Hi Emily,
here's the continuation of the VBF-Higgs feasibility study. I still focus on the $H \to \ell\ell\ell\ell$ channel. I have applied looser, yet more sophisticated lepton selection criteria, which are taken from the ATLAS Higgs discovery paper (arXiv:1207.7214v2), although they have a lot of additional, complicated cuts.

I've written a Rivet analysis that selects events in three steps:

Jet selection	at least two anti-$k_\perp(0.4)$ jets with $p_\perp > 25$ GeV and $\lvert\eta\rvert < 4.4$ that have no leptons harder than 7 GeV within $\Delta R = 0.3$
Lepton selection	at least four muons or electrons with $\lvert\eta\rvert < 2.47$. The four hardest leptons are selected if they form same-flavour opposite-charge pairs and have transverse momenta $p_\perp > 20, 15, 10$ and 7 GeV in the order of hardness, otherwise the event is not selected. Leptons are *dressed*, i.e. accompanying photon energies clustered
Higgs candidate selection	tetralepton mass in range (126 ± 25) GeV

At the truth level, of the order of 80% of signal events pass the jet selection, and around 35% pass the lepton selection and Higgs candidate selection.

Below are distributions that might be used for signal extraction by fitting shapes, compared for VBF and non-VBF Higgs boson production. The distributions are calculated for the events passing the full event selection, where there is practically no background (up to misidentification effects). They are shown both normalised to the cross section of the respective process, assuming an integrated luminosity of 50 fb^{-1}, as well as normalised to unit area for easier shape comparison.

Conclusion

Looser lepton selection criteria similar to those used in the ATLAS Higgs boson discovery improve the signal selection efficiency by a factor of 3 with respect to the ones I used previously, to a total of about 35%. With 50 fb^{-1} of data, a counting-based signal significance of order 2σ can be expected:

$$\text{significance} \sim \frac{N_{\text{signal}}}{\sqrt{N_{\text{background}}}} \approx \frac{8}{\sqrt{16}} = 2$$

when considering all events inclusively (in a single bin). Lets consider this as a 'lower bound', up to experimental effects. Next we could construct a statistical model to see how much this could be improved by fitting shapes. This is mostly unknown terrain to me, so input is welcome.

Should we do this analysis, it'd be a very low-statistics analysis on the timescale of my PhD in any case. On the other hand, we could reuse a lot of sophisticated methods developed for the original Higgs discovery to squeeze the most out of the few events that we could get.

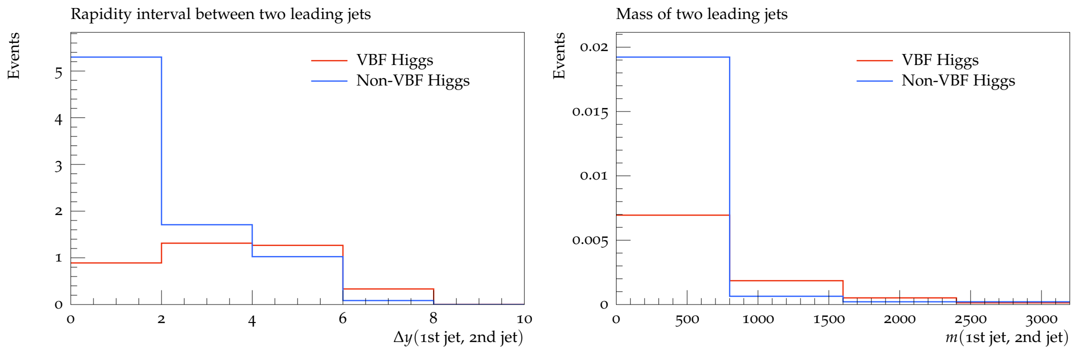

Figure 1: Jet variables provide separation power between VBF and non-VBF Higgs events. Assumed integrated luminosity 50 fb^{-1}.

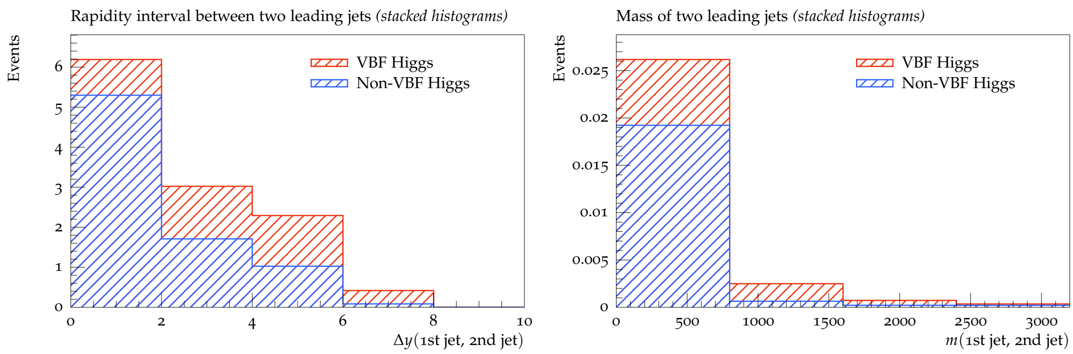

Figure 2: As previous figure, but signal stacked on top of non-VBF Higgs background. Assumed integrated luminosity 50 fb^{-1}.

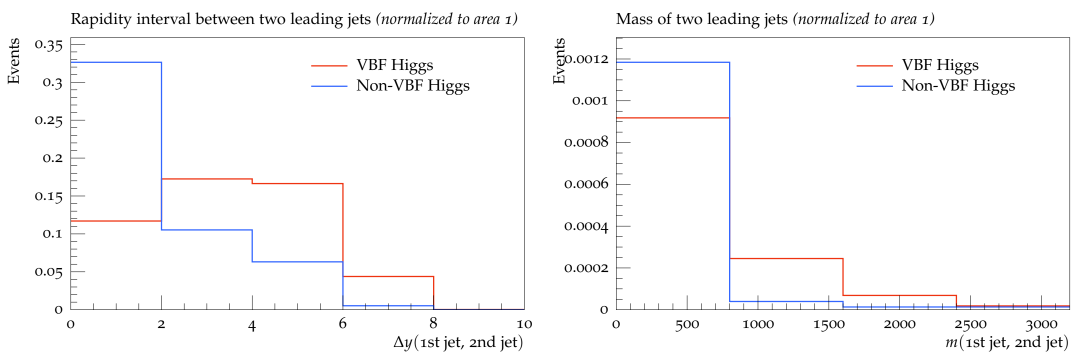

Figure 3: Distribution shape comparison; areas of the histograms normalised to unity.