

Measurement of Higgs boson production in association with a top-quark pair in the di-photon decay channel using LHC data collected at $\sqrt{s} = 13$ TeV by the ATLAS experiment

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Introduction

- ▶ The coupling of the Higgs boson to the top quark is of particular importance as the top is the heaviest particle in the Standard Model.
- ▶ Indirect measurements of the top Yukawa coupling have been performed by probing gluon fusion production and diphoton decay loops.
- ▶ However, **Higgs production in association with a pair of top quarks ($t\bar{t}H$)** presents a **direct** tree-level test of the top Yukawa coupling.
- ▶ In ATLAS, $t\bar{t}H$ production is measured by targeting various Higgs decay channels, including $\gamma\gamma$, four-lepton, multi-lepton, and $b\bar{b}$.
- ▶ The $\gamma\gamma$ channel is currently the most sensitive.

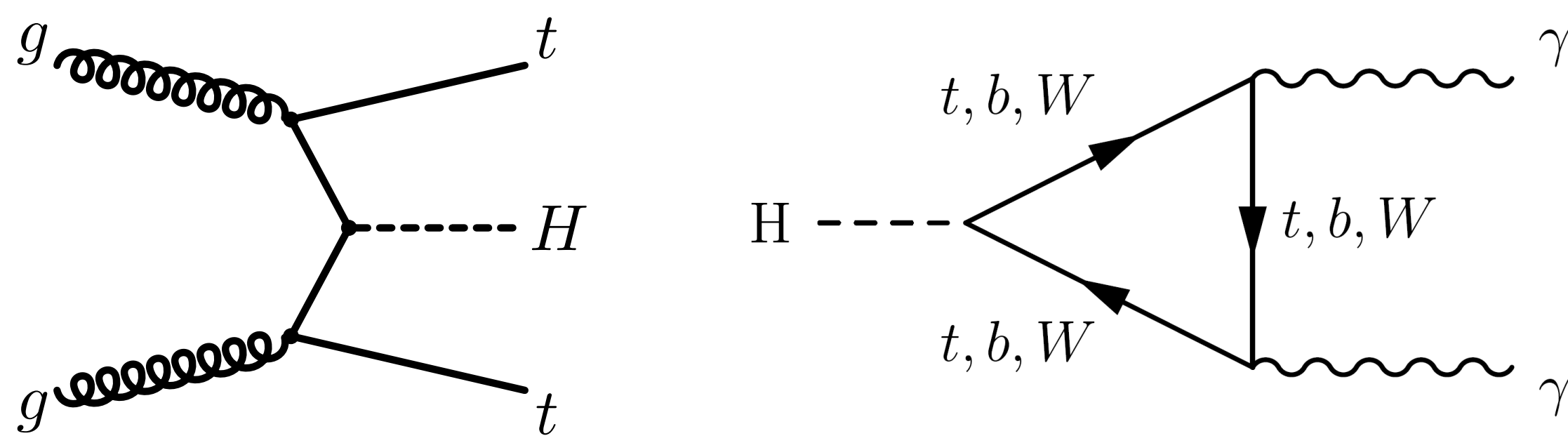


Figure 1: Representative diagrams for $t\bar{t}H$ production and $H \rightarrow \gamma\gamma$ decay.

- ▶ The most recent $t\bar{t}H(H \rightarrow \gamma\gamma)$ result is part of a larger measurement of Higgs properties in the $H \rightarrow \gamma\gamma$ channel including other production modes (ATLAS-CONF-2020-026).
- ▶ In this result, $t\bar{t}H$ production is measured in two ways.
 - ▶ Measurement of ggH , VBF , WH , ZH , and $t\bar{t}H + tH$ cross-sections.
 - ▶ Measurements of STXS (Simplified Template Cross Section) regions, in which Higgs production is partitioned by production process and kinematic and event properties.

Analysis Strategy

- ▶ Events with two photons are selected.
- ▶ A multi-class BDT creates various categories sensitive to particular STXS regions.
- ▶ A second binary BDT then rejects non-resonant background in each category.
- ▶ In the $t\bar{t}H$ sensitive categories, the main non-Higgs backgrounds include non-resonant $\gamma\gamma$ events with heavy flavor and $t\bar{t}\gamma\gamma$ production.
- ▶ Training variables include kinematic variables related to the photons, jets, and leptons.
- ▶ In particular, one training variable is a top reconstruction score indicating whether the event contains top quarks.

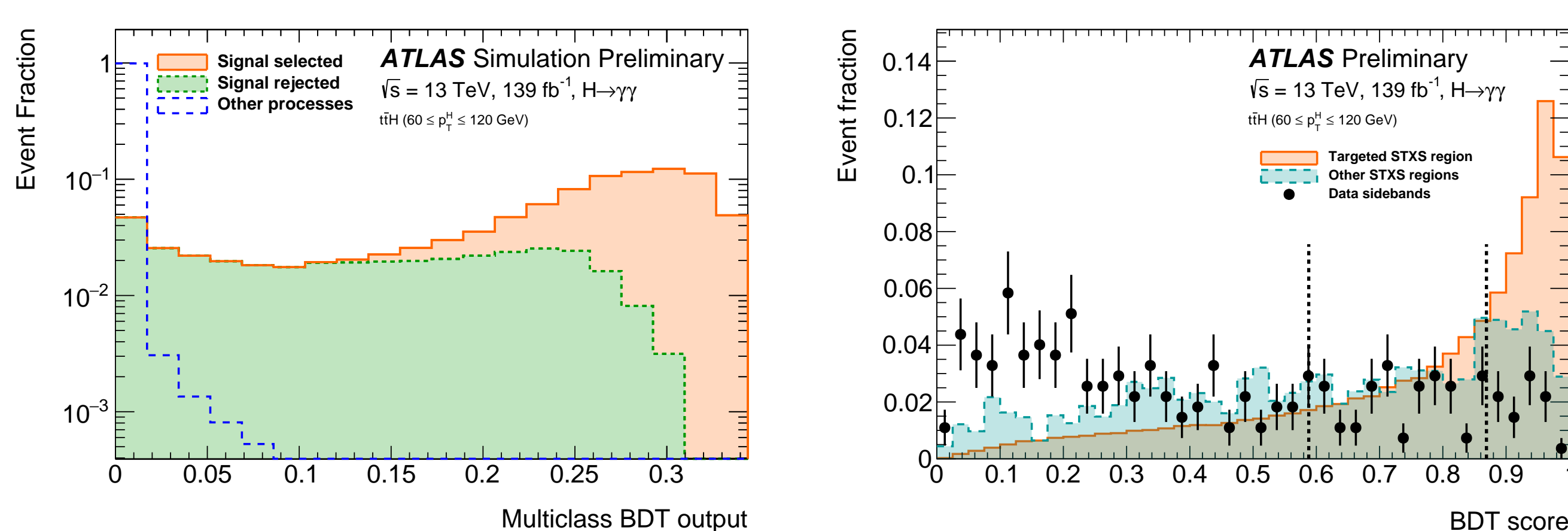


Figure 2: The multi-class (left) and binary (right) BDT discriminants for a representative $t\bar{t}H$ STXS category

- ▶ There are both $t\bar{t}H$ and tH dedicated categories. $t\bar{t}H$ STXS bins are separated by p_T^H as this can be sensitive to modifications to $t\bar{t}H$ CP or the Higgs self coupling.

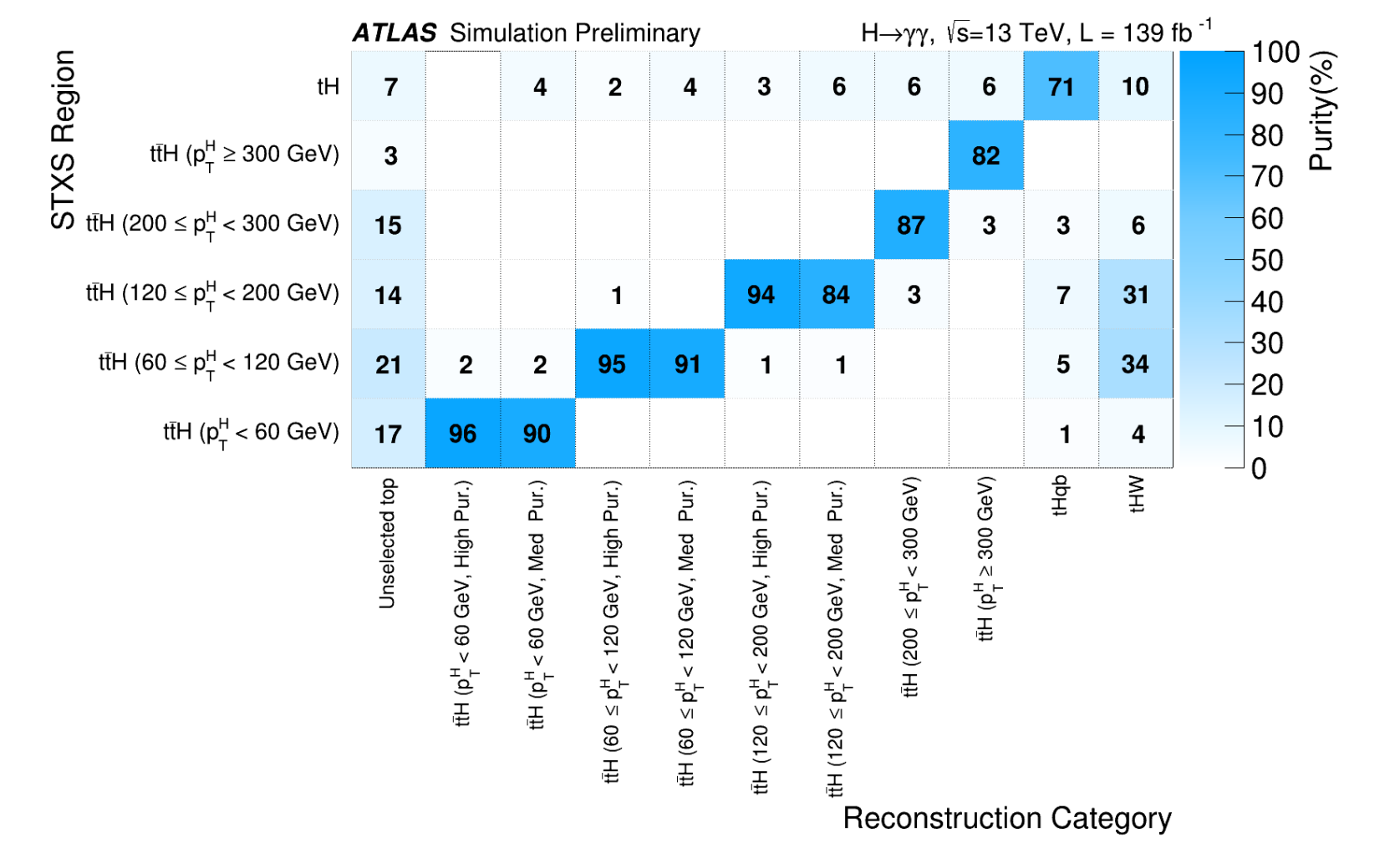


Figure 3: The contribution of various STXS regions to the top-sensitive reconstruction categories.

Statistical Results

- ▶ Higgs production cross sections are obtained from a simultaneous fit to the diphoton mass spectrum $m_{\gamma\gamma}$ across all categories.

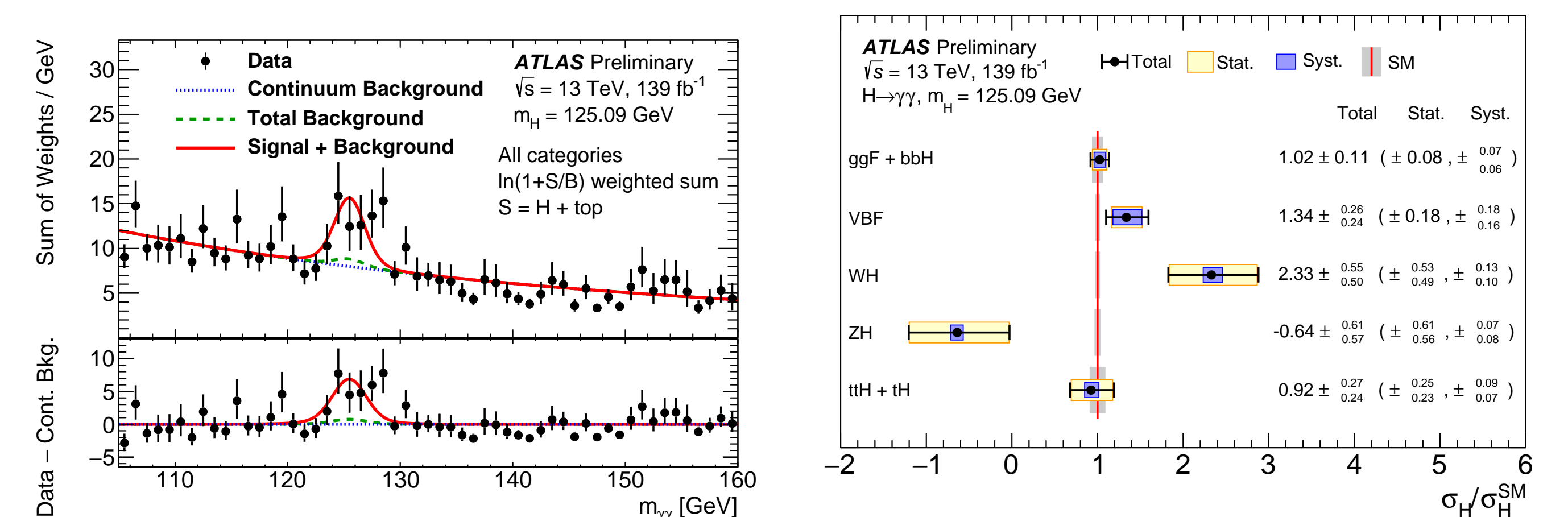


Figure 4: The diphoton mass spectrum of all categories, weighted by $\ln(1+S/B)$ of each category, where $S = t\bar{t}H + tH$ (left), and the result of the 5 cross section measurement (right)

- ▶ In the 5 cross section measurement, the observed (expected) $t\bar{t}H + tH$ significance is 4.7σ (5.0σ). The $t\bar{t}H + tH$ cross section times branching ratio is compatible with the Standard Model.
- ▶ $t\bar{t}H$ and tH STXS bins are probed as part of the STXS measurement. This is one of the first differential measurements of the $t\bar{t}H$ process. The tH limit is much improved with respect to previous ATLAS results.

STXS region ($\sigma_i \times \mathcal{B}_{\gamma\gamma}$)	Observed [fb]	SM prediction [fb]
$t\bar{t}H$ $p_T^H \in [0, 60]$ GeV	$0.2^{+0.2}_{-0.2}$	0.27 ± 0.04
$t\bar{t}H$ $p_T^H \in [60, 120]$ GeV	$0.3^{+0.2}_{-0.2}$	$0.40^{+0.05}_{-0.04}$
$t\bar{t}H$ $p_T^H \in [120, 200]$ GeV	$0.3^{+0.2}_{-0.2}$	0.29 ± 0.03
$t\bar{t}H$ $p_T^H \in [200, \infty]$ GeV	$0.2^{+0.09}_{-0.08}$	0.18 ± 0.02
tH	$0.2^{+0.6}_{-0.5}$	$0.19^{+0.01}_{-0.02}$

Summary

- ▶ $t\bar{t}H$ production in the diphoton decay channel has been measured and observed by ATLAS with 139fb^{-1} , to directly probe the Higgs boson Yukawa coupling to the top quark
- ▶ Measurements of inclusive $t\bar{t}H$ production and in bins of p_T^H show no significant deviations from the Standard Model.