Yale University

ttH, H->mumu @ 14 TeV

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Motivations

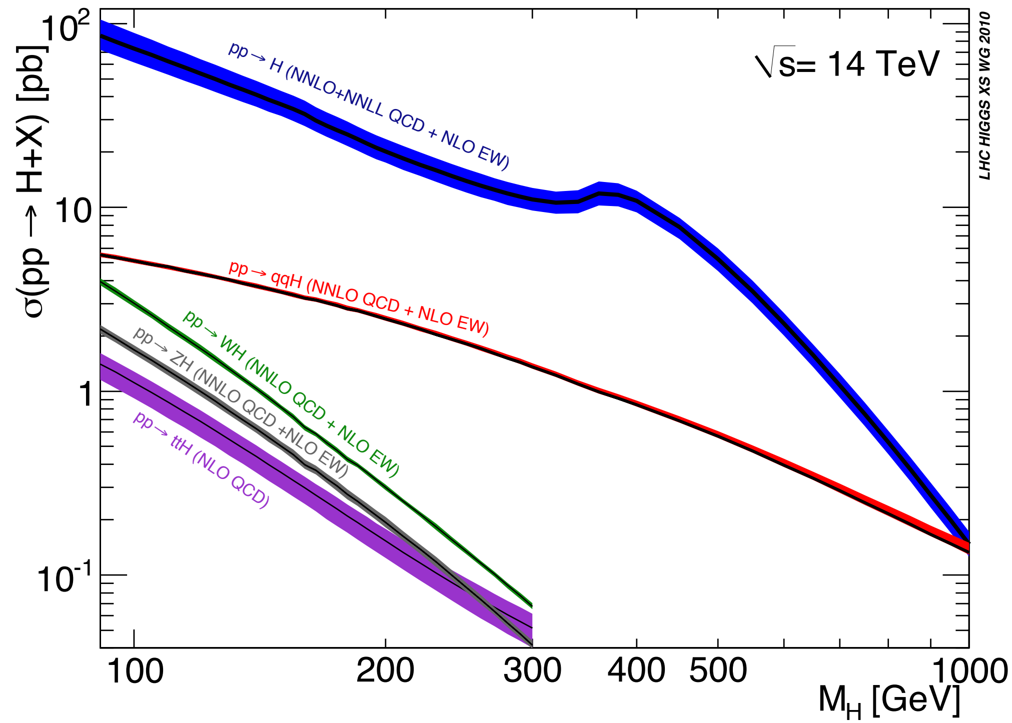
ttH, H->mumu

- It's a direct measurement of top-Yukawa coupling
- There are fermions both in production and decay, cleaner than bb or tau
- ttH is very difficult, every bit of statistics helps

Other feasibility studies for European Strategy are documented in ATL-COM-PHYS-2013-779

At 14 TeV, ttH cross-section

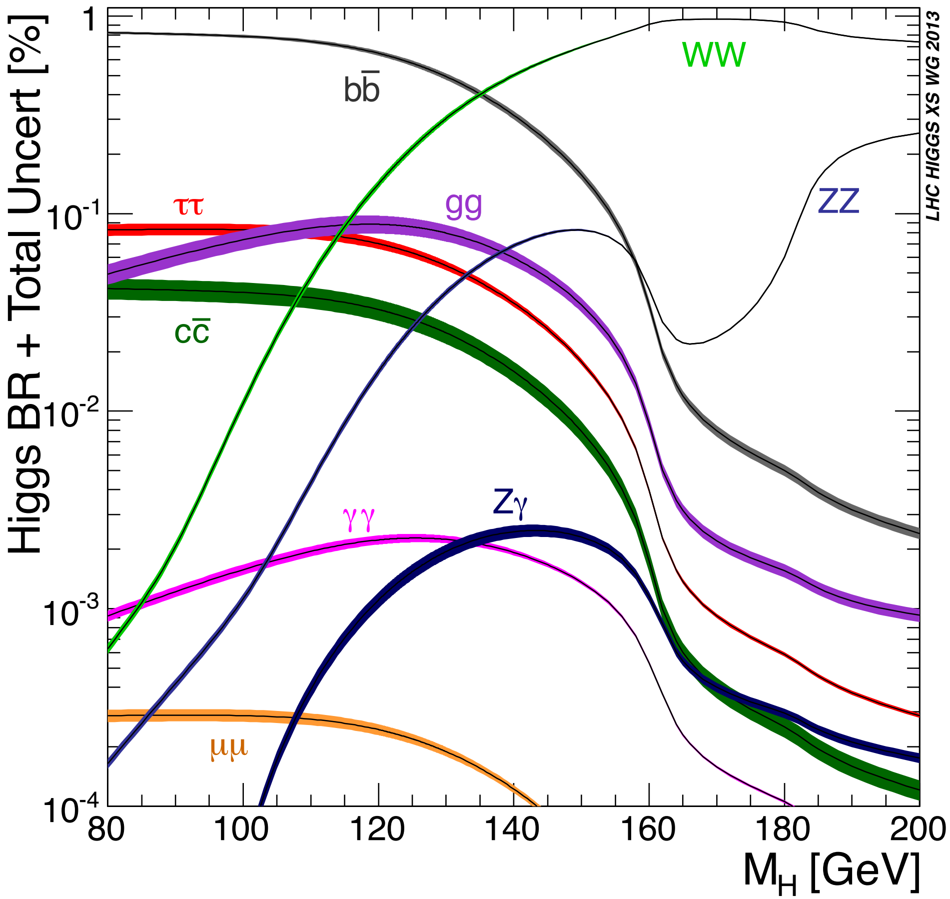
Increases 4.7x larger than 8 TeV



Challenges

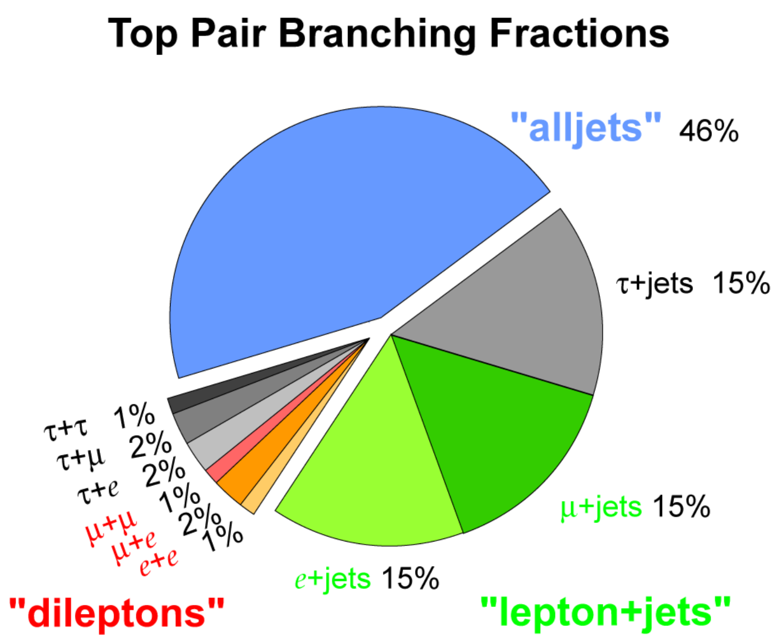
Small branching ratio for H->mumu

BR = 2.2 x 10^(-4)



The top-quark pair has 3 decay modes:

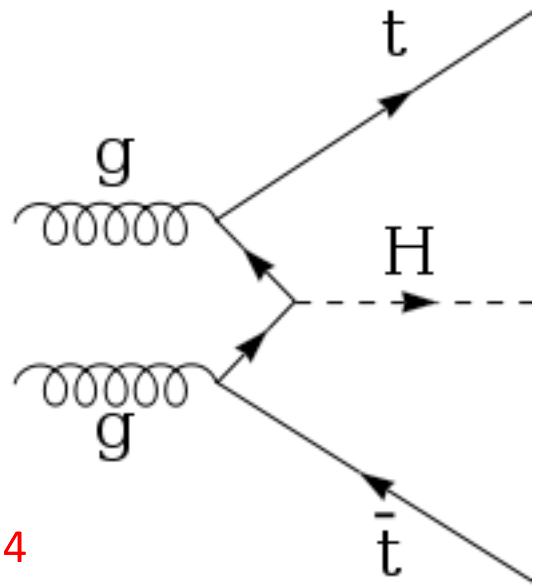
- **All Hadronic**
  Large BR (46%) but large BG
- **Dilepton**
  Small BR (6%) but small BG
- **Semi-Leptonic**
  Respectable BR (30%), manageable BG



Analysis Strategy

Focus on tri-lepton channel of ttH, good BR without too many combinations.
Very small branching ratio, so must look at full 3000/fb

- Higgs decays to OS dimuons
- Top-quark pair decays semi-leptonically
  - Define channel by top decay as either the muon (μμμ) or electron (eμμ) channel.
  - Optimize electron and muon channels separately



Start with a basic selection:

- == 3 Leptons (pt > 25 GeV , |η(e)| < 2.5 , |η(μ)| < 2.4
- >= 1 OS Muon pair
- >= 4 jets (pt > 30 GeV & |η| < 2.7)
- >= 1 btag

Optimize where appropriate to maximize significance.

Limited statistics, we will want to fit to our background and look at the Signal/Sqrt(BG) in Higgs mass window of 120-130 GeV

Higgs Reconstruction

- Electron channel: Take the OS muon pair to reconstruct the Higgs
- Muon channel: 2 OS muon pairs in the event.
  - take OS muon pair that gives a dimuon mass closest to 125 GeV
  - Reject events where any OS muon pair falls between 81-101 GeV

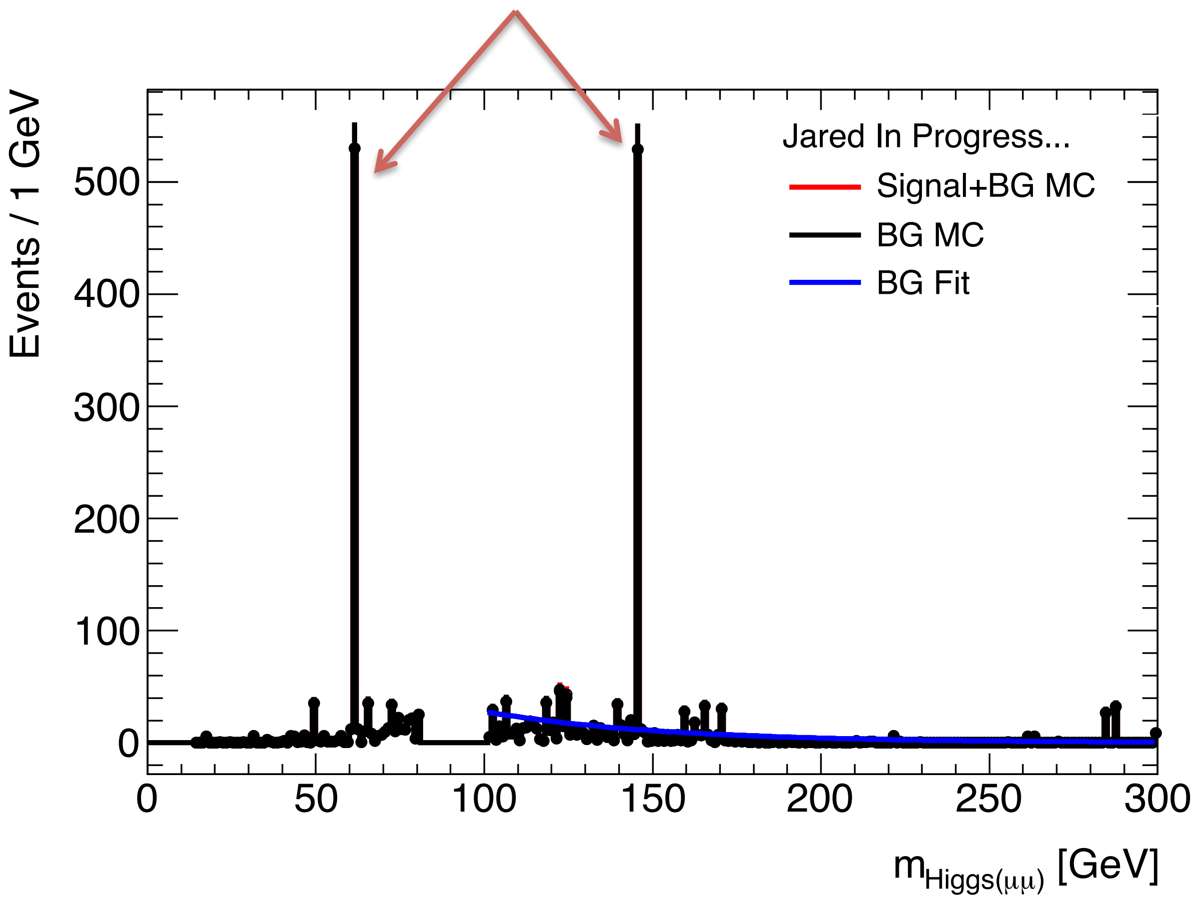
Backgrounds

- Major background is ttV (V = Z, W)

- For clarity, grouped backgrounds together
  - top+B : tB, ttW, ttWW & ttZ
  - top : tj & tt
  - BB : BB, LLB & BBB
  - B : B, Bj, Bjj, LL

Fake Muons in ttbar Sample

Only 2 ttbar events, each with
Event weight > 500



Poor statistics in low HT tt sample lead to spikes with very large event weights.

3 lepton events in the ttbar muon channel is coming from jets that are faking muons

Fake Muons in ttbar Sample

For smooth things out, we loop through each ttbar dilepton event with >= 4 jets and apply a per-jet fake rate probability to every jet in the event. This is done 2000x per event and normalized.

$$\text{fake rate} = \frac{2 \times N_{\text{fake events}}}{N_{\text{Jets in } \mu+\text{jets}}} = 6.5 \times 10^{-05}$$

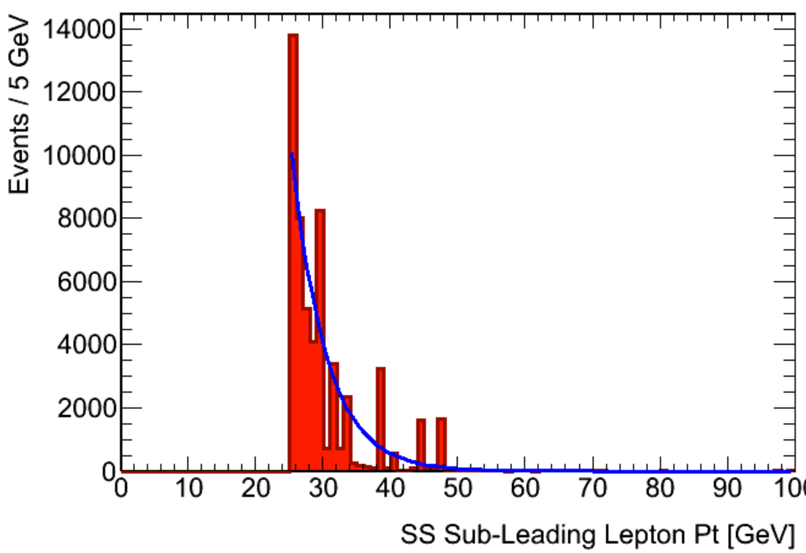
The jet faking muon rate was defined as

Where the number of fake events is counted in SS ttbar dimuon events.

Misidentified muons are assumed to have equal probability to be reconstructed as positive and negative, hence the factor of 2

The fake muon pt distribution is also taken from SS ttbar dimuon events assuming that the sub-leading lepton is the fake.

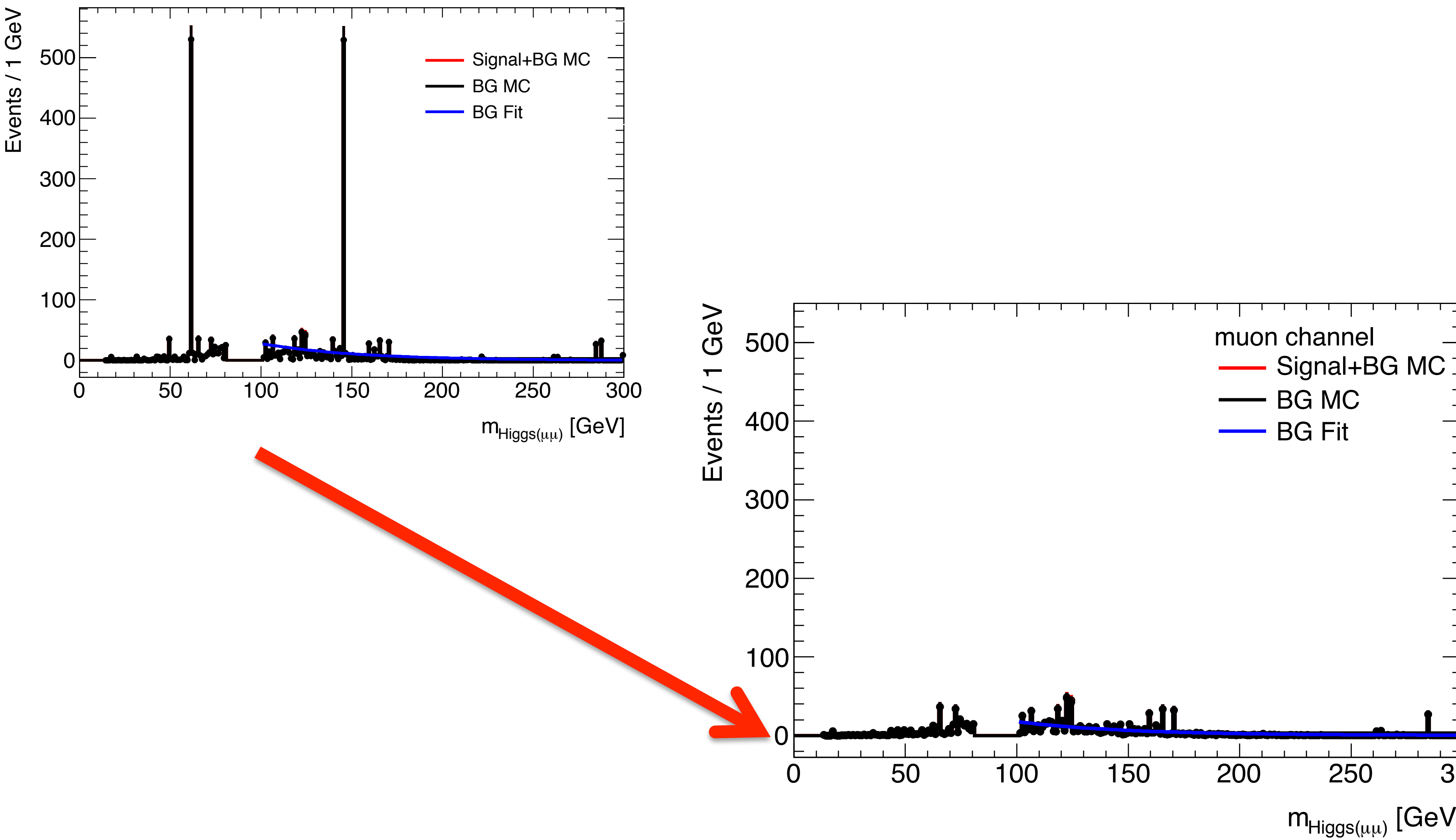
The pt distribution is fit and used at random



We neglect uncertainty on fake rate.

ttbar Fakes in Muon Channel

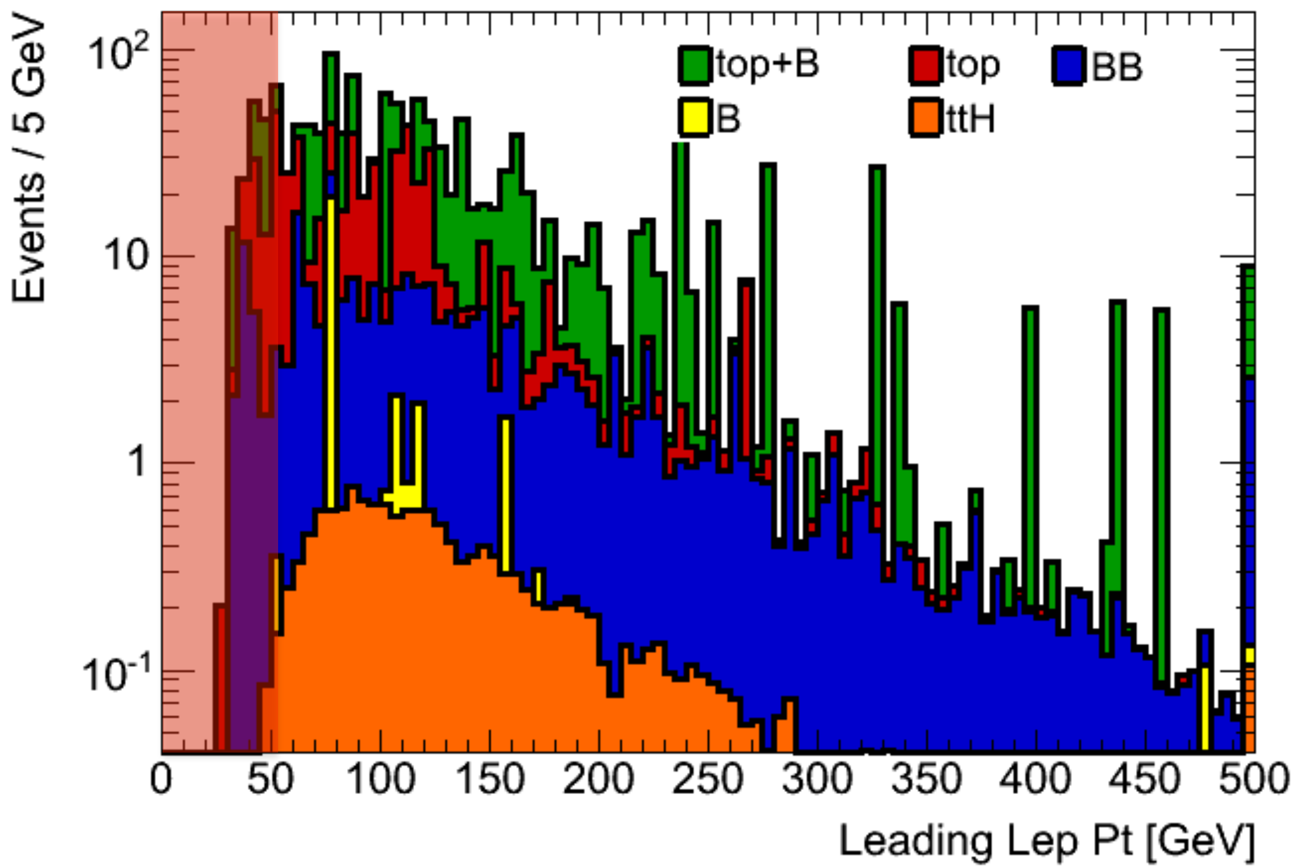
The method works to smooth out distributions as shown in the fit below.



Optimization

Optimization focuses on signal efficiency, while removing background where we can.

For instance, requiring the leading muon to have pt > 55 GeV removes a significant amount of background while removing a fraction of an event from the signal. Similar cuts were applied on HT for each channel.

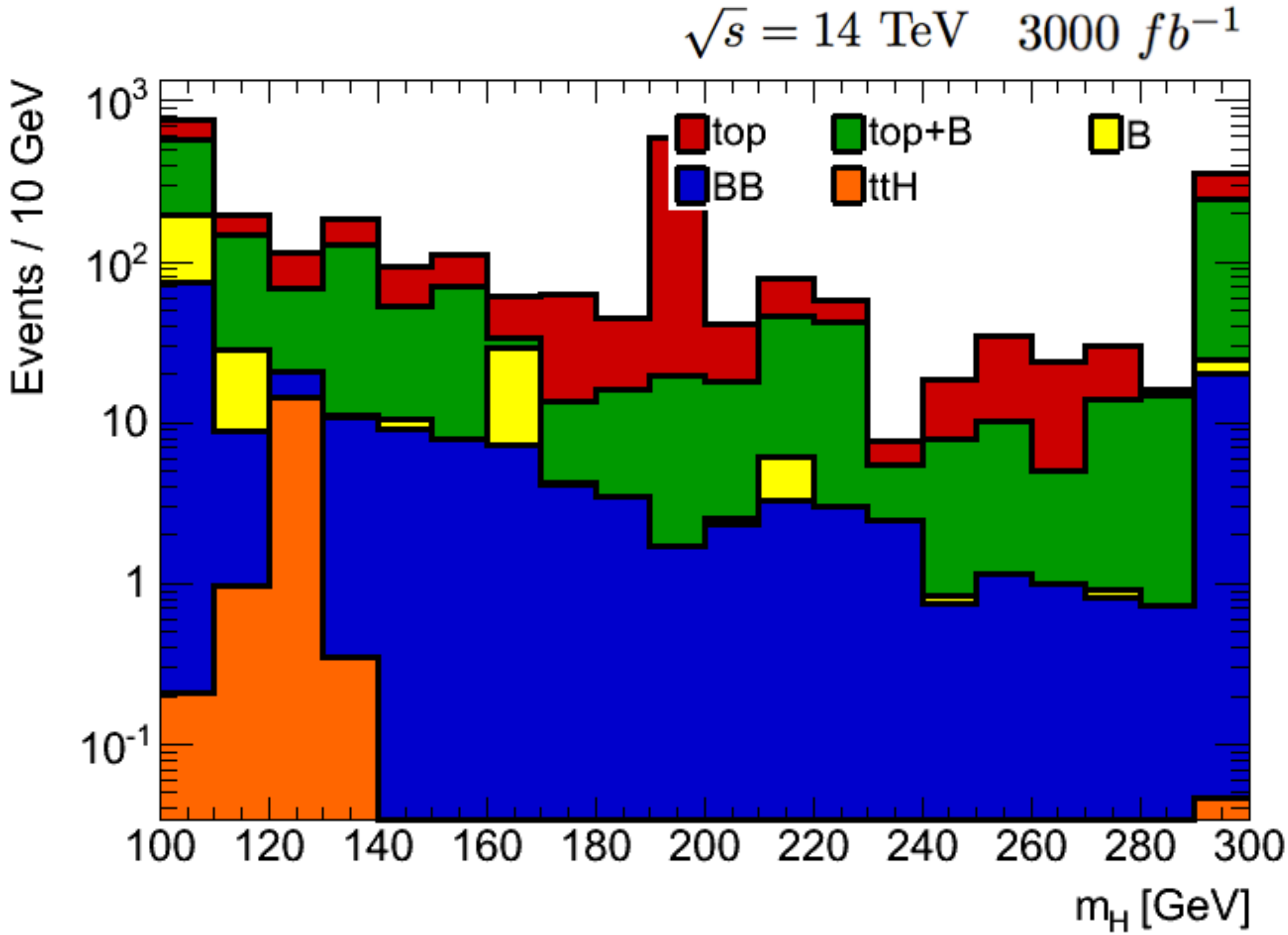


Final Event Selection

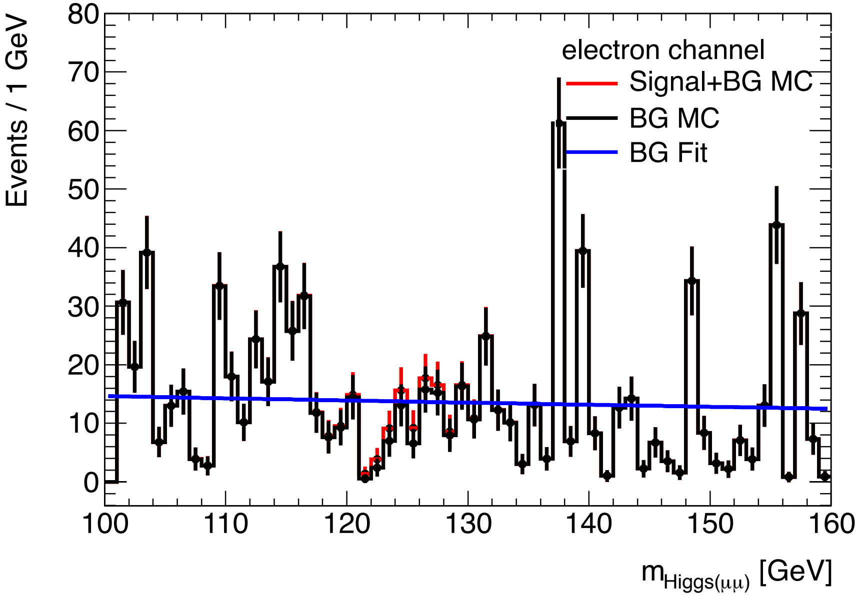
Muon Channel	ttH	ttZ	ttW	tt
== 3 Leptons	----	----	----	----
== 2 OS Muons + Muon	48.8%	24.2%	9.36%	6.83%
Leading Muon Pt > 55 GeV	97.8%	94.2%	79.0%	71.1%
>= 1 tag	78.5%	78.5%	86.7%	65.5%
>= 4 jets	83.9%	83.4%	76.9%	49.9%
HT > 350 GeV	99.1%	98.8%	100.%	91.7%
No OS muon pairs in Z window	87.2%	17.6%	90.0%	53.4%

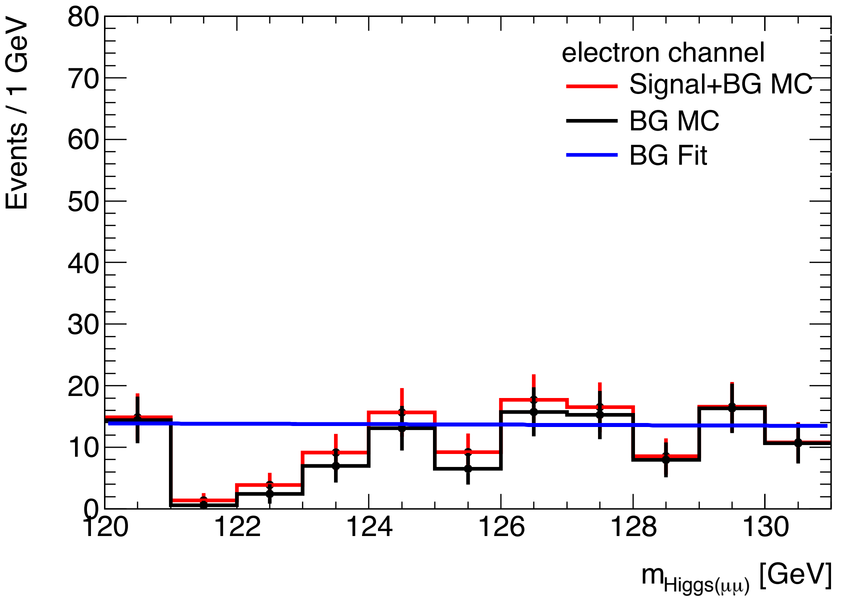
Electron Channel	ttH	ttZ	ttW	tt
== 3 Leptons	---	---	---	---
== 2 OS Muons + Electron	49.8%	26.8%	32.0%	31.8%
Leading Muon Pt > 55 GeV	95.2%	88.4%	73.9%	54.0%
>= 1 tag	78.1%	79.3%	83.3%	49.3%
>= 4 jets	83.4%	79.9%	80.0%	28.5%
HT > 350 GeV	99.3%	99.1%	100.%	99.6%
No OS muon pairs in Z window	96.4%	17.5%	59.4%	51.8%

Electron Channel – Higgs Mass



Electron Channel – Higgs Mass Fit





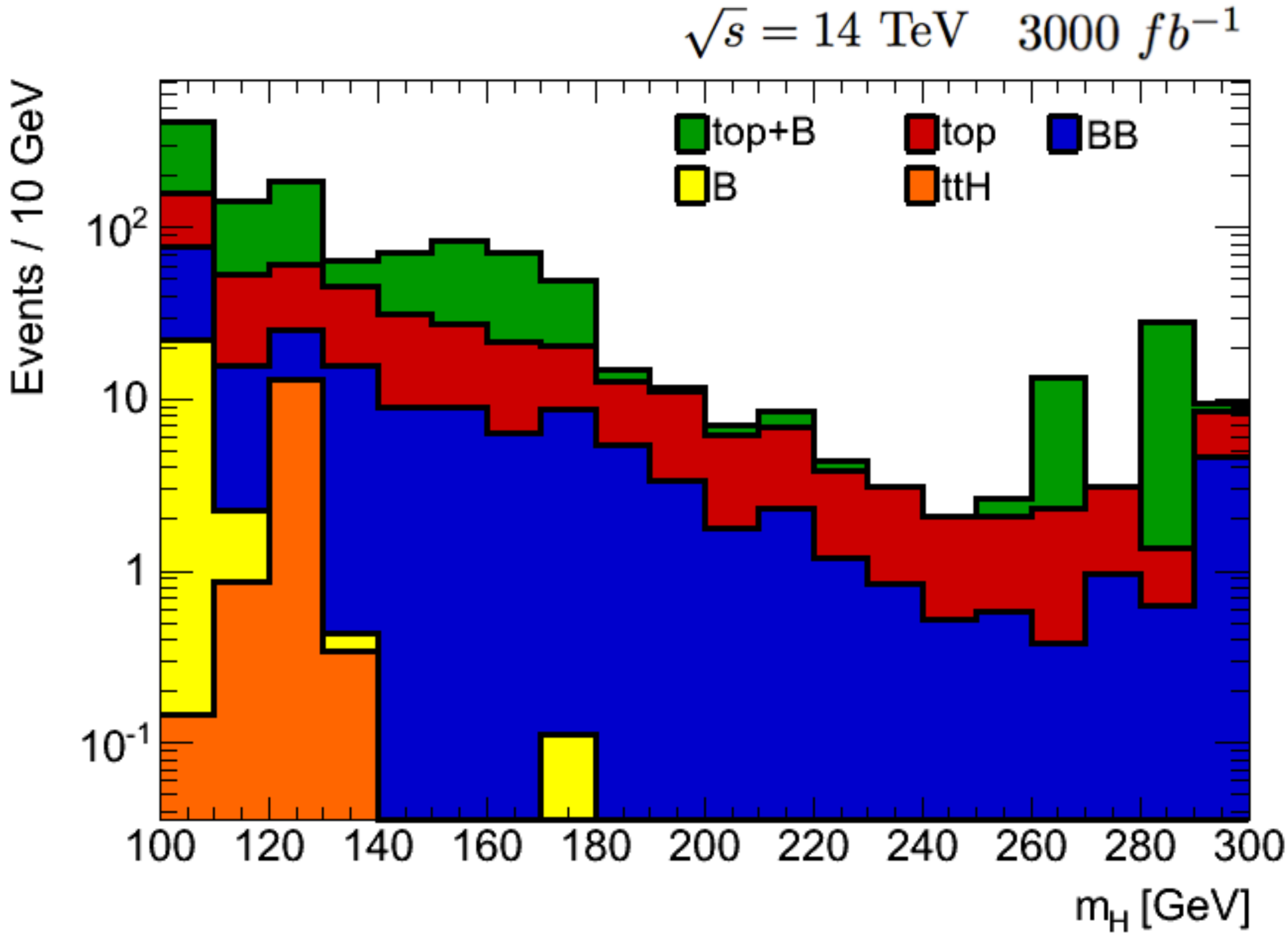
Background is fit to an exponential using a 1 GeV binning.

It is then integrated over the Higgs mass window of 120-130 GeV for our Background estimate.

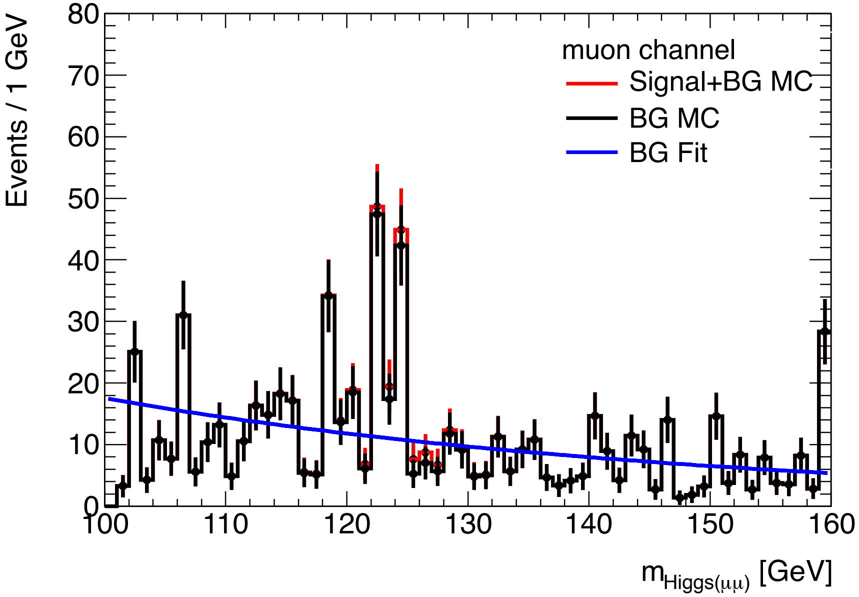
signal ttH, H->mumu events are counted in the mass window.

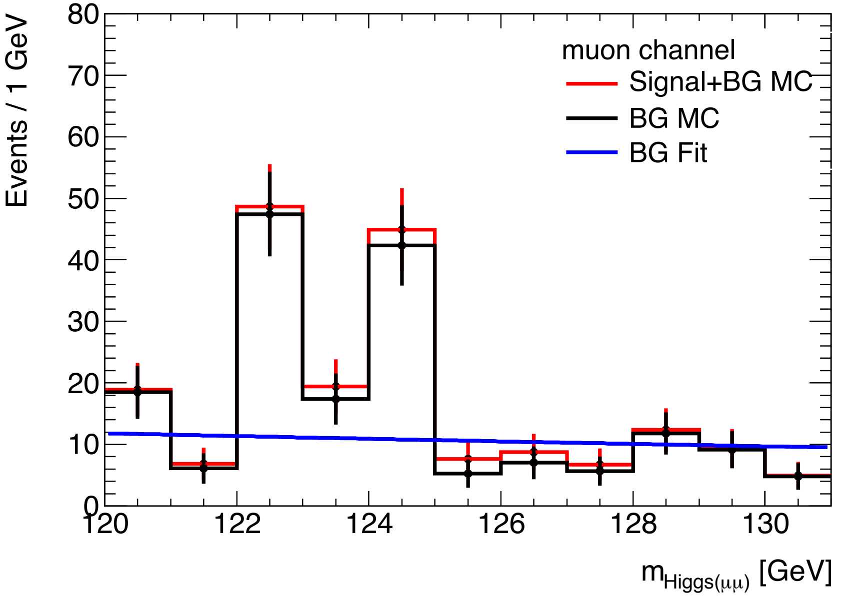
Background:	137.1 Events
Signal:	14.3 Events
S/Sqrt(B):	1.22

Muon Channel – Higgs Mass



Muon Channel – Higgs Mass Fit





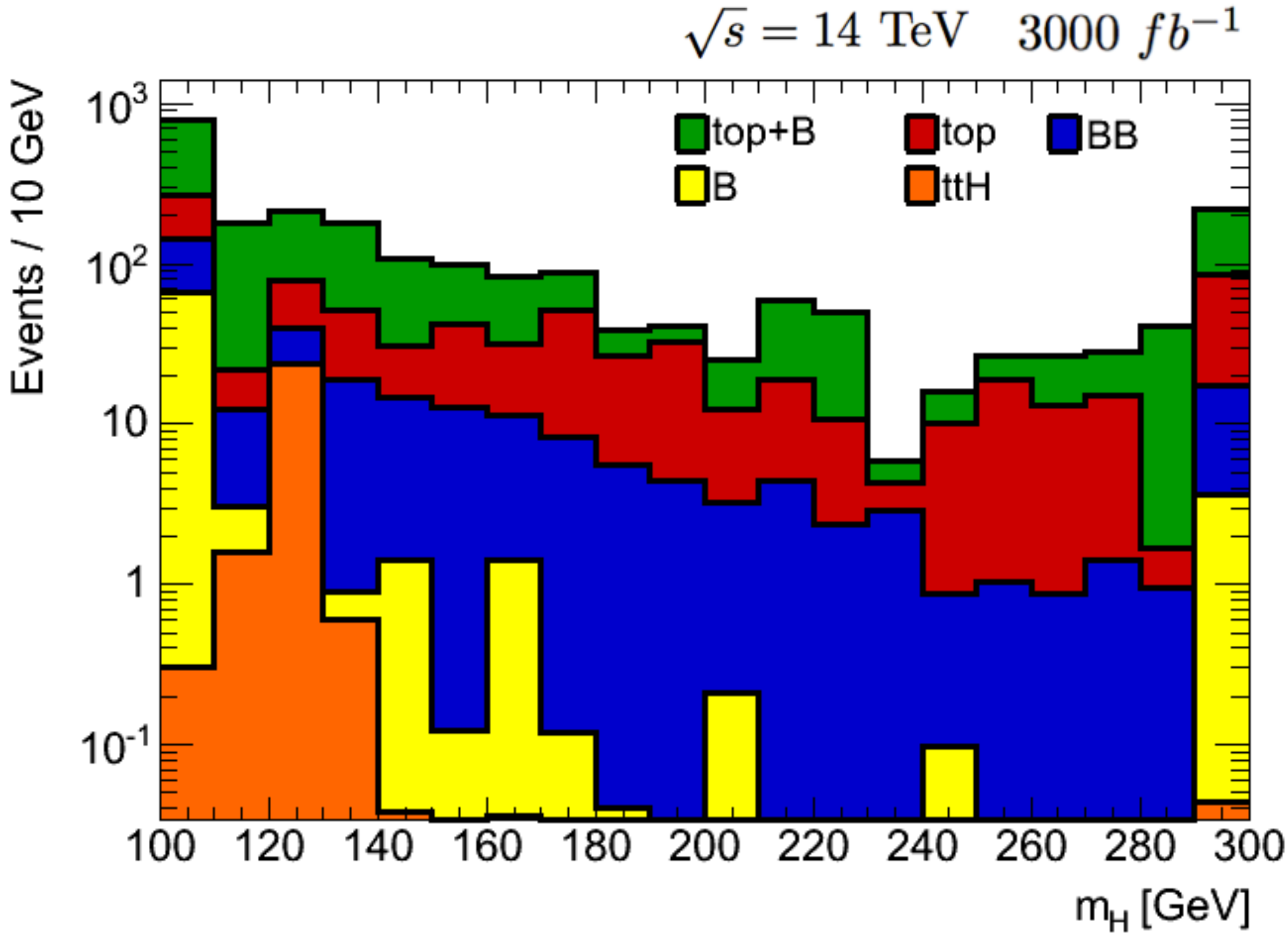
Background is fit to an exponential using a 1 GeV binning.

It is then integrated over the Higgs mass window of 120-130 GeV for our Background estimate.

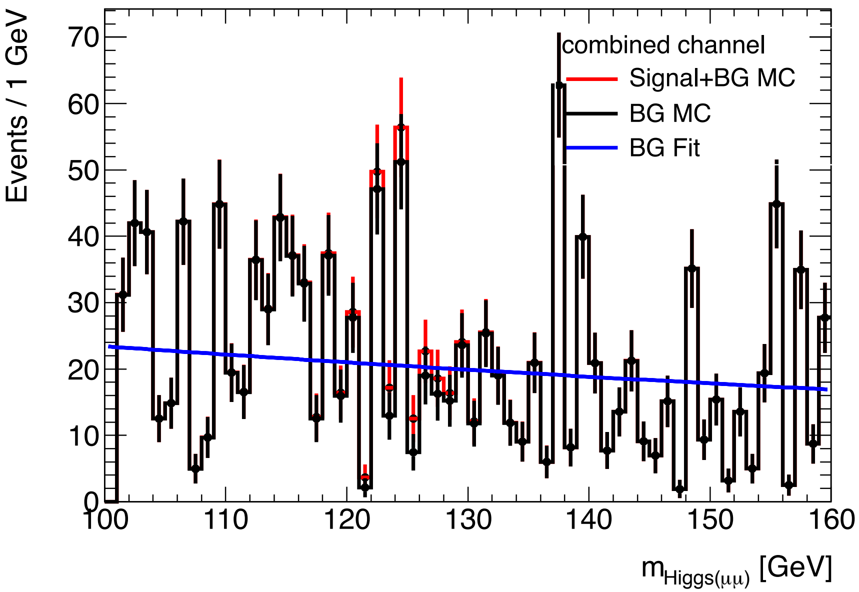
signal ttH, H->mumu events are counted in the mass window.

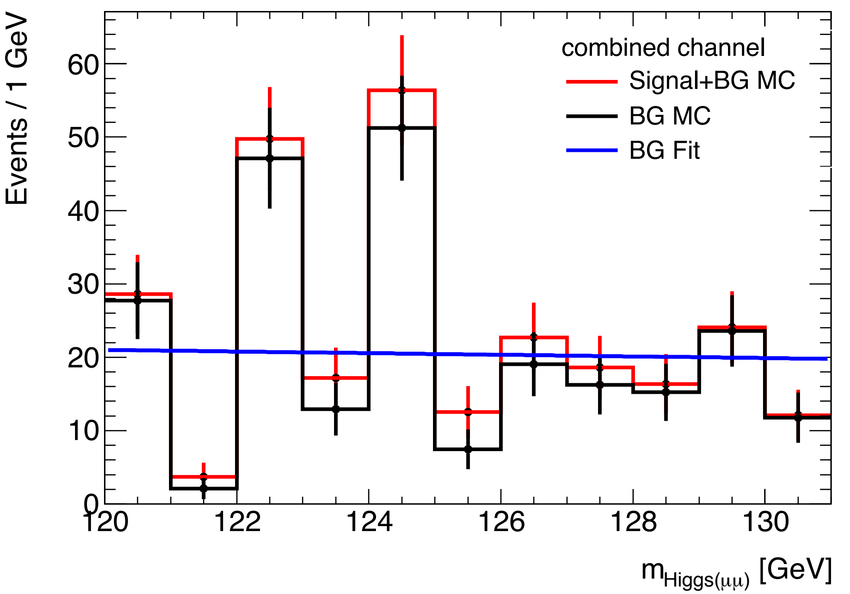
Background:	107.2 Events
Signal:	13.3 Events
S/Sqrt(B):	1.28

Combined Channel – Higgs Mass



Combined Channel – Higgs Mass Fit





Background is fit to an exponential using a 1 GeV binning.

It is then integrated over the Higgs mass window of 120-130 GeV for our Background estimate.

signal ttH, H->mumu events are counted in the mass window.

Background:	204.4 Events
Signal:	27.6 Events
S/Sqrt(B):	1.93

Conclusion / Prospects

- ttH, H->mumu is a very tough channel, even at 3000/fb
- Prospects
  - Add dilepton and all hadronic top decays
  - Consider looser b-tagging requirement
  - Look into multivariate techniques

Backup Slides

HT Plot (Muon Channel)