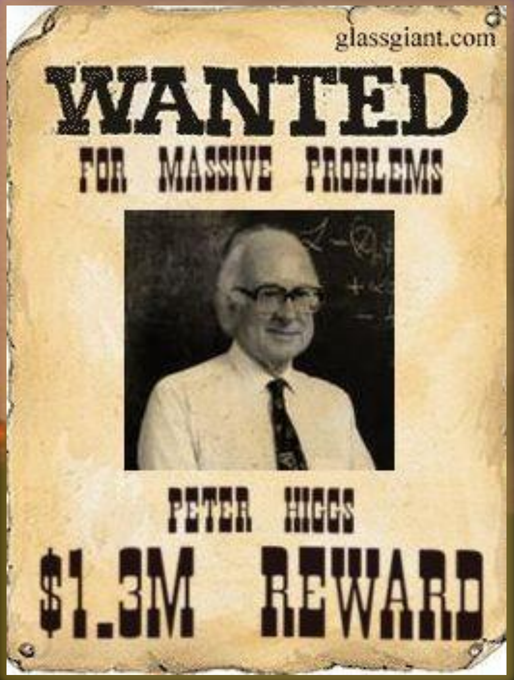
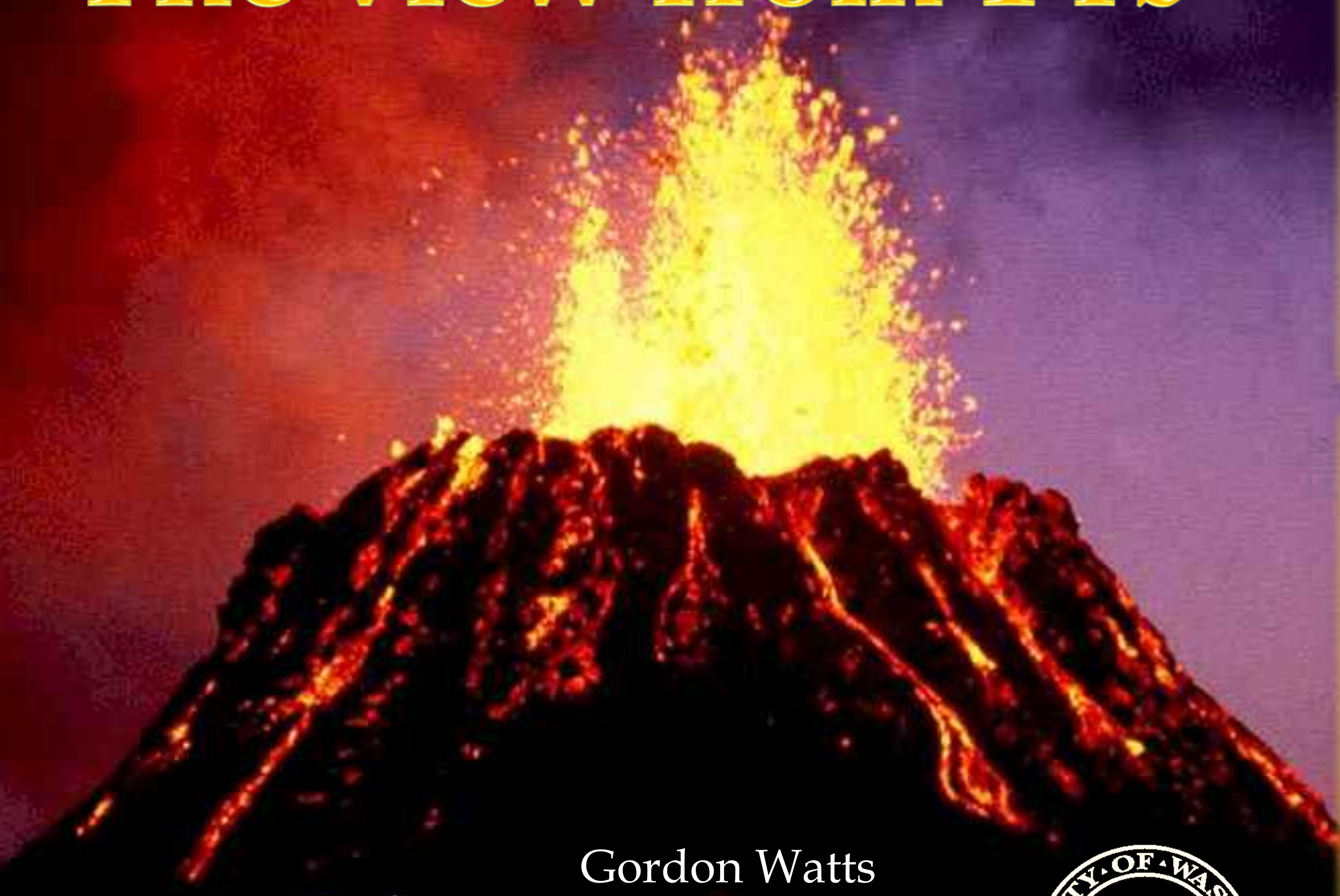
Climbing Mt. Higgs: The view from 1 fb^{-1}





Puu Oo Cone, Hawaii

Gordon Watts
University of Washington
For the DØ Collaboration

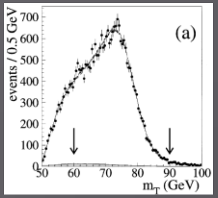
DPF 2006

The Almost Final Frontier: Higgs

If $SU(2)_L \times U(1)_Y$ were it…

The associated SU(2) gauge bosons would be massless…

We know that isn't correct!



To fix this the Higgs Field was added

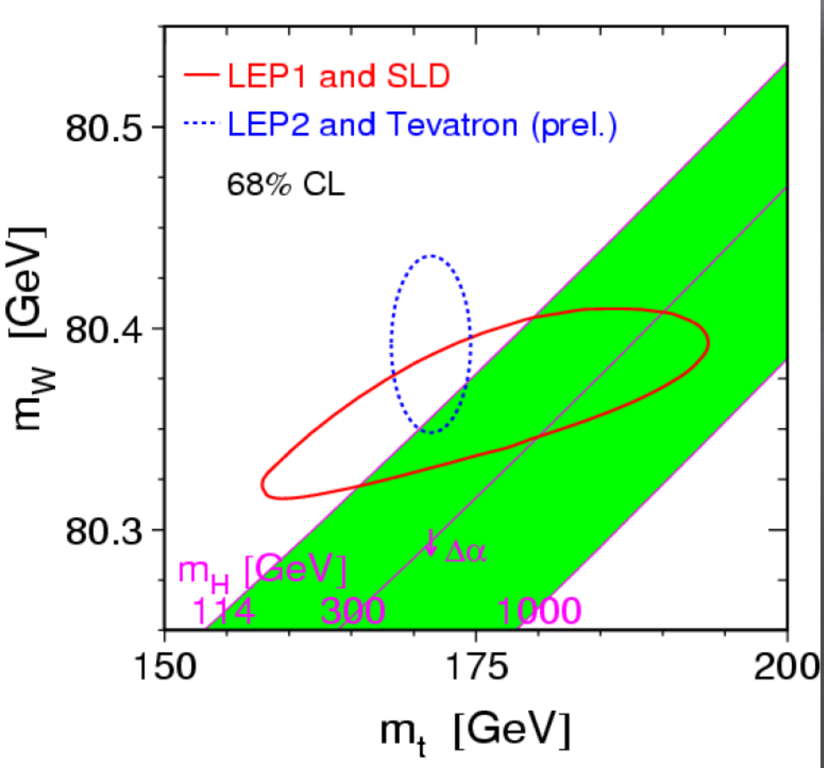
Add one complex doublet of scalar fields
Keeps the symmetries of the original $SU(2)_L \times U(1)_Y$
Gets the weak force right
W^+, W^-, and Z^0 bosons are massive
Non zero VEV and a Higgs!!

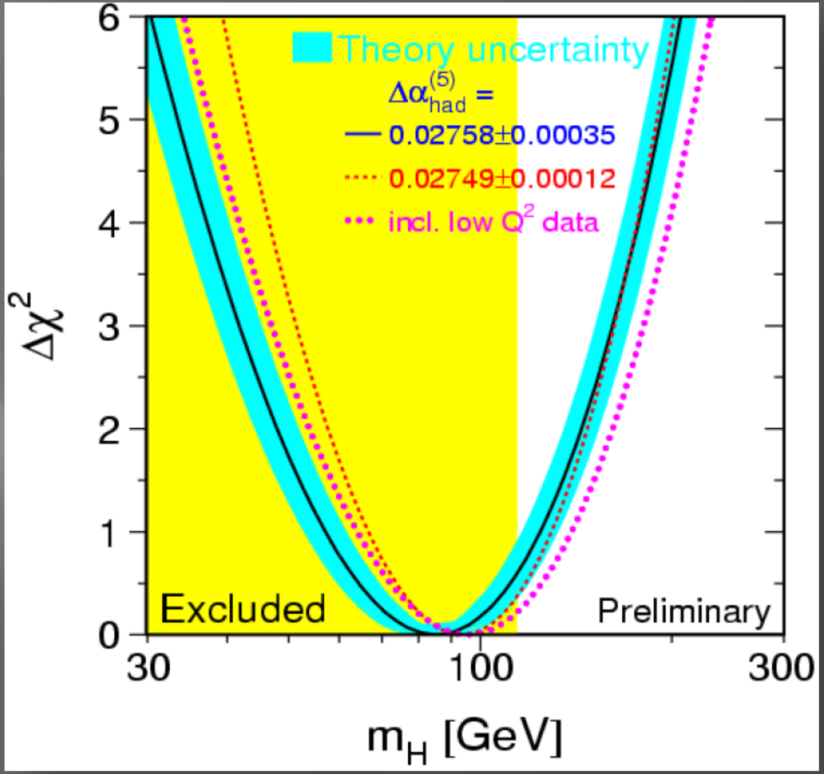
The Higgs is the only particle we've not seen yet!

Other Ways To Fix The Problem!

SUSY Higgs, 2HDM, Little Higgs, Technicolor
Our "SM" Higgs Field is just the simplest…

Where Are We Now?



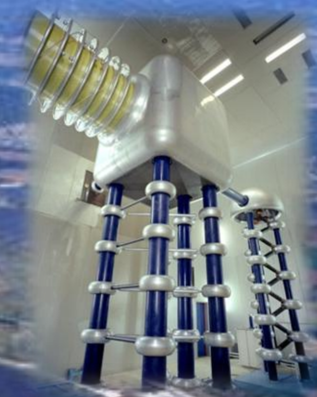


Direct Searches at LEP2
$m_H > 114.4$ GeV/c^2 @ 95% CL

Precision EW Fits
$m_H < 166$ GeV/c^2 @ 95% CL
$m_H < 199$ GeV/c^2 (w/LEP2 limit)

The Tevatron Run 2 Physics Program

- Improve M_t measurement Started
- Improve M_W measurement In Progress
- Find B_s mixing Done!
- Search for the Higgs In Progress
- Search for New Phenomena Always In Progress…



To Find The Higgs

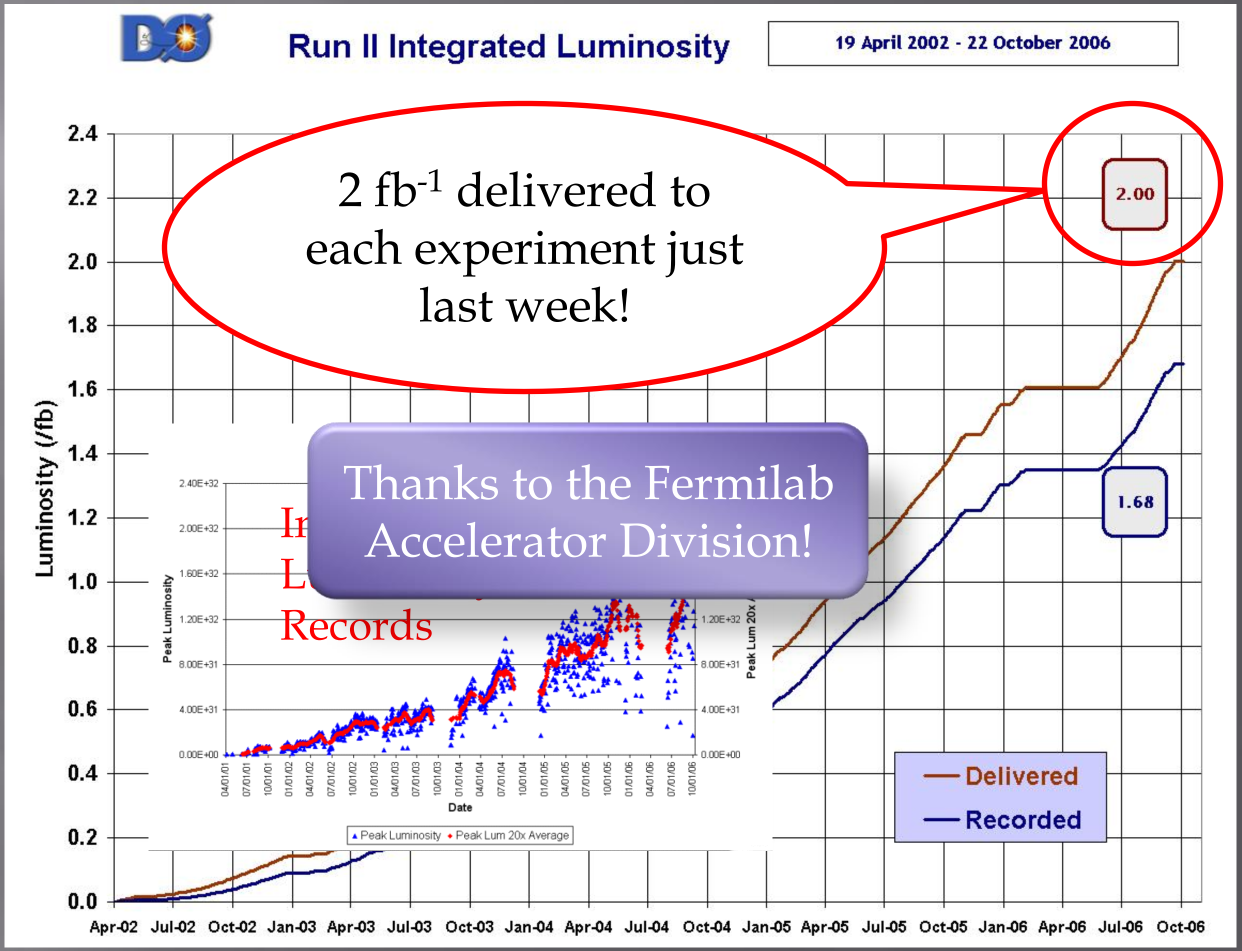
- ∫Ldt – Integrated Luminosity
- Good Detector
- Selection and Analysis driven by Production and Decay Channels

All have been changed, upgrade, and improved for Run 2

The Tevatron - Data

- DØ has close to 1.7 fb^{-1} on tape
- Tevatron Instantaneous Luminosity Records are all recent.
  - A challenge to the experiments

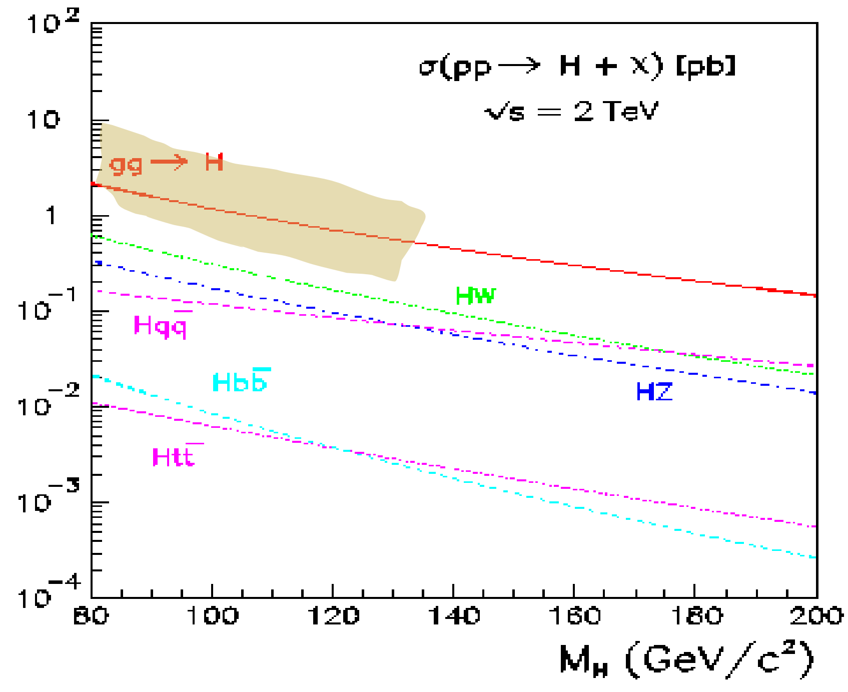
Both Experiments are continually improving their ability to handle the increased luminosity without sacrificing any of their Higgs search capabilities…

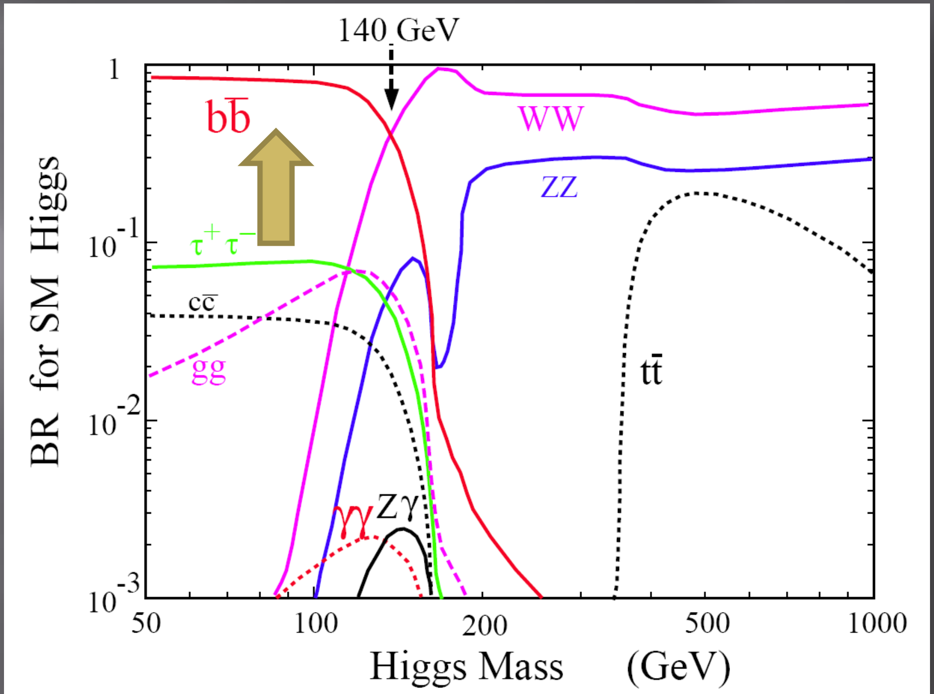


Most of the analyses presented here are over the first fb^{-1} of data

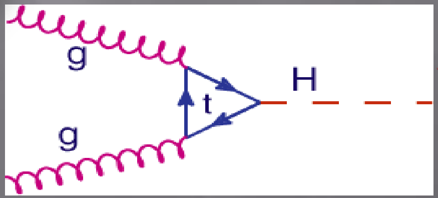
Search Strategy

Both production and decay determine how you can search!





1 Gluon Fusion

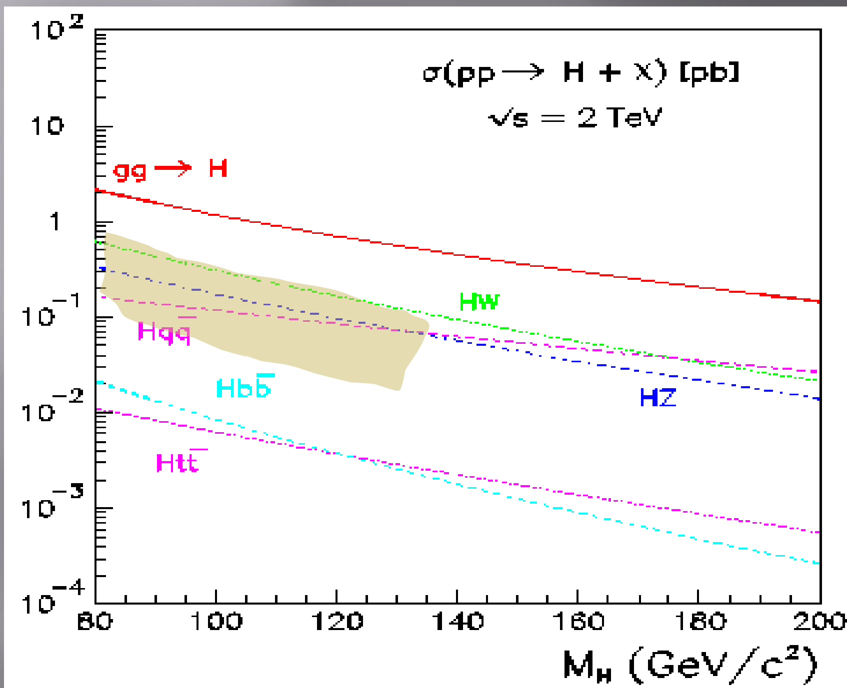


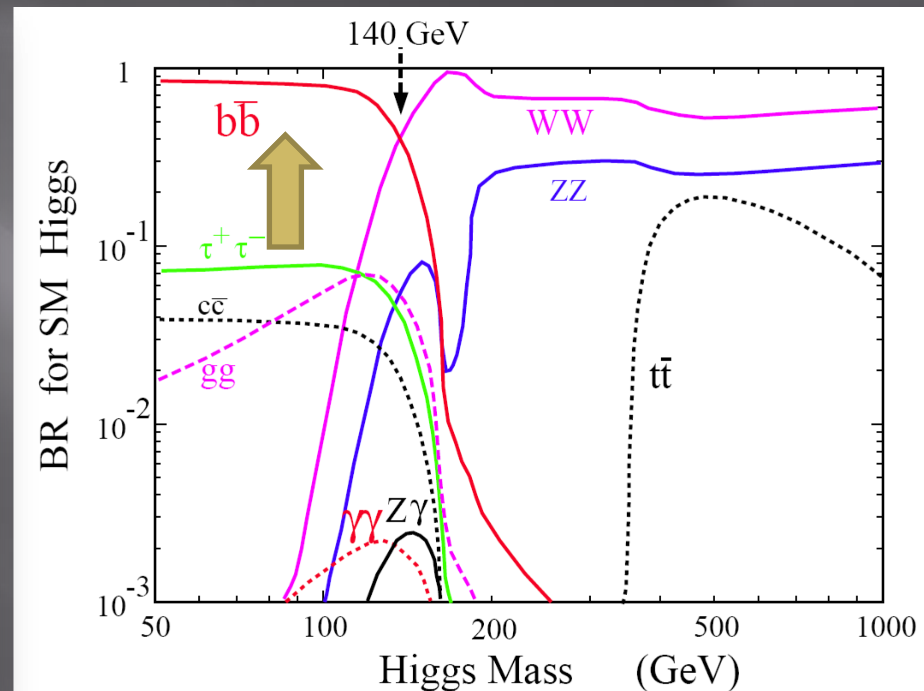
Highest Cross section production mode

- At low mass Higgs decay is lost to QCD bb background.
- At high mass Higgs decay to dibosons provides a clean signal.

Search Strategy

Both production and decay determine how you can search!





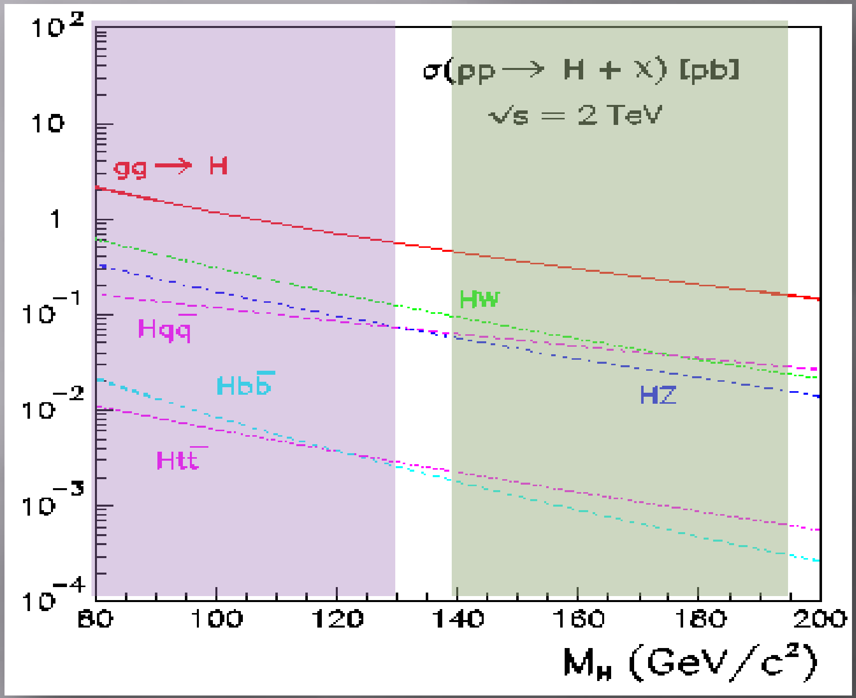
2 Associated Production

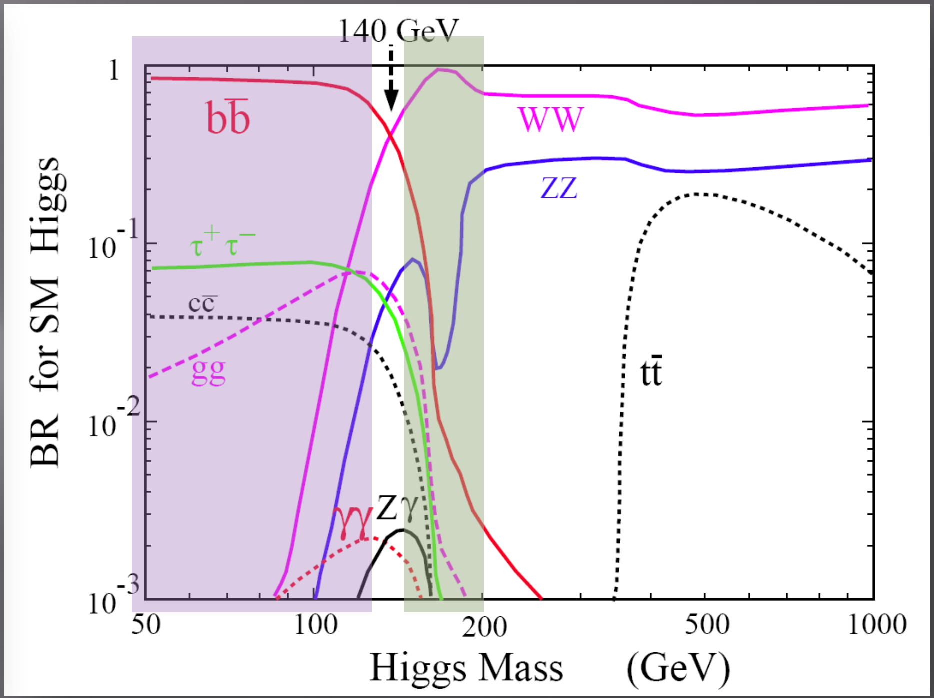
Lower cross section, but associated boson is easily identifiable.

Low Mass associated production search possible!

High mass possible, but gluon fusion has smaller background!

Search Strategy





M_H < 130 GeV/c² - Low Mass
Associated production and H→bb
Good lepton ID, Missing E_T, jet resolution, b-tagging

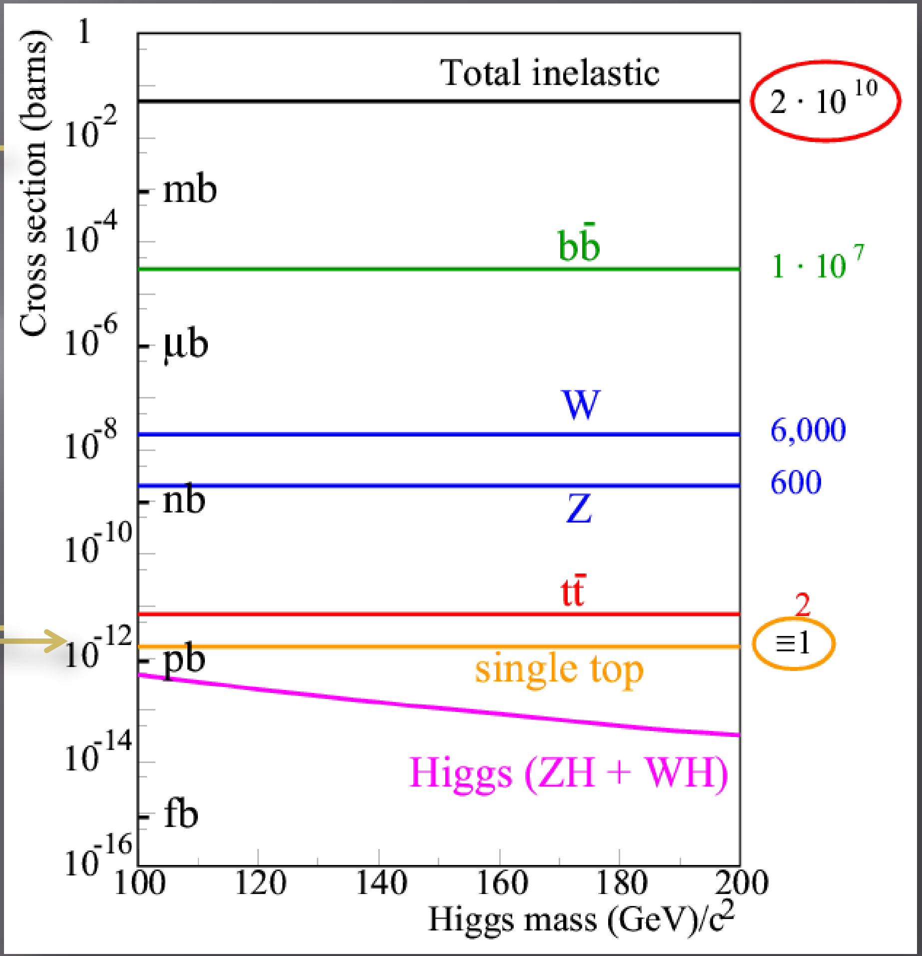
M_H > 150 GeV/c² - High Mass
Gluon Fusion and H→WW, ZZ
Good lepton ID and resolution

Why Haven't We Found It Yet?

Cross Sections at the Tevatron

Backgrounds for the Higgs Search…

State of the art searches are here…



We arrived at the tt line in 1995… We are probably months away from arriving at the single top line!

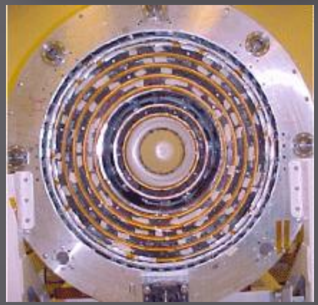
The DØ Detector

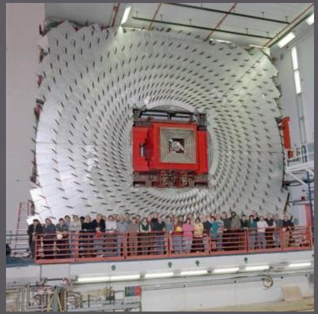
Low Mass Search: jet resolution, b-jet identification, lepton identification
High Mass Search: lepton identification and resolution

Many upgrades to the DØ Run 2 Detector were with this search in mind.

- New Central Fiber Tracker
- New Silicon Inner Tracking System
    - With Layer 0 added during winter 2006 shutdown
- Central Magnetic Field
- Preshower to help with lepton identification
- Improved muon coverage

New techniques to improve calibration and larger data sets to reduce systematic errors.





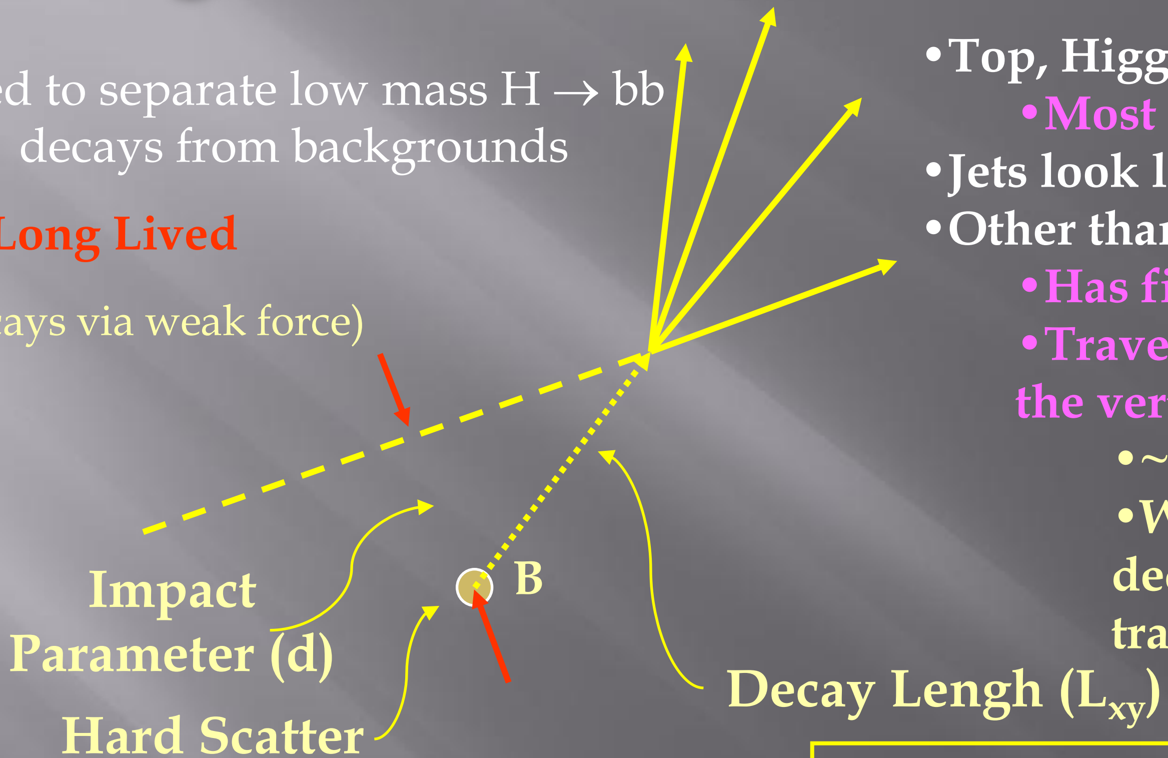
~700 Physicists
~90 Institutions
20 Countries

b-jet Identification

Used to separate low mass $H \rightarrow bb$ decays from backgrounds

A B is Long Lived

(decays via weak force)



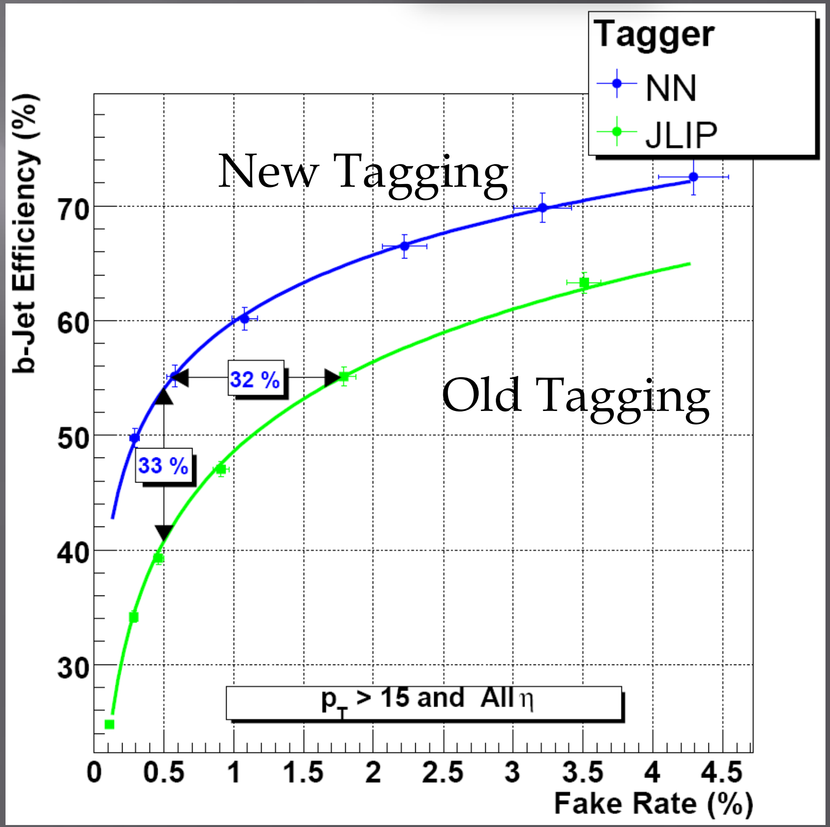
- **Top, Higgs contain b-quark jets**
  - **Most backgrounds do not**
- **Jets look like any light quark jet**
- **Other than contain a B meson**
  - **Has finite life time**
  - **Travels some distance from the vertex before decaying**
    - **~ 1mm**
    - **With charm cascade decay, about 4.2 charged tracks**

Impact Parameter Resolution	$d/\sigma(d)$
Decay Length Resolution	$L_{xy}/\sigma(L_{xy})$

NN Tagging

SVT, JLIP, CSIP } SVT L_{xy}, Fit χ^2, #tracks, Mass, #vertices; CSIP tag; JLIP Probability → Neural Network

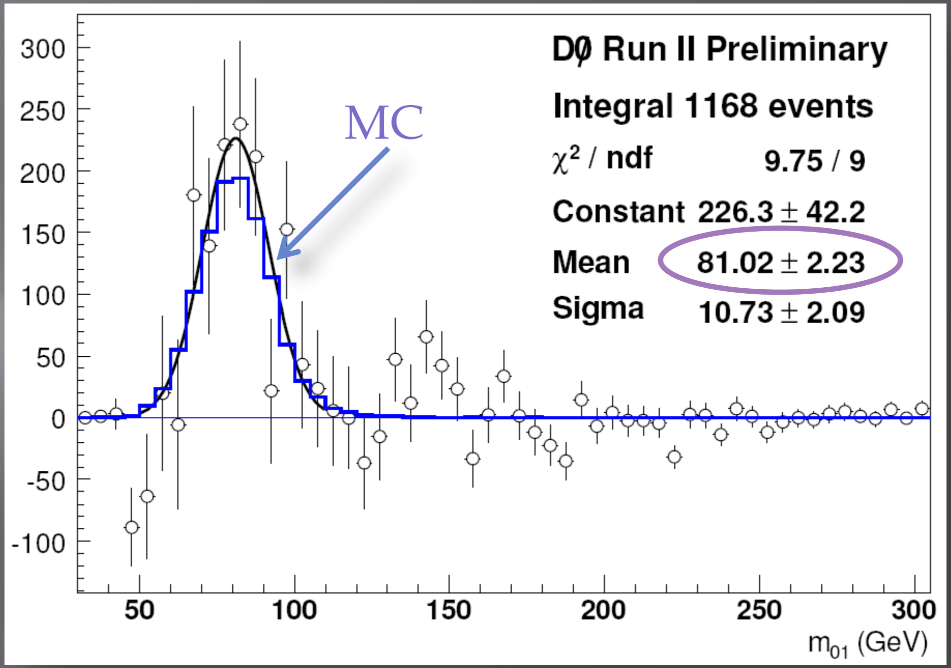
- Training on Monte Carlo
  - b-jet vs. light jet training
  - No explicit requirement on charm
- Standard data-based System 8 method to measure performance on data



In some channels it is estimated this is worth x2.5 in luminosity

Basics: Z→bb result

- Low mass Higgs search techniques look for a peak in the bb invariant mass.
- Calibration of b-jet-energy-scale.
- Z→bb is a background in these searches.
  - Trigger on soft lepton from b-quark decay (pre-STT)
  - Require two jets, each with a secondary vertex



Background from Data

Single Tagged Data → Apply 2-tag/1-tag rate function → Correct for shifts in Z Peak

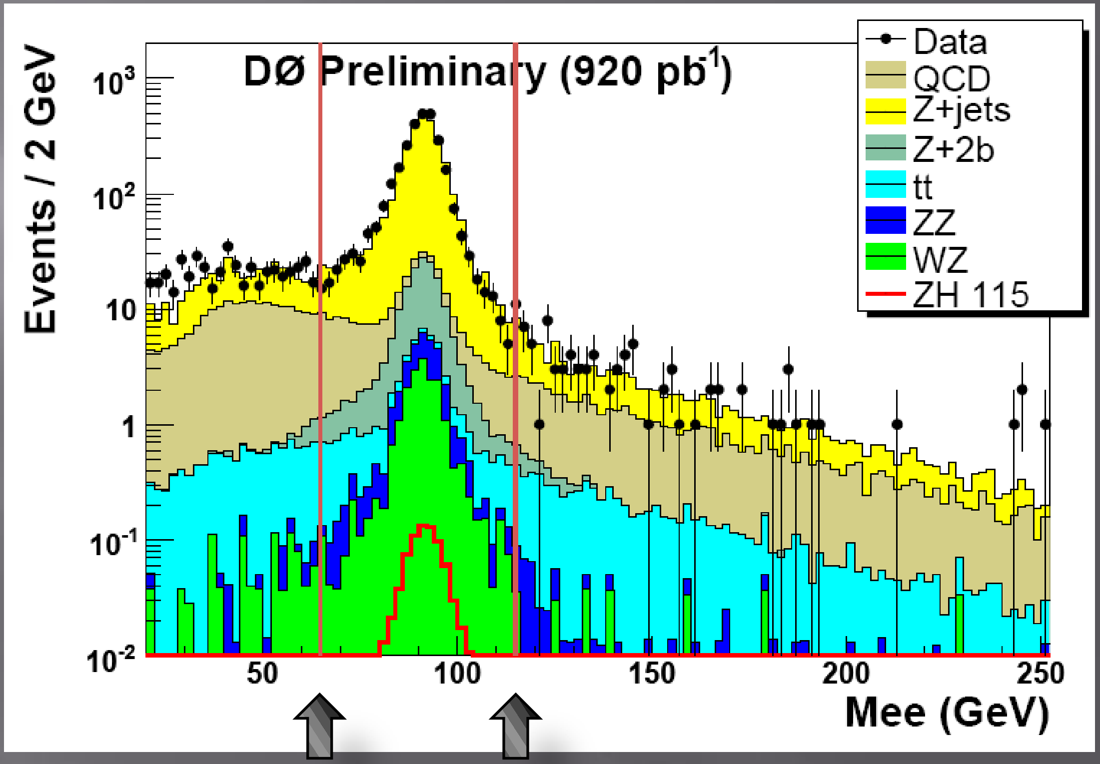
In 300 pb-1 of data see a 4.4σ result.

Search in ZH Associated Production

The Z decays to ee or μμ, and the Higgs to two b quarks.

1 Look for easy to find Z

Also require at least 2 loosely tagged b-tagged jets

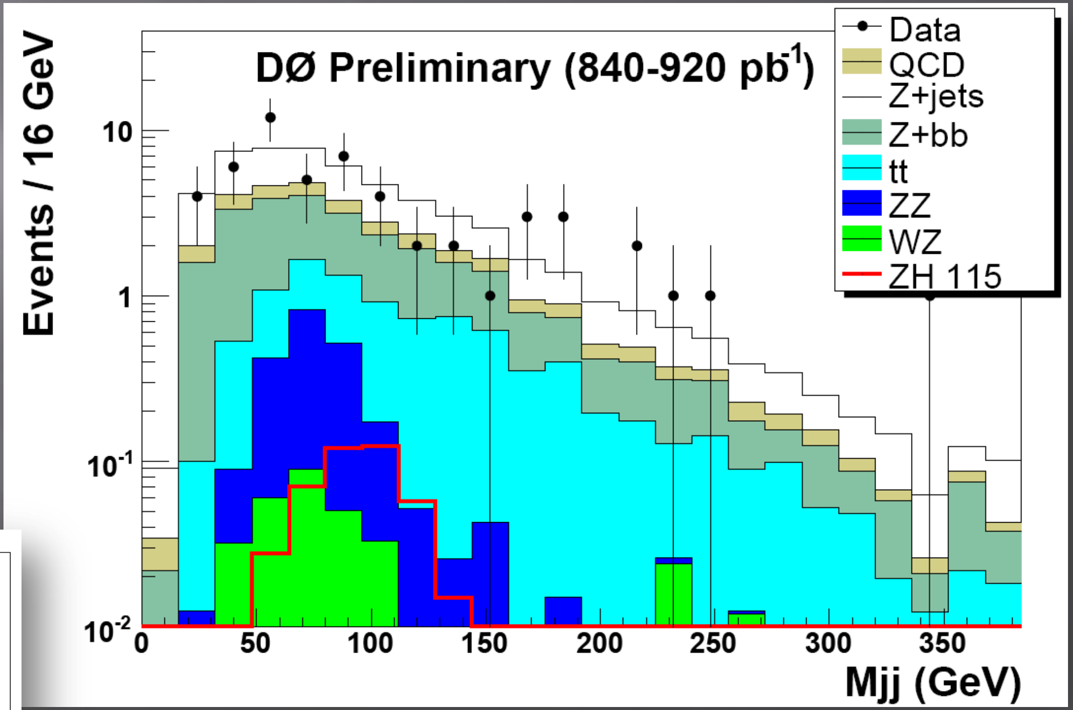


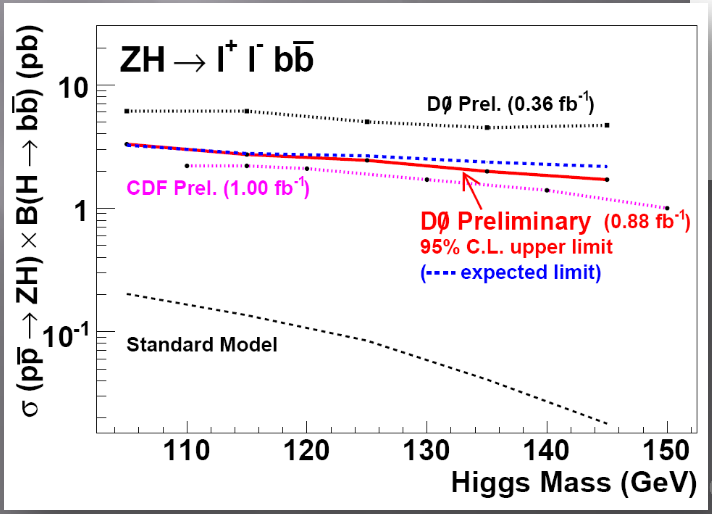
- Trigger on (e, μ) from the Z
- Normalize # of Z's in MC to Z peak in data
  - 70 GeV/c^2 < M_z < 110 GeV/c^2
- 2 loose b-tags required (4% background)
- QCD removed by fitting exponential (QCD) + Gaussian (Z) to the data

Search in ZH Associated Production

2 Look at the di-jet mass spectra for evidence of the Higgs

- $105 < M_H < 155$
- Higgs search window size is ± 1.5σ (e channel) and +1.0-2.0σ (μ)
- Cross check background model in 0 and 1 tagged samples, set limit in 2 tagged sample





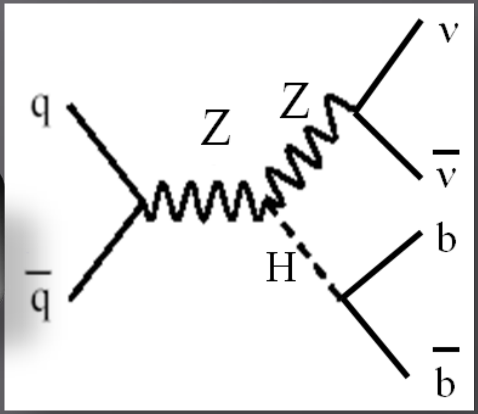
3 Set limits using modified frequentist approach (CLs)

Search in ZH Associated Production

The Z also decays to neutrinos!

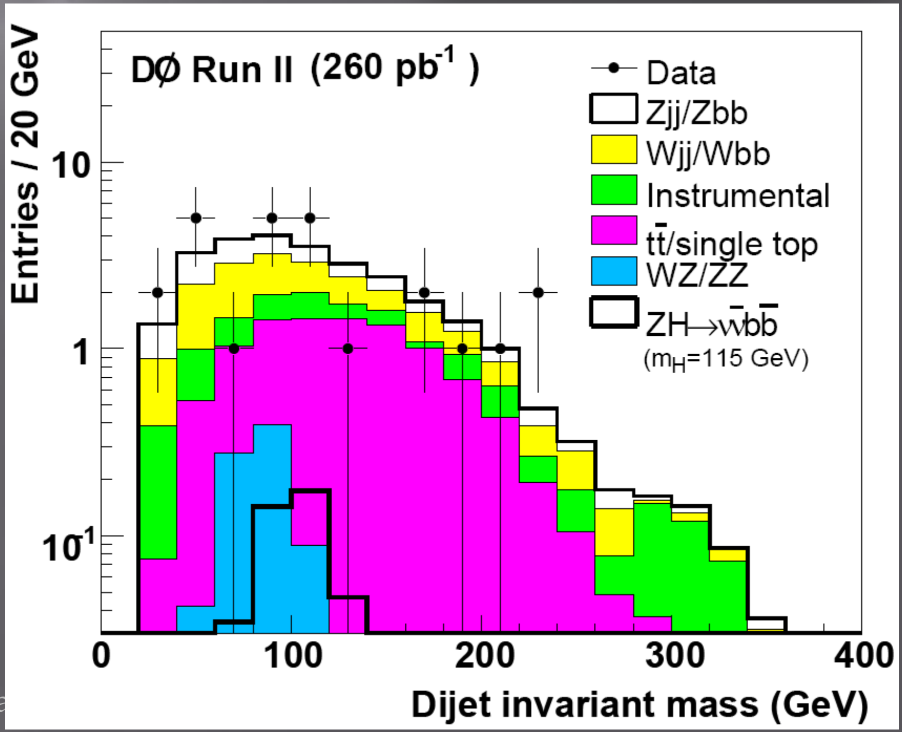
$\sigma(qq \rightarrow ZH) \times Br(Z \rightarrow \nu\nu, H \rightarrow bb) = 0.015$ pb @ $m_H = 115$ GeV
$\sigma(qq \rightarrow WH) \times Br(W \rightarrow l\nu, H \rightarrow bb) = 0.03$ pb (e, μ)

Comparable



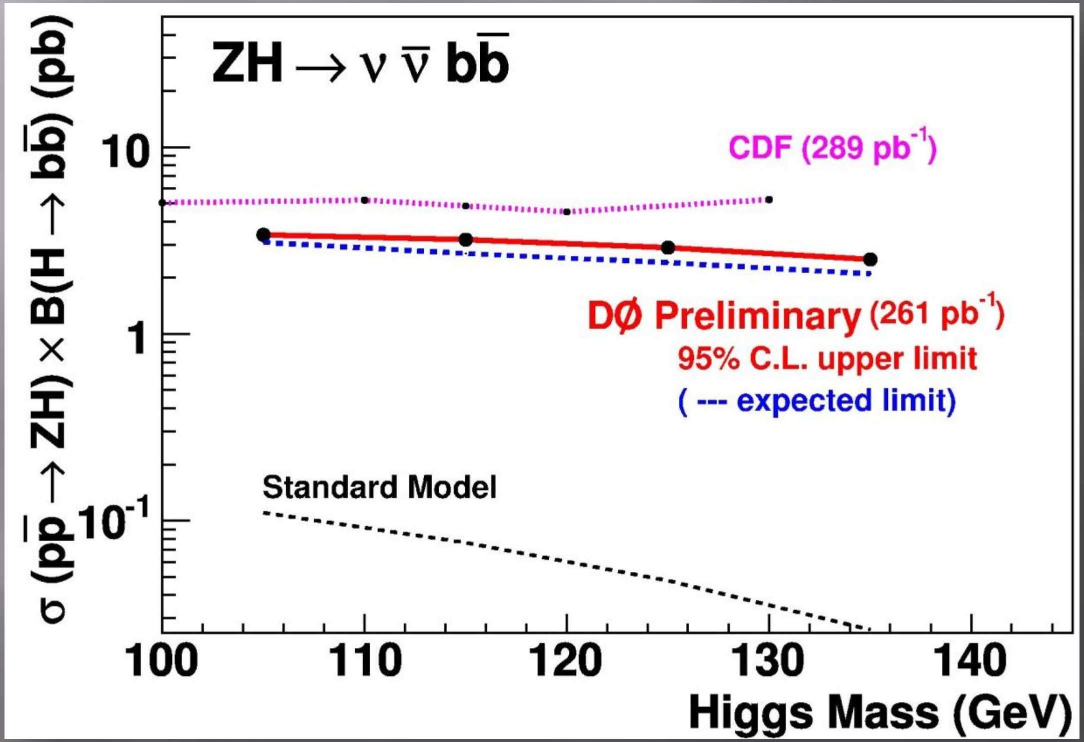
- Large Missing E_T (50 GeV)
- 2 b-quark jets
- Reject top events (H_T < 200)

- W+jets, Z+Jets, tt, WW, ZZ estimated by MC
- Instrumental Backgrounds from data



Search in ZH Associated Production

Combined 1 and 2 tag channels for limit



Composition	Single Tag (%)	Double Tag (%)
Zjj	8	3
Zbb	5	16
Wjj	38 ★	16
Wbb	5	12
Top	16	33 ★
WZ/ZZ	1	7
Instrumental	26	13

Search for Higgs in associated production: WH → lνbb

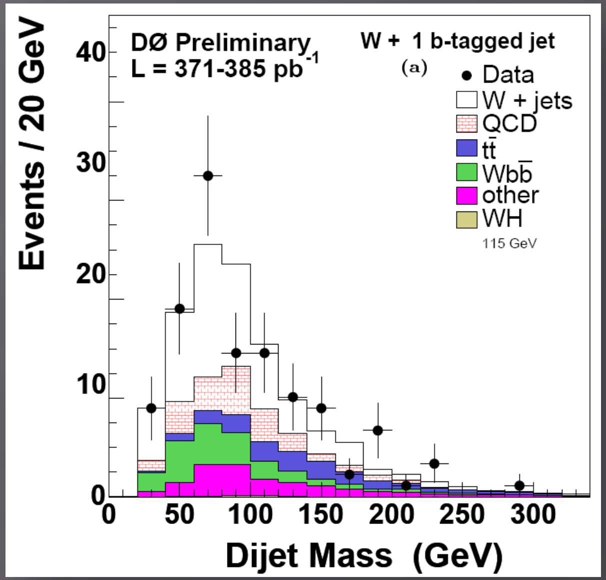
Look for a high p_T lepton and missing E_T and at least two jets.

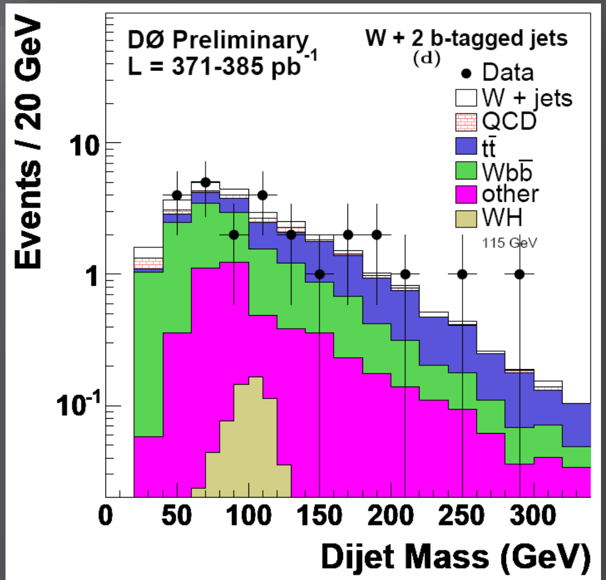
Asymmetric b-tagging
- Two loose tags, or
- One tight tag

QCD background determined from data

W+Jets, Wbb, Z+Jets, WW, ZZ, tt are from MC.

W+Jets normalized to data

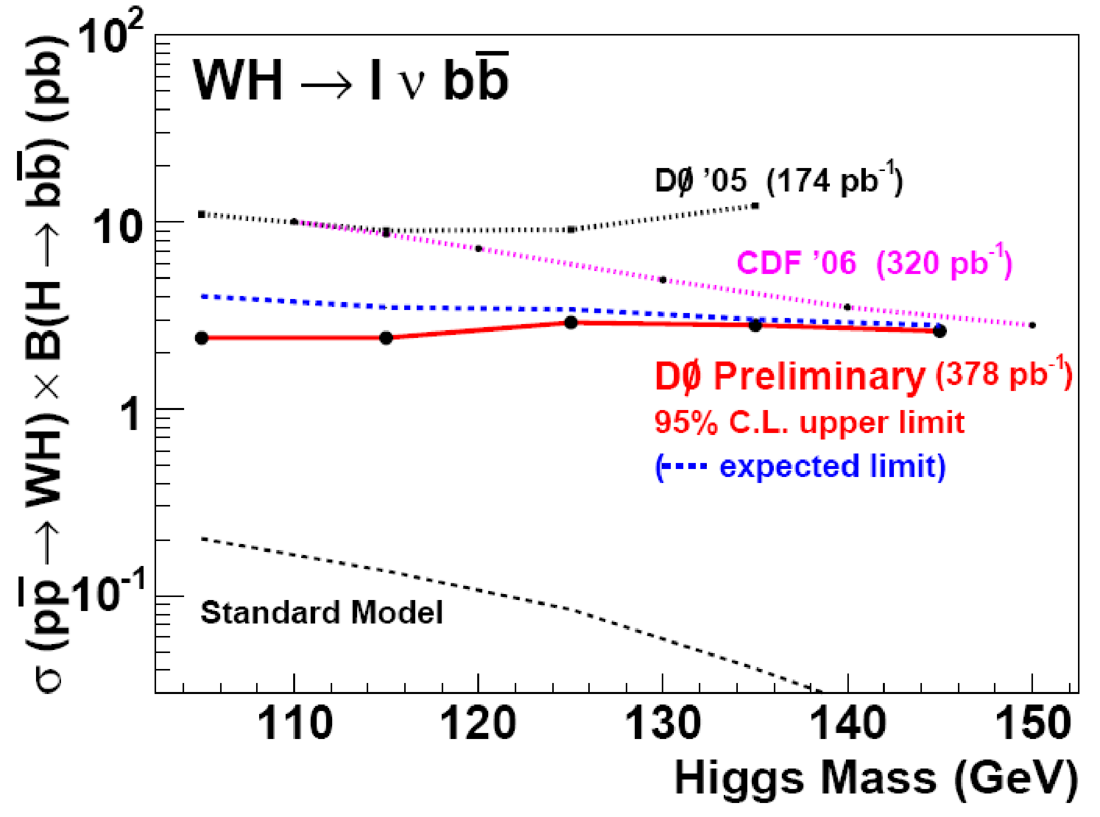




Search for Higgs in associated production: WH → lνbb

Combine single and double tag samples for cross section limit

- Most of the sensitivity comes from the double tagged events

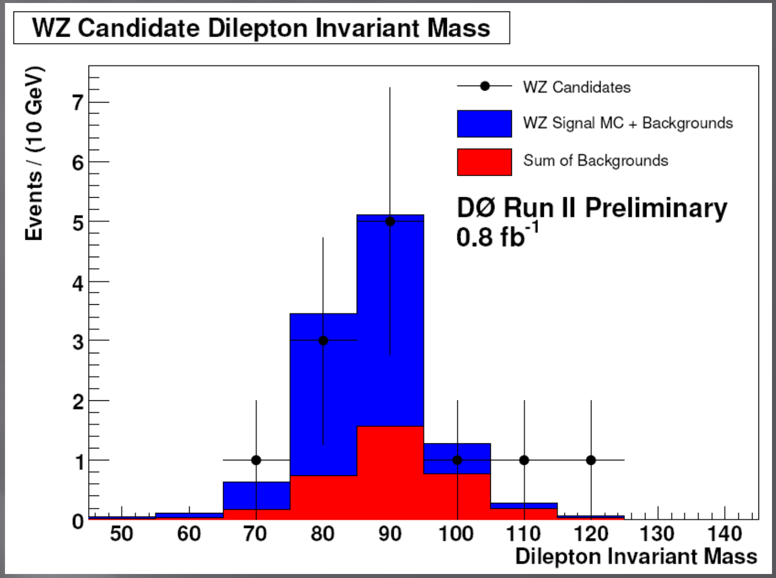


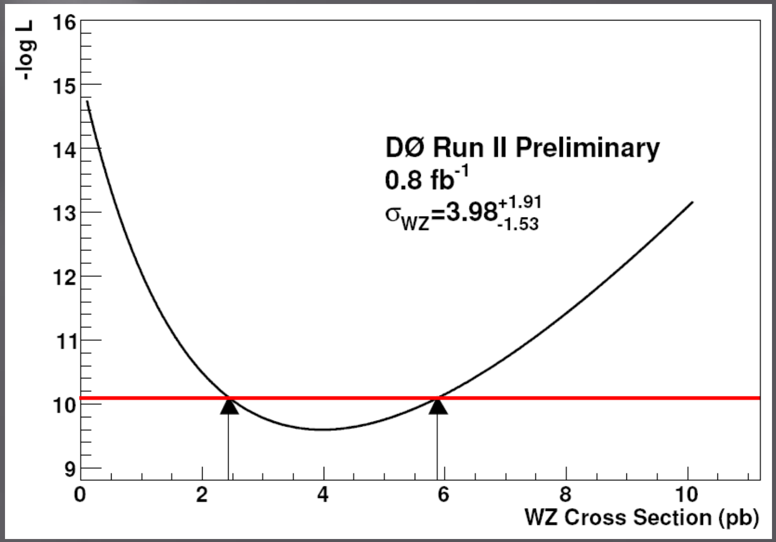
Basics: Evidence for WZ

- A multi lepton signal very similar to Higgs ZZ or WW.
- Final State is 3 leptons (e or μ).
  - Z peak is required.

Decay Channel	Number of Candidates	Overall Efficiency	Expected Signal	Estimated Background
eee	2	0.158±0.012	1.83±0.35	0.960±0.069
$ee\mu$	1	0.167±0.029	1.84±0.52	0.485±0.053
$\mu\mu e$	7	0.175±0.043	1.80±0.63	0.963±0.080
$\mu\mu\mu$	2	0.205±0.033	2.07±0.56	1.203±0.143
Total	12	-	7.54±1.21	3.61±0.20

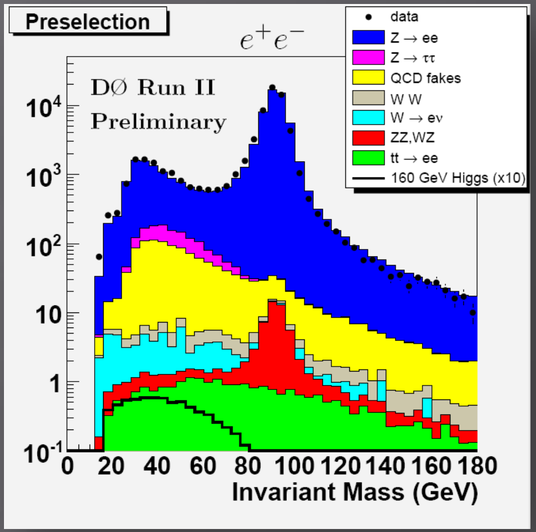
$\sigma_{WZ} = 3.68 \pm 0.22$ pb (MCFM)



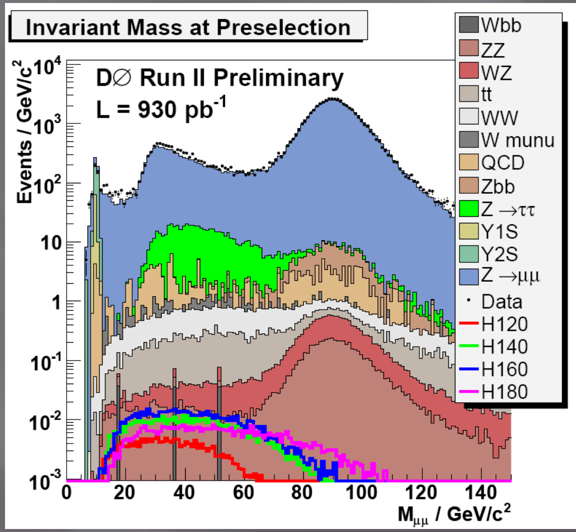


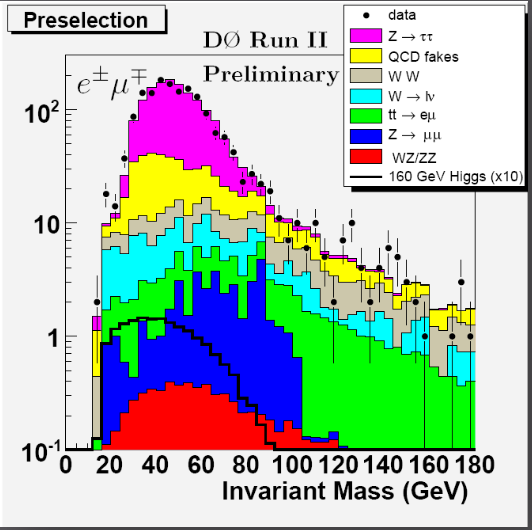
High Mass H → W^+W^- Search

- Di-lepton required (ee, μμ, eμ)
  - Require opposite charge
- Kinematic cuts to limit to Higgs-Like Decays
  - Low Jet Activity
  - p_T's of leptons and missing E_T is larger than $M_H/2$, but less than M_H.
  - Remove Z peak in appropriate channels
- Look at Higgs masses 120 GeV/c² < M_H < 180 GeV/c²
- Data Normalized to Z peak



Good agreement in data after basic cuts

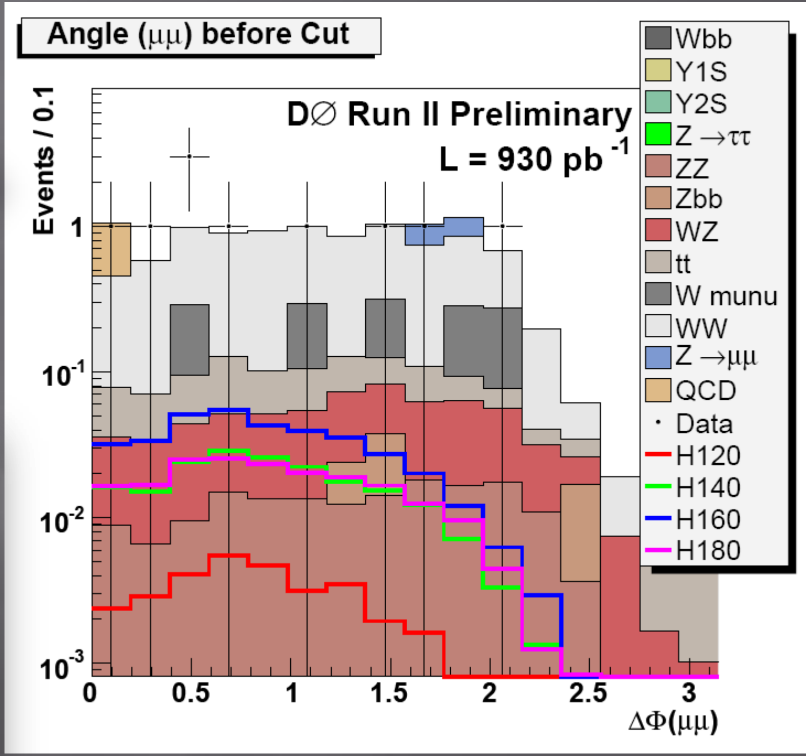


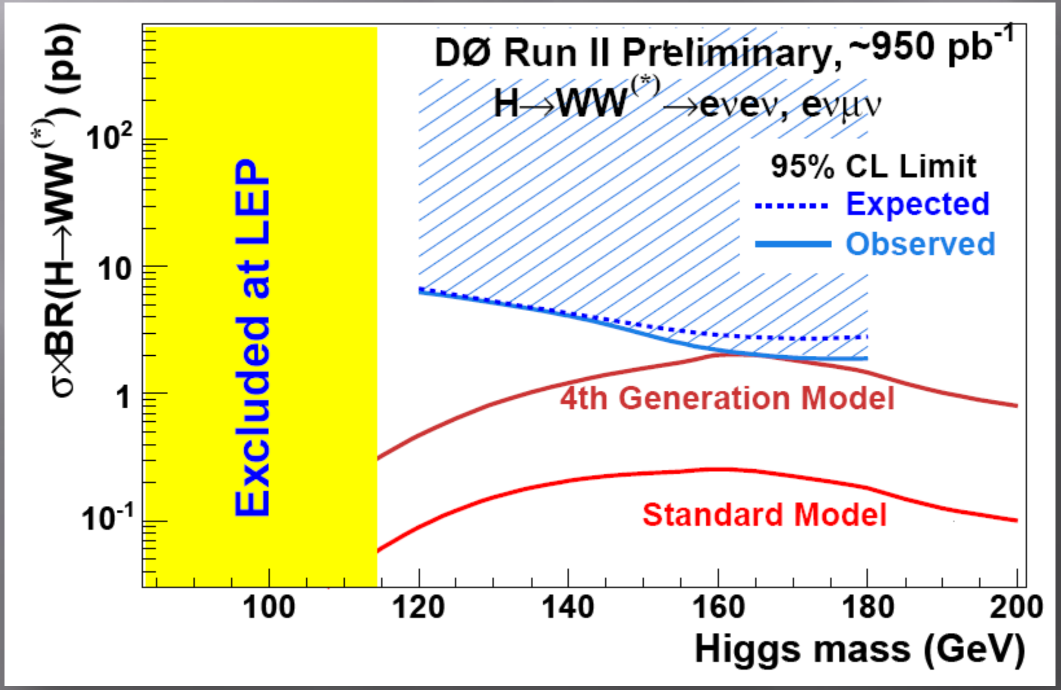


H -> WW->Leptons

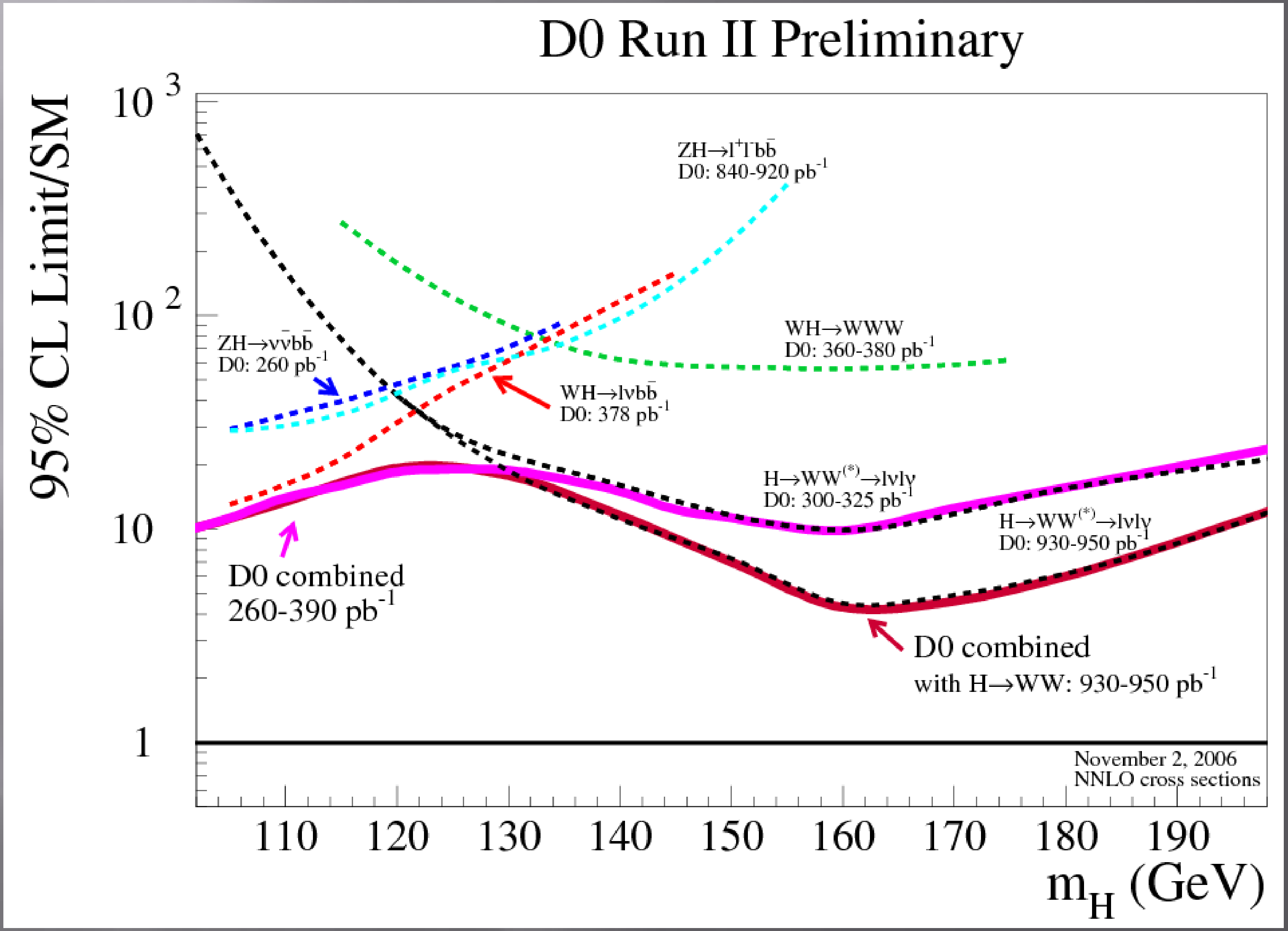
Final cut is opening angle between the two leptons

- The Higgs is a spin 0 particle which makes Δϕ a powerful cut.





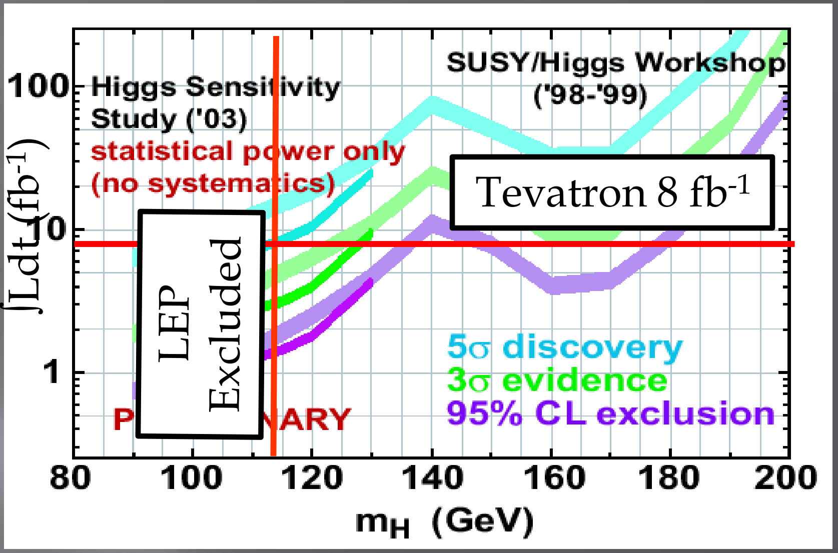
DØ Limit Summary



The Road Ahead

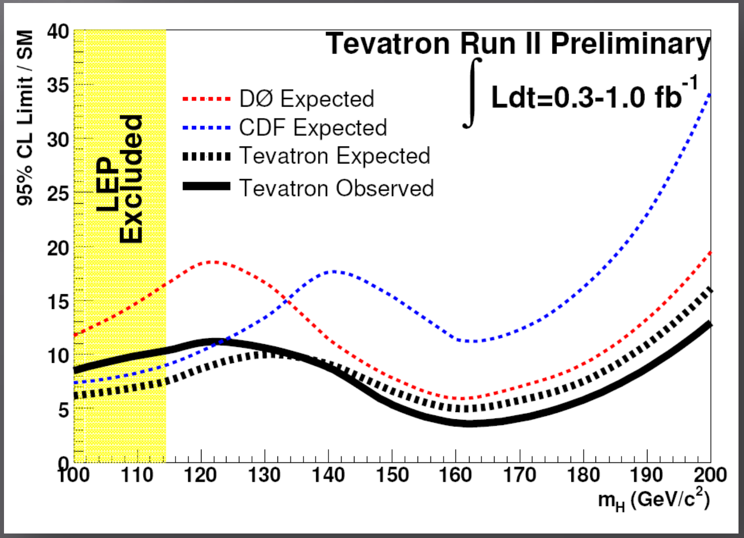
The 2003 Higgs Sensitivity Study

- Sensitivity in the mass region above LEP limit (114 GeV) starts at ~2 fb^{-1}
- With 8 fb^{-1}: exclusion 115-135 GeV & 145-180 GeV, 5 - 3σ discovery/evidence @ 115 – 130 GeV



The Tevatron New Phenomena & Higgs Working Group

- First Combination released Summer 2006
- Results better than either experiment individually



Higgs Prospects

Analysis

Improved Selection Techniques
- 20% improvement

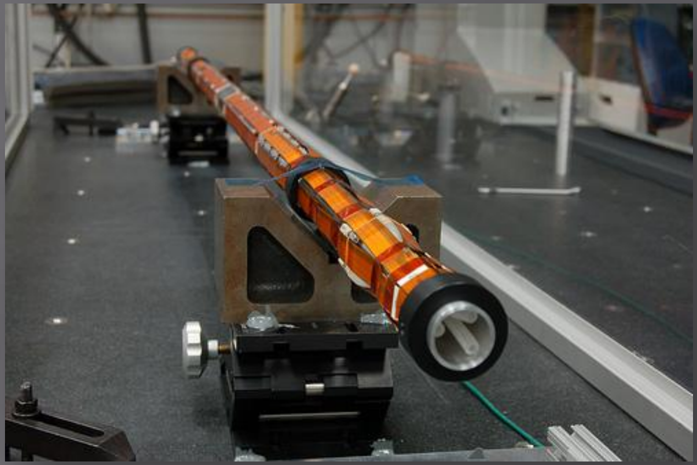
NN tagger used everywhere
- 25% improvement

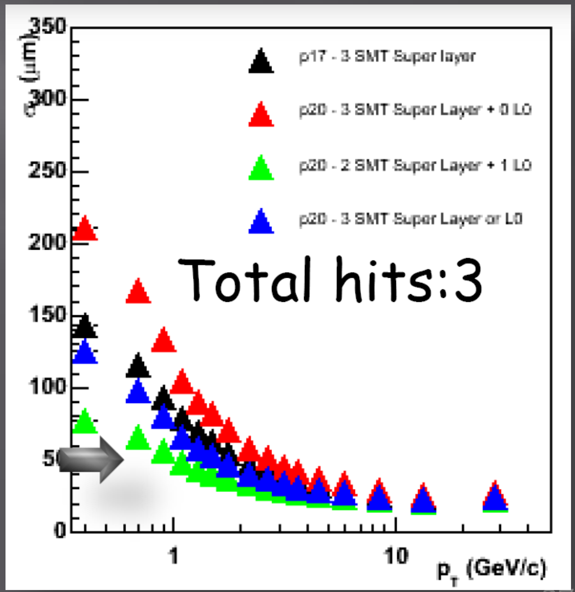
Larger Dataset reduces calibration errors and systematics – 25% improvement

Detector

All Analyses at 2 fb^{-1}
- 50% improvement

New Inner Layer Of Silicon
- 15% improvement





Conclusions

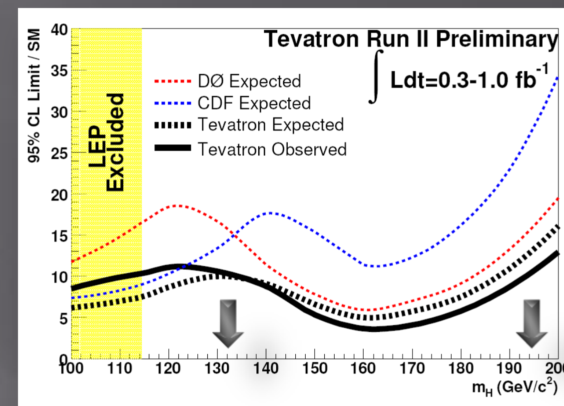
Hot topic hard to decide on!

Top, B, and New Phenomena groups all very active in DØ.

Higgs Searches will play a major roll in the future of the Tevatron

Active detector upgrade program designed to improve Higgs sensitivity

- Recent hardware upgrades should be measureable effect on Higgs sensitivity



Current Status: Measuring Backgrounds

Just fallen: WZ

Soon to fall: Single Top Production

Up Next

Most results updated to 1 fb^{-1} for winter conferences

This is a joint CDF/DØ endeavor!

We are here!