Higgs results from the Tevatron

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for the CDF and DØ Collaborations

PLHC 2011

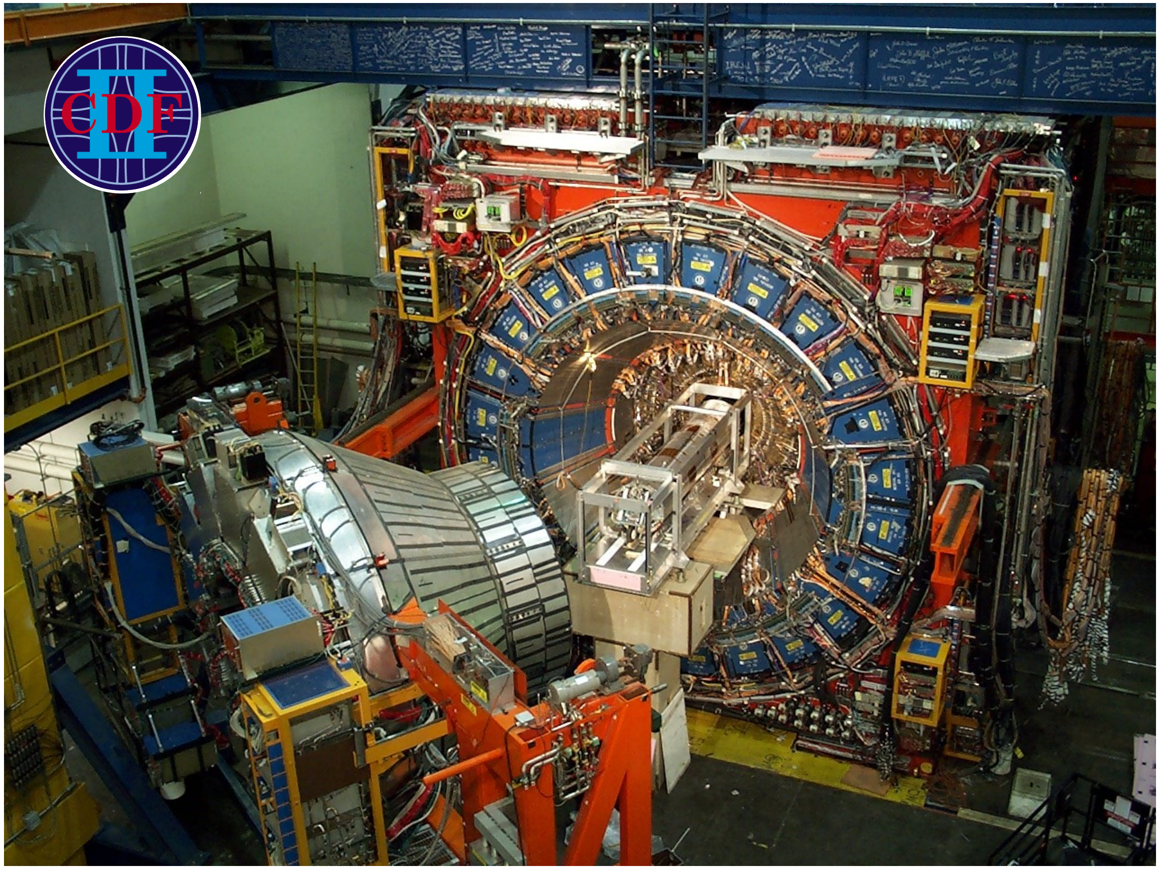
Perugia, Italy, June 6-11, 2011

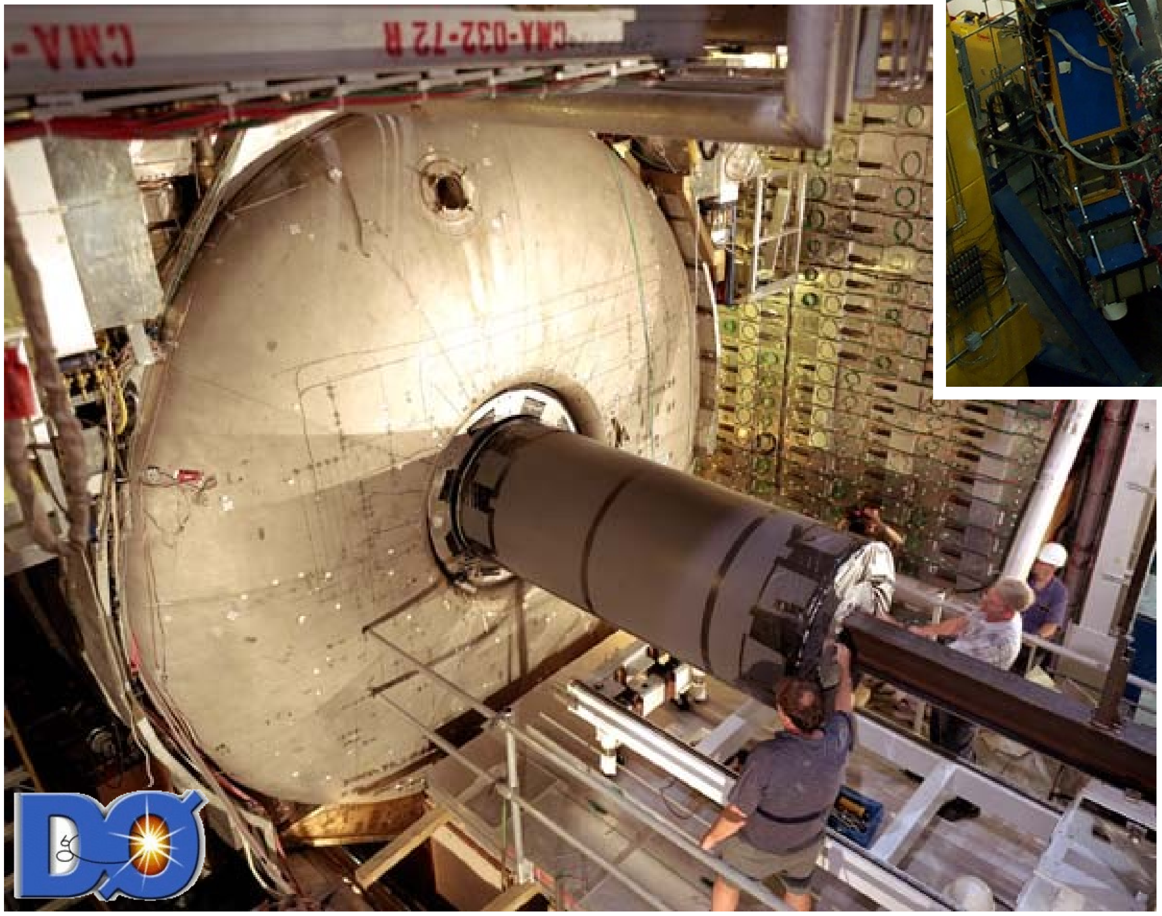
Talk outline

❶ The experimental apparatuses:
- the Tevatron accelerator,
- the CDF and DØ detectors;

❷ current experimental information on the Standard Model Higgs;

❸ SM Higgs production and decays;





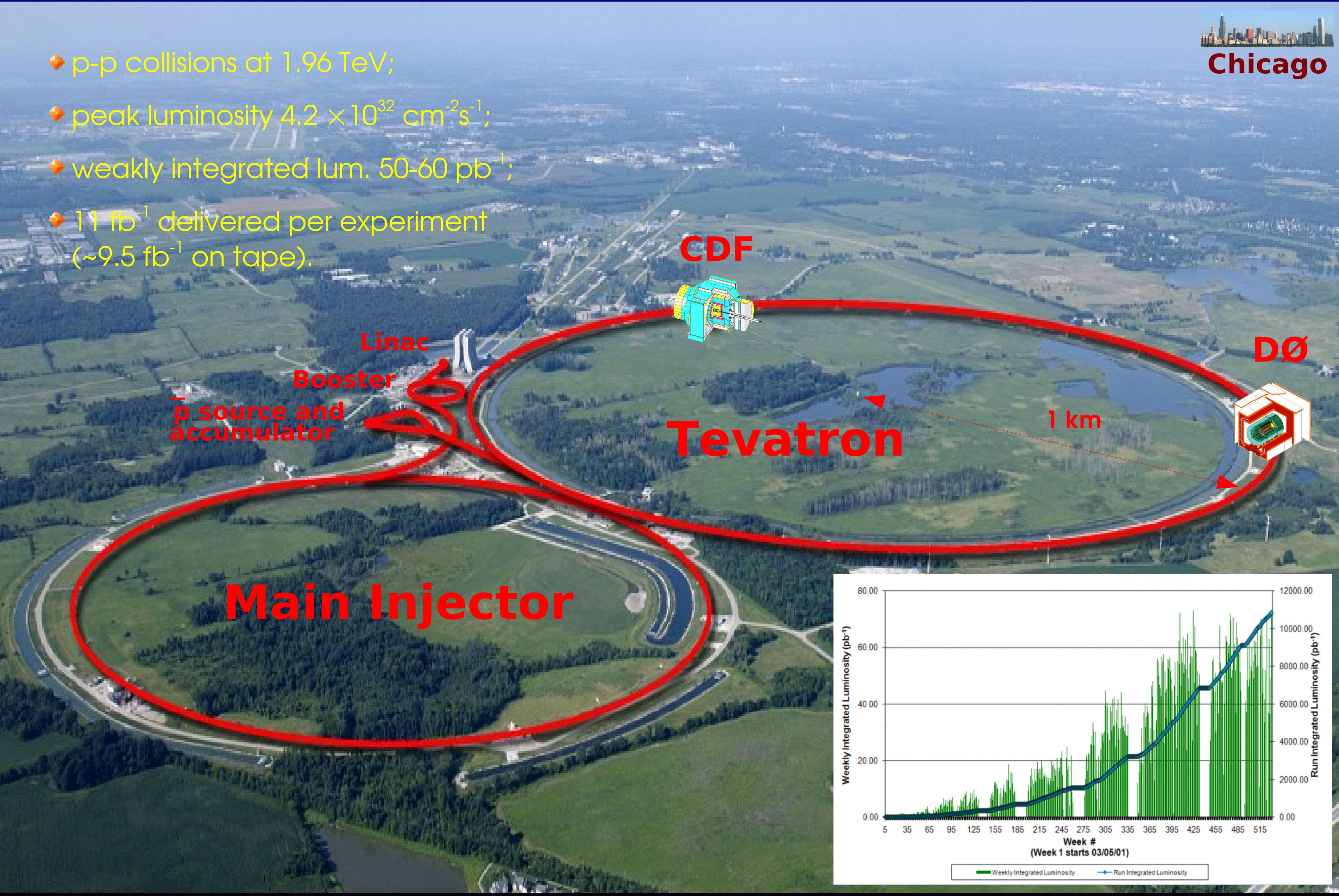
❹ overview of CDF and DØ searches with focus on most recent results (as of Spring 2011);

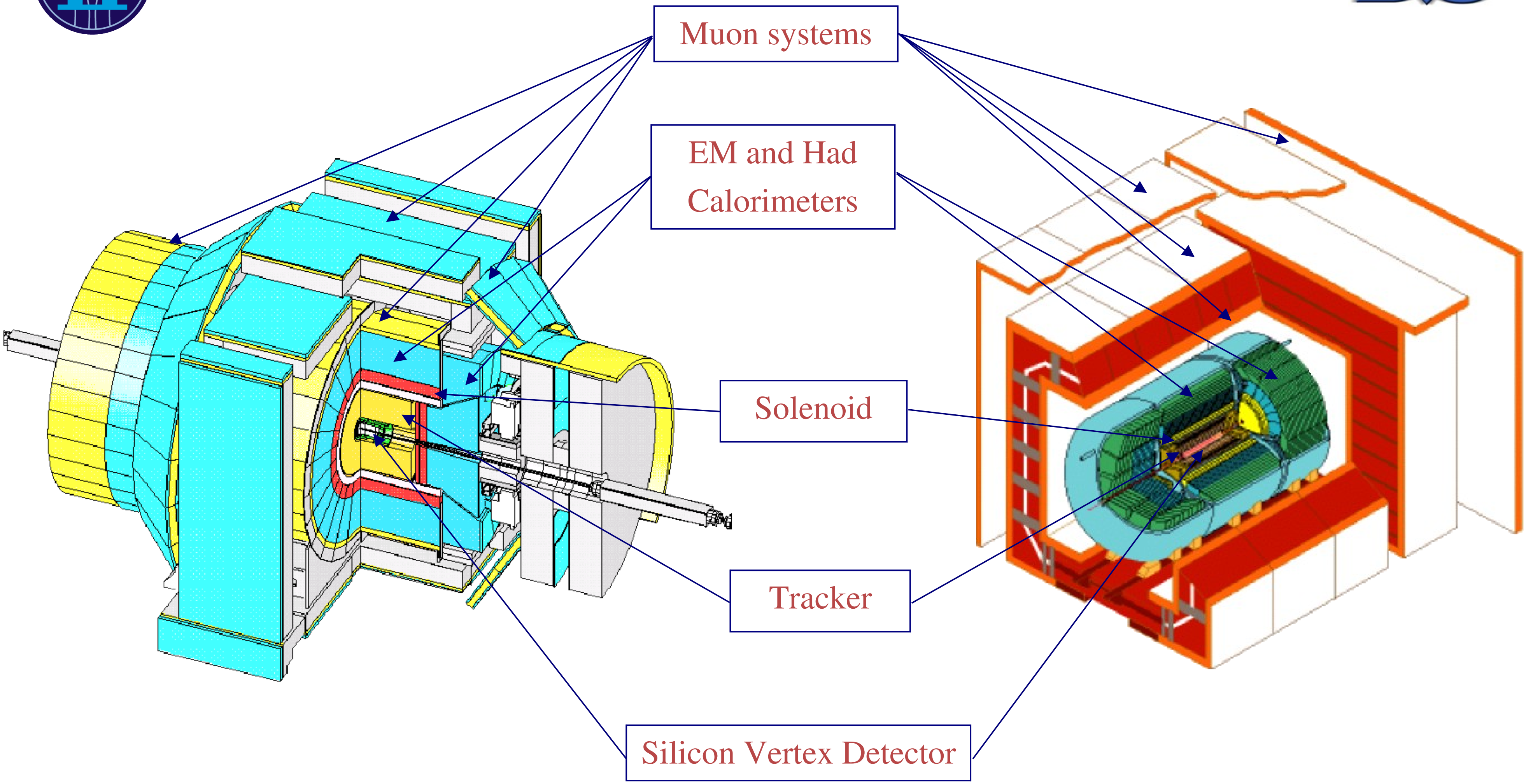
❺ perspectives for the final dataset of the Tevatron Run II;

❻ conclusion and plan.

The Tevatron accelerator

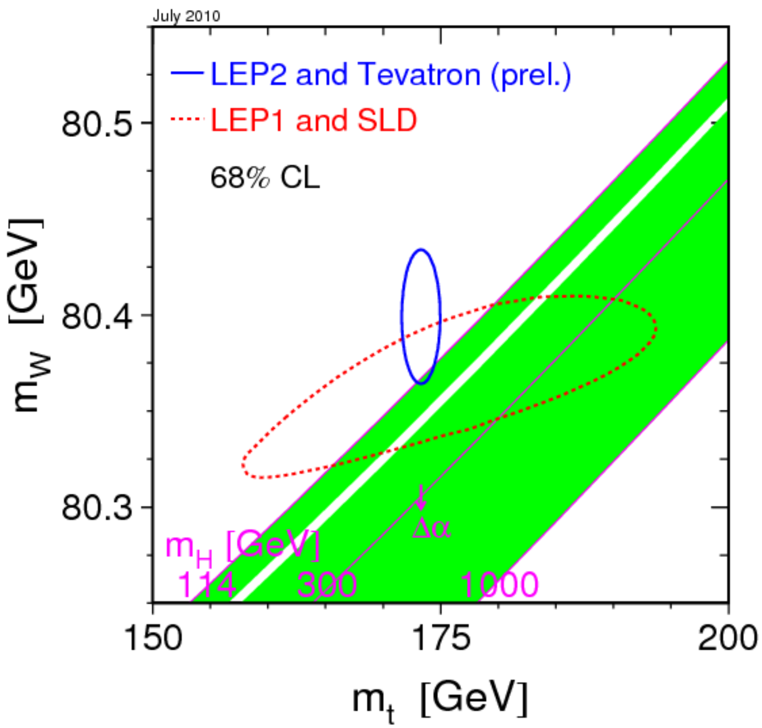
- p-$\bar{p}$ collisions at 1.96 TeV;
- peak luminosity 4.2×10^{32} cm^{-2}s^{-1};
- weakly integrated lum. 50-60 pb^{-1};
- 11 fb^{-1} delivered per experiment (~9.5 fb^{-1} on tape).

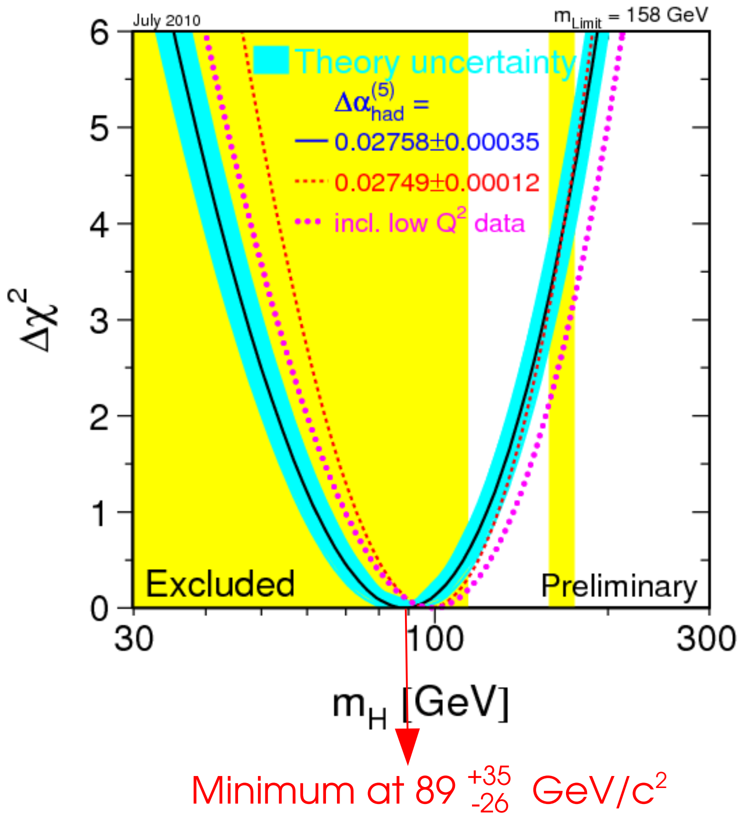



Muon systems
EM and Had
Calorimeters
Solenoid
Tracker
Silicon Vertex Detector

Experimental information on the SM Higgs

- Direct searches for a Standard Model Higgs boson:
  - LEP result: $M_H > 114.4$ GeV/c^2 at 95% C.L.;
  - Tevatron Summer '10 combination excludes at 95% C.L. the mass range: $158 < M_H < 175$ GeV/c^2.
- Indirect SM constraints and global EWK fits seem to prefer a light Higgs boson: $M_H < 158$ GeV/c^2 at 95% C.L.

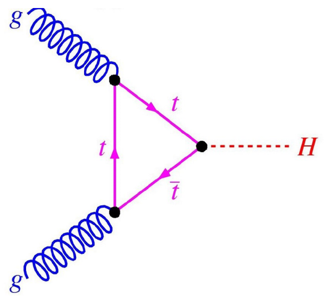




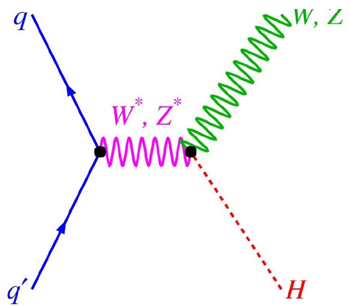
http://lepewwg.web.cern.ch/LEPEWWG

SM Higgs Production at the Tevatron

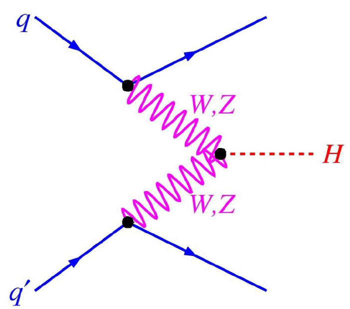
- Dominant Standard Model Higgs boson production channels at 1.96 TeV:
  - gluon-gluon fusion (gg→H):

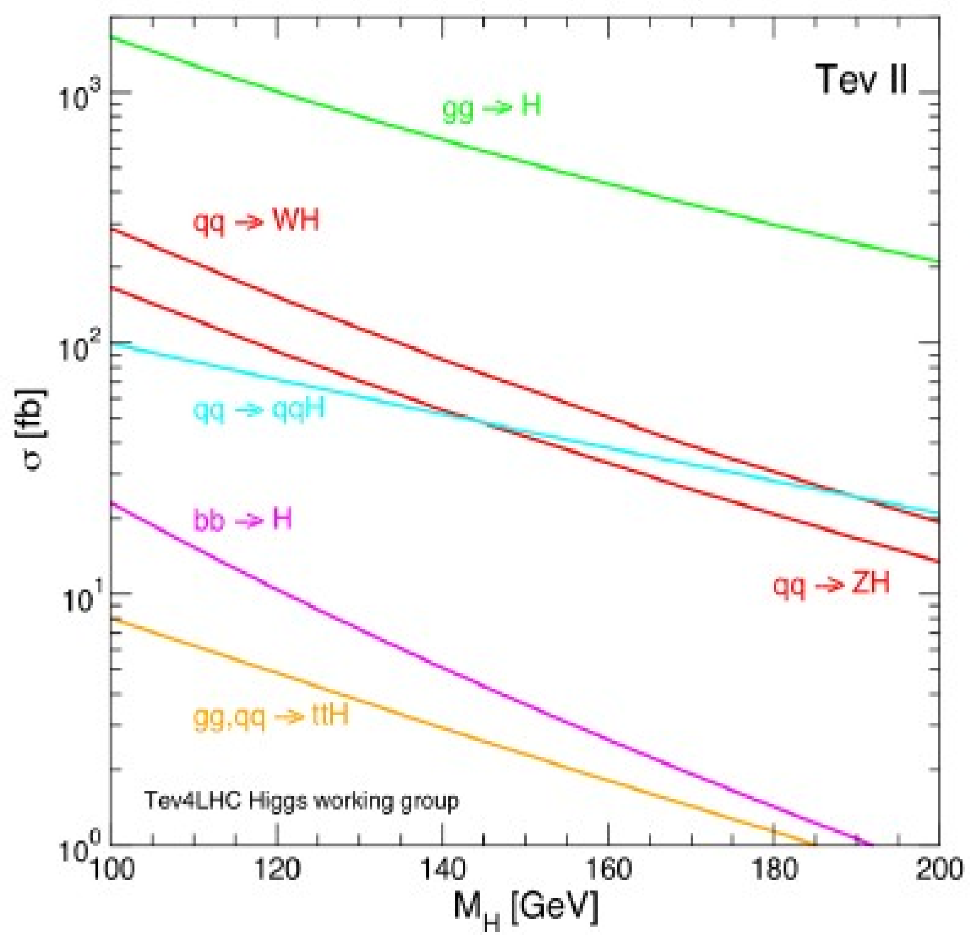


  - associated production (WH and ZH):



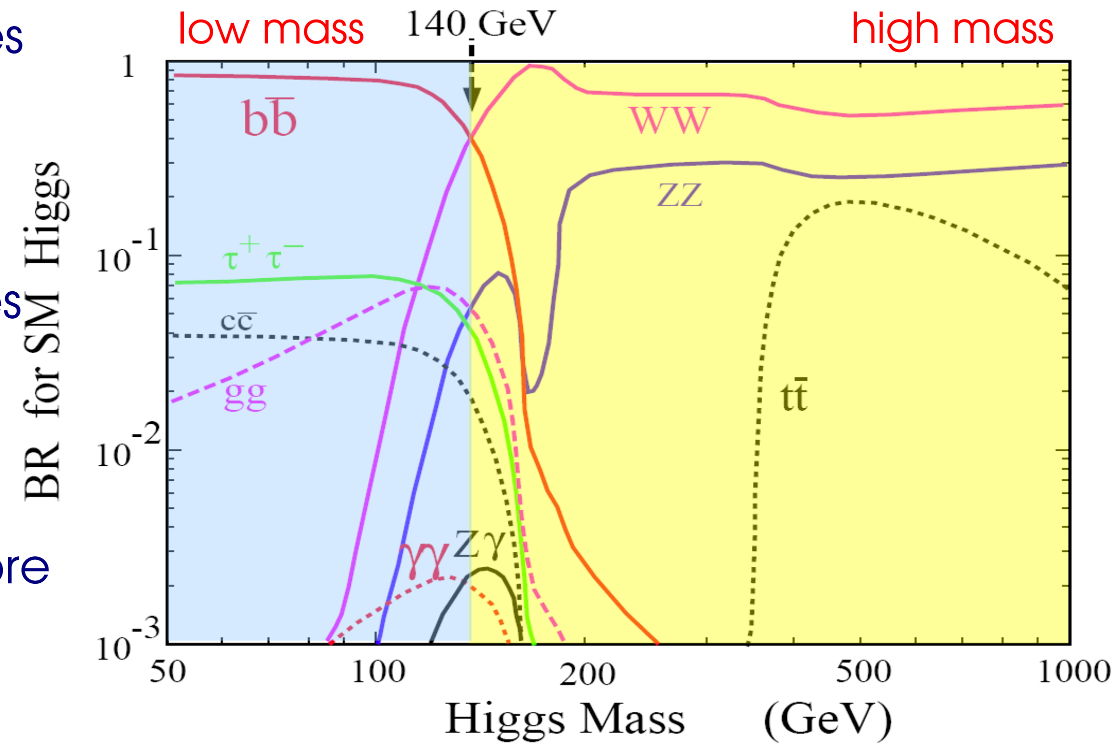
  - vector boson fusion (VBF):

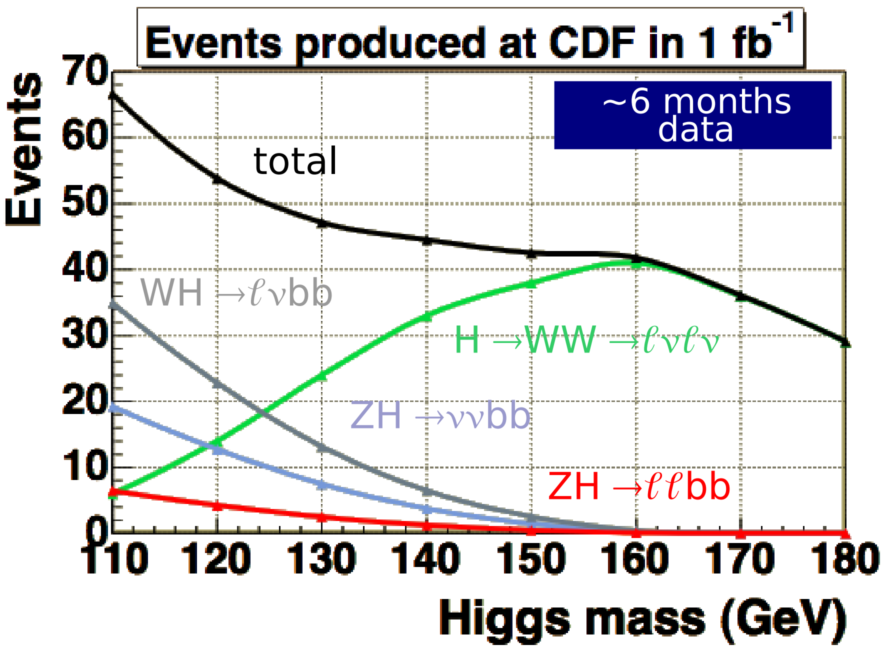




SM Higgs Decays

- The Higgs boson dominant decay modes are driving the search strategies:
  - low mass region: overwhelming multijet bkg, gg→H not viable; associated production provides cleaner experimental signatures;
  - high mass region: leptonic W decays provide clean final states, can take advantage of the more abundant direct production.





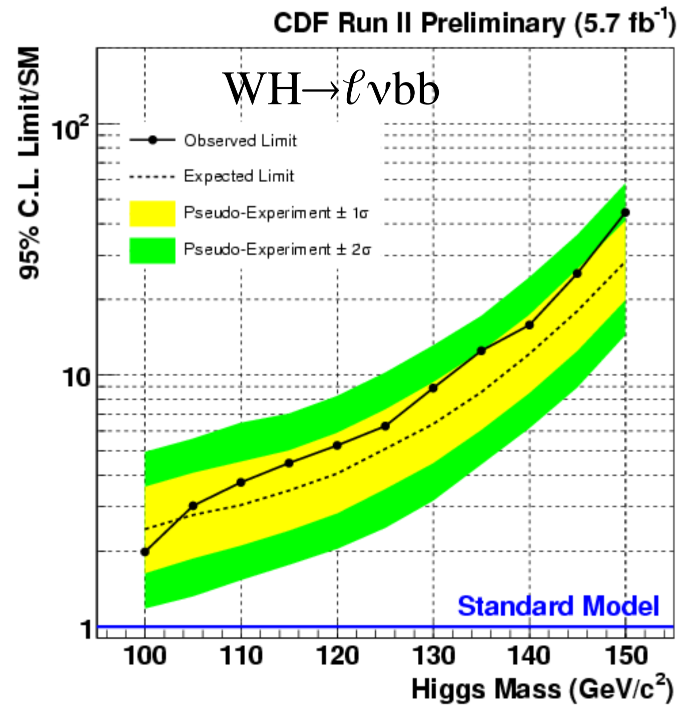
channel	events @ 115	events @ 165
WH→ℓνbb	28	0.1
ZH→ννbb	16	0.07
ZH→ℓℓbb	5	0.02
H→WW→ℓνℓν	9	38
total	58	38

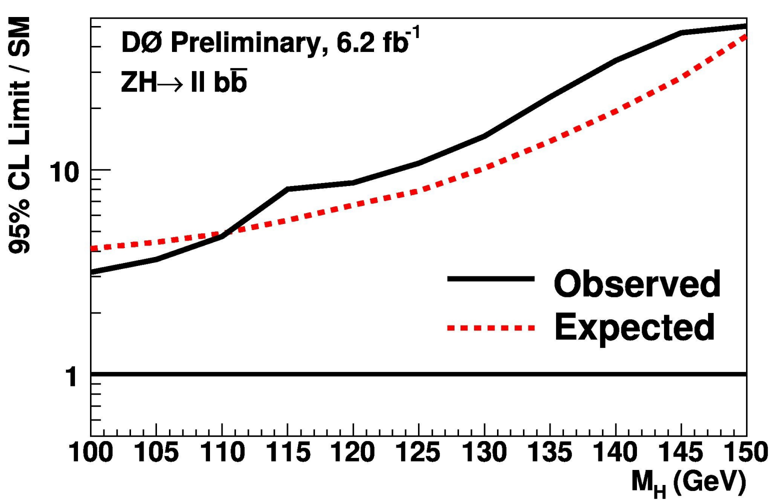
General overview of CDF and DØ searches

- CDF and DØ analyses present similar features and exploit common techniques:
  - SM backgrounds are in general estimated from Monte Carlo samples (mostly Pythia and ALPGEN), normalized to the highest-order cross-section calculation available;
  - multijet backgrounds and backgrounds from fakes usually estimated from data;
  - sets of control samples are defined to check and validate the background normalizations and modeling;
  - signal/background discrimination enhanced (~15-20%) by means of advanced multivariate techniques like artificial neural networks (ANN) and boosted decision trees (BDT), which combine information from kinematical, event global and particle identification variables.
- To improve the sensitivity to a particular production mechanism and better characterize the backgrounds, increasing the S/B discriminating power, each channel is further divided in "sub-channels" that are analised separately.
- Finally, combining is the main theme of Higgs searches: in order to maximize the sensitivity each experiment combines the results from different analyses and the results of both experiments are combined together.

Low mass searches

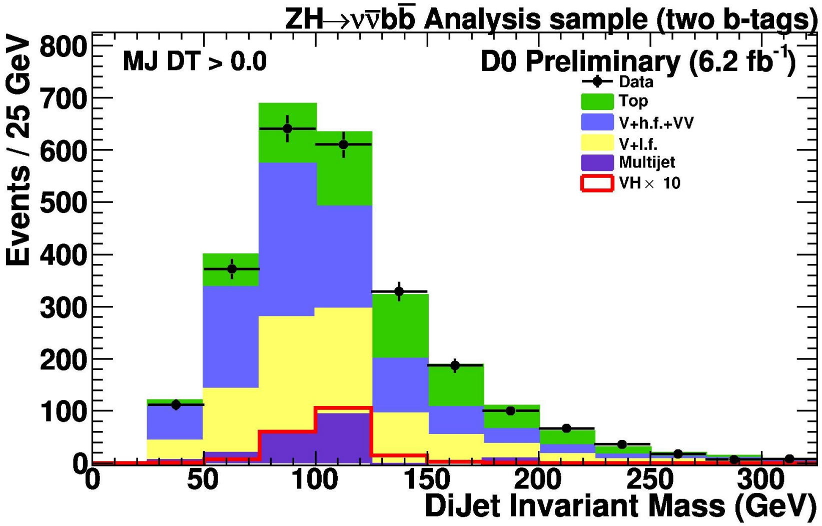
- Channels searched for in the low mass range:
  - WH → ℓνbb:
    - experimental signature: an energetic lepton, large missing energy and two jets;
    - the best compromise between signal yield and background level;
  - ZH → ℓℓbb:
    - looks for two leptons and two jets;
    - the cleanest mode, but suffers from low statistics;
  - ZH → ννbb/WH → (ℓ)νbb:
    - two jets and missing energy;
    - good signal acceptance, huge multijet backgrounds;
  - H→ττ:
    - one lepton and one hadronically decaying τ;
    - good sensitivity, but have to deal with high fake rates from jets;
  - H→γγ:
    - very clean signature: two EM energy deposits;
    - very low BR in the Standard Model.

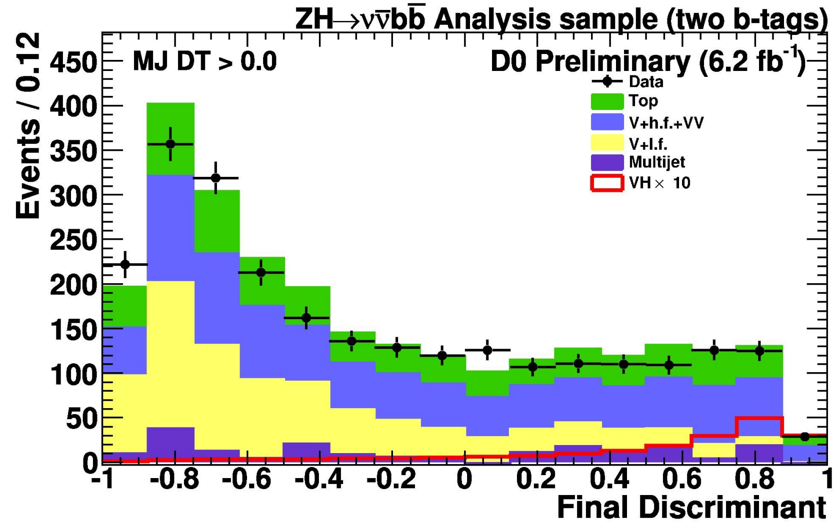




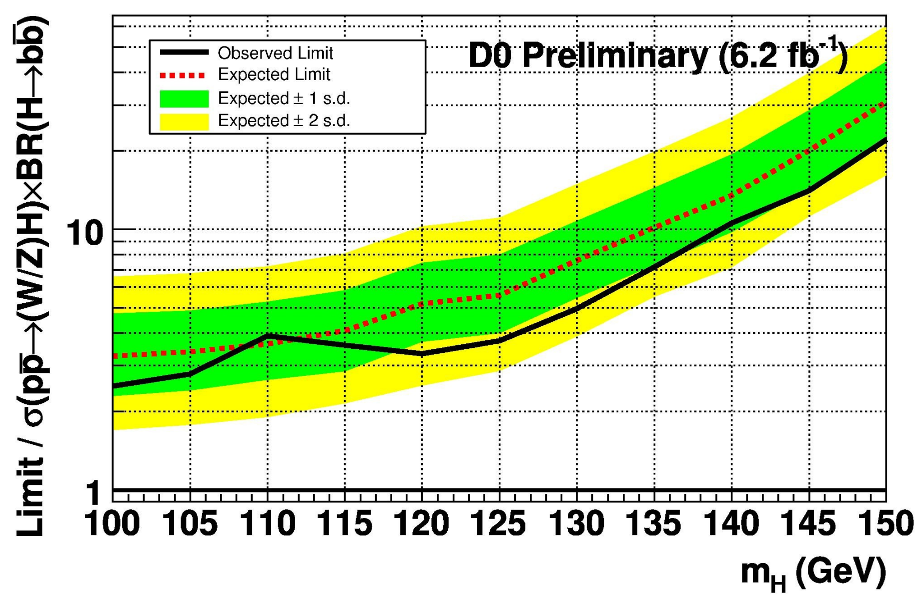
$ZH \to \nu\bar{\nu}b\bar{b}$ and $WH \to (\ell)\nu b\bar{b}$

- Takes advantage of large BR($Z\to\nu\nu$)~20%, but affected by huge multijet background.





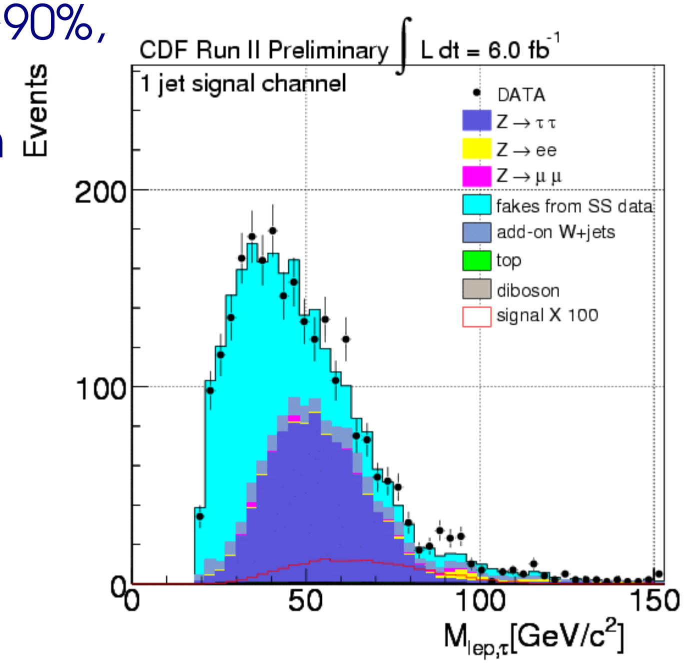
- Event selection:
  - missing transverse energy + 2 jets;
  - sensitive to $ZH\to\nu\nu bb$ and $WH\to(\ell)\nu bb$.
- Analysis technique:
  - BDT to tag b-jets;
  - BDT to remove overwhelming multijet background;
  - two search channels: one b-tag and two b-tags;
  - BDT for final event selection.

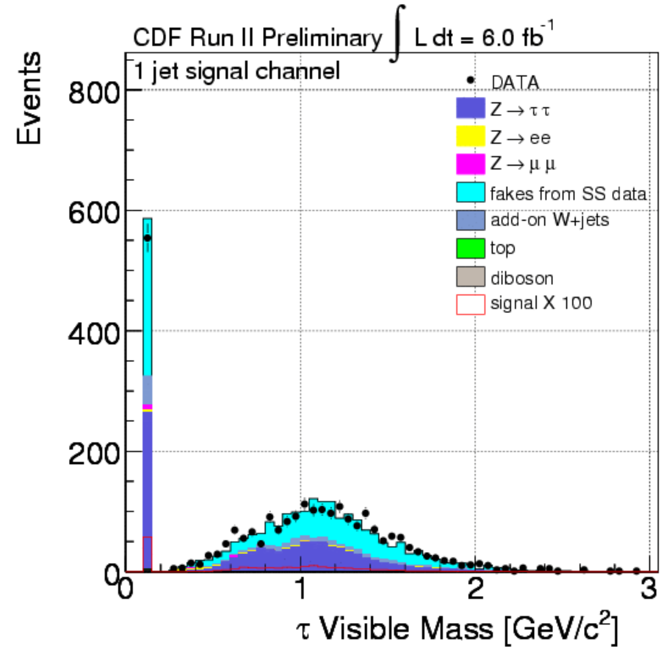


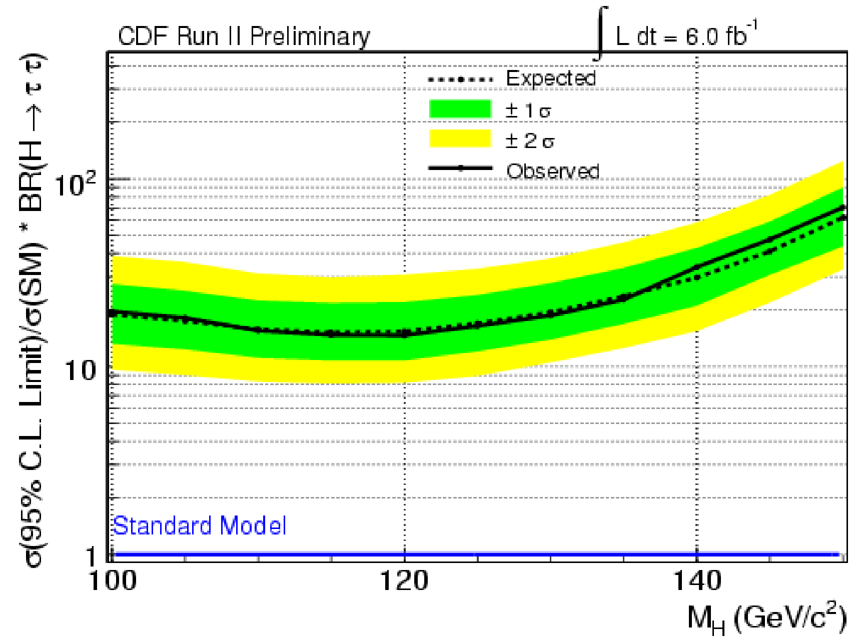
http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H98/

$H \to \tau\tau$

- $BR(H \to \tau\tau) \sim 10\%$ vs $BR(H \to bb) \sim 90\%$, but no b-tagging needed, hadronic taus reconstruction difficult.
  - Event selection:
    - one isolated e/μ + one hadronically decaying tau (τ_h) + jets;
    - sensitive to WH, ZH, VBF, $gg \to H$ production.
  - Analysis technique:
    - BDT for hadronic tau identification;
    - four search channels: $e/\mu + \tau_h$ + 1 jet and $e/\mu + \tau_h + \geq 2$ jets;
    - different BDTs trained against different backgrounds and combined to get a final discriminant.



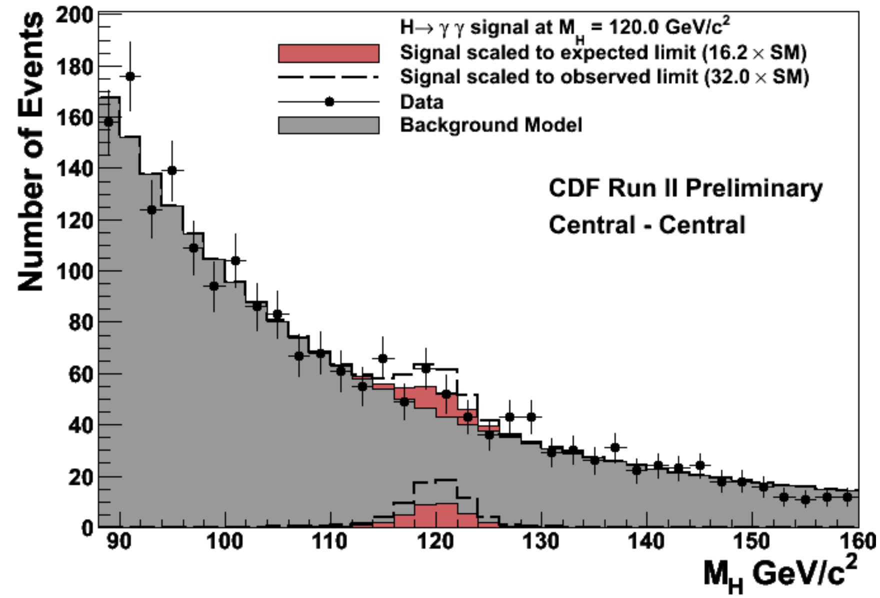


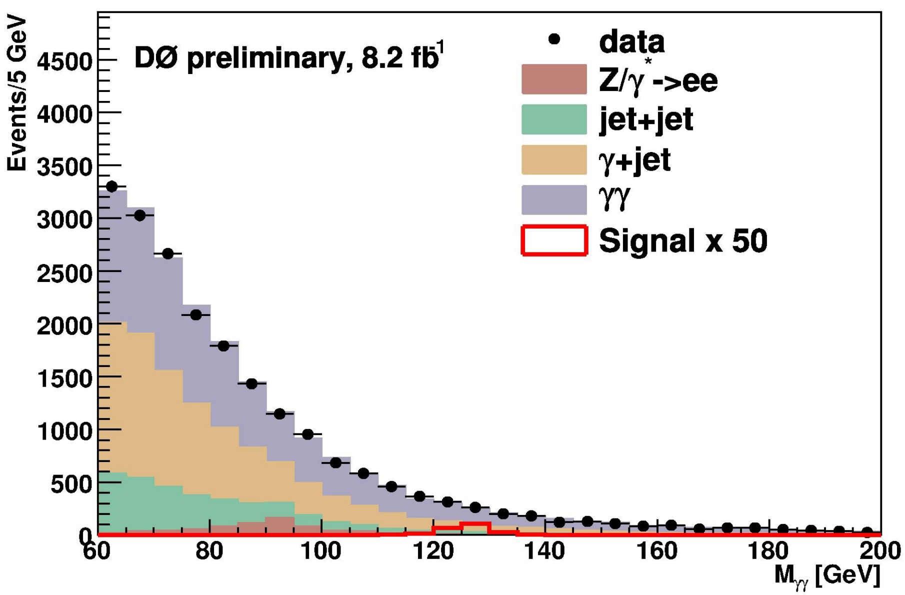


http://www-cdf.fnal.gov/physics/new/hdg/results/smtautau_mar11/home.html

$H \to \gamma\gamma$ (I)

- Very clean signature, takes advantage of better photon ID efficiency w.r.t. jets and high EM energy resolution, $\sigma(M_{\gamma\gamma})$ ~ few GeV/c^2, but BR($H \to \gamma\gamma$) ~ permil in SM.
  - Event selection:
    - two energetic reconstructed photons;
    - sensitive to WH, ZH, VBF, $gg \to H$ production.
  - CDF analysis:
    - three photon categories (central, plug, from conversions) combined in four search channels;
    - background from fit on data;
    - $M_{\gamma\gamma}$ used as a discriminant.
  - DØ analysis:
    - ANN to suppress contamination from jets;
    - BDT to build final discriminant.

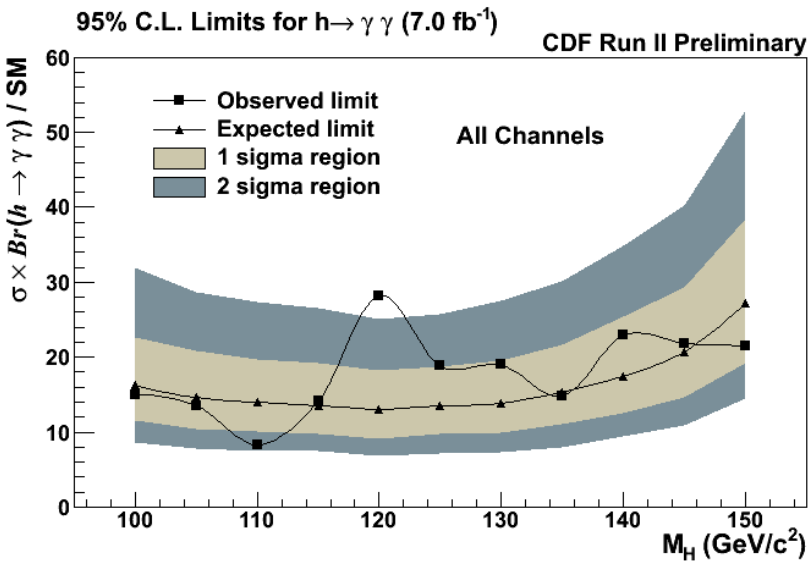


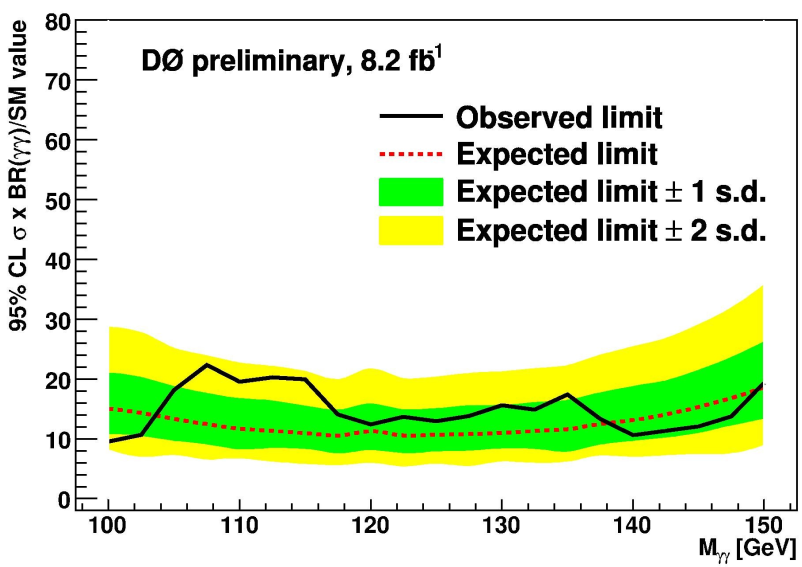


http://www-cdf.fnal.gov/physics/new/hdg/results/hgamgam_apr11/

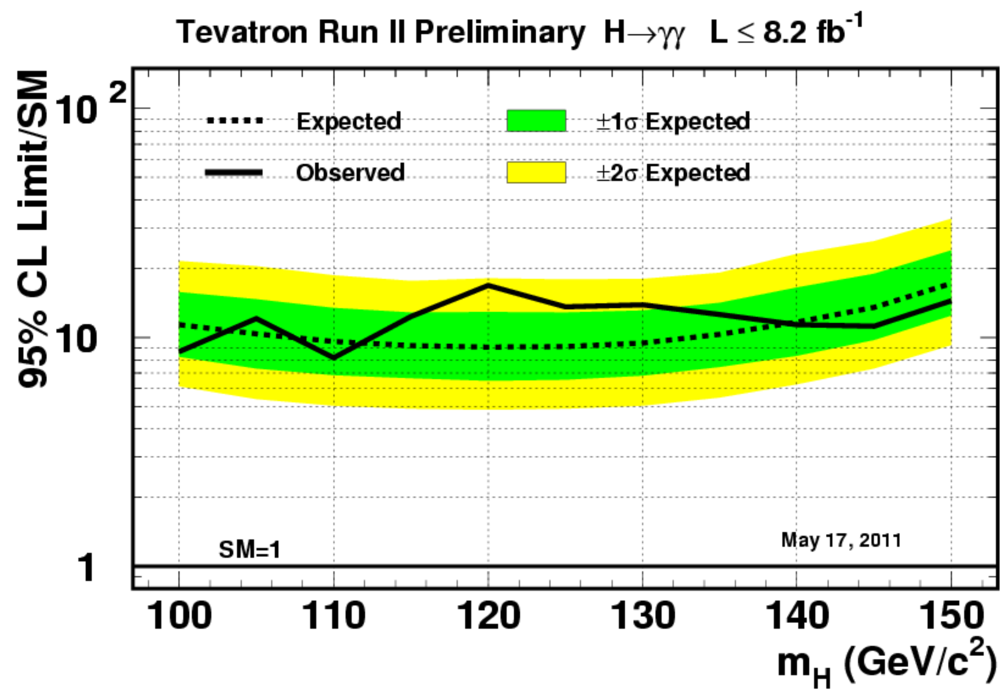
http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H99/

H → γγ (II)



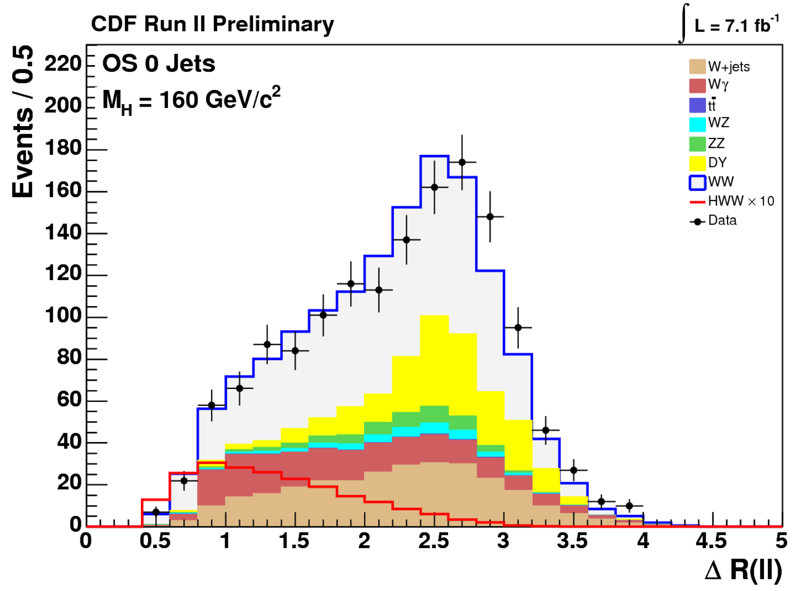


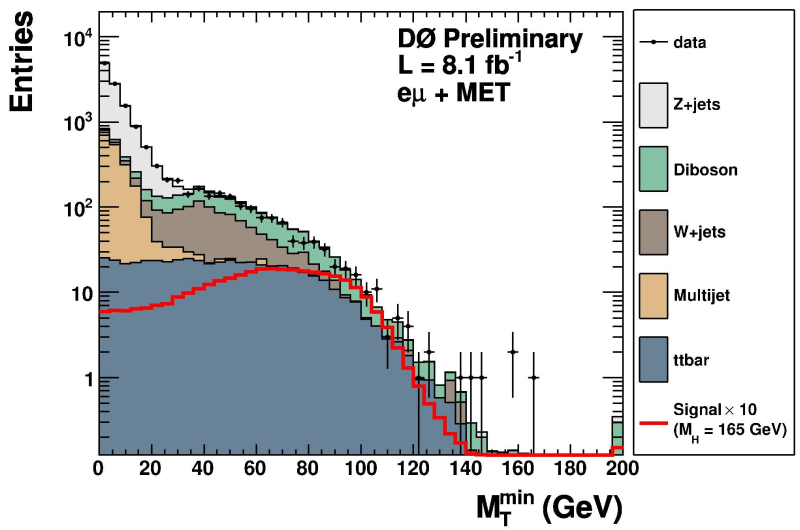
- CDF and DØ searches for a SM Higgs boson decaying to two Photons have been combined.



$H \rightarrow WW^*$ (I)

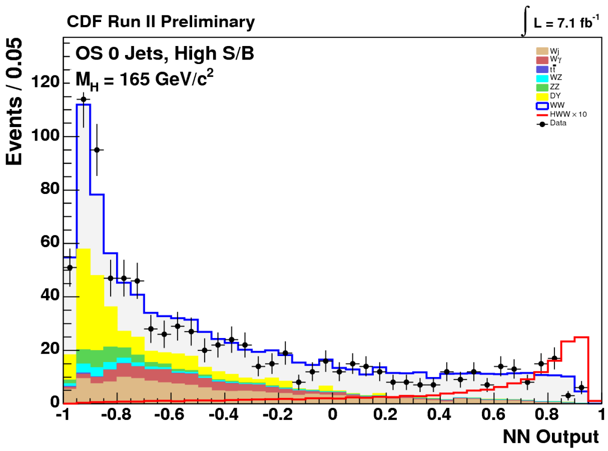
- Fully leptonic final states have BR($H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$) ~ 10%, but provide experimental signatures with relatively low backgrounds. SM Higgs acceptance is improved by final states with hadronically decaying taus.
  - Event selection:
    - two leptons + large missing energy;
    - sensitive to $gg \rightarrow H$ production, WH, ZH, VBF.
  - CDF analysis:
    - nine lepton categories;
    - ten channels: OS dileptons + 0, 1, ≥2 jets; SS dileptons + 1 jet; trileptons in Z mass + 1, 2 jets; trileptons outside Z mass; OS dileptons in low $M_{\ell\ell}$ region; $e\tau_h$ and $\mu\tau_h$;
    - ANN and BTD for final discriminants.
  - DØ analysis:
    - ten channels: three leptonic final states ($e\mu$, ee, $\mu\mu$) each with three jet bins (0, 1, ≥2); $\mu\tau_h$;
    - BDT to remove Z/γ^* bkg in ee, μμ channels;
    - BDT to build final discriminant.



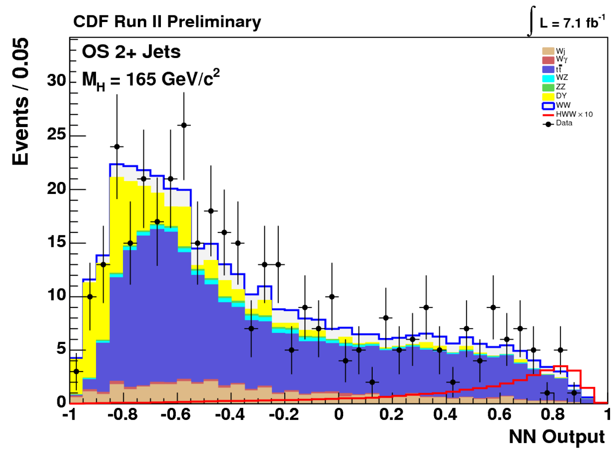


H → WW* (II)

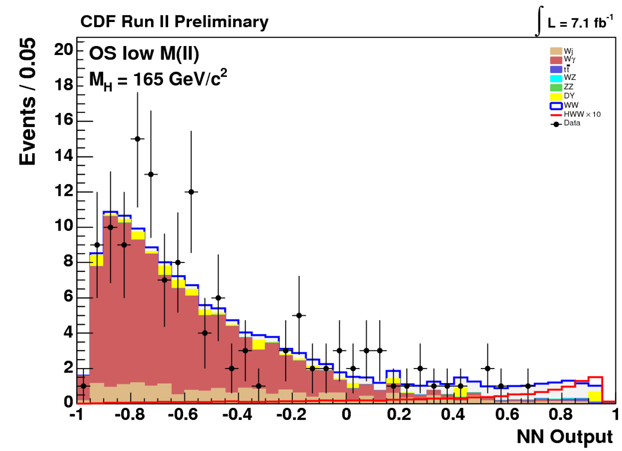
- Examples of final discriminants:



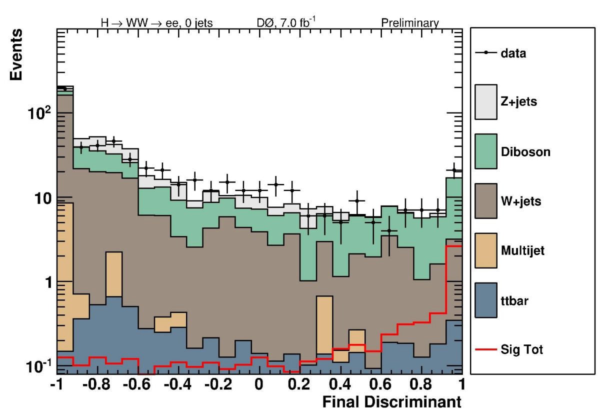
OS dilepton with 0 jets



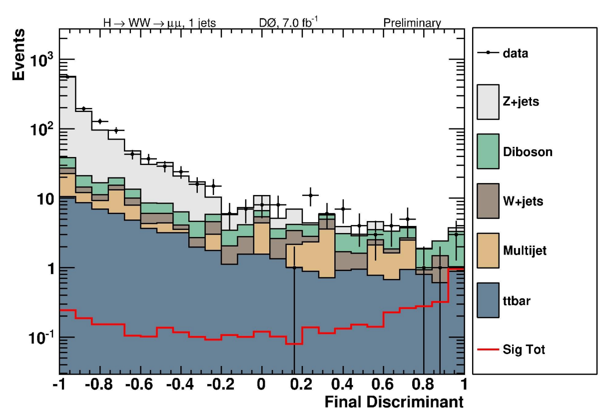
OS dilepton + 2 jets



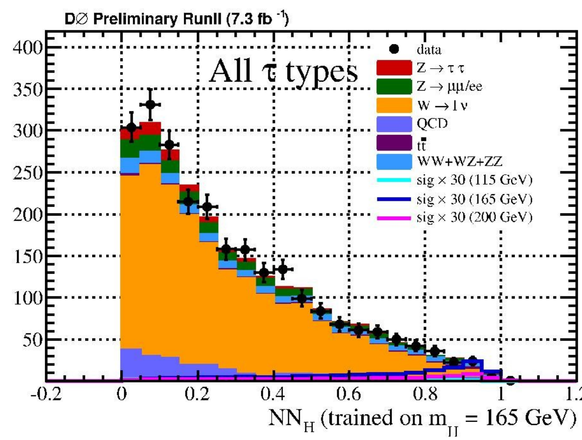
OS dilepton in low $M_{\ell\ell}$



ee channel with 0 jets



μμ channel + 1 jets



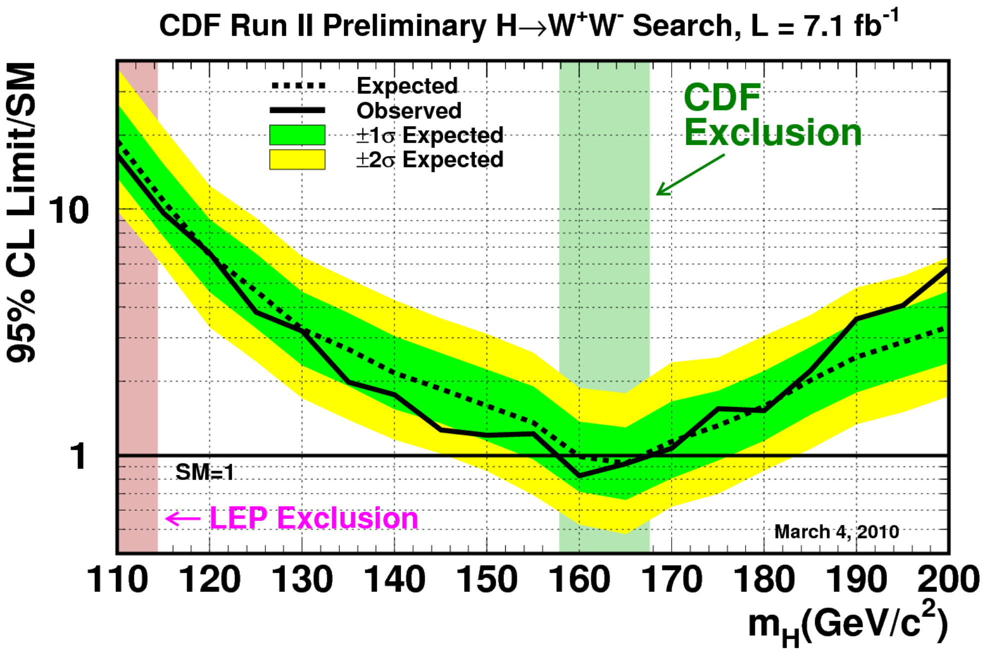
$\mu\tau_h$ channel

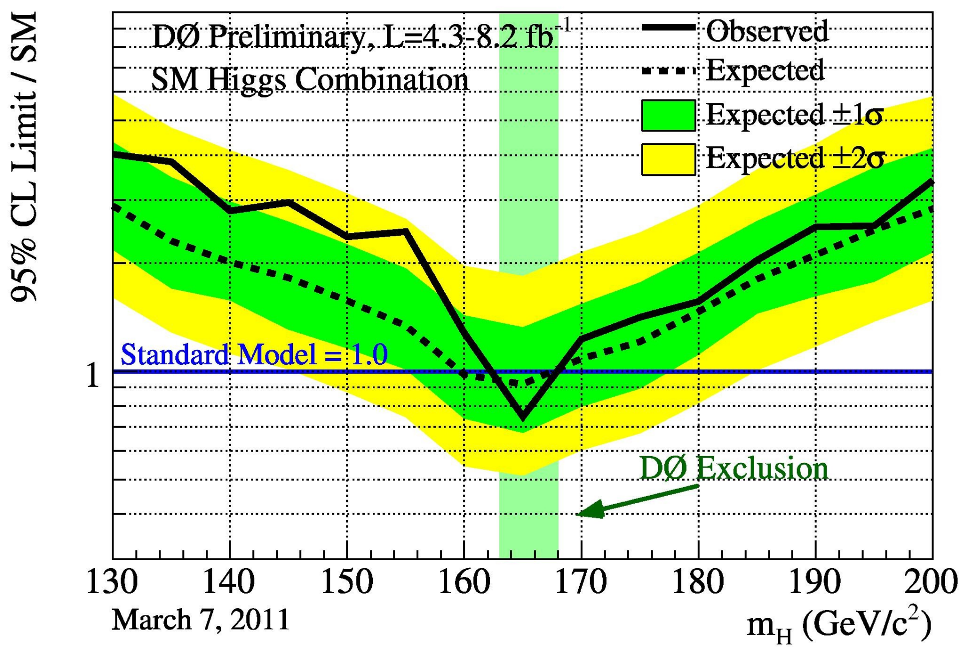
http://www-cdf.fnal.gov/physics/new/hdg/results/hwwmenn_110304/

http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H102/

H → WW* (III)

- CDF and DØ high-mass results:



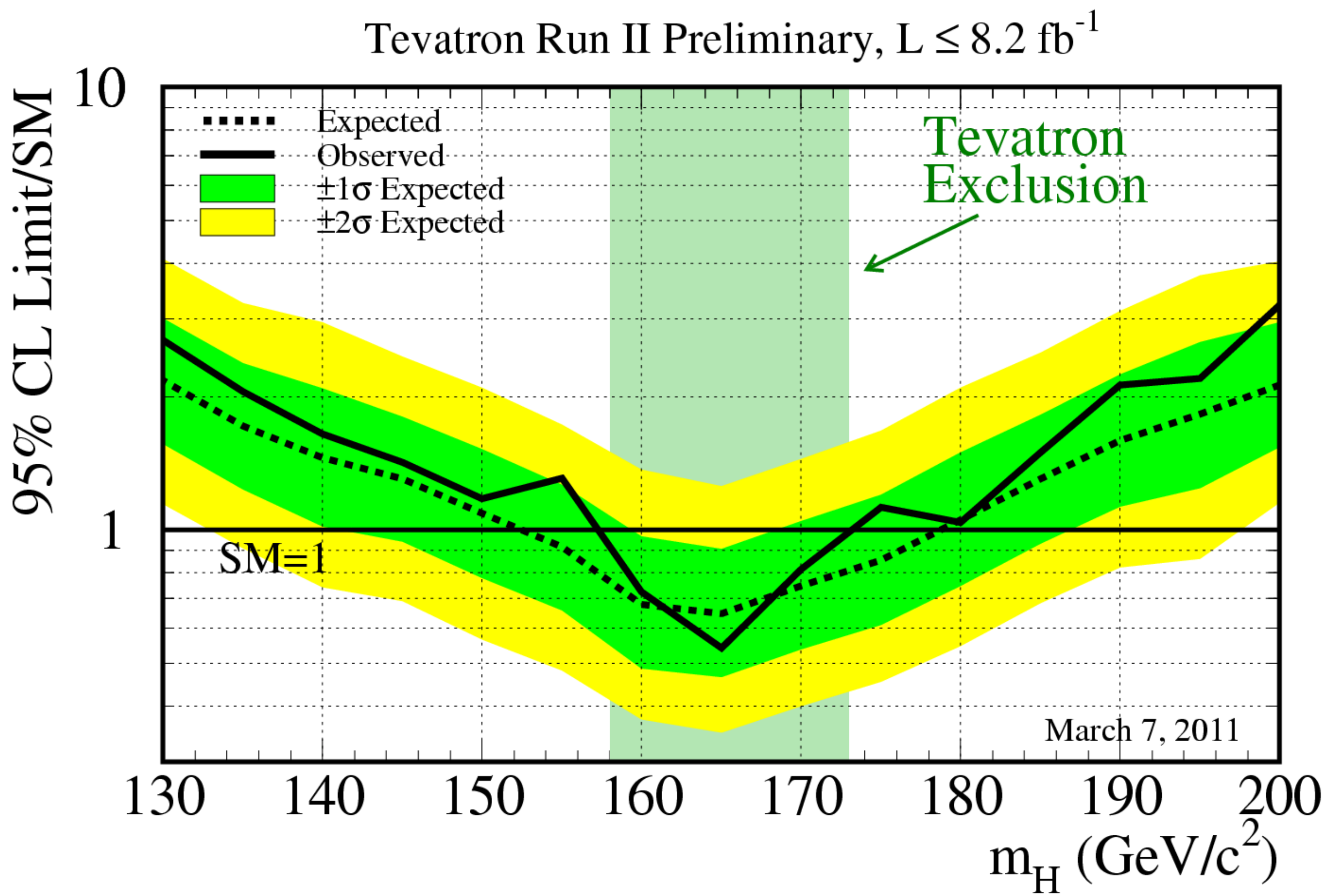


95% C.L. exclusion of the mass range $158 < M_H < 168$ GeV/c^2

95% C.L. exclusion of the mass range $163 < M_H < 168$ (*) GeV/c^2

(*) $\tau\tau$ and $\gamma\gamma$ channels included in the combination

Winter '11 Tevatron high-mass combination

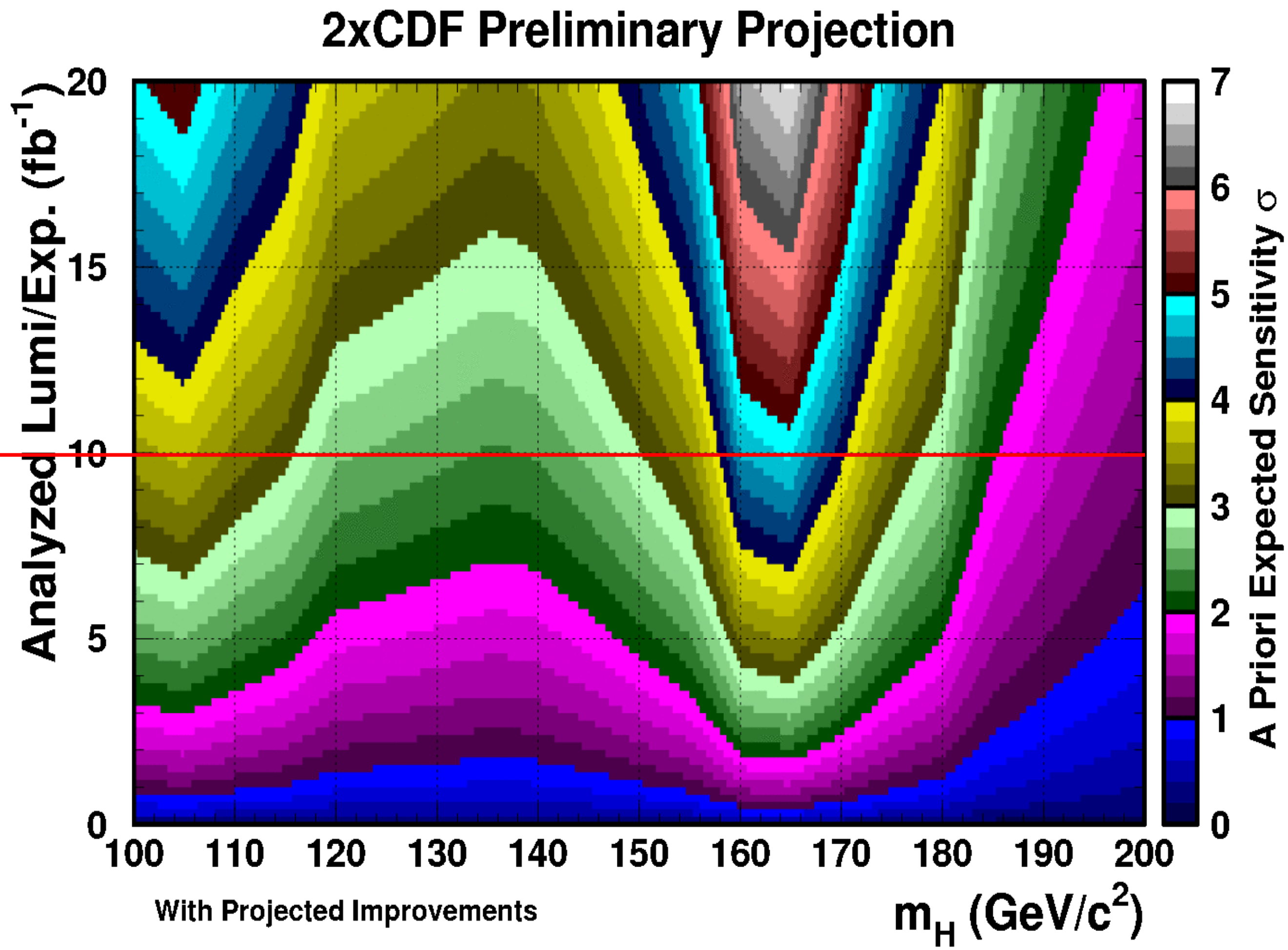


95% C.L. exclusion of the mass range $158 < M_H < 173$ GeV/c^2

http://tevnphwg.fnal.gov/results/SM_Higgs_Winter_11/

- The date of the Tevatron Run II termination has been written on stone: September 30, 2011.
- Expected ~10 fb^{-1} per experiment on tape.

expected better than 2.4 σ sensitivity up to 180 GeV/c^2



Conclusion and plan

- CDF and DØ experiments set the first single experiment exclusions:

CDF: $158 < M_H < 168$ GeV/c^2,

DØ: $163 < M_H < 168$ GeV/c^2.

- The Winter '11 Tevatron high-mass combination excludes at 95% C.L. the mass range:

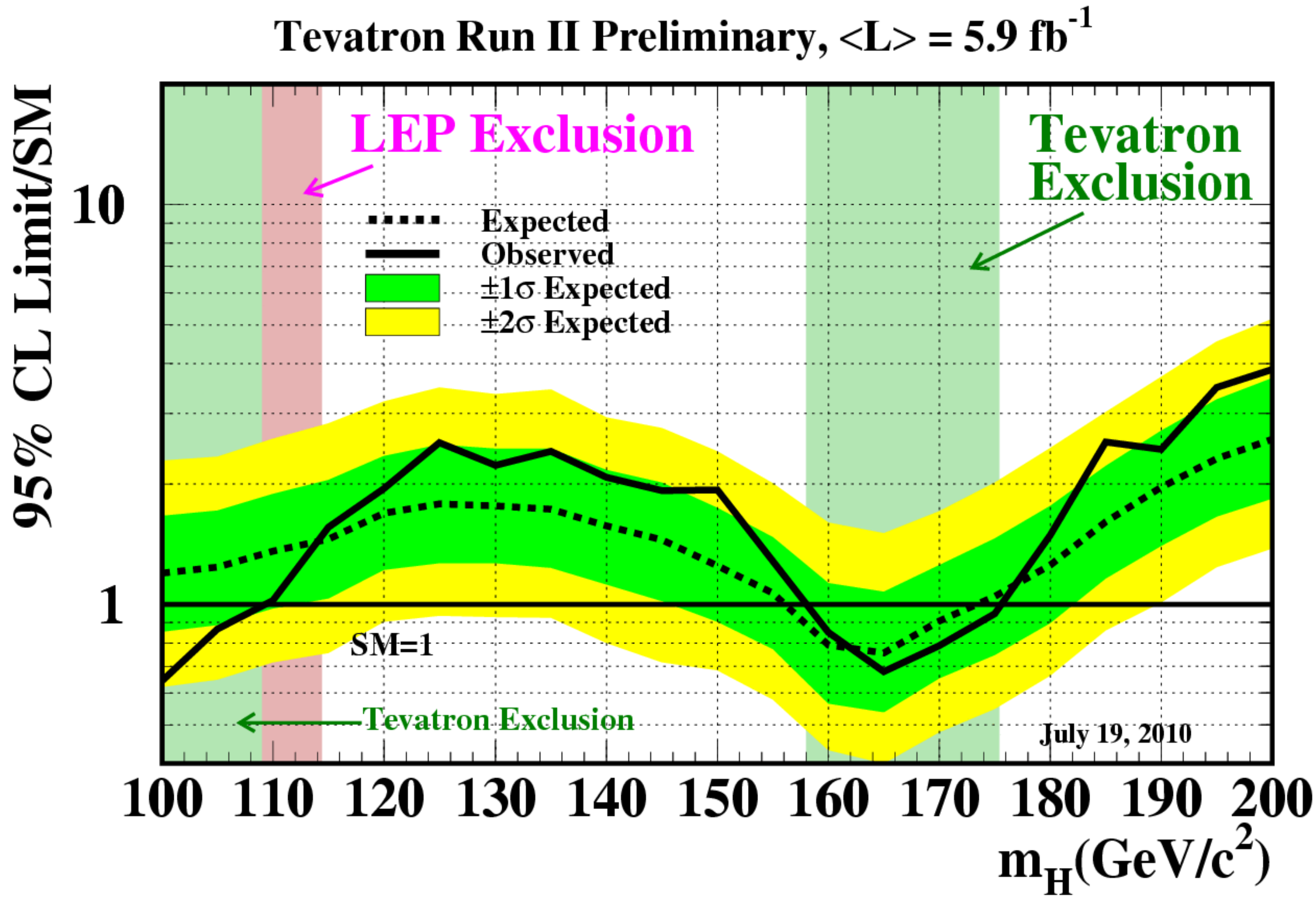
$158 < M_H < 173$ GeV/c^2.

- Improved analyses will be finalized in the Summer and a new Tevatron combination presented at EPS at the end of July.

- Results on the Tevatron Run II final dataset expected in 2012.

Backup slides

Summer '10 Tevatron combination



95% C.L. exclusion of the mass ranges

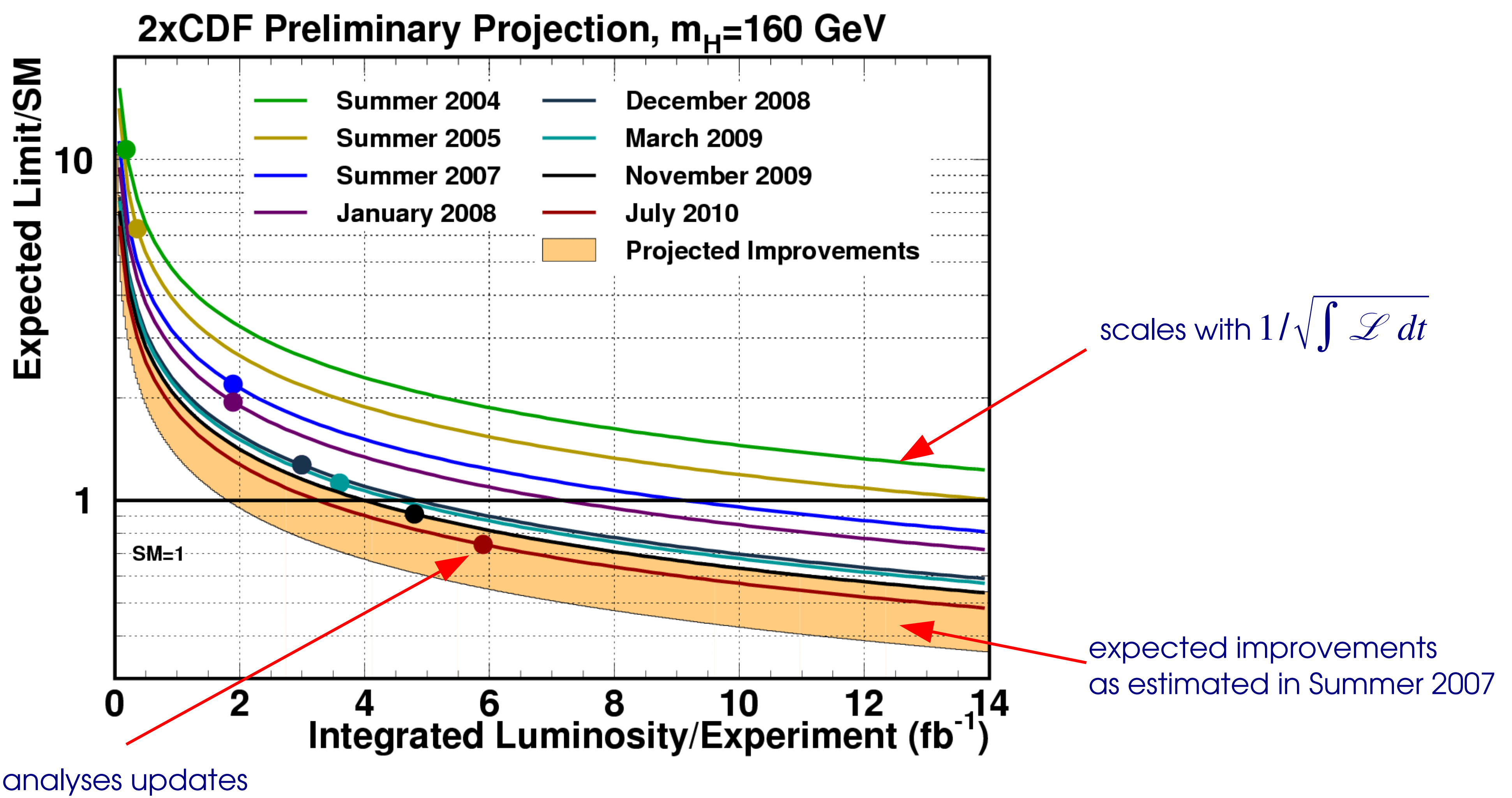
$M_H < 109$ GeV/c^2

$158 < M_H < 175$ GeV/c^2

http://tevnphwg.fnal.gov/results/SM_Higgs_Summer_10/

Expected limit projections

- CDF projections for the expected upper limit on the SM Higgs boson production cross section at M_H = 165 GeV/c^2:



Expected limit projections

- 2xCDF projections for the expected upper limit on the SM Higgs boson production cross section at M_H = 115 GeV/c^2: