Results of the SM and MSSM Higgs Search at L3 $\sqrt{s} = 189$ GeV

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April 13, 1999

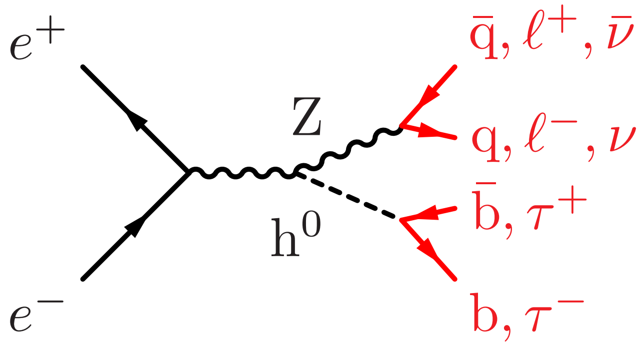
On behalf of the L3 collaboration

- Results from the SM Higgs search
- Results from the MSSM Higgs search
- Conclusions

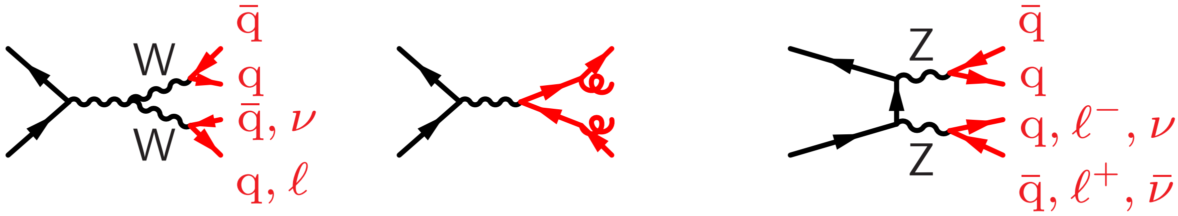
$\boxed{\text{ALL RESULTS PRELIMINARY!}}$

The Standard Model Higgs Search

Dominant Production Mechanism is the Higgs-strahlung Process



Lots of Background



- Analyses Performed for
  - $hZ \rightarrow b\bar{b}q\bar{q}$
  - $hZ \rightarrow b\bar{b}\nu\bar{\nu}$
  - $hZ \rightarrow b\bar{b}\ell^+\ell^-$ $(\ell = e, \mu, \tau)$
  - $hZ \rightarrow \tau^+\tau^- q\bar{q}$

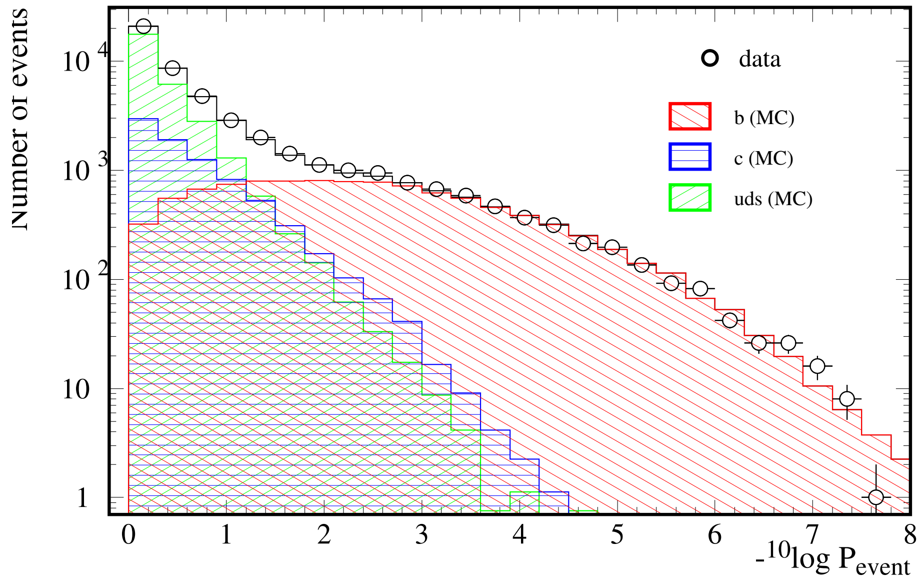
- Includes charm, gluonic decays $\Rightarrow \sim 96\%$ Br.

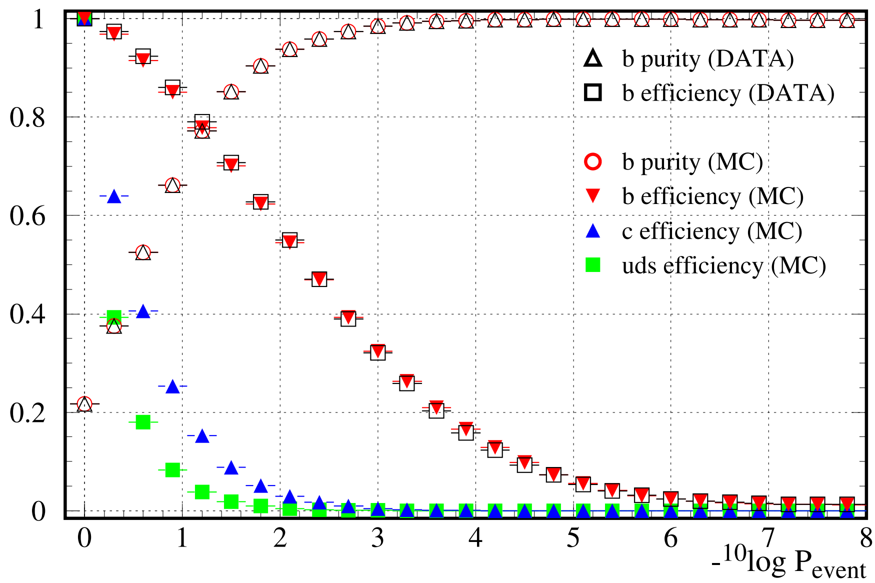
- Data collected: 176.4 pb^{-1}

The Standard Model Higgs Search

Higgs accessible at LEP decay to b quarks over 80% of the time. So the ability to identify b's is our most powerful tool.

The 1998 L3 btag performance as evaluated on $2.5\mathrm{pb}^{-1}$ of calibration data at the Z peak.





The Standard Model Higgs Search

Common Strategies for Higgs searches

1. Apply a preselection that keeps signal efficiency high for a range of Higgs masses but reduces background, especially $\gamma\gamma$.

2. Choose a function, which when minimized, maximizes the signal to background ratio. In half of the analyses we've performed this function is a Neural Network, in the other half this is another function which is used to optimize a set of straight cuts.

3. Make a powerful final variable which is a combination of discriminating variables (generally btag and mass), or the combination of the NN output and the reconstructed Higgs mass.

4. Interpret the data using the full spectrum of the final variable.

- Almost all channels are covered by two independent analyses, which generally give very similar performance.

Higgs to 4 jets Search

- The dominant channel with 58% of the expected signal events.

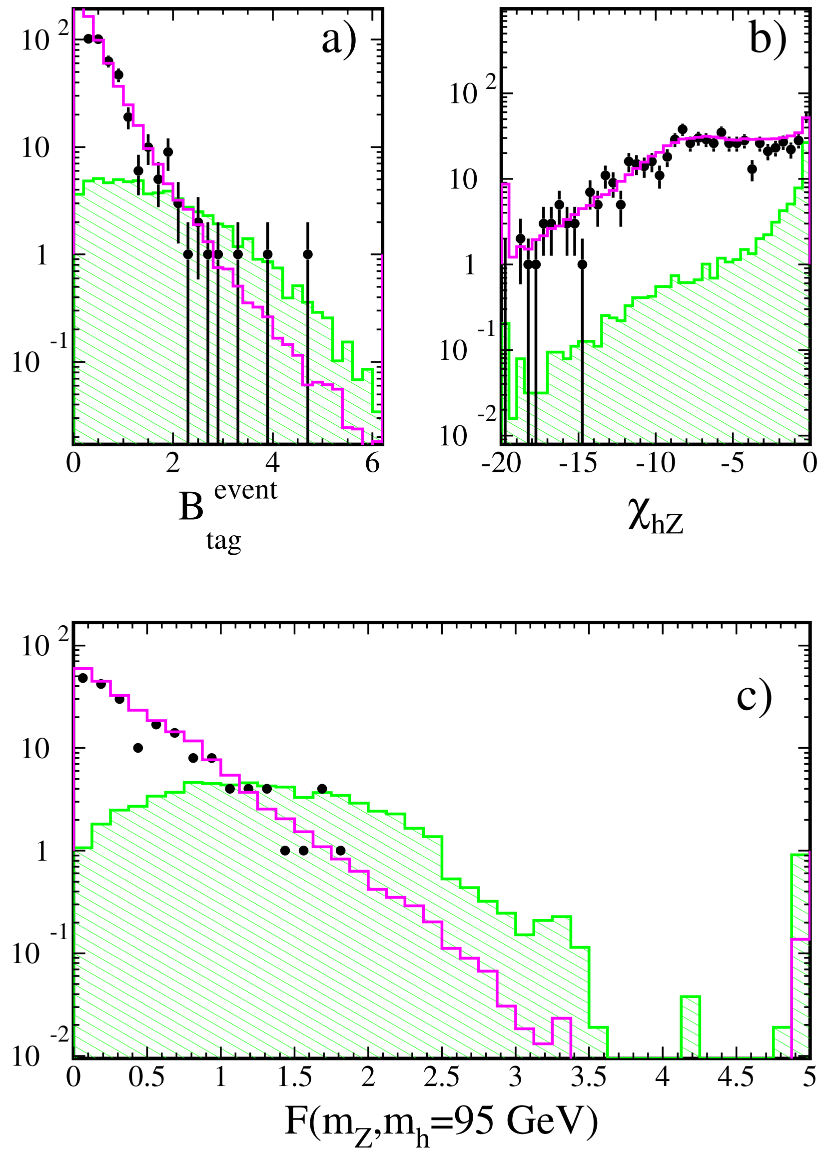
$$\mathrm{H} \to \mathrm{b\bar{b}} \qquad \mathrm{Z} \to \mathrm{q\bar{q}}$$

- The channel one would first expect to see a Higgs signal
- Efficiency is also evaluated for $\mathrm{H} \to \mathrm{c\bar{c}}$ and $\mathrm{H} \to \mathrm{gg}$

Highlights of the selection

- E_{vis}:$\gtrsim 60\%\sqrt{s}$ ensures all jets in detector, rejects semi-leptonic $\mathrm{W}^+\mathrm{W}^-$ and radiative returns.
- $P_{\|}^{\mathrm{miss}}/E_{\mathrm{vis}}$:$\lesssim 30\%$ well balanced event, removes rad. returns to Z with γ in beam pipe.
- Y_{34}^{D}:$\gtrsim 0.008$ ensures four-jet-like nature of event.
- $\max(\Delta E_{\mathrm{jet}})$:$\lesssim 35\%\sqrt{s}$ rejects soft gluon jets.
- $\min(m_i), \max(m_i)$:Minimum and maximum dijet mass removes gluon jets. Window usually $\gtrsim 10\%\sqrt{s}$, $\lesssim 80\%\sqrt{s}$.

SM $hZ \rightarrow b\bar{b}q\bar{q}$ Final Variable



- Basic idea: Instead of making tight cuts, use entire spectrum of most powerful variables $B_{\rm tag}^{\rm event}$, $\chi_{\rm hZ}$.

- From the background distributions of btag and $\chi_{\rm hZ}$ it is possible to calculate the probability for an event to come from background. We make a combination of the weighted probabilities to make the final variable.

SM Lepton Channels

- Leptonic Channels:

$$\mathrm{H}\rightarrow \mathrm{b}\bar{\mathrm{b}} \qquad \mathrm{Z}\rightarrow \mathrm{e}, \mu, \tau$$
$$\mathrm{H}\rightarrow \tau^+\tau^- \qquad \mathrm{Z}\rightarrow \mathrm{q}\bar{\mathrm{q}}$$

- $\sim 13\%$ of HZ events.
- Small Br, but would be very important for measuring m_{H}.
- Use B-Tag, well isolated leptons.
- Combine B-Tag and 5C mass information into one final variable.
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Electron Channel	
Expected events from background	9.3
Data events seen	9
95GeV Higgs signal efficiency	72.8%

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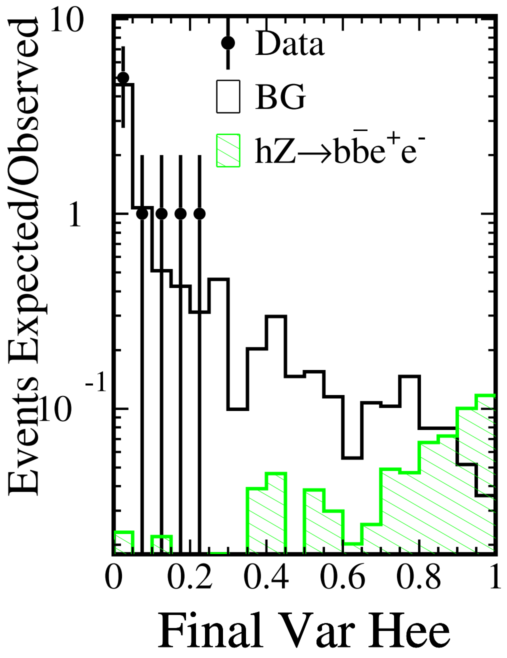
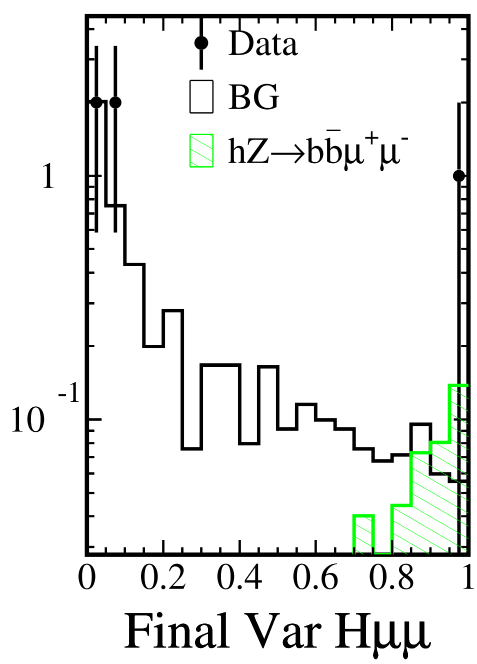
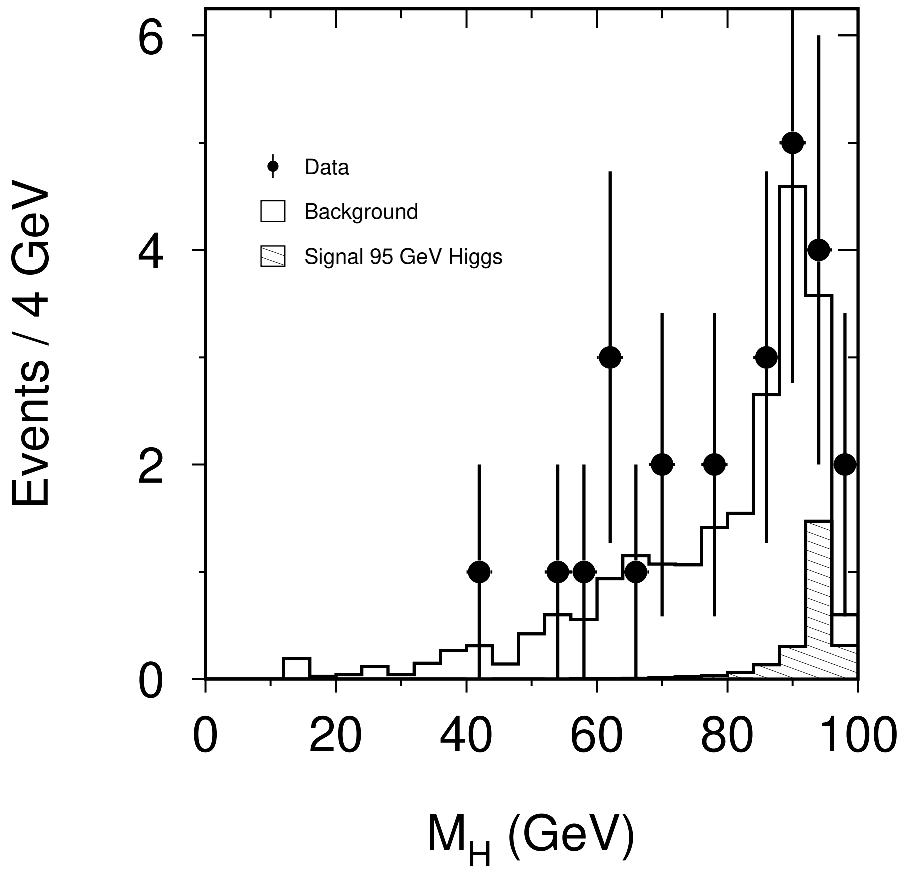
Muon Channel	
Expected events from background	5.1
Data events seen	5
95GeV Higgs signal efficiency	56.0%

SM Lepton Channels







SM Neutrino Channel

- Neutrino Channel:

  $H \rightarrow b\bar{b}$ $\quad Z \rightarrow \nu\bar{\nu}$

  Small Contribution from W^+W^- fusion

- $\sim 18\%$ of HZ events.

- Neural network analysis for kinematic variables including B-Tag.

- Combine NNet and Mass into one final variable (purity).

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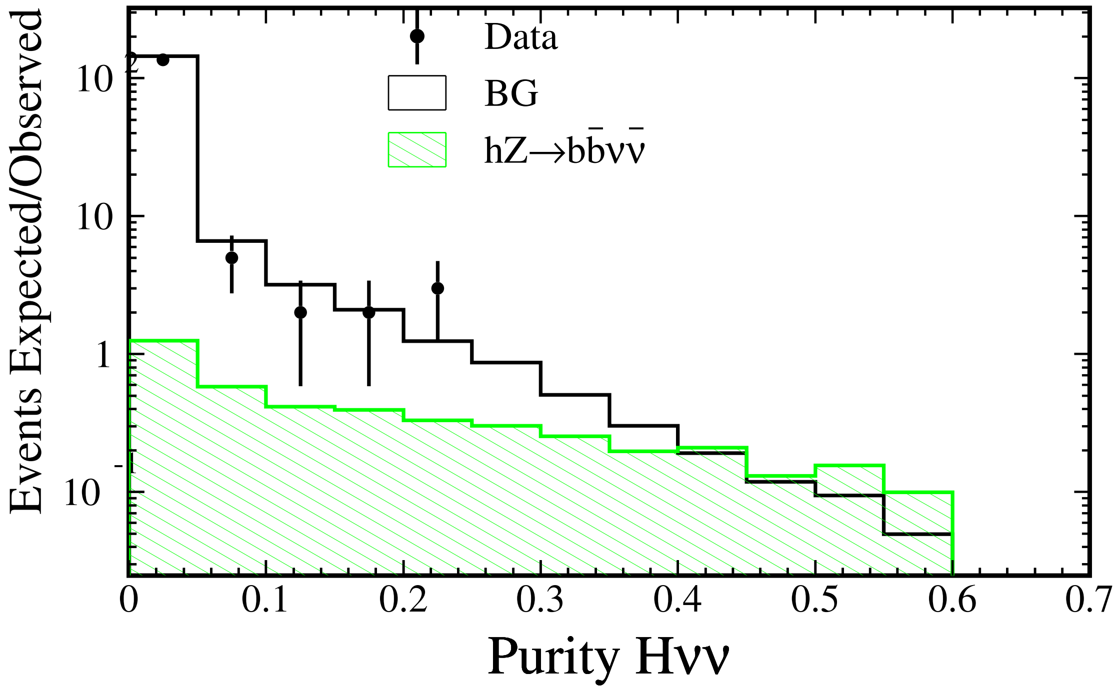
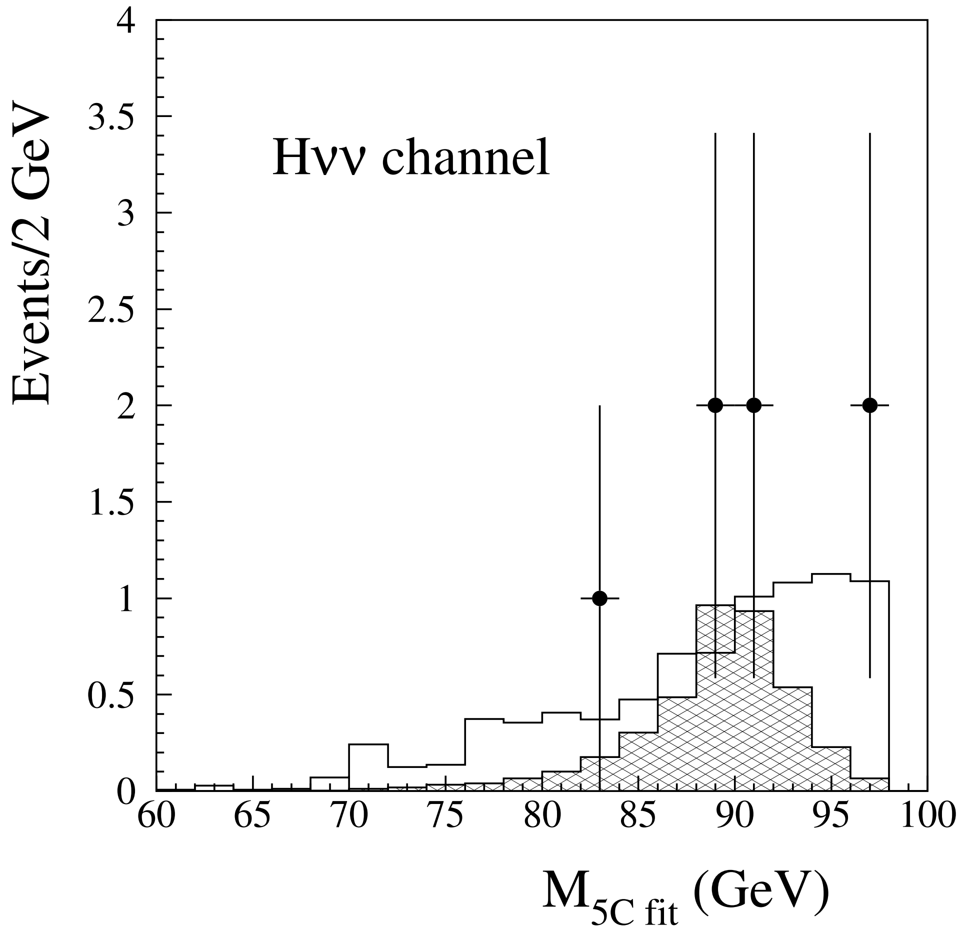
Missing Energy Channel (NN>0.5)	
Expected events from background	11.9
Data events seen	10
95GeV Higgs signal efficiency	47.7%

SM Neutrino Channel

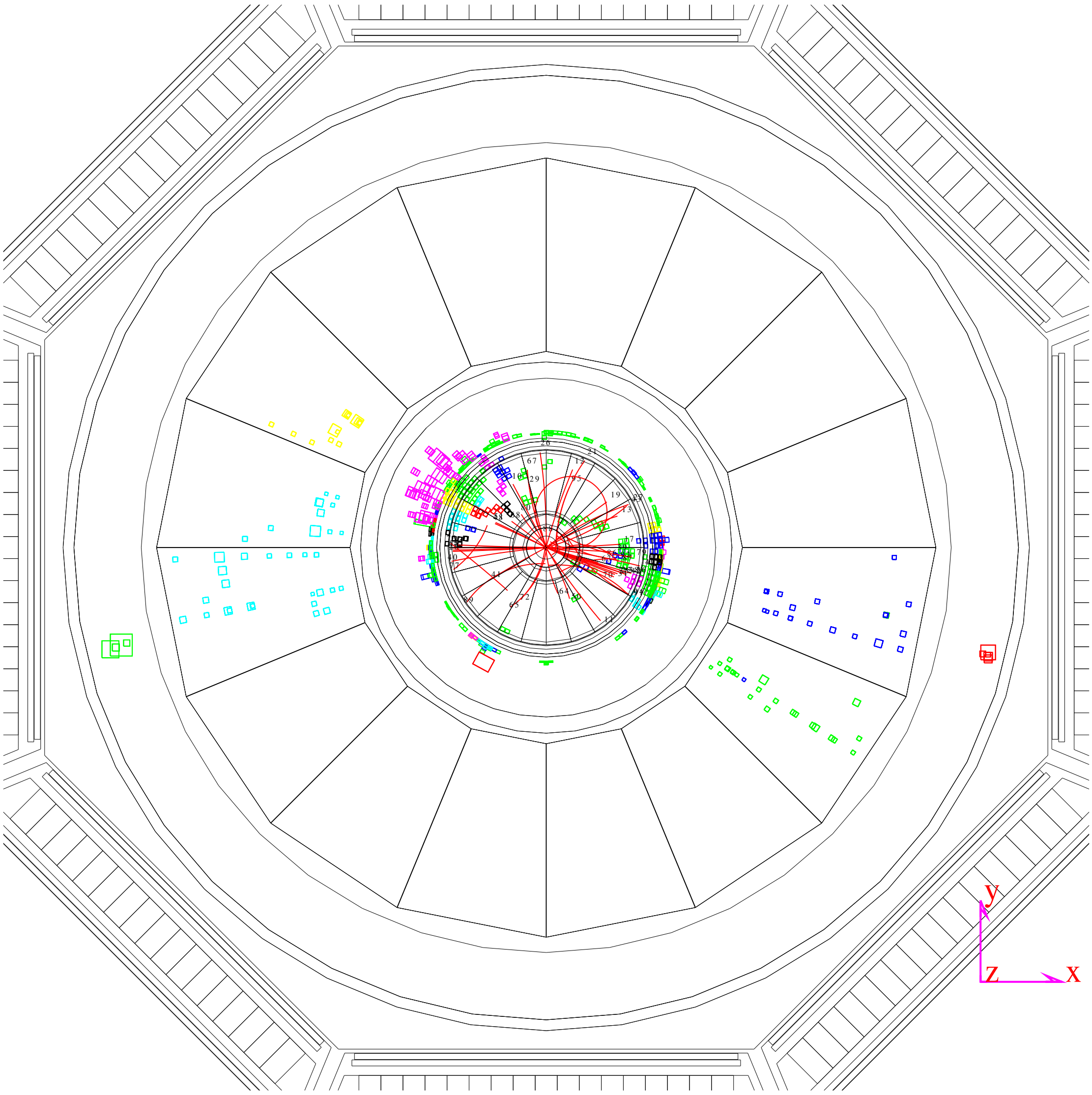




A Nice Candidate

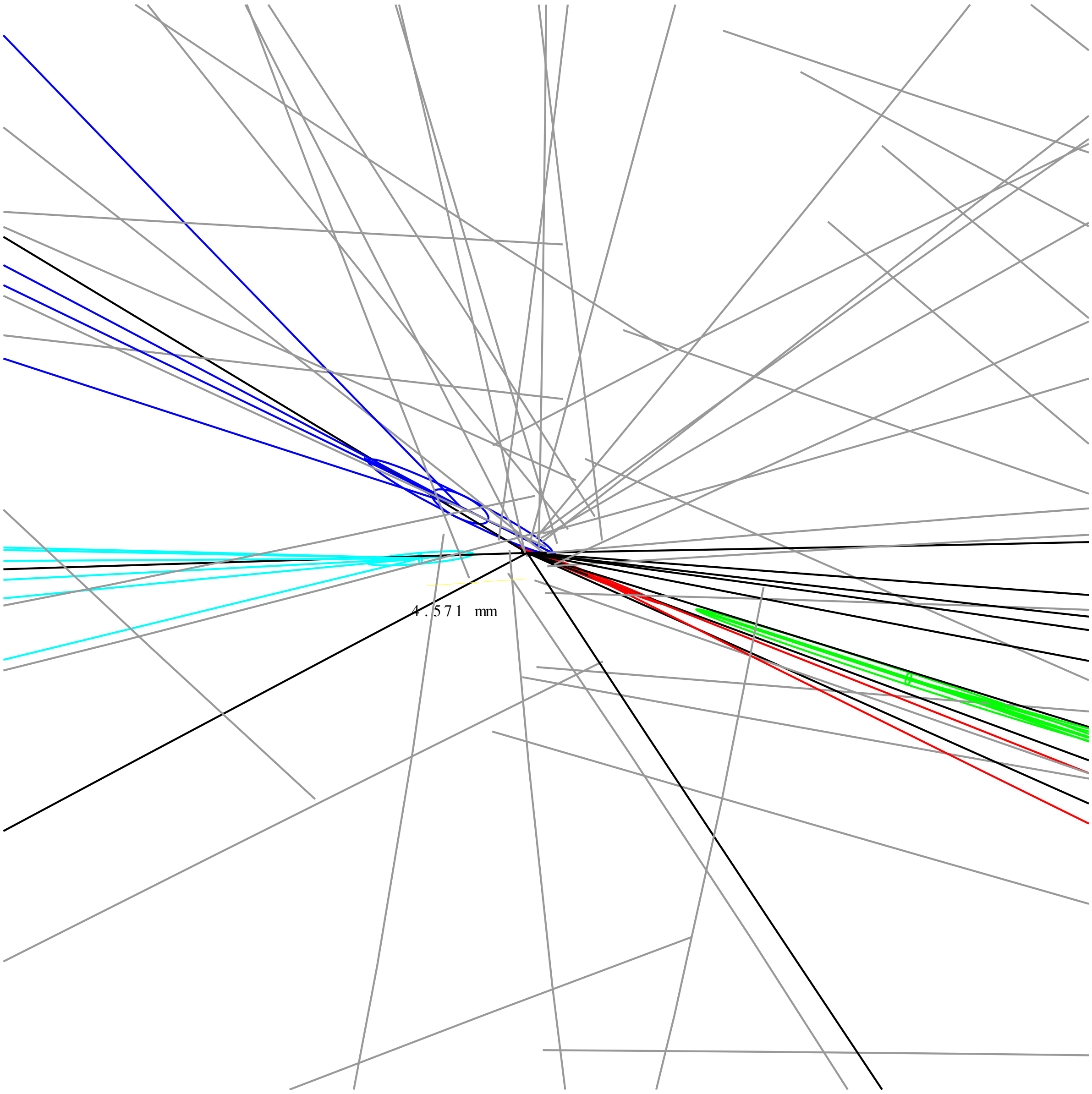
B-Tag 2.7, 5C Mass 90.1 GeV

Run # **697803** **Event #** **4765** Total Energy : 135.25 GeV

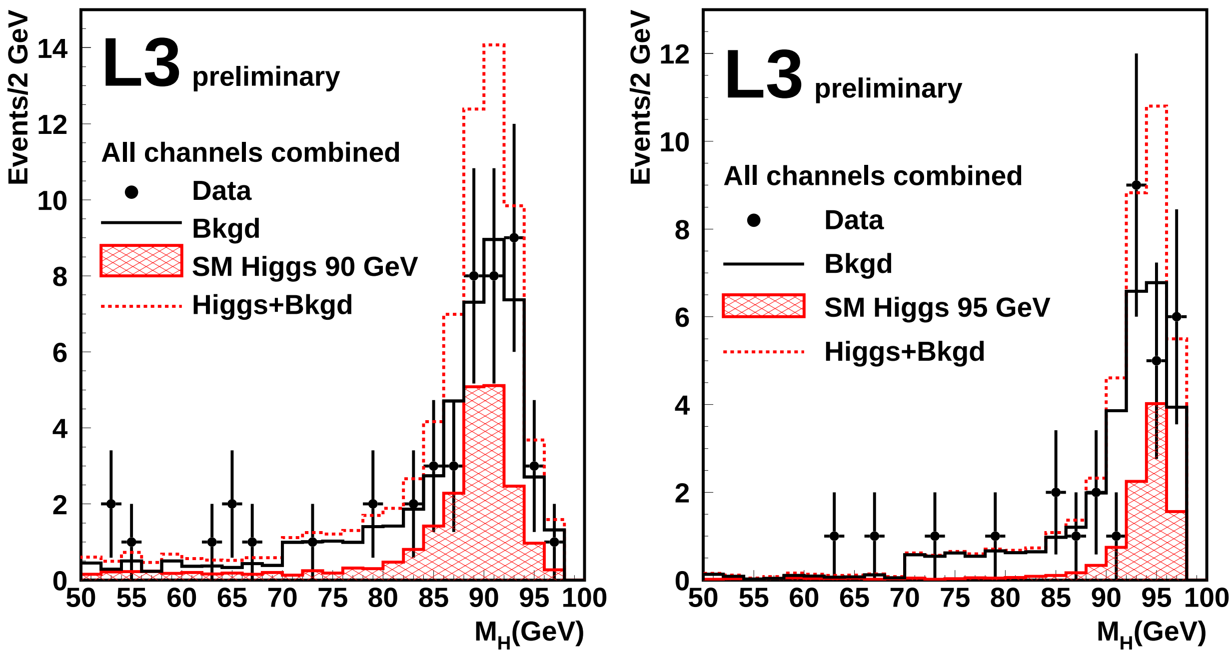


Transverse Imbalance : .1661		**Longitudinal Imbalance :** -.1736	
Thrust : .8535	**Major :** .3308		**Minor :** .2114
Event DAQ Time : *980613 222350*			

A Nice Candidate



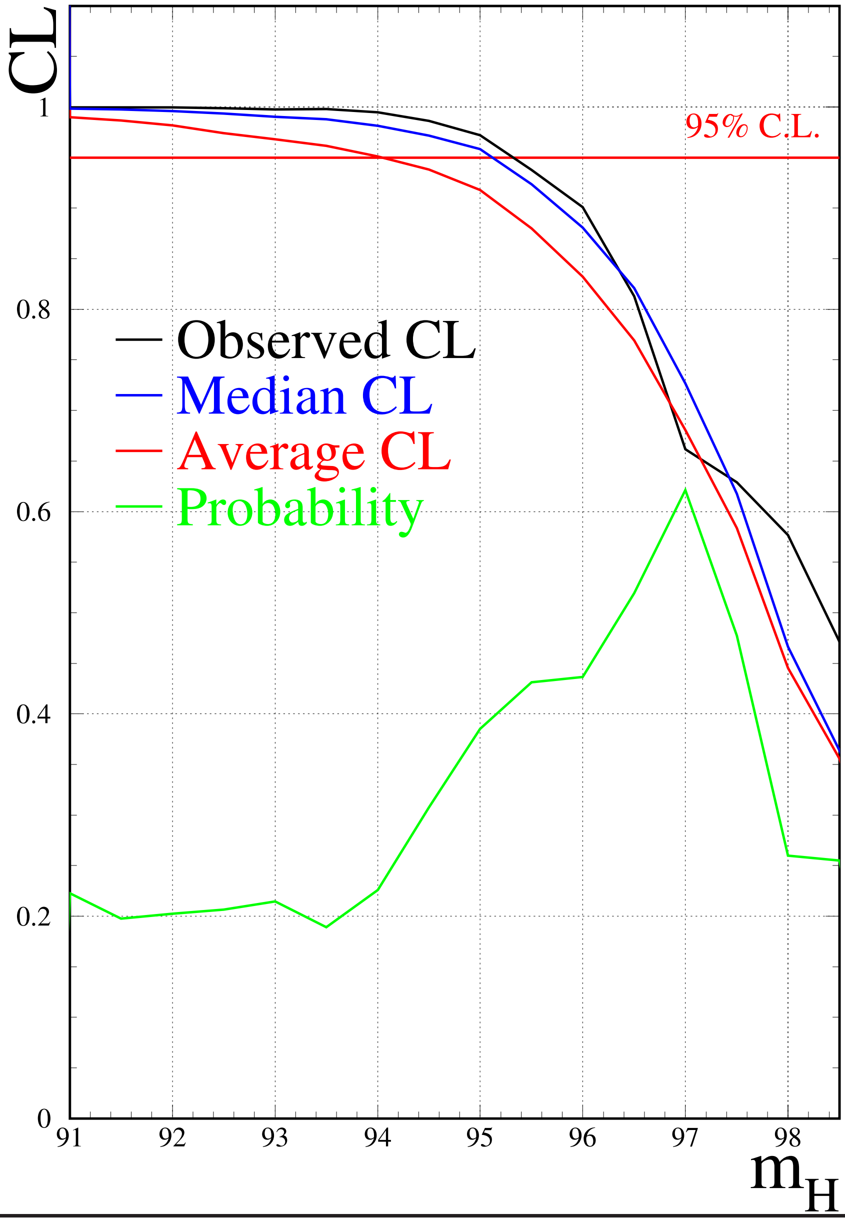
SM Higgs Search



- For illustration purposes, the mass distributions of the most significant candidates from the 90GeV and 95GeV Higgs mass.

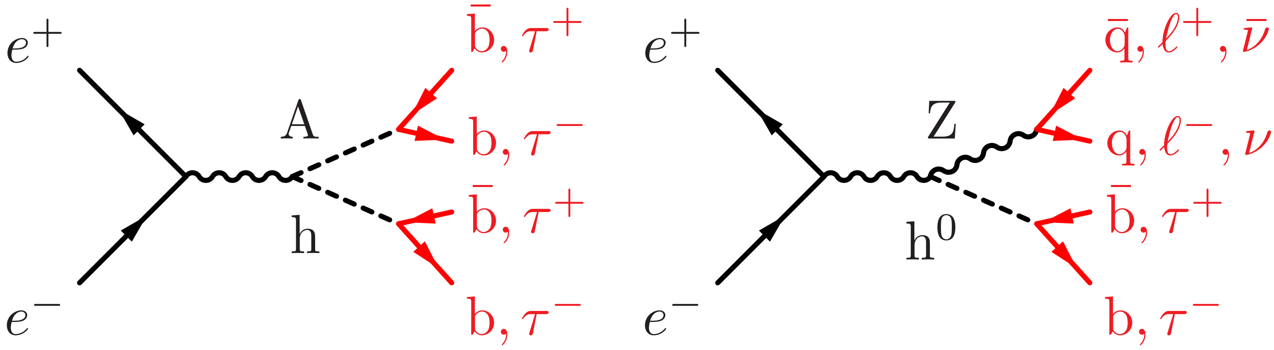
- These are not the distributions used to calculate the CL.

SM Higgs Search



No evidence of signal! $m_{\rm h} > 95.2$ GeV

The MSSM Higgs



- Now, in addition to SM-like hZ channels, we have $\mathrm{hA} \rightarrow \mathrm{b\bar{b}b\bar{b}}, \mathrm{b\bar{b}}\ \tau^+\tau^-$.

- Relative rates of $\mathrm{e^+e^-} \rightarrow \mathrm{Z}^* \rightarrow \mathrm{hZ}$ and $\mathrm{e^+e^-} \rightarrow \mathrm{Z}^* \rightarrow \mathrm{hA}$ change as a function of $\tan\beta$.

- $B_{\mathrm{tag}}^{\mathrm{event}}$ is more important for $\mathrm{hA} \rightarrow \mathrm{b\bar{b}b\bar{b}}$ than for $\mathrm{hZ} \rightarrow \mathrm{b\bar{b}q\bar{q}}$.

- Due to the similarities between the SM and the hZ production diagram we can recycle most of the SM search channels.

- We need dedicated channels to search for the $\mathrm{hA} \rightarrow$4-jets and the $\mathrm{hA} \rightarrow \mathrm{b\bar{b}}\tau\bar{\tau}$

The MSSM Higgs

The 4-jet search

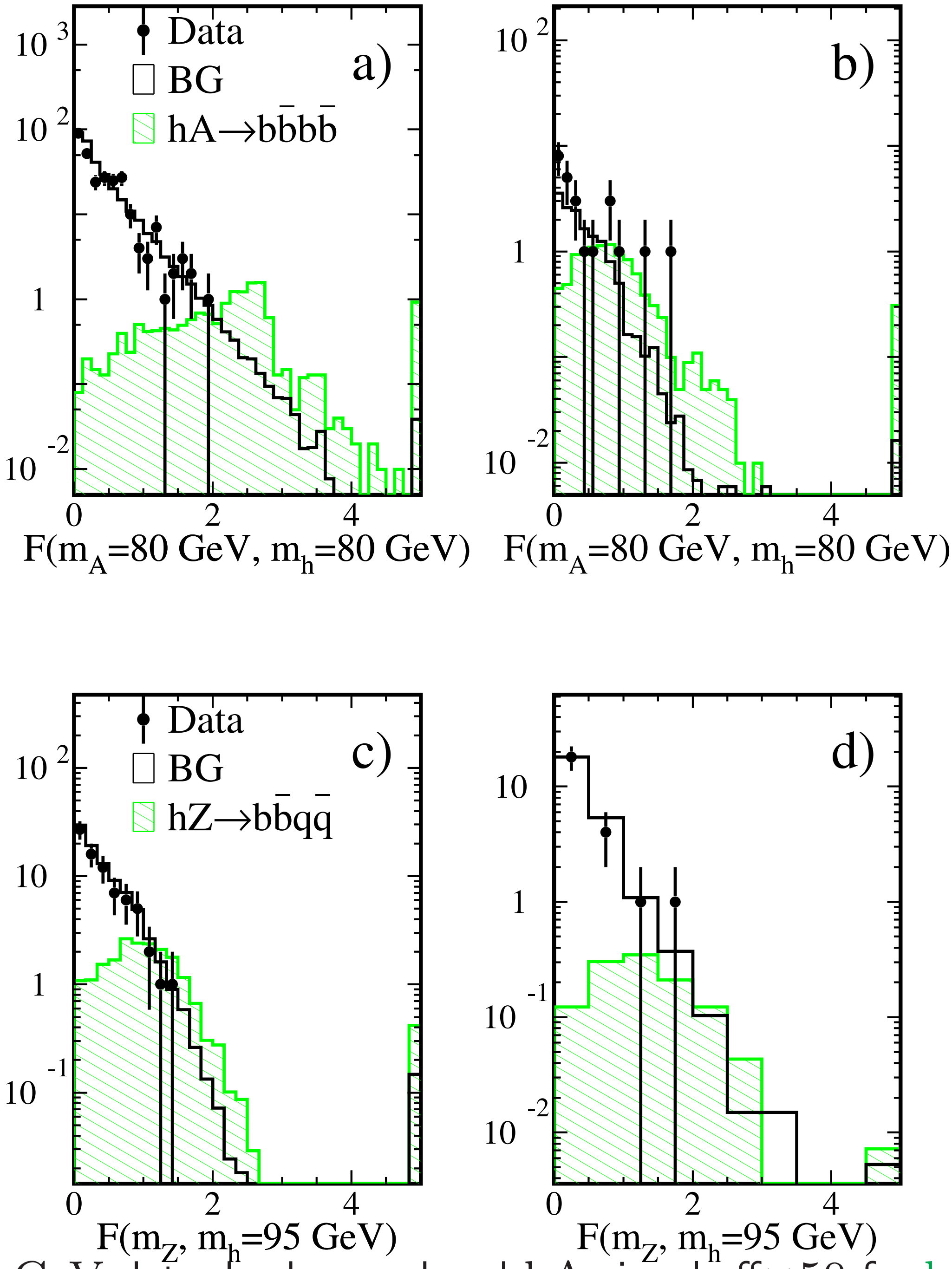
Choosing between $\mathrm{hZ} \rightarrow \mathrm{b\bar{b}q\bar{q}}$ and $\mathrm{hA} \rightarrow \mathrm{b\bar{b}b\bar{b}}$

- We have two sets of optimized cuts one for $\mathrm{hZ} \longrightarrow \mathrm{b\bar{b}q\bar{q}}$ and one for $\mathrm{hA} \longrightarrow \mathrm{b\bar{b}b\bar{b}}$ and there is a significant overlap. Approximately, half the hA events also pass the hZ selection cuts.

- If an event passes both sets of selection cuts it need to be assigned to hA or hZ so that the correct mass hypothesis can be applied for the mass part of the final variable.

MSSM Higgs

The Final Variable



a) 189 GeV data, background and hA signal eff$\times$50 for $\mathrm{hA}'_{\mathrm{b\bar{b}b\bar{b}}}$ analysis.

b) $\mathrm{hA}_{\mathrm{b\bar{b}b\bar{b}}}$ analysis.

c) $\mathrm{hZ}'_{\mathrm{b\bar{b}q\bar{q}}}$ analysis for hZ signal.

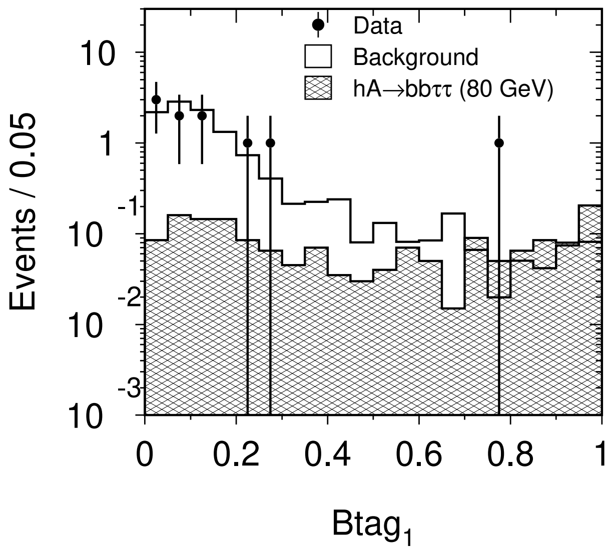
d) $\mathrm{hZ}_{\mathrm{b\bar{b}q\bar{q}}}$ analysis

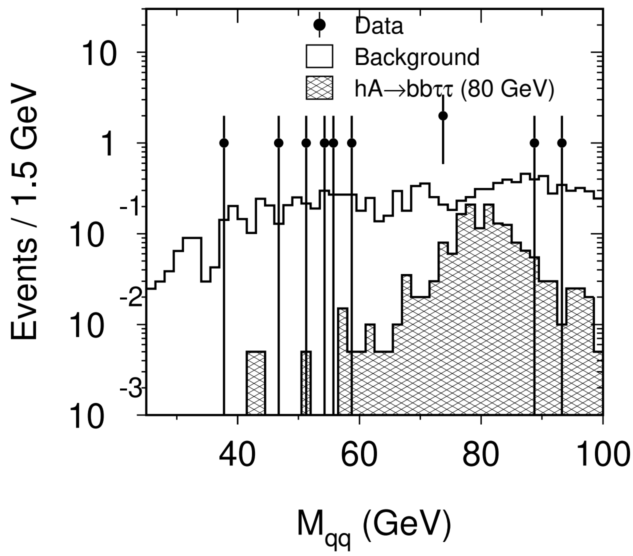
MSSM Higgs Searches with τ's

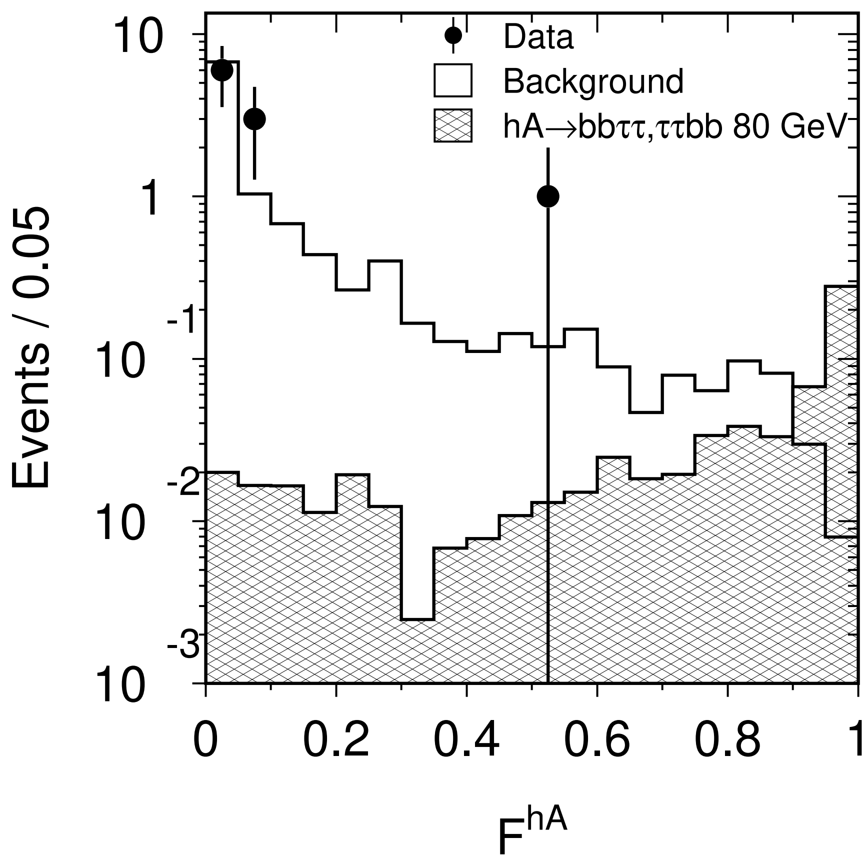
- hZ selection is the same as the SM Higgs search
- For hA there is a common preselection
- Two final selections
  1. Relies on the identification of two τ's
  2. Is a kinematic selection where the event is forced to four jets, two of the jets are required to be low multiplicity.
- Final variable is a likelihood combination of btag and $\mathrm{M}_{\tau\tau}$ or M_{jj}.
- Events that are selected by both the hA and hZ search are assigned to one based on the relative cross section.

MSSM Higgs

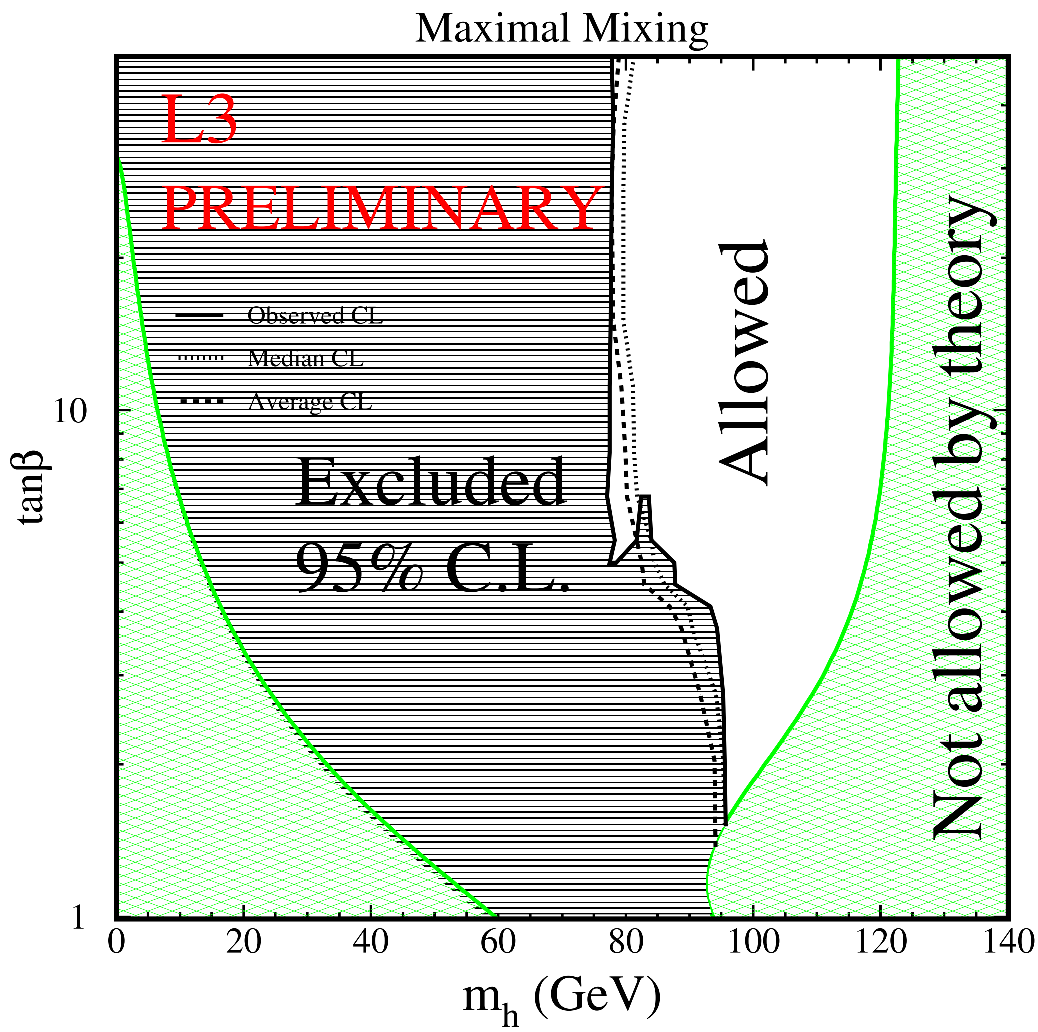
Searches with τ's







MSSM Higgs



- Some candidates around m_{W}, but no clear evidence of signal.
- $m_{\mathrm{h}} > 77\ \mathrm{GeV},\ m_{\mathrm{A}} > 78\ \mathrm{GeV}$ at 95% CL.
- $tan(\beta)$ excluded between 1.0 and 1.5 at the 95% CL, but this depends on m_{top}.

Conclusions

- No evidence for the Standard Model or the MSSM Higgs in the 1998 data set.

- We calculate mass limits for the SM and MSSM Higgs
  - SM $m_H > 95\mathrm{GeV}$
  - MSSM $m_h > 77\mathrm{GeV}$ and $m_A > 78\mathrm{GeV}$

- We'll be back this year to try again at a higher energy.