Topics for SM Higgs discussions

- experimental perspective -

11th June 2019

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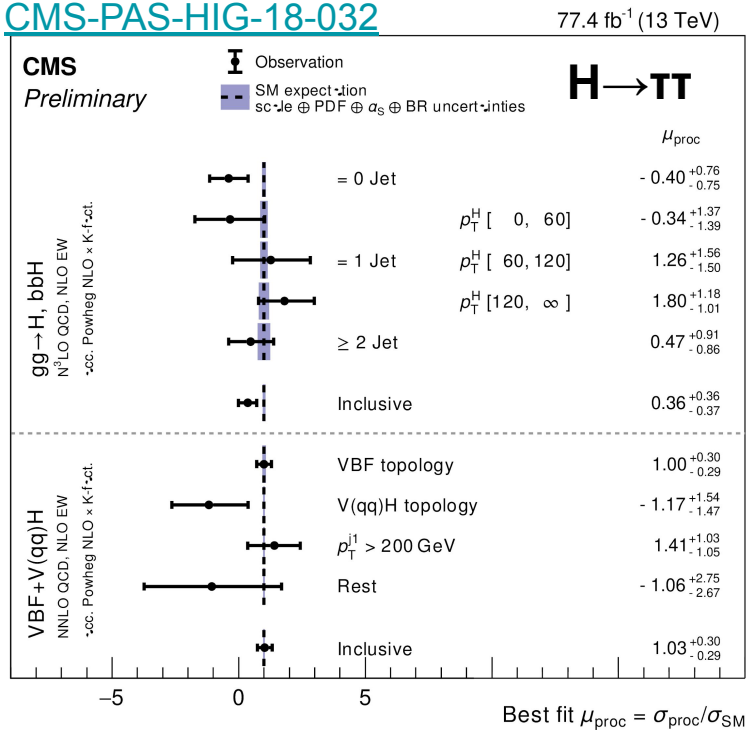
Experimental Highlights

STXS Higgs measurements

- STXS started in Les Houches 2015
- Both experiments have produced STXS measurements
- Kinematic information for ggH, VBF and VH is extracted

CMS-PAS-HIG-18-032



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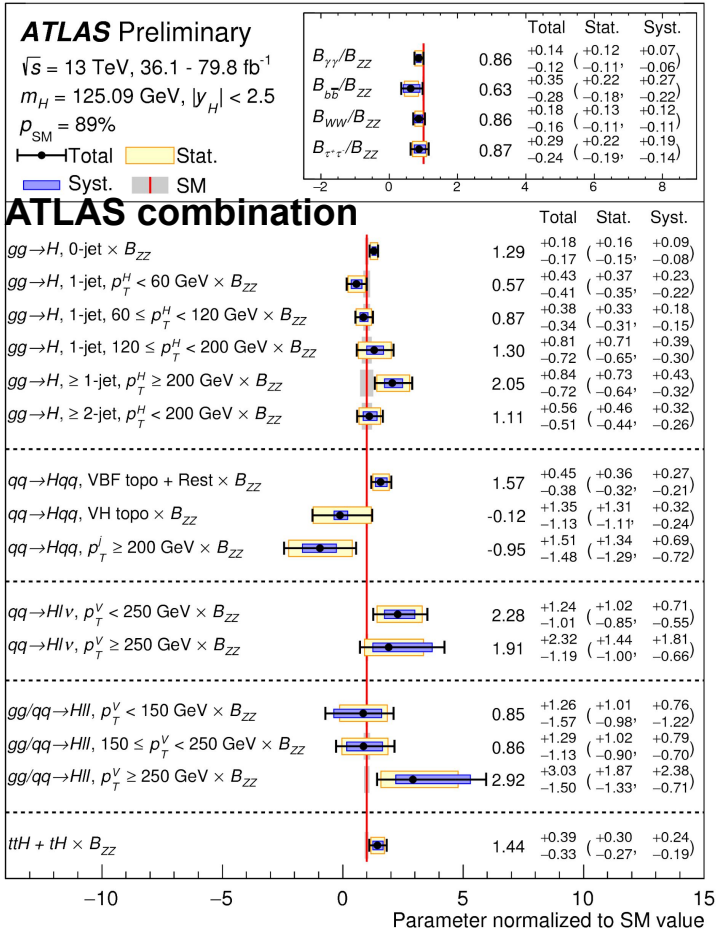

STXS interpretations

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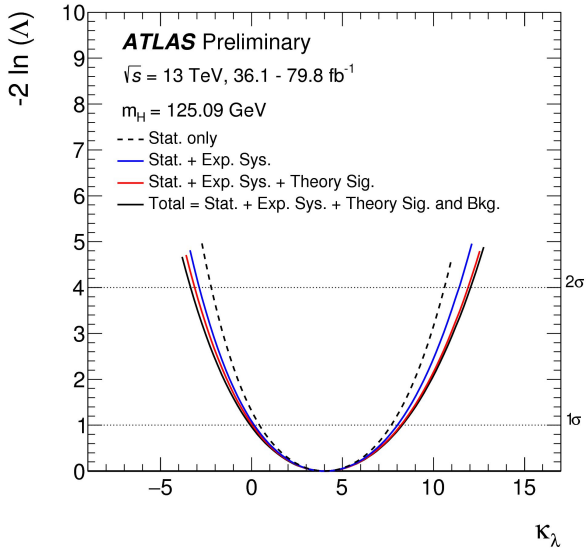

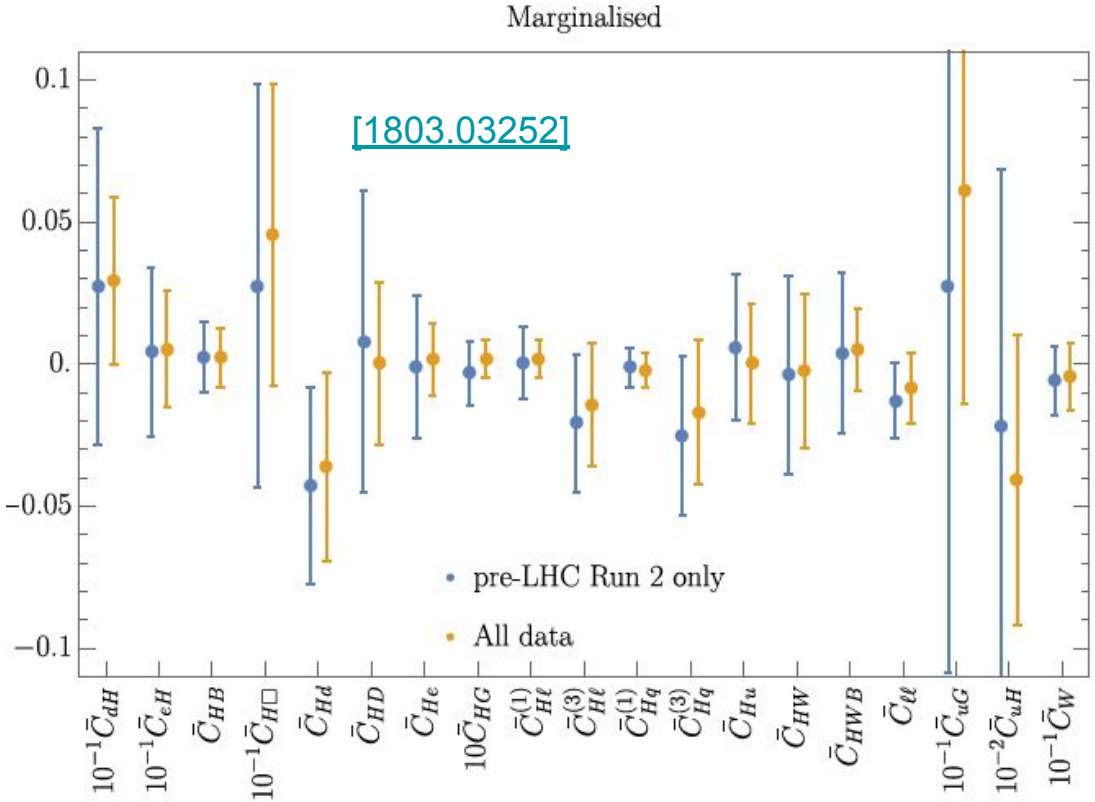

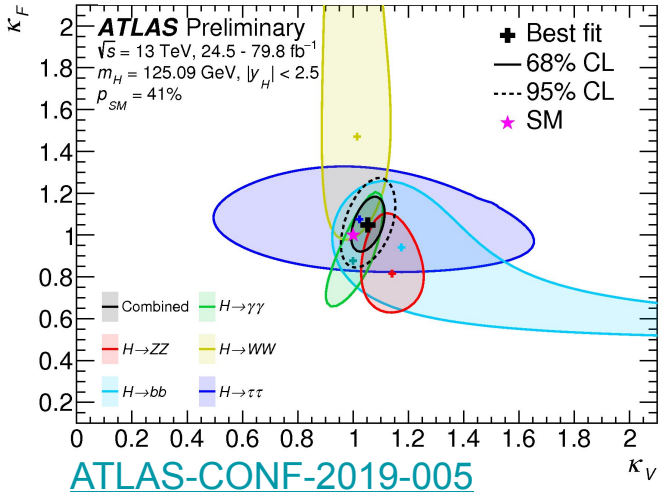

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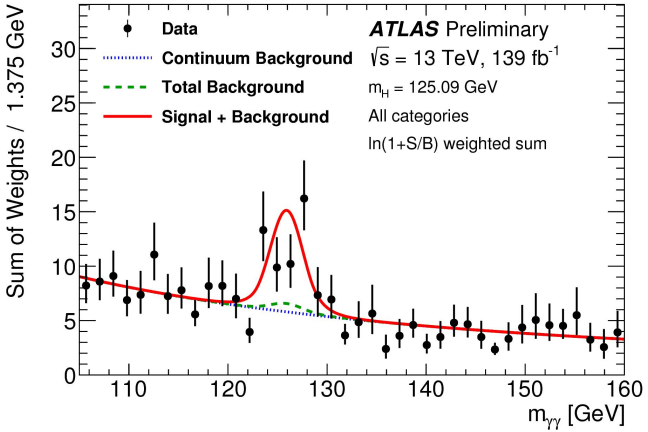
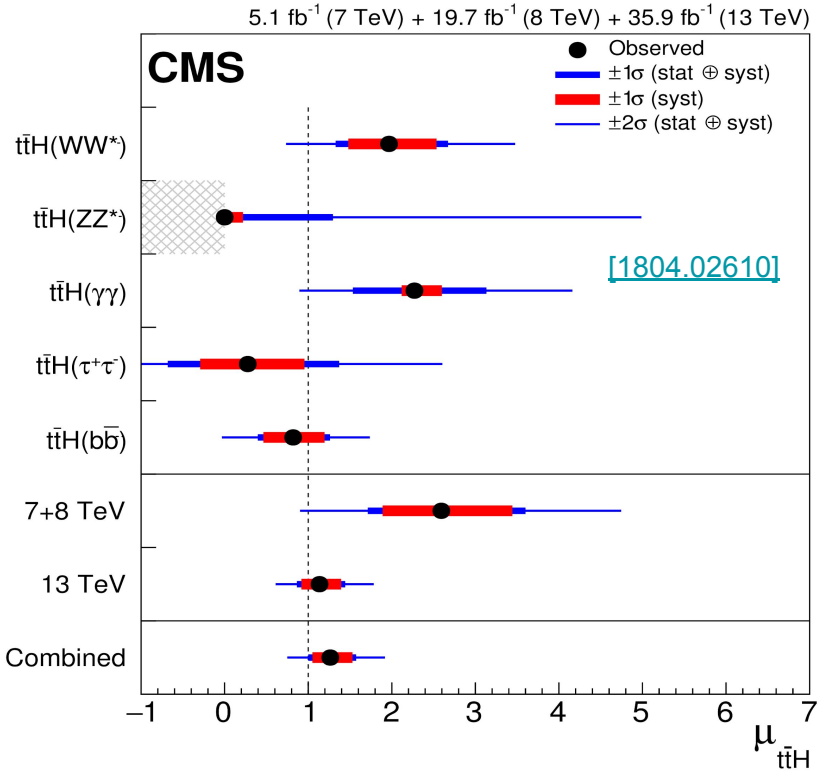
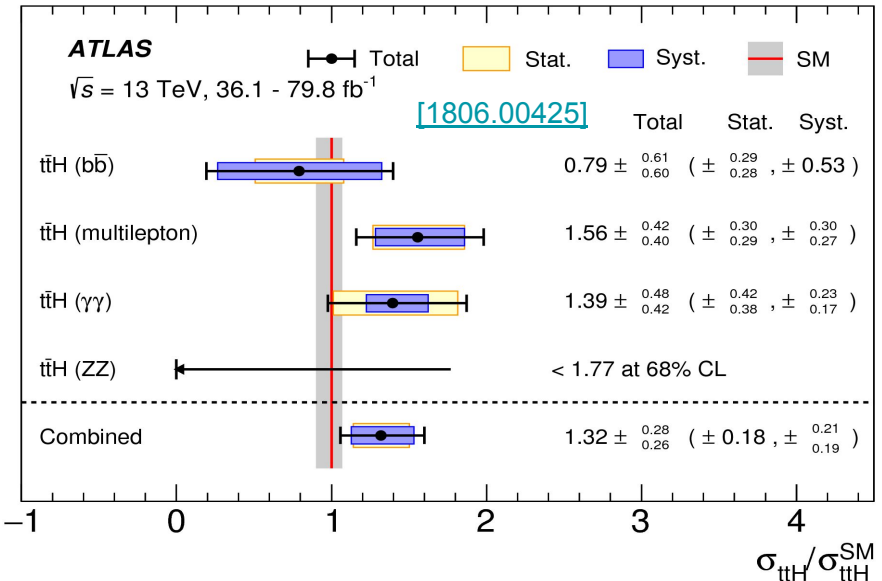
ttH measurements

- Observed Higgs production in association with tops
- Uncertainty O(20-30%)

ATLAS-CONF-2019-004

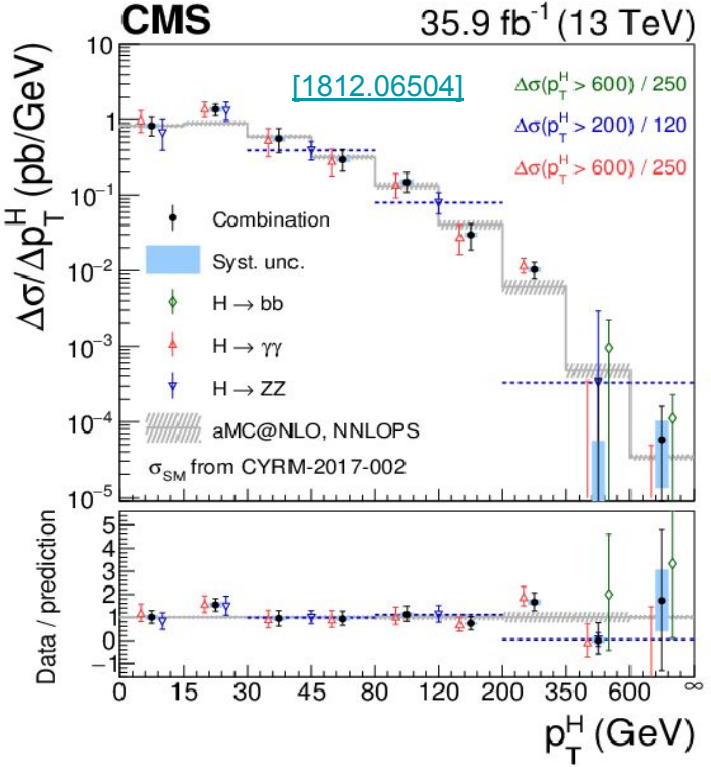


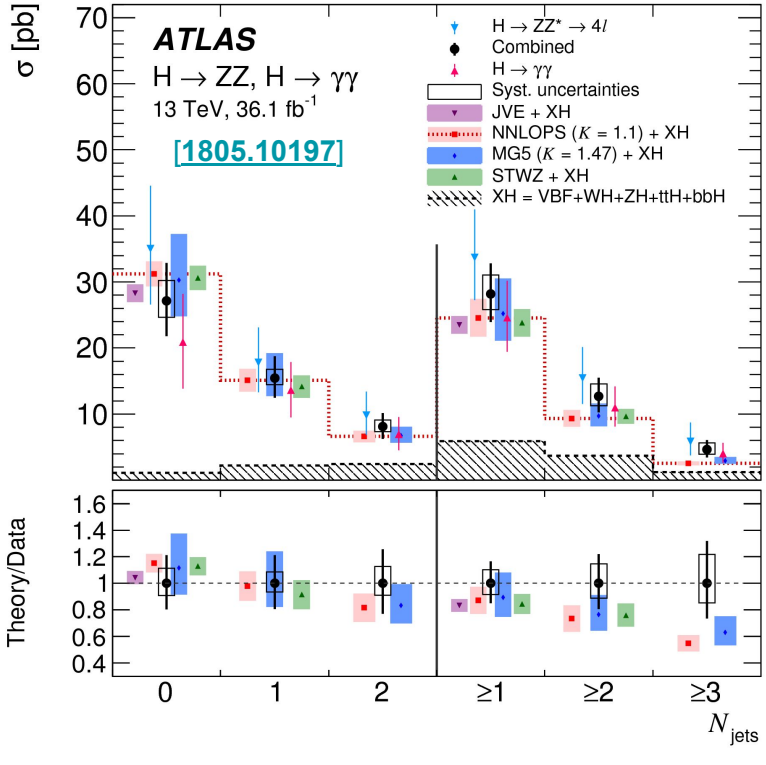




Differential cross section combination

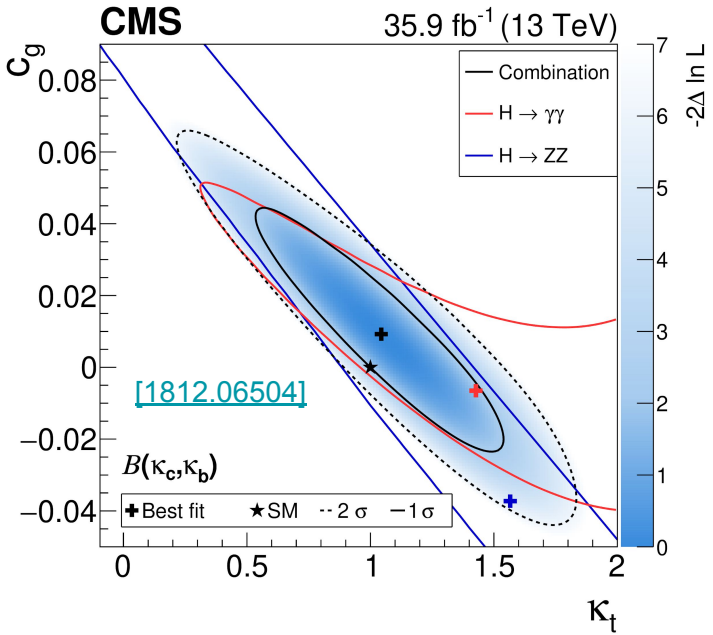
- Combined differential cross section measured in different final states to increase statistical power
- 30-40% uncertainty per bin (up to 25% better than H→γγ alone at low pT);
- 60% at high pT because of ggHbb

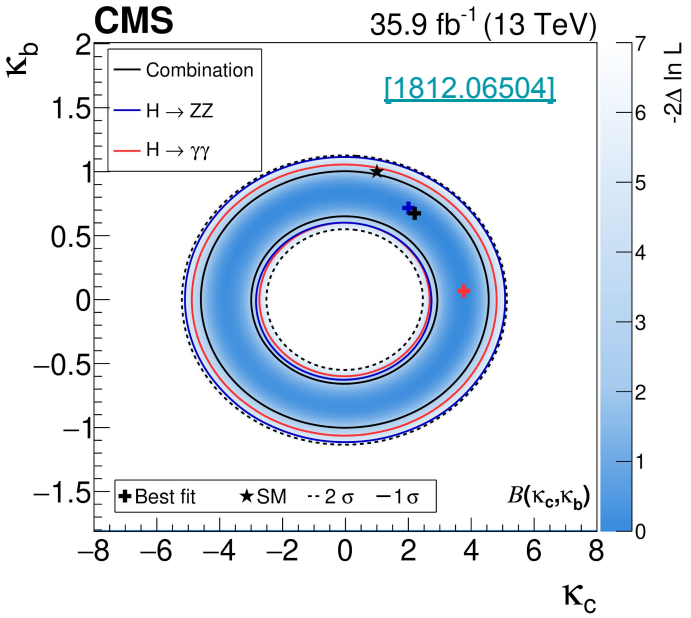




Differential cross section interpretation

- Parametrize differential cross sections as a function of couplings and constrain them fitting pT
- ggH contact interaction disfavoured. Interplay between normalization and shape information

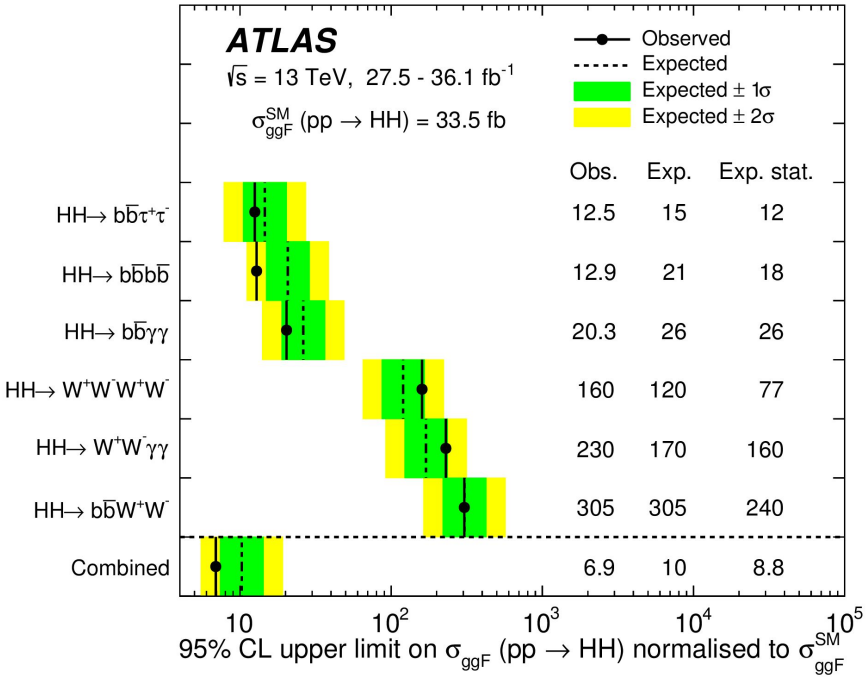




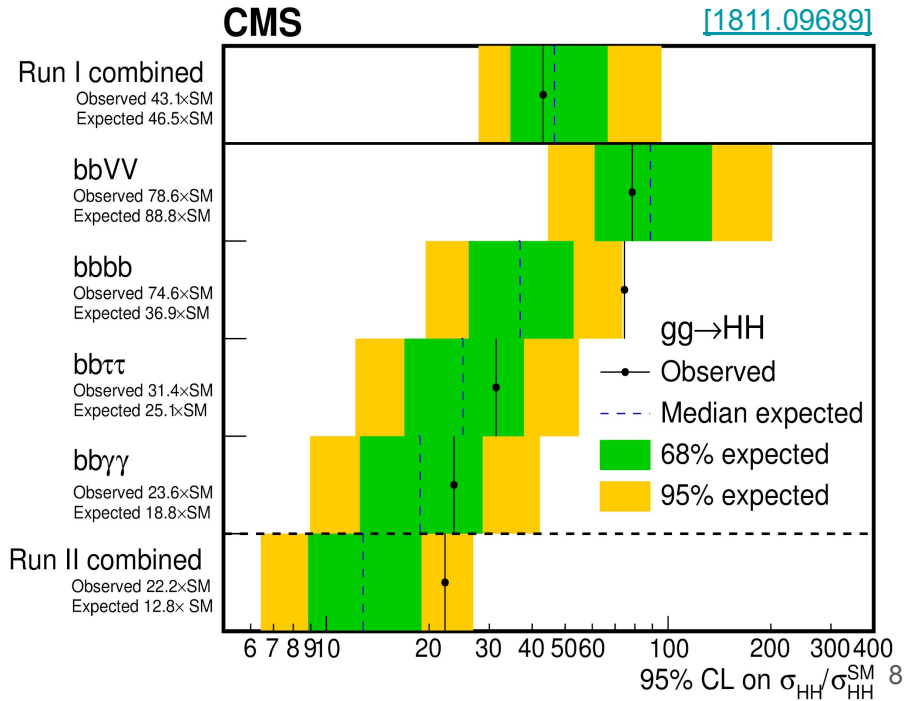
HH combination

- Combined upper limits on Higgs pair production
- Experiments have different sensitivities on the different channels, but similar when combined

[1906.02025]



[1811.09689]



Some proposed topics for the Les Houches discussions

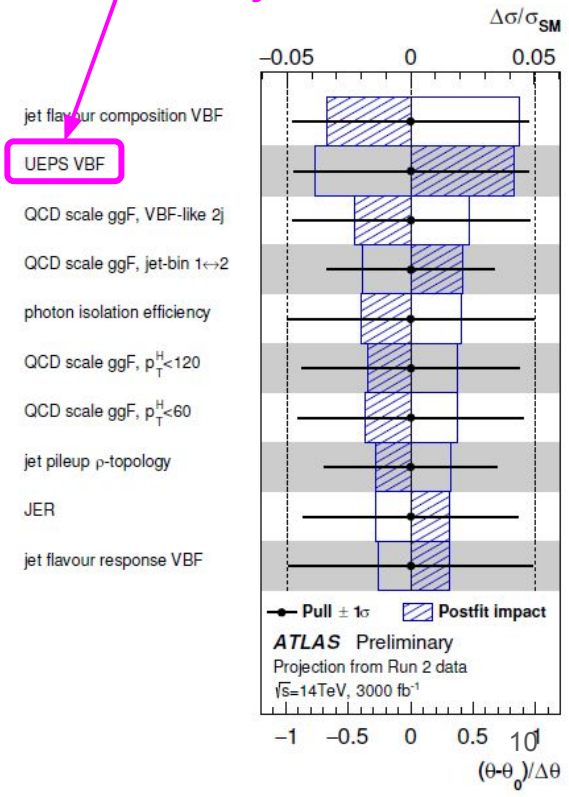
Here are some challenges in Higgs measurements. This list is for sure not complete, but rather intended to start the discussions!

- Parton shower systematics
- ttH backgrounds (might also apply to VHbb)
- Quark/gluon jet tagging
- ttH*(H*->tt) and tttt interference
- Background function choice for H->gamgam and H->mumu
- STXS in Higgs production (ttH, VBF/VH angles, …)
- Brainstorming for “STXS” or similar in Higgs decays
- EFT interpretation of Higgs measurements
- **Other topics are very welcome!**

Modelling systematics (parton shower)

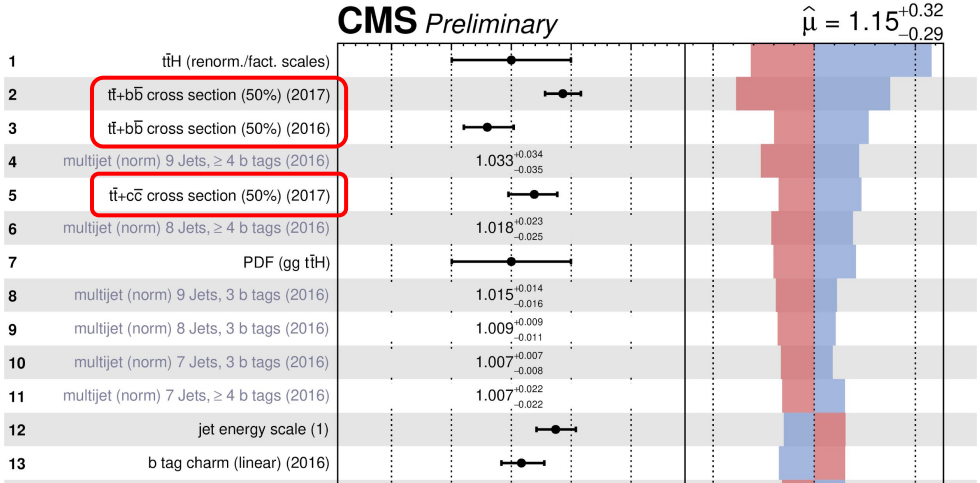
- A bit “fuzzy”, often experiments label everything that is not related to missing higher order (QCD scale) or PDF variations as modelling systematics, sometimes just “parton shower or underlying event+parton shower”
  - Actual parton shower tune variations
  - Comparisons between different (parton shower) generators
  - Possible hadronization effects
  - Possible underlying event effects
- Depending on the evaluation, effects can be sizeable and inclusion in experimental results is not fully consistent
- Some of the included variations double count other uncertainties, e.g. resummation uncertainties

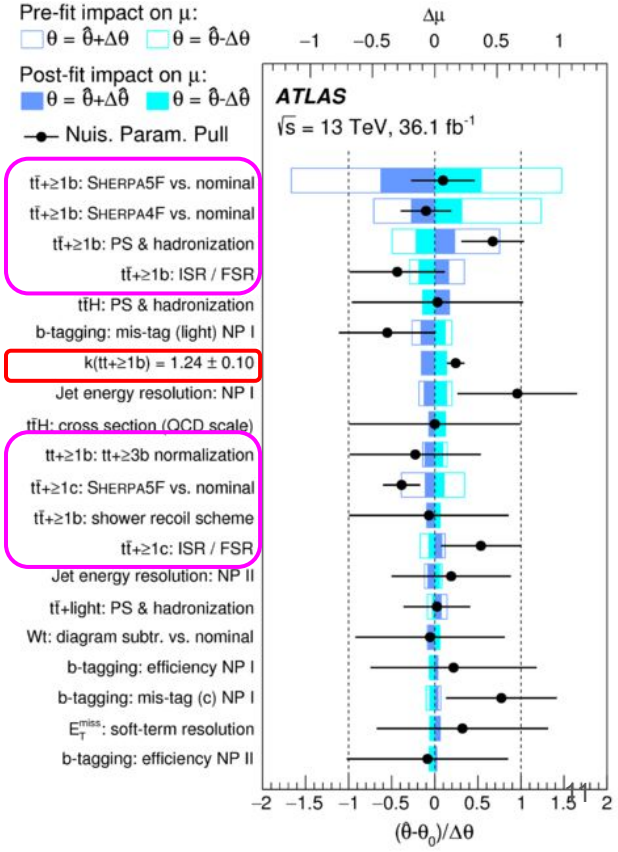
HL-LHC H→γγ: 50% of current UEPS uncertainty



ttH backgrounds (tt+bb)

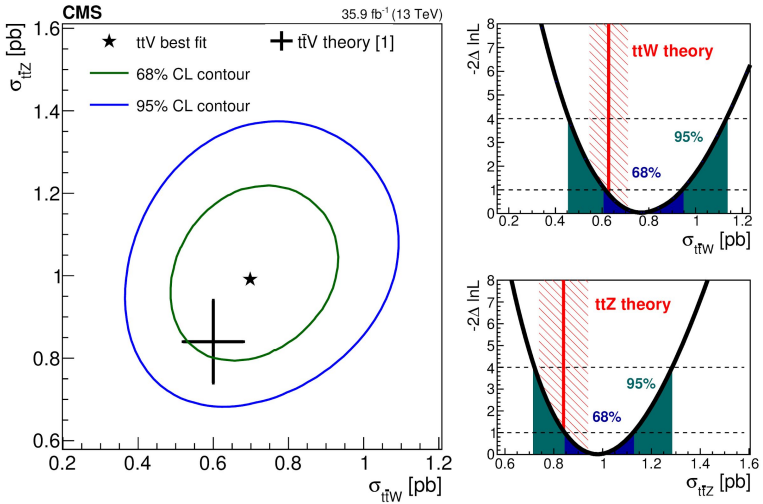
- tt+HF (HF=bb,cc) is the dominant background for ttHbb measurements and it's systematic uncertainty limits or will limit measurements
- On top of cross section systematics, also large systematics on the tt+HF modelling could play a role depending on the used tt+HF background model

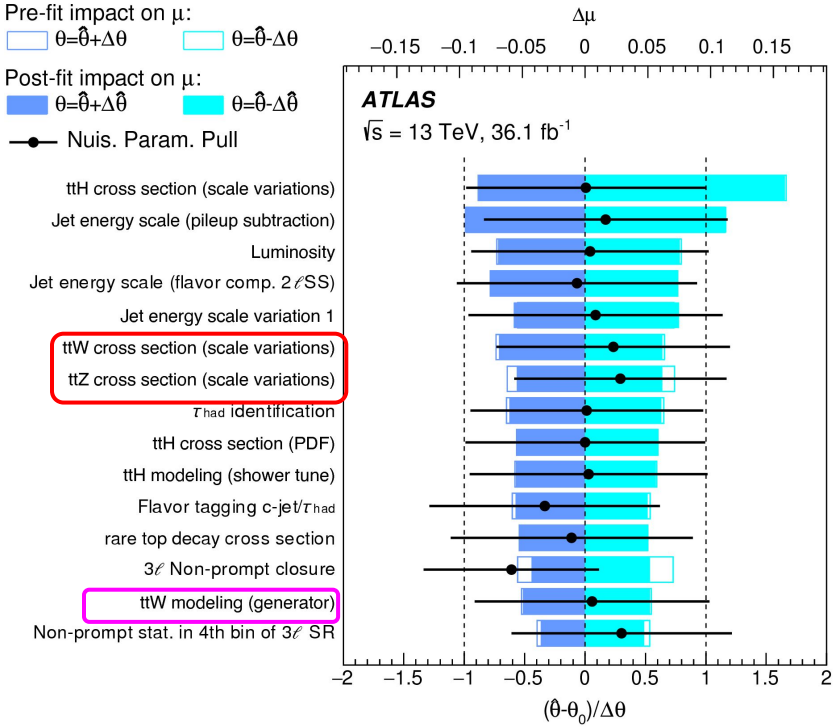




ttH backgrounds (ttV)

- ttZ and ttW are the main backgrounds to the ttH multilepton measurements and their cross section uncertainty has a large systematic impact
- Once ttZ or ttW are measured from control regions, the corresponding modelling systematics will likely become large/dominant

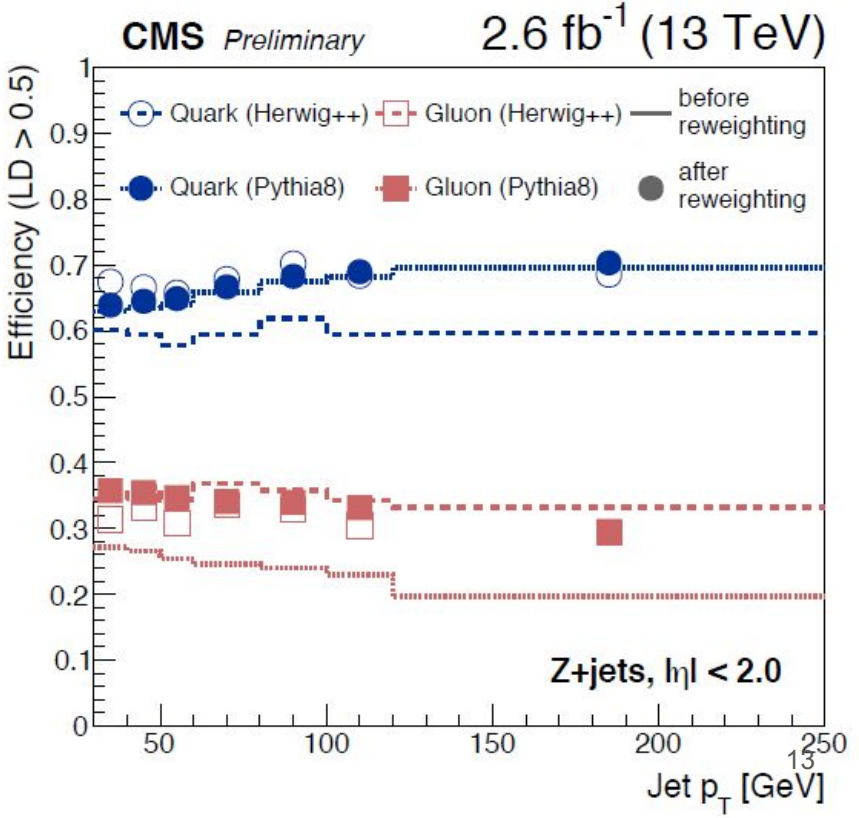




CMS: 2234117
ATLAS: ATL-PHYS-PUB-2017-009

Quark gluon jet tagging

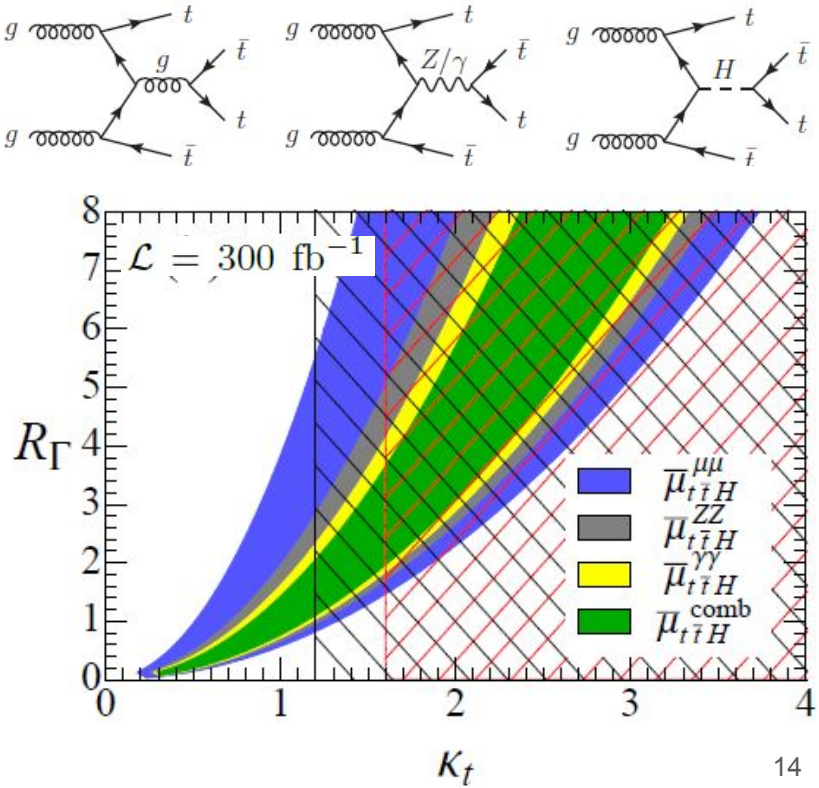
- Quark/gluon jet tagging is so far not widely used in Higgs measurements
- But promising to
  - better separate different Higgs production modes: ggH vs. VBF
  - Better discriminate against backgrounds
- Experiments have already included it in some Higgs measurements, but the full potentially is likely not used yet



ttH*(H*->tt) and tttt interference

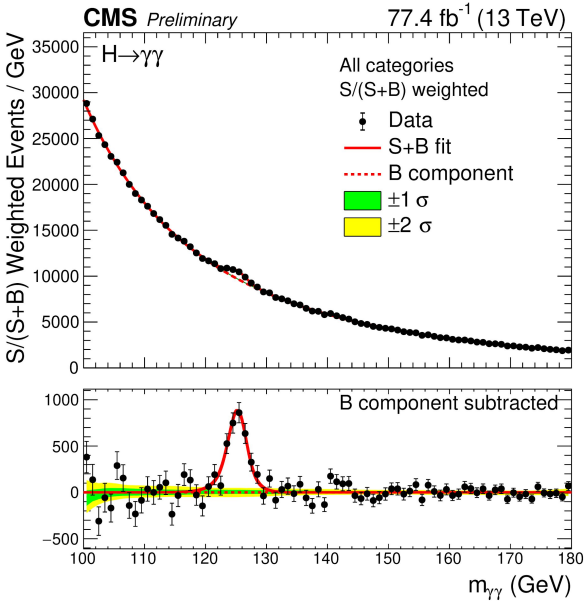
https://arxiv.org/abs/1602.01934

- Another way to measure a Higgs coupling in the off-shell regime, independent of the total width of the Higgs
- Allows to constrain the total width together with the on-shell measurements
- However, in 4-top events, so considerably more challenging compared to 4-leptons
- But also more sensitive



Backgrounds from functional form fits

- The background in H→γγ and H→μμ is determined from functional form fits
- ATLAS: spurious signal
  CMS: discrete profiling method of functional forms
- So far systematics not really limiting: experiments "improve" functional forms to ensure this
- But: with increasing data stats, finding good fitting functions and evaluating the systematics/bias is getting more challenging

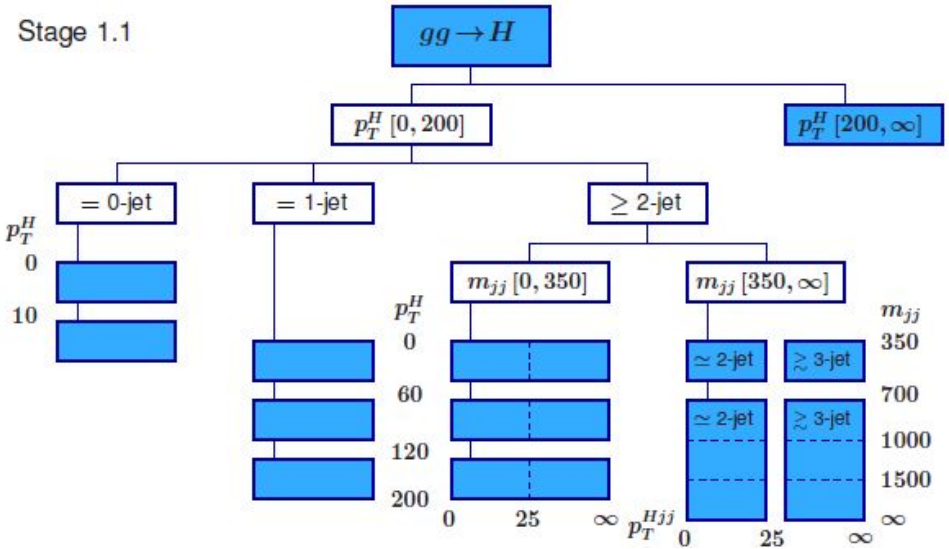


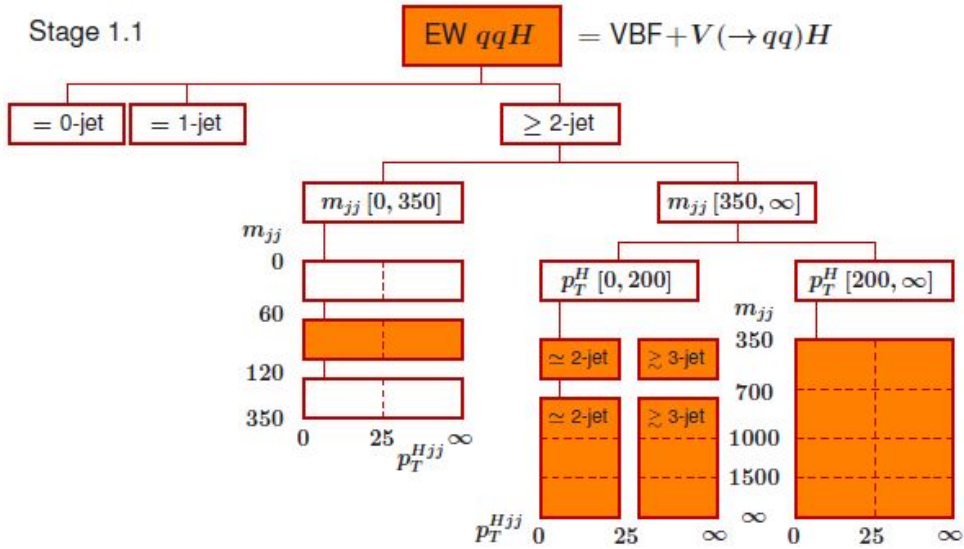
ATLAS: [1802.04146]

Source	Uncertainty in fiducial cross section				
	Diphoton	VBF-enhanced	$N_{\text{lepton}} \geq 1$	$t\bar{t}H$-enhanced	High $E_{\text{T}}^{\text{miss}}$
Fit (stat.)	17%	22%	72%	176%	53%
Fit (syst.)	6%	9%	27%	138%	13%
Photon energy scale & resolution	4.3%	3.5%	3.1%	10%	4.1%
Background modelling	4.2%	7.8%	26.7%	138%	12.2%

STXS in Higgs production

- The STXS framework for Higgs measurement is used by ATLAS and CMS to report fine grained kinematic measurements for ggH, VBF and VH
- Recent update to V1.1: [1906.02754]



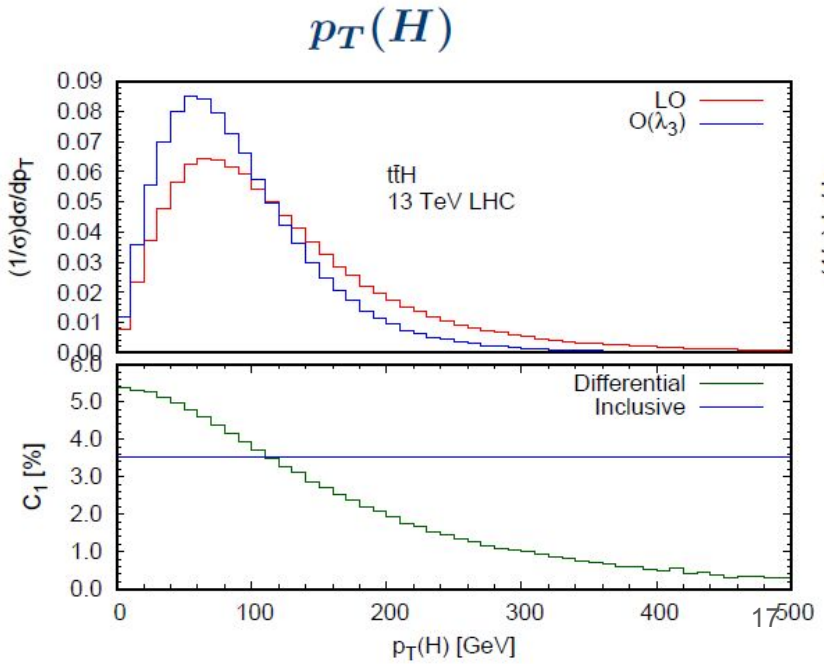


STXS in Higgs production (session Wed, 14-16:00)

- The STXS framework for Higgs measurement is used by ATLAS and CMS to report fine grained kinematic measurements for ggH, VBF and VH
- Recent update to V1.1: https://cds.cern.ch/record/2669925/

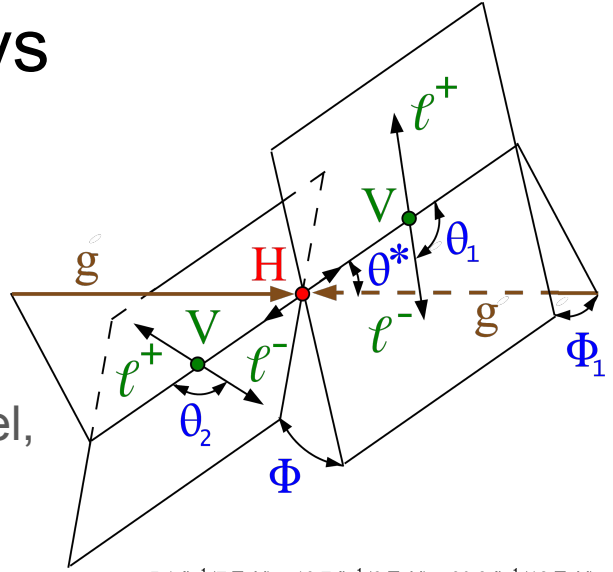
Several improvements are pending for STXS

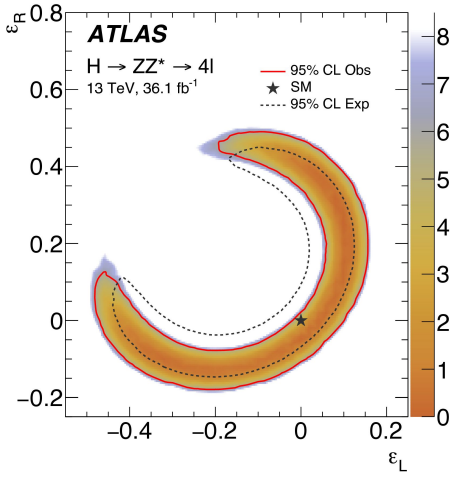
- ttH is just inclusive so far. How to bin ttH?
- ggH pT binning stops at 200 GeV, but the experimental reach goes further
- Angular correlations in VBF jets (dphi_jetjet?) provide interesting information, but are not extracted in STXS measurements so far
- Theory uncertainties and correlations for new STXS bins (and sub-bins)

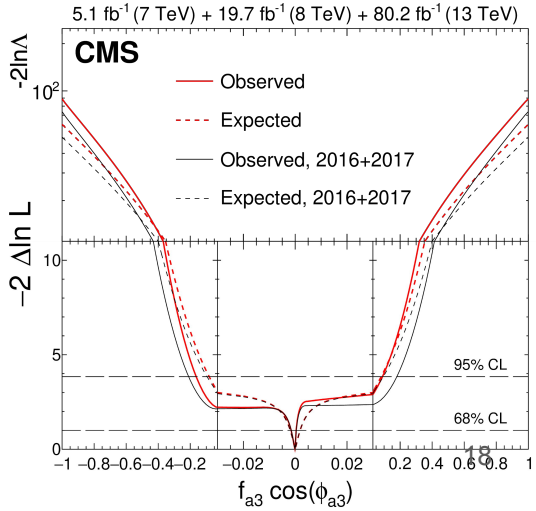


Brainstorming: “Something” for decays (session Wed, 16-18:00)

- Long pending question: how should experiments make general measurements of Higgs properties in Higgs decays (for example angular information in h->4l)
- Experiments have used the Higgs characterization model, effective Lagrangians, EFTs, f_{ai}, pseudo-observables, …
- But no general agreement!
  -> Decay information often not included in theory interpretations
- Differential measurements are usually 1D, maximal 2D, so limited
- **Les Houches is a good place for finding consensus and making proposals for something general**



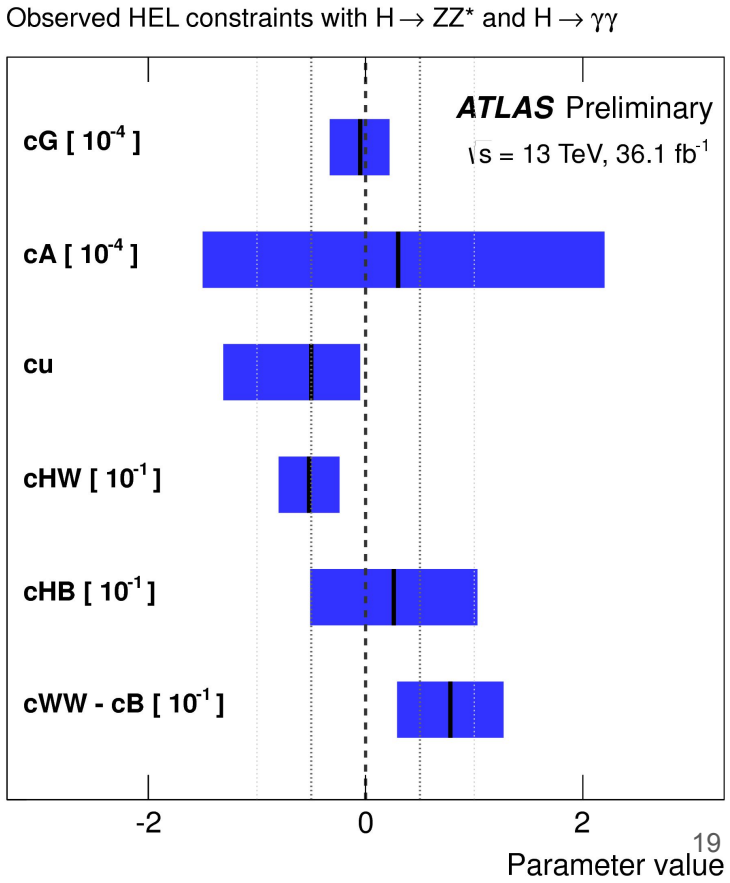




EFT interpretation of Higgs measurements (session Thu, 10-12:00)

Topics for discussion

- Selection of the EFT parameters (or combination of them) that a measurement is able to constrain in the Warsaw basis.
- Effects of neglecting, or how to properly include gg->ZH
- STXS acceptance extrapolation (related for STXS in decays)
- Simulation at NLO, in particular, if a common Madgraph syntax can be provided



Higgs brainstorming

Today, 17:30-18:30, Library!