Exotic searches with boosted *H* bosons

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on behalf of the
ATLAS Collaboration

BOOST 2016

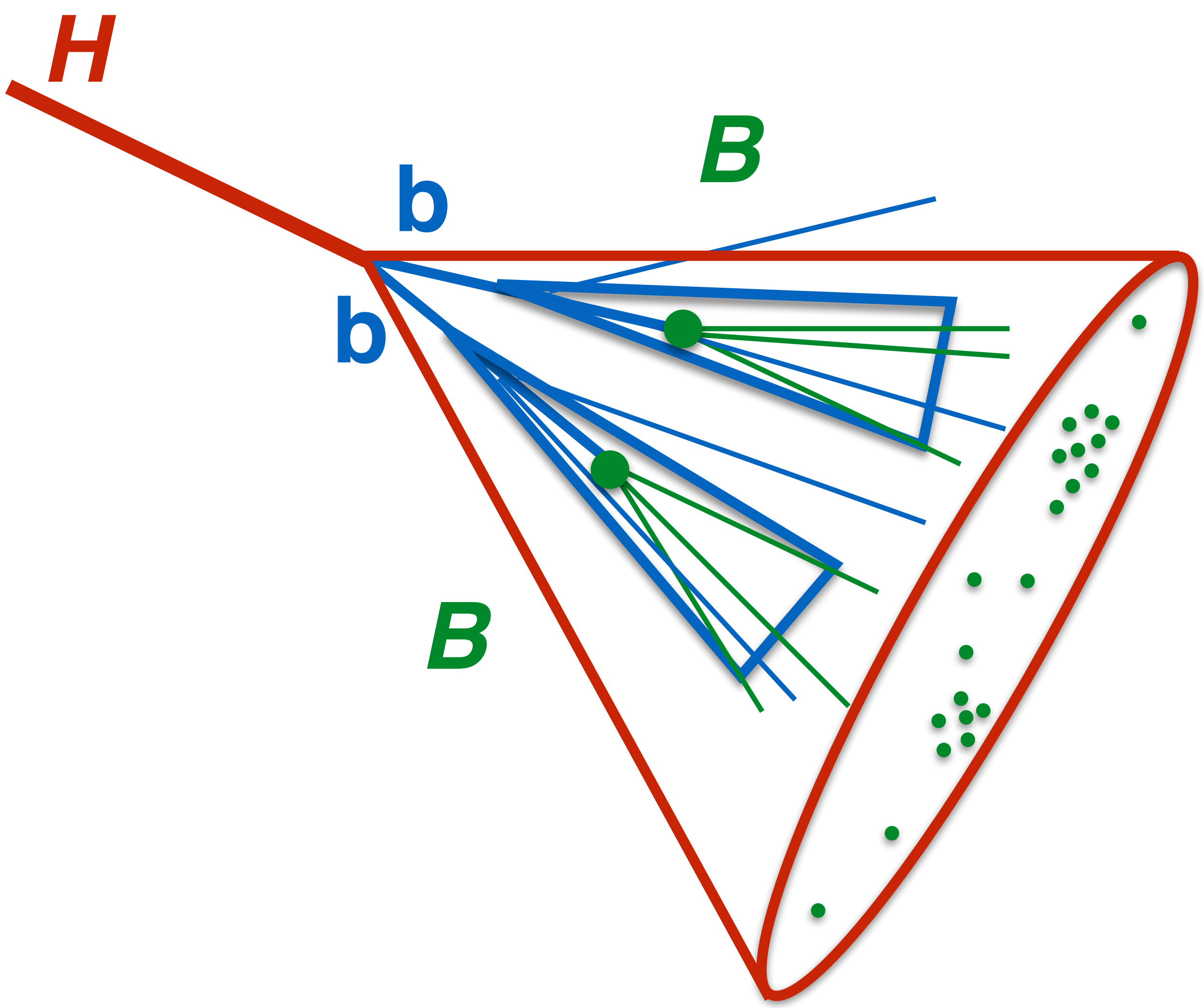
Motivation

"The Higgs boson could be the gateway to BSM physics…"

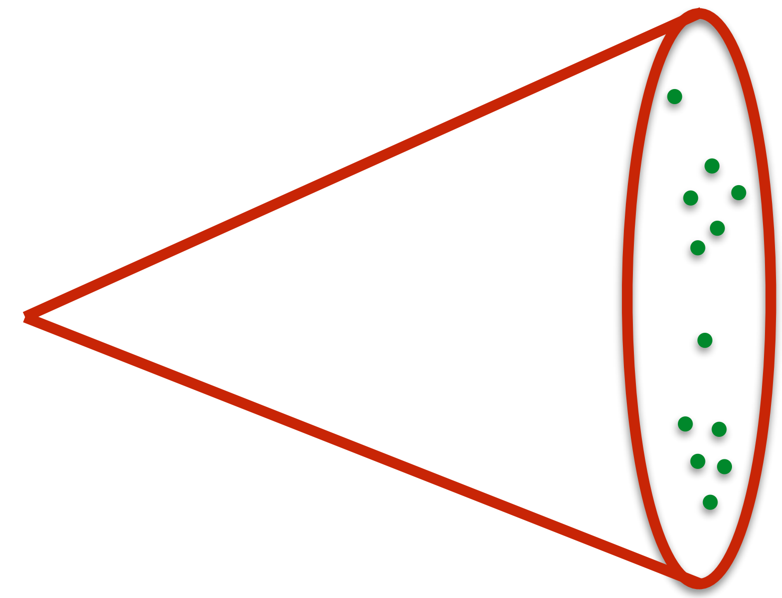
Many models predict new physics resulting in final state *H* bosons.

In this talk:
Dark Matter, RS Graviton, new heavy vector triplets

Boosted $H \rightarrow bb$ tagging: signal

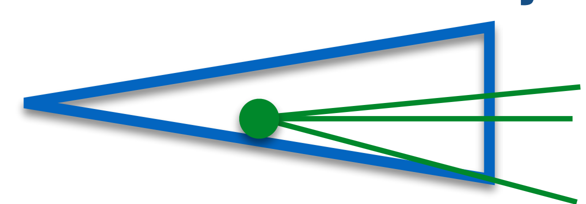


anti-k_t $R = 1.0$ calorimeter jet



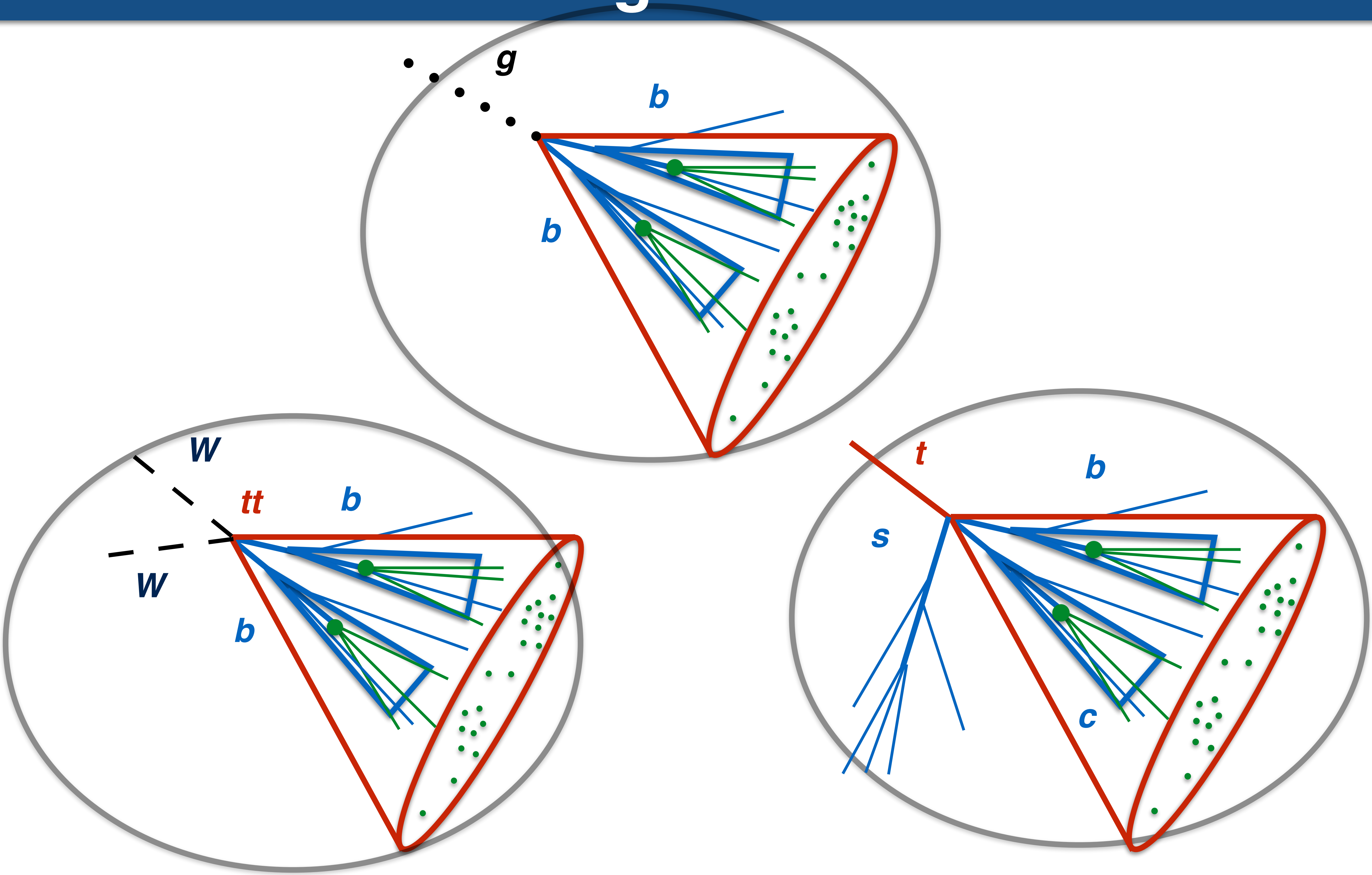
substructure

ghost-associated
anti-k_t $R = 0.2$ track jet



b-tagging

Boosted *H*→*bb* tagging: backgrounds



Boosted $H \rightarrow bb$ tagging: working points

Three primary working points defined

	Loose	Medium	Tight
efficiency	0.41 ±0.07	0.32 ±0.06	0.25 ±0.05
Multi-jet rejection			
Inclusive	260 ±50	460 ±90	800 ±210
Light-flavor	$\mathcal{O}(10^5)$	$\mathcal{O}(10^5)$	$\mathcal{O}(10^6)$
cl	$\mathcal{O}(10^3)$	$\mathcal{O}(10^3)$	$\mathcal{O}(10^4)$
bl	$\mathcal{O}(10^2)$	$\mathcal{O}(10^2)$	$\mathcal{O}(10^3)$
bc	$\mathcal{O}(10)$	$\mathcal{O}(10)$	$\mathcal{O}(10^2)$
cc	250 ±150	480 ±310	1200 ±900
bb	11 ±2	19 ±4	31 ±9
Hadronic top rejection			
Inclusive	67 ±17	110 ±30	160 ±50
bl	360 ±230	660 ±460	810 ±600
bc	24 ±6	39 ±11	53 ±16

- ~70% *b*-tagging efficiency per *b*-jet
- 90% efficient jet mass cut
- no further substructure requirements

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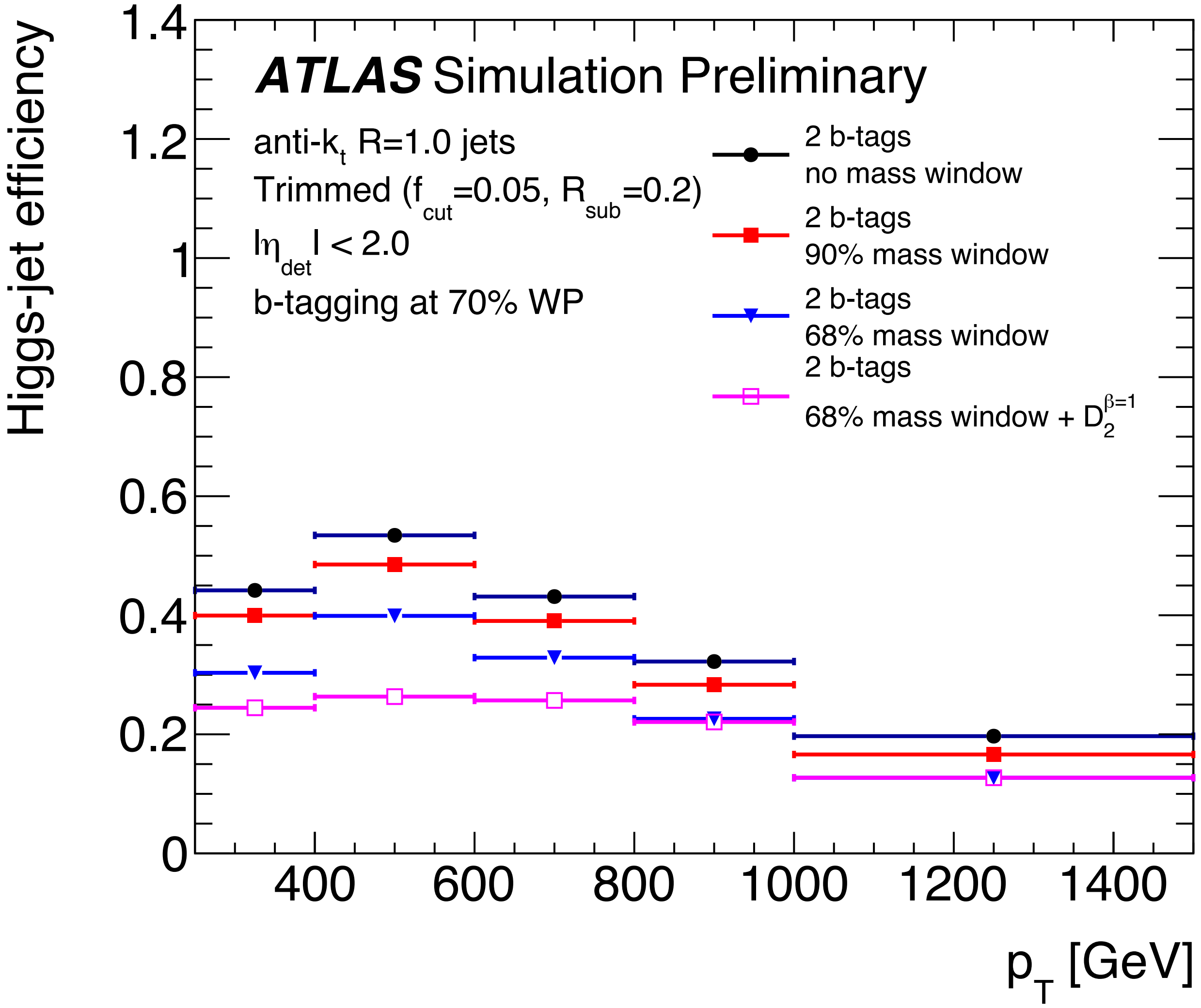
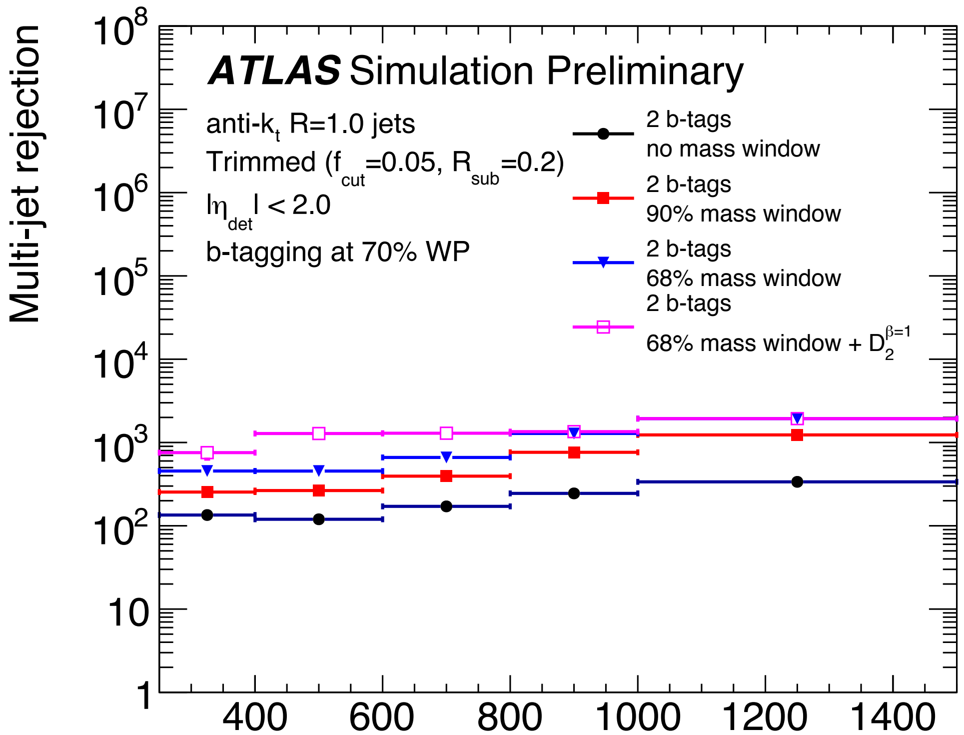
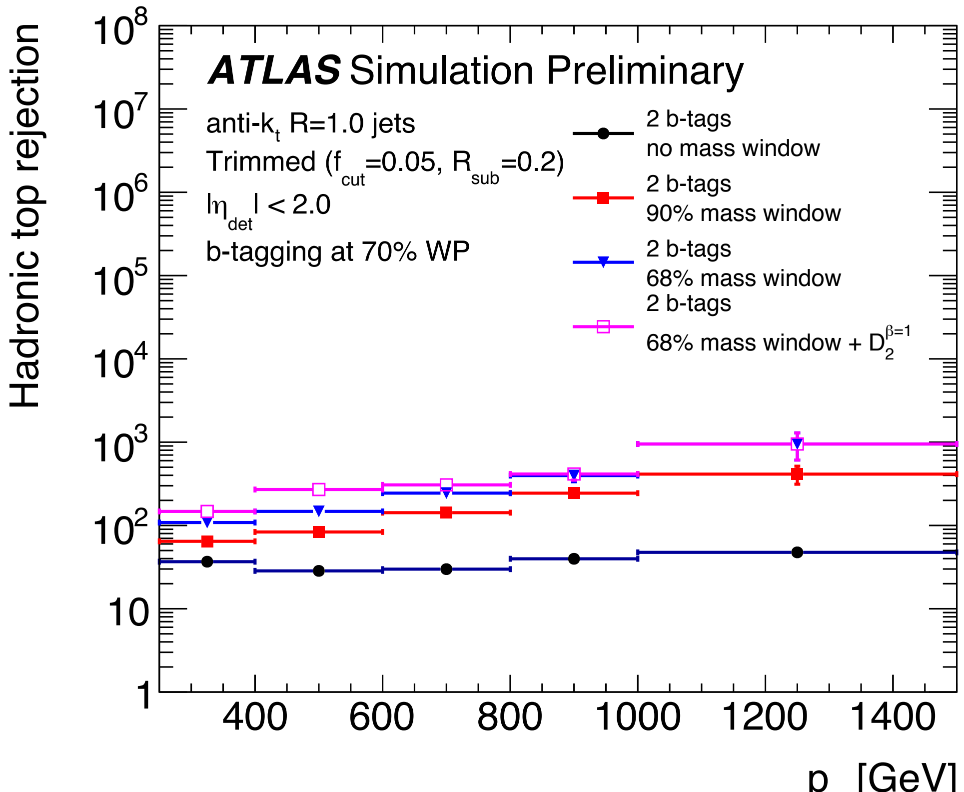
Boosted $H \to bb$ tagging: performance

ATL-PHYS-PUB-2015-035







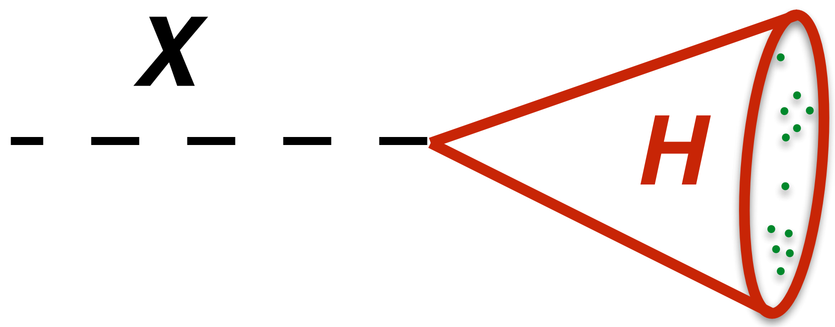
*see **Qi's earlier talk** for more details and improvements for 2016 analyses*

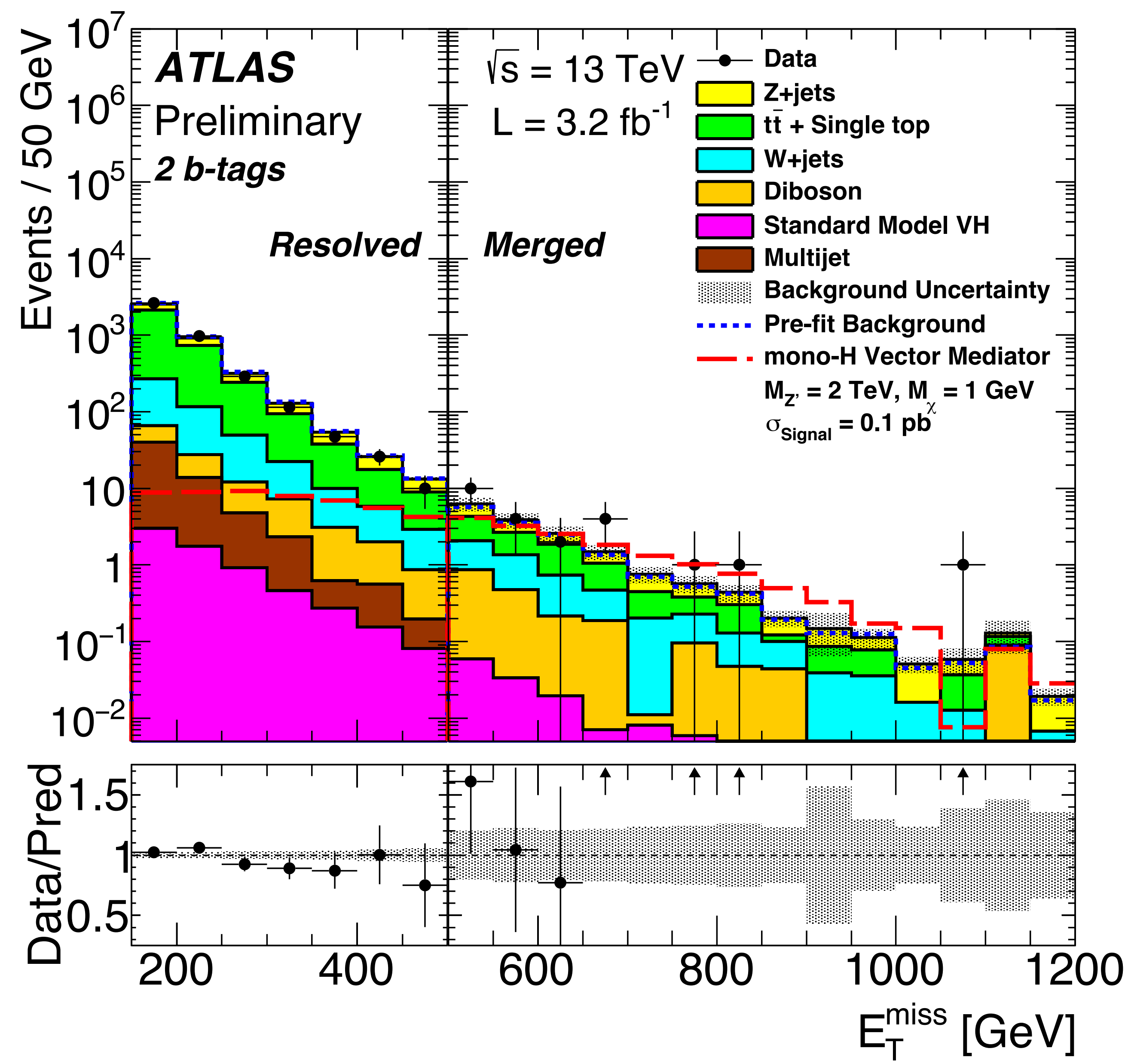
Caveat

Several analyses shown have both "resolved" and "merged" strategies for reconstructing Higgs boson decays.

I'll focus mainly on the "merged" strategies, but the resulting interpretations are based on both.

Search for dark matter in association with a Higgs boson





Event preselection:

- $E^T{}_{miss} > 150$ GeV
- $p^T{}_{miss} > 30$ GeV
- zero isolated leptons
- large-*R* jet $p_T > 250$ GeV
- categorize events by number of *b*-tags

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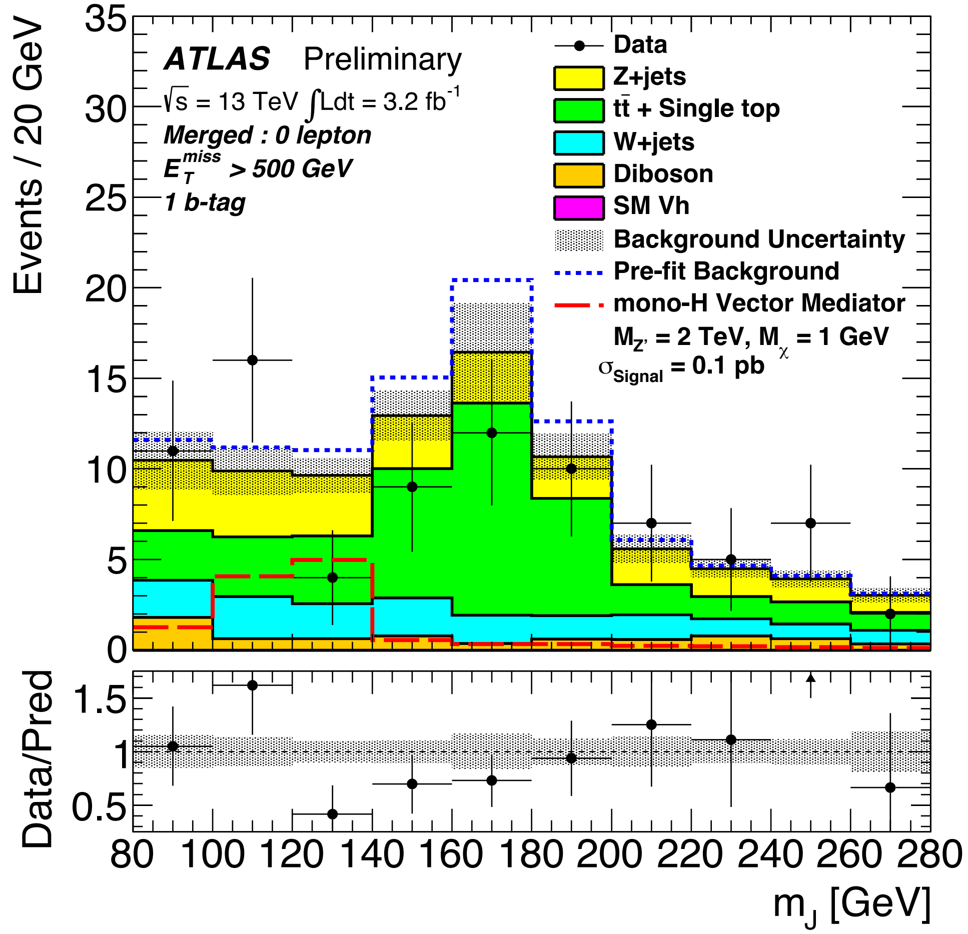
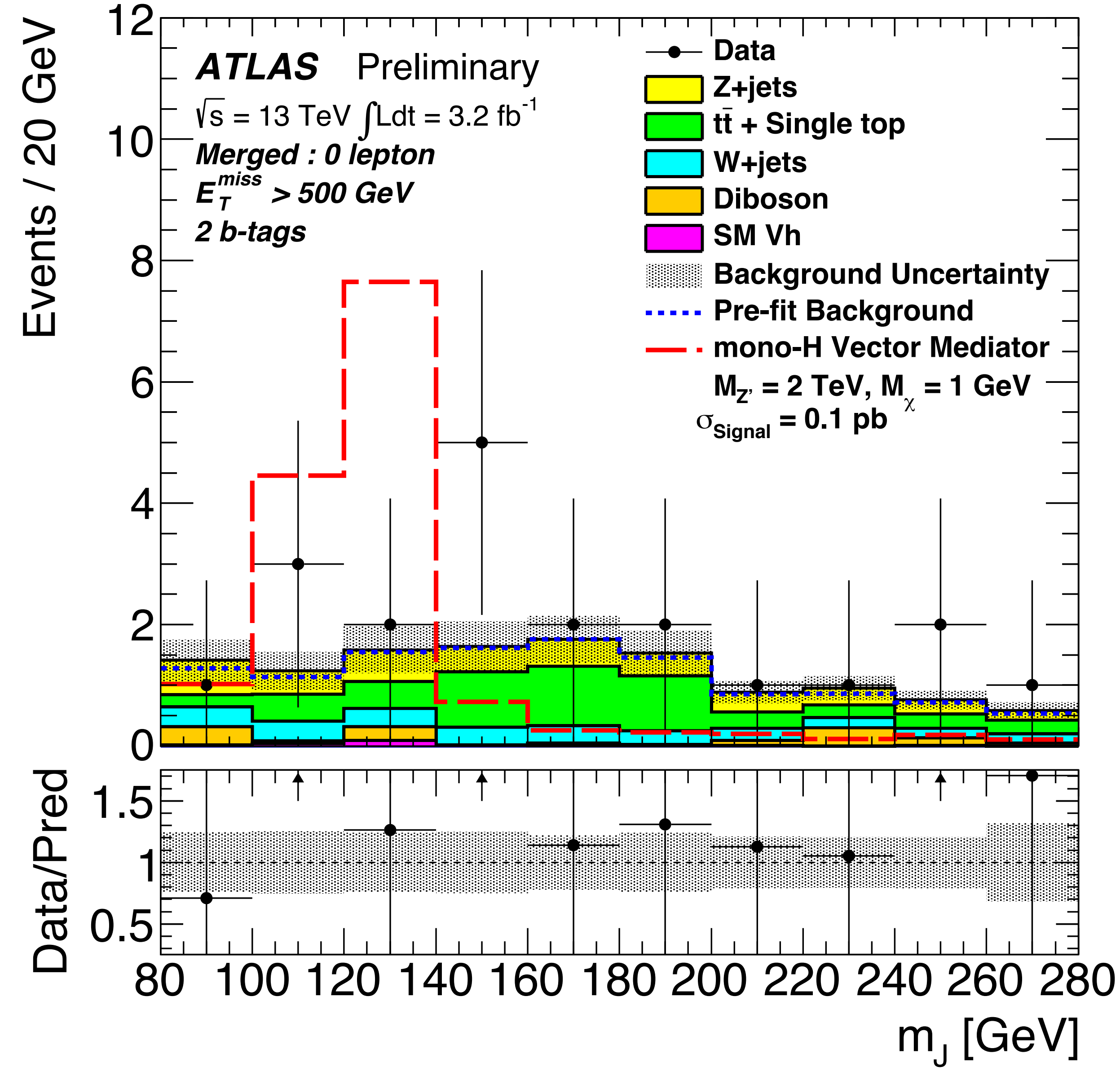
high-p_T mono-*H*: observable

Observable: m_J





Dominant uncertainties:

- Data statistics
- *b*-tagging efficiencies
- *tt* normalization
- Luminosity

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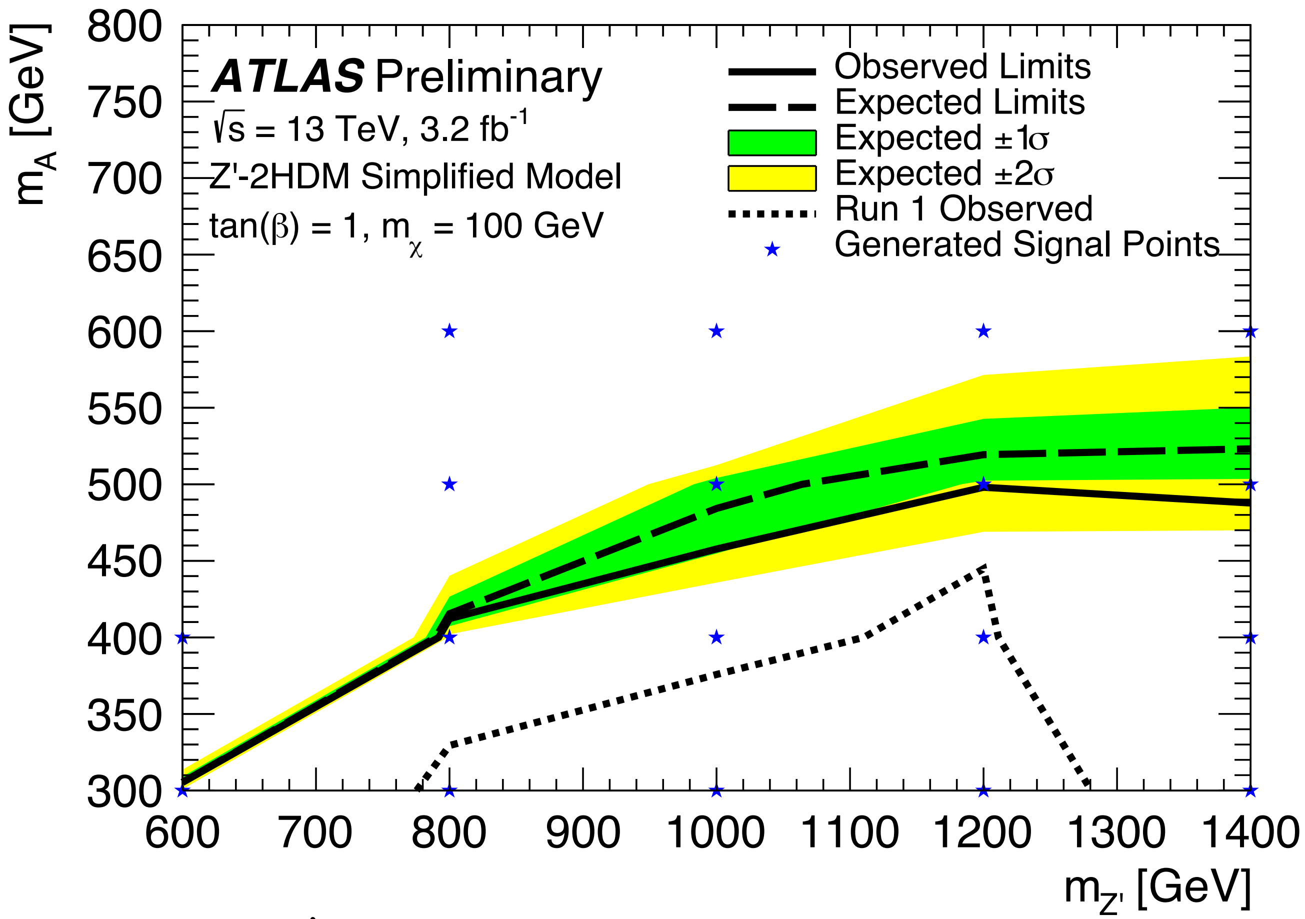
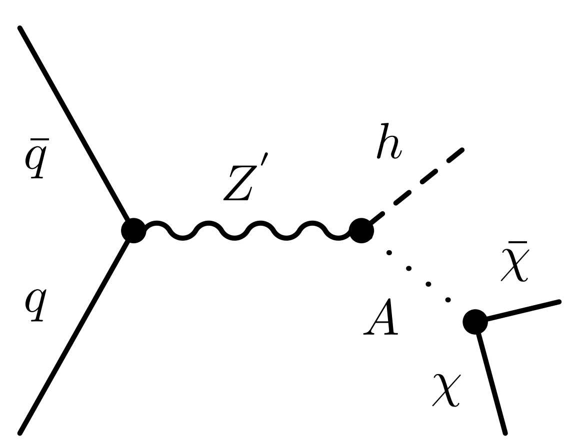
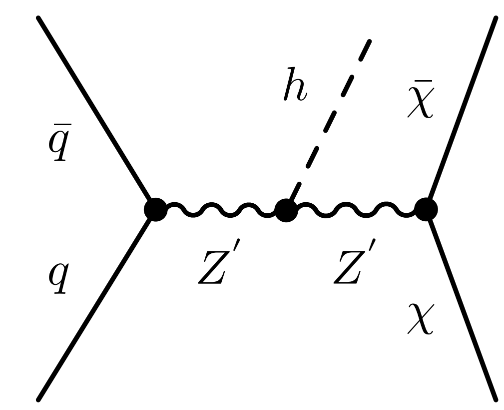
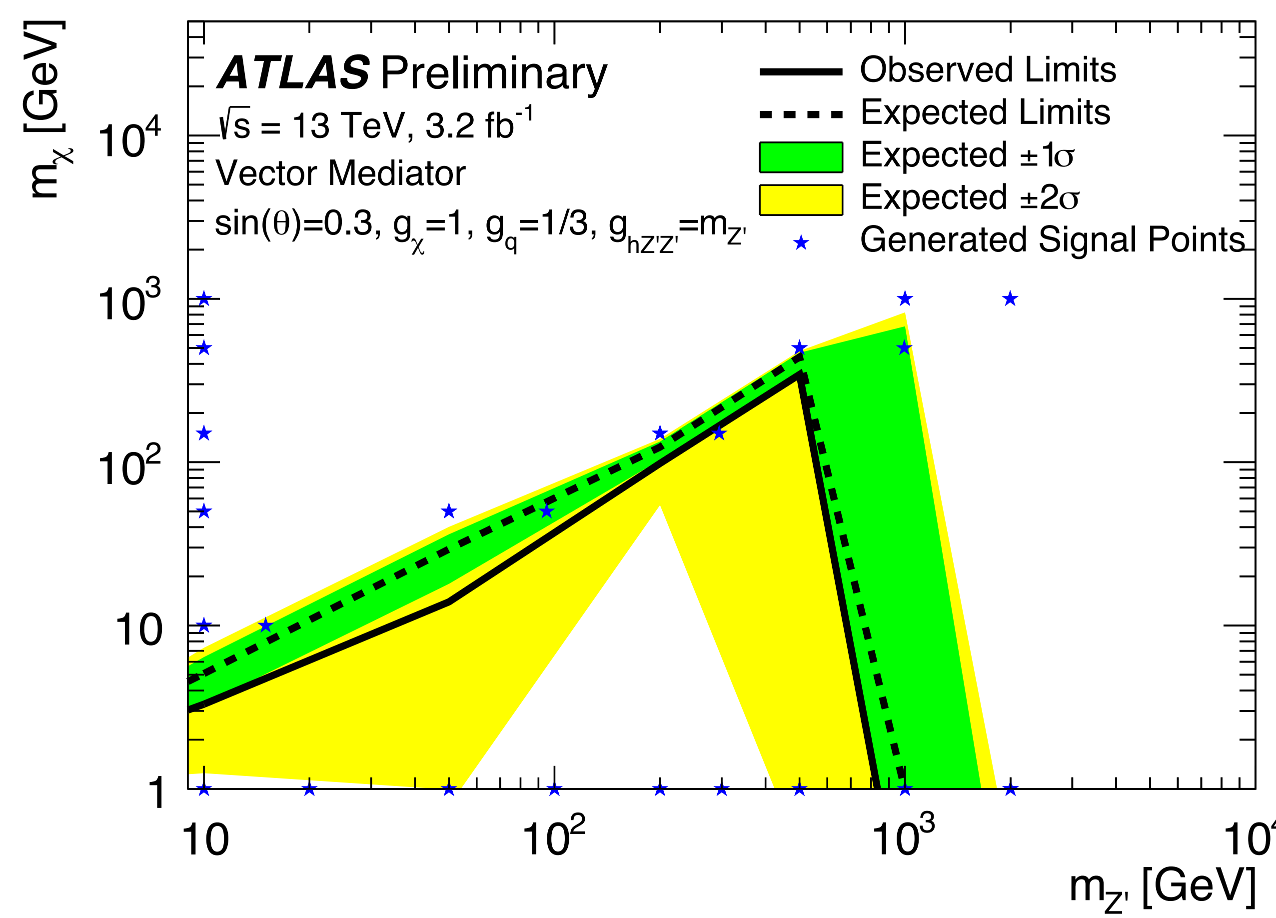
mono-*H* @ high-p_T: results









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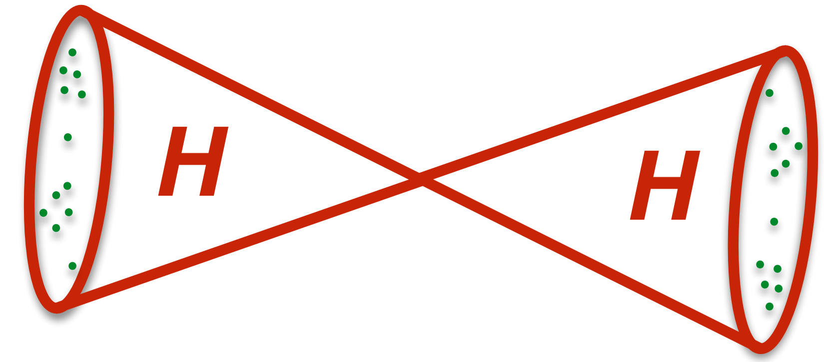
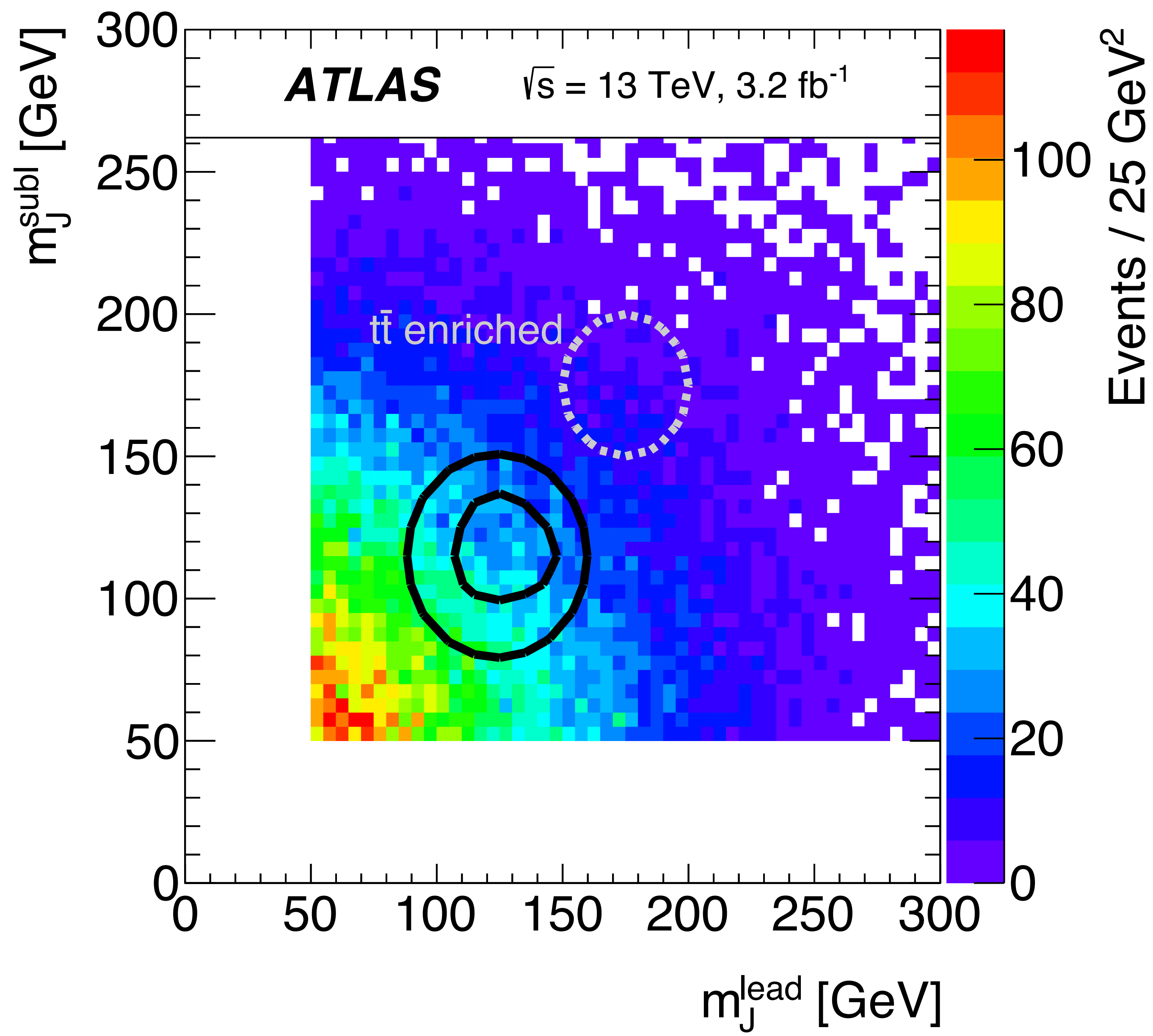
Search for high-mass *HH* resonances



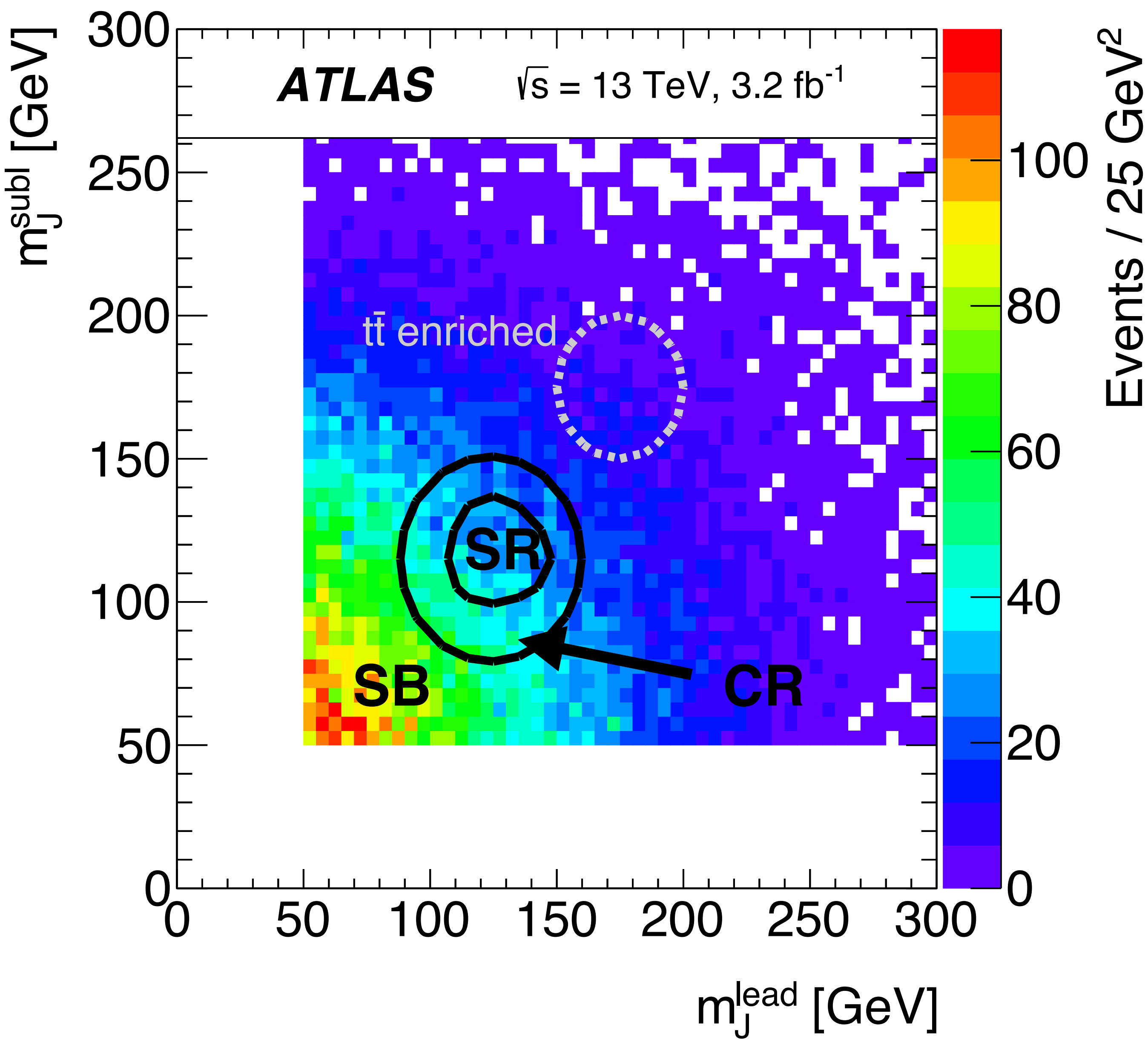
Event preselection:

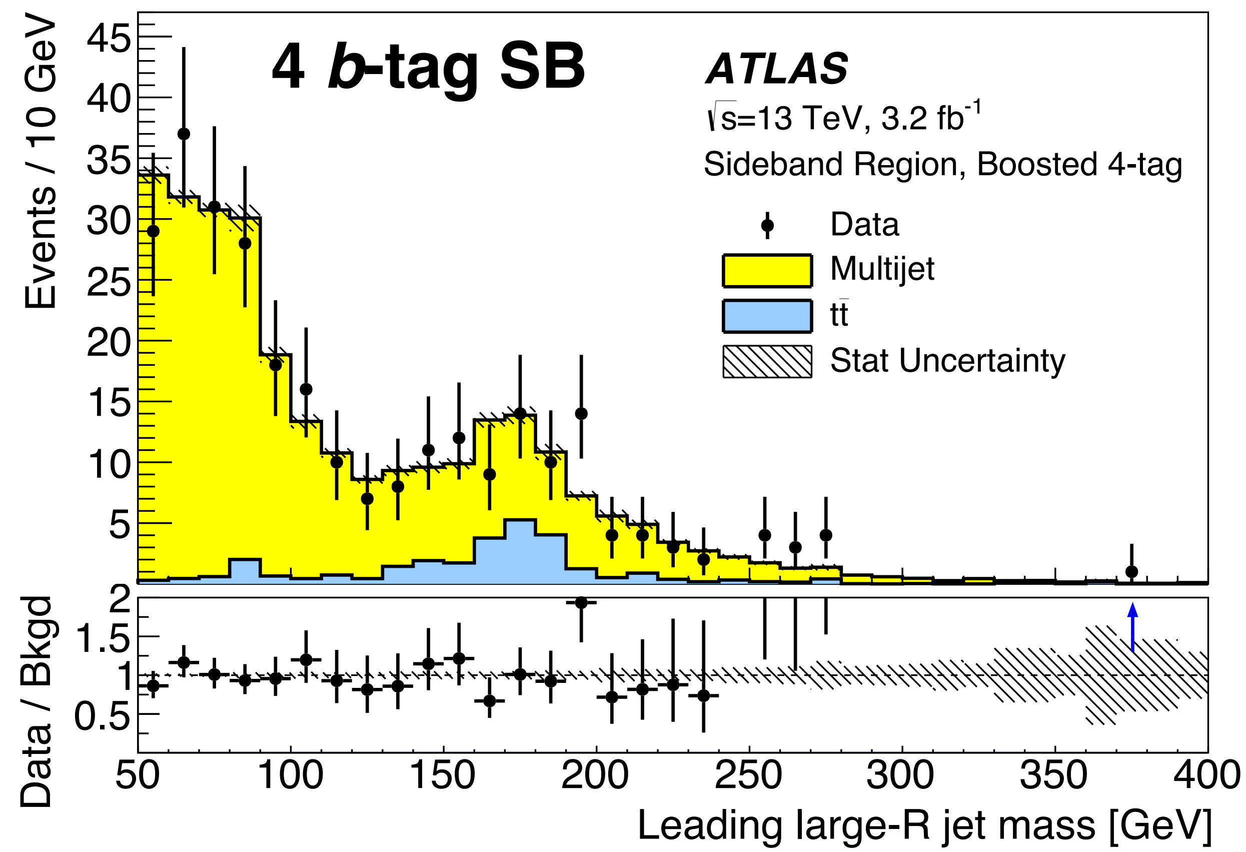
- >= 2 large-*R* jets with
  - $p_T > 250$ GeV
  - m > 50 GeV
  - >= 2 small-*R* track jets
- leading large-*R* jet $p_T > 350$ GeV (reduce top background)
- $|\Delta\eta(J,J)| < 1.7$
- categorize events by number of *b*-tags

arXiv:1606.04782



High-mass *HH*: background estimate





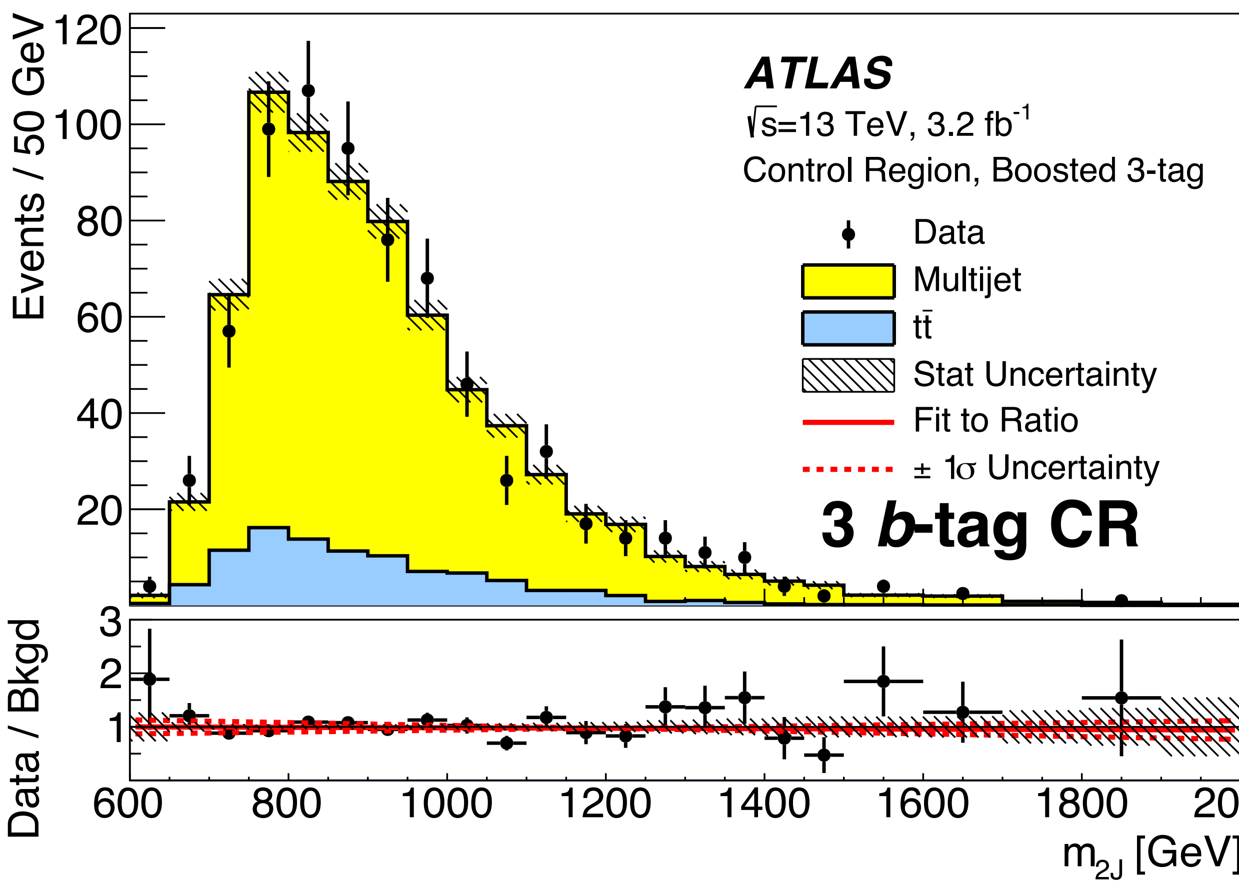
arXiv:1606.04782

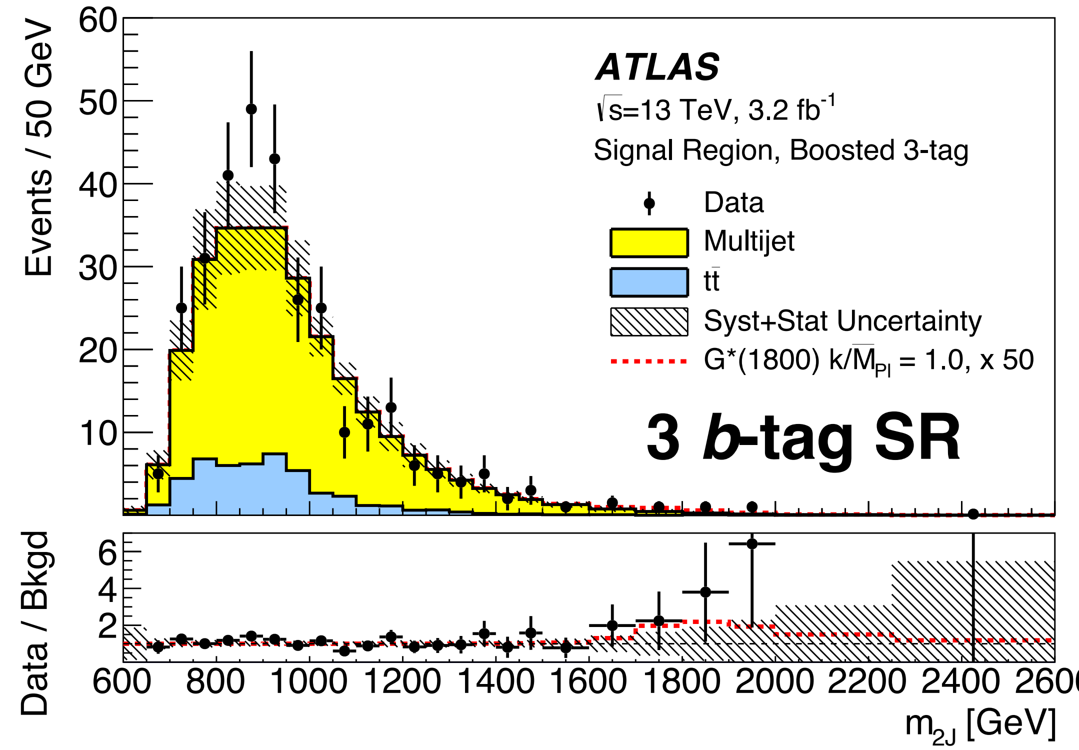
Dijet background estimate strategy:

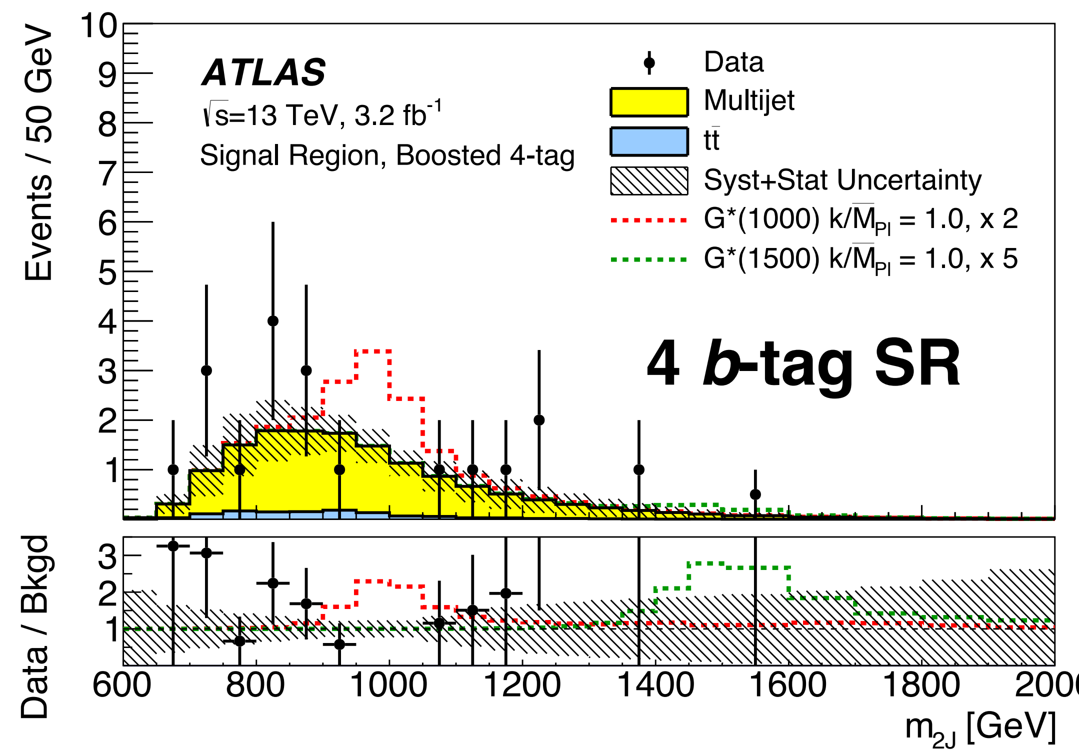
- take dijet shape from 2-*b*-tag **sideband region**
- correct kinematics and assess uncertainties on background estimate in the **control region**

High-mass *HH*: observable

arXiv:1606.04782



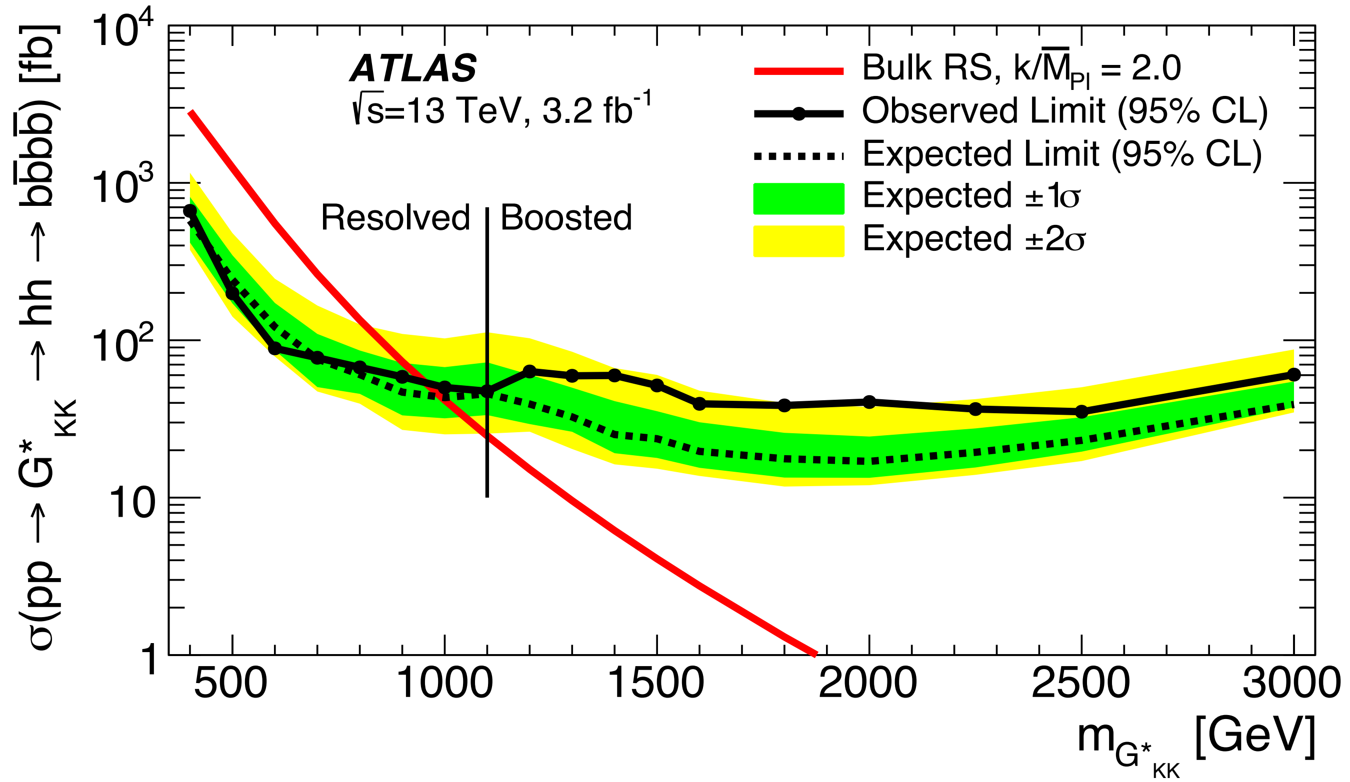




Dominant uncertainties:

- *b*-tagging efficiencies
- jet mass scale/resolution
- multijet normalization and shape

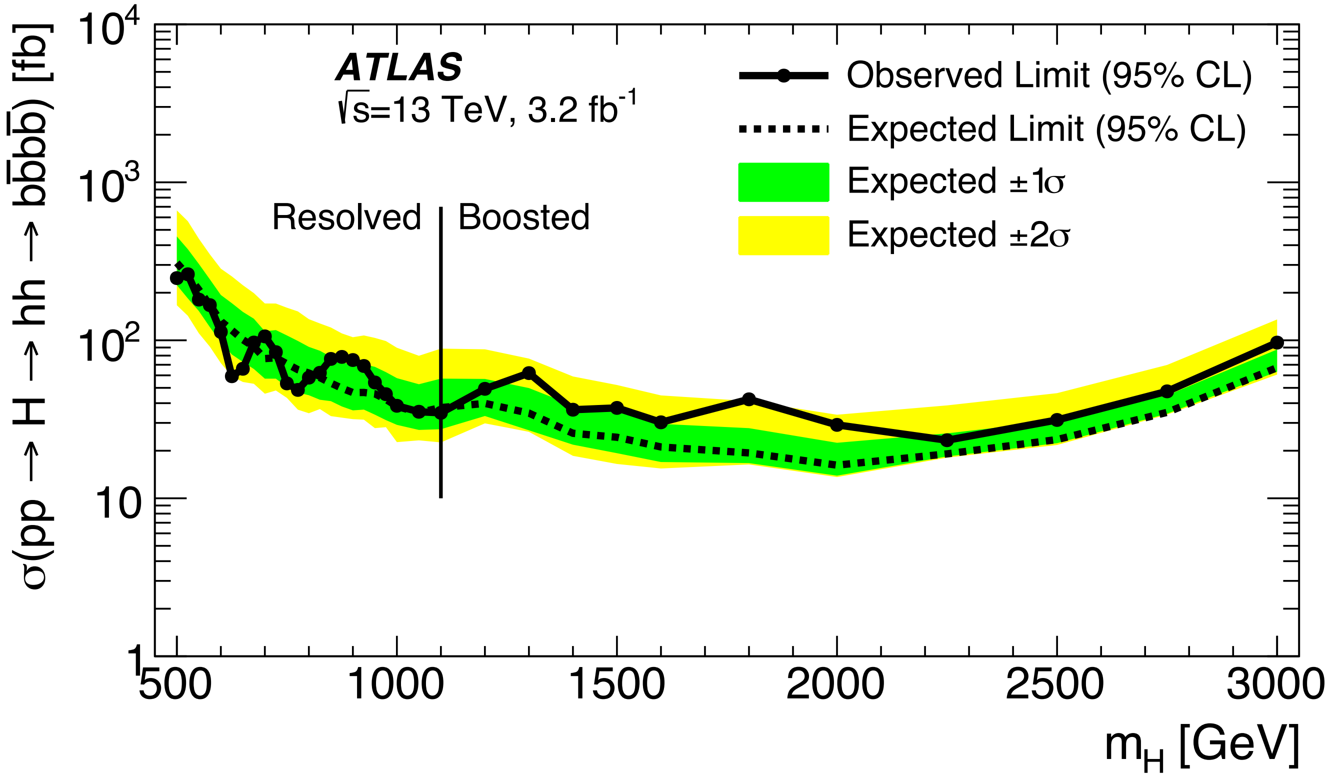
High-mass *HH:* interpretation



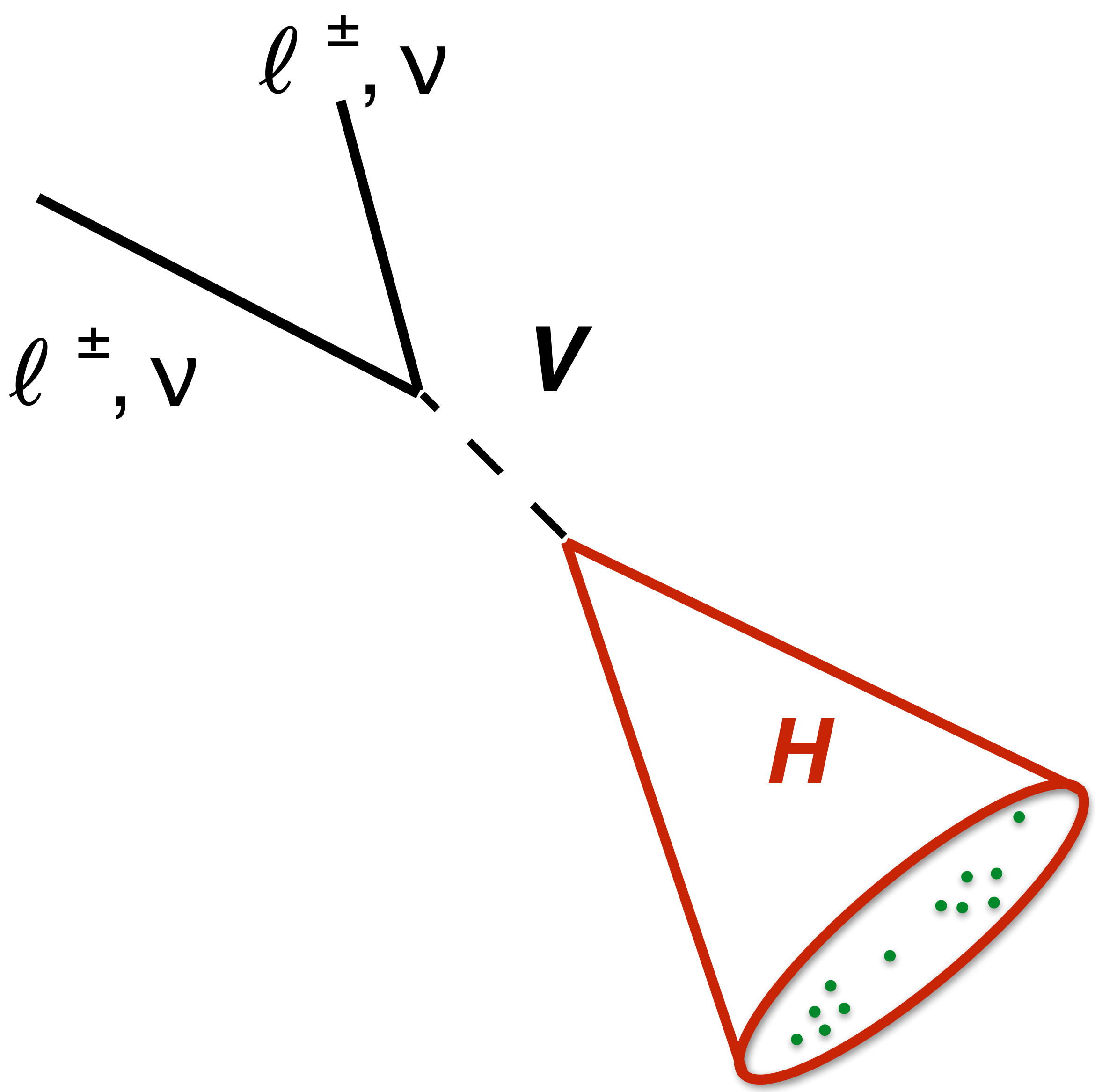
arXiv:1606.04782

RS KK Graviton

Spin 0, narrow Higgs boson



Search for high-mass *VH* resonances



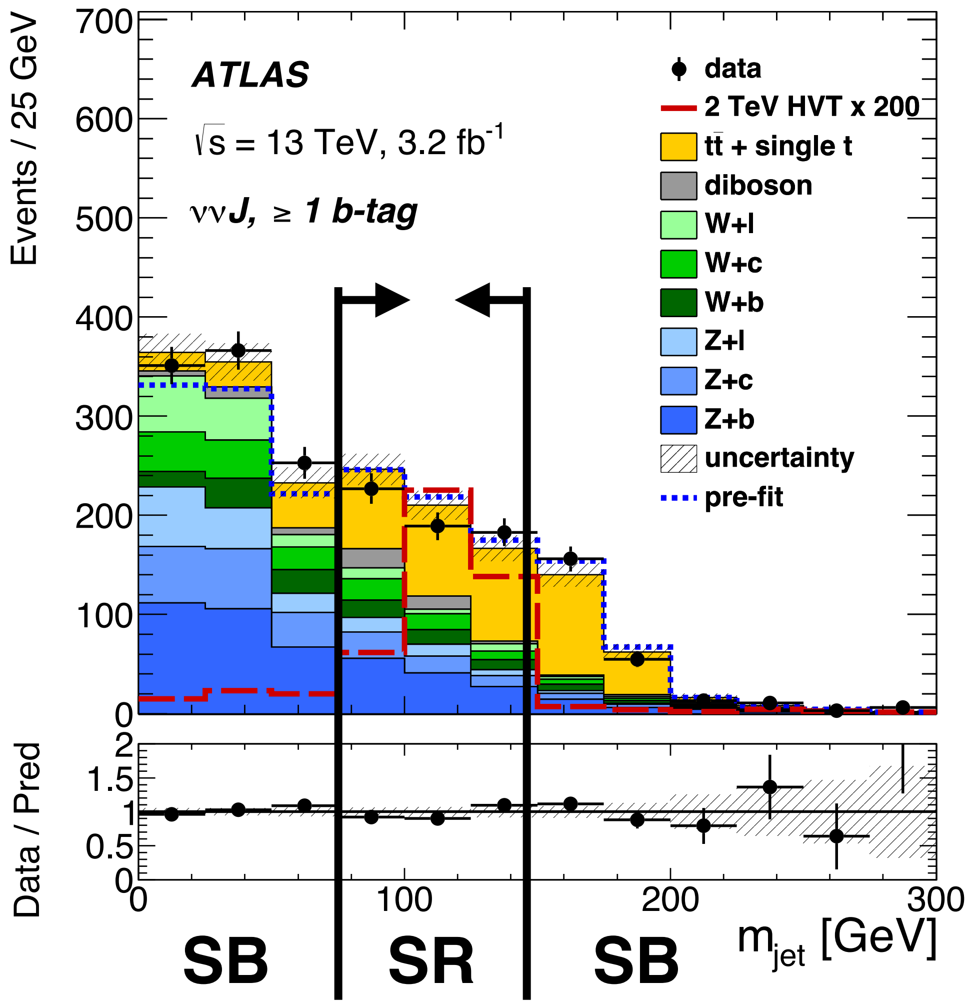
arXiv:1607.05621

Selection:

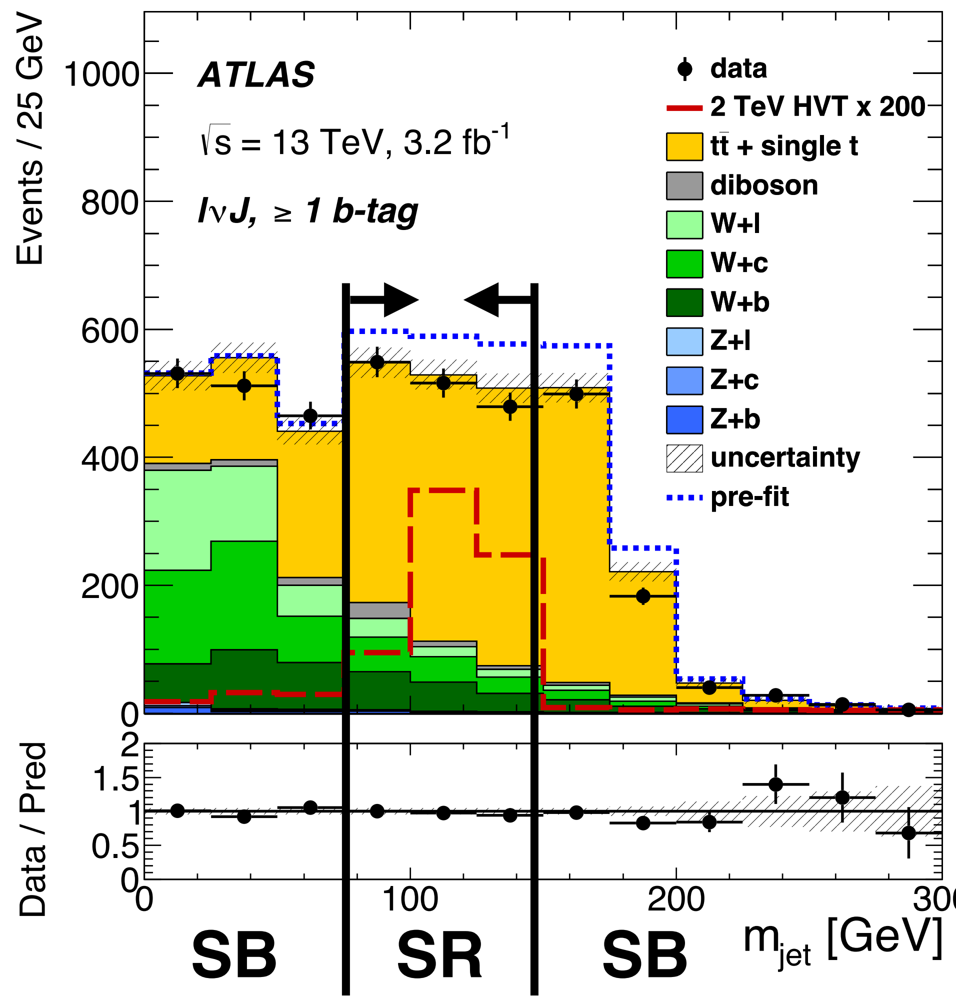
- >= 1 large-*R* jets with
  - p_T > 250 GeV
  - >= 1 *b*-tagged small-*R* track jets
- categorize events by number of *b*-tags associated (or not) to leading large-*R* jet
- categorize events by number of isolated charged leptons
  - E^T_{miss} > 200 GeV (0-lepton)
  - E^T_{miss} > 100 GeV (1-lepton)
  - *Z*-mass window (2-lepton)

High-mass *VH*: backgrounds I

0-lepton, >= 1 *b*-tag



1-lepton, >= 1 *b*-tag



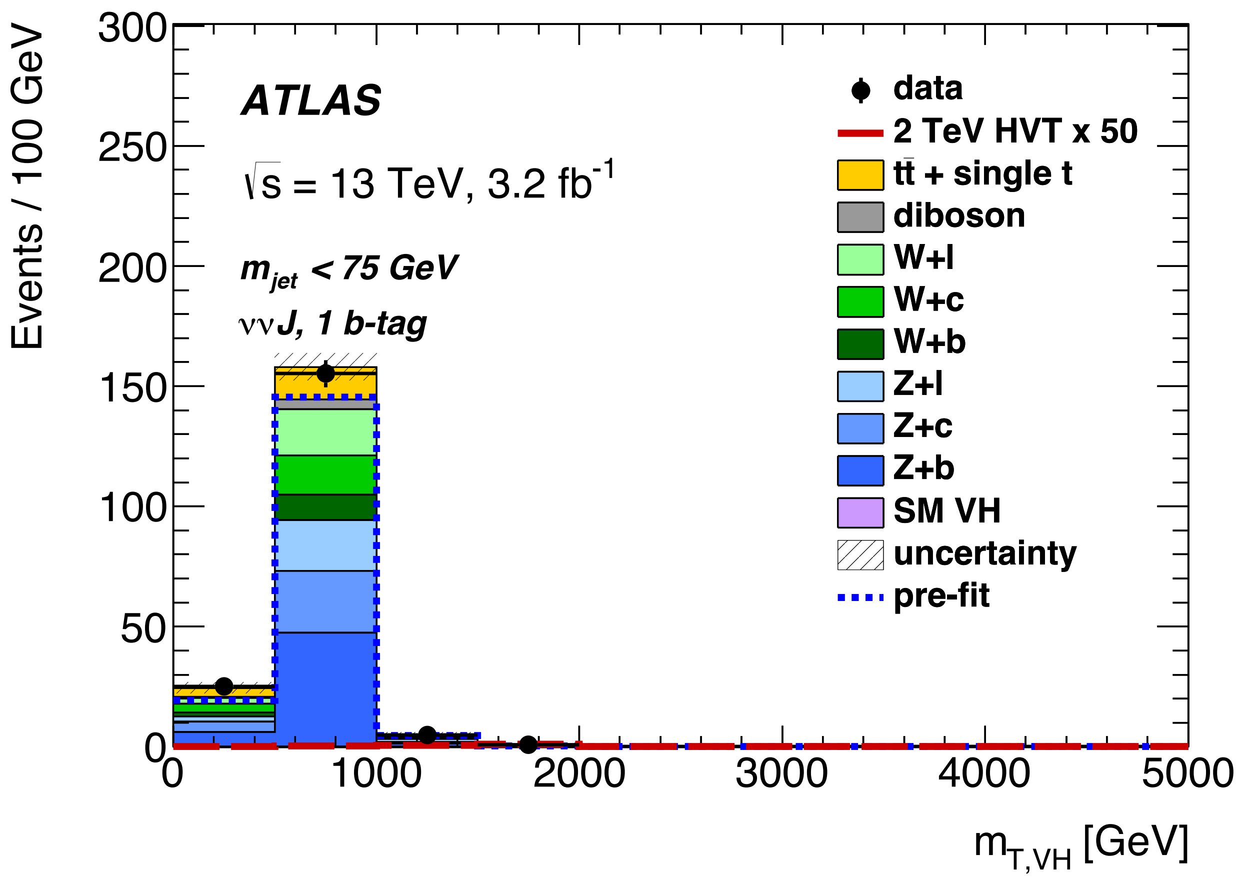
Background estimate strategy:

- define m_{jet} sideband regions above and below signal region (**75 - 145 GeV**)
- several background processes with non-negligible contributions

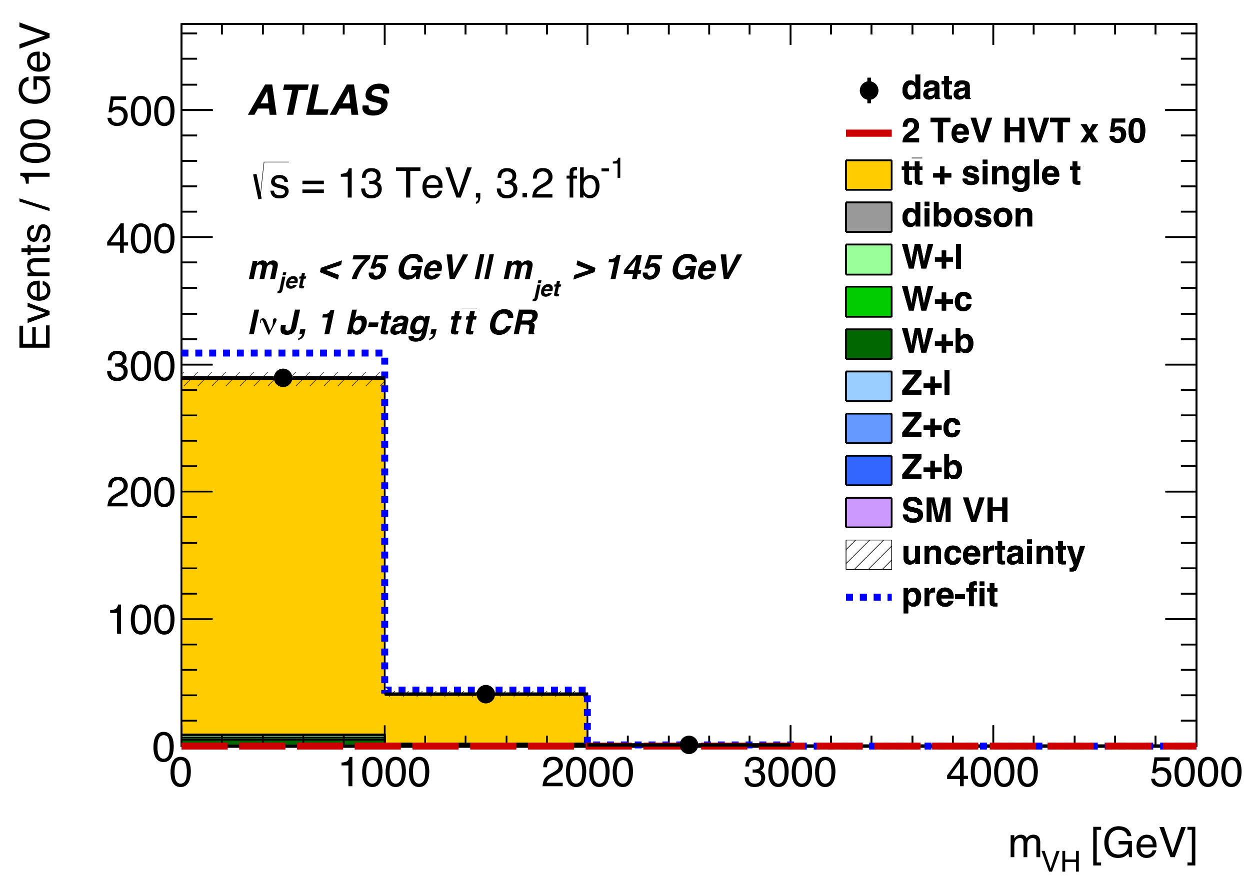
High-mass *VH*: backgrounds II

arXiv:1607.05621

0 lepton, 1 *b*-tag
low m_{jet} sideband



1 lepton, 1 *b*-tag
***tt* CR**

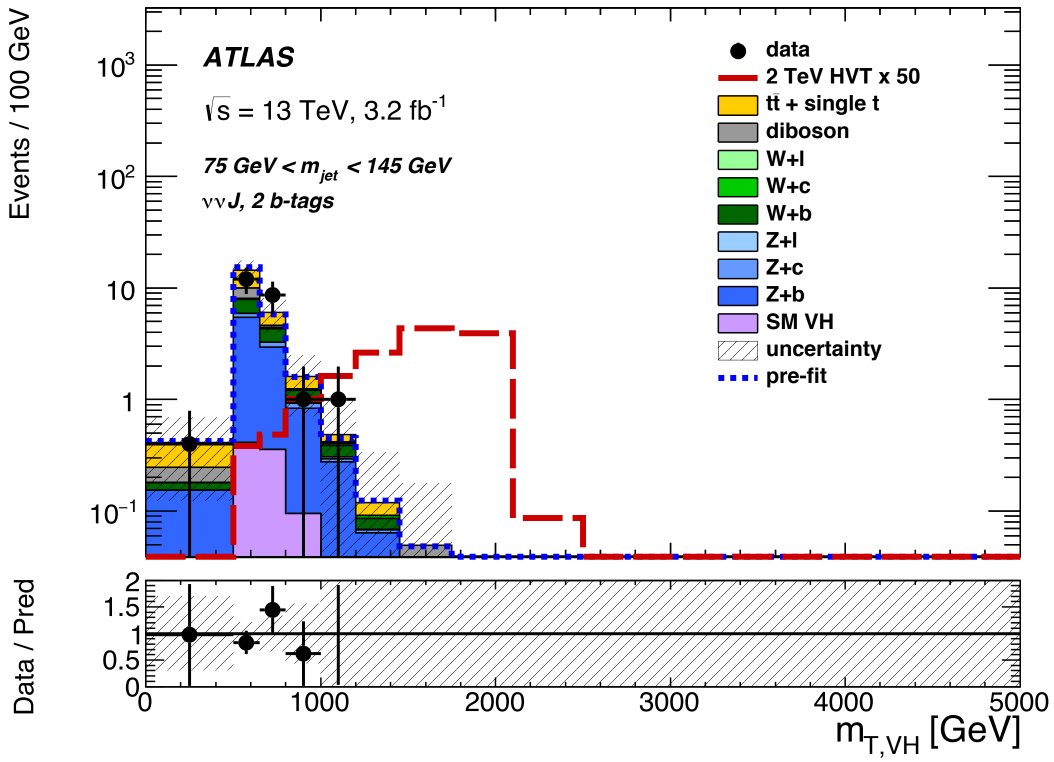


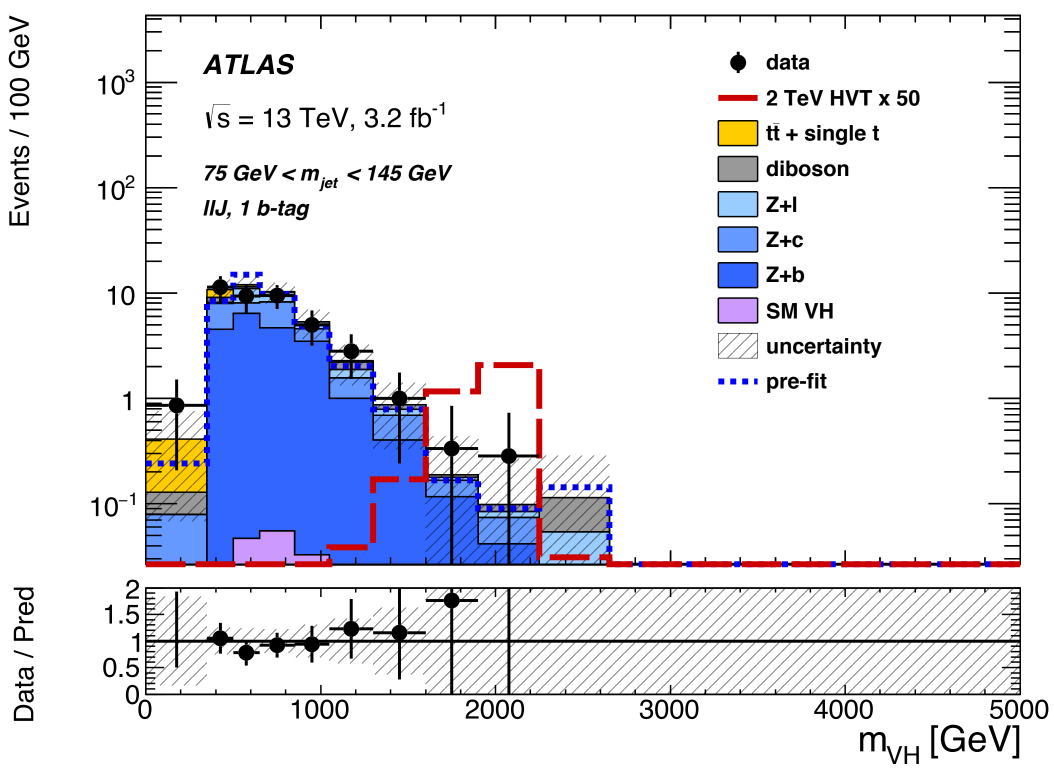
Background estimate strategy:

- define *tt* control regions based on additional b-tagged track jets in event (0-, 1-lepton) or *eμ* events (2-lepton).
- maximum-likelihood fit over all sidebands and signal regions to constrain/correct background modeling

High-mass *VH*: observable

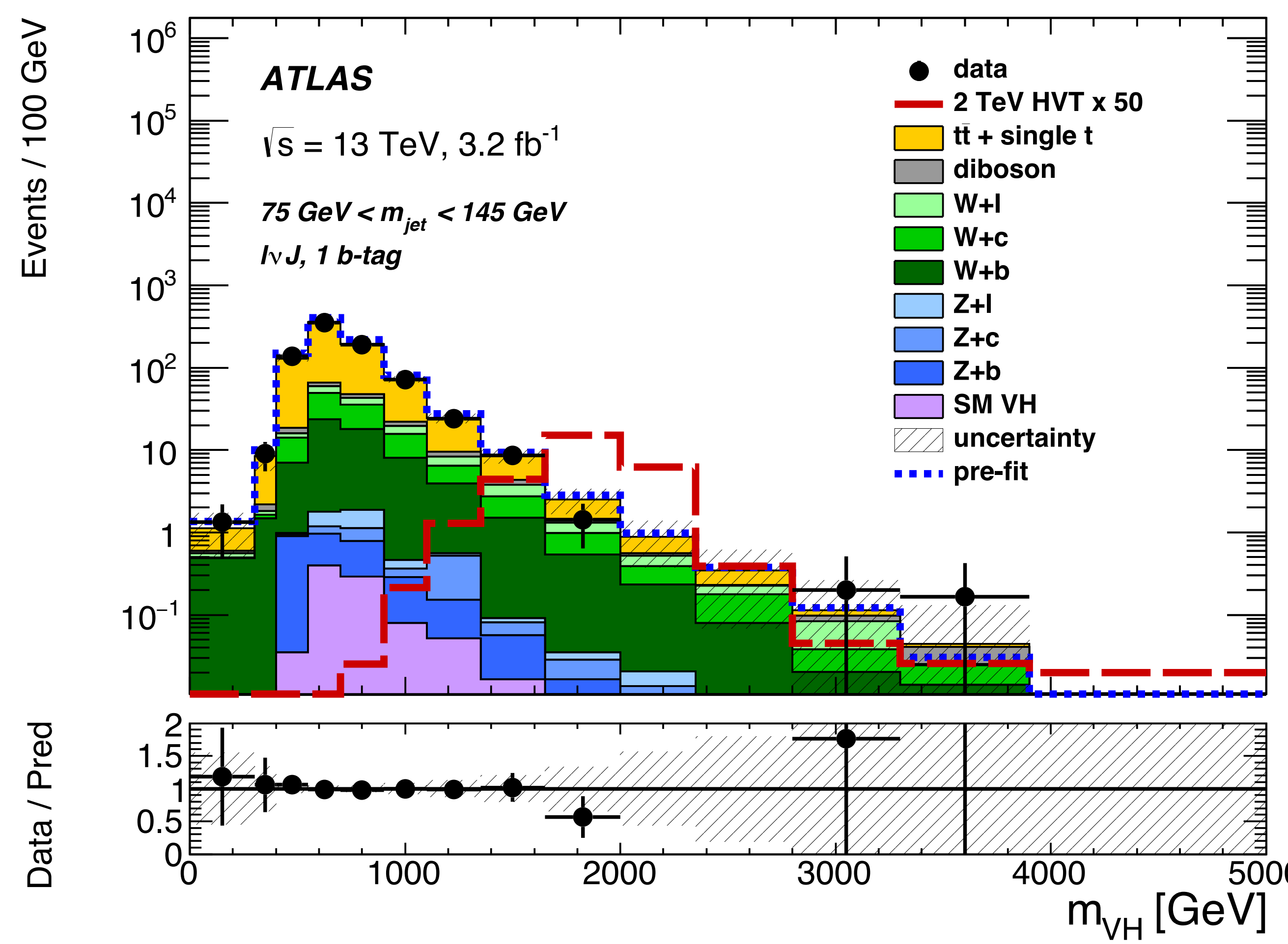
arXiv:1607.05621





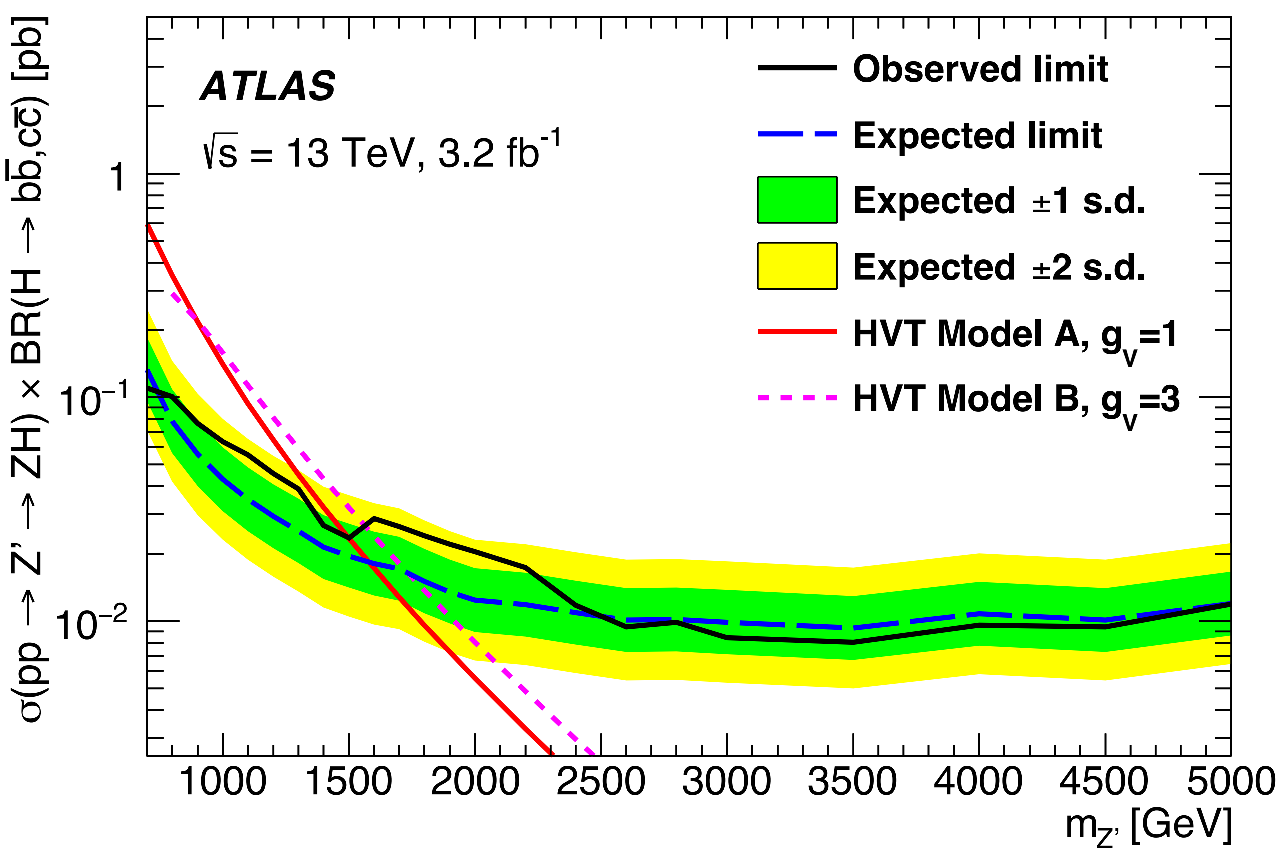
Dominant uncertainties:

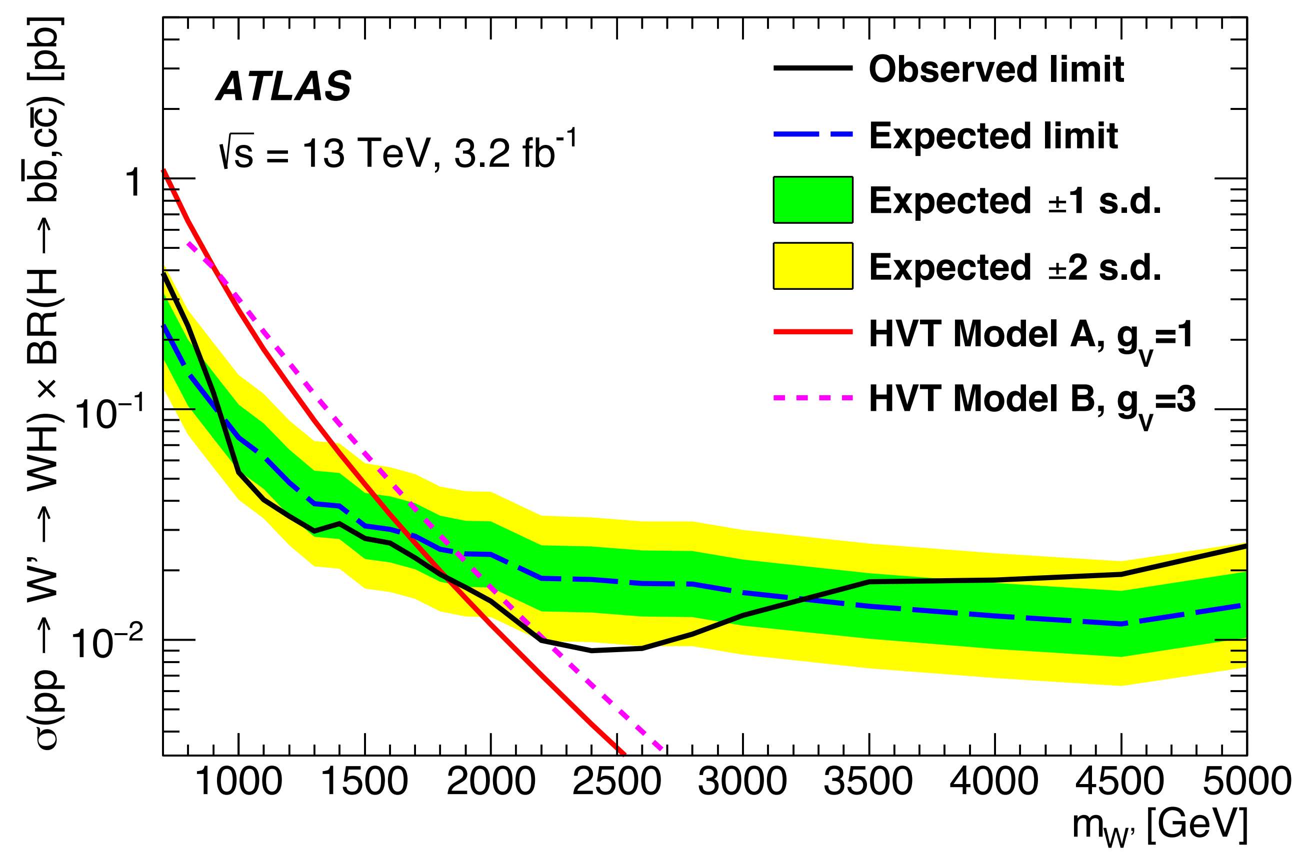
- data statistics
- *b*-tagging efficiencies
- *tt* normalization and modeling
- jet energy/mass scale/resolution



High-mass *VH*: results

Interpreted in a generic Heavy Vector Triplet model





Z'→ZH ***W'→WH***

arXiv:1607.05621

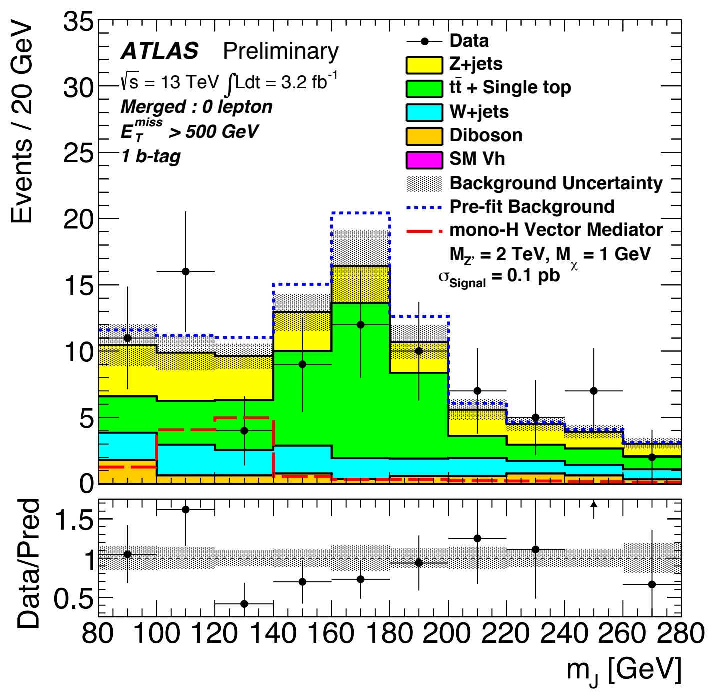
Summary

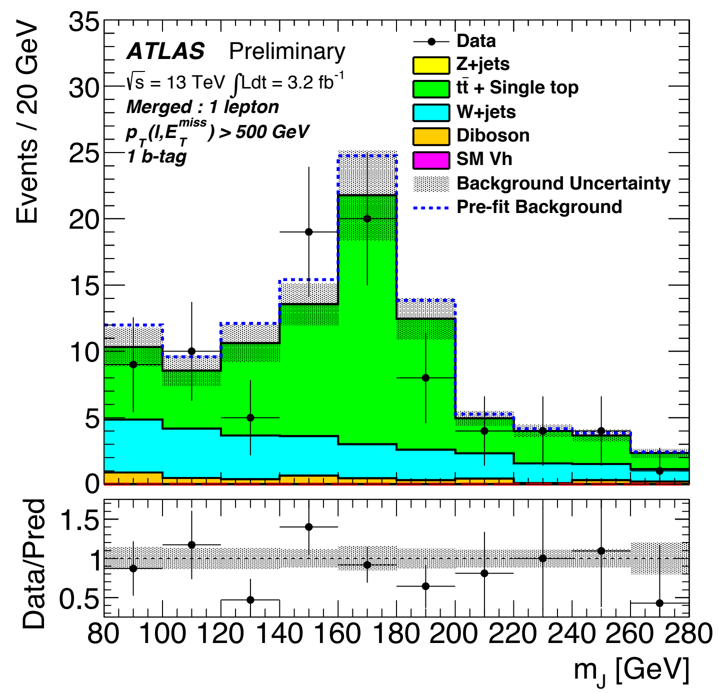
- There have been several successful applications of boosted Higgs boson tagging for physics results in Atlas with the 2015 data.
- High-mass limits were improved—in some cases—by several hundred GeV largely due to the applications of these techniques.
- As was previously shown, significant improvements have been developed for future analyses: **keep an eye out for more**.

High-p_T mono-*H*: regions

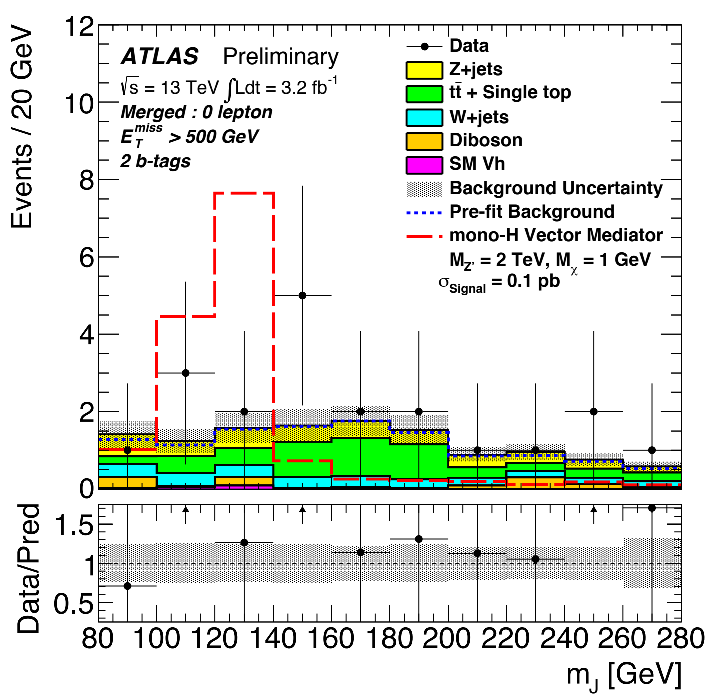
0 lepton | 1 lepton

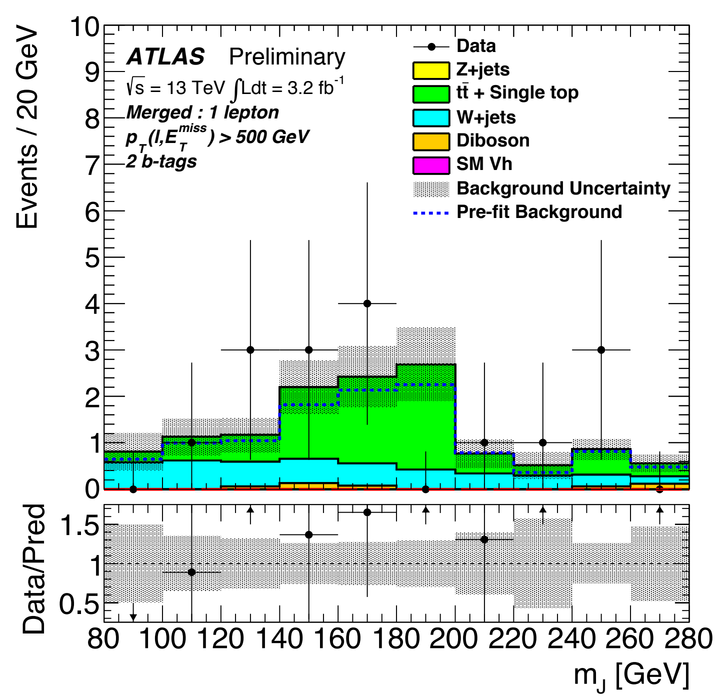
1 *b*-tag



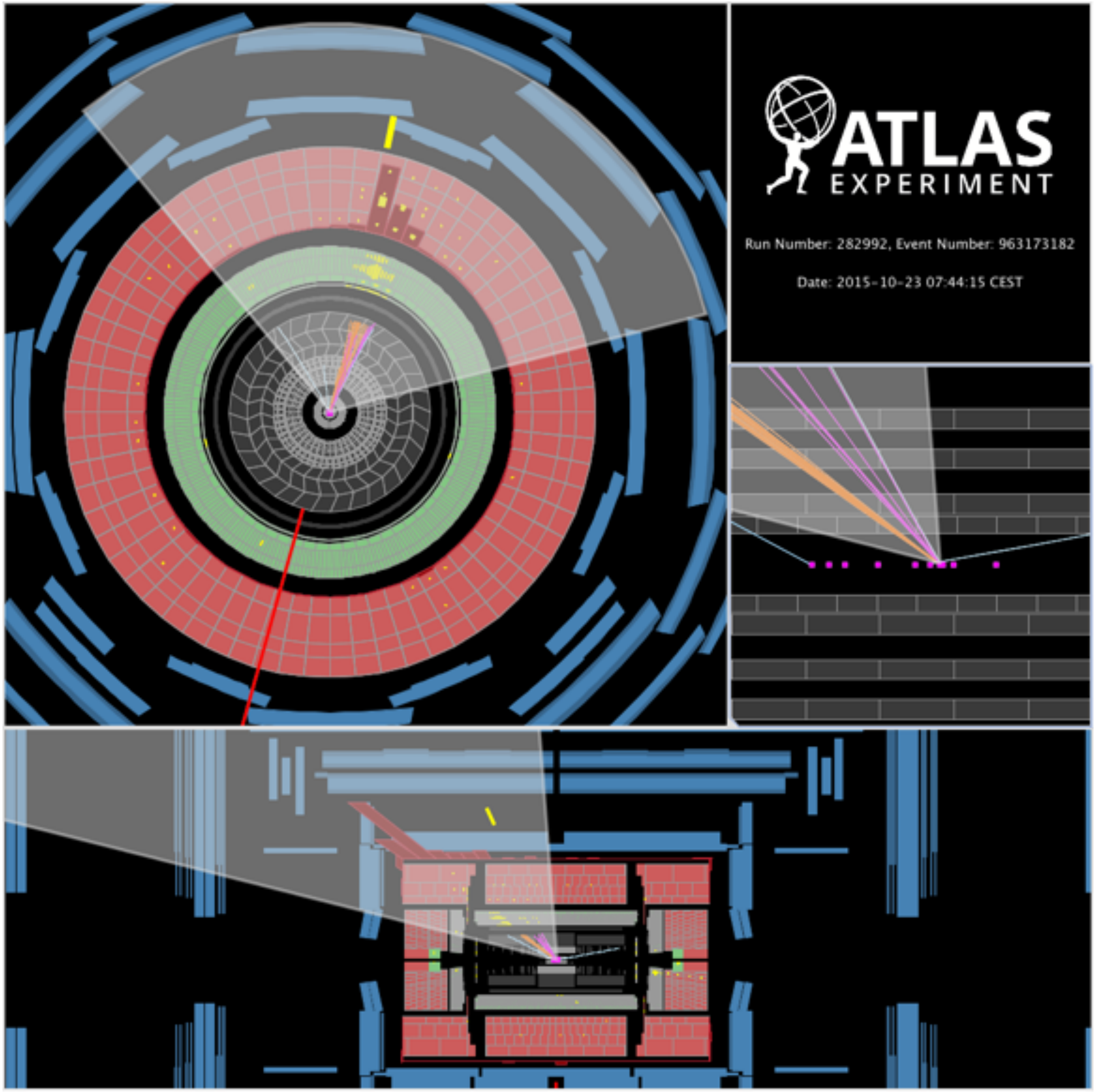


2 *b*-tag





High-p_T mono-*H*: event display

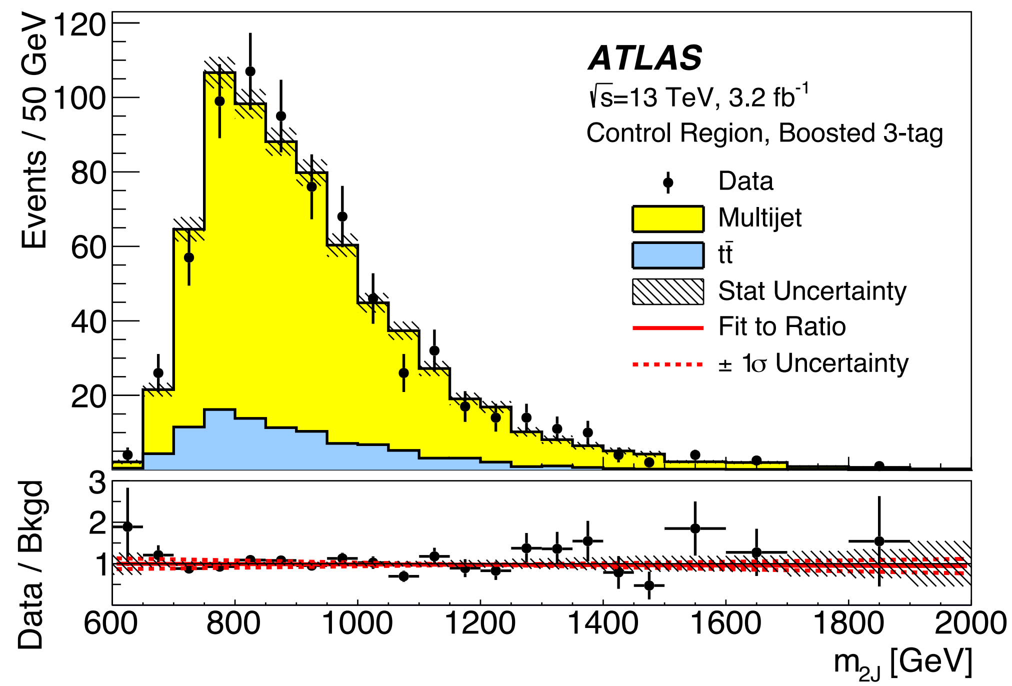


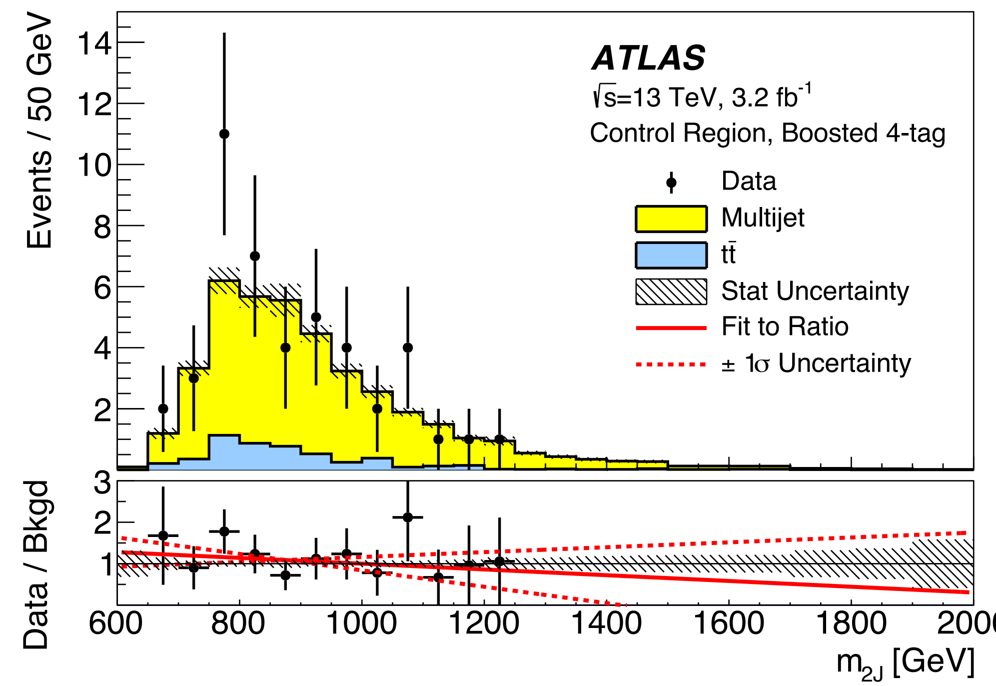
High-mass *HH*: regions

Control Region

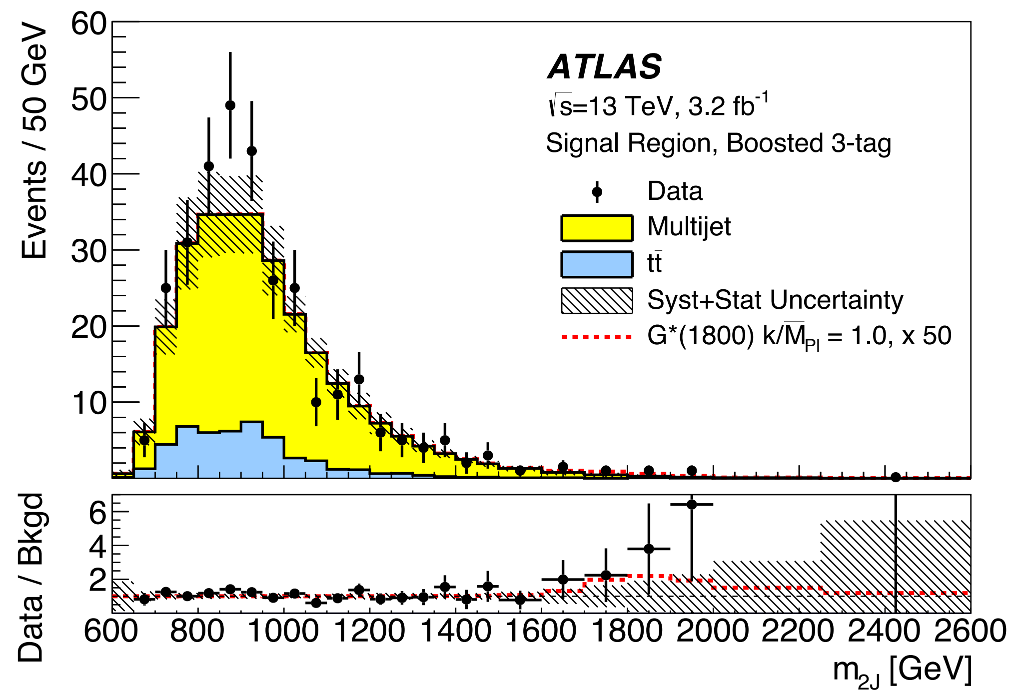
Signal Region

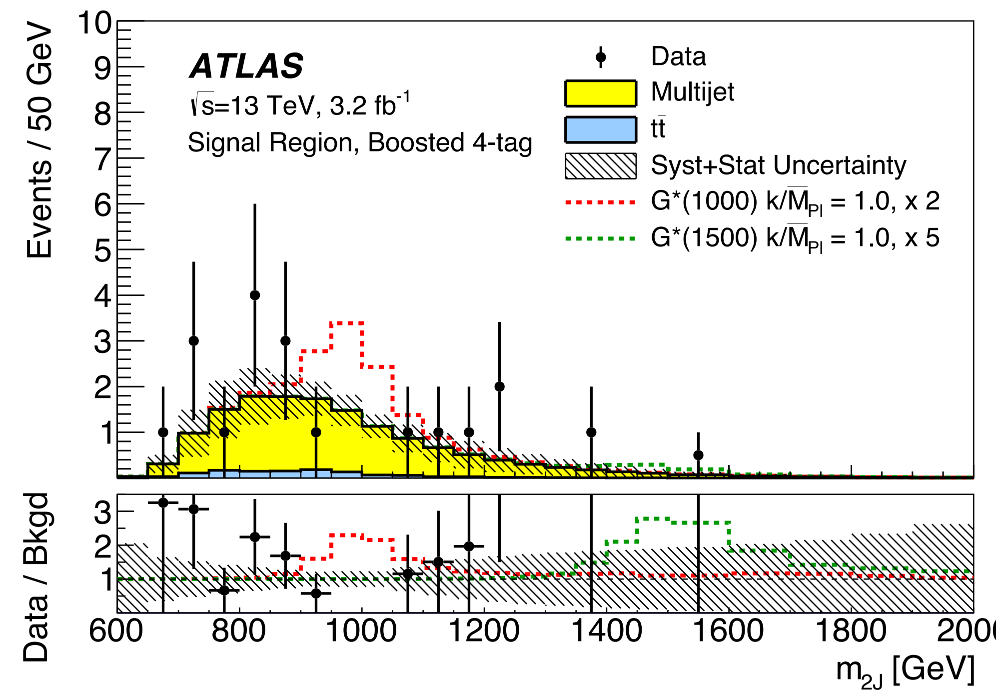
3 *b*-tag



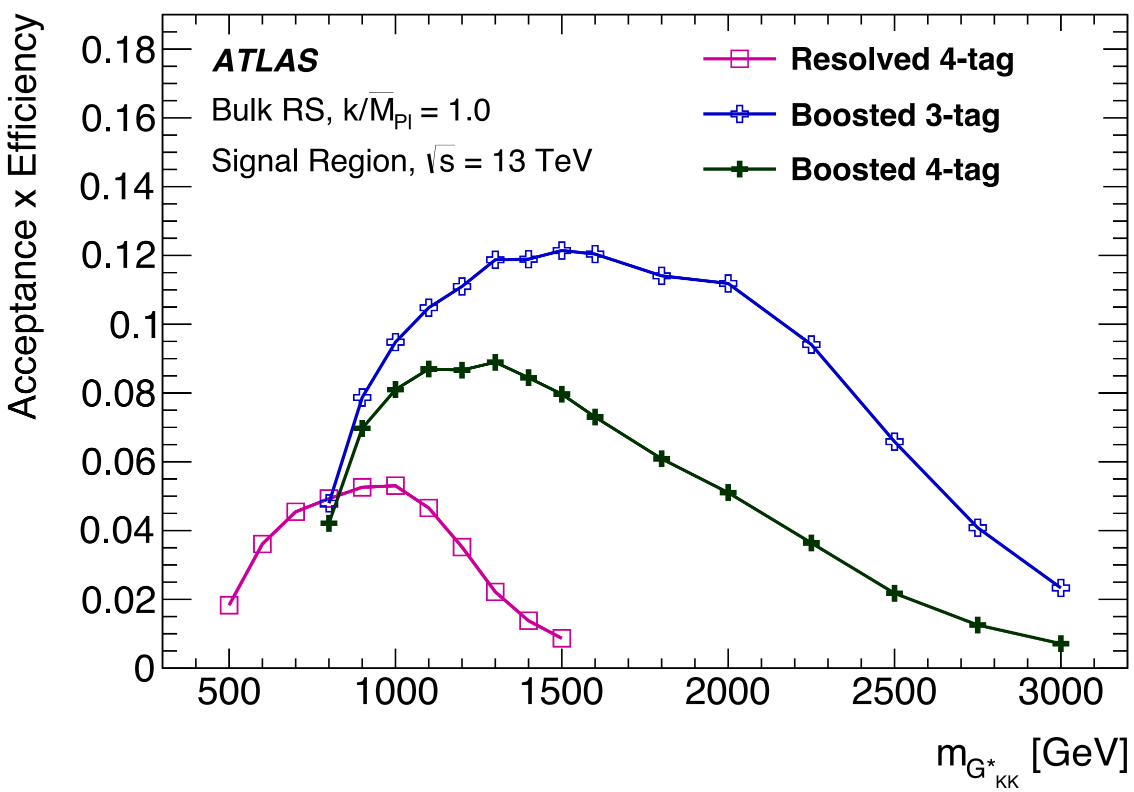


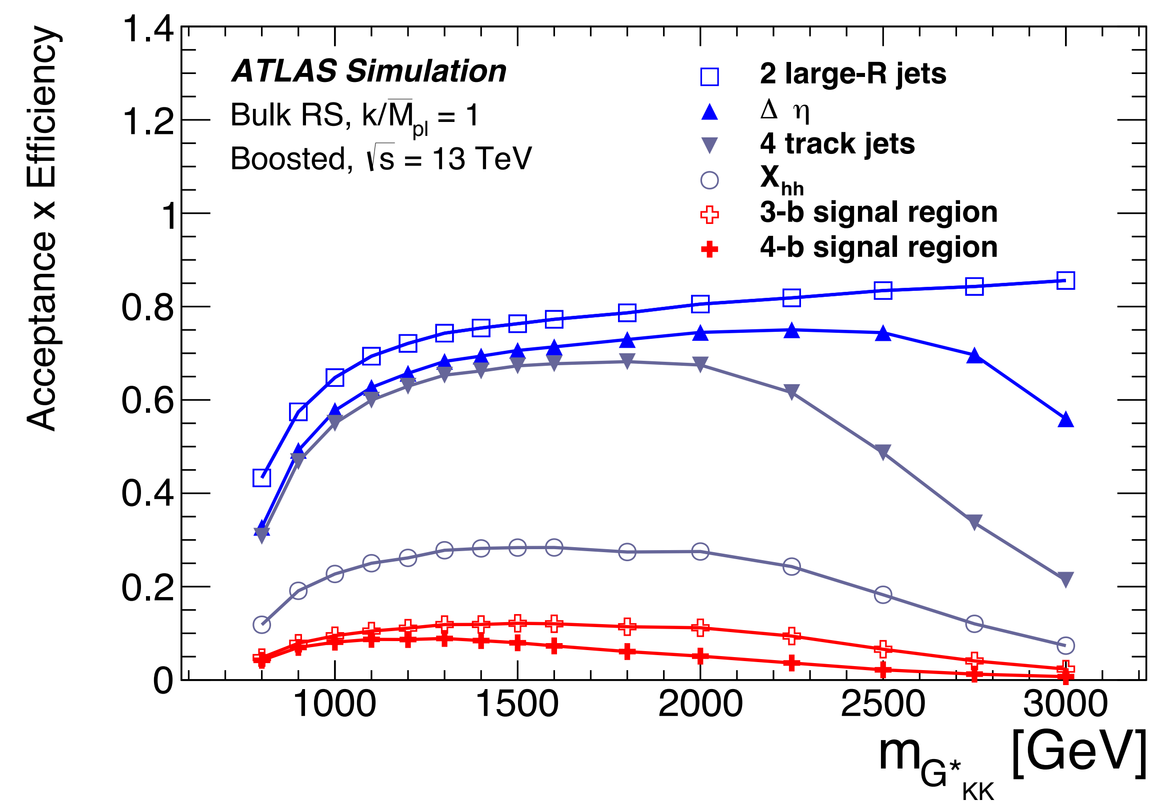
4 *b*-tag





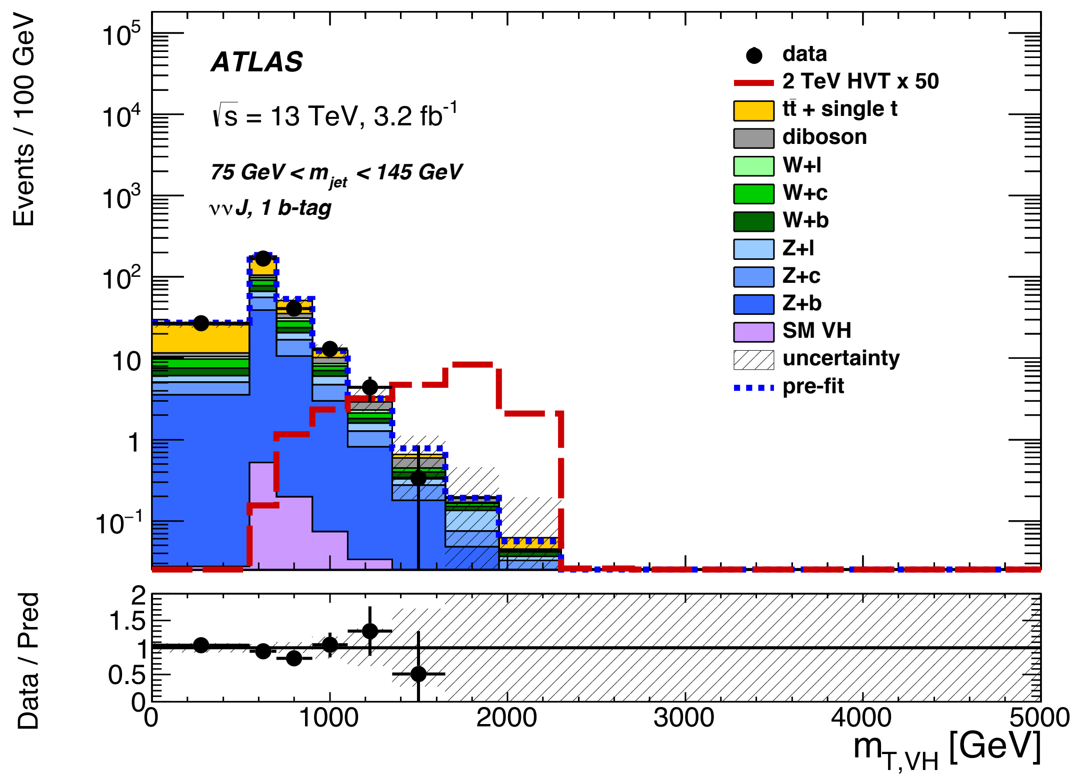
High-mass *HH*: efficiencies



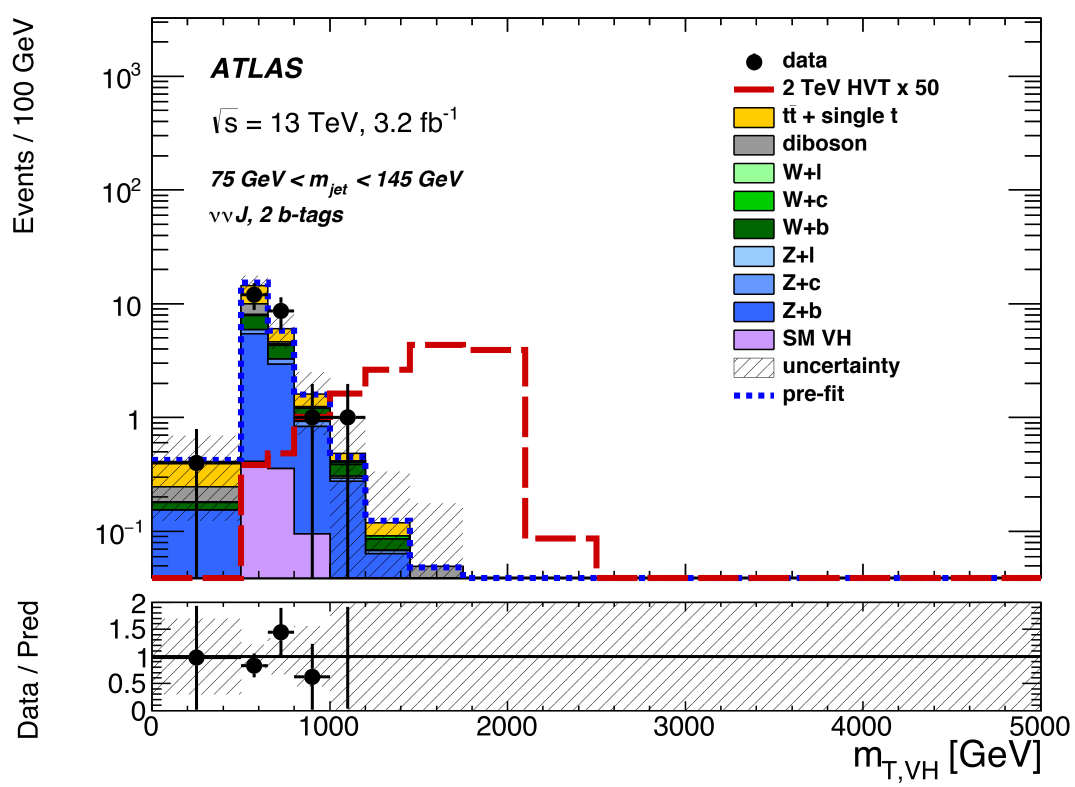


High-mass *VH*: 0 lepton SR

1 *b*-tag

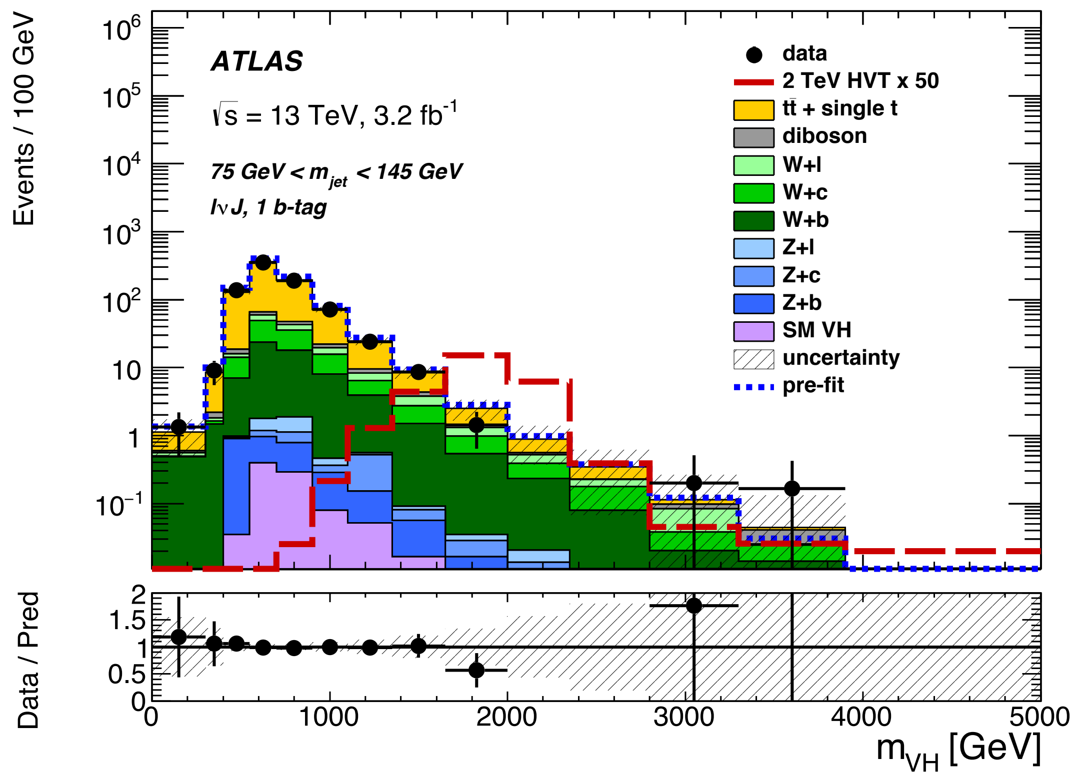


2 *b*-tag

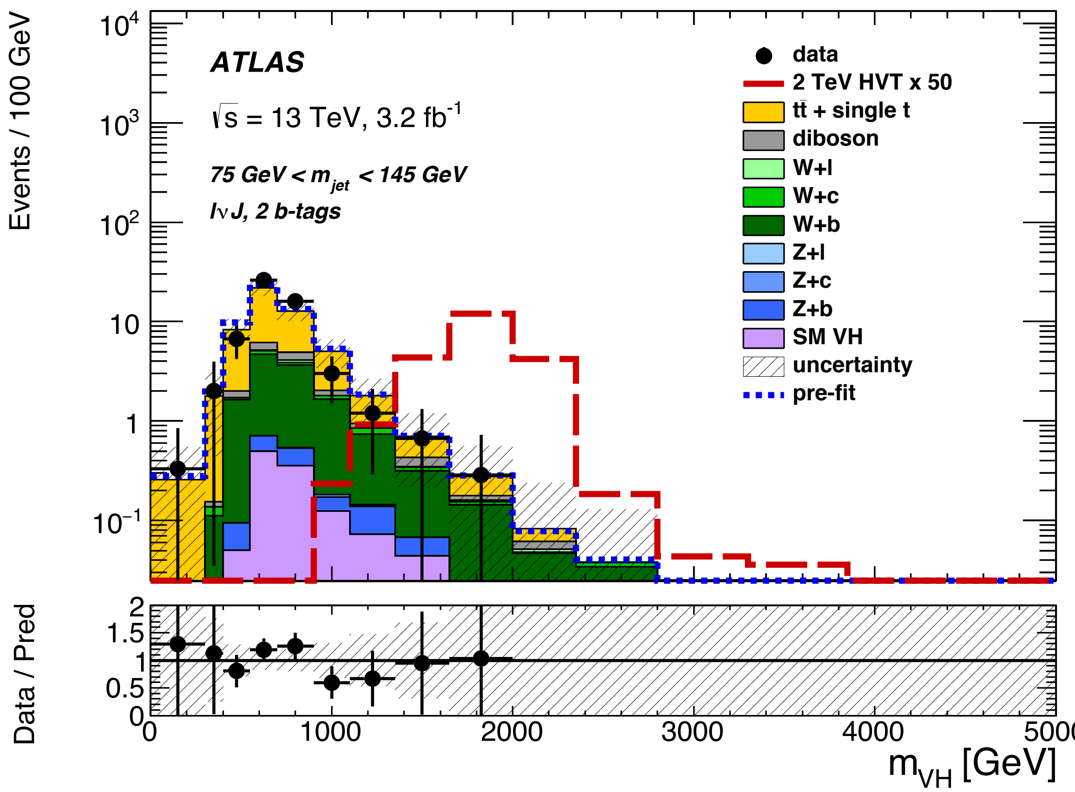


High-mass *VH*: 1 lepton SR

1 *b*-tag

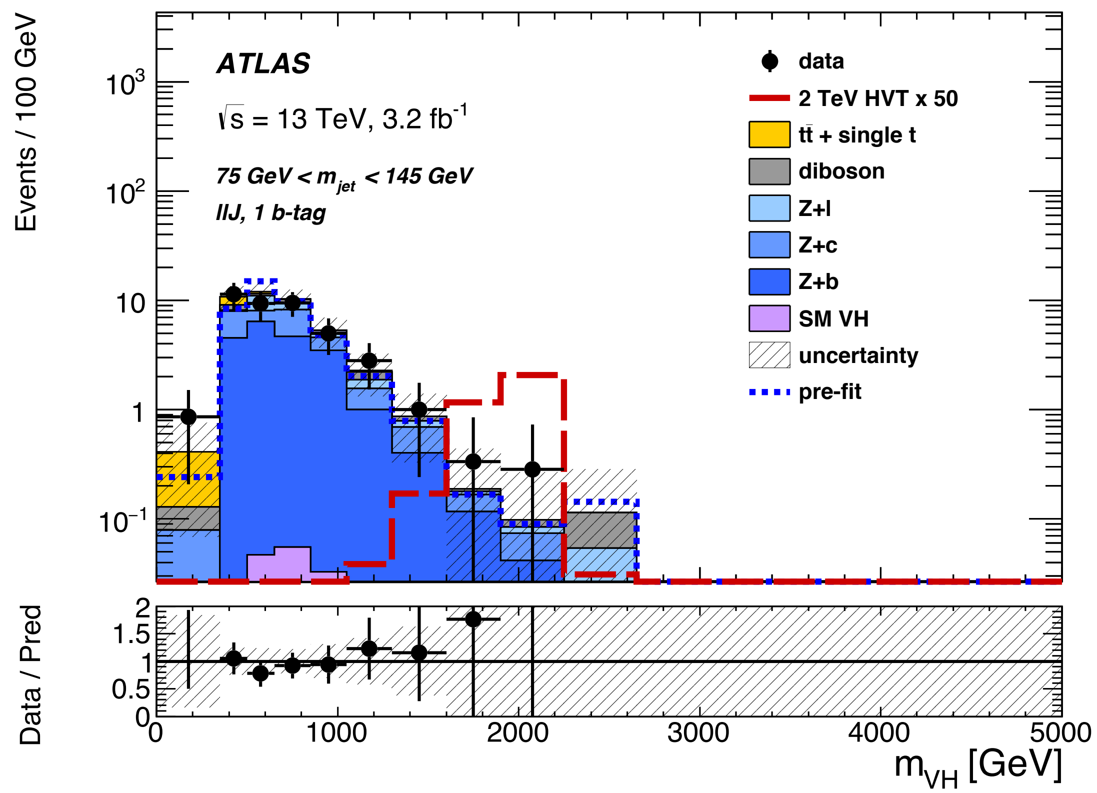


2 *b*-tag

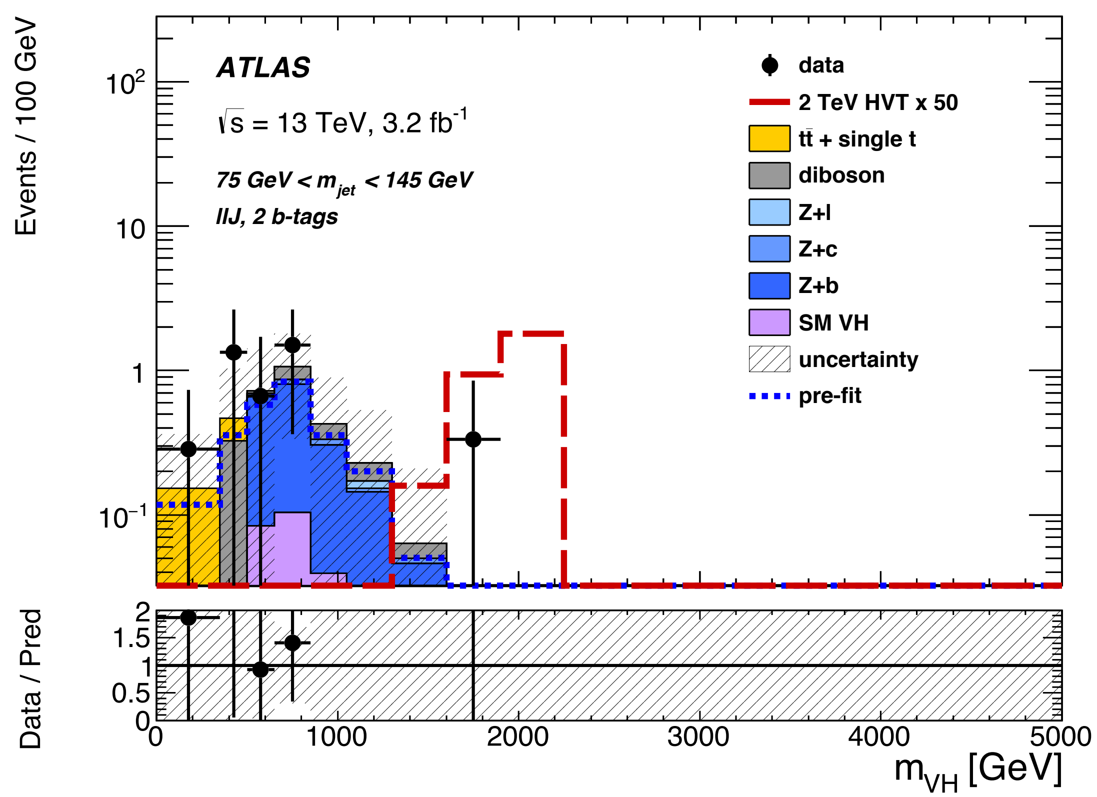


High-mass *VH*: 1 lepton SR

1 *b*-tag



2 *b*-tag



High-mass *VH*: interpretation