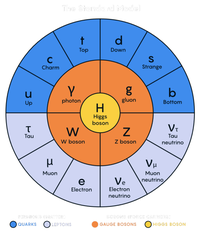
Search for Di-Higgs Decaying to bb$\gamma\gamma$ with the ATLAS Detector

ATLAS-CONF-2021-016, Jannicke Pearkes, jpearkes@slac.stanford.edu



The Higgs

In 2012, the ATLAS and CMS experiments at the Large Hadron Collider (LHC) announced the discovery of a particle consistent with the Standard Model (SM) Higgs boson. The Higgs boson completes the Standard Model of Particle Physics. However, the shape of the Higgs potential has yet to be measured.

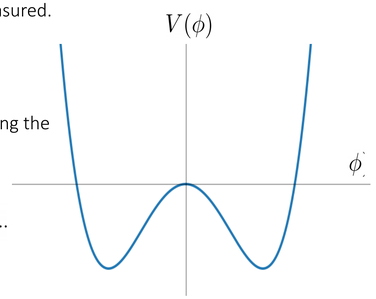
The Higgs Potential

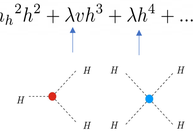
We can probe the Higgs potential by measuring the Higgs self-coupling (λ).

$$V(\phi) = -\mu^2\phi^2 + \lambda\phi^4$$

$$V(\nu + h) = V_0 + \frac{1}{2}m_h{}^2h^2 + \lambda v h^3 + \lambda h^4 + \ldots$$

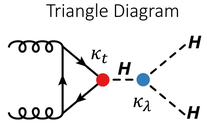
$$\kappa_\lambda = \frac{\lambda_{\text{measured}}}{\lambda_{\text{SM}}}$$



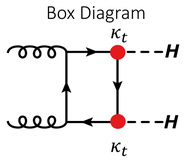


Main HH Production Modes

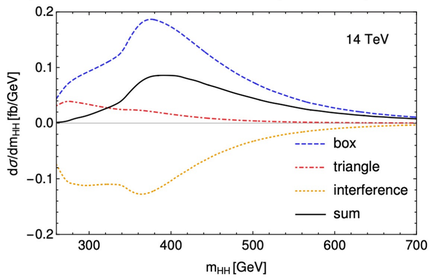
Triangle Diagram



Box Diagram

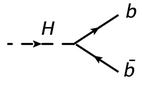


Large interference between leading order diagrams



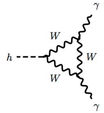
HH Decay Channels

Higgs to bb has a high branching ratio, but also a high background



H_2 \ H_1	bb	WW	ττ	ZZ	γγ
bb	33%				
WW	25%	4.6%			
ττ	7.4%	2.5%	0.39%		
ZZ	3.1%	1.2%	0.34%	0.076%	
γγ	0.26%	0.10%	0.029%	0.013%	0.0005%

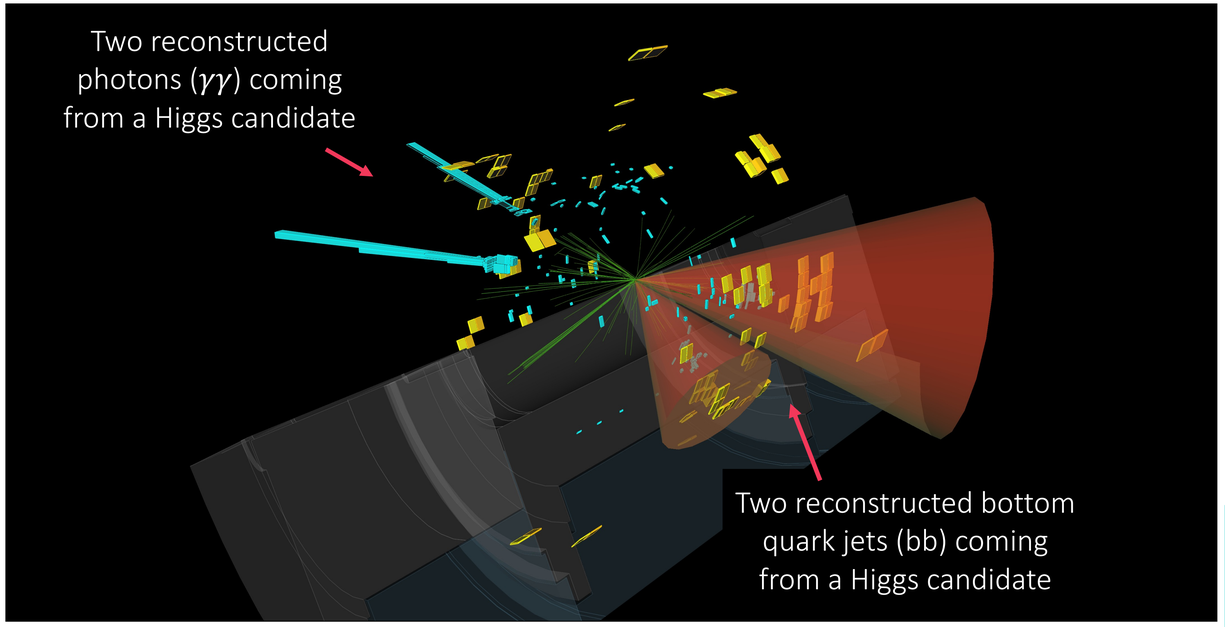
Higgs to $\gamma\gamma$ has a low branching ratio, but a very low background



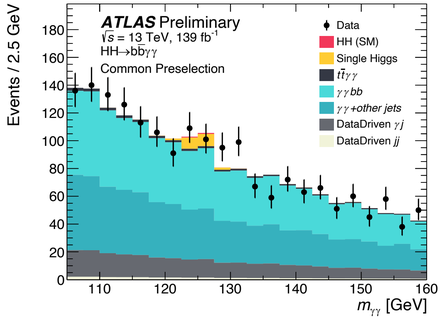
The bb$\gamma\gamma$ Search

The bb$\gamma\gamma$ channel is one of the most sensitive HH final states for measuring the Higgs self-coupling and di-Higgs production cross-section. This analysis capitalizes on the clean signature of the two photons in the final state combined with the high branching ratio of H(bb). We use a multivariate approach to target high and low HH mass regions to maximize the sensitivity to modifications of the Higgs self-coupling. Our analysis provides the strongest observed limits on the self-coupling and HH cross-section to date.

A Candidate Di-Higgs Event



Signal and Backgrounds

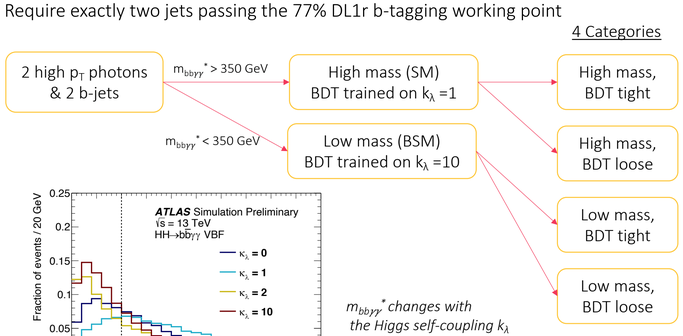


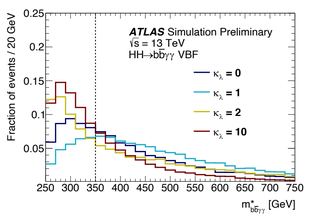
s/b in signal region after initial selection is = 0.6%

Event Selection

Trigger on photons and require : $p_{T,\gamma 1} / m_{\gamma\gamma} > 0.35$, $p_{T,\gamma 2} / m_{\gamma\gamma} > 0.25$

Require exactly two jets passing the 77% DL1r b-tagging working point



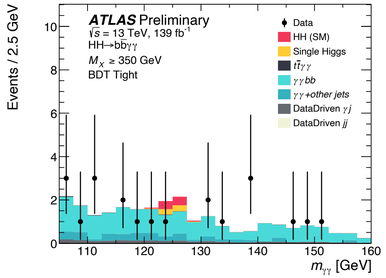


$m_{bb\gamma\gamma}^*$ changes with the Higgs self-coupling k_λ

$m_{bb\gamma\gamma}^* = m_{b\gamma\gamma} - m_{bb} - m_{\gamma\gamma} + 250$ GeV

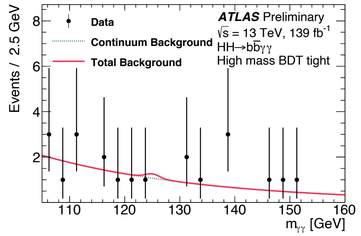
Post-Selection Data/MC

s/b in signal region after high mass BDT tight selection is = 25%



Signal Extraction

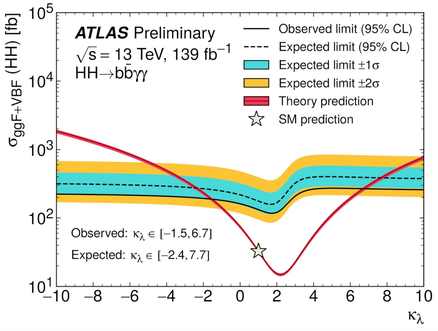
Use $m_{\gamma\gamma}$ as final discriminant.
Signal model: Double-Sided Crystal Ball
Background model: Exponential function



HH signal strength determined through maximum likelihood fit on $m_{\gamma\gamma}$ across all four categories

Results

95% CL limit on SM signal strength is 4.1xSM observed (5.5xSM expected).
Best limit on HH production to date.
Observed limits on k_λ : $-1.5 < k_\lambda < 6.7$



ATLAS EXPERIMENT

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