The search for Higgs at ATLAS using multivariate Techniques
Boosted Decision Trees and Neural Networks

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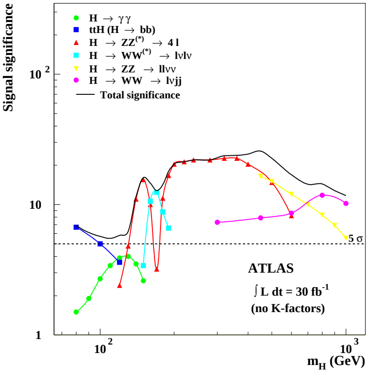
Outline

1. Introduction
2. Multivariate Analysis
3. Looking at a $H \rightarrow WW \rightarrow \mu\nu\mu\nu$ Analysis
4. Outlook

Focus

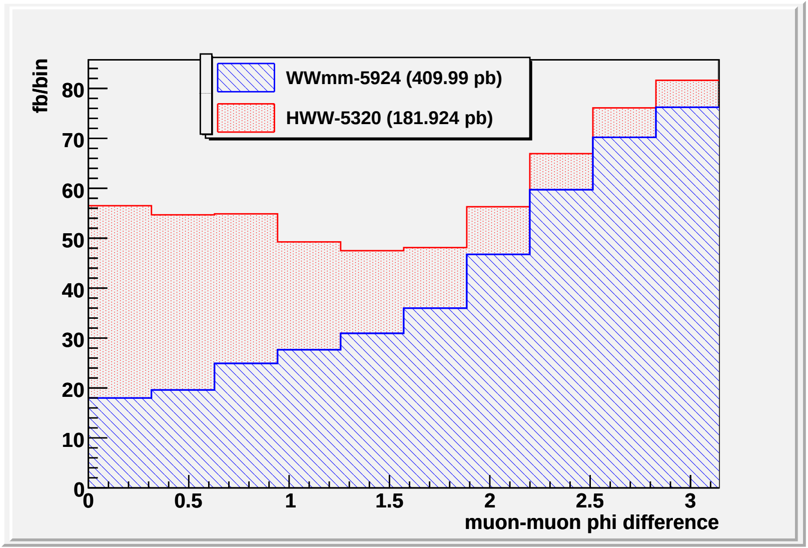
- Understand the 2-(high p_T, isolated, opposite charge)-muon processes at ATLAS
  (Search for the SM Higgs)
- Understand systematics of multivariate classifiers
  (Increase significance of results)

The Search for Higgs



Picture from the ATLAS TDR

- This Talk: Looking at the $H \rightarrow WW \rightarrow \mu\nu\mu\nu$ channel
- Two neutrinos, so mass reconstruction difficult
- But - the 2 Ws from Higgs are spin-corellated, so the two muons are (more often) in the same direction



PYTHIA gg+VBF $H \to WW \to \mu\nu\mu\nu$ and MC@NLO $WW \to \mu\nu\mu\nu$ in full detector simulation after requiring two good muons

TMVA

TMVA is a common framework for training, testing and applying multivariate methods

- Very important: Overtraining check
- Many methods quickly tested, toolbox for physicists doing analysis (yet systematics difficult to assess)

For example: Boosted Decision Trees and Multilayer Perceptrons

Boosted Decision Trees:

+ Selects many signal-like hypercubes, majority vote
! Many possibilities for overtraining - too confident results
- Theoretically better classification than hypercubes possible

Artificial Neural Networks:

+ Many nonlinear relationships can be described, little danger of overtraining
? Shifts in variables are unlikely to produce sudden shifts in efficiency - but systematics difficult to assess
- Long Training time
- In HEP practice already 'good' classification variables are preselected, so nonlinearity not really necessary

Shopping List

- Get Monte-Carlo samples
- Apply pre-selection cuts
- Train Multivariate classifiers
- Apply selection / multivariate cuts

$H \rightarrow WW \rightarrow \mu\nu\mu\nu$ - typical Background Processes

Approximately 2.2 Million events from full detector simulation were used for this Analysis

Signal: $H \rightarrow WW \rightarrow \mu\nu\mu\nu$

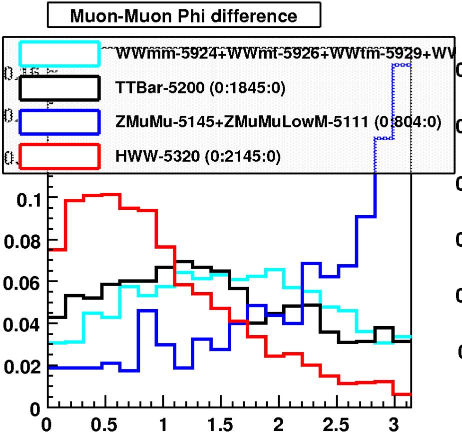
Background:

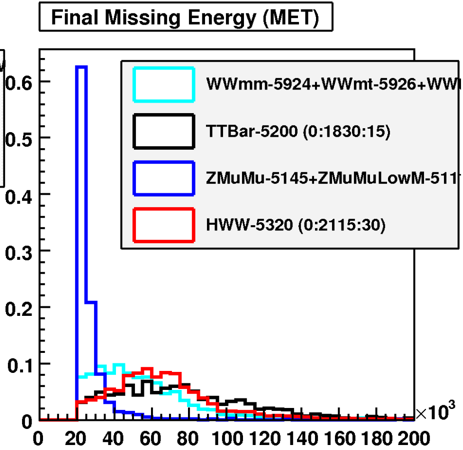
- $Z/\gamma^* \rightarrow \mu^+\mu^-$
- $t\bar{t}$ decays
- $WW \rightarrow \mu^+\mu^-$
- WZ
- Wbb

Event pre-selection requirements:

- Two well-reconstructed opposite-sign high-momentum ($p_T > 10 GeV$) Muons in the central detector region
- Muons isolated from hadronic activity
- At least $20 GeV$ of missing transverse momentum and an invariant mass of the dimuon system between $16 GeV$ and $80 GeV$

Interesting variables - $\Delta\phi_{\mu\mu}$ and $\not{E}_T$





PRELIMINARY

Results for $m_H = 170 GeV$ PRELIMINARY

PRELIMINARY

Events at $1 fb^{-1}$ or effective cross-section in pb:

	$H \rightarrow WW$	$Z/\gamma^* \rightarrow \mu\mu$	$t\bar{t}$	WW	WZ	Wbb
sample	1240	$3.0 \cdot 10^6$	$461 \cdot 10^3$	11900	13860	29000
presel	151	5107	1527	184	24	4.5
Cuts	49 ± 2	17 ± 16	17 ± 4	40 ± 3	1 ± 1	0 ± 1.5
BDT	50 ± 2	8 ± 13	37 ± 6	8 ± 1	2 ± 1	0 ± 1.5
ANN	54 ± 2	21 ± 16	31 ± 5	20 ± 2	2 ± 1	0 ± 1.5

PRELIMINARY

Total Signal vs Background at $1 fb^{-1}$

	$H \rightarrow WW$	Background	$S/\sqrt{B}$
Cuts	49 ± 2	80 ± 14	5.5
BDT	50 ± 2	56 ± 13	6.7
ANN	54 ± 2	79 ± 15	6.1

(only statistical errors)

Systematic error studies I

Warning: Your detector is not perfect!

- Systematic errors of the detector are not independent in a multivariate classifier
- Usual approach of just varying the scales individually is perhaps overly optimistic!

My approach:

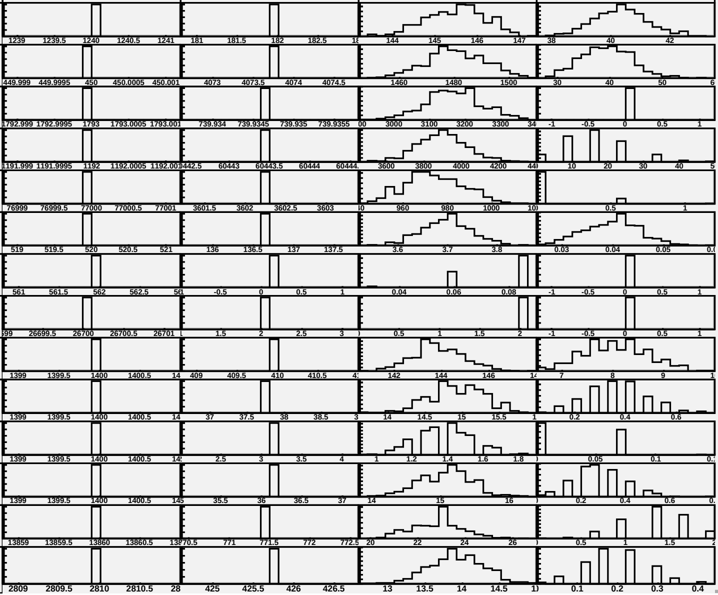
- Think of different sets of things that can happen (MET/Muon Energy, shift/resolution/populated tails...)
- Create a set of parametrized "error cases", and specify a distribution for the parameters
- Create for each error case a set of "error case samples", each of which corresponds to one real detector problem
- Do your Analysis for each of them, and look at the distribution of the classifier output.

Systematic error studies II

Result of decreasing the Missing Energy resolution
(smearing by an arbitrary 40% on average):

[*fb*]	S before	B before	S smeared	B smeared	$\Delta S[\%]$	$\Delta B[\%]$
Cuts	49	80	42	83	86%	104%
BDT	50	56	40	66	80%	118%
ANN	54	79	49	95	91%	120%

Cross-Section in fb	initial	twoGoodMuons	preselection	ClassifierBDT
HWW-5320				
TTBar-5200				
ZMuMu-5145				
ZMuMuLowM-5111				
ZTauTau-5146				
Zbb-4l-5177				
Wbb-6366				
Wt-5500				
WWmm-5924				
WWmt-5926				
WWtt-5927				
WWtm-5929				
WZ-5987				
ZZ-5986				



Outlook

- More study of Systematics with all three Analysis techniques
- Improve BDTand ANN settings
- Extend Analysis to other Higgs masses

Supplement: Cut-Based Analysis for $m_H = 170 GeV$

Selection Cuts:

- No (medium or tight) electrons with more than $20 GeV$
- $p_{T,Jets} = \sum_{HighPtViewC4Jet: p_T > 15 GeV} p_T < 60 GeV$
- $m_{\mu\mu} < m_Z - 25 GeV$
- $\not{E}_T > 45 GeV$
- $\Delta\phi_{\mu\mu} < 1.5$

Control Plots - $m_{\mu\mu}$ and $p_{T,Jets}$