Standard Model Higgs Searches at the Tevatron (Low Mass : $M_H \leq$ ~140 GeV/c^2)

For the CDF and DØ Collaborations

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University of Chicago

The XLIIIrd Rencontres de Moriond EW

La Thuile in Italy, March 1 - 8, 2008

Fermilab

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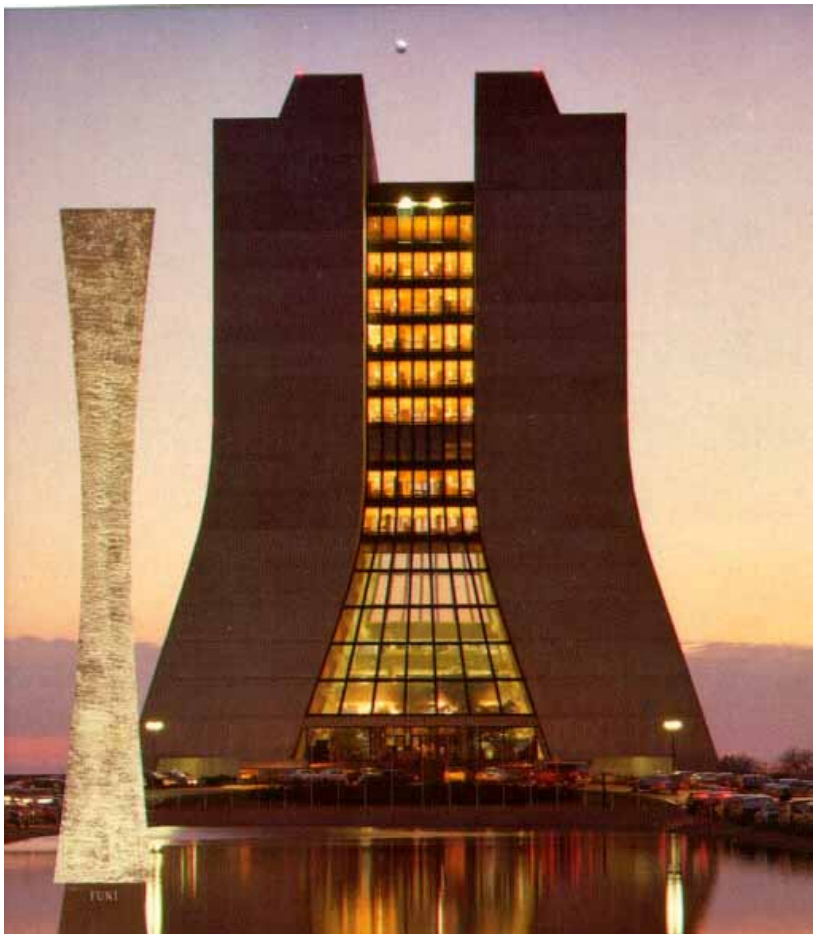

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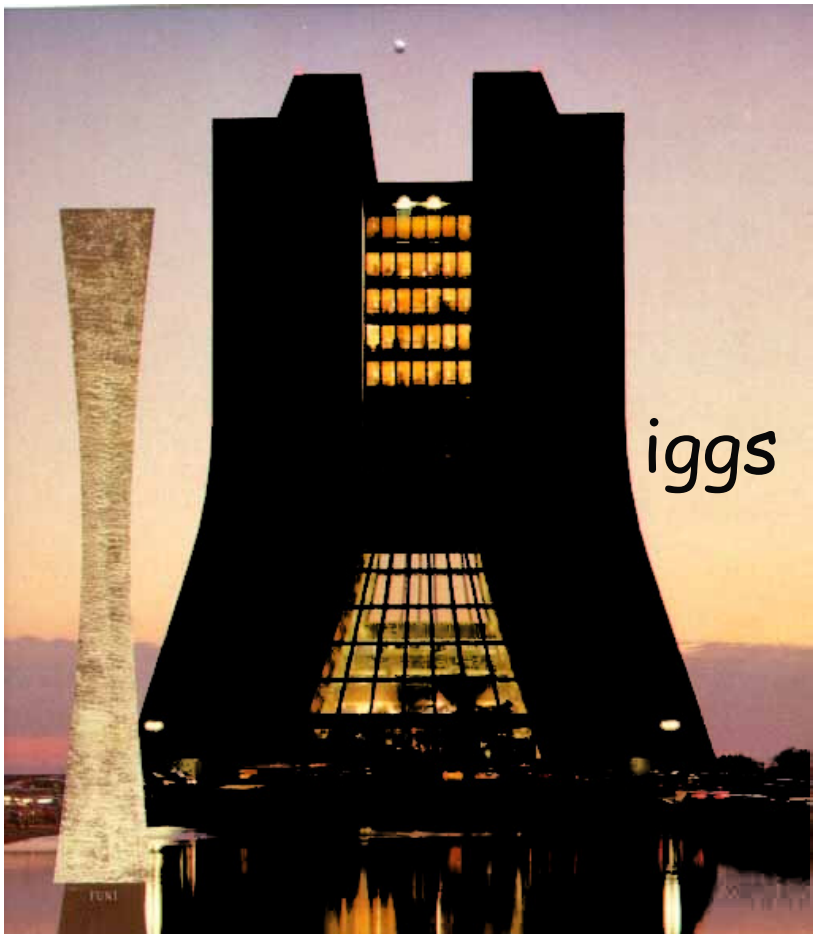
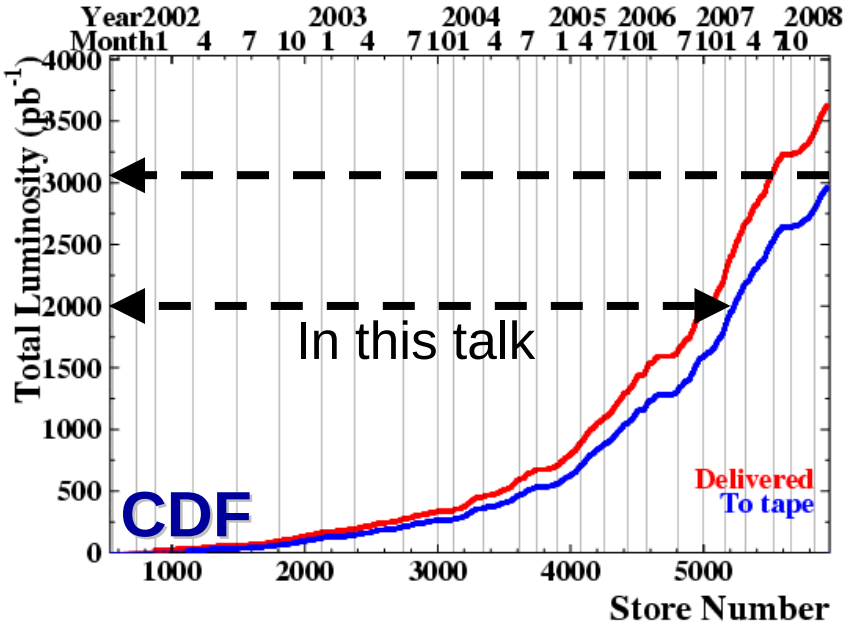
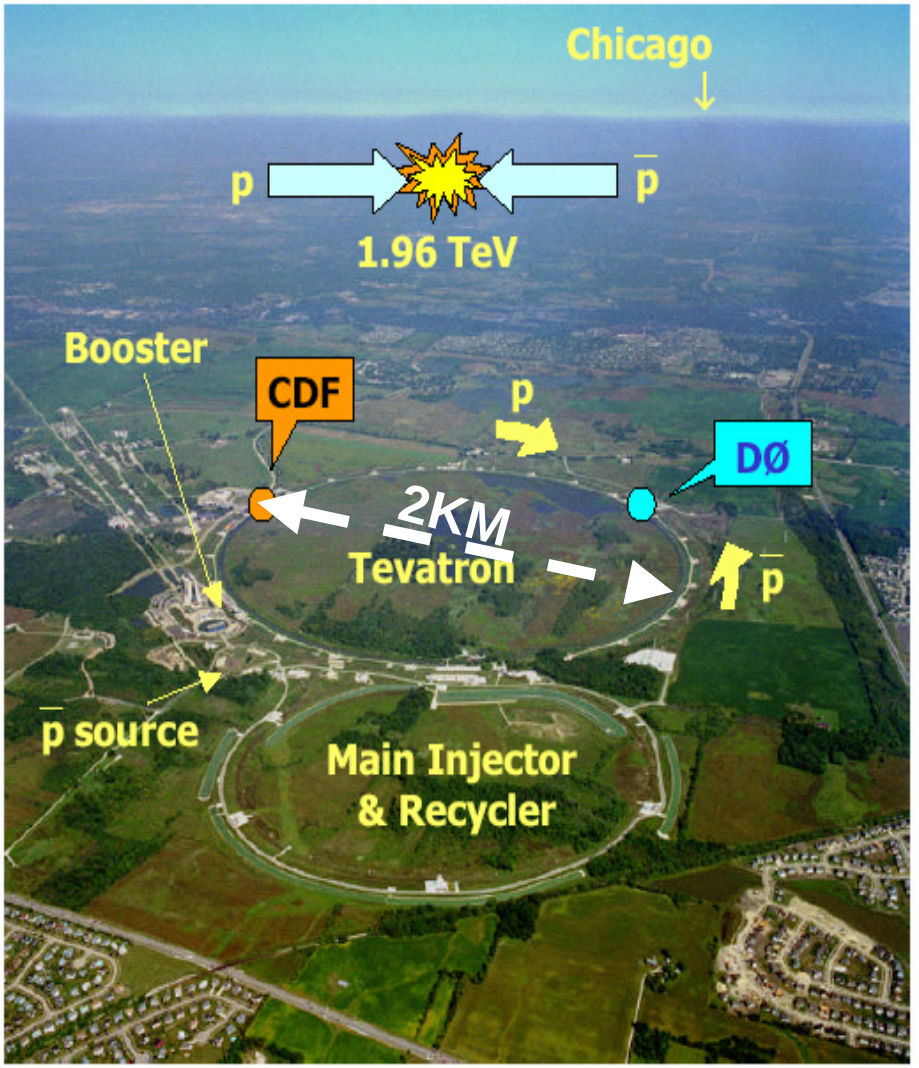


The Tevatron @ Fermilab

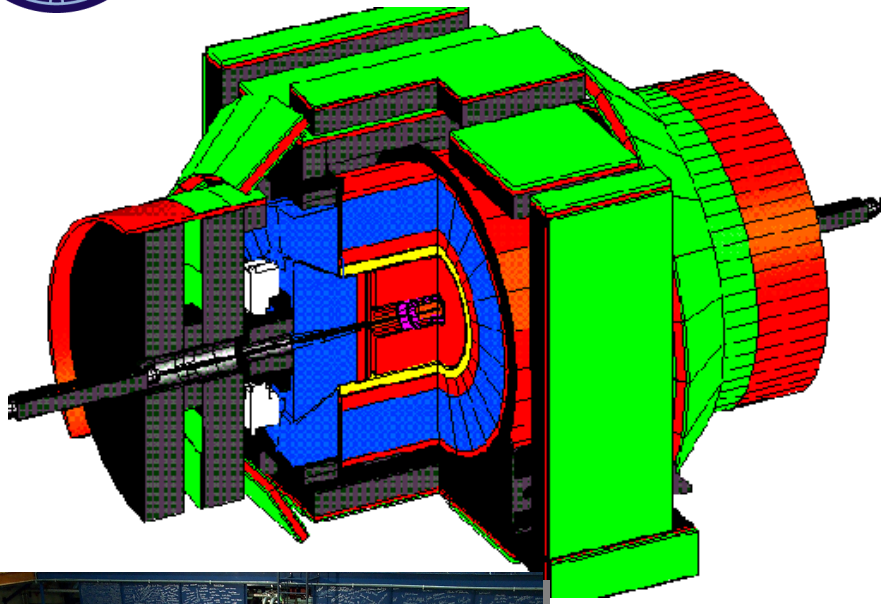
- $p\bar{p}$ collisions at 1.96 TeV
- 36x36 @ 396 ns bunch crossing

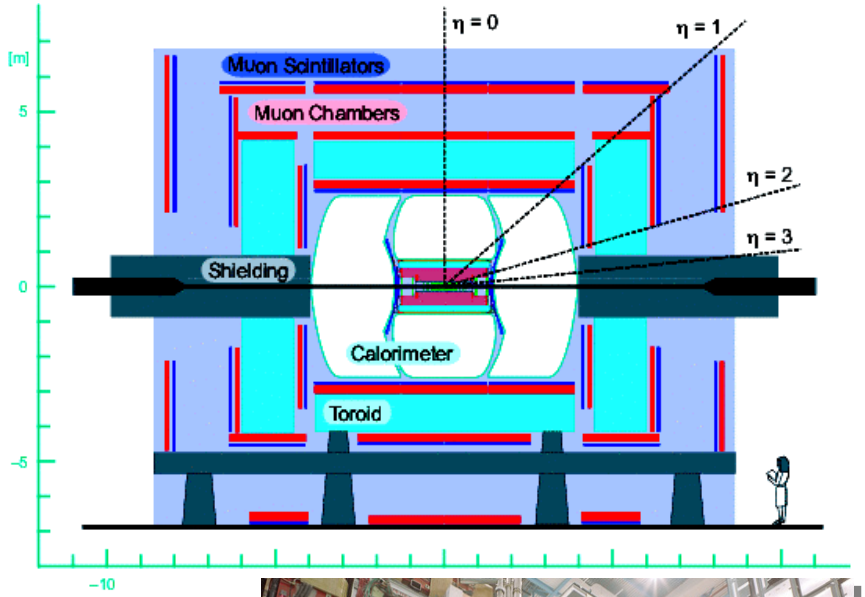


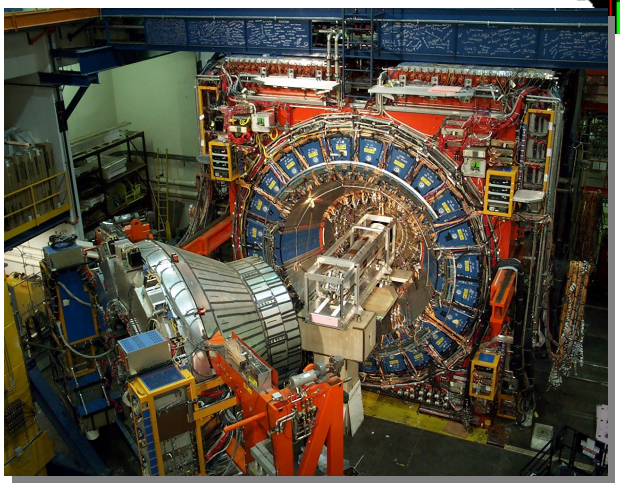
- ~3.0 fb^{-1} data on tape.
- Initial instantaneous luminosity
  Record: 2.9 x10^{32}cm^{-2}s^{-1}
- 6~8 fb^{-1} expected by end of 2009



CDF/DØ Detectors

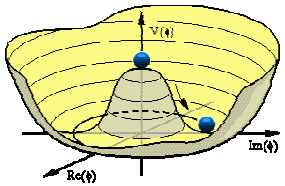




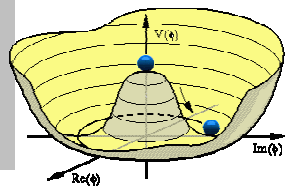


- Multipurpose detectors :
  "Classic onion-like design"
  - Trackers inside solenoid
  - Calorimeters(EM/Had)
  - Muon chambers
- Both running well !

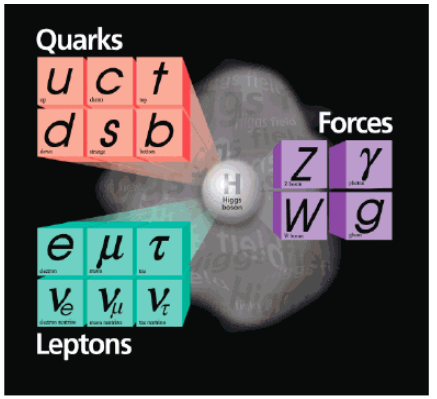
Broad physics programs are actively ongoing !



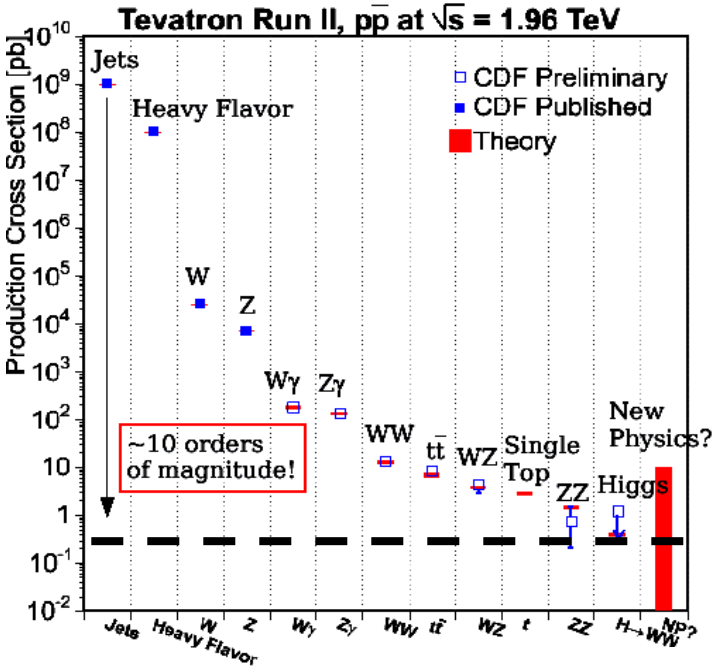
SM Higgs Boson



- The Standard Model has been well tested against experimental data and so far provided great success in particle physics.
  - BUT one particle undiscovered yet.
    - -> "Higgs Boson" :
      - "Origin of Mass" for all fermions & W/Z bosons.
      - "Origin of Electroweak symmetry breaking".
      - Spin 0, Charge 0



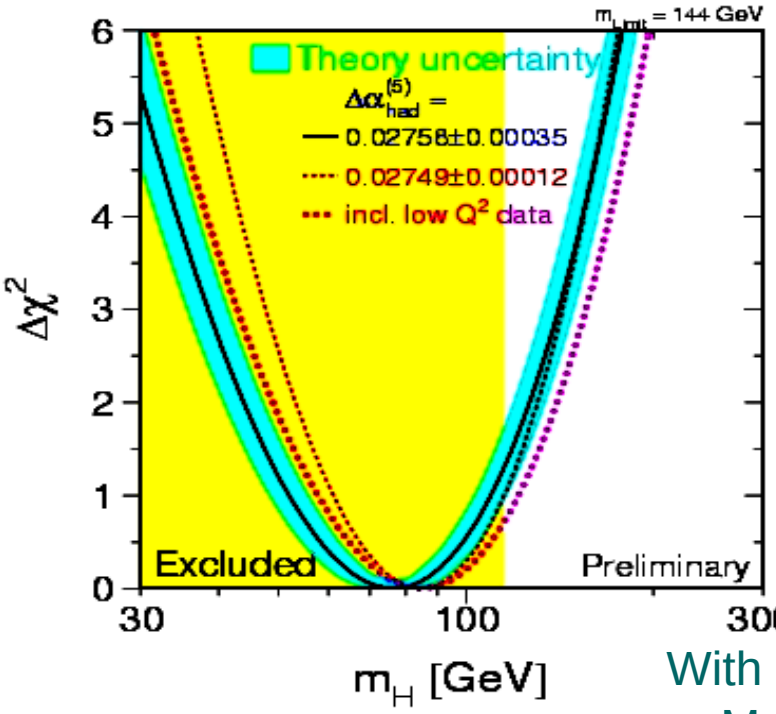
- Why so difficult to find Higgs ?
  - Small production cross section.
  - Large backgrounds.
  - The SM (by itself) does not predict the value of the Higgs boson mass directly. (possible through radiative corrections though)

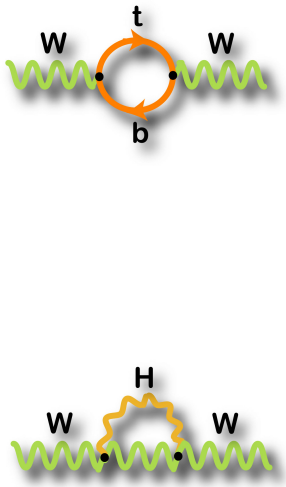


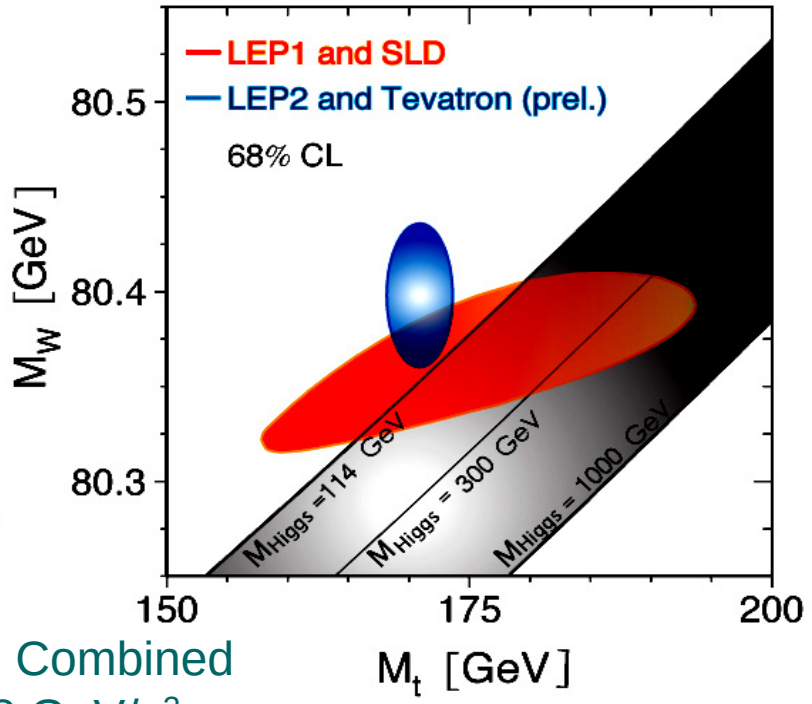
- Challenging but the most important task in High Energy Physics.

Low Mass Preferred !

- Direct search @ LEP excludes M_H<114.4 GeV @ 95% C.L.
- SM global fit gives the first indication on where to look !





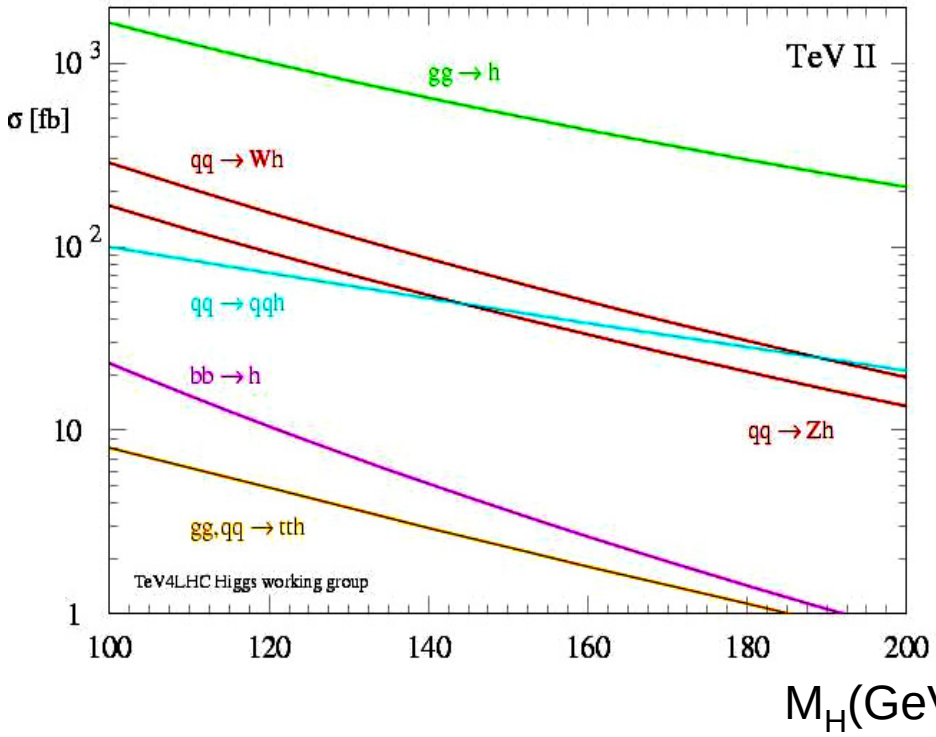


With 2007 Tevatron Combined
M_{top} = 170.9 ± 1.8 GeV/c^2

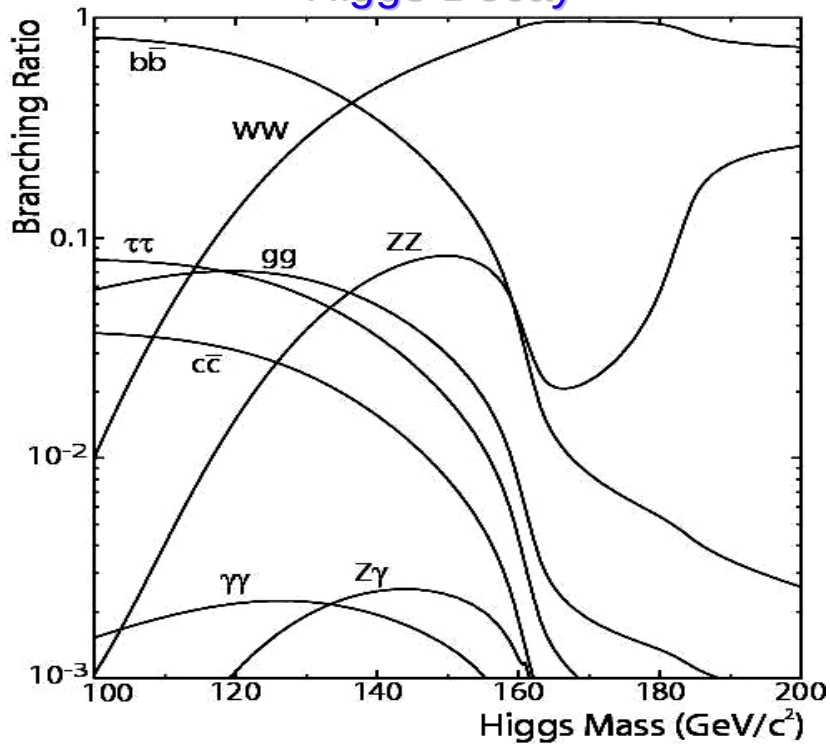
- The most probable value from SM global fit : $76 \pm^{33}_{24}$ GeV
  Upper bound (95% C.L) : <144 GeV (182 GeV if LEP limit included)

Production & Decay @ Tevatron

Production (pp @ 1.96 TeV)



Higgs Decay



- This talk focuses on ***low mass region***. (M_H<~140 GeV)
- High mass search will be presented by next speaker (L. Zivkovic).

- Main Channels @ Tevatron :
  - WH→lνbb
  - ZH→ννbb
  - ZH→llbb

* H→ττ : New results from CDF !

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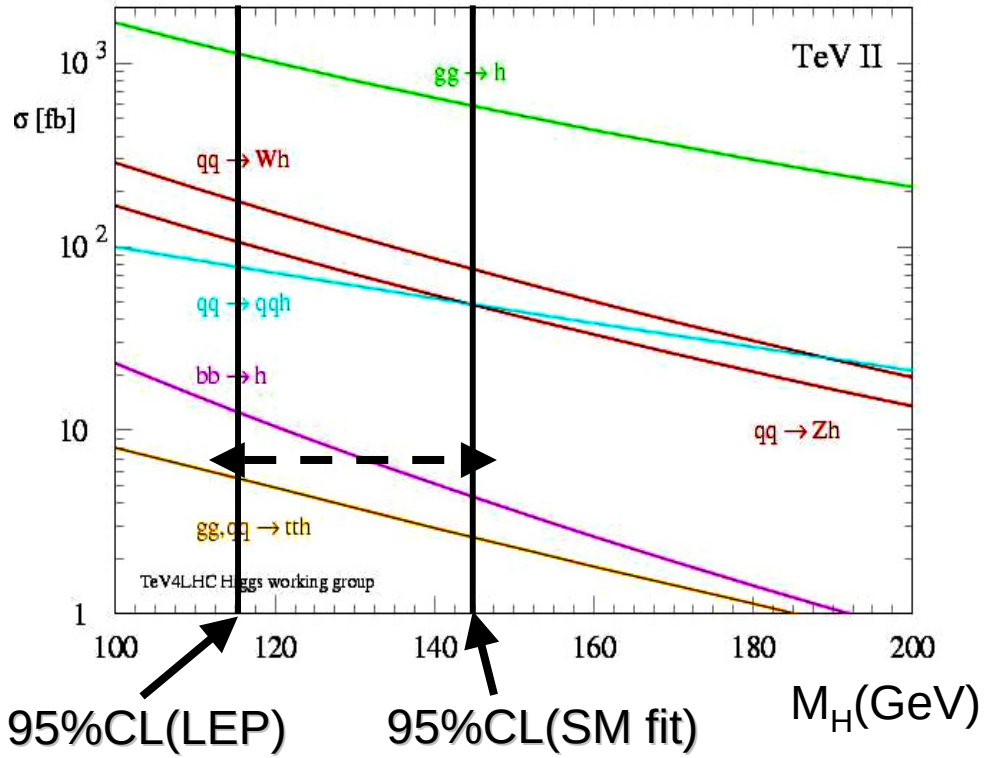

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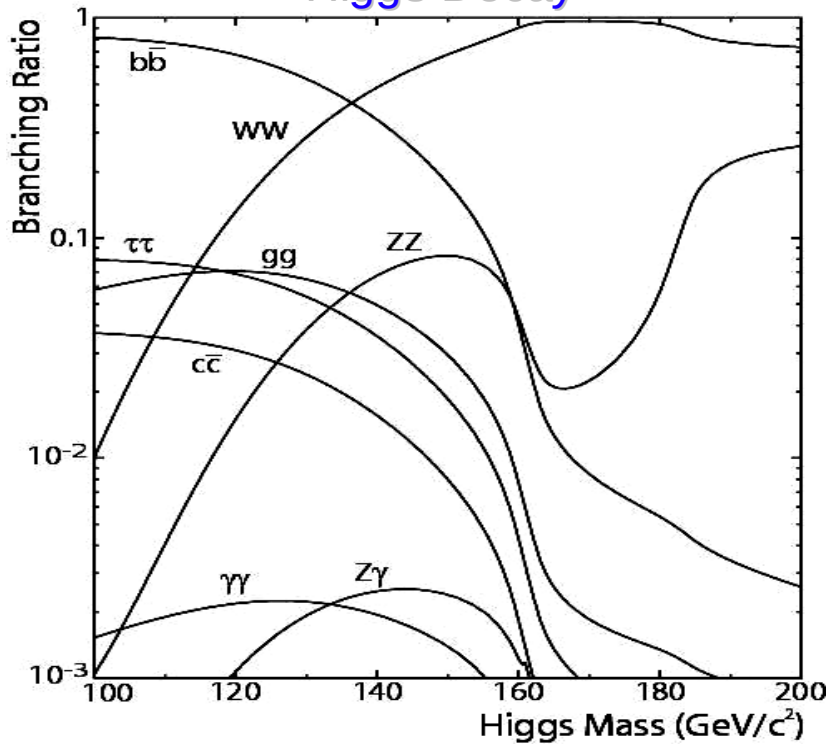

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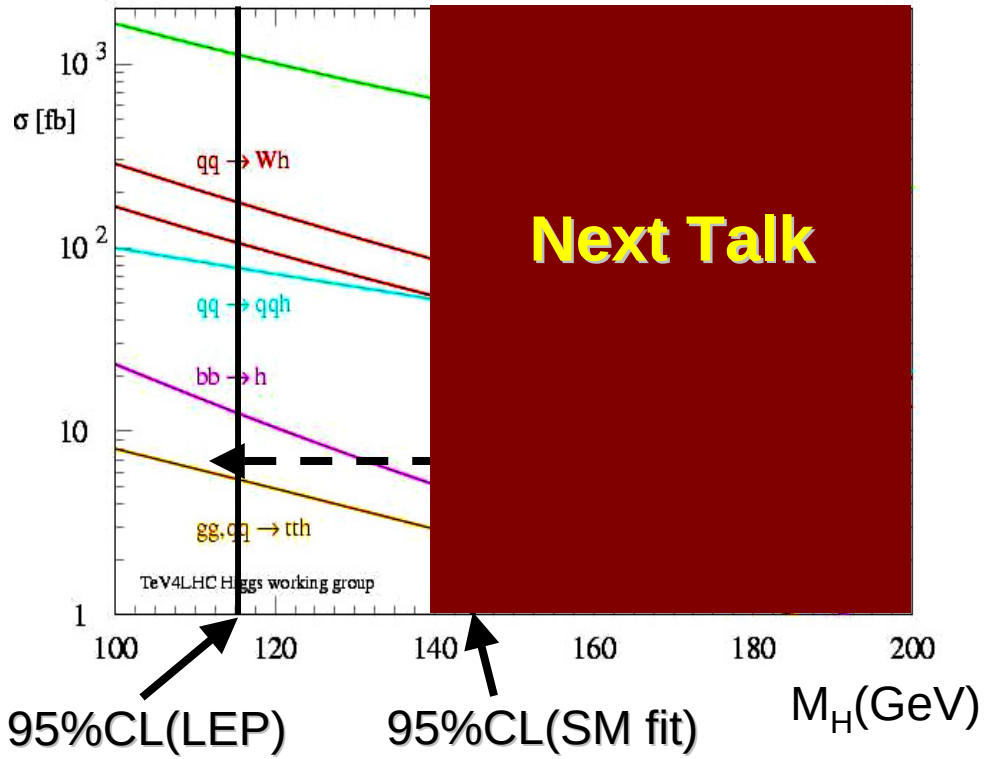
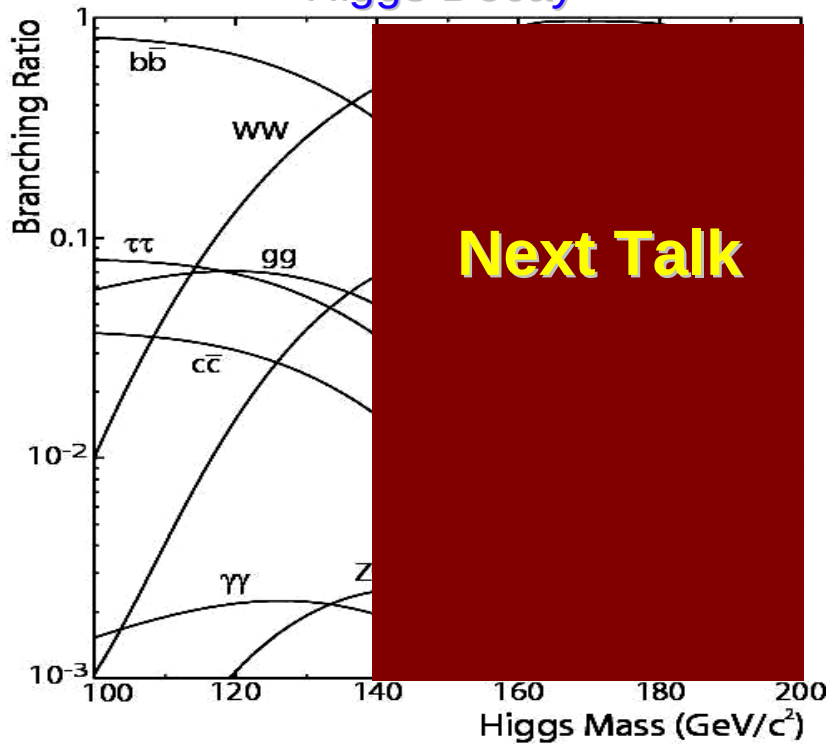


Higgs Decay



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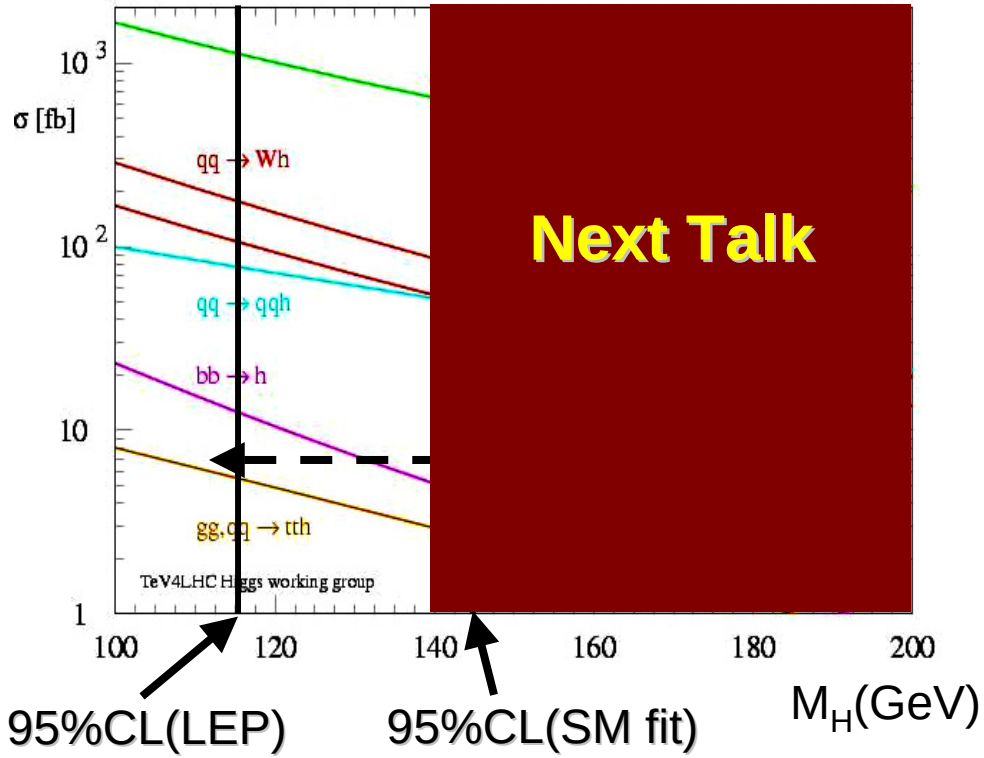

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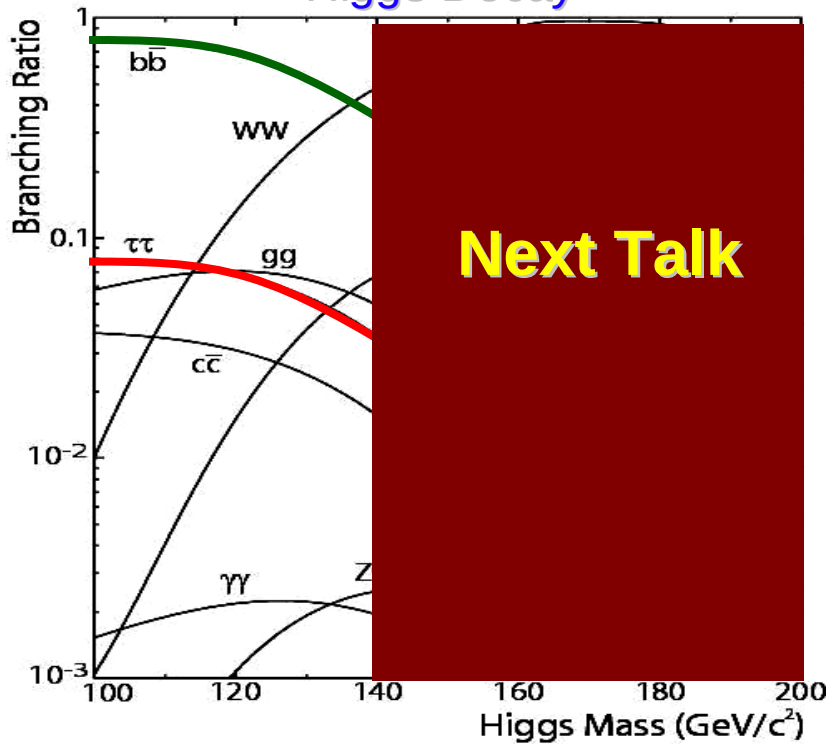

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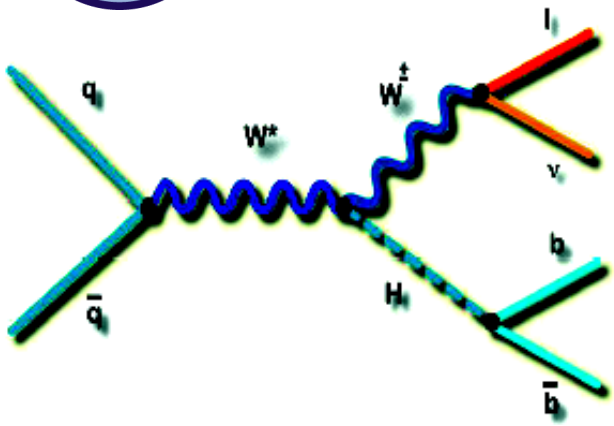
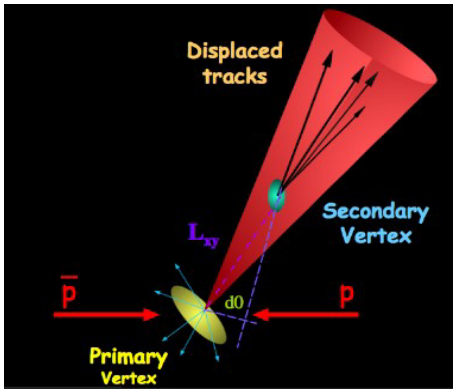
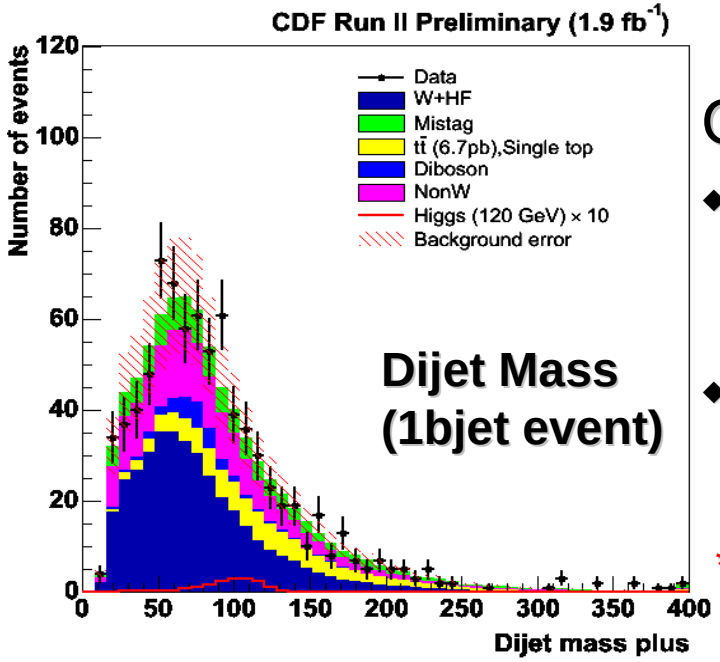
$WH \rightarrow l\nu b\bar{b}$



- Lepton P_T & Met > 20 GeV
- 2jets with 1 or 2 b-tagged.
- Main backgrounds are W+bb, QCD, ttbar.
- Employ Neural Net Technique to separate signal from bkg.

Bjet tagging

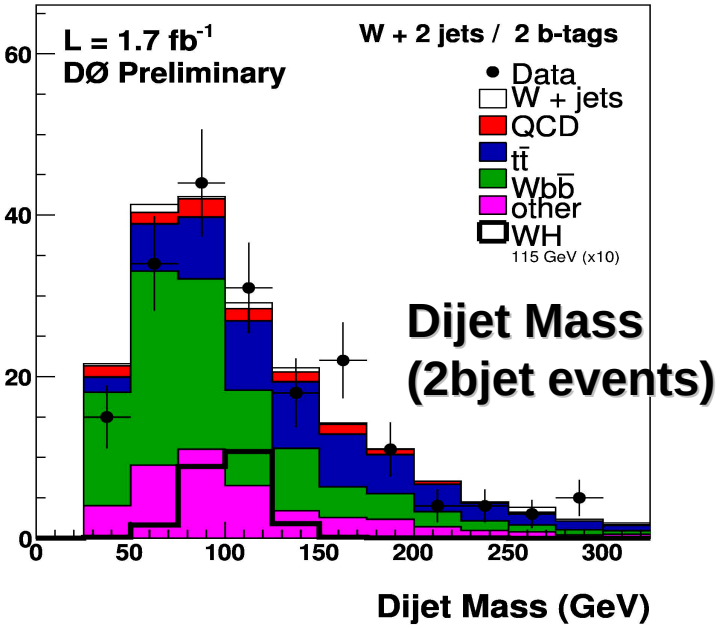




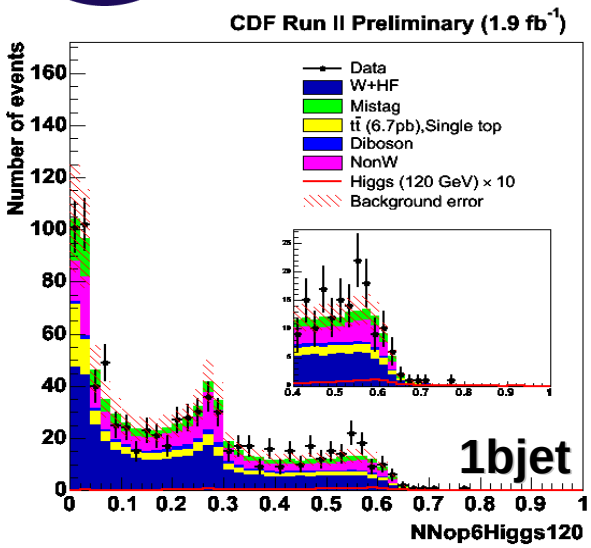
CDF updates:

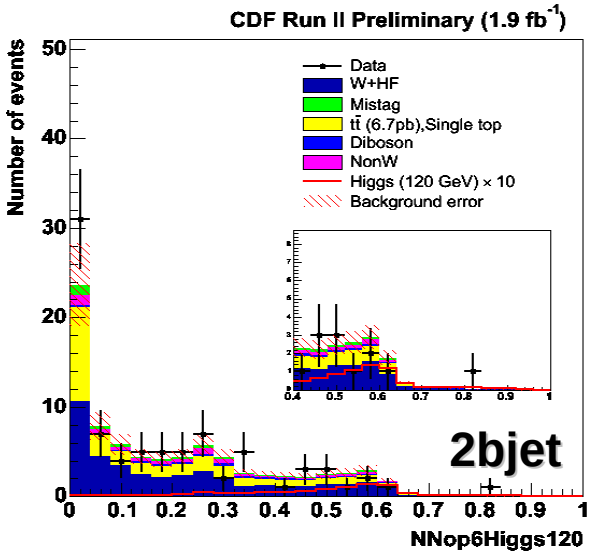
- Added 1 b events with NN flavor separation.
- Included forward electrons.

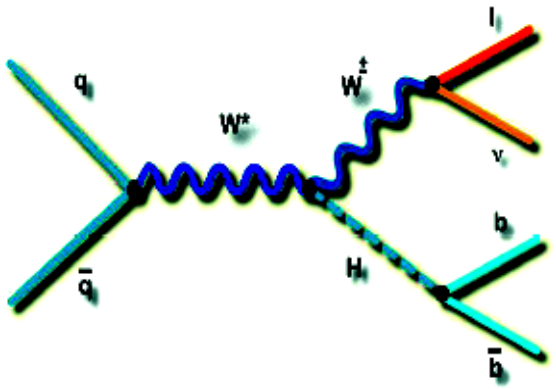
* See T. Masubuchi's talk in YSF.



WH → lνbb̄ (cont.)



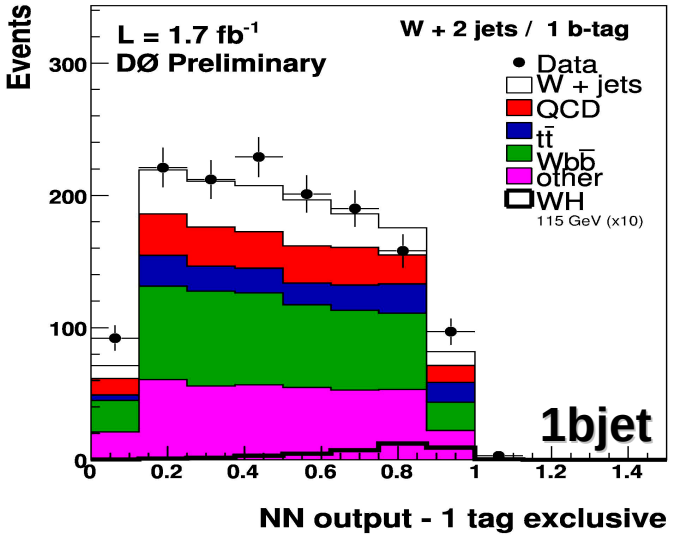


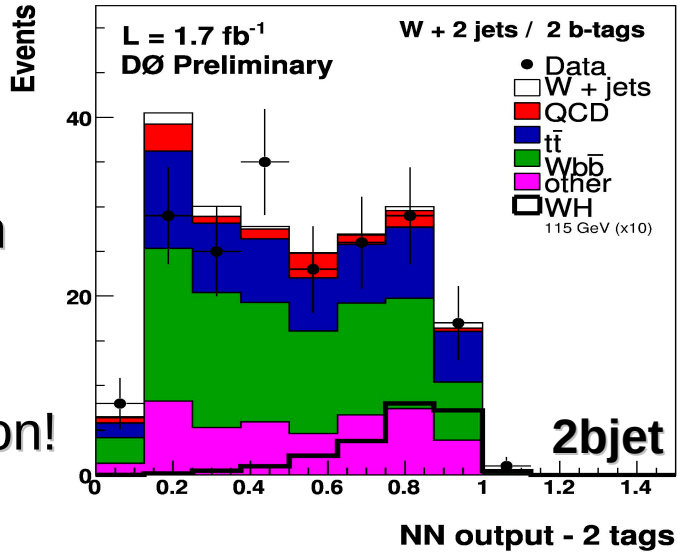


NN Configuration:
Signal → 1
Background → 0

No significant excess in signal region both in CDF/DØ.

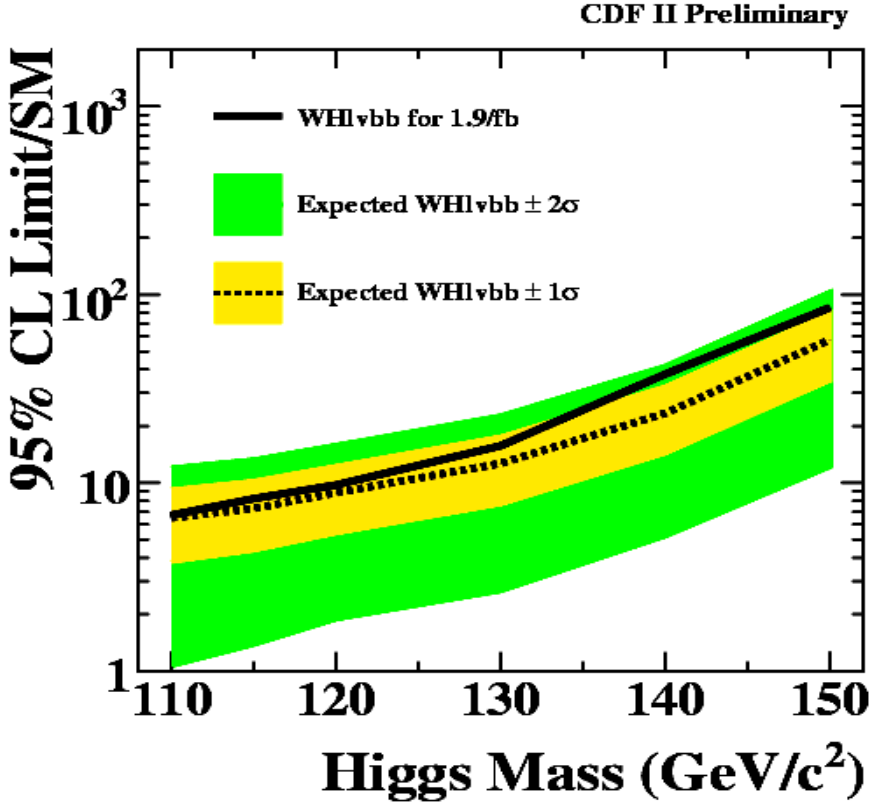
-> Set limits for exclusion!

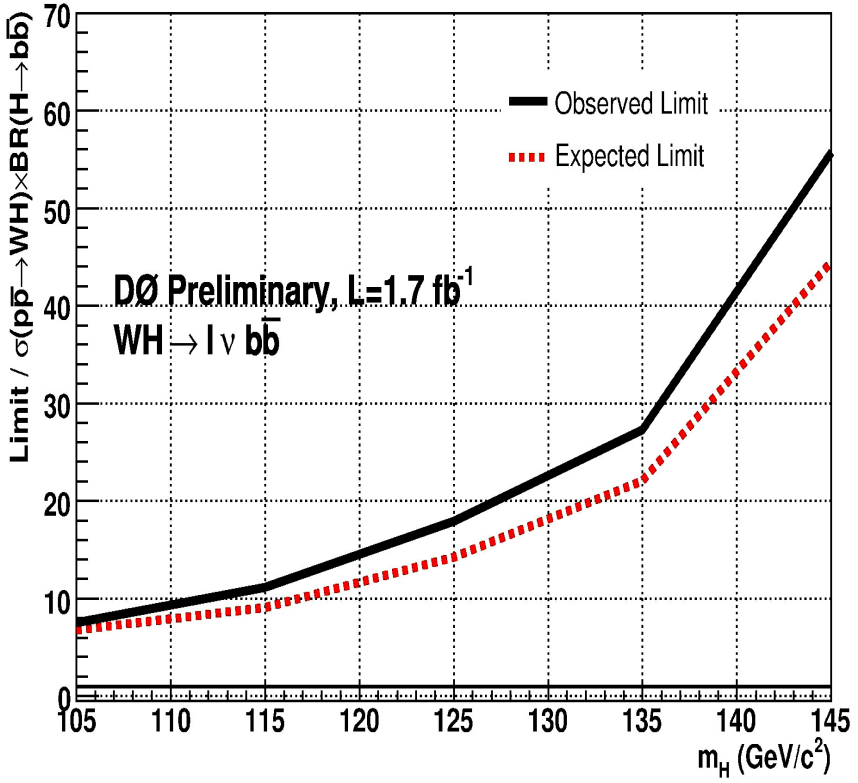




Limit on WH → lνbb̄

- 95% Confidence Level Upper limit is set by binned likelihood method.
  -> Showing σ(limit)/σ(SM) Ratio (i.e. If reached 1, it is excluded)

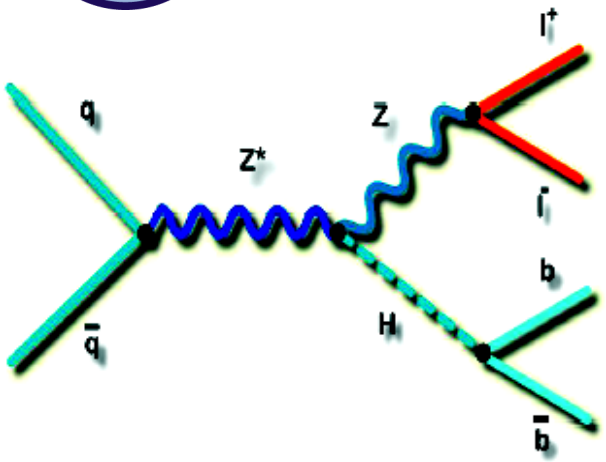




- CDF: (at M_H=115 GeV)
  σ(limit)/σ(SM) = 8.2/7.3 (obs./exp.)

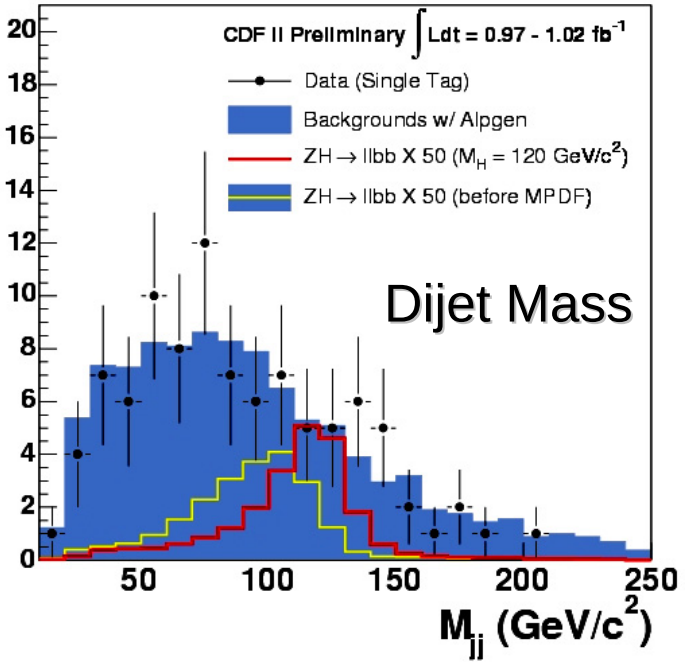
- DØ: (at M_H=115 GeV)
  σ(limit)/σ(SM) = 11/9 (obs./exp.)

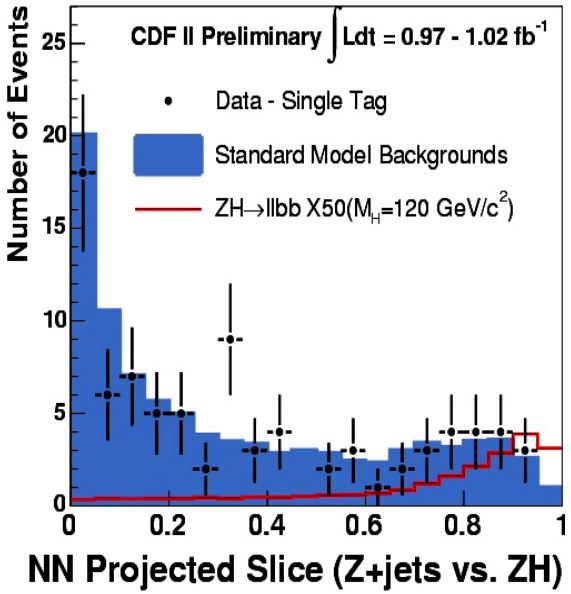
$ZH \rightarrow llb\bar{b}$ ($1fb^{-1}$ results)

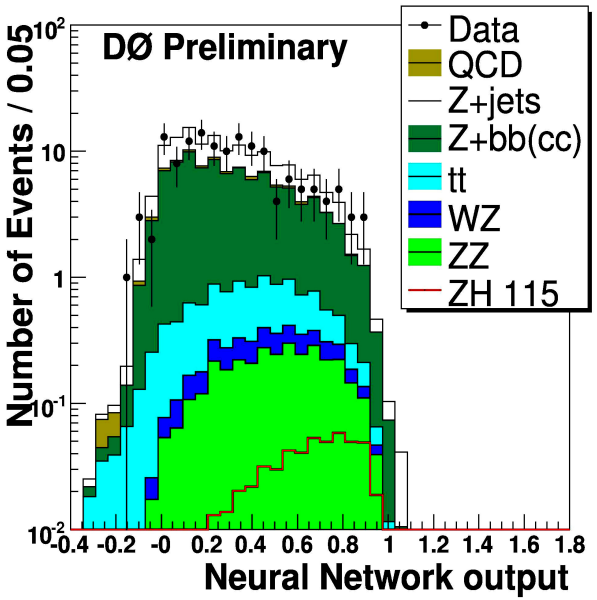


- 2 high P_T leptons from Z -> Clean signature !
- Improve dijet mass resolution with Met projection.
- Optimized by NN.

*Summer 2007 results

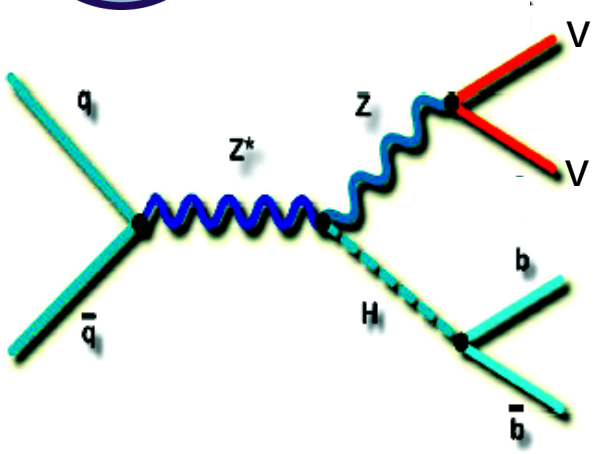






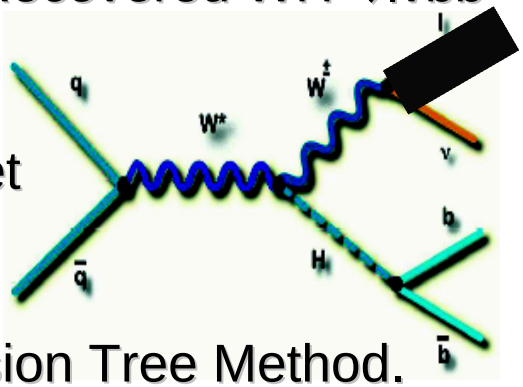
95% CL Limit (relative to SM)
CDF: 16/16 (obs./expected)
DØ : 18/20 (obs./expected)
at M_H=115 GeV

ZH → νν$b\bar{b}$ (Met+$b\bar{b}$)

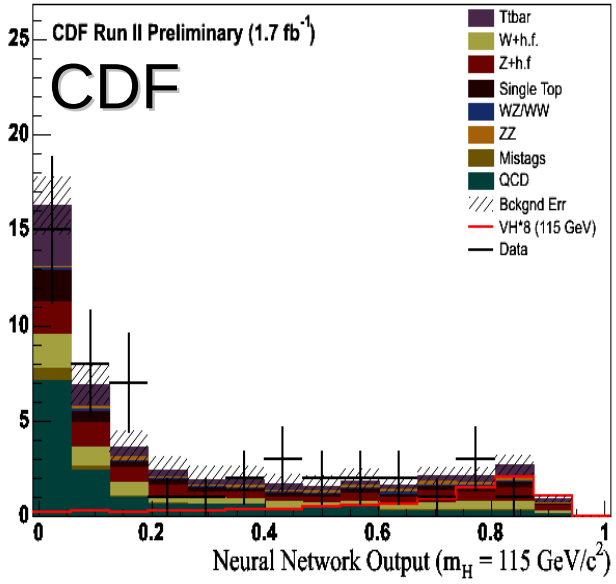


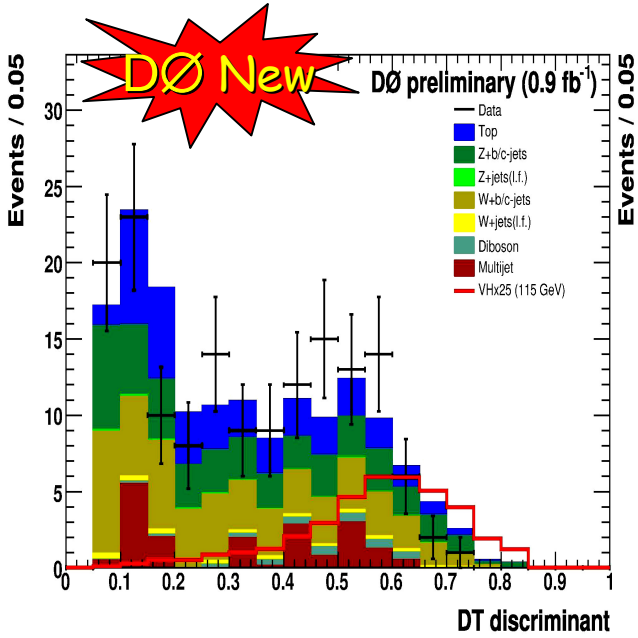
- Met > 50 GeV
- Require 2 b jets ↙ Data driven
- QCD estimate/reduction:
  CDF: NN with Track based Met
  DØ: Asymmetry between
  Met and SumEt etc
- New DØ result: Boosted Decision Tree Method.

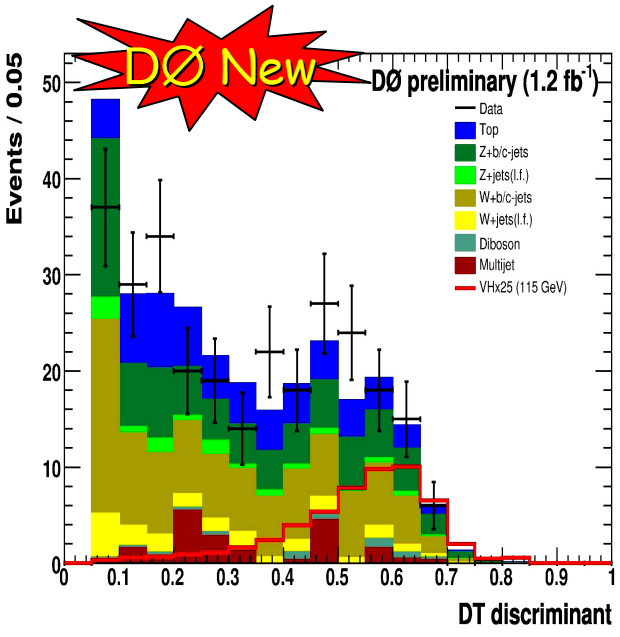
Recovered WH→lνbb



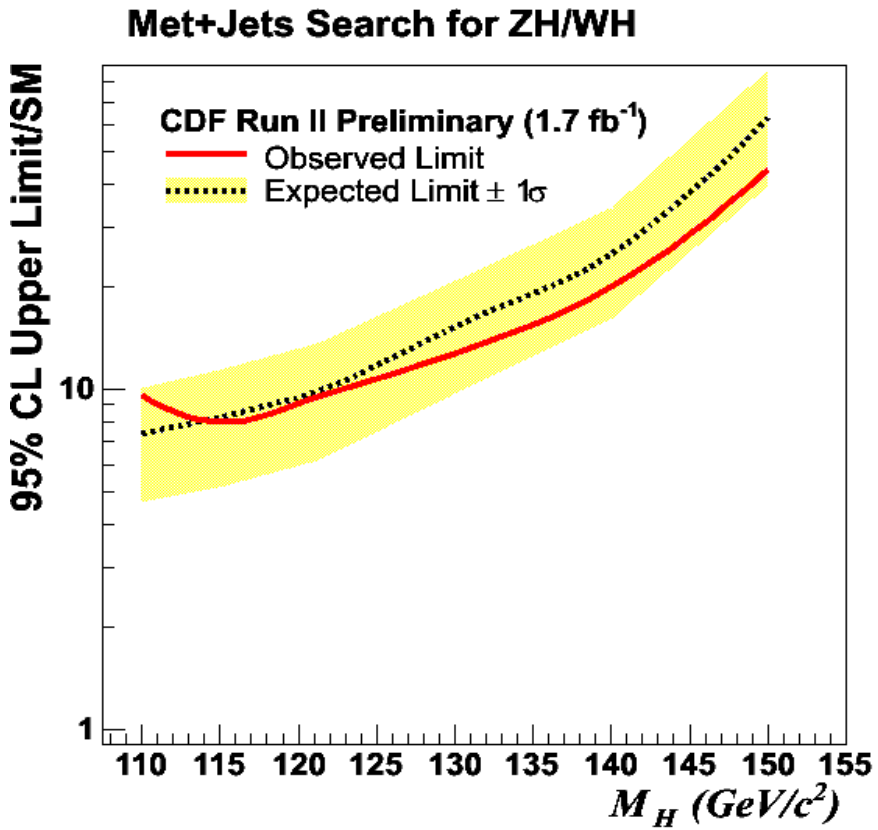
Double Vertex Tag (Signal Region)







Limit on Met+$b\bar{b}$ Channel



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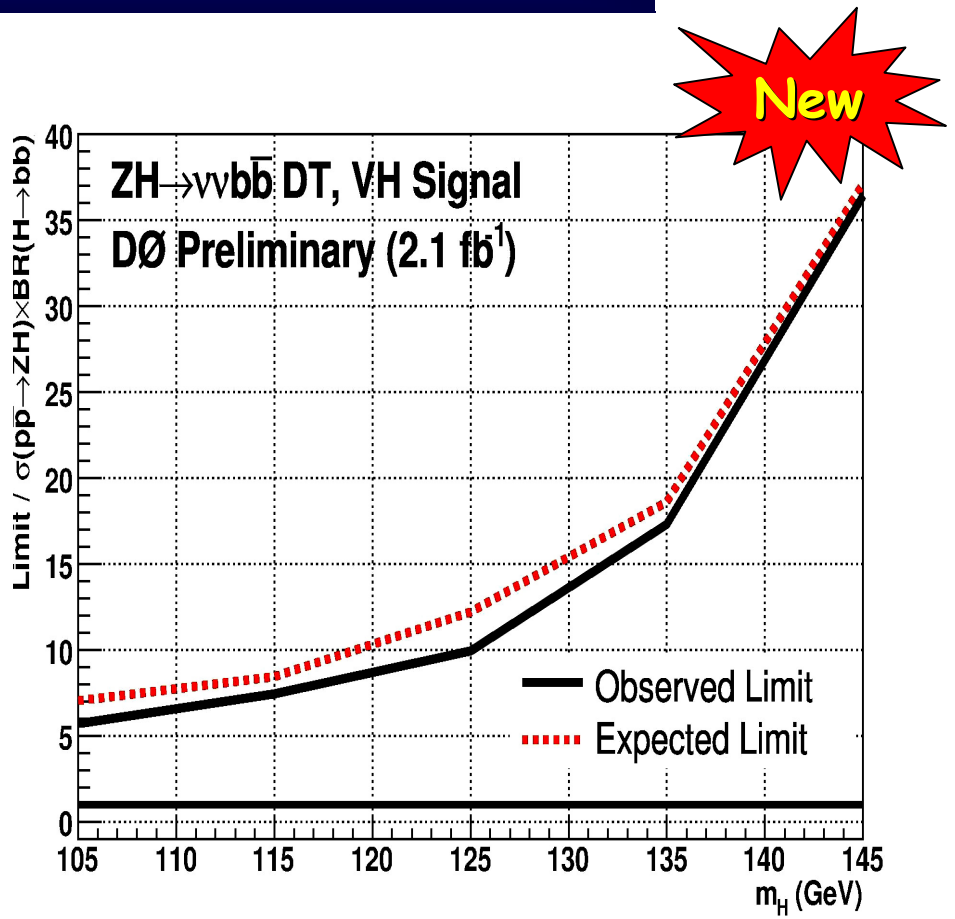
  σ(limit)/σ(SM) = 8/8.3 (obs./exp.)



- DØ : (at M_H=115 GeV)
  σ(limit)/σ(SM) = 7.5/8.4 (obs./exp.)

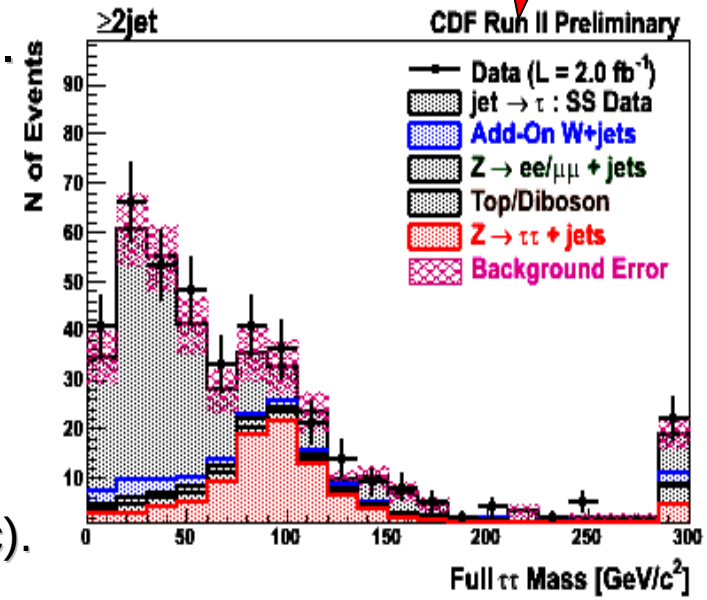
*See YSF talk by C. Ochando !

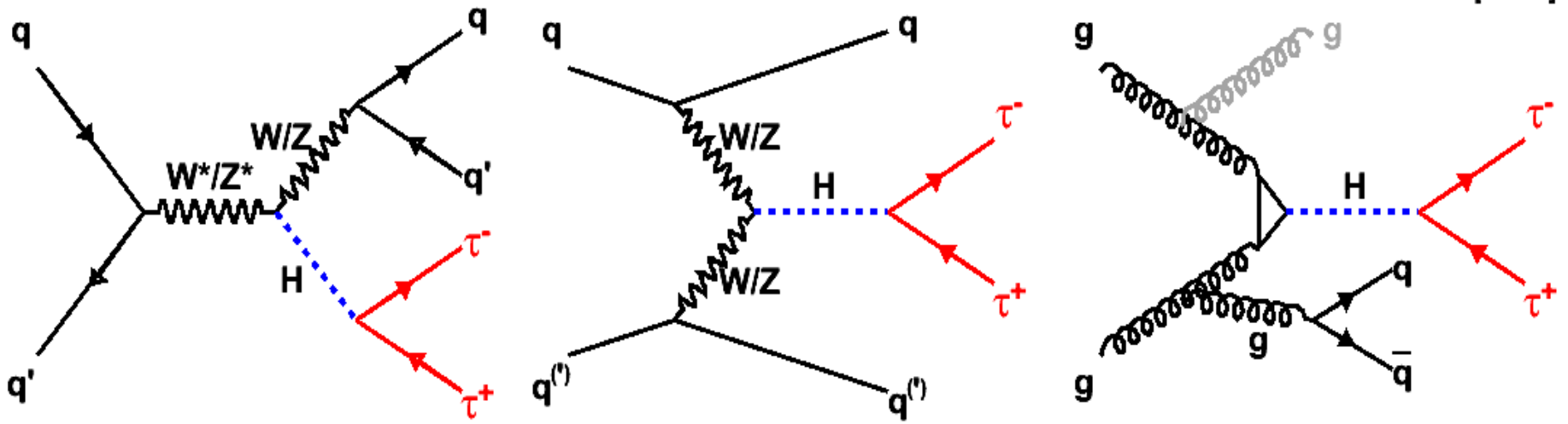
WH/ZH/VBF/ggH → ττ + 2jets

Brand New

- H → ττ is hard due to small BR (10% of $b\bar{b}$).
- But we should not give up ! Ideas are :

1. Recover BR by looking at W/Z->2jets:
   - W → lν(22%), Z → ll(6%), Z → νν(20%)
   - W → jj (67%), Z → jj(70%)
2. Add all possible channels:
   - Simultaneous search for WH+ZH+VBF+ggH
3. Many good kinematic variables to separate signal from backgrounds (dijet mass, dη(j,j) etc).

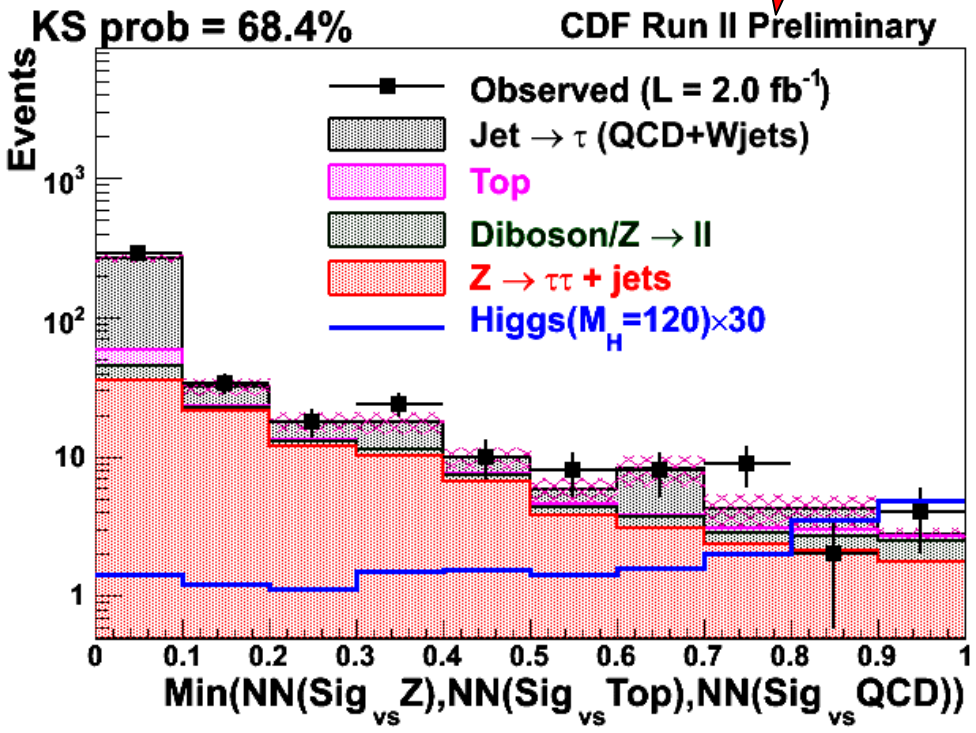


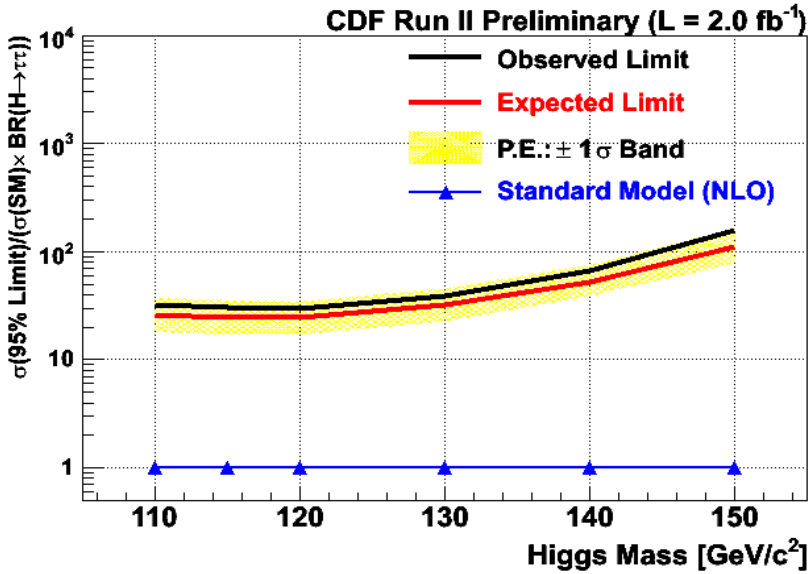


NEW Result: H → ττ Channel

Brand New

- Use $\tau_{lep}\tau_{had}$ mode.
  - Lepton P_T > 10 GeV
  - Hadronic τ P_T > 15 GeV
- 3 Neural Nets are trained:
  - Signal vs Z-> ττ + jets
  - Signal vs ttbar
  - Signal vs QCD
- Then select Minimum of 3 NN scores to fit the data.





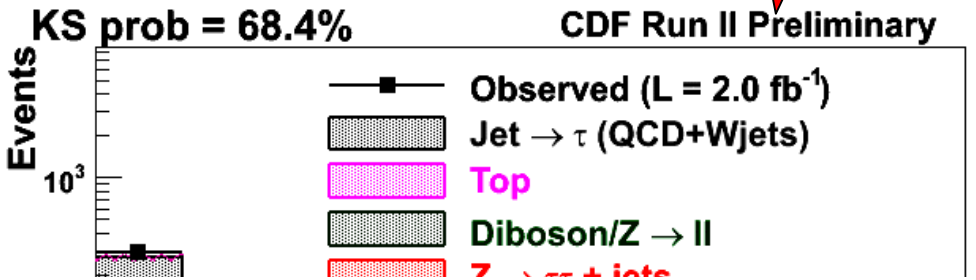
- CDF: (at M_H=120 GeV)
  σ(limit)/σ(SM) = 30/24 (obs./exp.)

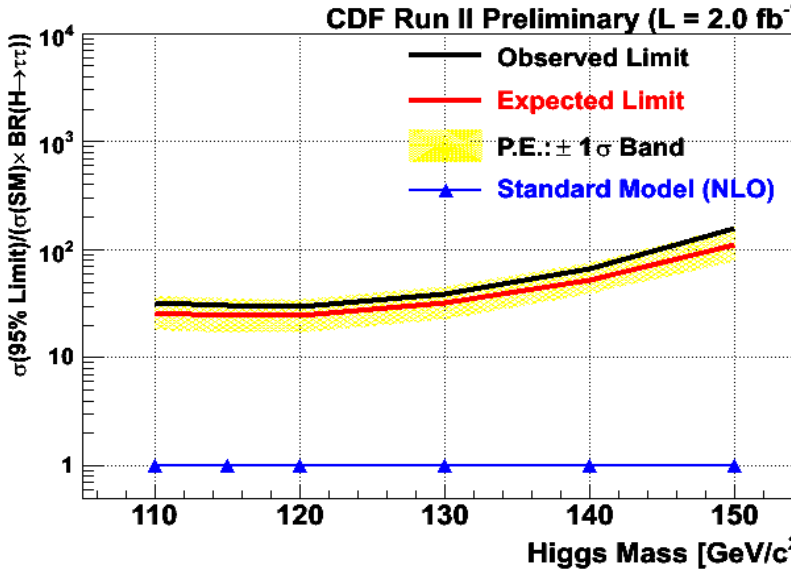
* Established background estimate & modeling.
* Further improvement by adding 0j/1jet events.
* Becomes more interesting at LHC.

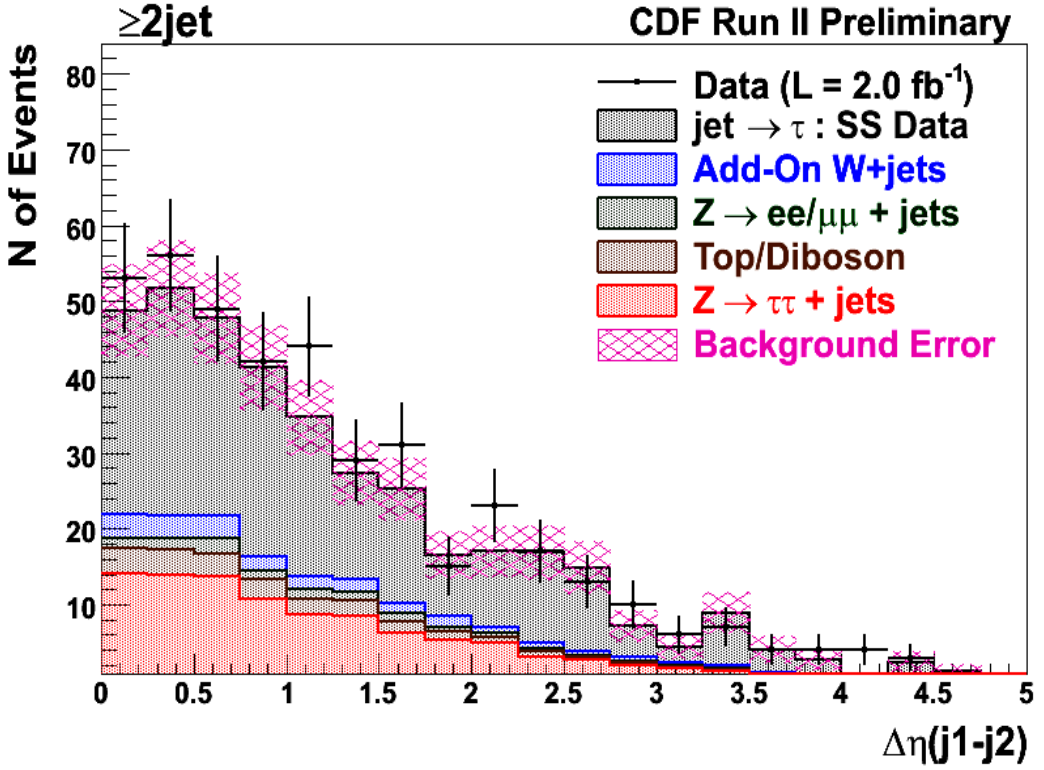
NEW Result: H → ττ Channel

Brand New

- Use $\tau_{lep}\tau_{had}$ mode.
  - Lepton P_T > 10 GeV
  - Hadronic τ P_T > 15 GeV
- 3 Neural Nets are trained:
  Signal vs Z-> ττ + jets
  Signal vs ttbar
  Signal vs QCD
- Then select Minimum of 3 NN scc to fit the data.





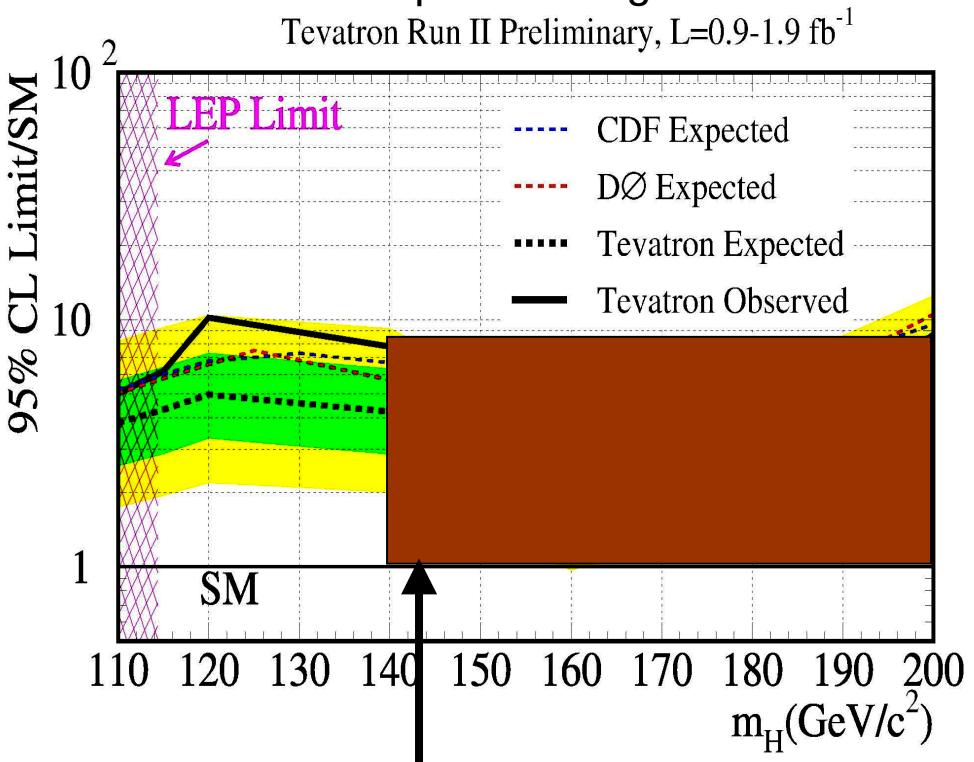


Combined Results

http://arxiv.org/abs/0712.2383

- Work still in progress to combine all updated & new analyses.
- Corresponding luminosity for each analysis used in combination in this talk.

Combined	CDF	DØ
WH→ lvbb	1.7 fb^{-1} (old !)	1.7 fb^{-1}
ZH→llbb	1.0 fb^{-1}	1.1 fb^{-1}
ZH→vvbb	1.7 fb^{-1}	0.93 fb^{-1} (old !)

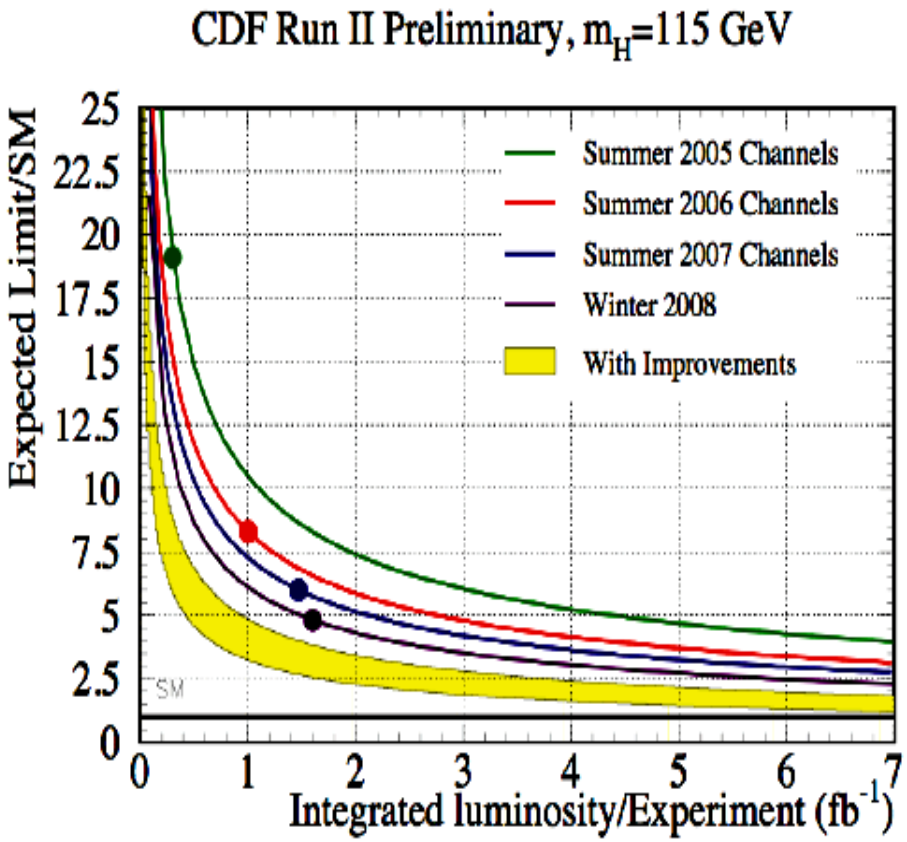


High mass search will be shown in next talk !

- Systematic uncertainties are treated as nuisance parameters with truncated Gaussian constraint. After combined,
  If significant excess found → Do more checks.
  If no excess → Set 95% C.L. Limit.
- At M_H=115 GeV, Observed Limit (σ(limit)/σ(SM)) is 6.2 while expected is 4.3 !
  We are getting close to exclude if No Higgs around this region !

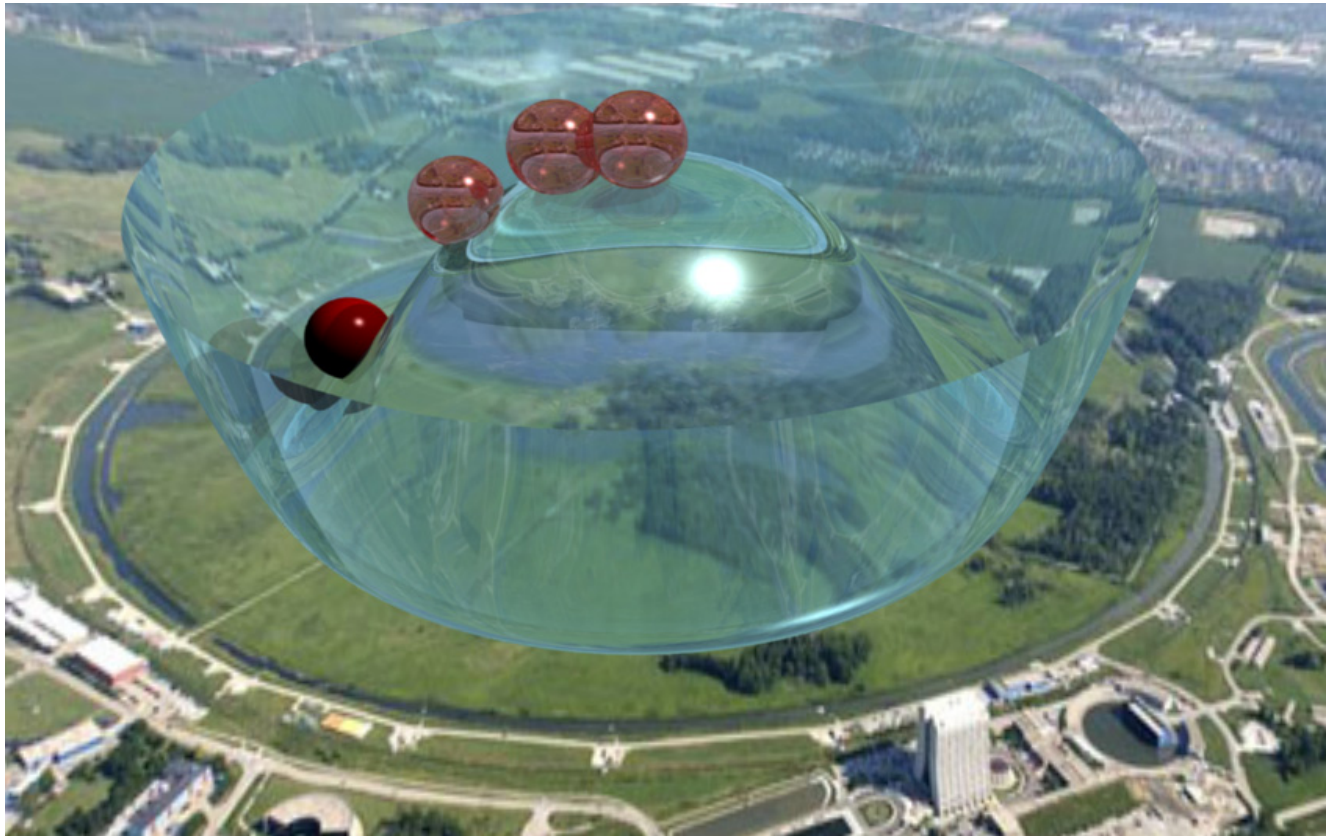
Summary & Prospects

- New results with ~2.0 fb^{-1} data.
  - We have +1.0 fb^{-1} already on tape.
  - New analysis ($H \rightarrow \tau\tau$) done.
- In low mass range, the exclusion limit is ~ x 5 to SM prediction, and improving beyond luminosity scaling.
  → Advanced technique and better understanding of data etc.
- Further improvements actively in progress in CDF/DØ :
  - Extending lepton coverage.
  - Improving btagging quality etc.
- More results coming soon !



- Details on each analysis and combined results:
  - CDF: http://www-cdf.fnal.gov/physics/new/hdg/hdg.html
  - DØ : http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

Conclusion

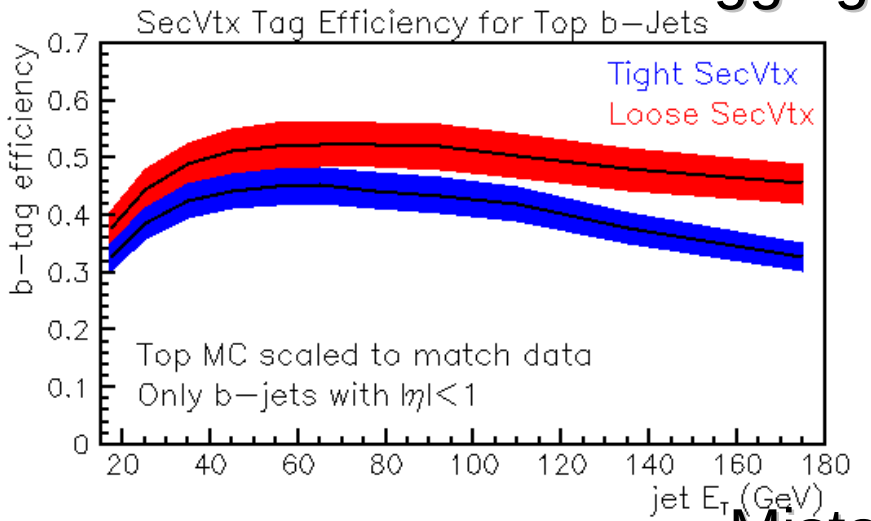


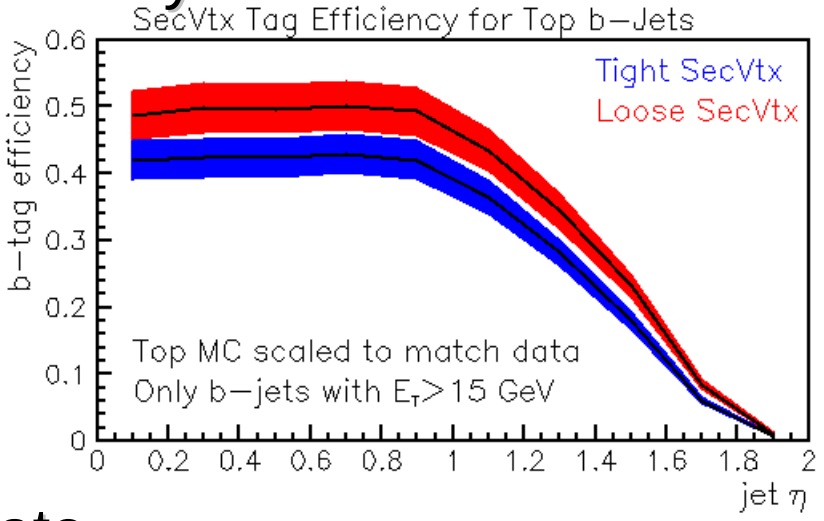
Yes, "Spontaneous Symmetry Breaking" might be seen at Tevatron !
Or if nature doesn't like SM Higgs, we need to exclude it a.s.a.p. !
In both cases, it is still a great time to search for SM Higgs at Tevatron.

Backup

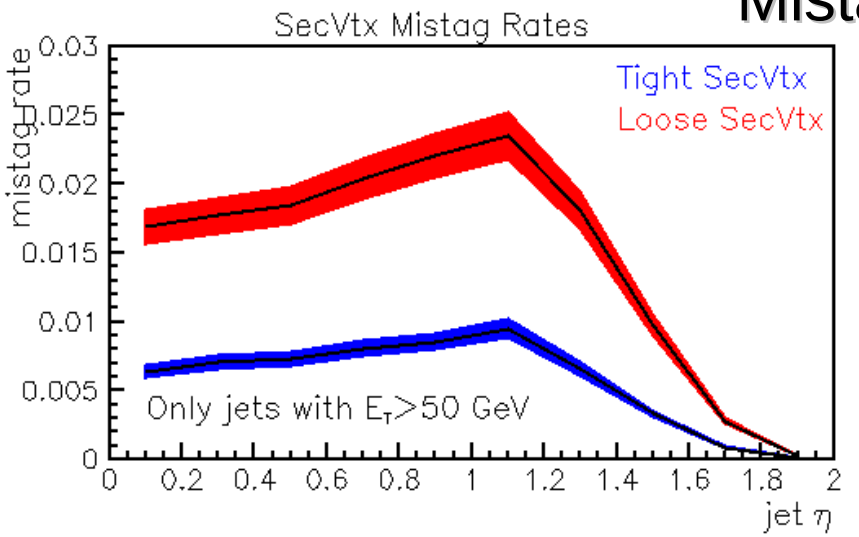
Ref.) CDF SECVTX btag

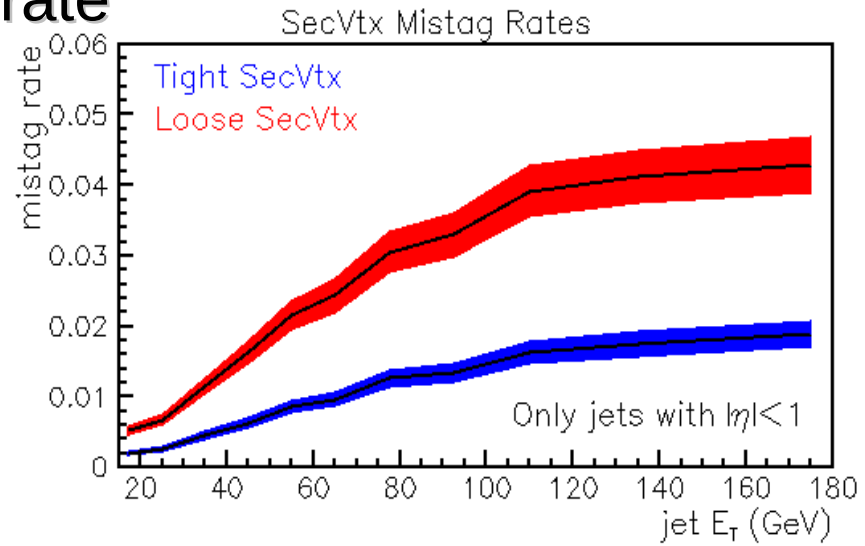
Tagging efficiency





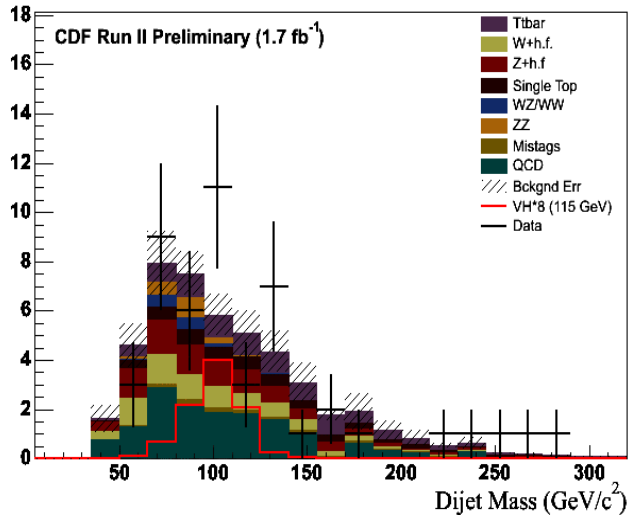
Mistag rate



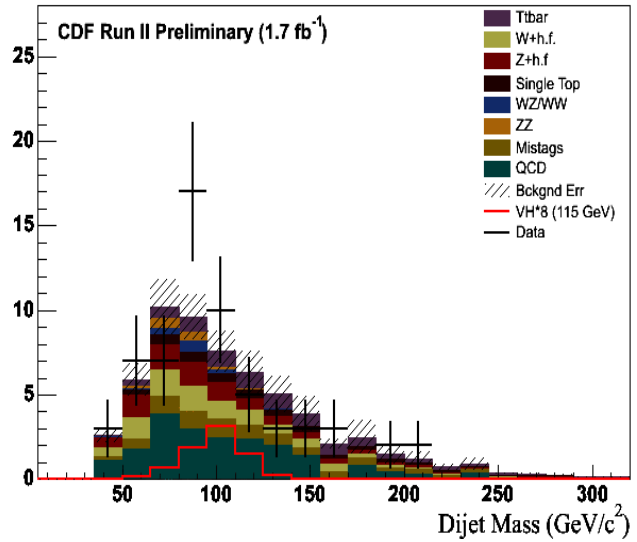


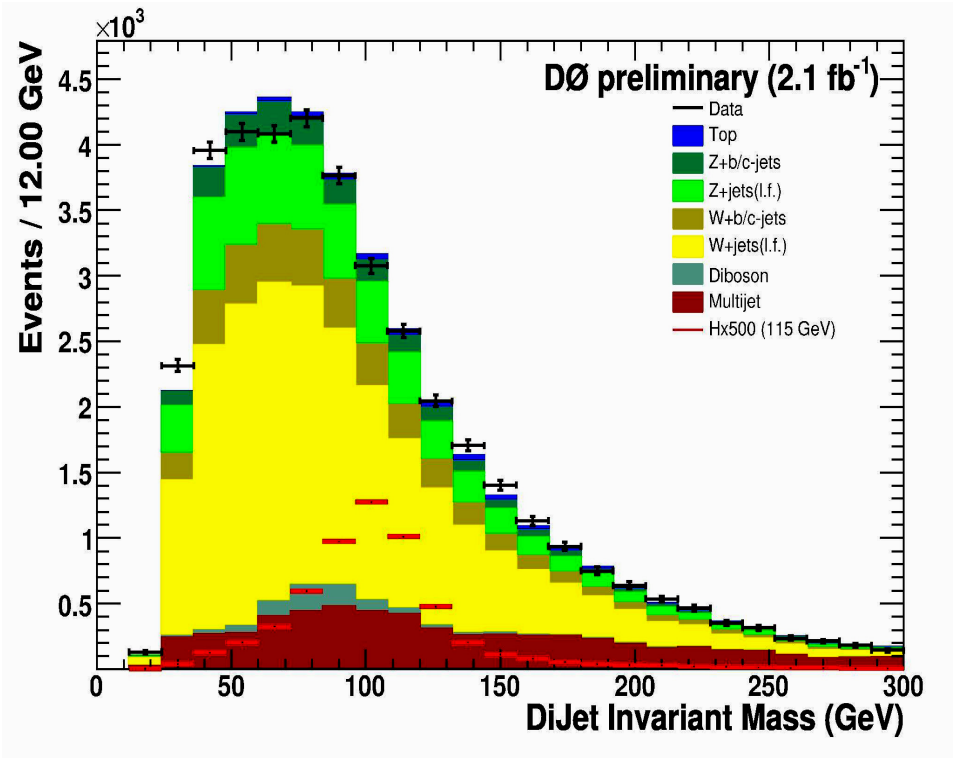
More Plots : Met+2jets

Double Vertex Tag (Signal Region)



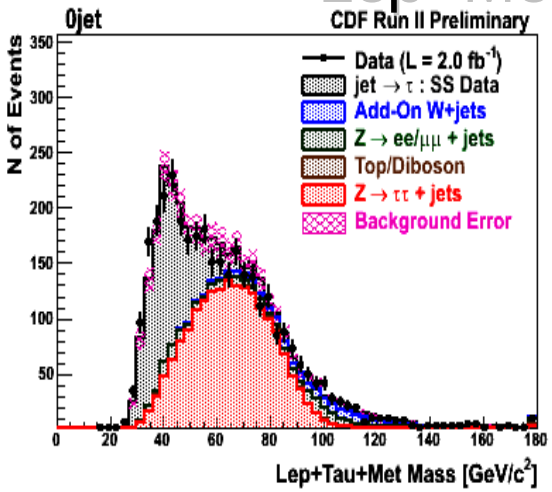
Vertex + Probability Tag (Signal Region)

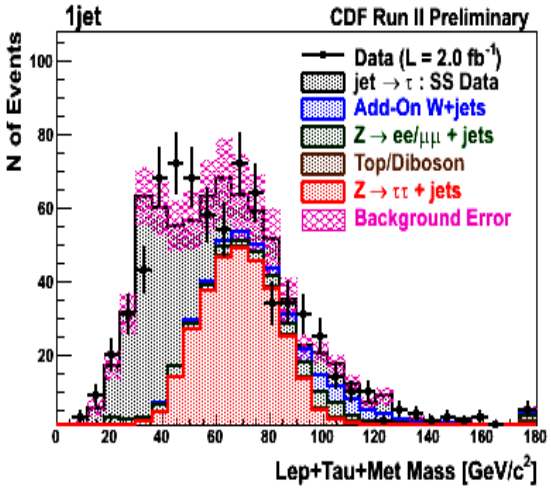


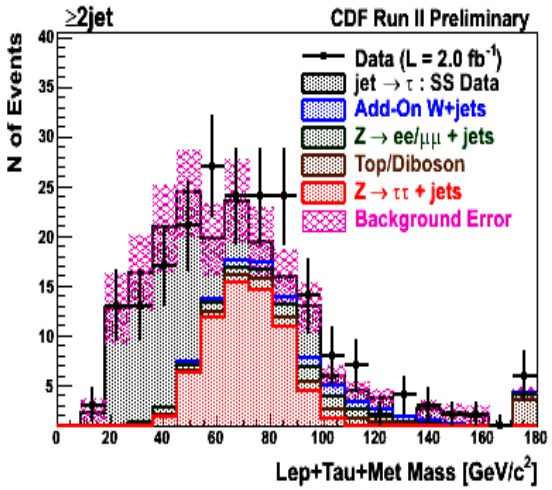


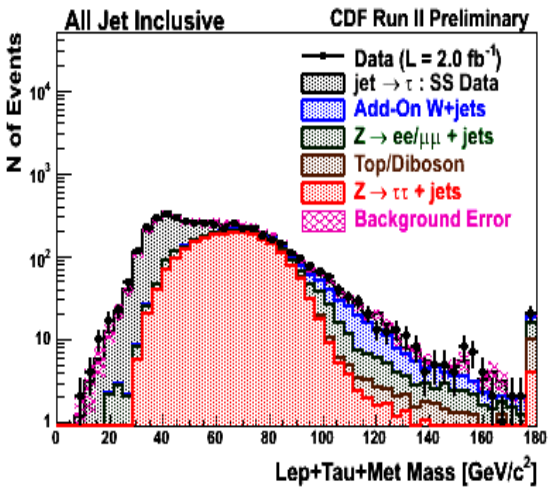
More Plots : H → ττ Channel

Lep+Met+Tau Mass

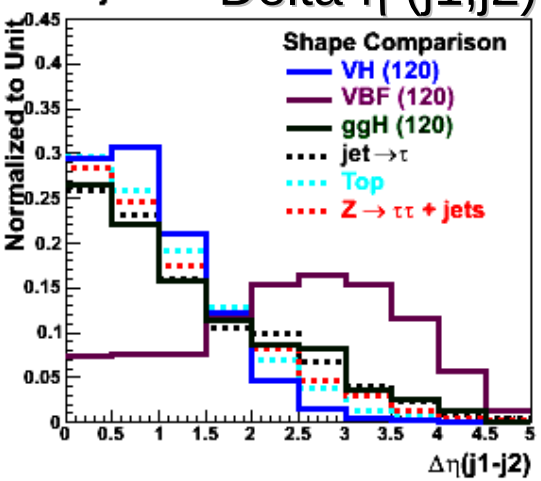




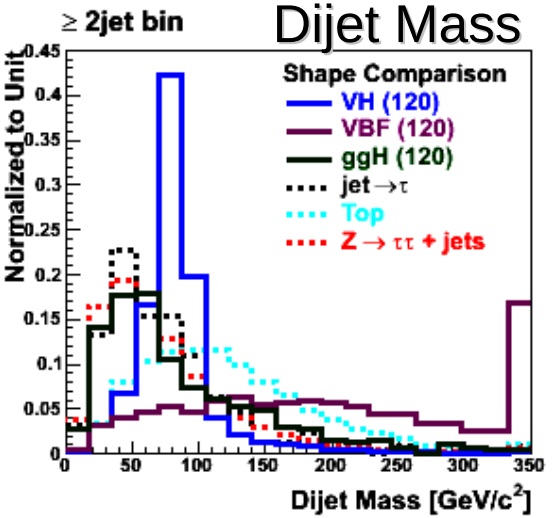




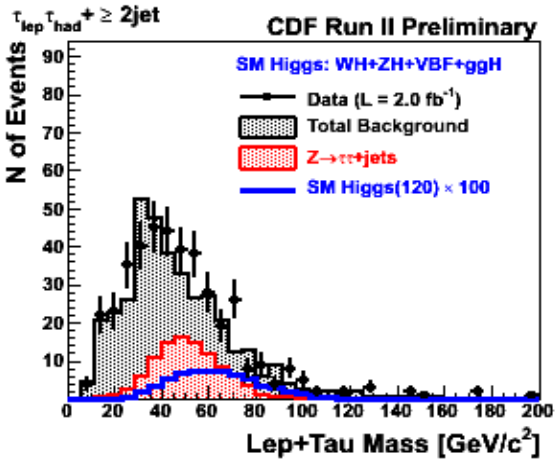
Delta η (j1,j2)

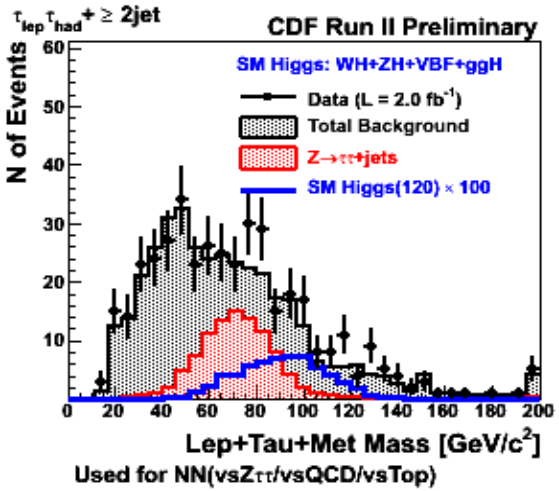


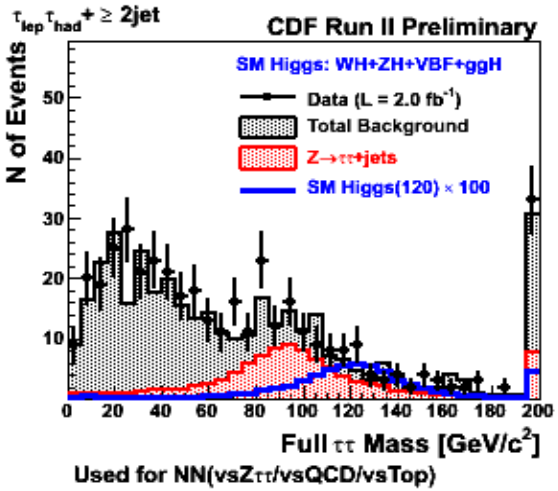
Dijet Mass



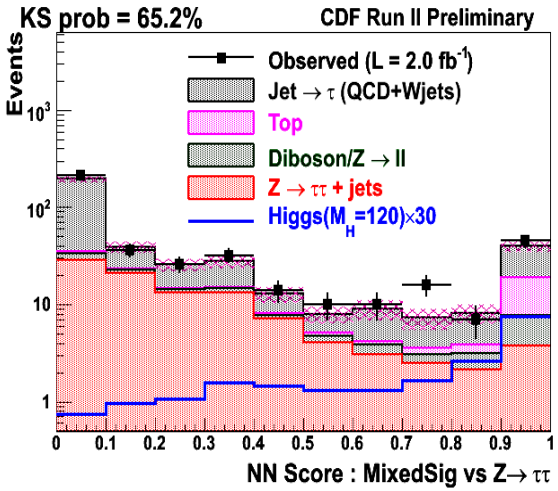
More Plots : H → ττ Channel

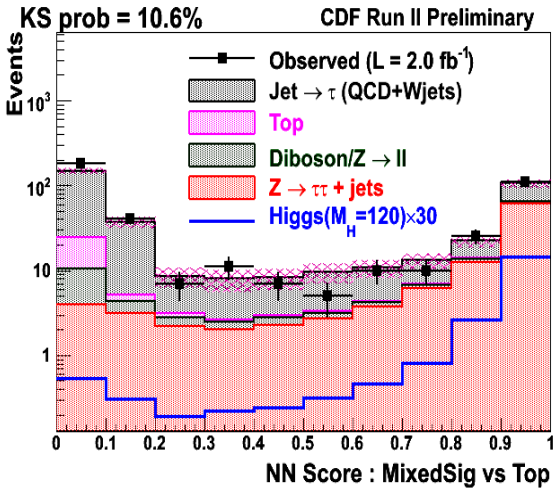


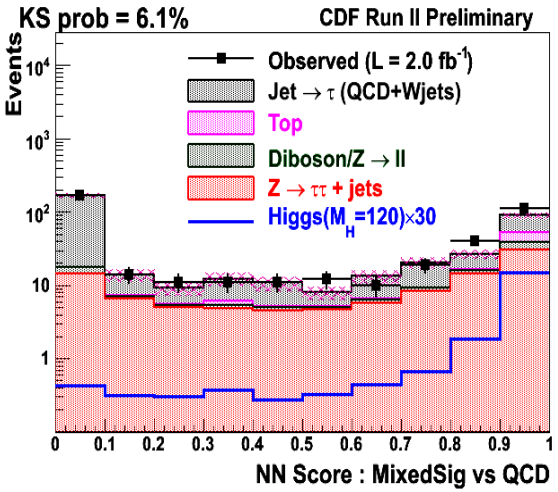




> 3 Neural Nets Distributions:







Further Combination

> Results we already have now, but not used in current combination:

1. WH -> lvbb(CDF):
   +200pb^{-1}, 1tag improvement, forward electron inclusion.
2. ZH -> vvbb(CDF):
   Data driven QCD estimate.
3. ZH -> vvbb(DØ):
   +1200pb^{-1} with Boosted Decision Tree Technique.
4. H -> $\tau\tau$(CDF):
   New analysis with 2.0fb^{-1}.

- All combined results coming very soon !

> Other analysis updates (e.g. ZH->llbb) are also ongoing and will be done shortly.