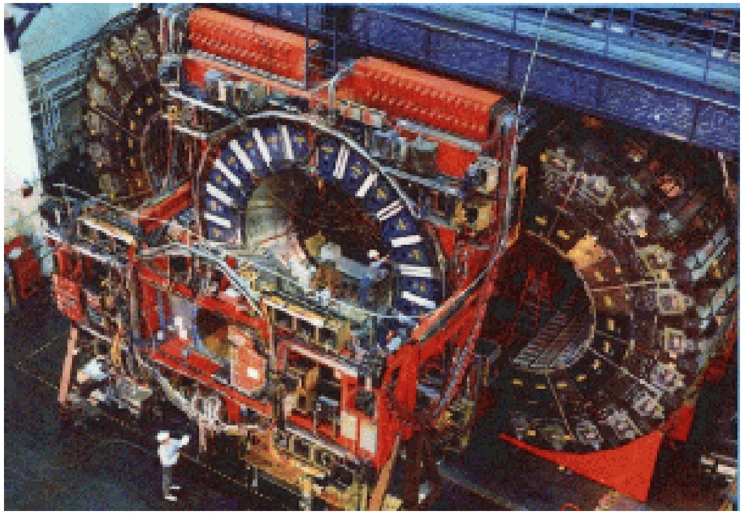
Searching for the light Higgs Boson with light at the Tevatron

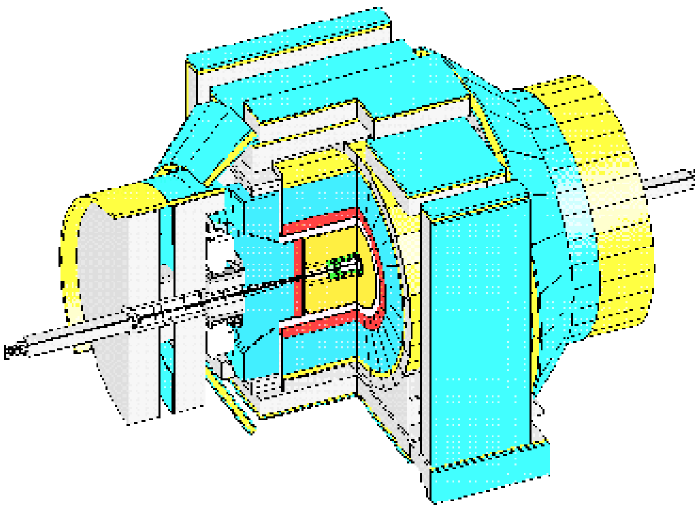


Callie DeMay
Craig Group and Raymond Culbertson

Fermi National Accelerator Laboratory

- Chain of Five Accelerators
- Last Chain = 4 mile Tevatron
- Protons and antiprotons collide head on at 1.96 TeV
- The beams are in packets which collide once every 120 nanoseconds (10^{-9} seconds)
- Collisions with high enough energies recorded by detectors (D0 or CDF) -> Triggers choose good events
- The energy of the beam is known, but the energy of the quarks and gluons is unknown

CDF



Layers

- Silicon Vertex Tracker
- Central Tracker
- Electromagnetic Calorimeter
- Hadronic Calorimeter
- Iron Absorbers
- Muon Chambers

The Higgs Boson

- Some believe it is needed for the Standard Model to be complete
- Could explain why elementary particles have mass
- First theorized by Peter Higgs in 1964

Imagine that a room full of physicists chattering quietly is like space filled with the Higgs field ...

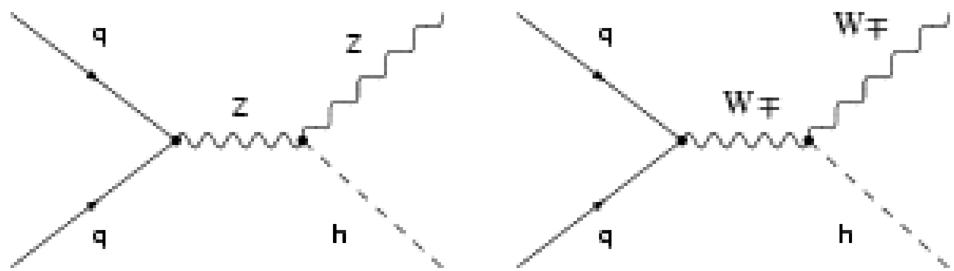
... a well-known scientist walks in, creating a disturbance as he moves across the room and attracting a cluster of admirers with each step ...

... this increases his resistance to movement, in other words, he acquires mass, just like a particle moving through the Higgs field...

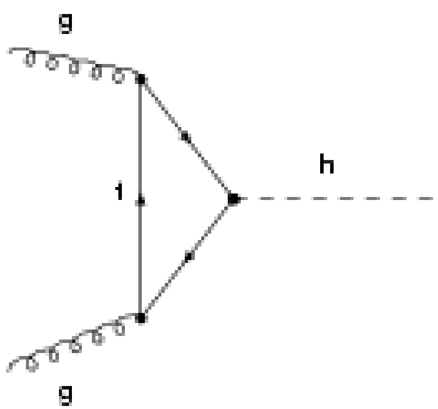
... if a rumor crosses the room, ...

... it creates the same kind of clustering, but this time among the scientists themselves. In this analogy, these clusters are the Higgs particles.

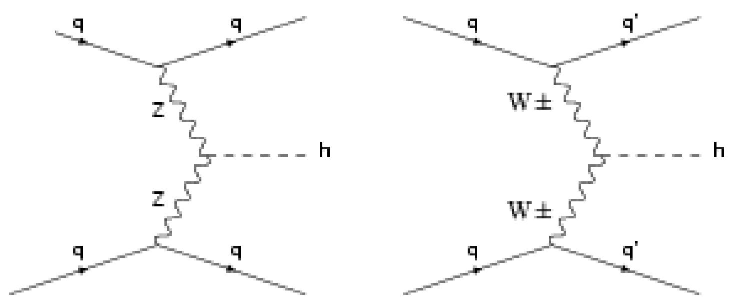
Standard Model Higgs Production Modes



Associated Production

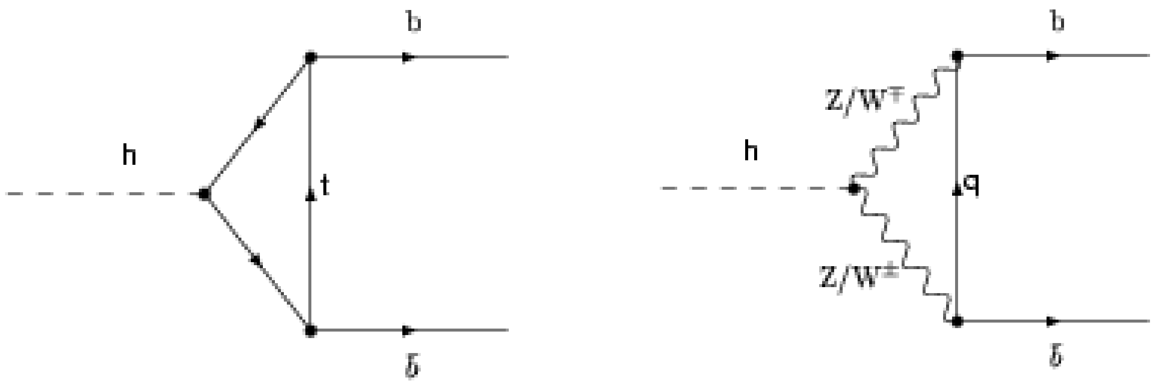


Gluon Fusion

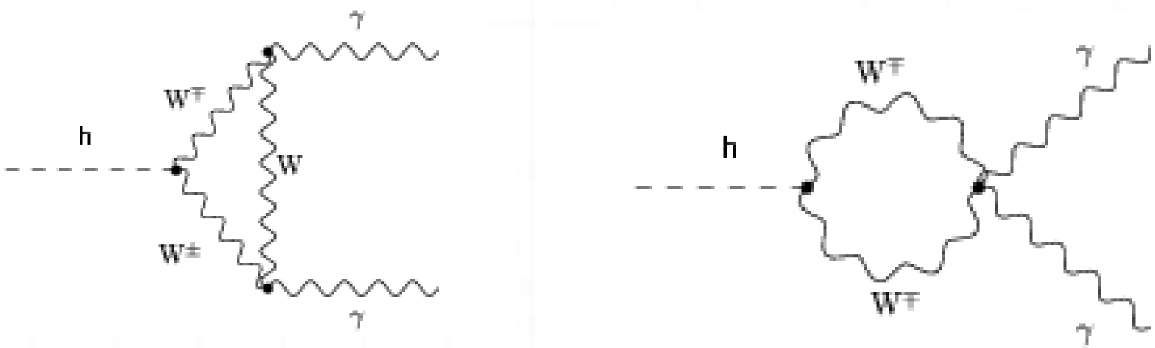


Vector Boson Fusion

Standard Model Higgs Decay Modes



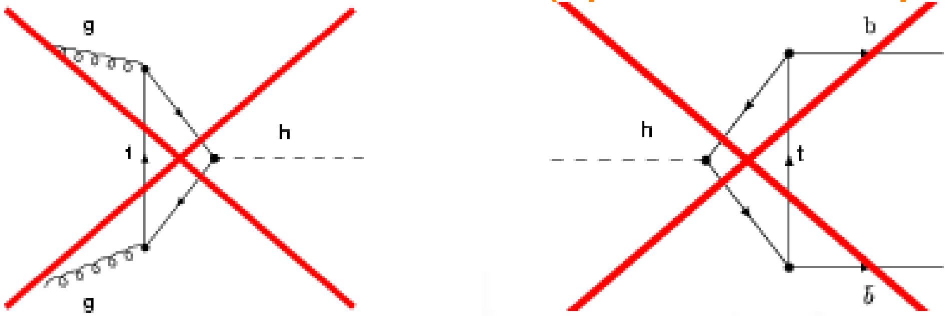
Higgs to b b-bar - dominant decay mode



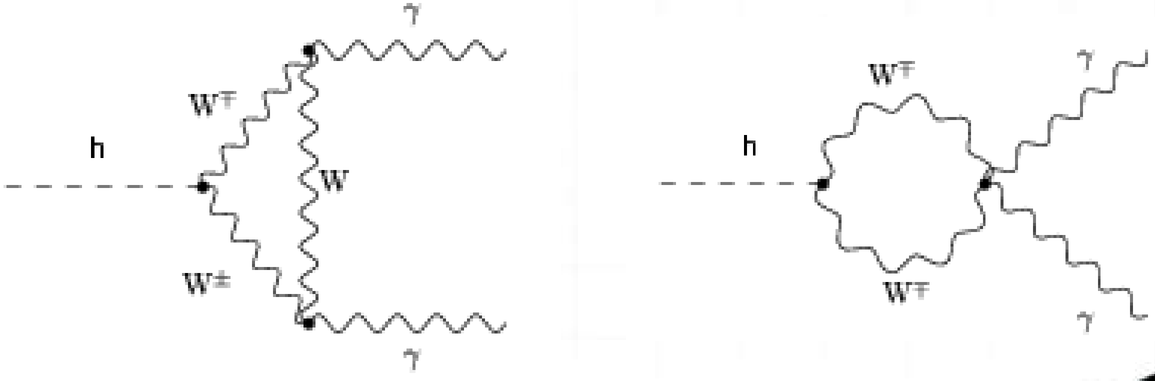
Higgs to gamma gamma - very small branching fraction

Fermiophobic Higgs

Does not couple to fermions (quarks or leptons)



H -> γγ becomes dominant decay mode



Why photons?

- Clean signature compared to b b-bar (no jet)
- Two photon signature study very useful in next generation colliders

How photons are tracked:

•No charge -> No track
•Isolated in EM Cal
•Small amounts of energy in the HAD Cal

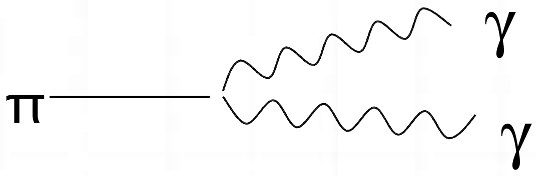
Background Events

Any events that pass our diphoton requirements, but are not the Higgs decaying to two photons

1. Fake photons

   -jet composed of pions which decay to two photons

   -angle so small between two photons, it looks like one

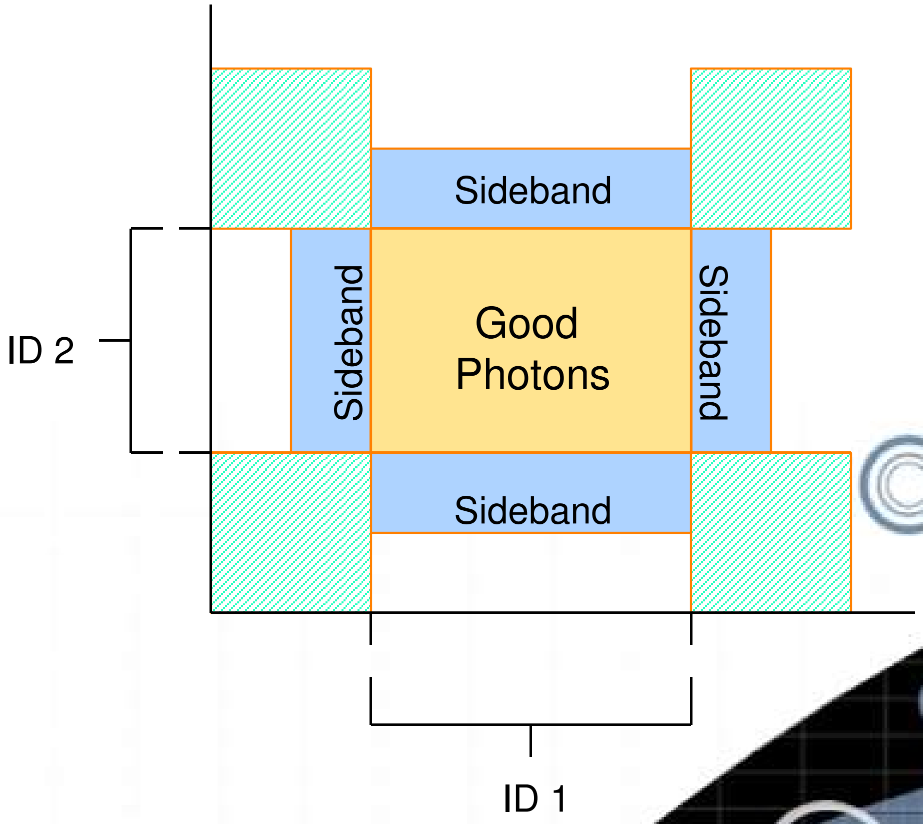


2. Standard Model Backgrounds

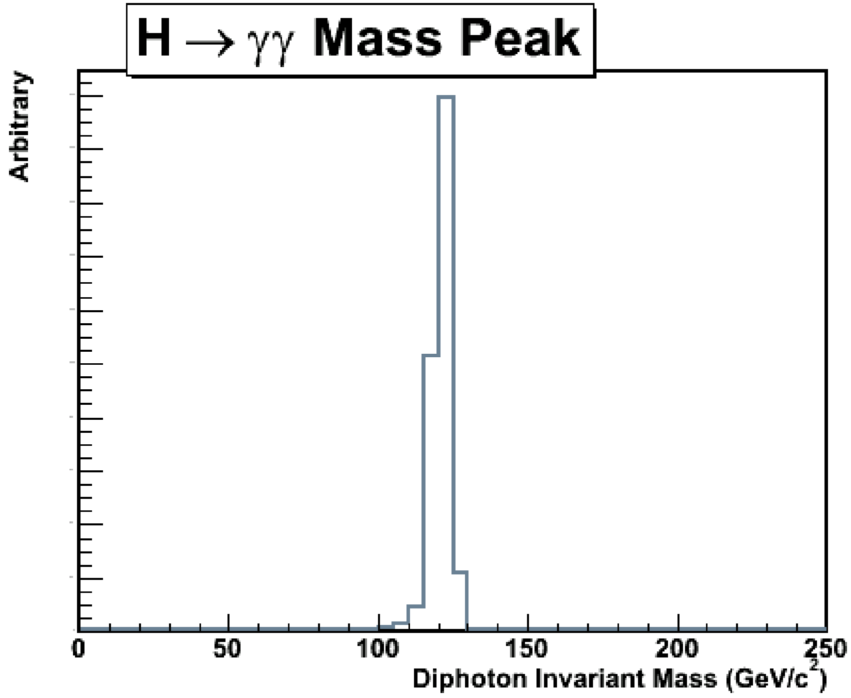
   -real diphotons

Sidebands

- To estimate fake photons
- Almost pass photon cuts, but are not clear photons
- Similar characteristics to fake background, therefore they are a good model to use

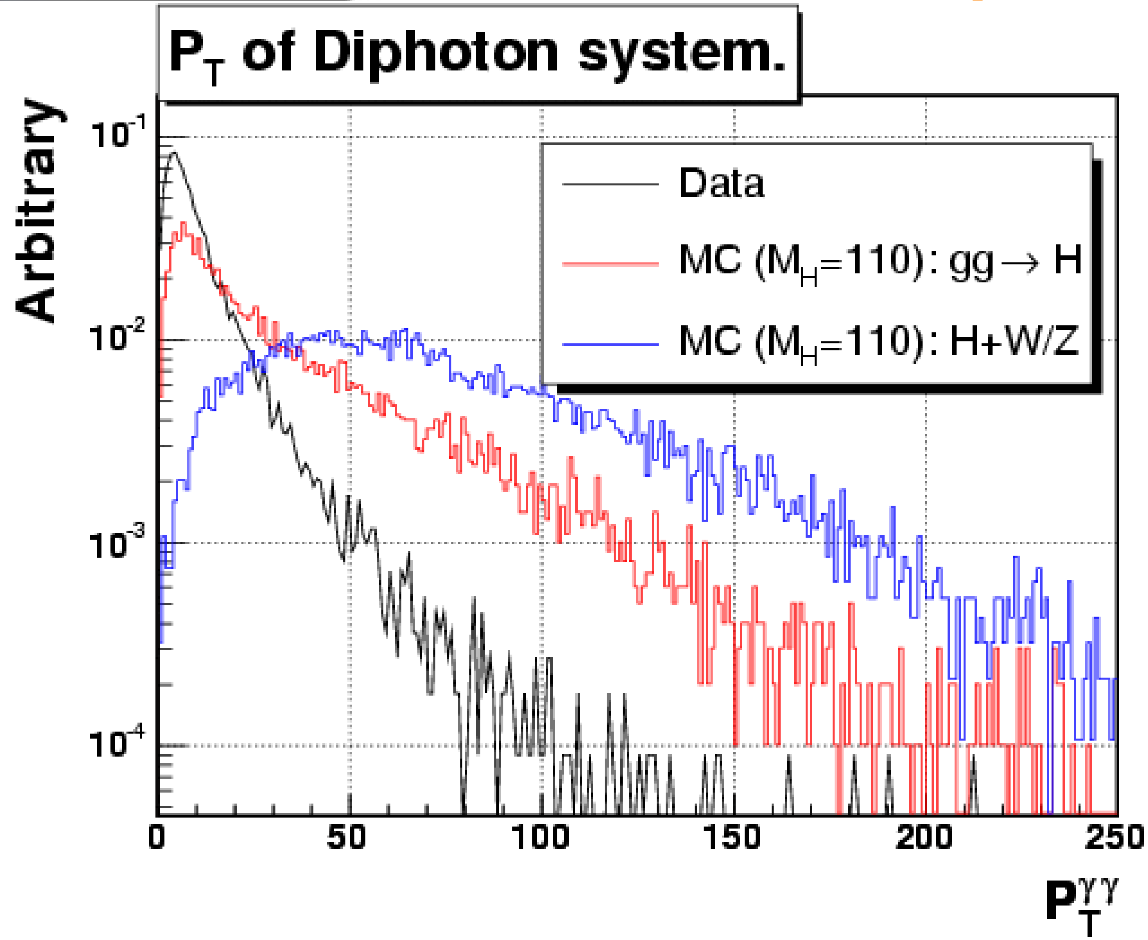


Mass Window Cut

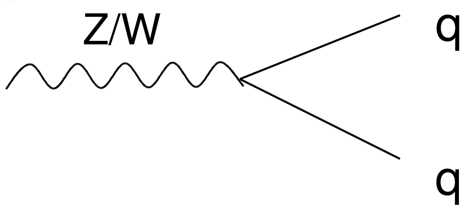


Mass Window Cut:
20 GeV

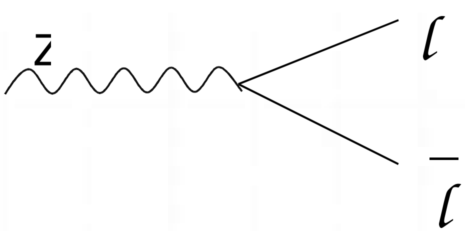
pT Distribution

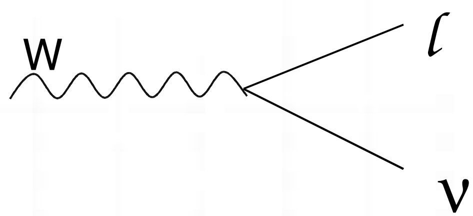


Z/W Decays

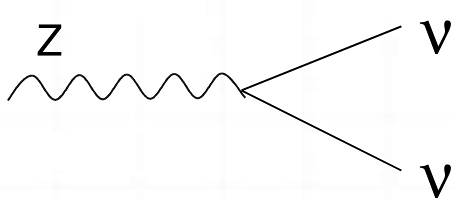


$\Rightarrow$ 2 Jets





$\Rightarrow$Isolated Track
$\Rightarrow$MET



$\Rightarrow$ MET

Optimize Cuts

To remove as many background events and to keep as many signal events as possible

Cut options:

- Transverse Momentum of diphoton pair (pT)
- Missing Transverse Energy (MET)
- pT of Second Jet
- pT of Isolated Tracks

Final Cut Choice

•Made a grid with pT of the diphoton pair cuts and an “or” between the MET, the pT of second jet, and the pT of the isolated track.

•Based on # Background events and # Signal events, we minimized the expected limit for each point

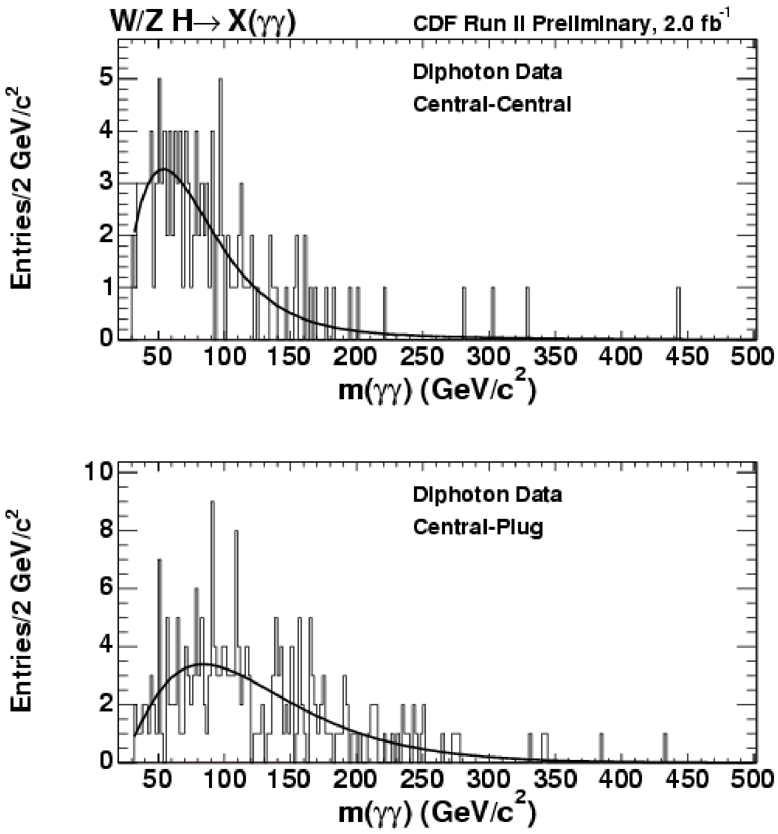
Our Final Choice:

pT Cut > 75 GeV

Reduced Signal by <50% and Background by >99%!

Mass Spectrum

The Higgs would show up as a bump in our mass spectrum graph



Since we did not see a bump, our focus shifted to placing a limit on the fermiophobic model's Higgs mass.

Acceptance Study

Acceptance = number of signal events/total number of events

Higgs Mass	Acceptance CC (%)	Acceptance CP (%)
70	2.9	1.8
80	3.8	2.4
90	4.4	3.2
100	4.9	3.7
110	5.4	4.5
120	6.0	5.2

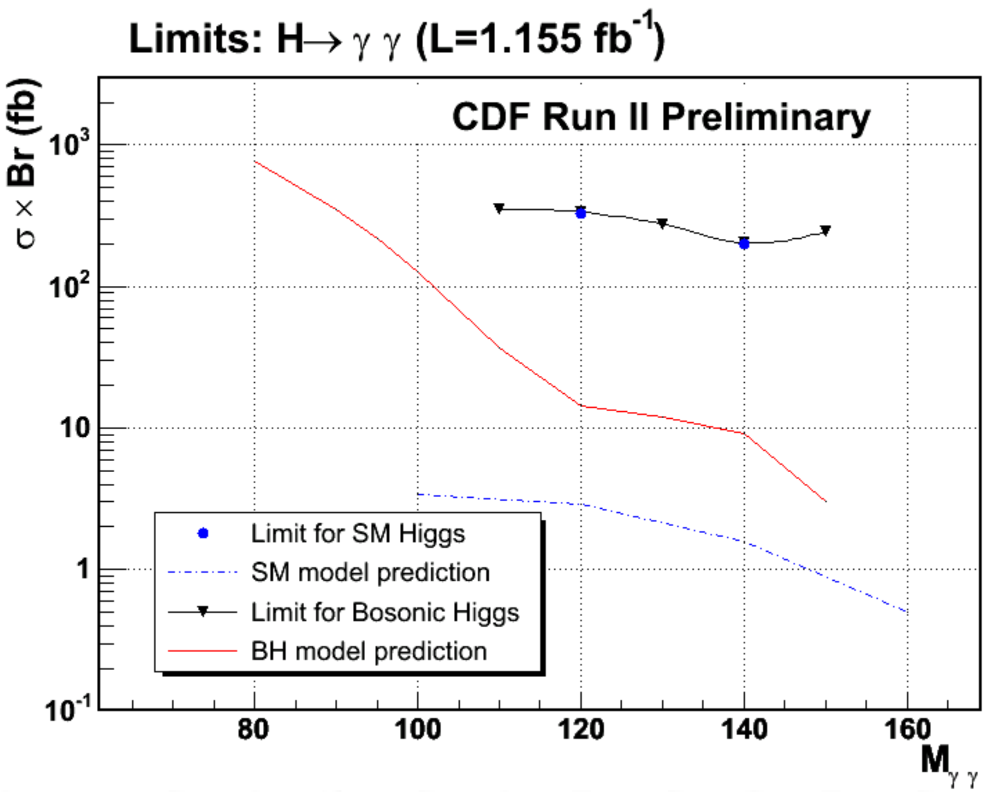
Cross Section Limit

- Compared the number of observed events with the number of expected background events

- Took statistical and systematic fluctuations into account

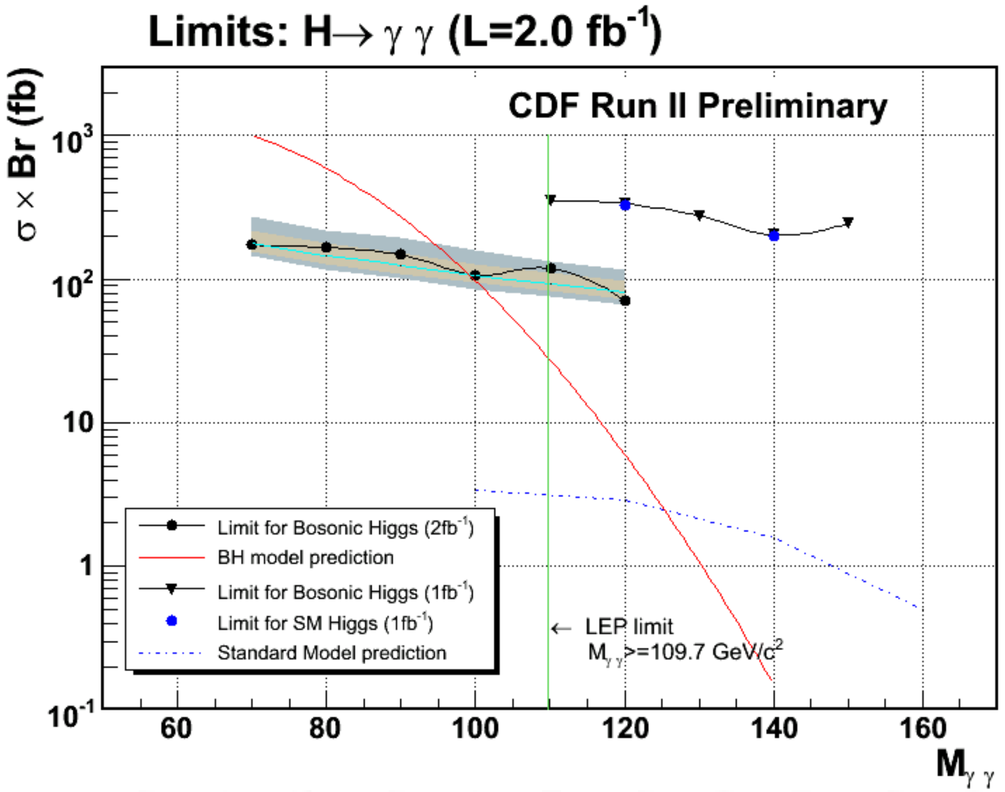
- Set a limit on the number of signal events we would be sensitive to

Before…



Limits: H→ γ γ (L=1.155 fb⁻¹)
CDF Run II Preliminary
σ × Br (fb)
10³
10²
10
1
10⁻¹
80
100
120
140
160
M γ γ
Limit for SM Higgs
SM model prediction
Limit for Bosonic Higgs
BH model prediction

After…

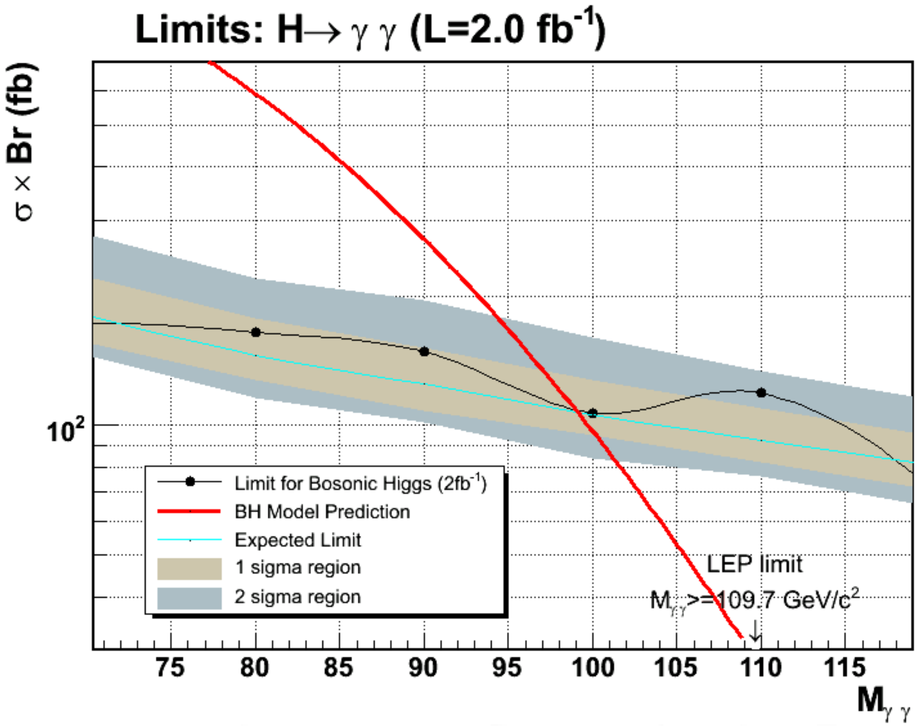


Limits: H→ γ γ (L=2.0 fb^{-1})
CDF Run II Preliminary
σ × Br (fb)
10^3
10^2
10
1
10^{-1}
60
80
100
120
140
160
$M_{\gamma\gamma}$
Limit for Bosonic Higgs (2fb^{-1})
BH model prediction
Limit for Bosonic Higgs (1fb^{-1})
Limit for SM Higgs (1fb^{-1})
Standard Model prediction
← LEP limit
$M_{\gamma\gamma}$>=109.7 GeV/c^2

Previous Limits

- CDF Run 1 -> 82 GeV
- D0 -> ~90 GeV
- LEP -> 109.7 GeV

RESULTS!



Bosonic Higgs Mass limit:
99 GeV

THANK YOU!