ttH/tH status report

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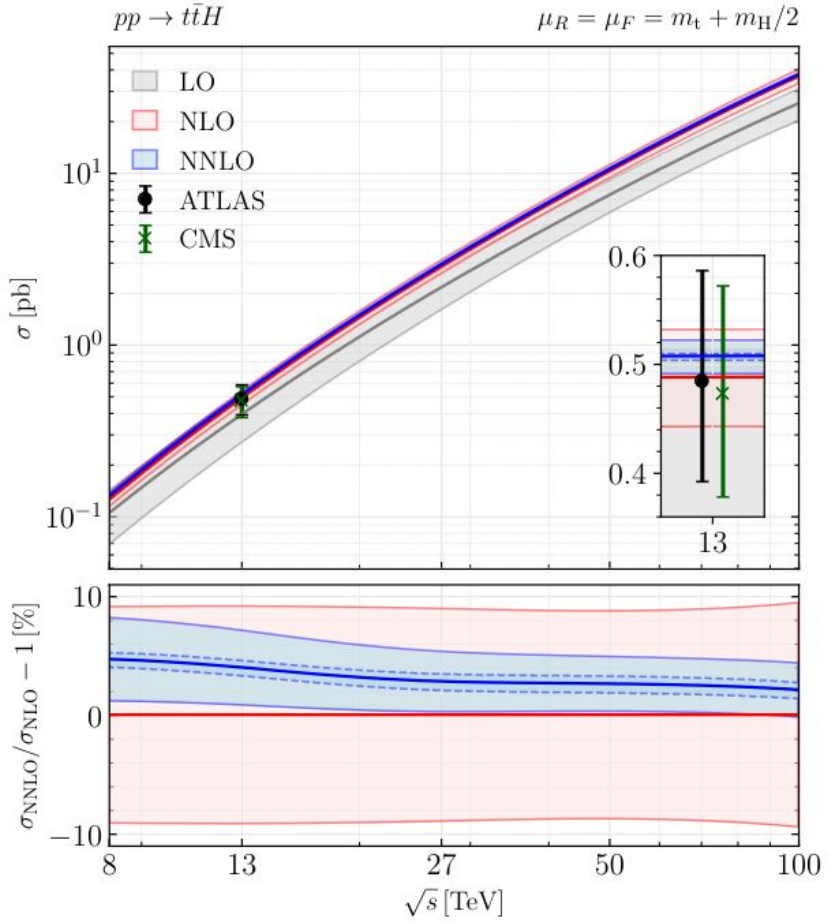
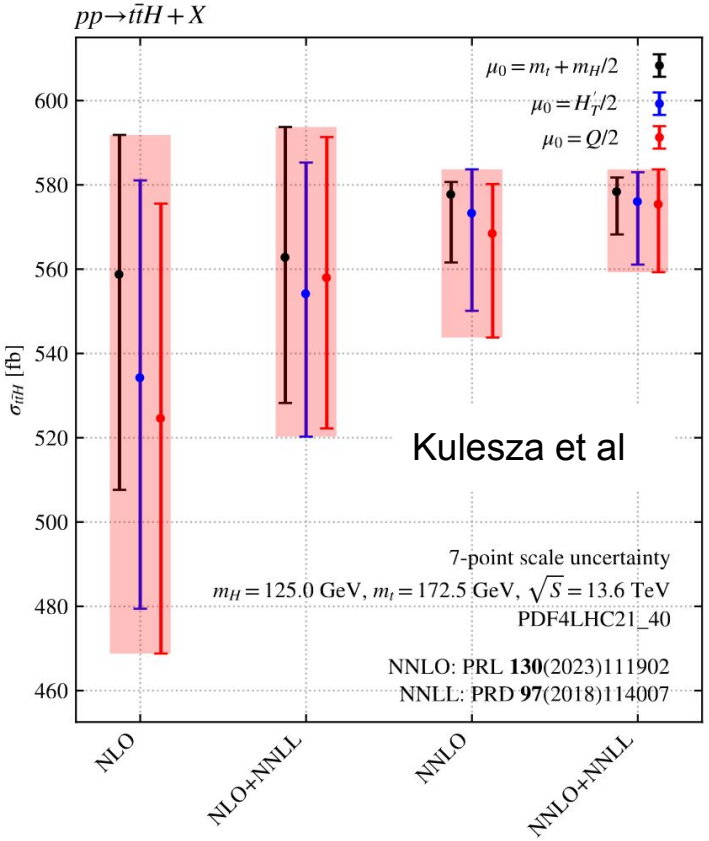
Latest theory results on ttH

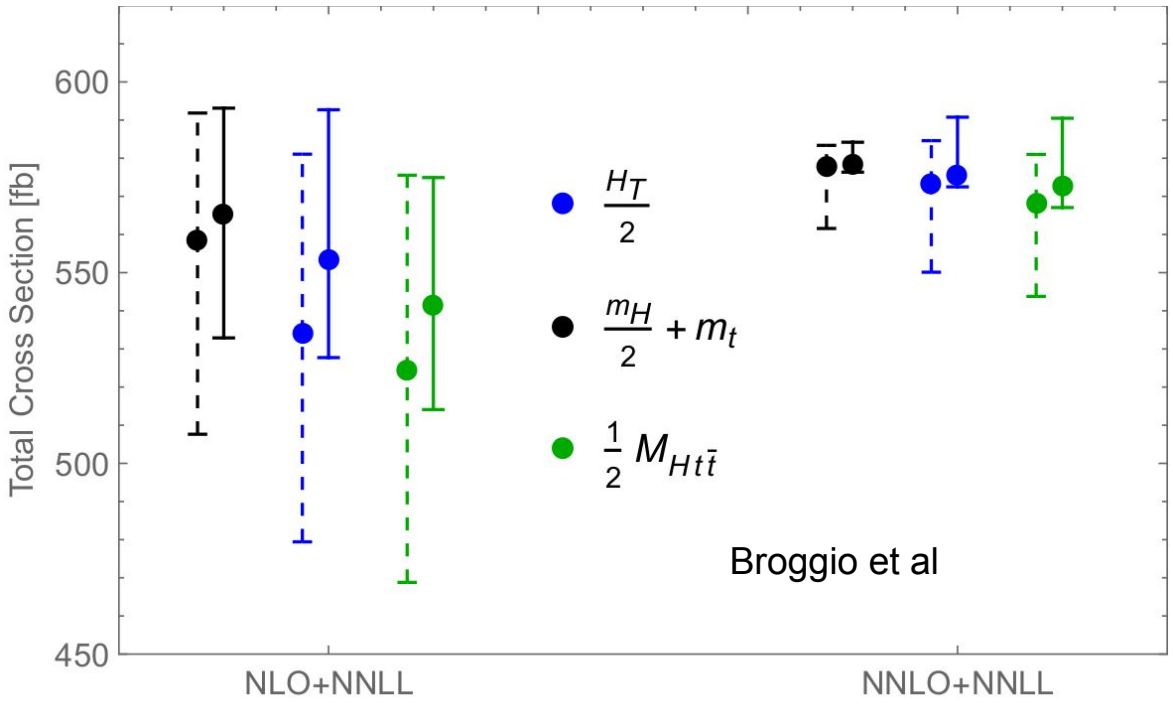
- Inclusive cross section at recently computed at approximate NNLO (arXiv:2210.07846)
- Offshell effects in ttH with CP violation (arXiv:2205.09983)
- Inclusion of electroweak corrections in NLO QCD+PS simulations (arXiv:2309.00452)
  - Showcased in ttH production → see talk by Timea in the WG1 parallel



Signal cross sections @ 13.6 TeV

- tH cross sections computed at the YR state of the art (NLO in QCD, 5 FS)
- For ttH production we aim for combining NNLO QCD + NNLL soft resummation + NLO EWK
  - First **preliminary results** are available
  - Currently the two resummation collaborations are comparing their scale settings

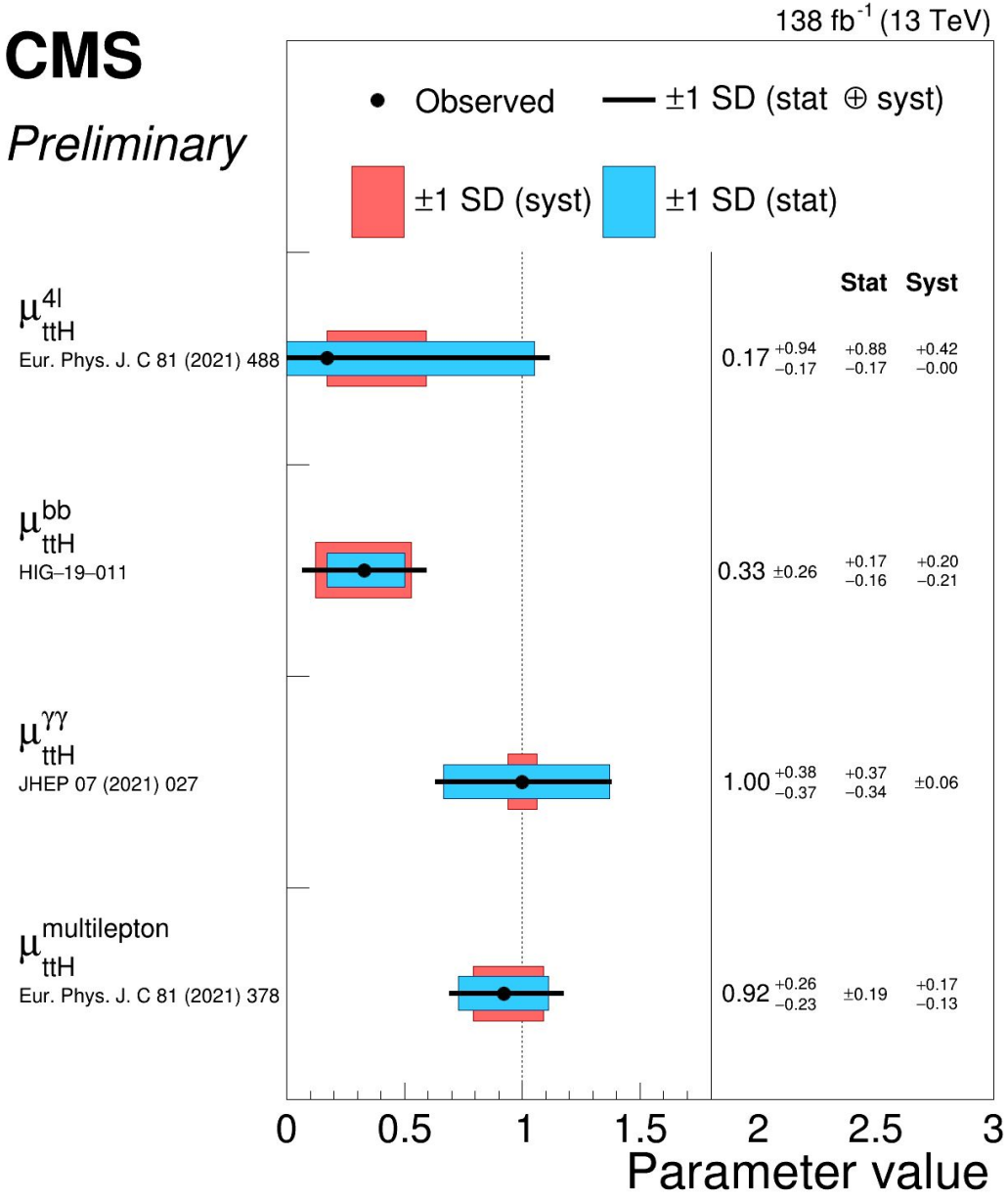




Broggio et al, 1907.04343; Kulesza et al, 2001.030301; Catani et al, 2210.07846

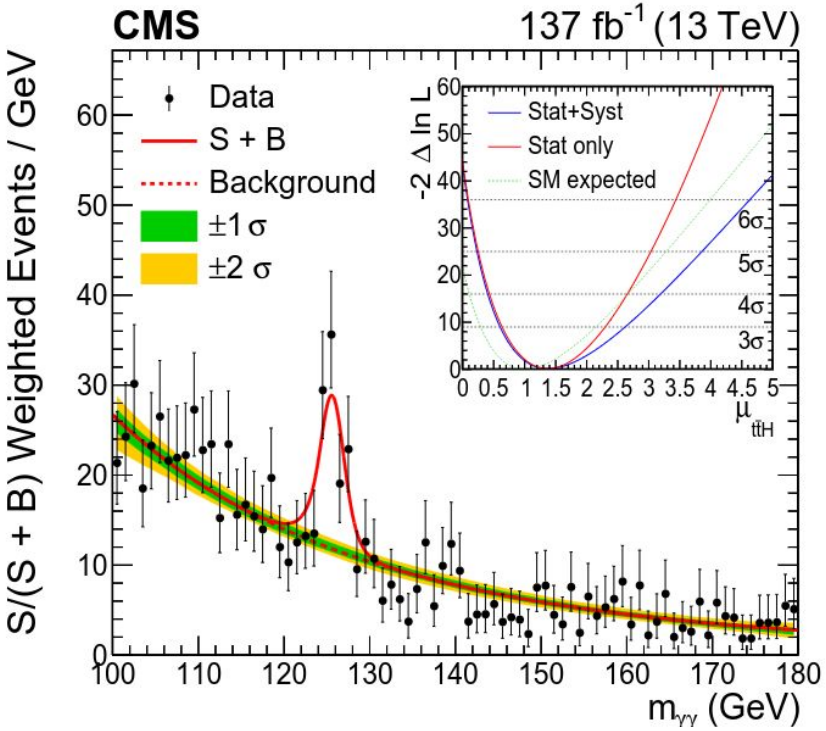
ttH experimentally

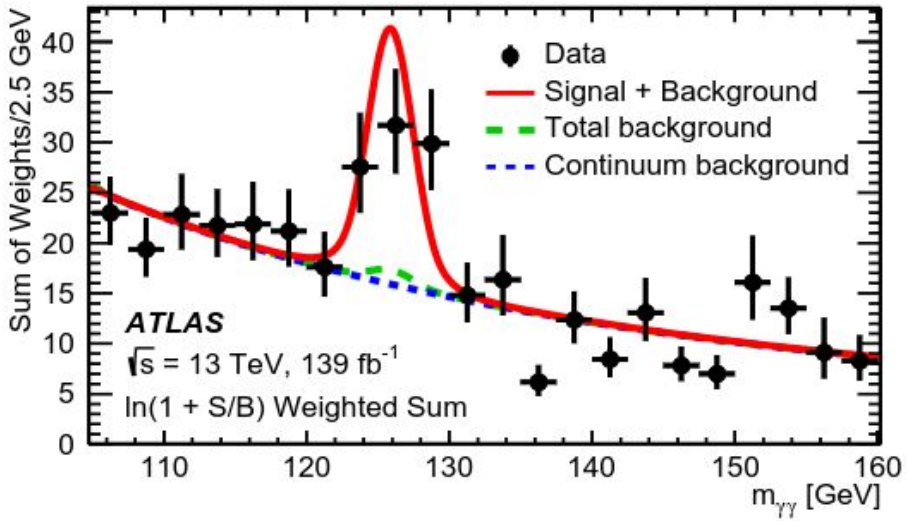
- ttH probed both by ATLAS and CMS in different final states
- Different challenges in each channel
- Significant contributions from backgrounds in some of the most precise channels
  - Uncertainties in the modeling of such backgrounds dominate the measurements

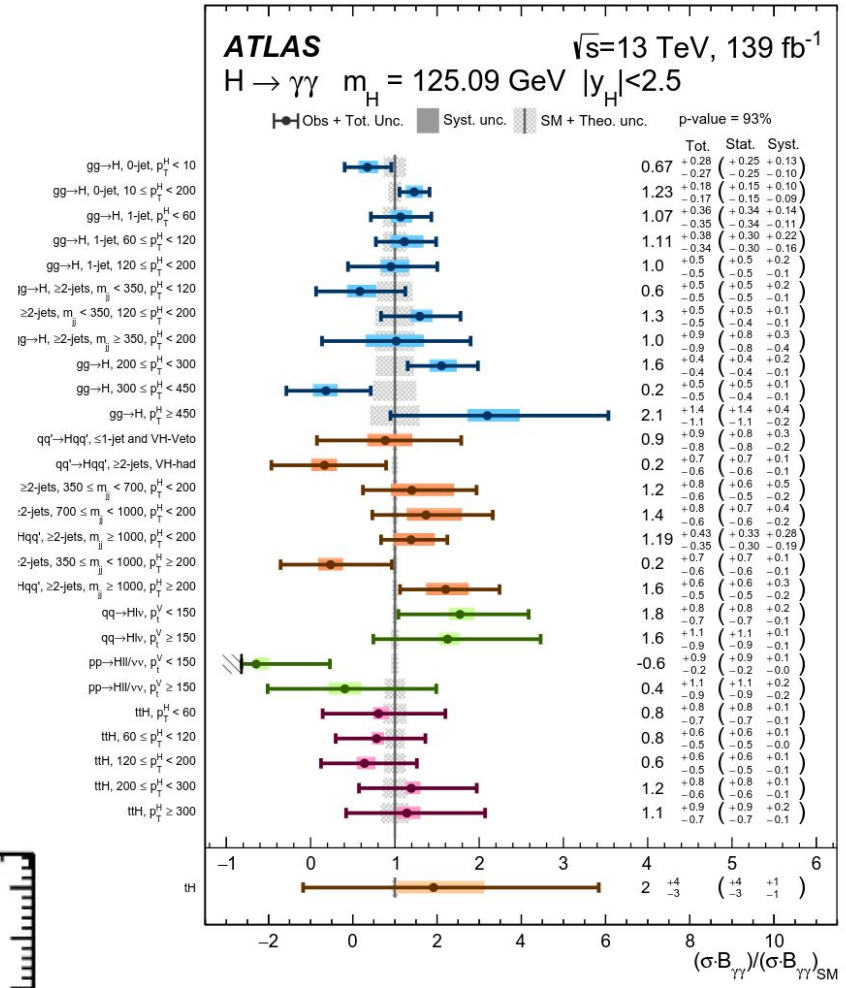


ttH/tH experimental status (diphoton)

- Measurements dominated by statistical uncertainties
- Relatively simple to keep background under control
- Higgs system can be easily resolved → useful for differential studies
  - First STXS measurements already available



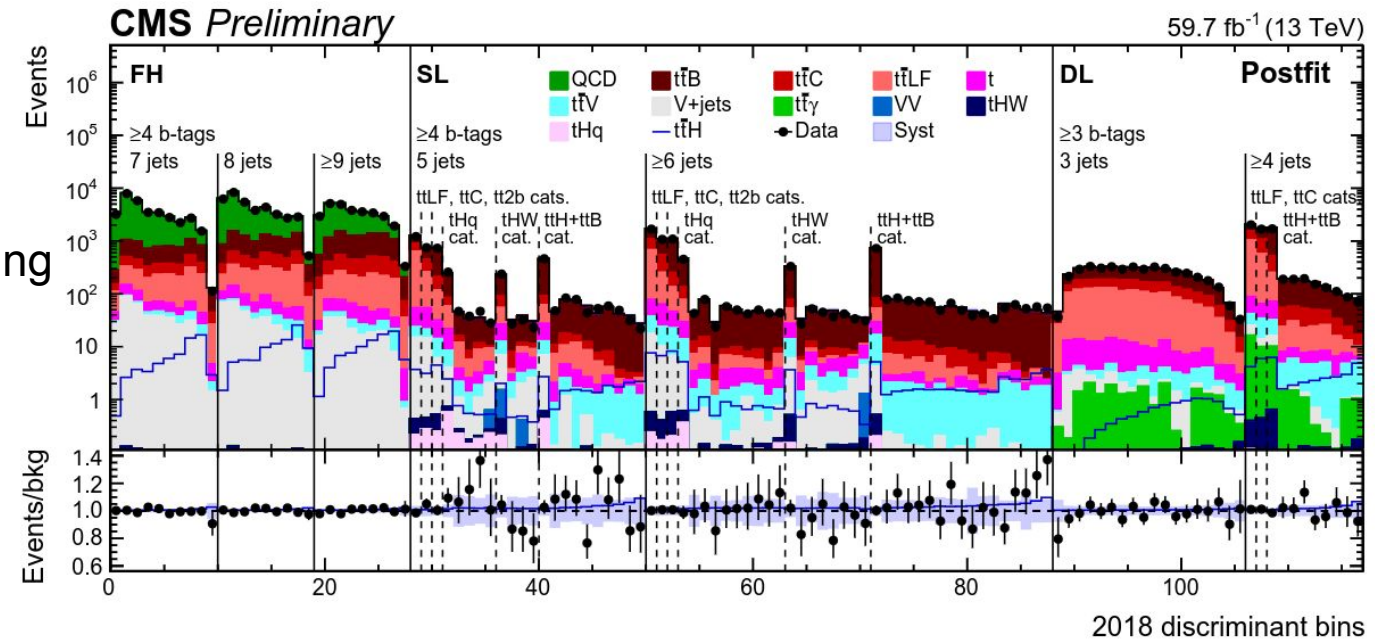


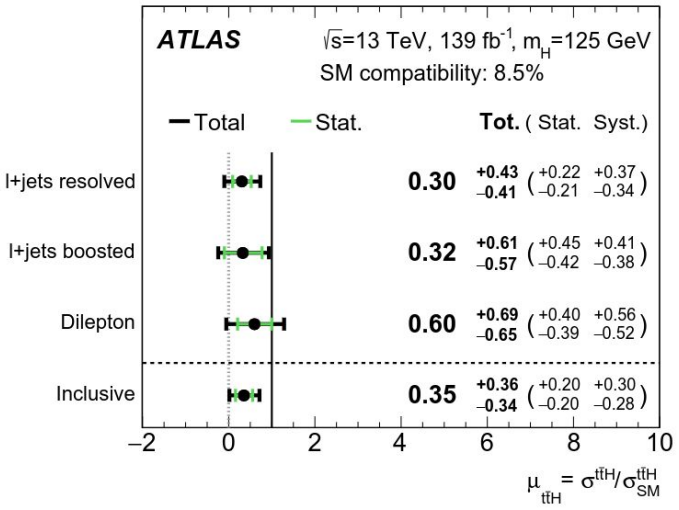


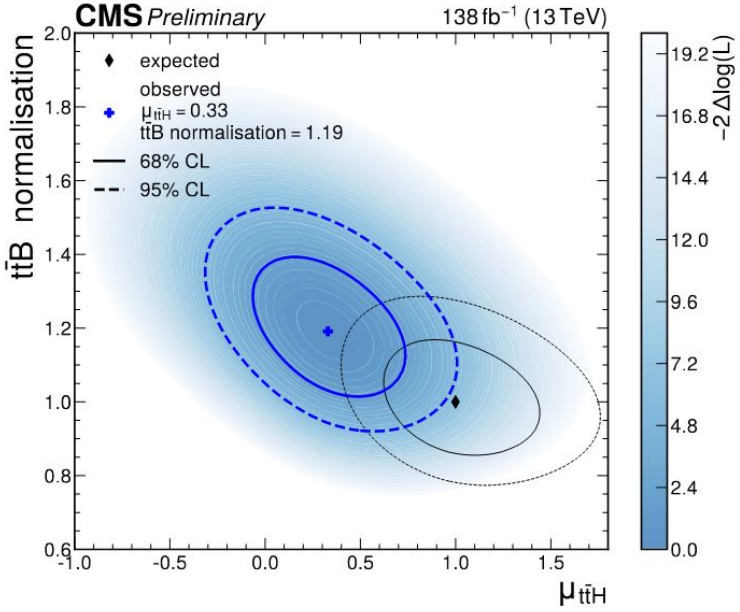
JHEP 07 (2023) 088
PRL 125, 061801 (2020)

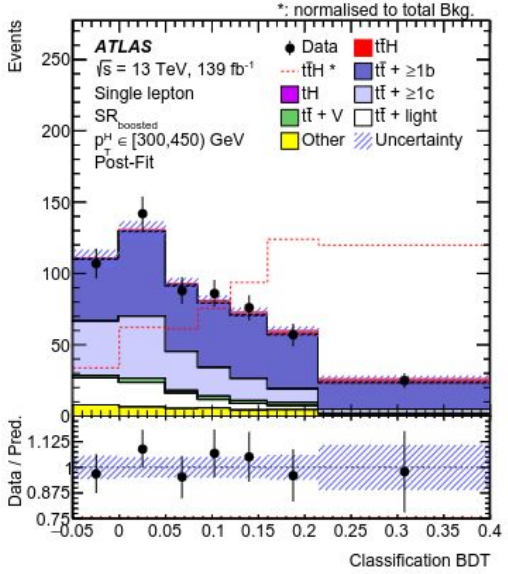
ttH/tH experimental status (H→bb)

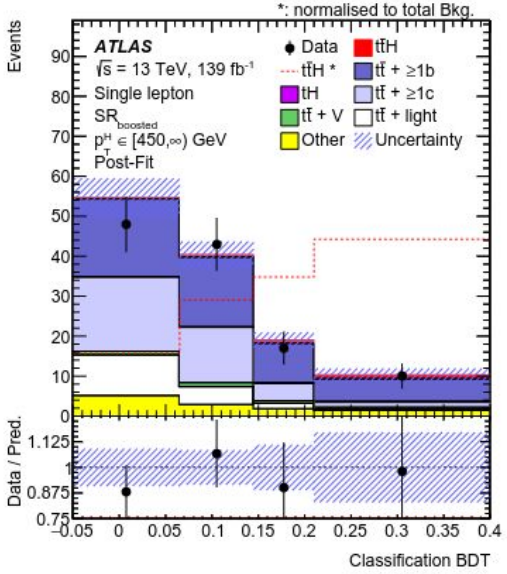
- Larger branching ratios, but large tt+jets backgrounds
- In particular, modeling of tt+heavy flavor very challenging
  - tt+heavy flavor normalization around 1.2-1.3 with 10% uncertainty
  - Signal strength in the order of 0.3 +/- 0.3











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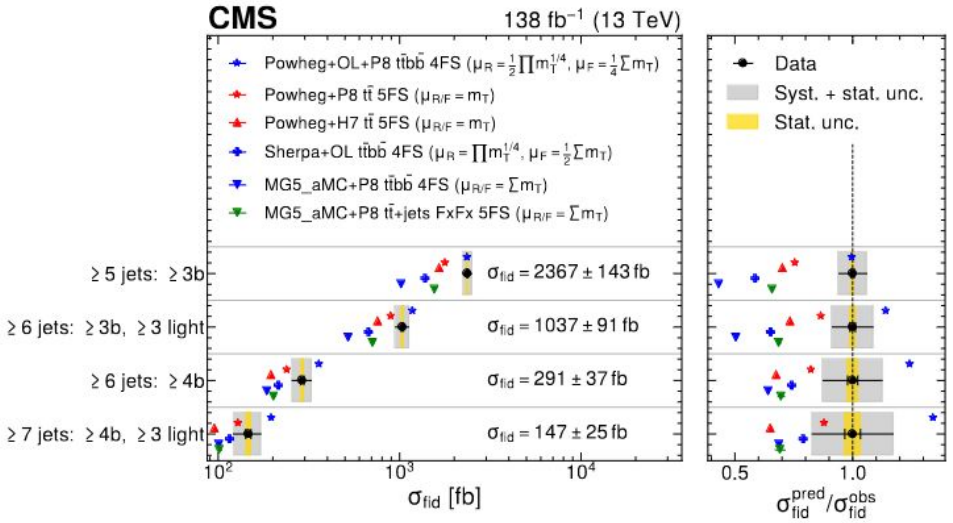
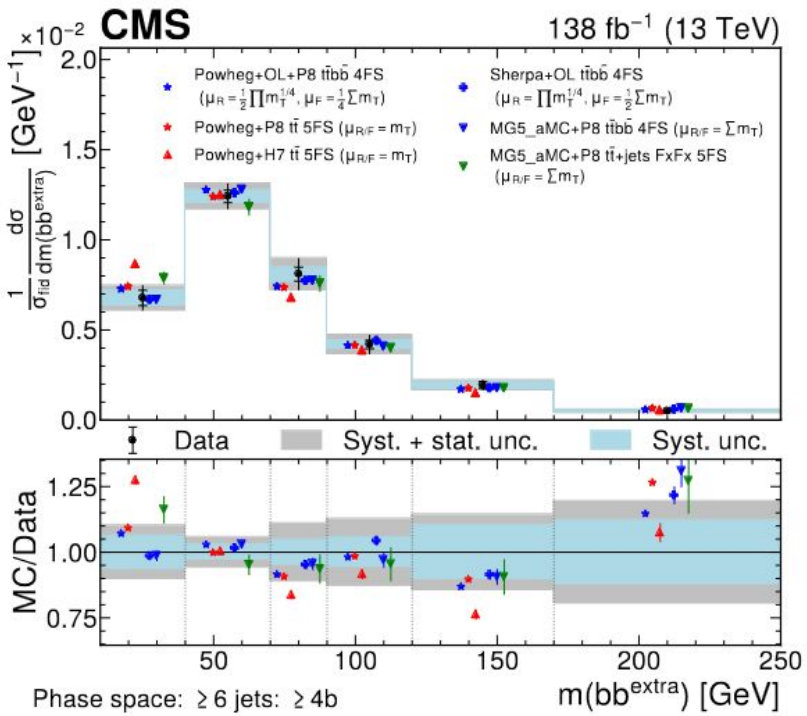
CMS-PAS-HIG-19-011

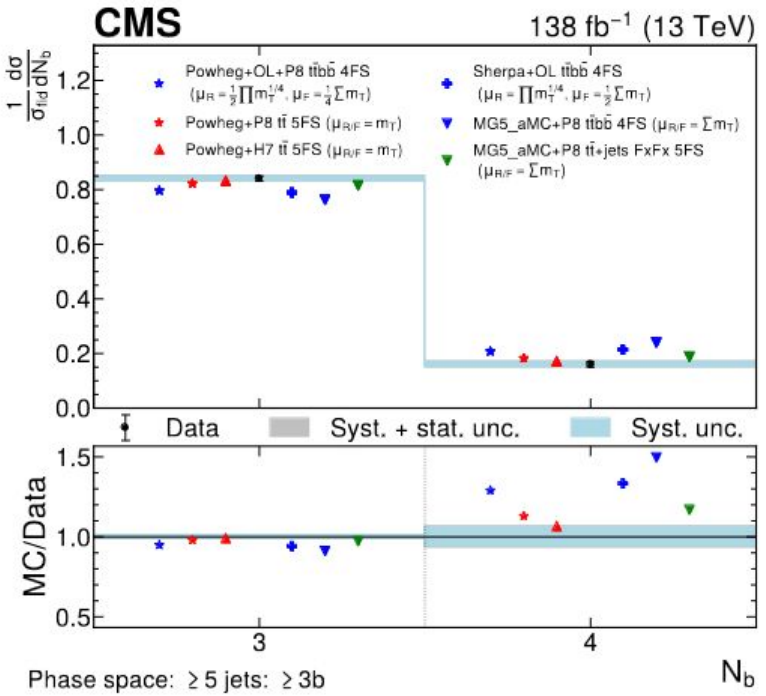
Latest results on ttbb

arXiv:2309.14442

- Inclusion and differential cross section measurement of ttbb production performed by CMS
- Most models underpredict fiducial cross section, with the exception of Powheg+OL
- **No generator describes well all distributions**
  - Variables associated to the extra bb pair described well by models with ME ttbb
  - b-jet multiplicity better described by inclusive ttbar models

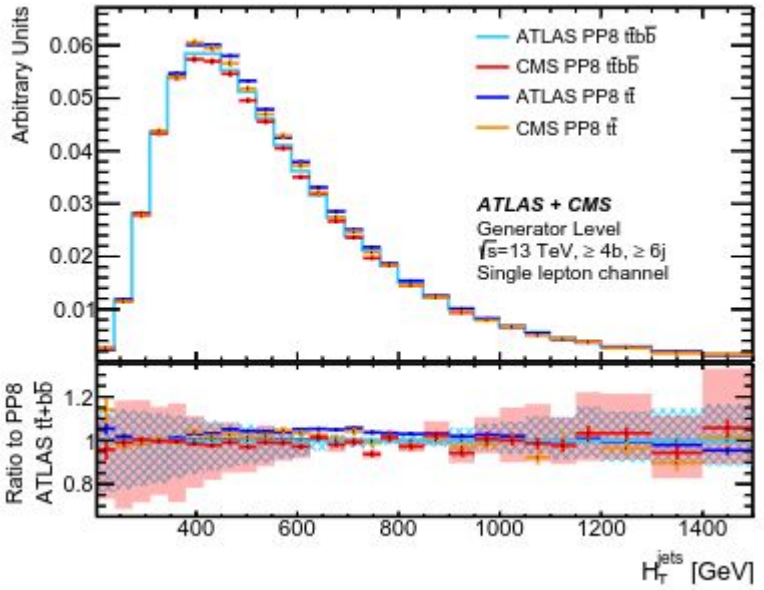




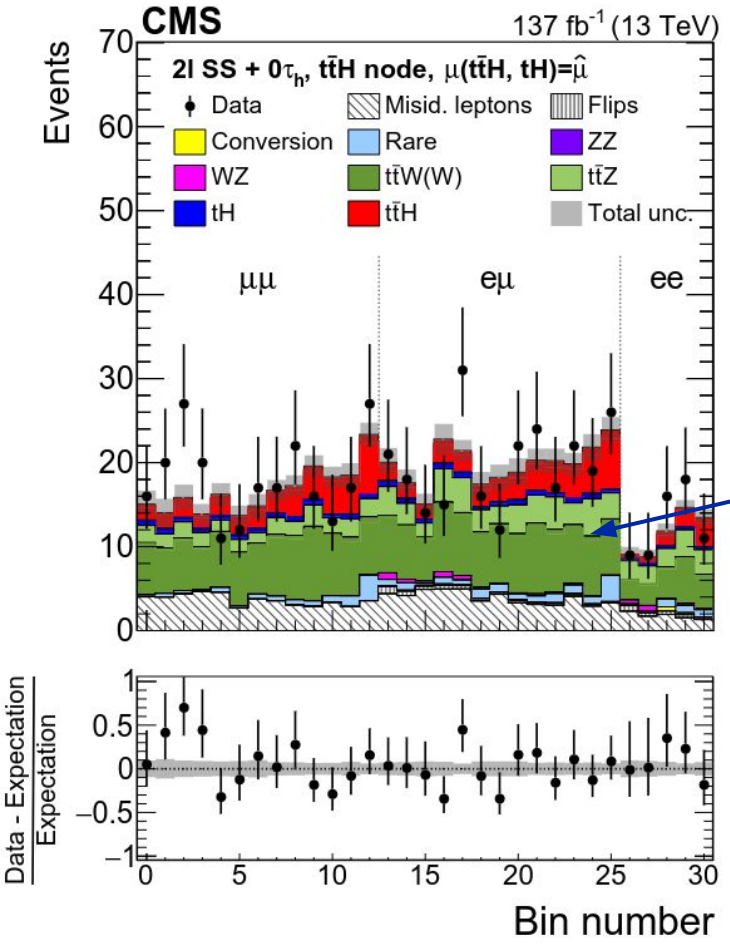


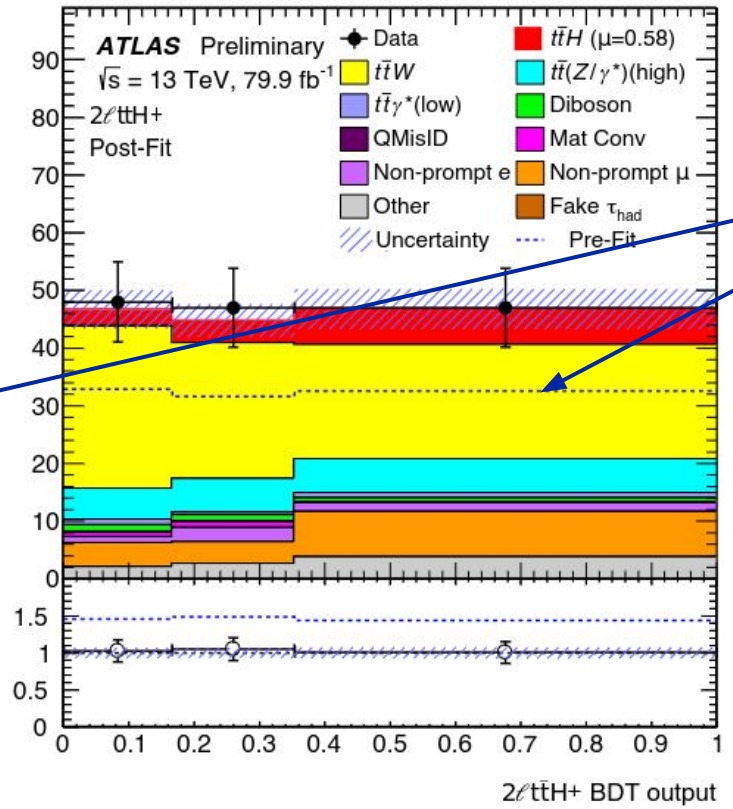
ATLAS/CMS sample comparison - ttbb

- Exercise of comparing samples used in ATLAS and CMS reported in LHCHWG-2022-003
- Good agreement between nominal samples used in latest versions of the analysis
- Uncertainty on the matching model is different between the collaborations:
  - ATLAS considering alternative models
  - CMS varying parameters of a single modeling
  - The two approaches give quite different sets of uncertainties

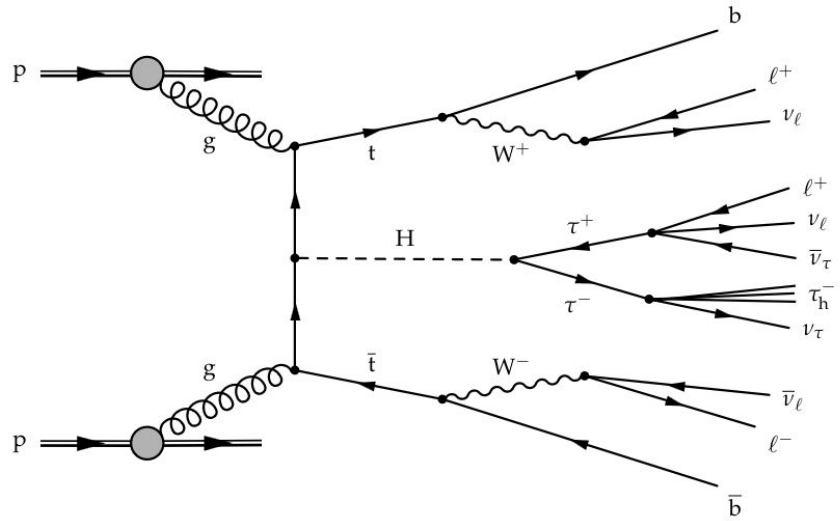


ttH/tH experimental status (multilepton)





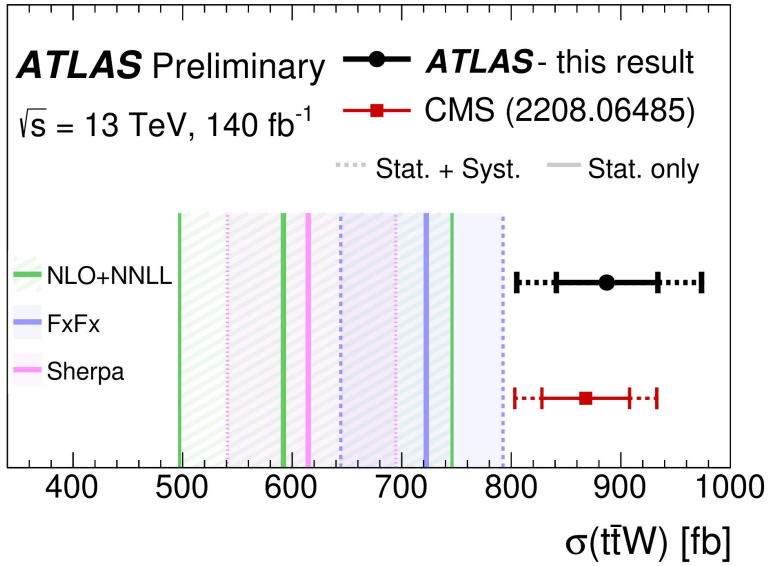
- Good trade off between rate and branching fraction
- Complex final states
  - Challenging reconstruction of top and Higgs systems
- Moderate background contributions from tt+X production, dominated by ttW

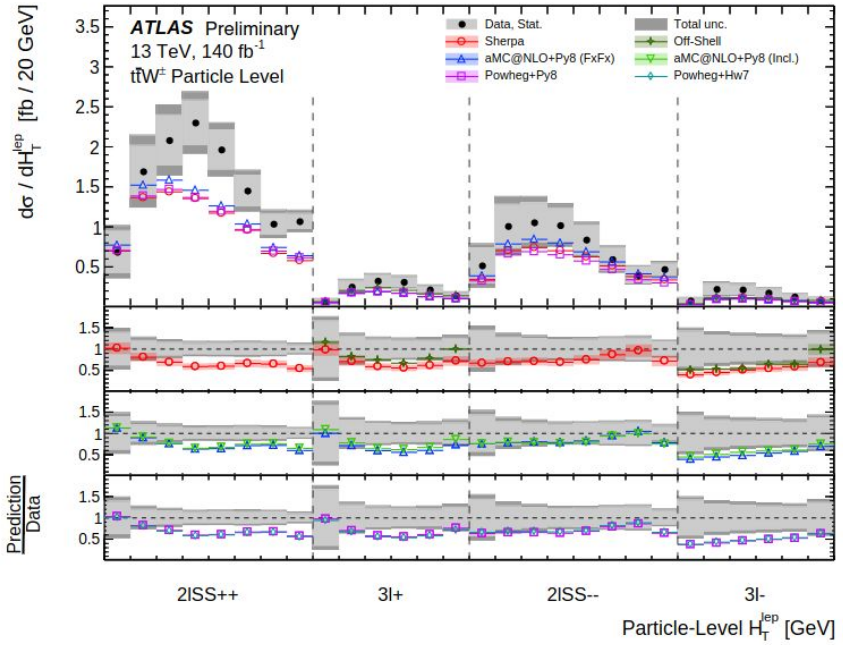


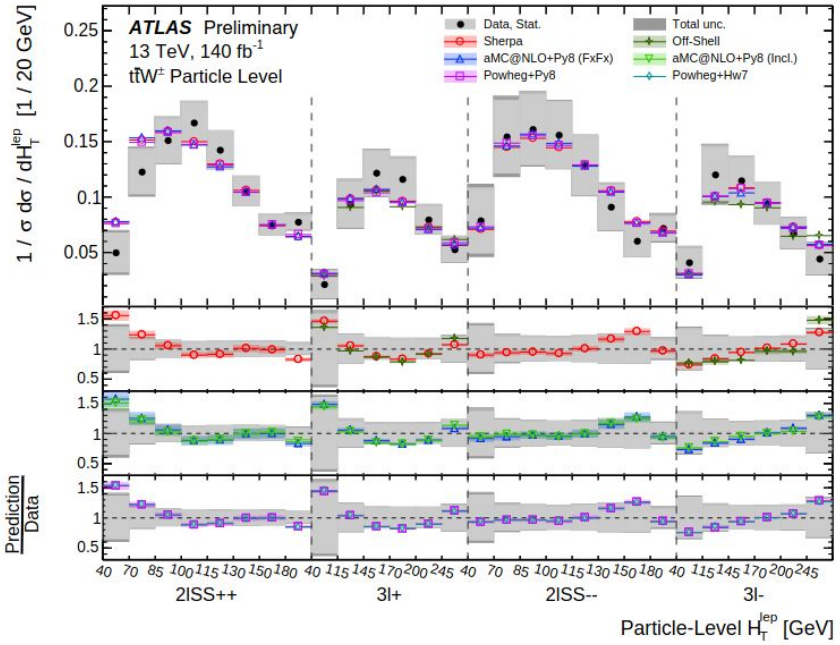
Eur. Phys. J. C 81 (2021) 378
ATLAS-CONF-2019-045

Latest experimental results on ttW

- ttW inclusive cross section measured by ATLAS and CMS in a phase space similar to ttH production
  - Normalization off by 20-40% wrt reference calculations
  - ~different predictions given by FxFx and Sherpa matching/merging schemes
- Process studied differentially by ATLAS (absolutely, relatively and charge asymmetry)
  - Some trends visible in the data but not statistically significant
  - Data doesn't favor particularly any of the models



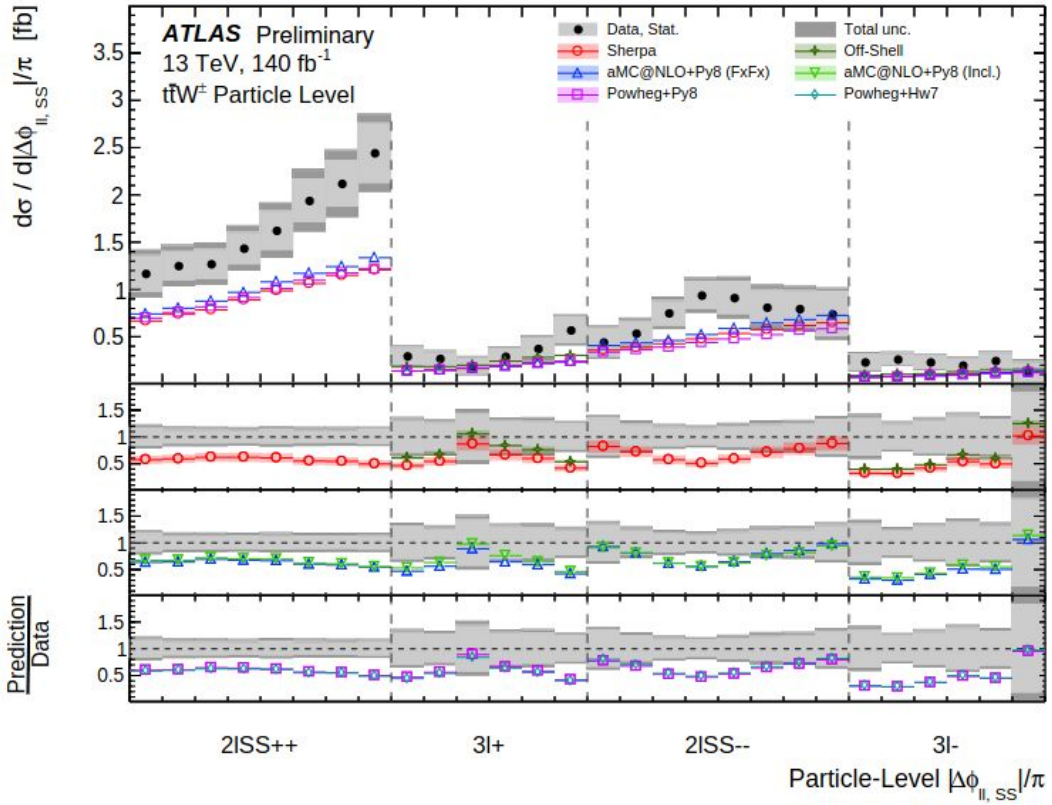


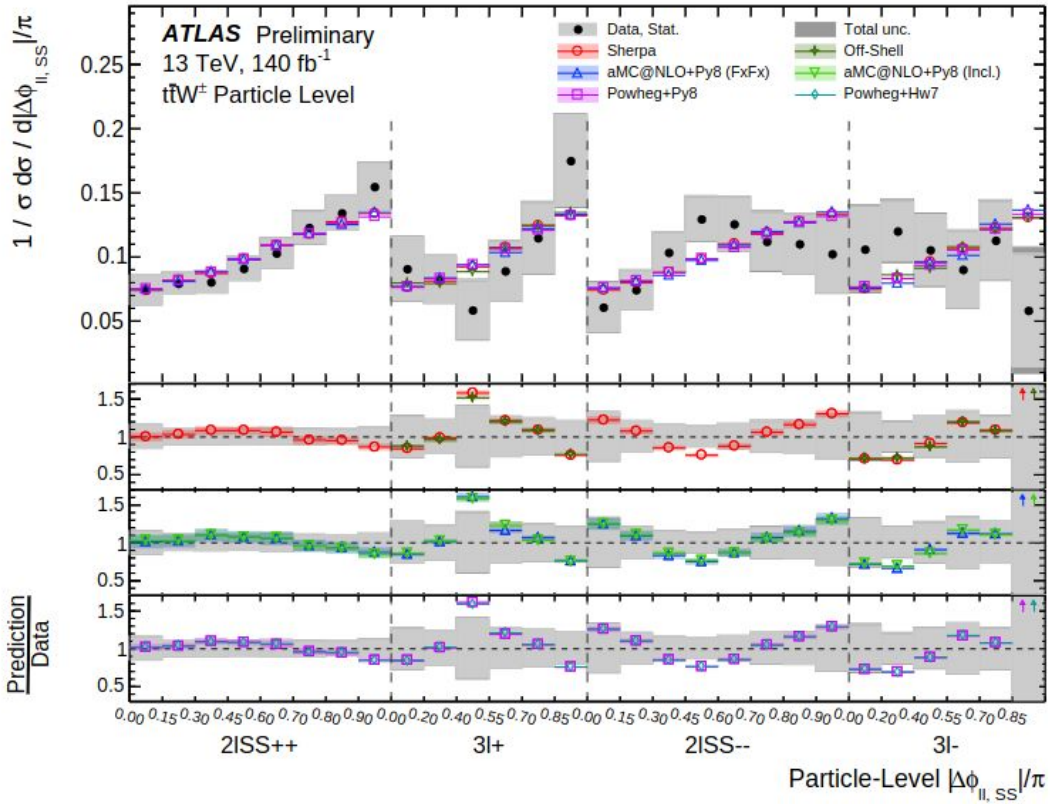


ATLAS-CONF-2023-019
JHEP 07 (2023) 219

Latest experimental results on ttW

- Process studied differentially by ATLAS (absolutely, relatively and charge asymmetry)
  - Some trends visible in the data but not statistically significant
  - Data doesn't favor particularly any of the models





ATLAS-CONF-2023-019

ATLAS/CMS sample comparison - ttW normalization

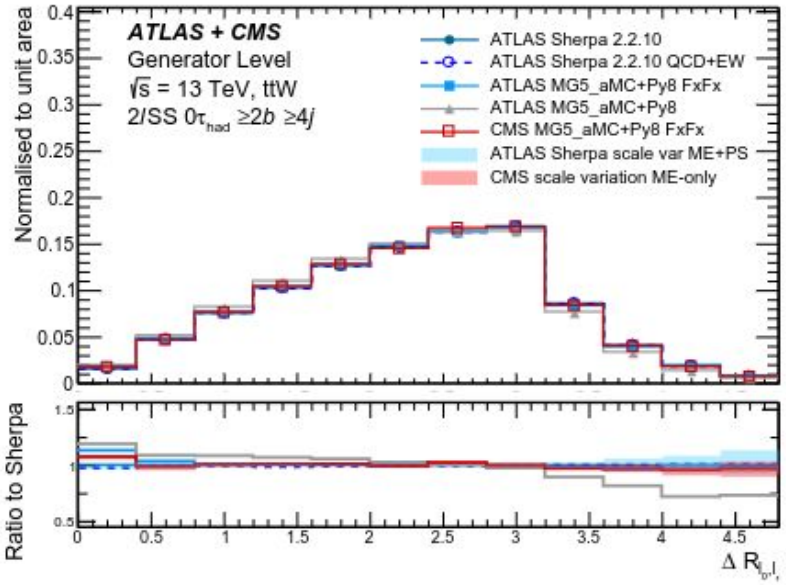
- Exercise of comparing samples used in ATLAS and CMS reported in LHCHWG-2022-003
- Disagreement between
  - "Improved" FxFx multijet merging → JHEP 11 (2021) 029
  - Sherpa with a-priori equivalent settings used by ATLAS

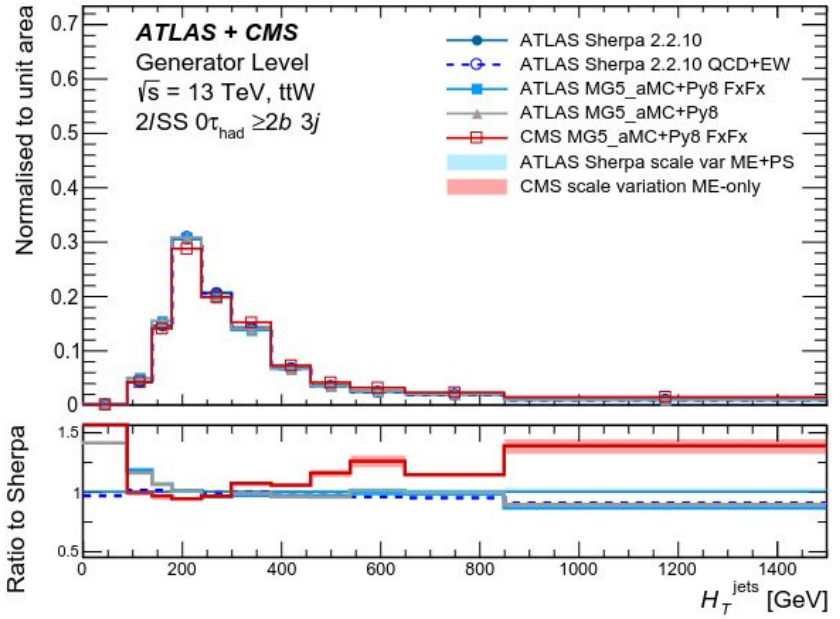
Label	ATLAS Sherpa 2.2.10
Process	$t\bar{t}W$ inclusive
Generator	SHERPA 2.2.10 [27]
order of QCD ME	0,1 j@NLO[a]
ME or core scale	$\mu_R = \mu_F = H_T/2$
order of EW corr.	-
Parton Shower	SHERPA 2.2.10
Merging Scheme	MEPs@NLO [62]
Merging Scale	30 GeV
PDF	NNPDF3.0 NNLO [71]
Tune	SHERPA default
Cross section[b]	597 fb

Order (default scale)	$\sigma \pm$ scale $\pm$ PDF [fb]
FxFx@2J	$691.1(8)^{+65.7(+9.5\%)}_{-74.1(-10.7\%)}{}^{+7.3(+1.1\%)}_{-7.3(-1.1\%)}$
FxFx@2J+NLO$^{\text{sub}}_{\text{EW}}$	$738.8(8)^{+75.0(+10.1\%)}_{-81.3(-11.0\%)}{}^{+7.5(+1.0\%)}_{-7.5(-1.0\%)}$
FxFx@2J+NLO$^{\text{lead}}_{\text{EW}}$+NLO$^{\text{sub}}_{\text{EW}}$	$722.4(8)^{+70.2(+9.7\%)}_{-77.7(-10.8\%)}{}^{+7.2(+1.0\%)}_{-7.2(-1.0\%)}$

ATLAS/CMS sample comparison - ttW shape

- Exercise of comparing samples used in ATLAS and CMS reported in LHCHWG-2022-003
- Different models considered
  - Sherpa and Madgraph with(out) multijet merging
  - ATLAS and CMS Madgraph equivalent models disagree in jet multiplicity variables, H_T, likely related to differences in merging scale
  - Clearly should be followed-up



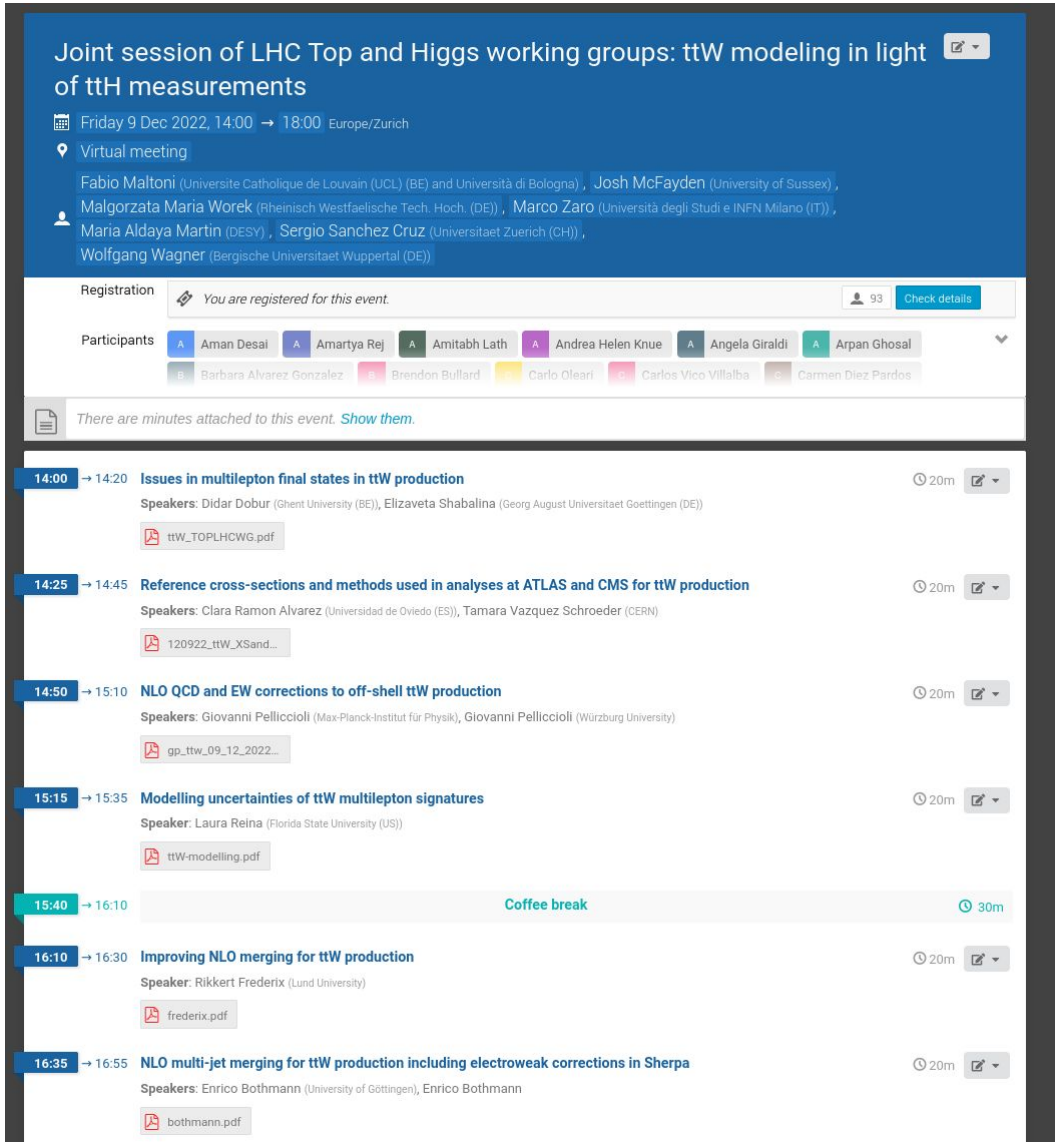


Current status on ttW

- Joint meeting of the LHC Top and Higgs working groups took place last december to discuss ttW
- Agreed on the necessity of pursuing:
  - Inclusive cross section comparisons between improved FxFx and Sherpa merging schemes
  - Shape comparisons between the ATLAS and CMS samples

- Inclusive ttW cross section at NNLO (arXiv:2306.16311) released this June
  - Results compatible with the improved FxFx matching scheme
  - **NNLO value is the current reference**

- Differential ttW cross sections at NNLO not yet available
  - **Dedicated and consistent comparisons between the different models are still needed**
  - Comparison studies currently on hold, due to limited person power



Improving collaboration between theory and experiment

- We have identified a few areas of improvement in the collaboration between theory and experiments
- The community relies on significant work by theorists which is often not rewarding, specially to young scientists
  - Detailed comparisons between different generators as the ones mentioned earlier
  - Producing predictions for a custom fiducial region/binning/center-of-mass energy
- The proposal and actions outlined by Gudrun yesterday go in the right direction to address these points

- Start experiment/theory communication early in the experimental analysis design process
  - Share fiducial region / binning, so predictions can be tailored to the analysis
- Come up with ways to encourage theorists producing predictions for experiments
  - Short term associate figure → allow them to sign specific papers and participate in collaboration meetings

- Pursue collaborations with other working groups, such as the Top LHC WG / EFT LHC WG

Next activities

- We are preparing a dedicated ttH meeting in January
- Will cover the latest set of experimental and theory results:
  - Latest ttH(bb) measurements
  - Off-shell and NLO contributions to CP-violation ttH
  - Matched NNLO+NNLL inclusive ttH cross section