The Higgs "Golden Channel" at 7 TeV

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Ongoing in collaboration with Jamie Gainer, Kunal Kumar and Ian Low

Overview

- Objective
- Review of the "Golden Channel"
- Statistical Analysis
- Detector Effects
- Results (preliminary)
- Conclusions/Future Work

Objective

- Use the matrix element method to extract the expected significance for the Higgs Boson signal as a function of Higgs mass ($170 - 350$ GeV) for a 7 TeV LHC
- Compare results obtained using the full angular information of the event with those using only the invariant mass (model independent)
- Compare matrix element analysis with a cut based analysis
- Set up our own chain of analysis in order to examine other signals and extract them from backgrounds

Golden Channel

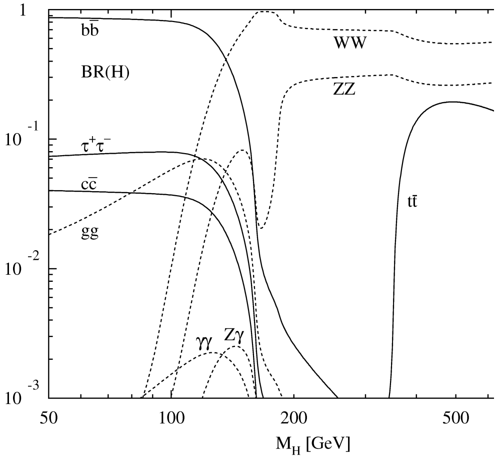
- Has been examined using the Matrix Element Method in earlier studies in the context of signal discrimination for 10 and 14 TeV

  De Rujula, Lykken et al: arXiv:1001.5300, Gao, Gritsan, Melnikov et al: arXiv:1001.3396

- Golden Channel: $H \to ZZ \to 4l$
- Very "clean" channel due to high precision with which e and μ are measured and is fully reconstructable
- Typically thought to be an "easy" mode of Higgs discovery...however...

Golden Channel

- Suffers from small cross sections due to branching fractions of $H \to ZZ \sim .3$ and Zs to leptons $\sim .0335$

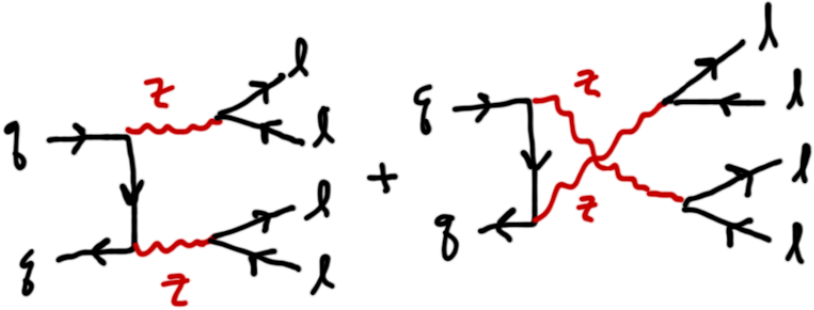


A. Djouadi, J. Kalinowski, M. Spira

hep-ph/9704448v1

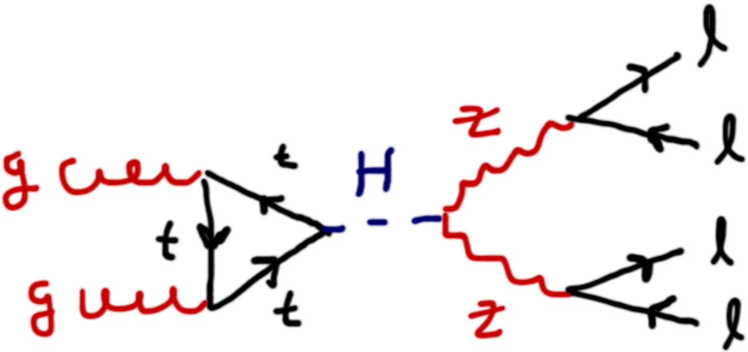
Golden Channel: Background

- $q\bar{q} \rightarrow ZZ \rightarrow l^+l^-l^+l^-$ is the dominant irreducible background for $170 < mh < 350$
- We include the 3 separate channels $ee\mu\mu$, 4μ and $4e$ at LO



Golden Channel: Signal

- The dominant production mechanism is $gg \to H \to ZZ \to l^+l^-l^+l^-$ through a top quark loop
- We consider the LO contribution only which is given by

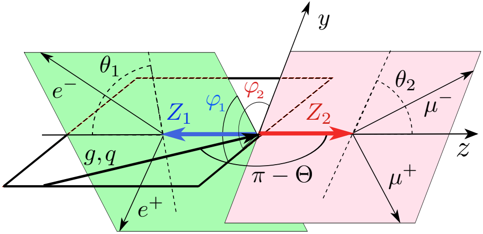


Golden Channel: Observables

- In the $ee\mu\mu$ channel there is no ambiguity in defining the lepton angles since the final states are distinguishable
- For the 4μ and 4e channels we use the reconstructed Z masses to distinguish the pairs
- In the massless lepton approximation there are 12 observables per event (pT, η, Φ for each lepton)
- Using momentum conservation and the azimuthal symmetry of the detector we can reduce these to the set $x_i \equiv (x1, x2, M1, M2, \hat{s}, \Theta, \theta_1, \phi_1, \theta_2, \phi_2)$

Golden Channel: Observables

- The angle Θ is defined in the ZZ rest frame



Lykken et al: arXiv:1001.5300

- The angles θ_1, ϕ_1 and θ_2, ϕ_2 are defined in the rest frame of the Z which decays to electrons and muons respectively

Analysis: Test Statistic

- The Matrix Element Method: "What Jamie said..."
- We define our significance as

$$\mathcal{S} = \sqrt{2 ln \mathcal{Q}}$$

where $\mathcal{Q}$ is the likelyhood ratio given by

$$\mathcal{Q} = \frac{\mathcal{L}_{s+b}}{\mathcal{L}_b}$$

and

$$\mathcal{L}_{s+b} = e^{-\mathcal{N}_t} \mathcal{N}_t^N \prod_{i=0}^{N} [f_s \mathcal{P}_s(m_h, x_i) + (1 - f_s)\mathcal{P}_b(x_i)]$$

where $\mathcal{P}_s$ and $\mathcal{P}_b$ are the signal and background PDFs respectively

Analysis: Expected Significance

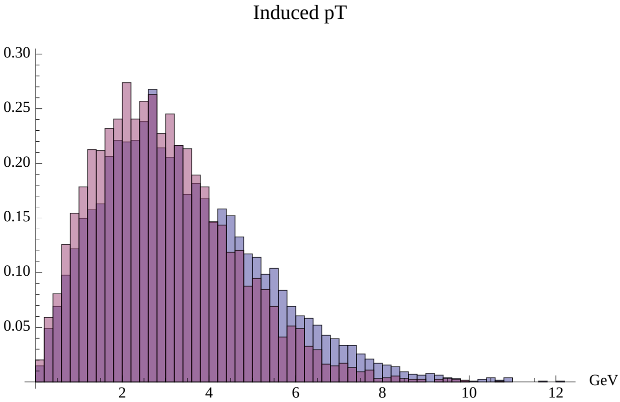
- To obtain the expected significance we construct the PDF for $\mathcal{S}$ by conducting a large number of psuedo experiments and obtaining $\mathcal{S}$ for each one
- To remove the dependance of $\mathcal{S}$ on the undetermined parameters we maximize the EML function prior to the construction of the likelihood ratio
- So we have for the likelihood ratio

$$\mathcal{Q} = \frac{\mathcal{L}_{s+b}(\hat{Nt}, \hat{fs}, \hat{mh}; x_i)}{\mathcal{L}_b(\hat{N}_t; x_i)}$$

  where $\hat{Nt}, \hat{fs}, \hat{mh}$ are the values which maximize the EML function for a given psuedo experiment
- Thus $\hat{Nt}, \hat{fs}, \hat{mh}$ are the most likely values for a given experiment

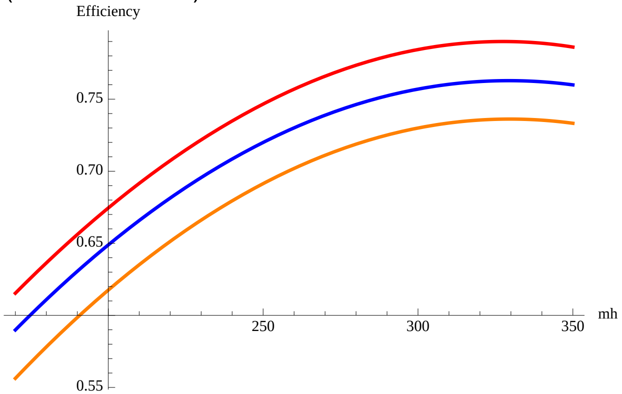
Detector Effects: pT dependence

- Cuts and detector smearing can shape distributions and introduce a *pT* dependence even when only considering the LO process
- To find the ZZ CM frame, must ensure *pT* is be properly boosted away on an event by event basis



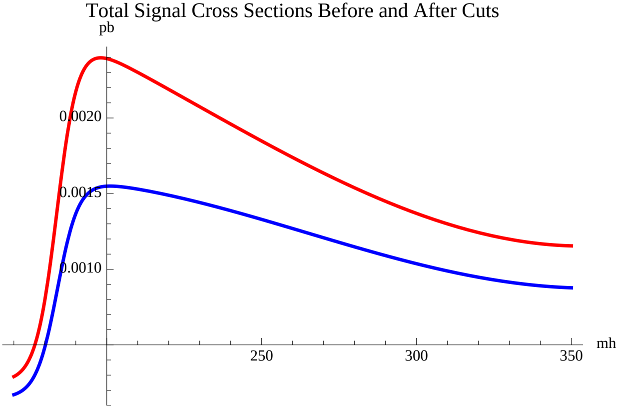
Detector Effects: Cuts/Efficiencies

- We require: pT > 10 GeV, η < 2.5, and $150 < \hat{s} < 450$
- For the background we obtain an efficiency of $\sim$ 45%
- For the signal the efficiency depends on the Higgs mass ($\sim 55\% - 78\%$)



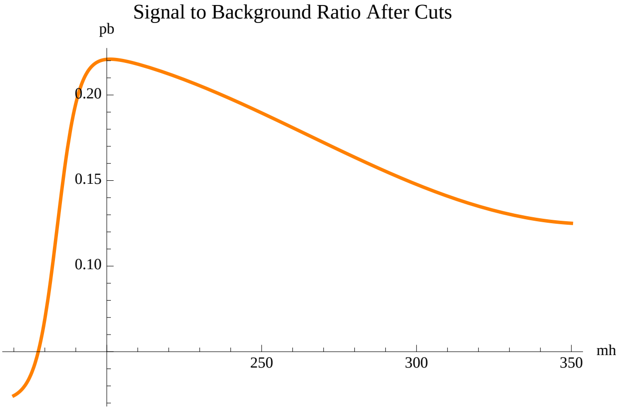
Total Cross Section (Normalization)

- For the background we obtain, after efficiency cuts, a total background of $\sim$ .003 pb
- For the signal we obtain the total cross section as function of Higgs mass before and after cuts



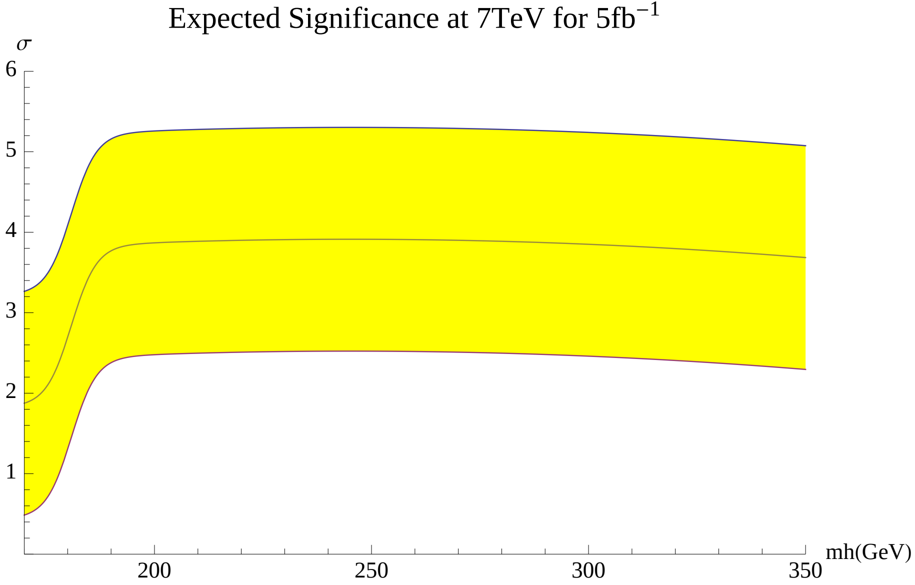
Signal to Background Ratio

- The signal to background ratio will of course also depend on the Higgs mass

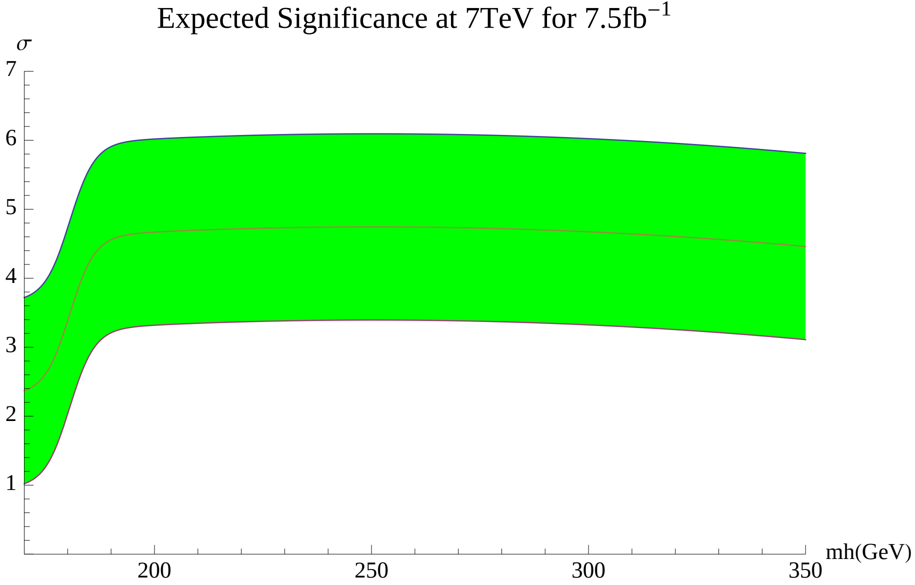


- Maximum value of .23 at $\sim$ 200 GeV
- Not necessarily where expected significance is peaked

Results (preliminary)

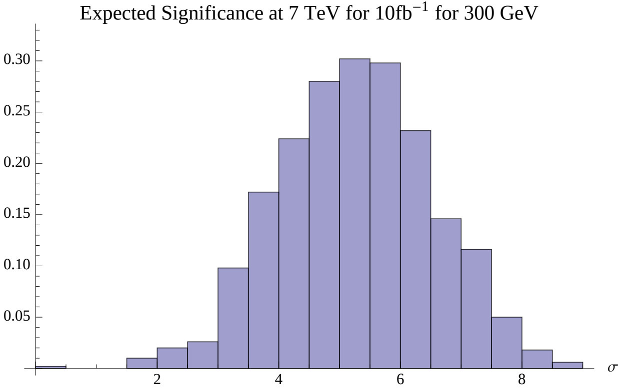


Results (preliminary)



Conclusions

- For less than $7.5fb^{-1}$ we may have to get slightly lucky to obtain a 5σ discovery of a heavy Higgs in the Golden Channel at 7 TeV
- With a bit more luminosity, energy, or the addition of other channels a discovery should be possible
- At 10 fb^{-1} we find a mean expected significance of 5.28σ for a 300 GeV Higgs



Ongoing and Future Work

- Finish analysis for $10fb^{-1}$
- Compare significance obtained using only invariant mass as discriminating variable (model independent)
- Conduct a cut based analysis to compare with matrix element method
- Conduct analysis at 14 TeV
- Implement analysis for other resonances including CP odd/even spin 1 and 2