Measurement of the H→WW* Branching Ratio at 1.4TeV Using the WW*→qqlv Decay Channel

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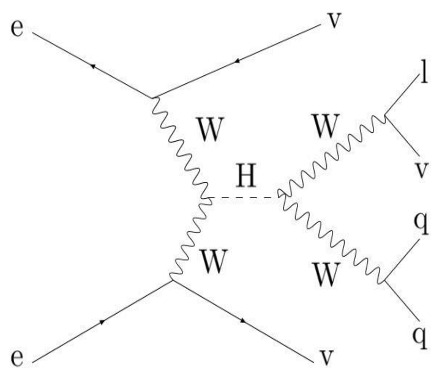
Motivation

- A key objective of any future e^+e^- collider is to perform a model independent measurement of the total Higgs width Γ_H
- Γ_H is expected to be ~4MeV and so is not easily measured directly
- Solution is to perform an indirect measurement by taking ratios of the following quantities:
  - $\sigma_{ZH} \propto g_z{}^2$
  - $\sigma_{ZH} \times BR(H \rightarrow b\bar{b}) \propto \frac{g_z{}^2 g_b{}^2}{\Gamma_H}$
  - $\sigma_{\nu\bar{\nu}H} \times BR(H \rightarrow b\bar{b}) \propto \frac{g_W{}^2 g_b{}^2}{\Gamma_H}$
  - $\sigma_{\nu\bar{\nu}H} \times BR(H \rightarrow WW^*) \propto \frac{g_W{}^4}{\Gamma_H}$

- As a stand alone measurement, deviations from the standard model could provide evidence for BSM physics (e.g. extended Higgs models) with the size of the deviation pointing towards the scale at which this new physics might exist.

Overview



- Analysis performed using ILCSoft v01-17-06
- $\sqrt{s} = 1.4\text{TeV},\ L = 1.5ab^{-1}$
- Final states with Tau leptons are not included

Process	Cross Section(fb)	Production ID[4]	Events Used
Signal: ee→H(WW* →qqlν)$\nu\nu$	18.9	2022[i]	70000
ee→H(WW*→qqqq)$\nu\nu$	25.6	2022[i]	140000
ee→H(→other)$\nu\nu$	199.6	2022[i]	750000
ee→qq	4009.5	2091	500000
ee→qqqq	1328.1	2163	300000
eγ→eqq (γ from EPA)	32308	2515[ii]	500000
γe→eqq (γ from BS)	56043	2527[ii]	500000
ee→qq$\nu\nu$	787.7	3243	500000
ee→qqll	2725.8	3246	400000
ee→qqlν	4309.7	3249	1000000

Analysis Flow

Event Reconstruction

Identify Isolated Lepton

↓

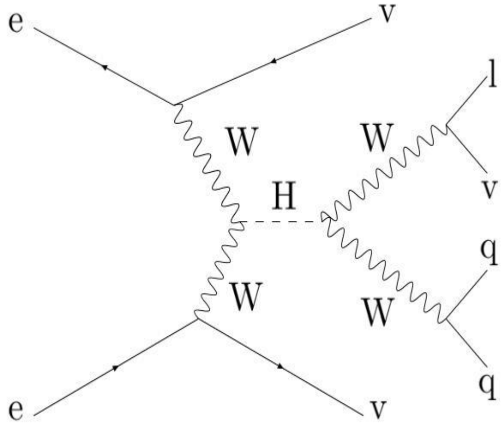
Group Remaining PFOs
Into 2 jets

↓

Reconstruct W and H
Bosons

↓

Flavour Tag



Background Separation

Preselection Cuts

↓

BDT Discriminator

Identification of the Isolated Lepton

- Two separate methods developed and tested

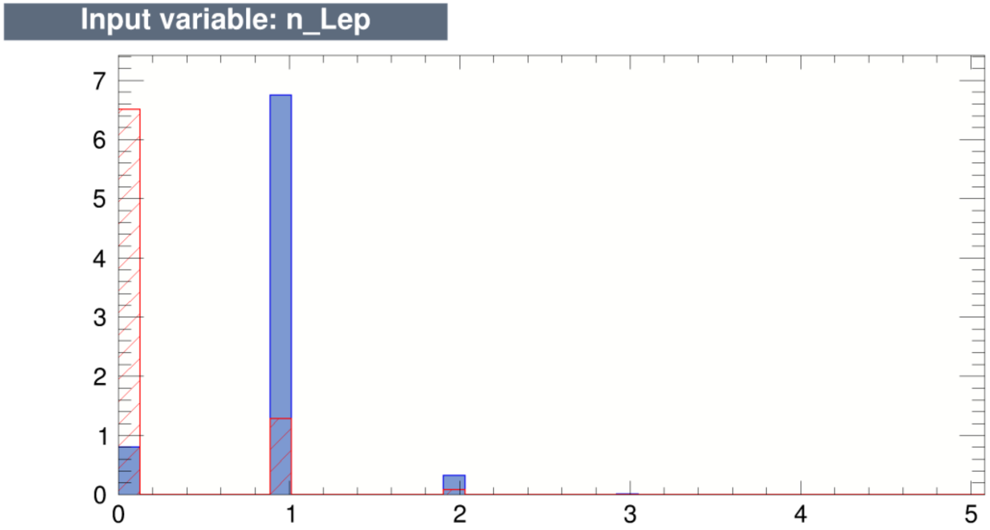
First Method :

- Use PID from Pandora to identify all electrons or muons
- Assume the isolated lepton is the highest energy particle out of all the leptons identified
- Efficiency = 93%
- Purity = 96%

Identification of the Isolated Lepton (2)

Second Method :

- Sort all PFOs into 4 jets
- Identify isolated particles based on the ratio of the PFO energy to jet energy
- Apply cuts on track energy, ratio of energy deposited in ECAL/HCAL and the ratio of the PFOs energy to momentum
- Efficiency= 91% Purity=74%
- Not as performant for identification…however, number of leptons selected by this method shows good discrimination between signal and backgrounds:



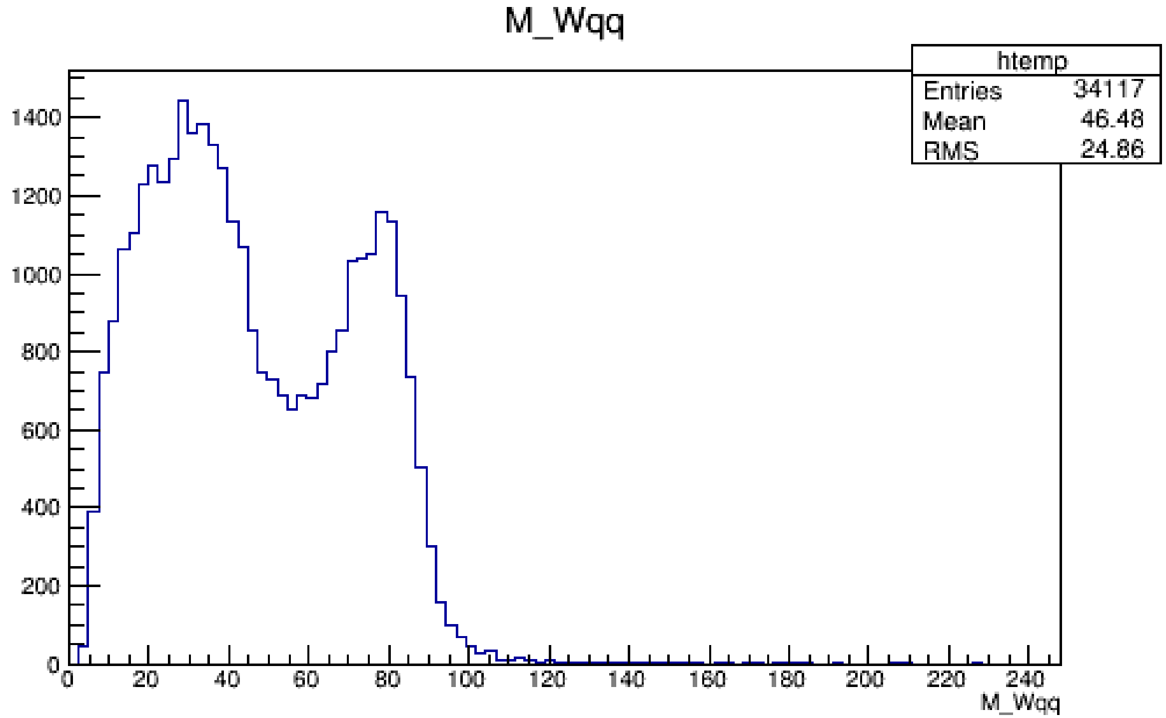
Identification of the Isolated Lepton (3)

Summary:

- First method identifies isolated lepton which is then used for reconstruction
- Second method provides discriminating variable for rejecting background

Jet Finding

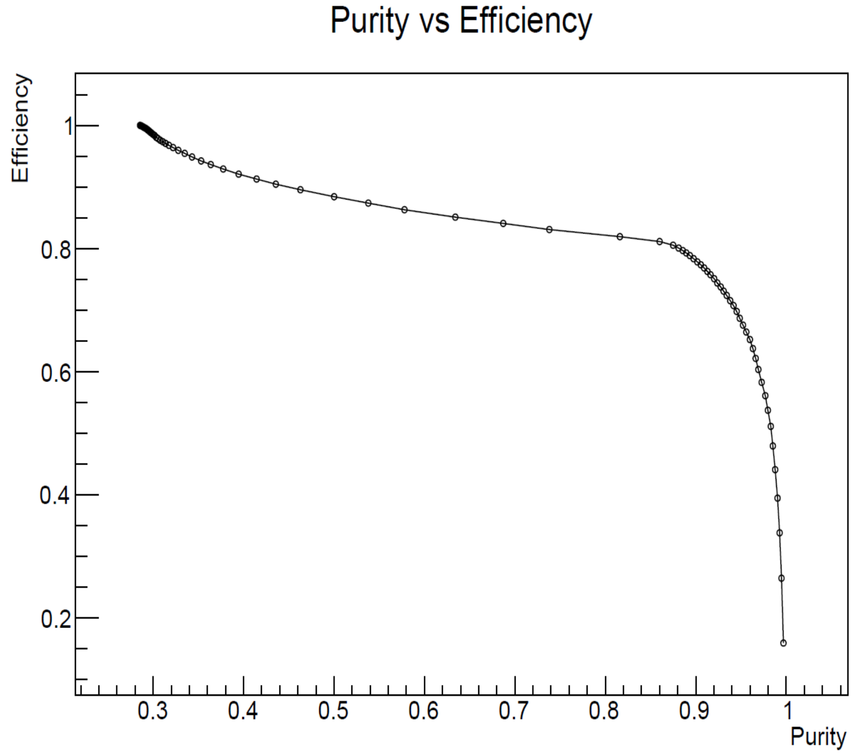
- FastJet used to force remaining PFOs into 2 jets using the kt-algorithm, E-scheme for recombination and R=0.4
- Jets were combined to reconstruct the hadronically decaying W



- W and isolated lepton then combined to reconstruct the Higgs

Flavour Tagging

- Useful for removing background events involving b jets e.g. H→bb
- Performed using LCFIPlus v00-05-02
- Neural nets trained and tested using 300,000 ee→Zνν, Z→qq events (Prod_ID 2801, 2804, 2807)
- Purity of 90% possible while retaining an efficiency of 80%



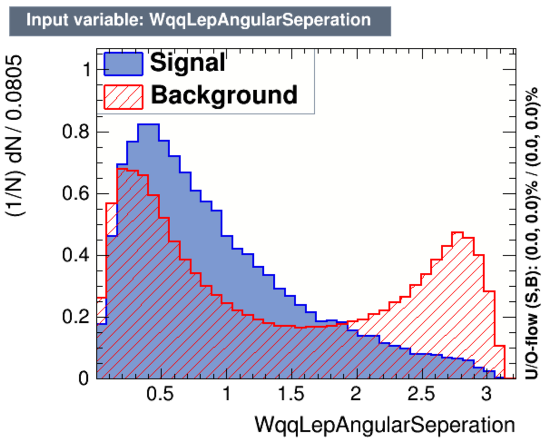
Training of the BDT with TMVA

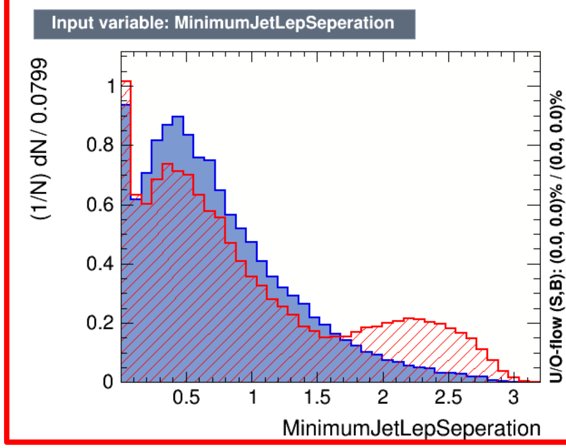
- 70,000 signal events and 4,600,000 background events split evenly between training and testing

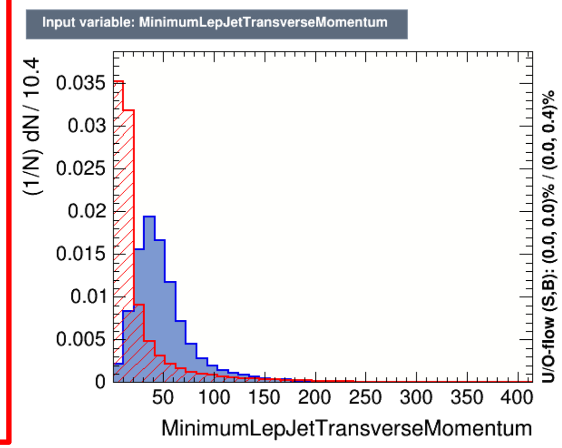
- 19 parameters used in the training. Most useful variables were found to be:
  - Mass of the reconstructed Higgs
  - Minimum angular separation between the isolated lepton and either jet
  - Missing energy
  - Mass of the reconstructed W
  - Number of isolated lepton candidates (as shown earlier…)

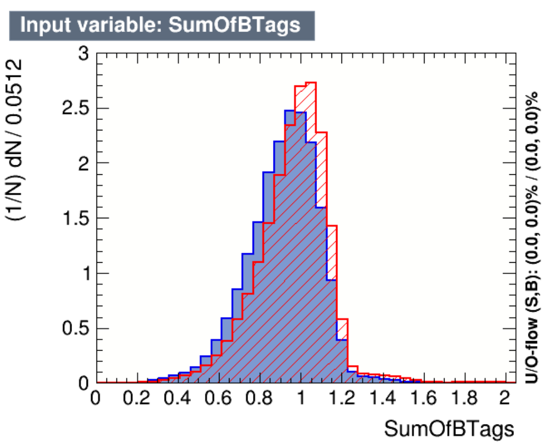
- Loose cuts applied: $E_{Wqq} < 590$GeV, $M_{Wqq} < 230$GeV, $M_H < 310$GeV, $E_{missing} > 670$GeV in TMVA

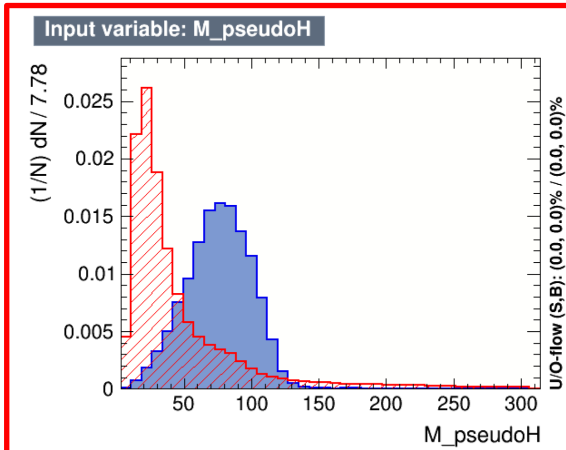
Input Variable Distributions

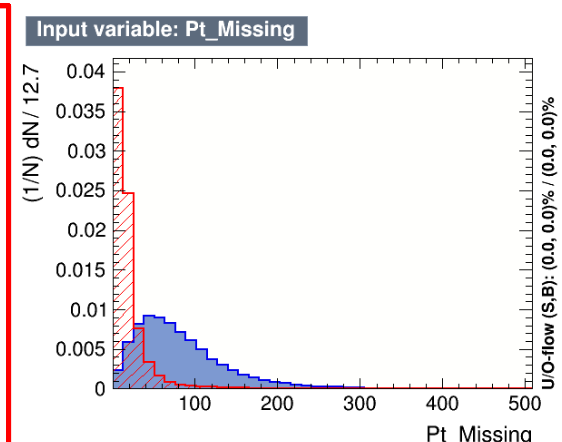




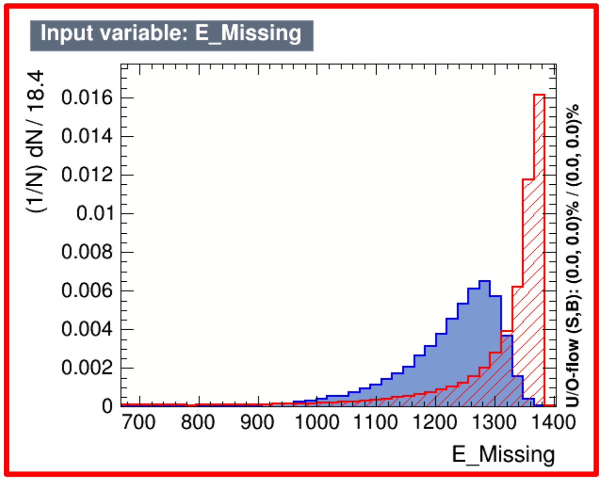


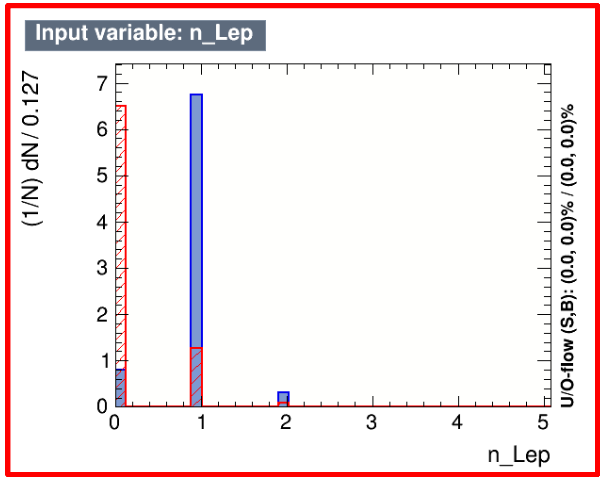


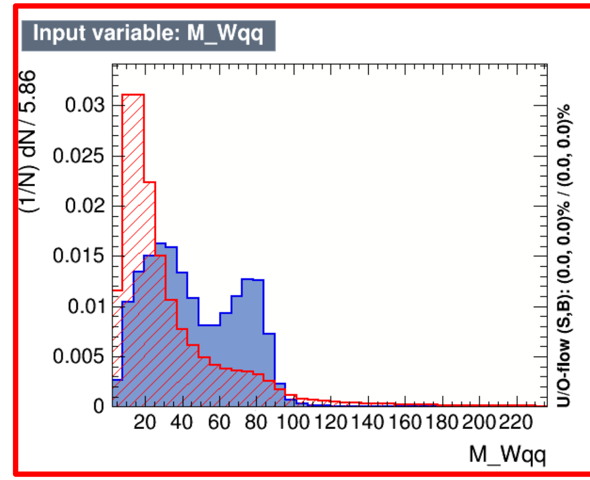


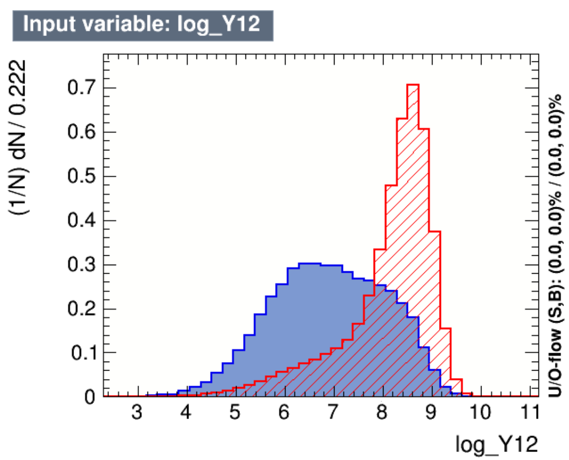


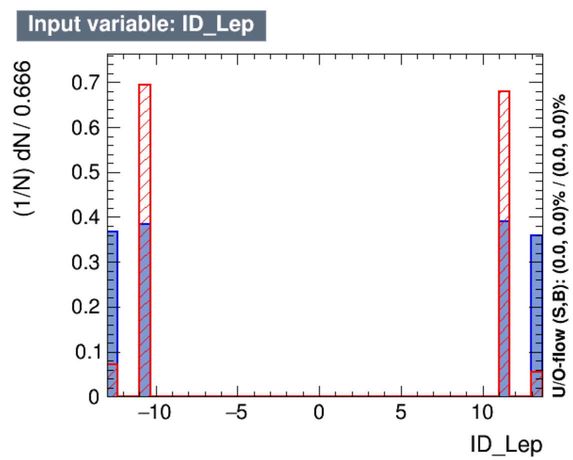
Input Variable Distributions (2)

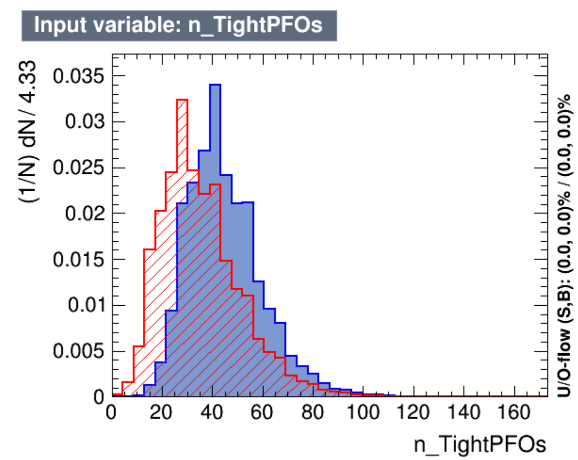




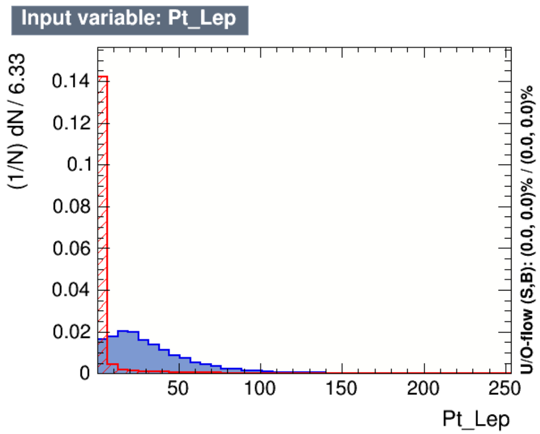


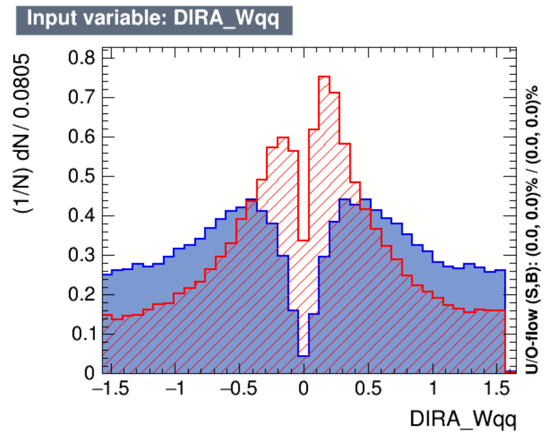


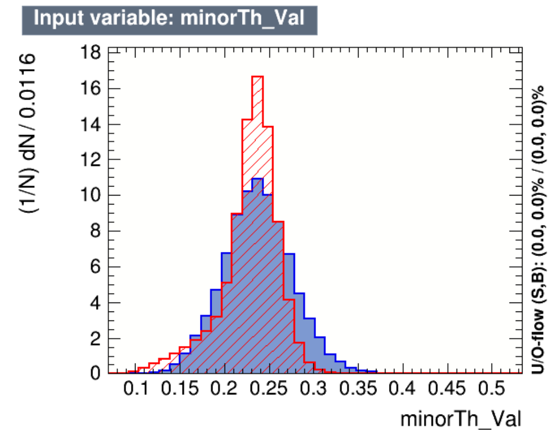


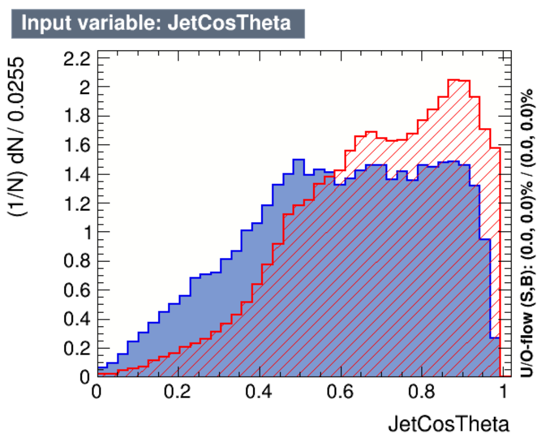


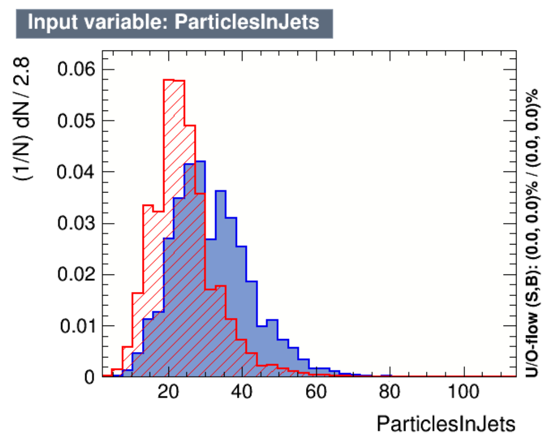
Input Variable Distributions (3)

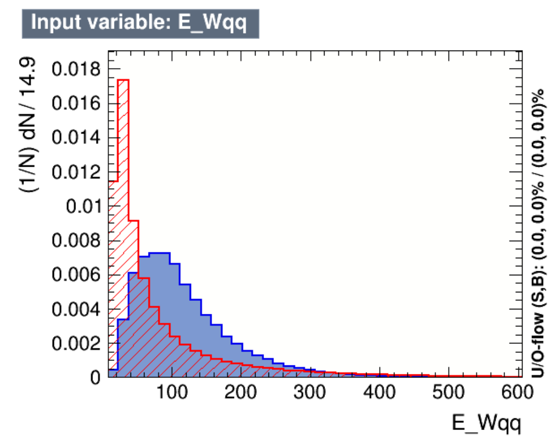




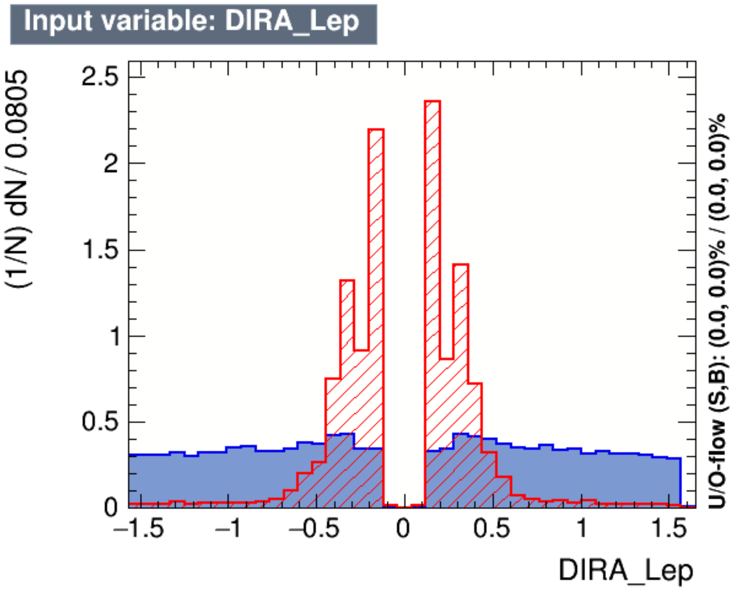




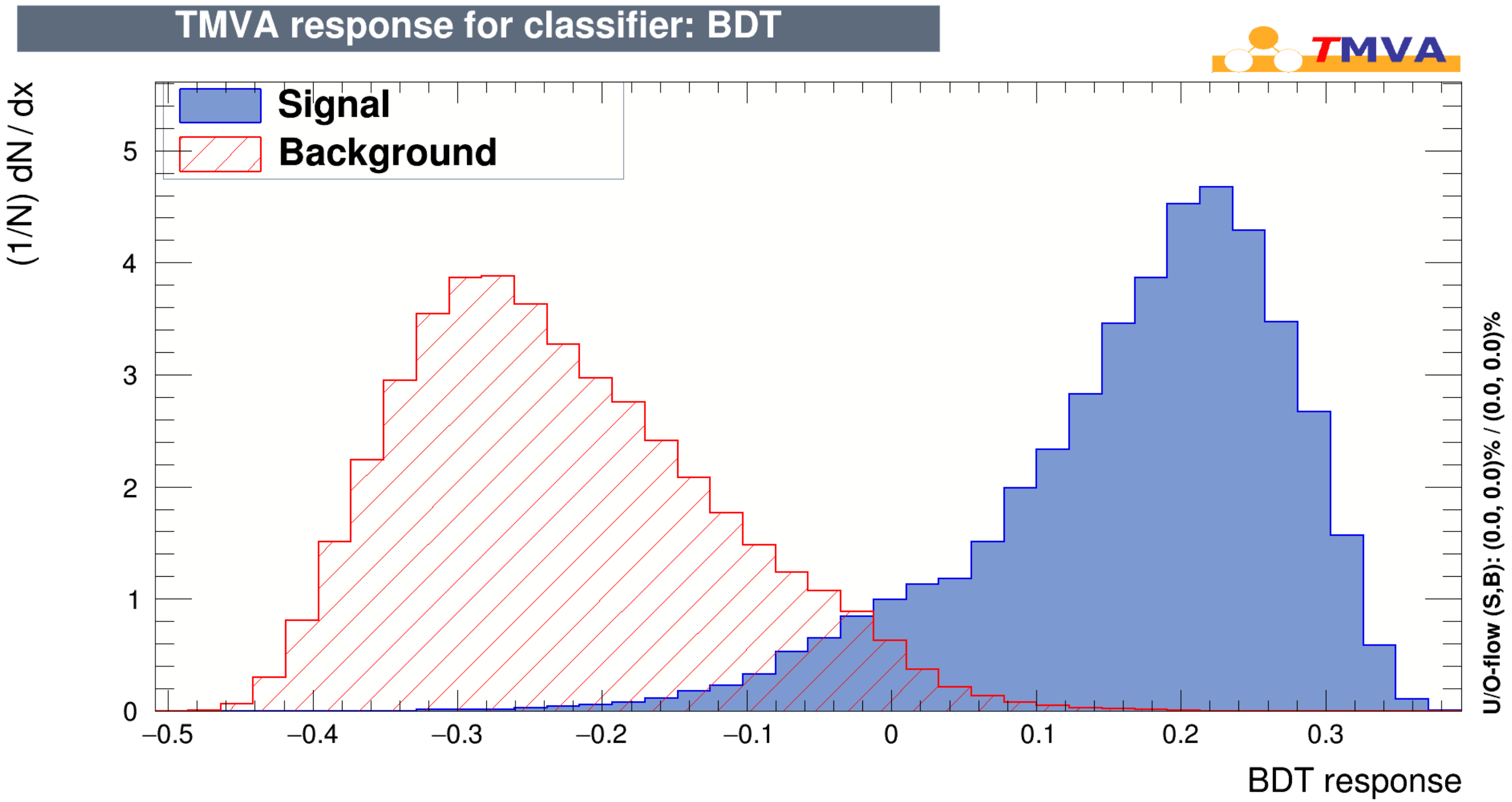




Input Variable Distributions (4)



BDT Classifier Output



Optimal cut found to be at 0.21

Results

Table 2: Efficiency for all processes following pre-selection and BDT response cuts (ε_{Pre} and ε_{BDT}) and the number of events expected to satisfy these requirements, for an integrated luminosity of 1.5ab^{-1}.

Process	Cross Section(fb)	$\varepsilon_{Pre}(\%)$	$\varepsilon_{BDT}(\%)$	Events After BDT
Signal	18.9	99.99	42.65	12091
$ee\to H(WW^* \to qqqq)\nu\nu$	25.6	99.96	1.79	687
$ee\to H(\to \text{Other})\nu\nu$	199.6	99.62	1.26	3767
$ee\to qq$	4009.5	76.95	<0.01	155
$ee\to qqqq$	1328.1	36.03	<0.01	27
$e\gamma\to eqq$ (γ from EPA)	32308	67.00	<0.01	816
$\gamma e\to eqq$ (γ from BS)	56043	95.84	<0.01	764
$ee\to qq\nu\nu$	787.7	96.59	0.07	777
$ee\to qqll$	2725.8	89.75	<0.01	257
$ee\to qql\nu$	4309.7	66.44	0.07	4812

- Resulting significance, $S/\sqrt{S+B}$, is 77
- **Statistical uncertainty is 1.3%**

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Mainly Tau Events!!

- Resulting significance, $S/\sqrt{S+B}$, is 77
- **Statistical uncertainty is 1.3%**

Conclusion

- A full analysis of the ee→Hνν, H→WW*→qqlν process has been presented showing the methods used for event reconstruction and background separation

$$\Delta\, \sigma_{H\nu\nu} \times BR(H \rightarrow WW^*) = 1.3\%$$

- Full analysis available on CDS: https://cds.cern.ch/record/2145982?
- Results are included in the upcoming CLIC Higgs Physics paper: https://cds.cern.ch/record/2144923?