Low Mass Higgs Searches at the Tevatron: Secondary Channels

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on behalf of CDF and D0 collaborations

Higgs Hunting Workshop, Orsay
28 July, 2011

Higgs Production at the Tevatron

- Indirect measurements prefer low mass Higgs

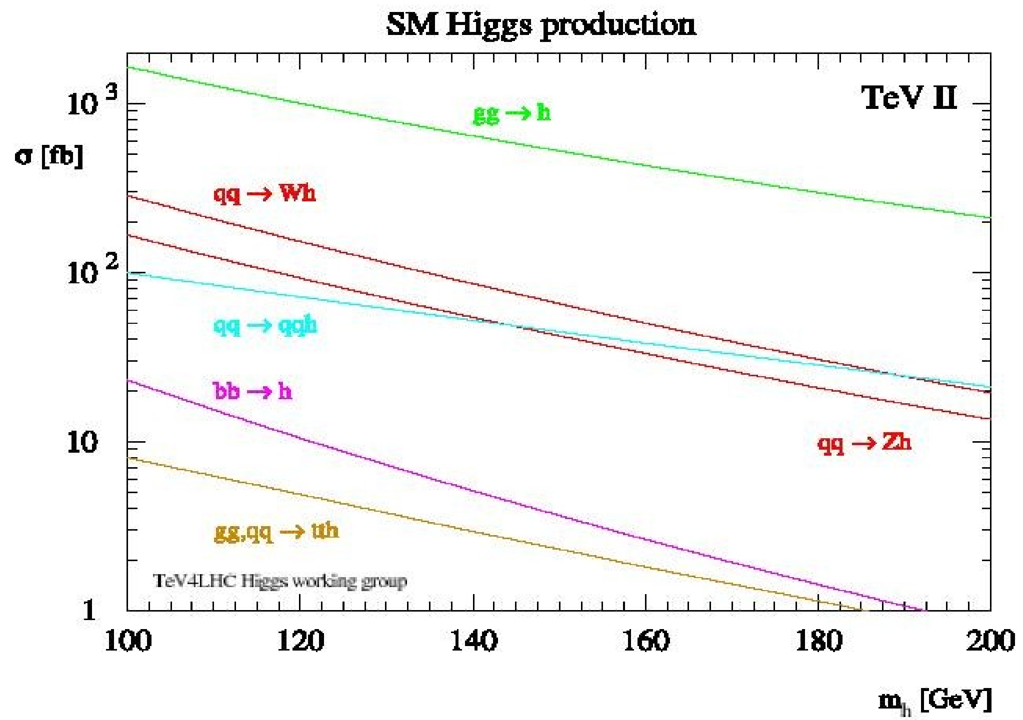
  $m_H < 157$ GeV/c^2 at 95% C.L.

- Higgs production cross sections:

  gluon fusion ~ 1.2 pb

  associated production ~0.2 pb

- Inelastic cross section ~ 70 mbarn



Separating signal from background very challenging

→ search in many optimized channels

Higgs search strategy at the Tevatron

No single channel provides enough sensitive to claim a discovery
→ combining channels provides best sensitivity

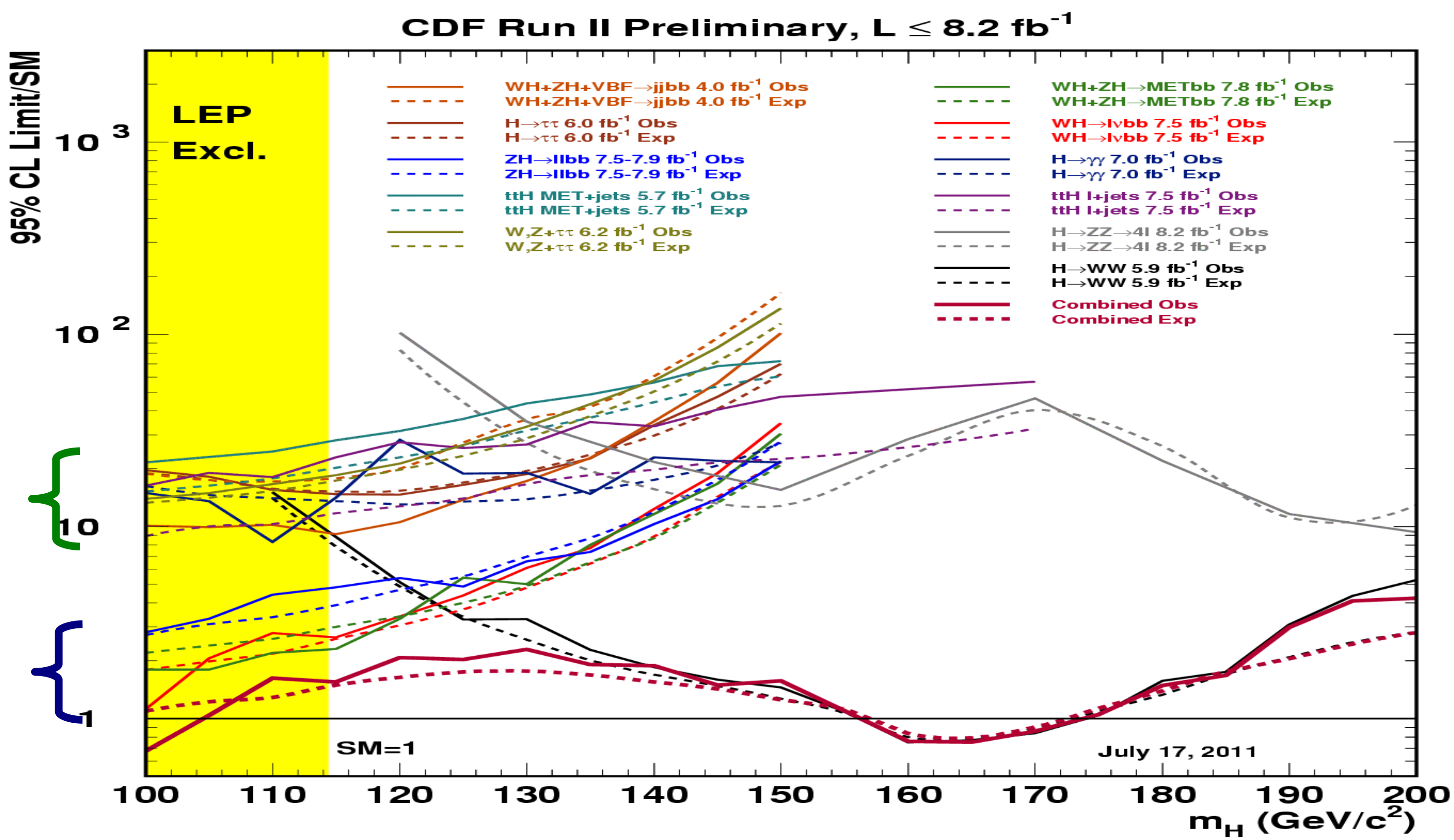
Search strategy determined by the Higgs decay modes

More Challenging Channels:

- Expected limit > 10 $\sigma_{S.M}$

Primary Channels:

- $H \rightarrow b\bar{b}$
- Associated VH production



Challenging Channels

- Sensitivities add in inverse quadrature sum $S = 1/\sqrt{\sum 1/S^2_{channel}}$

  rough combined limit for analysis presented in this talk $\sim$ 5.4 $\sigma_{S.M}$

  ~ sensitivity of primary channel!
- Very challenging: develop technique that could be used at LHC
- If Higgs existed, necessary to measure Branching fractions
- Sensitive to physics beyond S.M. (see talk by A. Patwa)

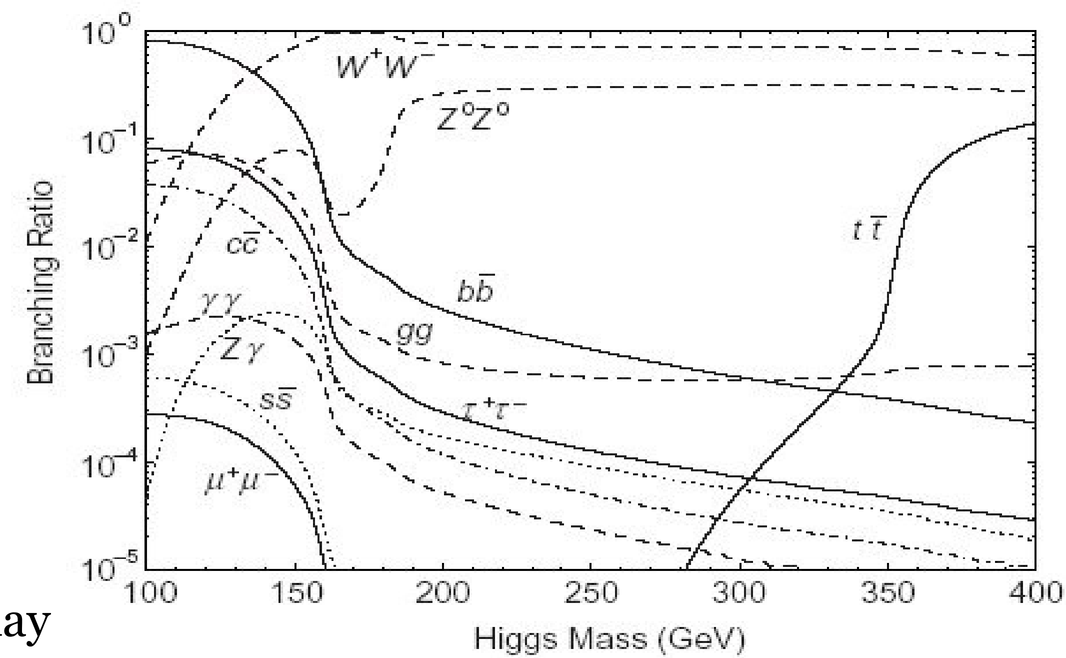
- Include analysis sensitive to:

  $H \rightarrow \gamma\gamma$

  $H \rightarrow \tau\tau$

  different productions mechanism

  (gluon fusion, VBF, ttH)



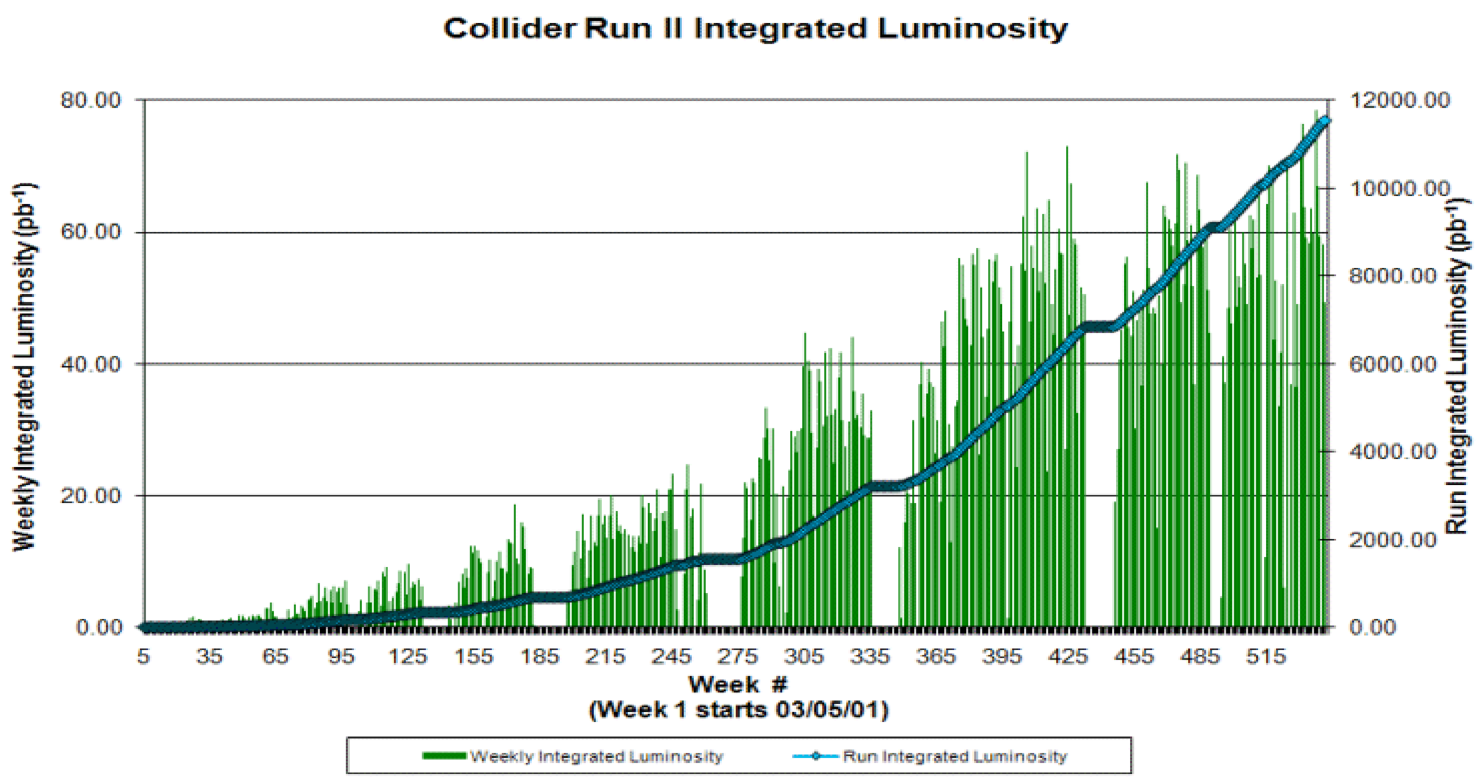
- Only new results for EPS presented today

Tevatron

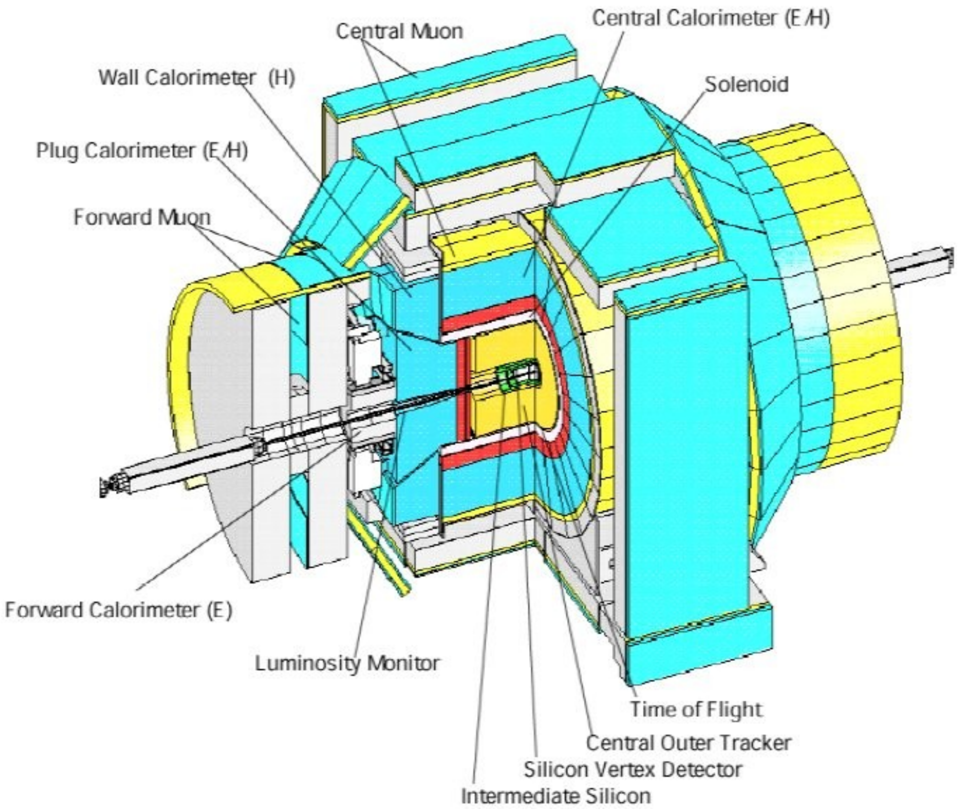
Tevatron is doing great:

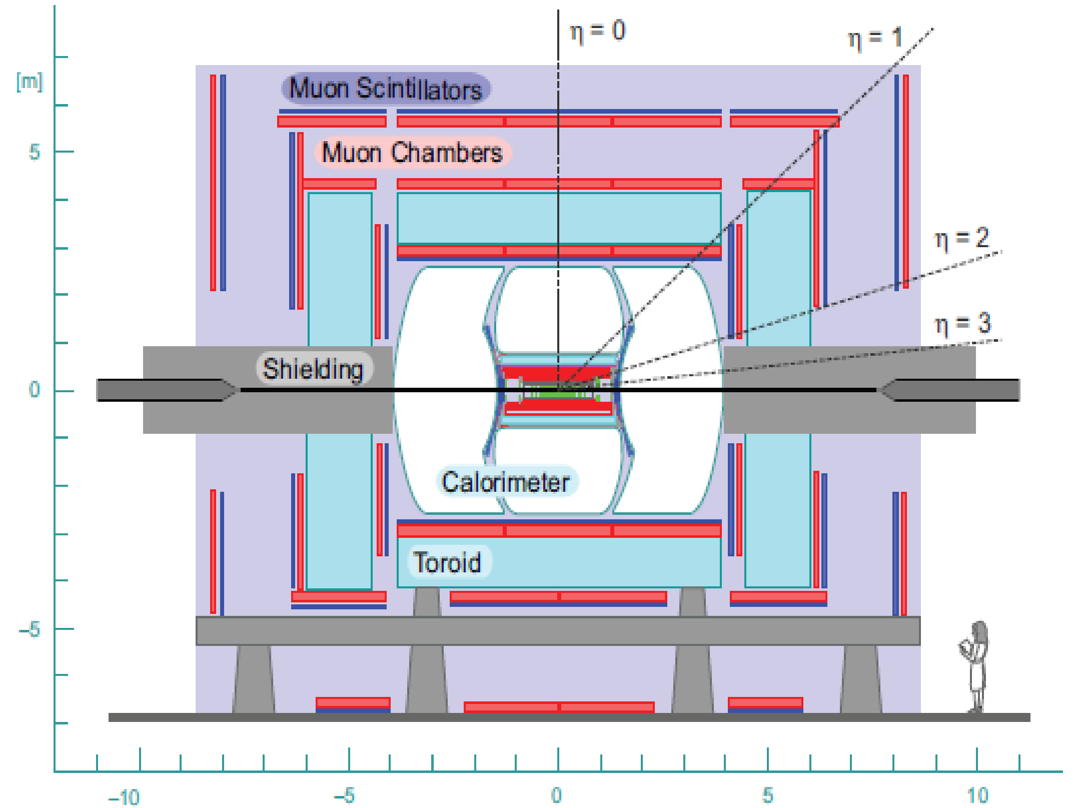
- Integrated delivered luminosity: 11.6 fb-1
- CDF acquired > 9.5 fb^{-1}
- D0 acquired > 10 fb^{-1}

Analysis presented today: $5.5\ fb^{-1} < \int L < 7.5\ fb^{-1}$



CDF and D0





	CDF	DO
Silicon	$\lvert\eta\rvert < 2$	$\lvert\eta\rvert < 3$
Tracking Chamber	$\lvert\eta\rvert < 1.1$	$\lvert\eta\rvert < 1.7$
Calorimeter	$\lvert\eta\rvert < 3.6$	$\lvert\eta\rvert < 4$
Muon Chambers	$\lvert\eta\rvert < 1.5$	$\lvert\eta\rvert < 2$

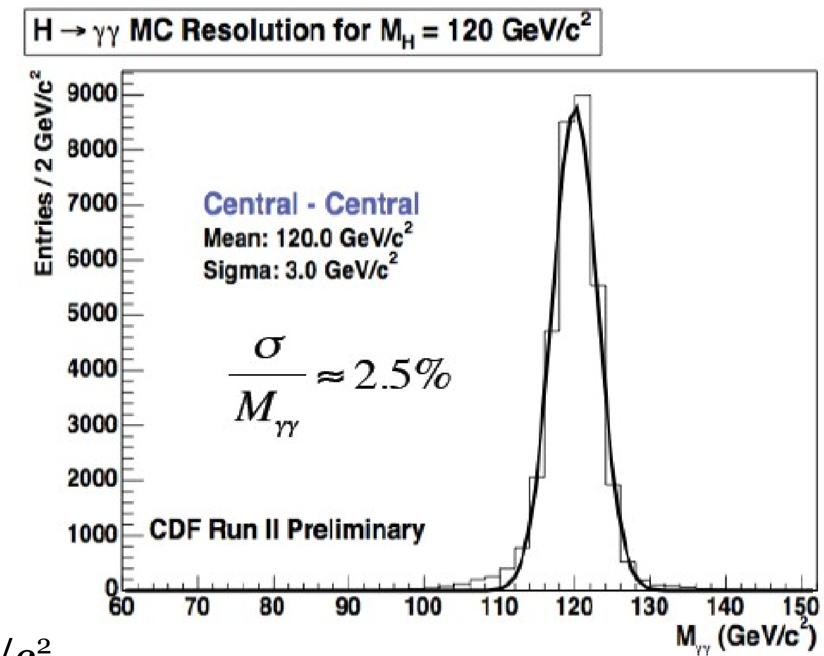
H → γγ

Advantages:

- mass resolution limited only by EM calorimeter resolution ~ 3 GeV

- Different production modes:
  gluon fusion, associated production, VBF

- Sensitivity ~ constant over a wide mass range



Challenge:

- small branching ratio: max 0.2% at m_H=120 GeV/c^2

◆ Primary channel at LHC

◆ Interesting for searches in Fermiophobic Models

H → γγ @CDF

Improve acceptance:

- include forward photons (1.2 < |η| < 2.8)
- include central converted photons

Improve purity:

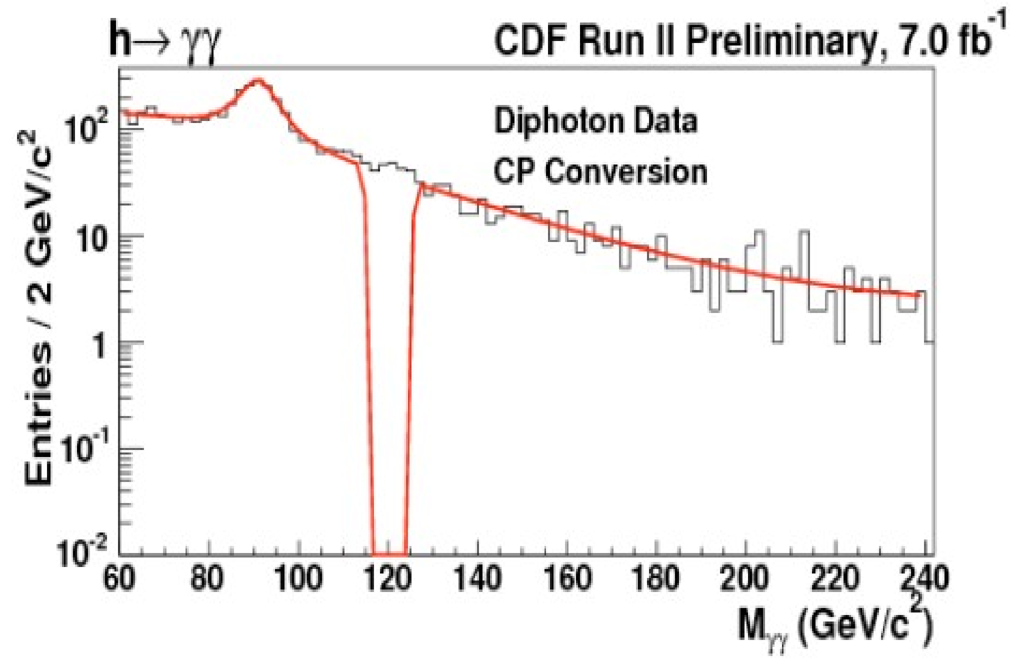
- use NN to reduce jets background
  (reduce by ~15%)

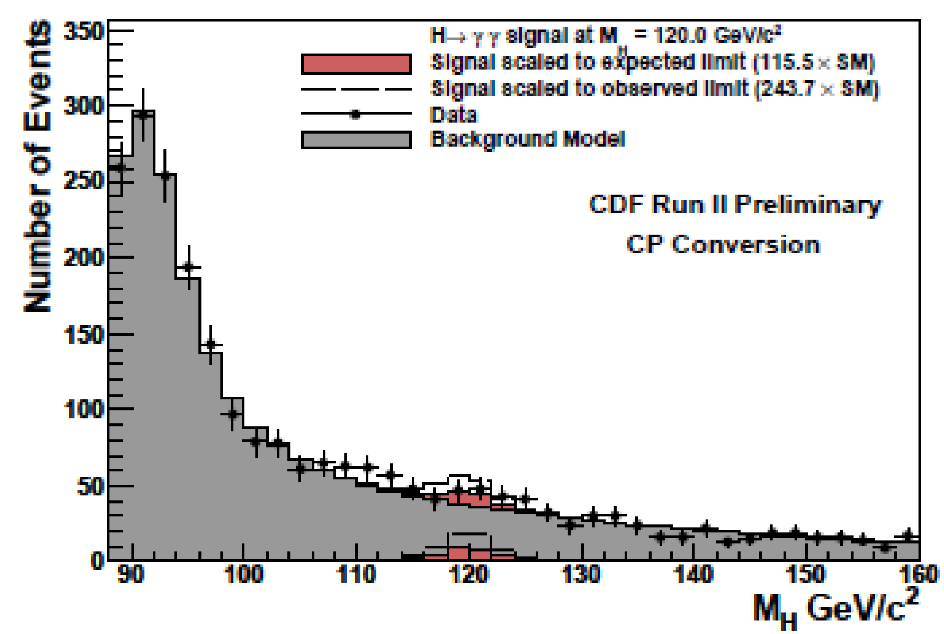
Data split in 4 channel:

- Central - Central
- Central – Forward
- Central – Central conversion
- Central conversion - Forward

Background:

- determined from the polynomial sideband fit
- interpolated into the 12 GeV/c^2 signal region





Background Modelling (D0)

Use NN to identify central photon ($O_{NN} > 0.75$)

Classify events depending on pass/fail NN cut

$$\begin{pmatrix} N_{ff} \\ N_{fp} \\ N_{pf} \\ N_{pp} \end{pmatrix} = E \times \begin{pmatrix} N_{jj} \\ N_{j\gamma} \\ N_{\gamma j} \\ N_{\gamma\gamma} \end{pmatrix}$$

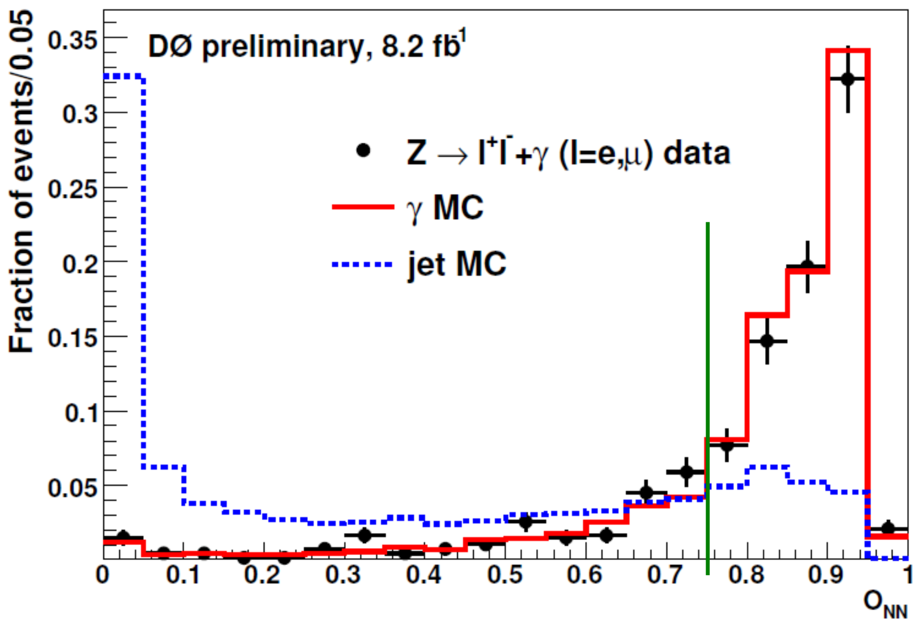
E = 4x4 efficiency matrix

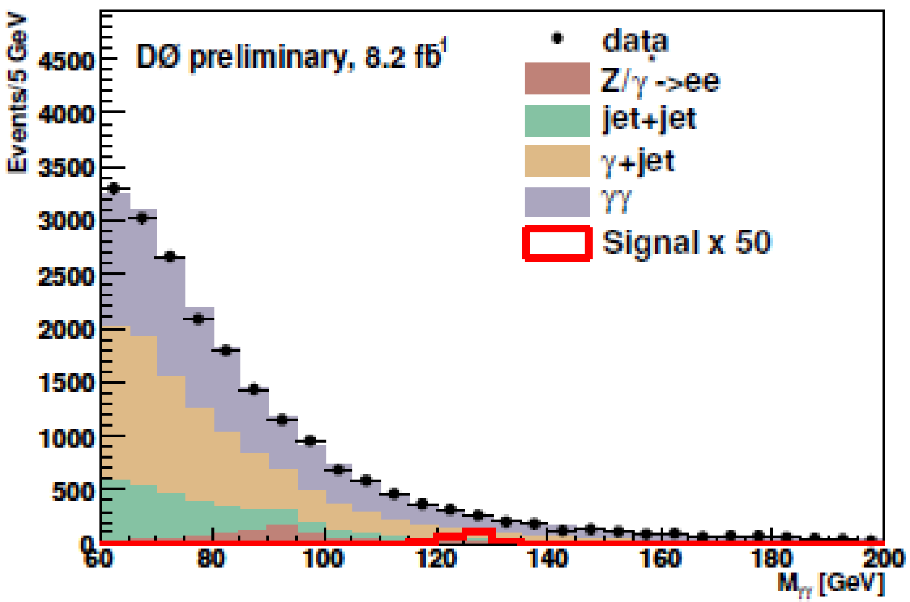
- determined in di-jet and di-photon MC
- efficiencies cross-checked in data

→ predict number of background events

Improve Sensitivity:

- Use Gradient Boosted Decision Tree as discriminant
  $M_{\gamma\gamma}$, photons E_T, $p_T^{\gamma\gamma}$, $\Delta\Phi(\gamma\gamma)$





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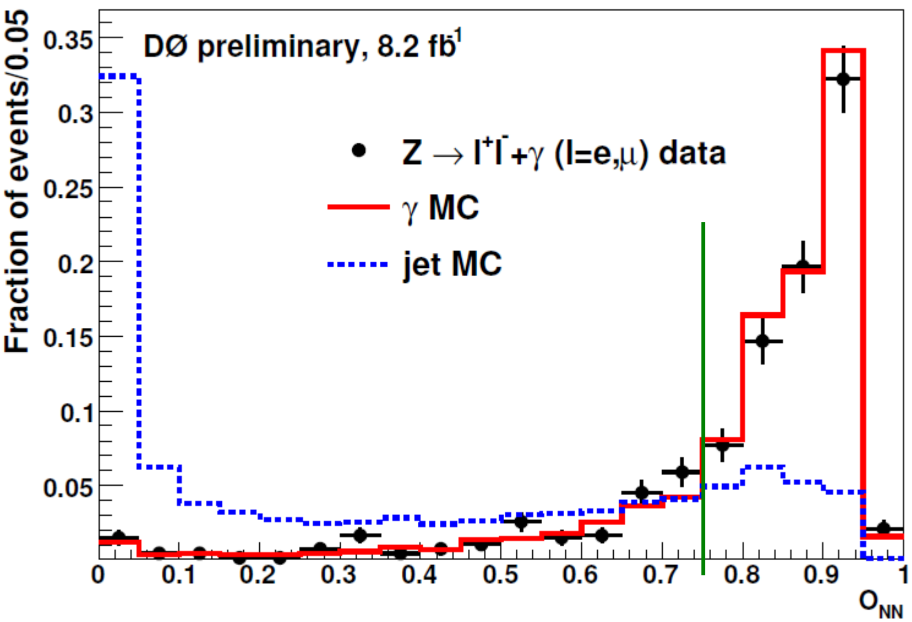
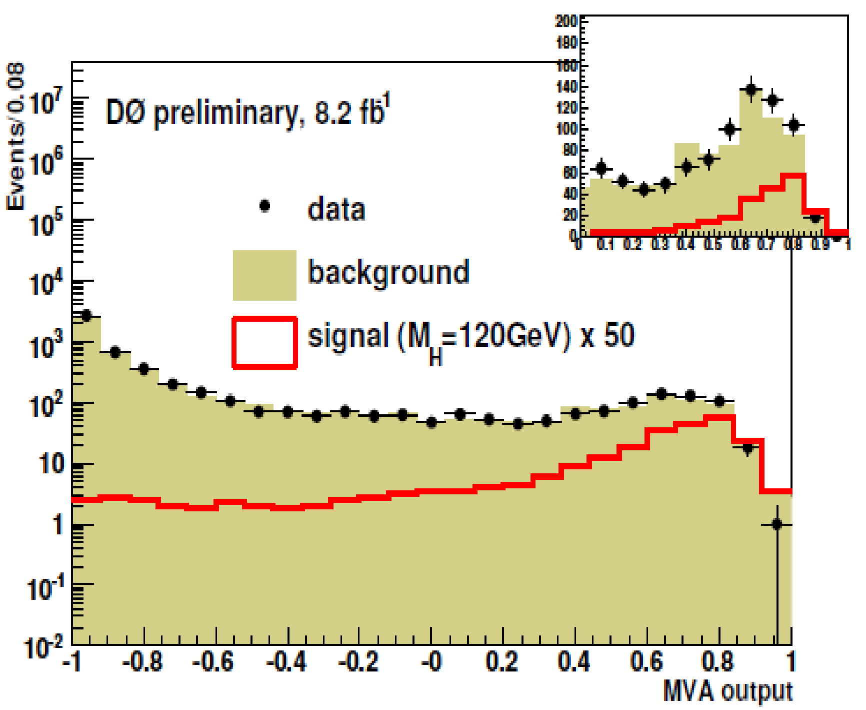
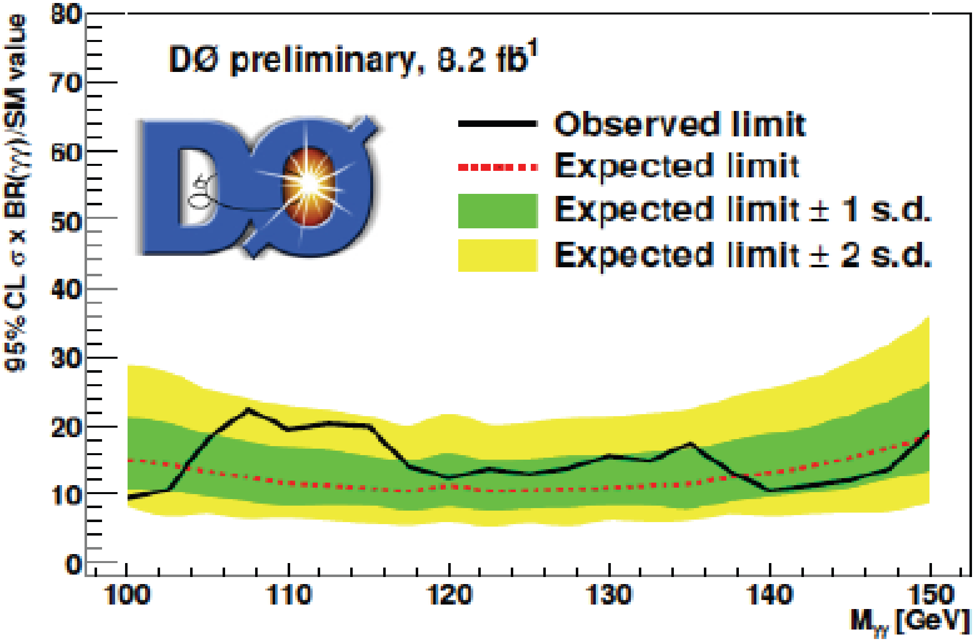
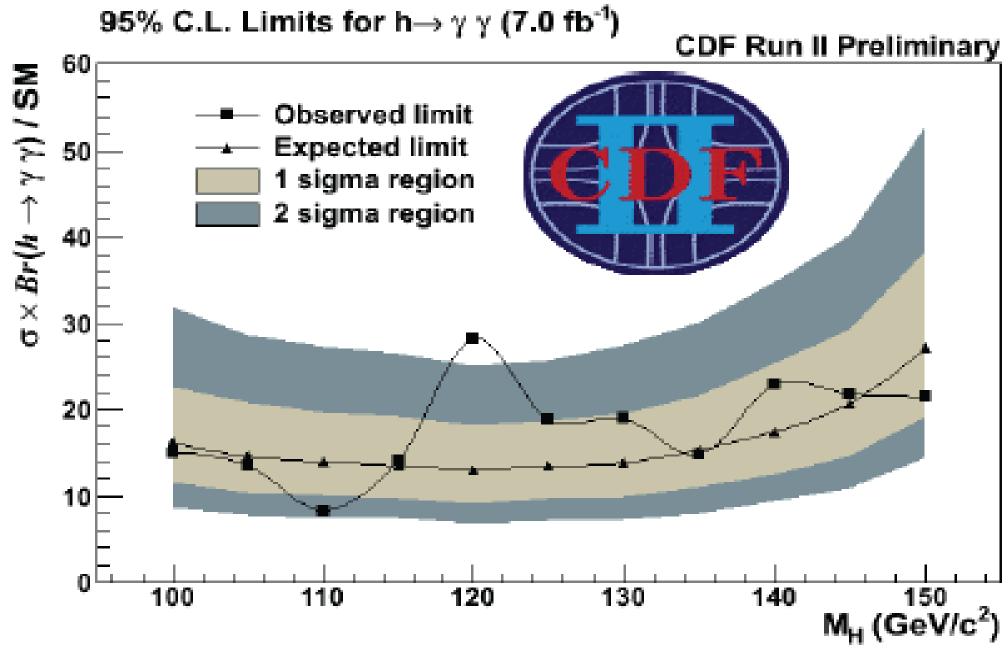




H→γγ: Results





Improvement in sensitivity since 5.4 fb^{-1}: ~ 33%

Limit at @ m_H =120 GeV/c^2

Obs (Exp) = 12.4 (11.3) $\sigma_{S.M.}$

Limit at @ m_H =120 GeV/c^2

Obs (Exp) : 28.2 (13) $\sigma_{S.M.}$

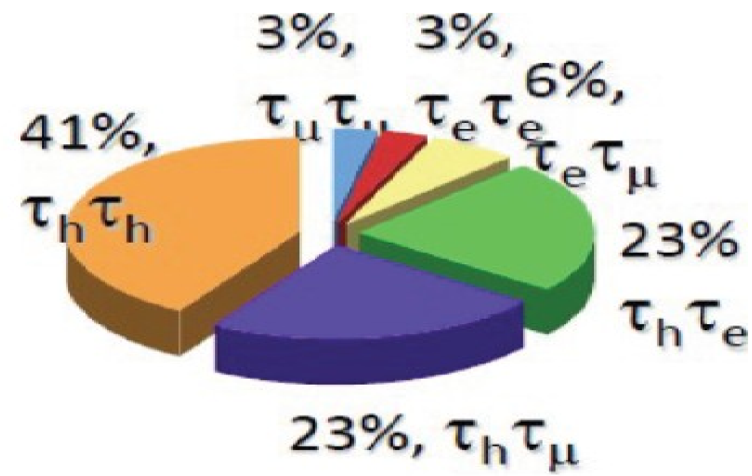
Observed limit is outside 2σ band:
considering trial factor, significance < 2σ

$H \to \tau\tau$ + jets

➢ Br($H \to \tau\tau$) ~ 10%

➢ Different production mechanism:
VH, VBF, gluon fusion

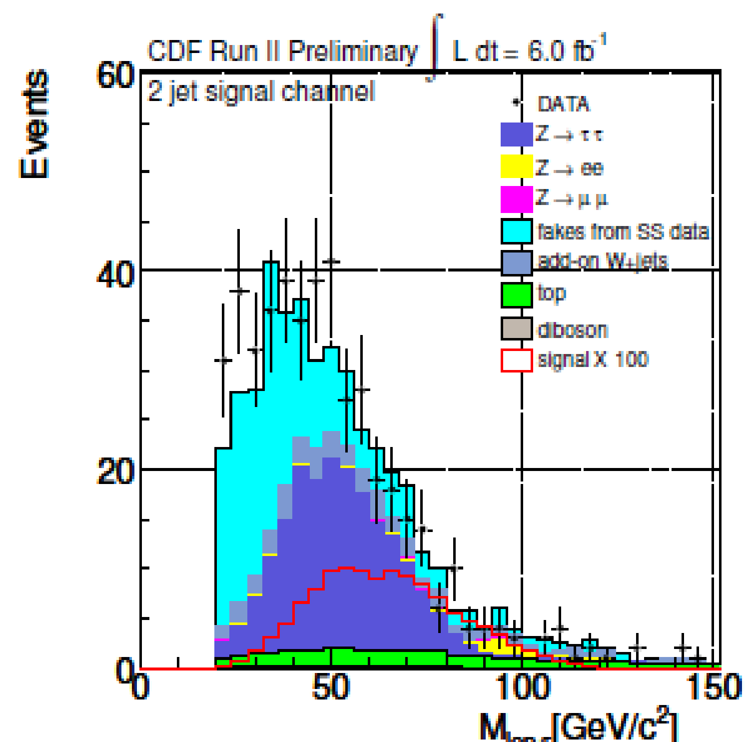
Consider only **hadronic τ + lepton** final state (46%)
Best $S/\sqrt{B}$



Challenges:

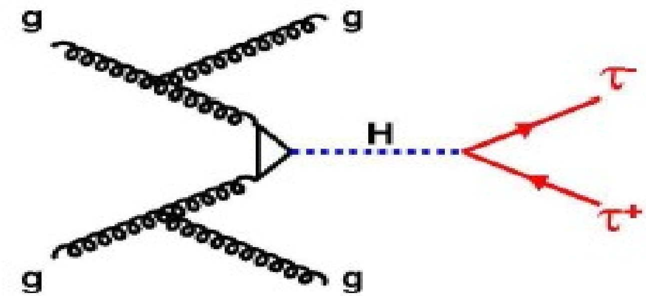
- Hadronic τ identification
- jet → τ fake rate non-negligible, and difficult to model
  Multivariate technique to improve purity of ID algorithm
- Neutrinos involved in τ decays
  measure only visible energy
- Irreducible $Z \to \tau\tau$ background

◆ σ(gg → H) enhanced in MSSM models
increased sensitivity in this channel



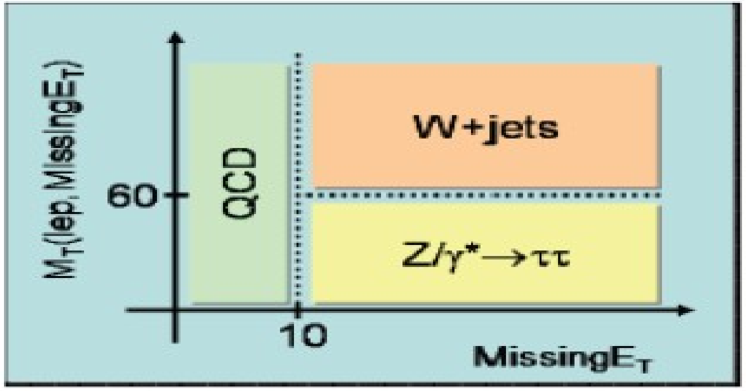
H→ττ + jets @CDF

τ identified by Boosted Decision Tree
 - different discriminant for 1 and 3 prongs τ candidate



Signal region:

- Njet =1   (mostly ggH)
- Njet >=2 (ggH, VH, VBF)

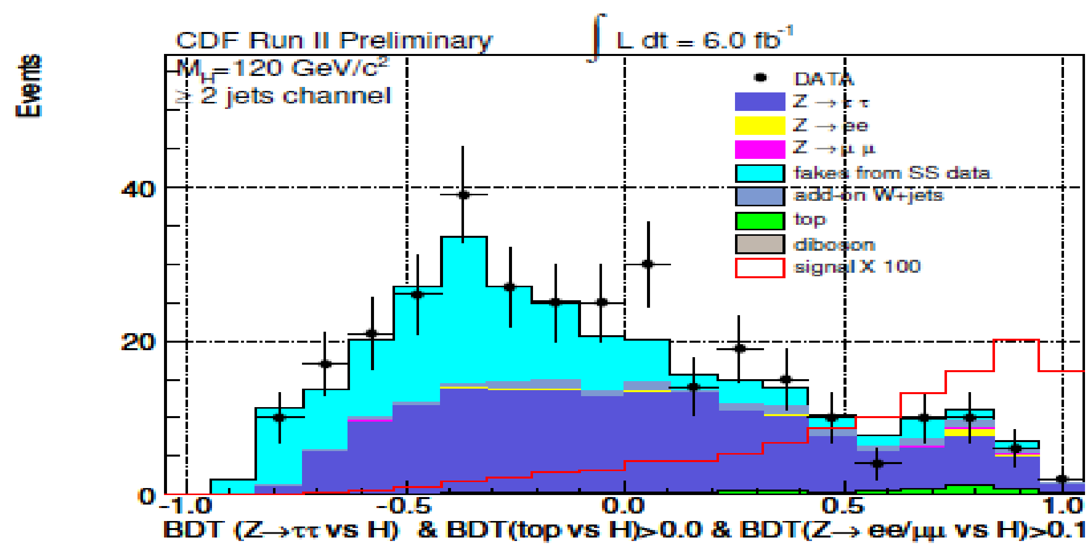


Control region: Njets = 0

- Z/γ* → ττ
- jet → τ fakes
- W+jets

Use BDT to reduce fakes,
W+jets and Z → ee/μμ contributions

Final discriminant trained against Z → ττ



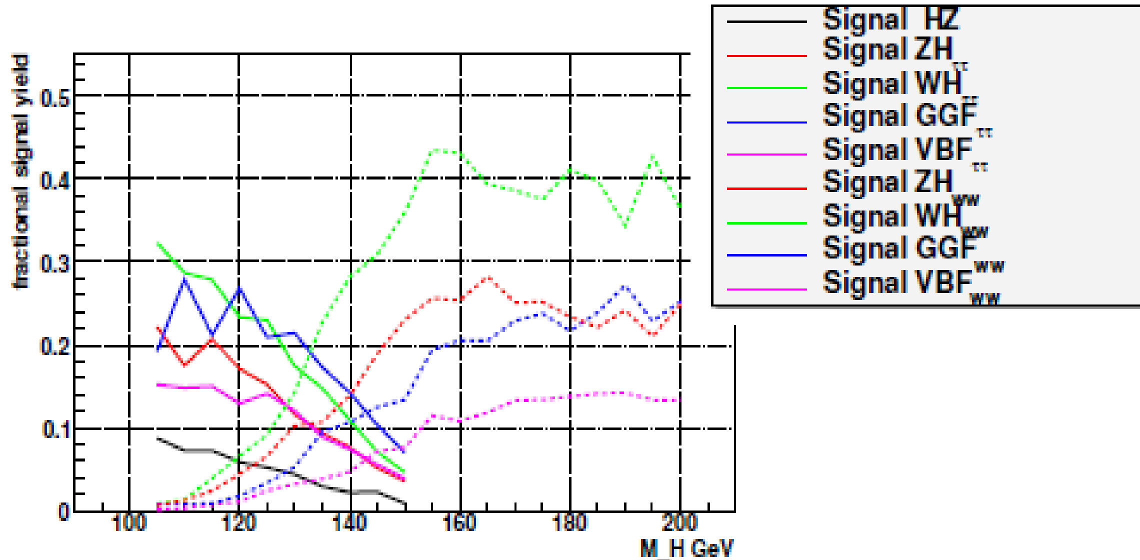
H→ττ + 2 jets @D0

Include H → WW decays at high mass

Signal region: Njet >=2

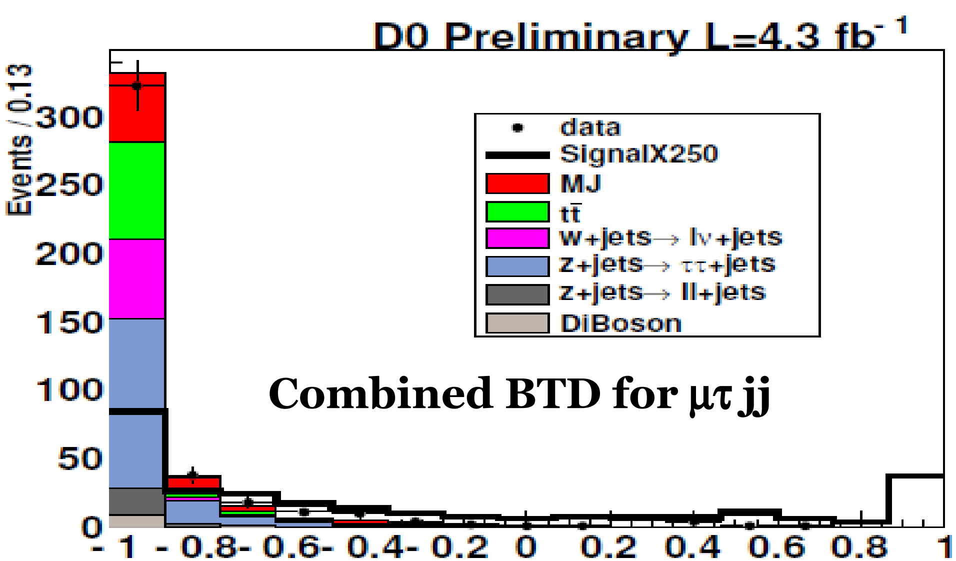
3 channels, for 3 class of τ candidate:

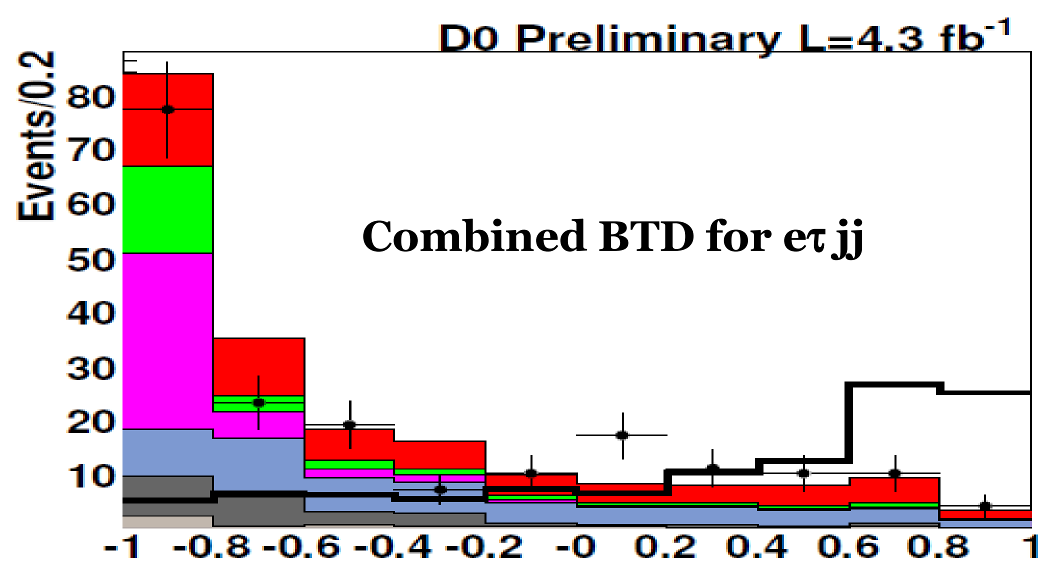
- $\tau \rightarrow \pi^{\pm} \nu$
- $\tau \rightarrow \pi^{\pm} \pi^{0} \nu$
- $\tau \rightarrow \pi^{\pm} \pi^{\pm} \pi^{\pm} (\pi^{0})$



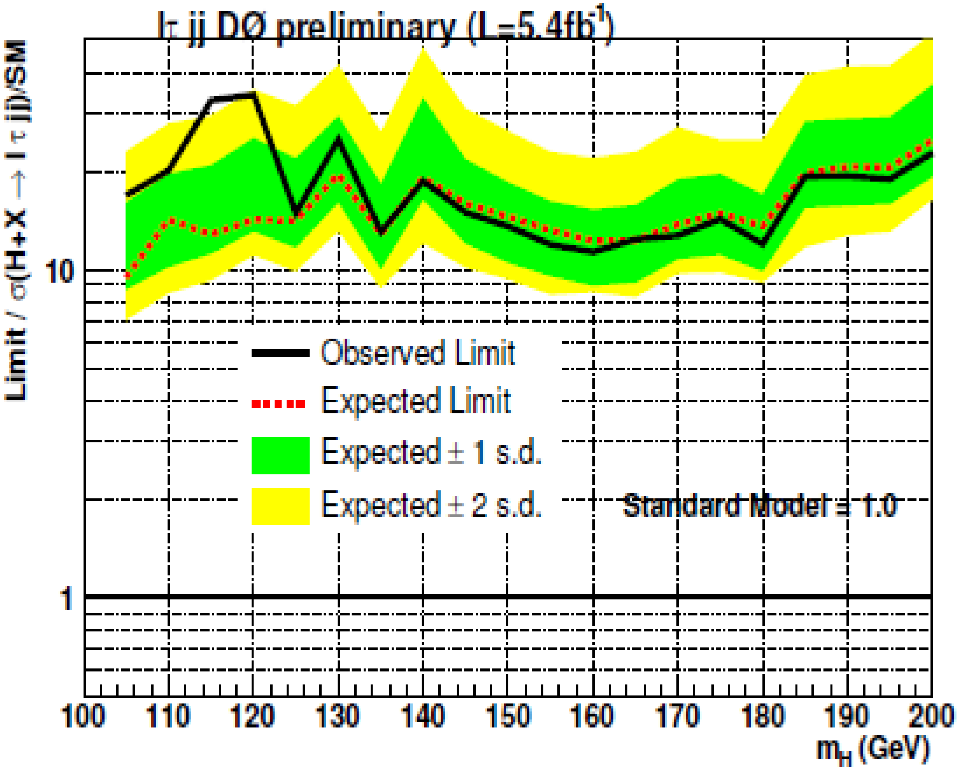
Train BDTs to separate each signal process from each background, in different mass regions

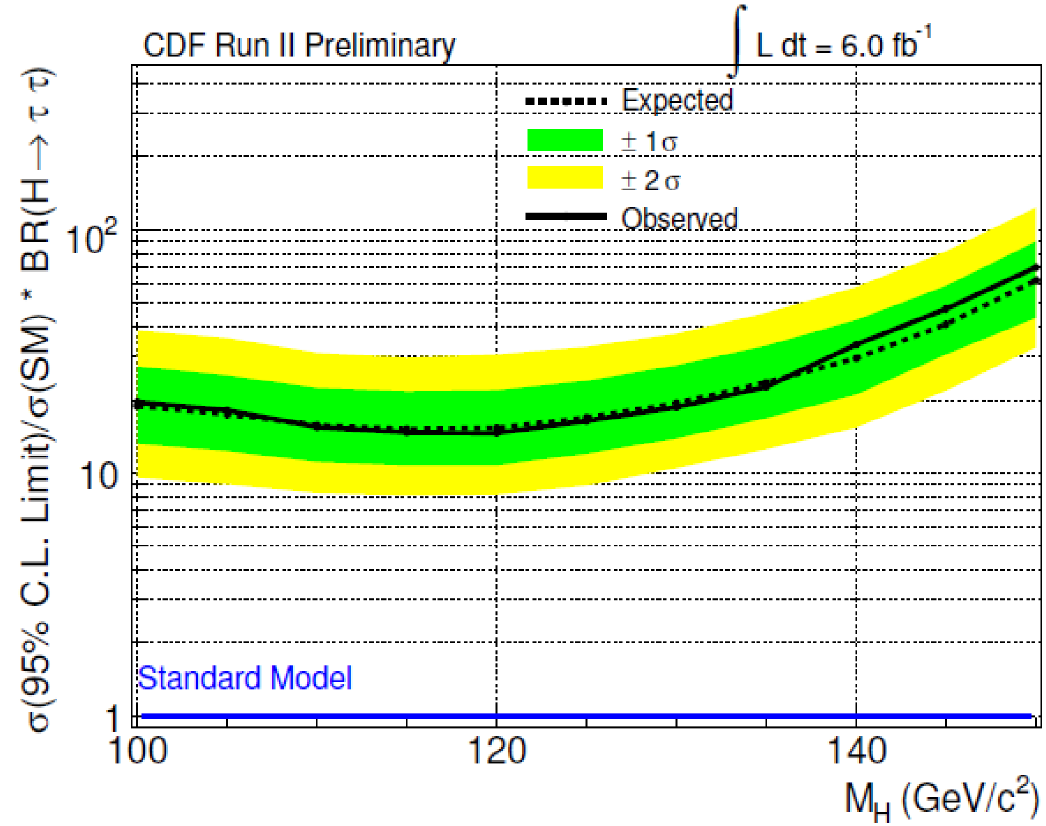
Output of BDTs used as input of final discriminant





$H \to \tau\tau$: results





Limit at @ m_H =115 GeV/c²

Obs (Exp) = 32.8 (12.8) $\sigma_{S.M.}$

Limit at @ m_H =115 GeV/c²

Obs (Exp) = 14.7 (15.2) $\sigma_{S.M.}$

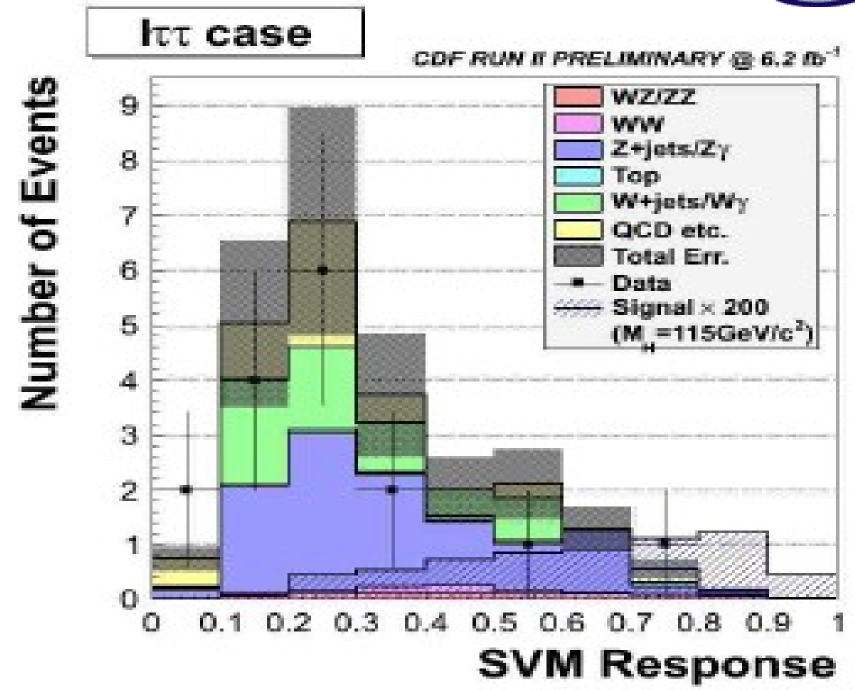
ZH → llττ/WH → lνττ

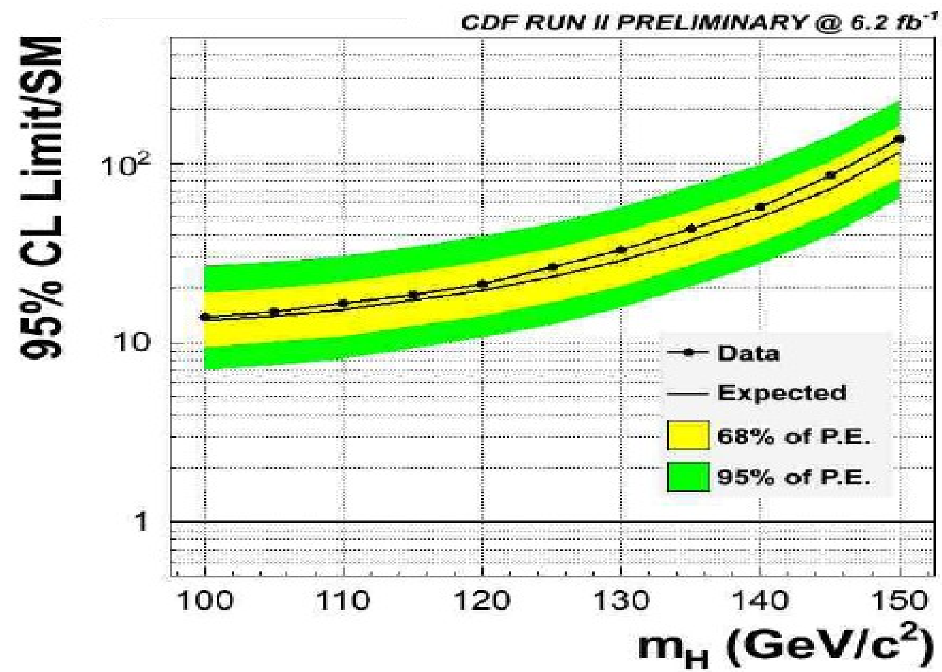
NEW

- Include all tau decay modes
- 5 channels:
  lll, $ll\tau_h$, e $\mu\tau_h$, $l\tau_h\tau_h$
  4 leptons (any type)
- Met Significance cut to reduce
  DY and QCD background contribution
- Discriminant: Support Vector Machine
  - effective in patter recognition in low statistic separable samples
  - classify events in 2 category in hyperspace with dimension equal to # input variables

Limit at @ m_H =115 GeV/c^2

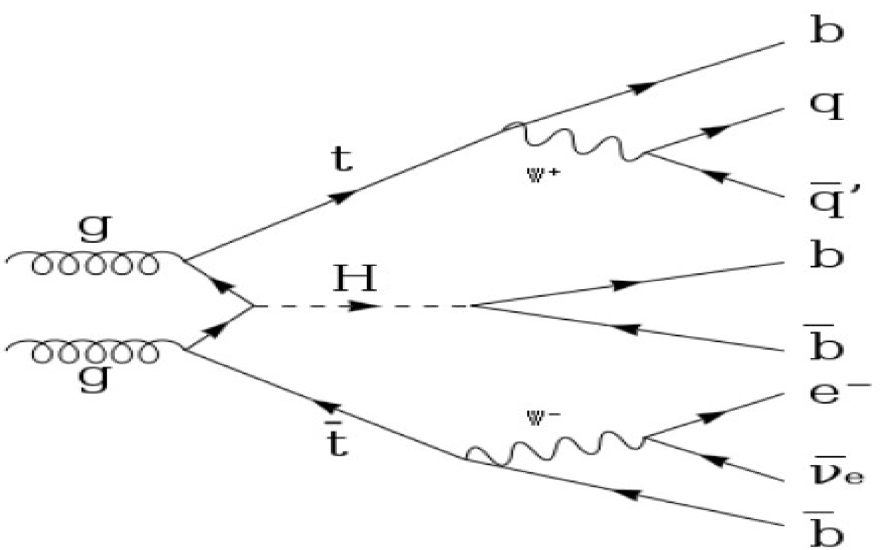
Obs (Exp) = 18.5 (17.3) $\sigma_{S.M.}$





ttH: production mechanism

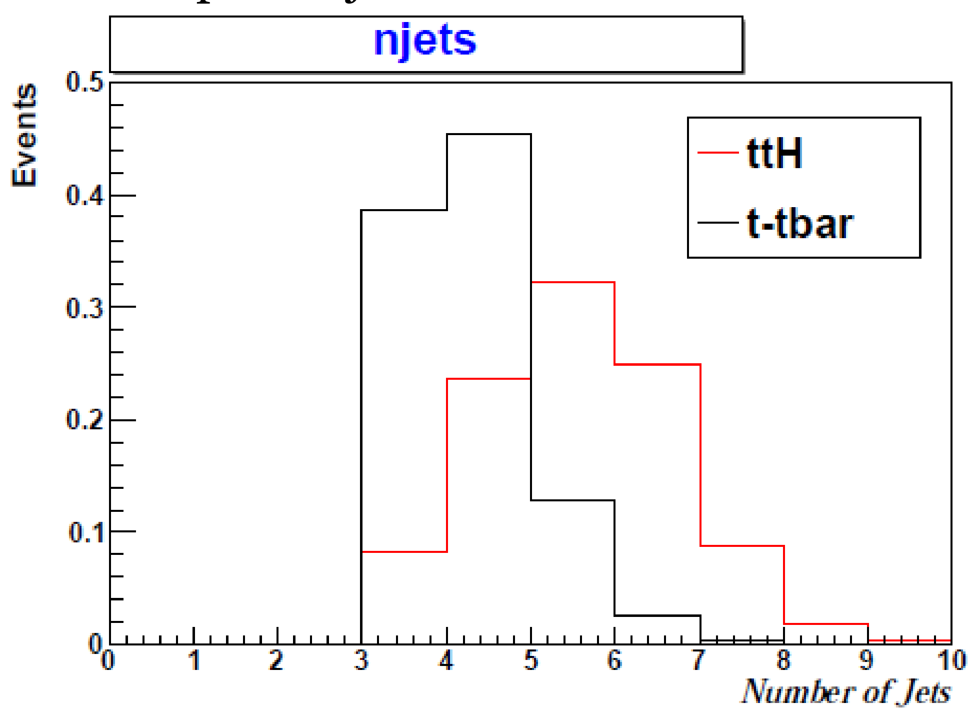
- Associated production of Higgs with ttbar pair
  $\sigma = 4.94$ fb ($m_H = 120$ GeV/c^2)



- Consider all hadronic decays of the Higgs
  $H \rightarrow b\bar{b}$, $H \rightarrow WW$, $H \rightarrow \tau\tau$

- Dominant background:
  top pair production

Lepton + jets selection



Signal characteristic:

- higher jet multiplicity
  Jet: $E_T > 20$ GeV $|\eta| < 2.0$
- ≥ 2 b-quarks in final state

ttH: lepton + jets channel

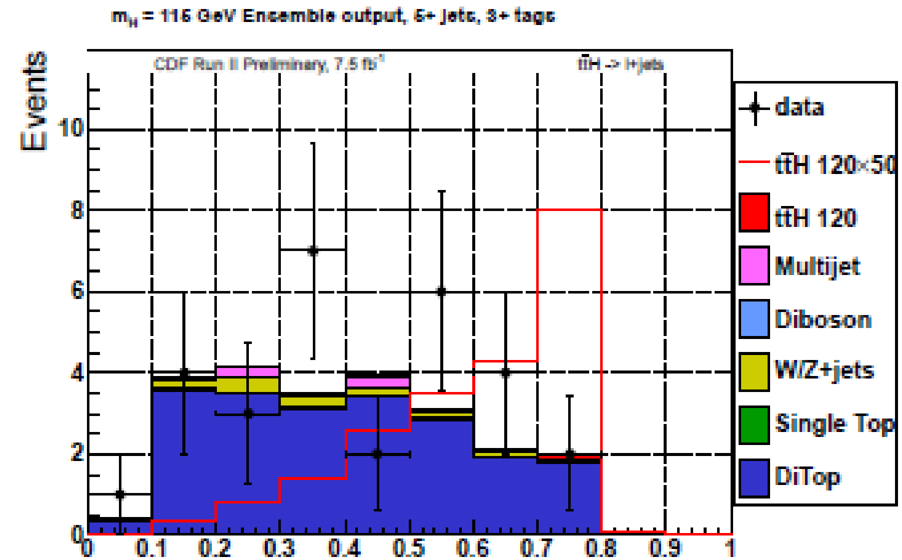
- Select events with high pt electron or muons
  same selection as for lepton + jets Top sample

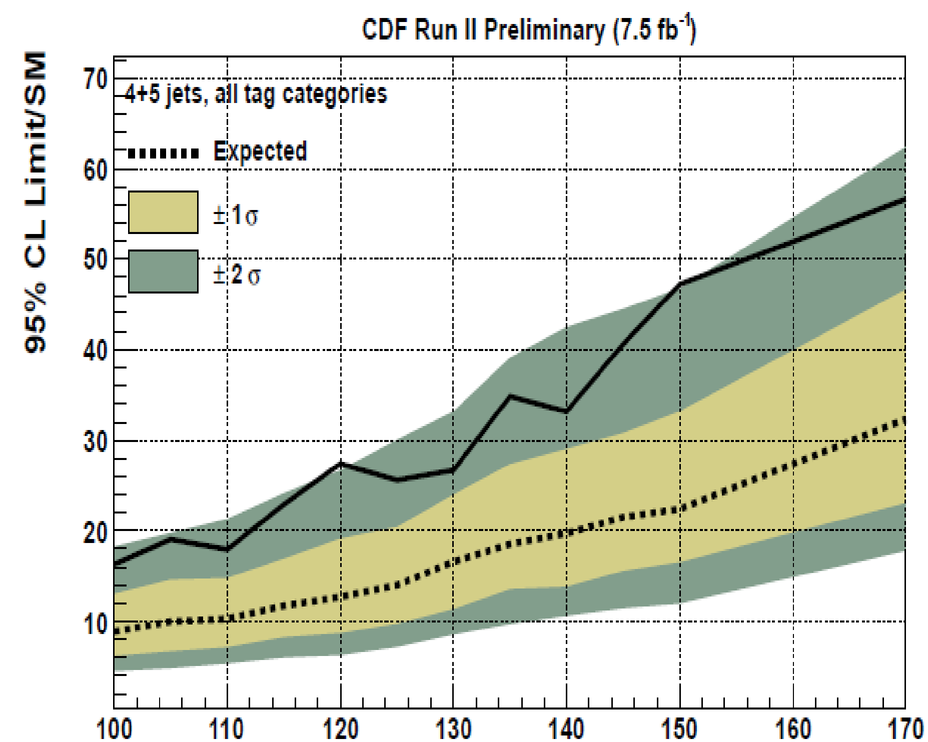
- Events classified by number of jets (4 or ≥ 5)jets
  and number of b-tagged jets (2 or ≥ 3)
  - when H → bb, more b - quarks in final state

- <u>Ensamble method</u>:
  final discriminant is average of S/(S+B)
  over an ensamble of NN output
  - same sensitivity than using a single NN
  - more stable observed limit

Limit at @ m_H =115 GeV/c^2

Obs (Exp) = 22.9 (11.7) $\sigma_{S.M.}$





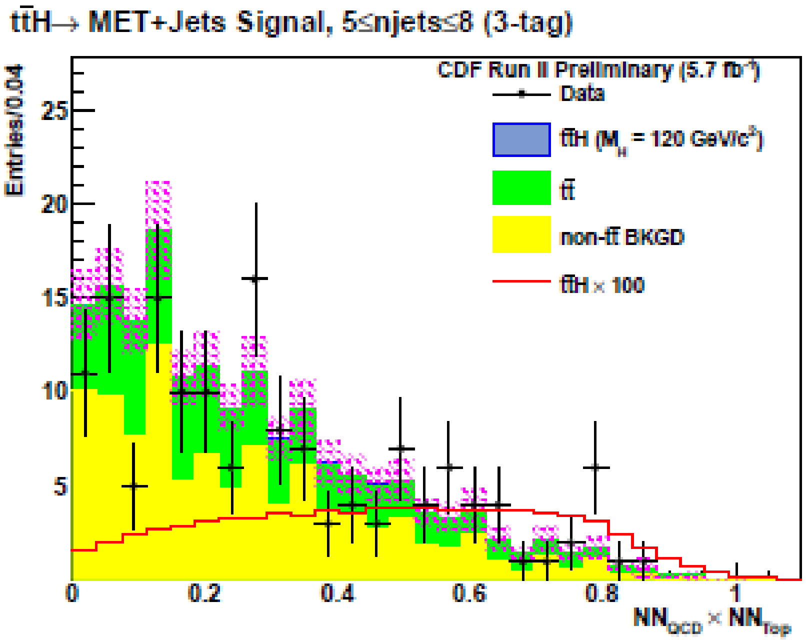
ttH: hadronic channel

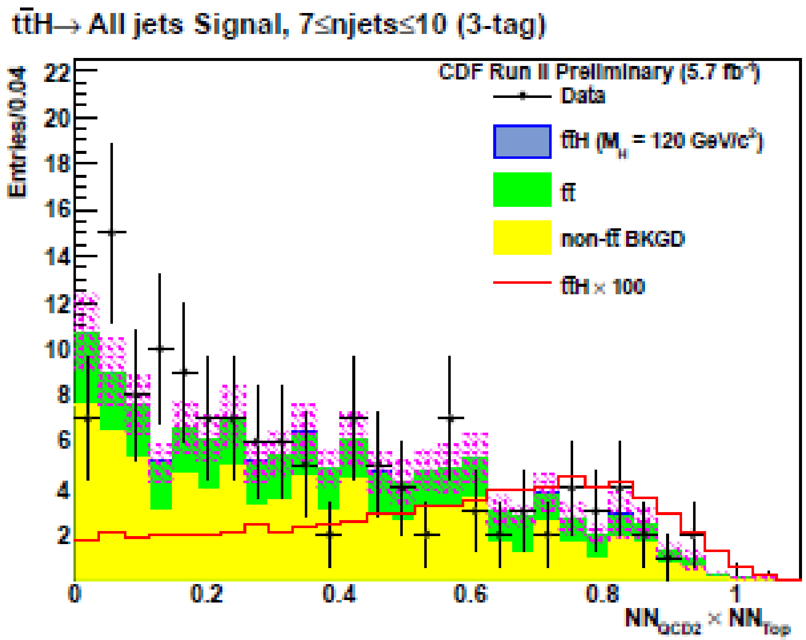
- Two channels:

  Met+ jets: ttH → lvb qq' b bb, lepton not detected

  All jets channel: both W decays hadronically

- Use combination of NN to reduce the overwhelming QCD background





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  All jets channel: both W decays hadronically

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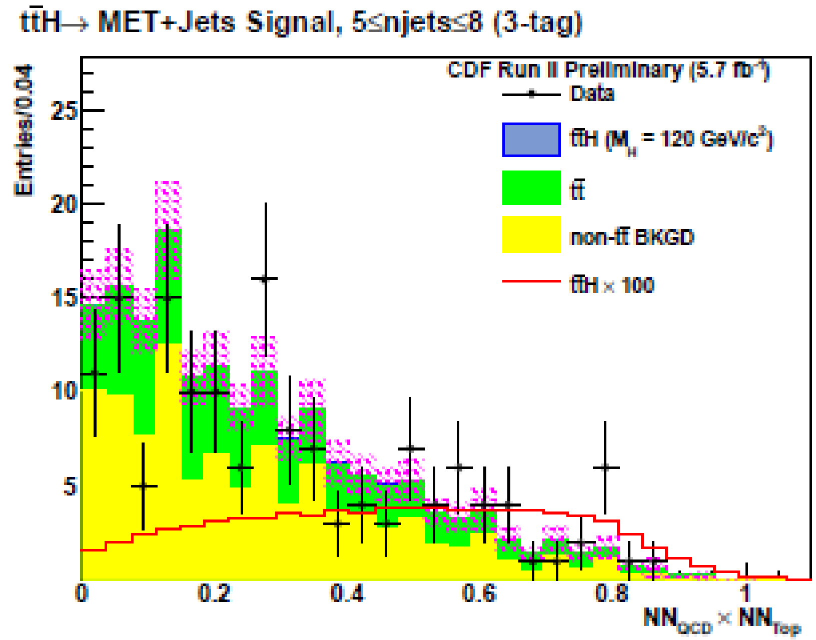
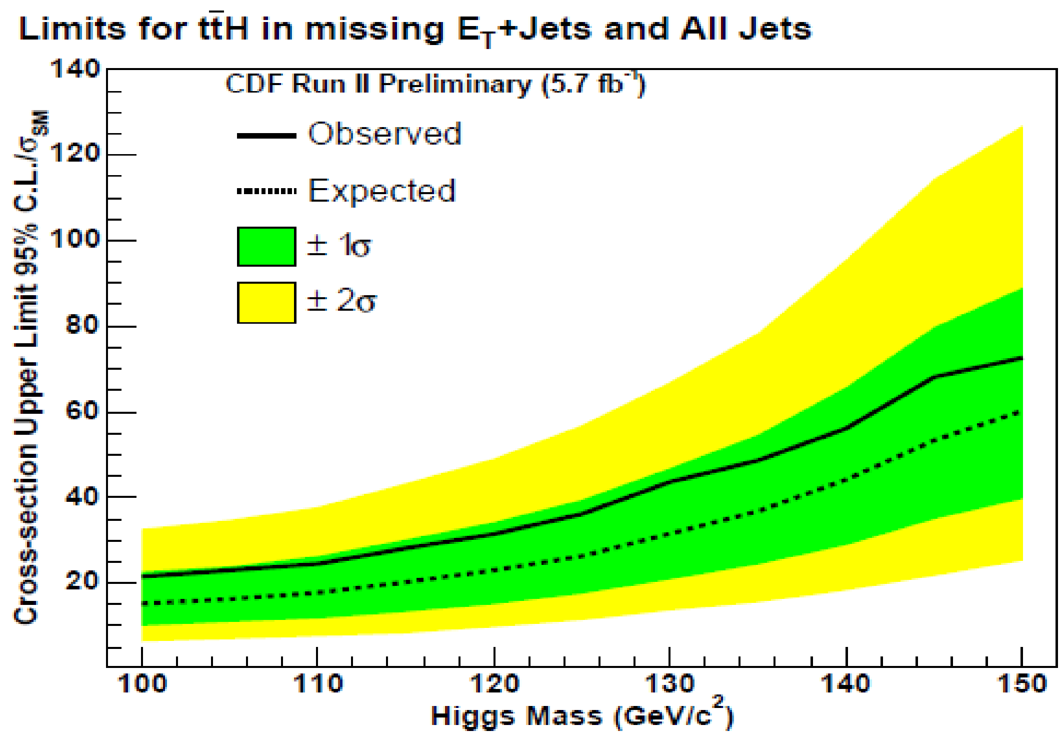
Limit at @ m_H =115 GeV/c^2

Obs (Exp) = 20.2 (28.1) $\sigma_{S.M.}$





Summary

Presented the newest Higgs searches in challenging channels at the Tevatron

- one channel never included before ($ZH \rightarrow ll\tau\tau / WH \rightarrow l\nu\tau\tau$)
- many new analysis at CDF
- lot of effort in both CDF and D0 to improve challenging channels

Their contribution is important

- contribution to the final limit comparable to one of the main analyses at m_H =115 GeV/c^2
- even more relevant at higher masses (m_H =130 GeV/c^2)
- if Higgs exists, necessary to measure branching fractions
- challenging analyses: development of sophisticated techniques, could be useful at LHC

Not all the available data analyzed yet

Stay tuned for more results!

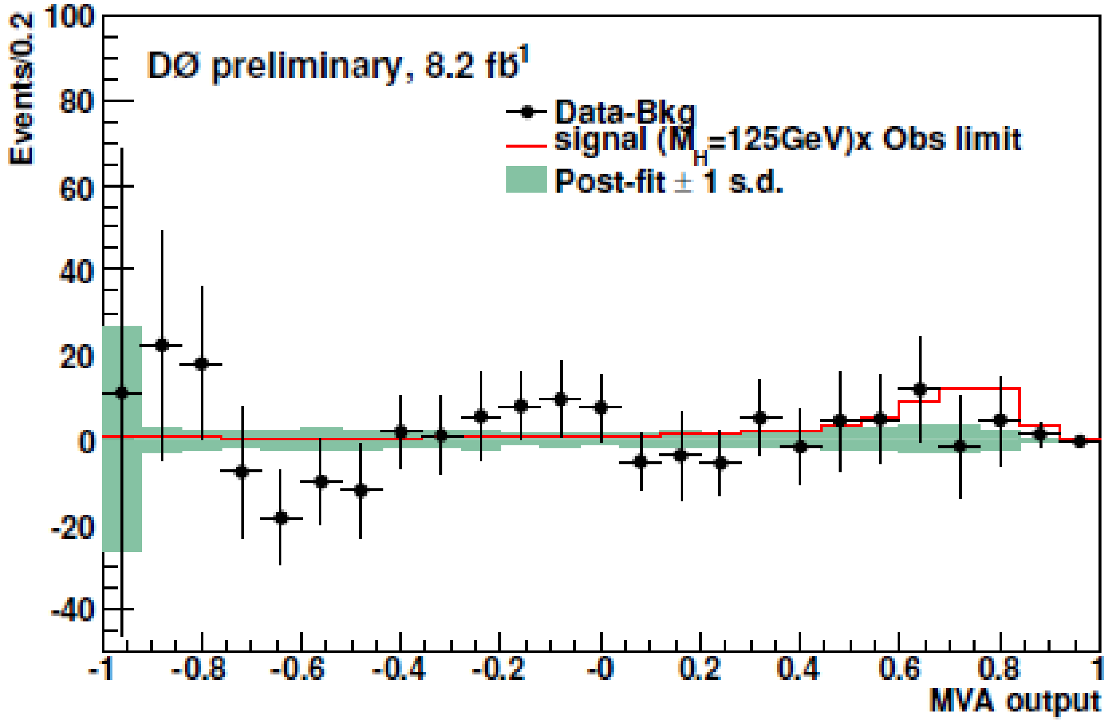
Back Up

$H \rightarrow \gamma\gamma$ @ $m_H = 125$ GeV/c^2

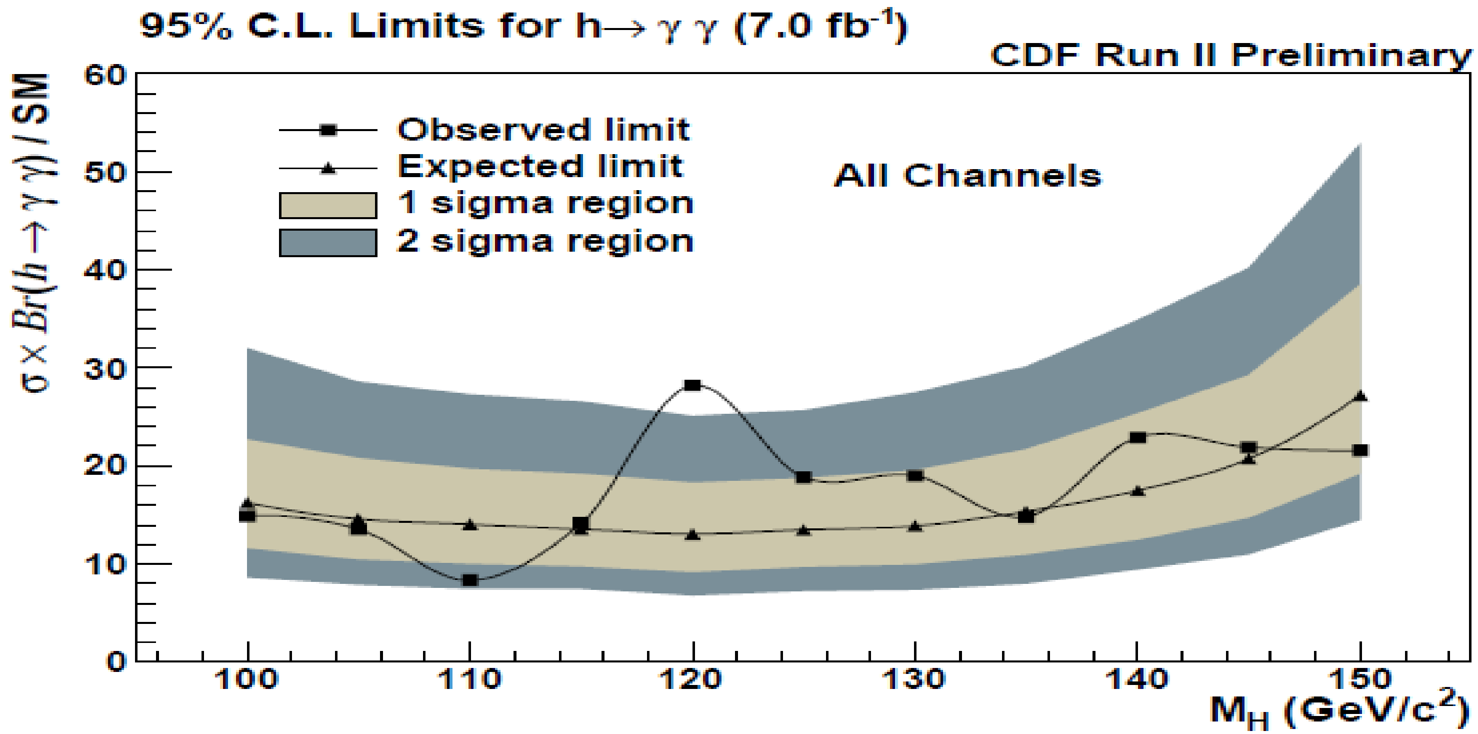
Post-fit background subtracted data distribution

Green area: post-fit 1σ under background only hypothesis

Red histogram: signal scaled by observed limit



$H \rightarrow \gamma\gamma$ @ m_H = 120 GeV/c^2



95% C.L. Limits at test mass m_H = 120

CDF Run II Preliminary $\int \mathcal{L} = 7.0$ fb^{-1}

Channel Alone	95% C.L. Limit/σ(SM)$\times B(h \rightarrow \gamma\gamma)$					
	-2σ	-1σ	Median Exp	+1σ	+2σ	Observed
CC	8.4	11.6	16.2	23.14	32.0	32.0
CP	18.4	24.7	35.3	50.3	67.8	50.4
CC Conv	17.2	23.8	32.9	46.8	66.7	35.5
CP Conv	60.5	81.9	115.5	166.0	229.5	243.7

$H \to \gamma\gamma$ @ $m_H = 120$ GeV/c^2