

# **Search for WH and ZH Production with the ATLAS Detector**

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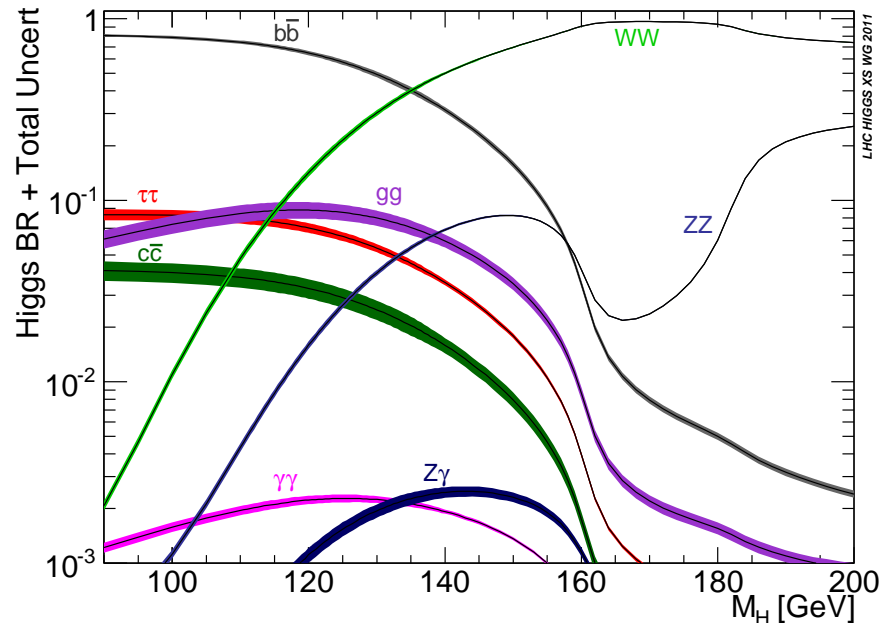
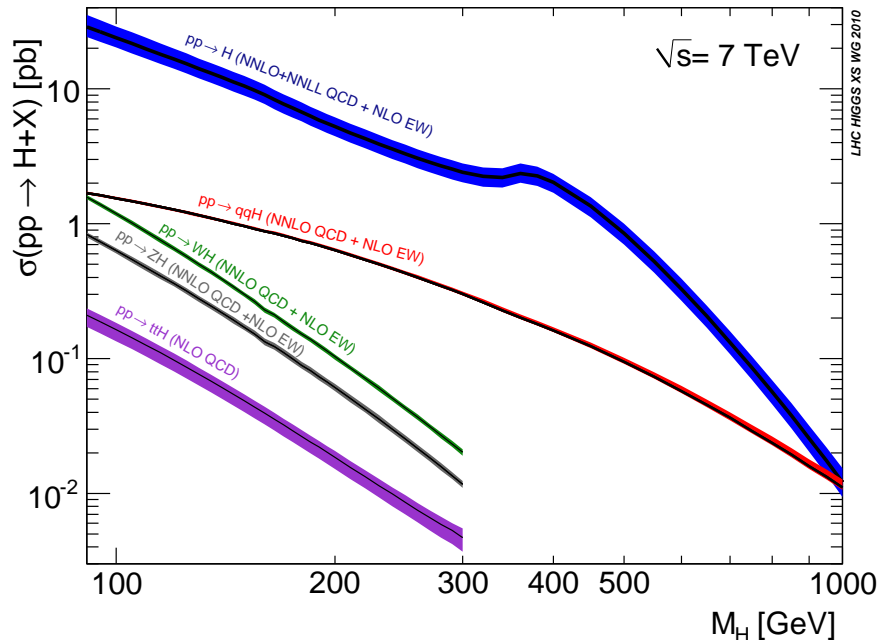
# Outline

- Why WH and ZH ?
- WH modeling with NLO generators
- WH and ZH search with ATLAS (ATLAS-CONF-2011-103)
- Conclusion

# Higgs Production & Decay

$pp \rightarrow H$  @  $\sqrt{s} = 7$  TeV

Higgs decay



- VH associated production: direct coupling of H to V
- $H \rightarrow b\bar{b}$  decay: direct coupling of H to  $b\bar{b}$
- Challenge:  $t\bar{t}$ ,  $Wb\bar{b}$ ,  $Zb\bar{b}$  backgrounds

# WH at NLO vs LO

– At NLO:

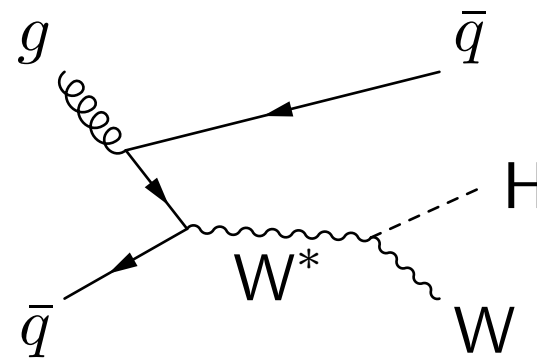
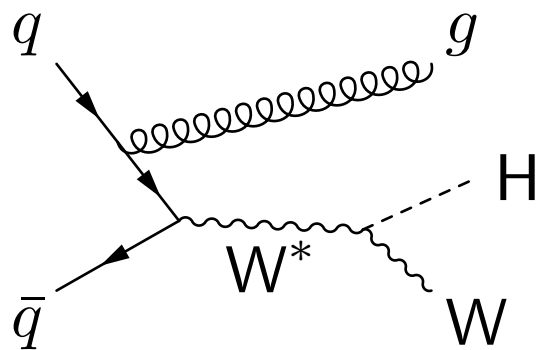
- \* Loop diagrams

- \* Gluon emission

  - Also from LO  $\otimes$  parton shower !

- \* Quark-gluon induced production

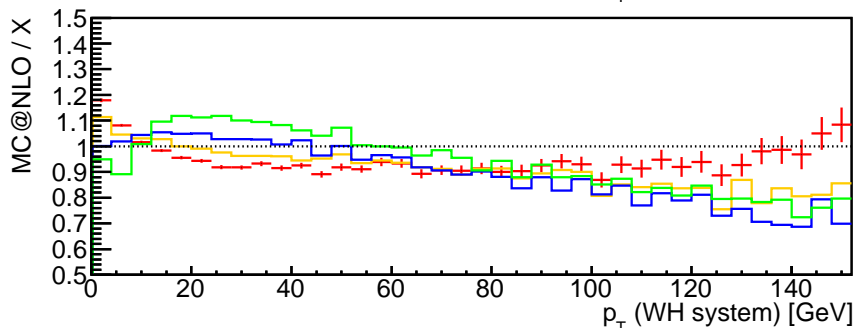
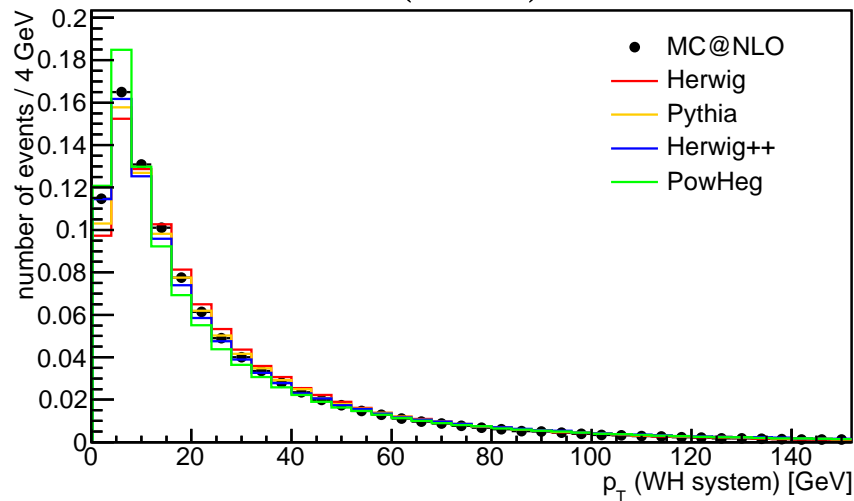
$\Rightarrow$  Expect more jets at NLO



# WH & H at NLO vs LO

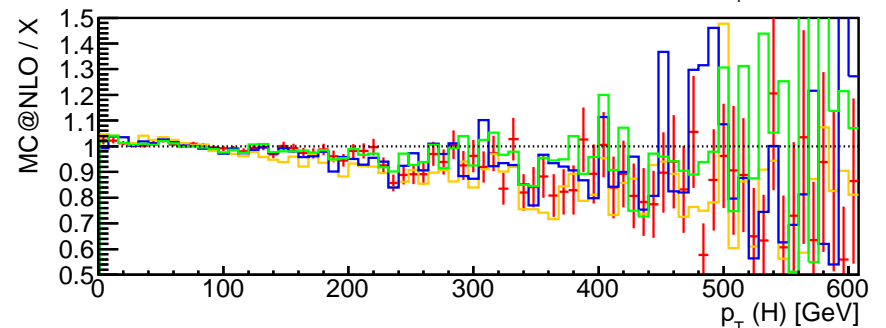
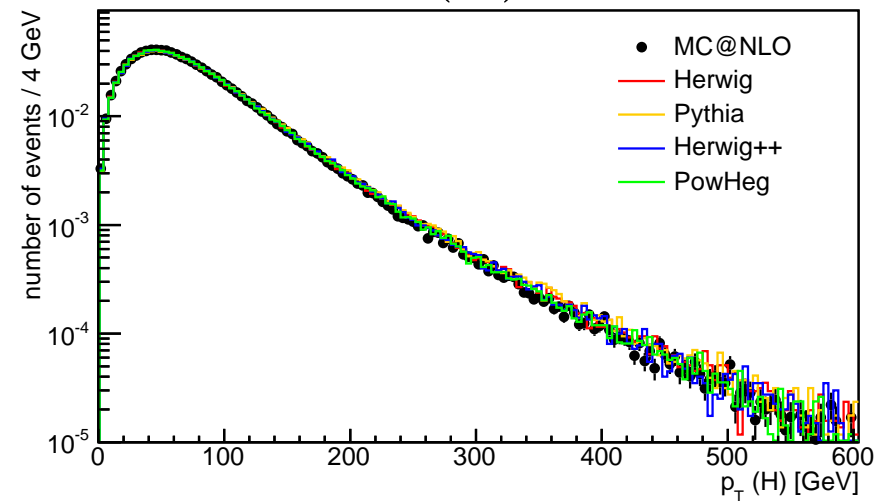
- LO: Pythia, Herwig, Herwig++
- NLO: MC@NLO (Herwig), PowHeg (Herwig++)

$p_T(\text{WH})$



$\text{NLO} \neq \text{NLO} !$

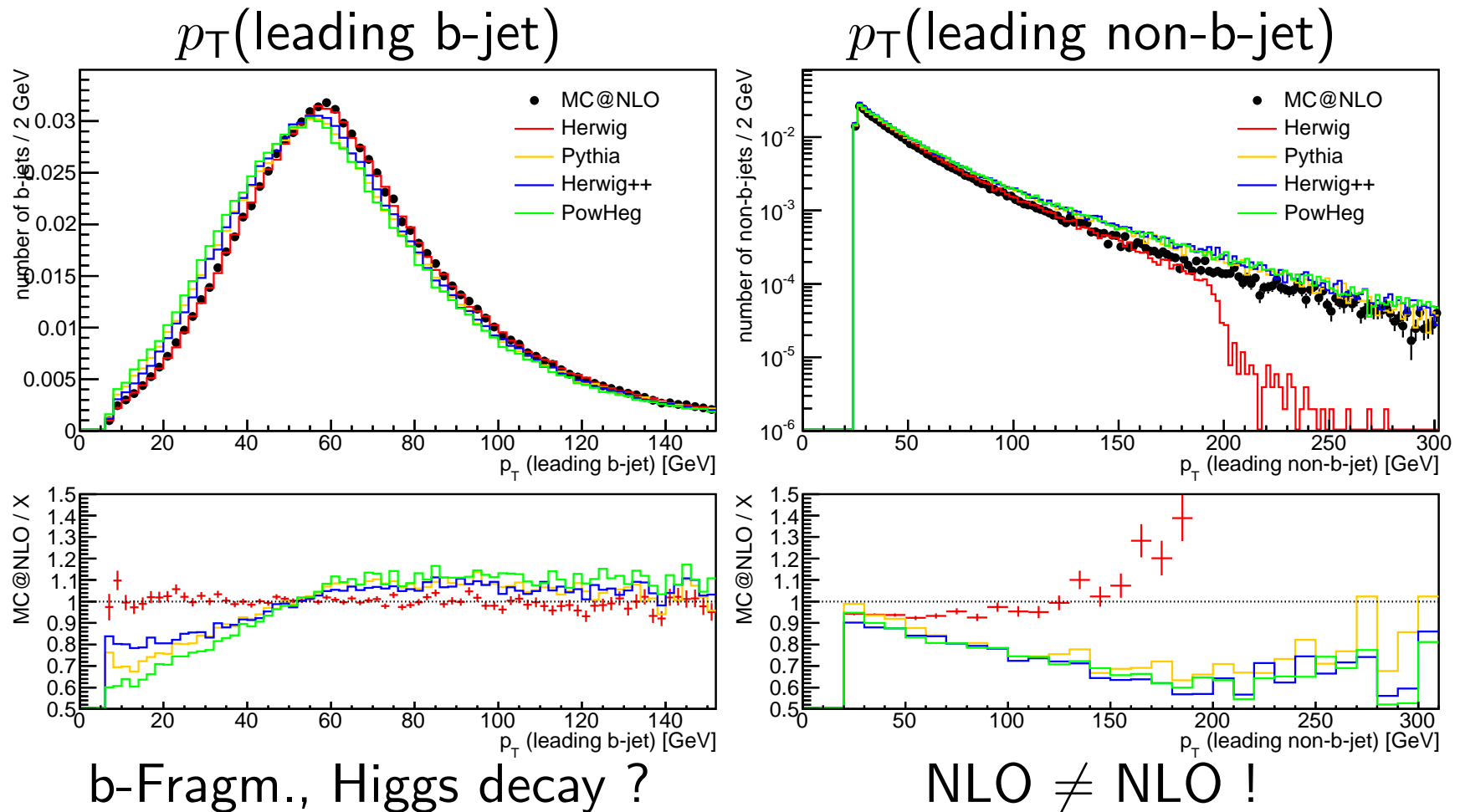
$p_T(\text{H})$



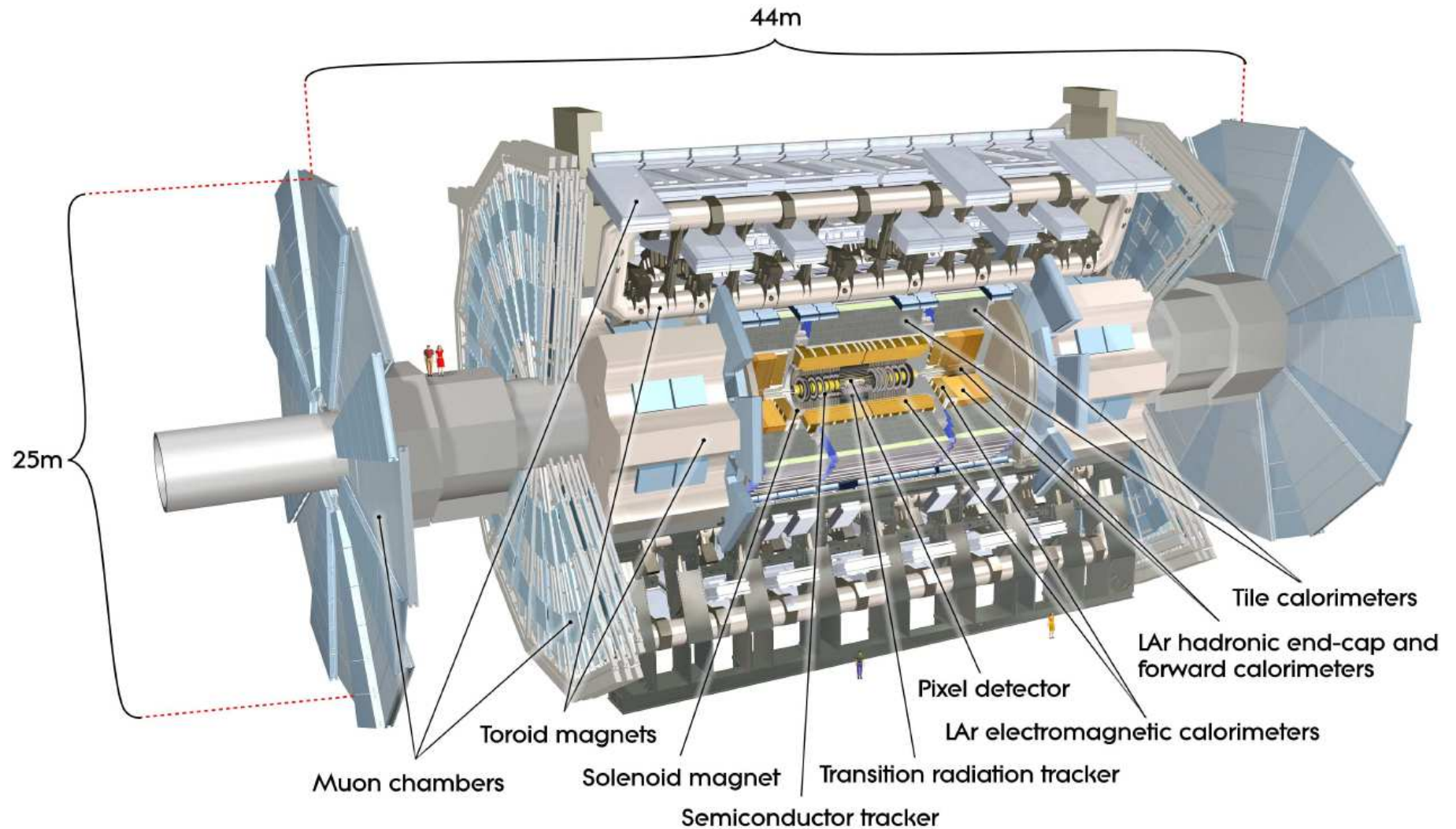
$\text{NLO} \simeq \text{LO} !$

# Jets from WH at NLO vs LO

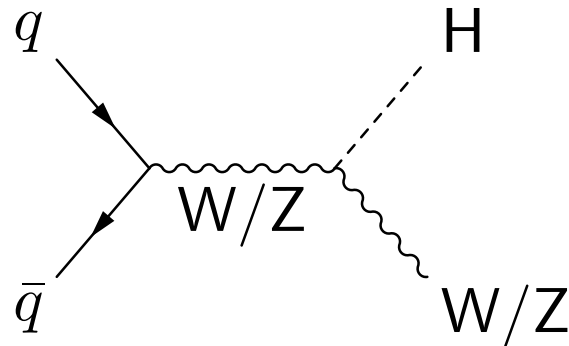
- Anti-kT jets,  $R=0.4$ , using stable particles
- Matched / not matched to b-hadrons



# Typical Particle Detector: ATLAS



# Higgs at Low Mass: WH/ZH

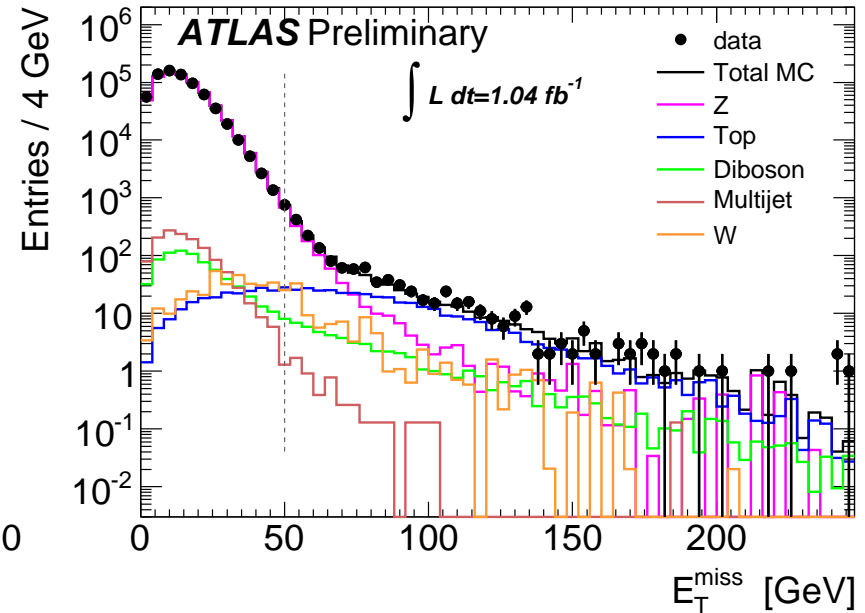
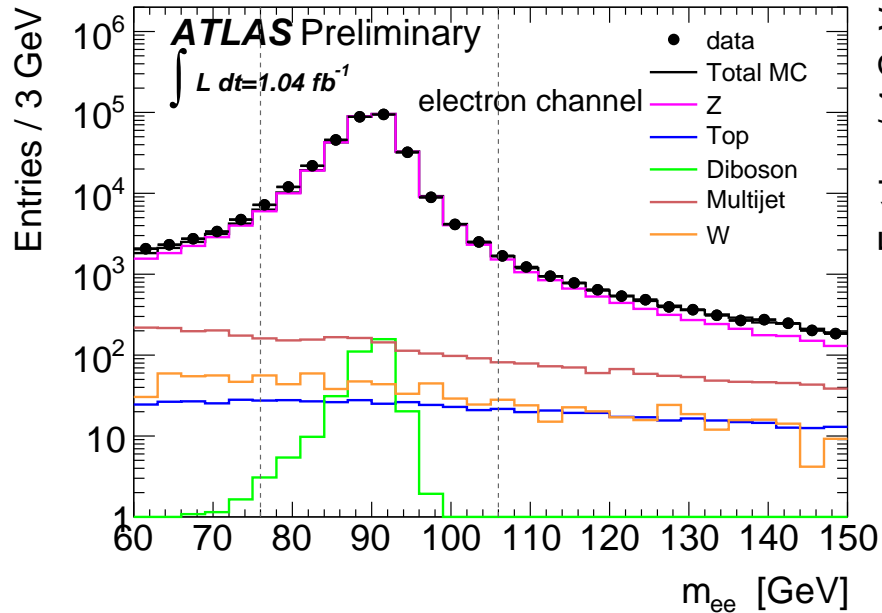


- $W \rightarrow l\nu$ : lepton +  $\cancel{E}_T$        $Z \rightarrow ll$ : leptons
- $H \rightarrow b\bar{b}$ : at least two jets
- Background sources:
  - \*  $W/Z$  with additional jets (including  $Wb\bar{b}$ ,  $Zb\bar{b}$ )
  - \*  $t\bar{t}$ , single top
  - \* Di-boson ( $WW$ ,  $WZ$ ,  $ZZ$ )
  - \* Multi-jet production with mis-ID of lepton /  $\cancel{E}_T$



# Two Charged Leptons: $ZH \rightarrow llb\bar{b}$

- Clean signature: two isolated leptons,  $m_{\text{inv}} \simeq m_Z$
- Expect no large  $\cancel{E}_T \rightarrow$  use to reject  $t\bar{t}$

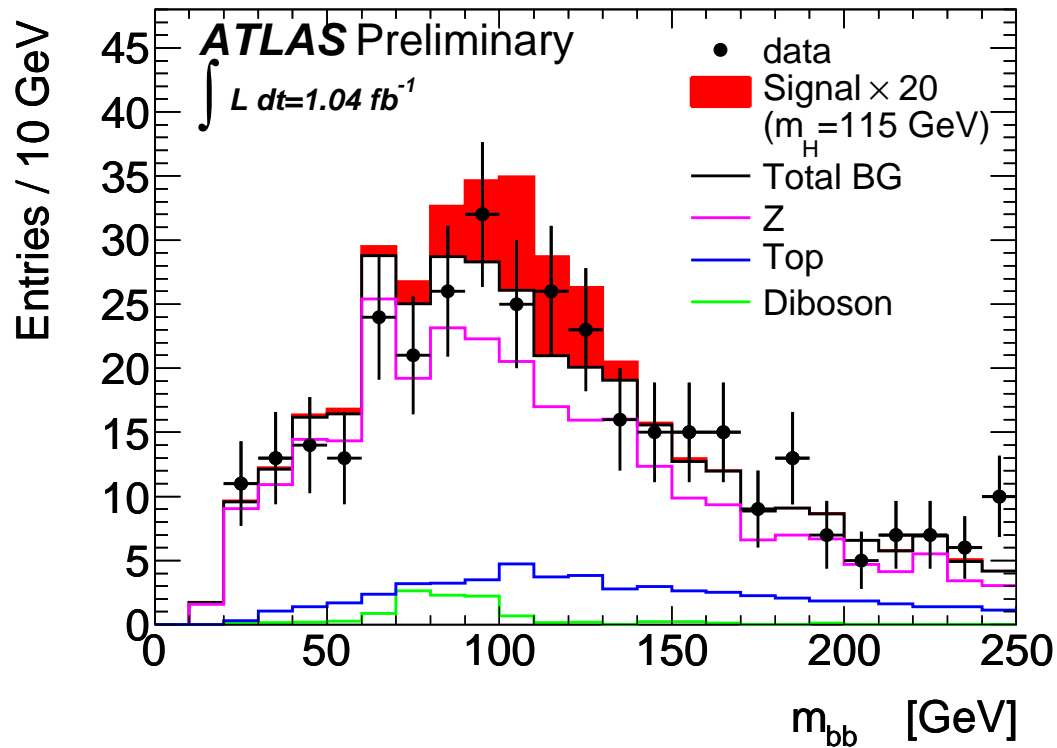


$$76 < m_{\ell\ell} < 106 \text{ GeV}$$

$$\cancel{E}_T < 50 \text{ GeV}$$

Require  $\geq 2$  jets, leading 2 jets b-tagged

# Two Charged Leptons: $ZH \rightarrow \ell\ell b\bar{b}$



1.9 Higgs events

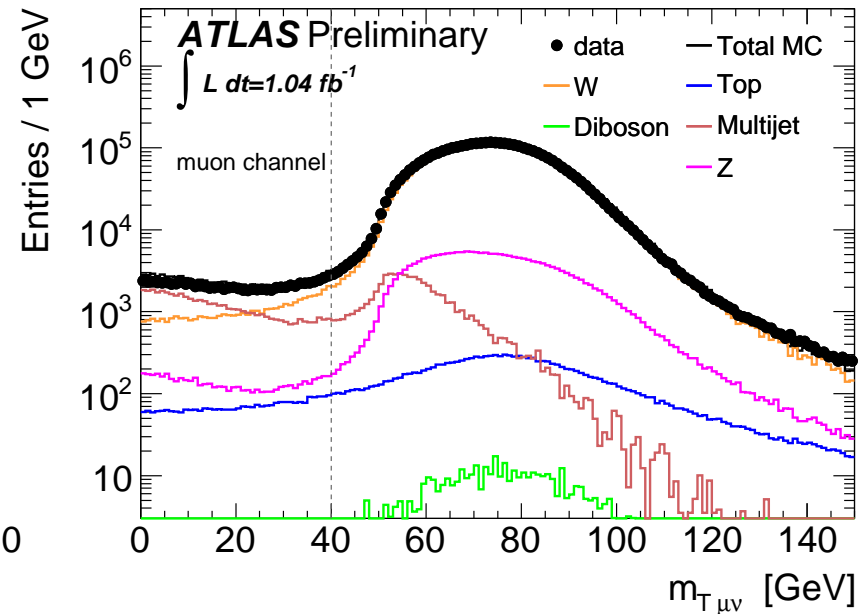
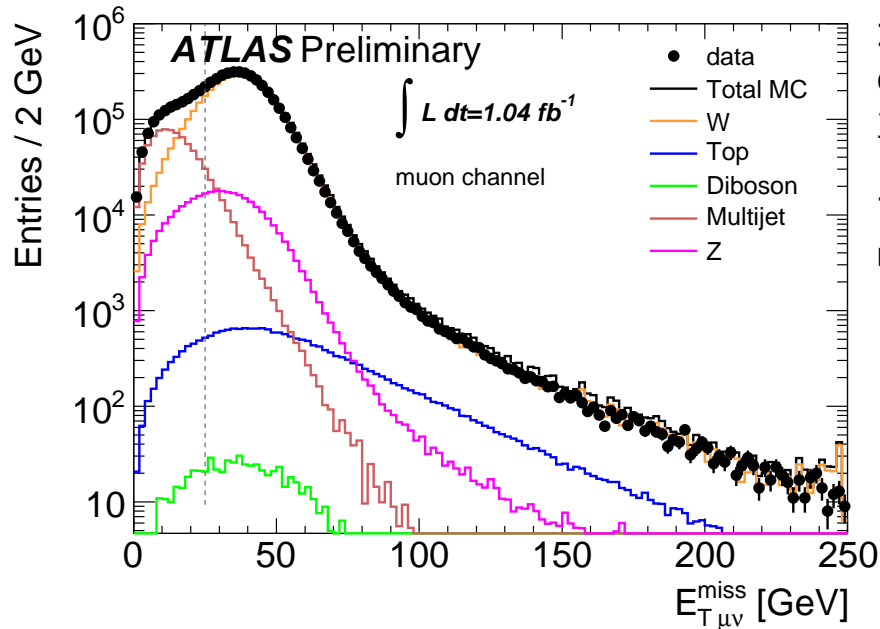
325 non-Higgs events

Z( $b\bar{b}$ ) background

- Z $b\bar{b}$  background normalized in  $m_{b\bar{b}}$  sideband
- $t\bar{t}$  background validated in  $m_{\ell\ell}$  sideband

# One Charged Lepton: $WH \rightarrow \ell\nu b\bar{b}$

- Signature: one isolated lepton, large  $\cancel{E}_T$

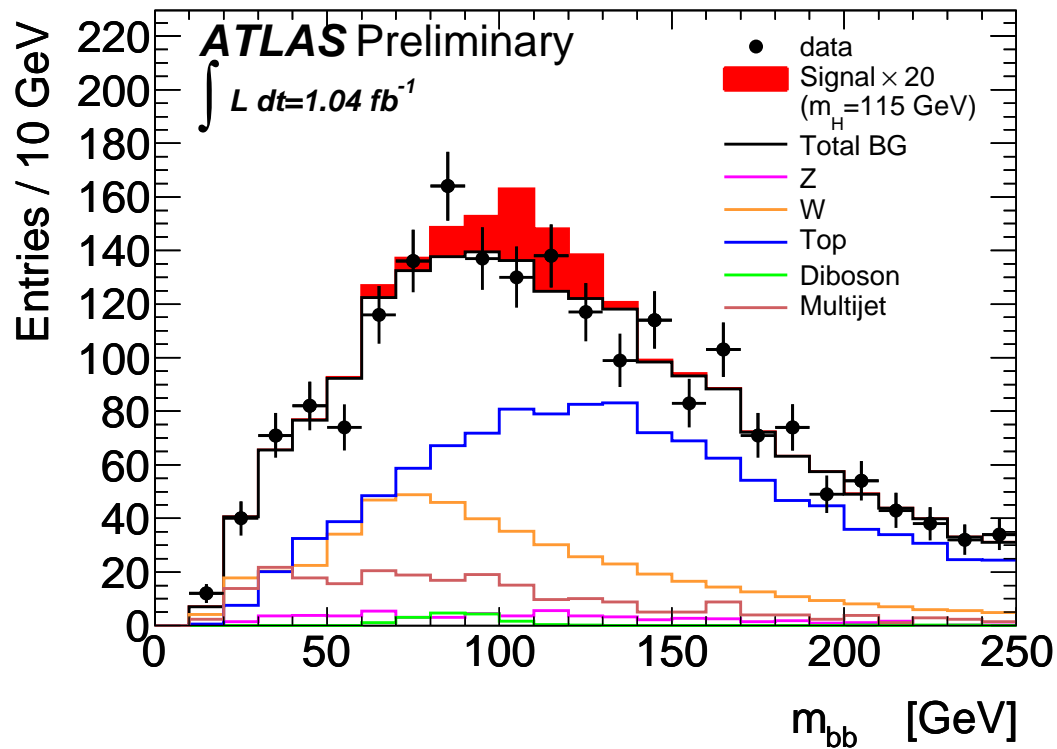


$$\cancel{E}_T > 25 \text{ GeV}$$

$$m_T > 40 \text{ GeV}$$

Require = 2 jets, b-tagged

# One Charged Lepton: $WH \rightarrow \ell\nu b\bar{b}$



5.3 Higgs events

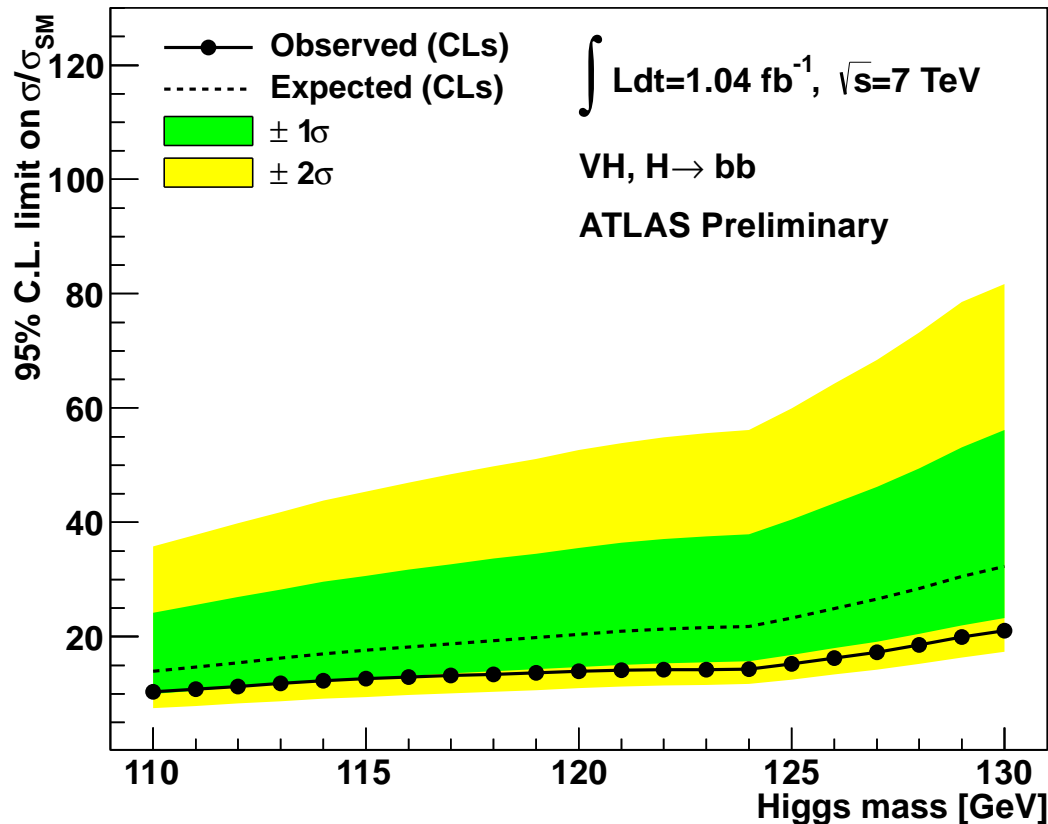
1877 non-H events

Top,  $W(b\bar{b})$  background

- $Wb\bar{b}$  background normalized in  $m_{b\bar{b}}$  sideband, using template from data
- $t\bar{t}$  background normalized in  $m_{b\bar{b}}$  sideband

# WH $\rightarrow \ell\nu b\bar{b}$ , ZH $\rightarrow \ell\ell b\bar{b}$ Result

- Good data-background agreement
- Estimate systematic uncertainties
- Combine WH and ZH channels  $\Rightarrow$  cross section limits



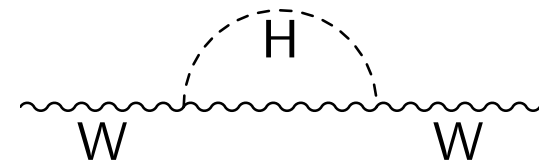
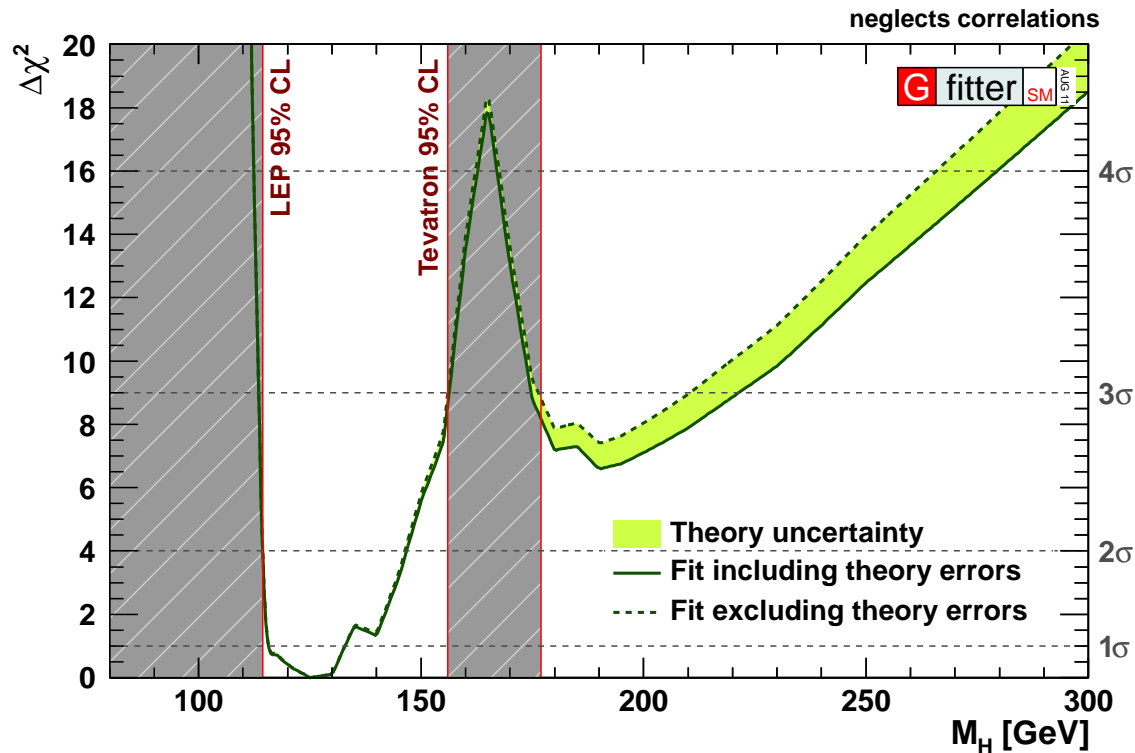
$\Rightarrow$  Exclude 10–20  $\times$  SM

# Conclusion / Outlook

- NLO generators don't agree
- No evidence for WH / ZH production
- Keep looking. . .
  
- Much more data in 2011, even more data in 2012
- Boosted Higgs, other multivariate techniques
- Discovering something is not the end of the story

# Where should the Higgs Boson Be?

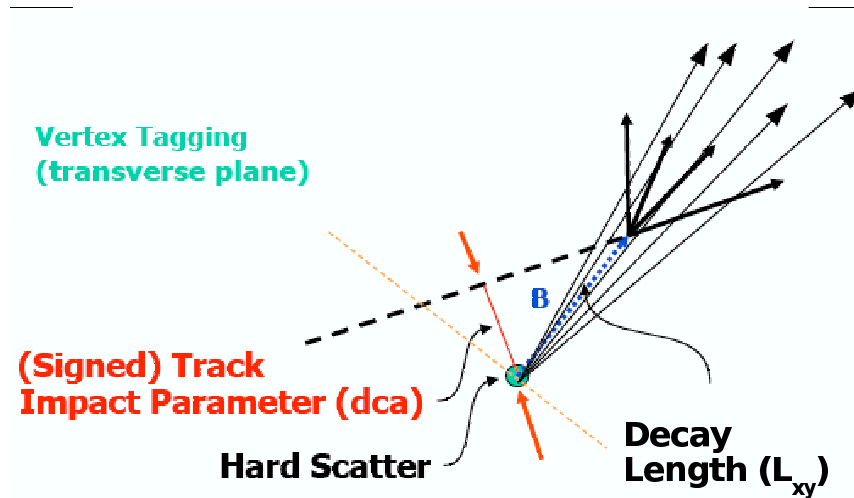
- Precision EW measurements at Tevatron, LEP and SLD
- Direct Higgs search results from LEP, Tevatron, LHC



$$m_H = 125^{+8}_{-10} \text{ GeV}$$

# B-Tagging

B-hadron decay:



– B-tagging:

- \* Find tracks with large impact parameter
- \* Reconstruct secondary vertices

– For  $H \rightarrow b\bar{b}$ , require two b-tagged jets