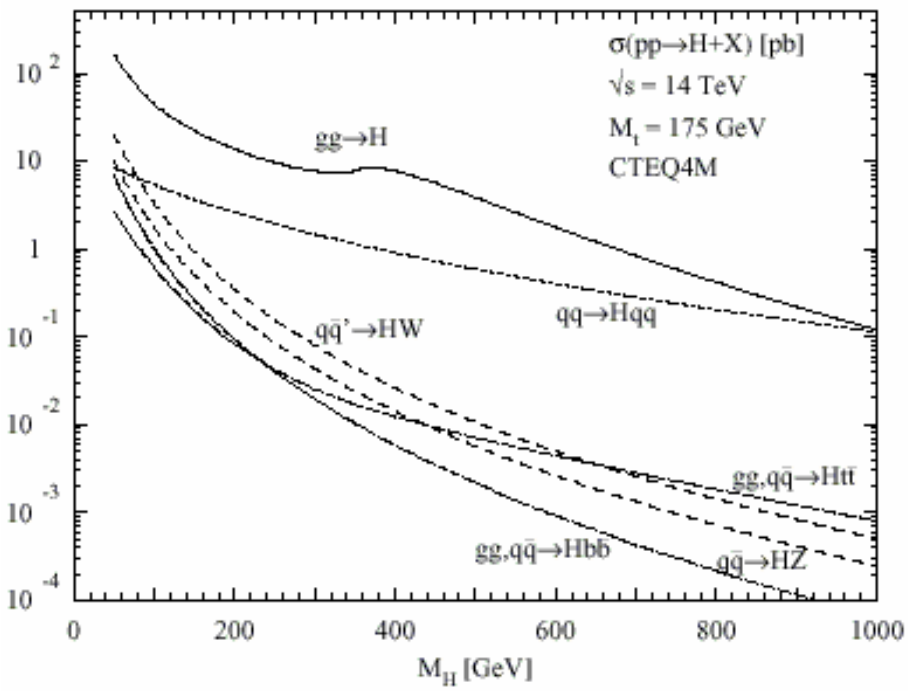
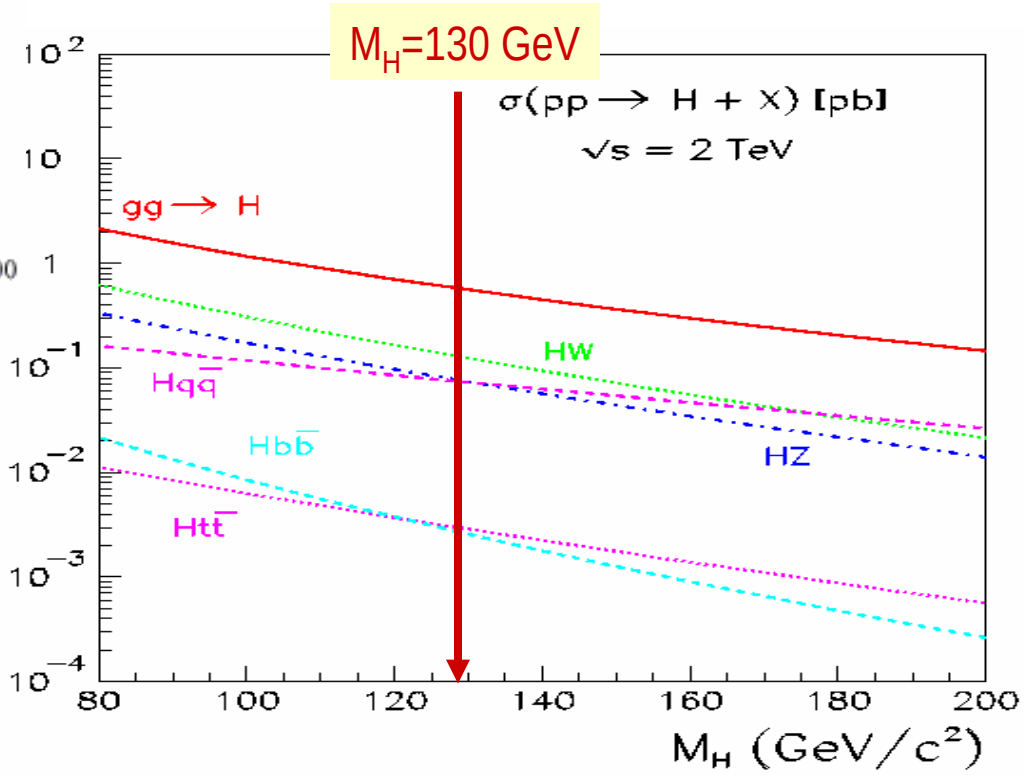
PHYS 5326 – Lecture #20

Wednesday, Apr. 25, 2007
Dr. Jae Yu

- Higgs Search Strategy
- Higgs Search Channels
- Backgrounds to Higgs Searches
- Requirement on Experiments for Higgs Searches

Hadron Collider SM Higgs Production σ



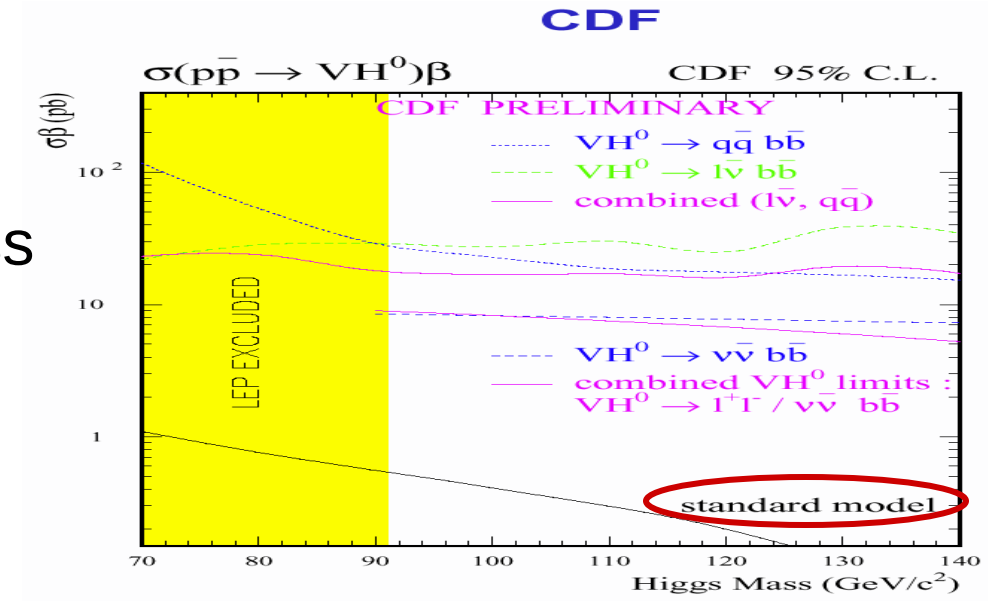


Tevatron Run I Results

- Run I limits are not very stringent

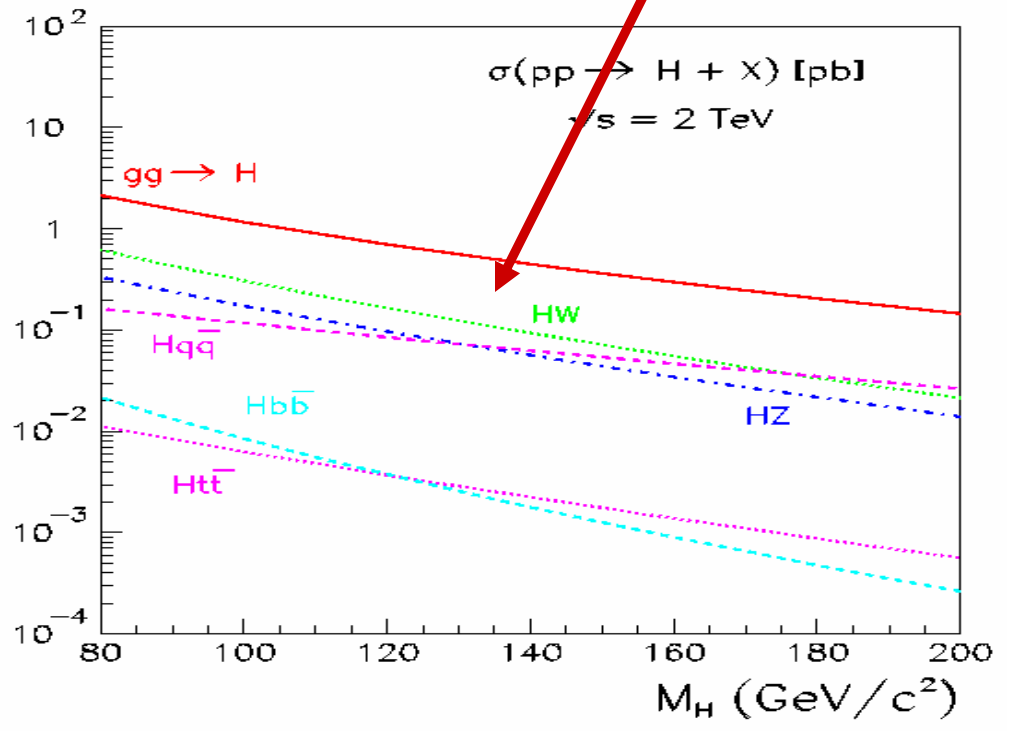
Channel	DØ (95% CL)	CDF(95% CL)	Theory
WH $\rightarrow \ell\nu bb$	<28 pb	<27 pb	0.07
ZH $\rightarrow \nu\nu bb$		<8 pb	0.10
ZH $\rightarrow \ell\ell bb$		<7.5 pb	0.11

No real mass limit here…

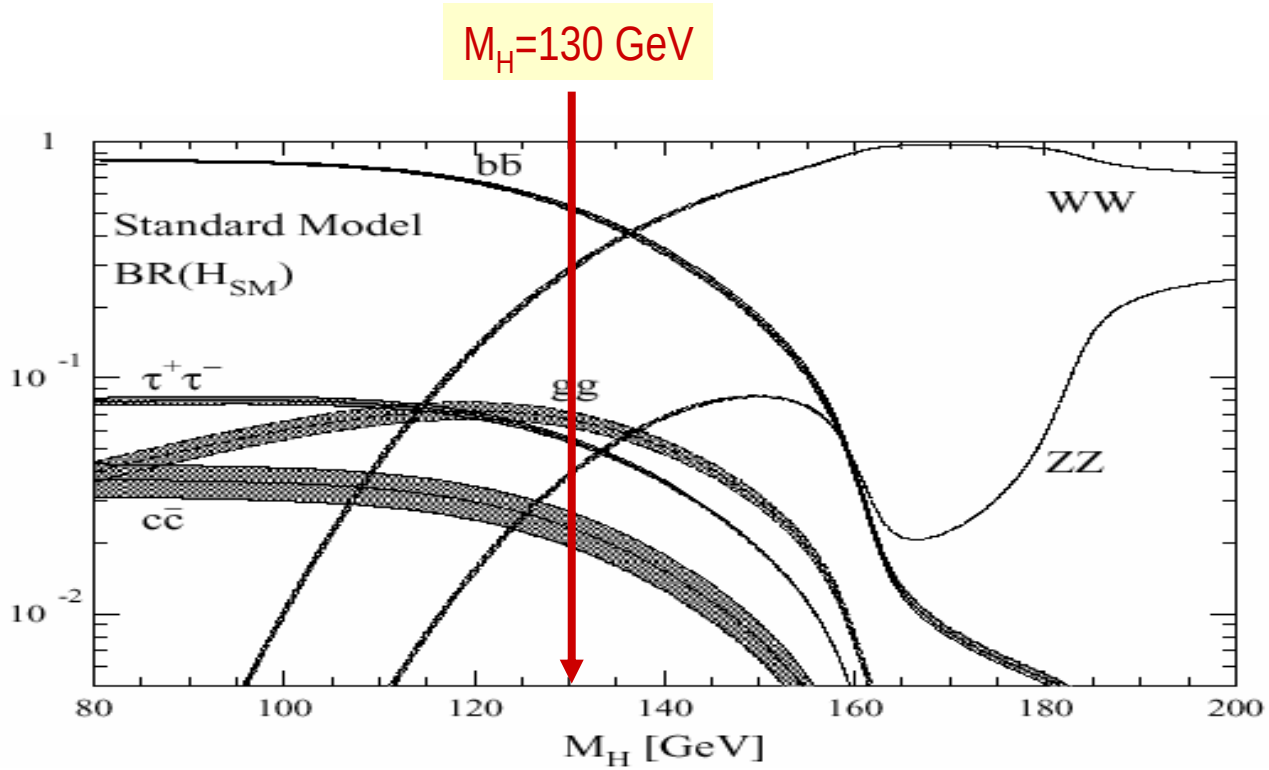


Tevatron Run II Higgs Physics

- $\sigma \times BR$ @ 2 TeV
  - Use associated H+W/Z production
    - $H \rightarrow b\,\bar{b}$



σ (pb) for M_H=100 GeV	
$gg \rightarrow H$	1.17
$qq,gg \rightarrow WH$	0.31
$qq,gg \rightarrow ZH$	0.17
$qq,gg \rightarrow H+2jets$	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
$W \rightarrow e\nu$	2800



For M_H<130GeV

- $H \rightarrow b\ \bar{b}$
- $H \rightarrow WW$
- $H \rightarrow gg$ or $\tau\ \bar{\tau}$
- $H \rightarrow c\ \bar{c}$

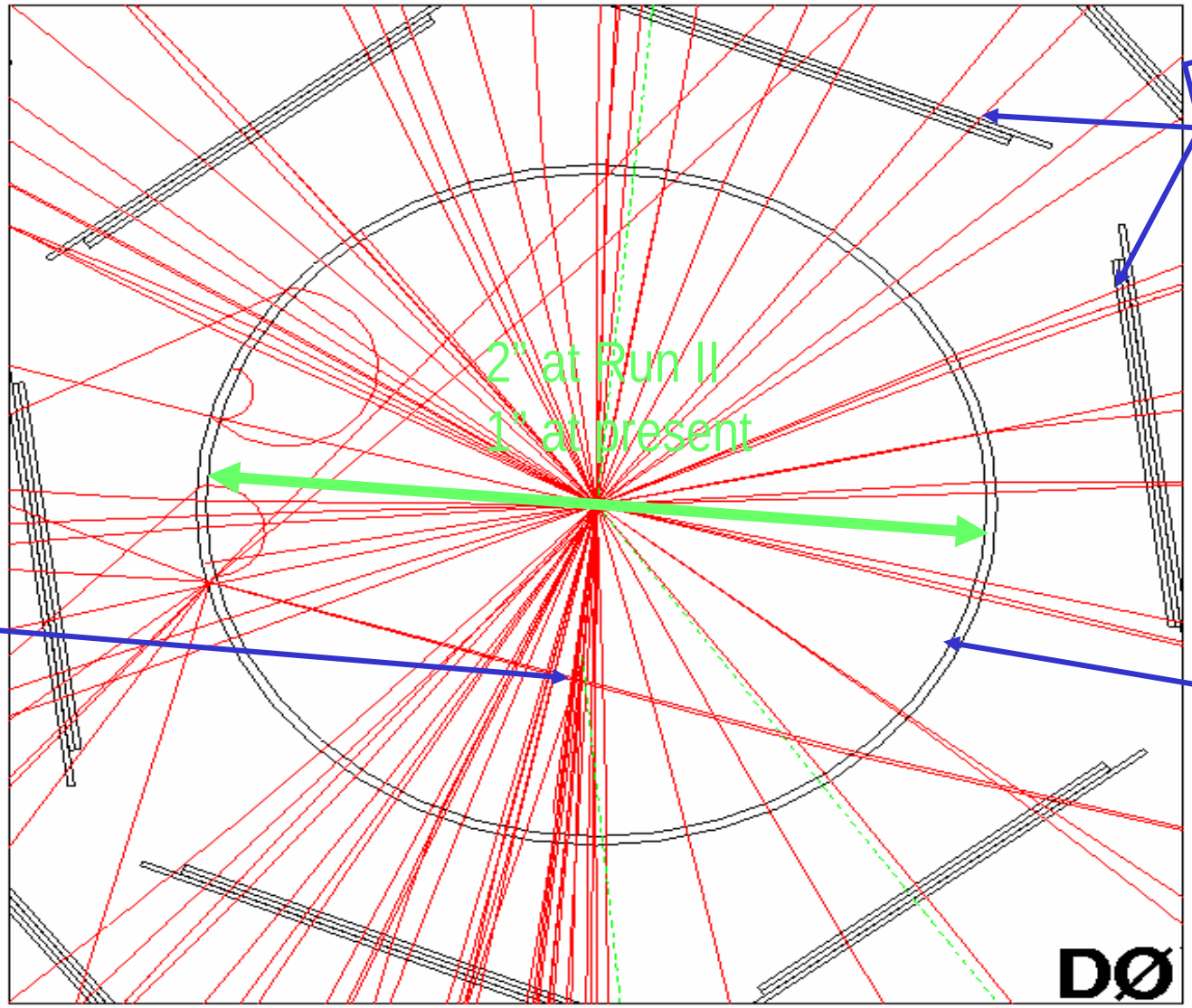
For M_H>130GeV

- $H \rightarrow WW/ZZ$
- $H \rightarrow b\ \bar{b}$
- $H \rightarrow gg$ or $\tau\ \bar{\tau}$
- $H \rightarrow c\ \bar{c}$

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

- 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 ($\ell+\nu$) 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 eμ) + 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:
  - $W \rightarrow qq$ channel very hard
    - depends on dijet mass resolution
  - $W \rightarrow e\nu, \mu\nu, \tau\nu$
    - 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

Higgs Backgrounds To WH

- $WH \rightarrow l\nu\ b\ \bar{b}$ backgrounds
  - $Wb\ \bar{b}$
    - Where the W decays leptonically
    - Cross section is $2.3nb*\alpha_s^2*m_b$-threshold factor for each lepton
  - WZ:
    - W decays leptonically while Z decays to $b\ \bar{b}$
    - Cross section is $2.3nb*\alpha_{EW2}$*b final state branching ratio
  - $t\ \bar{t}$: Each t decays to W and b pairs. How would this become a background?
  - single t: How?
- $WH \rightarrow qq\ b\ \bar{b}$ overwhelmed by QCD background since it has four jets in the final state

Higgs Backgrounds to ZH

- $ZH \rightarrow l\,l\,b\,\bar{b}$ final state for signature
  - $Zb\,\bar{b}$
    - Z decays to two leptons
    - Cross section is $0.2nb*\alpha_s^2*m_b$-threshold factor for each lepton
  - ZZ
    - One Z decays to two leptons while the other decays to $b\,\bar{b}$
    - Cross section is $2*0.2nb*\alpha_{EW}$*b branching ratio
  - $t\,\bar{t}$:How does this channel become background to ZH?

Higgs Backgrounds to ZH

- $ZH \rightarrow \nu\nu\, b\, \bar{b}$
  - QCD:How would this become background to this process?
  - $Zb\, \bar{b}$: Z decays to neutrinos
  - ZZ: One Z decays to neutrinos while the other decays to $b\, \bar{b}$
  - $t\, \bar{t}$: How would this process become background?

Higgs Backgrounds to $gg \rightarrow H \rightarrow WW^*$

- WW final state is a generic, inherent and irreducible background
- 2ℓ+MET final state
  - ZZ: One Z decays to two leptons while the other to two neutrinos
  - Drell-Yan ($q\ \bar{q} \rightarrow \gamma^* \rightarrow \ell\ell$)
  - $t\ \bar{t}$: How this could be the background to this process?
  - WZ: Z decays to two leptons, while W decays to $\ell+\nu$ where ℓ is lost
  - $\tau\tau$: Both τ's decay leptonically

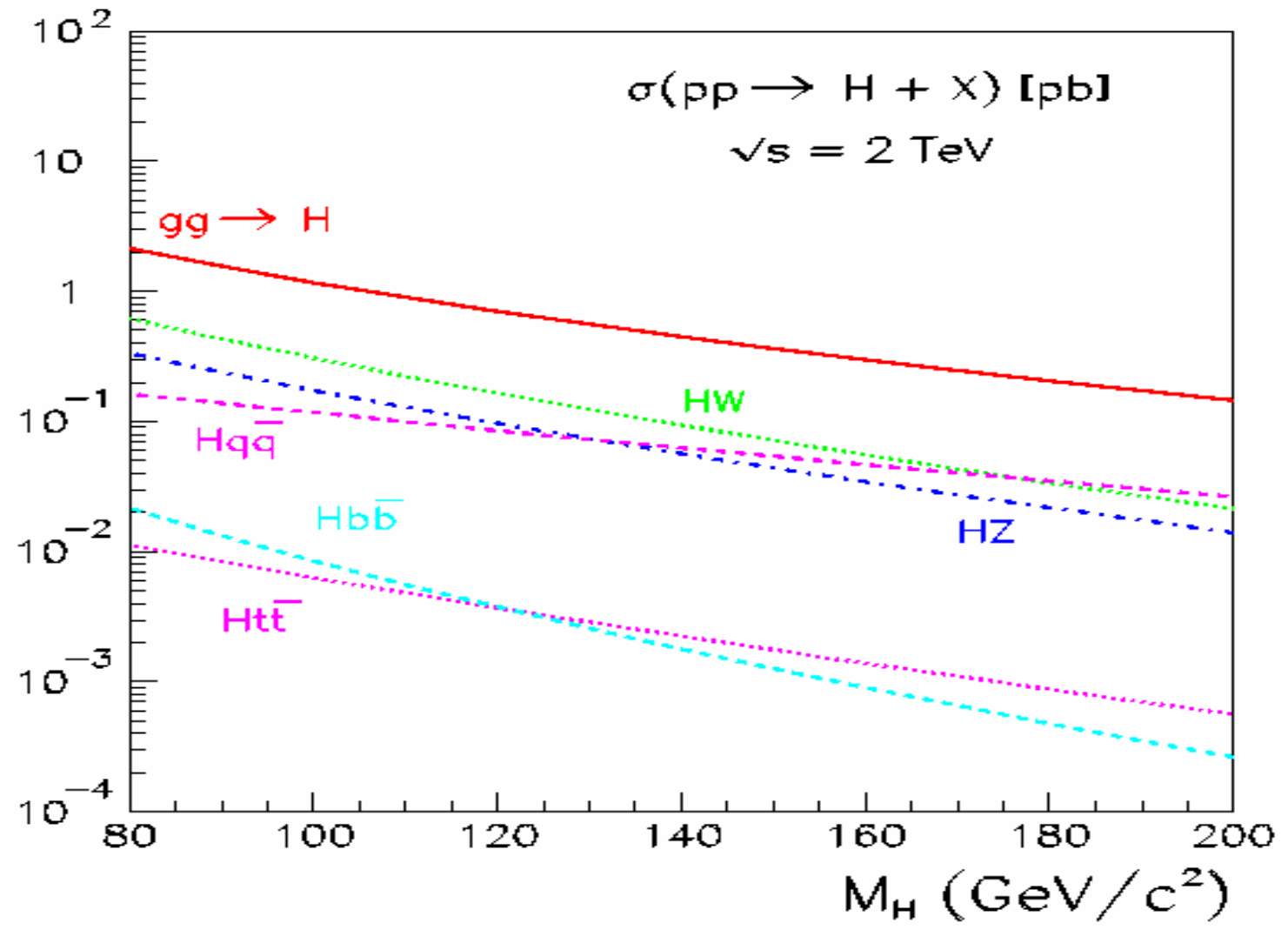
Higgs Backgrounds to $gg \rightarrow H \rightarrow WW^*$

- 1ℓ+MET+2jets final state
  - WZ: W decays to $\ell+\nu$ and Z decays to two jets
  - ZZ: One Z decays to two leptons (of which one is lost) while the other to two jets
  - $t\bar{t}$: How is this become a background to this process?
  - tW:How could this become a background to this process?

Summary of Higgs Physics Backgrounds

- The best discovery channel is with HW and HZ
- The background for $m_H < 130$ GeV are
  - $WH \rightarrow l\nu\, b\, \bar{b}$ backgrounds $Wb\, \bar{b}$, WZ, $t\, \bar{t}$, single t
  - $WH \rightarrow qq\, b\, \bar{b}$ overwhelmed by QCD background since it has four jets in the final state
  - $ZH \rightarrow l\, l\, b\, \bar{b}$ backgrounds $Zb\, \bar{b}$, ZZ, $t\, \bar{t}$
  - $ZH \rightarrow \nu\nu\, b\, \bar{b}$ backgrounds QCD, $Zb\, \bar{b}$, ZZ, $t\, \bar{t}$
- The background for $m_H > 130$ GeV are
  - $gg \rightarrow H \rightarrow WW^*$ backgrounds Drell-Yan, WW, WZ, ZZ, tt, tW, $\tau\tau$

Tevatron Higgs Production σ



TeVatron Run II Higgs S/N

- $H \rightarrow b\ \bar{b}$
  - S/N drops as M_H increases
    - Run out of events….
    - Ultimately limits the experimental reach
- $H \rightarrow WW/ZZ$ (virtual)
  - Depends on di-jet mass resolution

1 fb^{-1} delivered