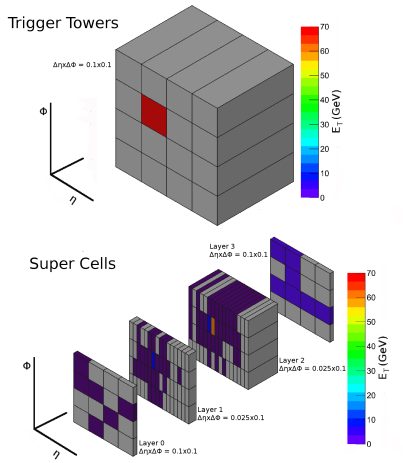
Search For Double Higgs Production in the $b\bar{b}WW^*$ Channel

John C.S. Myers

University of Oregon

May 19, 2019

About Me

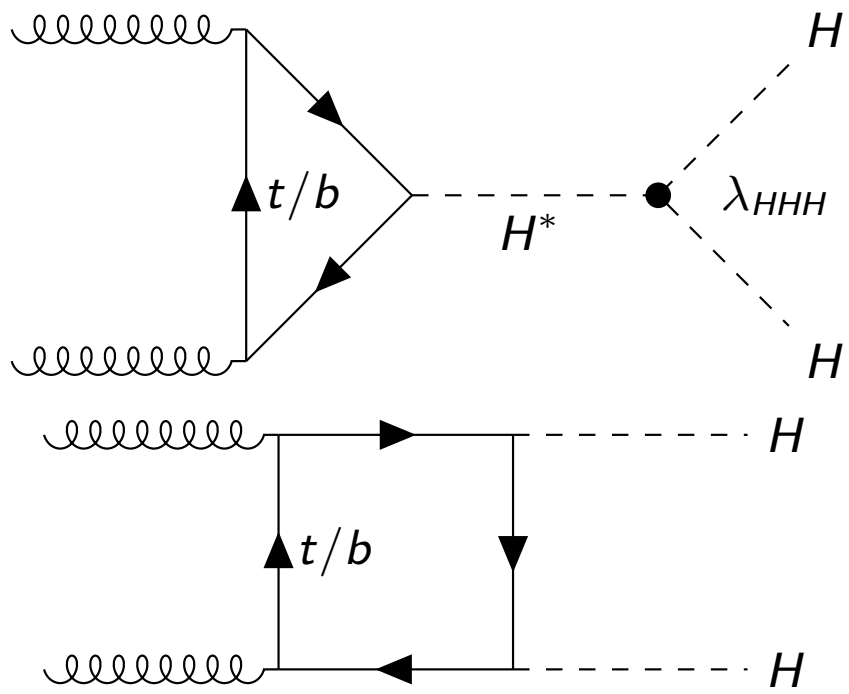


- B.Sc. at Ohio State University, 2013
  - Worked with Harris Kagan and KK. Gan on accelerated lifetime testing for IBL optical readouts
- Began work at UO with Stephanie Majewski in 2013
  - Worked on LAr Phase-II Upgrade TDR
- Began working with Eric Torrence in 2015 on τ trigger upgrade studies Qualification task
- Started work on full Run 2 Boosted $HH \to b\bar{b}WW^*$ analysis
  - 2015-2016 analysis needed manpower to move toward publication
- Started working as HLT Reprocessing Expert in 2017
  - Moved to Coordinator within 9 months
- Served as Trigger Online On-call during 2018

Motivation

SM di-Higgs production

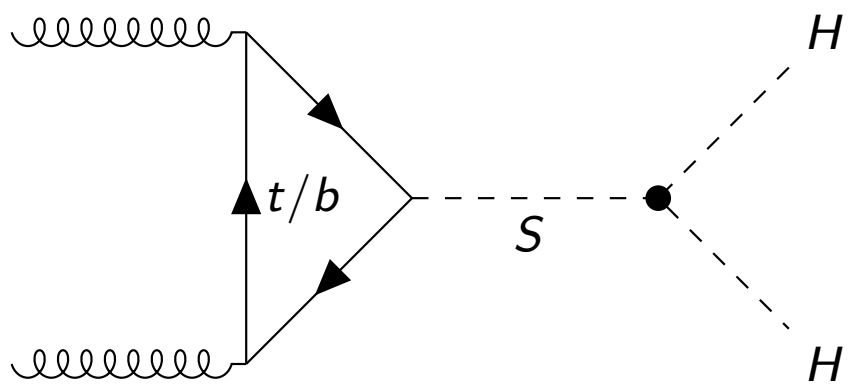
- Two dominant production modes
- Destructively interfere
- Gives very small cross section
- Measurement of trilinear Higgs coupling is an important measurement for the HL-LHC



Motivation

Resonant di-Higgs production

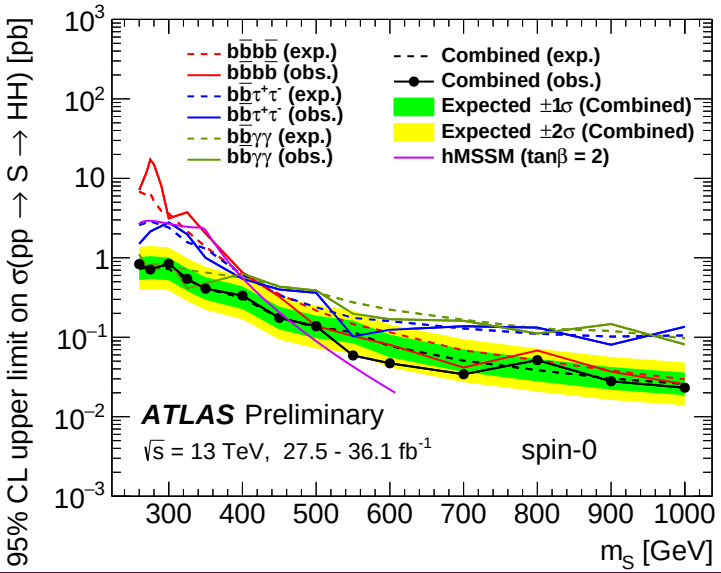
- Run 2, more interesting to perform search for BSM productionEg: Heavy Higgs-like Scalar
  - Couples to SM Higgs
  - Large enhancement to HH production rate
- This was the original focus of my thesis



$b\bar{b}WW^*$ semi-leptonic channel

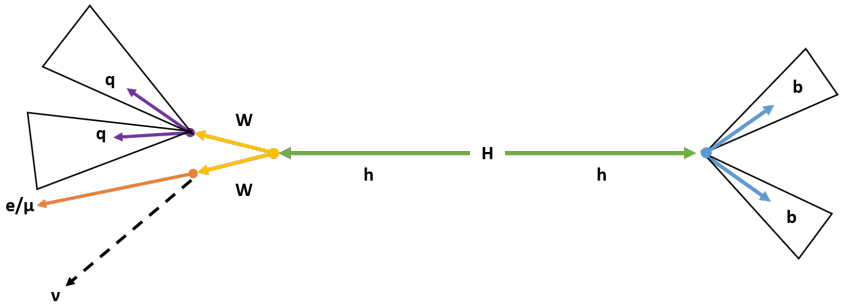
- Lower QCD background but more $t\bar{t}$ than 4b
- Lepton is strong discriminate for QCD but decay contains neutrino
- This search is not currently competitive for SM measurement
- Could be competitive at large resonant mass

	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%



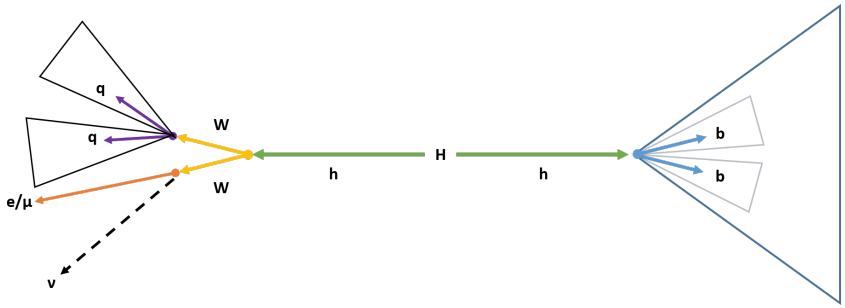
$HH \rightarrow b\bar{b}WW$ Analysis Strategy

Resolved Analysis



- SM production is not very boosted
- A resolved topology is used for a SM, non-resonant measurement and a low mass resonance search

Boosted Analysis



- As the resonant mass increases, the system becomes more boosted
- Boosted analysis focuses on high resonant masses (1-3 TeV)

Data and Background

Final State

- $b\bar{b}l\nu qq$

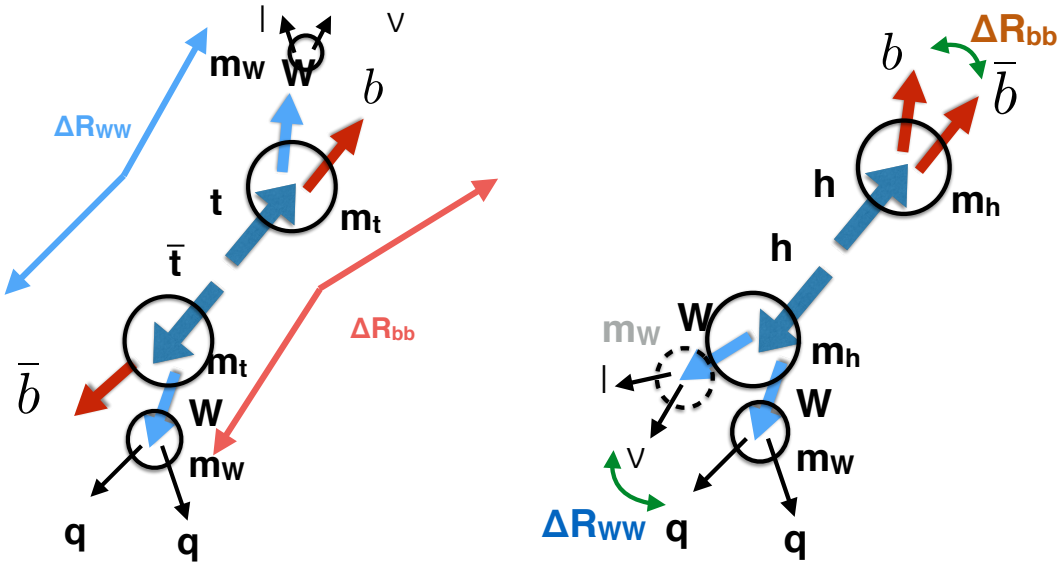
Data

- 36.1 fb^{-1}

Major Backgrounds

- $t\bar{t}$ ($\sim$ 50%)
- W+Jets ($\sim$ 20% ($\sim$ 5% Res.))
- QCD Multi-jet ($\sim$ 20%)
  - (from data)

$t\bar{t}$ vs signal



Resolved Event Selection

Pre-selection

- 1+ trigger matched electron or muon
- 4+ jets, exactly 2 b-tags

Event Selection

- $\not{E_T}$
- high p_T^{WW} and p_T^{bb}
- $m_{bb} \sim m_H$
- m_{HH} window
  - Depends on resonant signal mass hypothesis
  - I helped develop an implement these windows

Resolved Background Determination

$t\bar{t}$

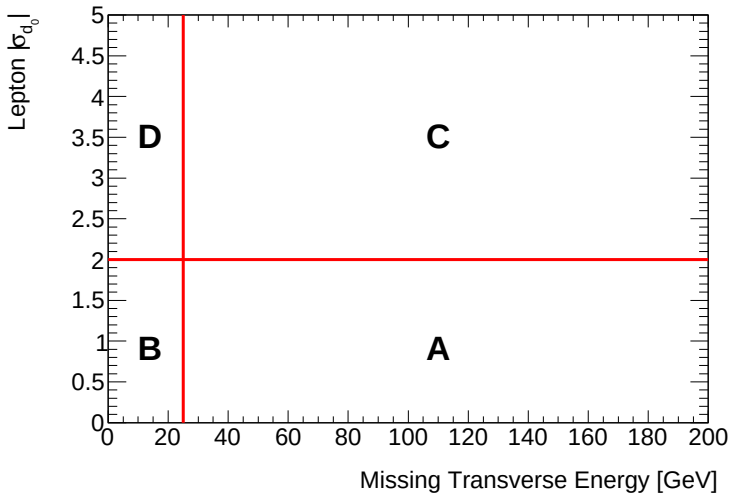
- Normalized in m_{bb} CRs
  - reversed m_{bb} cut

Other MC Bkg.

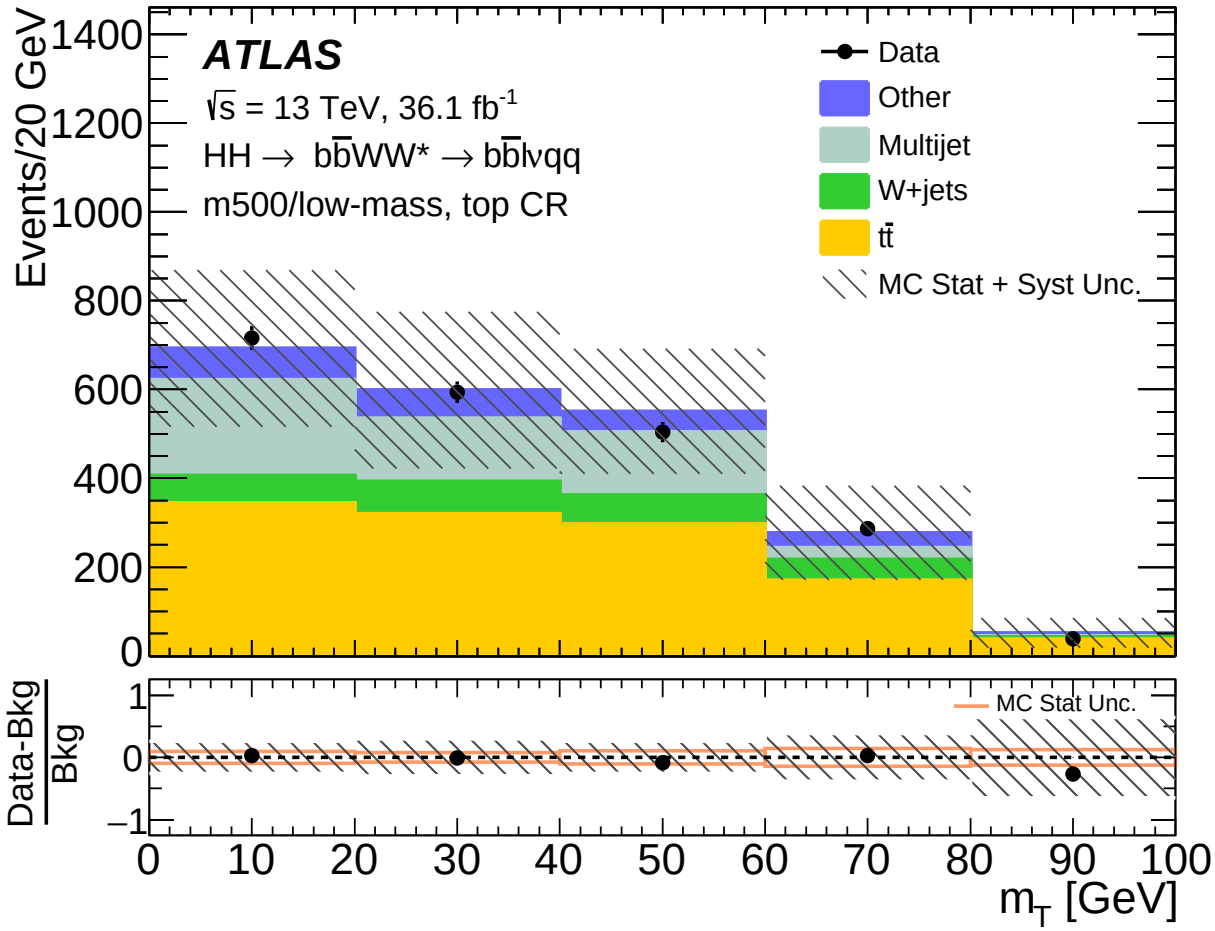
- Modeled using MC and normilized to SM XSec

QCD multi-jet background

- ABCD data driven estimate
  - $N_A = F N_C N_B / N_D$
  - F is a correction factor determined earlier in the cutflow
  - I developed the correction factor to overcome low stats in C region



Resolved Background Shape Check



$$m_T = \sqrt{2 p_T^l \not{E}_T \times (1 - \cos\Delta\phi)}$$

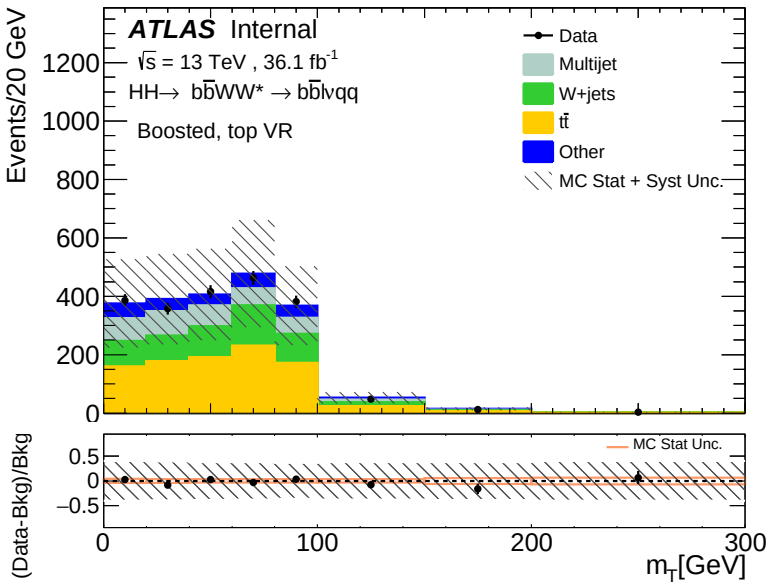
Boosted Analysis

Signal Region

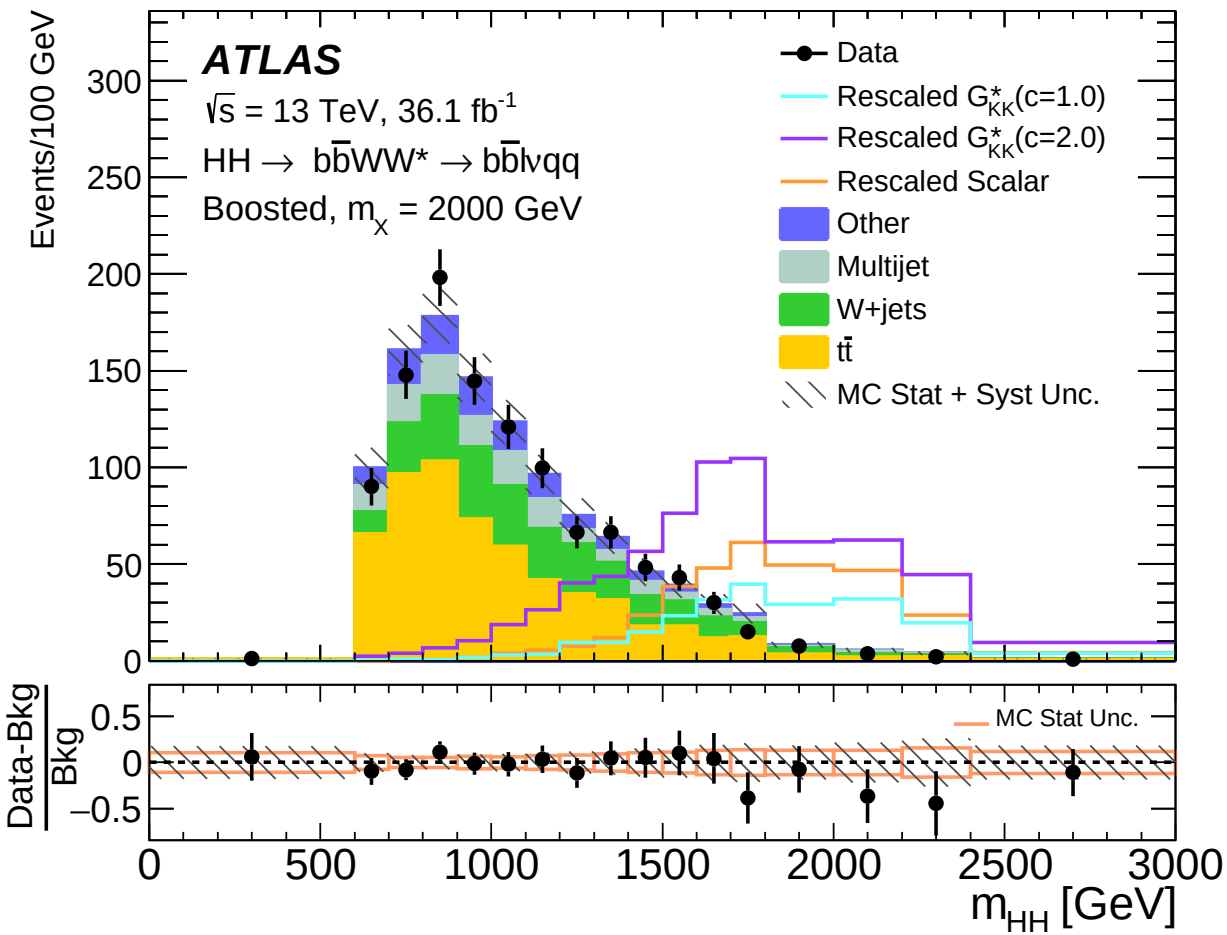
- slightly larger $\not{E_T}$ cut
- $m_{\mathrm{Large-R}} \sim m_H$

Background Modeling

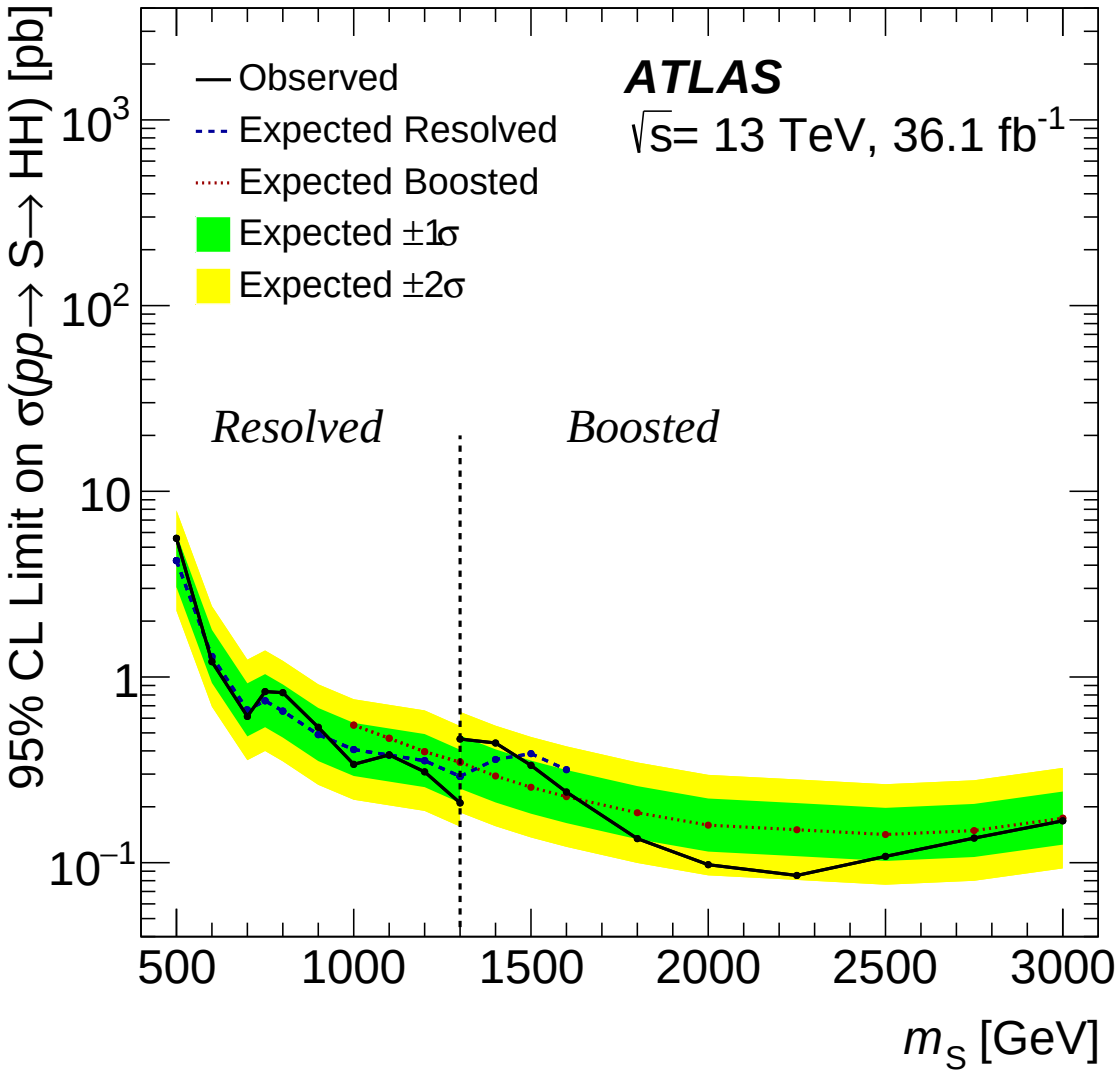
- $t\bar{t}$ VR
- Other MC Bkg: Normalized to SM XSec
- Multijet: Similar to resolved
  - $\not{E_T} > 50$ GeV
  - m_{HH} dist, taken from 1 b-tag selection



Results


ATLAS
√s = 13 TeV, 36.1 fb-1
HH → bb̄WW* → bb̄lνqq
Boosted, mX = 2000 GeV
Data
Rescaled G*KK(c=1.0)
Rescaled G*KK(c=2.0)
Rescaled Scalar
Other
Multijet
W+jets
tt̄
MC Stat + Syst Unc.
Events/100 GeV
Data-Bkg / Bkg
MC Stat Unc.
mHH [GeV]

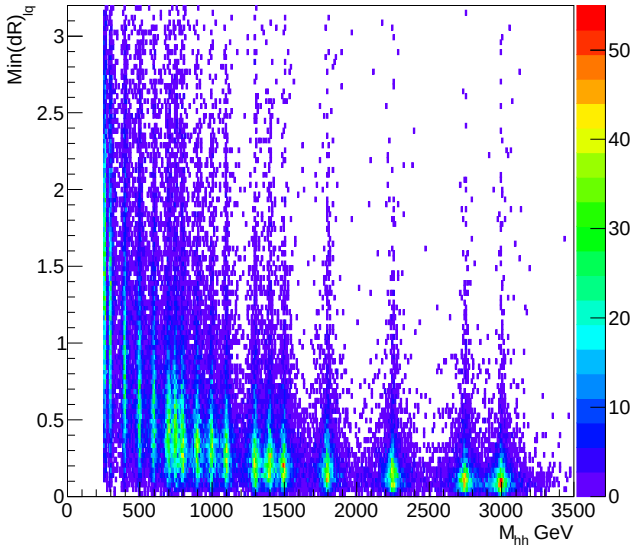
Combined Limit



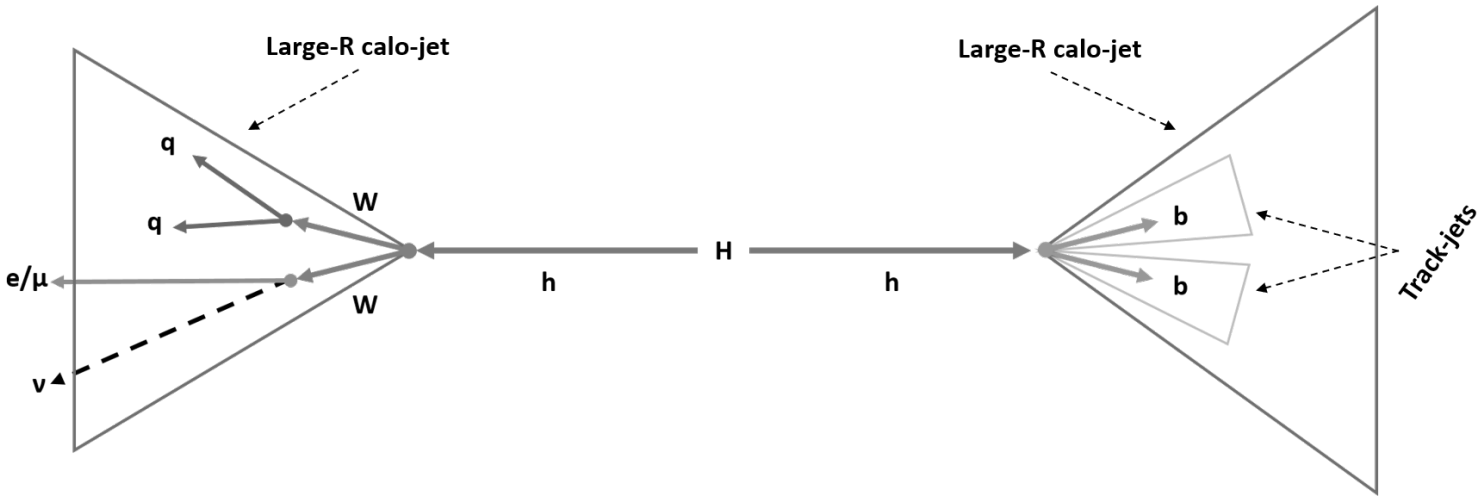
Improvements for Full Run II

Motivation

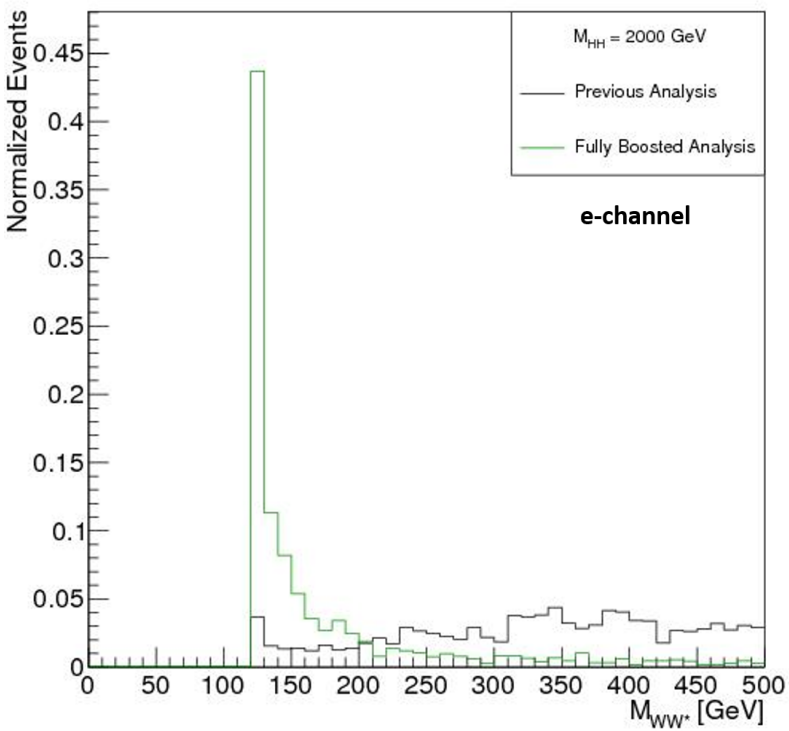
- $H \rightarrow WW$ becomes boosted around 1 TeV
- Quarks become too close together to use 0.4 jets
- Overlap removal with leptons kill efficiency
- A "Fully-Boosted" selection recovers lost efficiency at high m_S

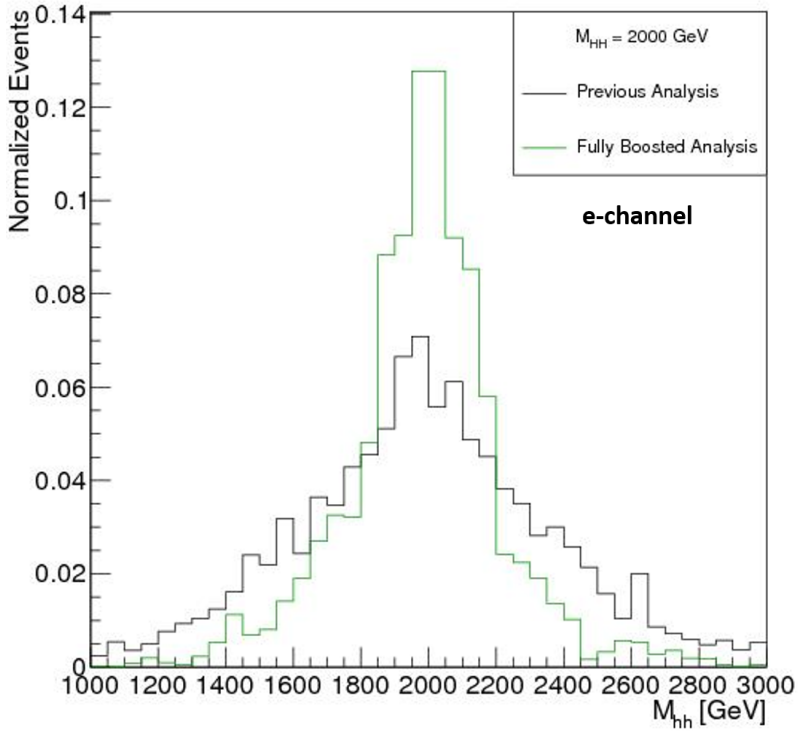


Event Selection



Signal Reconstruction



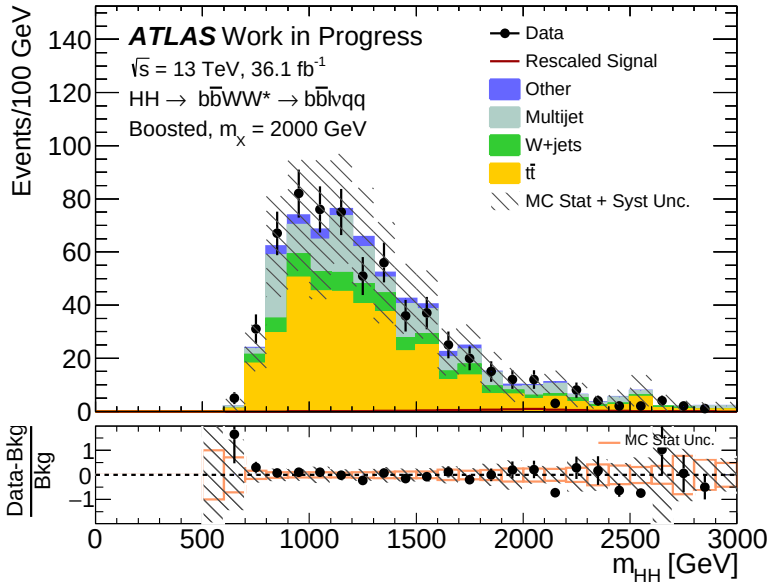


Background Modeling

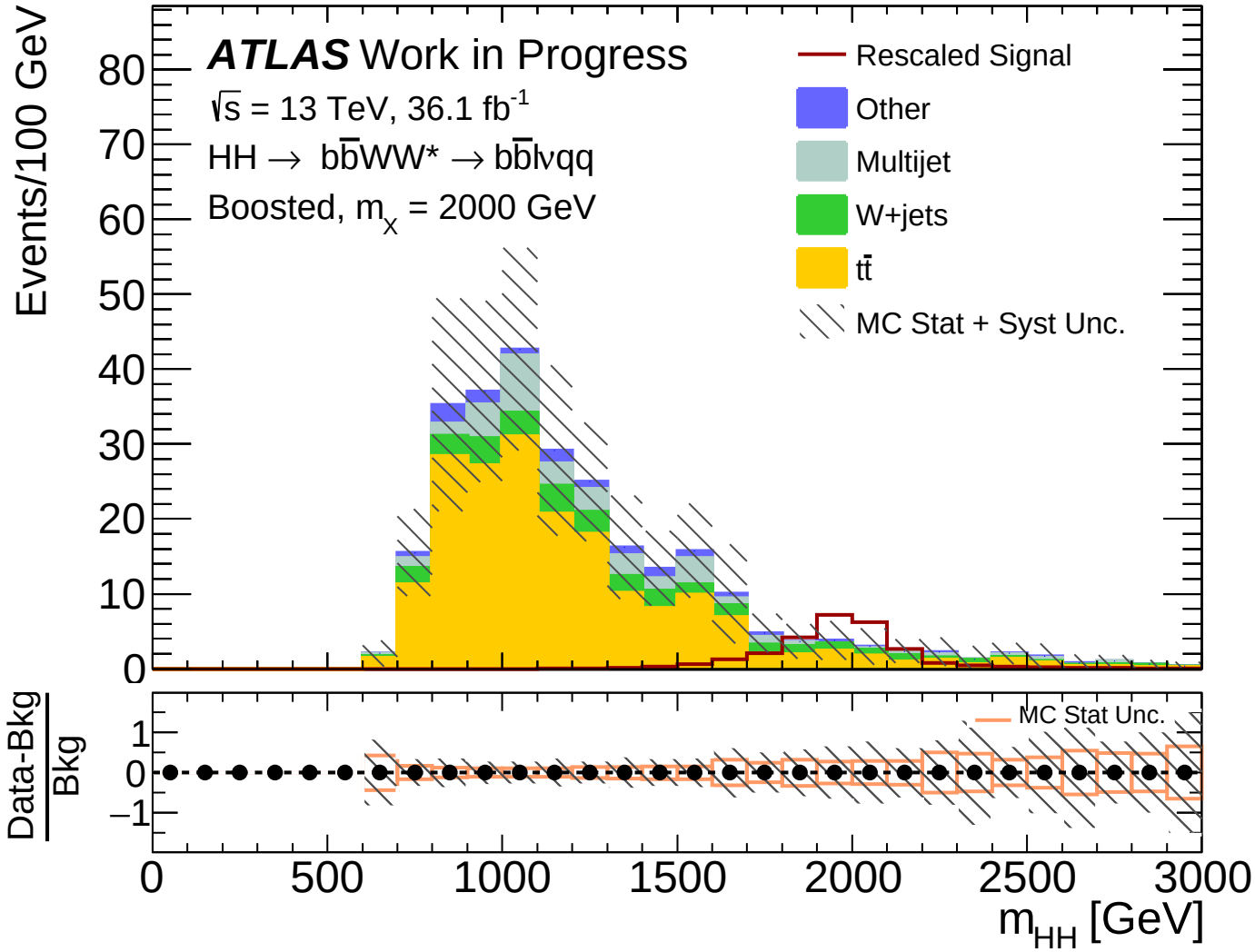
Similar to Boosted Analysis

- $t\bar{t}$ checked in m_{bb} VR
- QCD multijet: ABCD method
- Other: Norm to SM XSec

Sample	Yield	Stats Unc
$t\bar{t}$	187.7	$\pm$ 8.8
W+Jets	33.7	$\pm$ 1.9
QCD	34.5	$\pm$ 5.5
Single-top	7.0	$\pm$ 1.3
Z+Jets	4.7	$\pm$ 0.4
Dibosons	3.3	$\pm$ 0.6
Prediction	271.0	$\pm$ 10.7
Data	268	-
Data/Pred	0.99	-

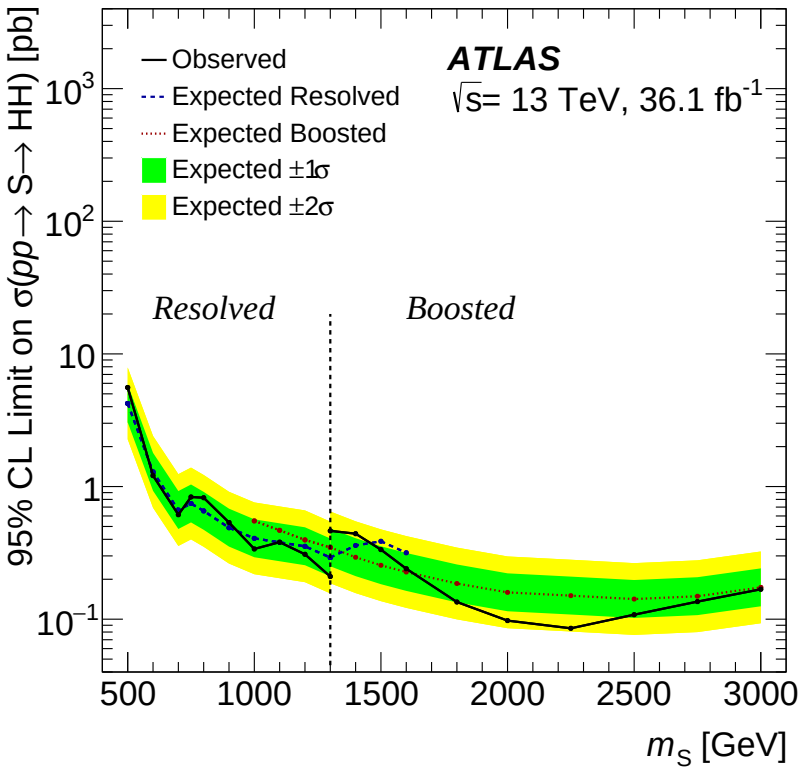


Results

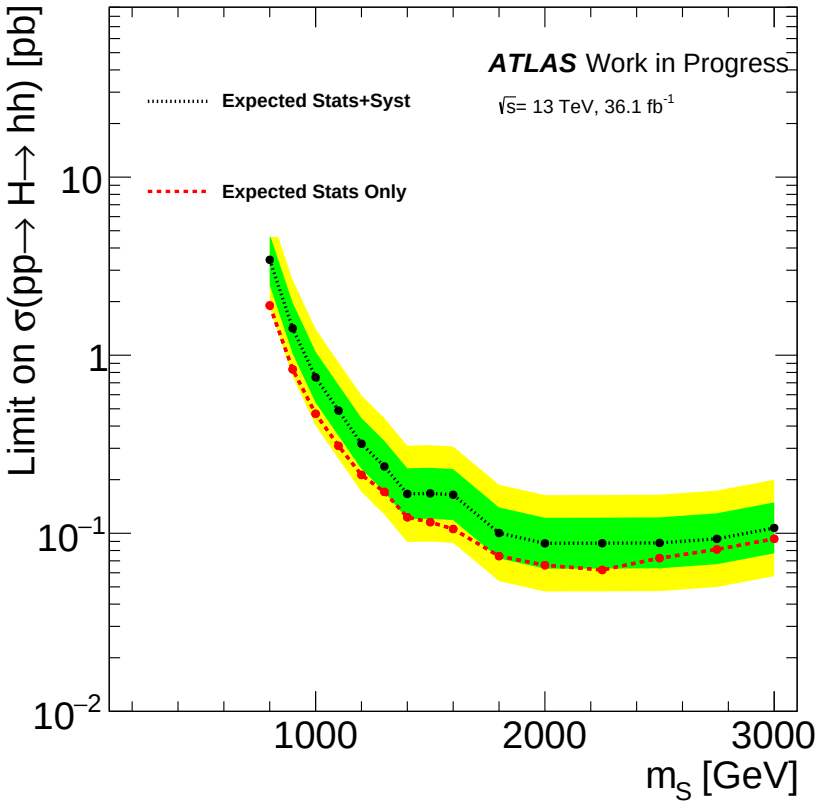

ATLAS Work in Progress
√s = 13 TeV, 36.1 fb-1
HH → bb̄WW* → bb̄lνqq
Boosted, mX = 2000 GeV
Rescaled Signal
Other
Multijet
W+jets
tt̄
MC Stat + Syst Unc.
Events/100 GeV
Data-Bkg / Bkg
MC Stat Unc.
mHH [GeV]

Results

Published Analysis



Improved Analysis



Backup