HIGGS TO PHOTONS

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On behalf of ATLAS and CMS collaboration

** Imperial College London*

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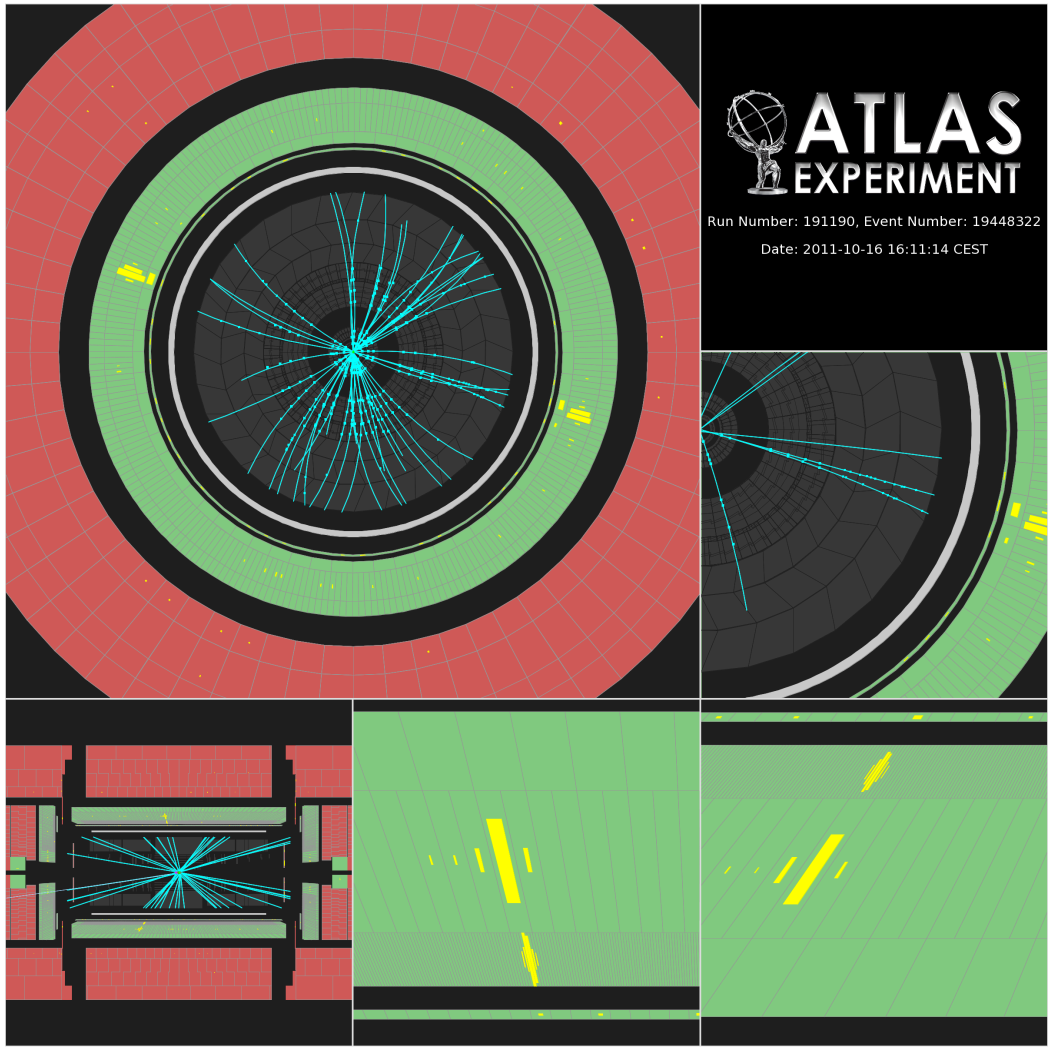
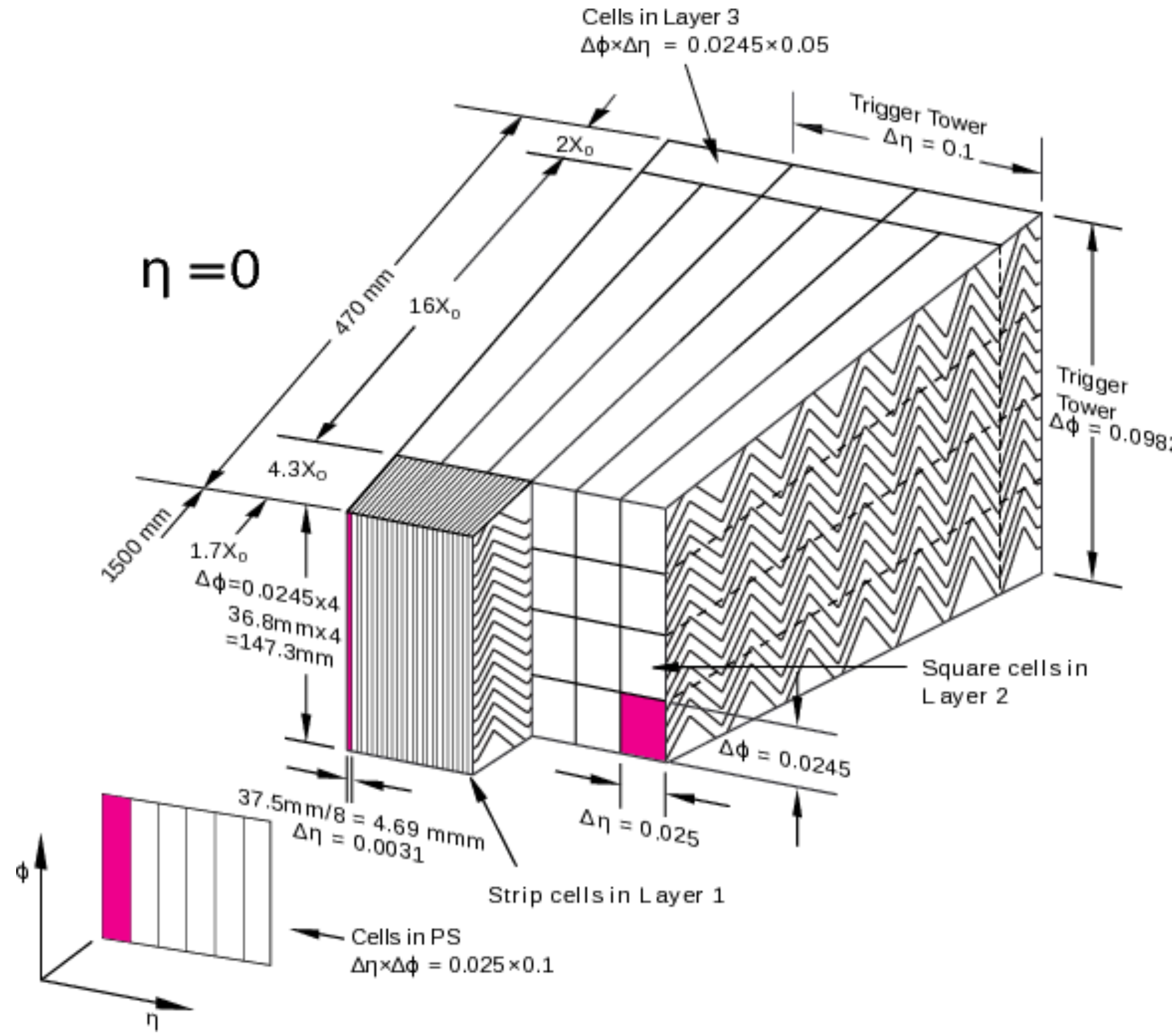
INTRODUCTION

- **H→γγ channel was one of the key channel in the discovery of the Higgs boson**
  - Good sensitivity: excellent mass resolution, clean signature
  - Ideal for measuring Higgs boson properties
  - Sensitive to BSM: loop-induced process
- **In this talk: recent Run 2 @13 TeV ATLAS & CMS results from H→γγ channel**
  - Coupling, Simplified Template cross section and mass measurements: **CMS-PAS-HIG-16-040, ATLAS-CONF-2017-045**
  - **Fiducial/Differential Measurement**
    - *More details on Domizia's talks [link]*
  - **Double Higgs production will be covered by Sebastien [link]**

- All results shown today along with all other public results can be found here:
  - **ATLAS** - http://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
  - **CMS** - http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/index.html

ATLAS ECAL & PHOTON RECONSTRUCTION





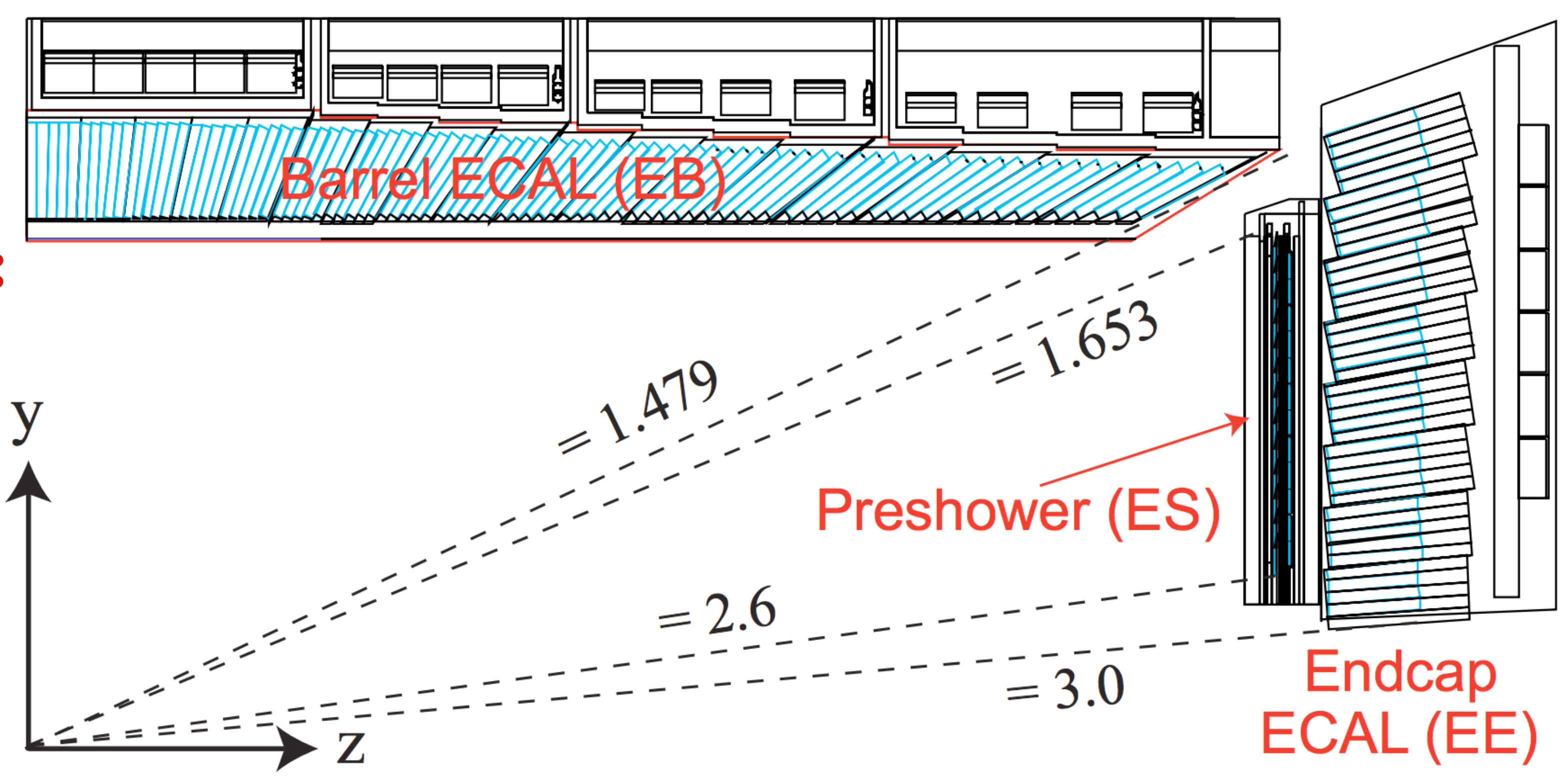
- **Liquid Argon sampling calorimeter with longitudinal layer structure**
    - *First **finely-segmented layer** allows a good rejection of neutral hadron*
    - ***Longitudinal shower information** used in diphoton vertex reconstruction*
- Sliding algorithm window for photon reconstruction
- Converted photon reconstructed by matching tracks consistent with conversion
- **MC-based calibration** using MVA regression techniques, with additional corrections from $Z \rightarrow ee$ comparison

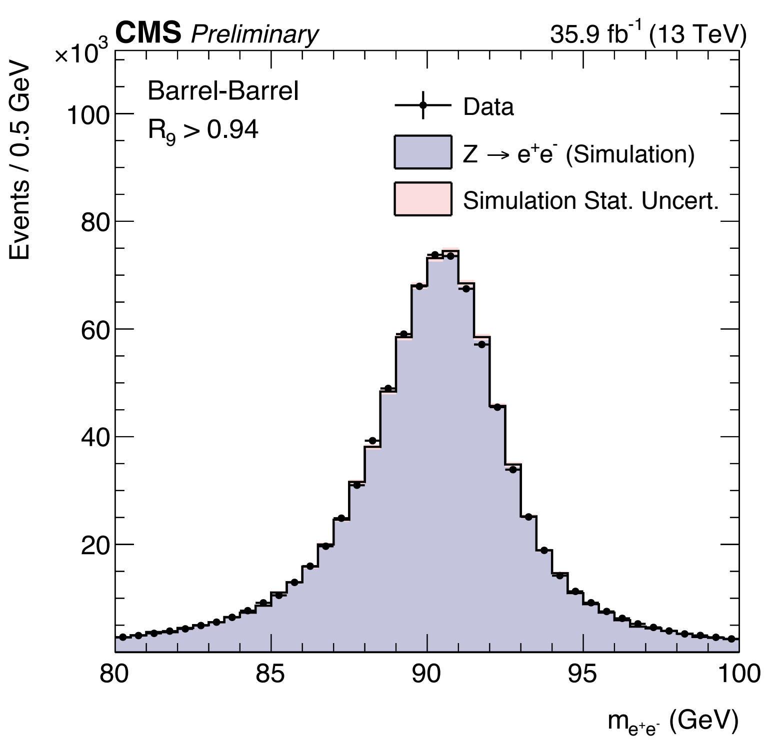
CMS ELECTROMAGNETIC CALORIMETER

PHOTON RECONSTRUCTION

CERN-LHCC-2006-001

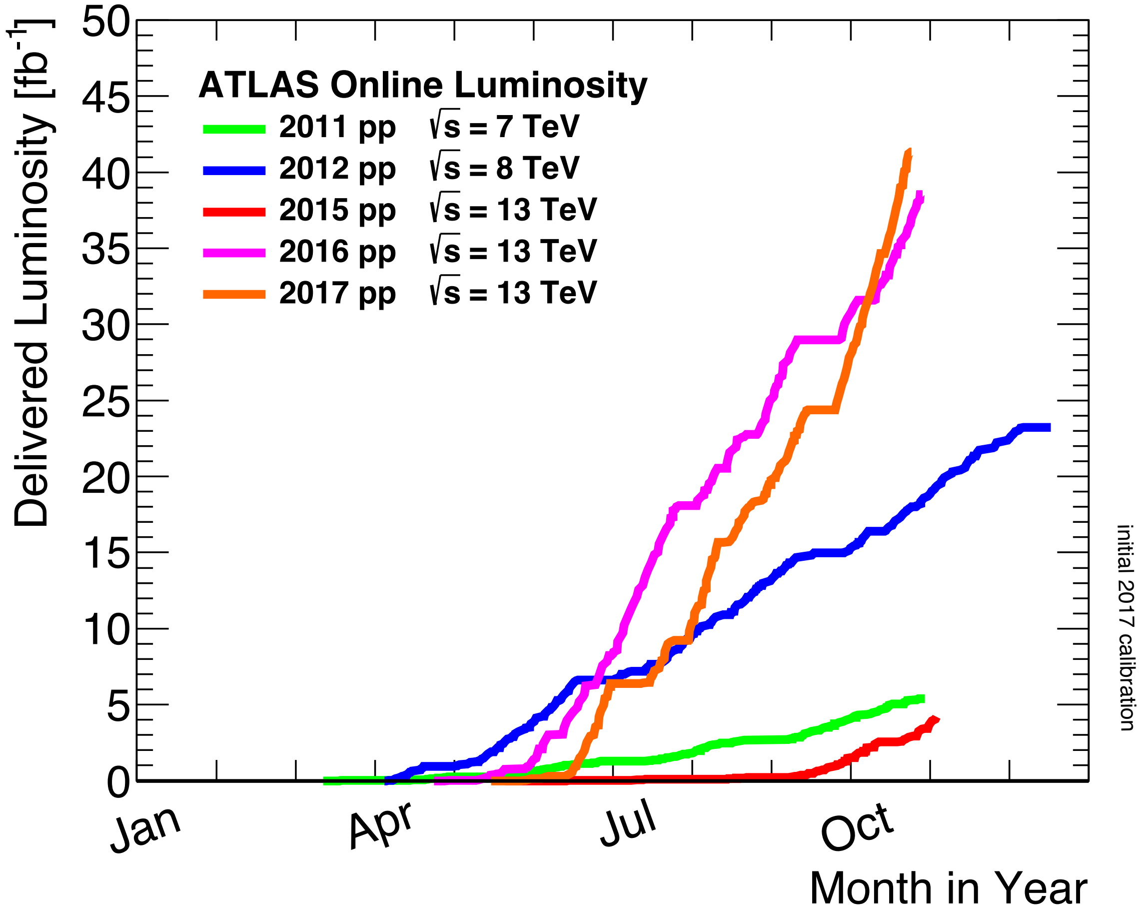
- High granularity **PbWO4** crystal layout
- **Particle-flow reconstruction:**
  - *Reconstructs all particles by combining the information from all the relevant sub-detectors*

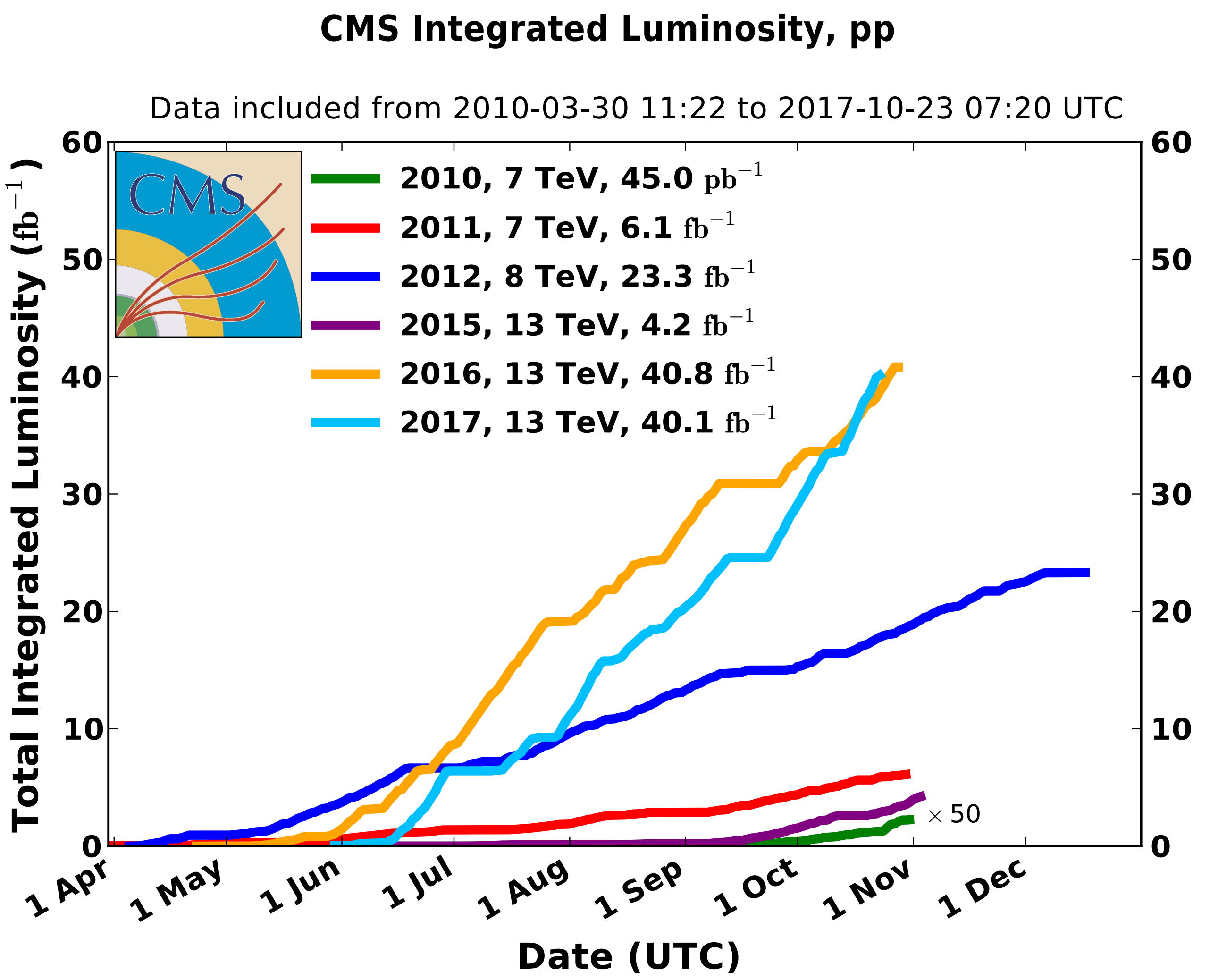




- **Photons are identified as ECAL deposits without associated track**
  - ***Diphoton vertex*** *determined using recoiling tracks*
  - *The energy is corrected for the EM showers and energy loss of converted photons*
    - *Regression method trained in simulation*
  - *Using electrons from Z→ee reconstructed as photons for correcting energy scale in data*

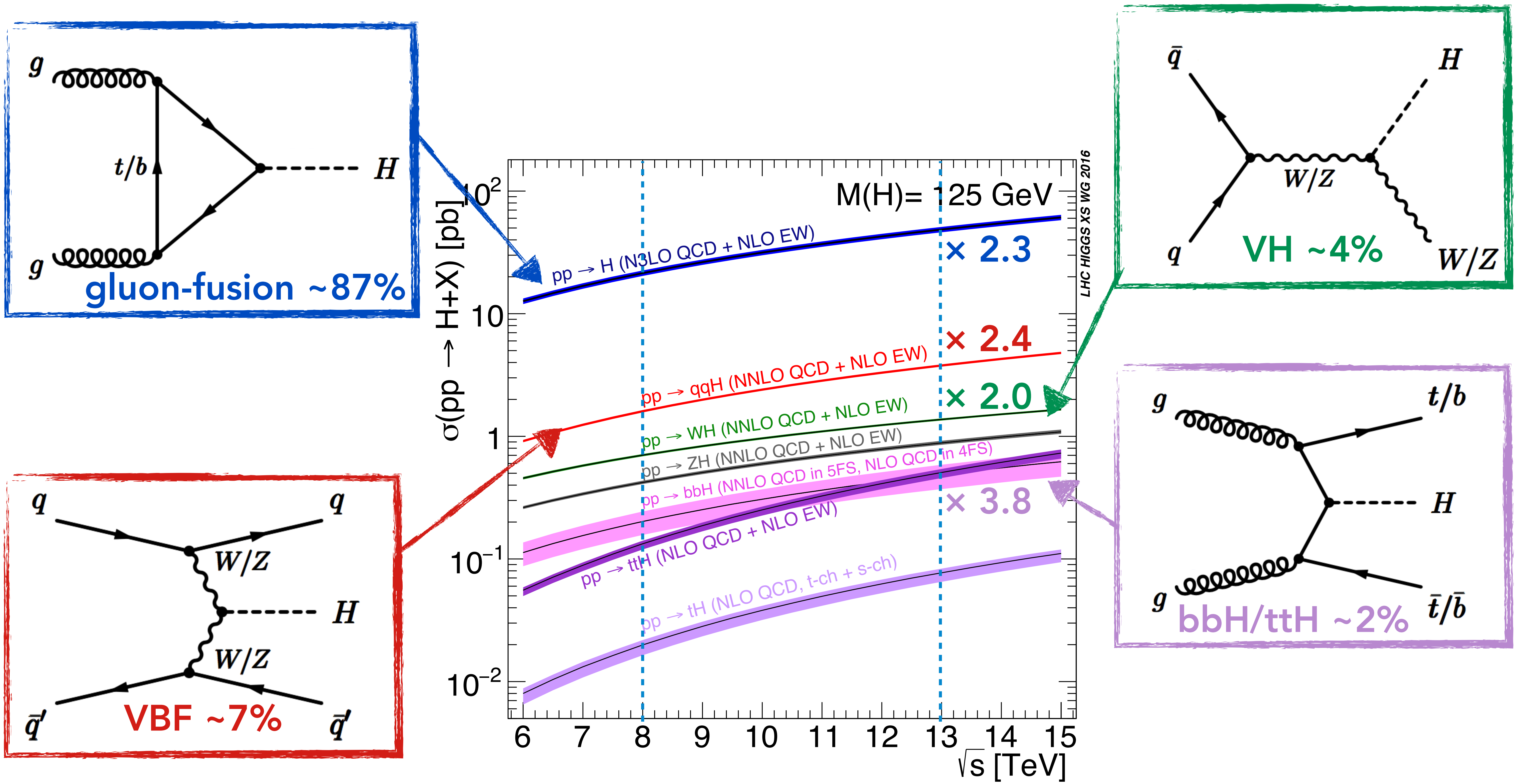
MORE AND MORE DATA





- **Run II of the LHC at 13 TeV is now making a large sample of Higgs boson event available for analysis**
  - 2016 was an excellent year for data with more than 36 fb^{-1} collected by both ATLAS and CMS
- **These data are increasing and opening up new channels to study the properties of Higgs boson and the SM particles**

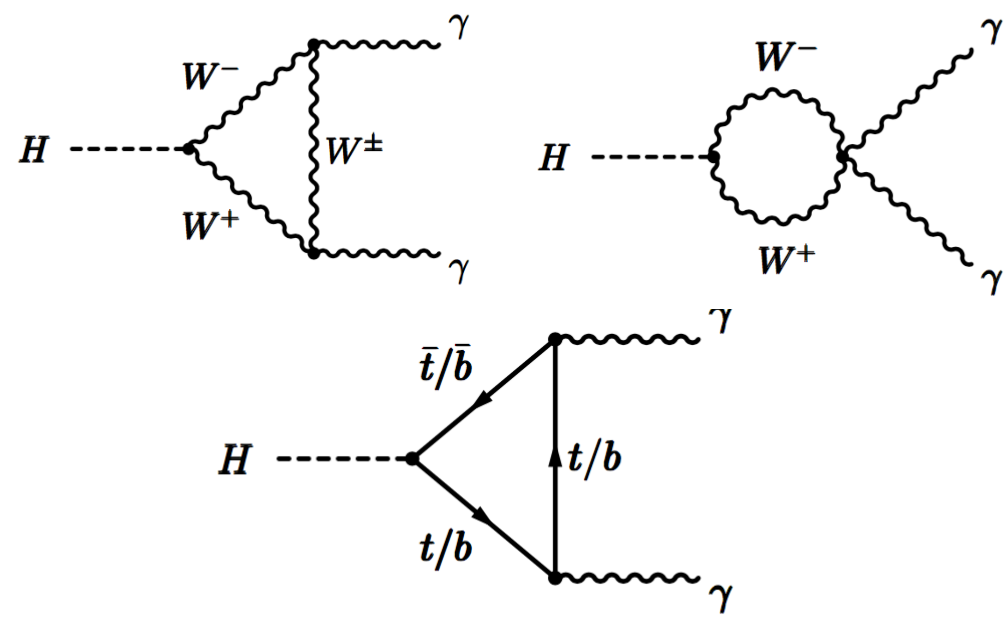
SM HIGGS PRODUCTION @LHC



- **Significant increase in production cross section from increased √s**
  - *Signal increased by a factor of 2 to 4 depending on the production mode*
  - *Background increased by a factor of ~2*
- **H→γγ gives access to all the production modes**

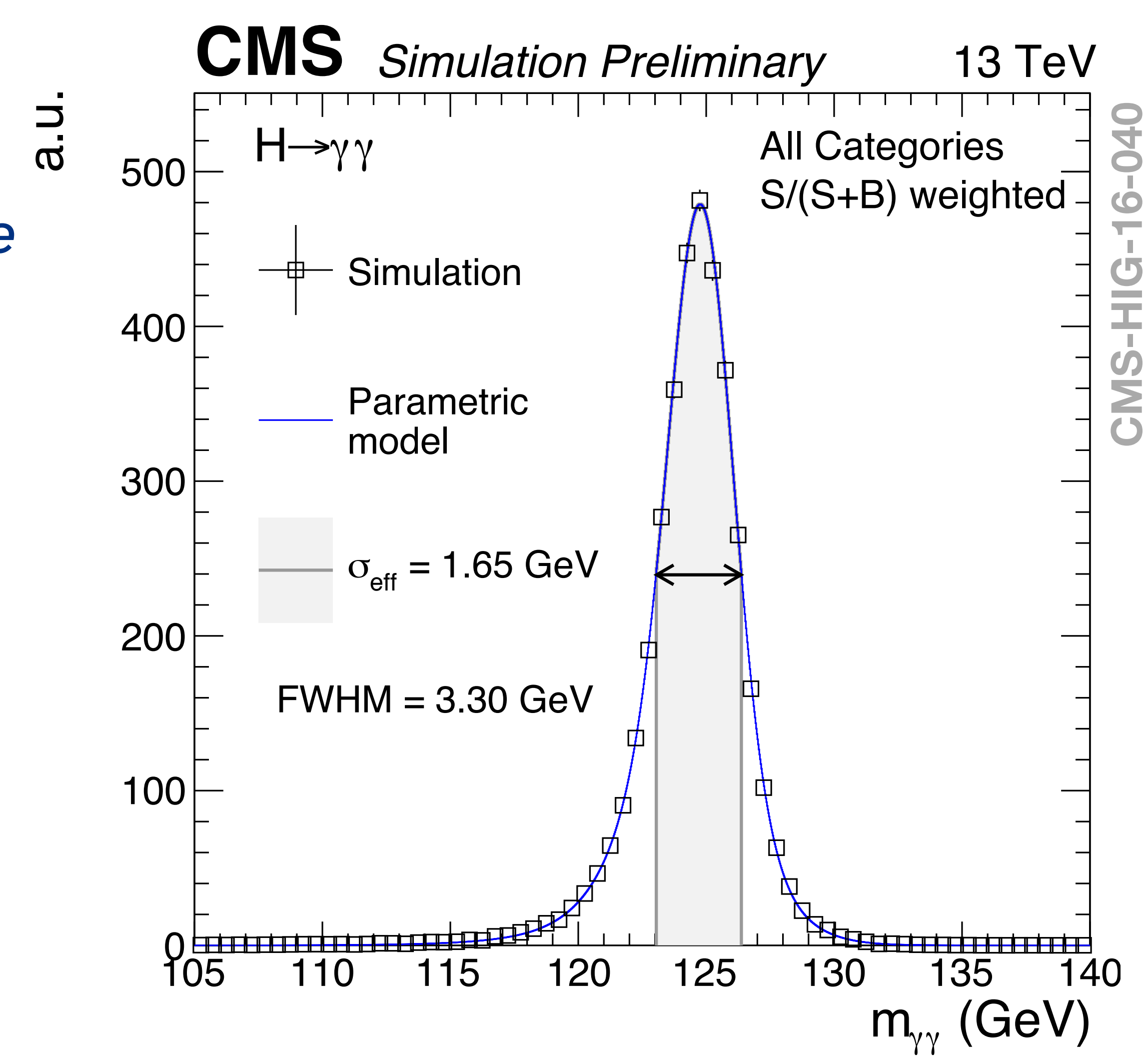
DECAY INTO DIPHOTON : H→γγ

- **Loop-induced decay**
  - Interference helps probe sign of couplings to SM particles
  - **Sensitive to BSM:** *new physics might contribute to the loop*



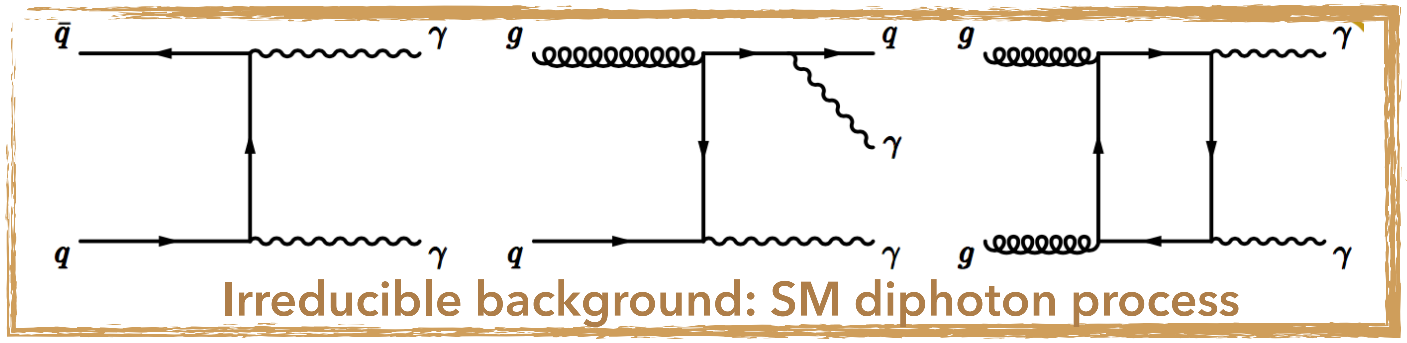
- Small branching fraction (0.2%) but **excellent mass resolution (1-2%)**
  - ***Mass resolution expected to be dominated by the detector resolution as the SM width is negligible***
- Modelling the signal shape:
  - ***ATLAS:** double-sided Crystal Ball function*
  - ***CMS:** sum of n-Gaussian functions (n<=5)*
- Requires a **good energy reconstruction** and **correct vertex assignment**

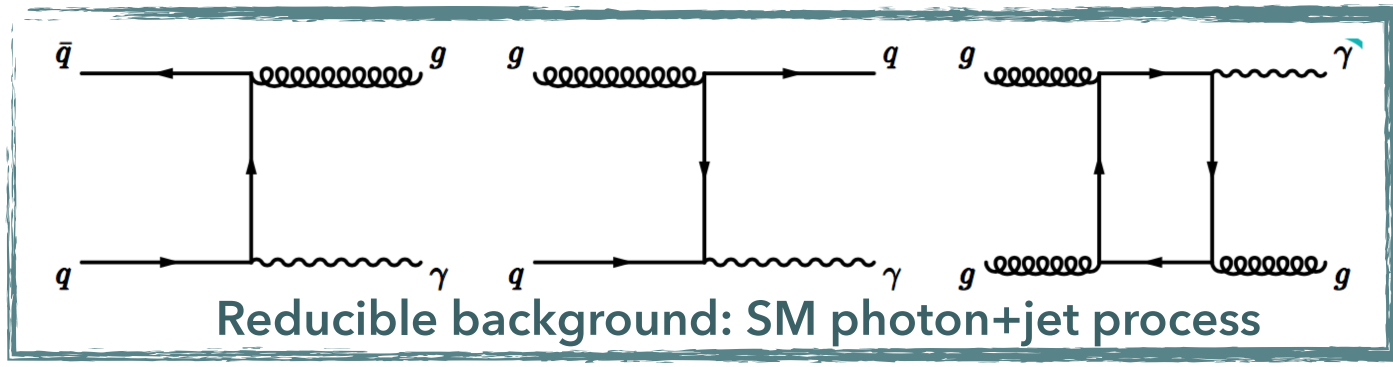
$$m^2_{\gamma\gamma} = E_{\gamma_1} E_{\gamma_2} (1 - \cos\alpha)$$

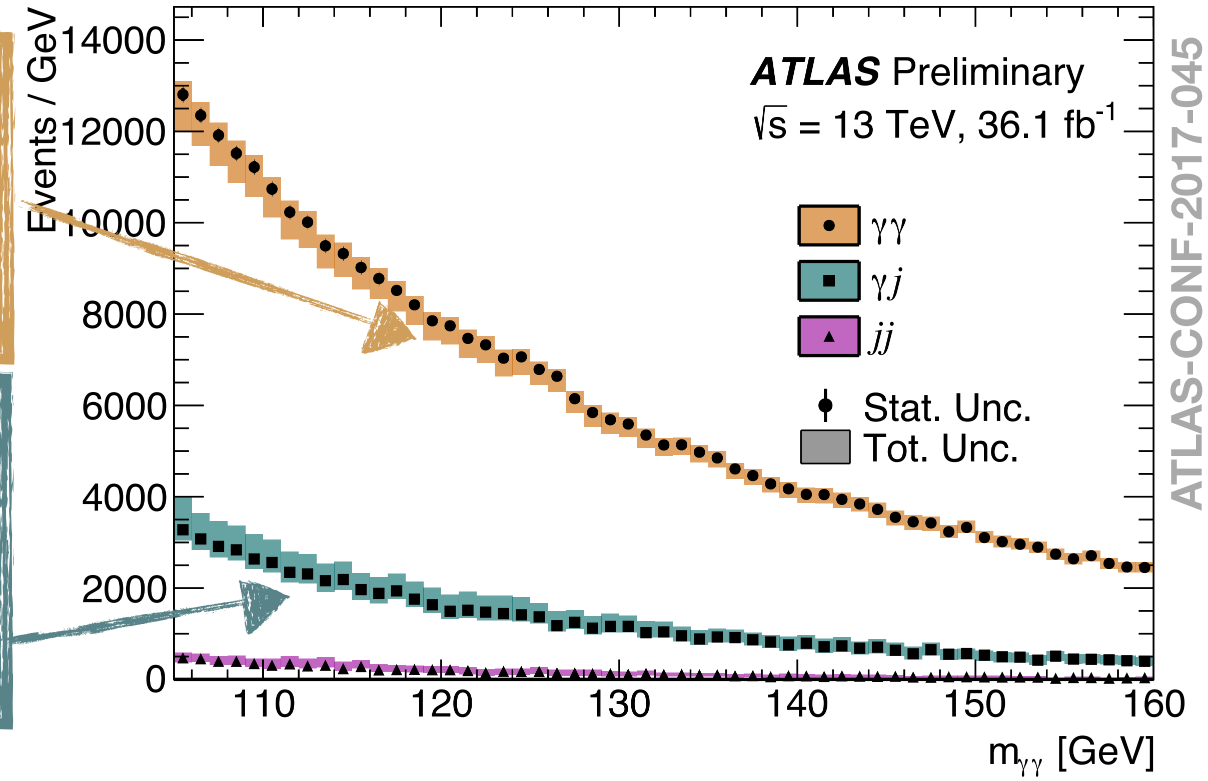


BACKGROUND COMPOSITION

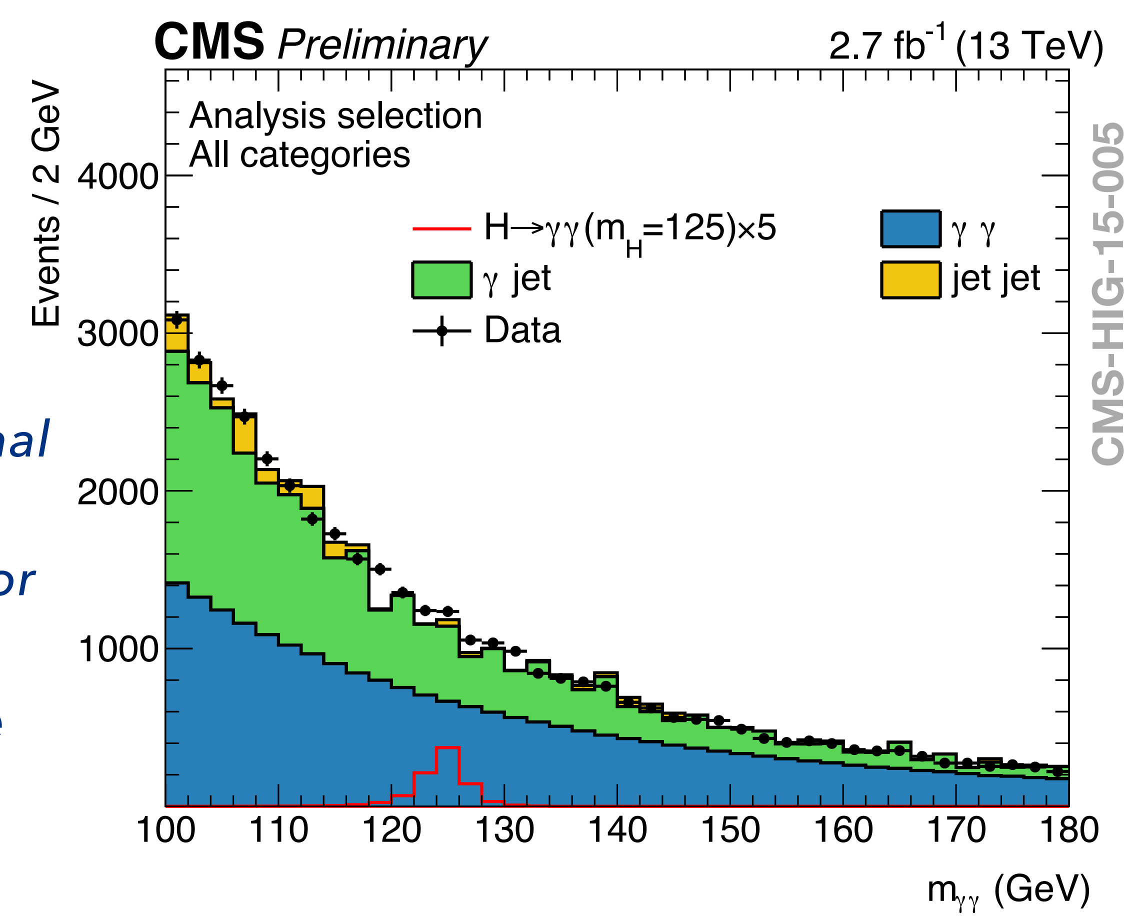
jj: O(500 μb) *γj*: O(200 nb) *γγ*: O(30 pb)





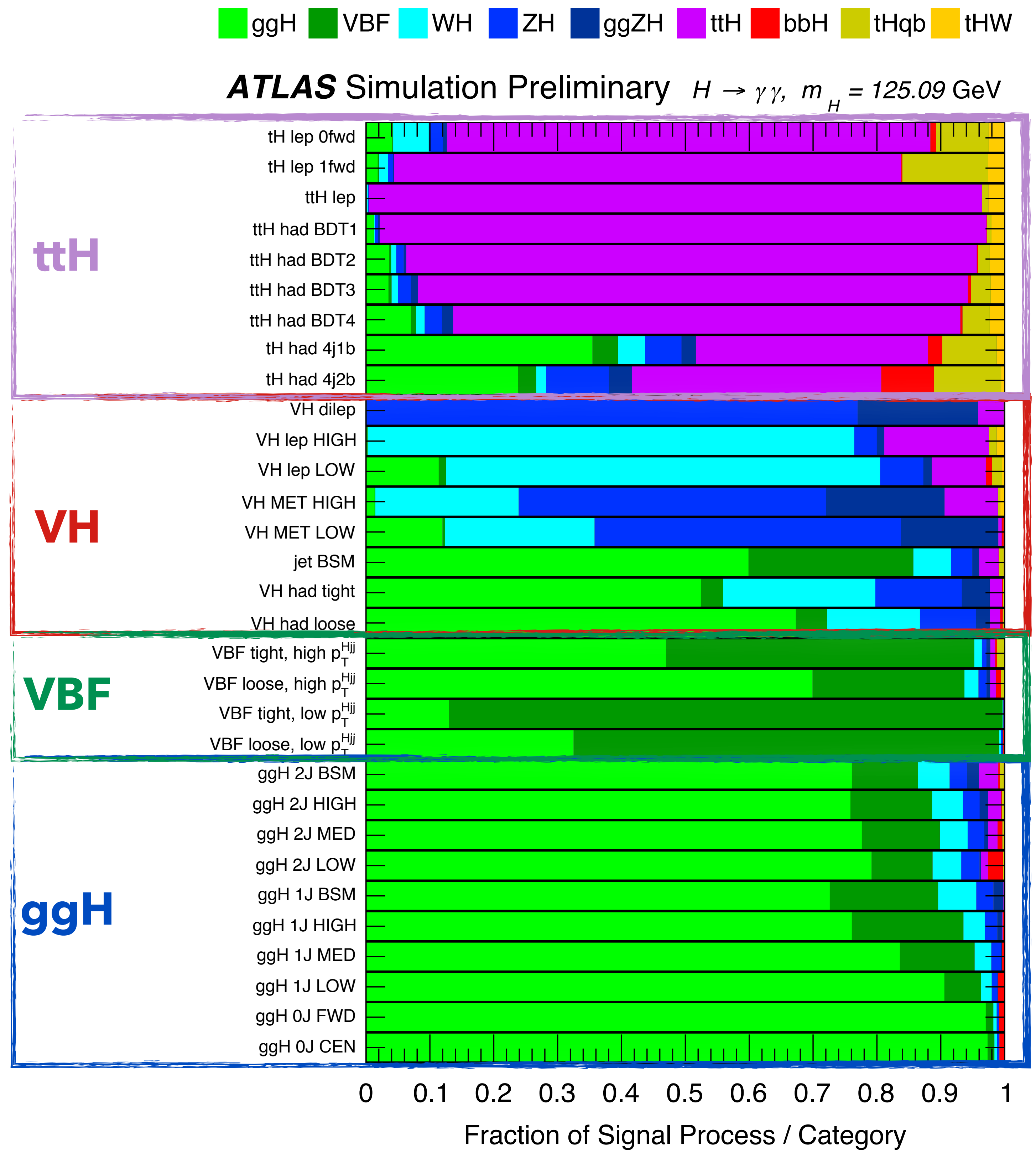


- **Small peaking signal on large falling background**
  - *Irreducible γγ, reducible γ-fake and fake-fake*
  - *Multivariate Photon ID to reject fakes*
- Background model **data-driven**:
  - **ATLAS:** parametrised with a continuous function for each category
    - *Function chosen as the one that minimises the fitted signal yield in a background-only sample (from CR or from MC)*
    - *Typically exponential for low-stat categories, power-law or exponential of polynomial for the others*
  - **CMS:** background functional form treated as **discrete nuisance** parameter in final minimisation
    - *Discrete profiling method [arXiv:1408.6865]*

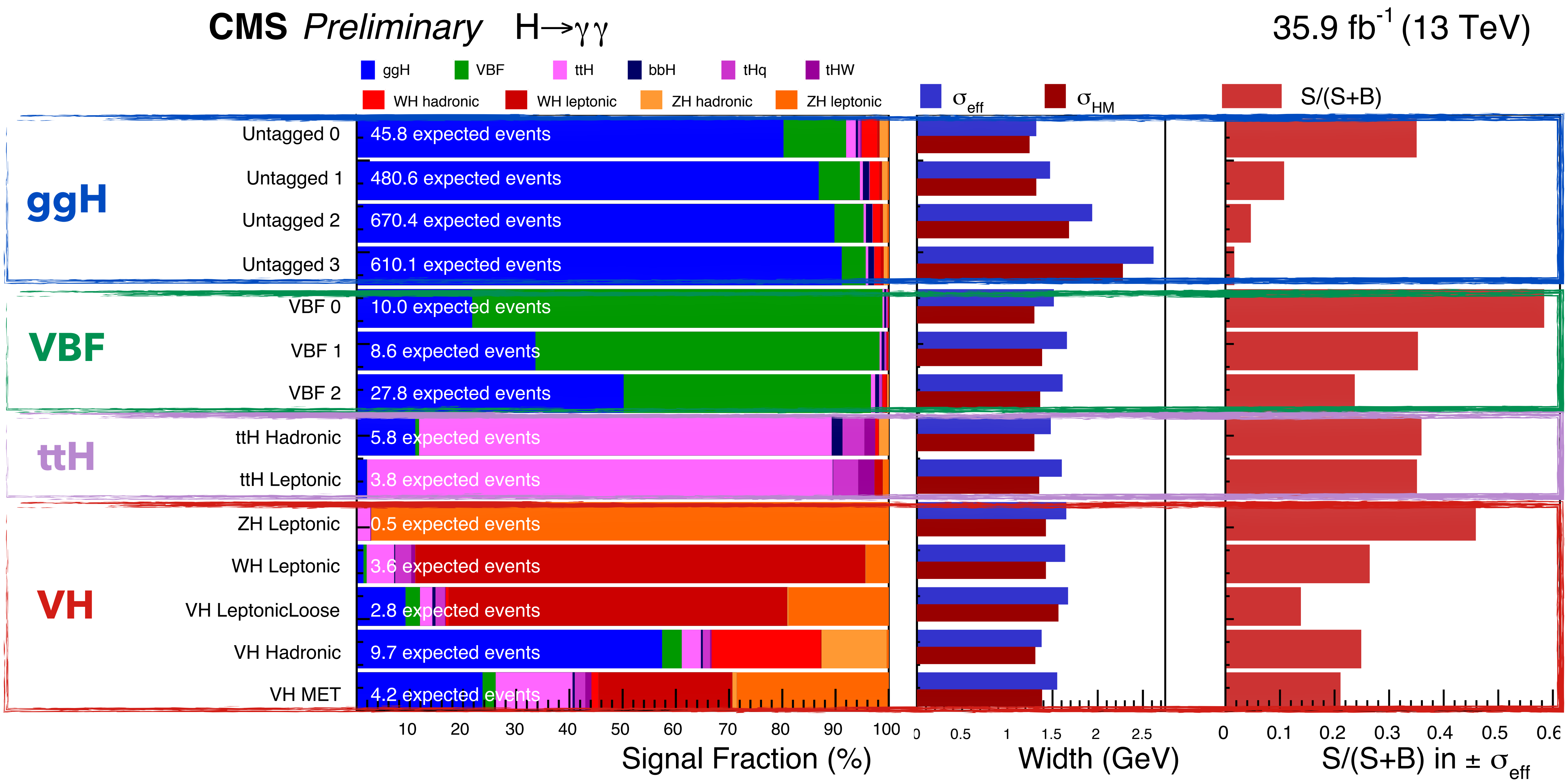


EVENT CATEGORISATION

- **Divide inclusive data samples into categories**
  - Events are sorted into **31 categories** to isolate **different production modes × additional kinematic information**
    (i.e. moving toward STXS stage 1)
  - Improve sensitivity by in S/B
  - Dedicated BDT used to increase the separation from ggH and background



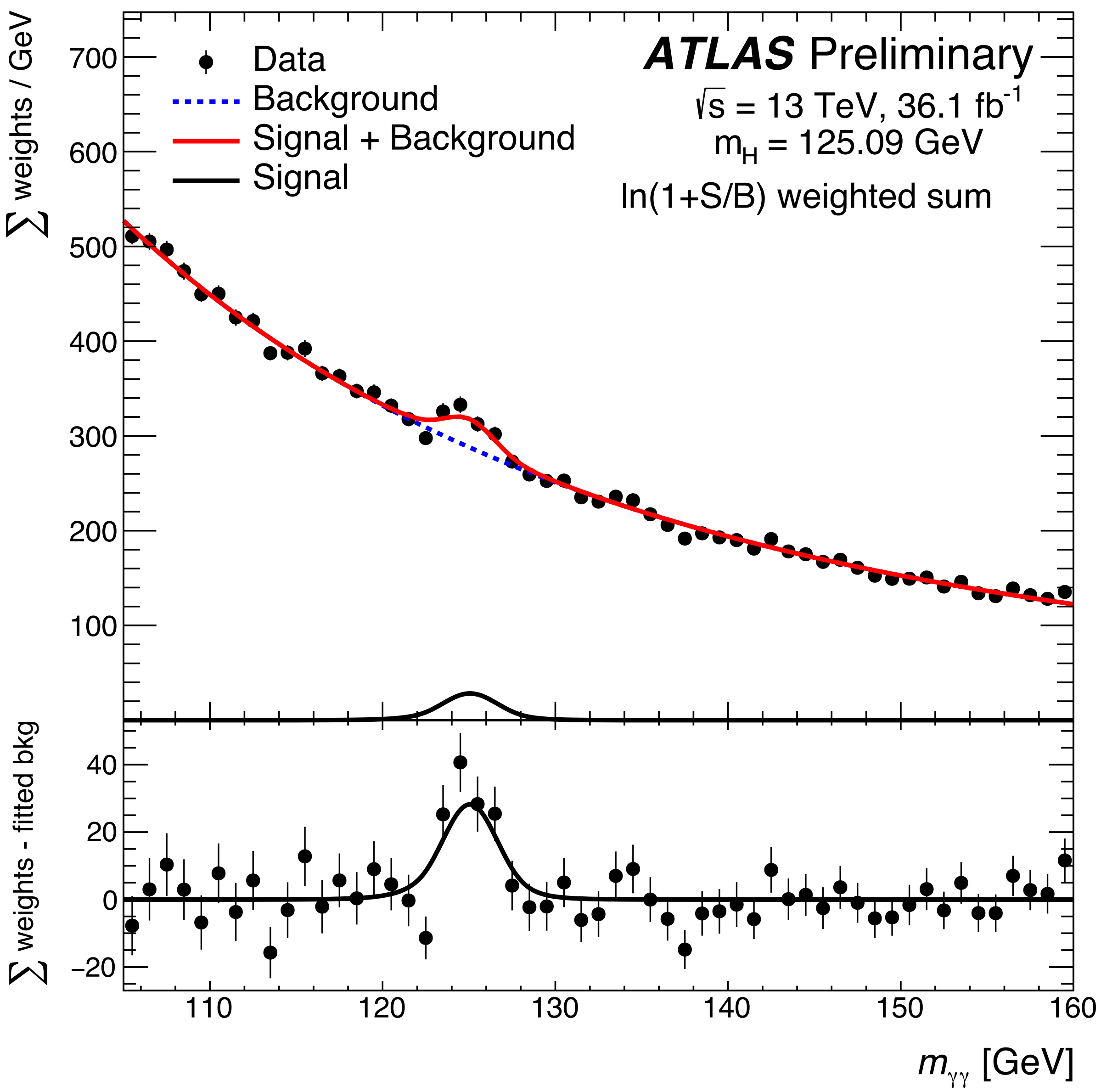
EVENT CATEGORISATION

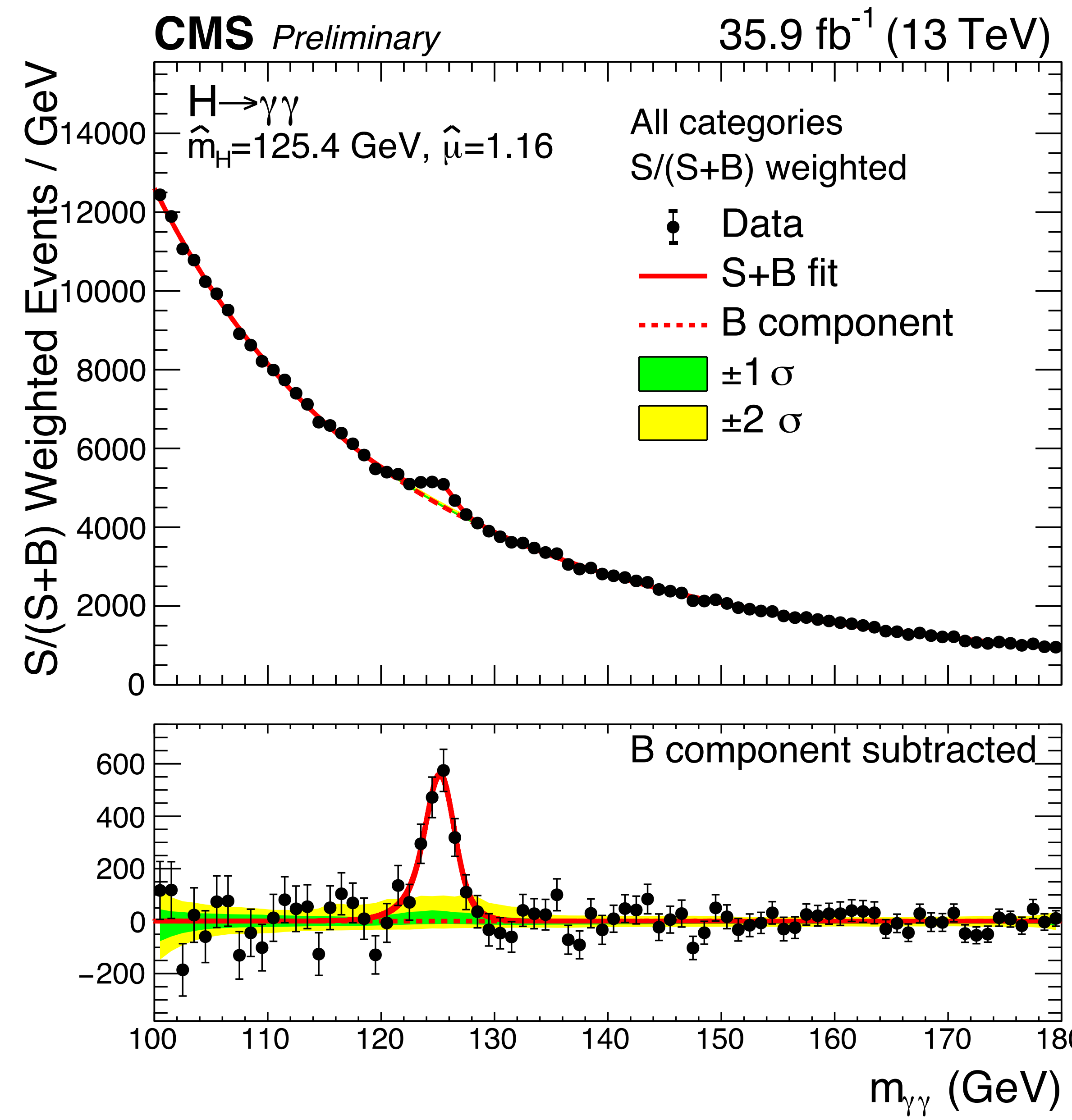


- **Divide inclusive data samples into categories**
  - Events are sorted into **14 categories** to isolate different production modes
  - Improve sensitivity by introducing categories in S/B and resolution
  - Dedicated BDT for VBF and ttH are used to increase the separation from ggH and background

DIPHOTON INVARIANT MASS

ATLAS-CONF-2017-045
CMS-HIG-16-040



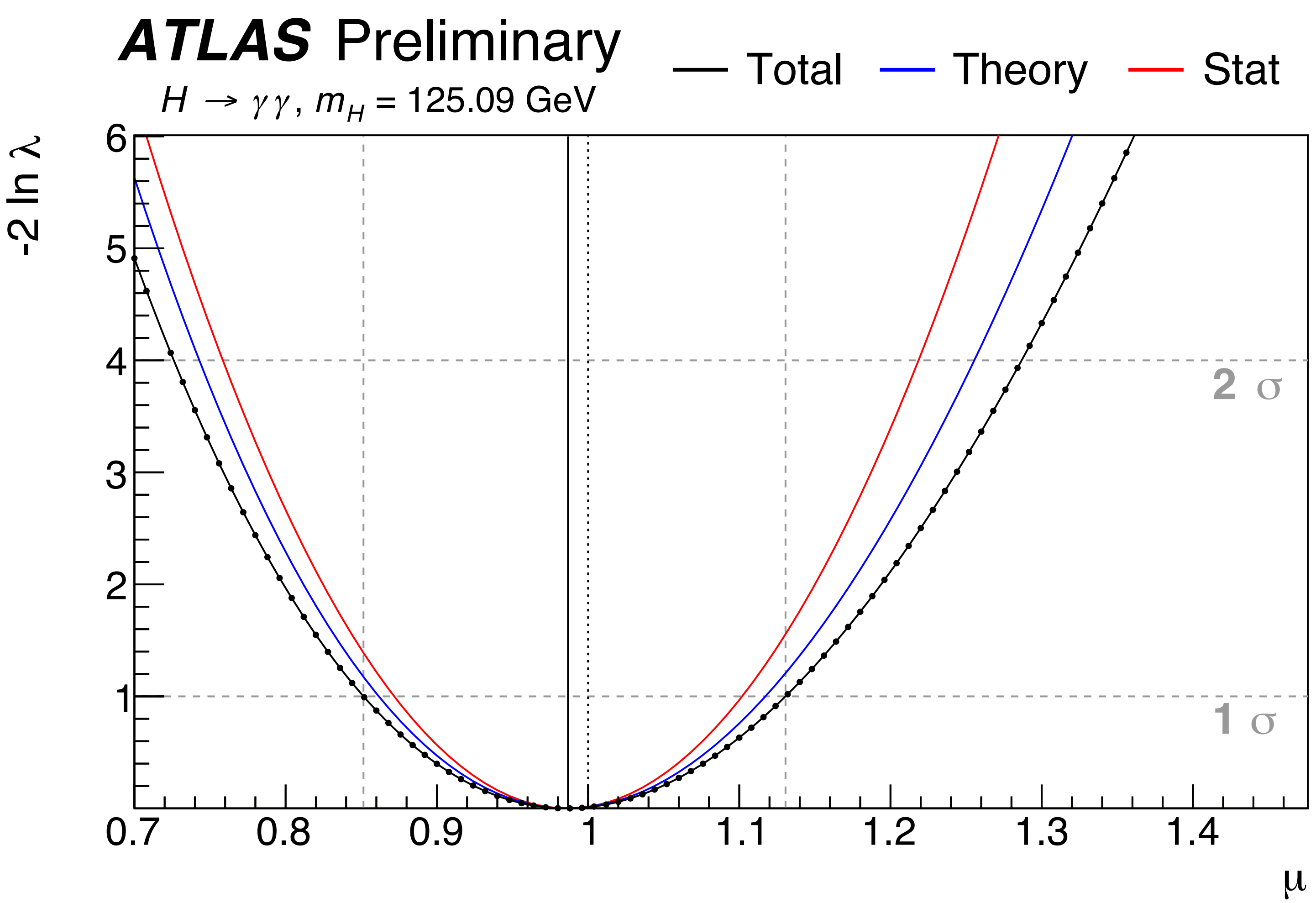


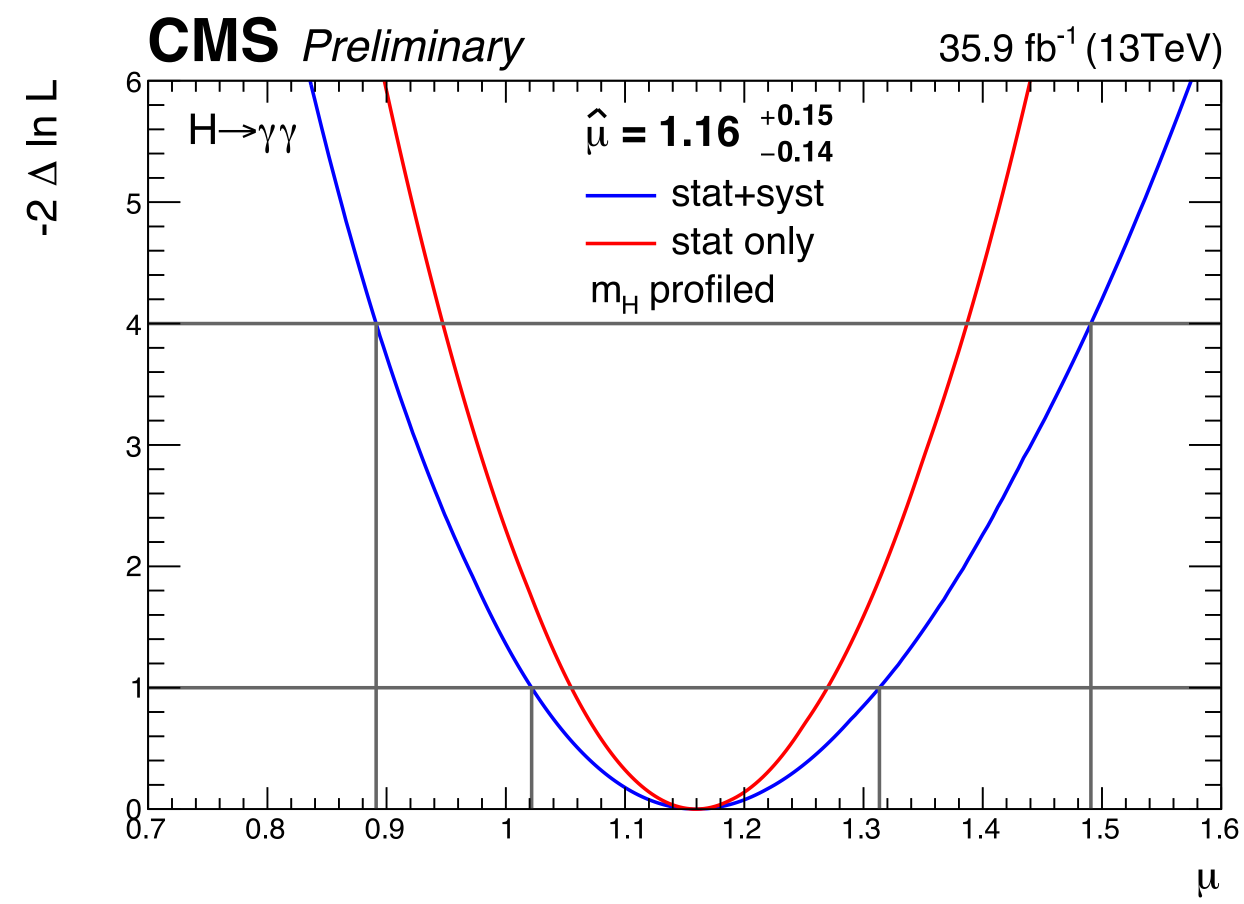
MEASUREMENTS

MEASURING THE SIGNAL STRENGTH

ATLAS-CONF-2017-045
CMS-HIG-16-040

- **Overall signal strength is consistent with standard model**
- **Main experimental syst. uncertainties:** photon energy scale and resolution, photon ID, luminosity



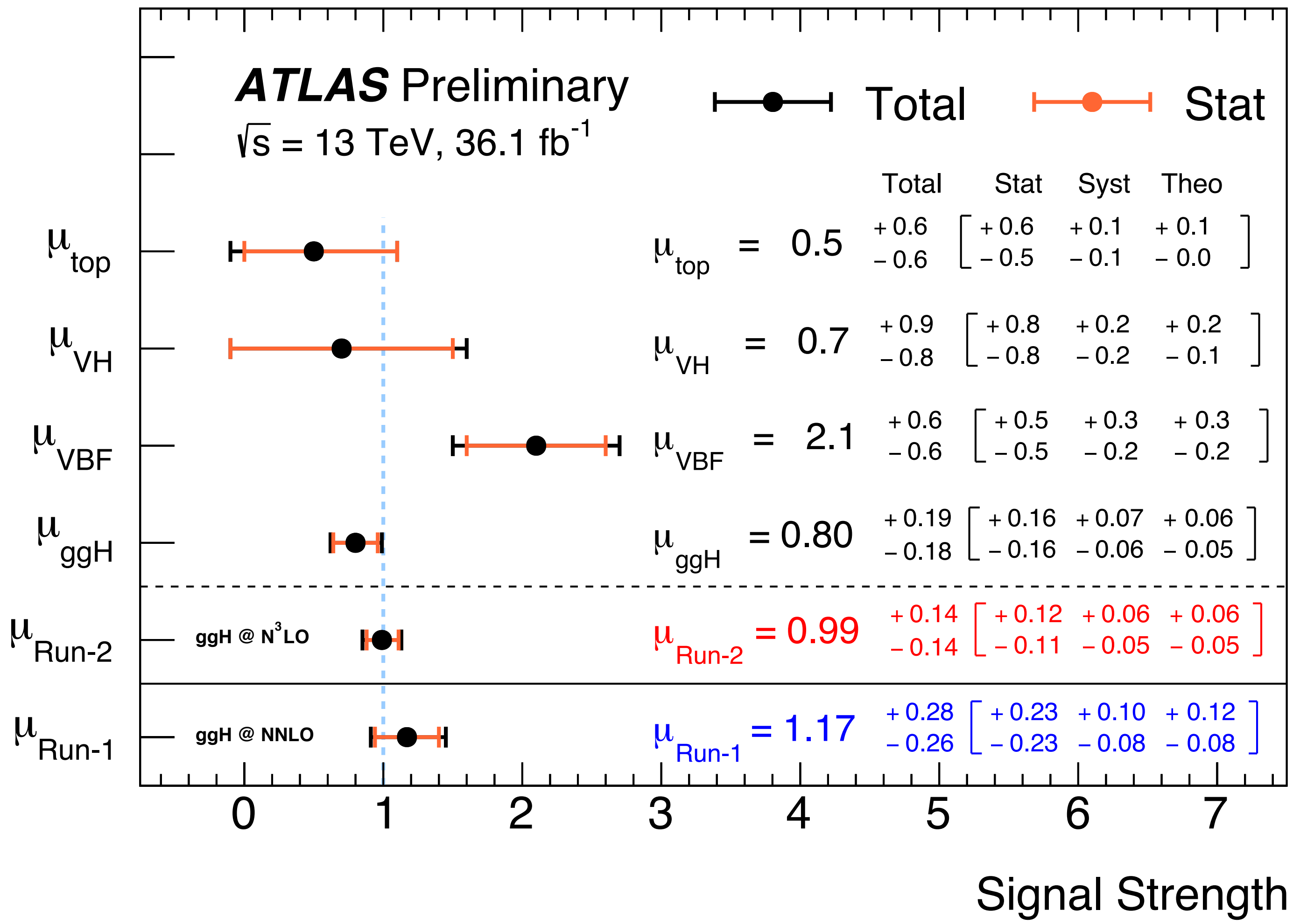


ATLAS : $\mu = \sigma/\sigma_{SM} = 0.99^{+0.12}_{-0.11}(\text{stat.})^{+0.06}_{-0.05}(\text{exp.})^{+0.06}_{-0.05}(\text{theory})$

CMS : $\mu = \sigma/\sigma_{SM} = 1.16^{+0.11}_{-0.10}(\text{stat.})^{+0.09}_{-0.08}(\text{exp.})^{+0.06}_{-0.05}(\text{theory})$

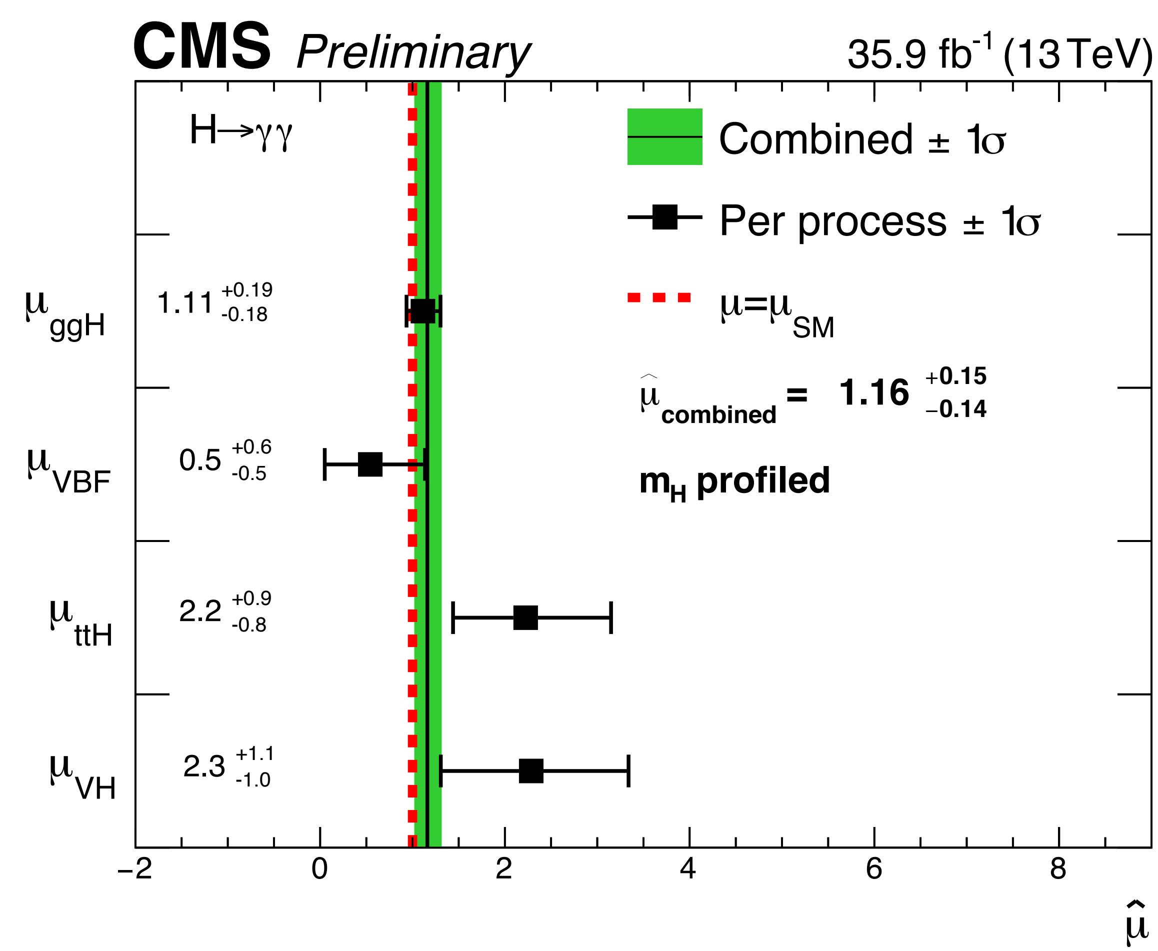
MEASURING THE SIGNAL STRENGTH

ATLAS-CONF-2017-045
CMS-HIG-16-040



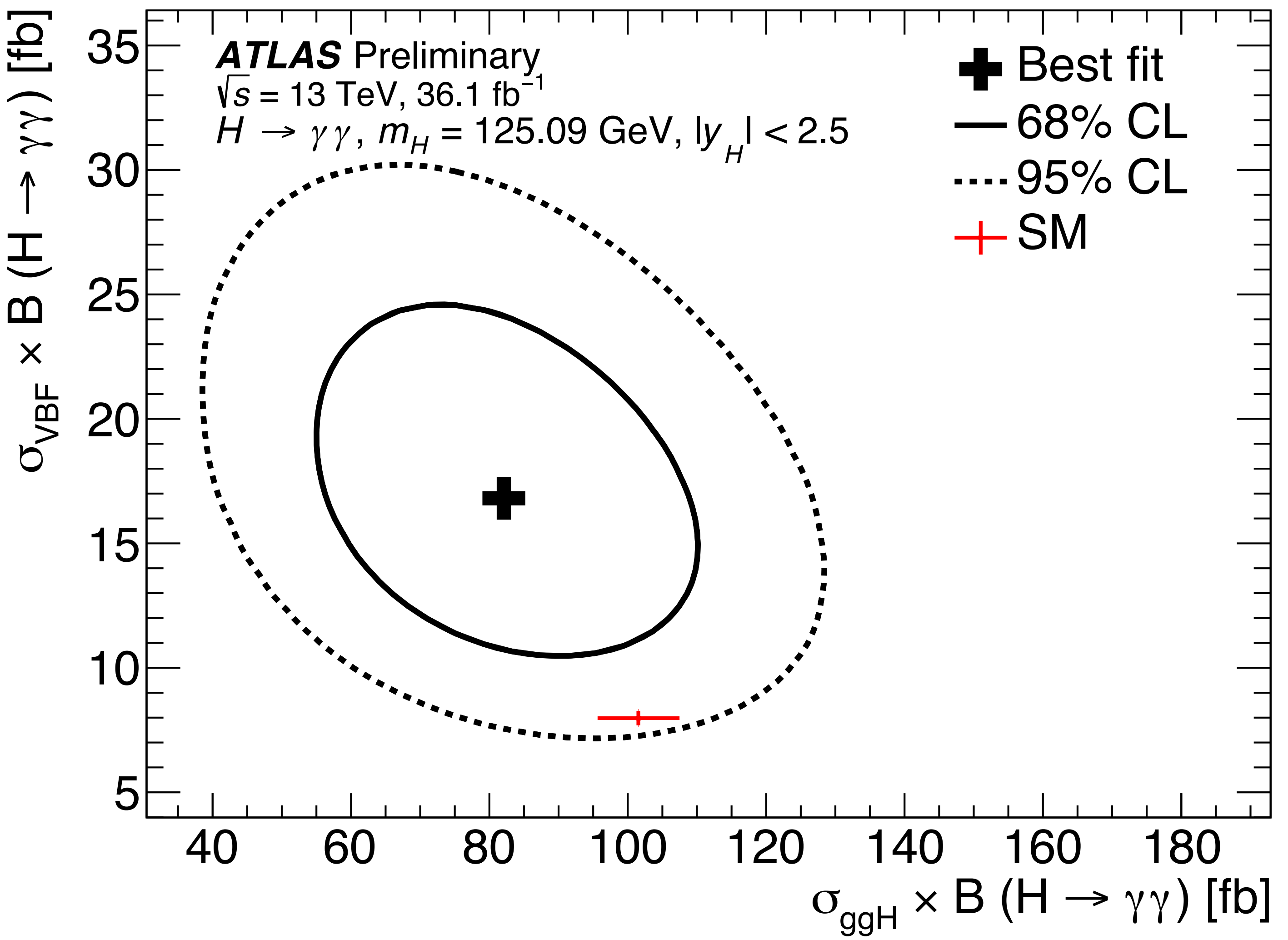
- **Signal strength is obtained for each Higgs boson production mode**
- **Categorise events by production topology**
  - ggH, VBF, VH, ttH

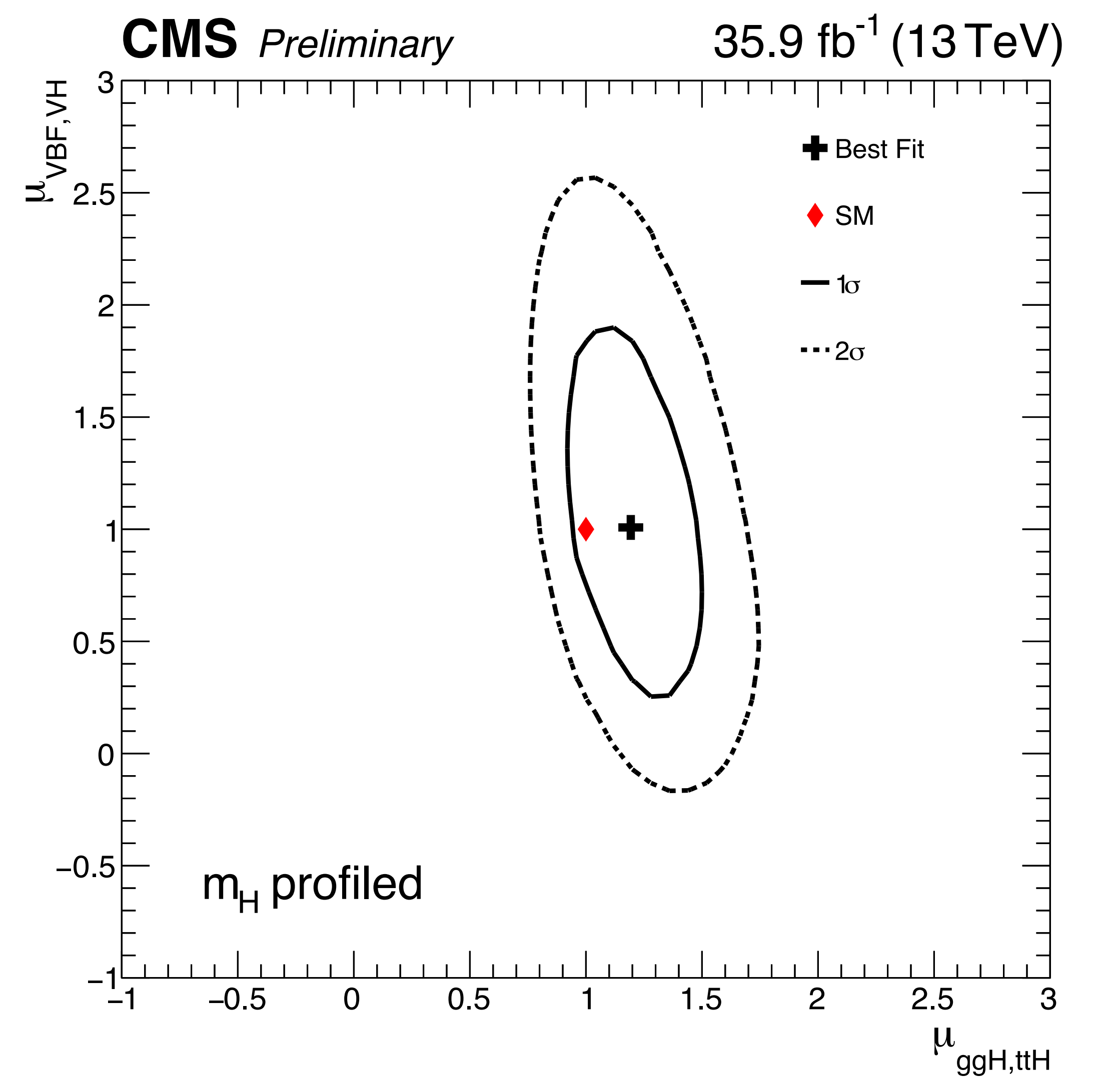
- **Large theory uncertainties remain for ttH and VBF**
  - Mainly ggH contamination, UE/PS uncertainty
- **Theory uncertainties improved a factor 2 comparing to Run-I**



MEASURING THE SIGNAL STRENGTH

ATLAS-CONF-2017-045
CMS-HIG-16-040





- **A likelihood scan of the signal strength (for CMS) or σ × BR (for ATLAS) are performed, profiling all other nuisances including the Higgs mass**

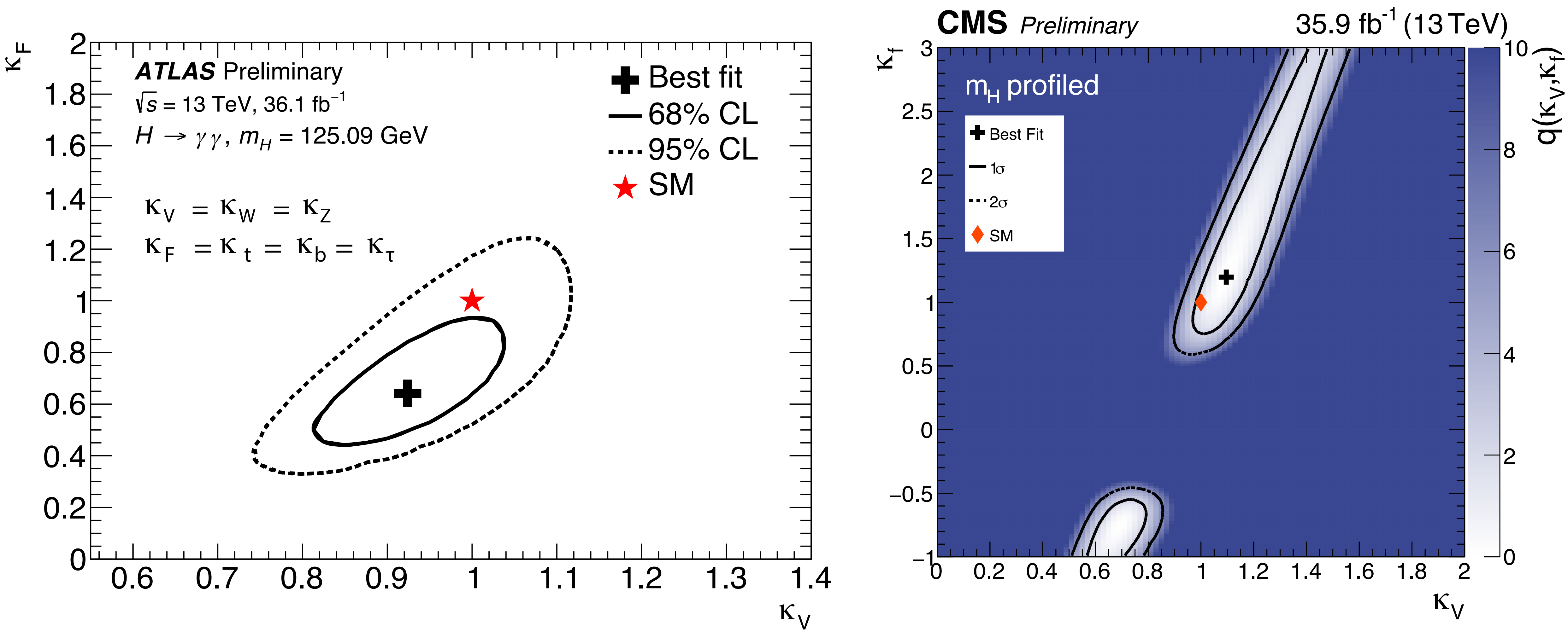
COUPLING MODIFIERS

KAPPA-FRAMEWORK

- **Interim framework for the analysis of Higgs couplings YR3 [arXiv:1307.1347]**
  - Coupling strength scaling factors κ_i introduced

$$(\sigma \cdot \mathrm{BR})\,(gg \to H \to \gamma\gamma) \;=\; \sigma_{\mathrm{SM}}(gg \to H) \cdot \mathrm{BR}_{\mathrm{SM}}(H \to \gamma\gamma) \cdot \frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_H^2}$$

  - Higgs boson production and decay kinematics are SM-like

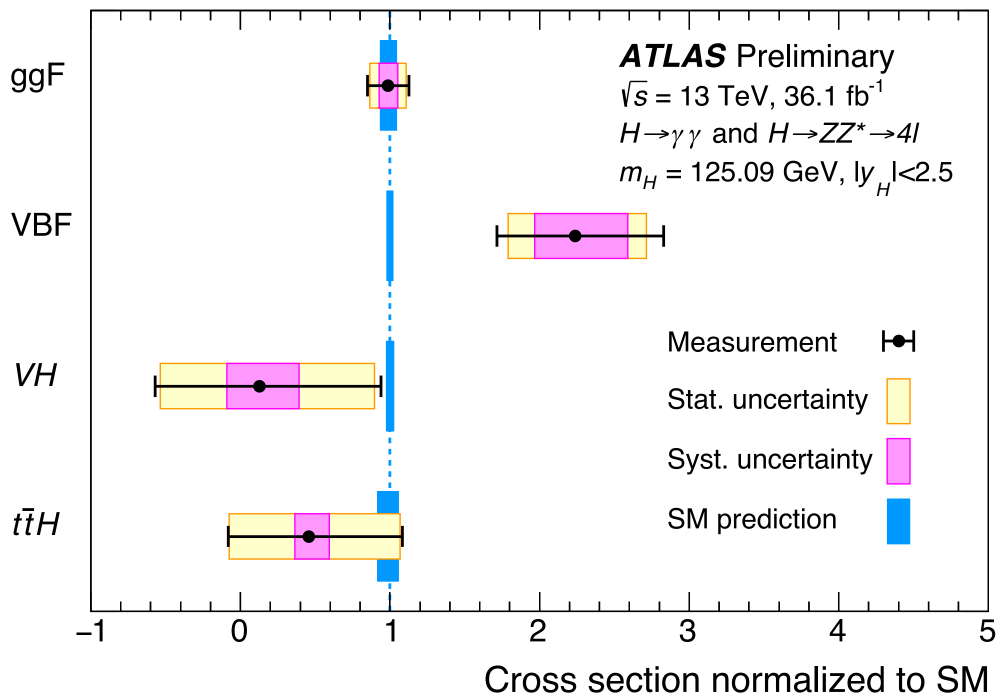


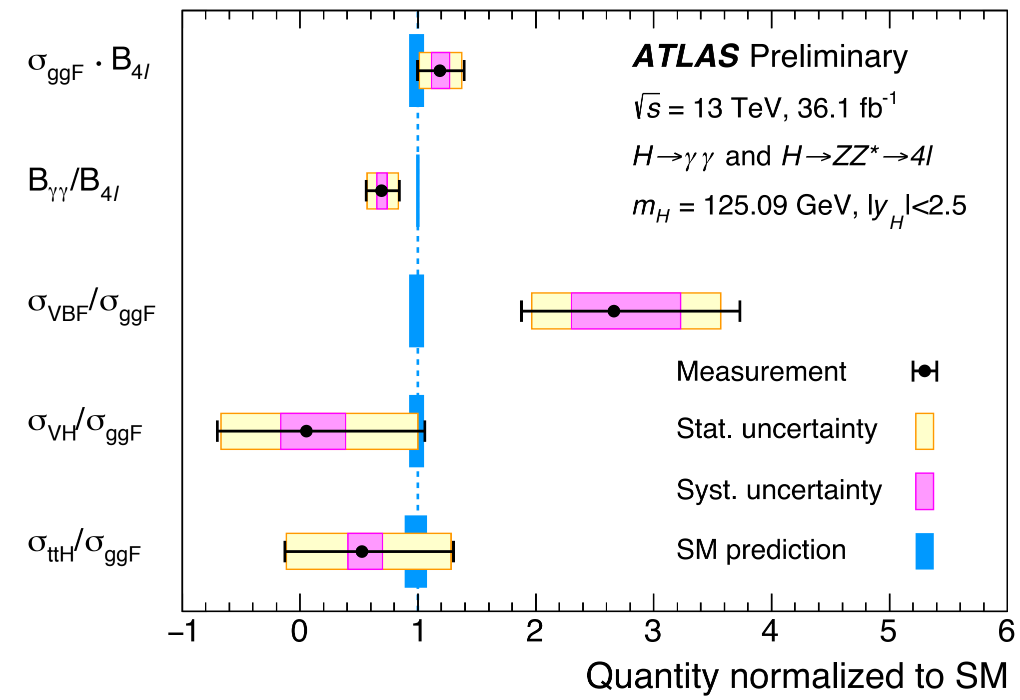
- *Slope due to negative interference between top and W-boson in the decay loop*
- *H→γγ channel provides crucial sensitivity for determining the relative sign of κ_f w.r.t. κ_v*

COMBINED COUPLING ($H \to \gamma\gamma$ & $H \to 4\ell$)

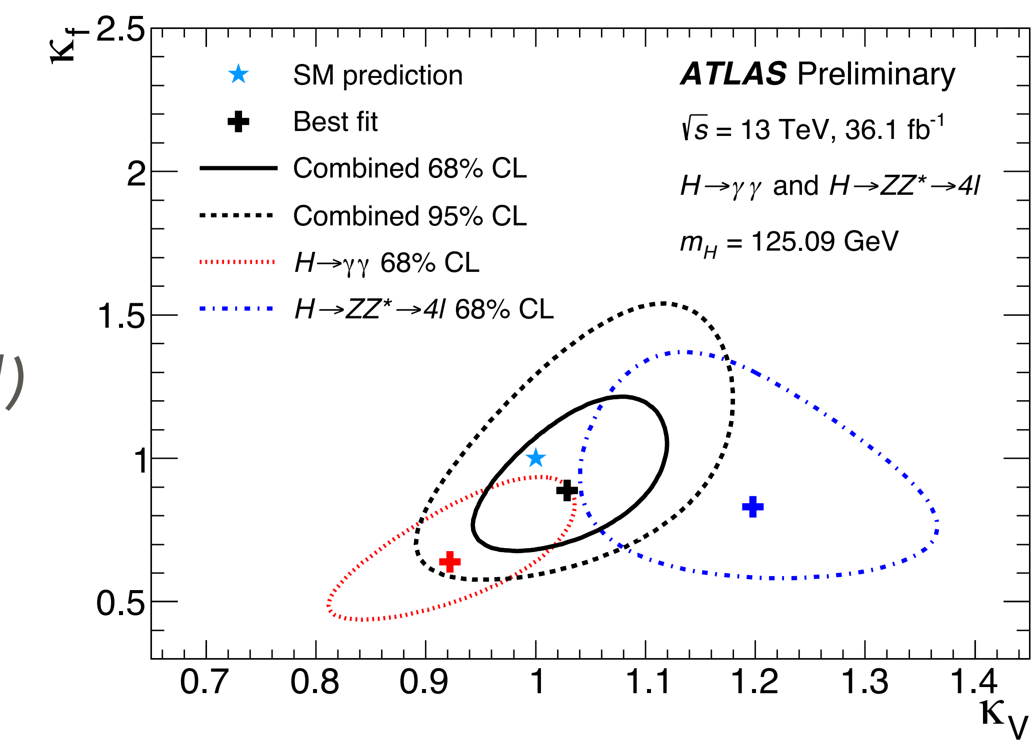
ATLAS-CONF-2017-047

- **ATLAS combined coupling measurement with $H \to \gamma\gamma$ and $H \to 4\ell$**



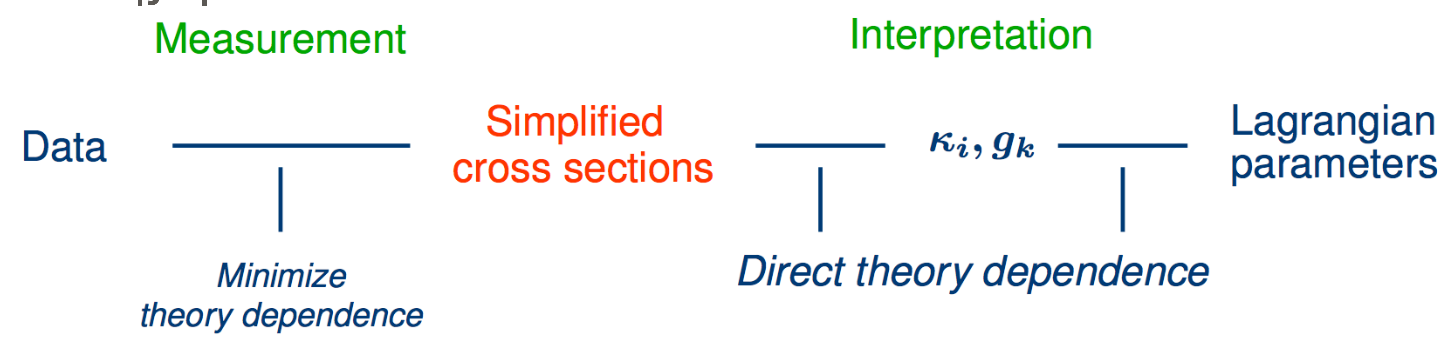


- **Cross sections for ggF, VBF, VH, and ttH shown normalised to the SM predictions**
  - *ggF rate is very consistent with SM*
  - *VBF rate is in excess of SM prediction*
  - *Branching fraction ratio $B(H \to \gamma\gamma)/B(H \to 4l)$ measured to be slightly below SM expectation*
- **Overall combination consistent with SM**

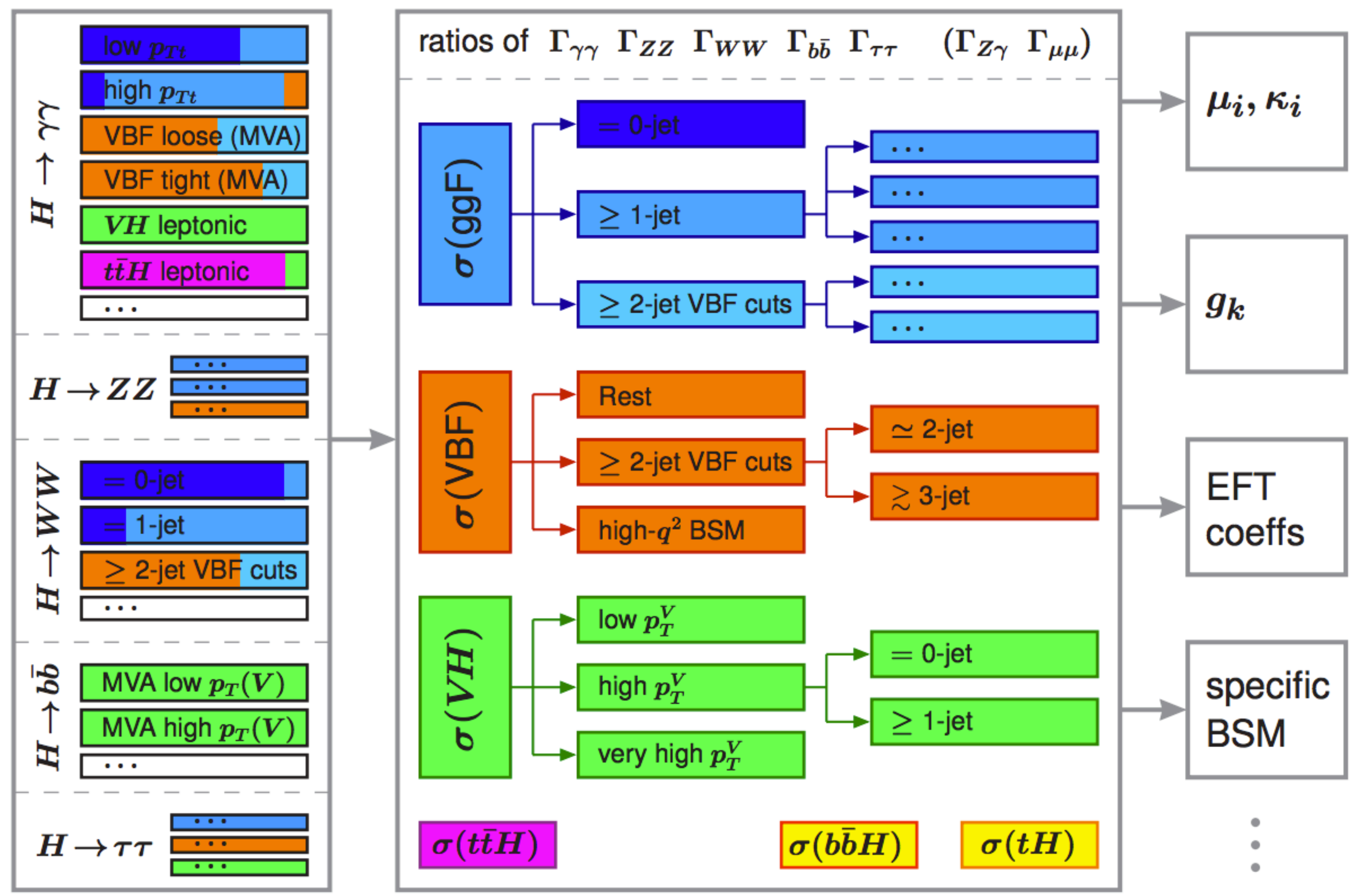


Simplified template cross-sections (STXS)

- **Provide interface between Measurement and Interpretations**
  - Production cross section times BR is measured in mutually exclusive phase space regions (production bins), with $|y_H| < 2.5$

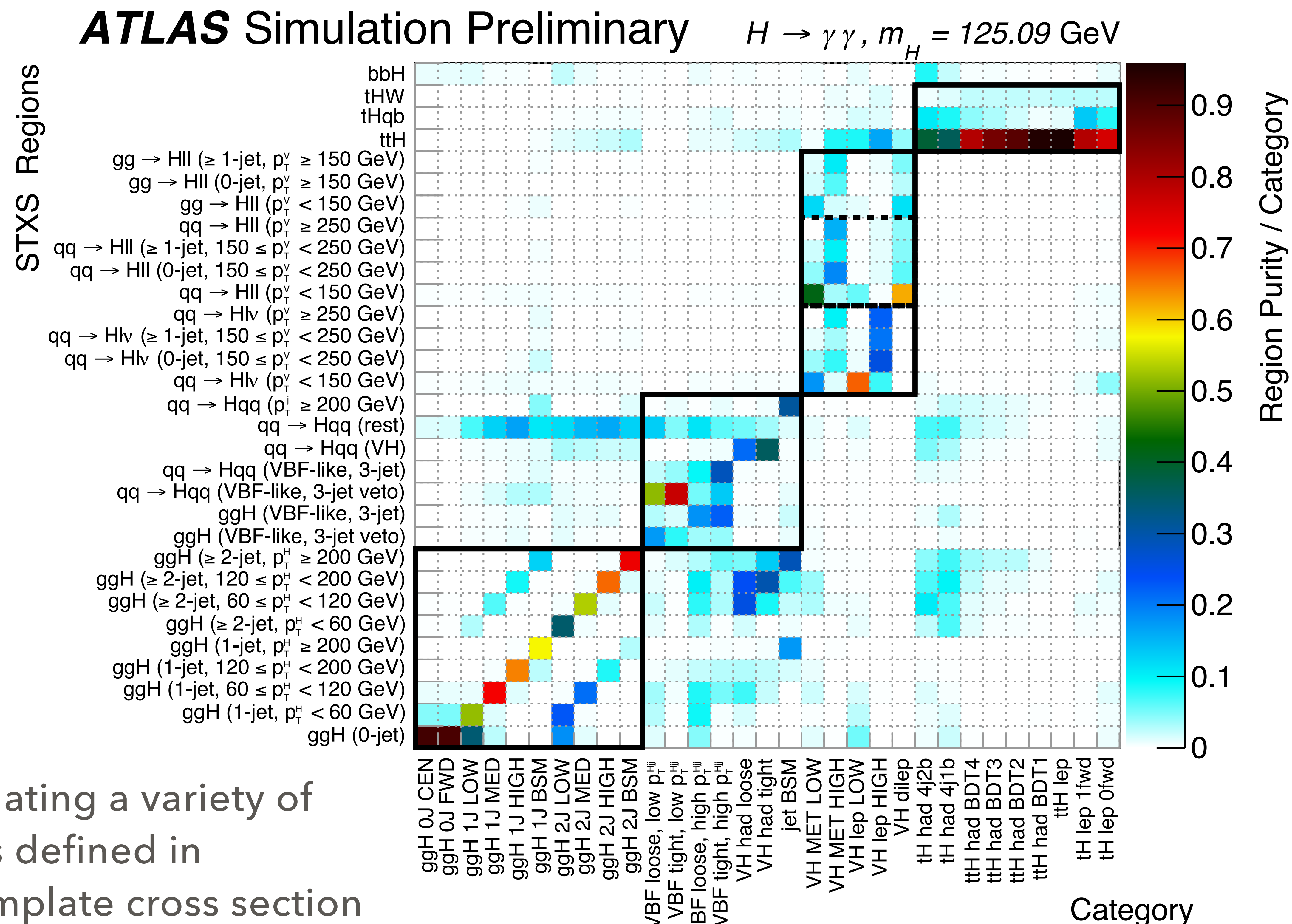


- **Minimise theory dependence in measurements**
  - Shift treatment of (dominant) theory uncertainties to interpretation level
  - Decouples measurements from specific interpretation/model assumptions/BSM scenarios
  - Measurements stay useful on the long shot
- **Complementary to differential cross section measurements**
  - Differential cross sections are optimised for model independence
  - Simplified template cross sections are optimised for sensitivity while also minimising theory dependence



* *More details on STXS bin definitions can be found in back up slides or Yellow Report 4 [arXiv:1610.07922]*

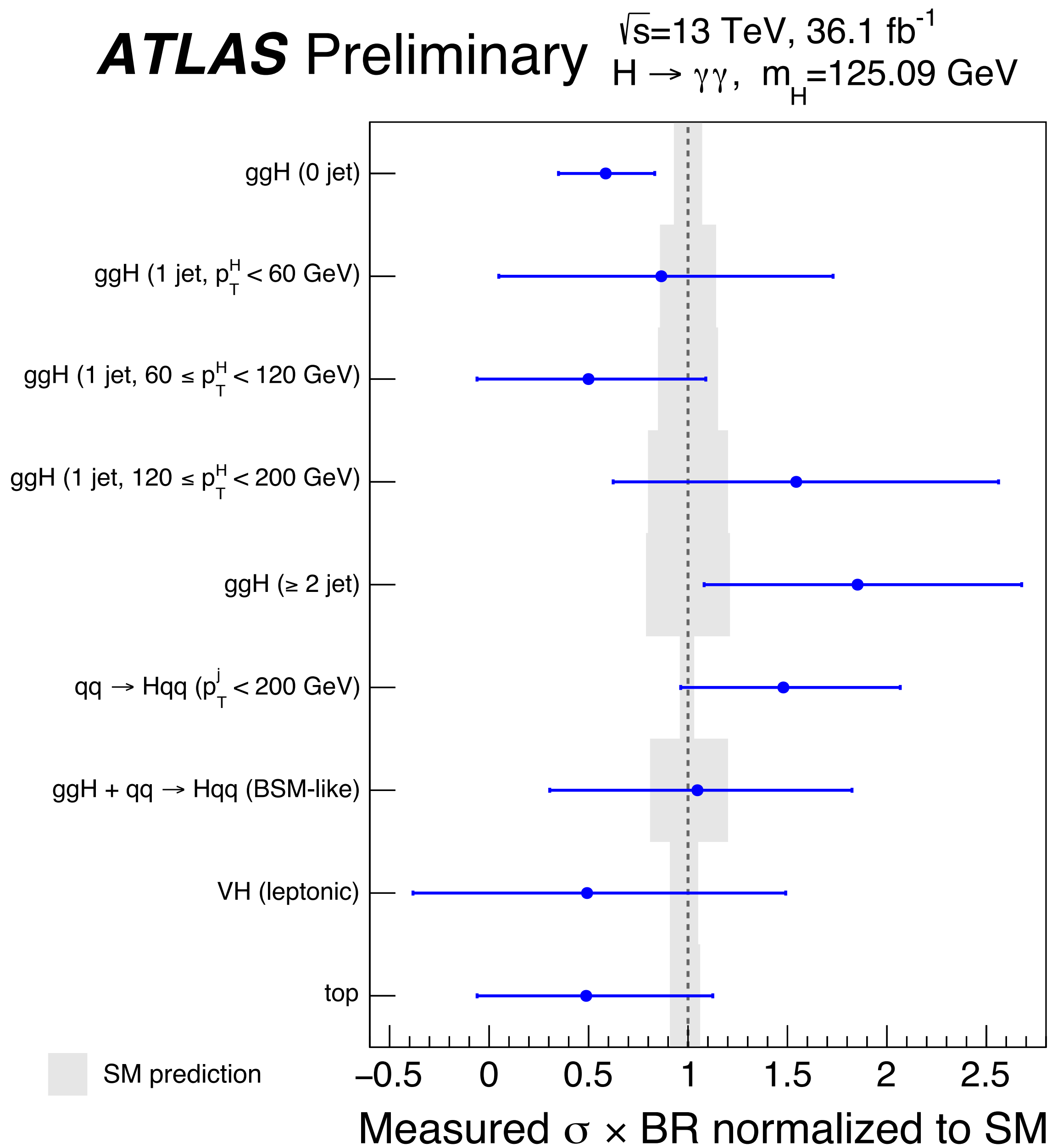
H→γγ : COUPLING MEASUREMENTS



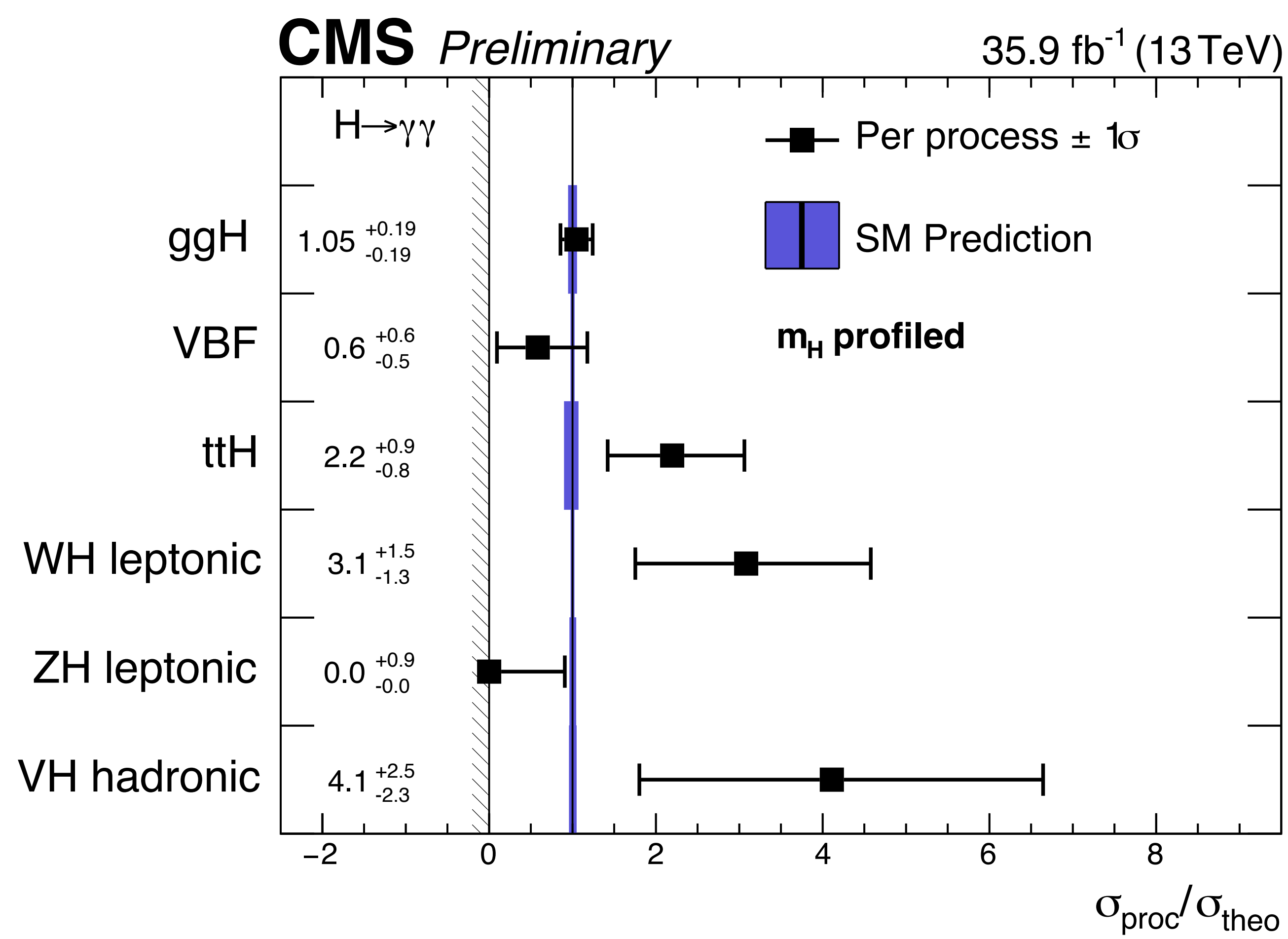
- Also start isolating a variety of phase spaces defined in simplified template cross section framework (STXS)

SIMPLIFIED TEMPLATE CROSS SECTION

ATLAS-CONF-2017-045
CMS-HIG-16-040



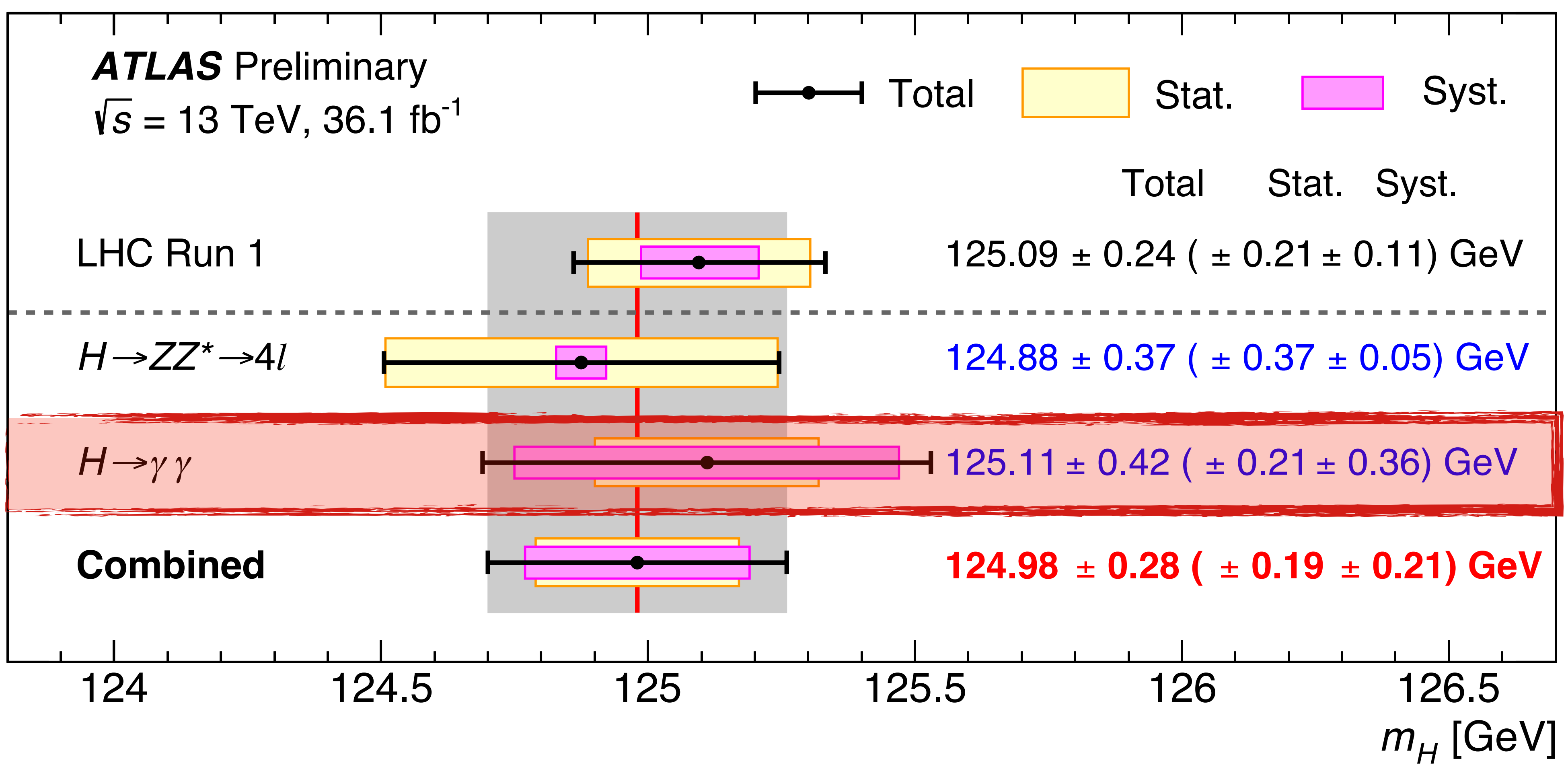
- **ATLAS** uses a merged version of "Stage-1" STXS framework: merged bins to improve sensitivity and reduce correlation between bins
- **Explore different kinematic regions:**
  - Jet and pT bins of ggH
  - High pT bin of ggH and high jet pT bin of VBF sensitive to BSM



- **CMS** uses "Stage-0" version of STXS that explores the production mode inclusively

MASS MEASUREMENT

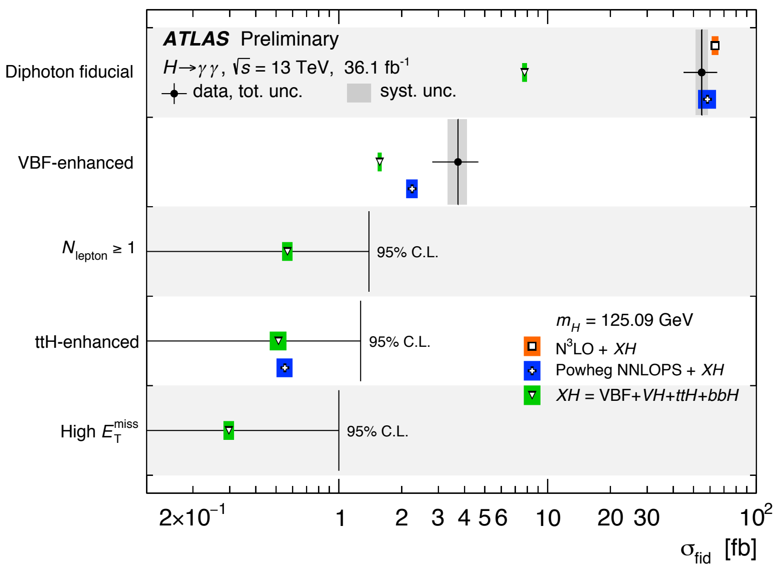
- Both ATLAS and CMS use coupling categories to measure m_H
  - **ATLAS**: **m_H = 125.11 ± 0.21 (stat.) ± 0.36 (syst.) GeV** from preliminary calibration leading syst. uncertainty from non-linearity and layer calibration
  - **CMS**: best fit mass at 125.4 GeV with ~150 MeV stat. uncertainty *syst. uncertainty preliminary estimated to be 200~300 MeV*
- Measurement starts to be limited by syst. uncertainty in H→γγ

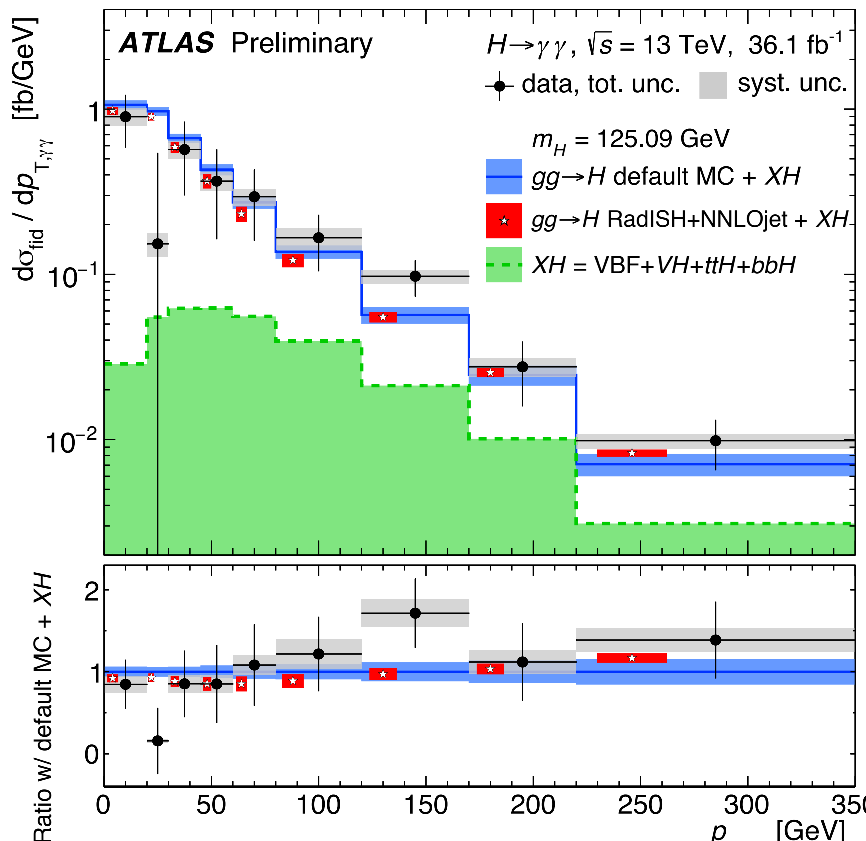


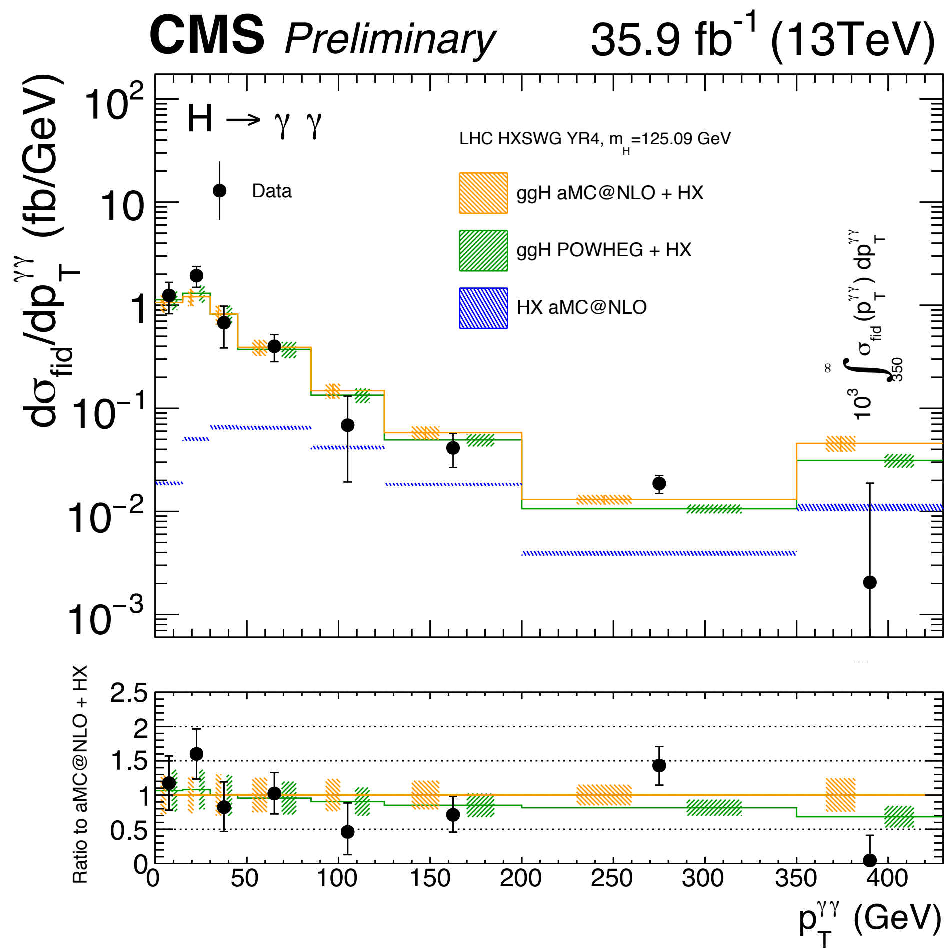
INCLUSIVE/FIDUCIAL FIDUCIAL CROSS SECTIONS

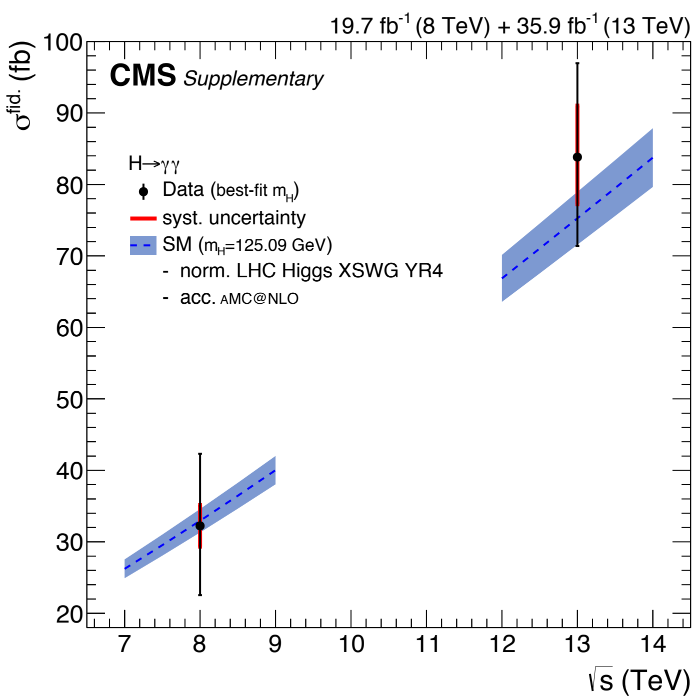
ATLAS-CONF-2017-045
CMS-HIG-16-020

- **Inclusive fiducial cross section** in agreement with theory prediction
- Fiducial cross sections in regions sensitive to either different production modes or BSM physics are also provided









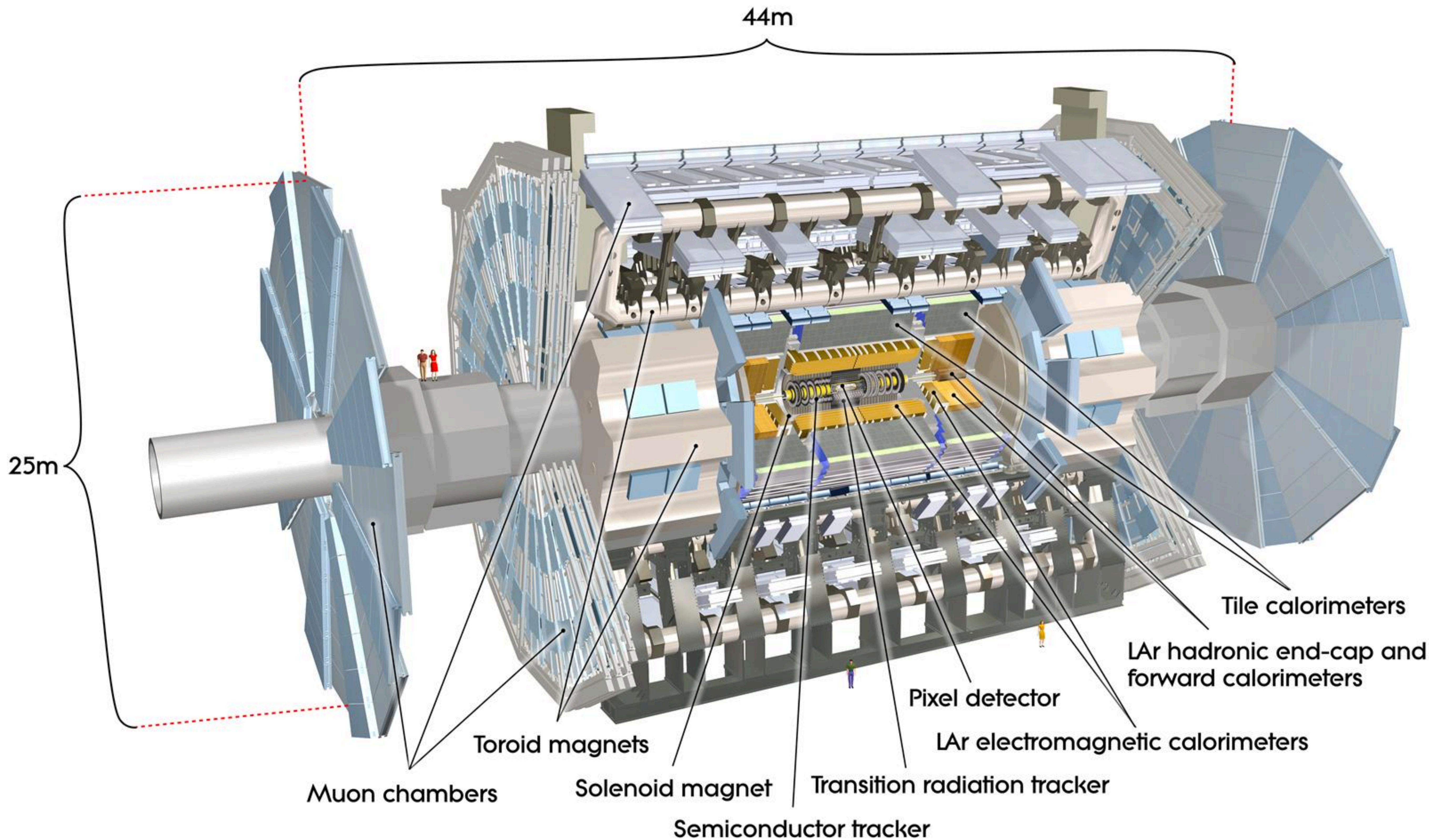
- Diphoton p_T spectrum probes perturbative QCD modelling of ggF. High p_T tail is sensitive to new physics in the ggF loop
- **Good agreement with SM given current stat.**
- **Precision still statistically dominated !**
  - *Further details on Domizia's talk*

CONCLUSION

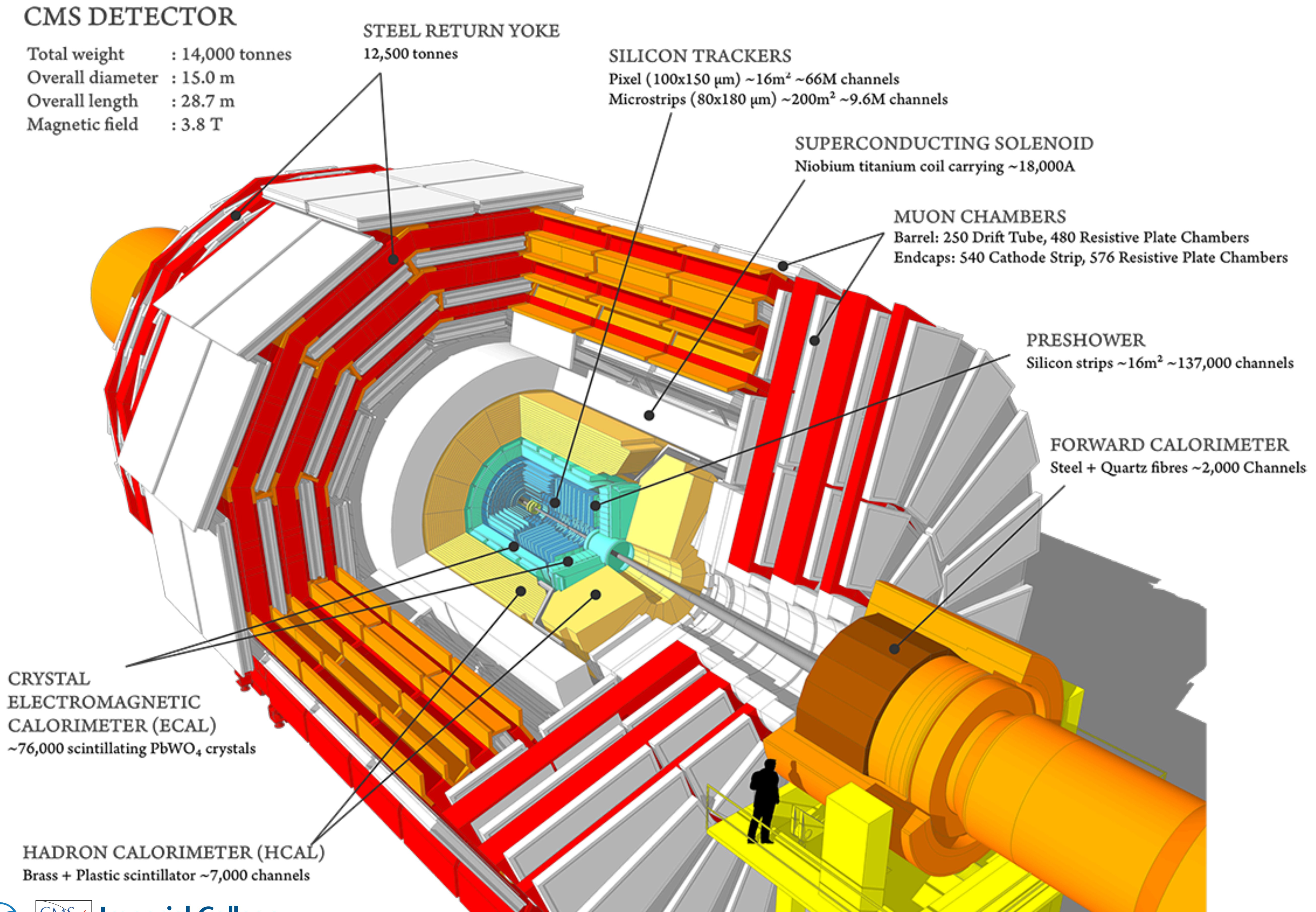
- **Measurements of Higgs boson properties agree with the SM**
  - Signal strength $\mu_{\gamma\gamma}^{ATLAS} = 0.99 \pm 0.14,\ \mu_{\gamma\gamma}^{CMS} = 1.16^{+0.15}_{-0.14}$
  - Signal strength/cross section for different production modes consistent with SM and dominated by stat. uncertainty
  - Mass measurement now dominated by syst. uncertainties
    - *ATLAS $m_{\gamma\gamma}$ = 125.11 ± 0.42 GeV*
    - *CMS best-fit at 125.4 GeV*
- **LHC Run 2 data-taking continues until the end of 2018**
  - Both experiments expect to record 120/fb in total
  - Statistical uncertainties will shrink to about half of the current level
  - Further optimisation of analyses as well as interpretations of data on the way

BACKUP

ATLAS DETECTOR



CMS DETECTOR



CMS BACKGROUND MODELLING

Employ a new strategy for modelling the background

Background shape is *a priori* unknown

The concept is to "profile" over several different function choices (i.e. all are considered in the fit)

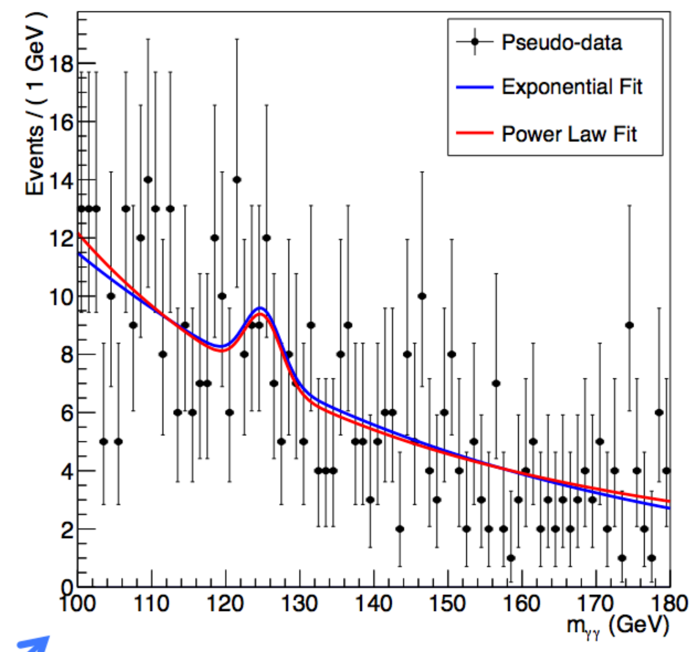
Allow the data to select the one which fits the best

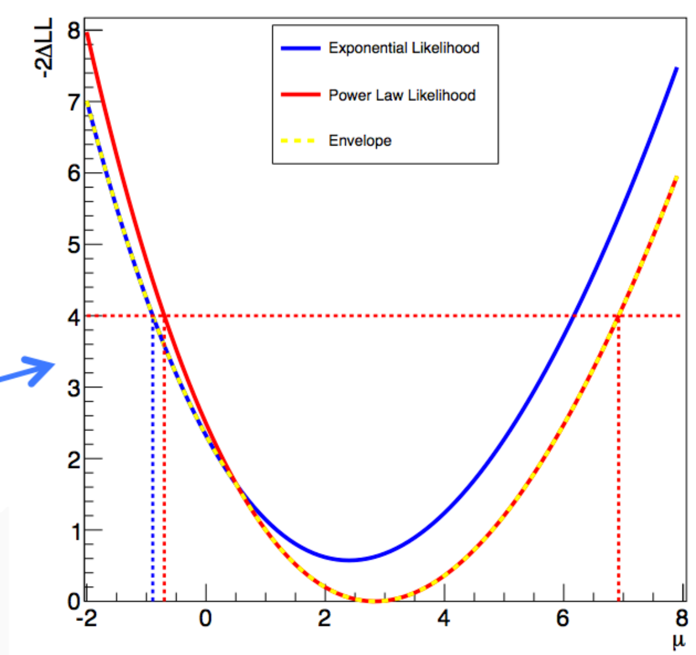
Subsequent "*envelope*" around NLL curve of different choices means uncertainty will take into account model assumption

Correct likelihood for functions with different numbers of parameters

Toy example

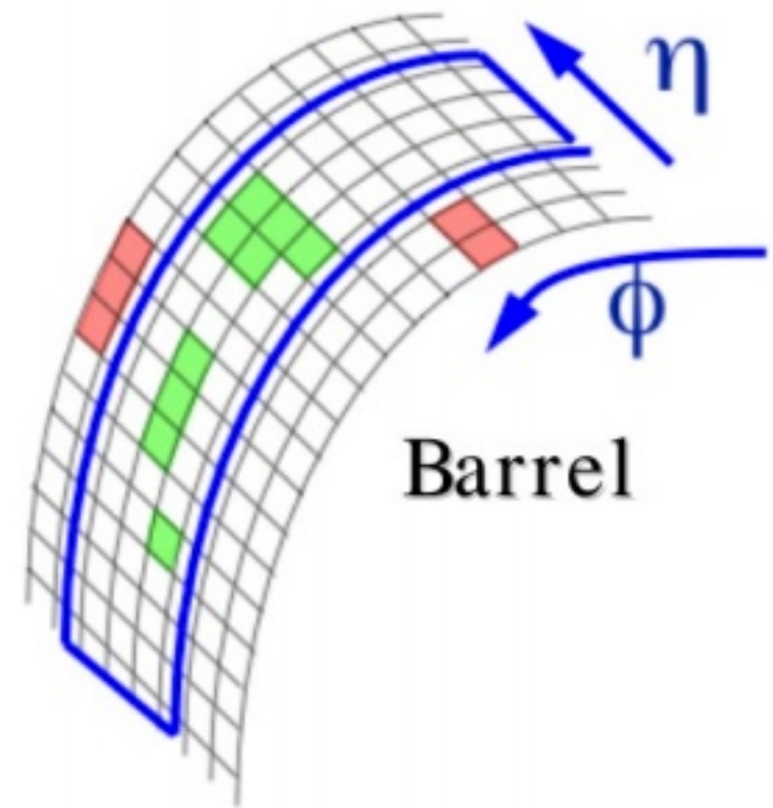
- 1 category, 2 function choices, e^{-px} and x^{-p}
- Profile "envelope" gives best fit with x^{-p}
- 2 sigma error is enlarged by the envelope
- In principle envelope method will increase uncertainty because of different function choices





PHOTON RECONSTRUCTION

- **Both experiments use ηxφ window algorithm**
- **CMS: is photon converts, large φ spread in strong B field:**
  - Barrel superclusters (SC), made from 5x1 sub clusters, may be extended up to 5x17
  - Endcap: multiple 5x5 matrices, combined if overlapping
- **ATLAS: Supercluster from middle layer, then sequentially seed clustering in other layers**
  - Choice between electrons and photon, and conversion finding, to determine window size

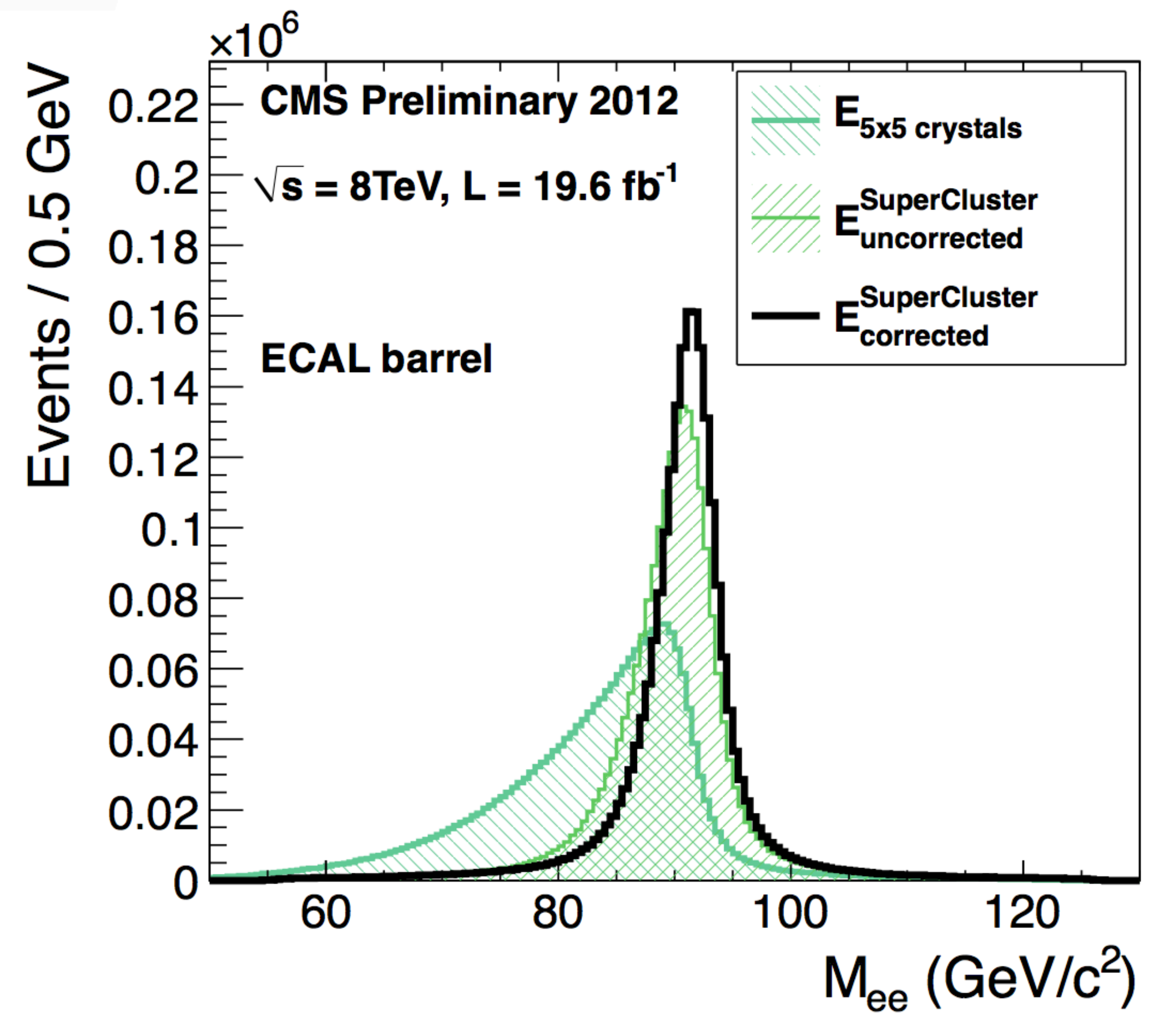


Order	Layer	$\Delta\eta_{cl}$ (units of 0.025)	$\Delta\phi_{cl}$ (units of 0.025)	Seed
1	Middle	$N_\eta^{cluster}$	$N_\phi^{cluster}$	$\eta_{precl}, \phi_{precl}$
2	Strips	$N_\eta^{cluster}$	6 or 8*	$\eta_{middle}, \phi_{middle}$
3	PS	$N_\eta^{cluster}$	6 or 8*	$\eta_{strips}, \phi_{strips}$
4	Back	$N_\eta^{cluster}+1$	$N_\phi^{cluster}$	$\eta_{middle}, \phi_{middle}$

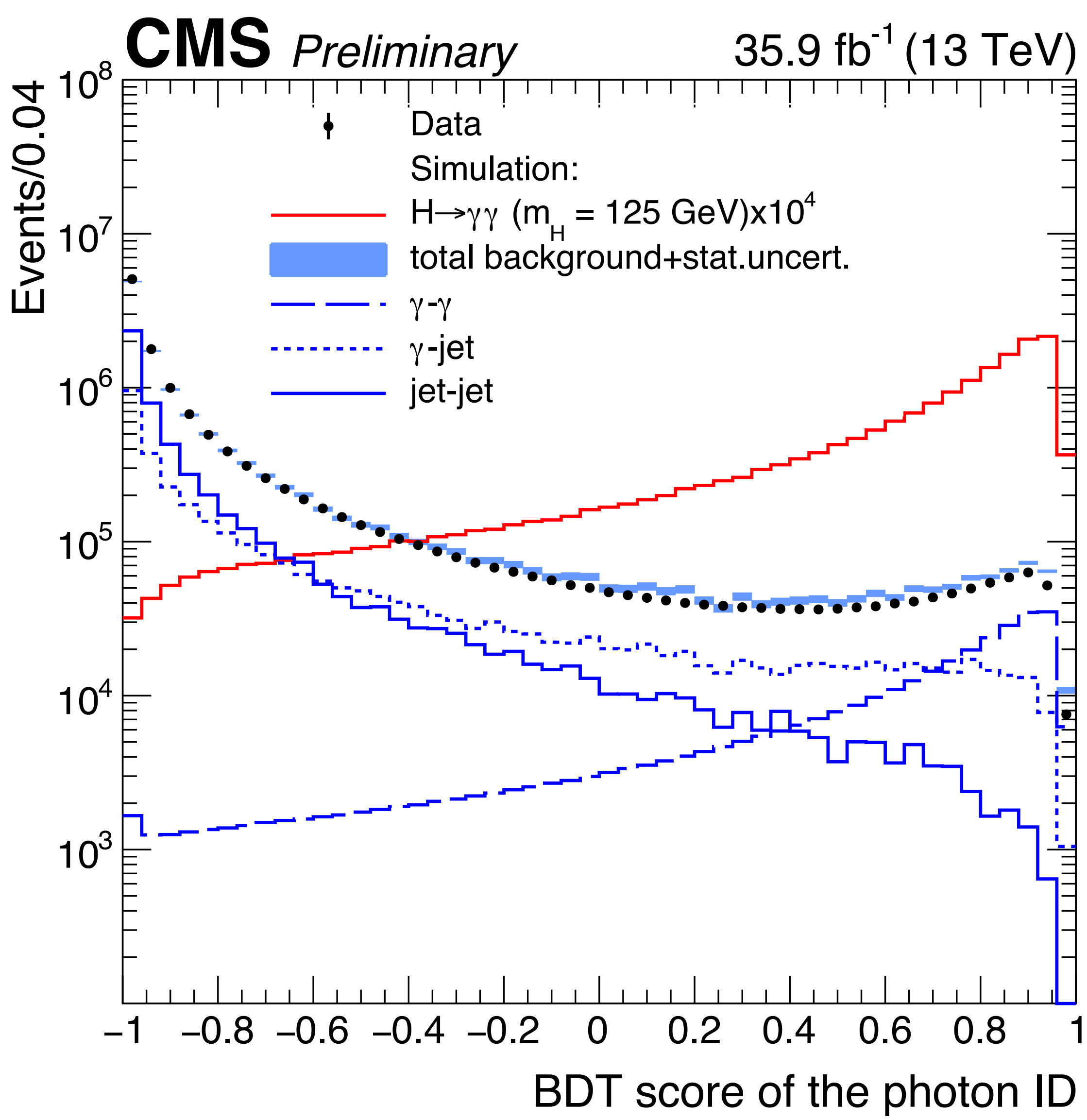
Particle Type	Barrel	Endcap
Electron	3×7	5×5
Converted photon	3×7	5×5
Unconverted photon	3×5	5×5

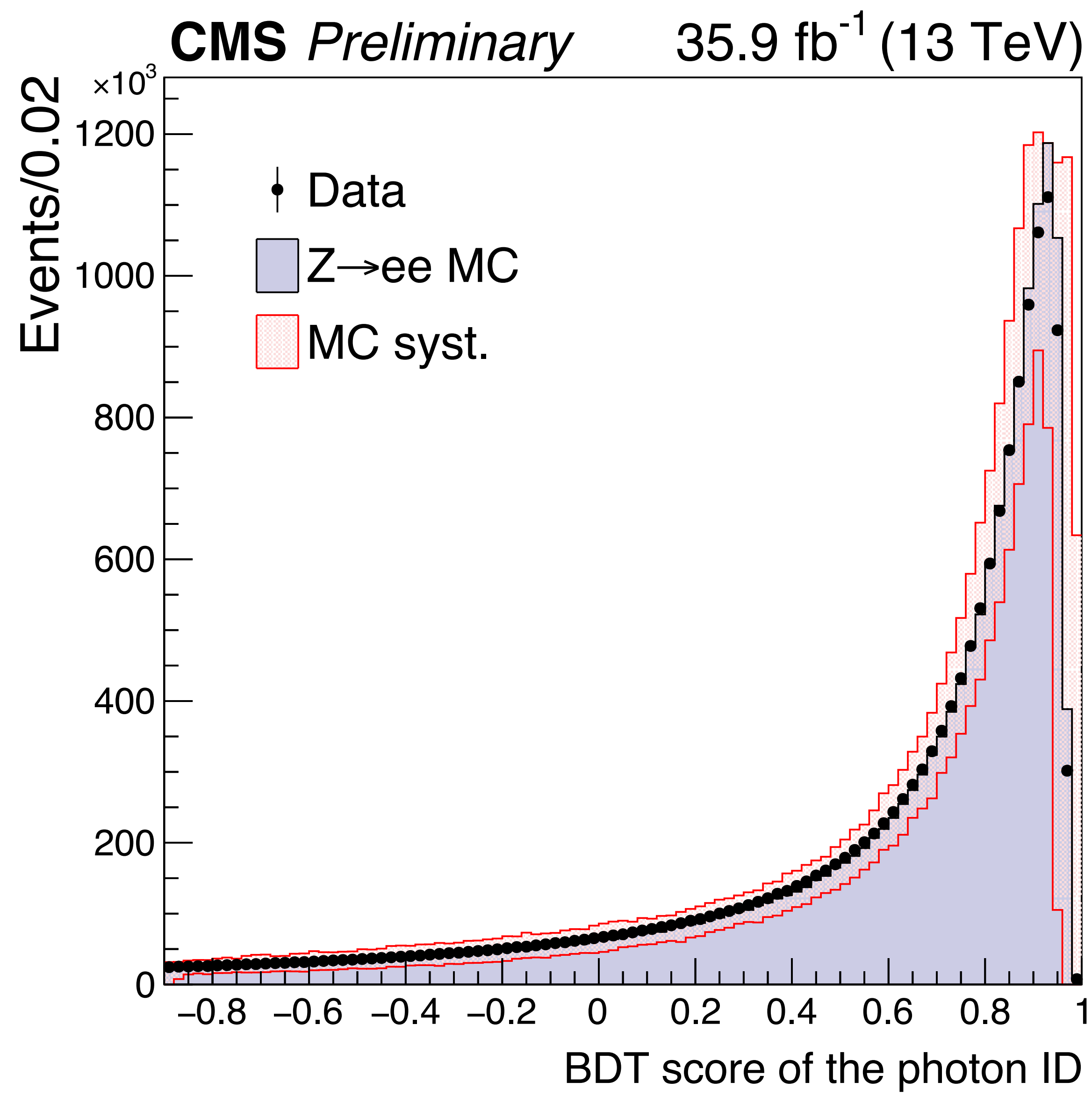
CMS PHOTON ENERGY

- **Electromagnetic calorimeter response**
  - Corrected through time
  - Uniformity Inter-calibration in eta and phi
  - Transparency correction
- **Energy and its uncertainty corrected fro local and global shower containment:**
  - Energy regression targeting the true energy (E_{true}/E_{reco})
- **Scale versus time and resolution calibration through time:**
  - Use Zee peak as a reference



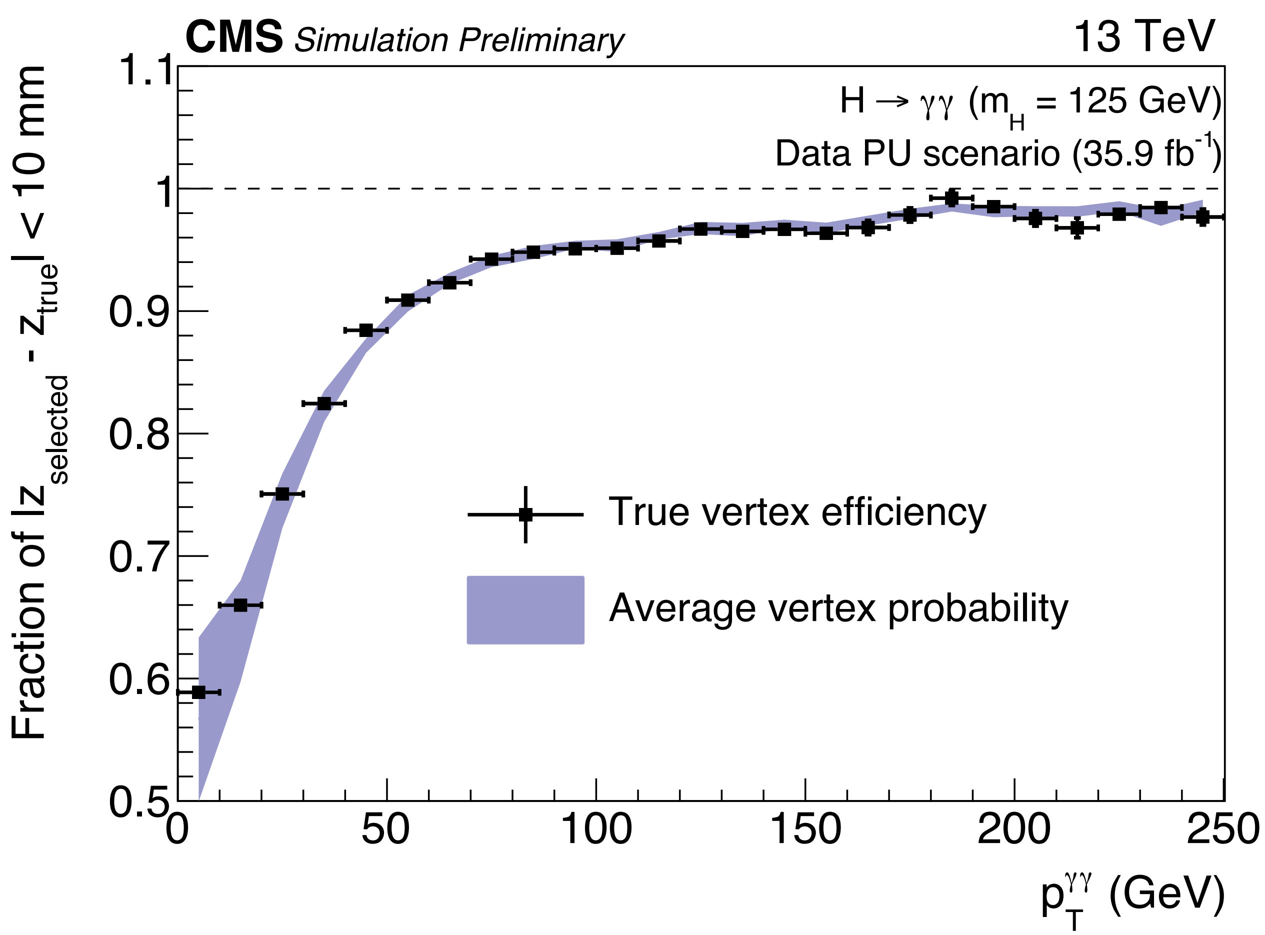
CMS PHOTON IDENTIFICATION

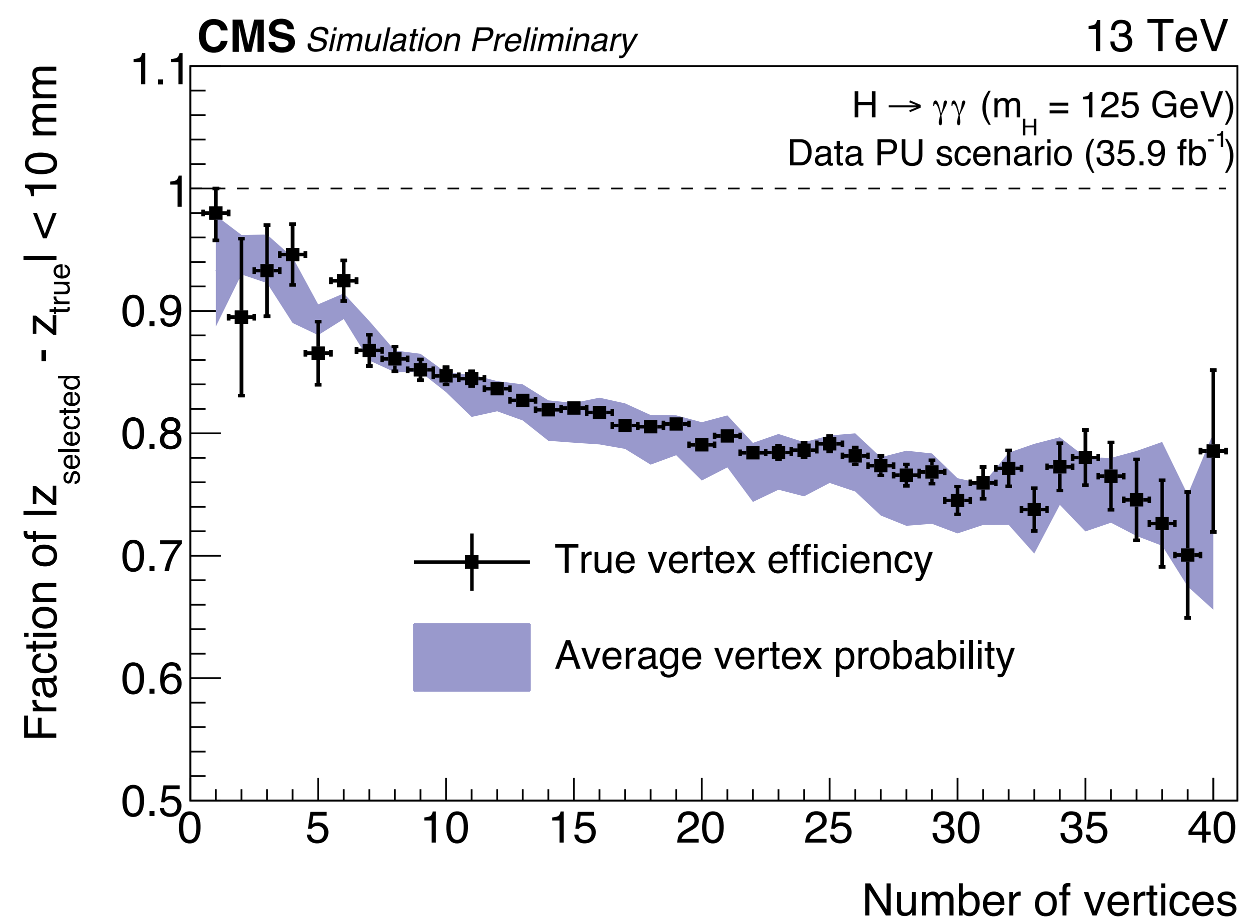




- Photon ID BDT discriminate real and fake photons (from jet fragments)

CMS PRIMARY VERTEX IDENTIFICATION





- BDT using recoiling tracks to assign vertex to diphotons
- Negligible impact on resolution

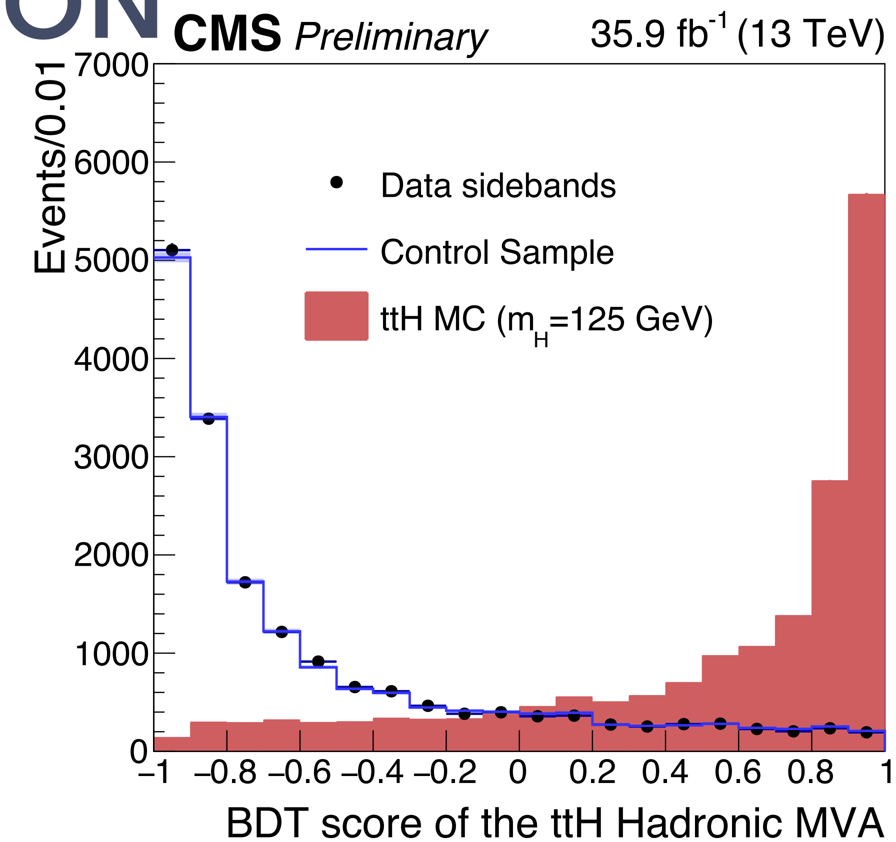
CMS H→γγ : CATEGORISATION

BY PRODUCTION

ttH (leptonic + hadronic)

- (sub-)lead-photon pT/$m_{\gamma\gamma}$ >1/2(1/4), at least one lepton ($\ell=\mu,e$) away from Z peak
- at least two jets with pT>25GeV, |η|<2.5
- at least one of the jet is b-tag

- At least 3 jets + 1 b-jet
- Train an MVA on MC ttH vs MC diphoton using the input variables : N_{jets}, lead b-tag , sub-lead b-tag, lead p_T



VH leptonic

- W → $\ell\nu$ or Z→ $\ell\ell$
- (sub-)lead-photon pT/$m_{\gamma\gamma}$ >1/2(1/4)
- at least one lepton ($\ell=\mu,e$) away from Z peak
- ΔR(γ,μ (e)) > 0.5 (0.2)
- diphoton MVA > 0.5
- MET > 45 GEV (WH leptonic)

VH Hadronic

- W → jj or W → jj
- (sub-)lead-photon pT/$m_{\gamma\gamma}$ >1/2(1/4)
- at least two jets
- p_T > 40 GeV, |η|<2.4, |cosθ*| < 0.5
- 60<m_{jj} < 120 GeV

VH MET

- W → $\ell\nu$ or W → $\nu\nu$
- MET > 85 GeV
- ΔΦ(γγ,MET) > 2.4
- diphoton MVA > 0.79

ttH (LEP) | VH (LEP) | ttH (HAD) | VBF | VH MET | VH (HAD) | Untagged

ATLAS EXPERIMENT | CMS | Imperial College London

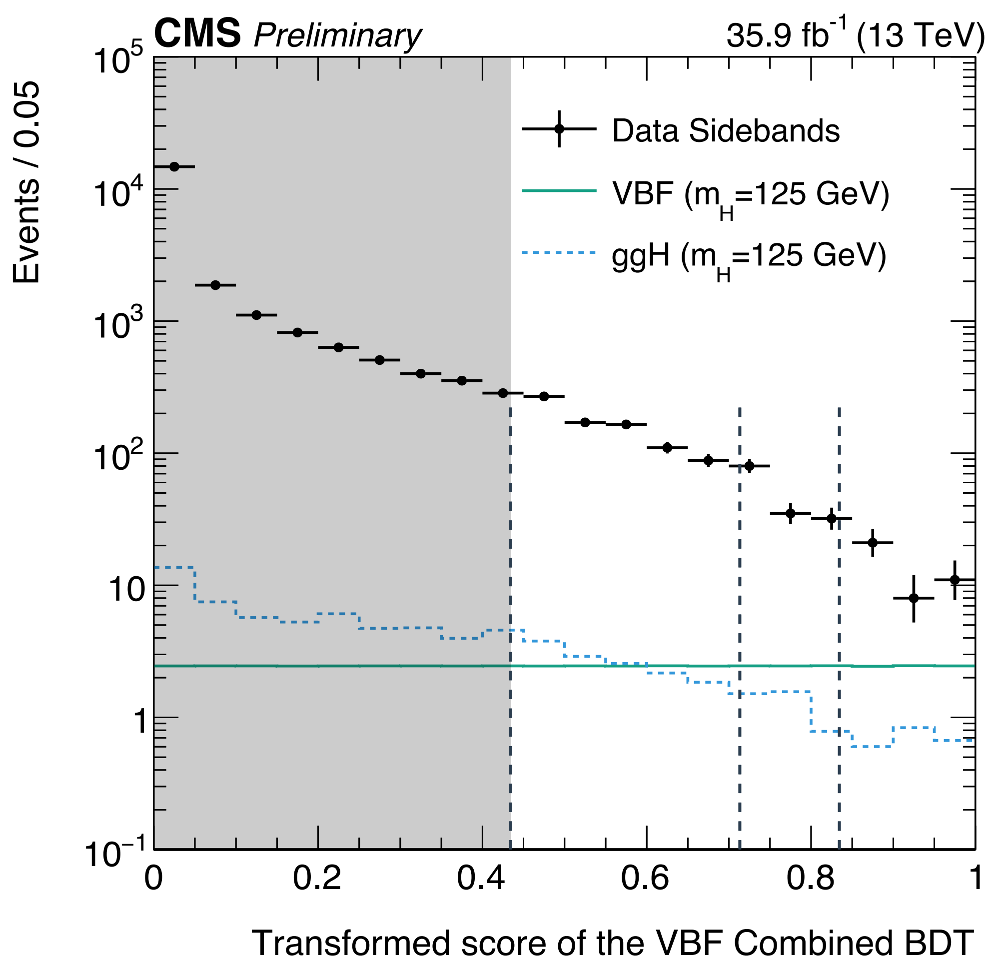
** Category priority: Tags are prioritised in order of S/B*

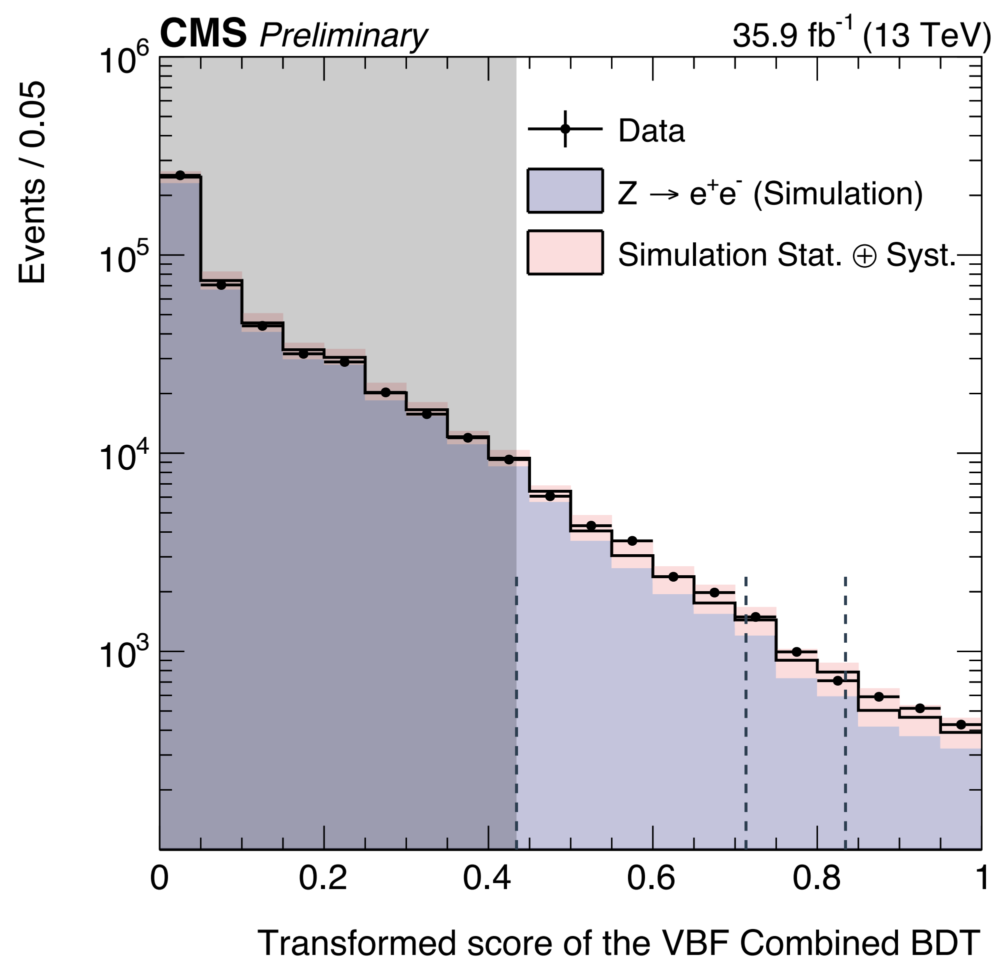
CMS H→γγ : CATEGORISATION

BY PRODUCTION

VBF (0−1)

- Require at least 2 jets with p_{T1} > 30GeV, p_{T2} >20 GeV, |η| < 4.7, m_{jj} >250 GeV
- A diphoton pair with (sub)lead $p_T/m_{\gamma\gamma}$ > 1/2(1/4)
- Construct a BDT to identify VBF dijet-like events using:
  - $p_T/m_{\gamma\gamma}$ of both photons, p_T of both jets, m_{jj}, $\Delta\eta_{jj}$, centrality variable, ΔΦjj,γγ, ΔRγj, ΔΦjj
- Final VBF classification combines dijet BDT with BDT estimating diphoton quality (see next slide)
- 3 VBF categories are then defined by sensitivity (VBF tag 0-1-2)

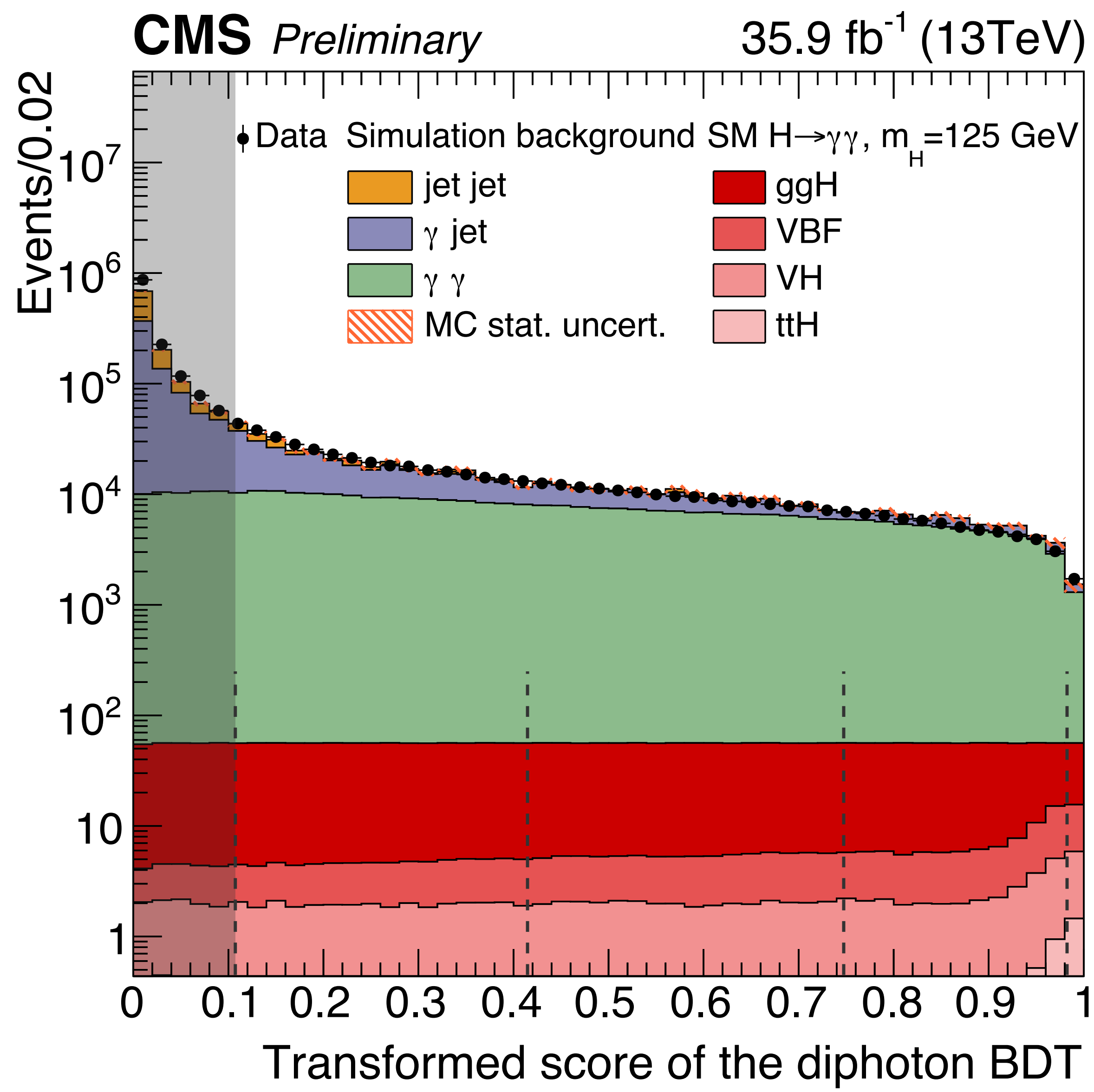




** Category priority: Tags are prioritised in order of S/B*

CMS H→γγ : CATEGORISATION

- Remaining events fall into the untagged category
- Construct MVA to select diphoton pairs with signal like kinematics, high photon ID score and good mass resolution
- Split events into categories based on output of classifier exploiting S/B ratios and mass resolution
- 4 untagged categories → **14 non-overlapping categories in total**



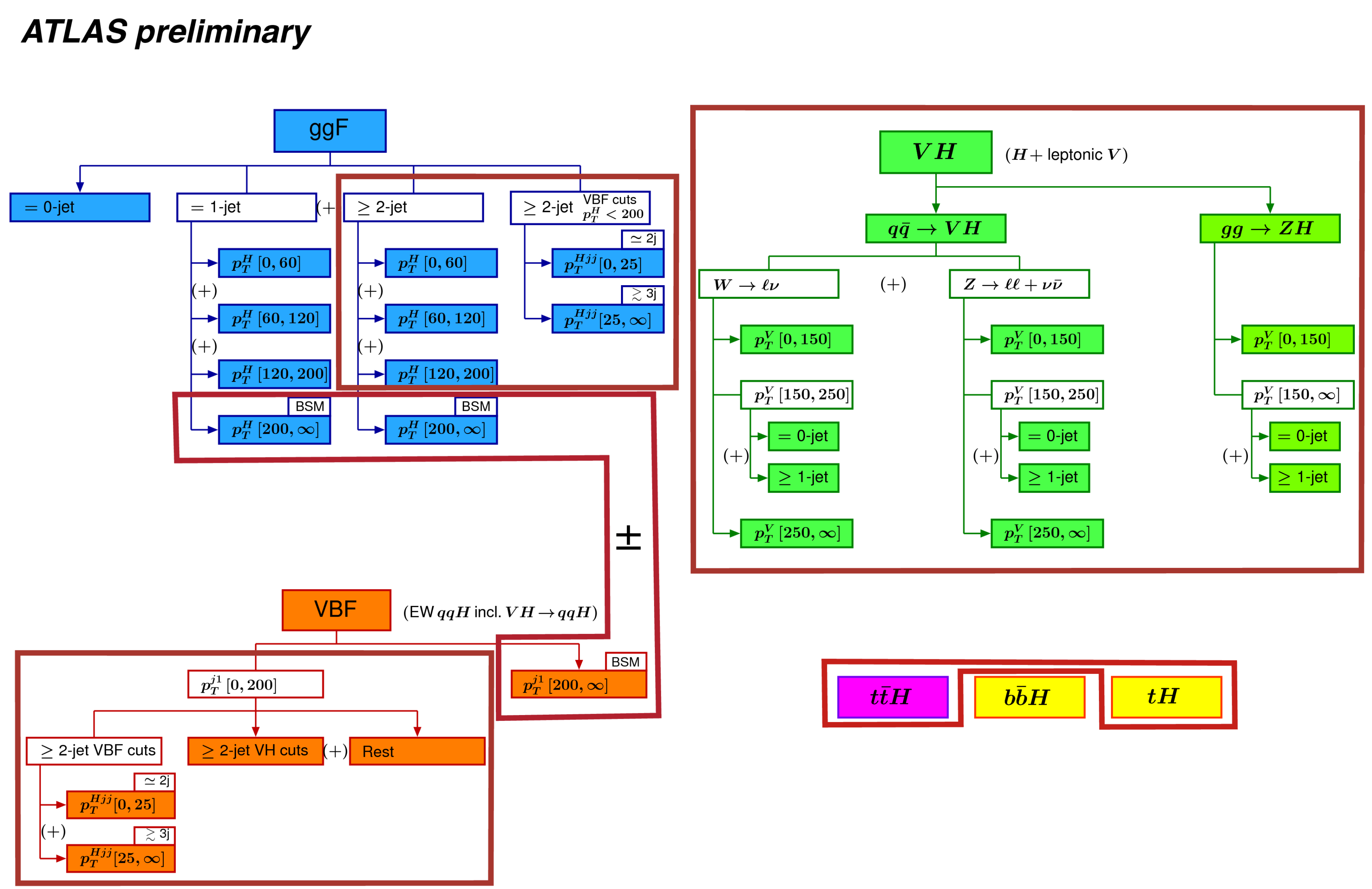
ttH (LEP)
VH (LEP)
ttH (HAD)
VBF
VH MET
VH (HAD)
Untagged

* *Category priority: Tags are prioritised in order of S/B*

ATLAS: KINEMATIC REGIONS OF THE STXS STAGE-1

Process	Measurement region	Stage 1 region
ggH + $gg \to Z(\to qq)H$	0-jet	0-jet
	1-jet, $p_T^H < 60\,GeV$	1-jet, $p_T^H < 60\,GeV$
	1-jet, $60 \leq p_T^H < 120\,GeV$	1-jet, $60 \leq p_T^H < 120\,GeV$
	1-jet, $120 \leq p_T^H < 200\,GeV$	1-jet, $120 \leq p_T^H < 200\,GeV$
	$\geq$ 1-jet, $p_T^H > 200\,GeV$	1-jet, $p_T^H > 200\,GeV$
		$\geq$ 2-jet, $p_T^H > 200\,GeV$
	$\geq$ 2-jet, $p_T^H < 200\,GeV$ or VBF-like	$\geq$ 2-jet, $p_T^H < 60\,GeV$
		$\geq$ 2-jet, $60 \leq p_T^H < 120\,GeV$
		$\geq$ 2-jet, $120 \leq p_T^H < 200\,GeV$
		VBF-like, $p_T^{Hjj} < 25\,GeV$
		VBF-like, $p_T^{Hjj} \geq 25\,GeV$
$qq' \to Hqq'$ (VBF + VH)	$p_T^j < 200\,GeV$	$p_T^j < 200\,GeV$, VBF-like, $p_T^{Hjj} < 25\,GeV$
		$p_T^j < 200\,GeV$, VBF-like, $p_T^{Hjj} \geq 25\,GeV$
		$p_T^j < 200\,GeV$, VH-like
		$p_T^j < 200\,GeV$, Rest
	$p_T^j > 200\,GeV$	$p_T^j > 200\,GeV$
VH (leptonic decays)	VH leptonic	$q\bar{q} \to ZH$, $p_T^Z < 150$ GeV
		$q\bar{q} \to ZH$, 150 $GeV < p_T^Z < 250$ GeV, 0-jet
		$q\bar{q} \to ZH$, 150 $GeV < p_T^Z < 250$ GeV, $\geq$ 1-jet
		$q\bar{q} \to ZH$, $p_T^Z > 250$ GeV
		$q\bar{q} \to WH$, $p_T^W < 150$ GeV
		$q\bar{q} \to WH$, 150 $GeV < p_T^W < 250$ GeV, 0-jet
		$q\bar{q} \to WH$, 150 $GeV < p_T^W < 250$ GeV, $\geq$ 1-jet
		$q\bar{q} \to WH$, $p_T^W > 250$ GeV
		$gg \to ZH$, $p_T^Z < 150$ GeV
		$gg \to ZH$, $p_T^Z > 150$ GeV, 0-jet
		$gg \to ZH$, $p_T^Z > 150$ GeV, $\geq$ 1-jet
top-associated production	top	$t\bar{t}H$
		tHW
		$tHqb$
$b\bar{b}H$	merged w/ ggH	$b\bar{b}H$

ATLAS: STXS STAGE-1 BIN MERGING



All regions enclosed by red boxes are merged, except for the sum and difference indicated by the ± sign connecting two merged ggH regions with one Hqq region. The bbH region is merged with the ggH bins.

EXPECTED YIELDS FOR THE FULL 2016 DATASET

Event Categories	SM 125 GeV Higgs boson expected signal								
	Total	ggH	VBF	ttH	bbH	tHq	tHW	WH lep	ZH
Untagged 0	45.83	80.19 %	11.75 %	1.83 %	0.40 %	0.47 %	0.22 %	0.41 %	0.1
Untagged 1	480.56	86.81 %	7.73 %	0.56 %	1.15 %	0.13 %	0.02 %	0.47 %	0.2
Untagged 2	670.45	89.76 %	5.48 %	0.44 %	1.18 %	0.08 %	0.01 %	0.51 %	0.3
Untagged 3	610.07	91.13 %	4.51 %	0.48 %	1.07 %	0.07 %	0.01 %	0.55 %	0.3
VBF 0	10.01	21.69 %	77.09 %	0.34 %	0.35 %	0.29 %	0.03 %	0.03 %	0.0
VBF 1	8.64	33.58 %	64.64 %	0.39 %	0.52 %	0.36 %	0.04 %	0.13 %	0.0
VBF 2	27.76	50.14 %	46.46 %	0.81 %	0.73 %	0.53 %	0.07 %	0.20 %	0.0
ttH Hadronic	5.85	10.99 %	0.70 %	77.54 %	2.02 %	4.13 %	2.02 %	0.09 %	0.0
ttH Leptonic	3.81	1.90 %	0.05 %	87.48 %	0.08 %	4.73 %	3.04 %	1.53 %	1.1
ZH Leptonic	0.49	0.00 %	0.00 %	2.56 %	0.00 %	0.02 %	0.13 %	0.00 %	97.3
WH Leptonic	3.61	1.26 %	0.59 %	5.18 %	0.18 %	3.03 %	0.73 %	84.48 %	4.3
VH LeptonicLoose	2.75	9.16 %	2.70 %	2.34 %	0.57 %	1.81 %	0.13 %	63.62 %	18.8
VH Hadronic	9.69	57.38 %	3.68 %	3.61 %	0.35 %	1.39 %	0.27 %	0.17 %	0.4
VH Met	4.25	23.63 %	2.46 %	14.45 %	0.41 %	2.00 %	1.14 %	25.17 %	28.6
Total	1883.77	86.96 %	7.09 %	1.00 %	1.09 %	0.15 %	0.04 %	0.81 %	0.4

GGH THEORY UNCERTAINTIES

from HXSWG workshop : https://indico.cern.ch/event/595100/contributions/2649194/attachments/1493264/2322052/ggF_Jul17.pdf

Interim 2017 uncertainty scheme

Documentation in preparation: LHCHXSWG-2017-001

9 independent sources of uncertainties

1. QCD scale variation
2. Resummation scale variation
3. 0 □ 1 jet migration
4. 1 □ 2 jets migration
5. VBF phase space
6. VBF phase space with 3rd jet veto
7. Higgs p_T 0-60/60-∞ GeV
8. Higgs p_T 60-120/120-∞ GeV
9. Finite top mass dependence: $p_T > m_t$

Jet bins: four sources
Taken from YR4, Tackmann et al.
Cross checked with JVE @N3LO

VBF topology uncertainties
Found consistent central values and uncertainties using Run-1 style, YR3 uncertainties (from MCFM + ST), and using GoSam+Sherpa HJJJ @ NLO

Uncertainties on the Higgs pT shape within a fixed jet multiplicity bin. Taken from QCD scale variations of Powheg NNLOPS

Uncertainty on finite top mass effects.
Taken from difference between LO and NLO rescaling.

GGH THEORY UNCERTAINTIES

from HXSWG workshop : https://indico.cern.ch/event/595100/contributions/2649194/attachments/1493264/2322052/ggF_Jul17.pdf

Different uncertainties

Different phase spaces

Cross sections and fractional uncertainties

STXS	sig		stat	mu	res	mig01	mig12	VBF2j	VBF3j	pT60	pT120	qm_top	Tot
Incl	48.52	+/-	0.00	+4.6%	+2.1%	-0.0%	-0.0%	+0.3%	-0.0%	+0.0%	+0.2%	+0.2%	+5.1%
FWDH	4.27	+/-	0.01	+4.5%	+1.9%	-0.5%	-0.2%	+0.0%	+0.0%	-0.3%	-0.1%	+0.0%	+4.9%
VBF_J3V	0.27	+/-	0.00	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	-32.0%	-1.6%	+1.1%	+0.1%	+37.8%
VBF_J3	0.36	+/-	0.00	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+23.5%	-0.2%	+2.5%	+0.2%	+31.0%
=0J	27.25	+/-	0.03	+3.8%	+0.1%	-4.1%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+5.6%
=1J_0-60	6.49	+/-	0.01	+5.2%	+4.5%	+7.9%	-6.8%	+0.0%	+0.0%	-4.8%	-1.6%	+0.0%	+13.5%
=1J_60-120	4.50	+/-	0.01	+5.2%	+4.5%	+7.9%	-6.8%	+0.0%	+0.0%	+4.8%	-0.9%	+0.0%	+13.4%
=1J_120-200	0.74	+/-	0.00	+5.2%	+4.5%	+7.9%	-6.8%	+0.0%	+0.0%	+10.0%	+10.1%	+0.5%	+18.9%
=1J_200->	0.15	+/-	0.00	+5.2%	+4.5%	+7.9%	-6.8%	+0.0%	+0.0%	+10.0%	+14.0%	+10.5%	+23.7%
>=2J_0-60	1.22	+/-	0.01	+8.9%	+8.9%	+4.4%	+18.2%	+0.0%	+0.0%	-5.9%	-1.6%	+0.0%	+23.3%
>=2J_60-120	1.86	+/-	0.01	+8.9%	+8.9%	+4.4%	+18.2%	+0.0%	+0.0%	-0.2%	-0.2%	+0.0%	+22.5%
>=2J_120-200	0.99	+/-	0.00	+8.9%	+8.9%	+4.4%	+18.2%	+0.0%	+0.0%	+6.6%	+10.6%	+0.6%	+25.8%
>=2J_200->	0.42	+/-	0.00	+8.9%	+8.9%	+4.4%	+18.2%	+0.0%	+0.0%	+10.0%	+14.0%	+11.8%	+30.7%
=0J	30.12	+/-	0.03	+3.8%	+0.1%	-4.1%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+5.6%
=1J	12.92	+/-	0.02	+5.2%	+4.5%	+7.9%	-6.8%	+0.0%	+0.0%	-0.1%	-0.4%	+0.2%	+12.5%
>=2J	5.47	+/-	0.01	+7.8%	+7.8%	+3.9%	+16.1%	+2.3%	-0.0%	+0.4%	+2.9%	+1.1%	+20.3%
>=1J 60-200	9.09	+/-	0.01	+6.2%	+5.8%	+6.4%	+1.9%	+0.9%	+0.1%	+4.2%	+1.7%	+0.1%	+11.8%
>=1J 120-200	1.96	+/-	0.01	+6.8%	+6.5%	+5.5%	+6.9%	+1.5%	+0.4%	+8.0%	+10.4%	+0.6%	+18.5%
>=1J >200	0.58	+/-	0.00	+7.9%	+7.7%	+5.4%	+11.6%	+0.0%	+0.0%	+10.0%	+14.0%	+11.4%	+26.7%
>=1J >60	9.68	+/-	0.01	+6.3%	+5.9%	+6.3%	+2.5%	+0.8%	+0.1%	+4.6%	+2.5%	+0.8%	+12.2%
>=1J >120	2.54	+/-	0.01	+7.0%	+6.8%	+5.5%	+8.0%	+1.2%	+0.3%	+8.4%	+11.2%	+3.0%	+19.9%
>=1	18.40	+/-	0.02	+6.0%	+5.5%	+6.7%	-0.0%	+0.7%	-0.0%	+0.0%	+0.5%	+0.4%	+10.6%