PHYS 5326 – Lecture #22

Wednesday, Apr. 16, 2003
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- Higgs Search Strategy
- Higgs Search Channels
- Requirement on Experiments

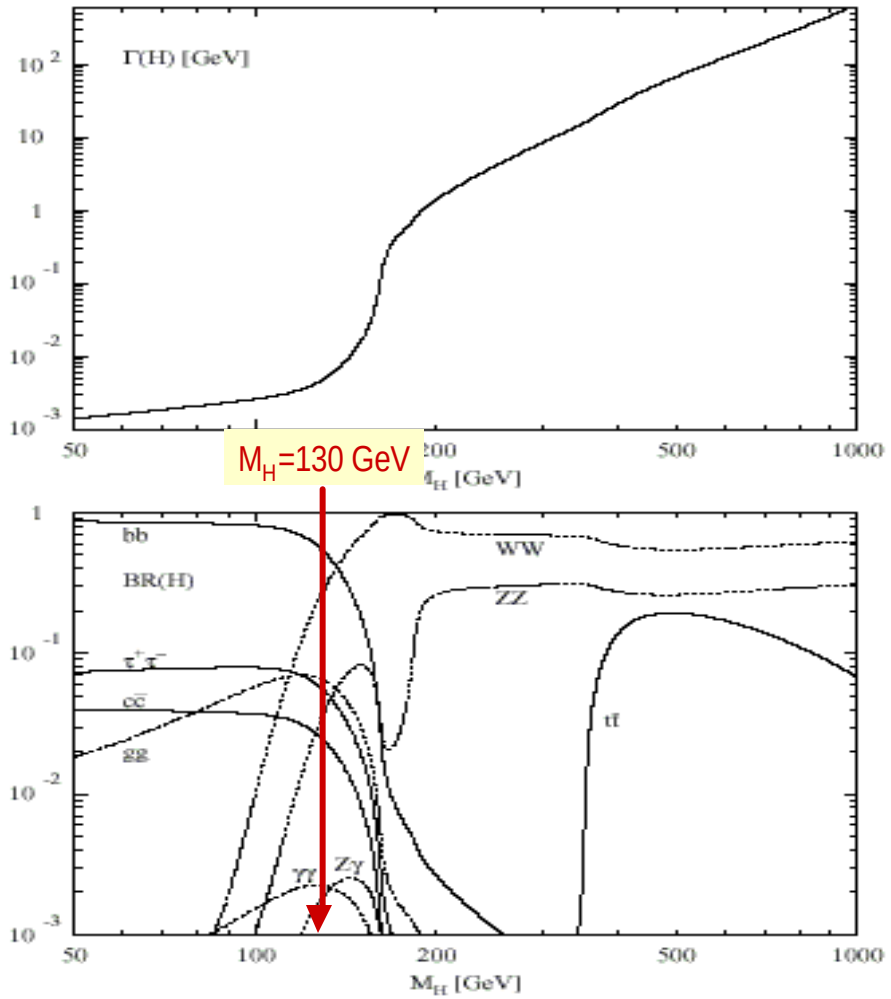
Higgs Particles

- What are the Higgs particles we are looking for?
  - Standard Model Higgs: Single neutral scalar
  - MSSM Higgs: Five scalar and pseudoscalar particles
    - h^0, H^0, $H^{+/-}$ and A^0
  - Higgs in Other Models
- What are the most distinct characteristics of Higgs particles?
  - In both SM and MSSM, the Higgs particles interact with fermions through Yukawa coupling whose strength mostly is set by the fermion masses.

Search Strategy

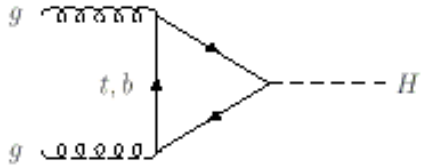
- What are the best ways of discovering Higgs?
  - Make assumptions in Higgs mass
  - Study the branching ratios
    - Study the most identifiable final states
  - Choose the channels w/ smallest background
  - Study ways to increase number of recorded Higgs
    - Accelerator dependent
    - Smarter triggers
  - Identify and Implement detector improvements that are needed
- Precision measurements for Higgs properties
  - To distinguish SM and SUSY model Higgs

Summary of SM Higgs Branching Ratio



Higgs Production Processes at Hadron Colliders

Gluon fusion: $gg \rightarrow H$

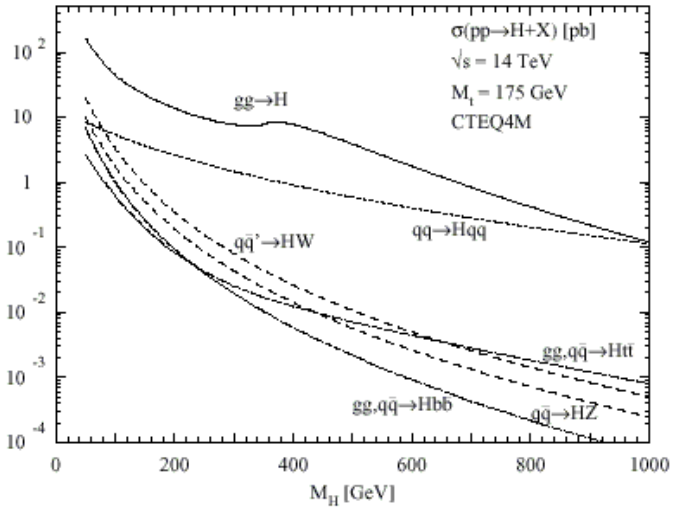


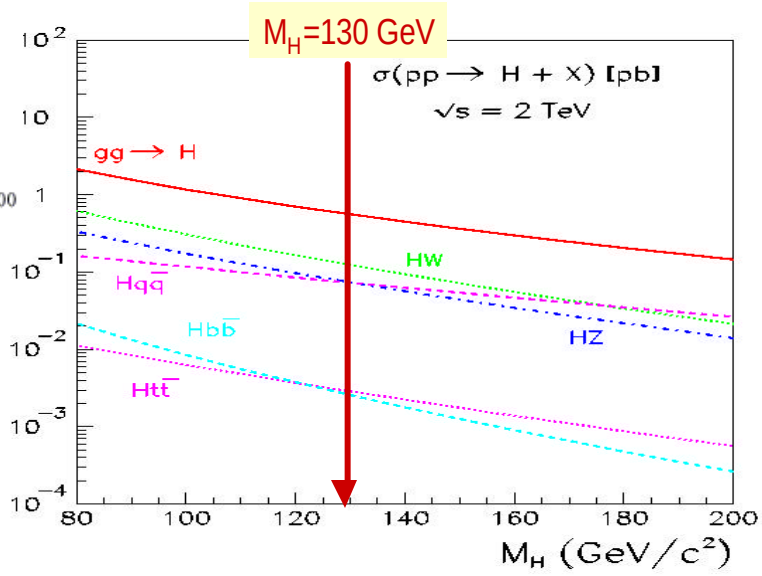
WW, ZZ Fusion: $W^+W^-, ZZ \rightarrow H$

Higgs-strahlung off W,Z: $q\bar{q} \rightarrow W^*, Z^* \rightarrow W, Z + H$

Higgs Bremsstrahlung off top: $q\bar{q}, gg \rightarrow t\bar{t} + H$

Hadron Collider SM Higgs Production σ



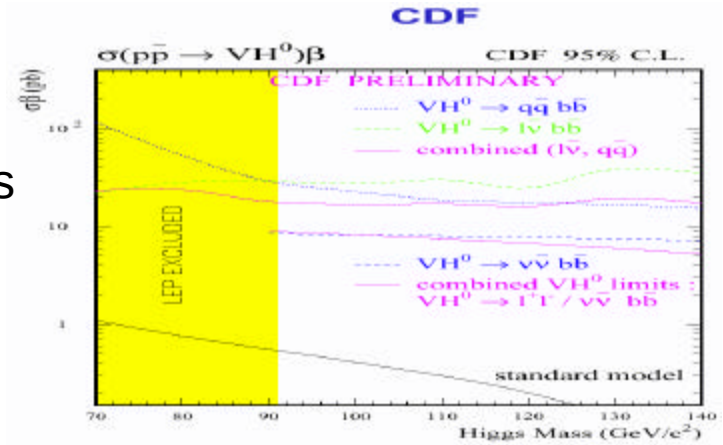


Tevatron Run I Results

- Run I limits are not very stringent

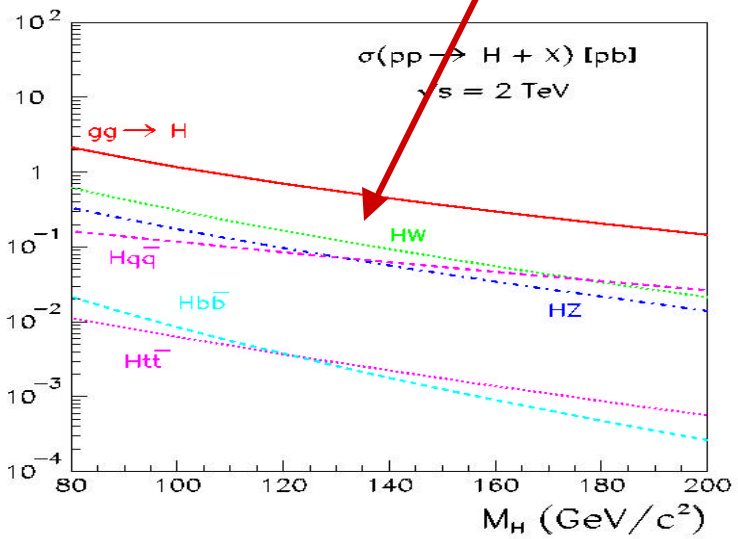
Channel	DØ (95% CL)	CDF(95% CL)	Theory
WH $\rightarrow l\nu bb$	<28 pb	<27 pb	0.07
ZH $\rightarrow \nu\nu bb$		<8 pb	0.10
ZH $\rightarrow ll\ bb$		<7.5 pb	0.11

No real mass limit here…

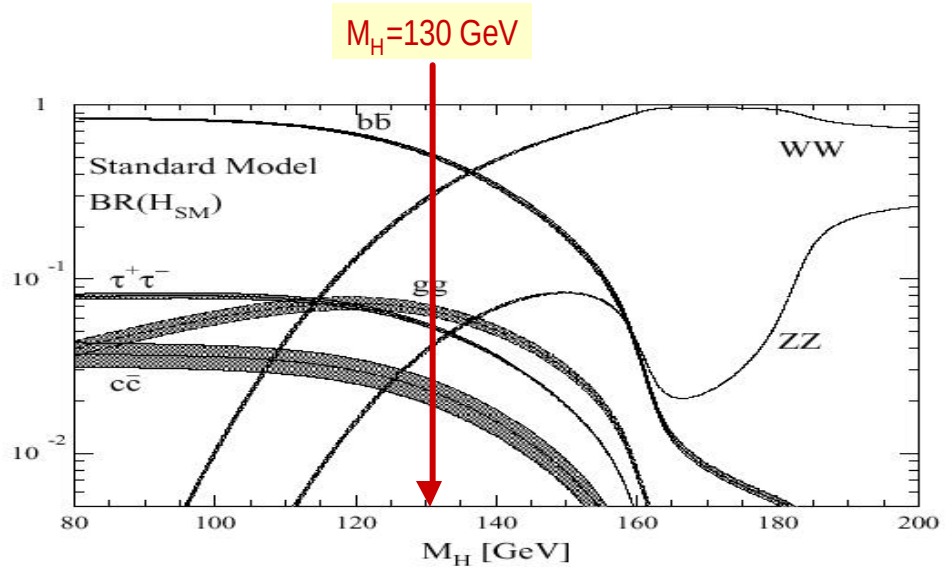


Tevatron Run II Higgs Physics

- s ´ BR @ 2 TeV
  - Use associated H+W/Z production
    - H ® b`b



σ (pb) for M_H=100 GeV	
gg → H	1.17
qq,gg → WH	0.31
qq,gg → ZH	0.17
qq,gg → H+2jets	0.12
All others	<0.02
Backgrounds	
WZ+ZZ	4.4
Wbb+Zbb	14
tt	7.5
tb+tq_tbq	3.4
QCD	O(10^6) dijet O(10^5) 4jet
W → ev	2800



For M_H<130GeV

- H → b $\bar{b}$
- H ® WW
- H ® gg or τ $\bar{\tau}$
- H ® c $\bar{c}$

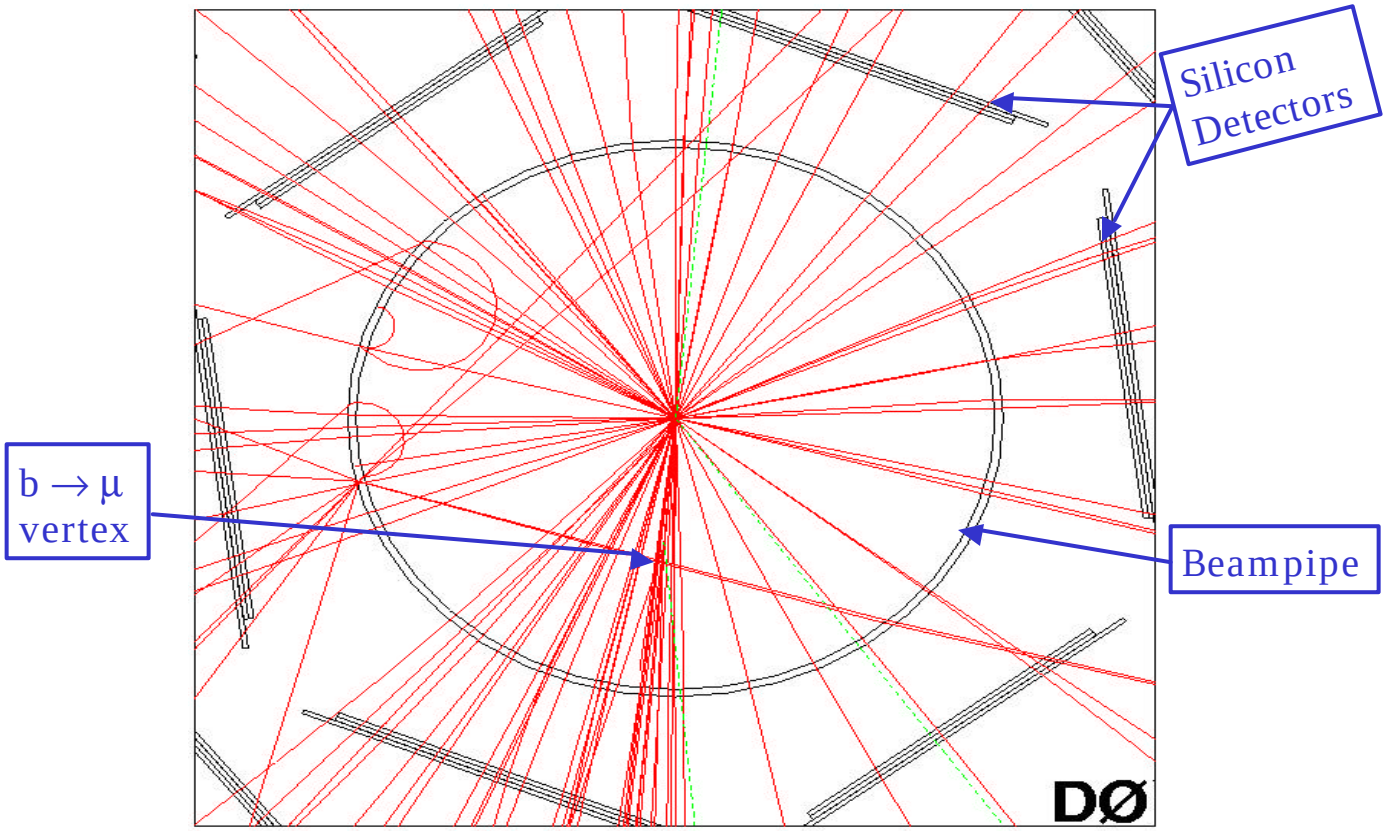
For M_H>130GeV

- H ® WW/ZZ
- H → b $\bar{b}$
- H ® gg or τ $\bar{\tau}$
- H ® c $\bar{c}$

$H(h) \rightarrow b\ \bar{b}$

- Two b-quark jets in the final state
- Look for signature of b-quark jets
  - b-quark jets contain B mesons
  - B-mesons have finite lifetime and decay in flight
- Final state of interest
  - A displaced vertex from the primary vertex
  - Existence of secondary leptons from b-quark semileptonic decay

How does a displaced vertex look?



H (h) →WW

- W's decay immediately
- Look for signature of W's
  - W branching ratios
    - ~11% to leptonic final state (l+ν) for each lepton
    - ~69% to quark and anti-quark final states
- Final states of interest
  - One high P_T lepton (e or μ) + missing E_T + two jets
  - Two opposite charge high P_T leptons (ee, $\mu\mu$, or em) + Missing E_T
  - Four jets

$H(h) \rightarrow \tau\ \bar{\tau}$

- τ's decay almost immediately
- Look for signature of τ's
  - τ branching ratios
    - ~17% to leptonic final state (e,μ+ν+ν) for each lepton
    - ~68% to hadrons (one or three charged hadrons)
- Final states of interest
  - One medium P_T lepton (e or μ) + missing E_T + one narrow jet
  - Two opposite charge medium P_T leptons (ee, $\mu\mu$, or eμ) + Missing E_T
  - Two narrow jets

For HW or HZ

- Cross section is about 10% of gg→H
- Both H and W/Z decay immediately
- Look for signature of vector bosons with H decay final states
- W or Z final state characteristics
  - Decay to Leptons or quark jets
- Final states of interest for HW
  - Higgs decay + One high P_T lepton
  - Higgs decay + two light quark jets

HZ Final States

- Z decay branching ratio
  - ~3% for each charged lepton pairs
  - ~20% two neutrino final states
  - ~70% quark, anti-quark final states
    - ~15% b $\bar{b}$ final states
- Final states of interest for HZ
  - Two high P_T lepton + Higgs decay channels
  - Large Missing E_T + Higgs decay channels
  - Four b-jet final states

Summary of Final States of Interest

- W decay:
  - $W \rightarrow qq$ hard
    - depends on dijet mass resolution
  - $W \rightarrow e\nu, \mu\nu$ (probably not tn)
    - Isolated lepton plus missing E_T
- Z decay
  - $Z \rightarrow qq$ same as W – difficult
  - $Z \rightarrow ee, \mu\mu$ (probably not $\tau\tau$)
    - Isolated lepton plus mass resolution
- Higgs decay:
  - Look for $b\bar{b}$ pairs
    - Impact parameter resolution
    - Silicon vertexing
    - Di-jet mass resolution

b-tagging is a MUST

Homework Assignment

- Compute the following quantities for WH and ZH final states with leptons for M_H=115 GeV and L=15fb^{-1}.
  - Expected percentage of various final states
  - Number of signal events for the final states
- Due: Wednesday, Apr. 23