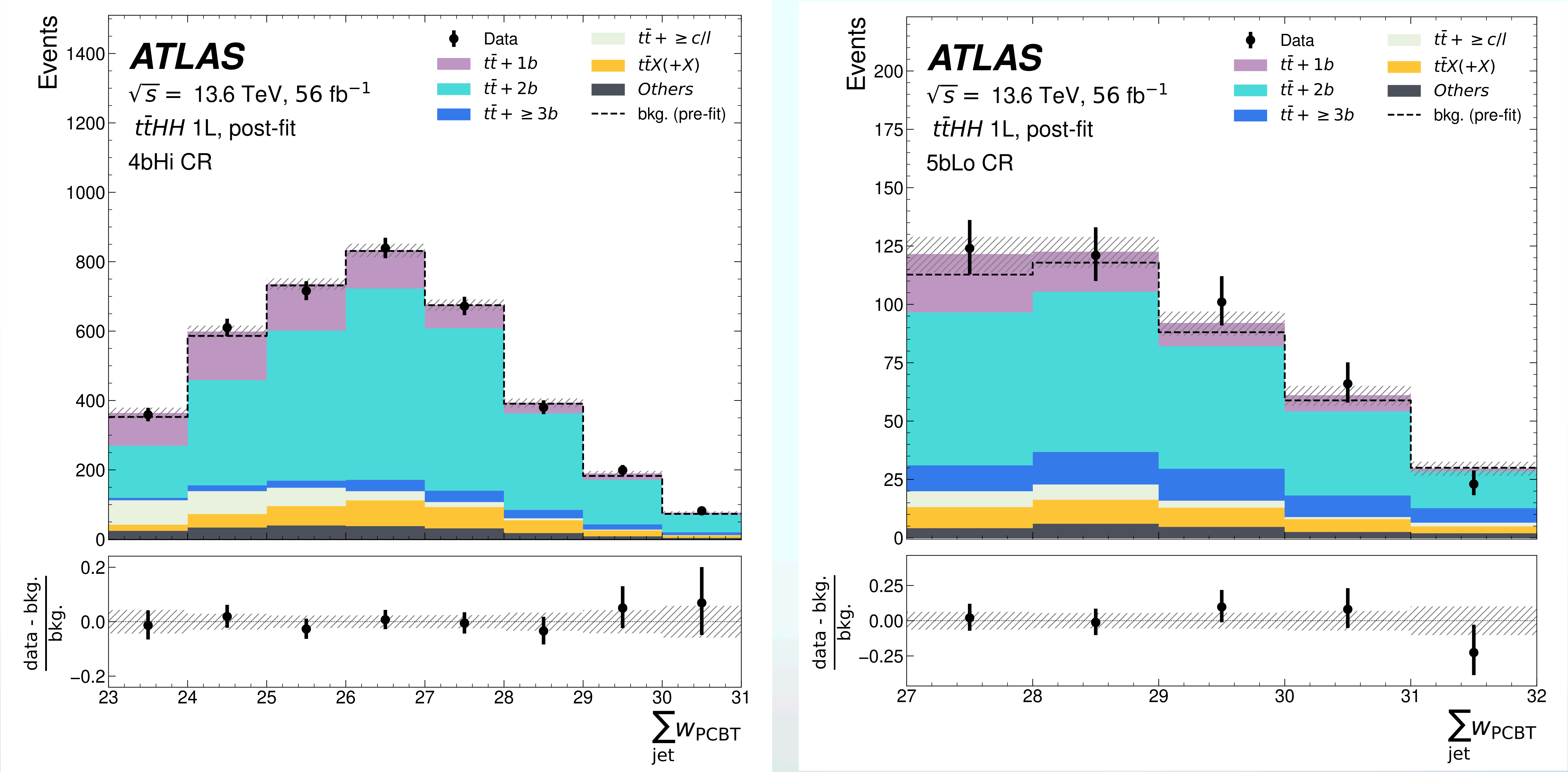








# 1L Run 3 CR distributions



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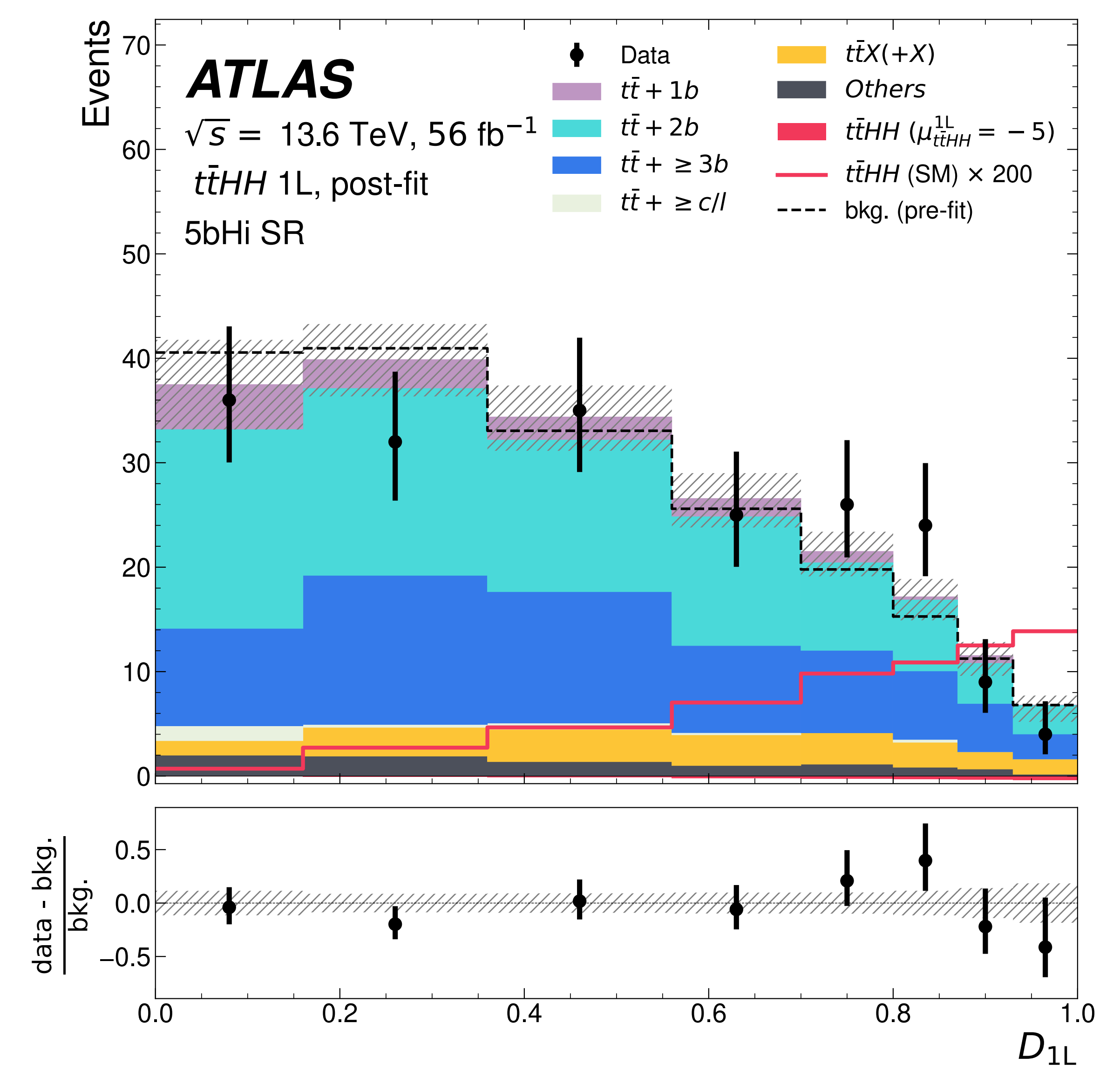
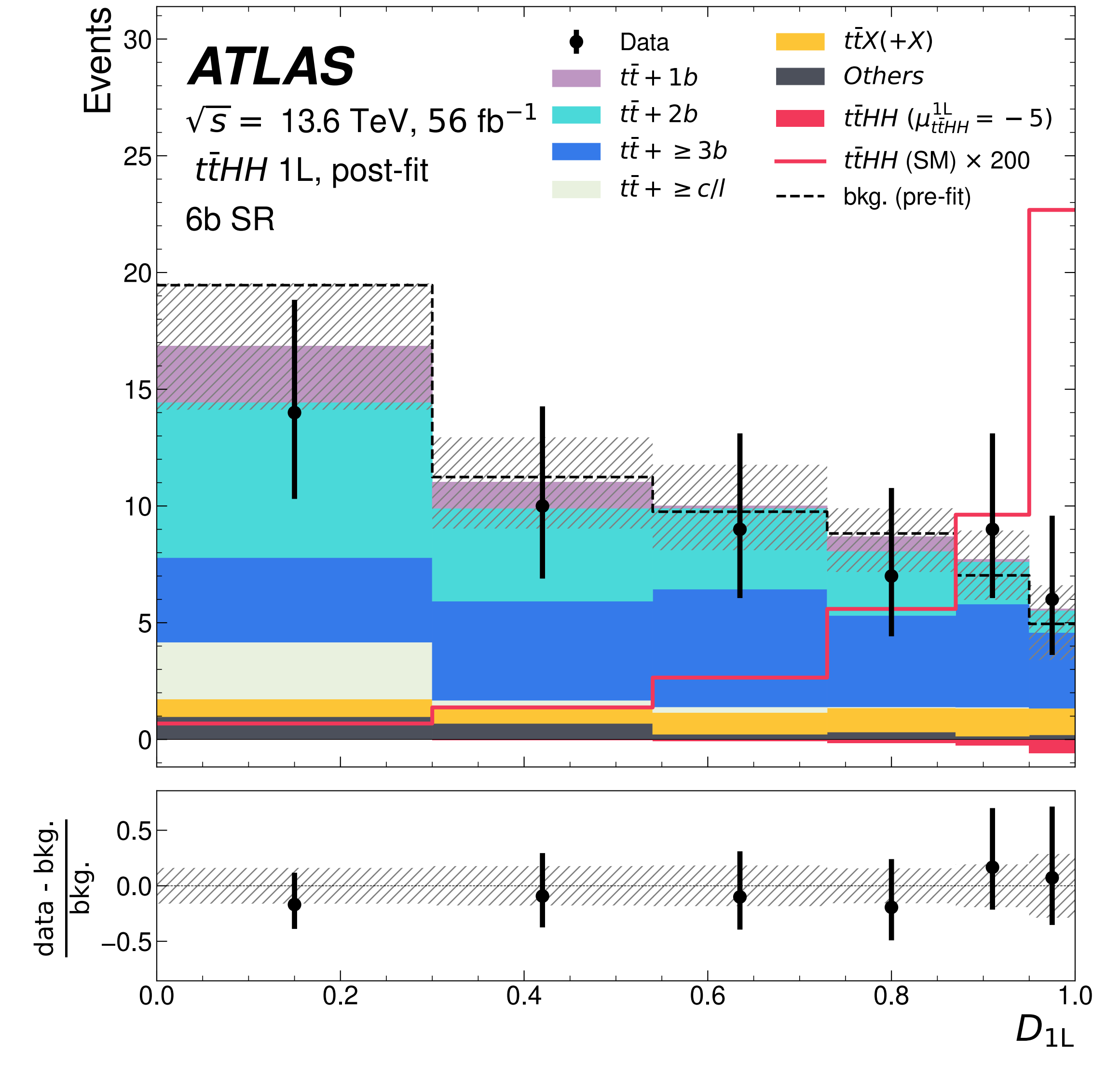
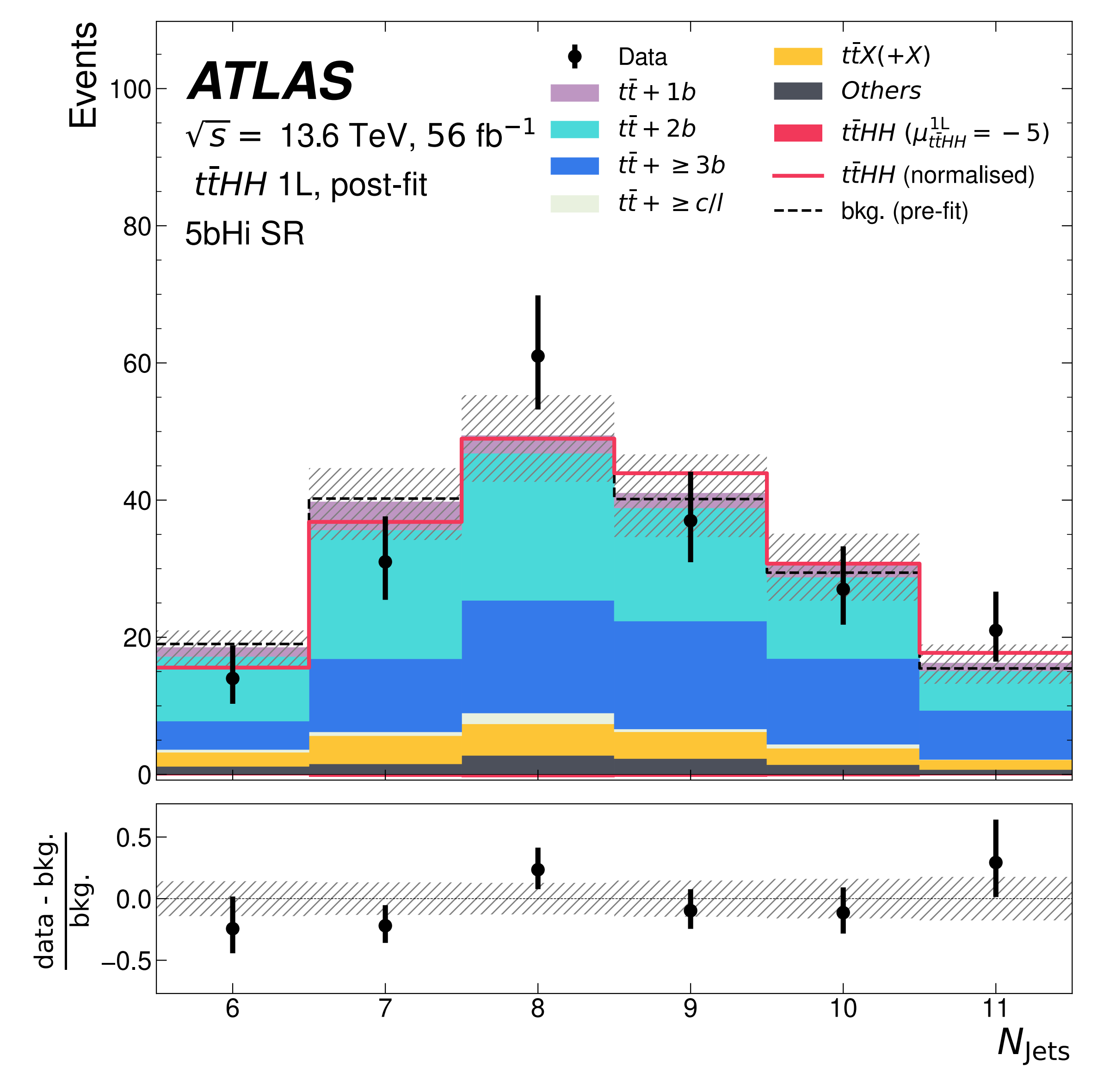
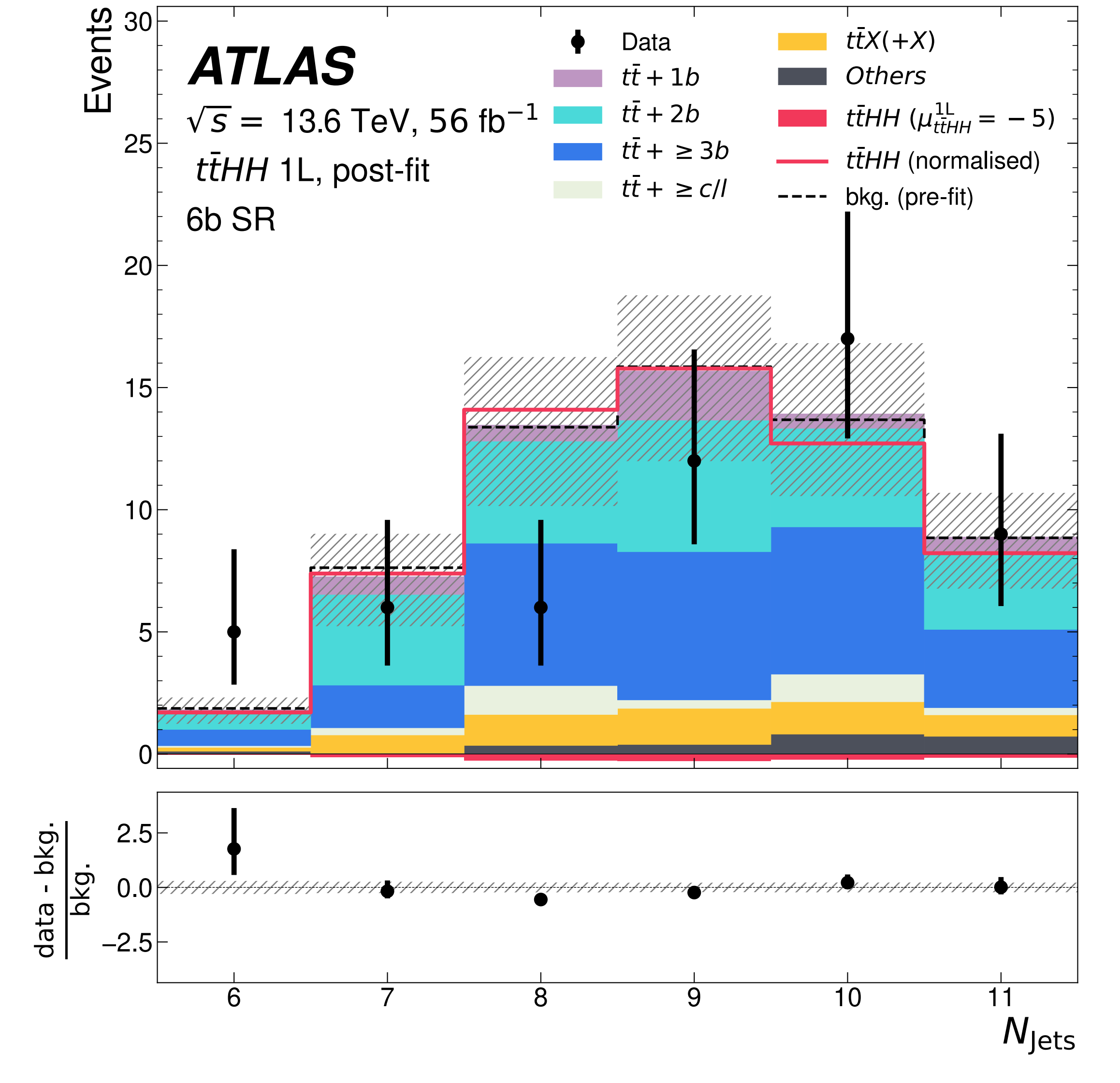
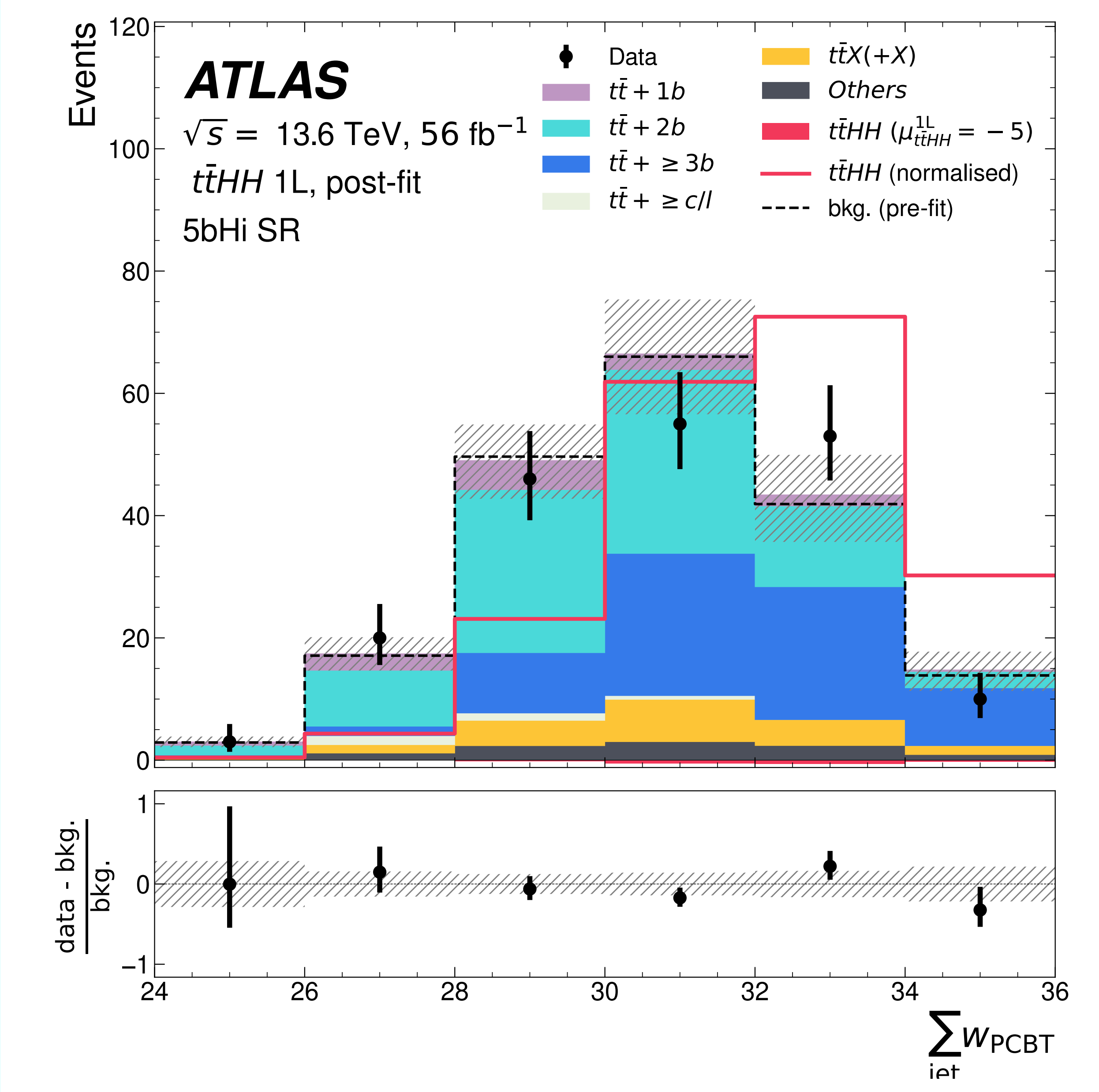
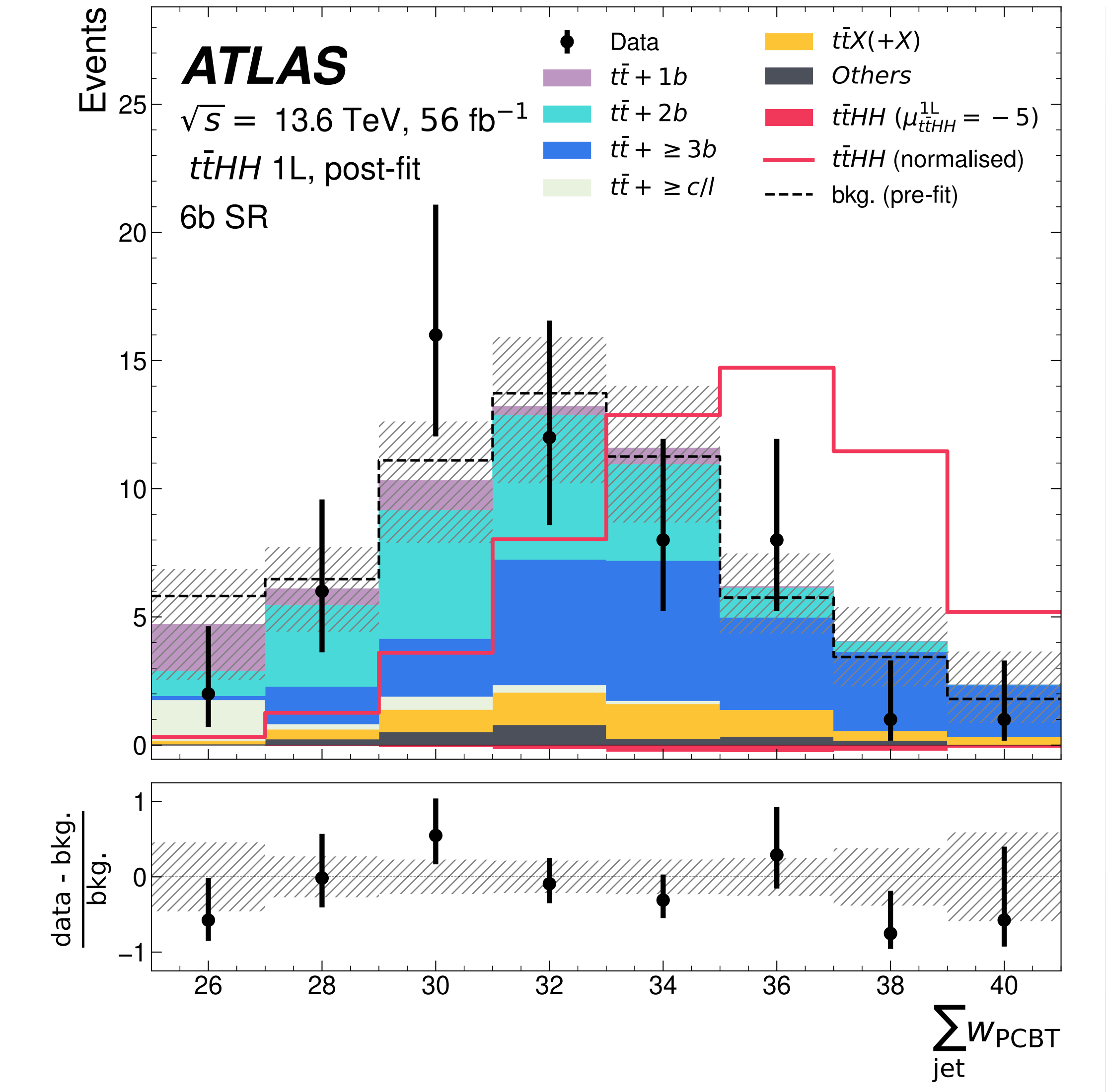












# Same-sign multi-lepton channel

**$\geq$ 2 b-tagged jets**

**$\geq$ 2 same-sign leptons from top and Higgs**

Dominant irreducible backgrounds :

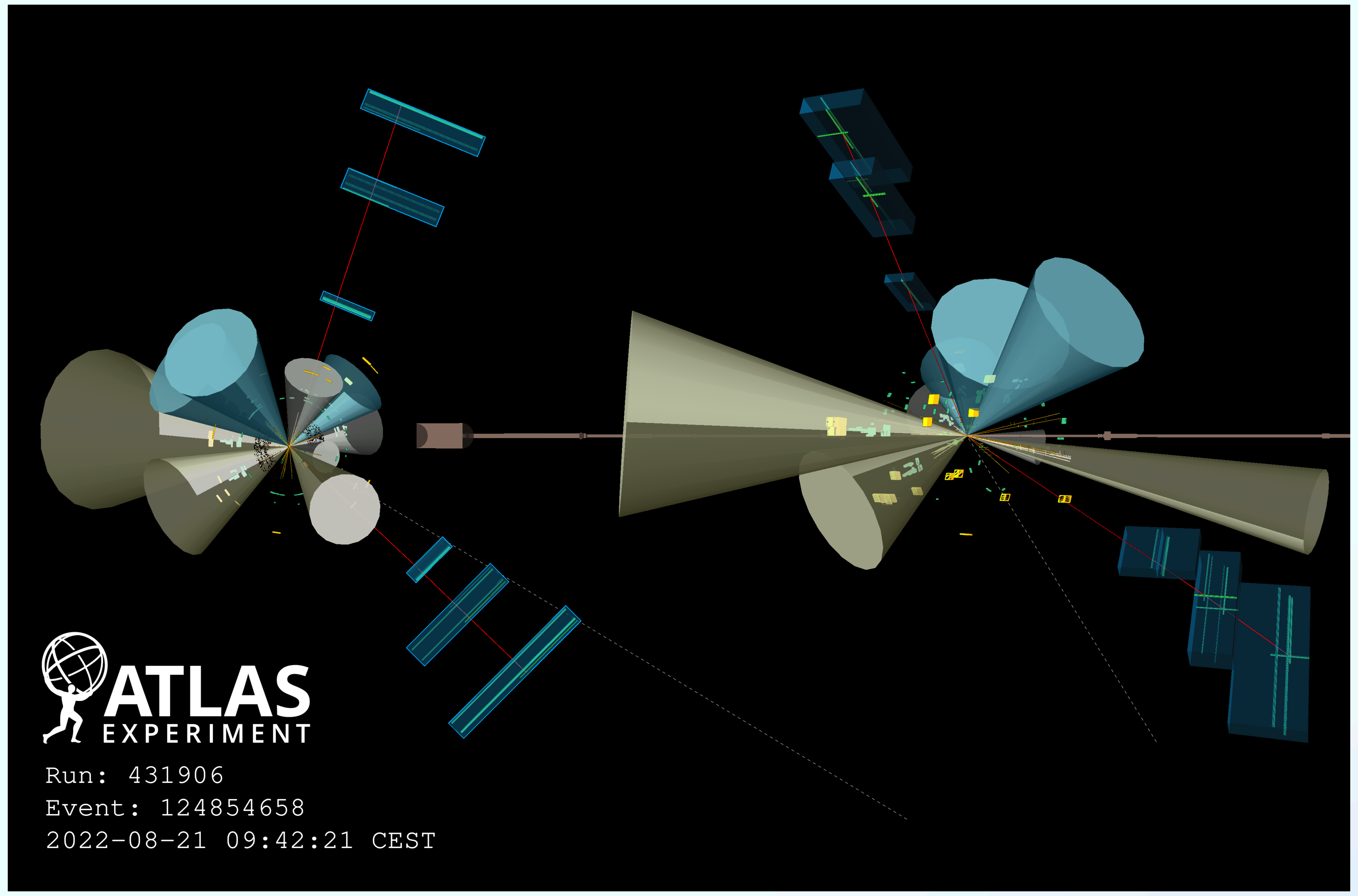
$t\bar{t}W$ and $t\bar{t}t\bar{t}$ normalization

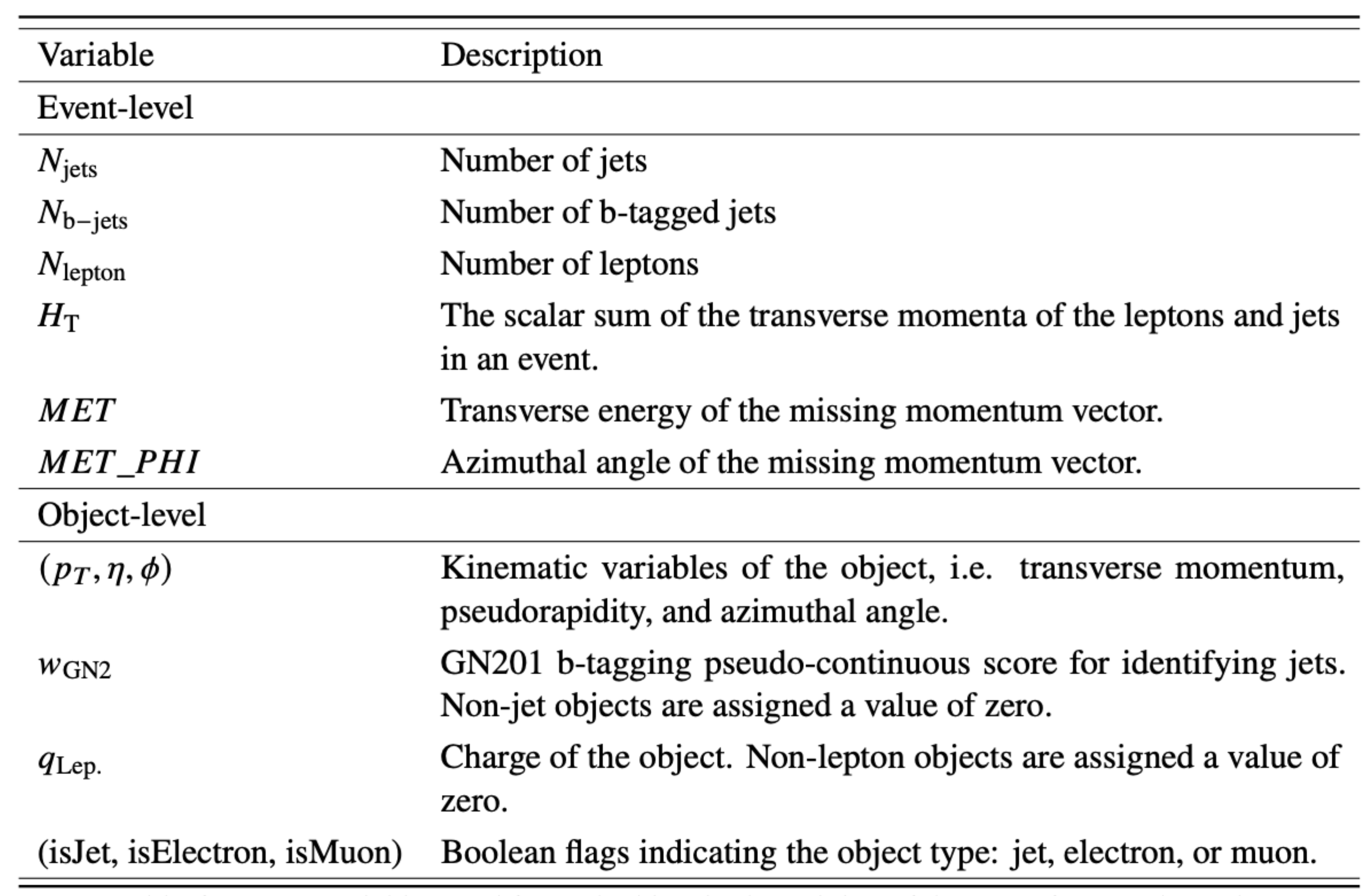
Channel which suffers a lot from instrumental backrounds :

→ Charge mis-identification

→ "Fake" leptons from HF decays or photon conversions

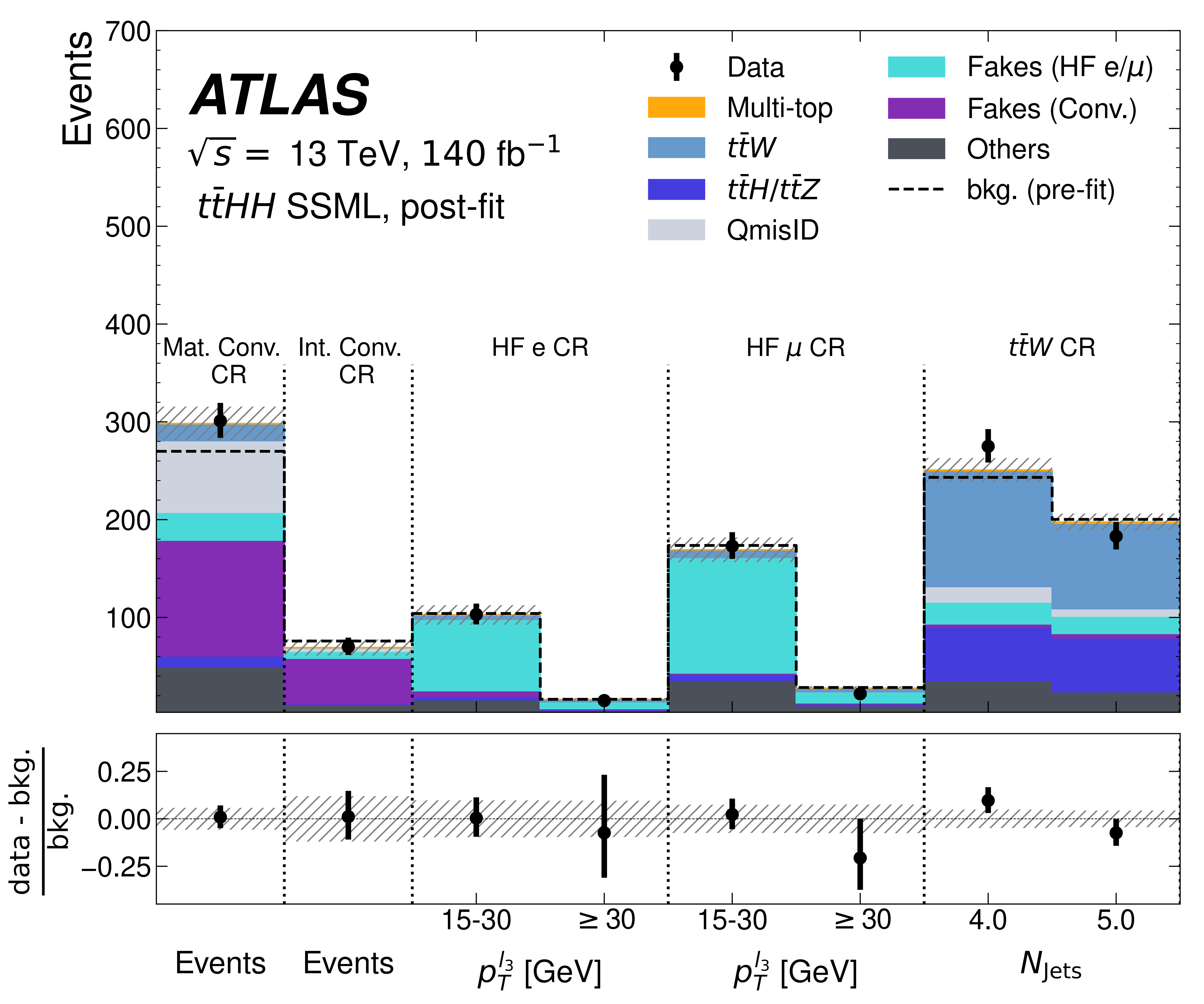
*i.e. photons which look like lepton*



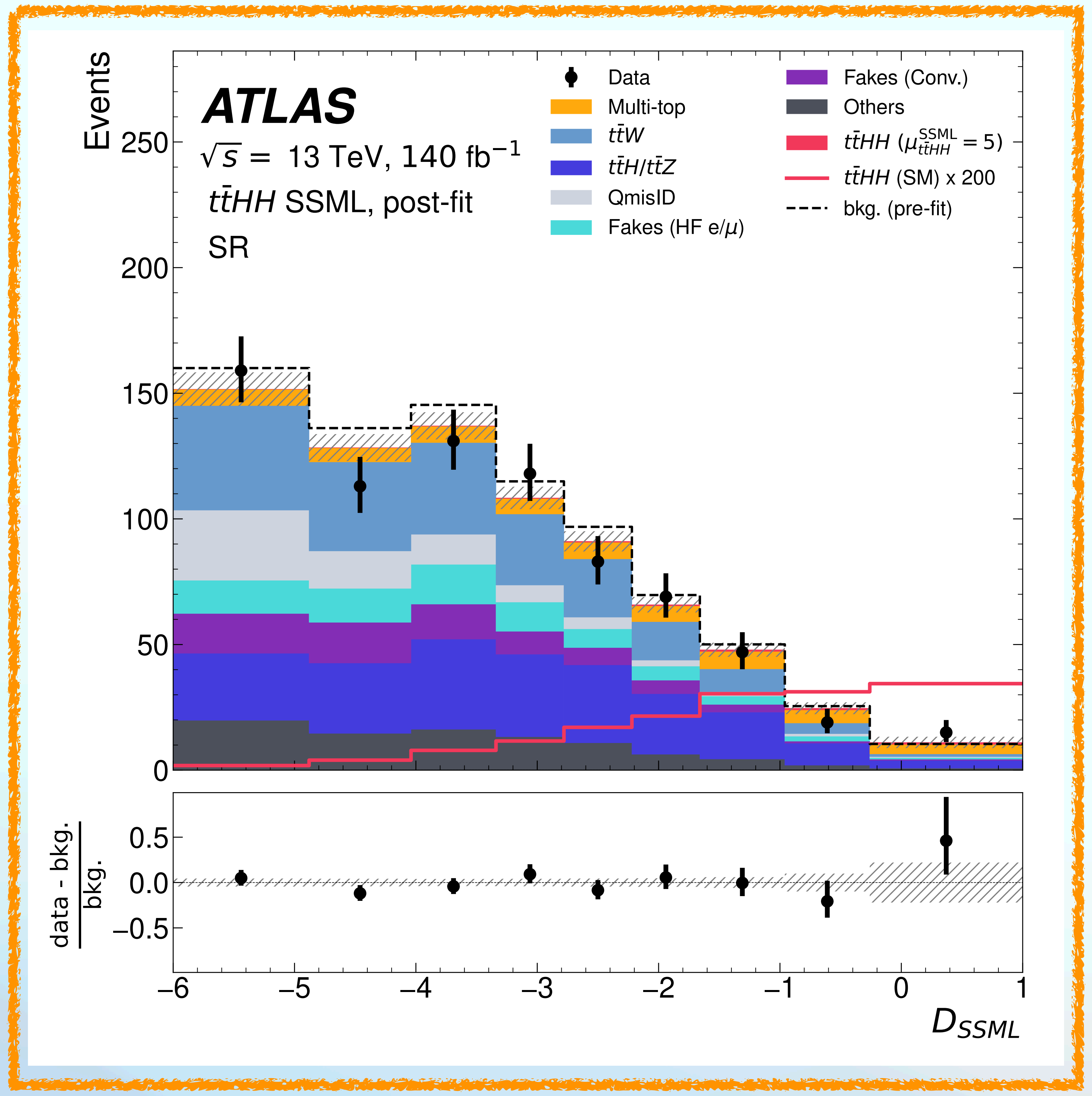


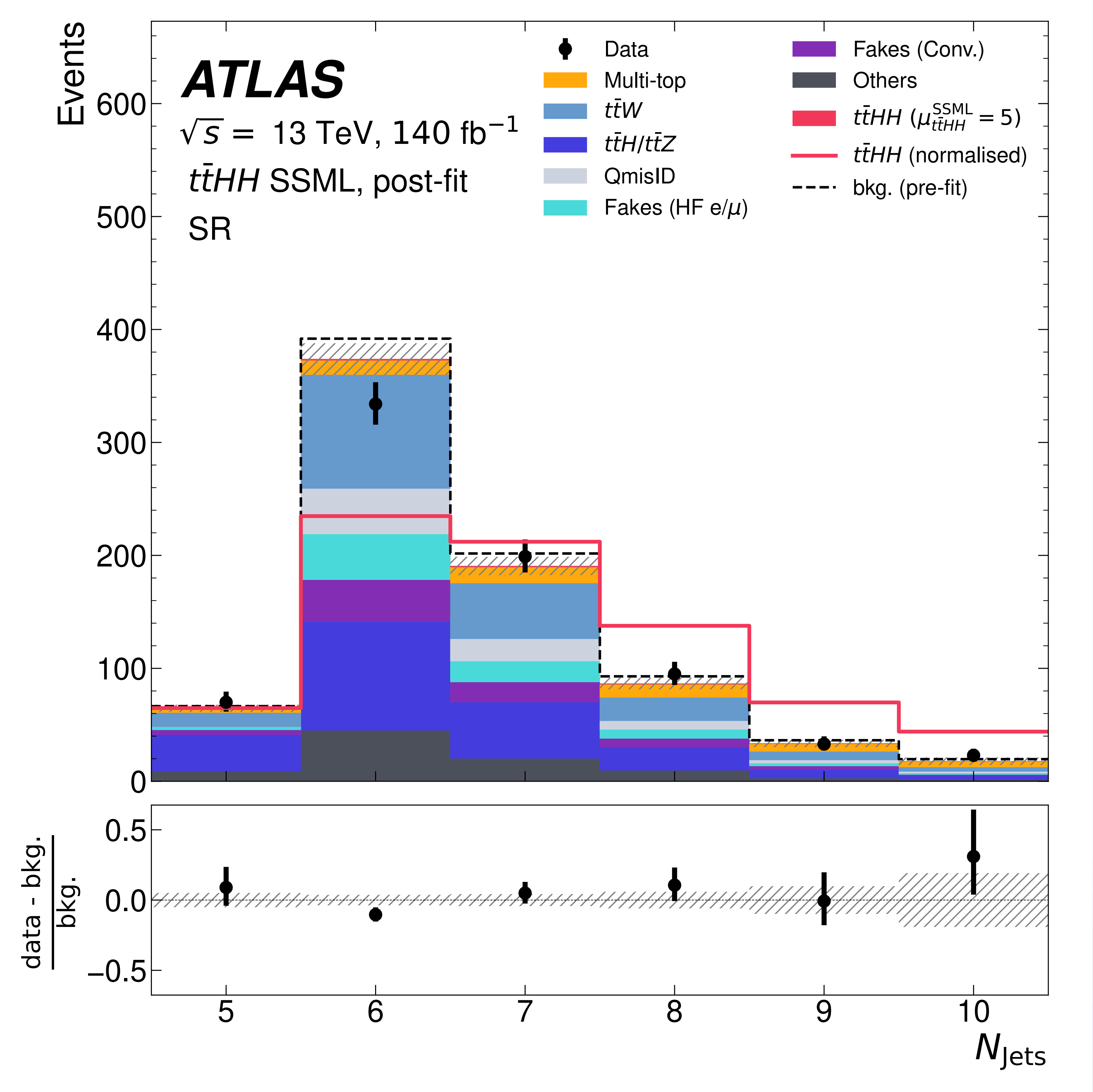
| Variable | Description |
|---|---|
| Event-level | |
| $N_{\text{jets}}$ | Number of jets |
| $N_{\text{b-jets}}$ | Number of b-tagged jets |
| $N_{\text{lepton}}$ | Number of leptons |
| $H_{\text{T}}$ | The scalar sum of the transverse momenta of the leptons and jets in an event. |
| $MET$ | Transverse energy of the missing momentum vector. |
| $MET\_PHI$ | Azimuthal angle of the missing momentum vector. |
| Object-level | |
| $(p_T, \eta, \phi)$ | Kinematic variables of the object, i.e. transverse momentum, pseudorapidity, and azimuthal angle. |
| $w_{\text{GN2}}$ | GN201 b-tagging pseudo-continuous score for identifying jets. Non-jet objects are assigned a value of zero. |
| $q_{\text{Lep.}}$ | Charge of the object. Non-lepton objects are assigned a value of zero. |
| (isJet, isElectron, isMuon) | Boolean flags indicating the object type: jet, electron, or muon. |

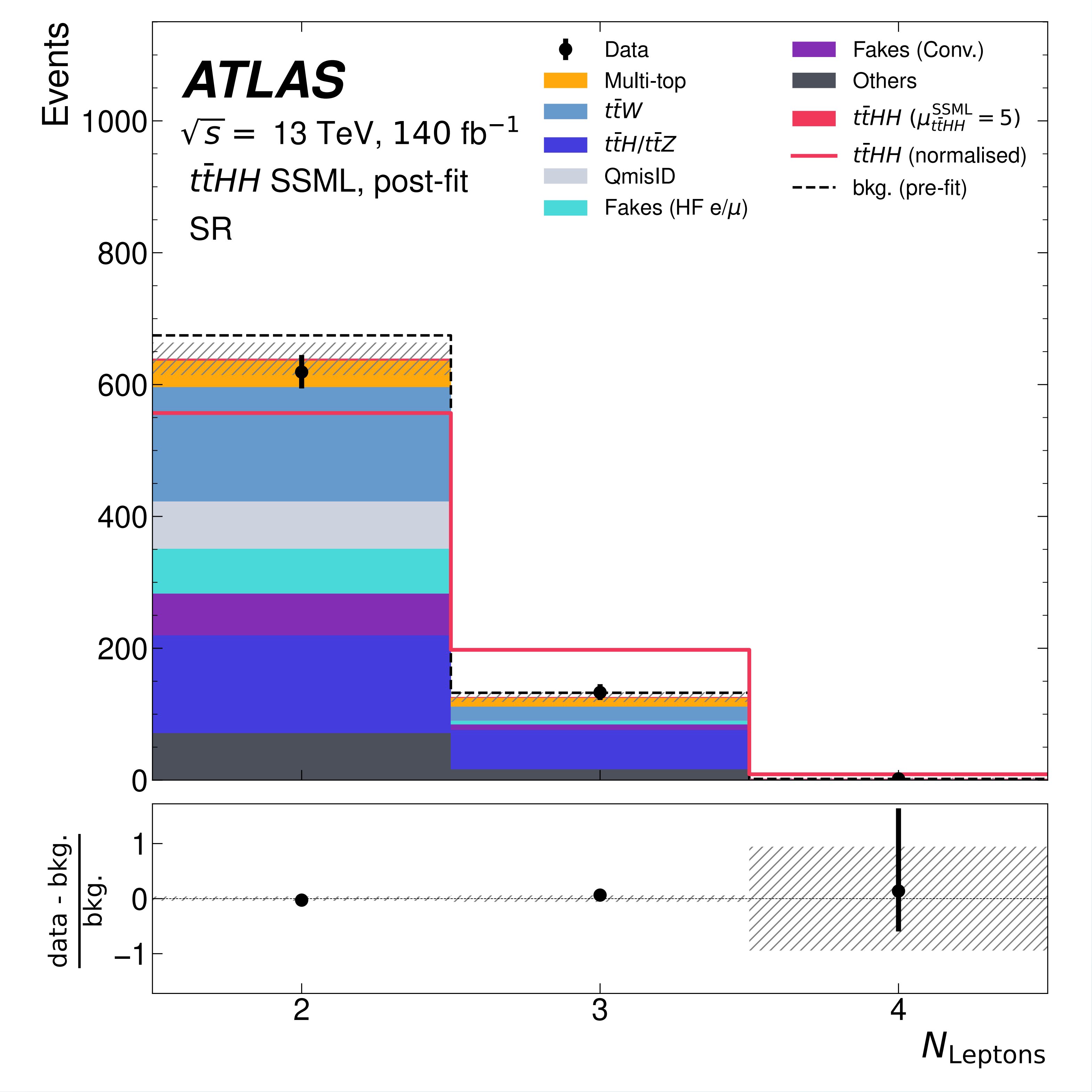
# ML Run 2 CR distributions



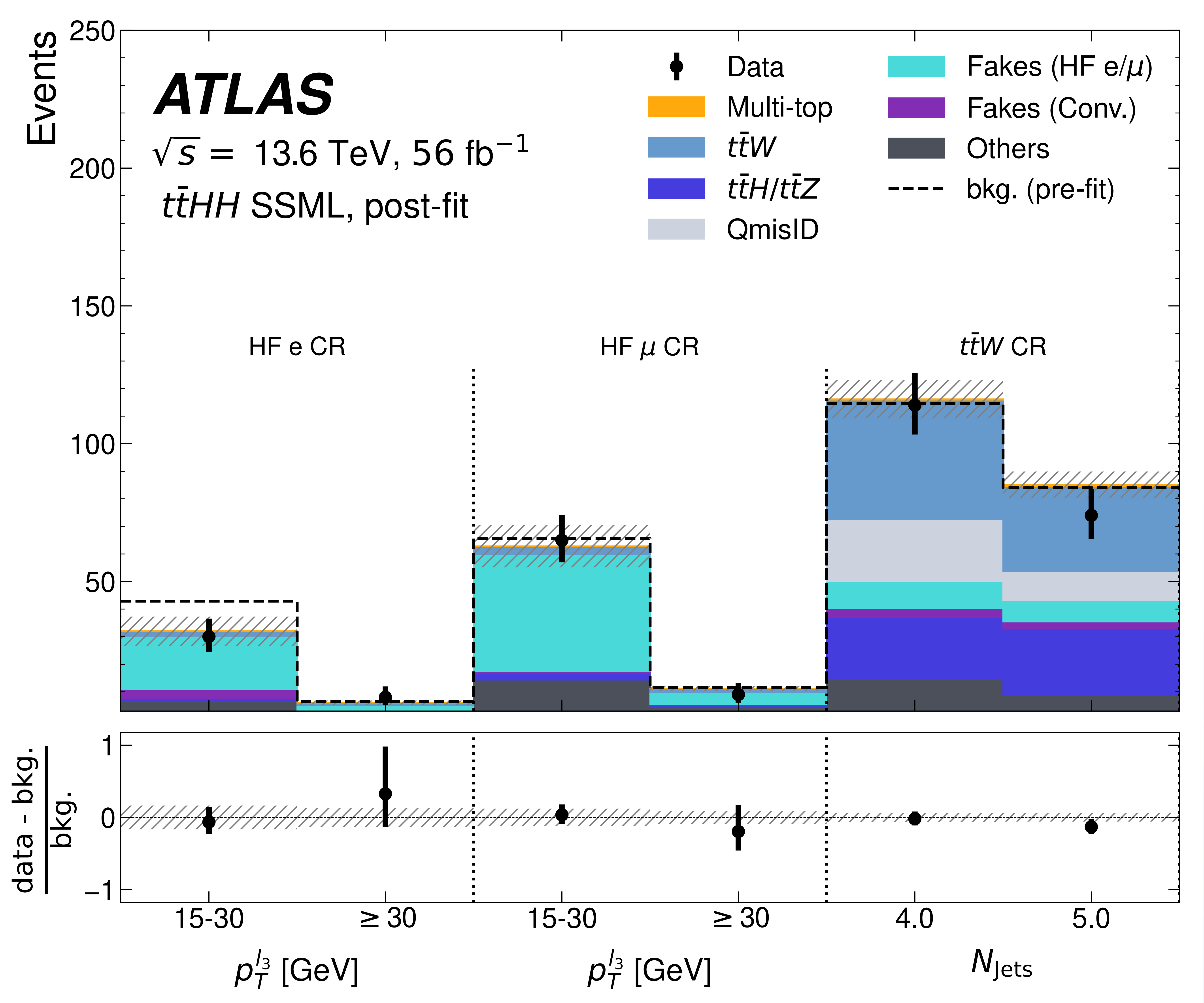
# ML Run 2 SR distributions







# ML Run 3 CR distributions



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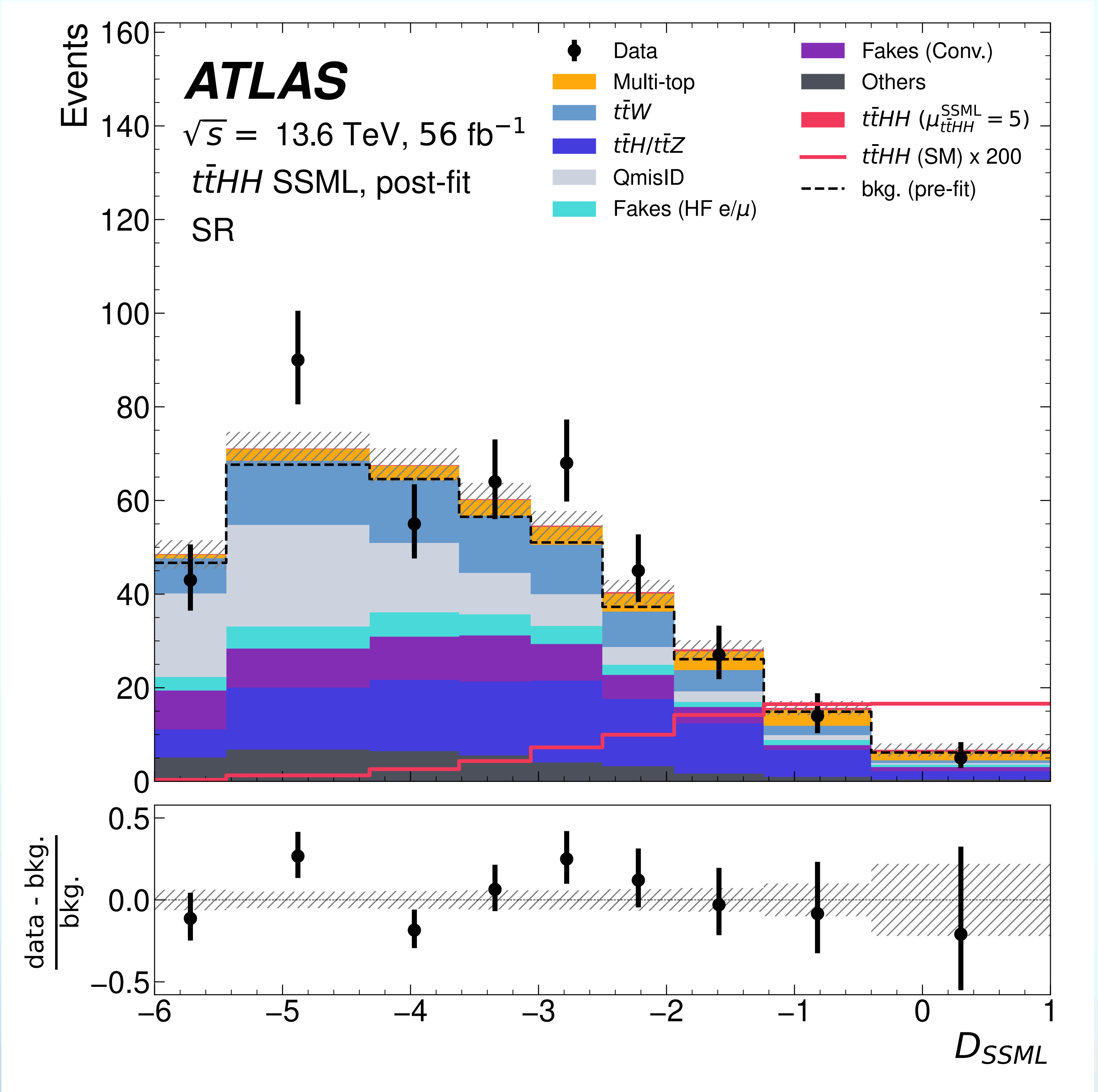
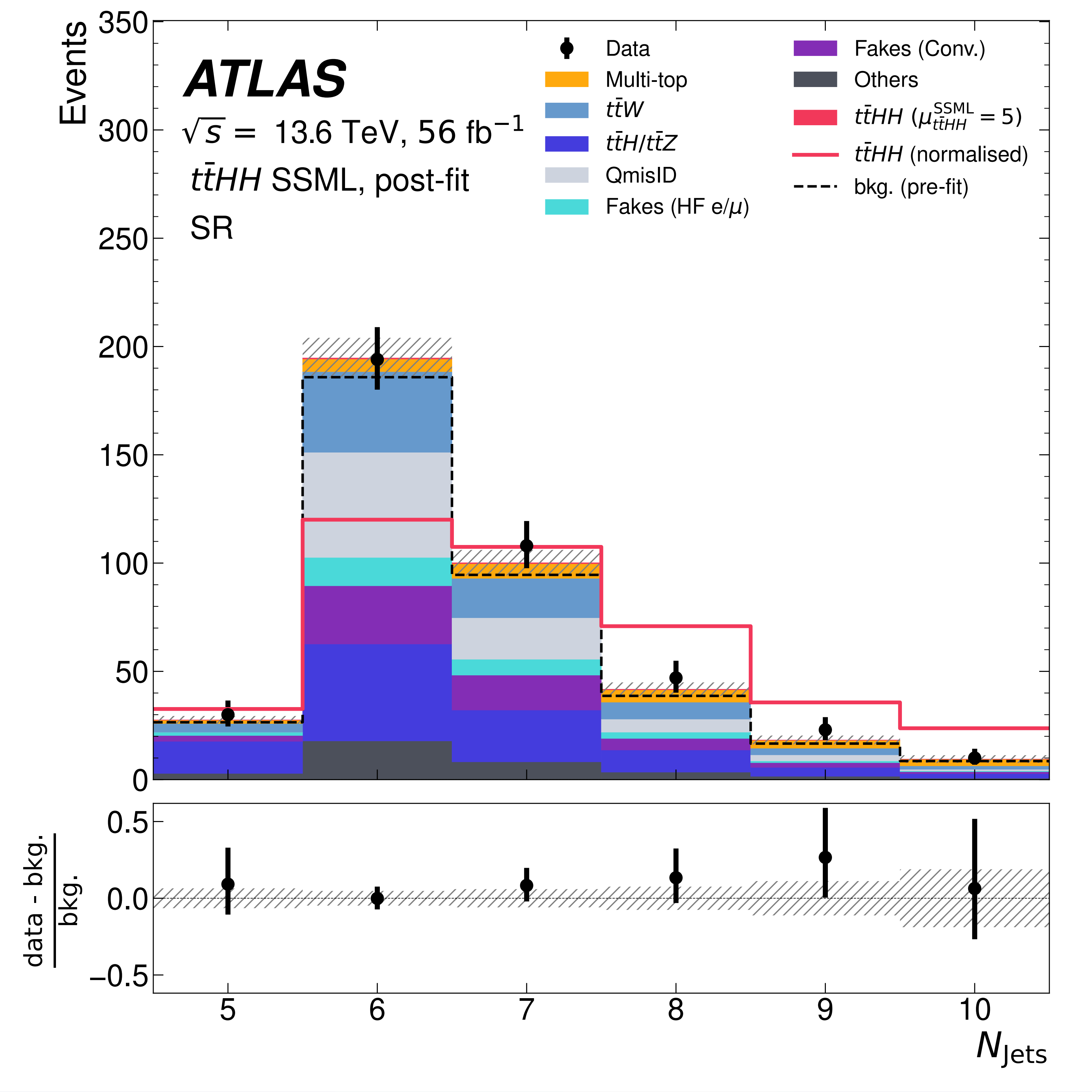
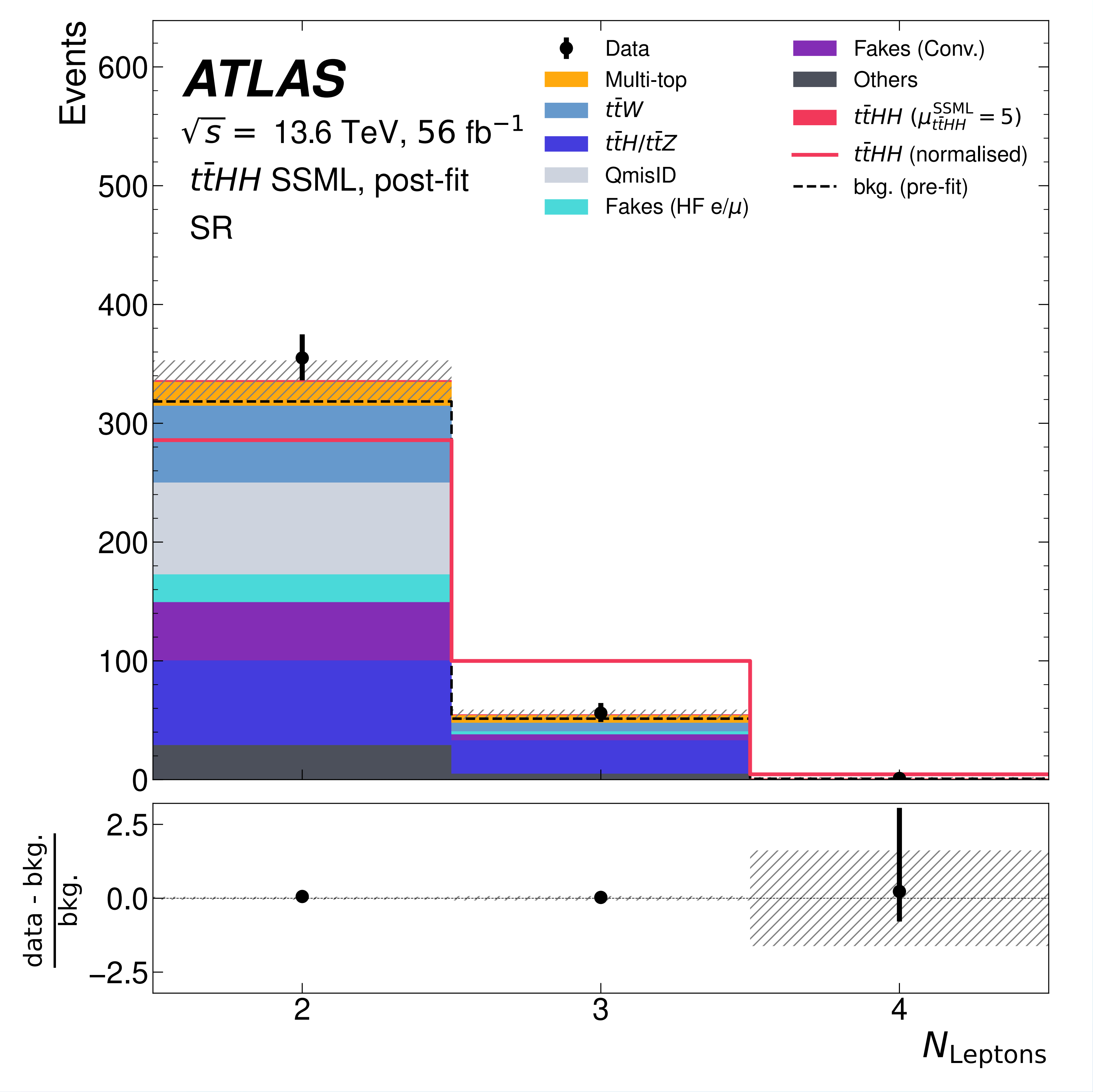
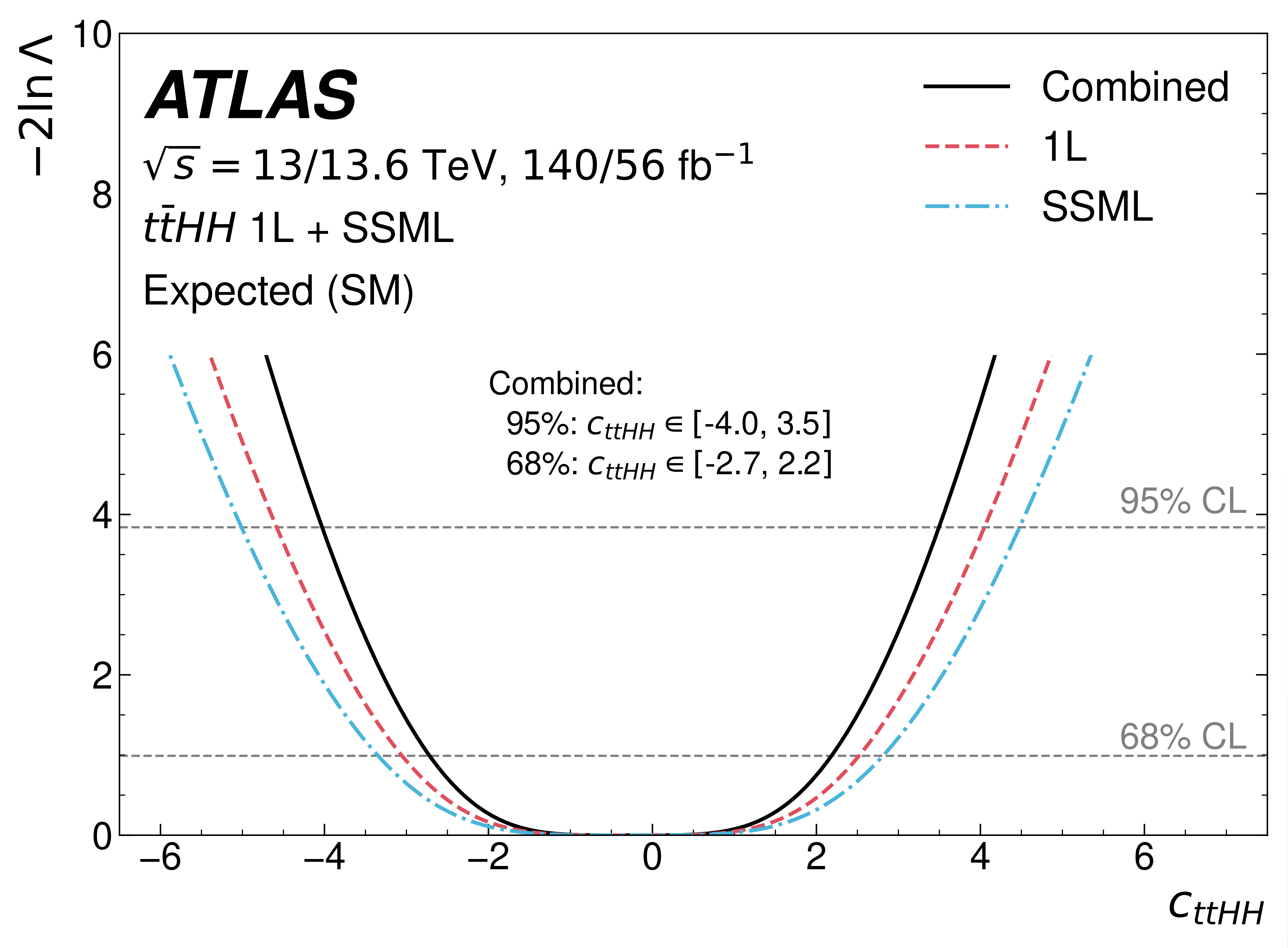




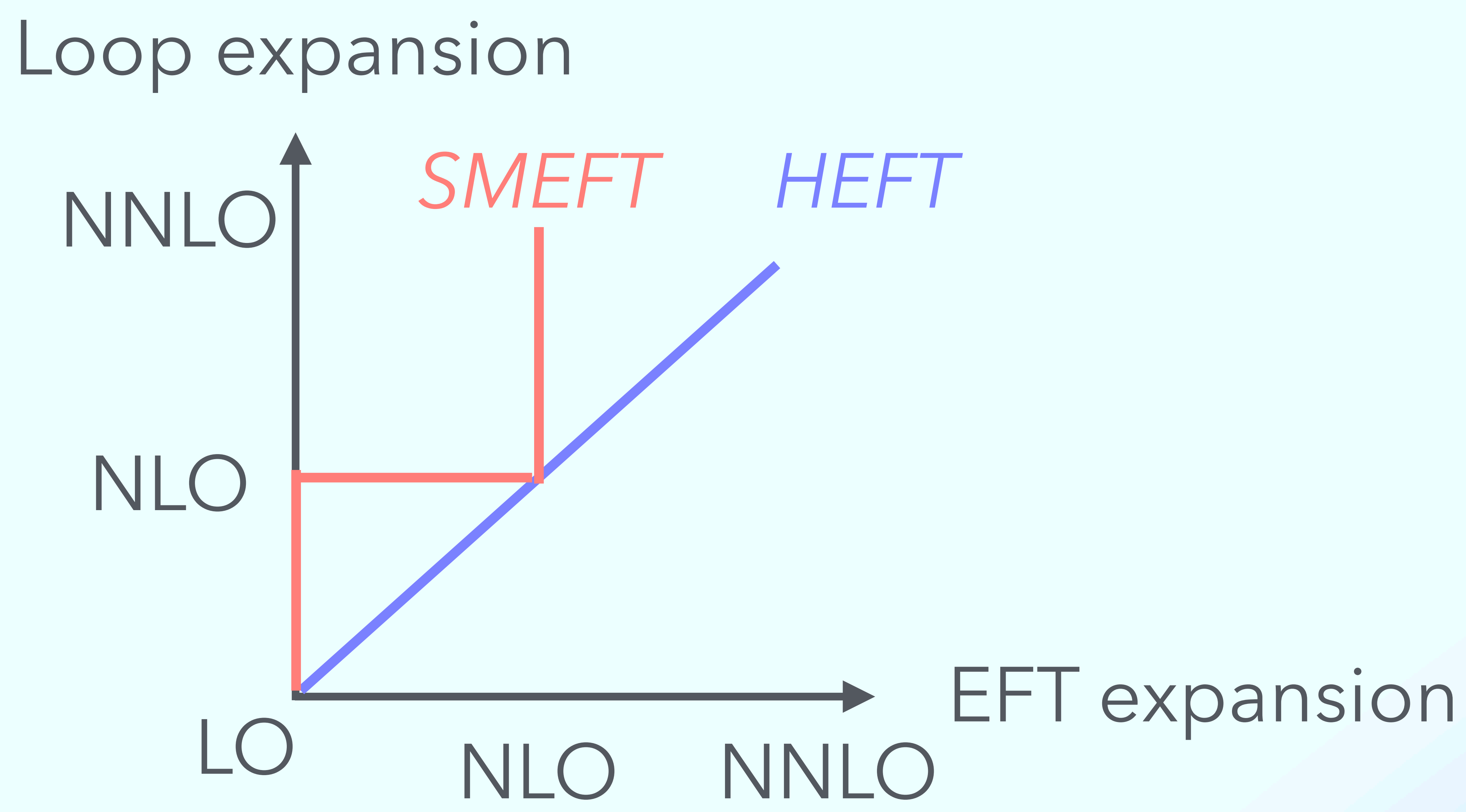


# Expected likelihood for EFT fit



# HEFT vs. SMEFT power counting

[arXiv:2511.23410]



SMEFT power counting keeps EFT independent of loop expansion

HEFT power counting counts loops, so one is constrained on the diagonal

# HEFT vs. SMEFT power counting

Lagrangian : $$\mathscr{L}_{\text{EFT}} = \mathscr{L}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \sum_i \frac{c_i^{(8)}}{\Lambda^4}\mathcal{O}_i^{(8)} + \cdots$$

Event rates : $$\sigma_{\text{EFT}} \sim |\mathscr{M}_{\text{SM}} + \underset{\textit{One d=6}}{\mathscr{M}_6} + \underset{\textit{Two d=6}}{\mathscr{M}_{6+6}} + \underset{\textit{One d=8}}{\mathscr{M}_8} + \cdots|^2$$

| | SM | One d=6 | Two d=6 | One d=8 |
|---|---|---|---|---|
| $\Lambda^0$ | $\sigma \sim \lvert\mathscr{M}_{\text{SM}}\rvert^2$ | | | |
| $\Lambda^{-2}$ | | $+Re(\mathscr{M}_6 \cdot \mathscr{M}_{\text{SM}})$ | | |
| $\Lambda^{-4}$ | | $+\lvert\mathscr{M}_6\rvert^2$ | $+Re(\mathscr{M}_{6+6} \cdot \mathscr{M}_{\text{SM}})$ | $+Re(\mathscr{M}_8 \cdot \mathscr{M}_{\text{SM}})$ |
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| $\Lambda^{-8}$ | | | $+\lvert\mathscr{M}_{6+6}\rvert^2$ | $+\lvert\mathscr{M}_8\rvert^2+Re(\mathscr{M}_8 \cdot \mathscr{M}_{6+6})$ |

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SMEFT linear d=6

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| | SM | One d=6 | Two d=6 | One d=8 |
|---|---|---|---|---|
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SMEFT linear d=6

SMEFT linear+quad d=6

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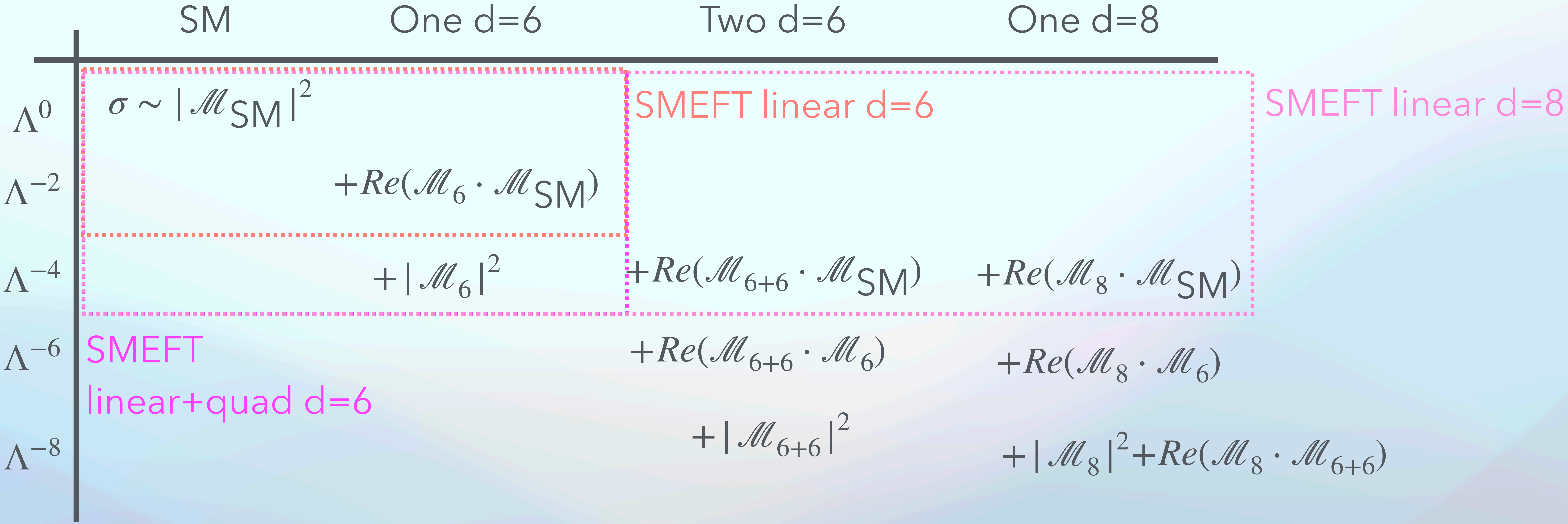
Lagrangian : $\mathscr{L}_{\text{EFT}} = \mathscr{L}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathscr{O}_i^{(6)} + \sum_i \frac{c_i^{(8)}}{\Lambda^4}\mathscr{O}_i^{(8)} + \cdots$

Event rates : $\sigma_{\text{EFT}} \sim |\mathscr{M}_{\text{SM}} + \underbrace{\mathscr{M}_6}_{\text{One d=6}} + \underbrace{\mathscr{M}_{6+6}}_{\text{Two d=6}} + \underbrace{\mathscr{M}_8}_{\text{One d=8}} + \cdots|^2$



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SMEFT linear d=6

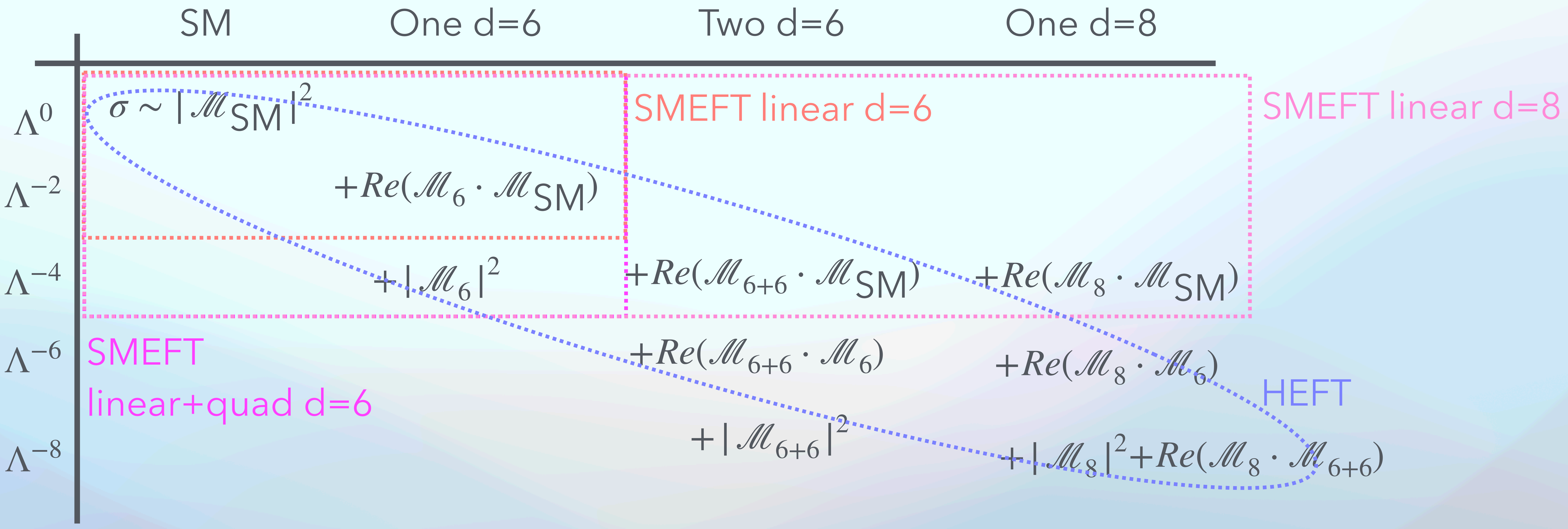
SMEFT linear d=8

SMEFT linear+quad d=6

# HEFT vs. SMEFT power counting

Lagrangian : $\mathscr{L}_{\text{EFT}} = \mathscr{L}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \sum_i \frac{c_i^{(8)}}{\Lambda^4}\mathcal{O}_i^{(8)} + \cdots$

Event rates : $\sigma_{\text{EFT}} \sim |\underbrace{\mathscr{M}_{\text{SM}}}_{} + \underbrace{\mathscr{M}_6}_{\textit{One d=6}} + \underbrace{\mathscr{M}_{6+6}}_{\textit{Two d=6}} + \underbrace{\mathscr{M}_8}_{\textit{One d=8}} + \cdots|^2$



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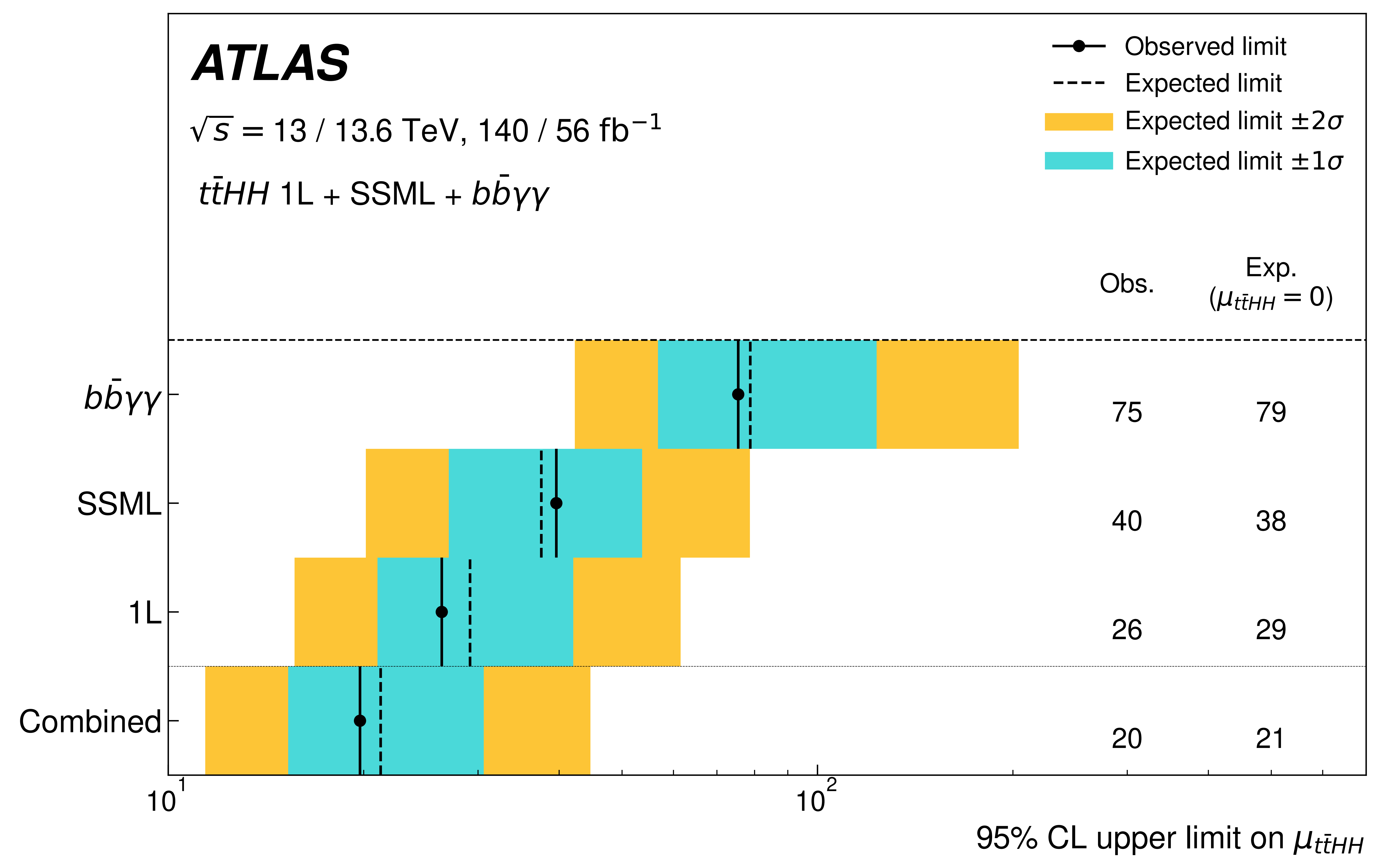
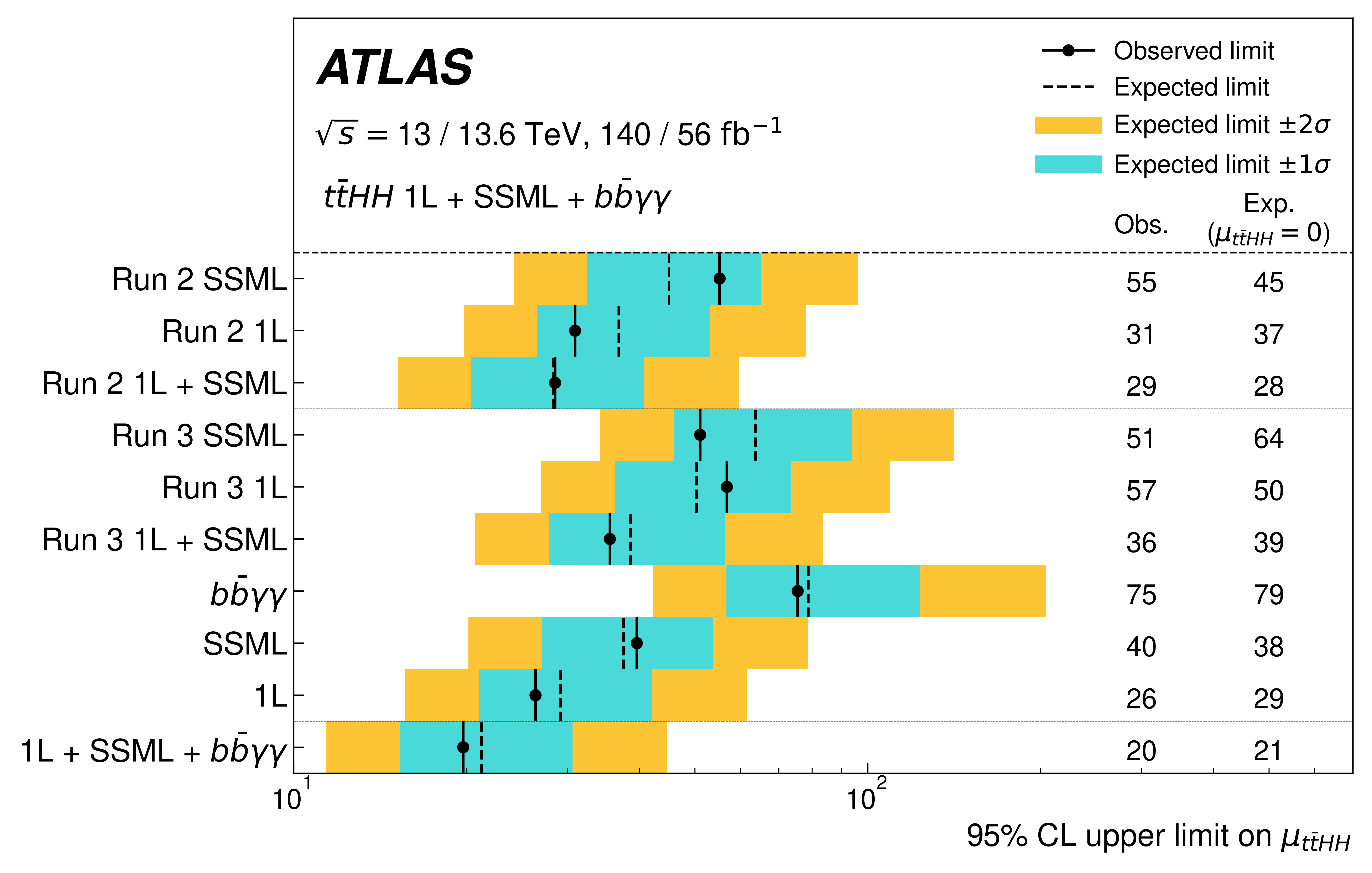
| $\Lambda^{-6}$ | | | $+Re(\mathscr{M}_{6+6} \cdot \mathscr{M}_6)$ | $+Re(\mathscr{M}_8 \cdot \mathscr{M}_6)$ |
| $\Lambda^{-8}$ | | | $+\lvert\mathscr{M}_{6+6}\rvert^2$ | $+\lvert\mathscr{M}_8\rvert^2+Re(\mathscr{M}_8 \cdot \mathscr{M}_{6+6})$ |

# Results on signal stength



- No excess observed
- 95% CL Upper Limits : **20 (21) x SM**
- Most stringent limits to date

# Signal strength results split by channels



- 1L and ML are the most sensitive channels

# Aparte : EFT modelling

Sample simulation is **expensive**

*in €, in time, and in CO2*

→ we need a way to <u>save ressources</u> while covering the most out of the phase space

1. Generate $t\bar{t}HH$ events at parton level (~ free)

2. Do it for multiple values of $c_{t\bar{t}HH}$

3a. Save the ratio of kinematic information
3b. Save the evolution of cross-section

4. Reapply it back to the fully simulated sample

Pros :

It's cheap!

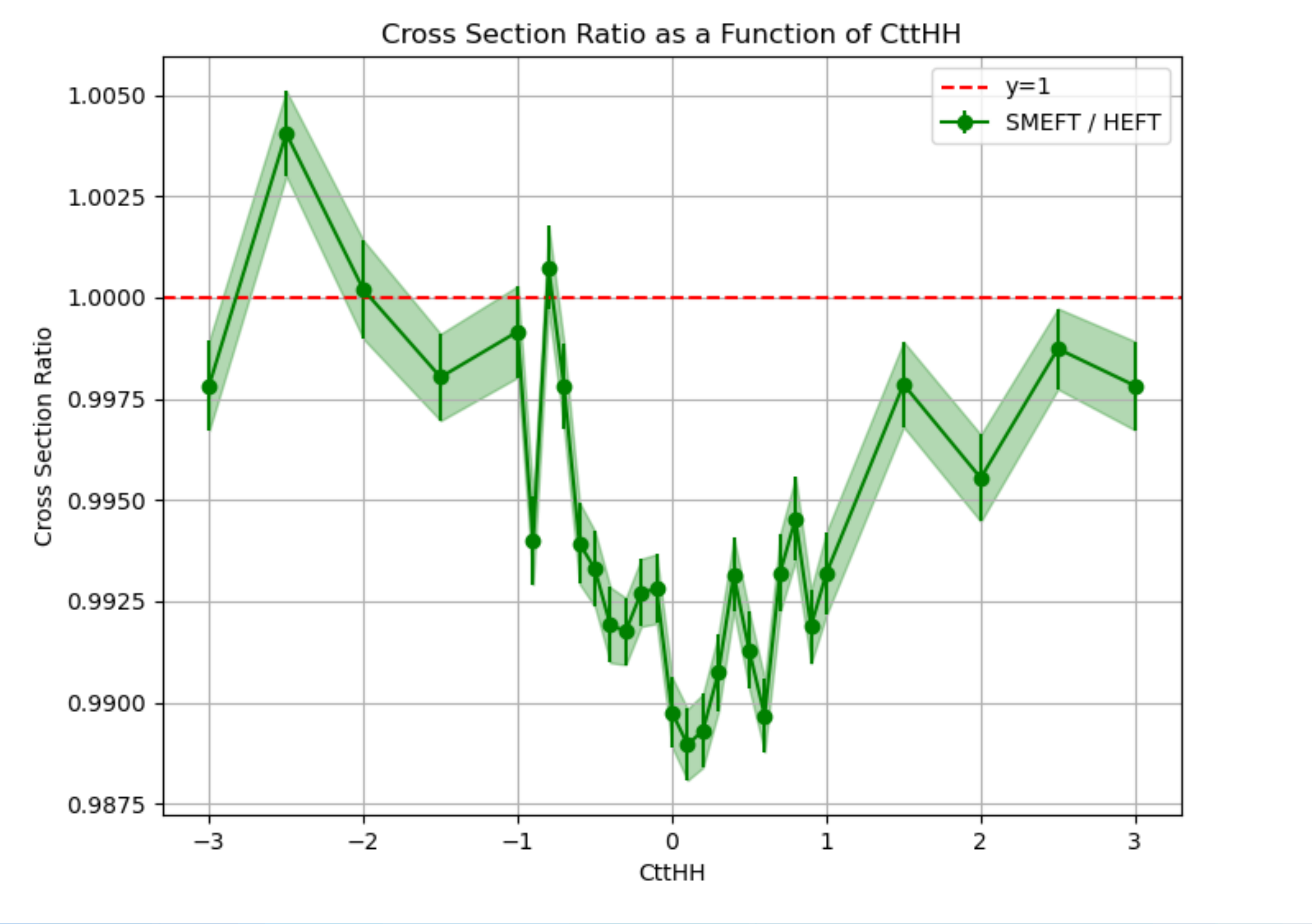
Cons :

How can we be sure that we capture well the dependances for the variable we fit?

*We can't, but we can estimate that the effect is ~small*

# First : we need a model!

- Modification of the SM Lagrangian with additional vertices $c_{t\bar{t}HH}, c_{t\bar{t}H}, \kappa_\lambda$
- Implemented by M. Ryczkowski & R. Groeber using FeynRules UFO model format. Can be found on [github.com/Ryczek/CttHH](https://github.com/Ryczek/CttHH)
- Model validated against SMEFT using SMEFTsim with internal studies



$$c_{t\bar{t}HH} = -\frac{3v^3}{2\sqrt{2}\Lambda^2 m_t}c_{uH} + \frac{v^2}{\Lambda^2}c_{H\Box} - \frac{v^2}{4\Lambda^2}c_{HD}$$

$$c_{HHH} = 1 - \frac{v^2}{\Lambda^2}(2\frac{v^2}{m_H^2}c_H - 3c_{H\Box} + \frac{3}{4}c_{HD})$$

$$c_{t\bar{t}H} = 1 - \frac{v^2}{\Lambda^2}(c_{H\Box} - \frac{1}{4}c_{HD}) - \frac{v^3}{\sqrt{2}\Lambda^2 m_t}c_{uH}$$

arXiv:2304.01968

→ **Agreement at ~1% level**

# A probe for HEFT vs. SMEFT

$$\begin{aligned}
c_{t\bar{t}HH} &= -\frac{3v^3}{2\sqrt{2}\Lambda^2 m_t}\boxed{c_{uH}} + \frac{v^2}{\Lambda^2}\boxed{c_{H\Box}} - \frac{v^2}{4\Lambda^2}\boxed{c_{HD}} \\
c_{HHH} &= 1 - \frac{v^2}{\Lambda^2}\left(2\frac{v^2}{m_H^2}\boxed{c_H} - 3\boxed{c_{H\Box}} + \frac{3}{4}\boxed{c_{HD}}\right) \\
c_{t\bar{t}H} &= 1 - \frac{v^2}{\Lambda^2}\left(\boxed{c_{H\Box}} - \frac{1}{4}\boxed{c_{HD}}\right) - \frac{v^3}{\sqrt{2}\Lambda^2 m_t}\boxed{c_{uH}}
\end{aligned}$$

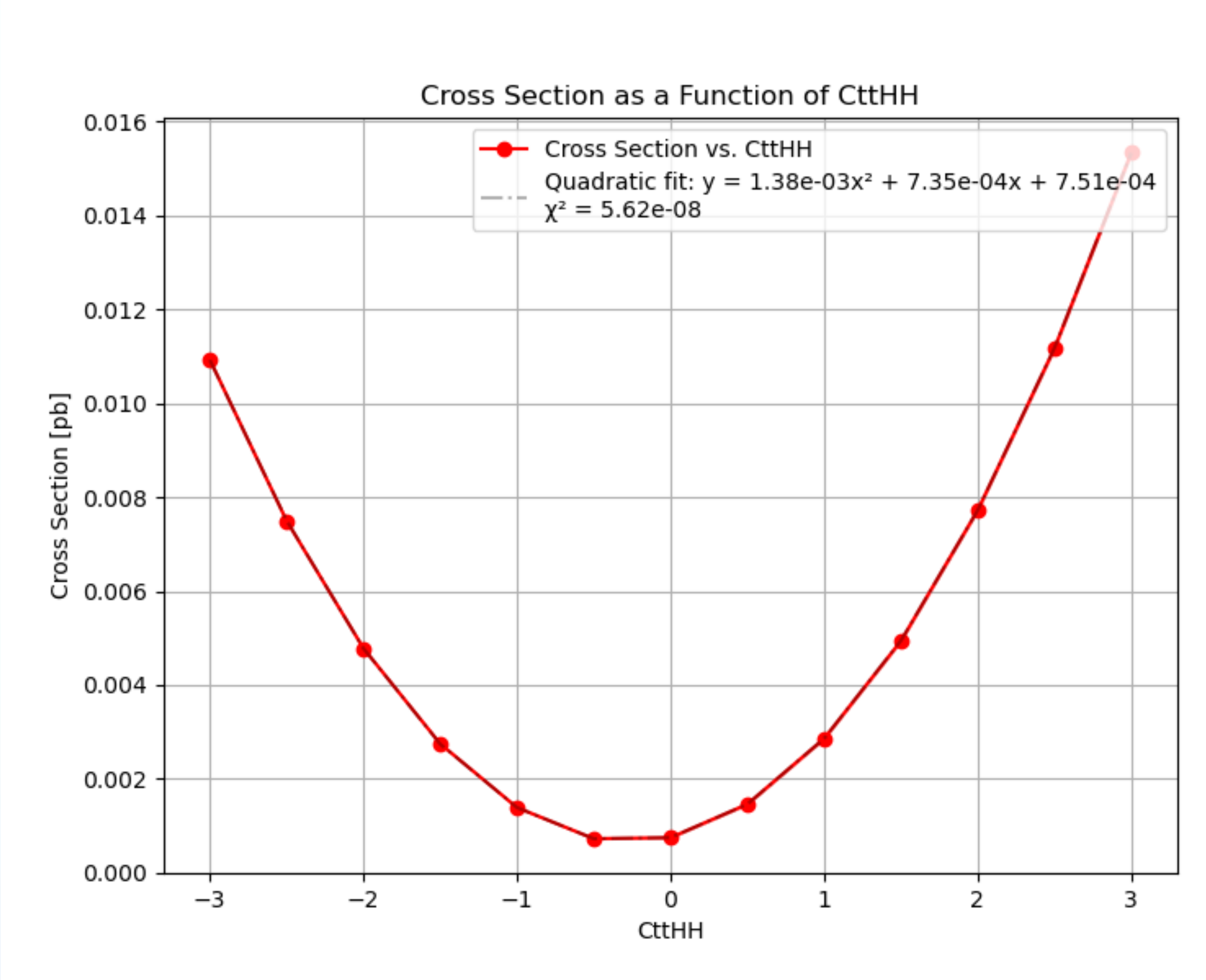
arXiv:2304.01968

Connects HEFT and SMEFT in $t\bar{t}HH$

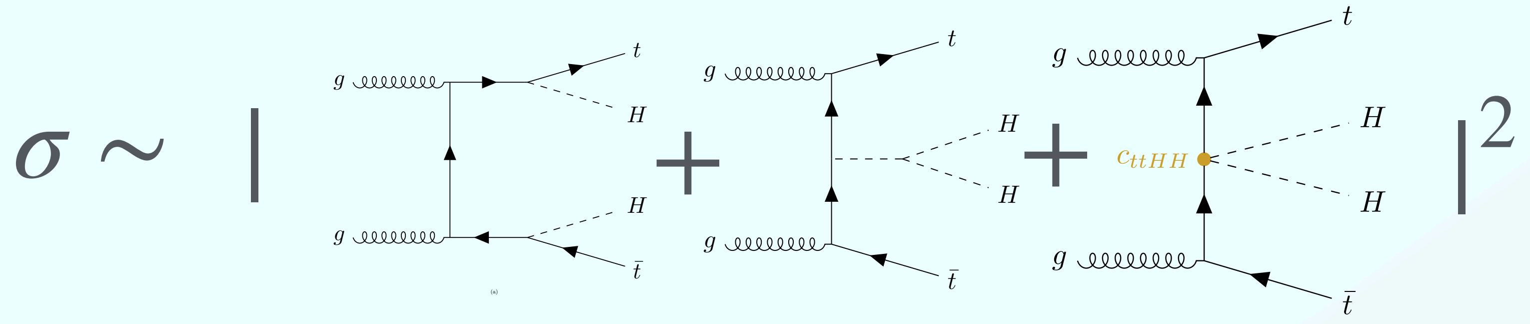
In SMEFT, $t\bar{t}HH$ and $t\bar{t}H$ processes are **bound together**

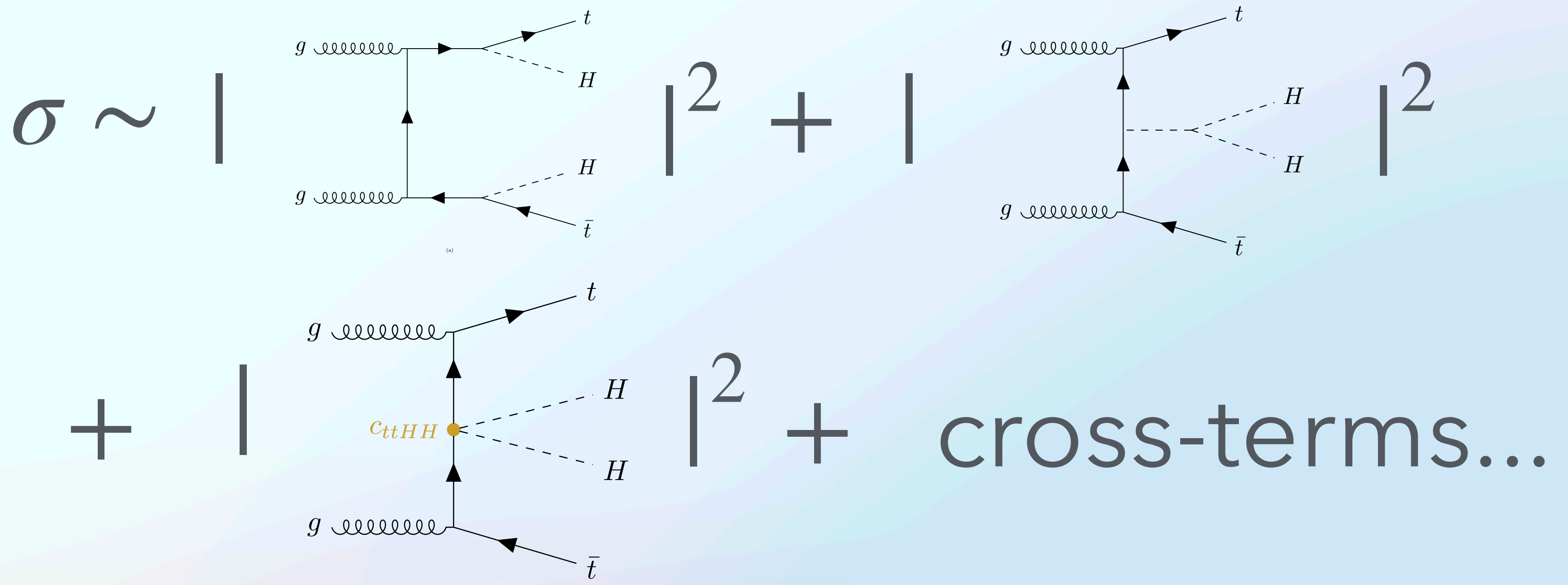
HEFT provides a way to **decorellate them** and study the Higgs mechanism

# Cross-section dependance



Quadratic dependance → **Expected**





*This also tells us that the cross-terms are small wrt. quad. terms*

# How to extract the most kin. information?

Ideally : $\sim \dfrac{\mathscr{M}_{SM}}{\mathscr{M}_{BSM}}$

→ optimal as long as phase-space is ~comparable

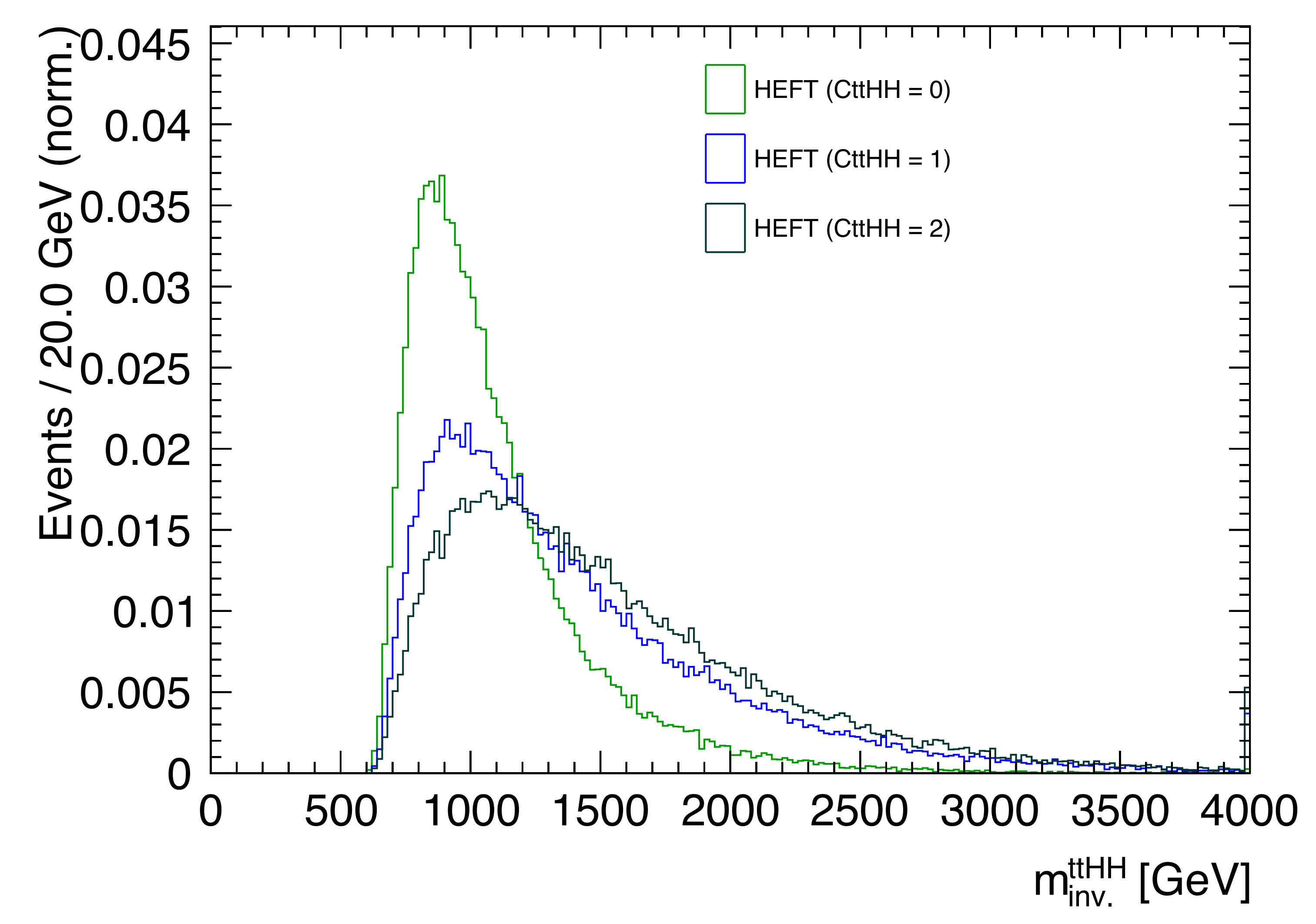
*not trivial as we proble heavy-mass*

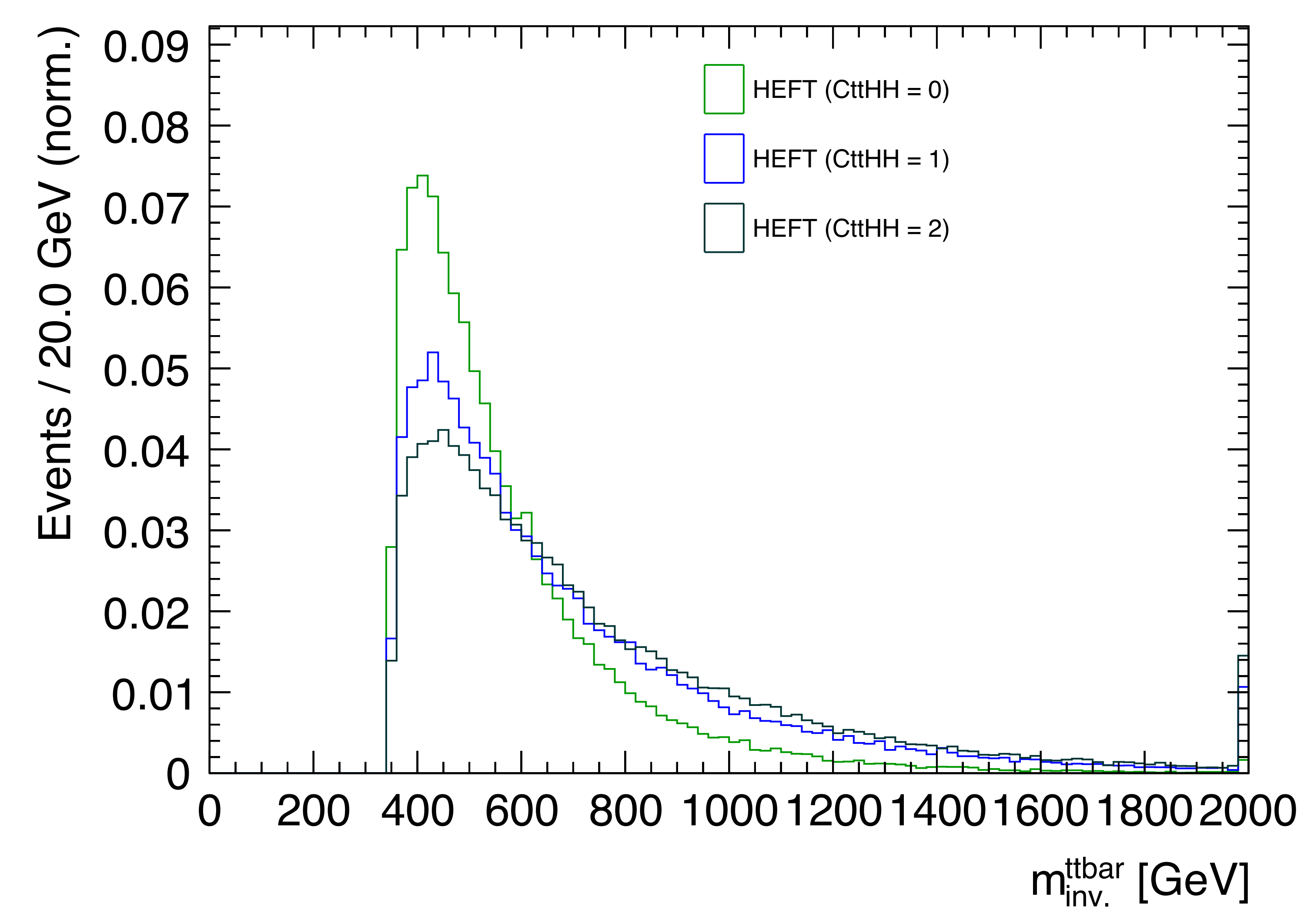
→ but require to define the Wilson coefficient space to be probed

*i.e. you need to know your plan in advance*
*no modifications a posteriori*

Not possible as no **HEFT** model existed at the time!

Instead we can take a sensitive distribution





**Or even better…**

# How to extract the most kin. information?

Ideally : $\sim \frac{\mathcal{M}_{SM}}{\mathcal{M}_{BSM}}$ → optimal as long as phase-space is ~comparable

*not trivial as we proble heavy-mass*

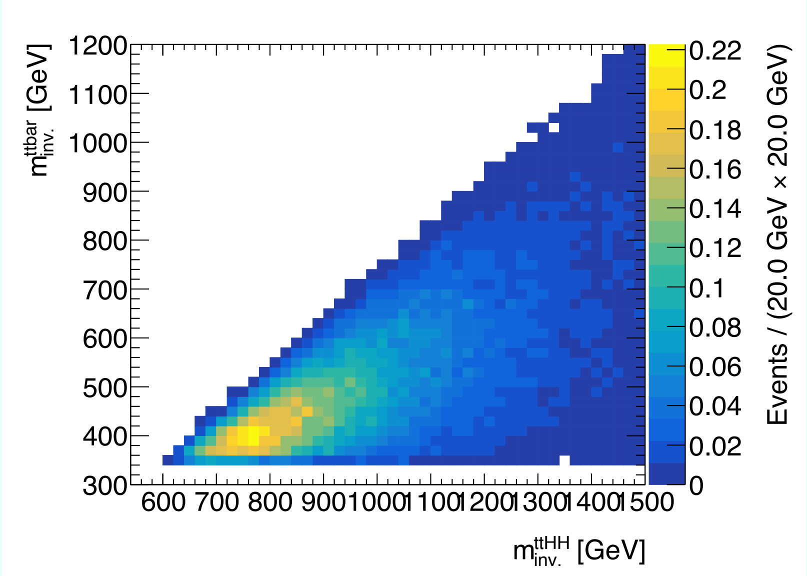
→ but require to define the Wilson coefficient space to be probed

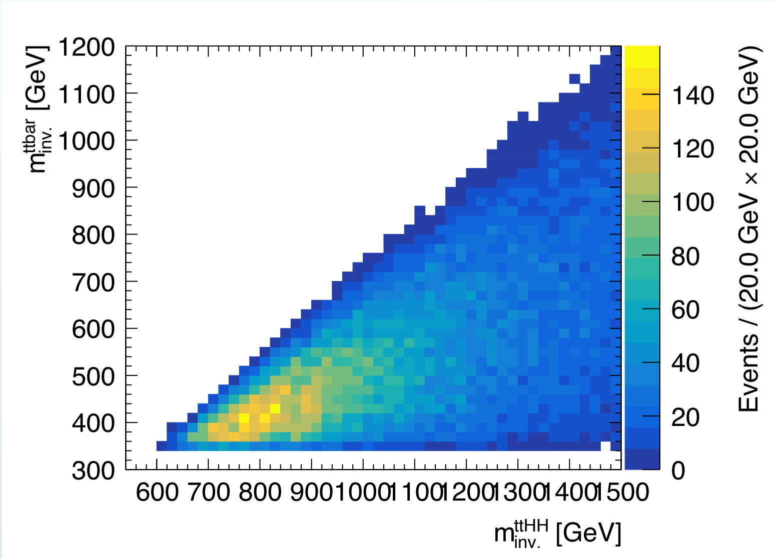
*i.e. you need to know your plan in advance*
*no modifications a posteriori*

Not possible as no HEFT model existed at the time!

We can take a **2D** distribution:

$$\frac{(m_{\text{inv.}}^{t\bar{t}HH}, m_{\text{inv.}}^{t\bar{t}})_{SM}}{(m_{\text{inv.}}^{t\bar{t}HH}, m_{\text{inv.}}^{t\bar{t}})_{BSM}} \rightarrow$$





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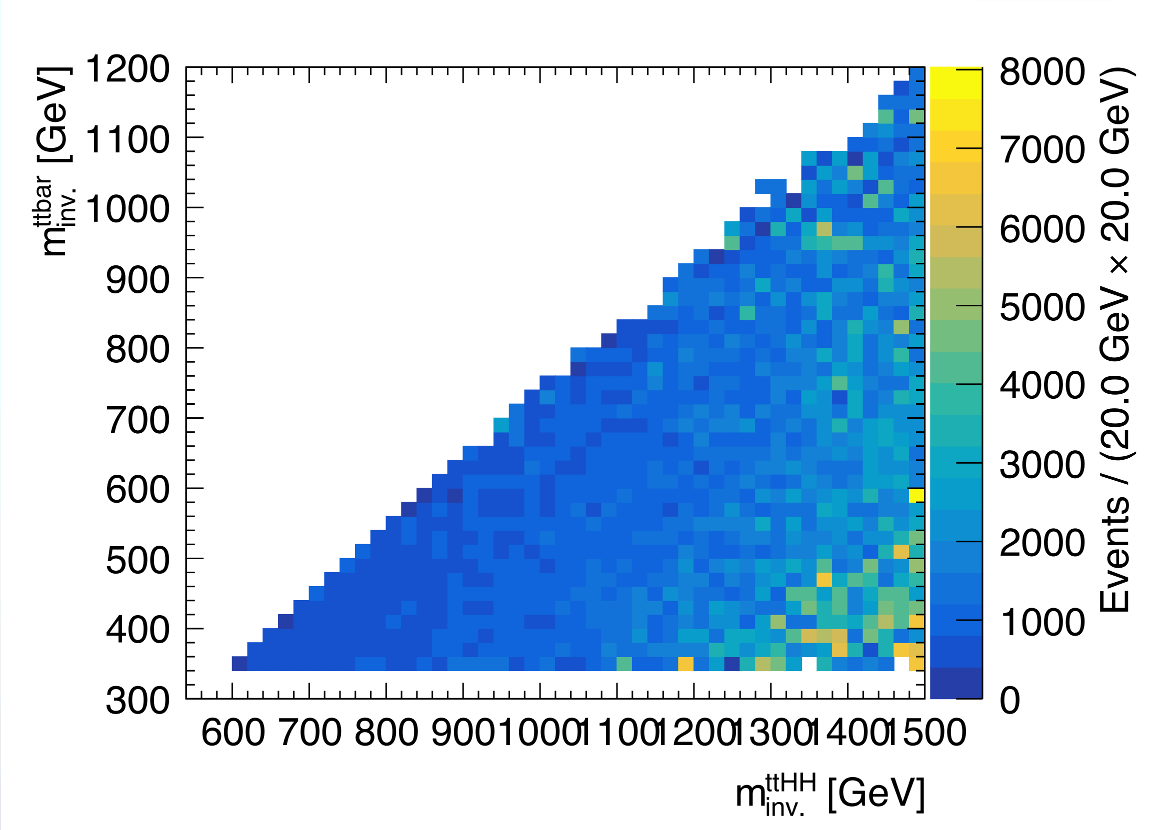


arXiv:2502.20976

*answers this question in the context of ggF diHiggs*

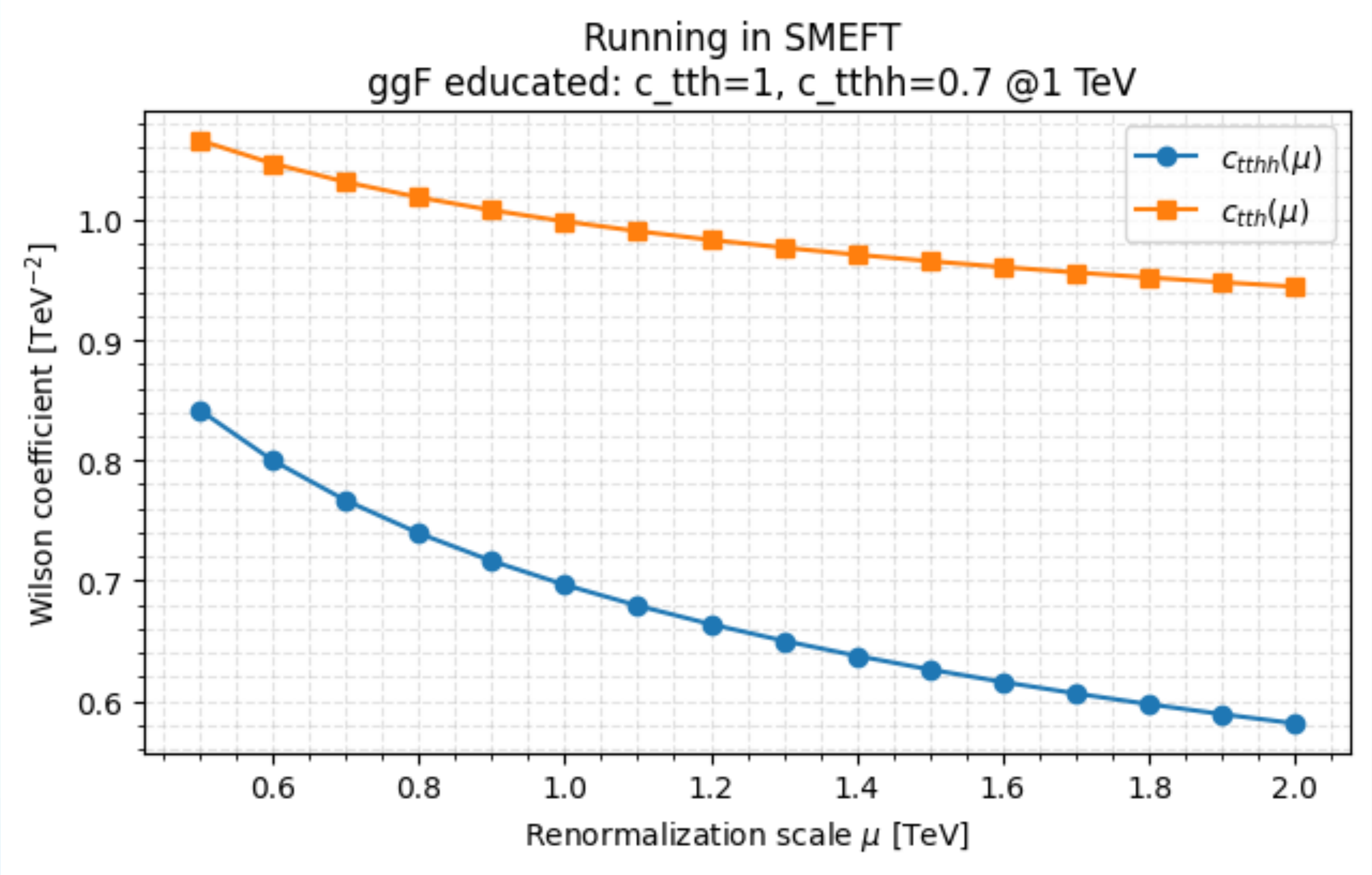
# Possible improvements

We set limits on Wilson coefficients at a **given scale**

*Effect of running?* *~1TeV @ LHC*

In effective theories : **operators mixing depends on $\Lambda$**

*Negligible operators could become ~important at higher scale*



- From SMEFT implementation of RGEs *renormalization group eqs*
- Educated guess ~ limits from ggF at typical LHC scale **~30% at 2 TeV**
- Subdominant for now, what about in the future?
- Other operators that could become important at higher scale

Is this running valid? → <u>proper implementation of HEFT running</u> needed
*probably not*