Reduction of TTBar Background in VBF Analysis

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Vector Boson Fusion

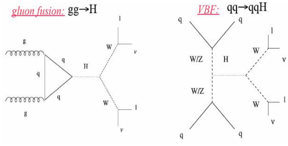


Figure: Gluon-Fusion (left) and Vector Boson Fusion (right)

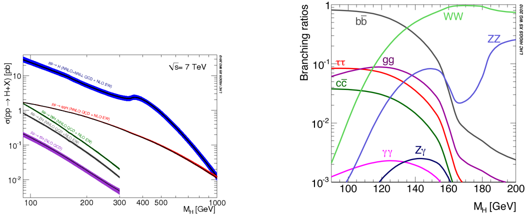


Figure: Production- and Decaycrosssection for Higgs-Boson

Higgs Production via VBF and H→WW $\rightarrow \ell\nu\ell\nu$ gives clear signature (Two high p$_t$ jets, forward-backward orientated).

Jet Definitions and Preselection

Jets:

- Jet Author: AntiKt4TopoEM
- $p_t > 25$ GeV
- $|\eta| < 4.5$

Preselection

- Apply Good Run List
- Primary Vertex Selection
- Event Cleaning
- Exactly one Electron one Muon
- First leading lepton $p_t > 25$Gev
- Two leptons have opposite charge
- $M_{\ell\ell}$ >10GeV
- METrel >25GeV

For VBF additional cuts on tagging jets

2 Jet Analysis

- **CS0** No. of Jets ≥ 2
- **CS1** Erase jet with $|\eta| < 2.5$ and JVF < 0.7
- **CS2** b-tag-veto
- **CS3** $\eta_1 \cdot \eta_2 < 0$
- **CS4** $\Delta\eta > 3.8$
- **CS5** $M_{jj} > 500$GeV
- **CS6**
  CJV: Reject event with add. Jet with $p_t > 25$GeV and $|\eta| < 3.2$
- **CS7** $p_{ttotal} < 30$GeV
- **CS8** $Z \rightarrow \tau\tau$ veto
- **CS9** $m_{ll} < 80$GeV
- **CS10** $\Delta\Phi < 1.3$
- **CS11** $0.75 m_H < m_t < m_H$

This study focuses on B-Tag-Veto and CJV

Cut Efficiencies

Main Background is TTBar.

Signal sample: Sherpa H→WW→ll (VBF 140GeV)

TTBar sample: PowHeg

Only those samples are considered in this study.

Efficiencies are normalized to 2 Jets Events in Sample.

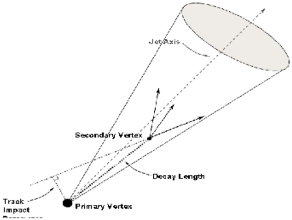
$Cutstage$	$Signal[\%]$	$TTBar[\%]$	$\frac{S}{\sqrt{B+S}}$	
$(3,0)$	100.00 ± 2.52	100.00 ± 0.86	0.003	$No.ofJets \geq 2$
$(3,1)$	90.63 ± 2.45	94.63 ± 0.85	0.002	$\vert\eta\vert < 2.5, JVF < 0.7$
$(3,2)$	86.25 ± 2.39	33.44 ± 0.55	0.007	$b - tag - veto$
$(3,3)$	62.96 ± 2.05	14.28 ± 0.36	0.011	$\eta_1 \cdot \eta_2 < 0$
$(3,4)$	37.30 ± 1.61	1.33 ± 0.10	0.067	$\Delta\eta > 3.8$
$(3,5)$	27.28 ± 1.36	0.70 ± 0.08	0.091	$M_{jj} > 500GeV$
$(3,6)$	23.78 ± 1.27	0.36 ± 0.06	0.146	CJV
$(3,7)$	17.95 ± 1.12	0.26 ± 0.06	0.154	$p_{ttotal} < 30GeV$
$(3,8)$	17.95 ± 1.12	0.26 ± 0.06	0.154	$Z \rightarrow \tau\tau veto$
$(3,9)$	16.46 ± 1.06	0.01 ± 0.01	0.763	$m_{ll} < 80GeV$
$(3,10)$	14.38 ± 0.98	0.00 ± 0.00	1.000	$\Delta\Phi < 1.3$

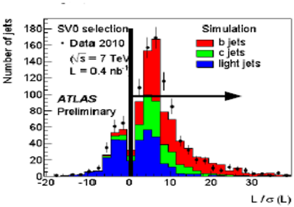
At CS0 about 385 $T\bar{T}$ Events on every VBF-Event

SV0 B-Tag Algorithm

Secondary Vertex Finder SV0

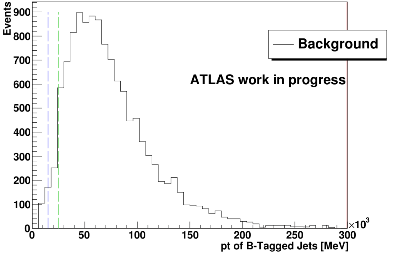
- Use tracks well separated from primary vertex (2.3σ)
- fits two tracks
- Remove K^0, Λ^0, photons and material interactions
- Then fits inclusive vertices from remaining tracks
- Excess at large flight length significance $L/\sigma(L) \rightarrow$ consistent with expectation from b-jets





Low p_t B-Tag

Jet-p_t cut leads to B Jets passing the B-Jet-Veto.



Before cut.

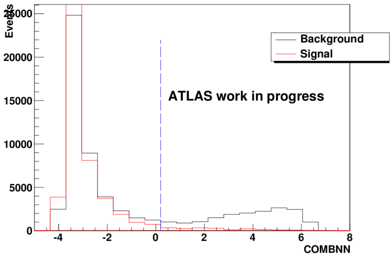
Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 2)	86.25 ± 2.39	33.44 ± 0.55	0.007

Apply B-tag Veto for Jets with p_t >15GeV and no JVF-Cut.

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 2)	86.04 ± 2.39	30.91 ± 0.53	0.007

Advanced B-Tag Algorithm

Multivariate Algorithm (CombNN) is more effective than SV0.



Set CombNN-Working Point to 0.2

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 2)	86.04 ± 2.39	30.91 ± 0.53	0.007

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 2)	83.02 ± 2.37	13.20 ± 0.36	0.016

Central Jet Veto

Old CJV:

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$	
(3, 6)	23.78 ± 1.27	0.36 ± 0.06	0.146	*CJV*

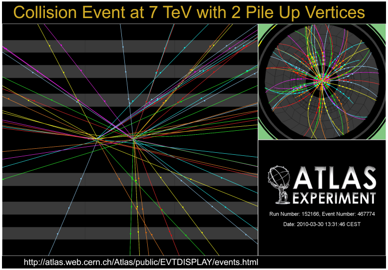
Cutflow (With CombNN-B-Tag)

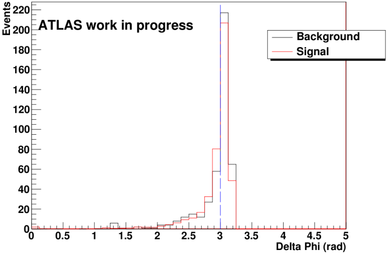
Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 0)	100.00 ± 2.52	100.00 ± 0.86	0.003
(3, 1)	90.63 ± 2.45	94.63 ± 0.85	0.002
(3, 2)	83.02 ± 2.37	13.20 ± 0.36	0.016
(3, 3)	60.99 ± 2.04	5.62 ± 0.23	0.027
(3, 4)	36.83 ± 1.61	0.90 ± 0.10	0.095
(3, 5)	26.92 ± 1.36	0.41 ± 0.07	0.144
(3, 6)	23.42 ± 1.27	0.27 ± 0.06	0.181
(3, 7)	17.89 ± 1.13	0.22 ± 0.06	0.176
(3, 8)	17.89 ± 1.13	0.22 ± 0.06	0.176
(3, 9)	16.23 ± 1.06	0.00 ± 0.00	1.000
(3, 10)	14.15 ± 0.98	0.00 ± 0.00	1.000

Lowering Jet-p_t threshold to 15 GeV also reduces background at Central Jet Veto

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 6)	18.06 ± 1.20	0.18 ± 0.06	0.206

Central Jet Veto





Signal gets reduced because of Pileup Jets which lies in $|\eta| < 3.2$. To avoid pile-up effects, look at $\Delta\Phi$.
Idea: Pile Up Jets tend to lie in opposite directions.
$\Rightarrow$Apply cut on $\Delta\Phi$ for additional jets.

$Cutstage$	$Signal[\%]$	$TTBar[\%]$	$\frac{S}{\sqrt{B+S}}$
$(3,6)$	18.06 ± 1.20	0.18 ± 0.06	0.206

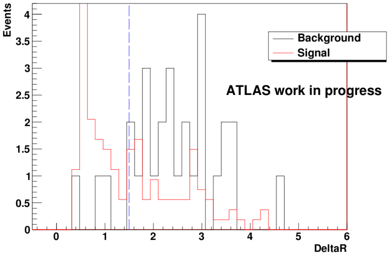
$Cutstage$	$Signal[\%]$	$TTBar[\%]$	$\frac{S}{\sqrt{B+S}}$
$(3,6)$	20.01 ± 1.22	0.18 ± 0.05	0.224

Central Jet Veto (TheoryDefinition)

Improve CJV by calling a Central Jet an additional Jet, which lies in between the two tagging jets.

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
$(3,6)$	20.81 ± 1.20	0.18 ± 0.05	0.230

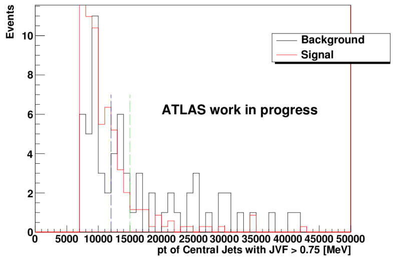
Final state radiation in signal is recognised as Central Jets.



$\Rightarrow$ Call Central Jets, which *Delta*R between tag Jet ≥ 1.5

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
$(3,6)$	25.16 ± 1.34	0.18 ± 0.05	0.266

Central Jet Veto



In background sample are Central Jets below p_t threshold. Consider low p_t Jets as Central Jets, if JVF > 0.75.

Initial CJV:

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$	
(3, 6)	23.78 ± 1.27	0.36 ± 0.06	0.146	*CJV*

Cutstage	*Signal*[%]	*TTBar*[%]	$\frac{S}{\sqrt{B+S}}$
(3, 0)	100.00 ± 2.52	100.00 ± 0.86	0.003
(3, 1)	90.63 ± 2.45	94.63 ± 0.85	0.002
(3, 2)	83.02 ± 2.37	13.20 ± 0.36	0.016
(3, 3)	60.99 ± 2.04	5.62 ± 0.23	0.027
(3, 4)	36.83 ± 1.61	0.90 ± 0.10	0.095
(3, 5)	26.92 ± 1.36	0.41 ± 0.07	0.144
(3, 6)	23.61 ± 1.31	0.13 ± 0.04	0.312
(3, 7)	17.74 ± 1.16	0.09 ± 0.03	0.341
(3, 8)	17.74 ± 1.16	0.09 ± 0.03	0.341
(3, 9)	16.08 ± 1.09	0.00 ± 0.00	1.000
(3, 10)	14.49 ± 1.04	0.00 ± 0.00	1.000

Conclusion and Outlook

Conclusion:

- Optimization of B-tag, CJV and Pileup-Jets leads to significant reduction of TTBar-background.
- There is almost no loss of signal!

Outlook:

- Higher Statistics (Release 17)
- Comparison to data