ZH Analysis

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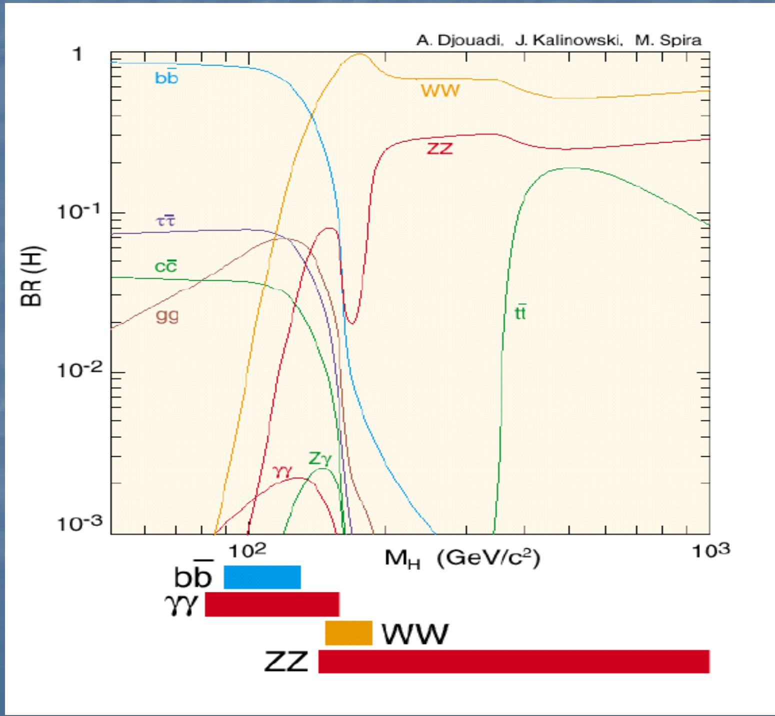
Introduction

- Measurement of the Higgs boson branching ratios is very important for detector optimisation at the ILC and allows for the measurement of relative coupling of the Higgs to fermions and the prediction of the Higgs mechanism.
- For $M_H \leq 140$ GeV, a number of branching ratios can be measured at the ILC .
- This analysis focuses on Higgs decay to cc-bar for 2 and 4 Jet channels



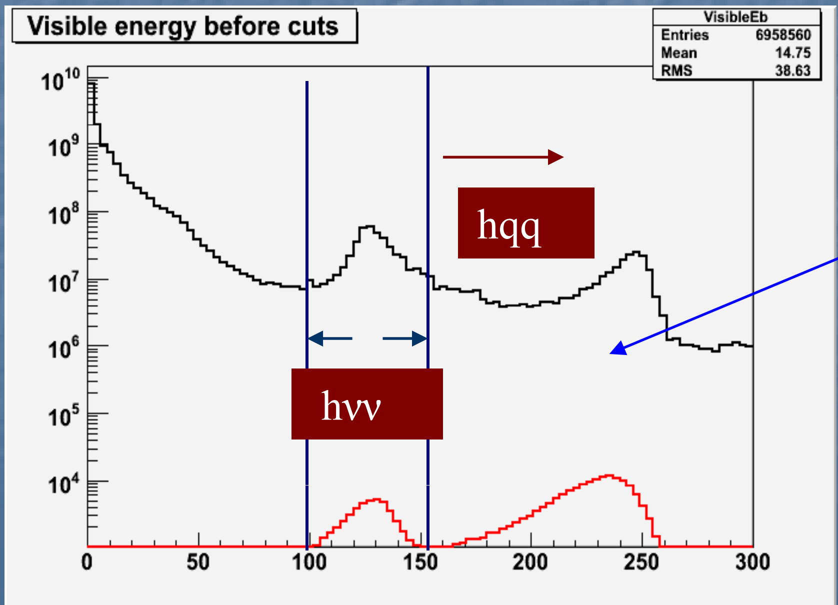
Branching ratio at different Higgs masses

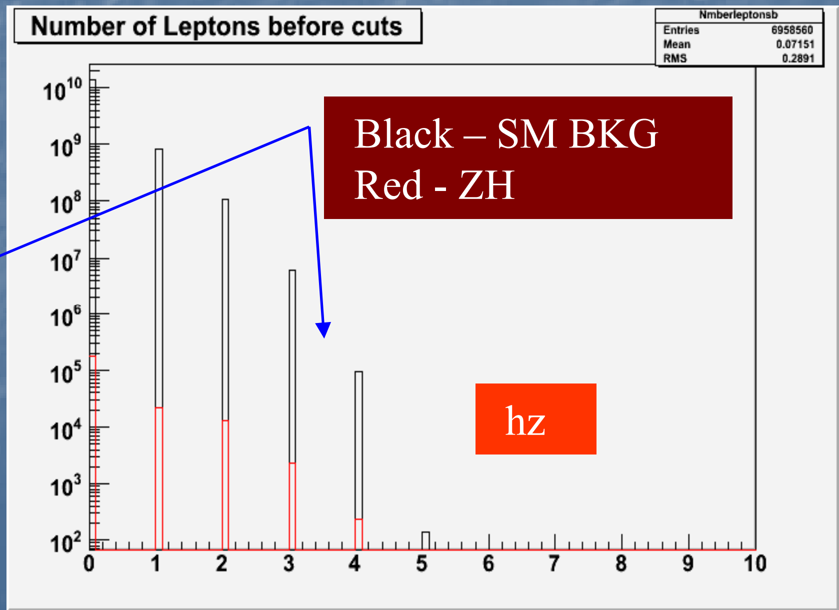
Data Samples

- For this analysis, the signal sample includes a Higgs boson produced through Higgsstrahlung, e+e- → ZH and the background includes a mixture of all standard model processes.
- For these data samples the following are assumed:
  - Centre-of-mass = 250 GeV
  - Integrated luminosity = 250 fb-1
  - Signal Higgs mass = 120 GeV
  - +80% e- polarization, -30% e+ polarization and -80% e- polarization, +30% e+ polarization.
- Currently, fully reconstructed samples are used for the study
  - ~ 7 Million Standard Model Background Events
  - ~ 200 000 signal events (with ~ 2000 ccvv)

Event Selection

- The selection of events used in the branching ratio calculation is performed in three steps.
- The first step involves classification of events into two decay modes depending on the decay products of the Z boson. This classification is done based on the visible energy and number of leptons in an event.
  - Visible energy here is the sum of the energies of reconstructed particles
  - A lepton is defined to be a reconstructed electron or muon with a minimum momentum of 15 GeV





Analysis strategy for neutrino and hadronic channel

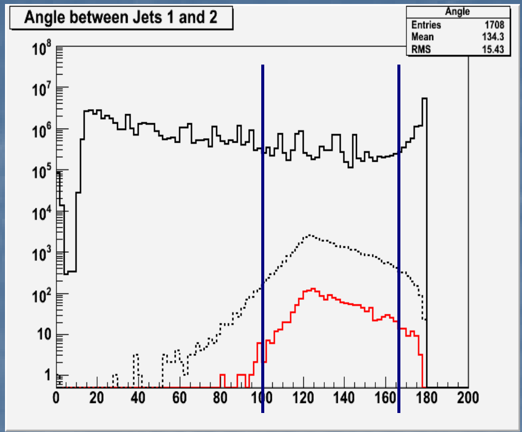
- Classification
- Preselection using (mild) cuts for kinematic variables
  - no flavour tagging information used
- Neural Net with tagging included
- Selection of signal sample using a cut on NN output
- Calculation of Br

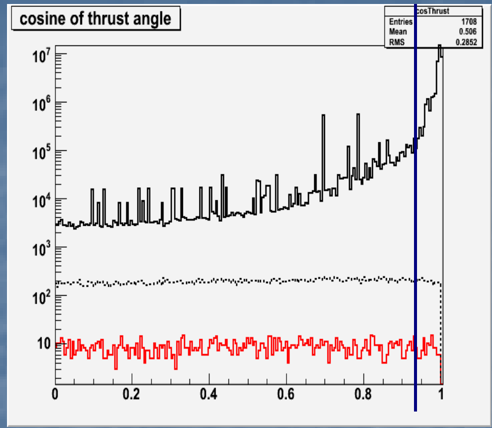
Event Selection for neutrino channel

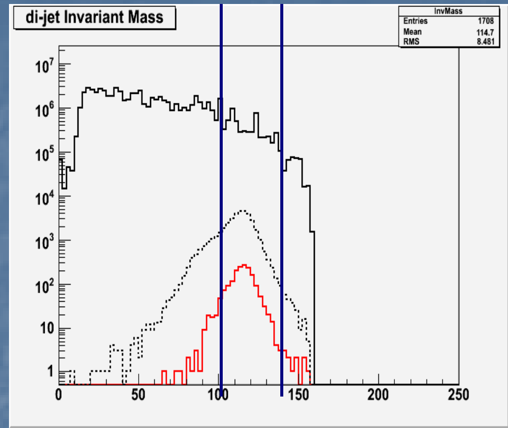
- The second step involves cut based selection in order to reduce the background in the selected sample.
- For the neutrino channel events are clustered into two jets. The following cuts are used:
  - 100 degrees < Angle between jets < 170 degrees
  - Thrust > 0.64, cosThrust < 0.98
  - pT of jets < 90 GeV
  - -log(ymin) < 0.8
  - 100 GeV < di-jet Mass < 140 GeV
  - Number of charged tracks in jet > 4
  - Number of particles in jet > 2
  - Photon energy < 10 GeV

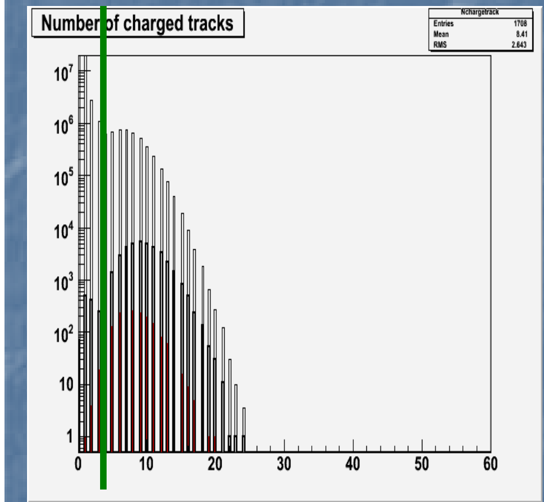
Cut	Sig %	Bkg %
0	100	100
angle	96	40.1
thrust	95.4	40
ymin	93.4	19.1
pT	93.3	19.1
cosThr	91.5	18.2
InvM	74.6	6.61
#Chrgd	74.5	5.91
γ E	73	5.41

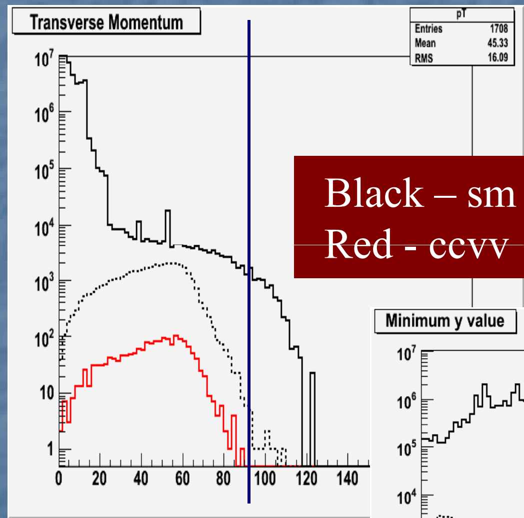
Distributions before cuts (neutrino)



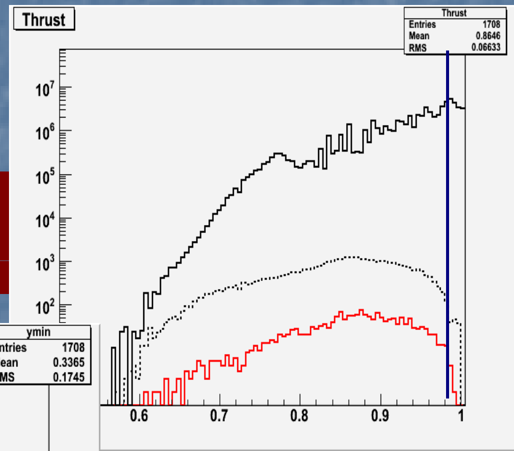


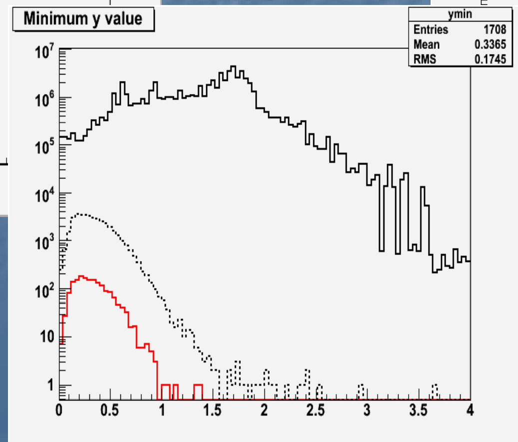






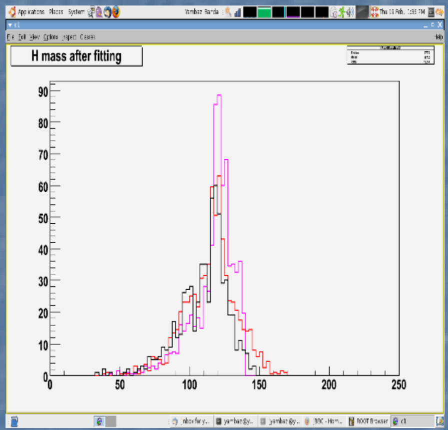
Black – sm and higgs bk
Red - ccvv

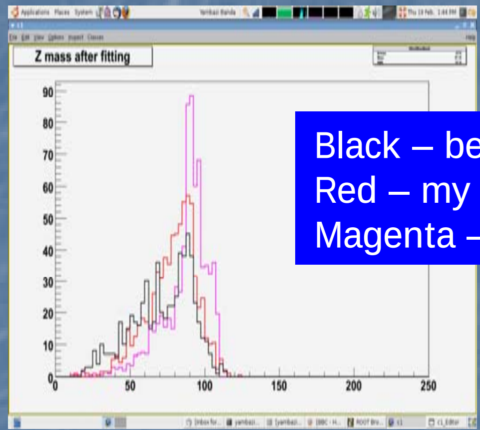




Event Selection for hadronic channel

- For the hadronic channel events are clustered into four jets. Kinematic fitting is used to help determine which jets originate from Z or Higgs boson.



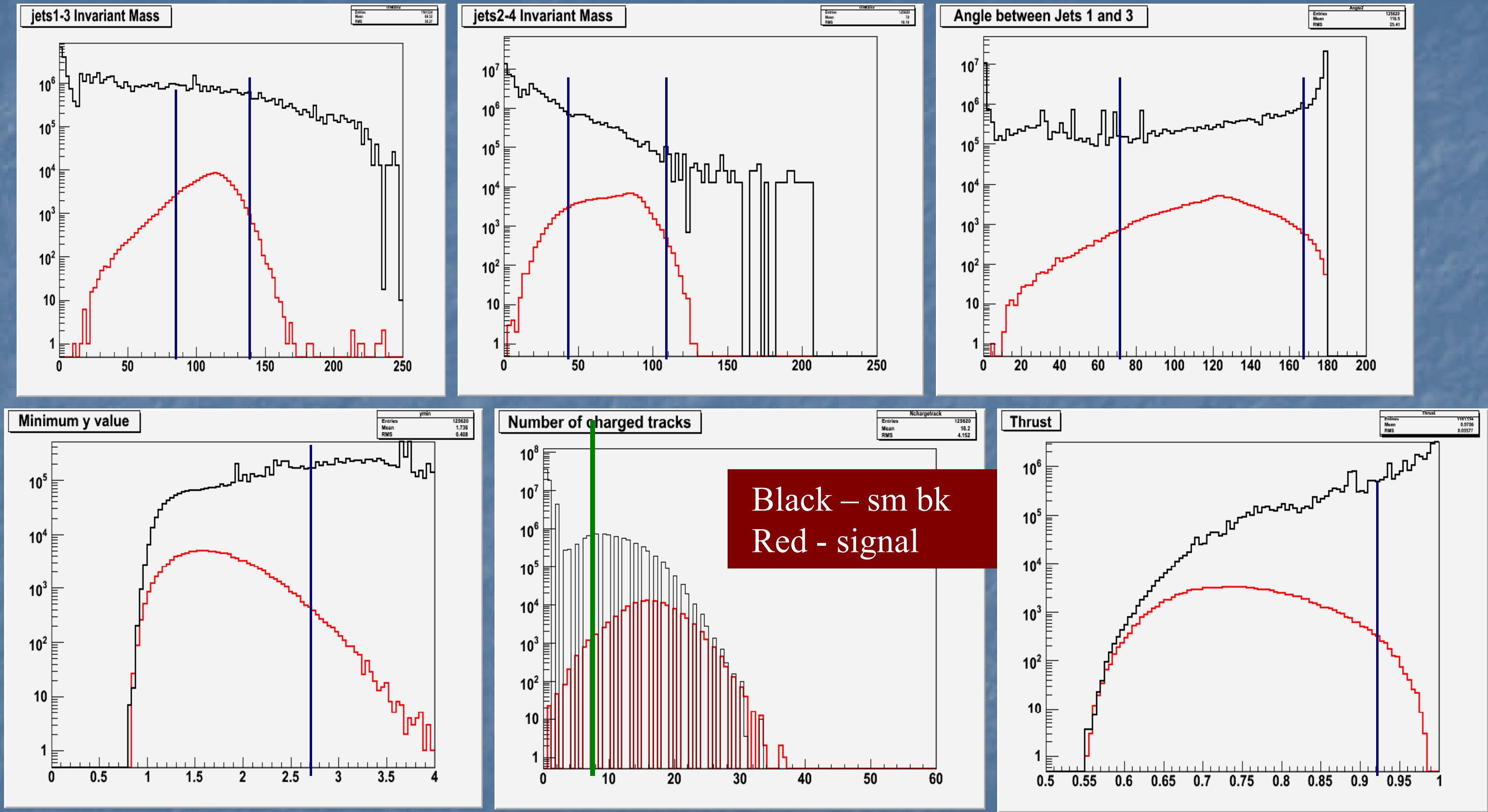


Black – before fitting
Red – my calculation
Magenta – after fitting

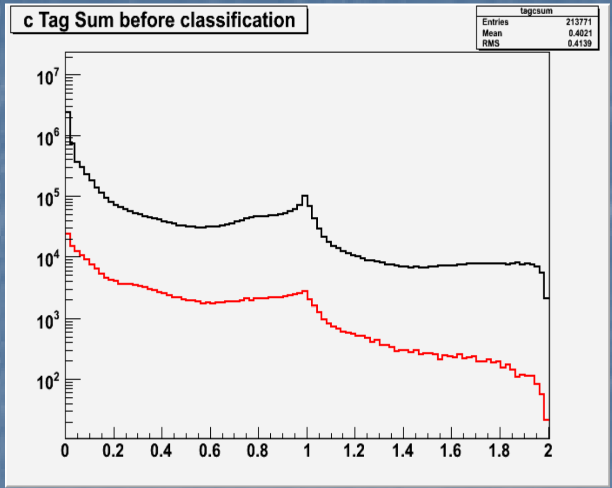
- The following cuts are used:
  - 75 deg < Angle between jet 1 and 3 < 165 deg
  - 50 deg < Angle between jet 2 and 4 < 150 deg
  - Thrust < 0.92, cosThrust < 0.85
  - -log(ymin) < 2.7
  - 95 GeV < di-jet Mass 1-3 < 145 GeV
  - 45 GeV < di-jet Mass 2-4 < 105 GeV
  - Number of charged tracks in jet > 6

Cut	Sig %	Bkg %
0	100	100
mas13	76.88	57.8
mass24	68.9	36.5
ang13	67.2	31.4
ang24	62.8	29.4
cosThr	51.45	18.1
thrust	51.3	17.2
ymin	51	15.2
#Chrgd	50.7	15.1

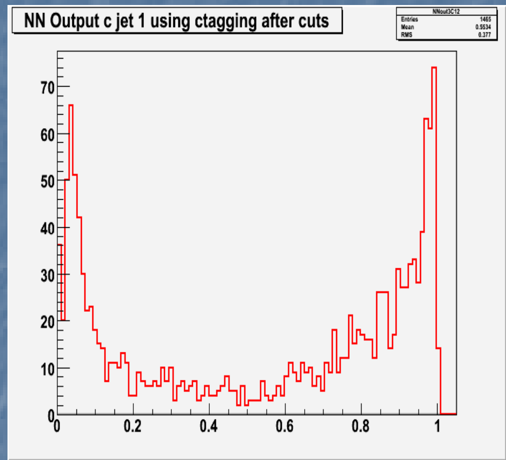
Distributions before cuts (hadronic)

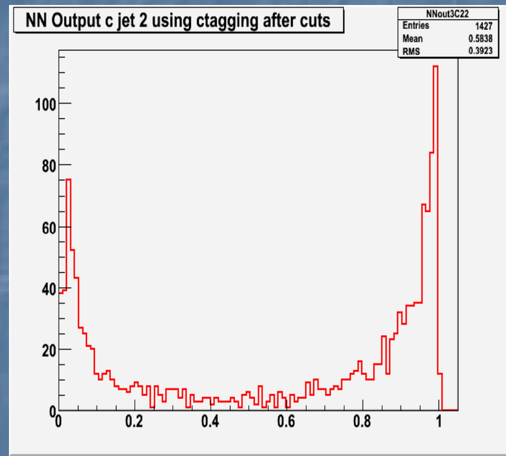


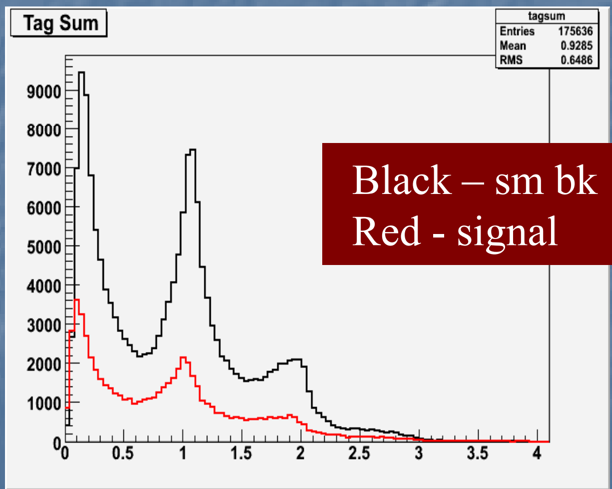
Tagging variables



Neutrino







Black – sm bk
Red - signal

Some flavour tagging distributions for the neutrino and hadronic channel. There is a massive drop in efficiency when using C-tagging (mis-tags dominate)

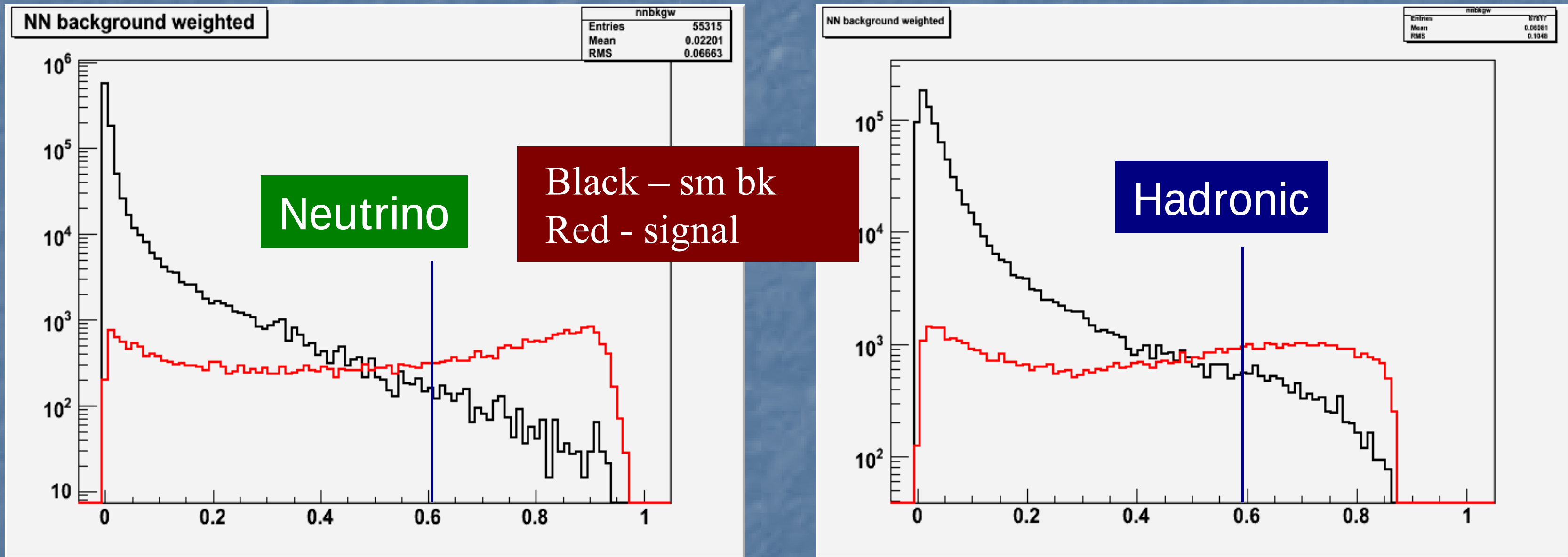
Hadronic

Neural net after pre-selection

- The third step involves a neural network selection in which training of signal events is performed by use of the FANN Package.
- For the neutrino channel, variables used as inputs to the neural network are:
  - invariant mass, thrust, pT, cosine of thrust angle,
  - angle between jets, ymin, ymax,
  - ctag1, ctag2, btag1, btag2, mistag1, mistag2
  - Visible energy
- For the hadronic channel, the variables used as neural network inputs are:
  - invariant masses of jets 1 and 3, and jets 2 and 4,
  - thrust, pT, cosine of thrust angle,
  - angle between jets 1 and 3, and jets 2 and 4,
  - ymin, ymax,
  - All 4 jets btags, ctags and mistags

Neural net after pre-selection

- The NN has the following structure:
  - 18 inputs for neutrino, 19 inputs for hadronic channel
  - 28 hidden layers
  - 1 output, etc.



BR Calculation

- The easiest way to extract branching ratios is by 'counting'. Quantities that should be known are:
  - Number of events in the sample (N_S)
  - Number of selected events in the chosen channel (N_{CH})
  - Fraction of non-Higgs background in sample (F_S)
  - Fraction of non-Higgs background in sample of chosen channel (F_{CH})
  - Efficiency of selection (ε)
  - Fraction of cross channel Higgs contamination (F_{CROSS})

$$BR(H \rightarrow \text{channel}) = \frac{N_{CH}(1 - (F_{CH} + F_{CROSS}))}{N_S(1 - F_S) * \varepsilon}$$

- After nn cut we obtain the following results:
  - Neutrino : BR = 0.036, error ~ 42%, signal efficiency ~ 30%
  - Hadronic : BR = 0.038, error ~ 55%, signal efficiency ~ 23%
- Poor signal efficiency and high error because of the small number of H→ cc events. To improve results we will need to increase our signal statistics.

Summary

- Fully reconstructed data samples are used for the analysis
- Cut based and neural net selection used to extract signal
- Higgs branching ratio to cc-bar obtained but need further background suppression (which is mainly Higgs cross-contamination) and improve error on value.
- In general should have much better results in time for LOI deadline.