

# Higgs decay to $WW^*$ at 3TeV CLIC

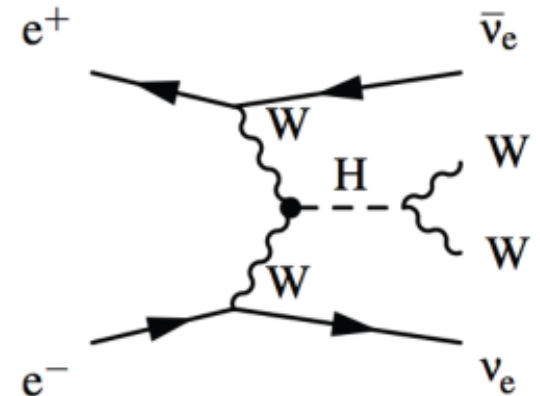
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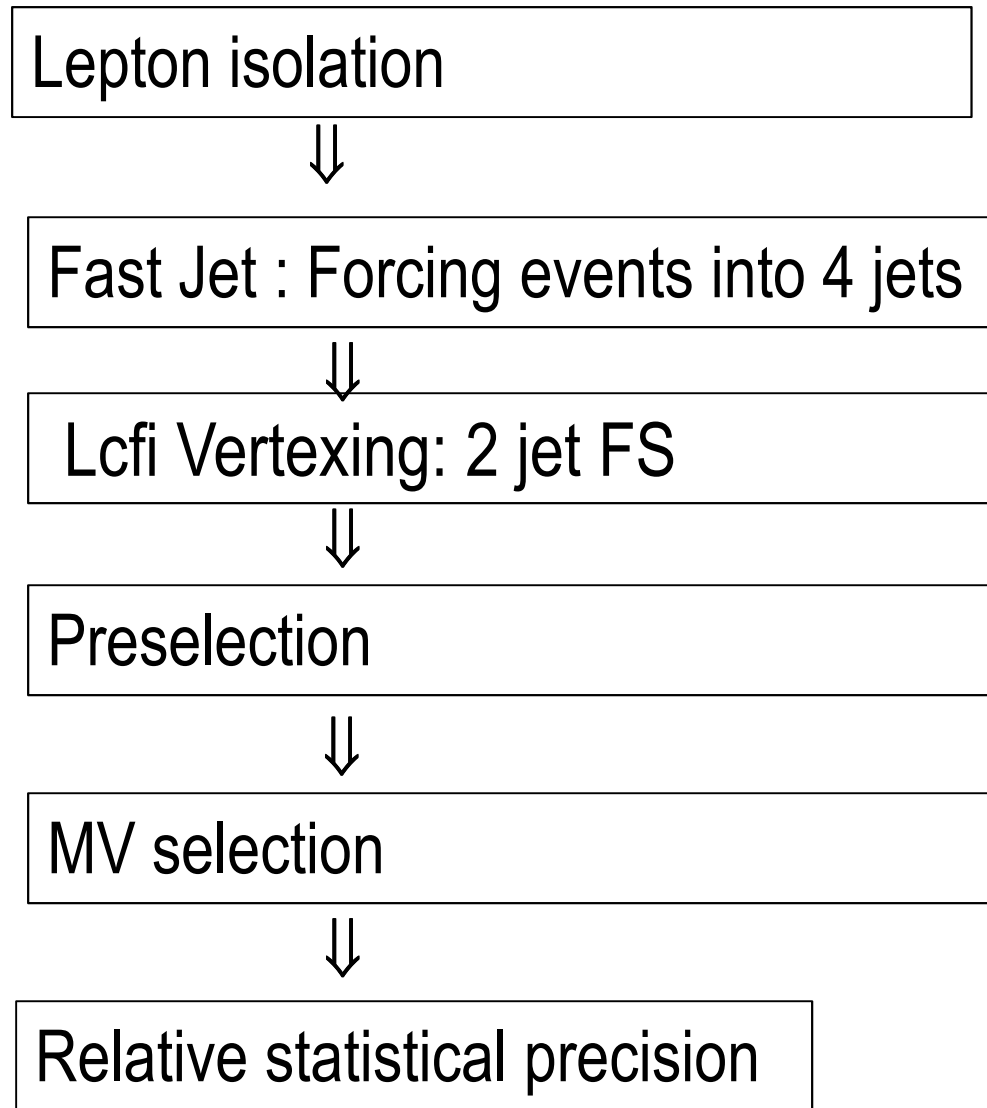
# Introduction

- Analyzed fully hadronic decay:  $H \rightarrow WW^* \rightarrow qqqq$  in  $WW^*$  fusion
- $\sigma(e^+e^- \rightarrow H\nu\nu) \sim 415.04 \text{ fb}$
- $BF_{(H \rightarrow WW)} \sim 21.5 \%$  ,  $BF_{(WW \rightarrow qqqq)} \sim 45.6 \%$
- $\Rightarrow \sigma \approx 40.69 \text{ fb}$
- $\# \text{evts}/2\text{ab}^{-1}$  in total Higgs sample  $\Rightarrow \sim 81000 \text{ evts}/2\text{ab}^{-1}$
- Polarization not included
- Higgs production in  $WW$ -fusion (t-channel)  
 $\Rightarrow$  Forward jets+missing energy



# Analysis strategy

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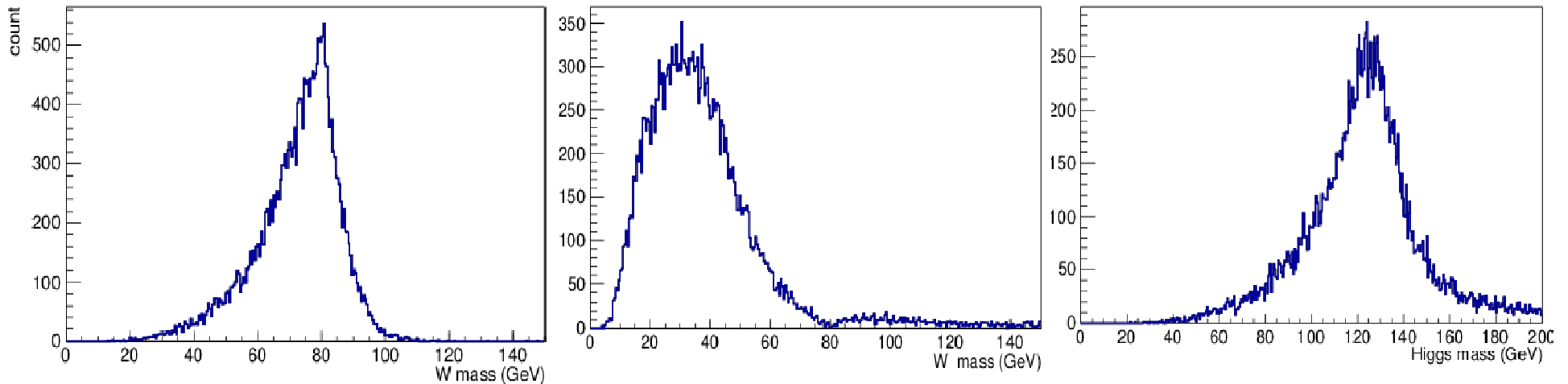


$$\frac{\Delta \sigma}{\sigma} = \frac{\sqrt{S + B}}{S}$$



# Simulation and reconstruction

- Event generation with WHIZARD V57 , ISR, BS, beam recoil
- CLIC\_ILD detector model
- Using Tight Selected Collection –reduction of beam background , R=0.9
- Force events into four jets
- Jet Pairing to form W, W\*  $\min(d_{ij}) = \min | M_{ij} - M_W |$



# Signal and background processes

Process	prodID	$\sigma$ [fb]
Signal $e^+e^- \rightarrow H\nu\nu$	Inclusive 6534	415.04
$H \rightarrow WW^* \rightarrow q\bar{q}q\bar{q}$		40.7
Other Higgs decays		374.34
qq	4586	2948.9
qqvv	6583	1317.5
qqlv	6747	5561.1
qqll	3048	3319.6
qqqq	6776	546.5
qqqqvv	6751	71.5
qqqqlv	6540	106.6
qqqqll	6754	169.3
qqqqv (EPA)	6571	542
qqqqv (BS)	6574	262.5
qqqqv (EPA)	6577	54.2
qqqqv (BS)	6580	262.3
qqqqe (EPA)	6733	287.8
qqqqe (BS)	6736	1268.6
qqqqe (EPA)	6739	287.8
qqqqe (BS)	6742	1267.3
qqqq (EPA)(EPA)	6721	402.7
qqqq (BS)(EPA)	6724	2423.1
qqqq (BS)(EPA)	6727	2420.6
qqqq (BS)(BS)	6730	13050.3

The dominant backgrounds:

qqvv

qqlv

other Higgs decays

$\gamma\gamma \rightarrow qqqq$

# Dominant background reduction

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Additional steps:

- **qqlv** – the leading background  $\Rightarrow$  tag the lepton in the event

The peaked-forward leptons

isolated lepton finder is tagged in the tracker region , above  $\sim 8^\circ$

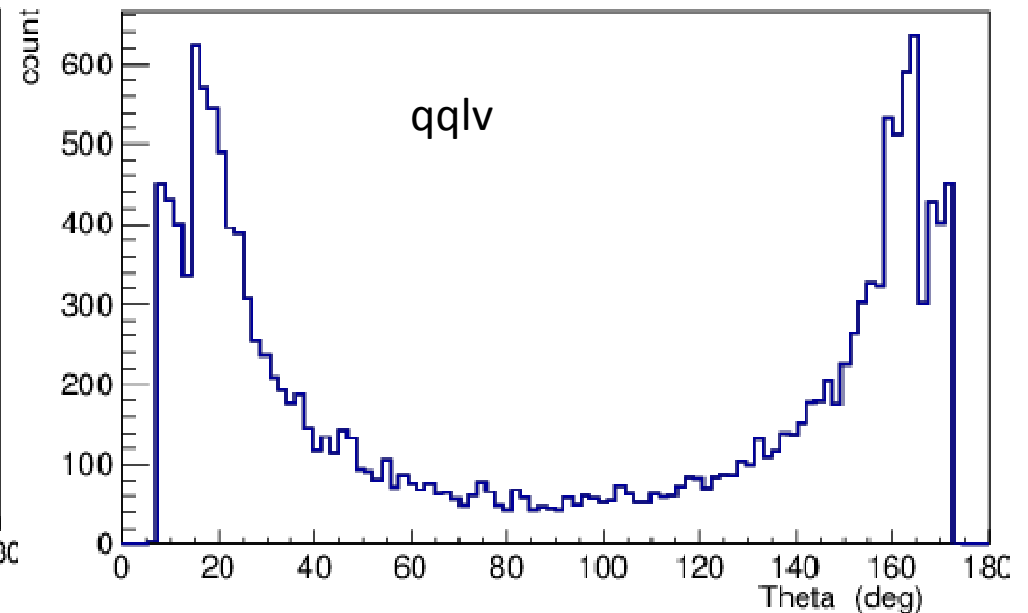
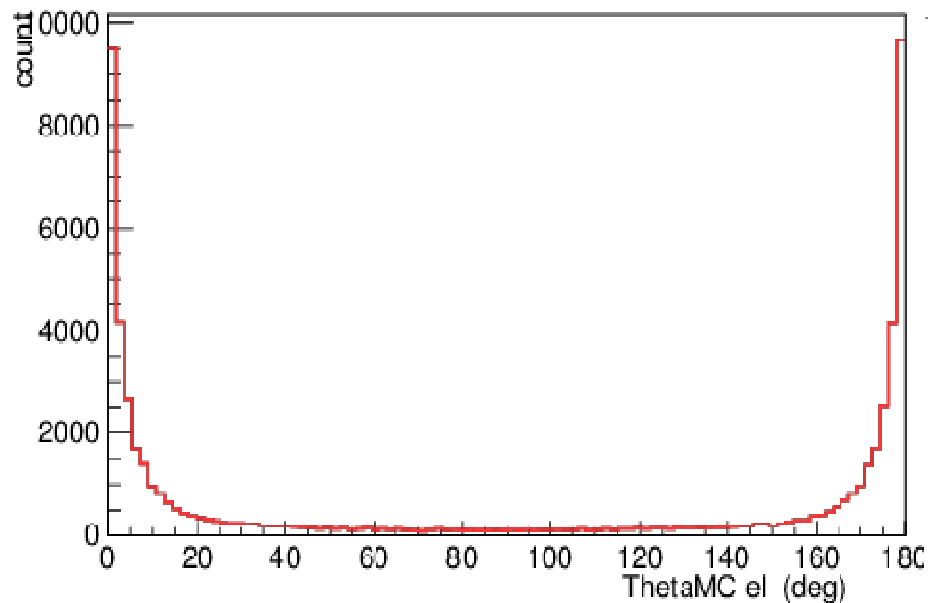
- **other Higgs decays:** treat separately  $H \rightarrow bb$ ,  $H \rightarrow cc$ ,  $H \rightarrow gg$ ,  $H \rightarrow \text{rest}$

- **$\gamma\gamma$ ,  $e\gamma$  backgrounds-** apply preselection cut on the jet pt



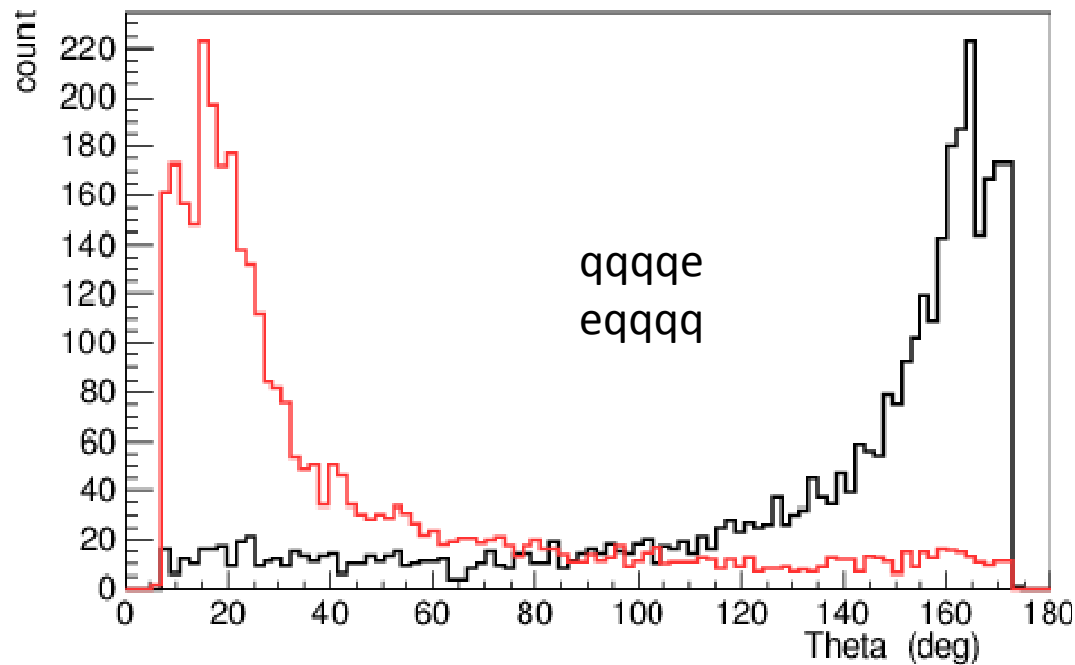
# qqlv reduction

- Dominant background
- Forward leptons
- Large fraction of leptons outside the tracker region  $8^\circ < \theta < 172^\circ$
- Using PID at isolated lepton finder and  $E_{\text{track}} > 15 \text{ GeV} \Rightarrow$  lepton identification
- Refine lepton identification
- Investigating forward electron tagging



# qqqqe

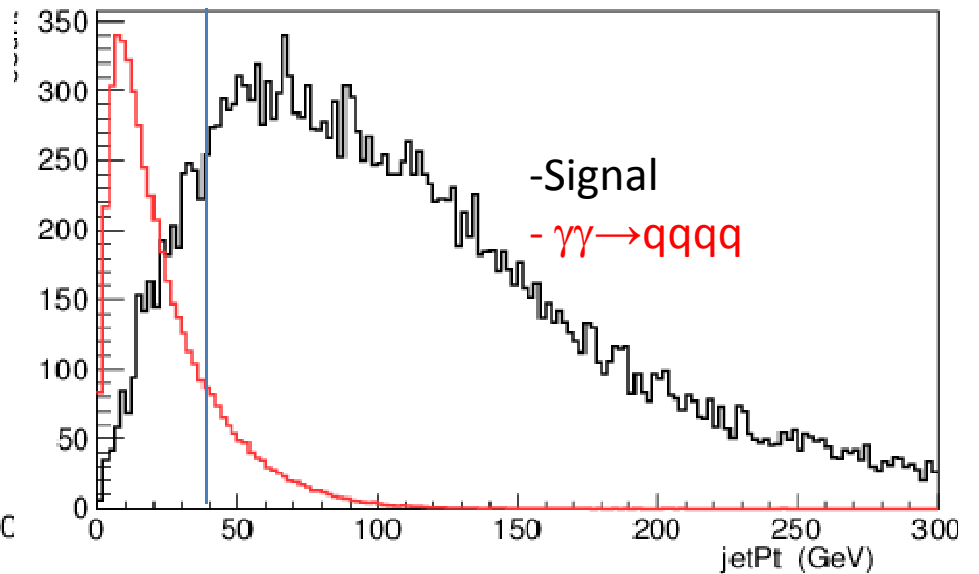
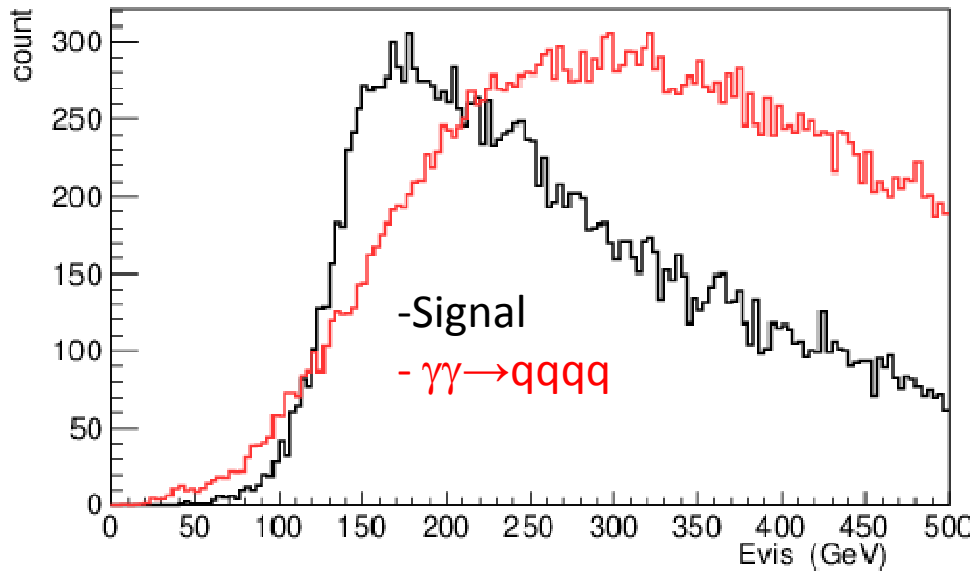
- Forward electrons
- Using PID at isolated lepton finder and  $E_{\text{track}} > 15 \text{ GeV} \Rightarrow$  lepton identification
- Large fraction outside the tracker region  $8^\circ < \theta < 172^\circ$





# $\gamma\gamma$ and $e^\pm\gamma$

- Luminosity scaling applied:
- $L_{e^\pm\gamma} = 0.79 L_{e^+e^-}$
- $L_{\gamma\gamma} = 0.69 L_{e^+e^-}$
- Preselection cut  $pt_{\text{Jet}} > 40 \text{ GeV}$

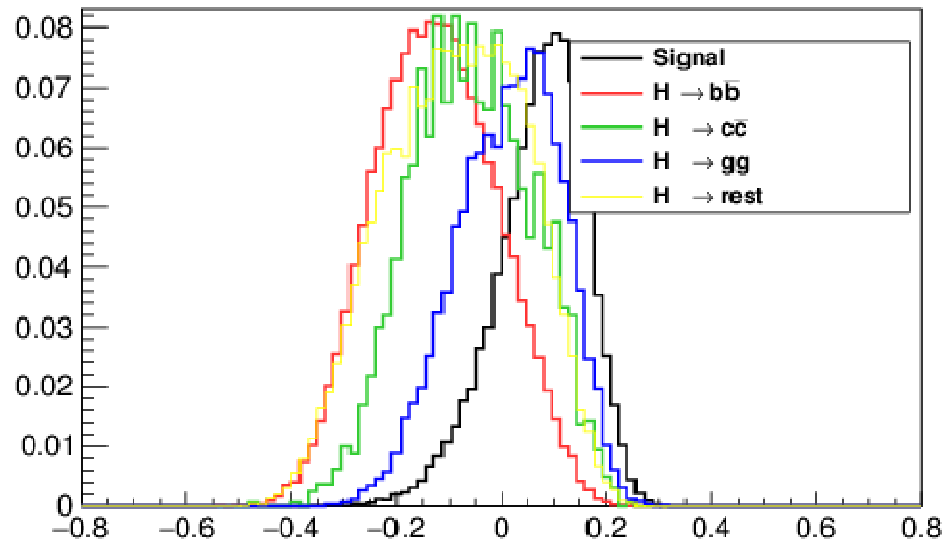


\*shape comparison



# Other Higgs decays

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The output variable of the BDT classifier

- **other Higgs decays:**  $H \rightarrow b\bar{b}$ ,  $H \rightarrow c\bar{c}$ ,  $H \rightarrow g\bar{g}$ ,  $H \rightarrow \text{rest}$
- the best reduction is achieved for  $H \rightarrow b\bar{b}$ ,  $H \rightarrow c\bar{c}$



# Event selection

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Preselection:

$90 < m_H < 150 \text{ GeV}$   $PtJet > 40 \text{ GeV}$

$N_{lept} = 0$

TMVA Input variables:

- Invariant masses:  $m_{\text{Higgs}}$   $m_W$   $m_{W^*}$
- NPFO  $E_{\text{vis}}$   $jetP_t$
- Event shape variables: thrust
- Jet transitions:  $y_{12}$   $y_{23}$   $y_{34}$   $y_{45}$   $y_{56}$   $y_{67}$
- Force event into 2 jet: btag1, btag2, ctag1, ctag2
- Angle between jets that comprise W real: ThetaPartW

Training included all the backgrounds



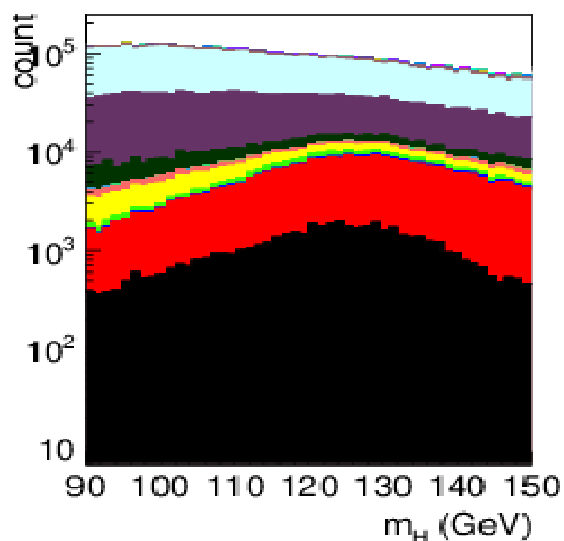
# Event selection

Process	prodID	$\sigma$ [fb]	$\epsilon_{\text{pres}}$ [%]	$\epsilon_{\text{tot}}$ [%]	#evts BDT
$e^+e^- \rightarrow H\nu\nu$	Inclusive 6534	415.04			
Signal $H \rightarrow WW^* \rightarrow q\bar{q}q\bar{q}$	10.52%	40.7	64.6	18.0	14534
Other Higgs decays	BF [%]	374.3			8248
$H \rightarrow b\bar{b}$	55.16	228.9	49.0	0.4	1627
$H \rightarrow c\bar{c}$	2.72	11.3	45.2	2.3	515
$H \rightarrow gg$	6.58	27.3	56.8	6.4	3466
$H \rightarrow \text{other}$	25.02	103.8	38.9	1.3	2640
qq	4586	2948.9	2.0	$<10^{-5}$	38
qqvv	6583	1317.5	45.8	0.3	7664
qqlv	6747	5561.1	26.3	0.1	12623
qqll	3048	3319.6	4.0	$<10^{-3}$	135
qqqq	6776	546.5	3.3	$<10^{-2}$	77
qqqqvv	6751	71.5	2.2	0.3	358
qqqqlv	6540	106.6	1.1	0.04	93
qqqqll	6754	169.3	1.8	0.05	172
qqqqv (EPA)	6571	54.2	2.1	0.15	161
qqqqv (BS)	6574	262.5	3.3	/	/
qqqqv (EPA)	6577	54.2	2.2	0.14	146
qqqqv (BS)	6580	262.3	3.2	$<10^{-3}$	4
qqqqe (EPA)	6733	287.8	2.0	0.05	306
qqqqe (BS)	6736	1268.6	2.6	0.04	1082
qqqqe (EPA)	6739	287.8	2.2	0.07	406
qqqqe (BS)	6742	1267.3	2.6	0.05	1182
qqqq (EPA)(EPA)	6721	402.7	2.8	0.04	368
qqqq (BS)(EPA)	6724	2423.1	2.8	0.24	1161
qqqq (BS)(EPA)	6727	2420.6	2.7	0.34	1659
qqqq (BS)(BS)	6730	13050.3	2.0	$<10^{-3}$	107

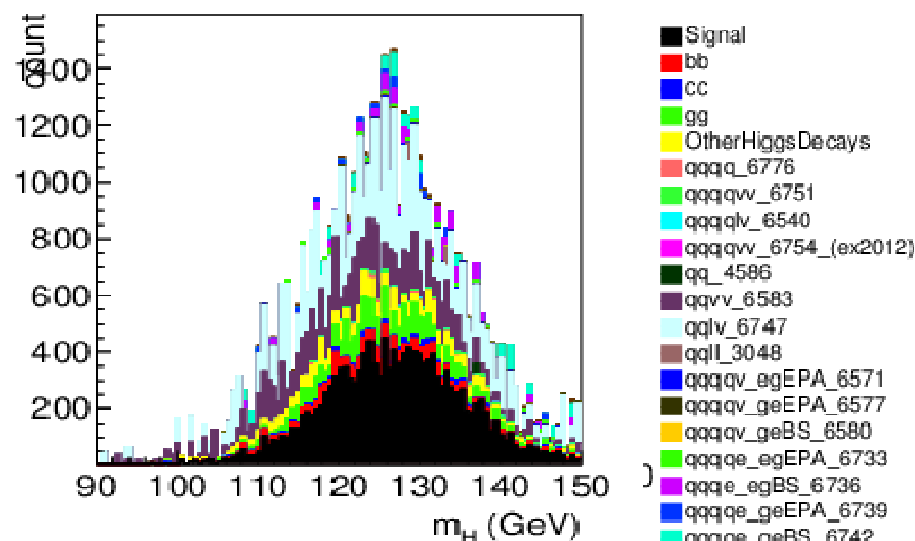


# Reduction after tmva

After preselection



After TMVA



- The dominant background after mva are the ones with jets and missing energy signature: qqlv and qqvv backgrounds and  $H \rightarrow gg$

$$\frac{\Delta \sigma}{\sigma} = \frac{\sqrt{S + B}}{S} \approx 1.5\%$$



# Summary

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- In order to reduce the dominant background,  $qqlv$ , the lepton isolation is applied
- Redefined the preselection
- Luminosity scaling for  $e\gamma$  and  $\gamma\gamma$  backgrounds included
- result of the relative statistical uncertainty is 1.5%
  
- Future Plans:
  - Refining lepton isolation
  - Considering electron tagging in the forward region



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# BACKUP

