Prospects for H -> WW searches at ATLAS

IoP meeting 2010

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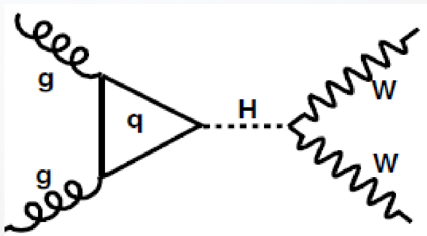
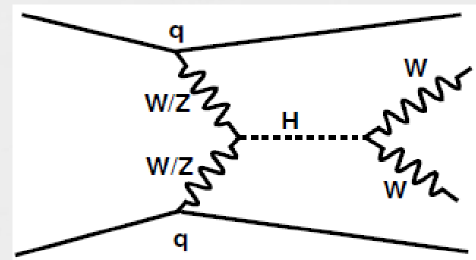
H -> WW signal

- Higgs produced via gluon-gluon fusion (ggF) and vector-boson fusion (VBF):

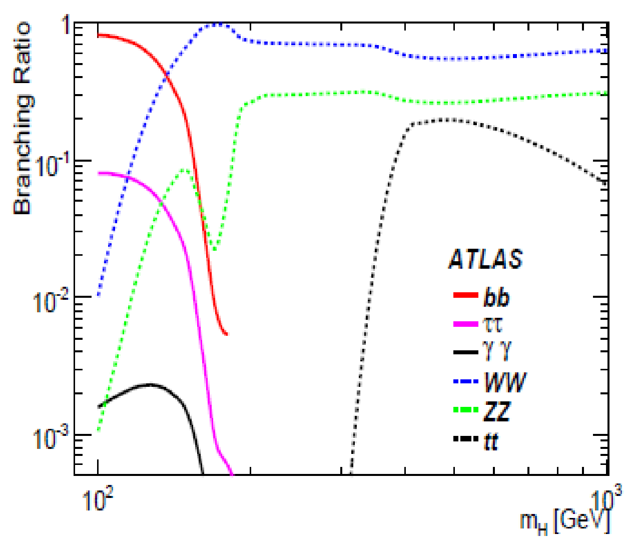
ggF

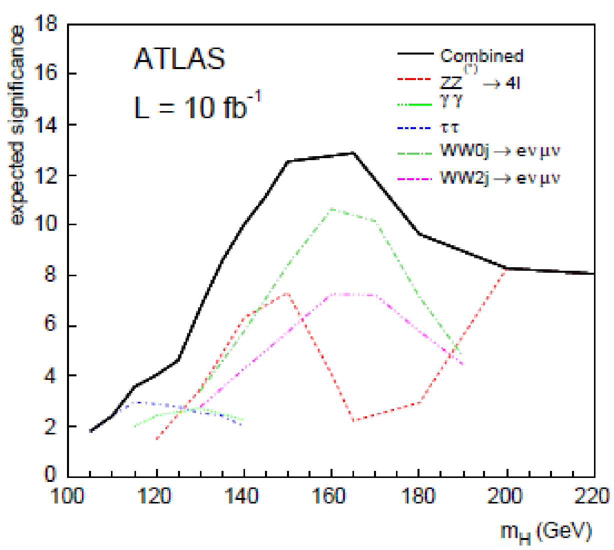


VBF



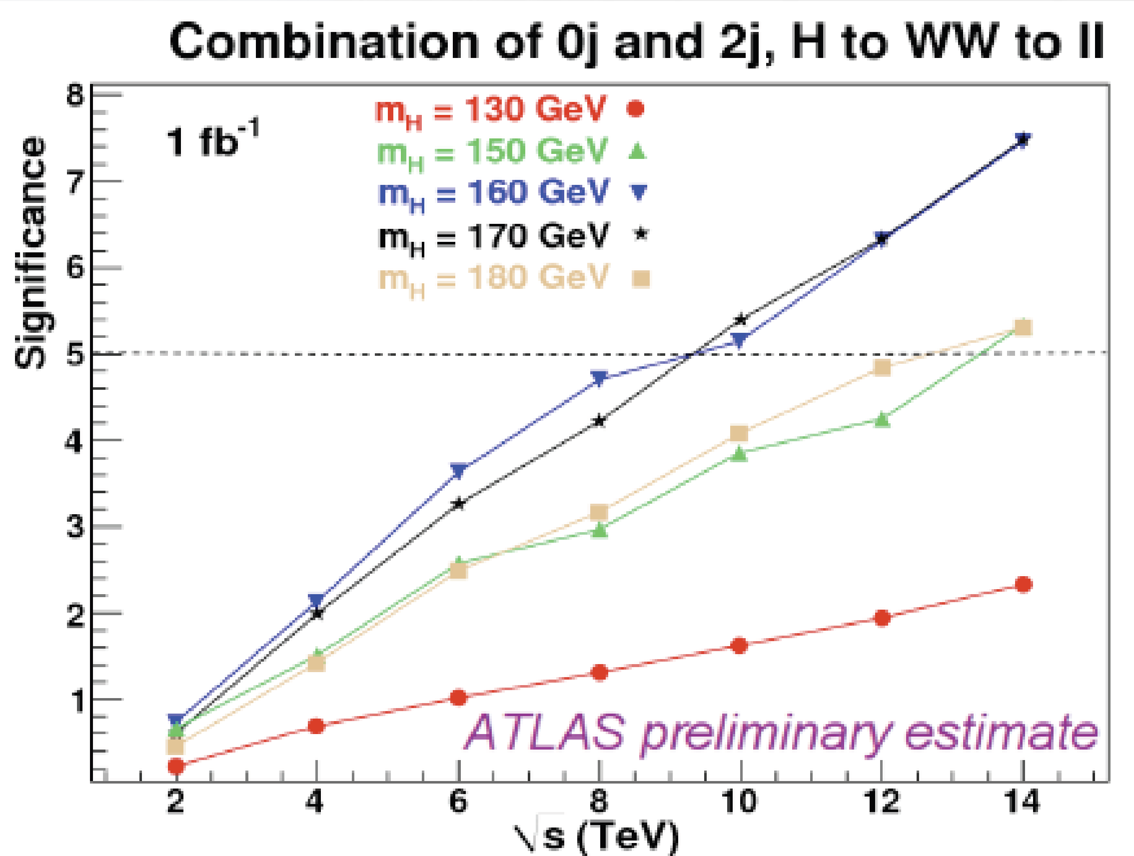
- Search for H -> WW with both Ws decaying leptonically
- Separate search into 0, 1 and 2 jet bins with tailored cuts for each channel
- Tevatron has excluded Higgs at 95% CL between 163 < M_H < 166 GeV
- With first data WW channel has best chance at improving this exclusion





Expected discovery potential

- ATLAS expects ~ 4σ discovery potential with 1 fb^{-1} if M_H = 160 GeV
- Will also be possible to extend exclusion to 150 – 180 GeV mass range
- This talk covers efforts to increase signal to background ratio using a matrix element method



Investigation of discriminating variables

- Table below shows expected number of events in 1 fb^{-1} in 0 jet channel after cuts for M_H = 170 GeV at 14 TeV
- Main background is WW continuum production

Taken from:
arXiv:0901.0512

	Higgs	WW	ttbar	W + jets
$N_{expected}$	29	29	1	38 +/- 38

- Used a ggF H -> WW sample with M_H = 160 GeV as signal for this study
- Used a WW -> ee sample as background
- Plotted main discriminating variables to show expected separation using simple cuts-based method for 0 jet bin

Lepton selection cuts

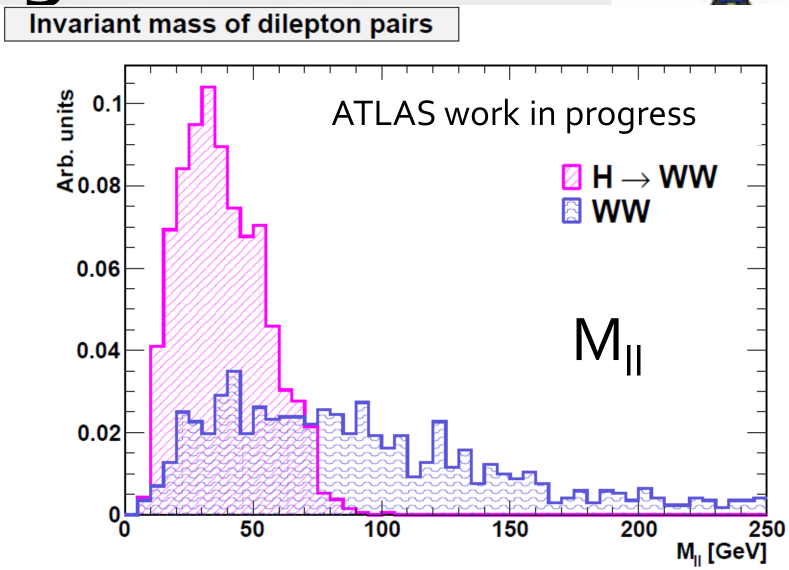
- Opposite sign, with P_T > 15 GeV and $|\eta| < 2.47$ excl. crack regions
- Applied standard tight ATLAS quality cuts as well as isolation cuts

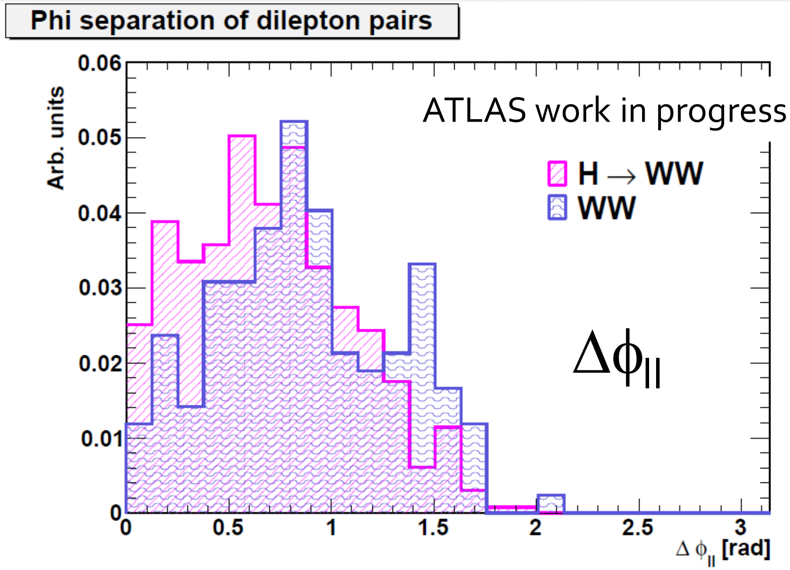
Higgs candidate pre-selection

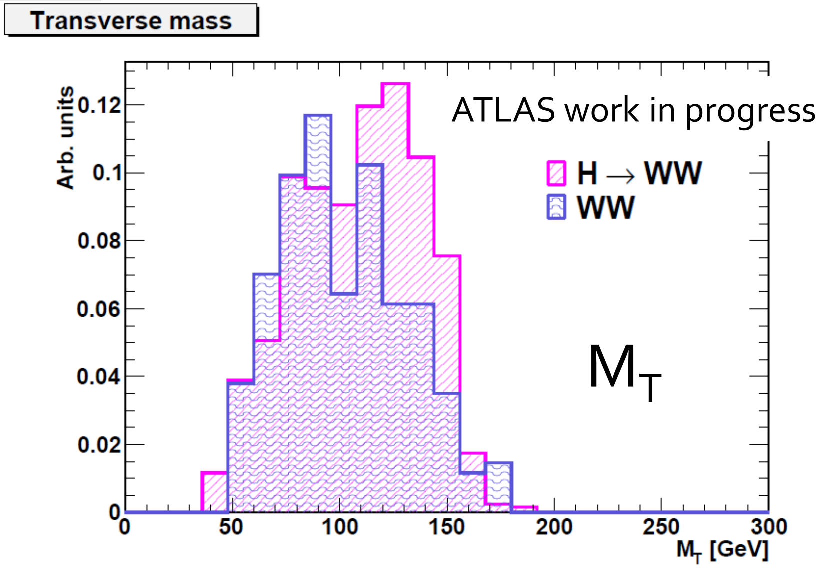
- Applied cut on invariant mass of lepton pair to reduce Z background
- Required missing E_T > 40 GeV
- Made transverse mass cut to reduce continuum background

Best discriminating variables

- After the previous cuts were applied, variables were investigated specifically to suppress WW background
- After prior selection, the latter two do not significantly reduce WW background
  -> can use matrix element method







Matrix element method

- The probability that an event is of type α is given by:

$$P(x,\alpha) = \sum_{i,j} \frac{1}{\sigma_{ij}} \int \frac{d\sigma_{ij}(y,\alpha)}{dy} G(x,y) dy$$

- The differential cross-section is given by:

$$\frac{d\sigma_{ij}(y,\alpha)}{dy} = \int d\Phi \frac{|M_{ij}(\alpha)|^2 f_i(x_1, Q^2) f_j(x_2, Q^2)}{8 x_1 x_2 E_{beam}^2}$$

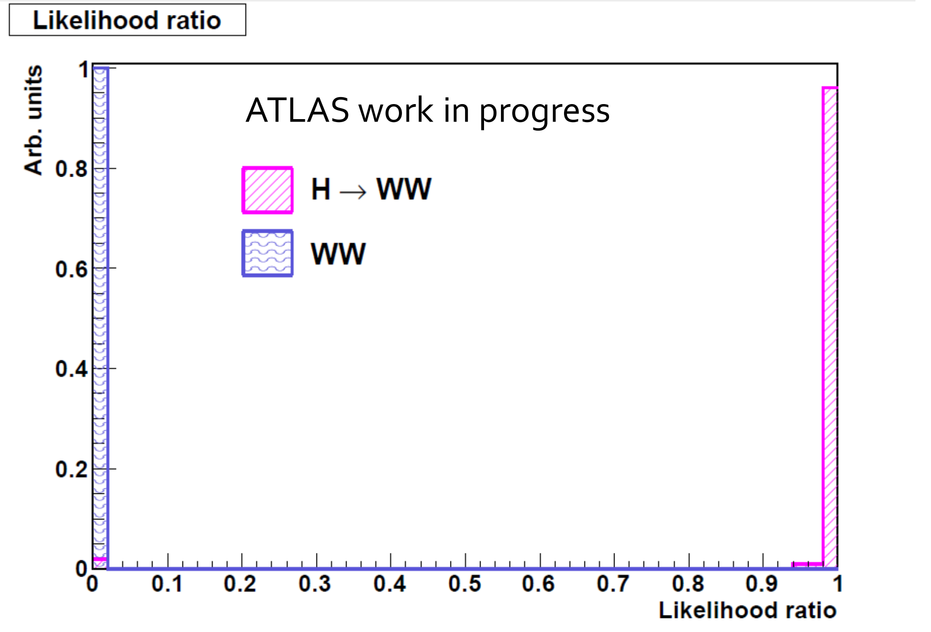
- The probability that an event is of certain type is determined directly from the matrix element
- Can use routines from a MC generator to calculate the matrix element for different processes
- These differ significantly between different types of events
-> allows separation of Higgs -> WW signal from irreducible WW background

Separation using full truth information

- Used MadGraph to generate WW and Higgs -> WW events
- Took the full initial and final state kinematic information from generator
- Used this to calculate the probability that each event was a WW event or a Higgs event for both samples using the simplified formula:

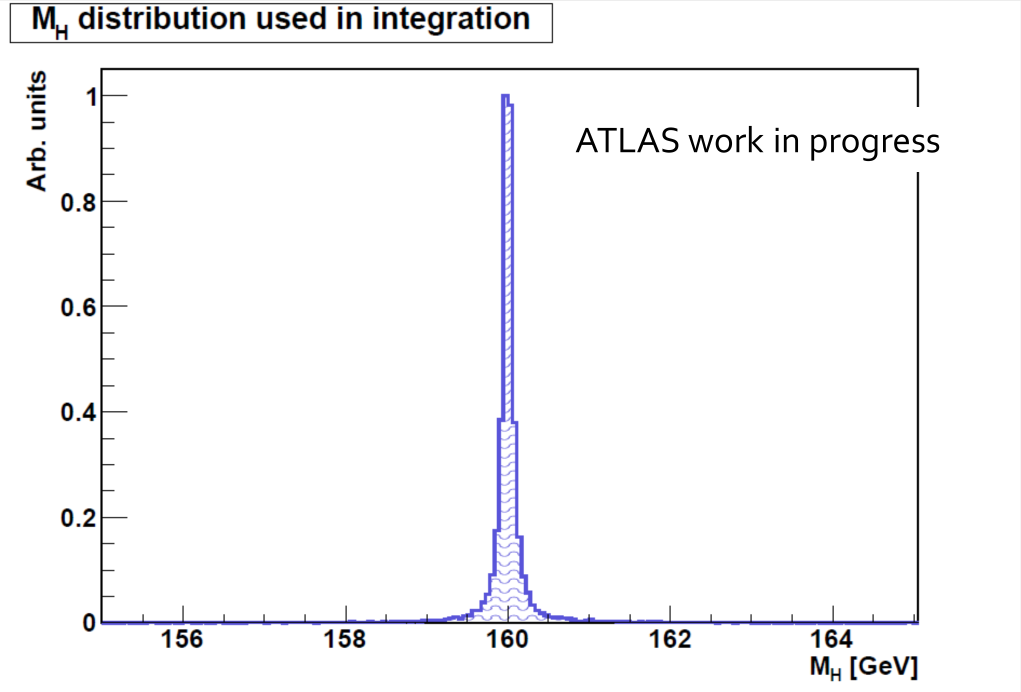
$$P(\alpha) = \sum_q \frac{1}{\sigma_q} |M_{q,\alpha}|^2 f_{PDF_q}$$

- f_{PDFq} was calculated for each possible initial state using CTEQ6L1 PDFs
- Constructed a likelihood ratio for Higgs & WW events: $\frac{P_H}{(P_H+P_{WW})}$



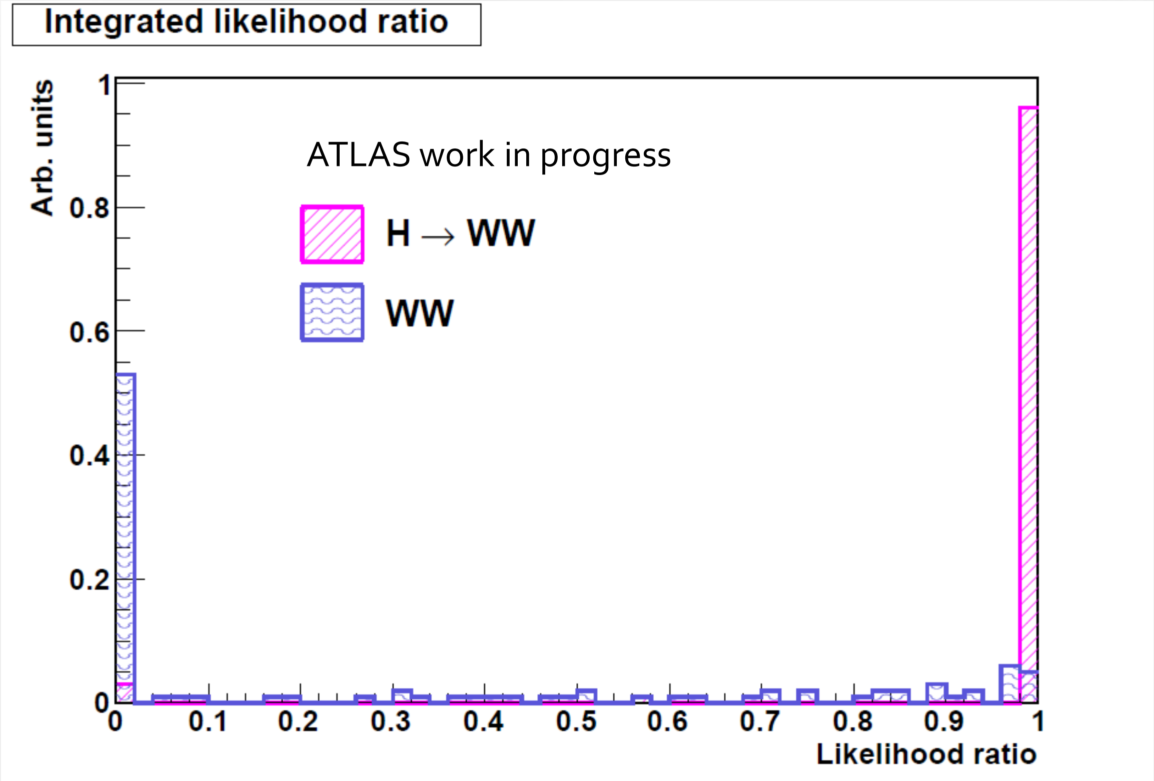
A more realistic matrix element method

- To make the calculation more realistic integrated over the 4 unknowns
- Chose variables that were peaked in phase space to allow best results
  - variables chosen were M_H, M_{W1} , $P_{x,\nu 1}$, $P_{y,\nu 1}$
- Using these variables, it was possible to solve for the other unknowns
- For details of the calculation see: http://lss.fnal.gov/archive/thesis/fermilab-thesis-2008-61.pdfxs
- Used importance sampling integration to minimise CPU time



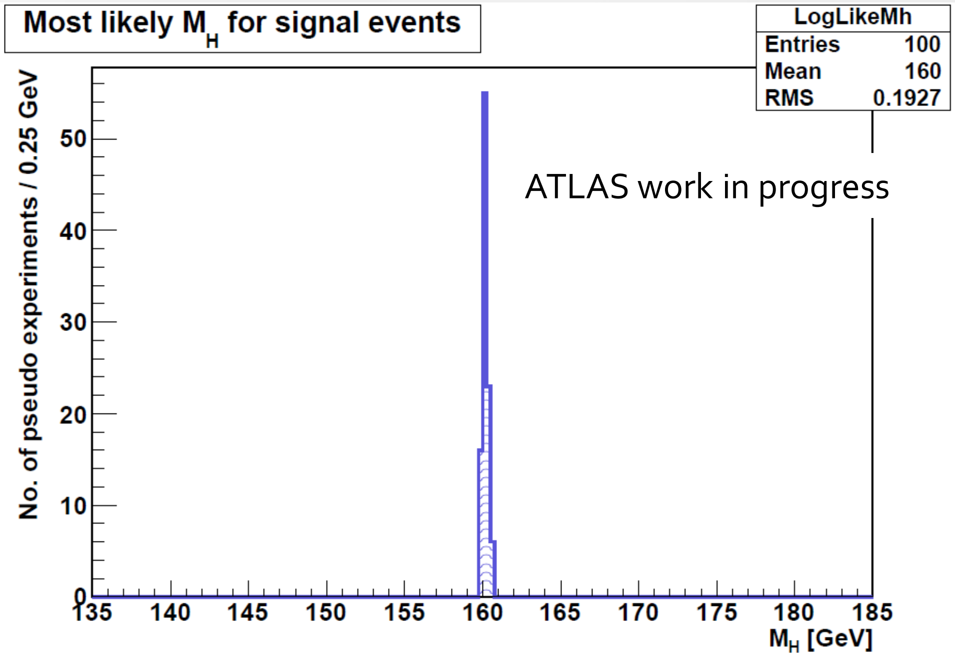
Separation using a more realistic method

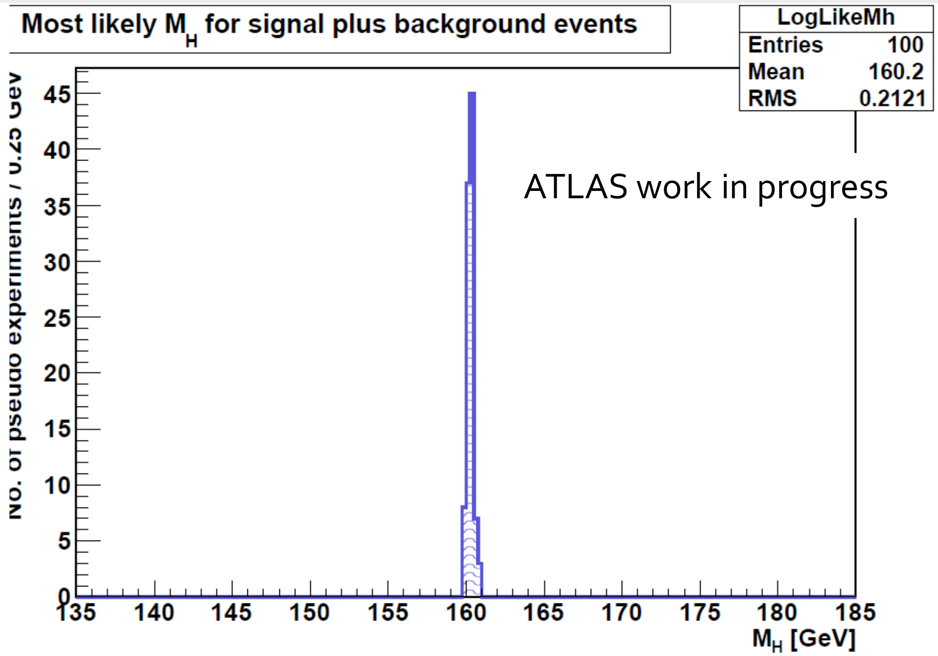
- Using importance sampling integration can achieve very good separation between signal and background
- Next need to include detector resolution effects for the lepton momentum
- Expect good resolution for leptons -> should only be a small effect on likelihood



Extraction of Higgs mass

- It is also possible to use the matrix element method to extract M_H from a sample of Higgs or Higgs + WW events
- Construct a joint log likelihood as a function of Higgs mass for a number of pseudo experiments
- Fill a histogram with the M_H which maximises the likelihood for each pseudo experiment
- Even with signal + background events can still extract correct M_H





Conclusions and future work

Conclusions

- H -> WW channel can extend Higgs exclusion to 150 – 180 GeV mass range with first ATLAS data
- It should be possible to expand these limits by improving separation of signal from background
- This channel is the primary Higgs discovery mode for $M_H > 140$ GeV
- Matrix element method provides a powerful way to separate H->WW events from WW background
- It also allows the Higgs mass to be determined

Future work

- Need to complete investigation on effect of detector smearing on results
- Plan to perform a study to quantify the gains over the cuts-based method