



# **$(X \rightarrow)hh \rightarrow 4b$ in ATLAS**

## **Run 1 result and Run 2 prospects**

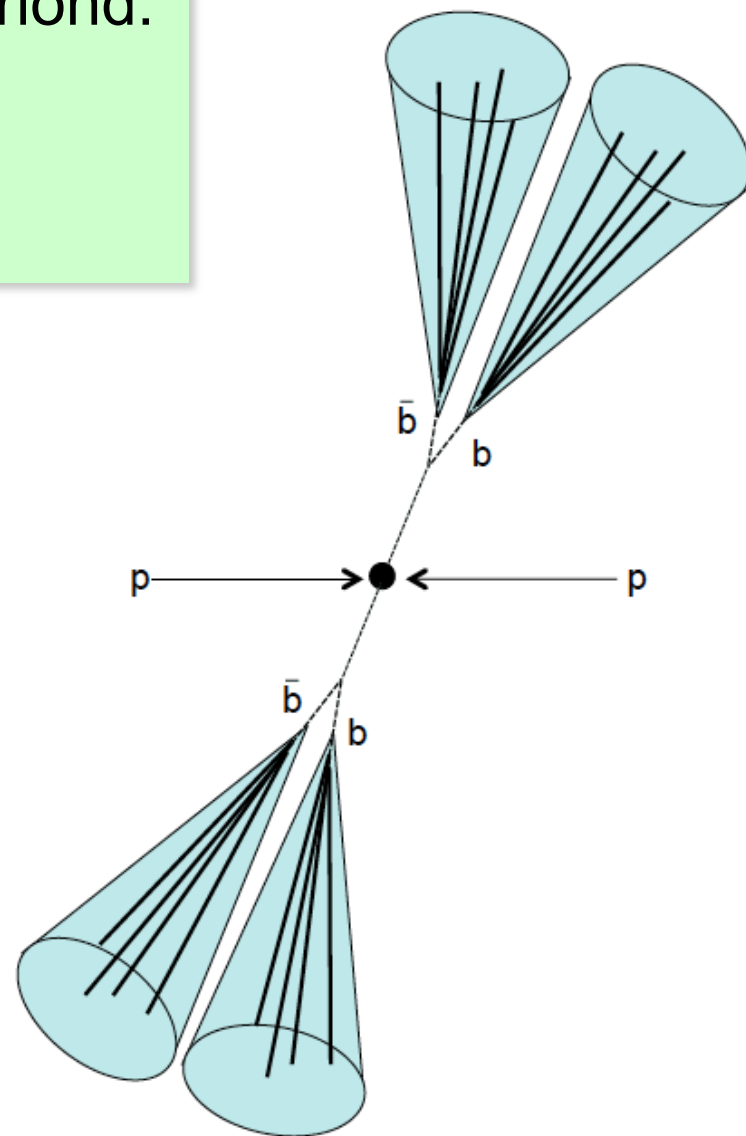
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LHCXSWG, 08/12/2014



$X \rightarrow HH \rightarrow bbbb$  preliminary result for Moriond:

ATLAS-CONF-2014-005



## $X \rightarrow HH \rightarrow bbbb$ candidate preselection:

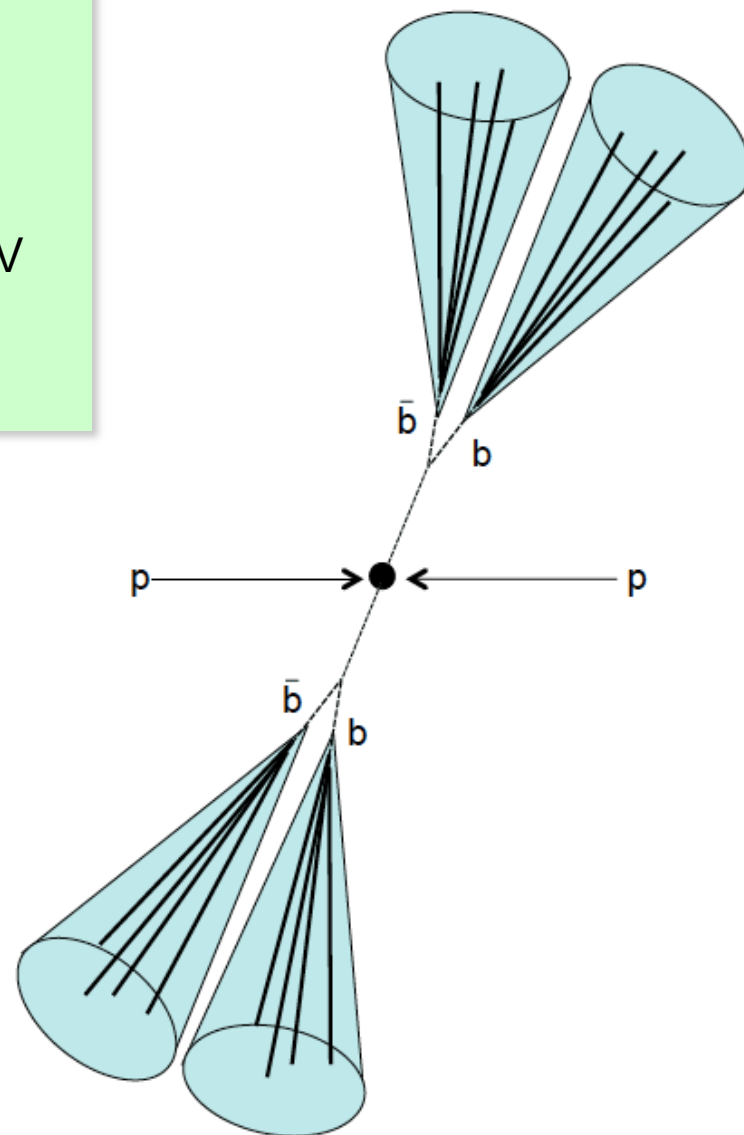
- Trigger: 5 jet triggers with online b-tagging
  - Trigger efficiency >99.5%
- 4 b-tagged anti- $k_t$   $R=0.4$  jets with  $|\eta| < 2.5$ ,  $p_T > 40 \text{ GeV}$
- Two dijets with  $\Delta R(\text{jet}, \text{jet}) < 1.5$ ,  $p_T > 200 \text{ GeV}$

## In addition:

- ttbar veto: 
$$X_{tt} = \sqrt{\left(\frac{m_W - 80.4}{0.1m_W}\right)^2 + \left(\frac{m_t - 172.5}{0.1m_t}\right)^2} > 3.2$$

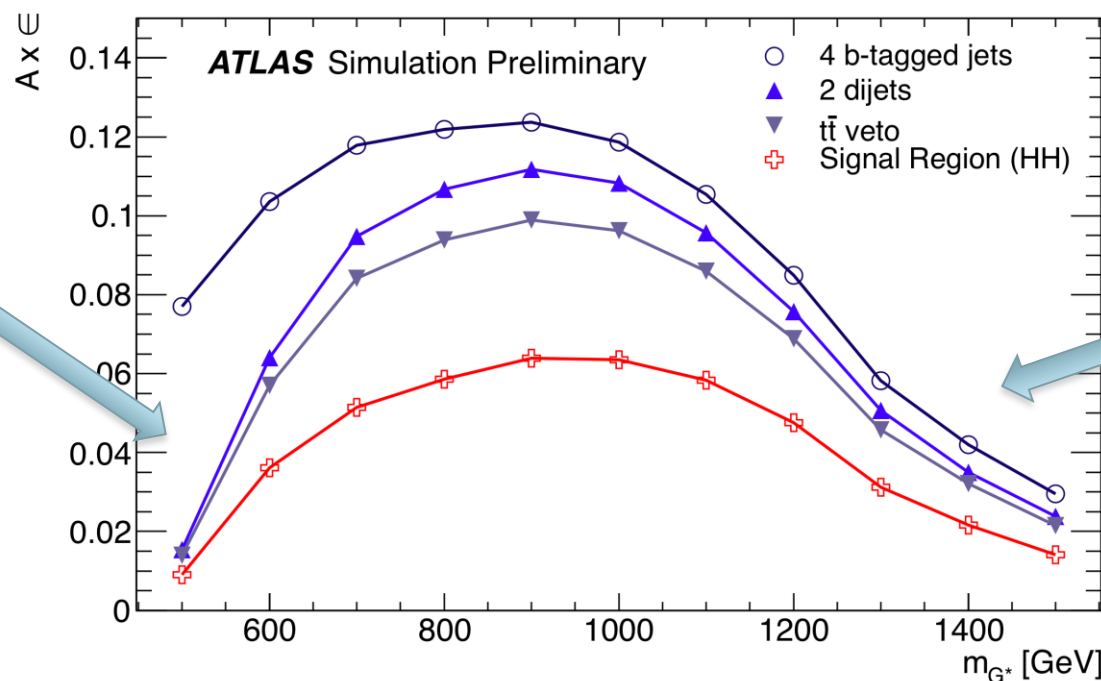
- HH signal region: 
$$X_{HH} = \sqrt{\left(\frac{m_1 - 124}{0.1m_1}\right)^2 + \left(\frac{m_2 - 115}{0.1m_2}\right)^2} < 1.6$$

Background: QCD multijets (~90%) and tt (~10%)



Used bulk Randal-Sundrum graviton  $G^*$  (spin=2)  
(CP3-Origins implementation) simulated with Madgraph+Pythia8

- $\text{BR}(G^* \rightarrow HH) \sim 7\%$
- Coupling  $k/\bar{M}_{\text{Pl}} = 1.0$  (as in ATLAS  $G^* \rightarrow ZZ/WW \rightarrow llqq/lvqq$  searches)
- Decay width smaller than detector resolution



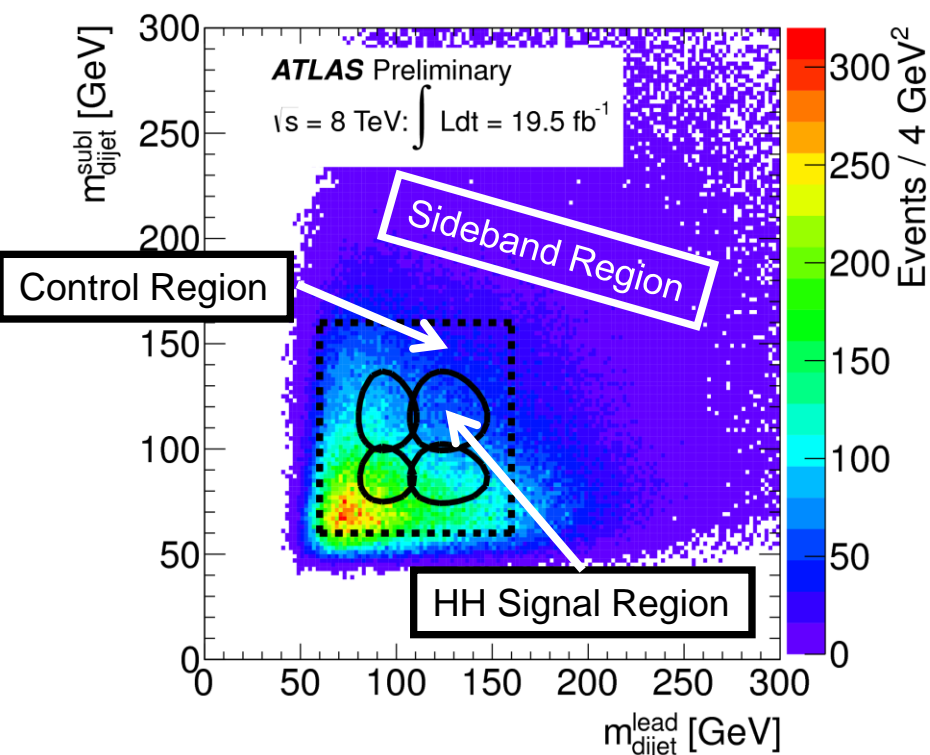
Efficiency drop due to kinematic selection

Efficiency drop due to merging of jets



## Data-driven estimation of QCD bkg:

- Use events where only one of the two dijets is required to be b-tagged (2-tag model)
- “2-tag to 4-tag” normalization estimated from sideband region, validated in control region and applied to HH signal region

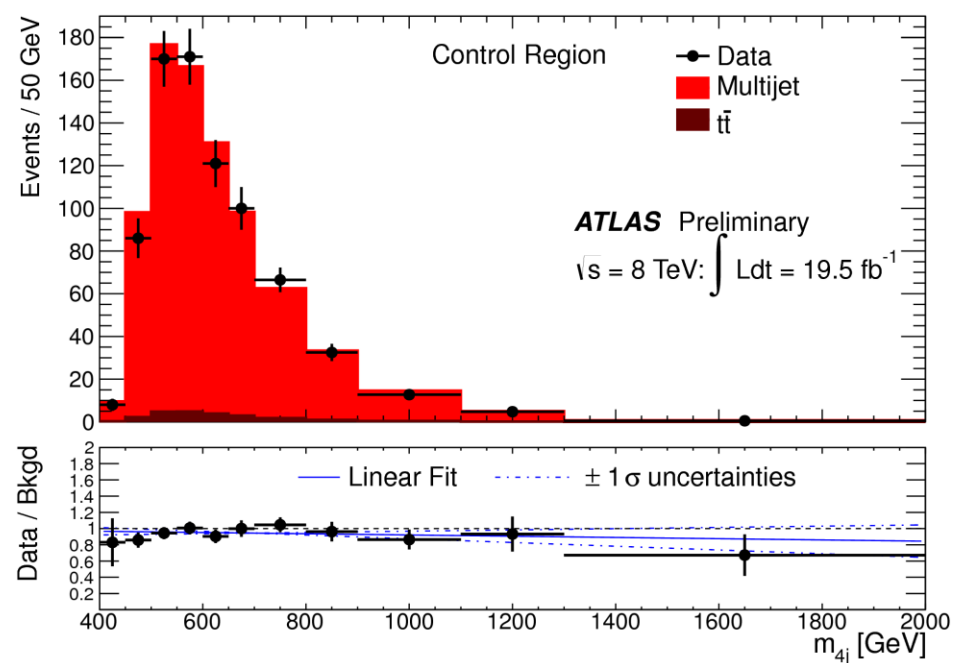
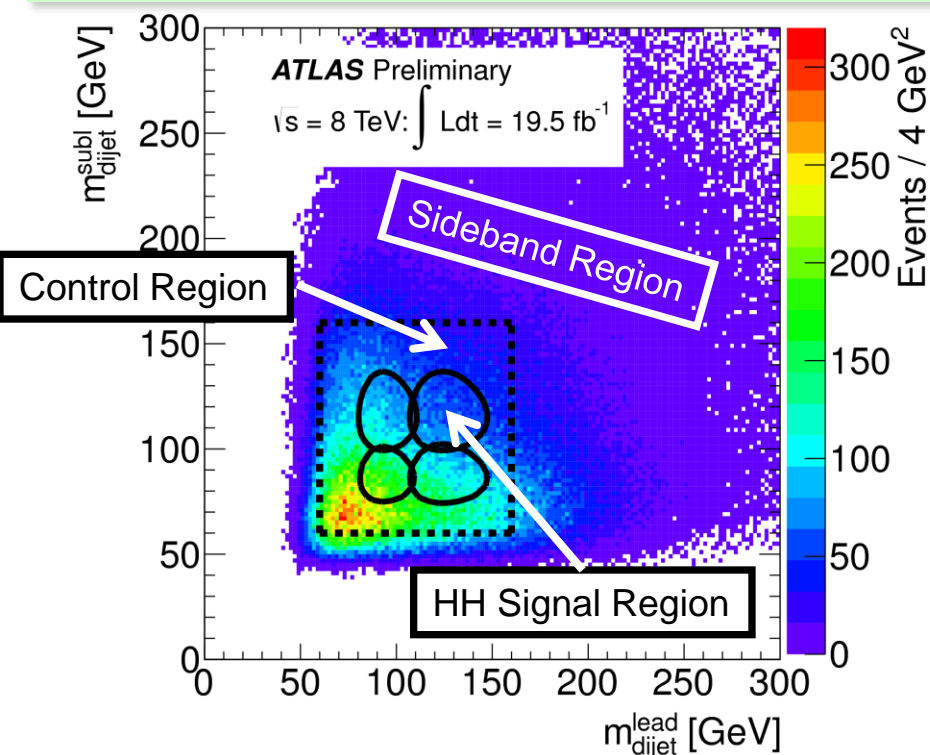


Type	Sideband Region	Control Region
Multijet	$903 \pm 3$	$935 \pm 3$
$t\bar{t}$	$19.0 \pm 0.2$	$26.7 \pm 0.3$
Z+jets	$11 \pm 1$	$17 \pm 1$
Total Bkgd	$933 \pm 3$	$979 \pm 3$
4-tag Data	933	933

Difference taken as systematic uncertainty on QCD normalization

## Data-driven estimation of QCD bkg:

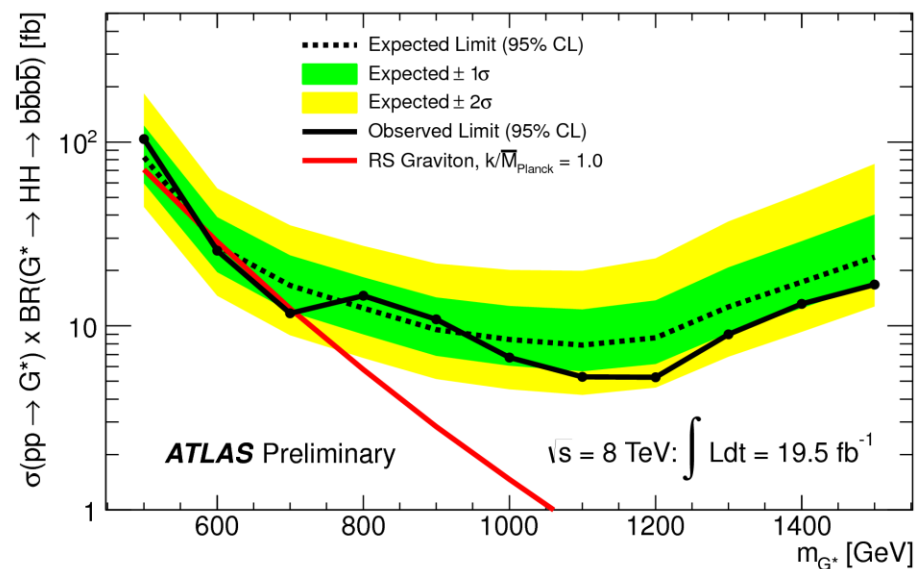
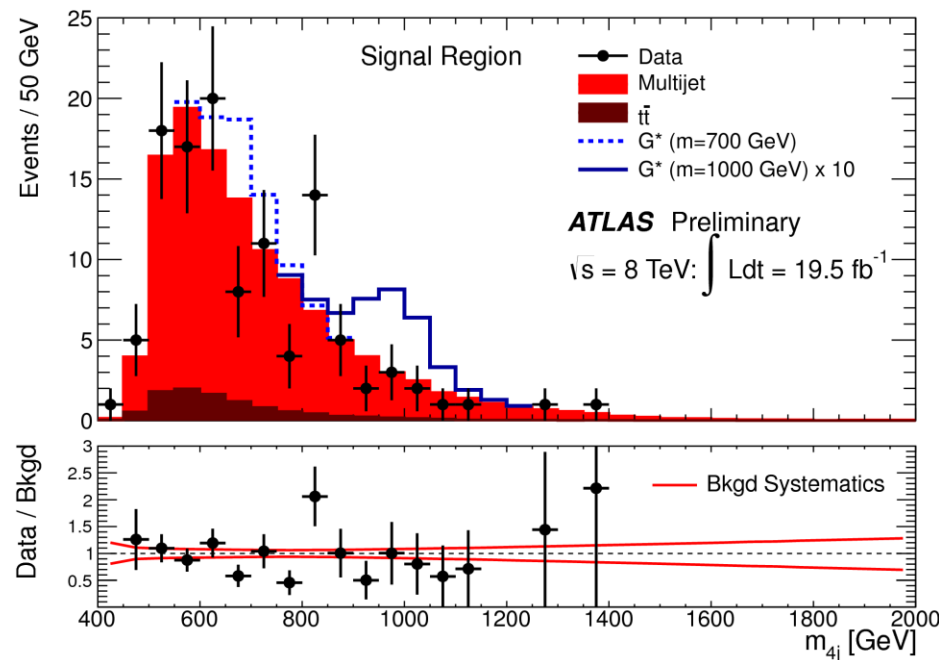
- Use events where only one of the two dijets is required to be b-tagged (2-tag model)
- “2-tag to 4-tag” normalization estimated from sideband region, validated in control region and applied to HH signal region
- $m_{4j}$  shape taken from 2-tag shape in HH signal region, after correcting for kinematic biases (due to additional b-tagging in 4-tag selection) using sideband





# $X \rightarrow HH \rightarrow bbbb$ results

Type	Signal Region
Multijet	$109 \pm 5$
$t\bar{t}$	$10 \pm 6$
Z+jets	$0.7 \pm 0.2$
Total Bkgd	$120 \pm 8$
Data	114
$G^* (m_{G^*} = 500 \text{ GeV})$	$12.5 \pm 0.4$
$G^* (m_{G^*} = 700 \text{ GeV})$	$12.5 \pm 0.2$





- Run 1 publication under final review stages, including
  - Much improved sensitivity compared to Moriond
  - Fat jet analysis with improved sensitivity above  $\sim 1.2\text{TeV}$
  - Non-resonant search result
  - Extended 2HDM interpretation of the resonant search
- Run 2 plans
  - Run 1 sensitivity superseded after  $\sim 5\text{fb}^{-1}$  @  $13\text{TeV}$
  - Depending on LHC performance, plan to have new results by end of year
- We would welcome feedback on
  - Non-resonant signal modelling and cross section
  - Other worthwhile models/topologies