# 1 Intermediate Mass Higgs Measurements

In the intermediate Higgs mass range, defined here to be the range from 150 GeV/c$^2$ to 300 GeV/c$^2$, the dominant decay is $H \to W^+W^-$. The branching fraction for this decay is a function of the weak coupling constant $g$ and kinematic constraints for off-shell $W$ bosons. Therefore, the most significant measurement one can make in most of this mass range is whether the BR($H \to W^+W^-$) is in agreement with the Standard Model prediction. Above $2M_Z$, the BR($H \to Z^0Z^0$) also becomes important, though smaller than BR($H \to W^+W^-$). For the low end of this mass range ($M_{Higgs} \lesssim 170$ GeV/c$^2$), there is also the possibility of measuring BR($H \to b\bar{b}$).

Our approach is a simple one. We assume that the detector design is adequate to identify decays of the type $Z^0 \to e^+e^-$ and $Z^0 \to \mu^+\mu^-$ with 80% efficiency. We then calculate the number of predicted $H \to W^+W^-$, $H \to Z^0Z^0$, $H \to b\bar{b}$ decays. For the meaurements described below, we make the following assumptions:

- 250 fb$^{-1}$ of delivered luminosity
- $\sqrt{s} = 500$ GeV
- Associated production of Higgs via the process $e^+e^- \to Z^0H$, followed by $Z^0 \to e^+e^-$ or $Z^0 \to \mu^+\mu^-$
- Identification of the Higgs events through the missing mass technique

We have constrained the sample to associated production to give a direct measurement of the branching ratios by measuring the number of Higgs events and the number of decay events in the same dataset, independent of luminosity measurements and cross section calculations. Extrapolations for other values of the luminosity should be straightforward.

## 1.1 Estimates of Statistical Uncertainties

In figure 1, we present the number of predicted $H \to W^+W^-$, $H \to Z^0Z^0$, and $H \to b\bar{b}$ events in 250 fb$^{-1}$ at $\sqrt{s} = 500$ GeV. We have not included any additional decay branching fractions or identification efficiencies at this stage.

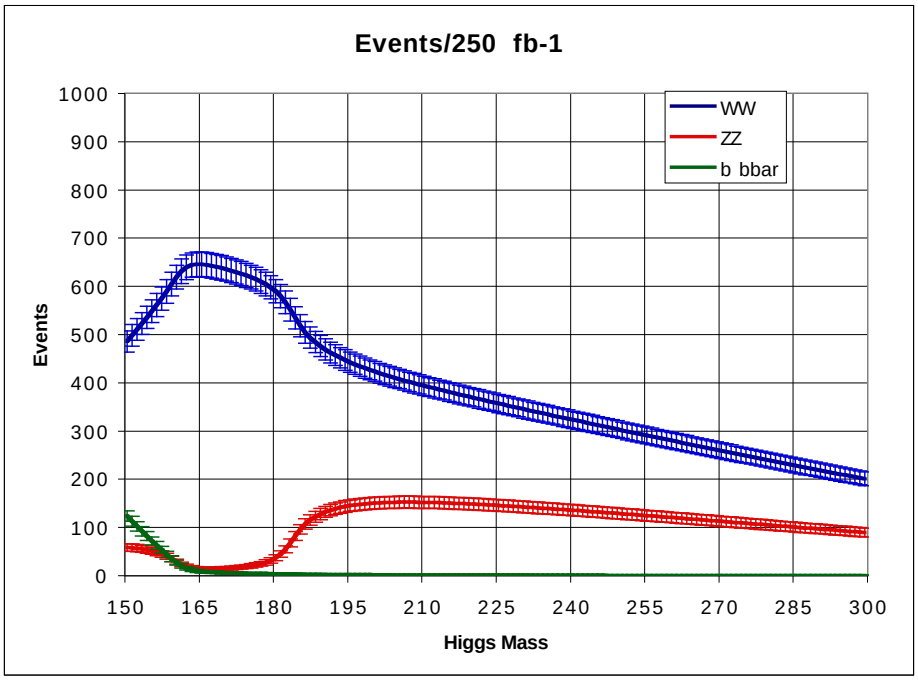


Figure 1: Number of $H \to W^+W^-$, $H \to Z^0Z^0$, and $H \to b\bar{b}$ events predicted for associated Higgs production with a center of mass energy of 500 GeV/c$^2$, 250 fb$^{-1}$ delivered luminosity, where the associated $Z^0$ is identified by decays into $e^+e^-$ or $\mu^+\mu^-$.

For reasonable expectations of $W$ identification efficiencies (50% or better) [1], we would expect to identify $\gtrsim$ 100 events over the entire mass range, with significantly more for $M_{Higgs}$ in the region 150 GeV/c$^2$ to 200 GeV/c$^2$. As a result, the statistical uncertainty on the measurement of BR($H \to W^+W^-$) will be $\lesssim$ 10%.

The $Z^0$ and $b$ measurements are more problematic. In figure 2, we show the predicted number of events for $H \to Z^0Z^0$ and $H \to b\bar{b}$. Unless we are able to distinguish hadronic $Z^0$ decays from hadronic $W$ decays, it will be difficult to have adequate statistics to measure BR($H \to Z^0Z^0$) as the total number of $Z^0Z^0$ events is $\lesssim$ 150 over the entire mass range. If we could identify one of the two $Z^0$'s in the Higgs decays (through leptons or $b\bar{b}$) 40% of the time, at best the statistical uncertainty of BR$H \to Z^0Z^0$) would be $\sim$ 11

With this approach, the measurement of BR($H \to b\bar{b}$) to better than 25% will only be possible for $M_{Higgs} \lesssim$ 160 GeV/c$^2$. For larger masses, the branching fraction into $b\bar{b}$ is too small.

### 1.2 Different Scenarios

A center of mass energy of 500 GeV/c$^2$ is not optimal for all Higgs masses in the range 150 GeV/c$^2$ to 300 GeV/c$^2$. As can be seen in figure 3, the cross section for associated Higgs production is dependent upon both the Higgs mass and the center of mass energy. For the low end of the mass range ($\lesssim$ 175 GeV/c$^2$, the production cross section goes up by a factor of 2 to 2.5 in going to $\sqrt{s} = 300$ GeV from the nominal value of $\sqrt{s} = 500$ GeV.

As stated above, the measurement of $H \to b\bar{b}$ is statistics limited for the entire mass range. A possible approach to increase the statistics in this sample is to look for the $\nu$ decays of the associated $Z^0$, with the experimental signature being two tagged $b$'s with mass consistent with the Higgs, along with significant missing energy from the 2 neutrinos. Since the BR($Z^0 \to \nu\overline{\nu}$ is 3 times that of $e^+e^-$ plus $\mu^+\mu^-$, the gain extends the reach to $M_{Higgs} \sim 165$ GeV/c$^2$ with a 25% statistical uncertainty.

## References

[1] **find reference to WW cross section measurements at Lep**

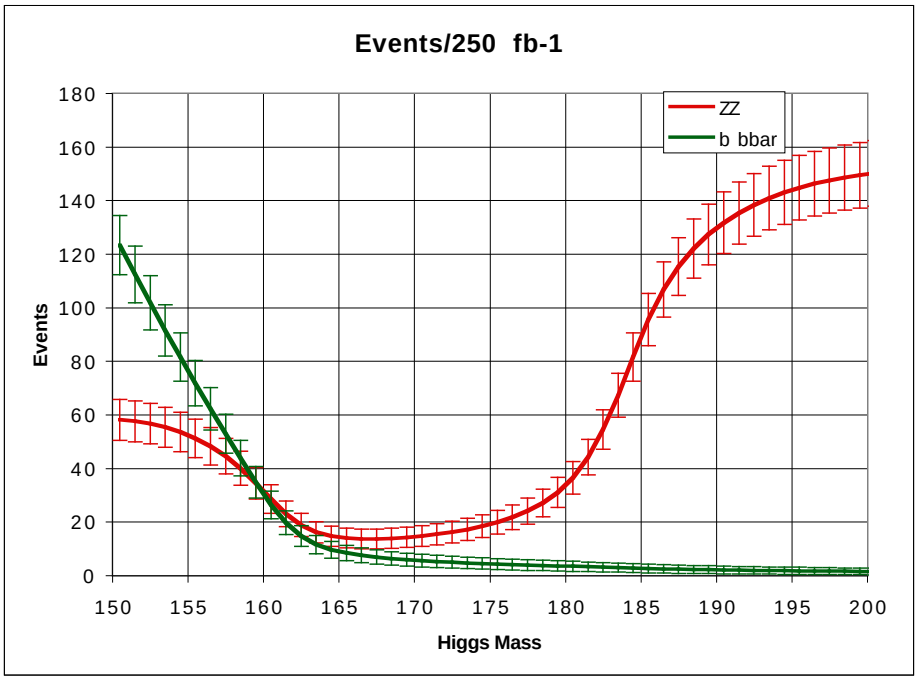


Figure 2: Number of $H \to Z^0 Z^0$, and $H \to b\bar{b}$ events predicted for associated Higgs production with a center of mass energy of 500 GeV/c$^2$, 250 fb$^{-1}$ delivered luminosity, where the associated $Z^0$ is identified by decays into $e^+e^-$ or $\mu^+\mu^-$.

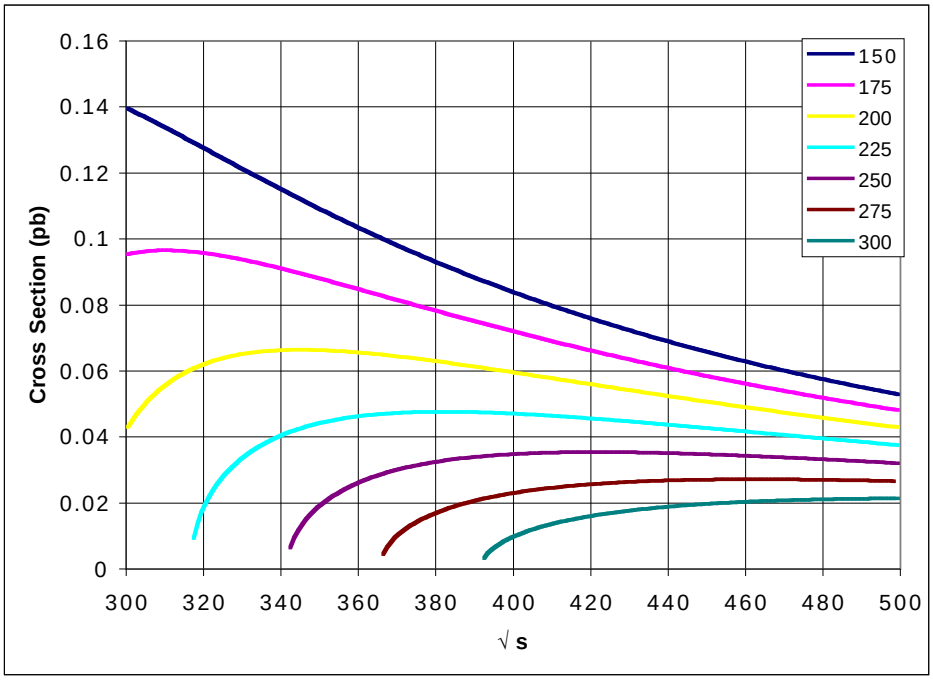


Figure 3: The cross section in $pb^{-1}$ for associated Higgs production versus center of mass energy. The 7 curves are for Higgs masses from 150 GeV/$c^2$ to 300 GeV/$c^2$. Note that for the lower Higgs mass values, the cross section goes up by a factor of 2 or more by going to center of mass of 300 GeV from the nominal value of 500 GeV. The peak value of the production cross section occurs at center of mass energy of $\sim M_{Z^0} + M_{Higgs} + 50$.