# Searching for the Higgs with ATLAS

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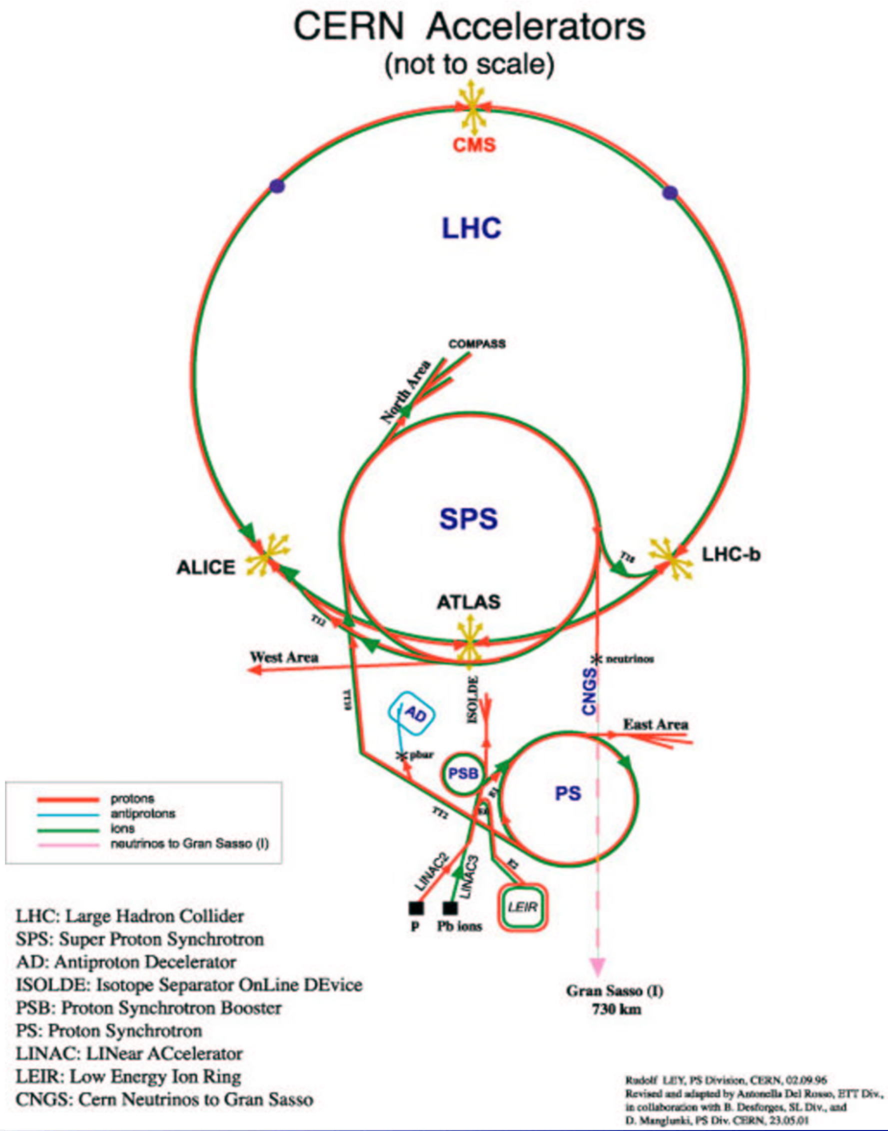
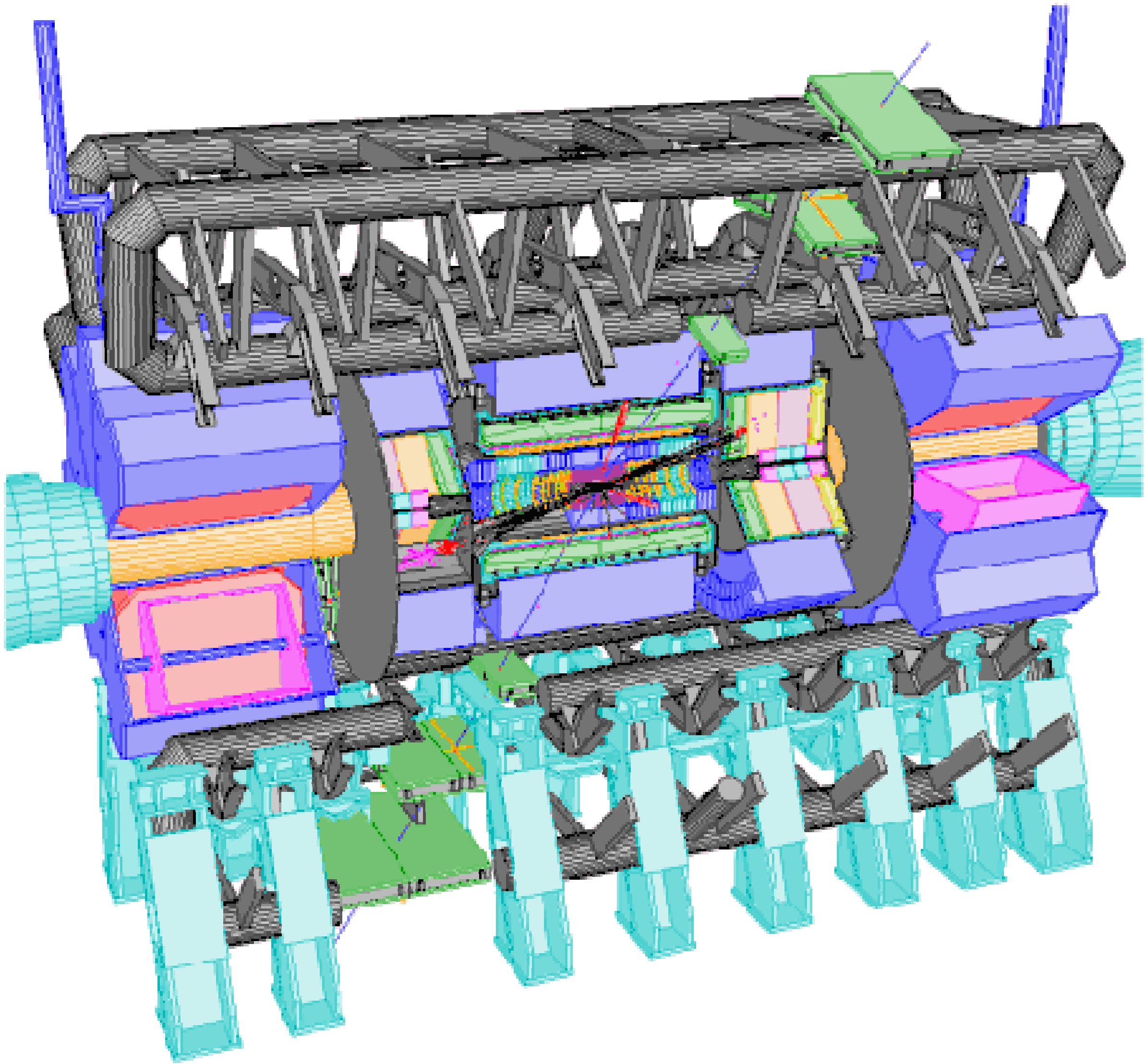
DPF Meeting 2004

# LHC




- $\sqrt{s}$=14 TeV p-p collider
- Luminosity
  - initial=$2\times10^{33}cm^{-2}s^{-1}$
  - design=$10^{34}cm^{-2}s^{-1}$
- Bunch crossings every 25ns (design lumi)
- High statistics
  - W, Z, top factory
  - Most precision measurements limited by systematic error

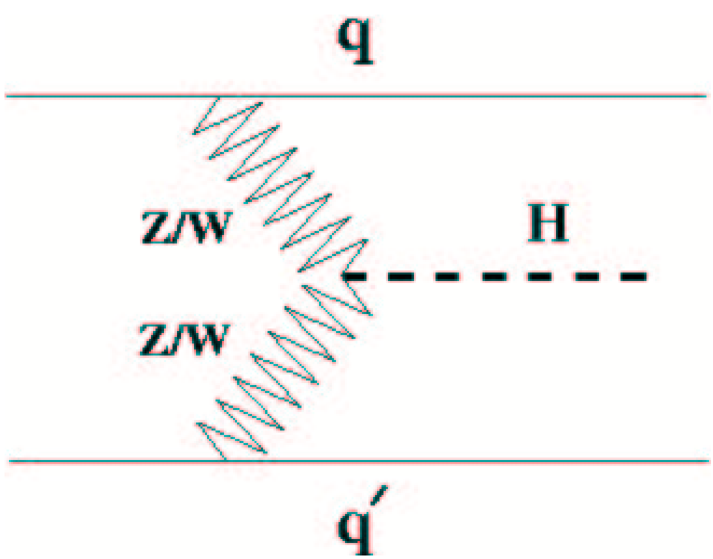
# ATLAS

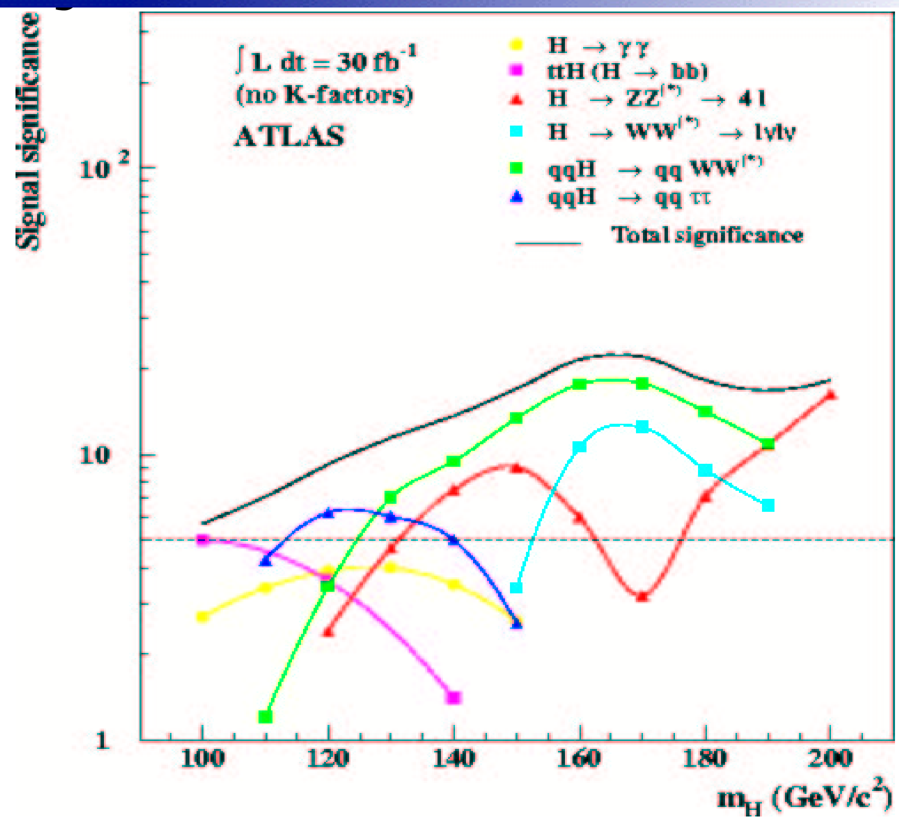


- Inner detector
  - Tracking in $|\eta|<2.5$
- Calorimetry
  - EM Cal. ($|\eta|<3.2$)
  - Had. Cal ($|\eta|<4.9$)
- Air-Core Toroid Muon Spectrometer

# Higgs Physics

- Lower limit on Higgs Mass from direct search: ~114 GeV
  - ATLAS has discovery potential over full mass range
- Strategy for low mass is to look for Higgs + two jets:



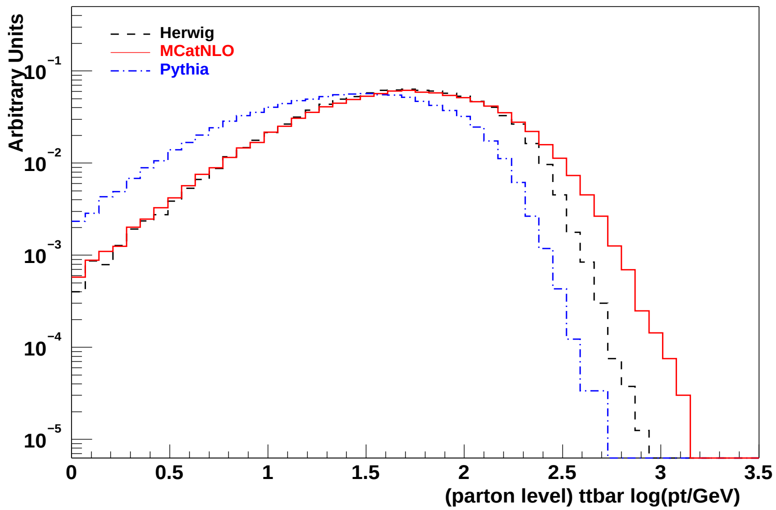



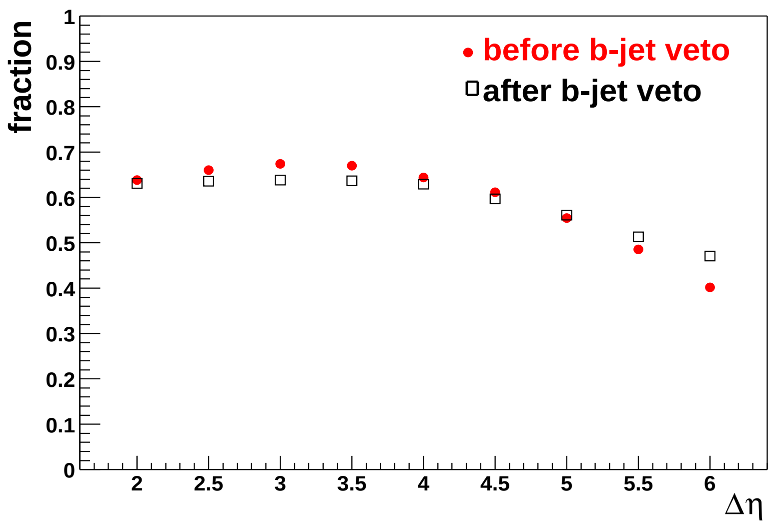

- Still work to be done
  - Optimizations, etc.
  - Control Samples & Systematics

# VBF $H \rightarrow WW \rightarrow l\nu l\nu$ (1)

- Two leptons, two forward jets, missing $P_T$
- Background dominated by:
  - Top quark pairs
  - Electroweak (i.e., t-channel exchange of vector boson) WW production
- Important features of recent analysis:
  - New description (MC@NLO) of top background
  - Neural Network analysis over broad mass range
  - Mass-dependent cut optimization to make comparison with Neural Network analysis fair

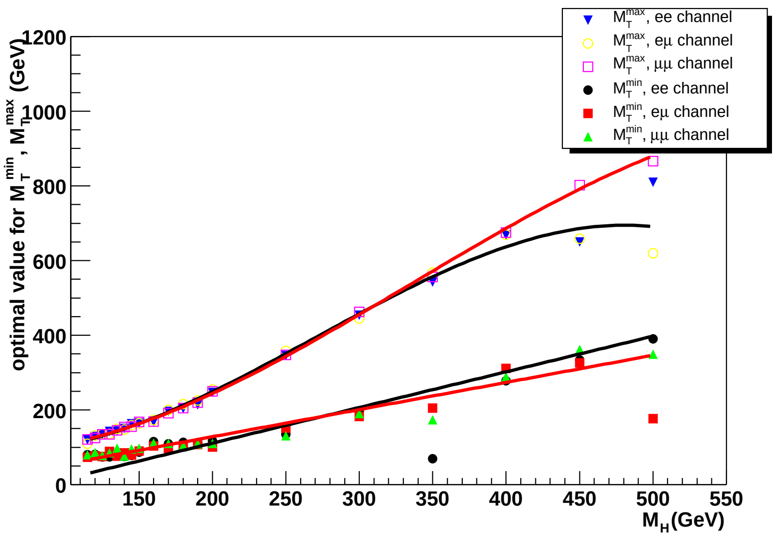
# VBF H→WW→lνlν(2)

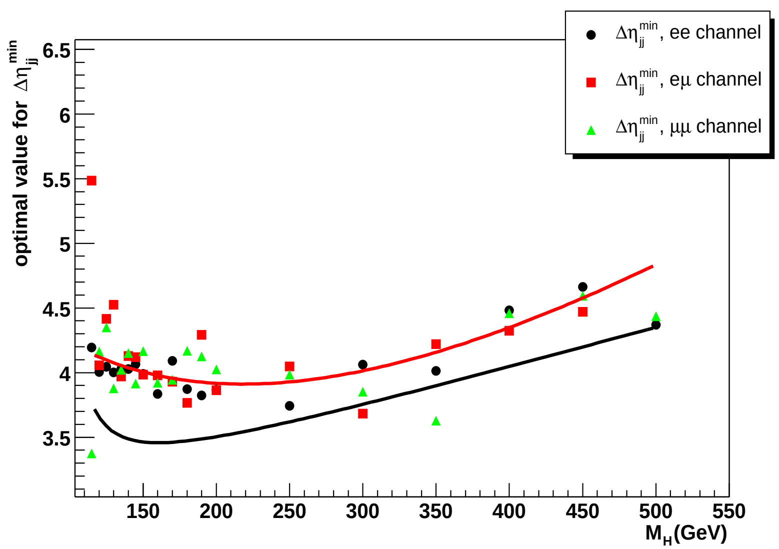



- Tree-level t-t monte carlo with parton shower underestimates $P_T$ of t-t system
  - Need matrix-element description of tt+1j, as in MC@NLO, becaue extra jet plays a large role
- b-tagging can be used to define a control sample

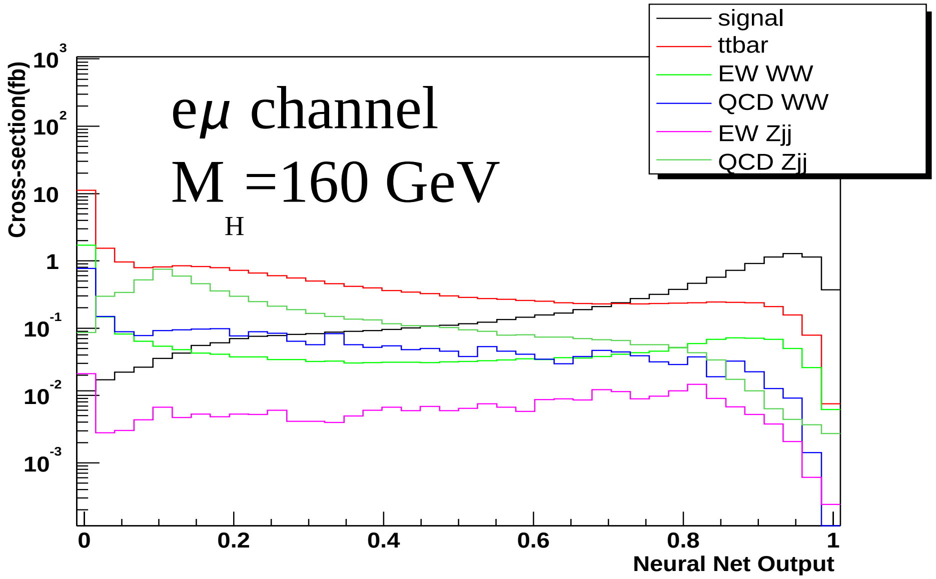
# VBF H→WW→$l\nu l\nu$(3)

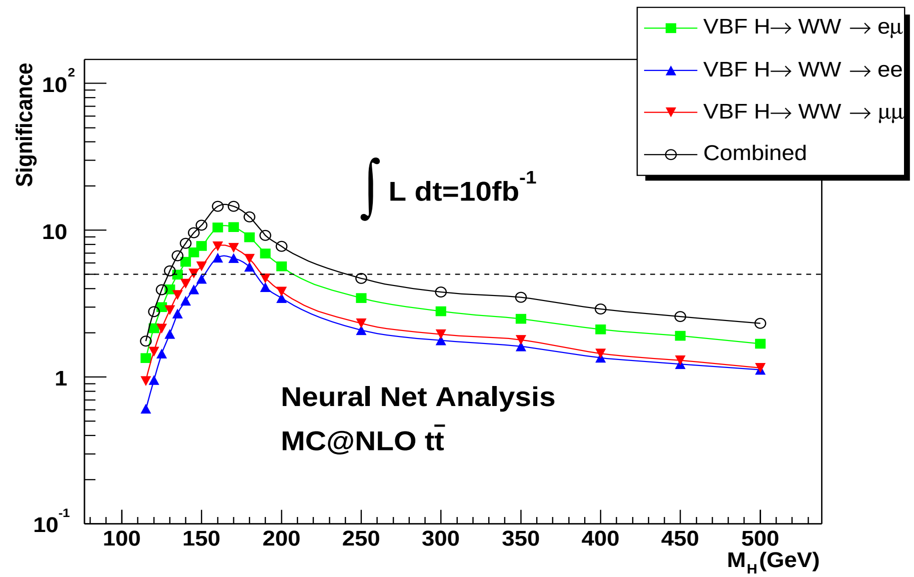


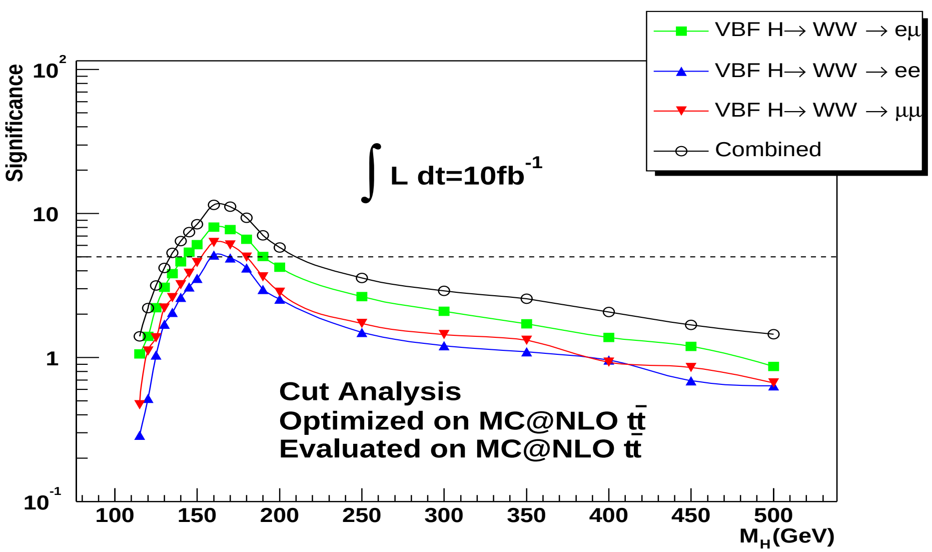




- Use genetic algorithm to optimize cuts independently for each mass
  - Separate optimizations for ee, e$\mu$, and $\mu\mu$ channels as a check
  - Perform optimization for Pythia (black curve) and MC@NLO (red curve) description of top quark background
    - Points are from MC@NLO
- Cuts are applied to $\Delta\eta_{jj}$, $M_{jj}$, $\Delta\eta_{ll}$, $\Delta\phi_{ll}$, $M_{ll}$, $M_T$

# VBF H→WW→lνlν(4)



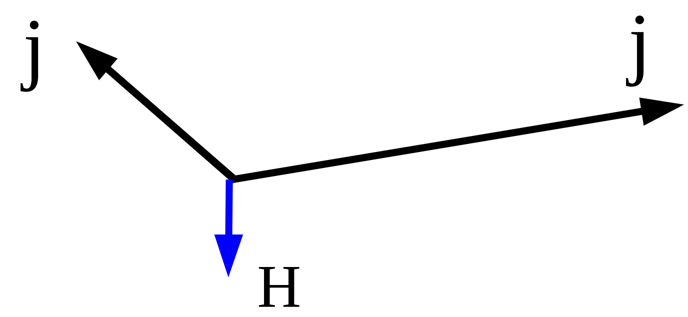




- Trained using Pythia tt, tested using MC@NLO tt
  - Same variables as GA, plus $\Delta\phi_{jj}$, not useful for cuts
- NN offers >~30% improvement over classical cuts

# Do We Need 2 Tag Jets?

- "Forward" tag jets?
  - Forward region is more difficult to understand: pileup, etc.
  - For low $M_H$, one jet is often central

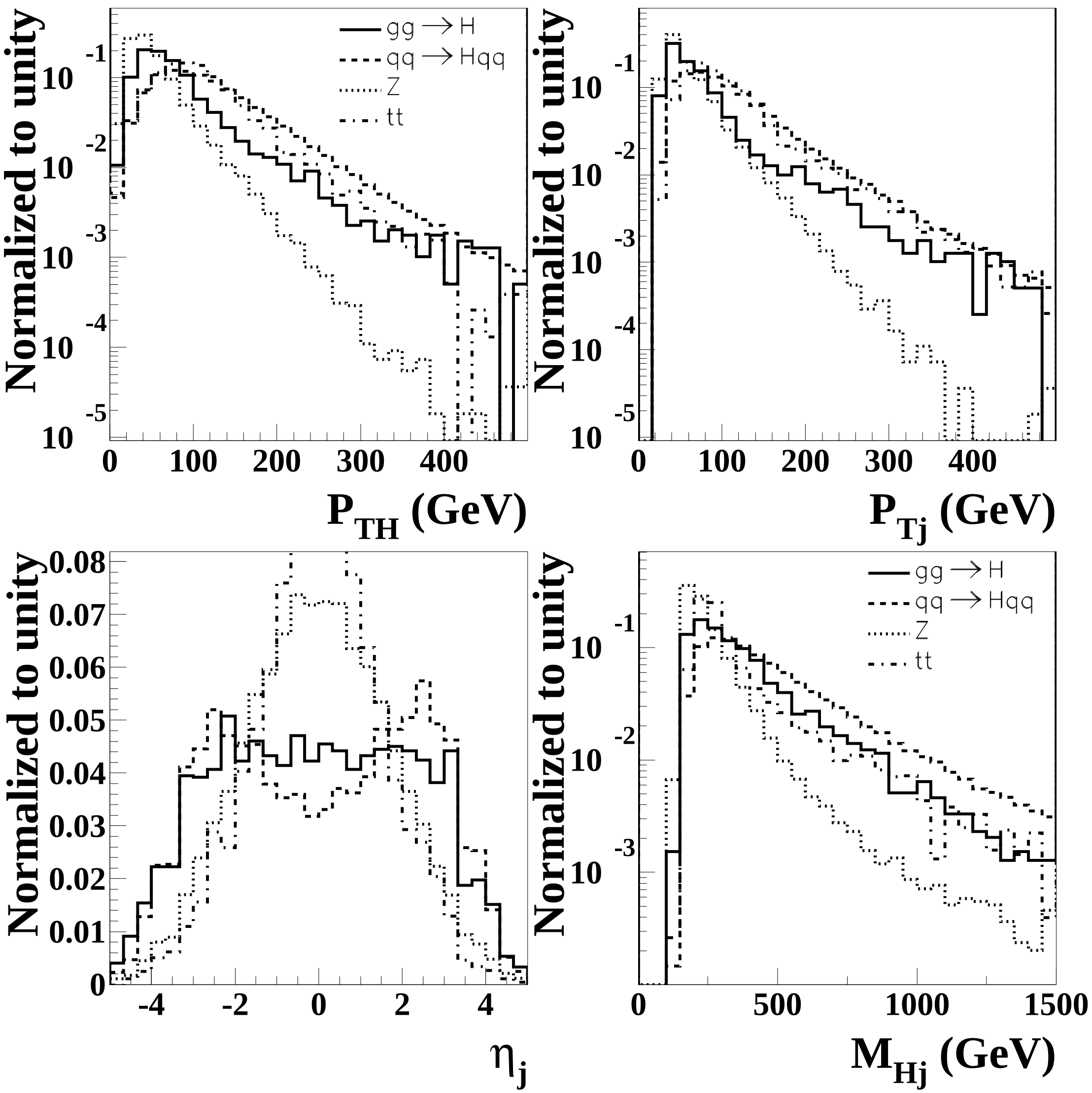



- Tagging two jets suppresses gluon fusion

- Strict Central Jet Veto: Reject event if any non-tag jet has $P_T$>20GeV in $|\eta|<3.2$
  - Underlying event & pileup may be small, but might not. This could complicate things.

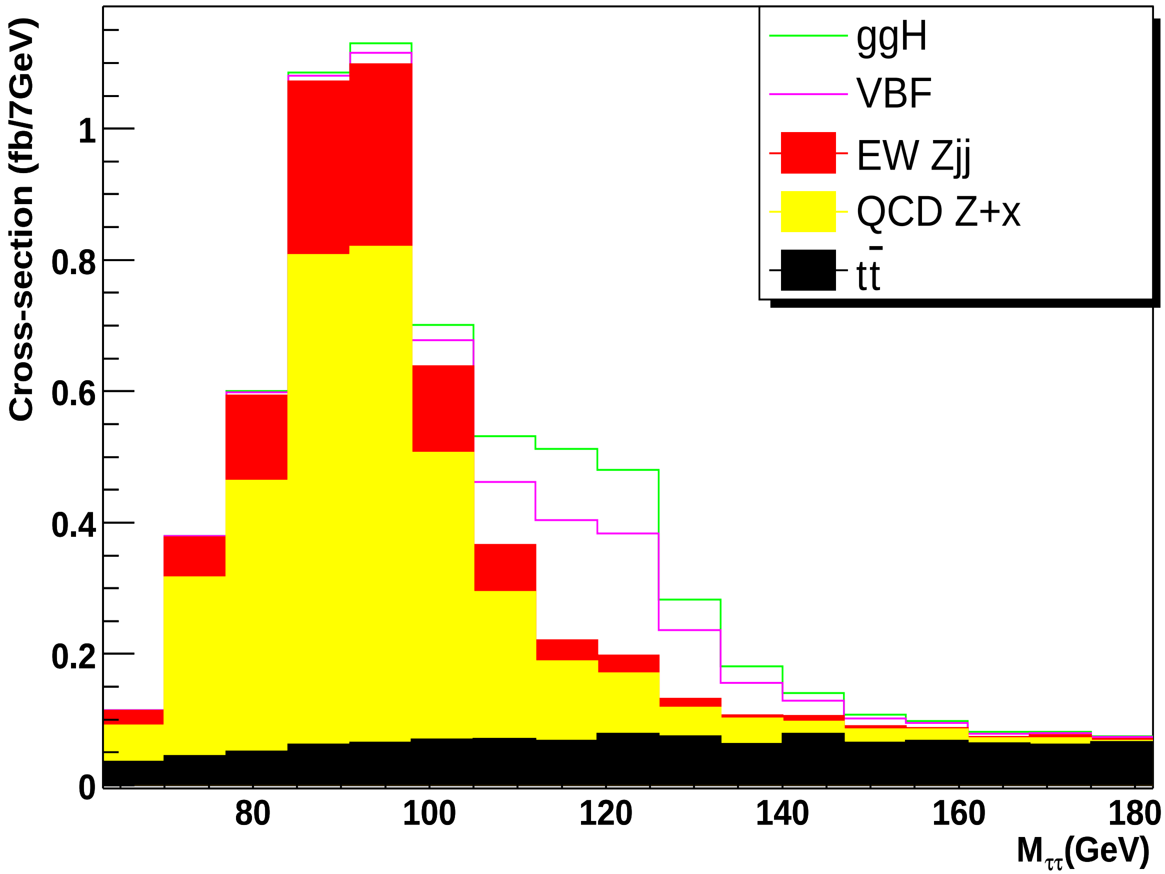
- New approach:
  - Only tag one jet
  - Cut on $M_{Hj}$
  - Weaker Central Jet Veto
- Can either complement or replace "two-tag" scheme

# $\tau\tau$+1j (1)




- Final state: One hard recoil jet, two leptons and missing $P_T$ from $\tau$ decays
- Recoil Jet tends not to be very central ($|\eta|>1$)
- $M_{Hj}$ and $P_T^{Higgs}$ provide strong handles to reject Z background
- Signal is ~35% gluon fusion and ~65% VBF

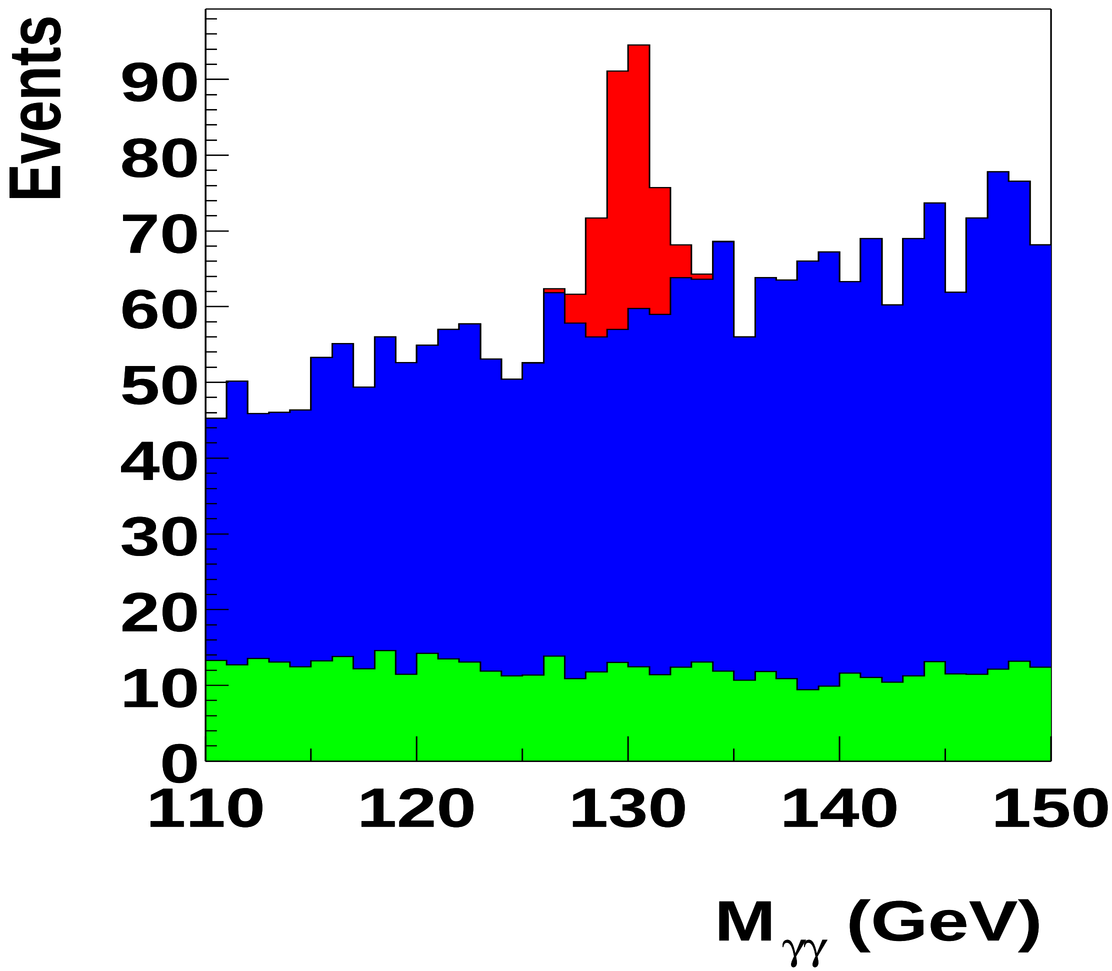
# $\tau\tau$+1j (2)




- Significance is 5.0$\sigma$ for $M_H$=120GeV, 30fb$^{-1}$
  - Compare to <~4$\sigma$ for "two-tag" analysis
- Control samples exist for Z+x and top quark backgrounds

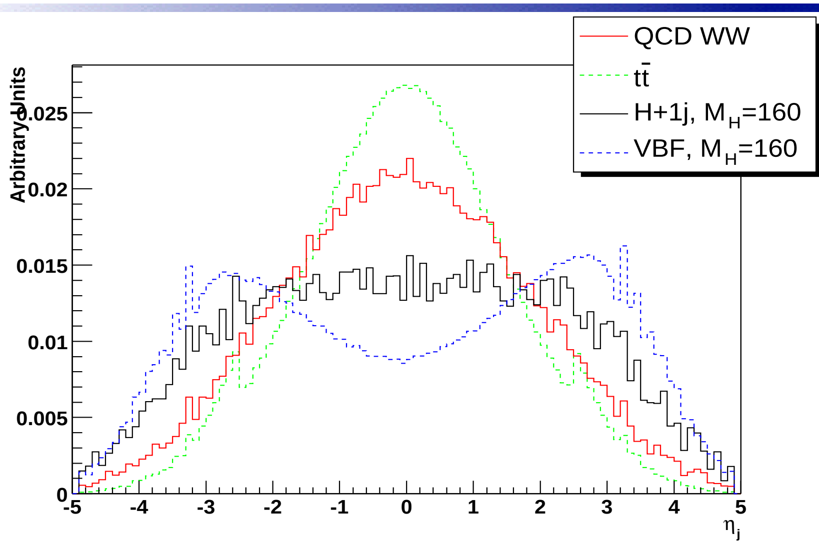
- See hep-ph/0406095 for more details

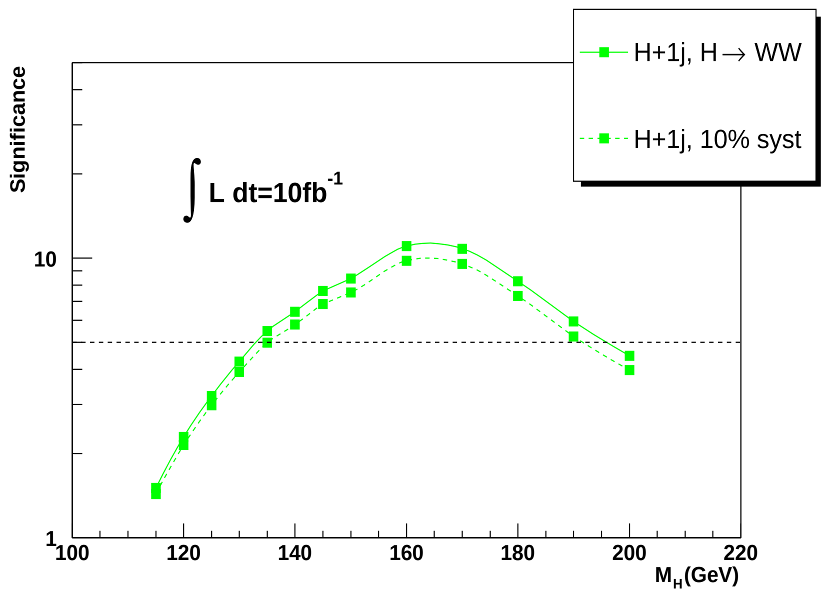
# $\gamma\gamma$+1j




- Divide "inclusive" sample of events into "tagged" and "untagged" samples
  - Use $P_T^{Higgs}$, $M_{\gamma\gamma}$, and $M_{\gamma\gamma j}$ (tagged only) as NN inputs
  - Gives a ~65% improvement over inclusive cut analysis

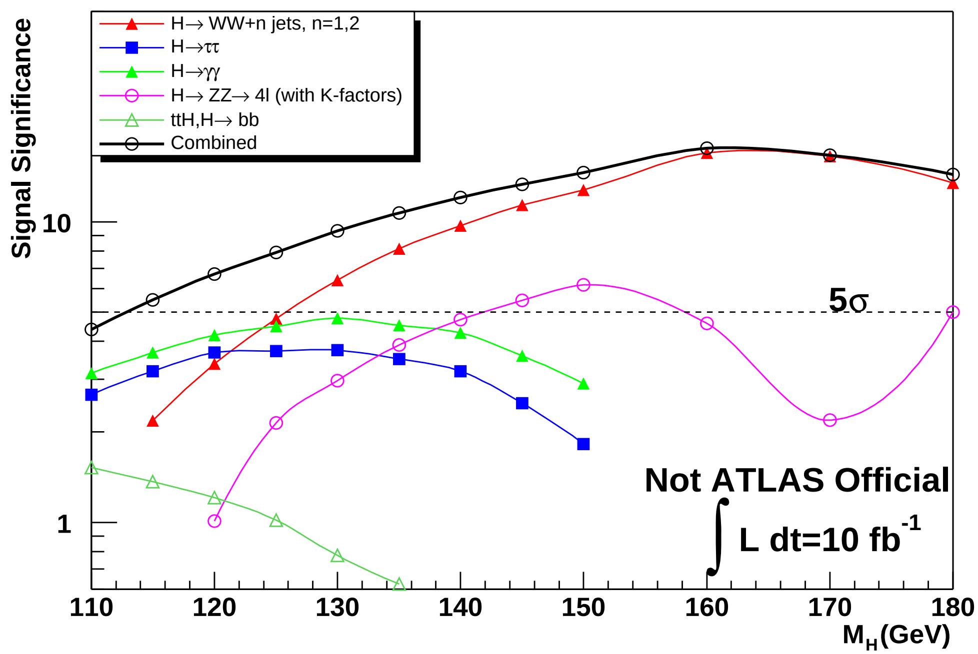
# WW+1j



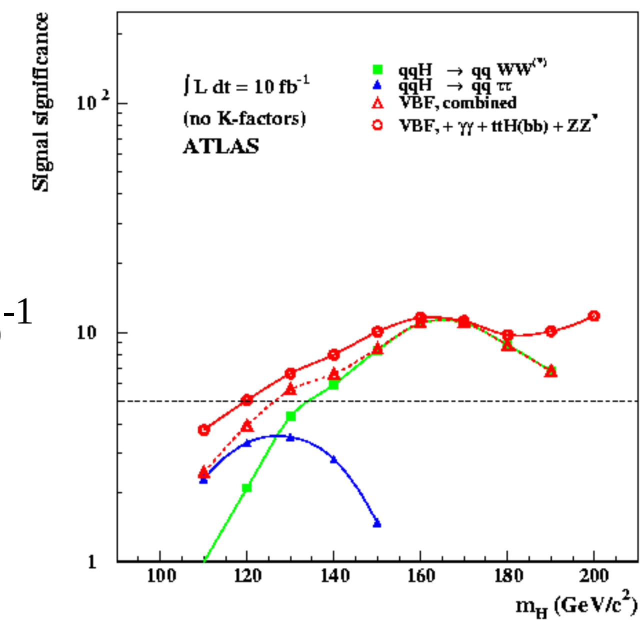

- Two neutrinos in final state: Can't reconstruct $M_H$ (or $M_{Hj}$)
  - Need to reqire tag jet be forward
- No overlap with "two-tag" H➔WW analysis (upper bound on $\Delta\eta_{jj}$)
  - Signal is ~88% gluon fusion
- Control Samples exist for QCD WW and tt backgrounds
  - Analysis is robust against larger uncertainties in background normalization

# Combined Significance




- Combined significance was calculated by adding curves together in quadrature

- Large improvement in coverage for $10fb^{-1}$
  - "Two-tag" can cover $M_H$ >~120 GeV
  - "Single-tag" can cover $M_H$ >LEP Limit



# Summary

- VBF H→WW→$l\nu l\nu$ analysis has improved:
  - New description of top quark background
  - Neural Networks yield 30-50% improvement over classical cuts (opimized for all masses with Genetic Algorithm)
- Higgs+1j final states: enhanced coverage & robustness
  - H→$\tau\tau$→ll$P_T^{miss}$: reach 5$\sigma$ with a cut analysis after 30fb$^{-1}$
  - H→$\gamma\gamma$: 65% enhancement with recoil jet tagging and 2 & 3 variable Neural Networks
  - H→WW→ll$P_T^{miss}$: No overlap with existing WW channels, discovery potential for $M_H$ >~135 GeV with 10fb$^{-1}$
  - Coverage extends below LEP limit with only 10fb$^{-1}$