ATLAS

Search for the 125 GeV Higgs boson in the ttH mode with the ATLAS detector (ID#99)

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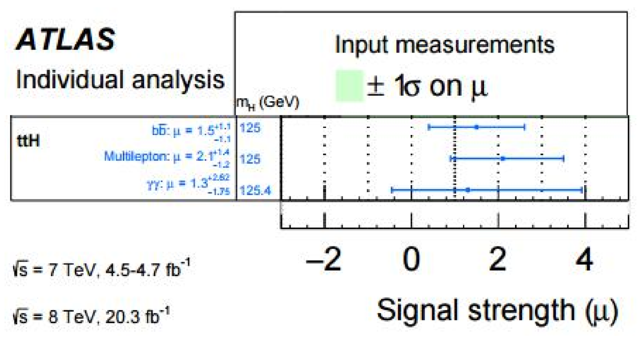
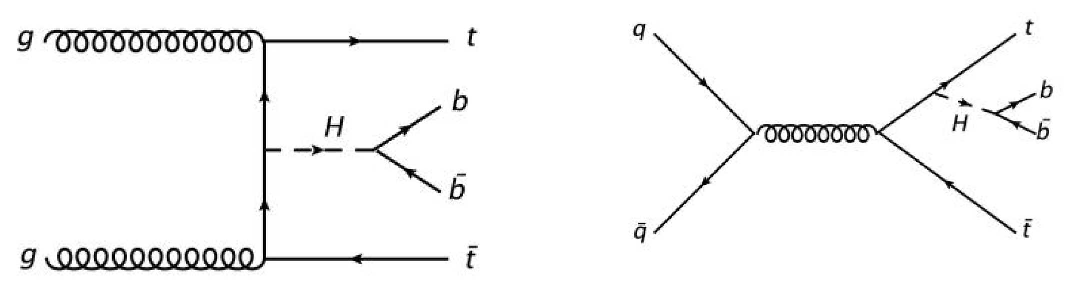
Introduction and Motivation

• The discvery of a new particle H with a mass of about 125 GeV in searches for the Standard Model (SM) Higgs boson at the LHC was reported by the ATLAS and CMS Collaborations in July 2012.

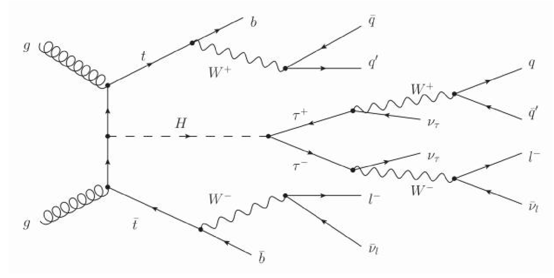
• A particle's Higgs Yukawa coupling strength should be proportional to the mass of the particle. The observation of ttH mode would allow the direct tree- level measurement of the largest top-Higgs Yukawa coupling, which will complete the fermion coupling measurements performed so far.



Run-1 Higgs signal strength measurement in ttH mode

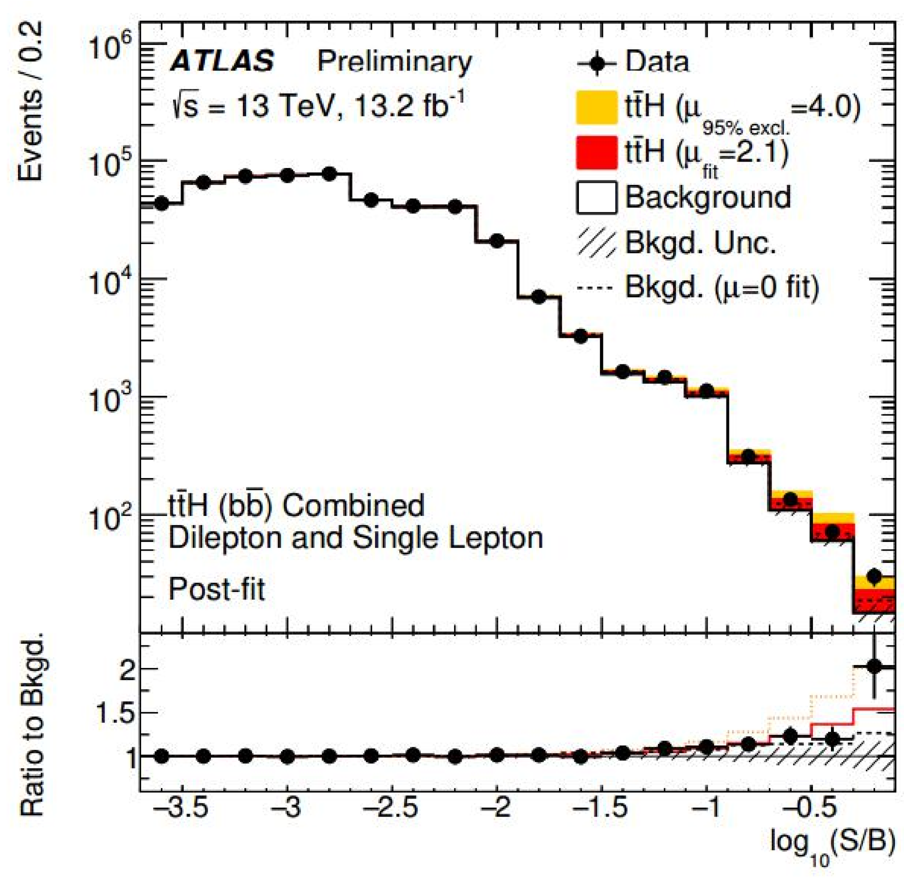


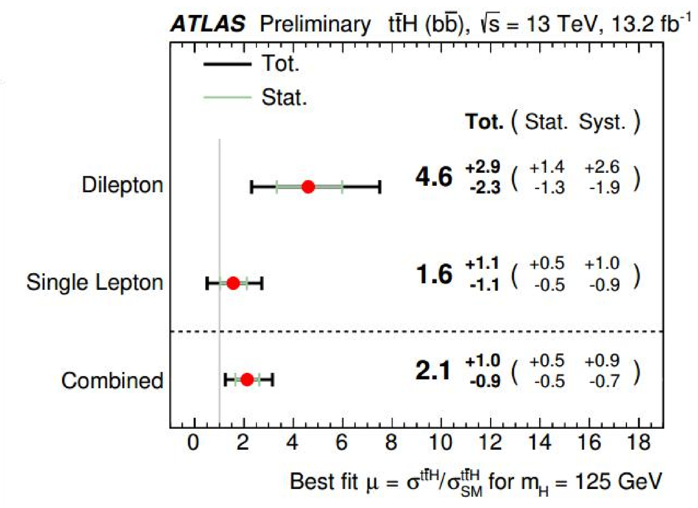
Representative tree-level Feynman diagram of ttH production

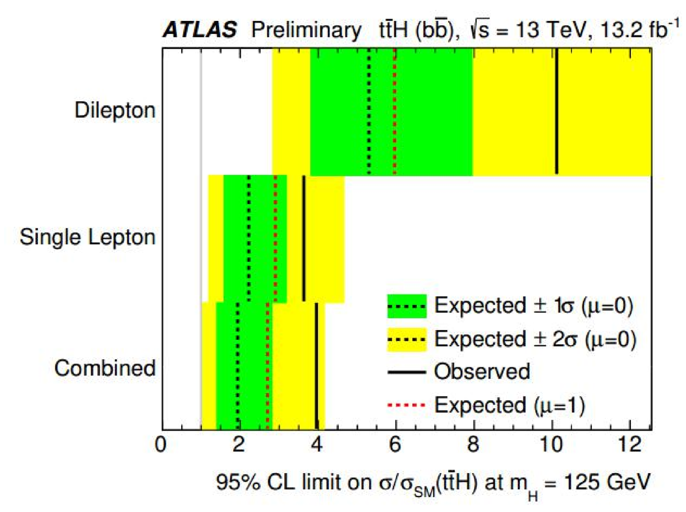


ttH(H->ττ->multilepton) decay channel

Results in ttH(bb) Channel



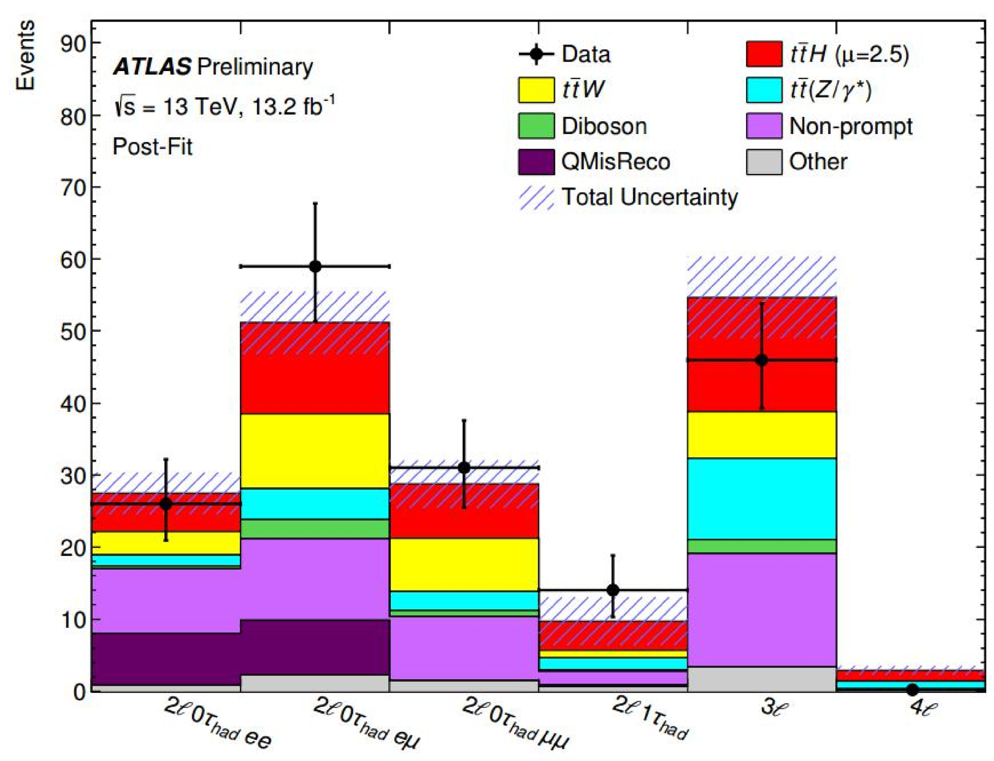


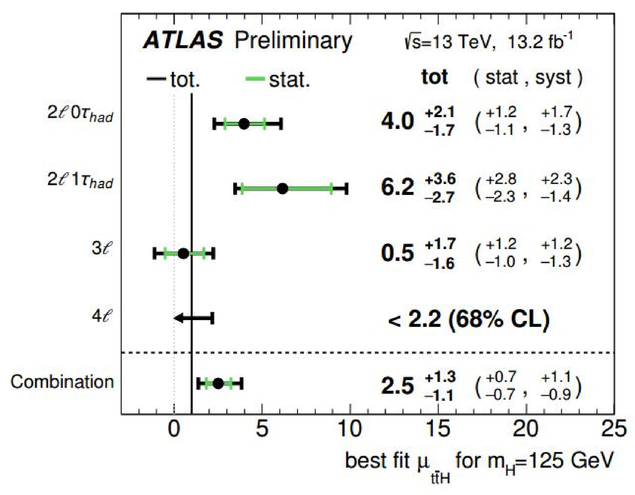


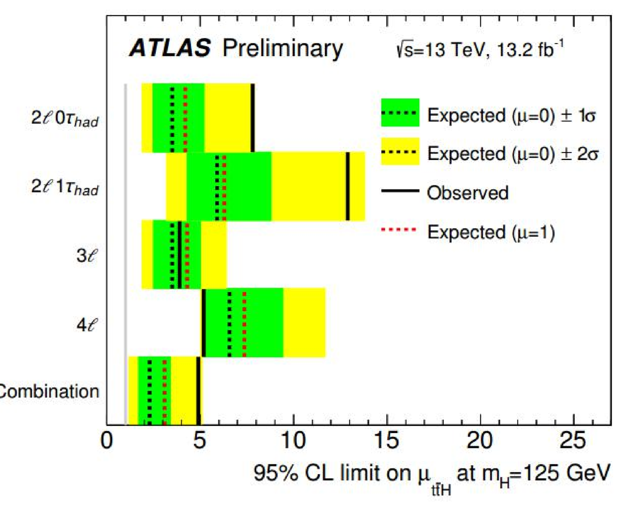
• The analysis in ttH(bb) channel is designed to be sensitive to Higgs boson decays to b-quarks, although all decay modes are considered as signal. Events with one or two leptons are considered, and exclusive regions are defined according to the number of leptons, jets and b-tagged jets.

• A two-step multivariate approach is used in regions with large signal contributions, which first matches reconstructed jets to final-state partons, and next classifies each event as more or less signal-like. These signal-rich regions are analysed together with the signal-depleted regions in a likelihood fit, which simultaneously determines the contributions from the ttH signal and the major backgrounds.

Results in Multilepton Channel







• The search in multilepton channel uses four final states distinguished by the number and flavor of leptons: two same-charge light leptons(e or μ) and no hadronically-decaying τ lepton candidates ($2l0\tau_{had}$); two same-charge light leptons and one hadronically-decaying τ lepton candidate ($2l1\tau_{had}$); three light leptons (3l); and four light leptons (4l). These signatures are primarily sensitive to H->WW* and H->ττ decays, and are effective in suppressing tt backgrounds.

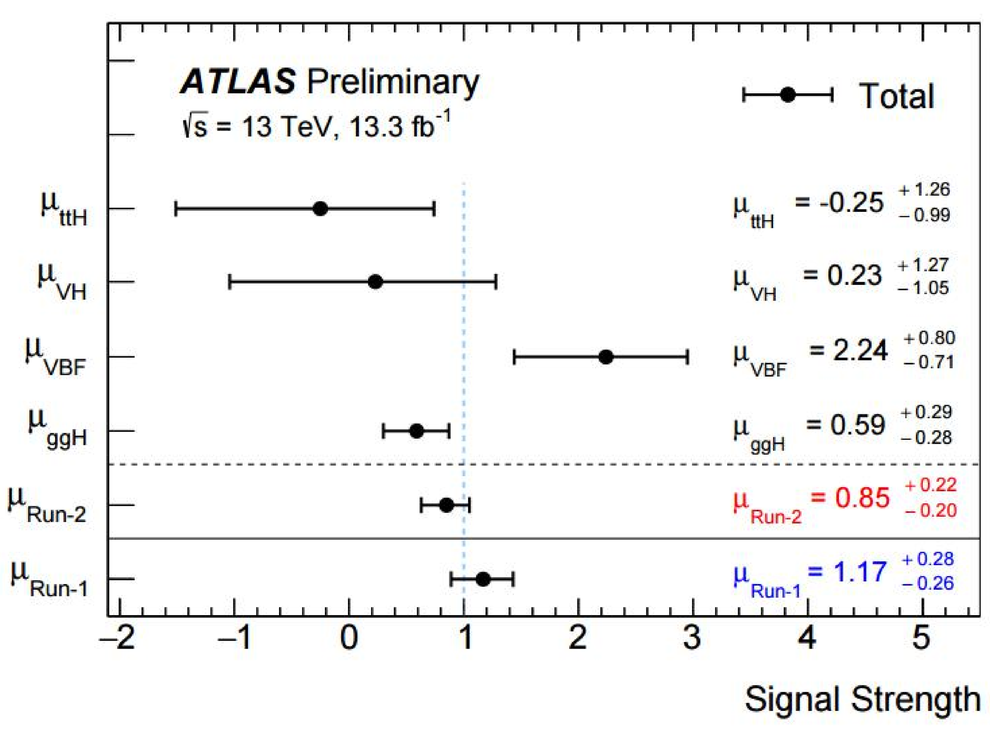
• Backgrounds are estimated with a combination of simulation and data-driven techniques, and a global fit to the yields in all final states is used to extract the best estimate for the ttH production rate.

Yields Table

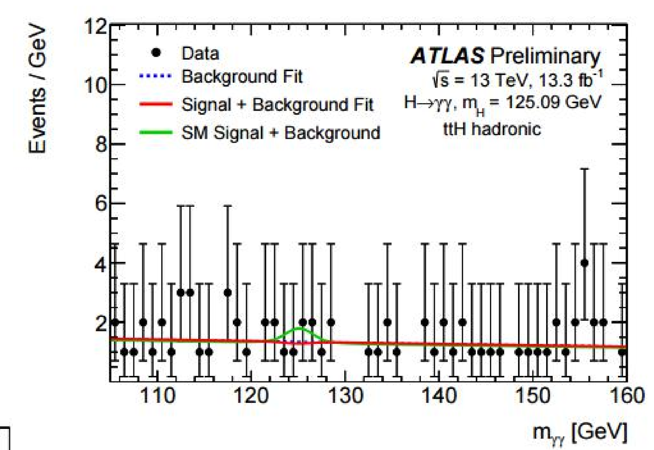
Channel	Region	$t\bar{t}H$ (S)	Bkgd (B)	$tHjb + WtH$	S/B	N_{Data}
$H \to \gamma\gamma$	all-hadronic	1.58	8.27	0.10	0.19	9
	leptonic	1.16	2.42	0.10	0.48	2
$H \to (WW, \tau\tau, ZZ)$	2ℓSS ee	1.99 ± 0.51	22.2 ± 3.4	0.10 ± 0.03	0.09	26
	2ℓSS $e\mu$	4.82 ± 0.95	38.5 ± 5.1	0.26 ± 0.07	0.13	59
	2ℓSS $\mu\mu$	2.85 ± 0.58	21.2 ± 3.8	0.15 ± 0.04	0.13	31
	2ℓSS $+\tau_{had}$	1.43 ± 0.31	5.7 ± 1.7	0.11 ± 0.03	0.25	14
	3ℓ	6.2 ± 1.1	38.9 ± 5.3	0.30 ± 0.08	0.16	46
	4ℓ	0.59 ± 0.10	1.42 ± 0.24	0.014 ± 0.006	0.42	0
$H \to b\bar{b}$	ℓ+jets (≥ 6j,3bj)	119 ± 16	11250 ± 240	6.2 ± 1.5	0.011	11561
	ℓ+jets (5j,≥ 4bj)	11.8 ± 2.6	429 ± 28	0.91 ± 0.14	0.028	418
	ℓ+jets (≥ 6j,≥ 4bj)	44.9 ± 9.4	1191 ± 55	2.10 ± 0.50	0.038	1285
	dilepton (≥ 4j,3bj)	20.6 ± 4.2	1423 ± 45	0.71 ± 0.20	0.014	1467
	dilepton (≥ 4j,≥ 4bj)	6.6 ± 2.0	133 ± 12	0.171 ± 0.053	0.050	154

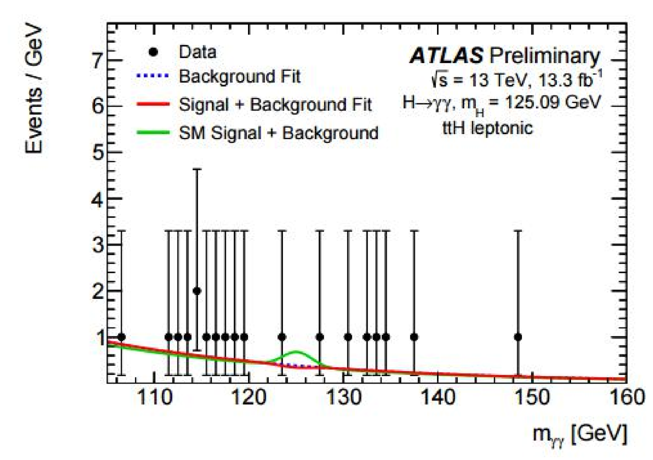
Summary of Analysis Stratege

	$H \to \gamma\gamma$		$H \to (WW, \tau\tau, ZZ)$				$H \to b\bar{b}$	
Analysis strategy	Narrow signal peak: fit to diphoton mass spectrum ($m_{\gamma\gamma}$)		Small signal and background: counting experiment				Moderate signal in large background: multivariate techniques	
Channels	leptonic	hadronic	2ℓSS	3ℓ	2ℓSS+$1\tau_{had}$	4ℓ	single lepton	dilepton
Control regions	-		-				(4j,2bj) (5j,2bj) (4j,3bj) (4j,4bj) (≥ 6j,2bj) (5j,3bj)	(3j,2bj) (4j,2bj)
Signal regions	$m_{\gamma\gamma}$		(ee) (eμ) ($\mu\mu$) AND (≥ 5j,≥ 1bj)	(3j,≥ 2bj OR ≥ 4j,≥ 1bj)	(≥ 4j,≥ 1bj)	(≥ 2j,≥ 1bj)	(5j,≥ 4bj) (≥ 6j,3bj) (≥ 6j,≥ 4bj)	(3j,3bj) (≥ 4j,3bj) (≥ 4j,≥ 4bj)



Results in ttH(γγ) Channel

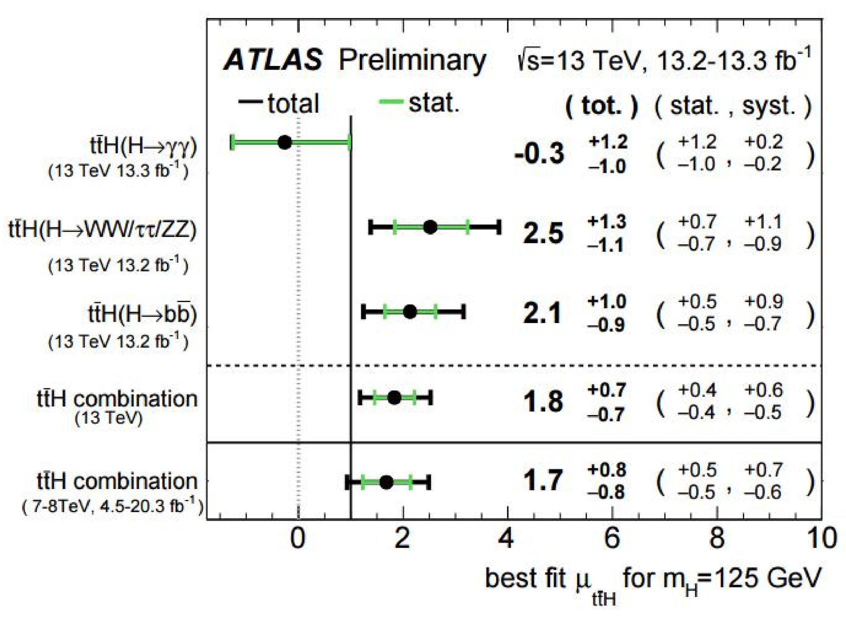


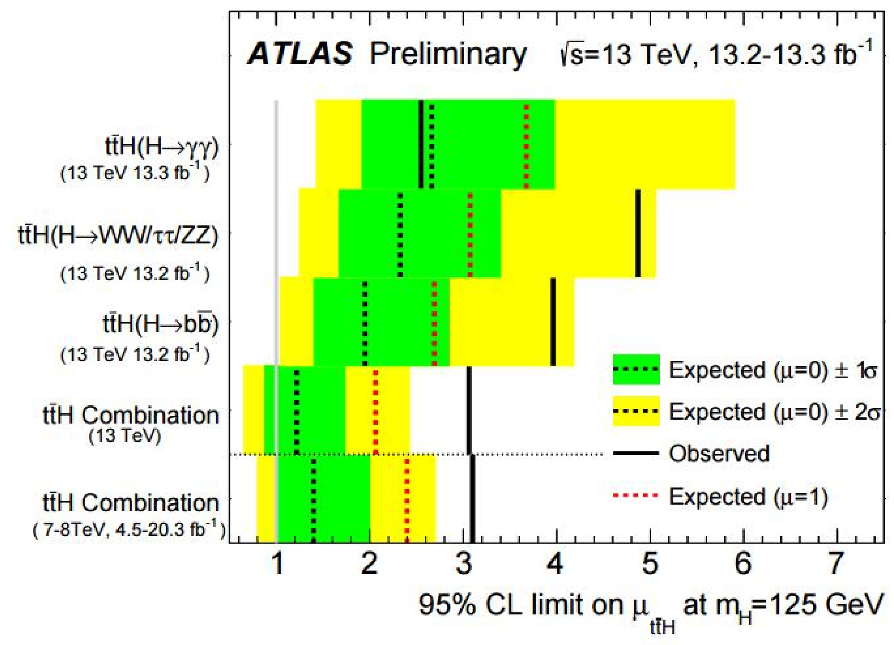


• The search in the ttH(γγ) channel exploits the excellent diphoton mass resolution to identify the H->γγ decay over the continuum background. The diphoton selection starts from the identification of two isolated photons, and two signal regions are formed according to the decay of the top quark pair. A leptonic selection requires at least one lepton with two jets, one of which should be identified as a b quark jet. A Z boson veto is applied based on the invariant mass of the diphoton system, as well as a loose requirement on missing transverse energy to enhance the top quark pair purity.

The hadronic selection requires that there are at least five jets with at least one b-tag. A fit to the diphoton mass spectrum in a wide range is used to extract simultaneously the signal and the redominant continuum background, which is assumed to have an exponenetial form.

Summary of Combined Results





Conclusion

• A combination of the ttH searches in the γγ, multilepton and $b\bar{b}$ decay channels has been performed using up to 13.3 fb⁻¹ of proton-proton collision data at √s=13TeV collected with the ATLAS detector at the LHC. The combined ttH signal strength is found to be $1.8^{+0.7}_{-0.7}$, which corresponds to an observed significance of 2.8 σ, where the expected value would be 1.8 σ in the presence of SM ttH. The sensitivity of this combination exceeds the Run-1 ttH expected significance of 1.5 σ. All three analyses are within 1.5 σ of the central value.