Searches for heavy ZZ and ZW resonances in the llqq and ννqq final states in pp collisions at √s = 13 TeV with the ATLAS detector

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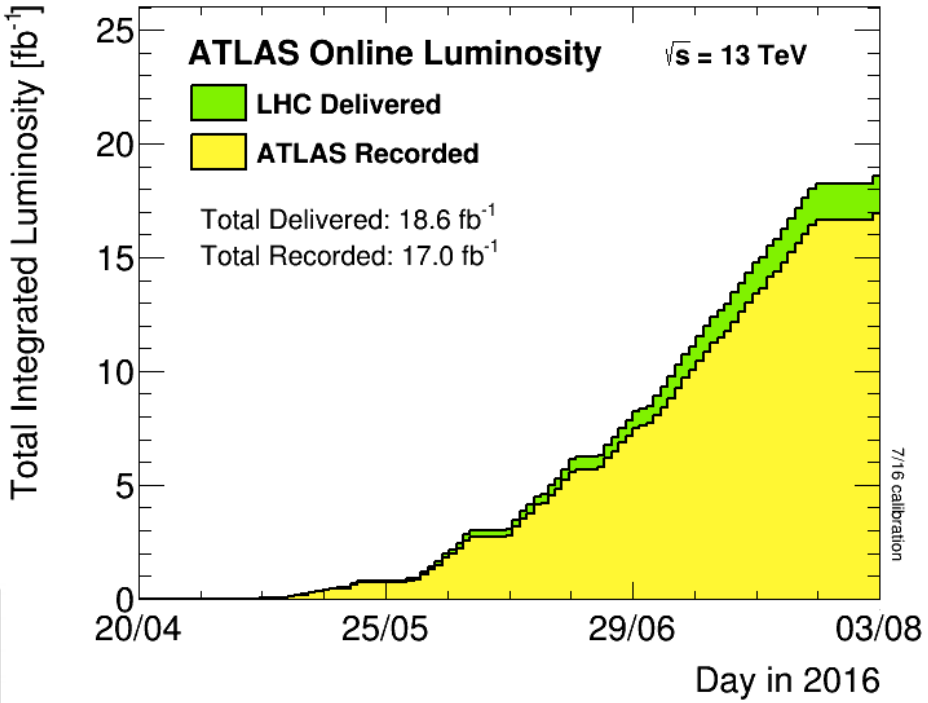
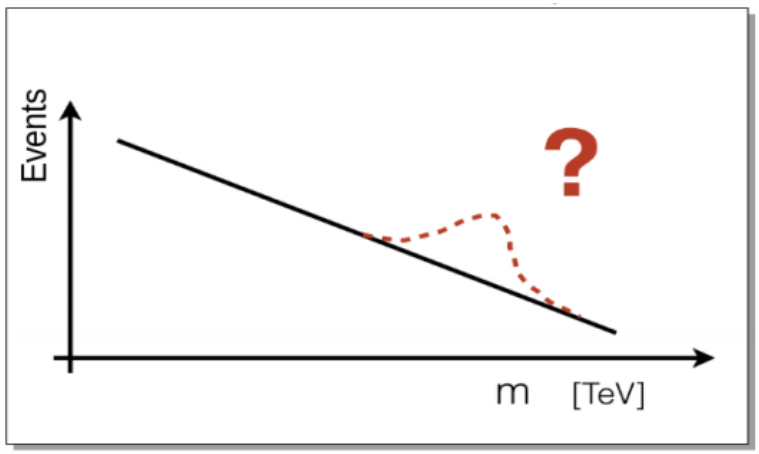
ATLAS Collaboration

Overview

- 2015 and 2016 data at 13TeV
  - 3.2 fb-1 from 2015
  - 10.0 fb-1 from 2016
- Benchmark models
  - spin 0,1,2





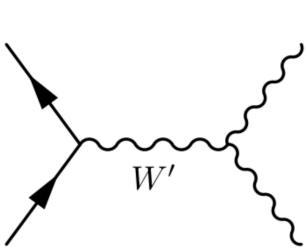
- Results—Pushing Limits

- Strategy – A search for a narrow resonance on smoothly falling background

Benchmark Models

Spin 0, spin 1, spin 2

Heavy Vector Triplet W'

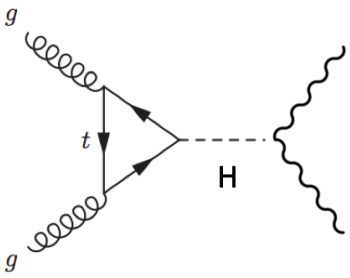


$W \rightarrow$ quarks

σ/m = 2.5%

$Z \rightarrow$ μμ, ee, νν

Heavy Scalar - ggF

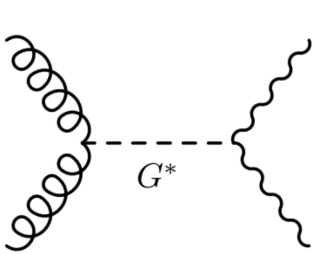


$Z \rightarrow$ quarks

σ/m = ~0%

$Z \rightarrow$ μμ, ee, νν

RS Bulk Gravitons

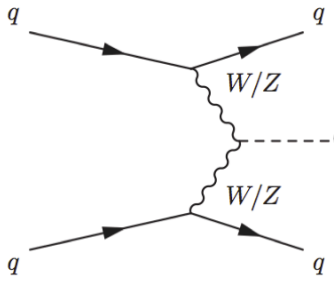


$Z \rightarrow$ quarks

σ/m = 6%

$Z \rightarrow$ μμ, ee, νν

Heavy Scalar – VBF (llqq)



$Z \rightarrow$ quarks

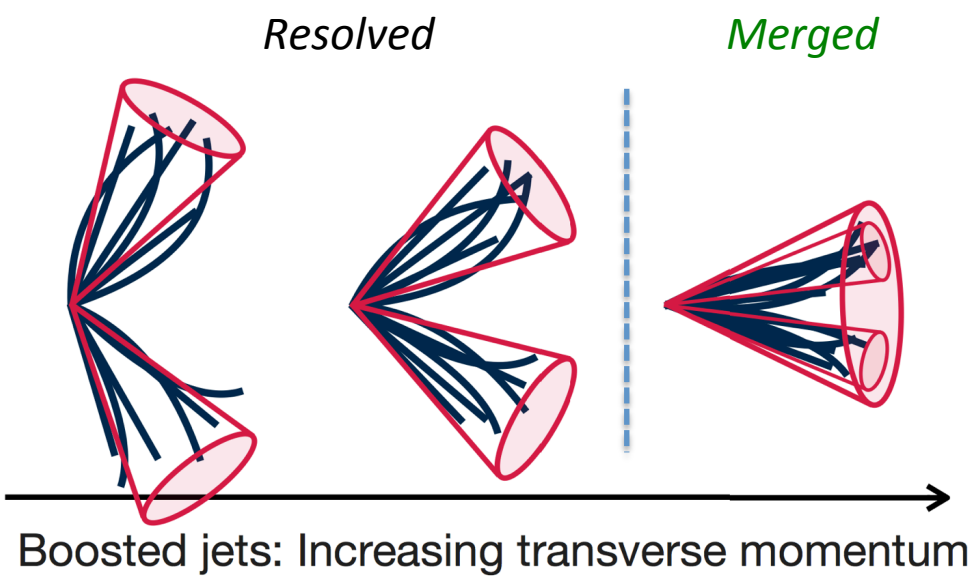
$Z \rightarrow$ μμ, ee

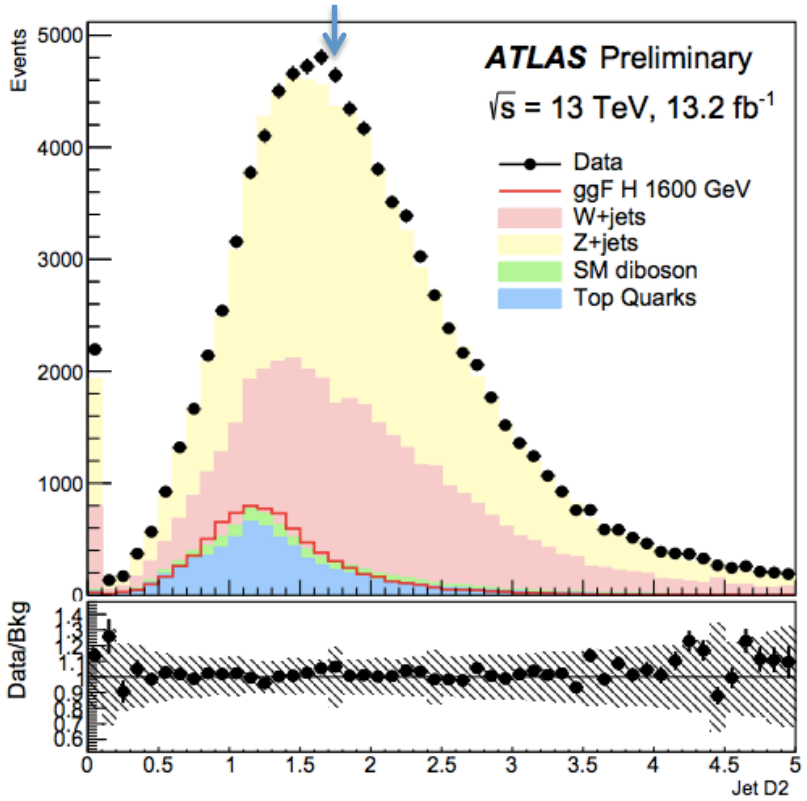
- A search is made for all 3 signals + the VBF production mode in the llqq channel

Treatment of Jets

- One boson decays to 2 jets, the other to leptons or neutrinos
- Regimes of the analyses: resolved vs. merged (high purity vs. low purity)
- Resolved jets: anti-kt R=0.4
- Merged-jets: anti-kt R=1.0, trimmed
  - D2: substructure variable—1 vs. 2-pronged jet

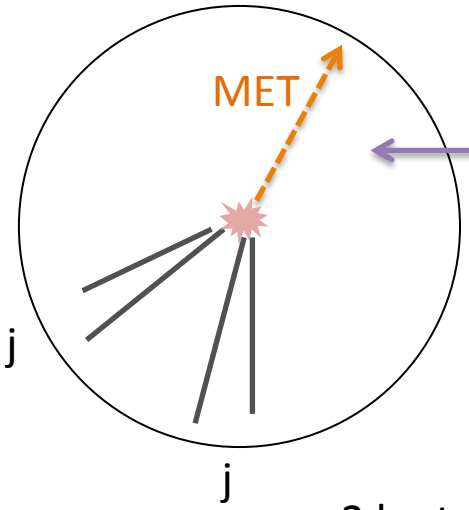
Cut: 50% eff. pT-dependent with a mass window





Strategy

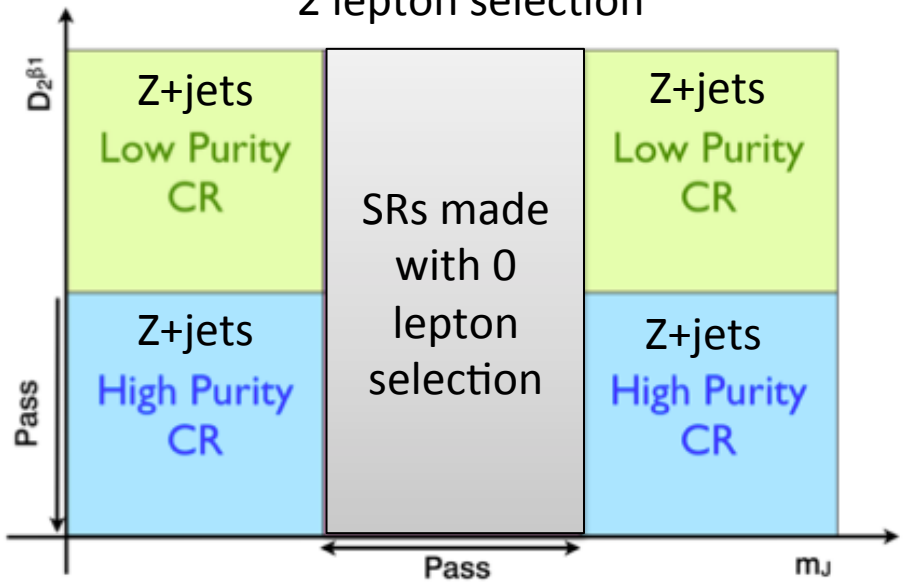
vvqq



Signal: 0 leptons

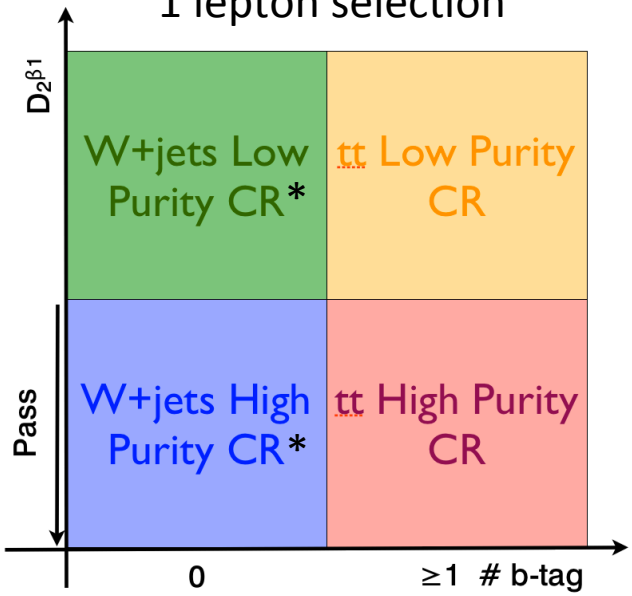
- Merged (high purity / low purity)
- Major backgrounds are W+jets, Z+jets, and $t\bar{t}$
- For each a control region to determine their normalization for data
- CRs have 2 leptons (Z) and 1 lepton (W, $t\bar{t}$)

2 lepton selection



+

1 lepton selection



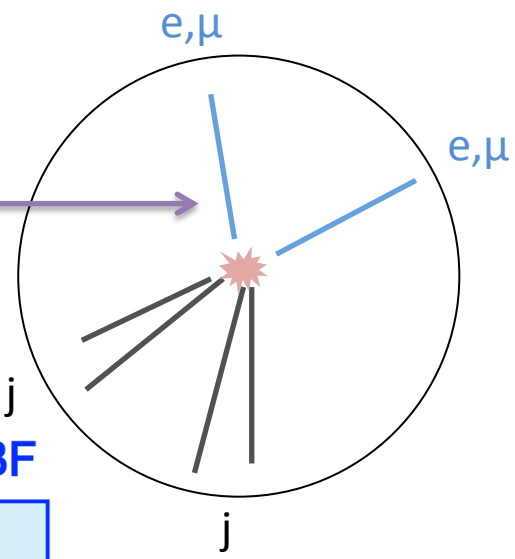
* + inverted W mass cut

The fit is made to all SRs and CRs simultaneously.

Strategy

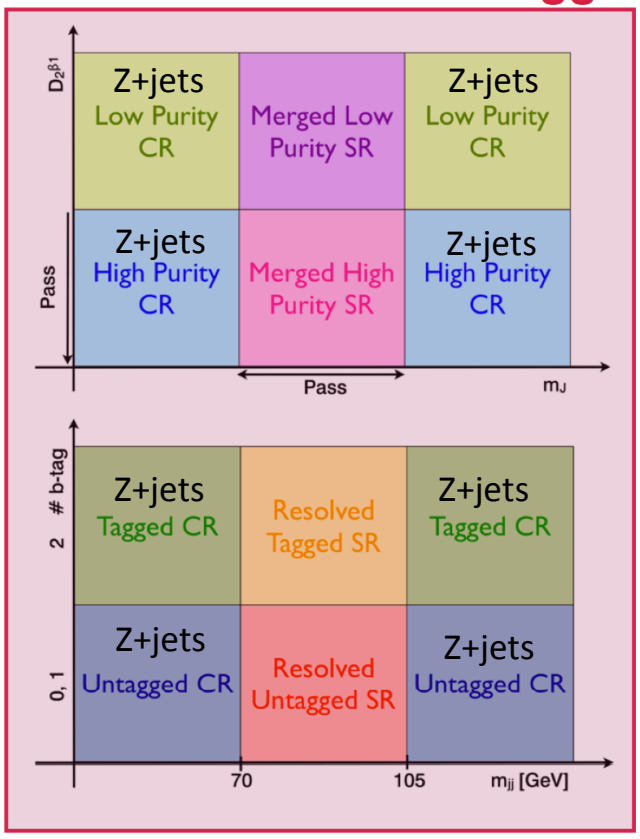
llqq

Signal: 2 leptons



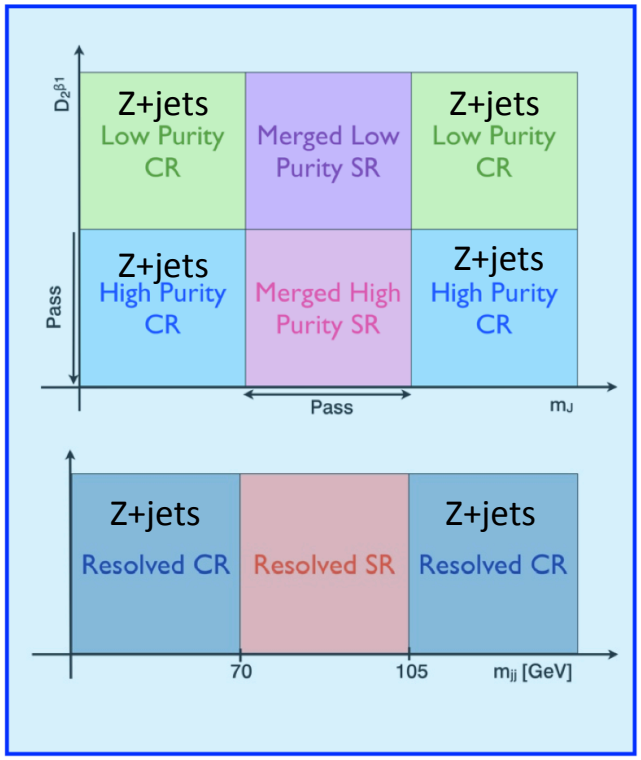
- Resolved jets (b-tagged/ untagged)
- Merged (high purity / low purity)
- Major background is Z+jets – mass window inversion

ggF



+

VBF



+

Top CR

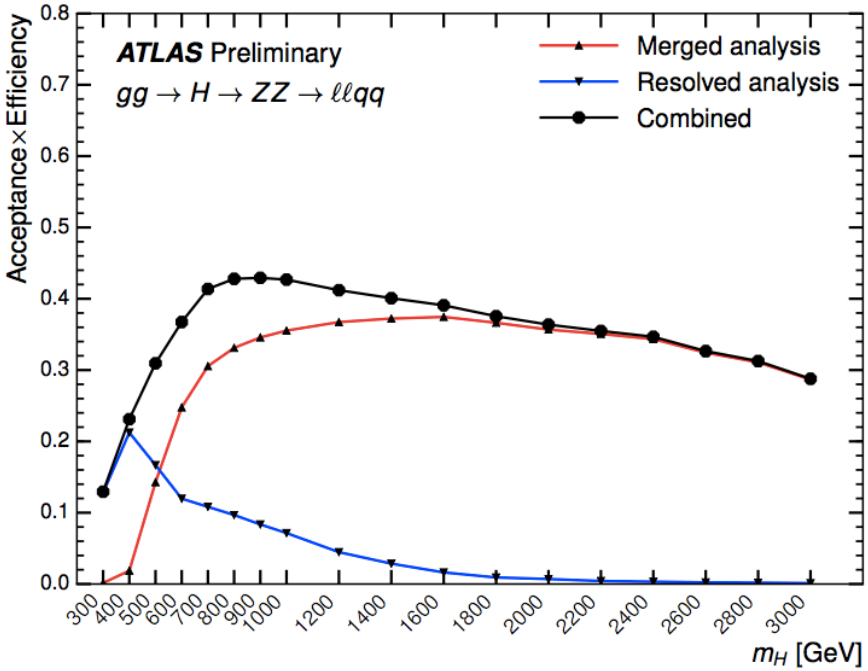
- VBF selection
  - tag 2 additional jets
  - $m_{jj} > 610$
  - $d\eta_{jj} > 3.1$

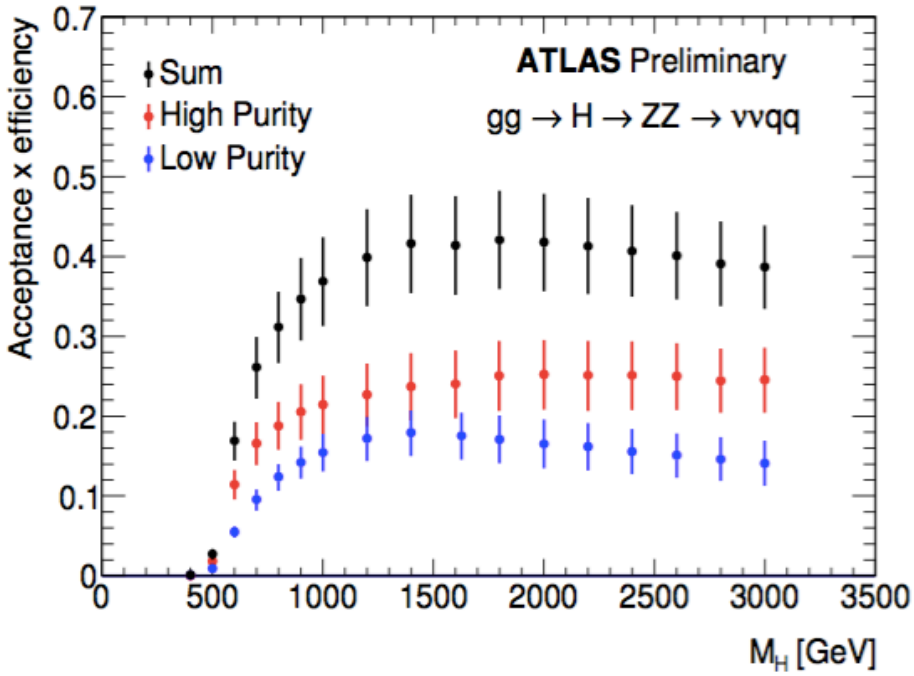
Selection
Signal Efficiency

- *Broadly speaking:* analysis designed for maximal signal efficiency
- Signal efficiency: cross-over from resolved to merged analysis at 600 GeV

Leading systematics

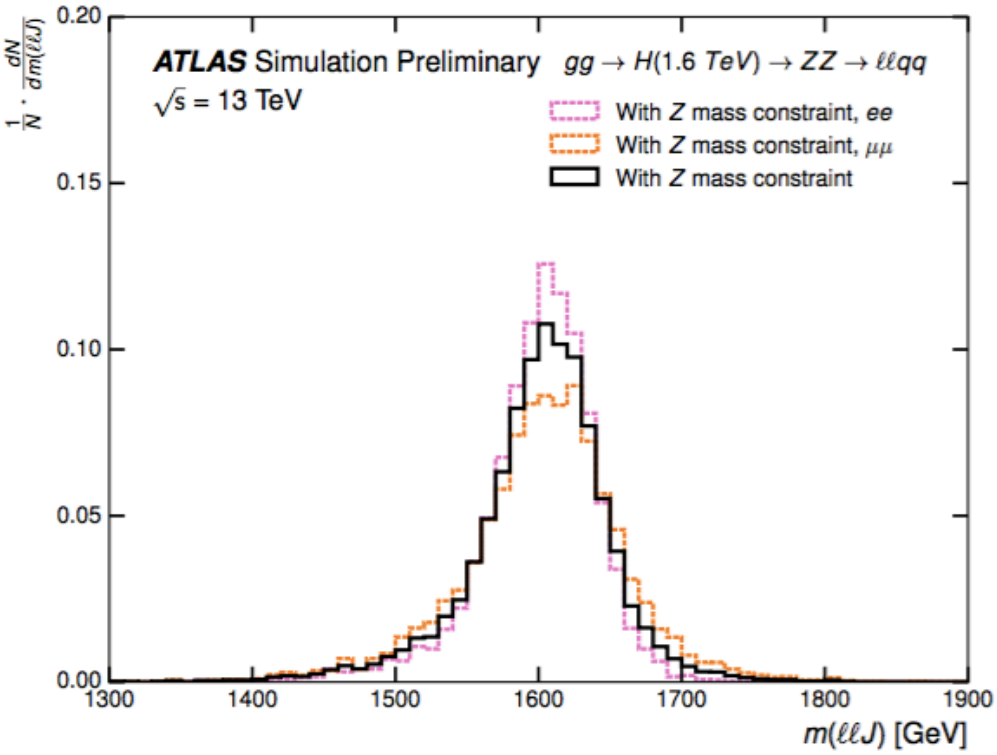
Large-R jet resolutions, scale, and background modeling





Selection
Aside on optimization

- Split the analyses: merged/resolved, b-tagged/untagged, high/low-purity
- General goal: Achieve maximal sensitivity across broad mass range
  - *Design pT-flat objects*: flavor tagging, boosted jet boson tagging
  - We use a *pT-dependent mass window* for Z →μμ to compensate for poor μ-resolution at high pT
  - *Z-mass constraint*: "one easy trick for significance that backgrounds hate"
    - scale Z_{pT}^{reco} by $Z_{m}^{nominal}/Z_{m}^{reco}$
    - Works where angular resolution is good and pT poor: i.e boosted Z →μμ
    - Brings μμ channel resolution on par with ee in high mass:

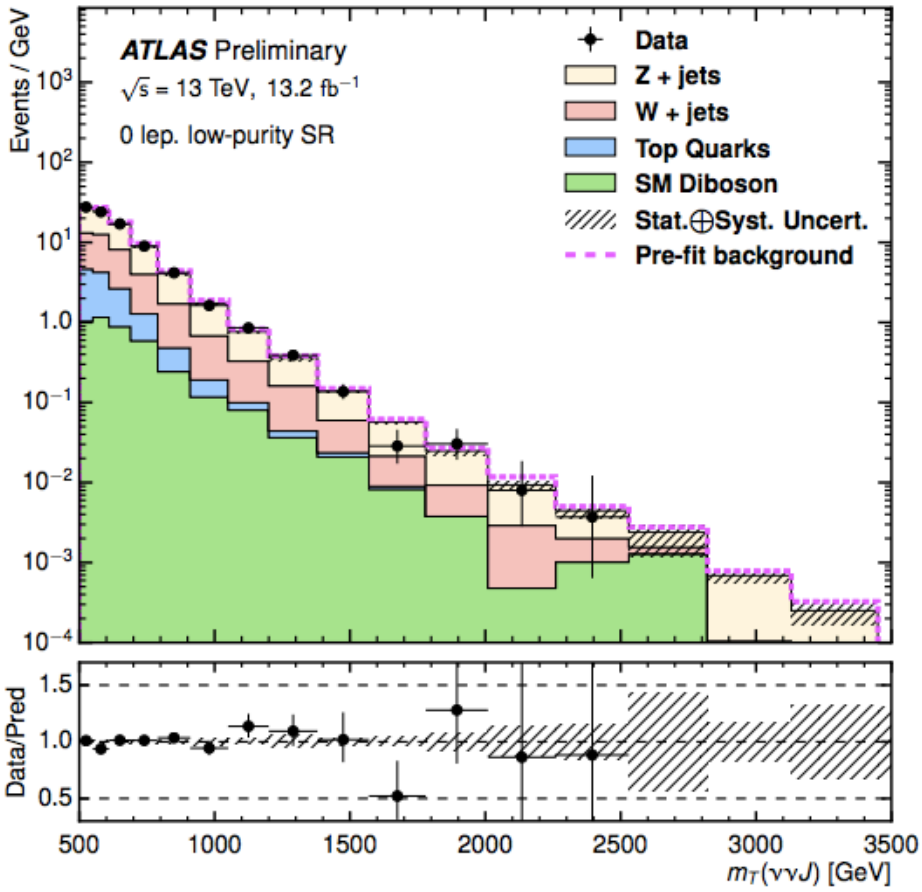


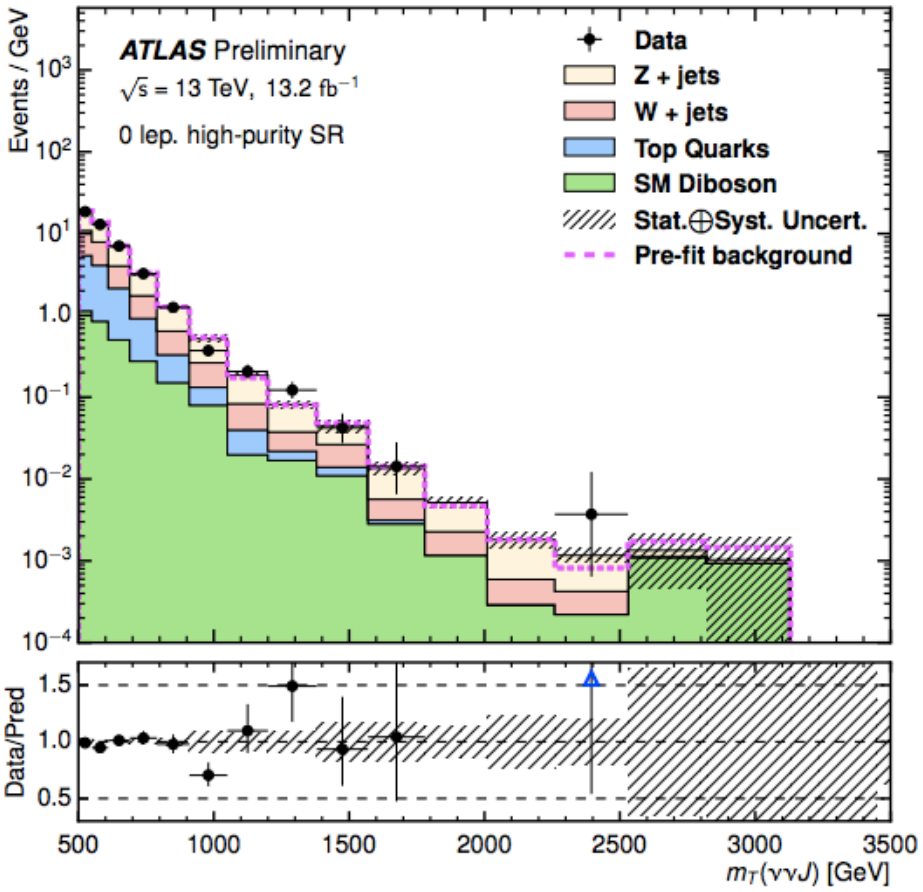
Signal Regions

vvqq

Final discriminant transverse mass $m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T},J} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\vec{p}_{\mathrm{T},J} + \vec{E}_{\mathrm{T}}^{\mathrm{miss}})^2}$

- Shape and magnitude well-fit

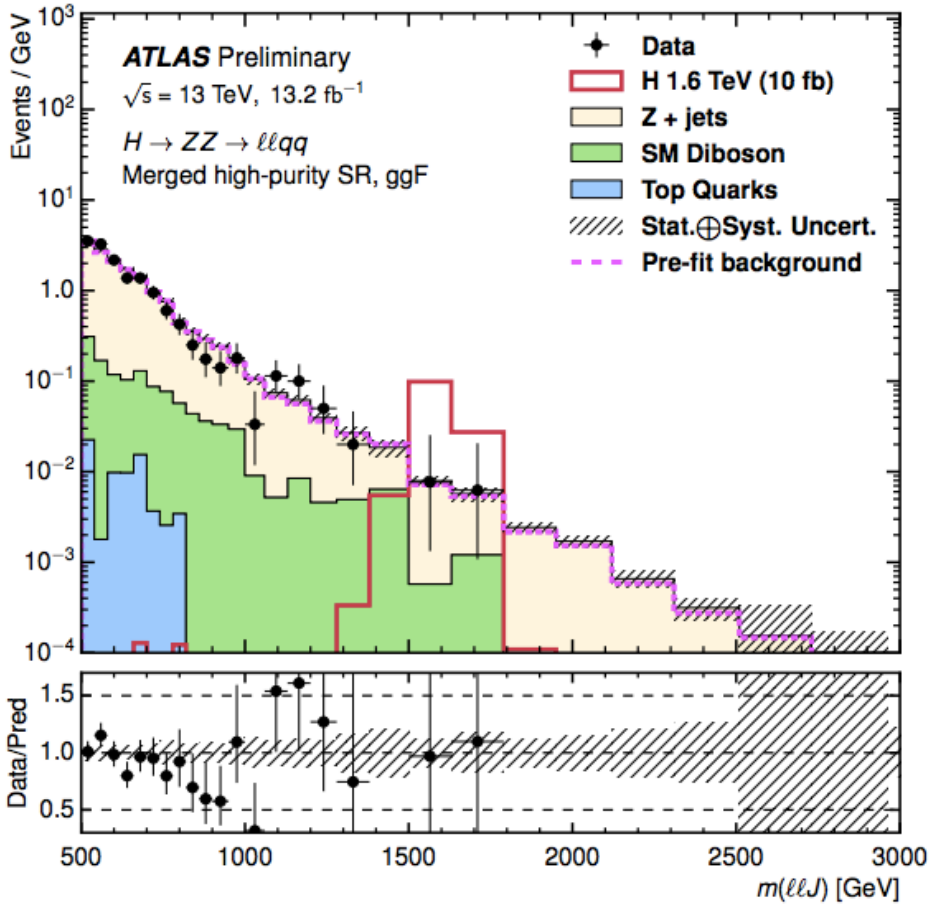


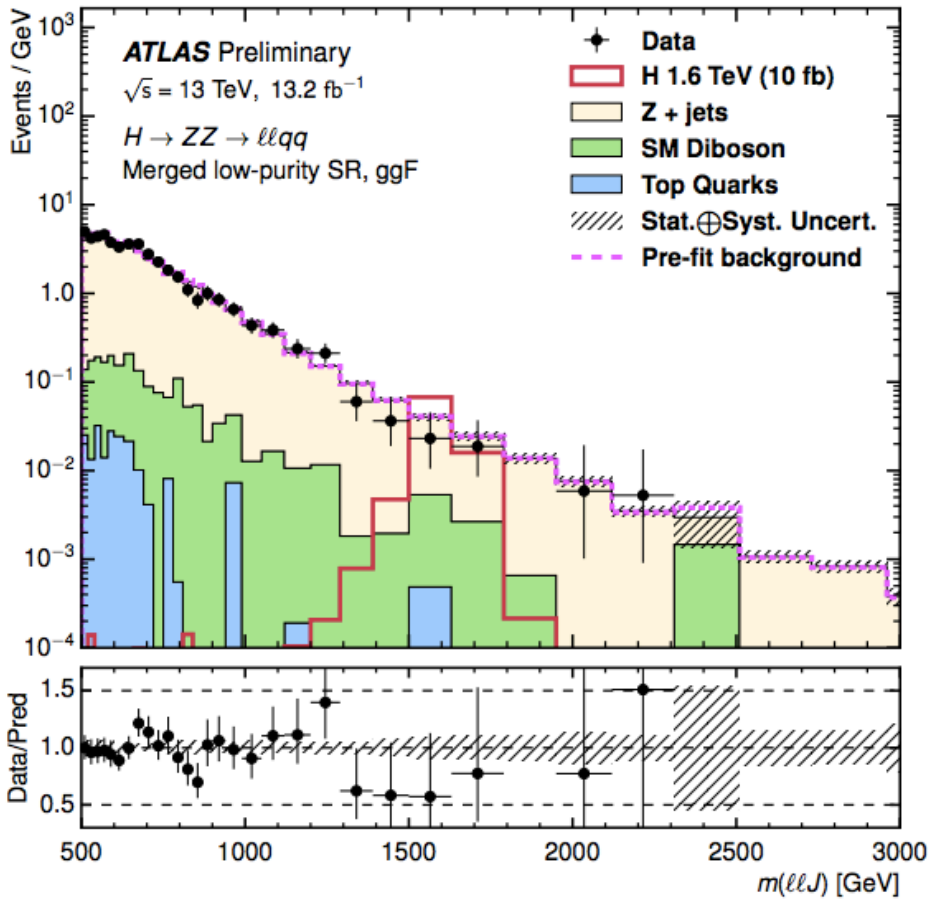


Signal Regions
llqq Merged

Final discriminant 3-body mass: llJ

- Shape and magnitude well-fit



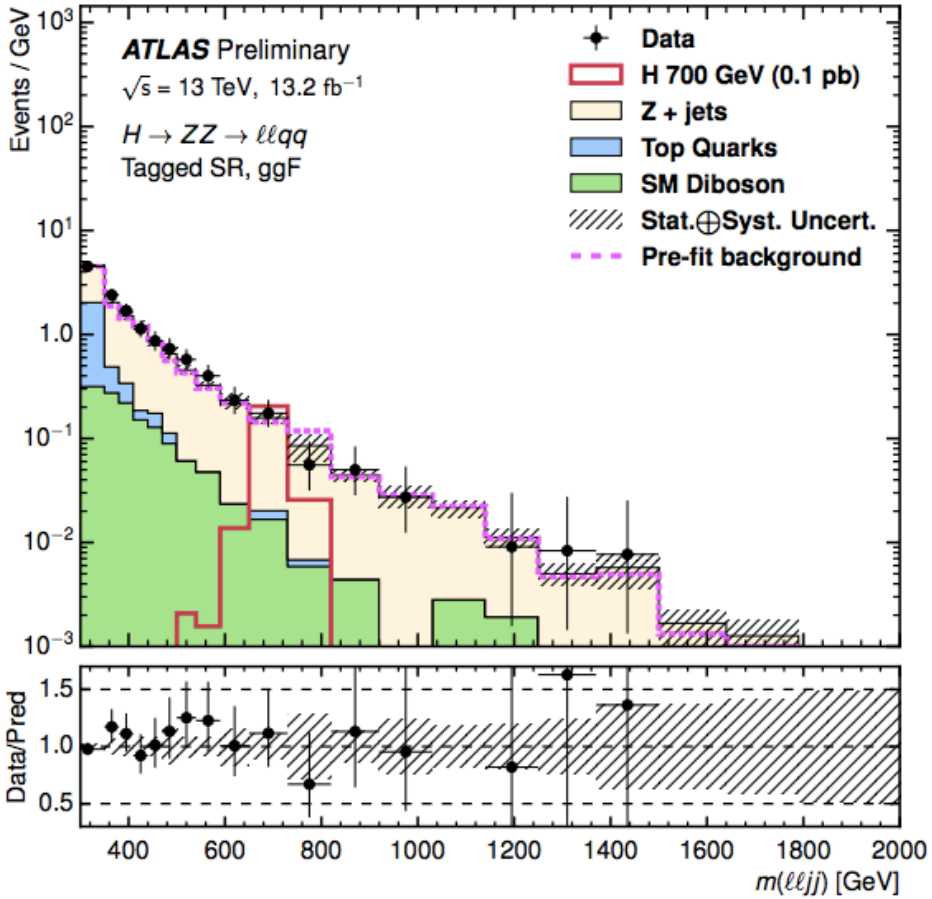


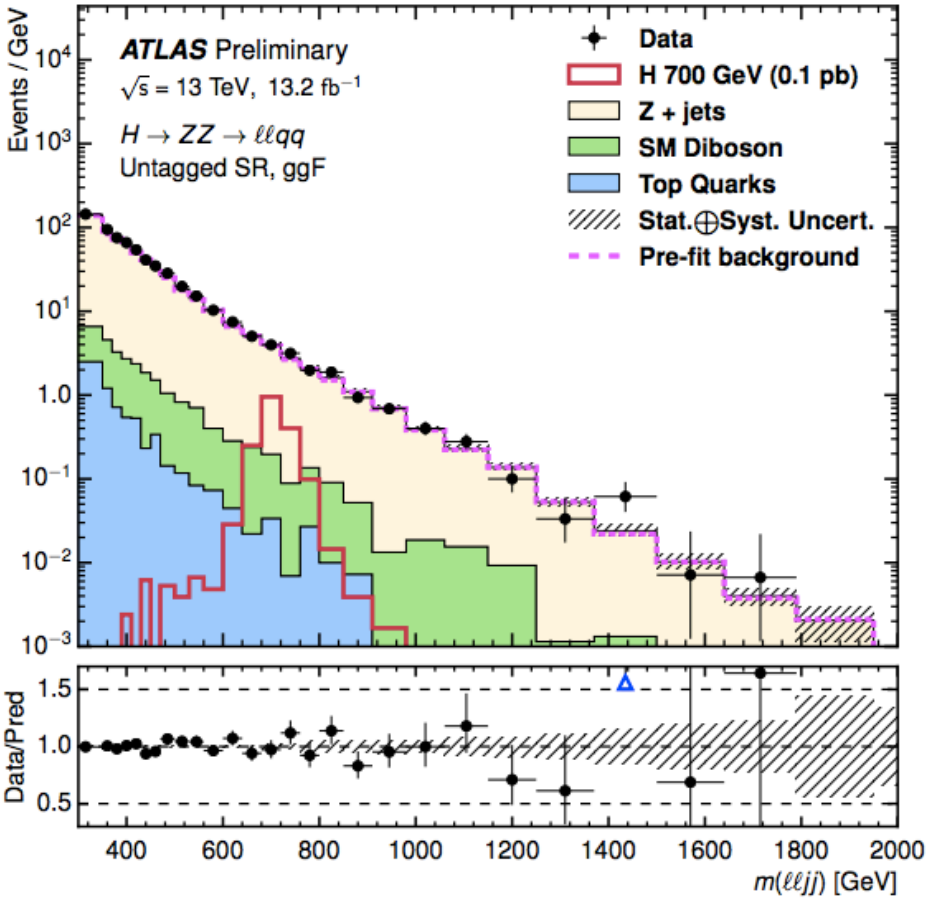
Signal Regions
llqq Resolved

No smoking gun!

Final discriminant 4-body mass: lljj

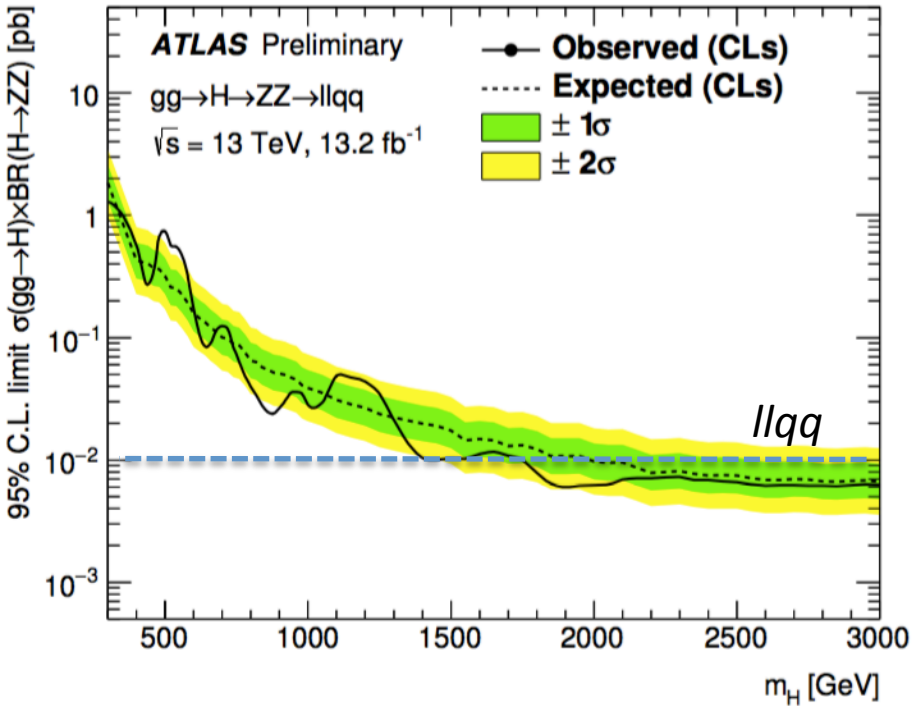
- Shape and magnitude well-fit
- In all searches the MC cross sections controlled within 10% of their nominal value and ~1σ

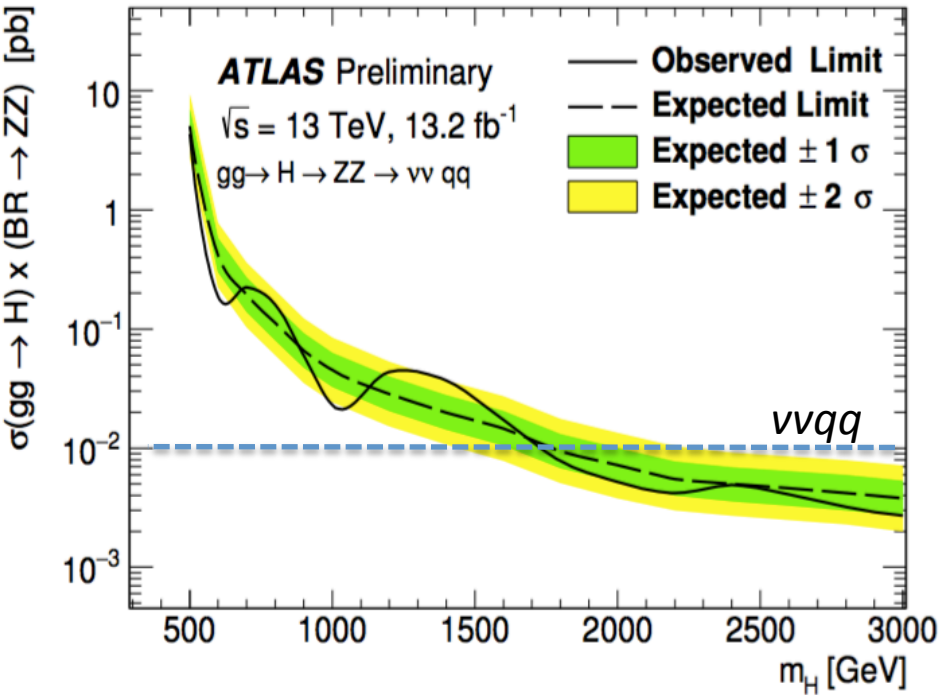




Limits and Conclusions
vvqq and llqq

- Limits set for a heavy narrow width Scalar/Higgs.
- llqq: Largest excess at 500 GeV with
  - *local significance: 2.7σ*
  - *global significance: 1.4σ*



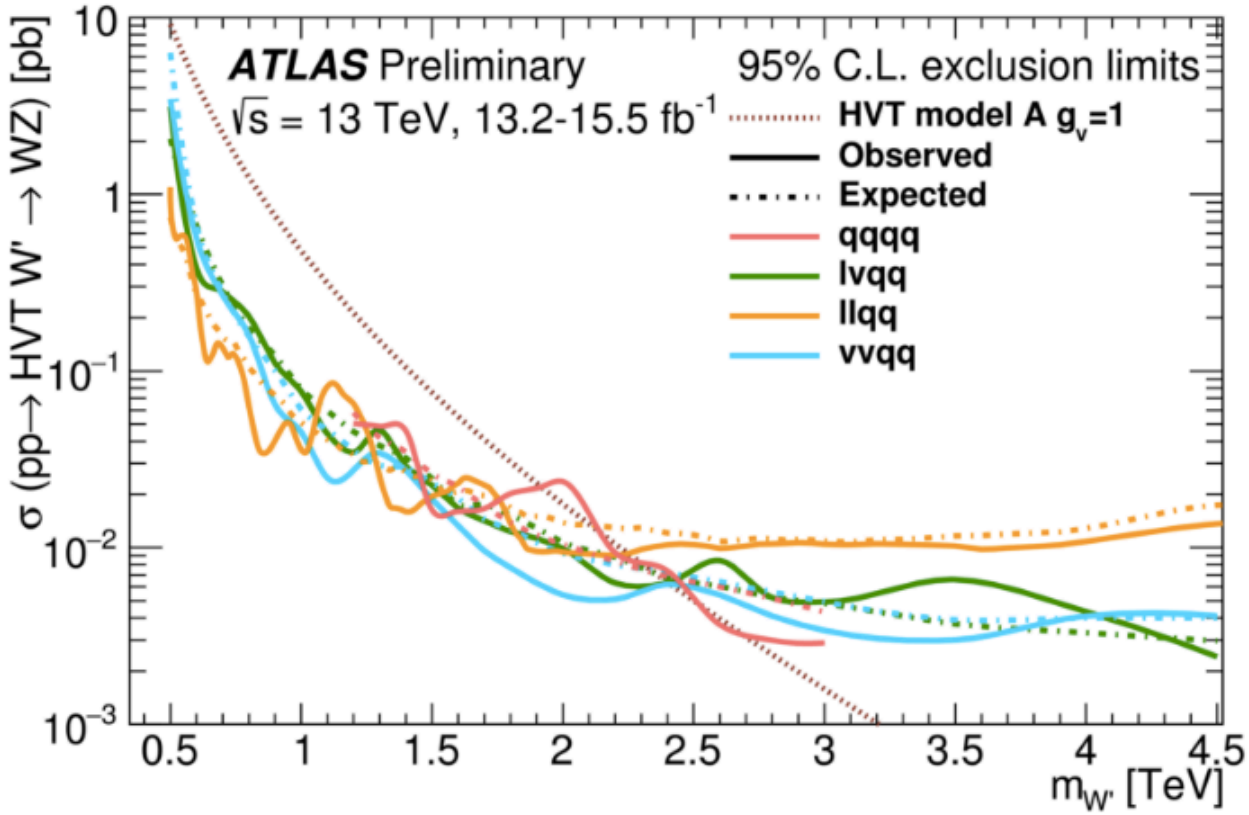


Limits and Conclusions

HVT limits in context

- Limits set per channel. Some features...but none in common.
- Awaiting combination with many other channels.
- Expecting to double the data in the coming months.

Excluded	llqq	vvqq
HVT	2225 GeV	2400 GeV
Graviton	1035 GeV	1100 GeV



Thanks for listening!

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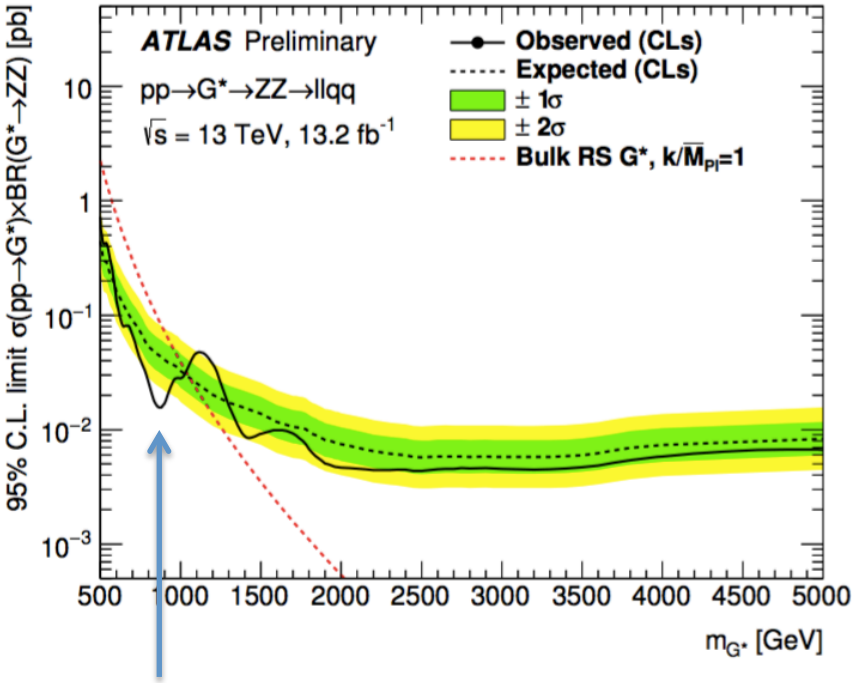
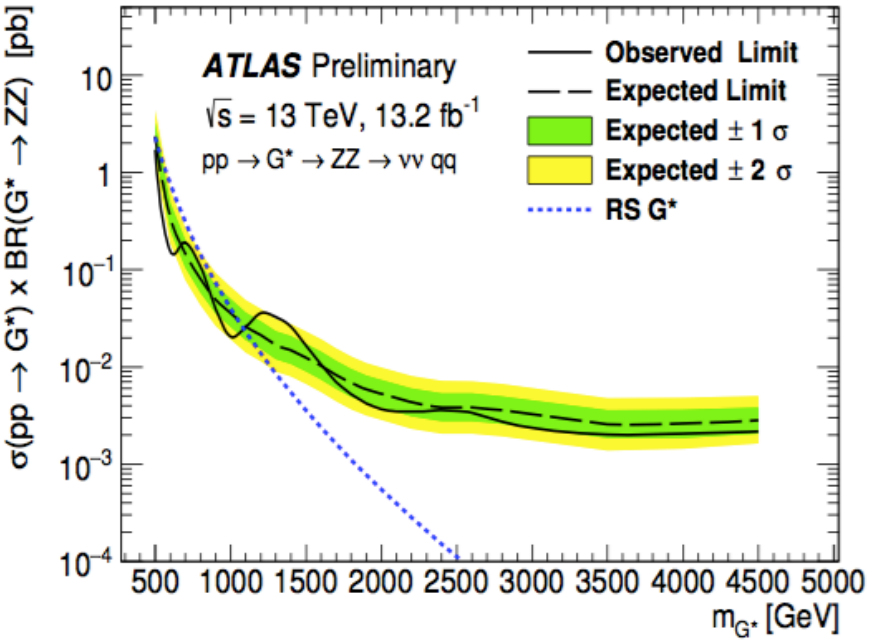
4th August 2016

Backup

Graviton
Limits

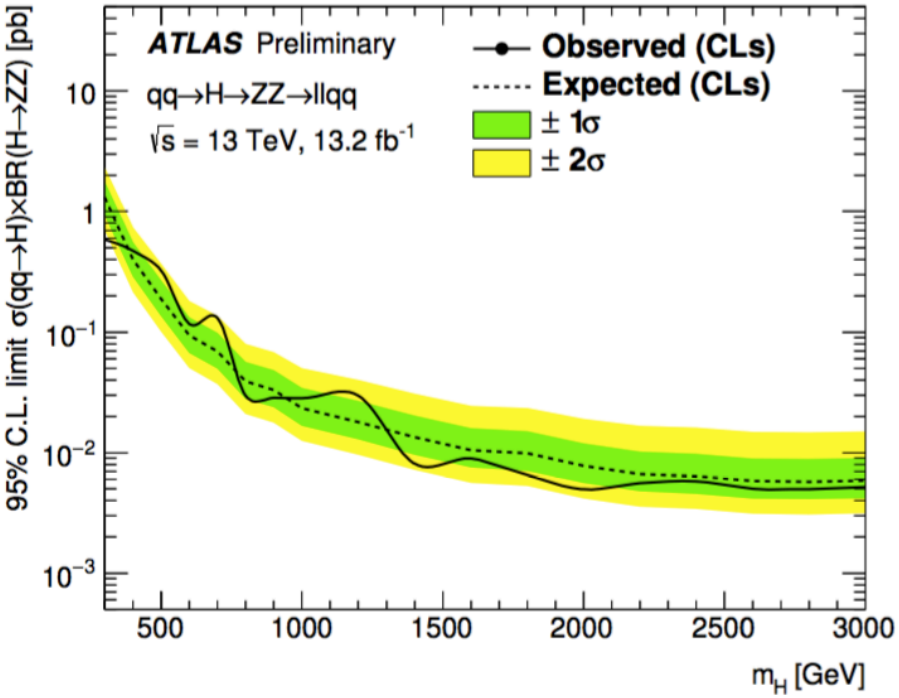




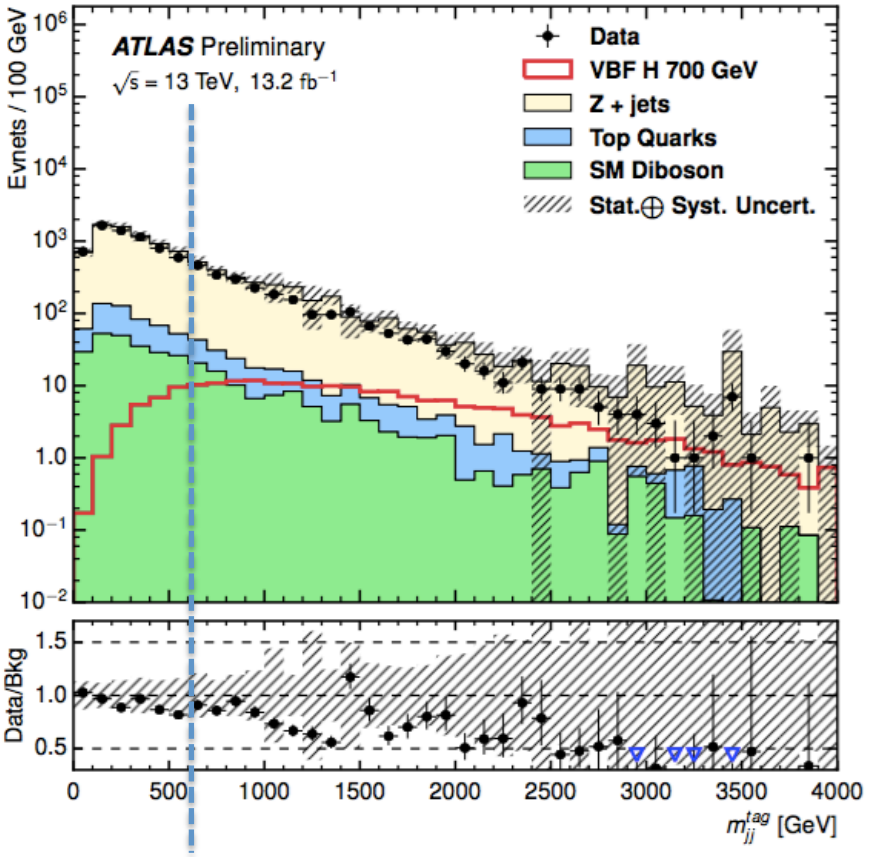
Deficit: global 2.8σ

VBF

Limit



Selection



Uncertainties
Systematics

- Both analyses dominated by boosted jet systematics uncertainties
- Jet resolution: mass, D2, energy
- Boson-tagging and jet scale: mass, energy, D2

Modeling

- llqq—maps data-mc differences in ZCR to SR as a NP
- vvqq—varies generator-level quantities in Sherpa