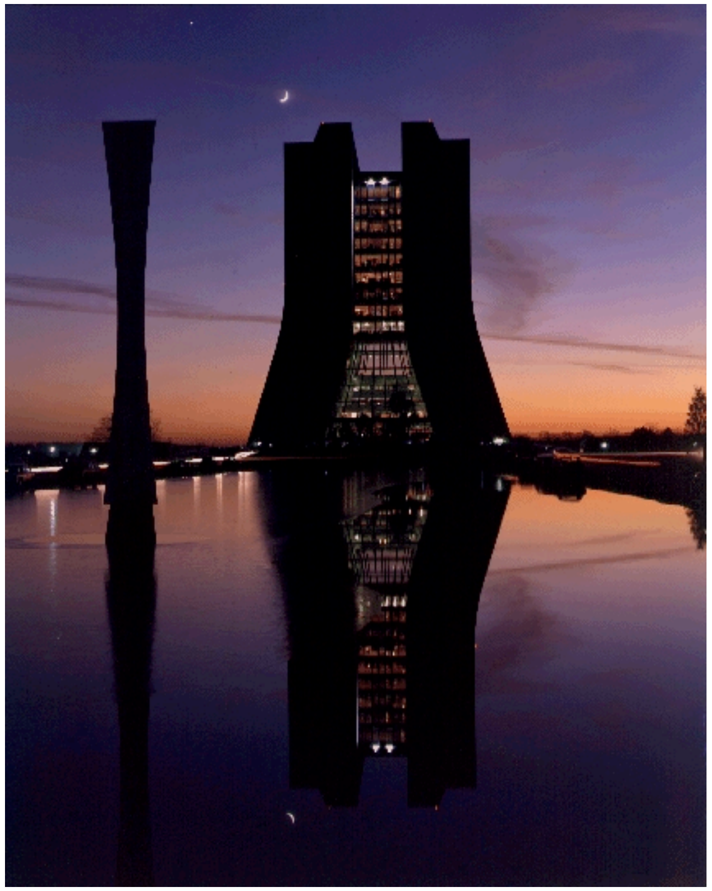
Higgs Searches at the Tevatron

XXVIII Physics in Collisions 2008

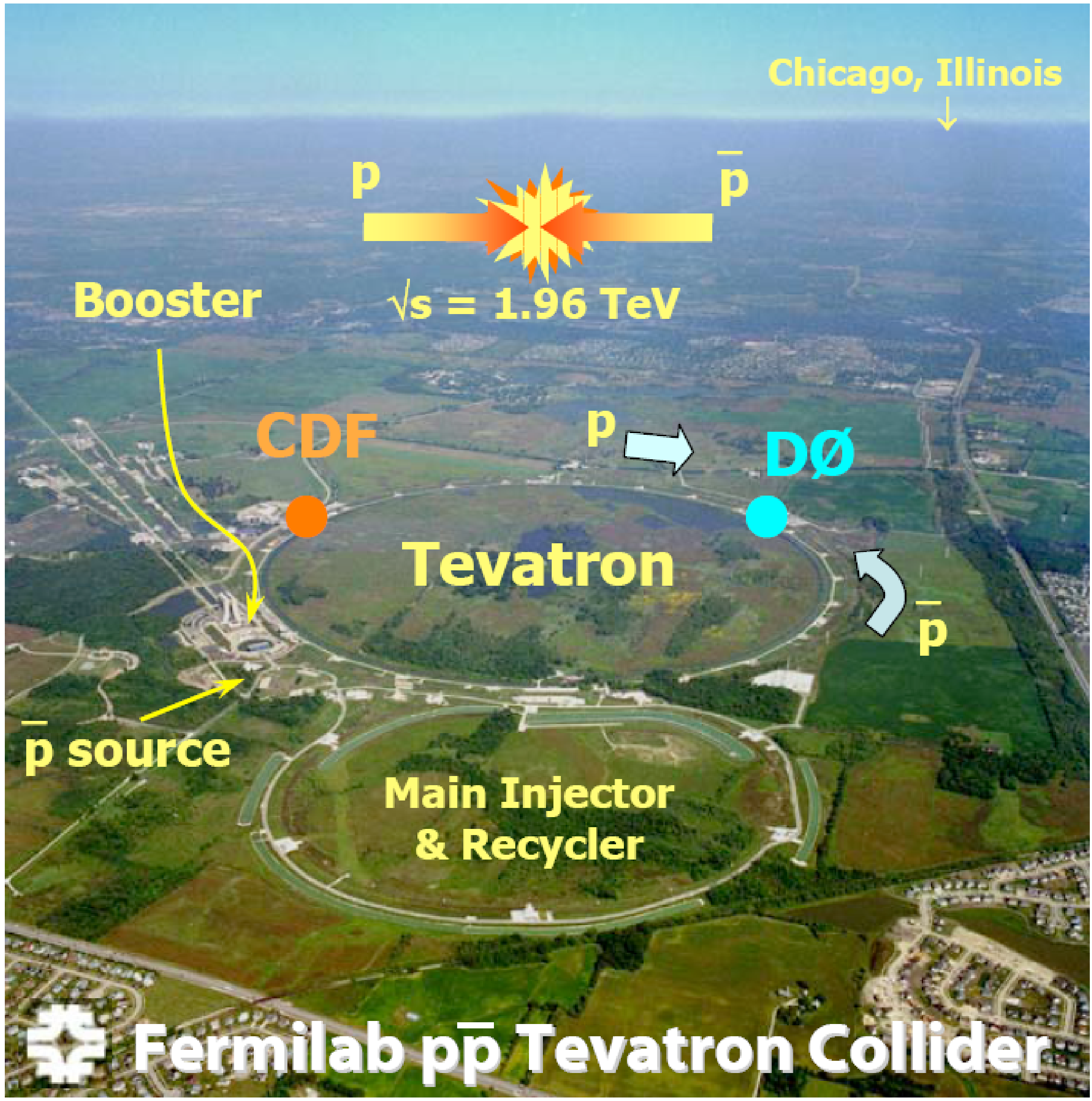
Anyes Taffard
For the CDF & DØ Collaborations



Outline

- Introduction
  - Tevatron
  - Experiments
- Standard Model (SM) Higgs
  - Introduction
  - Results
    - Low & High mass
    - Combination
- Non-SM Higgs
  - Introduction
  - Results
- Prospects & Conclusions

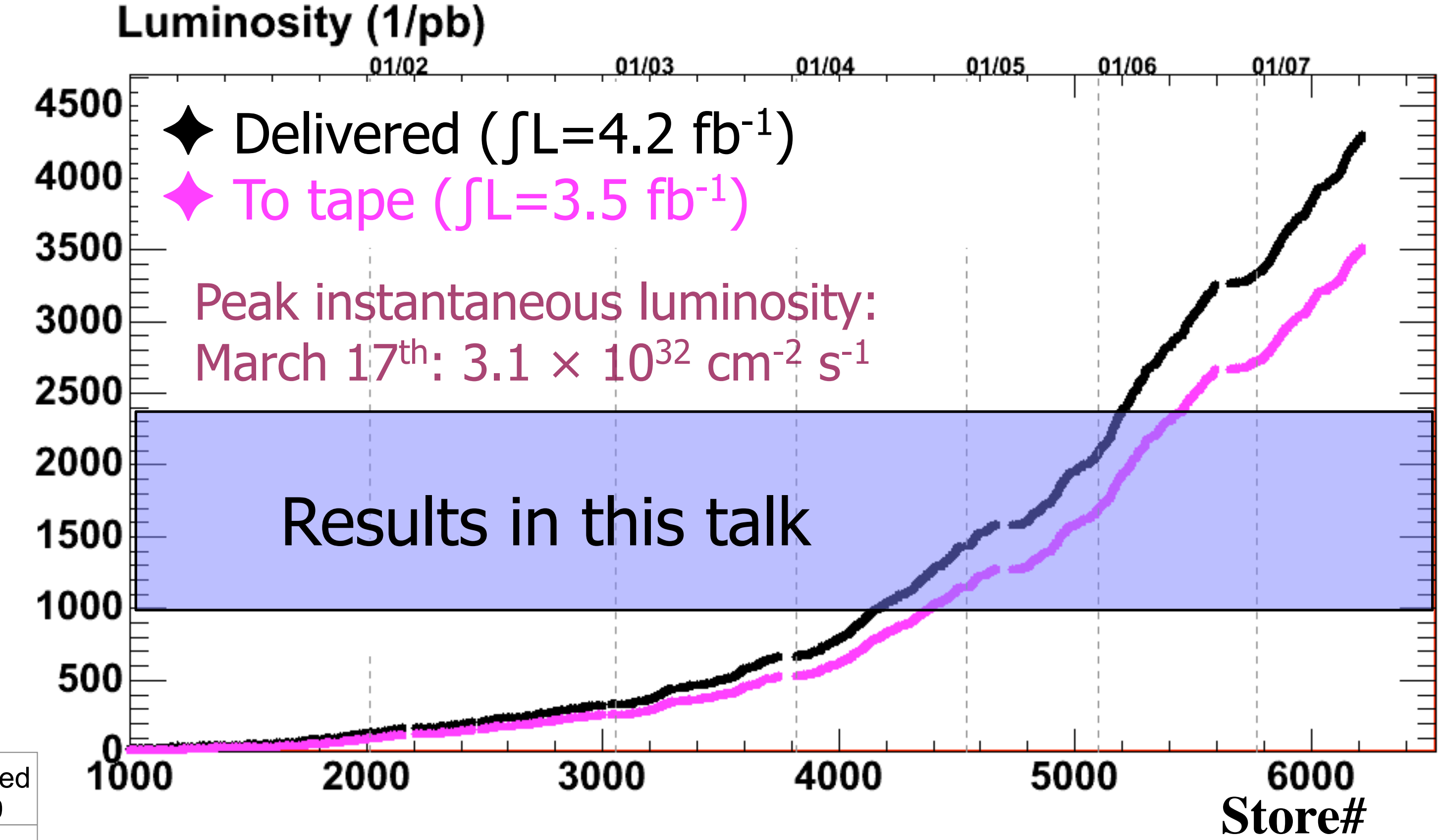
Many Thanks to all my Tevatron colleagues



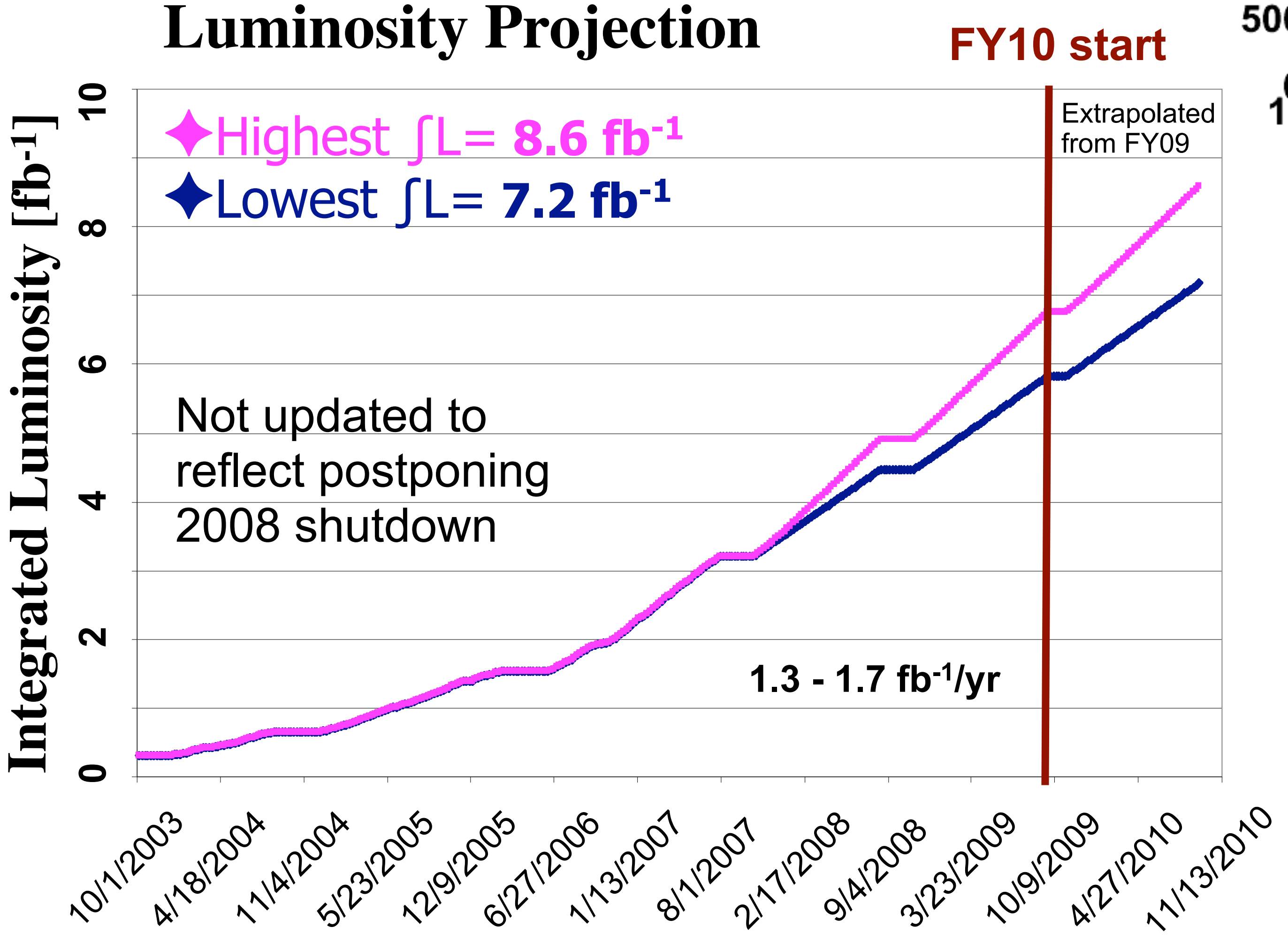
Results shown use up to ~2.4 fb^{-1}

Tevatron Performance

Tevatron continues to perform well

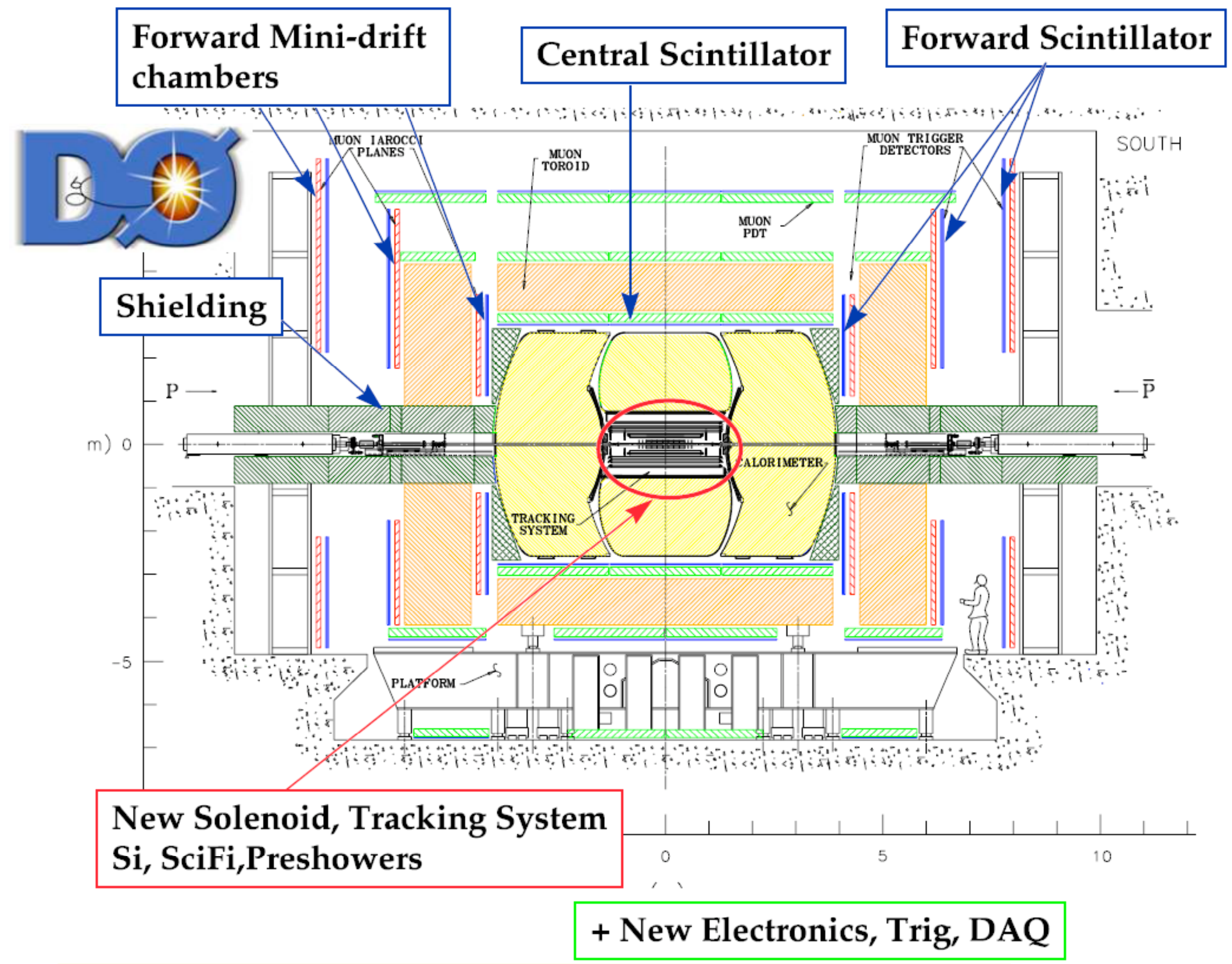


Luminosity Projection

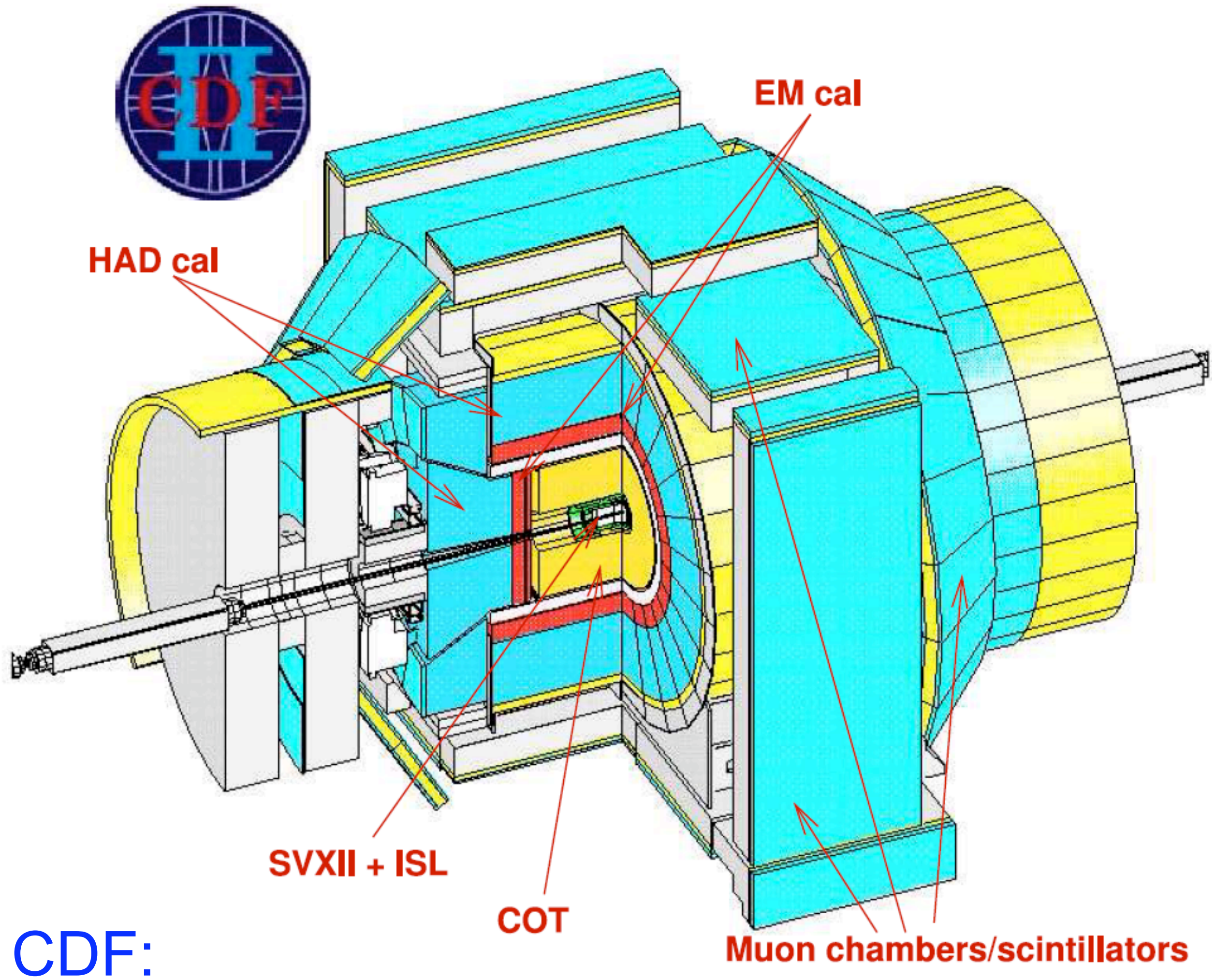


CDF & D0 Experiments

- Both detector upgraded for RunIIa
  - New silicon vertex detector
  - New tracking system
  - Upgrade muon chambers



DØ:
- New solenoid & preshowers
- RunIIb: New inner layer in SMT & L1 trigger



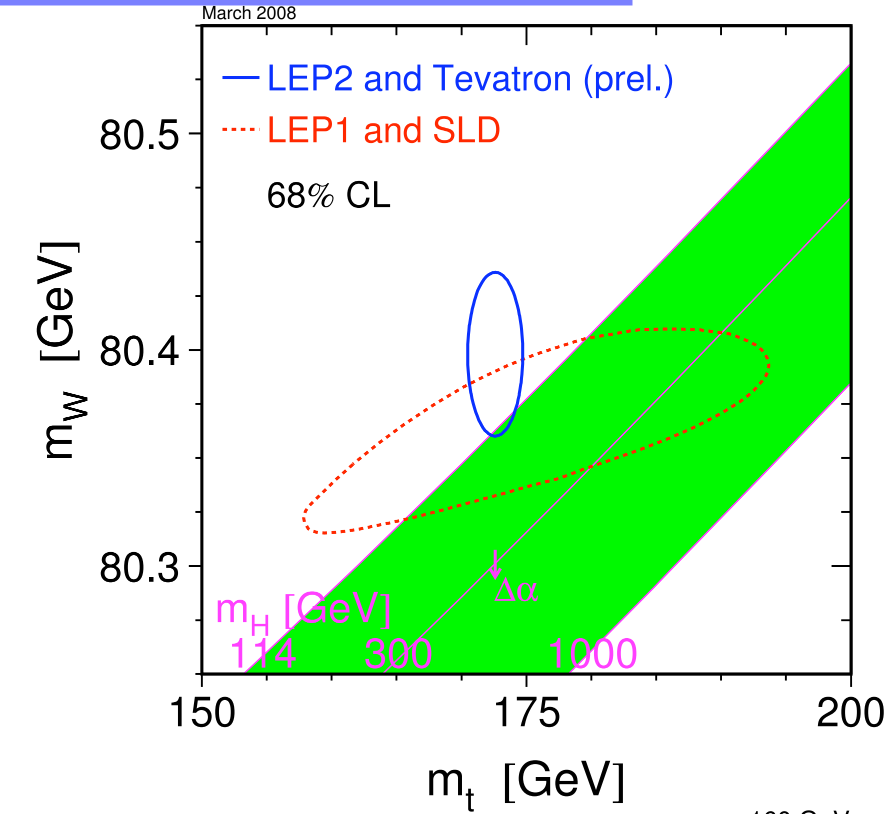
CDF:
- New plug calorimeter & ToF
- RunIIb: Upgrade Trigger (L1, L2)

Standard Model Higgs

- Introduction
  - Constraints on the Higgs
  - Higgs production & decay
  - Analyses techniques & status
- Low mass:
  - $ZH \rightarrow ll b\bar{b}$
  - $ZH \rightarrow \nu\nu b\bar{b}$
  - $WH \rightarrow l\nu b\bar{b}$
  - $VH, VBF, H \rightarrow \tau\tau + 2j$
  - $H \rightarrow \gamma\gamma$
- High Mass
  - $H \rightarrow WW$
  - $WH \rightarrow WWW^*$
- Combination

Standard Model Higgs

- Higgs Mechanism:
  - SM Higgs is the simplest way to break the EWK symmetry
    - ➙ mass to W, Z, quarks and leptons
    - Predicts neutral, spin 0 boson
      - But not its mass

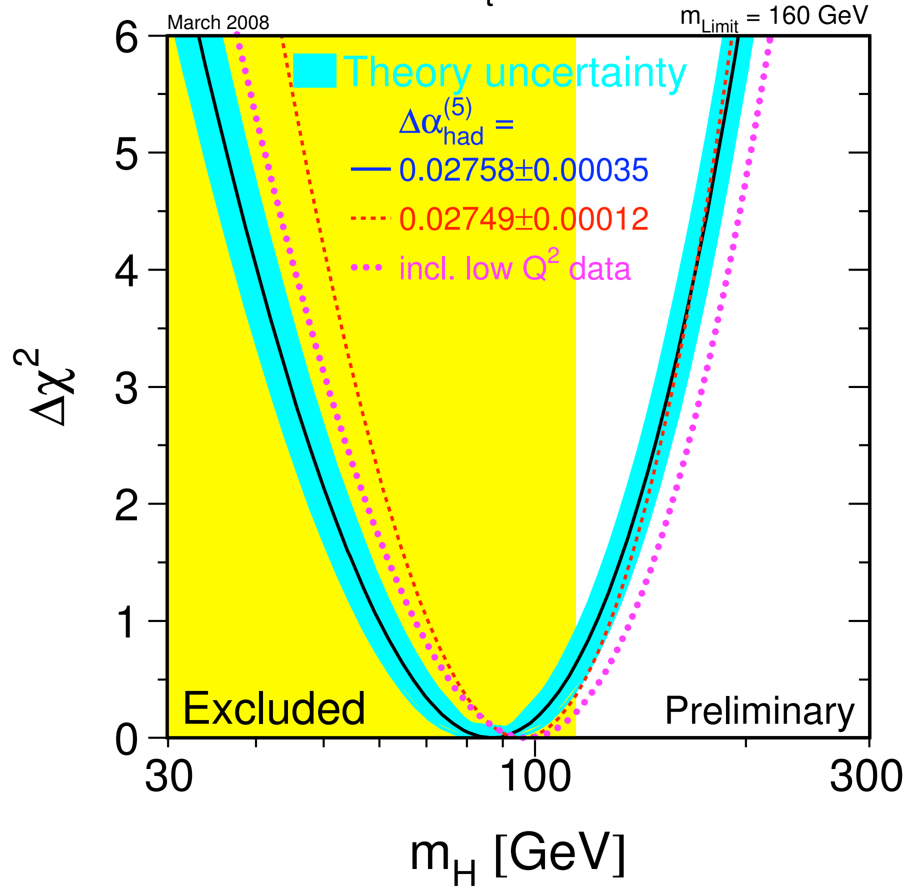


- Direct searches at LEP2
  - $m_H > 114.4$ GeV @ 95% C.L.

- Improved m_t & m_W tighten indirect constraints:
  - $m_H < 160$ GeV @ 95C.L. (EW fit)
  - $m_H < 190$ GeV with LEP2 limit included

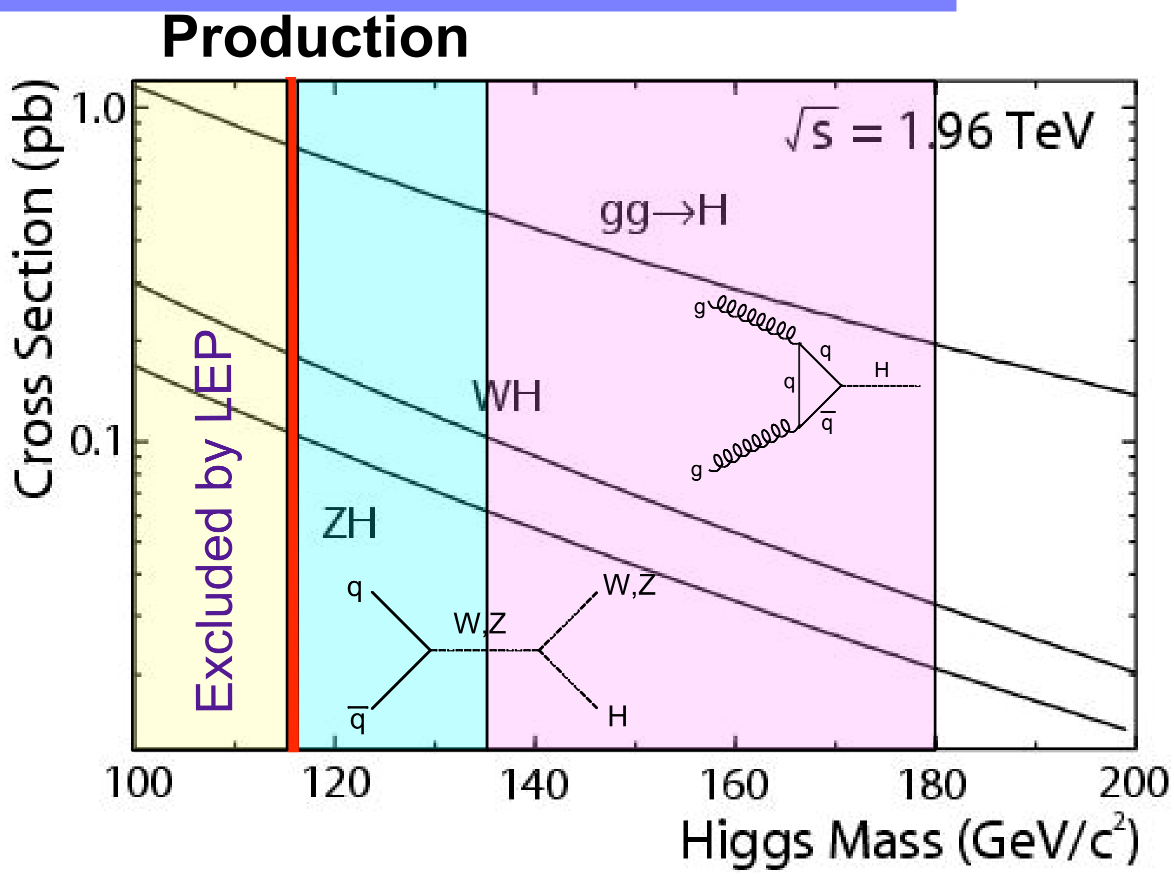
➙ A light Higgs is favored

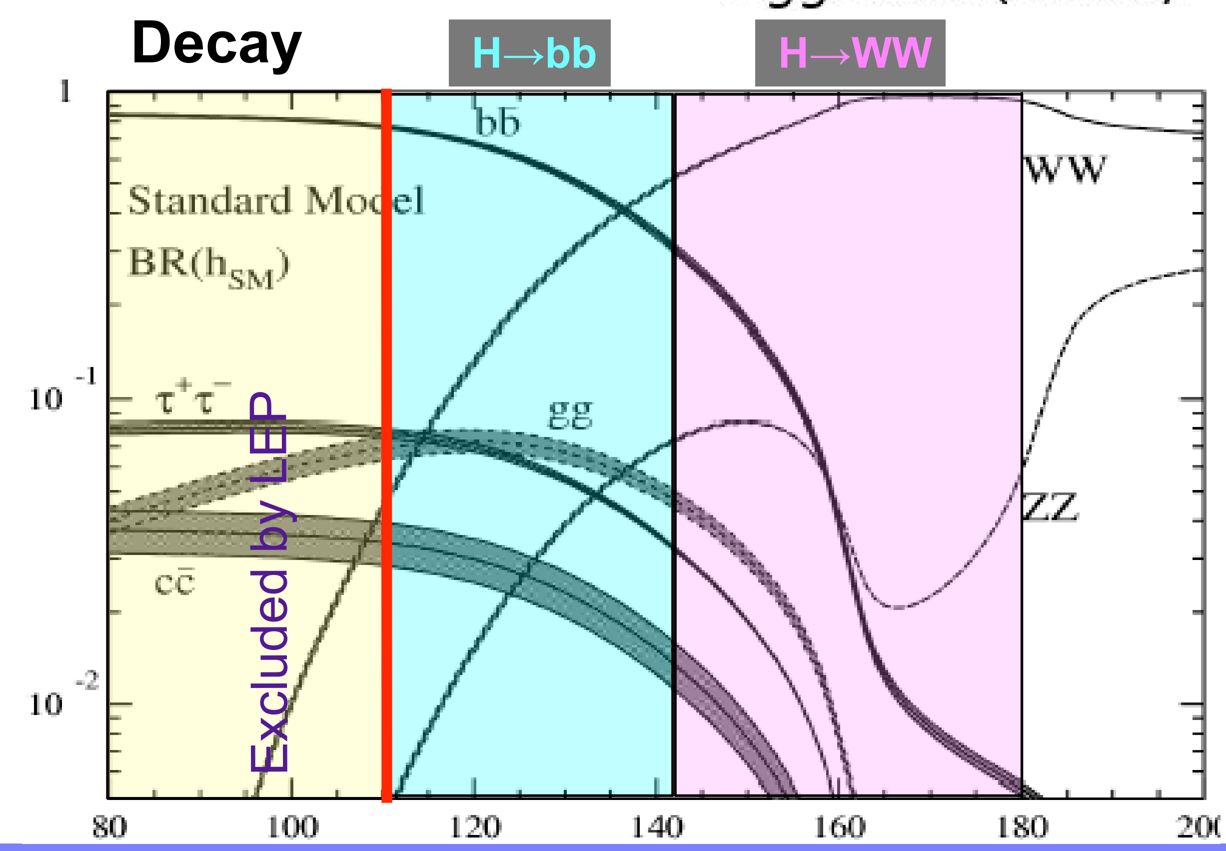
$m_H = 87^{+36}_{-27}$ GeV



SM Higgs Production & Decay

- Small production cross-section
  - [0.1,1] pb
    - WZ, ZZ and single top [1, 4] pb
- Branching ratio drive search strategy
  - m_H < 135 GeV
    - gg→H→bb
      - overwhelmed by multijet (QCD) background
    - Associated production WH & ZH, with H→bb
      - Main background Wbb, Zbb, W/Zjj, top, diboson, QCD
  - m_H > 135 GeV
    - gg→H→WW
    - Main background: WW

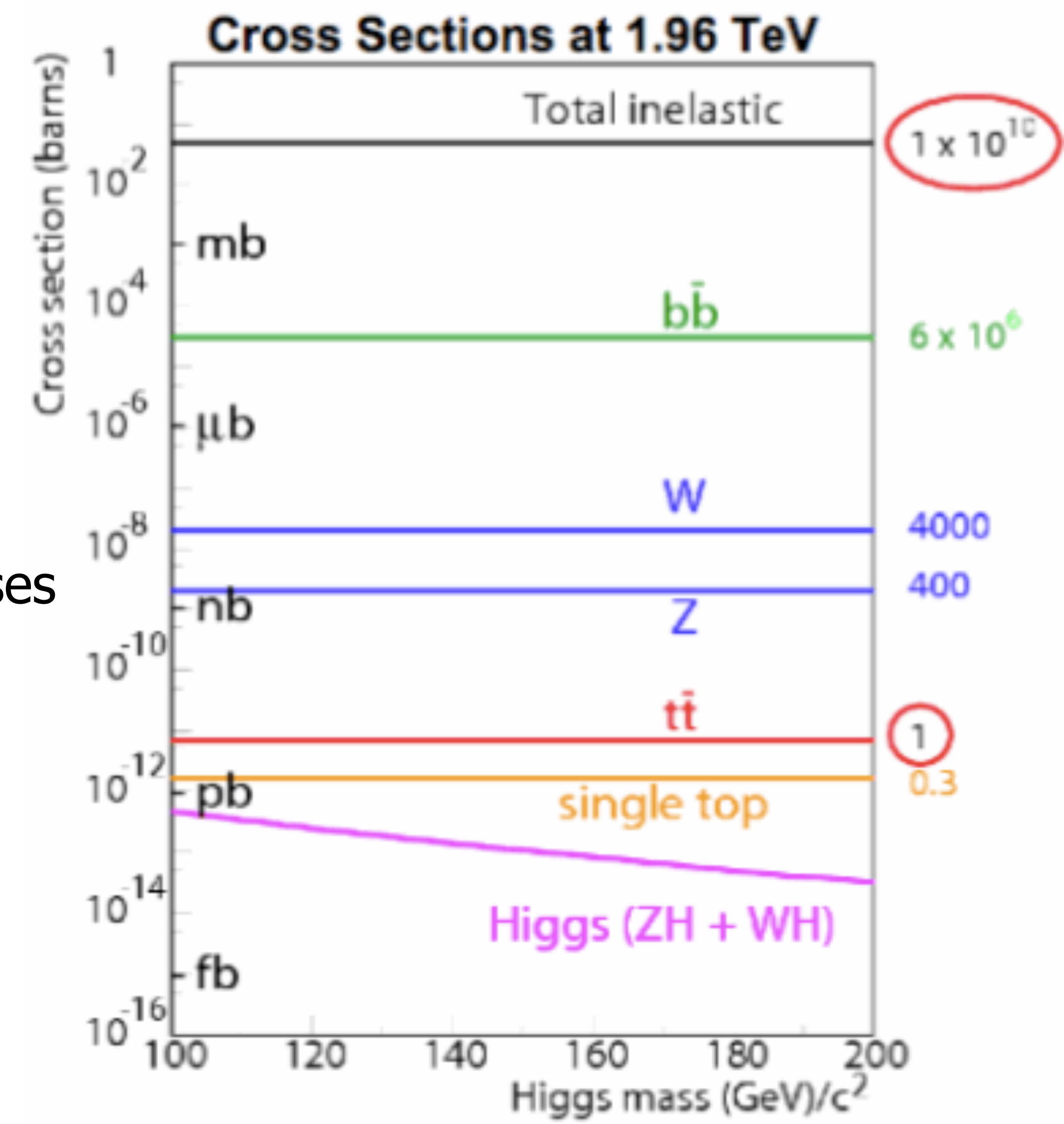


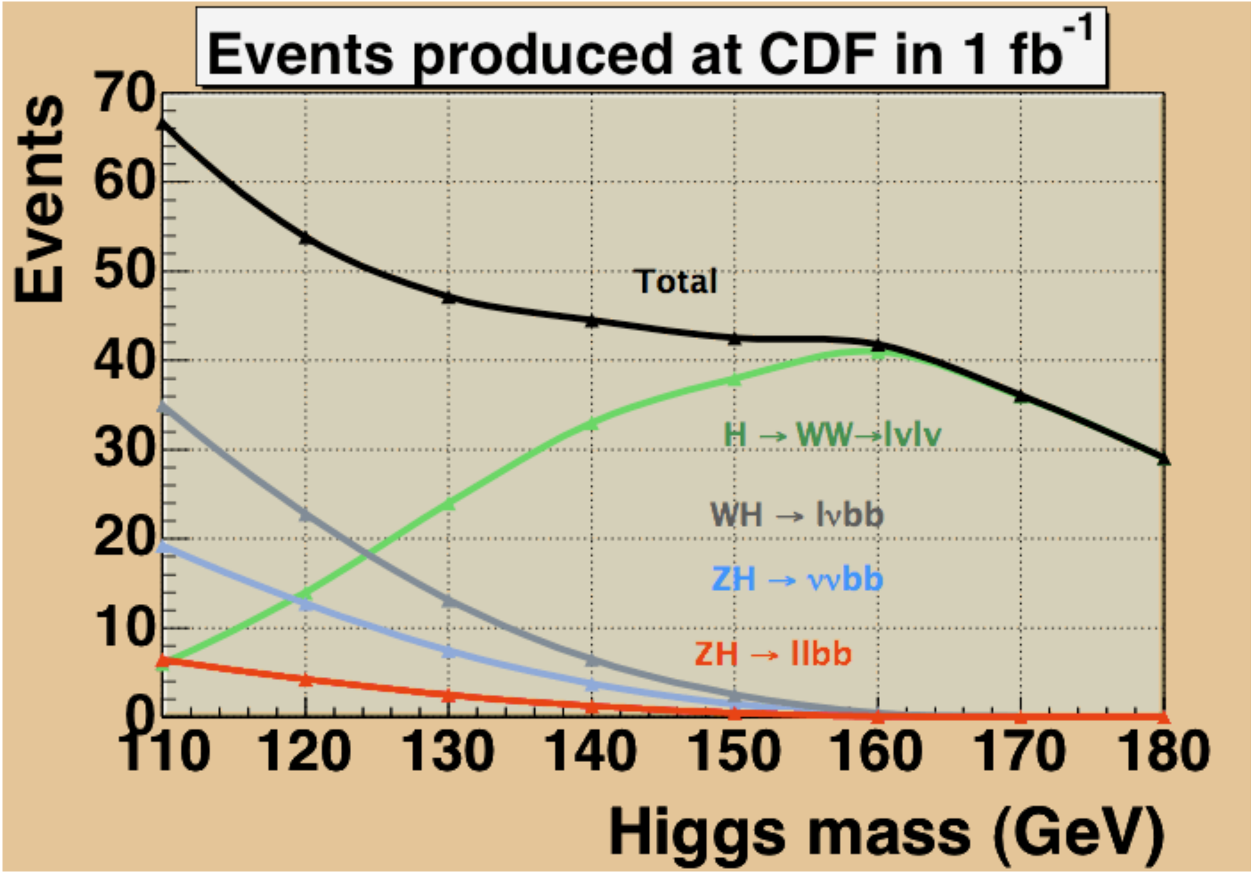


The Challenge

- Higgs production at Tevatron: very low rate
- Backgrounds: many order of magnitude larger
- Challenge: separating signal from background
  - Before anything: S:B ~ $1:10^{11}$
  - Select events with hight p_T lepton(s)
  - Select events with $\not{E}_T$
  - Select events with b-jets (low mass)

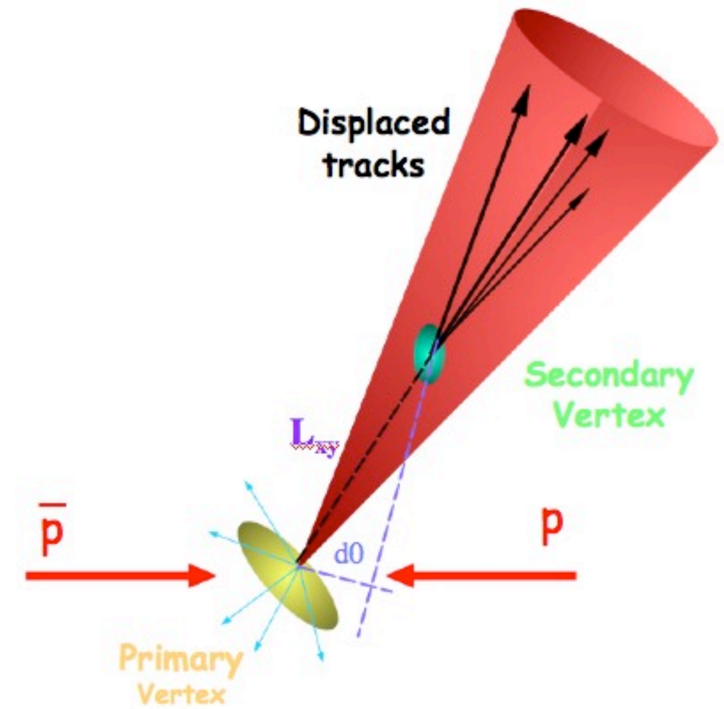
Details varies between analyses

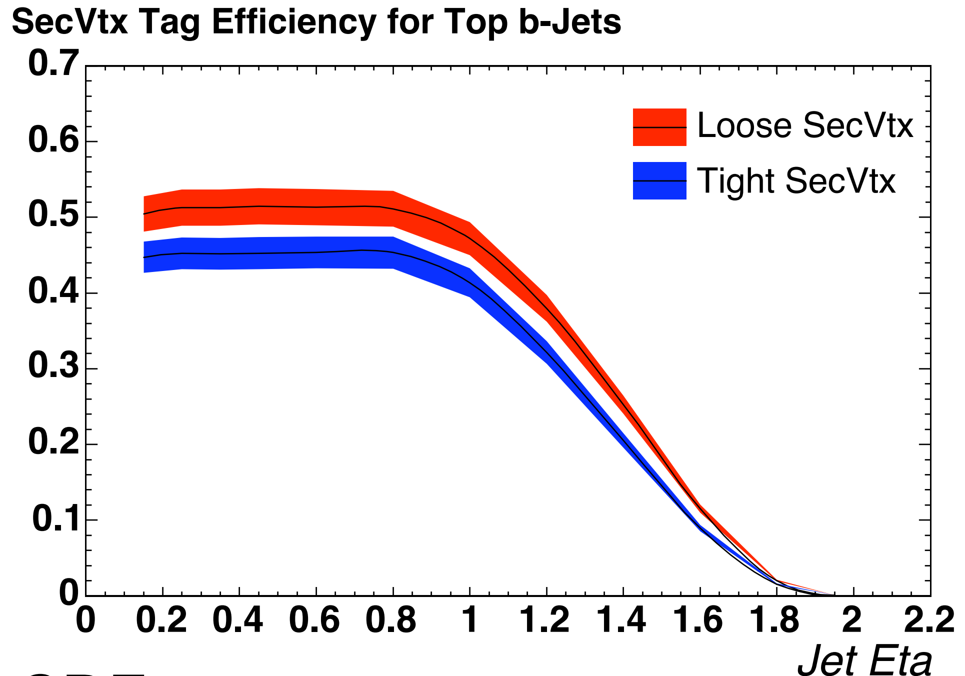


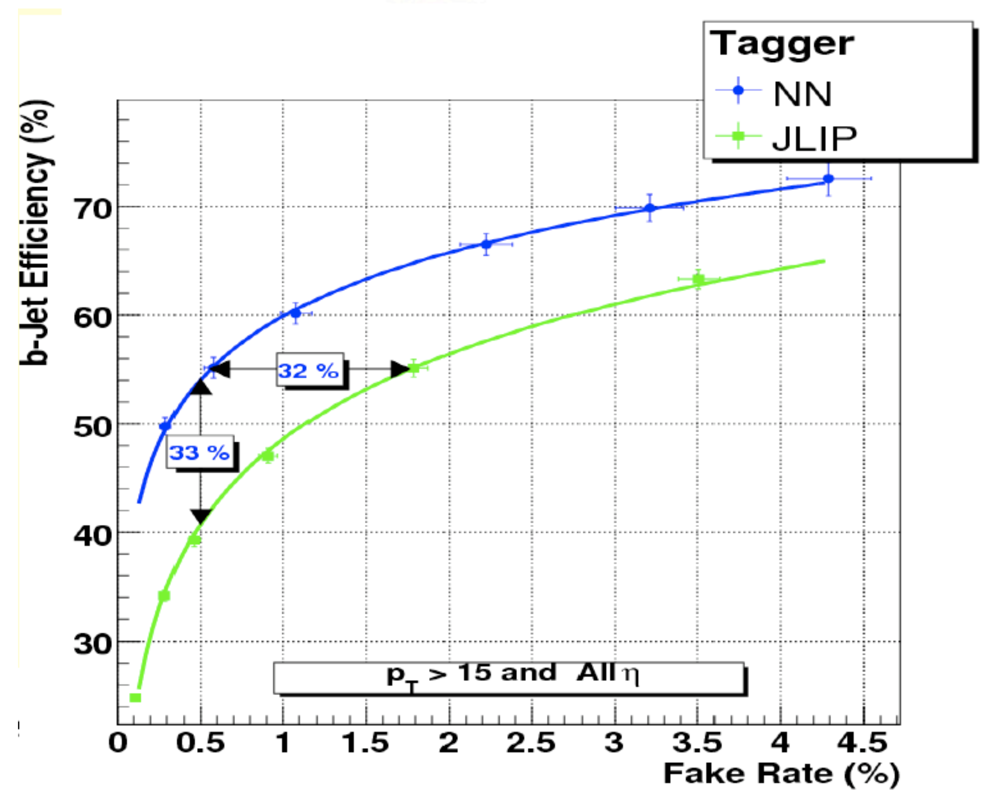


B-Tagging

- Critical for low mass H→bb
  - Improve S/B > 10
- Efficiency: ~50-70%
  - Depending on jet E_T and η
- Mistag rate: ~0.3 - 5%
  - Loose tagging helpful in double tag sample



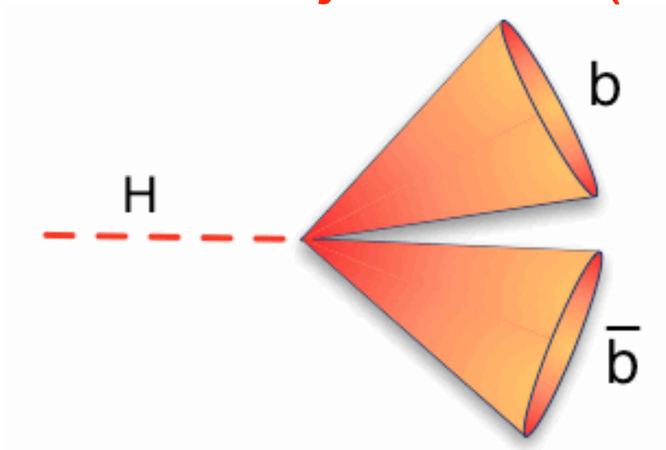


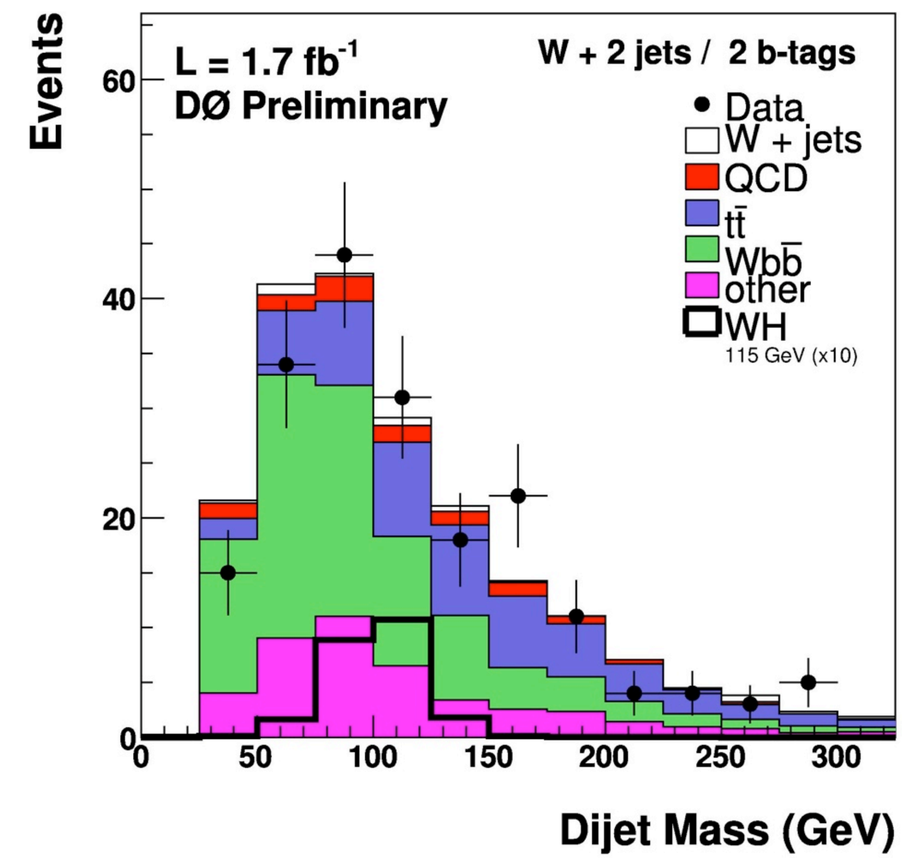


- CDF uses:
  - Secondary vertexing reconstruction
    - NN for flavor separation
  - Jet probability tagger
- DØ uses an NN tagger based on 7 discriminating B-lifetime variables

Using Advance Techniques

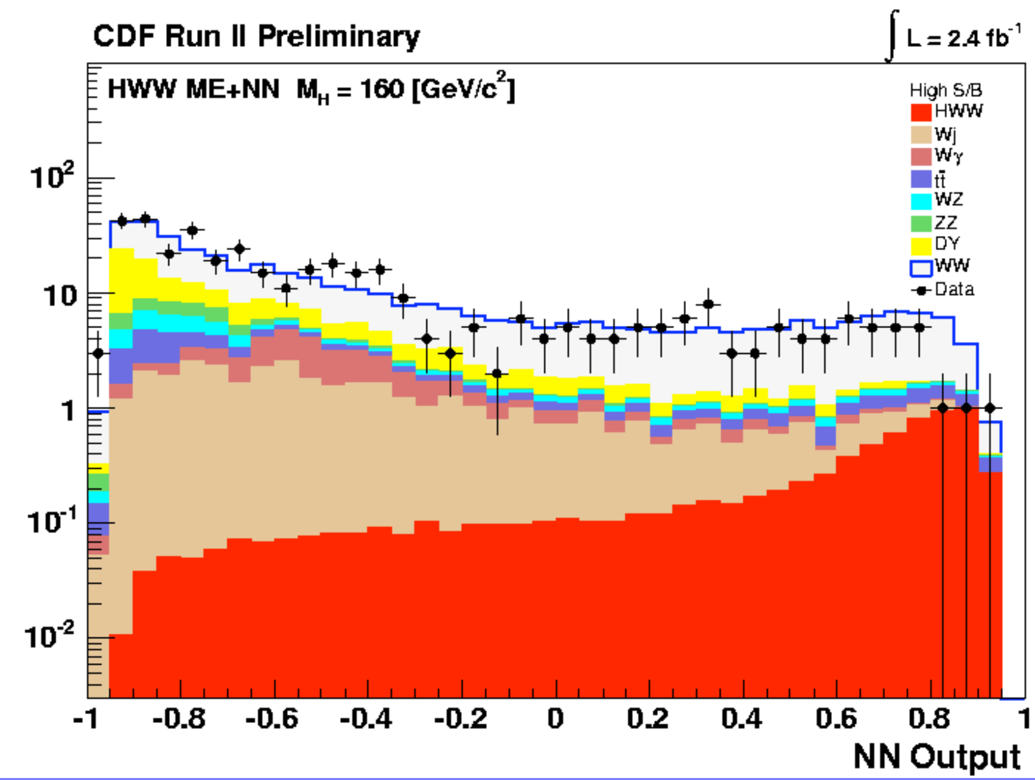
- Use other distinguishing features
  - Simplest approach: fit a kinematic distribution
    - Low m_H: fit di-jet mass ($m_{bb}=m_H$)





  - More sophisticated approach:
    - Use multivariate techniques:
      - Artificial Neural Network (ANN)
        - eg: combine E-based & shape-based kinematic variables
      - Matrix Element (ME)
      - Boosted Decision Tree (BDT)

      ➙ Improved discrimination & less sensitive to systematic effects



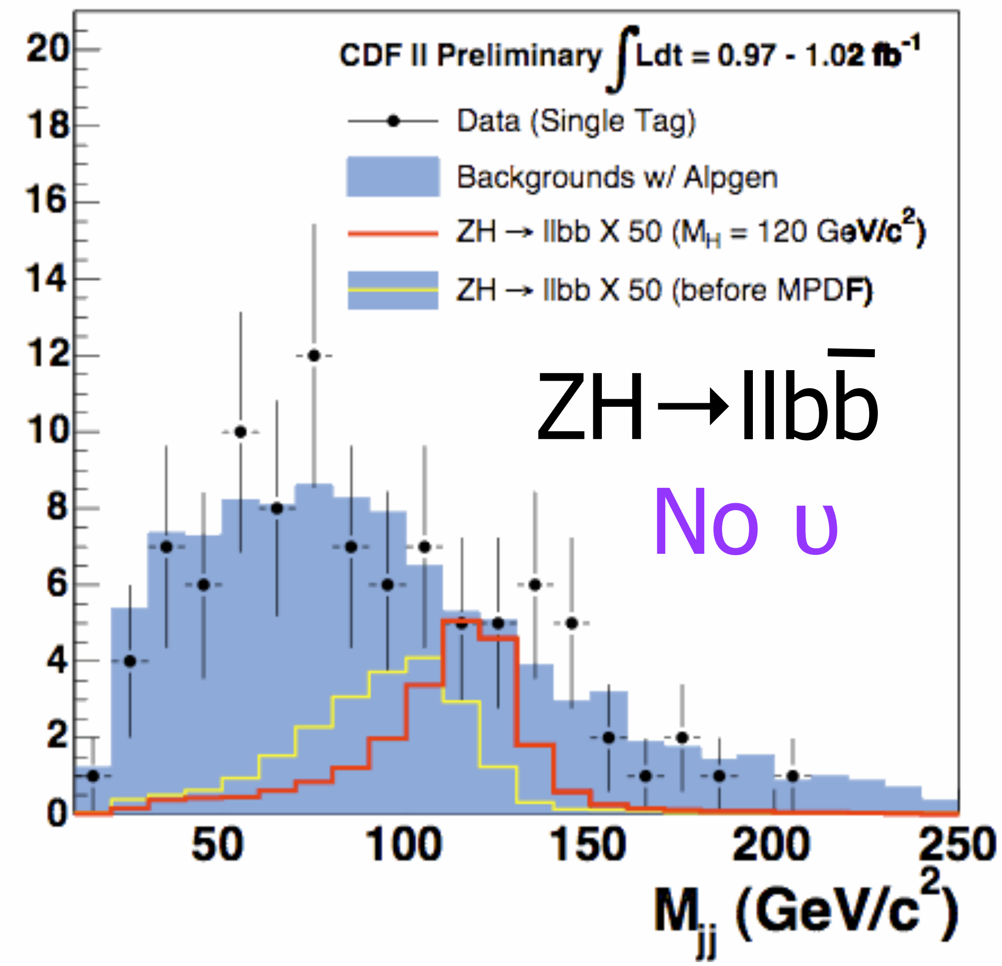
Optimization

- Intense on-going optimization efforts

This is the hard work

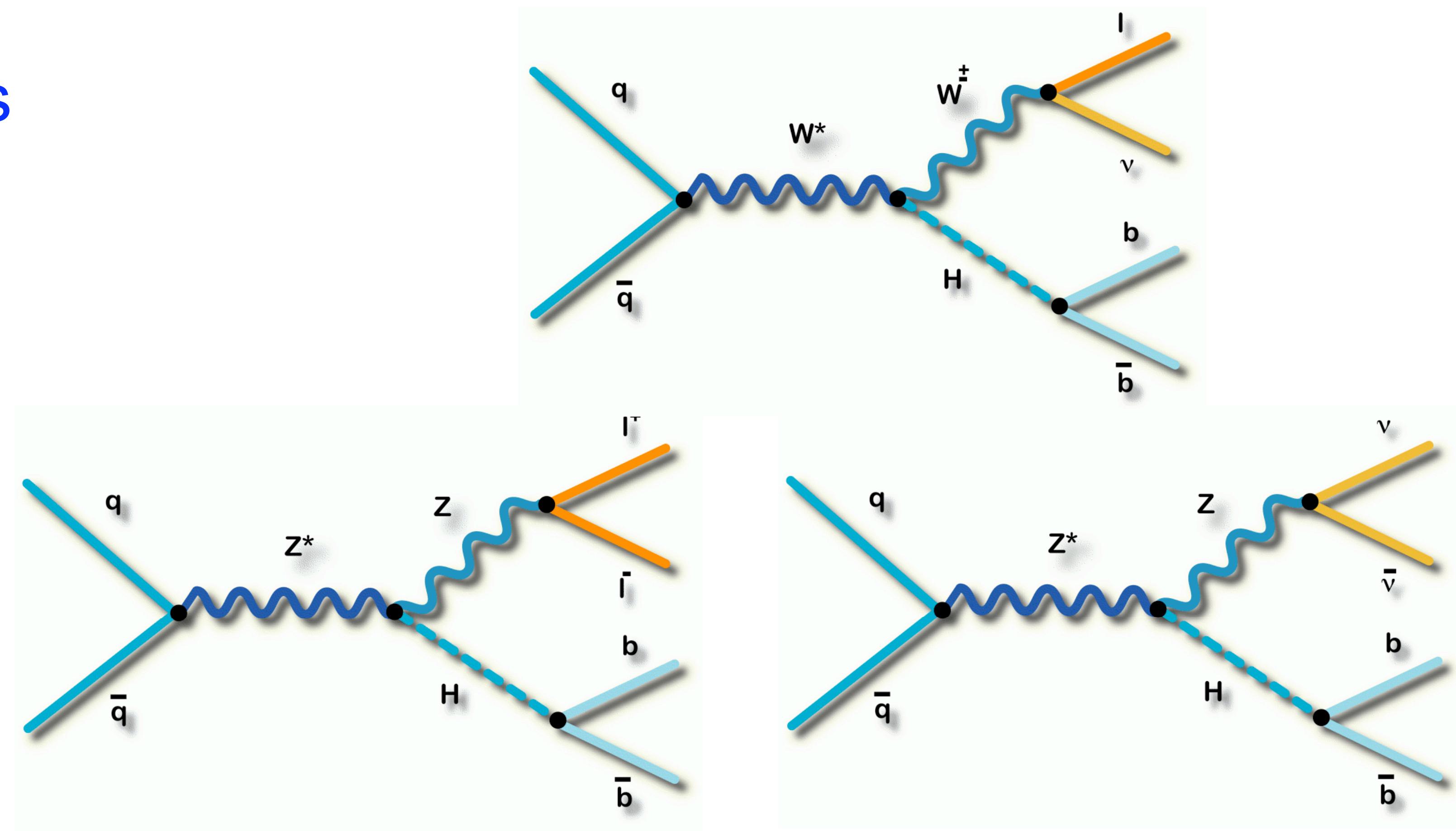
- Basic selection
  - Trigger configurations
  - Acceptance via high p_T leptons identification
- B-Tagging
  - Various tagging criteria
  - Neural Network Tagging
- $\not\!\!E_T$ & Jet Resolution
  - Critical for m_{jj} resolution
  - Multivariate inputs

e.g. Improved m_{jj}



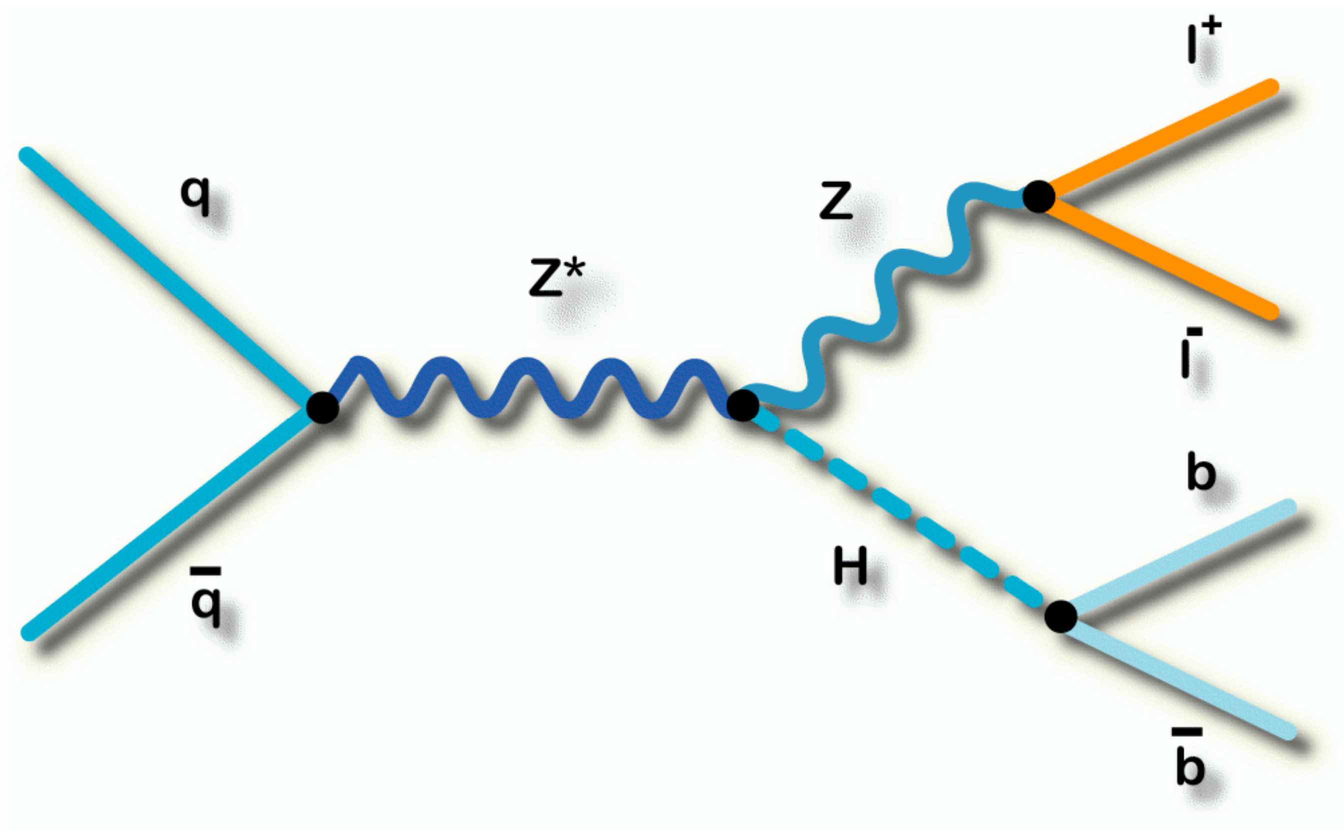
Low Mass SM Higgs

- Introduction
  - Constraints on the Higgs
  - Higgs production & decay
  - Analyses techniques & status
- Low mass:
  - $ZH \rightarrow llb\bar{b}$
  - $ZH \rightarrow \nu\nu b\bar{b}$
  - $WH \rightarrow l\nu b\bar{b}$
  - $VH, VBF, H \rightarrow \tau\tau + 2j$
  - $H \rightarrow \gamma\gamma$
- High Mass
  - $H \rightarrow WW$
  - $WH \rightarrow WWW^*$
- Combination



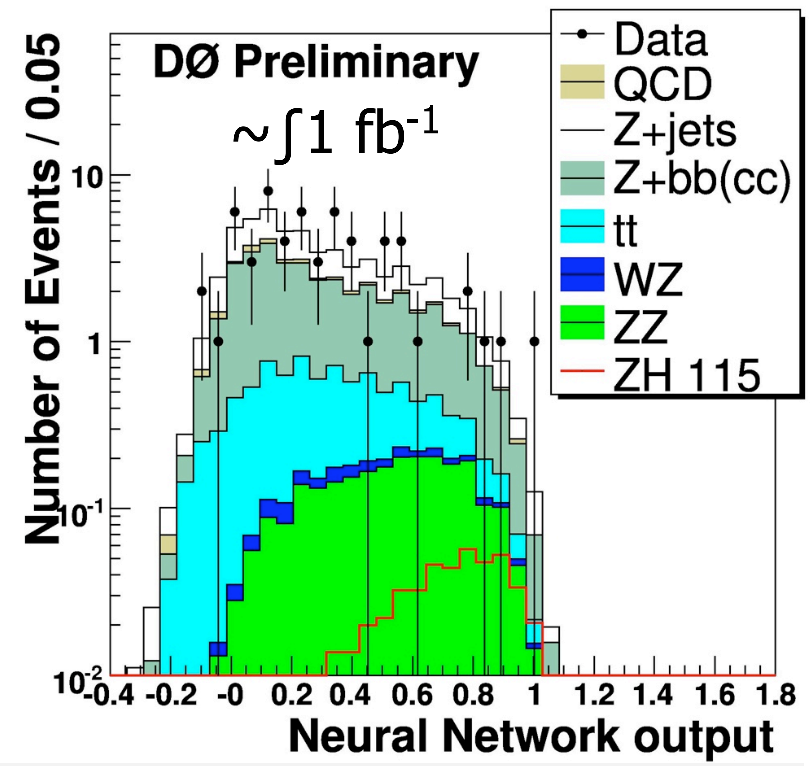
$ZH \rightarrow ll b\bar{b}$ channel

- Cleanest low mass channel but low σ×BR
  - Several tight constraints
    - $M_{ll} \cong M_Z$
    - "$\not\!\!E_T$" ➔ improve jet resolution
- Selection
  - Two high p_T leptons
  - No (direct) $\not\!\!E_T$
  - Two jets
    - Split up 1 & 2 b-tags
- Backgrounds
  - $Zb\bar{b}, Zc\bar{c}, Zqq'$
  - $t\bar{t}$
  - $WW + jj, WZ, ZZ$
  - $Z \rightarrow \tau\tau$



$ZH \rightarrow ll b\bar{b}$ channel

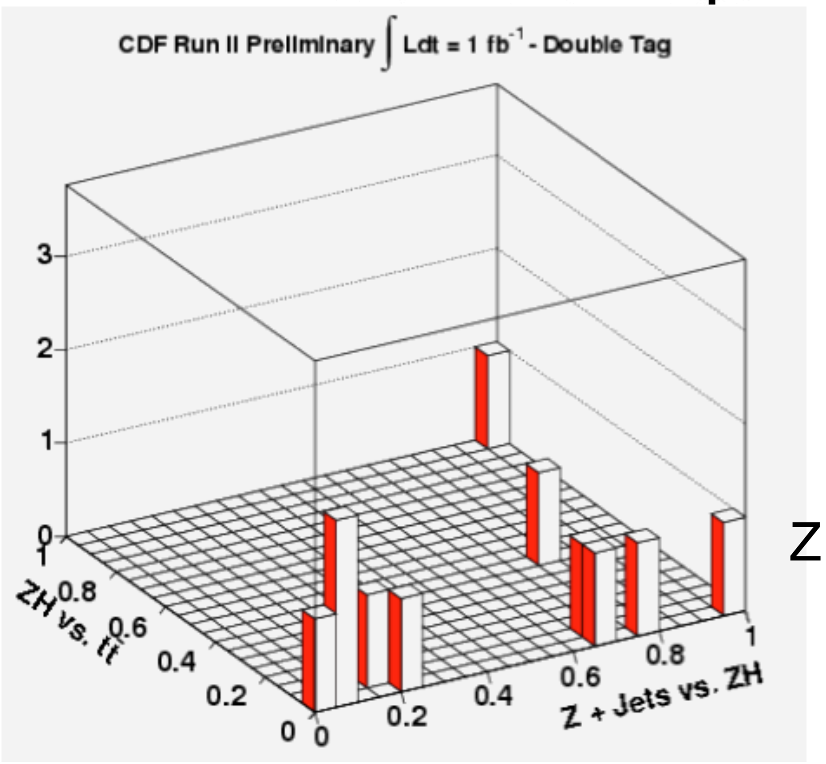
Double tag ANN



- ANN inputs
  - $M_{b\bar{b}},\ p_T^{j_1},\ p_T^{j_2},\ \Delta R_{ll},$
  - $|\Delta\eta_{jj}|,\ |\Delta\phi_{jj}|,\ \Delta R_{Zj_1},$
  - $|\eta_Z|,\ \not{E}_T,\ \sum E_T^i$
- Split 2-loose b-tags, 1-tight b-tag

- ANN correcting di-jets mass
- 2D ANN
  - $\not{E}_T,\ H_T,\ M_{jj},\ Sph,\ \eta_{j_2}$
  - $\Delta R_{Z,j_1},\ \Delta R_{Z,j_2},\ \Delta R_{j_1,j_2}$
- Split 1 b-tag, 2 b-tags

tt like



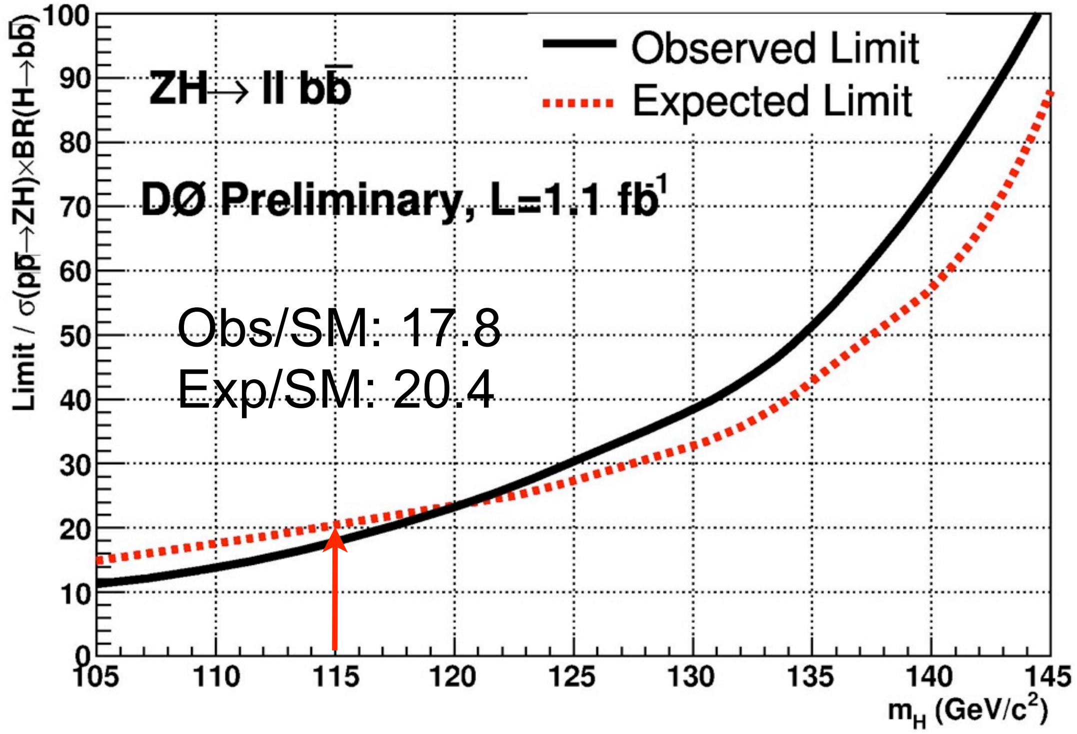
ZH like

Z+jets like

$ZH \rightarrow ll b\bar{b}$ channel

DØ

- ANN inputs
  - $M_{b\bar{b}},\ p_T^{j_1},\ p_T^{j_2},\ \Delta R_{ll},$
  - $|\Delta\eta_{jj}|,\ |\Delta\phi_{jj}|,\ \Delta R_{Zj_1},$
  - $|\eta_Z|,\ \not{E}_T,\ \sum E_T^i$
- Split 2-loose b-tags, 1-tight b-tag



CDF

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- 2D ANN
  - $\not{E}_T,\ H_T,\ M_{jj},\ Sph,\ \eta_{j_2}$
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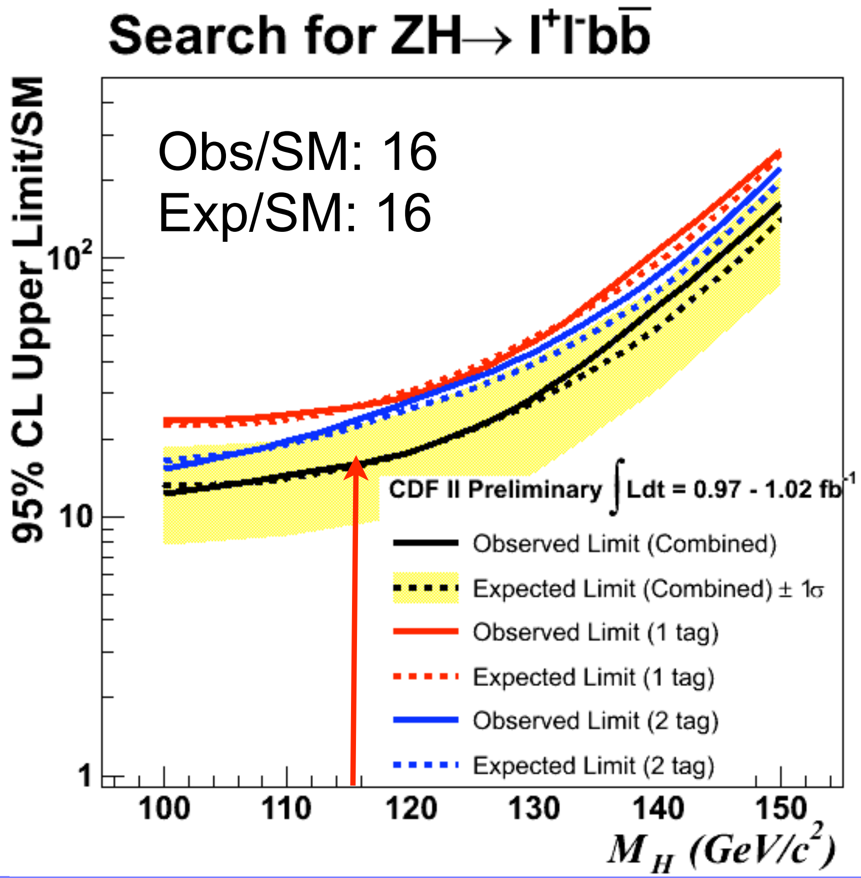
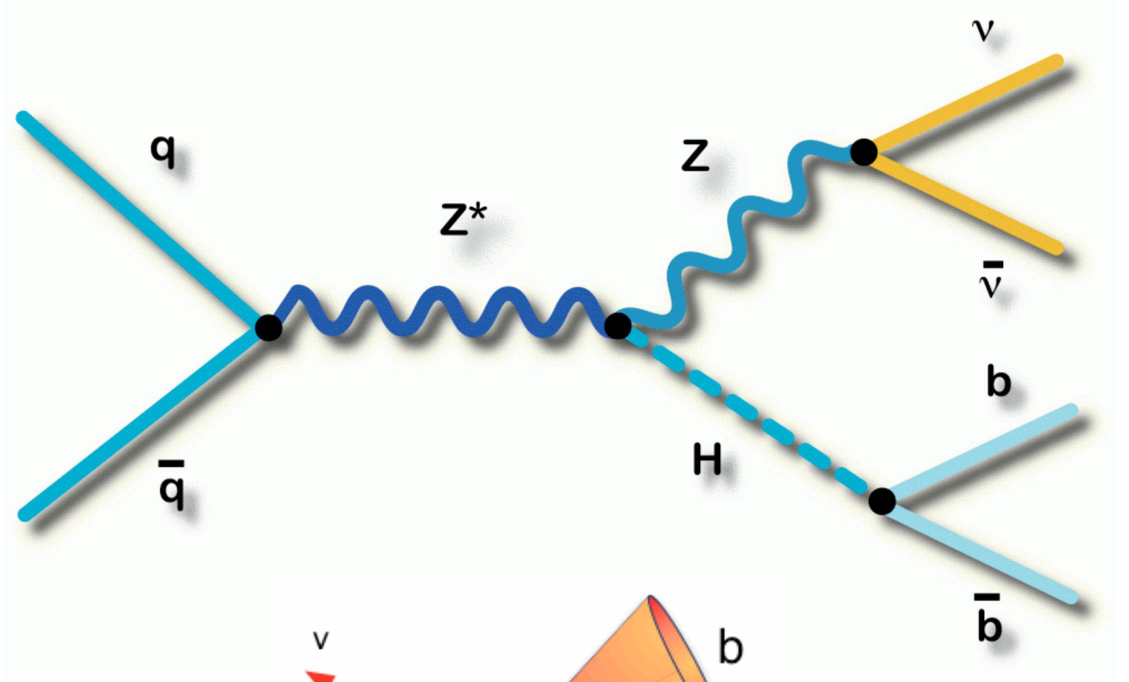
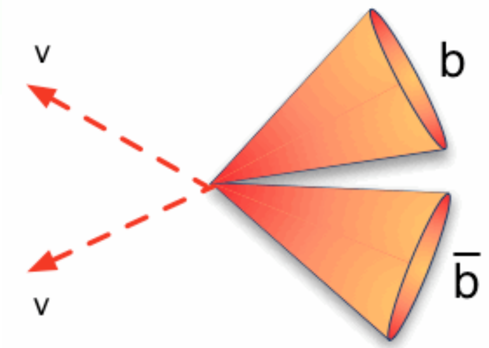


$ZH \rightarrow \nu\nu b\bar{b}$ channel

- Larger σ×BR but very challenging background and trigger wise
  - Contribution from WH channel when lepton is missed (~35%)
- Selection
  - No high p_T lepton
  - Large missing $\not{E}_T$ (not aligned in ϕ with jets)
  - Two jets
    - Split up 1 & 2 b-tags
- Backgrounds
  - QCD heavy flavor (data driven estimate)
  - $t\bar{t},\ W/Z + bb/c\bar{c},$
  - single top,
  - $ZZ,\ WZ,\ WW$



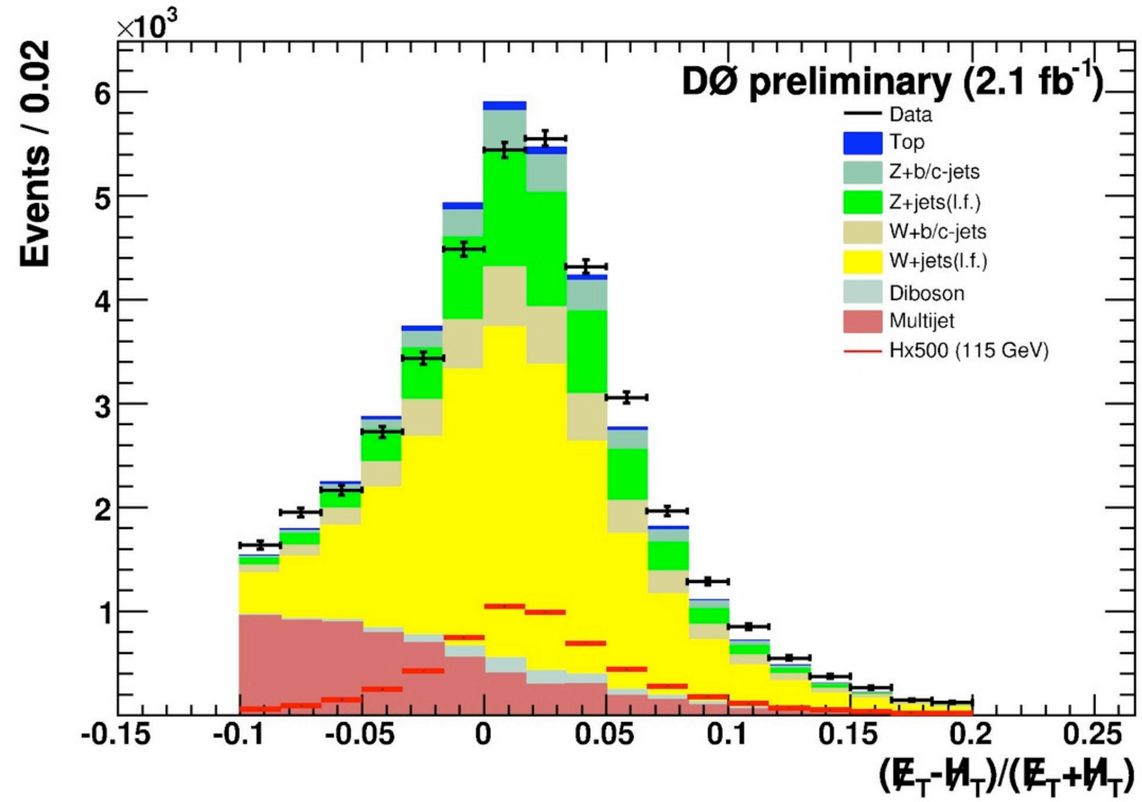


Challenges:

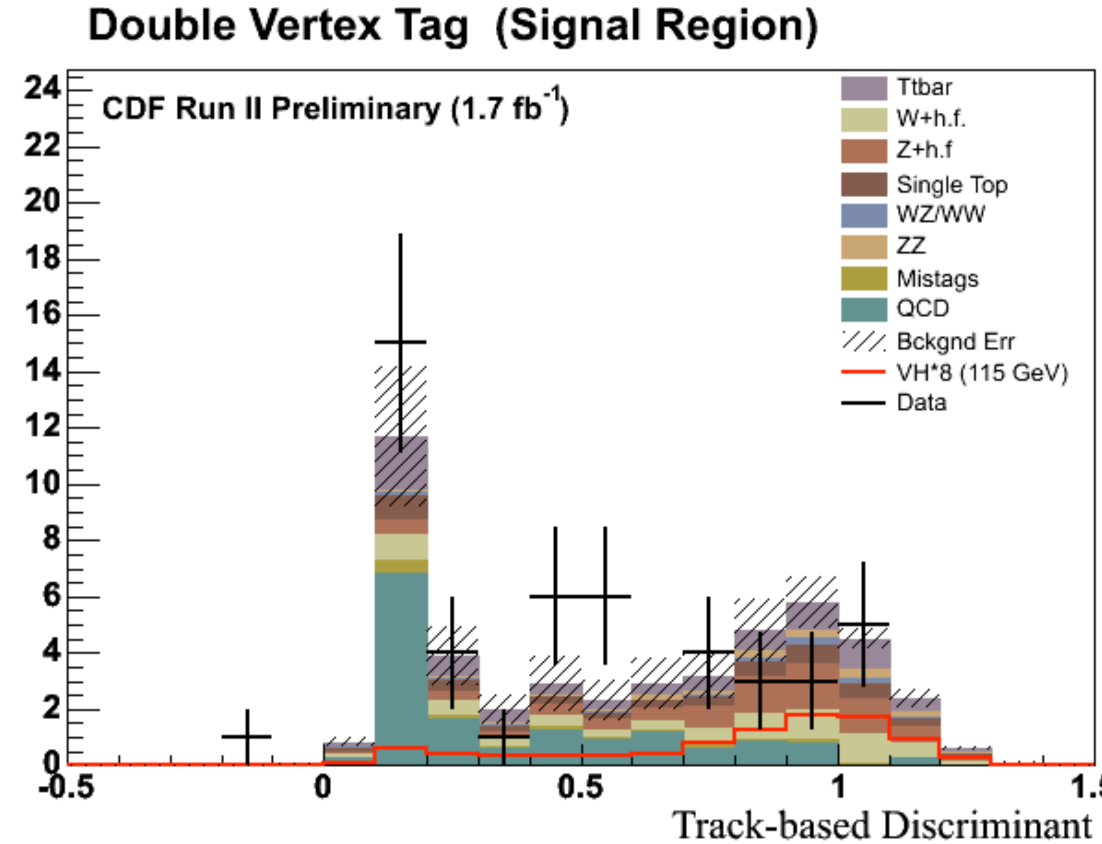
1. Trigger: $\not{E}_T$+2 jets
2. Large QCD/Fake backgrounds
   i. Difficult to simulate
   ii. Use data to estimate bkg

$ZH \rightarrow \nu\nu b\bar{b}$ channel

- Defines asymmetry between $\not{H}_T$ & $\not{E}_T$ to isolated mis-measured jets
  - $\not{H}_T$: measured with jets
  - $\not{E}_T$: measured with calorimeter cells
- Final discriminant: boosted decision tree
  - Inputs: 25 variables



- ANN based on charged track quantities to separate genuine $\not{E}_T$ from calorimetry mis-measurement
- ANN to separate ZH(WH) from QCD, $t\bar{t}$
  - $M_{jj},\ \not{E}_T,\ \Delta R_{j_1,j_2},$
  - $\not{E}_{T\,cal},\ \not{E}_{T\,trk},\ Trk_{NN}$



ZH→$\nu\nu b\bar{b}$ channel

DØ

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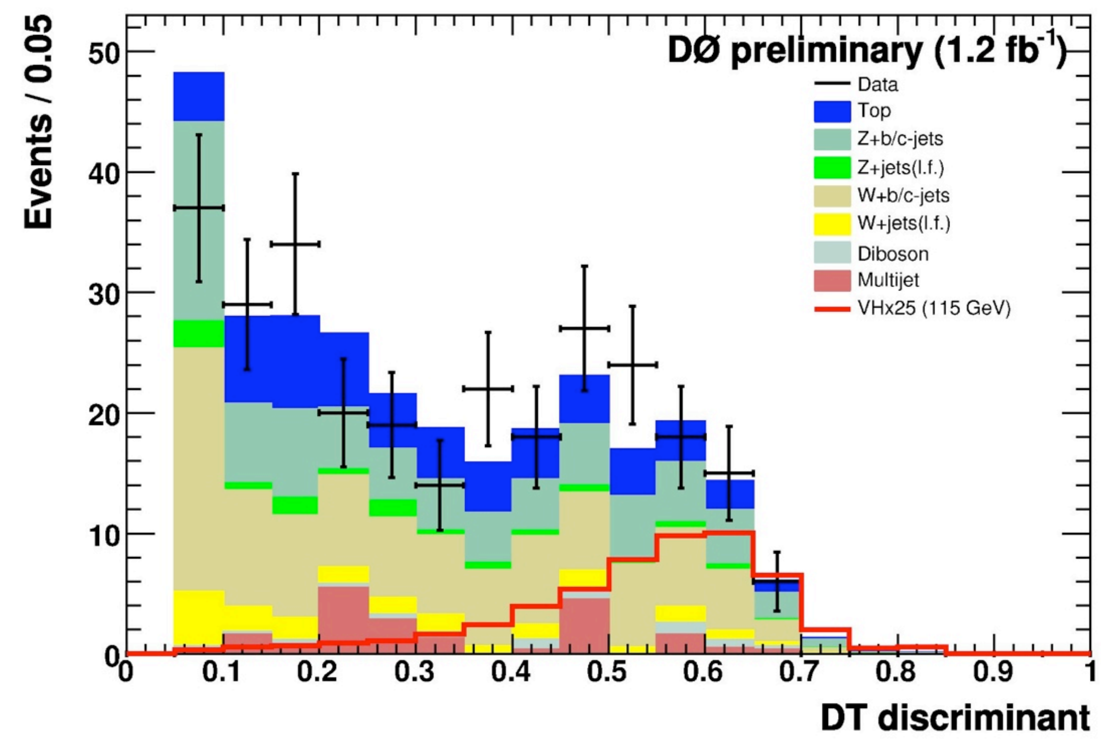

CDF

- ANN based on charged track quantities to separate genuine $\not{E}_T$ from calorimetry mis-measurement
- ANN to separate ZH(WH) from QCD, $t\bar{t}$
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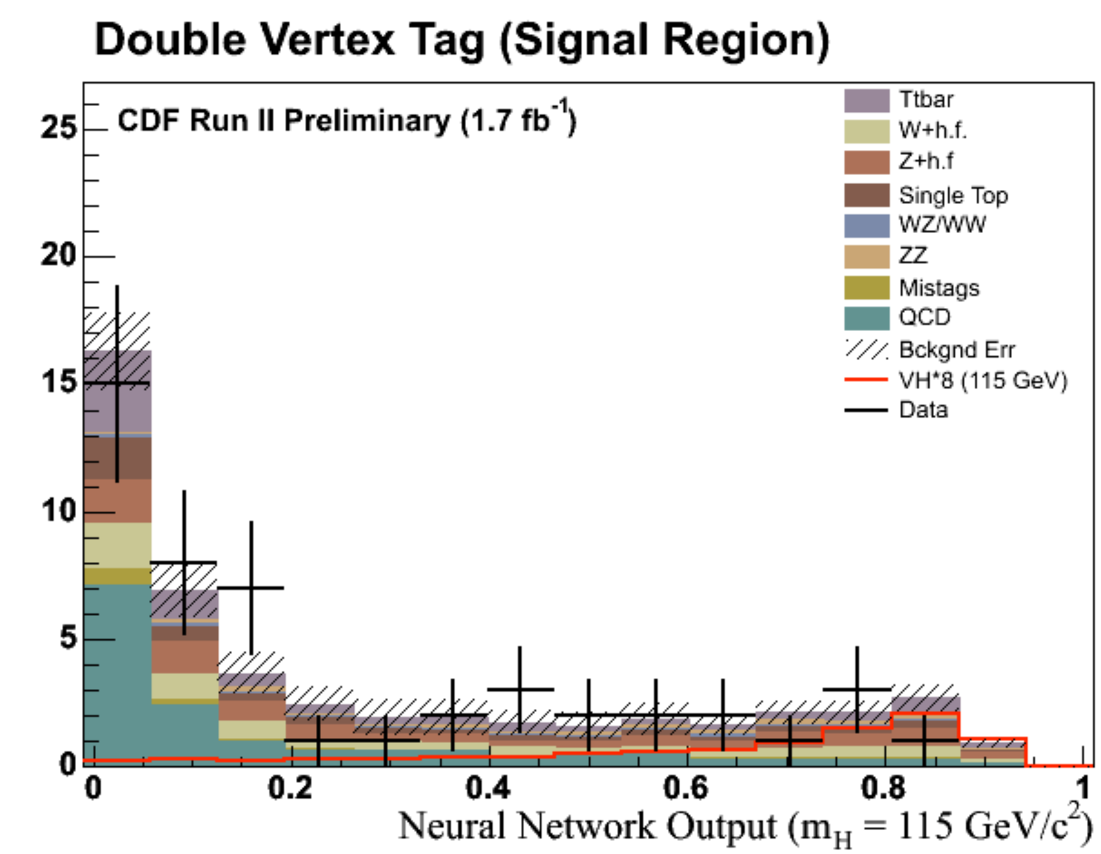

$ZH \rightarrow \nu\nu b\bar{b}$ channel

DØ

- Defines asymmetry between $\not{H}_T$ & $\not{E}_T$ to isolated mis-measured jets
  - $\not{H}_T$: measured with jets
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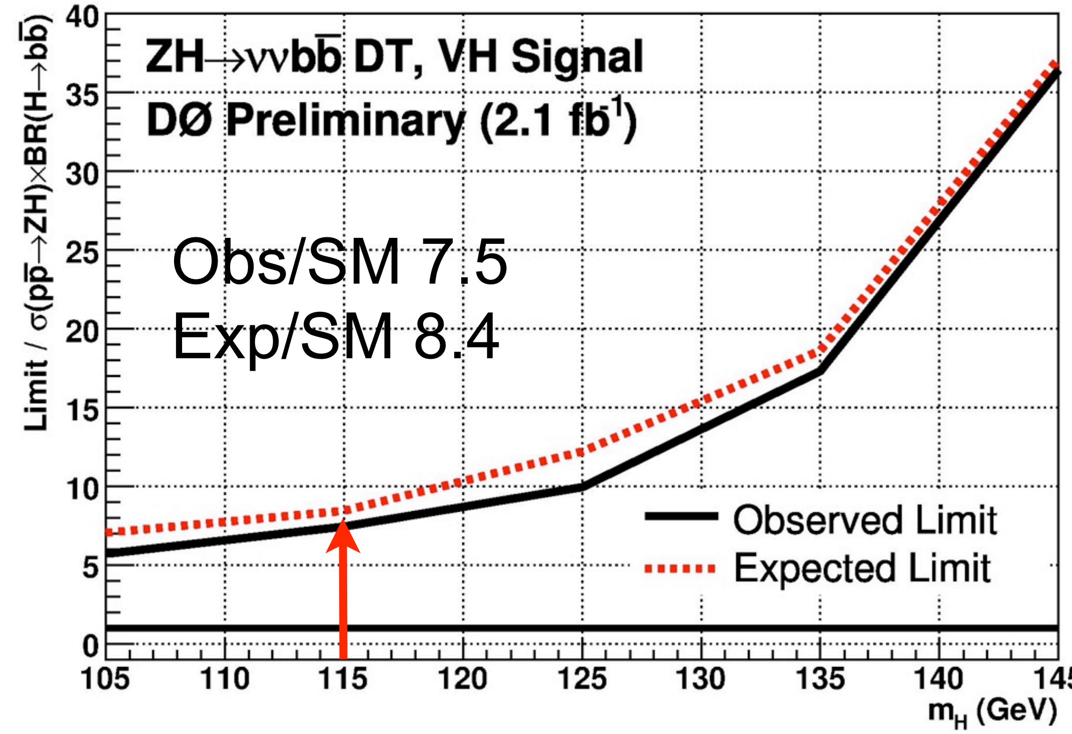
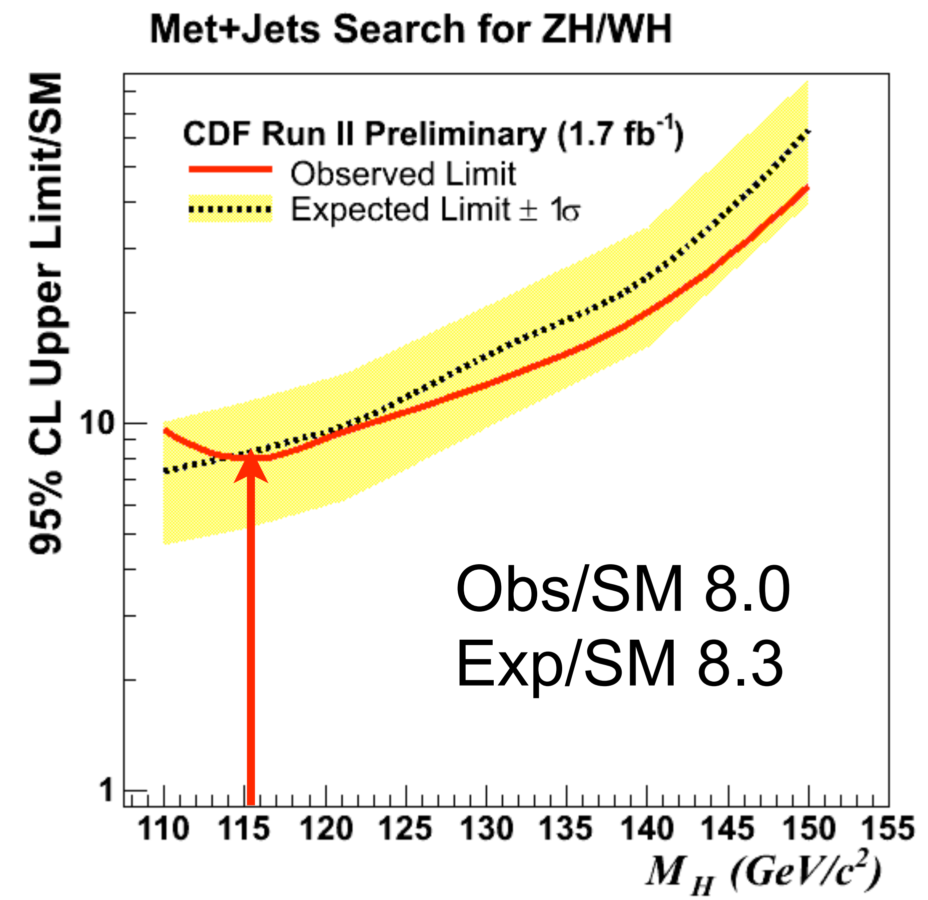


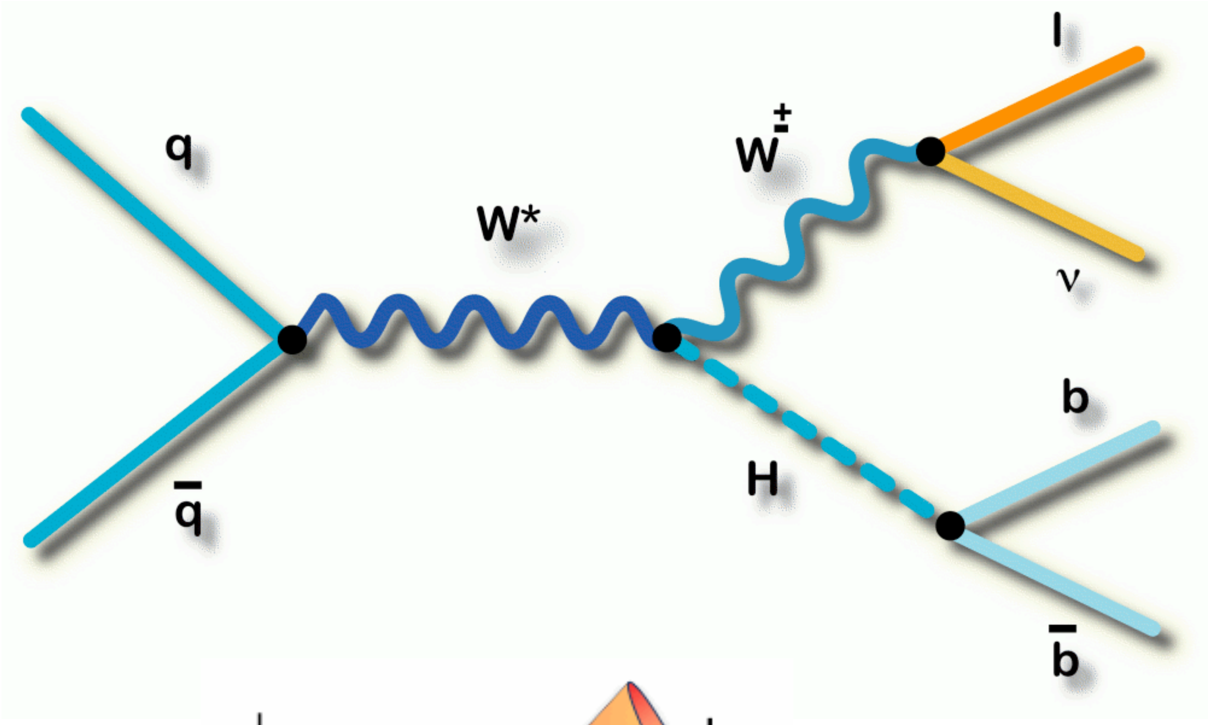
CDF II

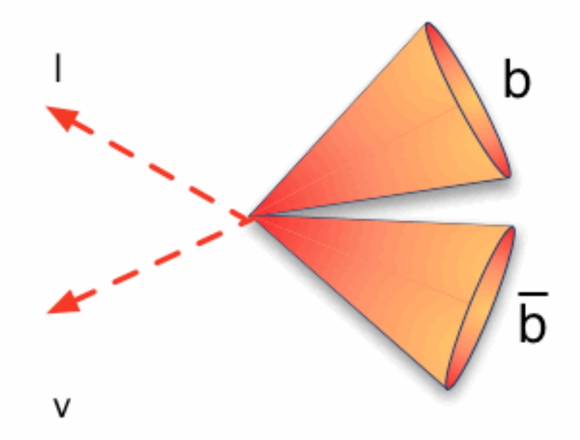
- ANN based on charged track quantities to separate genuine $\not{E}_T$ from calorimetry mis-measurement
- ANN to separate ZH(WH) from QCD, $t\bar{t}$
  - $M_{jj},\ \not{E}_T,\ \Delta R_{j_1,j_2},$
  - $\not{E}_{T\,cal},\ \not{E}_{T\,trk},\ Trk_{NN}$



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

- Largest σ×BR
  - Good acceptance (e, μ)
  - Final state similar to single top
- Selection
  - High p_T lepton
  - $\not{E}_T$
  - Two jets
    - Split up 1 & 2 b-tags
- Backgrounds
  - $Wb\bar{b}$, $Wc\bar{c}$, Wqq'
  - $t\bar{t}$, single top
  - QCD,
  - $WZ,\ WW,\ Z \rightarrow \tau\tau$

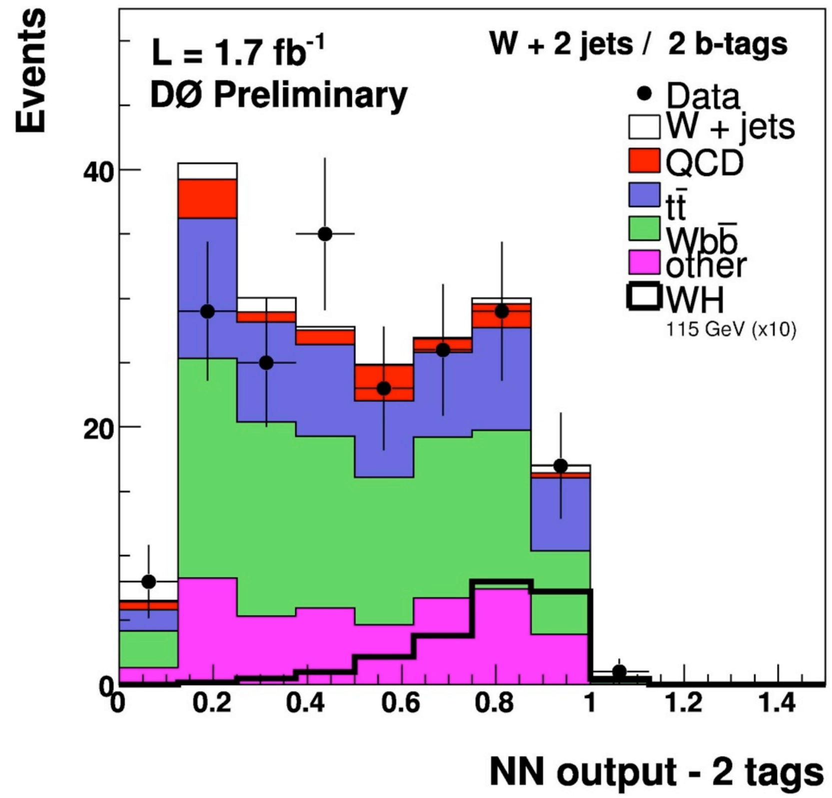




$WH \rightarrow l\nu b\bar{b}$ channel

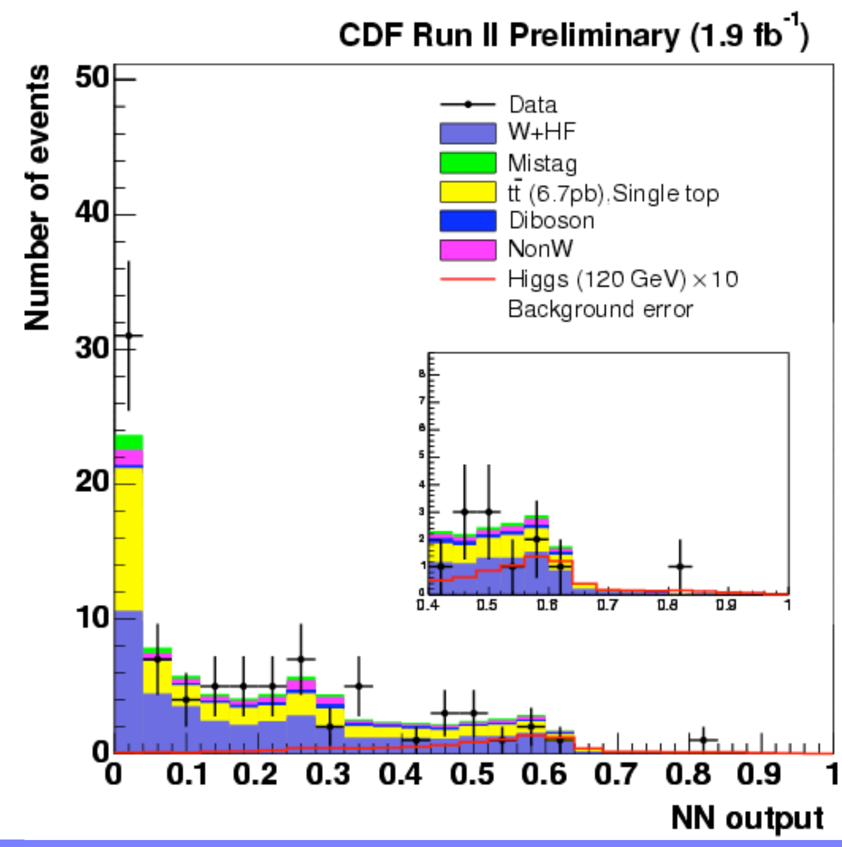
DØ

- ANN inputs
  - $p_T^{j_1}, p_T^{j_2}, \Delta R_{jj}, \Delta\phi_{jj}$
  - $p_T^{jj}, M_{jj}, p_T^{l-\not{E}_T}$
- 8 classes of events
  - Use e, μ
  - single & double tags
  - 2 data periods



CDF

- ANN inputs
  - $M_{jj}, p_T^{\text{imb}}, p_T^{\text{sys}},$
  - $M_{l\nu j}^{\text{min}}, \Delta R_{l\nu}, E_T^{\text{jets}}$
- 6 classes of events
  - Central (e,μ), plug (e)
  - 3 b-taggings



WH→lυbb̄ channel

DØ

- ANN inputs
  - $p_T^{j_1}, p_T^{j_2}, \Delta R_{jj}, \Delta\phi_{jj}$
  - $p_T^{jj}, M_{jj}, p_T^{l-\not{E}_T}$
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  - Use e, μ
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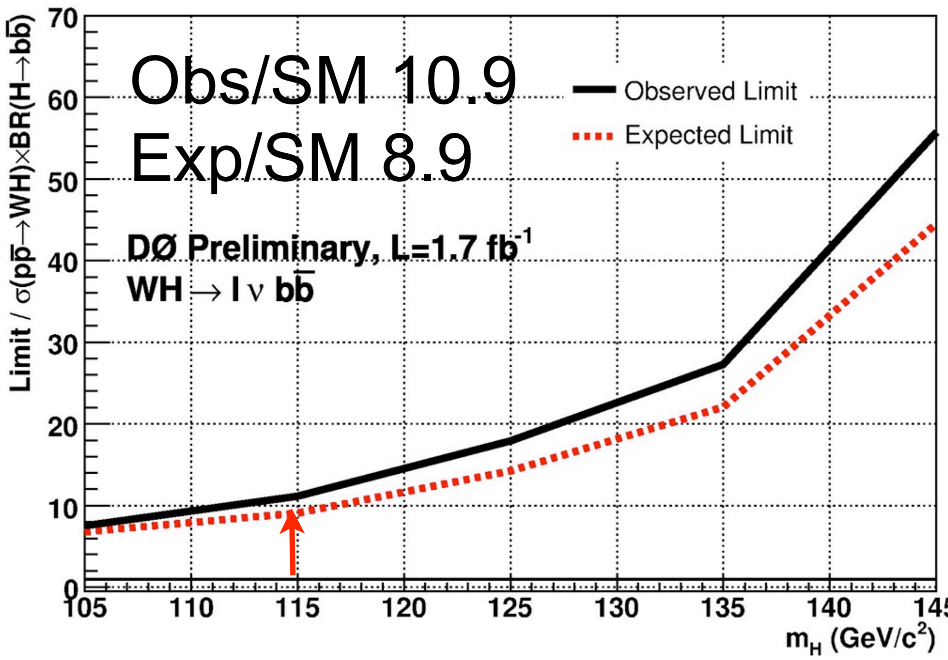

CDF

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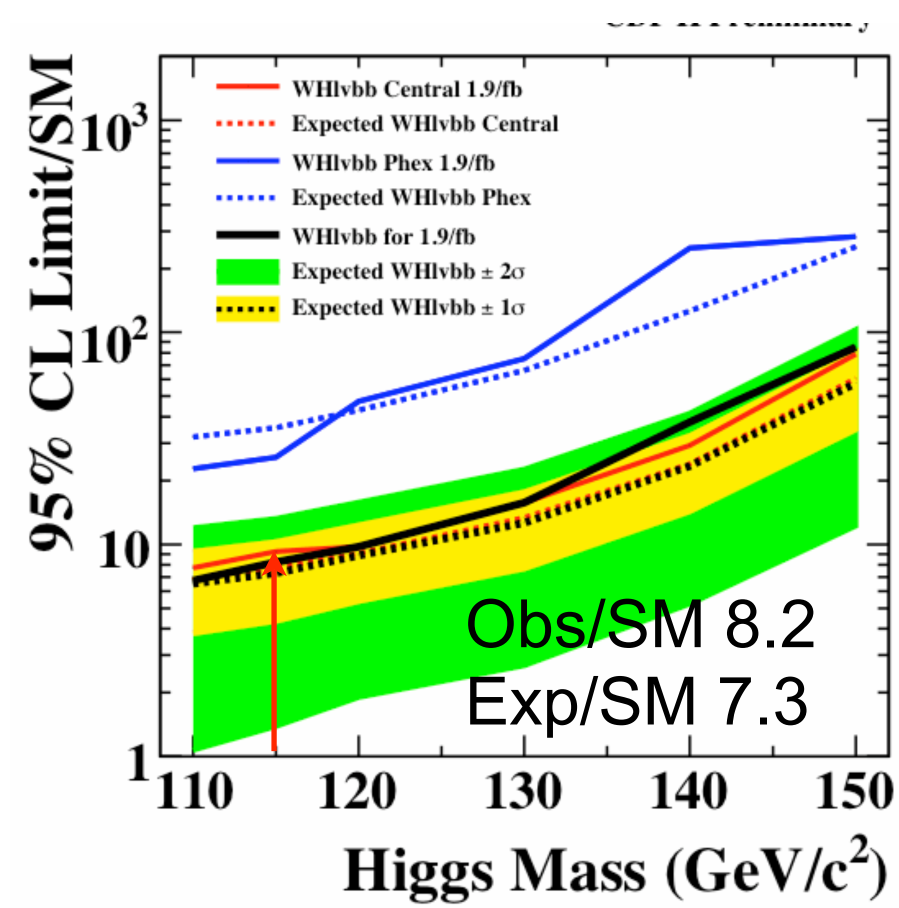
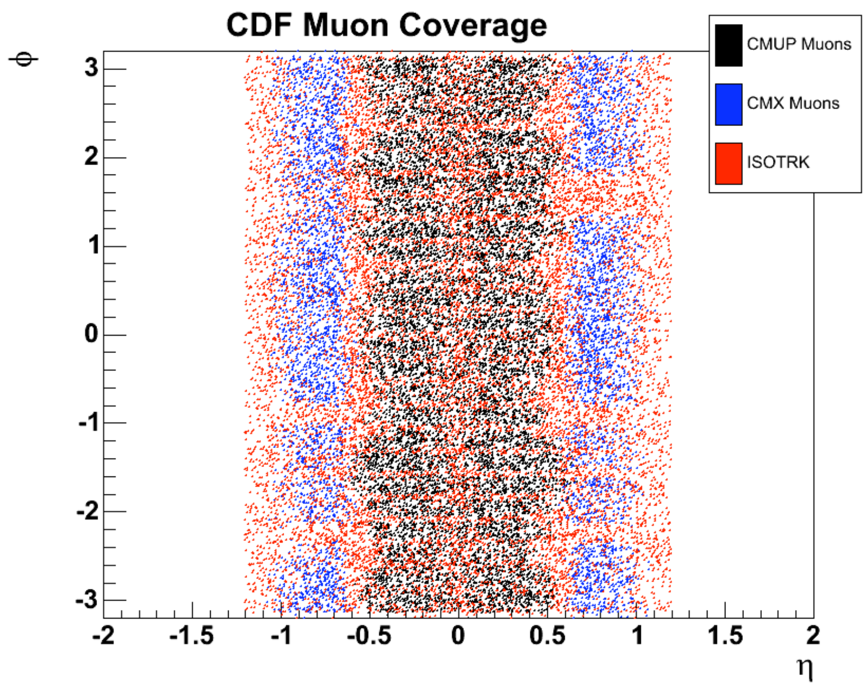


Adding acceptance to WH: isolated track

- Expand acceptance with high p_T isolated tracks failing standard e,μ selection
  - No calorimetry or muon chamber info
- Use $\not{E}_T$+2 jets trigger
- Increase acceptance by 25%



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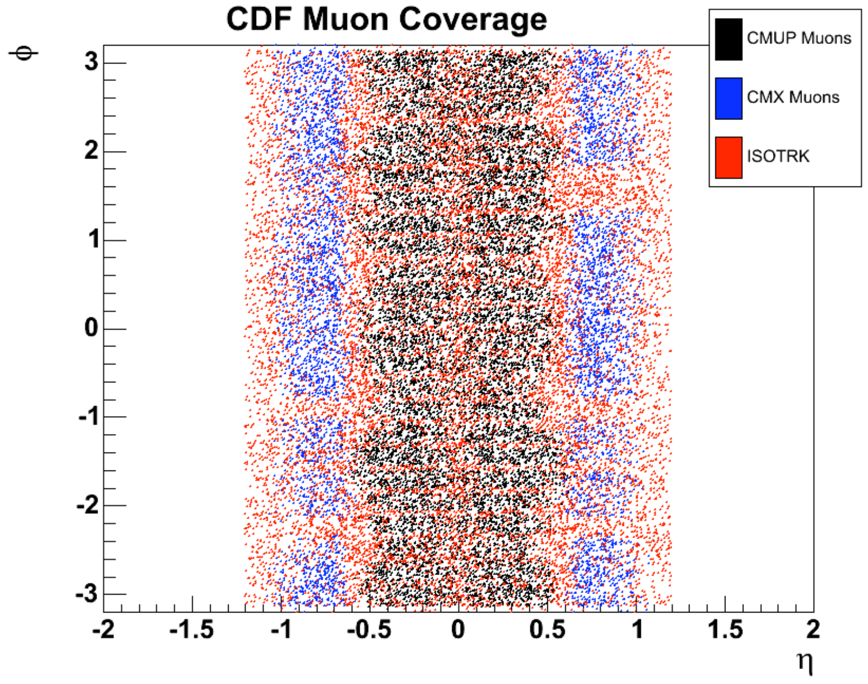

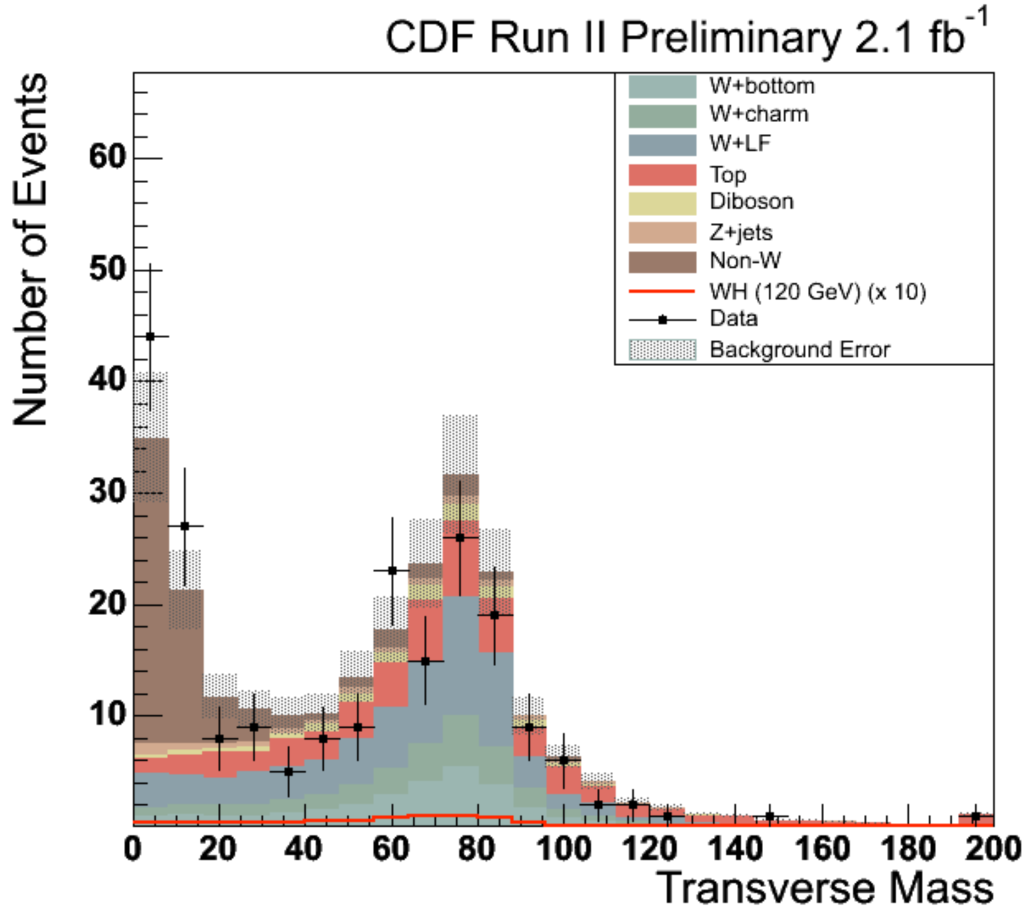

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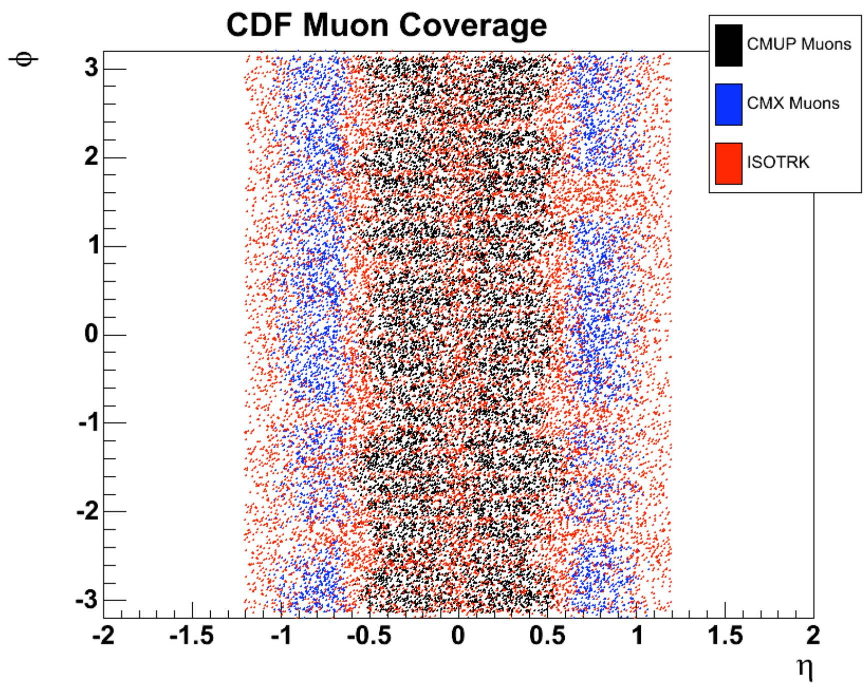
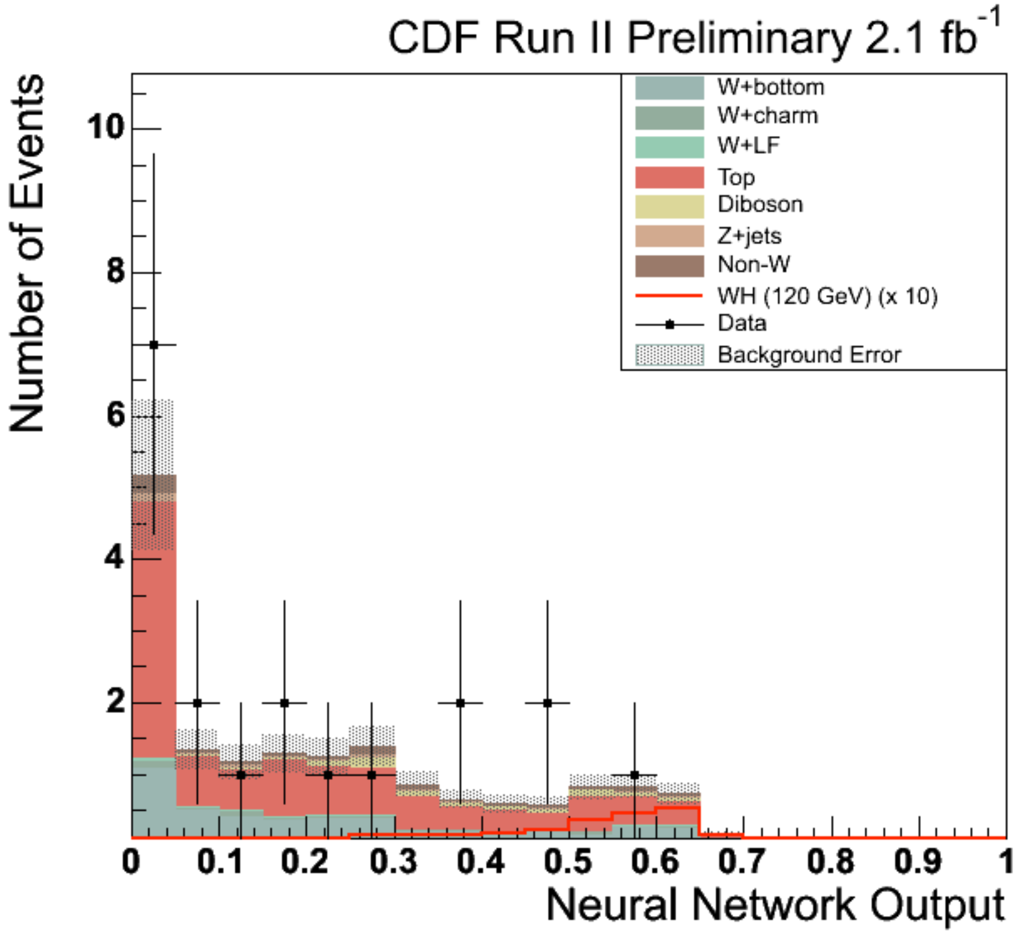
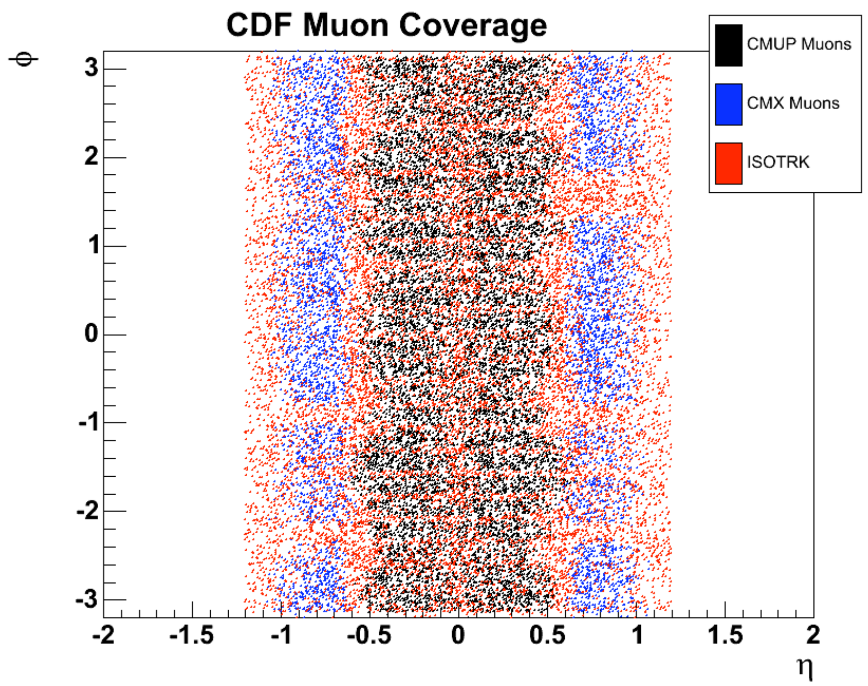
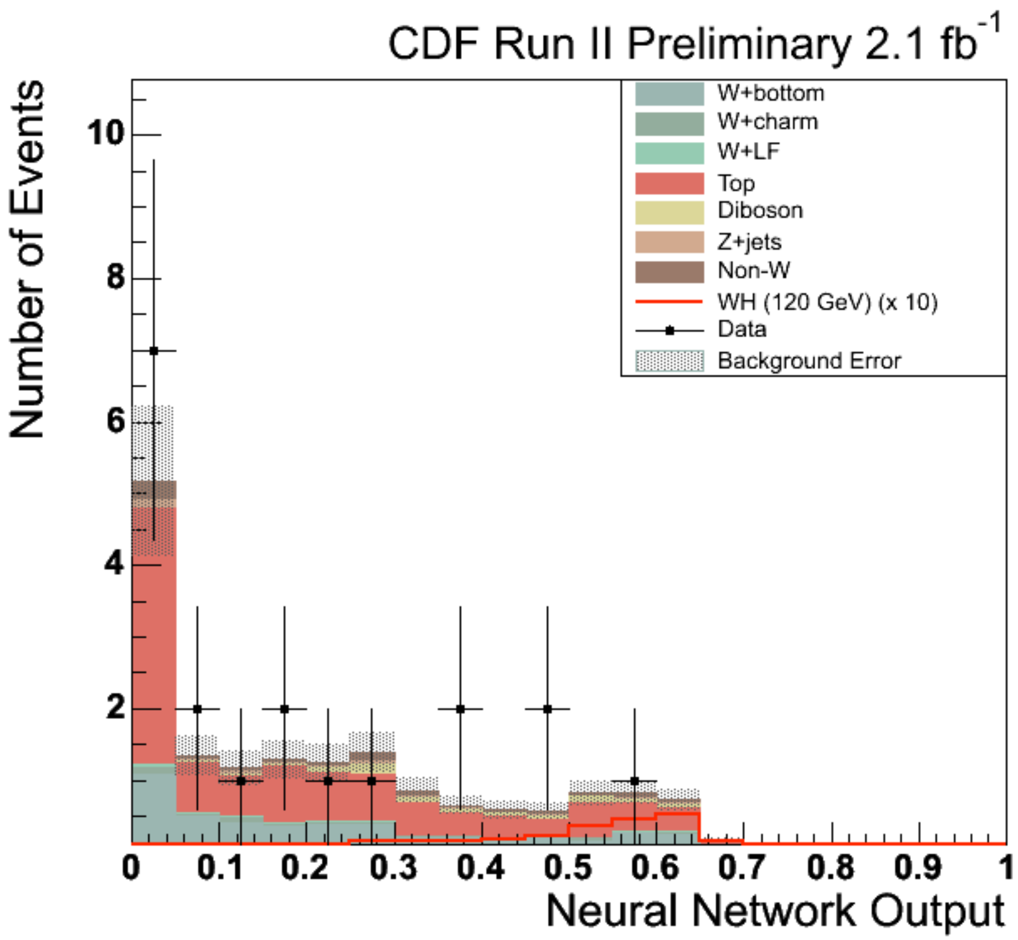




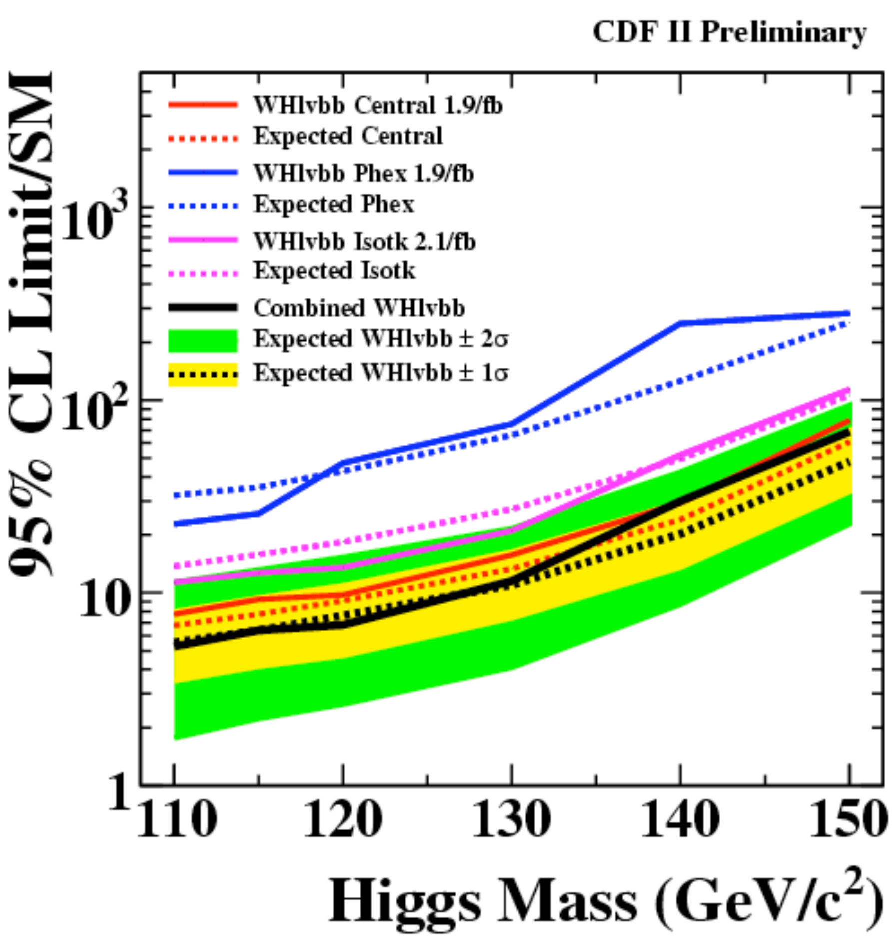
Adding acceptance to WH: isolated track

- Expand acceptance with high p_T isolated tracks failing standard e,μ selection
  - No calorimetry or muon chamber info
- Use $\not{E}_T$+2 jets trigger
- Increase acceptance by 25%

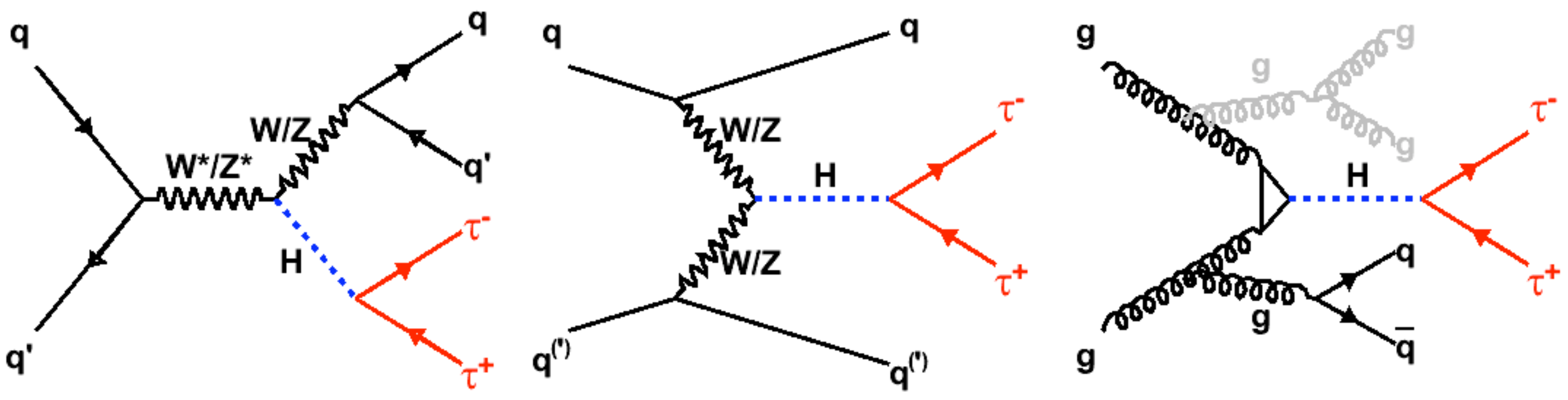




Exp/SM 6.4
14% improvement



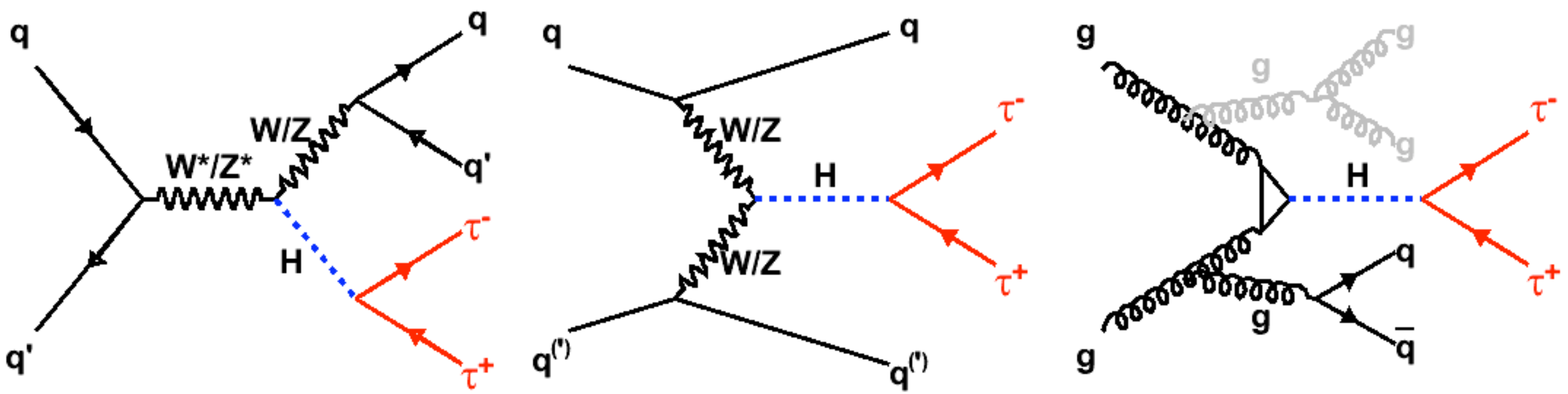
H → ττ + 2 jets



- Selection
  - 1 hadronic τ & 1 opp. signed lepton (45% BR)
    - 1- & 3-prong τ
  - Use lepton+track trigger
  - Two jets and Z veto

Process	Events ($2fb^{-1}$)
WH	0.18
ZH	0.11
VBF	0.12
ggH	0.26
Total	0.67
Background	374

$H \rightarrow \tau\tau$ + 2 jets



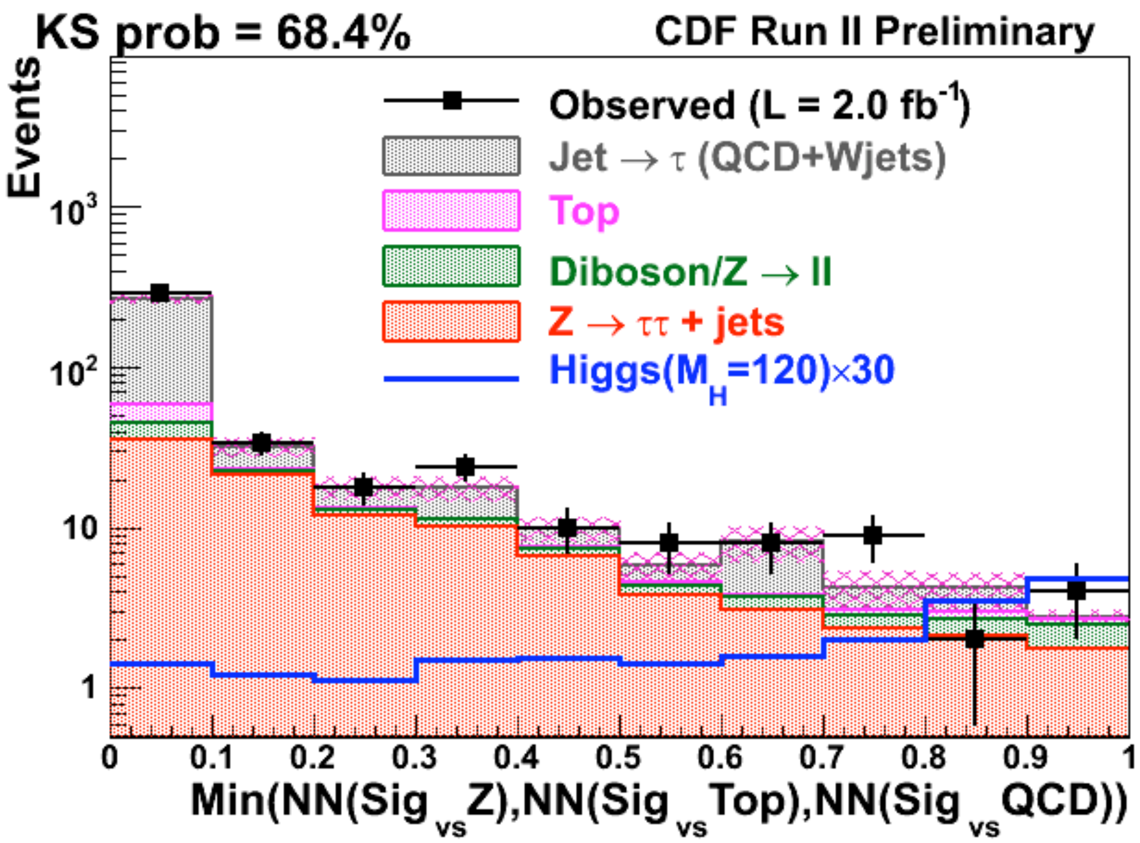
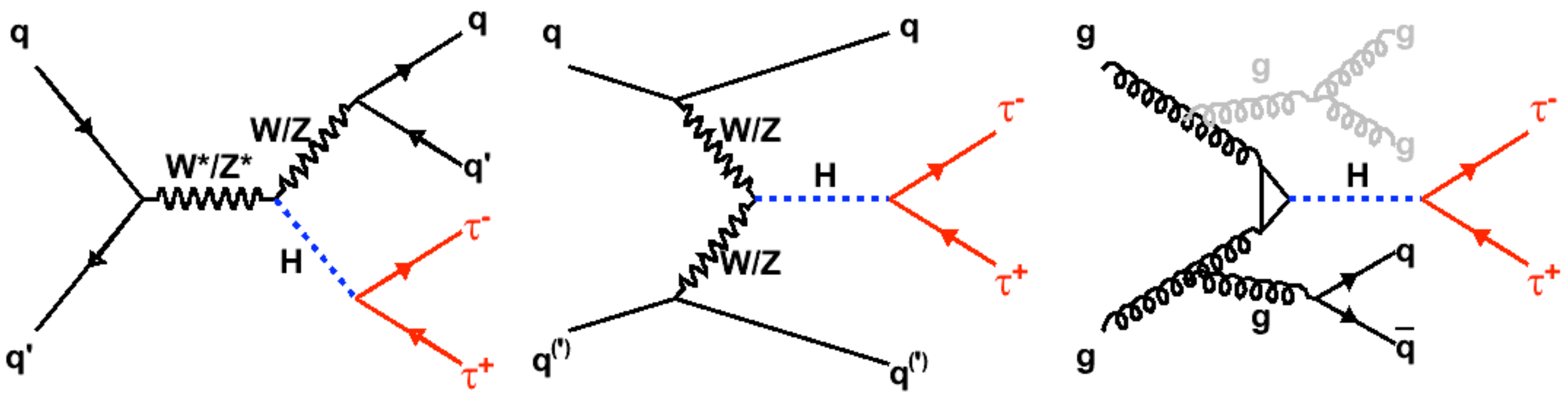


Figure of merit: minimum of 3 ANN:

- Signal -vs- $Z \rightarrow \tau\tau$
- Signal -vs- tt
- Signal -vs- QCD

H → ττ + 2 jets


q
q'
W*/Z*
W/Z
H
q
q'
τ-
τ+
q
q(')
W/Z
W/Z
H
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τ-
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g
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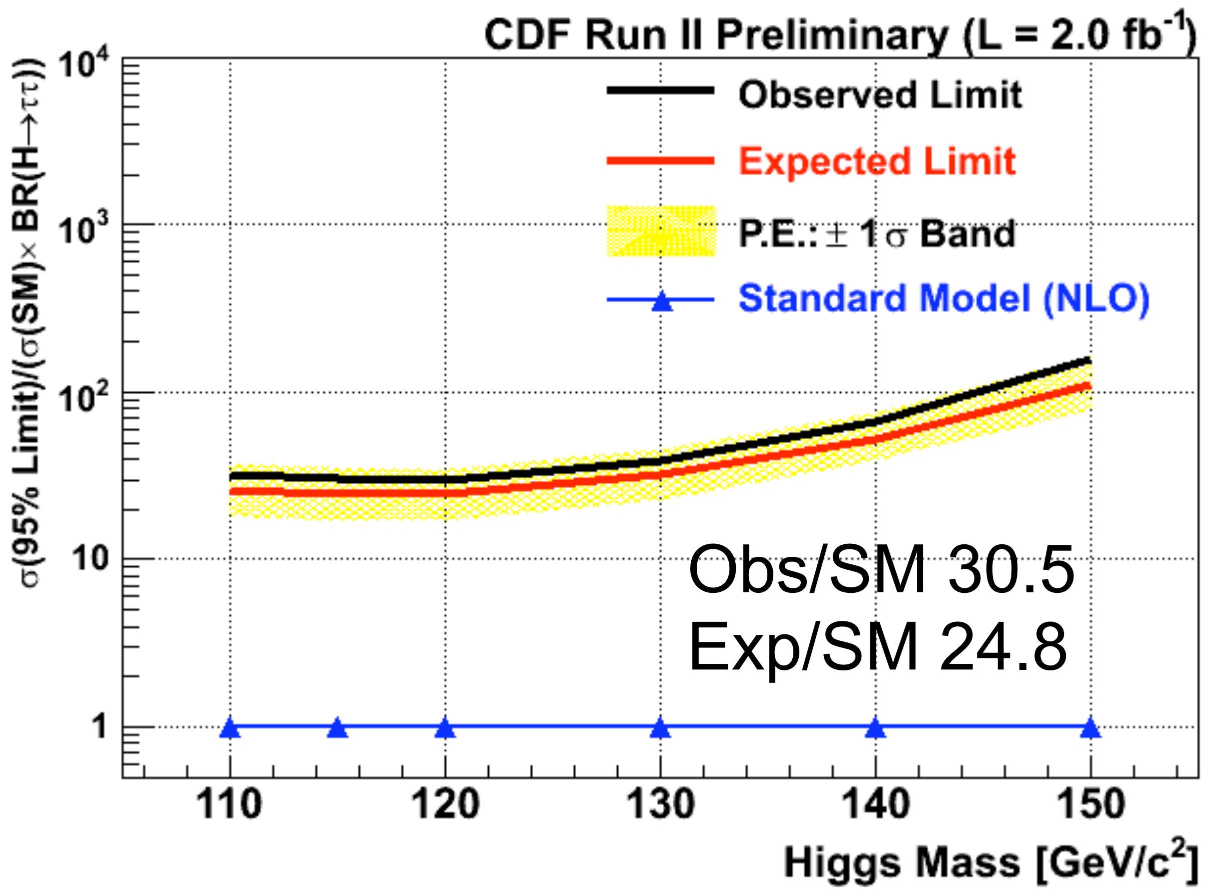
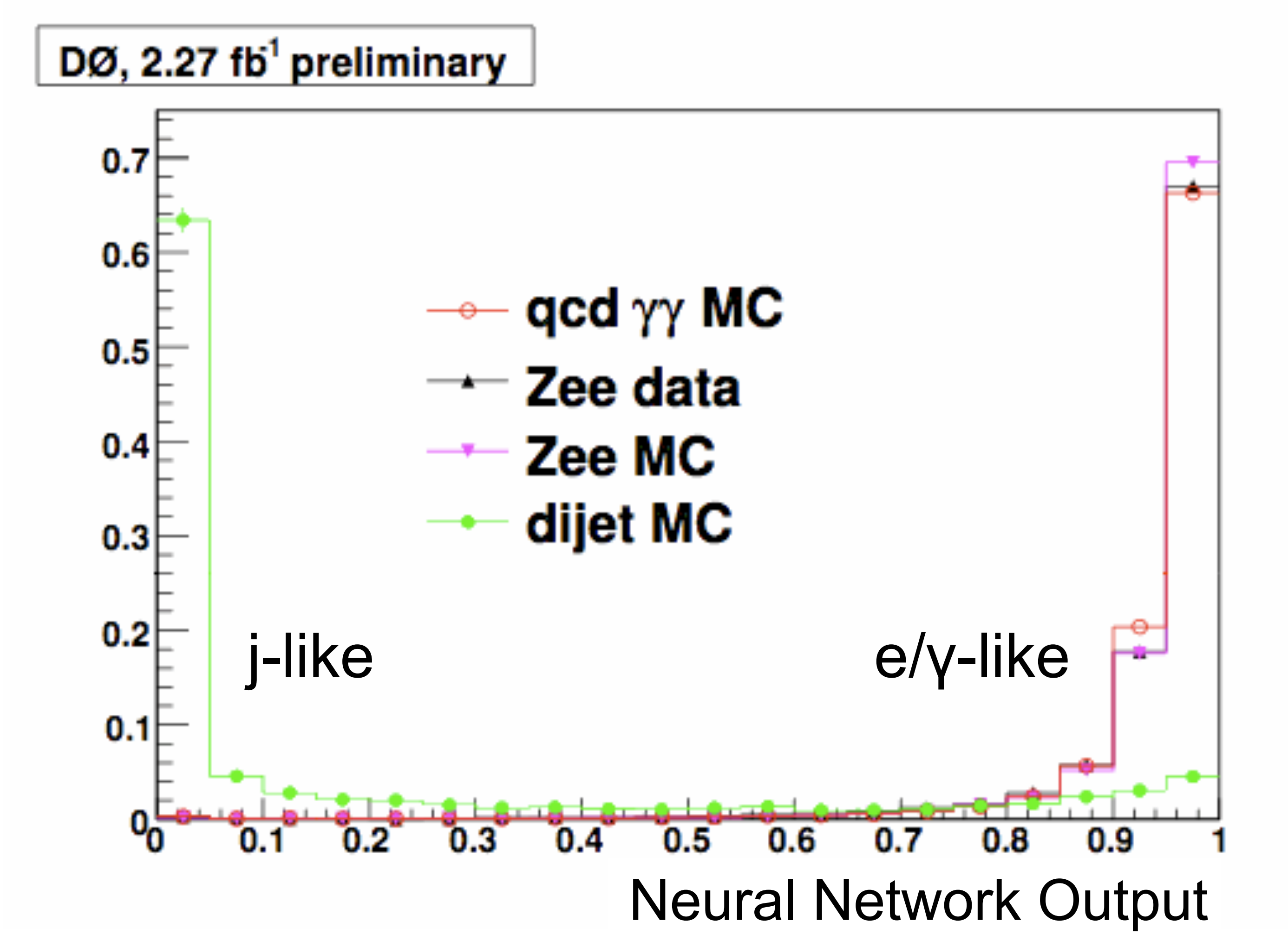
g
q
q
τ-
τ+


CDF Run II Preliminary (L = 2.0 fb-1)
Observed Limit
Expected Limit
P.E.: ± 1σ Band
Standard Model (NLO)
σ(95% Limit)/(σ(SM)× BR(H→ττ))
Higgs Mass [GeV/c2]
Obs/SM 30.5
Exp/SM 24.8

$p\bar{p} \rightarrow H \rightarrow \gamma\gamma$

- Low expected rate (BR ~0.22% @ M_h=130GeV)
  - but Nature could be different
- Selection
  - 2 high E_T photons
  - ANN to separate fake from e/γ objects
    - Trained using Zee & multi-jet data



Observed	13827	
Z→ee	741±102	MC
jet-jet	4779±1265	data
γ-jet	4677±1246	data
QCD γ	3400±711	MC

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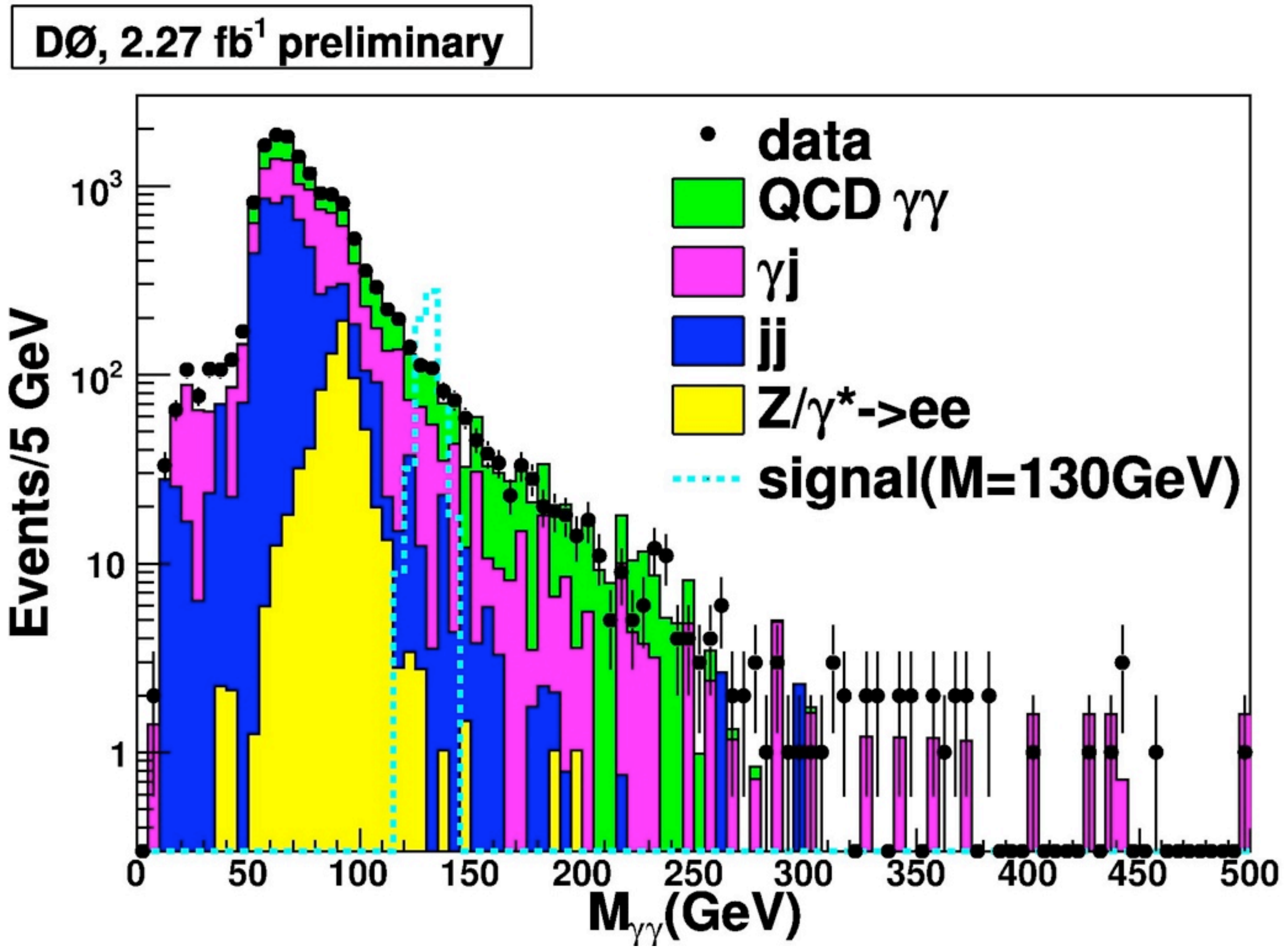

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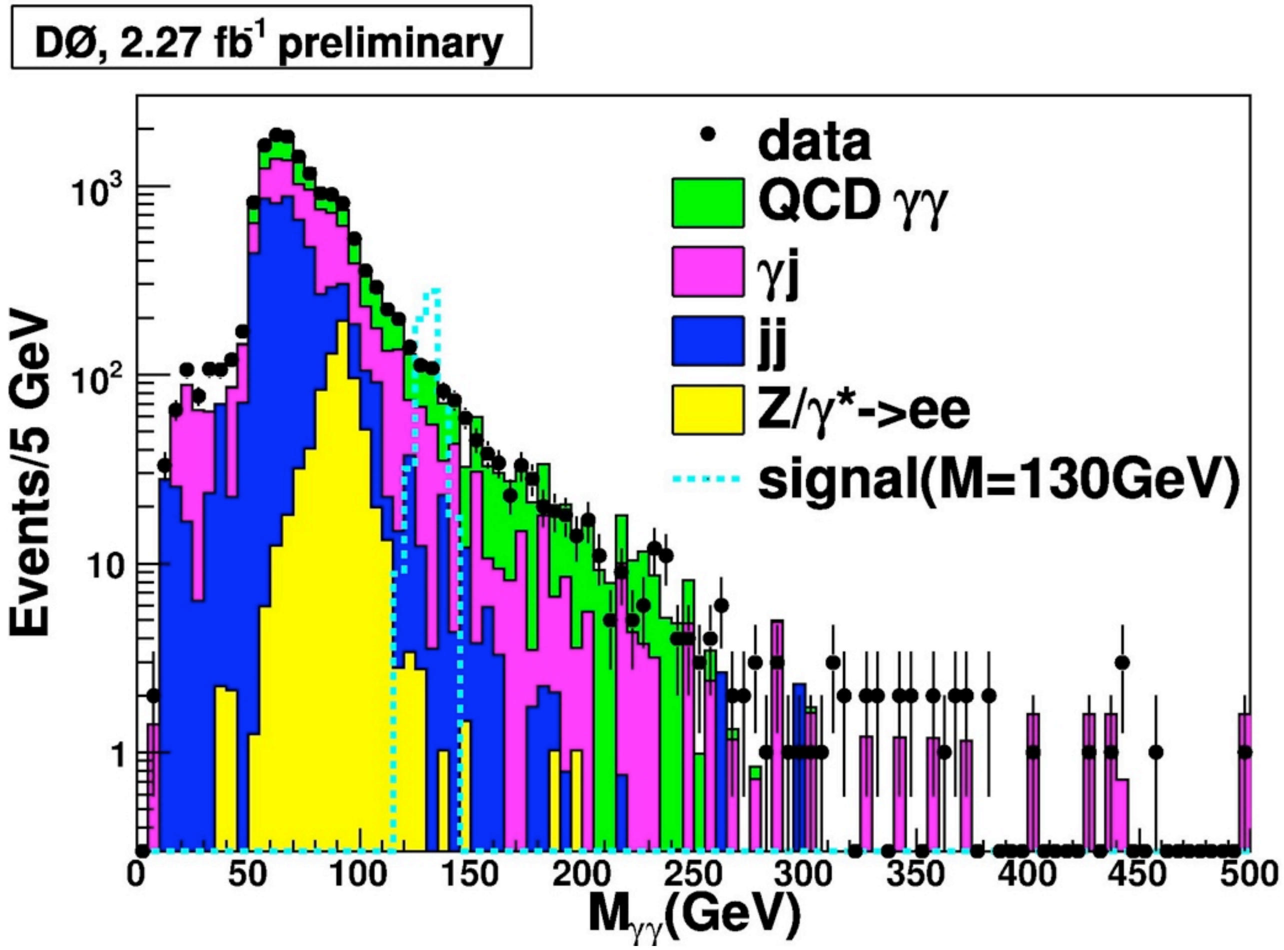
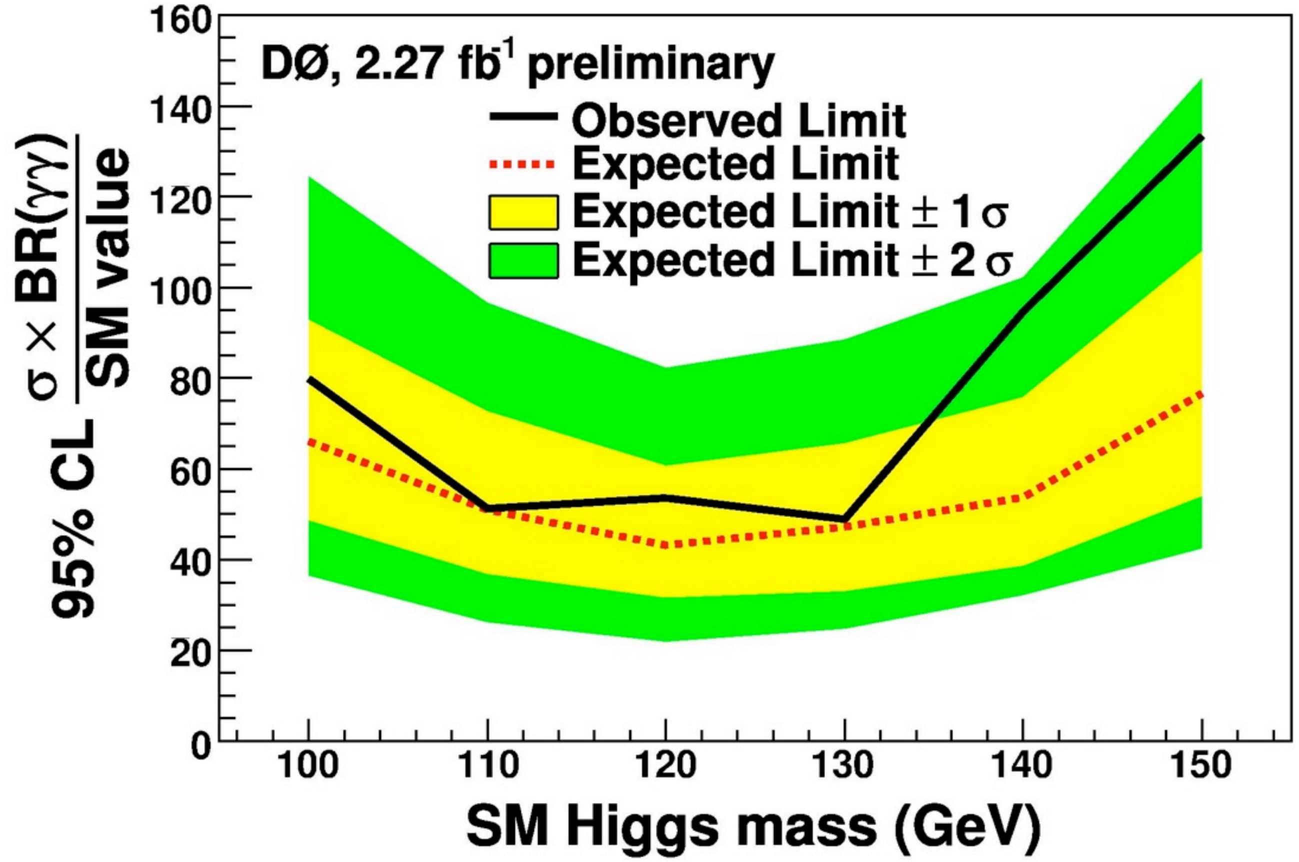
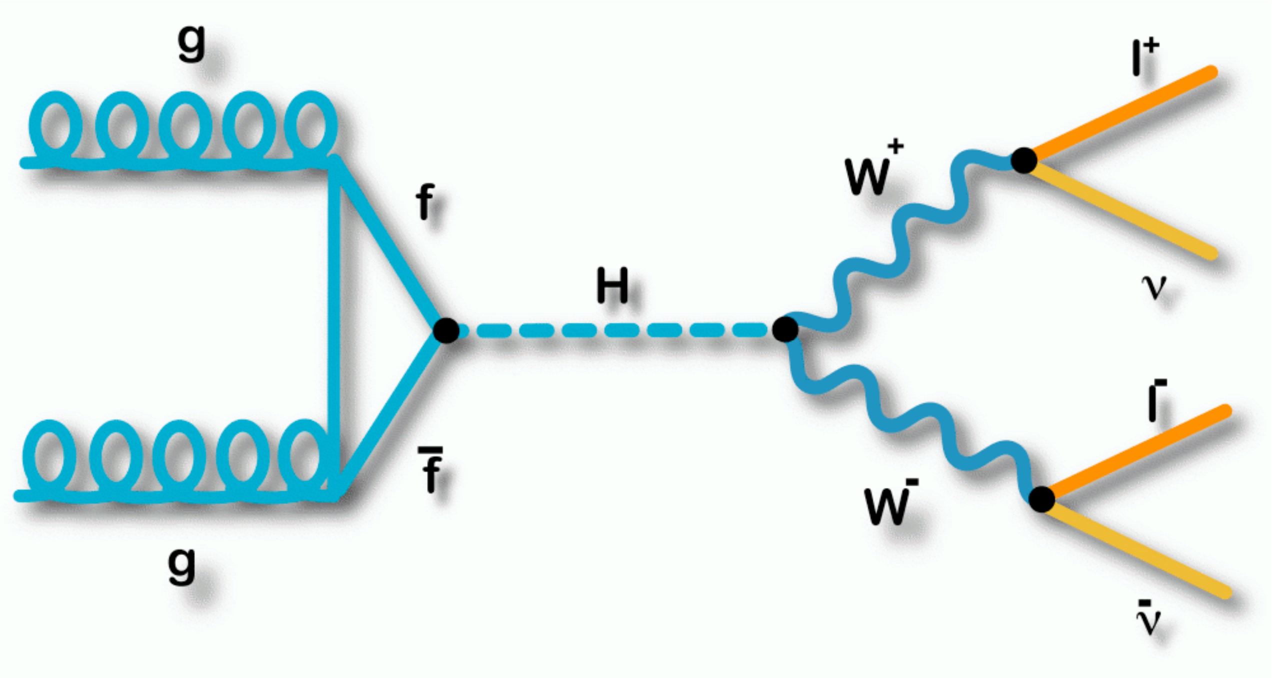




High Mass SM Higgs

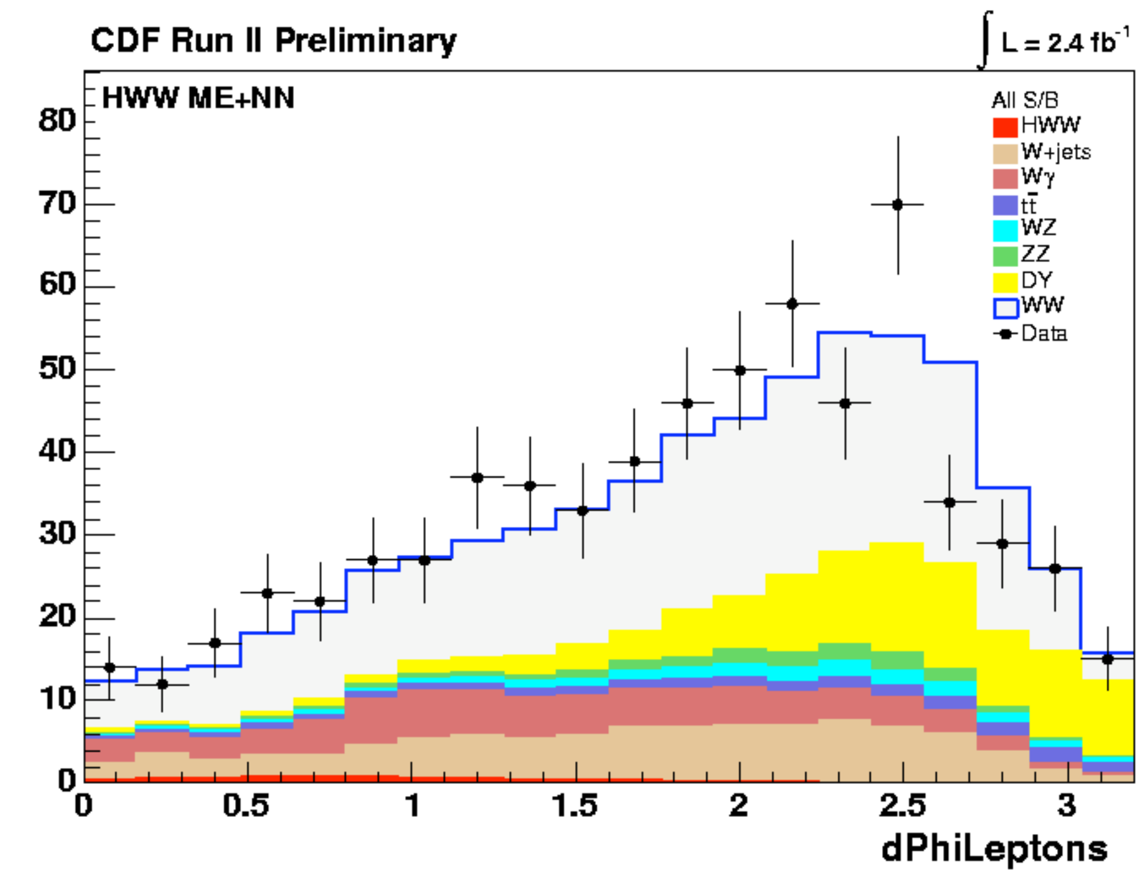
- Introduction
  - Constrains on the Higgs
  - Higgs production & decay
  - Analyses techniques & status
- Low mass:
  - $ZH \rightarrow llb\bar{b}$
  - $ZH \rightarrow \nu\nu b\bar{b}$
  - $WH \rightarrow l\nu b\bar{b}$
  - $VH, VBF, H \rightarrow \tau\tau + 2j$
  - $H \rightarrow \gamma\gamma$
- High Mass
  - $H \rightarrow WW$
  - $WH \rightarrow WWW^*$
- Combination

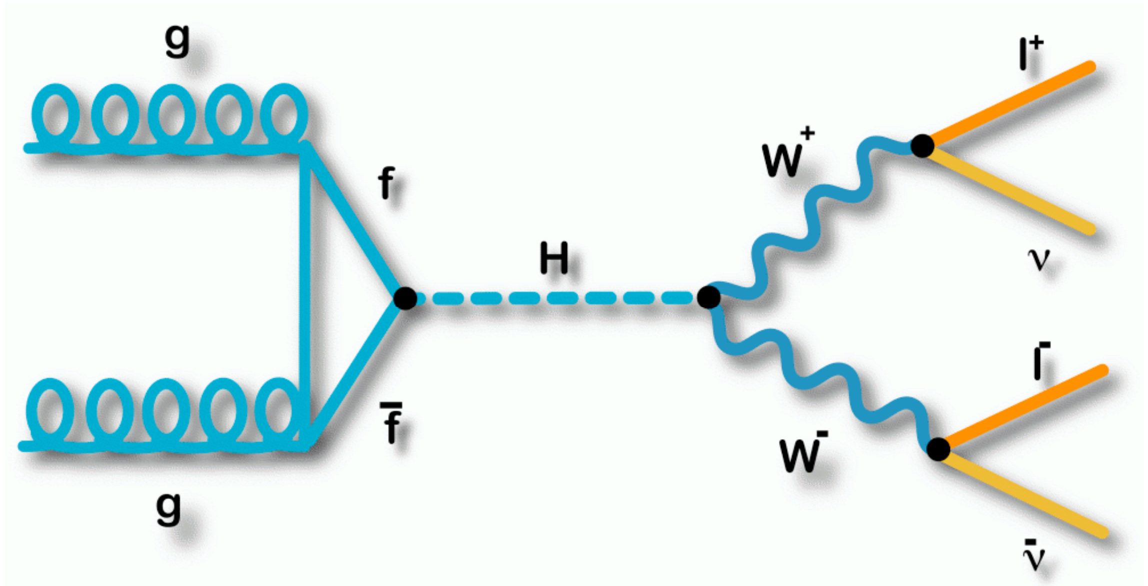


Main search for m_H>135GeV

$H \to WW^* \to l^+ \nu l^- \bar{\nu}$ channel

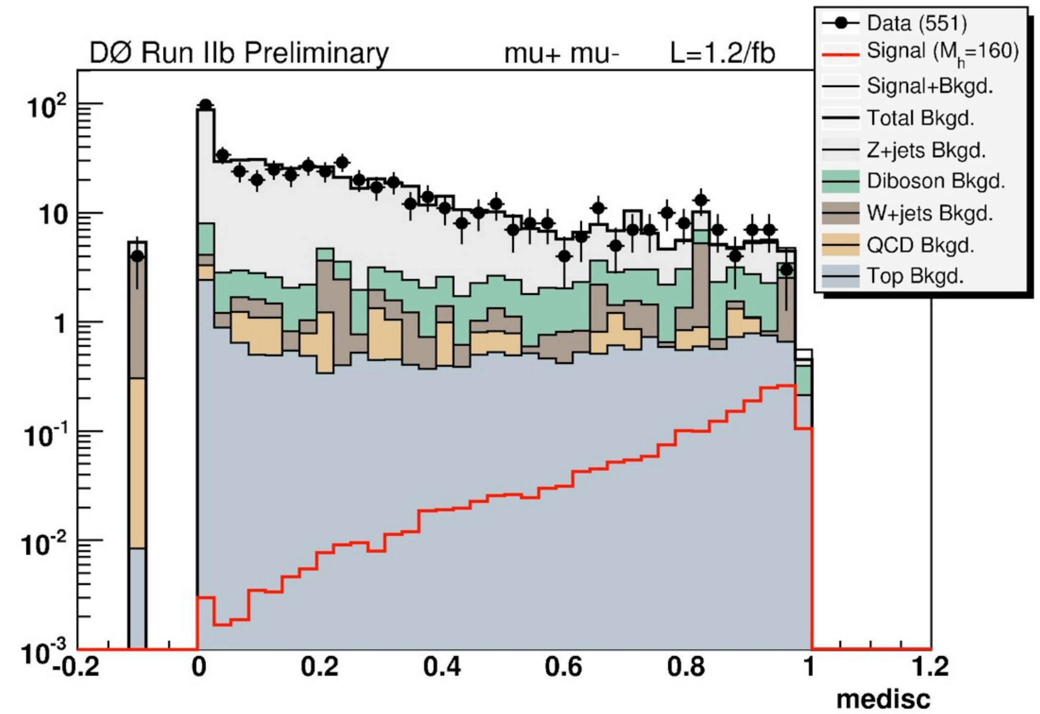
- Main search for m_H>135GeV
  - Higher production cross section
  - No b-tag efficiency reduction
  - Spin 0 Higgs ➔ angular correlation
  - No kinematic mass peak
- Selection
  - Two opp. signed high p_T leptons
    - ee, μμ, eμ
  - Large $\not{E}_T$
  - No significant jets
- Backgrounds
  - $WW,\ WZ,\ ZZ$
  - $W + jets,\ t\bar{t}$
  - $Z^{(*)} \to ll$





$H \rightarrow WW^* \rightarrow l^+\nu l^-\bar{\nu}$ channel

- 3 classes of event: ee, eμ, μμ
  - Preselection cuts optimized for each dilepton class and Higgs mass
    - Background distribution very different
- Figure of merit:
  - ANN with Matrix Element
  - Inputs:
    - ee: 11 vars + M.E.
    - eμ: 11 vars
    - μμ: 14 vars + M.E.



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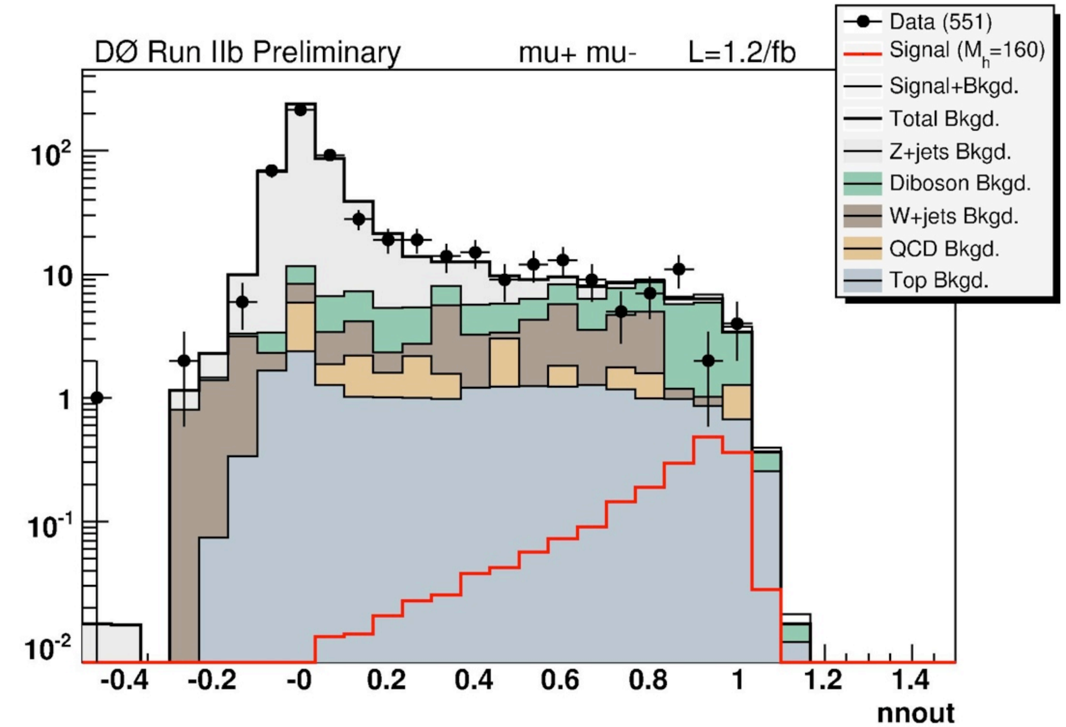

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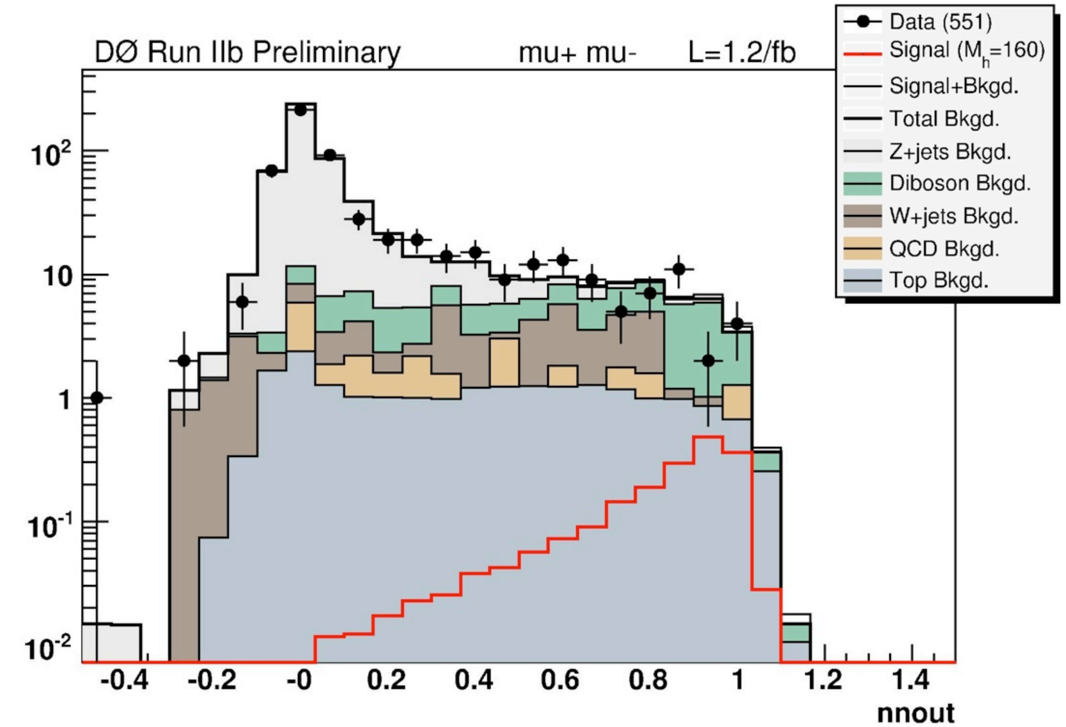
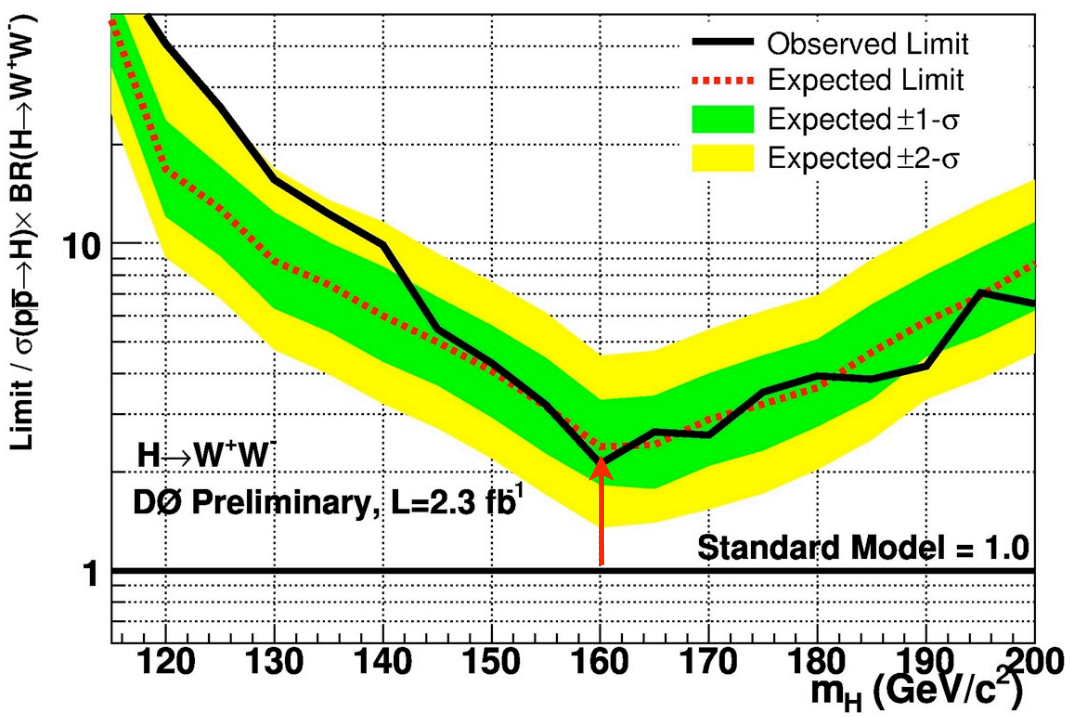
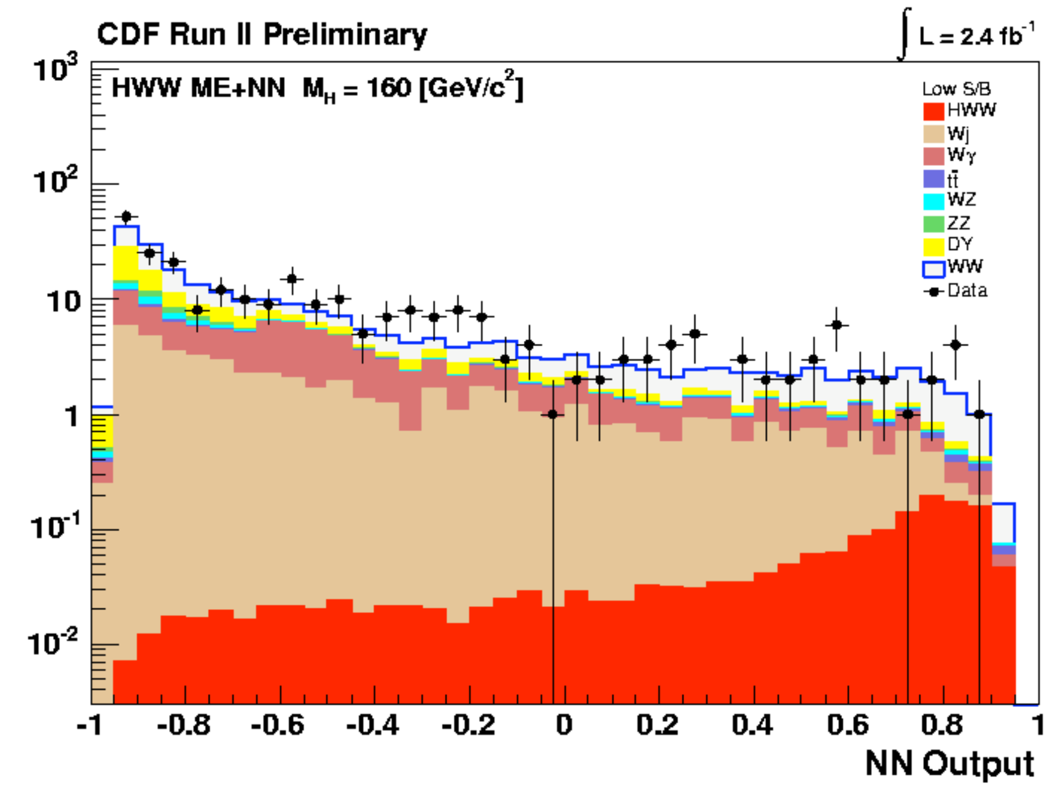




Obs/SM: 2.1
Exp/SM: 2.4

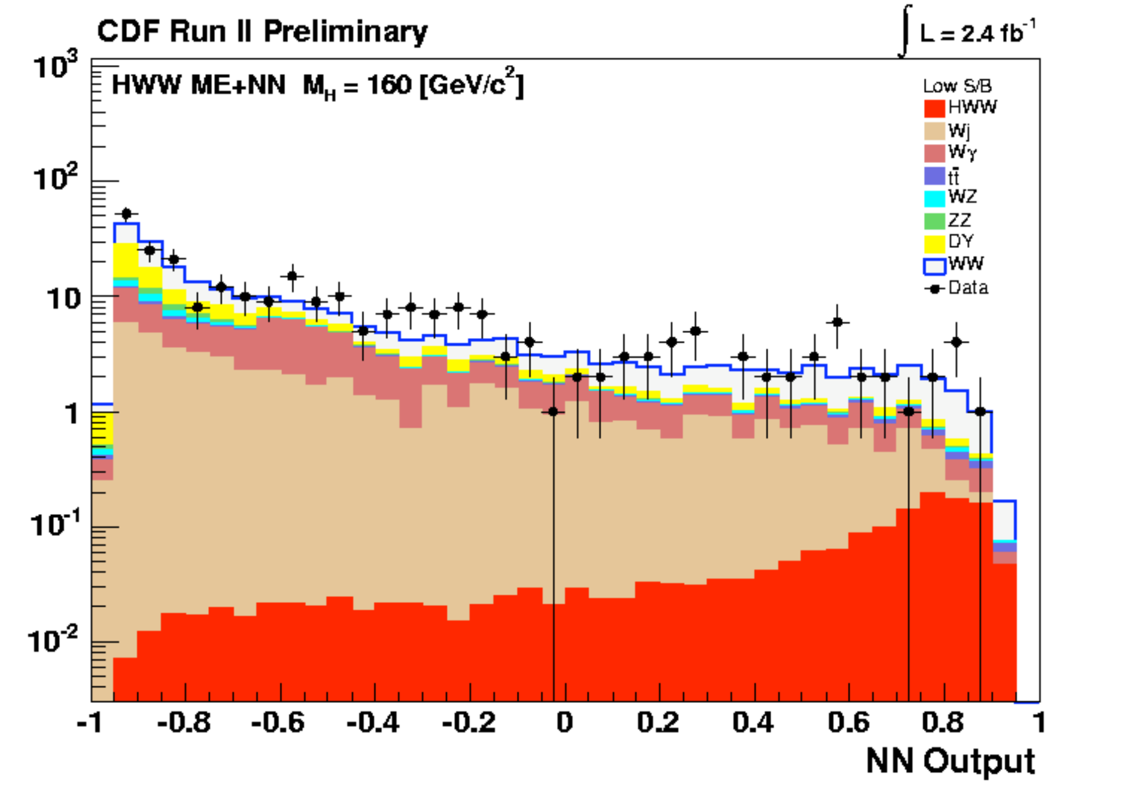
$H \rightarrow WW^{*} \rightarrow l^{+}\nu l^{-}\bar{\nu}$ channel

- 2 classes of event
- Lepton pairs:
  - ee, eμ, μμ
  - e+trk, μ+trk
- Figure of merit:
  - ANN with Matrix Element
  - Inputs:
    - $M_{ll},\ \Delta\phi_{ll},\ \Delta R_{ll},$
    - $\Delta\phi_{lj,\not{E}_T},\ \not{E}_T,\ \not{E}_{T\,Spec}$
    - 5 likelihood ratios
      - $H \rightarrow WW^{*}$, WW,
      - ZZ, Wγ, W+jets

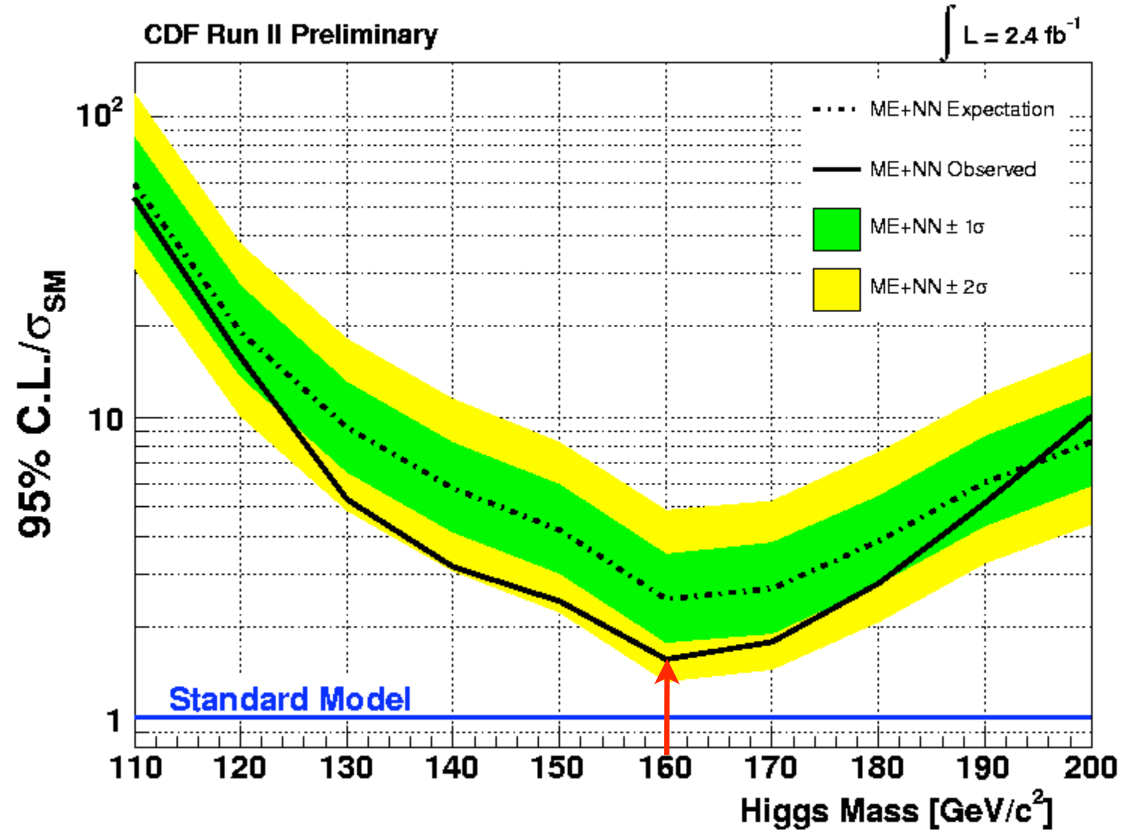


$H \rightarrow WW^* \rightarrow l^+\nu l^-\bar{\nu}$ channel

- 2 classes of event
- Lepton pairs:
  - ee, eμ, μμ
  - e+trk, μ+trk
- Figure of merit:
  - ANN with Matrix Element
  - Inputs:
    - $M_{ll},\ \Delta\phi_{ll},\ \Delta R_{ll},$
    - $\Delta\phi_{lj,\not{E}_T},\ \not{E}_T,\ \not{E}_{T\,Spec}$
    - 5 likelihood ratios
      - $H \rightarrow WW^*$, WW,
      - ZZ, Wγ, W+jets

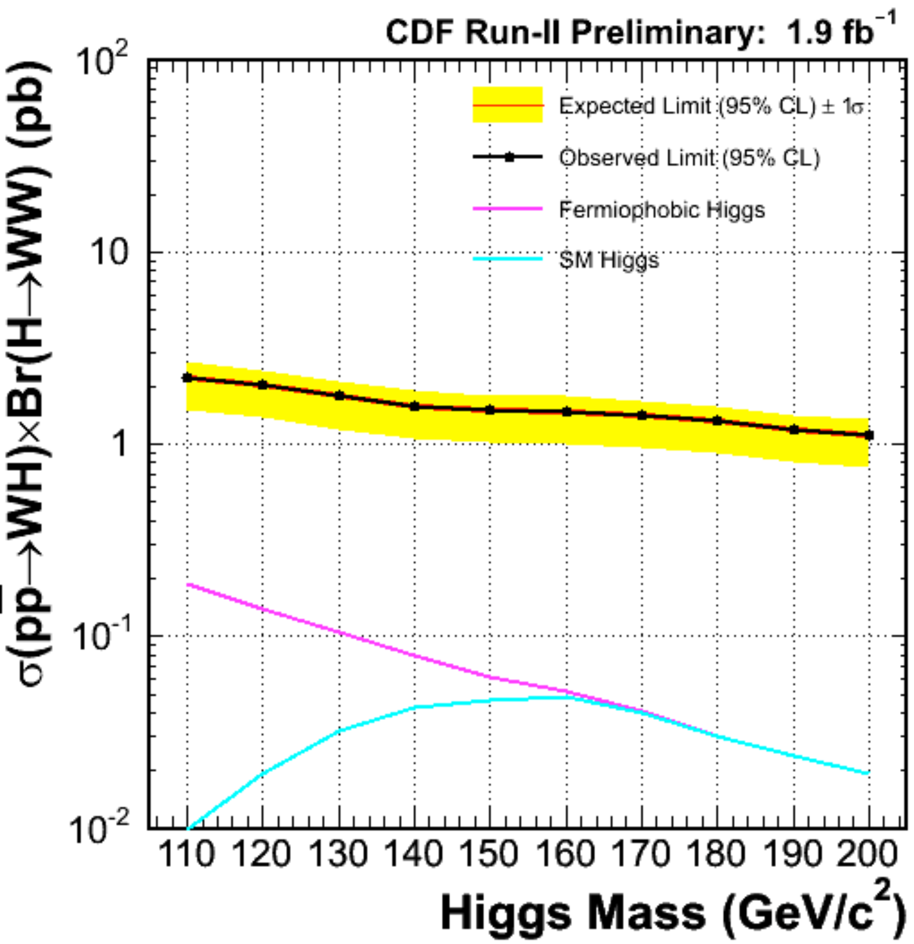


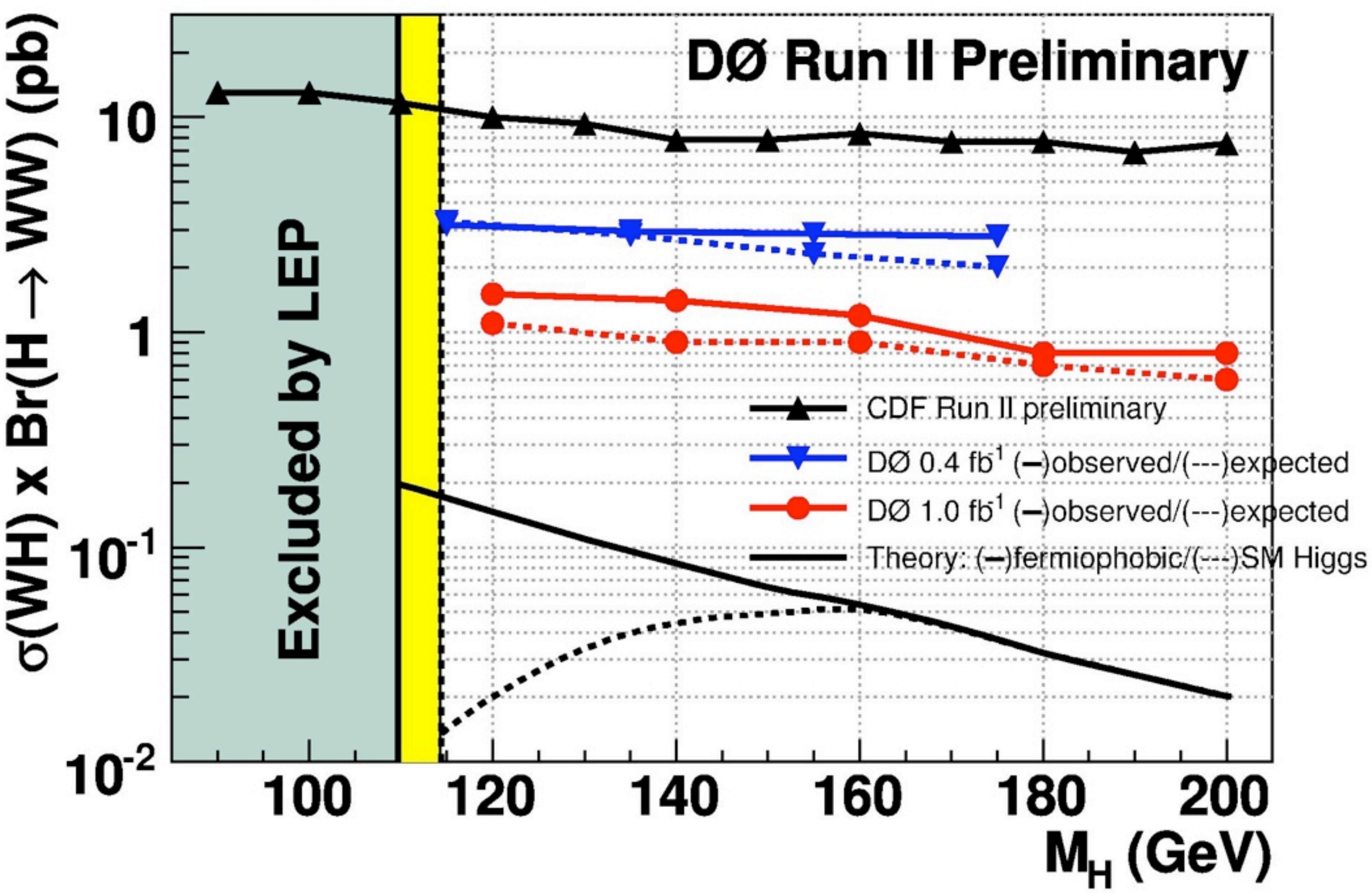
Obs/SM: 1.6
Exp/SM: 2.5



WH→WWW*

- Low BR, but important in the “intermediate region 125-145 GeV
- Selection:
  - Same charge di-leptons from W’s (one from H→WW, the other from prompt W)





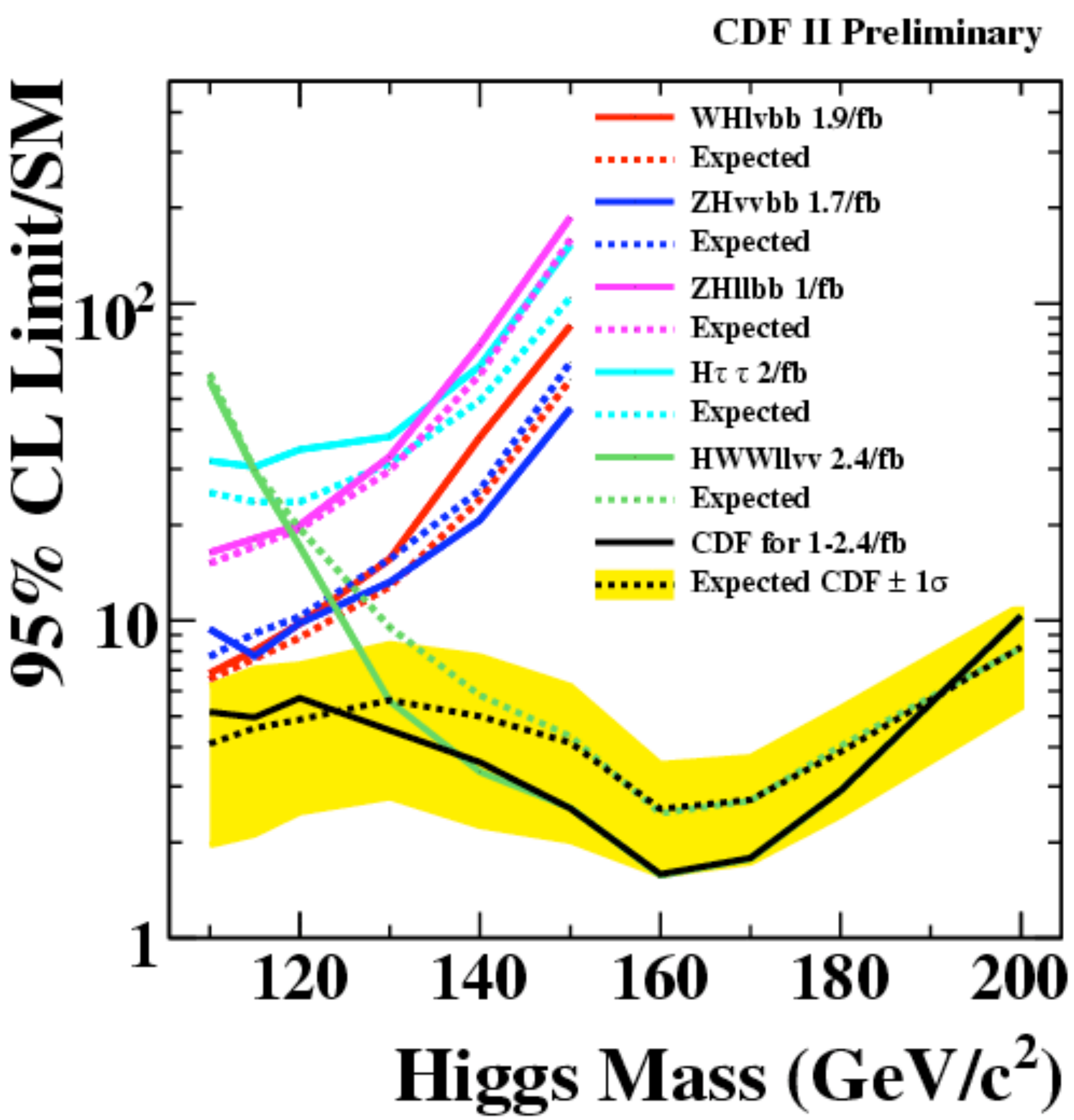
Best limits ~20xSM at 160GeV

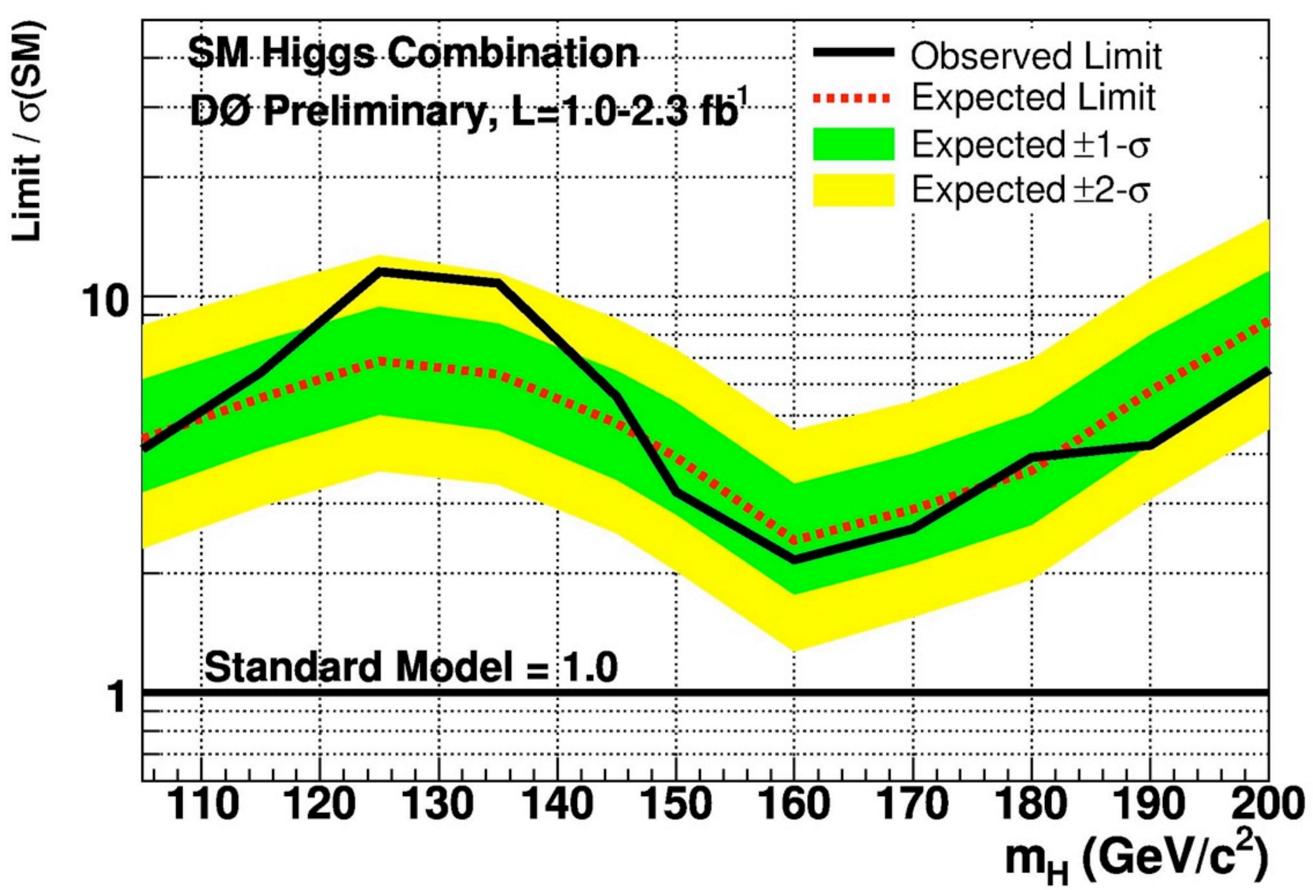
~24xSM at 140GeV

Useful for m_H=[125-145GeV] & fermiophobic Higgs search

Channel Combination

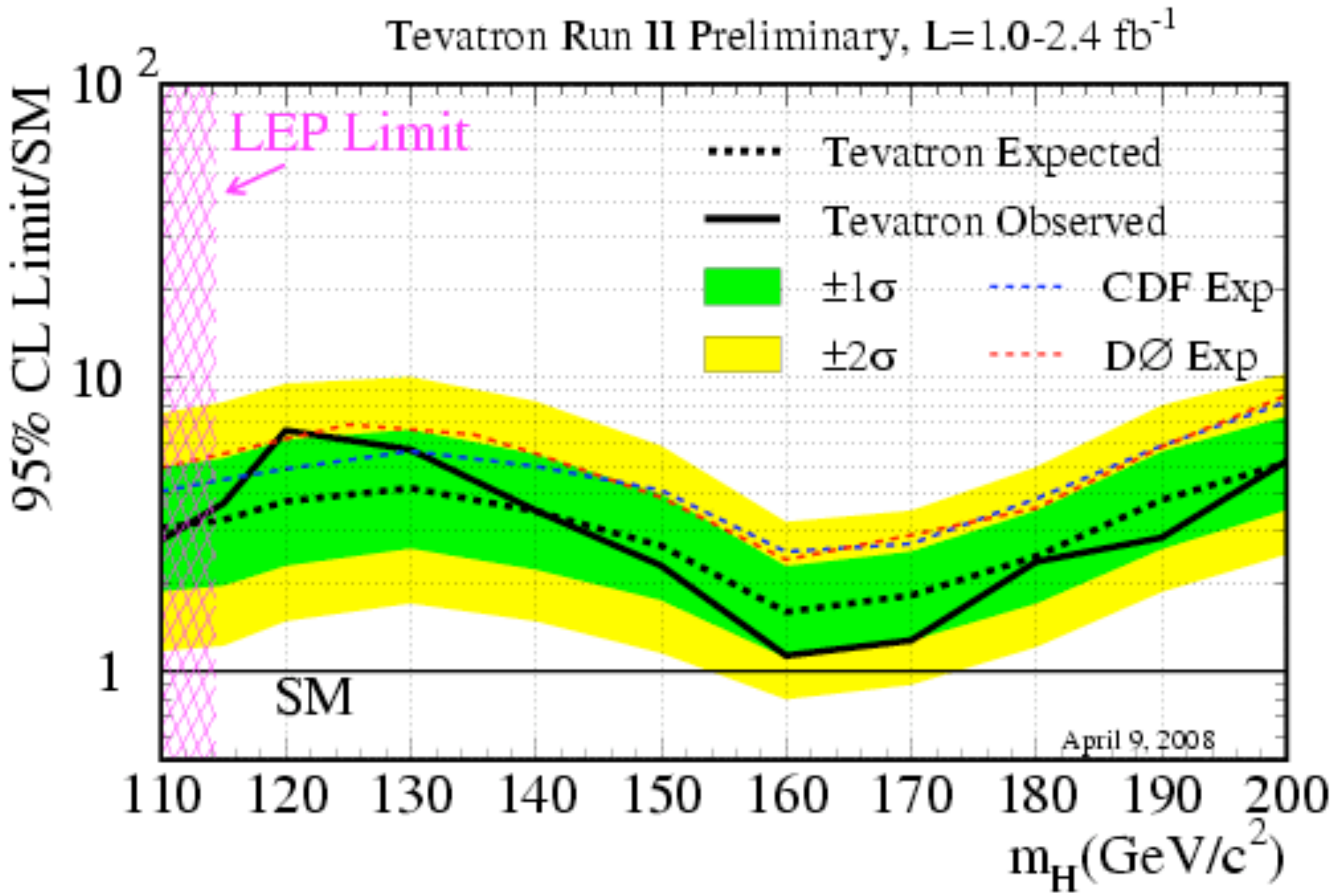
- No single decay channel has sufficient power to reach the SM prediction
- Statistically combine channels
  - Use procedure to properly account for correlated uncertainties





Tevatron Combination

- Neither experiment has sufficient power to span the full mass range m_H<~200GeV



Very close to excluding SM Higgs @160GeV

Non-SM Higgs

- Introduction
- SM Higgs
- Non-SM Higgs
  - Minimal SuperSymmetric Standard Model (MSSM)
    - Introduction
    - Neutral Higgs bosons (ϕ) searches
      - $\phi \rightarrow \tau\tau$
      - $b\phi \rightarrow bbb$
    - Charged Higgs: $H^{+} \rightarrow cs$
  - Fermiophobic Higgs $h_f \rightarrow \gamma\gamma$
  - Doubly charged Higgs $H^{++}H^{--}(H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm})$
- Prospects & Conclusions

Higgs bosons in the MSSM

- In Minimal Supersymmetric SM (MSSM) requires 2 Higgs doublets:
  - H_u (H_d) couple to up- (down-) type fermions
  - Ratio of VEV's: $\tan\beta=<H_u>/<H_d>$
  - 5 Higgs particles after the EWSB:
    - Three neutral (h, H, A) and 2 charged (H^+, H^-)
      - h has to be light: m_h < ~140 GeV
  - At tree level, 2 independent parameters: m_A & $\tan\beta$

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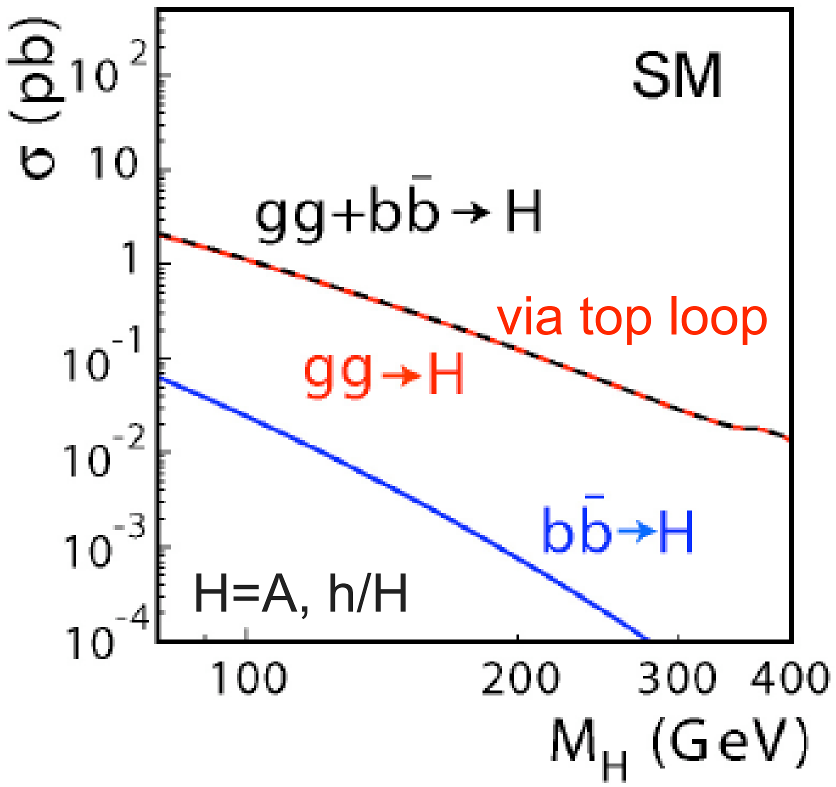
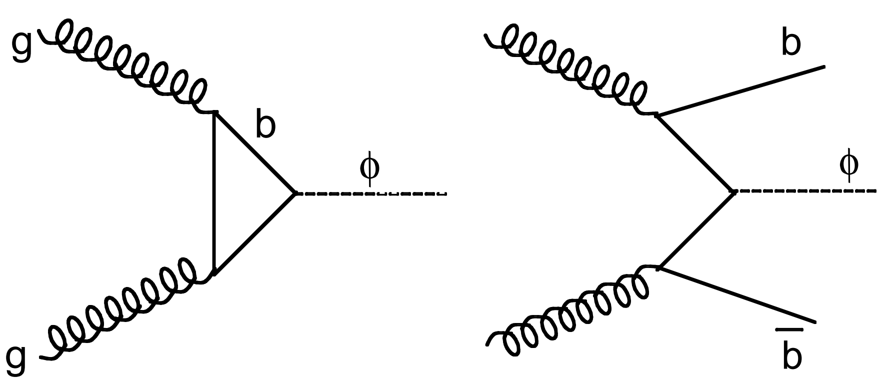


- For $\tan\beta$ near 1, h is SM-like. SM Higgs limit apply
- For $\tan\beta$ large:
  - Coupling of A, h/H to down-type fermions (goes like $\tan^2\beta$)
    - eg b-quark, enhanced w.r.t SM
  - h/H & A (denoted by ϕ) ~ degenerate in mass
    - Further increase in cross section



ϕ=A, h/H

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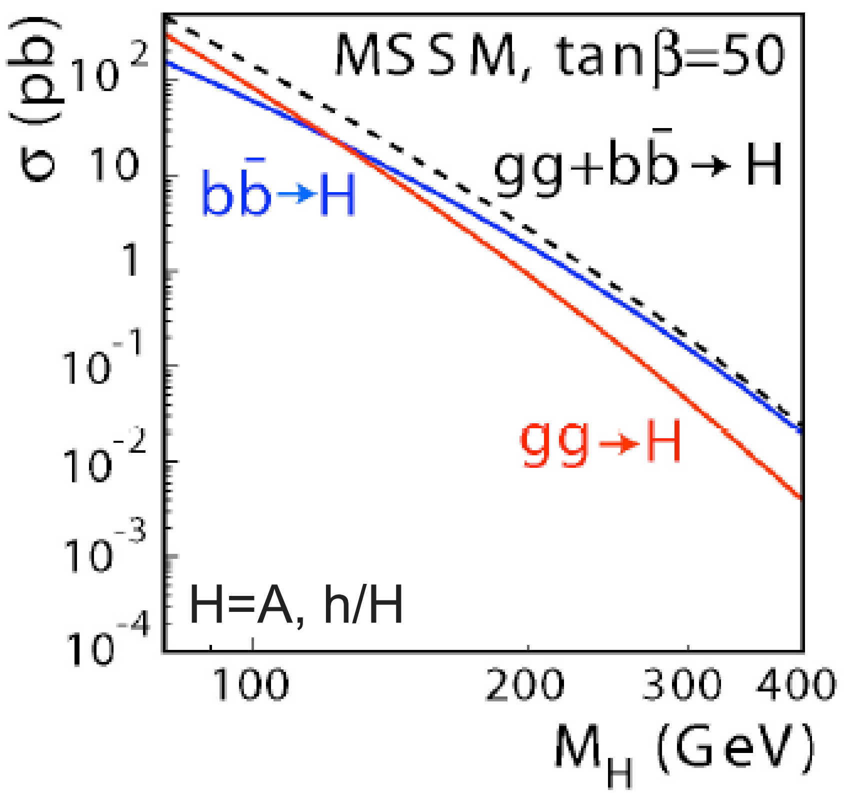

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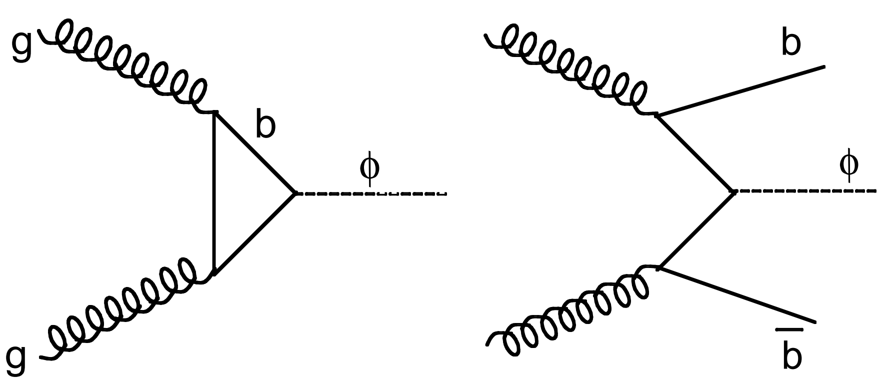
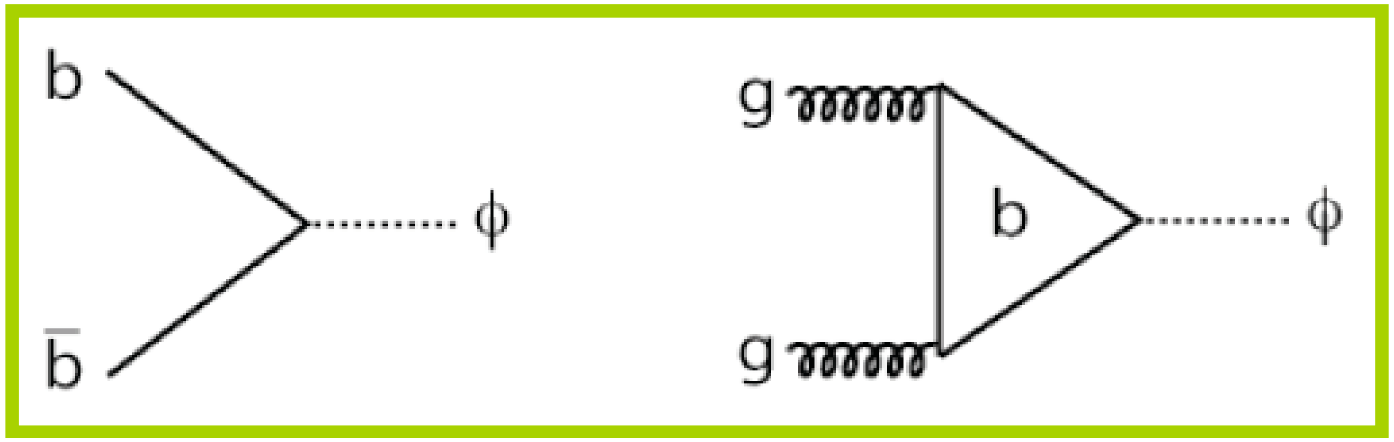


ϕ=A, h/H

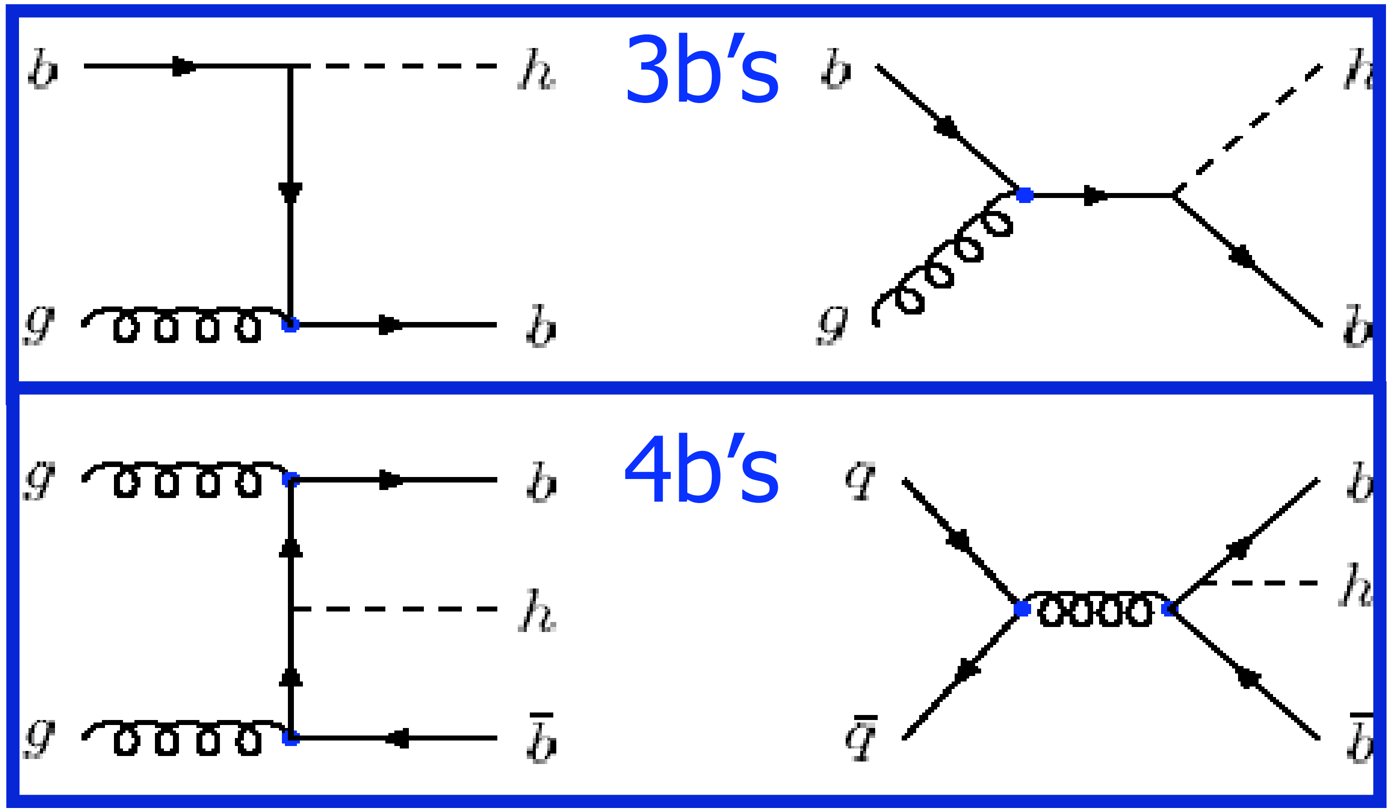
MSSM Higgs boson production

- Signature:
  - Higgs decays to 2 τ’s
    - Further decay of τ define final states

$\phi \to \tau\tau$



$\phi \to bb$



- Two high p_T b-jets from Higgs
- 1 or 2 extra b-quarks
- Search for peak in dijet invariant mass

- For low & intermediate masses
  - BR($\phi \to \tau\tau$) ~10%, BR($\phi \to bb$) ~90%

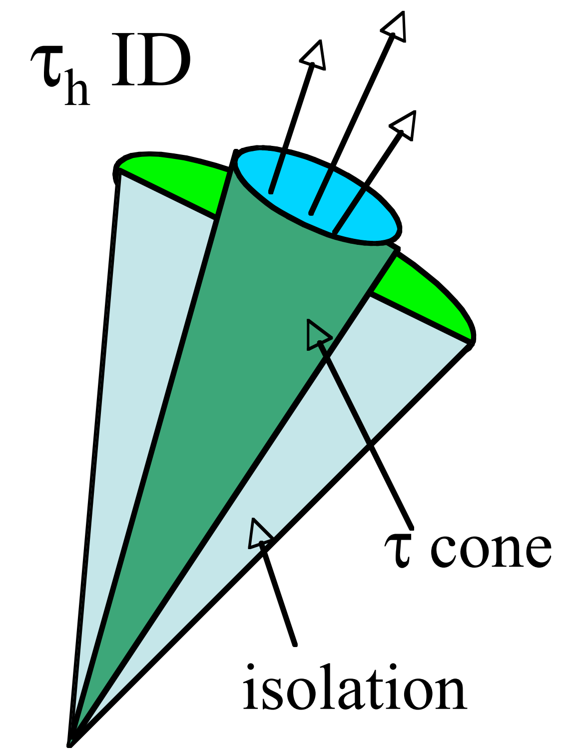
Overall, similar sensitivities

The $\phi \rightarrow \tau\tau$ Channel

- Considered final states: $\tau_e \tau_{\rm had}, \tau_\mu \tau_{\rm had}, \tau_e \tau_\mu$
- Background:
  - $Z \rightarrow \tau\tau$, W+jets, QCD multi-jets, dibosons
- Selection

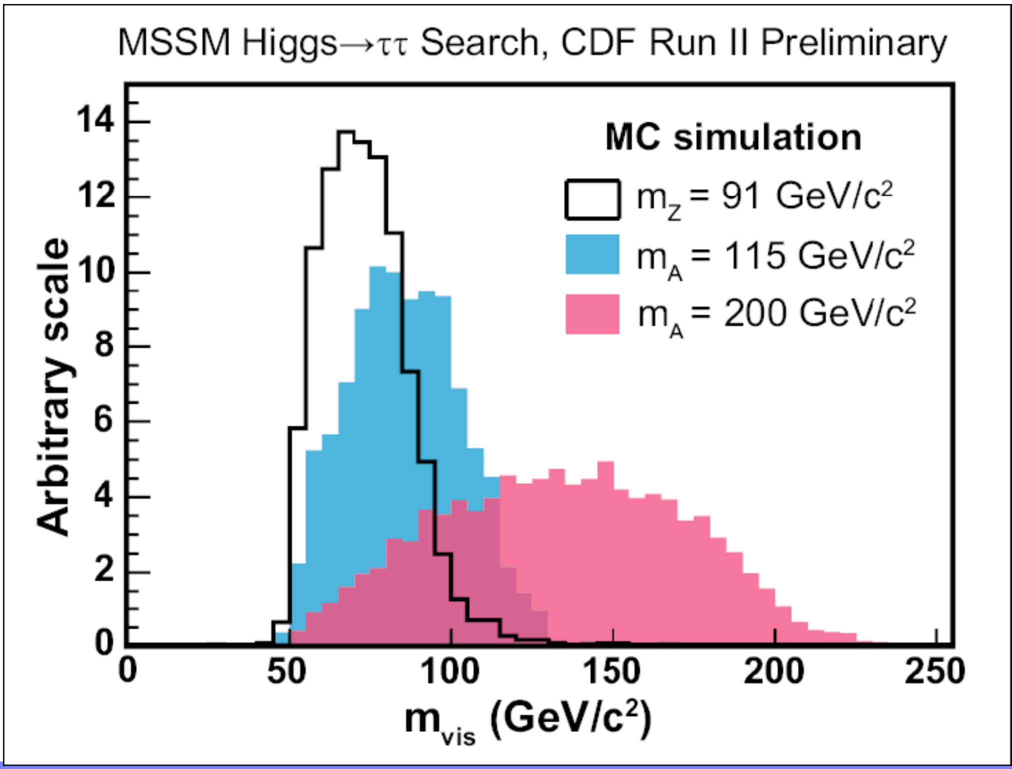
CDF

  - Isolated e/μ separated from τ_{had} w/ opp. sign
    - τ ID use variable-size cone
  - Jet background suppression: $H_T > 55$ GeV
  - Most of W+jets removed by cutting on relative directions of the visible τ decay products and $\not{E}_T$



DØ

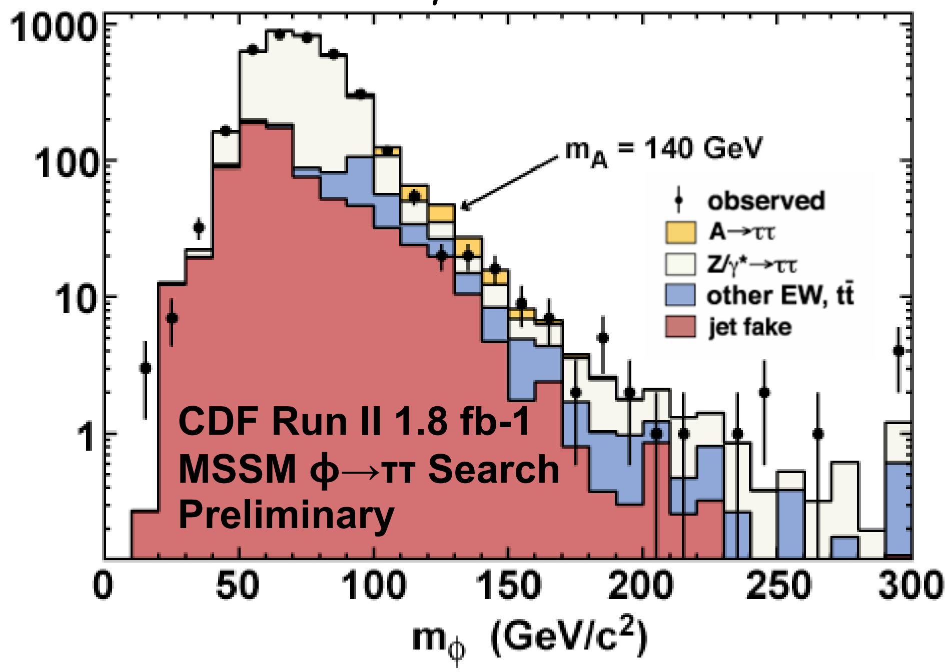
  - τ ID via ANN for 3 different τ-types ($\pi^\pm$, $\rho^\pm$, 3-prong), optimized to reject background
  - Cuts on M_W remove most of remaining W bkg
- Figure of merit: visible mass (m_{vis})
  - Cannot be well reconstructed the $m_{\tau\tau}$ due to ν's



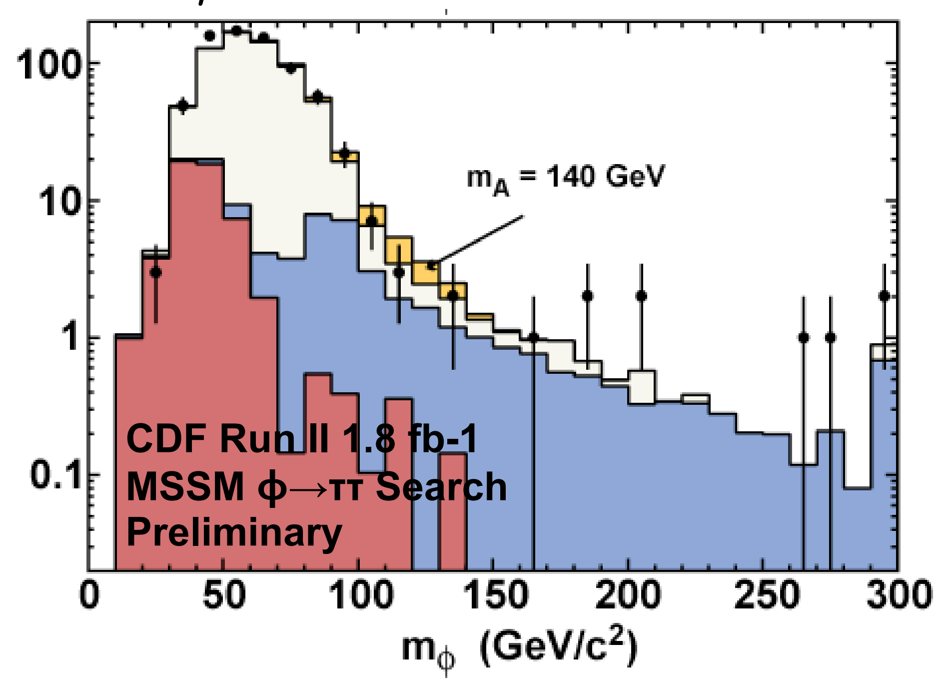
The $\phi\to\tau\tau$ Channel

- Last year CDF had a >2σ excess in e/μ+τ_{had} around 160GeV (<2σ over all m_ϕ)
  - With an additional 0.8fb^{-1} of data, no excess seen

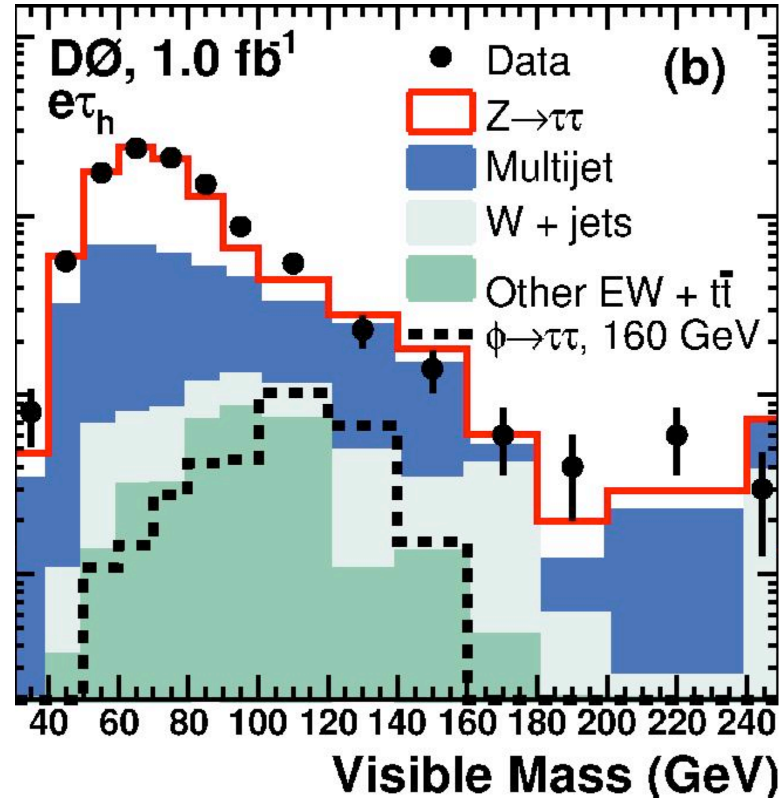
$\tau_e\tau_{\rm had} + \tau_\mu\tau_{\rm had}$ channels



$\tau_e\tau_\mu$ channel

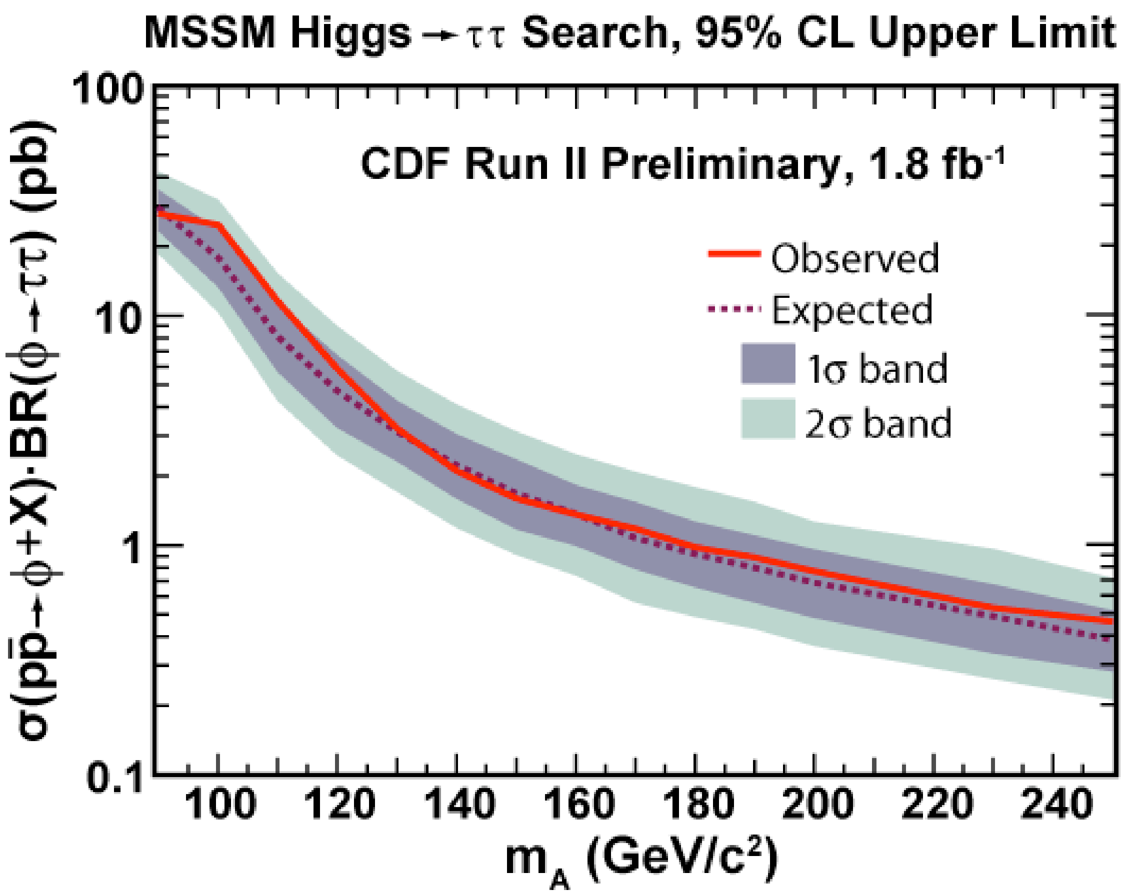


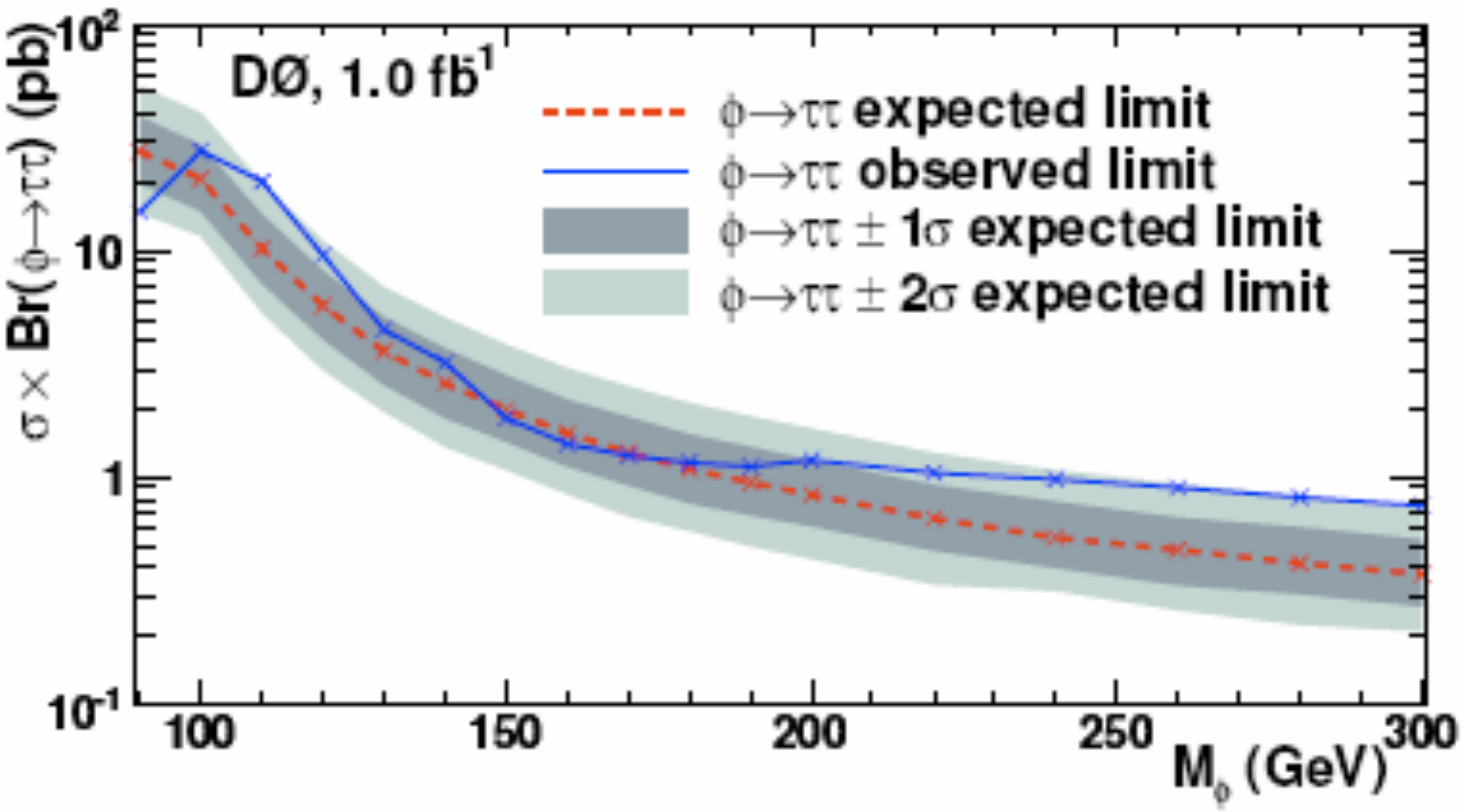
- DØ uses the full m_{vis} spectrum, separating for the various τ-types in the $\tau_e\tau_{had}$ & $\tau_\mu\tau_{had}$ to exploit the different S/B ratios



Limits and MSSM interpretation

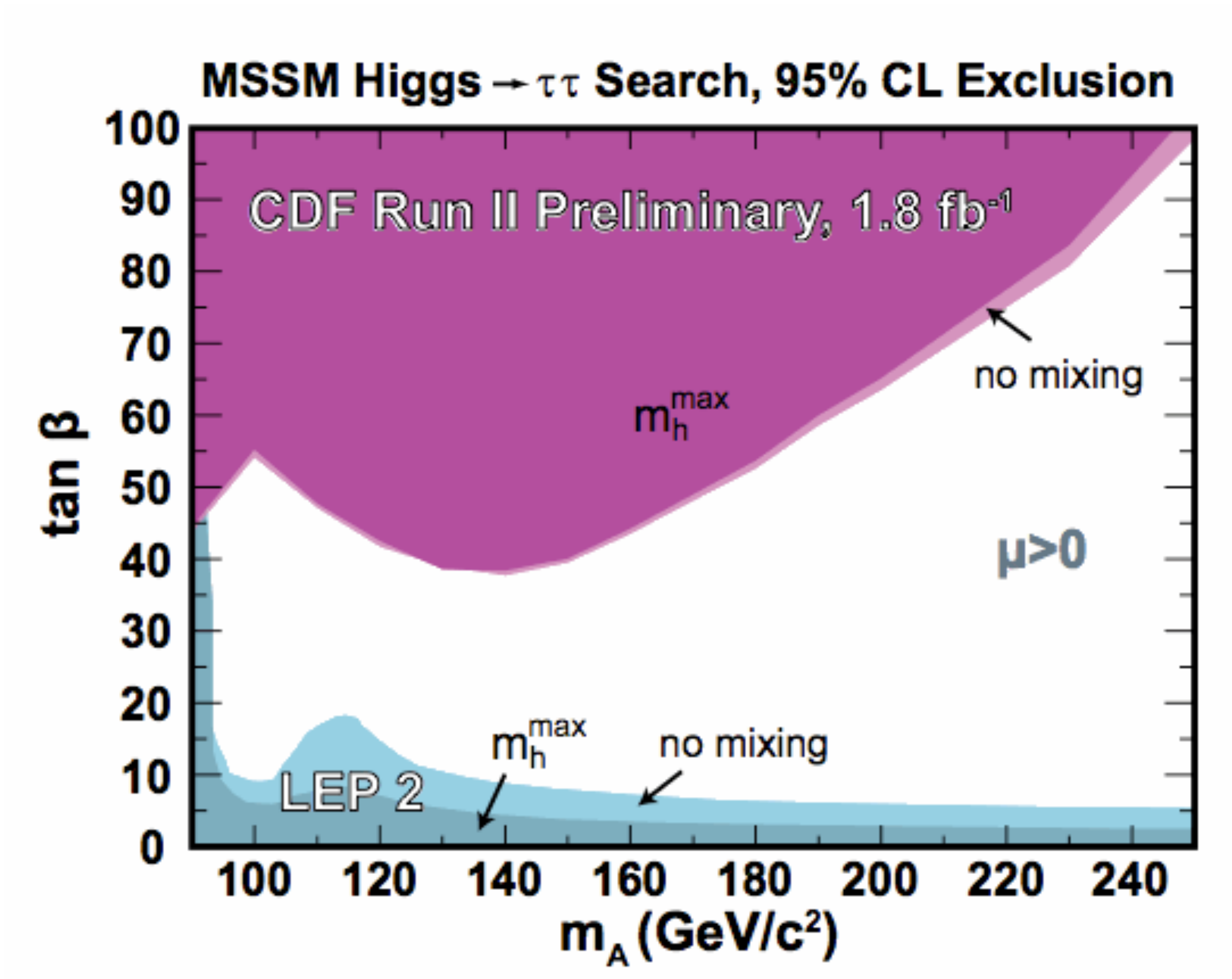
- Proceed to set limits on $\sigma\times BR(\phi\to\tau\tau)$

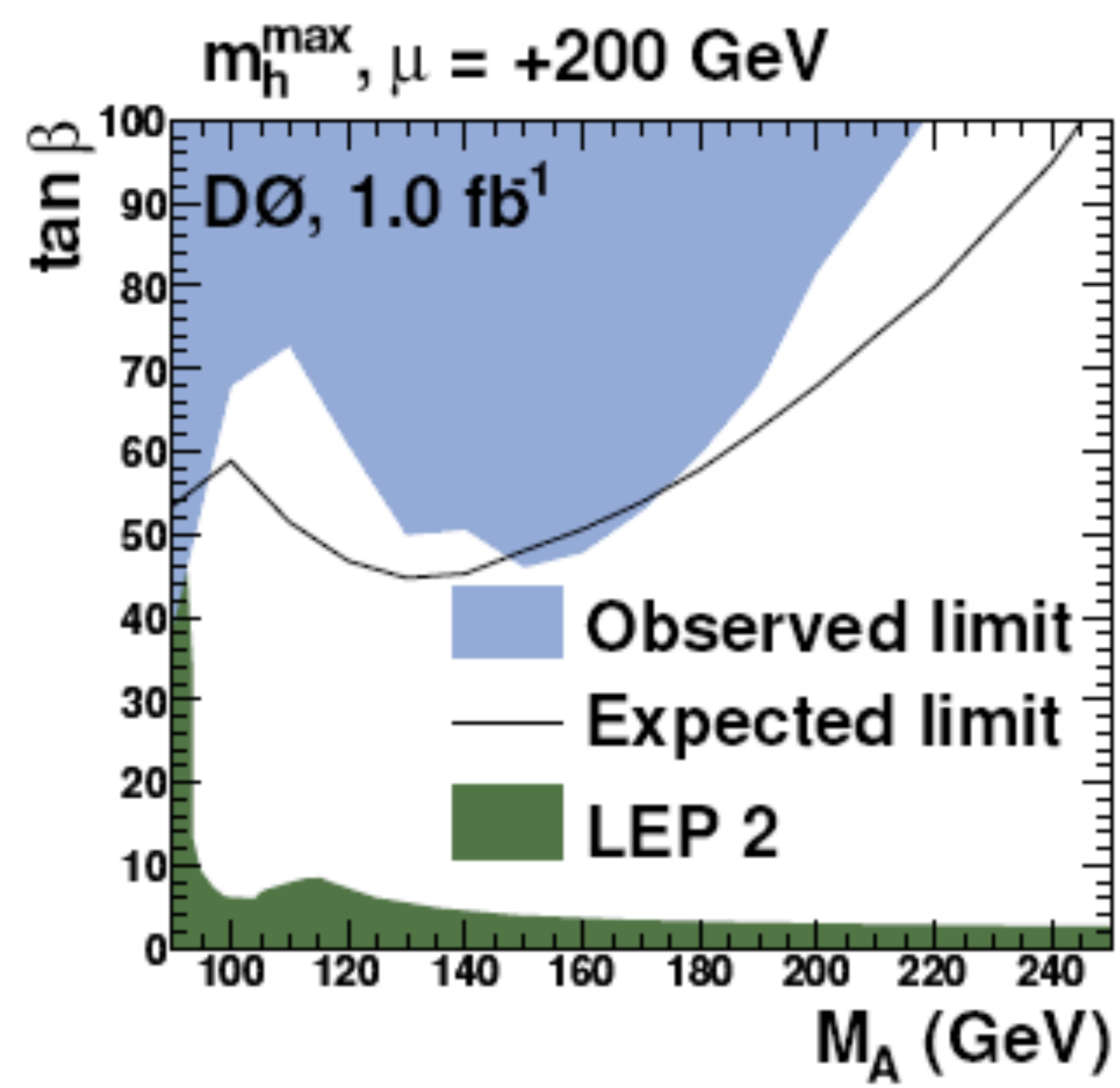




Limits and MSSM interpretation

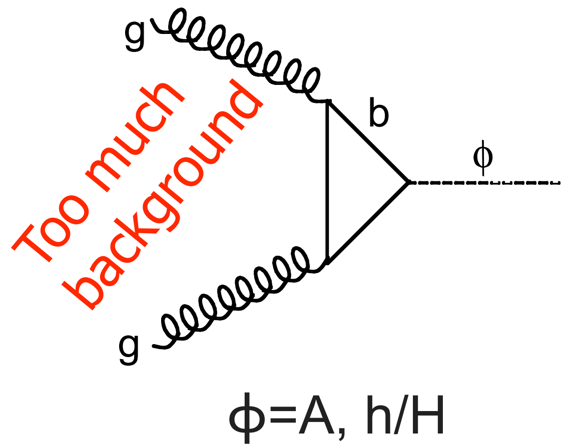
- Proceed to set limits on σ×BR(ϕ→ττ)
- Interpret σ×BR limit as limits on tanβ-vs-m_A in MSSM benchmark scenarios



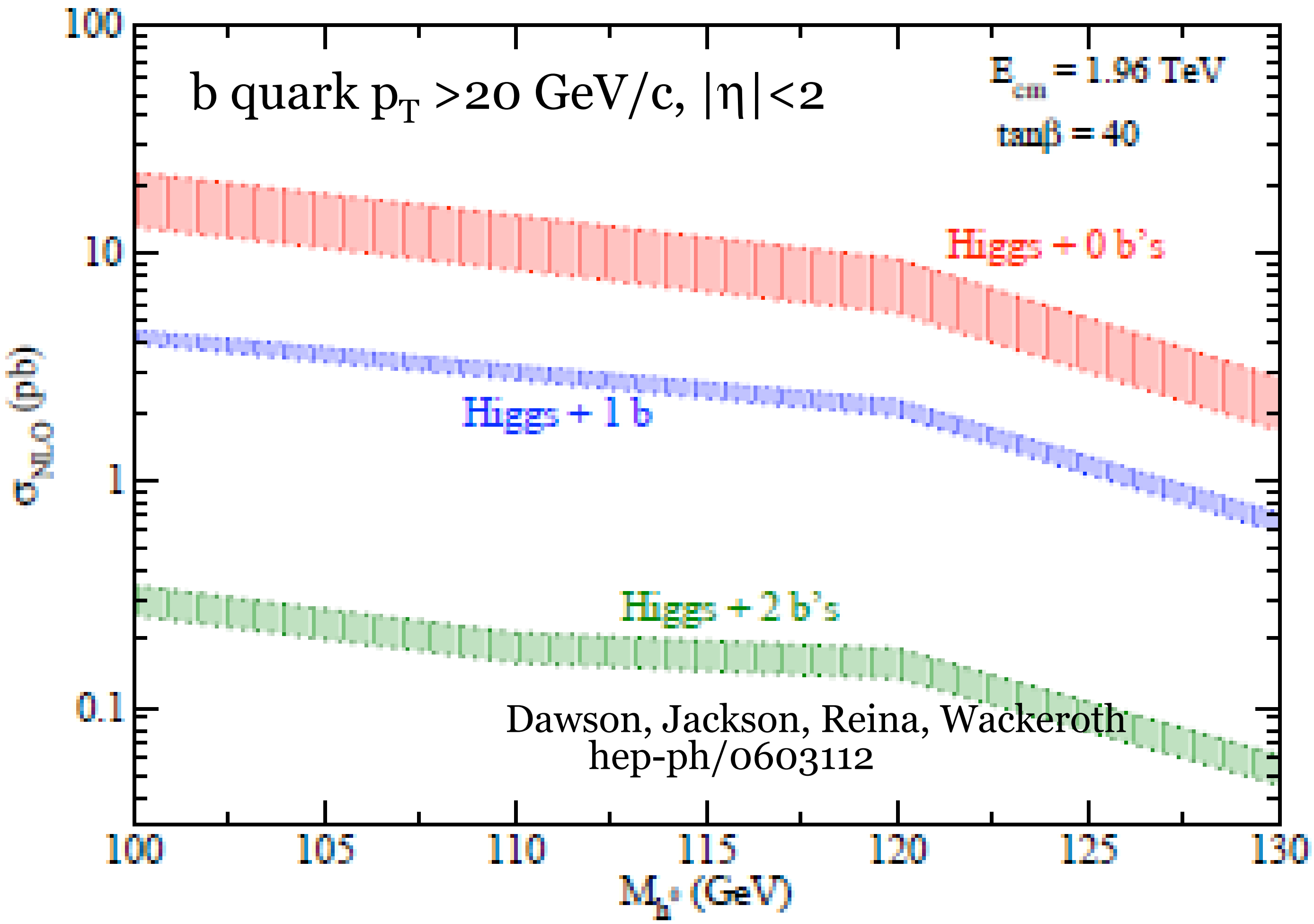


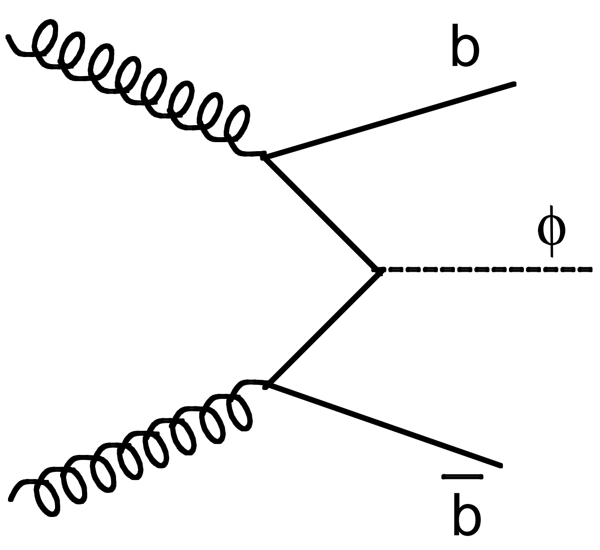
The ϕ→bb[b] Channel

- Inclusive ϕ→bb is too hard due to QCD background



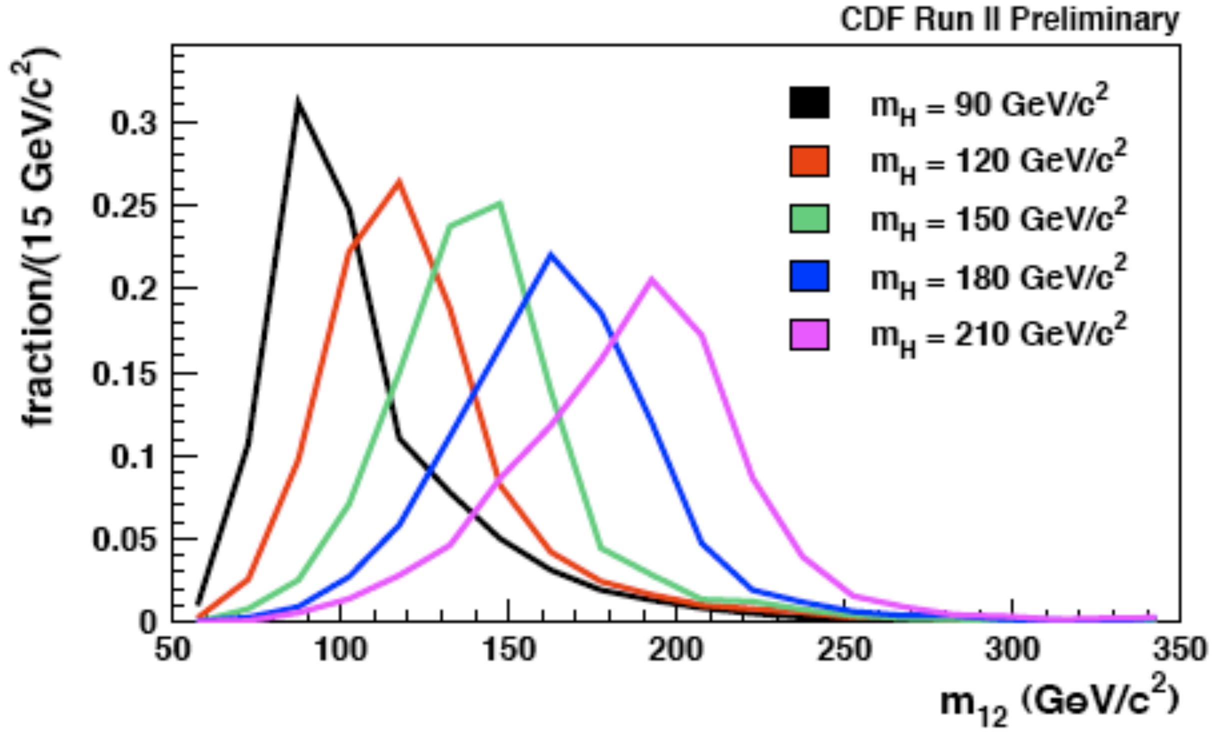
- Require one additional bottom quark beside the two from the Higgs decay
  - "3b" channel: best compromise between signal and background rates.





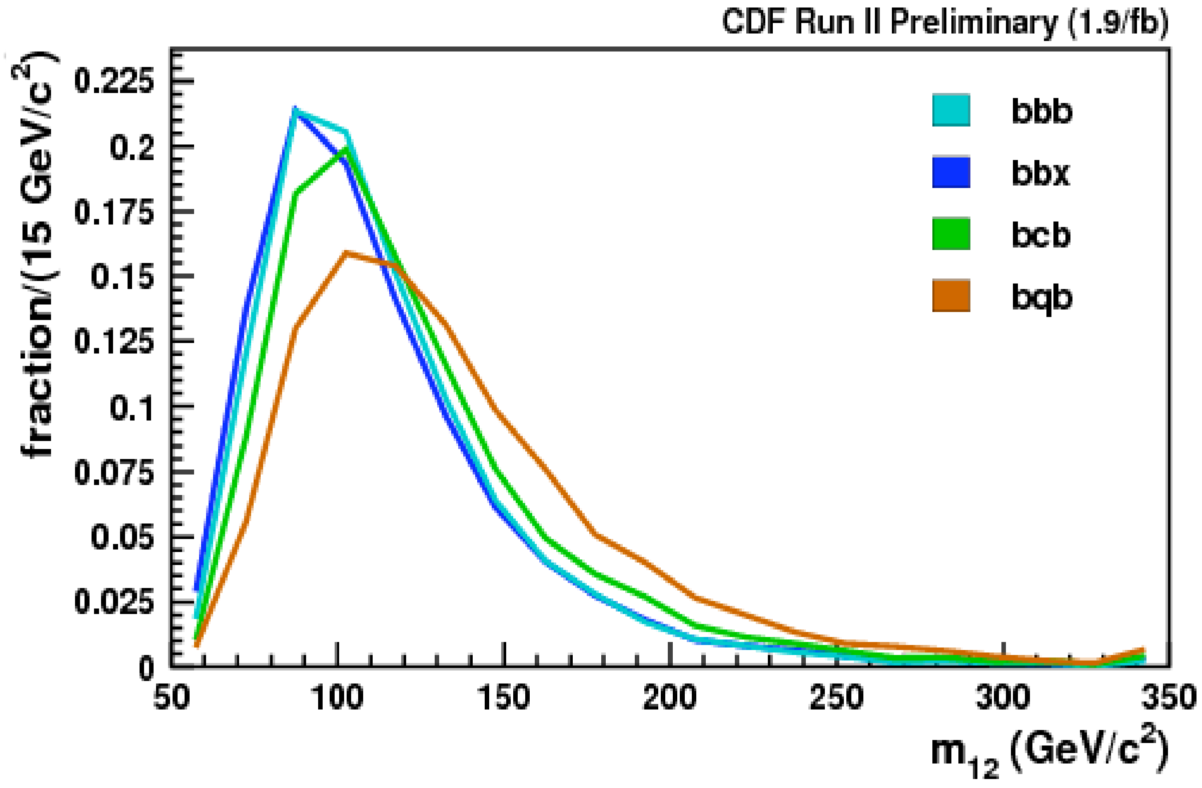
$\phi \rightarrow bb[b]$ Channel

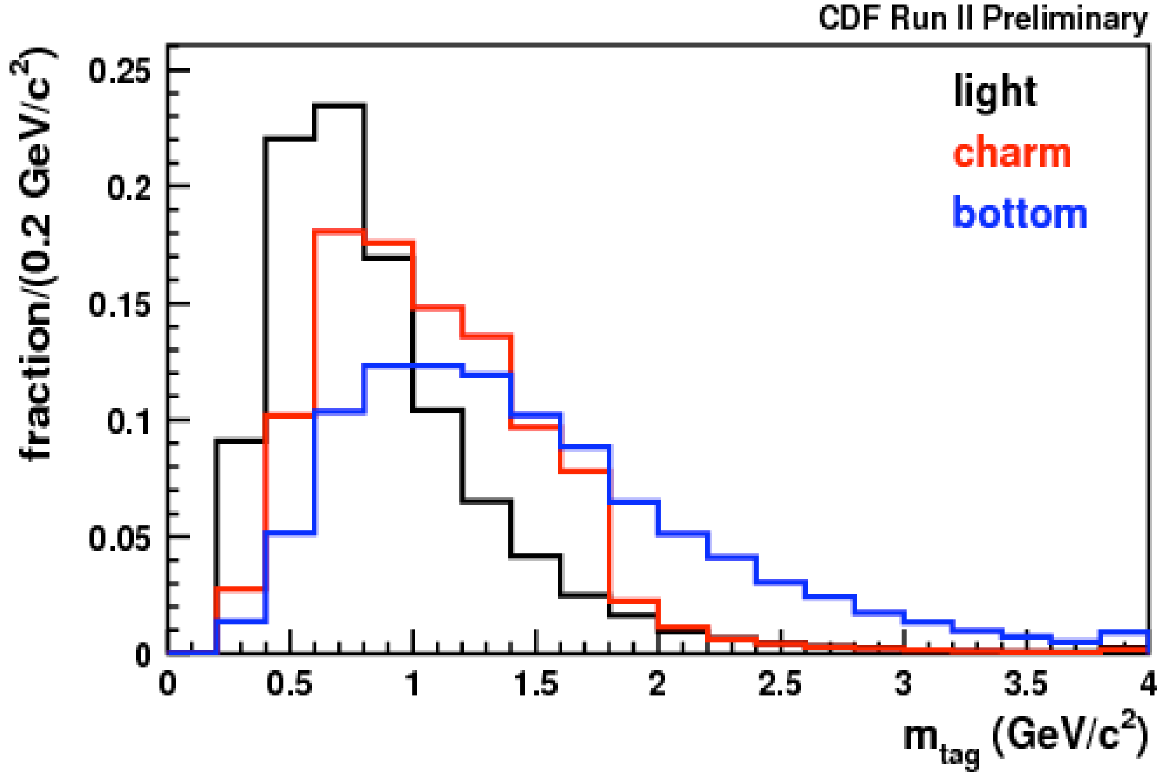
- Search uses invariant mass of the 2 leading jets in triple-tagged events
  - Peaks at Higgs mass



$\phi \rightarrow bb[b]$ Channel

- Search uses invariant mass of the 2 leading jets in triple-tagged events
  - Peaks at Higgs mass
- Backgrounds are QCD events with 2 true b-tags and a "b", "c" or "fake" tag
  - Characteristic spectra for each
  - Improve prediction of total background using invariant mass of vertex tag
    - $x_{tag}(m_1+m_2,m_3)$
  - Start from $b\bar{b}$ sample, weight events by flavor hypothesis





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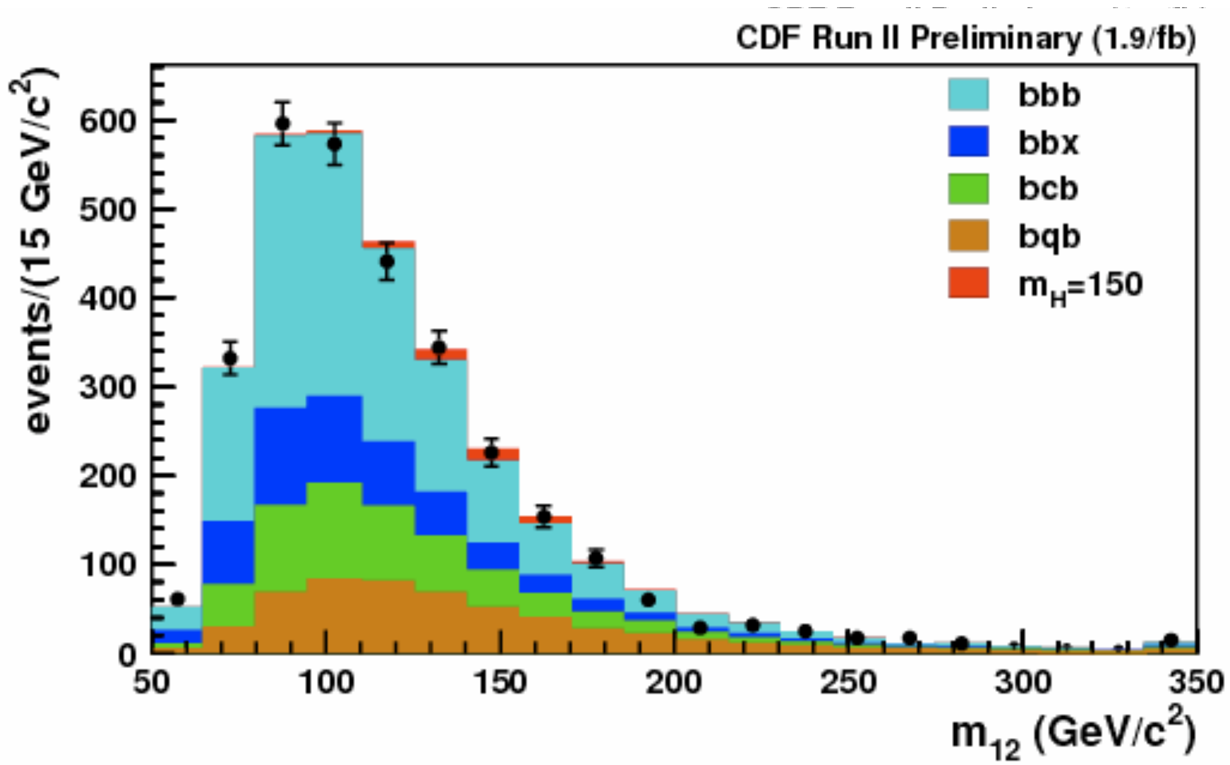
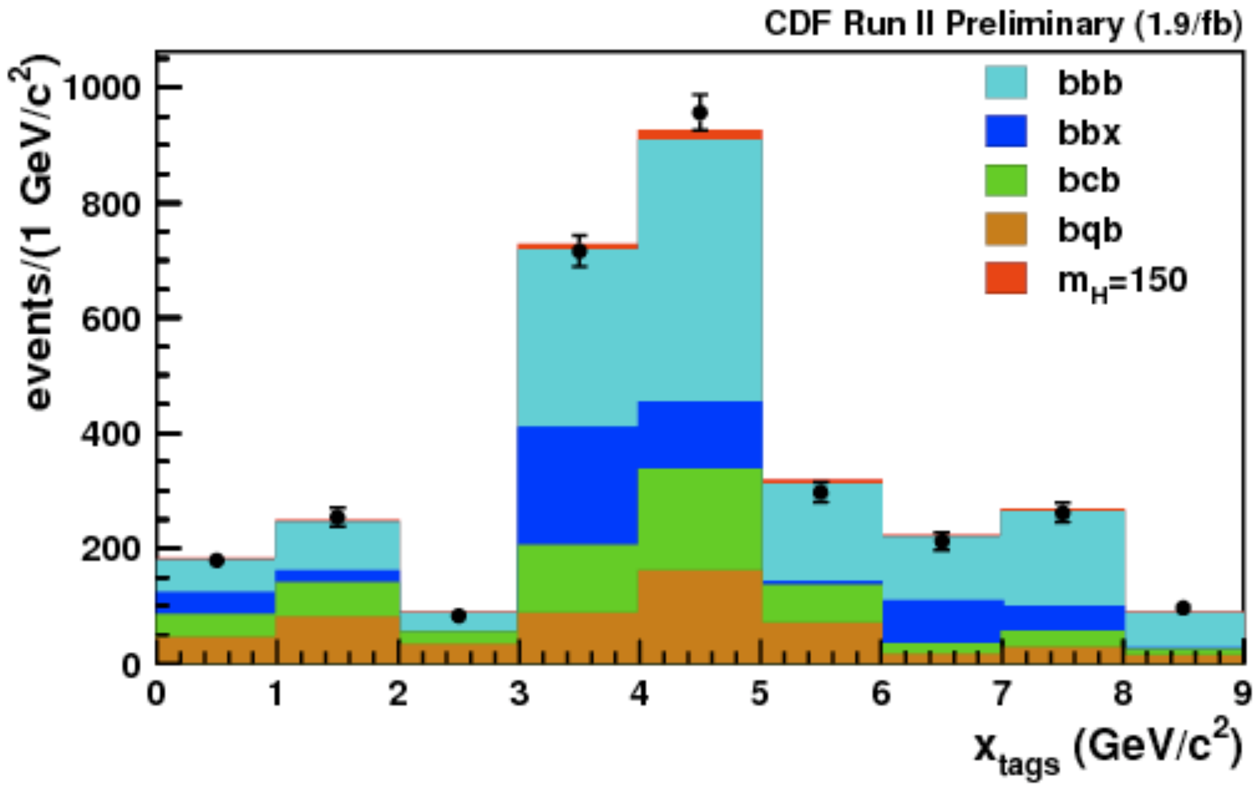
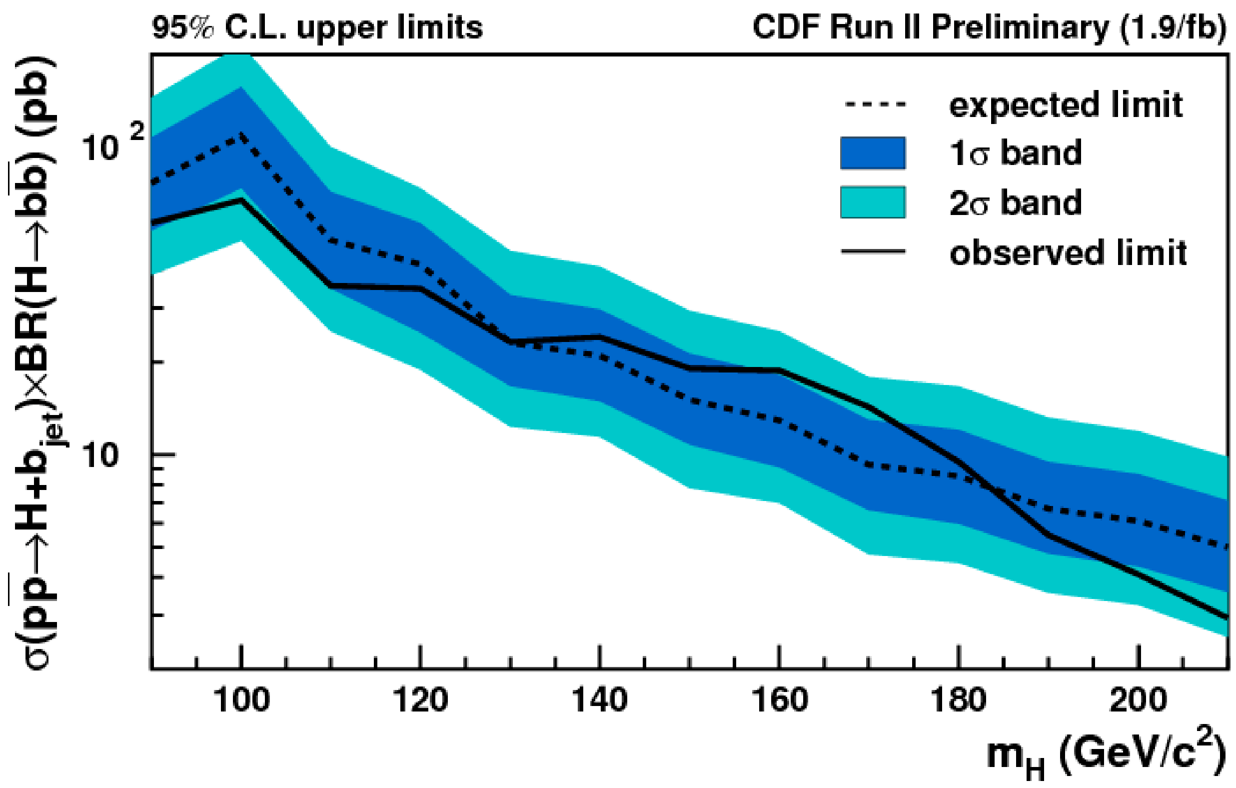
    - $x_{tag}(m_1+m_2,m_3)$
  - Start from $b\bar{b}$ sample, weight events by flavor hypothesis
- Fit the observed m_{12} -vs- x_{tag} spectrum:
  - Four backgrounds
  - Higgs shape.





The $\phi \rightarrow bb[b]$ Channel: interpretation

- Proceed to set limits on $\sigma \times BR(\phi \rightarrow bb)$
  - Loss of sensitivity at low mass due systematic on the jet E scale and gluon splitting



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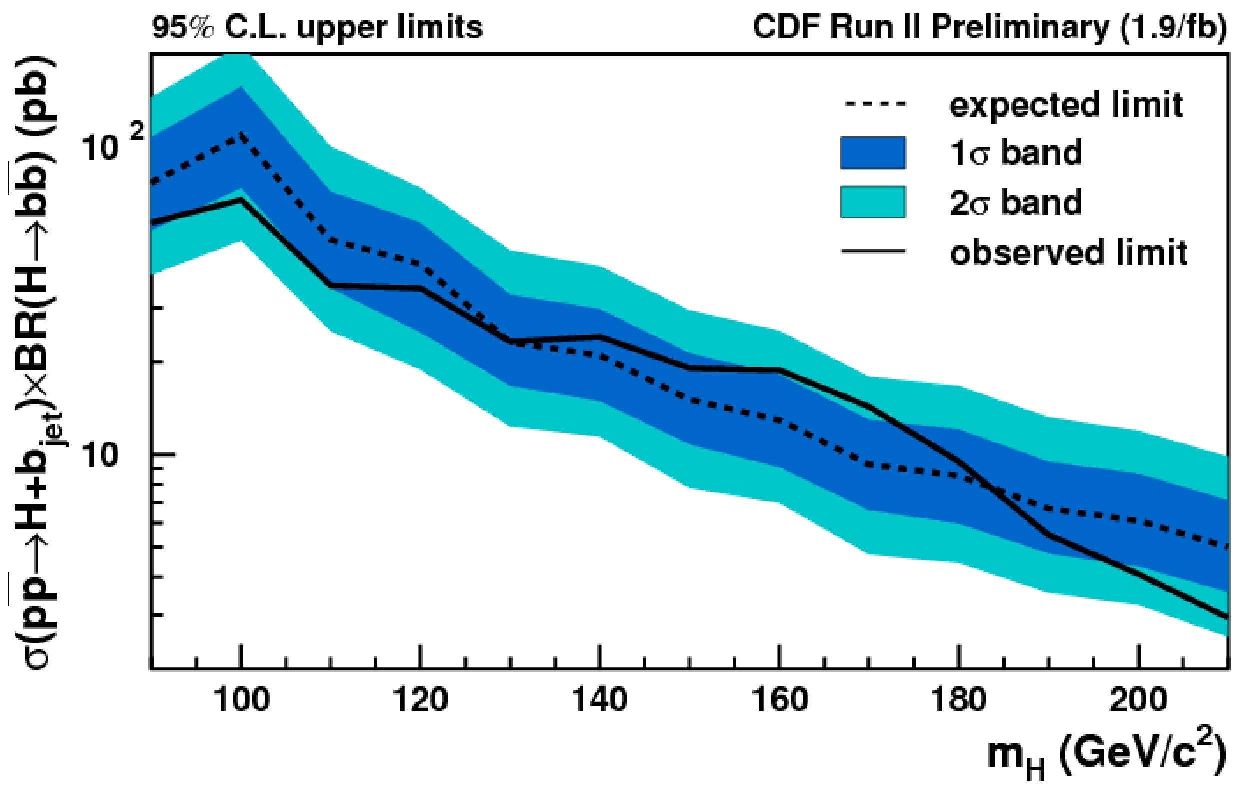
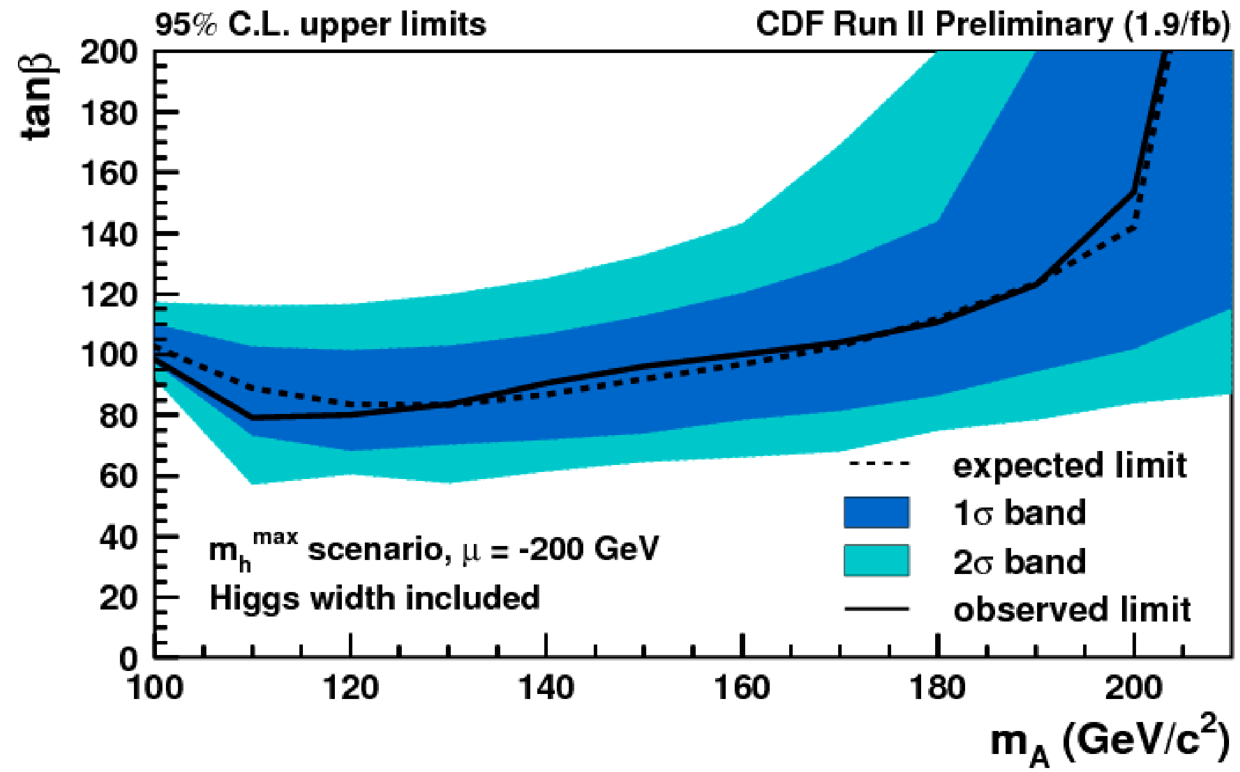


- Interpret in MSSM scenarios
  - Include effect of Higgs width
    - 20% for tanβ=100
  - Lose sensitivity (lower S/B)
  - Lowers event yield



$\phi \rightarrow bb[b]$ Channel

- Search uses invariant mass of the 2 leading jets in triple-tagged events
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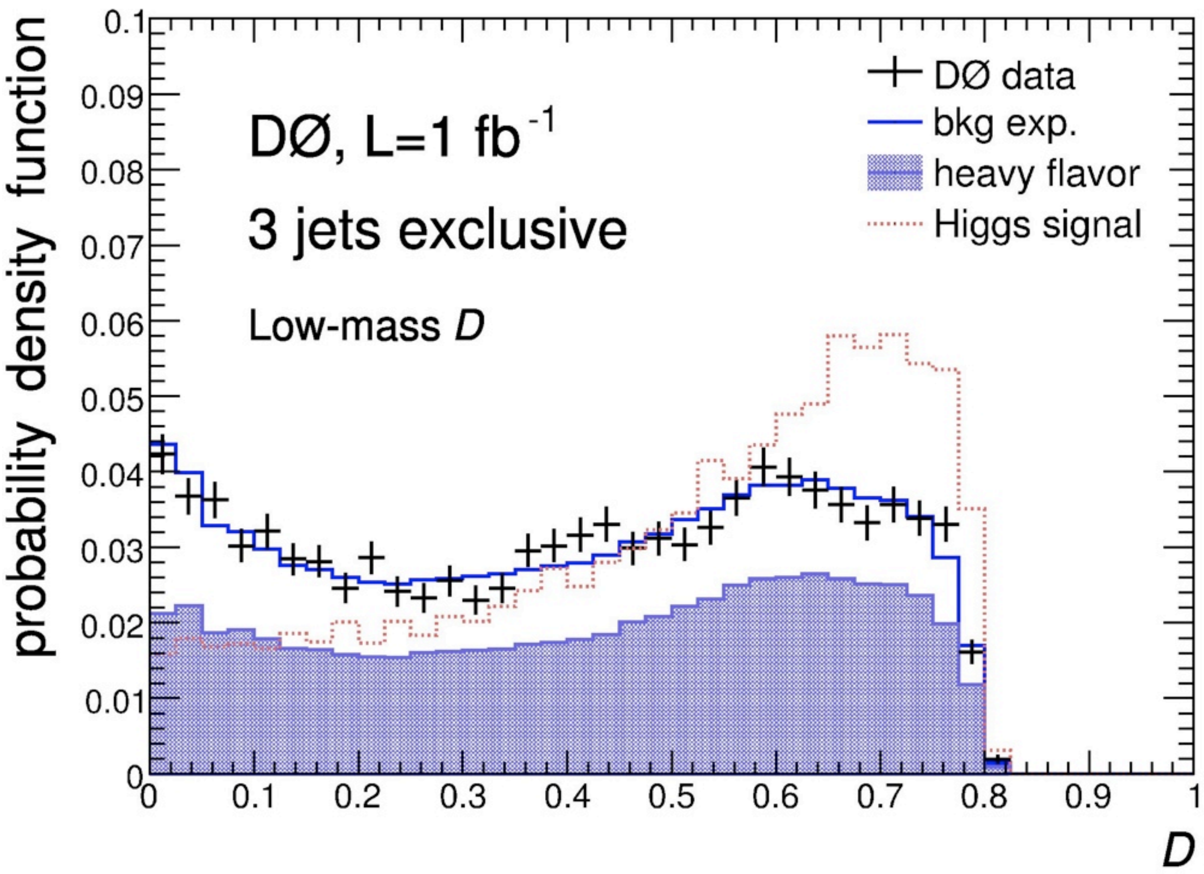
- Background shape derived from the double-tagged sample in data
  - Taking into account kinematics difference and tagging biases
  - Rate normalize to outside signal window.
- Further improve sensitivity by:
  - Splitting sample into 3, 4 and 5-jets channels
  - Use likelihood discriminant (D) based on 6 variables
    - Cut on D varies depending on jet multiplicity



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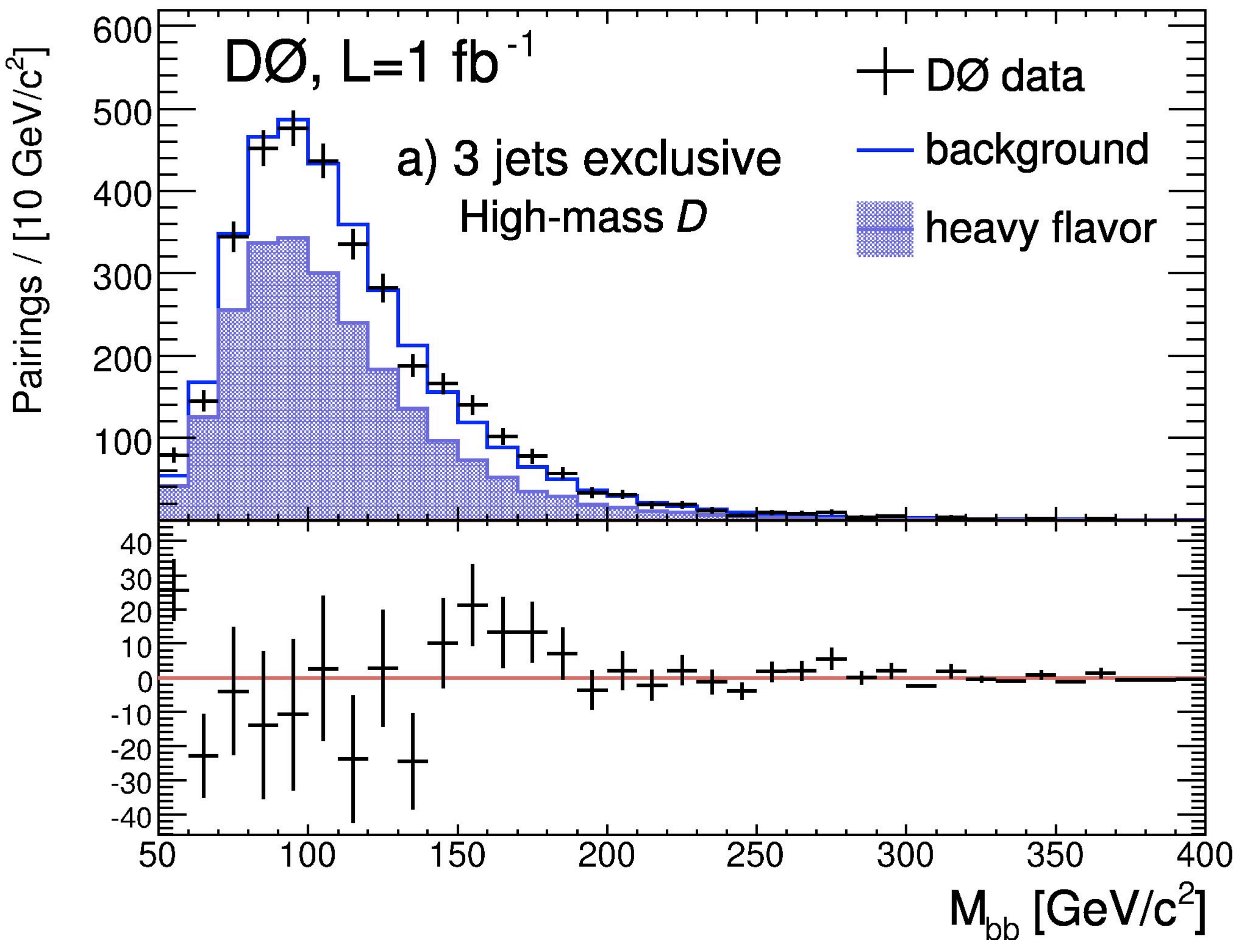

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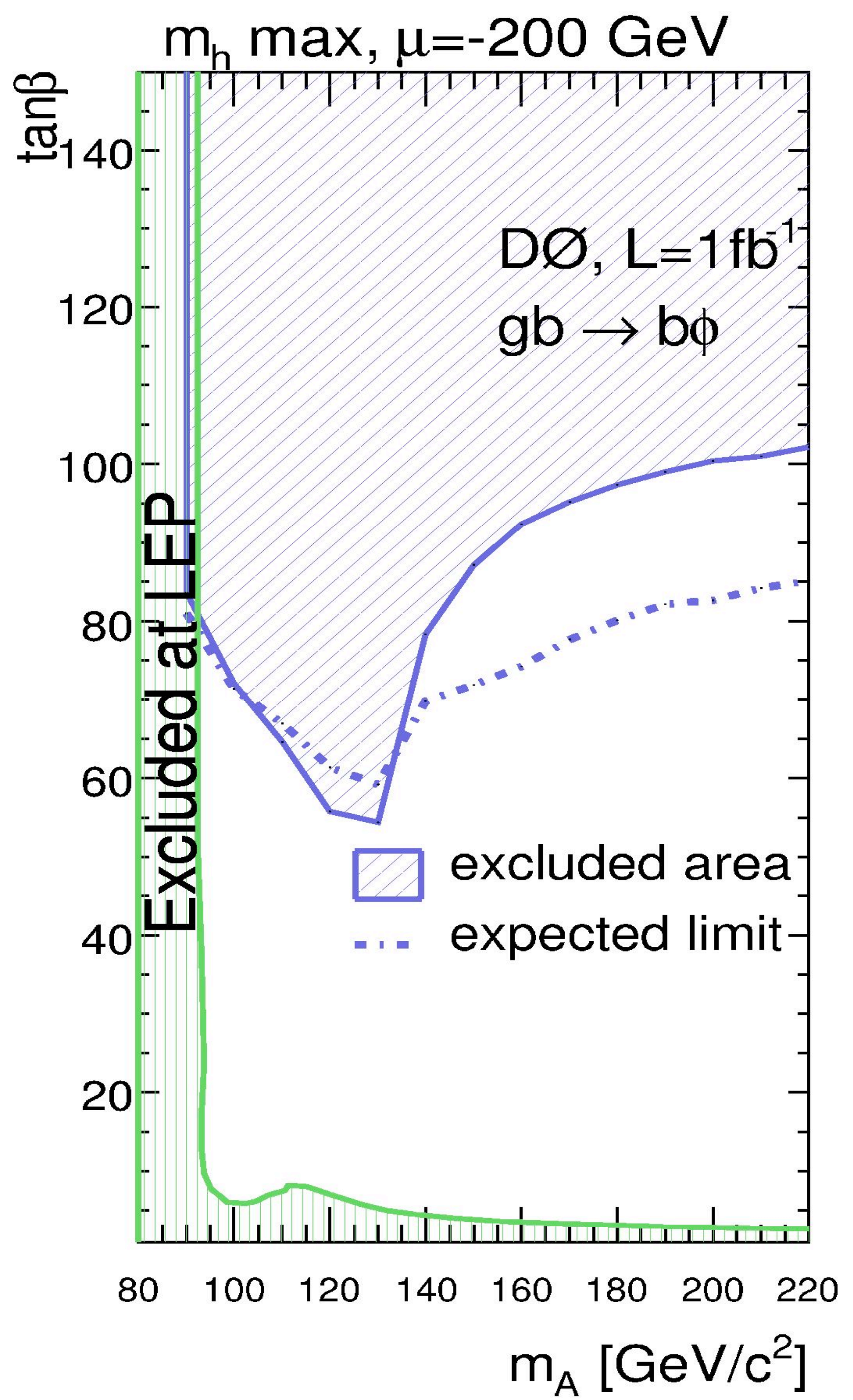
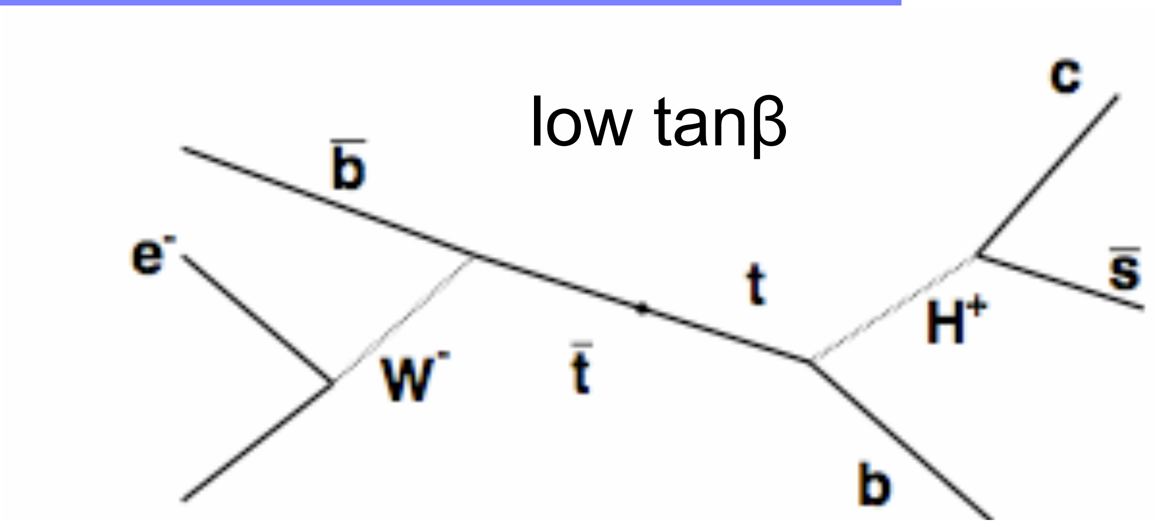
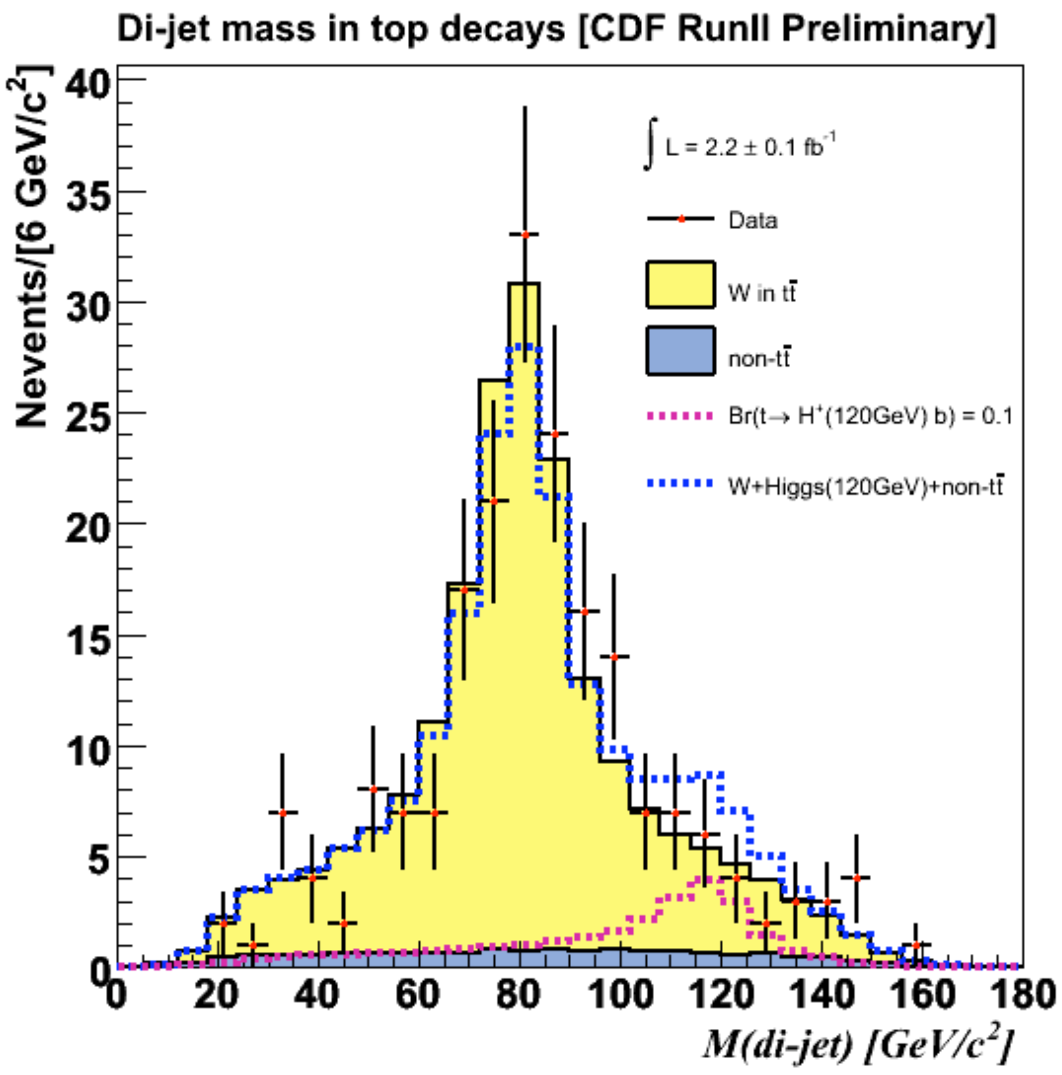
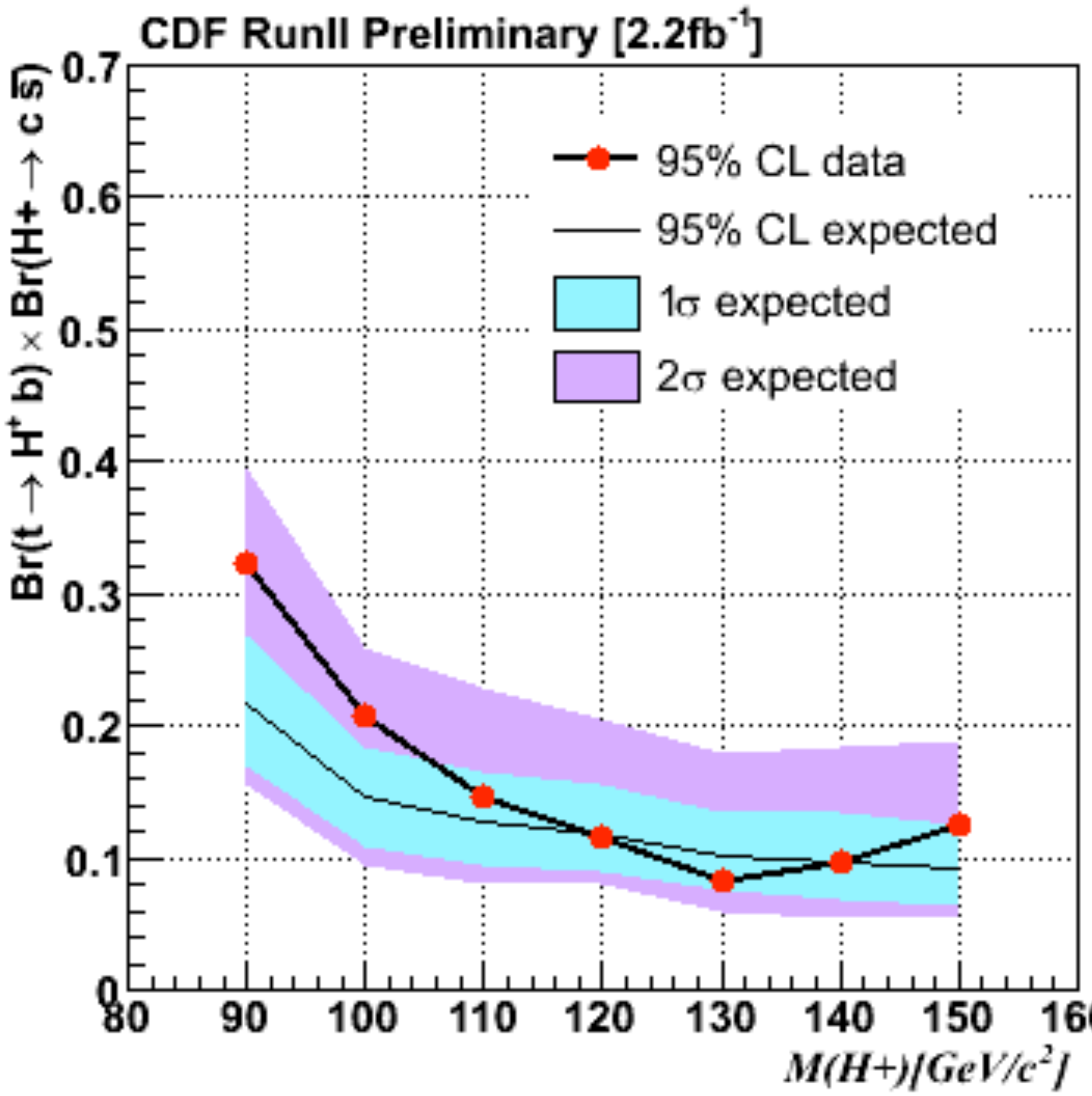


Charged Higgs: $H+\rightarrow c\bar{s}$

- Could be found in top decay if $m_{H+}<m_{top}$
  - Reconstructed via its dijet decay using double b-tags top l+jets sample
    - Improve di-jet resolution for low mass Higgs by adding extra-jet to closest leading jet

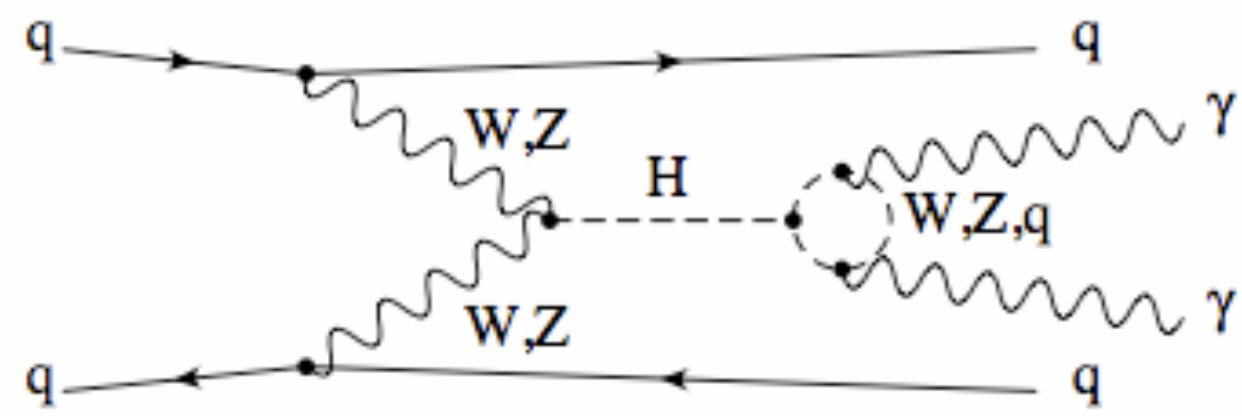


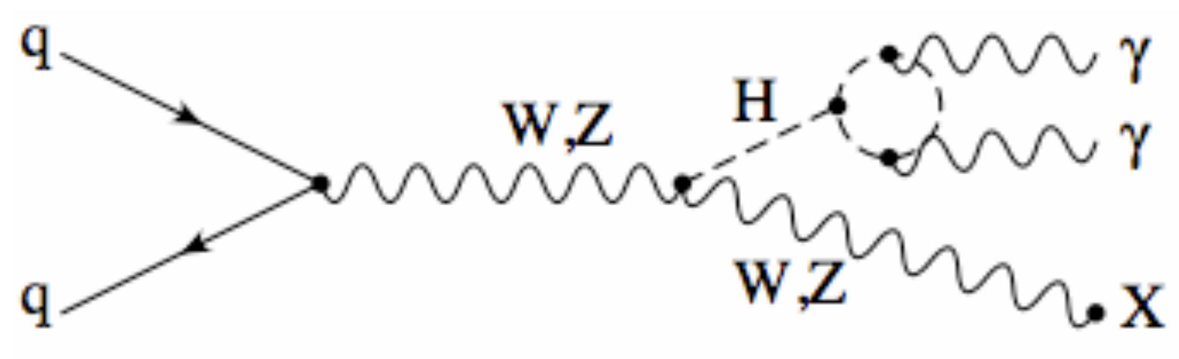


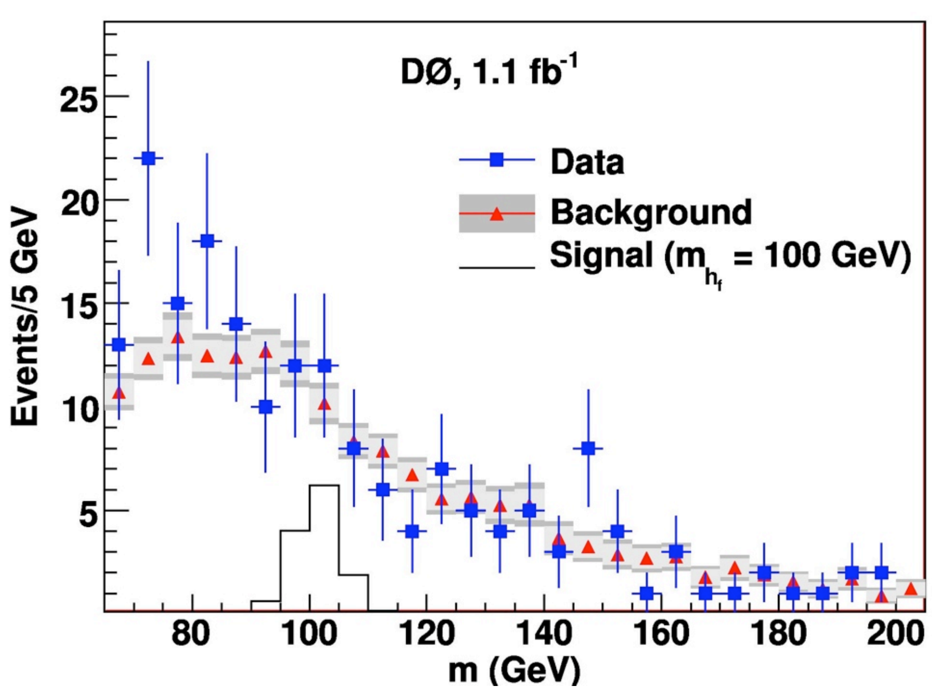


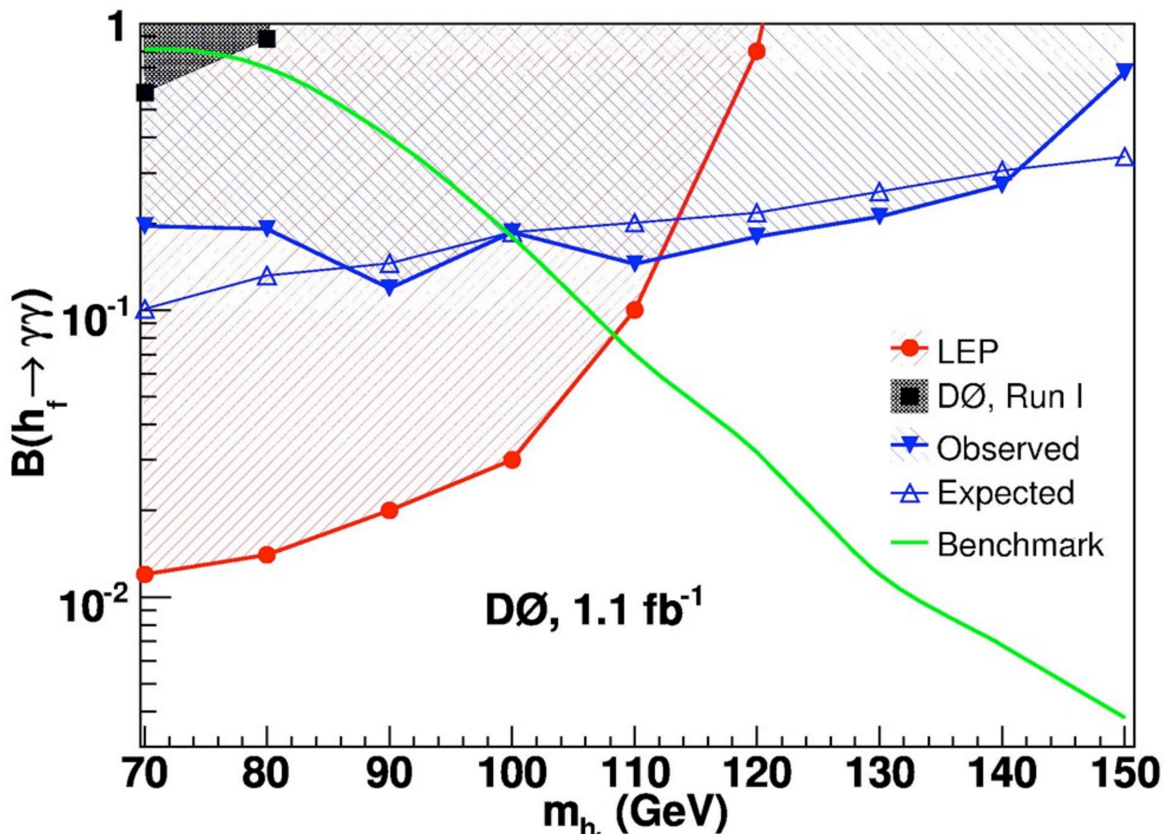
Fermiophobic Higgs

- Fermiophobic Higgs by vector-boson fusion or associated production:
  - Two isolated high E_T photon. Background from template fit.





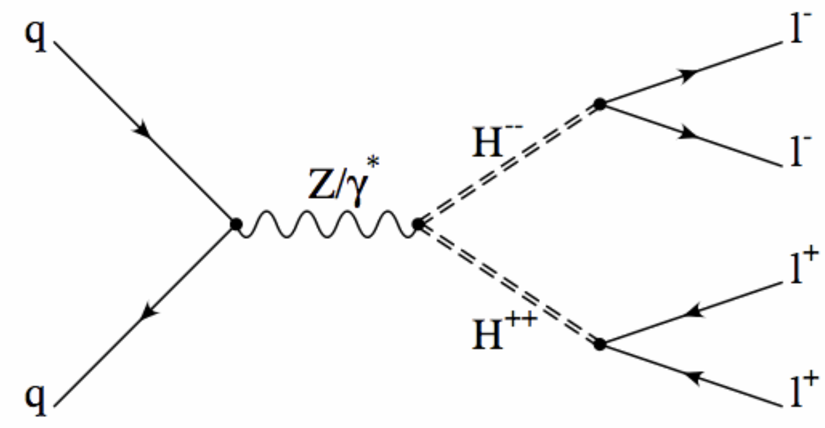


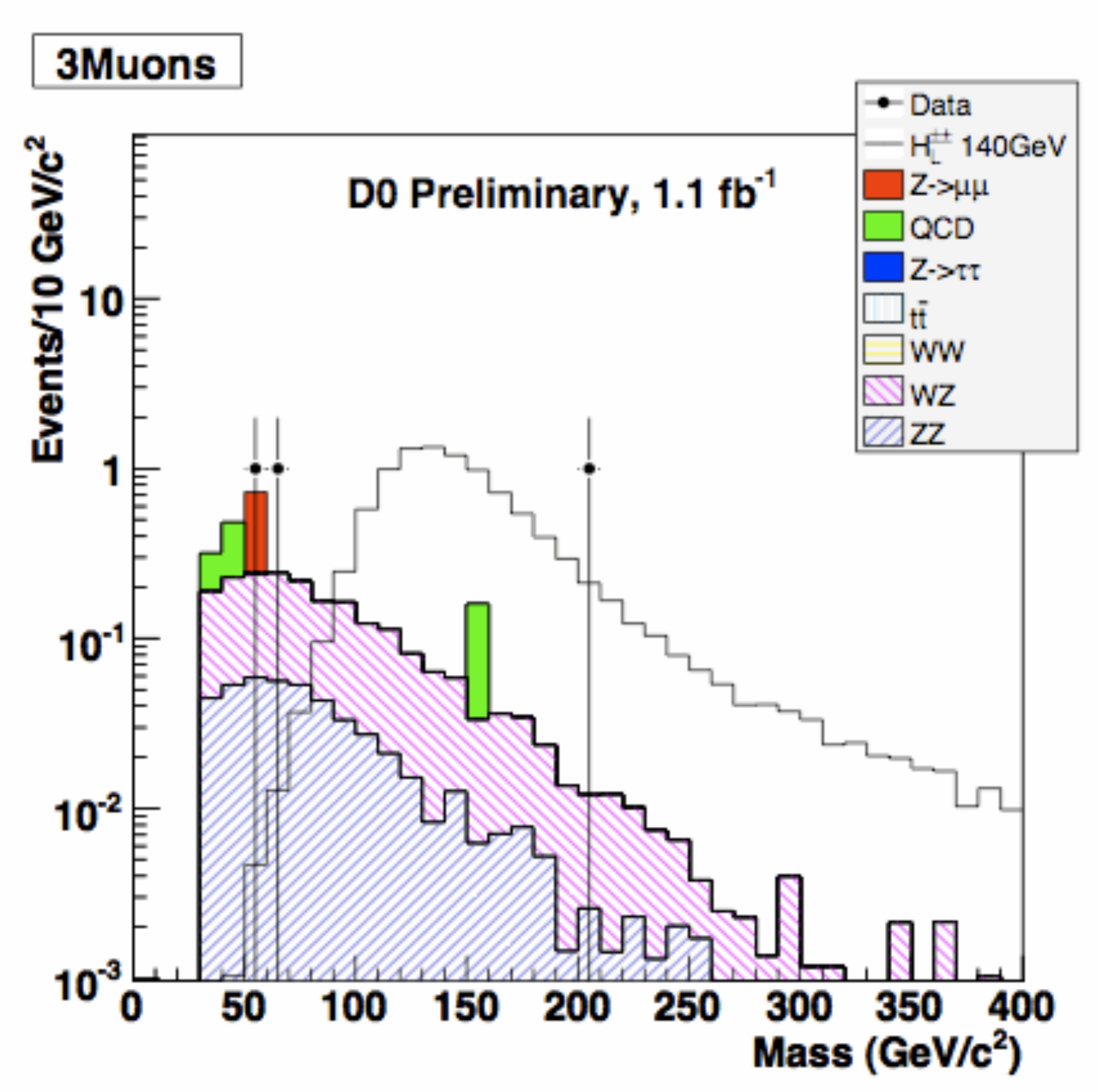


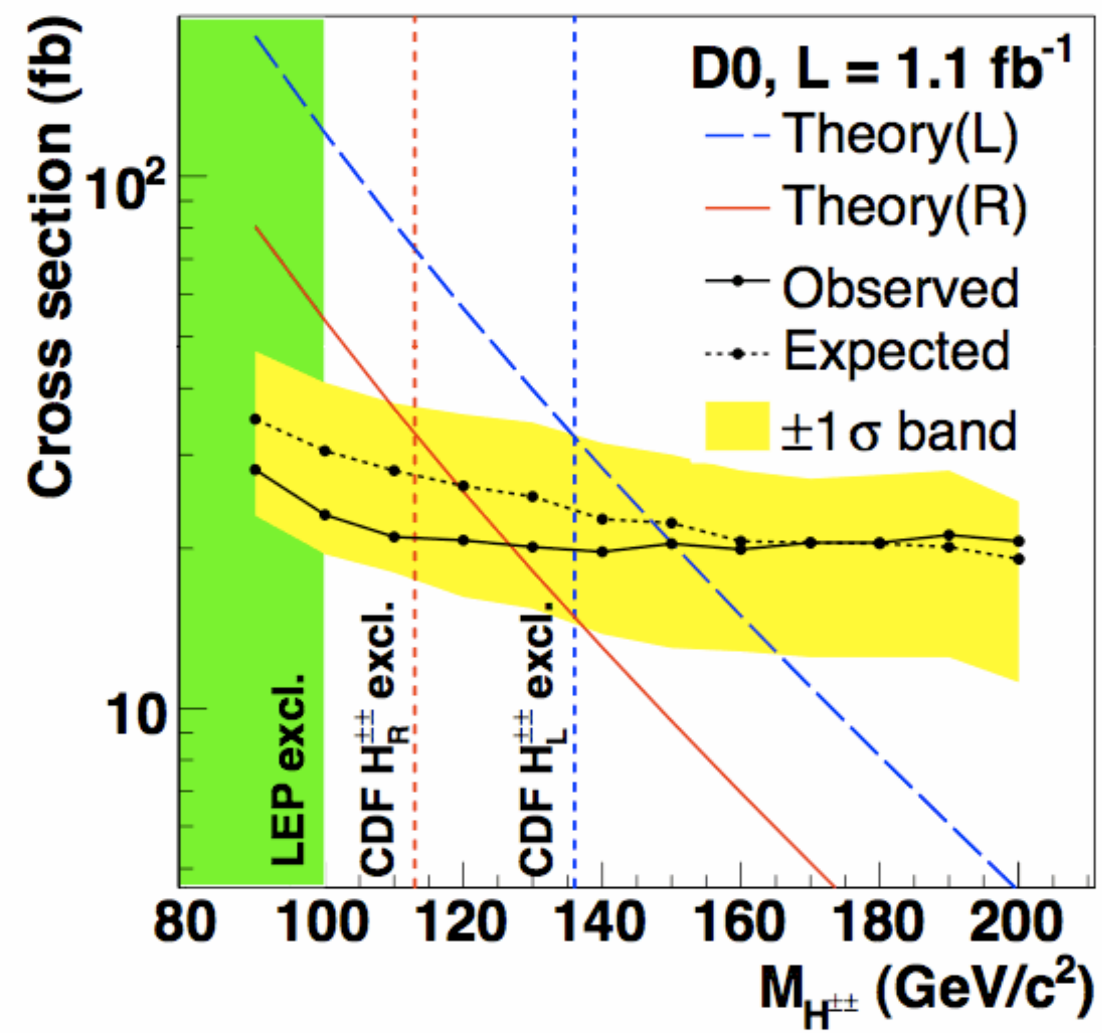
m_H>100GeV @95%C.L. (LEP m_H>109.7GeV)
Improves limits on BR for m_H>120GeV

Doubly Charged Higgs

- Appears in many scenarios: left-right symmetric, Higgs triplets, little Higgs
- DØ search: $H^{++}H^{--} \rightarrow \mu^+\mu^+\mu^-\mu^-$
  - require 3 muons, with at least 2μ with like-sign







Future Prospects: SM Higgs

- Improvements in the Higgs analyses have been exceeded that expected from more data.
- Analyses can add ideas from other channels
  - NN b-tagging
  - Improve dijet mass
- Combination of techniques within channels:
  - e.g. Combine M.E. & ANN
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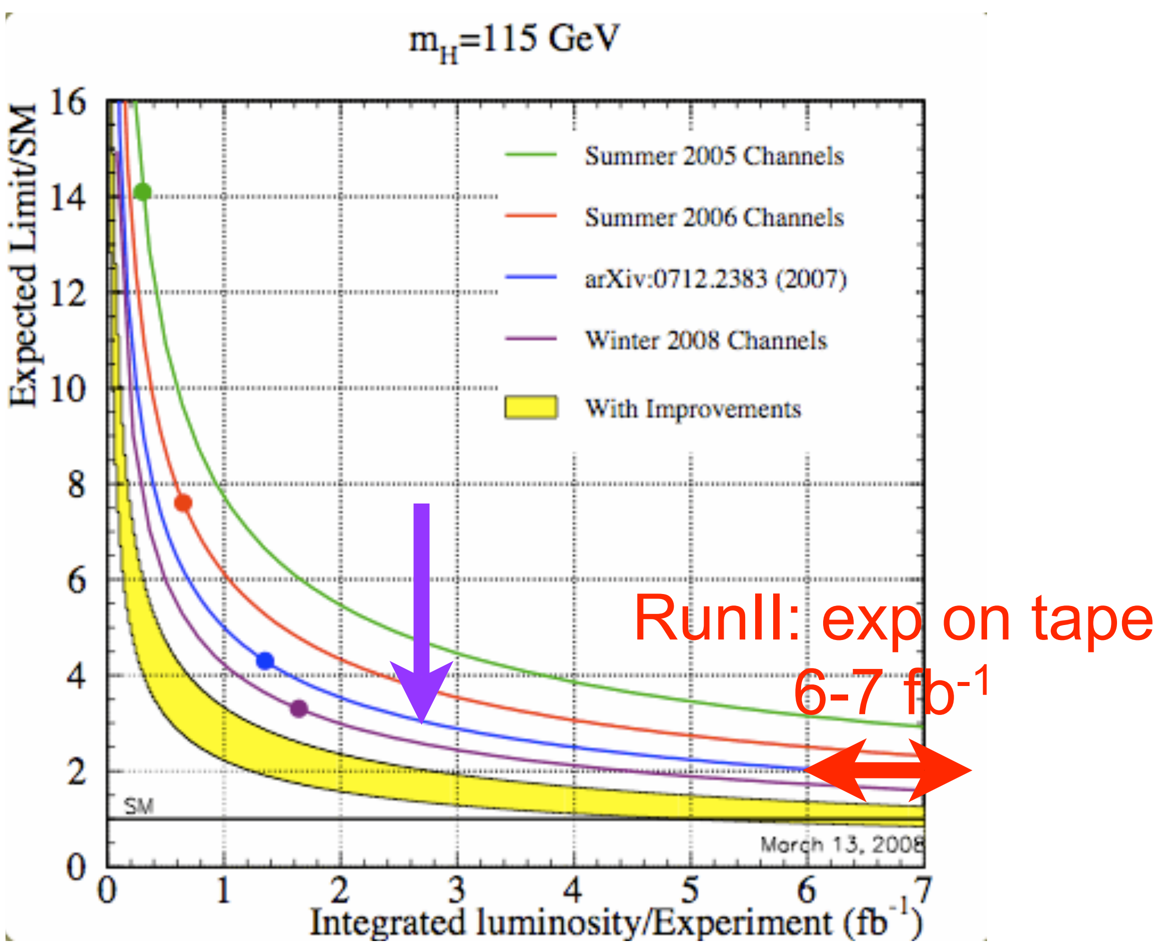
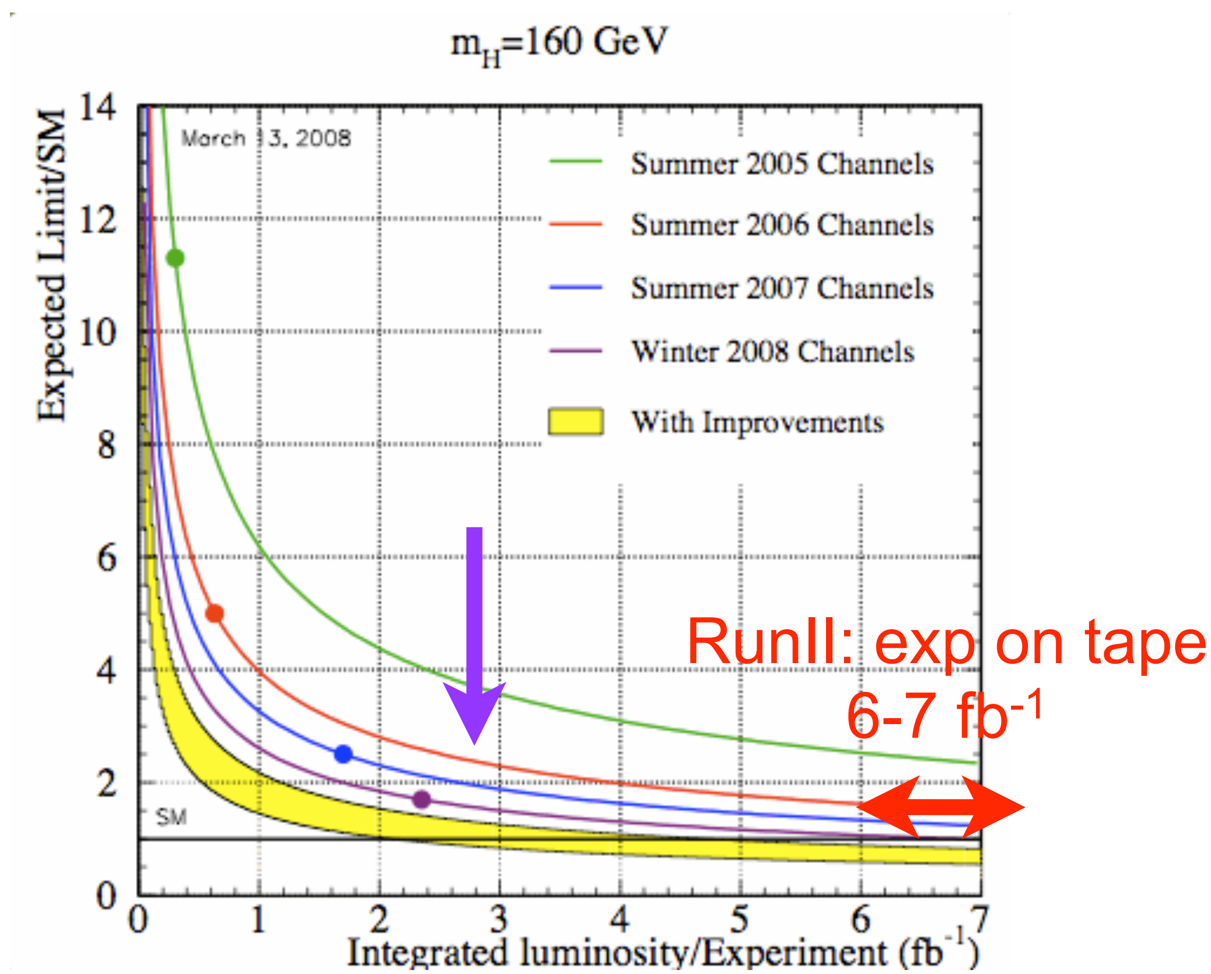
Extrapolate into the future:
1. Same analyses, add more data
2. Extend sensitivity for anticipated improvements





Future Prospects: MSSM Higgs

- CDF & DØ are actively searching for neutral MSSM Higgs
- Techniques are well advanced but still room for improvements
  - Taus: split samples to improve $m_{\tau\tau}$ and S/B with b-tagging
  - 3b's: background shape systematics (CDF)
- DØ updates of tau channels ($\tau\tau$, $b\tau\tau$) coming soon
- Combination of experiments/channel is planned

- With expected 6-7fb^{-1} by end of RunII, could probe down to tanβ in the 20's for low m_A
- Or discovery with the right tanβ & m_A

Conclusions

- Higgs search at Fermilab has become mature
- The collaborations are squeezing every last bit of sensitivity from all channels
- Improvements continue to occur:
  - b-taggers
  - Combine M.E. & ANN
  - Jet energy resolution
  - Increase acceptance: e.g. WH isolated track
- With the additional data expected, there is still an excellent opportunity for the Tevatron to weight in on the Higgs before the LHC takes over.
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http://www-cdf.fnal.gov/physics/new/hdg/hdg.html

http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

Stay Tuned