Search for Higgs boson in $VBF, H \longrightarrow b\bar{b}$ decay channel with the ATLAS detector

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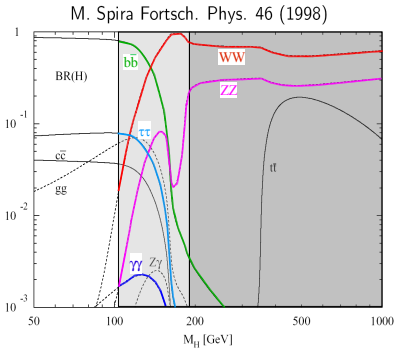
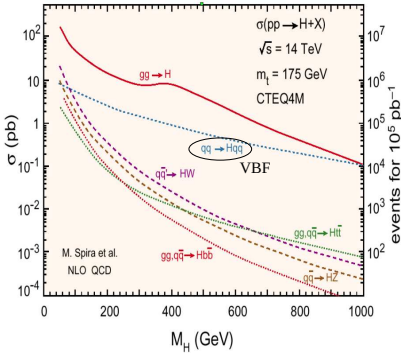
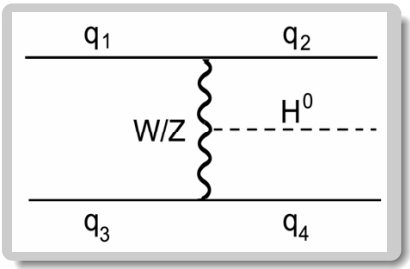
Introduction

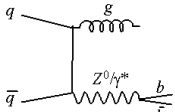


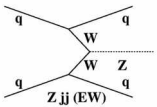


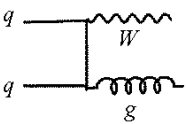
- In the low mass sector, the Higgs boson decays mostly to $b\bar{b}$, but two problems:
  1. it is hard to trigger on the $b\bar{b}$ final state
  2. huge cross section of multijet $b\bar{b}$ production
- Associated H production with $t\bar{t}$ pair seems to be free from these two problems, but according to ATLAS studies, the signal significance of ttH,H$\rightarrow b\bar{b}$ is around 3.0
- VBF production process has a larger cross section($\sim$4 pb @ M_H=120GeV, for comparison, σ_{ttH} $\sim$0.5 pb) and should be checked for its discovery potential
- VBF,H$\rightarrow b\bar{b}$ is still challenging channel due to the same problem of trigger and the larger backgrounds from $b\bar{b}$, $t\bar{t}$, W/Z+jets, single top, etc

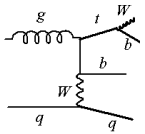
Produced Data samples

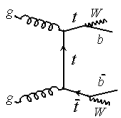


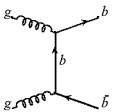












Produced MC samples for signal and backgrounds

Sample	σ(pb)	MC generator		$N_{simulated}$ (10^6)		$N_{expected\ for\ \mathcal{L}=30\ fb^{-1}}$ (10^6)
		Fast	Full	Fast	Full	
qqH H$\longrightarrow b\bar{b}$	2.8	Pythia	Pythia	1.2	0.11	0.084
bb	4.2×10^8	Pythia	-	1000.0	-	12.6×10^6
W+jets (W decay freely)	345300	Pythia	-	500.0	-	10359
Z+jets Z$\longrightarrow b\bar{b}$	18250	Pythia	-	250.0	-	547.5
$t\bar{t} \longrightarrow WWb\bar{b}$(*W decay freely*)	503.2	Pythia	-	30.0	-	15.096
single top (W decay freely)	327.9	TopRex	-	30.0	-	9.837

Trigger Efficiency

Data sample: 110000 fully simulated VBF signal events, with full trigger simulation

Trigger efficiency

Trigger signature		trigger efficiency(%)
one isolated electron with pT>21 GeV	e25i	0.014
two isolated electron with pT>11 GeV	2e15i	0
one muon with pT>6 GeV	μ6	13.1
one isolated muon with pT>20 GeV	μ20i	2.9
one jet with pT>400 GeV	1j400	1.1
three jets with pT>165 GeV	3j165	0.005
four jets with pT>110 GeV	4j110	0.0
Any trigger		14.0

Event selection

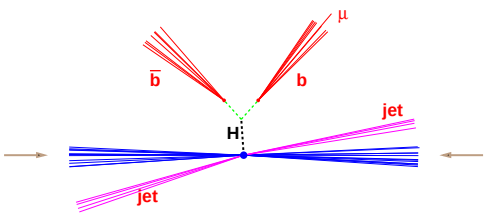
Initial event selection:

- at least one non-isolated muon with pT >6 GeV, $|\eta|$ <2.5
- Two forward jets—-two jets with the highest pT

  pT^{j1} >50 GeV, pT^{j2} >20 GeV, $|\eta^{j1,j2}|$ <5.0

  $\eta^{j1} \times \eta^{j2} < 0$, $\Delta\eta = |\eta^{j1} - \eta^{j2}| > 4.4$
- two b jets with pT >15 GeV, $|\eta|$ <2.5
- the b jets and the muon are central

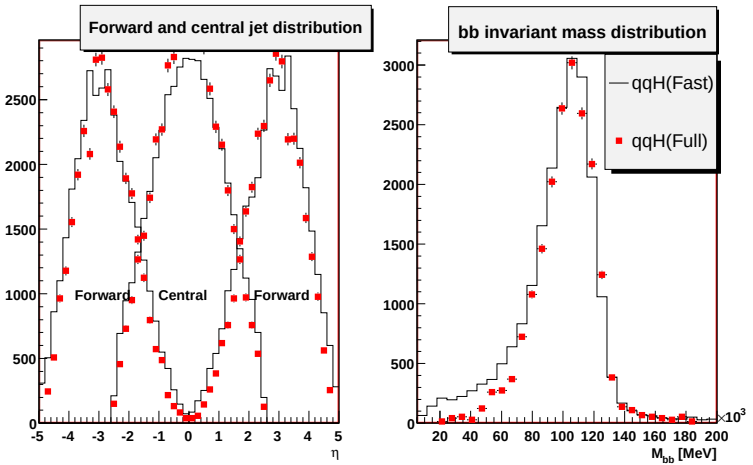
  $\eta^{j}_{min} + 0.7 < \eta^{b\ jet/muon} < \eta^{j}_{max} - 0.7$



Additional cuts:

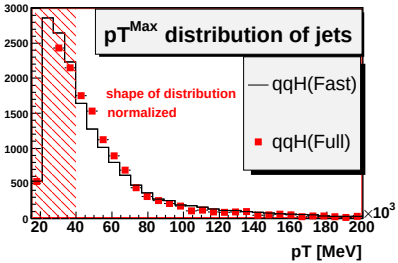
- maximum pT of additional jets
- missing pT
- invariant mass of two forward jets

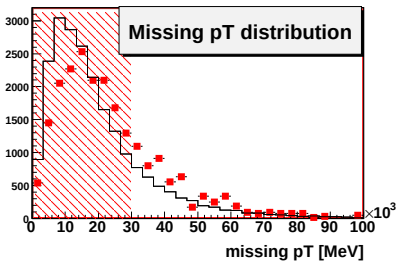
Comparison of Fast and Full simulation for signal

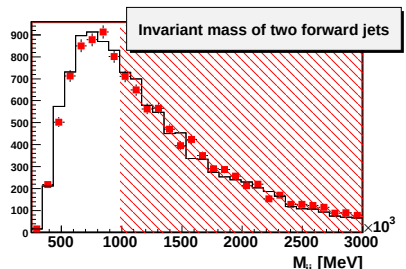


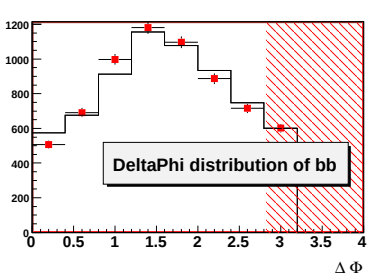
- After initial event selection: η distribution of forward and central jets agrees for ATLFAST and Full simulation
- The reconstructed $b\bar{b}$ invariant mass has a shift of about 15GeV. The b jet energy calibration should be improved

Additional cuts: comparison of Fast and Full simulation for signal



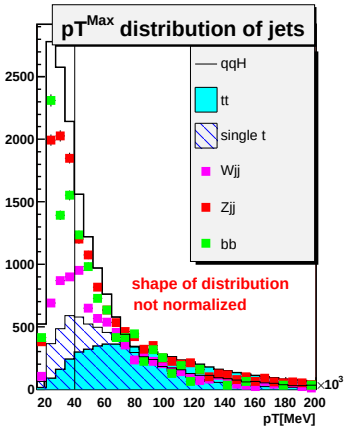


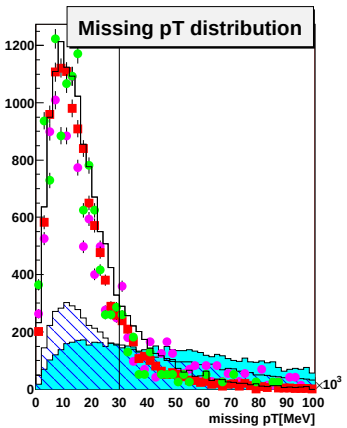


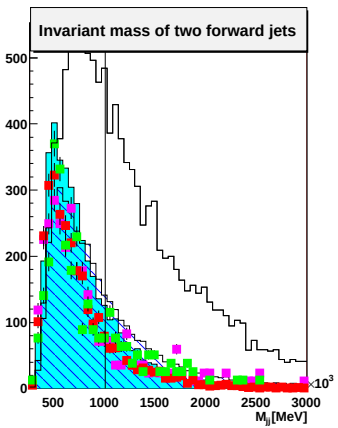


- Fast and Full simulation are in a reasonable agreement

Fast simulation: pT^{Max} of light jets,missing pT, jj mass distribution

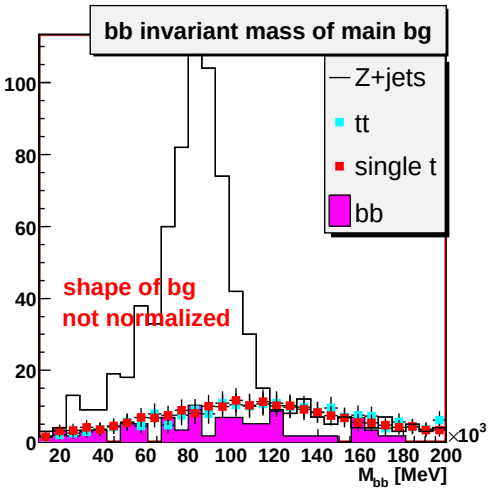


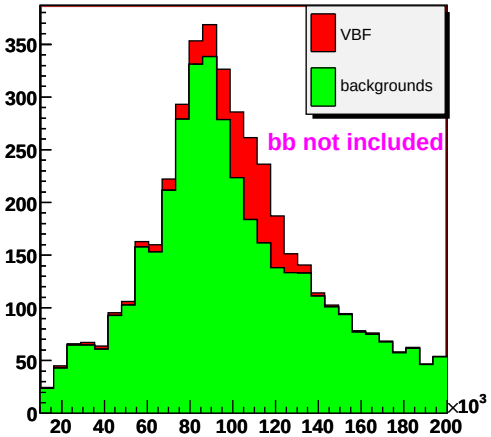




- pT^{Max} of additional non-forward jets: pT^{Max} <40GeV
- Missing pT: $pT_{missing}$ <30GeV
- Invariant mass of two forward jets: M_{jj} >1000GeV

Fast simulation: Invariant mass of two central b jets





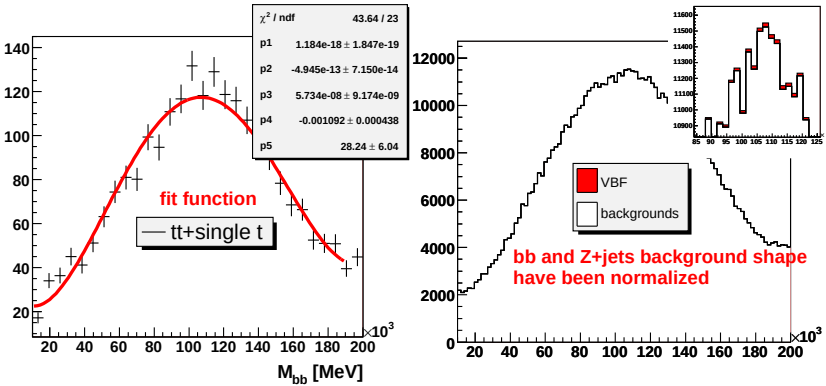
Fast simulation: Invariant mass of two central b jets

Assuming $b\bar{b}$ invariant mass from $b\bar{b}$ background has the same shape as $t\bar{t}$+single t.....

① Fit $b\bar{b}$ invariant mass spectrum from $t\bar{t}$+single t to get $b\bar{b}$ background shape (polynomial function)

② Produce a histogram normalized to the expected $b\bar{b}$ background rate with the bin content varied according to poisson fluctuations

③ Add signal and other backgrounds to the histogram



Signal and background events at 30 fb^{-1}(fast simulation)

Expected $qqH, H \rightarrow b\bar{b}$ signal and background events in m_{bb} mass window of $\pm 30 GeV/c^2$

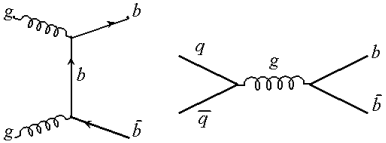
Decay channel	$N_{final\ events}$		Efficiencies		$N_{normalized\ to \mathcal{L}=\ 30\ fb^{-1}}$	
	Fast	Full	Fast	Full	Fast	Full
qqH H$\rightarrow b\bar{b}$	5354	365	4.5×10^{-3}	3.2×10^{-3}	328	243
single t	2689	-	9.0×10^{-5}	-	881	-
bb	25	-	2.5×10^{-8}	-	315000	-
W+jets	18	-	3.2×10^{-8}	-	331	-
Z+jets	311	-	1.2×10^{-6}	-	681	-
$t\bar{t} \rightarrow WWb\bar{b}$	404	-	1.4×10^{-5}	-	203	-
Total Background					317096	-
$S/\sqrt{B}$					0.6	-

- the bb background is overwhelming and gives this channel a very low potential

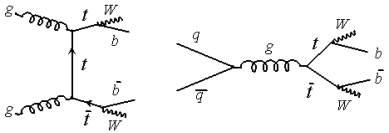
Summary and Plans

- 1×10^9 $b\bar{b}$ background events was produced to study the higgs discovery potential of H$\longrightarrow$ $b\bar{b}$ decay channel in VBF Higgs production (the largest $b\bar{b}$ sample up to date), which allowed for the first time to estimate $b\bar{b}$ background contribution for this channel
- The $b\bar{b}$ background is found to be overwhelming, giving this channel the signal significance of 0.6, without $b\bar{b}$ background the signal significance is around 7.0
- The trigger efficiency was also studied using full trigger simulation, and found to be around 14%
- A significant improvement in suppression of $b\bar{b}$ background is needed

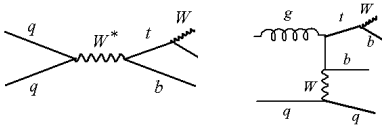
Background sources



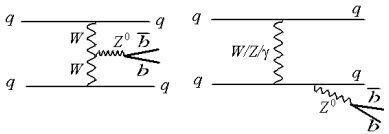
$b\bar{b}$ background



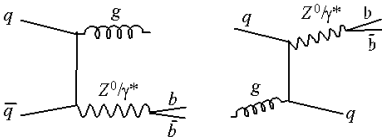
$t\bar{t}$ background



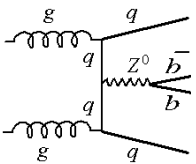
single top background



Z+2 forward jets background



Z+jet background



$gg \rightarrow$ Z+jets background

HLT efficiency after all reconstruction cut

Tabelle: HLT efficiency after all reconstruction cut

Trigger menu	trigger efficiency(%)
e25i	0.0
2e15i	0.0
μ6	79.7
μ20i	21.9
1j400	1.6
3j165	0.0
4j110	0.0
Any trigger	80.0

L1 Trigger requirement

data sample: 110000 full simulated VBF signal without filter

- Electrons
  - Isolation:
    - L1Em_Isol<3 GeV
    - L1Em_HdIso<2 GeV
    - L1Em_HdCore<2 GeV
  - e25i: EM cluster ET> 19 GeV
  - 2e15i: EM cluster ET> 11 GeV
- Muons
  - mu6: muon with PT threshold from muCTPI_ROI>=3
  - 2mu6: 2 muons with PT threshold from muCTPI_ROI>=3
  - mu20: PT threshold from muCTPI_ROI>=5
- Jets
  - 2J45
  - 3J45
  - 4J45

L1 Trigger efficiency

Tabelle: L1 Trigger efficiency

Trigger menu	trigger efficiency(%)
EM25I	4.8
2EM15I	0.7
$\mu 6$	2.6
$2\mu 6$	0.05
$\mu 20$	2.8
$2J45$	41.9
$3J45$	15.1
$4j45$	3.2
Any trigger	46.3 %

L2 Trigger requirement

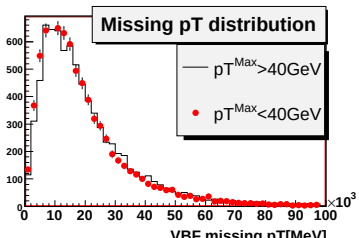
- Electrons
  - E_T Cluster
    - e25i: ET$>$ 19 GeV
    - 2e15i: ET$>$ 11 GeV
      - Calorimeter cuts

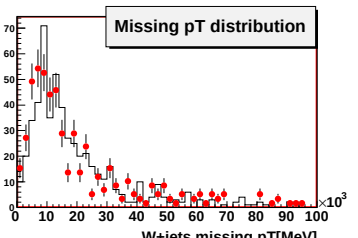
      Hadronic leakage, η width in EM second sampling, E_*stripe* ratio
      - Track matching
- muon
- Jet
  - 1J400
  - 3J165
  - 4J110

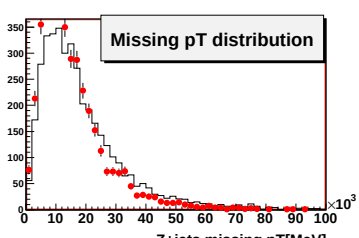
Tabelle: L2 Trigger efficiency

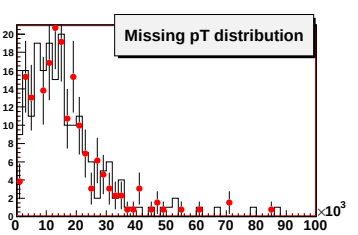
Trigger menu	trigger efficiency(%)
e25i	0.024
2e15i	0
μ6	14.4
μ20i	3.6
1j400	3.1
3j165	0.019
4j110	0.001
Any trigger	17.1

Fast simulation: pT^{Max} and Missing pT are incorrelate



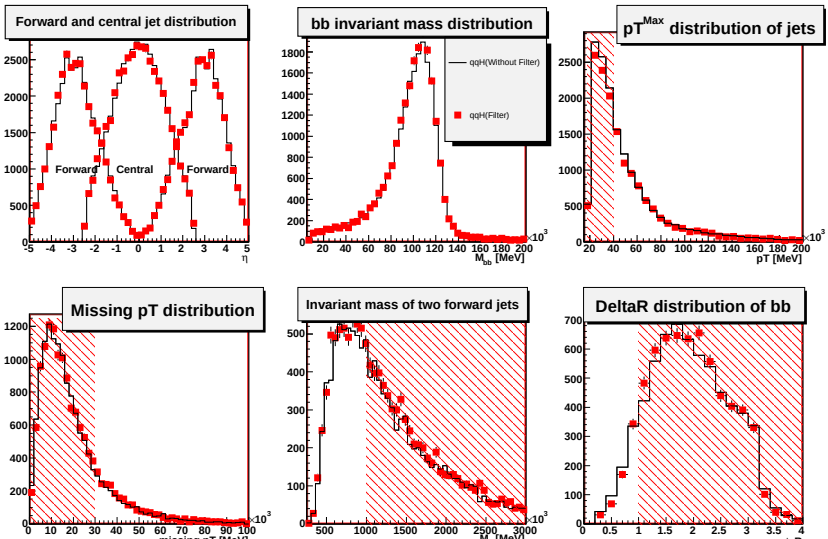






Missing pT distribution is almost the same with $pT^{Max} > 40GeV$ and $pT^{Max} < 40GeV$

Comparison signal distribution with Filter and without Filter



ATLFAST: Distributions with Filter and without Filter are agree well

Trigger efficiency from reconstruction level

Trigger menu		trigger efficiency(%)	
		Fast	Full
di-muons	$2\mu6$	1.2	4.2
	$2\mu10$	0.5	1.8
single muon/ electron	$\mu20$	4.0	4.5
	$\Delta R = 0.2$,$\mu20i20/e25i10$	-	2.3/0.3
	$\Delta R = 0.2$,$\mu20i10/2e15i10$	0.01	1.6/0.004
	$\Delta R = 0.2$ $\mu20i6$	-	1.3
jets	$4j110$	0.3	0.3
	$3j165$	0.3	0.4
	$1j400$	0.5	0.5
COMBINATION	$2\mu10+\mu20i20+4j110+3j165+1j400$	1.1	1.2