Preliminary Report

Jake Lane

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1 Introduction

This report outlines the aims of the project, the physics behind detecting a Higgs signal amongst background data and the initial planning as well as alternatives to problems.

2 Theoretical Background

2.1 Higgs Mechanism

The Higgs mechanism is an electroweak process that gives rise to mass terms to occur in each particle in the SM, which would otherwise have no mass.

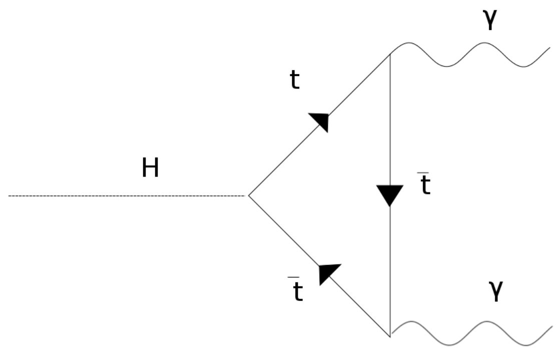
2.2 Higgs Production

The dominant production mode (88% of produced Higgs) for Higgs bosons is 'gluon fusion' $gg \to H$ (referred to as ggF.) This is followed by fusion of vector bosons (such as W^+W^-) called vector Boson fusion

2.3 Higgs Decay

Higgs decay into 2 photons via a heavy quark (top) loop. The nature of this decay (involving 3 vertices) mean that the branching ratio is orders of magnitude lower than other decays (such as that to $b\bar{b}$ pairs) The reason that the diphoton channel is used is mostly for experimental ease, since detecting more common Higgs decays involve detecting quarks which will come in 'jets' which requires tools with a lower resolution for the Higgs mass (2-3GeV for $H \to \gamma\gamma$, 14-15GeV for $H \to b\bar{b}$) [2, p. 2]

$$H \to \gamma\gamma \tag{1}$$



3 Plan

The photon data is simulated using 'Pythia' and outputs a series of 4 momenta (Energy and Momentum) of photons in a text file. The computational task is to take this text file, filter out all of the events into either Higgs produced photons (the Higgs signal) or background data.

3.1 Programming

The main programming language to do this is python. The main reason python is used was due to the more flexible nature of python compared to compiler based languages (such as C++) which would allow for changes to the program without rebuilding. The disadvantage of this is that python files tend to be larger and less efficient for larger scale programs. Given that this project does not have large amounts of data to work with (the total size of the photon data file is around 300MB) python is not likely to run into such problems, however larger data files may require a complier based language to be used (such as C++).

3.2 Filtering

The 'signature' of the 2 photons produced by a Higgs decay that we are looking for has the following:

1. At least 2 photons per event
2. Transverse momentum $p_T > 20$ GeV for each photon
3. Energy $E > 20$ GeV

This filtering often leaves 2 photon events that satisfy the criteria of being 2 Higgs events, however in the cases where more than 2 photons have the above properties, we employ 2 ways to 'pick' the photons produced by the Higgs.

1. Choose the 2 highest p_T values for the photons
2. Find the 2 photons whose azimuthal angles ϕ between them is closest to π rad.

This then ensures all of the photon events selected will always be a diphoton system that satisfies the condition for being the result of a Higgs decay. The second method is more intensive in terms of operations to the data, but is more related to the Higgs decaying into 2 photons as opposed to assuming that the 2 largest p_T are due to the Higgs. Again in the case where large data files are used it may be best to use the first method.

3.3 Plotting the results

The invariant masses of the diphoton systems in each event are calculated using

$$M_{\gamma\gamma}^2 = (E_{\gamma 1} + E_{\gamma 2})^2 - (\mathbf{p}_{\gamma 1} + \mathbf{p}_{\gamma 2})^2 \tag{2}$$

Since this is the invariant mass from a Higgs decay, this invariant mass (if a Higgs particle decayed into this system) should be present more often at $M_{\gamma\gamma} = M_H$. Where the estimate for $M_H = 126.0 \pm 0.8$ GeV [1, p. 1]

3.4 Weightings

The Higgs signals (Higgs to diphoton) must be weighted by accounting for the probability that a Higgs is produced and that it decays into 2 photons. This is compared to the probability of getting a background signal of getting diphoton.

$$w = \frac{\sigma_H B_{H\to\gamma\gamma}}{\sigma_{\gamma\gamma}} \tag{3}$$

Where $\sigma_H, \sigma_{\gamma\gamma}$ are the cross sections for producing Higgs and background photons respectively. The branching ratio of Higgs to 2 photons, $B_{H\to\gamma\gamma}$ is the ratio of the decay rate of Higgs to 2 photons to the total decay rate of the Higgs.

4 Conclusion

The project will use the following to look for a Higgs signal:

1. Parsing the data file of 4-momenta of photons
2. Filtering the photons that fit the profile of the Higgs decay
3. Calculate the invariant mass of the diphoton system
4. Plot the histogram of these invariant masses
5. Compare the peak (or lack of one) with the literature

References

[1] G. Aad *et al.* [ATLAS Collaboration], Phys. Lett. B **716** (2012) 1 [arXiv:1207.7214 [hep-ex]].

[2] J. L. Diaz-Cruz, D. K. Ghosh and S. Moretti, Phys. Rev. D **68** (2003) 014019 [hep-ph/0303251].

[3] S. Dittmaier *et al.* [LHC Higgs Cross Section Working Group Collaboration], arXiv:1101.0593 [hep-ph].