

LHC Higgs: $H \rightarrow b\bar{b}$ Subgroup



Chris Potter (ATLAS), Jim Olsen (CMS), Clara Mateuzzi (LHCb)

LHC Higgs Group: $H \rightarrow b\bar{b}$ Final State Subgroup

■ Talk Outline

- ◆ $VH \rightarrow Vb\bar{b}$ ATLAS/CMS
- ◆ $VH \rightarrow Vb\bar{b}$ LHCb
- ◆ $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$ ATLAS/CMS

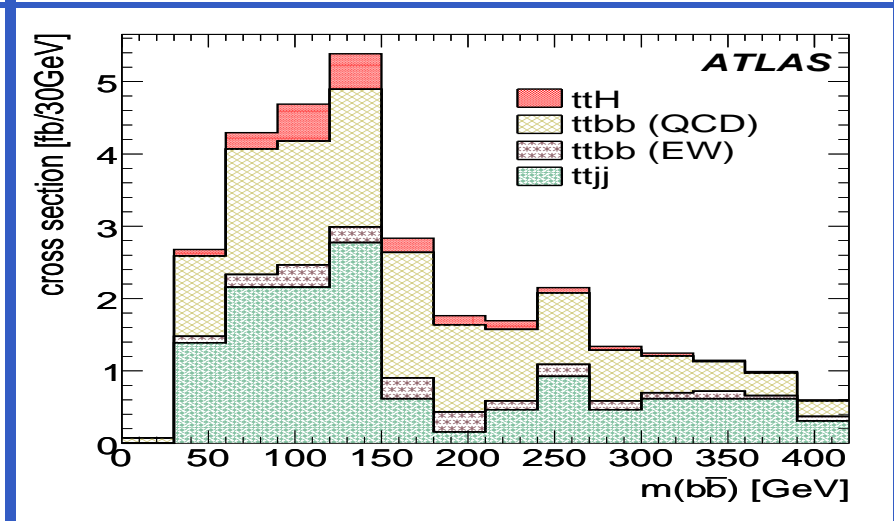
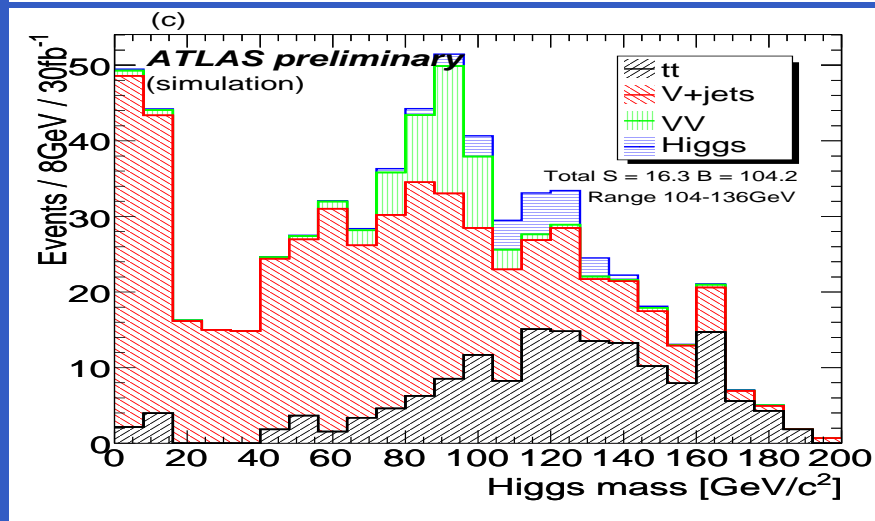
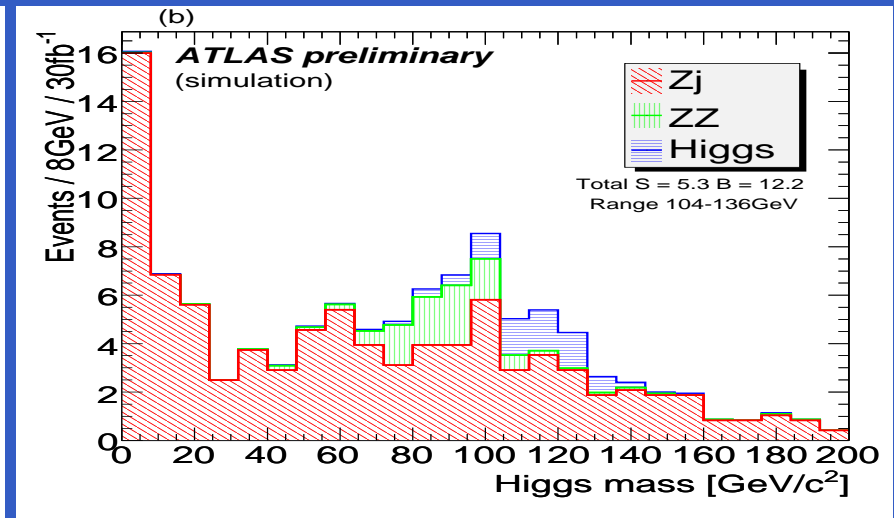
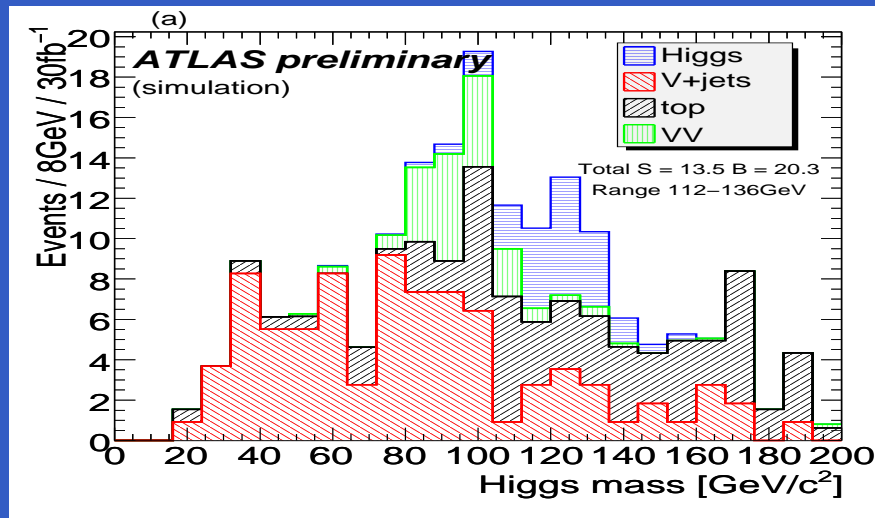
■ Reference Information

- ◆ Group Contacts: Chris Potter (Oregon), Jim Olsen (Princeton), Clara Matteuzzi (Milano-Bicocca)
- ◆ Group Members: Chris Potter (ttH), Jim Olsen (VH), Clara Matteuzzi (VH), Chris Neu (ttH), Chris Collins-Tooth (ttH), Giacinto Piaquadio (VH)
- ◆ TWiki: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/Bb>
- ◆ Sharepoint: <https://espace.cern.ch/lhc-higgs/Lists/Hbb/AllItems.aspx>

■ Public Studies on $H \rightarrow b\bar{b}$ at the LHC:

- ◆ ATLAS Sensitivity to the Standard Model Higgs in the HW and HZ Channels at High Transverse Momenta (ATL-PHYS-PUB-2009-088)
- ◆ Search for $H \rightarrow b\bar{b}$ in Association with a ttbar Pair at CMS (CMS-NOTE-2006-119)
- ◆ Search for $t\bar{t}H$ ($H \rightarrow b\bar{b}$) (CERN-OPEN-2008-020)

Public Studies: Results

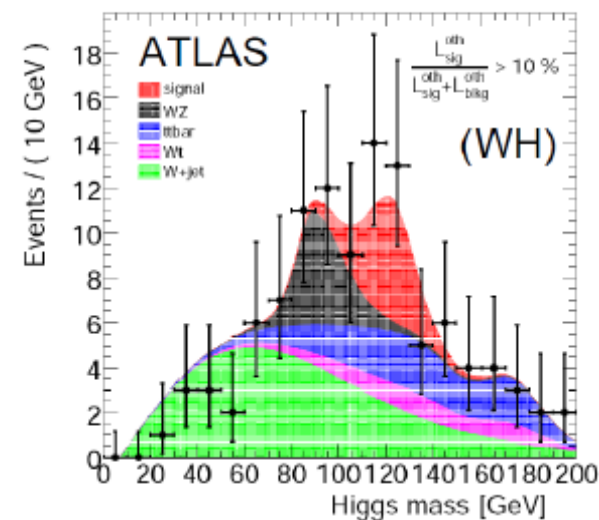
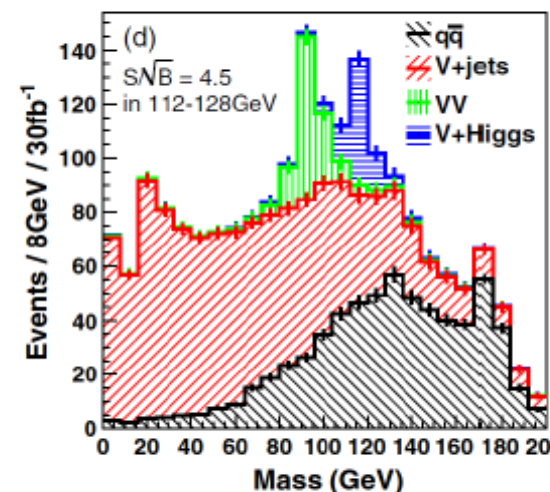


Public ATLAS highly boosted VH analysis (a-c) and ATLAS ttH analysis (lower right).

VH Analysis: Distribution of the invariant mass of the Higgs candidate after all selection cuts. (a) Inub channel (b) llbb channel and (c) MET bb channel. The signals (for $m_H = 120$ GeV) are shown on top of the backgrounds. All distributions are normalized to an integrated luminosity of 30 fb⁻¹.

Pre-Summary for Bari: VH , $H \rightarrow b\bar{b}$

- Reminders:
 - Highly boosted regime rescues VH @ LHC
 - PRL 100, 242001 (2008)
 - ATLAS confirms with detector simulation
 - ATL-PHYS-PUB-2009-088
 - CERN-THESIS-2010-27 (G. Piacquadio)
 - Internal CMS analysis complete, not public
 - CMS AN-10-265
- VH Xsec Subgroup active since February
 - Stefan Dittmaier (theory)
 - Robert Harlander (theory)
 - Giacinto Piacquadio (ATLAS)
 - Jim Olsen (CMS)
- $H \rightarrow b\bar{b}$ in VH is the same set of suspects (GP+JDO), help is welcome!
 - Nearly 100% overlap with existing plans for the VH cross section subgroup
 - See Giacinto's talk at the July CERN Workshop



1a), 1b), and 1c)

- 1a) Plan of Activity
 - Signal
 - Comparison of MC@NLO and POWHEG with LO (e.g., Pythia)
 - Pt-dependent k factors
 - Impact of analysis-level cuts on NLO vs. LO
 - Work has begun
 - Theory updates and cross-checks
 - NNLO QCD (R. Harlander); updated (integral) k factors
 - Comparison with NLO QCD+EW (HAWK)
 - Comparison with V2HV and MCFM
 - » V2HV done (check), work has begun on MCFM
 - Background
 - CMS gearing up for large-scale production of all backgrounds (V+jets, ttbar, VV, Wt, etc); goal is to fully treat MC as data in order to derive robust data-driven techniques
 - Given the requirement of only using public results, it is not clear to me (JDO) how CMS and ATLAS collaborate on this specific point. That's OK.
 - Theory input that would be useful
 - Fully differential NLO cross sections for signal compared to background
- 1b) List of MC: MC@NLO, POWHEG, Pythia, MCFM
- 1c) Wish list: Fully differential predictions

2) Common Selection

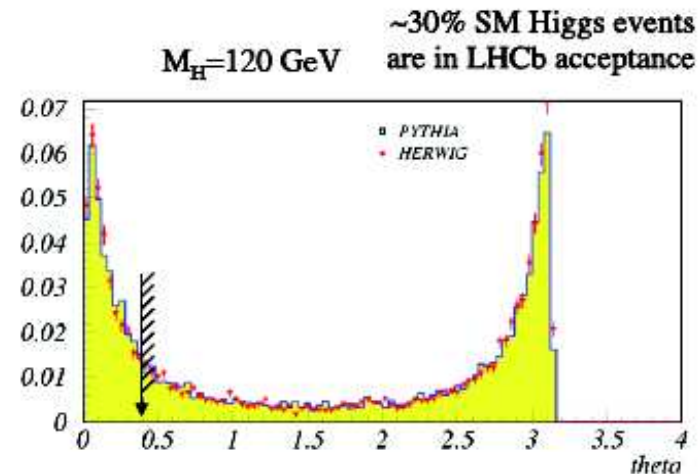
- Since we can only show public results, and the only public results are from ATLAS, one option is to use the ATLAS selection by default.
- However, Giacinto + JDO have discussed a reduced common set of variables:
 - **pt(H) > 200 GeV**
 - **pt(V) > 200 GeV**
 - **No additional C/A jets with pt > 20 GeV ($|\eta| < 2.4$)**
- This minimal selection is simple, yet captures most of the effects where theory input is critical



Low mass Higgs at LHCb

LHCb has a very good b-quark trigger and identification

→ about 100 Higgs evts in 2 fb^{-1} LHCb data at 14 TeV



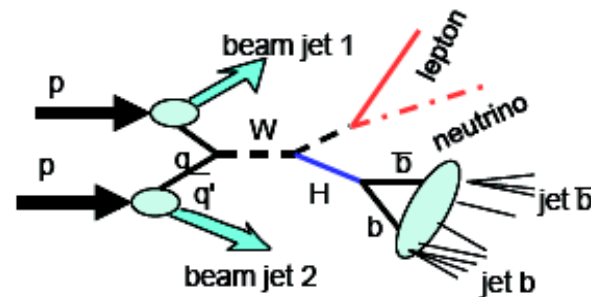
This is a field of search which is outside the main LHCb scope, still the potentialities of the detector are worth being investigated

$VH \rightarrow Vb\bar{b}$: LHCb (2)



Ways to look for low mass Higgs in LHCb

$$p p \rightarrow W/Z H$$



Experimental objects:

Leptons (e/ μ)

Jets (& b-tags)

SM predicts ~ 2.3 pb of $HZ + HW$ at $M_H = 115$ GeV

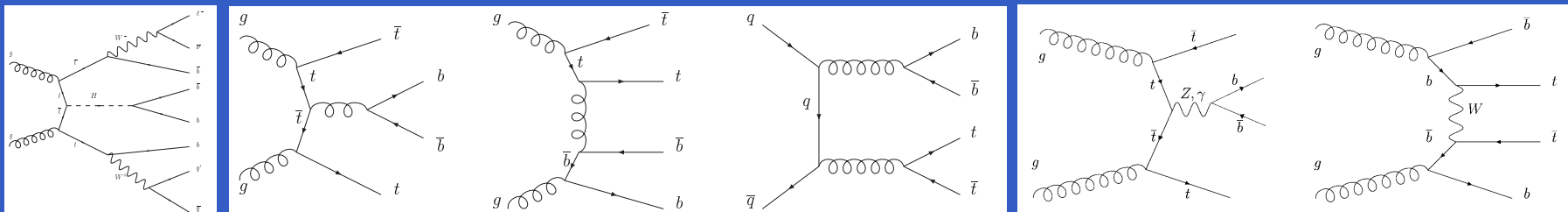
Background mainly t - \bar{t} ~ 570 pb.

But also ZZ (12 pb), ZW (30 pb), $W/\gamma/Z + b$ jets (10^5), b - \bar{b} (10^8),...

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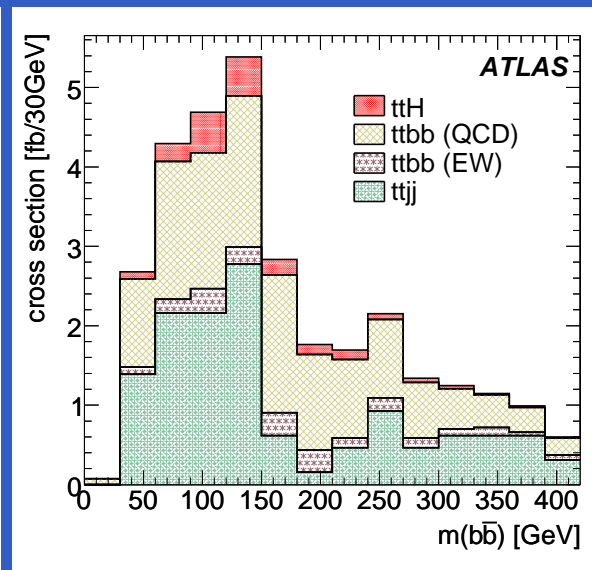
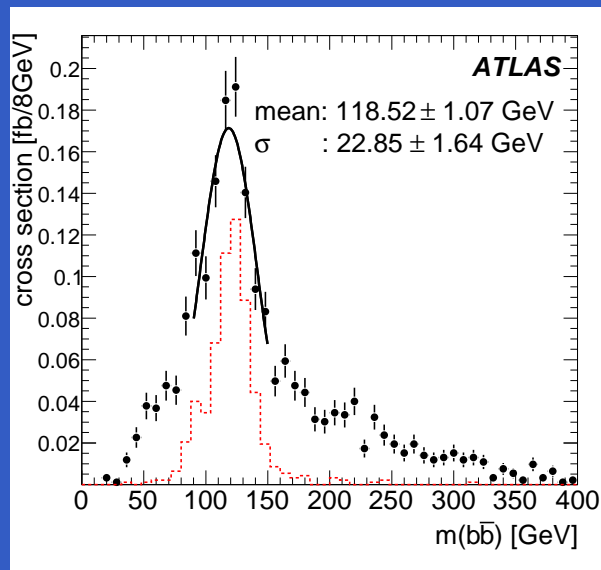
Clara Matteuzzi

$t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: ATLAS/CMS Generators



- Signal $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: LO Pythia no K-factor (ATLAS), LO CompHEP+Pythia (CMS)
- Background $t\bar{t}b\bar{b}$: LO AcerMC+Pythia no K-factor (ATLAS), LO CompHEP+Pythia (CMS)
- Background $t\bar{t}$ +jets: NLO MC@NLO (ATLAS), LO Alpgen+Pythia (CMS)
- Recent Developments at ATLAS (Chris Collins-Tooth):
 - ◆ Used Pythia 6.X for signal as standard, tried Sherpa for signal (found a bug in XS...)
 - ◆ Used AcerMC for $t\bar{t}+b\bar{b}$ (QCD+EW) background and Alpgen for $t\bar{t}+X$ (includes $t\bar{t}b\bar{b}$, will have to be removed)..
 - ◆ Would like to see a NLO MC.
- Recent Developments at CMS (Chris Neu):
 - ◆ Work has not yet begun, this will be a long term project.
 - ◆ Would like to see LO-NLO shape comparison for signal and background.

$t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: ATLAS/CMS Analysis Cuts (Semileptonic)



Requirement	ATLAS	CMS
Trigger	e22i or e55 or mu20	e26 or mu19
Lepton	exactly 1 isolated 25 GeV(20 GeV) $e(\mu)$	exactly 1 isolated $e(\mu)$
Jets	≥ 6 20 GeV jets	6 or 7 20 GeV jets
b-tag	≥ 4 jets	≥ 4 jets

Recent developments at ATLAS (Chris Collins-Tooth):

- Require 6 jets overall - possibly use partons separated by some margin from each other.
- Require 4 central jets - otherwise 4 hard partons separated by some margin from each other, all located inside $|\eta| < 2.5-3$

Summary

■ Plan of Activity

- ◆ $VH \rightarrow Vb\bar{b}$: comparison of NLO with LO (signal and background), pt-dependent K-factors, impact of NLO on analysis cuts
- ◆ $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: TBD

■ List of LO/NLO MC Used

- ◆ $VH \rightarrow Vb\bar{b}$: MC@NLO, POWHEG, Pythia, Herwig, MCFM
- ◆ $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: Pythia, CompHEP, AcerMC, MC@NLO, Alpgen

■ Wish List for Theorists

- ◆ $VH \rightarrow Vb\bar{b}$: fully differential parton-level predictions @ NLO (QCD + EW), $Zb\bar{b}$ and $Wb\bar{b}$ backgrounds @ NLO implemented in a parton shower program, fully differential parton-level predictions @ NNLO (QCD)
- ◆ $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: NLO signal and background MC, LO-NLO shape comparison for signal and background

■ Common Selection Cuts (ATLAS/CMS)

- ◆ $VH \rightarrow Vb\bar{b}$: $p_T(H) > 200$ GeV, $p_T(V) > 200$ GeV, no additional CA jets with $p_T > 20$ GeV.
- ◆ $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$: 1 isolated lepton with $p_T > 25$ GeV, ≥ 6 jets with $p_T > 20$ GeV, ≥ 4 b-tags

Discussion Items (from Reisaburo)

- Common cuts, how we should come to the agreement? With pre-selection cuts (to gain the phase space) or quasi-final cuts
- Which feedback can be made with NNLO/NLO study for NLO/LO MC? MC reweighting via Higgs p_T , rapidity etc.? Develop common tools?
- How should we define the theoretical errors in exclusive Higgs cross sections? Common recipe for extrapolation from control to signal regions (ex. QCD scale, PDF error)?
- Parton level vs PS-MC study? In which Higgs decay channel do we have to go into PS-MC study? How one can define jets, b-jet/tau, isolation, jet-veto etc.?
- How one can reflect these studies to each experiment where experimental details are different? Prepare tools? Parametrisation?
- How we should study the signal and background interference effect? With LO MC? How to extrapolate to higher order? ex. $qq/gg \rightarrow \gamma+\gamma$, $qq/gg \rightarrow WW/ZZ \rightarrow l\nu l\nu$ etc.
- Interplay between Higgs production and decay groups. How to organize future works among us, and milestones for possible publication.